Water-Table Elevation Map of Sauk County, Wisconsin

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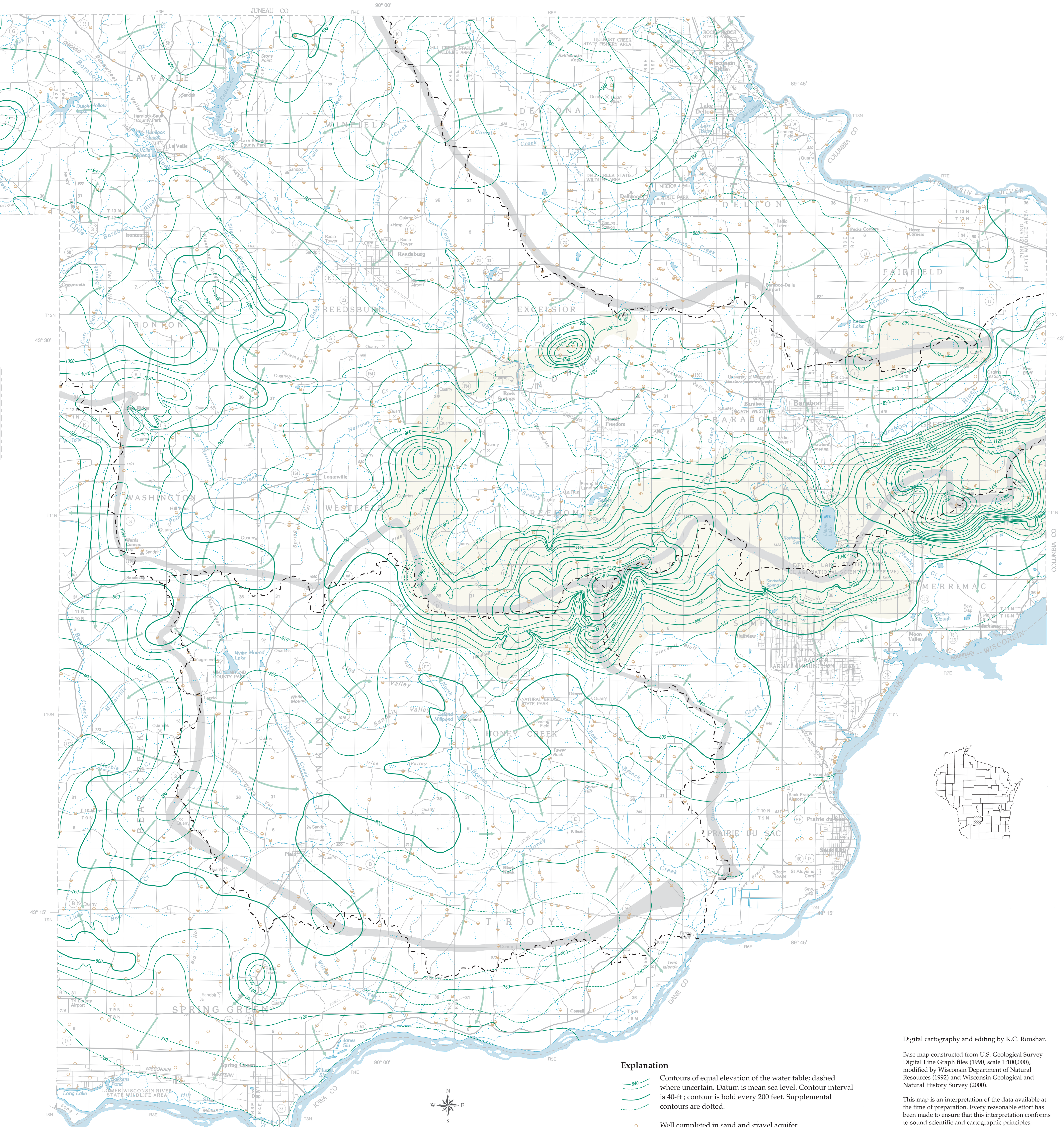
Miscellaneous Map 55



Introduction

This map is a product of the Sauk County Groundwater Project, a joint project of the Wisconsin Geological and Natural History Survey, the Sauk County Board of Supervisors, the Wisconsin Department of Natural Resources Bureau of Drinking Water and Groundwater, and the U.S. Geological Survey. The purpose of this project was to compile and analyze data regarding the county's groundwater resources.

