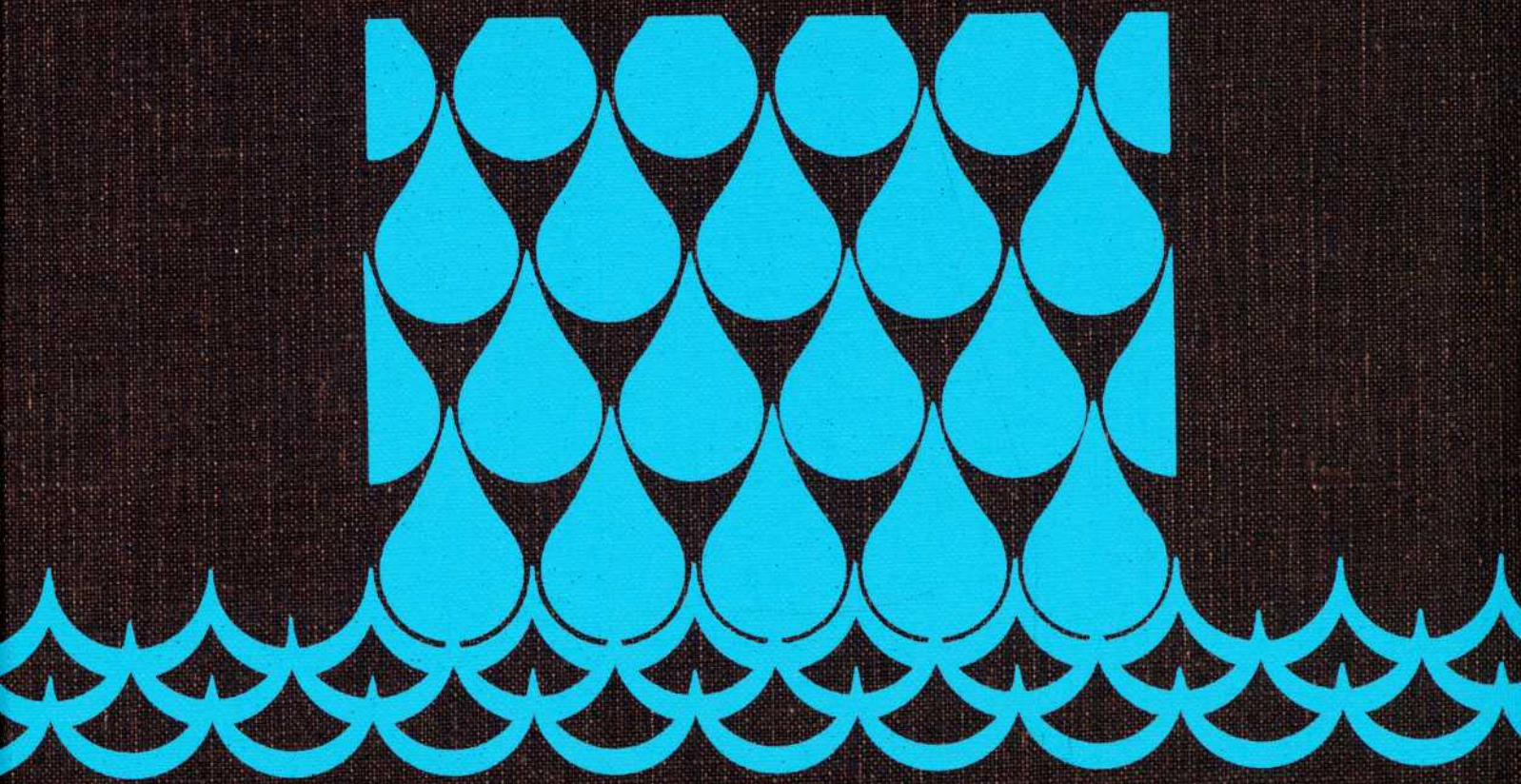
THE INDIANA WATER RESOURCE



AVAILABILITY, USES, AND NEEDS

The Indiana Water Resource

The Indiana Water Resource

Availability, Uses, and Needs

GOVERNOR'S
WATER RESOURCE STUDY COMMISSION,
STATE OF INDIANA

Edited by
G. Douglas Clark

Consulting Editor
Dorothy Larrison

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February 1, 1980

The Honorable Otis R. Bowen, M.D.
Governor
The State of Indiana
206 State House
Indianapolis, Indiana 46204

Dear Governor Bowen:

The Governor's Water Resource Study Commission presents herewith the phase one report, *The Indiana Water Resource: Availability, Uses, and Needs.*

The report contains an assessment of water availability and quality in Indiana and of the nature, extent, and magnitude of excess water conditions; an inventory of existing water resource development and uses and projections of future uses and needs for all purposes; and a summary of existing laws (including water rights), policies, and programs.

The material in the *Availability, Uses, and Needs* report provides the basis for further work of the Commission in the definition of those issues that need to be addressed and in the development of recommendations for an integrated system of policy, law, and management to meet the needs of tomorrow. In addition, it is anticipated that the report will serve as a compendium of water resource information.

The Commission transmits this report to you with the earnest hope that it will contribute to the wise use of our water resource.

Respectfully submitted,

William J Watt

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Chairman

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Map of Indiana showing the location of the eighteen study regions of the Governor's Water Resource Study Commission.

Introduction

The Governor's Water Resources Study Commission was created by Governor Otis R. Bowen on July 20, 1977, pursuant to Executive Order 11-77. The basic task of the Commission, as set forth in the order, is as follows:

> The Commission shall develop recommendations for an integrated system of policy, law, and management to provide the essential framework within which the human, social, and economic water needs of the people of Indiana may be satisfied in a timely and equitable manner. The Commission's recommended water policy shall be based upon a comprehensive examination of water availability, law, management, and present and projected human, social, and economic needs.

In addressing that charge, the Commission has adopted a two-phased plan of study.

The first phase involves a study of the general availability and overall quality of the water resource; an assessment of the nature, extent, and magnitude of excess water conditions; an inventory of the current development and uses of water in the state; the development of projections of future uses and needs for water for all purposes to the year 2000; and a compilation and summary of existing water resource policies, laws, institutions, and programs, including water rights.

The results of this study phase constitute the *Availability, Uses, and Needs* report. This report is designed to provide the reader with, first, a general perspective of the water resource on a statewide basis and, second, a more detailed analysis on a regional basis. The eighteen Planning and Development Regions, as shown in the following map of Indiana, are the same areas selected by the Commission to compile and display the regional information. To assist the reader, a glossary of technical terms is provided.

The second phase of the Governor's Water Resource Study Commission will consist in the identification and definition of those water resource problems, conflicts, and issues that need to be addressed and in the development of such new or amendatory laws, policies, and programs as are found to be necessary to provide an effective overall water program for Indiana. These findings and recommendations will be contained in the phase two report of *The Indiana Water Resource.*

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Editor's Note

The Indiana Water Resource documents the availability, uses, and needs of the water resource through the year 2000 A.D. The information is presented in three sections: the Statewide Analysis, the Regional Analysis, and the Appendixes.

A definition of the water resource, an explanation of its occurrence, the methods used to measure and describe its movement, and its distribution and associated conditions are included in the statewide analysis. These basic concepts when applied to specific areas of the state and combined with a study of the availability, uses, and needs of the resource constitute the regional analysis.

Both the statewide and regional information will facilitate the wise management of the water resource by state, regional, and local governments. The color coded maps indicate the general location of water and associated conditions. The information contained in these illustrations should not be applied to individual tracts of land for purposes of design.

The data quantifying the uses and needs of water is a close approximation and not an exact measurement. These estimates are based upon statistical analysis and population projections and are subject to change as population levels vary.

It is anticipated this report will serve a useful purpose for the next twenty years. To accomplish this end, appendixes are included that outline methods employed to measure and project the uses and needs of water and associated conditions. A glossary of terms follows the appendixes.

This *Availability, Uses, and Needs* report will provide a valuable tool to managers of the water resource and the lay reader alike by presenting a complete and detailed perspective of a single water resource as it changes in quantity, time, and space within Indiana.

Indianapolis
February 1980

G. Douglas Clark



"All the rivers run into the sea;
yet the sea is not full;
unto the place from whence the rivers come;
thither they return again."

Characteristics and Principles of Water

Water is one of that triad of resources, comprised of land, air, and water, which is essential to life itself and to man's physical, social, and economic well-being. Its intrinsic value is then in many respects beyond price. In the introduction to *Water* (Life Science Library, 1966), Abel Wolman said:

> "History is replete with the sagas of armies that fought over water, of monarchs and priests who worshipped it and health workers who have blessed it, of civilizations that dwindled after losing or mismanaging it, of people who died because of it."

Water may also be described as:

A *versatile* resource, in that it can and does exist in each of the three states of matter—solid, liquid and gaseous—and may be converted from one to the other with relative ease.

A *ubiquitous* resource, in that it is present, in some degree and in some state, everywhere at the same time.

A *peripatetic* resource, in that it has motion and mobility and is generally enroute from one locale to another, although its movement may be at rates ranging from miles per hour to inches per century.

A *finite* resource. Earth, so far as we know, is the only planet in our solar system that is endowed with large quantities of water. But while its water is in a constant state of change—in spatial location, in mode of occurrence, and in state of matter—there is the vitally important fact that the total supply neither grows nor diminishes. The world supply is believed to be almost precisely the same now as it has been for ages.

It has been estimated that planet Earth contains about 326 million cubic miles of water, of which some is on the earth's surface, some is found as deep as three miles under the earth's crust, and some exists as high as seven miles above its surface. But it is important to note that the oceans, the icecaps, and the glaciers comprise about ninety-nine and one-third percent of the earth's total water. The remaining two-thirds of one percent is apportioned among all the other manifestations of water around the globe, and only a small part of this is classified as fresh water.

The versatility, pervasiveness, and mobility of water have long been noted. Several thousand years ago, the author of the biblical book of Ecclesiastes wrote (Eccl. 1:7), "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come; thither they return again."

This seeming mystery is no doubt the earliest statement of what modern hydrologists call the "hydrologic cycle," a term used to describe the occurrence and movement of water through the continuous process of exchange between the earth and the atmosphere. In general terms, the process is that of evaporation and transpiration of water from the seas and the land to be drawn into the atmosphere; thence to return to earth in the form of precipitation; thence to result in surface runoff to streams and lakes or to infiltrate to the ground water and thence to streams, to drain to the seas, and then to begin the cycle anew.

As depicted in Figure 1, the general cycle is subject to many "short-circuits" and is therefore a very complex process indeed. The hydrologic cycle is useful in grasping not only the general occurrence and movement of water through the environment, but in illustrating the vital fact that although water may appear at different places at varying times and in diverse forms, it is a single resource. Thus, atmospheric water vapor, precipitation, soil moisture, ground water, and surface water are simply various manifestations of the same water resource in the overall hydrologic cycle.

Of the precipitation that falls upon a given area in a specific storm event, a portion may (1) become an increment to soil moisture, (2) be returned to the atmosphere by evaporation and transpiration, commonly referred to as evapotranspiration, (3) infiltrate into the ground and become an addition to ground water from where it will eventually emerge to become surface water, or (4) become surface water through the process of direct surface runoff to lakes and streams.

As to any given geographic area, the quantitative aspects of the several elements of the hydrologic cycle are influenced directly by the environmental conditions of the area.

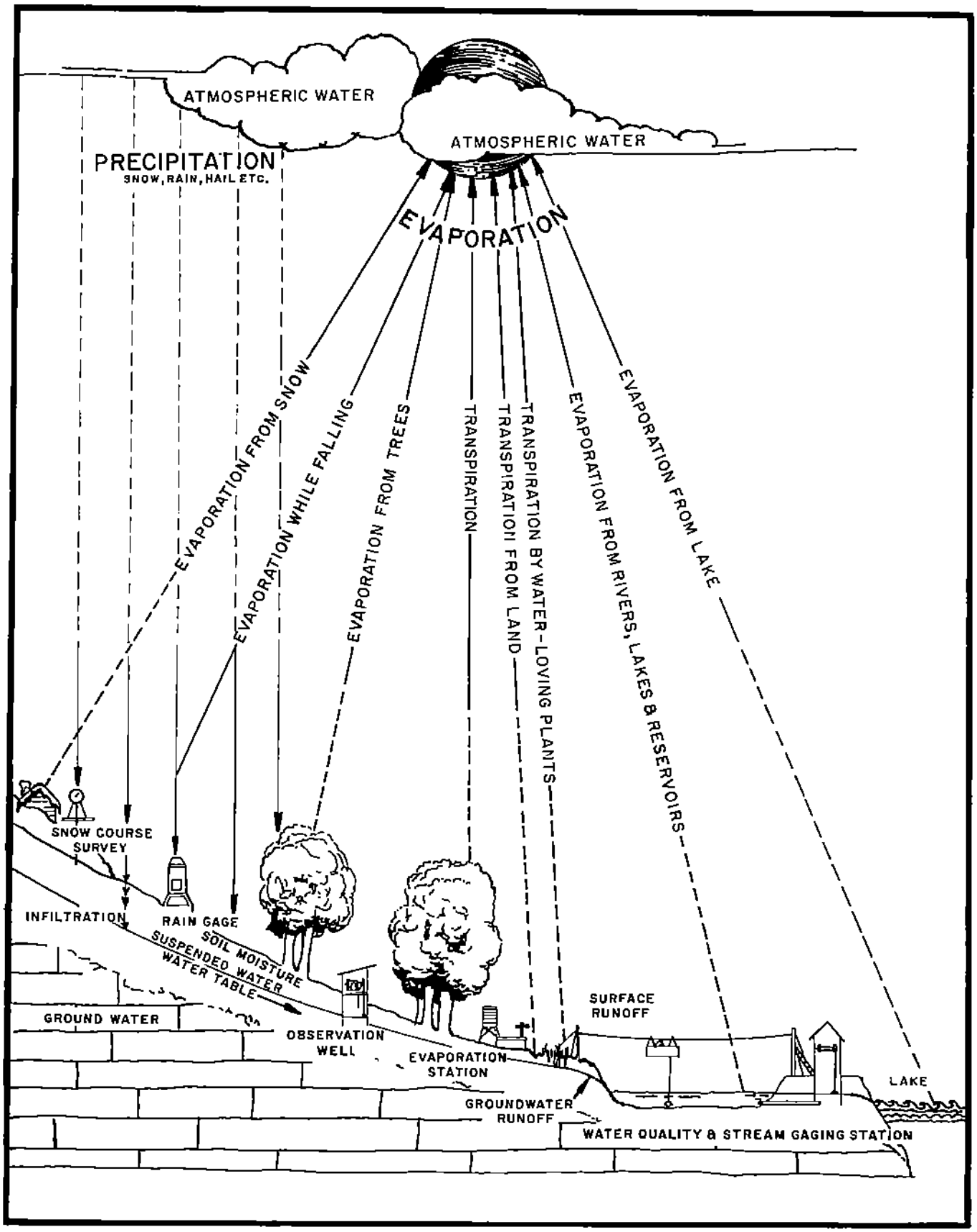


Figure 1
Illustration of the hydrologic cycle and how it is measured.

Indiana: The Perspective

The Northwest Ordinance of 1787 provided that not less than three nor more than five states should be formed from the Northwest Territory and that "whenever any of the said States shall have sixty thousand free inhabitants therein, such State shall be admitted by its Delegates into the Congress of the United States, on an equal footing with the original States, in all respects whatever."

A census of Indiana Territory, authorized in August 1814 and submitted to the House of Representatives in January 1816, showed a population of 63,897.

On December 11, 1816, President James Madison approved the "Resolution for admitting the State of Indiana into the Union." Indiana was then the nineteenth state to join the Union and the second to be created from the Northwest Territory.

The role of Indiana's water resource is inextricably interwoven with the development and growth of the state. The Indiana of 1816, with a population of well under 100,000, was an agrarian society whose principal concerns with water were related to drainage as a vital factor in converting the land to agricultural pursuits, to the utilization of streams as a means of transportation and water power, and with the family well or spring as a source for domestic use.

The Indiana of 1979, just one hundred sixty-three years later, presents a stark contrast in terms of the numbers and concentrations of the population, in the scope and range of economic pursuits, and in the interdependence of society for the provisions of goods and services.

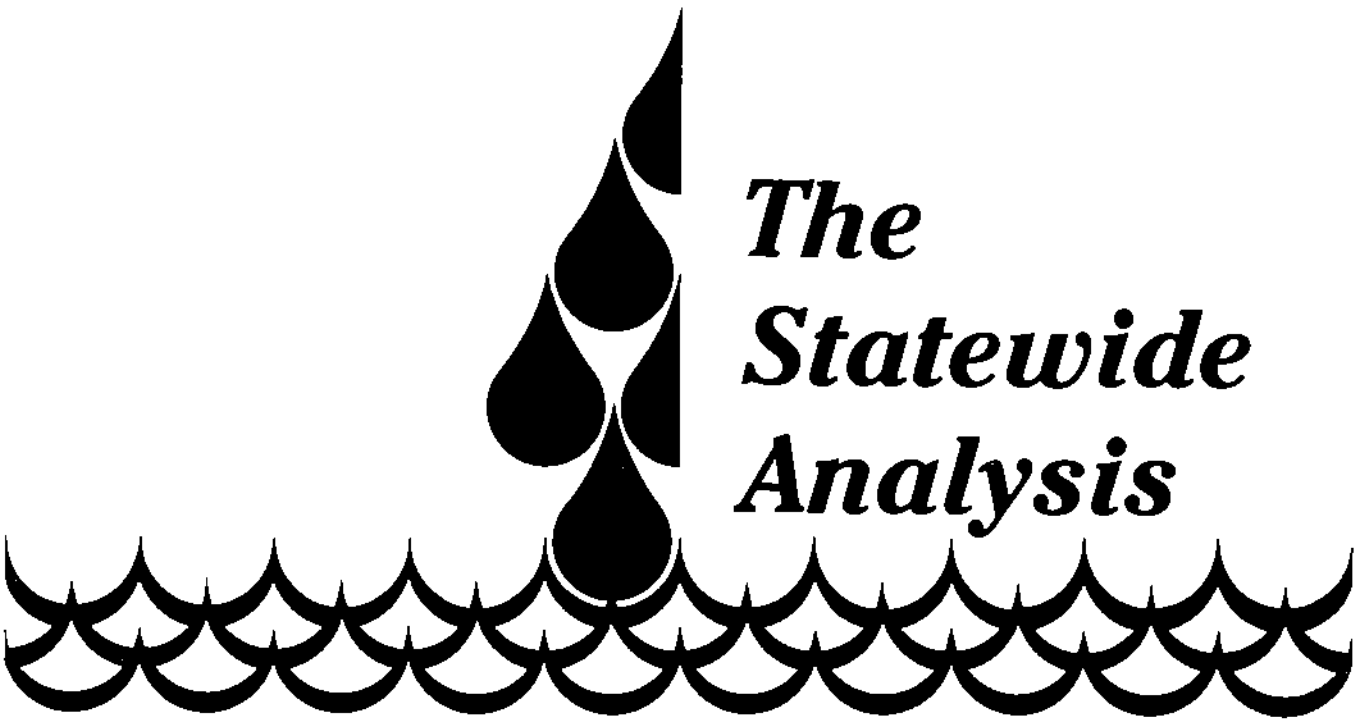
The population of the state has grown from its initial total of less than 100,000 to an estimated 5.4 million. With a total of 92 counties, about forty-nine percent of the population resides in eleven counties that have populations in excess of 100,000. Of these eleven counties, only two have populations in excess of 500,000; two have populations in the 200,000 to 300,000 range; and seven are in the range of 100,000 to 200,000.

From the original small and scattered farmsteads carved out by the settlers, some 16 million acres, or nearly seventy percent of the state, are now devoted to agriculture with cash receipts from farm marketing exceeding $3 billion annually. In contrast to the local smithy, the cabin artisan, and the community grist mill of pioneer days, the Indiana of 1979 has a diverse and vigorous manufacturing economy, with a total value of manufactured products in excess of $45 billion annually. More than fourteen billion kilowatts of electricity were generated in 1978 to meet the need for light, heat, and power.

Largely as a result of technological advances, people today possess a degree of affluence and leisure time undreamed of by the founders of the state. One of the fruits of this phenomenon is a rapid growth in demand for recreational opportunity, and especially for water-related recreation. Boating, fishing, waterskiing, and swimming are popular pursuits. There is concern for the preservation of some streams in their natural state, and for the protection of riparian habitat for fish and wildlife generally.

Despite its impressive record of growth in population, agriculture, industry, and transportation, and the accompanying increases in uses and demands for water, it must be remembered that the Indiana of 1979 has exactly the same land area and water resource that it had in 1816.

With diverse and growing demands upon the same finite water resource, the question of how multiple uses and needs can best be accommodated with equity faces the people of Indiana today.


The
Statewide
Analysis

Environmental Conditions

HYDROLOGIC SETTING

The geographic location of the state is important because it determines the climatic and geologic conditions to which it is subject. These, in turn, define the nature, amount, and distribution of precipitation and the consequent water resource, including its relative occurrence as ground or surface water.

The State of Indiana lies within the limits of latitude 37° 46′ 18″ and 41° 45′ 33″ north, for an extreme length of 275.5 miles in a north-south direction; and between longitude 84° 47′ 05″ and 88° 05′ 50″ west with an extreme width in an east-west direction of 142.1 miles.

The state has a maximum topographic relief of about 900 feet, with elevations ranging from about 300 feet above mean sea level at the mouth of the Wabash River to slightly more than 1,200 feet in Randolph County in east-central Indiana.

The gross area of the state is approximately 36,532 square miles (23,380,000 acres), of which approximately 241 square miles (154,240 acres) lie within Lake Michigan.

Climate As a result of its geographic setting, the climate of Indiana is classified as continental. It is influenced primarily by eastward moving masses of cold polar air from the north and warm gulf air from the south. These two forces form low pressure centers which generally move easterly over the state. Other characteristics include high humidity and frequent variations in temperature combined with considerable local precipitation.

The temperature regime in Indiana is important because it (1) defines the growing and dormant seasons, (2) is the major driving force in the process of evapotranspiration, which consumes about two-thirds of average annual precipitation, and (3) heavily influences the rainfall-runoff relationship, in that it serves in substantial measure to determine both the mode in which precipitation occurs and the ability of the soil to absorb precipitation.

Average annual temperatures range from 49°F. along the Michigan state line to more than 56°F. along the Ohio River. The average annual temperature in Indiana is approximately 53°F. Figure 2 illustrates the statewide distribution of average annual temperatures. The average monthly temperatures are subject to wide variations. January, the coldest month, has average annual temperatures ranging from 24°F. to 34°F. from north to south. July, the warmest month, has a temperature range of from 72°F. to more than 78°F. from the Michigan border to the Ohio River.

The average annual statewide precipitation in Indiana is 38 inches, ranging from 36 inches to 44 inches from north to south as shown on Figure 3. Of this amount, average annual snowfall ranges from 70 inches to 16 inches from north to south. Snowfall accounts for approximately two to seven inches of average annual precipitation.

Precipitation is normally well distributed with respect to the growing season (April through October), with about fifty-nine percent of the average annual total occurring within that period. April, May, June, and July each have a state annual average precipitation of about four inches, while October and December, the lowest months, each have about 2.5 inches.

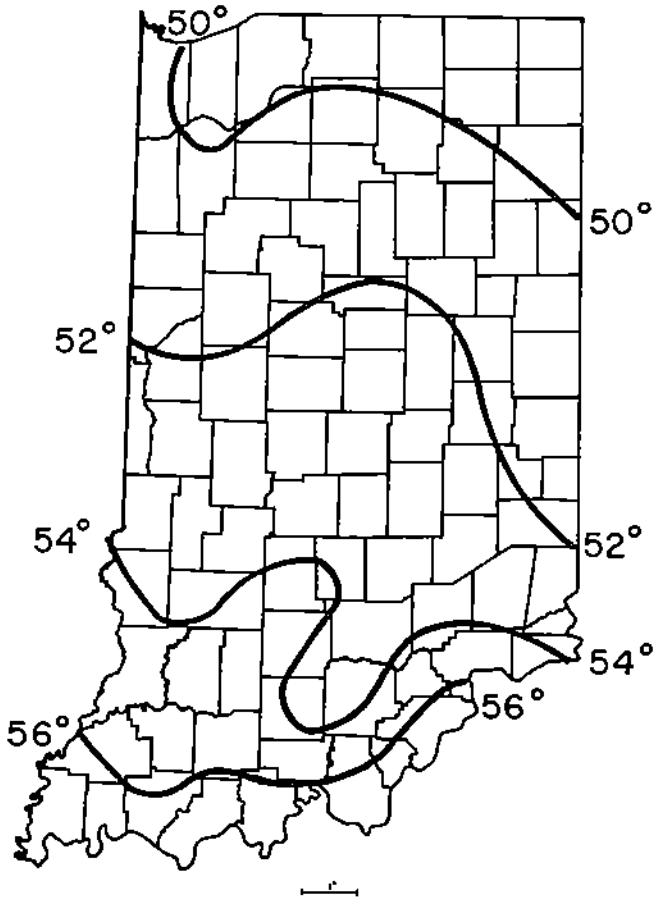


Figure 2
Map of Indiana showing annual temperature in degrees Fahrenheit.

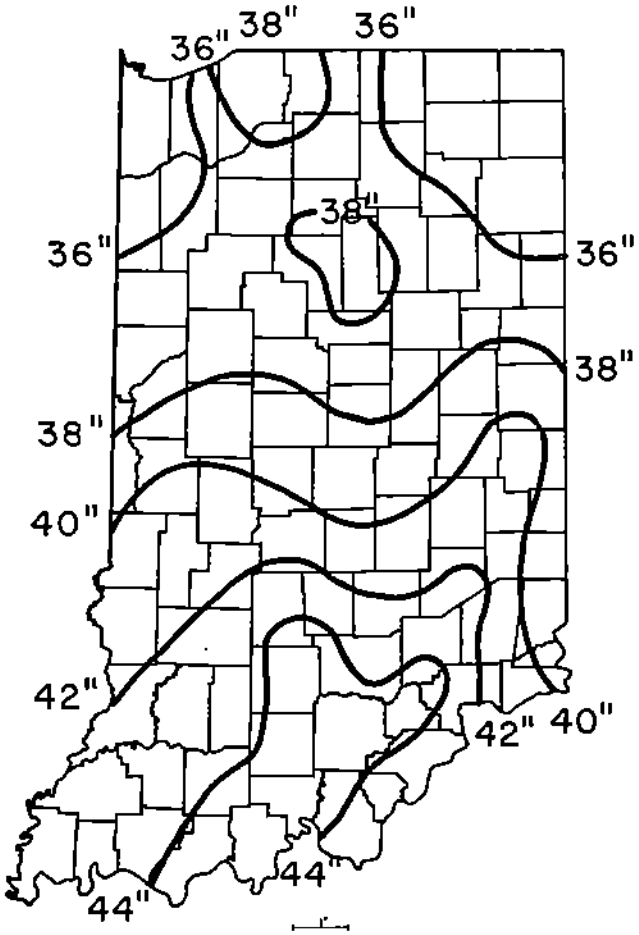


Figure 3
Map of Indiana indicating the distribution of annual average precipitation.

The average annual precipitation data does not provide information on the extremes, either of excess or deficiency, which characterize the state. For example, in the early 1930s and 1940s, Indiana experienced major droughts. Precipitation was sixty-five percent below normal in 1930 and sixty-eight percent below normal in 1941. On the other hand, 1957 was a particularly wet year, with precipitation being one hundred and thirty-five percent above the annual average value.

Extreme amounts of precipitation may occur during storm periods. In March 1913, the southern portion of the state received twenty-one percent (9 inches) of the annual average precipitation in five days, while in 1957 the west-central portion received twenty percent (8 inches) of the average annual precipitation in just one storm event.

In perspective, the climatic setting is such that Indiana on a long-term basis, has a relatively abundant supply of precipitation. Therefore Indiana does not have to contend with the many problems and consequences that would result from an arid or semi-arid climate.

The Geology

Of equal importance to the climatic setting, which controls the amount of precipitation, are the geology and topography of Indiana which influence the disposition of the precipitation and its availability as a water resource.

The location and availability of the Indiana water resource are intimately related to its geology and soils. The proportion of precipitation that runs off the land as surface water rather than infiltrating the soil is dependent in part upon the topography, the geologic conditions, and the soils. In addition, these same factors have substantial influence upon the amount and occurrence of ground water.

Glacial History Perhaps the largest single influence upon the topography of Indiana has been that of glaciation. Glacial lobes, the large, rounded projections from the main body of a glacier, repeatedly entered Indiana during the Ice Age. Figure 4 indicates the general extent of glaciation in Indiana and surrounding states. The glacial lobes entered the state from at least two directions, from the northeast out of the Lake Erie and Saginaw Bay basins and from the north out of the Lake Michigan basin.

As glaciers advance and retreat under the influence of climatic conditions, the topography is transformed. An advancing glacier scours the land surface while a retreating glacier leaves behind large deposits of materials previously scoured from the earth's surface. Glacial drift, the rock material transported by glaciers, covers the northern two-thirds of the state as a legacy of the most recent period of glaciation. Another one-quarter of the state is covered in part by drift of older glacial episodes.

Figure 5 illustrates the location of glacial drift and other unconsolidated deposits in Indiana. Deposits of the last major glaciation, the Wisconsinan (14,000–22,000 years ago), are well represented, but deposits of the Illinoian and older glaciations are much more discontinuous. Their positions and sequences are mostly pieced together from very fragmentary evidence. Eight or nine distinct till sheets (layers of unsorted debris representing mostly the melting out of the basal ice load) overlap one another in western Indiana. These deposits of both northern and eastern lobe origin represent at least six or seven principal glacial advances. Each till sheet is separated from the next overlying or underlying sheet by evidence of weathering or of pond sedimentation during interglacial periods similar to the present interglacial period. At least six or seven distinct till sheets, all of northeastern

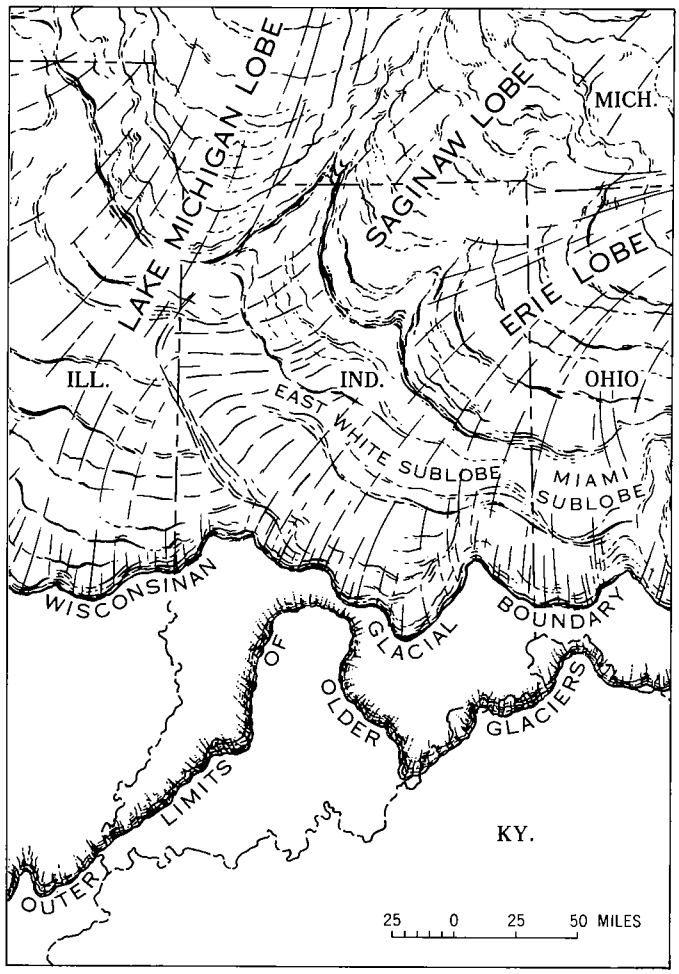


Figure 4
Map of Indiana and parts of adjoining states showing major ice lobes and sublobes during the Wisconsinan age.

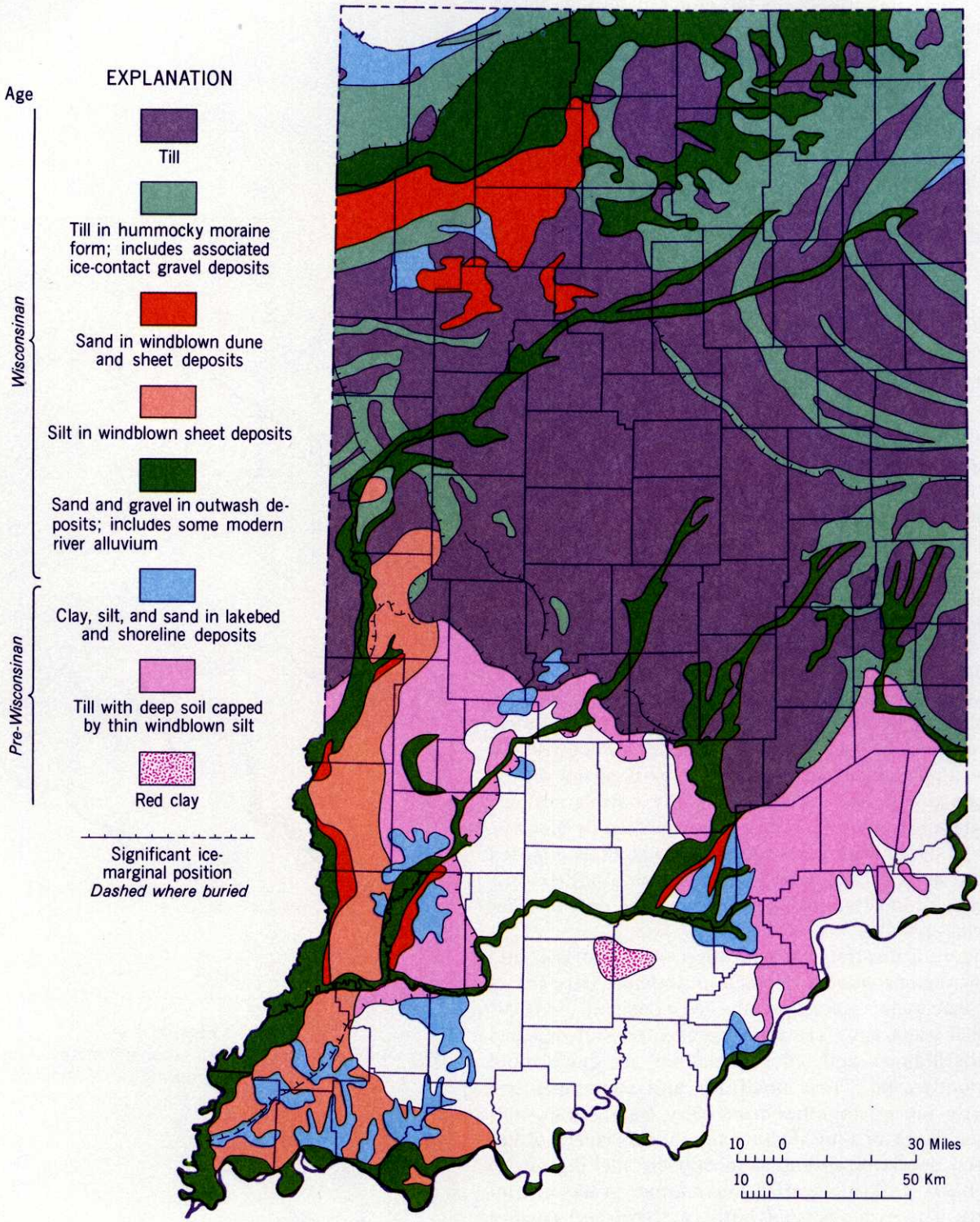


Figure 5
Map of Indiana showing general distribution of unconsolidated deposits. The uncolored areas in southern Indiana represent areas with little or no unconsolidated deposits.

origin and of at least three major glacial episodes, overlap one another in eastern Indiana.

Fewer drift sheets are present in central Indiana and in parts of northern Indiana because of glacial erosion of the earlier formed sheets, but these correspond in sequence and in time of deposition to some drifts in the marginal zones. These till sheets rest sharply one on the other in some places, but commonly they are separated by sands and gravels that were deposited by glacial meltwaters beneath or in front of the several ice sheets.

The remaining nonglaciated area of south-central Indiana shows evidence of drainage changes related to glacial activity. Examples of these changes include those that occurred during the creation of the Ohio River and its tributaries and the creation and eventual drainage of numerous ice-dammed lakes.

Bedrock Geology Indiana's bedrock formations have been assigned ages that place them in the Paleozoic Era of time. They are, therefore, more than two hundred million years old. Figure 6 illustrates the geologic timescale and the Indiana rock types associated with each geologic period. The principal bedrock formations in Indiana are associated with the Pennsylvanian, Mississippian, Devonian, and Silurian periods. These sedimentary rock formations consist mainly of sandstone, siltstone, shale, limestone, and dolomite. These are for the most part the deposits from a series of inland seas that occupied what is now Indiana and surrounding states through most of Paleozoic time. In addition, terrestrial sedimentary deposits are located in parts of Indiana and include large deposits of coal, the remnants of great swamp forests.

The typical sequence of rock types composing the various bedrock formations found in Indiana is shown in Figure 7. The Precambrian, Cambrian, and portions of the Ordovician bedrock are located only at the subsurface. On the other hand, the Pennsylvanian, Mississippian, Devonian, Silurian, and portions of the Ordovician formations are located near the surface or as outcroppings.

The various ages of bedrock which occur below the surface or as outcroppings in Indiana are shown in Figure 8. The bedrock in northeastern Indiana dips northward into a structural depression called the Michigan Basin. Bedrock in northwestern and central Indiana is draped like a stack of blankets over an archlike structure whose axis lies across the state approximately from Liberty in southeastern Indiana to Hammond in the northwestern corner of the state. The bedrock in southern Indiana dips southeastward into a structural depression known as the Illinois Basin.

The sequence of sedimentary rock is about 3,000

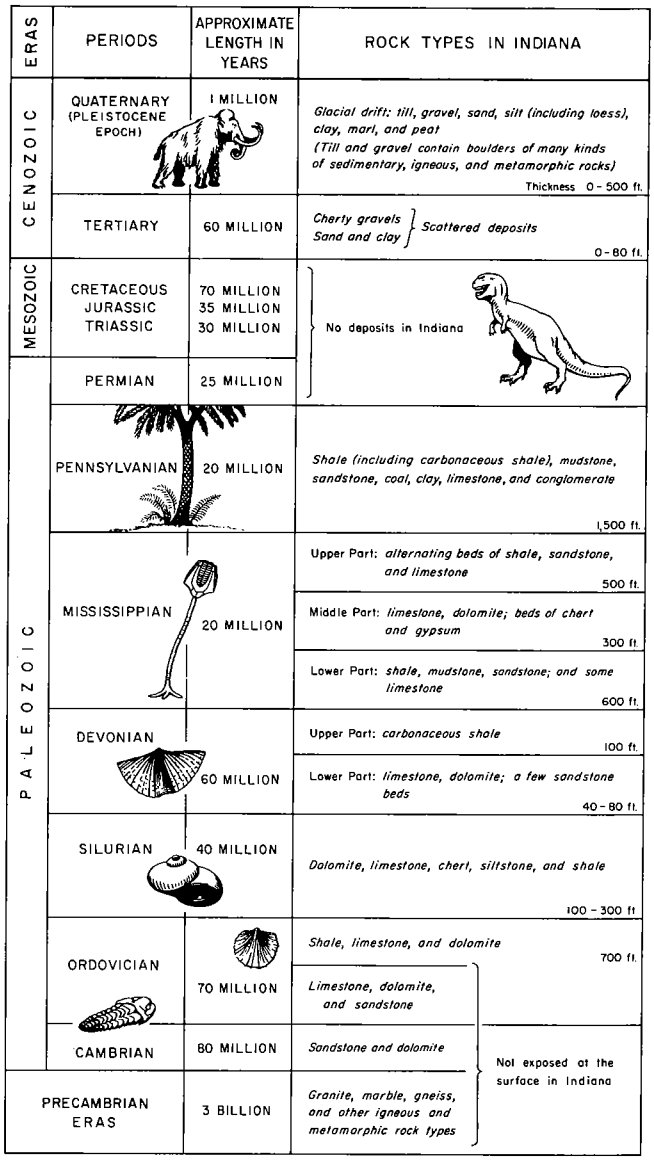


Figure 6
The geologic timescale and the Indiana rock types associated with each geologic period.

feet thick near Muncie but is 5,000 feet thick at the Michigan border and more than 12,000 feet thick at the southwest corner of the state. Erosion has removed great thicknesses of the sedimentary rocks and also has beveled them, so that the oldest (Ordovician) rocks lie at the bedrock surface near Richmond and

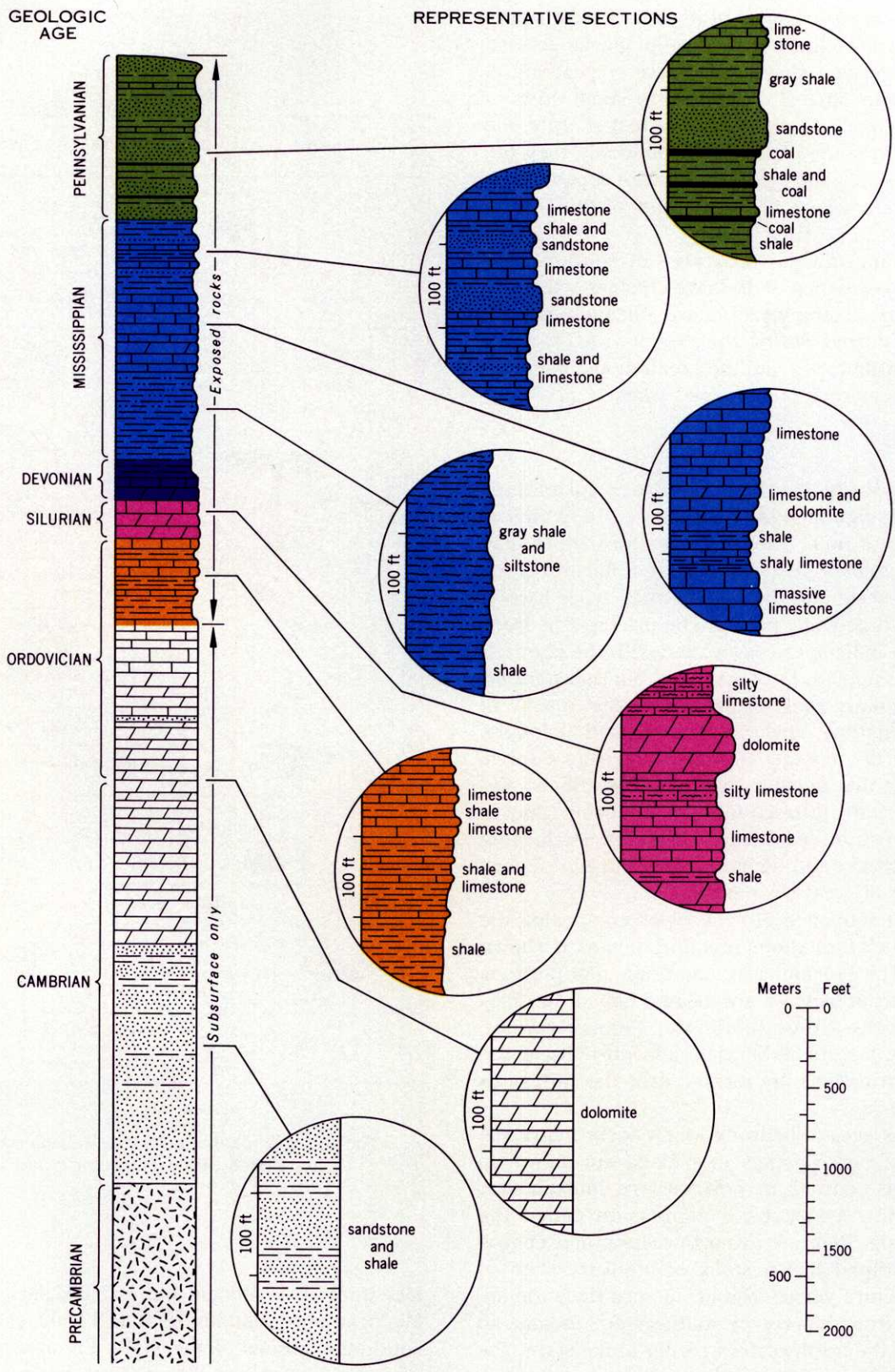


Figure 7
Schematic representation showing the sequence of rocks composing Indiana bedrock deposits during the Paleozoic Era.

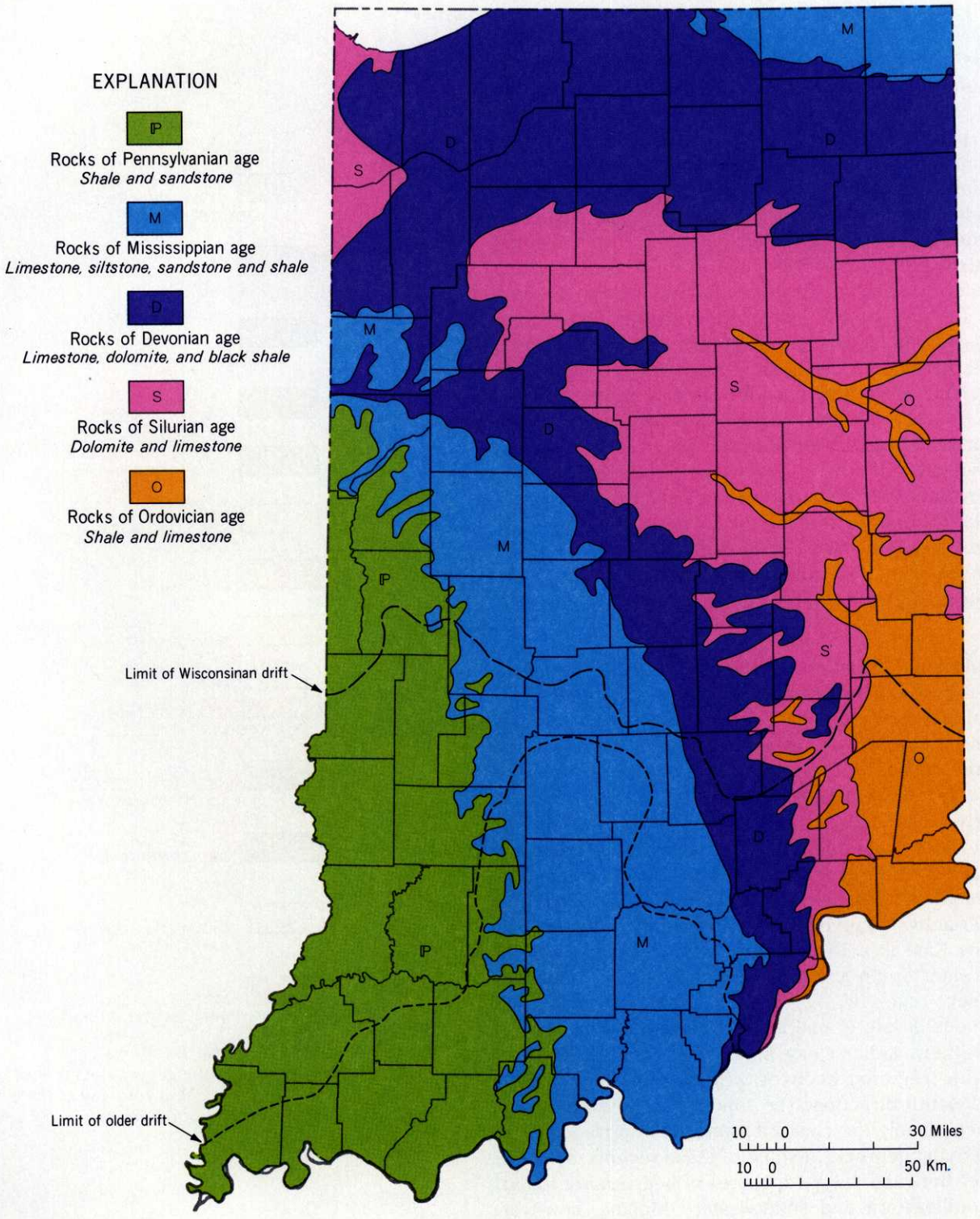


Figure 8
Map of Indiana showing general distribution of bedrock deposits.

Lawrenceburg, and the youngest (Pennsylvanian) rocks underlie Evansville and Terre Haute.

Soils The process of soil formation is controlled by regional climatic conditions. The basis of soil formation is the gradual weathering and decomposition of soil parent materials. The basic parent materials of Indiana soils are glacial drift and various bedrock formations. Figure 9 indicates the location of parent materials of Indiana soils.

During the process of soil formation vegetation establishes itself. As the vegetational communities develop, organic matter accumulates on the ground, and soil profiles are developed. With the introduction of vegetation, micro-flora and fauna also develop. Over time, the modern day soils were developed, each with individual characteristics and physical properties.

Soils and the underlying geologic formations create an intimate association with the water resource. Each individual soil has a distinctive permeability characteristic, which governs its capacity to absorb precipitation and to transmit it to underlying geologic formations. The basic components of soil are sand, clay, and silt. The higher the content of sand, the greater the permeability.

Landforms Northern and central Indiana can be divided into four principal and several subsidiary topographic regions on the basis of characteristic landforms, as shown in Figure 10. Table 1 describes the characteristics of these topographic regions. Only the dissected Wabash Valley region (3h) does not have a nearly completely glacially influenced origin. The upland rim of Lake Michigan (1b) and the northeastern (4) and central (3) regions are flat plains to rolling uplands whose origins relate primarily to deposition by either actively moving or disintegrating ice. The basin of the Kankakee River (2) is basically one of glacial meltwater origin and has been modified by wind. Two subsections (1a, 3g) are flat plains, the former lakebeds of late glacial Lakes Chicago and Maumee.

Southern Indiana can be divided into seven topographic regions, each of which is elongated in a north-south direction. The topography of each region reflects mainly the character and outcrop trend of the underlying bedrock. In some of these regions, soils are rather thin, and many exposures of bedrock are found. In southeastern and southwestern Indiana, however, deposits of the older glaciers extend essentially to the Ohio River, and in both these areas the bedrock surface is partly buried by deposits associated with glacial activity. On the hilltops these deposits commonly are only a few feet thick, but in the larger valleys their thicknesses may reach 100 or more feet.



Figure 9
Map of Indiana showing the general location of parent materials to Indiana soils. Map courtesy of the U.S. Soil Conservation Service.

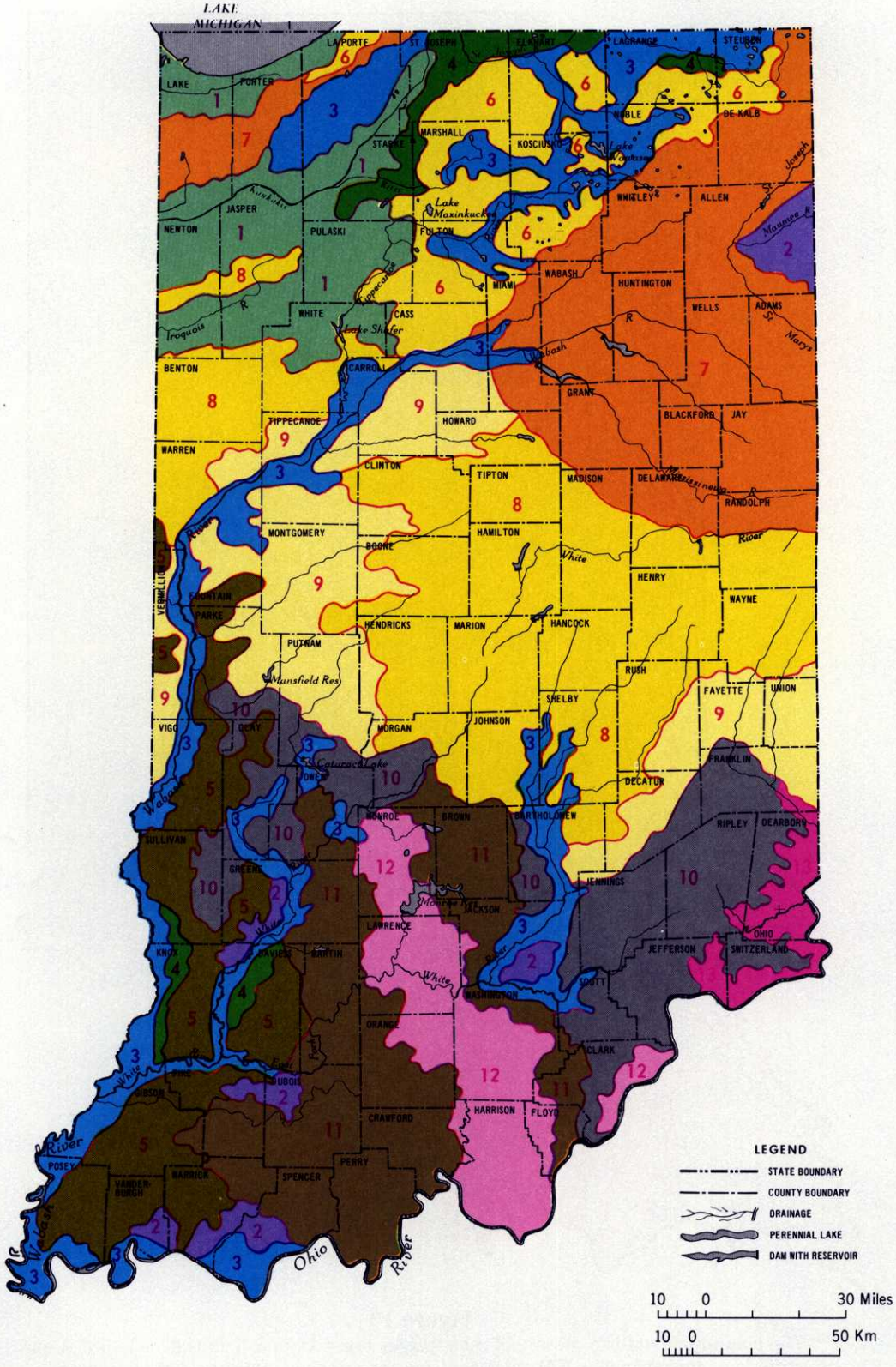

LAKE MICHIGAN
LAPORTE
ST. JOSEPH
ELKHART
LAGRANGE
STEUBEN
LAKE
PORTER
NOBLE
DE KALB
MARSHALL
STARKE
KOSCIUSKO
Lake Wawasee
Lake Maxinkuckee
JASPER
WHITLEY
ALLEN
NEWTON
PULASKI
FULTON
MIAMI
WABASH
HUNTINGTON
WHITE
CASS
Lake Shafer
WELLS
ADAMS
BENTON
CARROLL
GRANT
BLACKFORD
JAY
TIPPECANOE
HOWARD
WARREN
CLINTON
TIPTON
MADISON
DELAWARE
RANDOLPH
MONTGOMERY
BOONE
HAMILTON
HENRY
WAYNE
FOUNTAIN
PARKE
HENDRICKS
MARION
HANCOCK
PUTNAM
Mansfield Res
RUSH
FAYETTE
UNION
SHELBY
VIGO
CLAY
MORGAN
JOHNSON
Cataract Lake
FRANKLIN
DECATUR
MONROE
BROWN
BARTHOLOMEW
RIPLEY
DEARBORN
SULLIVAN
GREENE
JENNINGS
JACKSON
LAWRENCE
KNOX
DAVIESS
MARTIN
JEFFERSON
OHIO
SWITZERLAND
WASHINGTON
SCOTT
ORANGE
CLARK
DUBOIS
PIKE
GIBSON
CRAWFORD
HARRISON
FLOYD
POSEY
PERRY
VANDERBURGH
WARRICK
SPENCER
Wabash River
White River
Ohio River
LEGEND
STATE BOUNDARY
COUNTY BOUNDARY
DRAINAGE
PERENNIAL LAKE
DAM WITH RESERVOIR
10 0 30 Miles
10 0 50 Km



Figure 10

The map of Indiana is a mosaic of nine images taken from a "Landsat" satellite at an altitude of approximately 570 miles showing the principal and subsidiary topographic regions of Indiana.

Table 1

Description of the topographic regions located in Indiana.

Reference Number	*Topographic Unit*
1a	Low, flat, poorly drained clay and till plain of glacial Lake Chicago interspersed with sand, linear swales, and beach ridges
1b	Rolling, hummocky, clayey till on uplands of Valparaiso and Tinley Moraines
2	Low-lying sand and much outwash plain interspersed with sheet and dune, windblown sand
3a	Plain of mostly clayey till interspersed with looping belts of rolling, hummocky, ridged, morainic upland
3b	Morainic ridges and plain with interspersed ice-disintegration forms, dunes, and lake flats
3c	Generally flat but subtly east-west fluted till plain with oriented drainage
3d	Till plain and moraines of loam till, some southwest-oriented drainage troughs and outwash features, grades to dissected Wabash Valley region
3e	Till plain and moraines of loam till interspersed with large-scale, ice-drainage troughs
3f	Plain of clayey till interspersed with narrow looping belts of rolling, hummocky, ridged, moraine upland
3g	Low, flat, poorly drained till-plain bed of glacial Lake Maumee with marginal sandy beach deposits
3h	Stream-dissected till plain and valley bottom underlain by drifts of various ages, bedrock, outwash, and alluvium; grades into bordering topographic regions
4	Complex interlobate loam till and outwash moraine topography with interspersed lakes, bogs, and glacial drainage troughs and plains
5	Rolling plains underlain by loess, till, and bedrock; broad valley flats underlain by thick deposits of alluvium, outwash, and lake deposits
6	Hills of moderate to strong relief underlain principally by shale and sandstone bedrock
7	Broad uplands underlain by limestone, much dissected by streams in some areas and in others marked by a sinkhole plain with extensive underground drainage
8	Steep hills of strong to moderate relief mainly underlain by siltsone bedrock; a fringe area with lower relief has a patchy cover of till
9	Broad plains underlain mainly by till, outwash, and lake deposits; in southern part, low hills of shale bedrock with a thin cover of till
10	Broad uplands underlain by limestone with a thin, patchy till cover, much dissected by streams in most areas
11	Steep hills of strong to moderate relief, underlain by shale and limestone with a thin, patchy till cover

Major Drainage Basins

A very important landform from the water resource standpoint is the drainage basin. A drainage basin is an area that gathers water originating as precipitation and contributes it ultimately to a stream or other body of water. All streams, from the smallest to the largest, have associated drainage basins from which their flows are derived. The two major drainage basins in Indiana are the Great Lakes and the Mississippi River Basin, as shown in Figure 11.

The Great Lakes drainage consists of the Little and Grand Calumet Rivers and minor tributaries to Lake Michigan in northwestern Indiana; the St. Joseph River basin in northern Indiana, which also drains to Lake Michigan; and the Maumee River basin in the northeastern part of the state, which drains to Lake Erie. The Great Lakes drainage portion of Indiana totals approximately 3,545 square miles, including 241 square miles in Lake Michigan.

The Mississippi River drainage consists of two major areas of the state. The first of these is composed of the basins of the Kankakee and Iroquois Rivers, which drain westerly into Illinois and thence to the Mississippi River via the Illinois River. The total area within this section is approximately 3,016 square miles.

The second portion of the Mississippi River drainage, which encompasses about seventy-seven percent of the state, is made up of the basins of the Wabash River, the Whitewater River, and a number of minor tributaries to the Ohio River along the southern portion of the state. These all drain to the Ohio River and thence to the Mississippi. The total area within this section is approximately 29,730 square miles. Table 2 provides information on the major sub-basins and their respective drainage areas, including the out-of-state portions.

The availability of water in Indiana is not totally confined to that originating within the boundaries of the state. There are two general cases in which the availability of water to Indiana is or may be directly influenced by actions of other states.

The first case has reference to those interstate lakes and rivers that comprise a part of the boundaries of the state. These are Lake Michigan, the lower Wabash River, and the Ohio River. The quantities of water available to Indiana in this case are in part a function of water use developments in all the other states in the river or lake basin, and the water uses from the lake or stream in the state or states abutting on the boundary waters. It is perhaps reasonable, or at least conservative, to assume that the quantities of water available to Indiana in this case may tend to decrease rather than to increase.

The second case has reference to those streams entering into Indiana from the States of Michigan, Ohio, and Illinois. Again, the quantities of water entering into the state in this case are dependent upon water resource developments and uses within Michigan, Ohio, and Illinois. The reasonable assumption would be that in time quantities may well be subject to diminution as a result of uses in those states.

Table 2

The areal extent in square miles of the major drainage basins in Indiana and those portions that extend into surrounding states.

Drainage Basins and Rivers	*Indiana*	*Illinois*	*Michigan*	*Ohio*
Great Lakes Drainage Basin				
St. Joseph River	1,778	0	1,964	0
Calumet River	551	34	0	0
Maumee River	1,216	0	234	697
Upper Mississippi River Drainage Basin				
Kankakee and Iroquois Rivers	3,016	0	0	0
Wabash Drainage Basin				
Wabash River	23,950	8,704	0	285
Ohio River Tributary Drainage Basin				
Whitewater River	1,403	0	0	145
Minor Tributaries To Ohio River	4,377	0	0	0



Figure 11
Map of Indiana and adjacent states showing the major and minor drainage basins.

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

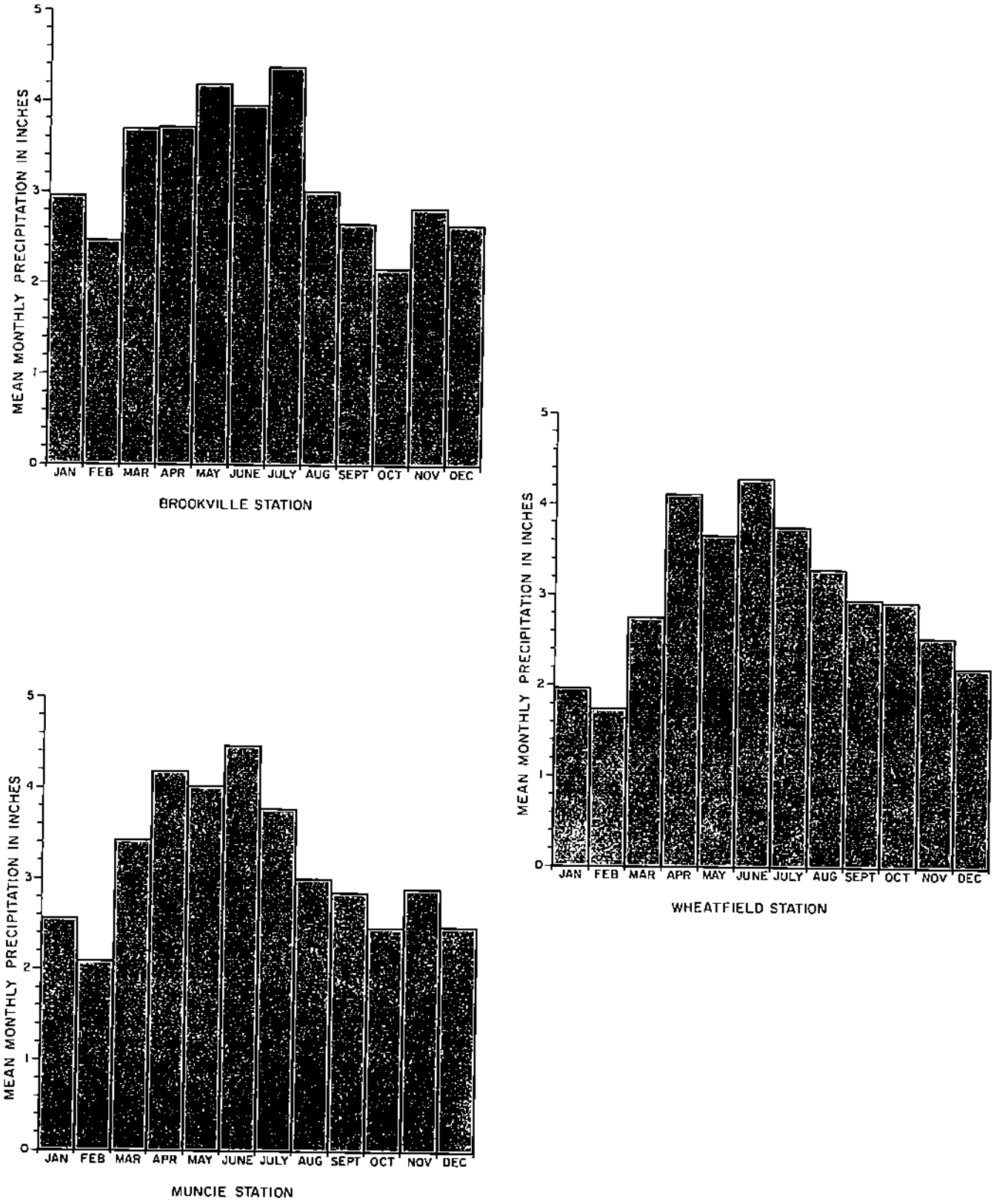


Figure 12
Graphs indicating the mean monthly precipitation for selected locations in northern (Wheatfield station), central (Muncie station), and southern (Brookville station) portions of Indiana.

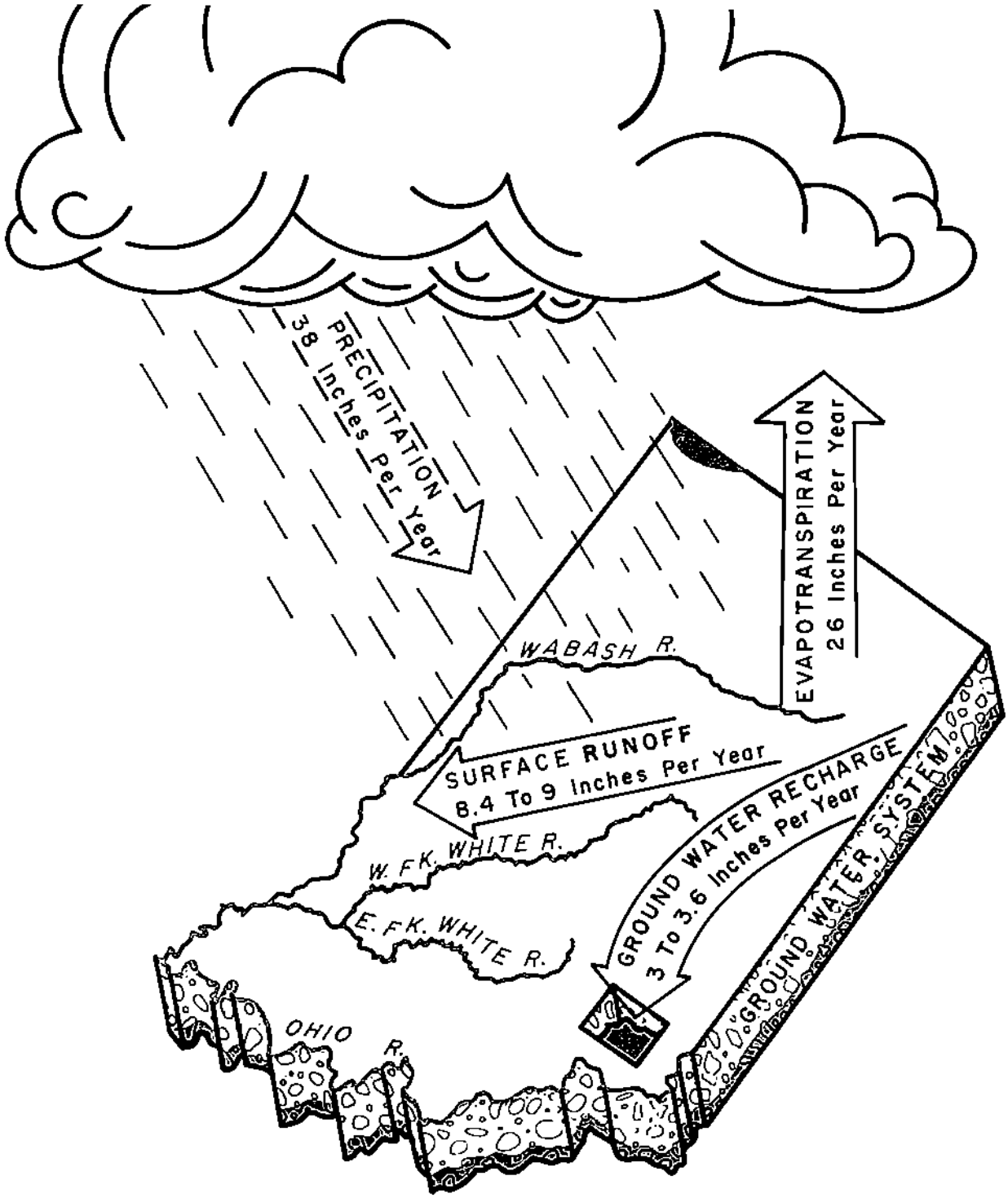


Figure 13
Illustration of the distribution of average annual precipitation in Indiana.

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.

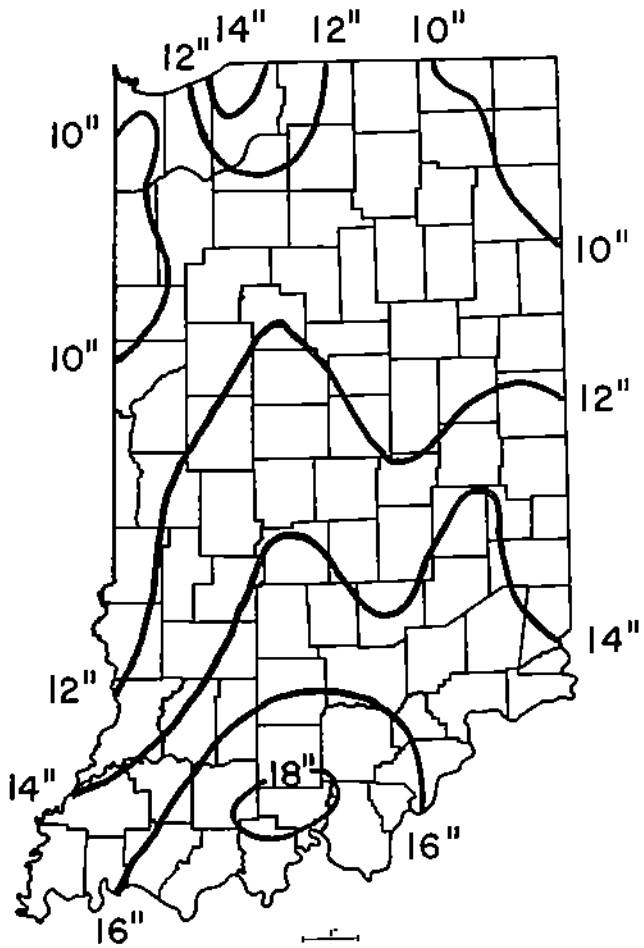
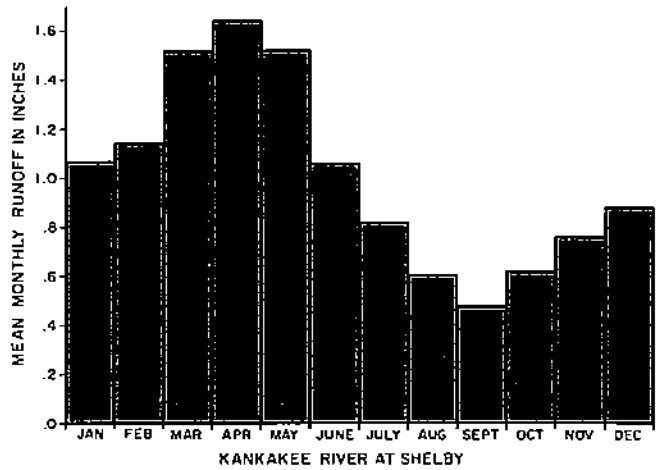
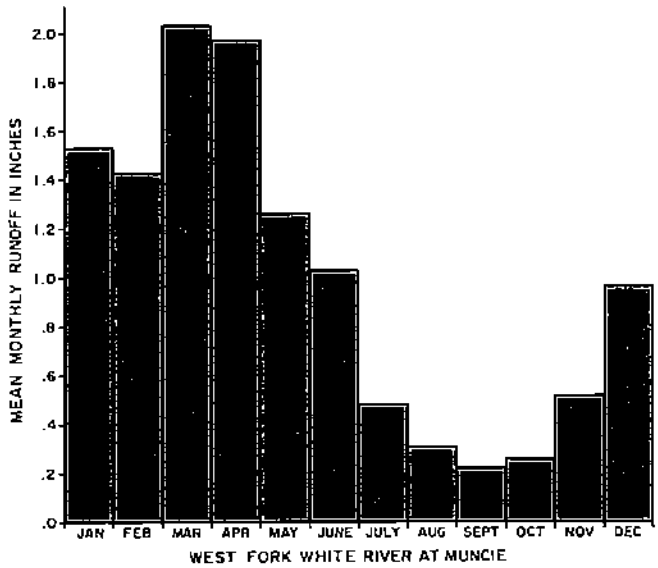


Figure 14
Map of Indiana showing the general distribution of average annual runoff in inches.





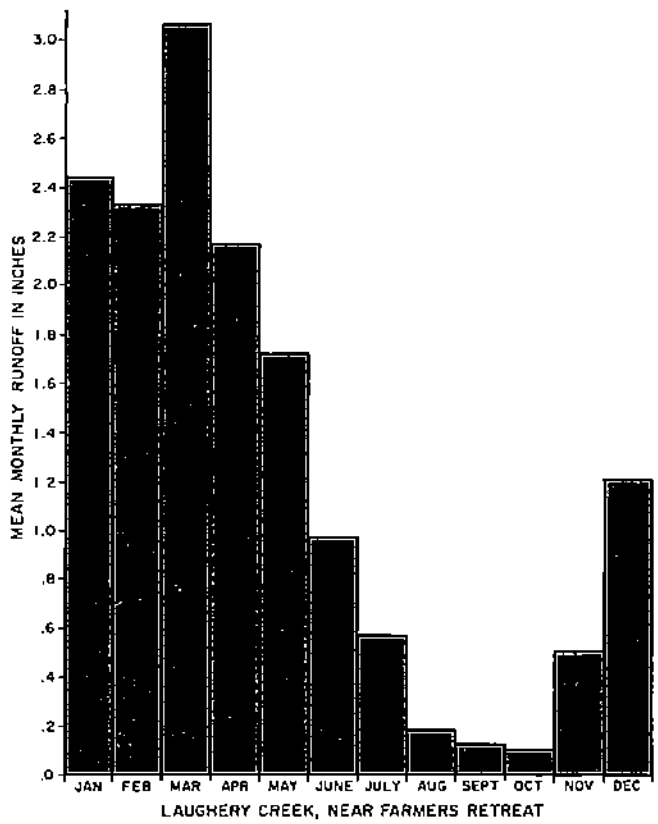


Figure 15 (Shown at right)
The mean monthly runoff for selected stations in northern (Kankakee River at Shelby), central (West Fork of the White River at Muncie), and southern (Laughery Creek near Farmers Retreat) Indiana.

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.

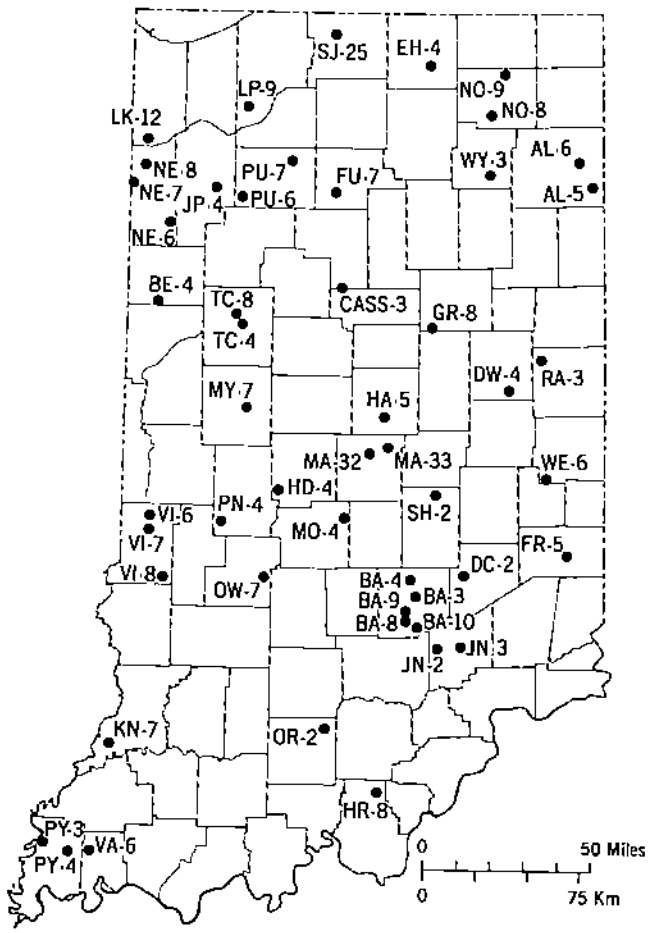


Figure 16
Map of Indiana showing the name and location of active ground-water observation wells.

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.

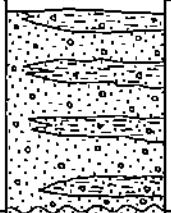
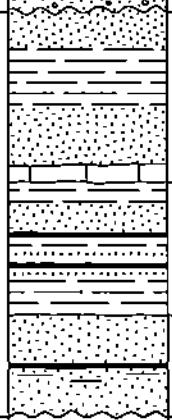
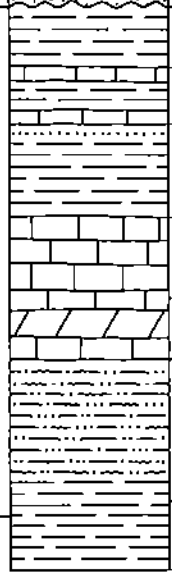
Other productive ground-water aquifers are the thick, inter-till sand and gravel deposits found in central and northern Indiana. The withdrawal potential of ground water from these unconsolidated aquifer systems ranges between 400 and 2,000 gpm from properly constructed, large diameter wells.

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. Wisconsinan S. Illinoian S. 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. Carbondale Gr. Raccoon Creek Gr.	Mattoon Fm. Bond Fm. Patoka Fm. Shelburn Fm. Dugger Fm. Petersburg Fm. Linton Fm. Staunton Fm. Brazil Fm. Mansfield 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.
MISSISSIPPIAN		Buffalo Wallow Gr. Stephensport Gr. West Baden Gr. Blue River Gr. Sanders Gr. Borden Gr. New Albany Sh.	Paoli Ls. Ste. Genevieve Ls. St. Louis Ls. Edwardsville Fm. New Providence Sh.		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. 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. 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. 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.

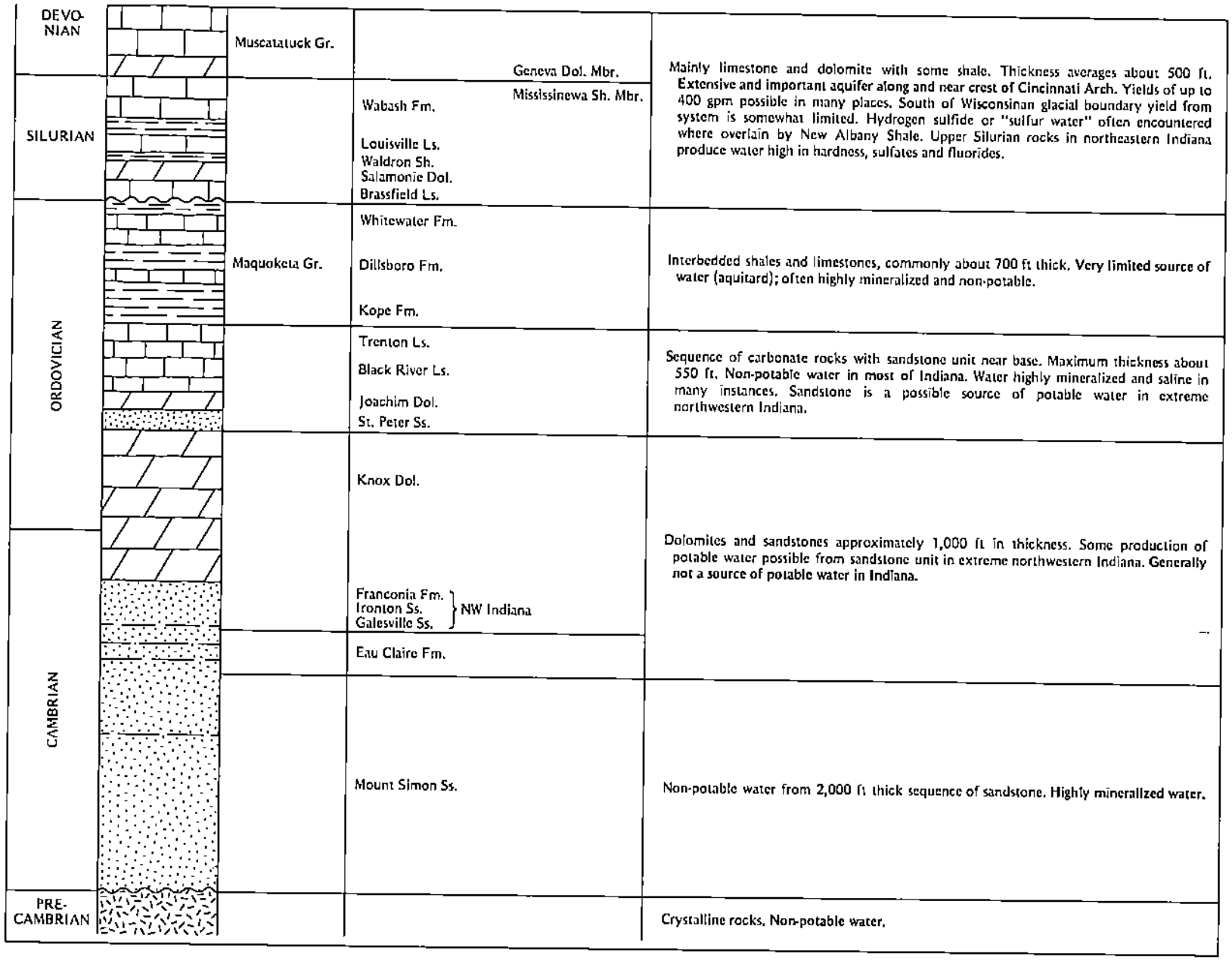


Figure 17
Geologic column showing the geologic age and the general water bearing characteristics of Indiana bedrock formations.

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.

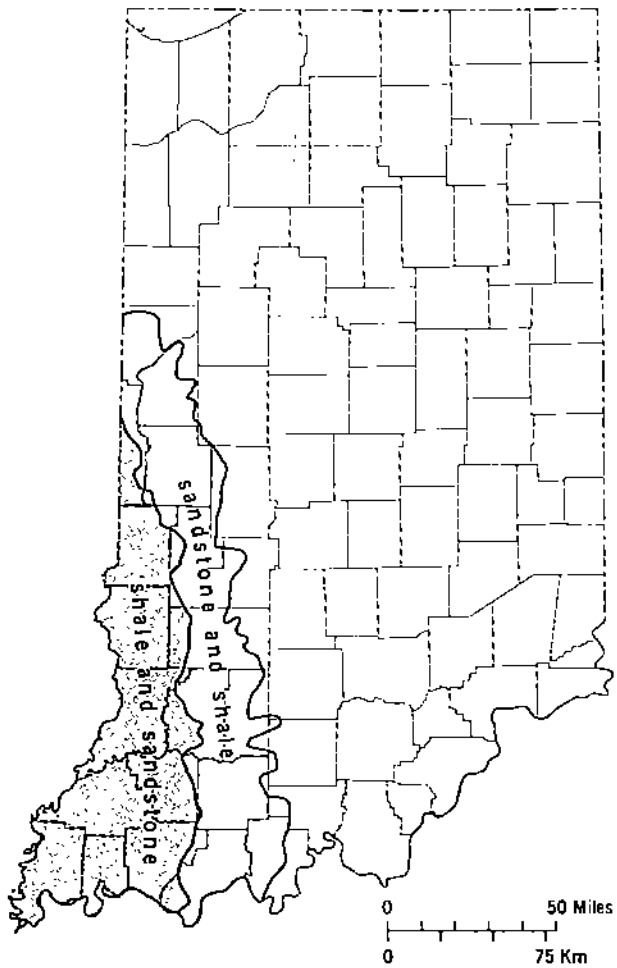


Figure 18
Map of Indiana showing those areas with underlying Pennsylvanian bedrock aquifers.

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

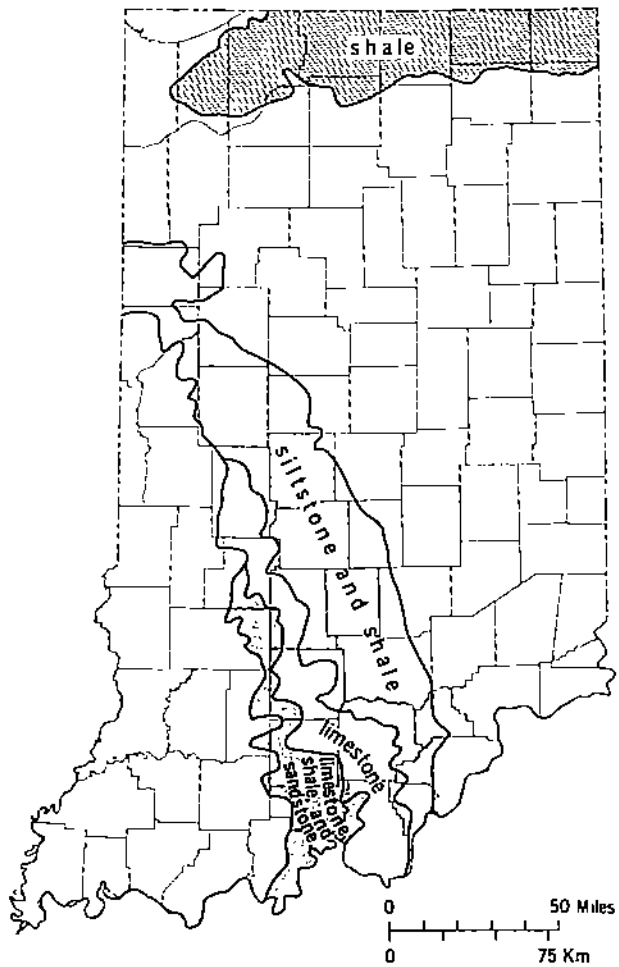


Figure 19
Map of Indiana showing those areas with underlying Mississippian bedrock aquifers.

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.

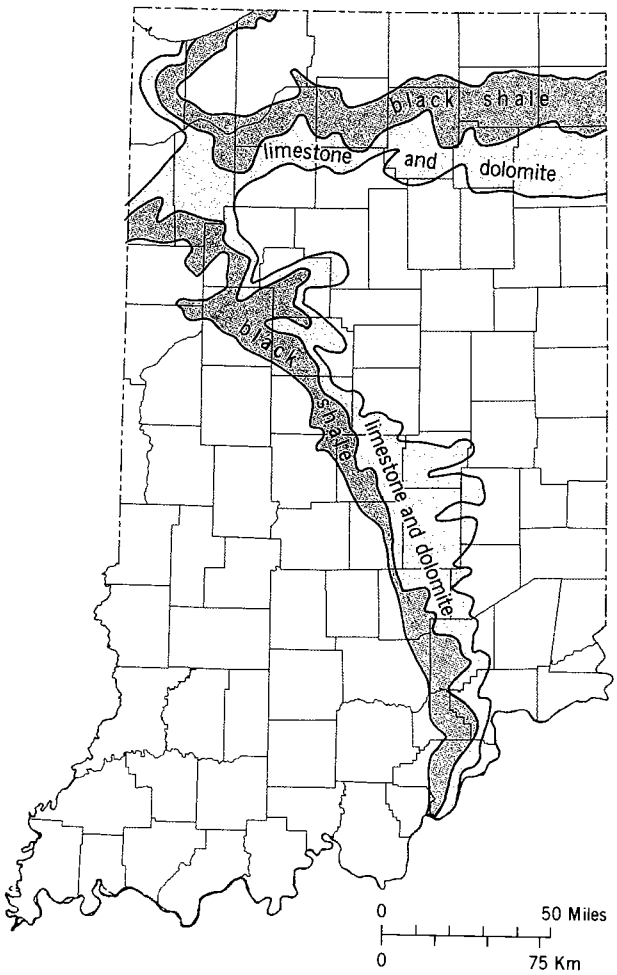


Figure 20
Map of Indiana showing those areas with underlying Devonian bedrock aquifers.

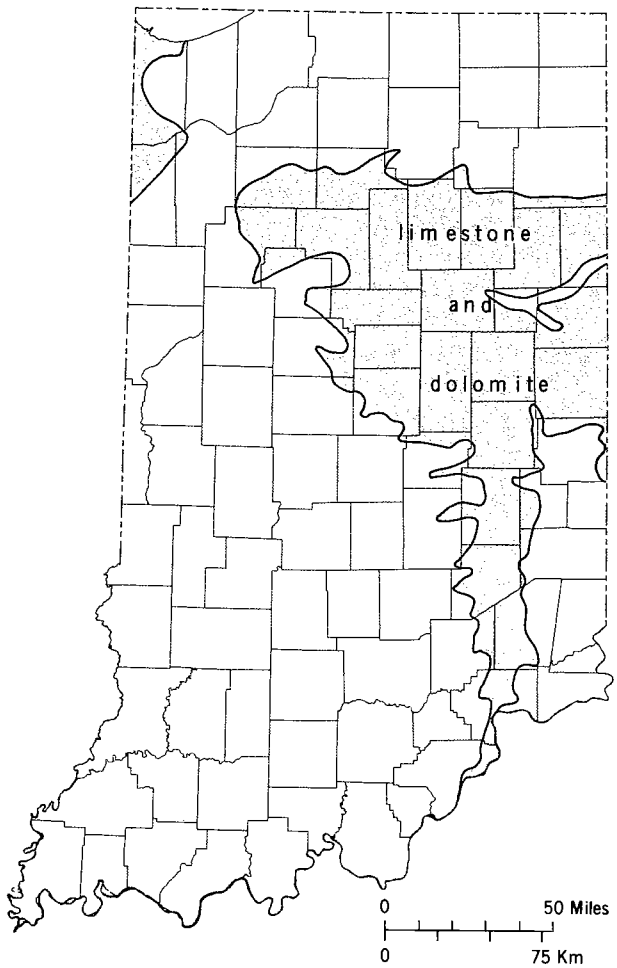


Figure 21
Map of Indiana showing those areas with underlying Silurian bedrock aquifers.

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.

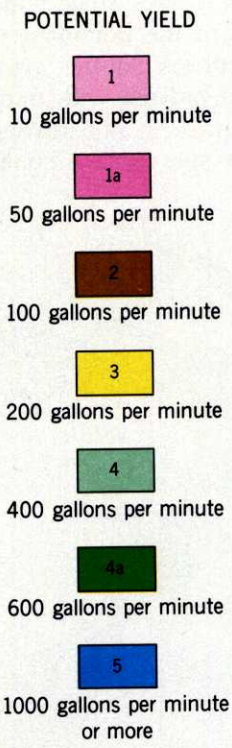
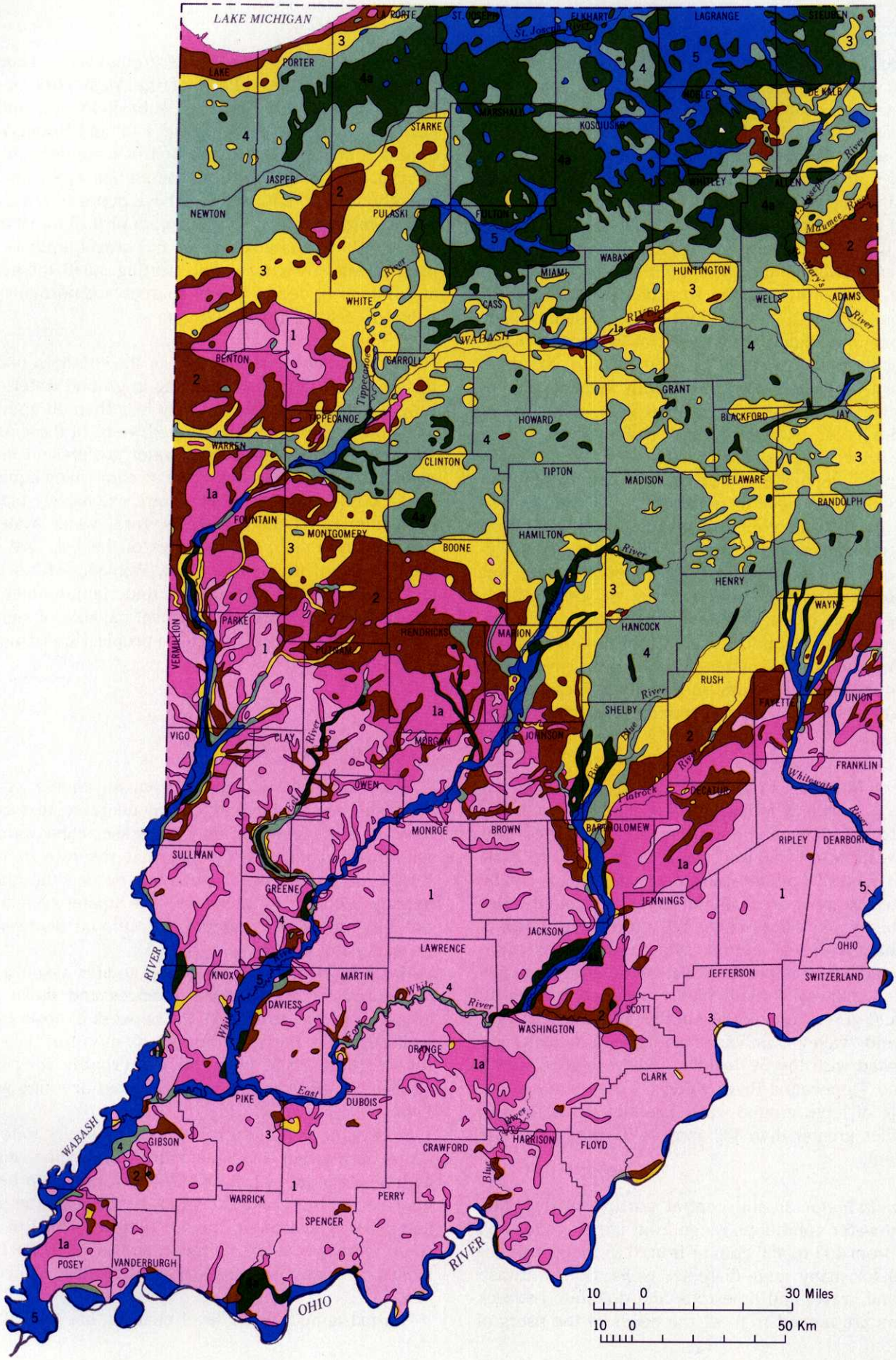


Figure 22
Map of Indiana showing the potential yield of ground water from properly constructed large diameter wells.

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
LAPORTE
ST. JOSEPH
ELKHART
LAGRANGE
STEUBEN
LAKE
PORTER
MARSHALL
KOSCIUSKO
DE KALB
STARKE
JASPER
NEWTON
PULASKI
FULTON
WHITLEY
ALLEN
MIAMI
WABASH
HUNTINGTON
WELLS
ADAMS
WHITE
CASS
WABASH RIVER
BENTON
CARROLL
GRANT
TIPPECANOE
HOWARD
BLACKFORD
JAY
WARREN
CLINTON
TIPTON
MADISON
DELAWARE
RANDOLPH
FOUNTAIN
MONTGOMERY
HAMILTON
BOONE
HENRY
PARKE
HENDRICKS
MARION
HANCOCK
WAYNE
VERMILLION
RUSH
SHELBY
UNION
VIGO
CLAY
MORGAN
JOHNSON
FRANKLIN
OWEN
DECATUR
MONROE
BROWN
BARTHOLOMEW
RIPLEY
DEARBORN
SULLIVAN
GREENE
JENNINGS
JACKSON
OHIO
LAWRENCE
KNOX
MARTIN
JEFFERSON
SWITZERLAND
DAVIESS
SCOTT
WASHINGTON
ORANGE
CLARK
PIKE
DUBOIS
CRAWFORD
HARRISON
FLOYD
GIBSON
WARRICK
PERRY
SPENCER
POSEY
VANDERBURGH
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.

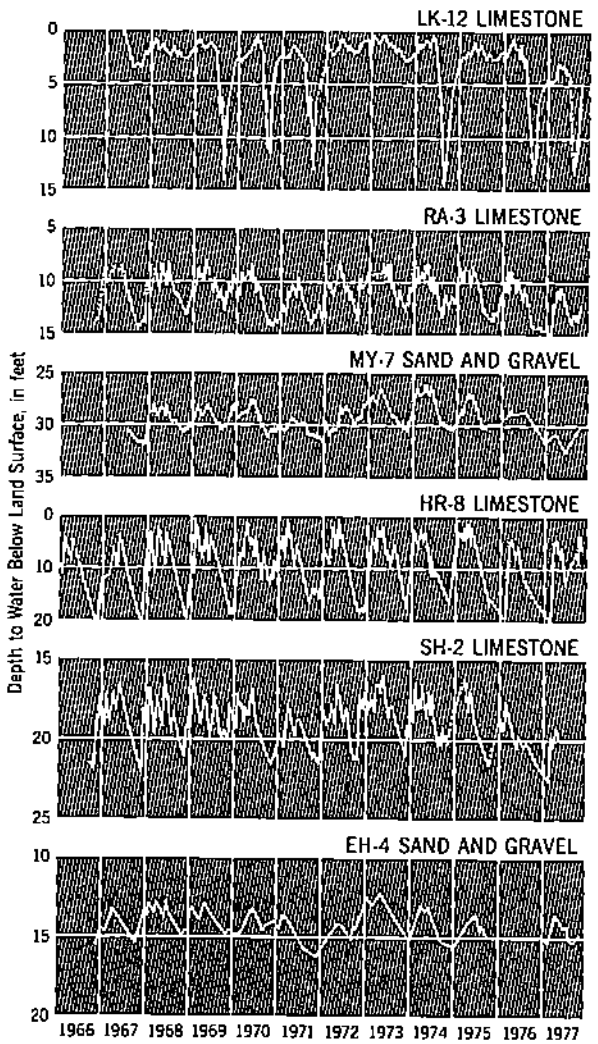


Figure 23
Water levels in selected observation wells from 1966 to 1977.

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.

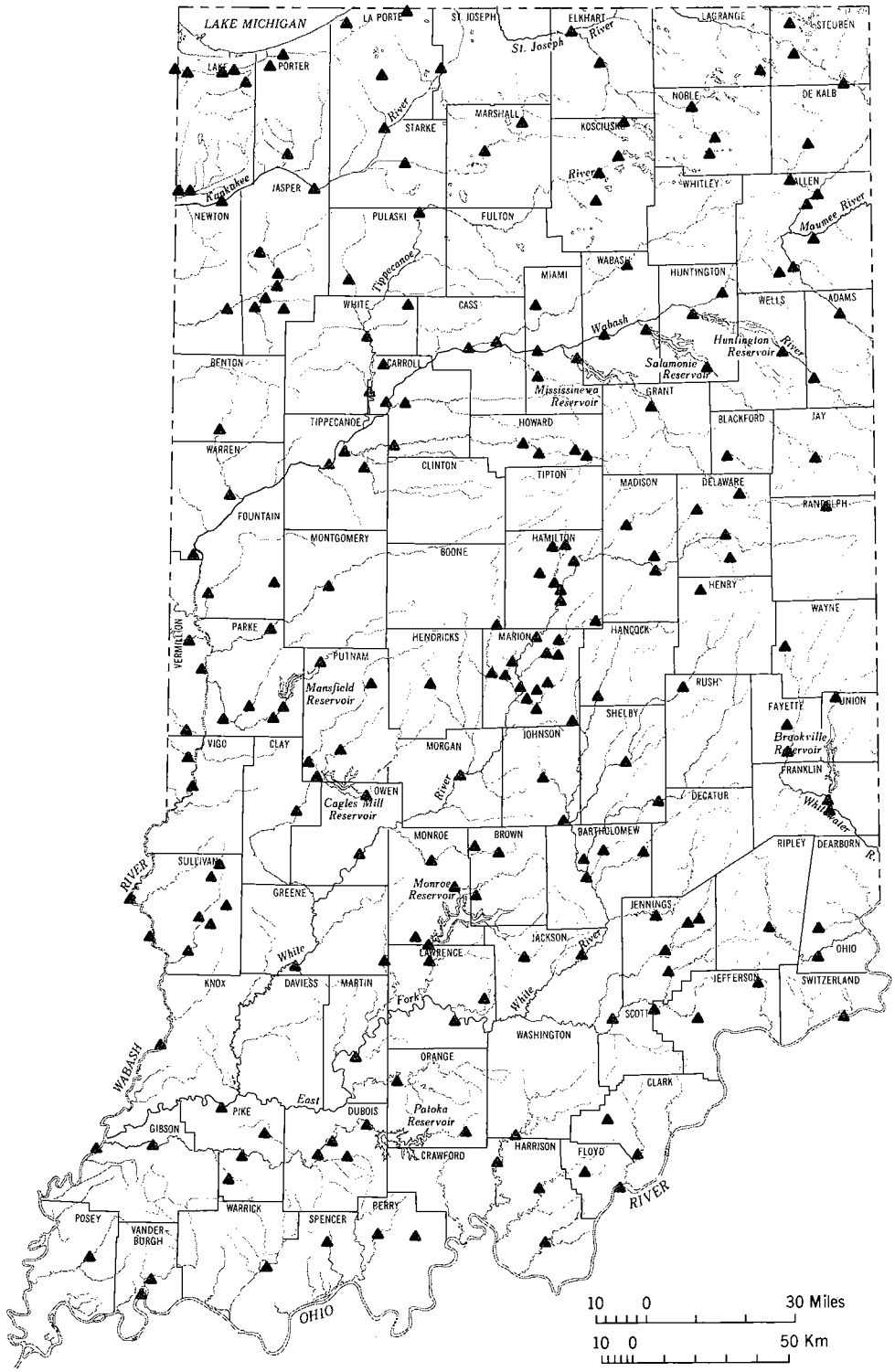


Figure 24
Map of Indiana showing the network of stream gaging stations.

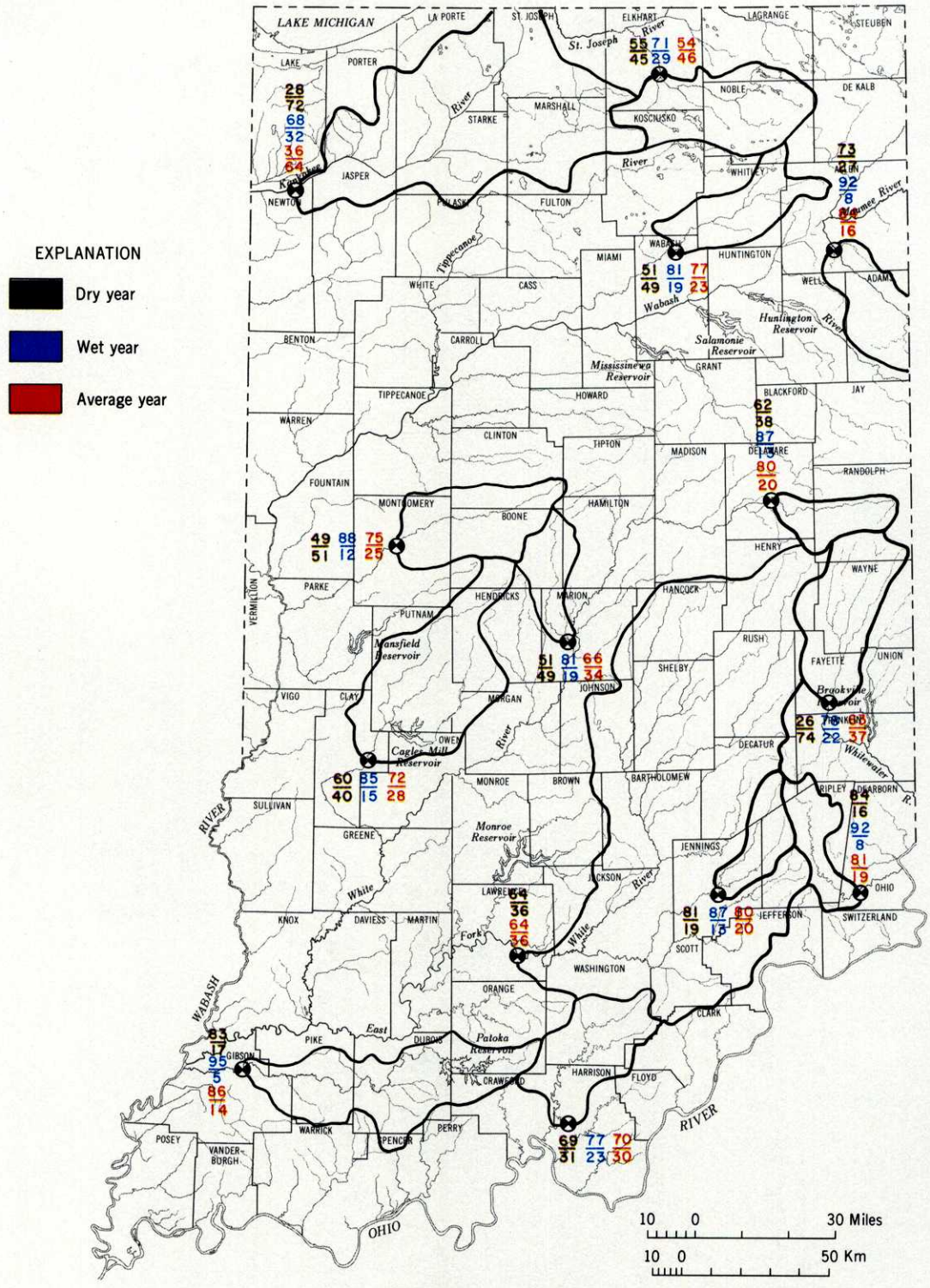


Figure 25

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.

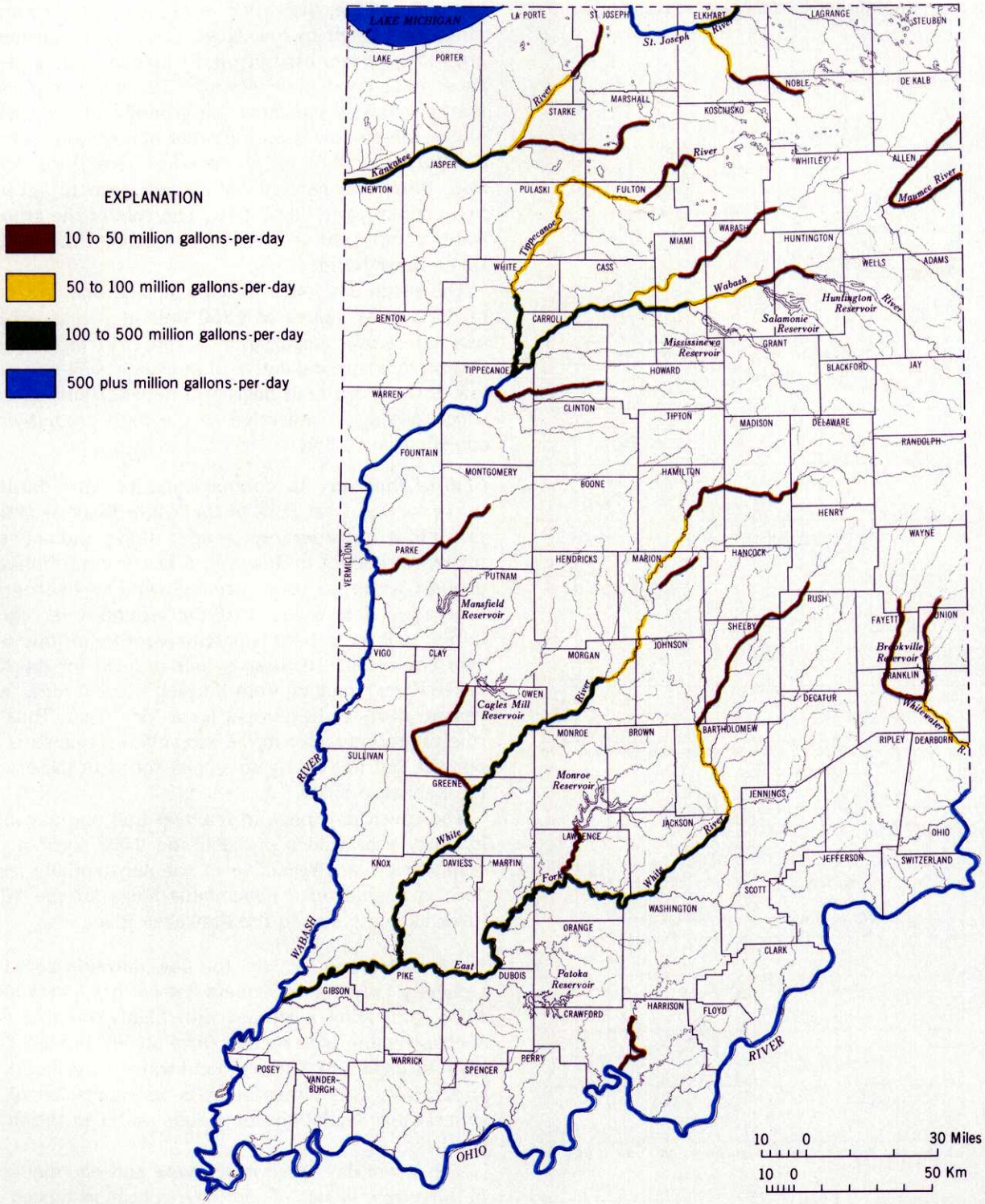


Figure 26
Map of Indiana showing the seven day, once in ten year low flows for selected streams in million-gallons-per-day.

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.

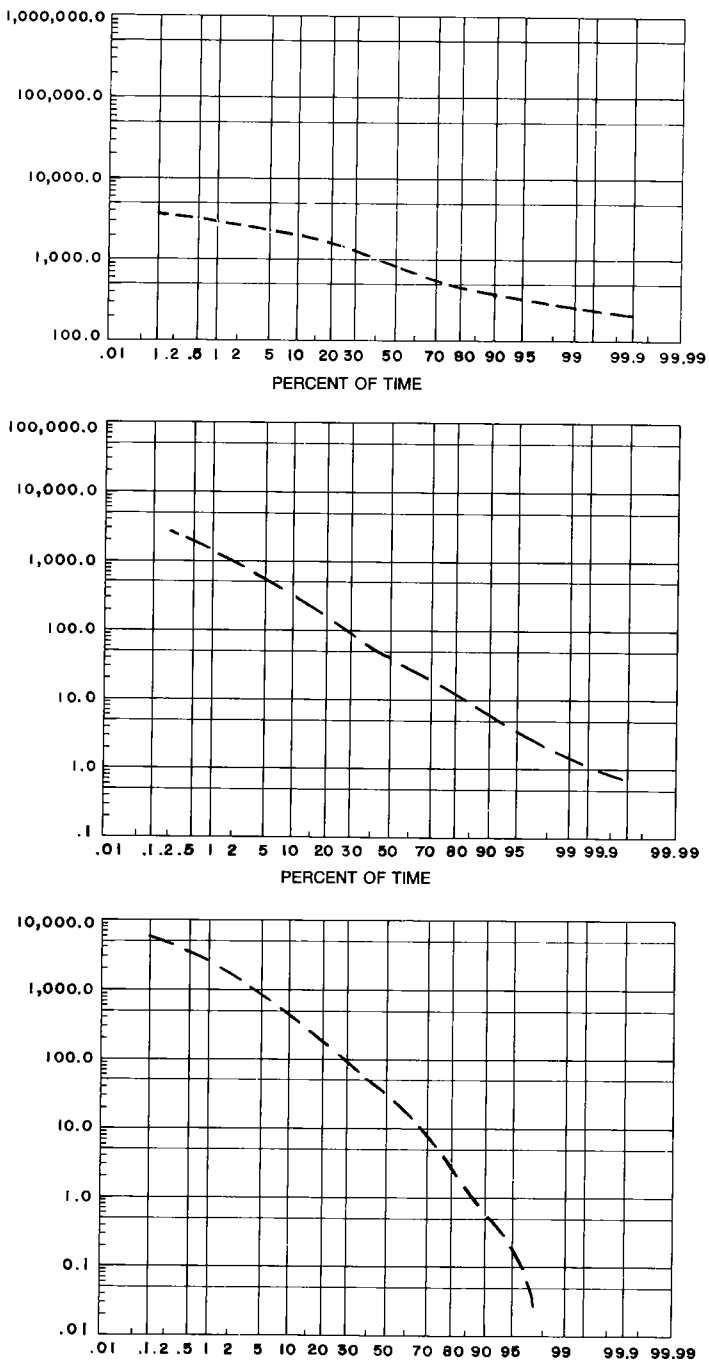


Figure 27

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.

Utilization of the Water Resource

As has been noted, water is one of the basic resources that is essential to life—not only that of man, but of the animal and plant communities as well. Its role is so pervasive that it is indeed difficult to visualize any phase of natural, human, social, or economic activity in which water is not utilized in some manner or degree. For the purposes of this report, water utilization is treated in two broad categories: instream uses and withdrawal uses.

Instream uses are defined as those that utilize water in place in streams, lakes, and reservoirs. Instream uses include navigation, hydroelectric power generation, waste-water assimilation, recreational boating, fish and wildlife habitat, swimming, and general environmental and aesthetic values. It should be noted that instream uses necessarily involve only the surface water component of the water resource, not ground water.

Withdrawal uses are defined as those uses that involve the physical removal of water from its ground or surface source. Withdrawal uses include both consumptive and nonconsumptive uses. Consumptive uses are those that, because of evaporation, transfer out of the basin of origin, incorporation into manufactured products, or other processes, preclude the return of some or all of the withdrawn water to its source. Nonconsumptive uses, as the term implies, are those in which the withdrawn water is returned to the supply system essentially undiminished in volume. Examples of withdrawal uses include municipal, industrial, and rural water supplies, irrigation, and the generation of energy.

INSTREAM USES

Fish and Wildlife

In addition to its obvious role in sustaining life, the water resource is vital to fish and wildlife with respect to the several habitats that are closely associated with surface water. These are described as the aquatic, riparian, and wetlands habitats, and each plays a special role.

The *aquatic habitat* is that provided by water itself, as found in streams, lakes, and reservoirs. It is obviously the essential habitat for fish and other aquatic life. The aquatic habitat also serves a vital role with respect to waterfowl and other bird and animal populations whose food supply is found in whole or in part in the aquatic environment.

The utility of the aquatic habitat is a function of both water quantity and quality. Both of these vital parameters are subject to considerable variability in nature and both may be, and frequently are, affected by human, social, and economic uses.

Traditionally, Indiana streams and lakes have supported populations of typical warm-water fishes, such as bass, blue gill, crappie, other sunfishes, catfish, and their food chain. In addition, other species, such as walleye, northern pike, striped bass, and muskellunge, have been introduced into selected streams or lakes. Trout are stocked in selected streams, primarily in northeastern Indiana. The Great Lakes states, including Indiana, have introduced several varieties of salmon into Lake Michigan, which has proven to be highly successful. In addition to the salmon, Lake

Michigan supports a variety of sport fishes, including yellow perch and several varieties of trout.

During 1975 approximately 670,000 fishing licenses were issued to fishermen between the age of 17 and 65. It is estimated that an additional 398,000 individuals younger than 17 and older than 65 are also active fishermen. A statewide survey indicated that the average fisherman made 32 fishing trips during 1975. Therefore, approximately 34,175,000 fishing trips were made by Indiana fishermen. If the average catch per fisherman per fishing trip was as low as four ounces, the total harvest of the Indiana fishery exceeded 8,500,000 pounds. In order to help meet this tremendous demand on the fisheries resource, the Department of Natural Resources annually conducts fish management on over 100 lakes and streams, including Lake Michigan.

Based upon a statewide survey, the projected demands on the fisheries resource for the years 1980, 1990, and 2000 is estimated at 41.0, 42.7, and 44.0 million fishing trips, respectively.

The *riparian habitat* is composed of vegetation which requires the availability of water that a streambank or lake shore can afford. These areas generally are associated with high species diversity with respect to both vegetation and wildlife. Not only are there more types of plants and animals associated with these areas but often they occur in larger numbers than found in the upland habitat types.

The *wetland habitat* is likewise inextricably associated with the water resource. Wetlands are commonly described as marshes, swamps, bogs, potholes, sloughs, and shallow ponds or lakes. In a more technical sense, wetlands are areas in which the water table is above or sufficiently near the ground surface with such regularity or proportion of time that soils and plants characteristic of an aquatic environment predominate. The soils are generally very high in organic content, resulting from the lush vegetation of those plant species adapted to growth in water or water-saturated conditions.

Wetlands are considered to be the most productive of the natural habitat types, both as to numbers and diversity of plant and animal life. They provide a nursery both for fish populations and for those smaller organisms that provide vital links in the food chain.

It has been estimated that over one million acres of wetlands in Indiana have been drained and devoted to other uses during the past century, a reduction of more than eighty percent of the original resource. Although the major draining of wetlands is no longer in progress, some surveys estimate that 300,000 acres are drained each year on a national basis, with Indiana sustaining a share of this loss.

As of 1977, it is estimated that there are approximately 200,000 acres of wetlands remaining in the state. These are located primarily in the northern two tiers of counties and in a narrow band along the Ohio River to the south, as shown on Figure 28. In most other areas of the state, wetlands exist as only small, widely scattered areas.

In general, about fifty percent of Indiana's wetlands are classified as the open-water type. They possess high fisheries value, but have the lowest value of any wetland group for wildlife. Shallow marshes, which account for another twenty percent of the wetlands, have generally low fisheries value, but possess the highest wildlife values.

The relative values of the other wetland types for fish and wildlife vary between these extremes. The approximate distribution of the other types is as follows: deep marshes, ten percent; shallow shrub swamps, fifteen percent; and deep shrub swamps, five percent. Two other types, bogs and wooded swamps, occur in Indiana but account for less than one percent of the total.

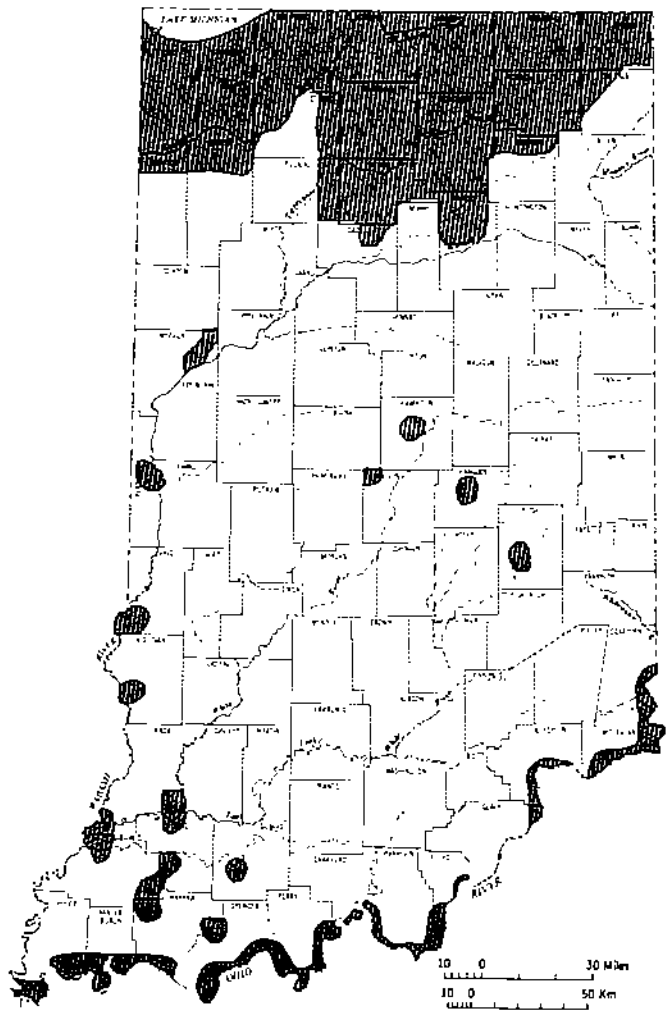


Figure 28
Map of Indiana showing the general distribution of wetlands.

Outdoor Recreation

The types of outdoor recreation under consideration are those that are essentially water-related. The major activities considered are boating, canoeing, waterskiing, swimming, ice-skating, and fishing.

The rivers, streams, and lakes of Indiana provide, or have the potential to provide, a substantial measure of water-related outdoor recreation opportunities. The "inland" waters — that is, those lakes, rivers, and streams exclusive of Lake Michigan and the Ohio River — suitable for one or more recreational activities total approximately 280,500 acres. The Indiana portion of Lake Michigan exceeds 154,000 acres and there is of course free access from Indiana waters to the remainder of this 14,272,000 acre lake. The Ohio River, in its 357 mile length of the southern boundary of the state, provides approximately 94,000 acres of interstate water. It should be noted that the approximate lower 200 miles of the Wabash River, extending from the Ohio River to a point about 14 miles downstream from Terre Haute, is also an interstate stream.

These approximate totals of surface-water acreage, while useful as a measure of overall gross supply, are by no means a definitive measure of resource availability for recreational purposes. These factors should be considered:

1. What are the legal rights of the public with respect to both access to and utilization of the water area?
2. The suitability of a particular water area for various recreational pursuits should be ascertained. For example, a stream may be suitable for fishing, but not power boating.
3. Lake Michigan, while affording a very large area which is physically and biologically capable of serving such pursuits as boating, fishing, and swimming, does pose serious problems with respect to public safety because of its size. Much of its water area is at relatively long distances from shore, harbors of safety for boaters are very limited and, of major importance, very rough water not only occurs frequently but may occur with very little advance warning.
4. The lower two hundred miles of the Wabash River are interstate waters between Indiana and Illinois and thereby subject to the jurisdiction of both states. There is reciprocity between the two states with respect to license for fishing and boating.
5. The Commonwealth of Kentucky claims that the entire Ohio River is within that state and thereby subject to its jurisdiction, including license and registration for fishing and boating on the river.
6. Finally, in considering the supply or availability of water for recreational purposes, travel time or distance for the participant must be considered.

The outdoor recreational activity needs for boating, canoeing, waterskiing, swimming, ice-skating, and fishing were generated by utilizing the statistical needs analysis developed for the *1979 Indiana Outdoor Recreation Plan*, as prepared by the Department of Natural Resources, Division of Outdoor Recreation.

A statewide summary of the supply and demand analysis for the six recreational activities is shown on Table 8 for the years 1980, 1990, and 2000. Particular attention is invited to the table footnotes and to the preceding discussions of the limitations of the analysis.

Table 8
The statewide outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	26	19.6 boats/acre/year[a]	341,250 acres[b]	100+	100+	100+
Waterskiing	9	34.4 skiers/acre/year[b]	109,650 acres[c]	100+	100+	100+
Canoeing	8	585 canoes/mile/year	2,300 miles	100+	100+	100+
Swimming	40	76,600 swimmers/acre/year	439 acres	96	89	82
Ice-Skating	8	6,678 skaters/acre/year	167 acres	60	58	55
Fishing	45	66 persons/acre/year[c]	434,750 acres[d]	71	68	64

This table is based upon the 1979 Indiana State Outdoor Recreation Plan.
[a]Includes 154,000 acres of Lake Michigan, 47,250 acres of the Ohio River, and 140,000 acres of inland waters.
[b]Includes 18,400 acres of Lake Michigan (30 square miles excluding 200 feet of shoreline), 47,250 acres of the Ohio River, and 44,000 acres of inland waters.
[c]Includes 154,000 acres of Lake Michigan, 47,250 acres of the Ohio River, and 233,500 acres of inland waters.

Indiana Natural, Scenic, and Recreational Rivers System The Natural, Scenic, and Recreational Rivers System Act enacted in 1973 establishes a procedure whereby certain rivers, largely in a natural condition, can be protected while not excessively limiting the use of other resources associated with the river.

As of 1979, the Blue River (from U.S. 150 in Fredricksburg downstream for 45.5 miles) and Cedar Creek (from river mile 13.7 to its confluence with the St. Joseph River) are components of the Indiana Natural Rivers System. Sugar Creek (from Darlington Covered Bridge to its confluence with the Wabash River) has not been included in the system but has been placed in a special protected status by the Natural Resources Commission. Figure 29 shows the location and status of those streams in the natural, scenic, and recreational river system.

Hydroelectric Power

Hydroelectric power generation is accomplished by utilizing the energy of falling water to drive hydraulic turbines connected to generators. The water energy available at a particular site, and hence the amount of electricity which may be generated, is a function of both the dependable flow of water and the "head" or differential in elevation above and below the turbines. This differential in elevation is most frequently provided by the construction of dams.

The five hydroelectric plants operating in Indiana in 1978 are shown on Figure 33 (page 61). The Indiana and Michigan Electric Company operates the Twin Branch Plant (Number 5) on the St. Joseph River in Mishawaka and the Elkhart Plant (Number 7) on the Elkhart River in Elkhart. Twin Branch has a capacity of 7.3 megawatts while Elkhart has a capacity of 3.4 megawatts. The Northern Indiana Public Service Company operates two hydroelectric plants on the Tippecanoe River in White County. These plants are known as the Norway (Number 9) and the Oakdale (Number 12) Plants with capacities of 6.7 and 11.0 megawatts, respectively. Public Service Indiana operates the largest hydroelectric plant in Indiana with a capacity of 81.0 megawatts. The Markland Plant (Number 27) is incorporated into the north end of the Markland Lock and Dam on the Ohio River.

The overall potential for additional hydroelectric power plants in Indiana is minimized by the low-flow characteristics of its streams and by generally flat topography. There is a potential for additional hydroelectric development at the Uniontown, Newburgh, and Cannelton Locks and Dams on the Ohio River. However, the plants at these sites would be located in Kentucky.

Commercial Navigation

The inland waterways of the United States are a key element in the economy of the interior. Indiana is served by both of the nation's major inland waterway systems, namely the Great Lakes–St. Lawrence System and the Ohio-Mississippi–Intercoastal Waterway System. Both systems provide Indiana industries and producers access to efficient, low cost transportation.

The Great Lakes Navigational System permits ocean-going cargo vessels to ascend the St. Lawrence River into Lake Ontario. Shipping then bypasses Niagara Falls through the Welland Canal into Lake Erie. Vessels can then pass into Lakes Huron and Michigan and through the locks at Sault St. Marie to Lake Superior. Although this system gives Indiana's Lake Michigan ports access to world trade routes, the greater part of traffic movement on the Upper Lakes (Superior, Huron, and Michigan) is between inland points.

The northwest Indiana steel complex was located largely to take advantage of water transportation and industrial water supply. Iron ore, now mostly in pellet form, moves from the western end of Lake Superior through the Soo locks into Lake Michigan and thence to the mills in northwest Indiana. This traffic movement is one of the most important in all of the Great Lakes. Other traffic moving through Indiana ports consists of coal, grain, and general overseas cargo.

In order to provide for the orderly growth of Indiana commerce and industry, the 1961 session of the General Assembly created the Indiana Port Commission. This commission was given the authority to construct and operate port facilities on Lake Michigan. That authority has subsequently been expanded to cover the Ohio River. The commission, with the cooperation of the U.S. Army Corps of Engineers, constructed the Port of Indiana-Burns Waterway Harbor at Portage, Indiana. This port became operational in 1970 and has since developed a reputation as one of the finest facilities on the Great Lakes. Other Indiana lake ports include Indiana Harbor, Buffington and Gary Harbors (which are privately owned and operated), and the harbor at Michigan City which now has only limited commercial traffic.

The Ohio River is the southern boundary of Indiana with about 357 miles of river frontage. This gives Indiana shippers access to a waterway reaching from above Pittsburgh on the east to Minneapolis by way of the Mississippi River on the north and to the Gulf of Mexico on the south. Access via the Illinois Waterway is available to Chicago and the Great Lakes, to Knoxville via the Tennessee River, to Tulsa via the Arkansas River and to the entire Gulf Coast of the United States via the Intercoastal Waterway. Improvements to

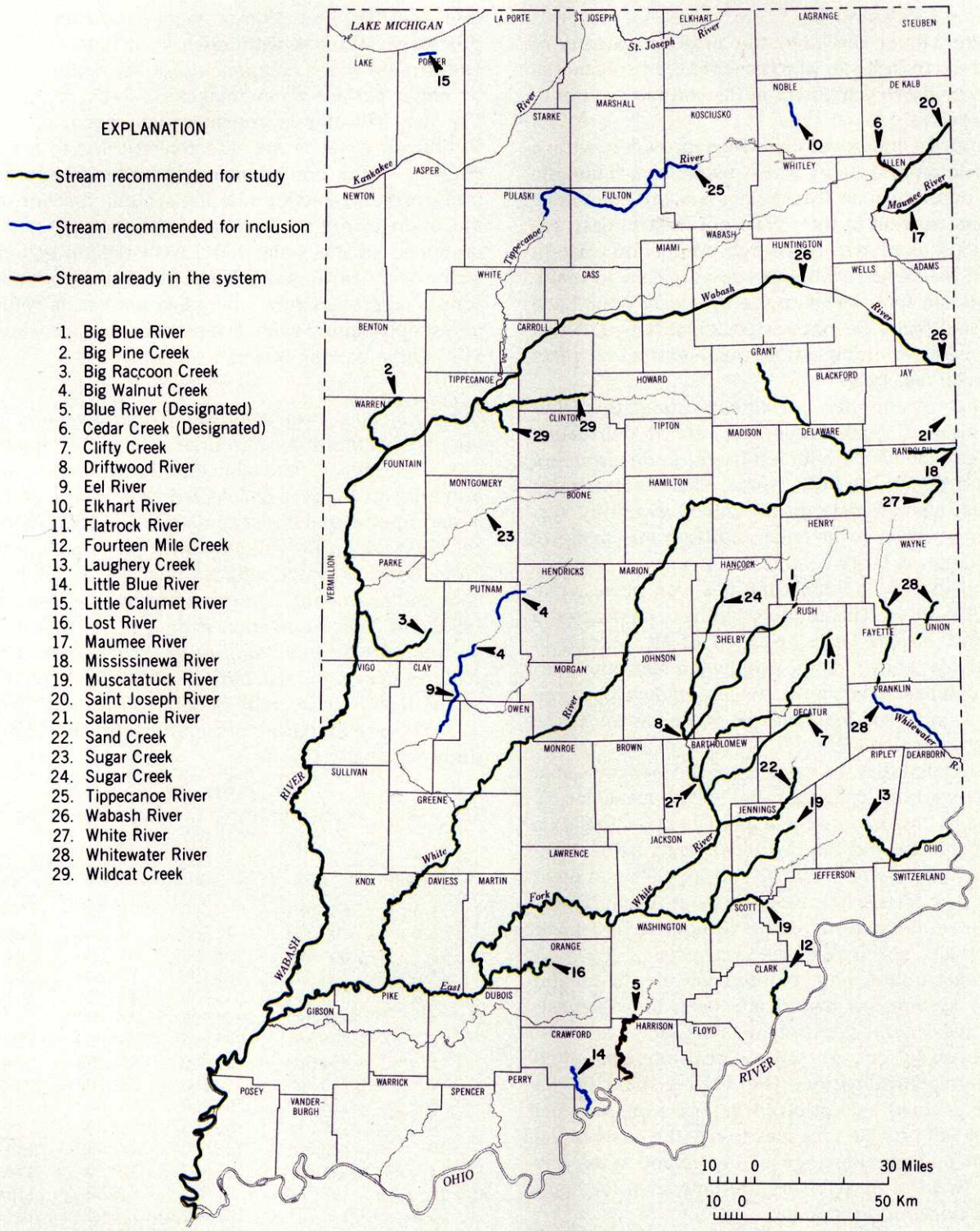


Figure 29
Map of Indiana showing the location and status of Indiana streams in the natural, scenic, and recreational river system.

navigation on the Ohio River were among the first internal transportation projects undertaken by the United States government.

The Ohio River provided the principal means of early access to Indiana, which accounts in substantial measure for the development of the state in a south to north direction.

The entire Ohio River has been provided with a series of locks and dams which maintain a minimum channel depth of nine feet. Navigation projects along the Indiana section of the river from west to east, are Smithland, Uniontown, Newburgh, Cannelton, MacAlpine, and Markland. Each consists of a dam to maintain minimum river levels in the upstream pool. Each project also has two locks, a principal lock 110 feet wide by 1,200 feet long and an auxiliary lock 110 feet wide by 600 feet long.

Principal commodity movements along the Ohio River consist of coal, crude and refined petroleum, aggregates, chemicals and fertilizers, grain, iron ore and iron products, and other ores. This list illustrates a common characteristic of the inland waterway system; that is, most of the traffic utilizing this mode of transportation is large volume, bulk cargo.

The Indiana Port Commission has also been active on the Ohio River. The commission has constructed a public port on the Ohio just east of Mt. Vernon in Posey County, known as the Southwind Maritime Center. The commission is in the process of developing an additional port near Jeffersonville to be known as the Clark Maritime Center.

It is estimated that the capacity of the Welland Canal (the bypass around Niagara Falls) will be exceeded by 1995. One of the locks on the upper Ohio (Gallipolis) is nearing capacity, and the two older dams below Indiana, Lock and Dam numbers 52 and 53, will soon be at capacity. The Mississippi River locks at Alton, Illinois (just below the mouth of the Illinois River) have reached their capacity and are congested.

The construction and maintenance of the inland waterway system has historically been the responsibility of the federal government. Port facilities, however, are usually constructed by local interests, often with federal participation. The 1978 session of the Congress enacted legislation to impose a marine fuel tax which will provide revenues to pay the costs of the operation and maintenance of the inland waterway systems. None of these rivers are now used for commercial navigation in Indiana.

WATER WITHDRAWALS

In addition to the instream uses of the water resource, man has a variety of needs for water. These water needs include public water supplies, industrial manufacturing processes, rural water supplies, irrigation, and the production of energy and energy-related processes. Water is withdrawn from both the surface and ground-water components of the water resource by either surface-water intakes or wells. A consumptive use of water is considered to occur when the withdrawn water is not directly returned to a supply source. Water consumption includes evaporation, transpiration, injection into the ground, transfer out of the basin of origin, and the water incorporated into products. Of the estimated 13,840 million gallons of water withdrawn daily from the Indiana water resource, approximately ninety-five percent is returned to a supply source while five percent, or approximately 615 million gallons of water, is consumed.

Estimating and Projecting the Withdrawal and Consumption of the Water Resource Current estimates of water withdrawal and consumption rates are based primarily on a survey of selected water consumers and in part upon population estimates, economic statistics, and information provided by local and state agencies. Projections of water withdrawals are based in part upon Indiana population estimates for the years 1980, 1990, and 2000. Population estimates are based upon the *Indiana County Population Projections, 1975–2000,* prepared for the Indiana State Board of Health by the Indiana University School of Business. Table 9 lists these population projections by the eighteen study regions.

Table 9

The Indiana population estimates by the eighteen study regions.

Region	*1975*	*1980*	*1990*	*2000*
1-A	643,084	666,900	719,500	767,000
1-B	69,373	76,500	87,600	98,200
2	568,407	598,300	647,000	694,100
3-A	138,497	151,100	174,500	200,300
3-B	373,164	395,100	445,500	493,800
4	254,499	264,500	280,000	292,200
5	236,661	249,000	268,000	283,300
6	474,589	489,800	512,800	527,000
7	213,940	219,700	221,200	221,900
8	1,138,753	1,208,800	1,364,900	1,531,100
9	149,971	156,100	168,300	170,700
10	102,214	108,500	121,700	133,000
11	148,107	155,300	173,700	192,400
12	92,753	97,300	106,800	116,300
13-A	145,721	152,400	159,000	164,000
13-B	263,206	270,300	285,100	303,000
14	202,202	217,600	249,500	281,600
15	94,057	98,500	105,700	112,300
Total	5,309,198	5,575,700	6,090,800	6,582,400

From *Indiana County Population Projections 1975–2000,* State Board of Health and School of Business, Indiana University, 1976.

Projections of water withdrawals and consumption include an analysis of past trends and growth patterns, as well as increased conservation factors. The methods of making the projections for public water supplies, industrial self-supplied water, rural water, irrigation, energy, and energy-related processes are presented in the Appendixes. All water withdrawal and consumption rates and projections are general estimates and provide a useful water resource planning and management tool, but are not intended for design purposes.

Public Water Supply

Any public utility which distributes water for sale to customers is defined as a public water supply. In general, a public water supply utility consists of three components: the source and intake of water, the water treatment facility, and the water distribution system.

The source of the public water supply is dependent upon the location and availability of the water resource. Approximately fifty-one percent of the water distributed by the public water supply utilities is derived from a surface-water source: from streams, reservoirs, and lakes, particularly Lake Michigan. The remaining forty-nine percent of the water supplied by public utilities is withdrawn from ground water. The location and source for public water supply systems are shown in Figure 30.

In general, the source of water for public utilities depends upon local geological and hydrological conditions. As indicated in the analysis of the statewide distribution of the water resource, the availability of ground water is greater in the northern and central portions of Indiana than in the southern part of the state. Usually, only those utilities with limited access to adequate quantities of ground water rely upon surface water sources. The four largest utilities in the state, serving the Indianapolis, Gary-Hobart, Fort Wayne, and Evansville areas, obtain at least ninety-five percent of their supply of water from surface sources.

Utilization of a surface-water source, particularly by large users or in areas of poor ground-water availability, will often require the construction of dams and reservoirs to assure a dependable supply of raw water.

The water treatment component of the public water supply system is designed to ensure that the water is safe for human consumption. Treatment of surface water is necessary to ensure adequate water quality standards as established by the Indiana State Board of Health and the United States Environmental Protection Agency. As a result of the Safe Drinking Water Act (P.L. 93-523) the Environmental Protection Agency has established federal standards for bacteriological, physical, chemical, and radiological quality of water supplied by a public water utility. In addition, the Indiana Environmental Management Board is legally responsible for enforcing standards for maintaining the quality of drinking water, although the State Board of Health monitors the water quality of these systems.

The three types of public supply systems in Indiana are the municipal, rural water, and subdivision utility systems. The municipal utility generally serves an incorporated city or town, but may serve developments outside city boundaries, and sometimes supplies water to other public water systems.

The rural public water supply systems are typically located in rural areas of southern Indiana where the water resource is limited as shown in Figure 31. These systems are usually formed by local residents after a period of time of dealing with undependable wells or cisterns. Many of these systems are financed through loans and grants from the Farmer's Home Administration. Unlike the municipal systems, the rural systems provide water only for household purposes. Due to a small capacity distribution system and higher rates, the commercial, industrial, and agricultural use of water through the rural systems is limited.

The third type of public water supply is the subdivision utility. These utilities are designed to serve only the residences within a single development. Subdivision systems have been developed for mobile home parks, isolated subdivisions, or industrial parks not having access to another water supply.

The customers of public water utilities may include anyone having access to the water mains, such as homes, apartments, various public and private institutions, commercial enterprises and industry. In 1975, sixty-eight percent or approximately 3,631,800 of Indiana's residents were supplied through a public water utility. In addition about eighty-seven percent of Indiana's industries, excluding the energy industry, were at least partially supplied by a public water utility. The water supplied to these industries represents seven percent of the total water used by Indiana industries. However, if the water withdrawals of the primary metal industry located in Lake and Porter Counties are excluded, forty-one percent of the water used by all other industries in Indiana is supplied by public utilities. Industrial customers account for less than one percent of total public water supplied, while they account for about forty percent of the total water supplied by public water utilities.

Projections Before projections of public water supplies may be made, it is necessary to determine the relationship between public water supplies and the self-supplied systems. In most Indiana counties there has been very little change over the past two decades

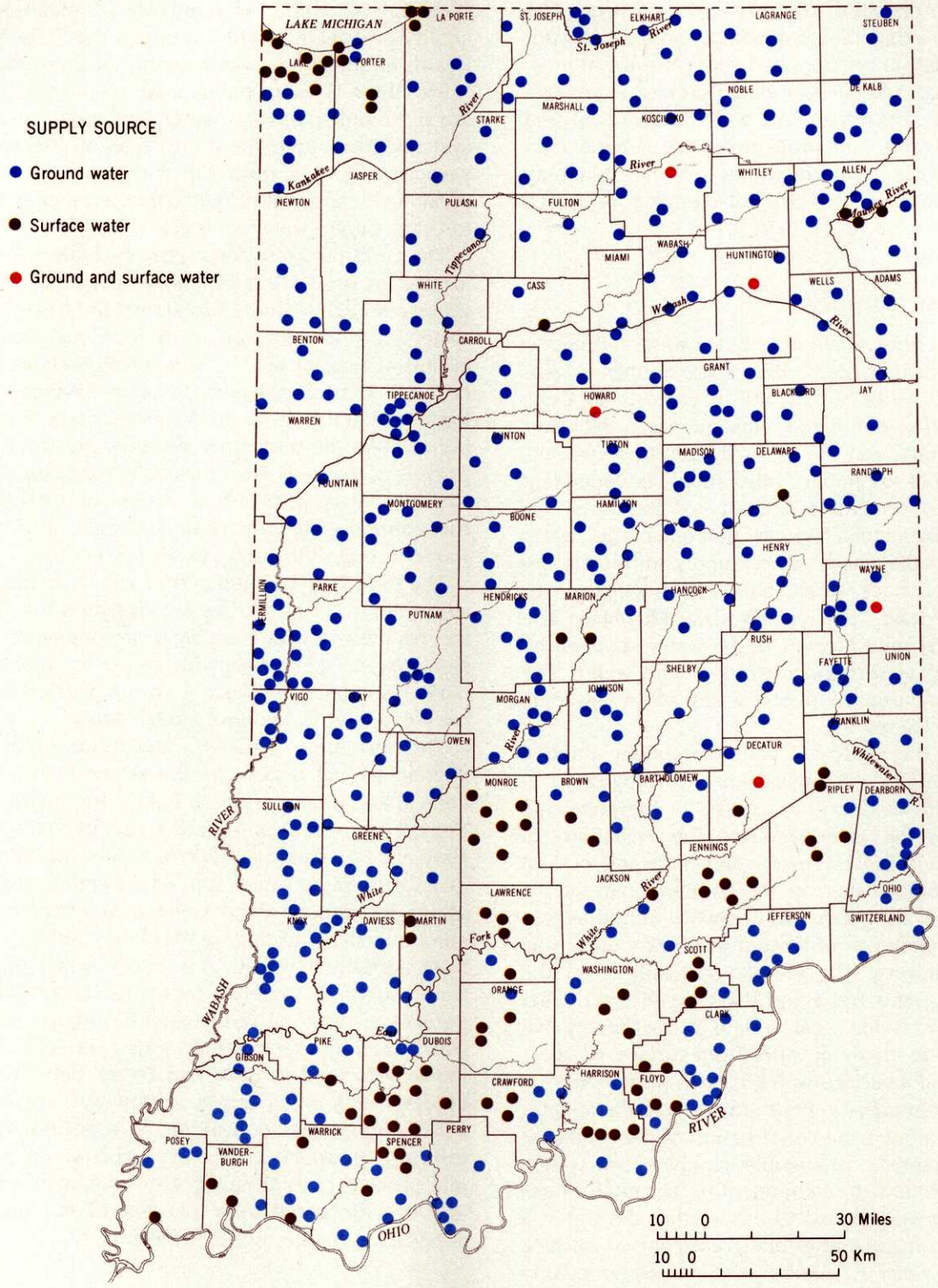


Figure 30
Map of Indiana showing the general location and source of public water supply systems in Indiana.

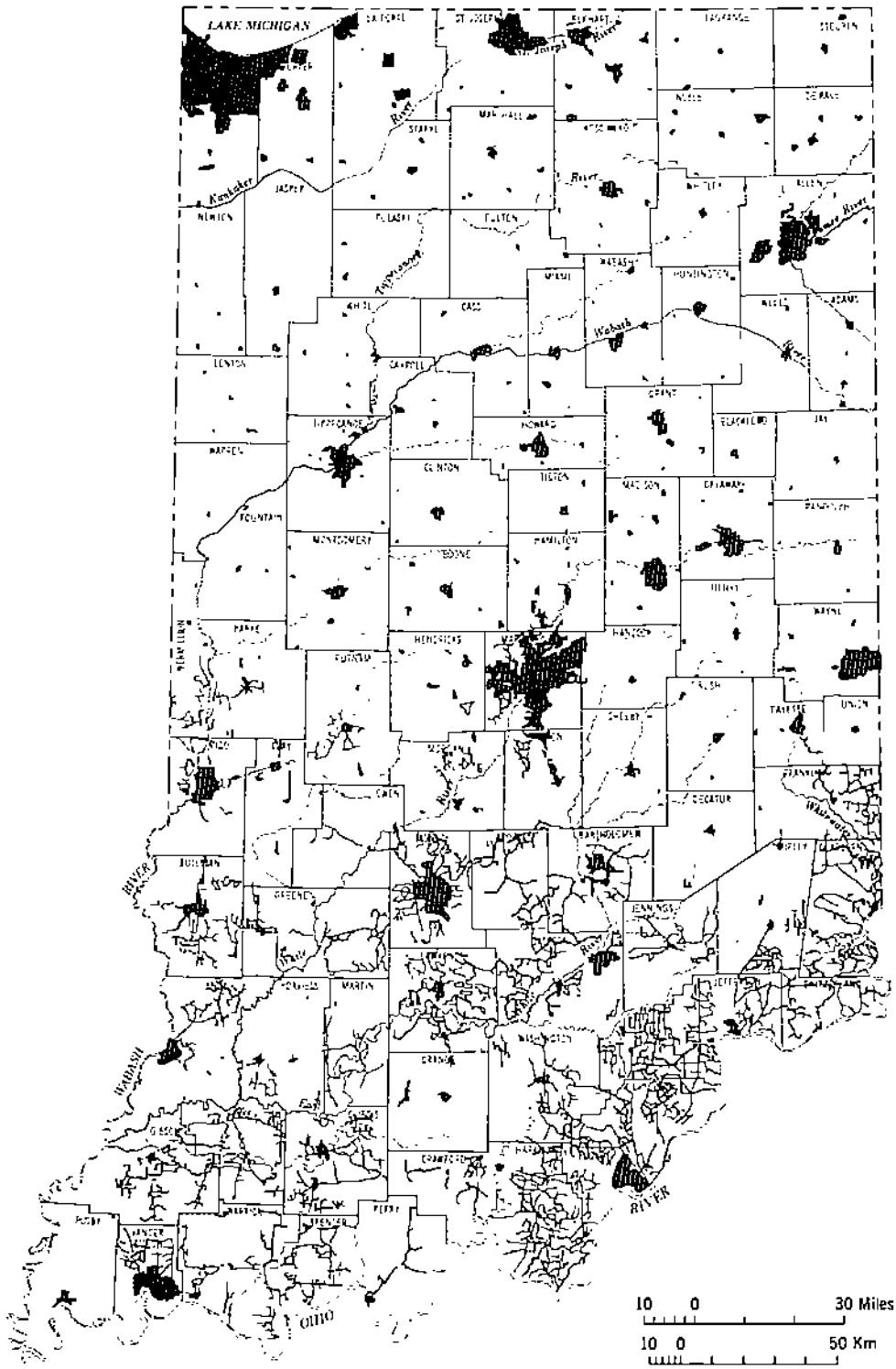


Figure 31
Map of Indiana showing the general location and extent of rural water supply systems.

in the proportion of the county population serviced by public water supplies versus self-supplied sources.

The water supply systems of seventeen representative counties were analyzed to predict the future proportion of Indiana citizens who will derive their water from self-supplied sources or from public water supplies. The following trends are expected to occur through the year 2000: (1) In the two large urban counties, Marion and Lake, there have been significant additions to the number of customers on public water systems, but the overall percentage of county population served has remained fairly stable. (2) There are a number of counties adjacent to major urban areas that are now undergoing rapid, suburban-type growth. Examples would be Porter, Hamilton, and Warrick Counties. In these counties, the percent of the population served by public water utilities is increasing rapidly. (3) There are a number of slower growing counties in southern Indiana with poor ground-water resources. In these counties there has been a rapid growth of rural water systems since about 1965. Consequently, there has been a rapid growth in the percent of the county population served by a water utility. This trend is expected to continue until approximately eighty to ninety percent of the county is served. (4) There are a number of counties in the north-central and northeastern parts of Indiana with abundant ground-water resources. These ground-water resources are so relatively abundant that there are a number of fair-sized towns which have no public water systems at all, and all water service is provided through individual wells. In these areas, there seems to be a modest decline in the overall percent of the county population served by a water utility.

The water withdrawal by public water utilities, from both the surface and ground-water resource, is projected to increase from approximately 554 million-gallons-per-day in 1977 to approximately 758 million-gallons-per-day by the year 2000, as indicated in Table 10. This represents an increase in water withdrawals of approximately 204 million-gallons-per-day over the next twenty-five years.

Table 10
Estimates of water withdrawals and water consumption for Indiana public water supplies.

Year	*Population Served*	*Million-Gallons-Per-Day*	
		Water Withdrawals	*Water Consumed*
1977	3,631,820	554	69
1980	3,800,700	578	72
1990	4,153,500	670	84
2000	4,500,000	758	96

The proportion of the total population deriving its water supply from public utilities should remain relatively constant at sixty-eight percent. The method of making public water supply projections is presented in Appendix One.

The majority of the water that is distributed through the public water supply systems is returned to a source of supply, generally through sewer systems and waste water treatment facilities. The water that is not returned to a source of supply is defined as "consumed." The rate of water consumption supplied through the public water utilities is projected to increase from approximately 69 million-gallons-per-day in 1977 to approximately 96 million-gallons-per-day by the year 2000.

There are a number of trends in America today that may affect these water withdrawal and consumption projections. For example, water has been regarded in the past as a more or less "free" commodity. That is, the cost is relatively minor as to not substantially affect the overall use. As standards of treatment become more rigorous, the cost of water will increase. The development of new sources of supply to meet increased demand may also increase the cost. These increased costs will be reflected in the consumer's bill. The higher utility costs may induce both domestic and industrial customers to conserve water, thereby decreasing demand.

Industrial Water Supply

Approximately 8,300 manufacturing establishments operate in Indiana, employing over 677,000 workers. According to the U.S. Department of Commerce (the *1976 Annual Survey of Manufactures*) the electric, electronic machinery, electrical equipment and supplies, primary metal products, transportation equipment, machinery except electrical, and fabricated metal products industries account for sixty-four percent of total employment of Indiana manufacturing establishments. The primary metal products, instruments and related products, electrical equipment and supplies, machinery except electrical and fabricated metal product industries account for sixty-eight percent of the Indiana manufacturing payroll.

Industries require the use of process water, cooling and condensing water, boiler feed water, and sanitary water. Process water, the most typical industrial use of water, comes into direct contact with the final product or materials during the manufacturing process. Cooling and condensing water is the largest single category of industrial water use. Boiler feed water is a major industrial water use to develop steam for various processes. Sanitary water is used for maintenance, health, and the general comfort of industry employees.

