Groundwater Atlas User Guide

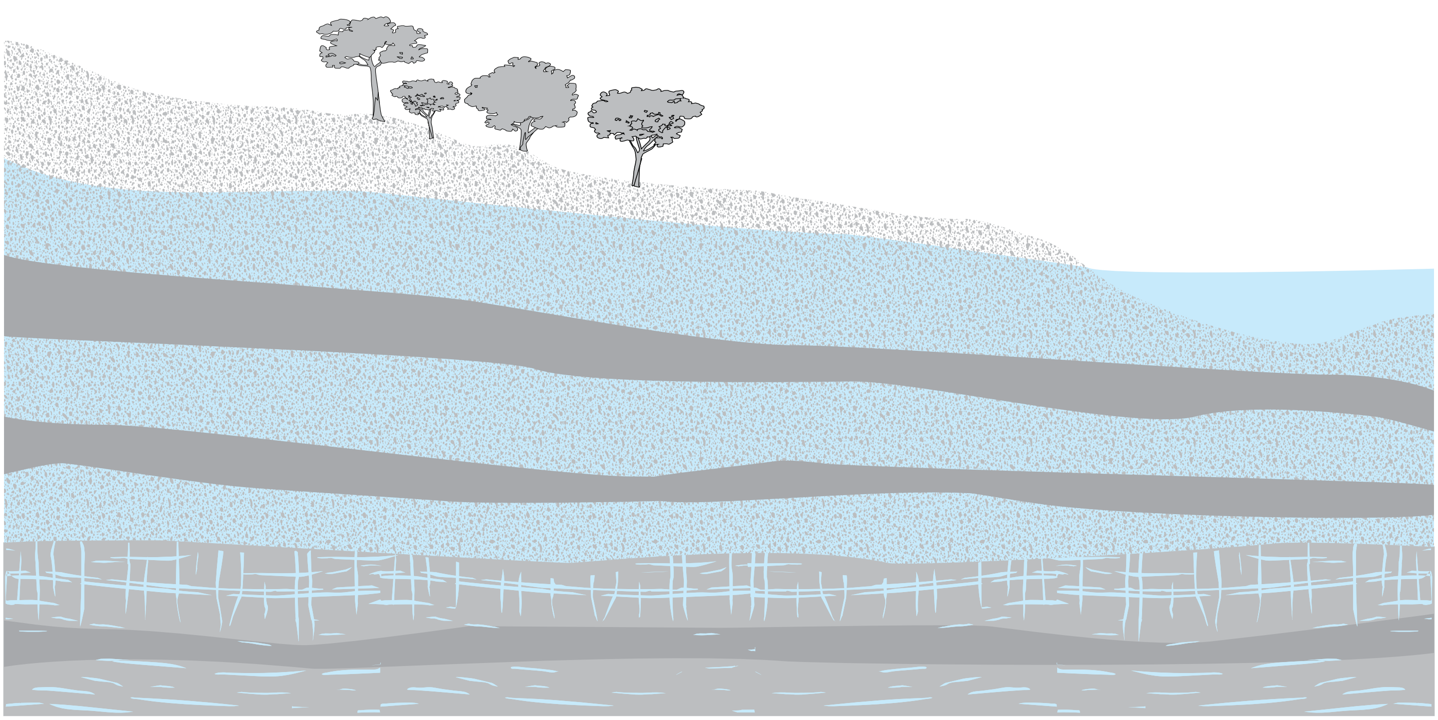
For Part B of the Minnesota County Atlas Series

DEPARTMENT OF NATURAL RESOURCES

St. Paul, March 2021

mndnr.gov/groundwatermapping

For Part A information see the
Minnesota Geological Survey: County Geologic Atlas Program
and the Geologic Atlas User Guide



Groundwater primer

This guide was created to help use a **County Groundwater Atlas (Part B).** The end of this document contains information on both parts A and B of the county atlases, how they are created, and where to find more information. This page begins with a foundation.

