GEOLOGY AND GROUND WATER

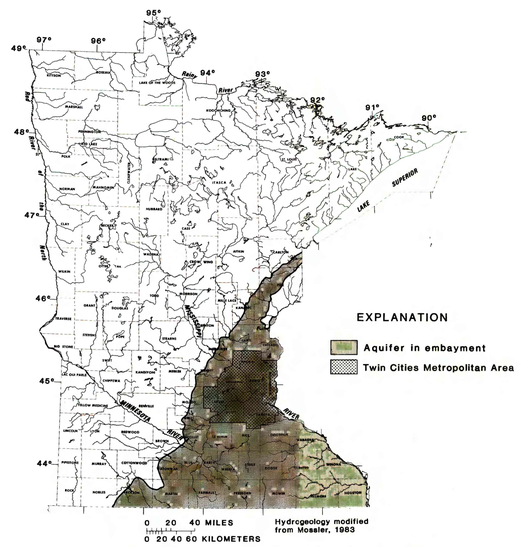


Figure 1.--Areal extent of Mount Simon-Hinckley aquifer and area of Hollandale embayment in southeast Minnesota

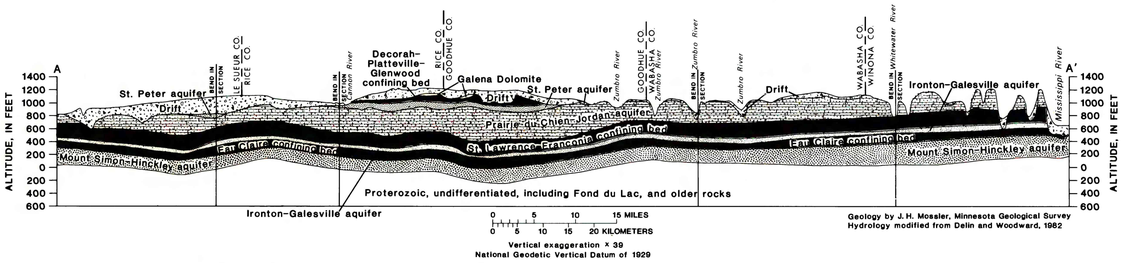


Figure 3.--Generalized section of hydrogeologic units in the bedrock sequence of southeast Minnesota

