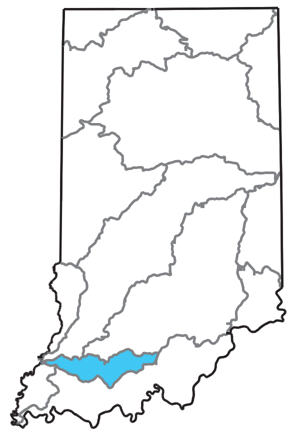


PATOKA RIVER BASIN

By David A. Cohen

General Description

The Patoka River drains 862 mi^2 (Hoggatt, 1975) within a long, narrow basin in southwestern Indiana. The basin is approximately 12 to 16 mi wide throughout most of its 78-mi length. The Patoka River basin includes parts of northern Gibson County, the southern three-quarters of Pike and Dubois Counties, the southern one-third of Orange County, the northeastern corner of Crawford County, and smaller areas in three adjacent counties (fig. 72).

Previous Studies

The ground-water hydrology of the Patoka River basin has not been intensively studied. Watkins (1963) briefly outlined the water resources of the basin with an emphasis on the area surrounding Patoka Lake (fig. 72). The major aquifers in Gibson County were described by Barnhart and Middleman (1990). Harrell (1935) summarized the water resources of each county in Indiana, and Bechert and Heckard (1966) and Clark (1980) constructed ground-water-availability maps for the entire State.

The effects of surface coal mining on ground- and surface-water hydrology were investigated by Corbett (1965, 1968) and Banaszak (1985). Banaszak (1980) also investigated the use of coal beds as aquifers in southwestern Indiana. Wangsness and others (1981) summarized hydrologic data for ground water and surface water in an area of the Eastern Coal Region that includes the Patoka River basin.

Physiography

The Patoka River basin lies in two distinct physiographic units as defined by Schneider (1966) and Malott (1922). The eastern one-half of the basin is part of the Crawford Upland and the western one-half is part of the Wabash Lowland (figs. 2 and 73).

The Crawford Upland is underlain by Upper Mississippian and Lower Pennsylvanian sandstone, shale, and limestone. Differential erosion has produced a deeply dissected upland with abundant stream valleys and a well-integrated drainage system (Gray and others, 1957, p. 5; Schneider, 1966, p. 47-48). This part of the Patoka River basin is typified by generally flat-topped drainage divides and steep-walled valleys with as much as 350 ft of relief (Renn, 1989, p. 9; Schneider 1966, p. 48). Level tracts of land are generally found only along the flood plains of the Patoka River and some large tributaries, such as Straight River and Polson Creek.

The boundary between the Crawford Upland and the Wabash Lowland (fig. 73) is not well defined, but it is probably best placed at Jasper, Ind., (fig. 72) or just a little to the west of Jasper (Gray, 1963, p. 6). In this area, relief gradually decreases to the west over several miles as valleys widen and become increasingly filled with alluvium above their bedrock floors (Malott, 1922, p. 98-99).

The Wabash Lowland is characterized by extensively aggraded valleys and uplands that consist of rolling plains. Drainage divides in this part of the Patoka River basin are commonly 100 ft above the valley floors, and maximum relief is about 150 ft (Schneider, 1966, p. 49). Lake plains are found in the northern part of the basin in Gibson, Pike, and Dubois Counties. These plains mark the sites of glacial lakes that were formed when northward-flowing streams were ponded by advancing Illinoian ice or Wisconsinan outwash (Fuller and Ashley, 1902, p. 4; Fuller and Clapp, 1904, p. 4; Malott 1922 p. 144-146, 251-255; Thornbury, 1950, p. 5, 10). Isolated bedrock hills that rise above the alluvium or silt of the surrounding lake plain are common in the Wabash Lowland (Malott, 1922, p. 103).

