PREPARED IN COOPERATION WITH THE
SOUTH BEND WATER WORKS

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of ground water in unconsolidated aquifers near South Bend, Indiana

GEOHYDROLOGIC CHARACTERISTICS

INTRODUCTION

The water supply for the City of South Bend, Indiana, and much of surrounding St. Joseph County (fig. 1) is provided by 36 municipal and community well fields. Some of these well fields are located near known or potential sources of ground-water contamination that could affect ground-water supplies in the near future. As population and industry grow, it will be necessary to find additional sources of water and determine their quantity and quality. Geohydrologic and water-quality data are available to identify areas for developing additional ground-water supplies, but these data have not been compiled into one source accessible to area water-resource managers.

This report presents a compilation of these geohydrologic and water-quality data for the ground-water system in and near South Bend that can be used to identify potentially favorable areas for developing additional ground-water supplies for municipal use. The data were compiled by the U.S. Geological Survey, in cooperation with the South Bend Water Works, for a study area of approximately 535 square miles that includes all of St. Joseph County and the eastern part of La Porte County (fig. 1). A map format has been used to facilitate comparison between geohydrologic and water-quality information.

Previously published geologic maps and cross sections describe the geologic setting and aquifer deposits of the study area (Fenelon and others, 1992), the hydrogeology of northeastern St. Joseph County (Bayless and Arihood, 1996), and the ground-water quality of northeastern St. Joseph County (Fenelon and others, 1995). Beaty (1990) and Clendenon and Beaty (1987) produced water-resource-availability reports for the St. Joseph and Kankakee River Basins.

METHOD OF STUDY

Data for this study were collected from several sources. Well-drillers' records, well-field-withdrawal rates, and water-quality information were obtained from the Indiana Department of Natural Resources, Division of Water. Geohydrologic and water-quality data from U.S. Geological Survey (USGS) reports also were compiled. Well-drillers' records from bordering areas in Michigan were collected from the Michigan Department of Environmental Quality. All data were added to the USGS data base for analysis.

From the USGS data base, transmissivity, horizontal hydraulic conductivity, and recharge rates were determined for the study area. Transmissivity and horizontal hydraulic conductivity values vary widely across the area. All calculated values are shown on figures 2 and 3 even though some error may be present in the field values used for the calculations. The map values (fig. 2 and 3), therefore, should be used only as indicators of variability in transmissivity and horizontal hydraulic conductivity. Recharge-rate values are based on streamflow records and represent an average for the drainage basin upstream from the streamflow-measurement site.

Ground-water levels were obtained from well-drillers' records and contoured. The thickness of the aquifers and the confining unit was estimated with well-drillers' records and geostatistical techniques. The distribution of values for selected water-quality characteristics and properties throughout the upper and lower aquifers near South Bend also was evaluated.

GEOHYDROLOGY

The study area is covered by unconsolidated glacial deposits ranging from 100 to 500 feet (ft) thick. The sands, sands and gravels, and gravels in the glacial drift were deposited as broad outwash plains and channels beyond the melting ice front. A clay-rich till interlayered with the sand and gravel deposits acts as a confining unit that separates those sand and gravel deposits into an upper and lower aquifer in most of the study area. The unconsolidated glacial deposits are underlain by a gently rolling bedrock surface, the Ellsworth Shale, which is of Devonian and Mississippian age. Because of the availability of water in the unconsolidated deposits, the shale rarely is used as a water-supply aquifer (Fowler, 1994).

The factors affecting the movement and distribution of ground water in the study area include transmissivity, horizontal hydraulic conductivity, aquifer recharge, ground-water levels, and aquifer thickness. Information on these factors can be used to identify potentially favorable areas for developing additional ground-water supplies for municipal use.