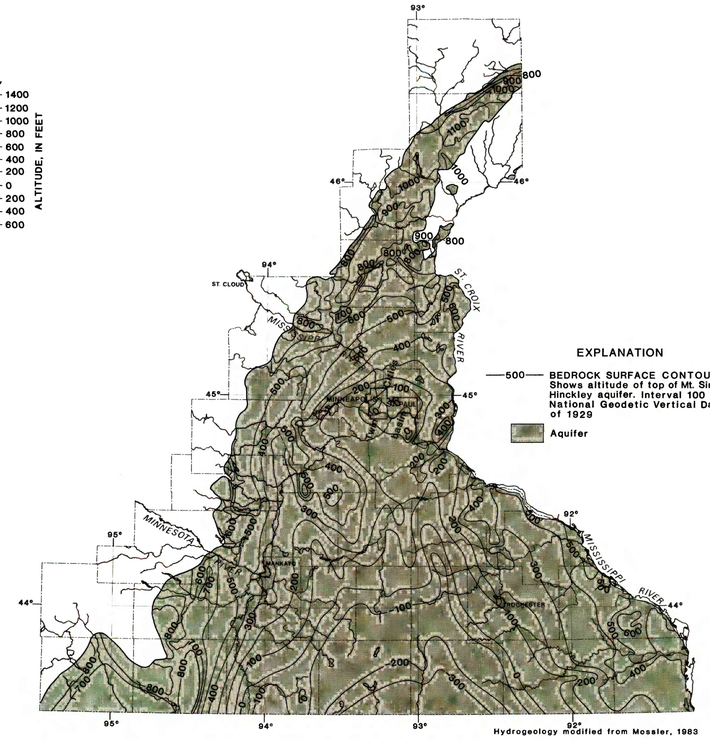


Figure 4.--Configuration of upper surface of the aquifer

ABSTRACT

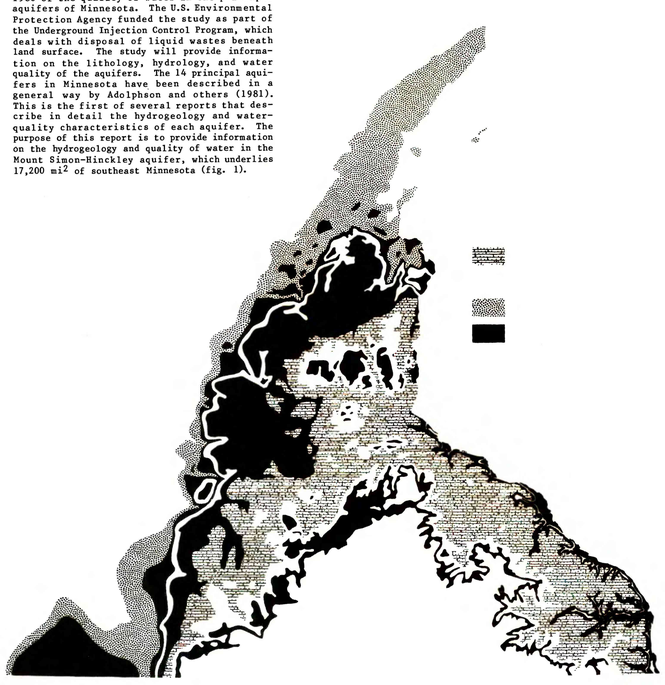
The Mount Simon-Hinckley aquifer in southeast Minnesota consists of a thick sequence of sandstone that generally yields large quantities of good-quality water to wells. The aquifer is most important as a source of water supply in the Twin Cities area, where it supplies approximately 10 percent of the ground water used. It is the uppermost bedrock aquifer and, locally, the principal source of domestic supply where it is present north of the Twin Cities. Yields to wells are generally about 500 gallons per minute but may be as high as 2,000 gallons per minute. The aquifer is a good potential source of water because of (1) large quantities of water in storage, (2) adequate yields to wells, and (3) good water quality.

The quality of water in the aquifer is generally acceptable for municipal, industrial, and domestic uses. The dissolved-solids concentration in water from the aquifer ranges from a minimum of 48 milligrams per liter to a maximum of 2,810 milligrams per liter. The lowest values are in the eastern and northern parts of the aquifer, where bedrock is at or close to land surface. The highest concentrations are in the southwestern part of the aquifer, where leakage from overlying Cretaceous rocks is highly mineralized water. Magnesium and sulfate concentrations are also high in the southwest. The dissolved-solids concentration generally increases with depth in the aquifer. The predominant water type in the aquifer is calcium magnesium bicarbonate, although sodium chloride waters are present at depth and in the discharge areas along large rivers.

This report is one of a series on the hydrogeology and water quality of the 14 principal aquifers in Minnesota prepared by the U.S. Geological Survey. The U.S. Environmental Protection Agency requested these studies because of the need for information to develop its Underground Injection Control Program.

INTRODUCTION

The U.S. Geological Survey began a study in 1980 of the quality of water in the principal aquifers of Minnesota. The U.S. Environmental Protection Agency funded the study as part of the Underground Injection Control Program, which deals with disposal of liquid wastes beneath land surface. The study will provide information on the lithology, hydrology, and water quality of the aquifers. The 14 principal aquifers in Minnesota have been described in a general way by Adolphson and others (1981). This is the first of several reports that describe in detail the hydrogeology and water-quality characteristics of each aquifer. The purpose of this report is to provide information on the hydrogeology and quality of water in the Mount Simon-Hinckley aquifer, which underlies 17,200 mi^2 of southeast Minnesota (fig. 1).



HYDROGEOLOGIC DESCRIPTION

Geologic Features

The Mount Simon and Hinckley Sandstones are part of a sequence of sedimentary rocks that are predominantly sandstone, limestone, dolomite, and shale. Deposition of these rocks began in Proterozoic time and continued to the Devonian Period of the Paleozoic Era. These rocks were deposited in seas that occupied the Hollandale embayment, a shallow depression that extended northward from Iowa into southeast Minnesota (Austin, 1972). Figure 1 shows the areal extent of the Mount Simon-Hinckley aquifer and the embayment.

