# The Water Resource

As discussed, the hydrologic cycle represents the constant movement of water between the earth's surface and atmosphere. As used hereafter, the term *water resource* refers only to water in its occurrence as surface and ground water. The original supply for the water resource is precipitation, which includes rain and snowfall. The average annual precipitation, which occurs within a particular geographic area, represents the overall or gross supply of water to that area.

The gross, long-term supply of water to Indiana, in the form of precipitation, amounts to a statewide annual average of 38.0 inches per year. However, as Figure 3 indicated, annual average precipitation in Indiana will vary between 36.0 inches in the north to 44.0 inches in southern Indiana. The mean monthly precipitation for selected stations in northern, central, and southern Indiana is shown on Figure 12.

Not all of the precipitation is directly available to maintain the water resource, as indicated in Figure 13. Much of the water is lost to evapotranspiration. It is estimated that approximately sixty-nine percent or 26.0 inches of the average annual precipitation in Indiana is returned to the atmosphere.

Therefore, of the original 38.0 inches of precipitation, approximately 12.0 inches represent the annual net supply of the water resource.

It is convenient to discuss Indiana's water resource in terms of its two major components, ground water and surface water. The distinction between the ground-water component and the surface-water component is implied by their names. Ground water occurs in consolidated and unconsolidated underground, geologic formations. Surface water occurs in surface streams and lakes.

In general, ground water is supplied by that portion of precipitation that infiltrates through the soil profile to underlying, geologic formations, or aquifers, that have the ability to absorb, store, and transmit water.

Although information is limited, it appears that approximately nine percent of the average annual precipitation recharges, or is contributed to, the ground-water system. In Indiana, this ground-water recharge from precipitation is equal to about 3.0 to 3.6 inches per year, as indicated in Figure 13. This translates into a range of 143,000 to 171,000 gallons-per-day-per-square-mile of precipitation being contributed to the ground-water system.

As the precipitation moves downward and into the aquifer systems there is a continuing and somewhat corresponding amount of water that moves out of the aquifer system as seepage and underflow into the streams, rivers, and lakes. This seepage, or "baseflow," constitutes the major portion of the normal and low flow of the streams and is a significant part of the water contained in the stream during periods between surface runoff-producing rainfall events.

About twenty-two percent, or 8.4 to 9.0 inches, of the annual average precipitation is direct, surface runoff to streams and lakes. This translates to a range of 400,000 to 429,000 gallons-per-day-per-square-mile of surface runoff from precipitation.

Since the outflow from the aquifer systems is to surface streams, the yield of the ground-water system is included in and measured as a part of the total stream flow, or runoff. Consequently, given the 38.0 inches of

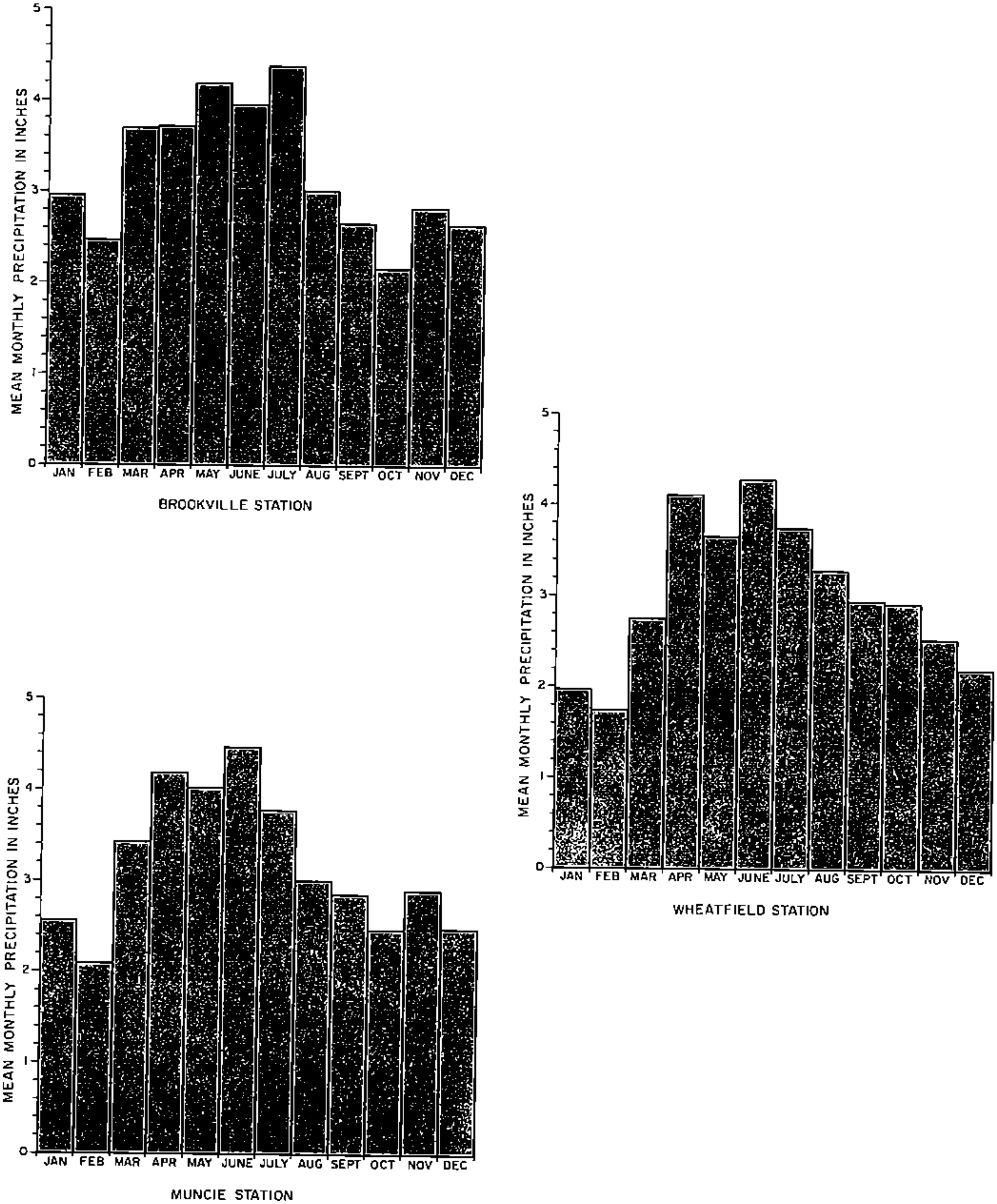



**Figure 12**
Graphs indicating the mean monthly precipitation for selected locations in northern (Wheatfield station), central (Muncie station), and southern (Brookville station) portions of Indiana.

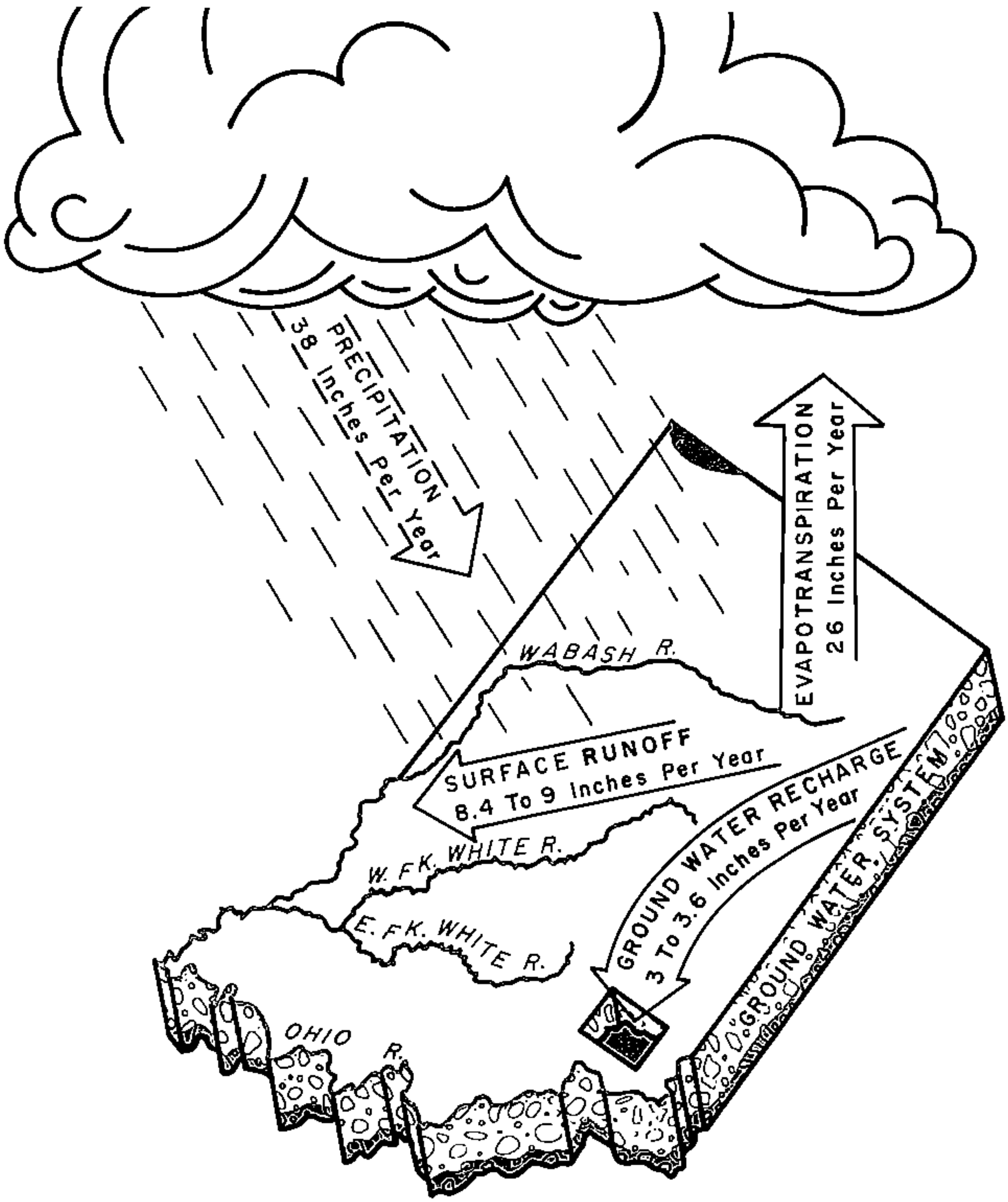



**Figure 13**
Illustration of the distribution of average annual precipitation in Indiana.

annual average precipitation in Indiana, less the 26.0 inches lost to evapotranspiration, the remaining 12.0 inches may be expressed as the total average annual runoff. As indicated in Figure 14, this average annual runoff of 12.0 inches ranges from 10.0 to 18.0 inches from northern to southern Indiana. The mean monthly runoff for selected stations in northern, central, and southern Indiana are shown in Figure 15.

The availability and occurrence of the ground-water and surface-water components of the water resource in Indiana are hereafter discussed separately.