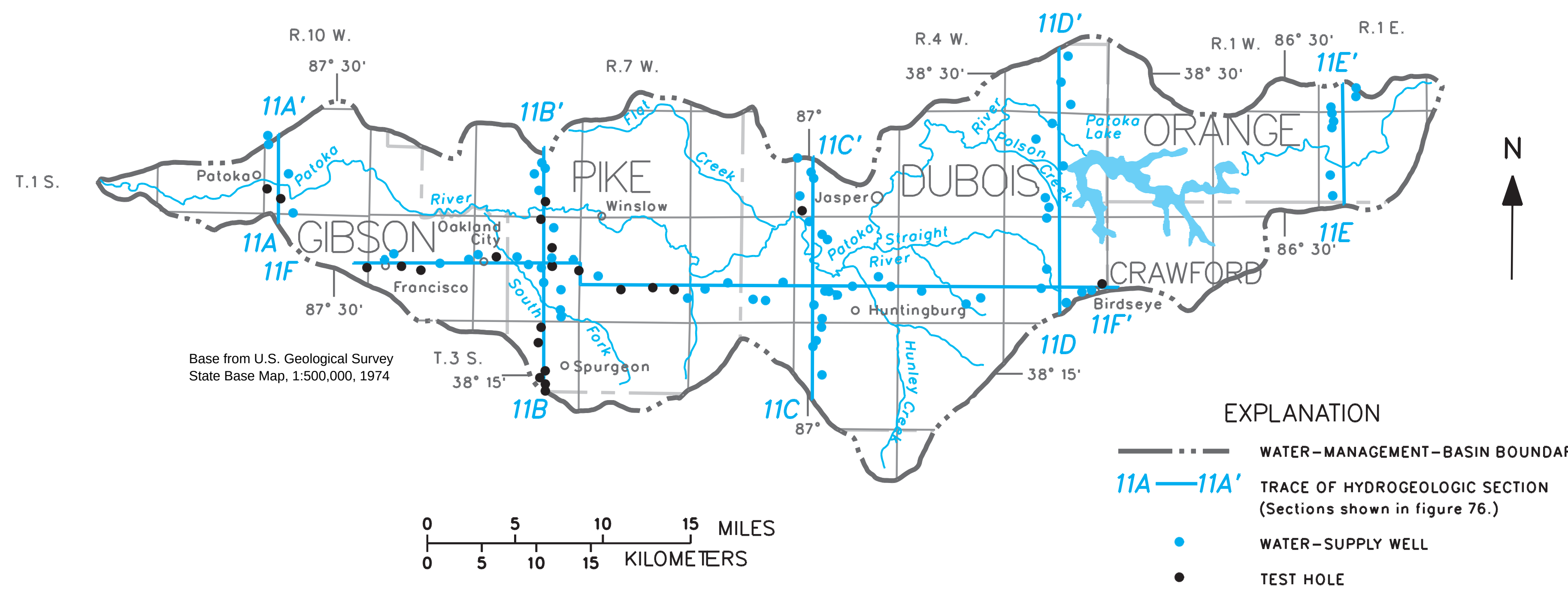


Figure 72. Location of section lines and wells plotted in the Patoka River basin.

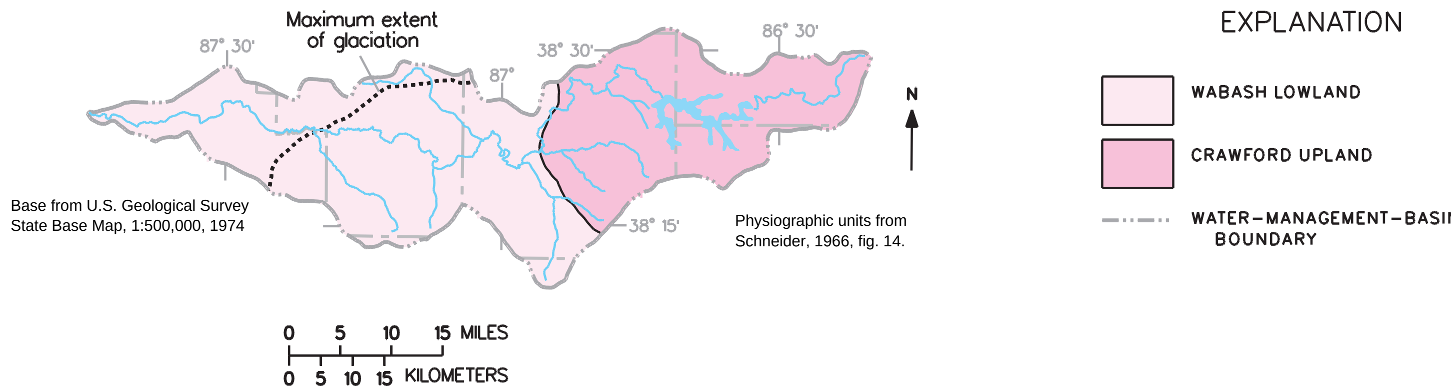


Figure 73. Physiographic units and extent of glaciation in the Patoka River basin.

Surface-Water Hydrology

The Patoka River originates in a group of hills in southeastern Orange County and flows westward to its mouth at the confluence with the Wabash River in extreme western Gibson County (fig. 72). The average gradient over this 161-river-mile course is approximately 1.74 ft/mi (Gray, 1963, p. 6; Hoggatt, 1975). The four largest contributing watersheds are Hunley Creek, South Fork Patoka River, Straight River, and Flat Creek (fig. 72) whose drainage areas are 82.0, 76.3, 67.6, and 58.9 mi^2 respectively (Hoggatt, 1975). These watersheds compose approximately one-third of the total area drained by the Patoka River.

For the period 1934 through 1985, the average discharge for the Patoka River approximately 1 mi upstream of hydrogeologic section 11A–11A′ (fig. 72) was 1,037 ft^3/s with a minimum daily mean discharge of zero during the period August 29 through September 12, 1936, and a maximum instantaneous discharge of 18,700 ft^3/s on January 26, 1937 (Arvin, 1989, p. 738).

Streamflow in the Patoka River has been regulated since 1978 by Patoka Lake (fig. 72). The reservoir, which is used for flood control, water supply, and recreation, is the third largest body of water in the State and has a capacity of 178,730 acre-ft (Renn, 1989, p. 11). Flow-duration analysis by Renn (1989, p. 27) indicates that regulation has generally increased low streamflows and decreased high streamflows downstream from the reservoir.

Streamflow in the Patoka River watershed can also be affected by spoil from surface coal mines (Martin and Crawford, 1987, p. 4). Corbett (1965, p. 2-3) concluded that cast overburden from surface coal mining is a significant source of streamflow in mined watersheds of the Patoka River during periods of extreme drought.

Geology

Bedrock Deposits

Bedrock underlying the Patoka River basin is part of the eastern limb of the Illinois Basin, a prominent regional downwarp centered in southeastern Illinois (fig. 4). Outcrops and subcrops in the Patoka River basin include, from east to west and oldest to youngest, the Blue River, West Baden, Stephensport, and Buffalo Wallow Groups of Mississippian age, and the Raccoon Creek, Carbondale, and McLeansboro Groups of Pennsylvanian age (Gray and others, 1987) (figs. 5 and 74). These rocks dip west-southwest at an average rate of approximately 25 to 30 ft/mi (Gray, 1979, p. K3).

The bedrock surface in the eastern quarter of the Patoka River basin is composed of Mississippian rocks (fig. 74). The middle Mississippian Blue River Group ranges in thickness from 150 to 650 ft and is composed predominantly of carbonate rocks with lesser amounts of evaporites, shale, chert, and calcareous sandstone. The three formations of the Blue River Group, in ascending order, are the St. Louis, Ste. Genevieve, and Paoli Limestones (Gray, 1979, p. K9; Shaver and others, 1986, p. 16).

