HYDROGEOLOGY OF THE SURFICIAL AQUIFERS

By

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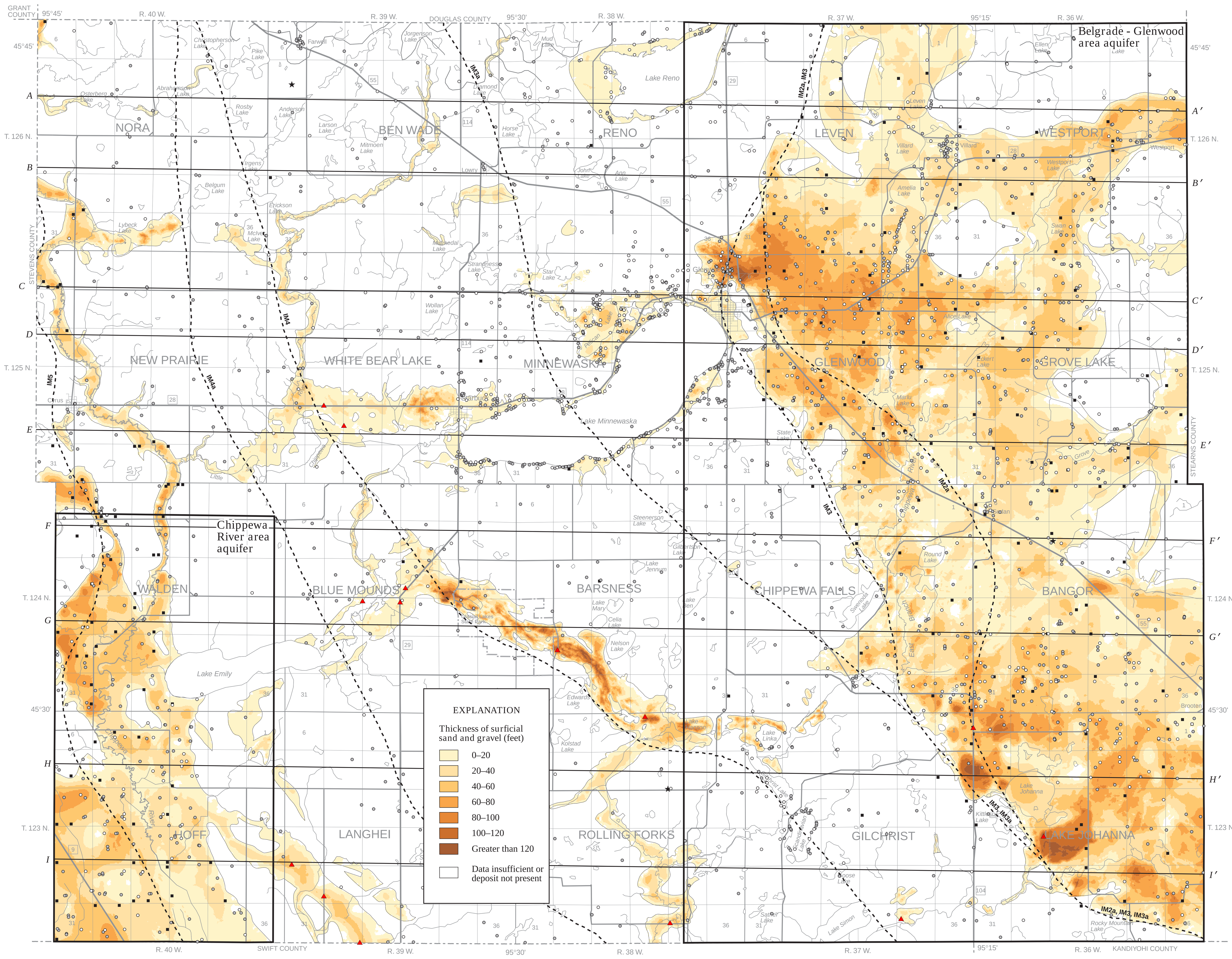

FIGURE 1. *Surficial sand and gravel thickness.* This map shows the thickness and distribution of surficial sand and gravel deposits in Pope County. With a few exceptions, the boundaries of these deposits are the same as the geologic map units delineating sand and gravel shown on Plate 3 in Part A. These surficial aquifers are the most important source of water for irrigation in the county. Irrigation is common in the eastern and southwestern portions of the county where the surficial aquifer is laterally extensive and relatively thick in many areas.