Aquifers and aquitards are defined by how they were formed, by the geologic characteristics of the sediment and bedrock. After precipitation filters through the topsoil, water is held in the spaces (pores) between grains of sediment, in bedrock fractures, or in limestone conduits.

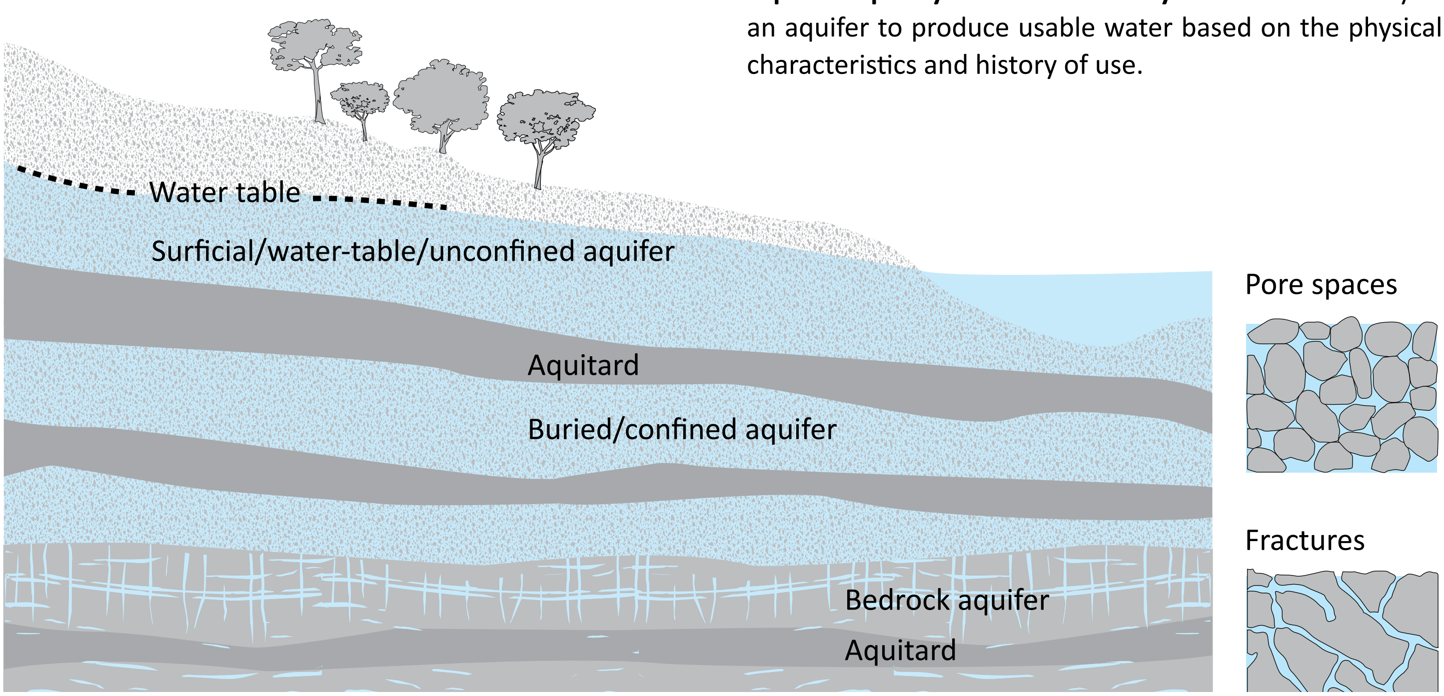
Aquifers hold enough water to allow pumping for practical use. More productive aquifers have a higher volume of pores (porosity) that are more connected (permeability). They generally contain coarser grains like sand and gravel or have fractures from ancient weathering. These qualities facilitate the movement of water through an aquifer.