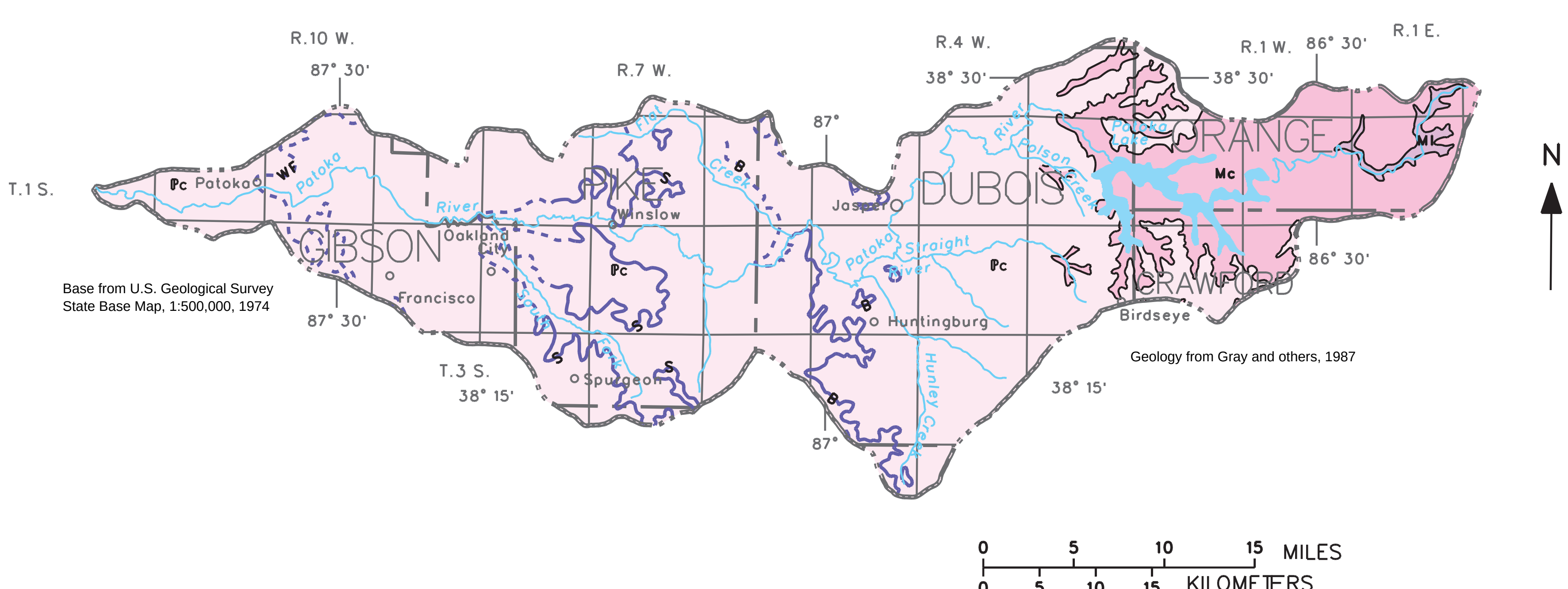
Overlying the limestone sequence of the Blue River Group are three Upper Mississippian groups that consist primarily of sequences of sandstone, shale, and limestone. The lowermost of these, the West Baden Group, ranges in thickness from 100 to 260 ft and is predominantly shale, mudstone, and sandstone, with lesser amounts of limestone. The West Baden Group is characterized by a predominantly clastic nature and by the irregularity of its limestone formations (Sullivan, 1972, p. 6; Shaver and others, 1986, p. 167).

Overlying the West Baden Group is the Stephensport Group, which consists of about equal parts of limestone, sandstone, and shale; it ranges in thickness from 130 to 230 ft. The formations of the Stephensport Group are, in ascending order, the Beech Creek Limestone, the Big Clifty Formation, the Haney Limestone, the Hardinsburg Formation, and the Glen Dean Limestone. The limestones in this group typically maintain their characteristic lithology throughout their outcrop areas, and they are more continuous and distinct than those in the underlying West Baden Group. The Beech Creek Limestone, at the base of the formation, is one of the best known, most widespread, and most reliable marker beds in rocks of Mississippian age in the Illinois Basin. In contrast, the clastic formations of the Stephensport Group commonly display abrupt lateral and vertical variations in lithology (Gray and others, 1957, p. 5-6; Gray and others, 1960, p. 41; Gray, 1979, p. K10; Shaver and others, 1986, p. 150-151).

The Buffalo Wallow Group overlies the Stephensport Group, and consists predominantly of shale, mudstone, and siltstone, with lesser amounts of sandstone and limestone. The Tar Springs Formation, at the base of the Buffalo Wallow Group, is probably the only formation in this group that is an outcrop or subcrop in the Patoka River basin. This formation is commonly about 65 ft thick and is primarily shale, although it contains local lenses of massive sandstone (Gray, 1978, p. 5; Shaver and others, 1986, p. 24).

Upper Mississippian rocks in the Patoka River basin are overlain unconformably by Lower Pennsylvanian rocks. The surface of this unconformity is a southwest-sloping plateau entrenched as much as 300 ft by southwest-trending relict stream valleys (Gray, 1979, p. K3).

Pennsylvanian rocks in Indiana consist of a dominantly clastic sequence of shale, siltstone, and sandstone, with intercalated thin but widespread beds of clay, coal, black shale, and limestone. Lateral facies changes are common and can be abrupt. Within short distances, individual beds or whole sequences can change in character so completely that they are scarcely traceable laterally (Gray and others, 1957, p. 5; Gray, 1979, p. K13). Pennsylvanian rocks compose the bedrock surface of the western three-quarters of the Patoka River basin (fig. 74), and include, in ascending order, the Raccoon Creek, Carbondale, and McLeansboro Groups.



