INTRODUCTION

LOCATION AND EXTENT

The Lake Michigan basin, as used in this report, is a 3,600 square mile drainage area that lies along eastern Wisconsin and borders the western shore of Lake Michigan. It consists of several subbasins whose main stem streams discharge directly into Lake Michigan and into Green Bay. The study area does not include basins whose main stem streams discharge into Green Bay from the west and south. Included in the Lake Michigan basin are Door, Kewaunee, Manitowoc, Ozaukee, and Sheboygan Counties and parts of Brown, Calumet, Fond du Lac, Kenosha, Milwaukee, Racine, Washington, and Waukesha Counties.

PURPOSE AND SCOPE

It is the purpose of this report to describe the water resources and water use of the Lake Michigan basin as an aid to water management. The report describes the distribution, characteristics, and physical environment of the resource, as well as the hydrologic budget, water problems, and water use. The information will be used to select sites for systematically monitoring the effects of a changing environment on the hydrology of the study area. Data for this report were gathered from various agencies and collected during field investigations.

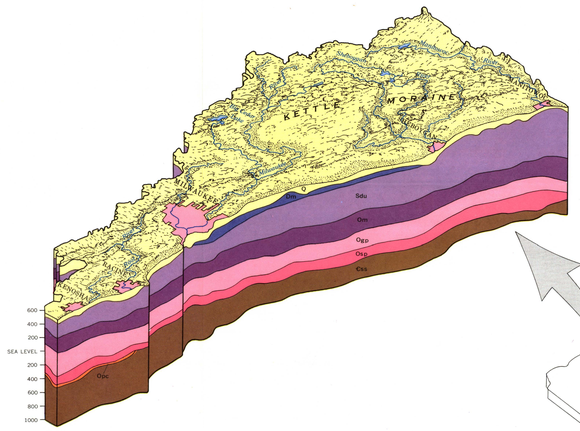
ACKNOWLEDGMENTS

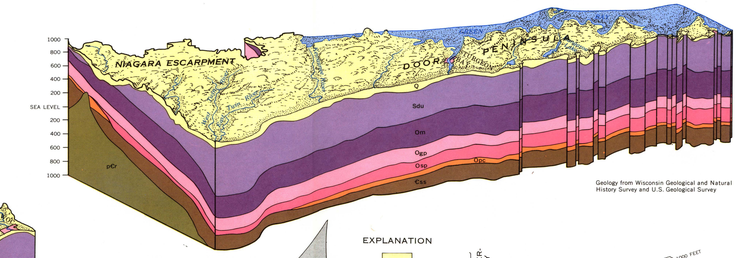
Much of the data used in compiling this report were supplied by other agencies. The University of Wisconsin-Extension, Geological and Natural History Survey furnished well-sample logs, geologic and soils maps, and technical assistance.

Chemical-quality data and water-use data obtained from the Wisconsin State Laboratory of Hygiene, the Wisconsin Department of Natural Resources, and the Public Service Commission of Wisconsin.

Municipal officials, county agricultural agents, and U.S. Soil Conservation Service personnel supplied valuable information.

PHYSICAL SETTING



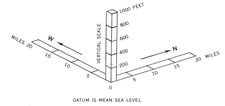


Geology from Wisconsin Geological and Natural History Survey and U.S. Geological Survey

BLOCK DIAGRAM OF THE LAKE MICHIGAN BASIN

EXPLANATION

Q — Glacial deposits	QUATERNARY
Om — Milwaukee Formation	SILURIAN
Sdu — Dolomites, undifferentiated	SILURIAN
Om — Maquoketa Shale	ORDOVICIAN
Ogp — Galena Dolomite, Decorah Formation, and Platteville Formation, undivided	ORDOVICIAN
Osp — St. Peter Sandstone	ORDOVICIAN
Opc — Prairie du Chien Group	ORDOVICIAN
Css — Sandstones, undifferentiated	CAMBRIAN
pCr — Crystalline rock	PRECAMBRIAN
Contact	



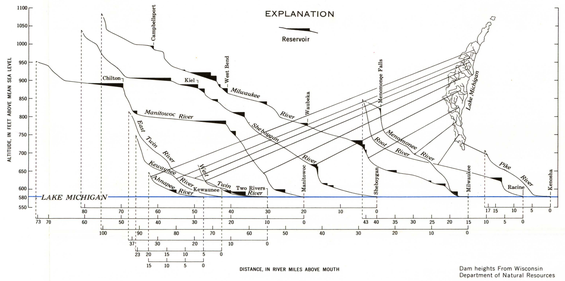
The block diagram shows the study areas as a raised section of the earth's crust. Surficial deposits overlie layered sedimentary rocks, which overlie crystalline rocks.