Industrial water intake is composed of water derived from public water supplies or from self-supplied industrial water withdrawals. Total industrial water intake in 1977 approached 3,720 million-gallons-per-day. Of this statewide industrial water use, approximately ninety-three percent was self supplied, while the remaining seven percent of industrial water use was supplied by public utilities.

The primary metal industries, located within one of the world's largest industrial centers along the Lake Michigan shoreline of Lake and Porter Counties (Region One-A), constitute over seventy-seven percent of all industrial self-supplied water withdrawals in Indiana. Excluding the Lake Michigan industrial complex, the state's industries withdrew 602 million-gallons-per-day of self-supplied water in 1977.

The significant statewide, self-supplied industrial water intake by industry group, is listed in Table 11. Of the 3,457 million gallons self-supplied by industry, approximately four percent is consumed.

Table 11
Self-supplied water withdrawals by industry.

Industry	*Million-Gallons-Per-Day*
Primary metal products	2,913
Petroleum refining and related products	213
Chemicals and allied products	96
Rubber and miscellaneous rubber products	30
Food and kindred products	56
Fabricated metal products	47
Transportation equipment	42
Electrical machinery, equipment and supplies	36
Machinery, except electrical	19
Other	5
Total	3,457

Projections Projections of industrial, self-supplied withdrawals and consumption were based upon a number of factors including current water use, projected population growth, projected industrial growth, and improvement in water use conservation techniques. The method of measuring current and projecting future industrial self-supplied uses is detailed in Appendix Two. Table 12 indicates the current and projected uses by industrial self-supplied systems between 1977 and 2000.

The 1977 self-supplied industrial withdrawals and the projected water withdrawals indicate that no major change in the rate of withdrawals is to be expected, although water consumption is projected to increase fifty-seven percent by the year 2000. Projected industrial self-supplied water withdrawals are expected to remain at current levels, even though Indiana industrial growth is estimated to increase by four to five percent each year. The difference between the projected water withdrawals and projected industrial growth rates is expected to be met by increasing water use efficiency and conservation practices.

Table 12
Current and projected self-supplied water withdrawals and consumption.

Year	*Million-Gallons-Per-Day*	
	Withdrawn	*Consumed*
1977	3,457	147
1980	3,286	155
1990	3,317	202
2000	3,430	257

Rural Water

Water used for livestock and residential purposes, and not supplied by a public water utility, constitutes a rural water use. Livestock includes animals such as hogs, dairy cattle, beef cattle, sheep, chickens, and turkeys. The current use of water was estimated by the population of livestock by class together with residential uses of water. The methodology for estimating current and projected rural water use through the year 2000 is included in Appendix Three. Table 13 indicates the current and projected rural water use in Indiana.

Table 13
Current and projected rural water use.

Year	*Million-Gallons-Per-Day*		
	Livestock	*Residential*	*Total*
1977	43	104	147
1980	44	111	155
1990	48	134	182
2000	53	156	209

In 1977, rural water use was estimated at approximately 147 million-gallons-per-day, with residential use constituting the largest portion at 104 million-gallons-per-day. The rural residential use of water is projected to increase by forty-four percent, while the livestock use many increase by twenty-three percent by the year 2000.

Irrigation

Irrigation is a seasonal water use, normally beginning in June with peak application rates during the months of July and August. During the season, irrigation water represents a significant portion of Indiana's total water withdrawal. Because irrigation water is intended to replace water transpired by the treated crop,

it is considered a total consumptive use. Irrigation water use will vary from year to year depending upon the amount and distribution of rainfall during the growing season. Above-normal rainfall will decrease the need for irrigation while below-normal rainfall will increase that need. Irrigation in Indiana is and will no doubt continue to be practiced as a supplement to seasonal precipitation, as opposed to the arid West where irrigation may be the major source of supply.

The purpose of irrigation is to increase crop yields by replacing water in the root zone. In general, it is those coarser-grained, reasonably well drained soils that are the prime candidates for the practice of irrigation. Figure 32 indicates the location and extent of those Indiana soil associations that appear to possess an economic potential for irrigation. Those soil associations with a *very high* rating are expected to respond yearly to irrigation. If crops respond favorably every three to four years out of five years the irrigation potential is *high*. However if crops respond to irrigation one to two years in five years the irrigation potential is *medium*. A *low* irrigation potential indicates little or no profitable response by crops to irrigation.

A soil association is a landscape that has a distinct pattern of soils. These associations are commonly composed of from two to four major soils plus a few minor soils. Indiana has been subdivided into fifty-five state soil associations. Some soil associations, identified as potentially irrigable may contain individual soils with no economic potential for irrigation.

Projections An extensive survey made in 1978 indicated that 64,600 acres were irrigated in 1977. It is projected that an estimated 157,300 acres may be irrigated by the year 2000. However, the total of Indiana soil associations having economic potential for irrigation exceeds 838,000 acres. Table 14 indicates current and projected agricultural irrigation water withdrawals through the year 2000.

Table 14
The 1977 and projected water withdrawals for agricultural croplands during wet, average, and dry irrigation seasons.

Year	*Million-Gallons-Per-Day*		
	Wet Year	*Average Year*	*Dry Year*
1977	135	170	227
1980	161	202	269
1990	248	309	411
2000	335	416	552

The range of water withdrawals represents estimated irrigation during wet, average, and dry years, depending upon the amount of precipitation during the growing season. Golf course irrigation accounted for an additional water withdrawal of approximately 27 million-gallons-per-day in 1977. Projected golf course irrigation by 2000 may approach 36 million-gallons-per-day.

The source of irrigation water is dependent upon the water availability in the region. Table 15 indicates current and projected ground-water withdrawals for irrigation on a statewide basis. The difference between ground-water withdrawal and total water withdrawal, as indicated on Table 14 represents the surface-water withdrawal for irrigation. The methodology for making water withdrawal projections for irrigation purposes is shown in Appendix Four.

Table 15
Current and projected ground-water withdrawals for the irrigation of croplands during wet, average, and dry irrigation seasons.

Year	*Million-Gallons-Per-Day*		
	Wet Year	*Average Year*	*Dry Year*
1977	67	81	107
1980	87	106	141
1990	153	189	251
2000	218	272	361

Energy Production

The production of energy, both directly through the generation of electric power and indirectly through the extraction of coal, oil, and gas places a significant demand on Indiana's water resource. Ninety-nine percent of the installed electric generating capacity in Indiana consists of coal-fired boilers providing steam to turbines coupled to generators. This process involves substantial amounts of water for cooling and is the largest single category of water use in Indiana.

Indiana's coal production amounted to about 24 million tons in 1977. The coal reserves are estimated at thirty-three billion tons. The extraction of coal requires water for coal washing, dust control, and maintenance of surface, coal mining operations.

Oil occurs in various geological formations in the state at depths ranging between a few hundred to over three thousand feet. Oil production in 1977 amounted to 5,314,470 barrels, and commercial gas production was 183 million cubic feet. Water is used in the production of oil through the process of water flooding, whereby water is pumped under pressure into the oil bearing formations resulting in substantially greater recovery of oil. Such water flooding, or secondary recovery, operations accounted for approximately forty-five percent of total production in 1977.

The major uses of water associated with energy production are electrical power generation, coal production, and oil recovery.

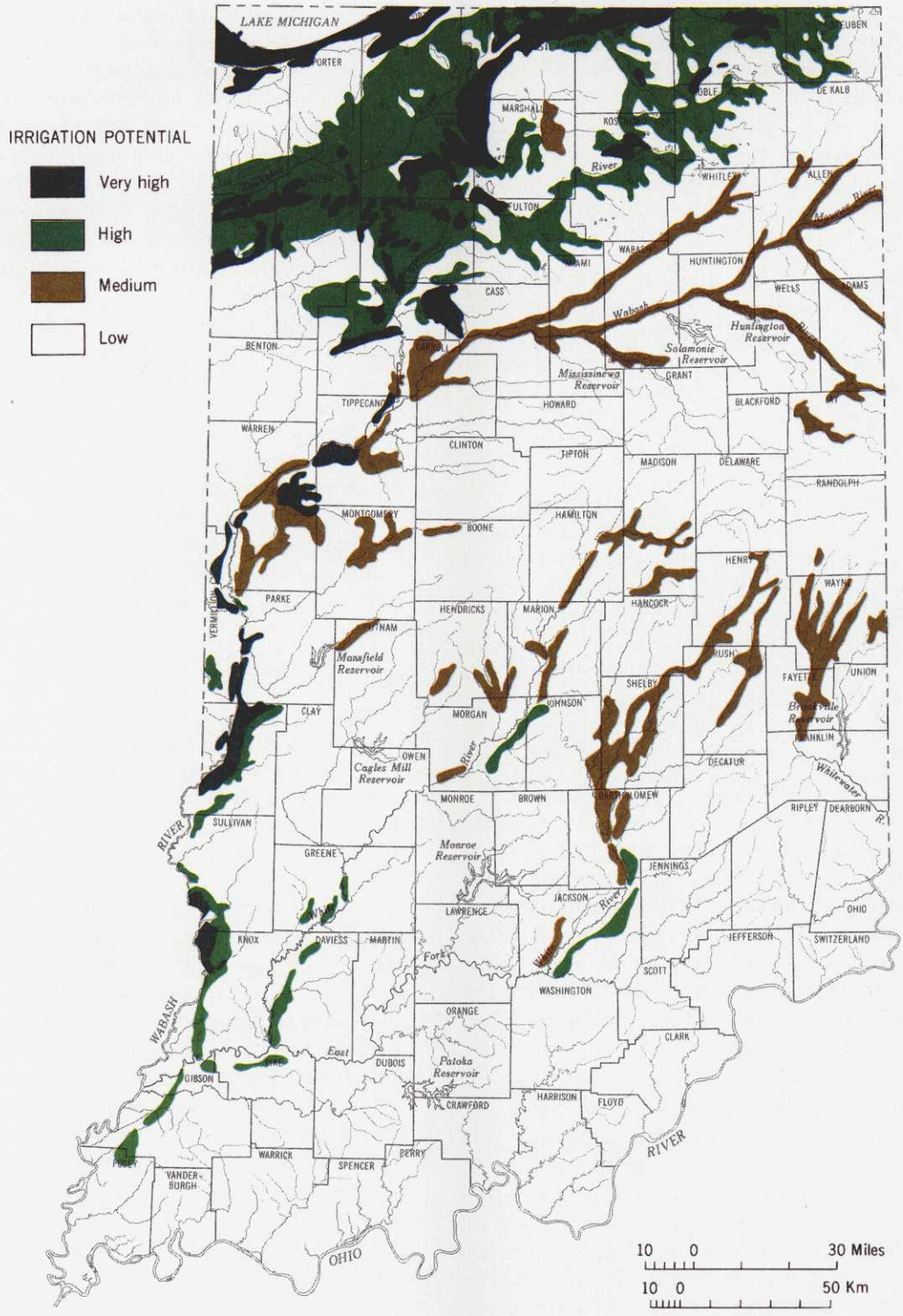


Figure 32
Map of Indiana showing the general location of soil associations with an economic potential for irrigation.

Electrical Power Generation There are three methods used to generate electrical power in Indiana: hydroelectric, internal combustion, and coal-fired. In 1976, less than one percent of electrical energy was generated by hydroelectric and internal combustion generating plants.

Hydroelectric power generation as discussed previously under "Instream Uses" does not constitute a consumptive use of water. Internal combustion generating facilities require only modest amounts of water.

Approximately ninety-nine percent of all electricity produced in 1977 was by coal-fired, steam generating plants. These coal-fired plants require substantial amounts of water. The coal-fired, steam generation process involves super-heating water to steam and passing the steam under high pressure to the steam turbines. Temperatures as high as 1,050 degrees Fahrenheit and pressures as high as 3,500 pounds per-square-inch are common in modern plants. The super-heated and pressurized steam is passed through a series of turbines, or large rotors, with affixed blades which in turn drive the electrical generators. A substantial amount of water is required to cool and condense the turbine exhaust steam back into water. As the once superheated steam is condensed back into water, it yields a significant quantity of heat. It is this heat which is removed by the cooling water. The common methods of removing this heat are once-through cooling, cooling lakes, and cooling towers.

The once-through cooling method involves withdrawing water from a river or stream and circulating this water through the condensers. The cooling water, which is heated in the process, is discharged back into the parent stream, with temperatures normally elevated from 10 to 15 degrees Fahrenheit. Small quantities of water are consumed in the process. The once-through cooling method is limited to those power plants located on or near streams with high, sustained flows.

The cooling lake method is similar to the once-through method except that water is withdrawn and returned to a lake rather than a surface stream. In order to utilize this method, the utility may create a lake by damming an existing stream or by creating an off-stream lake within containing dikes or levees. Water is circulated across the condensers in the same manner as the once-through method. The water on the surface of the lake is cooled by natural processes, giving up its heat to the atmosphere. This method has an advantage over the once-through procedure in that there are no adverse thermal impacts on streams in the area. Cooling lakes require makeup water to replace that lost by both natural and induced evaporation and hence have a much greater consumptive use of water than the once-through method.

Cooling towers are another method of dispersing the heat associated with steam turbines. In evaporative cooling towers, the warm water from the condenser is passed through the tower where it is exposed to a draft of air and the temperature is lowered, principally by the process of evaporation. The cooled water is then recirculated through the condenser. Because the cooling process is dependent upon evaporation, the water consumption rates are highest for the cooling tower method. Evaporation accounts for approximately eighty-five percent of the water consumed, with additional losses resulting from spray and the periodic flushing of the cooling towers.

The majority of Indiana's generating capacity is represented by thirty-seven plants owned by eight utilities and five municipalities. Eighty-one percent of Indiana's electrical generator capacity is operated by five major utilities: Public Service Indiana, Indiana and Michigan Electric Company, Northern Indiana Public Service Company, Indianapolis Power and Light Company, and Southern Indiana Gas and Electric Company. The service area and type of generating facility operated by each of these utilities is shown in Figure 33.

Other companies with significant generating capacity are: Commonwealth Edison Company, Indiana-Kentucky Electric Corporation and the Hoosier Energy Division of Indiana Statewide Rural Electric Cooperative, Inc. Commonwealth Edison operates the State Line plant in the extreme northwest tip of the State of Indiana. All power generated by this utility is utilized in Illinois. The Indiana-Kentucky Electric Corporation operates the Clifty Creek Plant at Madison. Power generated by this facility is used in an atomic energy processing facility located in Pike County, Ohio. The Hoosier Energy plant is used to supply part of the power needs of seventeen of the forty-two Indiana Rural Electric Cooperatives. In addition, there are five municipal plants utilizing coal-fired boilers with plant capacities ranging from 14.5 to 93 megawatts (mw).

The water use figures, shown in Table 16, represent the quantity, in million-gallons-per-day, for water withdrawals and water consumption for each major electrical generating station in Indiana based upon data provided by the electric utilities. The identification numbers of the generating stations in Table 16 correspond to the same numbers on Figure 33.

Projections The unprecedented growth of American industry, commerce, and standard of living which commenced in the middle of the nineteenth century is based upon liberal use of abundant sources of energy. For years, energy sources were considered to be inexhaustible. In the 1970s, the general public became

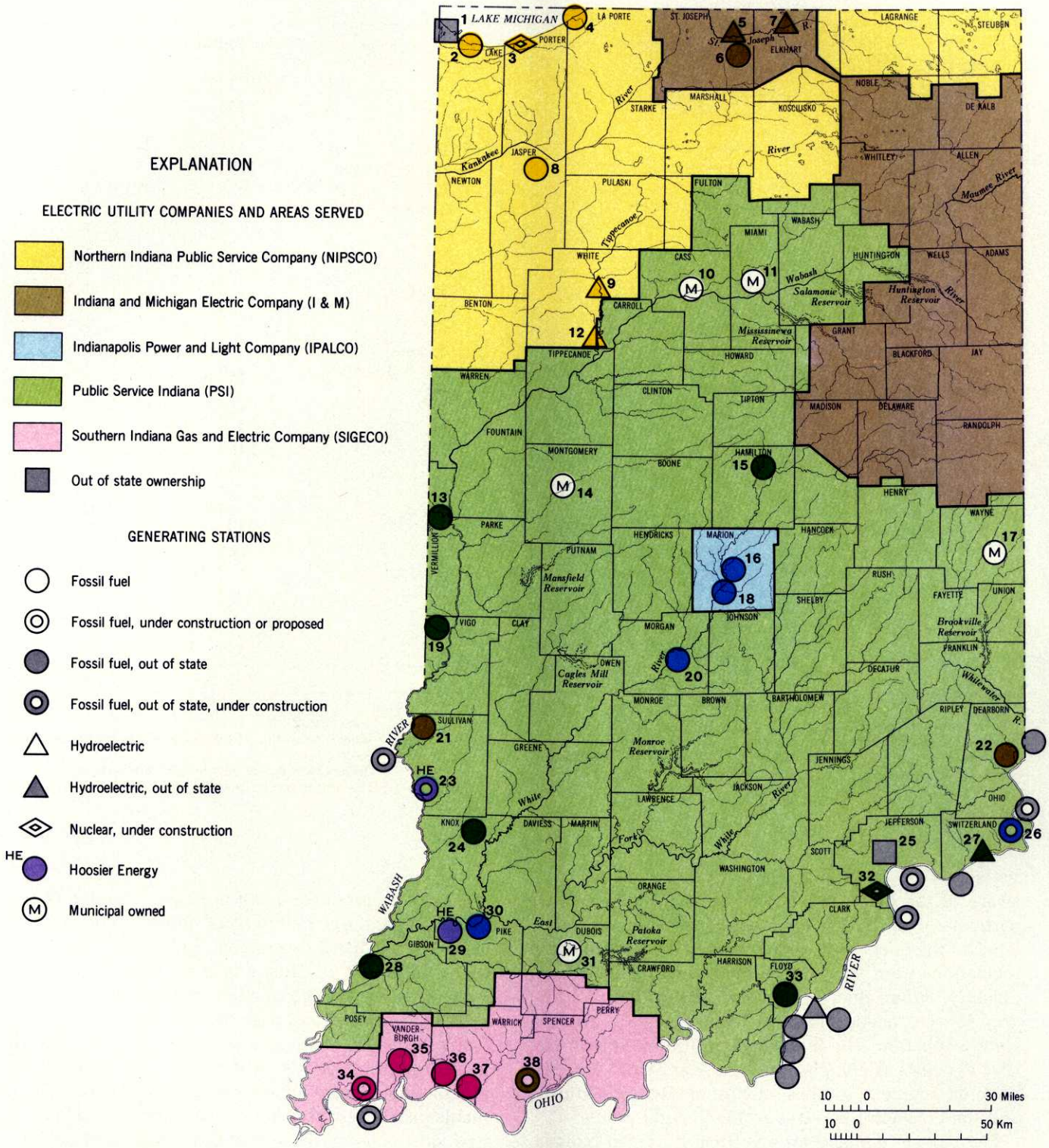


Figure 33

Map of Indiana showing the service areas of the major electrical utilities and the location of existing and proposed facilities. The numbers correspond to the reference numbers on Tables 16 and 17. The service areas and symbols representing generating stations are shown in corresponding colors.

Table 16

Indiana's electric generating stations, their gross generating potential, type, and water requirements.

Reference Number	Plant	Owner	Nameplate Rating Gross (mw)	Cooling Type	Million-Gallons-Per-Day	
					Withdrawn	Consumed
1	State Line	Con.Ed.[a]	968	OT[j]	750	0
2	Mitchell	NIPSCO[b]	581.6	OT	398	3.0
3	Bailey	NIPSCO	649.5	OT	341	3.0
4	Michigan City	NIPSCO	736	OT & Towers[k]	158	13.0
6	Twin Branch	I&M[c]	250	OT	275	0
8	Schahfer	NIPSCO	520.8	Towers[l]	6.3	2.8
10	Logansport	Mun.[d]	38.5	OT	29	0
11	Peru	Mun.	37.5	OT	29	0
13	Cayuga	PSI[e]	1,075	OT[m]	852	0
14	Crawfordsville	Mun.	24.15	Towers	0.7	0.7
15	Noblesville	PSI	111	OT	125	0
16	Perry	IPALCO[f]	59	OT	7.6	0
17	Richmond	Mun.	93	Towers	3.3	2.6
18	Stout	IPALCO	954	OT & Towers[n]	325	5.0
19	Wabash River	PSI	937	OT	747	0
20	Pritchard	IPALCO	412	OT	330	0
21	Breed	I&M	420	OT	318	0
22	Tanners Creek	I&M	1,066	OT	1,123	0
24	Edwardsport	PSI	175	OT	488	0
25	Clifty Creek	IKEC[g]	1,304	OT	1,424	0
28	Gibson	PSI	1,370	Pond	28.8	16.9
29	Hoosier Energy	HE[h]	255	OT	225	0
30	Petersburg	IPALCO	754	OT	386	0
31	Jasper	Mun.	14.5	Towers	0.18	0.1
33	Gallagher	PSI	680	OT	488	0
35	Ohio River	SIGECO[i]	128	OT	30	0
36	Warrick	SIGECO	732	OT	518	1.0
37	Culley	SIGECO	412	OT	373	0
Total			14,760.55		9,492.88	48.1

[a]Commonwealth Edison Company
[b]Northern Indiana Public Service Company
[c]Indiana and Michigan Electric Company
[d]Municipally owned
[e]Public Service Indiana
[f]Indianapolis Power and Light Company
[g]Indiana-Kentucky Electric Corporation
[h]Hoosier Energy
[i]Southern Indiana Gas and Electric Company
[j]Once-through
[k]Units representing 71 percent of plant capacity on towers
[l]Cooling tower
[m]Towers used during high temperature periods
[n]One unit is cooled by tower

aware of the finite nature of the fossil fuel reserves, particularly oil and natural gas. Energy prices escalated as the effect of fuel scarcities and environmental regulations were phased into the United States energy industry. Future energy demands, and the mix of energy sources needed to meet those demands, are not clearly apparent. The forecasting of future electric energy demands is complicated by the apparent scarcity of some energy resources, environmental regulations, and the consumption rates of the general public.

The current demand for electrical power in Indiana is increasing approximately three and one-half to four and one-half percent per year. A number of studies by the utility industry, public interest groups, and various government agencies have forecast future growth rates ranging from three to eight percent per year. The midrange estimate of future growth of five percent per year is most probable. Long term growth rates of less than three and one-half percent appear to be unlikely. On the other hand if economic growth is vigorous in the remainder of this century, growth rates of approximately six and one-half percent may occur.

It is anticipated that over the next twenty-five years, a number of the older, smaller, generating stations will be retired from service. At the same time, several utility companies have announced expansions to existing plants or the construction of generating facilities at new sites. A list of these facilities is indicated on Table 17 and they correspond with Figure 33.

Assuming all of these planned facilities will be constructed as announced, Indiana's installed nameplate capacity should grow from 14,761 megawatts (mw) in 1977 to 18,000 mw in 1980; 26,500 mw in 1990; and then decrease to 21,700 mw in the year 2000 as older

Table 17

Announced expansion and new generating facilities, their gross generating potential, type, and water requirements.

Reference Number	*Plant*	*Owner*	*Nameplate Rating Gross (mw)*	*Cooling Type*	*Fuel*	*Anticipated Consumption (mgd)*
3	Bailey	NIPSCO	660	Towers	Nuclear	5.8
8	Schahfer Unit (15)	NIPSCO	527	Towers	Coal	3.1
17	Whitewater Valley (Richmond)	Mun.	100	Towers	Coal	.6
23	Merom	HE	980	Lake	Coal	21.3
26	Patriot	IPALCO	1,950	Towers	Coal	25.5
28	Gibson Unit (3,4)	PSI	1,373	Pond	Coal	16.8
28	Gibson Unit 5	PSI	696	Pond	Coal	8.5
30	Petersburg	IPALCO	1,064*	Towers	Coal	6.2
32	Marble Hill	PSI	2,380	Towers	Nuclear	36.5
34	Brown	SIGECO	615	Towers	Coal	3.6
38	Rockport	I&M	2,600	Towers	Coal	32.3

Reference numbers correspond to plant location numbers on Figure 33.
*532 mw of the 1,064 listed became operational in 1977.

units are retired. It should be noted that the announced construction-anticipated retirement schedule is sufficient to support an approximate four and one-half percent growth rate to the year 1990, but that there may be an anticipated shortfall of 23,400 mw by the year 2000.

The electrical generating capacity necessary to support the projected five percent growth rate is presented in Table 18. Similar data for the three and one-half percent and six and one-half percent growth rates are indicated in Appendix Five. Listed under the heading "Shortfall" is the additional nameplate capacity which must be developed to sustain the possible growth rates. These predicted shortfalls may be overestimated if the utility companies leave older, less economical units in service longer than anticipated. On the other hand, the shortfall may be underestimated if the utilities do not implement their plans for new generating facilities.

Table 18

Projected, required, and available generating capacities based on the five percent growth rate.

Year	*Required Capacity Megawatts*	*Available Capacity Megawatts*	*Shortfall Megawatts*
1980	17,000	18,000	0
1990	27,700	26,500	1,200
2000	45,100	21,700	23,500

The translation of the shortfall capacity from terms of megawatts of capacity to numbers of new plants cannot be precise, due to the variability of size and the number of generating units installed at a particular site. However most new multi-unit plants range from 2,000 to 3,000 megawatts.

The projected electric power demand, based upon the five percent growth rate, is translated into water withdrawal and water consumption rates, as shown in Table 19. A substantial decrease in water withdrawals is projected between the years 1990 and 2000. This decrease in water withdrawals results from the anticipated retirement of a number of existing plants utilizing the once-through cooling method. The decrease from 9.5 billion gallons-per-day to approximately five billion gallons-per-day is not particularly influenced by the projected growth rates. As total withdrawal decreases, water consumption is expected to rise sharply as cooling towers and cooling lakes, with their high evaporative losses, replace the plants using the once-through cooling method.

Table 19

The current and projected water demands for a five percent growth rate in electric power production.

Year	*Million-Gallons-Per-Day*	
	Withdrawn	*Consumed*
1977	9,500	48
1980	9,500	78
1990	9,400	212
2000	5,000	354

Indiana is, in fact, expected to trade high water intake requirements for higher consumptive uses. As this expected transition occurs, the total water available for other purposes will decrease. Once-through cooling, while it has an adverse effect on water quality because of the increase in temperature, consumes (evaporates) substantially less water than the other cooling methods. In fact, the discharge from several existing once-through cooling stations forms part of the intake for a downstream generating facility.

New electric energy sites are expected to require water intake in the range of 30 to 80 million-gallons-per-day, depending upon the capacity of the generating station and the cooling method. About one-half of this water will be consumed. While this intake requirement is significantly lower than the intake requirements for existing plants, the state has only a few streams hydrologically capable of supporting new large scale energy facilities with their attendant consumptive uses. These streams are the Ohio River, the Kankakee River west of Starke County, portions of the St. Joseph River in St. Joseph and Elkhart Counties, the Wabash River below Lafayette, the West Fork of the White River below Marion County, and the East Fork of the White River downstream from Bartholomew County, and most of these would require supplemental storage. While Lake Michigan has the capacity to support numerous energy facilities, the shoreline of that lake is committed to other uses. The only practical way to utilize Lake Michigan waters for additional power production purposes is to convert an existing industrial site to power generation. Air quality regulations then may become the final determining factor of power plant siting along the Lake Michigan shoreline.

Production of Coal Indiana's annual coal production has exceeded 20 million tons since 1969. Of this amount, approximately eighty-five percent is used to produce steam for electrical generation; the remainder is used for home heating and miscellaneous uses. In 1976 about seventy-six percent of the coal produced in Indiana was mechanically cleaned in ten preparation plants by washing with water, a process that lowers the sulfur and ash content by removing parts of the pyrite, shale, and non-coal materials. These ten plants used an average of nine million gallons of water a day, and are located as shown on Figure 34.

Not all the water used in coal preparation is consumed; much is recycled. In many instances water is obtained by diverting drainage within the coal mine property to the slurry pond, or water is obtained from artificial lakes that develop in the "final cuts" of mining. Some water is lost by evaporation from the ponds but the amount of loss is difficult to estimate. Ponds that have a large surface area, such as those built in flat areas using dikes and levees, will have greater evaporation than those using a deep final cut with a smaller surface area.

Projections Estimates of future water needs for coal preparation assume that no new technologies will develop to change water requirements. Based on this assumption and the assumption that the same percentage of coal will be washed in the future as today, water requirements will be functions of the coal produced. With a national effort to place more reliance on coal as an energy source, Indiana's coal production is most likely to increase in the future. The historical growth from 1967 to 1976 has been at an average four and one-half percent yearly increase. It seems reasonable to assume that the growth production will parallel the growth of Indiana power generation. Thus, water requirements for coal preparation in 1985 and 2000 are estimated at 14.9 and 31.2 million-gallons-per-day, respectively, as indicated in the following table.

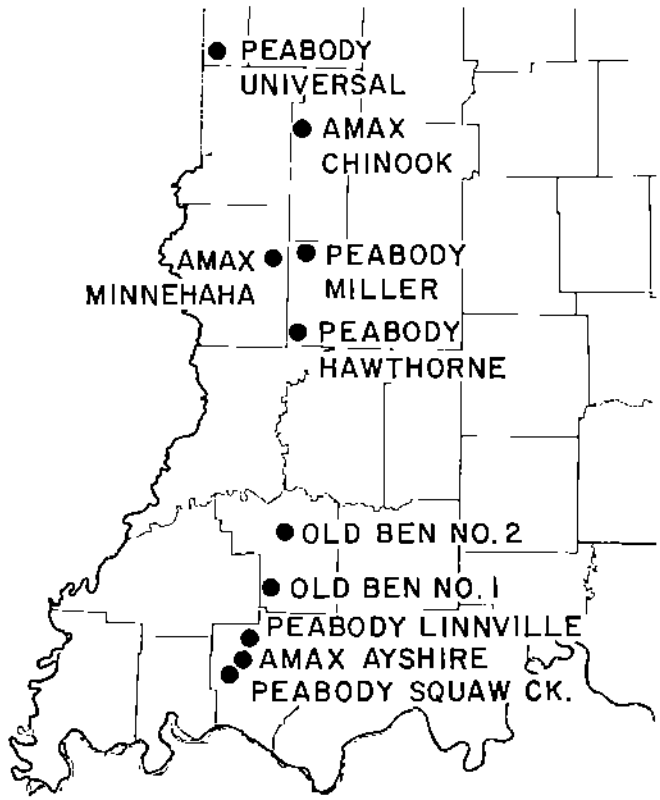


Figure 34
Map showing the location of coal preparation plants in Indiana.

Table 20
Water requirements to process coal by mechanical washing.

Year	*Amount of Coal Processed in Million Short-Tons*	*Water Required in Million-Gallons-Per-Day*
1976	19.3	9.2
1985	31.4	14.9
2000	65.4	31.2

Coal Conversion Coal is not currently being commercially converted to gas or liquid hydrocarbons in the United States. However, research sponsored by the United States Department of Energy is being con-

ducted to determine the best practical method of coal conversion. Coal conversion to oil and gas requires large quantities of water. The single largest consumptive use of water in the conversion process is for cooling. Water also is needed to supply hydrogen that combines with carbon in coal to produce hydrocarbons, to treat waste sludge and ash, and to take care of miscellaneous mine and plant uses.

The water requirements for the different coal conversion processes currently under investigation range from about 12,000 to 22,000 gallons-per-minute for a gasification plant capable of producing 250 million standard cubic feet of gas per day. To place this in perspective, the city of Evansville uses about 20,000 gallons of water per minute; Indiana produced about 190 million cubic feet of gas during 1976. Thus, a conversion plant producing 250 million standard cubic feet per day would require about the same amount of water as the city of Evansville, but it would produce more gas in a day than is now produced in Indiana in a year. Indiana's annual consumption of natural gas is approximately 560 billion cubic feet, about fifty-five percent of which is used during the five month heating season.

Oil Recovery The secondary recovery of oil from the geologic formations underlying Indiana requires water. Since this water is injected into deep geologic formations, it is essentially lost for other uses. The majority of the injected water is brine water produced in oil recovery operations and ground water.

Oil producers are not required to report the amounts of water used in their operations, so there are no reliable estimates of the amount of water consumed. The best current estimates are about one million gallons-per-day of potable water being used for oil recovery. Since Indiana's oil reserves are declining, it is anticipated that this figure will decline in the future, unless more sophisticated recovery methods are developed.

Summary

The total current and projected water demands on the Indiana water resource for public water supply, industrial self-supply, rural water supply, irrigation, energy production, coal processing, and oil well injection are shown in Table 21. As indicated, approximately 13,858 million-gallons-per-day were withdrawn in 1977 with less than five percent consumption. However, as water withdrawals decrease by the year 2000 to approximately 9,895 million-gallons-per-day, the rate of water consumption may increase more than fourteen percent. This decline in water withdrawals and increase in water consumption is due largely to a technological change from the once-through cooling method to cooling towers or cooling lakes in the production of energy. The unallocated energy category represents those additional power plants which would be constructed to meet the projected energy demand by the years 1990 to 2000.

Table 21
The current and projected water withdrawals and consumption in million-gallons-per-day within Indiana.

Water Use	*1977*		*1980*		*1990*		*2000*	
	Withdrawn	*Consumed*	*Withdrawn*	*Consumed*	*Withdrawn*	*Consumed*	*Withdrawn*	*Consumed*
Public Water Supply[a]	553.69[b]	68.75[b]	577.91	72.30	670.07	84.41	757.64	96.07
Industrial Self-Supply	3,456.94	146.71	3,286.29	154.69	3,317.45	201.71	3,430.35	256.53
Rural Water	147.27	147.27	155.36	155.36	182.42	182.42	209.37	209.37
Irrigation[c,d]	196.77	196.77	234.42	234.42	341.60	341.60	451.65	451.65
Energy[e]	9,492.88	48.13	9,490.68	77.73	9,359.18	204.73	4,705.33	203.88
Unallocated Energy[f,g]	0.00	0.00	0.00	0.00	15.40	7.50	308.00	150.00
Coal Processing	9.20	9.20	11.30	11.30	21.03	21.03	31.20	31.20
Oil Well Injection[h]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	13,857.75	617.83	13,756.96	706.80	13,908.15	1,044.40	9,894.54	1,399.70

[a]Public water supplies projections are from the "13 Cities" projection series.
[b]Figures for 1975 calendar year with exception of Region 10 which is 1977 data.
[c]Represents irrigation for an average year of precipitation during the irrigation season of July through August for croplands and golf courses.
[d]1980 and 1990 values by interpolation.
[e]Represents values attributed to existing and announced energy facilities.
[f]Represents withdrawal and consumption for future electric power generating stations. Sites for these stations have not yet been identified. No allowance has been made for coal classification or liquification.
[g]Projections are based on the midrange growth rate of 5 percent.
[h]Insufficient data to project trend.



Excess Water

Excess water, as the term is applied in this report, is not meant to suggest that there is yet another phase of the water resource discussed previously. Excess water describes aspects of the water resource which, because of the general prevalence and relative importance in the State of Indiana, merit separate discussion. The term is used to include the subjects of flooding, drainage, and soil erosion with consequent sedimentation. The use of the term *excess water* does not by any means suggest that the overall water resource of the state is excessive, but rather that "too much" water occurs at a particular place at a particular time, causing flooding, drainage problems, soil erosion, or problems of sedimentation.

FLOODS

The natural stream systems in Indiana have evolved in post-glacial periods under the influence of prevailing climatic, geologic, and hydrologic factors. In the typical case, each stream is characterized in its various reaches by a channel which, under the cumulative influence of the above-cited factors, is of such size and capacity as to convey within its banks a rate of flow roughly equivalent to that which may be expected to occur once or twice per year, on the average.

Flows in excess of the bank-full capacity of the channel, which spread out over the normally dry lands adjacent to the stream, known as flood plains, are referred to as floods or flooding.

The source of flood water is direct surface runoff, as opposed to the ground-water contribution to streamflow. Indeed, many hydrologists feel that the groundwater contribution to streams is generally inhibited, if not actually reversed, during the periods of high stream stages caused by floods.

Direct surface runoff to streams and lakes, results when precipitation occurs at rates in excess of the infiltration capacity of the land surface on which it falls. A flood results when precipitation events produce surface runoff at rates which exceed the capacity of the receiving stream.

The relative magnitude of flood events and their occurrence in time are directly influenced by the relative magnitude and time distribution of runoff-producing precipitation events. Since such precipitation events are highly variable in both time and space, so are floods. Thus, floods may occur at irregular intervals on an individual stream, on a reach of a single stream, or over a wide geographic area.

Major precipitation events, large enough to produce floods, are rarely predictable with any substantial degree of accuracy for more than a day or so in advance, and hence the prediction of floods suffers the same constraints. It is possible, once the storm event has occurred, to predict with relatively high accuracy both the magnitude and timing of resulting flooding on the major streams. The National Oceanic and Atmospheric Administration routinely performs such forecasting services.

For the purposes of planning, the application of probability theory to long-term gaging station records of streamflow produces estimates of flood magnitude and frequency. Such estimates are expressed in terms of the peak rate of flood flow which may be expected

to be equalled or exceeded once in some specified interval of time. For example, the "100-year flood" is that flood whose peak rate of discharge is expected to be equalled or exceeded once in one hundred years, on the average. It also is expressed as that flood that has a one percent chance of occurrence at any time.

While floods in Indiana may occur at any time of the year, the prevailing climatic conditions are such that the great majority of floods occur during the period from January through June.

A general discussion of floods would not be complete without pointing out that flooding may be greatly, and usually adversely, affected by the activities of man. All construction that results in a relatively impervious surface, such as that of houses, buildings, sidewalks, roads, streets, and parking lots, causes increased surface runoff. Inadequate bridges and culverts restrict streamflow capacity and cause increased flood stages. Land filling operations may produce the same effect by restricting the floodway. The indiscriminate dumping of trash and debris in floodways not only restricts floodway capacity but may wash into the stream channels to create debris jams.

Flood Damages

Presumably, floods were not a concern prior to the settlement and economic development of the state. As the flood plains were converted to agricultural pursuits, to commercial and industrial enterprises, and to the building of homes, floods resulted in economic and social losses. The adverse impacts of floods include erosion, deposition of infertile sediments, losses of crops, interruption to transportation, communication, and commerce, loss of industrial production, property damage, human suffering, and, on occasion, the loss of human lives.

Unobstructed flood plains reduce the rates of flood flows and flood stages by providing temporary flood water storage. Thus unobstructed flood plains help reduce the damages caused by flood flows.

Neither the total area of the flood plains of Indiana nor the extent of social and economic losses from floods are known with precision. However, the general location of major Indiana flood plains is indicated on Figure 35. Numerous studies have been made in the past on most of the larger streams of the state, primarily by federal agencies, which have included estimates of average annual flood damages, exclusive of the loss of life. In the course of this study, rather extensive efforts were made to collect available information with a view toward at least developing a reasonable portrayal of the flood damage situation across the state.

The results of these studies are summarized in Table 22, which indicates an order of magnitude of estimated average annual flood damages within the major drainage basins. The damage data were adjusted to reflect January 1978 price and cost levels and are segregated as to agricultural and urban damages.

Table 22
The order of magnitude of the estimated average annual flood damages within selected drainage basins.

Stream	*Urban Damages in 1978 Dollars*	*Rural Damage in 1978 Dollars*	*Flood Plain Acres*
Iroquois River	0	136,000	100,800
Kankakee River	0	3,700,000	81,700
Little Calumet River	17,935,000	183,000	3,800
Maumee River	8,424,000	171,000	19,600
Ohio River and Minor Tributaries	819,000	3,673,000	183,200
St. Joseph River	775,000	21,000	2,800
Wabash River	15,243,000	75,801,000	1,316,700
Total	43,176,000	83,531,000	1,708,600

Estimated flood damages represent the Ohio, Elkhart, Kankakee, Maumee, Wabash, and Great Lake Basin studies prepared by the U.S. Army Corps of Engineers and the U.S. Soil Conservation Service. All figures derived from these studies were updated to reflect January 1978 dollar values.

An appraisal of flood damages was made by determining the area flooded by different events. This involved a study of historical flood events to determine their magnitude and frequency. The area affected by each flood and the resulting physical damage were converted to monetary amounts. (Physical damage is the reduction of yields to agricultural products, or the actual resources that must be repaired or replaced in houses, businesses, roads, bridges, and other structures.) The monetary damage for each flood is evaluated with the frequency of the floods to determine the average damage, in dollars, that can be expected annually. This is referred to as average annual dollar damage.

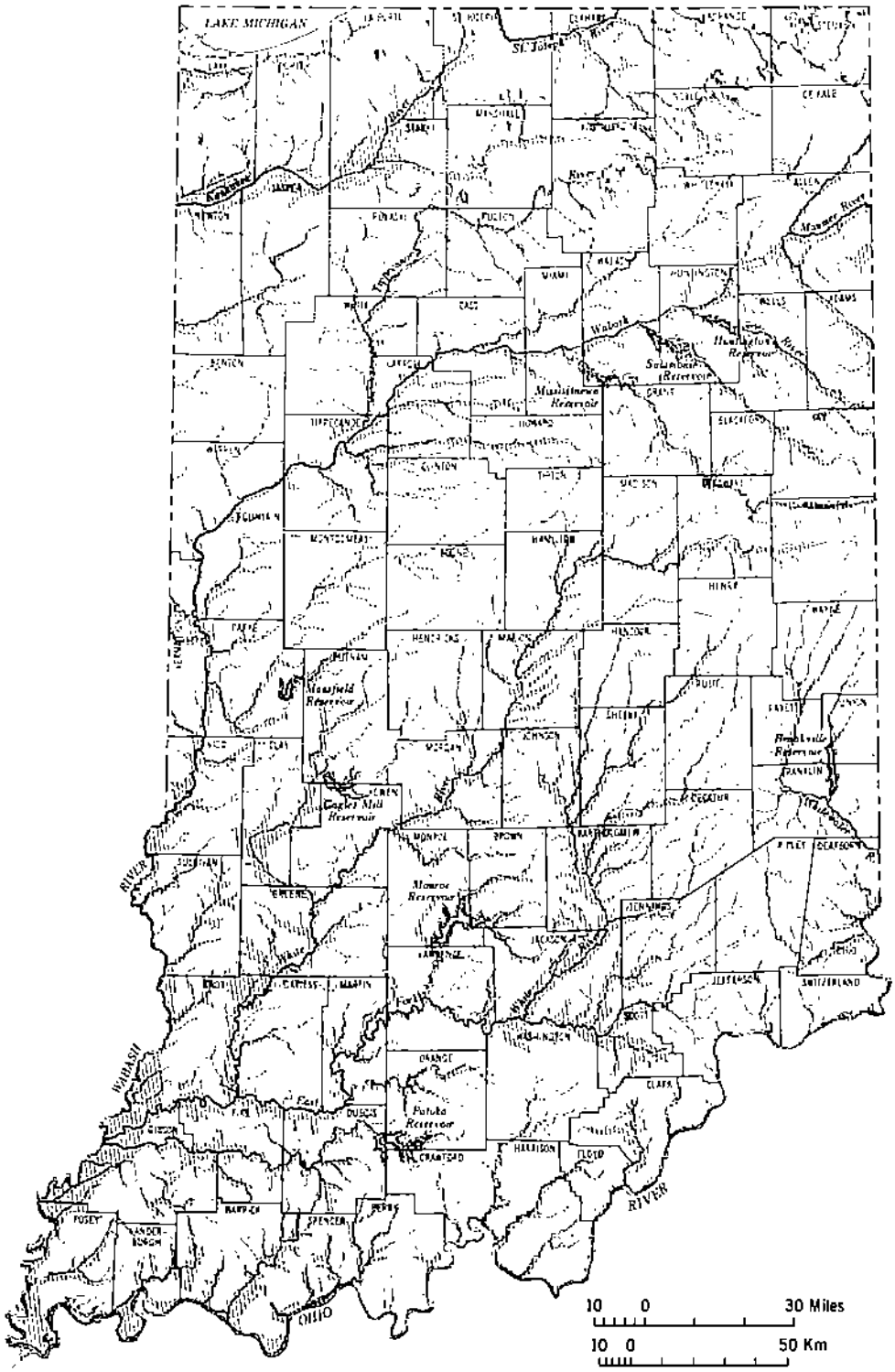


Figure 35
Map of Indiana showing the location of flood plains.

It is emphasized that these estimates do not include all flood plain areas, and that the dollar values shown are not represented to be absolute. Rather, they reflect the best estimates now available and are intended to serve to provide at least an impression of the relative magnitude of flood damages, both statewide and among the major drainage basins.

The areas prone to major urban flood damage are the Little Calumet River drainage basin, the Maumee River of the Great Lakes basin, and the upper West Fork White River area of the Wabash River basin. These three areas sustain about 81 percent of the slightly more than $43 million in urban flood damages.

Nearly ninety-one percent, or approximately $75.8 million, of the average annual rural flood damages are sustained in the Wabash River basin. The Kankakee River and the Ohio River basins are next in order, with average annual rural damages on the order of $3.7 million each.

Flood Projects and Programs

The extent of flooding and resultant damages have provided the impetus for many federal, state, and local projects and programs over the years.

The federal government, through the United States Army Corps of Engineers, began water resource development projects in Indiana during the 1800s. To date over $238 million have been expended by the corps of engineers on Indiana water projects, all of which were built in whole or in part for flood control purposes. Figure 36 indicates the location and stage of development of these projects.

The United States Department of Agriculture through the Soil Conservation Service, acting pursuant to the Small Watershed Program (Public Law 83-566), provides technical assistance and construction funds for watershed protection and flood protection projects in small watersheds. Over $22 million in federal funds have been invested on these small watershed projects in Indiana. By 1978, eight small watershed projects were complete and twenty-one were authorized for construction. The location of the active small watershed projects in Indiana is shown on Figure 37.

The Soil Conservation Service is also involved with the ninety-two county soil and water conservation districts in Indiana. The Soil Conservation and Domestic Act (under Public Law 74-46) empowers the Soil Conservation Service to provide technical and advisory assistance to individuals, groups, and other governmental agencies for soil and water management.

In addition, the Soil Conservation Service provides technical and financial assistance to Resource Conservation and Development Areas in planning and installing of measures such as flood prevention, sediment, and erosion control. Five Resource Conservation and Development Areas encompass thirty-one Indiana counties.

In addition to those projects and programs for structural methods of flood control, there are three flood plain management programs in force whose primary thrust is to mitigate damages in existing situations and to avert future damages.

Indiana Flood Control Act The first of these is the 1945 Indiana Flood Control Act, whereby the construction of places of abode within floodways is prohibited and all other construction within such floodways is subject to prior permit by the Natural Resources Commission. In acting upon applications for permit, the commission must consider whether the proposed construction will (1) adversely affect the capacity and efficiency of the floodway, (2) create an unreasonable hazard to the safety of life or property, and (3) have unreasonably detrimental effects upon fish, wildlife, or botanical resources.

Indiana Flood Plain Management Act The second flood plain management program is based upon the 1973 Indiana Flood Plain Management Act. The act requires that, on and after July 1, 1974, any local ordinance adopted in Indiana that contains flood plain management rules and regulations must receive the approval of the Natural Resources Commission prior to becoming effective. The commission's minimum standards for the regulation of flood hazard areas are: (1) Natural Resources Commission possesses primary regulatory jurisdiction over the floodways of Indiana, (2) developments in the floodway fringe areas must be provided with a flood protection grade of at least two feet above the 100-year frequency flood, and (3) nonconforming uses in flood hazard areas may be expanded on a one time only basis, provided that expansion and improvements are less than forty percent of the premarket value exclusive of the land. The counties and communities with flood plain management ordinances approved by the Natural Resources Commission are shown in Figure 38.

National Flood Insurance Program The third flood plain management program is the National Flood Insurance Program as established by the Flood Insurance Act of 1968 and strengthened by the 1973 Flood Disaster Protection Act. The program is designed to provide low cost, subsidized, flood insurance to participating communities. In 1978, 319 communities and 53 counties were participating in either the regular or emergency phase of the program, as shown in Figure 39. The regular phase of the National Flood Insurance Program includes a detailed engineering study of flood

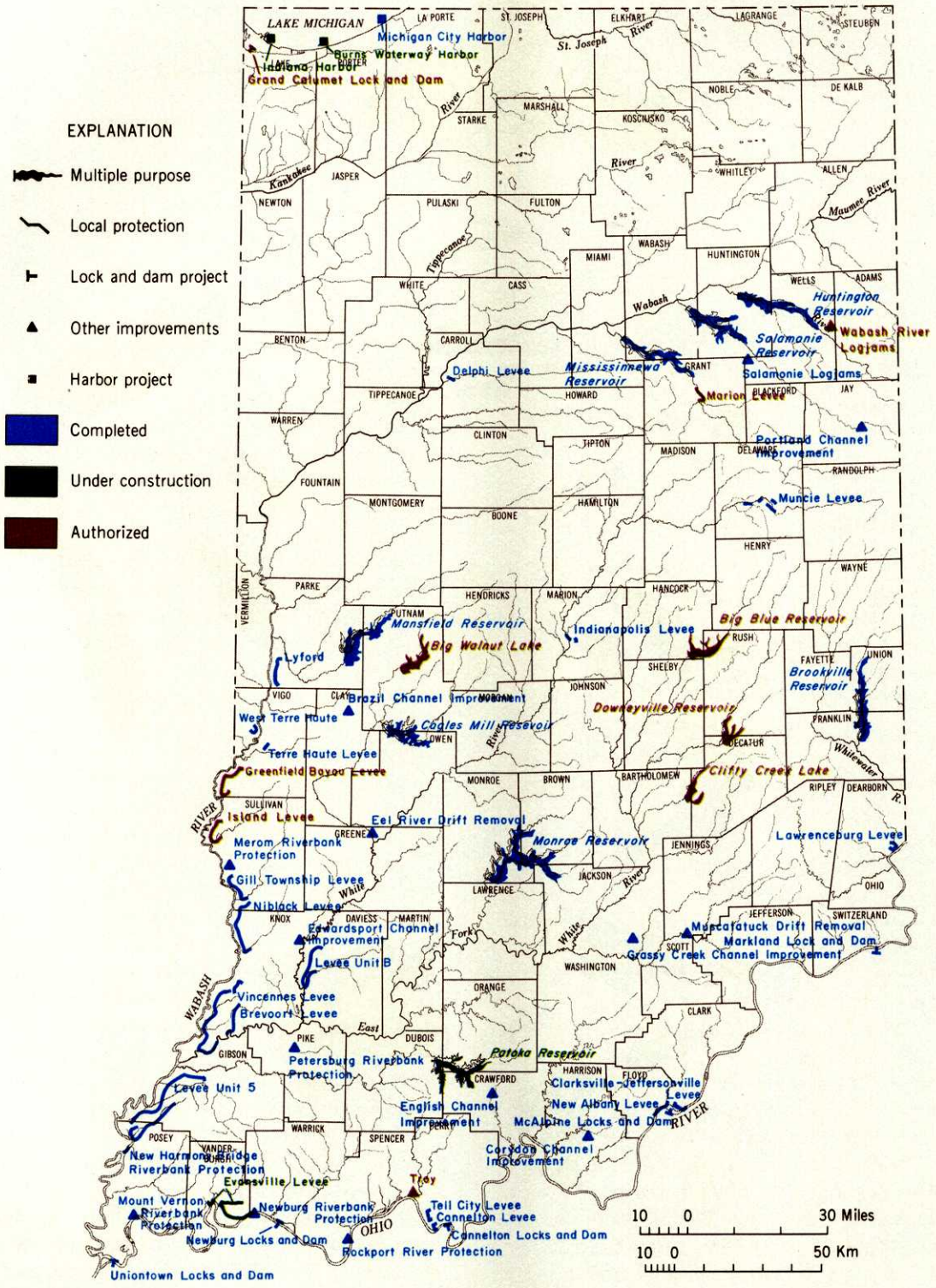


Figure 36
Map of Indiana showing the location and state of development of the U.S. Army Corps of Engineers water resource management projects.

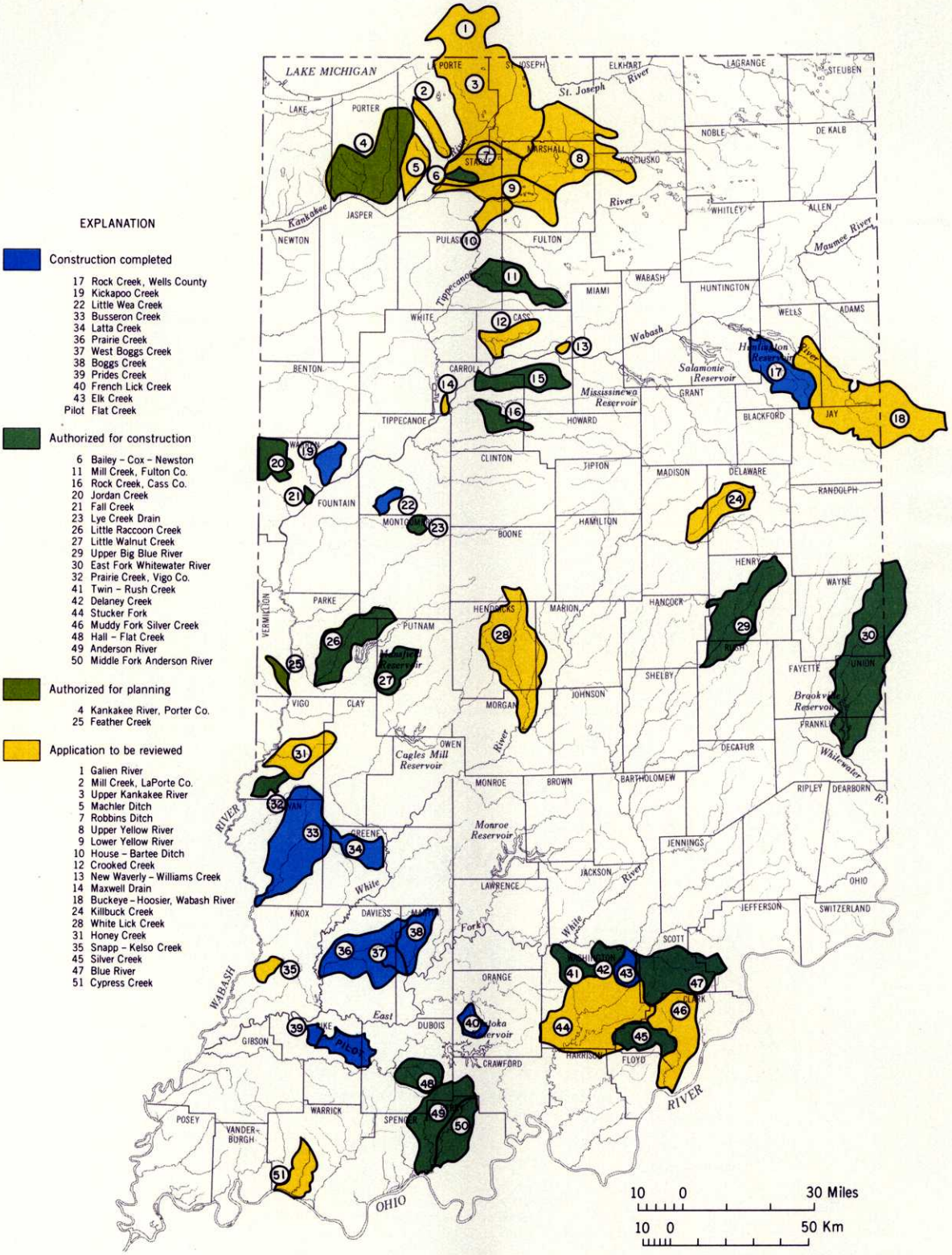


Figure 37
Map of Indiana showing the location and status of small watershed programs.

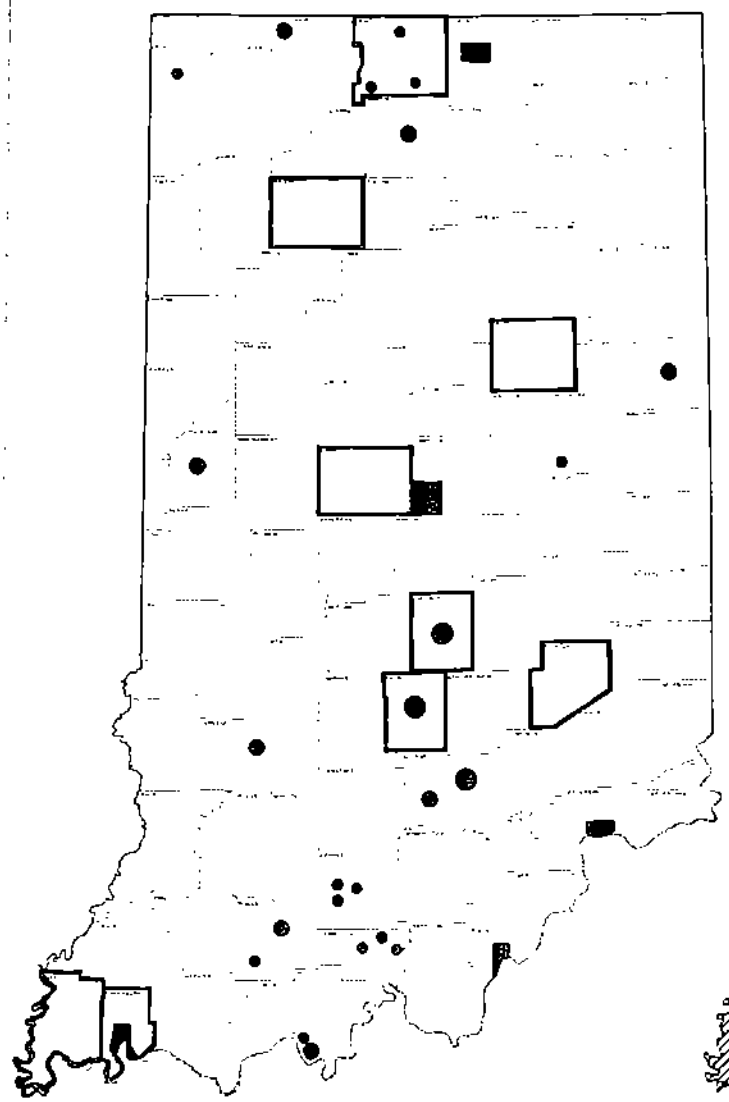


Figure 38
The communities and counties with floodplain management approved by the Natural Resources Commission.

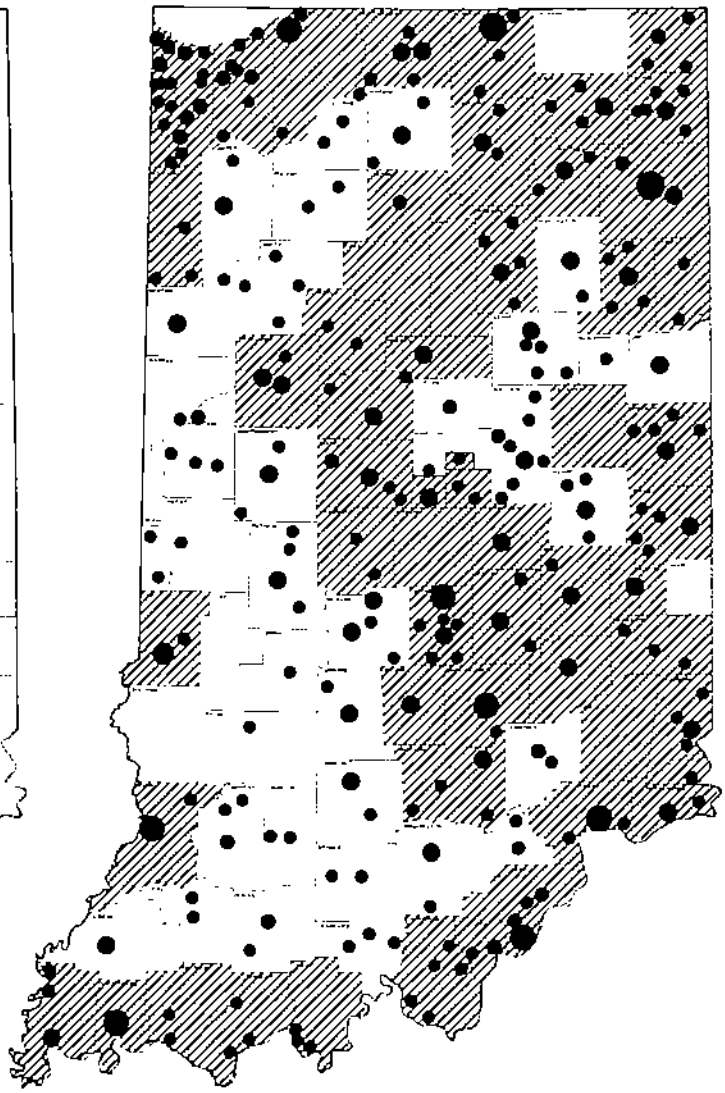


Figure 39
Map of Indiana showing the location of communities and counties participating in the National Flood Insurance Program.

prone areas and the adoption of flood plain ordinances by the participating community. The emergency phase of the program includes only the mapping of flood prone areas. The National Flood Insurance Program provides affordable flood insurance in flood prone communities in return for enactment of flood plain management rules and regulations. The regulations can be in the form of zoning ordinances, building codes, subdivision control regulations, and others, which will provide sound flood plain management in those areas designated by the study to be flood prone. In 1978, eleven communities had adopted regulations based upon detailed Flood Hazard Studies with an additional ninety studies underway.

AGRICULTURAL DRAINAGE

Cash receipts for crops in Indiana during 1977 were a record two billion dollars. Indiana ranked fifth in the nation in receipts from crops. Approximately eighty-eight percent of these crop receipts are derived from corn and soybeans which are grown under cultivation on high value land. Much of this land must be drained to achieve this level of production.

The size of the total farm business in Indiana, as well as the type of farming in any area, is greatly determined by the quality of its soils. The part of the soil that is plowed or cultivated is not the only portion of the soil that is important in the cultivation of a plentiful crop. The roots of a corn plant extend several feet into the soil beyond the area normally cultivated. The depth to which roots go in a soil depends partly on the water level in the soil profile. There are always some roots in the subsoil. These subsoil roots need water, oxygen, and nutrients just as do roots in the surface soil.

Soil bacterial action is essential for the transformation of soil components to forms available to plants. The presence of air in the soil is essential for soil bacterial growth. These bacteria change organic matter into organic acids which in turn dissolve the elements in the soil that furnish plant food. The roots of plants and the soil bacteria must have oxygen. Free water in the soil creates unfavorable conditions for plant growth because oxygen is excluded when the pore space is filled with water. Drainage provides air space in the soil, thus facilitating plant growth.

Soils were formed when various geologic materials such as glacial till, limestone, or wind-blown silt underwent physical, chemical, and biological changes as water moved through them. The soil that resulted depended on the kind of geologic material, the climate, kind of vegetation, the topography, and the length of time the soil had been forming. Indiana has a great variety of geologic materials resulting from different glaciers. A high percent of the glaciated area has a relatively level topography and is made up of rather impervious materials resulting in restricted natural drainage.

The productivity and water movement in any soil is determined by the properties of the different soil layers that extend down to the unweathered material from which the soil is formed. Some of the properties, such as texture (relative amounts of sand, silt, and clay), natural drainage, and the content of slowly soluble minerals, are fixed and change very slowly. Where the natural drainage is inadequate farms must supplement this drainage by the addition of various types of open channels and subsurface or tile drains.

The degree of artificial drainage to soils is determined by the amount of natural, external drainage (runoff) and the amount of internal drainage (percolation). Most waterlogged soils have dull, gray, poorly oxidized subsoils. Most well drained soils have brown subsoil which resulted from the oxidation of the soil minerals.

Agricultural drainage removes excess water (also known as free water or gravitational water) from or below the surface of the farmland in order to create favorable soil conditions for plant growth. The process of removing free water from the surface is referred to as surface drainage and the removal of free water from the subsoil is known as subsurface drainage. An adequate drainage system considers both surface and subsurface (tile) drainage.

A "legal drain" is a natural or artificial open channel or subsurface drain, or a combination of the two, that has been established under the Indiana drainage statute. These are sometimes called a public ditch, court drain, county ditch, or ditch of record. The county drainage board (county commissioners or appointed board) is responsible for construction, reconstruction, and maintenance of legal drains. Petitions for drainage construction or reconstruction are filed with the board, which determines whether they are practical or beneficial. The board determines assessments against property owners based on benefits they realize for the project. A "mutual drain" means a tile or open drain running through the lands of two or more owners and established by their mutual consent and not under the drainage statute. Indiana has more than thirty-six thousand miles of mutual drains. In 1976 alone, approximately thirty-five million feet of subsurface drains were installed at a cost of $17.5 million. More than 500 miles of legal drains occur in each of thirty-five Indiana counties.

The extent to which agricultural lands require drainage in order to maximize the agricultural yields is dependent upon the soil wetness characteristics of the individual soils. The wetness characteristics of Indiana soil associations are shown on Figure 40. These wetness characteristics are divided into three general categories. Soil associations with a *slight* degree of wetness represent soils with less than thirty acres per one hundred acres requiring drainage in order to maximize the agricultural yield. Soil associations with a slight degree of wetness are generally deep, well drained soils located on gently sloping to sloping topography as shown in the background of Figure 41-A. The *moderate* wetness characteristics represent soil associations with thirty to sixty-nine acres per one hundred acres requiring drainage. Soil associations with moderate wetness characteristics are generally deep and very poorly to somewhat poorly drained on nearly level topography as shown in the foreground

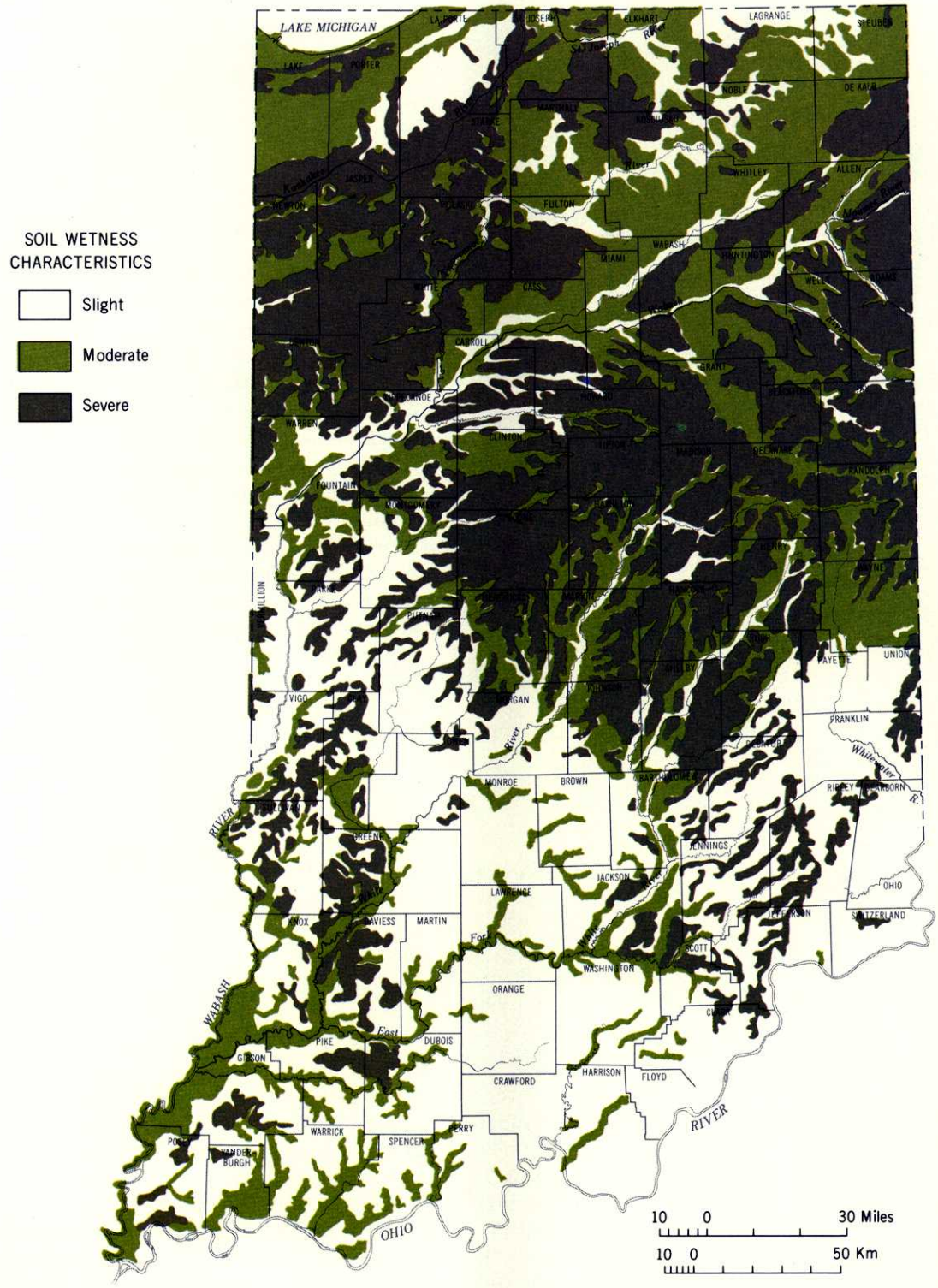


Figure 40
Map showing wetness characteristics of Indiana soil associations.



Figure 41-A
Deep, well drained soils located on gently to moderately sloping landscape are shown in the background. Deep and very poorly to somewhat poorly drained soils on nearly level ground are shown in the foreground.



Figure 41-B
Soils that are deep and very poorly to somewhat poorly drained are located on nearly level to depressional landscape.

(Photographs courtesy of the U.S. Soil Conservation Service)

of Figure 41-A. The *severe* wetness characteristics represent those soil associations with over seventy acres per one hundred acres requiring drainage to maximize agricultural yields. Soil associations with severe wetness characteristics are usually deep and very poorly to somewhat poorly drained on nearly level and depressional landscapes as shown on Figure 41-B. It should be noted that not all soils within each soil association require drainage to maximize agricultural yields and that existing land use was not considered when evaluating the wetness characteristics of the soil associations.

The *Indiana Farm Drainage Guide* has been prepared by the United States Soil Conservation Service and Purdue University to provide technical data on drainage for agricultural production. The guide provides drainage recommendations for all Indiana soils and design and construction information for various drainage methods. It lists the drainage practices needed for optimum field crop production for each soil type.

URBAN RUNOFF

During periods of moderate to heavy precipitation removal of excess water from urban areas is a necessity. Urban areas, by their developed nature, have less pervious ground surface and hence a high amount of runoff. This runoff has higher flow rates than in natural conditions. Without proper storm water drainage, much damage and inconvenience results. Problems of storm water removal, although widespread in Indiana, are generally local in nature and affect the individual urban area.

However, urban runoff problems may have widespread impacts when the storm water and sanitary sewer systems are combined. During periods of high urban runoff the capacity of the local sewage treatment plant is often exceeded and a direct combined storm water and sewage is discharged into streams. The results of the sewage treatment bypass caused by excess storm runoff is a significant degradation of water quality of the receiving waters.

SOIL EROSION

Soil erosion, in minute and almost imperceptible amounts, is a part of the weathering process naturally occurring over the past several hundreds of thousands of years. This process has resulted in our varied landscapes from the high relief areas of Brown County to the lowlands of Scott County. The normally slow, natural process of soil erosion, however, has in many areas been greatly accelerated by land disturbing activities of urban growth and the intensive cropping practices of a highly productive modern day agriculture.

Soil losses from croplands may annually range from a few tons per acre to several hundred tons per acre on exposed, strongly sloping land areas. When soil losses exceed the natural, regenerative capabilities of the soil, productivity declines.

As erosion occurs, soil is transported by wind and direct surface runoff and is ultimately deposited in streams and lakes. Sediment and other associated pollutants degrade water quality and aquatic life. The expense of removing sediment from drainageways, stream channels, and reservoirs is exorbitant.

The potential for severe soil erosion exists in many areas throughout Indiana. The Soil Conservation Service and the State Soil and Water Conservation Committee have assessed the soil erosion potential resulting from rain falling on land left in a fallow condition within Indiana. The methodology for estimating the average annual soil loss is described within Appendix Six. The estimates of soil erosion are based upon soil associations. Not all the soils within each association are subject to erosion. The four categories of erosion potential are *low, medium, high,* and *very high.*

The soil associations with *low* erosion potential represent soils that are deep and very poorly to somewhat drained on nearly level and depressional land as shown in Figure 42-A.

The soil associations with *medium* erosion potential represent soils that are deep and somewhat poorly drained on nearly level to slightly sloping topography as shown in Figure 42-B.

The soil associations with a *high* erosion potential represent soils that are deep and well drained and located on moderately to steeply sloped land, as shown in Figure 42-C. Severe erosion losses would be expected to occur on very steep land that is bare and left exposed for a prolonged period of time. However, much of this land in rural areas is protected by grassland and woodland uses and generally would not be found in a fallow condition.

Soil associations with a *very high* erosion potential represent those land areas with the most serious soil loss potential if not maintained under good protective cover. The soils are usually deep, well drained, and associated with very steep slopes, as shown in Figure 42-D.



Figure 42-A
Deep soils with low erosion potential are located on nearly level to depressional land.

(Photographs courtesy of the U.S. Soil Conservation Service)



Figure 42-B
Soils that are somewhat poorly drained and located on nearly level to slightly sloping landscape have a "medium" erosion potential.



Figure 42-C
Soils with "high" erosion potential are deep, well drained, and occur on moderate to steeply sloping land.



Figure 42-D
Soil associations that are usually deep, well drained, and occur on very steep slopes have a "very high" erosion potential.

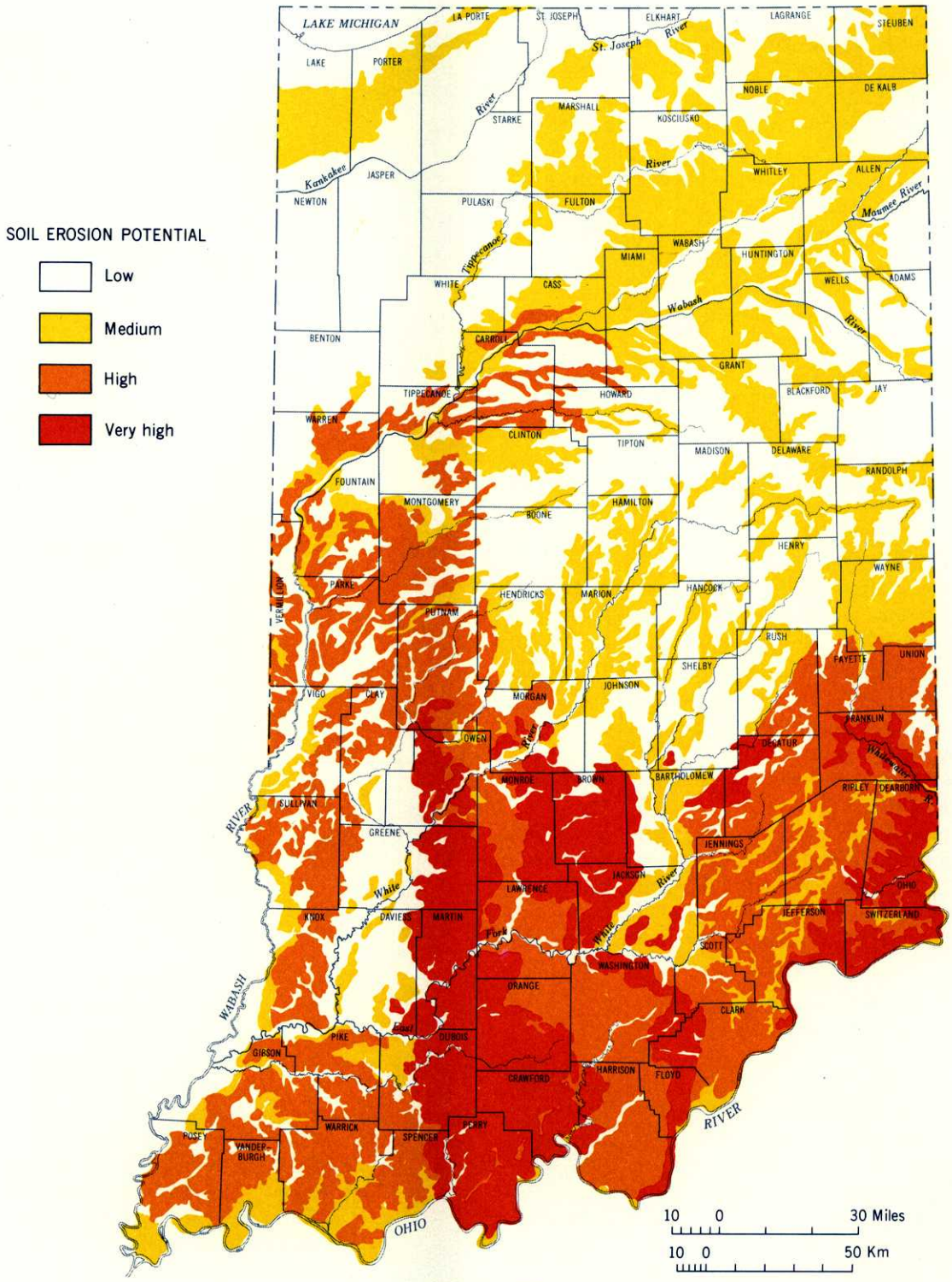


Figure 43
Map showing soil erosion potential of Indiana soil associations.

The assessment of the potential soil loss for land in fallow condition does not imply that the sloping lands of southern Indiana are losing more soil than other parts of the state. Many of these lands have adequate cover (trees and grass) and supplemental conservation practices to protect the land from erosion. Many farms throughout the state being intensively cropped on gentle and moderate slopes, without adequate conservation practices, are losing more soil to erosion than the more steep woodland and pasture areas. The general location of soil associations subject to erosion is shown on Figure 43.



As discussed previously, the purpose of the Governor's Water Resources Study Commission is to evaluate the effectiveness of current water resource management and existing legal authorities in light of current and projected demands on the water resource.

Therefore the subject of water quality is only addressed as it relates generally to the broad area of water resource management. The Federal Water Pollution Control Act (P.L. 92-500) as amended by the Clean Water Act of 1977 (P.L. 95-217) establishes the standards for water quality in Indiana. The Indiana Stream Pollution Control Board is responsible for water quality management and has established a program to work with the federal and local governments to implement water quality standards. Detailed information on the quality of the water of the state is available through the Stream Pollution Control Board and, due to the highly technical and voluminous nature of this material, it is not duplicated in this report.

However, the Commission did evaluate the general relationship between water quality and the utilization of the water resource. In particular, the Commission addressed the issue of the potential impact that water quality management may have on the quantity of water available for instream and withdrawal uses. The following discussion of water quality presents the information upon which the relationship between water quality and water quantity is based.

GROUND WATER

The natural chemical quality of ground water is the direct result of the mineral composition of the formations through which it has passed. During the slow process of the movement of water from the surface downward through the earth and into the aquifer systems, it dissolves and takes into solution various chemical elements including chlorides, fluorides, iron manganese and sulfate, and a number of other dissolved constituents. Therefore, the term *pure water* has little meaning since all natural waters contain varying amounts of chemical constituents.

The presence of dissolved elements may or may not be a problem depending upon the concentration, the intended use for the water, and consumer habits and preference. For example, "sulfur water" is perceived as a problem by most, while some pay a good price for bottled sulfur water to drink. However, iron is generally considered an undesirable element since it will usually cause staining and discoloration to laundry when present in amounts greater than 0.3 parts-per-million (ppm). *Water hardness,* a term used to describe the amount of carbonates, articularly calcium carbonate and other constituents, is important to water as they make it more palatable to the taste. Fluoride, when present in quantities greater than 1.0 ppm, may decrease tooth decay or may cause discoloration of the teeth in excessive amounts. Therefore, the presence of the various elements may either be desirable or undesirable depending upon the amount present and the intended use of the water.

Ground-water quality throughout the state is quite variable depending upon the aquifer system being sampled, geologic setting, and depth of the formation. For example, the hardness content of ground water may range from less than 100 ppm to over 600 ppm. In

general, the chemical quality of ground water in the state is good, meeting most of the basic requirements for household, municipal, industrial, and irrigation uses. However, the waters are normally hard, exceeding 180 ppm, and some form of iron or manganese treatment will be required in many situations.

Several key chemical constituents are of particular importance in assessing ground water for general household, municipal, and industrial uses. These usually include hardness, turbidity, iron, manganese, chloride, nitrate, sulfate, fluoride, and hydrogen-sulfide content. Table 23 presents selected chemical constituents, their significance, recommended maximum concentration, and the range of the normal values within the state.

Figure 44 shows selected, representative, regional water analyses for a number of the municipal water supplies. The analyses shown are predominantly for municipalities with ground-water sources; however, analyses for various stream sources, water supply reservoirs, and lakes scattered throughout the state also are displayed.

Table 23
Significance of selected chemical constituents in water.

Constituent	*Significance*	*Recommended Maximum Concentration*	*Normal Range of Values in Indiana*
Hardness ($CaCO_3$)	Hardness in water is due to the presence of calcium and magnesium compounds, such a bicarbonates, sulfates, and chlorides. Hardness is expressed as the calcium carbonate ($CaCO_3$) equivalent of the calcium and magnesium ions and a few other, but minor, ions. Hardness is a nuisance property, not a toxic or lethal factor. Water exceeding 120–180 ppm is considered "hard" and above 180 ppm it is considered "very hard". Most of Indiana's ground water exceeds 180 ppm, with typical ranges between 200–400 ppm. The major consequences of hard water in home usage are the formation of scum and curds, and reduced cleansing power of soaps and detergents. High hardness levels result in the formation of lime and scale deposits in water heaters, boilers, pipes, and utensils. Loss of efficiency, increases in fuel and repair costs, and high costs of soaps and detergents are associated expenses. In food processing hard water tends to toughen beans and peas and discolor beets and corn. Many industrial processes, including the manufacture of paper, textiles, chemicals, food, and beverages may be detrimentally affected by hard water, and treatment may be required.	none assigned	200–400
Iron (Fe)	Iron contained in ground water under natural conditions is found in the soluble ferrous state; however, when exposed to air it quickly oxidizes and converts to insoluble ferric oxide forming a brownish-yellow precipitate. The presence of "red water" is a common indicator of iron in water, with the resulting development of sediment and staining of clothing and plumbing fixtures. Iron adversely affects the quality of coffee, other beverages, and food, and imparts a taste to water. Iron is undesirable in many industrial processes and removal is often required. As little as 0.3 ppm of iron begins to create problems and at levels above 2.0 ppm control or removal is imperative. Iron in amounts above 0.5 ppm is common to most ground-water supplies in the state.	0.3	0–3.0
Manganese (Mn)	Even small quantities, 0.03 ppm, in combination with iron generally begin to be objectionable or detrimental for household and industrial use. Manganese oxidizes and precipitates much slower than iron and forms a dark brown or black precipitate that forms a filter-clogging sludge or slime. Manganese imparts an objectionable taste and is a potent stainer of materials, but is of little toxicological significance in drinking waters. Concentrations as small as 0.1 ppm are undesirable for some processing uses, and at 0.5 ppm the list of critical limitations is sizeable. Lakes and impoundments with limited flow-through or turn over capacity, and have little or no movement to create circulation, may form density layers (stratification) in which high concentrations of manganese are present in the deeper, more motionless waters. The complex chemical reactions relating to this condition are greatly facilitated by acidic waters draining from the debris of extensive hardwood areas. Concentrations of dissolved manganese as high as 7.0 ppm are known, and reports of 9 ppm to 17 ppm have been made for impoundments in the southern part of the state.	0.05	0.01–1.0

Table 23 (continued)

Constituent	*Significance*	*Recommended Maximum Concentration*	*Normal range of Values in Indiana*
Chloride (Cl)	Corrosive action and taste factors are the chief detrimental effects of chlorides in water. Concentrations are usually much lower than the 250 ppm "recommended" level, but small increases in chloride content cause drastic increases in both taste and corrosiveness. A "salty taste" is usually not noticed up to a concentration of 500 ppm (+ or − 200 ppm); however, adverse tastes can be imparted to tea, coffee, lemonade, and some cooked items at concentrations as low as 50 ppm. Varying amounts of chlorides are found in all of Indiana's ground waters. Deposits of sand and gravel usually contain low concentrations, while the chloride levels in bedrock formations vary considerably with concentrations almost always increasing with depth. Excessive concentrations of chlorides are known to occur as shallow as 100 feet below the surface in at least one area in Indiana, although normally wells will be much deeper before salty water is encountered.	250	10 – 50
Sulfate (SO_4)	High levels of sulfates form slimes, encrustation, and odorous waters. Commercial and industrial usage in metal, textile, food, and beverage processing may be adversely affected by concentrations as low as 100 ppm. The strength or concentration of sulfate in the state's ground waters varies greatly in response to such factors as depth, rock type, and geographic location. Concentrations ranging from 10 to 1,200 ppm are encountered in water supplies being used in Indiana. Sulfate in drinking water is more of a nuisance than a serious danger. Persons unaccustomed to using water high in sulfate, especially when the concentration is above 250 ppm, often have a cathartic reaction, which can be further aggravated by associated high sodium and/or magnesium levels.	250	0 – 1,000
Fluoride (Fl)	Fluorides occur naturally in most of Indiana's ground waters, although at levels below the accepted beneficial range. Fluoride concentrations from about 0.9 ppm to 1.7 ppm are considered to be beneficial to the structure and development of decay prevention in tooth enamel, especially in children. However, above 1.7 ppm fluoride may cause mottled teeth, and in excess of 6.0 ppm can cause serious mottling of teeth and adverse skeletal effects. Quantities in excess of the range of safety or desirability are not known in either shallow aquifers or in the deeper (nonpotable) aquifers in the state.	6.0	0.1 – 1.5
Nitrate (NO_3)	Nitrates impart a bitter taste to drinking water, and concentrations from 20 – 50 ppm are either noticeable or objectionable. Little is known about the long-range effects of consumption of water containing moderate nitrate concentrations. A nitrate content of even 5 ppm in the formula of infants under one year old can cause a blood-oxygen deficiency known as methemoglobinemia. Natural ground waters in Indiana generally contain much less than 5 ppm. Nitrate levels above 25 ppm, especially when prior analyses show lower concentrations, often indicate some form of contamination. Organic wastes, inorganic compounds, and chemical ferilizers are sources of nitrates associated with the activities of man.	45	0.1 – 3.0
Hydrogen Sulfide (H_2S)	Ground water containing hydrogen sulfide (H_2S), or the "rotten egg smell," quickly makes its presence known. Even very small quantities, as low as 0.1 ppm, are easily identifiable and highly objectionable. Hydrogen sulfide is generated by chemical reaction, and biological or bacteriological actions, on various sulfur compounds incorporated in the rocks through which the ground water has passed. H_2S or "sulfur water" is sometimes confused with water containing a high amount of iron, particularly in those incidences when complex reactions occur with the magnesium electrodes in electric hot water heaters. This is a definite nuisance although not a danger.	na	na
pH	The pH of water is a measure of the degree of acidity or alkalinity and is expressed in values ranging from 0 to 14. At a pH of 7 water is considered neutral; below 7 indicates acidity; above 7 it is alkaline. Most of Indiana's ground waters are neutral or so close to it as to pose no significance for most uses. Corrosive acid waters, with pH levels ranging from 3 – 6, are associated with the coal section (Pennsylvanian) formations in some areas. Also of interest is the fact that high "soda" or alkaline waters (pH ranges from 8 – 10) are found in other rock units within the Pennsylvanian formations.	none given	6.5 – 8.0

na: not available

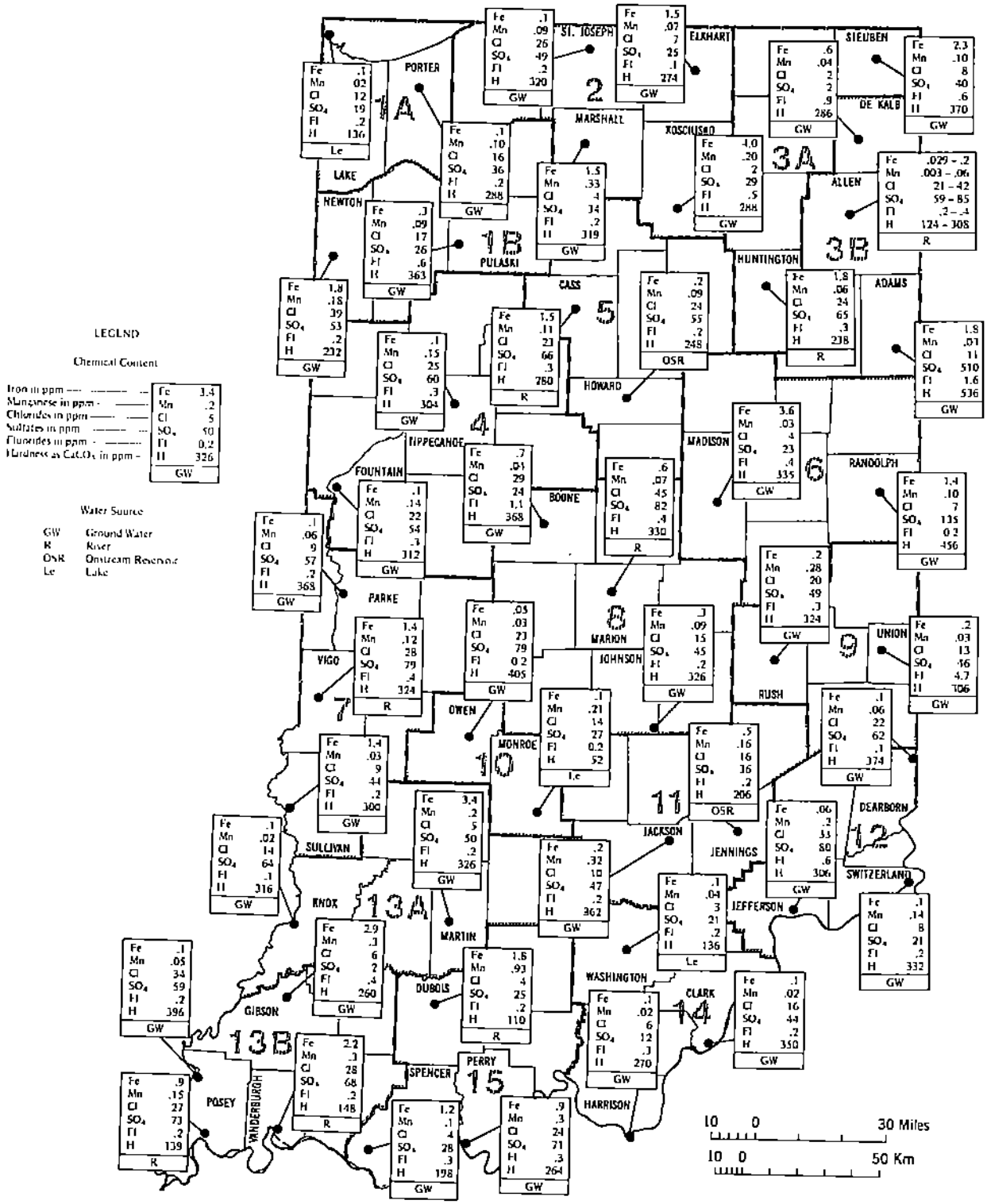


Figure 44
Map of Indiana showing the water quality for a number of municipal water supplies, and the sources of the supplies.

In general, the chemical content of ground water in Indiana is considered satisfactory for most household, municipal, commercial, and irrigation purposes, without significant treatment. Although the water from most aquifer systems is hard, exceeding the 180 parts-per-million classification for very hard waters, few municipal water supplies soften the water. Hardness levels above 300 ppm are present in much of the state, and portions of northeastern Indiana have hardness levels exceeding 600 ppm as indicated in Figure 45. Localized areas of high hardness are also found in extreme south-central Indiana in Harrison and Washington Counties and in northeastern Indiana in Lake County. A region of potentially softer water is present in the southwestern portion of the state where localized geologic conditions may be present in some of the aquifers where natural softening processes have reduced hardness levels below 100 ppm. This region corresponds to that underlain by the Pennsylvanian age bedrock. Other constituents of particular importance when viewing the state-wide chemical composition of ground water are iron, manganese, sulfate, fluoride, and hydrogen-sulfide.

The iron content of ground water is of concern primarily because of staining of plumbing fixtures and laundry. Figure 46 shows areas of low, moderate and high iron content within the state. For the most part ground water in Indiana contains more than 0.3 ppm of iron.

Manganese, often associated with high iron content is a nuisance when present in concentrations of over 0.05 ppm. The areas having the lowest manganese content in Indiana, as shown in Figure 47, are along the Wabash River, the Whitewater River in the southeastern part of the state and in areas underlain by Mississippian age limestone aquifers.

Sulfate levels vary in response to the type of geologic deposits present in an area. In northeastern Indiana sulfate levels in excess of 600 ppm are present, as shown in Figure 48. Elevated sulfate levels are also found in Harrison, Orange, Vermillion and Lake Counties.

Fluoride concentrations above 1 ppm, the recommended level for cavity prevention, are present in much of central and northeastern Indiana and in scattered parts of southwestern, west-central and northwestern Indiana, as indicated in Figure 49. Localized high fluoride concentrations in the western sectors of the state are attributed to geologic factors which have substantially changed the water chemistry of ground water in these areas.

Hydrogen-sulfide ("sulfur water") in even very small concentrations is particularly objectionable to domestic water users. Sizeable areas in northwestern Indiana are underlain by limestone bedrock containing water with a high level of hydrogen sulfide, as indicated on Figure 50. A shale bedrock capstone is present above the limestone in many places, and when the shale occurs at a shallow depth, it virtually eliminates all other alternative water supply possibilities.

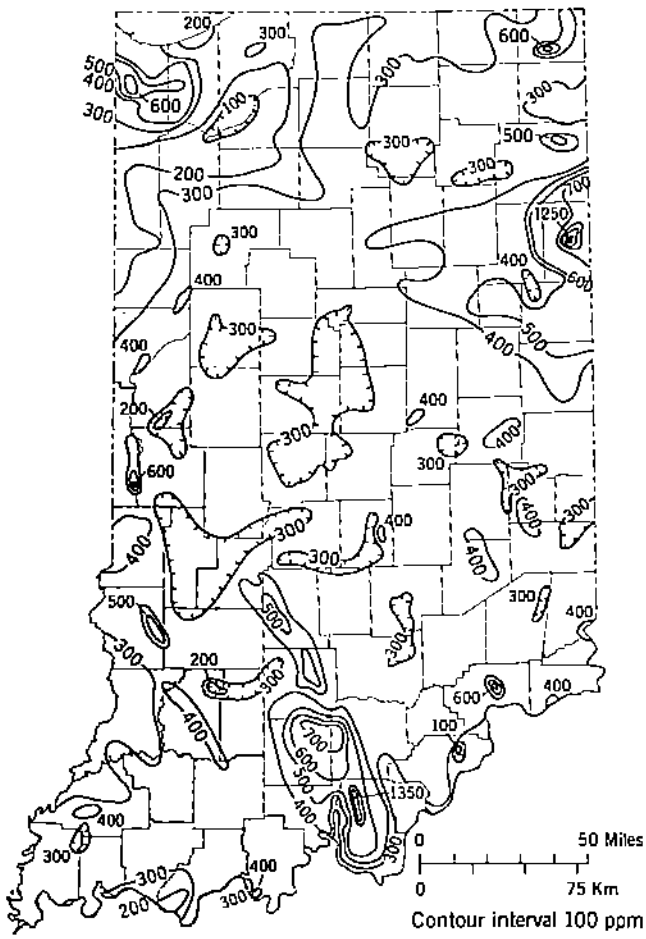


Figure 45
Map of Indiana showing the distribution of water hardness of ground water in parts-per-million.

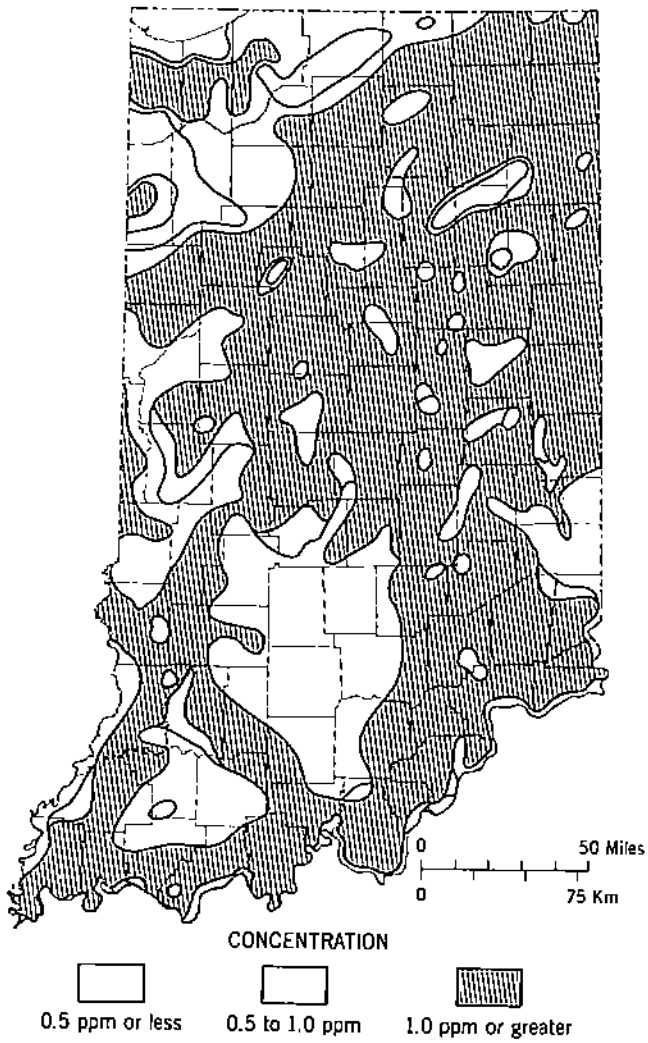


Figure 46
Map of Indiana showing the general concentration of iron in ground water in parts-per-million.

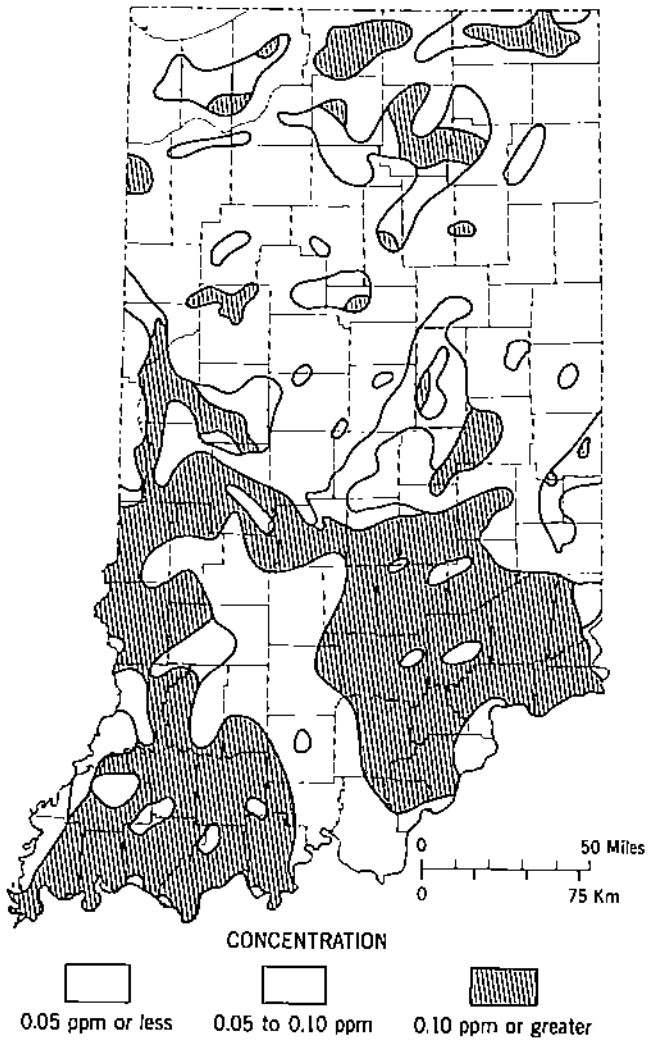


Figure 47
Map of Indiana showing the general concentration of manganese in ground water in parts-per-million.

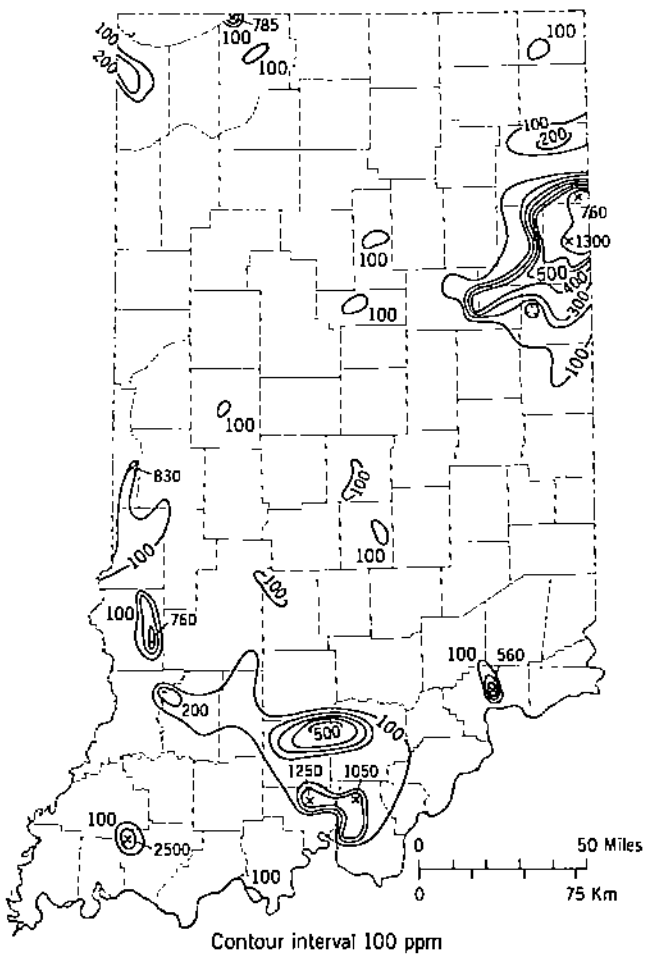


Figure 48
Map of Indiana showing the concentration of sulfate in ground water in parts-per-million.

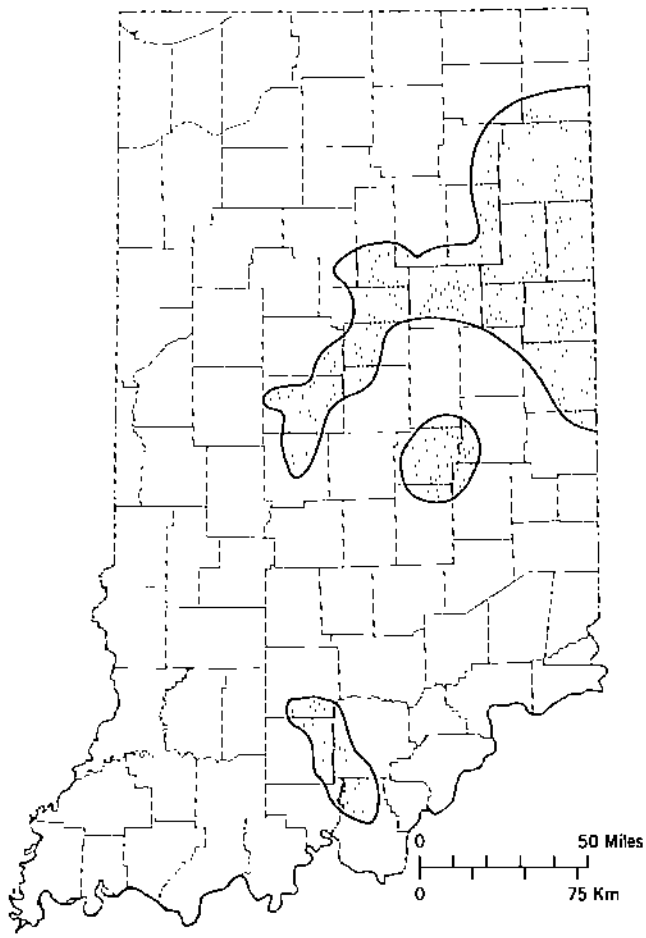


Figure 49
Map of Indiana showing the general distribution of fluoride in ground water.

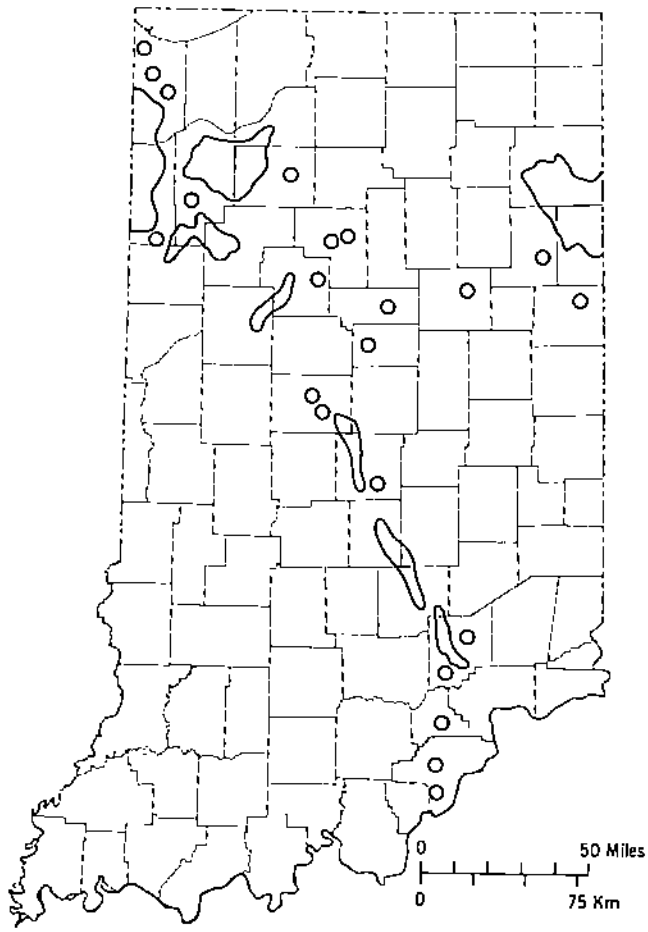


Figure 50
Map of Indiana showing the general distribution of hydrogen sulfide in ground water.

SURFACE WATER

The Stream Pollution Control Board was established in 1943 to abate or prevent pollution of Indiana waters. This board has established water quality standards for all Indiana streams and lakes. These standards are basically designed to protect both instream uses and withdrawal uses of the water resource.

Generally speaking, the standards established by the Stream Pollution Control Board are designed to mitigate the impact caused from the major sources of pollution. These sources are: municipal, industrial, land use, shipping, dredging activities, and miscellaneous spills of toxic substances.

Pollution From Municipal Sources The responsibility for control of pollution from municipal sources is legally vested in the Indiana Stream Pollution Control Board. All plans and specifications for abatement or correction of any polluted condition must be approved by this board, as required by law. All plans and specifications submitted to this board or the State Board of Health must be prepared by or under the supervision of a professional engineer legally registered in the State of Indiana, and must generally meet the minimum requirements as recommended in the *Ten States Standards for Sewage Works.*

A Wastewater Treatment Plant Operator Certification Law requires that the operation of all municipal wastewater treatment facilities be under the direct supervision of an operator certified under State Board of Health Regulation HSE 30-R. The regulation provides for the classification of wastewater treatment plants and sets the experience and educational requirements for operators. All licenses must be obtained by examination. There are provisions for revocation of licenses and fines for noncompliance.

Construction of all new wastewater treatment facilities within the state is generally required to provide average biological oxygen demand and suspended solids removal of at least eighty-five percent. In cases where the receiving stream lacks the capacity to assimilate secondary sewage treatment plant effluent discharges, a higher degree of treatment is to be provided so that the water quality standards of the receiving stream will be met.

The state requires each sewage treatment facility to submit monthly operation reports no later than the twenty-eighth day of the following month. A recommended schedule of laboratory tests is provided for each facility. The schedule indicates the type and frequency of tests depending on the size of the facility and its treatment processes.

The state established a schedule for correction of combined sewer overflows for several municipalities, and it will eventually require such control at all municipalities with combined sewers. A few projects have been completed and several others are progressing according to plan.

The selection of control methods is made on the basic engineering evaluation after investigating alternate methods. The state does not stipulate any one method for control. Any method selected must be capable of producing an effluent that will meet stream water quality standards after dilution.

Pollution from Industrial Sources The responsibility for control of pollution from industrial sources is legally vested in the Indiana Stream Pollution Control Board. All plans and specifications for abatement or correction of any polluted condition must be approved by this board.

The degree of treatment and control for industrial sources is determined by the amount of waste flow, type of waste, size of receiving stream, and downstream water uses. In all cases the degree of treatment

must be at least equivalent to best practicable treatment, as defined by the U.S. Environmental Protection Agency, for various industrial categories or secondary treatment. The applicable water quality standards are used to evaluate whether or not a proposed treatment system with its expected removal efficiencies is acceptable.

A Wastewater Treatment Plant Operator Certification Law requires that persons in responsible charge of the plant must be certified. Certification involves the passing of a written examination and the meeting of the educational and experience requirements established in Regulation HSE-30R. The law provides that a license may be revoked or a fine levied if it is determined that the operator has engaged in actions of fraud or has failed to perform his duties.

Regulation SPC-2 requires that all users and handlers of cyanide and cyanogen compounds provide facilities to isolate these compounds from any drain connected to a water course. The general isolation requirements are for the construction of curbed areas around or pits beneath the tanks or handling areas that will contain any leakage or spillage. There has been a significant reduction in cyanide-related fish kills and pollution incidents since full implementation of the regulation.

Radioactive materials have been monitored as part of regular survey work. Industrial inspections have revealed that radioactive materials are used mainly in insignificant quantities for analytical instruments.

Regulation SPC-11 requires all dischargers in the state to submit monthly reports to the Board of Health including flow measurements and effluent characteristics. Monitoring and the frequency of sampling are set individually for each plant. Surveillance of industries is accomplished by routine inspections, grab samples, and by periodic 24-hour surveys which monitor both the plants' discharges and the receiving waters.

Pollution from Land Use Activities In 1971, the Indiana General Assembly enacted a law regulating the distribution, sale, and use of pesticides and providing for the appointment of a Pesticide Review Board. The law specifies that all pesticides offered for sale in the state or transported within the state are to be registered in the office of the State Chemist. The Indiana Stream Pollution Control Board works with the State Chemist and the Pesticide Review Board to insure that pesticides are used in a manner that will not result in pollution of streams. The results of a pesticide monitoring program carried out by the state from the fall of 1969 to September 1971 indicate that there is not a significant pesticide problem in the Indiana portion of the Great Lakes Basin.

In 1971, a Confined Feeding Control Law became effective. This law defines confined feeding operations and requires that all operations exceeding 300 cattle, 600 swine or sheep, and 30,000 fowl, and those smaller operations causing violations of the Stream Pollution Control Law or Stream Pollution Control Board Regulations must receive approval of waste handling facilities from the board. The law further provides that all existing confined feeding operations over the numbers listed above must have submitted information of waste disposal practices to the board by July 1, 1973 for consideration. This provided an inventory of all operations above the indicated numbers.

Nutrient and sediment pollution contributed by agricultural runoff is a problem in portions of the Lake Michigan and Lake Erie Basins. However, sedimentation can be reduced by proper land and water management on the farms. The state works closely with the local Soil and Water Conservation Districts and encourages the development of Small Watershed Protection and Flood Prevention Projects under Public Law 566. In addition, the state encourages the use of agricultural practices that will minimize sediment and nutrient transport to tributaries of the Great Lakes.

Pollution from Shipping Activities In 1969, the Indiana General Assembly enacted an amendment to the 1957 Boating Law making it unlawful to operate any boat furnished with a toilet unless the toilet is equipped with a holding tank of sufficient capacity to store wastes for subsequent disposal at approved shoreside facilities or an incinerator or treatment system approved by the Stream Pollution Control Board. This amendment brought Lake Michigan under the same restriction as had previously been applied for all other waters of the state.

Pollution from Dredging Activities Indiana Harbor and other federal harbors on Lake Michigan are routinely dredged by the U.S. Army Corps of Engineers. Some of the material dredged is classified as polluted.

In 1969, disposal of these materials from Indiana Harbor by dumping in Lake Michigan was discontinued and all dredgings since that time have been placed behind the Inland Steel Company bulkhead-and-fill operation. Further concerns and restrictions on the disposal of polluted dredge spoil materials have raised substantial questions as to whether this site can continue to be used or another site made available. Current polluted dredge spoil from operations at Michigan City Harbor is disposed of at an approved inland site.

Pollution from Toxic Material Spills The Stream Pollution Control Board Regulation 16 requires the

immediate reporting of all spills and unauthorized discharges, of hazardous or objectionable substances to the stream board. It further specifies that the responsible person(s) for the spill or discharge take immediate action to contain and recover the toxic material. Failure to comply with these requirements may result in enforcement action by the board and civil penalties.

Spills of oil and hazardous material frequently pose threats to the environment either by fouling a lake or stream causing a fish kill, endangering livestock, or polluting a public water supply. In such events an "Emergency Response Team" is dispatched to the scene from the Water Pollution Control Division to evaluate and take appropriate action to clean up the spilled material. Citizen participation is also encouraged. Local industry, farmers, and residents living contiguous to the affected body of water are advised to consult local health departments for taking appropriate precautionary measures.

During 1977, two hundred and five spills were investigated. These investigations do not include discharges of partially treated sewage from treatment plants, other bypasses, sewer line breaks, or similar events. Spills which were reported and investigated often include instances of pipeline leaks and breaks, rail and truck accidents, storage tank leaks, ruptures, and various other incidents. With a high incidence of spillage, a correlation may exist between the type of spill with seasonal changes through the year. For example, slippery highways and poor visibility appear to be a significant contributing factor in transportation accidents during the winter and early spring. This may also account for the amount of agricultural spills resulting from the transportation of pesticides and fertilizers during the same period. Secondly, the thawing cycle in early spring may cause increased stress to underground pipelines. Hence, pipeline breaks and leaks appear to be a more common occurrence in the winter-spring cycle.

As indicated in Table 24, petroleum products were involved in sixty-four percent of the total spills investigated, representing thirty-two percent (158,320 gallons) of the total volume of spilled material, ranking second only to miscellaneous chemicals (255,135 gallons). It should be noted that a significant percentage of truck and pipeline incidents, twenty-three and sixteen percent respectively, and ship and barge accidents also involved petroleum products as indicated in Table 25.

Table 24
Type, number, and magnitude of toxic material spills.

Product	*Number of Spills*	*Percent of Spills*	*Amount of Product Spilled in Gallons*	*Percent of Total Spilled Material*
Petroleum Products	13	64	158,320	32
Acids and Bases	11	5	20,300	4
Miscellaneous Chemicals	18	9	251,135	50
Food Products	7	3	4,500	1
Agricultural Materials	22	11	61,305	12
Miscellaneous Materials	17	8	1,715	1

Table 25
Summary of the 1977 toxic spill investigation.

Source of Spill	*Percent of Sources*
Transportation Spills	
Trucks	23
Railroads	11
Ships and Barges	2
Industrial Spills	30
Pipeline Spills	16
Agricultural Spills	6
Miscellaneous and Unknown Sources	12

Fish Kills The aquatic habitat is the first to be impacted by pollution. Fish kills may result when a pollution event occurs. However, fish kills need not be expected in chronically polluted areas, since such areas do not usually support a significant fish population.

Fish kills generally result from unusual circumstances, such as an equipment failure, or a spill of toxic substances, or oxygen-demanding materials. Effects of such events are most severe when they occur during low-flow conditions in the summer and early fall. Fish kills usually occur during dry periods and

during dry years. Table 26 indicates the source of pollution causing the known fish kills which were investigated by the Stream Pollution Control Board during 1977.

Table 26
Summary of fish kill causes, 1960 to 1977.

Source and Number of Kills	*Percent of Total Kills*
Sewage Sources (102)	23.3
General (53)	12.1
Industrial Waste (17)	3.9
Combined Sewer Overflow and Bypassing (32)	7.3
Industrial Sources (143)	32.7
General (53)	12.1
Cyanide (9)	2.1
Canneries (24)	5.5
Oil (23)	5.3
Packing Plants (2)	0.5
Agriculture Plants (32)	7.3
Agriculture Sources (69)	15.8
Animal Wastes (42)	9.6
Silage (6)	1.4
Pesticides (10)	2.3
Ammonia (7)	1.6
Others (4)	0.9
Water Treatment Plants Sources (4)	0.9
Individual (7)	1.6
Natural Causes (19)	4.1
Undetermined Sources (94)	21.5

Lake Classification Program

Lakes, like living organisms, may be considered to undergo an aging process. Young lakes typically contain very low nutrient levels and consequently support very small populations of aquatic plants. As a lake matures, nutrients are generally introduced from direct surface runoff. As the nutrient level increases the population of aquatic plants increases. As the seasons pass, aquatic vegetation grows, dies, and settles on the lake bottom where it decomposes and releases its nutrients. With time, the nutrient levels increase, the density of aquatic vegetation increases, and the depth of the lake decreases. Eventually a lake may become a wetland and finally may revert back to land capable of supporting terrestrial vegetation.

The aging process of lakes is referred to as *eutrophication*. This aging process may be accelerated by the influence of man through the addition of nutrients. Lechates from septic fields not only decrease water quality but may cause massive growths of aquatic vegetation due to the increased nutrients available. This process of "cultural eutrophication" is common with lakes located near large population centers.

The Stream Pollution Control Board is completing the trophic or age classification of many fresh water lakes. As of February 1978, 404 natural lakes and 150 man-made impoundments totalling more than 87,500 acres were classified. These lakes are classified by age and quality in four "classes."

Class I is the least eutrophic (youngest) and has the highest quality of water. These lakes rarely support extensive populations of weeds or algae, an indicator of excessive nutrient levels. Lake uses are not normally impaired by the overall quality of water.

Class II lakes are of medium quality. These lakes frequently support extensive populations of weeds or algae. However, this plant growth seldom impairs existing lake uses.

Class III lakes always support extensive populations of weeds or algae which frequently impair existing lake uses.

Class IV lakes include remnant lakes which have become very shallow and always support extensive populations of weeds or algae. These remnant lakes are often transformed into wetlands. Tables 27 and 28 indicate the classification, number, and acreage of natural and man-made lakes classified as of 1978. The trophic levels of the lakes surveyed are indicated within the regional reports.

Table 27
Classification of natural lakes.

Class	*Number*	*Acres*
Class I	75	16,023
Class II	144	13,867
Class III	67	6,377
Class IV	118	2,448
Total	404	38,715

Table 28
Classification of man-made lakes.

Class	*Number*	*Acres*
Class I	44	31,157
Class II	62	14,748
Class III	44	2,813
Total	150	48,718

Summary

The Stream Pollution Control Board establishes and enforces water quality standards for streams and lakes within the state. The levels of wastewater treatment required of the various dischargers, such as municipal and industrial sources, are based upon these water quality standards. Any long-term change in the quantity of water resources may require changes in the

type and level of pollutant discharges. Some treatment changes will also occur due to increasingly stringent federal wastewater treatment requirements.

The reader who is interested in detailed information as to water quality standards, water quality management, programs, and the quality of ground or surface waters, including the various parameters of quality, should consult the Indiana Stream Pollution Control Board.

The Law of Water Rights

Classification of Water and Water Rights

Background and Policy Due to the movable and wandering nature of water, it is and must remain common property subject to right of use only. As stated by the United States Supreme Court:

> As long ago as the institutes of Justinian, running waters, like the air and the sea, were *res communes* — things common to all and property of none. Such was the doctrine spread by the civil-law commentators and embodied in the Napoleonic Code and in Spanish law. This conception passed into the common law.[1]

It is on this concept of common property that basic water law rights have evolved in the United States.

Water is essential to all life. Although water is the most abundant liquid on the face of the earth it is imperative that water resources be managed wisely. To do so it is necessary that a water resources policy be established and water rights defined, with both policy and rights designed to maximize beneficial uses and minimize water resource abuses.

The state's power to create and shape rights to the use of waters within its borders is, to some degree, limited by the constitutional power of the federal government to control commerce, provide for the common defense, make treaties, control compacts between states, and provide for the general welfare. However, the bulk of water law today remains as state law.

A detailed listing and description of both state and federal water laws by functional areas (instream uses, withdrawal uses, excess water, and water quality) is included in Appendixes 7 and 8.

Water rights are the result of both court decisions and legislative enactments. Although there are relatively few appellate court decisions involving water rights, much of the existing water rights law has been shaped by these decisions, many of which were decided prior to the turn of the century and rested on English common law doctrines and principles of law.

Prior to 1920 water policy was primarily formulated by local governments or local citizens operating by state permission. In 1919 the general assembly created the State Department of Conservation,[2] the earliest effort toward a statewide water resources policy. Further legislation designed to establish statewide water policies and the creation of new state agencies to carry out such policies was not forthcoming until the mid-1940s. The Stream Pollution Control Board was created in 1943[3] and the Flood Control and Water Resources Commission in 1945.[4] In 1965 the Department

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of Natural Resources was established,[5] bringing together in one agency the functions and responsibilities of the Department of Conservation, the Indiana Flood Control and Water Resources Commission, and the State Soil and Water Conservation Committee.[6]

Recognizing the need for protection against the loss of lives and property caused by flooding, the Flood Control Act of 1945[7] sought to regulate and supervise flood control works and structures, as well as to establish policies and practices to conserve the diminishing water resources of Indiana.

In 1947 the general assembly declared as a public right the preservation of natural scenic beauty of public fresh water lakes in Indiana, the act[8] reading in part as follows: "The natural resources and the natural scenic beauty of Indiana are declared to be a public right, and the public of Indiana is hereby declared to have a vested right in the preservation, protection and enjoyment of all the public fresh water lakes of Indiana in their present state, and the use of such waters for recreational purposes."[9]

A basic policy statement in respect to ground water is found in the Acts of 1951 wherein the general assembly declared as public policy of the state the conservation and protection of "the ground water resources of the state" and for that "purpose to provide reasonable regulations for its most beneficial use and disposition."[10] It was not until 1955 that the legislature recognized the need for management of surface water for beneficial uses. The general assembly declared "that the general welfare of the people of the State of Indiana requires that surface water resources of the state be put to *beneficial uses to the fullest extent and that the use of water for non-beneficial uses be prevented. . . .*"[11] The same act also provided that "water in any natural stream, natural lake or other natural body of water in the State of Indiana which may be applied to any useful and beneficial purpose is hereby declared to be a natural resource and public water of the State of Indiana and subject to control or regulation for the public welfare as hereinafter determined by the General Assembly of the State of Indiana."[12]

The acts creating the various state agencies and setting forth the basic water resources policy of the State of Indiana are not intended to be all-inclusive. They are sufficient, however, to indicate a conscious effort to establish a statewide water resources policy and agencies with responsibility for the carrying out of such policies. The various acts also indicate an effort to link water rights with water resources management in the interest of all citizens of the state.

At the present time both ground and surface water appear to be readily available and generally quite adequate in most parts of the State of Indiana; however, with more urbanization, increased industrialization, and the anticipated demand for recreational waters this may not be true in the future. Natural distribution of usable water may not always be paired with needs and may eventually require expensive diversion and conversion plans as the state seeks to balance availability with demands. Proper water resources management could do much to postpone such an eventuality.

Classification of Water All water is a part of the same hydrologic cycle, a never-ending process occurring in nature wherein moisture is drawn into the atmosphere from the land and sea to form moisture laden clouds. With changes in air pressure the clouds release the stored moisture which returns to earth in the form of rain, sleet, or snow. Much of this precipitation will run off into lakes, streams, and rivers from which a part, through evaporation, will begin the cycle again, with the remainder completing the journey to the sea before starting the cycle anew. Of that part that does not run off into watercourses, some will evaporate from the earth's surface while some will percolate into the soil. A portion of the water percolating into the soil will be taken up by plants to begin the cycle again through transpiration, while the remainder will percolate through the soil and become ground water to feed streams and rivers before starting the cycle again. All phases of the cycle must be considered in achieving a coherent and satisfactory water resources management program and in allocating rights to the use of waters.

Legal classifications of water are based on the location of water in relation to the earth's surface. Water could be broadly classified as: (1) occurring on the earth's surface, and (2) occurring below the surface of the earth.[13] Both case and statutory law recognizes separate and distinct water rights and doctrines with respect to three categories: (1) water below the surface of the earth or "ground water," (2) surface waters in a watercourse, and (3) diffused surface water. Water rights will be discussed under these three categories after the following brief definitions of water in each category.

Ground Water[14] Ground water includes all subterranean water regardless of location and form.[15] While the distinction has been challenged,[16] the common law of ground water recognizes two classes: (1) that which was diffused through the ground as percolating water, and (2) that found in underground streams.[17] There is a presumption that subterranean water is percolating water, and the burden is on the party asserting an underground stream to prove the existence thereof.[18]

Surface Water in a Watercourse In general surface water in a watercourse,[19] to which riparian rights at-

tach, may be defined as water that flows with regularity and dependability along a definite course and in a definite channel with bed and banks or sides.[20] This may include not only ordinary surface water in streams and rivers but also lakes, ponds, swales, and marshes through which the watercourse flows.[21] Surface water in a watercourse also includes flood waters overflowing the banks of a natural watercourse.

Diffused Surface Water[22] Diffused surface water, or overland flow, or excess water are those waters that are derived from falling rains, melting snow or springs, and that diffuse themselves and flow vagrantly over the surface of the earth, following no defined course or channel.[23] It is not the source that determines diffused surface water but rather the fact that such water follows no defined course or channel. Diffused surface water retains its characteristics until it reaches some well defined channel or becomes a part of a watercourse.[24] Diffused surface waters may include floodwaters which have become permanently separated from the water in a watercourse.[25]

References

1. *United States v. Gerlach Live Stock Co.*, 339 U.S. 725, 744-45, 70 S. Ct. 955, 965 (1950).
2. Act of March 11, 1919, ch. 60, 1919 Ind. Acts 375 (now codified at Ind. Code §§ 14-3-1-1 to 29 [1976 & Supp. 1978]).
3. Act of March 8, 1943, ch. 214, 1943 Ind. Acts 624 (now codified at Ind. Code §§ 13-1-3-1 to 18 [1976 and Supp. 1978]).
4. Act of March 7, 1945, ch. 318, 1945 Ind. Acts 1480 (now codified at Ind. Code §§ 13-2-22-1 to 20 [1976 & Supp. 1978]).
5. Act of March 13, 1965, ch. 441, 1965 Ind. Acts 1402 (now codified at Ind. Code §§ 14-3-2-1 to 9 [1976 & Supp. 1978]).
6. With the creation of the Department of Natural Resources, the Department of Conservation and the Flood Control and Water Resources Commission were abolished.
7. Act of March 7, 1945, ch. 318, § 2, 1945 Ind. Acts 1480 (now codified at Ind. Code § 13-2-22-2 [1976 & Supp. 1978]).
8. Act of March 13, 1947, ch. 301, § 1, 1947 Ind. Acts 1233 (now codified at Ind. Code § 13-2-14-1 [1976]).
9. It does not necessarily follow that individual citizens of the state have the use of fresh water lakes for recreational purposes as a result of the language of the statute, *i.e.*, declaring that the public of Indiana has a vested right in the use of such waters for recreational purposes. This recreational use will depend on whether a public right has been acquired by acquiescence. See Chapter II-A, p. 10.
10. Act of Feb. 21, 1951, ch. 29, § 2, 1951 Ind. Acts 64 (now codified at Ind. Code § 13-2-2-2 [1976]).
11. Act of March 11, 1955, ch. 251, § 1, 1955 Ind. Acts 643 (emphasis added) (now codified at Ind. Code § 13-2-1-1 [1976]).
12. *Id. See also* Ind. Code § 13-2-1-8 (1976), which provides, "The policy that surface waters of Indiana are declared to be public waters and subject to regulation by the Indiana general assembly, shall be the accepted policy of the state of Indiana."
13. Wells Hutchins, a noted water law authority, classified all waters into two broad categories: (1) waters on the surface of the earth, and (2) waters under the surface of the earth. He further classified waters on the surface as follows: (1) diffused surface waters, (2) surface waters in a watercourse, (3) surface waters in lakes or ponds (when evidence fails to indicate connection with a stream system), (4) spring waters, and (5) waste waters. Vol. I, *Waters and Water Rights* § 3.1, at 18 (R. Clark, ed. 1967) [hereinafter referred to as R. Clark].
14. For a discussion of ground water, see Page 94 *infra*.
15. R. Clark *supra* note 13, § 52.2, at 322; Vol. 6A, *American Law of Property* § 28.65 (A.J. Casner, ed. 1954).
16. Thomas, *Underground Sources of Water*, USDA Yearbook: *Water* 62, 66-67 (1955); Thomas, *Hydrology vs. Water Allocation in the Eastern United States, The Law of Water Allocation in the Eastern United States* 165, 169-170 (1958).
17. R. Clark, *supra* note 13, § 52.2, at 322.
18. *Id. See also* 93 C.J.S. *Waters* § 87 (1956).
19. For a discussion of what constitutes a watercourse, *see* p. 99 *infra*.
20. *Lowe v. Loge Realty Co.*, 138 Ind. App. 434, 214 N.E.2d 400 (1966); *Vandalia R.R. v. Yeager*, 60 Ind. App. 118, 124, 110 N.E. 230, 234 (1915).
21. R. Clark *supra*, note 13, § 52.1B, at 311. *See also* discussion of watercourse at p. 99 *infra*.
22. For a complete discussion, including the characteristics of and rights to diffused surface water, *see* p. 119 *infra*.
23. *Capes v. Barger*, 123 Ind. App. 212, 109 N.E.2d 725 (1953); R. Clark, *supra* note 13, § 52.1A, at 300-01. *See also* the statutory definition, which parallels the common law definition, Ind. Code § 13-2-1-4 (3) (1976).
24. R. Clark *supra* note 13, § 52.1A, at 300-01.
25. *Dunn v. Chicago I. & L. Ry.*, 63 Ind. App. 553, 114 N.E. 888 (1917).

Ground Water

Definition and Classification

Ground water may be defined as water that lies or flows under the earth and is not artificially confined.[1] Courts early made a distinction between underground water flowing in a defined channel as an underground stream, and ground water, which merely percolates[2] (passes gradually through small spaces or a porous substance) through underground formations. At the time the law was in its formative stages, the geophysical qualities of ground water were largely unknown, a fact recognized by the Indiana Supreme Court.[3] Modern hydrologists and geologists challenge this distinction on the premise that all underground water flows, and it should not matter whether it moves through large openings as a stream or trickles through small openings.

However, regardless of the possible inaccuracy of making a distinction between underground streams and percolating ground water, the early law in most jurisdictions evolved with those two distinct categories in mind, and different rules were applied to each.

As a general rule, the rights of landowners over an underground stream parallel the rights of riparian owners on a surface watercourse. Thus, if the jurisdiction is one that recognizes reasonable use for riparians, the owners of land above an underground stream must exercise reasonable use of the water in the underground stream. On the other hand, if the ground water is not part of an underground stream, but is percolating ground water, different doctrines define the rights to use the water. Although a number of doctrines have at one time or another been applied to percolating ground water, they fall roughly into two categories: the absolute ownership doctrine, and the correlative rights doctrine.

Absolute Ownership Doctrine Jurisdictions that have adopted the absolute ownership doctrine consider that percolating ground water is a part of the land in which it is found, and the owner of the land above it may divert or appropriate it for the benefit of his land even though by doing so he may injure his neighbor.[4] Accordingly a landowner may dig a well and drain off for his own use any ground water under his land even though, by removal, he drains water from under the surface of his neighbor's land. Some jurisdictions adopting this doctrine have qualified it so that a landowner may not act maliciously to the detriment of his neighbor.[5]

Correlative Rights Doctrine Courts applying this doctrine have held that all owners of land over a common supply of ground water have correlative rights to the reasonable use of the water on overlying lands. If a surplus of water exists above that necessary for reasonable use on overlying lands, it may be appropriated for reasonable use on nonoverlying lands. However, if a shortage occurs, the courts will be called upon to apportion the water to the owners according to their needs. This doctrine is analogous to the rights of riparian owners on surface watercourses under the reasonable use doctrine.[6]

Ground-Water Rights

Following the general pattern of the development of the Indiana water law, the earliest law pertaining to the use of ground water was articulated by the courts, whereas the more recent law has been created by the state legislature.

Case Law Three early Indiana cases left the Indiana ground-water law in a state of confusion. The first, *New Albany & Salem Railroad v. Peterson*,[7] was a case in which the defendant railroad, in excavating a roadbed, changed the pattern in which the ground water flowed to such an extent that the plaintiff's well on neighboring land went dry. In denying plaintiff's prayer for damages, the court noted that the same law that applies to water above ground need not apply to ground water.

> The court reasoned: We think the present case . . . is not to be governed by the law which applies to rivers and flowing streams, but it rather falls within that principle which gives to the owner of the soil all that lies beneath his surface; that the land immediately below is his property, whether it is solid rock, or porous ground, or venous earth, or part soil part water; that the person who owns the surface may dig therein, and apply all that is there found to his own purpose, at his free will and pleasure; and that if in the exercise of such right, he intercepts or drains off the water collected from underground springs in his neighbor's well, this inconvenience to his neighbor falls within the description of *damnum absque injuria*, which cannot become the ground of an action.[8]

Thus, the Indiana Supreme Court in 1860 clearly and unreservedly adopted the absolute ownership doctrine in regard to ground water.

In 1864, the Indiana Supreme Court again addressed the problem of ground water in *City of Greencastle v. Hazelett*,[9] a case brought by the plaintiff landowner to enjoin the defendant city from building a cemetery on adjoining land which might pollute his ground-water supply. The court cited the earlier case for the proposition that everything found below one's land is one's absolute property, thus reaffirming the absolute ownership doctrine.[10] In addition, the court apparently rejected the distinction between rights in underground streams and other ground water and indicated the absolute ownership doctrine applies to all ground water.[11]

The third and leading case in Indiana on the subject of ground water is *Gagnon v. French Lick Springs Hotel Co.*[12] The plaintiff owned a health resort in the French Lick Valley that depended for its success upon the flow of certain allegedly medicinal springs. The defendant, a bitter enemy of plaintiff, owned land adjacent to the resort. He sank a number of wells upon his own property and pumped millions of gallons of the medicinal waters which he allowed to run into French Lick Creek. The effect of this was to diminish the flow from the springs on plaintiff's property to the point that the springs were virtually dry. From the evidence at trial, it was clear that the defendant's express purpose in pumping the water was to ruin the plaintiff's business.

The plaintiff sought to enjoin defendant's activities, but the defendant asserted that according to the absolute ownership doctrine, he had an absolute right to do what he pleased with the ground water which came from his own land. Without even referring to prior Indiana Supreme Court cases which had espoused the absolute ownership doctrine, the court affirmed the trial court's grant of the injunction in favor of plaintiff, thereby denying the defendant's right to pump the water from his land.

Obviously the appropriate result was reached in this case. To allow the defendant to intentionally and maliciously waste millions of gallons of valuable water would have been ridiculous. However, the court's reasoning left Indiana's ground-water law unsettled.

While recognizing the general rule applied to subterranean waters that the owner may do what he wishes with the water, the court also recognized a need for flexibility in regard to ground-water law.[13] The court went on to note specifically exceptions to the general rule recognized in other jurisdictions. For example, it recognized that a malicious diversion of ground water may be enjoined[14] and that ground water may not be merely wasted.[15]

Unfortunately, it is not clear from the case whether the court characterized the medicinal spring water in question as an underground stream or as percolating ground water. Therefore, it is difficult to know how to interpret the court's reference to two California cases. Ignoring the prior Indiana Supreme Court case which had apparently held the absolute ownership doctrine controlled the use of underground streams, the court cited one California case in which it was held that if water flows in a definite channel underground, the same rules apply to it as apply to surface streams and the landowner may not destroy it.[16] However, the court also cited another California case which held that percolating ground water cannot be withdrawn for sale if other overlying landowners are deprived of the profitable enjoyment of their land as a result.[17] It is impossible to know which (if either) rule was applied to the case at hand. Furthermore, the phrase "profitable enjoyment" used in the latter case is enigmatic. Presumably a "sale" was not the kind of profitable enjoyment the court envisioned. Possibly "profitable enjoyment" should be interpreted to mean "beneficial enjoyment" — also a vague term but at least one that is used with regularity in water law.

The court went on to refer to "the strong trend of the later cases . . . toward a qualification of the earlier doctrines that the landowner could exercise unlimited and irresponsible control over subterranean waters on his own land without regard to injuries which might thereby result to land of other proprietors in the neighborhood."[18] However, it did not make clear whether the later cases were those it had specifically cited (some of which were as early or earlier than the earliest Indiana cases) or whether it was merely referring in general to a modern trend away from the absolute ownership doctrine.

In either event, the court purported to be "following the lead of the later cases, which, we think proceed

upon just and correct principles. . . ."[19] If by this the court intended to adopt the holdings of the cases it had specifically cited with approval, then the effect was to adopt the correlative rights doctrine for Indiana in the area of percolating ground water and the reasonable use doctrine for underground streams. On the other hand, the court may have only intended to adopt the qualification on the absolute ownership doctrine that a malicious or wasteful use of ground water will not be tolerated. This is the more likely intent. Thus, at the very least the court held that a malicious or wasteful use of ground water will not be tolerated; at the very most it held that Indiana applies the correlative right doctrine to percolating ground water and a reasonable use doctrine to underground streams.

Although it is obvious from *French Lick* that wasteful uses of ground water will be prohibited, it is difficult to determine what uses are deemed permissible. Should the case be interpreted to mean a withdrawal for sale (commercial use) will not be permitted if it denies another overlying landowner "profitable enjoyment"? Will a municipality be precluded from drilling wells and withdrawing water for sale if any other overlying landowner could show he was injured thereby?

Even if the absolute ownership doctrine pertaining to ground water still applied in Indiana after *French Lick*, it is unlikely that the rationale for applying it exists today. The reason given by the early courts for using the absolute ownership doctrine was that the location and quantity of ground water was unknown and unknowable. However, in the years since those early cases were decided, the sciences of hydrology and geology have evolved to the point that there is a greatly increased potential for predicting the location, amount, and flow patterns of water below the earth's surface. Therefore, in light of the more equitable doctrines that have evolved in other areas of water law such as the reasonable use doctrine for riparian owners it is unlikely that the absolute ownership doctrine would be strictly applied today.

Statutory Law Legislation in Indiana pertaining to ground water makes no distinction between underground streams and percolating ground water. Ground water is defined by statute as, "all water filling the natural openings under the earth's surface including all underground streams, artesian basins, reservoirs, lakes and other bodies of water below the earth's surface."[20] Although the statute does not speak to the doctrines that will apply to ground water, whatever limitations are prescribed by statute apply to all ground water unless specifically stated otherwise.

The importance of Indiana's ground-water resources cannot be overemphasized. Changes in ground-water levels may cause serious surface ramifications: crops which have always been easily grown may fail to thrive; buckling and cave-ins may occur; surface lakes and streams dependent upon underground springs may run dry. In addition, much of Indiana is dependent upon wells for drinking water and other domestic uses. Recognizing the importance of ground water as a valuable resource, the general assembly has declared it to be the public policy of the state to protect ground water and provide reasonable regulations to apply it to its most beneficial use.[21]

The Legislature has limited a landowner's or lessor's right to unlimited use of ground water under certain circumstances.[22] If the Department of Natural Resources determines that the withdrawal of ground water in an area exceeds or threatens to exceed its natural replenishment, it may designate that area as a restricted use area. If such a designation is made, all users (except publicly or privately owned utilities) must obtain a permit in order to withdraw more than 100,000 gallons-per-day. Prior users must obtain a permit in order to withdraw 100,000 gallons-per-day in addition to the quantity they were using at the time the order became effective. In determining whether a permit should be issued, the department will consider the future supplies in the area, the use to be made of the water, the effect on present users, the future replenishment, the future demands, and the best interest of the public. Those committing waste may be required to return water to the ground insofar as that is safe or practicable. Use of ground water for air cooling may be waste if it is not used more than once and if it is not put to any further beneficial use.

To the extent that these statutes constitute an interference with a vested property right, they may be subject to challenge on the constitutional ground. However, it is probable that they are nothing more than a legitimate exercise of the police power which may be used to protect against nonbeneficial uses of a valuable water resource.

The legislature has also addressed itself to the conservation of potable ground water.[23] Owners of flowing water wells may be required to reduce the flow to prevent the loss or waste of potable water that is not being put to a beneficial use. Furthermore, a permit must be obtained from the Department of Natural Resources before potable ground water may be introduced into underground formations that contain nonpotable water. The permit may be denied if the department determines the potable ground water would be wasted, the supply impaired or exhausted, and if, nonpotable ground water is available. However, potable water may be used by anyone operating a flood water project unless an emergency effecting household or farm uses should arise.

A 1959 act requires that well-drilling contractors be

licensed.[24] This includes anyone who owns or leases well-drilling equipment and drills or drives wells, unless the drilling occurs on land he owns or holds under a valid lease.[25] The statute further requires that accurate records be kept as to the location of the well, the depth, the diameter, the date it was completed, the character and thickness of the formation drilled, and the performance data of the well.

Recognizing that the waters and lands of the state must be protected against pollution, a procedure is provided by statute for the plugging of abandoned or leaking wells that were drilled for the exploration, development, or production of oil or gas.[26] Similar provisions are made for the plugging of test holes drilled in connection with the following investigations: fluid disposal, mineral resources, engineering projects, and geologic.[27]

In 1978, the general assembly repealed the Act of 1909 (passed possibly in response to *French Lick*) prohibiting tampering with the flow of or polluting mineral medicinal waters.[28] Thus, all ground water, regardless of its mineral content, is treated the same under the current statutory scheme.

In summary, although it is clear that ground water should be protected from pollution and put to beneficial use, it is difficult to glean from the statutes just what uses the general assembly considers beneficial. Publicly owned and privately owned utilities are exempted from obtaining permits to use ground water in restricted use areas. This exemption may imply that the general assembly considers that the supplying of public utilities is a beneficial use of ground water. Prior users in restricted use areas are limited to 100,000 gallons-per-day *in addition to* their prior use, whereas new users are limited to 100,000 gallons-per-day. This provision implies that the prior appropriation doctrine may apply in restricted use areas. The use of ground water in a restricted use area for air cooling may be waste if the water is used only once. However, it may be a beneficial use if it is used more than once or in conjunction with other beneficial uses. Flood water projects are sufficiently beneficial that potable water may be used to implement them unless that water becomes necessary for household or farm use.

From the foregoing, it is obvious that the acceptable uses of ground water in Indiana are not clear. However, it is clear that the legislature has recognized the importance of Indiana's ground-water resources and has taken numerous measures to assure their protection. The Water Resources Research Act of 1965 lists the mapping of the location and availability of ground water as an urgent necessity.[29]

In addition, the quality of ground water will be protected by the Stream Pollution Control Board which has the jurisdiction to control and prevent pollution in waters in the state from any deleterious substance.[30] Furthermore, the Environmental Management Board was created to evolve and implement policies for comprehensive environmental development and control on a statewide basis.[31] It is bound to protect the public water supply which includes ground water.

Thus, the general assembly recognizes the value of Indiana's ground-water resources and has enacted legislation showing a strong, statewide protection policy.

References

1. *Restatement of Torts* § 845 (1939).

2. Another type of ground water is water that does not move but has been absorbed by underground formations and makes up part of the water table. This water is generally categorized with percolating ground water.

3. In *City of Greencastle v. Hazelett*, 23 Ind. 186, 187 (1864), the court noted, "Their courses, and even their existence are often unknown, until accident discovers them. The geologist has no knowledge which enables him to trace their channels. They can as a general thing, be definitely ascertained only by excavation."

4. The absolute ownership doctrine was first articulated in the English case, *Acton v. Blundell*, 12 M. & W. 324, 152 Eng. Rep. 1223 (1843).

5. *See* Annot., 55 A.L.R. 1385, 1390-98 (1928), for a state-by-state summary of how the doctrine is applied; *see also* Annot., 29 A.L.R.2d 1354, 1357-61 (1953).

6. Some jurisdictions purport to apply a "reasonable use doctrine" to ground water. However, application of the reasonable use doctrine is difficult to distinguish from the correlative rights doctrine.

7. 14 Ind. 112 (1860).

8. *Id.* at 114 (quoting Acton v. Blundell, 12 M. & W. 324, 152 Eng. Rep. 1223 [1843]).

9. 23 Ind. 186 (1864).

10. There is some troublesome language in the case suggesting that the absolute ownership doctrine might not be strictly applied if actual damage can be shown. The court stated:

> Should this injunction be sustained, it is quite possible, and not very improbable, that the city of *Greencastle* will be restrained from making a use of its own property, upon the mere conjecture that such use will injure *Hazelett*, when in fact it will not. Such is the nature of the subject, that no certain knowledge exists as to whether he would be injured or not. He is not positive about it in his complaint, because indeed he could not be. It is mere matter of opinion. Intelligent and reputable citizens, whose affidavits were read upon the application, differ upon the question. A geologist, who is a professor of natural science in *Asbury University*, thinks that much of the cemetery grounds are so situated that streams beneath the surface flow, not toward, but away from, the plaintiff's spring. But we do not decide this case upon any inclination to approve either of these differing opinions; the circumstances are alluded to only to show that the subject is of such a nature that the law regulating rights in surface streams ought not to be held applicable to it.

Id. at 188.

11. The court's specific rejection of the correlative rights doctrine for underground streams leads to the inescapable conclusion that the absolute ownership doctrine applies to underground streams as well as percolating ground water. The court said:

> It seems to result, from this view of the matter, in the light of just principle and sound public policy, without regard to authority, that it would probably be also impossible to establish correlative rights in a subterraneous stream, the situation of which is not known, by any set of rules which the law-making power could devise, without doing injustice or creating great embarrassment in the use of property.

Id.

12. 163 Ind. 687, 72 N.E. 849 (1904).

13. The court's statement that "there are well recognized exceptions to these rules, and doubtless further exceptions and departures from them will from time to time be found necessary or expedient" illustrates the court's willingness to allow changing conditions to shape the applicable law. *Id.* at 696, 72 N.E. at 851.

14. *Id.* (citing *Miller v. Black Rock Springs Imp. Co.*, 99 Va. 747, 40 S.E. 27 [1901]).

15. 163 Ind. at 696, 72 N.E. at 851 (citing *Stillwater Co. v. Farmer*, 89 Minn. 58, 93 N.W. 907 [1903]).

16. 163 Ind. at 696, 72 N.E. at 851-52 (citing *Southern Pac. Ry. v. Dufour*, 95 Cal. 615, 30 P. 783 [1892]).

17. 163 Ind. at 697, 72 N.E. at 852 (citing *Katz v. Walkinshaw*, 141 Cal. 116, 70 P. 663 (1902), *reversed on rehearing*, 141 Cal. 116, 74 P. 766 [1903]).

18. 163 Ind. at 697, 72 N.E. at 852.

19. *Id.* at 698, 72 N.E. at 852.

20. Ind. Code § 13-2-2-1 (1976).

21. *Id.* § 13-2-2-2.

22. *Id.* §§ 13-2-2-1 to 13.

23. *Id.* §§ 13-2-3-1 to 3.

24. *Id.* §§ 25-39-1-1 to 5.

25. *Id.* § 25-39-1-5 (Supp. 1978).

26. *Id.* §§ 13-4-4-1 to 8 (1976).

27. *Id.* §§ 13-4-5-1 to 11.

28. *Id.* §§ 13-2-6-1, *repealed by* Act of March 9, 1978, Pub. L. No. 2, § 1331, 1978 Ind. Acts 2.

29. Ind. Code §§ 13-2-7-1 to 4 (1976).

30. *Id.* § 13-1-3-4.

31. *Id.* §§ 13-7-1-1 to 13-7-18-1.

Surface Water in Natural Watercourses

Riparian Rights

Two natural watercourse rights doctrines have emerged, prior appropriation and riparian. Where the common law has not been changed, owners of land abutting on bodies of water have rights commonly referred to as "riparian rights."[1] Riparian rights are based on land ownership bounding upon the flow of a watercourse. As stated by an Indiana appellate court, "There can be no riparian rights unless the land involved borders on a body of water, as a stream or lake."[2] In contrast, the doctrine of "prior appropriation," which originated in the semi-arid and arid regions of the western United States, is based on the separation of water rights from land ownership.[3] Riparian rights attach by virtue of lateral contact of owned land with the water and do not depend upon soil ownership under the water.[4] Further, riparian rights attach to navigable as well as nonnavigable bodies of water, limited only by public rights that appertain to navigable waters.[5]

Indiana has long recognized the "riparian rights doctrine."[6] Before discussing what rights a riparian has in the waters of a natural watercourse, one must first establish what constitutes a "natural watercourse" and what land can be said to be "riparian land."

Watercourse Defined While there is no single, all-inclusive definition of what constitutes a watercourse, certain characteristics of a watercourse clearly emerge from Indiana case law. It must have a substantial existence and unity, regularity and dependability of flow along a definite course,[7] and a definite channel with bed, banks, or sides.[8] Although a source of supply and permanence of flow are generally considered essential, the flow need not be continual but should be present for a substantial period each year.[9] A watercourse should ordinarily flow "in a certain direction"[10] with a traceable flow from one tract to another,[11] and nature must have played a major role in the creation of the watercourse channel.[12] Once a watercourse has been established, it may continue without some of the usual characteristics. Thus, when a watercourse has been closed and the land improved by the landowners, it does not lose its characteristics as a watercourse by confinement to an artificial channel.[13]

It has been held that a watercourse includes not only ordinary surface waters therein but also lakes, ponds, swamps, swales, and marshes through which the watercourse flows.[14] An Indiana appellate court quoted with approval the following language from an earlier Wisconsin case: "If a watercourse is lost in a swamp or lake, it is still a watercourse if it emerges therefrom in a well-defined channel; or if it spreads over a meadow, and can be identified or traced as the same stream it is still a watercourse."[15] Although this would appear to be an appropriate classification, an Indiana statutory section recognizes that there may be some differences as to both private and public rights in such waters, and it appears to exclude waters in lakes and swamps from the "watercourse" classification:

> The term "watercourse" shall include both the upstream and downstream portions of a watercourse which is lost in a swamp or lake, if it emerges in a well defined channel.[16]

Early Indiana cases[17] held floodwaters — that is waters which overflow the banks of a natural watercourse — to be diffused surface waters. However, today such overflowing water as follows the course of the stream and eventually returns to the watercourse on subsidence is considered water of the natural watercourse.[18]

Riparian Land Indiana has never defined riparian land except that the existence of riparian rights requires such land to border on the waters of a natural watercourse or body of water. The important question

of geographical limits remains unanswered. Court decisions from other states provide us with no single definition. One line of cases uses what may be called the "source of title" test, which limits riparian land to land that abuts on the watercourse, is held in one ownership, and has never been severed from the stream from time of patent from the government. By this test, an entire tract bordering on and contiguous to the water would be riparian land, no matter how large the tract, as long as the entire tract was patented as a single unit. If and when the patentee or his successor conveyed portions of the tract not bordering on the water to others, such land would become nonriparian, and repurchase by the owner of the remaining riparian land would not affect its nonriparian status.[19] This test does not depend on the riparian land being situated in the watershed.[20]

Another line of cases uses what may be called the "unity of title" test, holding that all land held in a single title which is contiguous to the watercourse is riparian land.[21] Unlike the "source of title" test, riparian land may not only diminish in area by conveyance of a part of the contiguous tract, but it may also expand if contiguous land is purchased by the riparian owner. This test does not limit riparian land to land within the watershed.