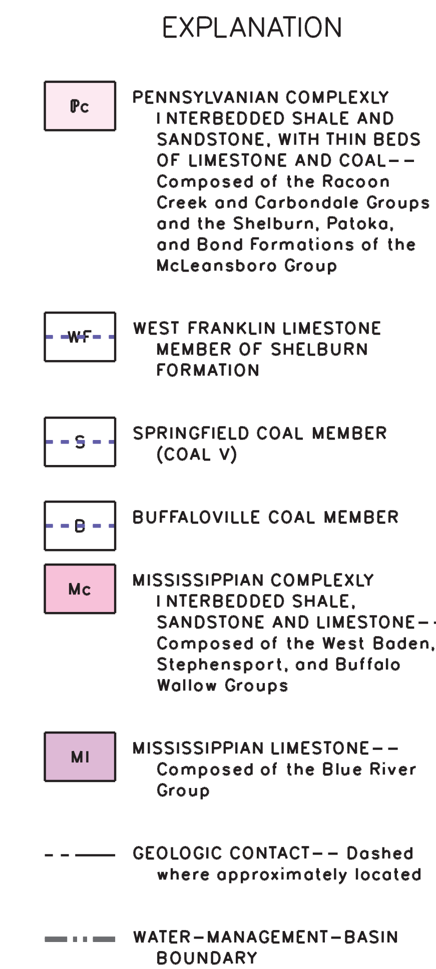


Figure 74. Bedrock geology of the Patoka River basin.

The Lower Pennsylvanian Raccoon Creek Group consists of more than 95 percent shale and sandstone and less than 5 percent clay, coal, and limestone. In ascending order, this group consists of the Mansfield, Brazil, and Staunton Formations. The Mansfield Formation is composed primarily of sandstone, shale, and mudstone, and it includes six named coal members. This formation is generally divided into an upper and lower unit; the upper unit is predominantly shale and mudstone, whereas the lower unit is mostly sandstone. The Mansfield Formation is roughly 200 to 400 ft thick in the Patoka River basin (Gray and others, 1960, p. 22-26; Gray, 1963, p. 11-12; Shaver and others, 1986, p. 86-87, 89, 120-121). The Brazil Formation, approximately 40 to 90 ft thick, consists of shale, sandstone, underclay, and coal. This formation is characterized by irregularities in both the thickness and lateral continuity of recognizable beds. The Brazil Formation contains the Buffaloville Coal Member, and the Upper Block Coal Member (Coal IV), a low-ash, low-sulfur coal. The Staunton Formation consists of 75 to 150 ft of sandstone and shale and as many as eight coal beds (Shaver and others, 1986, p. 21, 25, 150, 159; Weir, 1973, p. 18).

The Middle Pennsylvanian Carbondale Group includes, in ascending order, the Linton, Petersburg, and Dugger Formations. The Linton Formation consists of 40 to 160 ft of shale, sandstone, limestone, coal, and clay. At the base of the formation is the Coxville Sandstone Member, a 10- to 60 ft-thick fine- to coarse-grained, thickly bedded sandstone. The Petersburg Formation, 40 to 120 ft thick, includes three coal members, one limestone member, and unnamed beds of shale, sandstone, siltstone, and underclay. At the top of the formation is Indiana’s most economically important coal, the Springfield Coal Member (Coal V) (Wier, 1973, p. 19, 27). The Dugger Formation includes 73 to 185 ft of sandstone, shale, limestone, coal, and clay. In the upper part of the Dugger Formation is the Anvil Rock Sandstone Member, a siltstone and sandstone that is present not only as a widespread sheet deposit but also as a channel-fill deposit. The Anvil Rock Sandstone Member can exceed 100 ft in thickness where the sheet phase overlies the channel-fill phase (Shaver and others, 1986, p. 6, 27, 32, 39, 80, 112, 149).

The Upper Pennsylvanian McLeansboro Group in the Patoka River basin consists of the Shelburn, Patoka, and Bond Formations, in ascending order. The Shelburn Formation ranges in thickness from 50 to 250 ft and is composed of shale, siltstone, and sandstone with lesser amounts of limestone, clay, and coal. At the base of this formation is the Busseron Sandstone Member, a fine- to medium-grained, massive sandstone, 48 to 77 ft thick, that fills erosional cutouts. More than 85 percent of the Patoka Formation is shale and sandstone; less than 15 percent is clay, limestone, and coal. Near the base of the formation is the fine-grained, 20-to 80-ft-thick Inglefield Sandstone Member (Shaver and others, 1986, p. 62, 85, 109, 142-43).

Unconsolidated Deposits

Unconsolidated deposits in the Patoka River basin are 0 to 150 ft thick (fig. 75). In the extreme western part of the basin, where the Patoka and Wabash River flood plains coincide, outwash sands and gravels overlain by alluvium commonly exceed 100 ft in thickness (Fidlar, 1948, p. 23-24, 43). Farther upstream, along the Patoka River, most unconsolidated deposits thin to 50 ft or less (fig. 75) and consist primarily of fine-grained alluvial materials of the Martinsville and Prospect Formations (Gray, 1963, p. 7-10).

