STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS

COUNTY ATLAS SERIES
ATLAS C-14, PART B, PLATE 8 OF 10
Hydrogeology of the Unconsolidated and Bedrock Aquifers

HYDROGEOLOGY OF THE UNCONSOLIDATED AND BEDROCK AQUIFERS

By

Todd A. Petersen

2005

POTENTIOMETRIC SURFACE OF THE JORDAN AQUIFER AND THE WATER TABLE IN THE QUATERNARY SAND AND GRAVEL AQUIFER

Cross sections shown on Plate 9

Modeled water-table elevation of the Quaternary aquifer

Elevation of water table in Quaternary geologic material (in feet above mean sea level)

951–1000	751–800
901–950	701–750
851–900	651–700
801–850	

Potentiometric contour of the Jordan aquifer

— 900 — Potentiometric contour of the Jordan aquifer in feet above mean sea level. Contour interval is 25 feet. Line is dashed where uncertain.

Extent of Jordan Sandstone

MAP EXPLANATION

Well symbols and labels

Shape indicates aquifer. Larger symbol ●, well sampled for water chemistry; smaller symbol •, water-level data taken from the County Well Index.

- Quaternary water-table and buried unconfined aquifers
- Jordan
- St. Lawrence
- St. Lawrence-Franconia
- Franconia
- Franconia-Ironton-Galesville
- Ironton-Galesville

Color indicates tritium age

- Recent—Water entered the ground since about 1953 (10 or more tritium units).
- Mixed—Water is a mixture of recent and vintage waters (greater than 1 tritium unit to less than 10 tritium units).
- Vintage—Water entered the ground before 1953 (less than or equal to 1 tritium unit).
- Well or spring not sampled for tritium.

5.5 If shown, nitrate-nitrogen concentration equals or exceeds 3 parts per million.

9.1 If shown, chloride concentration equals or exceeds 5 parts per million.

2000 If shown, ground-water age in years, estimated by carbon-14 isotope analysis.

Map symbols

Bedrock aquifer unconfined at well

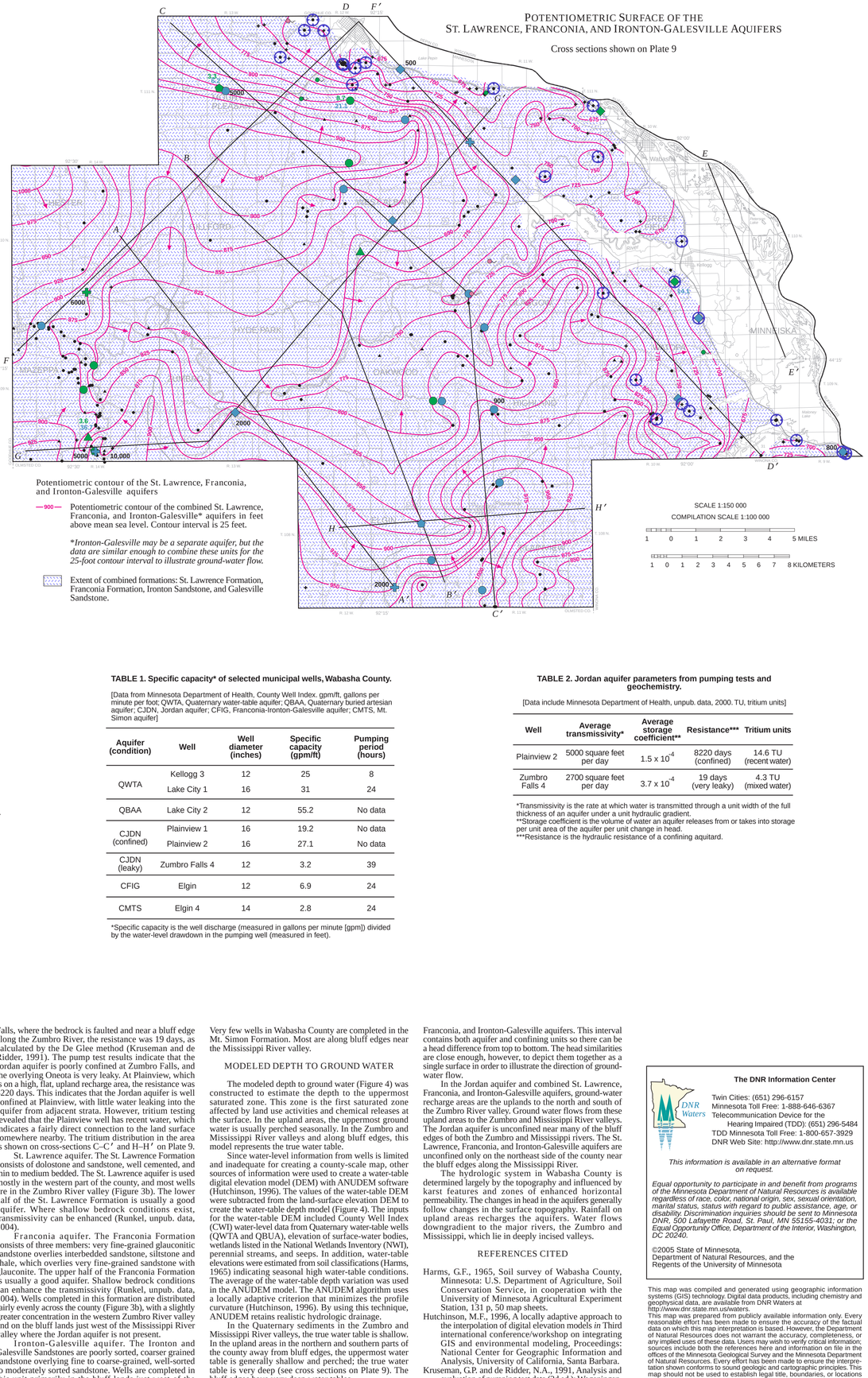
Spring; sample collected for chemical analysis; color indicates tritium age.