Surficial or *water-table aquifers* are *unconfined* and readily affected by activity on the surface.

Buried aquifers are *confined* between aquitards.

Aquitards or **confining layers** slow water infiltration from the surface because they are made of finer material (silt and clay). This limits the porosity and permeability and can protect the aquifers below from surface contamination. The best protection comes from aquitards that are thick, continuous, fine in texture, or have little fracturing. The more aquitards above an aquifer, the better the protection.

Figure 1. Groundwater elements



Confining layers put aquifers under pressure, affecting **groundwater flow direction.** Groundwater typically flows with gravity and away from pressure. Mapping the hydraulic head of wells can help predict flow direction to wells, lakes, and rivers, and can indicate paths of contamination.

Certain **groundwater conditions** can redirect typical flow. Examples include aquifer connections to surface water or shallower aquifers, lateral or upward flow, or drops in pressure caused by high-volume pumping.

Water chemistry provides clues about the path the water has traveled. Some chemicals travel with water from the surface unchanged. Others are dissolved out of rock on the way to an aquifer.

The chemistry provides information on when the water entered the ground (residence time), travel time (pollution sensitivity), connections between aquifers (groundwater conditions), interaction with surface water (evaporative signatures), possible sources of contamination (recharge sources), and areas of concern for human health.

Groundwater that entered the surface long ago indicates slow travel time. This longer **residence time** can indicate that modern contaminants have not reached the aquifer, but also that the recharge is slow and that this limited resource should be managed wisely.

Pollution sensitivity of an aquifer is based on the time it takes water to flow through various types and thicknesses of soils and geologic materials. Pollutants are assumed to travel with water at the same rate.

Aquifer capacity and transmissivity indicates the ability of an aquifer to produce usable water based on the physical characteristics and history of use.

Aquifer mapping

Figure 2. Aquifer maps

Aquifers are mapped by layers of similar geology.

The horizontal maps represent aquifers (Figures 4 and 5).

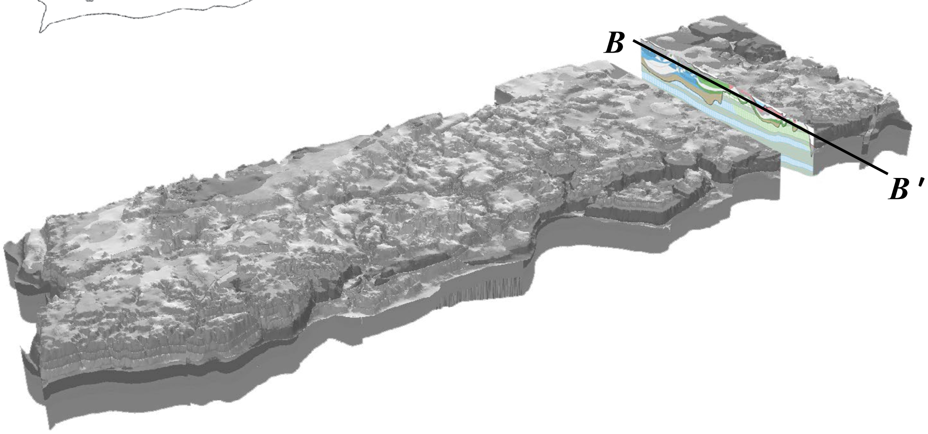
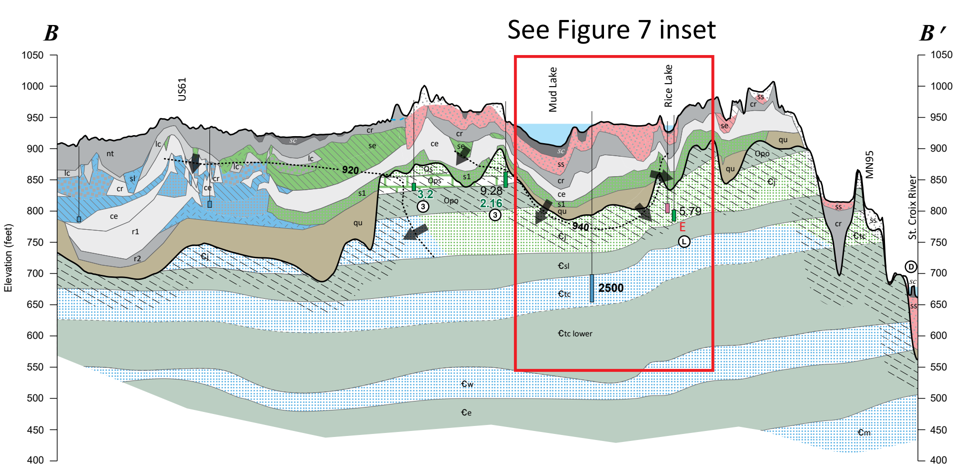