A third line of cases uses what might be referred to as the "restricted unity of title" test. Under this test, not only must there be unity of title, but the contiguous riparian land is restricted to land within the watershed.[22] As used in relation to riparian land, "watershed" has been defined to mean "the area drained by the watercourse . . . the area from which rain would find its way into the watercourse . . . and whose waters, once in the watercourse, flow by the land of the complaining riparian."[23]

Since no Indiana court has had occasion to decide what land constitutes riparian land, there is no indication of which definition the courts will choose to follow. It is arguable that legislative intent indicates a preference for "unity of title" test. The general assembly has declared that the welfare of the people of the state requires maximum beneficial use of the state's surface water resources.[24] This statute may well require use beyond the watershed. Certainly a test that would have the effect of constantly reducing land on which riparian rights may be exercised, as would be the case under the "source of title" test, would not promote beneficial use. Further, the general assembly, when defining land to which riparian rights attach, used the following language: "The owner of land *contiguous* to or encompassing a public watercourse. . . ."[25] There is nothing in the statutory language to indicate an intention that "contiguous" was to be restricted by location within the watershed.

There may be disadvantages to the broader definition. As will be noted in the next section, Indiana follows a reasonable use doctrine. Under this doctrine the prescriptive period for acquiring a right to use, regardless of injury to other riparian owners, does not commence running until the use becomes unreasonable in the light of the rights of others. Thus, a riparian owner is faced with the possibility of going to great expense in making the necessary works and improvements to carry the water to riparian land outside the watershed, only to have the use declared unreasonable before recovering his expense, and without much hope of acquiring a prescriptive right to continue the use. Such a potential result could have a limiting effect on achieving the declared policy of the state to make beneficial use of surface water resources "to the fullest extent."[26]

The Reasonable Use Doctrine

In the process of developing and refining riparian rights two theories have emerged: the natural flow theory and the reasonable use theory.[27]

The natural flow theory, adopted by the English courts and some American courts, allows the riparian proprietor the absolute right to use the natural flow of the water to fulfill his "natural" wants and the qualified right to use the water for "extraordinary" or "artificial" uses, to the extent that "such uses do not sensibly or materially affect the natural quantity or quality of the water, and are made on or in connection with the use of the riparian land."[28] The reasonable use theory, adopted by a number of American courts, gives each riparian proprietor the privilege "to make a beneficial use of the water for any purpose, provided such use does not unreasonably interfere with the beneficial uses of others."[29]

Indiana has adopted a *modified* reasonable use policy, which essentially merges the absolute "natural wants" priority of the natural flow theory with the "beneficial use" balancing approach of the reasonable use theory. This policy has been further modified by statutory declarations altering the common law beneficial uses. For instance, numerous Indiana statutes list the various uses that are deemed in furtherance of the state policy of beneficial use of water resources: domestic, municipal, agricultural (including irrigation), industrial, commercial, recreational, power, transportation, stream pollution abatement, health, sewage dilution, maintenance of desirable levels of stream flow, and flood prevention and control.[30]

Thus, in Indiana, a riparian's "right to the natural flow of a stream, or the natural level of a lake, is limited by the rights of other riparians . . . to use [and withdraw] the water [reasonably]."[31] In 1855, the Indi-

ana Supreme Court clarified this doctrine in *Dilling v. Murray*,[32] which allowed a downstream mill owner to enjoin an upstream mill owner from obstructing the stream and unreasonably detaining the water impounded behind the dam such that plaintiff could only operate his mill part-time. The court reasoned:

> Every riparian proprietor has an equal right to the flow of the water through his land, and no one has a right to use it to the material injury of those below him. He has no property in the water itself; but only a right to use it as it flows along. If he diverts the stream he must return it to its natural channel when it leaves his estate. . . . But it is not every injury to the proprietor below that will confer a right of action, or justify an order to remove the obstruction. . . .
>
> The difficulty is not so much in the rule as in the application of it; in which it is necessary to take into consideration . . . all the attendant circumstances; and when all these are properly considered, if the proprietor below is materially injured; that is, materially, when considered in relation to the facts of the particular case, he is entitled to redress.[33]

Under the reasonable use doctrine, whether a particular use is reasonable is a question of fact,[34] and each riparian's right to use water is limited to uses that are reasonable under the circumstances. In an action against a municipal water company for wrongful diversion of water from a small lake, an Indiana appellate court stated:

> The question whether the quantity which [the upper riparian owner] is diverting is reasonable is not to be determined . . . by the requirements of business, but rather by determining whether his use is reasonable and proportionate with reference to the quantity of water usually in the stream or body of water, and whether the complaining riparian owner is substantially damaged by being deprived of his reasonable use.[35]

The party who asserts the unreasonableness of the upper riparian's use has the burden of proof.[36]

Because the reasonableness of the use is dependent upon all the attendant circumstances — quantity of water in the stream, whether a natural or artificial use, the use which other riparians wish to make, and whether such riparians are materially injured — what may be reasonable use in one circumstance will not be reasonable at another and vice versa.

To better describe "reasonable use" and the application of the reasonable use doctrine in Indiana, various riparian uses will be discussed under *withdrawal uses* and *instream uses*.

Withdrawal Uses

Domestic Use In jurisdictions recognizing the reasonable use doctrine, the courts generally recognize a distinction between domestic and artificial uses,[37] and allow a riparian to withdraw water sufficient to satisfy his domestic needs, even to the detriment of downstream riparians.[38] Although an 1899 Indiana Supreme Court case did not appear to make this distinction,[39] an 1897 Indiana appellate court decision clearly made the distinction.[40] In 1963 the general assembly recognized and gave priority to the *domestic* terminology:

> The owner of land contiguous to or encompassing a public watercourse shall at all times have the right to the use of water therefrom in the quantity necessary to satisfy his needs for domestic purposes, which shall include, but not be limited to, water for household purposes, drinking water for livestock, poultry and domestic animals. The use of water for domestic purposes shall have priority and be superior to any and all other uses.[41]

This statutory recognition of domestic uses is not unlike the law of other riparian rights jurisdictions where courts have ruled that domestic uses include water for drinking,[42] cooking,[43] laundry and sanitation,[44] the maintenance and sustenance of the proprietor and his family,[45] and the watering of stock and other domestic animals.[46] The distinction between domestic and artificial uses is a recognition of the need to prefer satisfaction of natural wants over the use of water for artificial or commercial uses.

Municipal Water Courts have adopted varying terms for domestic uses, that is, *ordinary purposes* and *natural needs*, as opposed to *extraordinary uses*.[47] Their decisions in the area of municipal water supply and use have been fairly uniform in holding that such use is extraordinary, not domestic, and "can only be exercised reasonably and with regard for the rights of other proprietors."[48] Although recognizing a municipality as a riparian proprietor with rights of withdrawal for some purposes, the cases from *Valparaiso City Water Co. v. Dickover*[49] through *City of Elkhart v. Christiana Hydraulics, Inc.*[50] have held that municipalities as upper riparian owners "may not use or divert water from a stream in such a way as to destroy

or render it unavailable for use of a lower riparian proprietor."[51]

In *Christiana Hydraulics* the court stated:

> While a riparian owner may have a right to divert and use a riparian amount of water from a bordering stream for some purposes, a waterworks company does not have a right as a riparian owner to divert water from a stream in order to make merchandise of it and distribute it to all the residents of a city.[52]

Christiana Hydraulics would appear to deny the existence of a riparian right of withdrawal by a waterworks company, including a municipal waterworks, where such withdrawal is for the purpose of merchandising and distributing water to the residents of the municipality. Whether this was intended as an absolute denial of withdrawal right in the absence of injury to other riparian proprietors is not clear. However, such construction would appear to be contrary to the state's declared policy of making beneficial use of surface water resources "to the fullest extent."[53]

Where the municipality is denied the right to divert water for purpose of merchandising and distributing, the necessary water supply must be provided in one of the following ways: (1) drilling of wells,[54] (2) exercise of eminent domain,[55] or (3) acquisition of water from a nearby reservoir.[56]

In *Valparaiso City Water Co. v. Dickover*[57] the municipality argued its use (withdrawal for distribution to residents of city) was beneficial to the public, nonnegligent, and therefore a proper exercise of a riparian right. The court appeared to give little weight to the fact that a municipality was claiming the riparian withdrawal right, nor did it consider the comparative social utility of competing uses. Certainly the restrictive language of *Christiana Hydraulics*[58] reaffirms this aspect of *Valparaiso City Water Co. v. Dickover.*

A few jurisdictions have denied the right of municipal water companies to divert water for purpose of merchandising and distributing on the ground that the use of water on nonriparian lands (sale to resident nonriparian owners) violates the riparian legal doctrine.[59]

Agricultural Use Aside from those withdrawal uses designated as domestic in the statute ("drinking water for livestock, poultry and domestic animals")[60] and those domestic uses within to purview of "purposes . . . ordinarily incident to the use and enjoyment of his riparian premises,"[61] other agricultural uses must be balanced against the nondomestic reasonable needs of fellow riparians and exercised in proportion to those competing needs. Unreasonable uses may be enjoined.

Although very little Indiana case law exists on the subject of agricultural uses, the Indiana Supreme Court commented in 1899 that every riparian owner had a correlative right to

> the reasonable use and enjoyment of the stream. . . . He may dam it and divert it for mechanical purposes and fish ponds if he will return it to its channel before leaving his premises; he may use it for purposes of agriculture; his animals may take water from it at will; he may clear away the forests, plant crops, fertilize his field, feed his animals in lots, and permit the storm water from his fields and feed yards to flow by natural ways into the stream . . . even though such drainage corrupts the waters of the stream and sends them on to the owners of the servient estates less pure than he received them.[62]

This passage indicates that a fishery may be a reasonable agricultural use if the water is returned to the watercourse so as not to constitute an unreasonable diversion.[63]

The Indiana statute classifying "drinking water for livestock, poultry and domestic animals"[64] as a domestic use has not yet been interpreted or in any way restricted by the Indiana courts. This broad construction of the statute leaves in doubt the issue of whether a commercial feedlot qualifies for an absolute water use priority as a domestic use for watering livestock. An Ohio court held that the watering of three hundred thirty-three head of livestock constituted a domestic use and was therefore entitled to priority over nondomestic water uses.[65] However, when one considers that a commercial riparian's right to use water for reasonable purposes may be limited by the "domestic" use of an upstream or downstream commercial feedlot, this interpretation hardly seems justified.

Irrigation A considerable dispute has arisen over the use of riparian water for irrigation purposes. Two objections have been voiced against classification of irrigation as a reasonable use of water: (1) irrigation is a diverted or consumptive nondomestic use of water,[66] and (2) the withdrawn water is sometimes used on nonriparian land, thereby depriving the use of its validity under the riparian doctrine.[67]

Although an 1899 Indiana Supreme Court case conceptually approved water use for "agricultural purposes,"[68] no Indiana court has ever faced the issue of whether irrigation is a reasonable use. However, several Indiana statutes indicate legislative approval of irrigation as a reasonable use. The statute giving domestic uses priority also approves the impound-

ment of water for irrigation, subject to state regulation.[69] In addition, the statute empowering the Natural Resources Commission of the Department of Natural Resources to acquire land for reservoirs sets out thirteen water uses that are increasing the demand for water supply storage, and the fifth-listed use is "agricultural, including irrigation, use."[70]

This language does not resolve the beneficial use issue, nor does it address the problems of diversion or nonriparian use. With irrigation becoming an increasingly prevalent agricultural practice,[71] there is a need for statutory recognition of irrigation as a beneficial riparian use and a clarification of whether the term riparian lands includes lands beyond the watershed for purposes of irrigation.

Industrial and Commercial Uses There appears to be no Indiana case law in the area of industrial and commercial uses, with the exception of the controversy over municipal water supply companies. Such companies, as earlier noted,[72] are usually considered commercial users, based on their corporate structure and the nondomestic nature of their use.[73] Two water supply statutes expressly mention commercial and industrial uses as being potentially beneficial.[74] Industrial and commercial uses are subject to the same "reasonable use" balancing process applied to nondomestic uses.[75]

Power and Energy Withdrawal Uses Generation of power is one of the listed beneficial uses for water supply and reservoir water supply storage.[76] Power plants generally require great quantities of water for cooling of machinery, thereby generating excessive quantities of heated water. Thermal pollution regulations set the maximum amount of temperature fluctuation from the normal seasonal temperatures in various bodies of water in Indiana.[77] Thermal polluters are allowed to divert such heated water to "holding ponds," which allow the water to cool and are exempted from the definition of public waters, as are all holding ponds designed to reduce pollution.[78]

Because of the massive amounts of water used by a power plant and returned to the stream, such a user may be required to minimize its use in order to allow for other beneficial riparian uses. It may be that in the balancing off of the social value of competing uses the public interest served by a municipal or regional power plant may justify greater withdrawals when in competition with other commercial enterprises.

Stream and Lake Modification

"A riparian owner has a common-law right to the natural flow of the water of a stream running through or along his land, in its accustomed channel. . . ."[79] Based on this common-law right, a riparian may divert or change the channel of a stream within his own property boundaries, if he returns the flow to its original channel by the time it leaves his land, unless that diversion somehow alters the nature of the flow so as to injure another riparian. Thus, a riparian above or below the point of diversion may seek a remedy for changes in the velocity, direction, or sedimentation of stream flow, if those changes were caused by the channel modification.[80]

Although lake level regulation[81] might appropriately be treated under "instream uses" it is treated herein for two reasons: (1) establishment and enforcement of lake levels affect withdrawal rights, and (2) such treatment will facilitate discussion of public rights under "instream uses."

The Indiana Legislature has seen fit to accord lakes of ten or more acres special protection from certain actions that would lower a lake below its legally established level.[82] The various acts forbid the lowering of such lake levels by means of (1) a ditch or dam,[83] (2) a ditch or drain lower than lake level and within one hundred sixty rods of the lake,[84] or (3) a ditch or drain cutting through a line of lakes or within one hundred and sixty rods of a lake unless an existing dam will protect the lake levels.[85] Another act forbids lowering a twenty-or-more-acre artificial lake by more than twelve inches below the lake's high water mark,[86] unless the lake is an artificial lake used for municipal water supply or electric power generation, an artificial lake controlled by the Department of Natural Resources, or one of several other specified exceptions.[87]

The statute contains a procedure whereby a party contemplating actions that could possibly lower a lake level can request the Department of Natural Resources to approve the project if the lake level will remain unchanged. The Department of Natural Resources is required to conduct a thorough investigation of the effect of the project before granting approval, and must specify any safeguards to be taken in its written approval. The statute provides for hearing and appeal, upon the Department of Natural Resources' refusal to approve.[88]

Although there is no case law on point, these lake level statutes may prohibit a landowner within the lake's watershed area from damming, impounding, or otherwise retaining surface water run-off on his own property, because such an action would arguably lower the lake level.[89] Although not covered by statute or regulation, it is arguable that drilling of wells and pumping of subterranean water in amounts sufficient to lower the water below the established lake level might be prohibited.

Another statute empowers the county circuit or

superior court to entertain petitions to repair or construct a lake level control structure of some sort. Such a petition can be filed by the Department of Natural Resources, the county commissioners, or twenty percent of the owners of land within four hundred and forty yards of a lake containing ten or more acres.[90] However, a written remonstrance by at least fifty-one percent of such landowners will be sufficient to have the petition dismissed.[91] If the petitioners obtain a judgment in their favor, project costs are apportioned among the petitioning parties in predetermined statutory fractions.[92] Thus, the statute allows local landowners to determine the type of lake level control they desire, while providing for state input. In addition, the statute strives to counter the interest of nonresident sportsmen who would otherwise petition for additional water recreation sites and improvement of existing sites, with the rationalization that the sites would be paid in part with public money.

Instream Uses

Coexisting Private and Public Riparian Rights The preceding sections discussed the rights of riparian owners to withdraw water from adjacent watercourses and lakes for various uses. Withdrawal rights are "private rights" arising out of ownership of land abutting on a body of water. In general, there are no common law *public rights* of withdrawal. The term public rights in water refers to public uses of water which the law protects in persons, regardless of whether they own land abutting on the water.[93] Unlike withdrawal uses, both public and private rights may exist as to "instream uses."[94] Public rights may be either a common-law right or the result of statutory enactment. With the exception of the common-law public right of navigation, most public rights in water are statutory and quite recent.[95]

Public rights are not held to be paramount to every conflicting private riparian right[96] or public activity. Resolution of conflicting interests, as well as statutory expansion of public rights, are influenced by the state's economic interests.[97] While public rights may exist only in waters denominated as "public water" by statute[98] or by common-law definition,[99] such rights do not exist in all public waters. As will be discussed later, public rights in lakes appear to be limited to those lakes that are used by the public under the doctrine of acquiescence and which meet the statutory criteria.[100] However, to limit lakes subject to public rights to those lakes used by acquiescence poses a question: If a navigable stream flows into or out of a lake not otherwise subject to public rights, does that lake also become navigable and therefore public, or does the lake retain its private nature until public use is gained by acquiescence? Indiana case law and statutes have never clearly addressed this issue.[101]

The class of waters susceptible to public rights has been substantially broadened by the Indiana General Assembly to include artificial lakes,[102] waters overlying private lands dedicated to the public,[103] artificial channels adjoining watercourses and public lakes,[104] and rivers under the Natural, Scenic and Recreational Rivers Act which are subject to a "water use easement."[105]

Although clear-cut priorities are rare in the field of water rights, Indiana has accorded domestic riparian water uses an unequivocal priority over public rights and other riparian uses.[106] Beyond this point, however, private (riparian) uses and public uses must be balanced to obtain the most "beneficial use" of state water resources.[107] To a degree the general assembly has already provided a balancing of rights in certain lakes through the lake level statutes.[108] Established levels will tend to promote navigation, protect fish and wildlife, and encourage recreation, while protecting riparian owners on the lake from drastic fluctuations of lake levels on the shoreline.

The principal private rights, public rights, and instream use issues will be discussed under two major headings: *navigation and navigability*, and *recreational uses*.

Navigation and Navigability A judicial ruling on a watercourse's navigability affects the state's jurisdiction over that water, the right to erect obstructions, rights contingent on bed ownership, and various recreational uses associated with public water rights.

The issue of various watercourses' navigability has been extensively litigated, more so in the 1800s than in recent times, when the legislature has become the leading force in public water rights.

In 1833, the Indiana Supreme Court first considered the issue of navigability. In *Cox v. State*,[109] defendant was prosecuted by the state for maintaining a mill dam across the White River which completely blocked navigation. The court upheld the state's right to compel removal of such an obstruction, based on concurrent state and federal jurisdiction over "navigable waters," as mandated by the Northwest Ordinance, in the form re-enacted by Congress.[110]

The ordinance originally declared that

> the navigable waters leading into the Mississippi and the St. Lawrence, and the carrying places between the same, shall be common highways, and forever free, as well to the inhabitants of said territory as to the citizens of the United States, and of those of any other states that may be admitted into the confederacy, without any tax, impost, or duty therefor.[111]

The *Cox* court construed this language to mean that the state was prohibited from "converting [the streams] to any other use than public highways, and from obstructing them with any artificial obstruction, and from levying any tax, impost, or duty on any of those citizens who may navigate them."[112]

The court also relied on the common-law protection of navigable waters from physical obstructions, but avoided deciding the issue of bed ownership because of the state's power to remove nuisances and obstructions from navigable waters, regardless of whether the bed is publicly or privately owned.

An 1851 case cited the Northwest Ordinance,[113] but neglected to mention the fact that Congress had adopted the ordinance as federal law, thereby making it appear that the court was drawing on legislation enacted before the Constitution. As explained by the same court three years later in *Depew v. Board of Trustees,*[114] the Northwest Ordinance was enacted in July 1787, prior to the framing of the United States Constitution in September 1787. Because the Constitution took effect after the passage of the ordinance, it superseded the ordinance with respect to the various "states" of the Northwest Territory as they achieved statehood. However, the United States Supreme Court subsequently ruled that Congress had since recognized and readopted the provision of the ordinance governing navigable streams.[115]

Depew was the first Indiana case that delineated two classes of nontidal, navigable streams:

> One of these classes is only navigable for certain kinds of craft, certain distances within the state, and is not visited by vessels coming from and going to, by continuous voyages, navigable waters of other states. . . . These streams are highways for trade and commerce within the state. The other class of navigable streams is composed of those which are navigable, in fact, for vessels coming out of, and returning into, by continuous voyages, the navigable waters of other states.[116]

The state has exclusive jurisdiction over the first class and may authorize obstructions for the public good, such as dams, bridges, and mills. The state and federal governments have concurrent jurisdiction over the second class, subject to preemption by Congress's exercise of its power to regulate interstate commerce,[117] as exercised by its reenactment of the Northwest Ordinance navigability provision.[118]

Based on the lack of interstate traffic on the stream in question, the *Depew* court held that the stream belonged to the first class of navigable rivers and that the public interest was better served by the "artificial highway" or canal.[119] The court remarked that state policy did not favor enlarging the federally navigable class of streams, because by increasing the latter class, the state decreased both its power over state water and its ability to construct bridges, railroads, canals, and other potential obstructions.[120]

The *Depew* holding probably reflected the growing concern of the day regarding state control of Indiana affairs and the need to encourage development of the Indiana economy.[121] Read in context, the language of the opinion shows a strong bias in favor of the state's newly constructed canal system, a top priority in the mid-1800s.[122]

In *Neaderhouser v. State,*[123] the court had occasion to apply the *Depew* classification of navigable waters. In a public nuisance — criminal prosecution of a mill owner on the Wabash — the court held that that portion of the Wabash was not federally navigable and was used only by small local boats.[124] Because the mill owner's predecessor had built the mill dam under state authorization, the court held that such a dam was indeed a legitimate exercise of exclusive state control in the public interest.[125]

Although the *Neaderhouser* court mentioned the readopted version of the navigability provision of the Northwest Ordinance, it did not rely on it for precedential value. During the 1840s and 1850s, judicial favor shifted to the view that the reenacted ordinance "was not intended to be operative after a region attained statehood."[126] Reliance, in turn, shifted to the common-law and statutory provisions.

The Indiana Supreme Court passed midway into the twentieth century before it was once again confronted with a navigability issue. In *State v. Kivett,*[127] a 1950 case, the state brought an action seeking an injunction against a commercial riparian for the removal of sand, gravel, and minerals from the bed of the White River in Morgan County.

In the decade after *Neaderhouser* and before *Kivett,* the United States Supreme Court had finally decided several leading cases on navigability in the federal context, the following of which were relied on by the *Kivett* court. In 1870, the Court formulated its classic definition of navigable waters in *The Daniel Ball:*[128]

> Those rivers must be regarded as public navigable rivers in law which are navigable in fact. And they are navigable in fact when they are used, or are susceptible of being used, in their ordinary condition, as highways for commerce, over which trade and travel are or may be conducted in the customary modes of trade and travel on water. And they constitute navigable waters of the United States within the meaning of the acts of Congress, in contradistinction from the navigable waters of the States, when they form in their

> ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other States or foreign countries in the customary modes in which such commerce is conducted by water.[129]

This ruling is essentially congruent with the *Depew* rationale, which gave rise to two classes of navigable streams: those streams involved in interstate commerce (or otherwise subject to congressional regulation thereof), and those streams supporting intrastate commerce which are only subject to the state's exclusive jurisdiction and exercise of powers.[130]

Four years later the Court elaborated on *The Daniel Ball* definition in *The Montello:*[131]

> The true test of the navigability of a stream does not depend on the mode by which commerce is, or may be, conducted, nor the difficulties attending navigation. If this were so, the public would be deprived of the use of many of the large rivers of the country over which rafts of lumber of great value are constantly taken to market.
>
> It would be a narrow rule to hold that in this country, unless a river was capable of being navigated by steam or sail vessels, it could not be treated as a public highway. The capability of use by the public for purposes of transportation and commerce affords the true criterion of the navigability of a river, rather than the extent and manner of that use. If it be capable in its natural state of being used for purpose of commerce, no matter in what mode the commerce may be conducted, it is navigable in fact, and becomes in law a public river or highway.[132]

In *United States v. Utah,*[133] the Court held that the issue of navigability was to be resolved with reference to the navigability of the specific waters on the date the governing state attained statehood. This 1931 ruling put an end to the various judicial theories concerning the Northwest Ordinance and its reenactment.

With this barrage of high court precedent, the Indiana Supreme Court tackled the navigability issue in *Kivett* noting that the test for the stream's navigation was

> whether or not [the stream] was available and was susceptible for navigation according to the general rules of river transportation at the time Indiana was admitted to the Union [1816]. It does not depend on whether it is now navigable. . . . The true test seems to be the capacity of the stream, rather than the manner or extent of use. And the mere fact that the presence of sandbars or driftwood or stone, or other objects, which at times renders the stream unfit for transportation, does not destroy its actual capacity and susceptibility for that use.[134]

The court reviewed extensive evidence of interstate commercial navigation on the White River in Morgan County as far back as 1821,[135] and held that portion of the river to be navigable in the federal sense.[136]

The court also refused to adopt defendant's argument that since Morgan County and Indianapolis were first settled several years after the year of statehood, there could not have been any navigation on the White River in 1816. The court stated that "this was not material in the decision of this case, for the use of the river a few years later was sufficient to show its sufficiency and availability in 1816."[137]

Bed Ownership The primary issue in *Kivett* was ownership of the river bed from which the defendant was removing materials.[138] In *United States v. Holt State Bank,*[139] the United States Supreme Court held that

> lands underlying *navigable* waters within a state belong to the state in its sovereign capacity and may be used and disposed of as it may elect, subject to the paramount power of Congress to control such waters for the purposes of navigation in commerce among the states and with foreign nations. . . .[140]

Thus, according to *Kivett*, if the stream was navigable as of the date of statehood, then title to the bed of the river passed from the Northwest Territory to the State of Indiana, and could not be conveyed incident to the adjoining riparian property without a legislative act.[141] If the river were not navigable in 1816, then title to the river bed would have passed with the adjoining riparians' titles, to the thread of the river. By holding that specific portion of the White River to be navigable, the court ruled that the bed title was held by the state and therefore disallowed defendant's alleged riparian right to remove minerals therefrom.[142]

The court also noted that "since the effect upon the title to [the river bed] is the result of federal action in admitting a state to the Union, the question, whether the waters within the State under which the lands lie are navigable or non-navigable, is a federal" question and is "determined according to the law and usages recognized and applied in the federal courts, even though, as in the present case, the waters are not capable of use for navigation in interstate or foreign commerce."[143]

Although Indiana ownership along the Ohio River

extends to the low-water mark by virtue of the established state boundary,[144] federal cases have consistently held that the appropriate line of demarcation (in absence of a contrary state boundary) is the high-water mark,[145] and *Kivett* declared that federal law must be applied to such issues.[146]

As noted in *Kivett,* if a watercourse is nonnavigable, bed ownership generally lies with the adjoining riparians to the center or thread of the stream or channel.[147] Title to the bed is not affected by *avulsion*, the sudden and rapid change of a watercourse channel. After an avulsion, the contiguous owners continue to own to the center of the abandoned channel. However, if the stream shifts its channel by means of a gradual and imperceptible deposit of sediment, a process known as *accretion*, the center or thread of the stream remains the boundary line of adjoining riparians.[148]

Ownership of lake beds relies on different methods of delineating property lines. At common law, lake owners take title to the bed roughly in proportion to their shoreline footage. The method of dividing the bed depends on the shape of the lake. If the lake is elongated and narrow, the lines are drawn perpendicular to the median line of the lake, in a manner similar to the division of a nonnavigable stream bed. If the lake shape is rounded, lines are drawn to form proportional pie-shaped wedges, but if the shape is so irregular as to prevent the above methods, portions are divided in proportion to shore frontage.[149]

The general assembly has never specified when the state holds title to lake beds. The state can obtain title to a bed by the exercise of eminent domain in reservoir condemnation proceedings and similar actions.[150] However, mere acquiescence to public use by private lake owners does not disturb their title to the bed, as specified by the general assembly in the preamble to the lake level statutes. Some clarification is needed as to whether the "navigability" of a lake, that is, the flow of a navigable watercourse into or out of the lake, serves to vest bed title in the state. A 1934 Indiana Supreme Court case *implied* that private bed ownership of a lake was predicated on the lake's nonnavigability, but never expressly stated its reasoning or precedent.[151]

Bed ownership of any body of water gives a private owner the following rights: to remove materials from the bed, to exclude the public from use of the overlying waters,[152] and to cut and remove ice.[153] If the state owns the bed, it has the duty to regulate and apportion the above rights for the public good.

The *Kivett* court sustained the state's assertion of jurisdiction over and title to the river bed lands in question. This ruling supported a statute (already in existence) that gives the Department of Natural Resources power "to issue permits to any person, firm or corporation to take coal, sand, gravel, stone, gas, oil or other mineral or substance from or under the bed of any of the navigable waters of the state."[154] Moreover, these permits are exempted from the provisions of the lake level statute prohibiting lake shoreline enroachment or excavation without Department of Natural Resources approval.[155] However, the mineral removal permit system is probably superseded, with respect to petroleum, by a separate, later act providing for petroleum exploration on state property. This construction turns on the later act's definition of "public lands": "Lands and areas belonging to, or subsequently acquired by the state or any of its institutions, including lands of every kind and nature."[156] Based on *Kivett,* this definition would include the beds of navigable rivers.

In a 1918 case, the state obtained an injunction against an Illinois corporation's removal of sand from the state's bed under Lake Michigan. The court stated that the state lake bed land was held *in trust* for the benefit of the state citizens.[157] This appellate court mention of the "public trust" with regard to water rights has never been adopted by the Indiana Supreme Court.[158]

The owner of a lake or stream bed also has the right to cut and remove ice from the surface of the lake.[159] This right is usually considered an instream use, rather than a withdrawal use, because it falls within uses that are contingent on bed ownership, not within the domestic-commercial priorities familiar to withdrawal uses. The public has joint rights to cut ice from lakes to which the state owns the bed.[160] However, since the advent of the electric refrigerator, this right has decreased considerably in importance.

Public and Private Rights to Obstruct Navigable Watercourses As set out in *Depew,*[161] the two classes of navigable watercourses are (1) the waters navigable by interstate and foreign commerce, which are subject to state jurisdiction, except when preempted by federal control; and (2) the waters available for navigation on the intrastate level, subject to exclusive state jurisdiction.

With regard to the former class, neither a state nor a private party may obstruct such a watercourse, because of the pervasive nature of the federal interest in interstate commerce. It would seem that the federal government could obstruct such a watercourse if it determined such an obstruction to be of sufficient public benefit so as to justify impeding interstate commerce.

In 1854, in *Board of Commissioners v. Pidge,*[162] the court refused to award a shipowner damages from a bridge which allegedly obstructed the channel. The state had previously authorized the construction of a lock and dam to ease navigation around rapids on the

St. Joseph River, a federally navigable stream by virtue of its Indiana-Michigan traffic.[163] The state subsequently erected a bridge to clear the new channel formed by the dam and lock. However, when the dam broke, the bridge partially obstructed the only passable channel. Noting that the bridge was not a nuisance when it was built, the court reasoned that although the state cannot obstruct a federally navigable stream, it can improve navigation by erecting works that do not otherwise injure navigation.[164] The court refused to level blame for the obstruction, noting instead that the demise of the dam had caused shift of the channel and mentioning God, nature, and the dam-builders as possible parties sharing the blame.

In 1856, in *Porter v. Allen,*[165] the court held that a riparian businessman had the right to remove a "snag" obstructing the Ohio River, but that when he hauled the offending drift material to the nearest sandbar, such that a boat passed over and wrecked upon the snag when the flow rose that night, he was liable for a breach of duty to exercise ordinary care.[166] The court rejected the defense that the boat had not been in the channel of the river, and ruled that boats should be able to safely run anywhere in a navigable river, not in just the channel.[167]

This case may at first glance seem to conflict with *Pidge,* until one distinguishes *Porter* and *Pidge* on the basis of both the party causing the obstruction and the cause of action. *Pidge* involved a state-authorized lock and dam, a state-constructed bridge, and a claim of nuisance against the state. *Porter* dealt with a natural obstruction and negligent interference by a private party. The *Pidge* court allowed the state to reasonably obstruct all but the legal, federally navigable channel, while the *Porter* court prohibited private interference with any portion of a federally navigable stream.

With regard to the intrastate navigable class of rivers, either state projects or state authorized projects may obstruct such a watercourse if the state first determines the obstruction to be in the public interest. In *Neaderhouser v. State,* the legislative authorization of defendant's dam was held to be a complete defense to a prosecution for nuisance, where the dam was upstream of the federally navigable portion of the stream.[168] In *Williams v. Beardsley,* a pre-*Depew* case, the court allowed the partial obstruction of a navigable stream by a privately built bridge, where the bridge served the greater public good and could be navigated around with a greater exercise of boating skill.[169] Lastly, in *Depew v. Board of Trustees,* the court gave a state canal aqueduct priority over the navigation of an intrastate stream, based on the greater public good.[170]

Several state statutes allow municipalities to utilize eminent domain and to erect structures so as to improve a harbor, channel, or watercourse.[171] Another statute allows private and public riparians to construct dams and obstructions across public watercourses for legitimate riparian uses, including irrigation, after first obtaining approval from the Department of Natural Resources.[172] Flood control and water supply dams will be discussed in a later section.[173]

Statutes Affecting Navigability Aside from the common-law provisions, a stream may also be declared navigable under state law by the county commissioners, upon petition by at least twenty-four property owners in the county, "residing in the vicinity of the stream."[174] Although the statute provides no criteria by which to ascertain navigability, if the commissioners examine the stream and find it to be navigable,[175] the stream is then subject to restrictions on piers, wharves, and docks;[176] to penalties on and provisions for removing obstructions;[177] and to an exemption for already erected, unabandoned mills, dams, bridges, aqueducts, viaducts, and machinery on the stream.[178]

A separate statute has declared the Kankakee River to be navigable within the boundaries of Indiana for purpose of exercising Indiana police powers.[179]

The enabling statute of the Department of Natural Resources gives the department "general charge of the navigable waters of the state," including the regulation of fishing and hunting activities within five hundred yards of such a body of water,[180] as well as boat registration[181] and safety rules.[182]

Recreation In comparison to other water uses, "use . . . for recreational purposes is a minimum consumptive use."[183] The Indiana General Assembly has declared a broad public policy favoring a "vested [public] right in the preservation, protection and enjoyment of public fresh water lakes."[184] The enumerated statutory recreational uses include boating, swimming, fishing, and "any purpose for which said lakes are ordinarily used and adopted."[185] Similar statutory protection of watercourses has been adopted in the natural, scenic, and recreational watercourses statute, which empowers the Department of Natural Resources to designate certain "rivers of unusual natural, scenic or recreational significance [to] be set aside and preserved for the benefit of present and future generations before they have been destroyed."[186] The statute also recognizes the public interest in maintaining "close contact with such natural, scenic and recreational rivers" in order "to benefit from the scientific, aesthetic, cultural, recreational, scenic, and spiritual values [these rivers] possess."[187] The Department of Natural Resources may designate such rivers as natural, scenic, or recreational,[188] and thereafter acquire sufficient title and easements to guarantee protection

of the designated river.[189] The statute provides the following definitions:

> (c) The term "natural river" shall mean any river which, free of impoundments, is generally unpolluted, undeveloped, and unaccessible.
>
> (d) The term "scenic river" shall mean any river which is free of impoundments, accessible in several places, and with minimal pollution and shore line developments.
>
> (e) The term "recreational river" shall mean any river which does not contain those characteristics necessary to qualify as a natural or scenic river, but which still maintains scenic or recreational characterisitcs of unusual and significant value.[190]

In preserving the inherent value of such rivers, the state is empowered to obtain the following types of easements: (1) water use easement "granting of the right of the general public to travel along or across all water portions of the river,"[191] (2) scenic easement granting "protection of adjacent land in its present state to preserve its natural or scenic characteristics,"[192] (3) land use easement granting "the right of the general public to use the adjacent lands,"[193] and (4) "conservation easement."[194]

The protection of watercourses under the scenic watercourse statute resembles the protection of lake resources under the lake level statute,[195] in that both lake level and scenic watercourse statutes seek to preserve and maintain the water resources of the state for the benefit of the public and its recreational uses. However, the former statute concentrates on environmental and aesthetic concerns, while the latter statutes primarily control ditches, dams, drains, and excavations which would lower a lake below its established level.

The lake level statutes declare public recreational use rights (fishing, boating, swimming, and other activities) in all "public fresh water lakes"[196]—"lakes which have been used by the public with the acquiescence of any or all riparian owners."[197] This concept of acquiescence has never been defined or dealt with in detail by the Indiana courts. Although *Sanders v. DeRose,*[198] a 1943 Indiana Supreme Court case, held that each owner abutting a nonnavigable lake had the exclusive right to enjoin public use of the waters overlying his portion of the lake bed,[199] the subsequent statutory enactment of the lake level statutes has resulted in the following ambiguous language: "acquiescence of *any or all* riparian owners."[200] Although one commentator has concluded that the acquiescence of *any one* lake owner to a *substantial* public use is sufficient to trigger a public right to use such waters,[201] no authority is available to support this view. Furthermore, this interpretation leaves two questions unanswered: (1) How much and what nature of public use is sufficient to establish acquiescence? (2) If only one owner's acquiescence is sufficient to open up an entire lake to public use, by what means can other lake owners prevent the establishment of public rights, especially if the right to exclude others from an in-stream use of the water is dependent on ownership of the bed underlying the water?

In *Sanders v. DeRose,* plaintiff and another party owned the land surrounding a twenty-acre nonnavigable lake which was not connected to any public waters. Plaintiff owned a boat livery and charged the public to boat and fish on his portion of the lake. Defendant entered upon plaintiff's portion of the lake, claiming that the public had a right to fish and boat on the entire lake and encouraging the public to use the lake accordingly. The court held that plaintiff had the right to enjoin public use of the portion of the lake overlying his land. Reasoning that "the right to fish follows the title to the soil," the court applied the common law in holding that "where . . . the portion of the several owners of the bed of [an inland nonnavigable] lake may be determined by congressional survey, each owner has the right to the free and unmolested use and control of his portion of the lake bed and water thereon for boating and fishing."[202]

Although *Sanders* did not specifically address the issue, an extension of the ruling would imply that public fishing rights exist in navigable waters if the state owns the bed of navigable lakes. *Sanders* also did not rule on public recreational uses other than fishing and boating. Of course, the broad legislative policy in favor of varied recreational uses would encourage extension of the *Sanders* rule to a wide variety of recreational uses.[203]

In the only other case in this area, the appellate court held that the public had no right to fish or otherwise use an artificial lake which was created by an amusement park from a nonnavigable stream.[204]

Special Areas Of State Regulation

Fish and Wildlife Protection The Bureau of Land, Forest and Wildlife Resources in the Department of Natural Resources[205] has responsibility for

> the protection, reproduction, care, management, survival and regulation of wild animal populations *regardless of whether they are present on public or private properties of this state* and organize and pursue a program of research and management of wild animals that will serve the best interests of the resources and the people of the state of Indiana.[206]

The statutory and regulatory provisions of the Fish and Wildlife Act govern waters beyond the scope of public recreational rights. The most extensive control exists in the statewide protection of nongame and endangered species, regardless of where the violation occurs.[207] Regulation of species allowed to be captured or caught generally extends to all but the owner's lands, and fish licenses are required "when fishing in waters containing state-owned fish, waters of this state or boundary waters of this state."[208] This includes all lakes and watercourses except "private waters," that is, "waters wholly on the land of an individual or individuals which are not connected with public waters and which will not allow the ingress of fish into such private waters."[209] The statutes governing unlawful fish stocking and unlawful fishing methods and devices govern the same waters in which fishing licenses are required.

Other provisions restrict chemical treatment of aquatic vegetation,[210] fishing near a dam,[211] ice fishing holes and shanties,[212] and the necessity of "fish ladders" around certain dams.[213]

The Enforcement Division of the Department of Natural Resources has the responsibility to detect and prevent violation of department statutes and regulations. The division's conservation officers have all the powers of local law enforcement officers, but only in furtherance of Department of Natural Resources matters.[214]

The Stream Pollution Control Board has jurisdiction overlapping that of the Department of Natural Resources in the prevention of pollution which destroys "any fish life or any beneficial animal or vegetable life" or injuriously affects "the growth or propagation thereof."[215]

Pollution and Waste Disposal The federal, state, and local pollution and waste disposal standards apply to *all* parties discharging into public waters, not just riparian owners.

Thermal Pollution[216] Any party discharging large quantities of heated water back into the watercourse or lake may be subject to the thermal pollution regulations. These regulations set the maximum allowable temperature fluctuations in certain bodies of water, based on the tolerance of existing fish life.[217] The usual means of cooling such water is to channel the heated discharge into "holding ponds" until the water has cooled to a suitable temperature.[218]

Chemical Pollution Any party discharging chemical pollutants into bodies of water may be subject to the water quality standards enforced by the Indiana Stream Pollution Control Board under the supervision of the Indiana Environmental Management Board, both of which function within the State Board of Health. These state agencies are responsible for enforcing both state and federal water quality standards in Indiana, based on the federal Environmental Protection Agency's approval of the Indiana statutory enforcement scheme.[219]

The regulations specify water quality standards applicable to every body of water in Indiana (except privately owned ponds), depending on the type of use, such as: whole or partial body contact recreation, warm or cold water fish maintenance, public or industrial water supply, or agricultural purposes. For each type of water use, the regulation specifies a variety of criteria: pH and temperature ranges, taste and order, toxicity, dissolved solid and oxygen concentrations, and contamination limitations on bacterial, chemical, and radioactive substances.[220] These standards do not apply to the dispersion area of each user's stream discharge. However, the "mixing zone" in the stream must be free of substances that are putrescent, unsightly, harmful, or toxic, or which constitute a nuisance.[221]

Parties wishing to drain cyanide-type compounds,[222] phosphorus-containing detergents,[223] and polychlorinated biphenyls (PCB's)[224] into sewer systems and watercourses must first obtain agency approval. Strip mine owners must dispose of or cover their mining refuse so as to minimize acid mine drainage into state waters,[225] and spills of oil and other hazardous substances must be contained, reported, and thoroughly cleaned up.[226] The Stream Pollution Control Board enforces these standards by means of a complex permit system, hearings, and court actions.[227]

Because pollution violations often cause fish and wildlife kills, the Department of Natural Resources and the Stream Pollution Control Board work together to prosecute polluters. Violation of a department regulation could bring misdemeanor charges, a civil action for damages sustained from the fish kill, and even a suit in equity to enjoin further pollution. The Department of Natural Resources fish kill figures may also be incorporated into the Stream Pollution Control Board's complaint.

Municipal Sewage Disposal Probably the most infamous case in Indiana water use was decided in 1899 by the Indiana Supreme Court. In *City of Valparaiso v. Hagen*,[228] nineteen downstream riparians brought a nuisance suit against the city, seeking to enjoin the dumping of sewage which was ruining their lands. The court framed the issue in these words:

> May a municipality, acting in conformity with statutes, skilfully and without negligence or

> malice, pursuing the only natural and reasonably possible line of drainage, be enjoined from discharging its sewage into a natural watercourse and thereby polluting its waters to the injury of the lower riparian owners?[229]

This conveniently framed issue allowed the court to deny the injunction, based on sovereign immunity and the technological void of alternative means of sewage purification and disposal.[230] The opinion seemed to imply that the city had a right to pollute, even to the great detriment of downstream riparians.

Fortunately, thirteen years later, in *Penn American Glass Co. v. Schwinn*,[231] the same court commented that the exception allowing cities to make "avail of streams for sewerage without liability . . . grew up from a supposed necessity, but the same reasons which seemed to be grounds for the exception to the rule in regard to pollution of streams by cities are the very ones which must sooner or later reverse it."[232] Although technically not reversing *Hagen*, the *Penn* court noted that *Hagen* was "based on unsound premises."[233] The *Penn* court was very careful to distinguish "between obstructing a natural stream and befouling its waters," as opposed to "the detention and temporary diversion to ordinary use" of riparian waters.[234]

Although *Hagen* has never expressly been overruled, the passage of stream pollution legislation in the 1960s and 1970s has had the effect of reversal.[235]

State statutes now regulate most facets of waste disposal, with joint regulatory responsibility being shared by the State Board of Health, the Stream Pollution Control Board, and the Department of Natural Resources. All three agencies must approve any sewage disposal facilities of housing developments greater than five lots, if the development is "an integral part of any change in shore line" of a public lake.[236] Any applicant with plans to construct a channel to a river or stream must first obtain approval from all three agencies.[237]

The operators of all waste water treatment control plants and water supply systems must be certified as to their competency by the Environmental Management Board. All such plants must be run by certified operators.[238] Municipal sewage treatment plants must also obtain approval from the Public Service Commission.[239] Any private entity seeking to connect a private drain to an already approved drain must first obtain approval from the Stream Pollution Control Board and the applicable local agency, if the private drain serves more than two family residences.[240]

Interstate transport of sewage requires approval by the general assembly and the county commissioners of the affected counties.[241]

Operating sewage disposal facilities are often subject to concurrent, stringent regulation by any or all of the above mentioned state agencies as well as local agencies.[242] Because of the high cost of constructing new municipal waste treatment plants, EPA-approved facilities will receive seventy-five percent federal funding.[243]

Sewage overflows or spills into watercourses that violate pollution standards may be subject to prosecution by the Environmental Management Board, the Stream Pollution Control Board, and the Department of Natural Resources.[244]

Water Power and Energy

As noted previously, water use for generation of power is one of the approved statutory "beneficial uses" of water.[245] The Natural Resources Commission is in charge of recommending and investigating the best allocations of state resources, including "the department of water power."[246] The Department of Natural Resources also has the power to acquire property for constructing reservoirs in order to generate hydroelectric power.[247] The "Reservoir Coordinating Committee" oversees the planning and development of state reservoirs.[248]

Such reservoirs are exempt from the lake level statute governing artificial lakes of twenty acres or more. Thus, the water level of a power-generating reservoir can dip more than twelve inches below the dam's high water mark.[249]

The Natural Resources Commission has "jurisdiction and supervision over the state of the maintenance and repair of dams, levees, dikes, floodwalls and appurtenant works in, on or along the rivers, streams and lakes of the state." Although the owners of such structures must bear the cost of repair, the commission has the right to inspect and take necessary emergency measures; a related section absolves the commission from any liability in connection with such structures. The commission also has the power to contract to sell quantities of reservoir water, either by release from the reservoir impoundment or by direct withdrawal from the reservoir. Funds from such sales are recycled back into reservoir maintenance and acquisition.[250]

These provisions are closely related to the flood control statute, both of which fall within the supervision of the Natural Resources Commission.

Flood Water Defined and Classified

Flood water from a natural watercourse has been defined as "overflow water [which] follows the course of the stream to its outlet or . . . returns to the channel . . ."[251] If flood water does not " . . . become separated from the main stream so as to prevent its return," it does not lose its character as part of the watercourse,

and the rules applicable to watercourses apply to it.[252] If, however, flood water leaves "its ordinary channel, and spreads out over adjacent lands, running in different directions or settling in pools and flats,"[253] it becomes diffused surface water and the rules of surface water will apply.

Case Law Although early Indiana cases addressing the problem of flood water appeared not to make the distinction between flood water and diffused surface water,[254] several later Indiana cases involving the construction of railroads near watercourses clearly made the distinction.[255] The courts consistently held that high water from a watercourse which followed the course of the stream or returned to the stream was flood water. They found the railroads liable for the diversion of that water onto another's land.

The later cases, however, found the classification of water as diffused surface water or as flood water to be determinative of liability. The only thing made clear from the court's most recent approach to the flood water problem is that the burden is on the one claiming interference with the flood channel to produce evidence that the obstruction altered the course of the stream during flooding thereby damaging him.[256]

Statutory Law Insofar as flood water remains in or returns to a watercourse and does not become diffused surface water, it keeps its public character and is subject to such regulation as may become necessary. Although a detailed examination of all the statutory enactments pertaining to flood control is beyond the scope of this survey, a brief summary of the high points will demonstrate that the Indiana General Assembly has developed complex statutory schemes for preventing and controlling floods. In 1965, the powers and duties of the Flood Control and Water Resources Commission and the Department of Conservation were abolished, and their powers and duties were transferred to the newly created Department of Natural Resources.[257] The department has the power to investigate, compile and disseminate information and make recommendations concerning flood prevention. Further, the department has the overriding responsibility for coordinating, acquiring, and inspecting flood control and stream modification projects in Indiana and a duty to "encourage . . . local initiative and effort in providing flood control and the development of water resources.[258] In addition, the department has administrative control over the Flood Control Revolving Fund which makes loans to municipalities[259] for the purpose of flood control or prevention if approved by the department and the State Finance Board.[260]

The Indiana Flood Control Act[261] was passed to minimize both the loss of life and damage to property which are caused by floods. The act recognizes that watercourses of rivers and streams should be regulated so as to minimize the extent of floods. It further recognizes that a comprehensive program for flood control should include provisions for the accumulation and preservation of the state's water resources.[262]

The general assembly has developed a complex statutory scheme for the construction and maintenance of levees for the purpose of controlling floodwater.[263] Levee districts may be created with boards endowed with broad powers to construct and maintain levees.[264] In addition, major levee projects may be constructed by the United States Army Corps of Engineers if local units agree to provide rights-of-way and maintenance for the completed projects.[265]

Several Indiana cities have their own flood control commissions,[266] which are subject to close supervision by the Department of Natural Resources.[267] In addition, a procedure is provided by statute for the creation of conservancy districts to deal with "serious problems of water management."[268] The statute lists numerous reasons for their creation, the first of which is flood prevention and control.[269] The districts have the power of bonding, taxing, exercising eminent domain, and operating and maintaining the works that may be constructed. Furthermore, a district may assume responsibility for and assure local operation and maintenance of federal projects constructed under the directives of the Watershed and Flood Prevention Act, and in cooperation with the Soil Conservation Service of the United States Department of Agriculture.[270] Though the districts are subject to the supervision of state agencies, it has been suggested that the Conservancy District Act may delegate too much control over the state's water resources to a local district.[271]

Acquisition of Water Rights by Prescription

In Indiana, rights to use water may be acquired by prescription if the use is adverse, continuous, uninterrupted, exclusive, and under a claim of right for the prescriptive period.[272] Acquisition of rights by prescription is based on the theory that a continuous user should eventually gain an interest against a riparian who fails to object to the use. The uses that may be acquired by prescription include (among others) the right to use water for recreational or agricultural purposes, the right to drain water onto the land of another, the right to divert water away from the land of another, the right to maintain dams, and other rights.

The Prescriptive Period By statute in Indiana the time required to acquire an easement by prescription is twenty years. Section 32-5-1-1 of the Indiana Code reads:

> The right of way, air, light, or other easement, from, in, upon, or over, the land of another, shall not be acquired by adverse use, unless such use shall have been continuously uninterrupted for twenty (20) years.

The prescriptive period begins to run at the moment the adverse use begins even if no actual damage is caused to a riparian owner.[273] Thus, if a riparian owner (or a nonriparian owner) withdraws water for use on nonriparian land, presumably the prescriptive period would commence to run. On the other hand, if a riparian withdraws water for use on riparian land the prescriptive period would not commence until such time as that use might become unreasonable in regard to fellow riparians.

Prescriptive Rights in Public Water Although Indiana courts have not specifically addressed the problem of whether an individual may acquire prescriptive rights in public water, the Indiana Supreme Court has held that "an easement cannot be acquired by prescription against the government."[274] It seems likely that in a case involving acquisition of prescriptive rights in public water, the courts in Indiana would find this holding applicable and deny such rights.

Case Law Although prescriptive rights in water may take many forms, the most frequently litigated issue in Indiana is the acquisition of a drainage easement by prescription.[275] In addition, the Indiana Supreme Court has addressed the problem of whether the right to have an unnatural condition maintained may be acquired by prescription. In *Burk v. Simonson,*[276] a case in which the defendant had maintained a lock for thirty years, the court held that the plaintiff, whose land would have been flooded had the lock been removed, had acquired a prescriptive right to have the lock maintained. Thus, prescriptive rights in water extend not only to an actual use or disposal of water, but also to a right to have a certain condition maintained.

Transfer of Water Rights

As a general rule, rights to water are not inextricably bound to the land to which they are incident. Therefore, they may be conveyed although the land itself is retained by the grantor. On the other hand, the rights to the water may be retained although the land itself is conveyed. However, if the land that has appurtenant water rights is conveyed, the deed passes not only the land, but also the water rights unless the grantor expressly reserves them.

Although these general rules appear to be simple enough at first glance, they raise serious questions. If the reasonable use doctrine contemplates use of the water on riparian land, how can title to the land and the right to the water be separated? In Indiana, may a riparian owner convey riparian withdrawal rights to a nonriparian or nonriparian land?[277]

Remedies to Protect Water Rights Equitable relief may be available to enjoin interference with water rights or to prevent threatened interference.[278] Injunctions are usually granted only if the legal remedy is inadequate.

In Indiana, an injunction may be granted even though the plaintiff is not a riparian owner suffering interference with his riparian rights. A number of injunctions have been sought on grounds that the defendant was maintaining a nuisance.[279] In such cases, the court in deciding what remedy should be granted may rely upon the law pertaining to private nuisance.[280] It may balance the equities and weigh the economic hardship an injunction would cause the defendant or the beneficial aspects of the alleged nuisance against the injury to the plaintiff in deciding what remedy is appropriate.[281] Even if the court denies an injunction, it may still recompense the plaintiff for his injury through an award of damages. Indiana courts have regularly awarded damages for injury caused by interference with riparian rights.[282]

Declaratory Judgment The reasonable use doctrine can cause uncertainty for a riparian owner who would like to be assured that his use of water will be acceptable. What may be considered a reasonable use today in relation to the uses of his fellow riparians may not be reasonable tomorrow if his fellow riparians change their uses.

This uncertainty might cause a riparian owner to seek an assurance that his use will continue to be reasonable. Although a declaratory judgment[283] would settle the issue of whether his use was reasonable at the time of the action, it would not assure that the use would continue to be reasonable in the future. A court might anticipate foreseeable water use demands and attempt to provide for them, but a certain amount of insecurity in regard to what will remain a reasonable use is unavoidable.

Miscellaneous In addition to traditional remedies provided by the courts, the Department of Natural Resources' Division of Water may mediate disputes among diverters of surface water within any watershed area.[284] A mediation may be instituted by filing a request with the division. The benefits of this mediation procedure are questionable in that the division's recommendations do not bind the parties and will not prejudice their rights to bring the matter to court.

REFERENCES

1. The doctrine of riparian rights arose out of the common law and has been refined and adopted in regions having an abundance of water. Vol. 1, *Waters and Water Rights* § 4.3, at 34; § 16, at 66. (R. Clark, ed. 1967). *See also* G. Waite, *Indiana Water Law and Suggestions for Action* 4 (1968); C. Kinney, *A Treatise on the Law on Irrigation and Water Rights* § 452, at 763 (2d ed. 1912).

2. *Tuesburg Land Co. v. State*, 78 Ind. App. 327, 330, 131 N.E. 530, 531 (1912). Section 13-2-1-3 of the Indiana Code affirms this principle by limiting riparian rights to "owners of land contiguous to or encompassing a public watercourse." Ind. Code § 13-2-1-3 (1976).

3. Vol. 1, *Waters and Water Rights* § 4.3, at 34, §§ 4.22-.23, at 112-14 (R. Clark, ed. 1967).

4. Vol. 1, H. Farnham, *The Law of Waters and Water Rights* § 63, at 281 (1904).

5. *Bainbridge v. Sherlock*, 29 Ind. 364 (1868), *modified*, 41 Ind. 35 (1872); Vol. 1, H. Farnham, *supra* note 4, §§ 62-63, at 280-81. A few jurisdictions have limited riparian rights to nonnavigable waters. *See Port of Seattle v. Oregon & W. R.R.*, 255 U.S. 56 (1921); Vol. 1A, G. Thompson, *Commentaries on the Law of Real Property*, § 275, at 448 (1964).

6. The reasonable use doctrine of riparian rights was judicially recognized as early as 1855 by the Indiana Supreme Court in *Dilling v. Murray*, 6 Ind. 324 (1855).

7. *Vandalia R.R. v. Yeager*, 60 Ind. App. 118, 124, 110 N.E. 230, 234 (1915).

8. *Lowe v. Loge Realty Co.*, 138 Ind. App. 434, 214 N.E.2d 400 (1966); Vol. 1, *Waters and Water Rights* § 52.1B, at 308 (R. Clark, ed. 1967). In *Mitchell v. Bain*, 142 Ind. 604, 614, 42 N.E. 230, 233 (1895), the court stated, "A stream does not cease to be a watercourse and become mere surface water because at a certain point it spreads over low ground several rods in width and flows for a distance without a definite channel. . . ." Relative to water resource projects and the development and improvement of water resources, the Indiana General Assembly has defined watercourse to mean "a channel, having defined banks, which is cut by erosion of running water through turf, soil, rock or other material and over the bottom of which water flows for substantial periods of the year . . . , and shall include any watercourse which has been improved by confining it in an artificial channel." Ind. Code § 13-2-1-4(4) (1976).

9. *Lowe v. Loge Realty Co.*, 138 Ind. App. 434, 214 N.E.2d 400 (1966); *Vandalia R.R. v. Yeager*, 60 Ind. App. at 124, 110 N.E. at 233. *See also Trout v. Woodward*, 64 Ind. App. 333, 340, 114 N.E. 467, 470 (1916), in which the court found that a six to nine month flow per year "from time immemorial" provided the necessary permanency.

10. *Trout v. Woodward*, 64 Ind. App. at 339, 114 N.E. at 470; *Vandalia R.R. v. Yeager*, 60 Ind. App. at 124, 110 N.E. at 233.

11. *New Jersey, Ind. & Ill. R.R. v. Tutt*, 168 Ind. 205, 211, 80 N.E. 420, 422-23 (1907); Vandalia R.R. v. Yeager, 60 Ind. App. at 124, 110 N.E. at 233.

12. *Trout v. Woodward*, 64 Ind. App. at 340, 114 N.E. at 4; *Vandalia R.R. v. Yeager*, 60 Ind. App. at 124, 110 N.E. at 233.

13. *Trout v. Woodward*, 64 Ind. App. at 340, 144 N.E. at 470; *Walley v. Wiley*, 56 Ind. App. 171, 177-78, 104 N.E. 318, 320 (1913). This holding is in accord with Indiana Code definition of a watercourse. Ind. Code § 13-2-1-4(4) (1976).

14. Vol. 1, *Water and Water Rights* § 52.1B, at 311 (R. Clark, ed. 1967).

15. *Trout v. Woodward*, 64 Ind. App. at 339, 114 N.E. at 470 (quoting *Case v. Hoffman*, 84 Wis. 438, 54 N.W. 793 [1893]).

16. Ind. Code § 32-2-1-4(4) (1976). This definitional statute relates to water resource projects and the development and improvement of all water resources and was not intended to define waters to which riparian rights attach.

17. *Taylor v. Fickas*, 64 Ind. 167 (1878); *Jean v. Pennsylvania R.R.*, 9 Ind. App. 56, 36 N.E. 159 (1894).

18. *Watts v. Evansville, Mt. C. & N. Ry.*, 191 Ind. 27, 129 N.E. 315 (1921).

19. *Anaheim Union Water Co. v. Fuller*, 150 Cal. 327, 88 P. 978 (1907); *Boehmer v. Big Rock Irrigation Dist.*, 117 Cal. 19, 48 P. 908 (1897); *Watkins Land Co. v. Clements*, 98 Tex. 578, 86 S.W. 733 (1905); *Yearsley v. Carter*, 149 Wash. 285, 270 P. 804 (1928).

20. G. Waite, *supra* note 1, at 173-74.

21. *Clark v. Allaman*, 71 Kan. 206, 80 P. 571 (1905); Jones v. Connecticut, 39 Ore. 30, 64 P. 855 (1901). *See* Vol. 4, *Restatement of Torts* § 843, comment c (1939).

22. *Sayles v. City of Mitchell*, 60 S.D. 592, 245 N.W. 390 (1932). Although some commentators have claimed that the "restricted unity of title" test is the general rule, Vol. 1, *Waters and Water Rights* § 53.5(C) (R. Clark, ed. 1967), other authorities have indicated that the "unity of title" definition is said to be used by the majority of jurisdictions, Vol. 6A, *American Law of Property* § 28.55 (A.J. Casner, ed. 1954). One authority referred to the "restricted unity of title" test as the "watershed theory" and stated, "The watershed theory is the leading rule in riparian states." Vol. 1A, G. Thompson, *supra* note 5, § 275, at 449.

23. Ind. Code § 13-2-1-1 (1976). *See also* G. Waite, *supra* note 1, at 174.

24. Act of March 11, 1955, ch. 251, § 1, 1955 Ind. Acts 643 (now codified at Ind. Code § 13-2-1-1 (1976)).

25. *Id.* § 3 (emphasis added) (now codified in Ind. Code § 13-2-1-2 [1976]).

26. Ind. Code § 13-2-1-1 (1976). For a more extensive discussion of this problem, *see* G. Waite, *supra* note 1, at 176.

27. *See Restatement of Torts*, ch. 41, topic 3, introductory note, at 342-44 (1939).

28. *Id.* at 343.

29. *Id.* at 344.

30. Ind. Code §§ 13-2-1-4(10), 13-2-9-1 (1976).

31. G. Waite, *supra* note 1, at 6.

32. 6 Ind. 324 (1855).

33. *Id.* at 327-28.

34. *Penn Am. Plate Glass Co. v. Schwinn*, 177 Ind. 645, 657, 98 N.E. 715, 719 (1912); *Muncie Pulp Co. v. Koontz*, 33 Ind. App. 532, 537, 70 N.E. 999, 1001 (1904).

35. *Valparaiso Water Co. v. Dickover*, 17 Ind. App. at 237, 46 N.E. at 592.

36. *Dilling v. Murray*, 6 Ind. at 327-28.

37. *Jones v. Tennessee Coal, Iron & R. Co.*, 80 So. 463, 464, 202 Ala. 381, 382 (1918). *See* 93 C.J.S. *Waters* § 12 (1956).

38. Vol. 6A, *American Law of Property* § 28.57 (A.J. Casner, ed. 1954).

39. *City of Valparaiso v. Hagen*, 153 Ind. 337, 340, 54 N.E. 1062, 1063 (1899). The court stated in dicta:

> Every owner of land, through which a stream of water flows, is entitled to the reasonable use and enjoyment of the stream. His right to do so is not an acquired property right, but a natural right appurtenant to his freehold, and is in common and equal with all others owning land upon the stream. He may dam it and divert it for mechanical purposes and fish ponds, if he will return it to its channel before leaving his premises; he may use it for purposes of agriculture; his animals may take water from it at will. . . .

40. *Valpariaso City Water Co. v. Dickover*, 17 Ind. App. 233, 238, 46 N.E. 591, 592-93 (1897). In determining the use that may be made of water by a riparian owner, one must take into account the quantity of water in the stream or lake. If the flow is only sufficient to supply the primary, or ordinary, wants for domestic purposes, no one may use the water for any secondary, or extraordinary, purpose.

41. Ind. Code § 13-2-1-3(1) (1976).

42. *Meng v. Coffee*, 67 Neb. 500, 93 N.W. 713 (1903).

43. *Crawford Co. v. Hathaway*, 67 Neb. 325, 93 N.W. 781 (1903).

44. *Salem Flouring Mills Co. v. Lord*, 42 Or. 82, 69 P. 1033 (1902).

45. *Hough v. Porter*, 51 Or. 318, 98 P. 1083 (1909).

46. *Crawford Co. v. Hathaway*, 67 Neb. 325, 93 N.W. 781 (1903); *Montelious v. Elsea*, 11 Ohio Op. 2d 57, 161 N.E.2d 675 (Ct. C.P. 1959); *Martin v. Burr*, 111 Tex. 57, 228 S.W. 543 (1921).

47. *Jones v. Tennessee Coal, Iron & R. Co.*, 202 Ala. at 382, 80 So. at 464, *quoted in* Note, *Water Rights in Indiana*, 32 Ind. L.J. 39, 43 n.22 (1956).

48. *Valparaiso City Water Co. v. Dickover*, 17 Ind. App. 233, 238, 46 N.E. 591, 592-93 (1896).

49. 17 Ind. App. 233, 46 N.E. 591 (1896).

50. 223 Ind. 242, 59 N.E.2d 353 (1944).

51. *Id.* at 256, 59 N.E.2d at 358 (citing *Lowe v. Indiana Hydroelectric Power Co.*, 197 Ind. 430, 151 N.E. 220 [1926]; *City of Logansport v. Uhl*, 99 Ind. 531 [1884]; *Bump v. Sellers*, 54 Ind. App. 146, 102 N.E. 875 [1913]).

52. *Id.* at 258, 59 N.E.2d at 359 (citing *Van Dissel v. Holland-Horr Mill Co.*, 91 Wash. 239, 157 P. 687 [1916]). The *Van Dissel* court cited an earlier Washington case which indicated that the permanent diversion of the water gave the use its unlawful character. *Rigney v. Tacoma Light & Power Co.*, 9 Wash. 576, 38 P. 147, 148 (1894). *See generally* 78 Am. Jur. 2d *Waterworks and Water Companies* §§ 23-24 (1975).

53. Ind. Code § 13-2-1-1 (1976).

54. Drilling of wells to provide a water supply may not provide a solution. To the extent such pumping interferes with an established lake level, restrictions could be imposed. *See* discussion of lake level statutes, p. 104. Should wells be drilled in such a manner that pumping materially reduces the flow of a stream to the detriment of riparian owners, it would seem that the courts should treat such pumping in the same manner as direct withdrawal from the watercourse. The same result would be brought about by the enactment of minimum flow regulations.

55. Ind. Code §§ 32-11-1-1 to 13 (1976 & Supp. 1978).

56. *Id.* §§ 13-2-9-1 to 8.

57. 17 Ind. App. 233, 46 N.E. 591 (1897).

58. *City of Elkhart v. Christiana Hydraulics, Inc.*, 223 Ind. 242, 59 N.E.2d 353 (1944).

59. *See* 78 Am. Jur. 2d *Waterworks and Water Companies* §§ 23-24 (1975).

60. Ind. Code § 13-2-1-3 (1) (1976).

61. 78 Am. Jur. 2d *Waters* § 285 (1975). This limitation would probably allow water to be used for a family garden or greenhouse.

62. *City of Valparaiso v. Hagen*, 153 Ind. at 340, 54 N.E. at 1063.

63. *See* discussion of diversion, p. 104.

64. Ind. Code § 13-2-1-3(1) (1976).

65. *Montelious v. Elseu*, 11 Ohio Op. 2d 57, 161 N.E.2d 675 (Ct. C.P. 1959).

66. *See* discussion of diversion, p. 104.

67. Whether this is a valid objection depends upon the test used to determine the extent of riparian land. For a full discussion of what land is riparian, *see* p. 100.

68. *City of Valparaiso v. Hagen*, 153 Ind. at 340, 54 N.E. at 1063.

69. Ind. Code § 13-2-1-3(2), (3) (1976).

70. *Id.* § 13-2-9-1.

71. G. Waite, *supra* note 1, at 58 n.47. Although Waite's data concerning Indiana irrigation acreage is more than ten years old, one may assume that similar irrigation use has continued.

72. *See* discussion of municipal water use, p. 101.

73. *See City of Elkhart v. Christiana Hydraulics, Inc.*, 223 Ind. at 258, 59 N.E.2d at 359.

74. Ind. Code §§ 13-2-1-4(10), 13-2-9-1 (1976).

75. *Indianapolis Water Co. v. American Strawboard Co.*, 53 F. 970 (C.C. D. Ind. 1890).

76. Ind. Code § 13-2-1-4(10) (1976) (water supply use); *id.* § 13-2-9-1 (reservoir water supply use); *id.* § 13-2-22-11 (powers of the natural resources commission).

77. Ind. Admin. Rules & Reg. [(13-1-3-7)-28(c)(2), (d)(2) (Burns Supp. 1978).

78. Ind. Code § 13-2-11-7 (Supp. 1978). *See* discussion of thermal pollution, p. 111.

79. 78 Am. Jur. 2d *Waters* § 10, at 454 (1975).

80. *Id.* § 11. *See generally id.* §§ 10-14.

81. For discussion of lake level statutes, as related to public rights, *see* p. 104.

82. Ind. Code §§ 13-2-11-3, 13-2-13-1 to 2, 13-2-14-2 (1976 & Supp. 1978). *See also Holle v. Drudge*, 190 Ind. 520, 129 N.E. 229 (1920).

83. Ind. Code § 13-2-14-3 (1976).

84. *Id.* § 13-2-15-1 (Supp. 1978).

85. *Id.* § 13-2-17-1 (1976).

86. *Id.* § 13-2-16-1 (Supp. 1978).

87. *Id.* § 13-2-16-2 (1976).

88. *Id.* § 13-2-15-1 to 2 (1976 & Supp. 1978).

89. *See id.* § 13-2-14-3 (1976).

90. *Id.* § 13-2-18-1.

91. *Id.* § 13-2-18-6.

92. *Id.* § 13-2-18-8.

93. Waite, *Public Rights in Indiana Waters*, 37 Ind. L.J. 467 (1962).

94. Under the heading of "instream uses," rights in lakes as well as streams will be discussed. Technically an owner whose land abuts on a lake or sea is referred to as a "littoral owner" with littoral rights, while one whose land abuts on a stream is referred to as a "riparian owner" with riparian rights. However, "riparian" is used also coextensively with "littoral" and will be used herein to refer to owners of land abutting on a body of water, whether stream, lake or sea. *See generally* 78 Am. Jur. 2d *Waters* § 260 (1975).

95. Other than the right of navigation, most public rights concern recreational uses, such as fishing, boating, and swimming. Such uses did not receive statutory recognition in Indiana until the late 1940s. See Act of March 13, 1947, ch. 301, § 1, 1947 Ind. Acts 1233 (now codified at Ind. Code § 13-2-14-1 [1976]).

96. *See* p. 101.

97. *See* G. Waite, *supra* note 1, at 78.

98. *See* Ind. Code § 13-2-1-2 (1976).

99. At early common law, public rights were recognized in navigable waters, R. Clark, *supra* note 1, § 35.2.

100. *See* Ind. Code §§ 13-2-11-1, -3, 13-14-1, to 2 (1976 & Supp. 1978). *See also* discussion of acquiescence, p. 110.

101. One commentator asserts that the statutory public recreational use rights, as set forth in the lake level statutes, only attach to lakes subject to public rights by virtue of acquiscence. G. Waite, *supra* note 1, at 79 & 100. This view would limit public rights in navigable lakes not meeting the statutory acquiescence test to the following common law public rights: the right of navigation and free passage (subject to legitimate state-authorized obstructions); the right to use the shore to protect life and limb in an emergency, *id.* at 78; and possibly the right to remove materials from the lake bed, Ind. Code § 14-3-1-14(10) (Supp. 1978), if a lake is a "navigable body of water" under the statute. Such lakes would not receive the additional statutory protection against encroachments, excavations, and artificial lake level fluctuations, except as granted by other statutes of limited application. *See id.* §§ 13-2-11-1 to 6, 13-2-14-1 to 8, 13-2-15-1 to 6, 13-2-16-1 to 3, 13-2-17-1 to 6 (1976 & Supp. 1978). This class of lakes may be subject to very limited recreational rights, as compared to the broad statutory recreational rights in acquiescence-affected lakes, depending on the nature of common-law recreational rights in Indiana. Although decisions in this area are extremely limited, it is possible that the Indiana courts would uphold rights equally as broad as the statutory public rights, based on legislative policy. G. Waite, *supra* note 1, at 100.

102. *See* Ind. Code §§ 13-2-11-3, 13-2-16-1, 14-3-1-20 (1976 & Supp. 1978).

103. *See id.* §§ 13-2-18.5-5, 13-2-26-3(i), -10 (1976).

104. *Id.* §§ 13-2-14-5, 13-2-18.5-5. *See* [1961] Ind. Att'y Gen. Op. 101.

105. Ind. Code § 13-2-26-3(i) (1976). *See generally id.* §§ 13-2-26-1 to 11.

106. *Id.* § 13-2-1-3.

107. *Id.* §§ 13-2-1-1 to 2.

108. *Id.* §§ 13-2-11-1 to 13-2-18-25 (1976 & Supp. 1978).

109. 3 Blackf. 193 (Ind. 1853).

110. *Id.* at 194-95 (citing the Northwest Ordinance, *as reenacted in part in* Act of March 26, 1804, ch. 35, § 6, 2 Stat. 277.)

111. 3 Blackf. at 196.

112. *Id.*

113. *Williams v. Beardsley*, 2 Ind. 591, 594-95 (1851).

114. 5 Ind. 8 (1854).

115. *Pennsylvania v. Wheeling Bridge Co.*, 54 U.S. (13 How.) 518 (1851); *Pollard v. Hagan*, 44 U.S. (3 How.) 212 (1845).

116. 5 Ind. at 9.

117. U.S. Const. art. I, § 8, cl. 3.

118. 5 Ind. at 10.

119. *Id.* at 12.

120. *Id.*

121. G. Waite, *supra* note 1, at 84.

122. *See* 5 Ind. at 12.
123. 28 Ind. 257 (1867).
124. *Id.* at 266.
125. *Id.* at 268-69.
126. G. Waite, *supra* note 2, at 86 (citing Note, 1939 Wisc. L. Rev. 547, 548-53). The Indiana courts' last mention of the Ordinance occurred in *Sherlock v. Bainbridge*, 41 Ind. 35, (1872), in which the court relied on the common law instead of the ordinance, and in *State v. Wabash Paper Co.*, 21 Ind. App. 167, 174 (1898), in which the court looked to the stream's navigability in 1804, the year in which the ordinance was reenacted. *See* Act of March 26, 1804, ch. 35, § 6, 2 Stat. 277.
127. 228 Ind. 623, 95 N.E.2d 145 (1950).
128. 77 U.S. (10 Wall.) 557 (1870).
129. *Id.* at 563.
130. *See* discussion of *Depew v. Board of Trustees*, p. 108.
131. 87 U.S. (20 Wall.) 430 (1874).
132. *Id.* at 441-42. Admittedly, this passage, when applied to present-day circumstances, could apply to a stream's potential use for recreational purposes by the public, if such a use were perceived as either transportation or commerce. "The United States Supreme Court has suggested that the type of commerce known at the time statehood was attained is not conclusive, because the fundamental question is the capacity of a watercourse to be commercially useful under changing social and economic conditions." G. Waite, *supra* note 1, at 190 (citing United States v. Utah, 283 U.S. 64, 83 [1931]).
133. 283 U.S. 64 (1931).
134. 228 Ind. at 629-30, 95 N.E.2d at 148 (citations omitted).
135. *Id.* at 626-27, 95 N.E.2d at 147.
136. The court refused to acknowledge the alleged precedential value of six prior Indiana Supreme Court cases which held the White River to be nonnavigable: *Brown v. Powers*, 182 Ind. 145, 104 N.E. 857 (1914); *Illyes v. White River Light & Power Co.*, 175 Ind. 118, 93 N.E. 670 (1910); *Indianapolis Water Co. v. Kingan & Co.*, 155 Ind. 476, 58 N.E. 715 (1900); *Sizor v. City of Logansport*, 151 Ind. 626, 50 N.E. 377 (1898); *Ross v. Faust*, 54 Ind. 471 (1876); *Depew v. Board of Trustees*, 5 Ind. 8 (1854). Instead, the court distinguished those cases from the case at hand, based on the private parties in the prior cases, the federal question involved in the present case, and the failure of the prior cases to evaluate the navigability as of 1816. In an interesting passage, the court stressed that a determination of the rights and duties between two riparian owners was not determinative of the public's right to abate a nuisance created or maintained by either of the riparian owners. 228 Ind. at 635-36, 95 N.E.2d at 151-52.
137. *Id.* at 634-35, 95 N.E.2d at 150 (citing United States v. Utah, 283 U.S. 64 [1931]).
138. *See* G. Waite, *supra* note 1, at 20, for a discussion of a prior case, *Ross v. Faust*, 54 Ind. 471 (1876).
139. 270 U.S. 49 (1925).
140. *Id.* at 54-55, *quoted in State v. Kivett*, 288 Ind. at 628, 95 N.E.2d at 148 (emphasis added). *See also Ross v. Faust*, 54 Ind. 471 (1876).
141. 228 Ind. at 630, 95 N.E.2d at 148.
142. *Id.* at 630-31, 95 N.E.2d at 152.
143. *Id.*
144. [1933] Ind. Att'y Gen. Op. 538, 541-42.
145. *United States v. Oregon*, 295 U.S. 1 (1935); *Barney v. Keokuk*, 94 U.S. 324 (1876); *Goodtitle v. Kibbe*, 50 U.S. (9 How.) 471 (1849).
146. 228 Ind. at 629, 95 N.E.2d at 148.
147. *Id.* at 636, 95 N.E.2d at 151.
148. *Nebraska v. Iowa*, 143 U.S. 359, 12 S. Ct. 396 (1891); *Longabaugh v. Johnson*, 321 N.E.2d 865, 867 (Ind. Ct. App. 1975).
149. 78 Am. Jur. 2d *Waters* § 399 (1975).
150. Ind. Code §§ 13-2-9-1 to 8, 32-11-1-1 (1976).
151. *Sanders v. DeRose*, 207 Ind. 90, 191 N.E. 331 (1934).
152. *Id. See* discussion of *Sanders*, p. 110.
153. *See* discussion of ice removal, p. 108.
154. Ind. Code § 14-3-1-4(10) (1976).
155. *Id.* §§ 13-2-14-5, 8.
156. *Id.* § 14-4-3-25. *See generally id.* §§ 14-4-3-1 to 24.
157. *Lake Sand Co. v. State*, 68 Ind. App. 439, 120 N.E. 714 (1918).
158. G. Waite, *supra* note 1, at 81, 90.
159. *Water Works Co. v. Burkhart*, 41 Ind. 364 (1872); *State v. Pottmeyer*, 33 Ind. 402 (1870); *John Hilt Lake Ice Co. v. Zahrt*, 29 Ind. App. 476, 62 N.E. 509 (1902).
160. *See John Hilt Lake Ice Co. v. Zahrt*, 29 Ind. App. 476, 62 N.E. 509 (1902).
161. *See* discussion of *Depew*, p. 108.
162. 5 Ind. 13 (1854).
163. *Id.* at 15.
164. *Id.* at 16.
165. 8 Ind. 1 (1856).
166. *Id.* at 4.
167. *Id.* at 5.
168. 28 Ind. 257 (1867).
169. 2 Ind. 591 (1851).
170. 5 Ind. 8 (1854).
171. Ind. Code §§ 19-4-14-1 to 19-4-16-7, 19-8-2-8 to 14 (1976 & Supp. 1978).
172. *Id.* § 13-2-1-3 (1976).
173. *See* p. 113.
174. Ind. Code § 13-2-4-1 (1976).
175. *Id.* § 13-2-4-2.
176. *Id.* § 13-2-4-5.
177. *Id.* §§ 13-2-4-3, -7.
178. *Id.* § 13-2-4-6.
179. *Id.* § 13-2-5-1.
180. *Id.* § 14-3-1-14(9) (Supp. 1978).
181. Ind. Admin. Rules and Reg. § (14-1-2-5)-1 (Burns 1976).
182. *Id.* §§ (14-1-1-43)-1, (14-1-1-56)-1.
183. G. Waite, *supra* note 1, at 142.
184. Ind. Code § 13-2-14-1 (1976). *See* G. Waite, *supra* note 1, at 142.
185. Ind. Code § 13-2-11-1 (1976).
186. *Id.* § 13-2-26-2.
187. *Id.*
188. *Id.* § 13-2-26-5.
189. *Id.* § 13-2-26-8.
190. *Id.* § 13-2-26-3(c), (d), (e).
191. *Id.* § 13-2-26-3(i).
192. *Id.* § 13-2-26-3(j).
193. *Id.* § 13-2-26-3(k).
194. *Id.* § 13-2-26-3. The term *conservation easement* is defined in *id.* § 14-4-5.5-1.
195. *See* discussion of lake level statutes, p. 104.
196. Ind. Code §§ 13-2-11-1, 13-2-14-1 (1976).
197. *Id.* §§ 13-2-11-3, 13-2-14-2 (Supp. 1978).

> Navigability is not the test of the lakes to which the public rights declared by the statute attach. The statute does not apply to Lake Michigan or to lakes entirely or partially situated within the corporate limits of any city of the second class located in a county whose population according to the last preceding census is not less than 400,000 and not more than 650,000. Apart from these exceptions, the statute applies to lakes that "have been used by the public with the acquiescence of any or all riparian owners." In those unlikely lakes that are navigable but that do not meet the public use-riparian acquiescence test, and in the lakes excepted from the statute, it seems only the common-law rights obtain. However, when the case comes up, a court might well expand the common-law rights to include those conferred by the statute.
>
> G. Waite, *supra* note 1, at 100.

198. 207 Ind. 90, 191 N.E. 331 (1934).
199. *Id.*
200. Ind. Code §§ 13-2-11-3, 13-2-14-2 (Supp. 1978) (emphasis added).
201. Waite, *Public Rights in Indiana Waters*, 37 Ind. L.J. 478-82 (1962).
202. 207 Ind. at 95, 191 N.E. at 333.
203. G. Waite, *supra* note 1, at 100.
204. *See* quoted material in note 197 *supra*.
205. Ind. Code § 14-3-3-6(a) (1976).
206. *Id.* § 14-2-3-2(1).

207. *Id.* §§ 14-2-8.5-1 to 14.
208. *Id.* § 14-2-7-3.
209. *Id.* § 14-2-2-1 (Supp. 1978). *See also id.* §§ 14-2-5-1, -8 (1976 & Supp. 1978).
210. *Id.* § 14-2-5-10 (Supp. 1978).
211. *Id.* § 14-2-5-3.
212. *Id.* § 14-2-5-2 (1976).
213. *Id.* § 14-2-5-9 (Supp. 1978).
214. *Id.* § 14-3-4-9.
215. *Id.* § 13-1-3-4.
216. Thermal stream pollution is under the same regulations and enforcement statutes as chemical stream pollution.
217. Ind. Admin. Rules and Reg. § (13-1-3-7)-28(c)(2) & (d)(2) (Burns Supp. 1978).
218. Ind. Code § 13-2-11-7 (Supp. 1978).
219. However, the complexity and urgency of pollution problems in the Gary-East Chicago Area has led the EPA to retain considerable concurrent control in that locale. Note, *The Indiana Environmental Protection Agencies: A Survey and Critique*, 10 Ind. L. Rev. 955, 969 n.112 (1977).
220. Ind. Admin. Rules and Reg. §§ (13-1-3-7)-10, -22 (Burns 1976 & Supp. 1978).
221. *Id.* § (13-1-3-7)-22 (Burns Supp. 1978).
222. *Id.* § (13-1-3-7)-2 (Burns 1976).
223. Ind. Code § 13-1-5.5-3 (Supp. 1978).
224. *Id.* §§ 13-7-16.5-1 to 8 (Supp. 1978).
225. *Id.* § 14-4-2-5(d) (1976); Ind. Admin. Rules and Reg. § (13-1-3-7)-3 (Burns 1976).
226. Ind. Admin. Rules and Reg. §§ (13-1-3-7)-12, -13 (Burns 1976).
227. Ind. Code §§ 13-1-3-9, -11, -12, -14, -15 (1976 & Supp. 1978).
228. 153 Ind. 337, 54 N.E. 1062 (1899).
229. *Id.* at 339-40, 54 N.E. at 1063.
230. *Id.* at 341-44, 54 N.E. at 1063-64.
231. 177 Ind. 645, 98 N.E. 715 (1912).
232. *Id.* at 657-58, 98 N.E. at 719.
233. *Id.* at 658, 98 N.E. at 720.
234. *Id.* at 657, 98 N.E. at 719.
235. *See* discussion of pollution abatement, p. 111.
236. Ind. Code §§ 13-2-11-4, 13-2-14-4 (1976).
237. *Id.* § 13-2-18.5-5.
238. *Id.* §§ 13-1-6-1, -3, -6.
239. *Id.* § 19-3-7-1.
240. *Id.* § 19-4-6-7.
241. *Id.* § 13-1-11-1.
242. Note, *supra* note 219, at 975.
243. 33 U.S.C. §§ 1281-1282 (1976). *See id.* § 1284.
244. *See generally* Note, *supra* note 219, at 969 & 975.
245. Ind. Code §§ 13-2-1-4(10), 13-2-9-1 (1976).
246. *Id.* §§ 13-2-22-11, 14-3-1-3.
247. *Id.* §§ 13-2-9-1 to 8.
248. *Id.* §§ 13-2-10-1 to 9.
249. *Id.* § 13-2-16-1.
250. *Id.* § 13-2-1-7.
251. *Watts v. Evansville, M.C. & N. Ry.*, 191 Ind. 27, 45, 129 N.E. 315, 321 (1921).
252. *Dunn v. Chicago, Indpls. & Louisville Ry.*, 63 Ind. App. 553, 559, 114 N.E. 888, 890 (1917). Floodwater has been defined by statute as "water which is flowing or standing above the top level or outside the banks of a watercourse." Ind. Code § 13-2-1-4(7) (1976).
253. *Cleveland, C.C. & St. L. Ry. v. Woodbury Glass Co.*, 80 Ind. App. 298, 310, 120 N.E. 426, 430-31.
254. *Taylor v. Fickas*, 64 Ind. 167 (1879); *Jean v. Pennsylvania R.R.*, 9 Ind. App. 56, 36 N.E. 159 (1894).
255. *Watts v. Evansville, M.C. & N. Ry.*, 191 Ind. 27, 129 N.E. 315 (1921); *Evansville M.C. & N. Ry. v. Scott*, 67 Ind. App. 121, 114 N.E. 649 (1917); *Dunn v. Chicago I. & L. Ry.*, 63 Ind. App. 553, 114 N.E. 888 (1917).
256. *Thompson v. Dyar*, 126 Ind. App. 70, 130 N.E.2d 52 (1955).
257. Ind. Code §§ 14-3-3-1 to 20 (1976 & Supp. 1978).
258. *Id.* § 13-2-22-11.
259. *Id.* § 13-2-23-1 defines municipality as "any city, town, county and any special taxing district created by law."
260. *Id.* §§ 13-2-23-1 to 11.
261. *Id.* §§ 13-2-22-1 to 20.
262. The act provides a master plan for flood control and accumulation and preservation and protection of watercourses to be investigated and augmented by the Department of Natural Resources (Natural Resources Commission). The department has jurisdiction over public and private waters of the state and lands adjacent to those waters for flood control purposes. It further has authority to act on behalf of the state in matters of flood control with the United States government or any agency of the United States. The department may order the establishment of floodways. It is unlawful to erect, use or maintain in or on any floodway any structure or obstruction which would adversely affect the efficiency of or restrict the capacity of the floodway. Anyone wishing to erect a structure in a floodway must file an application with the commission. Floodplain management is also under the authority of the Natural Resources Commission. Floodplain is defined as "the area adjoining the river or stream which has been or may be hereafter covered by water." Ind. Code § 13-2-22.5-1 (1976).

The act states that floodways of rivers and streams "should not be inhabited and should be kept free and clear of interference or obstructions which will cause any undue restriction of the capacity of the floodways." *Id.* § 13-2-22-2. The term *floodway* is defined as "the channel of a river or stream and those portions of the floodplains adjoining the channel which are reasonably required to efficiently carry and discharge the floodwater or flood flow of any river or stream." *Id.* §13-2-22-3(12). This definition may pose difficulty for owners of land in the floodplain of a river who are unsure whether their land is a part of the floodway. Obviously some floods are more serious than others and will require larger portions of the floodplain to discharge the flood water. Thus, there may be some uncertainty as to just what land is included in the floodway. However, this uncertainty may be minimized by the fact that the Division of Water of the Department of Natural Resources has the power to delineate floodway boundaries. Should any question arise, application should be made to the division to exercise that power.

Furthermore, the Division of Water controls the system by which construction of structures in a floodway may be permitted. The basic premise on which this system operates is that any structure built in a floodway so as to adversely affect or unduly restrict the capacity of the floodway is an actionable nuisance. *Id.* § 13-2-22-13. Those unsure of the effect of their structures may file an application for a permit. Thus, practically speaking, anyone wishing to build a structure in what might be a floodway should apply for a permit. The effect of the system is to control land use in floodways by what is essentially a zoning scheme.

263. *See, e.g., id.* §§ 19-4-11-1 to 8; *id.* § 19-4-13-1 to 14; *id.* §§ 19-4-20-1 to 23 (1976 & Supp. 1978).
264. *Id.* §§ 19-4-12-1 to 33.
265. G. Waite, *Indiana Water Law and Suggestions for Action* 192 (1968).
266. *See, e.g., id* §§ 19-4-21-1 to 17.
267. *Id.* § 13-2-24-1.
268. *Id.* § 19-3-2-1-106 (1976 & Supp. 1978).
269. *Id.* § 19-3-2-3. In addition to flood prevention and control, conservancy districts may be established to improve drainage; provide for irrigation; provide water supply, including treatment and distribution for domestic, industrial, and public use; provide for the collection, treatment, and disposal of sewage and other liquid wastes produced within the district; develop forests, wildlife areas, and parks and recreational facilities where feasible in connection with beneficial water management; and prevent the loss of top soil from injurious water erosion.
270. G. Waite, *supra* note 7, at 191-94.
271. *Id.* at 220.
272. *Gaskill v. Barnett*, 52 Ind. App. 654, 101 N.E. 40 (1913). *See also* Ind. Code § 32-5-1-1 (1976).
273. *Walley v. Wiley*, 56 Ind. App. 171, 104 N.E. 318 (1914).
274. *Verrill v. School City of Hobart*, 222 Ind. 214, 216, 52 N.E.2d 619, 620 (1944).
275. *See, e.g., Walley v. Wiley*, 56 Ind. App. 171, 104 N.E. 318 (1914).

276. 104 Ind. 173, 2 N.E. 309 (1885).

277. *See* G. Waite, *Indiana Water Law and Suggestions for Action* 47 (1968).

278. *See, e.g., Penn Am. Plate Glass Co. v. Schwinn,* 177 Ind. 645, 98 N.E. 715 (1912); *Valparaiso City Water Co. v. Dickover,* 17 Ind. App. 233, 46 N.E. 591 (1897).

279. *Foster v. Marlsbary,* 86 Ind. App. 411, 157 N.E. 446 (1927).

280. *See, e.g., Penn Am. Plate Glass Co. v. Schwinn,* 177 Ind. 645, 98 N.E. 715 (1912); *West Muncie Strawboard Co. v. Slack,* 134 Ind. 21, 72 N.E. 879 (1904).

281. For a general discussion of the law of private nuisance *see* W. Prosser, *Handbook of the Law of Torts,* § 89 (4th ed. 1971).

282. *See, e.g., Barnard v. Shirley,* 135 Ind. 547, 34 N.E. 600 (1893).

283. For the law relating to declaratory judgments in Indiana, *see* Ind. Code §§ 34-4-10-1 to 16 (1976).

284. *Id.* § 13-2-1-6 (1976).

Diffused Surface Water

Diffused surface water or overland flow has been defined in Indiana as "water from falling rains or melting snows which diffused over the surface of the ground or which temporarily flow upon or over the surface as the natural elevations and depressions of the land may guide it but which has no definite banks or channel."[1] In addition, if flood water from a natural watercourse escapes its natural channel never to return, and spreads over adjacent land running in different directions or settling in pools or flats, it ceases to be a part of the stream and is considered diffused surface water.[2] It is "water of a casual and vagrant character,"[3] which cannot be used regularly for recreation, domestic, or commercial needs because its existence cannot be counted on. For this reason diffused surface water is generally considered to have no public consequences.[4]

Right to Use

Two distinct problems arise in the area of diffused surface water. The first and less important is the question of who owns diffused surface water and what use may be made of it. The second, and frequently litigated question, is how a landowner may rid himself of or fend off unwanted diffused surface water.

As to ownership and use, the general rule is that diffused surface water belongs to anyone who captures and collects it on his land. The water may be diverted for any private or commercial use even if it would not be considered a beneficial or reasonable use by the usual tests.[5] Indiana has adopted this general rule:

> The property in the lost water that percolates the soil below the surface of the earth, in hidden recesses, without a known channel or course, and property in the wild water that lies upon the surface of the earth, or temporarily flows over it as the natural or artificial elevations or depressions may guide or invite it, but without a channel, and which may be caused by the falling of rain or the melting of snow and ice, or the rising of contiguous streams, or rivers, fall within the maxim that a man's land extends to the centre of the earth below the surface, and to the skies above, and are absolute in the owner of the land, as being a part of the land itself.[6]

Right to Dispose of or Protect Against Diffused Surface Waters

The most significant legal dilemmas in the area of diffused surface water arise when owners of land attempt to get rid of unwanted water on their land or alternatively attempt to protect themselves against such water. An alteration of the natural drainage pattern of diffused surface water by one landowner may injure another landowner by causing that water to flow across or collect upon his land.

Two major rules have evolved concerning a landowner's right to change the natural flow of diffused surface water: the civil-law rule and the common-enemy rule.

Civil-Law Rule This rule is based on an easement theory and provides that lower lands are servient to the natural drainage of diffused surface water from upper lands. Therefore, the owner of the lower land charged with the servitude may not alter the drainage pattern by setting up obstructions. On the other hand, this rule applies only to water that collects naturally on the upper land. Therefore, the owner of the upper land cannot change the natural drainage pattern if it would change the flow across the lower land.

Common-Enemy Rule The common-enemy rule is the common-law rule. It provides that diffused surface water is the common enemy of man and that a landowner may take whatever action he deems necessary to rid himself of it even if it means injuring an adjoining landowner. Thus, an upper landowner may divert diffused surface water from his land onto the land of another even if the other land is injured thereby. Similarly, a lower landowner may change the grade of his

property or construct dams in order to keep diffused surface water from flowing onto his land even if it causes the diffused surface water to back up onto the upper land.[7]

Indiana Case Law Perhaps in the interest of encouraging the development and improvement of land, Indiana early adopted the common-enemy rule in its purest form. In *Taylor v. Fickas*[8] the defendant altered the natural drainage pattern of diffused surface water by planting a border of trees on his property line, causing water and debris to be deposited on plaintiff's property. In spite of the contention by plaintiff that land should be used in such a way as to avoid injury to others, the court denied relief, holding:

> While the owners of lands may not obstruct watercourses to the injury of others, they must be permitted to fence and cultivate their fields and improve their lands in the way which best subserves their interests, without being responsible for the accidents of floods, or the shiftings of surface water occasioned thereby, although sometimes slight and temporary injuries may result therefrom to adjoining owners. These are accidents which must be borne alike by all.[9]

However, it was not long before the potential harshness of this doctrine was perceived and it was qualified in Indiana.

The qualifications on the common-enemy rule can most readily be understood if the two interests at stake: (1) the interest of the upper owner on the one hand in ridding himself of diffused surface water and (2) the interest of the lower owner on the other hand in preventing it from coming into his land, are viewed separately.

Upper Landowners Soon after the court's initial adoption of the common-enemy rule, a modification was made. In *Templeton v. Voshloe,*[10] the court recognized that:

> The owner of the upper field may not construct drains or excavations so as to form new channels on to the lower field, nor can he collect the water of several channels and discharge it on the lower field so as to increase the wash upon the same. The right of the owner of the upper field to make drains on his own land is restricted to such as are required by good husbandry and the proper improvement of the surface of the ground, and as may be discharged into natural channels, without inflicting palpable and unnecessary injury on the lower field.

Thus the right of an upper landowner to rid himself of unwanted diffused surface water is not absolute.[11]

As recently as 1975, in *Gene B. Glick Co. v. Marion County Construction Corp.,*[12] the court reaffirmed earlier court holdings to the effect that a landowner may not collect surface water into a body of water and then discharge it in unnatural amounts or concentrated flow onto another's land. The *Glick* court quoted the following pertinent language from *Smith v. Atkinson:*

> Accordingly, an upper landowner may not by a channel, sewer, ditch or drain, collect or concentrate the surface water and cast it on the lands of the lower proprietor, either intentionally or negligently, without incurring liability for the damages caused thereby.[13]

However, Indiana courts early held that if a landowner diverted the water by artificial means into any existing watercourse, then the qualification did not apply, and the upper landowner was not liable to the lower owner.[14] Of course, the question of what constitutes a natural watercourse is a factual issue which must be resolved on a case-by-case basis. Furthermore, *Gene B. Glick v. Marion Construction Co.* casts doubt on whether a diversion by artificial means into a natural watercourse will always allow the upper landowner to escape liability. The court there held "there is liability for any damage which may result from the *concentrated* discharge of waters upon land or into existing watercourses not previously subject to such discharge,"[15] and "though the quantity of water may be the same . . . , if by means of ditches the rate of discharge into an existing watercourse is increased, liability may fall upon the landowner so discharging the water."[16] Thus an upper owner may be liable to a lower owner merely by increasing the rate of flow in an existing watercourse if the lower owner is damaged, even if the *quantity* of water is the same.

A somewhat different but related limitation on a landowner's right to deal with diffused surface water is the rule that an upper landowner may not pollute or contaminate diffused surface water that flows from his land onto the land of another.[17]

Although these qualifications on upper owners may curtail their efforts to get rid of diffused surface water, the law pertaining to prescriptive easements applies in the area of drainage of diffused surface water to another's land. Thus, if an upper landowner has for a period in excess of twenty years used an artificial drainage channel openly, notoriously, exclusively, and adversely[18] to drain diffused surface water from his land to the land of an adjoining property owner, the upper landowner has a prescriptive drainage easement and is not liable in damages to the lower landowner.[19]

Another problem which is related to the drainage of diffused surface water is the collection or impoundment of water which is later discharged in a sudden, unplanned flow onto adjoining land. In *Central Indiana Railroad Co. v. Mikesell*[20] the court held if the discharge could have been prevented by the exercise of ordinary care, the upper landowner was liable to the lower landowner. This qualification is based on the theory that the defendant's negligence was the proximate cause of the injury to the plaintiff's property. The principle was recently affirmed in *Gumz v. Bejes*[21] in which the court held that an upper landowner who artificially creates an impoundment of flood waters on his land will be liable to the lower landowner if the water escapes and the lower land is thereby injured.

In summary, the common-enemy rule as modified in Indiana now precludes an upper landowner from ridding himself of diffused surface water by means of an artificial channel, unless he has a prescriptive right to do so or he discharges it into a natural watercourse (provided, however, that the rate of flow is not increased to the detriment of the lower landowner).

Lower Landowners In its purest form, the common-enemy rule allows a lower landowner to ward off diffused surface water in any way necessary, even if another landowner is damaged thereby. Thus, early Indiana courts held that a lower landowner may put dams on his land to turn back the flow of diffused surface water.[22] One early Indiana case, *Ramsey v. Ketcham*,[23] stated the rule to be, "Every landowner has the right, provided he does not interfere with a natural or prescriptive watercourse, to construct or build on his own land levees and embankments or other barriers to protect his property from surface water."[24] Often stated as the general rule, the above quoted language embodies in it one of the limitations on the lower landowner. A lower landowner may not interfere with a watercourse—whether it be a natural watercourse or a channel that has become a prescriptive drainage easement. Furthermore, in the area of drainage of diffused surface water, it appears Indiana courts may be willing to go out of their way to find a watercourse. In *Gwinn v. Meyers*,[25] the defendant dammed a ditch, which had apparently been created originally by adjoining landowners to handle run-off of diffused surface water, after it had been ordered tiled as a public drain. Although the ditch did not fall within the normal definition of a watercourse in that it did not have regularity and certainty of flow, the Supreme Court found the ditch to be a natural watercourse and compelled the defendant to remove the dam. One commentator has suggested that this case demonstrates the need to categorize comparatively created artificial drains as privileged, diffused, surface-water channels.[26]

Another qualification on the common-enemy rule for lower landowners parallels a like qualification on upper landowners. Just as an upper owner may not create an artificial channel to direct diffused surface water onto a lower owner's land, a lower owner may not, by tampering with a channel (whether a watercourse or prescriptive drainage easement), cause diffused surface water to back up onto the upper land. In *Newton v. Lyons*,[27] the defendant cut down the flow of diffused surface water to his own land by attaching a twelve-inch pipe to a twenty-four-inch culvert, thereby causing much of the diffused surface water, which had hitherto run onto his own land, to back up onto the plaintiff's land. The court, after stating general rule "that no natural easement or servitude exists in favor of a higher landowner for the drainage of surface water, and that the proprietor of the lower land may turn the surface water back from his own lands where he commits no act inconsistent with the due exercise of dominion on his own soil,"[28] found that various courts applied this rule with certain restrictions and modifications."[29] It further found that the facts in this case constituted one of the restrictions or modifications on a lower landowner. In holding the defendant liable, the court stated that "we do not have a situation where a landowner is engaged in the due exercise of dominion over his own soil in repelling surface water, but a situation where by his acts surface water is collected in an artificial channel and consequently thrown back upon the higher landowner."[30]

Another way a lower landowner may ward off diffused surface water is by changing the level of his land. The court in *Hart v. Sigman*,[31] recognized the right of a lower property owner to raise the grade of his land in order to prevent flooding. Thus, although the use of artificial channels is frowned upon by the courts, a building up of land or a damming against water by a lower landowner is acceptable. In fact, the viability of the general rule that a lower owner may dam his land against encroaching diffused surface water was recently reaffirmed by the Indiana Court of Appeals. The court stated:

> It is . . . well established under what has been termed the "Common Enemy Doctrine" that a lower property owner may dam against such water to prevent it from entering onto his land and that he cannot be held liable for damages resulting from the accumulation of water above the obstruction or because such obstruction causes the water to flow onto the lands of another.[32]

Governmental Units Another question which arises in the area of diffused surface water is whether govern-

mental units (that is, counties, municipalities, townships) have rights different from those of private citizens in dealing with the problem of diffused surface water. Can a governmental unit construct drains in such a way as to change the direction and flow of diffused surface water to the detriment of a landowner?

The Indiana courts have held that a municipality has no more right than a private property owner to change the course of diffused surface water even if the municipal improvement is for the common good. Although in one early case[33] the court recognized that a municipality has a duty only to provide a nonnegligent execution of a reasonable drainage plan, thus perhaps giving a municipal defendant some advantage, it further recognized that a city has any citizen's right to fight diffused surface water but that it must avoid channeling diffused surface water onto its neighbor's land.

The holding in a later case involving a township[34] was based on a nuisance theory. In finding the township liable for injury to the plaintiff's land, the court said, "A public corporation has no more right to collect water in an artificial channel and cause it to flow upon the land of another . . . than has a private landowner."[35] The court went on to dispense with the protection afforded cities which nonnegligently execute reasonable plans in situations in which the municipality constructs artificial ditches to divert surface water. Thus, the rights and duties of municipalities in regard to diffused surface water appear to parallel the rights afforded any owner of land.

However, the current viability of the holdings in these cases may be affected by the enactment of extensive drainage legislation by the Indiana General Assembly. The provisions for remonstrances and judicial review of adverse decisions of drainage boards leave the impression that governmental units may for the general good take action adversely affecting landowners in regard to diffused surface water. Because courts bow to legislative intent, any conflict between the case law and statutory law would in all likelihood be resolved in favor of the latter.

Statutory Law Relating to Drainage

In 1965, the Indiana General Assembly enacted the Indiana Drainage Code into law. The implementation of this code should have a broad impact on the problem of diffused surface water. If each county constructs and maintains effective drains, property owners should not need to resort to individual measures to rid themselves of unwanted, diffused, surface water.

The drainage code[36] provides for county drainage boards to be created in each county of the state to have jurisdiction over all "legal drains."[37] The term "legal drain" includes open ditches and tiled ditches. As defined in the code, "'legal open ditch' means a natural or artificial open channel for the carrying off of surplus water from the land, which channel was established pursuant to, or made subject to, any drainage statute of the State of Indiana."[38] A "legal tiled ditch" is "a tiled channel for the carrying off of surplus water from the land, which channel was established pursuant to, or made subject to, any drainage statute of the State of Indiana."[39]

In addition to the drainage board, each county has a county surveyor whose duties are to investigate, evaluate, and survey all legal drains and prepare reports, plans, and profiles necessary for proposed improvements.[40] Furthermore, it is the duty of the county surveyor to classify all legal drains in the county as to whether they are in need of reconstruction, maintenance, or should be vacated.[41] In submitting his report to the board setting forth priorities, the surveyor may designate any drain as an urban drain if a reasonable portion of land within the watershed has been or is being converted from rural to urban land.[42]

Additionally, the code provides a procedure for abandoning existing legal drains.[43] Although the abandonment of a drain could pose a problem to a landowner whose land might be damaged by a backup of water, the code includes procedures for judicial review for aggrieved landowners.[44]

The code further provides procedures for the establishment of new legal drains.[45] If a new legal drain cannot be established without affecting the land of others, a petition must be submitted to the drainage board.[46] Remonstrances to the petition may be filed.[47] In addition, if the petition is rejected, an appeal procedure is provided.[48]

If the county surveyor should find it necessary, legal drains may be reconstructed,[49] and periodic maintenance of legal drains will be done when needed.[50]

The drainage code may affect a landowner's right to exclusive enjoyment of his land because under its provisions, the county surveyor, the board, or any duly authorized representative has the right to enter upon land within seventy-five feet of a legal drain.[51] In addition, owners of land over which the right-of-way runs may not use the land in any way which might interfere with the proper operation of the drain.[52]

The county surveyor is responsible for removing any obstructions from legal drains and repairing damage.[53] If the obstruction or damage is caused by an owner of land affected by the drain, the owner will be required to remove the obstruction and repair the damage.[54] If the owner fails to do so, the surveyor will make repairs, but the owner may be charged with the repairs in the next assessment.[55]

If it is necessary to construct a legal drain in such a

way that an owner of land is deprived of ingress or egress, the board will award damages to the owner in an amount equal to the cost of constructing a proper crossing.[56] Private drains may be connected with legal drains if permission is granted by the county surveyor.[57] But if the connection would cause or add to pollution of the receiving waters, written approval must be obtained from the Stream Pollution Control Board and filed with the county drainage board.[58]

If land is assessed as being benefited by a legal drain, but no ditch connects the land to the legal drain, the owner of such land may petition the board to construct a ditch through the land of another to connect his land to the legal drain.[59]

The drainage code also provides for the formation of joint boards if more than one county of the state would be affected by a drainage improvement[60] and the formation of interstate boards if the improvement would affect lands in Indiana and an adjoining state.[61]

Finally, any owner of land affected by a final order or determination of a drainage board is entitled to judicial review.[62]

In addition to the drainage code, the general assembly has provided a statutory framework for the construction and regulation of sewers and drains in first- and second-class cities. The boards of public works of such cities have the power to construct, reconstruct, maintain, repair, and regulate use of sewers and drains within their territorial limits.[63] Insofar as a department of sanitation of a first- or second-class city has power over sewers and drains, its power is not exclusive but is concurrent with the board of public works.[64]

Cities of the first class and second class,[65] which have been designated sanitary districts, may establish departments of public sanitation with boards of sanitary commissioners to regulate and control sewage disposal, incinerating or reduction plants, and any other facilities necessary for the disposal of waste—both domestic and industrial.[66] If a board of sanitary commissioners finds that a river, stream, or other watercourse is being polluted, it may study the feasibility of building a sewage treatment plant and adopt a resolution stating the necessity for such a plant.[67] In addition, the board of sanitary commissioners has concurrent power with the board of public works to construct and maintain main sewers and submain sewers[68] and to construct and maintain storm sewers.[69]

From the foregoing, it should be clear that local governmental units wield considerable power over drainage. However, even though proper construction and maintenance of drains is critical to water management and control, a drainage board's power over drains may be limited by the provisions relating to the maintaining of lake levels as discussed previously.[70]

Another statutory scheme which might affect a landowner's efforts to deal with diffused surface water is the Soil and Water Conservation Districts Act[71] which recognizes that the preservation of Indiana's land and water resources is necessary to protect and promote the health, safety, and general welfare of its people. It further finds that the failure to utilize rainfall and runoff water have contributed to the waste of these resources. The act provides for the creation of the State Soil and Water Conservation Committee,[72] as well as the creation of soil and water conservation districts with supervisors to carry out preventive and control measures within the district.

Although an exhaustive, in-depth study of the legislation pertaining to drainage, sewage, and sanitation (and other areas which might bear on diffused surface water) is beyond the scope of this survey, it should be apparent from the brief foregoing synopsis that the Indiana General Assembly has made a serious attempt to achieve efficient methods for dealing with them.

REFERENCES

1. *Capes v. Barger*, 123 Ind. App. 212, 214, 109 N.E.2d 725, 726 (1953).
2. *New York C. & St. L. R. v. Hamlet Hay Co.*, 149 Ind. 344, 47 N.E. 1060 (1897).
3. *Ramsey v. Ketcham*, 73 Ind. App. 200, 204, 127 N.E. 204, 205 (1920).
4. Indiana has adopted this general rule by statute. Ind. Code § 13-2-1-2 (1976) provides that "diffused surface water flowing vagrantly over the surface of the ground shall not be regarded as public water and the owner of the land on which such water falls, pools, or flows, shall have the right to its use."
5. Vol. 6A, *American Law of Property* § 28.62 (A.J. Casner, ed. 1954).
6. *Taylor v. Fickas*, 64 Ind. 167, 172 (1878).
7. Some states have modified the common-enemy rule and allow the landowner to alter the natural surface drainage only when it is reasonable, thus adopting a reasonable-use doctrine. Reasonableness under this test is determined by balancing the needs of the landowner and potential injury to others.
8. 64 Ind. 167 (1878).
9. *Id.* at 176.
10. 72 Ind. 134, 136 (1880).
11. *See also Weddell v. Harper*, 124 Ind. 315, 24 N.E. 368 (1890); *Smith v. Atkinson*, 133 Ind. App. 430, 180 N.E.2d 542 (1962).
12. 331 N.E.2d 26 (Ind. Ct. App. 1975).
13. *Id.* at 31.
14. *Cairo & Vincennes R.R. v. Houry*, 77 Ind. 364 (1881).
15. 331 N.E.2d at 33.
16. *Id.*
17. *Central Indiana Coal Co. v. Goodman*, 111 Ind. App. 480, 39 N.E.2d 484 (1942).
18. Ind. Code § 32-5-1-1 (1976).
19. *Trout v. Woodward*, 64 Ind. App. 333, 114 N.E. 467 (1916); *Seigmund v. Tyner*, 52 Ind. App. 581, 101 N.E. 20 (1913).
20. 139 Ind. App. 478, 211 N.E.2d 794 (1966).
21. 321 N.E.2d 851 (Ind. Ct. App. 1975).
22. *See, e.g.; Cairo & Vincennes R.R. v. Stevens*, 73 Ind. 278 (1881); *Taylor v. Fickas*, 64 Ind. 167 (1878); *Capes v. Barger*, 123 Ind. App. 212, 109 N.E.2d 725 (1953).
23. 73 Ind. App. 200, 127 N.E. 204 (1919).

24. *Id.* at 205, 127 N.E. at 206. It is unclear from the case what the court meant by "prescriptive watercourse." If it meant an artificial channel which had been used to drain diffused surface water for a period in excess of twenty years, it would have been more accurate to call it a prescriptive drainage easement.

25. 234 Ind. 560, 129 N.E.2d 255 (1955).

26. Shaffer, *Surface Water in Indiana*, 39 Ind. L.J. 69, 96 (1963).

27. 120 Ind. App. 465, 90 N.E.2d 917 (1950).

28. *Id.* at 470, 90 N.E.2d at 919.

29. *Id.*

30. *Id.* at 471-72, 90 N.E.2d at 919.

31. 32 Ind. App. 227, 69 N.E. 262 (1903).

32. *Cloverleaf Farms, Inc. v. Surratt*, 349 N.E.2d 731, 732 (Ind. Ct. App. 1976).

33. *Weis v. City of Madison*, 75 Ind. 241 (1881).

34. *Patoka Township v. Hopkins*, 131 Ind. 142, 30 N.E. 896 (1891).

35. *Id.* at 143, 30 N.E. at 896.

36. Ind. Code §§ 19-4-1-1 to 19-4-10.1-4 (1976 & Supp. 1978).

37. *Id.* § 19-4-5-1 (1976). However, the jurisdiction of a county drainage board does not extend to drains in conservancy districts, *id.* § 19-4-5-2(a) (Supp. 1978); drains in flood control projects, *id.* § 19-4-5-2(b); private and mutual drains, *id.* § 19-4-5-3(a) (1976); or drains under drainage maintenance and repair districts or levee associations, *id.* § 19-4-5-6.

38. *Id.* § 19-4-1-2.

39. *Id.*

40. *Id.* § 19-4-1-9.

41. *Id.* § 19-4-1-10.

42. *Id.* § 19-4-10-1.

43. *Id.* § 19-4-1-11.

44. *Id.*

45. *Id.* § 19-4-2-1.

46. *Id.* This section provides that the petition may be filed by the owners of ten percent of the affected land or the landowners having twenty-five percent or more of the assessed valuation of the land (outside the corporate limits of a city or town) alleged by the petition to be affected by the improvement; by the board of commissioners of a county to provide for highway drainage; by the township trustee or school board to drain the grounds of a public school; or the common council of a city or the board of trustees of a town to provide for the drainage of the land of such city or town.

47. *Id.* § 19-4-2-8.

48. *Id.* § 19-4-2-5.

49. *Id.* §§ 19-4-3-1 to 7.

50. *Id.* §§ 19-4-4-1 to 8.

51. *Id.* § 19-4-6-1.

52. *Id.*

53. *Id.* § 19-4-6-2.

54. *Id.* § 19-4-6-2.

55. *Id.*

56. *Id.* § 19-4-6-6.

57. *Id.* § 19-4-6-8.

58. *Id.* § 19-4-6-7.

59. *Id.* § 19-4-6-10.

60. *Id.* § 19-4-1-14.

61. *Id.* § 19-4-9-2.

62. *Id.* §§ 19-4-8-1 to 7.

63. *Id.* § 19-2-11-1.

64. *Id.* § 19-2-11-3.

65. Provisions pertaining to sanitation control have been enacted for smaller cities and towns also. *See*, e.g., *id.* §§ 19-2-27-1 to 3 (1976 & Supp. 1978); *id.* §§ 19-2-28-1 to 7 (1976); *id.* § 19-2-28.5-1; *id.* §§ 19-2-29-1 to 12.

66. *Id.* §§ 19-2-14-1 to 32.

67. *Id.* § 19-2-14-9.

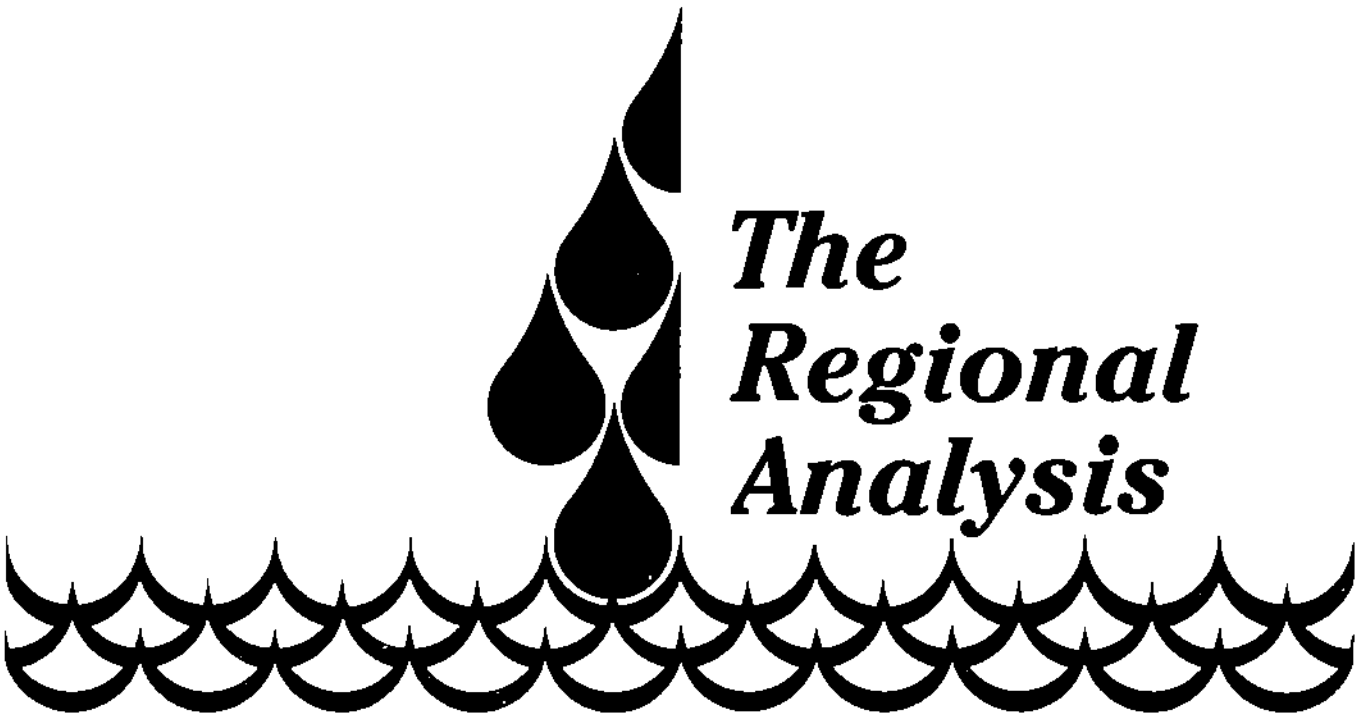
68. *Id.* § 19-2-21-1.

69. *Id.* § 19-2-22-1.

70. *See id.* §§ 13-2-14-3, 13-2-15-1 to 6, 13-2-17-1 to 4 (1976).

71. *Id.* §§ 13-3-1-1 to 14 (1976).

72. *Id.* § 13-3-1-4 (Supp. 1978) states that the statutory entity created by this section was abolished and all powers, duties and functions terminated, effective June 30, 1937 by *id.* § 4-26-3-27.


The
Regional
Analysis

Region One-A

Lake and Porter Counties, located in the extreme northwest corner of Indiana, form Region One-A. The region contains approximately 939 square miles and is bounded by Lake Michigan to the north, the Porter-LaPorte county line to the east, the Kankakee River to the south, and the Indiana-Illinois state line to the west, as shown in Figure 51.

The population of Region One-A in 1975 was 643,084, of which eighty-five percent resided in Lake County. The official Indiana projections for 1975 to the year 2000 indicate that the region's population may increase by nineteen percent. The major population growth is expected to occur in Porter County. The projections for each county follow.

Table 29
The 1975 and projected populations for Region One-A.

County	*1975*	*1980*	*1990*	*2000*
Lake	546,757	559,100	578,800	585,700
Porter	96,327	107,800	140,700	181,300
Totals	643,084	666,900	719,500	767,000

The major population centers within the region are Hammond, Gary, and East Chicago in Lake County, and Valparaiso and Portage in Porter County. These urban centers accounted for fifty-six percent of the region's 1975 population.

One of the world's largest industrial and commercial complexes is located within the region along the shoreline of Lake Michigan. The lake provides a plentiful supply of water and invaluable transportation for this industrial complex.

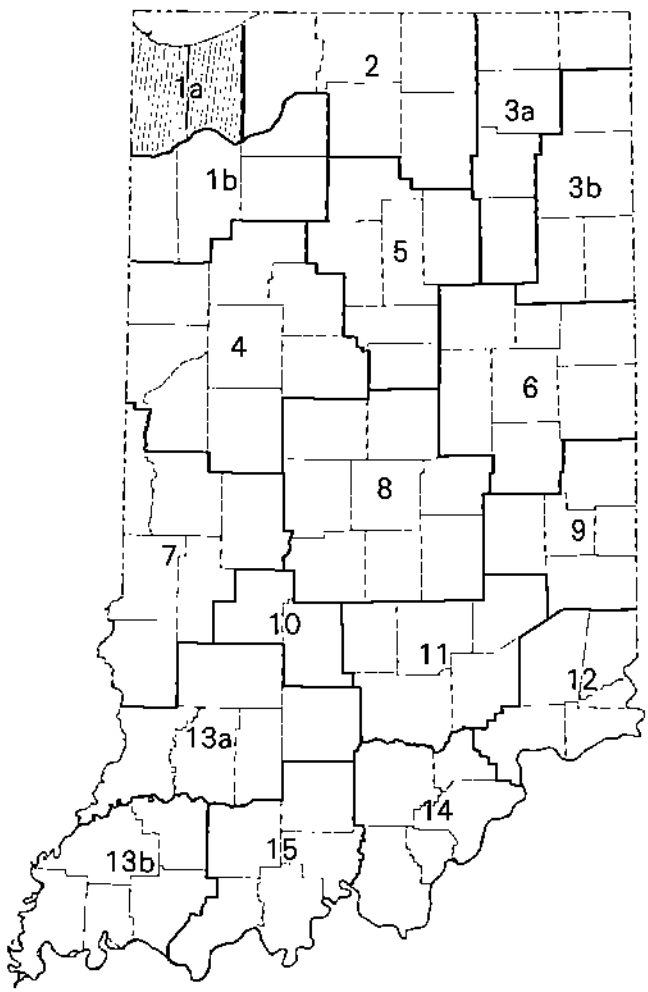


Figure 51
Map of Indiana showing the location of Region One-A.

More than seventy percent of the region's work force was employed within Lake County during 1975. Manufacturing provides approximately forty-seven percent of the total employment while wholesale and retail enterprises provide approximately twenty-two percent.

Agriculture is the dominant land use within the region with more than sixty-seven percent of the area devoted to this purpose. Approximately seven percent of land is forested while the remaining twenty-six percent is urban and miscellaneous land uses.

The region is generally characterized by flat to gently rolling topography, with the exception of the sand dunes associated with the current shoreline of Lake Michigan. The dominant land form is the Valparaiso Moraine which forms the major drainage divide within the region. Streams located north of the moraine flow toward Lake Michigan, while those located south flow into the Kankakee River.

The climate of the region is directly influenced by Lake Michigan. Such influence is most pronounced just inland from the shore of the lake and diminishes rapidly with distance. Cold air passing over the warmer lake water produces precipitation leeward of Lake Michigan in the fall and winter. In the spring, daily maximum temperatures are lower near the lake because of the cooling effect of the lake. Average minimum temperatures in the fall are higher in northwestern Indiana than those further to the south.

Average annual precipitation in the region is approximately 36.0 inches with average monthly values ranging from a high of 4.0 inches in April to a low of 1.5 inches in February. Of the 36.0 inches of average annual precipitation approximately 26.0 inches are consumed through evapotranspiration while approximately 10.0 inches appear as streamflow. The region has average temperatures ranging from 24°F. in January to 73°F. in July. The average annual temperature is 50°F. Data from the nearest recording weather station, Chicago Midway Airport, indicates the annual prevailing wind is from the west at 10.4 miles per hour.

THE WATER RESOURCE

Ground Water

The unconsolidated deposits located in Region One-A were formed by glacial action, wind, and shoreline processes associated with ancestral Lake Michigan. The thickness of these materials varies from less than 50 to over 300 feet; and the types of deposits present include lake clays, glacial till, dune sand, and outwash sand and gravel. Sand and gravel deposits serve as important aquifers in much of the area, particularly south of the Valparaiso Moraine. Fine sand and lake clays, which predominate in areas near Lake Michigan, do not constitute a major ground-water source.

Beneath these materials are found bedrock formations of Silurian and Devonian ages. The youngest of these rocks is the black shale found beneath the unconsolidated deposits in nearly all of Porter County. In Lake County, Silurian and Devonian limestones and dolomites form the underlying bedrock and represent an important source of ground water, especially in the southern and western portions of the county.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In this region, there is a pronounced variability in ground-water occurrence from north to south, as shown in Figure 52. In areas near Lake Michigan, well yields are generally less than 100 gallons-per-minute (gpm) and may be even lower in some localities. Shallow, fine sand is the primary aquifer source in these areas and does not yield water readily. Beneath the sand are found either fine grained lake clays or glacial till deposits which do not yield water. Further south, well yields improve appreciably where outwash sand and gravel deposits occur that are capable of producing 200 to 600 gpm. These deposits are associated with the Kankakee River valley and are thickest in eastern Porter County. In addition, higher well yields are also obtainable in southwestern Lake County from the Silurian limestone-dolomite aquifer, although hydrogen sulfide may be encountered in some instances.

Ground water within the region is generally hard (300 to 500 parts-per-million), although ground water in the southern and eastern portions of the region is softer (90 to 210 parts-per-million).

Surface Water

Streamflow The majority of streams in Lake and Porter Counties have their origins within the two counties and do not have large drainage areas. These streams have their headwaters near the center of the counties on the low ridges that parallel the Lake Michigan shoreline. They either flow south into the Kankakee River or northward into the Little Calumet River and Lake Michigan. The only streams of consequence originating outside the two counties are Plum Creek which originates in Will County, Illinois, and the Little Calumet River which has its source in LaPorte County.

The Calumet River system has a long history of modifications, flow reversals and diversions into and out of the river. The river is known as the Grand Calumet or the Little Calumet. The Little Calumet River in Indiana is divided into the east and west arms. About seven miles of the west arm has been replaced

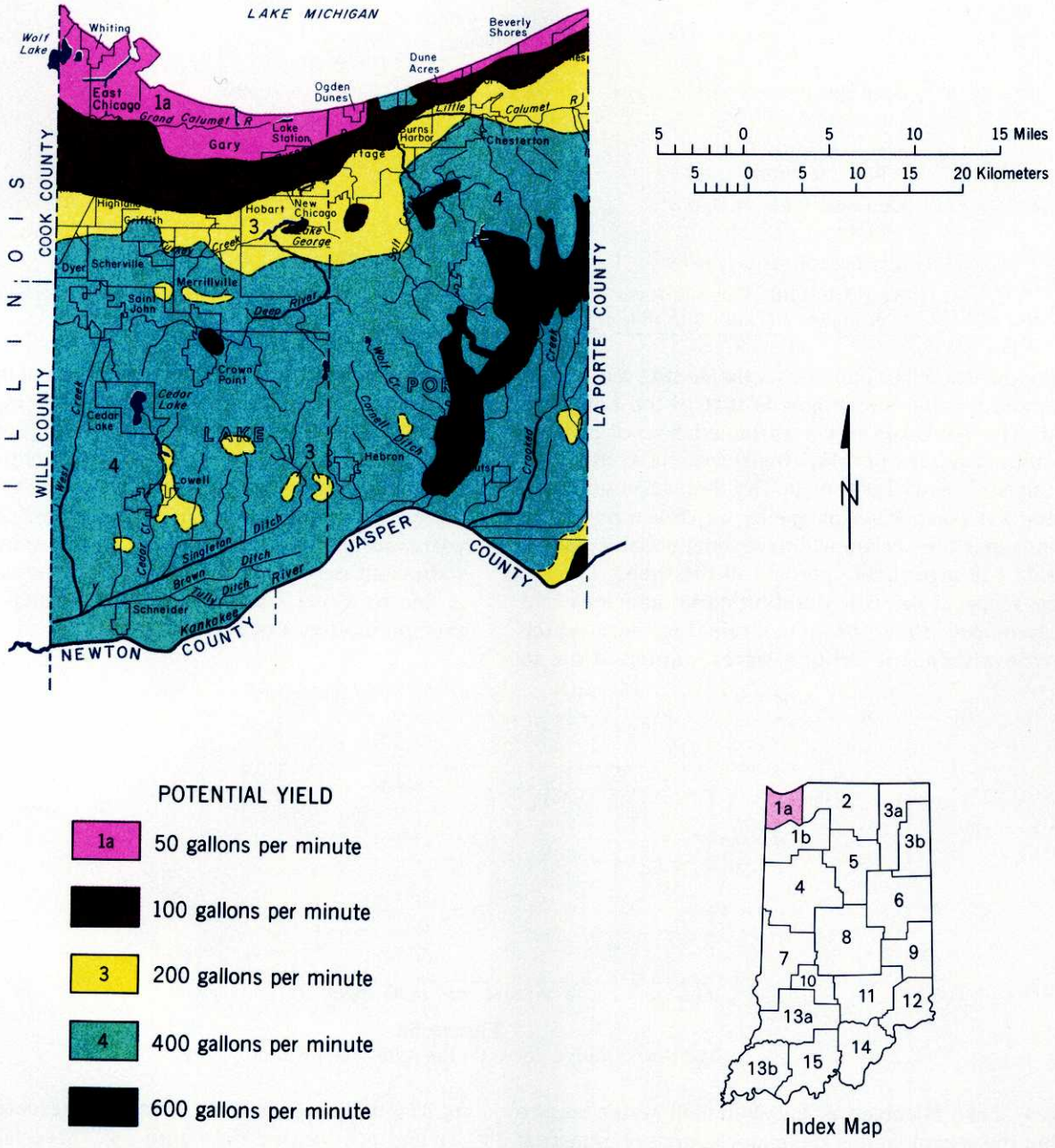


Figure 52
Map of Region One-A showing the general location and potential yield of ground water from properly constructed large diameter wells.

by Burns Ditch. Burns Waterway furnishes the outlet into Lake Michigan for the east arm of the Little Calumet River, Deep River, and all of the west arm of the Little Calumet River east of Griffith. From Griffith westwardly, the Little Calumet flows into Illinois and eventually into the Illinois River. The Grand Calumet River discharges its limited flows into Lake Michigan by way of the Indiana Harbor Canal.

The seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and the average annual flow in million-gallons-per-day for streams with gaging stations within Region One-A are presented below.

Table 30
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Deep River below Lake George in Hobart	124	60	3.3	2.5
East Arm Little Calumet River at Porter	66	46	13.0	11.0
Kankakee River at Dunns Bridge	1,352	825	210.0	180.0
Kankakee River at Shelby	1,779	1,010	270.0	220.0
West Arm Little Calumet River at Munster (Flows into Illinois)	90	43	2.1	1.3

The low-flow characteristics indicate that the largest and most reliable streamflow is that of the Kankakee River. The Kankakee has a sustained flow of at least 220 million-gallons-per-day (mgd), and its average annual flow exceeds 1,000 mgd. The flow duration curve for the Kankakee River at Shelby, as shown by Figure 53, indicates the stream will have a dependable flow of at least 400 mgd ninety percent of the time.

The slope of the flow duration curve indicates that the Kankakee River basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to seventy-two, sixty-four, and thirty-two percent for "dry," "average," and "wet" years, respectively. Conversely, from twenty-eight to sixty-eight percent of the flow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or from snowmelt.

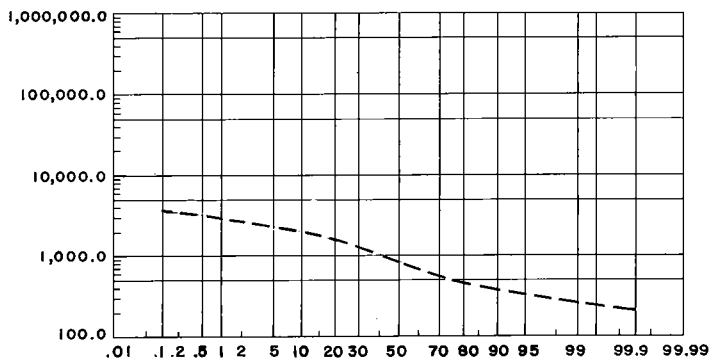


Figure 53
The flow duration curve for the Kankakee River at Shelby.

Lakes Lake Michigan is the dominant water feature within the region, and is the major source of industrial and public water supplies. Approximately 154,000 acres of Lake Michigan are included within Indiana.

The remaining fourteen lakes within the region that are at least 50 acres in size or have a storage capacity of 32.5 million gallons or more, are presented in Table 31 and are located on Figure 54. These lakes have a combined surface area of approximately 2,770 acres with a gross storage capacity of approximately 4,900 million gallons.

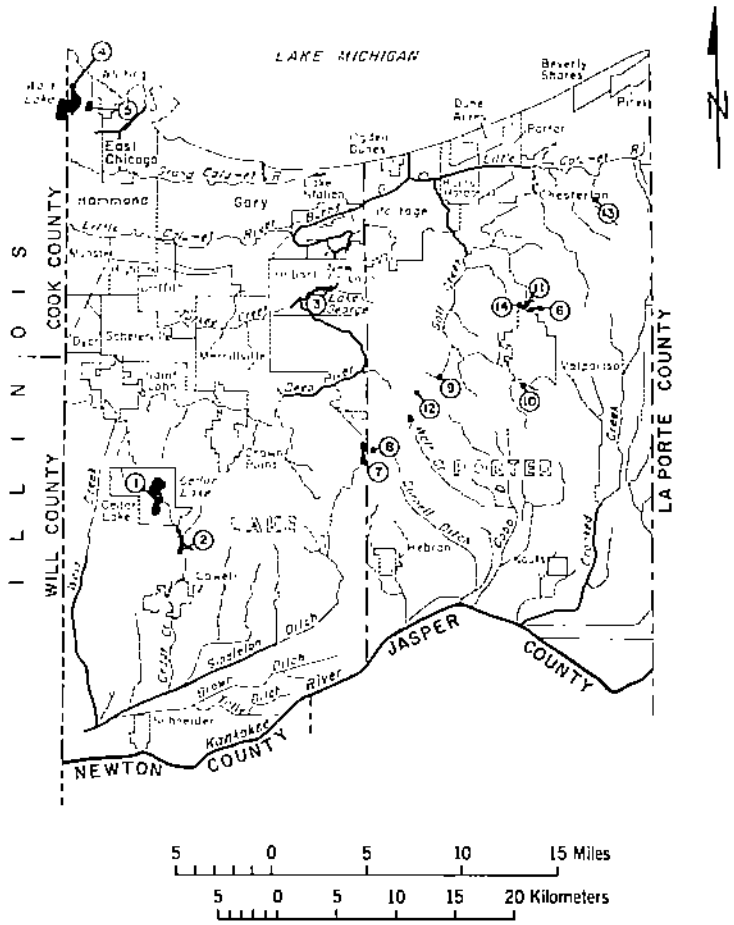


Figure 54

Map of Region One-A showing the location of lakes that are at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more. Lake numbers correspond to the lake numbers in Table 31.

Table 31
Lakes at least 50 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Cedar Lake	8.14	781.0	2,199
2	Dalecarlia Lake	20.10	193.0	na
3	Lake George at Hobart	124.00	282.0	879
4	Wolf Lake	5.72	999.0	na
5	Lake George at Hammond	na	78.0	na
6	Flint Lake	2.62	86.0	na
7	Lake of the Four Seasons Nos. A and B	na	na	133
8	Lake of the Four Seasons No. C	na	na	553
9	Lake Louise	2.56	228.0	645
10	Lake of the Woods	na	24.5	65
11	Long Lake	1.31	65.0	169
12	Norman Olson Lake	0.23	14.0	38
13	Rice Lake	na	38.3	58
14	Spectacle Lake	0.53	62.0	175

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region One-A is presented in Table 32. The existing supply for recreational activity is expressed as a percentage of the projected demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the existing supply as a percentage of demand is less than one hundred percent, the supply is less than the projected demand.

Boating and Waterskiing Both Lake and Porter Counties have rivers available for boating and waterskiing. Deep River in Lake County is used for waterskiing. Waterskiing on the Kankakee River is dangerous due to occasional debris in the water. Boating is allowed on other streams, including the Little Calumet River. Lake Michigan is used extensively for boating and some waterskiing. Dangerous conditions can come up quickly on this lake; therefore, boating on Lake Michigan is limited to craft larger than sixteen feet during favorable conditions. Cedar and Wolf Lakes also provide waterskiing in Lake County. Porter County has only Lake Michigan suitable for waterskiing, although boating is allowed on most other lakes.

Table 32
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	27	19.6 boats/acre/year	157,000 acres[a]	100+	100+	100+
Waterskiing	7	34.4 skiers/acre/year	19,200 acres[b]	100+	100+	100+
Canoeing	10	585 canoes/mile/year	97 miles	100+	100+	93+
Swimming	57	76,600 swimmers/acre/year	105 acres[c]	100+	100+	100+
Ice-Skating	12	6,678 skaters/acre/year	45 acres	100+	100+	100+
Fishing	43	66 persons/acre/year	161,400 acres[d]	100+	100+	100+

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.
[a]Includes 154,000 acres of Lake Michigan and 3,000 acres of inland waters.
[b]Includes 18,400 acres of Lake Michigan (thirty square miles excluding the two hundred feet from the shoreline) and 800 acres of inland waters.
[c]Does not include Lake Michigan.
[d]Includes 154,000 acres of Lake Michigan and 7,400 acres of inland waters.

Cedar Lake, Flint Lake, Wolf Lake, and Lake Michigan have some form of public access. Access to the Kankakee River is available at the LaSalle Fish and Wildlife Area in Lake County. Access to other rivers is limited by the lack of boat ramps and parking facilities. Due to the recreational potential of Lake Michigan, no shortage of boating and waterskiing areas is projected to occur in Region One-A. However, access to Lake Michigan is limited by a shortage of boat storage and launching opportunities.

Canoeing Canoeing opportunities in the region are numerous. Eleven miles along Deep River in Lake County is canoeable. A ten mile trip is available on the East Branch of the Little Calumet River. The Kankakee River along the southern border of the region is an excellent canoeing stream.

The region does not have a current need for additional canoeing stream mileage. However, the demand is expected to increase by the year 2000 when a shortage of canoeing opportunities may occur.

Swimming and Ice-Skating Swimming is available in Lake Michigan at municipal beaches, the Indiana Dunes State Park, and the Indiana Dunes National Lakeshore. In addition swimming is available on inland lakes and numerous public pools. Ice-skating is available on the smaller lakes within the region, but is not available on Lake Michigan due to safety considerations. The demand and supply analysis indicates that the supply of swimming and ice-skating areas will exceed the demand generated by residents of Region One-A through the year 2000.

Fishing The quality of the fisheries habitat is indicated on Figure 55. Many of the lower reaches of the streams in southern Lake and Porter Counties have been straightened and dredged to provide agricultural drainage. The Kankakee River serves as the main outlet of this southern drainage, and although it has been extensively channelized, provides good aquatic habitat. It flows steadily with sufficient depth to provide food and cover for warmwater fishes such as bluegill, crappie, largemouth and smallmouth bass, other sunfishes, catfish, and suckers. Northern pike and walleye are also present, using tributaries and flooded woods and backwaters for spawning in the spring. Crooked Creek contains suitable aquatic habitat and water quality to support a "put-and-take" trout fishery. With these exceptions, most southern streams offer limited aquatic habitat due to their channelized bed, lack of aquatic plants, and overall lack of diversity.

In general, streams have been channelized less in the northern portion of the region, but aquatic habitat suitable for game fish is limited in some streams by poor water quality. The West Arms of the Little Calumet and the Grand Calumet Rivers offer poor aquatic habitat due to heavy input from industrial and domestic pollution sources. They may support only rough fish populations including carp and white suckers. In contrast, Salt Creek and the East Arm of the Little Calumet River are used by Lake Michigan trout and salmon for spawning. Salt Creek also provides habitat for a put-and-take trout fishery.

The region has fewer lakes than the other parts of northern Indiana, and intense shoreline development is characteristic of most of its lakes. Moderately good aquatic habitat can be found in most lakes in the region as is indicated by the presence of thriving game fish populations. Lake Michigan provides an abundance of fishing water and is especially noted for coho and chinook salmon; steelhead, lake, and brown trout; and yellow perch. Fancher Lake is stocked with trout, besides supporting a warmwater fishery. Wolf Lake is noted for largemouth bass, bluegill, and northern pike fishing. Another example of good aquatic habitat is Flint Lake, evidenced by its bluegill, black crappie, and largemouth bass fishing. In comparison, Cedar Lake provides spawning areas in the wetlands along its south end, but desirable game fish populations are limited by poor water quality.

Fishing access to streams and lakes can usually be found at bridges or city and county parks. Almost two-thirds of the lakes have public access for fishing. A state-owned public fishing site is located on Cedar Lake. Lake Michigan offers beach and pier fishing at municipal parks, the Indiana Dunes State Park, the Indiana Dunes National Lakeshore, and fishing from boats.

Lake Michigan and an additional 3,000 acres of inland waters insure that the demand for fishing through the year 2000 will be met. Use of Lake Michigan is limited, however, by the frequent occurrence of rough water and by inadequate public access.

Riparian Habitat The quality of the wildlife habitat associated with surface streams is indicated in Figure 56. The streams and lakes of the region differ greatly in the quality of habitat associated with their banks. The Kankakee River offers some of the most valuable riparian and wetland habitats, attracting furbearers, waterfowl, and other mammals such as deer and squirrels. The most outstanding wetlands of the region are the backwaters and wooded swamps along the lower portion of the Kankakee River. The LaSalle Fish and Wildlife Area located adjacent to the Kankakee River increases the wildlife production with the intensive management practiced on the property. Salt Creek and Crooked Creek also offer good wildlife habitat. Their

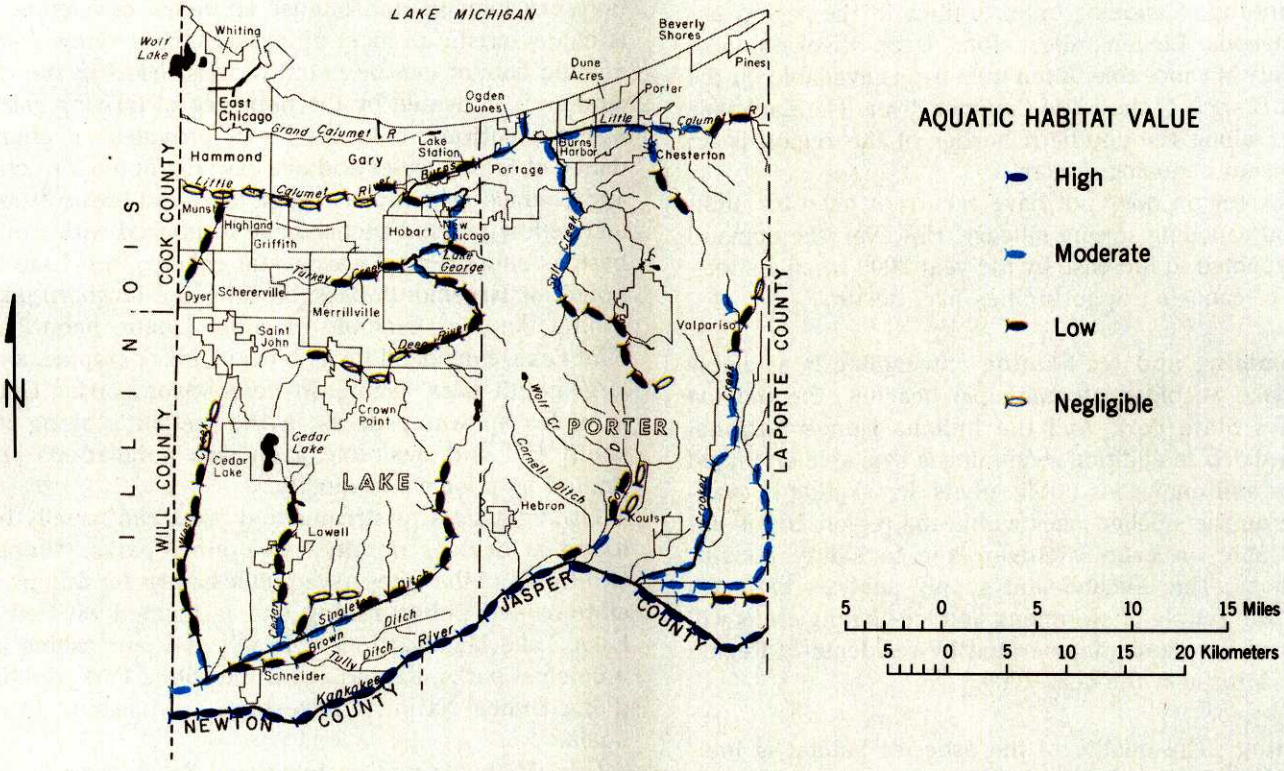


Figure 55
Map of Region One-A showing the quality of fisheries habitat.

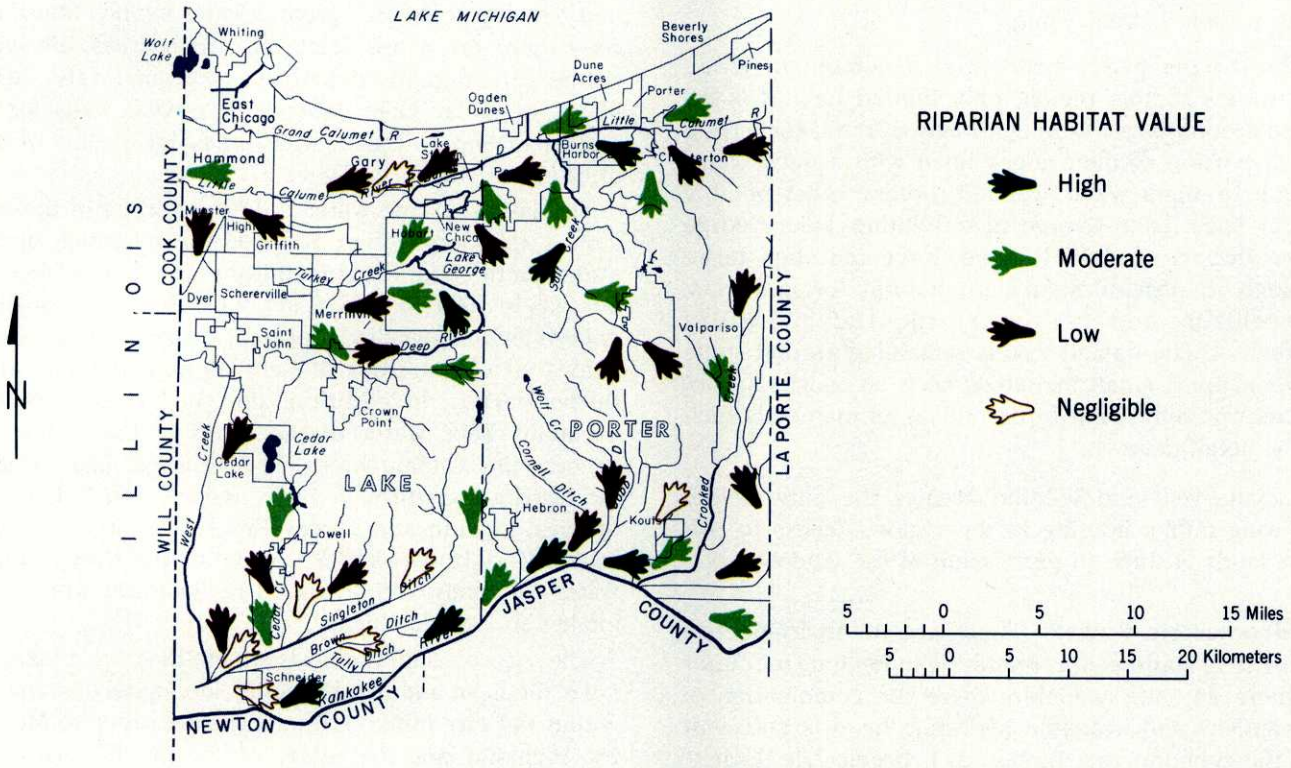


Figure 56
Map of Region One-A showing the quality of riparian habitat.

banks have a sufficient amount and diversity of vegetation to provide food and cover for many species of animals. Some of the straightened streams, such as parts of the Singleton Ditch and West Creek in Lake County, offer very poor riparian habitat. If their banks are grass covered, however, they will attract game birds such a pheasants and bobwhite quail. Other animals use them as nesting areas or travel lanes. The streams in northern urban areas provide small mammal and game bird habitat in the city and county parks. Large stretches of these streams, however, offer little wildlife habitat value.

Due to the heavy residential development along lakeshores in this region, only limited habitat is offered around lakes. Although many of the lakes have a small portion of their edges lined with a deep water marsh or open water wetland, others, most notably Cedar Lake, Lake George near Whiting, Lake George near Hobart, and Wolf Lake, have marshes large enough to provide significant habitat for muskrats, shorebirds, and various residential migratory waterfowl. The upland woods remaining around some lakes support small mammals such as squirrels, raccoons, opossums, songbirds, and larger mammals such as whitetail deer.

LaSalle Fish and Wildlife Area is the only facility allowing public hunting in the region. Access to private lands is through permission of the landowners.

Hydroelectric Power There are no hydroelectric generating stations now operating in Region One-A nor is there any site available where the combination of streamflow and available hydraulic head is sufficient for the economic production of hydroelectric power.

Commercial Navigation Lake Michigan is part of the Great Lakes – St. Lawrence navigation system, one of the most important inland waterway systems in the world. There are four commercial harbors in the region which provide access to this waterway. These are: Indiana Harbor, Gary Harbor, Buffington Harbor, and the Port of Indiana.

Traffic through these harbors consists of both interlake and overseas cargo. Harbor commerce consists of iron ore, petroleum, steel, grain, and general cargo.

Indiana Harbor was completed by the Corps of Engineers in the 1930s. Periodic dredging is necessary to maintain project depths. Gary and Buffington Harbors are private and are privately owned and maintained. The Port of Indiana (Burns Waterway Harbor) is owned and operated by the Indiana Port Commission, a state agency established for the purpose of developing and operating such facilities.