The Paleozoic sedimentary rocks and underlying Proterozoic Hinckley Sandstone in southeast Minnesota comprise five major bedrock aquifers and four major confining beds (Lindholm and Norvitch, 1976; Delin and Woodward, 1982). Table 1 shows this aquifer classification scheme and schematically represents the vertical position of these hydrologic units, including Cretaceous deposits and drift. Kanivetsky and Walton (1979) and Adolphson and others (1981) have proposed classifications that are slightly different because they include the Franconia Formation as part of the Ironton-Galesville aquifer and the Fond du Lac Formation as part of the Mount Simon-Hinckley aquifer. Figure 2 shows the areal extent of the aquifers and confining beds listed in table 1 for southeast Minnesota. Figure 3 is a generalized section of the hydrogeologic units along an east-west line through southeast Minnesota.

The Mount Simon and Hinckley Sandstones are in the lower part of the bedrock sequence. The Hinckley overlies the Fond du Lac Formation, a fine-grained sandstone and siltstone, and underlies the Mount Simon as far north as the Twin Cities basin. The Hinckley subcrops glacial drift or crops out in the northern part of the study area. The Eau Claire Formation, a fine- to medium-grained sandstone interbedded with shale, overlies most of the Mount Simon.

The Mount Simon and Hinckley Sandstones yield most of the water produced from the aquifer. However, the Fond du Lac Formation, in combination with the Hinckley Sandstone, yields water north of the Twin Cities basin (Helgesen and others, 1973; Lindholm and others, 1974a). The Fond du Lac Formation is indistinguishable from the overlying Hinckley Sandstone north of the Twin Cities basin except for some limited areas (Lindholm and others, 1974b), and it has not been tapped by wells south of the basin because of its considerable depth below land surface. Not enough is known about the Fond du Lac Formation to rigorously classify it as either an aquifer or a confining unit. Therefore, in this report, the Fond du Lac Formation is excluded from the Mount Simon-Hinckley aquifer and is grouped with the underlying rocks (fig. 3).

MOVEMENT OF GROUND WATER

Movement of water in the Mount Simon-Hinckley aquifer is primarily from recharge areas on the west edge of the aquifer eastward to the St. Croix and Mississippi Rivers and southward to Iowa (fig. 6). Flow is locally toward smaller streams north of the Twin Cities basin. A ground-water divide that coincides with a topographic high north of the Twin Cities basin separates flow north and south (Delin and Woodward, 1982). In the Twin Cities basin, flow is toward the Minnesota River and a cone of depression in the western part of the Twin Cities Metropolitan Area. Withdrawals from many municipal, commercial, and industrial wells are the cause of the cone. South of the Twin Cities basin, the flow pattern is influenced by the Root River and other tributaries to the Mississippi River. The potentiometric surface appears to be flat throughout the interior of the aquifer where water-level data are scant. Along the western periphery and in the northern part of the aquifer, water enters the aquifer by infiltration through overlying drift. Elsewhere water enters the aquifer by vertical leakage through overlying bedrock aquifers and confining units.

Hydrologic Characteristics

The Mount Simon-Hinckley aquifer is continuous and is the most extensive of the bedrock units in southeast Minnesota. The structure of the aquifer is shown in figure 4. Although the aquifer is undeveloped as a source of water supply in much of the area, it is a good potential source because of (1) large quantities of water in storage, (2) adequate yields to wells, and (3) good water quality, with dissolved solids less than 1,000 mg/L. The hydrogeologic characteristics of the aquifer are different in the following areas: (1) the area north of the Twin Cities basin, where the Mount Simon Sandstone is absent and the Hinckley Sandstone and Fond du Lac Formation act as a single hydraulic unit, and (2) the remainder of the study area, where the Mount Simon Sandstone is present and the aquifer underlies the Eau Claire Sandstone or Cretaceous beds.