Most of the sand and gravel was deposited by meltwater from glaciers as they receded to the west and north. The ice margin lines (from Part A, Plate 3) show the approximate edges of two different ice lobes at various stages of recession (Lower Goose River group, ice margin [IM] 2a through IM4a, and Upper Goose River group, IM5). At these ice margins, the edge of the ice lobes, which was the source of the meltwater and sediment, remained long enough to create the patterns of distribution and thickness variations that are shown on this map.

INTRODUCTION

Like ground water in most counties in western and central Minnesota, most ground water in Pope County is pumped from unconsolidated bodies of sand and gravel. Eastern Pope County is dominated by a portion of one of the largest surficial sand deposits in the state: the Belgrade-Glenwood sand plain, which is a major source of irrigation water in the region (Figure 1, Belgrade-Glenwood area aquifer). The northern Chippewa River sand plain in southwestern Pope County is another important irrigation district in the region (Figure 1, Chippewa River area aquifer). Beneath these surficial aquifers are complex, layered glacial deposits that contain other important ground-water supplies for the county (Plate 7).

The purpose of this atlas is to provide data and maps showing the distribution and physical characteristics of the most important aquifers in the county (Plates 6 and 7); to describe the ground-water flow patterns, flow directions, aquifer connections, and important ground-water chemical characteristics (Plates 6, 7, and 8); and to assess sensitivity to pollution of the surficial and buried aquifers (Plate 9). This atlas is designed for units of government and citizens to use in planning for land use, water supply, and pollution prevention.

DATA SOURCES

Much of the information used to produce the maps, cross sections, and tables of this atlas came from well records: the database of well logs (County Well Index [CWI]) maintained by the Minnesota Geological Survey (MGS) and the Minnesota Department of Health (MDH), as well as well logs from holes that were drilled for several previous hydrogeolgical investigations of this region by the U.S. Geological Survey (USGS) (Van Voast, 1971a; Van Voast, 1971b; Wolf, 1976; Soukup and others, 1984; Delin, 1986a; Delin, 1986b; Delin, 1988; Delin, 1991). An additional information source was electrical resistivity data collected by DNR Waters staff for this report.

The CWI data include descriptions by drillers that are made as the well is drilled. Most of these well locations are verified in the field by staff from the MGS or MDH. The dataset also contains well logs with unverified locations. Unverified data were used in the maps and cross sections of this atlas; however, some of the unverified data were ignored if the information seemed inconsistent with other more reliable information.

The electrical resistivity data (red triangles shown on Figure 1) were particularly useful where drill hole data were rare or absent and an estimate of the thickness of sand and gravel deposits was important. The sand and gravel was detected by its resistivity difference from other material. The base of the surficial sand and gravel deposit is interpreted as an abrupt change between the higher electrical resistivities of the sand and gravel and the lower resistivities of the clay and silt of the underlying fine-grained glacial materials (generally glacial till).

CHARACTERISTICS OF SAND AND GRAVEL AQUIFERS

Depositional Characteristics of Surficial Aquifers

Figure 1 shows the thickness and distribution of two major surficial sand and gravel deposits and other surficial sand and gravel deposits in the county. The geologic history of surficial sand deposition is derived from descriptions on Plate 3, Part A. Several advances and recessions of ice lobes, which moved into Minnesota from the northwest through the area that is now occupied by the Red River, dominate the late glacial history of the county. The ice margins shown as dashed lines on Figure 1 represent the approximate positions that the ice lobe edges occupied long enough for huge volumes of meltwater and associated sand and gravel to be discharged in some areas from the melting ice.

The largest and thickest deposit from glacial meltwater in the county is the Belgrade-Glenwood sand plain in the eastern portion of the county, which is part of the Brooten-Belgrade sand plain that extends into Stearns County. This deposit is really a composite derived from two different areas as suggested by the two distinct north and south areas with thick sand and gravel. The northern area deposits appear to have been transported through the Lake Minnewaska area to a location north of Glenwood. The southern area deposits appear to have been derived from a topographically low area near Lake Simon through locations north and south of Lake Johanna. Sand and gravel thicknesses range from less than 10 feet in the east-central portion of the county, in the vicinity of Sedan and Round Lake, to 100–140 feet in the two thick sand areas previously described.