Withdrawal Uses

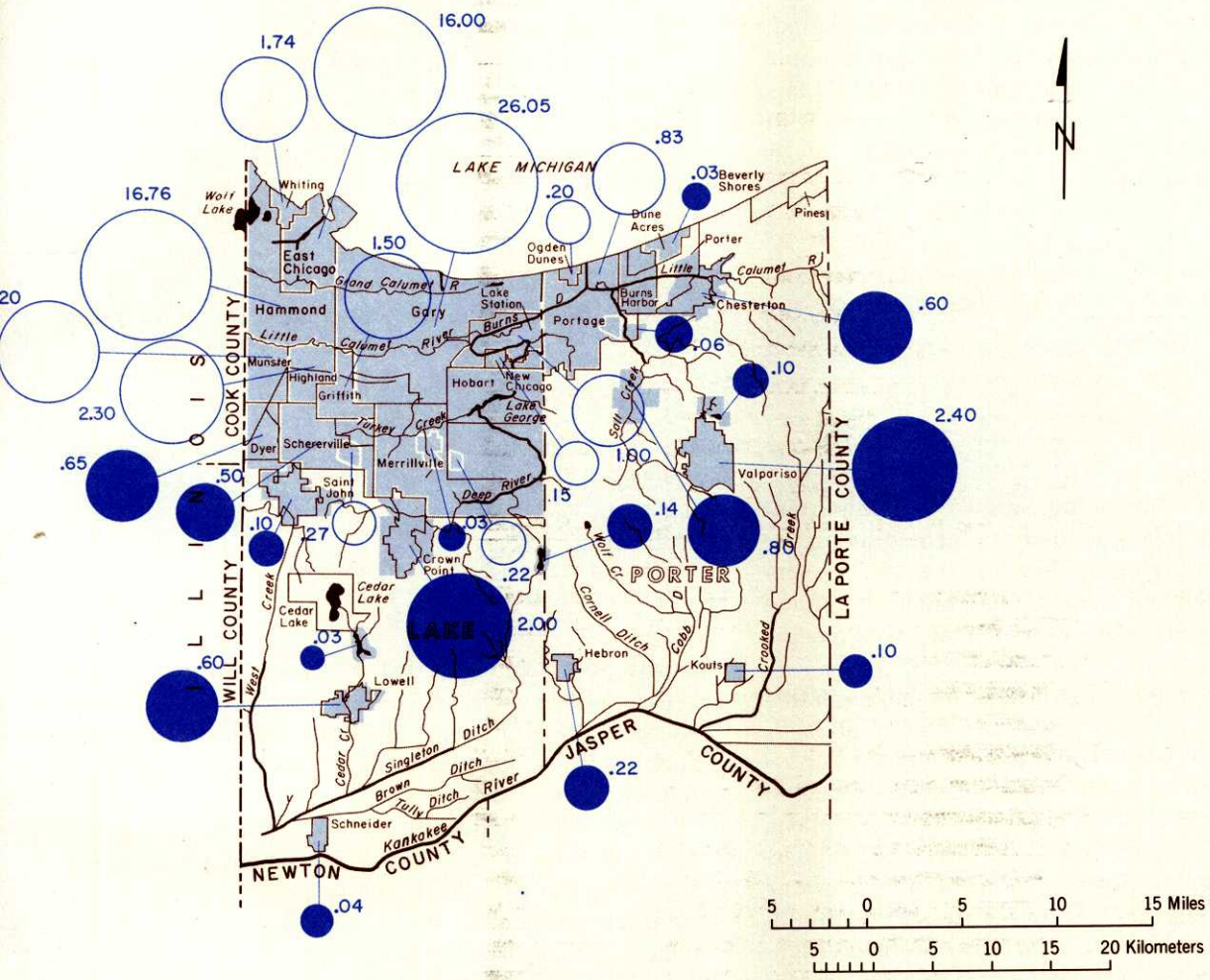
Public Water Supply Lake and Porter Counties are served by twenty-nine public water utilities. Eighty-nine percent of the population was served by a public utility in 1975. The utility systems in Lake County consist of several large utilities located along Lake Michigan, all withdrawing water from the lake. These utilities either serve or sell water to a "row" of towns just south of the lakefront communities. Further south, a third and sometimes a fourth "row" of communities had developed its own ground-water supply. South of Gary there are a few scattered urban areas, all with public water supplies dependent on ground water. Residents of Cedar Lake depend on private wells for a source of water. The service areas for public water utilities are shown in Figure 57.

The largest single water utility operating in the region is the Gary-Hobart Water Company which operates in both counties. This utility served about 248,600 persons in 1975. In 1977, it supplied an average of 29.1 million-gallons-per-day. Its direct distribution area includes all of the cities of Gary, Hobart, Portage, and Burns Harbor. In addition, the Gary-Hobart Water Company sells water to the cities of Lake Station, Schererville, Ogden Dunes, New Chicago, and Griffith for distribution through their lines. Two subdivision utilities, Lincoln and Turkey Creek, are also supplied by the Gary-Hobart Water Company. The Gary-Hobart Water Company withdraws all of its water from two intakes in Lake Michigan.

The city of Hammond also maintains an intake in Lake Michigan and in addition to serving all customers within the city limits, Hammond sells water to Munster, Highland, and the village of Lansing, Illinois.

Other large utilities in 1975 included the Hammond system which served 105,900 persons and withdrew 16.8 mgd, and the East Chicago system which served 44,200 and withdrew 16.0 mgd. Valparaiso, Highland, Munster, and Crown Point all pumped over 2.0 mgd in 1975. The towns of Whiting, Griffith, and Lake Station each withdrew between 1.0 and 2.0 mgd in 1975. Many of these systems, particularly those directly on the lake, serve industries that consume large amounts of water. The remaining systems to the south of the lakeshore primarily serve residential customers, withdrawing 0.6 mgd or less.

In 1975 these twenty-nine utilities withdrew an average of 77.3 mgd. Lake County accounted for 72.0 mgd while Porter County accounted for the remaining 5.3 mgd. About 67.0 mgd of the total public water supply is withdrawn from Lake Michigan, while 2.0 mgd is withdrawn from other surface water sources, principally Flint Lake. The remaining 8.4 mgd is withdrawn from ground-water sources.



EXPLANATION

Service area

Surface-water withdrawals

Ground-water withdrawals

.06 Mgd average daily use

Figure 57

Map of Region One-A showing the service areas of the public water utilities, and average daily use in million-gallons-per-day.

Because of the relatively good ground-water conditions in the southern three-fourths of the region, most communities relying on well supplies are able to develop well fields either within their community or within easy reach of their boundaries.

Projections of public water supply withdrawals indicate that water withdrawals by the region's public water supplies may increase to approximately 104 mgd by the year 2000. The 1977 and projected water withdrawals and consumption rates by public water utilities are presented below.

Table 33
The 1977 and projected withdrawal and consumption rates of public water supplies, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	77.3	80.2	92.5	104.0
Consumption	9.9	10.4	12.0	13.5

Industrial Water One of the nation's most important concentrations of heavy industry is located along the Lake Michigan shoreline of Region One-A. These industries are dependent upon an essentially unlimited supply of water and access to the Great Lakes navigation system.

The amount of water withdrawn by industries in this region constitutes eighty-eight percent of all self-supplied industrial water withdrawn in Indiana. An estimated 3,125 mgd of water was withdrawn by Region One-A industries in 1977. Of the total industrial intake, 3,093 mgd is self-supplied from Lake Michigan. Approximately 32.0 mgd is purchased from public water utilities. Water supplied to industries from public water companies in Hammond, Whiting, Munster, Highland, Griffith, Gary, Hobart, Portage, and Burns Harbor is withdrawn from Lake Michigan. About 91.0 mgd is evaporated or otherwise consumed in the manufacturing process.

The largest water-using industry group is primary metals. Bethlehem Steel, Inland Steel, Midwest Steel, U.S. Steel, and the Youngstown Sheet and Tube Company are located on the shoreline of Lake Michigan. These industries support, and in turn are supported by, a host of smaller ancillary industries. The primary metals industry utilizes approximately 2,874 mgd.

The second largest water-using industry group is petroleum and refinery. This industry group uses less than ten percent of the water used by the primary metals group. Other industry groups using significant quantities of water are quarrying operations and manufacturers of chemicals, machinery, transportation equipment, and paper products.

Accurate projections of the future industrial water use in Region One-A are dependent upon the steel industry, which itself is influenced by the demand for steel, new technical processes, foreign competition, ore availability from western Lake Superior, and future environmental regulations. The projections assume that these factors will remain constant and no radical shifts in operating techniques will occur.

Industrial production by the year 2000 is expected to increase sixty-three percent above the 1977 value (United States Water Resources Council). Although industrial output is expected to increase, total industrial water intake is expected to decrease initially due to plant efficiency and then rise slowly as output increases. The current and projected self-supplied withdrawals and rates of consumption for industries located in Region One-A are presented in the following table.

Table 34
The 1977 and projected self-supplied withdrawal and consumption rates for industries in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	3,093.0	2,920.0	2,928.0	3,010.0
Consumption	89.7	92.2	117.2	145.8

Rural Self-Supplied Water The majority of rural self-supplied water is withdrawn from ground-water sources. An estimated 73,300 persons lived in homes supplied by individual wells in 1975. It is estimated that residential use of water approached 4.2 mgd in 1975. An estimated 6,500 additional persons may depend on their own wells for household water in the region by the year 2000. The withdrawal of rural self-supplied residential water may increase to approximately 5.8 mgd by the year 2000.

In 1975 an estimated 56,400 head of livestock and 106,000 chickens were located within the region. Collectively, these animals consumed approximately 0.5 mgd. Water withdrawals for livestock and chickens may increase slightly to 0.54 mgd by the year 2000.

The total withdrawal of rural self-supplied water may increase from the current 4.8 mgd to approximately 6.3 mgd by the year 2000, as presented below.

Table 35
The 1977 and projected water withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	4.8	5.0	5.7	6.3
Consumption	4.8	5.0	5.7	6.3

Irrigation Water The soil associations with irrigation potential as shown in Figure 58 are located mainly in the north among the dune and old beach ridges

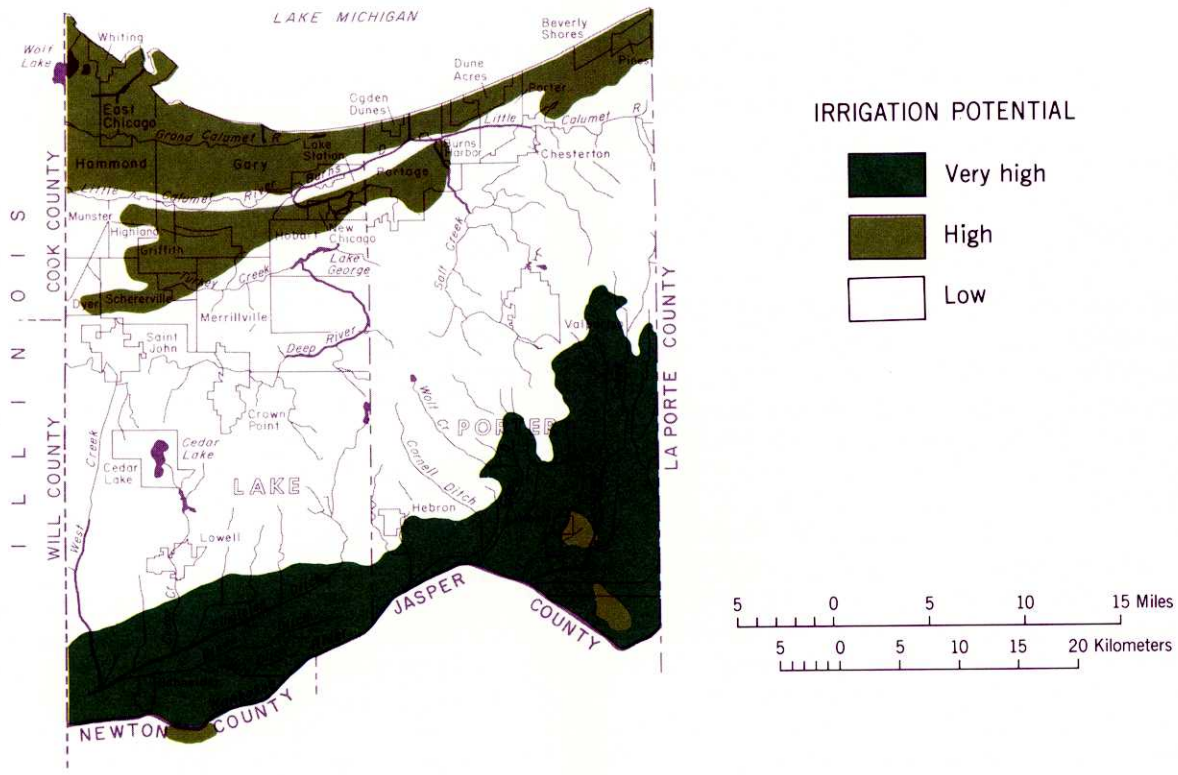


Figure 58
Map of Region One-A showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

along Lake Michigan and in the south in the outwash plain and dunes of the Kankakee valley. Poorly drained soils are found in the Kankakee valley where irrigation is through water table control or subirrigation.

Based upon the survey of irrigated croplands, approximately 2,000 acres were irrigated in the region in 1977: 1,200 acres in Lake County, and 800 acres in Porter County. The principal crops irrigated were vegetables and corn.

Assuming 1977 as a normal growing year, these crops would have required about 5.4 mgd during the peak irrigation period of July and August.

It is estimated that about 40,000 acres of croplands could be profitably irrigated. Approximately 5,500 acres of croplands may be irrigated by the year 2000. Almost all of this additional irrigated acreage will be in the Kankakee valley. The expansion of irrigation acreage is expected to increase the peak July–August irrigation demand in an "average" season to 14.7 mgd. The "average" season increase in ground-water withdrawal for irrigation is expected to increase from the current 0.7 to 3.7 mgd by the year 2000.

In addition to the irrigation for agricultural use, there are about 655 acres of irrigated fairways and greens on the region's golf courses. About 2.0 mgd is applied to these areas during the peak July–August irrigation period.

The total withdrawal for irrigation of croplands and golf courses during the "average" irrigation season of 1977 was approximately 7.4 mgd. These withdrawals may increase to 18.0 mgd during the "average" growing season by the year 2000, as presented here.

Table 36
The 1977 and projected withdrawal of irrigation water for croplands and golf courses during the average growing season, in million-gallons-per-day

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	7.4	9.5	13.7	18.0
Consumption	7.4	9.5	13.7	18.0

Electric Energy There are three electric generating stations all located on Lake Michigan. The three existing stations are the State Line Generating Station, the Dean H. Mitchell Generating Station, and the Bailly Generating Station. The State Line plant is owned by the Consolidated Edison Company which exports all power generated by this facility to Illinois. Mitchell and Bailly are owned and operated by the Northern Indiana Public Service Company which serves northwest Indiana.

The State Line plant is rated at 968 megawatts (mw), the Mitchell Station is rated at 581.6 mw, and the Bailly Station is rated at 649.5 mw. Intake requirements are 750 mgd for State Line, 398 mgd for Mitchell, and 341 mgd for Bailly.

The Northern Indiana Public Service Company is in the process of enlarging its generating capacity by adding a nuclear-powered generating unit to the Bailly Generating Station. The new unit, now under construction, is rated at 685 mw. The new unit will use a closed cycle cooling system. The addition of the Bailly unit will increase the intake requirements to 353 mgd. About 9.2 mgd will be lost through evaporation.

Water withdrawals for the production of electricity during 1977 were approximately 1,489 mgd. Water withdrawals are expected to decrease to 432 mgd by the year 2000 as presented below.

Table 37
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	1,489.0	1,501.0	1,501.0	432.0
Consumption	6.0	11.8	11.8	9.4

EXCESS WATER

Flooding

Approximately 24,600 acres of the region are subject to flooding. The major flood plains are shown in Figure 59. The average annual damages due to flooding were estimated in 1977 to be $19.3 million, of which some ninety-two percent occurred in urban areas. Most of the urban damage occurs along the Little Calumet River in Lake County. This flooding problem has long been considered by the Department of Natural Resources to be the most serious urban flooding problem in Indiana. Figure 60 shows the estimated average annual flood damages in Region One-A.

Virtually all of the streams are subject to flooding. Flash flooding on streams in the area is uncommon due to the flat topography. The Kankakee, Little Calumet, and Grand Calumet Rivers are subject to slow rates of rise and long flood durations.

Flood Control Partial flood protection along the Kankakee River is provided by levees (spoil banks) that were constructed from dredge spoil. The levees are of variable top elevation and exhibit little uniformity in cross section. The levees along the Kankakee River in southern Lake County, coupled with the Singleton Ditch drainage system, kept Kankakee River

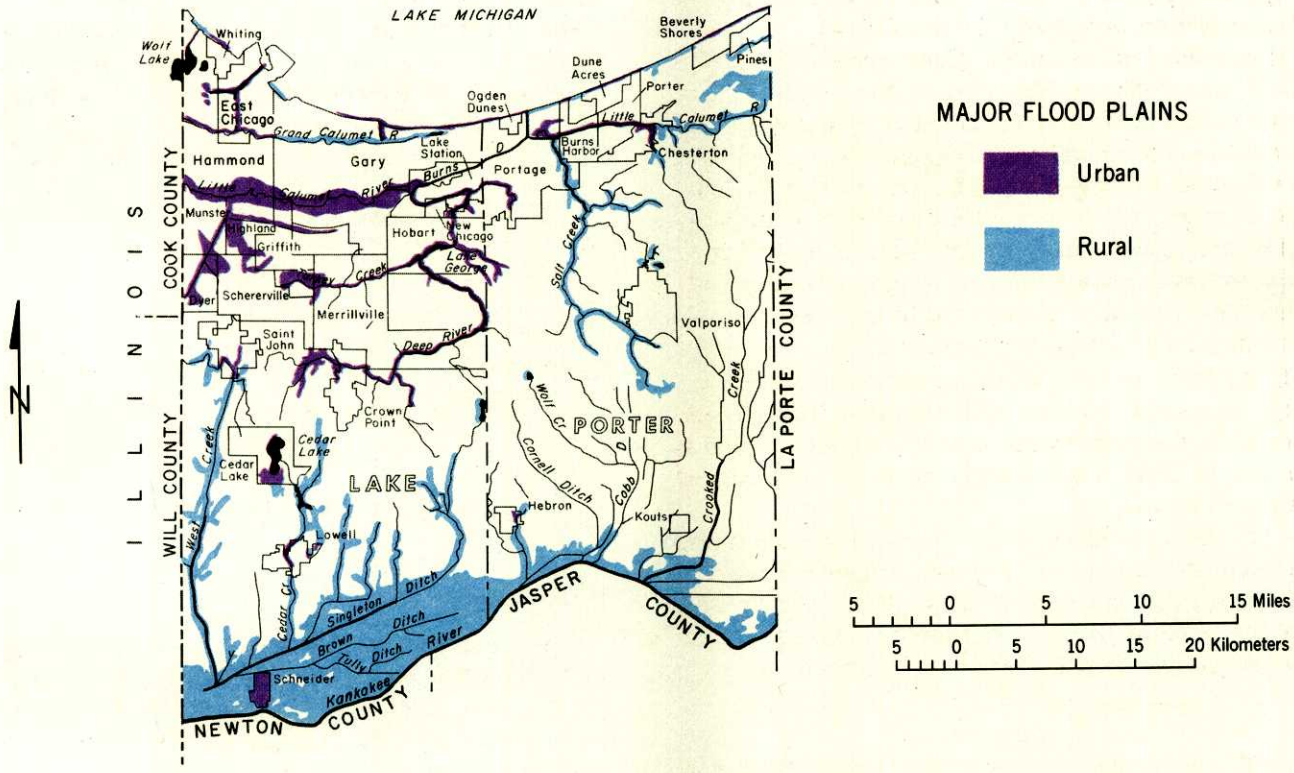


Figure 59
Map of Region One-A showing the major flood plains.

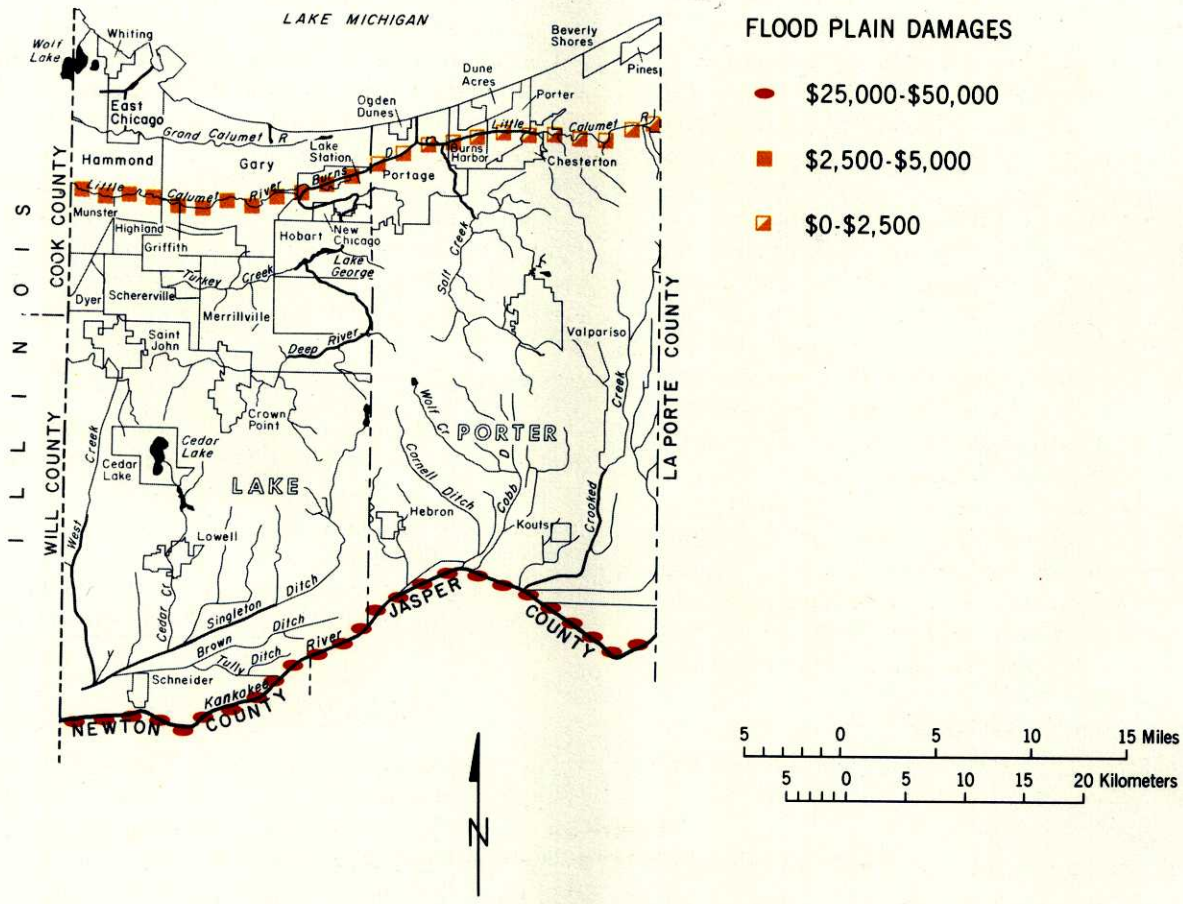


Figure 60
Map of Region One-A showing the estimated average annual flood damages per mile along selected streams.

floodwaters out of southern Lake County for many years. Very little maintenance has been performed and the degree of protection varies with the condition of the levee. The major flood damages in this watershed are agricultural in nature.

The major flooding problem on the Little Calumet River occurs in the highly urbanized area located between the Indiana-Illinois state line and Deep River. Large areas of the flood plain have been developed for residential and commercial purposes. Over 9,000 residences and commercial buildings have been constructed in areas that are subject to flooding.

The Grand Calumet River, a minor system in the region, drains a narrow strip of flat areas and beach ridges along Lake Michigan. Flooding along the Grand Calumet River is influenced by high stages on Lake Michigan.

The Chicago District, United States Army Corps of Engineers, is currently doing advanced engineering and design work on the proposed Little Calumet River project. This project consists of twenty-three miles of work on the West Arm of the Little Calumet River, Burns Ditch, and Burns Waterway to provide a safe outlet for floodwaters. Associated with the flood control facilities will be recreational facilities and a marina providing access to Lake Michigan.

The Kankakee River Basin Commission was formed in 1977 to study the problems of the Kankakee River. The basin commission has adopted a plan of channel work, levees, floodplain zoning, and land treatment, which protects, enhances, and maintains the wildlife and fisheries habitat and provides for land and water based recreation.

The Porter County – Kankakee River subarea is the only small watershed project, authorized for planning, located within the region.

Flood Plain Management All of the political jurisdictions in the region are participating in the emergency phase of the National Flood Insurance Program. Griffith, Highland, and Beverly Shores are participating in the regular National Flood Insurance Program. Residents of the areas can purchase insurance against property losses due to flooding.

Agricultural Drainage

Approximately thirty-six percent of the soil associations have "severe" wetness characteristics, fifty-nine percent have "moderate" wetness characteristics, while five percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics are shown in Figure 61.

Extensive investments in private and public surface and subsurface drainage systems have been made to overcome the high water table. There are 1,600 miles of legal drains in the two-county region. In much of the agricultural rural area paralleling the Kankakee River, lift pump drainage systems have been installed to carry water from the drainage system catch basin up and over river levees. Water table control, by regulating the water level in the drainage ditches, is also practiced. The complex drainage networks are dependent on the size and maintenance of the river and stream outlet system.

The urban areas of the region experience the drainage problems typical to most urban areas in Indiana. These include undersized drainage systems which lack capacity to handle the runoff from storms of any significant magnitude; combined storm water and sanitary sewer systems which contribute heavily to treatment plant bypassing and consequent stream pollution; and inadequate maintenance, primarily from lack of adequate local funding.

Soil Erosion

The erosion potential of soil associations within Region One-A is shown in Figure 62. Forty-four percent of the 601,000 acres is rated as having a "medium" soil erosion hazard. This land area lies in a belt across the central portion of the region. The remaining fifty-six percent of the land is predominantly level and ranks as having a "low" erosion potential.

WATER QUALITY

The surface streams routinely surveyed for water quality in 1978 by the Indiana State Board of Health were the Grand Calumet River, Little Calumet River, Burns Ditch and Waterway, Salt Creek, Indiana Harbor Ship Canal, and the Kankakee River. In addition, Lake Michigan and Wolf Lake were surveyed. Water quality standards for the region were established by the Stream Pollution Control Board regulations SPC IR-4 (Water Quality Standards for the State of Indiana), SPC 4R-2 (Water Quality Standards for Lake Michigan and Contiguous Harbor Areas, 1978), SPC 7R-3 (Water Quality Standards for the Grand Calumet River and the Indiana Harbor Ship Canal, 1978), SPC 10R-2 (Water Quality Standards for Wolf Lake, 1978) and SPC 12R (Natural Spawning, Rearing, and Imprinting Areas, 1978).

The dissolved oxygen concentration at the Gary water intake on Lake Michigan has ranged above the minimum standard. In addition, the concentration of total coliform bacteria was within the standards for raw drinking water. The fecal coliform bacterial level

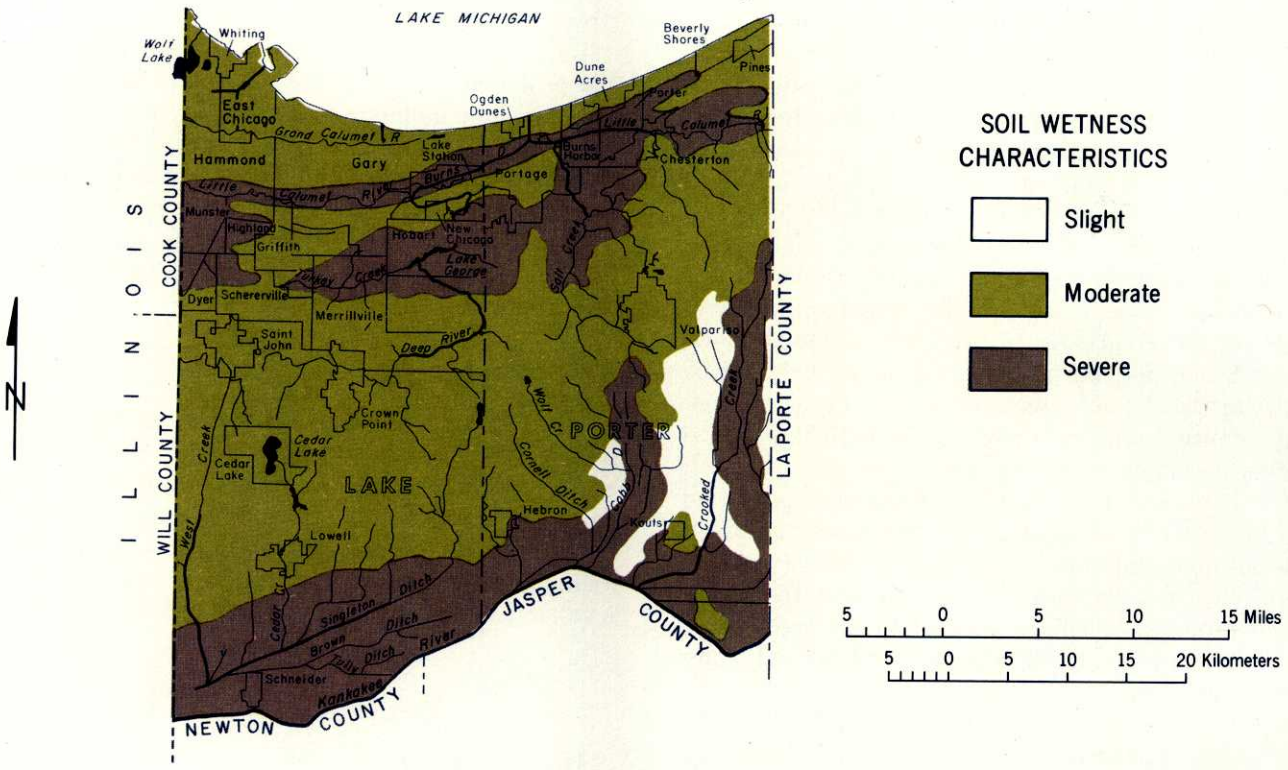


Figure 61
Map of Region One-A showing the general location of the wetness characteristics of soil associations.

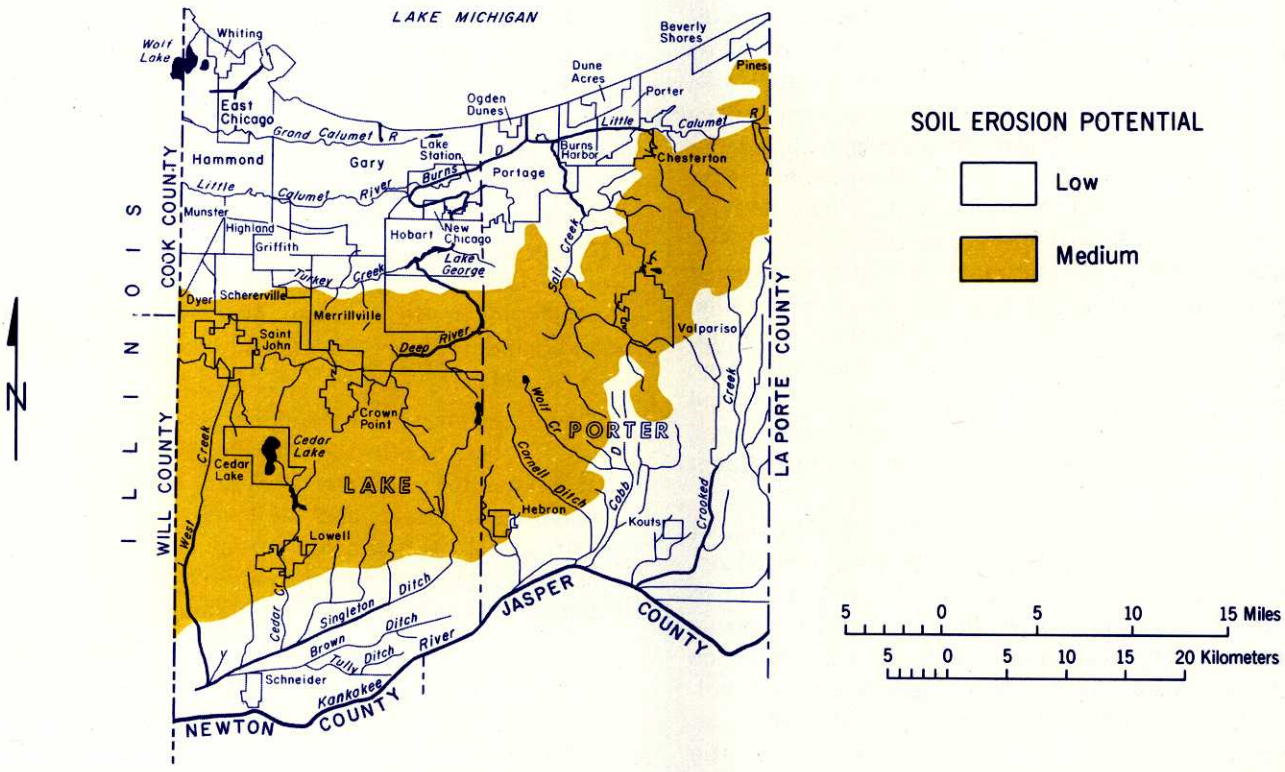


Figure 62
Map of Region One-A showing the erosion potential of the soil associations under fallow land conditions.

at various sampling points in Lake Michigan was not exceeded from April through October, when whole-body contact recreation was allowed. The pH, a measure of the acidity or alkalinity of a substance, of the water at the Gary intake generally remained within the recommended range as established by SPC 4R-2.

The Grand Calumet River consists almost entirely of both treated wastewater and wastewater of nonpoint source origin. The unnatural character of the stream indicates that even when all wastewater discharges are provided with best available treatment technology, the Calumet River may not be capable of sustaining a diverse fishery. The Grand Calumet River is classified as waters for partial body contact and limited aquatic life.

In this region, the Grand Calumet River experiences temperature violations, usually occurring during the months of October and November. The dissolved oxygen content at the Indiana-Illinois state line has violated the standard established by SPC 7R-3 approximately fifty percent of the time. Most of the dissolved oxygen violations occurred during the summer. One contributing factor to the low oxygen levels is the uptake of oxygen by bacteria decomposing the large amount of organic material discharged into the Grand Calumet by natural runoff, stormwater from sewers, and discharge from municipal and industrial treatment plants.

Other parameters evaluated for the Grand Calumet River include nitrate, pH, and biochemical oxygen demand: a measure of the amount of oxygen consumed in the biological processes that breakdown organic matter in water. Nitrate levels of the Calumet River fell within acceptable levels. Water quality samples collected in Gary indicated the biochemical oxygen demand was at an acceptable level. However, the biochemical oxygen demand levels that occurred at the Indiana-Illinois state line were higher than desirable. The pH values of the Grand Calumet River fell within the recommended range at both stations.

The Grand Calumet River is designated for partial body contact recreation. The levels of fecal coliform bacteria appear to exceed the criteria for partial body contact at the Indiana and Illinois state line. This violation could possibly be associated with chronic chlorination problems at the Gary wastewater treatment facility.

No temperature violations were recorded for the Indiana Harbor Ship Canal, but dissolved oxygen values were often not in compliance with the standards. In the canal, both nitrates and the biochemical oxygen demand were usually at acceptable levels and maximum and minimum pH values were found to be within standards.

Portions of the Little Calumet River and Burns Ditch are designated for partial body contact recreation and are capable of supporting a cold water fishery. Data for the Little Calumet River and Burns Ditch did not indicate temperature violations, although temperatures taken at Hohman Avenue Bridge in Hammond and State Road 149 northwest of Porter indicated the presence of thermal inputs between the two stations.

In the upper reaches of the Little Calumet River, a cold-water fishery migration route, the concentration of dissolved oxygen met the standard. The dissolved oxygen concentration in the reaches near Hammond usually met the water quality standard for warmwater fish. Most dissolved oxygen violations occurred in late summer and early autumn. Data indicates that nitrate and pH levels were generally within the recommended levels, but the biochemical oxygen demand often exceeded its levels, especially during the fall.

The Little Calumet River is designated for partial body contact recreation at the station at State Road 149 northwest of Porter. However, this standard was not met during summer and fall months. The station downstream at the Hohman Avenue Bridge in Hammond could not meet this standard except during June and August.

One of the streams that augments the Little Calumet River is Burns Ditch. Data for Burns Ditch indicated that temperature, dissolved oxygen, biochemical oxygen demand, nitrate, and pH levels were acceptable year-round. Designated for partial body contact recreation, the fecal coliform bacterial levels in Burns Ditch occasionally exceeded the standards.

Salt Creek, which also augments the Little Calumet River, has twelve wastewater dischargers, the largest of which is the city of Valparaiso. The standard for dissolved oxygen was met above the Valparaiso treatment plant but dropped below the standard downstream from the plant. Similarly, the biochemical oxygen demand met the recommended level upstream of Valparaiso but exceeded the recommended level downstream from the treatment plant. The number of fecal coliform bacteria exceeded the standard downstream of Valparaiso. It is anticipated that once Valparaiso completes its additional ammonia-nitrogen and disinfection facilities, instream standards will be achieved.

Temperature, dissolved oxygen, and nitrate levels for the Kankakee River were acceptable. The biochemical oxygen demand seldom exceeded the standard.

Regulation SPC 10R-2 (Water Quality Standards for Wolf Lake, 1978) designates Wolf Lake to be maintained not only for full body contact recreation but also for a warmwater fishery. Temperature, dissolved oxygen, and fecal coliform bacterial levels were within the state standards. Some monthly pH maximums have exceeded the limit for Wolf Lake.

The trophic or age classification of those lakes surveyed by the Stream Pollution Control Board in Region One-A follow.

Table 38
Trophic classification of lakes surveyed.

Lake	*County*	*Age Classification*
Clear	Porter	I
Flint	Porter	I
Morgan	Porter	II
Sagars	Porter	II
Wahab	Porter	II
Long	Porter	II
Billington	Porter	II
Canada	Porter	II
Spectacle	Porter	II
Fancher	Lake	II
Eliza	Porter	II
Mink	Porter	II
Dale Carlia	Lake	III
Lake George (Hammond)	Lake	III
Lake George (Hobart)	Lake	III
Loomis	Porter	III
Wolf Lake	Lake	III
Cedar	Lake	III

Region One-B

Jasper, Newton, Pulaski, and Starke Counties, located in northwestern Indiana, form Region One-B. The region contains approximately 1,716 square miles and is bounded by the Kankakee River to the north; the Illinois-Indiana state line to the west; Benton, White, and Cass Counties to the south; and Marshall and Fulton Counties to the east, as indicated in Figure 63.

The region's population in 1977 was 69,373. The official Indiana County Population Projections for 1975 to the year 2000 estimate that the region's population may increase by thirty-two percent. Population growth is expected to occur uniformly throughout the region. The 1975 population and the population projections for each county are presented below.

Table 39
The 1975 and projected populations for Region One-B.

County	*1975*	*1980*	*1990*	*2000*
Jasper	22,919	25,700	30,200	34,500
Newton	13,007	14,900	18,000	21,000
Pulaski	12,780	13,200	13,900	14,600
Starke	20,667	22,700	28,500	28,100
Total	69,373	76,500	87,600	98,200

The major urban centers are Rensselaer in Jasper County and Knox in Starke County. These urban centers accounted for eleven percent of the region's 1975 population.

Agriculture is the dominant land use within the region with more than eighty percent of the land area devoted to agricultural purposes. Approximately seven

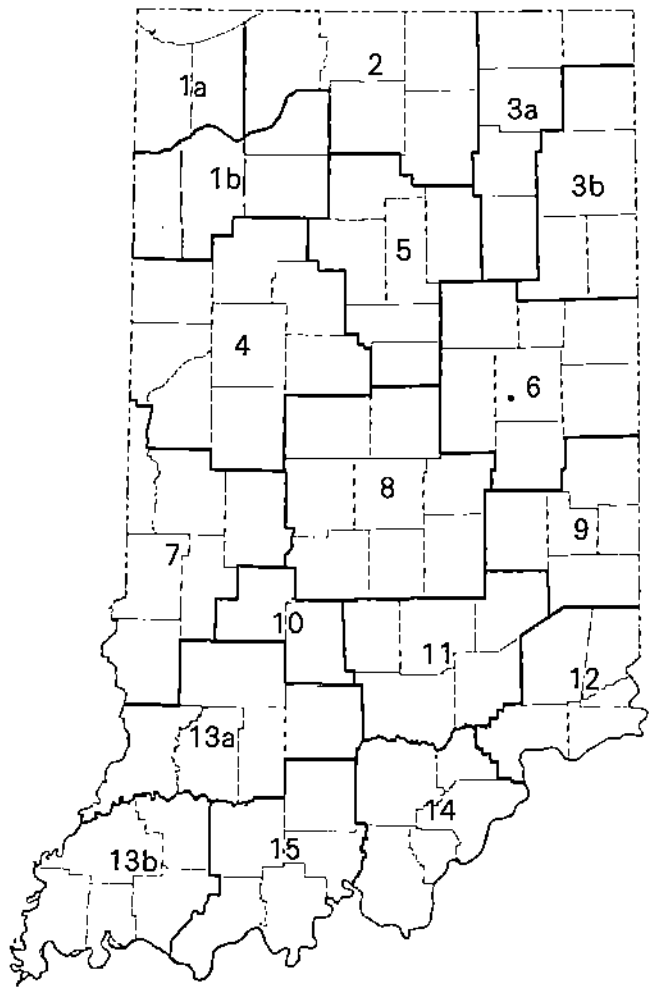


Figure 63
Map of Indiana showing the location of Region One-B.

percent is forested while the remaining thirteen percent is urban and miscellaneous land uses.

Although agriculture is by far the major land use, it employs only sixteen percent of the work force. Nonmanufacturing equipment, including wholesale and retail trade, dominates the employment picture with over thirty-five percent of the total. Manufacturing employs almost thirty-five percent of the work force.

The climate of Region One-B is influenced by Lake Michigan. The region receives approximately 36.5 inches of precipitation annually. This varies from a high of 4.0 inches in July to a low of 1.8 inches in February. Of the 36.5 inches of annual precipitation, approximately 11.0 inches appear as streamflow while 25.5 inches are consumed through evapotranspiration. The area has average temperature ranging from 25°F. in January to 73°F. in July. The average annual temperature is 50.5°F. Data from the nearest recording weather station, the South Bend Michiana Regional Airport, indicates the annual prevailing wind is from the south-southwest at 10.6 miles per hour.

THE WATER RESOURCE

Ground Water

All of the region was covered by the continental ice sheets which retreated from Indiana some 20,000 years ago. The deposits left by the glacial ice range in thickness from less than twenty-five to over two hundred feet and include dune sand, lake clays, glacial till, and outwash sand and gravel. In portions of this area thin inter-till sand and gravel zones are found within the glacial drift. The outwash sand and fine gravel deposits are prevalent adjacent to the Kankakee River and are relatively important sources of ground water. Lake clays, glacial till, and wind-blown sand predominate in southern portions of the region.

Sedimentary rock formations ranging in age from Silurian through Mississippian underlie the glacial deposits. Shales and siltstones of the Mississippian age Borden Group overlie the New Albany shale of lower Mississippian – upper Devonian age in southern Newton and Jasper Counties. These shales and siltstones are relatively poor water producers. Silurian and Devonian limestone and dolomite occur along a line running northwest to southeast across the remainder of the region. These rocks make up the most important bedrock aquifer within the region and are widely tapped by irrigation wells.

Overall ground-water availability in the region ranges from poor to excellent as shown in Figure 64. In southern Newton and Jasper Counties substantial areas of limited ground-water supplies occur, with wells producing from 10 to 50 gallons-per-minute (gpm) or less of potable water. Wells produce from 100 to 400 gpm throughout the remainder of the region. Yields of 600 gpm to 1,000 gpm are possible in eastern Pulaski County.

In much of southern Jasper and Newton Counties well yields are limited to less than 100 gpm. However, in areas near Brook, Kentland, and Remington, localized sand and gravel aquifers yield up to 400 gpm. In the northern portions of the region deep limestone aquifers from the Silurian-Devonian bedrock yield up to 1,500 gpm.

Limited ground-water conditions and shallow shale bedrock are present in southwest Starke County, northeastern Jasper, and northwestern Pulaski Counties. Deeper wells in these areas often encounter hydrogen sulfide gas. Locally limited areas are also present in north-central Starke County in the vicinity of Knox where shallow fine sand deposits predominate. In eastern Pulaski and Starke Counties and northwest Starke County well yields of 400 to 1,000 gpm are feasible from deposits of inter-till and outwash sand and gravel. Elsewhere in these counties yields of 100 to 200 gpm are possible from properly constructed, large diameter wells.

Ground-water quality ranges from very hard, with nuisance amounts of hydrogen sulfide gas, to fairly soft water with little or no iron and no hydrogen sulfide. In general, however, water hardness ranges between 200 and 300 parts-per-million (ppm), with iron concentrations varying from 0.2 to 1.8 ppm. Some form of iron treatment or removal will be required in most instances. Hydrogen sulfide is commonly encountered in the limestone bedrock in north-central Jasper, western Newton, northwestern Pulaski, and southwestern Starke Counties. The occurrence of hydrogen sulfide is particularly noticeable in those areas where the limestone is overlain by or is in close proximity to the black New Albany Shale.

Surface Water

Streamflow Surface water in the region is primarily located in streams. Significant streams in the region include the Kankakee, Iroquois, Tippecanoe, and Yellow Rivers. The majority of the region is drained by the Kankakee, Iroquois, and Yellow Rivers which ultimately discharge into the Upper Mississippi drainage system. The remaining portion is drained by the Tippecanoe River and its tributaries which flow into the Wabash River, a tributary to the Ohio River.

The Kankakee River may be the most reliable large stream in the state as far as providing a dependable flow. This characteristic dependability is shared, but to a lesser degree, by the Yellow and Tippecanoe Rivers.

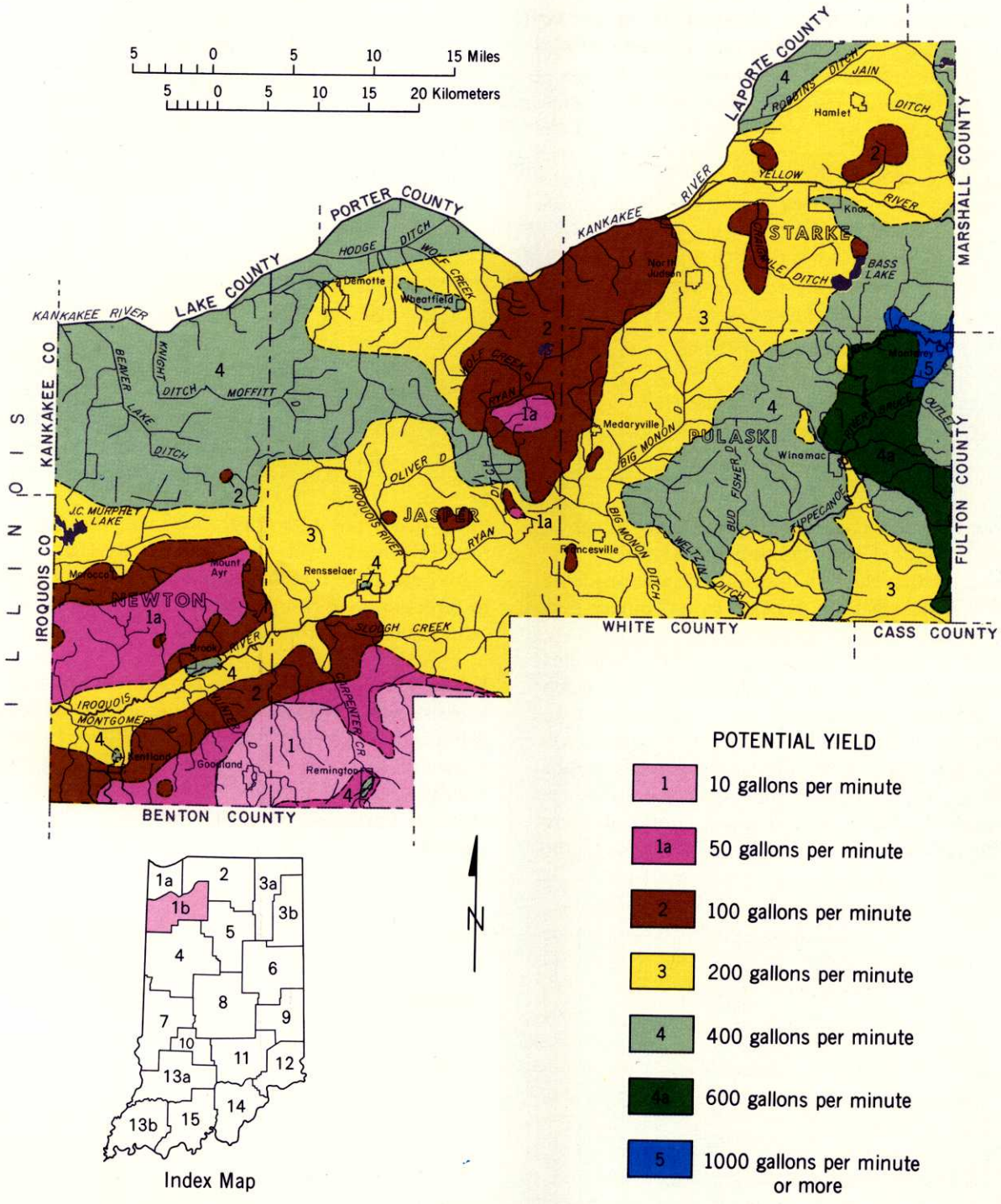


Figure 64
Map of Region One-B showing the general location and potential yield of ground water from properly constructed large diameter wells.

Because of less favorable geologic conditions, the Iroquois River does not have a dependable flow.

The following table lists the seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and the average annual flow in million-gallons-per-day for streams with gaging stations in Region One-B.

Table 40
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Iroquois River near Foresman	449	230	6.5	4.0
Iroquois River at North Meridian	144	79	2.5	1.3
Iroquois River at Rensselear	203	103	3.3	1.9
Iroquois River at Rosebud	36	16	1.2	0.6
Kankakee River at Davis	537	320	120.0	100.0
Kankakee River at Dunns Bridge	1,352	830	210.0	180.0
Kankakee River at Shelby	1,779	1,010	270.0	220.0
Tippecanoe River at Ora	856	520	80.0	63.0
Yellow River at Knox	435	250	46.0	35.0

The flow duration curve for the Kankakee River at Shelby has a minimal slope, as shown in Figure 65. The curve indicates that the stream will have a dependable flow of 400 million-gallons-per-day (mgd) ninety percent of the time.

The slope of the flow duration curve also indicates that the Kankakee River basin contains aquifers which provide significant ground-water contributions to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to seventy-two, sixty four, and thirty-two percent for "dry," "average," and "wet" years respectively. Conversely, from twenty-eight to sixty-eight percent of the flow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or from snowmelt.

Lakes The lakes within the region that are at least 50 acres in size or have a storage capacity of 32.5 million gallons or more are presented in Table 41, and are shown on Figure 66. These nine lakes have a combined surface area of approximately 6,000 acres with a gross storage capacity of approximately 7,700 million gallons.

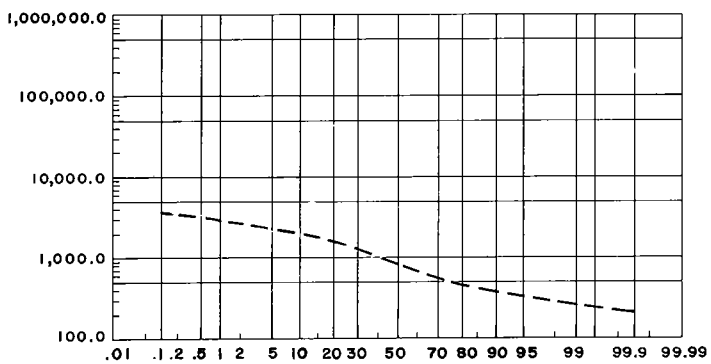


Figure 65
The flow duration curve for the Kankakee River at Shelby.

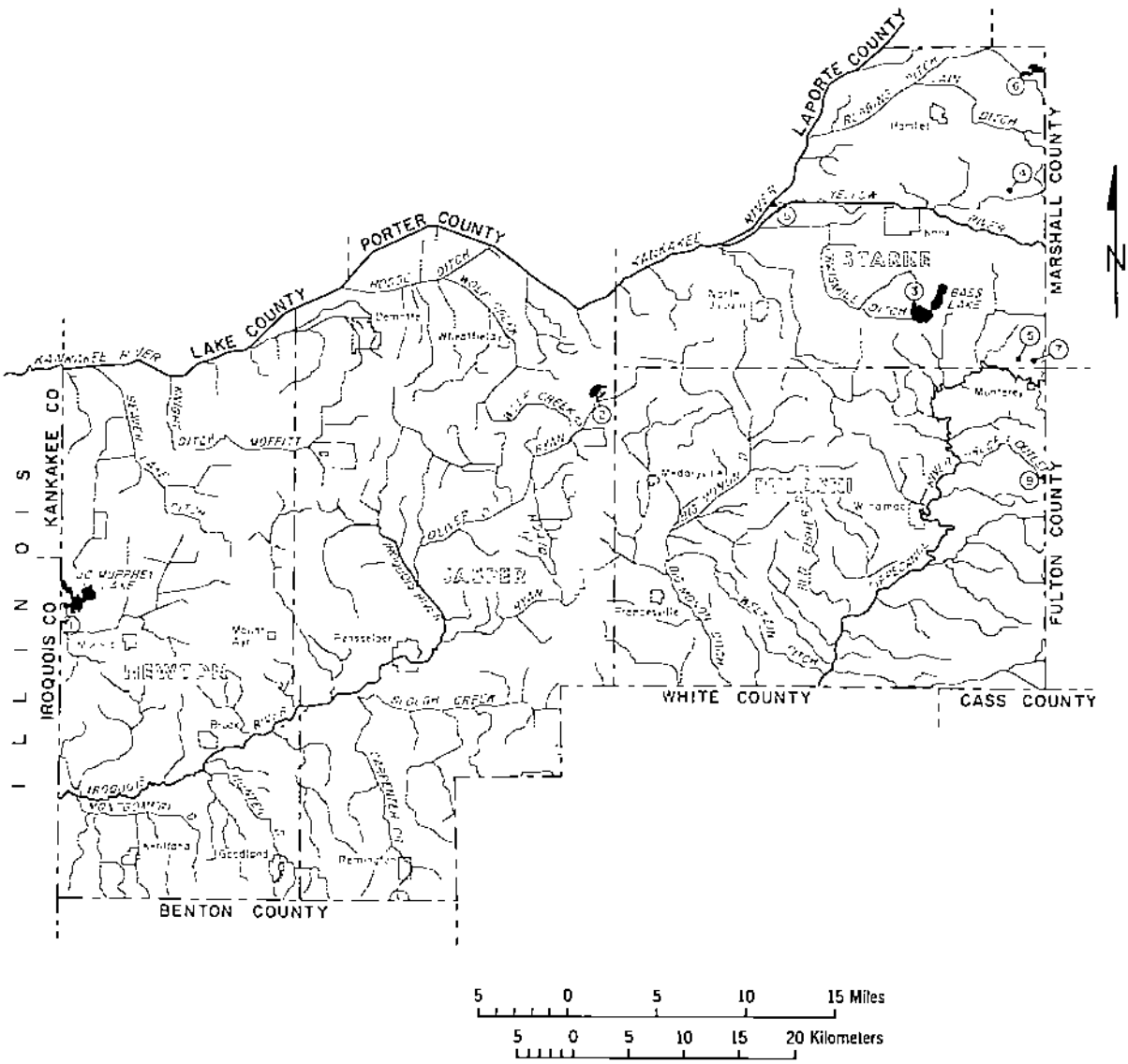


Figure 66
Map of Region One-B showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

Table 41
Lakes at least 50 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	J.C. Murphy Lake	13.00	1,515.0	5,826
2	Ringneck Lake	1.94	1,400.0	na
3	Bass Lake	5.18	1,400.0	na
4	Eagle Lake	25.50	24.0	52
5	Hartz Lake	na	28.0	120
6	Koontz Lake	6.25	346.0	1,032
7	Langenbaum Lake	0.72	48.0	84
8	Skilz Lake	na	1,000.0	na
9	Bruce Lake	6.38	245.0	583

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region One-B is presented in Table 42. The existing supply for recreational activities is expressed as a percentage of the demand. When this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred it is less than the projected demand.

Boating and Waterskiing The lakes of this region provide surface water to meet the current demand for recreational boating and waterskiing. However, the projected demand for boating is expected to exceed the supply by the year 2000.

Table 42
Outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	26	19.6 boats/acre/year	4,400 acres	100+	100+	91
Waterskiing	11	34.4 skiers/acre/year	1,500 acres	100+	100+	100+
Canoeing	8	585 canoes/mile/year	96 miles	100+	100+	100+
Swimming	51	76,600 swimmers/acre/year	5 acres	83	83	71
Ice-Skating	8	6,678 skaters/acre/year	8 acres	100+	100+	100+
Fishing	42	66 persons/acre/year	8,500 acres	83	75	71

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

Bass Lake is the fourth largest natural lake in Indiana and absorbs much of the boating activity in this region. Boating occurs on the Kankakee River, although floating debris can create hazards to boaters and especially waterskiers. Small-craft boating is available on the Tippecanoe and Iroquois Rivers. The proximity and abundance of Lake Michigan as a boating resource may serve to somewhat alleviate the shortages of boating opportunities that are expected in the future.

Canoeing The Kankakee, Iroquois, and Tippecanoe Rivers are all used for canoeing in Region One-B. The Kankakee offers excellent canoeing due to its steady flow and is accessible from numerous county, state, and federal highways as well as the LaSalle and Kankakee State Fish and Wildlife Areas.

Local canoeing demands are not in excess of the present supply of canoeing streams, and projected figures anticipate no shortage of canoeing opportunities by the year 2000.

Swimming and Ice-Skating The swimming demand generated by the residents exceeds the supply of existing swimming facilities. The demand is projected to exceed supply by over thirty percent by the year 2000.

The ice-skating needs are currently met by existing resources with no future shortage anticipated.

Fishing The quality of the fisheries habitat within Region One-B is shown in Figure 67. The streams in the northern portion of this region are in the Kanakakee River drainage basin. Due to channelization of streams, the aquatic habitat values range from low, near the upper ends of tributaries, to high, at the confluence with the Kankakee River. Warmwater fish populations dominate the Kankakee River drainage basin. Northern pike use the tributaries of the Kankakee River for spawning.

The main branches of the Tippecanoe and Iroquois Rivers provide good aquatic habitat for warmwater fish, most notably smallmouth bass. The Tippecanoe River also provides spawning habitat for white bass and other fish from Lake Schafer. Unlike streams in the northern part of the region, these streams have high pool and riffle ratios, especially closer to the Tippecanoe and Iroquois Rivers, which improves the aquatic habitat.

Public access to rivers other than the Tippecanoe is somewhat limited. Tippecanoe River State Park offers public access. Two other public fishing sites on the Tippecanoe are located at the Haschell Bridge northeast of Winamac and four miles south of Winamac. LaSalle and Kankakee State Fish and Wildlife Areas provide access to the Kankakee River, and Willow Slough offers lake fishing. Bass Lake is accessible through the state beach on the east side of the lake and on the west by the dam.

The demand for fishing opportunities by residents of the region exceeds the supply. By the year 2000, only two-thirds of the needed surface waters may be available to fishermen seeking quiet, uncrowded surroundings in the region. The proximity of the fishery resource in Lake Michigan to fishermen from Region One-B may partially alleviate the shortage.

Riparian Habitat The quality of the riparian habitat associated with surface streams is shown in Figure 68. Skitz Lake is entirely wetland, mainly wooded swamp with areas of deep water marsh. It provides excellent habitat for migratory and resident waterfowl, furbearers, (especially muskrat, beaver, and raccoon), and many other wildlife. Round Lake and J.C. Murphy Lake provide large areas of deep water marsh comprised mainly of cattails.

Extensive areas of wooded swamp are found along the Iroquois River. Stretches along the banks of the Tippecanoe River, Iroquois River, and their tributaries are lined by upland woods which attract deer, rabbits, squirrels, and upland game birds besides waterfowl. The grassy banks of some tributaries to the Iroquois River offer habitat for gamebirds, especially pheasants. Ryan Ditch, Slough Creek, and Curtis Creek, provide little habitat due to the amount of cropland.

Willow Slough, LaSalle, Jasper-Pulaski, Kankakee, and the Winamac Fish and Wildlife Areas offer public hunting opportunities and habitat for a variety of wildlife.

Withdrawal Uses

Public Water Supplies Jasper, Newton, Pulaski, and Starke Counties are served by twelve public water utilities. Thirty percent of the population of Region One-B was served by a public utility in 1975. There are no rural water utilities in this region.

The largest single utility is located in Rensselaer. The Rennsselaer utility withdrew an estimated 0.7 mgd during 1975. Other large utilities are located in Knox and Winamac, which withdrew .05 mgd in 1975. The public water utility in Kentland withdrew 0.2 mgd. Figure 69 shows the water service areas within Region One-B.

The public water utilities withdrew an average of 2.6 mgd in 1975, with a maximum daily use of about 5.0 mgd. Withdrawals by the region's public water utilities should increase to about 3.8 mgd by the year 2000, as indicated in Table 43. The water supply for these utilities is derived from ground-water sources.

Table 43

The 1977 and projected water withdrawal and consumption rates of public water supplies by the year 2000, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	2.6	2.8	3.3	3.8
Consumption	0.3	0.3	0.3	0.4

Communities in the region developed well fields within or just outside their corporate limits. The exception is Goodland, which relies on a well field two miles directly north of the town.

Industrial Water Region One-B is a rich, agricultural area, consequently, the largest water demands come from the food processing industry. Metal fabricators and transportation equipment manufacturers in the region use more modest amounts of water.

Industrial establishments had an estimated water intake averaging 1.3 mgd in 1977. Of the total industrial intake, 0.6 mgd is self-supplied by the industries themselves while 0.7 mgd is purchased from the region's public water utilities. Because of the general availability of ground water in the area, most of the

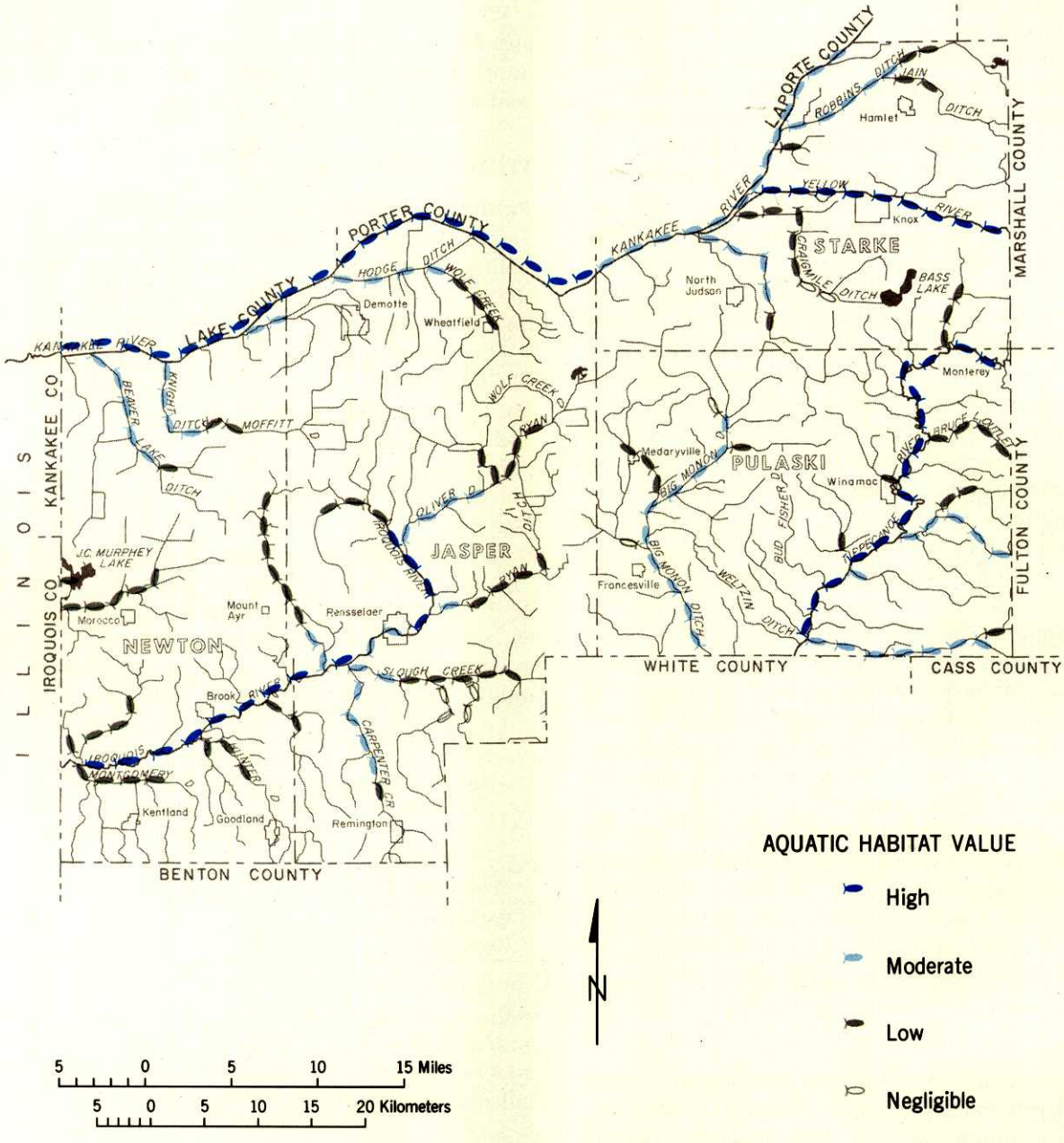


Figure 67
Map of Region One-B showing the quality of the fisheries habitat.

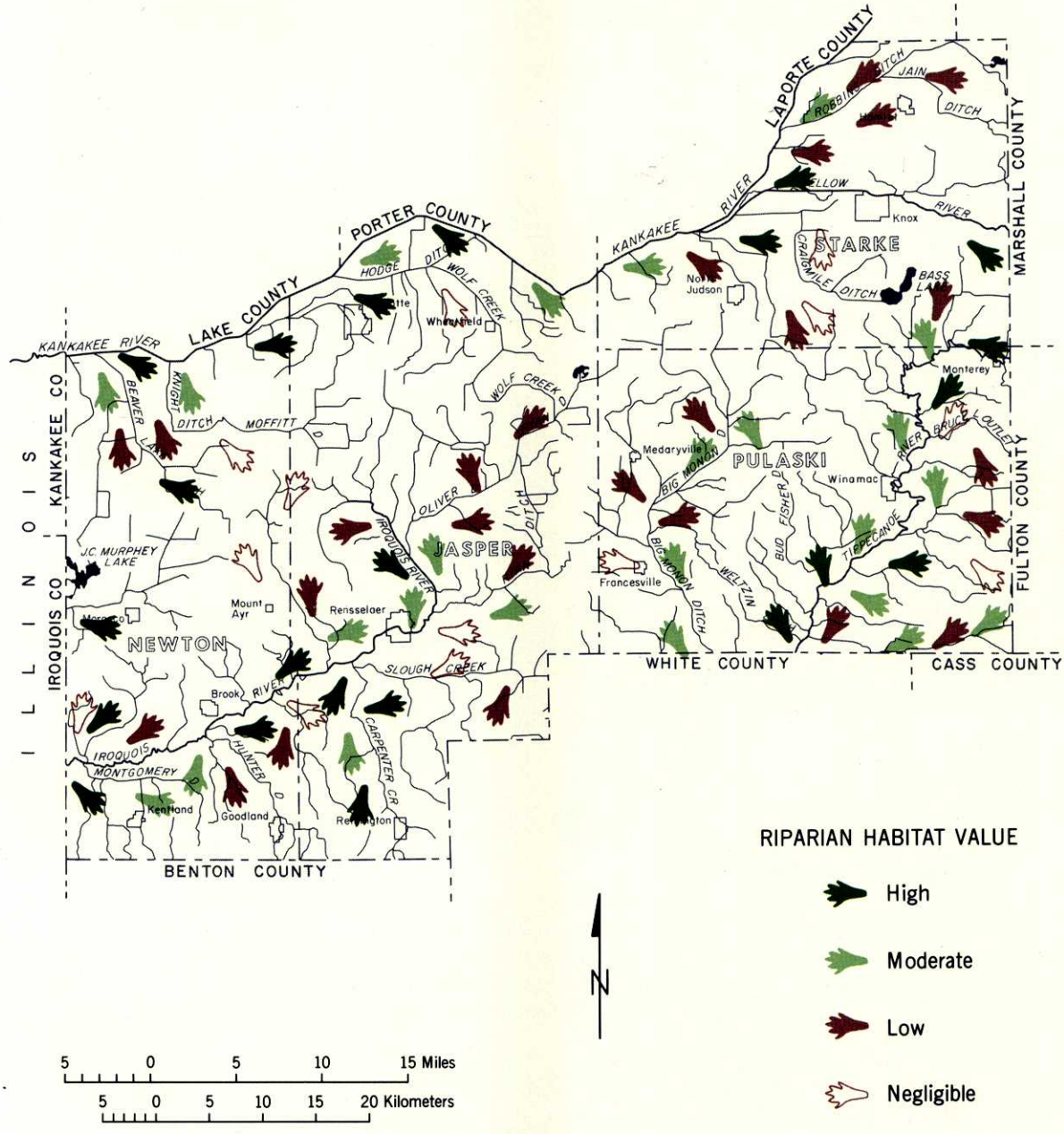


Figure 68
Map of Region One-B showing the quality of the riparian habitat.

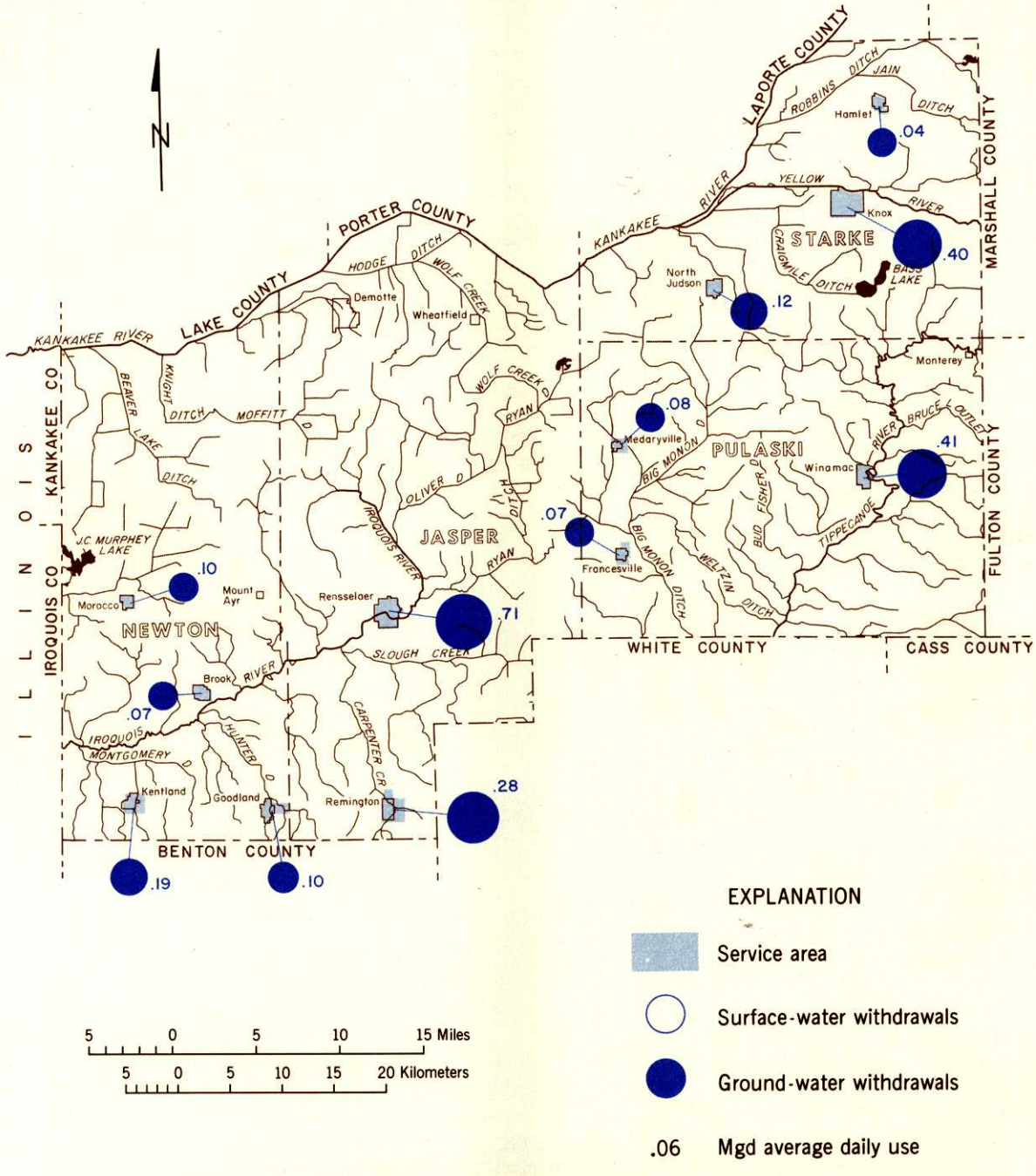


Figure 69
Map of Region One-B showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

self-supplied industrial water is withdrawn from wells, usually located on plant property.

Industrial production by the year 2000 is expected to increase two hundred percent above the 1977 value (United States Water Resources Council). In spite of this predicted increase in industrial output, total industrial water intake is expected to increase slightly from 1.3 mgd to 1.5 mgd. The self-supplied component of the projected industrial use of water is expected to increase from 0.6 mgd to 0.7 mgd. The current and projected self-supplied withdrawals and rates of consumption for industries located in Region One-B are presented in the following table.

Table 44
The 1977 and projected self-supplied withdrawal and consumption rates for industries in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.6	0.6	0.7	0.7
Consumption	0.2	0.2	0.3	0.4

Rural Self-Supplied Water An estimated 49,010 persons lived in homes supplied by individual wells in 1975. Approximately 2.9 mgd of water were used for residential purposes in 1975. An estimated 21,800 additional persons may depend on their own wells for household water by the year 2000. This withdrawal of rural self-supplied residential water may increase to 5.3 mgd by the year 2000.

In 1975 there were an estimated 260,000 head of livestock and about 545,400 chickens in Region One-B. Collectively, these animals consumed 1.8 mgd. By the year 2000, ground-water withdrawals for livestock are expected to increase to about 2.06 mgd.

The total withdrawal of rural self-supplied water may increase from the current 4.9 mgd to about 7.4 mgd by the year 2000, as projected here.

Table 45
The 1977 and projected water withdrawal and consumption rates for self-supplied rural water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	4.9	5.2	6.3	7.4
Consumption	4.9	5.2	6.3	7.4

Irrigation Water Soil associations with irrigation potential are located mainly in the northern half of the region, including an area in southeastern Jasper County. Figure 70 shows these potential irrigation areas. Based upon the survey of irrigated lands, approximately 12,050 acres were irrigated. The principal crop was corn, at 7,400 acres, followed by potatoes at 2,000 acres, and mint at just under 2,000 acres. Other crops irrigated included soybeans and vegetables.

Assuming 1977 as a normal growing year, these crops would have required about 31.7 mgd during the peak irrigation period of July and August. It is estimated that approximately 190,000 acres of croplands could be profitably irrigated. The 12,350 irrigated acres in 1977 are expected to increase to 23,500 acres by the year 2000. This expansion of irrigation acreage is expected to increase the peak July–August irrigation demand in an "average" year to about 62 mgd. The average ground-water use is expected to increase from the current 13.1 mgd to 33.7 mgd by the year 2000.

In addition to agricultural irrigation, there are about 93 acres of irrigated fairways and greens on the region's golf courses. About 0.3 mgd is applied to golf courses during the peak July–August irrigation period.

The total withdrawal for irrigation of croplands and golf courses during the "average" season of 1977 was approximately 31.9 mgd. These withdrawals may increase to 62.1 mgd during the "average" growing season by 2000, as presented here.

Table 46
The 1977 and projected withdrawals of irrigation water for croplands and golf courses in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	31.9	35.9	49.0	62.1
Consumption	31.9	35.9	49.0	62.1

Electric Energy The Rensselaer Municipal Electric Utility and the R.M. Schahfer Generating Station are the electric generating stations located in this region. The Schahfer Generating Station, located northeast of Wheatfield in Starke County, is owned and operated by the Northern Indiana Public Service Company. Schahfer is the only generating facility located on the Kankakee River in Indiana.

The Rensselaer plant is rated at 18.3 megawatts (mg). It utilizes internal combustion devices to drive its turbines and consequently, has only minor water needs. The Schahfer plant is rated at 520.8 mw. It utilizes a closed cycle cooling system for its coal-fired steam turbine, and withdraws approximately 6.3 mgd from the Kankakee River. Of this total, 3.5 mgd is returned to the river, resulting in a net consumption of approximately 2.7 mgd.

The Northern Indiana Public Service Company is in the process of enlarging the generating capacity of the Schahfer plant. Construction is presently under way on Unit Number 15 which will have a capacity of 527 mw and is scheduled for operation in 1979. Tentative plans call for the ultimate installation of four units at this

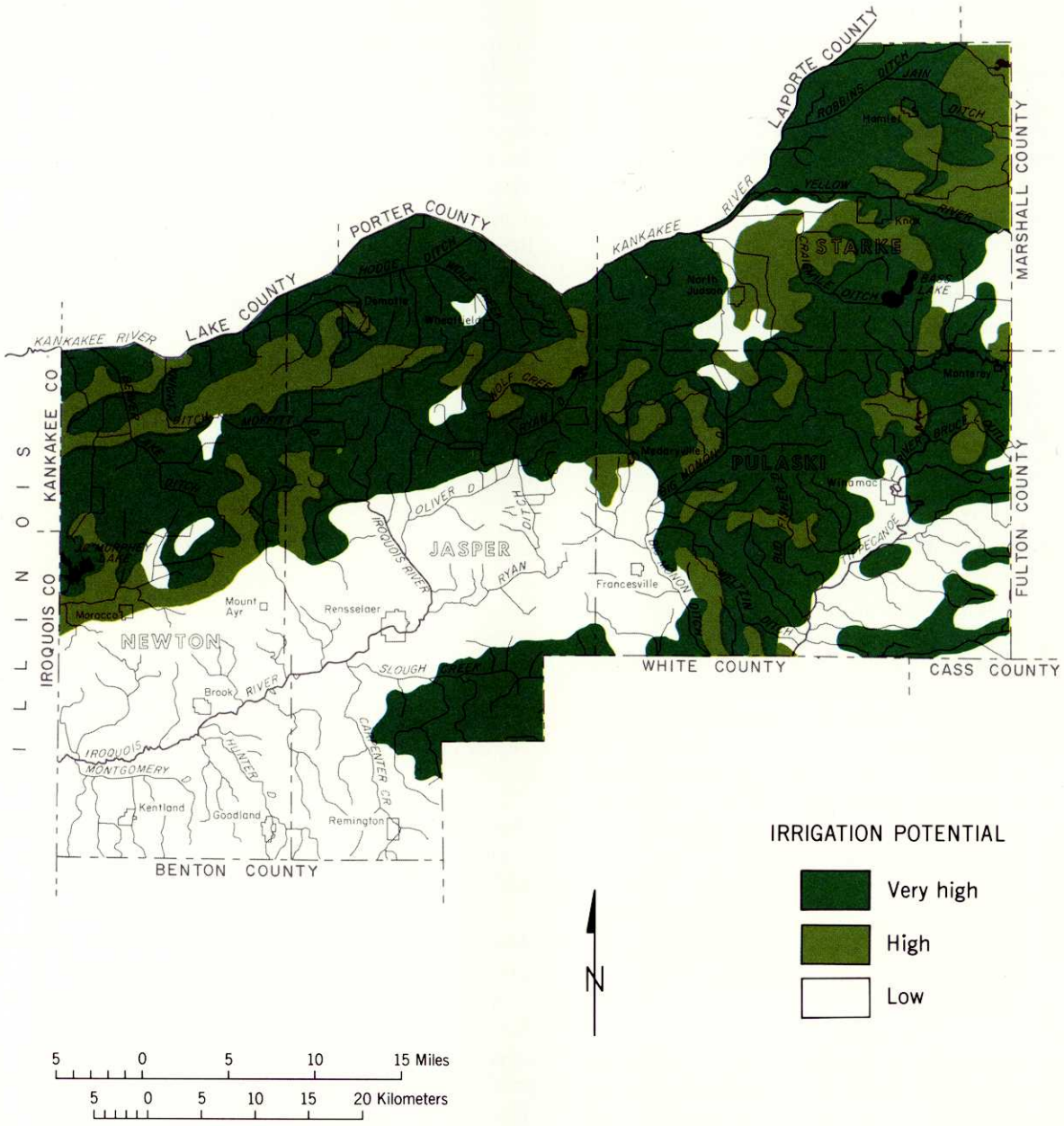


Figure 70
Map of Region One-B showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

site. The Northern Indiana Public Service Company has received a permit from the Department of Natural Resources for withdrawals from the Kankakee River of up to 68.5 mgd.

Because of its excellent sustained flow characteristics, the Kankakee River is a candidate for additional power sites and development. Another possible candidate is the Tippecanoe River in eastern Pulaski County.

The current and projected quantity of water withdrawals and consumption for the production of electricity in Region One-B are presented below.

Table 47
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.3	13.0	13.0	13.0
Consumption	2.8	6.0	6.0	6.0

EXCESS WATER

Flooding

Approximately 147,000 acres, or seven to eight percent of Region One-B, are subject to flooding. The major flood plains are shown in Figure 71. Figure 72 indicates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be over two million dollars.

Virtually all of the streams in this region are subject to flooding. Flash flooding on streams in the area is uncommon due to the flatness of the topography. The Kankakee and Tippecanoe Rivers are the two major watersheds. These streams are subject to long flood durations.

Some flood protection is provided by a number of private levees in the Kankakee and Yellow River basins. Many of these levees were constructed from dredge spoil at the time of the original dredgings of these streams. Maintenance of these works has been poor in recent years.

Flood Control The Bailey-Cox-Newston Small Watershed Protection Project in Starke County is the only federally funded ongoing structural flood control project in the region.

The town of Kentland in Newton County has formed a conservancy district and has developed a plan to relieve its flooding and drainage problems.

The Iroquois Conservancy District was formed for the purposes of providing flood control, improving drainage, and preventing soil erosion. The district has developed a plan to relieve the flooding and drainage conditions of the Iroquois River.

Flood Plain Management Several communities are participating in some phase of the National Flood Insurance Program. Remington and Rensselaer in Jasper County, Newton County unincorporated; Brook, Goodland and Kentland in Newton County; Monterey and Winamac in Pulaski County; and Hamlet and Knox in Starke County are participating in the emergency phase of the National Flood Insurance Program. De Motte in Jasper County is participating in the regular phase of the National Flood Insurance Program.

Agricultural Drainage

Approximately seventy-two percent of the soil associations have "severe" wetness characteristics, twenty-six percent have "moderate" wetness characteristics, while two percent have "slight" wetness characteristics. The general location of soil associations with these wetness characteristics is shown in Figure 73. There are 3,220 miles of legal drains in the four-county region. This highly complex network of drains serves as the main collector and outlet for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage board or, in a limited number of cases, of conservancy districts. This network of drains has enabled the region to become one of the most agriculturally productive areas in the nation.

Soil Erosion

The soils of the region were evaluated as to their potential for erosion and classified as to high, medium, or low erosion hazards as shown in Figure 74. Fewer than three percent of the 1,098,000 acres in Region One-B has a "medium" soil erosion hazard. The remaining ninety-seven percent is ranked as having a "low" erosion potential for land in a fallow state. Surface water runoff from these areas is slow, and erosion control methods are primarily associated with the construction of drainage ditches and the maintenance of outlet ditches and prevention of siltation.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the Iroquois, Kankakee, and Tippecanoe Rivers. Water quality standards for the region are established by the

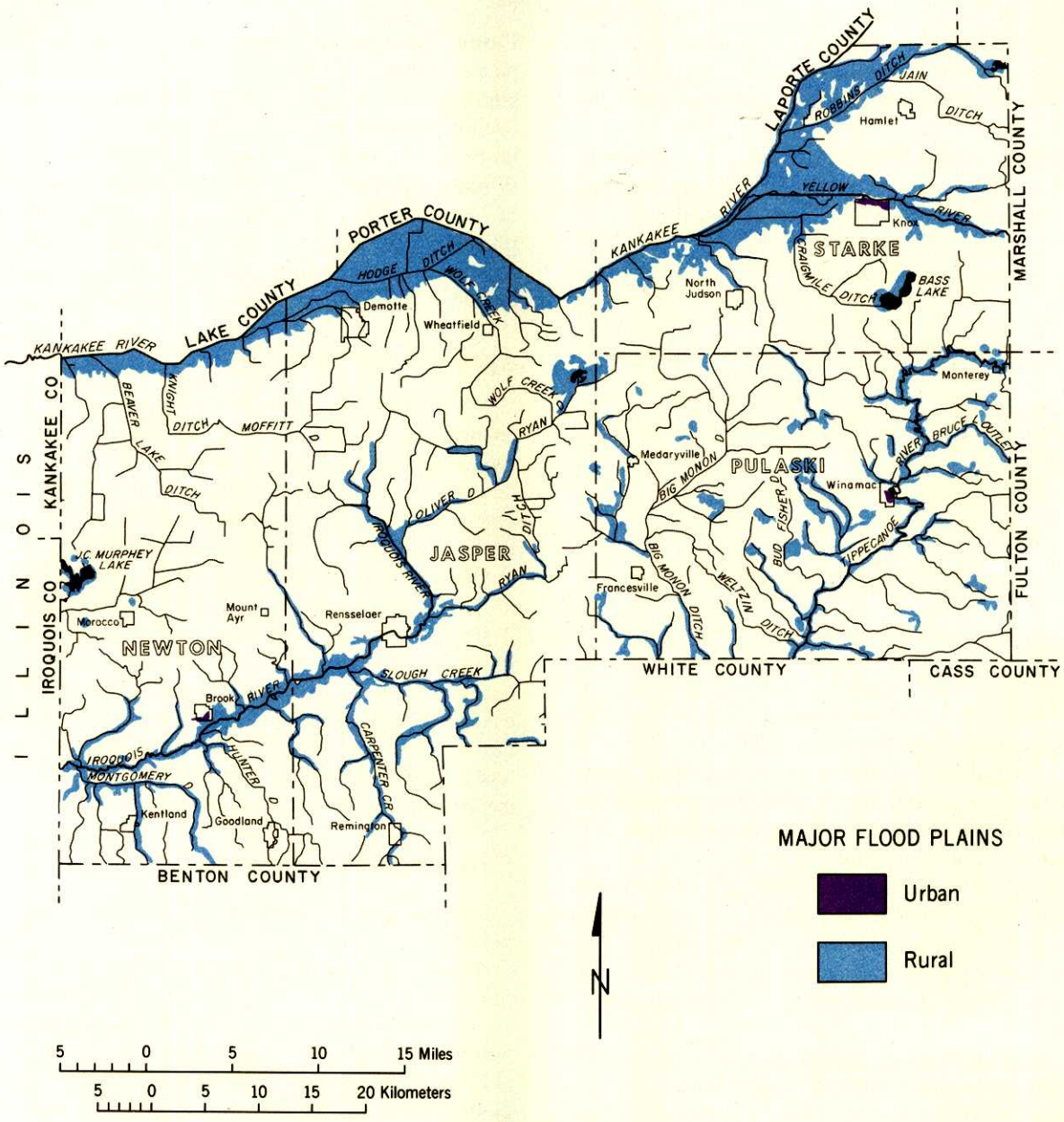


Figure 71
Map of Region One-B showing the major floodplains.

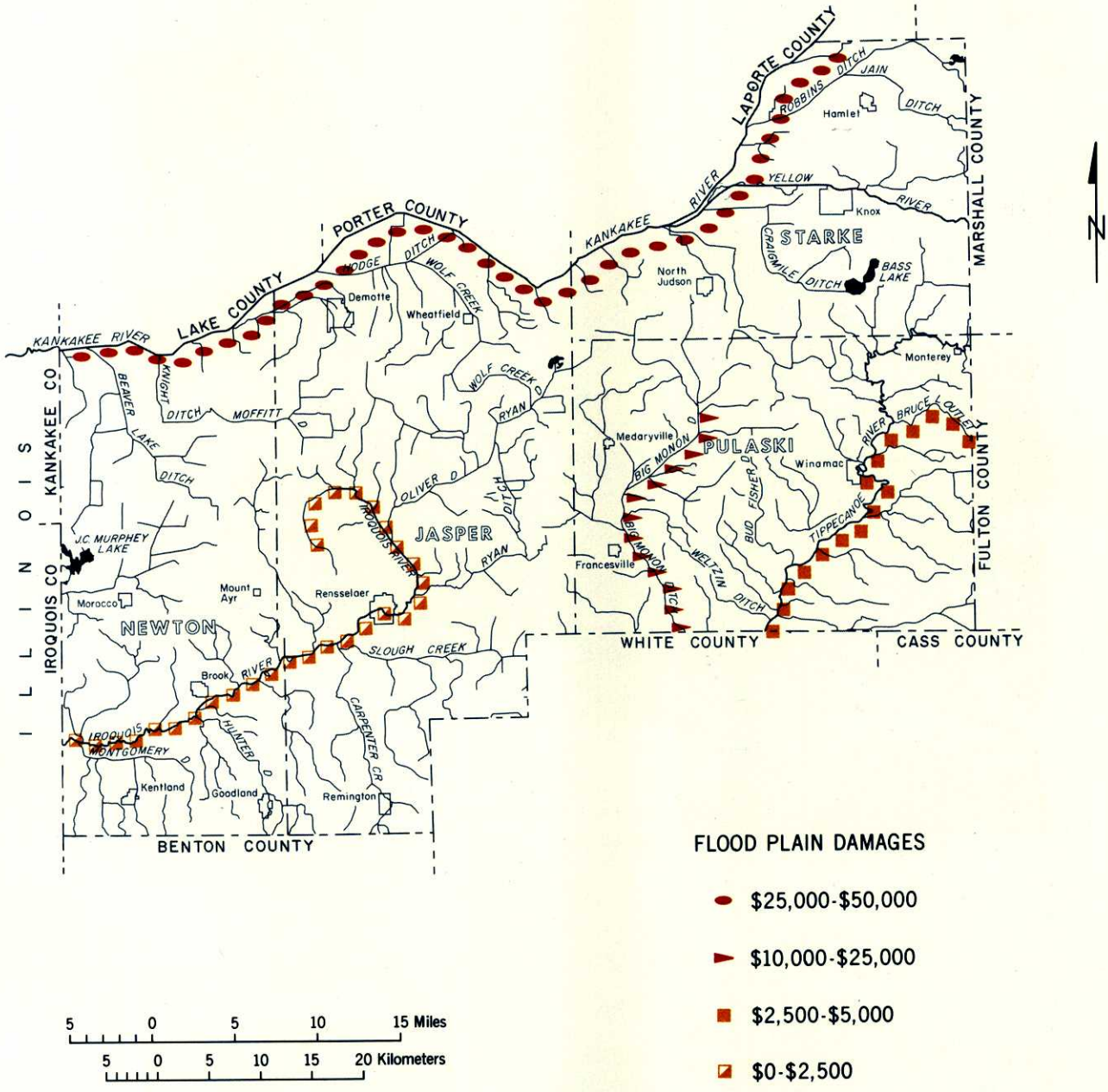


Figure 72
Map of Region One-B showing the estimated average annual flood damages per mile along selected streams.

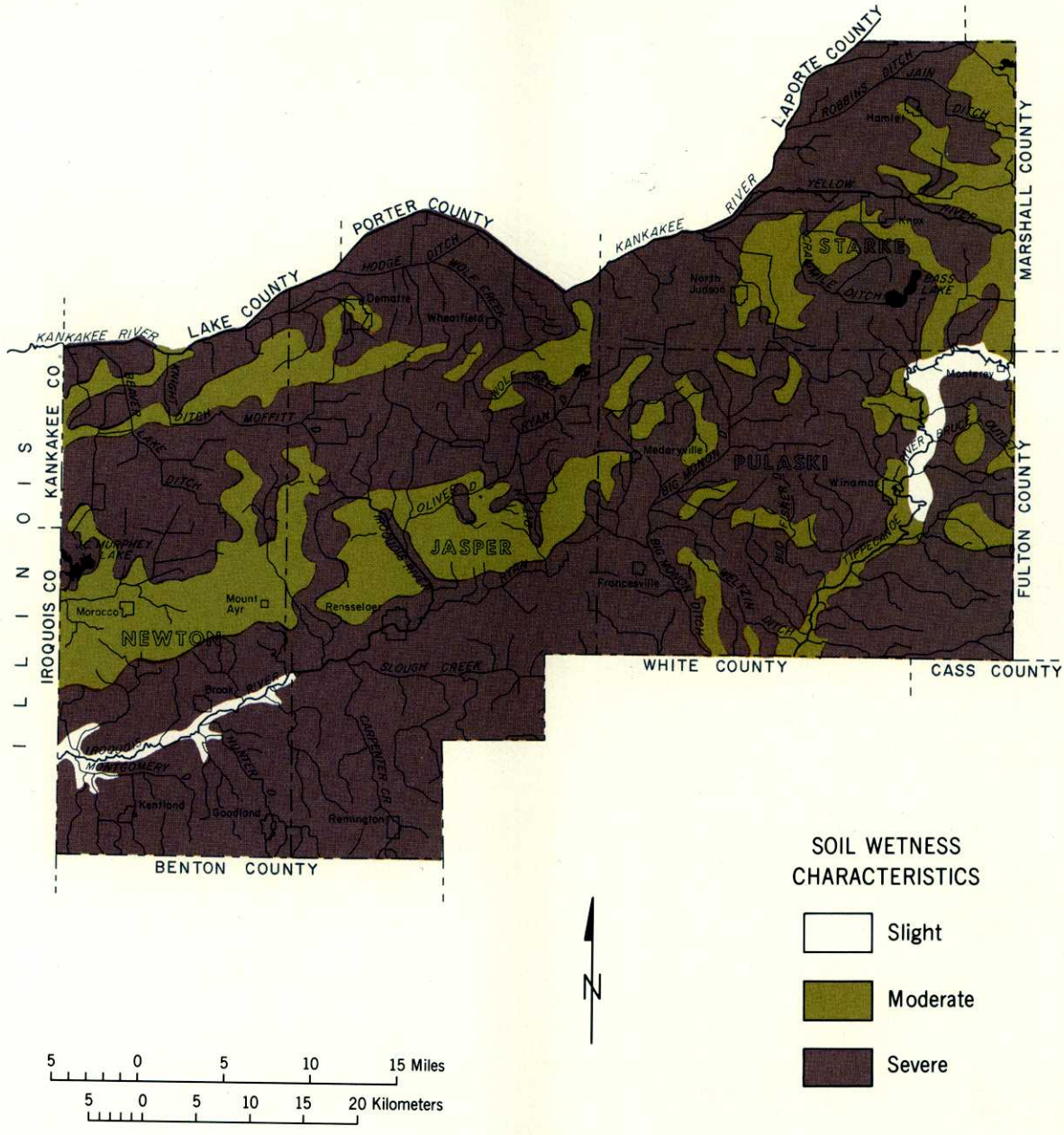


Figure 73
Map of Region One-B showing the general location of the wetness characteristics of soil associations.

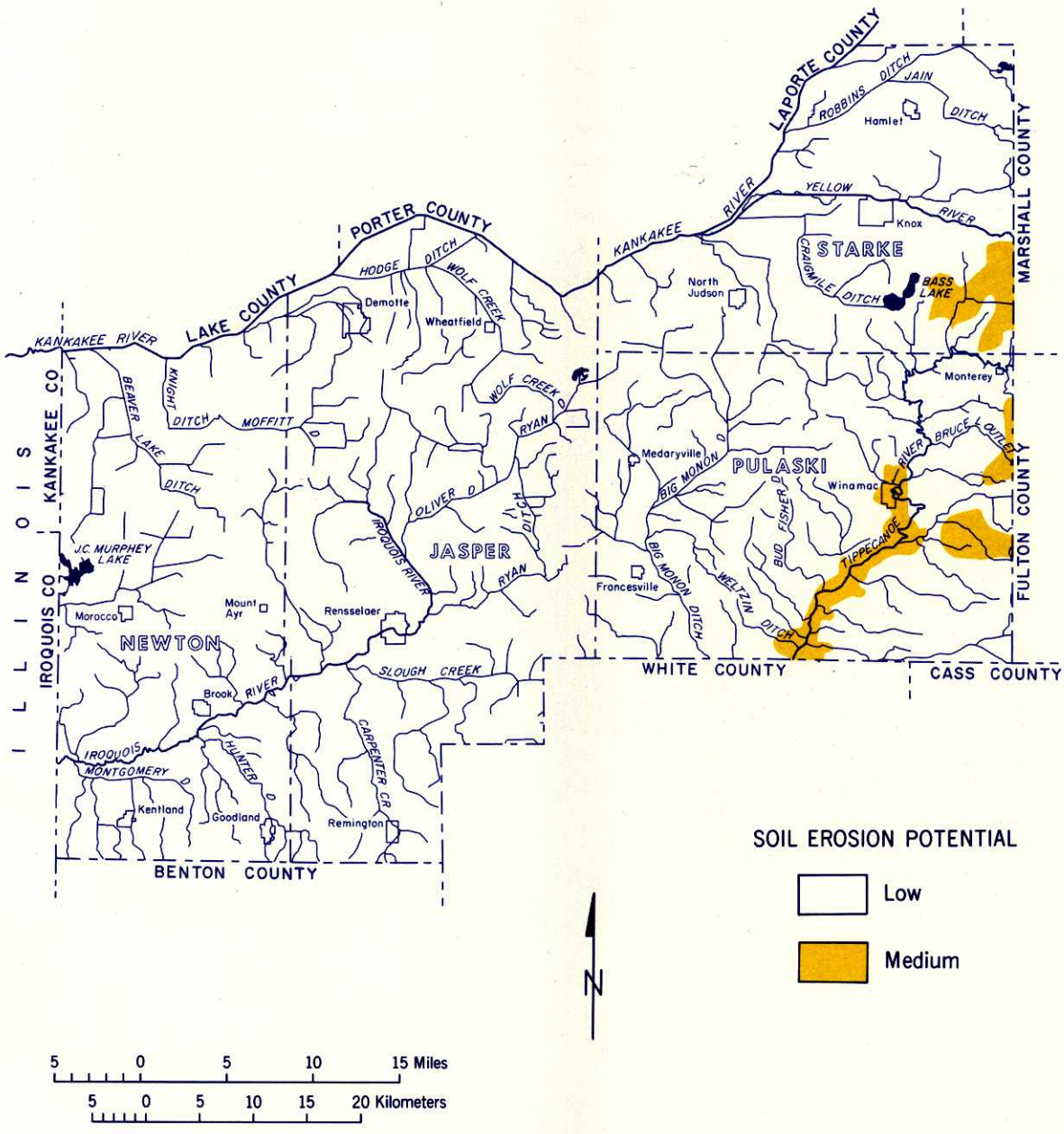


Figure 74
Map of Region One-B showing the erosion potential of the soil associations.

Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

The Iroquois River at Foresman met both the temperature and dissolved oxygen standards established by SPC IR-4. The biochemical oxygen demand, a measure of the amount of oxygen consumed in the biological processes that breakdown organic matter in water, generally remained within acceptable levels. The pH, a measure of the acidity and alkalinity of a substance, ranged between the permissible values in the Iroquois River at Foresman.

Data obtained from the Kankakee River near Shelby indicated that temperature, dissolved oxygen, nitrates, and the biochemical oxygen demand were within acceptable levels. The Tippecanoe River also has shown acceptable levels for these parameters.

The trophic, or age classification, of those lakes surveyed by the Stream Pollution Control Board in Region One-B follows.

Table 48
Trophic classification of lakes surveyed.

Lake	*County*	*Age Classification*
Bass	Starke	II
Hartz	Starke	I
Longenbaum	Starke	III

Region Two

Elkhart, Kosciusko, LaPorte, Marshall, and St. Joseph Counties, located in the north-central portion of Indiana, form Region Two. The region contains approximately 2,500 square miles and is bounded by Porter County on the west; Wabash and Fulton Counties on the south; Whitley, Noble, and Lagrange Counties on the east; and Lake Michigan and the State of Michigan to the north, as shown in Figure 75.

The population was 568,407 in 1975. Forty-two percent of the population resided in St. Joseph County. The official Indiana Population Projections for 1975 to 2000 estimate that the region may increase by twenty-one percent by the year 2000. The 1975 population and projection for each county are presented below.

Table 49
The 1975 and projected populations for Region Two.

County	*1975*	*1980*	*1990*	*2000*
Elkhart	131,900	148,900	175,100	201,600
Kosciusko	52,224	58,100	69,600	82,100
LaPorte	105,857	108,100	114,200	120,000
Marshall	37,941	42,000	49,000	55,700
St. Joseph	240,655	241,100	239,100	234,700
Total	568,407	598,200	647,000	694,100

The major population centers are Elkhart in Elkhart County, Warsaw in Kosciusko County, Michigan City in LaPorte County, Plymouth in Marshall County, and South Bend in St. Joseph County. These urban centers account for thirty-seven percent of the region's population.

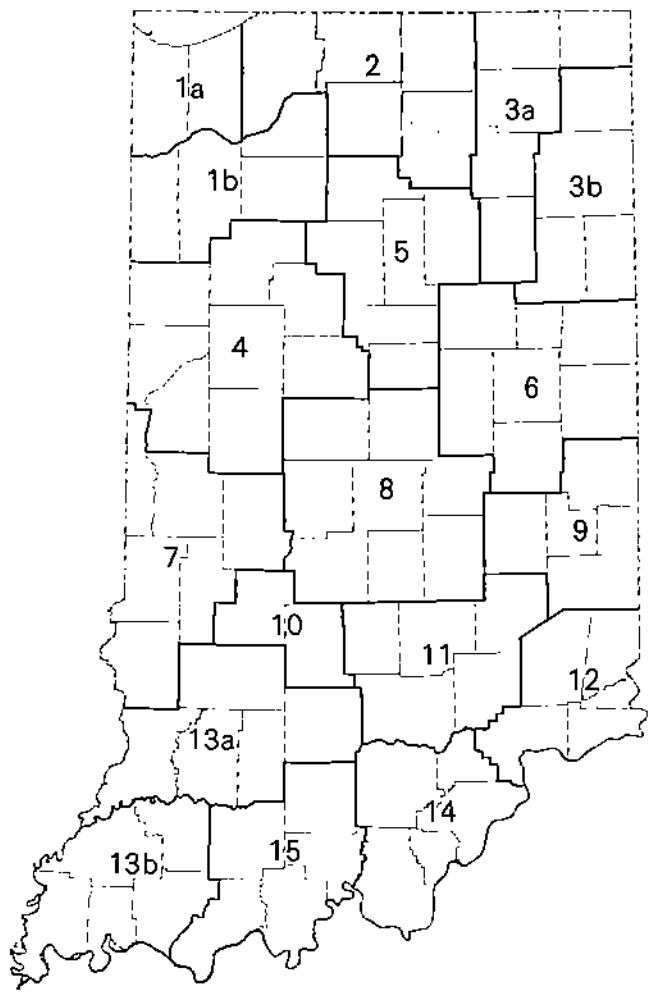


Figure 75
Map of Indiana showing the location of Region Two.

Agriculture is the dominant land use with more than seventy-two percent of the land area devoted to agricultural purposes. Approximately eight percent of the land is forested while the remaining twenty percent comprises urban and miscellaneous uses.

More than seventy percent of the region's work force is employed within Elkhart and St. Joseph Counties. Manufacturing employs approximately forty-seven percent of the total work force while agriculture employs approximately sixteen percent.

The topography of the region is a mixture of level prairie, some of which is former marshland, interspersed with moraines and hills.

The climate is directly influenced by Lake Michigan. The effect of Lake Michigan on the climate is most pronounced just inland from the shore, and it diminishes greatly with distance. Cold air passing over the warmer lake water produces precipitation leeward of the lake in the fall and winter. As a direct result of this phenomenon, winter precipitation, especially snowfall, is greatest in the extreme northwestern counties. Severe local snowstorms often occur just inland from Lake Michigan. In the spring daily maximum temperatures decrease in the immediate vicinity of the lake because of its cooling effect. Average daily minimum temperatures in the fall are higher in northwestern Indiana than further south in the state.

The region receives approximately 37.5 inches of precipitation annually. This varies from a high of 4.0 inches in July to a low of 1.75 inches in February. Approximately 12 inches of the annual precipitation appear as streamflow while 25.5 inches are consumed through evapotranspiration. The region has average temperatures ranging from 24°F. in January to 72.5°F. in July. The average annual temperature is 50°F. Data from South Bend Michiana Regional Airport indicates the annual prevailing wind is from the south-southwest at 10.6 miles per hour.

THE WATER RESOURCE

Ground Water

Of particular importance in this region are the glacially derived, unconsolidated deposits which contain the major sources of ground water. The deposits of Wisconsinan and Illinoian glacial stages consist of glacial till, inter-till sand and gravel, outwash-plain and valley-train sand and gravel, lake clays, dune sand, and ice-contact stratified drift. These materials range in thickness from about one hundred to five hundred feet. Significant outwash-plain and valley-train sand and gravel deposits are located adjacent to the Valparaiso Moraine and along the Kankakee, Elkhart, St. Joseph, and Tippecanoe Rivers. Complex inter-till sand and gravel aquifer systems are present in the moraines that are in Kosciusko, Marshall, and Elkhart Counties. A sequence of lake clays and wind-blown dune sand are found along Lake Michigan in LaPorte County.

Beneath the thick cover of glacial materials are bedrock formations of Mississippian, Devonian, and Silurain ages. The Mississippian rocks are generally composed of siltstone and shales while the Devonian rocks contain black shale and dolomitic-limestone units. A small area of Silurian limestone and dolomite may be present in extreme southeastern Kosciusko County beneath the unconsolidated deposits. The bedrock aquifers are not considered to be an important source of water in this portion of Indiana because of their depth, low yielding character, and the general occurrence of good aquifers within a glacial drift.

Glacial deposition has been a major controlling factor in the availability of ground water in Region Two. Figure 76 indicates the maximum potential yield of the aquifers within the region. The area of lowest potential yield capability is located in northwestern LaPorte County where fine sand deposits are not likely to yield more than 50 gallons-per-minute (gpm). Southeast of this area conditions begin to improve as sand and gravel deposits become more prevalent and yields up to 400 gpm are possible. From LaPorte eastward ground-water availability increases substantially, and properly constructed, large diameter wells will yield from 400 to 2,000 gpm. Outwash plain deposits of sand and fine gravel occurring in western St. Joseph County and extending southwesterly into LaPorte County, constitute one of the major aquifer systems in the state. This system, the Kankakee Aquifer, is capable of producing 600 to 1,000 gpm to properly constructed wells. Further east, extensive outwash sand and gravel aquifers in St. Joseph, Elkhart, and Kosciusko Counties form another area of major ground-water availability. Estimated recharge rates of 500,000 gallons-per-day per square mile are applicable to much of the area. The recharge rate, when combined with the large, available storage and permeable nature of the Kankakee aquifer, indicates that tremendous quantities of ground water are available for development.

Ground-water quality is typical of most parts of Indiana. Ground water is generally hard and relatively high in iron content. Hardness ranges in concentration from 180 to 400 parts-per-million (ppm) with areas of softer waters of 180 to 200 ppm occurring in southern LaPorte County. The iron content of ground water averages between one and two ppm with locally low iron concentrations in the outwash sand and gravel of northern Elkhart and St. Joseph Counties.

Manganese is below recommended maximum levels (below 0.05 ppm) in areas of western Elkhart and

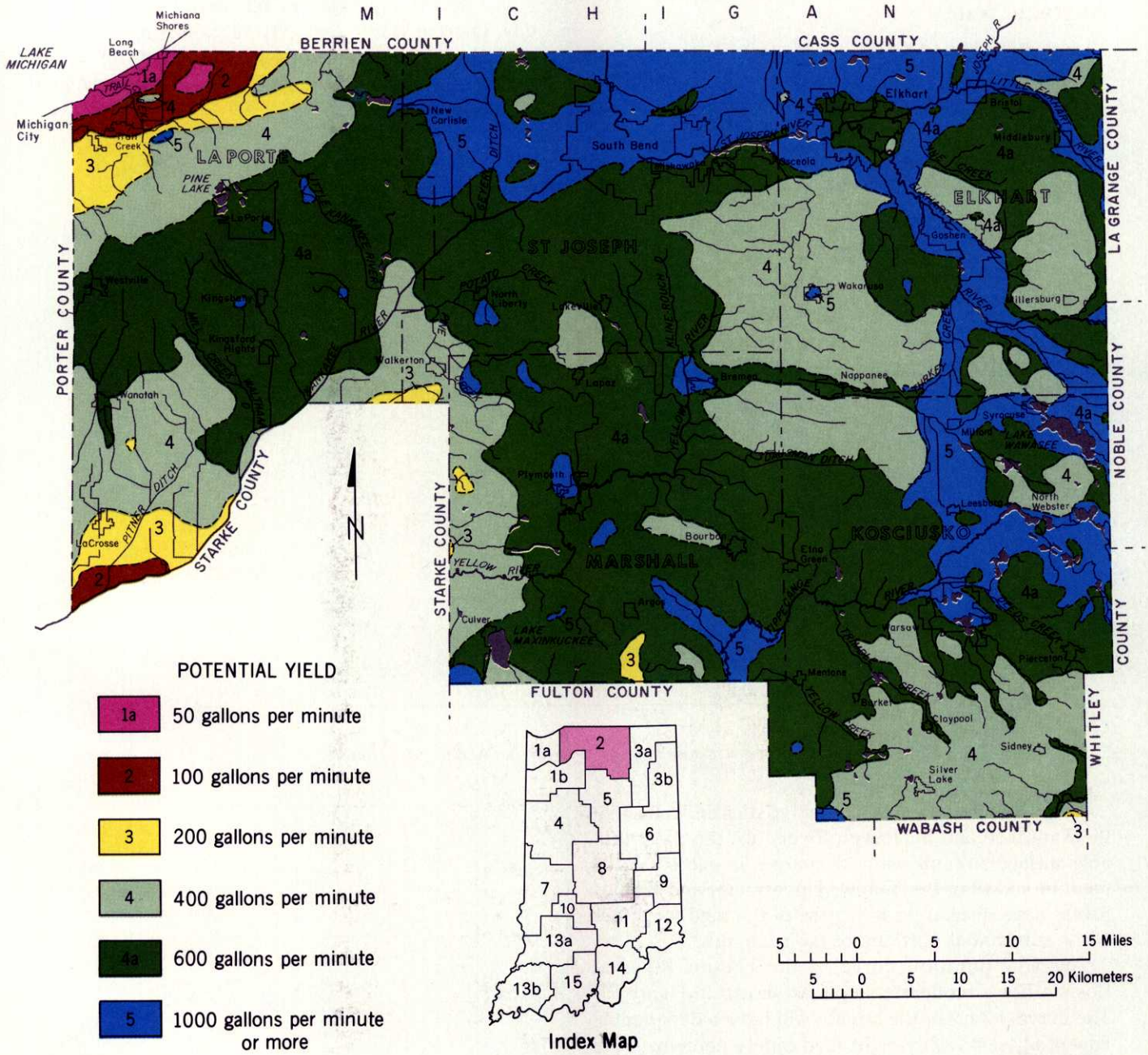


Figure 76

Map of Region Two showing the general location and potential yield of ground water from properly constructed large diameter wells.

northern Kosciusko and Marshall Counties. High manganese levels are present in various localities throughout the region. Fluoride, sulfate, and hydrogen sulfide are usually all within recommended levels.

Surface Water

Streamflow Three major river systems occur within Region Two. The major drainage systems include the St. Joseph River and its tributaries of Little Elkhart and Elkhart Rivers, that drain into Lake Michigan; the Kankakee and Yellow Rivers, that discharge into the Upper Mississippi River basin; and the Tippecanoe River, that flows into the Wabash and Ohio Rivers. Stream drainage is usually in a westerly direction.

The seven day, once in ten year (Q7-10); the one day, once in thirty year (Q1-30); and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations in Region Two are indicated in the following table.

Table 50
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Elkhart River at Goshen	594	320	51.0	10.0
Kankakee River at Davis	537	320	120.0	100.0
Kankakee River at North Liberty	174	94	36.0	29.0
Little Kankakee River at* Mill Creek	na	22	15.3	na
St. Joseph River at Elkhart	3,370	2,000	520.0	270.0
Tippecanoe River at Osweld	113	63	0.9	0.1
Trail Creek at* Michigan City	54	28	12.8	na
Turkey Creek at New Paris*	160	68	11.5	na
Yellow River at Bremen	na	67	4.1	3.6
Yellow River at Plymouth	294	160	12.0	9.7

na: not available
*Flow characteristics estimated from stream gaging stations with short periods of record.

Analysis of the low-flow characteristics indicates that the Kankakee and St. Joseph Rivers are the most reliable surface streams, with discharges in excess of 100 mgd. In addition, the Yellow, Tippecanoe, and Elkhart Rivers have discharges in excess of ten mgd for either all or substantial portions of their lengths.

The flow duration curve of the Elkhart River at Goshen has a moderate slope, as shown in Figure 77. The curve indicates the stream will have a dependable flow of at least eighty-eight mgd ninety percent of the time. The curve's moderate slope also indicates that the Elkhart River basin contains aquifers which provide significant ground-water contributions to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to forty-five, forty-six and twenty-nine percent for "dry," "average," and "wet" years respectively. Conversely, from forty-five to seventy-one percent of the flow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or from snowmelt.

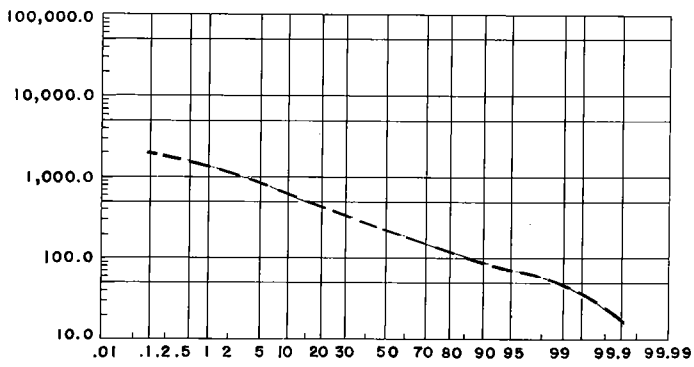


Figure 77
The flow duration curve for the Elkhart River at Goshen.

Lakes Lake Michigan is the dominant surface-water feature in Region Two, and is the major water supply to Michigan City. Approximately 154,000 acres of Lake Michigan are included within Indiana. The remaining lakes within the region that are at least fifty acres in size or have a storage capacity of 32.5 million gallons or more are listed in Table 51 and are located on Figure 78. These seventy-eight lakes have a combined surface area of approximately 16,875 acres with a gross storage capacity of approximately 92,900 million gallons.

Table 51

Lakes at least 50 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Clear Lake	0.65	106.0	247
2	Dingler Lake	na	na	39
3	Hog Lake	na	59.0	224
4	Hudson Lake	7.92	432.0	1,648
5	Lower Fish Lake	10.40	134.0	283
6	Pine Lake	10.70	564.0	na
7	Saugany Lake	2.34	74.0	713
8	Silver Lake	1.72	54.0	na
9	Stone Lake	10.70	140.0	na
10	Union Mills Lake	na	20.9	58
11	Upper Fish Lake	9.65	139.0	338
12	North Chain Lake	3.89	88.0	456
13	Riddles Lake	11.70	77.0	208
14	South Chain Lake	6.32	90.0	87
15	Goshen Pond	na	164.5	358
16	Heaton Lake	9.33	87.0	208
17	Hunter Lake	0.51	99.0	364
18	Indiana Lake	0.62	122.0	1,107
19	Simonton Lake	7.44	282.0	508
20	Wolf Lake	1.29	100.0	na
21	Cook Lake	na	93.0	537
22	Dixon Lake	na	33.0	156
23	Flat Lake	na	26.0	68
24	Gilbert Lake	na	37.0	159
25	Holem Lake	na	40.0	127
26	Lake Latonka	5.77	100.0	159
27	Lake of the Woods	9.45	416.0	2,219
28	Lawrence Lake	na	69.0	514
29	Maxinkuckee Lake	13.70	1,864.0	14,858
30	Mill Pond	5.34	168.0	332
31	Myers Lake	1.41	96.0	651
32	Pretty Lake	0.85	97.0	697
33	Banning Lake	0.48	12.0	35
34	Beaver Dam Lake	2.83	146.0	1,068
35	Big Barbee Lake	44.70	304.0	1,837
36	Big Chapman Lake	4.17	581.0	1,981
37	Boner Lake	na	40.0	120
38	Caldwell Lake	na	45.0	260
39	Carr Lake	2.27	79.0	436
40	Center Lake	0.73	120.0	671
41	Crystal Lake	0.45	76.0	303
42	Dewart Lake	8.05	551.0	2,932
43	Diamond Lake	3.92	79.0	417
44	Flatbelly Lake	4.66	326.0	na
45	Hill Lake	0.85	67.0	423
46	Hoffman Lake	8.07	180.0	1,029
47	Irish Lake	50.90	182.0	759
48	James Lake	55.90	282.0	2,469
49	Kuhn Lake	3.85	137.0	420
50	Little Barbee Lake	49.00	74.0	312
51	Little Chapman Lake	7.13	177.0	648

Table 51 (continued)

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
52	Little Pike Lake	na	25.0	45
53	Loon Lake	3.59	40.0	218
54	McClures Lake	1.29	32.0	97
55	Muskelonge Lake	11.80	32.0	97
56	North Little Lake	2.89	12.0	55
57	Oswego Lake	113.00	83.0	254
58	Palestine Lake	32.40	290.0	381
59	Papakeechie Lake	5.52	300.0	488
60	Pike Lake	41.50	203.0	922
61	Ridinger Lake	34.60	136.0	944
62	Robinson Lake	7.15	59.0	381
63	Rock Lake	2.74	56.0	117
64	Sawmill Lake	51.80	36.0	120
65	Sechrist Lake	0.58	105.0	811
66	Sellers Lake	na	32.0	110
67	Sherburn Lake	5.51	15.0	74
68	Shock Lake	na	37.0	394
69	Silver Lake	6.31	102.0	495
70	Syracuse Lake	38.20	414.0	1,746
71	Tippecanoe Lake	113.00	768.0	9,247
72	Wabee Lake	14.60	187.0	1,547
73	Wawasee Lake	36.90	3,060.0	21,900
74	Webster Lake	49.20	774.0	1,906
75	Weimer-Black Lake	1.40	29.4	63
76	Winona Lake	32.10	562.0	5,435
77	Wyland Lake	na	6.0	32
78	Yellow Creek Lake	11.10	151.0	1541

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Two is shown in Table 52. The existing supply for recreational activities is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred, the supply exceeds the demand. Conversely, when the supply as a percentage of demand is less than one hundred the supply is less than the projected demand.

Table 52
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	26	19.6 boats/acre/year	173,100 acres[a]	100+	100+	100+
Waterskiing	8	34.4 skiers/acre/year	28,000 acres[b]	100+	100+	100+
Canoeing	9	585 canoes/mile/year	134 miles	100+	100+	100+
Swimming	42	76,600 swimmers/acre/year	36 acres[c]	62	56	53
Ice-Skating	11	6,678 skaters/acre/year	15 acres	54	52	48
Fishing	37	66 persons/acre/year	172,100 acres[d]	100+	100+	100+

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.
[a]Includes 154,000 acres of Lake Michigan and 19,000 acres of inland waters.
[b]Includes 18,400 acres of Lake Michigan (thirty square miles excluding the two hundred feet from the shoreline) and 9,600 acres of inland waters.
[c]Does not include Lake Michigan.
[d]Includes 154,000 acres of Lake Michigan and 18,100 acres of inland waters.

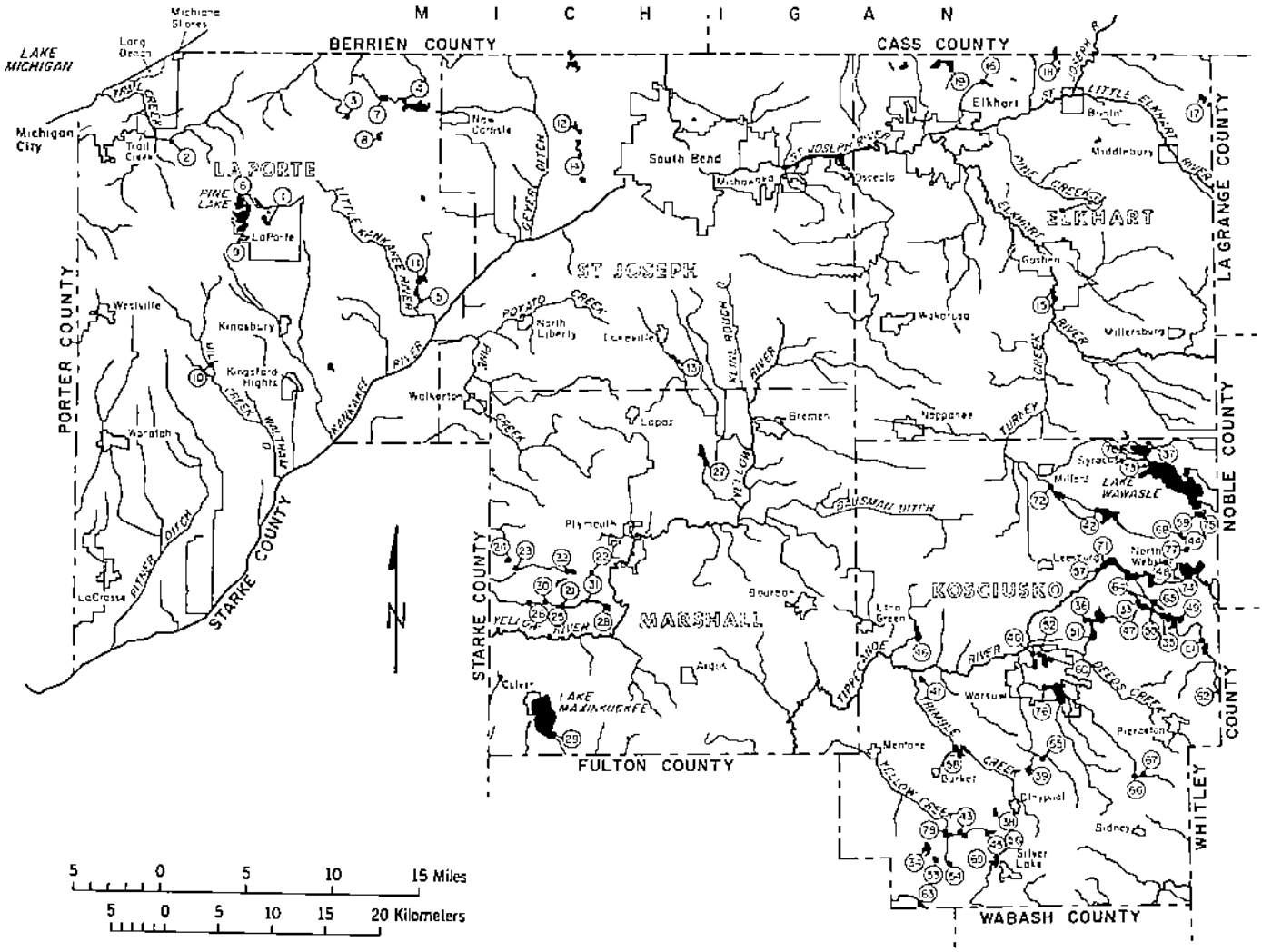


Figure 78
Map of Region Two showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

Boating and Waterskiing Portions of the St. Joseph River in St. Joseph and Elkhart Counties are used for waterskiing. The Tippecanoe and Kankakee Rivers are used for boating but not waterskiing, due to their size, depth, and number of obstacles.

There are several lakes available for boating and waterskiing, the majority being in Kosciusko County. Lakes Wawasee, Webster, and Tippecanoe are the most heavily used recreational lakes in Kosciusko County and provide the most waterskiing acreage within the region.

The additional supply provided by Lake Michigan guarantees adequate boating and waterskiing opportunities well into the future. Access is available in Michigan City at the Washington Park Marina, Sprague Marina, and three private marinas for both boat launching and storage, although considerable demand for boat storage has created waiting lists at all facilities.

Canoeing The Kankakee, Tippecanoe, St. Joseph, and Elkhart Rivers offer canoeing opportunities. Although some streams (St. Joseph River in particular) have sluggish currents, the rivers all flow freely enough to provide enjoyable trips. Other streams in the region may also occasionally be used by canoeists. Approximately thirty-three miles of the St. Joseph River, thirty miles of the Elkhart, and the entire Kankakee River may be canoed within Region Two. The current supply of canoeable streams will meet the demand by canoeists through the year 2000.

Swimming and Ice-Skating There is a deficit of water available both for swimming and ice-skating. The demand for swimming acreage may exceed the supply by fifty percent by the year 2000. Swimming areas include the Potato Creek State Park, the Indiana Dunes National Lakeshore, and the Indiana Dunes State Park.

Fishing The quality of the fisheries habitat is indicated on Figure 79. The Kankakee and the Tippecanoe Rivers sustain stable warmwater fish populations. Both rivers also contain northern pike which use their tributaries and backwaters for spawning in the spring. The Tippecanoe and Yellow Rivers are noted for smallmouth bass fishing. The aquatic habitat value is reduced in each of these rivers where pools and riffles are removed by dredging, and where vegetation is cleared from the stream banks and stream beds. Despite water quality problems, the St. Joseph River and Trail Creek attract annual migrations of trout and salmon from Lake Michigan. The Little Kankakee River, Potato Creek, Cobus Creek, Little Elkhart River, and Solomon's Creek have sufficient aquatic habitat and public usage to support a put-and-take trout fishery program.

The usual assortment of warmwater fish found in Indiana — sunfish, yellow perch, and catfish — are present in the lakes of this region. The many natural lakes of Kosciusko County attract fishermen year-round. The large areas of aquatic vegetation and bordering marshes found in many of the lakes are vital to the existence of desirable game fisheries. Wyland Lake, in the Tri-County Fish and Wildlife Area, is stocked with trout while other lakes have their fisheries supplemented with walleye and northern pike. Lake Michigan offers excellent habitat for many varieties of fish and is well known for coho and chinook salmon, steelhead, lake, and brown trout.

Access to the streams and lakes is available on many state-owned properties. Two public fishing sites are located on the St. Joseph River in Elkhart County. One public fishing site is located in St. Joseph County. The old Tip Town site in Marshall County and the Mollenhour site in Kosciusko County allow access to the Tippecanoe River. The Kingsbury and Kankakee Fish and Wildlife Areas, provide access to the Kankakee River. The Potato Creek State Park provides fishing access to Potato Creek. Public fishing sites are located on sixteen lakes scattered throughout the region.

Riparian Habitat The quality of riparian habitat is shown in Figure 80. Urban development along stretches of Trail Creek and the Elkhart and St. Joseph Rivers reduces suitable riparian habitat for many desirable species of wildlife. The wooded swamps and marshes along the Tippecanoe, Kankakee, and Elkhart Rivers and Turkey Creek are excellent habitat for waterfowl such as mallards, blue wing teal, woodduck, various shorebirds, beaver, muskrat, raccoon, and upland game. Many tributaries to these larger streams have little wildlife habitat as they pass through agricultural areas. However, those with grassy or vegetated banks may attract pheasants and bobwhite quails.

Most large lakes in the region, Lake Wawasee, Syracuse Lake, Winona Lake, and Lake Maxinkuckee, are heavily developed and provide sparse wildlife habitat except in wetland areas. Smaller, less developed lakes, such as Wyland Lake, Flat Lake, and Lake Lee, have more extensive riparian habitat. Deep water cattail and spatterdock marshes, such as those on Lake Wawasee, Syracuse Lake, and Simonton Lake, are valuable habitat, especially for waterfowl and muskrats. Deep water or shrub swamps occur on several lakes in northern St. Joseph County and central Elkhart County. The wetlands also support waterfowl, muskrats, and shorebirds.

Public hunting is allowed on the Kankakee, Kingsbury, and Tri-County Fish and Wildlife Areas. Hunting is also permitted on the Maxinkuckee Wetland Conservation Area in Marshall County.

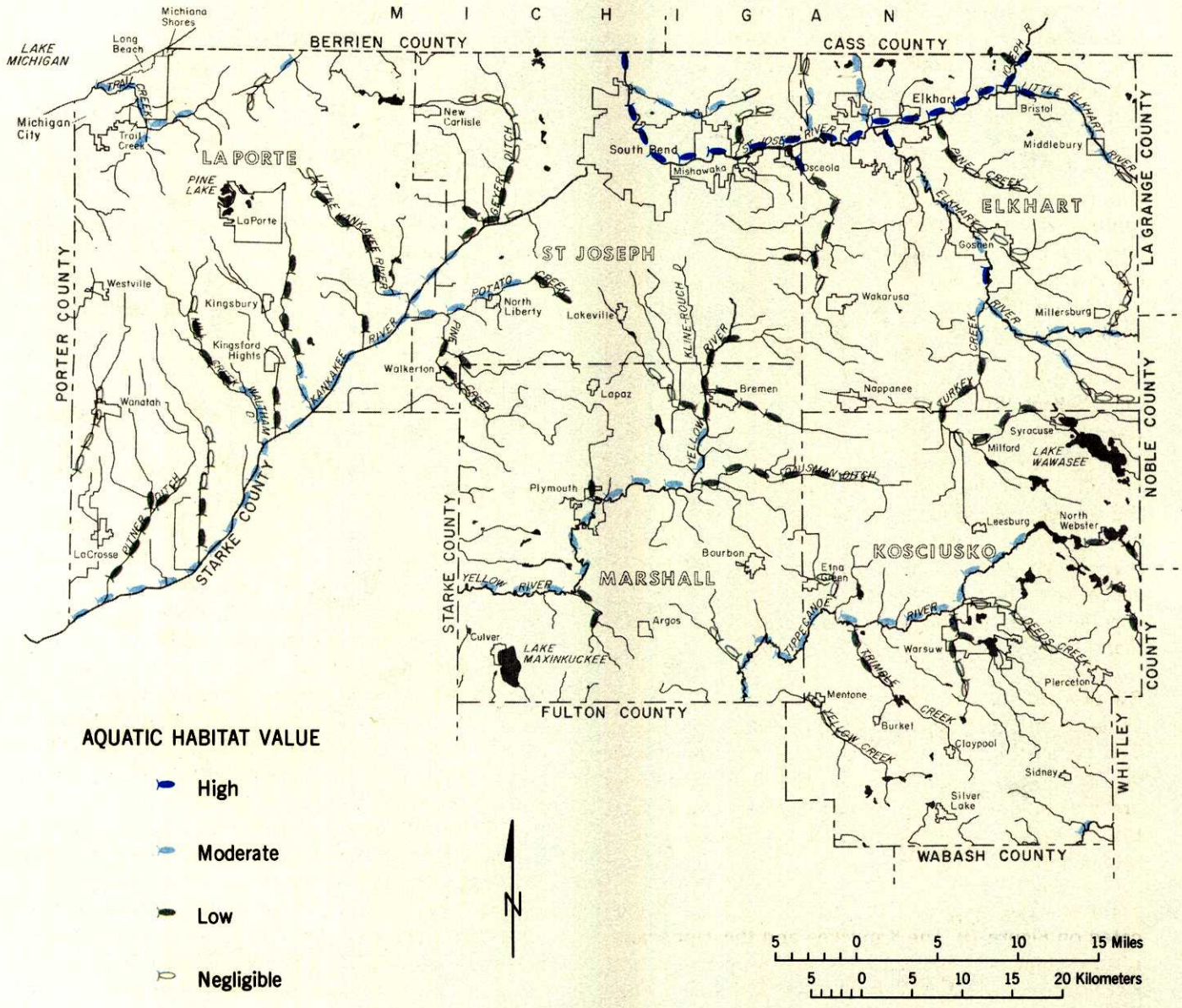


Figure 79
Map of Region Two showing the quality of the fisheries habitat.

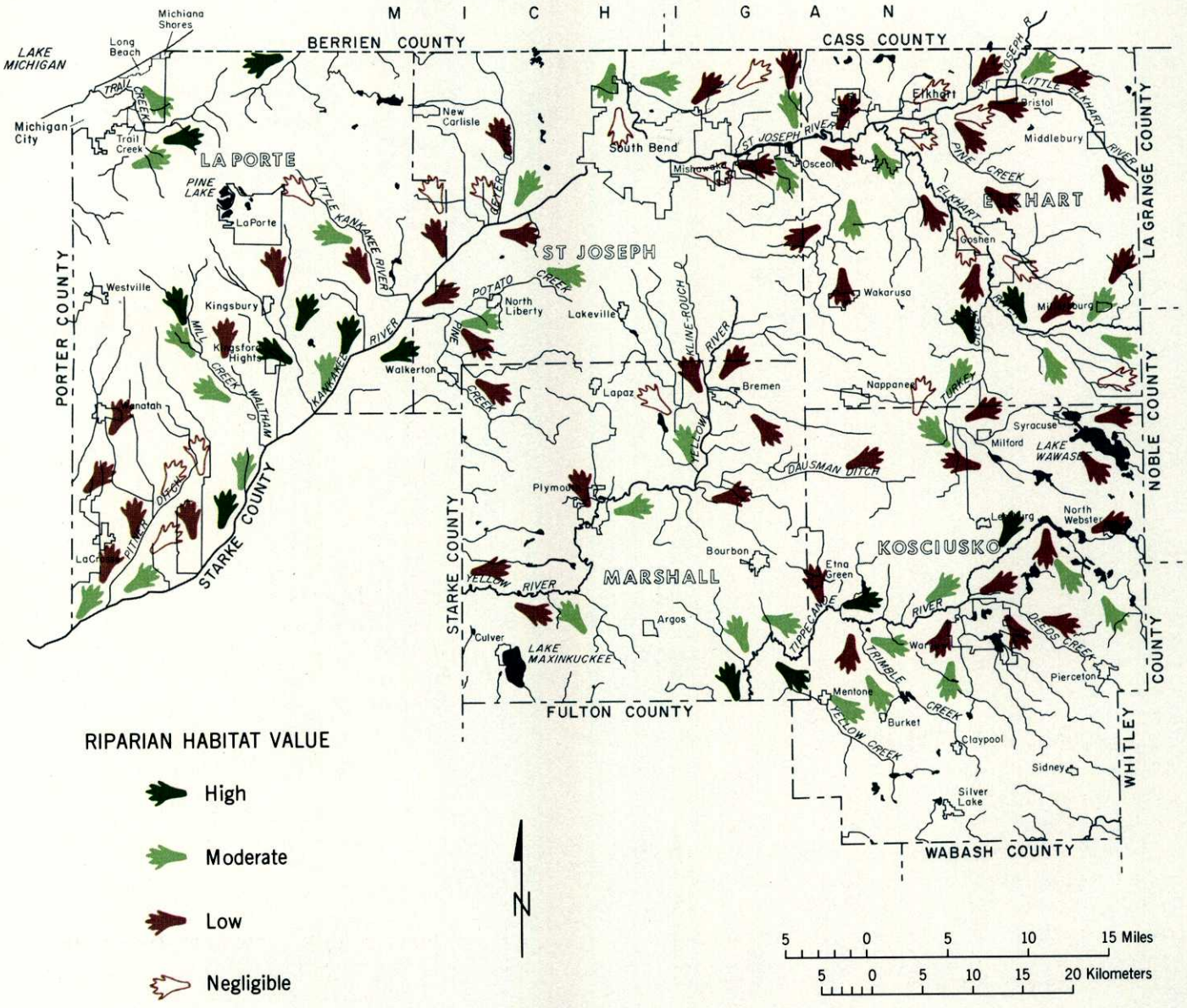


Figure 80
Map of Region Two showing the quality of the riparian habitat.

Navigation Michigan City Harbor is a project constructed by the U.S. Corps of Engineers and operated by the Michigan City Port Authority. This harbor provides for limited commercial use and a considerable amount of recreational traffic. It also provides access to one of the most important inland waterways in the world, the Great Lakes – St. Lawrence system. Approximately 51,000 tons of cargo per year are transported through Michigan City Harbor.

Hydroelectric Power The two operating hydroelectric plants in Region Two are the Twin Branch Generating Station at South Bend and the Elkhart Generating Station at Elkhart. Both are owned by the Indiana and Michigan Electric Company. Twin Branch is rated at 7.3 megawatts (mw) and was completed in 1903. The Elkhart station was completed in 1913 and is rated at 3.4 mw.

There are no additional sites available in the region that could support substantial hydroelectric development. However, consideration is being given to increasing the capacity of Twin Branch to 14.8 mw and Elkhart to 9.2 mw.

Withdrawal Uses

Public Water Supplies Elkhart, Kosciusko, LaPorte, Marshall, and St. Joseph Counties are served by forty-four public water utilities. An estimated 345,800 persons, or sixty-one percent of the population, were served by a public utility in 1975.

The largest, single, water utility operating in the region is the South Bend Public Utility. This utility served approximately 117,000 persons in 1975. In 1977, the South Bend utility withdrew an average of 25.5 mgd. Other large utilities are located in Michigan City, Elkhart, and Mishawaka, all of which pump more than 5.0 mgd; and in LaPorte, Goshen, and Warsaw, which pump more than 2.0 mgd. Figure 81 shows the water service areas within Region Two.

Public utilities in this region generally serve only those customers living within their corporate boundaries; however, Mishawaka, Elkhart, Warsaw, Michigan City, and other utilities provide service to some customers outside their corporate limits.

These forty-four public water utilities withdrew an average of 61.3 mgd in 1975. St. Joseph County accounted for 31.7 mgd; LaPorte County, 13.4 mgd; Elkhart County, 10.6 mgd; Kosciusko County, 3.3 mgd; and Marshall County, 2.3 mgd. Approximately fifty-four mgd of the total public water supply is withdrawn from ground water. All of the public utilities in the region with the exception of those in the Michigan City and the Warsaw areas are supplied from ground water. Withdrawals from Lake Michigan average 7.7 mgd while supplying 49,200 persons.

Projections of public water supplies indicate that the region's water withdrawals may increase to approximately 71.3 mgd by the year 2000. Consumptive use of this public water supply is expected to increase from approximately 7.0 mgd in 1975 to 8.2 mgd by 2000. The 1977 and projected water withdrawals and consumption rates by public water utilities by the year 2000 are presented in the following table.

Table 53
The 1977 and projected withdrawal and consumption rates of public water supplies by the year 2000, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	61.3	63.0	8.0	71.3
Consumption	7.0	7.2	7.8	8.0

Industrial Water Industrial establishments had an estimated water intake averaging 102 mgd in 1977. Of this total intake, 53.1 mgd was self-supplied by the industries while 48.9 mgd was purchased from the region's public utilities. Approximately 12.3 mgd is consumed in the manufacturing process.

Most of the industries in the region purchase their water from local utilities. However, significant numbers, including all the large water users, are self-supplied from ground water. A few industries in Elkhart and St. Joseph Counties use significant amounts of water from the St. Joseph River.

The largest water-using industries in the region are rubber and plastics, fabricated metal products, chemicals and allied products, and transportation equipment.

Industrial production for the year 2000 is expected to increase eighty-seven percent above the 1977 value (United States Water Resources Council). Despite the predicted increase in industrial output, total industrial water intake is expected to decrease initially due to plant efficiency, and then increase slowly as output increases. The current and projected self-supplied water withdrawals and rates of consumption for industries located in Region Two are now presented.

Table 54
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	53.1	54.8	56.2	59.1
Consumption	6.4	7.2	9.3	11.8

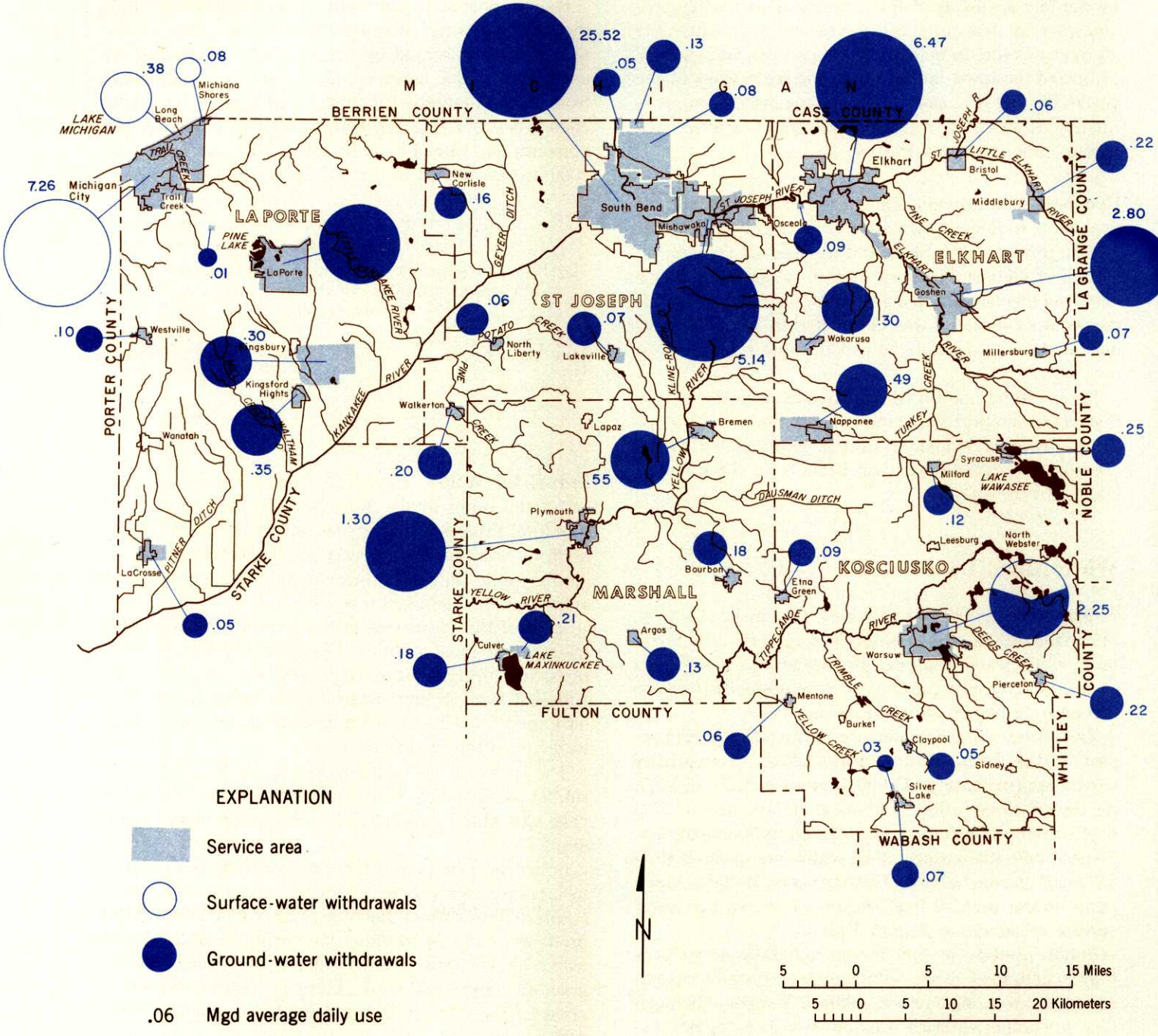


Figure 81
Map of Region Two showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Rural Self-Supplied Water In 1975 an estimated 222,600 persons lived in homes supplied by individual wells. Approximately 13.1 mgd of water was used for residential purposes in 1975. Approximately 111,100 additional residents may depend on their own wells for household water by the year 2000. The withdrawal of rural, self-supplied, residential water may increase to 25.1 mgd by the year 2000.

Approximately 3.4 mgd was withdrawn for 453,500 head of livestock and 2,100,100 chickens in 1975. By the year 2000 these withdrawals may increase to 4.1 mgd. Ground water is generally the source for these rural, self-supplied uses of water.

The total withdrawal of rural, self-supplied water may increase from the current 18.0 mgd to approximately 29.2 mgd by the year 2000, as indicated in the following table.

Table 55
The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	18.0	19.4	24.3	29.2
Consumption	18.0	19.4	24.3	29.2

Irrigation Water Soil associations with irrigation potential are located in all but a small corner of LaPorte County; all but the southwestern third of St. Joseph County; in a wide band up the St. Joseph and Elkhart Rivers in Elkhart County; and in broad areas across the Yellow and Tippecanoe Rivers in Marshall and Kosciusko Counties. Figure 82 shows the potential irrigation areas.

Based upon the survey of irrigated lands, approximately 21,100 acres of cropland were irrigated in 1977. This represents the largest irrigated acreage of any of the eighteen Indiana regions. The principal crops irrigated were corn, soybeans, hay, and pasture. Other irrigated crops were mint and vegetables including potatoes. Assuming 1977 as a normal growing year, these crops would have required about 55.4 mgd during the peak irrigation season of July–August.

Approximately 205,000 acres of croplands could be profitably irrigated in Region Two. Approximately 45,100 acres of croplands may be irrigated by the year 2000. This expansion of irrigation acreage is expected to raise the peak July–August irrigation demand in an "average" year to about 118.3 mgd. The ground water withdrawal during the "average" season of precipitation is expected to increase from the current 34.6 mgd to 88.0 mgd by the year 2000.

In addition to the irrigation for agricultural use, there are about 1,520 acres of irrigated fairways and greens on the region's golf courses. About 4.7 mgd is applied to these areas during the peak July–August irrigation period.

The total withdrawal for the irrigation of crops and golf courses during the "average" irrigation year of 1977 was approximately 60.1 mgd. These withdrawals may increase to 123.6 mgd by the year 2000 as indicated here.

Table 56
The 1977 and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	60.1	68.3	95.9	123.6
Consumption	60.1	68.3	95.9	123.6

Electrical Energy Region Two contains four electric generating stations, two of which are hydroelectric stations and two are fossil-fuel fired steam turbines. The two hydroelectric plants owned and operated by the Indiana and Michigan Electric Company are discussed as an "instream use."

The two fossil-fueled plants are the Michigan City Generating Station and the Twin Branch Generating Division. The Michigan City plant is owned by Northern Indiana Public Service Company, and Twin Branch is owned by Indiana and Michigan Electric Company. The Michigan City plant is rated at 736 megawatts, and the Twin Branch station is rated at 250 mw. Intake requirements are 275 mgd from the St. Joseph River for Twin Branch and 158 mgd from Lake Michigan for Michigan City. Neither utility has announced plans to expand its existing plant nor have any plans been announced for construction of new generating facilities in this region.

The Michigan City Generating Station consists of four active generating units. Three of the four units, representing 215 mw capacity, are cooled by a once-through process. The remaining unit, representing 521 mw capacity, is cooled by a closed system cooling tower.

Because of its excellent sustained flow characteristics, the St. Joseph River is a potential candidate for siting of additional power plants. Due to severe restraints on site development, Lake Michigan with its virtually unlimited water, is not considered to be available for additional electric power development.

Water withdrawals for the production of energy in Region Two were approximately 433 mgd in 1977, but this is expected to decrease to 158 mgd by the year 2000 as shown in Table 57.

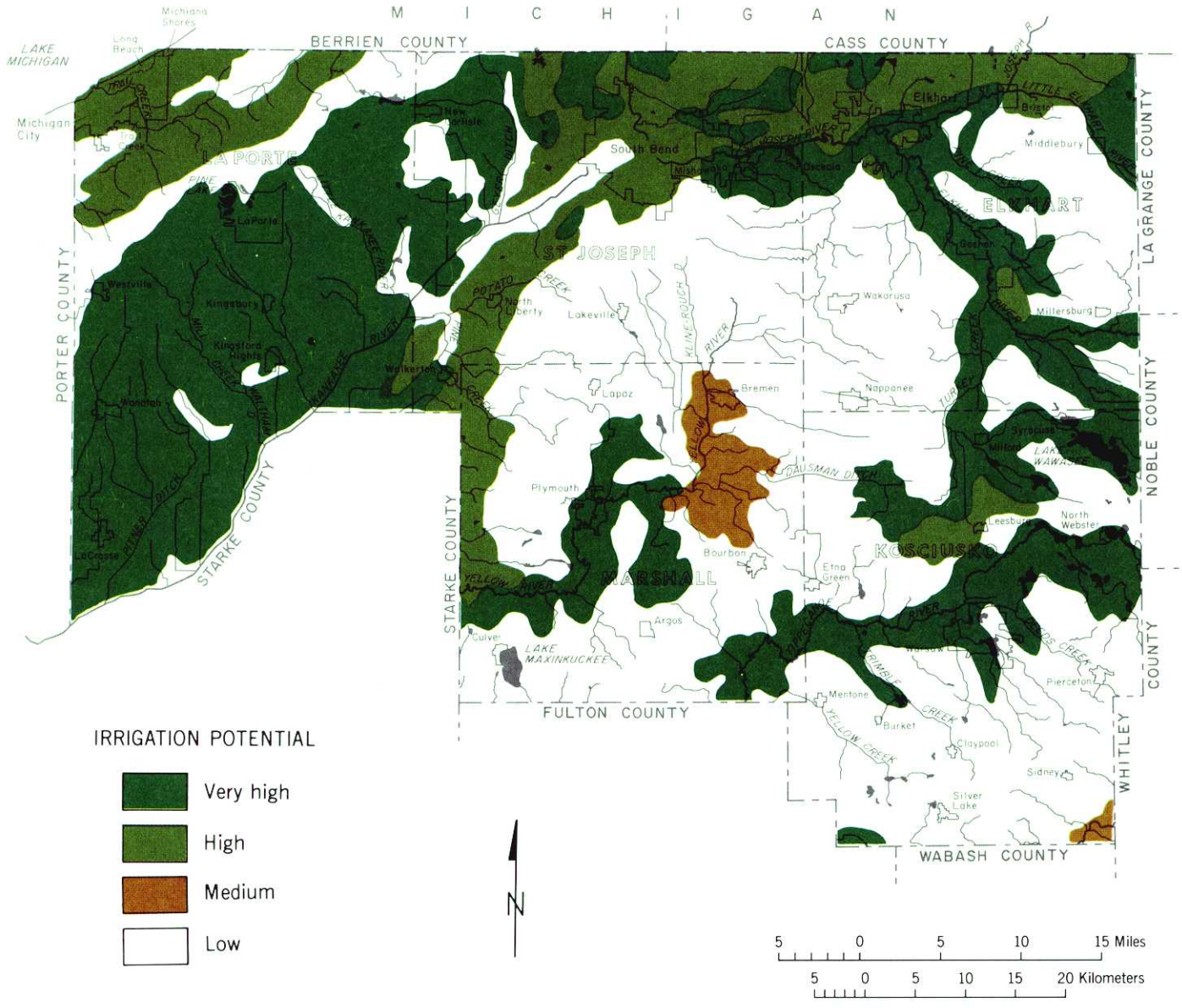


Figure 82
Map of Region Two showing the general location of soil associations that appear to possess an economic potential for the irrigation of croplands.

Table 57
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	433.0	433.0	433.0	158.0
Consumption	13.0	13.0	13.0	13.0

EXCESS WATER

Flooding

An estimated 38,000 acres are subject to flooding. The major flood plains within the region are shown in Figure 83. Figure 84 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be 1.5 million dollars.

Virtually all of the streams in Region Two are subject to flooding. Flash flooding on streams in the area is uncommon due to the flatness of the topography and prevailing geologic conditions. The Kankakee, St. Joseph, and Tippecanoe Rivers are the three major streams in the region. These streams are subject to long flood durations. There are no major flood control projects planned.

Flood Plain Management The unincorporated parts of Elkhart, Kosciusko, LaPorte, and St. Joseph Counties — along with the incorporated areas of Bremen, Bristol, Culver, Elkhart, Goshen, LaCrosse, Michigan City, Mishawaka, Nappanee, North Liberty, South Bend, Syracuse, Walkerton, Warsaw, and Winona Lake — are participating in the emergency phase of the National Flood Insurance Program. Lakeville, Long Beach, Plymouth, and Roseland are participating in the regular phase of the National Flood Insurance Program. Residents in these areas can purchase insurance against property losses due to flooding.