Figure 3. Cross sections

Cross sections represent vertical slices of a county and illustrate the aquifer and aquitard distribution in a third dimension (inset detail is in Figure 7).



Navigating a groundwater atlas

The following pages summarize atlas topics and give an approach to reading the maps for a project. It includes what to look for, where to find it, what it means, and some examples.

Keep in mind that the atlases are only generalized interpretations based on the limited number of wells that could be sampled. Once you have evaluated an area you should proceed with a more localized investigation.

Locate the aquifers

Aquifers are represented and described throughout the atlases in several ways.

- The **Geology and physical hydrogeology** section describes the geological makeup. More detail is in the **Part A geologic atlas**.
- The **maps** name the aquifers in the figure captions, show coverage area with colors and patterns, indicate groundwater flow directions with arrows, and symbolize wells by aquifer.
- The **stratigraphic column** shows the vertical position of the aquifers and aquitards in relation to the geologic layers (Figure 6).
- The **hydrogeologic cross sections** represent aquifers with patterns, and with colors indicating residence time (Figure 7).

Are the aquifers sensitive to pollution?

Aquifers are least sensitive when they are confined under multiple aquitards that slow the flow of water from the surface (lower the hydraulic conductivity). Look for aquitards that are thick and continuous, and are composed of finer-grained material or have few fractures. Ensure there are no breaks or connections to surface-water bodies (lakes and open water wetlands) or other more sensitive aquifers.

- The **stratigraphic column** (Figure 6) and the **hydrogeologic cross sections** (Figures 3 and 7) indicate hydraulic conductivity in solid shades of color.
- **Pollution sensitivity** maps indicate sensitivity ratings of areas by color.
- **Groundwater flow direction** is indicted with arrows, illustrating how groundwater moves due to gravity and pressure. This gives clues to the recharge sources and discharge areas, and helps evaluate the path of potential contamination.
- **Groundwater conditions** present possible scenarios for groundwater movement, especially when contrary to typical gravity and pressure. Groundwater conditions are symbolized by circled letters or numbers, described in the legend, and detailed in the main text.

What does the chemistry indicate?

Groundwater chemistry can act as tracers from the surface or indicate what is resident in the ground. It can indicate groundwater travel speed and direction, confirm pollution sensitivity ratings, and identify areas of health concern for drinking water.

- The **Groundwater recharge sources** section indicates known aquifer connections to surface water. If found, the *evaporative signatures* are indicated on maps with a red "E" and are explained in a graph with text. This type of recharge commonly moves more rapidly through thin aquitards or gaps, penetrating from shallow sensitive aquifers into deeper aquifers.
- **Residence time** indicates when precipitation entered the ground. Shorter (recent/modern) time generally indicates greater potential for aquifer contamination.

  It is represented in **tritium age** depicted by color in the well symbols and aquifer patterns on the cross sections.