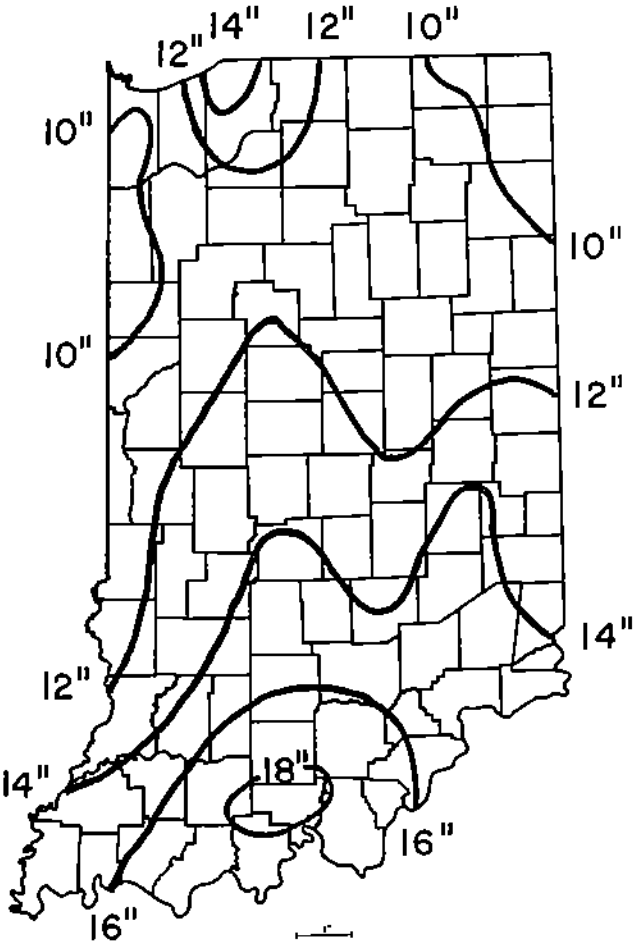



**Figure 14**
Map of Indiana showing the general distribution of average annual runoff in inches.

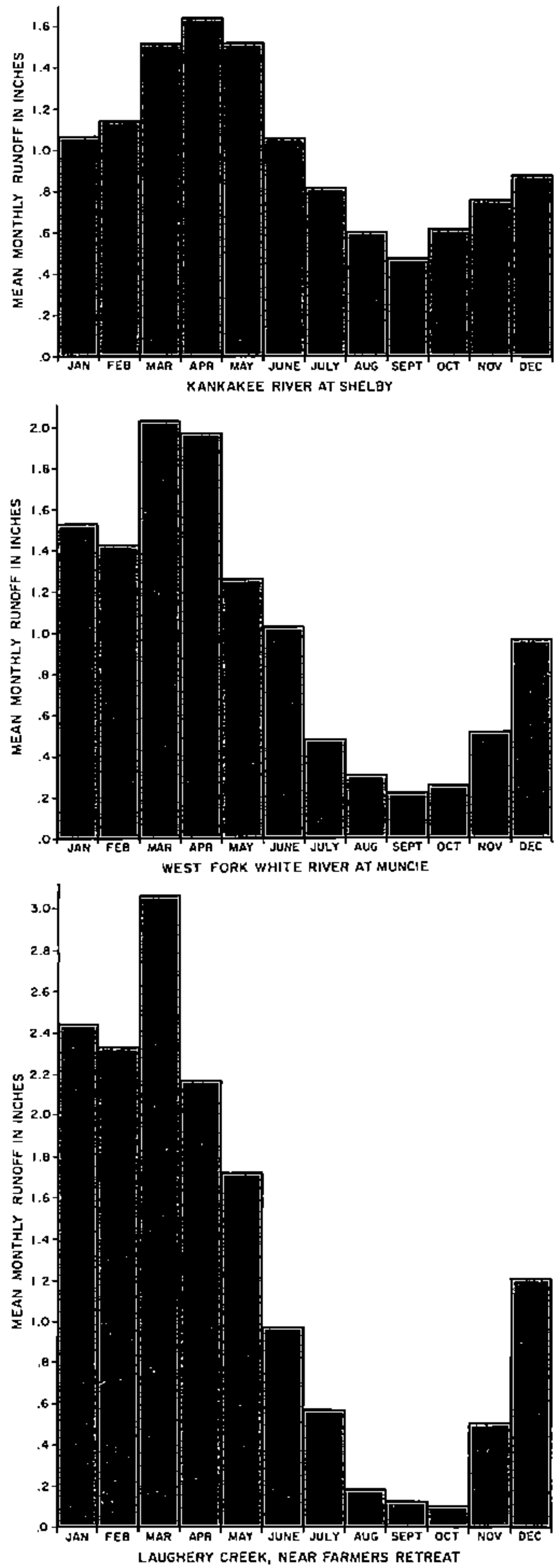



**Figure 15** (Shown at right)
The mean monthly runoff for selected stations in northern (Kankakee River at Shelby), central (West Fork of the White River at Muncie), and southern (Laughery Creek near Farmers Retreat) Indiana.

# GROUND WATER

Ground water in Indiana occurs in a variety of both unconsolidated and bedrock aquifer systems capable of yielding potable water in sufficient quantity to provide a source of supply. The most significant of these aquifers are the various unconsolidated outwash sand and gravel deposits associated with glacial drift and the limestone, dolomite, and sandstone bedrock formations.

General ground-water availability from unconsolidated and bedrock aquifers is determined by delineating the areal extent and saturated thickness of the geologic formations and estimating their relative porosity, permeability, and yield capabilities. Potential yields for both unconsolidated and bedrock aquifers are defined by utilizing existing geologic information and data, and available water well records. The water well records, such as pumping rates and ground-water levels, are collected from a network of ground-water observation wells and records provided by professional well drillers. The network of the ground-water observation wells is shown in Figure 16.

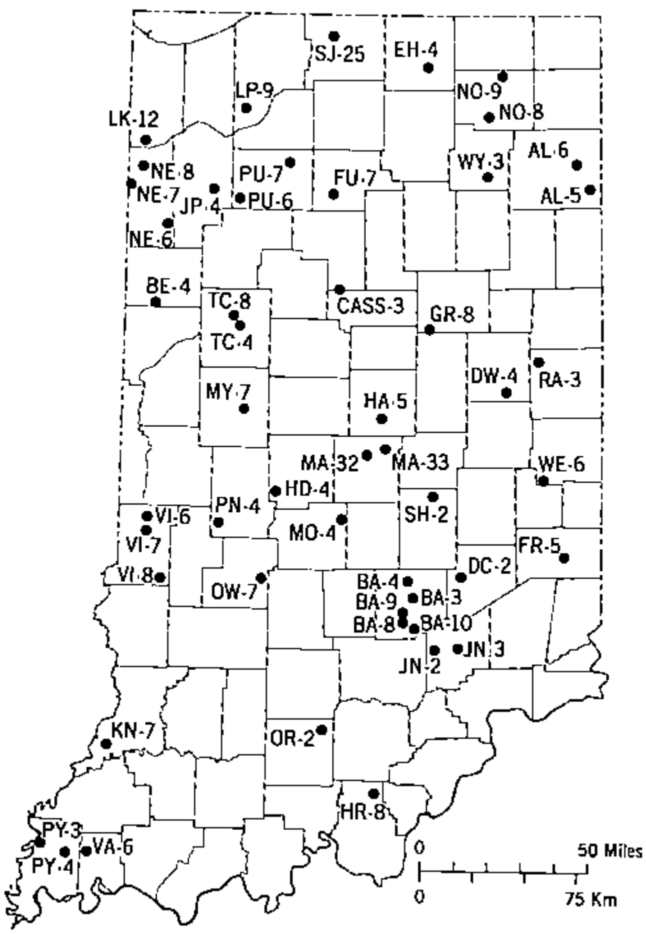



**Figure 16**
Map of Indiana showing the name and location of active ground-water observation wells.

The potential yield of ground water is expressed in terms of gallons-per-minute. For convenience, Table 3 converts the measure of gallons-per-minute into the corresponding rates in million-gallons-per-day.

**Table 3**
The measure of gallons-per-minute and the corresponding measure in million-gallons-per-day.

| *Gallons-Per-Minute* | *Million-Gallons-Per-Day* |
|---|---|
| 10 | 0.14 |
| 50 | 0.72 |
| 100 | 0.144 |
| 200 | 0.288 |
| 400 | 0.576 |
| 600 | 0.863 |
| 1,000 | 1.1,439 |
| 2,000 | 2.878 |

## Unconsolidated Aquifers

The most productive ground-water aquifers are associated with glacially derived outwash sand and gravel deposits that occur in the major river valleys. These unconsolidated materials were deposited as a result of glaciation. Drainage courses, which were cut by glacial melt waters and now occupied by a number of rivers and streams, were in many cases filled with such deposits. These aquifers are capable of yielding 2,000 gallons-per-minute (gpm) or more to properly constructed, large diameter wells.

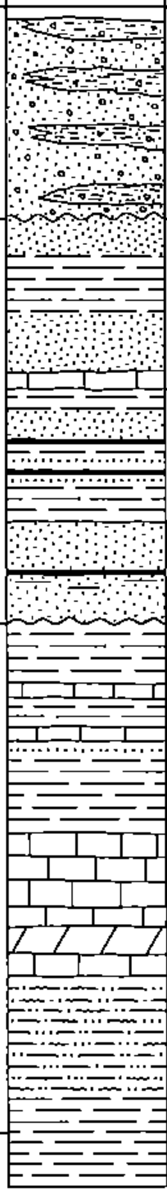
Other productive ground-water aquifers are the thick, inter-till sand and gravel deposits found in central and northern Indiana. The withdrawal potential of ground water from these unconsolidated aquifer systems ranges between 400 and 2,000 gpm from properly constructed, large diameter wells.

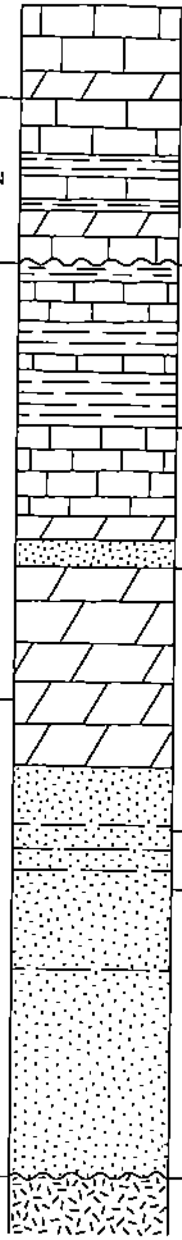
## Bedrock Aquifers

Like the unconsolidated deposits, the bedrock formations also have the ability to absorb, store, and transmit water. The major bedrock aquifers which occur in Indiana are the Pennsylvanian, Mississippian, Devonian, and Silurian aquifers. A geologic column indicating the age and water bearing characteristics of these bedrock formations is shown on Figure 17.

On a general basis, the incidence of mineralized or even saline ground water in Indiana increases rapidly at bedrock depths below 300 feet, and even shallower in some areas. Therefore a discussion and evaluation of the ground-water potential of the bedrock aquifers is essentially confined to those geologic units lying above the expected limits of nonpotable water.