A thick surficial sand and gravel deposit along the western margin of the county is associated with the Chippewa River and ice margin 5 (IM5). This sand and gravel was deposited along the eastern edge of a major ice lobe to the west. The broadening of this deposit south of cross-section F–F′ and west of Lake Emily to the southwestern corner of the county represents deposits from a delta that was associated with Glacial Lake Benson that existed to the south in Swift and Chippewa counties (Patterson and others, 1999). The thickness of this deposit is fairly well known from drill hole data except for an eastern channel branch near the southern portion of the county. The sand and gravel in this Chippewa River area commonly is 20–40 feet thick; the thickest portion (40–60 feet) occurs generally west of Lake Emily.

In south-central Pope County, a large sand and gravel deposit extends northwest from the Linka and Gilchrist lakes area in the east to Glacial Lakes State Park. This deposit is parallel to ice margin 4 (IM4). The relatively high topographic relief of this area, along with drill hole and electrical resistivity data, suggests that the thickness of this deposit is highly variable. In some places, the deposit is 100–120 feet thick.

Two smaller surficial sand deposits exist in the central portion of the county around the Lake Minnewaska-Starbuck area and around Lake Reno in the north-central portion of the county. The thicker portions of the Lake Minnewaska-Starbuck deposit consist of small areas of glacial outwash combined with thinner postglacial (Holocene) lakeshore deposits. The thin sand around Lake Reno is interpreted to be mostly Holocene lakeshore deposits.

Hydrogeologic Characteristics of Surficial Aquifers

Estimating the yield of ground water from an aquifer requires information about an aquifer's extent and thickness, hydraulic conductivity (an aquifer's ability to transmit water), and other data sources. The maps of the surficial aquifers on this plate (Figures 1, 2, and 3) provide information about basic aquifer extent and thickness. Data used for estimating aquifer yields are obtained by pumping water from a well at a constant rate for a certain period of time. Table 1 shows a data summary from CWI of the simplest test of this type called a specific capacity test. This test is defined as well discharge, which is measured in gallons per minute divided by feet of water-level drawdown (gpm/ft) in the pumped well. High specific capacity values indicate that large amounts of ground water can be withdrawn with slight water-level drawdown in the well. In addition, high specific capacity values usually indicate high values of hydraulic conductivity.

The specific capacity values of wells in the surficial (water table or unconfined) aquifers differ from the specific capacity values of wells in the buried (confined) aquifers in the county (Plate 7). Extensive networks of buried sand and gravel aquifers were deposited by meltwater from earlier episodes of glacial advances, subsequent melting, and associated sand and gravel deposition. These aquifers are described in more detail on Plates 7 and 8. Wells in the surficial aquifers have higher specific capacities than wells in the buried aquifers with mean values of 38 gpm/ft and 77 gpm/ft for the eastern and western sand plains, respectively (Table 1). Wells in the buried aquifers have lower mean values (20–21 gpm/ft) because the aquifers are generally confined, thinner, and more limited in areal extent. The range of specific capacity values of wells in the surficial aquifers shows much greater variability than the values from the buried aquifers. This greater variability of specific capacity values of wells in the surficial aquifers is probably due to the greater range of aquifer thickness values and wider range of aquifer boundary conditions. As a result, specific capacities of wells in the surficial aquifers generally will be higher but less predictable than the buried aquifers.

Water table depth, elevation, and ground-water flow direction. The water table depth and elevation characteristics of the eastern and western surficial aquifers are shown in Figures 2 and 3 (the water table extends into adjoining nonaquifer materials that are not shown). These maps are generalized estimates and are mostly useful for comparisons of water table depth and elevation across the county. The data used to derive these maps were collected periodically each year during various climatic conditions from the 1960s to 2005. Water table depth varies seasonally and yearly according to precipitation conditions. Water table depth is useful to determine the type of septic system that might be needed for a new dwelling or development or to evaluate the sensitivity of the surficial aquifer to other potential pollutant sources besides the septic system.

The water table elevation maps are useful for depicting ground-water flow directions. Since much of the water in the lakes and streams in sand plain areas is ground-water discharge, the ground-water source areas of those surface-water bodies can be identified from these maps. This information can assist local units of government in managing these water bodies. In addition, ground-water flow gradients can be derived from these maps, which can be used along with other information, to estimate ground-water flow velocity. For all of these applications, additional site-specific information would be required to make accurate determinations.