Continental glaciers moved across the basin from north and east, scouring rocks and transporting rock debris in the ice. This unconsolidated material was deposited on the bedrock as the glaciers melted to form the present-day landforms. The most prominent of these landforms is the Kettle Moraine. The Niagara Escarpment and Door Peninsula are also striking features that were, in part, shaped by the moving glaciers.

The sedimentary rocks are solidified marine sediments and are shown on the block diagram between the glacial deposits and Precambrian crystalline rocks. Sedimentary rocks dip and thicken to the southeast and east and range in total thickness from about 500 feet in the west-central part of the basin to about 3,500 feet (Hutchinson, 1970) in the southeastern corner.

Precambrian rocks are within 600 feet of the land surface in the west-central part of the basin. However, their upper surface slopes sharply, and in the southeast they are nearly 4,000 feet below the land surface. Their thickness is not known but is very great.

TOPOGRAPHY AND DRAINAGE



Dam heights From Wisconsin Department of Natural Resources

STREAM PROFILES

The Lake Michigan basin has a rolling topography of moderate relief. Altitudes in the basin range from about 580 feet above mean sea level at Lake Michigan to 1,260 feet on a hilltop southwest of West Bend, in Washington County. The topography is the result of bedrock configuration and glacial deposition and erosion. Also, streams have cut through the glacial drift into some rock units in forming the river drainage system. The topography has been and continues to be modified locally by the activities of man and his use of the land.

Gradients of major streams in the basin range from an average of 5 feet per mile in the Milwaukee and Manitowoc Rivers to 9 feet per mile in the Menomonee River. The average gradient for all major streams in the basin is 6 feet per mile. Gradients are steep in the headwaters of most streams, and the gradients of streams along the northern part of the basin become subdued in their courses to Lake Michigan. Abrupt changes in slope in streams draining the southern part of the basin reflect bedrock and moraines. Each of these streams has a steep gradient within 10 miles of Lake Michigan and a moderate gradient near the lake.

LAND USE

In the Lake Michigan basin 60 percent of the area is agricultural, 16 percent is urban or built-up, 14 percent is private, State, or Federal forests, 8 percent is "other land," which includes county-owned lands and ungrazed marshes, and 2 percent is water (U.S. Department of Agriculture, Soil Conservation Service, oral commun., 1968).

HYDROLOGIC CYCLE

The hydrologic cycle is the circulation of water between the earth and atmosphere. Water occurs on the earth as liquid or solid, passes into the atmosphere as vapor, then condenses and falls to earth again.

This report concerns water between the time it enters the basin and the time it returns to the atmosphere. Part of the water evaporates at the time of precipitation, part of it flows overland to streams, and part of the water penetrates the earth. Some of the water in the earth returns to the atmosphere by evaporation and transpiration (evapotranspiration), and some percolates to the ground-water reservoir. Release of water from this reservoir sustains base flow in streams during dry periods and supplies water to wells. Regardless of which path the water takes following precipitation, it eventually returns to the atmosphere as vapor.

The quantities of water involved in each of the water cycle in the Lake Michigan basin are shown below.

PRECIPITATION (INCHES)	RUNOFF (INCHES)	CHANGE IN STORAGE (INCHES)	UNDERFLOW (INCHES)	EVAPOTRANSPIRATION (INCHES)
DRY YEAR (1930) 20.2	DRY YEAR (1930) 6.2	DRY YEAR (1930) LOSS, ABOUT 1	DRY YEAR (1930) 0.2	DRY YEAR (1930) ABOUT 14.8
AVERAGE (1931-60) 29.0	AVERAGE (1931-60) 7.7	AVERAGE (1931-60) 0.0	AVERAGE (1931-60) 0.2	AVERAGE (1931-60) 21.1
WET YEAR (1959) 39.3	WET YEAR (1959) 12.9	WET YEAR (1959) GAIN ABOUT 1	WET YEAR (1959) 0.2	WET YEAR (1959) ABOUT 25.2

The average annual precipitation is 29.0 inches, based on U.S. Weather Bureau records for 1931-60. The range between wet and dry year extremes is about 19 inches. Precipitation within the basin is the source for nearly all the water entering the basin, and, therefore, the amount of water in the other budget items is dependent upon precipitation.