The water cycle

The *water cycle* is a continuous cycling of water through the Earth's atmosphere, oceans, lakes, rivers, soil, and rock (fig. 1). Precipitation that reaches the land surface can flow downhill as overland runoff, evaporate, transpire through plants, or infiltrate into the ground. Water that infiltrates the ground percolates through pore spaces and fractures in soil and rock. Where these pores and fractures are completely filled with water, the material is *saturated*.

The top of this saturated zone is the *water table*, where hydraulic pressure on the pores is equal to atmospheric pressure. *Groundwater* is the water contained in the saturated zone beneath the water table. Above the water table, where pores and fractures are filled completely with air or with some air and some water, is the *unsaturated zone*. The amount of infiltrating precipitation is one of the factors that determines the position, or elevation, of the water table, which fluctuates seasonally and from one year to another.

In Sauk County, about 30 to 32 inches of precipitation fall on the ground surface during an average year. Approximately 70 to 75 percent of this amount cycles back to the atmosphere by evaporation and transpiration by plants (Hindall and Borman, 1974). The remainder either flows as runoff on the land surface to streams and lakes or infiltrates through soil or rock to the water table, where it *recharges* the groundwater system. Many factors, such as topography, vegetation, rainfall intensity, and soil and rock type, affect the amount of precipitation that reaches the groundwater system. For example, in areas where the land surface is covered extensively by pavement (such as parking lots and roadways), stormwater runoff to surface water is increased and groundwater recharge is decreased.

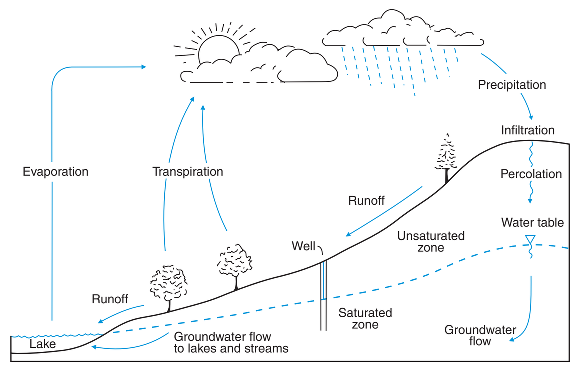


Figure 1. *The water cycle (modified from Dunne and Leopold, 1978).*

Groundwater flow and discharge

An *aquifer* is geologic material (such as sand and gravel deposits or a bedrock layer) that is saturated and yields water to wells. *Hydraulic conductivity* is a measure of an aquifer's ability to transmit groundwater; it is dependent on the nature of the material through which the water is flowing. Large pores or fractures can hold more water than small ones, but for water to flow effectively within an aquifer, these pores or fractures must be connected.

Aquifers that have many well connected pore spaces (such as the sand and gravel deposits in the Wisconsin River valley) have a large hydraulic conductivity and are prolific aquifers because they readily yield water to wells. Porous sandstone, which is the type of bedrock that makes up the Wisconsin Dells, is also a relatively prolific aquifer. Very dense rock, such as the crystalline quartzite of the Baraboo Hills, has very low hydraulic conductivity except where it is fractured. If the fractures are well connected, the quartzite can transmit water easily. However, if there are only a few poorly connected fractures, this rock will transmit little water and yield only small volumes of water to wells.

Groundwater can travel rapidly (at rates up to several feet per day) through sand and gravel or porous sandstone aquifers. Much slower rates of groundwater flow (as little as an inch per year) can be expected in clayey deposits and unfractured crystalline rock.

Regardless of the rate at which groundwater flows, the natural direction of groundwater flow is in response to gravity, from areas of higher water-table elevation to lower water-table elevation, generally perpendicular to lines of equal water-table elevation. This map shows the approximate elevation of the water table; each contour line on the map connects points of equal water-table elevation. The arrows on the map indicate the direction of shallow groundwater flow.