Chippewa River area aquifer (western sand plain surficial aquifer). The water table of the western surficial aquifer (Figure 2) is mostly shallow (0 to 10 feet below land surface) except in the area west of Lake Emily. Nowhere is the water table deeper than approximately 30 feet below land surface in this area. The water table elevation map (Figure 3) shows that most shallow ground-water flow converges toward the Chippewa River and provides some portion of its discharge. The water table in this area has a relatively low gradient.

Belgrade-Glenwood area aquifer (eastern sand plain surficial aquifer). A broad range of water table depths are shown on Figure 2 in the eastern surficial aquifer area. Relatively shallow water table depths, ranging from 0 to 20 feet below land surface, characterize most of the central portion of the sand plain. Much greater depths (40 feet to 80 feet below land surface) are found in the thicker and topographically higher portions of the sand plain east of Glenwood and beneath the hills surrounding Lake Johanna in southeastern Pope County.

The Belgrade-Glenwood area aquifer straddles the boundaries of three major Minnesota watersheds: the Chippewa River to the west, the North Fork Crow River to the southeast, and the Sauk River to the northeast (Figure 3). In sandy, shallow water table areas, the ground-water flow directions are often similar to the surface-water flow directions. Therefore, the flow network of the surface-water system (Minnesota Department of Natural Resources, 2006) and the water table flow directions are shown together to create a comprehensive picture of shallow ground-water and surface-water movement in this area.

Shallow ground-water movement in the northeastern portion of the sand plain converges on the Swan-Westport chain of lakes. Surface- and ground-water discharges to Ashley Creek and subsequently flows east from the county. In the east-central portion of the sand plain, ground-water flow converges on Grove Lake and the North Fork Crow River and leaves the county to the east. South of the Grove Lake area, ground-water flow converges on Sedan Brook and an unnamed wetland and creek northwest of Brooten. This water also leaves the county to the east.

Most of the northwestern portion of this sand plain is dominated by surface drainage and ground-water flow through the Leven-Villard-Amelia chain of lakes. Surface water from this lake chain discharges to the East Branch of the Chippewa River that also captures most of the shallow ground-water discharge in this portion of the sand plain. Beyond the sand plain, the East Branch of the Chippewa River drains southwest to Linka and Gilchrist lakes. For a small portion of the western part of this sand plain, in an area around Glenwood, the ground water flows west toward Lake Minnewaska.

In summary, ground-water movement through the eastern sand plain area can be understood by dividing the aquifer into the three major surface watersheds, following the ground-water flow to the major surface drainage features, and tracking the surface-water flow to the edge of the study area.

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TABLE 1. Specific capacity of selected large-capacity wells*.

Aquifer	Well diameter range (inches)	Specific capacity (gpm/ft) Mean	Minimum	Maximum	Number of tests
Surficial (see this plate)					
Belgrade-Glenwood (eastern surficial)	5–24	38	1	129	147
Chippewa River (western surficial)	12–24	77	13	500	108
Combined	5–24	58	1	500	255
Buried (see Plate 7)					
CW	5–16	20	2	67	31
BROW	5–16	21	2	230	78
Combined	5–16	20	2	230	109

*Specific capacity was measured by well discharge in gallons per minute per foot (gpm/ft) of water-level drawdown. Tests conducted on wells with large-capacity rates (greater than 100 gallons per minute). Data adapted from the County Well Index.