*Pennsylvanian Becrock* Aquifers contained within the Pennsylvanian age bedrock are generally of low yielding capability, seldom supplying more than 20 gpm to a properly constructed well. However, their value is

| GEOLOGIC AGE | GENERALIZED LITHOLOGY (not to scale) | GROUP OR STAGE | SELECTED UNITS |  | WATER-BEARING CHARACTERISTICS |
|---|---|---|---|---|---|
|  |  |  | FORMATION | MEMBER |  |
| QUATERNARY (PLEISTOCENE) |  | Holocene S.<br>Wisconsinan S.<br>Illinoian S.<br>Pre-Illinoian |  |  | Unconsolidated deposits consisting of water-laid sand and gravel, glacial till, lake deposits and windblown silt. Variable thickness, ranging up to 500 ft. Major ground-water source; important aquifers are present in the outwash sand and gravel deposits associated with meltwater channels and present day stream valleys, and various inter-till sand and gravel deposits contained within the Wisconsinan and older drift. Well yields range from 5 - 2000 gpm. |
| PENNSYLVANIAN |  | McLeansboro Gr. | Mattoon Fm.<br>Bond Fm.<br>Patoka Fm.<br>Shelburn Fm. | Inglefield Ss. Mbr. | Mostly shale and sandstone with coal and limestone. Maximum thickness about 1,500 ft in southwestern Indiana. Minor ground-water source; yields from aquifers in sandstone and coal units generally less than 20 gpm – most wells yield less than 10 gpm. Basal sandstone in Mansfield Formation may produce up to 100 gpm in some areas. Mineralized or saline water often encountered in deeper wells. |
|  |  | Carbondale Gr. | Dugger Fm.<br>Petersburg Fm.<br>Linton Fm. |  |  |
|  |  | Raccoon Creek Gr. | Staunton Fm.<br>Brazil Fm.<br>Mansfield Fm. |  |  |
| MISSISSIPPIAN |  | Buffalo Wallow Gr.<br>Stephensport Gr.<br>West Baden Gr. |  |  | Primarily shale, limestone and sandstone. Maximum thickness about 600 ft, although thinner in many places. Minor ground-water source; not generally used as a source of water. Low permeability sandstones yield only limited amounts of water, generally less than 5 gpm. |
|  |  | Blue River Gr. | Paoli Ls.<br>Ste. Genevieve Ls.<br>St. Louis Ls. |  | Primarily limestone which is commonly about 600 ft thick. Potable water zone is found near outcrop area where thickness is less. Moderate to limited ground-water source; yields are generally less than 10 gpm to most wells; however, in limited areas yields in excess of 100 gpm are obtained. Locally, areas of high hardness, sulfate and fluoride content are present. |
|  |  | Sanders Gr. |  |  |  |
|  |  | Borden Gr. | Edwardsville Fm.<br>New Providence Sh. |  | Siltstone and shale with some limestone lenses. Maximum thickness in excess of 600 ft. Poor to limited ground-water source (aquitard); yields are less than 10 gpm with dry holes common. Generally not a good source of ground-water, although yields up to 250 gpm have been reported in west-central Indiana where permeable glacial deposits overlie it. Mineralized and saline waters are encountered in deep wells. |
|  |  |  | New Albany Sh. |  | Carbonaceous shale, average thickness about 100 ft. Poor ground-water source (aquitard); dry holes are common, yields less than 5 gpm. Often associated with "sulfur water," mineralized, or saline water. |



| System | Group | Formation | Member | Water bearing characteristics |
|---|---|---|---|---|
| DEVONIAN | Muscatatuck Gr. | | Geneva Dol. Mbr. | Mainly limestone and dolomite with some shale. Thickness averages about 500 ft. Extensive and important aquifer along and near crest of Cincinnati Arch. Yields of up to 400 gpm possible in many places. South of Wisconsinan glacial boundary yield from system is somewhat limited. Hydrogen sulfide or "sulfur water" often encountered where overlain by New Albany Shale. Upper Silurian rocks in northeastern Indiana produce water high in hardness, sulfates and fluorides. |
| SILURIAN | | Wabash Fm.<br>Louisville Ls.<br>Waldron Sh.<br>Salamonie Dol.<br>Brassfield Ls. | Mississinewa Sh. Mbr. | |
| ORDOVICIAN | Maquoketa Gr. | Whitewater Fm.<br>Dillsboro Fm.<br>Kope Fm. | | Interbedded shales and limestones, commonly about 700 ft thick. Very limited source of water (aquitard); often highly mineralized and non-potable. |
| ORDOVICIAN | | Trenton Ls.<br>Black River Ls.<br>Joachim Dol.<br>St. Peter Ss. | | Sequence of carbonate rocks with sandstone unit near base. Maximum thickness about 550 ft. Non-potable water in most of Indiana. Water highly mineralized and saline in many instances. Sandstone is a possible source of potable water in extreme northwestern Indiana. |
| ORDOVICIAN / CAMBRIAN | | Knox Dol.<br>Franconia Fm.<br>Ironton Ss.<br>Galesville Ss. } NW Indiana | | Dolomites and sandstones approximately 1,000 ft in thickness. Some production of potable water possible from sandstone unit in extreme northwestern Indiana. Generally not a source of potable water in Indiana. |
| CAMBRIAN | | Eau Claire Fm. | | |
| CAMBRIAN | | Mount Simon Ss. | | Non-potable water from 2,000 ft thick sequence of sandstone. Highly mineralized water. |
| PRE-CAMBRIAN | | | | Crystalline rocks. Non-potable water. |

**Figure 17**
Geologic column showing the geologic age and the general water bearing characteristics of Indiana bedrock formations.

most significant to the homes and farms utilizing these sources in southwestern Indiana, and to those water-flood oil operations requiring fresh water for injection and re-pressurization of oil-bearing formations. Those portions of Indiana with underlying Pennsylvanian age bedrock aquifers are shown in Figure 18.

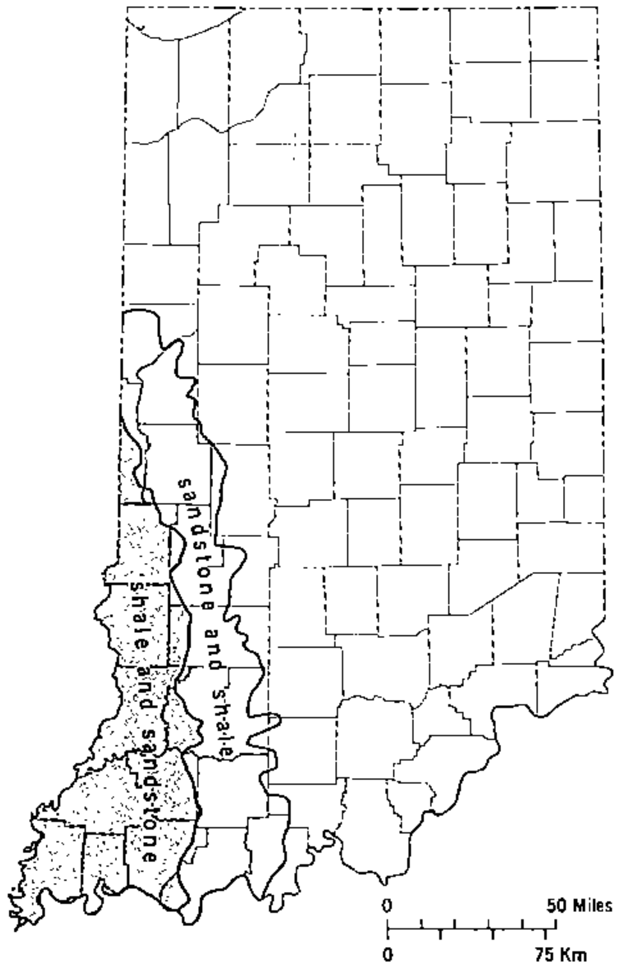



**Figure 18**
Map of Indiana showing those areas with underlying Pennsylvanian bedrock aquifers.

Potentially higher yielding wells may be obtained in the thicker sandstone members of the Mansfield Formation along the eastern fringes of the outcrop area in Warren, Fountain, Parke, Clay, Greene, Daviess, Dubois, and Spencer Counties, where some wells approaching 100 gpm could be obtained. In addition the Inglefield Sandstone of the McLeansboro Group in Posey, Vanderburgh, and Gibson Counties could yield up to 100 gpm.

In general, well depths are greater in the Pennsylvanian rocks than in other geologic systems in the state, and depths approaching 300 feet are common. Well casing diameters are usually six inches or greater, indicating the low yield capabilities of these aquifers. Because of the low permeability of the bedrock, the abundance of shale confining zones both above and below aquifer systems, and the limitations in available drawdown, it is seldom possible to divert large volumes of water into any particular pumpage center.

*Mississippian Bedrock* The Mississippian age bedrock aquifers can be broken into three reasonably distinct groups, as shown in Figure 19. They include the uppermost alternating limestone-shale-sandstone units, which are not considered an important aquifer source and contain only small amounts of water (generally yielding less than 10 gallons-per-minute); the middle Mississippian age limestone sequence that is prominent in south-central Indiana and which can in localized areas yield up to 100 gpm, particularly in Harrison, Orange, and Washington Counties, but normally yields only small amounts sufficient for home use; and finally the siltstone and shale formations of the lower Borden Group that yield little ground water. A notable exception to this broad classification is the higher than

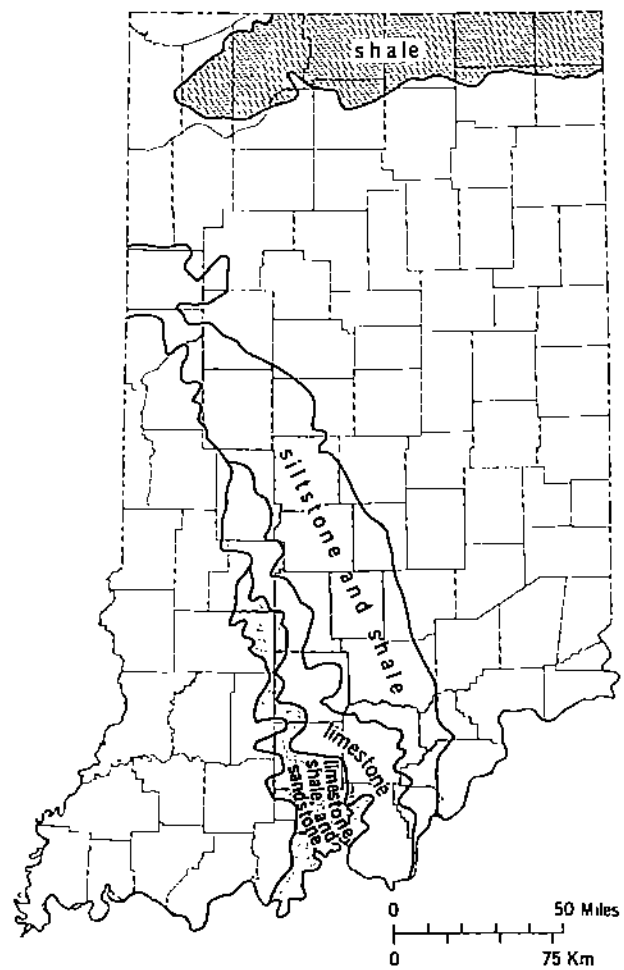



**Figure 19**
Map of Indiana showing those areas with underlying Mississippian bedrock aquifers.

normal yields that can be expected from the lower Mississippian Borden Group in near northwestern Indiana where glacial deposits containing scattered amounts of sand and gravel overlie these bedrock formations. Yields in excess of 200 gpm have been obtained from properly constructed wells in these bedrock aquifers.

In general the Mississippian aquifers are not considered major sources of ground water in the state and exclusive of the anomalous conditions in Montgomery and Fountain Counties, average well yields are less than 10 gpm. Well depths vary widely, ranging from 50 to 350 feet.

*Devonian Bedrock* Black shale, limestone, and dolomite formations are the dominant rock types of the Devonian age bedrock aquifer system in the state. Those portions of Indiana with underlying Devonian age bedrock aquifers are shown in Figure 20. Significant aquifer sources are confined to the limestone and dolomite units, and marked differences exist between the water-bearing characteristics of these formations. From the northern part of the state southward to the Ohio River radical changes occur in the water-yielding capabilities of the limestone-dolomite units. These changes can be attributed to the direct effects produced by glaciation in the state.