F___F′ Line of cross section

Arrow indicates the general direction of ground-water movement.

POTENTIOMETRIC SURFACE OF THE ST. LAWRENCE, FRANCONIA, AND IRONTON-GALESVILLE AQUIFERS

Cross sections shown on Plate 9



Potentiometric contour of the St. Lawrence, Franconia, and Ironton-Galesville aquifers

— 900 — Potentiometric contour of the combined St. Lawrence, Franconia, and Ironton-Galesville* aquifers in feet above mean sea level. Contour interval is 25 feet.

**Ironton-Galesville may be a separate aquifer, but the data are similar enough to combine these units for the 25-foot contour interval to illustrate ground-water flow.*

Extent of combined formations: St. Lawrence Formation, Franconia Formation, Ironton Sandstone, and Galesville Sandstone.

SCALE 1:150 000

COMPILATION SCALE 1:100 000

1 0 1 2 3 4 5 MILES

1 0 1 2 3 4 5 6 7 8 KILOMETERS

FIGURE 1. *Upland and river valley areas of Wabasha County.*

Geologic Unit		Aquifer	Hydrologic Condition
Quaternary deposits		Sand and gravel	Unconfined in major river valleys. Localized confined, buried sands.
St. Peter Sandstone		St. Peter aquifer	Present only locally on bedrock highs. No longer used.
Shakopee Formation	Prairie du Chien Group	Prairie du Chien aquifer	Confined in southern part of county and part of Zumbro River valley; mostly unconfined elsewhere.
Oneota Dolomite	Prairie du Chien Group		Under "deep" conditions, Oneota can act as confining unit and is not an aquifer.
Jordan Sandstone		Jordan aquifer	Mostly confined aquifer; unconfined near bluff edges.
St. Lawrence Formation		St. Lawrence-Franconia aquifer	Under "deep" conditions, can be confining unit.
Franconia Formation			Mostly confined aquifer.
Franconia Formation (lower)			Confining unit; fractured near bluff edges.
Ironton and Galesville Sandstones		Ironton-Galesville aquifer	Mostly confined aquifer.
Eau Claire Formation		Eau Claire aquifer	Mostly confined aquifer. Under "deep" conditions, Eau Claire can act as confining unit.
Mt. Simon Sandstone		Mt. Simon aquifer	Mostly confined aquifer.

