GEOLOGY AND GROUND–WATER QUALITY

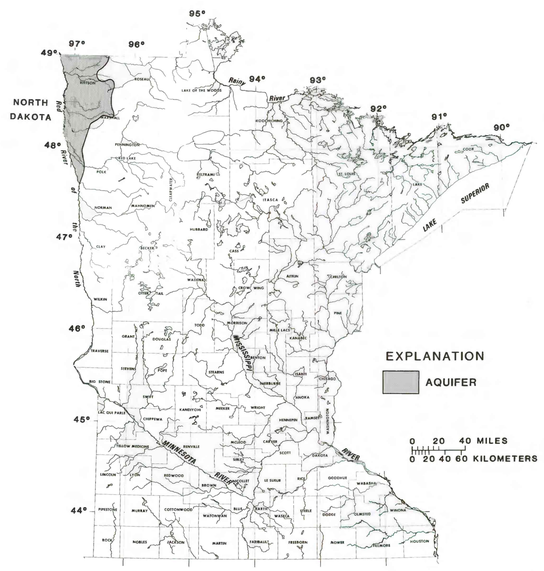


Figure 1.--Areal extent of aquifer in northwestern Minnesota

ABSTRACT

The Red River-Winnipeg aquifer of Ordovician age occupies a depression in the Proterozoic crystalline bedrock of northwestern Minnesota. The Winnipeg Formation, which underlies the Red River Formation, consists of two units: A lower shaley mudstone and an upper medium-grained sandstone. The Red River Formation consists of a lower dolomitic, dark-gray limestone and upper, slightly less-dolomitic, limestone. A porous zone at the top of the upper limestone yields most of the water to wells in the Red River-Winnipeg aquifer.

Ground water generally flows eastward through the aquifer from North Dakota and discharges upward to wells and to overlying deposits. Yields of wells open to the full thickness of the aquifer range from 100 to 250 gallons per minute. The water is unsuitable for most uses because of the high mineral content. Dissolved-solids concentrations range from about 3,000 milligrams per liter in the eastern part of the aquifer to about 60,000 milligrams per liter in the northwestern corner of Minnesota.

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 initial report of the study designated 14 aquifers in the State and provided general information about their geologic, hydrologic, and water-quality characteristics (Adolphson and others, 1982). This report, one in a series that describes individual aquifers in more detail, concerns the Red River-Winnipeg aquifer.

Stratigraphy

The Red River and Winnipeg Formations occupy a significant depression in the Proterozoic crystalline bedrock in northwest Minnesota (fig. 1). The formations consist predominantly of limestone, mudstone, sandstone, and shale of Ordovician age. Rocks of Cretaceous age and unconsolidated drift of Quaternary age overlie the Red River Formation (fig. 2). The rocks of the aquifer generally dip and thicken toward the Red River of the North (fig. 3), forming a regional, basin-shaped structure (figs. 4 and 5). The combined thickness of the formations ranges from about 400 to 500 feet, and is greatest at the Minnesota-North Dakota border in Kittson County (Maclay and others, 1972).

The overlying rocks are discontinuous; they generally are less than 50 feet thick and locally are less than 25 feet thick (Maclay and others, 1972). The drift, which ranges in total thickness from about 200 to 400 feet, is mostly till and, to a lesser extent, outwash, ice-contact deposits, and beach sand.

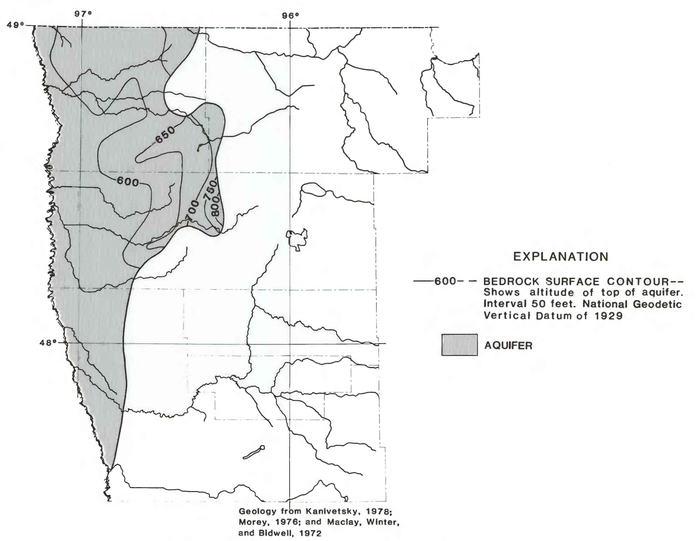
The Winnipeg Formation comprises two units. The lower unit, which is about 95 feet thick, comprises gray, red, purple, and green mottled and variegated shale and mudstone. Some thin beds of limestone are present, and a thin sandstone less than 10 feet thick is at the base of the shale sequence (Maclay and others, 1972). The upper unit is predominantly a well-sorted, medium-grained, friable sandstone about 70 feet thick. Thin beds of shale and well-cemented sand also are present in this unit.