Groundwater flows through aquifers from recharge areas to discharge areas. The uplands, where the water-table elevation is higher, tend to be areas where water infiltrates the ground and recharges groundwater. Lowland streams, lakes, wetlands, and springs are typically areas of groundwater discharge. An example of flow from recharge to discharge areas can be seen on the map along the ridge north of Spring Green. There, the water-table elevation is approximately 800 ft. Arrows on the map illustrate that shallow groundwater flows to the south, where groundwater discharges to the Wisconsin River at an elevation of approximately 700 ft.

Water wells are manmade points of groundwater discharge. Pumping lowers the water level in the well, and groundwater then flows into the well. Pumping can cause a drop in the level of the water table, called a *cone of depression*, around the well. However, the relatively low volume of groundwater that is currently withdrawn from wells in Sauk County does not cause a cone of depression large enough to be seen at the scale of this map.

In Wisconsin and other parts of the humid Midwest, surface-water bodies are typically points of groundwater discharge. Such discharge occurs when the nearby water-table elevation is higher than the elevation of a stream, and groundwater flows into the stream. Most rivers and streams have some water flowing in them even during extended periods of drought because they are fed by groundwater. However, lakes and streams that are high in the landscape or are fed primarily by surface-water runoff may be locations of groundwater recharge. For example, this map shows that the elevation of Devils Lake (963 ft) is higher than the surrounding water-table elevation. Over most of Devils Lake, water percolates downward from the lake and recharges the underlying aquifer (Krohelski and Batten, 1995).

Groundwater flow directions near dams can be complex. For example, the dam on the Wisconsin River at the southern end of Lake Wisconsin maintains the water level in Lake Wisconsin at approximately 774 ft and the water level in the river at the base of the dam at approximately 735 ft. Groundwater does not discharge to the southern part of Lake Wisconsin because the water level in the lake is maintained by the dam above groundwater levels. Groundwater above the dam flows away from the lake and discharges to the Wisconsin River below the dam.

A *surface-water divide* is a line of separation, commonly along a ridge or tract of high ground, that divides surface waters that flow naturally into one basin from those that flow naturally into a different basin. All the major streams and rivers in Sauk County flow into the Wisconsin River. However, several minor surface-water divides separate the basins of Dell and Leech Creeks, the Baraboo River, and Honey Creek.

A *groundwater divide* is similar to a surface-water divide, in that it is a ridge along the highest elevations of the water table. Shallow groundwater moves away from this divide, toward groundwater discharge areas. Groundwater divides do not necessarily coincide with surface-water divides. The major groundwater divides in Sauk County are along or relatively close to surface-water divides. Groundwater divides are illustrated on this map as wide and approximate areas because the location of the divide may change as the water table rises and falls in response to periods of rainfall and drought. Significant amounts of groundwater pumping from wells drilled near divides may also cause a divide to shift.

The groundwater divides in Sauk County can be used to identify the areas in which shallow groundwater flows toward particular stream systems. For example, in northeastern Sauk County, groundwater flows toward the Dell Creek basin, discharging to Dell Creek or its tributaries, Leech Creek, small streams and wetlands, or directly into the Wisconsin River. In northwestern Sauk County and the basin of the Baraboo range, groundwater flow is toward the Baraboo River and its tributaries. In southwestern Sauk County, the groundwater divide delineates the area where groundwater flows toward Honey Creek from the area where flow is toward Bear Creek, Wilson Creek, and the Wisconsin River. In the southeastern part of the county, the divide shows where groundwater flows toward Honey Creek or Otter Creek and the Wisconsin River.

Geology and groundwater availability

The varied topography and geologic history of Sauk County have strongly influenced the type and distribution of aquifers: Well depths and yields differ dramatically with changes in the landscape. Figure 2 shows the extreme differences in elevation across the county. Three geologically and geographically distinct regions are present in Sauk County: the areas of glacial deposits; the unglaciated area, called the Driftless Area; and the Baraboo Hills (fig. 3; Clayton and Attig, 1990).