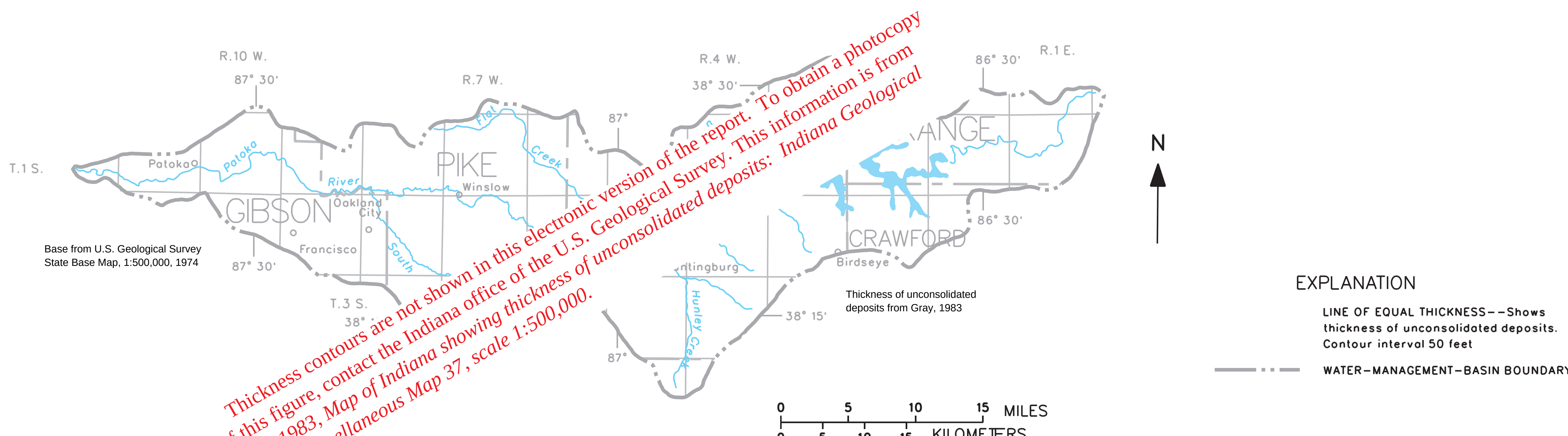


Figure 75. Thickness of unconso… …e Patoka River basin.

In some northern parts of the basin in Gibson, Pike, and Dubois Counties, fine-grained lake (lacustrine) sediments, deposited in lakes of Illinoian and Wisconsinan ages, are 50 to more than 100 ft thick (Fidlar, 1948, p. 62-63; Gray and others, 1957, p. 7; Gray, 1963, p. 7-10). Illinoian till deposits are restricted to the northwestern part of the basin (fig. 73) and are generally less than 20 ft thick (Fuller and Clapp, 1904, p. 4).

Aquifer Types

Six hydrogeologic sections, totaling almost 100 mi in length, were constructed for the Patoka River basin (fig. 72). A total of 98 drillers' logs from water wells, coal-exploration test holes, and oil- and gas-exploration test holes, were used to construct the sections. Information from Wier and Stanley (1953), Friedman (1954), Hutchison (1964), Gray and others (1970), Gray and others (1987), and Keller (1990), aided interpretation of the drillers' logs. The average density of drillers' logs along the section lines is one per mile. Sections 11A–11A′ to 11E–11E′ (fig. 76) are oriented south-north, approximately perpendicular to the Patoka River, and are 14 to 16 mi apart. Section 11F–11F′ (fig. 76) is oriented west-east and is parallel to the long axis of the basin.

The different types of aquifers in the Patoka River basin include surficial sand and gravel deposits composed of outwash; discontinuous sand and gravel lenses interbedded with glacial, lake, and alluvial deposits; Upper Mississippian and Pennsylvanian sandstones; and Middle and Upper Mississippian carbonate rocks. Quantities of ground water sufficient to meet commercial and industrial needs can be obtained only from thick outwash sand and gravel deposits in the extreme western part of the basin. Yields from this aquifer can exceed 1,000 gal/min. The remaining aquifers in the Patoka River basin are generally capable of producing only enough water to meet domestic and livestock needs. Yields from these aquifers generally range from less than 1 to 25 gal/min and rarely exceed 100 gal/min. The four aquifer types in the Patoka River basin are summarized in table 13. The table includes range of aquifer thickness, range of reported yields, and common aquifer names used by other authors. The general areal extent of each aquifer type in the basin is shown in figure 77.

Unconsolidated and bedrock aquifers in the Patoka River basin are recharged primarily by direct infiltration and percolation of precipitation. Recharge may also occur as percolation from surface water in upland lakes and from mining impoundments. Flow in the shallow bedrock is probably complex and locally controlled; recharge occurs in upland areas, and ground water discharges to streams that flow on or near the bedrock surface (Martin and others, 1990, p. B22). Flow in deeper parts of the bedrock is primarily regional and probably follows the southwestward dip of the strata to points of discharge along the Wabash and Ohio Rivers.

Unconsolidated Aquifers

Unconsolidated aquifers in the Patoka River basin consist primarily of surficial sand and gravel, and discontinuous sand and gravel lenses. These aquifers are present in the western three-quarters of the basin (fig. 77). Unconsolidated deposits in the eastern one-quarter of the basin are relatively thin and impermeable and are not suitable sources of ground water (Gray and others, 1960, p. 22; Harrell, 1935, p. 162-163, 388).

Surficial Sand and Gravel Aquifers

Outwash sands and gravels are a major source of ground water along the lower reach of the Patoka River where the flood plains of the Wabash, White, and Patoka Rivers coalesce (Barnhart and Middleman, 1990, p. 9; Harrell, 1935, p. 215-218). The general areal extent of this aquifer type is shown as surficial sand and gravel aquifer in figure 77. Some wells completed in these deposits yield more than 1,000 gal/min (Barnhart and Middleman, 1990, p. 9).