Well yields from the limestone-dolomite aquifers range from 100 to 600 gpm, for the more productive systems in the northern half of the state, to generally less than 50 gpm for the southern sectors where most well yields will be less than 10 gallons-per-minute. Well yields from the New Albany shale are not significant, and dry holes and wells yielding less than five gpm are common.

*Silurian Bedrock* The Silurian age bedrock aquifers, shown in Figure 21, are composed primarily of limestones and dolomite with some interbedded shale units.

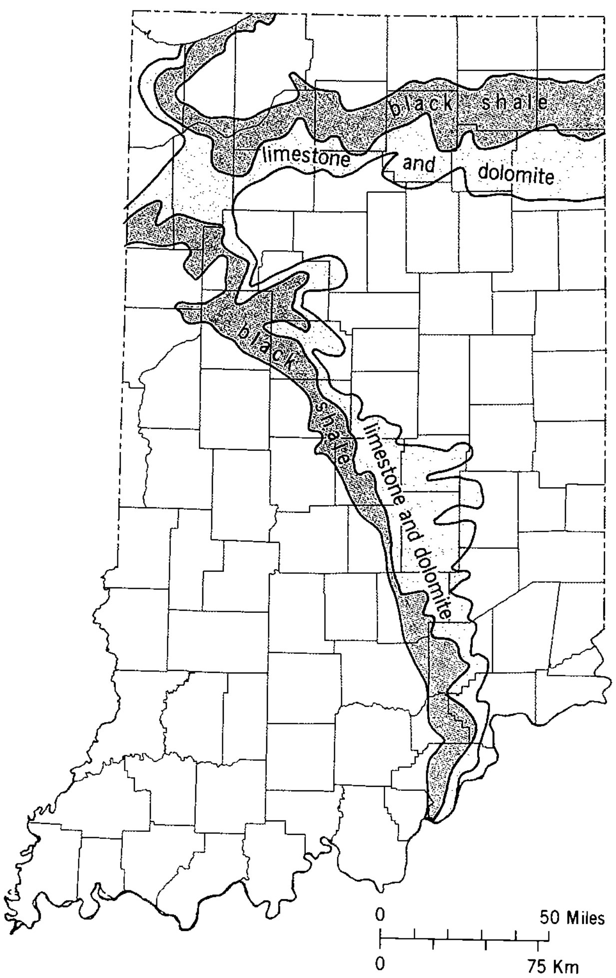



**Figure 20**
Map of Indiana showing those areas with underlying Devonian bedrock aquifers.

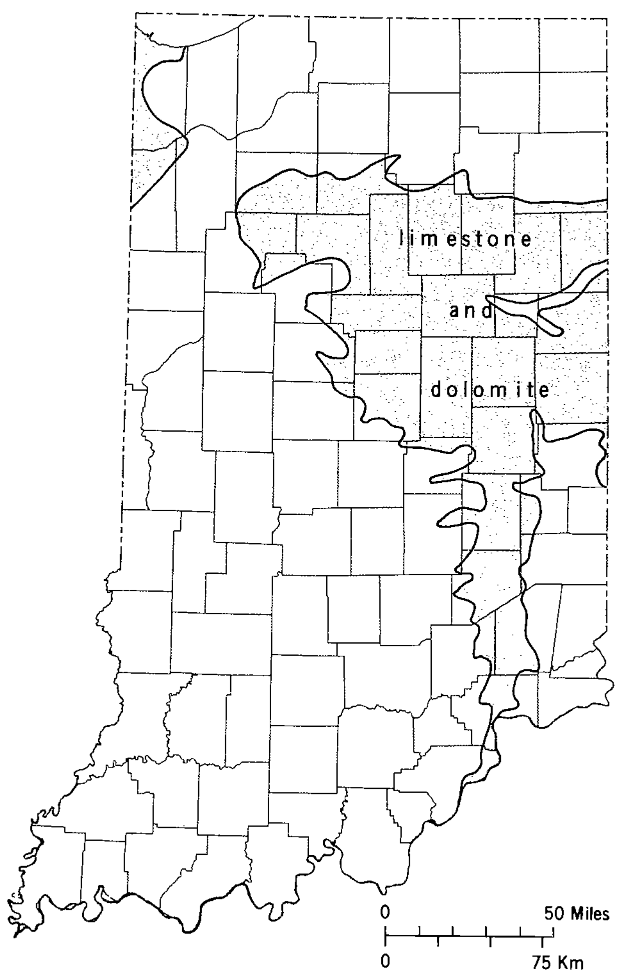



**Figure 21**
Map of Indiana showing those areas with underlying Silurian bedrock aquifers.

Silurian bedrock aquifers are an important source of water for many communities in the northern half of the state and are also utilized by thousands of residents served by individual domestic wells. In portions of Lake, Newton, and Jasper Counties they are tapped by numerous irrigation wells.

Potential yields from the Silurian aquifer system vary from 10 gallons-per-minute to 600 gpm. Highest well yields generally occur in areas that were covered during the Wisconsinan glaciation, especially where permeable sand and gravel deposits directly overlie the Silurian rocks. Shale units within the Silurian aquifer system such as the Mississinewa shale and the Waldron shale limit the hydraulic connection between the water-producing zones. However, in most of the northern portion of Indiana, the limestone and dolomite aquifers can be expected to yield up to 400 gpm from properly constructed wells. In southeastern Indiana where the glacial deposits are thinner well yields range from 5 to 100 gpm.

*Cambrian and Ordovician Bedrock* The Cambrian and Ordovician age bedrocks form a thick sequence of shales, limestones, dolomites, and sandstones. Aquifers from these formations produce nonpotable water in nearly all of Indiana. Upper Ordovician shales and limestones, exposed in southeastern Indiana are of such low permeability that they are considered to be nonwater units. Throughout the remainder of the state, the Cambrian and Ordovician rocks are deeply buried by the younger rock units. The only possible source of potable water within this sequence occurs in extreme northwestern Indiana where the St. Peter sandstone of the lower Ordovician may produce moderate quantities of nonmineralized water. Elsewhere, water from the Cambrian and Ordovician sequence is either saline or highly mineralized. Beneath these rocks are the Precambrian crystalline rocks which do not contain either recoverable or useable water.

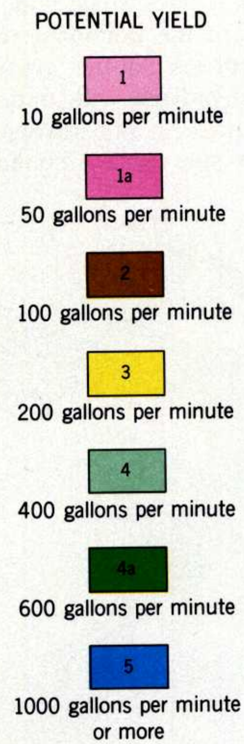
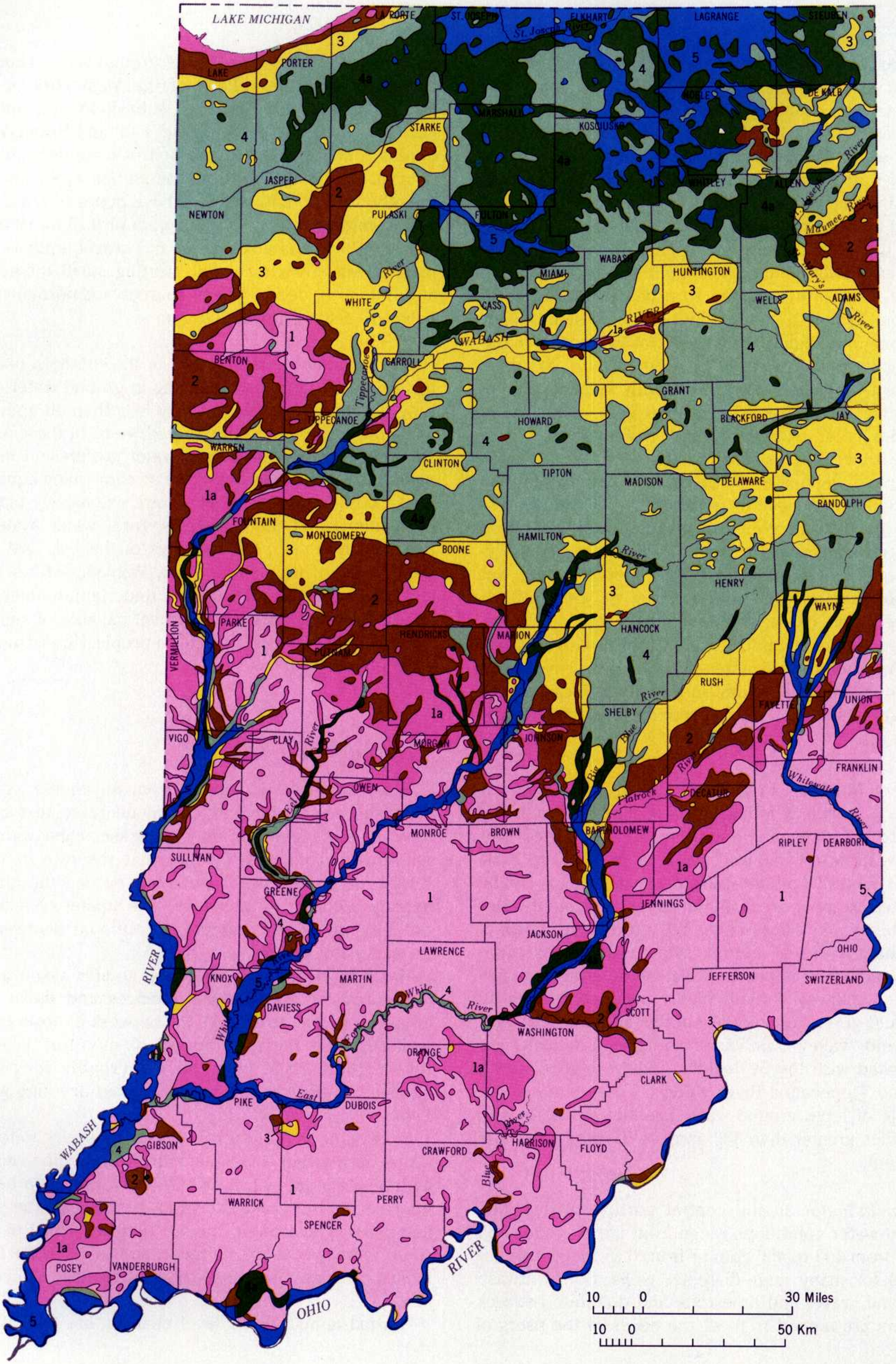



**Figure 22**
Map of Indiana showing the potential yield of ground water from properly constructed large diameter wells.

## Ground-Water Availability

Ground-water capabilities vary widely in the state ranging from as little as 10 gpm or less to over 2,000 gpm to properly constructed, large-diameter wells. The availability of ground water on a statewide basis is shown on Figure 22. This generalized ground-water potential map portrays the range of probable maximum yields which can be expected from a properly constructed large-diameter well penetrating the full thickness of the aquifer. The ground-water yield potential represents a consolidation of both unconsolidated and bedrock aquifers with similar water yielding characteristics.