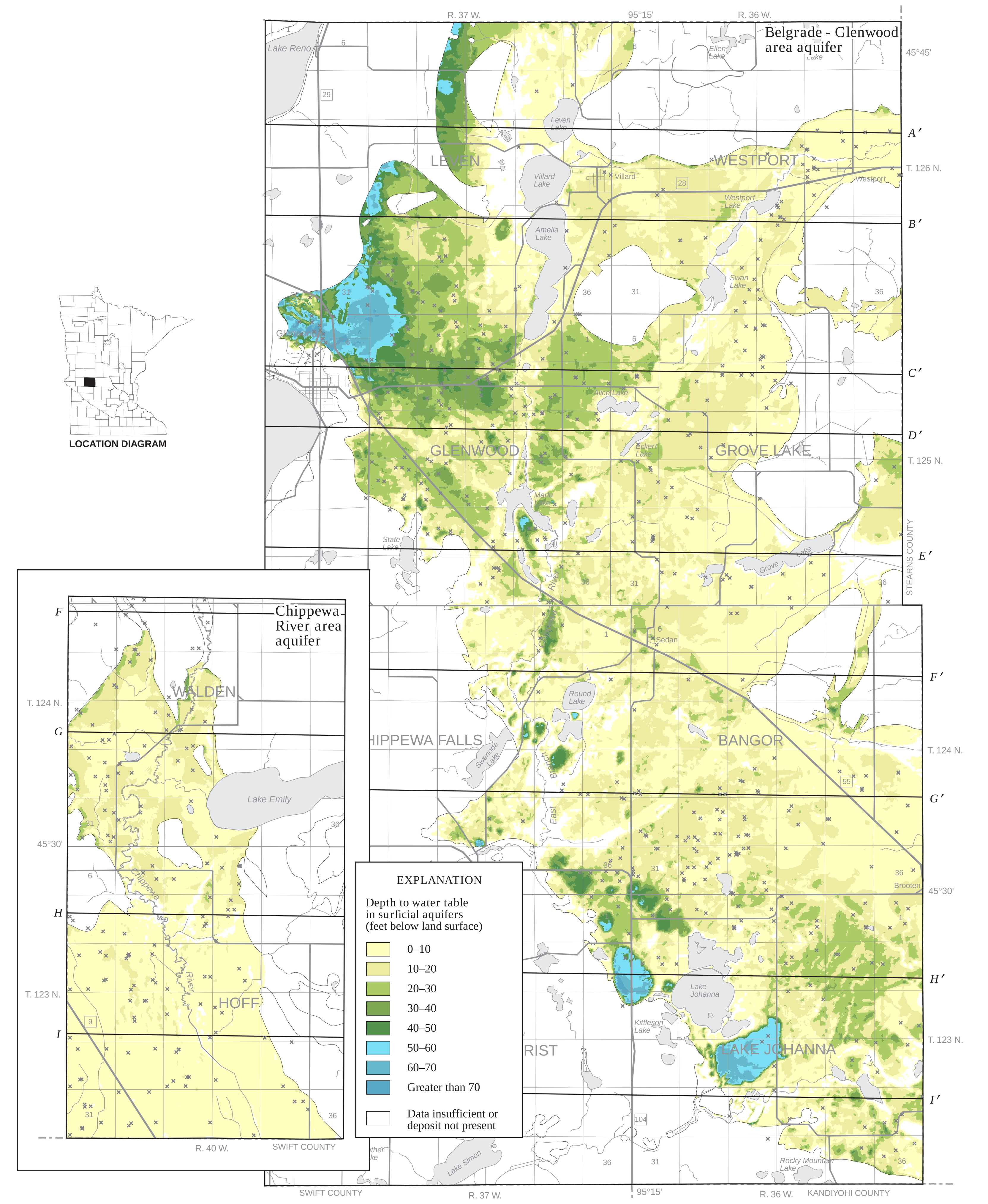

FIGURE 2. *Depth to water table from the land surface in the surficial aquifers.* The water table aquifers are generally not used as a drinking water source except in a few older wells. Where the water table is shallow, contaminants may reach the water table faster compared to the deep water table areas. The deep water table areas near Glenwood and Lake Johanna in southeastern Pope County generally correspond to areas of thickest sand and gravel (Figure 1). Shallow water table conditions generally prevail in the southwestern and east-central parts of the county.

SCALE 1:100 000

1 0 1 2 3 4 5 MILES

1 0 1 2 3 4 5 6 7 8 KILOMETERS

MAP EXPLANATION
Figures 1, 2, 3

Well symbols

- Static (nonpumping) water-level data from the County Well Index (CWI).
- Verified well.
- Unverified well.
- U.S. Geological Survey well or test hole.

Map symbols and labels

- Rotosonic drill log.
- Resistivity test.
- Arrow indicates the general direction of ground-water movement.
- Arrow indicates the downstream direction of streamflow.
- F F′ Line of cross section. See Plate 8, Hydrogeologic Cross Sections.
- IM3 Ice margin (IM) boundary.
- Surface watershed boundary.
- Extent of mapped surficial sand and gravel.