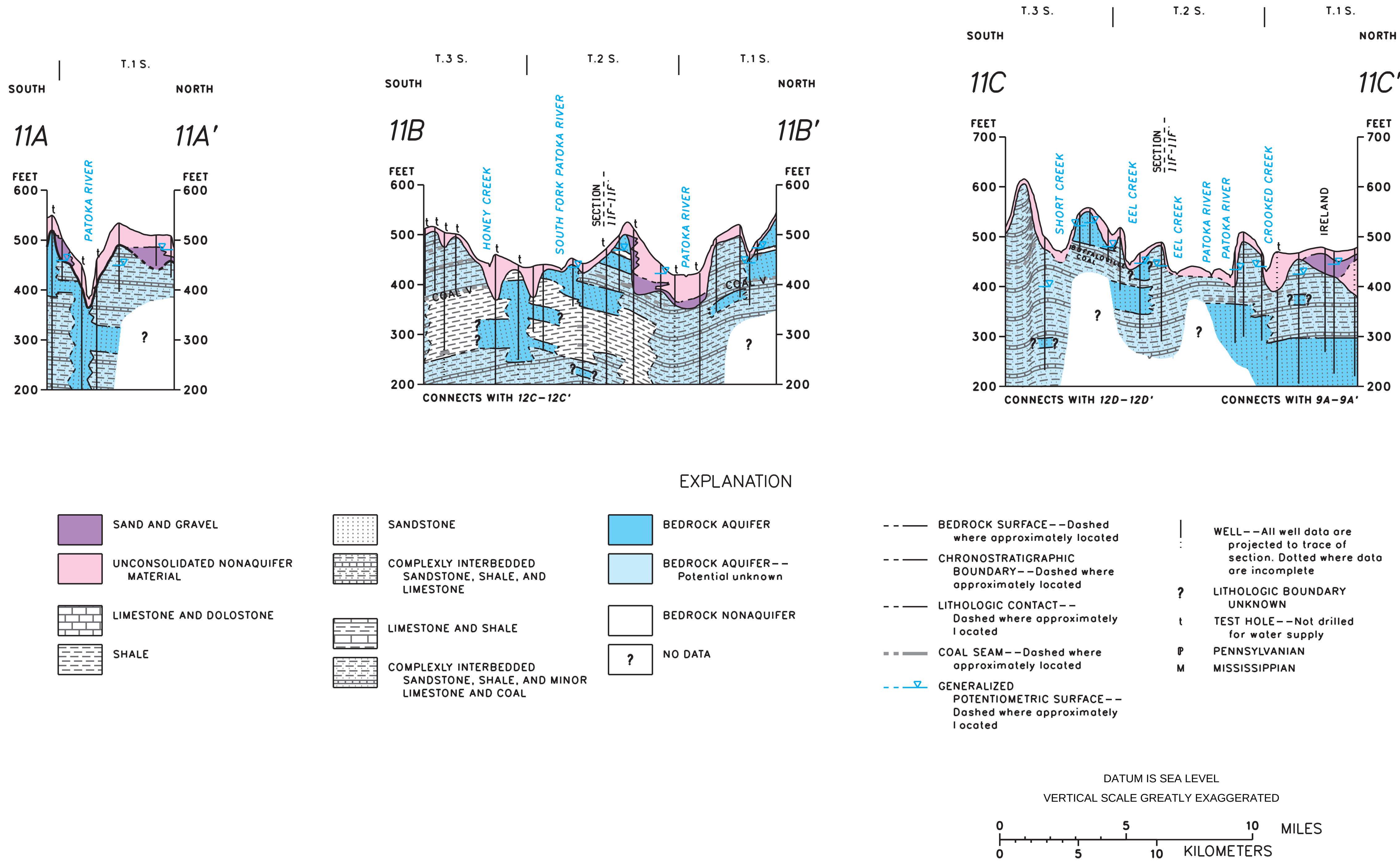


Figure 76. Hydrogeologic sections *11A–11A′* to *11F–11F′* of the Patoka River basin.

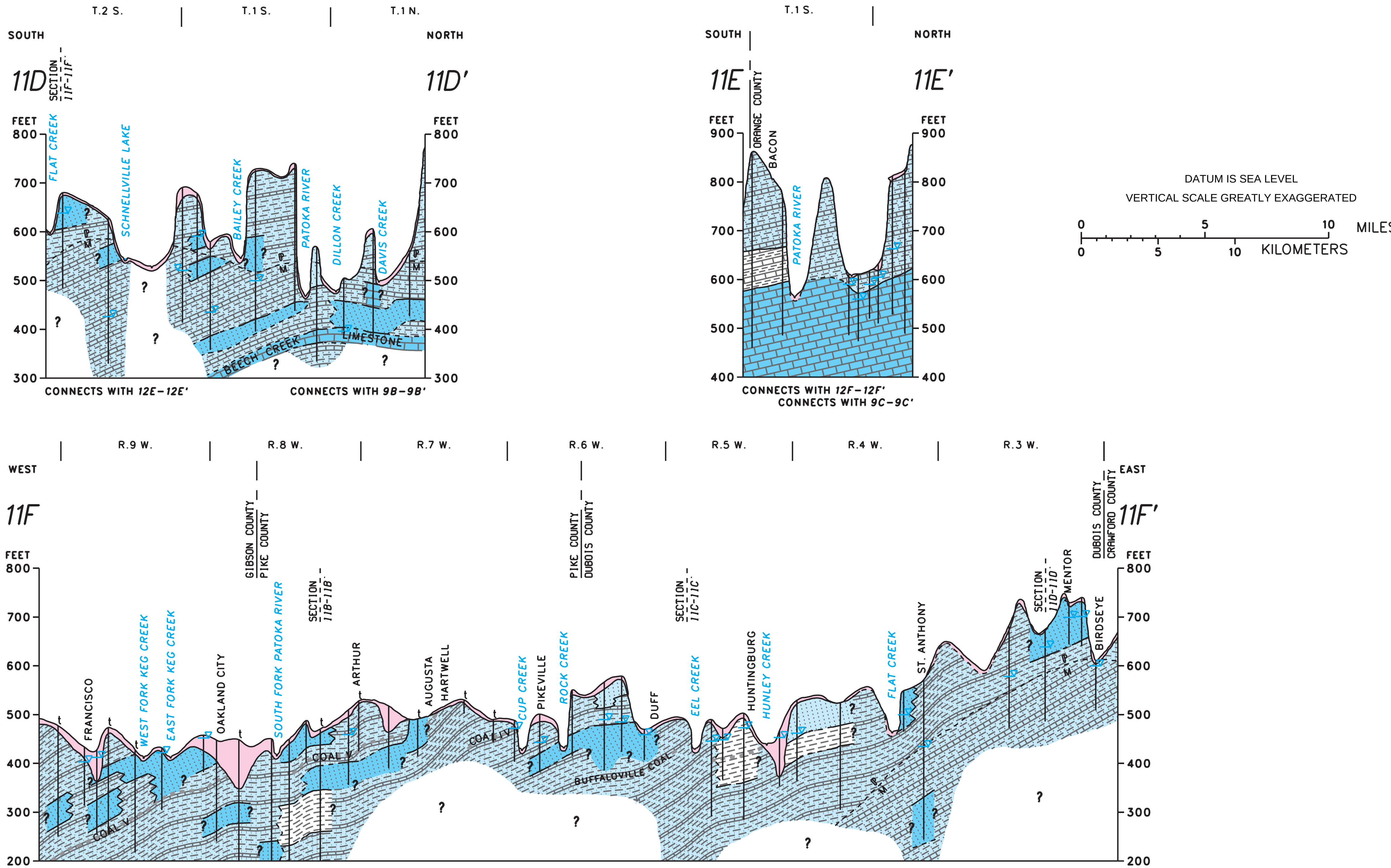


Figure 76. Hydrogeologic sections *11A–11A′* to *11F–11F′* of the Patoka River basin—Continued.