  Longer residence times may be represented by bold **carbon-14** number values near the well symbols.
- **Elevated chemistry values** can indicate greater sensitivity to pollution (e.g., chloride or nitrate from the surface) and/or possible drinking water health concerns (e.g., arsenic or manganese from the local geology). These are indicated with color-coded number values near the well symbols.

  If shown, values are above a certain level as indicated in the water chemistry section.

Are the aquifers productive?

The **aquifer characteristics and groundwater use** section outlines output results from historical wells and aquifer tests and gives an indication of what to expect.

Check both dimensions

The **hydrogeologic cross sections** represent vertical slices of the earth in a third dimension (Figures 3 and 7).

Figure 4. Pollution sensitivity of the bedrock surface

Map interpretation

Lower left and upper right:

Very High sensitivity is indicated by red areas, recent/modern tritium age (pink well symbols), and high chloride and nitrate values (16.4, 1.4, 15.6).

A known connection to surface water is indicated by the red E (evaporative signature).

Groundwater conditions offer possible explanations of water movement (circled 1 and 2).

Middle:

Moderate to low sensitivity is indicated by yellow and light green backgrounds, mixed tritium age (green well symbols), and some elevated chloride and nitrate values (10.4, 1.1).

Lower right:

Very Low sensitivity is indicated by the green background, vintage/premodern tritium age (blue well symbols), no elevated chloride or nitrate values, and carbon-14 values of thousands of years (2,000 and 10,000).

General flow is south and east, indicated by arrows.