LAKE MICHIGAN
LA PORTE
ST. JOSEPH
ELKHART
LAGRANGE
STEUBEN
LAKE
PORTER
NOBLE
DE KALB
STARKE
MARSHALL
KOSCIUSKO
JASPER
WHITLEY
ALLEN
NEWTON
PULASKI
FULTON
MIAMI
WABASH
HUNTINGTON
WHITE
CASS
WELLS
ADAMS
BENTON
CARROLL
GRANT
TIPPECANOE
HOWARD
BLACKFORD
JAY
WARREN
CLINTON
TIPTON
MADISON
DELAWARE
RANDOLPH
FOUNTAIN
MONTGOMERY
BOONE
HAMILTON
HENRY
WAYNE
PARKE
VERMILLION
HENDRICKS
MARION
HANCOCK
PUTNAM
RUSH
FAYETTE
UNION
VIGO
CLAY
MORGAN
JOHNSON
SHELBY
FRANKLIN
OWEN
DECATUR
MONROE
BROWN
BARTHOLOMEW
RIPLEY
DEARBORN
SULLIVAN
GREENE
JENNINGS
JACKSON
LAWRENCE
OHIO
KNOX
MARTIN
JEFFERSON
SWITZERLAND
DAVIESS
WASHINGTON
SCOTT
ORANGE
CLARK
PIKE
DUBOIS
GIBSON
CRAWFORD
HARRISON
FLOYD
WARRICK
PERRY
SPENCER
POSEY
VANDERBURGH
St. Joseph River
St. Joseph River
Maumee River
St. Mary's River
Tippecanoe River
WABASH RIVER
Wabash River
White River
Blue River
Big Blue River
Flatrock River
Whitewater River
Eel River
White River
East Fork White River
Blue River
OHIO RIVER
10 0 30 Miles
10 0 50 Km

There are seven ground-water yield categories in Indiana as shown on Figure 22. Category 1 shows the poorest water yielding areas with well yields usually less than 10 gpm. Dry holes are common in many of these areas. Category 1a depicts areas of marginal ground-water supplies with well yields generally less than 10 gpm; however yields of 50 gpm occur in localized areas. Some dry holes may also occur in these areas. Category 2 represents areas of limited ground-water availability, but slightly better than categories 1 and 1a. Wells are expected to produce between 5 to 100 gpm, although yields may be less in some areas. Category 3 includes areas with fairly good ground-water conditions, with yields from 100 to 200 gpm. Category 4 indicates those areas with wells capable of producing yields from 200 to 400 gpm. Category 4a identifies areas with very good ground-water conditions with well yields usually between 400 to 600 gpm. Category 5 delineates those areas where wells may potentially yield 1,000 or more gpm.

The various categories of ground-water yields are only a measure of the relative productivity of the several aquifer systems. These yield potentials do not indicate that an unlimited number of wells, of the specified yield, can be developed in any given location. Detailed studies including exploratory drilling and test pumping should be conducted to adequately evaluate the ground-water resource in any given area and the resultant change in water level as produced by the pumpage.

*Northern Indiana* In general, the ground-water resource of northern Indiana can be classified as being good to excellent, and exclusive of some areas near northwestern Indiana, well yields of from 200 to 2,000 gpm or 0.3 to 2.8 million-gallons-per-day (mgd) can be expected in most areas. Major areas of ground-water availability are found where the productive Silurian-Devonian bedrock aquifer system underlies large areas, and where deposits of glacial material up to 500 feet in thickness contain highly productive inter-till sand and gravel aquifers. A number of major outwash plain and "valley train" sand and gravel deposits are associated with the St. Joseph, Elkhart, Pigeon, Fawn, Eel, and Tippecanoe River valleys. These sources are capable of large ground-water production. Wells with capacities greater than 400 gpm, or 0.6 mgd, are quite prevalent.

*Central Indiana* In the central portion of the state ground-water conditions range from fair to good. Well yields from 100 to 400 gpm or from 0.15 to 0.6 mgd are typical for many large-diameter wells. Both outwash sand and gravel and limestone and dolomite bedrock aquifers are tapped to meet the needs of the users of large volumes of water. Major ground-water sources are present in the valleys of the West Fork of the White, Whitewater, Eel, and Wabash Rivers, and in portions of the valleys of Eagle, Fall, and Brandywine Creeks and the Blue River. Bedrock aquifers in the Silurian-Devonian limestone sequence are also frequently utilized, and wells in these deposits are capable of yielding from 100 to 600 gpm or 0.15 to 0.9 mgd. Locally, thicker inter-till sand and gravel aquifers are present that are capable of meeting small municipal and industrial needs. These sources are normally capable of yielding up to 300 gpm.

*Southern Indiana* Many areas of the southern part of the state are particularly lacking in ground water, and only limited amounts, generally less than 10 gpm are available to properly constructed wells. In these areas the major sources of ground water are present in the sand and gravel deposits of the stream valley aquifers. These sand and gravel aquifers are extensively tapped by a number of municipalities, rural water systems, and irrigation users. The valleys of the Eel, East and West Forks of the White, Ohio, Wabash, Whitewater, and main stem of the White are underlain by thick deposits of outwash sand and gravel capable of supplying over 1,000 gpm or 1.4 mgd to properly constructed, large diameter wells.

## Ground-Water Levels

When water is withdrawn from an aquifer system the water level in the aquifer may decrease, just as the level of surface water may decrease when water is withdrawn from it. Providing that the rate of withdrawal of ground water does not exceed the annual average recharge to the aquifer, the aquifer system will not be "mined" or undergo a continual decrease in ground-water levels.

Water level changes for many aquifer systems are monitored for both natural changes and those produced by pumpage through the network of observation wells. During the long period of monitoring water levels, there have been no discernable long-term changes, in the form either of lowered or rising water levels.

In general, ground-water levels naturally follow a rather consistent seasonal pattern, reaching annual high levels in late April or early May, and then beginning a slow but continuous decline through the summer growing season. In the fall, with the onset of seasonal increases in precipitation and major reductions in evapotranspiration, the ground-water levels begin to rise.

Normal annual water level changes are typically in the range of three to seven feet in most aquifers. The extreme ground-water level changes range from as little as two feet to over fifteen feet, depending upon the aquifer's extent, thickness, and other physical properties. The "drought" conditions of late 1976 and early 1977 produced some of the lowest water levels that have been noted in the last twenty years. However, even these extremes were only slightly below normal low water levels, and the declines were quickly corrected by increased precipitation in late 1977, with water levels rising to, or above, average.

Statewide water level trends have reflected no long-term rise or decline in water levels, as shown in Figure 23. Large ground-water withdrawals, however, have caused pronounced declines in local water levels, particularly near municipal well fields, stone quarries, sewer dewatering projects and in some areas of irrigation usage.

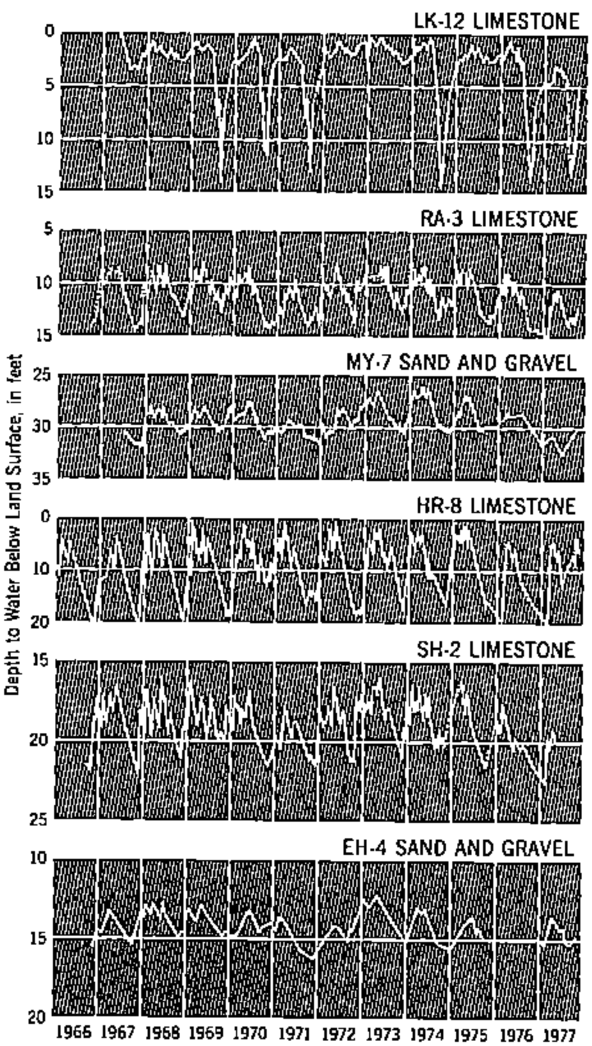



**Figure 23**
Water levels in selected observation wells from 1966 to 1977.

## SURFACE WATER

As noted in the introductory statement on the water resource, surface water in Indiana, defined herein as water in lakes and watercourses, has three components of supply. These are (1) that portion of precipitation that falls at rates in excess of the infiltration capacity of the land surface and consequently runs off over the land surface to watercourses, (2) the ground-water contribution to streamflow, and (3) that portion of precipitation that falls directly on lakes and streams.

The predominant characteristic of streamflow in Indiana is *variability*. Examination of the components of supply will reveal that each is directly or ultimately reflective of precipitation, which in itself is highly variable in both time and space.

The surface runoff component, which on a statewide basis comprises approximately seventy to seventy-five percent of the average annual surface water yield, is directly and intimately related to specific precipitation events in volume, in space, and in time. Surface runoff normally occurs only when precipitation is falling at rates in excess of the infiltration capacity of the receiving land surface, and it stops when precipitation ceases to fall at such rates, although surface runoff can result from the melting of accumulated ice and snow without the advent of further precipitation. Therefore streamflow is highly variable and may, within a period of a few days, and even less on small streams, range from high flood flows to rates that are essentially comprised of the ground-water contribution.

On the other hand, the variability of precipitation does not immediately affect the contribution of ground water to surface streams. As precipitation infiltrates downward through the soil it supplements the water occurring in the aquifers. Eventually, depending upon the permeability of the aquifer, the ground water will migrate to a surface stream where it will emerge as baseflow to that stream. This baseflow constitutes the major portion of the normal and low flow of the stream and is a significant part of the water contained in the stream during periods between runoff-producing rainfall events.

The availability of water in streams therefore cannot be simply described or evaluated. There must be considered such questions as: At what point on a stream is a determination of availability desired? On what basis of dependability is the assessment to be made? Is the assessment to be made on the basis of the natural regimen of flow or on the basis of regulated streamflows?

## Streamflows

The basis of our knowledge of streamflows in Indiana is a statewide network of stream gaging stations strategically located on the rivers and streams where continuous records of flow are collected. While there are a few gaging stations dating back to the 1920s and earlier, the modern network was developed in 1940. The major portion of this network is operated on a cooperative basis between the United States Geological Survey and the State of Indiana, and in 1978 there were 181 permanent stations in operation, together with 196 "partial record" stations where information is obtained only on either high or low flows. The network of stream gaging stations is shown on Figure 24.

Several analytical tools may be employed to describe streamflow availability, and these are described here to assist in developing an overall impression of the surface-water resource.

*Hydrograph Separation* One of the areas of interest is that of the relative proportions of streamflow contributed by surface runoff and by ground water. A reasonable approximation of these relative contributions may be gained from the technique of hydrograph separation. A discharge hydrograph is a graphic plot of the flow of a stream with respect to time. Hydrograph separation involves an analysis of the annual hydrograph of streamflows to separate the surface runoff and ground-water components of flow. This has been accomplished for a limited number of gaging stations around the state for a typical "wet," "dry," and "average" year, as indicated on Figure 25. While these cannot be broadly generalized, they do assist in understanding the relative role of the two components of flow. The relative proportions of surface runoff and ground-water contribution to total streamflow are dependent upon the various climatic and geologic settings that occur within Indiana.