Transmissivity

Aquifer transmissivity is a measure of the rate at which an aquifer can transport water through a unit width of the aquifer under a unit hydraulic gradient (Freeze and Cherry, 1979). Because transmissivity is the product of the aquifer thickness and horizontal hydraulic conductivity, its value differs from place to place within an aquifer. The transmissivity values for the upper and lower aquifers were calculated from a modified version of the Theis equation (Prudic, 1991) and were corrected (using a method described by Butler, 1957) for partial penetration of the well screen into the aquifer. The data used to calculate transmissivity values were obtained from well-drillers' records and include the pumping rate and duration, drawdown, screen diameter, and aquifer thickness.

Transmissivity values of the upper and lower aquifers vary as a result of differences in geologic materials. The average transmissivity in the upper aquifer is approximately 1,200 feet squared per day (ft^2/d) (fig. 2); in the lower aquifer, the average transmissivity is approximately 6,600 ft^2/d. Generally, transmissivity values are highest in areas with thick, permeable deposits and are lowest in areas of thin, less permeable deposits.

Horizontal Hydraulic Conductivity

Hydraulic conductivity is a measure of the volume of water that will move in a unit of time under a unit hydraulic gradient through a unit area. Hydraulic conductivity depends on the size and arrangement of the water-transmitting openings in a geologic formation (Heath, 1983). Horizontal hydraulic conductivity values of the upper and lower aquifers were determined by dividing the calculated transmissivities by the aquifer thickness. The average horizontal hydraulic conductivity in the upper and lower aquifer is about 27 feet per day (ft/d) and 220 ft/d, respectively (fig. 3).

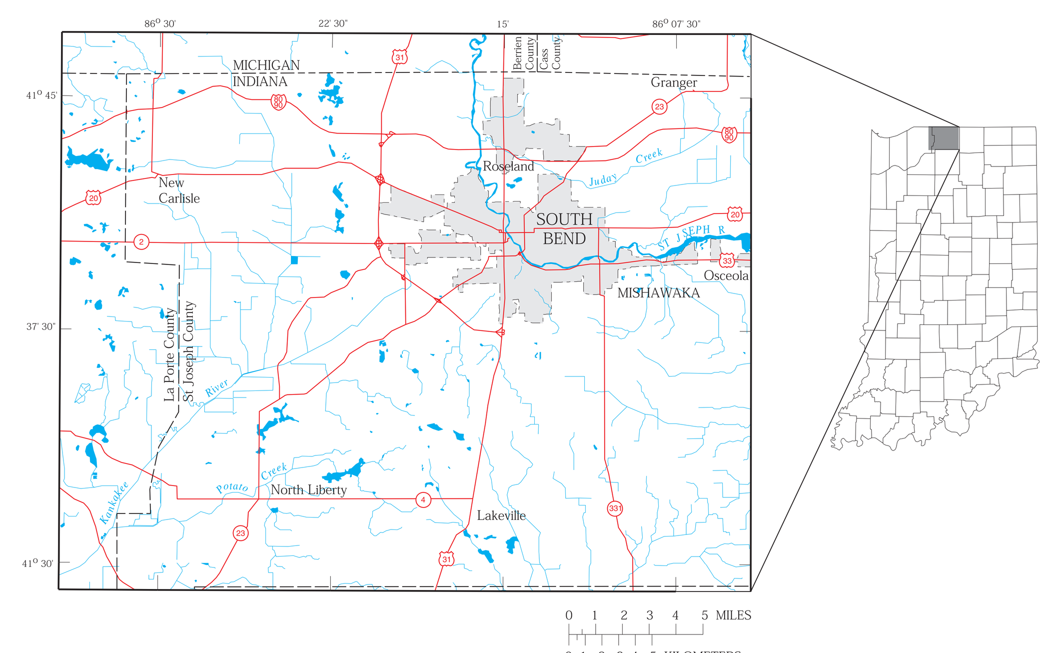

Figure 1. Location of study area.