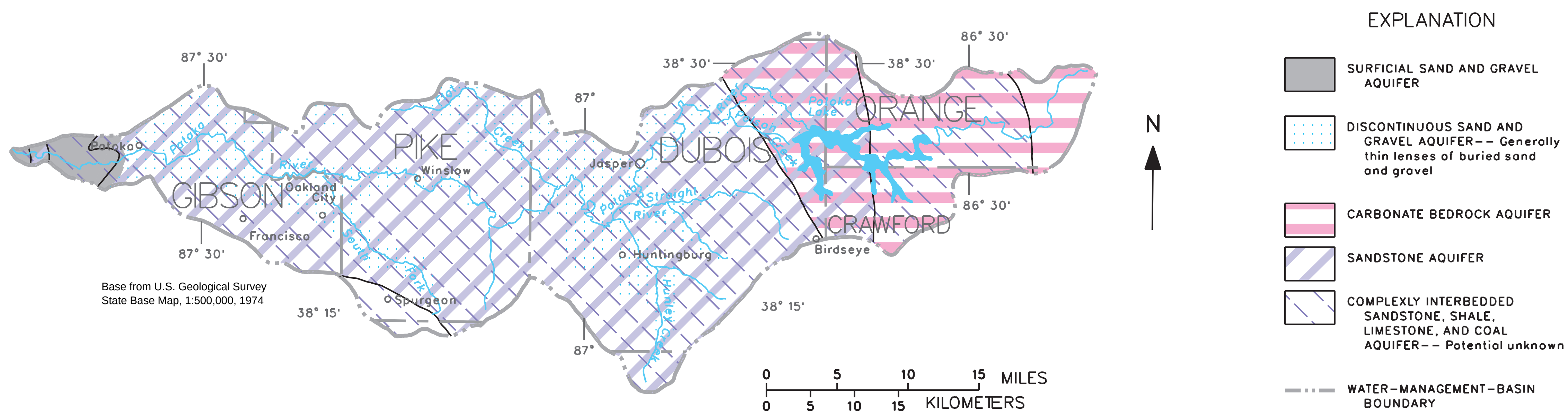


Figure 77. Extent of aquifer types in the Patoka River basin.

Discontinuous Sand and Gravel Aquifers

Another source of ground water from unconsolidated deposits is laterally discontinuous sand and gravel lenses interbedded with finer grained glacial, lake, and alluvial deposits (Barnhart and Middleman, 1990, p. 9). These deposits are found in the Patoka River and tributary valleys, other bedrock valleys, and in the northern part of the basin in Gibson, Pike, and Dubois Counties. The sand and gravel lenses are generally less than 30 ft thick but can be as much as 125 ft thick in places (Clark, 1980, p. 412; Barnhart and Middleman, 1990, p. 9). Wells in these deposits generally yield less than 100 gal/min; these deposits are mapped as discontinuous sand and gravel aquifer in figure 77. One well along the northern part of section 11A–11A′ (fig. 76) taps this type of aquifer. Other examples of this type of aquifer can be seen beneath the Patoka River valley in sections 11A–11A′ and 11B–11B′, and along the northern part of section 11C–11C′ (fig. 76).

Bedrock Aquifers

Carbonate Bedrock Aquifers

Middle and Upper Mississippian limestones are present in approximately the eastern one-third of the Patoka River basin and include limestone members of the Blue River, West Baden, and Stephensport Groups. These limestones are identified in figure 77 as the carbonate bedrock aquifer. Dissolution along joints, fractures, and bedding planes has generally increased the permeability of these rocks and is responsible for well yields of 5 to 10 gal/min (Harrel, 1935, p. 162-63; Jenkins, 1956, p. 13, 20; Gray and others, 1960, p. 43-44, 51; Gray and Powell, 1965, p.13-14; Bechert and Heckard, 1966, p. 108; Clark, 1980, p. 30). Mississippian carbonate bedrock aquifers are depicted in sections 11D–11D′ and 11E–11E′ (fig. 76).

The carbonate bedrock aquifers in section 11D–11D′ (fig. 76) are part of the Stephensport Group. Gray (1963, p. 13) and Gray and others (1960, p. 43-44, 48) indicate that the Beech Creek Limestone is the most extensive and highest yielding aquifer in the Stephensport Group. The wells along section 11E–11E′ (fig. 76) are completed in more than 50 ft of continuous limestone belonging to the Paoli Limestone and possibly the upper part of the Ste. Genevieve Limestone of the Blue River Group. Drillers' logs from four of the wells along this section indicate yields of 5 to 23 gal/min.

Sandstone Aquifers

Upper Mississippian and Pennsylvanian sandstone aquifers underlie virtually all but the eastern end of the Patoka River basin (fig. 77). With the exception of sand and gravel deposits, these sandstones are probably the primary source of ground water in the western two-thirds of the basin. In the Patoka River basin, yields of wells that tap these sandstones are generally low, ranging from less than 1 to 5 gal/min, with one notable exception; sandstones in the lower part of the Mansfield Formation, which are reputed to have the highest yields in the entire Pennsylvanian section (Gray and others, 1960, p. 29; Cable and Wolf, 1977, p. 9, 12-14), produce as much as 100 gal/min (Clark, 1980, p. 27-30). Wells along the northern one-half of section 11C–11C′ (fig. 76) tap thick sandstones that are probably the lower Mansfield Formation. Drillers' logs for three of these wells indicate yields that range from 7 to 20 gal/min—yields that are higher than those of most other wells that tap sandstones along other sections in the basin.