FIGURE 2. *Sequence of geologic units and aquifers in Wabasha County. The middle column shows that some rock units are aquifers or confining units wherever they exist in the county. Other rock units such as the Oneota Dolomite and the Eau Claire Formation are aquifers only under shallow bedrock conditions (overlain by less than 200 feet of bedrock or near bluff edges). The lower St. Lawrence and upper Franconia Formations are low-yielding aquifers under deep conditions (overlain by more than 200 feet of bedrock); they are better aquifers under shallow conditions due to the development of secondary porosity.*

EXPLANATION

Aquifer use area

- Quaternary sand and gravel
- Jordan
- St. Lawrence and Franconia
- Ironton-Galesville

Well symbol

Shape or color of well symbol indicates aquifer.

- Quaternary
- Jordan
- St. Lawrence
- St. Lawrence-Franconia
- Franconia
- Franconia-Ironton-Galesville
- Ironton-Galesville

FIGURE 3. *Distribution of aquifer use. The aquifers in the county have distinct use areas, although use areas may overlap. Figure 3a indicates the Quaternary aquifer and Jordan aquifer use areas. Figure 3b shows the other major bedrock aquifer use areas, St. Lawrence, Franconia, and Ironton-Galesville aquifers. Most domestic wells are typically drilled only to a depth needed to provide adequate water supply and comply with the state well code.*

TABLE 1. Specific capacity* of selected municipal wells, Wabasha County.

[Data from Minnesota Department of Health, County Well Index. gpm/ft, gallons per minute per foot; QWTA, Quaternary water-table aquifer; QBAA, Quaternary buried artesian aquifer; CJDN, Jordan aquifer; CFIG, Franconia-Ironton-Galesville aquifer; CMTS, Mt. Simon aquifer]

Aquifer (condition)	Well	Well diameter (inches)	Specific capacity (gpm/ft)	Pumping period (hours)
QWTA	Kellogg 3	12	25	8
	Lake City 1	16	31	24
QBAA	Lake City 2	12	55.2	No data
CJDN (confined)	Plainview 1	16	19.2	No data
	Plainview 2	16	27.1	No data
CJDN (leaky)	Zumbro Falls 4	12	3.2	39
CFIG	Elgin	12	6.9	24
CMTS	Elgin 4	14	2.8	24

*Specific capacity is the well discharge (measured in gallons per minute [gpm]) divided by the water-level drawdown in the pumping well (measured in feet).

TABLE 2. Jordan aquifer parameters from pumping tests and geochemistry.

[Data include Minnesota Department of Health, unpub. data, 2000. TU, tritium units]

Well	Average transmissivity*	Average storage coefficient**	Resistance***	Tritium units
Plainview 2	5000 square feet per day	1.5×10^{-4}	8220 days (confined)	14.6 TU (recent water)
Zumbro Falls 4	2700 square feet per day	3.7×10^{-4}	19 days (very leaky)	4.3 TU (mixed water)

*Transmissivity is the rate at which water is transmitted through a unit width of the full thickness of an aquifer under a unit hydraulic gradient.
**Storage coefficient is the volume of water an aquifer releases from or takes into storage per unit area of the aquifer per unit change in head.
***Resistance is the hydraulic resistance of a confining aquitard.

INTRODUCTION

Ground-water supplies in Wabasha County are pumped from nine bedrock aquifers and surficial sand and gravel aquifers. Two very different ground-water systems exist in the county: the river valley system and the upland area system (Figure 1).

The Mississippi and Zumbro River valleys were both deeply incised and aggraded during the Pleistocene Epoch of the Quaternary, the youngest geologic period. The valley fill consists largely of sand and gravel deposits or glacial outwash (Plate 3, Part A). Most wells in the Mississippi and Zumbro River valleys are completed in this Quaternary sediment.

In the upland areas of the county, north and south of the Zumbro River, most wells are completed in bedrock. The Jordan Sandstone is the most commonly used bedrock aquifer, followed by the Franconia Formation. The relationships between geologic units and aquifers, as well as the hydrologic conditions of those aquifers, are shown in Figure 2.