The Red River Formation, which overlies the Winnipeg Formation, also comprises two units, as determined from a test hole near the northwestern corner of Minnesota (Maclay and others, 1972). The lower unit is a dark gray to purple slightly dolomitic limestone that is approximately 100 feet thick. The upper unit consists mostly of yellow or tan dolomitic limestone that is approximately 135 feet thick; it contains many solution channels and irregular cavities in the upper 40 feet.

Hydrologic Characteristics

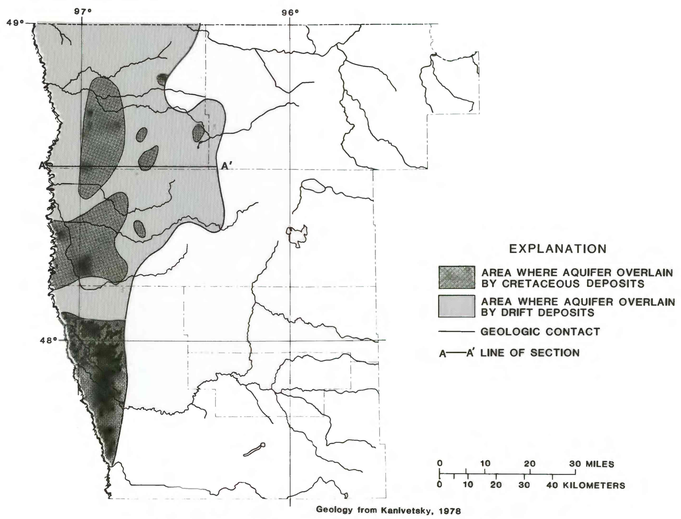
General information about the Red River-Winnipeg aquifer and other aquifers in the region is summarized in table 1. Little information about the hydrogeologic characteristics of the Red River-Winnipeg aquifer is available because of scant field data. Wells in the aquifer furnish water for livestock and fire protection. Water from the aquifer is not known to be used for other purposes because of high salinity. Wells open to the full thickness of the aquifer yield 100 to 250 gal/min of saline water (Maclay and others, 1972). Porous zones at the top of the upper dolomitic limestone unit in the Red River Formation and, to a lesser extent, in the upper sandstone unit of the Winnipeg Formation yield most of the water to wells. The lower limestone unit of the Red River Formation and the lower unit of the Winnipeg yield little water to wells. Hydraulic conductivity of the aquifer ranges from 3 to 8 ft/d (Kanivetsky and Walton, 1979).

Ground water in the Red River-Winnipeg aquifer generally flows eastward from corresponding Ordovician bedrock units in North Dakota. Part of the flow discharges upward into overlying Cretaceous sediments and glacial lake plain deposits because of confined conditions in the aquifer (fig. 3). Water is under sufficient head to flow freely from wells, particularly in the eastern part of the study area where the aquifer pinches out against underlying crystalline bedrock. Test wells open to the aquifer have yielded flows up to 60 gal./min. (Maclay and others, 1972).



Geology from Kanivetsky, 1978; Morey, 1976; and Maclay, Winter, and Bidwell, 1972