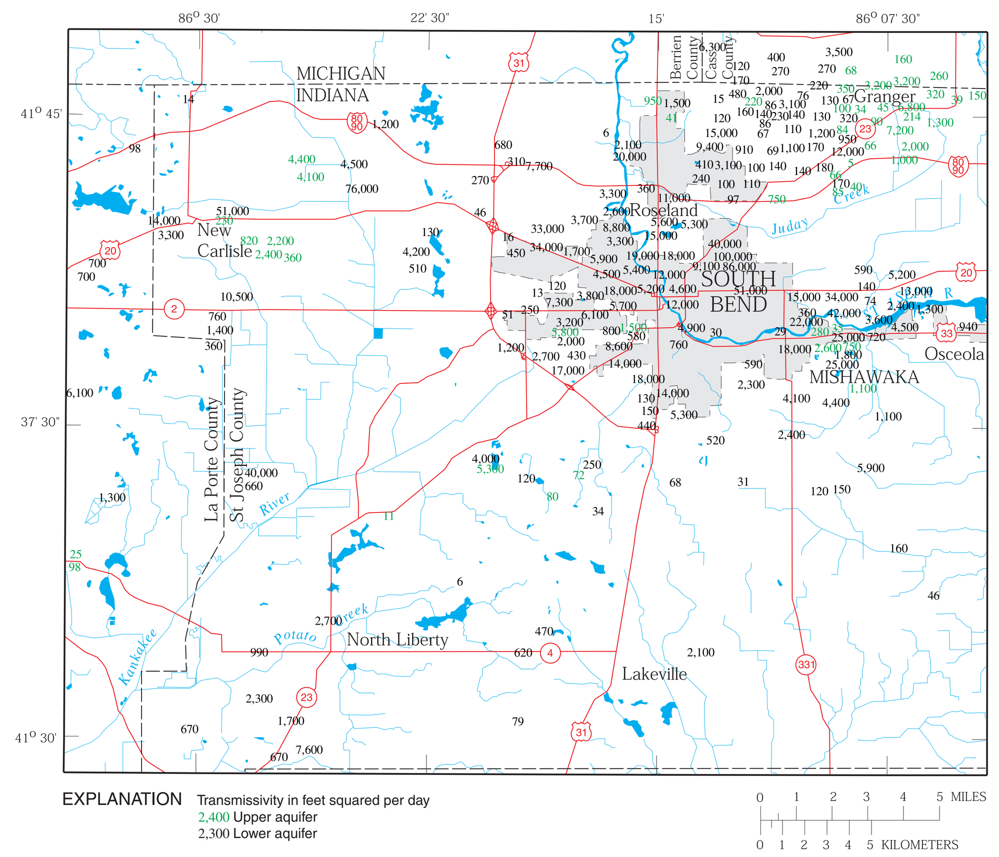

Figure 2. Transmissivity in the upper and lower aquifers.