The transmissivity of the aquifer ranges from 270 to 9,400 ft^2/d and the hydraulic conductivity ranges from 2 to 23 ft/d (Kanivetsky and Walton, 1979). The average transmissivity and storage coefficient, determined from aquifer tests in the Twin Cities Metropolitan Area (Norvitch and others, 1973), was 2,600 ft^2/d and 2.8 x 10-3, respectively. The median hydraulic conductivity as determined by laboratory analyses was 0.48 ft/d north of the Twin Cities basin and 3.2 ft/d to the south.

The Hinckley Sandstone and Fond du Lac Formation produce enough water north of the Twin Cities basin for rural domestic and municipal water supplies. The Hinckley Sandstone is a permeable, medium- to coarse-grained sandstone as thick as 400 feet. It grades downward into the Fond du Lac Formation, which is a less permeable fine-grained sandstone containing siltstone and shale. Locally, the combined formations are hydraulically connected and as much as several thousand feet thick. Yields to wells in the upper sandstone generally range from 100 to 400 gal/min, but may reach 1,000 gal/min locally (Helgesen and others, 1973). Yields from the Fond du Lac in areas north of the Twin Cities basin, where the Fond du Lac can be distinguished from the Hinckley, range from 15 to 120 gal/min (Lindholm and others, 1974b).

Table 1.--Stratigraphic nomenclature for southeast Minnesota and general descriptions of the corresponding aquifers and confining beds

Stratigraphic nomenclature			Hydrogeology	
Erathem	Period or system	Geologic unit (group, formation, or bed)	Hydrogeologic unit (aquifers or confining beds)	Water-bearing characteristics and dominant lithology
Cenozoic	Quaternary	Drift	Surficial sand and gravel aquifer	Largly outwash, but includes alluvium along major streams and local ice-contact deposits. Slightly used, with additional development of supplies possible. High potential for contamination because the water table is at or near land surface. Yields as much as 1,000 gal/min in places.
			Confining beds	Till and clay of low permeability. Not a source of water to wells.
			Buried sand and gravel aquifers	Outwash and ice-contact deposits confined by till of low permeability. Slightly to moderately developed for water supplies with potential for additional development, especially in buried valleys. Yields range from 100 to 1,000 gal/min.
Mesozoic	Cretaceous	Cretaceous beds	Cretaceous confining beds	Shale beds of low permeability. Not a source of water.
			Cretaceous aquifer	Sandstone lenses near base of predominantly shale section. Slightly developed, may yield additional small supplies. Typical yields to wells are 5 to 50 gal/min, but may be as much as 250 gal/min. Water is highly mineralized, particularly in the basal units along the western border of the State.
Paleozoic	Devonian	Cedar Valley Limestone	Upper Carbonate aquifer	Limestone, dolomite, and dolomitic limestone. Major aquifer in the south-central part of embayment. Wells generally yield 200 to 500 gal/min from solution channels, joints, and fissures.
	Ordovician	Maquoketa Shale Dubuque Formation	Confining bed	Relatively impermeable shale, dolomitic limestone, and limestone. Platteville yields about 25 gal/min from local fractures and solution channels.
		Galena Dolomite Decorah Shale Platteville Limestone Glenwood Shale		
		St. Peter Sandstone	St. Peter aquifer	Fine- to medium-grained sandstone. A major aquifer, but seldom used for public supply because larger yields are available from wells in other aquifers. Typical yields range from 100 to 250 gal/min.
			St. Peter confining bed	Contains siltstone and shale that restrict vertical flow. Areal extent unknown. Not a source of water to wells.
		Prairie du Chien Group	Prairie du Chien-Jordan aquifer	Mainly dolomite and sandstone. The major aquifer in the area. Commonly yields 500 to 1,000 gal/min. Supplies 75 percent of water in Twin Cities metropolitan area. Karstic conditions are common in extreme southeast.
	Cambrian	Jordan Sandstone		
		St. Lawrence Formation Franconia Formation	Confining bed	Silty, sandy dolomite interbedded with layers of fine-grained sandstone and siltstone. Generally a poor source of water to wells; however, yields from the Franconia in the northwest part of the area are adequate for domestic use.
		Ironton Sandstone Galesville Sandstone	Ironton-Galesville aquifer	Very fine to coarse-grained sandstone interbedded with shale, siltstone, and dolomite; an important aquifer outside the limits of other major aquifers. Yields range from 250 to to 500 gal/min.
		Eau Claire Sandstone	Confining bed	Sandstone, siltstone and shale, gray to reddish brown. Normally not a source of water; however, sandstone beds may yield small quantities to wells in the south.
		Mount Simon Sandstone	Mount Simon-Hinckley aquifer	Thick sequence of sandstone, siltstone, and shale. The secondary aquifer in Twin Cities area and only bedrock aquifer in the northern part of the Hollandale embayment; little used for water supply in extreme southeast. Wells generally yield from 400 to 700 gal/min, but may be as much as 2,000 gal/min.
Precambrian	Proterozoic	Hinckley Sandstone		
		Fond du Lac Formation	Hydrologic properties little known	Fond du Lac Formation, in combination with Hinckley Sandstone, yields water north of the Twin Cities metropolitan area where the Mount Simon is absent. Elsewhere, the Fond du Lac is deeply buried and undeveloped as a source of water supply.
		Sedimentary, metamorphic, and igneous rocks	Hydrologic properties unknown	Lack of detailed subsurface information precludes evaluation of hydraulic characteristics.