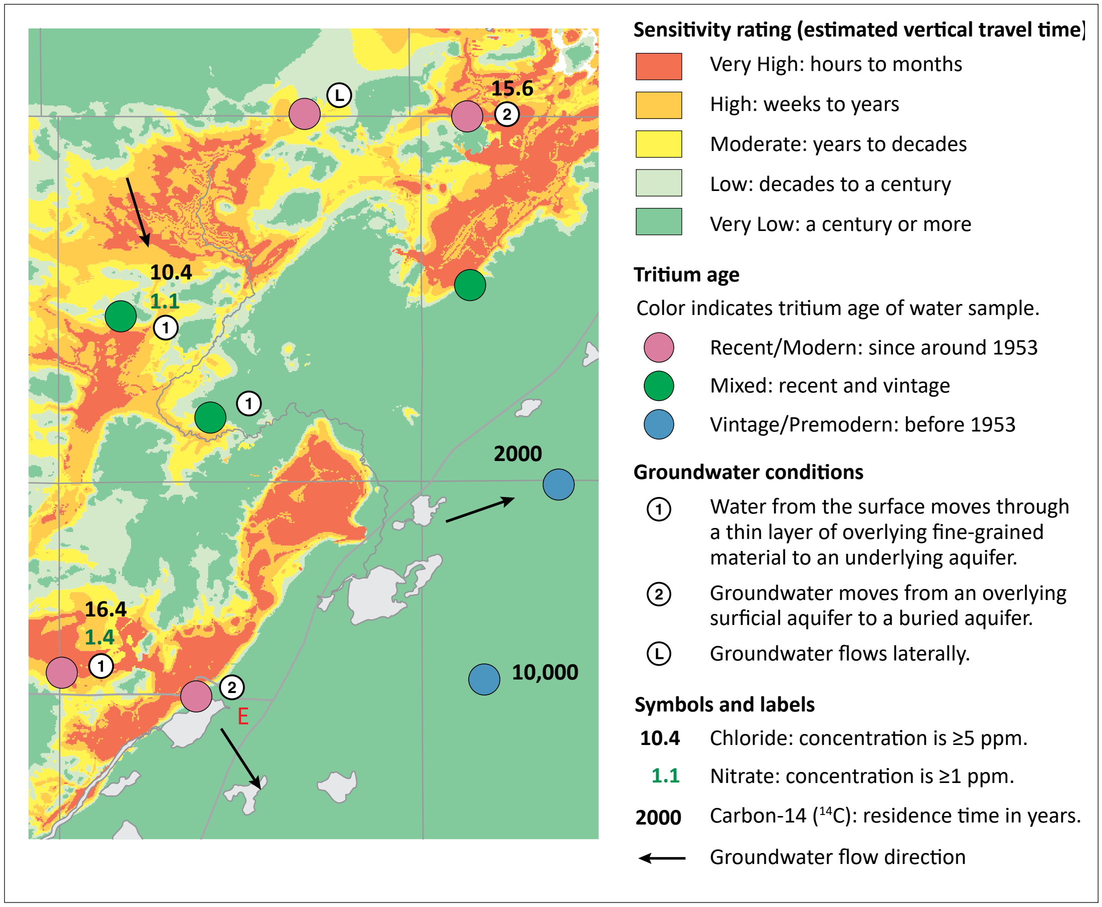


Figure 5. Chemistry

Chemical values shown on the maps are above a certain level, as described in the water chemistry section of each atlas.

Map interpretation

Lower left:

Higher sensitivity is indicated by recent tritium age in the pink symbols (aquifer sample rlf) and higher chloride values.

Upper left:

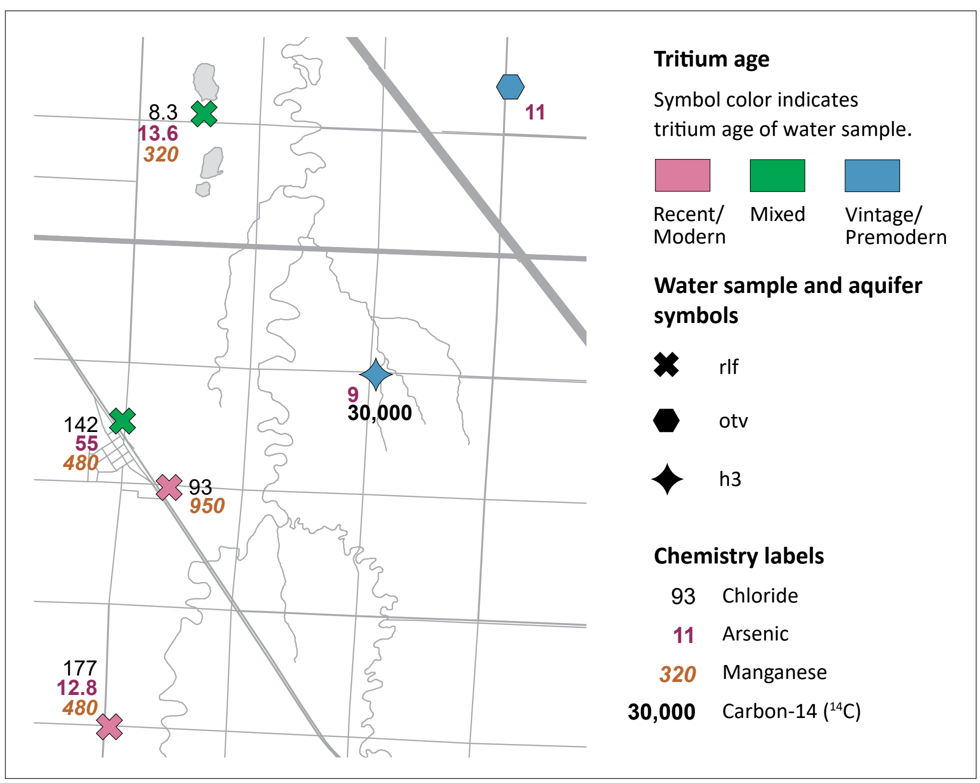
Moderate sensitivity is indicated by mixed tritium age in the green symbols (aquifer sample rlf) and elevated chloride values.

Right side:

Lower sensitivity is indicated by vintage tritium age in the blue symbols (aquifer samples otv and h3), the absence of chloride values, and the presence of carbon-14 values (30,000).