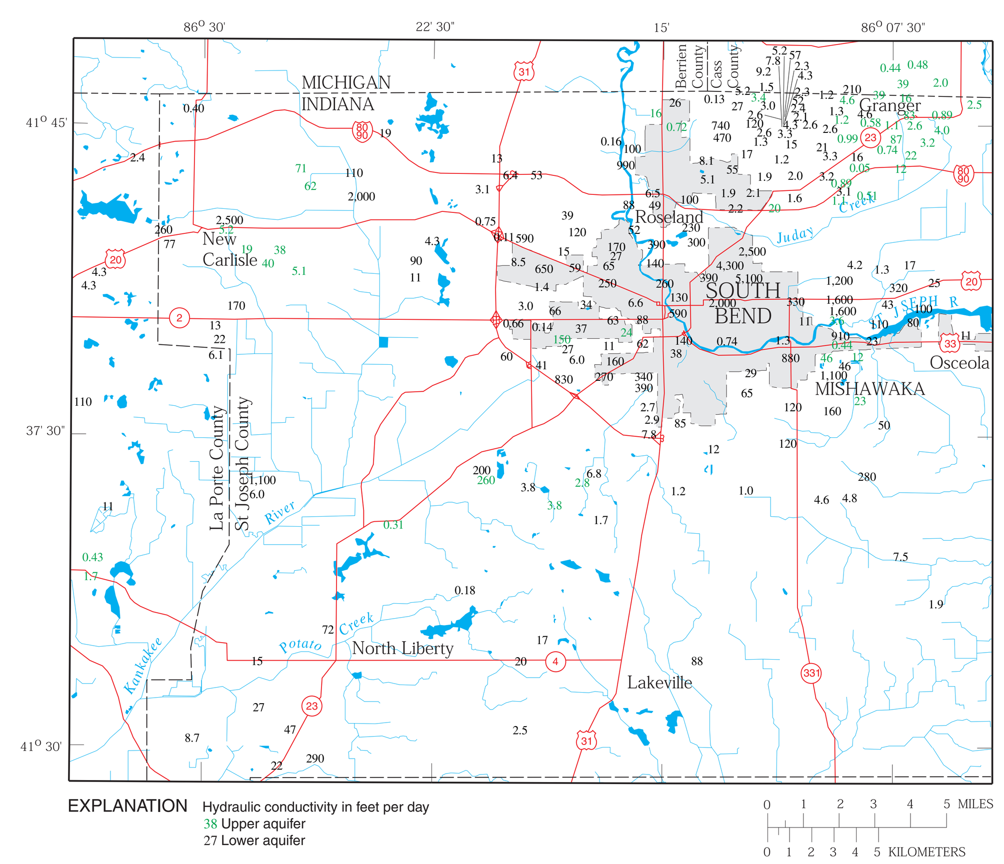

Figure 3. Hydraulic conductivity in the upper and lower aquifers.

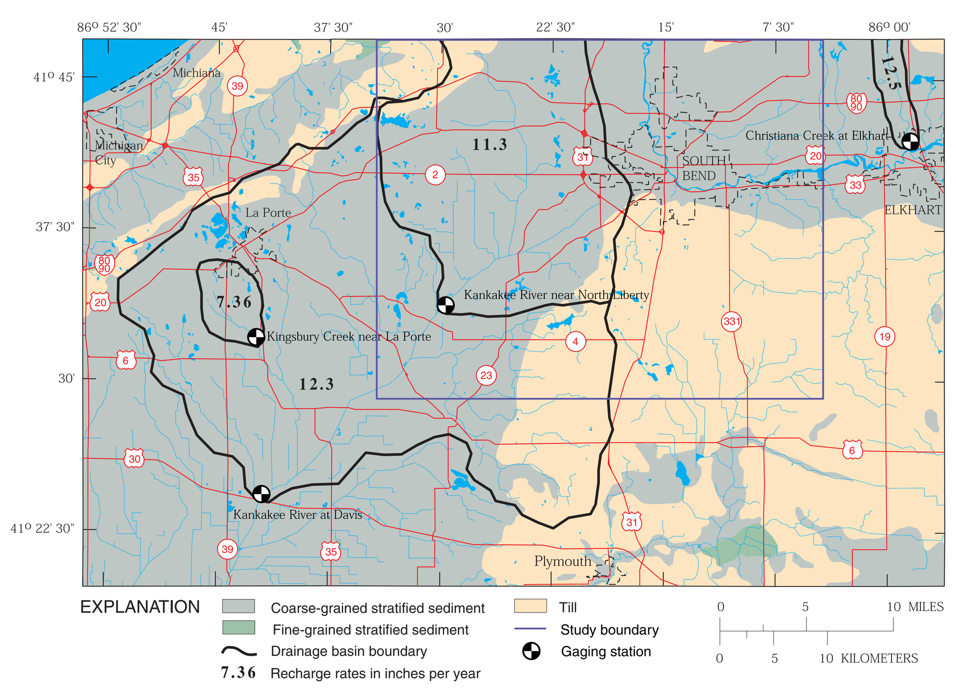

Figure 4. Recharge rates of the upper aquifer in selected drainage basins and surficial deposits in northwestern Indiana.