*Average Flow* Average flow is a significant parameter used to describe streamflow and is a measure of the overall yield of the stream. Obviously, it does not provide information as to the degree of variability in flow, but it is useful in providing guidance as to the general significance of the particular stream. It represents the theoretical upper limit of the yield which can be developed from the stream even with flow regulation works. The average flow for a given stream at a given point is primarily a function of the size of its contributing drainage areas, the precipitation regime, the geology, the soils, and the topography.

*Flow Duration Curve* A second tool that helps to define the flow characteristics of given streams at specific points is the flow duration curve. This is a graph that indicates the percent of time that a given rate of flow is equalled or exceeded. The flow duration curve is a measure of streamflow reliability, or percent of total time that a specific flow in the stream can be expected to be equalled or exceeded. The horizontal axis of the flow duration curve represents the percent of time the streamflow is equalled or exceeded. The vertical axis represents the streamflow in million-gallons-per-day per square mile of drainage area. The flow is expressed in million-gallons-per-day per square mile of drainage area in order to minimize the effect of differences in the size of drainage basins.

Moreover, the flow duration curve provides valuable information about the geologic and hydrologic characteristics of the drainage basin. The overall slope of the curve is an indicator of the degree of variability in streamflow. A curve with a steep slope is typical of a stream whose flows are primarily due to surface runoff from specific precipitation events and which is therefore highly variable. A curve with a flat slope indicates a stream whose drainage basin is characterized by substantial ground-water contributions to streamflow, which raises the lower end of the curve, and by large amounts of flood plain storage that work to reduce high discharges and thus lower the high end of the curve.

*Low Flows* Two other parameters, based upon statistical and probability analysis of gaging station records, are the seven day, once in ten year low flow and the one day, once in thirty year low flow. The seven day, once in ten year low flow represents the lowest average discharge, over a period of seven consecutive days, which is expected to occur once in ten years, on the average, or that which has a ten percent chance of occurrence in any given year. The general range of the seven day, once in ten year low flows for selected streams in Indiana is shown in Figure 26. The one day, once in thirty year low flow represents the lowest average one day flow expected to occur once in thirty years, on the average. Such a flow is a useful expression of the capability of a stream to furnish water on a highly dependable basis.

**Regional Streamflow Patterns** As an example of the insight into surface-water availability that may be gained from these analyses, three streams have been selected: the Kankakee River at Shelby, the West Fork of the White River at Muncie, and Laughery Creek near Farmers Retreat. These streams are located in northern, central, and southern Indiana, respectively, and therefore serve to illustrate the difference in streamflow characteristics resulting from regional differences in geologic and hydrologic settings.

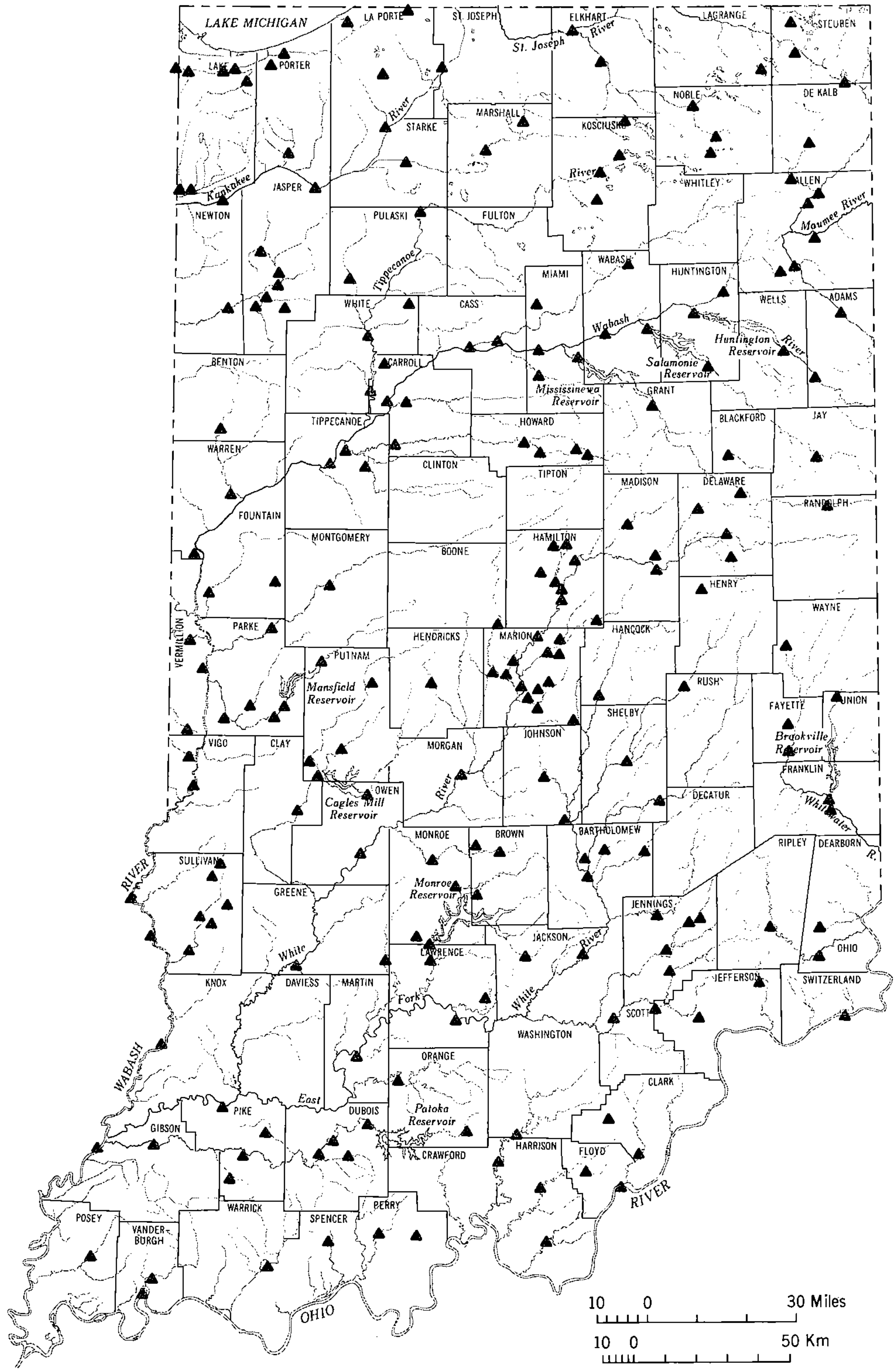



**Figure 24**
Map of Indiana showing the network of stream gaging stations.

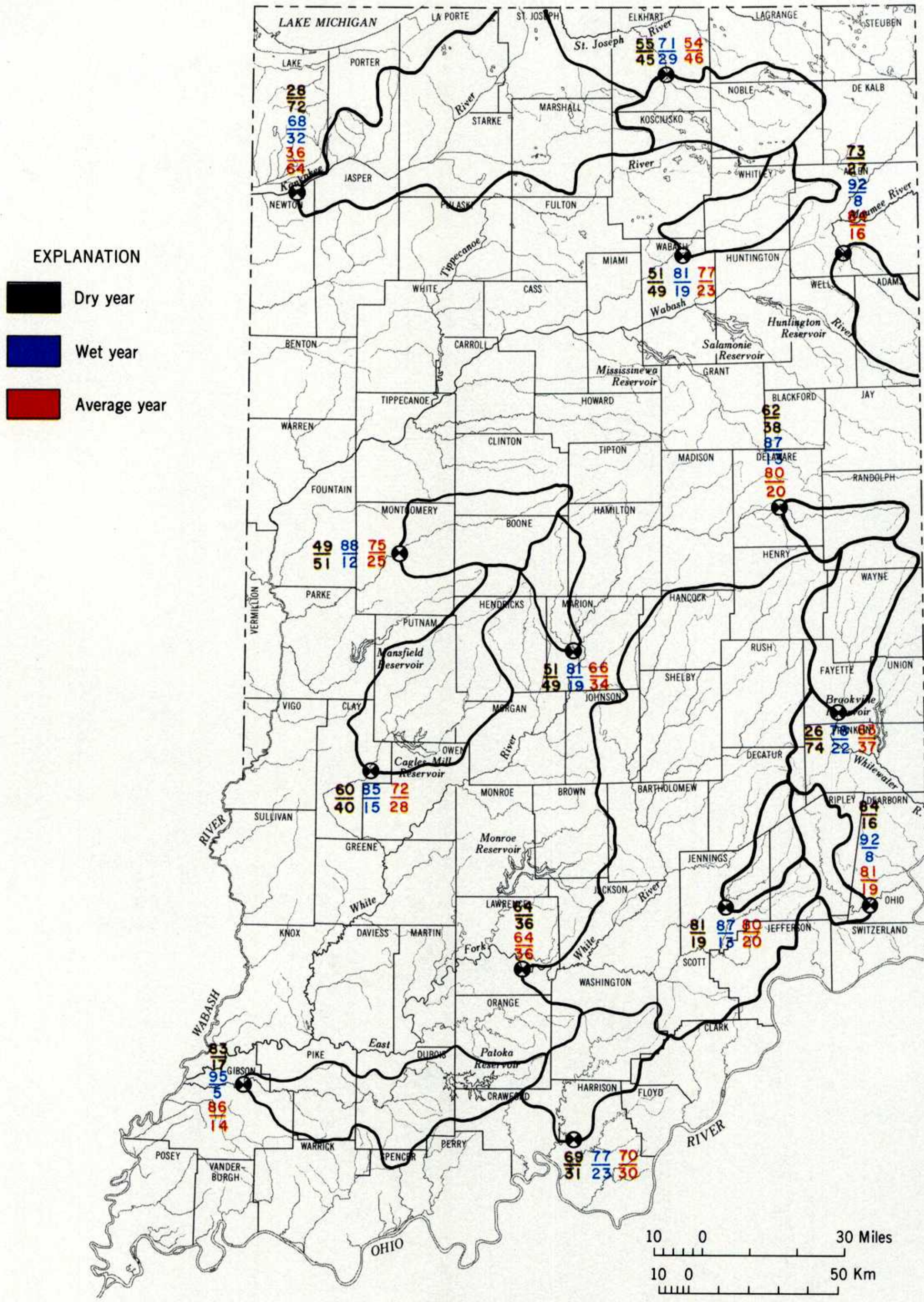



**Figure 25**

Map of Indiana showing hydrograph separations for selected stream gaging stations during typical wet, average, and dry years of precipitation. The numerator represents the direct surface runoff contribution to streamflow. The denominator represents the contribution of ground water to streamflow.