Lake Michigan influences the annual distribution of precipitation within the basin. Generally winter precipitation is higher, and summer precipitation is lower in the basin than in most of the rest of the State.

Average annual runoff leaving the basin by surface drainageways is 7.7 inches, based on gaging station records on the Root, Milwaukee, Menomonee, Sheboygan, and Kewaunee Rivers and Cedar Creek. This runoff varied about 7 inches between wet and dry years. Runoff includes ground water discharged to streams as well as overland flow.

The amount of water stored in lakes and surface reservoirs, in the soil zone, and in the ground-water reservoir may increase or decrease between wet and dry periods. However, the average annual change in storage during 1931-60 is negligible.

The greatest range between wet and dry periods is probably about 2 inches, and the wet and dry years of 1959 and 1930 are entered in the budget as +1 and -1 inch respectively. The declining water levels in the Milwaukee area show significant losses from storage locally, but these losses represent less than 0.1 inch of water over the entire basin for the 1931-60 period.

Underflow, water entering or leaving the basin through the ground-water system, remains fairly constant. About 17 mgd (million gallons per day) enters the basin through the sandstone aquifer, and about 12 mgd enters through the Niagara and sand and gravel aquifers from the west. About 20 mgd leaves the basin from the sandstone aquifer and 46 mgd from the Niagara and sand and gravel aquifers to the east and north. This accounts for a net loss of about 37 mgd or about 0.2 inch each year. Generally underflow enters the basin from the west and moves toward Lake Michigan or pumpage centers at Green Bay, Milwaukee, and Chicago (see potentiometric map, sheet 2).

Evapotranspiration is the return of water to the atmosphere by transpiration (loss of water by plants) and evaporation. It is the net difference, in volume, between the amount of precipitation and the sum of runoff, change in storage, and underflow. Average annual evapotranspiration (1931-60) was calculated to be 21.1 inches and varied less than 10 inches between wet and dry year extremes.

GEOLOGY AND SOILS

This map shows the bedrock surface as it would appear if the glacial deposits were stripped away. The formation pattern results from erosion of southeasterly dipping strata, which exposes progressively younger rocks from west to east (see block diagram). Silurian dolomite is the upper bedrock unit over about 95 percent of the basin and is exposed along the Door Peninsula and in numerous quarries. The Galena Dolomite, Decorah Formation, and Platteville Formation (Galena-Platteville unit), Maquoketa Shale, and the Prairie du Chien Group are the bedrock surface in the remaining 5 percent of the basin.

A thick series of sedimentary rocks that consist largely of sandstone underlies the Galena-Platteville unit. These units, as shown by the block diagram, are the St. Peter Sandstone, the Prairie du Chien Group, and the undifferentiated Cambrian sandstones. The St. Peter Sandstone was deposited on an old erosional surface and ranges from 0 to 360 feet thick. The Prairie du Chien Group is largely dolomite and ranges from 0 to 140 feet in thickness. It is absent in the central part of the basin. The Cambrian sandstones are about 3,500 feet thick in the southeastern part of the basin (Hutchinson, 1970) and several hundred feet thick throughout most of the basin. They are missing in the west-central part of the basin over a Precambrian high.

Glacial drift overlies most of the bedrock in the basin. It consists of unsorted till, which is deposited as ground and end moraines, and of sorted and stratified outwash and glacial lake deposits. The drift ranges in thickness from less than 50 feet in Door County to 350 feet in end moraines and bedrock lows in the southern two-thirds of the basin.

Ground moraine, which has an undulating surface, covers about two-thirds of the basin. It is primarily a clayey, silty till but contains deposits of stratified sand and gravel.

End moraines form discontinuous bands of hills paralleling Lake Michigan. In the eastern part of the basin they consist primarily of till, which has low permeability. The Kettle Moraine in the central part of the basin consists of permeable stratified sediments and till. Kettle lakes are common in the Kettle Moraine.