Recharge Rates

Ground-water recharge is the absorption and addition of water to the saturated zone. Recharge rates were calculated by use of streamflow records and a base-flow-separation program. The program uses streamflow partitioning of ground-water recharge to estimate the average rate of ground-water discharge, which is assumed to be equivalent to effective recharge (Rutledge, 1993). The estimated recharge rates are averages for all lithologies and do not separate sand and gravel from silt and clays; therefore, these rates tend to be lower than those published for individual lithologies (Bayless and Arihood, 1996). Data from four USGS continuous-record streamgaging stations either within or near the study area (fig. 4) were used in the base-flow-separation program. The four stations, selected on the basis of length of record and proximity to the study area, include Kankakee River at Davis (0551550), Kankakee River near North Liberty (05515000), Kingsbury Creek near La Porte (05515400), and Christiana Creek at Elkhart (04100000). The estimated recharge rates for the drainage areas upstream from the four streamgaging stations range from 7.36 to 12.5 inches per year (fig. 4).

Ground-Water Levels

Water-level contours (fig. 5) are based on water-level information obtained from well-drillers' records. The contours are in 20-ft intervals relative to sea level. Water-level measurements obtained during different seasons and different years from both aquifers were combined into one data set; locations of wells with measured water levels are shown in figure 5. The variation in water levels caused by combining data from different seasons and aquifers is considered small and random relative to actual water-level variation across the study area.

Kriging, a geostatistical technique, was used to contour the water-level data. Kriging identifies spatial patterns in the water-level data and uses the patterns to calculate an unbiased estimate of the water-level surface while minimizing the effect of measurement and other sources of error on the estimated value. Bayless and Arihood (1996) indicate that yearly water-level fluctuations in northeastern St. Joseph County are about 2 to 3 ft. Water-level data compiled for this study and the measured water levels from Bayless and Arihood (1996, pp. 42-45) were, on the average, within ±4 ft. The water-level contours (fig. 5) are presented as general indicators of ground-water-flow direction and water-level altitude.

Aquifer Saturated Thickness and Confining Unit Thickness

Saturated thickness maps of the upper aquifer and lower aquifer and a thickness map of the confining unit are based on lithologic data obtained from well-drillers' records. The saturated thicknesses of the upper aquifer vary across the study area and are divided into four ranges. The upper aquifer is absent locally but is as thick as 150 ft in other areas. Areas with saturated thickness of more than 40 ft are in the northeast near Granger, the northwest near New Carlisle, and southwest at the county line (fig. 6). Areas with thickness of less than 40 ft are in the central part of the study area. The thinnest areas are in the north, west, and southeast. The average saturated thickness of the upper aquifer is approximately 23 ft. The lower aquifer is generally thicker than the upper aquifer and has an average saturated thickness of approximately 45 ft (fig. 7). The saturated thickness of the lower aquifer ranges from less than 10 ft to 180 ft but, in much of the study area, it ranges between 40 and 80 ft in thickness. The confining unit is 40 ft thick or less in much of the northern half of the study area (fig. 8). The thickness of the confining unit ranges from 0 to about 90 ft, with an average of about 41 ft; thicknesses are greatest in the southern and eastern areas.

The thickness maps (figs. 6, 7, 8) are in agreement with previously published maps (Bayless and Arihood, 1996). Total thicknesses of the aquifers and confining unit were compared to total thickness of unconsolidated deposits as described by Beaty (1990) and Clendenon and Beaty (1987). Although direct comparisons with previously published maps were difficult to make because of the differences in thickness intervals, the general trends shown in previously published maps appear to be consistent with those shown in figures 6, 7, and 8.