The Mount Simon-Hinckley functions as a single aquifer in the Twin Cities basin (table 2). In the center of the basin, between the faults where the Hinckley is thin or missing and the Fond du Lac is absent, the thickness of the aquifer ranges from 150 to 200 feet. West of the basin, however, it is as much as 550 feet. Well yields are about 500 gal/min but yields may be as much as 2,000 gal/min locally (Norvitch and others, 1973).

Table 2.--Water-bearing characteristics of the aquifer in Minnesota

Region	Formations	Saturated thickness, in feet	Well yield, in gallons per minute	Altitude of aquifer formation surface, in feet above (+) or below (-) sea level
North of Twin Cities basin	Hinckley Sandstone and Fond du Lac Formation	200 to 400	Generally 100 to 400; maximum 1,000	+1,000 to +400
Twin Cities basin and area to the south	Mount Simon and Hinckley Sandstones	200 to 300	Generally 500; maximum 2,000	+800 to -300

South of the Twin Cities basin, the Mount Simon and Hinckley Sandstones are fine to coarse grained. The thickness of the combined Mount Simon and Hinckley Sandstones reaches a maximum of 350 feet along the Mississippi River; it averages about 200 feet over the rest of the area (fig. 5). Little information is available on the water-bearing characteristics of the lower part of the Fond du Lac and the underlying rocks, which may be permeable enough to yield several hundred gallons per minute to wells.

WATER USE

Water from the aquifer is used for domestic, municipal, industrial, and irrigation supplies. Logs of wells finished in the aquifer and data from Norvitch and others (1973) indicate the following:

1. Many wells have been drilled in the area north of the Twin Cities basin, where the aquifer is the uppermost bedrock unit and, locally, is the only aquifer. The aquifer is the principal source of domestic supplies in this area. In some agricultural areas, water from the aquifer is used extensively for irrigation (Lindholm, 1980).
2. Many wells tap the aquifer for municipal and industrial use in the Twin Cities Metropolitan Area and along the Mississippi River.
3. Only a few wells are found in the area south of the Twin Cities basin, especially in the interior area, where the aquifer is deeply buried and overlain by other highly productive aquifers at shallower depths.
4. The aquifer is little used in the southwest, where leakage from overlying Cretaceous rocks is highly mineralized.

Pumpage from the aquifer increased from a very small amount in the late 1800's to a peak of 80 billion gallons during the 1960's in the Minneapolis-St. Paul Metropolitan Area, where the pumpage is about three quarters of the statewide total for the aquifer (Horn, 1983). During 1970-80, municipal use accounted for more pumpage from the aquifer than other uses (fig. 7). Prior to 1970, pumpage was greatest for industrial use.