Most of the upper bedrock aquifers, Jordan and above, are often under shallow bedrock conditions: less than 200 feet of overlying bedrock (Runkel and others, 2003). Generally, areas of bedrock that are within 200 feet of the bedrock surface contain more fractures and other secondary porosity than more deeply buried bedrock. Because of this, some bedrock units under shallow conditions have higher hydraulic conductivity and are better aquifers than the same formation that has more than 200 feet of overlying bedrock, which Runkel and others (2003) call deep conditions. Most tested wells that are completed in the Prairie du Chien Group or Jordan Sandstone have relatively young water based on tritium content. Most of the wells completed in the Franconia Formation or lower rock units have older (vintage) water with little or no tritium content. Wells completed in the Franconia Formation near bluff edges often have mixed water based on tritium content.

CHARACTERISTICS OF MAJOR AQUIFERS

Aquifer yields can be compared by using specific capacity information from high-volume wells (Table 1). Based on very limited data, the Quaternary aquifers (both water table and buried artesian) and the Jordan aquifer have the highest specific capacities. The Franconia-Ironton-Galesville aquifer has a much lower specific capacity. The one well test in the Mt. Simon aquifer indicates it has the lowest specific capacity of all aquifer test results from municipal wells.

The following geologic unit descriptions are based on Plates 2 and 3, Part A.

Quaternary sand and gravel aquifer. The Quaternary sand and gravel aquifer is present only in the major valleys of the Zumbro and Mississippi rivers. The aquifer is generally productive, and it is used for both municipal and domestic supply.

Prairie du Chien aquifer. The Prairie du Chien aquifer is the uppermost bedrock aquifer currently in use. There are only a few wells, mostly older domestic and farm wells, completed in the Prairie du Chien Group. The Prairie du Chien Group consists of the Shakopee Formation and the Oneota Dolomite. The Shakopee Formation contains interbedded dolostone and sandstone overlying a sandstone. The Oneota Dolomite has thicker dolostone beds overlying interbedded sandstone and sandy dolostone. The Prairie du Chien aquifer is usually the uppermost bedrock aquifer, and in most of the county there is little overlying Quaternary sediment. It is usually unconfined. Because there is little overlying bedrock, this aquifer usually exists under shallow bedrock conditions (Runkel and others, 2003). When under shallow bedrock conditions, the entire Prairie du Chien Group is somewhat permeable. In areas where the Oneota Dolomite is partially or completely under deep conditions, it acts as a confining unit (Figure 2).

Karst and paleokarst occur in both the Shakopee Formation and the Oneota Dolomite (Plate 5, Part A). These conditions can greatly increase the horizontal and vertical permeability of the Prairie du Chien aquifer.

Jordan aquifer. The Jordan Sandstone is an upward coarsening sequence of two facies: (1) a quartzose, friable sandstone and (2) a feldspathic fine-grained sandstone. The Jordan aquifer is the second most used aquifer in Wabasha County (Figure 3a). Wells completed in the Jordan Sandstone are found predominantly in the western two-thirds of the county, except in the extreme western portion of the Zumbro River valley, where it is eroded. The Jordan aquifer is typically fully saturated, but on the eastern side of the county and near the Zumbro River, the Jordan aquifer becomes dewatered near the bluff edges and is no longer an aquifer.

Two pumping tests in the Jordan aquifer were done by the Minnesota Department of Health (unpub. data, 2000) for the cities of Zumbro Falls and Plainview (Table 2). The calculated transmissivity and storage coefficients were similar in both tests, but the resistance of the overlying confining unit was very different. At Zumbro Falls, where the bedrock is faulted and near a bluff edge along the Zumbro River, the resistance was 19 days, as calculated by the De Glee method (Kruseman and de Ridder, 1991). The pump test results indicate that the Jordan aquifer is poorly confined at Zumbro Falls, and the overlying Oneota is very leaky. At Plainview, which is on a high, flat, upland recharge area, the resistance was 8220 days. This indicates that the Jordan aquifer is well confined at Plainview, with little water leaking into the aquifer from adjacent strata. However, tritium testing revealed that the Plainview well has recent water, which indicates a fairly direct connection to the land surface somewhere nearby. The tritium distribution in the area is shown on cross-sections C–C′ and H–H′ on Plate 9.