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot squared per day (ft^2/d)	0.09290	meter squared per day
foot per day (ft/d)	0.3048	meter per day
inch per year (in/yr)	2.54	centimeter per year

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$°F = 1.8(°C) + 32$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)–a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units used in this report: Chemical concentrations are given in metric units, either milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

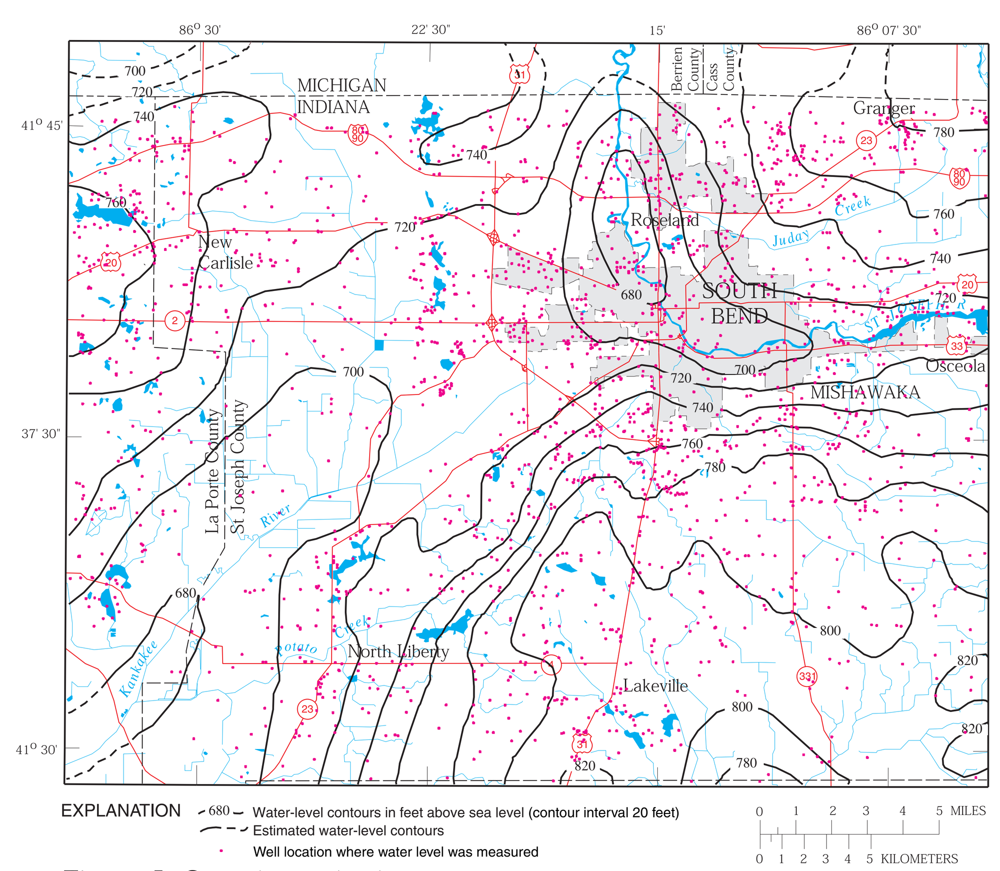

Figure 5. Ground water levels.