Agricultural Drainage

Approximately twenty-four percent of the soil associations in Region Two have "severe" wetness characteristics, forty-seven percent have "moderate" wetness characteristics, while twenty-nine percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics is shown in Figure 85. There are at least 3,764 miles of legal drains in the five-county area. Maintenance of this system is the responsibility of the individual county drainage boards.

Soil Erosion

The soils of the region were evaluated as to their potential for erosion and classified as to high, medium, and low erosion hazards as shown in Figure 86. Nearly thirty-eight percent of the 1,615,900 acres are rated as having a "medium" erosion hazard. Approximately sixty-two percent of the region has a "low" soil erosion hazard for those lands in a fallow condition.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health were the St. Joseph River, Elkhart, and Trail Creek. In addition, Lake Michigan was surveyed.

Water quality standards for the region were established by the Stream Pollution Control Board regulation SPC IR-4 (the Water Quality Standards for the State of Indiana), SPC 4R-2 (Water Quality Standards for Lake Michigan and Contiguous Harbor Areas) and SPC 12-R (Natural Spawning, Rearing, and Imprinting Areas).

The temperature and dissolved oxygen values were within the required ranges at various sampling stations along the St. Joseph River. The pH values within the river were within the acceptable range. The concentration of fecal coliform bacteria was in violation of the standards set for whole body contact recreation along most parts of the St. Joseph River.

Sampling on Trail Creek's main channel and its tributaries in 1974 indicated that water quality would support a fresh-water fishery. Dissolved oxygen concentrations were also well above the standard, and temperature stayed within the recommended range. The biochemical oxygen demand was low downstream from Michigan City's sewage treatment plant, but suspended solids and oil concentrations were higher than desired. Some contributing factors to Trail Creek's water quality degradation were the effluents from semi-public sewage treatment facilities along the tributaries of Trail Creek.

Water quality for Lake Michigan at Michigan City exhibited temperature values well within standards established by the Stream Pollution Control Board. Dissolved oxygen concentrations were above the water quality standards. Although pH values occasionally fell below minimum standards, they generally fell within the recommended range. The raw water met the total coliform bacteria standard set for drinking water supply and the fecal coliform bacteria standard for whole body contact.

Satisfactory water quality conditions occurred in the mainstem of the Elkhart River. Data indicated that

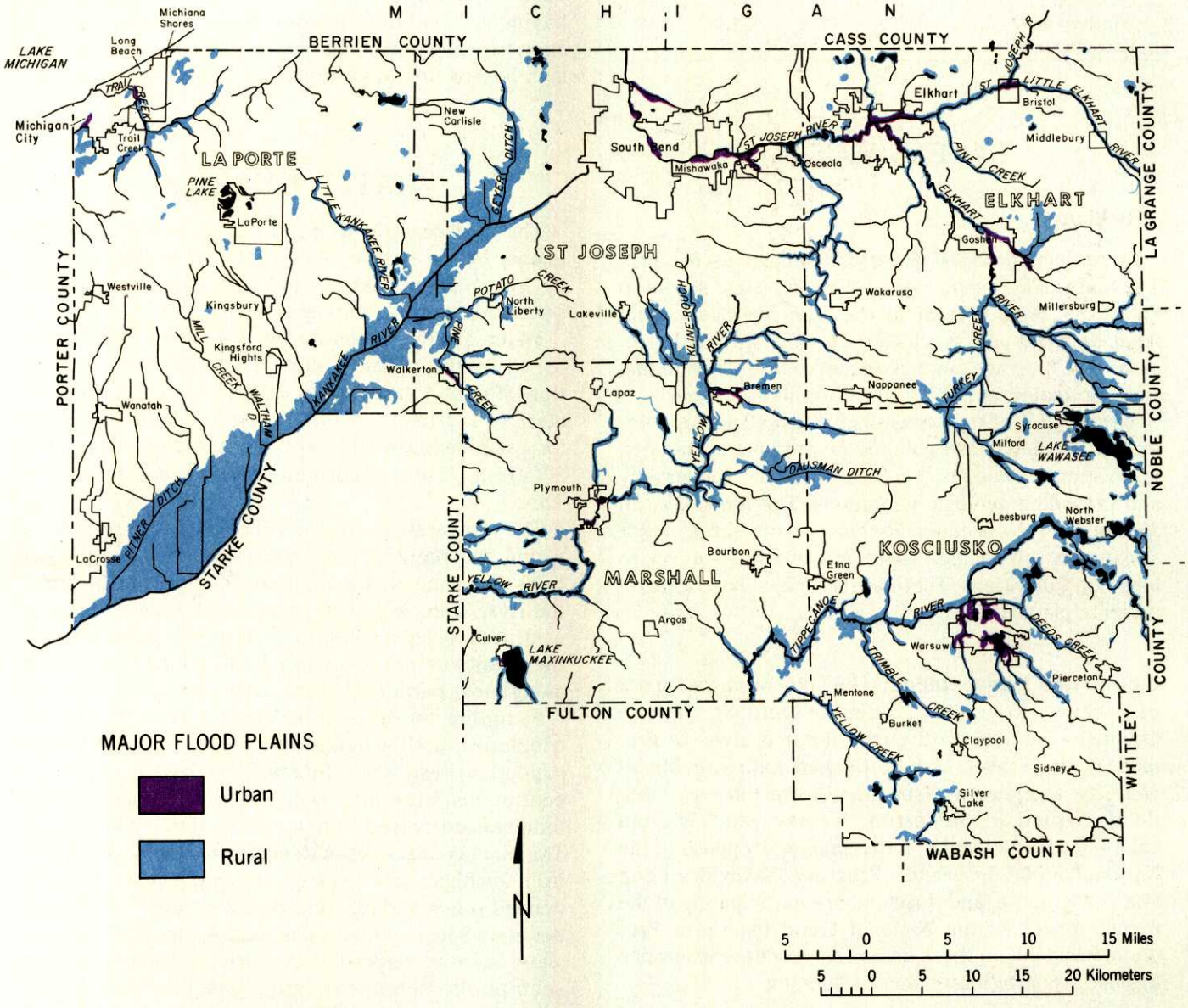


Figure 83
Map of Region Two showing the major floodplains.

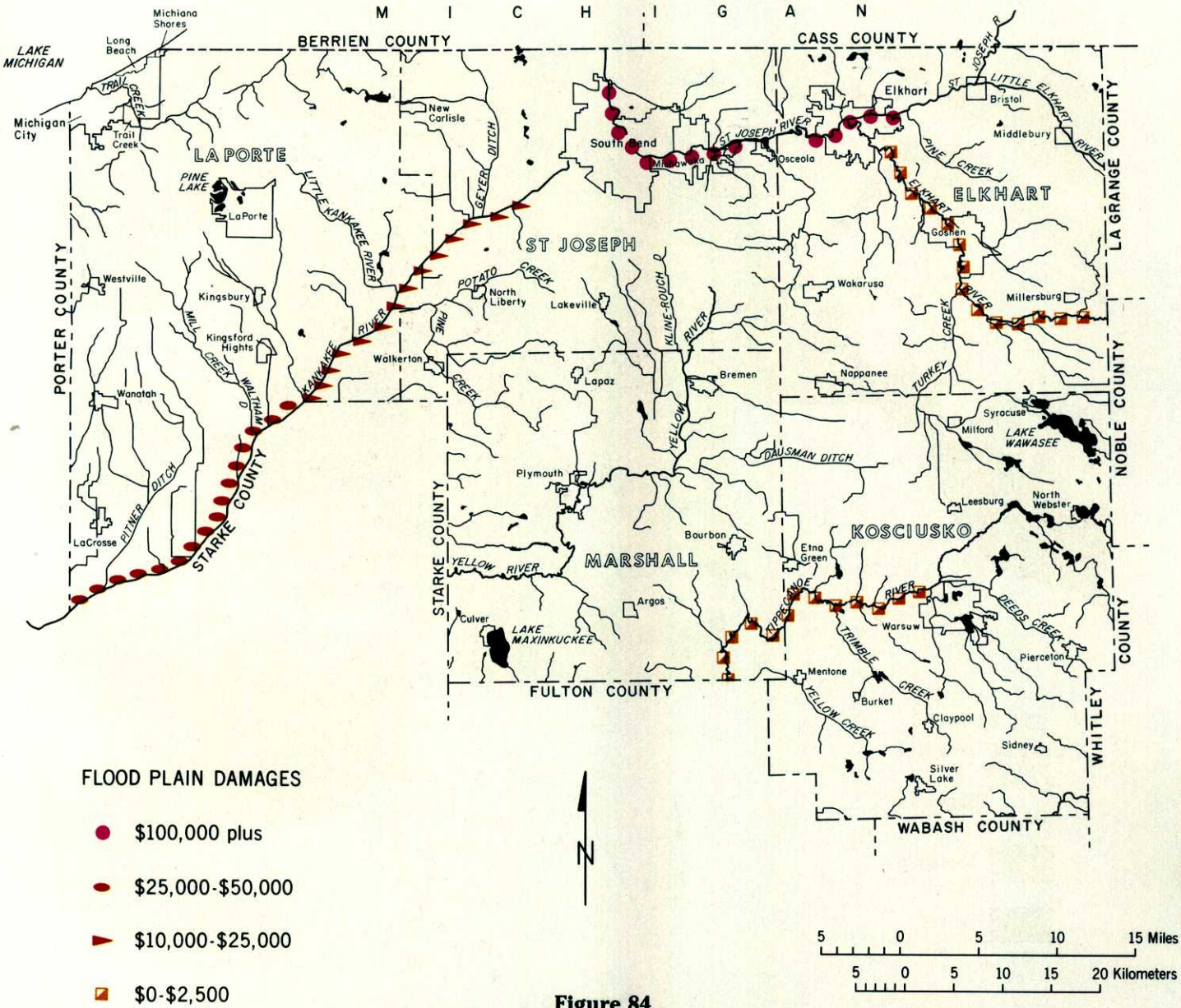


Figure 84

Map of Region Two showing the estimated average annual flood damages per mile along selected streams.

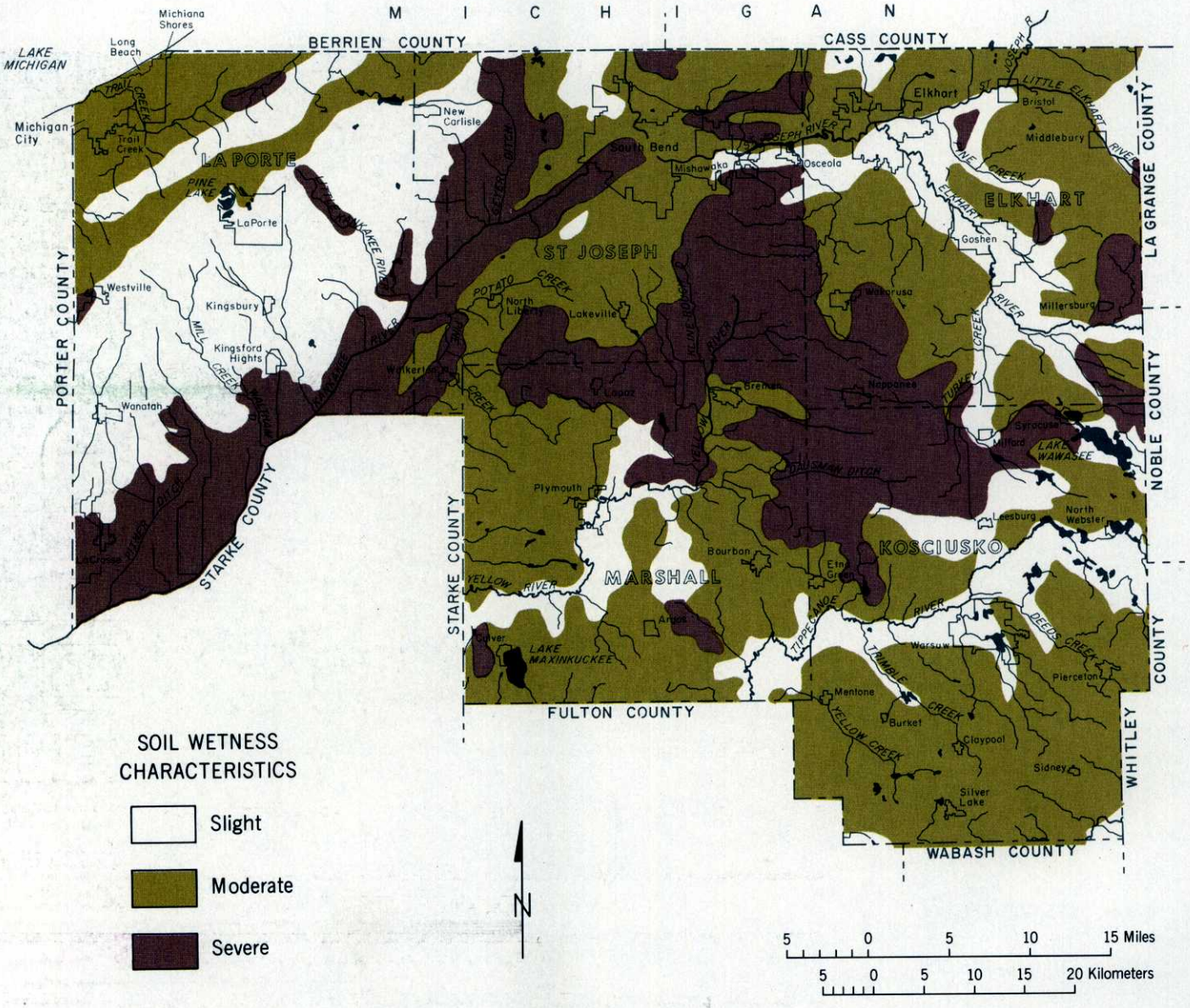


Figure 85
Map of Region Two showing the general location of the wetness characteristics of soil associations.

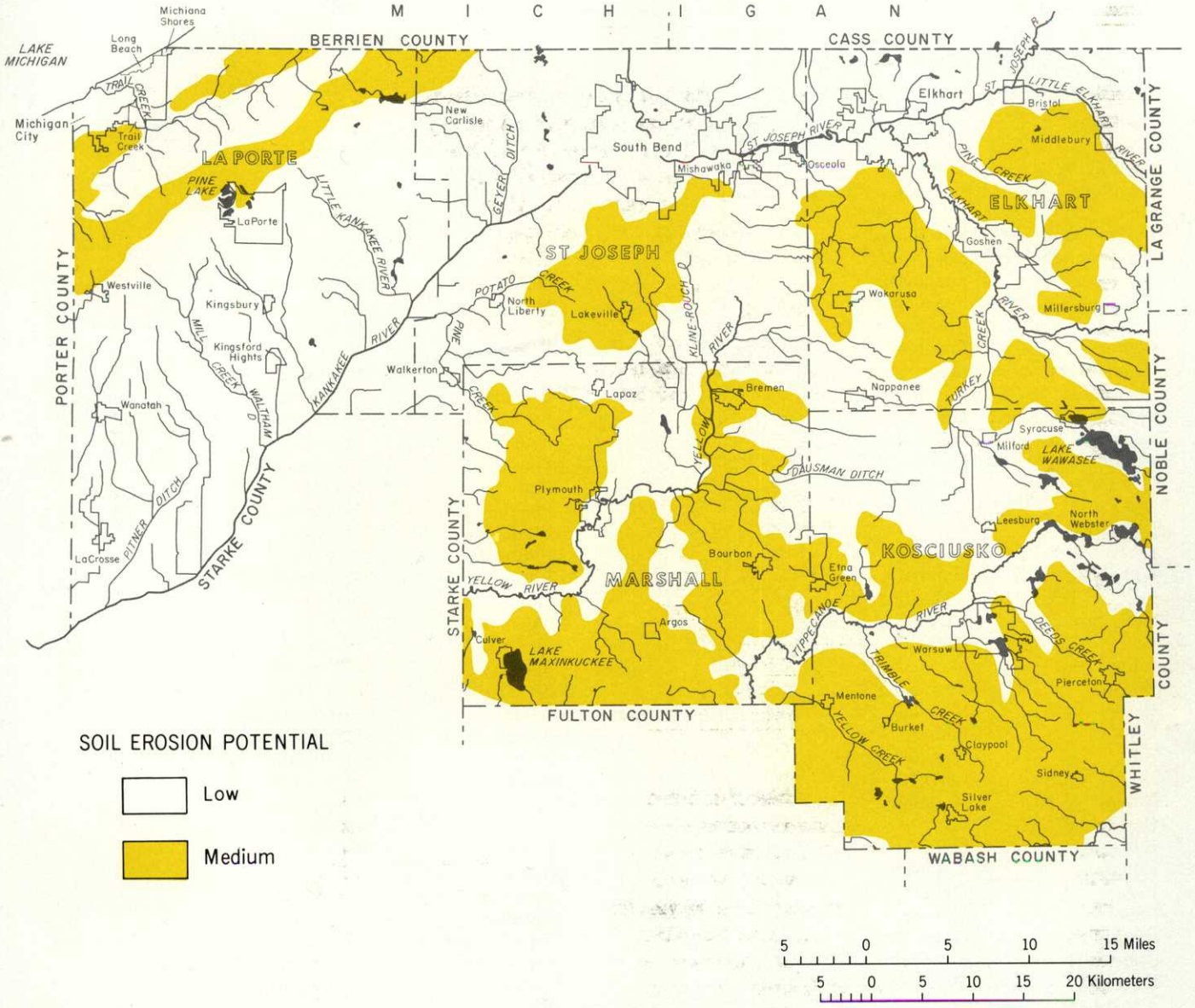


Figure 86
Map of Region Two showing the erosion potential of the soil associations.

potential problems related to bacterial contamination occurred in Pine Creek, a tributary of the Kankakee River. Water quality problems in the mainstem of the Yellow River were related to high fecal coliform, ammonia nitrogen, and phosphorus concentrations in the Plymouth area.

The trophic classification of those lakes surveyed by the Stream Pollution Control Board in Region Two are indicated in the following table.

Table 58
Trophic classification of lakes surveyed.

Lake	*County*	*Age Classification*
Banning	Kosciusko	II
Barrel	Kosciusko	II
Bass	St. Joseph	I
Beaver Dam	Kosciusko	III
Big Chapman	Kosciusko	I
Boner	Kosciusko	II
Caldwell	Kosciusko	II
Carr	Kosciusko	II
Center	Kosciusko	II
Chamberlain	St. Joseph	III
Chrystal	Kosciusko	I
Clear	LaPorte	II
Cook	Marshall	II
Crane	LaPorte	II
Czmanda	St. Joseph	III
Dewart	Kosciusko	II
Diamond	Kosciusko	III
Dixon	Marshall	II
Eddy	Marshall	II
Fish	Elkhart	II
Fish Trap	LaPorte	I
Flat	Marshall	II
Gilbert	Marshall	III
Goose	Kosciusko	I
Hawks	Marshall	III
Heaton	Elkhart	I
Hill	Kosciusko	II
Hog	LaPorte	I
Holem	Marshall	I
Horseshoe	LaPorte	III
Hudson	LaPorte	I
Huffman	Kosciusko	I
Hunter	Elkhart	I
Indiana	Elkhart	I
Irish	Kosciusko	II
James	Kosciusko	II
Koonty	Marshall	II
Kreighbaum	Marshall	II
Kuhn	Kosciusko	I
Lake of the Woods	Marshall	II
Lawrence	Marshall	I
Little Bar Bee	Kosciusko	III
Little Chapman	Kosciusko	I

Table 58 (continued)

Lake	*County*	*Age Classification*
Little Pike	Kosciusko	II
Little Winona	Kosciusko	III
Lower Fish	LaPorte	I
Loon	Kosciusko	III
Maxinkuckee	Marshall	I
McLures	Kosciusko	II
Mud	St. Joseph	III
Muskellonge	Kosciusko	II
Myers	Marshall	I
Oswego	Kosciusko	II
Palestine	Kosciusko	III
Papkeetchie	Kosciusko	III
Peterson	St. Joseph	II
Pike	Kosciusko	II
Pine	LaPorte	I
Pretty	Marshall	II
Riddles	St. Joseph	II
Ridinger	Kosciusko	III
Rock	Kosciusko-Fulton	III
Saugany	LaPorte	I
Sawmill	Kosciusko	II
Sechrist	Kosciusko	I
Shock	Kosciusko	II
Shoe	Kosciusko	I
Silvers	Kosciusko	III
Simonton	Elkhart	I
Sously	St. Joseph	III
South Clear	St. Joseph	III
Spear	Kosciusko	II
Stanton	Kosciusko	I
Stone	LaPorte	I
Swede	LaPorte	II
Syracuse	Kosciusko	I
Thomas	Marshall	III
Tippecanoe	Kosciusko	I
Upper Fish	LaPorte	I
Wabee	Kosciusko	III
Walton	LaPorte	II
Wawasee	Kosciukso	I
Webster	Kosciusko	II
Winona	Kosciusko	III
Yellow Creek Lake	Kosciusko	III

Region Three-A

LaGrange, Steuben, Noble, Whitley, and Huntington Counties, located in northeastern Indiana, form Region Three-A. The region contains approximately 1,825 square miles and is bounded by Michigan to the north; the Indiana-Ohio state line, Dekalb, Allen, and Wells Counties to the east; Wells and Grant Counties to the south; and Wabash, Kosciusko, and Elkhart Counties to the west, as shown in Figure 87.

The population of Region Three-A was 138,500 in 1975. The official Indiana population projections for 1975 to 2000 indicate the region's population may increase to approximately 200,000 by the year 2000. The 1975 population and projections for each county are presented in the following table.

Table 59
The 1975 and projected populations for Region Three-A.

County	*1975*	*1980*	*1990*	*2000*
Huntington	35,232	37,300	40,000	42,100
LaGrange	23,157	25,900	32,600	41,100
Noble	32,761	35,300	40,300	46,100
Steuben	22,314	25,400	29,400	32,800
Whitley	25,033	27,200	32,200	38,200
Total	138,497	151,100	174,500	200,300

The major population centers within the region are Huntington in Huntington County, Kendallville in Noble County, Angola in Steuben County, and Columbia City in Whitely County. These urban centers contained sixteen percent of the region's 1975 population.

Agriculture is the dominant land use within the region with more than seventy-nine percent of the area devoted to agricultural purposes. Approximately nine

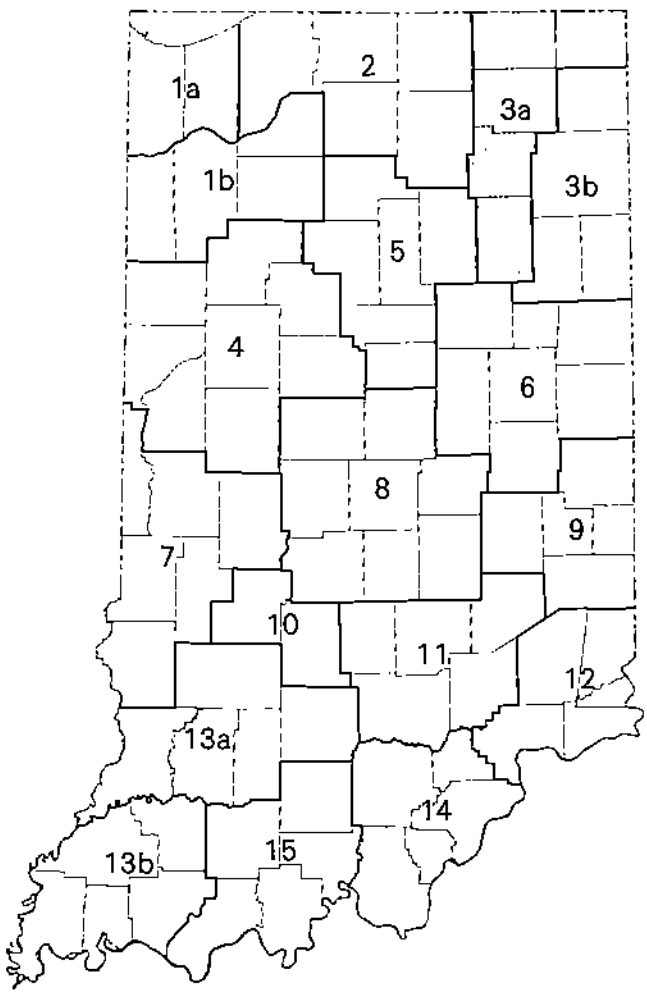


Figure 87
Map of Indiana showing the location of Region Three-A.

percent of the land is forested, six percent comprises lakes and associated wetlands, and six percent comprises urban and miscellaneous uses.

Approximately thirty-five percent of the work force was employed within the region plus an additional 2,800 persons from outside the region in 1975. The major employers are the electrical machinery, fabricated metal products, and transportation industries.

The region is generally characterized by flat or gently rolling areas and low, morainal ridges. A series of northeast to southwest trending ridges are located in southern Noble and northern Whitley Counties. These moraines cause nearby rivers to be deflected toward the north or south. Small lakes dating from postglacial times are scattered throughout the northern portion of the region.

Region Three-A receives approximately 36.0 inches of precipitation annually. This varies from a high of 3.9 inches in June and July to a low of 1.7 inches in February. Of the 36.0 inches of precipitation, approximately 10.0 inches appear as streamflow while 26.0 inches are consumed through evapotranspiration. The region has moderate temperatures with averages ranging from 24.5°F. in January to 72.5°F. in July. The average annual temperature is 50°F. Data from airports in South Bend and Fort Wayne indicate the annual prevailing wind is from the southeast at 10.3 miles per hour.

THE WATER RESOURCE

Ground Water

The effects of past glacial action have been important factors in the occurrence of ground water within Region Three-A. Thick deposits of till, outwash sand and gravel, ice contact, stratified drift, windblown sand, and alluvium have resulted from successive advances of glacial ice which ended with the Wisconsinan glaciers that retreated from the area about 12,000 years ago. Numerous natural ice-block lakes and deposits of sand and gravel dot the landscape of northern Noble, LaGrange, and northwestern Steuben Counties. Extensive outwash sand and gravel aquifers are also found in these areas. In Whitley and Huntington Counties glacial till and end moraines are the predominant glacial deposits.

Bedrock formations range from Silurian limestones and shales in Huntington and Whitley Counties to Devonian limestones, dolomites and shales in Whitley and Noble Counties, and Mississippian age shales in LaGrange and Steuben Counties. The shales underlying Noble, LaGrange, and Steuben Counties are not considered a source of ground water. The Devonian limestones are sources of ground water in southern Whitley and in Huntington Counties. The Silurian limestone is frequently utilized as a water source.

Region Three-A contains some of the most significant ground-water resources in Indiana with an excellent potential for large scale ground-water development. The availability of ground water is associated with the nature and type of aquifer materials present in a given area. As Figure 88 indicates, well yields in the region decrease in a southerly direction with the highest yields associated with the permeable sand and gravel aquifers of LaGrange, Noble, and Steuben Counties. In most of LaGrange County, except for the southeast corner, properly constructed wells can produce over 1,000 gallons-per-minute (gpm). In the southeast corner of the county, and some scattered areas throughout the county, wells of 600 gpm can be expected. In Steuben County, wells yielding 600 gpm can usually be expected in the western part, while well yields further east range from 200 to 400 gpm. In Noble County, well yields of 600 to 1,000 gpm can usually be anticipated in the northern and western parts while in the eastern and southeastern areas, wells could yield in the range of 100 to 400 gpm. Further to the south in Whitley and Huntington Counties, sand and gravel deposits within the glacial drift offer yields of 200 to 400 gpm. The Silurian limestone and dolomite sequence can generally be expected to yield similar quantities of water. Some northwestern and eastern areas of Whitley County could provide wells yielding up to 600 gpm, and wells in one area near the center of the county could yield up to 1,000 gpm. In the northern half of Huntington County and the southwestern tip of Whitley County, well yields of 200 gpm could be expected with two small areas possibly yielding only 100 gpm. Wells in the southern half of Huntington County yield approximately 400 gpm.

Ground water is usually hard with concentrations ranging from 300 to 400 parts-per-million. Iron concentrations are usually between 0.1 and 3.0 parts-per-million. Iron treatment or removal is required for many purposes.

Surface Water

Streamflow The streams in Steuben, LaGrange, and Noble Counties are primarily flowing in a westerly direction and lie within the St. Joseph River basin draining into Lake Michigan. The exception is the southeast corners of Steuben and Noble Counties where the drainage is to the southeast into the Maumee River basin. The major streams in these counties include the north and south branches of the Pigeon and Elkhart Rivers. In general, the streams in Whitley and Huntington Counties lie within the Wabash River drainage

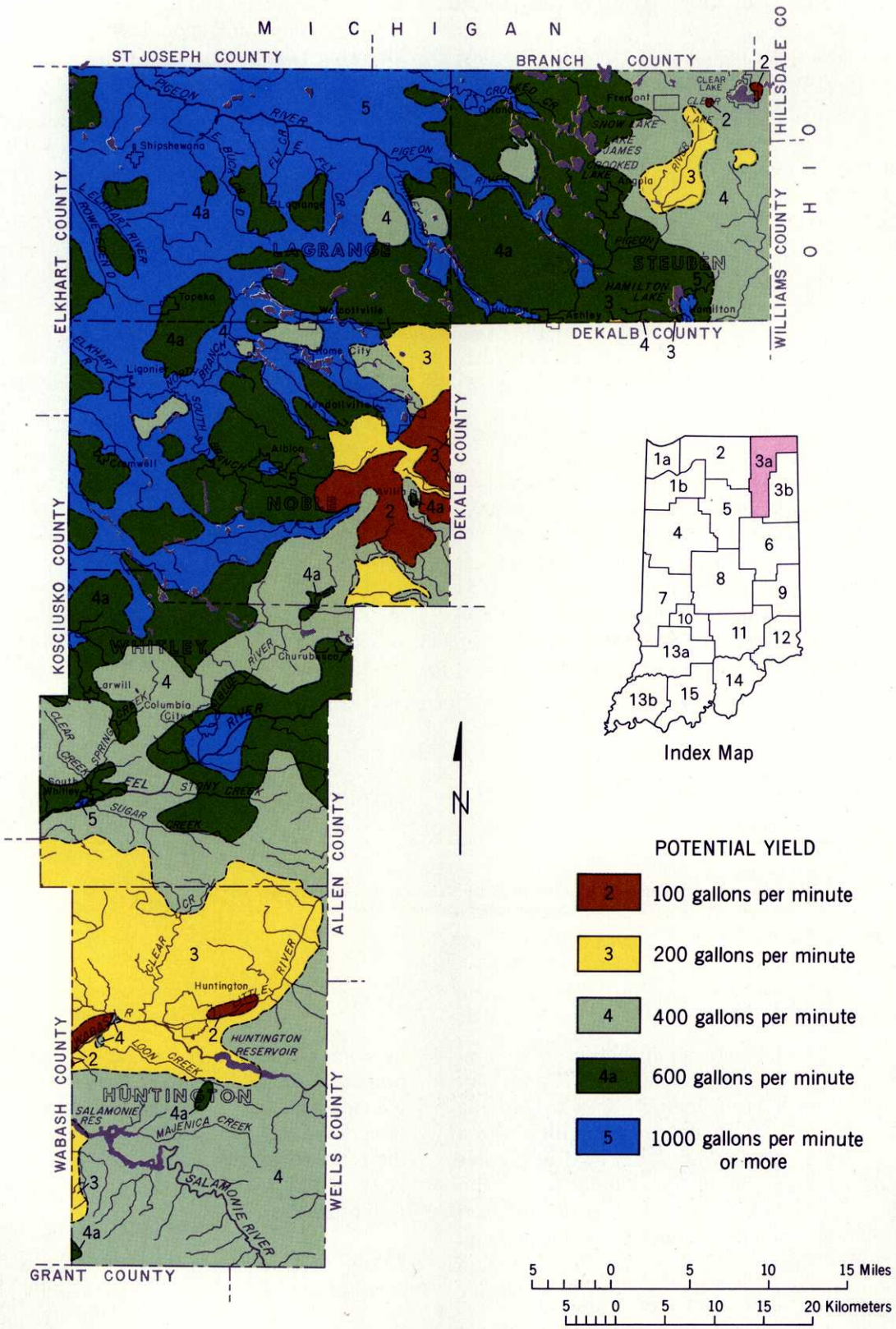


Figure 88
Map of Region Three-A showing the general location and potential yield of ground water from properly constructed large diameter wells.

basin and include the Eel, Little, Wabash, and Salamonie Rivers.

The seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations in Region Three-A are indicated in the following table.

Table 60
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Aboite Creek near Aboite[a]	53	6.1	0.4	na
Blue River near Columbia City[a]	61	9.7	2.0	na
Eel River near Columbia City[a]	77	15.5	3.7	na
Forker Creek near Burr Oak[a]	19	3.0	0	0
Little River near Huntington[b]	263	150.0	2.3	1.0
North Branch Elkhart River near Cosperville	133	68.0	2.8	1.4
Pigeon Creek near Angola	102	46.0	3.9	2.5
Pretty Lake inlet near Stroh[a]	2	0.1	0	0
Salamonie River near Warren	425	240.0	4.7	3.1
Sugar Creek at South Whitley[a]	31	2.9	0.2	na

na: not available
[a]Flow characteristics estimated from stream gaging stations with short periods of record.
[b]Flows were recorded prior to the construction of Huntington Reservoir.

Despite good ground-water contribution to streamflow, especially in the northern half of the region, very few systems drain a large enough area to provide substantial low flows. The only streams with a seven day, once in ten year low flow of ten mgd or greater are the Elkhart River below the confluence of the North and South Branches, the Eel River downstream from South Whitley, and the Wabash River downstream from Huntington Reservoir. No streams in the region have a one day, once in thirty year low flow greater than ten mgd.

The low flow characteristics indicate that the region is dominated by many small to medium stream systems rather than any particularly large one. Because of the short period of record for many stream gages, flow duration curves are not available. However, the north branch of the Elkhart River near Cosperville will have a dependable flow of eleven mgd ninety percent of the time. Similarly, the Salamonie River near Warren and the Little River near Huntington will have dependable flows of 10.0 and 6.7 mgd respectively ninety percent of the time.

Lakes The lakes within the region that are at least 50 acres in size or have a storage capacity of 32.5 million gallons or more are listed in Table 61, and are located on Figure 89. These one hundred and fifty lakes have a combined surface area of approximately 18,800 acres and a gross storage capacity of approximately 10,900 million gallons.

Table 61

Lakes at least fifty acres in size with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Adams Lake	5.62	308.0	2,505
2	Appleman Lake	na	52.0	192
3	Atwood Lake	1.23	170.0	508
4	Big Long Lake	4.77	388.0	na
5	Big Turkey Lake	35.80	450.0	2,378
6	Blackman Lake	0.98	67.0	394
7	Buck Lake	na	18.0	48
8	Cass Lake	0.68	89.0	284
9	Cedar Lake	1.60	120.0	332
10	Cline Lake	na	20.0	114
11	Dallas Lake	39.80	283.0	3,248
12	Emma Lake	13.60	42.0	228
13	Eve Lake	na	31.0	218
14	Fish Lake	10.60	100.0	1,319
15	Fish Lake	6.21	139.0	834
16	Hackenburg Lake	55.40	42.0	166
17	Lake of the Woods	5.25	136.0	1,782
18	Little Turkey Lake	56.50	135.0	505
19	Martin Lake	4.93	26.0	290
20	Mateer Lake	na	18.0	48
21	McClish Lake	1.28	35.0	394
22	Messick Lake	56.40	68.0	472
23	Mongo Reservoir	213.00	76.0	237
24	Nasby Mill Pond	na	43.2	114
25	North Twin Lake	1.54	135.0	690
26	Olin Lake	5.81	103.0	2,991
27	Oliver Lake	11.10	362.0	na
28	Ontario Millpond	na	31.2	175
29	Pigeon Lake	na	61.0	377
30	Pretty Lake	2.89	184.0	1,538
31	Rainbow Lake	na	16.0	81
32	Royer Lake	4.69	69.0	531
33	Shipshewana Lake	6.74	202.0	439
34	South Twin Lake	2.22	116.0	1,173
35	Still Lake	na	30.0	202
36	Stone Lake	1.51	152.0	671
37	Wall Lake	1.61	141.0	534
38	Westler Lake	37.80	88.0	576
39	Witmer Lake	36.10	204.0	2,293
40	Ball Lake	11.60	87.0	1,146
41	Barton Lake	na	94.0	436
42	Bass Lake	0.39	61.0	146
43	Bell Lake	na	38.0	166
44	Big Otter Lake	21.30	69.0	580
45	Bower Lake	84.60	25.0	91
46	Center Lake	na	46.0	127
47	Clear Lake	6.86	800.0	8,143
48	Crooked Lake	10.40	828.0	3,440
49	Fish Lake	na	59.0	244
50	Fox Lake	1.25	142.0	1,026
51	Golden Lake	88.80	119.0	589
52	Hamilton Lake	16.50	802.0	5,409
53	Handy Lake	na	16.0	94
54	Hog Lake	na	48.0	185
55	Hogback Lake	103.00	146.0	472
56	Howard Lake	3.90	27.0	42
57	Jimmerson Lake	51.60	434.0	1,431
58	Lake Anne	na	17.0	91
59	Lake Gage	17.30	332.0	3,304

Table 61 (continued)

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
60	Lake George	14.80	488.0	na
61	Lake James	47.80	1,034.0	10,943
62	Lake Pleasant	3.18	424.0	1,137
63	Lime Lake	na	30.0	107
64	Lime Lake	17.50	57.0	139
65	Little Turkey Lake	na	58.0	254
66	Little Otter Lake	15.70	34.0	241
67	Long Lake	2.80	154.0	241
68	Long Lake	67.90	92.0	501
69	Loon Lake	2.13	138.0	205
70	Mirror Lake	na	9.0	39
71	Otter Lake	6.91	118.0	638
72	Pigeon Lake	35.30	61.0	303
73	Pleasant Lake	1.12	53.0	387
74	Round Lake	7.25	30.0	110
75	Silver Lake	3.79	238.0	827
76	Snow Lake	40.20	310.0	2,606
77	Walters Lake	na	53.0	179
78	Bartley Lake	na	34.0	140
79	Baugher Lake	31.00	32.0	127
80	Bear Lake	6.98	136.0	987
81	Big Lake	8.89	228.0	1,834
82	Bixler Lake	5.28	120.0	681
83	Bowen Lake	na	30.0	351
84	Bristol Lake	na	27.0	241
85	Crane Lake	na	28.0	117
86	Cree Lake	4.85	58.0	296
87	Crooked Lake	1.51	206.0	2,945
88	Deer Lake	na	36.0	136
89	Diamond Lake	4.80	105.0	840
90	Dock Lake	na	16.0	74
91	Duely Lake	11.20	21.0	58
92	Eagle Lake	3.22	81.0	342
93	Engle Lake	4.19	48.0	218
94	Gilbert Lake	0.37	28.0	159
95	Gordy Lake	9.40	31.0	221
96	Harper Lake	2.76	11.0	52
97	High Lake	4.43	123.0	404
98	Hindman Lake	8.66	13.0	45
99	Horseshoe Lake	1.62	18.0	81
100	Jones Lake	70.30	114.0	312
101	Knapp Lake	6.02	88.0	990
102	Latta Lake	2.52	42.0	293
103	Little Long Lake	4.55	71.0	570
104	Long Lake	12.00	40.0	205
105	Lower Long Lake	4.35	66.0	508
106	Marl Lake	na	30.0	166
107	Marvin Morgan Lake	na	na	42
108	Miller Lake	na	11.0	52
109	Millers Lake	na	28.0	133
110	Muncie Lake	42.80	47.0	188
111	Niezer Lake	0.14	26.0	48
112	Norman Lake	na	14.0	91
113	Northport Feeder Lake	na	658.2	2,851
114	Pleasant Lake	0.29	20.0	175
115	Port Mitchell Lake	na	15.0	58
116	Richard Grieger Lake	na	na	55
117	River Lake	18.60	24.0	123
118	Round Lake	3.47	99.0	697
119	Sacarider Lake	1.43	33.0	241

Table 61 (continued)

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
120	Sand Lake	14.90	47.0	413
121	Schockopee Lake	na	21.0	91
122	Silver Lake	0.28	34.0	71
123	Skinner Lake	14.00	125.0	570
124	Smalley Lake	27.10	69.0	495
125	Sparta Lake	0.69	31.0	55
126	Steinbarger Lake	24.30	73.0	518
127	Sweet Lake	na	16.0	68
128	Sylvan Lake	33.80	575.0	na
129	Tamarack Lake	15.90	50.0	286
130	Tamarack Lake	19.40	84.0	436
131	Upper long Lake	2.08	86.0	619
132	Village Lake	12.00	12.0	52
133	Waldron Lake	134.00	216.0	1,016
134	Wible Lake	na	49.0	211
135	Williams Lake	na	46.0	348
136	Black Lake	na	24.0	130
137	Blue Lake	3.58	239.0	1,632
138	Brown Lake	na	23.0	188
139	Cedar Lake	0.79	131.0	na
140	Goose Lake	1.51	84.0	na
141	Larwill Lake	na	9.0	55
142	Little Wilson Lake	0.52	8.0	42
143	Loon Lake	11.10	222.0	1,867
144	New Lake	0.29	50.0	286
145	Old Lake	2.81	32.0	202
146	Round Lake	3.36	125.0	na
147	Shriner Lake	0.94	111.0	na
148	Troy Cedar Lake	5.33	93.0	827
149	Wilson Lake	0.46	29.0	127
150	Huntington Lake	721.00	905.0	4,066

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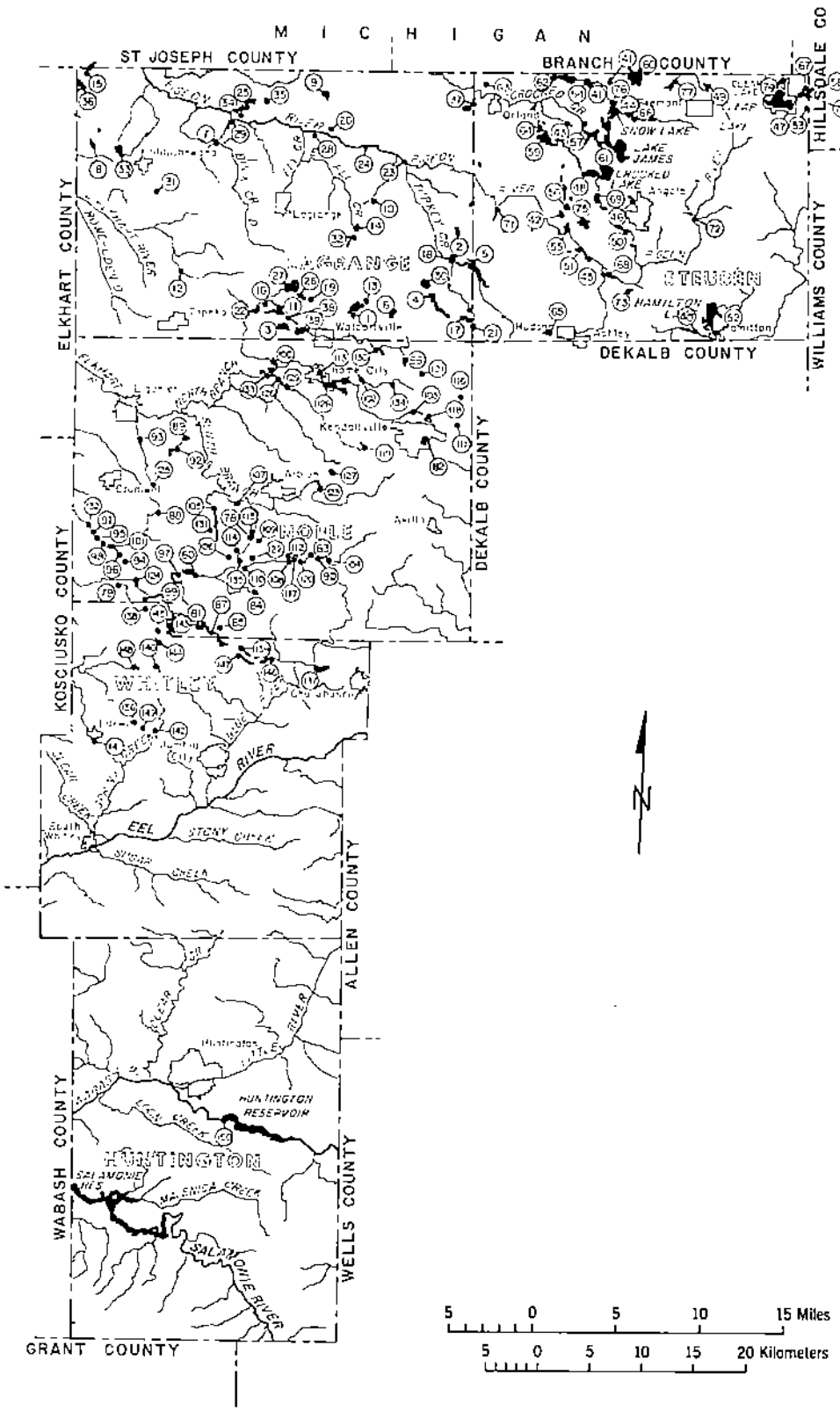


Figure 89
Map of Region Three-A showing the location of lakes that are at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Three-A is presented in Table 62. The existing supply for recreational activities is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply as a percentage of demand is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing Three of the lakes rank among the largest twenty-five of the state. Salamonie Lake, Lake James, and Huntington Lake represent the best water in the region for boating recreation. The control structure of Salamonie Lake lies within Region Five, but the lake extends into Region Three-A. Pigeon River State Fish and Wildlife Area and Chain-O'Lakes State Park offer boating opportunities to smaller craft. Additionally, many of the numerous private lakes in the region offer boating and waterskiing opportunities to residents of those localities.

Table 62
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	31	19.6 boats/acre/year	21,800 acres	100+	100+	100+
Waterskiing	7	34.4 skiers/acre/year	7,900 acres	100+	100+	100+
Canoeing	8	585 canoes/mile/year	93 miles	100+	100+	100+
Swimming	42	76,600 swimmers/acre/year	94 acres	100+	100+	100+
Ice-Skating	9	6,678 skaters/acre/year	4 acres	44	40	36
Fishing	56	66 persons/acre/year	29,000 acres	100+	92	88

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

There are currently no existing or projected shortages in meeting the demand for boating and waterskiing. However, shortages do exist in Region Three-B, east of Region Three-A, and many of the boating and waterskiing enthusiasts in the region look to the waters of Region Three-A for recreational opportunities. Seventy-five percent of Pokagon State Park's visitation and over fifty percent of Chain O'Lakes State Park's visitation originate outside of Region Three-A. Similarly, eleven percent of the visitation to Salamonie Lake originates outside Region Three-A.

Canoeing Ninety-three miles of lakes and streams provide canoeing, which is adequate to meet the demand generated within the region. Of all the canoe trips in the region, Pigeon River with thirty-six miles is the longest and in itself meets the current and projected demand generated by residents of Region Three-A.

Swimming and Ice-Skating Swimming for residents within the region is currently met by the existing number of lakes with public beaches as well as by public pools. Private swimming areas are available at a number of lakes.

Ice-skaters experience a shortage of available opportunities in the region. Currently forty-four percent of the demand by ice-skaters is met by available supply and projected to decline to thirty-six percent by the year 2000. This estimate does not include opportunities available to residents with access to private lakes.

Fishing The quality of the fisheries habitat is shown on Figure 90. The warmwater fishery is one of the finest in the state. Major rivers support good populations of smallmouth bass, rock bass, northern pike, and channel catfish. Additionally, trout are stocked in Bloody Run, Little Elkhart River, Pigeon River, Rowe-Eden Ditch, Turkey Creek, Curtis Creek, Clock Creek, the North Branch of the Elkhart River, and Fawn River.

Fishing in the hundreds of lakes in Region Three-A exceeds the opportunities for stream fishing. Steuben and Noble Counties each have over one hundred natural lakes in excess of five surface areas; however, most of these are not available to the public. Twelve of the lakes are stocked with trout. Others offer walleye and northern pike, especially those lakes in the Pigeon River and Elkhart River drainages. Sunfish, yellow perch, and catfish abound in most of the lakes. Cisco is

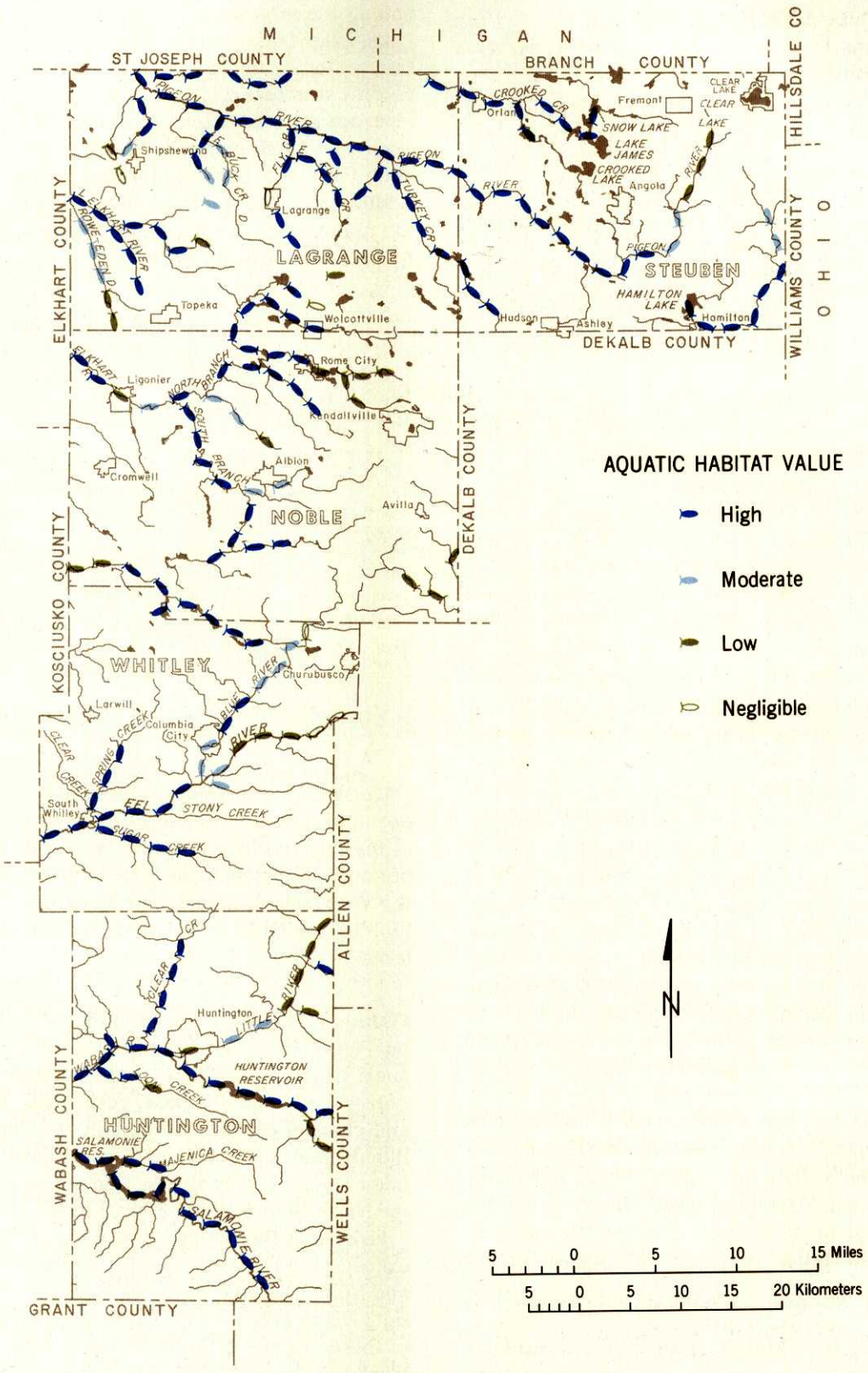


Figure 90
Map of Region Three-A showing the quality of the fisheries habitat.

found in a few lakes, most notably Crooked Lake in Noble and Whitley Counties.

Public access to Pigeon River is available at Scott and the Pigeon River Fish and Wildlife Area. Dukes Bridge, near Wawaka, and the Mallard Roost Wetland Conservation Area provide fishing access to the North Branch and the South Branch of the Elkhart River, respectively. Other state properties: Marsh Lake Wetland Conservation Area, Pokagon and Chain O'Lakes State Parks, and Huntington and Salamonie Lakes provide public lake fishing opportunities. Thirty-five public access sites are found on various lakes with shorelines in private ownership. City and county parks and road crossings may provide additional public access to lakes and streams.

Fishing opportunities currently satisfy the demand of the region's residents. However, the demand may exceed the supply by the year 1990.

Riparian Habitat The quality of the riparian habitat associated with lakes and streams is shown in Figure 91. Riparian habitat is mainly comprised of the extensive wetlands associated with the natural lakes and streams of the northern two-thirds of the region and the wooded streambanks in the southern third. The South Branch of the Elkhart River is particularly noted for its adjacent wetlands providing habitat for waterfowl, shorebirds, and most active wildlife species. Many lakes in the region are bordered, at least partially, by sizable marshes and swamps. Waterfowl, shorebirds, furbearers, and upland game are common.

State properties allowing public hunting include Pigeon River and Tri-County Fish and Wildlife Areas, Marsh Lake and Mallard Roost Wetland Conservation Areas, and areas adjacent to the Salamonie and Huntington Lakes.

Hydroelectric Power Rinkel Dam, located on the Fawn River in LaGrange County, is the only hydroelectric plant in the region. The Rinkel Dam plant has the capacity to generate 144 kilowatts of electricity. Region Three-A has neither adequate sites to provide the required difference of elevation nor the adequate sustained flow to support a large hydroelectric plant.

Withdrawal Uses

Public Water Supplies Huntington, LaGrange, Noble, Steuben, and Whitley Counties are served by twenty public water utilities. An estimated 51,200 residents of Region Three-A were served by a public water utility in 1975. Noble County contains six systems, Huntington County has five, while the remaining three counties each have three systems.

The Huntington public water utility, the largest in the region, withdrew an average of 2.2 mgd in 1975. Of the remaining communities, only Kendallville approached withdrawal rates of one mgd. Angola and Columbia City each withdrew approximately 0.6 mgd. The service areas for the public water utilities in Region Three-A are shown in Figure 92.

The twenty public water utilities withdrew an average of 6.8 mgd with a maximum withdrawal of approximately 11.5 mgd. Rural water systems do not occur due to the widespread availability of ground water.

Because of the widespread availability of ground water, all utilities except the Huntington utility have made ground water their sole source of supply. Huntington withdraws twenty-five percent of its supply from surface water. Well fields are located in or near the communities served.

Projections of public water supply withdrawals, as shown in the following table, indicate that withdrawals may increase from 6.8 mgd to 9.0 mgd by the year 2000.

Table 63

The 1977 and projected withdrawal and consumption rates for public water supplies by the year 2000, in million-gallons-per-day.

Public Water	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.8	7.1	8.1	9.0
Consumption	0.7	0.7	0.8	0.9

Industrial Water Industrial establishments had an estimated water intake averaging 6.3 mgd in 1977. Of the total industrial intake, 2.8 mgd was self-supplied by the industries while 3.5 mgd was purchased from the region's public water utilities. Ground water is the major source of industrial, self-supplied water.

The largest water-using industry group is comprised of smaller industries, which utilize an estimated 1.5 mgd. Metal fabricating establishments are the second largest users, with a withdrawal rate of 1.1 mgd. Electrical industries in the region also use large quantities of water.

Industrial production by the year 2000 is expected to increase substantially (United States Water Resources Council). Industrial water requirements are likewise expected to increase to 7.6 mgd. The self-supplied withdrawals may then increase from the current rate of 2.8 mgd to 3.2 mgd by the year 2000. In spite of the predicted increase in industrial output, total industrial water intake is expected to fall initially due to increased plant efficiency and then rise slowly as output increases. Data for industrial self-supplied withdrawals is presented in Table 64.

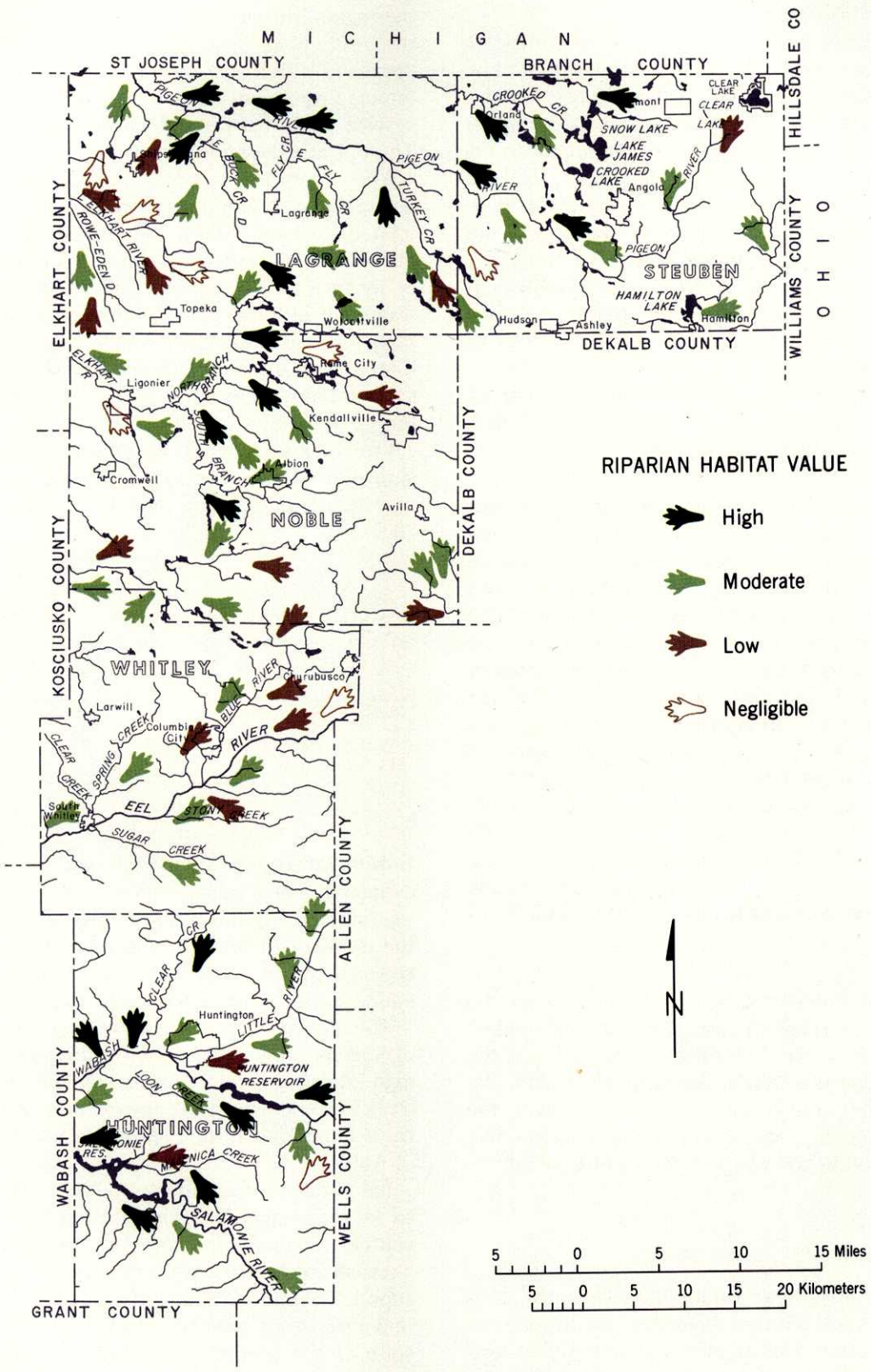


Figure 91
Map of Region Three-A showing the quality of the riparian habitat.

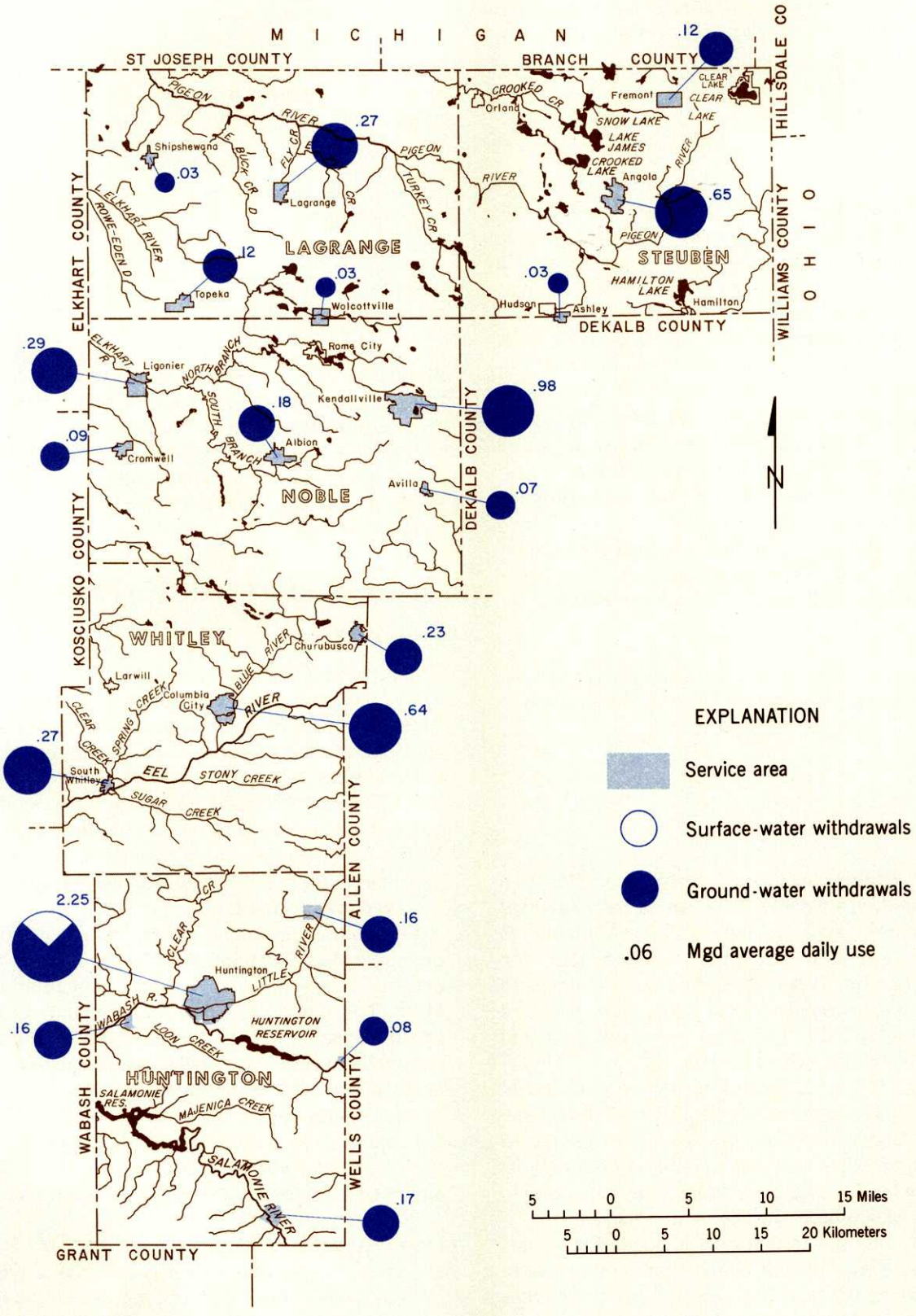


Figure 92
Map of Region Three-A showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Table 64
The 1977 and projected withdrawal and consumption rates for industrial self-supplied water, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	2.8	2.9	3.0	3.2
Consumption	0.3	0.4	0.5	0.6

Rural Self-Supplied Water An estimated 88,000 persons lived in homes supplied by individual wells in 1975. Approximately 5.2 mgd of this rural self-supplied water was used for residential purposes. By the year 2000, the population may increase by 61,800. An estimated 52,600 additional persons may depend on their own wells for household water. The withdrawal of rural self-supplied residential water may increase to approximately 10.6 mgd by the year 2000.

In 1975, an estimated 386,100 head of livestock and 1,070,000 chickens were located within the region. Collectively, these animals will consume approximately 3.2 mgd by the year 2000.

The total withdrawal for rural self-supplied water may increase from the current 8.8 mgd to approximately 13.9 mgd by the year 2000, as presented here.

Table 65
The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	8.8	9.4	11.7	13.9
Consumption	8.8	9.4	11.7	13.9

Irrigation Water LaGrange, Noble, and Steuben Counties are the most favorable areas for expanded irrigation of croplands in Region Three-A. Figure 93 shows the soil associations with potential for profitable irrigation. Based upon the survey of irrigated croplands, approximately 14,850 acres were irrigated in the region in 1977. The principal crops irrigated were corn, potatoes, and soybeans.

Assuming 1977 as a normal growing year, these crops would have required about 39.0 mgd during the peak July– August irrigation season. It was estimated that approximately 80,000 acres could be profitably irrigated. The 1977 irrigated average was expected to increase to 23,800 acres by the year 2000.

In addition to the irrigation for agricultural use, fairways and greens on the region's golf courses were irrigated. About 0.9 mgd was applied to these areas during the peak July-August irrigation season.

The expansion of irrigation acreage, and the irrigation of golf courses, is expected to raise the peak July-August irrigation demand in an "average" season to about 63.8 mgd as indicated in Table 66. In wetter growing years, less water will be required while during drier seasons, more water will be applied. The average season withdrawal of ground water for croplands is expected to increase from the current rate of 26.8 mgd to 46.0 mgd by the year 2000.

Table 66
The 1977 and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	40.0	43.1	53.4	63.8
Consumption	40.0	43.1	53.4	63.8

Electrical Energy Rinkel Dam is the only hydroelectric power facility in the region. Hydroelectric power is discussed in the section "Instream Uses." At the present time no electrical generating stations, other than the Rinkel hydroelectric plant, occur in Region Three-A nor are any anticipated within the next twenty-five years.

EXCESS WATER

Flooding

Approximately 40,200 acres of the region are subject to flooding. The major flood plains are shown in Figure 94. Figure 95 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $900,000, of which some eighty-eight percent occurs in rural areas. A portion of the St. Joseph River basin is also located in the region, but information on flood damage and flood plain acreage is not available at this time.

Minor flood problems of the nuisance type occur once or twice a year on the Pigeon, Elkhart, and Tippecanoe Rivers. Severe flooding is a relatively rare event. The numerous lakes and wetlands in the area retain excess water and thereby help to reduce flooding on the rivers. Some lakes, however, have flooding problems due to the fluctuating water stages caused by inadequate outlet conditions. The Little, Salamonie, Eel, and Wabash Rivers are prone to frequent and severe flooding, which is primarily due to the large amount of precipitation during the winter and spring.

Flood Control Huntington Lake, the only flood control project in the region, was completed in 1969 by the United States Army Corps of Engineers in cooperation with the State of Indiana. The control structure and dam for Huntington Lake is located in Huntington County about two miles south of the city of Huntington. The lake receives runoff from a drainage area of

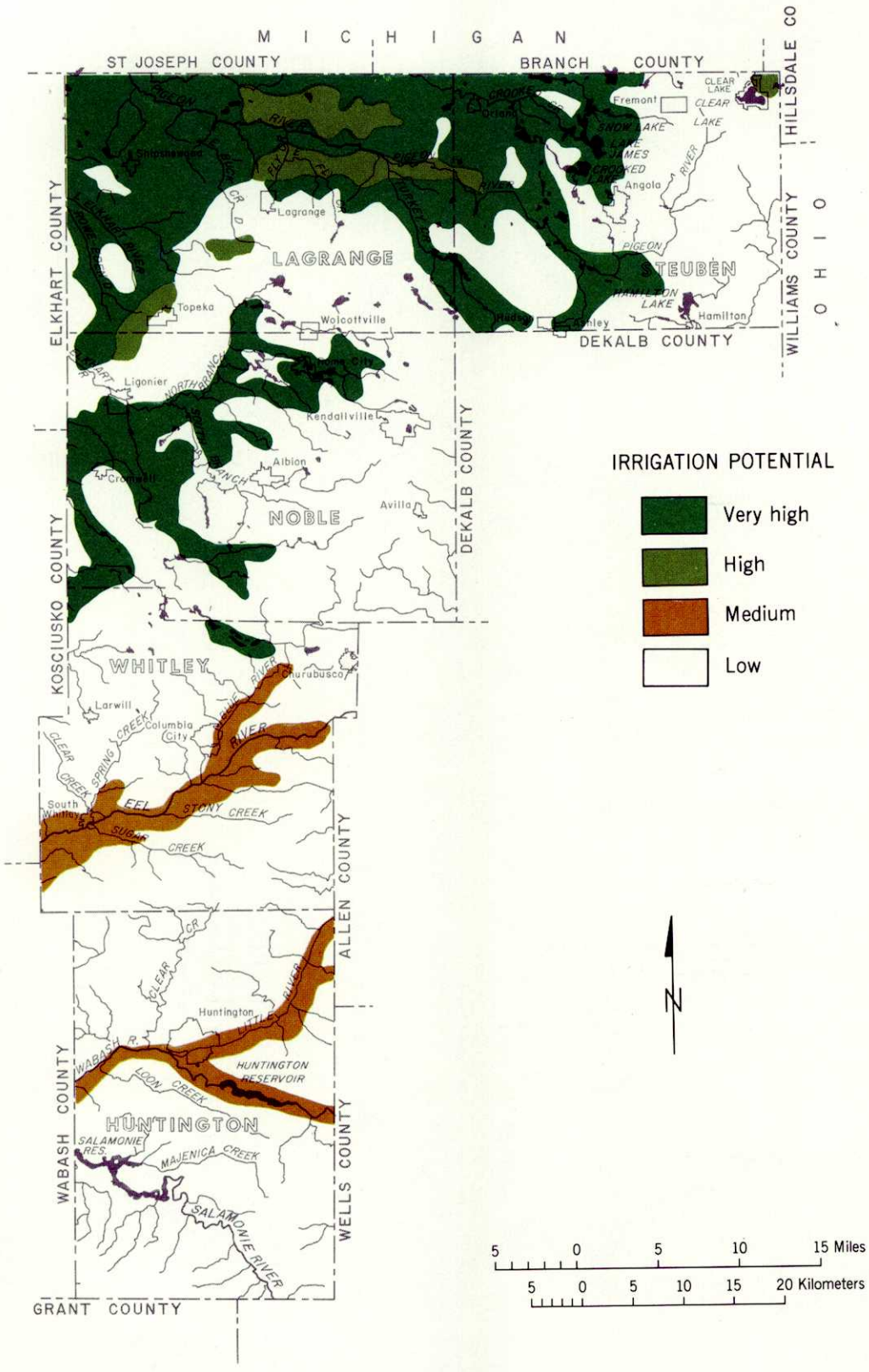


Figure 93
Map of Region Three-A showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

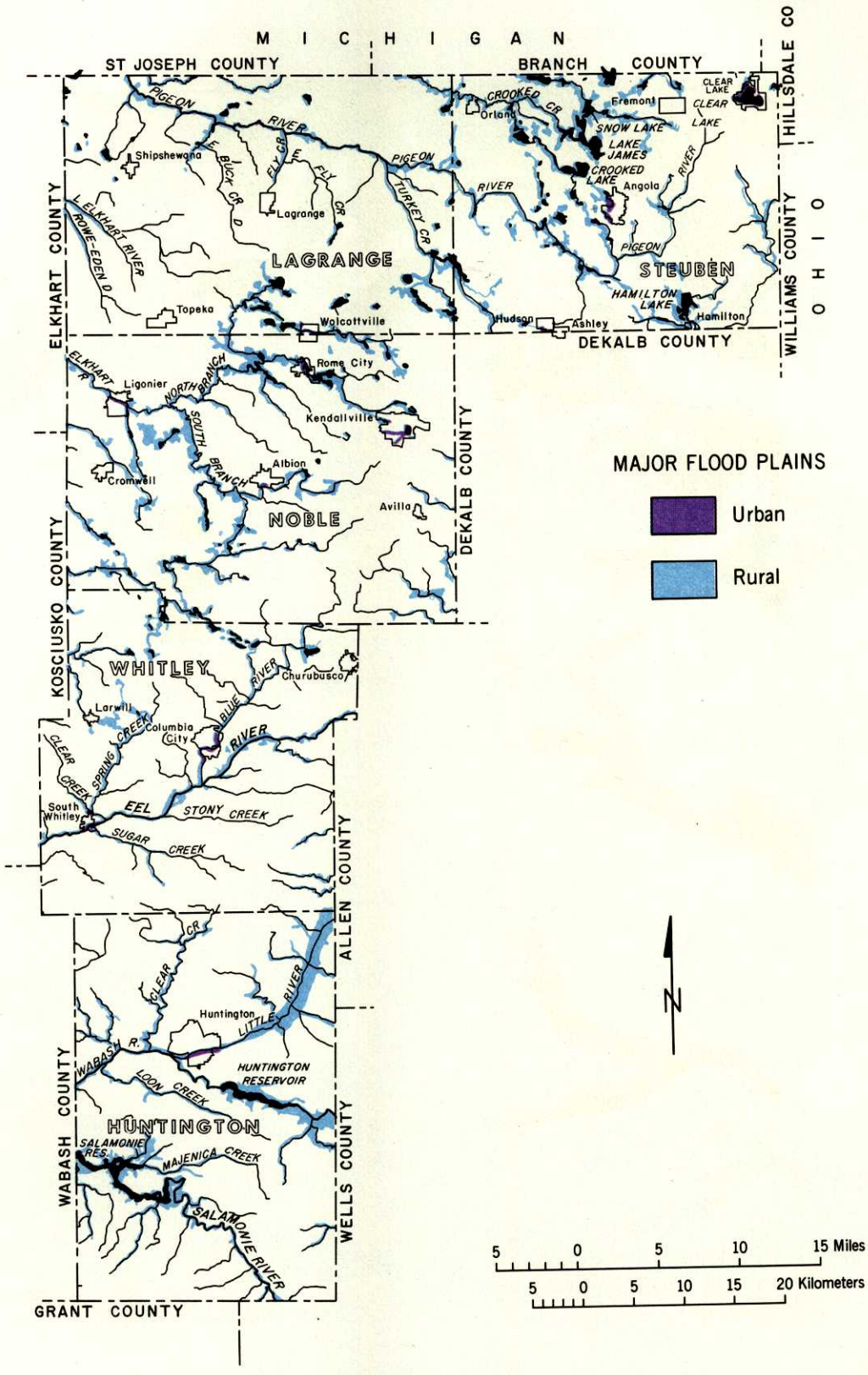


Figure 94
Map of Region Three-A showing the major floodplains.

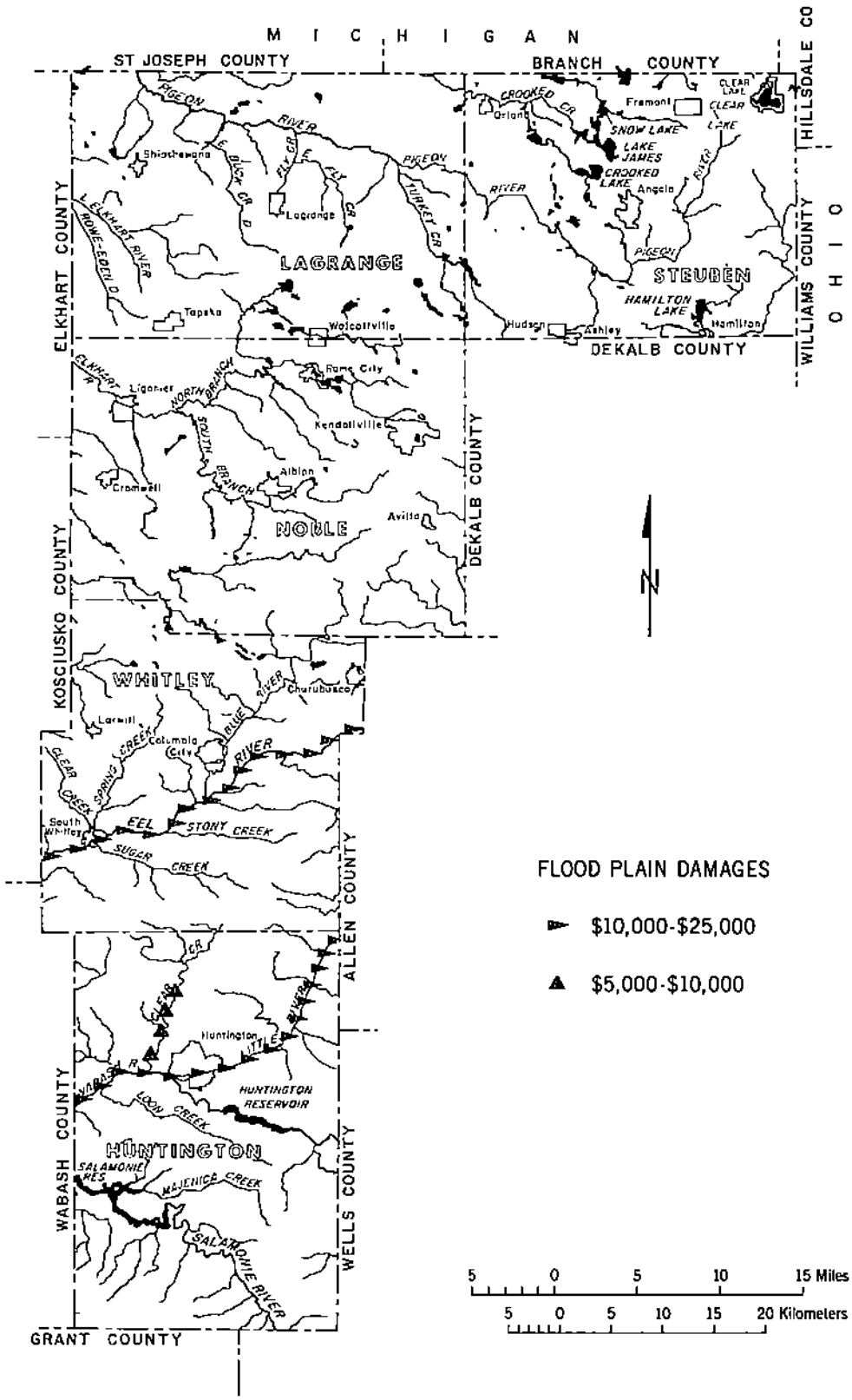


Figure 95
Map of Region Three-A showing the estimated average annual flood damages per mile along selected streams.

approximately 707 square miles, including parts of Wells and Adams Counties and the State of Ohio.

The Rock Creek Small Watershed Project is the only small watershed project within the region. The major works of improvement include 24.1 miles of debris removal on Mossberg Drain. Supplemental additions to reduce the adverse environmental effects include 14.7 miles of one-sided channel construction, fish pools throughout most of the length of the Rock Creek main channel, and replanting of approximately fifty-one acres of trees and shrubs adjacent to the berm. This project is designed to reduce flood water damages on Rock Creek by sixty-four percent.

Flood Plain Management Several communities are participating in the emergency phase of the National Flood Insurance Program as listed in the following table. Unincorporated Noble County and Churubusco are participating in the regular phase of the National Flood Insurance Program.

Table 67
Communities participating in the emergency phase of the National Flood Insurance Program.

Angola	South Whitley
Cedar Lake	Steuben County, unincorporated
Columbia City	Whitley County, unincorporated
Hamilton	Warren
Hudson	
Huntington	

Agricultural Drainage

Approximately nineteen percent of soil associations in Region Three-A have "severe" wetness characteristics, fifty-eight percent have "moderate" wetness characteristics, while twenty-three percent have "slight" wetness characteristics. The general location of soil associations with these wetness characteristics are shown in Figure 96. Those areas with "slight" wetness are located along the basins of the Fawn and Pigeon Rivers in northern Steuben and LaGrange Counties, along the Eel River in Whitley County, and along Little River in Huntington County.

Approximately 3,600 miles of legal drains occur in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards or, in a limited number of cases, of conservancy districts.

Soil Erosion

The erosion potential of soil associations within Region Three-A are shown in Figure 97. Fifty-seven percent of the 1,167,900 acres in the region are rated as having a "medium" soil erosion hazard. Such land has a moderate potential for soil loss when not adequately protected by vegetation or when conservation techniques are not practiced. These areas are located primarily in the eastern half of Steuben and Noble Counties, the southeastern corner of LaGrange County, the northern half of Whitley County, and along the Wabash, Little, and Salamonie Rivers in Huntington County. The remaining forty-three percent of the land is predominately level and ranks as having a "low" erosion potential for land in a fallow state.

WATER QUALITY

The surface streams within Region Three-A routinely surveyed for water quality by the Indiana State Board of Health are the Wabash, Salamonie, Pigeon, and the North and South Branches of the Elkhart River. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

Water quality for the Salamonie River at Lancaster was within the recommended standards for temperature and dissolved oxygen. The biochemical oxygen demand, a measure of the amount of oxygen consumed in the biological processes that breakdown organic matter in water, was at an acceptable level. The only parameter which occasionally reached unacceptable levels was nitrate, a potential nutrient source for algae. Also, concentrations of fecal coliform bacteria often violated the state's partial body contact standard.

Nitrate levels in the Wabash River near Huntington exceeded recommended levels for raw drinking water in June and July. Although the concentrations of fecal coliform bacteria met the criterion for partial body contact, total coliform bacteria levels have at times been in violation of the raw drinking water criterion.

The North and South Branches of the Elkhart River were found to have good water quality as related to various parameters examined. Only minor violations of National Pollution Discharge Elimination System limits were found within the stream's basin during intensive surveys.

The Pigeon River, Crooked Creek, and Fawn River have had problems that relate primarily to inadequate treatment at the municipal sewage treatment plants and semi-public dischargers. The municipalities have various projects under way to alleviate these problems.

The trophic or age classification of those lakes surveyed by the Stream Pollution Control Board in Region Three-A are presented in Table 68.

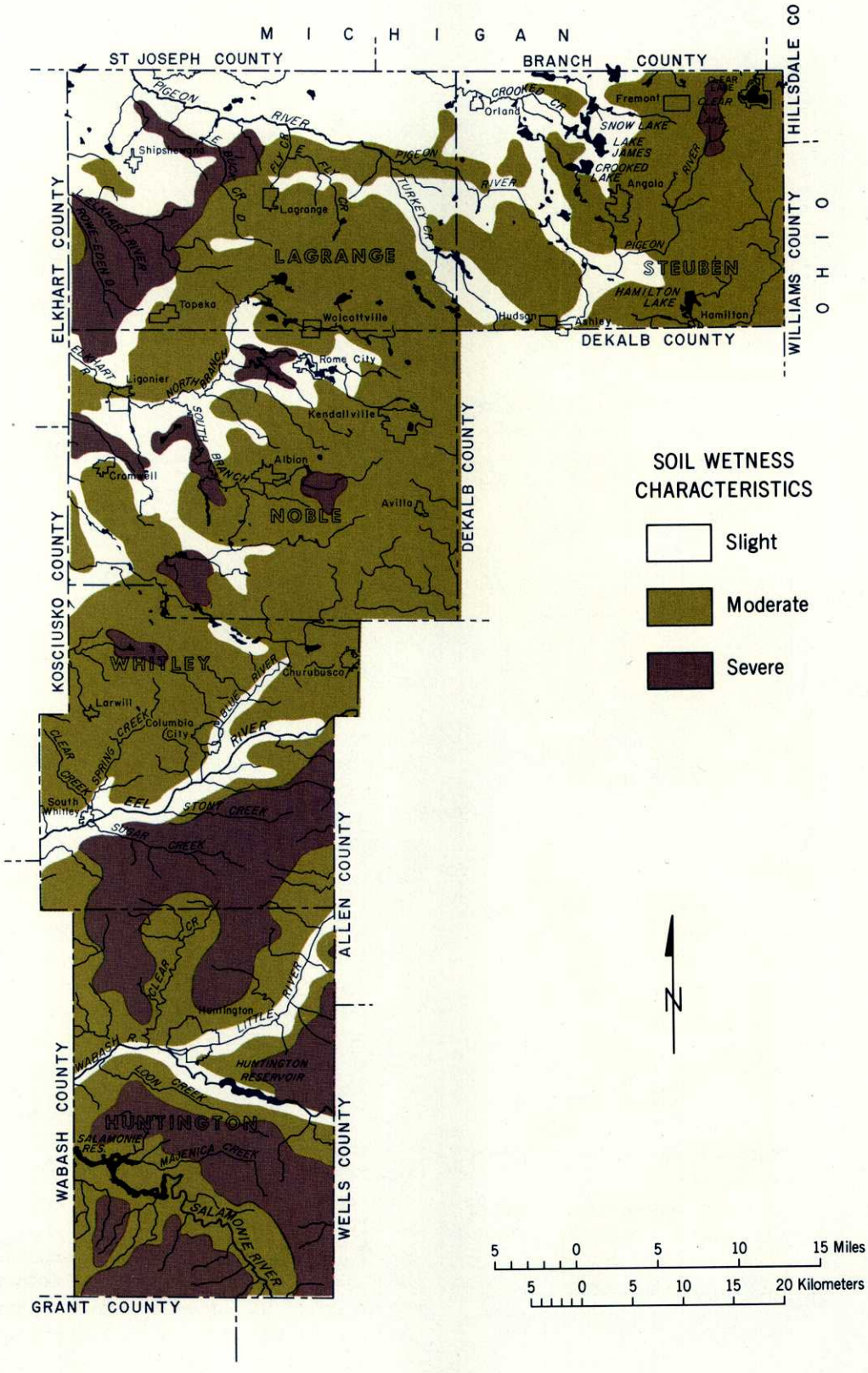


Figure 96
Map of Region Three-A showing the general location of the wetness characteristics of soil associations.

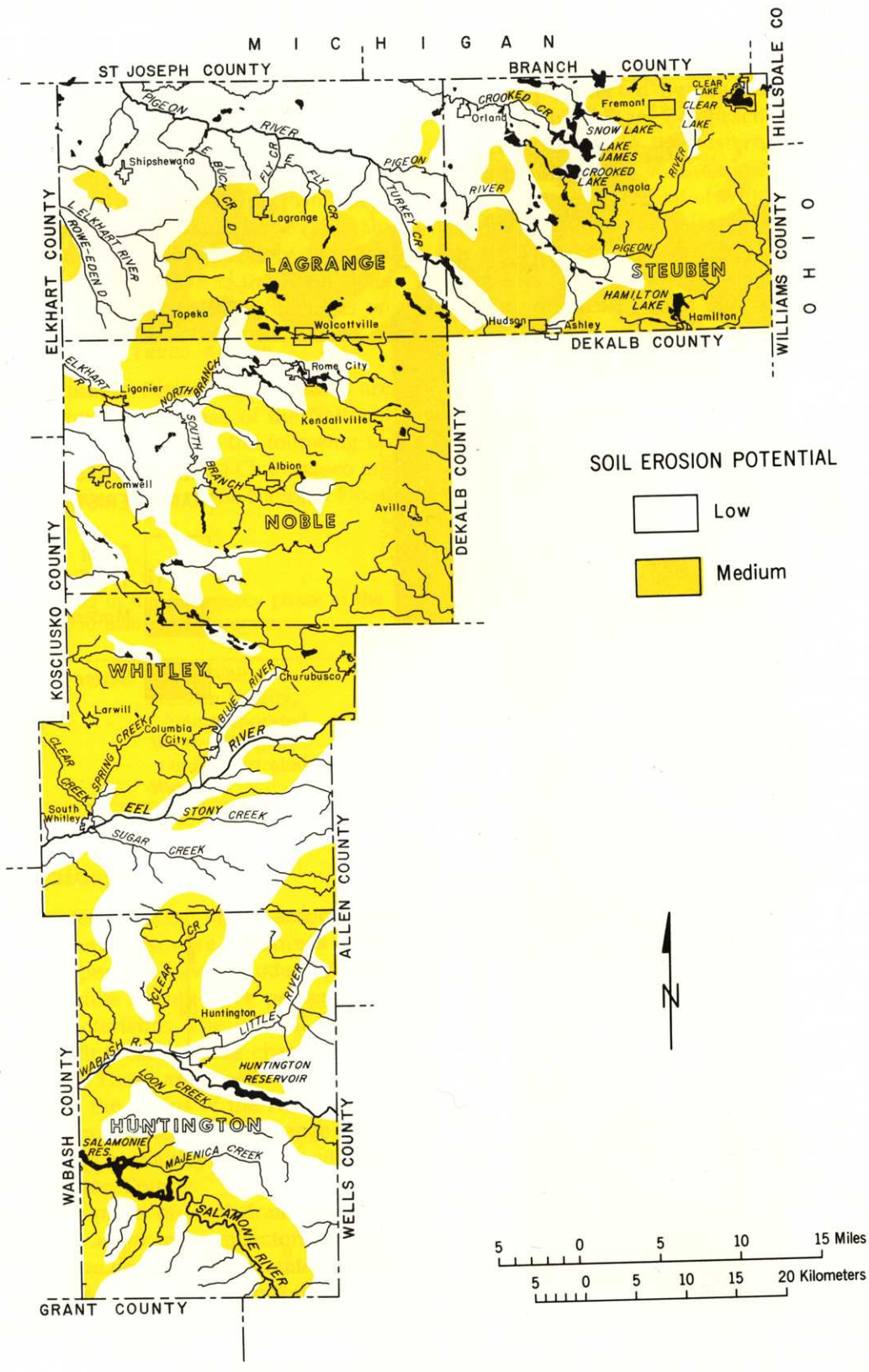


Figure 97
Map of Region Three-A showing the erosion potential of the soil associations.

Table 68
Trophic classification of lakes surveyed.

Lake	*County*	*Age Classification*
Adams	LaGrange	II
Anne	Steuben	II
Appleman	LaGrange	II
Atwood	LaGrange	I
Ball	Steuben	II
Bartley	Noble	II
Bass	Steuben	II
Baugher	Noble	III
Bear	Noble	II
Bell	Steuben	I
Big	Noble	II
Big Bar Bee	Noble	II
Big Bower	Steuben	III
Big Center	Steuben	III
Big Long	LaGrange	II
Big Otter	Steuben	III
Big Pigeon	Steuben	III
Big Turkey	Steuben	II
Bixler	Noble	II
Black	Steuben	II
Blackman	Steuben	I
Blue	Whitley	II
Bowen	Noble	II
Bristol	Noble	II
Brokeshaw	LaGrange	I
Buck	Steuben	II
Cass	LaGrange	II
Cedar	LaGrange	I
Cedar	Whitley	I
Cheeseboro	Steuben	II
Clear	Steuben	I
Cotton	LaGrange	III
Crane	Noble	II
Cree	Noble	II
Crooked	Noble-Whitley	I
Crooked	Steuben	I
Dallas	LaGrange	II
Deep	Noble	II
Diamond	Noble	I
Dock	Noble	II
Emma	LaGrange	II
Engles	Noble	II
Eve	LaGrange	I
Failing	Steuben	I
Femmel	LaGrange	II
Fish	LaGrange	II
Fish	Steuben	III
Fox	Steuben	II
Gage	Steuben	I
George	Steuben	I
Gillbert	Noble	II
Golden	Steuben	III
Goose	Whitley	III
Gooseneck	Steuben	I
Gordy	Noble	II
Grass	Steuben	I
Gravel	Steuben	I
Green	Steuben	I
Greene	LaGrange	III
Hackenburg	LaGrange	II

Table 68 (continued)

Lake	*County*	*Age Classification*
Hall	Noble	I
Hamilton	Steuben	II
Harper	Noble	III
Hayward	LaGrange	II
Henderson	Noble	III
Henry	Steuben	II
High	Noble	III
Hogback	Steuben	III
Horseshoe	Noble	II
Howard	Steuben	III
Jimmerson	Steuben	I
Jones	Noble	II
Knapp	Noble	II
Lake James	Steuben	I
Lake Pleasant	Steuben	II
Lake of the Woods	LaGrange	I
Larwill	Whitley	II
Latta	Noble	II
Lindsey	Noble	II
Lime	Steuben	I
Little Bower	Steuben	III
Little Center	Steuben	III
Little Crooked	Whitley	II
Little Long	Noble	II
Little Otter	Steuben	III
Little Pigeon	Steuben	III
Little Turkey	LaGrange	II
Loon	Whitley	II
Loon	Steuben	III
Long	Steuben	I
Long	Steuben	III
Long	Noble	II
Marsh	Steuben	III
Martin	LaGrange	II
McLish	Steuben	I
Meserve	Steuben	I
Messick	LaGrange	II
Meteer	Steuben	I
Middle Center	Steuben	III
Millers	Noble	II
Mirror	Steuben	I
Muncie	Noble	II
Navoo	LaGrange	II
New	Whitley	I
Norman	Noble	II
North Twin	LaGrange	I
Old	Whitley	II
Olin	LaGrange	I
Oliver	LaGrange	I
Otter	Steuben	II
Pigeon	LaGrange	II
Pleasant	Noble	II
Pleasant	Steuben	I
Port Mitchell	Noble	II
Pretty	LaGrange	I
Rainbow	LaGrange	II
Pine	Whitley	II
Rivir	Noble	II
Round	Steuben	I
Round	Steuben	II

Table 68 (continued)

Lake	*County*	*Age Classification*
Round	Steuben	I
Round	Steuben	I
Round	Whitley	II
Royer	LaGrange	II
Sacanider	Noble	II
Sand	Noble	I
Scott	Whitley	I
Shipshewanna	LaGrange	III
Shockopee	Noble	II
Shriner	Whitley	I
Silver	Noble	II
Silver	Steuben	II
Skinner	Noble	II
Smalley	Noble	II
Snow	Steuben	I
South Twin	LaGrange	I
Sparta	Noble	II
Stayner	Steuben	III

Table 68 (continued)

Lake	*County*	*Age Classification*
Still	LaGrange	I
Stone	LaGrange	I
Strenbarger	Noble	II
Sweet	Noble	II
Sylvan	Noble	III
Tamarack	Noble	II
Tamarack	Noble	III
Taylor	LaGrange	II
Troy-Cedar	Whitley	III
Upper Long	Noble	II
Village	Noble	III
Waldron	Noble	II
Wall	LaGrange	I
Warner	Steuben	II
Westler	LaGrange	I
Wible	Noble	III
Williams	Noble	II
Witmer	Steuben	II

Region Three-B

Adams, Allen, DeKalb, and Wells Counties, located in northeastern Indiana, form Region Three-B. The region contains approximately 1,749 square miles and is bounded by Steuben County to the north, the State of Ohio to the east, Blackford and Jay Counties to the south, and Huntington, Whitley and Noble Counties to the west, as shown in Figure 98.

The population was 373,164 in 1975. The Indiana Population Projections for 1975 to 2000 indicate the population may increase to approximately 493,000 by the year 2000. The 1975 population and the projections for each county are tabulated below.

Table 69
The 1975 and projected populations for Region Three-B.

County	*1975*	*1980*	*1990*	*2000*
Adams	27,434	28,400	30,700	32,800
Allen	288,796	306,400	347,100	384,900
DeKalb	32,057	33,600	37,300	41,700
Wells	24,877	26,700	30,400	34,400
Total	373,164	395,100	445,500	493,800

The major population centers within the region are Fort Wayne and New Haven in Allen County, Auburn in Dekalb, Bluffton in Wells, and Decatur in Adams. These urban centers contained about fifty percent of the region's 1975 population.

Agriculture is the dominant land use within the region with more than seventy-nine percent devoted to agricultural purposes. Approximately ten percent of the land is forested while the remaining eleven percent

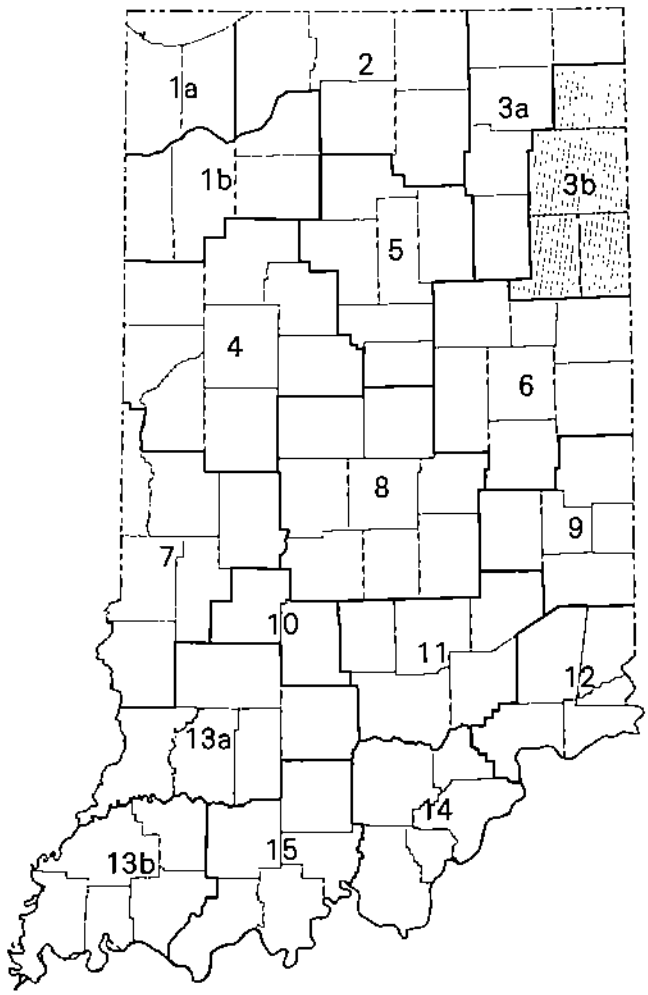


Figure 98
Map of Indiana showing the location of Region Three-B.

comprises urban and miscellaneous uses. The region is characterized by a flat to slightly rolling topography.

More than thirty-seven percent of the work force is employed within the region, along with an additional 8,300 nonresident employees. The major employers are electrical machinery, transportation, and nonelectrical machinery industries. Region Three-B is one of the major livestock and corn producing areas of Indiana.

The region receives approximately 36.0 inches of precipitation annually varying from a high of 4.0 inches in June to a low of 1.9 inches in February. Of the 36.0 inches of precipitation falling annually, approximately 10.0 inches appear as streamflow while 26.0 inches are consumed through evapotranspiration. Average temperatures range from 25°F. in January to 72.5°F. in July. The average annual temperature is 50°F. Data from Baer Field in Fort Wayne indicate that the annual prevailing wind is from the southwest at 10.3 miles per hour.

THE WATER RESOURCE

Ground Water

Multiple glacial advances during the Illinoian and Wisconsinan periods have left a thick mantle composed primarily of till, with scattered deposits of ice-contact sand and gravel, lake bed deposits, and some outwash sand and gravel throughout the region. Several end moraines of Wisconsinan age are present in the form of concentric lines lying diagonally across the area. The combined Fort Wayne–Wabash Moraines served in blocking meltwaters from the receding glacier and created ancient Lake Maumee which at one time covered most of east-central Allen County and large areas of northwestern Ohio.

Beneath the glacial deposits in southern Adams County are remnants of the buried valley of the former Teays River which flowed through central Indiana prior to the Ice Age. The Teays Valley contains drift materials in excess of a 300 foot thickness in places. In general, glacial drift ranging in thickness from 50 to 200 feet is common, with the thickest materials occurring in northwestern Allen County and the Teays Valley.

Bedrock formations of Silurian and Devonian ages underlie the region. Dolomitic limestone, dolomite, and limestone are the common bedrock types in the area with carbonaceous shale of Devonian age occurring in northwestern Allen County. Silurian bedrock occurs beneath much of Adams and Wells Counties, with younger Devonian rocks predominating in Allen County.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In this region, there is a slight variability in ground-water occurrence, as shown in Figure 99. Exclusive of an area in east-central Allen County, large diameter wells will yield from 200 to 600 gallons-per-minute (gpm). Major ground-water supplies are present in the Berns and Geneva areas from sand and gravel deposits within the buried Teays Valley and from thick inter-till sand and gravel aquifers in northwestern Allen County.

The availability of ground water in Allen County is generally good in the western half with yields ranging from 200 to 600 gpm. Wells are expected to produce 50 to 200 gpm from the Silurian limestone and dolomite aquifers in eastern Allen County. Ground-water conditions in Wells and Adams Counties are quite similar, and well yields of 200 to 400 gpm are possible. The Silurian bedrock is the major aquifer in parts of Adams and Wells Counties, due to the absence of sand and gravel aquifers.

In DeKalb County, well yields range from 100 gpm in a few western areas to 1,000 gpm near Butler and Auburn. Remaining areas of the county contain aquifers capable of yielding 200 to 600 gpm.

Ground water, while generally of a quality satisfactory for most uses, contains one of the more unique mineral assemblages within the state. High hardness, with sulfate and fluoride contents, is common. Most hardness levels are in excess of 400 parts-per-million (ppm), and many are above 600 ppm. Sulfate levels greater than 250 ppm are present in nearly all of Adams County, much of eastern and northern Wells County, and the southeastern portion of Allen County. Fluoride concentrations above one ppm can be expected from most ground-water supplies. Locally, hydrogen sulfide is encountered in Adams, Allen, and parts of Wells Counties; however, its incidence is less than in northwestern Indiana.

Surface Water

Streamflow The majority of the streams drain through the St. Joseph and St. Marys River systems to the Maumee River, and ultimately to Lake Erie. Two exceptions are the southwest quarter of the region which is drained westwardly by the Wabash River and the northwest corner which drains into the Pigeon River. None of the major streams have their origin within the region.

The seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations within Region Three-B are given in Table 70.

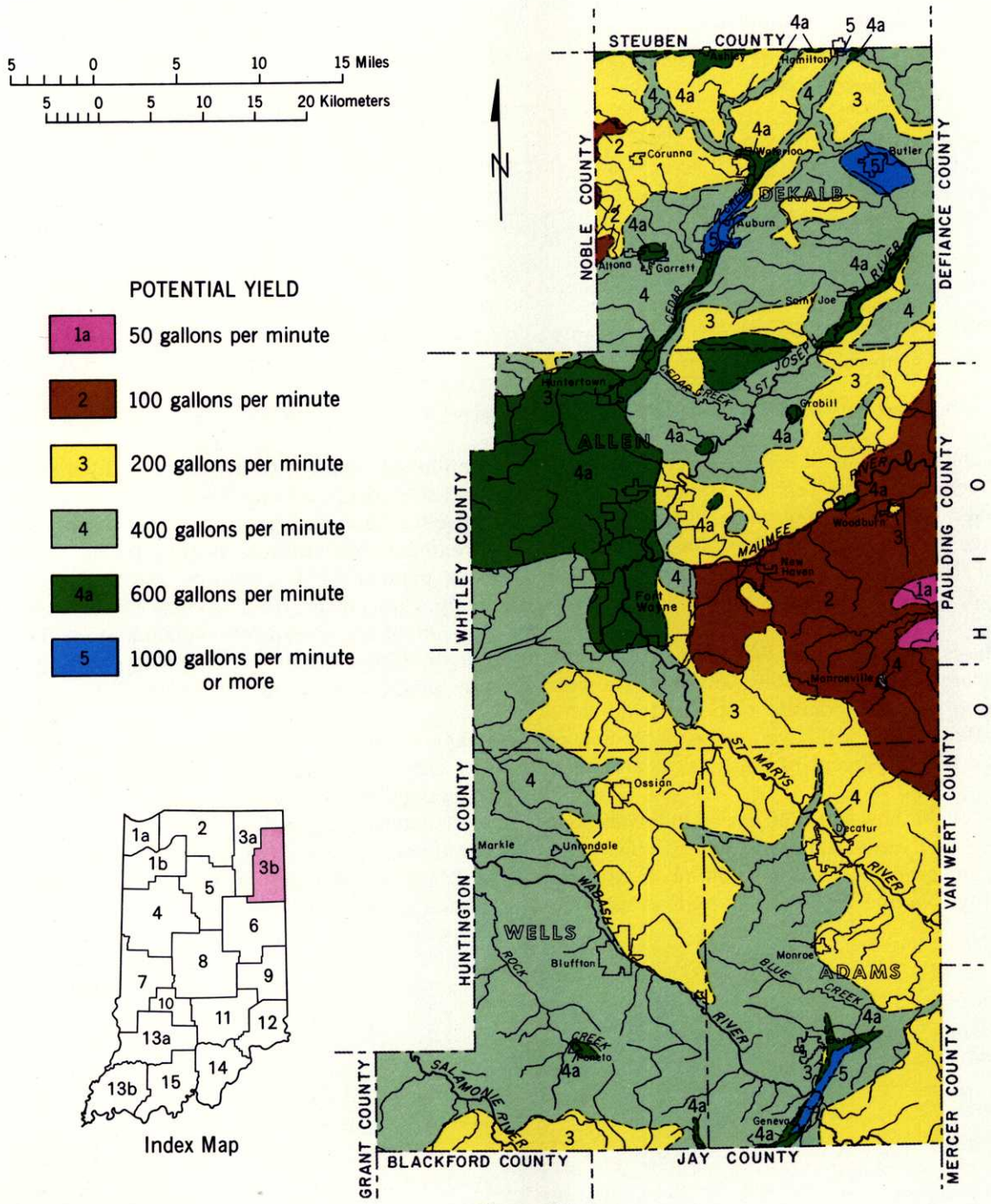


Figure 99

Map of Region Three-B showing the general location and potential yield of ground water from properly constructed large diameter wells.

Table 70
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Cedar Creek at Auburn*	87	43	1.2	0.5
Maumee River at New Haven	1,967	1,000	45.0	31.0
St. Joseph River at Cedarville	763	380	17.0	13.0
St. Joseph River near Fort Wayne	1,060	630	30.0	23.0
St. Joseph River near Newville	610	320	12.0	9.0
St. Marys River at Decatur	621	320	6.1	4.0
St. Marys River near Fort Wayne	762	380	5.8	3.6
Wabash River at Bluffton	532	250	3.3	2.4

*Flow characteristics estimated from a stream gaging station with a short period of record.

The flow characteristics of surface streams indicate that the largest and most reliable streamflow is the Maumee River. The seven day, once in ten year and one day, once in thirty year low flows for the Maumee River reveal that the river has a sustained flow of at least 31 mgd, while the average annual flow exceeds 1,000 mgd.

The St. Marys River near Fort Wayne has an average annual discharge of approximately 380 mgd. The flow duration curve has a moderate slope and indicates that the St. Marys River will have a dependable flow of fourteen mgd ninety percent of the time, as shown in Figure 100.

The slope of the flow duration curve indicates that the Maumee River basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to twenty-seven, sixteen, and eight percent for dry, average, and wet years, respectively. Conversely, from seventy-three to ninety-two percent of the streamflow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or snowmelt.

Lakes The lakes within the region that are at least fifty acres in size or have a storage capacity of 32.5 million gallons or more are presented in Table 71 and are located on Figure 101. These thirteen lakes have a combined surface area of approximately 720 acres with a gross storage capacity of approximately 4,090 million gallons. Included with the region's lakes are

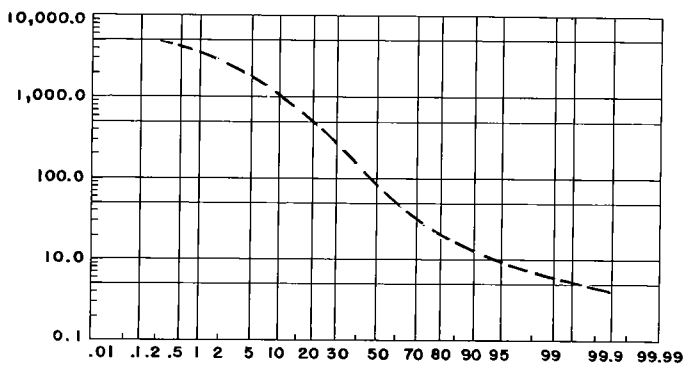


Figure 100
The flow duration curve for the St. Marys River near Fort Wayne.

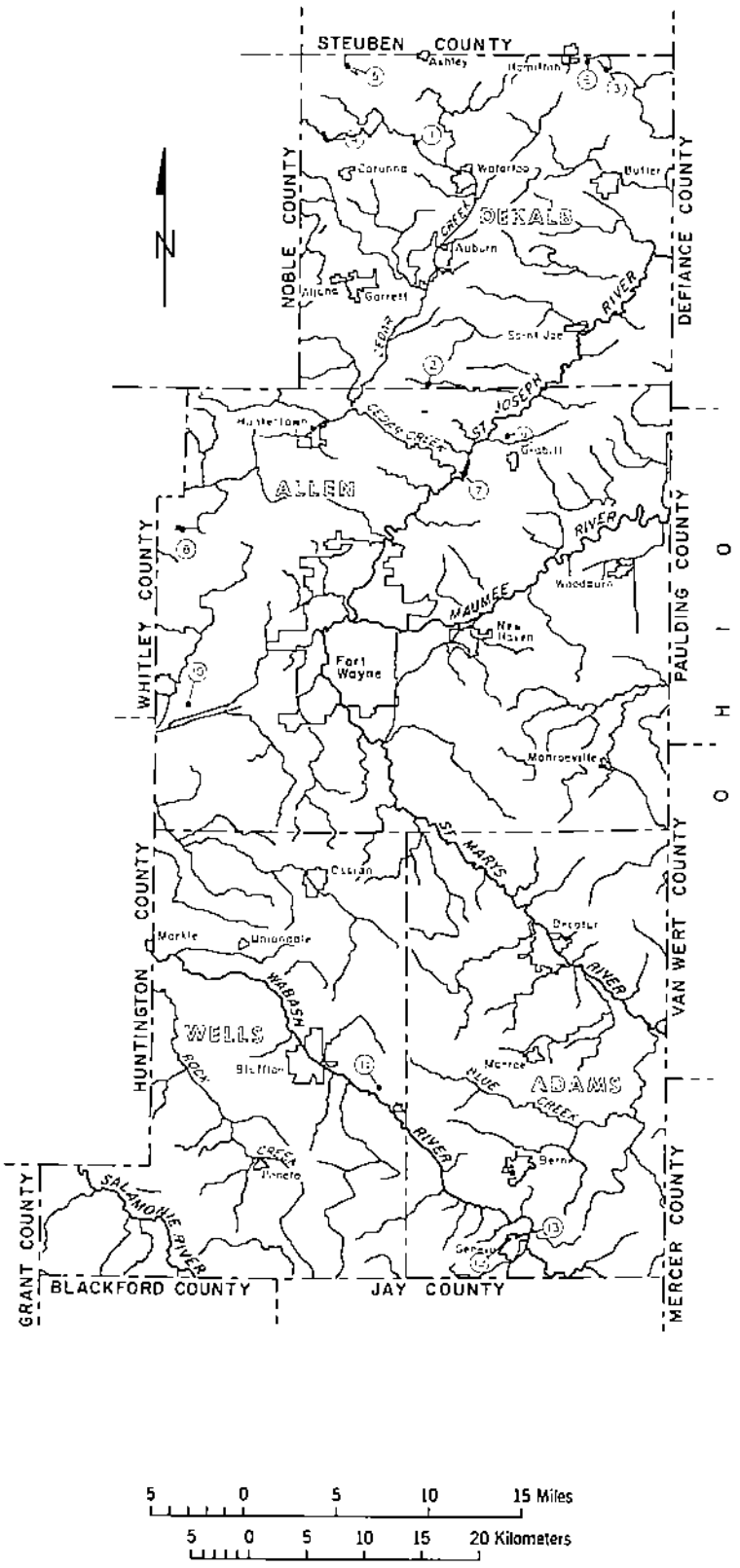


Figure 101
Map of Region Three-B showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

Table 71
Lakes at least 50 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Cedar Lake	23.40	28.0	74
2	Dunton Lake	na	21.0	110
3	Grey Stone Pond	na	na	39
4	Indian Lake	3.76	56.0	397
5	Story Lake	3.16	77.0	332
6	Terry Lake	na	17.0	52
7	Cedarville Reservoir	764.00	366.8	694
8	Everett Lake	1.07	43.0	211
9	Hurshtown Reservoir	na	na	1,889
10	Kekionga Lake	na	na	32
11	Kunkel Lake	na	25.0	48
12	Lake of the Woods	0.26	37.0	61
13	Rainbow Lake	na	51.1	153

na: not available.

the Cedarville and Hurshtown Reservoirs, which are water supply sources for the city of Fort Wayne. Cedarville Reservoir has a storage of 554 million gallons while Hurshtown Reservoir has a storage of 1,889 million gallons.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Three-B is presented in Table 72. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply will exceed the demand. Conversely, when the supply as a percentage of demand is less than one hundred the supply will be less than the projected demand.

Boating and Waterskiing Only one percent of the needs for waterskiing are met by existing recreational facilities. No lakes within the region are suitable for waterskiing. Twenty acres of the St. Joseph River are available for waterskiing. About 1,100 acres of water are available for boating, but this supply will meet only four percent of the projected 1980 demand.

These shortages indicate that recreationists from the region are traveling to other regions to participate in boating and waterskiing activities. Data from the *Origin-Destination and Out-of-State Visitor Study*, compiled for the Department of Natural Resources, suggests that Region Three-B residents are traveling to Region Three-A to meet their water based recreation needs.

Canoeing Canoeing is available along forty miles of the St. Joseph River, thirty-nine miles of the Wabash River, and fourteen miles of Cedar Creek. The St. Joseph River and Cedar Creek present the most natural conditions for canoeing. Cedar Creek has been designated for protection under Indiana's Natural Scenic and Recreational Rivers System for the fifteen miles above the confluence with the St. Joseph River. The

Table 72
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	30	19.6 boats/acre/year	1,100 acres	4	4	4
Waterskiing	13	34.4 skiers/acre/year	20 acres	1	1	1
Canoeing	12	585 canoes/mile/year	93 miles	100+	100+	100+
Swimming	48	76,600 swimmers/acre/year	3 acres	11	10	9
Ice-Skating	13	6,678 skaters/acre/year	29 acres	100+	100+	100+
Fishing	44	66 persons/acre/year	3,500 acres	12	11	11

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands by residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

supply of ninety-three miles of available canoeing streams and rivers is adequate to meet the region's demand for canoeing opportunities through the year 2000.

Swimming and Ice-Skating The demand for swimming opportunities currently exceed the available supply and may continue to exceed the supply through the year 2000. Ice-skating opportunities within the region are abundant. The projected demand is expected to be met by the current supply through the year 2000.

Fishing The quality of the fisheries habitat is indicated in Figure 102. The upper St. Joseph River, Cedar Creek, Eightmile Creek, Fish Creek, and the Salamonie River are noted for the best stream fishing in the region, although good aquatic habitat is also found in other streams. Because spawning is limited in the Wabash and St. Marys Rivers, the smaller tributaries maintain the game fish populations. Bluegill, smallmouth bass, catfish, and other warmwater species comprise the fishery resource.

Most lakes are bordered by residential development. The undeveloped shoreline is associated with deep marshes and swamps and is used by some fish for spawning. Warmwater fish also comprise lake fisheries. The most notable game fish are bluegill and largemouth bass. Aquatic habitat is good in all the lakes but limited mainly by water quality.

State-owned access for fishing is provided on Story Lake in DeKalb County. Otherwise public access is limited to roadways and bridges.

Region Three-B's supply of fishing lakes and streams for public use meets only twelve percent of the demand. By the year 2000, eleven percent of the projected demand may be fulfilled. Use of fishing waters in other regions, especially Region Three-A, is expected to compensate for the shortages.

Riparian Habitat The quality of the riparian habitat associated with streams is shown in Figure 103. Riparian habitat is rated from moderate to good on most large streams, with the best habitat occurring along the St. Joseph River and Cedar Creek in northern Allen and DeKalb Counties. Significant wetlands are limited to the undeveloped shorelines of natural lakes in the region. The expanding residential construction has become a primary limiting factor to wildlife habitat in the region. Areas of sufficient habitat support and are frequented by resident and migrant waterfowl, other birds, high populations of furbearers (especially raccoon and muskrat), and most native upland game. Hunting is not available on state properties within the region.

Hydroelectric Power Up-River Dam is the only hydroelectric plant located in Region Three-B. The dam is located on the St. Joseph River in Allen County, and is capable of producing 175 kilowatts. The plant is owned by the Fort Wayne Municipal Utility which uses the power to operate pumps for movement of water to a filtration plant. The potential for developing additional hydroelectric plants in the region is minimal.

Withdrawal Uses

Public Water Supplies Adams, Allen, DeKalb, and Wells Counties are served by twenty-five public water utilities. An estimated 259,000 persons or sixty-nine percent of the population was served by a public utility in 1975. Allen, DeKalb, Adams, and Wells Counties contain twelve, six, four, and three public water utilities respectively.

The Fort Wayne Water Utility, the largest in the region, supplies an average of 28.8 mgd to approximately 185,300 customers. Auburn is the second largest, withdrawing an estimated 2.2 mgd. The four largest utilities in the region account for approximately twenty-five percent of the public water withdrawals in the region. The twenty-five public water utilities withdrew an average of 38.0 mgd in 1975. Maximum daily withdrawals are estimated at 65.3 mgd. The water service areas are shown in Figure 104.

The majority of public water utilities depend upon ground water as a source of supply. Most of these towns obtain their water from well fields located in or close to the corporate limits, although Decatur obtains its water from a well field located nearly fourteen miles from town. Fort Wayne obtains water from the St. Joseph River and Cedarville Reservoir to meet its present needs, and may utilize the Hurshtown Reservoir to supply future demands. New Haven purchases water from the Fort Wayne system. Bluffton obtains parts of its water needs from the Wabash River and the remainder from ground water.

Projections of public water supplies indicate that withdrawals of the region's public water supplies should increase to about 55.8 mgd by the year 2000 as shown here.

Table 73

The 1977 and projected water withdrawal and consumption rates of public water supplies, in million-gallons-per-day.

Public Water	*1977*	*1980*	*1990*	*2000*
Withdrawal	38.0	40.2	48.4	55.8
Consumption	3.8	4.0	4.8	5.6

Industrial Water Industrial establishments had an estimated water intake averaging 62.3 mgd in 1977. Ten mgd of the intake was consumed. Of the total indus-

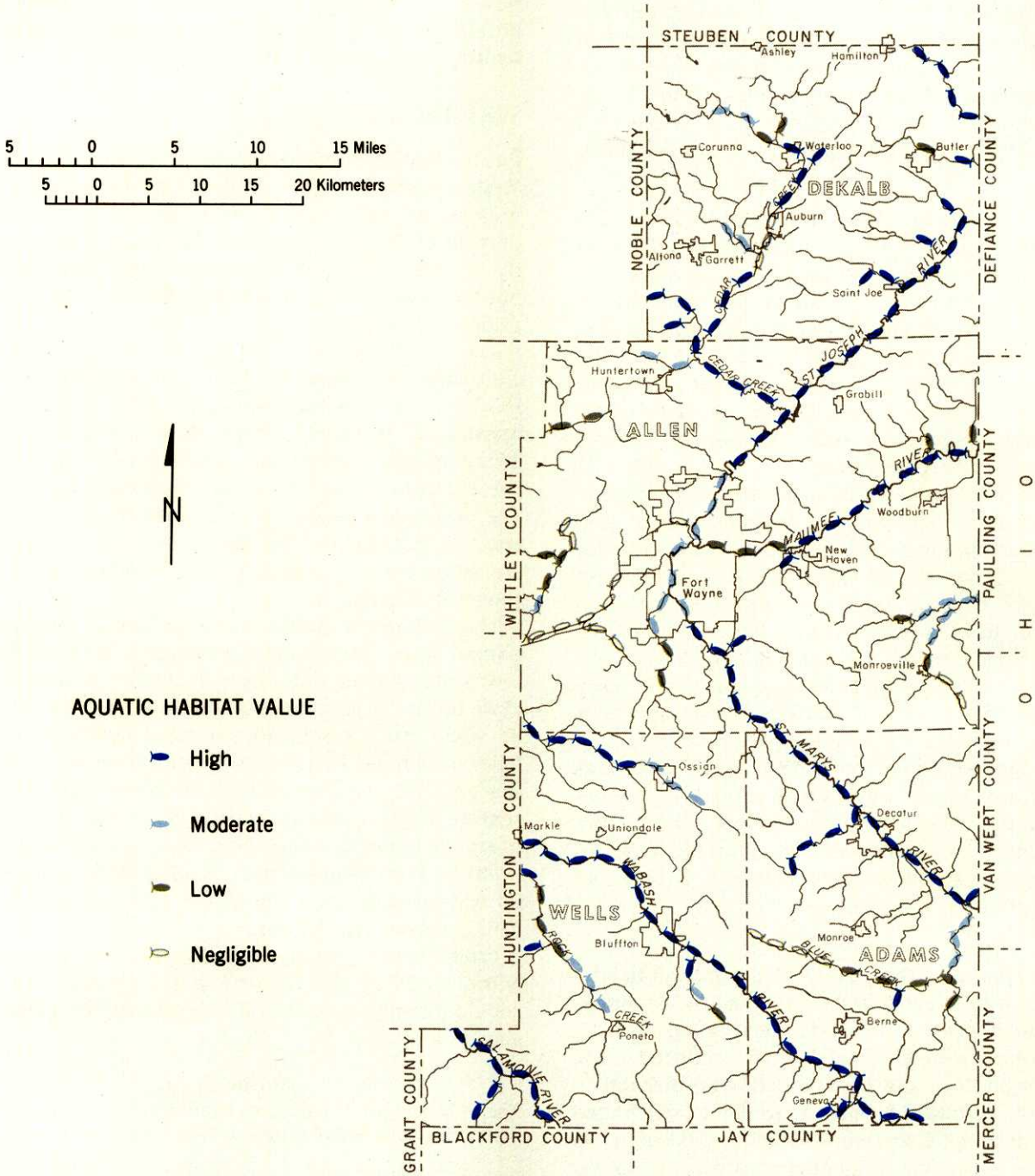


Figure 102
Map of Region Three-B showing the quality of the fisheries habitat.

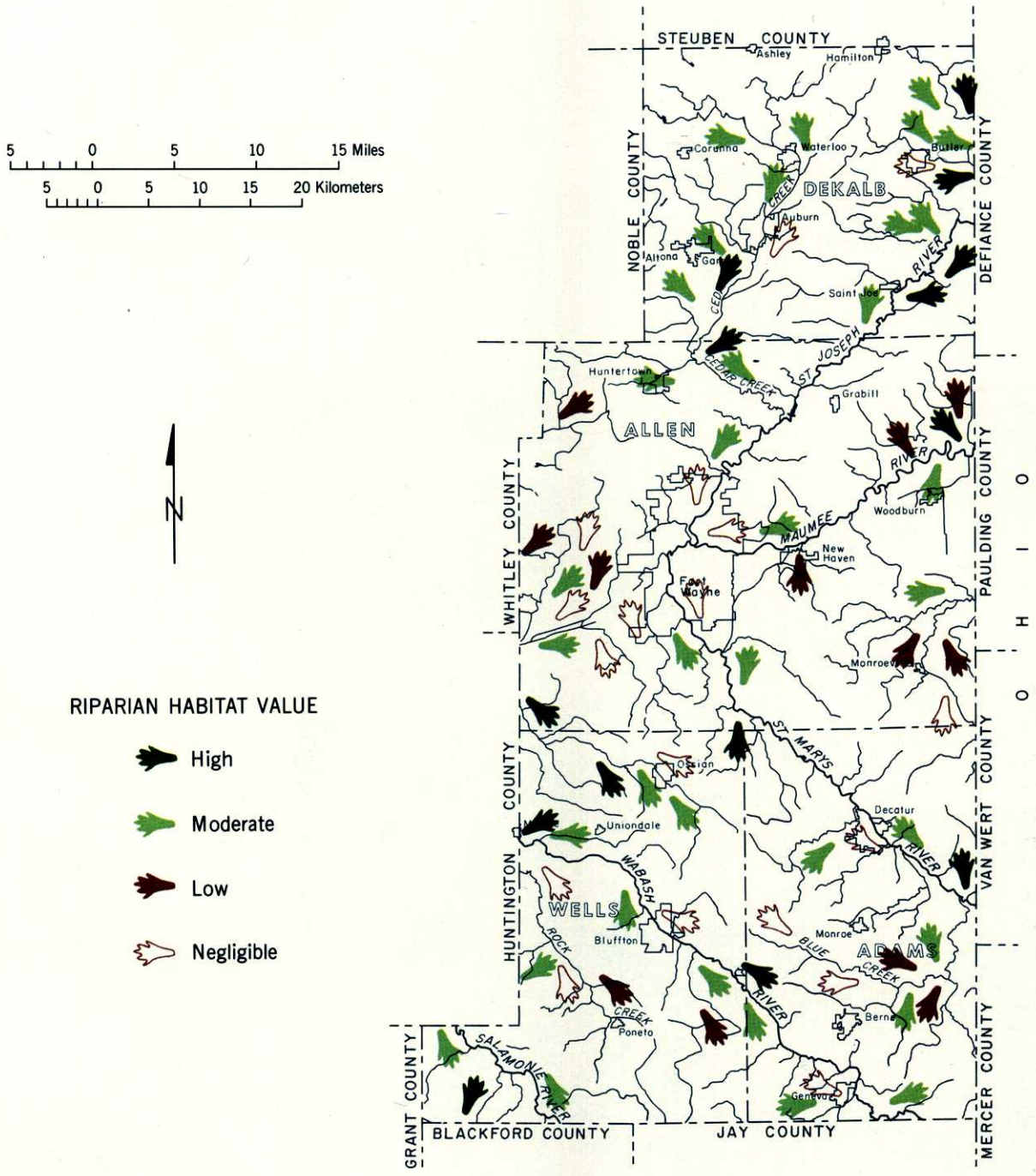


Figure 103
Map of Region Three-B showing the quality of the riparian habitat.

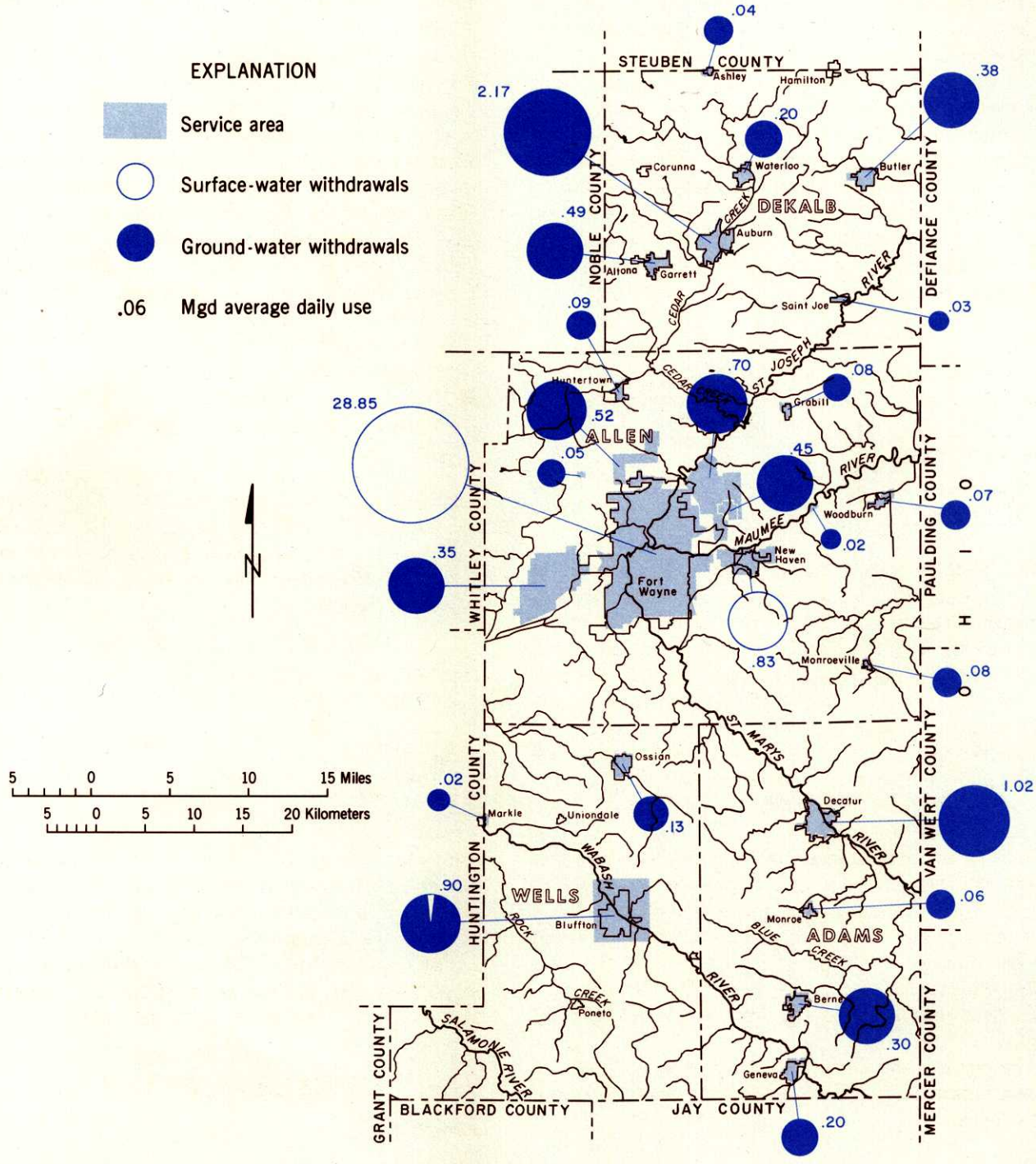


Figure 104

Map of Region Three-B showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

trial intake, approximately 39.7 mgd is self-supplied while approximately 22.6 mgd is purchased from public water utilities. Most of the self-supplied water is withdrawn from ground-water sources.

Small industries withdrew approximately 29.0 mgd in 1977. Processors of food and related products withdrew over 13.0 mgd.

Growth in industrial production over the next twenty-five years could result in an increase of water withdrawal to 69.0 mgd by the year 2000. The self-supplied component is expected to increase to nearly 48.0 mgd. Total industrial water intake is expected to fall initially due to increased plant efficiency and then increase slowly as output increases. Information of industrial self-supplied withdrawals are presented in the following table.

Table 74
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	39.7	39.9	43.7	47.8
Consumption	6.4	7.0	9.6	12.8

Rural Self-Supplied Water The majority of rural self-supplied water is withdrawn from ground-water sources. An estimated 114,000 persons lived in homes supplied by individual wells in 1975. It is estimated that these residents withdrew approximately 6.7 mgd during 1975. By the year 2000, an estimated 39,400 additional persons may withdraw ground water for household use. These residents, along with the anticipated general rise in the standard of living, are expected to increase rural water use to about 11.5 mgd by the year 2000.

In 1975, an estimated 309,000 head of livestock and about 906,000 chickens and turkeys were raised in Region Three-B. Collectively, these animals consumed approximately 2.1 mgd. The amount of water required by the domestic animal population may increase to approximately 2.4 mgd by the year 2000. The water for animals is usually withdrawn from wells on individual farms.

The current and projected withdrawals and rates of consumption for rural self-supplied water are tabulated here.

Table 75
The 1977 and projected withdrawal and consumption rates of self-supplied rural water, in million-gallons-per-day.

Rural Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	9.2	9.8	11.9	13.9
Consumption	9.2	9.8	11.9	13.9

Irrigation Water The few areas of soil associations with irrigation potential within Region Three-B are mainly located in river valleys, as shown by Figure 105. Based upon the survey of irrigated lands, approximately 839 acres were irrigated in the region in 1977. Assuming 1977 as a normal growing year, these crops would have required about 2.2 mgd during the peak irrigation period of July and August.

It is estimated that 15,000 acres of croplands could be profitably irrigated. Approximately 2,000 acres may be irrigated by the year 2000. This expansion of cropland acreage may increase the peak July and August irrigation demand in an "average" season to 5.2 mgd. The "average" season increase in ground-water withdrawal for the irrigation of croplands may increase from the current 0.4 mgd to 2.6 mgd by the year 2000.

In addition to the irrigation for agricultural use, water is withdrawn to irrigate fairways and greens on the region's golf courses. About 2.2 mgd is applied to these areas during the peak July– August irrigation period.

The total withdrawal for the irrigation of croplands and golf courses during the "average" irrigation season of 1977 was approximately 4.4 mgd. These withdrawals may increase to 8.2 mgd during the "average" irrigation season by the year 2000 as tabulated here.

Table 76
The 1977 and projected withdrawal of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	4.4	4.9	6.6	8.2
Consumption	4.4	4.9	6.6	8.2

Electric Energy Up-River Dam, a hydroelectric power facility, is the only generating station located in the region. It does not require water withdrawals and is, therefore, discussed within "Instream Uses."

There are no rivers in the region that possess a sustained streamflow capable of supporting generating stations of the type currently being built.

EXCESS WATER

Flooding

Approximately 31,700 acres of the region are subject to flooding. The major flood plains are shown in Figure 106. The flood plains of these rivers are broad and prone to frequent and severe flooding, particularly in winter and spring. Floods in these areas usually occur when warm rain falls on frozen or snow-covered ground, and runoff from these storms often exceeds

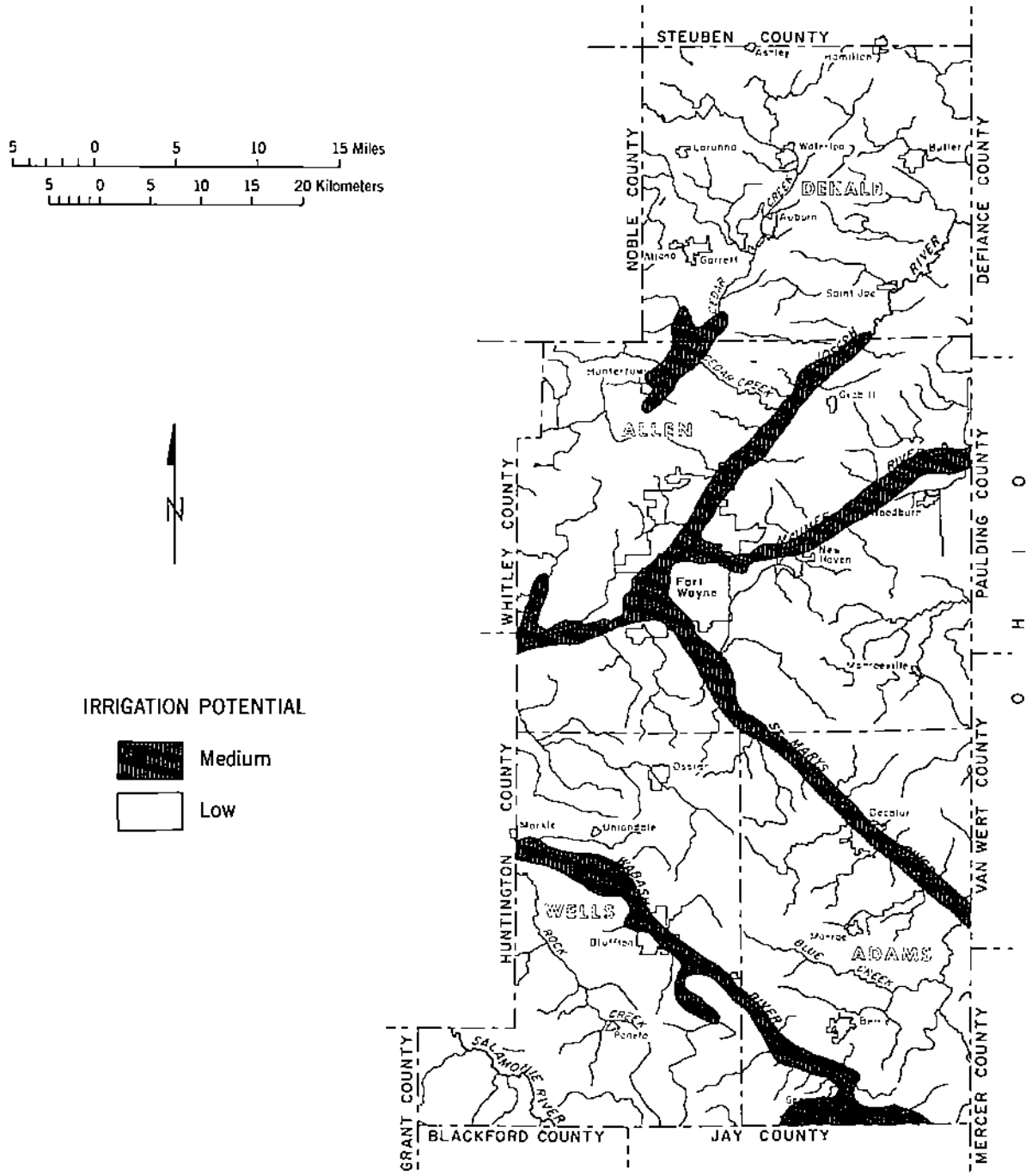


Figure 105
Map of Region Three-B showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

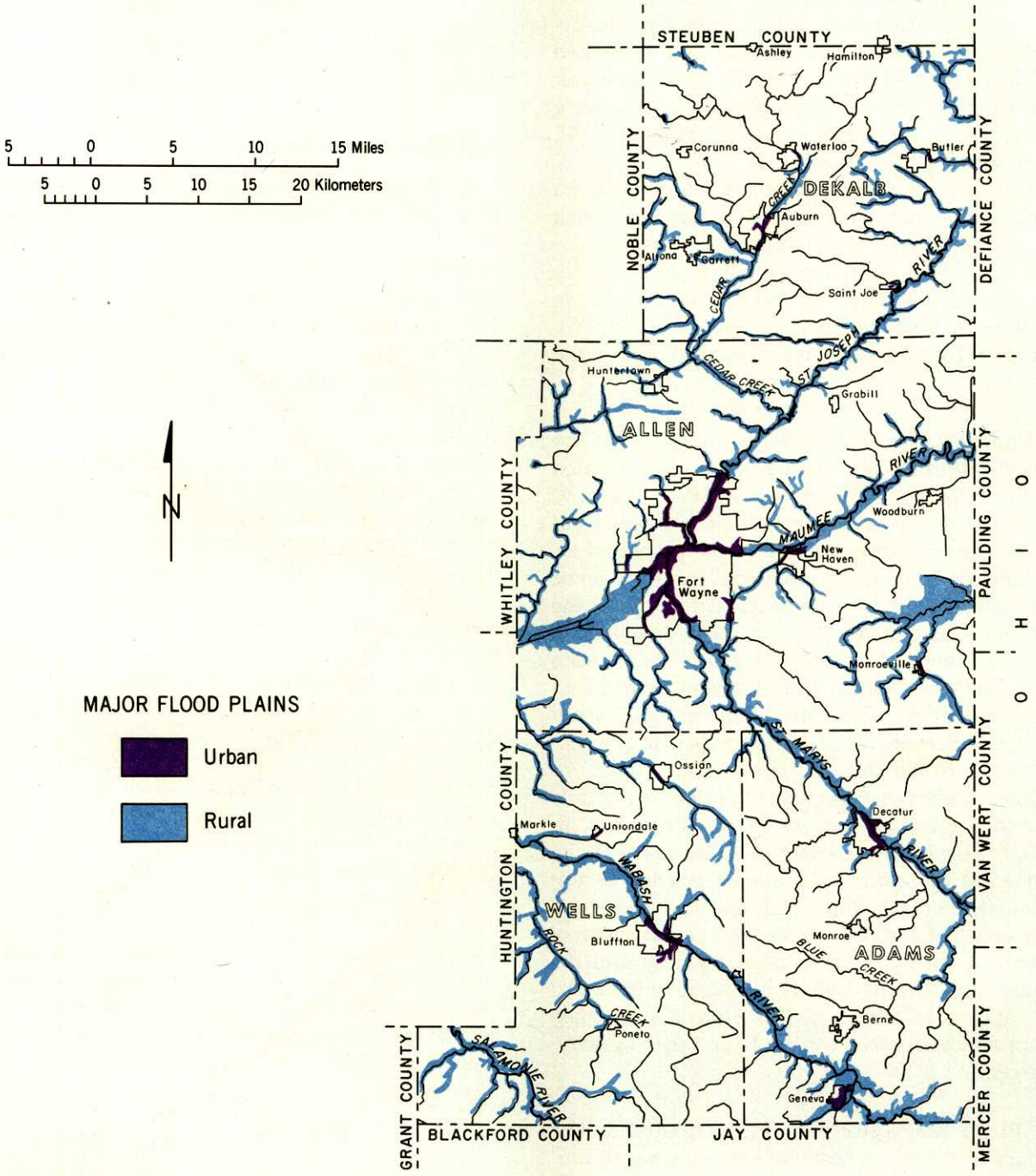


Figure 106
Map of Region Three-B showing the major floodplains.

the capacities of the major waterways. Winter flooding problems are sometimes complicated by ice jams. Flooding along the smaller streams and ditches can occur any time during the year, but it is most prevalent during the late fall and early spring.

Figure 107 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $10,241,000, of which some eighty-four percent occurred in urban areas. These damages were concentrated in the Maumee River Basin, the St. Joseph River, and the Wabash River.

The major rivers usually exhibit a low to medium slope which increases the potential for flooding. When storms are localized over one of the rivers, the Maumee or a tributary may flood while nearby rivers remain inbank. Flooding may occasionally occur in the St. Joseph River when floodwater from the St. Marys cuts across the fairly level terrain between the two rivers.

Flood Control The Fort Wayne levee system is the only flood control project in the region. It is located along the St. Joseph, Maumee, and St. Marys Rivers to help confine streamflow during periodic high water. Although flooding is prevented within the protected localities, the areas up and downstream can experience flooding as the water spreads out at either end of the levee system. Levees also tend to foster the illusion that an area protected by such a system is secure from flooding. Constant maintenance is needed in order to prevent tree roots and burrowing animals from weakening the levees. Such maintenance is particularly essential in the Fort Wayne system.

The Rock Creek Small Watershed Project is the only such project within the region. The major works include 24.1 miles of debris removal on Mossberg Drain. Supplemental additions to reduce the adverse environmental effects include 14.7 miles of one-sided channel construction, fish pools throughout most of the length of the Rock Creek main channel, and the replanting of approximately fifty-one acres of trees and shrubs adjacent to the berm. This project is designed to reduce floodwater damages on Rock Creek by sixty-four percent.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include the unincorporated areas of Adams, Allen, DeKalb, and Wells Counties as well as the communities listed in Table 77. Garrett, Ossian, Ponets, and Uniondale are participating in the regular phase of the National Flood Insurance Program. Residents in these areas can purchase insurance against property losses due to flooding.

Table 77
Communities participating in the emergency phase of the National Flood Insurance Program.

Altona	Geneva
Auburn	Huntertown
Bluffton	New Haven
Butler	St. Joe
Decatur	Vera Cruz
Fort Wayne	Waterloo

Agricultural Drainage

Approximately fifty-two percent of the soil associations in Region Three-B have "severe," forty-one percent have "moderate," while seven percent have "slight" wetness characteristics. The soil associations with these wetness characteristics are shown in Figure 108. The few areas that do not require drainage in order to maximize crop production are located in the northern and central parts of the region along the St. Joseph, Maumee, and St. Marys Rivers and, in the southern portion, along the Wabash River.

There are approximately 5,505 miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards or, in a limited number of instances, of conservancy districts. Inadequate maintenance can limit the effectiveness of the system. No legal entity exists to maintain drainage along the other streams in the region.

Soil Erosion

The erosion potential of soil associations is shown in Figure 109. Thirty-five percent of the 1,118,600 acres is rated as having a "medium" soil erosion hazard potential. These areas are located primarily in the northwest corner of DeKalb County, the central portion of Allen County, along the north bank of the Wabash River, Salamonie River and Rock Creek in Wells County, and in the northwest and southeast corners of Adams County. The remaining sixty-five percent of the land is predominantly level and has a "low" erosion potential.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the Maumee, St. Marys, Wabash, and St. Joseph Rivers and Cedar Creek. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

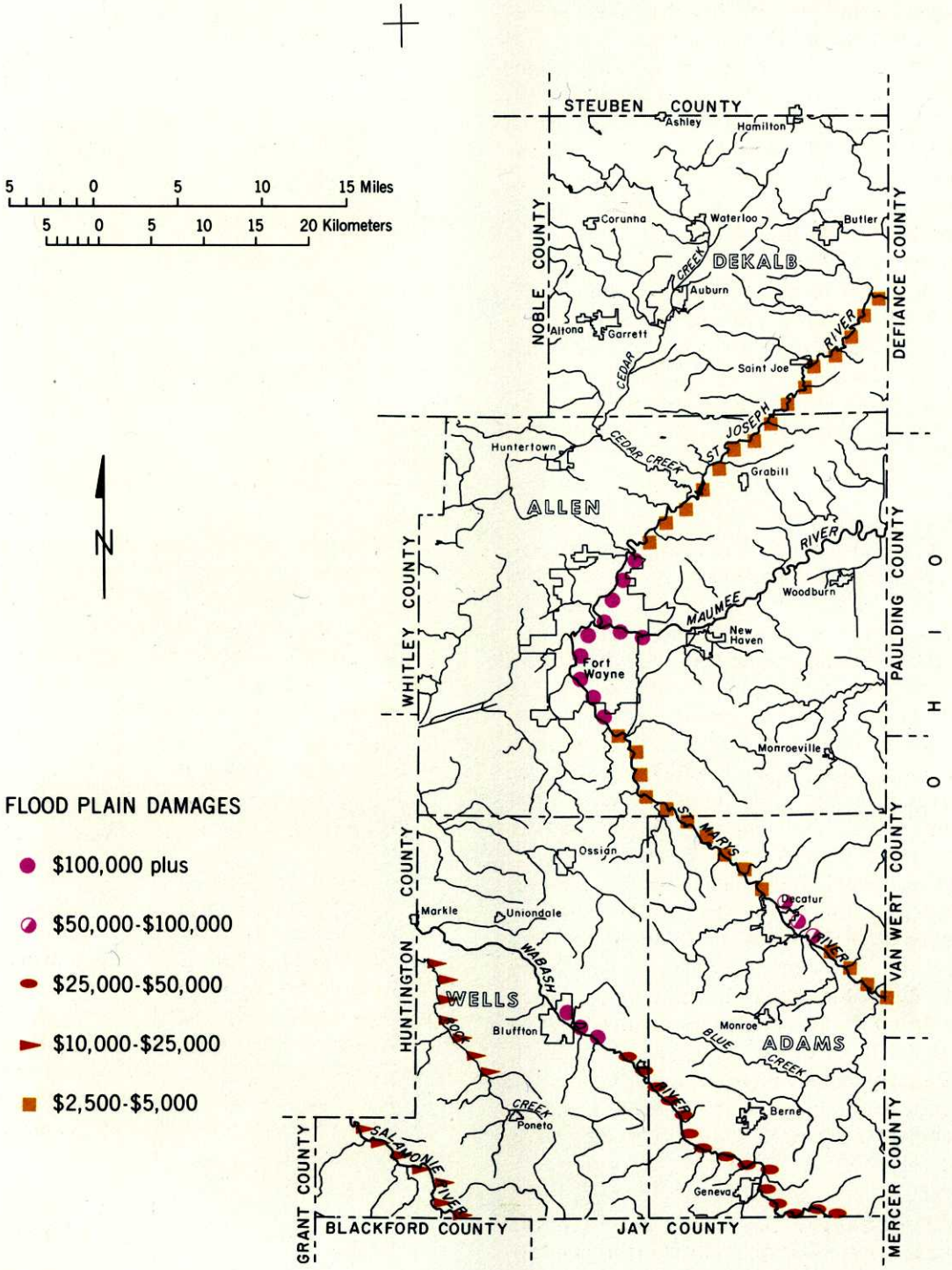


Figure 107
Map of Region Three-B showing the estimated average annual flood damages per mile along selected streams.

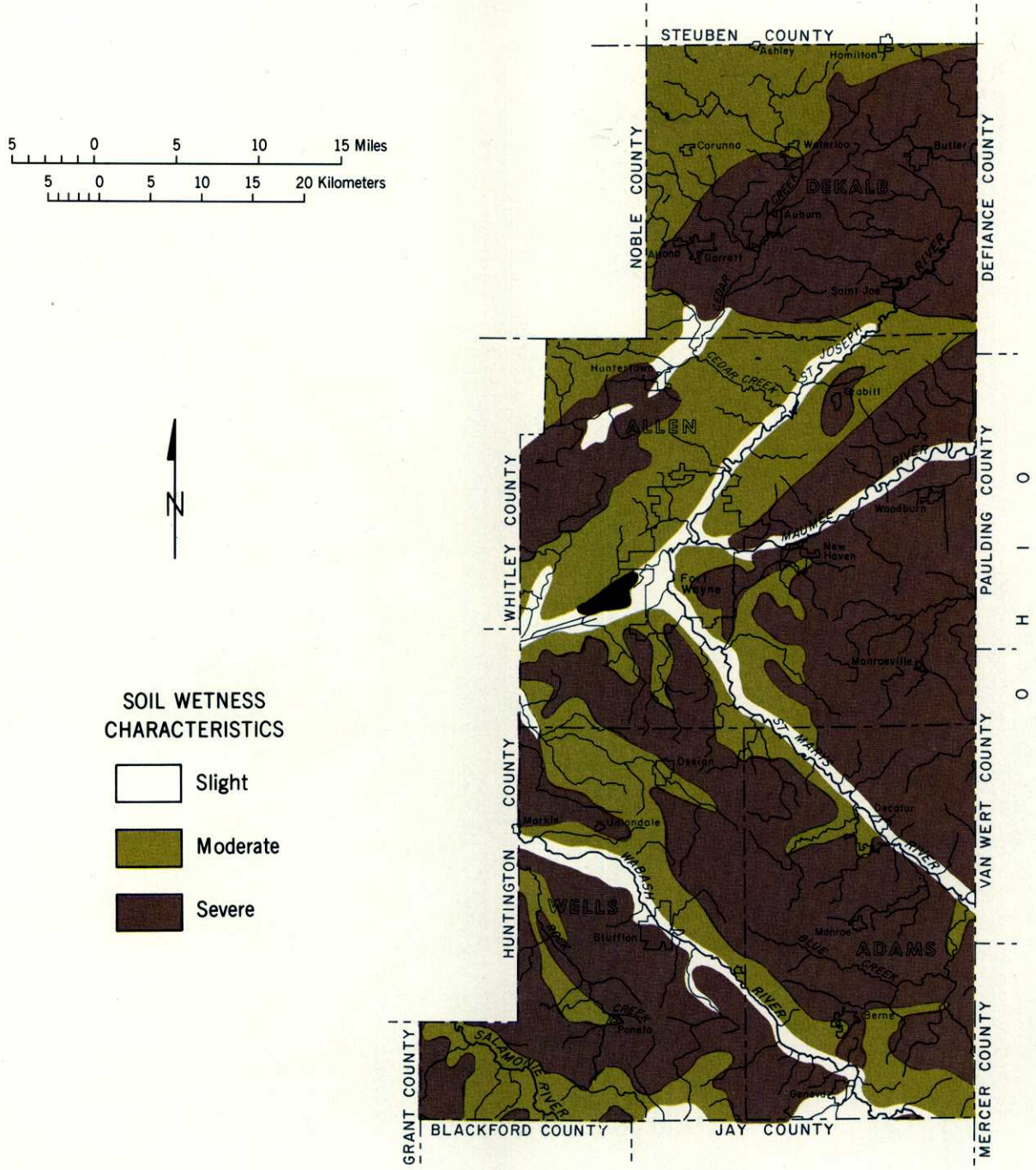


Figure 108
Map of Region Three-B showing the general location of the wetness characteristics of soil associations.