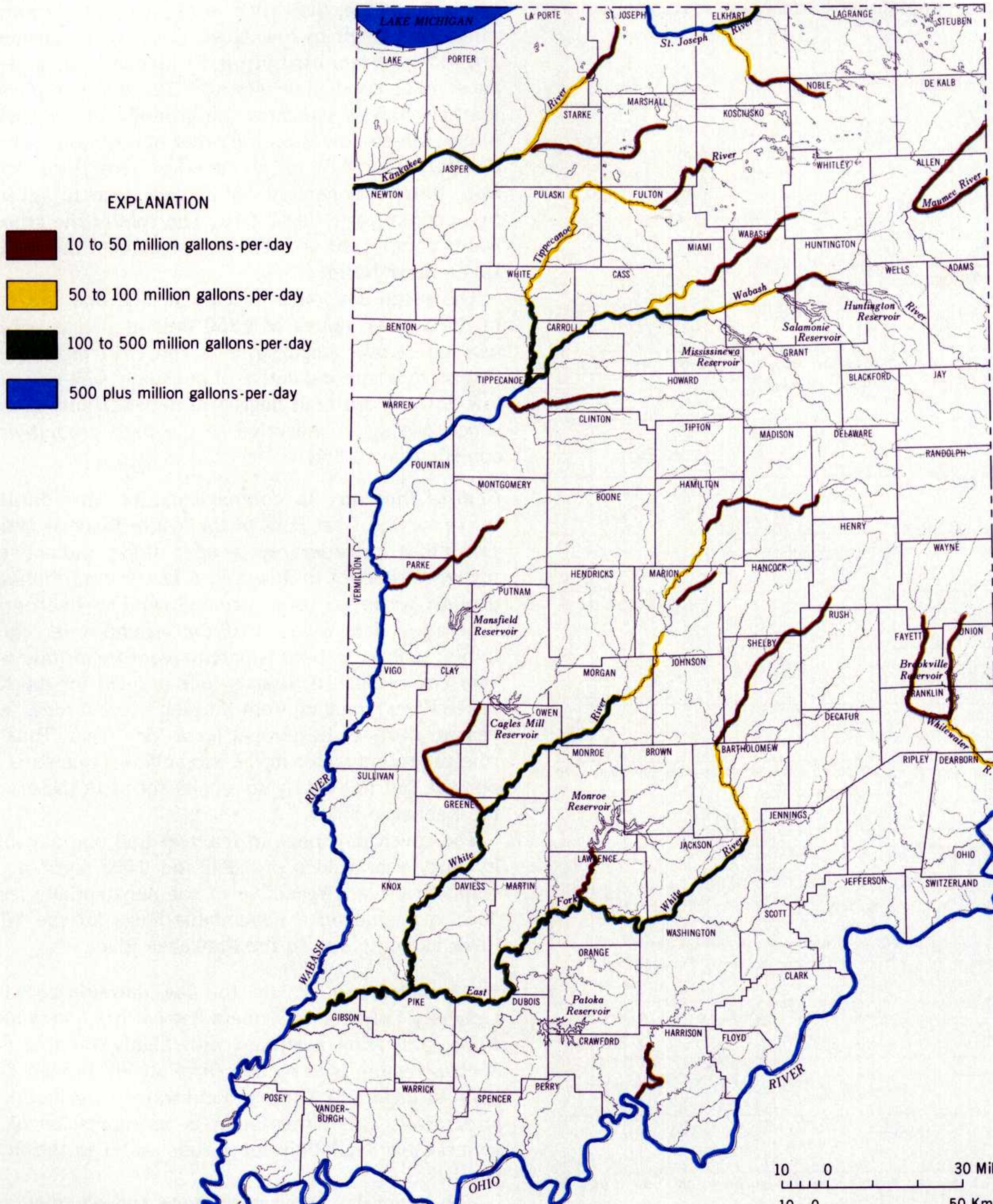



**Figure 26**
**Map of Indiana showing the seven day, once in ten year low flows for selected streams in million-gallons-per-day.**

The flow duration curves for the Kankakee River at Shelby, the West Fork of the White River at Muncie, and Laughery Creek near Farmers Retreat is shown by Figure 27.

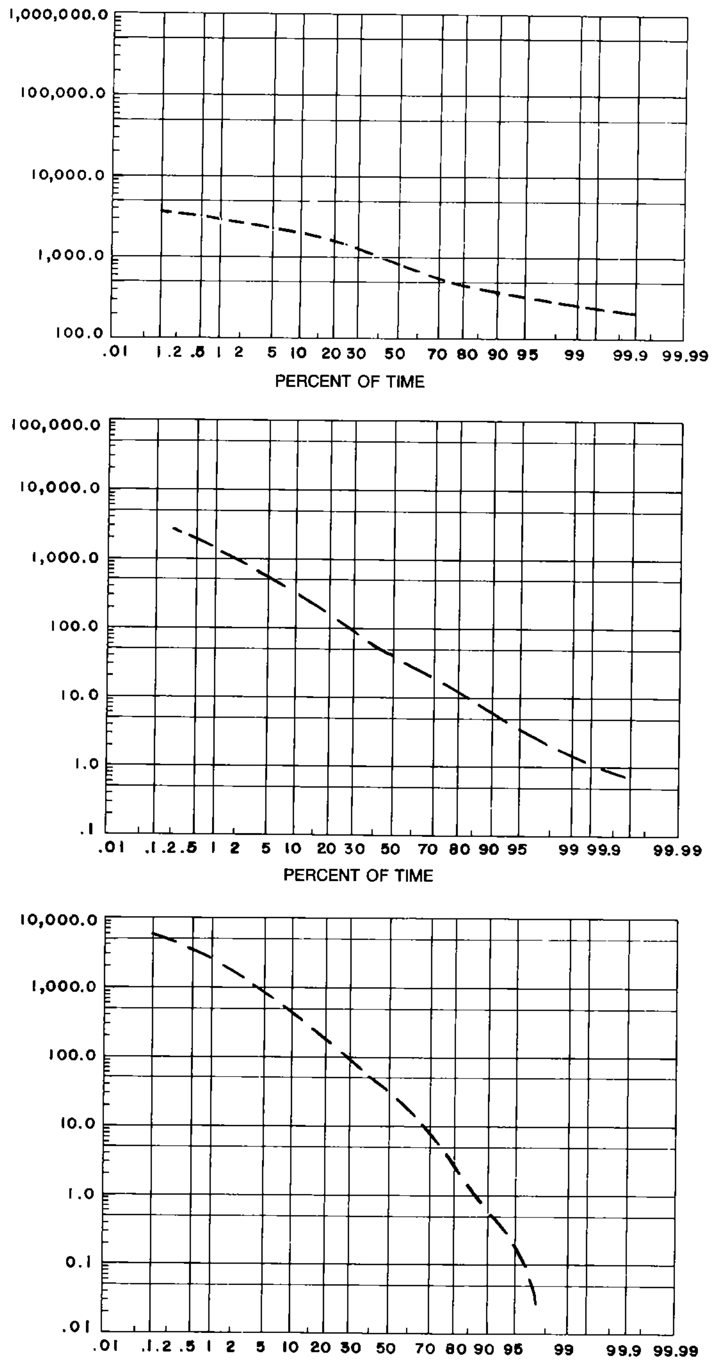



**Figure 27**

The flow duration curve (from top to bottom), for the Kankakee River at Shelby, the West Fork of the White River at Muncie, and Laughery Creek near Farmers Retreat. The horizontal axis represents the percent of time the streamflow is equalled or exceeded. The vertical axis represents the streamflow in million-gallons-per-day per square mile of drainage area.

*Northern Indiana* Considering first the Kankakee River at Shelby, it is noted that the flow duration curve has a flat slope, indicative of (1) a relatively narrow range from high to low flows, (2) a very substantial ground-water contribution to streamflow, and (3) substantial flood plain storage. The hydrograph separation analysis indicates the ground-water contribution to streamflow is on the order of sixty-four percent of total streamflow for an "average" year, and ranges from thirty-two percent for a "wet" year to seventy-two percent for a "dry" year. The role of the ground-water component is extremely significant in the Kankakee River basin.

The seven day, once in ten year and one day, once in thirty year values of 0.150 million-gallons-per-day per square mile (mgd/sq. mi.), and 0.121 mgd/sq. mi., respectively, are indicative of unusually well-sustained low flows and a high degree of dependability of flow, which are again reflective of the high ground-water contribution to flow.

*Central Indiana* In comparison, the flow duration curve for the West Fork of the White River at Muncie exhibits a considerably steeper slope, indicative of higher variability in flow and a lesser contribution of ground water to total streamflow. The hydrograph separation data reveal that the ground-water contribution to flow is about twenty percent for an "average" year (as compared to sixty-four percent for the Kankakee River), ranging from thirteen percent for a "wet" year to thirty-eight percent for a "dry" year. Thus the role of ground water in the streamflow regimen is important, but not nearly so significant as in the case of the Kankakee River.

The seven day, once in ten year and one day, once in thirty year values of 0.006 and 0.002 mgd/sq. mi., respectively, are reflective of the substantially lesser flows available on a dependable basis for the White River as compared to the Kankakee River.

*Southern Indiana* Lastly, the flow duration curve for Laughery Creek near Farmers Retreat has a very steep slope, indicating a stream with highly variable flow. Such a regime is reflective of relatively limited flood plain storage and a low ground-water contribution to streamflow. This latter factor is an expression of the general low availability of ground water in the drainage basin.

The seven day, once in ten year and one day, once in thirty year values of zero flow in both instances emphasize the fact that streamflow is made up largely of direct surface runoff, is highly variable, and has low reliability of flow. Hydrograph separation indicates the ground-water contribution to streamflow is only seventeen percent for an "average" year, eighteen percent for a "wet" year, and eight percent for a "dry" year.

*Statewide Streamflow Data* Tables 4, 5, 6, and 7 are a summary of flow characteristics of streams located in the Great Lakes, Wabash, Upper Mississippi, and the Ohio River tributary drainage basins. The streams, listed in alphabetical order by drainage basins, are those with stream gaging stations where relatively long periods of record are available.

The mean 'annual flow characteristics in million-gallons-per-day per square mile represent the annual average streamflow adjusted to the size of the drainage basin. Expressing annual average streamflow in million-gallons-per-day per square mile (mgd/sq. mi.) minimizes the differences in the size of drainage basins. Usually, the annual average flow characteristics of a stream with a small drainage basin will be greater than the stream in a larger drainage basin. In other words stream discharge is expected to increase as the size of the drainage basin decreases. When two streams with drainage basins of the same size have different flow characteristics, in mgd/sq. mi. and similar periods of record, the difference may be accounted for in the difference in the topgraphy between the drainage basins. Generally the steeper the terrain, the higher the discharge of the stream. Conversely, the drainage basin with moderate relief may have discharges of less magnitude.

Tables 4, 5, 6 and 7 also present the hydrograph separation data where available. This information is represented as the percent of streamflow in an average year of precipitation for both the ground -and surface-water contribution to streamflow. The following parameters provide a perspective of the streamflow characteristics of Indiana streams.