General:

The local geology presents a potential health concern for drinking water, indicated by the magenta arsenic values in most of the aquifer samples and the orange manganese values near the rlf aquifer samples.



Hydrogeologic cross sections

Cross sections represent vertical slices of the county that illustrate groundwater connections. Map symbols correlate with those on the previous page. The following provides a quick review for this vertical representation. Examples from Figure 7 are given in parentheses.

Aquifers

Aquifers are depicted with patterns.

Colors represent **residence time** by tritium age to indicate how long ago the precipitation entered the ground.

Longer residence times may be represented by bold carbon-14 values near the well symbols (2,500).

Chemistry sample results (above a certain threshold) appear near well symbols and are color coded by chemical (5.79).

Evaporative signatures indicate known areas where groundwater has been recharged by at least one surface-water body (**E**).

Groundwater conditions are indicated by circled letters or numbers and explain possible scenarios of groundwater flow or situations that are unknown (L lateral flow).

Aquitards

Aquitards are depicted without patterns.

Quaternary colors are represented in shades of gray to indicate **relative hydraulic conductivity.** Darker shades represent lower sand content and slower water movement, indicating slower recharge and greater protection for the aquifers below.

Bedrock aquitards are generally represented in green.

Groundwater flow

Groundwater flow direction is indicated by arrows.

Movement is toward decreasing pressure (upgradient to downgradient).

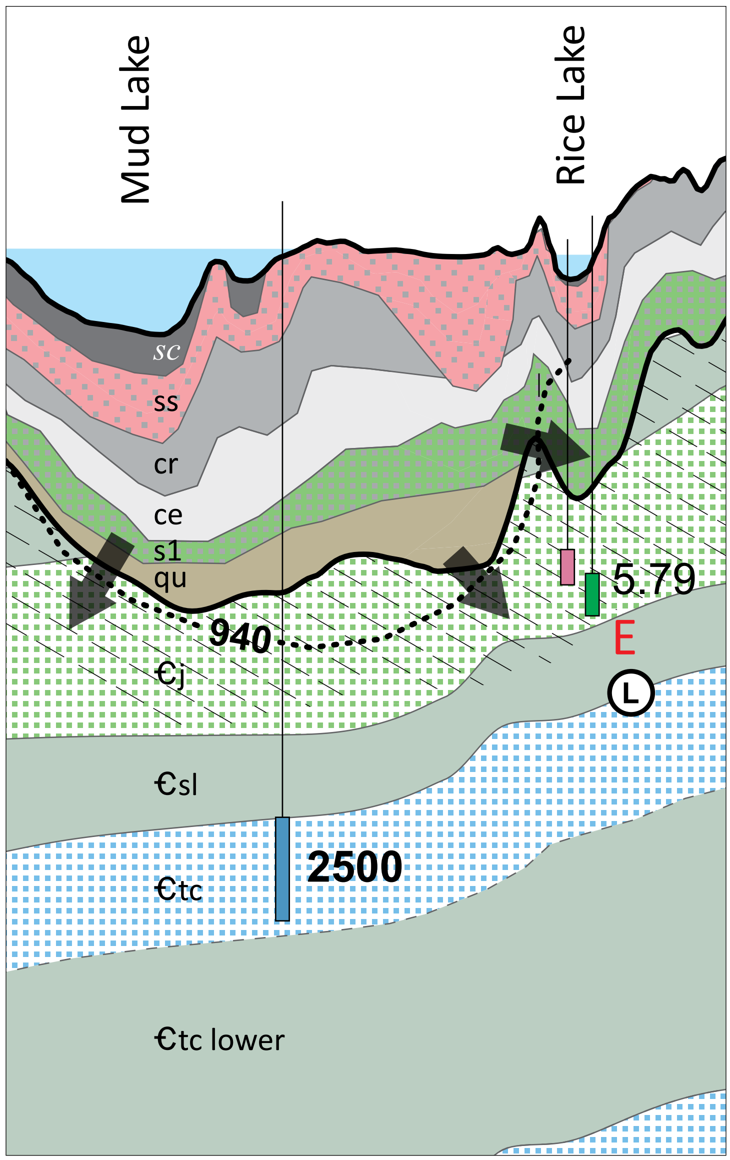
Arrows are perpendicular to the dashed *equipotential lines* where the pressure head of groundwater is the same (e.g., 940).