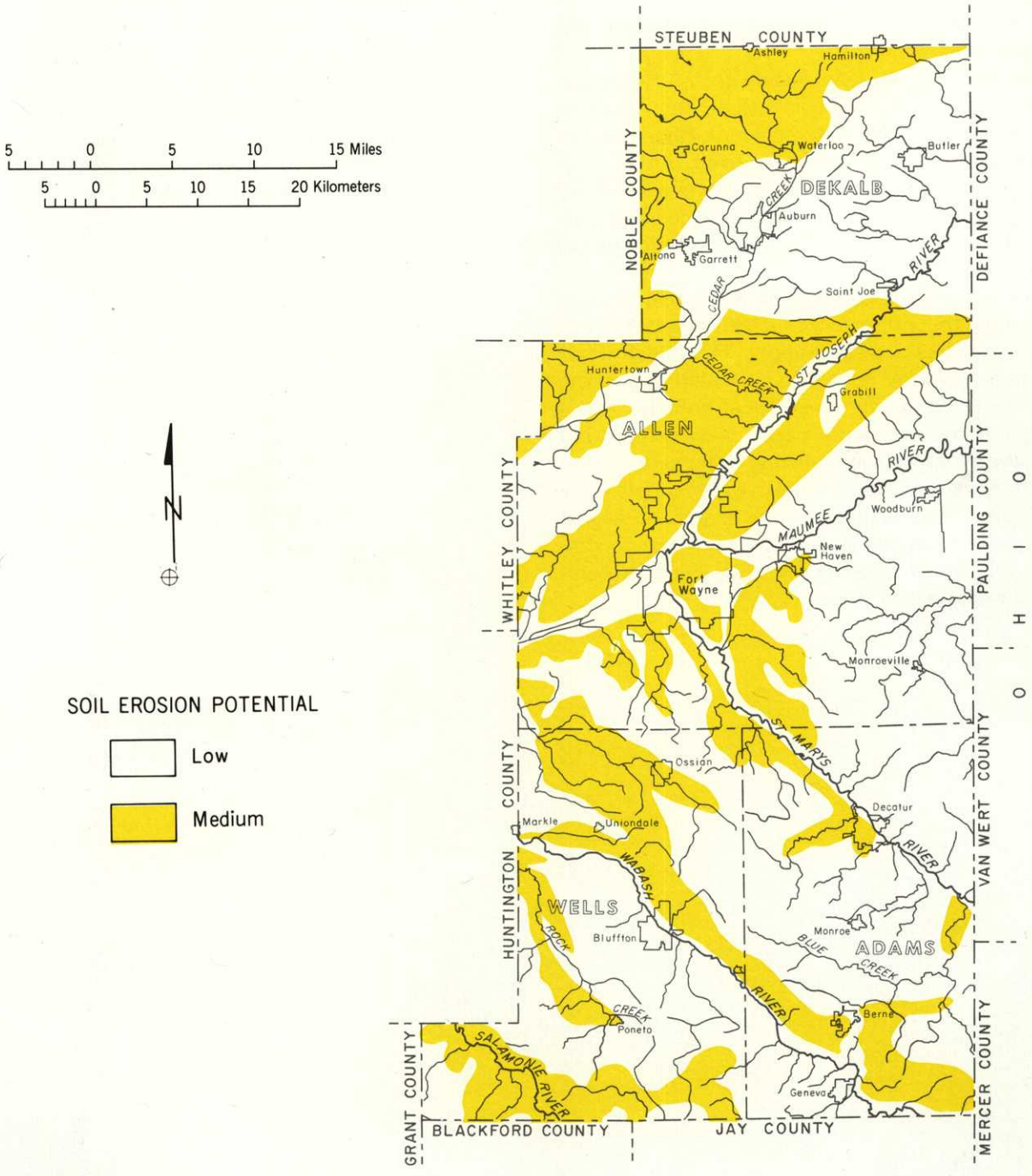


Figure 109
Map of Region Three-B showing the erosion potential of the soil associations.

Water quality in the St. Marys River at Ft. Wayne indicated that dissolved oxygen concentrations, temperature, and pH, were in compliance with the standards. Nitrate values were high in May and June and were very close to exceeding the suggested limit for drinking water. Fecal coliform bacteria levels met the criteria for partial body contact with occasional minor violations.

The Maumee River's water quality at New Haven had minimum dissolved oxygen levels in August which were in violation of the state standard. High levels of biochemical oxygen demand occurred during June through August, indicating water quality was adversely affected by upstream discharges. Fecal coliform bacteria levels were in excess of those allowed for partial body contact.

The water quality of the Wabash River near Bluffton should meet the criteria for drinking water since Bluffton uses it as a water supply. The major water supply problems were related to the coliform bacteria and nitrate levels in the river. Fecal coliform levels generally met the criteria for partial body contact, but total coliform limits set for drinking water supply were exceeded. Nitrate levels for public water supply were also exceeded occasionally. In the month of August 1975, dissolved oxygen levels fell below the recommended criterion but generally have been in compliance the rest of the time.

Water quality assessment for the St. Joseph River indicated that all water quality indicators were within state standards. However, problems did arise in localized tributary streams where inadequately treated effluents occurred.

The combined discharges of industrial and municipal effluents decreased the levels of dissolved oxygen in Cedar Creek. The values did, however, remain above minimum standards and no unusually high biochemical oxygen demand values were noted in the stream.

The tropic classification of those lakes surveyed by the Stream Pollution Control Board in Region Three-B are indicated in the following table.

Table 78
Trophic classification of lakes surveyed.

Lake	*County*	*Age Classification*
Cedar	DeKalb	II
Dunton	DeKalb	II
Everett	Allen	III
Indian	DeKalb	II
Lintz	DeKalb	III
Story	DeKalb	III
Viberg	Allen	II
White	Allen	II

Region Four

Benton, Carroll, Clinton, Fountain, Montgomery, Tippecanoe, Warren, and White Counties, located in west-central Indiana, form Region Four. The region contains approximately 3,459 square miles and is bounded by Illinois to the west; Newton, Jasper, and Pulaski Counties to the north; Cass, Howard, Tipton, Boone, and Hendricks Counties to the east; and Putnam, Parke, and Vermillion Counties to the south, as shown in Figure 110.

The 1975 population of Region Four was 254,499, of which forty-four percent resided in Tippecanoe County. The official Indiana Population Projections indicate that by the year 2000 the region's population may increase by almost fourteen percent, with the greatest growth in Tippecanoe County. The 1975 population and projections for each county are presented below.

Table 79
The 1975 and projected populations for Region Four.

County	*1975*	*1980*	*1990*	*2000*
Benton	10,828	10,880	10,500	10,200
Carroll	17,962	19,100	21,000	23,200
Clinton	30,518	31,100	31,300	31,300
Fountain	18,419	19,000	19,500	19,600
Montgomery	34,444	35,100	36,700	37,600
Tippecanoe	112,408	117,600	127,000	134,100
Warren	8,290	8,600	8,700	8,800
White	21,630	23,200	25,300	27,400
Total	254,499	264,500	280,000	292,200

The major population centers within the region are Lafayette and West Lafayette in Tippecanoe County,

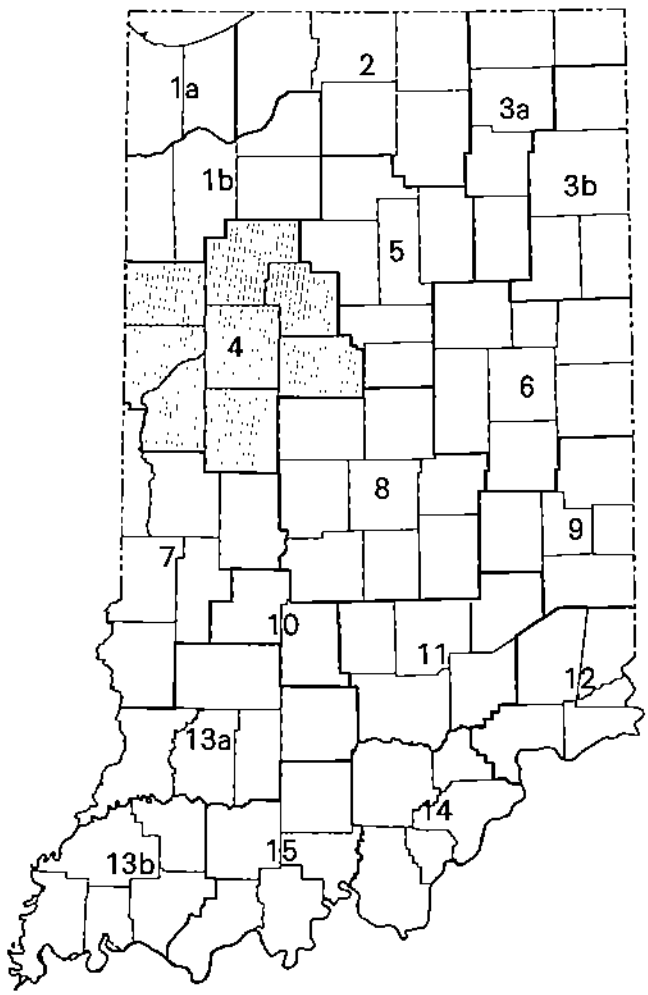


Figure 110
Map of Indiana showing the location of Region Four.

Frankfort in Clinton County, and Crawfordsville in Montgomery County. These cities accounted for thirty-seven percent of the 1975 population.

Agriculture is the dominant land use within the region with more than eighty-five percent of the area devoted to farming purposes. Approximately six percent of the land is forested, while the remaining nine percent is urban and of miscellaneous character.

Although agriculture is by far the most significant land use, it is not the major source of employment. Nonmanufacturing activities, including wholesale and retail trade, services, and government employ fifty-four percent of the work force. Manufacturing employs thirty-six percent of the work force. The three largest industrial employers are electrical machinery, primary metals, and printing. More than fifty percent of the region's work force is employed in Tippecanoe County.

The region receives approximately 37.5 inches of precipitation annually. This varies from a high of 4.3 inches in May, June, and July to a low of 2.0 inches in February. Of the 37.5 inches of precipitation, approximately 11.5 inches appear as streamflow while 26.0 inches are consumed through evapotranspiration.

Region Four has a moderate temperature with monthly averages ranging from 26°F. in January to 74°F. in July. The average annual temperature is 51.5°F. The annual prevailing wind, determined by averaging data from surrounding regions, is from the southwest at 10.0 miles per hour.

THE WATER RESOURCE

Ground Water

The occurrence of ground water in Region Four is controlled largely by the effects of glaciation, especially the Wisconsinan glacial advance. The unconsolidated deposits consist of till, outwash sand and gravel, wind-blown sand, and alluvium. The thickness of these materials varies from less than ten feet to over four hundred feet. The deeper deposits are associated with the buried Teays River Valley which contains variable amounts of glacial till, sand and gravel, and fine sand. Elsewhere, glacial till predominates in areas away from the major stream valleys, while extensive outwash and valley train sand and gravel are found adjacent to the Wabash River, Tippecanoe River, and Wildcat Creek. Windblown sand occurs at the surface in northern White County and overlies the till and outwash deposits.

In areas where the unconsolidated deposits are thin or do not contain adequate ground water supplies, wells are completed in the underlying bedrock. These sedimentary rocks range in age from the older Silurian limestone and dolomite sequence through the Pennsylvanian age sandstone, shale, and coal deposits. Silurian and Devonian limestones and dolomites make up the most important bedrock aquifers. The Mississippian and Pennsylvanian bedrock units generally have lower permeabilities and do not readily yield water.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In this region, there is a pronounced variability in ground-water occurrence from west to east, as shown in Figure 111.

In significant portions of Benton, White, Warren, Tippecanoe, Fountain, and Montgomery Counties, the scarcity of adequate sand and gravel zones and the low water-yielding potential of the bedrock usually limits well yields to less than 100 gallons-per-minute (gpm). Several areas, most notably in northwestern White County and parts of Warren and Fountain Counties, have very poor ground-water potential. Well yields up to 10 gpm appear to be a maximum, with some dry holes reported. Potentially higher yields, of 400 to 1,000 or more gpm, are possible in areas near the Wabash River or in the buried Teays drainage system. The Teays Valley is currently under study and additional information will be available in the future. In areas around and east of Lafayette, properly constructed wells can produce from 200 to 600 gpm, with sand and gravel deposits and limestone and dolomite bedrock being the main sources of water. Well yields of up to 2,000 gpm can be obtained in saturated sand and gravel deposits associated with the Wabash River in the Lafayette and West Lafayette area.

Ground-water hardness within the region is normal (300 to 400 parts-per-million) with iron ranging from 0.2 to 1.5 ppm. Iron is low enough in Lafayette to preclude the need for iron removal while West Lafayette, across the river, controls iron by chemical treatment. Other communities having higher iron concentrations utilize iron removal plants. High sulfur concentrations exist in wells in portions of White, Carroll, Tippecanoe, and Benton Counties.

Surface Water

Streamflow Most of the region is within the Wabash River basin except northern Benton and White Counties, which are drained by the Iroquois River system. Flowing in a northeast to southwest direction, the major streams are Sugar Creek, Big Pine Creek, Wildcat Creek, Tippecanoe River, and the Wabash River. Big Pine Creek and Sugar Creek originate within the region.

The seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and average annual flow in million-gallons-per-day (mgd) for streams with gaging stations in Region Four are presented in Table 80.

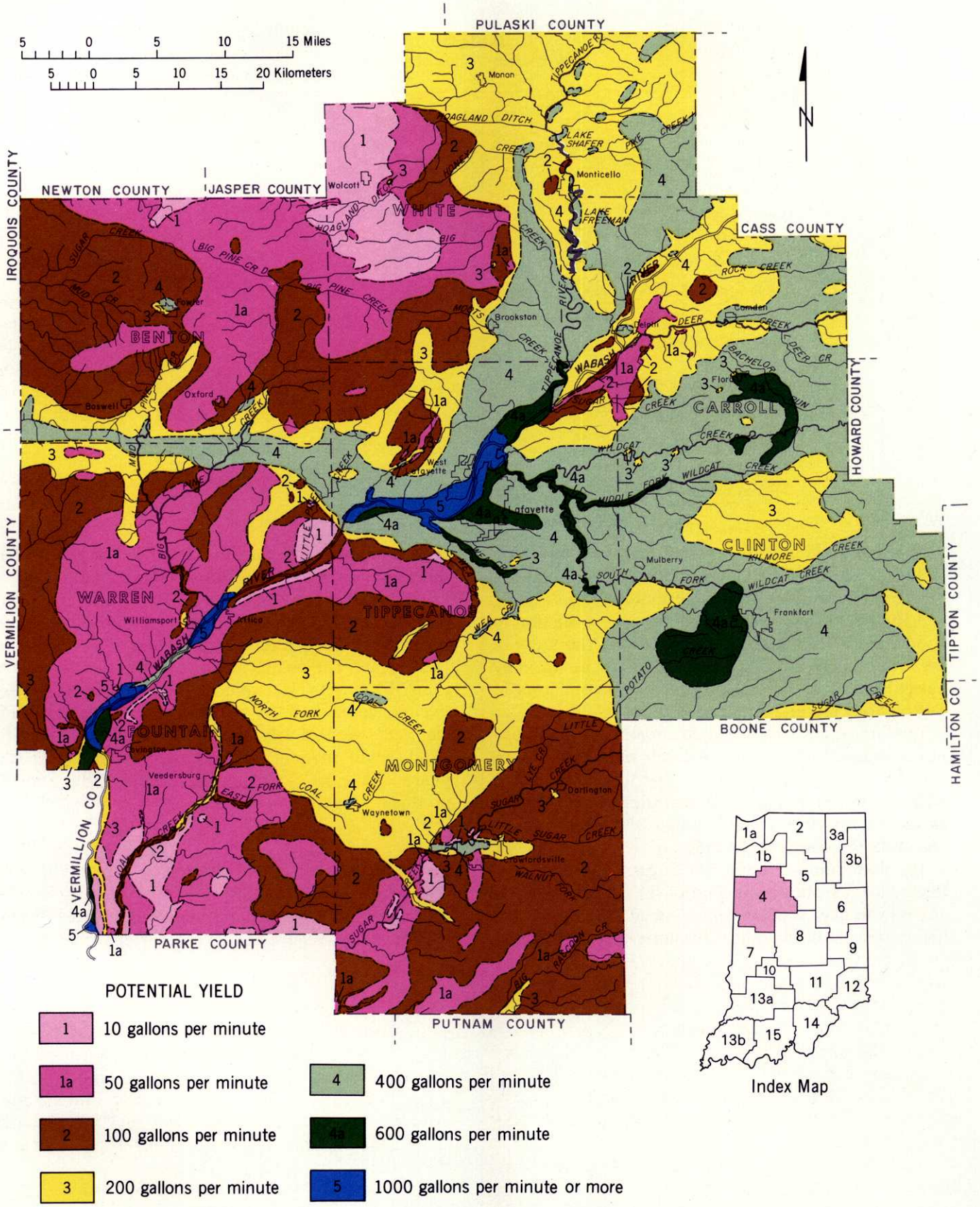


Figure 111
Map of Region Four showing the general location and potential yield of ground water from properly constructed large diameter wells.

Table 80
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Big Pine Creek near Williamsport	323	160	5.1	3.5
Coal Creek at Coal Creek	214	na	3.0	na
Deer Creek near Delphi	274	146	6.0	4.2
Sugar Creek at Crawfordsville	509	304	4.5	2.3
Tippecanoe River at Delphi	1,865	1,040	120.0	65.0
Tippecanoe River near Monticello	1,732	960	120.0	66.0
Wabash River at Covington	8,218	4,600	460.0	340.0
Wabash River at Delphi	4,072	2,120	143.0	110.0
Wabash River at Lafayette	7,267	4,100	370.0	280.0
Wildcat Creek near Lafayette	794	470	36.0	26.0
Wildcat Creek at Owasco	396	230	12.0	7.8

na: not available.

As is typical in Indiana streams, there is a wide variability of stream flow. Flows in the Wabash River are modified by operation of the Salamonie, Mississinewa, and Huntington reservoirs, resulting in a reduction in flood flows and an increase in low flows. The flows of the lower reaches of Tippecanoe River are modified by Lakes Shafer and Freeman. Otherwise streamflows in Region Four are essentially unregulated.

The largest and most reliable streamflows are those in the Wabash River. The seven day, once in ten year, and the one day, once in thirty year low flows for the Wabash River at Delphi reveal that the river will have a sustained flow of at least 110 mgd, while the average annual flow exceeds 2,100 mdg.

The flow duration curve for Sugar Creek at Crawfordsville, as shown by Figure 112, indicates the stream will have a dependable flow of at least 18 mgd ninety percent of the time. The slope of the flow duration curve suggests that the Sugar Creek basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to fifty-one, twenty-five, and twelve percent for dry, average, and wet years respectively. Conversely, from forty-nine to eighty-eight percent of the flow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or from snowmelt.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million or more gallons are presented in Table 81 and are located on Figure 113. These thirteen lakes have a

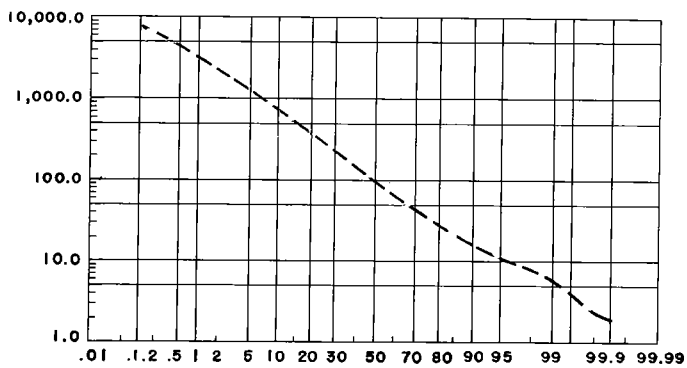


Figure 112
The flow duration curve for Sugar Creek at Crawfordsville.

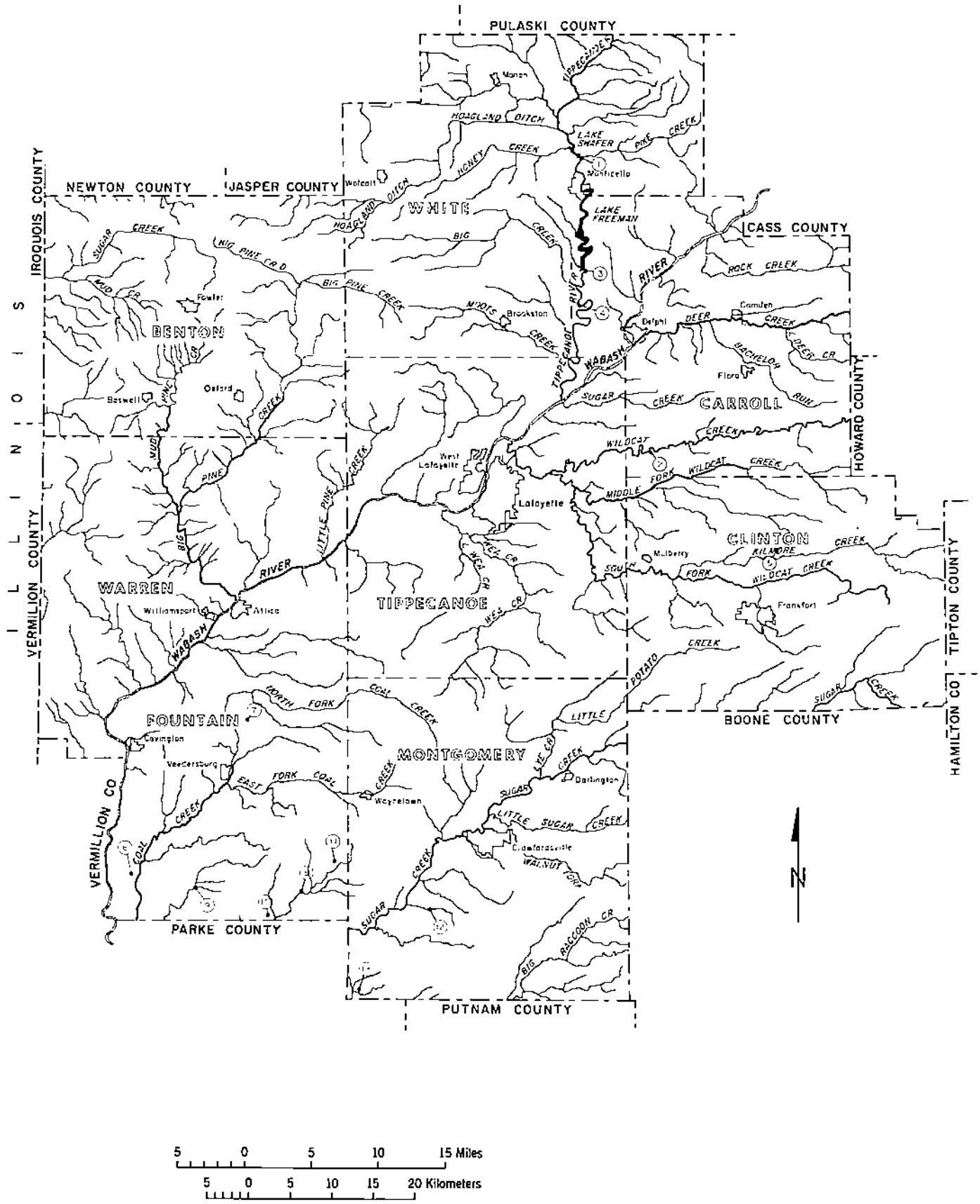


Figure 113
Map of Region Four showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

combined surface area of approximately 3,600 acres with a gross storage capacity of 15,450 million gallons.

Lake Shafer in White County and Lake Freeman in White and Carroll Counties, both located on Tippecanoe River, are the two largest reservoirs in the region. They have a combined surface area of approximately 2,840 acres and a combined gross storage of 12,747 million gallons.

The third largest reservoir, Waveland Lake in Montgomery County, has a surface area of 360 acres and a gross storage of 1,199 million gallons.

Table 81
Lakes at least 50 acres in size or with a storage capacity of 32.5 million gallons.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Lake Shafer	1,732.00	1,291.0	4,275
2	Knop Lake	na	na	55
3	Lake Freeman	1,792.00	1,547.0	8,472
4	Wally's Woods Lake	na	na	48
5	Little Lake	na	na	74
6	Colfing Brothers Lake	na	31.2	78
7	Harrison Lake	na	8.8	32
8	Hemlock Lake	na	31.2	58
9	Mill Creek Lake	12.10	122.0	273
10	Painter Lake	na	13.0	42
11	Sugar Mill Lake	2.50	32.3	68
12	Holiday Lake	na	182.3	793
13	Waveland Lake	11.30	358.0	1,198

na: not available

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Four is presented in Table 82. The existing supply for recreational activity is expressed as a percentage of the demand. When this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply as a percentage of demand is less than one hundred the supply will be less than the projected demand.

Boating and Waterskiing Lakes Shafer and Freeman are the largest in the region and number among the twenty largest lakes in Indiana. These lakes, in conjunction with the Wabash and Tippecanoe Rivers and Waveland Lake, make up the major recreational sites and constitute the major supply of the region's boating and waterskiing resources. It is estimated that by 1980 only seventy-two percent of the boating needs and eighty-two percent of the waterskiing needs will be met by the existing supply of open water within the region. The demand for boating and waterskiing by residents of Region Four is expected to exceed the available supply of open waters through the year 2000.

Table 82
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	24	19.6 boats/acre/year	7,500 acres	72	66	63
Waterskiing	9	34.4 skiers/acre/year	2,500 acres	82	82	81
Canoeing	13	585 canoes/mile/year	265 miles	100+	100+	100+
Swimming	39	76,600 swimmers/acre/year	11 acres	41	39	38
Ice-Skating	10	6,678 skaters/acre/year	12 acres	86	92	80
Fishing	39	66 persons/acre/year	10,200 acres	48	46	45

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands by residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

Canoeing Approximately 165 miles of free-flowing streams provide opportunities for canoeing. The canoeable streams include sixteen miles of Sugar Creek, forty miles of Wildcat Creek (including the North and South Forks), nineteen miles of the Tippecanoe River, seventy-five miles of the Wabash River, and fiteen miles of Big Pine Creek. Sugar Creek is probably the most popular canoeing stream in Indiana.

The available canoeing streams are more than enough to meet current and future demands. Projections for the year 2000 indicate a surplus of canoeing streams.

Swimming and Ice-Skating The supply of swimming areas, both beach and pool acreage, does not meet the current or projected demands for residents of Region Four. Estimates indicate the existing supply will meet only forty-one percent of demand by 1980 and thirty-eight percent by the year 2000.

The demand for ice-skating, including both natural and man-made acreage, exceeds the supply. A shortage of ice-skating acreage may continue through the year 2000.

Fishing The quality of the fisheries habitat is indicated in Figure 114. The size of the Tippecanoe and Wabash Rivers is primarily responsible for the excellent warmwater fisheries. Both streams offer sunfish, white bass, sauger, and catfish to sport fishermen. The majority of streams provide good aquatic habitat for warmwater fish, however, the fisheries habitat in some smaller tributaries decreases in quality in agricultural areas. Pine Creek in Warren County is known for smallmouth bass fishing. Big Raccoon Creek in Montgomery County is noted for sunfish, white bass, and catfish; and Sugar Creek for sunfish, sauger, and catfish.

The four man-made lakes: Lake Schafer, Lake Freeman, Waveland Lake, and Clingan Mill Lake, also support warmwater fisheries. Waveland Lake has the least developed shoreline and is noted for largemouth bass, other sunfish, catfish, and suckers.

Shades State Park, on Sugar Creek, offers the only state-owned access for fishing. Other access for fishing is available in city and county parks or from private boat rentals.

Approximately forty-eight percent of the fishing demand by residents of Region Four is being met. By the year 2000, nearly forty-five percent of the demand will be supplied by the fisheries resource.

Riparian Habitat The quality of the wildlife habitat associated with lakes and streams is shown in Figure 115. Wetlands along smaller streams are limited by high stream gradients and rocky stream beds. Wooded stream banks, occurring predominantly in the central and southern counties, are heavily used by upland game and various birds. Significant wetland areas are not associated with many of the lakes. Waveland Lake has the least residential development and consequently provides good wildlife habitat.

Hydroelectric Power The Northern Indiana Public Service Company operates two hydroelectric plants on the Tippecanoe River. These plants are located in the dams of Lakes Freeman and Shafer and are known as the Oakdale Plant and Norway Plant respectively. Their combined power capacities are only ten megawatts (mw). Due to the limitations of topography and streamflow characteristics, no future commercial hydroelectric developments are anticipated.

Withdrawal Uses

Public Water Supplies The eight counties of Region Four are served by forty-nine public water utilities. An estimated 157,800 or sixty-two percent of the population was served by a public utility in 1975. Information about public water systems is tabulated below. Figure 116 shows the water service areas.

Table 83
The 1975 public water supply system.

County	*Number of Systems*	*Service Population*	*Total Average Daily Use in Million-Gallons-Per-Day*
Benton	6	6,200	.62
Carroll	3	4,900	.69
Clinton	5	17,600	3.78
Fountain	5	9,800	1.64
Montgomery	9	19,400	2.19
Tippecanoe	11	86,800	14.53
Warren	3	2,500	.20
White	7	10,600	1.52
Total	49	157,800	25.17

Forty-one of the public water utilities primarily serve a particular city or town. Seven serve suburban developments near or within existing municipalities. One of these subdivision systems is near Monticello in White County while the other six are in or near Lafayette and West Lafayette in Tippecanoe County. A special category of public water supply is Purdue University's self-supplied system in West Lafayette.

The public water utilities withdrew an average of 25.2 mgd, with ten percent consumption in 1975. All systems obtain their water from ground water derived from well fields usually located within the limits of the city or subdivision.

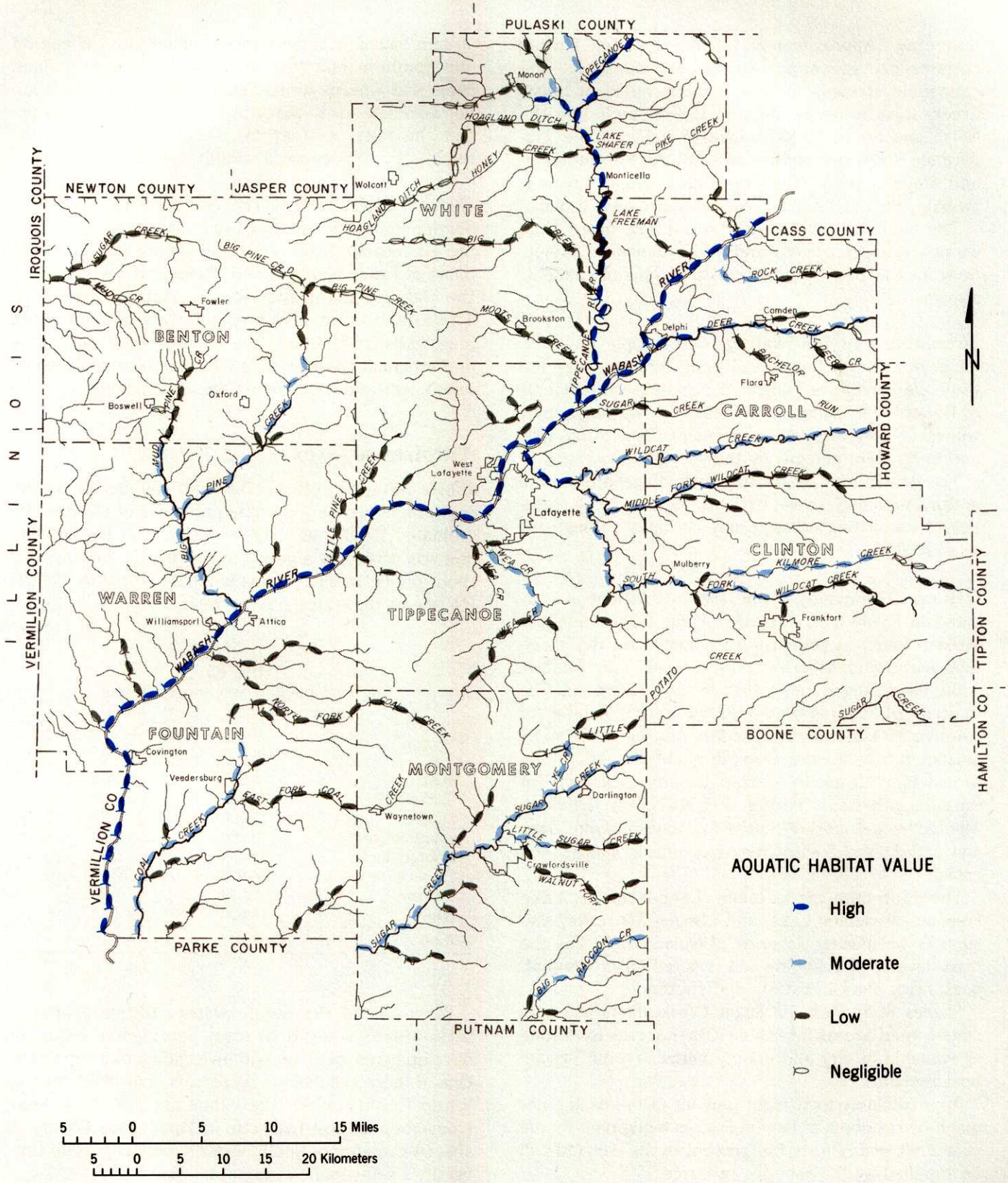


Figure 114
Map of Region Four showing the quality of the fisheries habitat.

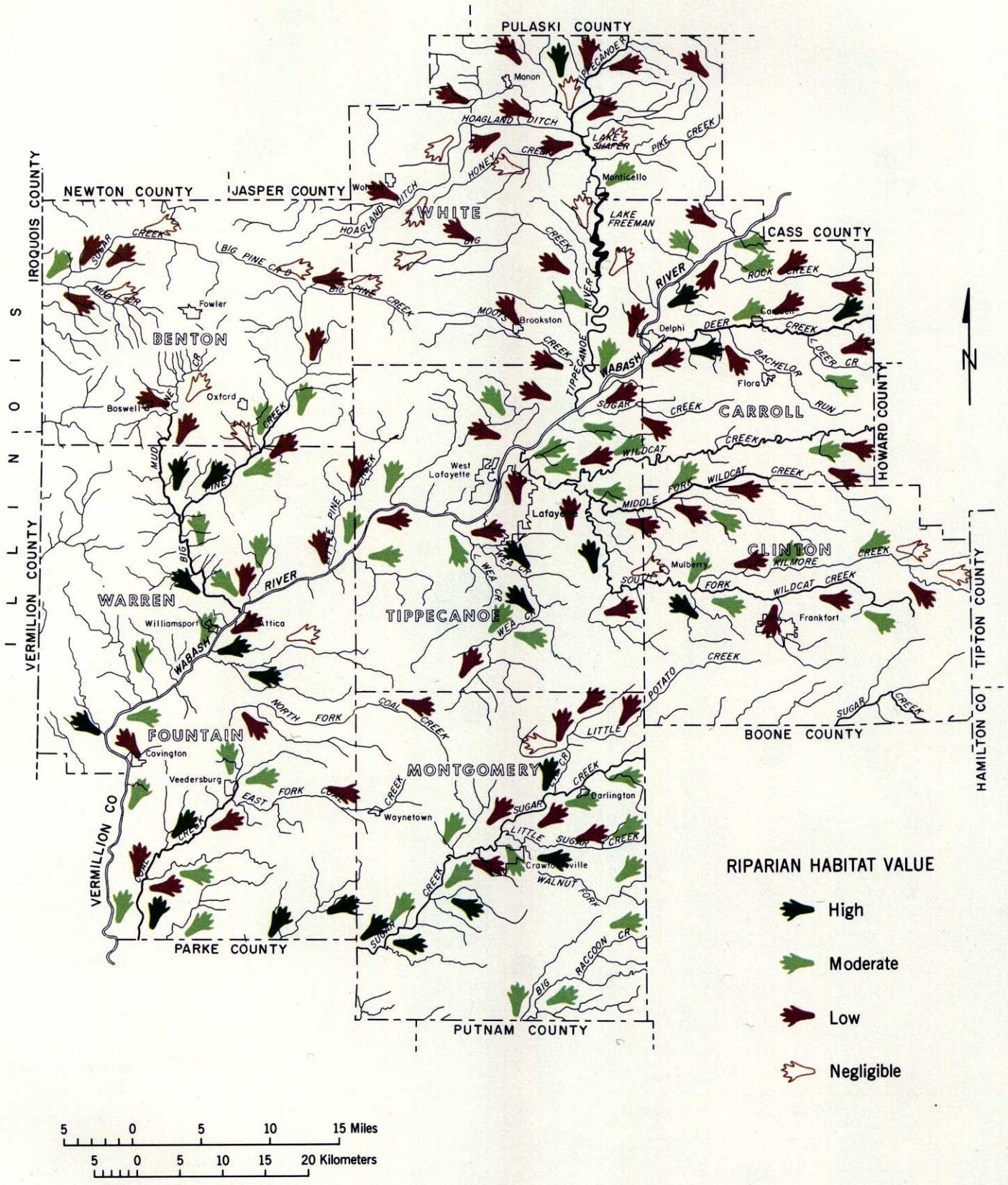


Figure 115
Map of Region Four showing the quality of the riparian habitat.

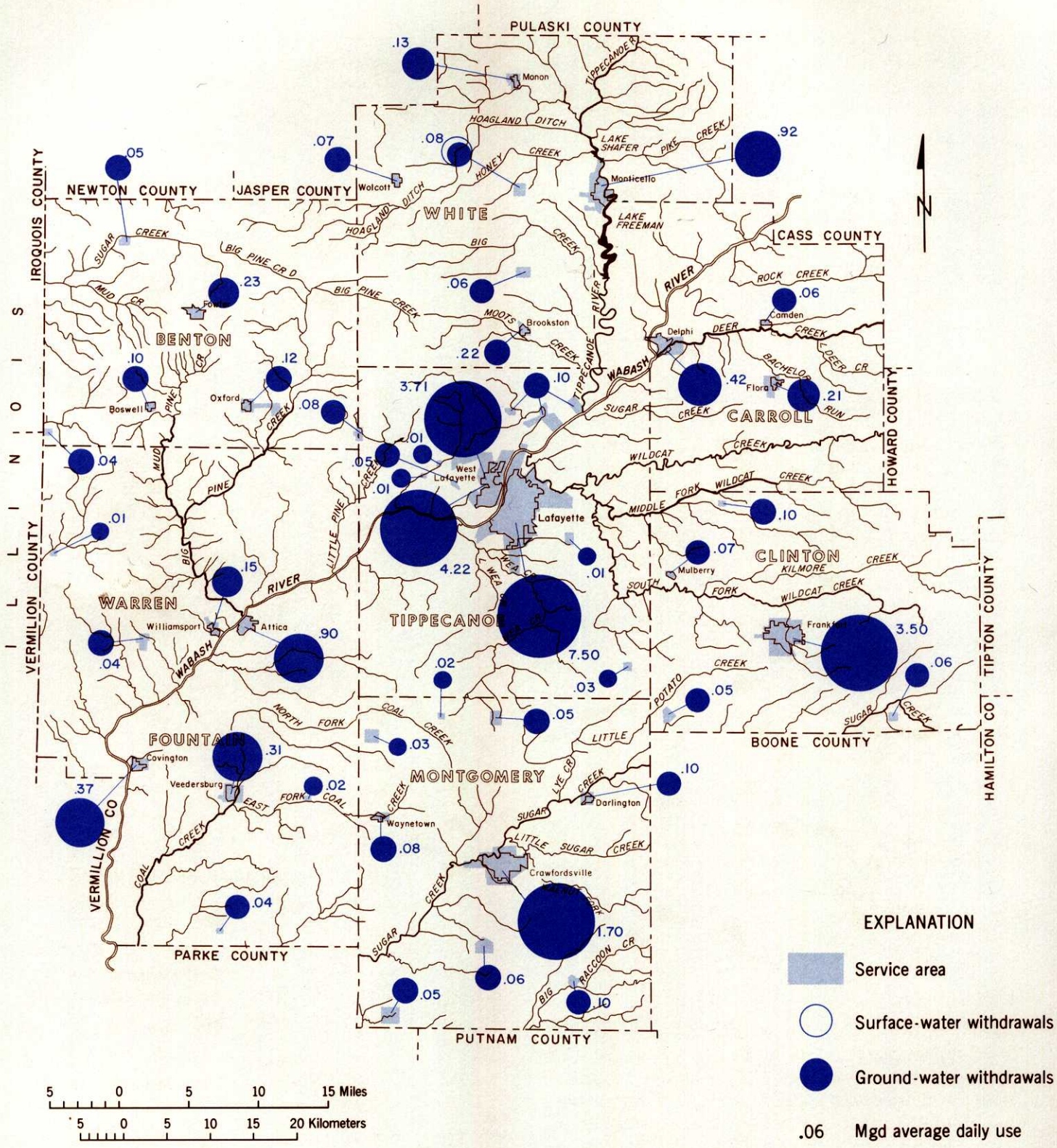


Figure 116
Map of Region Four showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Projections of public water supplies indicate that withdrawals by the region's public water utilities may increase to approximately 33.8 mgd by the year 2000, as presented in the following table.

Table 84
The 1975 and projected withdrawal and consumption rates of public water supplies by the year 2000, in million-gallons-per-day.

Public Water Supply	*1975*	*1980*	*1990*	*2000*
Withdrawal	25.2	27.3	30.9	33.8
Consumption	2.5	2.7	3.1	3.4

Industrial Water Industrial establishments had a water intake averaging 35.9 mgd in 1977. Of the total industrial intake, approximately 30.0 mgd was developed by the industries themselves while 5.9 mgd was purchased from the region's public water utilities. Approximately 3.6 mgd of the self-supplied water was consumed in 1977. The chemical industry is the largest water-using group, followed by food processing, primary metals, and electrical industries.

Industrial water use may increase to approximately 44.6 mgd by the year 2000. Industrial self-supplied withdrawals from ground water may increase to 38.5 mgd. Industrial use of water supplied by public utilities is expected to increase to 6.1 mgd by the year 2000. Data for industrial self-supplied withdrawals is presented in the following table.

Table 85
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	30.0	31.6	34.9	38.5
Consumption	3.6	4.1	5.8	7.7

Rural Self-Supplied Water The majority of rural self-supplied water in Region Four is withdrawn from ground-water sources. In 1975, rural self-supplied water withdrawals averaged 5.7 mgd. Ground-water withdrawals for household water are expected to increase to 8.3 mgd by the year 2000. Livestock in the region required an estimated 3.6 mgd in 1976. This withdrawal of ground water is expected to increase to 5.4 mgd by the year 2000.

The total withdrawal of rural self-supplied water may increase from the current 9.7 mgd to approximately 13.7 mgd by the year 2000, as presented here.

Table 86
The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	9.7	10.2	12.0	13.7
Consumption	9.7	10.2	12.0	13.7

Irrigation Water Soil associations with irrigation potential are located in northern White County, adjacent to the Wabash and Tippecanoe Rivers, and in the Deer, Wea, Coal, and Upper Sugar Creek watersheds. Figure 117 shows the potential irrigation areas within the region.

Based upon the survey of irrigated lands, approximately 960 acres were irrigated in the region in 1977. Six hundred acres of croplands were irrigated in Tippecanoe County, and approximately 360 acres were irrigated in Carroll and Clinton Counties.

Assuming 1977 as a normal growing year, agricultural irrigation would have required about 2.5 mgd during the peak irrigation period of July to August.

It is estimated that approximately 87,000 acres in the region could be profitably irrigated: 35,000 acres in White County, 15,000 in Tippecanoe County, 10,000 in Fountain County, 9,000 in Montgomery County, 6,000 in Carroll and Warren Counties, and 6,000 in Benton and Clinton Counties. The 1977 irrigated average is expected to increase to 11,000 by the year 2000. This expansion of irrigation acreage is expected to increase the peak July–August irrigation demand in an "average" year to about 29.1 mgd. During wetter growing seasons less water will be required, while during drier seasons more irrigation water will be applied.

In addition to the irrigation for agricultural use, fairways and greens on the region's golf courses are irrigated. About 1.5 mgd was applied to these areas during the peak July– August irrigation period of 1977.

The total withdrawal for irrigation of croplands and golf courses during the average season of 1977 was approximately 4.1 mgd. These withdrawals may increase to 30.6 mgd during the average growing season by the year 2000, as presented below.

Table 87
The 1977 and projected withdrawal of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	4.1	7.5	19.1	30.6
Consumption	4.1	7.5	19.1	30.6

Energy There are three electric generating plants located in Region Four. Two of the plants, at Norway and Oakdale, are hydroelectric powered, and are discussed

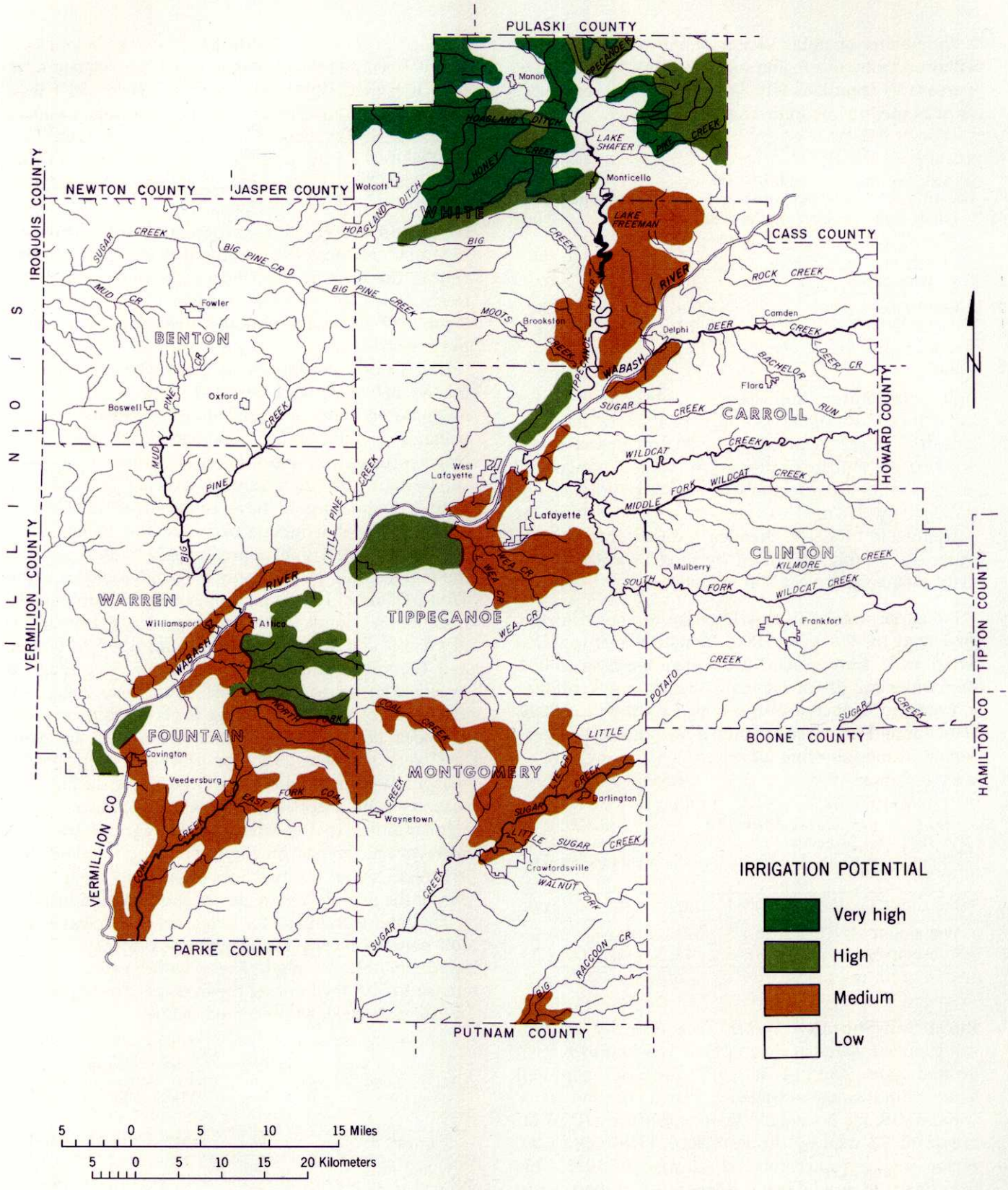


Figure 117
Map of Region Four showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

as an "Instream Use." The Crawfordsville plant is a coal-fired municipal facility with a generating capacity of 24.1 mw. This plant withdraws and consumes an average of 0.7 mgd of ground water.

Water withdrawals for energy during 1977 were approximately 0.7 mgd but are expected to decrease to 0.4 mgd by the year 2000 as shown below.

Table 88
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.7	0.7	0.7	0.4
Consumption	0.7	0.7	0.7	0.4

While no plans for any new electrical generating facilities were announced in 1978, the region's water resource is capable of supporting additional power facilities. Both the Wabash and Tippecanoe Rivers possess flows which could support a power plant, although withdrawals of the magnitude required by electrical generation facilities would affect the low flows of these streams.

EXCESS WATER

Flooding

Approximately 95,000 acres of the region are subject to flooding. The major flood plains are shown in Figure 118. Figure 119 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $3.94 million, of which some ninety-four percent occurred in rural areas. Most of the urban damages occurred along the Wabash River in the Lafayette–West Lafayette area and along Sugar Creek at Crawfordsville.

Flood Control A number of small watershed projects are either completed or under construction, as presented in the following table. Rutan Farms Dam in Tippecanoe County is the only privately owned flood control structure in Region Four.

Table 89
The name and status of small watershed projects.

Project	*Status*
Little Wea Creek	complete
Kickapoo Creek	complete
Little Raccoon Creek	complete
Jordon Creek	under construction
Lye Creek Drain	under construction
Bachelor Run Creek	under construction
Rock Creek	under construction
Fall Creek	not started

The Delphi Levee on the Wabash River at Delphi was constructed by the U.S. Army Corps of Engineers in 1962. It protects approximately 310 acres, and was constructed to be effective against floodwaters equaling the maximum flood of record, which occurred in March 1913. The operation of the Salamonie, Mississinewa, and Huntington reservoirs, located upstream of Region Four, enhances the degree of protection afforded by the Delphi Levee project. These reservoirs also reduce flood stages on the main stem of the Wabash River.

Flood Plain Management Participants in the National Flood Insurance Program are listed below.

Table 90
Communities participating in the National Flood Insurance Program.

Community	*Phase Status*
Attica	emergency
Battle Ground	emergency
Burlington	emergency
Carroll County, unincorporated	emergency
Chalmers	regular
Clinton County, unincorporated	emergency
Covington	emergency
Crawfordsville	emergency
Darlington	emergency
Delphi	emergency
Flora	emergency
Fowler	emergency
Frankfort	regular
Hillsboro	emergency
Lafayette	emergency
Monon	regular
Monticello	regular
Mulberry	emergency
Tippecanoe County, unincorporated	emergency
Veedersburg	emergency
Waveland	emergency
West Lafayette	emergency
Williamsport	emergency
Wolcott	regular

Agricultural Drainage

Approximately forty-seven percent of the soil associations in Region Four have "severe" wetness characteristics, twenty-five percent have "moderate" wetness characteristics, while twenty-eight percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics is shown in Figure 120. There are approximately 4,151 miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards or, in a limited number of cases,

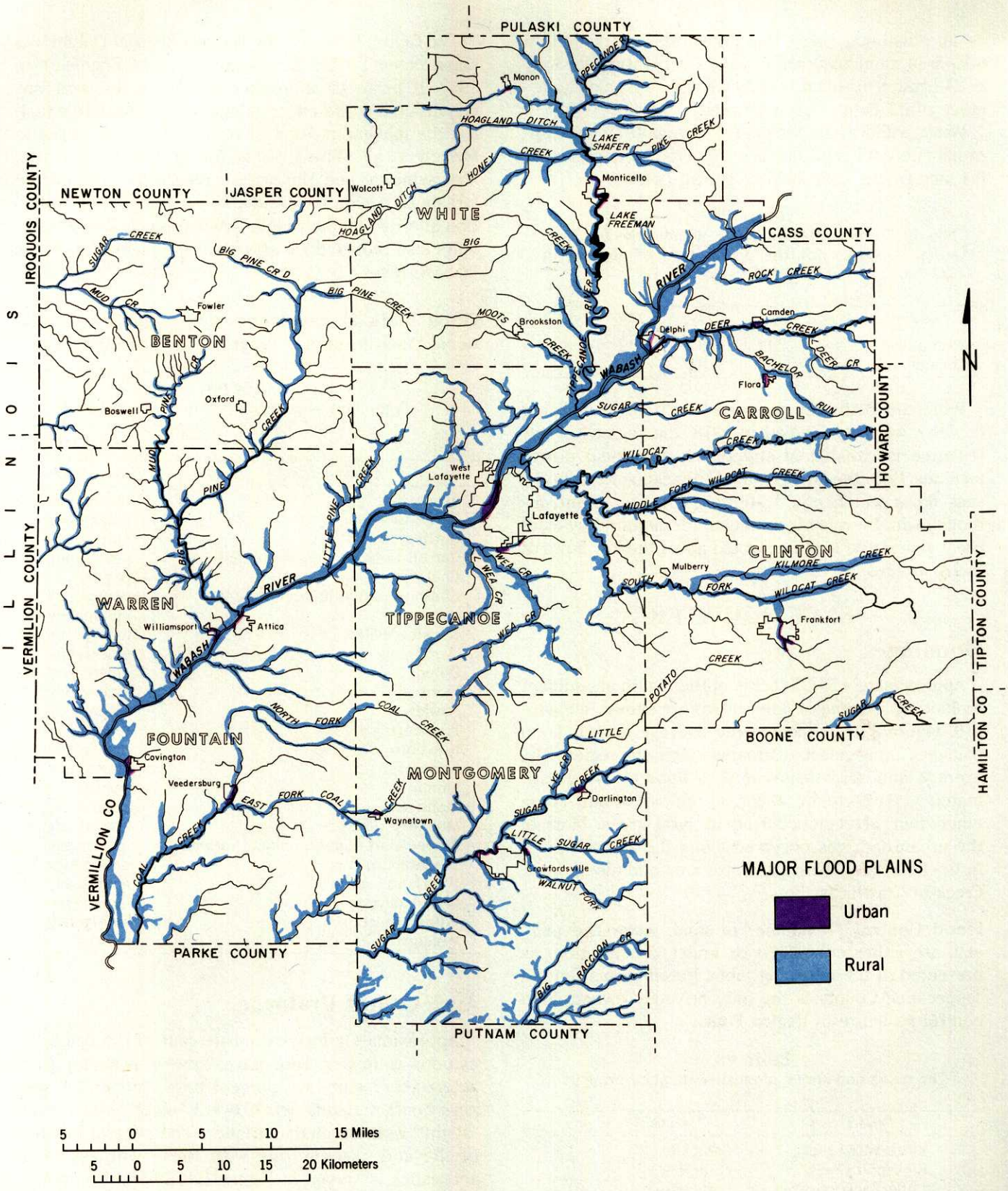


Figure 118
Map of Region Four showing the major floodplains.

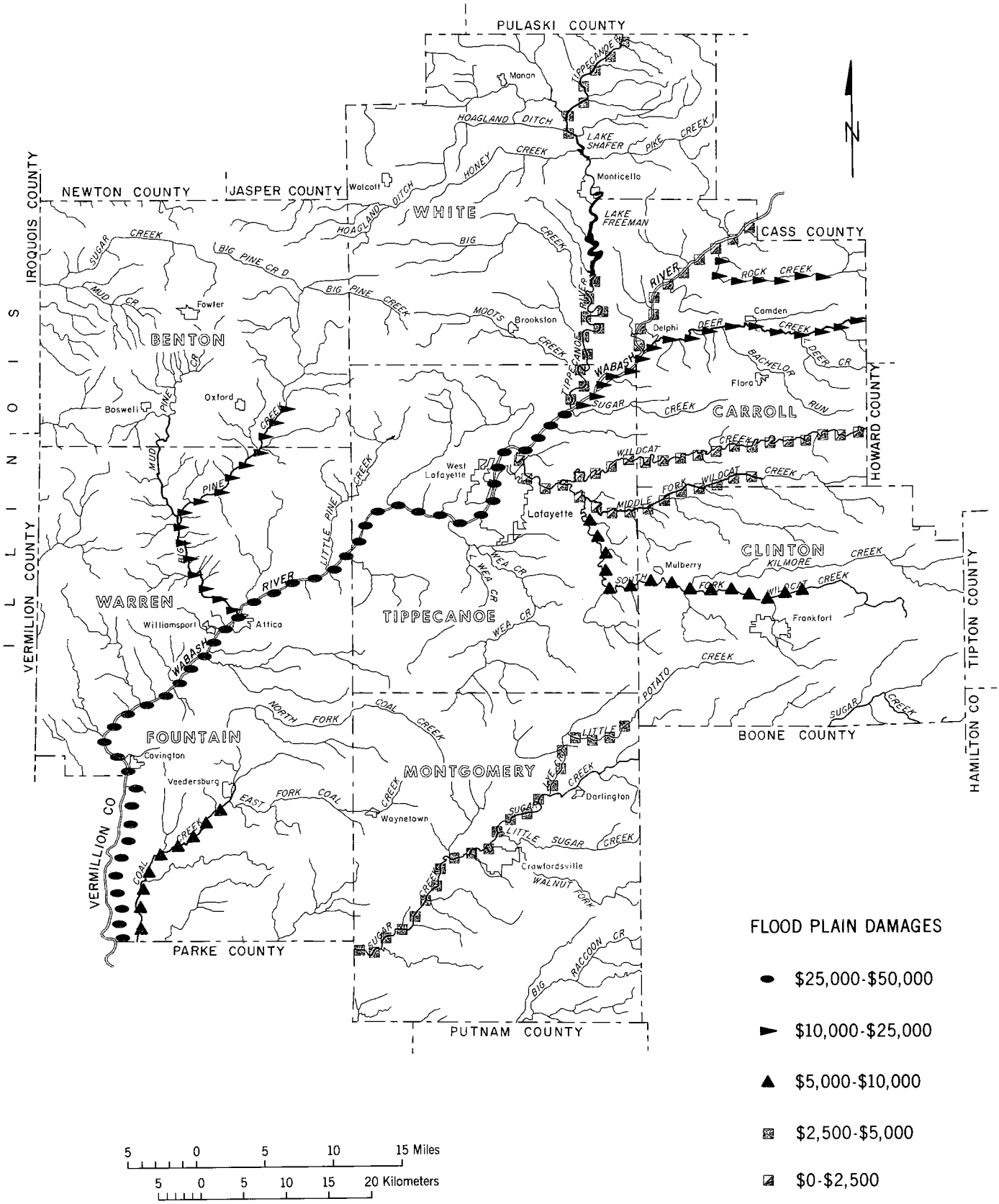


Figure 119
Map of Region Four showing the estimated average annual flood damages per mile along selected streams.

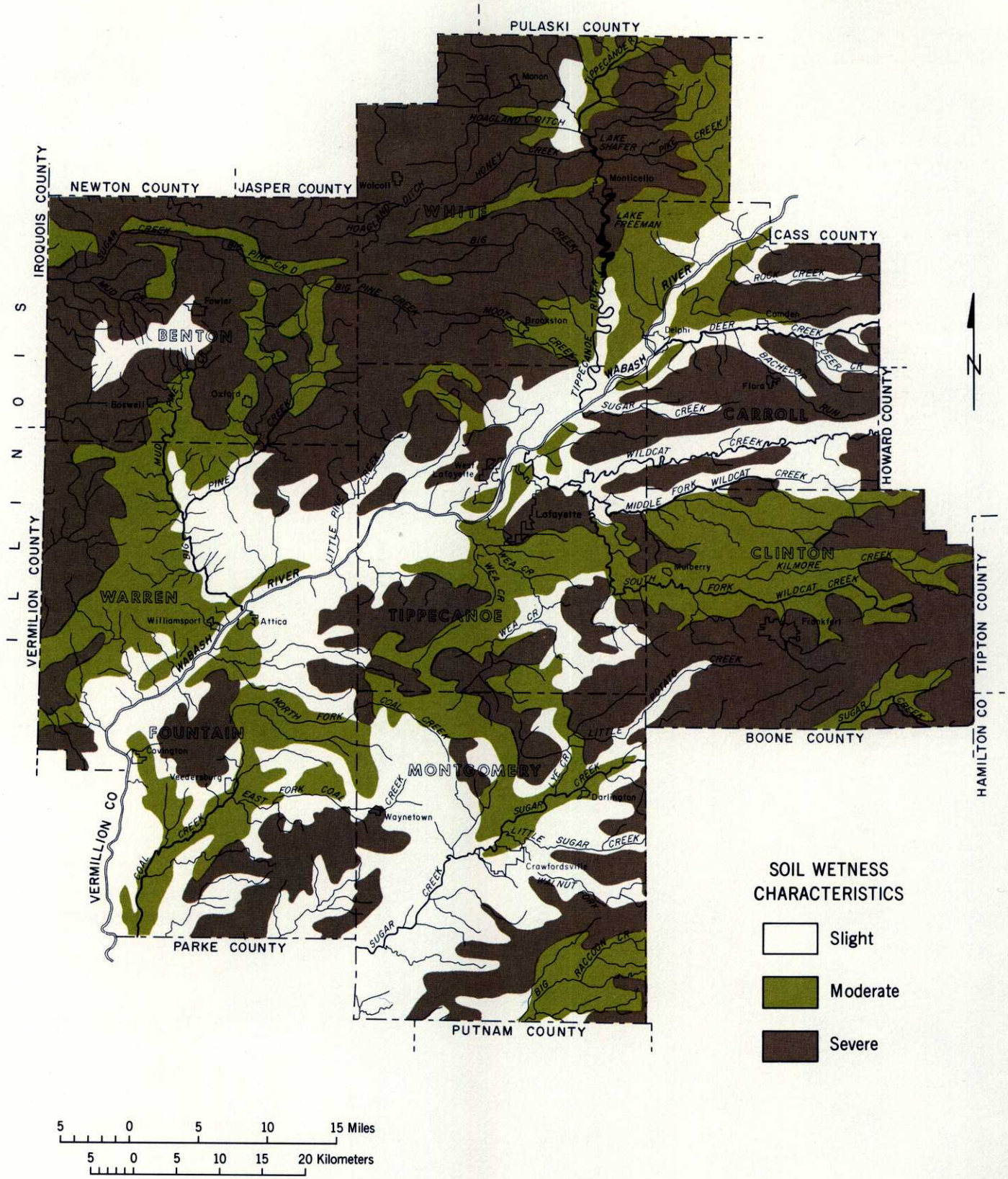


Figure 120
Map of Region Four showing the general location of the wetness characteristics of soil associations.

conservancy districts. No legal entity exists to maintain drainage along the other streams in the region.

Soil Erosion

The soils of the region have been examined as to their potential for erosion and are classified as "high," "medium," or "low" hazards as shown in Figure 121. Twenty-one percent of the 2,214,000 acres are rated as having a high soil erosion hazard potential while fifteen percent are classified in the medium potential erosion hazard category. These areas are located in the northeastern part of Carroll County, the northwestern part of Warren County, the eastern parts of Tippecanoe and Warren Counties, and most of Fountain and Montgomery Counties. The remaining sixty-four percent of land in Region Four have a low erosion potential for land left in a fallow state.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the Wabash and Tippecanoe Rivers as well as Wildcat and Sugar Creeks. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

Data collected along the main stem of the Wabash River indicated that both temperature and dissolved oxygen concentration met the standards. Values for pH fell below the minimum allowable value. The fecal coliform bacteria levels were well within the standards for partial body contact recreation.

The Tippecanoe River, a tributary to the Wabash River, also exhibited temperature and dissolved oxygen values within acceptable limits. The biochemical oxygen demand, a measure of the amount of oxygen consumed in the biological processes that break down organic matter in water, was well within the recommended level. Both maximum and minimum pH levels were in compliance with state standards. A temporary source of water quality degradation in the Tippecanoe River was the City of Monticello's sewage treatment plant, but the city was in the process of correcting the problem.

In the lower reaches of Wildcat Creek, water quality standards for temperature and dissolved oxygen were not being violated. In addition, the level of the biochemical oxygen demand and pH values were within acceptable limits.

No temperature violations were recorded for Sugar Creek near Shades State Park. The dissolved oxygen concentrations were adequate to support a diverse biological community. Biochemical oxygen demand levels have remained relatively low for the past four-year period of record. Generally, pH values and fecal coliform bacterial levels were within the recommended standards. Severe localized problems existed in the Crawfordsville area due to conditions at the municipal wastewater treatment plant. These conditions were, however, in the process of being corrected.

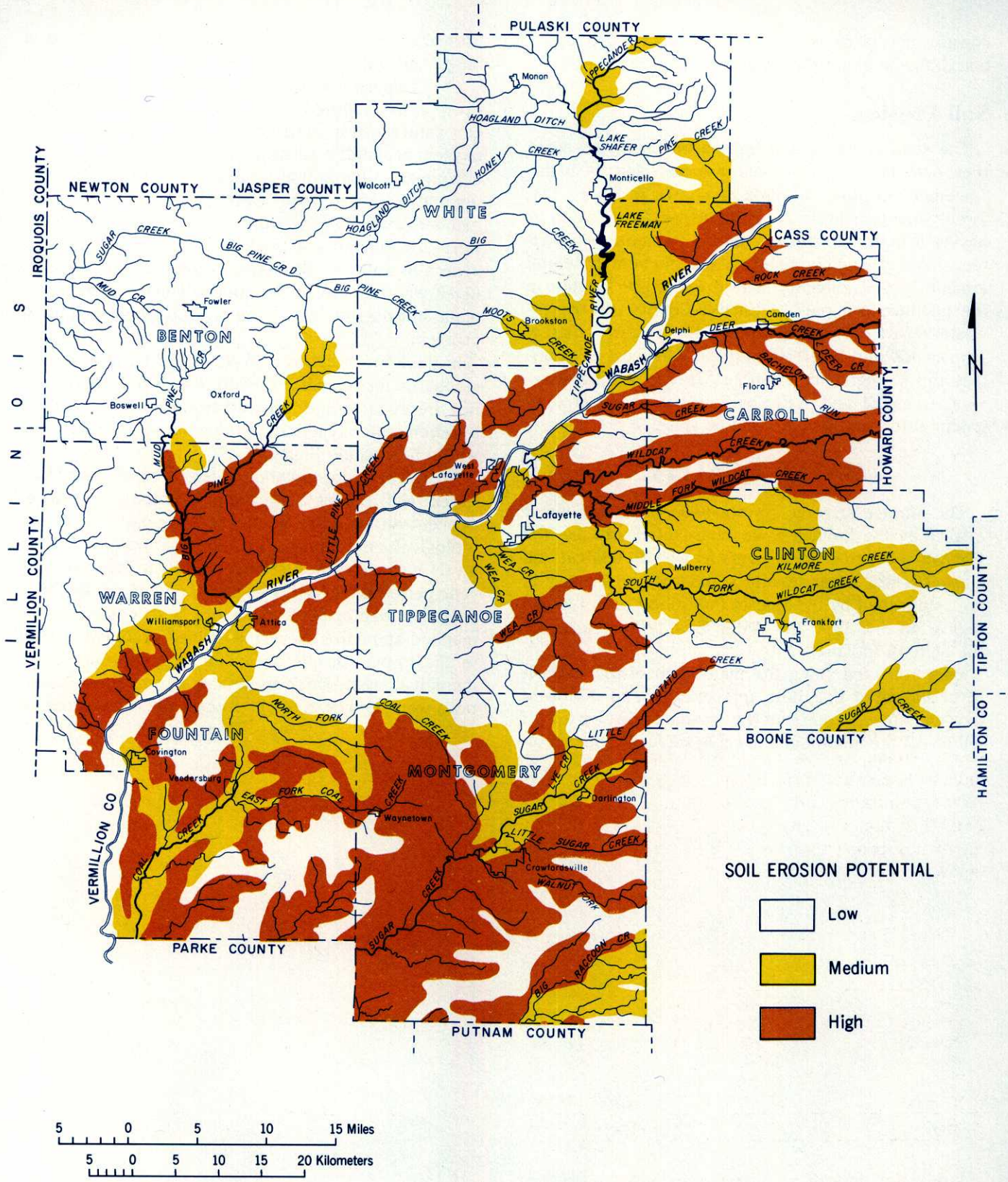


Figure 121
Map of Region Four showing the erosion potential of the soil associations.

Region Five

Cass, Fulton, Howard, Miami, Tipton, and Wabash Counties, located in north-central Indiana, form Region Five. The region contains approximately 2,136 square miles and is bounded by Marshall and Kosciusko Counties to the north; Huntington, Grant, and Madison Counties to the east; Hamilton County to the south; and Clinton, Carroll, White, and Pulaski Counties to the west as shown in Figure 122.

The 1975 population was 239,500, of which thirty-seven percent resided in Howard County. The official Indiana Population Projections indicate that the region's population may increase to approximately 283,300 by the year 2000. The 1975 population and the population projections for each county are tabulated below.

Table 91
The 1975 and projected populations for Region Five.

County	*1975*	*1980*	*1990*	*2000*
Cass	40,800	41,300	42,000	42,500
Fulton	17,900	18,900	20,400	22,000
Howard	89,200	96,200	111,000	124,200
Miami	40,500	41,700	43,500	43,600
Tipton	15,800	15,300	14,800	14,500
Wabash	35,300	35,600	36,300	36,500
Total	239,500	249,000	268,000	283,300

The major population centers within the region are Kokomo in Howard County, Logansport in Cass County, Peru in Miami County, and Wabash in Wabash County.

Agriculture is the dominant land use within the region with more than eighty-two percent of the area

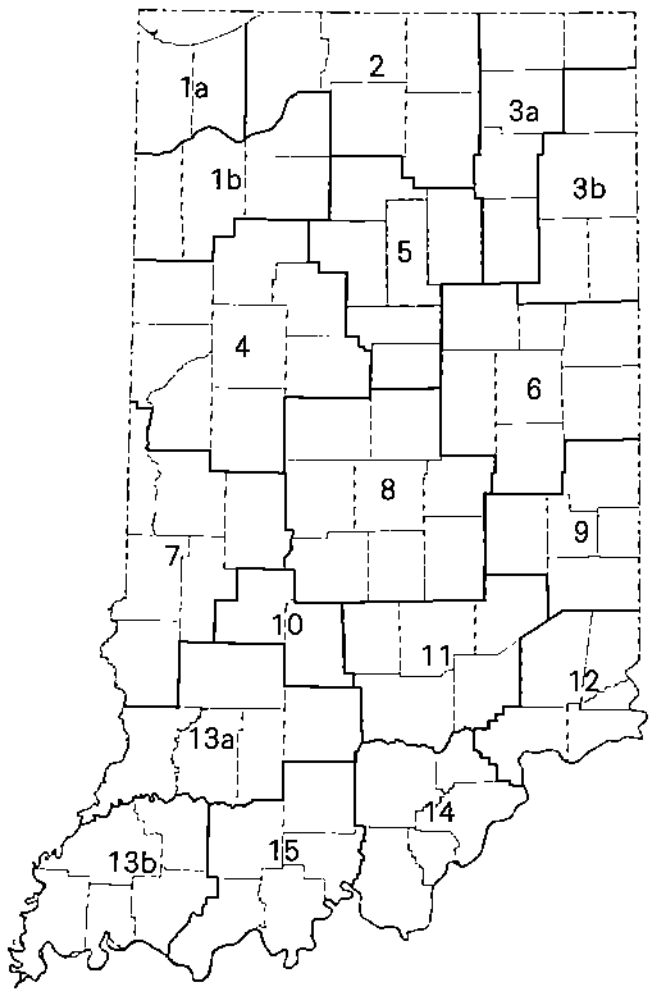


Figure 122
Map of Indiana showing the location of Region Five.

devoted to that purpose. Approximately seven percent of the land is forested and eleven percent is devoted to urban and miscellaneous uses.

Although agriculture is the major land use, it is not the major source of employment. Manufacturing employs approximately fifty-three percent of the work force. Electrical machinery, transportation, and primary metals are the major industries. Nonmanufacturing business employs approximately forty-six percent of the work force. Wholesale and retail trade employs almost half of the nonmanufacturing work force, followed by services, transportation, communications, and utilities.

The region has a diverse topography. Howard and Tipton Counties, southwestern Fulton and northwestern Cass Counties are flat, relatively treeless, and contain intensive agriculture. The remainder of the region has considerable local relief.

The region receives approximately 38.0 inches of precipitation annually. This varies from a high of 4.5 inches in July to a low of 2.0 inches in February. Of the 38.0 inches of precipitation, approximately 11.0 inches appear as streamflow while 27.0 inches are consumed through evapotranspiration. The area has average temperatures ranging from 26°F. in January to 73.5°F. in July. The average annual temperature is 51.5°F. The annual prevailing wind at the Baer Field Airport in Fort Wayne is from the southwest at 10.3 miles per hour.

THE WATER RESOURCE

Ground Water

The occurrence of ground water in Region Five has been affected by thick glacial deposits that blanket most of the area. These deposits were left by successive glacial advances and contain permeable zones of sand and gravel which act as storage reservoirs for large amounts of water. The glacial drift is thickest and most productive in Fulton County in the northern part of the region where outwash deposits of sand and gravel occur. The drift generally thins to the south into southern Tipton County where increasing thicknesses are again encountered. The glacial till also contains numerous inter-till sand and gravel units which are utilized as a source of water in many areas.

Underlying the unconsolidated deposits are bedrock formations of Silurian and Devonian ages. The Silurian rocks are primarily dolomitic limestone with some shale members, while the Devonian sequence is composed of black shale, dolomite, and limestone. The shale deposits are not considered to be important ground-water sources, but the Silurian and Devonian limestones and dolomites are significant aquifers.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. An unusual feature that affects ground-water availability in this region is the buried Teays Valley drainage system which trends almost east to west through Wabash, Miami, and Cass Counties. The Teays consisted of a major preglacial drainage system whose valley was completely filled with glacial material. These glacial deposits contain significant amounts of coarse sand and gravel capable of yielding up to 1,000 gallons-per-minute (gpm). The Indiana Department of Natural Resources is currently involved in a study of the glacial history and ground-water potential of the Teays system statewide.

Ground-water availability within the region is generally very good, as shown in Figure 123. The thick deposits of sand and gravel in Fulton County and along the Wabash River in Miami and western Wabash Counties offer the largest potential with yields exceeding 1,000 gpm. Yields in areas adjacent to the Eel River in Wabash and Miami Counties are as high as 600 gpm, while portions of the Wabash River valley in Cass County can produce up to 200 gpm. In Howard and Tipton Counties, the bedrock represents a significant ground-water source and is capable of producing up to 600 gpm.

Ground-water hardness ranges from 250 to 400 parts-per-million (ppm). The iron content falls within values averaging between 1.5 and 2.0 ppm. Several communities have municipal softening and iron removal treatment. The town of Akron does not remove iron even though its water has one of the highest iron contents in the region. Parts of Miami, Cass, Howard, and Tipton Counties exhibit fluoride levels higher than one ppm. Areas of hydrogen sulfide or "sulfur water" can be encountered in parts of Cass, Howard, and Tipton Counties.

Surface Water

Streamflow The major streams flowing through the region include the Wabash, Salamonie, Tippecanoe, Mississinewa, and Eel Rivers and Wildcat Creek. The surface streams within the region flow from east to west and are included within the Wabash River drainage basin. Fifty-two miles of the Wabash River are located within the region.

The seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations within Region Five are presented in Table 92.

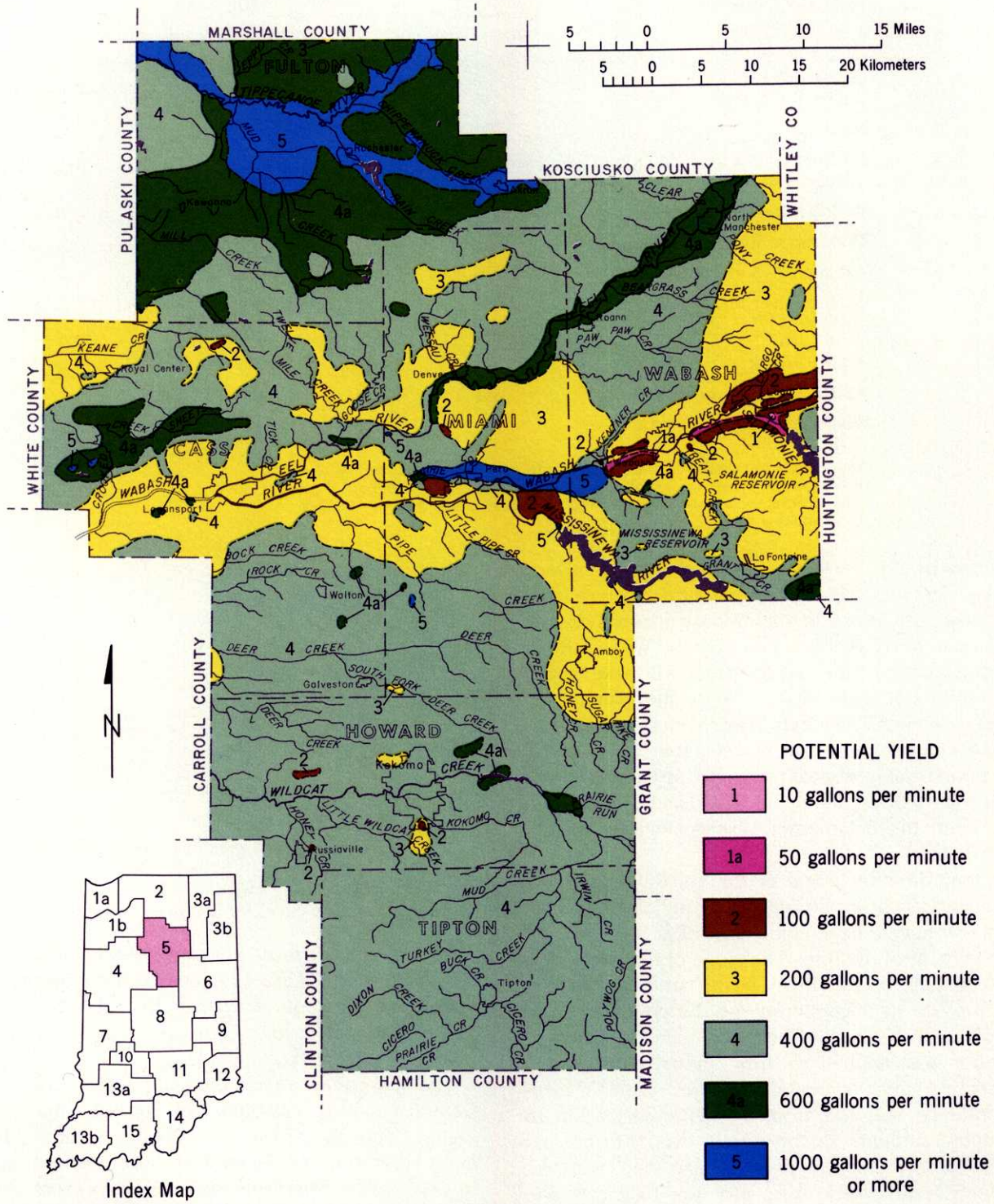


Figure 123
Map of Region Five showing the general location and potential yield of ground water from properly constructed large diameter wells.

Table 92
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Chippewanuck Creek near Rochester[a]	44	na	3.2	na
Eel River at Logansport	789	470	63.0	49.0
Eel River at North Manchester	417	230	22.0	12.0
Mud Creek near Windfall[a]	75	na	0.3	na
Tippecanoe River at Ora	856	496	75.0	59.0
Wabash River at Logansport[b]	3,779	2,059	123.0	90.0
Wabash River at Peru[b]	2,686	1,477	59.0	43.0
Wabash River at Wabash[c]	1,768	928	18.0	12.0
Wildcat Creek at Greentown	168	100	1.0	0.6
Wildcat Creek at Kokomo[a]	242	131	6.5	4.3
Wildcat Creek near Jerome	146	77	1.1	0.6

[a]Flow characteristics estimated from stream gaging stations with short periods of record.
[b]Flows recorded prior to the construction of the Salamonie, Mississinewa and Huntington Lakes.
[c]Flows recorded prior to the construction of the Salamonie and Mississinewa Lakes.
na: not available.

Analysis of the low-flow characteristics of surface streams indicates that the largest and most reliable streamflows are those in the Wabash River. The one day, once in thirty year low flows for the Wabash River at Logansport indicate that the river will have a sustained flow of at least 90 mgd, while the average annual flow exceeds 2,000 mgd. These generally excellent low-flow characteristics are a reflection of relatively high ground-water contributions to streamflow from the alluvial aquifers along the river and low-flow releases from the Salamonie, Mississinewa, and Huntington Lakes.

The flow duration curve of the Eel River at North Manchester, as shown by Figure 124, indicates that the stream will have a dependable flow of at least 39 mgd ninety percent of the time. The slope of the curve also indicates that the Eel River basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to forty-nine, twenty-three and nineteen percent for dry, average, and wet years, respectively. Conversely, from fifty-one to eighty-one percent of the flow, depending on the year, is due directly to surface runoff from runoff-producing precipitation events or from snowmelt.

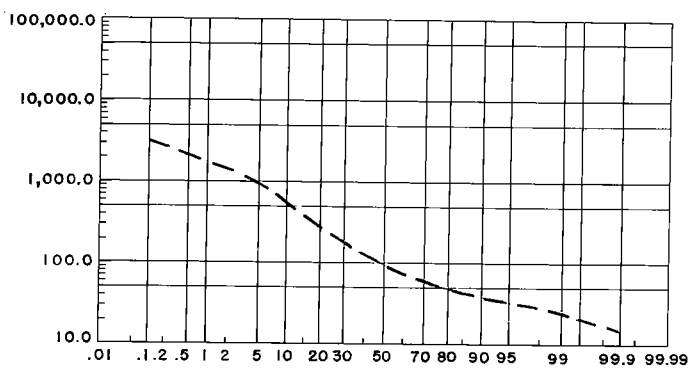


Figure 124
The flow duration curve for Eel River at North Manchester.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are presented in Table 93, and are located on Figure 125. The region's twenty-three lakes have a combined surface area of approximately 7,730 acres and a gross storage capacity of approximately 51,460 million gallons.

The Mississinewa Lake in Miami, Wabash, and Grant Counties and the Salamonie Lake in Wabash and Huntington Counties are two large flood control and recreation reservoirs whose control structures are located in Region Five. Mississinewa Lake has a gross storage of about 24,500 million gallons and a summer surface area of about 3,180 acres. Salamonie Lake has a gross storage of about 19,800 million gallons and a summer surface of about 2,855 acres.

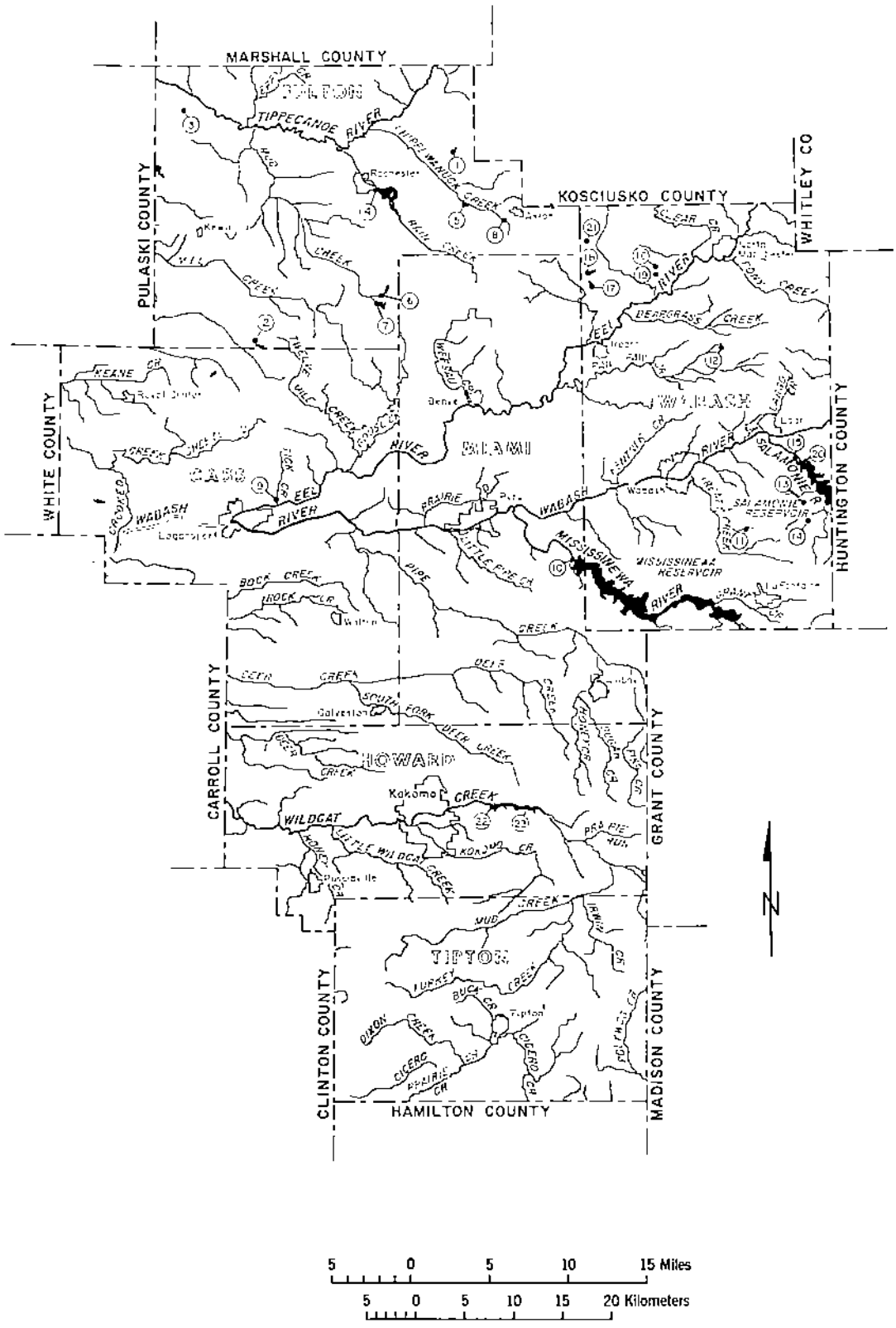


Figure 125
Map of Region Five showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

Table 93
Lakes at least 50.0 acres in size or having a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Barr Lake	na	22.0	153
2	Fletcher Lake	0.67	45.0	286
3	King Lake	1.98	18.0	58
4	Lake Manitou	44.20	1,156.0	3,311
5	Lake 16	na	27.0	71
6	Nyona Lake	7.59	104.0	436
7	South Mud Lake	4.53	94.0	332
8	Town Lake	2.77	23.0	71
9	Lake Perry	7.75	17.0	43
10	Mississinewa Lake	807.0	3,180.0	24,498
11	Baer Pond	na	na	87
12	Dean Gifford	na	na	49
13	Dick Thomas Pond	na	na	78
14	George Barlow Lake	na	na	53
15	Hominy Ridge Lake Dam	na	13.0	52
16	Long Lake	0.55	48.0	247
17	Lukens Lake	1.76	46.0	329
18	McColley Lake	na	28.0	133
19	Round Lake	na	48.0	175
20	Salamonie Lake	556.0	2,800.0	18,980
21	Twin Lakes	na	18.0	61
22	Kokomo Waterworks Reservoir No. 1	na	na	259
23	Kokomo Waterworks Reservoir No. 2	179.0	40.1	1,699

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water within Region Five is presented in Table 94. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the percentage is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing Region Five contains three of the fourteen largest lakes in Indiana, including Mississinewa Lake, Salamonie Lake and Lake Manitou. These lakes, in conjunction with the Wabash and Tippecanoe Rivers, comprise the major recreational sites for boating and waterskiing in the region.

The demand for boating by residents of the region slightly exceeds the available supply. It is estimated that the supply of open water for boating in 1980 will meet ninety-six percent of the demand. By the year 2000, the boating demand will be met by recreational facilities within the region. A surplus of waterskiing

Table 94
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	27	19.6 boats/acre/year	12,700 acres	96	100+	100+
Waterskiing	9	34.4 skiers/acre/year	3,300 acres	100+	100+	100+
Canoeing	8	585 canoes/mile/year	152 miles	100+	100+	100+
Swimming	35	76,600 swimmers/acre/year	18 acres	100+	100+	100+
Ice-Skating	10	6,678 skaters/acre/year	7 acres	54	54	54
Fishing	49	66 persons/acre/year	13,700 acres	54	55	55

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

opportunities exists within the region and may continue through the year 2000.

Canoeing A total of 152 miles of streams and rivers is available for canoeing in the region. The Wabash, Tippecanoe, and Eel Rivers are the best canoeing streams. The availability of canoeing miles exceeds the demand, and the surplus of canoeing opportunities is expected to continue through the year 2000.

Swimming and Ice-Skating Swimming areas, including both beach and pool acreage, are capable of meeting the demands generated within the region through the year 2000.

The current demand for ice-skating generated by residents within the region exceeds the supply by approximately fifty-four percent. The shortage of ice-skating opportunities is expected to continue through the year 2000.

Fishing The quality of the fisheries habitat is shown in Figure 126. Excellent aquatic habitat is located along the Tippecanoe, Eel, Wabash, Salamonie, and Mississinewa Rivers. The Eel and Tippecanoe Rivers have excellent fishing for smallmouth bass, rock bass, and channel catfish. All streams support a variety of warmwater fish common to Indiana; however, some have lower aquatic habitat from poor water quality, a lack of aquatic vegetation, or altered drainage systems in intensively farmed areas.

Most of the natural lakes are located in Fulton and northern Wabash Counties. The wetlands on Lake Manitou provide spawning habitat for the northern pike population. Bass Lake, Fletcher Lake, and Hominy Ridge Pond are recommended for largemouth bass and other sunfish fishing. The highly-rated, aquatic habitat in Salamonie and Mississinewa Lakes supports such warmwater fish as crappie, striped and white bass, channel catfish, largemouth and smallmouth bass, and northern and walleye pike.

Public access to the streams is limited to state fishing sites on the Eel, Wabash, and Tippecanoe Rivers in Fulton and Wabash Counties or to bridges and private facilities. Several of the lakes in Fulton County have public access sites. Salamonie and Mississinewa Lakes are accessible from state recreation areas and boat ramps. City and county parks may also provide lake access.

The supply of fishing water in Region Five is capable of fulfilling only fifty-four percent of the demand by residents of the region. By the year 2000, fifty-five percent of this demand will be met.

Riparian Habitat The quality of the riparian habitat associated with lakes and streams is indicated in Figure 127. Many streams in Howard, Tipton, northwestern Cass, and southwestern Fulton Counties are channelized to improve agricultural drainage. When vegetation is removed from their banks, these streams provide little riparian habitat. However, muskrat production is high on those streams that have been sufficiently revegetated. The wooded streambanks of less altered streams such as the Tippecanoe, Wabash, and Eel Rivers, provide habitat for beaver, deer, squirrels, raccoons, and other upland game, and a variety of birds.

Wetlands on the natural lakes, such as Lake Manitou, offer valuable habitat for migratory and resident waterfowl, shorebirds, furbearers, and upland game. The well vegetated shores of Mississinewa and Salamonie Lakes provide upland game habitat, and the wooded swamps in the backwaters are especially attractive for waterfowl and shorebirds. Limited wildlife habitat is offered around heavily developed lakes like Kokomo Lake. Public hunting is allowed on public land located on Salamonie and Mississinewa Lakes.

Withdrawal Uses

Public Water Supplies Cass, Fulton, Howard, Miami, Tipton, and Wabash Counties are served by twenty-six public utilities. Data on public water supply systems follows.

Table 95
The public water supply systems as of 1975.

Counties	*Number of Systems*	*Service Population*	*Total Average Daily Use in Million-Gallons-Per-Day*
Cass	5	22,300	3.8
Fulton	3	6,000	1.2
Howard	4	60,500	14.1
Miami	4	16,400	2.5
Tipton	4	6,500	1.2
Wabash	6	20,600	4.5
Total	26	132,200	27.3

Twenty-two of the public water utilities primarily serve cities or towns, while four public water utilities serve suburban developments near or within existing municipalities. Cass, Howard, Miami, and Wabash Counties each have one subdivision system.

Public water supply systems in Howard County withdrew the largest amount of water in the region, accounting for 14.1 mgd in 1975. Water withdrawals in Wabash County averaged 4.5 mgd. Withdrawals in Fulton and Tipton Counties averaged less than 1.2 mgd. Approximately ten percent of the water withdrawn is consumed. Figure 128 shows the water service areas within Region Five.

On a county-wide basis, Cass County derives

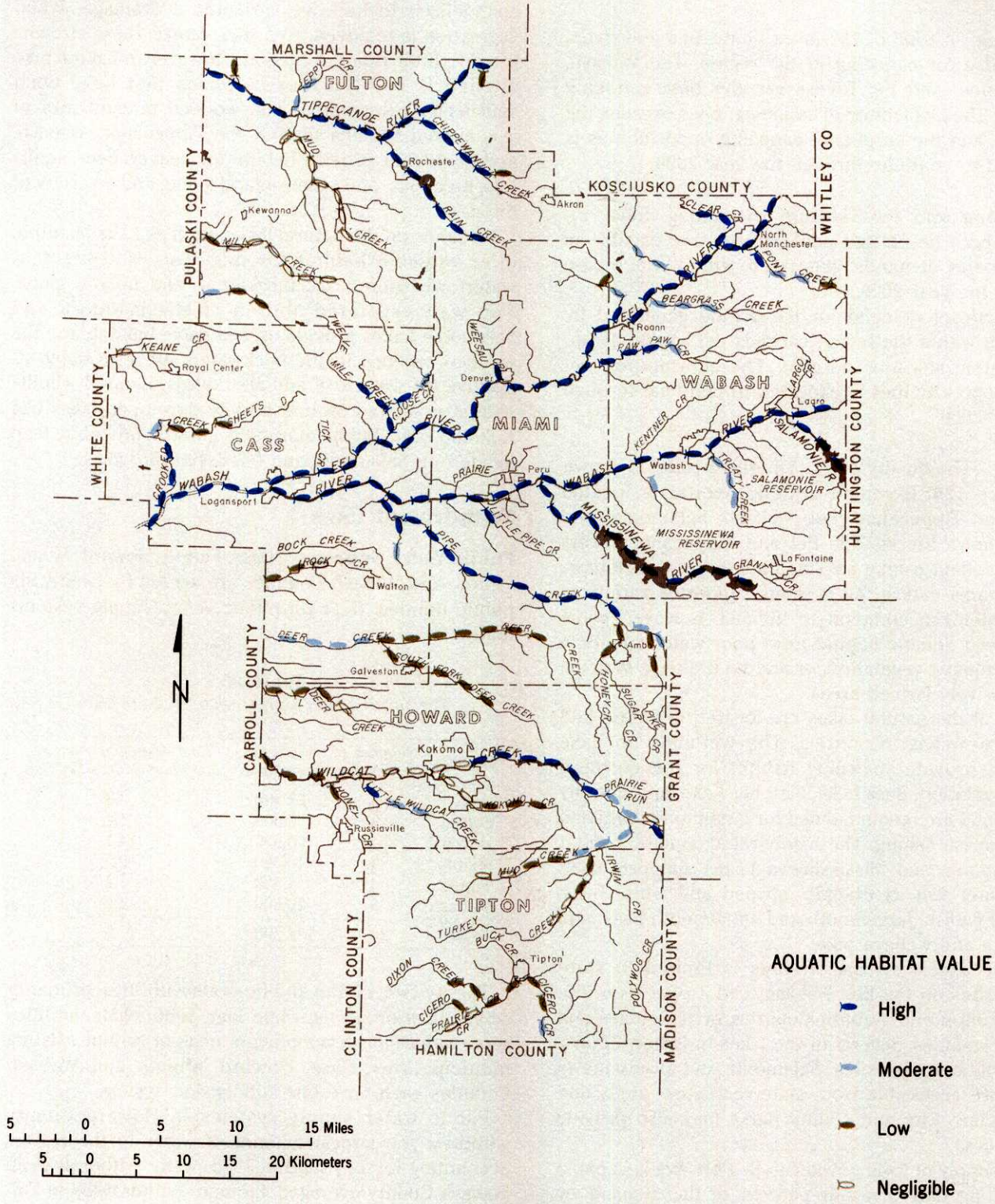


Figure 126
Map of Region Five showing the quality of the fisheries habitat.

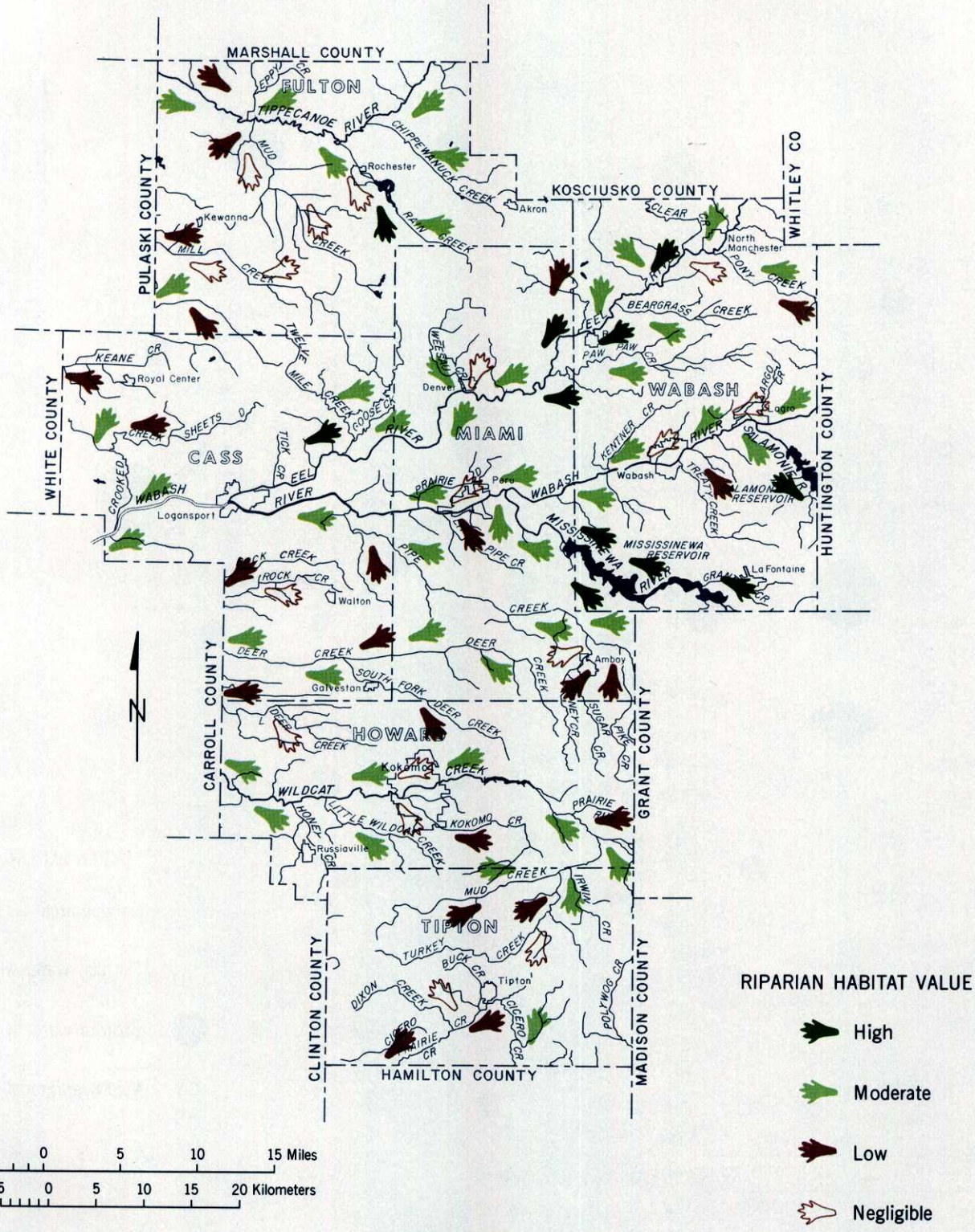


Figure 127
Map of Region Five showing the quality of the riparian habitat.

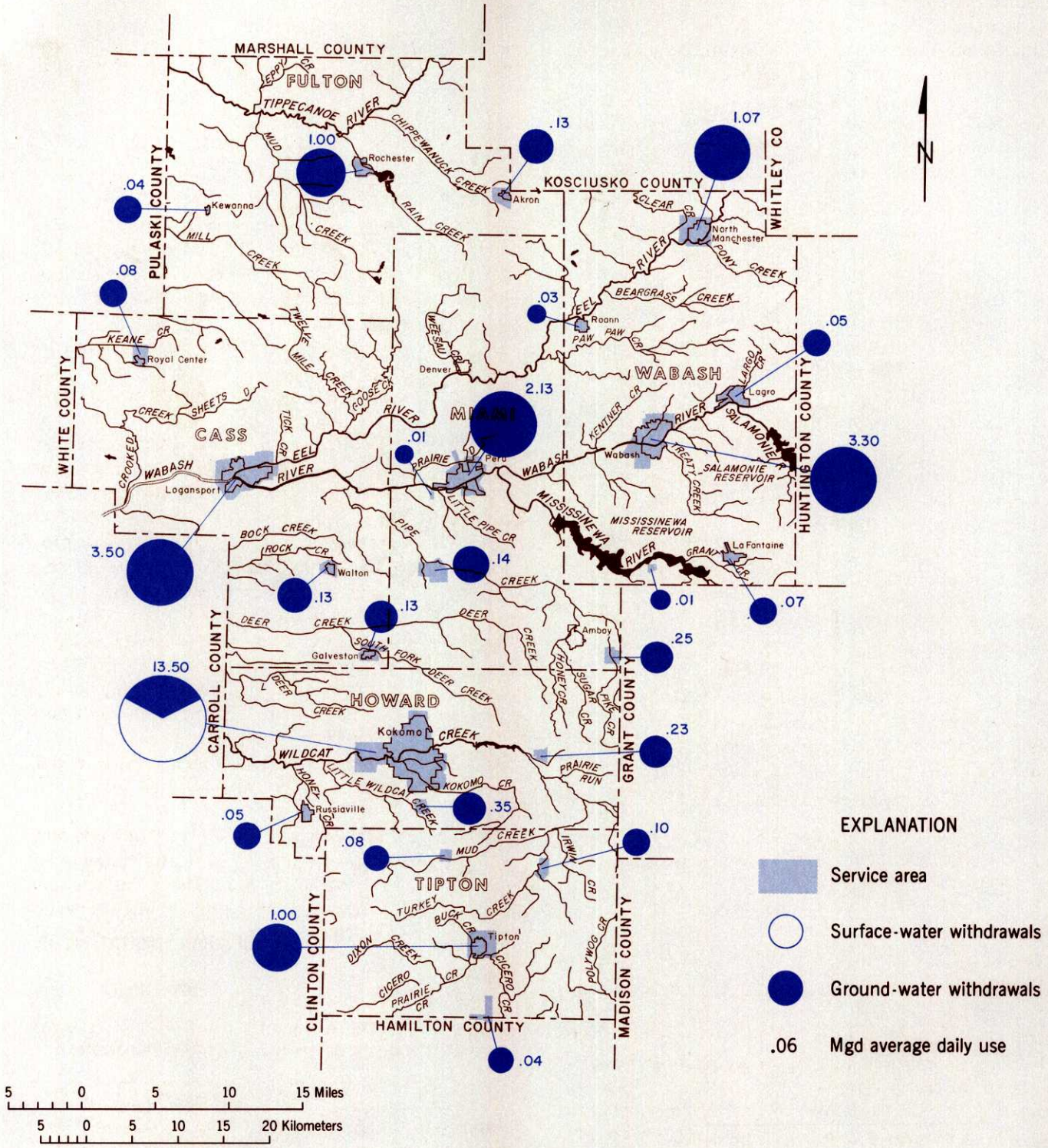


Figure 128
Map of Region Five showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

approximately eighty-two percent of its supply from surface water sources while Howard County depends on surface water for fifty-eight percent of its supply. The remaining water withdrawals are made from ground-water sources. Well fields are normally located within or near the areas being served.

Projections of public water supplies indicate that withdrawals by the public water utilities may increase to approximately 37.2 mgd by the year 2000, as shown below.

Table 96

The 1977 and projected withdrawal and consumption rates for public water supplies by the year 2000, in million-gallons-per-day

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	27.4	28.9	33.3	37.2
Consumption	2.8	2.9	3.3	3.7

Industrial Water Industrial establishments had a water intake averaging 34.0 mgd in 1977. Of the total industrial intake, 15.4 mgd was developed by the industries themselves while 18.5 mgd was purchased from the region's public utilities. Most of the self-supplied water is withdrawn from ground-water sources. Approximately 2.5 mgd of the self-supplied industrial water was consumed in 1977.

Although industrial output is expected to increase, total industrial water intake is expected to decrease due to increased plant efficiency. Industrial water use in the region is expected to decrease to 30.7 mgd by the year 2000. The self-supplied component may increase to 15.9 mgd, while the water supplied by public utilities may decrease to 14.8 mgd. Data for industrial self-supplied withdrawals is presented below.

Table 97

The 1977 and projected self-supplied withdrawal and consumption rate for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	15.4	15.1	15.5	15.9
Consumption	2.5	2.6	3.4	4.3

Rural Self-Supplied Water The majority of rural self-supplied water is withdrawn from ground-water sources. Residential use of self-supplied water amounted to 6.2 mgd in 1975. Withdrawals of self-supplied water for households may increase to 9.2 mgd by the year 2000.

Livestock accounted for 3.2 mgd of rural self-supplied water. By the year 2000, water withdrawals for livestock may increase to 4.4 mgd.

The total withdrawal of rural self-supplied water may increase from the current 9.7 mgd to approximately 13.7 mgd by the year 2000, as indicated in the following table.

Table 98

The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	9.7	10.2	12.0	13.7
Consumption	9.7	10.2	12.0	13.7

Irrigation Water Soil associations with irrigation potential are shown in Figure 129. Approximately 1,560 acres were irrigated in the region in 1977, consisting of 1,200 acres in Fulton County and 360 acres in Cass and Miami Counties.

Assuming 1977 as a normal growing year, agricultural croplands would have required approximately 4.3 mgd during the peak irrigation period of July and August.

It is estimated that about 57,000 acres in the region could be profitably irrigated. Central Fulton County has an estimated 30,000 acres with irrigation potential, Cass County has 15,000 acres, Miami County has 5,000 acres, and Wabash County has 7,000 acres. It is projected that 9,200 acres will be under irrigation by the year 2000. This expansion is expected to increase the peak July–August irrigation demand in an "average" season to about 26.1 mgd. The average season ground-water withdrawals may increase 13.0 mgd by the year 2000. Surface water sources currently supply seventy-seven percent of current irrigation water and may supply fifty percent by the year 2000.

Irrigation of the region's golf courses requires about 1.3 mgd during the peak July–August irrigation period.

The total withdrawal for irrigation of croplands and golf courses during the average irrigation season of 1977 was approximately 5.6 mgd. These withdrawals may increase to 27.7 mgd during the average growing season by the year 2000, as shown in the following table.

Table 99

The 1977 and projected withdrawal of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	5.6	8.6	18.1	27.7
Consumption	5.6	8.6	18.1	27.7

Electric Energy Two coal-fired, electric generating plants, each having a generating capacity of thirty-eight megawatts, are located in Region Five. The Logansport and Peru facilities each withdraw

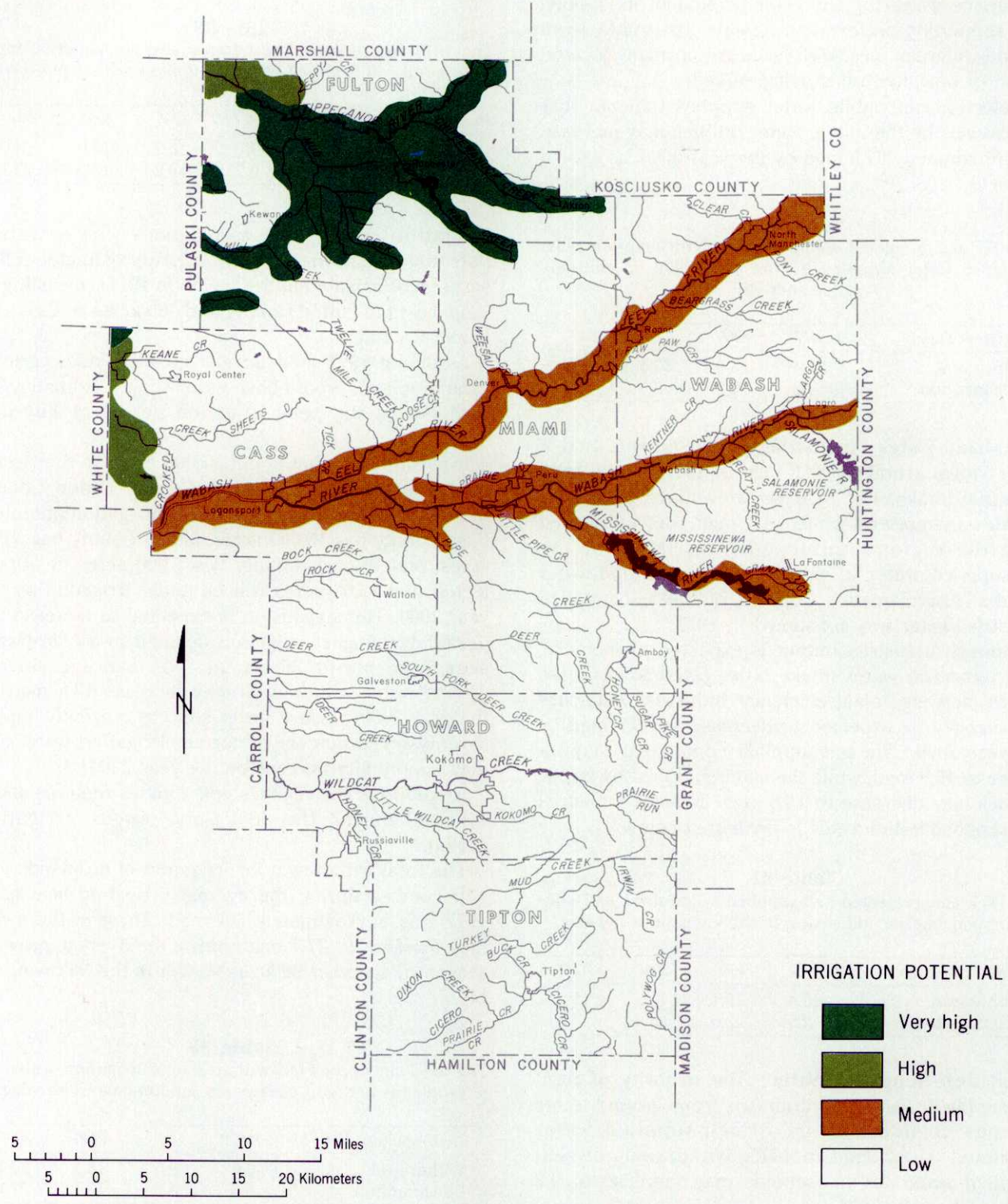


Figure 129
Map of Region Five showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

approximately 26 mgd from the Eel and Wabash Rivers. All of the water used in the cooling systems of these two plants is returned to the parent stream.

No plans have been announced for any new electrical generating facilities. The Wabash, Tippecanoe, and Eel Rivers possess flows that could support a power plant.

Water withdrawals for the production of energy in 1977 were approximately 58.0 mgd but are expected to decrease to 15.0 mgd by the year 2000, as tabulated below.

Table 100
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	58.0	52.0	45.0	15.0
Consumption	0	0	0	0

EXCESS WATER

Flooding

It is estimated that approximately 37,000 acres of the region are subject to flooding. The major flood plains are shown in Figure 130. Figure 131 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $277,500 in urban areas and $465,000 in rural areas. Approximately seventy-two percent of the urban damages occur along the Wabash River.

Flood Control As of 1978 a number of flood control projects were completed or were being constructed. The small watershed projects included Mill Creek, which has been completed, and Bachelor Run and Rock Creek, both under construction.

Mississinewa and Salamonie Lakes are the two U.S. Army Corps of Engineers multiple purpose projects in the region. Mississinewa Lake was completed in October 1967. The control structure is located in Miami County about seven miles southeast of Peru. It is estimated that the project has prevented $13,279,000 in flood damages on the Wabash and Ohio Rivers since its completion. Salamonie Lake is located in Wabash County about ten miles east of the town of Wabash. It was completed in September 1966 and controls the drainage of 533 square miles in the Salamonie River watershed. It is estimated that the project has prevented flood damages in the amount of $13,068,000 to date.

These reservoirs, along with Huntington Lake farther upstream in Huntington County, have considerable impact on flooding along the Wabash River. The cities of Logansport and Peru benefit from all three projects while the city of Wabash benefits from the Salamonie and Huntington Lakes.

Flood Plain Management The communities participating in the emergency phase of the National Flood Insurance Program are listed below. Residents of these areas can purchase insurance against property losses due to flooding.

Table 101
Communities participating in the emergency phase of the National Flood Insurance Program.

Cass County, unincorporated	Miami County, unincorporated
Denver	North Manchester
Galveston	Peru
Fulton County, unincorporated	Roann
Howard County, unincorporated	Rochester
Kokomo	Russiaville
LaFontaine	Tipton
Lagro	Wabash
Logansport	Wabash County, unincorporated
	Walton

Agricultural Drainage

Approximately forty-seven percent of the soil associations in Region Five have "severe" wetness characteristics, thirty-six percent have "moderate" wetness characteristics, while seventeen percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics are shown in Figure 132. There are approximately 4,351 miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards or, in a limited number of cases, of conservancy districts. There is no legal entity responsible for maintenance of drainage for the other streams of the region.

Soil Erosion

The erosion potential of soil associations is shown in Figure 133. Fifty-nine percent of the 1,367,000 acres is classified as having a "low" erosion potential for land left in a fallow state. Thirty-six percent of the region is rated as having a "medium" soil erosion hazard, while approximately five percent is rated as having a "high" soil erosion hazard.

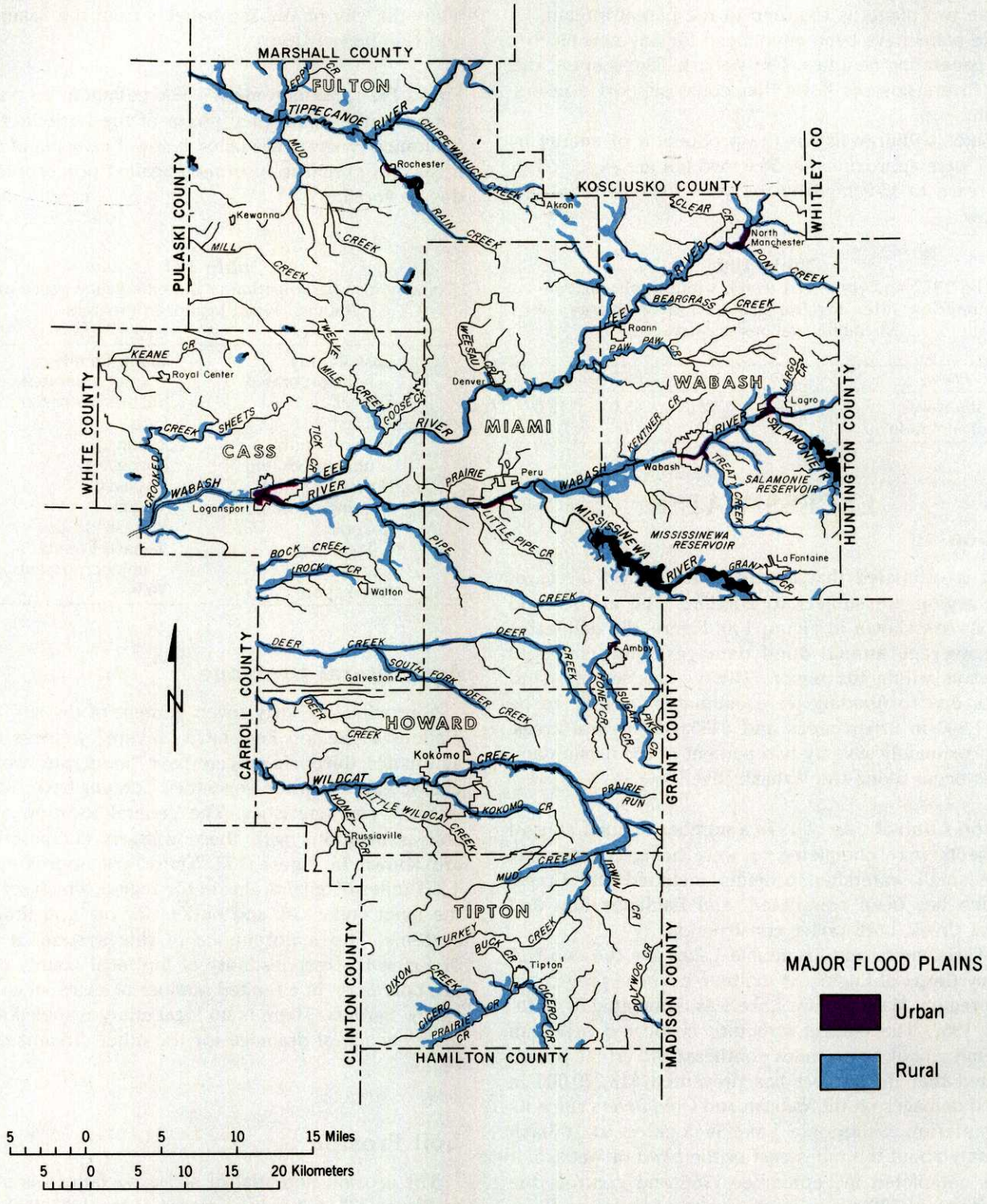


Figure 130
Map of Region Five showing the major floodplains.

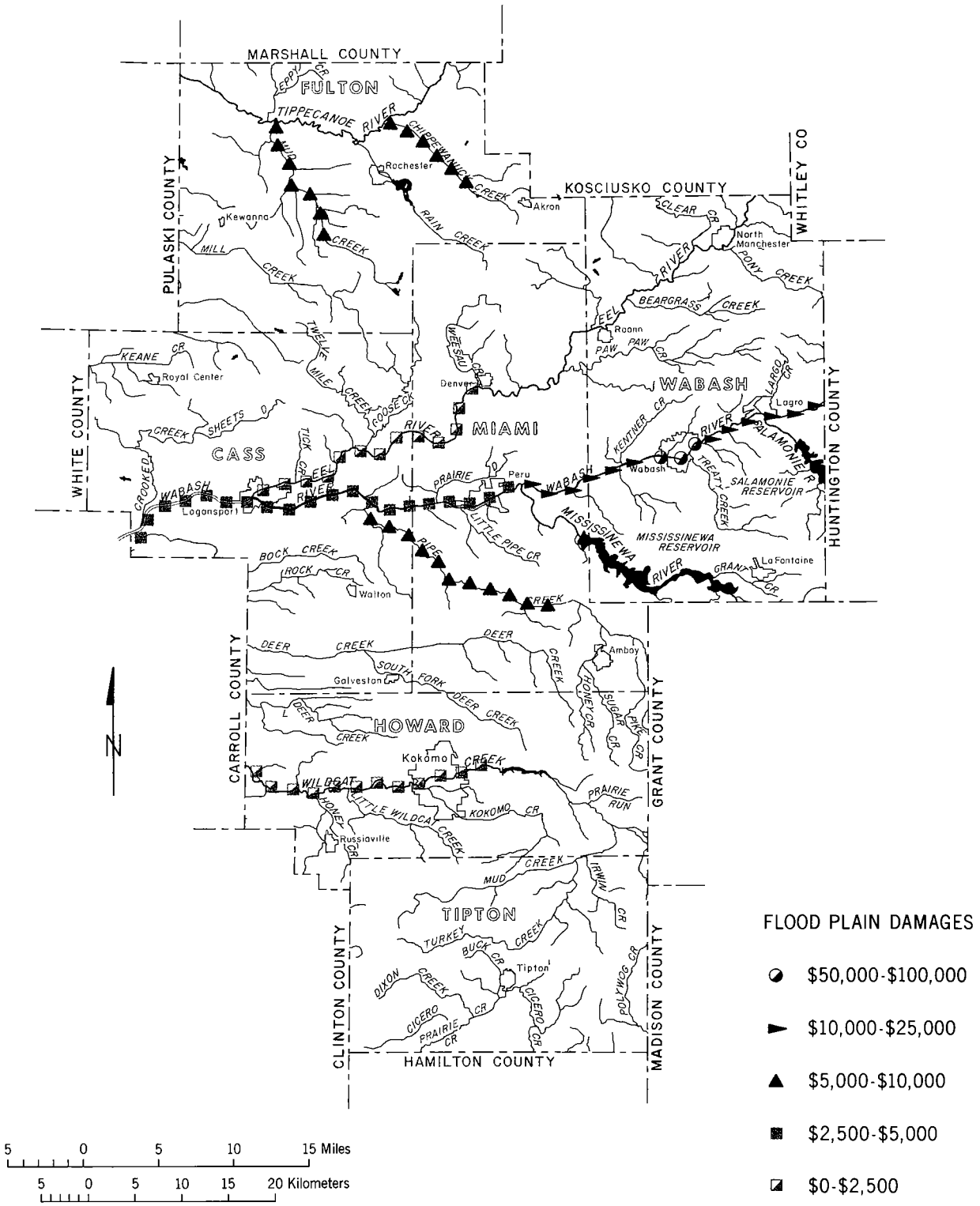


Figure 131
Map of Region Five showing the estimated average annual flood damages per mile along selected streams.

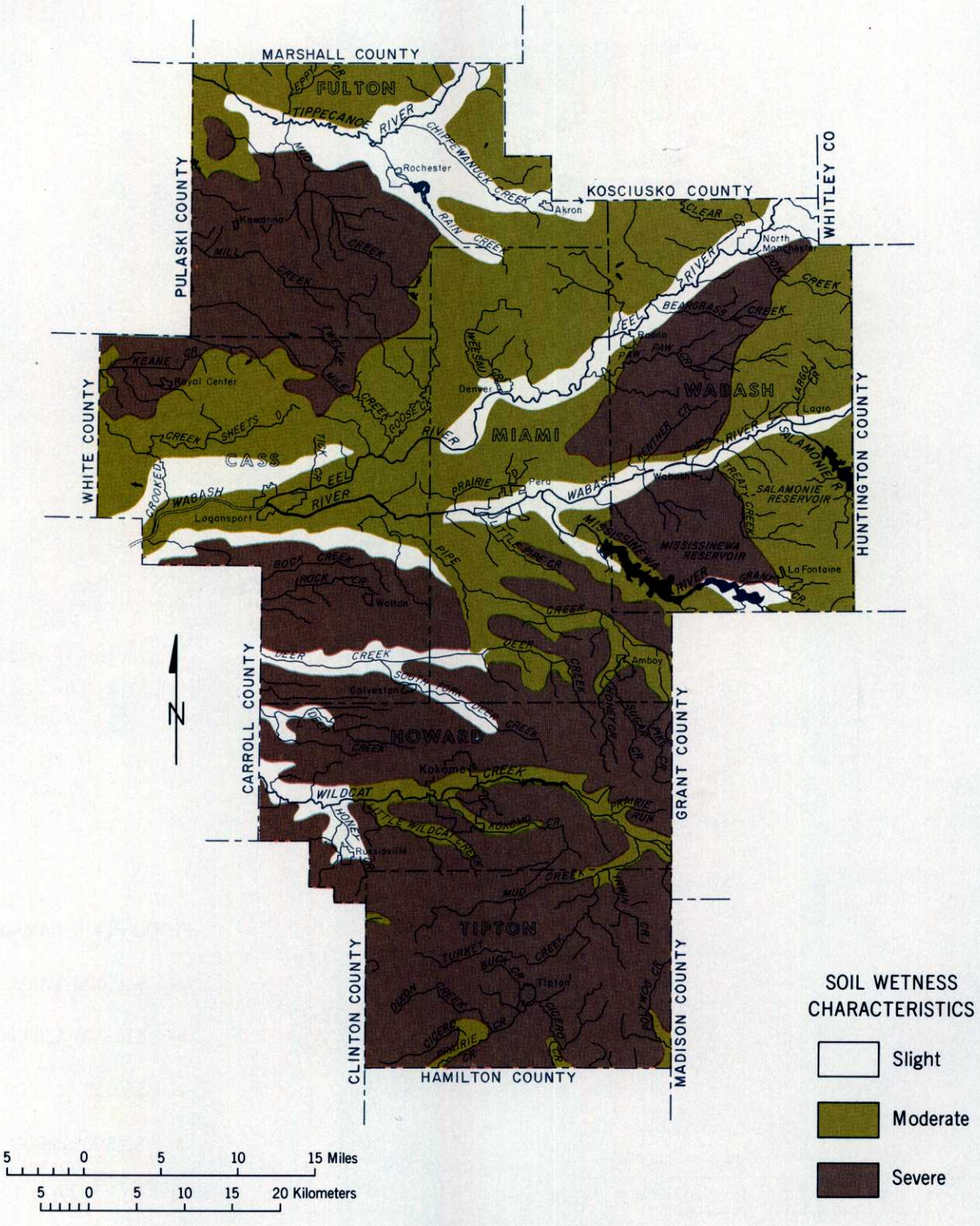


Figure 132
Map of Region Five showing the location of wetness characteristics of soil associations.

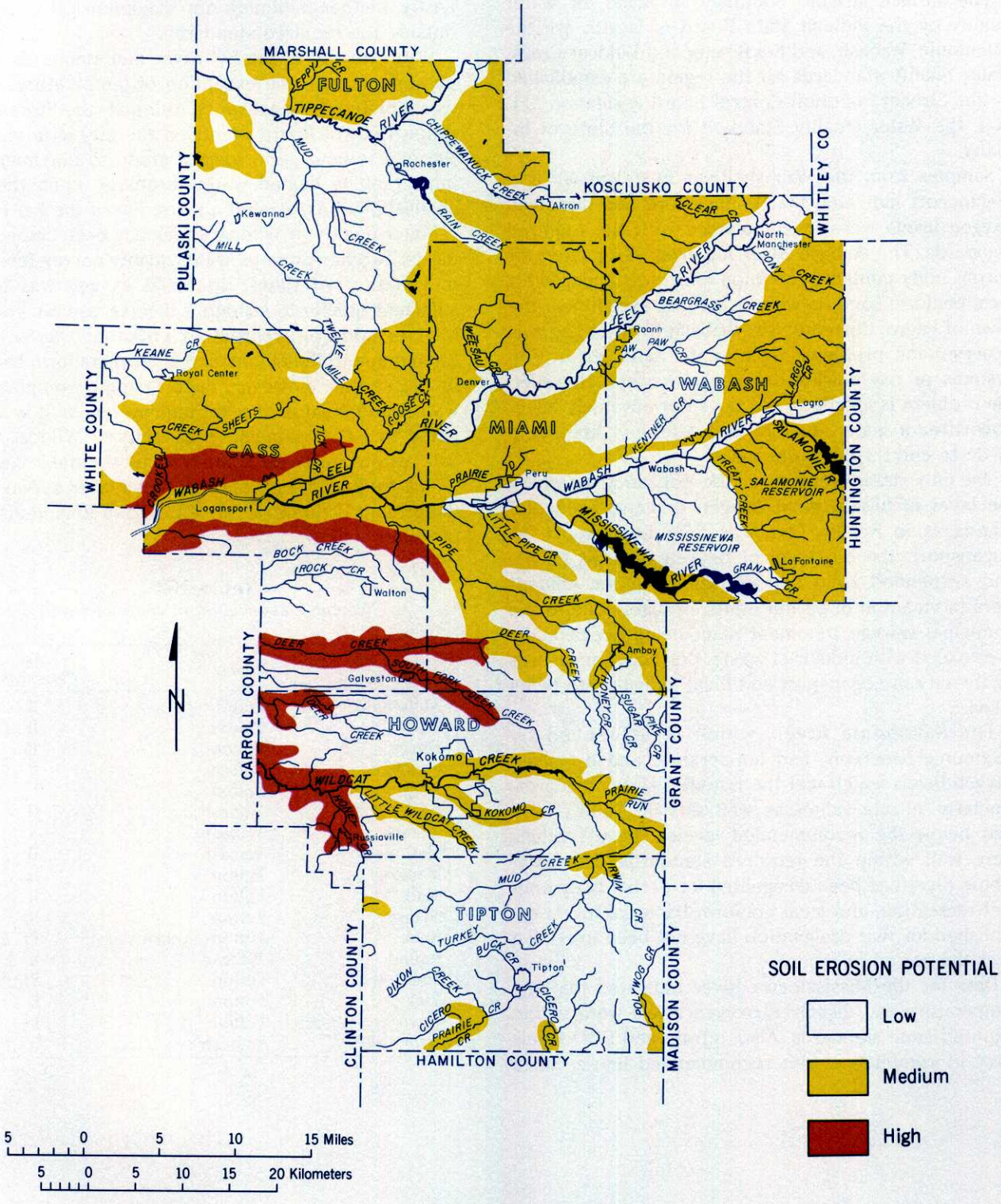


Figure 133
Map of Region Five showing the erosion potential of the soil associations.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the Salamonie, Wabash, and Eel Rivers, and Wildcat Creek. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standard for the State of Indiana.

Samples from the Wabash River near Wabash and Logansport indicated that temperature and dissolved oxygen levels were in compliance with the required standards. The Wabash River has been designated for partial body contact recreation and the standards for fecal coliform bacteria were being met except near the town of Lagro. Currently, the Wabash River at Lagro is experiencing problems from septic tank absorption systems or overflowing drains and sewers. However, the problem is localized and does not adversely affect downstream water quality, and attempts are being made to correct the problems.

The only stream segment of the Wabash River where the level of biochemical oxygen demand exceeded standards in Region Five was near Logansport. At Logansport, the biochemical oxygen demand (BOD) and suspended solid concentrations in the effluent were in violation of permit limits, probably due to the municipal sewage treatment plant being occasionally overloaded with industrial waste. Corrective measures by the city of Logansport and local industry are being taken.

The Salamonie River, which is influenced by Salamonie Reservoir, had temperature and dissolved oxygen levels which met the required state standards. Similarly, nitrate values as well as BOD values were also below the recommended levels. The pH values were well within the required standards. The Salamonie River has been designated for partial body contact recreation, and fecal coliform bacterial levels established for that designation have not been exceeded over the period of record.

Data for the Mississinewa River indicated that the temperature and dissolved oxygen levels were within required state standards. Also, nitrate and BOD levels were in compliance with recommended levels. Since fecal coliform concentrations were low, the stream was within permissible limits for partial body contact. Lastly, neither minimum nor maximum pH values fell outside the required standards.

Water quality of the Eel River met standards for all parameters with the exception of temperature, which was violated at Logansport. Although the Stream Pollution Control Board identified the city as a violator, the city is now performing a study to document the impact of its heated water discharge upon the fish, shellfish, and associated aquatic life of the Eel River.

Water quality in Wildcat Creek has been below standards. Two fundamental water quality parameters were in violation. At times, dissolved oxygen was not of sufficient quality to sustain a diverse aquatic community. In addition, recreation potential was severely limited due to the abundance of fecal coliform bacteria in the stream. However, once Kokomo completes its wastewater treatment plant improvements, it is anticipated that the assimilative capacity of Wildcat Creek will restore instream conditions to a suitable level.

The trophic classification of those lakes surveyed by the Stream Pollution Control Board in Region Five are presented below.

Table 102
Trophic classification of lakes surveyed.

Lake	*County*	*Age Classification*
Anderson	Fulton	II
Barr	Fulton	II
Bruce	Fulton	II
Fletcher	Fulton	II
King	Fulton	I
Long	Wabash	II
Lukens	Wabash	II
McColley	Wabash	II
Manitou	Fulton	II
Mud	Fulton	II
Nyona	Fulton	II
Rock	Fulton – Kosciusko	III
Round	Wabash	II
South Mud	Fulton	III
Tink	Fulton	II
Town	Fulton	III
Twin Lakes	Wabash	II

Region Six

Blackford, Delaware, Grant, Henry, Jay, Madison, and Randolph Counties, located in west-central Indiana, form Region Six. The region contains approximately 2,680 square miles and is bounded by Ohio to the east; Wayne, Rush and Hancock Counties to the south; Hamilton, Tipton, Grant, and Miami Counties to the west; and Wabash, Huntington, Wells, and Adams Counties to the north, as shown in Figure 134.

The 1975 population was 474,600. The official Indiana Population Projections indicate that by the year 2000, the region's population may increase to 527,000. The 1975 population and the projections for each county are tabulated below.

Table 103
The 1975 and projected populations for Region Six.

County	*1975*	*1980*	*1990*	*2000*
Blackford	15,859	16,500	17,300	18,100
Delaware	128,989	135,200	141,600	144,100
Grant	83,896	86,500	90,500	92,000
Henry	53,720	54,300	56,500	58,400
Jay	24,183	24,900	26,500	27,900
Madison	138,548	141,900	148,100	152,100
Randolph	29,294	30,500	32,300	34,400
Total	474,589	489,800	512,800	527,000

The major population centers are Anderson in Madison County and Muncie in Delaware County. These urban centers accounted for fifty-six percent of the region's 1975 population.

Agriculture is the dominant land use with more than eighty-three percent of the area devoted to that purpose. Approximately seven percent of the land is

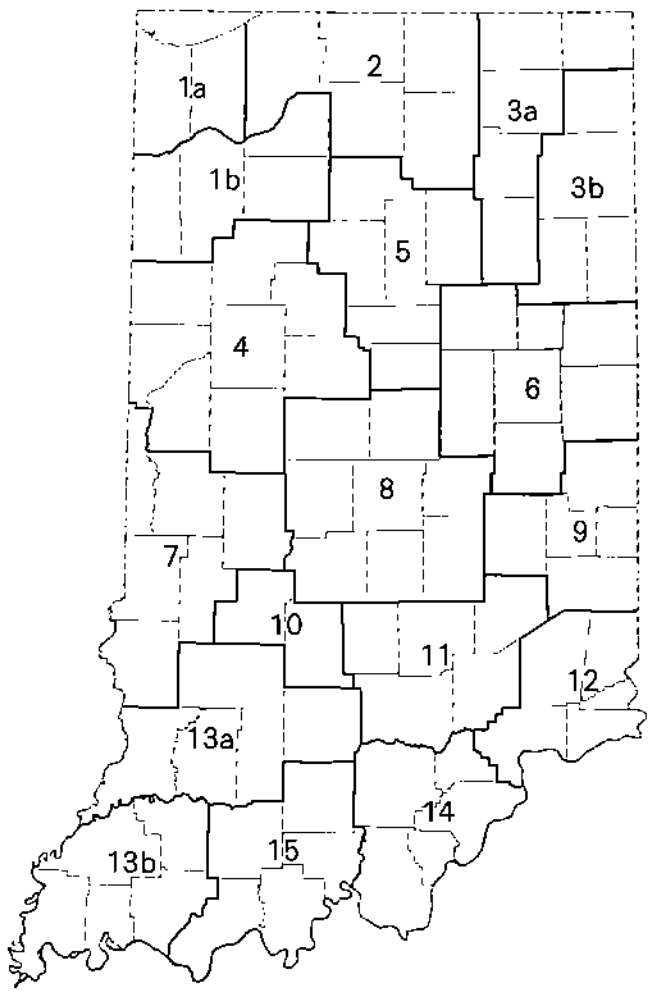


Figure 134
Map of Indiana showing the location of Region Six.

forested while the remaining ten percent is utilized for urban and miscellaneous purposes.

Thirty-five percent of the region's population, plus an additional 5,880 persons, were employed within the region. The electrical machinery, transportation equipment, and fabricated metal industries employ thirty percent of the work force.

The region has gently rolling highlands divided by stream valleys with moderate to wide flood plains. The curving, northwestern to southeastern trending moraines shape the drainage pattern of the Wabash, Salamonie, and Mississinewa Rivers which flow toward the northwest parallel to the moraines.

The region receives approximately 38.5 inches of precipitation annually. This varies from a high of 4.5 inches in June and a low of 2.2 inches in February. Of the 38.5 inches of precipitation, approximately 11.5 inches appear as streamflow while 27.0 inches are consumed through evapotranspiration. The average temperatures range from 27°F. in January to 73.5°F. in July. The average annual temperature is 51.5°F. Data from surrounding areas indicate the prevailing wind is from the southwest at 8.9 miles per hour.

THE WATER RESOURCE

Ground Water

The entire region was glaciated during the last Wisconsinan glacial advance. The materials deposited include ice-contact sand and gravel, glacial till, lake sediments, and valley train and outwash sand and gravel. The glacial drift is over 300 feet thick where the buried Teays drainage system has been filled with glacial deposits. The drift is absent in a few areas where erosion has exposed the underlying bedrock. Concentric bands of glacial deposits or end moraines are found throughout this region, marking the extent of various glacial advances. Till is the predominant glacial deposit in most of this area. Within the till exist scattered sand and gravel units which often supply moderate amounts of ground water. For the most part, till and the outwash sand and gravel deposits are the primary glacial aquifers.

Bedrock deposits, ranging in age from Ordovician to Silurian, occur beneath the cover of glacial materials. The Ordovician rocks occur in areas where erosion of the Teays Valley has cut through the younger Silurian formations. Shales with interbedded limestone lenses are common among these Ordovician rocks. Silurian limestones and dolomites occur beneath the glacial drift in most of the region and are usually good producers of ground water. The degree of fracturing and the nature of overlying material will strongly affect the capability of the bedrock to yield water to wells.

Of particular interest is the area in northwestern Jay and northcentral Grant Counties where the buried pre-glacial Teays Valley contains varying thicknesses of water-bearing sand and gravel. It is estimated that 600 or more gallons-per-minute (gpm) may be the potential yield from wells tapping this aquifer, as shown in Figure 135. In addition, bedrock aquifers, particularly the Silurian limestones and dolomites, offer a moderate yield of 200 to 400 gpm to properly constructed, large-diameter wells.

In Grant County, potential well production is estimated to range between 200 and 400 gpm. Small areas associated with the buried Teays Valley may yield 600 gpm. Yields of 600 gpm are expected from sand and gravel within Jay and Blackford Counties adjacent to the Teays Valley. Ground-water availability in Delaware and Madison Counties is generally good and wells may produce 200 to 400 gpm. A small area in central Madison County may be capable of producing up to 600 gpm. The northwestern two-thirds of Henry County can be characterized as having ground-water resources capable of producing 400 to 600 gpm, while in the southeastern portion of the county, well yields of 100 to 200 gpm are normally expected. In Randolph County, well yields of 100 gpm are expected in the extreme southeastern portion, while 200 to 400 gpm may be developed elsewhere. Small areas of thicker sand and gravel deposits in central and southern Randolph County may yield up to 600 gpm.

The ground-water quality is strongly affected by the glacial drift and the underlying bedrock formations. Notable consituents are sulfates and fluorides which occur in higher than normal concentrations. Hardness levels range from 300 to 500 parts-per-million (ppm). The iron content for ground water ranges from 0.3 to 3.0 (ppm).

Surface Water

Streamflow The major streams include the Mississinewa River, Salamonie River, and the West Fork of the White River. These streams generally flow in a westerly direction and are within the Wabash River drainage basin. The Salamonie River and the West Fork of the White River originate within the region.

The seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and the average annual flow for major streams with gaging stations within Region Six are presented in Table 104.

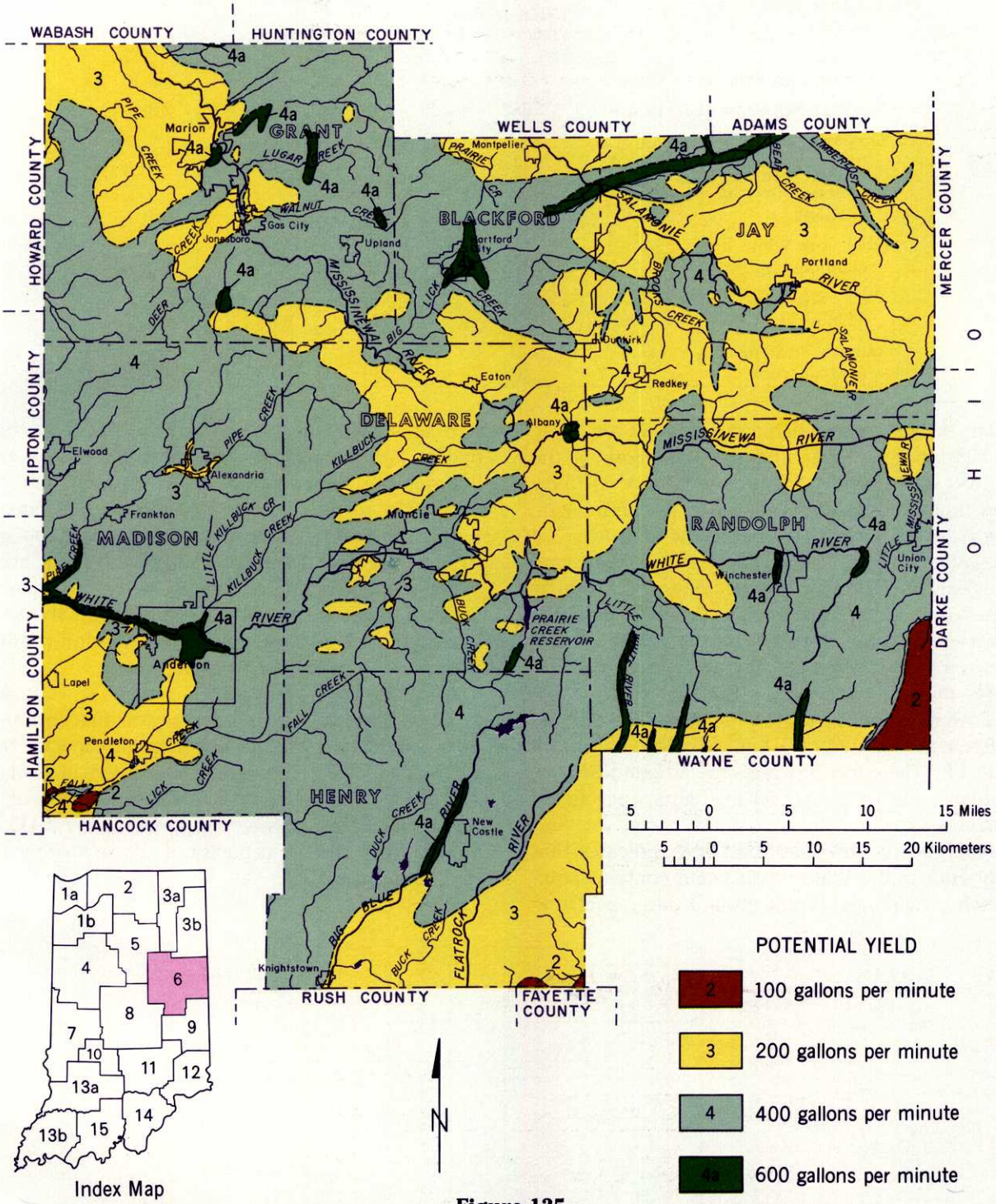


Figure 135

Map of Region Six showing the location and potential yield of ground water from properly constructed large diameter wells.

Table 104
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Mississinewa River near Eaton	310	170	1.9	1.2
Mississinewa River at Marion	682	420	12.0	2.3
Mississinewa River near Ridgeville	133	80	0.6	0.3
Salamonie River at Portland	86	46	0.6	0.3
West Fork White River at Anderson	406	240	26.0	19.0
West Fork White River at Muncie	241	130	1.4	0.6
Wabash River near New Corydon	262	130	1.3	0.9

The largest and most reliable streamflows are those in the Mississinewa River and the West Fork of the White River at Anderson. The one day, once in thirty year low flows for the Mississinewa at Marion indicate that the river will have a sustained flow of at least 2.3 million-gallons-per-day (mgd), while the average annual flow exceeds 420 mgd. The one day, once in thirty year low flows for the West Fork of the White River at Anderson indicate the river will have a sustained flow of at least 19 mgd, while the average annual flow exceeds 240 mgd.

The flow duration curve for the West Fork of the White River at Muncie has a minimal slope as shown in Figure 136. The curve indicates the stream will have a dependable flow of at least 6.1 mgd ninety percent of the time.

The slope of the flow duration curve indicates that the West Fork of the White River basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to thirty-eight, twenty, and thirteen percent for dry, average, and wet years respectively. Conversely, sixty-two to eighty-seven percent of the flow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or from snowmelt.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are presented in Table 105, and are located on Figure 137. These eleven lakes have a combined surface area of approximately 2,440 acres with a gross storage capacity of approximately 14,140 million gallons.

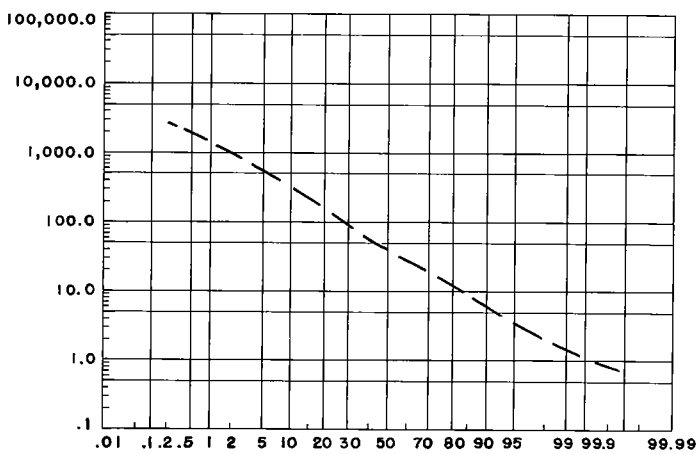


Figure 136
The flow duration curve for the West Fork of the White River at Muncie.

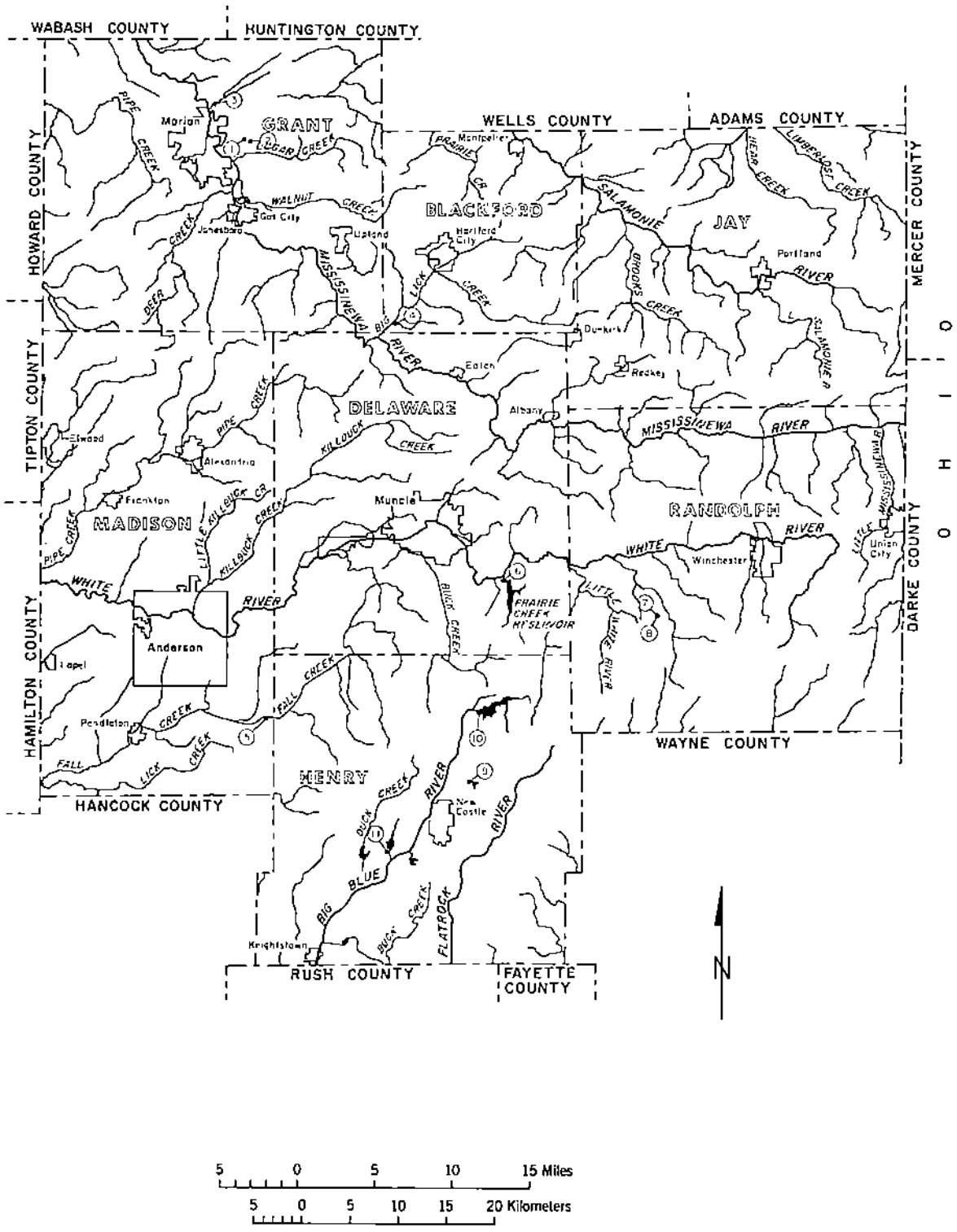


Figure 137
Map of Region Six showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

Table 105

Lakes at least 50 acres in size or having a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Loew Lake, North	na	10.4	71
2	Loew Lake, South	na	23.4	114
3	Wagner Lake	na	42.1	65
4	Lake Mohee	na	24.2	104
5	County Line Fishing Lake	na	9.4	42
6	Prairie Creek Reservoir	16.80	1,275.0	7,168
7	Indian Trail Lake No. 1	na	na	97
8	Indian Trail Lake No. 2	na	na	97
9	Big Blue River Structure No. 15	4.86	67.7	248
10	Big Blue River Structure No. 20	8.90	815.0	5,181
11	Westwood Run Structure No. 13	na	173.0	953

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Six is presented in Table 106. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely when the supply as a percentage of demand is less than one hundred, the supply is less than the projected demand.

Boating and Waterskiing According to estimates, only five percent of the demand for boating is met by available boating areas. This shortage may continue through the year 2000. None of the demand for waterskiing acreage is satisfied. This shortage is expected to continue through the year 2000.

Canoeing Canoeing opportunities in the region are available primarily on the Mississinewa and Salamonie Rivers, and the West Fork of the White River.

A total of 144 miles of streams in Region Six has been identified as suitable for canoeing. This supply represents a surplus of the current canoeing demand. The surplus is expected to continue through the year 2000.