**Table 4**
Flow characteristics in million-gallons-per-day per square mile of Indiana streams located within the Great Lakes drainage basin.

| *Representative Streams* | *Drainage Area (square miles)* | *Mean Annual Flow Characteristics (mgd/sq. mi.)* | *Low Flow (mgd/sq. mi.)* | | *Percent of Streamflow in an "Average" Year of Precipitation* | |
|---|---|---|---|---|---|---|
| | | | *Q7-10* | *Q1-30* | *Ground-Water Contribution* | *Surface-Water Contribution* |
| Elkhart River at Goshen | 594 | .544 | .086 | .017 | 46 | 54 |
| East Arm Little Calumet River at Porter | 66 | .694 | .195 | .166 | na | na |
| Maumee River at New Haven | 1,967 | .508 | .023 | .016 | na | na |
| North Branch of the Elkhart River near Cosperville | 134 | .508 | .021 | .010 | na | na |
| St. Marys River at Decatur | 621 | .508 | .010 | .006 | 16 | 84 |
| St. Marys River near Ft. Wayne | 762 | .492 | .008 | .005 | na | na |
| St. Joseph River at Cedarville | 763 | .502 | .014 | .003 | na | na |
| St. Joseph River at Elkhart | 3,370 | .581 | .155 | .081 | na | na |
| St. Joseph River near Ft. Wayne | 1,060 | .589 | .028 | .022 | na | na |
| St. Joseph River near Newville | 610 | .525 | .020 | .015 | na | na |

na: not available

**Table 5**
Flow characteristics in million-gallons-per-day per square mile of Indiana streams located within the Wabash River drainage basin.

| *Representative Streams* | *Drainage Area (square miles)* | *Mean Annual Flow Characteristics (mgd/sq. mi.)* | *Low Flow (mgd/sq. mi.)* | | *Percent of Streamflow in an "Average" Year of Precipitation* | |
|---|---|---|---|---|---|---|
| | | | *Q7-10* | *Q1-30* | *Ground-Water Contribution* | *Surface-Water Contribution* |
| Big Blue River at Carthage | 184 | .683 | .094 | .070 | na | na |
| Big Blue River at Shelbyville | 421 | .702 | .062 | .051 | na | na |
| Big Pine Creek near Williamsport | 323 | .501 | .016 | .011 | na | na |
| Busseron Creek near Carlisle | 228 | .596 | .001 | .0 | na | na |
| Busseron Creek near Hymera | 17 | .723 | .0 | .0 | na | na |
| Busseron Creek near Sullivan | 138 | .643 | .009 | .005 | na | na |
| Eagle Creek at Zionsville | 103 | .584 | .0 | .0 | na | na |
| East Fork White River near Bedford | 3,861 | .606 | .040 | .026 | 36 | 64 |
| East Fork White River at Columbus | 1,707 | .686 | .048 | .037 | na | na |
| East Fork White River at Seymour | 2,341 | .656 | .046 | .035 | na | na |
| East Fork White River at Shoals | 4,927 | .692 | .033 | .015 | na | na |
| Eel River at Bowling Green | 830 | .633 | .013 | .009 | 28 | 72 |
| Eel River near Logansport | 789 | .589 | .079 | .062 | na | na |
| Eel River at North Manchester | 417 | .539 | .053 | .029 | 83 | 77 |
| Fall Creek near Fortville | 169 | .621 | .060 | .045 | na | na |
| Fall Creek at Millersville | 298 | .545 | .082 | .066 | na | na |
| Flatrock River at St. Paul | 303 | .666 | .004 | .001 | na | na |
| Graham Creek near Vernon | 77 | .780 | .0 | .0 | na | na |
| Little River near Huntington | 263 | .551 | .009 | .004 | na | na |
| Mississinewa River near Eaton | 310 | .554 | .006 | .004 | na | na |
| Mississinewa River at Marion | 682 | .610 | .017 | .003 | na | na |
| Mississinewa River near Ridgeville | 133 | .603 | .005 | .002 | na | na |
| Muscatatuck River near Austin | 365 | .685 | .002 | .0 | na | na |

## Table 5 (continued)

| Representative Streams | Drainage Area (square miles) | Mean Annual Flow Characteristics (mgd/sq. mi.) | Low Flow (mgd/sq. mi.) | | Percent of Streamflow in an "Average" Year of Precipitation | |
|---|---|---|---|---|---|---|
| | | | Q7-10 | Q1-30 | Ground-Water Contribution | Surface-Water Contribution |
| Muscatatuck River near Deputy | 293 | .737 | .0 | .0 | na | na |
| North Fork Salt Creek near Belmont | 120 | .702 | .0 | .0 | na | na |
| North Fork Salt Creek at Nashville | 76 | .644 | .0 | .0 | na | na |
| Patoka River near Ellsworth | 171 | .775 | .001 | .0 | na | na |
| Patoka River at Jasper | 262 | .861 | .002 | .0 | na | na |
| Patoka River near Princeton | 822 | .751 | .001 | .0 | 14 | 86 |
| Patoka River at Winslow | 603 | .715 | .001 | .0 | na | na |
| Pleasant Run at Arlington Avenue | 7 | .586 | .0 | .0 | na | na |
| Pleasant Run at Brookville Road | 10 | .596 | .0 | .0 | na | na |
| Salamonie River at Portland | 86 | .532 | .007 | .003 | na | na |
| Salamonie River near Warren | 425 | .574 | .011 | .007 | na | na |
| Salt Creek near Peerless | 573 | .739 | .002 | .001 | na | na |
| South Fork Salt Creek at Kurtz | 38 | .676 | .0 | .0 | na | na |
| Sugar Creek near Byron | 670 | .606 | .021 | .014 | na | na |
| Sugar Creek at Crawfordsville | 509 | .597 | .009 | .004 | 25 | 75 |
| Tippecanoe River near Delphi | 1,865 | .560 | .062 | .035 | na | na |
| Tippecanoe River near Monticello | 1,732 | .554 | .068 | .038 | na | na |
| Tippecanoe River near Ora | 856 | .602 | .093 | .073 | na | na |
| Tippecanoe River at Oswego | 113 | .559 | .008 | .001 | na | na |
| Vernon Fork near Butlerville | 86 | .696 | .002 | .0 | na | na |
| Vernon Fork at Vernon | 198 | .706 | .0 | .0 | 20 | 80 |
| Wabash River at Bluffton | 532 | .470 | .006 | .004 | na | na |
| Wabash River at Covington | 8,218 | .565 | .056 | .042 | na | na |

## Table 5 (continued)

| Representative Streams | Drainage Area (square miles) | Mean Annual Flow Characteristics (mgd/sq. mi.) | Low Flow (mgd/sq. mi.) | | Percent of Streamflow in an "Average" Year of Precipitation | |
|---|---|---|---|---|---|---|
| | | | Q7-10 | Q1-30 | Ground-Water Contribution | Surface-Water Contribution |
| Wabash River at Lafayette | 7,267 | .564 | .044 | .039 | na | na |
| Wabash River at Linn Grove | 453 | .542 | .009 | .007 | na | na |
| Wabash River at Montezuma | 11,118 | .550 | .049 | .035 | na | na |
| Wabash River at Mt. Carmel | 28,635 | .598 | .051 | .039 | na | na |
| Wabash River near New Corydon | 262 | .477 | .005 | .002 | na | na |
| Wabash River at Riverton | 13,161 | .554 | .057 | .045 | na | na |
| Wabash River at Terre Haute | 12,265 | .550 | .052 | .038 | na | na |
| Wabash River at Vincennes | 13,206 | .542 | .056 | .042 | na | na |
| West Fork White Lick Creek at Danville | 29 | .614 | .0 | .0 | na | na |
| West Fork White River at Anderson | 406 | .587 | .064 | .046 | na | na |
| West Fork White River at Centerton | 2,444 | .634 | .060 | .044 | na | na |
| West Fork White River at Indianapolis | 1,635 | .542 | .021 | .009 | na | na |
| West Fork White River at Muncie | 241 | .555 | .006 | .002 | 20 | 80 |
| West Fork White River at Newberry | 4,688 | .628 | .044 | .033 | na | na |
| West Fork White River at Noblesville | 858 | .613 | .058 | .041 | na | na |
| West Fork White River near Noblesville | 828 | .619 | .051 | .037 | na | na |
| West Fork White River near Nora | 1,219 | .563 | .060 | .047 | na | na |
| West Fork White River at Spencer | 2,988 | .640 | .049 | .037 | na | na |
| White Lick Creek at Mooresville | 212 | .624 | .011 | .005 | na | na |
| White River at Petersburg | 11,125 | .657 | .044 | .033 | na | na |
| Wildcat Creek near Jerome | 146 | .527 | .008 | .004 | na | na |
| Wildcat Creek near Lafayette | 794 | .590 | .045 | .033 | na | na |
| Wildcat Creek at Owasco | 396 | .590 | .031 | .020 | na | na |

na: not available

**Table 6**
Flow characteristics in million-gallons-per-day per square mile of Indiana streams located within the Upper Mississippi River drainage basin.

| Representative Streams | Drainage Area (square miles) | Mean Annual Flow Characteristics (mgd/sq. mi.) | Low Flow (mgd/sq. mi.) | | Percent of Streamflow in an "Average" Year of Precipitation | |
|---|---|---|---|---|---|---|
| | | | Q7-10 | Q1-30 | Ground-Water Contribution | Surface-Water Contribution |
| Iroquois River near Foresman | 449 | .518 | .014 | .009 | na | na |
| Iroquois River near North Marion | 144 | .550 | .017 | .009 | na | na |
| Iroquois River at Rensselaer | 203 | .507 | .016 | .006 | na | na |
| Iroquois River at Rosebud | 36 | .459 | .034 | .016 | na | na |
| Kankakee River at Davis | 537 | .594 | .220 | .187 | na | na |
| Kankakee River at Dunns Bridge | 1,352 | .610 | .158 | .134 | na | na |
| Kankakee River at North Liberty | 174 | .543 | .204 | .167 | na | na |
| Kankakee River at Shelby | 1,779 | .570 | .150 | .121 | 64 | 36 |
| Little Calumet River at Munster | 90 | .476 | .023 | .014 | na | na |
| Yellow River near Bremen | 135 | .496 | .030 | .026 | na | na |
| Yellow River at Knox | 435 | .568 | .105 | .080 | na | na |
| Yellow River at Plymouth | 294 | .547 | .042 | .033 | na | na |

na: not available

**Table 7**
Flow characteristics in million-gallons-per-day per square mile of Indiana streams located within the Ohio River Tributary drainage basin.

| Representative Streams | Drainage Area (square miles) | Mean Annual Flow Characteristics (mgd/sq. mi.) | Low Flow (mgd/sq. mi.) | | Percent of Streamflow in an "Average" Year of Precipitation | |
|---|---|---|---|---|---|---|
| | | | Q7-10 | Q1-30 | Ground-Water Contribution | Surface-Water Contribution |
| Blue River near White Cloud | 476 | .842 | .018 | .013 | 30 | 70 |
| East Fork Whitewater River at Abington | 200 | .746 | .074 | .058 | na | na |
| Laughery Creek near Farmers Retreat | 248 | .732 | .0 | .0 | 19 | 81 |
| Middle Fork Anderson River at Bristow | 40 | .851 | .0 | .0 | na | na |
| Silver Creek near Sellersburg | 189 | .716 | .0 | .0 | na | na |
| Whitewater River near Alpine | 529 | .658 | .060 | .042 | 37 | 63 |

na: not available

## Lakes and Dams

There are approximately 520 natural lakes and artificial impoundments having a surface area of 50.0 or more acres or with a storage capacity of 100 acre-feet (32.5 million gallons) or more. These lakes and reservoirs have a combined surface area of about 92,800 acres and a gross storage capacity of some 606,000 million gallons. Of this total approximately 195,500 million gallons are dedicated to the purpose of water supply.

The major water supply reservoirs in the state are Cedarville and Hurshtown (Fort Wayne), Geist, Morse and Eagle Creek (Indianapolis), Prairie Creek (Muncie), Kokomo Reservoir (Kokomo), Middle Fork (Richmond), and the water supply pools of the Monroe, Brookville, and Patoka Reservoirs of the U.S. Army Corps of Engineers. The water supply storage in these latter three projects has been purchased by and is under the direct control and management of the State of Indiana.

## Geographic Advantages

There are two natural features of great significance to the water resource of Indiana. One of these is Lake Michigan, of which some 241 square miles (154,240 areas) lie within the boundaries of the state. Lake Michigan and Lakes Superior, Huron, Erie, and Ontario comprise the Great Lakes and together constitute a fresh water resource whose annual outflow through the St. Lawrence River averages about 239,000 cubic-feet-per-second or approximately 154,640 million-gallons-per-day. As a riparian state, Indiana has the use of Lake Michigan water within that portion of the state lying within the Lake Michigan drainage basin.

The other feature is that of the Ohio River, one of the great rivers of the United States, which borders Indiana for some 357 miles on its southern boundary. The average flow of this river at Louisville, Kentucky is 73,680 million-gallons-per-day.