Areas of glacial deposits

In the glaciated area, the glacial lake basins, and the outwash plains of eastern and southern Sauk County (fig. 3), the uppermost aquifer is the sand and gravel aquifer. In the outwash plains, this aquifer is composed of sand and gravel deposits that are up to 300 ft thick and yield large volumes of water to wells. To the east of the terminal moraine (for example, near Leech Creek), this aquifer consists of till deposits of variable composition. Wells completed in the till intersect layers of sand or sand and gravel that are of limited thickness and areal extent. These wells produce less water than those in the outwash plains.

Driftless Area

Steep-sided valleys surround narrow uplands in the Driftless Area (fig. 2). A thin (generally less than 25 ft thick) layer of soil or clay covers the uplands. This cover is typically unsaturated; the water table is in the uppermost bedrock. In some parts of the uplands, the uppermost bedrock unit is dolomite. In areas where the dolomite has been eroded, the uppermost rock is sandstone. Over a large part of Sauk County, this bedrock aquifer is very thick, consisting of up to 500 ft of interbedded sandstone, dolomite, and shale. It underlies the sand and gravel aquifer where the sand and gravel aquifer is present. The sandstone and dolomite layers are absent throughout much of the Baraboo Hills (fig. 3).

The larger valleys of the Driftless Area (for example, Honey Creek valley or the Baraboo River valley) contain thick *alluvial* (river) deposits overlying sandstone. In these areas, the sand and gravel aquifer provides sufficient groundwater for domestic wells. Along the edges of these valleys, where alluvial deposits are very thin or not present, the uppermost aquifer is the bedrock aquifer. Some municipal water supply wells, which require larger volumes of water, are drilled through the alluvial deposits and pump from the underlying dolomite/sandstone bedrock aquifer. This is the case in the village of Plain, where two deep municipal wells supply groundwater from the bedrock aquifer to residences and businesses.

Baraboo Hills

The Baraboo Hills consist of Precambrian quartzite and rise more than 800 ft above the surrounding land (fig. 2). Throughout much of the Baraboo Hills, the quartzite, which is crystalline rock, is the uppermost geologic material; the soil is very thin and the sandstone and dolomite aquifer is not present. The quartzite itself is relatively impermeable; groundwater flows primarily through fractures in the rock. Wells open to the quartzite do not produce large amounts water. Although the water table is mapped as a continuous surface across this area, groundwater flow directions in fractured rock aquifers can be more complex than in porous aquifers. Flow directions in the quartzite may not be predicted accurately from the water-elevation contours presented on the map; flow-direction arrows are not shown for this area.

Figure 2. *Shaded relief map of Sauk County. High-elevation areas are lighter than those of low elevation. Data used to generate this map were taken from USGS (2001).*

Contamination of groundwater

Because groundwater originates from precipitation that percolates down from the land surface, any water-soluble material or liquid that comes into contact with the percolating water has the potential to be transported to the uppermost aquifer. Common groundwater pollutants include constituents of gasoline and other fuels from surface spills or underground storage tanks. Nitrogen, pesticides and herbicides from lawn care products, septic systems, or agricultural sources may also affect groundwater quality.

Figure 3. *Major geologic regions of Sauk County (modified from Clayton and Attig, 1990). The map shows the area covered by ice during the most recent glaciation (gray), outwash plains (light orange), and glacial lakes basins (blue). The sand and gravel aquifer overlies the dolomite/sandstone aquifer in these areas and in modern stream valleys in the Driftless Area. The dolomite/sandstone aquifer is the uppermost aquifer in the uplands of the Driftless Area. In the Baraboo Hills, groundwater flows primarily through fractures in the quartzite bedrock.*

The unsaturated zone can serve as a natural filter for potential contaminants through a variety of physical, chemical, and biological processes. In general, thick deposits of fine-grained materials (such as clays) are better able to attenuate contaminants. Aquifers that are not protected by overlying clayey deposits, such as areas of sandy soils where the water table is shallow, or where thin, sandy soils overlie bedrock, are particularly susceptible to groundwater contamination. Once a contaminant reaches the water table, it has the potential to move with groundwater and discharge to wells or surface-water bodies. Contamination that occurs today may not become evident for several years because groundwater can move as slowly as a few inches per year. Groundwater contamination in the saturated zone can be reduced by the processes of dilution, adsorption onto fine-grained particles, and chemical or biological breakdown. However, once contaminated, groundwater is difficult to purify and may take many decades to be cleaned.