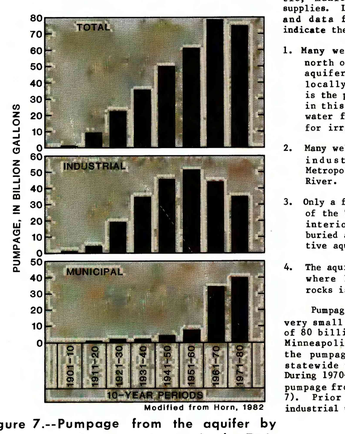


Figure 7.--Pumpage from the aquifer by major use category in the Twin Cities Metropolitan Area for 10-year periods from 1900 to 1980

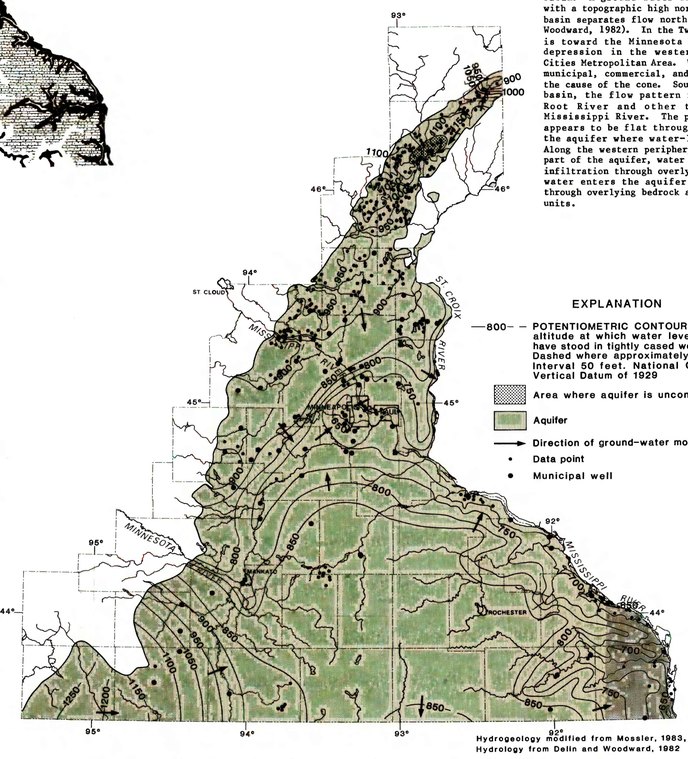


Figure 6.--Altitude and configuration of potentiometric surface, (1970-80)

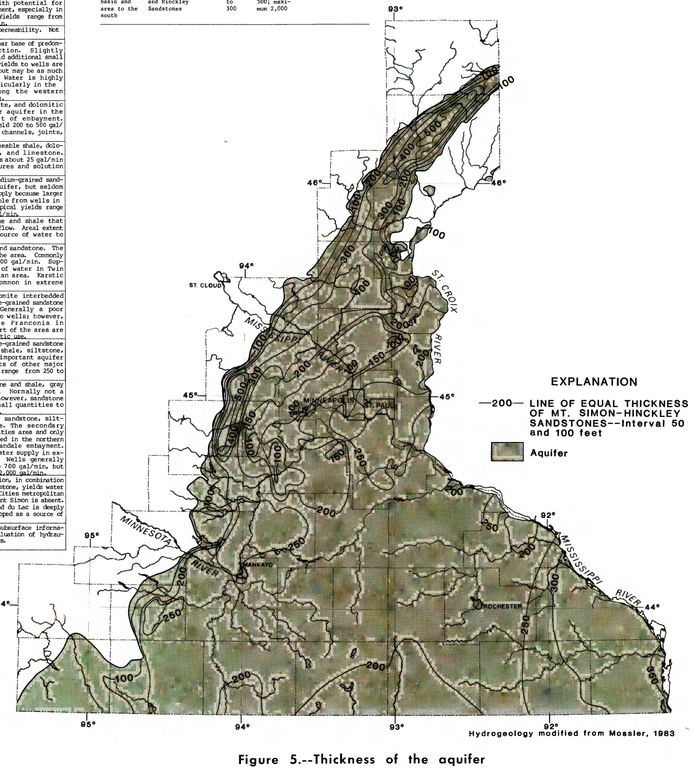


Figure 5.--Thickness of the aquifer

Base from U. S. Geological Survey
State base map, 1:1,000,000, 1965

HYDROGEOLOGIC AND WATER-QUALITY CHARACTERISTICS OF THE MOUNT SIMON-HINCKLEY AQUIFER, SOUTHEAST MINNESOTA

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