Figure 6. Stratigraphic column

The column relates the Part A geology to the Part B aquifers (patterns) and aquitards (solid shades) shown on the cross sections.

	Part A	Part B
surficial organic clayey silt		*sc*
Laminated Holocene		*sl*
surficial sand and gravel	ss	ss
New Ulm Formation	Qnt	nt
Lake Lind	*Qsl*	sl
Cromwell Formation, Automba phase	Qlc	lc
sand and gravel	*Qsc*	sc
Cromwell Formation, St. Croix phase	Qcr	cr
sand and gravel	*Qse*	se

Figure 7. Hydrogeologic cross section (from Figure 3)



The Minnesota County Atlas Program

A county atlas provides information about the geology and groundwater resources of a county, featuring groundwater quality, sensitivity to pollution, flow direction characteristics, and groundwater connections to surface water.

Maps and reports are available in print or online as PDFs or geographic information system (GIS) files. Most atlases are available in two parts (since 1992), and are created in sequence: geology in Part A, followed by groundwater in Part B.

Originally both parts were titled the "**Geologic** Atlas of X County." In 2019 the Part B title was changed to "**Groundwater** Atlas of X County" to distinguish the content.

For a detailed study on geology and groundwater, see the Geologic Atlas User Guide.

How is a county studied?

Part A: Geology

County staff meet with the Minnesota Geological Survey (MGS) and request the preparation of an atlas. Counties must be ready to provide in-kind support.

Geologists from the MGS investigate the properties and distribution of earth materials beneath the land surface using existing water well databases, field sampling, and laboratory analysis. Subsurface information is obtained from geophysical studies and rock and sediment sampling from outcrops and drill holes.

The information is used to produce maps of the geology, geologic layering, sand distribution, bedrock surface elevation, and depth to bedrock.

County Geologic Atlas Program
Minnesota Geological Survey
(612) 626-2969

Part B: Groundwater

After Part A is complete, hydrologists from the Minnesota Department of Natural Resources (DNR) study the groundwater resources of the county. A network of wells is selected from the most commonly used aquifers, sampled for chemistry, and measured for water levels.

The completed groundwater atlas includes text and maps identifying groundwater flow direction, chemistry, residence time, and pollution sensitivity by aquifer.

Atlases can address special conditions upon request. Previous studies have included geologic resources, lake-groundwater interaction, sinkholes, and springs.

Groundwater Atlas Program
Minnesota Department of Natural Resources
(651) 296-4800

How are groundwater atlases used and funded?

Potential uses include the following:

- Identify aquifers for water supply.
- Identify pollution sensitivity of aquifers and protect critical groundwater recharge areas and valuable natural resources.
- Make informed decisions on land use and water resources.
- Inform plans for long-term stable water supplies; wellhead protection and abandonment; and general locations of septic systems, landfills, industrial sites, and feedlots.

The program is supported by the following:

- The DNR budget as appropriated by the legislature
- The Minnesota Environment and Natural Resources Trust Fund
- The Clean Water Fund of the Clean Water, Land and Legacy Amendment
- County contributions of in-kind service to the project
- Other sources that support geologic mapping at the MGS

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Funding for this project was provided by the following:

The Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Citizen Commission on Minnesota Resources (LCCMR).

The Clean Water Fund, which receives 33 percent of the sales tax revenue from the Clean Water, Land and Legacy Amendment, approved by voters in November 2008.