Data compilation and interpretation

Data were compiled by Cheryl Buchwald, William G. Batten, and Kurt K. Zeiler. Groundwater elevations were estimated from the elevations of surface-water features such as streams, lakes, and wetlands and from the depth to water recorded on 1,103 Wisconsin Department of Natural Resources well constructor's reports. U.S. Geological Survey digital data for hydrography (derived from USGS, 2001), topographic quadrangles (7.5-minute series; USGS, 1996–97), and the National Elevation Dataset (USGS, 2001) were used as aids in estimating these elevations and contouring the data.

The location of each well constructor's report used in making this map is indicated with a symbol representing the type of geologic material in which the well was completed. This information can be used to determine where the sand and gravel and dolomite/sandstone bedrock aquifers are present in sufficient thickness to supply groundwater to wells. The area of Sauk County where these aquifers are thin or not present, roughly corresponding to the area of the Baraboo Hills, is also shown on the map.

The accuracy of the map varies throughout the study area, increasing near surface-water bodies and where there is a greater density of wells. Where the contour lines are dashed, groundwater-elevation data were not available; in these areas, the water-table elevation is inferred from topography. The water-table elevations shown on this map are an approximation; water levels may vary due to seasonal fluctuations in recharge or due to recent, large-volume pumping from groundwater wells. The groundwater flow directions shown on this map are not, however, typically affected by seasonal variations in recharge.

The use of water levels recorded on well constructor's reports to create this map may also be a source of inaccuracy. Water-supply wells are not ideal measuring points for determining the water-table elevation because most of these wells are open to the aquifer over long intervals that extend far below the top of the saturated zone. In low-lying areas, such as the outwash plains, this well design provides a good measurement of depth to groundwater because groundwater flow is predominantly horizontal. At higher elevations and in areas of steep terrain, groundwater flow may have a significant vertical component to its flow. In such areas, the water level measured in a well may be lower than the water-table elevation. For this reason, it is difficult to determine accurately the water-table elevation on ridgetops in the uplands.

This map is intended for use at the scale of publication (1:100,000). It is a regional interpretation of the water table and may not be sufficient for use at a site-specific scale. Limited field surveys of stream headwaters were conducted to assess seasonal variability in the stream locations shown on the 7.5-minute topographic maps. Shallow geophysical surveys were conducted at two locations in the uplands of the Driftless Area and confirmed that a perched aquifer—a saturated zone separated from the underlying main body of saturated material by an unsaturated zone—was not present in the surficial deposits overlying the bedrock aquifer at the time the surveys were performed (midsummer). Information used from the well constructor's reports was not field verified.

Scale 1:100,000

KILOMETERS 1 0 1 2 3 4 5 6 7 8 9 10

MILES 1 0 1 2 3 4 5

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Explanation

- Contours of equal elevation of the water table; dashed where uncertain. Datum is mean sea level. Contour interval is 40-ft ; contour is bold every 200 feet. Supplemental contours are dotted.
- Well completed in sand and gravel aquifer
- Well completed in dolomite/sandstone aquifer
- Well completed in crystalline bedrock
- Direction of regional shallow groundwater flow
- Approximate locations of surface-water divides
- Stream, dashed where ephemeral
- Approximate locations of groundwater divides
- (963) Lakes and ponds; where shown, value is average stage in feet above mean sea level.
- Area where sand and gravel aquifer and dolomite and sandstone aquifer are typically thin or not present. Wells completed in sandstone in this area indicate that the sandstone is of sufficient thickness to yield water to wells.

Digital cartography and editing by K.C. Roushar.

Base map constructed from U.S. Geological Survey Digital Line Graph files (1990, scale 1:100,000), modified by Wisconsin Department of Natural Resources (1992) and Wisconsin Geological and Natural History Survey (2000).

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