Most of the wells along sections 11B—11B′, 11C–11C′, and 11F–11F′ (fig. 76) tap Pennsylvanian sandstone aquifers. Some of these sandstones are fluvial (also known as channel-fill) deposits, which are relatively thick, narrow deposits that fill erosional

Table 13. Characteristics of aquifer types in the Patoka River basin

[<, less than; >, greater than; locations of aquifer types shown in fig. 77]

Aquifer type	Thickness (feet)	Range of yield (gallons per minute)	Common name(s)
Surficial sand and gravel	30-<150	[1,2]25->1,000	Valley train[1]; flood plain deposits[3]; alluvium and outwash[4]; outwash sand and gravel[2]
Discontinuous sand and gravel	<30- 125	[1,2]5- 250	Sand and gravel lenses, outwash plain deposits[1]; sand and gravel deposits[2]
Carbonate bedrock			
Middle Mississippian	>100	[2,5]5- <100	Blue River Group[6]
Upper Mississippian	8- 40	[2]1- 10	Beech Creek Limestone[6]
	20- 40	No data	Haney Limestone[6]
	9- 30	No data	Glen Dean Limestone[6]
Sandstone			
Upper Mississippian	30- 70	[2]<1- 5	Big Clifty Formation[6]
	20- >60	[2]<1- 5	Hardinsburg Formation[6]
Pennsylvanian	10- 150	[2]<1- 100	Mansfield Formation[2,3,5,7]
	10- 60	[2]<1- 10	Coxville Sandstone Member[6] or Linton Aquifer[7]
	10- 160	[2]<1- 10	Anvil Rock Sandstone Member[6]
	20- 90	[1,2]<1- 10	Busseron Sandstone Member[1]
	20- 40	[1,2]3- 300	Inglefield Aquifer[1] or Inglefield Sandstone Member[2]

[1]Barnhart and Middleman, 1990.
[2]Clark, 1980.
[3]Harrell, 1935.
[4]Fidlar, 1948.
[5]Bechert and Heckard, 1966.
[6]Shaver and others, 1986.
[7]Cable and Wolf, 1977.

cutouts in underlying strata. Wells in channel sandstones may have higher yields than wells in sheet sandstones because of the greater thickness and higher permeability of channel sandstones. Their higher permeability is attributed to generally larger grain size, better sorting, and smaller amounts of clay compared to sheet sandstones (Hopkins, 1958, p. 12; Cable and Wolf, 1977, p. 9; Martin and others, 1990, p. B22). The thick sandstone sequence shown in section 11A–11A′ (fig. 76) probably consists of several stacked channel-fill deposits and includes, at least in part, the Anvil Rock Sandstone Member of the Dugger Formation. Another channel sandstone is evident on section 11B–11B′ (fig. 76) between Honey Creek and South Fork Patoka River.

Complexly Interbedded Sandstone, Shale, Limestone, and Coal

In areas where unconsolidated aquifers are absent, and where sandstone and limestone aquifers are either unproductive or too deep for the economical installation of wells, ground water can be obtained from coal seams and(or) complexly interbedded sequences of sandstone, shale, limestone, and coal. Banaszak (1980, p. 235-240) indicates that coal seams hydraulically connected to a source of recharge and underlain by a confining unit can yield as much as 10 gal/min. Only 8 of the well logs used to construct sections in the Patoka River basin indicate that the wells obtain water primarily from coal seams and(or) complexly interbedded lithologies; three of the logs indicate well yields of less than 1 gal/min. In contrast, a fourth well log, plotted on section 11B–11B′ (fig. 76) as the first water-supply well south of the Patoka River, indicated a yield of 12 gal/min. The source of ground water for this well is strata immediately downdip of a bedrock surface overlain by sand and gravel. Basal sands and gravels probably increase recharge to the underlying bedrock and increase net storage in the immediate area, resulting in anomalously high yields. With local exceptions such as this, coal seams and(or) complexly interbedded lithologies are not generally a primary source of ground water in the Patoka River basin, and these materials are shown as “aquifer—potential unknown” on all the hydrogeologic sections.

Summary

The Patoka River basin encompasses 862 mi^2 in southwestern Indiana. Major sources of ground water in the Patoka River basin include surficial sand and gravel composed of outwash, discontinuous sand and gravel, Mississippian carbonate rocks, and Mississippian and Pennsylvanian sandstones.

Outwash sand and gravel deposits can produce in excess of 1,000 gal/min but they are present only in the extreme western part of the basin. Discontinuous sand and gravel interbedded with fine-grained material are present in the western three-quarters of the basin along the Patoka River and tributary valleys and in areas once covered by lakes during Illinoian and Wisconsinan glaciations. Well yields as much as 250 gal/min are available from these deposits.

Sandstone and carbonate bedrock aquifers in the basin are generally capable of producing only enough water to meet domestic and livestock needs. Sandstone aquifers underlie most of basin, whereas carbonate bedrock aquifers, composed primarily of limestone, are present only in the eastern one-third. Well yields from the sandstone aquifers are generally less than 1 to 5 gal/min but seem to be somewhat higher in the lower Mansfield Formation. Wells in the carbonate bedrock aquifers typically yield 5 to 10 gal/min. Recharge to bedrock aquifers and net storage may be increased in areas where sand and gravel directly overly the bedrock surface. Bedrock wells downdip from these areas may have higher yields. Coal seams and complexly interbedded sequences of sandstone, shale, limestone, and coal are infrequently a primary source of ground water, and their potential as aquifers can be adequately evaluated only on a local basis.

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