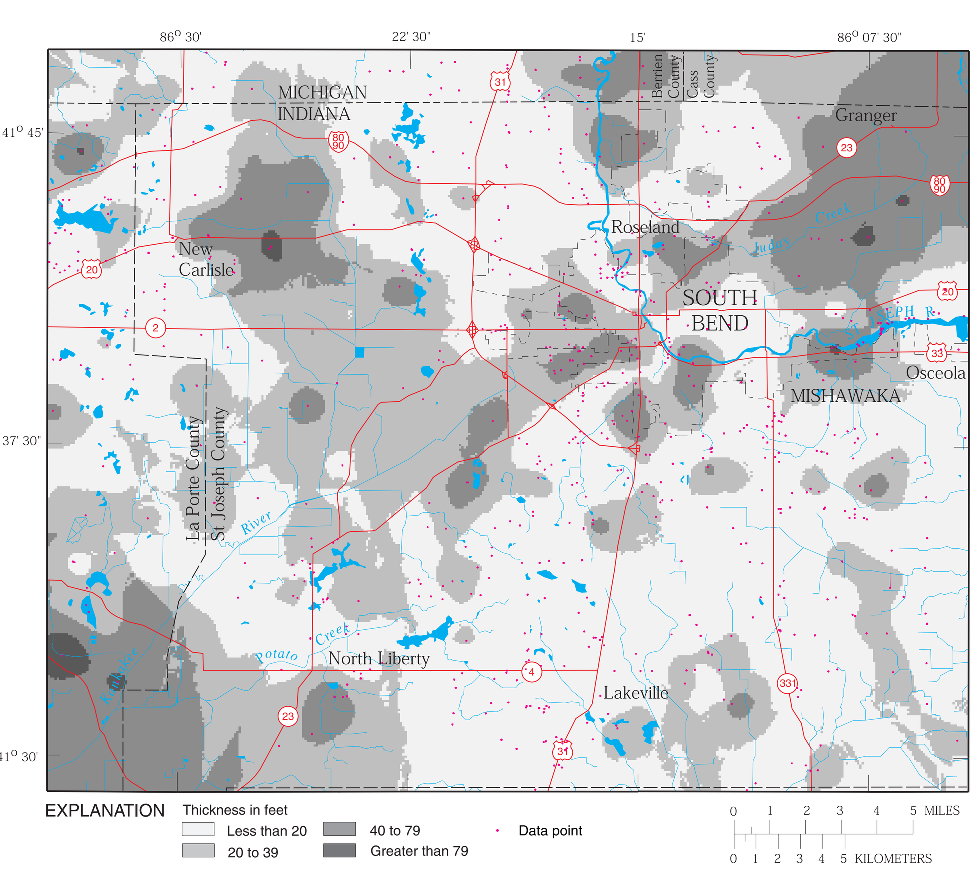

Figure 6. Saturated thickness of the upper aquifer.