Swimming and Ice-Skating The current demand for swimming opportunities exceeds the available supply. This shortage is expected to continue through the year 2000. Ice-skating facilities are not sufficient to

Table 106

The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	28	19.6 boats/acre/year	1,600 acres	5	5	5
Waterskiing	9	34.4 skiers/acre/year	400 acres	0	0	0
Canoeing	7	585 canoes/mile/year	144 miles	100+	100+	100+
Swimming	39	76,600 swimmers/acre/year	28 acres	51	53	52
Ice-Skating	8	6,678 skaters/acre/year	20 acres	67	67	65
Fishing	45	66 persons/acre/year	5,200 acres	10	10	10

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

meet the current and projected demand through the year 2000.

Fishing The quality of the fisheries habitat is indicated on Figure 138. The Mississinewa River contains the region's best stream fishery, with the white bass spawning run of special interest to fishermen. Along most of their lengths, the Salamonie River and West Fork of the White River offer good aquatic habitat, although stretches of each stream are limited by poor water quality. Many smaller streams have been adversely affected by adjacent land uses and consequently offer lower quality aquatic habitat attracting less desirable fish.

Prairie Creek Lake has the best lake fishing in the region. This warmwater fishery consists of sunfish, bass, catfish, walleye pike, and yellow perch. Other lakes, with a few exceptions, do not have good fisheries habitat due to heavy siltation.

Public access for fishing is limited mainly to city and county properties or road crossings. Mounds State Park and Wilbur Wright Fish and Wildlife Area offer limited fishing access.

Ten percent of the demand for fishing opportunities generated by residents of Region Six is currently being met by the supply. This shortage is expected to continue through the year 2000.

Riparian Habitat The quality of the habitat associated with streams and lakes is indicated in Figure 139. Riparian habitat is good along the Mississinewa River and stretches of the other major rivers in the region. The banks of these rivers provide habitat for upland game, various birds, and some muskrats. Waterfowl and shorebirds make use of the larger streams also. Many smaller streams, especially in intensively farmed areas, have low wildlife habitat values. Many of the region's lakes are also farmed up to the edge so little riparian habitat is available. The shoreline of Prarie Creek Lake offers some grass and shrub habitat which is valuable to many types of wildlife. A narrow border of deep marsh exists in Lake Placid. Wilbur Wright Fish and Wildlife Area has man-made marshes along the Blue River to attract waterfowl and also offers the only state-owned public hunting area in the region.

Withdrawal Uses

Public Water Supplies Blackford, Delaware, Grant, Henry, Jay, Madison, and Randolph Counties are served by forty public water utilities. Information on public water supply systems in Region Six follows.

Table 107
The public water supply systems as of 1975.

Counties	*Number of Systems*	*Service Population*	*Total Average Daily Use in Million-Gallons-Per-Day*
Blackford	3	10,360	1.8
Delaware	5	85,278	13.3
Grant	8	59,452	8.9
Henry	8	27,845	4.5
Jay	3	11,775	1.3
Madison	10	98,621	18.9
Randolph	5	12,957	2.0
Total	42	306,288	50.8

The Anderson Water Utility, the largest water utility in the region, withdraws an average of 15.7 mgd for nearly 69,500 customers. The Marion, Muncie, and New Castle water systems are also large suppliers to their respective communities. Marion and Anderson withdraw ground water from well fields. Figure 140 shows the water service areas within Region Six.

Public water utilities withdrew an average of 50.8 mgd with maximum daily withdrawals of 70.0 mgd in 1975. Approximately 5.3 mgd of the total withdrawals is consumed. Seventy-four percent of public water withdrawals is from ground-water sources. Only Montpelier, Muncie, and the Indiana Reformatory systems withdraw from surface water.

Muncie utilizes ground water as an auxiliary supply source. Its primary supply is derived from the White River, supplemented by discharge from Prairie Creek Reservoir during periods of low flows. The Salamonie River is used as a water source by Montpelier.

Those community systems utilizing ground water generally withdraw from wells located in or near their service areas. The region does not contain any rural water systems.

Projections of public water supply withdrawals indicate that these withdrawals may increase to 62.9 mgd by the year 2000, as indicated in the following table.

Table 108
The 1977 and projected withdrawal and consumption rates of public water supplies by the year 2000, in million-gallons-per-day.

Public Water	*1977*	*1980*	*1990*	*2000*
Withdrawal	50.8	52.5	58.4	62.9
Consumption	5.3	5.5	6.1	6.6

Industrial Water Industrial establishments had an estimated water intake averaging 54.4 mgd in 1977. Of this amount, 7.5 mgd was consumed. Of the total industrial intake, approximately 33.4 mgd was developed by the industries themselves while 20.1 mgd was purchased from the region's public utilities. Virtually all of

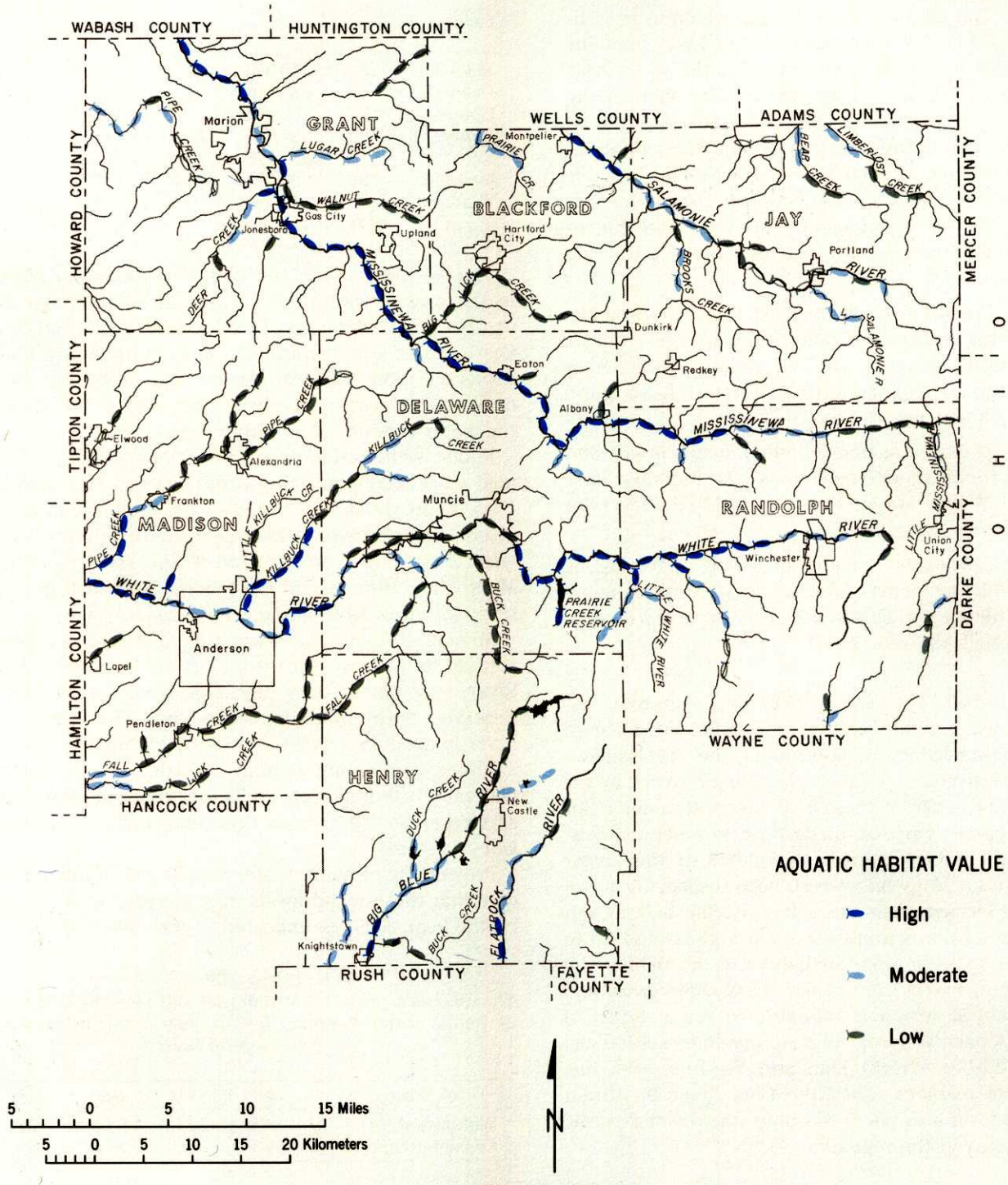


Figure 138
Map of Region Six showing the quality of the fisheries habitat.

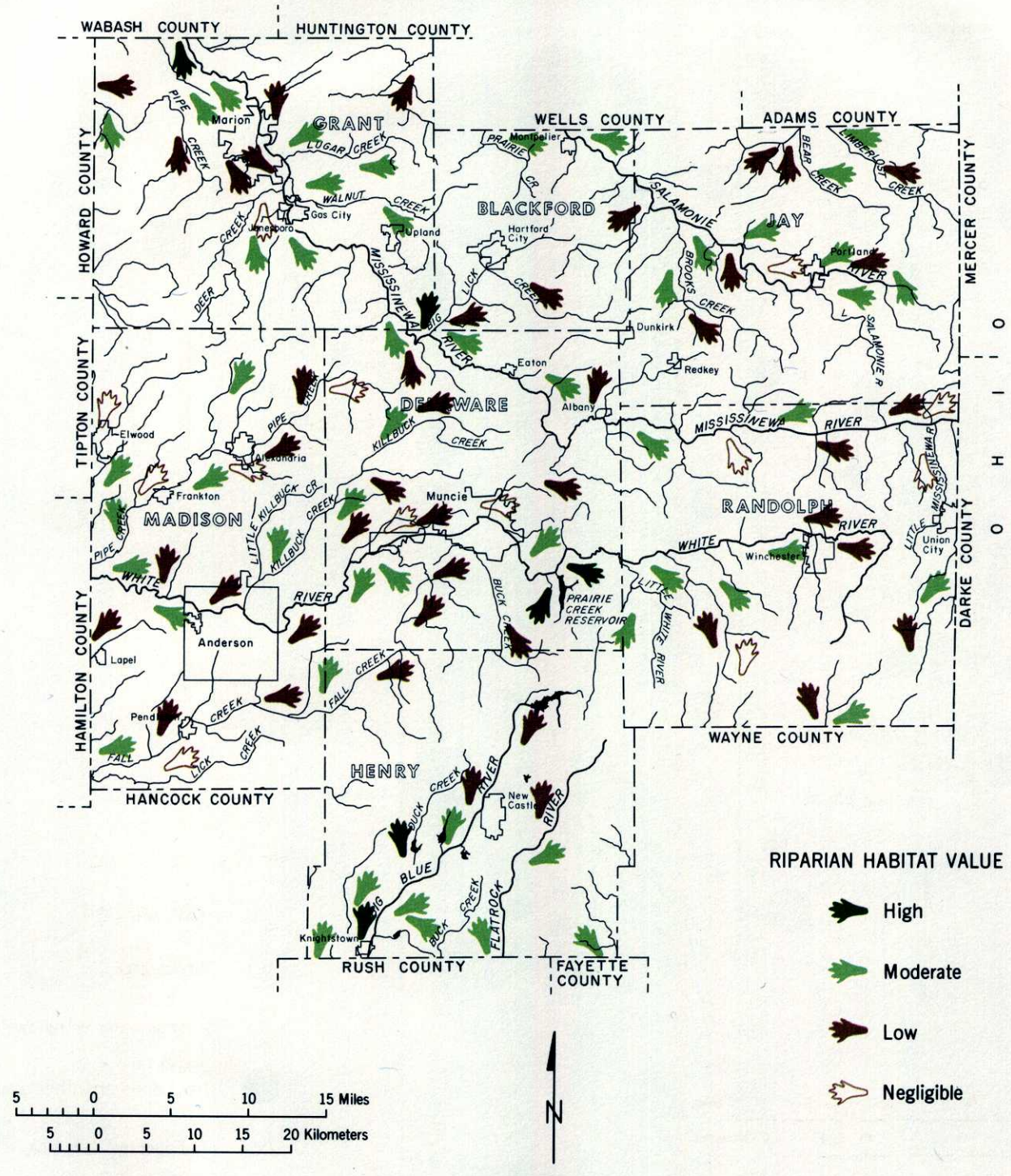


Figure 139
Map of Region Six showing the quality of the riparian habitat.

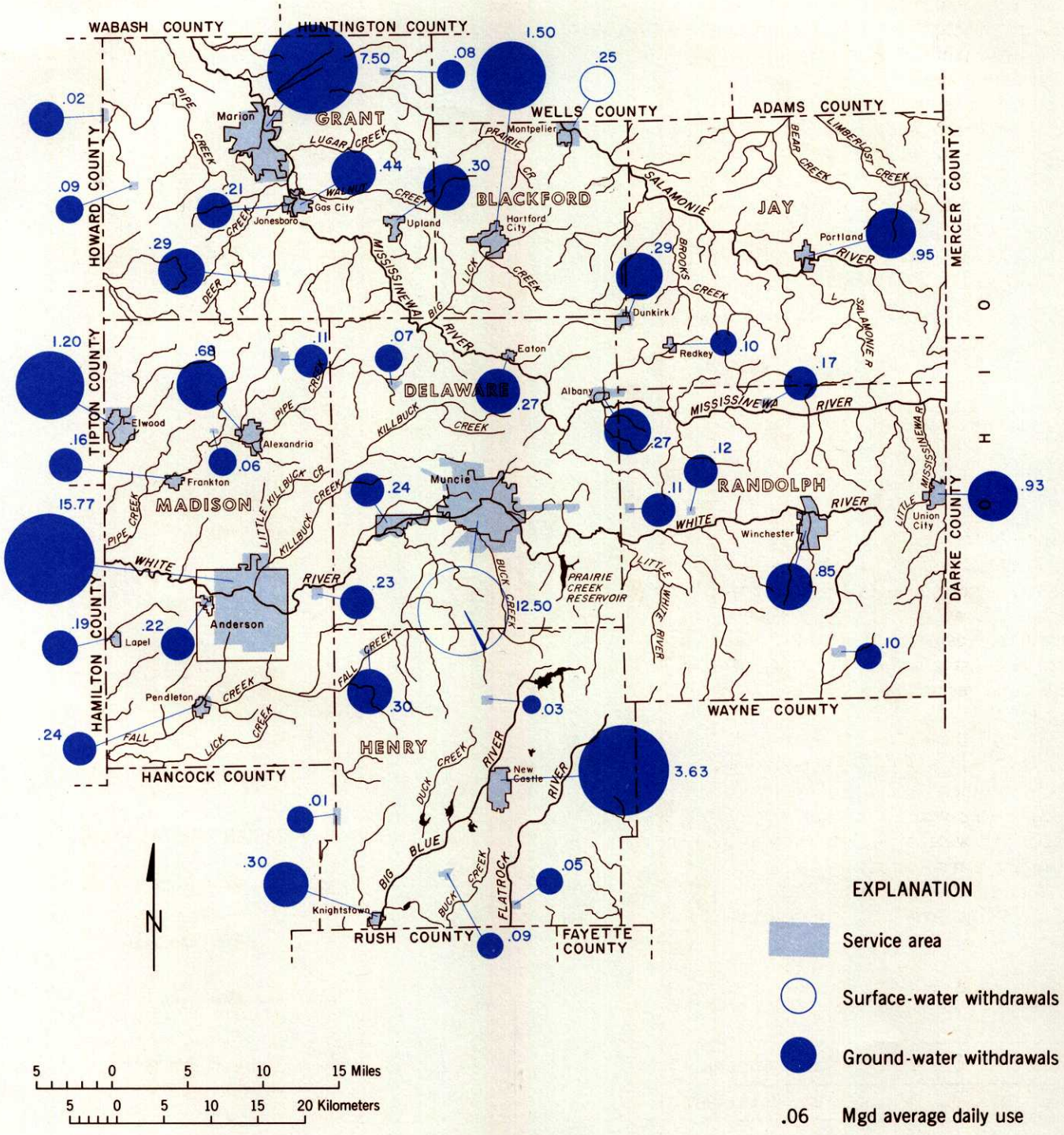


Figure 140

Map of Region Six showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

the self-supplied water was derived from wells located on the individual plant properties.

The largest water-using industry group was comprised of small industries which withdrew 14.8 mgd. The manufacture of transportation equipment required 14.2 mgd, while the primary metals group used 6.5 mgd during 1977.

Although industrial output is expected to increase, total industrial water intake is expected to decrease initially due to plant efficiency and then slowly rise as output increases. In Region Six, industrial water usage is projected to decline to approximately 47.0 mgd by the year 2000. Self-supplied withdrawals may be reduced to 31.3 mgd. Data for industrial self-supplied withdrawals is given below.

Table 109

The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	33.4	32.3	31.4	31.3
Consumption	4.7	5.0	.1	7.3

Rural Self-Supplied Water An estimated 168,300 residents of Region Six lived in homes supplied by individual wells in 1975, with estimated water withdrawals of approximately 9.9 mgd. By the year 2000, additional residents, along with the anticipated general rise in the standard of living, are expected to increase this rural residential water use to approximately 14.1 mgd.

In 1975 there were an estimated 492,700 head of livestock and about 440,400 chickens and turkeys. Collectively, these animals consumed approximately 2.9 mgd. By the year 2000, these animals may require 3.8 mgd. This water is usually supplied from wells on individual farms.

Total rural self-supplied water use for 1977 and the year 2000 is presented in the following table.

Table 110

The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	13.2	13.8	15.9	18.0
Consumption	13.2	13.8	15.9	18.0

Irrigation Water Based upon the survey of irrigated lands, approximately 400 acres were irrigated in 1977. Figure 141 shows the potential irrigation areas. Assuming 1977 as a normal growing year, the irrigation of agricultural cropland would have required about 1.1 mgd during the peak irrigation period of July and August. Only 0.3 mgd of ground water is currently contributed to this irrigation demand.

It is estimated that 3,600 acres may be irrigated by the year 2000. The peak July–August irrigation demand in an "average" year is expected to increase to about 9.5 mgd. The "average" year ground-water use for agricultural demands is expected to increase to 5.11 mgd in the year 2000.

In addition to the irrigation for agricultural use, there are fairways and greens on the region's golf courses that require irrigation. About 2.58 mgd is applied to these areas during the peak July–August irrigation period.

The total withdrawal for irrigation of croplands and golf courses during the "average" irrigation season of 1977 was approximately 3.6 mgd. These withdrawals may increase to 12.1 mgd by the year 2000, as presented here.

Table 111

The 1977 and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	3.6	4.7	8.4	12.1
Consumption	3.6	4.7	8.4	12.1

Electric Energy Region Six does not contain any active electric power generating stations and none are anticipated.

EXCESS WATER

Flooding

Approximately 73,000 acres of the region are subject to flooding. The major flood plains are shown in Figure 142. Figure 143 delineates the average annual flood damages along selected streams. The average annual damages due to flooding were estimated in 1977 to be $2,264,000, of which some fifty-three percent occurred in urban areas.

Flood Control The primary flood control project in the region is the levee system on the West Fork of White River in Muncie. This levee system was designed to improve the floodway channel between walls and levees. The project is comprised of 3.6 miles of earth levee, 0.9 mile of earth levee enlargement, 0.7 mile of concrete wall, 3.8 miles of channel improvement, pumping facilities to dispose of sewage and drainage from the protected areas during floods, and other associated structures. The protected area encompasses approximately 580 acres.

The Upper Big Blue River Small Watershed Project, authorized for construction in 1966, is the only small

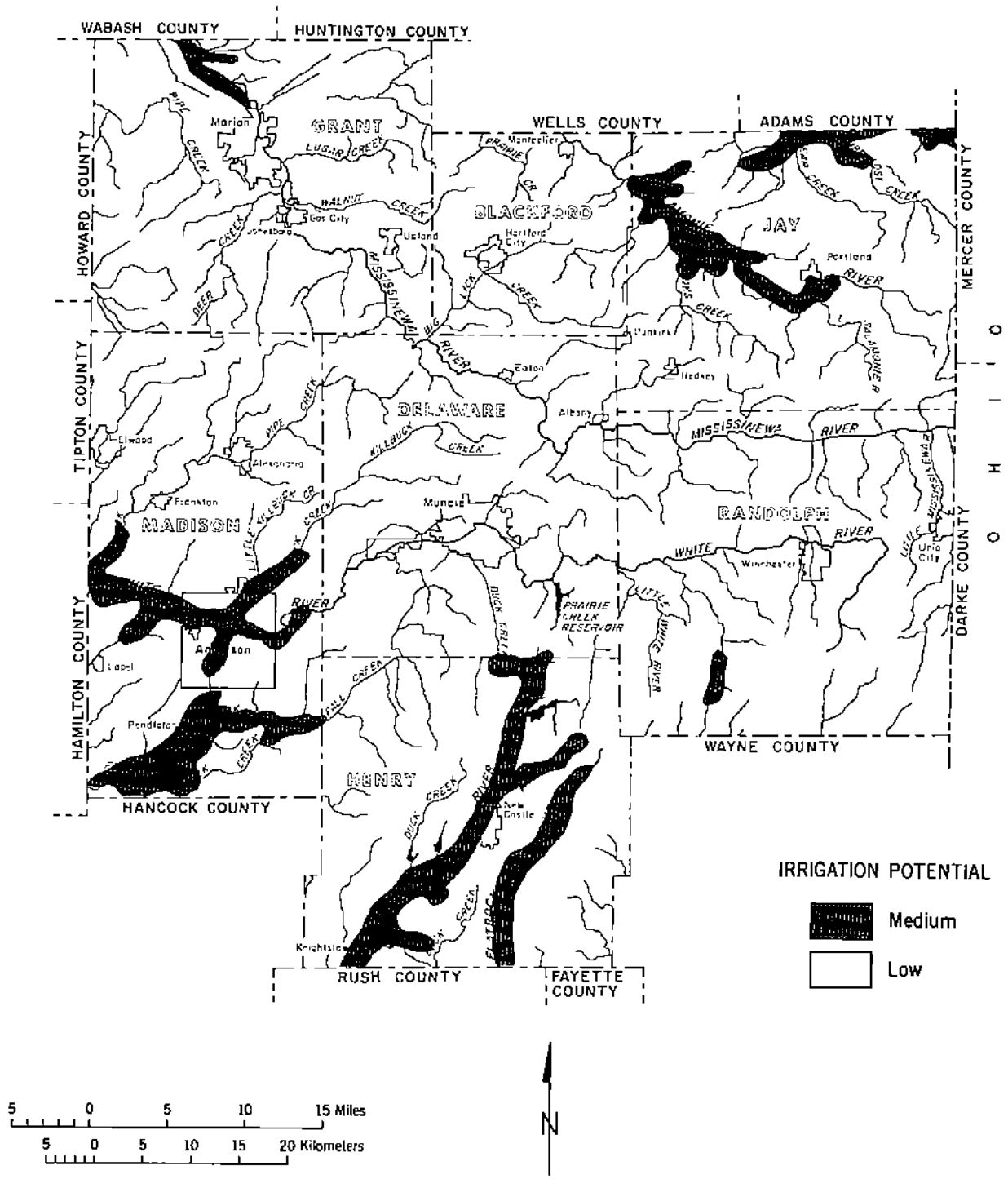


Figure 141
Map of Region Six showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

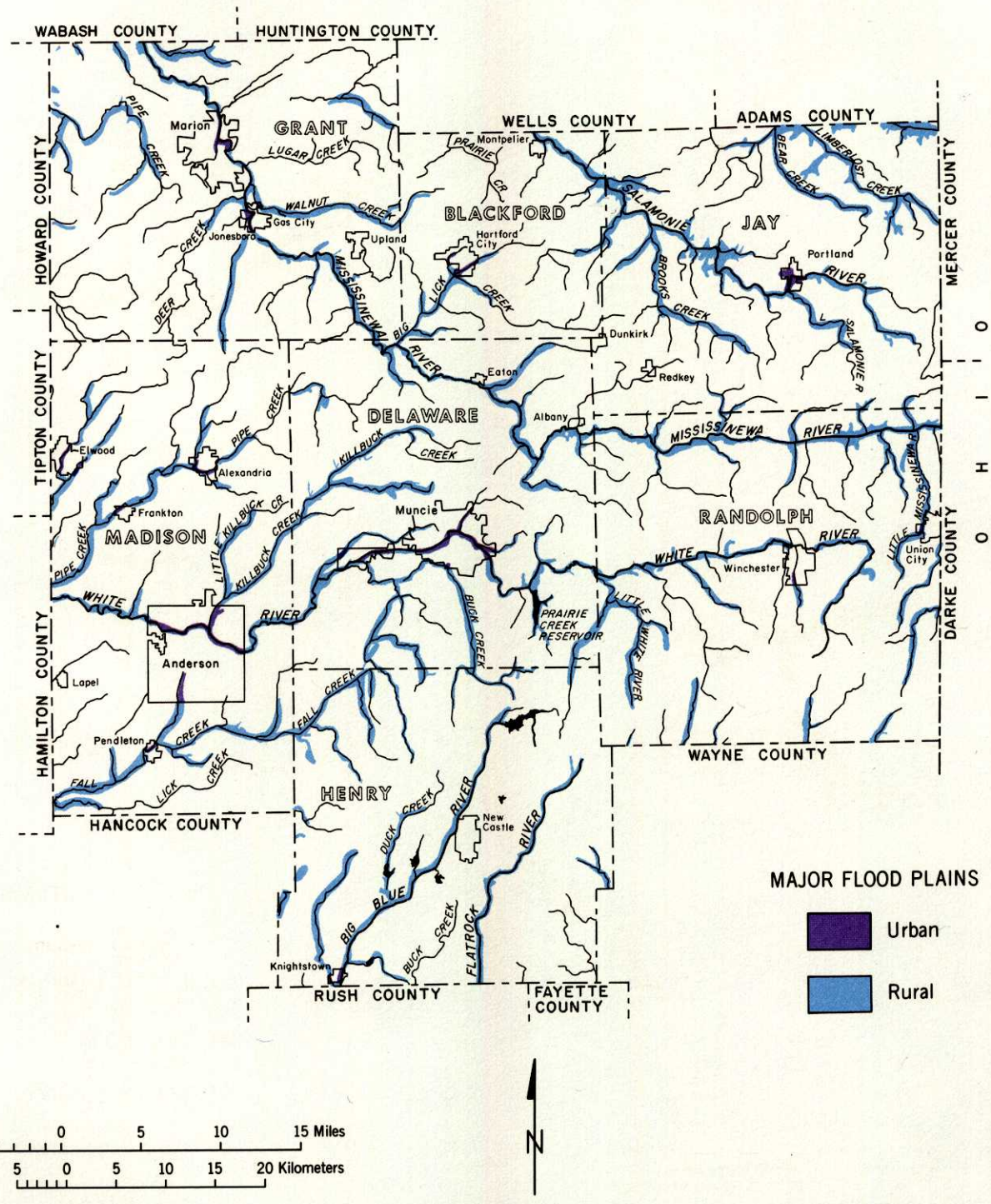


Figure 142
Map of Region Six showing the major floodplains.

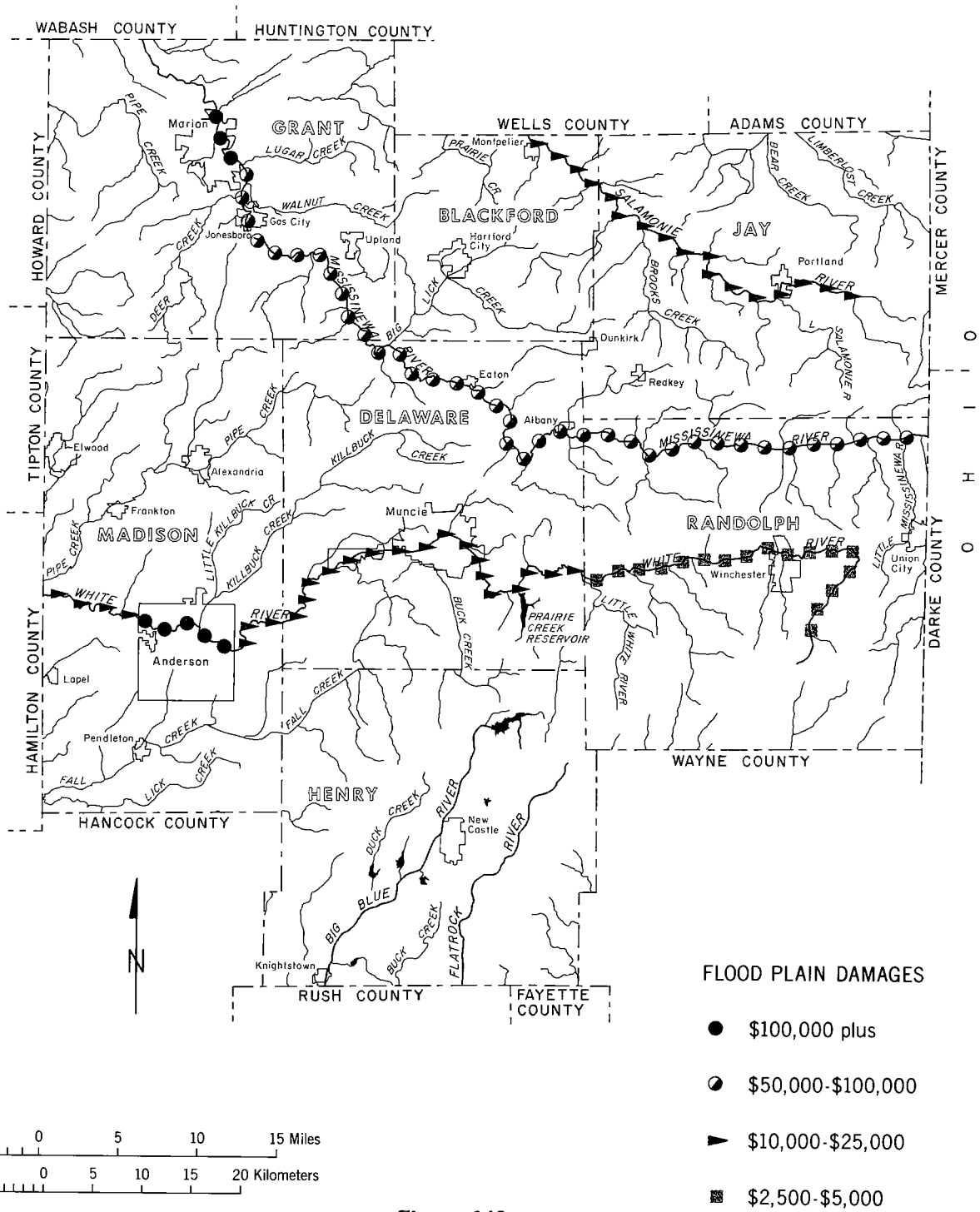


Figure 143
Map of Region Six showing the estimated average annual flood damages per mile along selected streams.

watershed project within the region. The structural measures included in this project are seven single-purpose flood water retarding structures, two multiple-purpose structures for flood prevention and low flow augmentation, two multiple-purpose structures for flood prevention water supply and recreational development, and 32.8 miles of channel improvement.

Of the region's several dams, four are used as water supplies while the remainder are utilized for recreation and flood control.

Flood Plain Management The communities that are participating in the emergency phase of the National Flood Insurance Program are listed below. Summitville in Madison County and Portland in Jay County are participating in the regular phase of the National Flood Insurance Program.

Table 112
Communities participating in the emergency phase of the National Flood Insurance Program.

Albany	Marion
Alexandria	Matthews
Anderson	Middletown
Chesterfield	Muncie
Delaware County, unincorporated	New Castle
Eaton	Parker City
Elwood	Pendleton
Fairmont	Portland
Farmland	Randolph County, unincorporated
Frankton	Ridgeville
Gas City	Springport
Hartford City	Summitville
Ingalls	Union City
Jonesboro	Winchester
Lewisville	Yorktown

Agricultural Drainage

Approximately sixty-six percent of the soil associations in Region Six have "severe" wetness characteristics, twenty-five percent have "moderate," while nine percent have "slight" wetness characteristics. The general location of the soil associations with these characteristics are shown in Figure 144.

Those areas that do not have a severe potential for soil wetness are located in Jay County in the northwest corner along the Salamonie River and in the north-central portion of the county along Limberlost Creek, in Madison County in the southwest corner along Fall Creek and west-central portion along Killbuck Creek and the West Fork White River, and in Henry County along the Big Blue and Flatrock Rivers.

There are approximately 4,500 miles of legal drains in the region, which serve as the main collector and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards or, in a limited number of cases, conservancy districts. No legal entity exists to maintain drainage systems for the other streams in the region.

Soil Erosion

The erosion potential of soil associations within the region are shown in Figure 145. Twenty-four percent of the 1,715,200 acres are rated as having a "medium" soil erosion hazard. Such land has a moderate potential for soil loss when not protected by vegetation, or when appropriate conservation techniques are not practiced. These areas are usually located adjacent to major streams in the region. The remaining seventy-six percent of the land is predominantly level and ranks as having a "low" erosion potential for land left in a fallow state.

WATER QUALITY

The surface streams within Region Six routinely surveyed for water quality by the Indiana State Board of Health are the Mississinewa and West Fork of the White River. Water quality standards for the region are established by the Stream Pollution Control Board Regulation SPC IR-4, the Water Quality Standard for the State of Indiana.

Samples from the Mississinewa River at Marion indicated that the dissolved oxygen, temperature, and pH were in compliance with water quality standards. The level of the biochemical oxygen demand sometimes exceeded acceptable levels in July and August. On one occasion nitrate values exceeded desirable levels in June. Furthermore, levels of fecal coliform bacteria indicated that the stream did not meet standards for partial body contact recreation at the sampling location near Marion.

Dissolved oxygen levels in the White River frequently fell below the required concentration to support a diversified aquatic community. High levels of fecal coliform bacteria frequently violated standards for partial body contact recreation. No values which violate nitrate or pH standards were observed.

Nine fish kills in the region have been reported to the Indiana State Board of Health during the period 1974 to 1977. Five fish kills have been investigated in Delaware County and resulted from a sewer bypass into the White River, a chemical spill into the White River, a sewage treatment package plant malfunction into Thurston Ditch, and two spills of undetermined cause. The highest fish mortality was approximately 8,800 during the sewer bypass incident in the Muncie

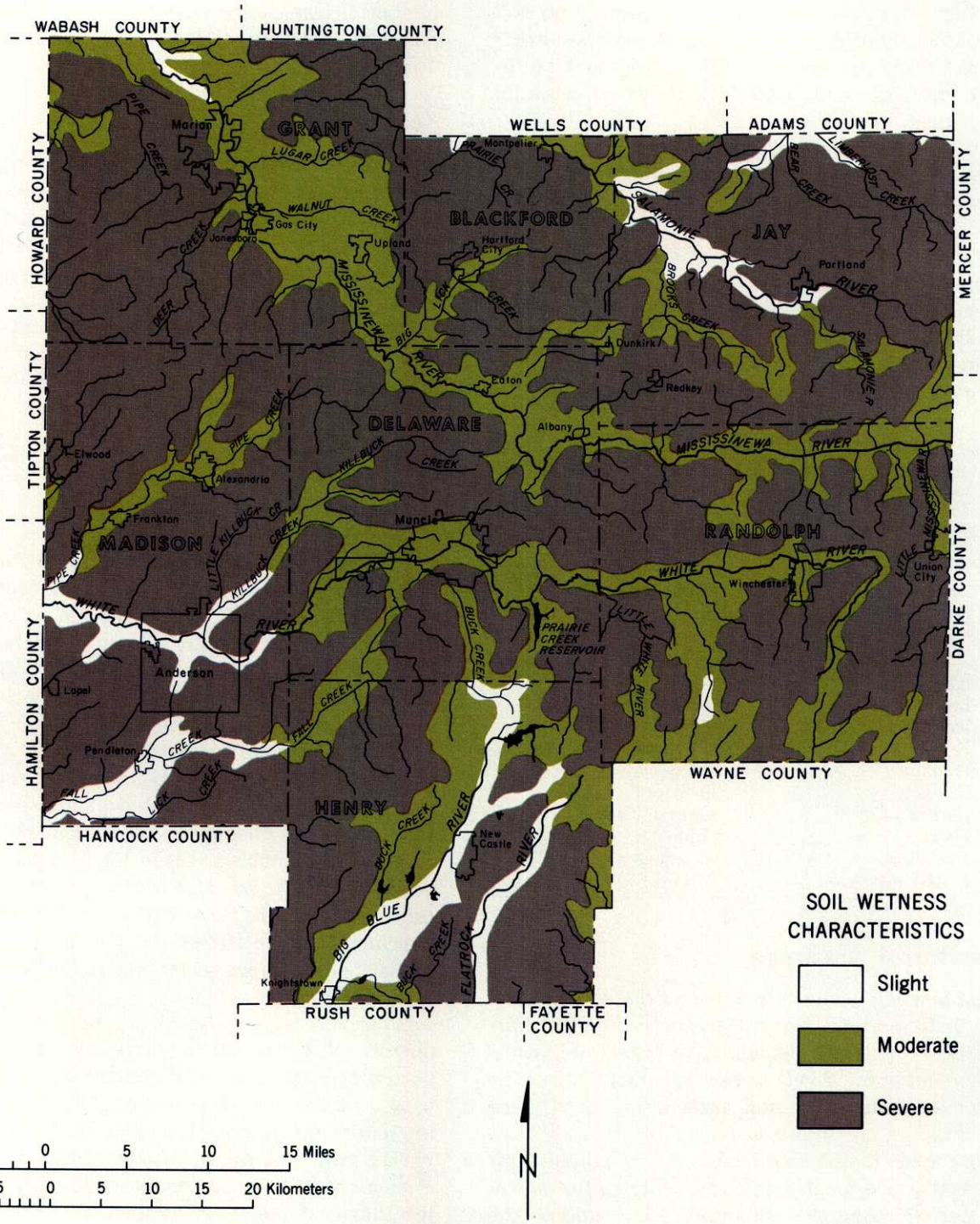


Figure 144
Map of Region Six showing the general location of the wetness characteristics of soil associations.

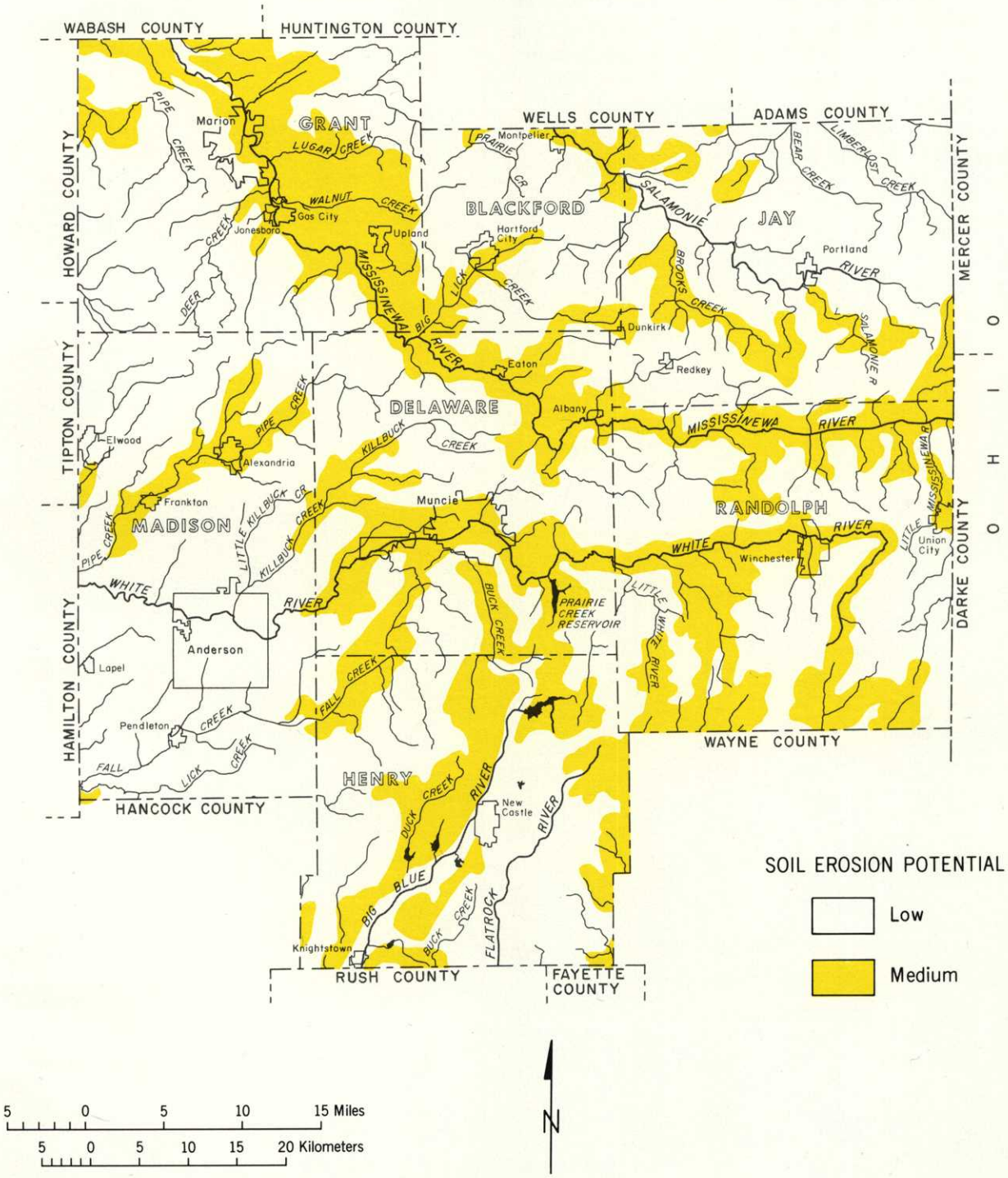


Figure 145
Map of Region Six showing the erosion potential of the soil associations.

area. Three fish kills have been reported in Grant County with two resulting from industrial discharge to Little Pipe Creek near Swayzee. Only one fish kill (680 fish) was reported from Jay County and resulted from a discharge of inadequately treated sewage to the Salamonie River. Reported fish kills have not been frequent and were confined primarily to urban areas.

The trophic classification of those lakes surveyed by the Stream Pollution Control Board in Region Six is presented in Table 113.

Table 113
Trophic classification of lakes surveyed.

Lake	*County*	*Age Classification*
Galacia	Grant	III
Kilgore	Grant	III

Region Seven

Clay, Parke, Putnam, Sullivan, Vermillion, and Vigo Counties, located in west-central Indiana, form Region Seven. The region contains approximately 2,435 square miles and is bounded by Illinois to the west; Warren, Fountain, and Montgomery Counties to the north; Hendricks, Morgan, and Owen Counties to the east; and Greene and Knox Counties to the south, as shown in Figure 146.

The 1975 population was 213,950, of which fifty-one percent resided in Vigo County. The official Indiana Population Projections indicate that the region's population will increase nearly four percent to 221,900 by the year 2000.

The 1975 population and the projections for each county are tabulated below.

Table 114
The 1975 and projected populations for Region Seven.

County	*1975*	*1980*	*1990*	*2000*
Clay	24,310	25,200	26,500	28,000
Parke	15,440	16,700	18,800	21,000
Putnam	27,300	28,800	29,700	30,400
Sullivan	19,540	19,000	18,100	17,300
Vermillion	16,850	17,600	18,900	21,200
Vigo	110,510	112,400	109,200	104,000
Total	213,950	219,800	221,200	221,900

The major population centers are Terre Haute in Vigo County, Brazil in Clay County, and Clinton in Vermillion County. These urban centers accounted for forty-three percent of the region's 1975 population.

Agriculture is the dominant land use within the region with more than sixty-six percent of the area

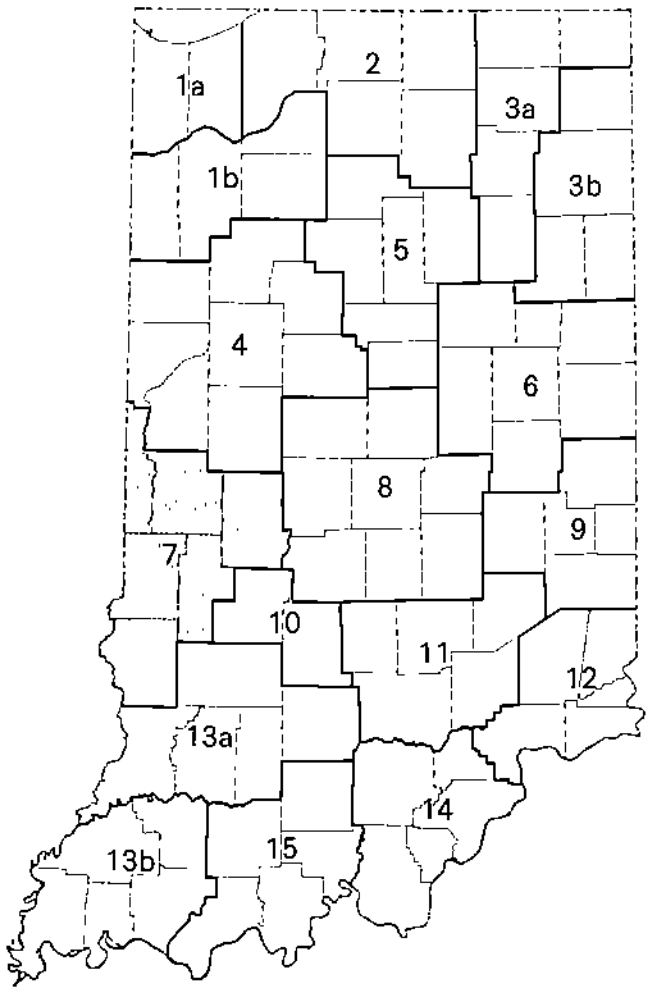


Figure 146
Map of Indiana showing the location of Region Seven.

devoted to farming. Approximately twenty-two percent of the land is forested, five percent is urban while the remaining six percent includes strip mines and other land use classifications.

Nonmanufacturing employment, including wholesale and retail trade, services, and government, represents sixty-seven percent of the work force. Manufacturing employs nearly thirty-three percent, and electrical machinery, chemicals, and paper product manufactures are the largest industrial employers.

The region receives approximately 40.5 inches of precipitation annually. This varies from a high of 4.8 inches in June to a low of 2.3 inches in February. Of the 40.5 inches of precipitation, approximately 12.5 inches appear as streamflow while 28.0 inches are consumed through evapotranspiration. The area has average temperatures ranging from 29°F. in January to 75°F. in July. The average annual temperature is 53°F. The annual prevailing wind at the Indianapolis International Airport is from the southwest at 9.7 miles-per-hour.

THE WATER RESOURCE

Ground Water

The availability of ground water is affected by both glacial deposits and the underlying bedrock. The surficial and unconsolidated deposits consist of both Illinoian and Wisconsinan age glacial material except for Clay and Sullivan Counties which contain strictly Illinoian age deposits. Incorporated within these deposits are glacial till, outwash sand and gravel, dune sand, and lake clays. The thickness of the glacial drift ranges from 100 to 200 feet. The most important water bearing formations are the outwash sand and gravel aquifers associated with the Wabash and Eel River valleys and their major tributaries. Glacial till predominates, with isolated sand and gravel lenses where Illinoian glacial drift covers the area south of the Wisconsinan glacial boundary in Clay, Sullivan, Vigo, and southwestern Putnam Counties.

Underlying the glacial deposits are bedrock formations which range in age from Mississippian to Pennsylvanian. Mississippian bedrock is located in the eastern portion of Putnam County and consists of Borden Group shales and siltstones and overlying limestone units. North of the Wisconsinan glacial boundary, well yields in the Mississippian bedrock are generally higher than in areas south of the boundary due to the influence of the more permeable and more abundant glacial materials. Further west, Pennsylvanian bedrock consists of shale, sandstone, coal, and limestone.

Ground-water availability is generally quite limited as shown in Figure 147. In areas not associated with major stream valleys, yields generally are less than fifty gallons-per-minute (gpm). Ten gpm is the highest expected yield in many areas. Most wells in these low yield areas are located in the Pennsylvanian rocks under Parke, Clay, Vermillion, Vigo, and Sullivan Counties. Sand and gravel deposits located in the Wabash River, Eel River, Raccoon Creek, and Big Walnut Creek valleys consititute the most favorable aquifers for the development of high capacity wells. Properly constructed wells in the Wabash valley sand and gravel aquifers are capable of yields exceeding 2,000 gpm.

Ground-water quality within the region is usually satisfactory for most water needs. Water hardness ranges from 200 to 400 parts-per-million (ppm) except in localities where "soda" water is encountered in wells completed in the Pennsylvanian bedrock. This naturally soft or soda water exhibits a high pH and is found in areas where hardness levels of less than 180 ppm occur. Iron contents are extremely variable, and concentrations range from 0.1 to 5.9 ppm. Lower iron contents usually occur in the outwash sand and gravel aquifers. Iron removal is practices at several municipalities. Water softening is practiced only at Roachdale and Terre Haute. High sulfate concentrations may occur in a portion of Vermillion County where water is withdrawn from bedrock.

Surface Water

Streamflow Region Seven is drained from north to south by the Wabash River and Eel River and their tributaries. The tributaries of the Wabash River include the Vermillion River, Sugar Creek, Coal Creek, Big Raccoon Creek, and Busseron Creek. Big Walnut Creek is a major tributary of the Eel River.

The seven day, once in ten year (Q7-10); one day, once in thirty year (Q1-30); and the average annual flow for streams with gaging stations within Region Seven are tabulated in Table 115.

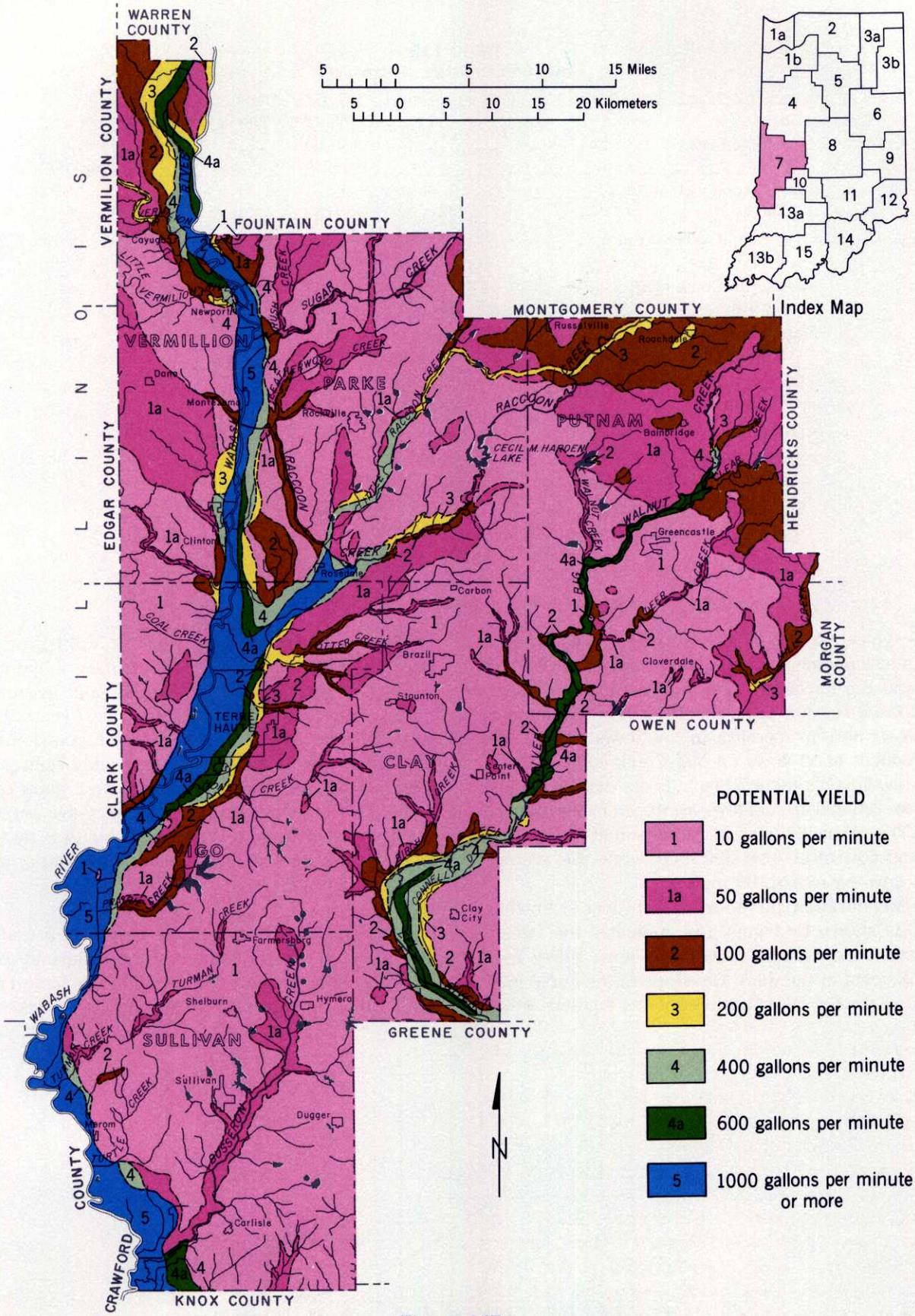


Figure 147
Map of Region Seven showing the general location and potential yield of ground water from properly constructed large diameter wells.

Table 115
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Flow in Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Big Raccoon Creek near Fincastle*	132	115	1.9	1.5
Big Walnut Creek near Reelsville	326	318	4.3	1.7
Busseron Creek near Carlisle	228	140	0.3	0
Busseron Creek at Hymera	17	12	0	0
Busseron Creek at Sullivan	138	89	1.2	0.6
Sugar Creek near Byron	670	406	14.0	10.0
Wabash River at Montezuma	11,100	6,100	550.0	390.0
Wabash River at Riverton	13,100	7,300	750.0	590.0
Wabash River at Terre Haute	12,200	6,700	630.0	470.0

*Flows recorded prior to construction of Cecil Harden Lake.

As is typical of Indiana streams, there is wide variability in streamflow in the region. Flows in the Wabash River and Big Raccoon Creek are modified by operation of Cecil Harden Lake, resulting in a reduction in flood flows and an increase in low flows. Cagles Mill Lake reduces flood flows on Mill Creek and Eel River.

The low-flow characteristics indicate that the largest and most reliable streamflows are those in the Wabash River. The Wabash River at Montezuma will have a sustained flow of at least 390 mgd, while the average annual flow exceeds 6,100 mgd.

The flow duration curve for the Eel River at Bowling Green, as shown by Figure 148, indicates the stream will have a dependable flow of at least thirty mgd ninety percent of the time. The slope of the curve indicates that the Eel River basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to the streamflow amounts to forty, twenty-eight, and fifteen percent for dry, average, and wet years respectively. Conversely, from sixty to eighty-five percent of the flow, depending on the year, is due directly to surface runoff from runoff-producing precipitation events or from snowmelt.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are presented in Table 116 and are located on Figure 149. These forty-four lakes have

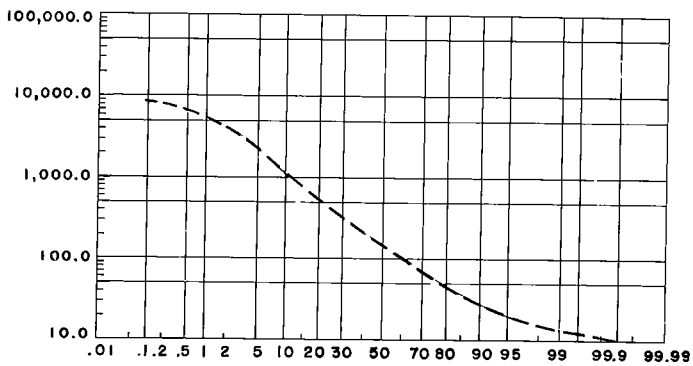


Figure 148
The flow duration curve for the Eel River at Bowling Green.

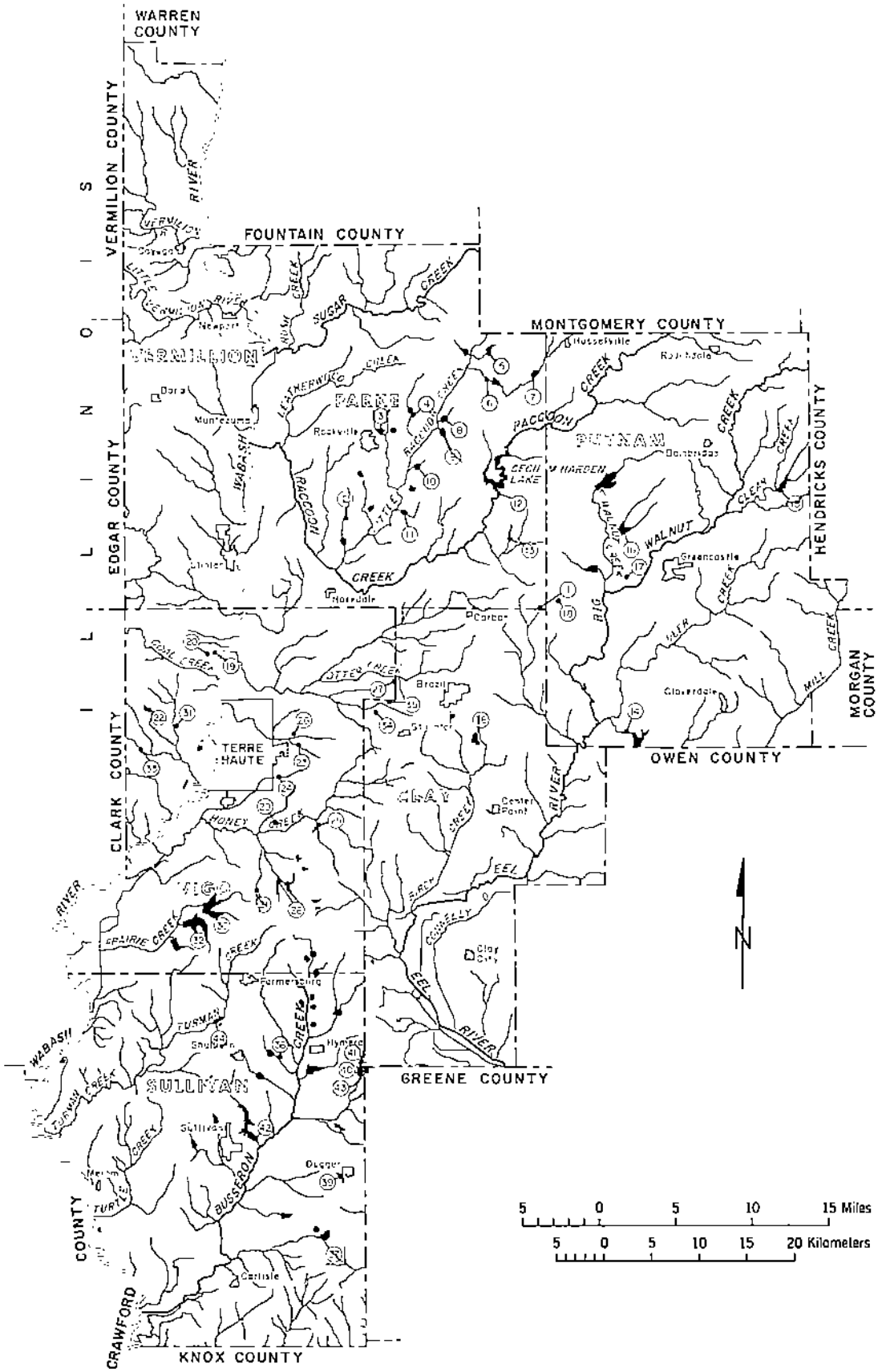


Figure 149
Map of Region Seven showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

a combined surface area of approximately 5,717 acres and a gross storage capacity of approximately 36,780 million gallons.

Cecil Harden Lake in Parke and Putnam Counties and Cagles Mill Lake in Owen and Putnam Counties are the two largest reservoirs in the region. Cecil Harden Lake, located on Raccoon Creek, has a storage of approximately 16,100 million gallons and a surface area of approximately 2,060 acres. Cagles Mill Lake, located on Mill Creek, has a storage of approximately 8,830 million gallons and a surface area of approximately 1,400 acres. Both of these reservoirs were developed primarily for flood control but are also used for recreation and fish and wildlife purposes. While both reservoirs regulate to some extent the low flow conditions in the streams below the respective dams, Cagles Mill has no design minimum release. However, the U.S. Army Corps of Engineers maintains an actual minimum release from Cagles Mill of from 0.6 to 1.3 mgd to protect the downstream fishery. Cecil Harden Lake has a minimum release of 13 mgd.

Table 116

Lakes at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Alma Lake	na	20.3	74
2	Little Raccoon Structure No. 1	4.49	32.0	58
3	Little Raccoon Structure No. 2-C	4.69	99.5	365
4	Little Raccoon Structure No. 3	4.77	35.0	65
5	Little Raccoon Structure No. 11	5.14	26.5	46
6	Little Raccoon Structure No. 12	14.10	101.0	162
7	Little Raccoon Structure No. 12-B	14.10	61.0	115
8	Little Raccoon Structure No. 14	2.22	25.0	44
9	Little Raccoon Structure No. 15	4.67	18.0	42
10	Little Raccoon Structure No. 16	4.16	18.6	42
11	Little Raccoon Structure No. 18	2.78	23.0	53
12	Cecil Harden Lake	216.00	2,060.0	16,052
13	Rocky Fork Lake	1.22	63.5	322
14	Cagles Mill Lake	293.00	1,400.0	8.834
15	Heritage Lake	10.30	375.0	1,955
16	Little Walnut Creek Structure No. 5	12.90	74.0	187
17	Oakalla Lake	na	22.2	105
18	Thomas Lake	na	18.4	78
19	Farmer Lake	na	na	37
20	Farmer Lake West	na	na	32
21	Fowler Park Lake	na	na	52
22	Green Valley Mine Pond	na	39.0	925
23	Hulman Lodge Lake	na	38.2	247
24	Hulman Street Lake	na	8.8	45
25	Lakewood Subdivision Lake	na	28.1	127
26	Maple Avenue Lake	na	18.1	52
27	Morey Lake	na	21.9	110
28	Paint Mill Lake	na	82.3	430
29	Patton or Hartman Lake	na	14.0	208
30	Prairie Creek Structure No. 1	9.76	93.2	102
31	Tri-Land Estates Lake	na	15.1	158
32	Vigo Conservancy Dam	na	na	65

Table 116 (continued)

Lake Number	Lake Name	Drainage Area (square miles)	Surface Area (acres)	Gross Storage (million gallons)
33	Windemere Lake	na	5.7	39
34	Izaak Walton Lake	na	11.4	48
35	Twin Beach Lake	na	9.4	48
36	Lake of the Woods	na	28.9	104
37	Busseron Creek Structure No. A-3	4.56	43.3	49
38	Busseron Creek Structure No. I-2	2.41	20.0	46
39	Dugger Lake	na	52.6	208
40	Lake Kickapoo	na	na	2,456
41	Lake Shakamak	1.54	60.4	606
42	Lake Sullivan	na	507.8	1,609
43	Shakamak Lake, Dam No. 7	na	56.0	198
44	Thunderbird Lake	24.60	90.0	175

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Seven is presented in Table 117. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing Cecil Harden and Cagles Mill Lakes in conjunction with the Wabash and Eel Rivers constitute the major supply of the region's boating and waterskiing resources. A few of the strip mine lakes also offer boating and waterskiing opportunities.

The supply of boating opportunities is sufficient to meet the current boating demand as well as the projected demand through the year 2000. The available supply of waterskiing areas is expected to meet only eighty-five percent of the anticipated demand by Region Six residents. A shortage of waterskiing opportunities is expected to continue through the year 2000.

Canoeing There are 210 miles of free-flowing streams with sufficient base flow to provide opportunity for canoeing. The Wabash River, Big Walnut Creek, and Sugar Creek are good canoeing streams. The available supply of canoeable streams is more than enough to meet current and projected demands.

Swimming and Ice-skating Swimming areas, both beach and pool acreage, do not meet current or projected demands by residents of Region Seven. It is estimated that the 1980 supply will meet only sixty-one percent of the projected swimming demand. The ice-skating demand also exceeds the current and projected supply.

Fishing The quality of the fisheries habitat is indicated on Figure 150. Many of the smaller streams

Table 117
The outdoor recreation demand and supply analysis.

Activity	Percent of Population Participating	Density Guideline	Approximate Supply	Existing Supply as a Percentage of Projected Demand		
				1980	1990	2000
Boating	19	19.6 boats/acre/year	10,300 acres	100+	100+	100+
Waterskiing	7	34.4 skiers/acre/year	2,000 acres	85	90	90
Canoeing	9	585 canoes/mile/year	210 miles	100+	100+	100+
Swimming	33	76,600 swimmers/acre/year	14 acres	61	64	61
Ice-Skating	4	6,678 skaters/acre/year	5 acres	56	63	63
Fishing	44	66 persons/acre/year	17,900 acres	77	81	81

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

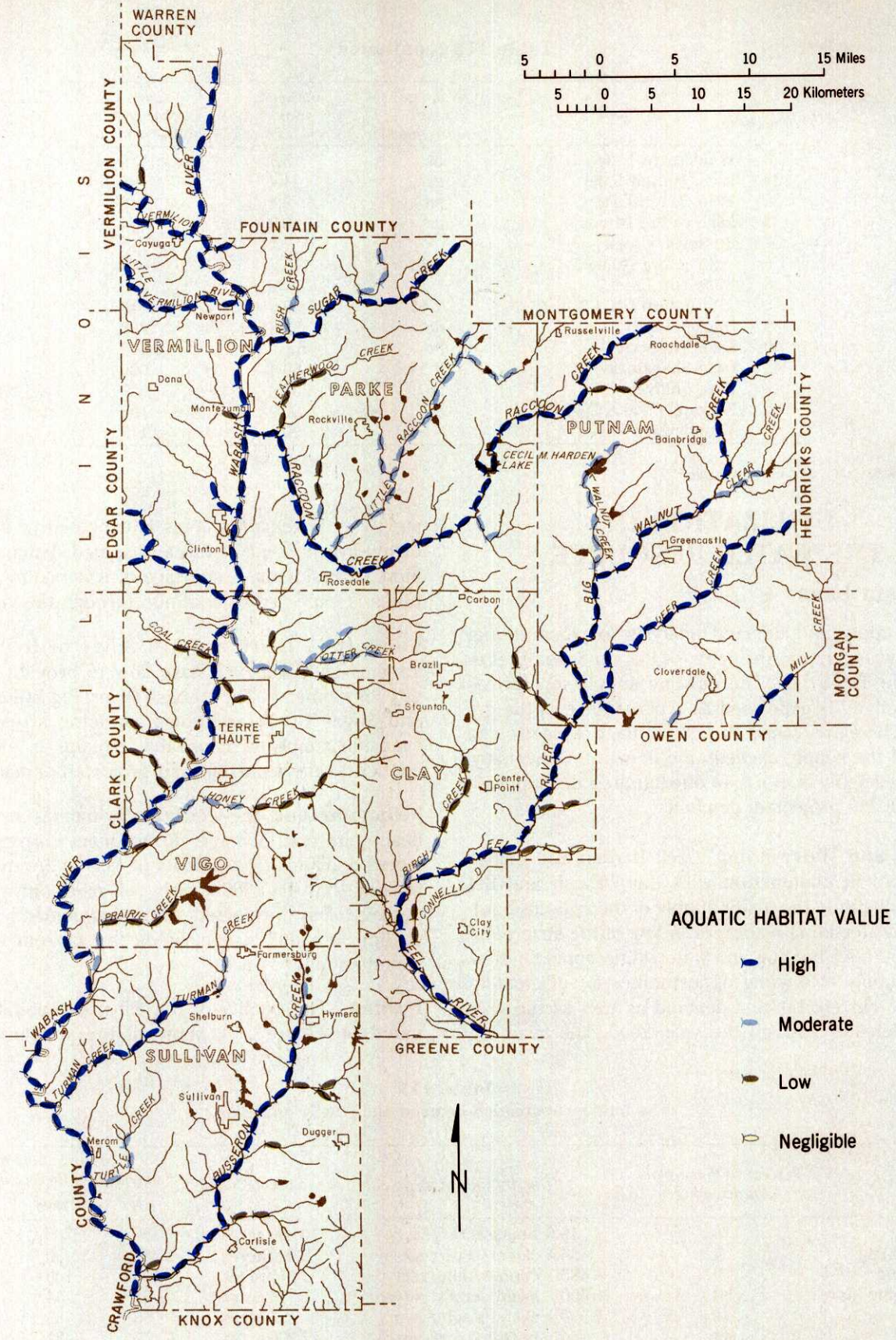


Figure 150
Map of Region Seven showing the quality of the fisheries habitat.

within the region maintain seasonal fisheries. During the spring high water they have spawning runs of fish, but at drier times of the year they carry only enough water for some forage fish and small sunfish. The Wabash River, Raccoon Creek, Big Walnut Creek, Eel River, and Sugar Creek are large enough to have year-round fisheries. The Wabash River not only is important for sport fishing but also commercial fishing, offering freshwater drum, buffalo, and bait minnows. All the larger streams have excellent aquatic habitat for sunfish and catfish, and in some streams, northern pike.

Most man-made and strip mine lakes have good aquatic habitat for warmwater fisheries. Cecil Harden Lake, the largest reservoir, and Cagles Mill Lake provide excellent habitat for walleye, catfish, bass, and other sunfish. A variety of sunfish and catfish also live in many of the smaller lakes.

State-owned public access sites are available at Raccoon Creek in Putnam County and the Wabash River in Sullivan and Vermillion Counties. Four lakes in Sullivan County are accessible from state fishing sites. Fishing is available in the Green Valley State Fishing Area, Cecil Harden and Cagles Mill Lakes, and in Turkey Run State Park.

It is estimated that seventy-seven percent of the demand for fishing will be met by 1980, increasing to eighty-one percent by 2000.

Riparian Habitat The quality of the riparian habitat associated with streams and lakes is indicated in Figure 151. The best wildlife habitat along streams occurs on larger waterways, such as the Wabash and Eel Rivers, Raccoon Creek, Big Walnut Creek, and some tributaries. Streamside vegetation is predominantly hardwoods with some interspersion of grass or cropland. Upland game and furbearers utilize streamside habitat for feeding. Various birds, including wood ducks, nest along the streams. Riparian habitat around the lakes is similar to the stream bank habitat and attracts many of the same wildlife species. Resident and especially migratory waterfowl may be more attracted to the lakes.

Withdrawal Uses

Public Water Supplies Clay, Parke, Putnam, Sullivan, Vermillion, and Vigo Counties are served by 53 public water utilities. Information on public water supplies in Region Seven is presented in Table 118. The water service areas are shown in Figure 152.

In 1975, these 53 public water utilities withdrew an average of 16.0 mgd. Approximately thirteen percent of this total was consumed. All public water utilities, with the exception of Terre Haute, withdraw their supplies from ground-water sources. Terre Haute withdraws approximately 6.8 mgd from ground-water sources and 2.0 mgd from the Wabash River.

Table 118
The public water supply systems as of 1975.

Counties	*Number of Systems*	*Service Population*	*Average Daily Withdrawals in Million-Gallons-Per-Day*
Clay	10	11,100	1.3
Parke	8	6,900	0.8
Putnam	10	15,000	2.0
Sullivan	10	10,600	1.4
Vermillion	10	12,600	1.3
Vigo	7	71,100	9.0
Total	55*	127,300	15.8

*Because of multi-county systems, the county totals do not add up to the regional total.

Several public utilities not only supply water to their service areas, but also sell water to one or more other utilities in the region. Several utilities in Putnam County purchase their water from Greencastle. Likewise, Brazil supplies water to many of the other Clay County systems. Other suppliers in the region include Clinton, Fayette Township, Terre Haute, and Sullivan. Most of the region's systems withdraw water originally obtained within the county of use. However some systems may buy water from out-of-county and out-of-region systems (such as Linton and Jasonville). The relationships between public water suppliers and buyers are presented in the following table.

Table 119
Public water utility suppliers and purchasers.

Suppliers	*Purchasers*
Brazil City Water Works	Carbon Water Corporation Center Point Water Company Knightsville Water Works
Clinton Water Utility	Clinton Township Water Company St. Bernice Water Corporation
Fayette Township Water Association	L & S Water Supply
Greencastle Water Department	Big Walnut Water Corporation North 43 Water Corporation Reelsville Water Company South 43 Water Association 240 Water Corporation

Table 119 (continued)

Suppliers	*Purchasers*
Jasonville Water Department*	Hymera Water Works Wilfred Water Corporation
Linton Municipal Water Utility*	Dugger Water Utility Pleasantville Water Company
Sullivan District	Shelburn Water Works Utility Farmersburg Water Works
Terre Haute Water Works Corporation	Seelyville Water Works

*Supplier located outside of Region Seven.

Projections of public water supply withdrawals indicate that withdrawals by the region's public water utilities may increase to approximately 18.5 mgd by the year 2000, as shown below.

Table 120
The 1977 and projected withdrawal and consumption rates of public water supplies, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	16.0	16.5	17.6	18.5
Consumption	2.1	2.1	2.3	2.4

Industrial Water Use Industrial establishments had an estimated water intake averaging 38.5 mgd in 1977. Of the total industrial intake, 34.8 mgd was withdrawn by the industries themselves while 3.7 mgd was purchased from the region's public water utilities. Approximately 6.9 mgd of industrial water is consumed. The majority of the self-supplied water is withdrawn from ground-water sources.

Total industrial water use will increase to 50.9 by the year 2000. The self-supplied component is expected to increase by approximately thirty-six percent to 47.2 mgd, as indicated below. Public utility supplied industrial water may decline to 3.6 mgd.

Table 121
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	34.8	36.0	41.4	47.2
Consumption	7.0	7.8	11.4	15.8

Rural Self-Supplied Water Domestic rural water use in 1975 was approximately 5.1 mgd. Residential rural water use may increase to 7.4 mgd by the year 2000. The bulk of domestic water is withdrawn from ground-water sources, however some water may be trucked in and stored in cisterns. Rural self-supplied water use for livestock amounted to 2.0 mgd in 1975, and is projected to increase to 2.6 mgd by 2000. Water for livestock often is supplied from ponds, streams, and springs. The total withdrawal of rural self-supplied water may increase from the current 7.2 mgd to approximately 9.4 mgd by the year 2000, as indicated in the following table.

Table 122
The 1977 and projected water withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	7.2	7.5	8.5	9.4
Consumption	7.2	7.5	8.5	9.4

Irrigation Water Soil associations with irrigation potential are generally located adjacent to the Wabash River. Figure 153 shows these potential irrigation areas.

Based upon the survey of irrigated lands, approximately 2,200 acres of croplands were irrigated in 1977: 2,000 acres in Sullivan County and 100 acres in Parke County. Assuming 1977 as a normal growing year, approximately 5.6 mgd would have been applied during the peak irrigation period of July and August. Irrigation water is currently withdrawn from ground-water sources.

It is estimated that approximately 46,200 acres of croplands in the region could be profitably irrigated. Irrigation of croplands is expected to increase to 10,000 acres by the year 2000. Sullivan County has an estimated 15,000 acres with irrigation potential. Vermillion and Vigo Counties have 10,000, and Parke County has 6,000 acres of potential irrigation. The projected increase in irrigation acreage by the year 2000 is expected to increase the peak July–August irrigation demand for agricultural purposes in an "average" season to approximately 26.4 mgd. The average year increase in ground-water use is expected to increase to 19.0 mgd by the year 2000.

In addition to the irrigation for agricultural use, fairways and greens on the region's golf courses are irrigated. Approximately 1.2 mgd was applied to these areas during the peak July–August 1977 irrigation period.

The total withdrawal for irrigation of croplands and golf courses during the average irrigation season of 1977 was approximately 6.8 mgd. These withdrawals may increase to 27.6 mgd by the year 2000, as indicated in Table 123.

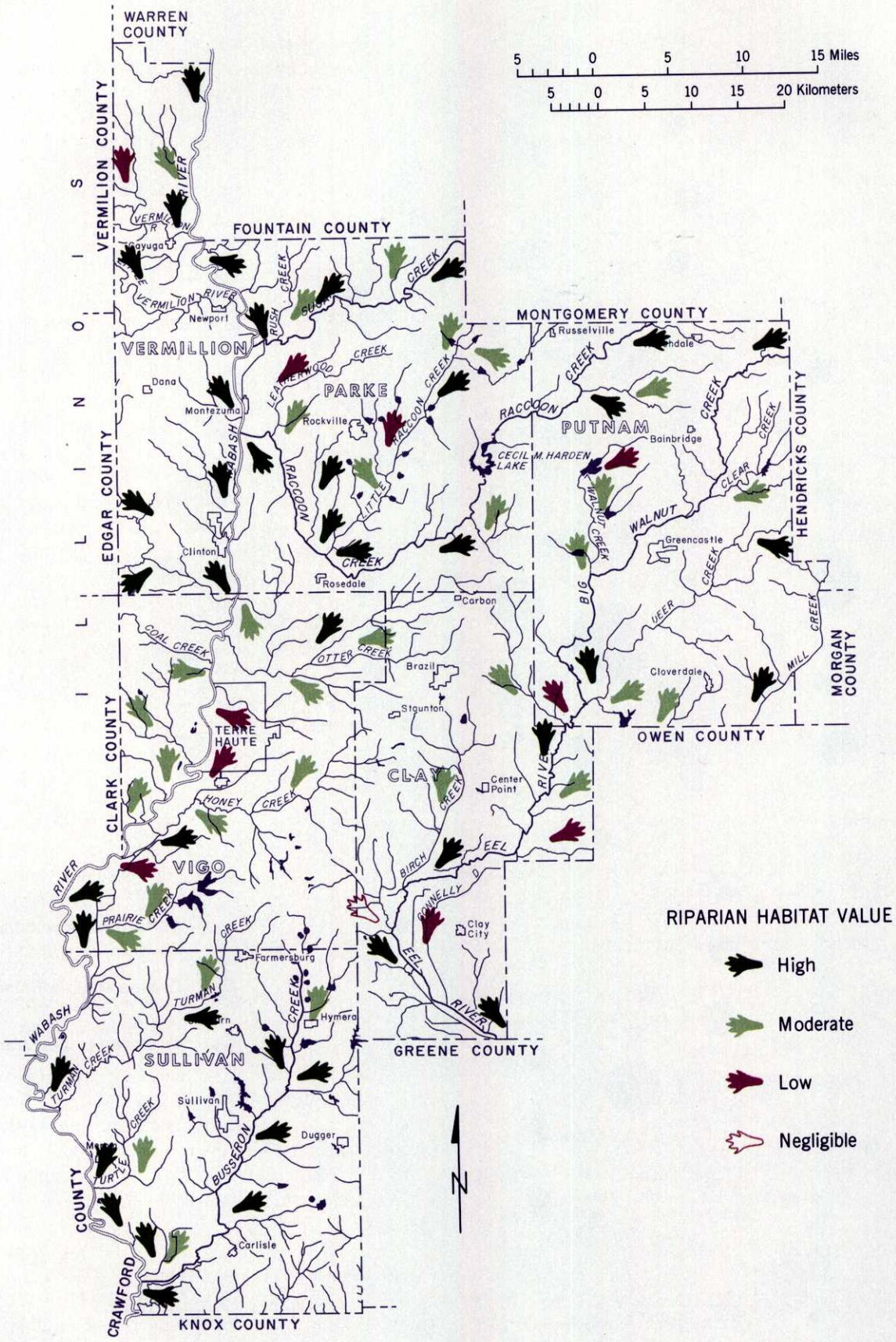


Figure 151
Map of Region Seven showing the quality of the riparian habitat.

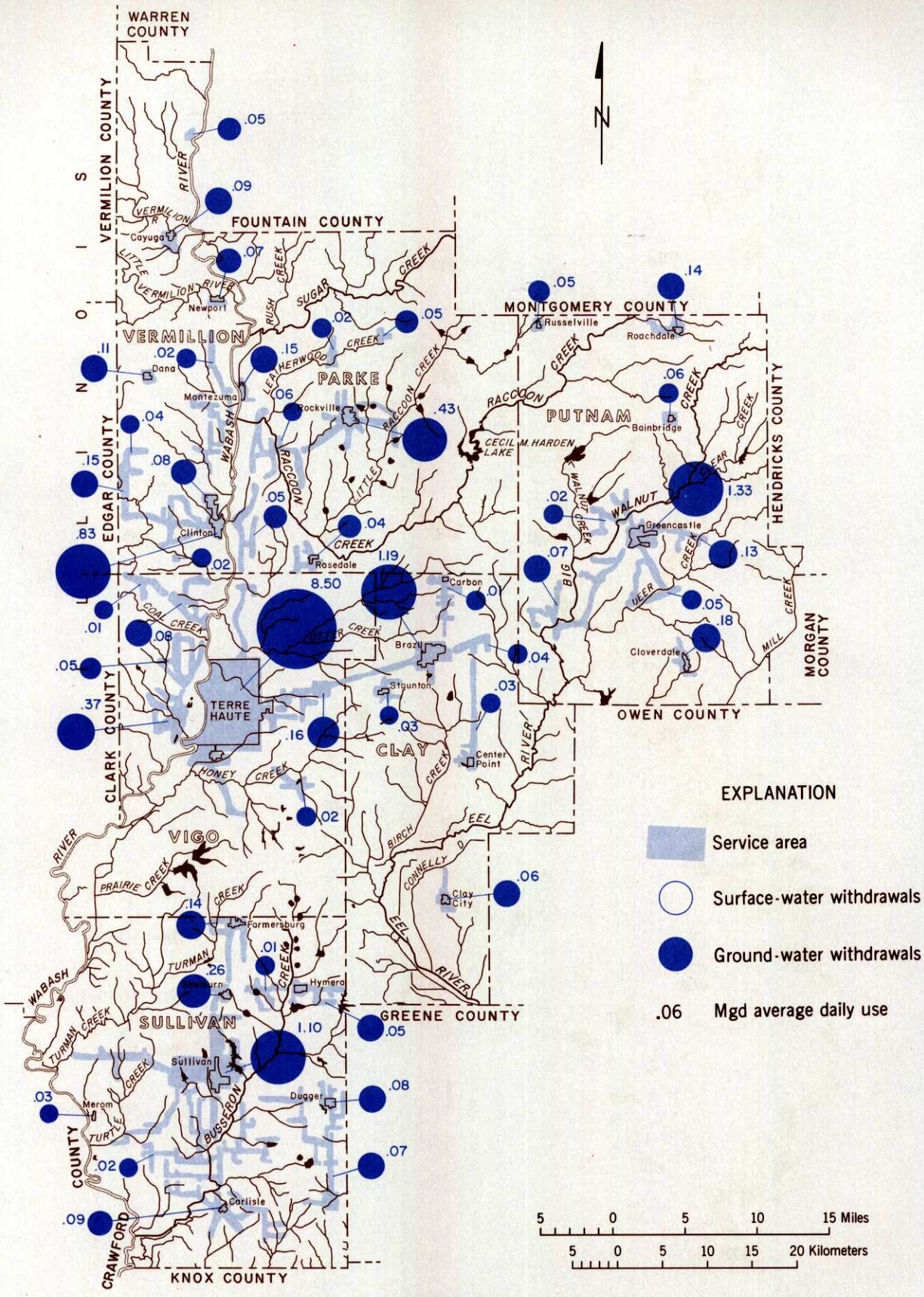


Figure 152
Map of Region Seven showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

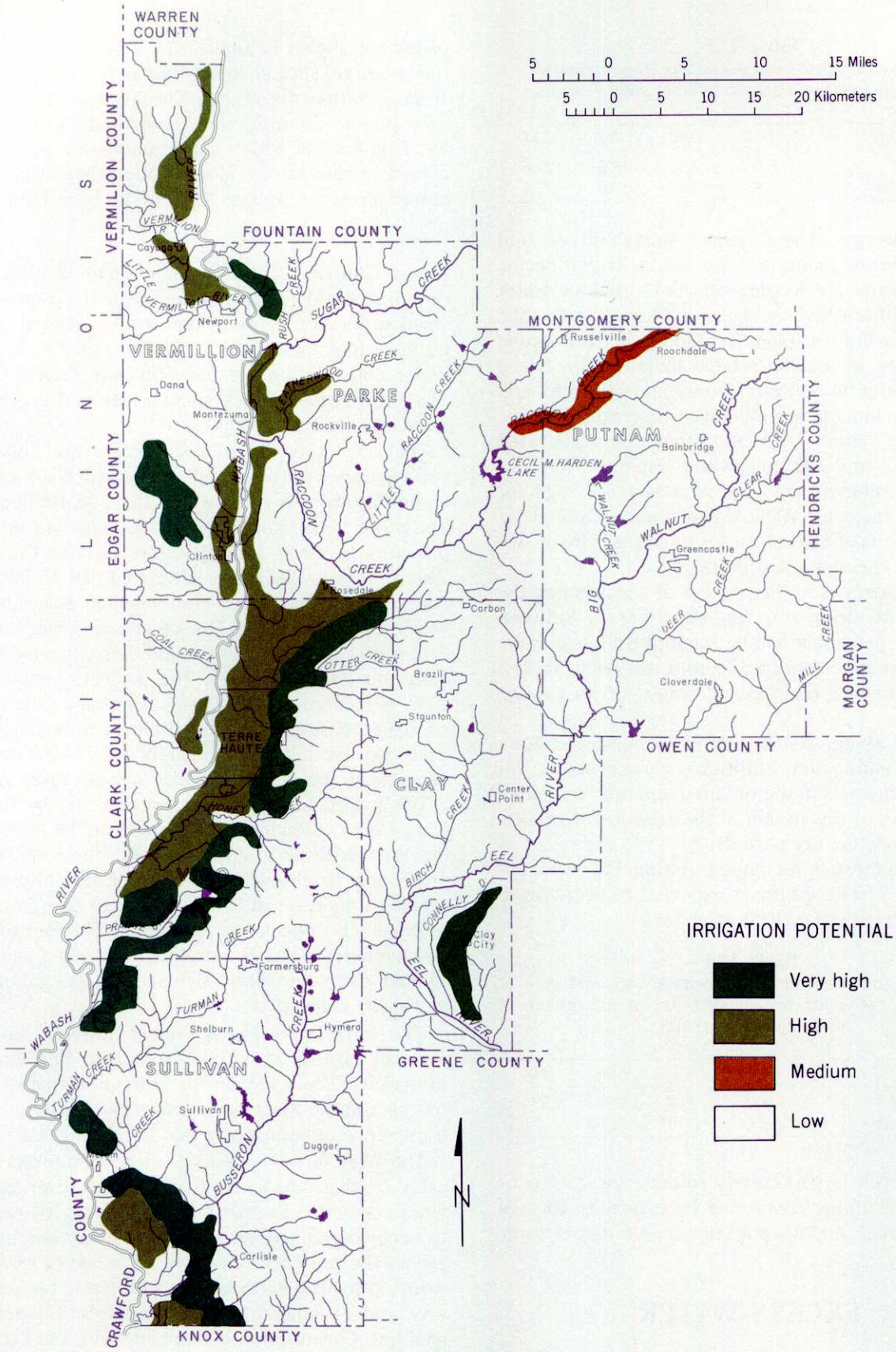


Figure 153
Map of Region Seven showing the general location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

Table 123
The current and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.8	9.5	18.5	27.6
Consumption	6.8	9.5	18.5	27.6

Electric Energy The Cayuga, Wabash River, and Breed generating plants are located in Region Seven. All three plants are located on, and withdraw water from, the Wabash River. Cayuga, in Vermillion County, and the Wabash River plant in Vigo County are owned and operated by Public Service Indiana. The Breed plant is located in Sullivan County and is owned and operated by Indiana and Michigan Electric Company. The Cayuga, Wabash River, and Breed plants are rated at 1,075, 937, and 420 megawatts respectively. Water intake requirements are approximately 852 mgd for Cayuga, 747 mgd for Wabash River, and 318 mgd for Breed. These facilities return to the parent stream approximately the amount withdrawn.

Hoosier Energy is in the process of constructing the Merom Plant along the Wabash River in Sullivan County. The new plant will be rated at 980 megawatts. The intake requirements for Merom will result in 21.3 mgd consumed as replacement water for its cooling pond.

In Region Seven, the Wabash River possesses flows capable of supporting additional power plants, although withdrawals in the required amounts will affect the low flows of the stream in the absence of supplemental storage for dry periods.

Water withdrawals for energy during 1977 was approximately 1,917 mgd but is expected to decrease to 1,586 mgd by the year 2000 as shown.

Table 124
The 1977 and projected water withdrawals and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	1,917	1,917	1,960	1,586
Consumption	0	0	21.3	21.3

Region Seven is particularly suitable for coal conversion plant siting because of its proximity to coal producing areas, and it would require additional water withdrawals.

EXCESS WATER

Flooding

It is estimated that approximately 138,000 acres of Region Seven are subject to flooding. The major flood plains are shown in Figure 154. Figure 155 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $5.28 million, of which some ninety-one percent occurred in rural areas. Most of the urban damage occurred along the Wabash River in the Terre Haute area.

Flood Control There are a number of existing or on-going flood control projects in the region. The small watershed projects that are completed include Little Walnut Creek and Little Raccoon Creek. Those under construction are Busseron and Prairie Creeks. The Big Raccoon Creek small watershed project has been authorized.

The U.S. Army Corps of Engineers has completed two reservoirs in the region, one of which is located in Parke County and is known as Cecil M. Harden Lake. The project was completed in 1960 and was designed primarily for flood control in the Raccoon Creek and Wabash River valleys. It is estimated that $5,380,000 in flood damages has been circumvented since the lake has been in operation. The other U.S. Army Corps of Engineers reservoir is Cagles Mill Lake, located in Putnam and Owen Counties. The project, completed in 1952, is located on Mill Creek in Putnam County, and controls 295 square miles of drainage area. Cagles Mill Lake has averted approximately $20,314,000 in flood damages in the Eel, White, and Wabash River valleys.

The Lyford Levee Project, constructed by the U.S. Army Corps of Engineers, is located on the left bank of the Wabash River in Parke County. The levee affords protection to about 3,500 acres of agricultural land against a flood equal in magnitude to one that could be expected to occur on an average of seven times in one hundred years. The project has been a safeguard against estimated flood damages in the amount of $1,390,000 since 1943.

The Terre Haute Levee Project protects about 110 acres of partially developed land at the northern edge of the city. The levee affords protection against floods on the Wabash River having an expected frequency of occurrence once in every one hundred years.

The West Terre Haute local protection project is located on the right bank of the Wabash River and provides protection against a flood that may be expected to occur on an average of once in every one hundred years. The project consists of 2.8 miles of protection works, primarily earth levees, with traffic ramps, highway and railroad closures, and internal drainage facilities. Construction is complete with the exception of a section of levee. It is estimated that the project has prevented flood damages totaling $14,000 since construction started in 1970.

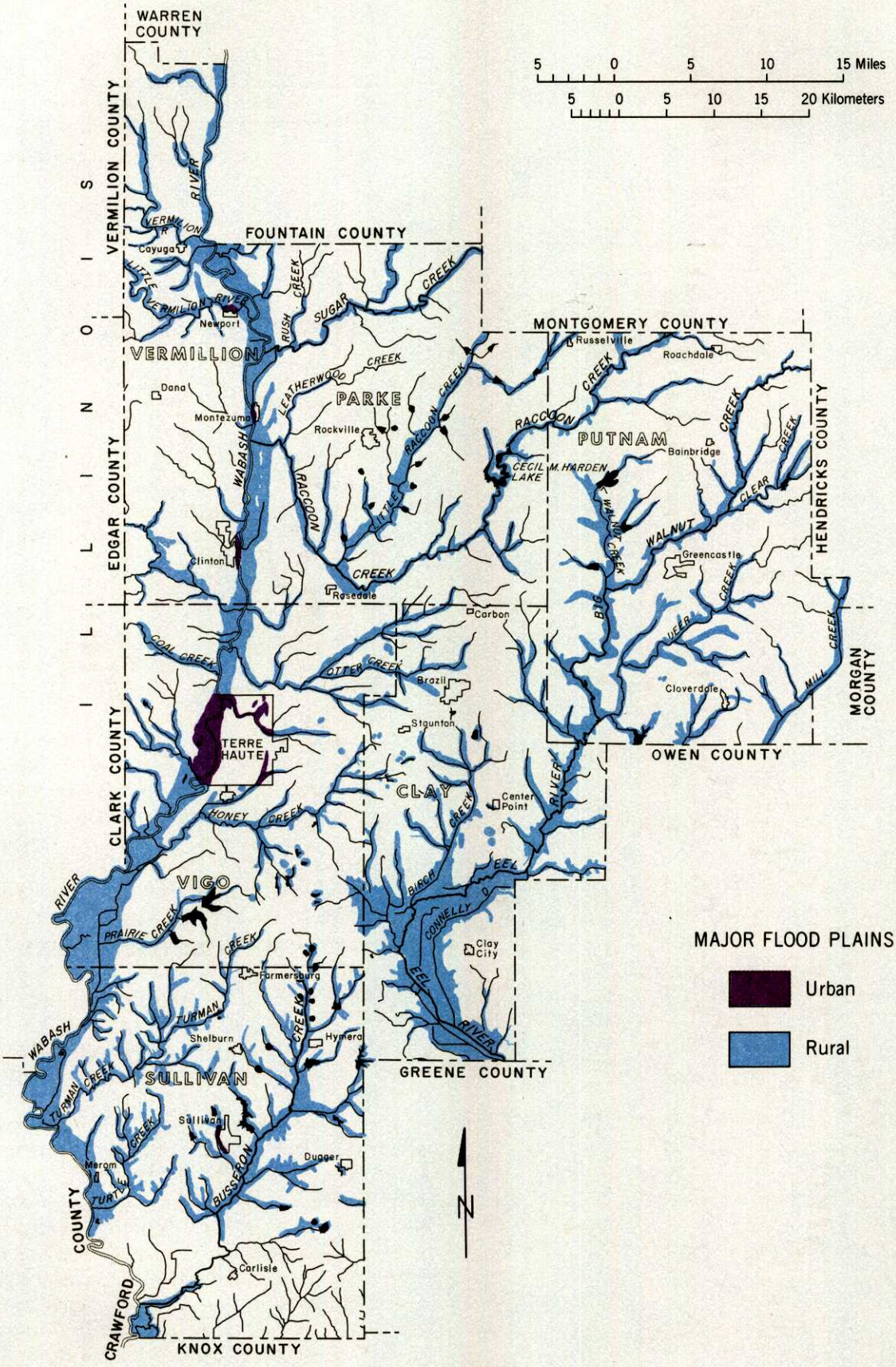


Figure 154
Map of Region Seven showing the major floodplains.

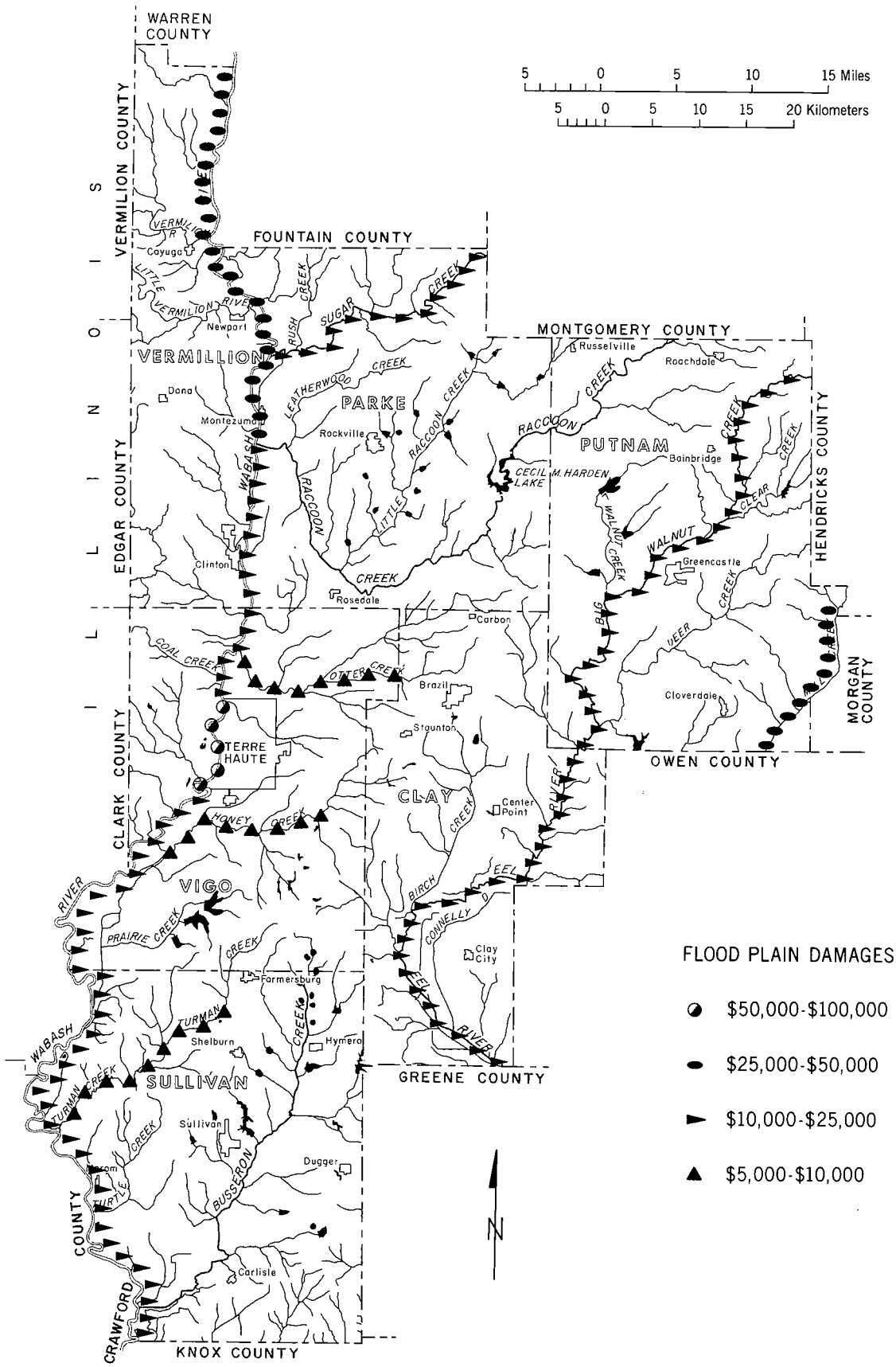


Figure 155
Map of Region Seven showing the estimated average annual flood damages per mile along selected streams.

The U.S. Army Corps of Engineers has completed two agricultural protection projects. The Gill Township project, located on the left bank of the Wabash River in Sullivan County, consists of a system of earth levees with pumps designed to dispose of drainage from the protected area during flood periods. This project protects 12,000 acres and the small community of Riverton. It is estimated that the project has averted flood damages amounting to approximately $8,000,000 since 1941.

The Niblack Levee, located in Knox and Sullivan Counties along the left bank of the Wabash River, consists of eighteen miles of earth levees. Pumping facilities were installed in 1976. The Niblack Levee protects about 15,900 acres of agricultural land against floods equal in magnitude to a flood that can be expected to occur on an average of seven times in every one hundred years. An estimated $2,585,000 in flood damages was prevented since the completion of the levee in 1965.

The Greenfield Bayou Levee and the Island Levee are both locally-constructed agricultural projects within Region Seven.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include Montezuma in Parke County; Bainbridge, Cloverdale, Greencastle, and Roachdale in Putnam County; Clinton in Vermillion County; and Terre Haute and unincorporated areas in Vigo County. Those involved in the regular phase of the National Flood Insurance Program include Dana in Vermillion County and Seelyville in Vigo County.

Agricultural Drainage

Approximately twenty-eight percent of the soil associations have "severe" wetness characteristics, ten percent have "moderate", while sixty-two percent have "slight" wetness characteristics as shown in Figure 156.

Approximately 315 miles of legal drains serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system, vital to its effectiveness, is the responsibility of the local county drainage boards, or in a limited number of cases, of conservancy districts. No legal entity is responsible for the maintenance of drainage for the other streams and ditches in the region.

Soil Erosion

The erosion potential of soil associations within Region Seven is shown in Figure 157. Forty-five percent of the 1,560,200 acres in the region is classified as having a "high" potential erosion hazard, five percent is classified in the "medium" potential erosion hazard category, while the remaining fifty percent is considered to be in the "low" category for land in a fallow condition. The high and medium potential erosion hazard areas are located throughout the region on the gently sloping land between ridges and streams.

WATER QUALITY

The surface streams within Region Seven routinely surveyed for water quality by the Indiana Board of Health are the Wabash, Vermillion, and Eel Rivers and Sugar, Honey, Big Raccoon, Busseron, and Big Walnut Creeks. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standard for the State of Indiana, and SPC 3, dealing with coal mine wastes and drainage.

Samples from the Wabash River indicated that the temperature, dissolved oxygen content, and pH met the required standards of the state. The data showed that the biochemical oxygen demand and the concentrations of nitrate were also at acceptable levels. However the fecal coliform bacteria levels were at times in violation of standards for partial body contact recreation.

Most of the larger streams of the region are relatively pollution free and support good fish populations. Some exceptions are: the Vermillion River, containing effluents from the Danville, Illinois Sewage Treatment Plant and industrial and strip mining waste; Honey Creek in Vigo County having a high biochemical oxygen demand and perhaps carrying industrial pollutants; and Sugar Creek, in Vigo County, showing prevalent acid mine drainage.

Some of the smaller streams located in the region have had dissolved oxygen and pH values which were often far below the required minimums. These low values were probably due to extensive acid mine drainage into these smaller streams.

The Eel River and its tributaries in the eastern portion of the region were relatively pollution free and supported good fish populations. Some high coliform values have been reported in these streams, but these values have fluctuated widely.

A total of six fish kills has been reported in the region in the period from 1974 to 1977. Three were in Clay County near Brazil and resulted from an industrial oil spill into Penniel Creek, a sewer bypass into the city reservoir, and an animal waste discharge into Croys Creek. Of these, the largest resulted in an estimated 1,200 fish killed. Two fish kills have been reported in Putnam County from hog wastes discharged into Mosquito and Mud Creeks. One fish kill was reported in Vigo County near Terre Haute caused by an industrial spill into Jordan Creek.

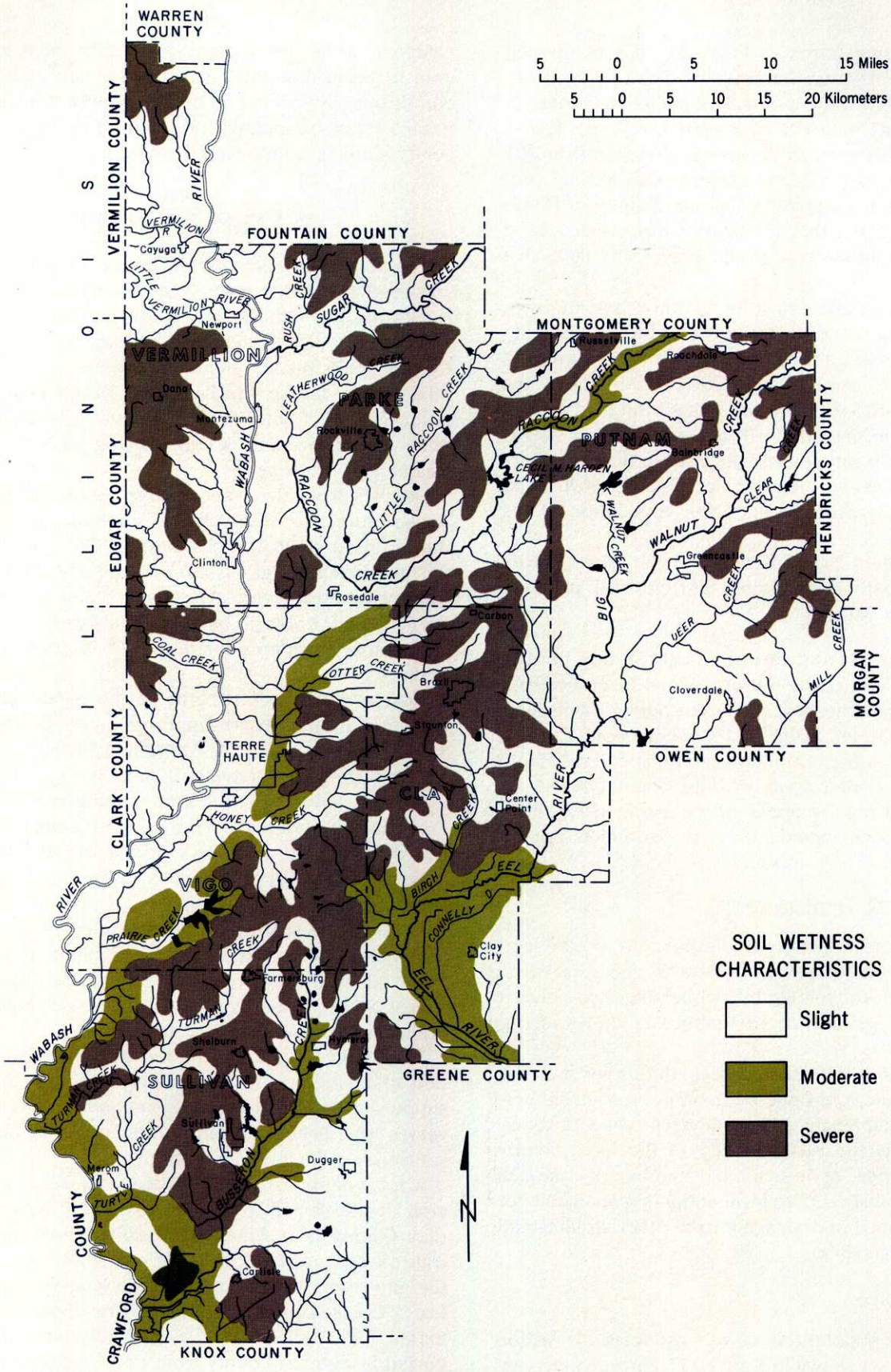


Figure 156
Map of Region Seven showing the general location of the wetness characteristics of soil associations.

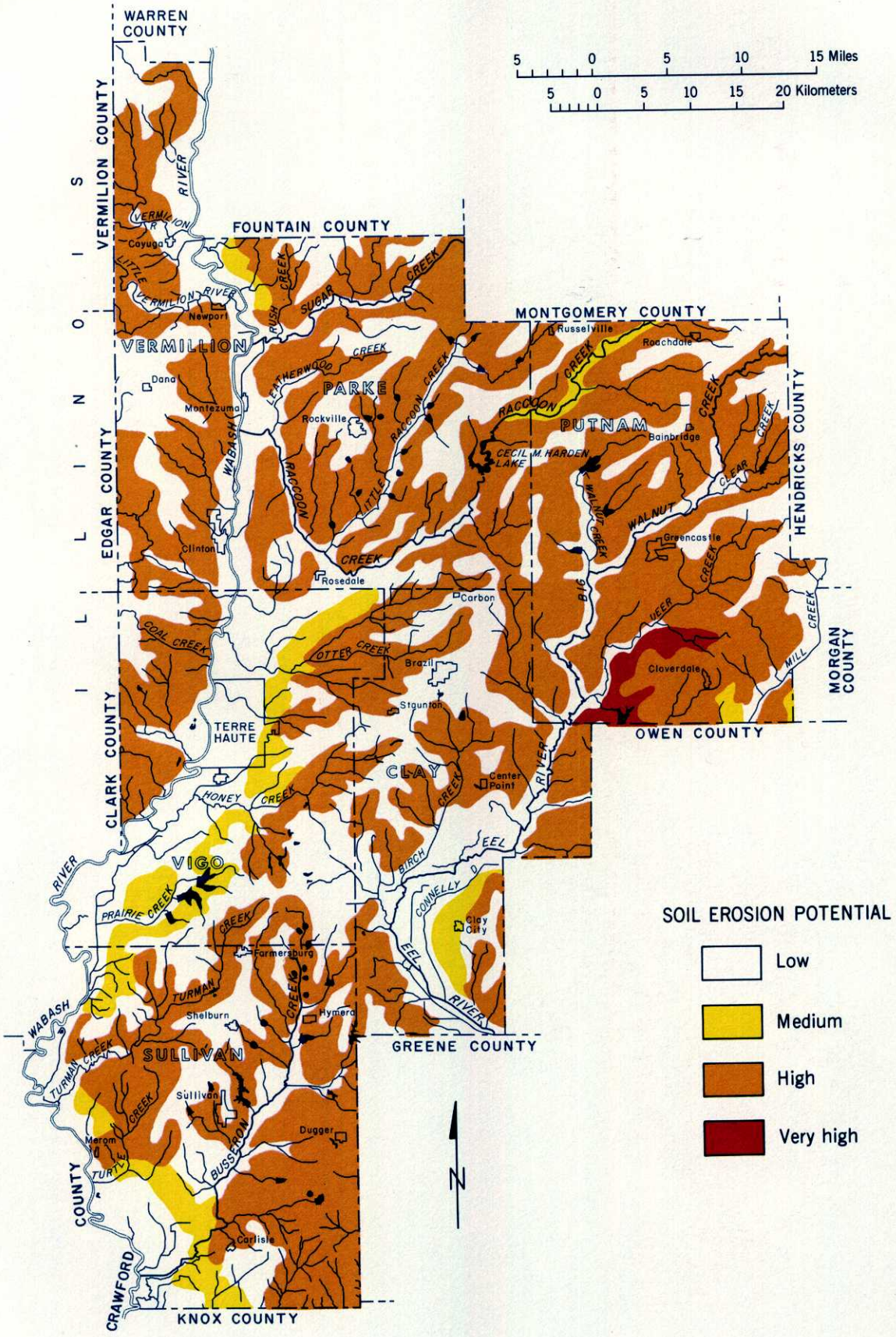


Figure 157
Map of Region Seven showing the erosion potential of the soil associations.

Region Eight

Boone, Hamilton, Hancock, Hendricks, Johnson, Marion, Morgan, and Shelby Counties, located in central Indiana, form Region Eight. The region contains approximately 3,081 square miles and is bounded by Clinton, Tipton, and Madison Counties to the north; Henry, Rush, and Decatur Counties to the east; Bartholomew, Brown, and Monroe Counties to the south; and Owen, Putnam, and, Montgomery Counties to the west, as shown in Figure 158.

The 1975 population of Region Eight was 1,138,753 of which sixty-four percent resided in Indianapolis. The official Indiana Population Projections indicate that the region's population will increase to 1,531,100 by the year 2000, with the major growth in Marion County. The 1975 population and the population projections for each county are tabulated below.

Table 125
The 1975 and projected populations for Region Eight.

County	*1975*	*1980*	*1990*	*2000*
Boone	32,618	33,700	37,500	41,900
Hamilton	68,260	81,300	118,300	170,000
Hancock	40,294	48,300	65,500	86,100
Hendricks	61,290	68,800	88,100	110,700
Johnson	66,880	78,800	103,500	132,100
Marion	782,139	804,400	843,700	863,800
Morgan	48,480	52,200	62,800	74,800
Shelby	38,792	41,300	45,500	49,700
Total	1,138,753	1,208,800	1,364,900	1,531,100

Agriculture is the dominant land use within the region with more than seventy-one percent of the area devoted to farming. Approximately nine percent of the

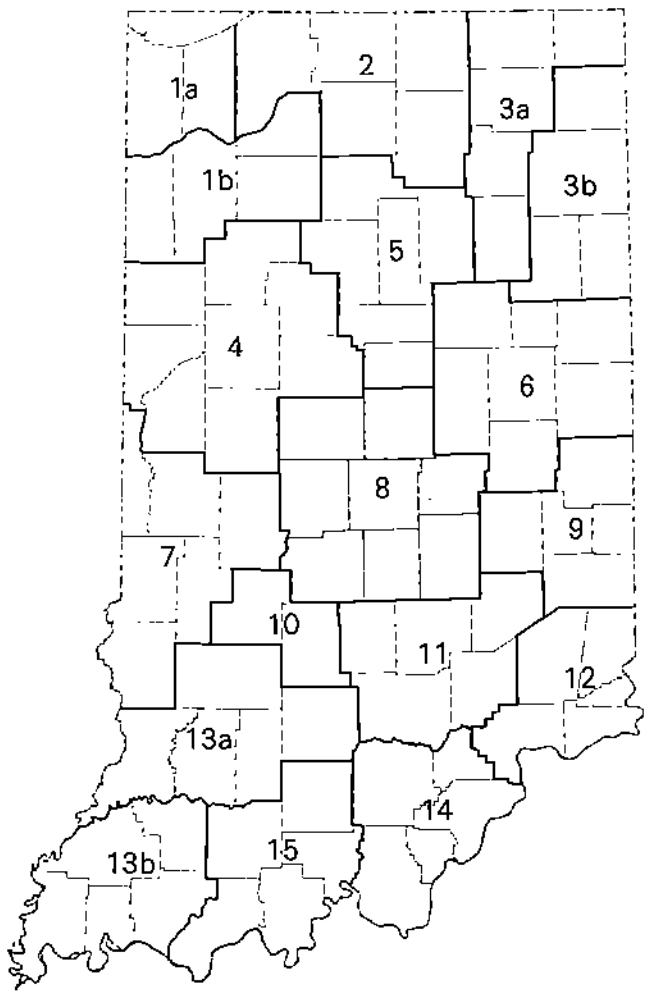


Figure 158
Map of Indiana showing the location of Region Eight.

land is forested while the remaining twenty percent comprises urban and miscellaneous uses.

Approximately thirty-six percent of the work force is employed within the region. The transportation equipment, electrical machinery, and nonelectrical machinery industries employ sixteen percent of the work force. Eighty-five percent of the entire work force is employed in Indianapolis.

The region is characterized by gently rolling to nearly flat topography. However, portions of Morgan County are characterized by steep ridges and relatively rugged topography.

Average annual precipitation for the region is approximately 39.5 inches. This varies from a high of 4.3 inches in May to a low of 2.4 inches in February. Of the 39.5 inches falling annually, approximately 13.0 inches appear as streamflow while 26.5 inches are consumed through evapotranspiration.

The area has moderate temperatures with averages ranging from 28°F. in January to 75°F. in July. The average annual temperature is 53°F. The annual prevailing wind at the Indianapolis International Airport is from the southwest at 9.7 miles per hour.

THE WATER RESOURCE

Ground Water

Virtually all of Region Eight was covered by the Wisconsinan continental glaciers that advanced through Indiana some 20,000 years ago. The deposits left by these ice sheets consist predominantly of glacial till, scattered deposits of ice contact sand and gravel, silt, lake clays, outwash sand and gravel, and alluvial materials. Of particular importance are the permeable sand and gravel deposits found in the valleys of the West Fork White River, Fall Creek, Eagle Creek, White Lick Creek, Blue River, and Brandywine Creek. Also contained within the glacial drift are numerous, thin, intertill sand and gravel zones.

Beneath the glacial and alluvial materials are sedimentary rock formations of Mississippian, Devonian, Silurian, and Ordovician ages. In the extreme southwestern portion of the region, middle Mississippian limestone is present. Further eastward, siltstone, shale, and lenses of limestone of the Borden Group occur beneath about one-third of the region. The New Albany shale, a black carbonaceous formation, underlies the cities of Franklin, western Indianapolis, and Zionsville. The remaining eastern portion of the region is underlaid by limestone and dolomite of Silurian and Devonian ages and thin, interbedded shale and limestone of Ordovician age.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. The availability of ground water in Region Eight is shown in Figure 159. Well yields are usually limited to ten to one hundred gallons-per-minute (gpm) in much of the western portion of the region, particularly in areas underlaid by Mississippian bedrock formations. However, well yields from 250 to 1500 gpm are obtained from aquifer systems in the valleys of White Lick Creek, West Fork of the White River and Eagle Creek, and in the vicinities of Brownsburg and Thorntown.

In the central portion of the region, an area running northwest to southeast has good ground-water conditions, and anticipated maximum well yields range from 100 to 400 gpm. Major ground-water sources occur in the West Fork of the White River valley sand and gravel aquifer system and the underlying limestone and dolomite bedrock aquifers.

Groundwater potential in the eastern portion of Region Eight is good, and except for a small area in extreme southeastern Shelby County, well yields from 200 to 400 gpm are generally available. In some portions of Hancock and Shelby Counties, well yields of 600 to 1000 gpm can be developed from thick sand and gravel aquifers.

The easily recharged aquifers of the West Fork of the White River, Fall Creek, and Blue River valleys contain an estimated 125 billion gallons of water in storage and offer the best potential for ground-water development in Region Eight. However, because of physical constraints only a portion of this amount could be removed without creating adverse impacts. A 1975 study by the U.S. Geological Survey estimated that, depending on hydraulic characteristics, the sand and gravel aquifers in Marion County are capable of producing 59 to 103 million-gallons-per-day (mgd) from a system of wells.

Surface Water

Streamflow The greatest area of Region Eight is drained in a northeast to southwest direction by portions of Big Blue River and the West Fork of the White River. Other major streams include Sugar Creek, located in the Driftwood River drainage basin, Sugar Creek located in Boone County, Flatrock River and Big Walnut Creek. Of these larger streams, only Sugar Creek, located in the Driftwood drainage basin, and Big Walnut Creek originate within the region.

The seven day, once in ten year (Q7-10); one day once in thirty year (Q1-30); and the average annual flow for streams with gaging stations within Region Eight are shown in Table 126.

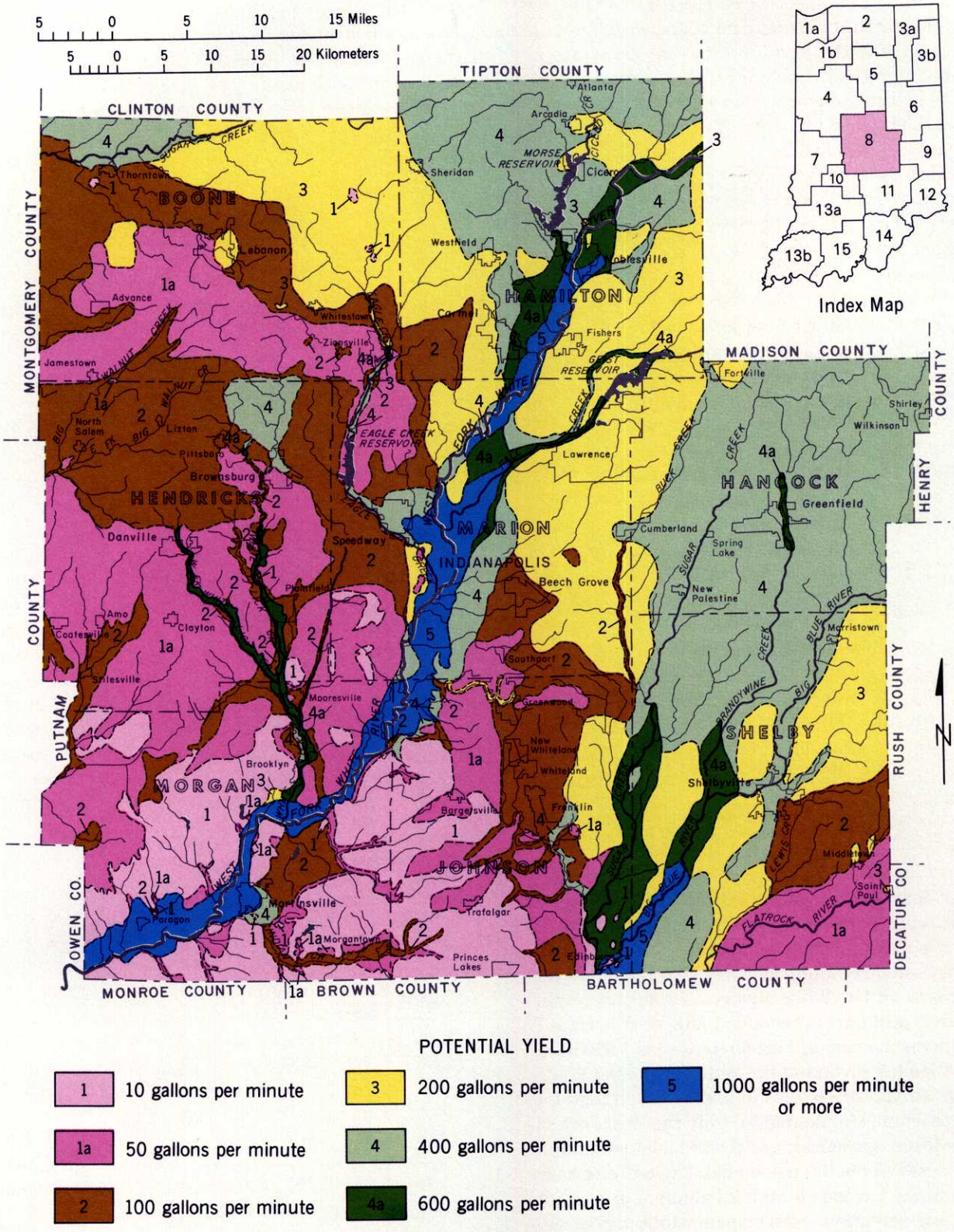


Figure 159

Map of Region Eight showing the general location and potential yield of ground water from properly constructed large diameter wells.

Table 126
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Big Blue River at Shelbyville	421	295	26.2	21.7
Eagle Creek at Indianapolis[a] [b]	162	96	2.6	2.6
Eagle Creek at Zionsville	103	60	0	0
Fall Creek near Fortville	169	105	10.1	7.6
Fall Creek at Millersville[a]	298	178	24.6	19.7
Flatrock River at St. Paul	303	202	1.3	0.5
Pleasant Run at Arlington Avenue	7.6	4	0	0
Pleasant Run at Brookville Road	10	6	0	0
West Fork of the White Lick Creek at Danville	29	18	0	0
West Fork of the White River near Centerton	2,444	1,550	145.4	107.3
West Fork of the White River at Indianapolis[b]	1,635	885	34.8	14.2
West Fork of the White River at Noblesville	858	530	49.9	34.9
West Fork of the White River near Noblesville	828	510	42.5	31.0
West Fork of the White River near Nora[a]	1,219	690	73.0	56.9
White Lick Creek at Mooresville	212	130	2.3	1.1

[a]Flow characteristics include low-flow augmentation from reservoirs.
[b]Flows reduced by water supply withdrawals upstream from gaging stations.

The *low-flow* characteristics indicate that the largest and most reliable streamflows are those in the West Fork of the White River in southwestern Morgan County. The one day, once in thirty year low flows for the West Fork of the White River at Centerton reveal that the river will have a sustained flow of at least 107 mgd, while the average annual flow exceeds 1,500 mgd. Both the Big Blue River and the West Fork of the White River have stream discharges in excess of ten mgd for their entire lengths in the region. Only the West Fork of the White River downstream of White Lick Creek has a yield in excess of one hundred mgd. Eagle Creek Lake has a required release of approximately 2.6 mgd for low-flow augmentation. Some augmentation also occurs in Cicero and Fall Creeks from Morse and Geist Lakes.

The flow duration curve for Eagle Creek at Indianapolis, as shown by Figure 160, indicates the

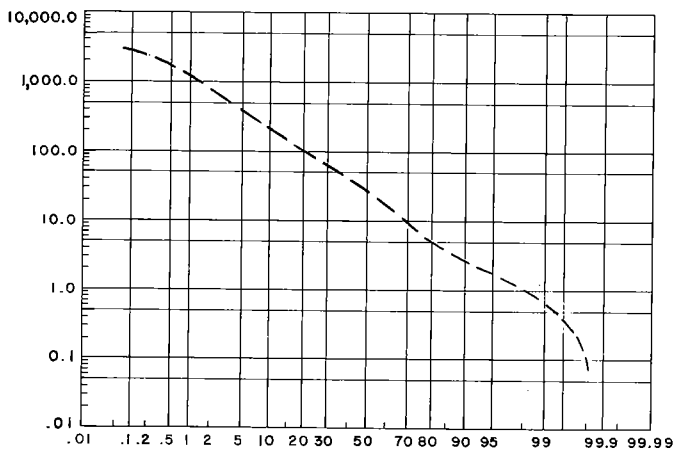


Figure 160
The flow duration curve for Eagle Creek at Indianapolis.

stream will have a dependable flow of at least 2.5 mgd ninety percent of the time.

The slope of the curve also indicates that the Eagle Creek basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs at the Indianapolis gaging station, representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to forty-nine, thirty-four, and nineteen percent for dry, average, and wet years, respectively. Conversely, from fifty-one to eighty-one percent of the flow, depending on the year, is due directly to surface runoff from runoff-producing precipitation events or from snowmelt. Ground-water contribution to streamflow provides a moderate supplement to most streams in the region with the exception of those in Boone and Hendricks Counties.

Lakes The lakes within the region which are at least 50.0 acres in size or have a storage capacity of 32.5 million or more gallons are presented in Table 127, and are located on Figure 161. These forty-nine lakes have a combined surface area of approximately 5,840 acres and a gross storage capacity of approximately 30,150 million gallons. Region Eight contains three major supply structures: Eagle Creek and Geist and Morse Lakes. They possess storages of 7,820, 6,902, and 6,901 million gallons respectively, and are used as a source of water for the Marion County area.

Table 127

Lakes at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Russel Lake	na	6.7	32
2	Wurster Lake	1.01	35.0	51
3	Morse Reservoir	214.00	1,375.0	6,900
4	Valley Forge Lake	0.33	19.0	54
5	Beck Lake	na	7.0	39
6	Danville Conservation Club Lake	na	na	32
7	Je-To Lake	na	10.1	48
8	Manor Lake	na	na	32
9	Stout Lake	na	15.6	52
10	College Park Lake	1.33	12.0	35
11	Eagle Creek Reservoir	168.00	1,350.0	7,820
12	Geist Reservoir	215.00	1,776.0	6,901
13	Indian Lake	25.40	53.6	136
14	Traders Point Lake	na	14.0	48
15	Sugar Hills Lake	na	77.1	100
16	Dalton Lake	na	10.9	58
17	Echo Lake	na	7.8	52
18	Fish Hatchery Lake	na	30.8	104
19	Foxcliff Lake	0.60	42.0	161
20	Hart Lake	na	22.6	58
21	Lahr Lake	na	10.4	58
22	Lake Bodona	na	14.0	45
23	Lake Edgewood	na	50.0	217
24	Lake Holiday	na	na	619
25	Lake Maxine	na	8.2	35
26	Little Nebo Lake	0.36	48.0	288
27	Lower Spring Lake	na	7.1	52
28	North Lake Dillman	na	10.1	48
29	Ole Swimming Hole Lake	na	105.6	391
30	Patton Lake Dam	15.10	94.7	651
31	South Lake Dillman	na	8.2	45
32	Twin Oaks Lake	na	7.0	91
33	Upper Spring Lake	na	6.6	48
34	Vandenbark Lake	na	32.5	260
35	Whip-Poor-Will Lake	na	9.4	32
36	Whip-Poor-Will Lake	na	25.0	202
37	Whispering Wind Lake	na	12.0	39
38	Wildwood Lake	na	na	78

Table 127 (Continued)

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
39	Bell Lake	na	8.8	391
40	Earlham Lake	na	20.8	169
41	Earth Lake, West	na	na	44
42	Hants Lake	na	9.4	58
43	Hood Lake	na	11.4	117
44	Lamb Lake	2.98	60.9	521
45	Lamb Lake Estates	9.10	309.0	2,362
46	Peoga Lake	na	14.6	97
47	Princes East Lake	2.61	63.0	332
48	Princes North Lake	na	20.3	78
49	White Lake	0.19	10.9	71

na: not available.

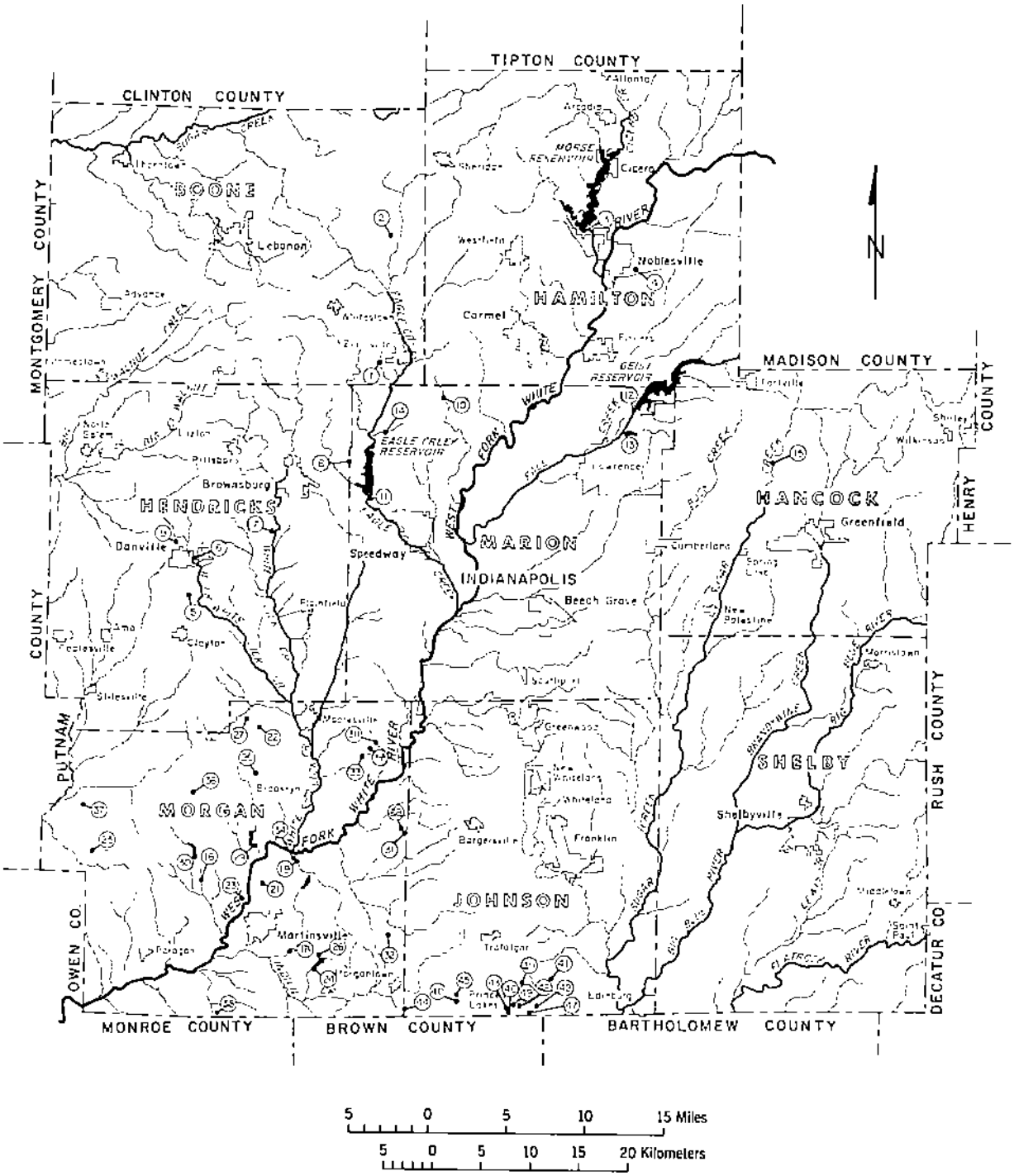


Figure 161
Map of Region Eight showing the location of lakes that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Eight is presented in Table 128. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the percentage is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing Eagle Creek Reservoir and Geist and Morse Lakes are the only lakes in the region that provide boating. Morse Lake is used extensively for waterskiing. Waterskiing is prohibited on the Eagle Creek Reservoir and Geist Lake.

The available supply of open water meets only sixteen percent of the demand for boating generated by residents of Region Eight. The demand for boating may exceed the supply through the year 2000. Waterskiing opportunities are more scarce than those for boating. The current demand exceeds the supply by ninety-six percent, a trend that is expected to continue through the year 2000.

Table 128
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	29	19.6 boats/acre/year	7,700 acres	16	14	14
Waterskiing	15	34.4 skiers/acre/year	600 acres	4	4	4
Canoeing	12	585 canoes/mile/year	123 miles	71	68	63
Swimming	43	76,600 swimmers/acre/year	39 acres	41	35	34
Ice-Skating	8	6,678 skaters/acre/year	8 acres	14	13	13
Fishing	41	66 persons/acre/year	13,500 acres	8	8	8

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

Canoeing The major canoeing streams in the region are Flatrock River and the West Fork of the White River. A total of 123 miles is available to the canoeist, passing through both highly developed and rural areas. However, this stream mileage falls short of the estimated demand within the region. Approximately seventy-one percent of the demand for canoeing opportunities will be met in 1980, declining to sixty-three percent by the year 2000.

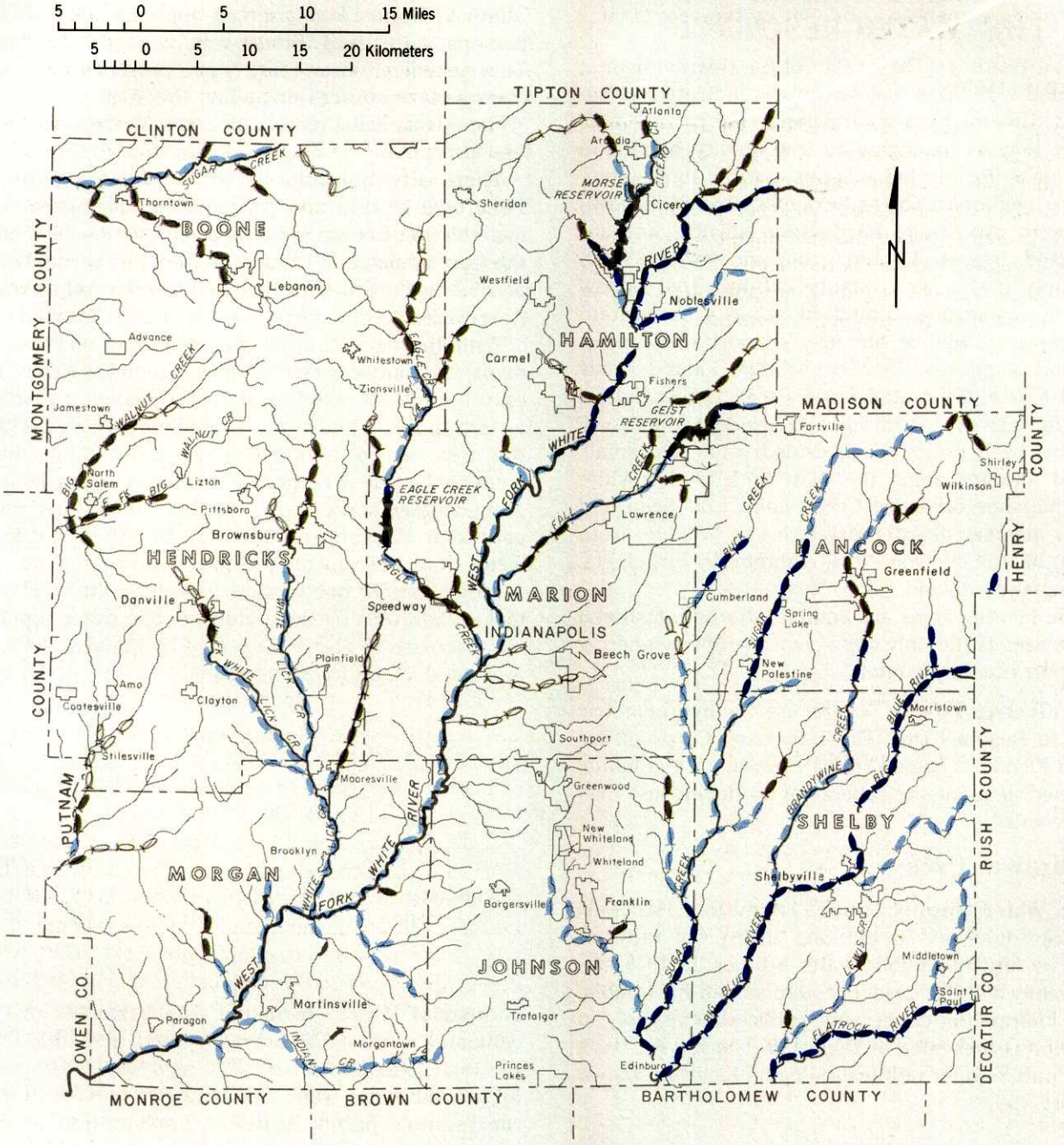
Swimming and Ice-Skating The demand for swimming opportunities exceeds the supply. It is estimated that only forty-one percent of the needed public pools and beaches will be available by 1980, and only thirty-four percent will be supplied by the year 2000.

There is a deficiency of ice-skating facilities as well. Estimates reveal that only fourteen percent of the demanded ice-skating opportunities will be available by 1980, and thirteen percent by the year 2000.

Fishing The quality of the fisheries habitat in Region Eight is indicated on Figure 162. Larger streams, such as the West Fork of the White River, the Big Blue River, Flatrock River, and both Sugar Creeks have the best overall aquatic habitat. The West Fork of the White River has an excellent fisheries habitat in Hamilton County but it decreases slightly downstream in Marion County. A lower quality aquatic habitat is found in the smaller tributaries to the West Fork of the White River, especially in Marion County, and in smaller streams in agricultural areas that are affected by siltation. Warmwater game fish, such as sunfish and catfish, are found in most of the streams. More stable populations of desirable game fish occur in streams with a better quality habitat. Sugar Creek in Boone County is an example of a good fishing stream and is recommended for its sunfish, catfish, and sauger.

Lake Clare, Morse Lake, Eagle Creek Lake, and Geist Lake, all man-made impoundments, offer the best lake fishing opportunities. They all have excellent aquatic habitat and support a variety of sunfishes and catfish. Some of the lakes at the Atterbury Fish and Wildlife Area also provide excellent aquatic habitat for warmwater game fish.

State-owned public access for fishing is available at Atterbury Fish and Wildlife Area, Boone's Pond State Fishing Area, West Fork of the White River in Morgan County, and the Big Blue River at Shelbyville.



AQUATIC HABITAT VALUE

- High
- Moderate
- Low
- Negligible

Figure 162
Map of Region Eight showing the quality of the fisheries habitat.

Estimates indicate that only eight percent of the region's fishing demand will be met by the year 2000.

Riparian Habitat The quality of the riparian habitat associated with lakes and streams is indicated in Figure 163. Streams have good riparian habitat for most of their lengths, changing to low quality habitat in urban areas, mainly Indianapolis, and in some intensively farmed areas. The higher quality habitat is vegetated with mixed-age hardwoods shrubs, and interspersed grasses. Upland game and various birds commonly prefer high quality habitat. The narrow strips of streamside habitat in urban areas attract fewer types of wildlife but may support small mammals and songbirds. Excellent wildlife habitat exists around Morse, Geist, and Eagle Creek Lakes. Upland game, furbearers, migratory and resident waterfowl, and other birds utilize the lakeside habitat. The small, wooded swamps along the West Fork of the White River, marshes on Eagle Creek Lake, and deep and shallow marshes at Atterbury Fish and Wildlife Areas provide habitat for waterfowl, shorebirds, furbearers, and frequently upland game.

Public hunting areas are limited. Atterbury Fish and Wildlife Area is the only state-owned property offering hunting in riparian habitat.

Hydroelectric Power There are no hydroelectric plants in Region Eight. The U.S. Army Corps of Engineers identified Eagle Creek Reservoir as a potential hydroelectric plant site capable of producing less than 100 kilowatts.

Withdrawal Uses

Public Water Supply Boone, Hamilton, Hancock, Hendricks, Johnson, Marion, and Shelby Counties are served by fifty-four public water utilities. In 1975, approximately 883,500 residents were served by a public utility. Information concerning public water supply in the region is presented in Table 129. The service areas for the public water utilities in Region Eight are shown in Figure 164.

Table 129
The public water supply systems as of 1975.

Counties	*Number of Systems*	*Service Population*	*Average Daily Withdrawals in Million-Gallons-Per-day*
Boone	6	15,300	1.33
Hamilton	10	35,270	4.99
Hancock	4	15,300	2.69
Hendricks	7	23,940	2.08
Johnson	8	40,590	7.17
Marion	4	715,510	97.81
Morgan	11	21,680	2.15
Shelby	4	15,900	2.02
Total	54	883,500	120.24

The Indianapolis Water Company, the largest water utility in Region Eight, served approximately 676,000 persons in 1975 and withdrew an average of 93.3 mgd. This system withdraws ninety-five percent of its water from surface sources, including the West Fork of the White River, Fall Creek, and Geist, Morse, and Eagle Creek Reservoirs.

These fifty-four utilities withdrew an average of 120.2 mgd in 1975 and consumed an average of 12.6 mgd. Marion County systems accounted for 99.0 mgd; those in Johnson and Hamilton Counties withdrew 7.2 and 5.0 mgd, respectively. In each of the other counties, average withdrawals were less than 3.0 mgd.

With the exception of the Speedway and the Indianapolis public water utilities, ground water is the only source of withdrawals for the region's public water utilities. In most cases, wells are located within the area served, although a few communities have gone beyond their corporate limits to locate adequate ground-water sources. In addition, rural water companies in Morgan and Johnson Counties withdraw water from wells located in major stream valleys.

Projections of public water supply utilities indicate that withdrawals by the region's public water supplies may increase to about 178.6 mgd by the year 2000, as presented in the following table.

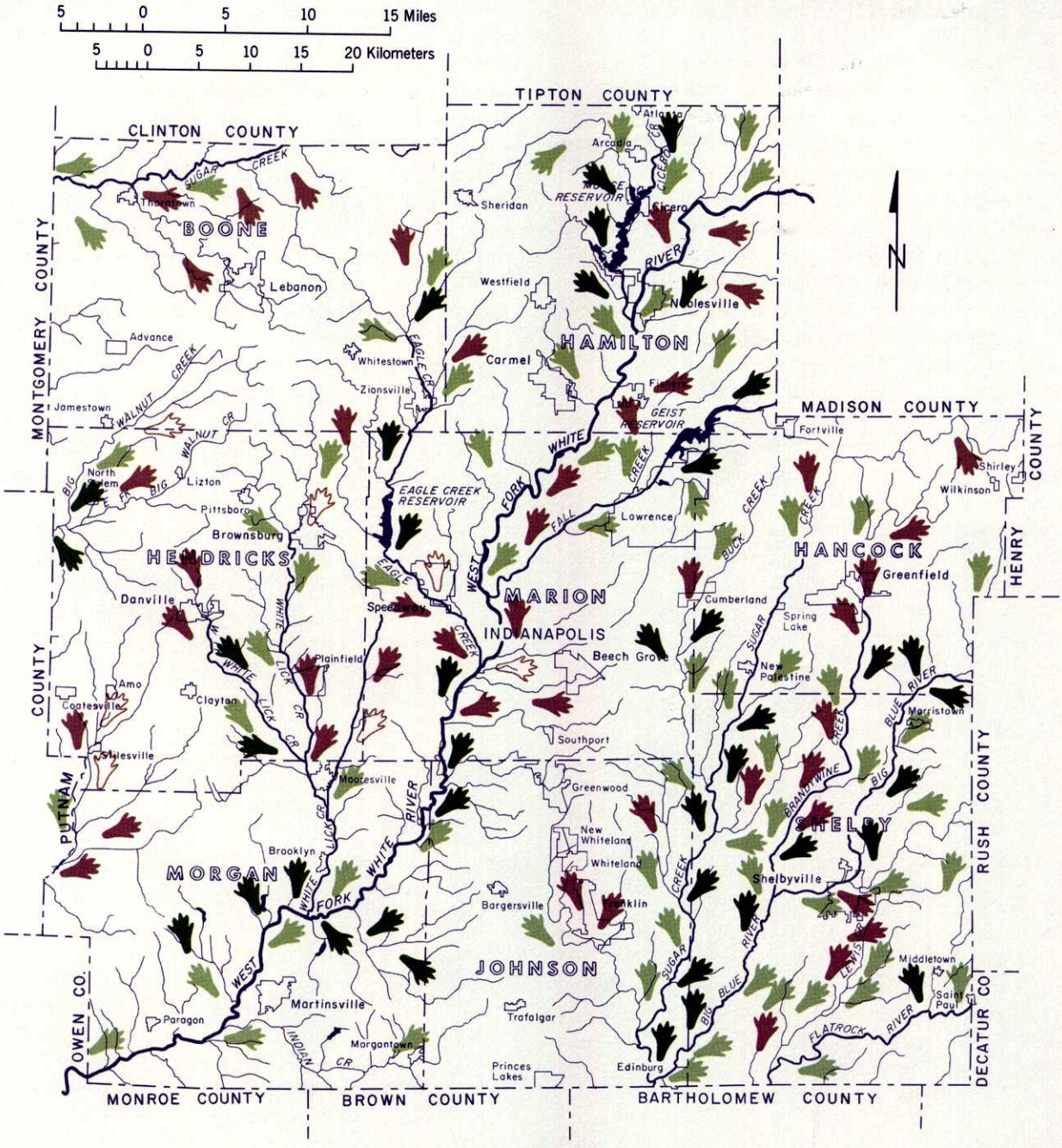
Table 130
The 1977 and projected withdrawal and consumption rates of public water supplies by the year 2000, in million-gallons-per-day.

Public Water Supplies	*1977*	*1980*	*1990*	*2000*
Withdrawal	120.2	126.8	151.9	178.6
Consumption	12.6	13.3	15.9	18.7

Industrial Water Industrial establishments had an estimated water intake averaging 149.0 mgd in 1977. Of the total industrial intake, 93.0 mgd was self-supplied by the industries while 56.0 mgd was purchased from the region's public utilities. Consumption of self-supplied water amounts to approximately 16.7 mgd. Ground water is currently the main source of water for the region's self-supplied industries, although surface water is important to selected industries.

The largest water-using group is comprised of small industries, which as a whole withdraw over 47.0 mgd. Manufacturers of chemicals, transportation equipment, stone, clay, and glass also use large amounts of water.

Although industrial output is expected to increase, total industrial water intake is expected to decrease initially due to plant efficiency and then rise slowly as output increases. Data for industrial self-supplied withdrawals is presented in Table 131.



RIPARIAN HABITAT VALUE

High

Low

Moderate

Negligible

Figure 163
Map of Region Eight showing the quality of the riparian habitat.

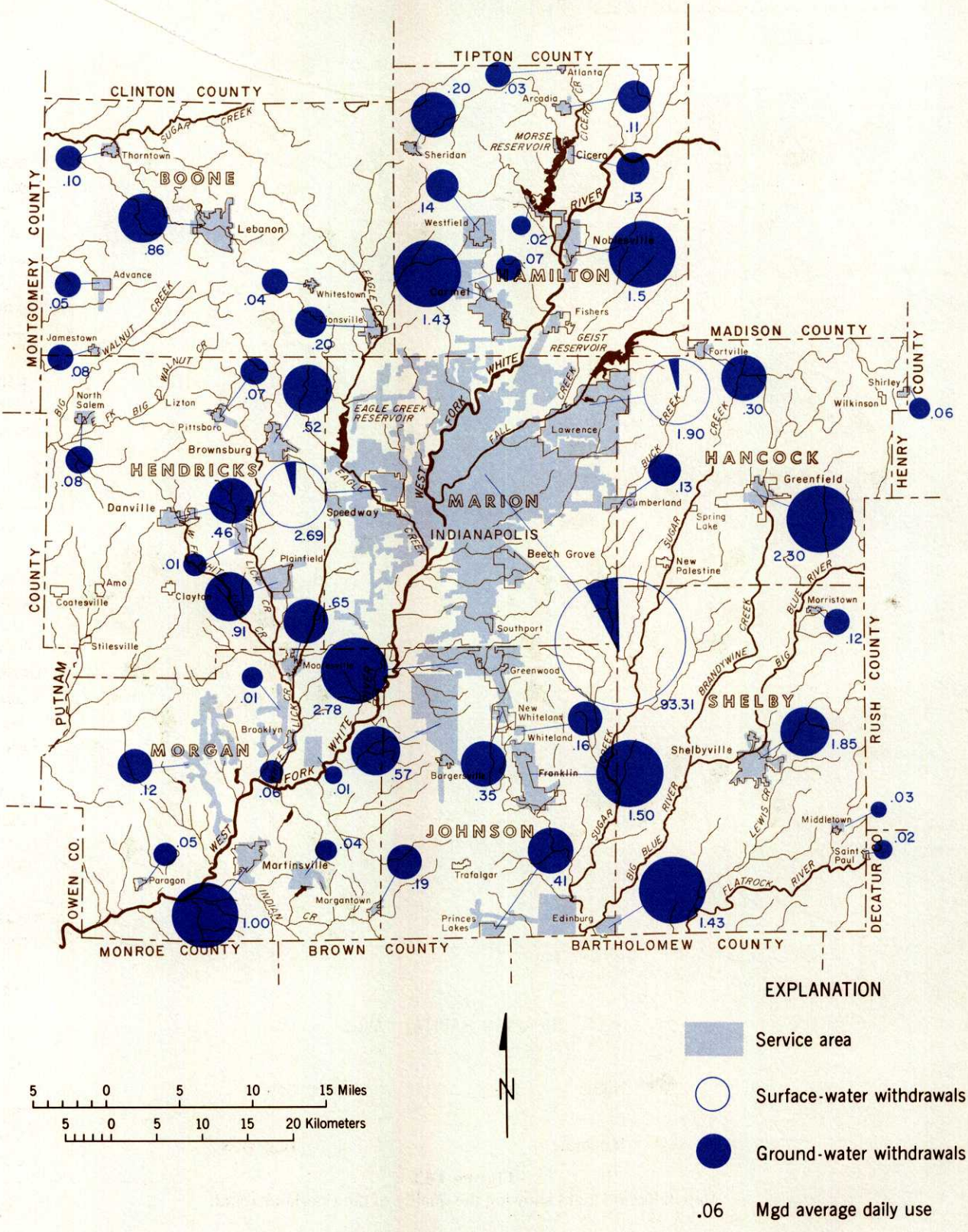


Figure 164
Map of Region Eight showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Table 131
The 1977 and projected industrial self-supplied withdrawal and consumption rates, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	92.9	91.6	95.9	102.8
Consumption	16.7	18.0	23.8	30.9

Rural Self-Supplied Water An estimated 355,000 persons lived in areas supplied by individual water systems in 1975. An estimated 15.0 mgd was withdrawn for residential purposes in 1975. Additional residents and the increase in the standard of living are expected to increase rural residential water use to approximately 26.7 mgd by the year 2000.

An estimated 515,000 head of livestock and about 384,000 chickens were raised in Region Eight in 1975. Collectively, these animals consumed nearly 3.0 mgd. As the animal population increases, water consumption may increase to approximately 4.1 mgd by the year 2000. Rural self-supplied water is withdrawn from ground water supplied from wells on individual farms.

The total withdrawal of rural self-supplied water may increase from the current 19.1 mgd to approximately 30.9 by the year 2000 as indicated below.

Table 132
The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	19.1	20.6	25.7	30.9
Consumption	19.1	20.6	25.7	30.9

Irrigation Water Soil associations with irrigation potential are generally located along streams, especially the West Fork of the White River, Sugar Creek, and Big Blue River. Figure 165 shows the potential irrigation areas within the region.