Figure 4.--Altitude of the top of the aquifer



Geology from Kanivetsky, 1978

Figure 2.--Areal extent of overlying deposits on the aquifer

Table 1.--Summary of ground-water conditions for aquifers in northwest Minnesota

Aquifer	Occurrence and lithology	Thickness, in feet	Yields to individual wells, in gallons per minute	Water quality	Present and potential development	Problems
Surficial outwash deposits	Beach ridges consisting of unconsolidated fine- to medium-grained sand.	35	Commonly 5 to 20, locally may be as high as 100.	Dissolved-solids concentration generally less than 500 mg/L. Very hard; high iron.	Used for domestic and stock supplies. Will support some additional development.	Wells in sandy beach ridges may go dry in summer. Easily contaminated.
	Outwash and ice contact consisting of sand and gravel.	Generally 20 to 80. Maximum 100.	Commonly several hundred, locally greater than 1,000.		Used for domestic and stock supplies. Being developed for irrigation supplies. Will support considerable additional development.	Easily contaminated. Extensive development will lower lake levels and decrease streamflow.
Buried outwash	Lenses of fine to coarse sand and gravel in till or lake sediments.	Generally less than 50. Maximum 100.	Commonly 10 to 40, several hundred in some areas.	Dissolved solids generally greater than 500 mg/L; may be several thousand. Very hard except in lake plain along the western side of the study area. High iron, high chloride in northwest part.	Used for public supply as well as domestic and stock. Will support additional development but amount unknown.	High mineralization limits use in some areas. Requires extensive test drilling to locate large supply. High hydraulic head, if unexpected, complicates well completion; flowing wells can be developed locally.
Cretaceous deposits	Lenses of fine to coarse sandstone in shale.	50	Commonly less than 10; 100 to 200 locally in southern part of basin.	Dissolved solids to 2,000 mg/L. Unsuitable for some uses.	Used for public supply along Red River where drift is inadequate. May support some additional development.	High mineralization limits use.
Red River-Winnipeg	Bedded sandstone and limestone.	500	100 to 250	Dissolved solids 3,000 to 60,000 mg/L (saline). Unsuitable for most uses.	Sparingly used. Quality presently prohibits most uses. Large supply available if quality not important.	Highly mineralized. Saline in places.
Precambrian	Crystalline metamorphic rocks.	Unknown.	Yields little water.	Unknown.	Unused.	Not applicable.

Modified from Lindholm and Norvitch, 1976.

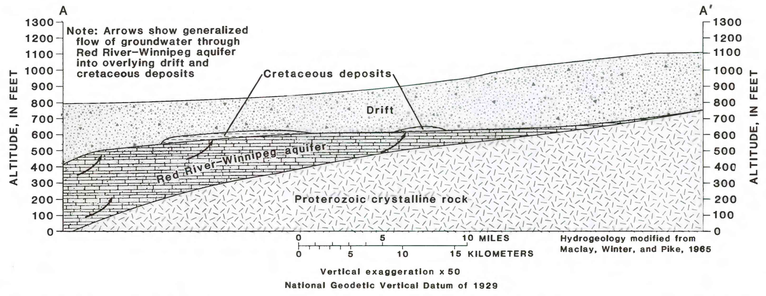
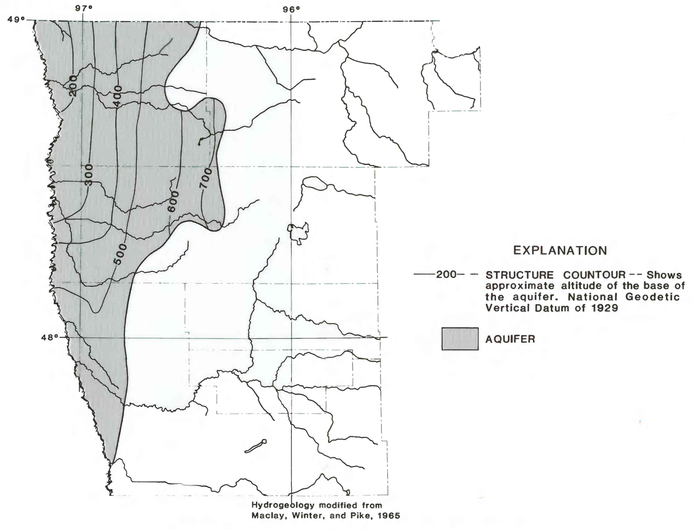


Figure 3.--Generalized hydrogeologic section of drift and bedrock units in northwest Minnesota

CONVERSION FACTORS

For use by readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
foot per day (ft/d)	0.305	meter per day (m/d)



Hydrogeology modified from Maclay, Winter, and Pike, 1965

Figure 5.--Altitude of the base of the aquifer

HYDROGEOLOGIC AND WATER–QUALITY CHARACTERISTICS OF THE RED RIVER–WINNIPEG AQUIFER, NORTHWESTERN MINNESOTA

BY
J. F. RUHL AND D. G. ADOLPHSON, 1986

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