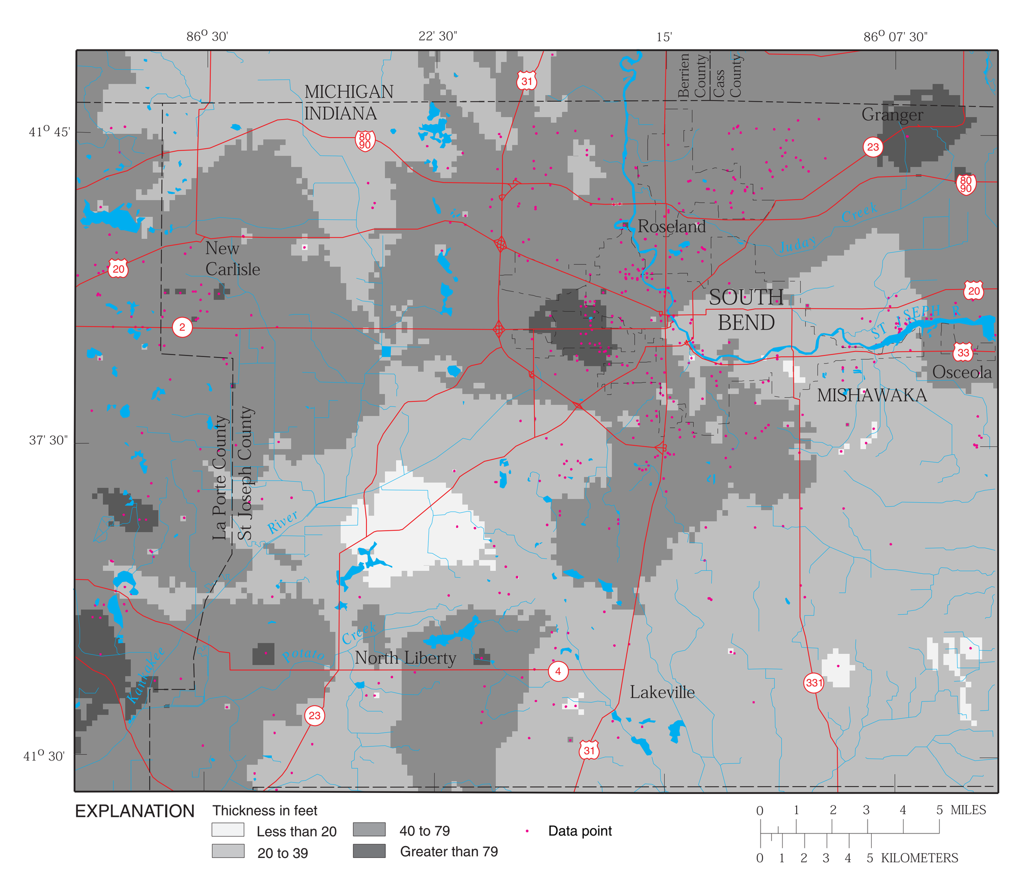

Figure 7. Thickness of the lower aquifer.

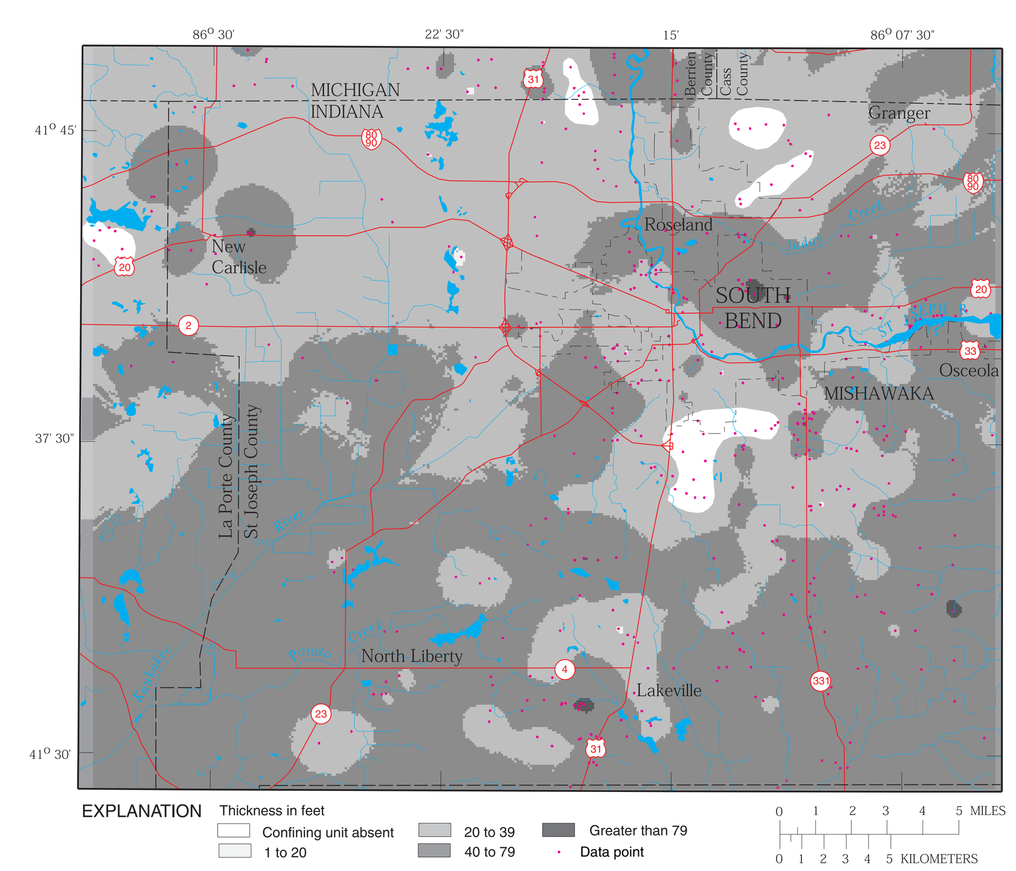

Figure 8. Thickness of the confining unit.

Base maps from U.S. Geological Survey digital data, 1:100,000 1983
Albers Equal Area projection
Standard parallels 29° 30' and 45° 30', central meridian -86°

GEOHYDROLOGY AND QUALITY OF GROUND WATER IN UNCONSOLIDATED AQUIFERS NEAR SOUTH BEND, INDIANA

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1998