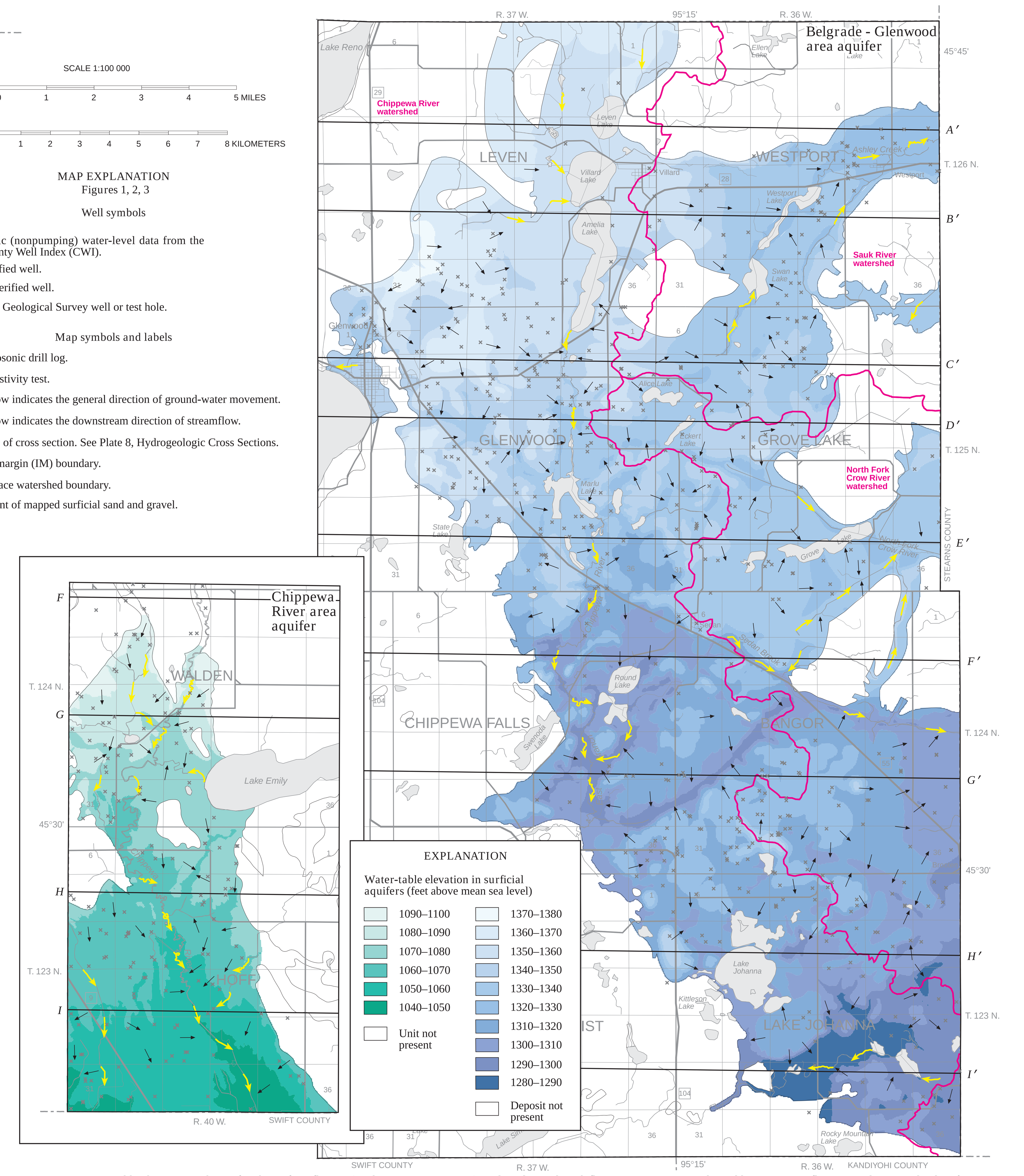

FIGURE 3. *Water table elevation in the surficial aquifers, flow directions of ground water at the water table, and discharge direction of surface water.* The flow network in the Chippewa River area aquifer (southwestern Pope County) is relatively simple with flow converging toward the river and ultimately discharging south. The flow network in the Belgrade-Glenwood area aquifer in eastern Pope County is complicated because water flows toward topographic low features (lakes, wetlands, small ponds), especially in the southern portion, and because water flow in the area is split by three major watersheds.

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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 2004 to 2005 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 Jim Berg and Greg Massaro.
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