St. Lawrence aquifer. The St. Lawrence Formation consists of dolostone and sandstone, well cemented, and thin to medium bedded. The St. Lawrence aquifer is used mostly in the western part of the county, and most wells are in the Zumbro River valley (Figure 3b). The lower half of the St. Lawrence Formation is usually a good aquifer. Where shallow bedrock conditions exist, transmissivity can be enhanced (Runkel, unpub. data, 2004).

Franconia aquifer. The Franconia Formation consists of three members: very fine-grained glauconitic sandstone overlies interbedded sandstone, siltstone and shale, which overlies very fine-grained sandstone with glauconite. The upper half of the Franconia Formation is usually a good aquifer. Shallow bedrock conditions can enhance the transmissivity (Runkel, unpub. data, 2004). Wells completed in this formation are distributed fairly evenly across the county (Figure 3b), with a slightly greater concentration in the western Zumbro River valley and on the bluff lands just west of the Mississippi River valley where the Jordan aquifer is not present.

Ironton-Galesville aquifer. The Ironton and Galesville Sandstones are poorly sorted, coarser grained sandstone overlying fine to coarse-grained, well-sorted to moderately sorted sandstone. Wells are completed in this unit primarily in the bluff lands just west of the Mississippi River and in the Zumbro River valley (Figure 3b).

Eau Claire aquifer. The Eau Claire Formation consists of sandstone, siltstone, and shale interbedded in thin to medium beds. Less than 1 percent of Wabasha County wells are completed in the Eau Claire Formation. All wells completed in the Eau Claire Formation are near bluff edges.

Mt. Simon aquifer. The Mt. Simon Sandstone consists of friable, fine to coarse-grained quartz sandstone. Very few wells in Wabasha County are completed in the Mt. Simon Formation. Most are along bluff edges near the Mississippi River valley.

MODELED DEPTH TO GROUND WATER

The modeled depth to ground water (Figure 4) was constructed to estimate the depth to the uppermost saturated zone. This zone is the first saturated zone affected by land use activities and chemical releases at the surface. In the upland areas, the uppermost ground water is usually perched seasonally. In the Zumbro and Mississippi River valleys and along bluff edges, this model represents the true water table.

Since water-level information from wells is limited and inadequate for creating a county-scale map, other sources of information were used to create a water-table digital elevation model (DEM) with ANUDEM software (Hutchinson, 1996). The values of the water-table DEM were subtracted from the land-surface elevation DEM to create the water-table depth model (Figure 4). The inputs for the water-table DEM included County Well Index (CWI) water-level data from Quaternary water-table wells (QWTA and QBUA), elevation of surface-water bodies, wetlands listed in the National Wetlands Inventory (NWI), perennial streams, and seeps. In addition, water-table elevations were estimated from soil classifications (Harms, 1965) indicating seasonal high water-table conditions. The average of the water-table depth variation was used in the ANUDEM model. The ANUDEM algorithm uses a locally adaptive criterion that minimizes the profile curvature (Hutchinson, 1996). By using this technique, ANUDEM retains realistic hydrologic drainage.

In the Quaternary sediments in the Zumbro and Mississippi River valleys, the true water table is shallow. In the upland areas in the northern and southern parts of the county away from bluff edges, the uppermost water table is generally shallow and perched; the true water table is very deep (see cross sections on Plate 9). The bluff edges have very deep water tables.

POTENTIOMETRIC SURFACES OF THE UPPERMOST WATER-SUPPLY BEDROCK AQUIFERS

The map on the upper left shows the potentiometric surface of the Jordan aquifer (contour lines) and the water table in the Quaternary sand and gravel aquifer (colored surface). The map on the upper right shows the potentiometric surface of the combined St. Lawrence, Franconia, and Ironton-Galesville aquifers. This interval contains both aquifer and confining units so there can be a head difference from top to bottom. The head similarities are close enough, however, to depict them together as a single surface in order to illustrate the direction of ground-water flow.