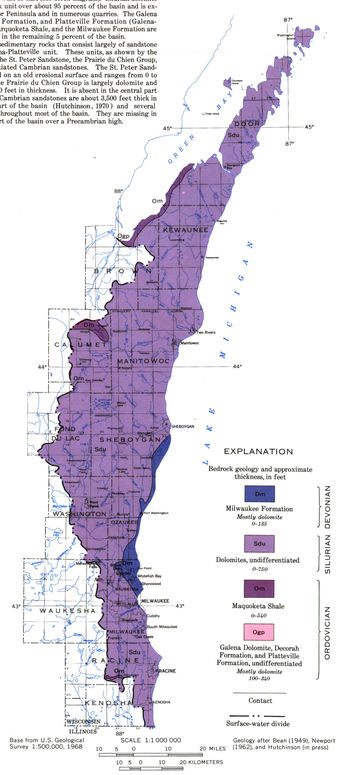
Outwash and kame deposits of permeable sand and gravel are largely associated with the Kettle Moraine in the Lake Michigan basin. The largest deposits are found in Washington and southern Sheboygan Counties.

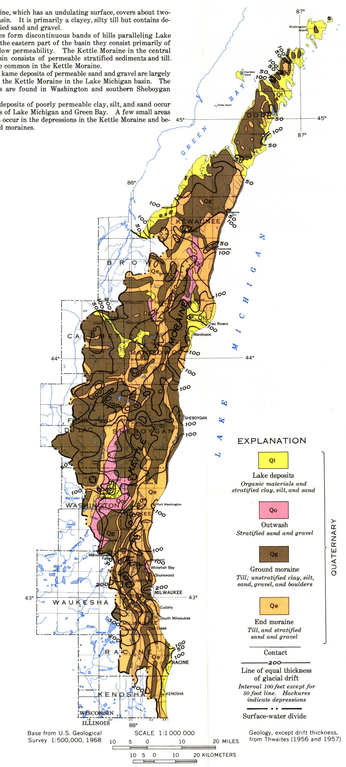
Glacial lake deposits of poorly permeable clay, silt, and sand occur along the shores of Lake Michigan and Green Bay. A few small areas of lake deposits occur in the depressions in the Kettle Moraine and between other end moraines.

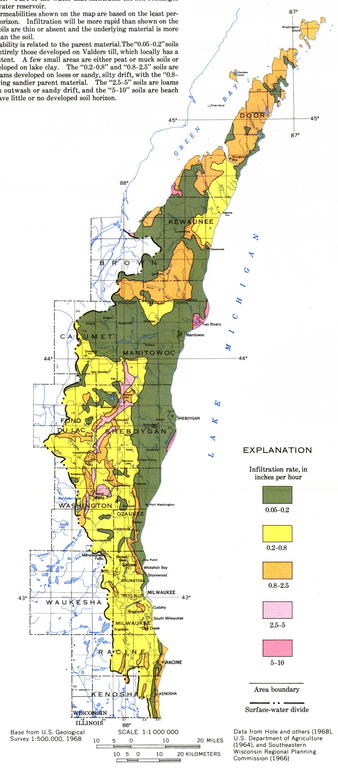
Soil permeabilities are important to the hydrology of an area because they affect the runoff and infiltration of precipitation. Low soil permeability contributes to rapid surface runoff and low infiltration. High soil permeability allows rapid infiltration of precipitation and decreases surface runoff. Part of the water that infiltrates the soil recharges the ground-water reservoir.

The soil permeabilities shown on the map are based on the least permeable soil horizon. Infiltration will be more rapid than shown on the map where soils are thin or absent and the underlying material is more permeable than the soil.

Soil permeability is related to the parent material. The "0.05-0.2" soils are almost entirely those developed on Valders till, which locally has a high clay content. A few small areas are either peat or muck soils or are soils developed on lake clay. The "0.2-0.8" and "0.8-2.5" soils are mostly silt loams developed on loess or sandy, silty drift, with the "0.8-2.5" soils having sandier parent material. The "2.5-5" soils are loams developed on outwash or sandy drift, and the "5-10" soils are beach sands that have little or no developed soil horizon.







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WATER RESOURCES OF WISCONSIN—LAKE MICHIGAN BASIN

By
Earl L. Skinner and Ronald G. Borman

1973

For sale by U.S. Geological Survey, price $1.50 per set