In the Jordan aquifer and combined St. Lawrence, Franconia, and Ironton-Galesville aquifers, ground-water recharge areas are the uplands to the north and south of the Zumbro River valley. Ground water flows from these upland areas to the Zumbro and Mississippi River valleys. The Jordan aquifer is unconfined near many of the bluff edges of both the Zumbro and Mississippi rivers. The St. Lawrence, Franconia, and Ironton-Galesville aquifers are unconfined only on the northeast side of the county near the bluff edges along the Mississippi River.

The hydrologic system in Wabasha County is determined largely by the topography and influenced by karst features and zones of enhanced horizontal permeability. The changes in head in the aquifers generally follow changes in the surface topography. Rainfall on upland areas recharges the aquifers. Water flows downgradient to the major rivers, the Zumbro and Mississippi, which lie in deeply incised valleys.

REFERENCES CITED

Harms, G.F., 1965, Soil survey of Wabasha County, Minnesota: U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the University of Minnesota Agricultural Experiment Station, 131 p, 50 map sheets.

Hutchinson, M.F., 1996, A locally adaptive approach to the interpolation of digital elevation models *in* Third international conference/workshop on integrating GIS and environmental modeling, Proceedings: National Center for Geographic Information and Analysis, University of California, Santa Barbara.

Kruseman, G.P. and de Ridder, N.A., 1991, Analysis and evaluation of pumping test data (2d ed.): Wageningen, The Netherlands International Institute for Land Reclamation and Improvement, p. 76-78.

Runkel, A.C., Tipping, R.G., Alexander, E.C., Jr., Green, J.A., Mossler, J.H., Alexander, S.C., 2003, Hydrogeology of the Paleozoic bedrock in southeastern Minnesota: Minnesota Geological Survey, Report of Investigations 61, 105 p., 2 pls.

MAP EXPLANATION

Modeled depth to ground water (in feet below land surface)

- No data available
- 0–20
- 20–50
- 50–100
- 100–200
- Greater than 200
- Body of water
- Land not included in depth model

F F′ Line of cross section

FIGURE 4. *Modeled depth to ground water. This model is an estimate of the depth to the first saturated zone. In the upland areas, this model represents the depth to a perched water table; the true water table is much deeper (see Plate 9 cross sections). In the Zumbro and Mississippi River valleys and along bluff edges, this model represents the depth to the true water table.*

The DNR Information Center

Twin Cities: (651) 296-6157
Minnesota Toll Free: 1-888-646-6367
Telecommunication Device for the Hearing Impaired (TDD): (651) 296-5484
TDD Minnesota Toll Free: 1-800-657-3929
DNR Web Site: http://www.dnr.state.mn.us

This information is available in an alternative format on request.

This map was compiled and generated using geographic information systems (GIS) technology. Digital data products, including chemistry and geophysical data, are available from DNR Waters at http://www.dnr.state.mn.us/waters
This map was prepared from publicly available information only. Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based. However, the Department of Natural Resources does not warrant the accuracy, completeness, or any implied uses of these data. Users may wish to verify critical information; sources include both the references here and information on file in the offices of the Minnesota Geological Survey and the Minnesota Department of Natural Resources. Every effort has been made to ensure the interpretation shown conforms to sound geologic and cartographic principles. This map should not be used to establish legal title, boundaries, or locations of improvements.
Digital base composite
Roads and county boundaries - Minnesota Department of Transportation GIS Statewide Base Map (source scale 1:24,000)
Hydrologic features - U.S. Geological Survey Digital Line Graphs (source scale 1:100,000)
Digital base annotation - Minnesota Geological Survey
Project data compiled from 2003 to 2004 at a scale of 1:100,000. Universal Transverse Mercator projection, grid zone 15, 1983 North American datum. Vertical datum is mean sea level.
GIS and cartography by Todd Petersen and Greg Massaro. Edited by Nick Kroska.

GEOLOGIC ATLAS OF WABASHA COUNTY, MINNESOTA