Based upon the survey of irrigated lands, approximately 870 acres of croplands were irrigated in the region in 1977. Had 1977 been a normal growing year, agricultural land would have required about 2.5 mgd during the peak irrigation period of July and August. It is estimated that approximately 26,000 acres could be profitably irrigated in Region Eight. As much as 3,900 acres of croplands may be irrigated by the year 2000. This potential expansion of croplands is expected to increase the peak July–August irrigation demand in an "average" year to about 10.9 mgd. The average year increase in ground water use is expected to increase from 1.6 mgd to 6.8 mgd by the year 2000.

In addition to the irrigation for agricultural use, fairways and greens on the region's many golf courses are irrigated. About 5.5 mgd is applied to these areas during the peak July–August irrigation season. This demand is expected to increase to 10.4 mgd by the year 2000.

The total withdrawal for the irrigation of croplands and golf courses during the "average" irrigation season of 1977 was approximately 8.0 mgd. These withdrawals may increase to 21.3 mgd during the "average" growing season by 2000 as tabulated below.

Table 133
The 1977 and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	8.0	11.2	15.8	21.3
Consumption	8.0	11.2	15.8	21.3

Electric Energy There are four electric generating plants, all located along the West Fork of the White River. The four existing stations are Pritchard, Stout, Perry, and Noblesville. All of these stations use once-through cooling systems. Stout also uses a cooling tower on one of its units. Pritchard, Stout, and Perry are owned and operated by Indianapolis Power and Light Company. Noblesville is owned and operated by Public Service Indiana.

Stout, Pritchard, Noblesville, and Perry are rated at 954.0, 412.0, 111.0 and 58.5 megawatts respectively. Intake requirements for the four plants total 787.6 mgd. Stout withdraws 325 mgd, Pritchard withdraws 330 mgd, Noblesville withdraws 125 mgd and Perry withdraws 7.6 mgd. The Stout plant consumes water at the rate of 5.0 mgd.

There are no announced plans for any new generating facilities in Region Eight. Projections indicate that regional water withdrawals for generation of electricity will decline from 787.6 mgd to 257.0 mgd by the year 2000 as presented in the following table. Phase out of existing units is the reason for the anticipated reduction in water withdrawals.

Table 134
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	787.6	753.0	587.0	257.0
Consumption	5.0	5.0	4.0	4.0

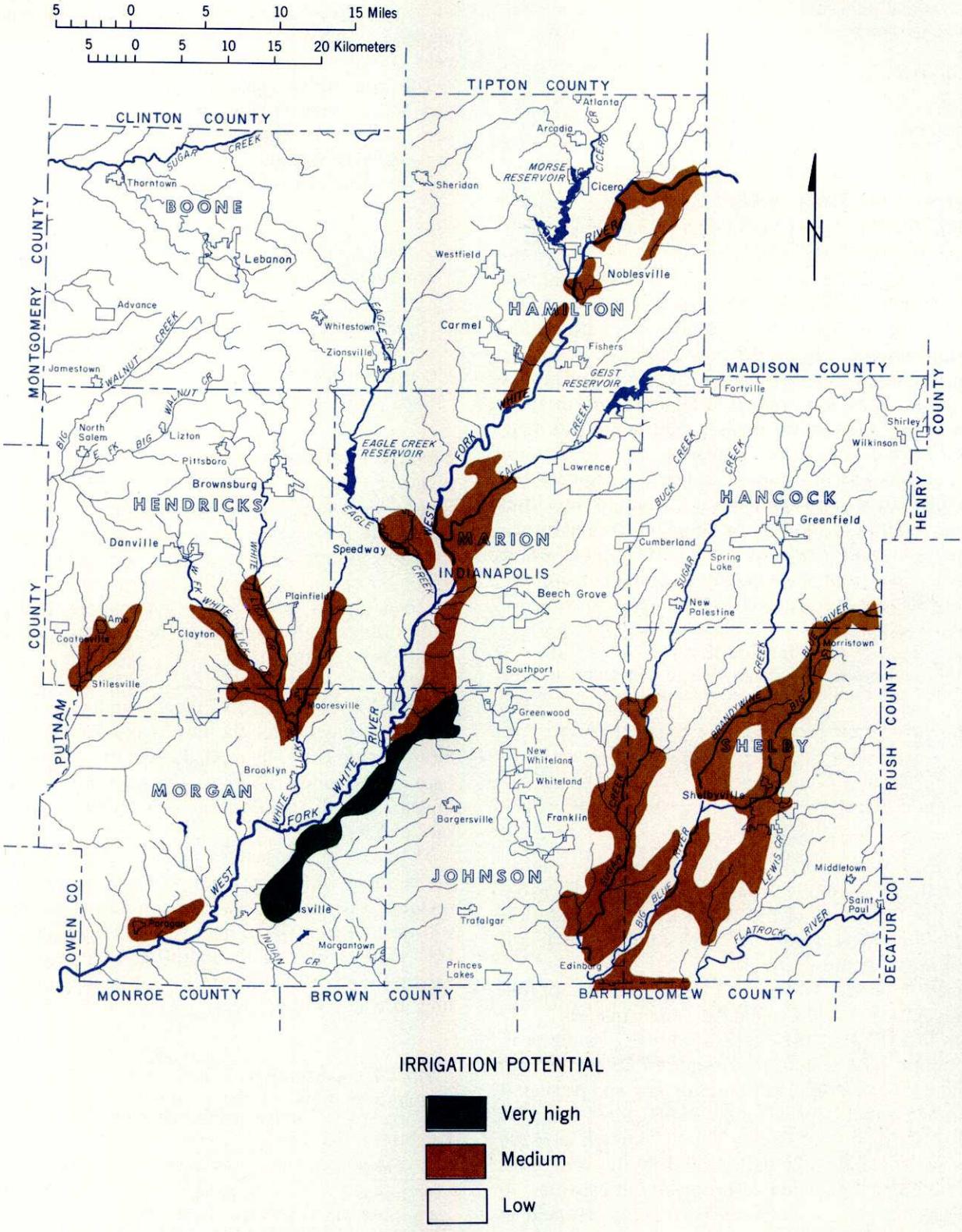


Figure 165
Map of Region Eight showing the location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

EXCESS WATER

Flooding

Approximately 126,800 acres of the region are subject to flooding. The major flood plains are shown in Figure 166. The region is drained predominantly by the West Fork of the White River, East Fork of the White River and a small portion of the Wabash River Basin. Figure 167 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $12,918,000, with fifty-eight percent occurring in urban areas.

Flood Control The flood control structures of the region include both dams and levees. The primary flood control dam is the Eagle Creek reservoir structure, which controls runoff from a drainage area of 162 square miles.

In addition to the Eagle Creek reservoir, the city of Indianapolis has constructed a comprehensive flood protection project on Eagle Creek. The stream channel has been enlarged from 21st Street to White River, and levees have been constructed along both banks with the exception of a short reach downstream from Kentucky Avenue and a short reach between Washington Street and the Pennsylvania Railroad.

The city of Indianapolis, with help from the U.S. Army Corps of Engineers, developed a comprehensive flood protection project along the West Fork of the White River. This project entailed enlarging the river's channel from West 38th Street on the north to West Raymond Street on the south. Levees and boulevard levees and flood walls have been constructed along the banks.

Further north on the West Fork of the White River, between Kessler Boulevard upstream to Broad Ripple Dam, levees have been constructed. Another levee has been constructed on the left bank of the West Fork of the White River at Rocky Ripple.

In order to alleviate flooding of Dry Run, a tributary to Little Eagle Creek, a diversion channel was constructed north of 25th Street to carry the additional water to Little Eagle Creek.

Fall Creek, which flows through southeastern Hamilton and northeastern Marion Counties, has several levees, boulevard levees, and floodwalls within the city of Indianapolis.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include unincorporated Boone, Hancock, Hendricks, Johnson, and Shelby Counties as well as the communities listed in Table 135. Bargersville, Fishers, Morgantown, and Morristown are participating in the regular phase of the National Flood Insurance Program.

Table 135
Communities participating in the emergency phase of the National Flood Insurance Program.

Brooklyn	Mooresville
Carmel	New Whiteland
Cicero	Noblesville
Clay	Plainfield
Danville	Princes Lake
Edinburgh	Shelbyville
Franklin	St. Paul
Greenfield	Thorntown
Greenwood	Westfield
Indianapolis	Whitestown
Lebanon	Whiteland
Martinsville	Zionsville

Agricultural Drainage

Approximately fifty percent of the soil associations in Region Eight have "severe" wetness characteristics, twenty-nine percent have "moderate" wetness characteristics, while twenty-one percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics is shown in Figure 168. Although the majority of lands are classified as having soil wetness characteristics, there are some areas that have soils of sufficient permeability to keep the land well drained. These areas include lands lying along the West Fork of the White River, the area along the Blue River and Sugar Creek in the southeastern corner of the region, and most of the southwest corner of the region.

There are approximately 3,235 miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards, or in a limited number of cases, of conservancy districts. No legal entity is responsible for maintaining drainage for the other streams in the region.

Soil Erosion

The erosion potential of soil associations are shown in Figure 169. Thirty percent of Region Eight is rated as having a "medium" soil erosion hazard. These areas for the most part are adjacent to the major streams and their tributaries. Ten percent of the land is classified as having a "high" soil erosion potential. These areas are located in the southeastern portion of the region. The remaining sixty percent of the region is rated as having a "low" potential erosion hazard for land in a fallow condition.

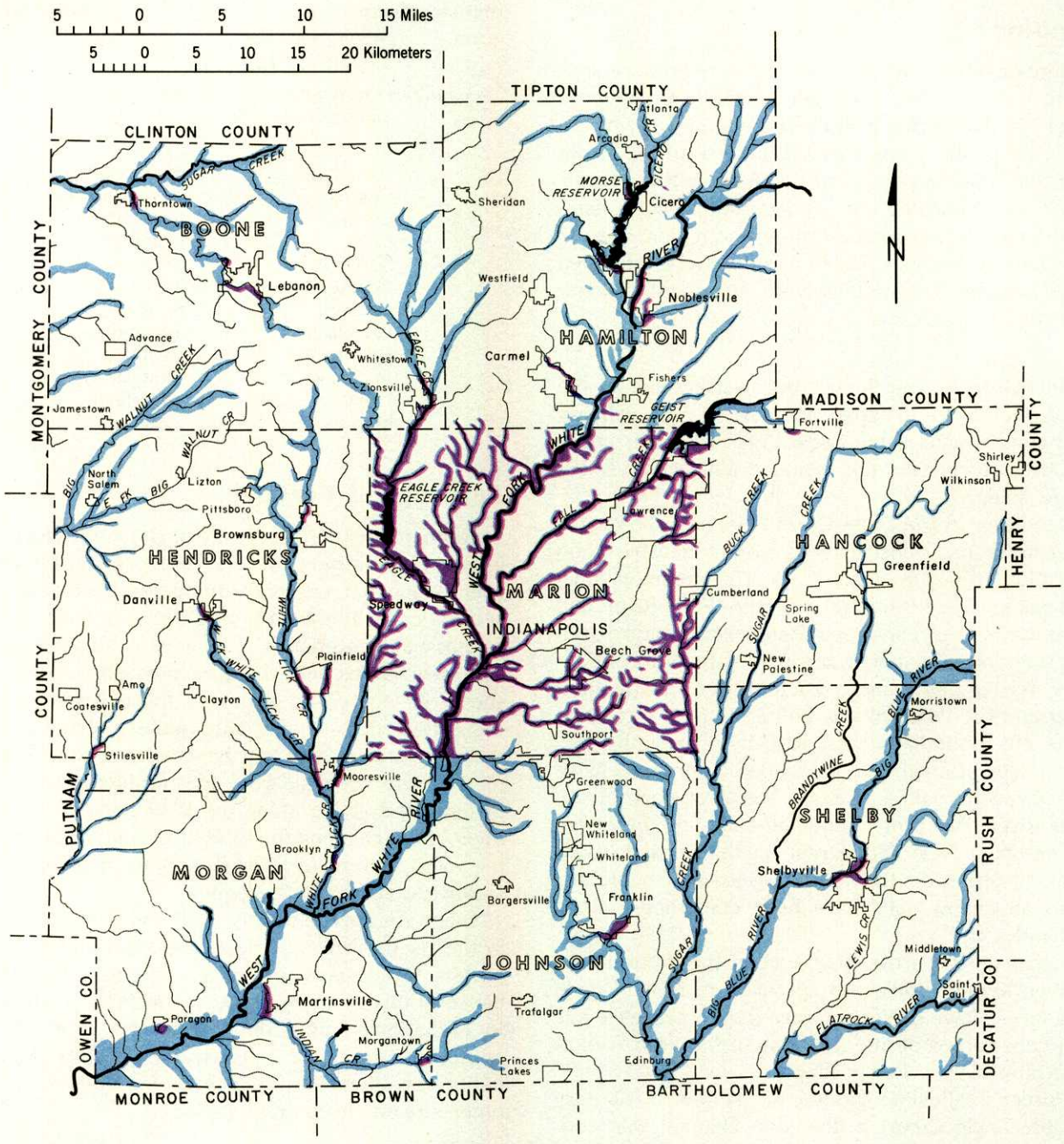


Figure 166
Map of Region Eight showing the major flood plains.

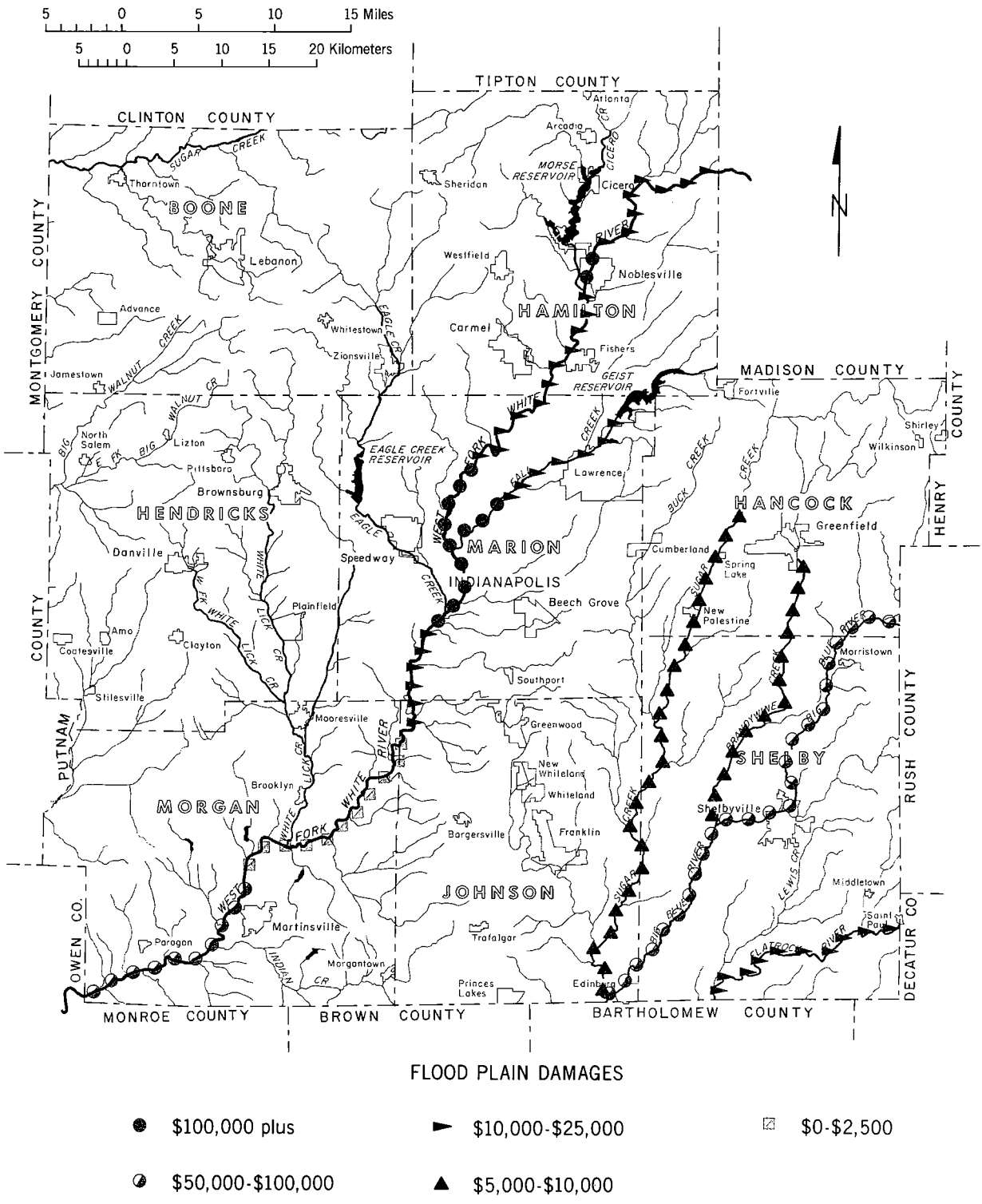
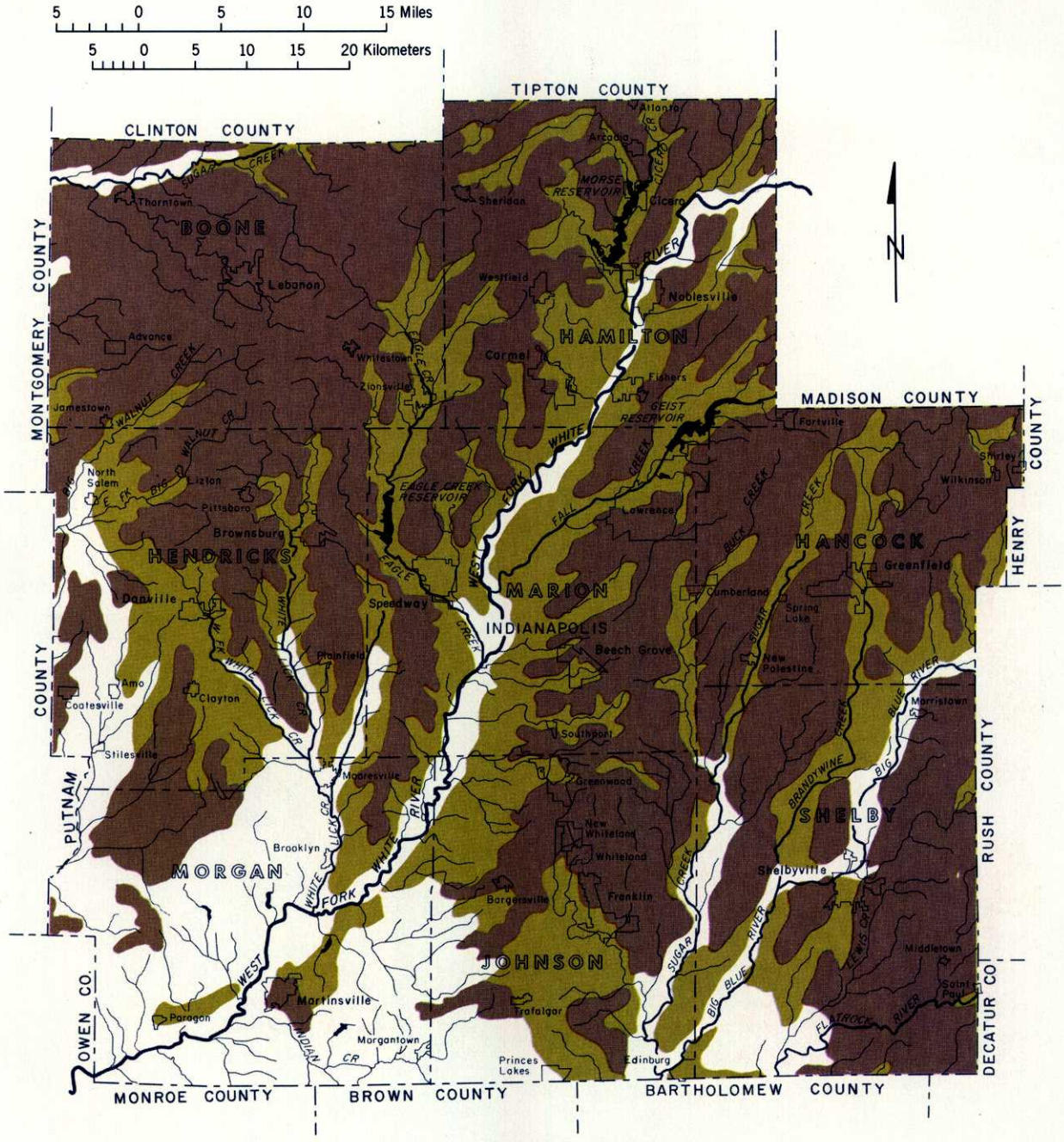


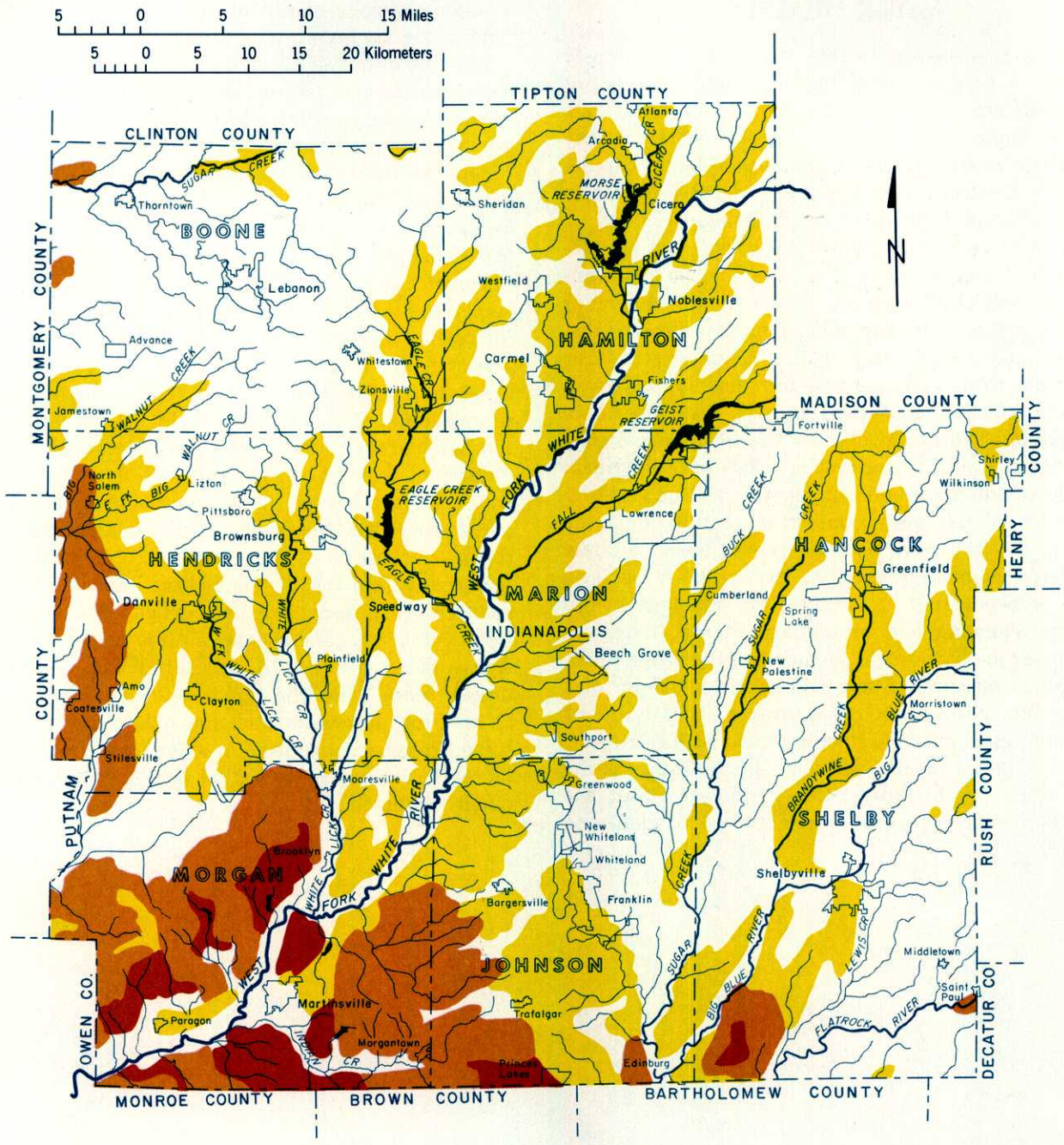
Figure 167
Map of Region Eight showing the estimated average annual flood damages per mile along selected streams.



SOIL WETNESS CHARACTERISTICS

- Slight
- Moderate
- Severe

Figure 168
Map of Region Eight showing the location of the wetness characteristics of soil associations.



SOIL EROSION POTENTIAL

- Low
- Medium
- High
- Very high

Figure 169
Map of Region Eight showing the erosion potential of the soil associations.

WATER QUALITY

The surface streams within Region Eight routinely surveyed for water quality by the Indiana State Board of Health are White and Big Blue Rivers, and Fall, Cicero, Eagle, and Whitelick Creeks. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standard for the State of Indiana.

The West Fork of the White River exhibited two different levels of water quality, one for the river upstream from Indianapolis, and one for the river downstream from Indianapolis. Temperatures and dissolved oxygen levels were within required standards upstream from Indianapolis, but dissolved oxygen levels often violated state standards downstream of Indianapolis. Nitrate levels and the biochemical oxygen demand were at acceptable levels both upstream and downstream of Indianapolis. This stream is designated for partial body contact recreation, thus the level of fecal coliform bacteria should meet the state standards for this designation. Fecal coliform bacteria levels were violated in March, April, and June in upstream segments and in January, March, June and November in downstream segments of the White River. The pH, a measure of the acidity and alkalinity of a substance, showed no violations of maximum or minimum standards in either segment of the river.

Samples from Cicero Creek, a major tributary of the West Fork of the White River, indicated that the biochemical oxygen demand, dissolved oxygen, and ammonia nitrogen were at acceptable levels at the time of the survey.

Samples from Fall Creek indicated that temperature, dissolved oxygen, nitrate, and fecal coliform bacteria values were at acceptable levels. Neither the maximum nor minimum limits for pH were violated.

Samples from near the mouth of Eagle Creek indicated that the temperature and dissolved oxygen levels have met state standards. The biochemical oxygen demand levels have been abnormally high from August to December. The pH values of Eagle Creek sometimes fell below minimum standards. Ammonia nitrogen concentrations have exceeded desirable levels in the months July through November. Eagle Creek has been designated for partial body contact recreation, but fecal coliform levels from January through March failed to meet the necessary criteria.

Samples from Whitelick Creek indicated that dissolved oxygen concentrations occasionally fell below minimum acceptable levels. In addition, ammonia nitrogen concentrations exceeded desirable levels.

Samples from the Big Blue River indicated the dissolved oxygen and ammonia nitrogen concentrations were within acceptable levels. Although low concentrations of dissolved oxygen were measured downstream from the Shelbyville wastewater discharge, the depression did not violate in-stream dissolved oxygen concentration standards. However, the recreation criterion for partial body contact was frequently violated.

Region Nine

Fayette, Franklin, Rush, Union, and Wayne Counties, located in eastern central Indiana, form Region Nine. The region contains approximately 1,595 square miles and is bounded by Henry and Randolph Counties to the north; the State of Ohio to the east; Dearborn and Ripley Counties to the south; and Decatur, Shelby and Hancock Counties to the west; as shown in Figure 170.

The 1975 population of Region Nine was 149,971, of which forty-five percent resided in Richmond, Connersville, and Rushville. The official Indiana Population Projections indicate the region's population may increase to 170,000 by the year 2000. The population and projections for each county are tabulated below.

Table 136
Existing 1975 and projected populations for Region Nine.

County	*1975*	*1980*	*1990*	*2000*
Fayette	27,604	29,100	32,000	34,600
Franklin	17,679	18,300	19,800	21,400
Rush	20,596	21,800	27,300	24,900
Union	6,741	6,800	7,100	7,400
Wayne	77,351	80,100	82,100	82,400
Total	149,971	156,100	168,300	170,700

Approximately thirty-three percent of the region's population is employed within Region Nine. The electrical machinery, nonelectrical machinery, and fabricated metal industries employ nearly thirty percent of the work force.

Agriculture is the dominant land use with more than eighty percent devoted to that purpose. Approximately fourteen percent of the land is forested while the

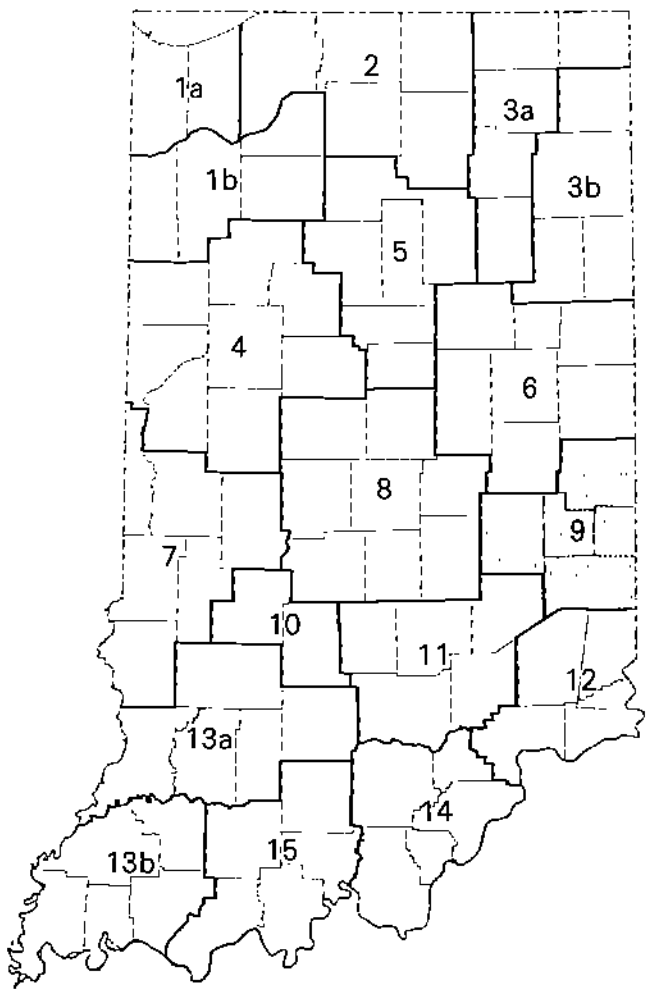


Figure 170
Map of Indiana showing the location of Region Nine.

remaining six percent represents urban and miscellaneous uses.

Average annual precipitation for the region is approximately 40.0 inches. This varies from a high of 4.3 inches in May to a low of 2.5 inches in February. Of the 40.0 inches falling annually, approximately 13.5 inches appear as streamflow while 26.5 inches are consumed through evapotranspiration. The region experiences moderate temperatures with monthly averages ranging from 28°F. in January to 74°F. in July. The average annual temperature is 52°F. The annual prevailing winds appear to be from the southwest at 8.4 miles per hour.

THE WATER RESOURCE

Ground Water

The Wisconsinan glacial advance extended as far south as the Whitewater River in Franklin County. The area southwest of the Whitewater River was unglaciated during the Wisconsinan period. The thickness of glacial deposits ranges from less than ten feet in parts of Franklin, Union, and southeastern Wayne Counties to cover 350 feet in a buried preglacial valley in western Wayne County. The types of deposits include glacial till, valley train outwash sand and gravel, ice contact sand and gravel, and alluvium. The most important glacial deposits in evaluating ground-water occurrence are the outwash sand and gravels deposited by glacial meltwaters in numerous stream courses. The entire Whitewater River valley and its major tributaries contain thick and permeable deposits of sand and gravel which constitute the major groundwater source in the region. Elsewhere, sand and gravel units occur as scattered deposits contained within the glacial till.

Underlying the unconsolidated materials are bedrock formations ranging in age from upper Ordovician through middle Devonian. The Ordovician rocks consist of shales and interbedded limestones. These rocks are essentially impermeable, and well yields are nearly always poor, with "dry holes" common in southern Franklin County. Elsewhere limestone and dolomite rocks constitute the Silurian and Devonian aquifers. The carbonate rocks generally yield moderate amounts of water depending on the nature of the overlying glacial drift.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. There is a pronounced variability in ground-water occurrence in Region Nine, as shown in Figure 171.

Well yields within the region are quite variable, and in some parts of the area, dry holes can be found within a mile of wells producing 1,000 gallons-per-minute (gpm). In upland areas of Franklin, Fayette, and Union Counties, wells can be expected to yield between 10 and 50 gpm with yields of less than 10 gpm common. However, in these same counties, properly constructed wells in the East Fork, West Fork, and the main stem of the Whitewater River valleys produce 400 to 1,000 gpm. In Rush County, well yields are, in general, best in the northern one-half of the county where 100 to 400 gpm can be developed. In the southern portion of the county, yields range from 10 to 100 gpm. Wayne County contains the best ground-water resources in the region due to the nature of the Wisconsinan glacial deposits. The only limited groundwater areas of Wayne County are the southeastern and extreme southwestern sections. From 400 to 1,000 gpm is available in sand and gravel deposits in the valleys of the East Fork, West Fork, and main stem of the Whitewater River, Martindale Creek, Greens Fork, and Nolands Fork.

The quality of ground water in the region is generally good with hardness levels of 300 to 400 parts-per-million (ppm) and iron contents of 0.1 to 3.0 ppm. Iron removal is often required to alleviate staining problems. Water from deep wells drilled into the Ordovician shales and limestones can be of poor quality with high levels of chlorides and mineralized water often reported.

Surface Water

Streamflow The streams in Fayette, Franklin, Union, and Wayne Counties flow predominantly in a north to south direction through the Whitewater River system, most of whose headwaters are contained within the region. The Flatrock and Big Blue River systems flow to the southwest, draining most of Rush County and part of Fayette County.

The seven day, once in ten year (Q7-10); one day, once in thiry year (Q1-30); and the average annual flow for streams with gaging stations within Region Nine are shown in Table 137.

Analysis of the low-flow characteristics of surface streams within the region indicates that the largest and most reliable streamflows are those in the West Fork of the Whitewater River. Brookville Lake has a required low flow release of approximately 25.8 million-gallons-per-day (mgd) for low-flow augmentation of the Whitewater River.

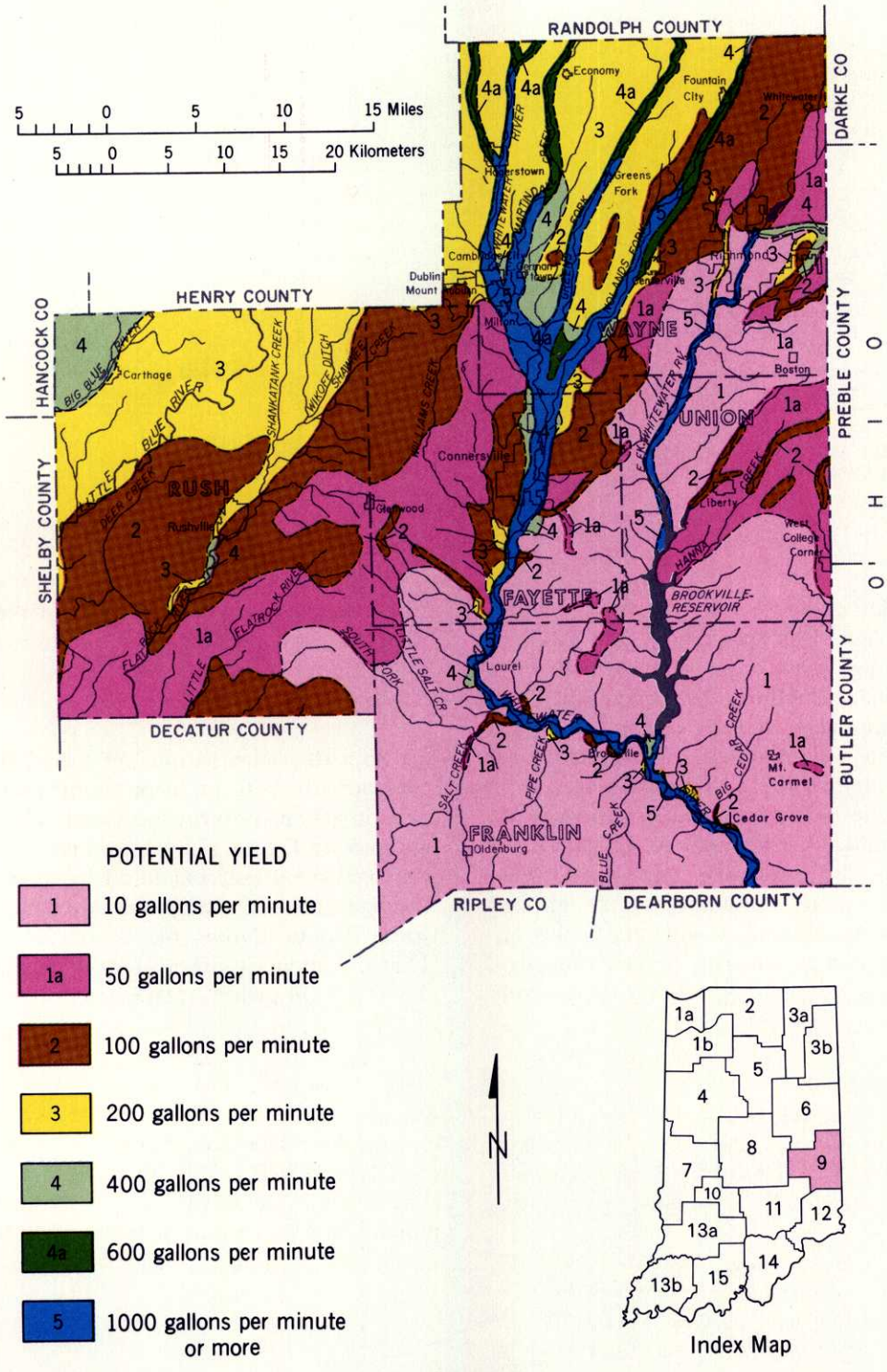


Figure 171

Map of Region Nine showing the location and potential yield of ground water from properly constructed large diameter wells.

Table 137
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Big Blue River at Carthage	184	130	17.0	13.0
West Fork Whitewater River near Alpine	529	350	32.0	22.0
East Fork Whitewater River at Abington	200	150	15.0	12.0
Martindale Creek near Cambridge City*	58	na	0.8	na
East Fork Whitewater River at Richmond*	121	75	2.2	na
Salt Creek near Metamora*	115	na	0.2	na

*Flow characteristics estimated from a stream gaging station with a short period of record.
na: not available.

The flow duration curve for the West Fork of Whitewater River near Alpine, as shown by Figure 172, indicates the stream will have a dependable flow of 50 mgd ninety percent of the time. The slope of the curve also indicates that the West Fork of the Whitewater River basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs at the gaging station, representing "dry," "average," and "wet," years, respectively. The results indicate that the ground-water contribution to streamflow amounts to seventy-four, thirty-seven, and twenty-two percent for "dry," "average," and "wet" years, respectively. Conversely, from twenty-six to seventy-eight percent of the flow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or from snowmelt.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are listed in Table 138, and are located on Figure 173. These lakes have a combined surface area of approximately 5,740 acres and a gross storage capacity of approximately 63,400 million gallons. Two reservoirs, the Brookville and Whitewater Lakes, contain storages of 29,100 million gallons and 1,190 million gallons, respectively.

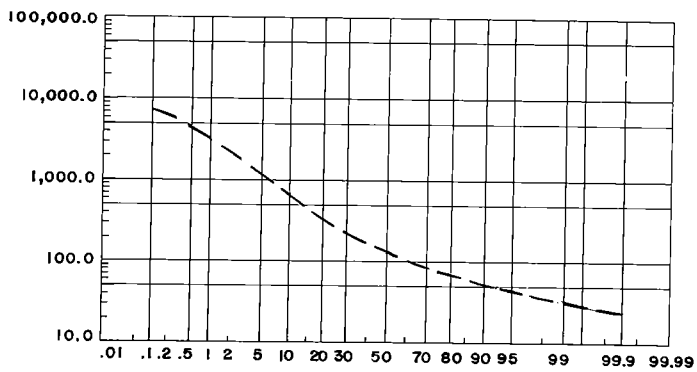


Figure 172
The flow duration curve for the Whitewater River near Alpine.

Table 138
Lakes at least 50 acres in size or having a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Middle Fork Reservoir	na	195.1	2,017
2	Big Blue River Structure No. 2	5.03	25.3	50
3	Big Blue River Structure No. 3	11.40	44.0	115
4	Manlove Lake	na	16.4	65
5	Whitewater Lake	19.20	199.0	1,189
6	Brookville Lake	379.00	5,260.0	59,959

na: not available

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Nine is presented in Table 139. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred, the supply is less than the projected demand.

Boating and Waterskiing The current demand for boating and waterskiing is being met by Brookville Lake. A surplus of water available for boating and waterskiing is expected to exceed the demand through the year 2000.

Canoeing Canoeing is available primarily on the West Fork of the White River. A total of 79 miles of canoeing is available in the region, which meets the current and projected demand by the year 2000.

Table 139
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	29	19.6 boats/acre/year	5,900 acres	100+	100+	100+
Waterskiing	8	34.4 skiers/acre/year	2,500 acres	100+	100+	100+
Canoeing	11	585 canoes/mile/year	79 miles	100+	100+	100+
Swimming	35	76,600 swimmers/acre/year	6 acres	60	60	60
Ice-Skating	3	6,678 skaters/acre/year	1 acres	20	20	20
Fishing	41	66 persons/acre/year	6,700 acres	53	50	50

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

Swimming and Ice-Skating The demand for swimming and ice-skating opportunities exceeds the available supply. This shortage of supply is expected to continue through the year 2000.

Fishing The quality of the fisheries habitat is indicated on Figure 174. The Flatrock River, East and West Forks of the Whitewater River, Greens Fork, and Nolands Fork are the major waterways and have good to excellent aquatic habitat. Various stretches of smaller streams have been more adversely affected by agricultural practices and have lower quality aquatic habitat. Most streams in the region have warmwater fisheries typical to Indiana, with sunfish, bass, catfish, and various rough and forage fish. The East Fork of the Whitewater River, downstream of Brookville Lake, is also stocked with trout. This stream has spawning runs of white bass and walleye above the reservoir.

Brookville Lake, the largest man-made lake in the region, has excellent aquatic habitat. It is noted for its populations of white and striped bass, sunfish, walleye, channel catfish, and bullheads. Good aquatic habitat is

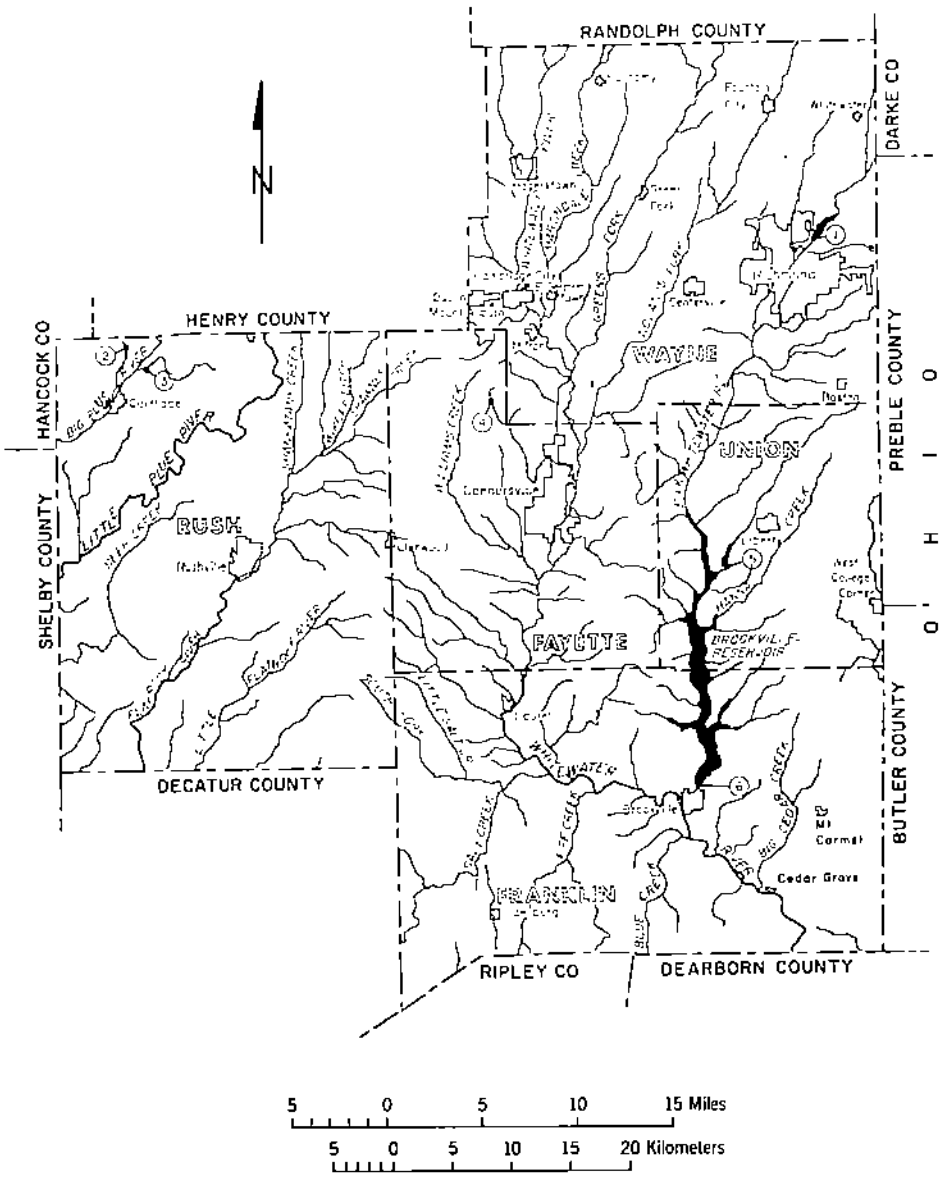
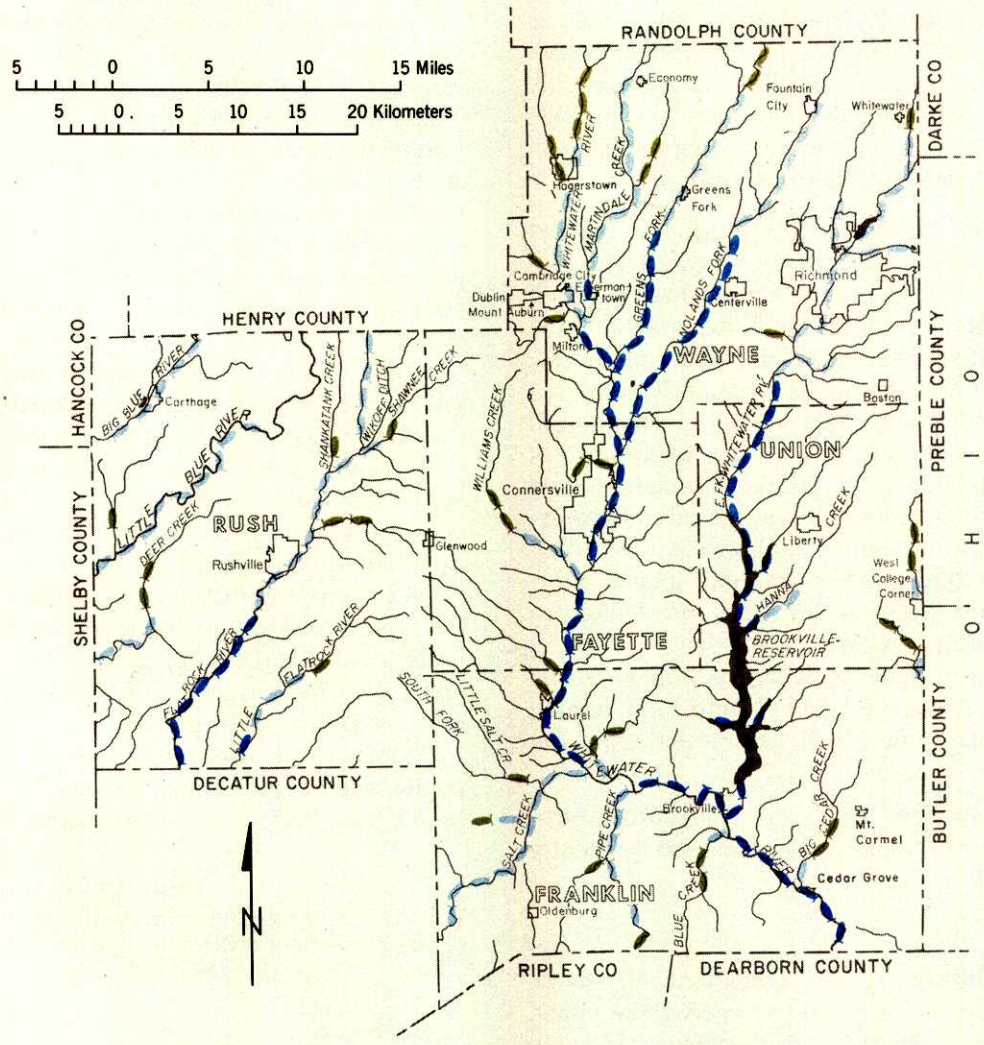


Figure 173
Map of Region Nine showing the location of lakes that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more.



AQUATIC HABITAT VALUE

- High
- Moderate
- Low
- Negligible

Figure 174
Map of Region Nine showing the quality of the fisheries habitat.

also found in Manlove Park Lake in Fayette County and in Whitewater Lake in Union County. Middle Fork Lake and the Martindale State Fishing Area are not so highly rated for their fisheries.

Fishing access through state-owned properties is available at the Martindale State Fishing Area, Brookville Lake, and Whitewater State Park. City and county parks, bridges, and roadside pullovers may provide additional access. The demand for fishing in 1980 will exceed the supply by fifty-three percent.

Riparian Habitat The quality of the riparian habitat associated with lakes and streams is indicated on Figure 175. Highly rated riparian habitat is found along all the larger streams in Region Nine. Hardwoods line the streambanks that are used by upland game, furbearers, and birds commonly found in Indiana. Recent discoveries of colonies of the endangered Indiana bat, in Rush and Wayne Counties, indicate the importance of the riparian habitat. Except for the Martindale State Fishing Area and Middle Fork Lake, the lakes have excellent riparian habitat for migratory and resident waterfowl, other birds, furbearers, and upland game. Significant wetland areas in the region are limited to the upper end of Brookville Lake.

Public hunting in riparian habitat is limited to the public lands of Brookville Lake. Hunting on private property is available only with permission from the landowners.

Hydroelectric Power There are no hydroelectric power plants in the region, and none are presently envisioned.

Withdrawal Uses

Public Water Supply Fayette, Franklin, Rush, Union, and Wayne Counties are served by twenty-three public water utilities. An estimated 91,000 residents of Region Nine were served by a public utility in 1975. Three of these systems — Everton Water Corporation, Franklin County Rural Water Corporation, and the North Dearborn Water Corporation — primarily serve rural areas. Information on public water utilities is presented in Table 140. Service areas for the public water utilities are shown in Figure 176.

Table 140
The public water supply systems as of 1975.

Counties	*Number of Systems*	*Service Population*	*Average Daily Withdrawals in Million-Gallons-Per-Day*
Fayette	5	19,460	4.82
Franklin	5	7,383	.89
Rush	4	8,476	1.07
Union	2	2,531	.22
Wayne	7	53,333	10.31
Total	23	91,183	17.31

The largest single water utility in this region is the American Water Works in Richmond. This utility serves more than 44,000 persons. In 1977, it withdrew an average of 8.7 mgd. Sixty percent of Richmond's water withdrawals are obtained from the Middle Fork Reservoir, and the remainder is withdrawn from groundwater sources located in sand and gravel aquifers.

The Batesville – Oldenburg system in Franklin County withdrew an estimated 0.1 mgd from a series of small reservoirs. The system also provides 0.1 mgd to the town of Oldenburg. In 1975, these twenty-three utilities pumped an average of 17.3 mgd. About thirty percent of this total is supplied from surface water sources while seventy percent is derived from ground water.

Ground water is the exclusive source for the region's public water systems, with the exception of Richmond, Batesville, and Oldenburg. For the most part, the well fields are in or adjacent to the area they serve. However, sometimes it is necessary to place well fields outside the area served in order to withdraw adequate quantities of water. The Franklin County Rural Water Corporation, which serves much of the eastern one-half of Franklin County, is supplied by wells located on the Fairfield Causeway over Brookville Lake. These wells tap the sand and gravel aquifers in the valley beneath the lake.

Projections of withdrawals indicate that the region's public water supplies may increase to about 22.4 mgd by the year 2000, as indicated below.

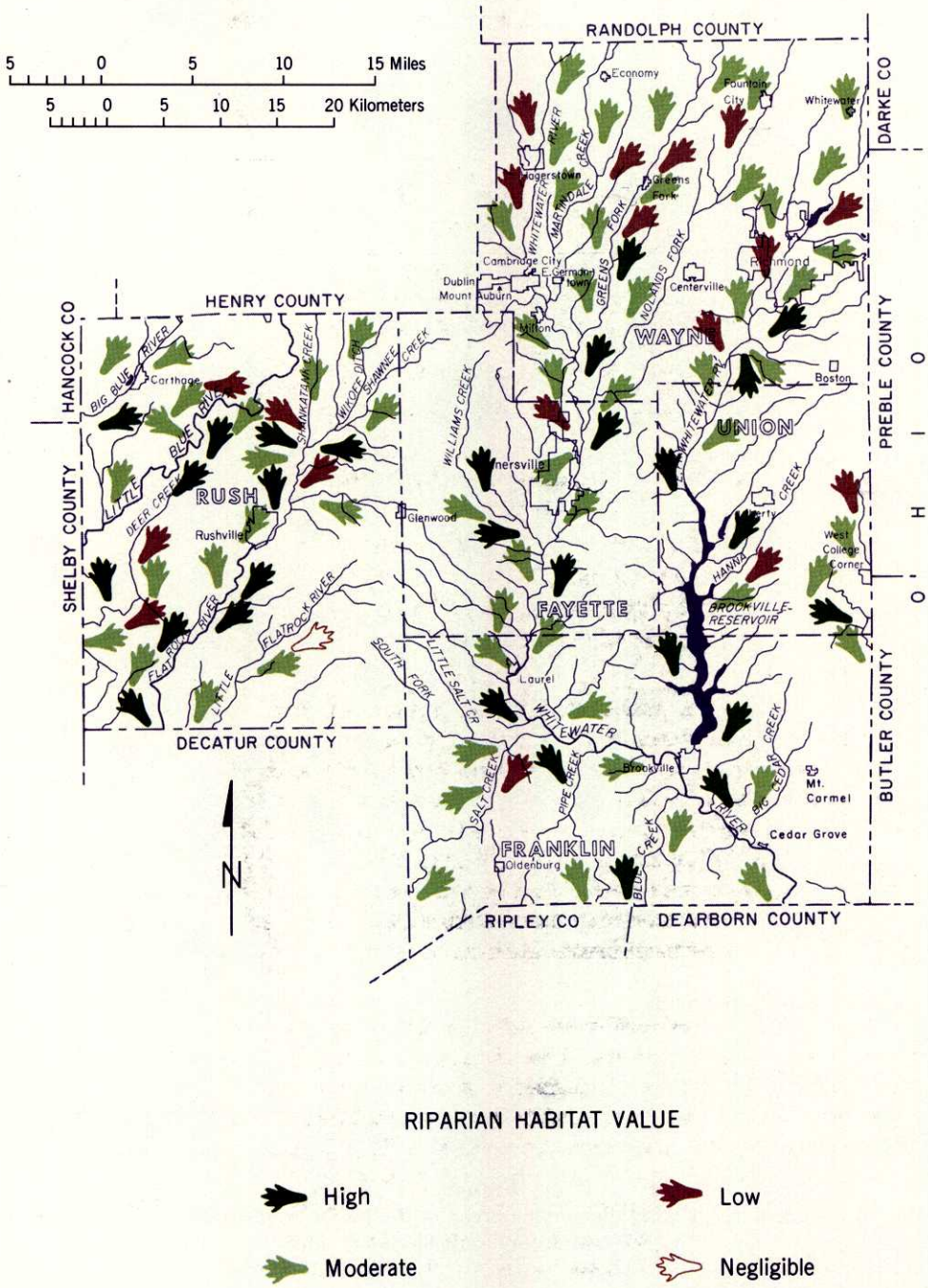
Table 141
The 1977 and projected withdrawal and consumption rates of public water supplies by the year 2000, in million-gallons-per-day.

Public Water	*1977*	*1980*	*1990*	*2000*
Withdrawal	17.3	18.1	20.8	22.4
Consumption	1.9	2.0	2.3	2.5

Industrial Water Industrial establishments had a water intake averaging 17.9 mgd in 1977. Of the total industrial intake, 8.1 mgd was withdrawn by the industries themselves while 9.8 mgd was purchased from the region's public utilities. About 1.2 mgd was consumed during the manufacturing process. The majority of self-supplied water is derived from ground-water sources located on plant property.

The largest water-using industry group is comprised of small industries which as a whole use approximately 8.6 mgd. Machinery industries account for 3.8 mgd and metal fabricators use 1.5 mgd.

Although industrial output is expected to increase, the total water intake is expected to decrease initially due to plant efficiency and then rise slowly as output



RIPARIAN HABITAT VALUE

High

Low

Moderate

Negligible

Figure 175
Map of Region Nine showing the quality of the riparian habitat.

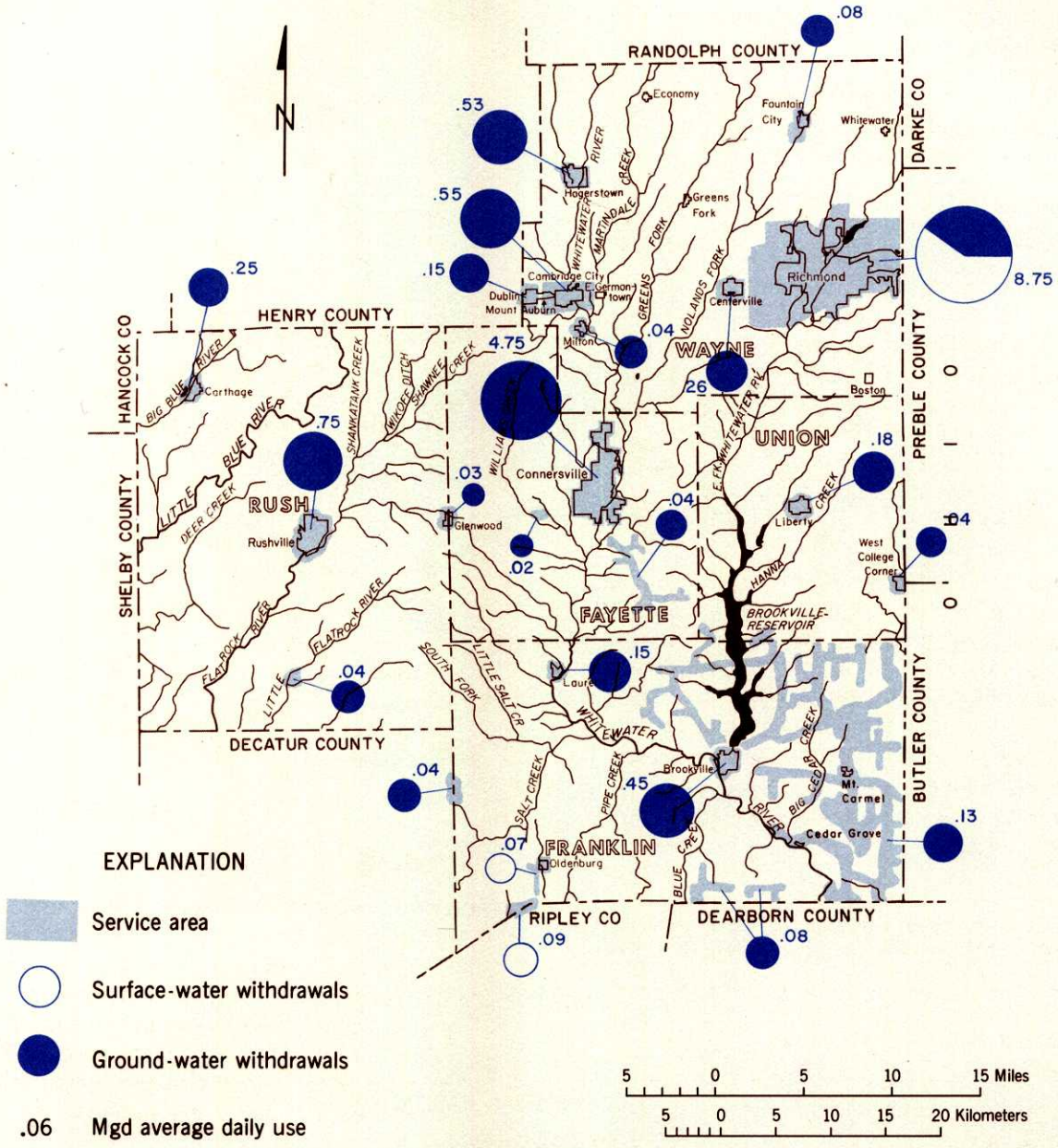


Figure 176

Map of Region Nine showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

increases. Industrial water use is expected to increase to 17.9 mgd by the year 2000. The self-supplied component may increase to approximately 8.5 mgd. Data for industrial self-supplied withdrawals are presented in the following table.

Table 142
The 1977 and projected water withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	8.1	8.0	8.2	8.5
Consumption	0.5	0.6	0.8	1.0

Rural Self-Supplied Water An estimated 58,000 persons lived in homes supplied by individual wells in 1975. It is estimated that these people used about 3.4 mgd for residential purposes in that year. As additional numbers become dependent on their own wells for water, and as the standards of living rise, rural residential water use is expected to increase to 4.9 mgd by the year 2000.

In 1975 there were an estimated 497,000 head of livestock and about 108,000 chickens. Collectively, these animals used just about 2.8 mgd. By the year 2000, increases in the animal population should raise water usage to 3.8 mgd. Most rural livestock needs are met by wells located on the farm property, although cisterns and ponds are used in some areas.

The total withdrawal of rural self-supplied water may increase from the current 6.4 mgd to 8.7 by the year 2000, as shown below.

Table 143
The 1977 and projected withdrawals and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.4	6.7	7.8	8.7
Consumption	6.4	6.7	7.8	8.7

Irrigation Water Soil associations with irrigation potential are located mainly in the major stream valleys. Figure 177 shows the potential irrigation areas within the region.

It is estimated that 3,300 acres may be irrigated by the year 2000. The increase of irrigation acreage is expected to increase the peak July–August irrigation demand in an "average" year to about 8.7 mgd by the year 2000. The average year increase in ground-water withdrawals is expected to increase to 5.1 mgd. Irrigation of golf courses currently requires the withdrawal of approximately 0.7 mgd.

The total withdrawal for irrigation of croplands and golf courses during the "average" irrigation season of 1977 was approximately 0.7 mgd. These withdrawals may increase to 9.4 mgd during the average growing season by the year 2000, as shown in the following table.

Table 144
The 1977 and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.7	1.8	5.6	9.4
Consumption	0.7	1.8	5.6	9.4

Electric Energy Region Nine contains one electrical generating facility, operated by the city of Richmond. This plant withdraws 3.3 mgd, of which 2.6 mgd is consumed through the cooling process. Expansion of this facility is planned and may result in a net increase in water withdrawals by the year 2000 as shown below.

Table 145
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	3.3	3.3	5.3	3.8
Consumption	2.6	2.6	3.2	2.0

EXCESS WATER

Flooding

Approximately 41,100 acres of the region are subject to flooding. The major flood plains are shown in Figure 178. Figure 179 delineates the average annual flood damages along selected streams within the region. These damages were estimated in 1977 to be $1,644,800, of which some eighty percent occurred in rural areas. Most flooding in the region is caused by excessive rainfall occurring between the months of December and May.

Flood Control Brookville Lake, the only major flood control project in the region, was completed in 1974 by the U.S. Army Corps of Engineers in cooperation with the State of Indiana. It is located in Franklin and Union Counties and controls runoff from a drainage area of 379 square miles. Brookville Lake is designed to provide flood control, water supply, and recreational facilities.

The East Fork of the Whitewater River Project, authorized for construction under the U.S. Soil Conservation Service, is the only small watershed project within the region. The project will consist of the

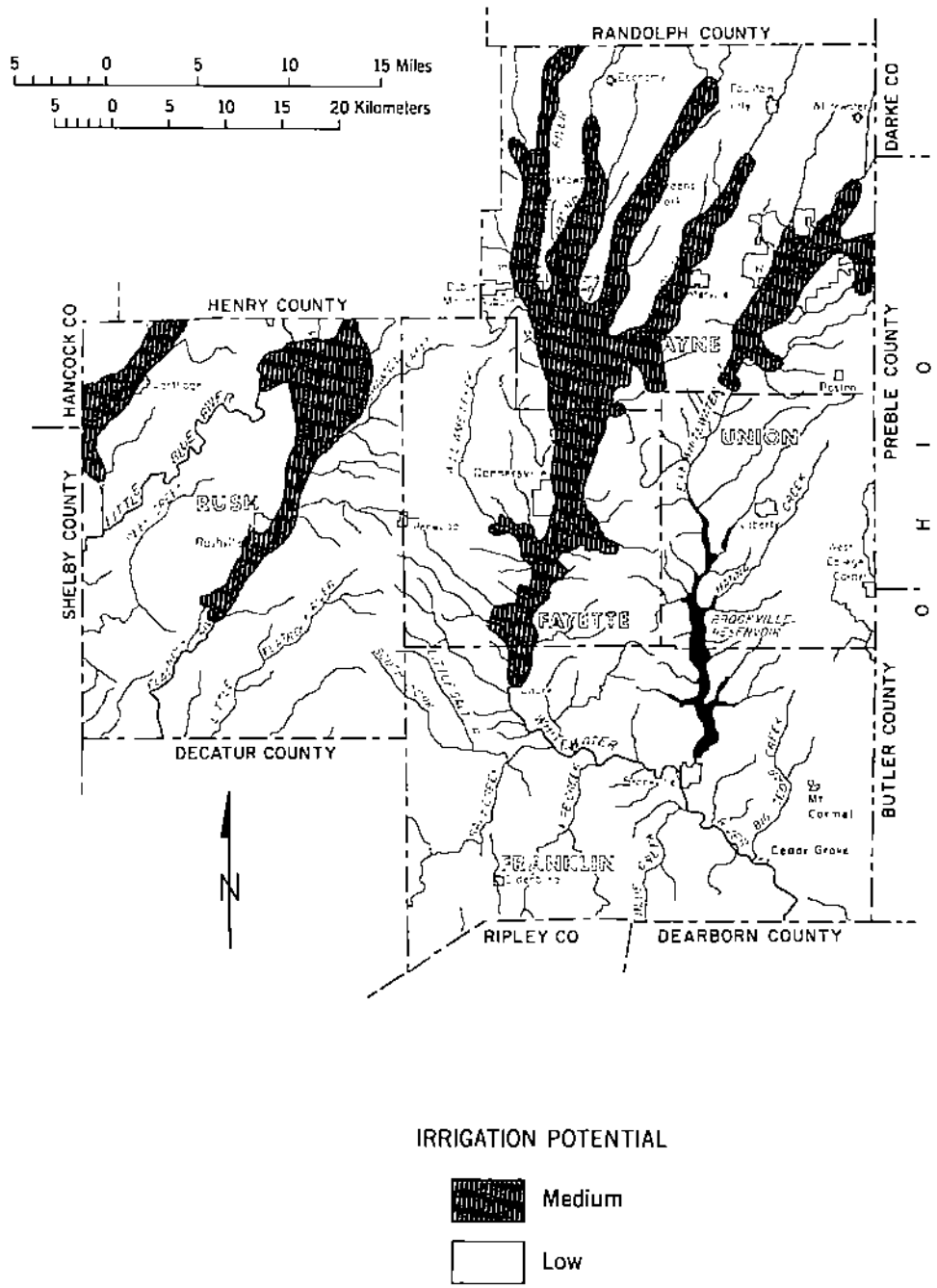
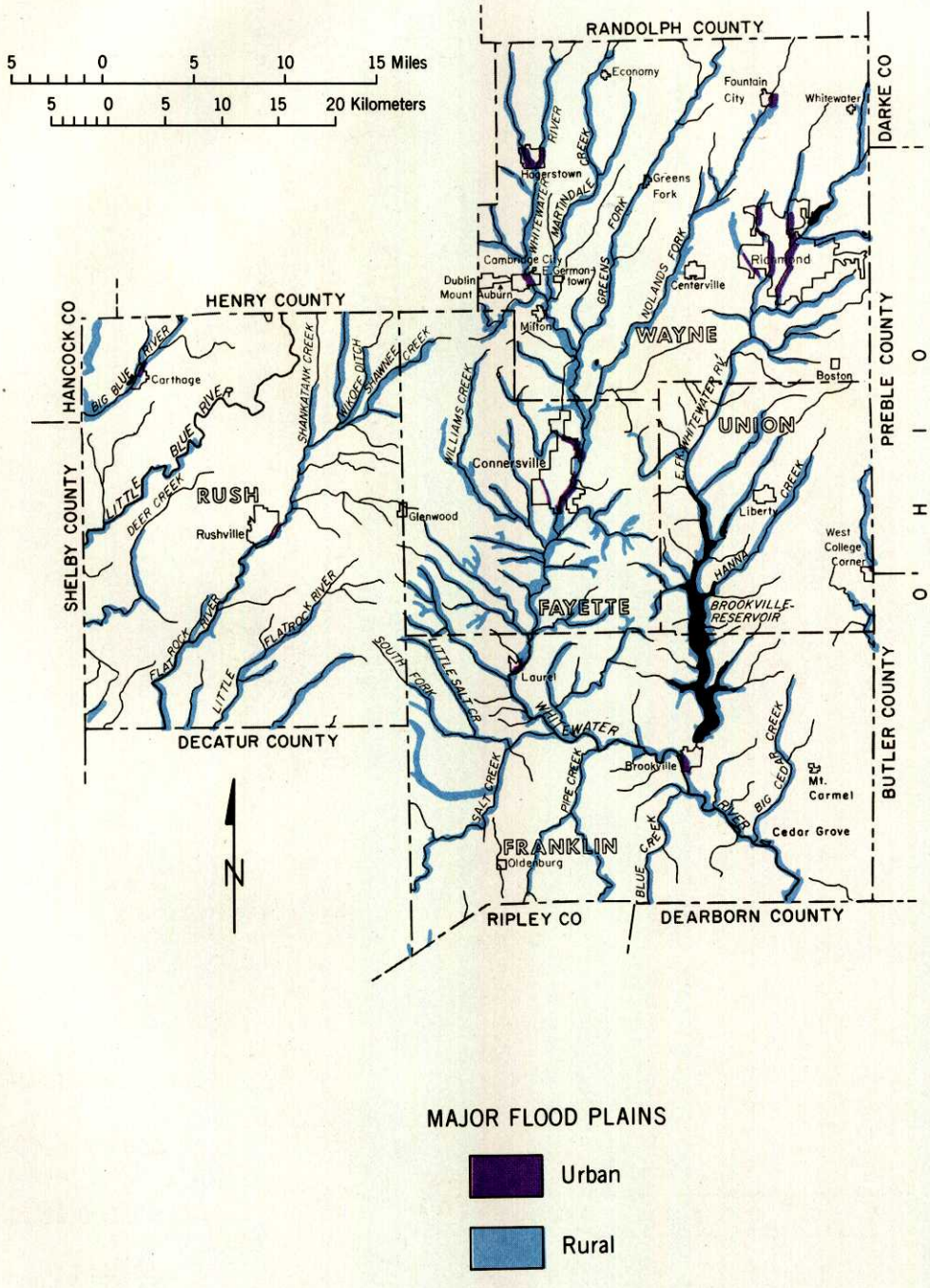


Figure 177
Map of Region Nine showing the location of the soil associations that appear to possess an economic potential for the irrigation of croplands.



MAJOR FLOOD PLAINS

Urban

Rural

Figure 178
Map of Region Nine showing the major flood plains.

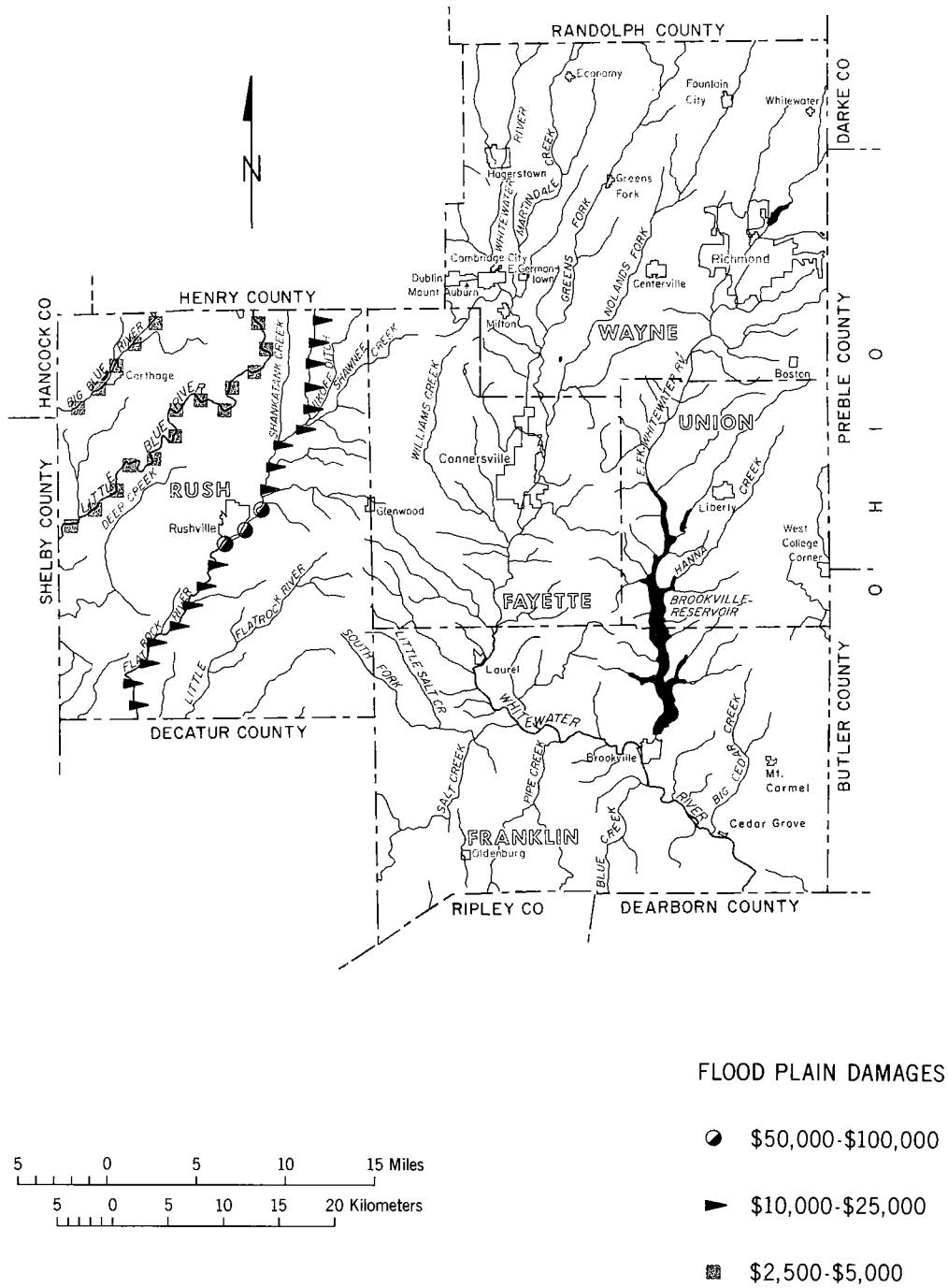


Figure 179
Map of Region Nine showing the estimated average annual flood damages per mile along selected streams.

construction of one flood water retarding structure, three multi-purpose flood water retarding-recreation structures with public-recreation facilities, two multi-purpose flood retarding-water supply structures, one channel recreation development, and 17.6 miles of multipurpose flood prevention and drainage cannel work. The project is designed to reduce flood water damages on about 6,800 acres of land but has not been implemented because local landowners are dissatisfied with aspects of the project.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include unincorporated Fayette, Franklin, Rush, and Wayne Counties as well as the communities listed below.

Table 146
Communities participating in the emergency phase of the National Flood Insurance Program.

Brookville	Hagerstown
Cambridge City	Laurel
Carthage	Milton
Cedar Grove	Richmond
Connersville	Rushville
Greenfork	Spring Grove

Agricultural Drainage

Approximately twenty-five percent of the soil associations in Region Nine have "severe" wetness characteristics, twenty-six percent have "moderate" wetness characteristics, while forty-nine percent have "slight" wetness characteristics. The general location of the soil associations with these soil wetness characteristics are shown in Figure 180.

There are approximately 512 miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards or, in a limited number of cases, of conservancy districts. No legal entity is responsible for maintaining drainage on the other streams in the region.

Soil Erosion

The erosion potential of soil associations within the region are shown in Figure 181. Thirty-five percent of the region is rated as having a "high" erosion hazard potential and five percent a "very high" erosion hazard potential. These areas are located along the Whitewater River and its tributaries within the lower two-thirds of the region. Twenty-eight percent of the region is rated as having a "medium" soil erosion potential. This represents areas in the northern portion of the region in Wayne County, and along the Flatrock and Little Blue Rivers in Rush County. The remaining thirty-two percent of the land is predominantly level and ranks as having a "low" erosion potential for land left in a fallow state.

WATER QUALITY

The surface streams within the region routinely surveyed for water quality by the Indiana State Board of Health are the West and East Forks of the Whitewater, Flatrock, and Blue Rivers. Water quality standards are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

Samples from the West Fork of the Whitewater River did not indicate any serious violations of standards. The discharge from Cambridge City to the river caused a slight rise in the biochemical oxygen demand, suspended solids, and fecal coliform bacteria levels. These levels quickly returned to those levels found upstream of the city.

Samples of the water quality of the East Fork of the Whitewater River did not indicate any violations of standards that limit water use. All discharge permit holders surveyed were in compliance with permit limits.

Samples of the Whitewater River did not indicate any violation of standards. The fecal coliform bacteria levels in the Whitewater River were elevated in the Brookville, New Trenton, and West Harrison areas of the river, but there were no reports of these levels inhibiting water uses.

The Flatrock River receives considerable agricultural drainage and municipal and industrial effluent from the city of Rushville. However, water quality standards were generally maintained except during extreme low-flow conditions.

The Blue River also receives a large amount of agricultural runoff water. Water quality samples indicated no violation of standards that inhibited stream uses.

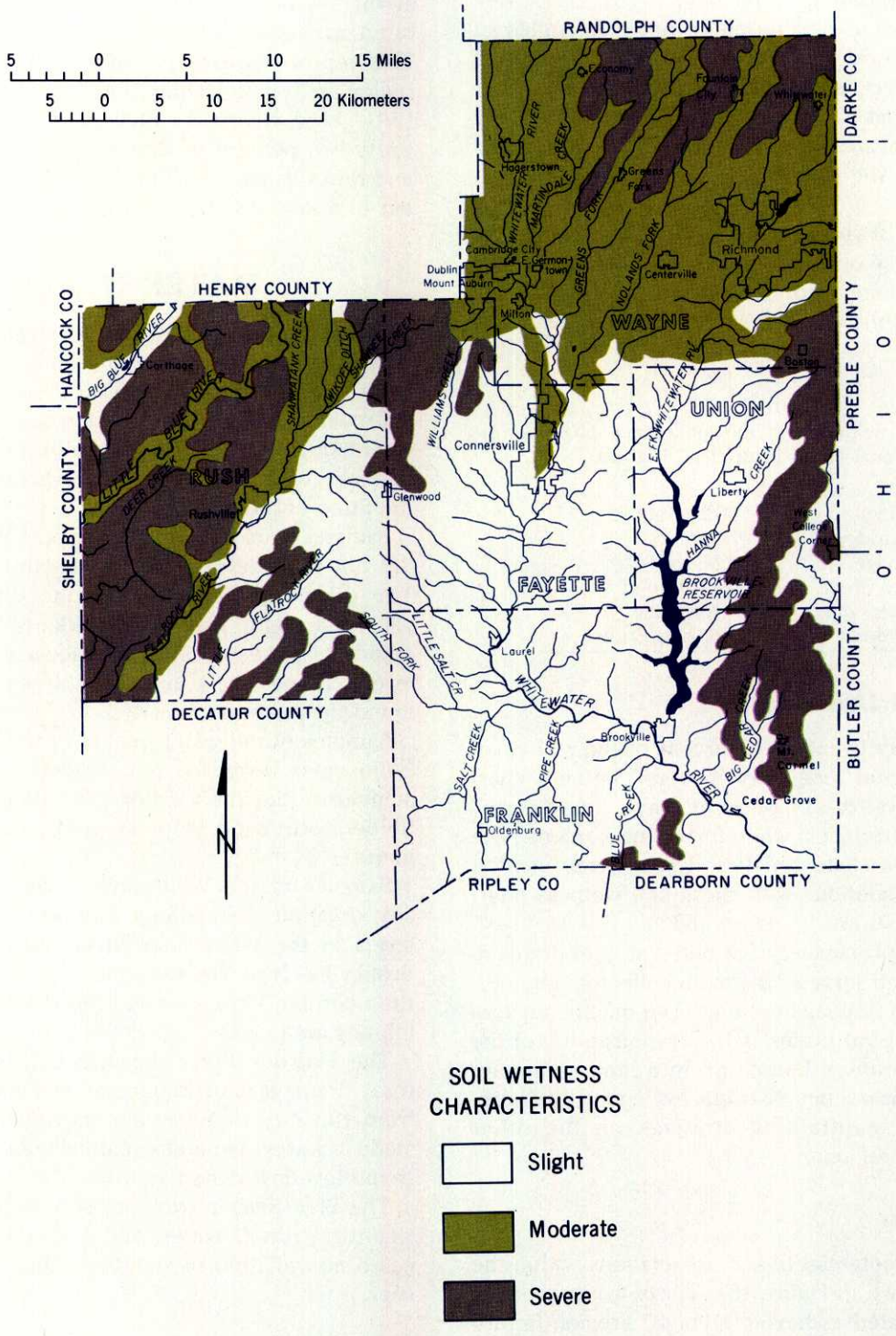
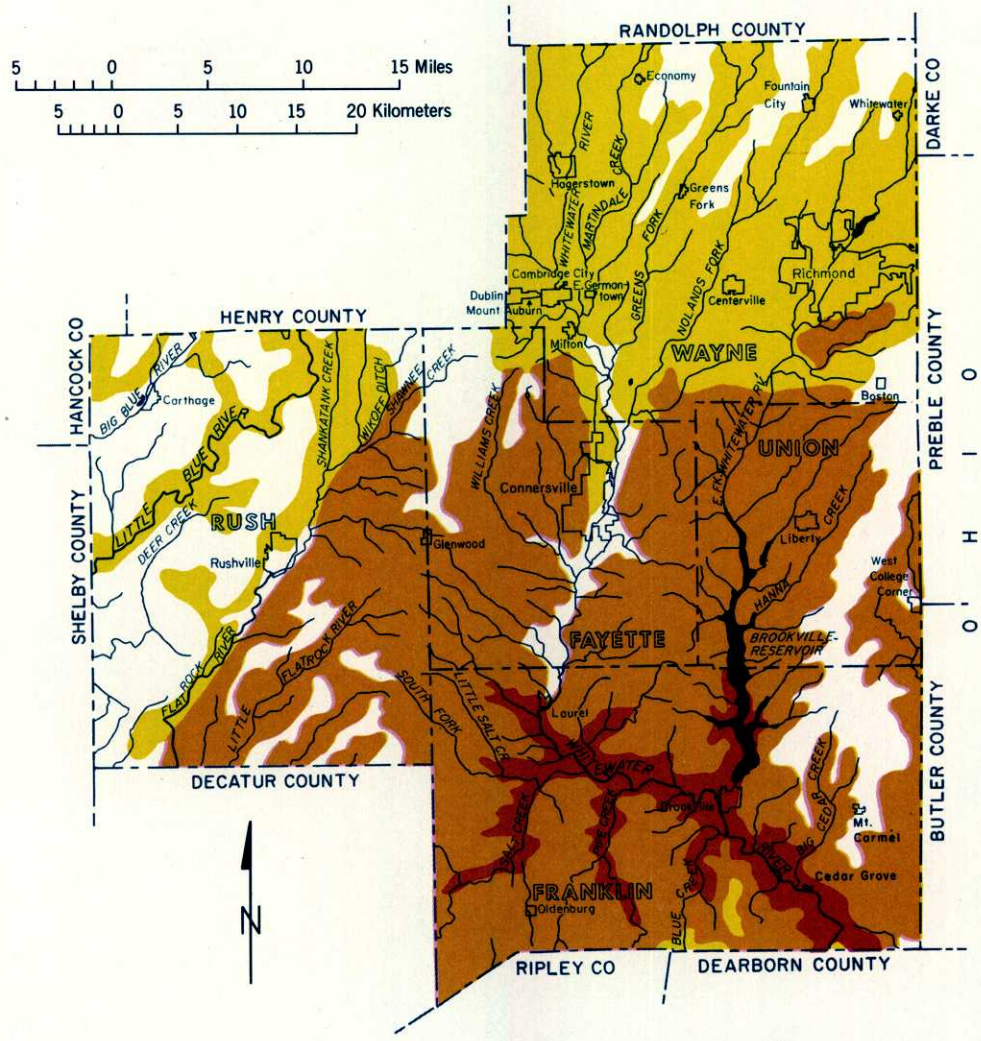


Figure 180
Map of Region Nine showing the location of the wetness characteristics of soil associations.



SOIL EROSION POTENTIAL

- Low
- Medium
- High
- Very high

Figure 181
Map of Region Nine showing the erosion potential of the soil associations.

Region Ten

Monroe and Owen Counties, located in south-central Indiana, form Region Ten. The region contains approximately 770 square miles and is bounded by Putnam and Morgan Counties to the north; Brown and Jackson Counties to the east; Lawrence and Greene Counties to the south; and Clay County to the west, as shown in Figure 182.

The 1975 population of the region was 102,214, of which forty-eight percent resided in Bloomington. The official Indiana Population Projections indicate that by the year 2000 the region's population may increase to 133,000. The 1975 population of each county and the projections for future growth are indicated in the following table.

Table 147
The 1975 and projected populations of Region Ten.

County	*1975*	*1980*	*1990*	*2000*
Monroe	88,925	94,100	104,800	113,100
Owen	13,289	14,400	16,900	19,900
Total	102,214	108,500	121,700	133,000

Approximately fifty percent of the region is forested, forty-five percent is agricultural, while five percent represents urban and miscellaneous land uses.

Approximately thirty-six percent of the population is employed within the region. The three largest employers are electrical machinery, primary metals, and education (Indiana University). The region is known nationally for high quality limestone. The mining industry, including limestone and gravel, contributes significantly to the area's economy.

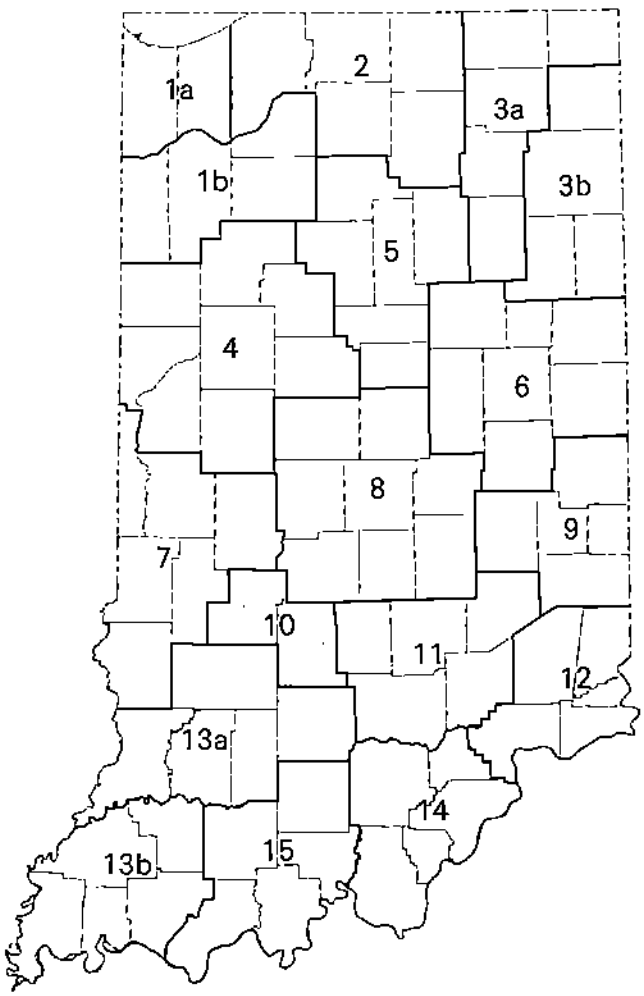


Figure 182
Map of Indiana showing the location of Region Ten.

Average annual precipitation is approximately 43.0 inches. This varies from a high of 4.9 inches in June to a low of 2.5 in October. Of the 43.0 inches falling annually, approximately 14.5 inches appear as streamflow while 28.5 inches are consumed through evapotranspiration. Temperatures are moderate with monthly averages ranging from 30.5°F. in January to 75.5°F. in July. The average annual temperature is 54°F. The annual prevailing wind at Indianapolis International Airport is from the southwest at 9.7 miles per hour.

THE WATER RESOURCE

Ground Water

Owen County was almost completely covered by the Illinoian glacial advance, while Monroe County received almost no glacial deposits. The unconsolidated deposits in this region include lake clays, glacial till, and valley train sand and gravel.

Beneath the cover of glacial and surficial deposits are bedrock deposits which range in age from Mississippian to Pennsylvanian. The Mississippian age rocks of Monroe County and eastern Owen County consist of shales, limestones, and sandstones. In western Owen County the Pennsylvanian bedrock includes shale and sandstone primarily, with some minor amounts of limestone and coal.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In this region, there is a pronounced variability in ground-water occurrence, as shown in Figure 183.

Ground-water conditions are generally poor, with Monroe County having very limited ground-water resources. Except for a very small area adjacent to the West Fork of the White River in the northwestern portion of the county, where well yields of 1,000 gallons-per-minute (gpm) are possible, wells can normally produce only 10 gpm or less. In nearly all of Monroe County the Mississippian shales and limestones can be expected to supply only meager amounts of water.

In Owen County the potential for higher yielding wells is much improved because of the presence of glacial deposits, particularly sand and gravel. The West Fork of the White River valley contains thick sand and gravel aquifers which can yield in excess of 1,000 gpm. Another area of higher well yields occurs adjacent to Jordan Creek near Cagles Mill Lake where sand and gravel deposits are located. Wells can produce 50 to 400 gpm from these materials. Most upland areas in Owen County have limited ground-water resources, although the incidence of dry holes is much less than in Monroe County.

Water hardness is usually quite high, ranging between 300 to 400 parts-per-million (ppm) due largely to the presence of limestone in much of the area. Softer waters are possible locally in northwestern Owen County. Iron concentrations range from a low of 0.1 ppm in Owen County to around 0.9 ppm along the West Fork of the White River in northwestern Monroe County. The sand and gravel deposits along the West Fork of the White River also contain objectionable amounts of manganese. In general, ground-water quality is good and, exclusive of the need for iron and possible manganese removal in some areas, is satisfactory for most purposes.

Surface Water

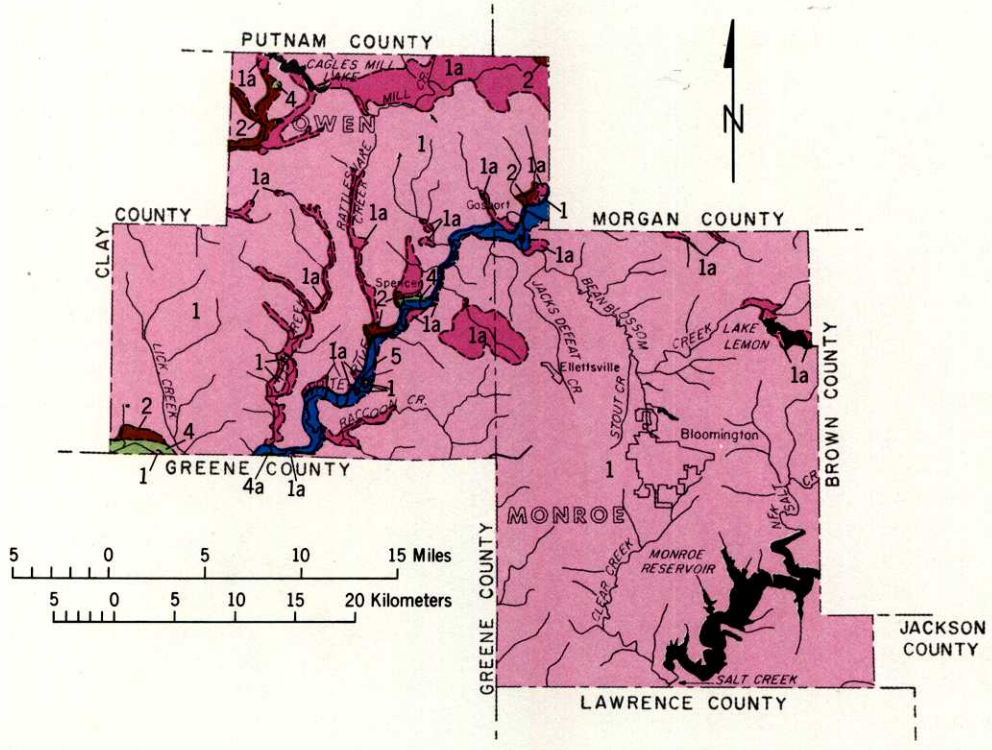
Streamflow Most of the region is drained by a collection of small and medium sized stream systems which eventually contribute to the West Fork of the White River. The only notable exception is the northwest corner of Owen County which drains into the Eel River system before contributing to the West Fork of the White River. Some of the river systems draining the region are Salt Creek, Bean Blossom Creek, Raccoon Creek, Fish Creek, Lick Creek, and Mill Creek.

The seven day, once in ten year (Q7-10), one day, once in thirty year (Q1-30) and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations within Region Ten are presented in Table 148.

Analysis of the low-flow characteristics of streams indicates that the largest and most reliable streamflows are those in the West Fork of the White River. The one day, once in thirty year low flows for the West Fork of the White River at Spencer reveal that the river will have a sustained flow of at least 110 mgd while the average annual flow will be 1,900 mgd.

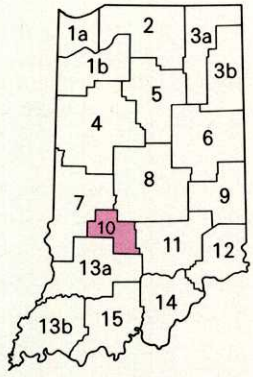
Ground-water contribution to streamflow in the region is generally quite poor and, hence, significant annual variability in streamflow occurs in most streams. Only the West Fork of the White River, because of a better ground-water contribution in its upstream reaches, exhibits reasonably good low-flow characteristics.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are listed in Table 149, and are located on Figure 184. These eighteen lakes have a combined surface area of approximately 12,630 acres and a gross storage capacity of approximately 66,000 million gallons. Lake Monroe has a surface area of approximately 10,750 acres with a gross storage capacity of nearly 59,400 million gallons.



POTENTIAL YIELD

1	10 gallons per minute
1a	50 gallons per minute
2	100 gallons per minute
4	400 gallons per minute
4a	600 gallons per minute
5	1000 gallons per minute or more



Index Map

Figure 183
Map of Region Ten showing the location and potential yield of ground water from properly constructed large diameter wells.

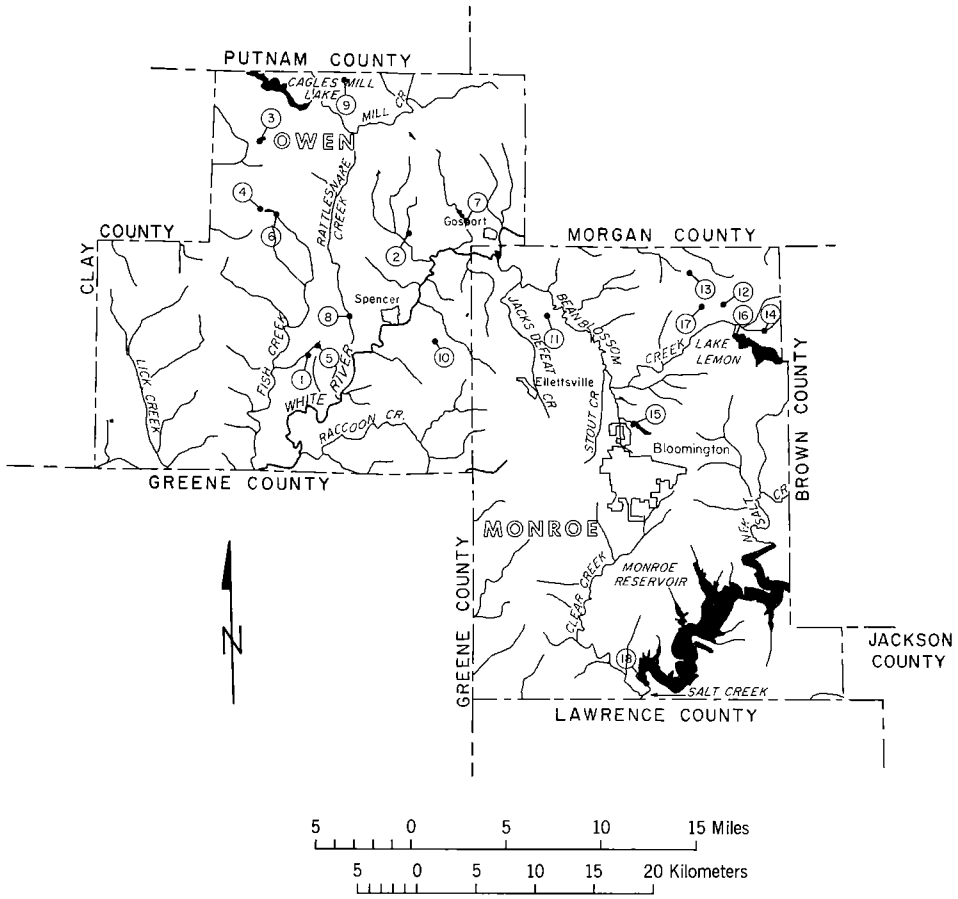


Figure 184
Map of Region Ten showing the location of lakes that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more.

Table 148
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Salt Creek near Harrodsburg[a]	432	153	0.1	na
West Fork White River at Spencer	2,988	1,900	150.0	110.0
Mill Creek near Cataract[b]	245	78	0.3	na

[a]These flows recorded prior to the construction of Lake Monroe.
[b]Flow characteristics estimated from stream gaging stations with short periods of record.
na: not available.

Table 149
Lakes at least 50.0 acres in size or having a storage capacity of 32.5 million gallons or more.

Lake Number	Lake Name	Drainage Area (square miles)	Surface Area (acres)	Gross Storage (million gallons)
1	A.M. Thomas Lake	na	10.0	35
2	Amazon Lake	2.85	44.1	203
3	Barnes Lake	na	30.4	101
4	Clifton E. Barnes Lake	na	na	65
5	Cottons Little Pine Lake	na	11.5	35
6	Greybrook Lake	na	33.3	130
7	Hollybrook Lake	na	29.1	123
8	Mills Pond	0.92	21.0	70
9	Paradise Lake	na	3.6	78
10	Unnamed	na	na	32
11	Baugher Lake	na	7.8	52
12	Bean Blossom Lake	na	14.6	83
13	Bryant Creek Lake	na	11.4	45
14	Egenolf Lake	1.35	26.0	76
15	Griffy Reservoir	8.02	115.5	762
16	Lake Lemon	70.90	1,506.0	4,698
17	Lazy Lake	na	17.2	65
18	Monroe Lake	432.00	10,750.0	59,386

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Ten are presented in Table 150. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing The three large man-made lakes provide an ample supply of surface water to meet local demands for boating and waterskiing. Lake Monroe is the largest inland body of water in the state. The pool of Cagles Mill Reservoir, although its control structure is in Putnam County, provides open water for recreation. Lake Lemon also provides space for boating and waterskiing, and Griffy Reservoir supplies boating acreage.

The demand of resident recreationists for boating and waterskiing is projected to be satisfied by the existing supply into the year 2000. However, the data

does not reflect recreationists from outside the region that migrate to use the recreation facilities. According to the *Origin-Destination and Out-of-State Visitor Study* (Department of Natural Resources), fifty-four percent of the visitation to Paynetown Recreation Area on Lake Monroe is generated from outside Region Ten. This migration will cause a much greater demand of the region's water resources than is indicated in the supply and demand analysis.

Table 150
The outdoor recreation demand and supply analysis for Region Ten.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	27	19.6 boats/acre/year	12,300 acres	100+	100+	100+
Waterskiing	9	34.4 skiers/acre/year	8,100 acres	100+	100+	100+
Canoeing	6	585 canoes/mile/year	32 miles	100+	100+	100+
Swimming	45	76,600 swimmers/acre/year	12 acres	100	86	80
Ice-Skating	10	6,678 skaters/acre/year	3 acres	38	33	33
Fishing	34	66 persons/acre/year	7,700 acres	90	75	69

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands by residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

Canoeing Thirty-two miles of the West Fork of the White River is the only canoeable stream in the region. This supply will fulfill the canoeing demand through the year 2000.

Swimming and Ice-Skating It is estimated that the current swimming needs are being met by the existing combination of municipal pools and public swimming beaches at Monroe and Cagles Mill Lakes. However, only eighty percent of the needed facilities may be available by the year 2000. Public ice-skating facilities currently meet only thirty-eight percent of the demand and are projected to satisfy only thirty-three percent of the demand by the year 2000.

Fishing The quality of the fisheries habitat is indicated on Figure 185. The streams contain sunfish, bass, and catfish, the typical mixture of warmwater fish in Indiana. Beanblossom Creek, Mill Creek, Raccoon Creek, North Fork Salt Creek, Clear Creek, and the West Fork of the White River have good to excellent aquatic habitat. The last two streams occasionally experience water quality problems which reduce the value of their fisheries habitat. Some small streams, such as Fish Creek, support seasonal game fisheries due to low flow in dry seasons. South Mill Creek is known for good smallmouth bass fishing. Walleye are available on the Eel River during the spawning run.

All of the public lakes have good aquatic habitat for warmwater game fish. Monroe Lake and Hill Lake contain sunfish, white and yellow bass, northern and walleye pike, and channel catfish as well as a variety of rough and forage fish.

Public access for fishing is available on all the lakes except Lazy Lake. A state-owned fishing site is located on the West Fork of the White River in Spencer.

The demand for fishing acreage by residents of Region Ten currently exceeds the supply by ten percent. Use of the region's waters by fishermen from outside the region is extensive.

Riparian Habitat The quality of the riparian habitat associated with lakes and streams is indicated on Figure 186. Most of the streams offer good riparian habitat. Hardwoods and shrubs line the streambanks and provide suitable habitat for upland game, songbirds, shorebirds, waterfowl (especially wood ducks), furbearers, and other wildlife. The environment around the lakes is similar to that along the streams and is used by many of the same wildlife. The most extensive wetlands in the region have been developed on Monroe Lake along the North Fork of Salt Creek. Wetlands occur in the upper end of Cagles Mill Lake and seasonally along the West Fork of the White River. These wetlands are used by various types of wildlife especially migratory and resident waterfowl. Public hunting is available on state and federal lands.

Withdrawal Uses

Public Water Supplies Monroe and Owen Counties are served by eleven public water utilities. An estimated 67,000 persons were served by public utilities in 1975. Monroe County had approximately 61,000 while Owen County had 5,800 residents served by public water utilities. Figure 187 shows the service areas and withdrawals of public water utilities in Region Ten.

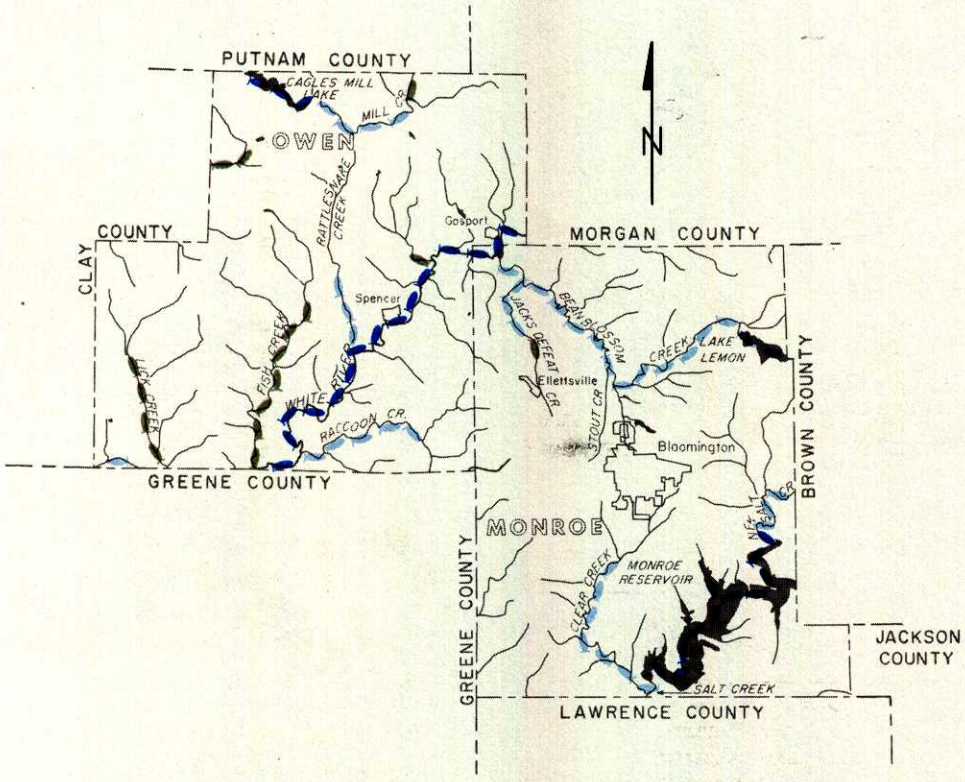


Figure 185
Map of Region Ten showing the quality of the fisheries habitat.

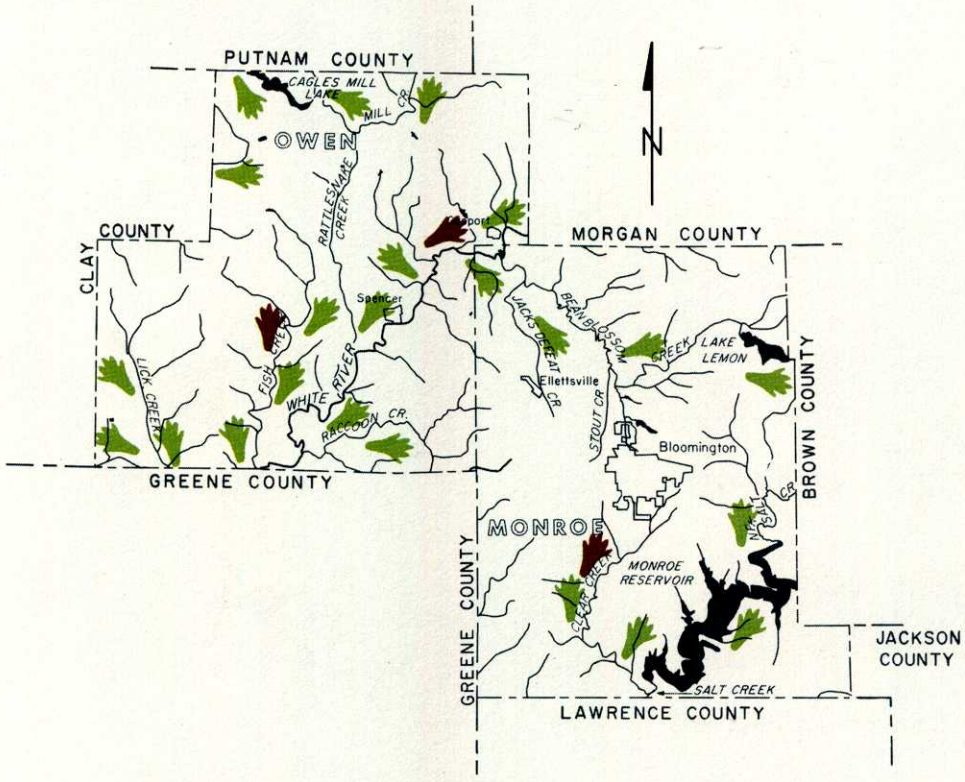


Figure 186
Map of Region Ten showing the quality of the riparian habitat.

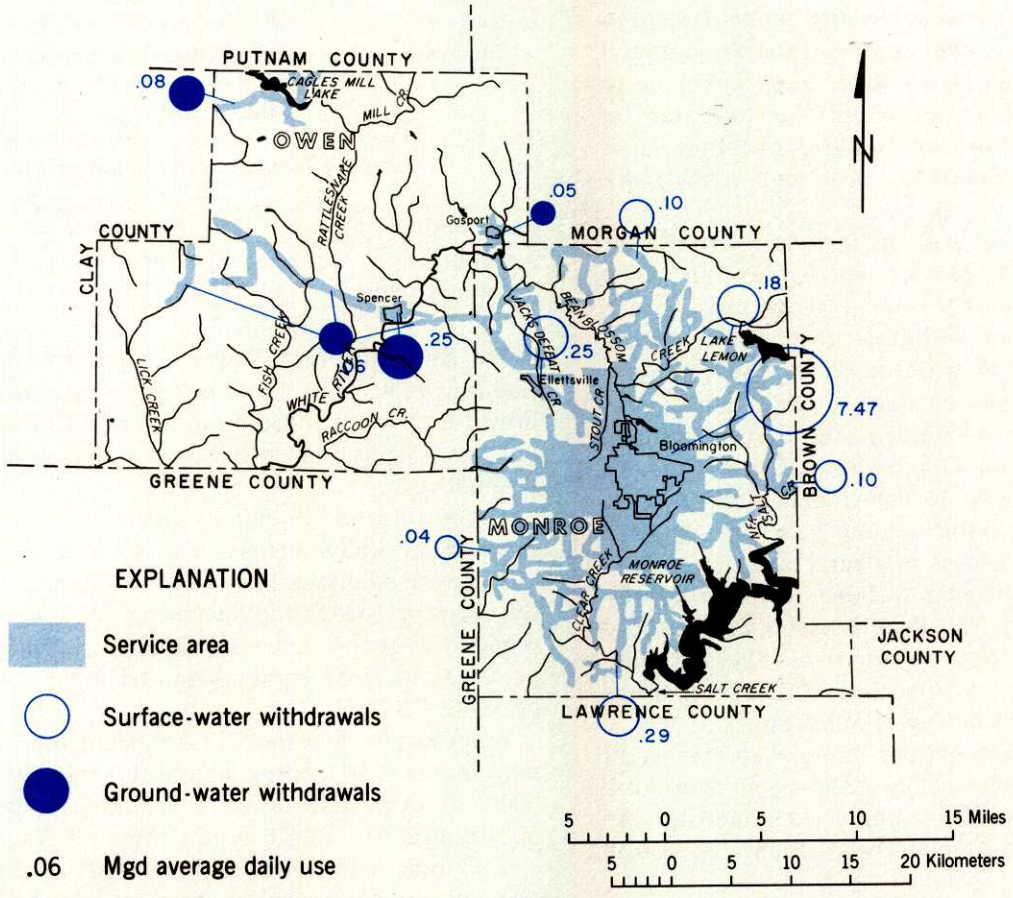


Figure 187

Map of Region Ten showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Four of the utilities in the region are municipal systems, and the remainder are rural water systems. The Bloomington Municipal System, the largest single water utility operating in the region, served about 50,000 residents in 1975. It withdraws an average of 11.6 mgd and sells approximately 1.3 mgd to six rural water systems in Monroe County. The Bloomington system withdraws approximately eighty-one percent of the region's public water supply. The Bloomington utility depends primarily on water supply storage in Monroe Lake, which is purchased from the State of Indiana. Bloomington and Bedford together have guaranteed withdrawals of 17.0 mgd from Lake Monroe.

Additional municipal systems include Ellettsville in Monroe County and Gosport and Spencer in Owen County which withdraw 0.4 and 1.0 mgd respectively. Gosport and Spencer withdraw ground water from aquifers in the West Fork of the White River valley.

Seven rural water systems serve this region of generally limited water resources. These rural utilities have been rapidly expanding in the past few years. An estimated 12,000 persons have been connected to rural water systems in the last four years. Nearly all of Monroe County has access to a rural water line. Many of these rural utilities purchase water from the Bloomington system. The Bean Blossom-Patricksburg Water Corporation buys water from Spencer. The Cataract Lake Water Corporation obtains its water from wells southwest of Cagles Mill Lake.

In 1975, these eleven utilities pumped an average of 12.1 mgd, with maximum daily withdrawals of approximately 15.8 mgd. Monroe County accounted for approximately 11.7 mgd while Owen County used 0.38 mgd.

Projections of public water utilities indicate that water withdrawals may increase to approximately 20.5 mgd by the year 2000, as presented here.

Table 151

The 1977 and projected withdrawal and consumption rates of public water supplies by the year 2000, in million-gallons-per-day.

Public Water Supplies	*1977*	*1980*	*1990*	*2000*
Withdrawal	12.1	13.1	16.8	20.5
Consumption	2.3	2.5	3.3	4.0

Industrial Water Industrial establishments had an estimated water intake averaging 7.8 mgd in 1977. Of the total industrial intake, 6.0 mgd was developed by the industries themselves while approximately 1.7 mgd was purchased from the region's public utilities. About 1.6 mgd was consumed in the manufacturing process, 1.3 mgd of which was self-supplied.

The largest water-using industry group is comprised of smaller industries, which together use approximately 4.4 mgd. The region's limestone quarries withdraw a significant amount of the self-supplied water.

Although industrial output is expected to increase, total industrial water intake is expected to decrease initially, due to plant efficiency and then rise slowly as output increases. Data for industrial self-supplied withdrawals are presented in the following table.

Table 152

The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.0	6.2	6.7	7.2
Consumption	1.3	1.4	1.9	2.5

Rural Self-Supplied Water In Monroe and Owen Counties most of the rural self-supplied water is withdrawn from wells located on farms and rural residential lots. Cisterns are often used where wells are not productive.

An estimated 35,000 persons lived in homes supplied by individual wells in 1975. It is estimated that they used about 2.1 mgd for residential purposes. By the year 2000, additional residents and an anticipated use in the general standard of living are expected to increase rural residential water withdrawals to about 2.3 mgd.

Water use for livestock totaled 0.6 mgd in 1975. This may increase to approximately 0.7 mgd by the year 2000. Although wells furnish residential water supplies, farm ponds are often used for livestock watering.

The total withdrawal of rural self-supplied water may increase to approximately 3.0 mgd by the year 2000 as presented below.

Table 153

The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supplied Water	*1977*	*1980*	*1990*	*2000*
Withdrawal	2.7	2.7	2.9	3.0
Consumption	2.7	2.7	2.9	3.0

Irrigation Water Soil associations with irrigation potential are located primarily in the valley adjacent to the West Fork of the White River in Owen County. Based upon the survey of irrigated lands, approximately 130 acres of cropland were irrigated in the region. Assuming 1977 as a normal growing year, this agricultural land would have required about 0.3 mgd during the peak irrigation period of July–August.

It is estimated that about 1,000 acres in the region could be profitably irrigated. An estimated 300 acres of

croplands may be irrigated by the year 2000. All of the additional acreage is expected to occur in Owen County. This expansion of irrigation acreage for agricultural land is expected to increase the peak July–August irrigation demand in an "average" year to about 0.8 mgd. The average year increase in ground-water withdrawal is expected to increase to 0.3 mgd by the year 2000.

In addition to the irrigation for agricultural use, fairways and greens on the region's golf courses are irrigated. About 0.5 mgd, is applied to these areas during the peak July–August irrigation period. During average year conditions the amount of water used by golf courses exceeds that used to irrigate crops. This is projected to continue until 1990 when the irrigation demand for golf courses will be approximately 0.7 mgd.

The total withdrawal for irrigation of croplands and golf courses during the "average" irrigation season of 1977 was approximately 0.9 mgd. These withdrawals may increase to 1.5 mgd during the "average" growing season by the year 2000, as presented in the following table.

Table 154

The 1977 and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.9	1.0	1.2	1.5
Consumption	0.9	1.0	1.2	1.5

Electric Energy Region Ten contains no electrical generating plants of any type. There are, however, fossil-fueled plants just outside the boundaries of the region at Centerton and Edwardsport.

EXCESS WATER

Flooding

Approximately 28,000 acres of the region are subject to flooding. The major flood plains are shown in Figure 188. The most extensive flood plains are found along the West Fork of the White River. Virtually all of the streams are subject to flooding, and some may be subject to flash flooding. Figure 189 delineates the average annual flood damages along selected streams within the region.

Flood Control The two flood control projects are Lake Monroe and Cagles Mill Lake. Both projects are designed and operated to provide flood control to downstream reaches of the East and West Forks of the White River, the Wabash and the Ohio Rivers. Lake Monroe also provides flood control benefits to Salt Creek in southern Monroe County.

Flood control is afforded by thirty-three of the thirty-six dams in the region. There are no small watershed projects.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include Ellettsville in Monroe County and Spencer in Owen County. Bloomington is participating in the regular phase of the National Flood Insurance Program.

Agricultural Drainage

Approximately four percent of the soil associations have "severe" wetness characteristics, five percent have "moderate" wetness characteristics, while ninety-one percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics are shown in Figure 190.

Because of the well-developed natural drainage in the region, neither Monroe nor Owen Counties have a system of legal drains.

Soil Erosion

The erosion potential of soil associations are shown in Figure 191. Thirty-seven percent of the land is rated as having a "very high" potential erosion hazard. Most of these areas are located along the eastern boundary of Monroe County and in the central portion of Owen County. Forty-five percent of the land is rated as having a "high" potential erosion hazard. These areas are located centrally within the region and along the western border of Owen County. The remaining eighteen percent is rated as having a "low" potential erosion hazard for land left in a fallow state.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the West Fork of the White River and Clear and Salt Creeks. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

Water samples of the White River indicated that the dissolved oxygen, temperature, and nitrate levels were within acceptable limits. Although the White River is designated for partial body contact recreation, the level of fecal coliform bacteria was too high to permit this use on a year-round basis.

An investigation of Clear Creek south of Bloomington and of Salt Creek below its confluence with Clear Creek indicated high levels of PCB's in fish, water, and sediments.

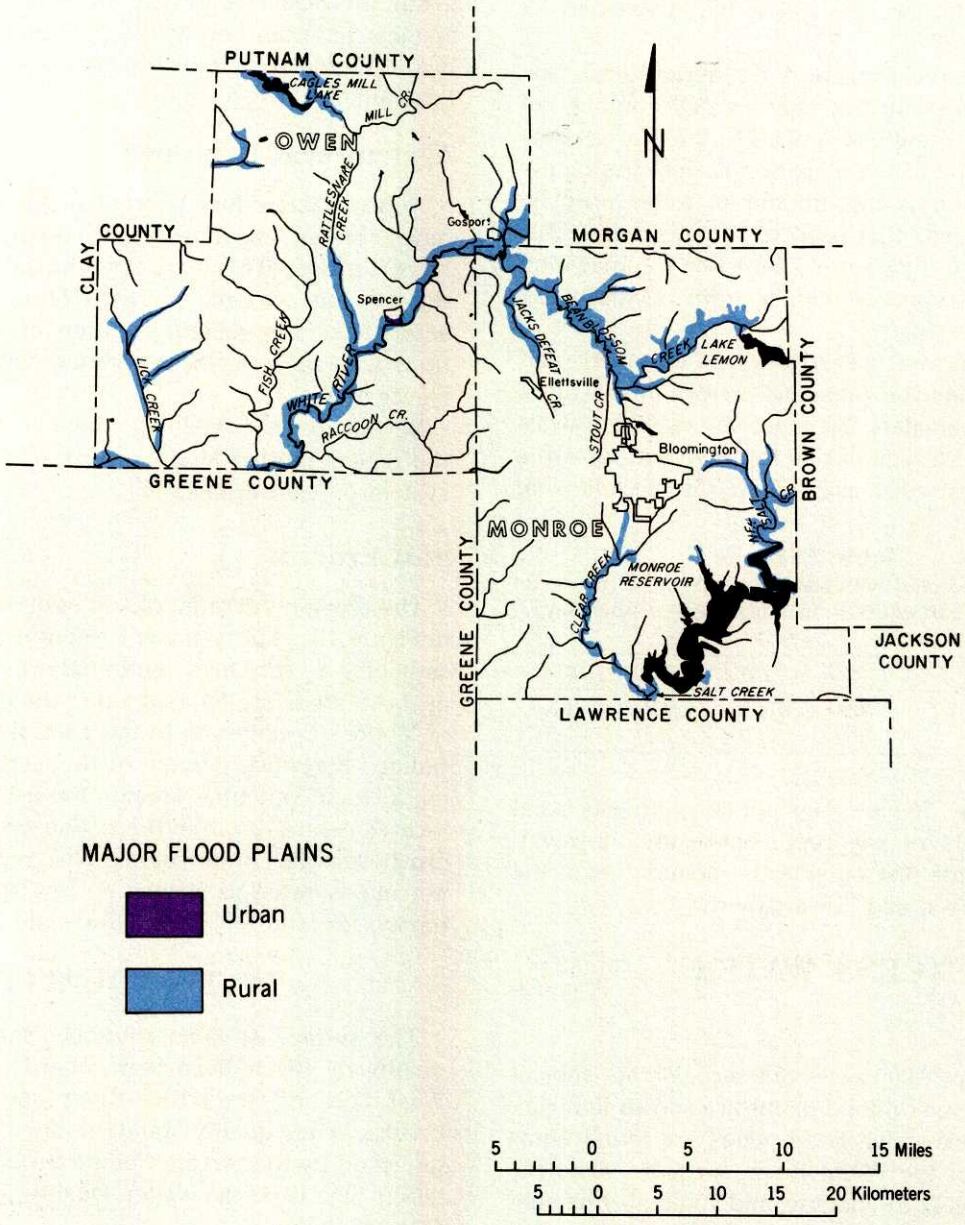


Figure 188
Map of Region Ten showing the major flood plains.

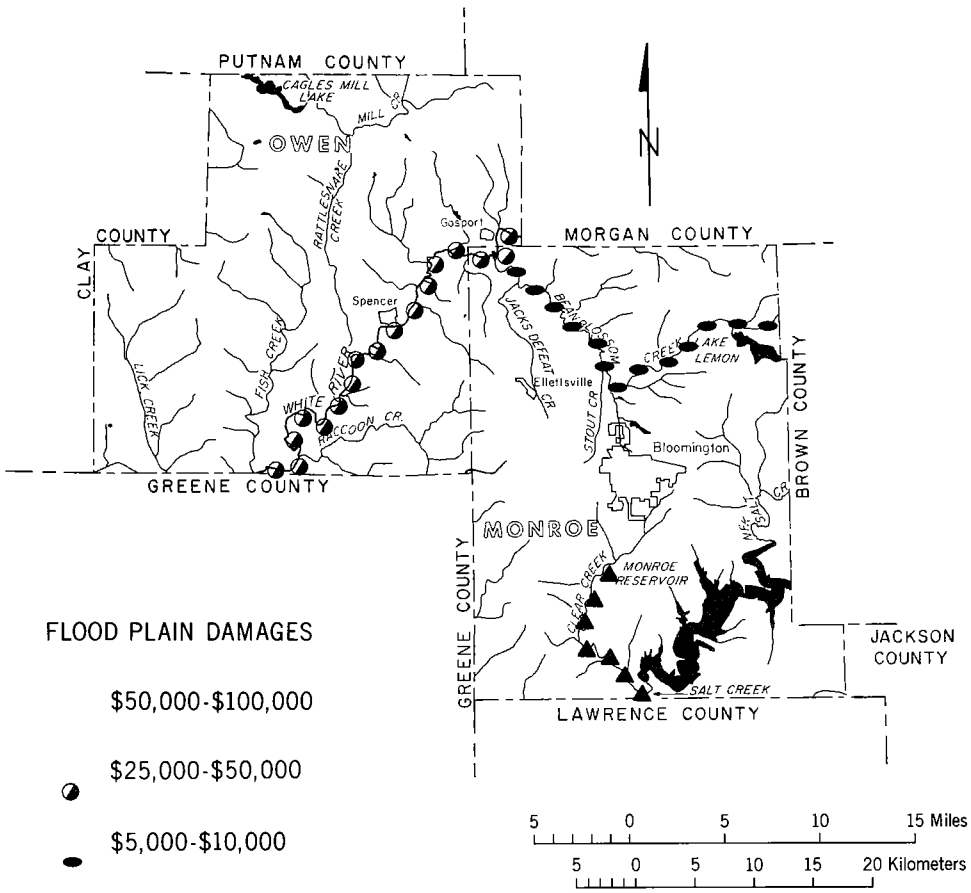


Figure 189

Map of Region Ten showing the estimated average annual flood damages per mile along selected streams.

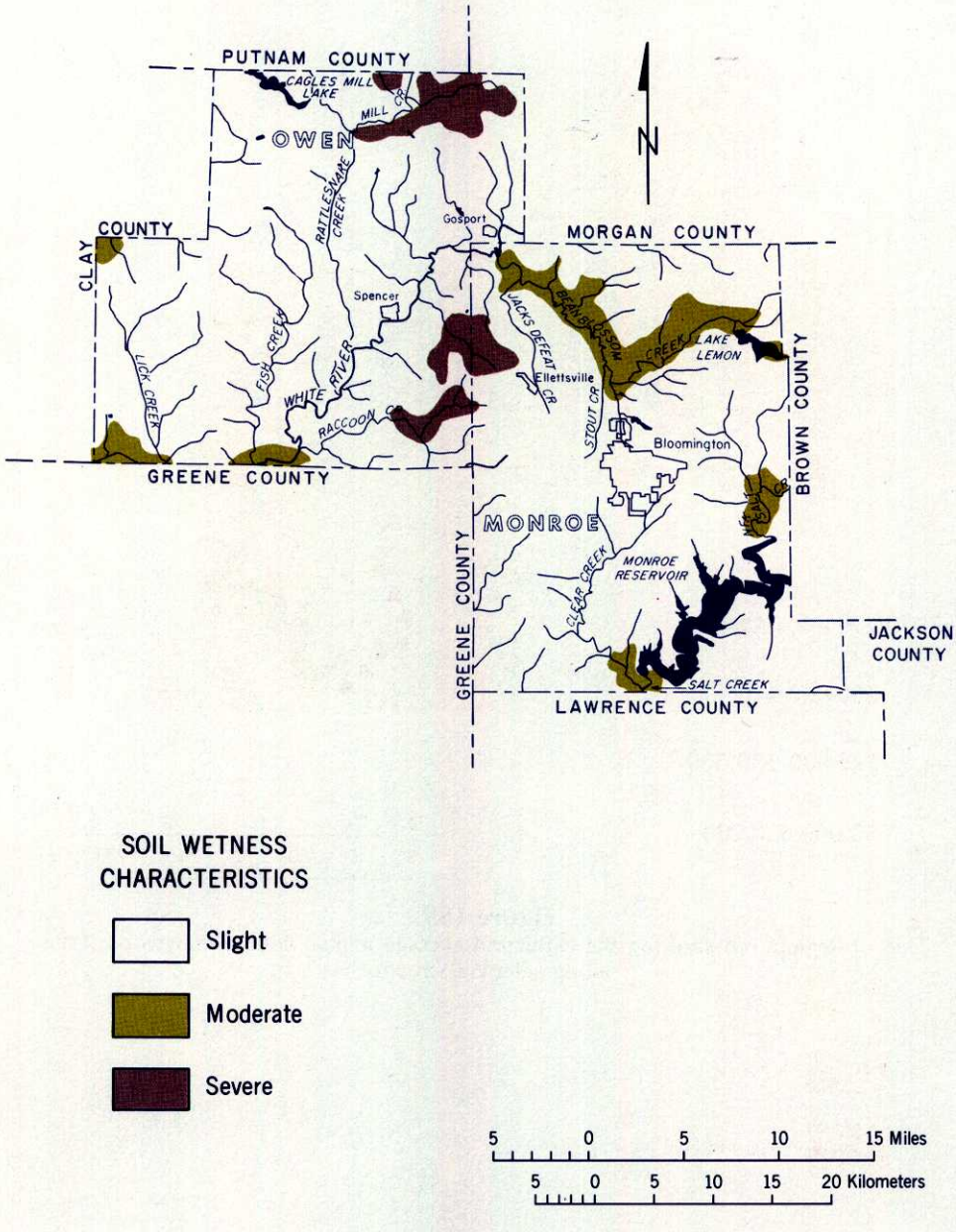


Figure 190
Map of Region Ten showing the location of the wetness characteristics of soil associations.

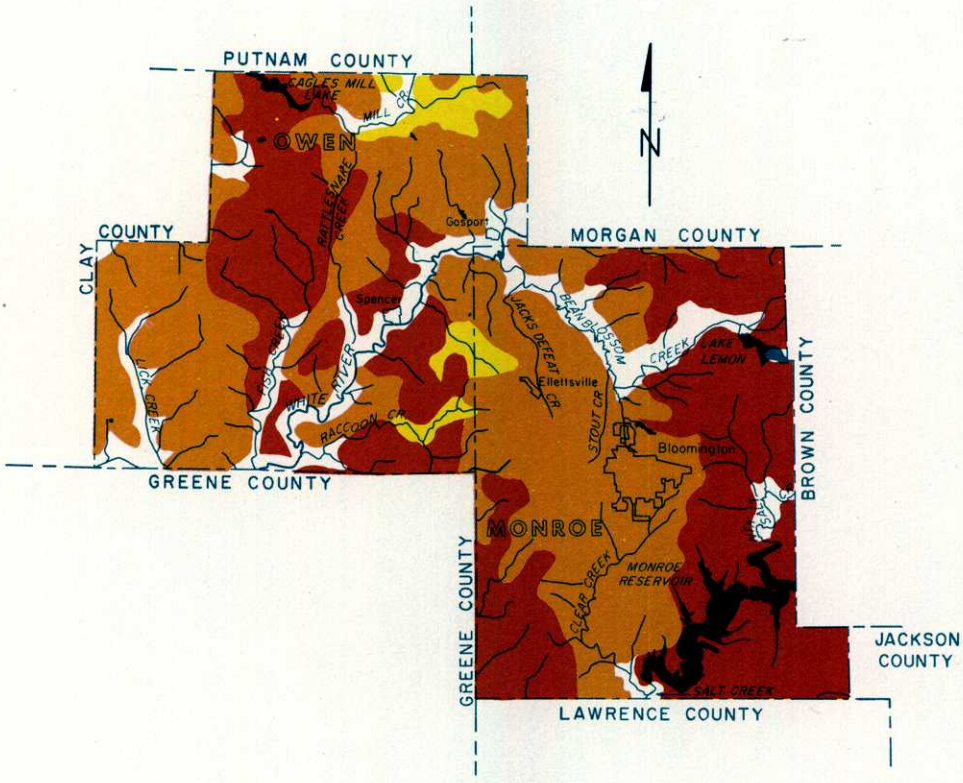


Figure 191
Map of Region Ten showing the erosion potential of the soil associations.

Region Eleven

Bartholomew, Brown, Decatur, Jackson, and Jennings Counties, located in south-central Indiana, form Region Eleven. The region contains approximately 1,990 square miles and is bounded by Morgan, Johnson, Shelby, and Rush Counties to the north; Franklin and Ripley Counties to the east; Jefferson, Scott, and Washington Counties to the south; and Lawrence and Monroe Counties to the west as shown by Figure 192.

The 1975 population was 148,107 of which forty percent resided in Bartholomew County. The official Indiana Population Projections indicate the population may increase by thirty percent by the year 2000. The 1975 population of each county and the projections for future growth are listed below.

The 1975 and projected populations for Region Eleven.

County	*1975*	*1980*	*1990*	*2000*
Bartholomew	59,664	62,600	69,700	76,200
Brown	9,831	10,600	12,900	15,800
Decatur	23,628	24,100	26,800	30,000
Jackson	34,109	35,800	38,700	41,200
Jennings	20,875	22,200	25,500	29,200
Total	148,107	155,300	173,600	192,400

The major population centers within the region are Columbus in Bartholomew County, Greensburg in Decatur County, Seymour in Jackson County, and North Vernon in Jennings County. These urban centers accounted for thirty-seven percent of the region's 1975 population.

Agriculture is the dominant land use comprising more than fifty-five percent of the area. Approximately

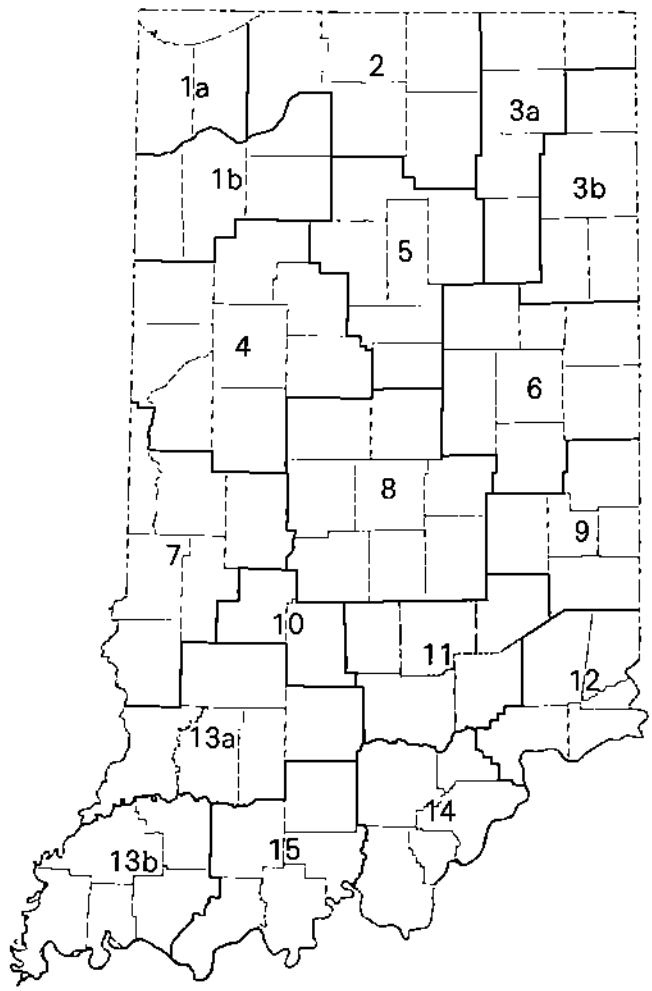


Figure 192
Map of Indiana showing the location of Region Eleven.

twenty-seven percent of the land is forested while the remaining nine percent represents urban and miscellaneous uses.

Topographic and physiographic conditions within the region are quite varied, ranging from poorly drained flat lands and till plain areas in the eastern portions of the region to the rich bottom lands, alluvial deposits, and gravel terraces in the central portion, and finally to the rolling hills and timbered "knobs" of Brown, Jackson, and Bartholomew Counties.

Average annual precipitation is approximately 43.0 inches. This varies from a high of 4.5 inches in May to a low of 2.5 inches in October. Of the 43.0 inches falling annually, approximately 15.0 inches appear as streamflow while 28.0 inches are consumed through evapotranspiration.

The area has a moderate temperature with averages ranging from 30.5°F. in January to 76°F. in July. The average annual temperature is 53.5°F. The annual prevailing winds appear to be from the south-southwest at approximately 8.1 miles per hour.

THE WATER RESOURCE

Ground Water

Much of the region was covered by continental glaciers which occurred in Indiana during the Wisconsinan, Illinoian, and older glacial periods. The materials left by these ice sheets have materially altered the region leaving behind clay-rich glacial tills, fine-grained lake deposits, sizeable amounts of sand and gravel in the major river valleys, and wind-blown sand and silt along the East Fork of the White River valley.

Most of Decatur and Bartholomew Counties were covered by the more recent Wisconsinan deposits, while the remaining portions of these counties, including Jennings and parts of Brown and Jackson Counties, received materials from the Illinoian and older glacial periods. A "driftless" area not covered by glaciers is found in much of Brown County and to a limited degree in Jackson County.

Bedrock formations of various types ranging in age from Mississippian to Ordovician underlie the glacial deposits of this region. In the western part of the area in Brown, Jackson, and western Bartholomew Counties, the rolling timbered hills and "knobs" mark the presence of bedrock composed of shale, siltstone, and fine-grained sandstone. These formations comprise the Borden Group of lower Mississippian age. These deposits are some of the poorest water-bearing formations in the state, exclusive of limited areas where glacial deposits are present, or in the valley of the East Fork of the White River. Eastward in Jennings, Bartholomew, eastern Jackson, and western Decatur Counties, black shale and limestone of Devonian age are present. These formations yield limited quantities of water and, except for an occasional well, are expected to yield less than ten gallons-per-minute (gpm). Similar circumstances apply to the Silurian age limestones and dolomites which occur eastward of the outcrop area of the Devonian age bedrock. Exceptions to this availability pattern exist in the vicinity of Greensburg where an occasional well has been recorded as yielding one hundred gpm or greater. Rocks of Ordovician age are not considered to be potential water-bearing formations.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In general, ground-water availability is quite limited in much of the region as shown in Figure 193. Expected well yields are less than ten gpm under most circumstances. In a number of areas, particularly in Brown and Jackson Counties, "dry holes" are common. The major ground-water sources are confined to the sand and gravel deposits of the East Fork of the White River valley. These deposits contain significant amounts of ground water and extend southward from Edinburg through the Columbus, Seymour, Brownstown, and Medora areas. A number of municipal, industrial, irrigation, and rural water system wells tap these deposits. Well yields from this aquifer system commonly exceed 1,000 gpm to properly constructed wells, and yields as great as 4,200 gpm have been obtained in the Columbus area.

Elsewhere, moderate amounts of ground water are available in the Flatrock River valley of northern Bartholomew County, along some of the tributary streams to the East Fork of the White River, in localized areas near Crothersville, and to a limited degree in the Greensburg area. Beyond these areas and beyond the sand and gravel deposits in the White River bottoms water is lacking.

Water hardness levels in the region normally are in the range of 270 to 466 parts-per-million (ppm), and iron is usually present in sufficient amounts as to require some form of iron removal or treatment. Chemical constituents of note include the presence of locally high manganese levels in the sand and gravel deposits of the East Fork White River valley, particularly in the Brownstown, Columbus, and Seymour areas, and the presence of hydrogen sulfide in aquifers below the New Albany shale in portions of Jennings and Bartholomew Counties. Highly mineralized or even "salt water," may be encountered in deep wells in bedrock aquifers of western Bartholomew and Jackson Counties.

Surface Water

Streamflow The East Fork of the White River is the major stream along with its primary tributaries of

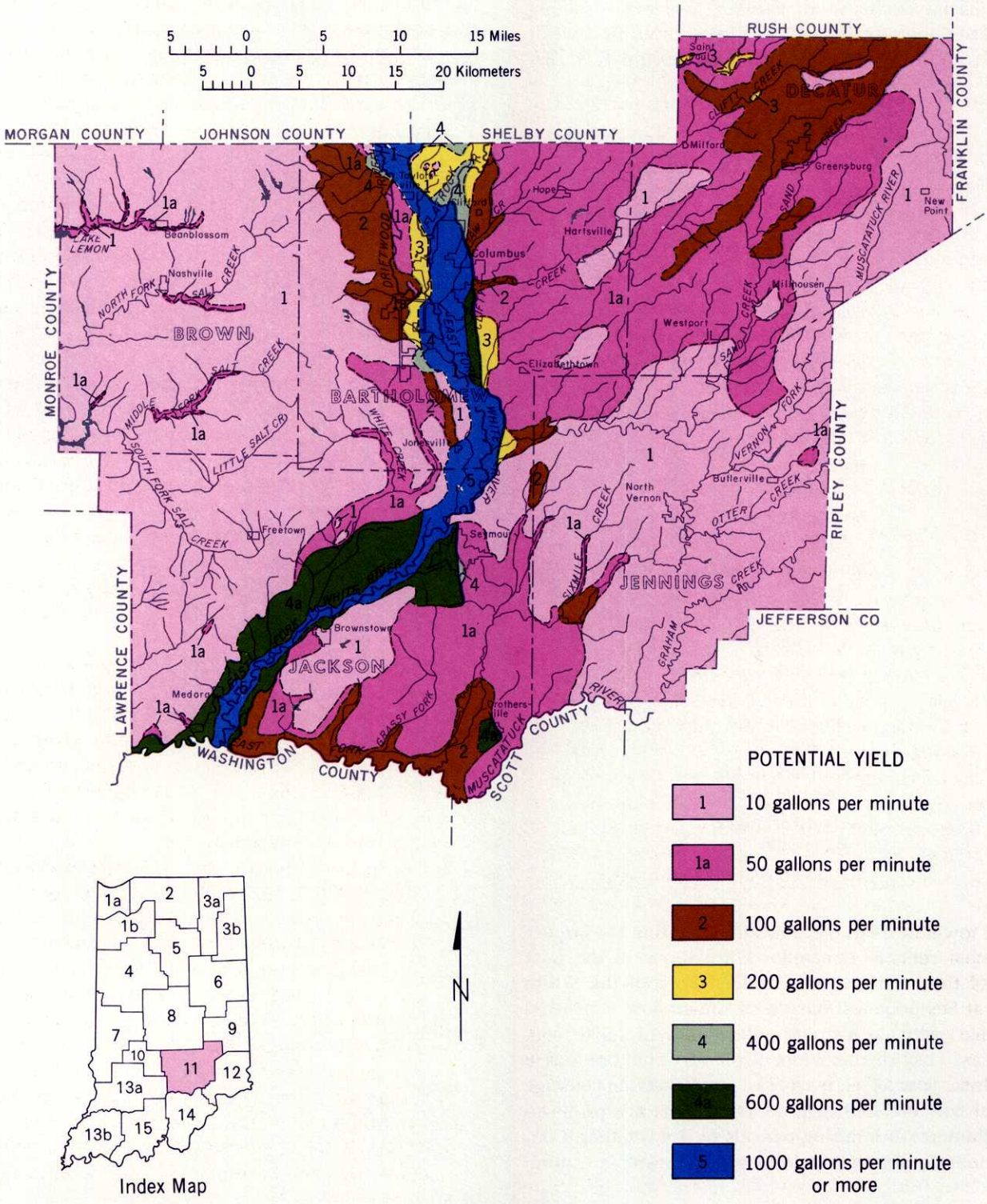


Figure 193
Map of Region Eleven showing the location and potential yield of ground water from properly constructed large diameter wells.

Driftwood, Flatrock, and Muscatatuck Rivers and Clifty, Sand and Salt Creeks. A small portion of the region drains southeasterly into Laughery Creek and the Ohio River basin. Exclusive of the southeasterly draining tributaries the streams of this region drain in a westerly to southwesterly direction and ultimately discharge into the East Fork of the White River, a member of the Wabash River basin.

The seven day, once in ten year (Q7-10), one day, once in thirty year (Q1-30) and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations are presented in the following table.

Table 155
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Clifty Creek at Hartsville	9	64	0	0
East Fork of the White River at Columbus	1,707	1,200	81.0	63.0
East Fork of the White River at Seymour	2,341	1,500	109.0	83.0
Graham Creek near Vernon	77	60	0	0
Haw Creek near Columbus	51	9	0.06	0
Middle Fork of the Salt Creek near Story	38	5	0	0
Muscatatuck River at Austin	359	250	0.6	0.1
North Fork Salt Creek at Belmont	120	84	0	0
North Fork Salt Creek at Nashville	76	49	0	0
Sand Creek near Brewersville	155	108	0	0
South Fork of the Salt Creek at Kurtz	38	26	0	0
Vernon Fork near Butlerville	86	60	0.01	0
Vernon Fork at Vernon	198	140	0.1	0

The low-flow characteristics indicate that the largest and most reliable streamflows are those in the East Fork of the White River. The East Fork of the White River at Seymour will have a sustained flow of at least 83 (mgd) with an average annual flow of 1,500 mgd. The East Fork of the White River at Columbus has a sustained flow of at least 63.0 mgd with an average annual flow of 1,200 mgd. Most streams are prone to very limited flows during periods of dry weather. Contributions to streamflow from ground water are minimal.

The flow duration curve for the Vernon Fork of the Muscatatuck River at Vernon, as shown by Figure 194, indicates the stream will have a dependable flow of 1.0 mgd ninety percent of the time.

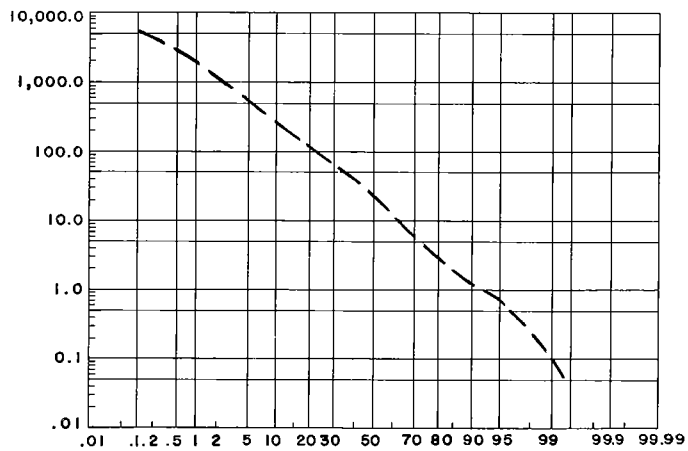


Figure 194
The flow duration curve for the Vernon Fork at Vernon.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are presented in Table 156, and are located on Figure 195. These fifty-five lakes have a combined surface area of approximately 2,500 acres and a gross storage capacity of approximately 16,460 million gallons.

Table 156

Lakes at least 50.0 acres in size or having a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Bear Lake	na	9.4	57
2	Berry Farm Lake	1.02	13.0	34
3	Cordry Lake	1.07	166.0	2,059
4	Deerskin Lake	0.02	2.6	32
5	Don Fox Lake	0.10	14.4	48
6	Gallahue Lake	0.83	35.0	114
7	Green Lake	1.63	51.0	280
8	Greenbriar Lake	na	10.9	81
9	Happy Hollow Lake	0.80	11.4	38
10	Hidden Valley Lake	na	21.9	247
11	Jeanson Lake	na	15.0	48
12	Lake LaSalle	1.38	37.0	138
13	Lutheran Church Camp Lake	0.14	18.0	45
14	Newport Lake	0.30	3.7	187
15	Ogle Lake	1.03	20.0	81
16	Parkview Lake	na	3.9	45
17	Pfau Lake	na	10.0	40
18	Somerset Lake	0.75	28.4	138
19	Strahl Lake	na	11.7	45
20	Stuart Lake	na	na	153
21	Sweetwater Lake	2.31	275.0	3,095
22	Tousley Lake	3.44	31.0	110
23	Woodland Lake	na	15.1	143
24	Yellowwood Lake	6.88	133.0	615
25	Echo Lake	na	18.0	32
26	F.O.P. Lake	na	23.4	234
27	Forest Lake Estates	0.07	8.2	39
28	Grandview Lake	1.97	211.8	2,215
29	Grouse Ridge Lake	na	20.6	208
30	Harrison North Lake	na	50.5	604
31	Harrison South Lake	na	38.0	371
32	Lake Barbara	na	na	68
33	Lake Schaefer	na	92.6	195
34	Lutheran Lake	na	79.6	338
35	Shure Lake	na	9.4	42
36	Tamerix Lake	na	8.0	39
37	Terrace Lake	na	9.9	48
38	Greensburg Reservoir	0.45	na	84
39	Lake McCoy	4.62	43.7	241
40	Lake Santee	4.63	250.0	883
41	Leming and Robinson Lake	1.83	21.7	68
42	Middle Fork Lake	na	28.6	260
43	Reed's Lake	na	na	55
44	C.J. Rust Lake	0.31	35.1	210
45	Hillview Lake	na	13.1	48
46	Knob Lake	na	9.4	52
47	Lake and Forest Lake	1.45	55.2	651
48	Lake Pyoca	0.59	21.9	117
49	Lake Tarzian	1.83	56.0	263
50	Starve Hollow Lake	6.67	145.0	319
51	Timber Lake	na	5.1	71

Table 156 (continued)

Lake Number	Lake Name	Drainage Area (square miles)	Surface Area (acres)	Gross Storage (million gallons)
52	Broomsage Ranch Lake	0.35	22.0	33
53	Brush Creek Reservoir	14.30	170.0	664
54	Crosley Lake	na	14.0	42
55	Hickory Lake	na	35.9	97

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Eleven are presented in Table 157. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing The demand for boating and waterskiing opportunities currently exceeds the supply within the region. This shortage of supply is expected to remain through the year 2000. Sweetwater and Lemon Lakes in Brown County, and Lake Santee in Decatur County provide the only opportunity for waterskiing.

Table 157
The outdoor recreation demand and supply analysis.

Activity	Percent of Population Participating	Density Guideline	Approximate Supply	Existing Supply as a Percentage of Projected Demand		
				1980	1990	2000
Boating	29	19.6 boats/acre/year	4,300 acres	62	57	55
Waterskiing	8	34.4 skiers/acre/year	1,000 acres	60	56	54
Canoeing	7	585 canoes/mile/year	122 miles	100+	100+	100+
Swimming	38	76,600 swimmers/acre/year	23 acres	100+	100+	100+
Ice-Skating	8	6,678 skaters/acre/year	5 acres	71	63	63
Fishing	46	66 persons/acre/year	10,000 acres	54	49	46

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

Canoeing At least 122 miles of canoeing streams are available. The East Fork of the White, Flatrock, Driftwood, and Muscatatuck Rivers are all recommended for canoe trips. There is no current or projected shortage of canoeing mileage.

Swimming and Ice-Skating The swimming needs are adequately met by the existing supply of public beaches and pools. No shortages are expected to occur through the year 2000. The demand for ice-skating opportunities exceeds the supply and is projected to exceed the supply through the year 2000.

Fishing The quality of the fisheries habitat is shown on Figure 196. The aquatic habitat with the highest value to the fisheries resource is located in steadily flowing streams with sand, gravel, and rock beds lined with pools and riffles. Streams with poor low-flow characteristics such as the Fall Fork of Clifty Creek, Bear Creek, and Wyaloosing Creek, or streams subject to intensive agricultural practices, have lower aquatic habitat values. Warmwater fish are present in most streams in the region, especially sunfish and catfish. Spring sucker fishing is recommended in Clifty Creek, Sand Creek, and the Driftwood River. Smallmouth bass use Big and Little Graham Creeks and Ninevah Creek for spawning. Jackson Creek above Yellowwood Lake supports a "put-and-take" trout fishery. The larger streams, such as the East Fork of the White River and Muscatatuck River generally have good aquatic habitat.

All public lakes in the region are man-made, with the exception of the old river oxbows. The oxbows are landlocked most of the year but restock their fisheries during periods of high water. Except for Greensburg City Park Lake, all the lakes have good habitat for

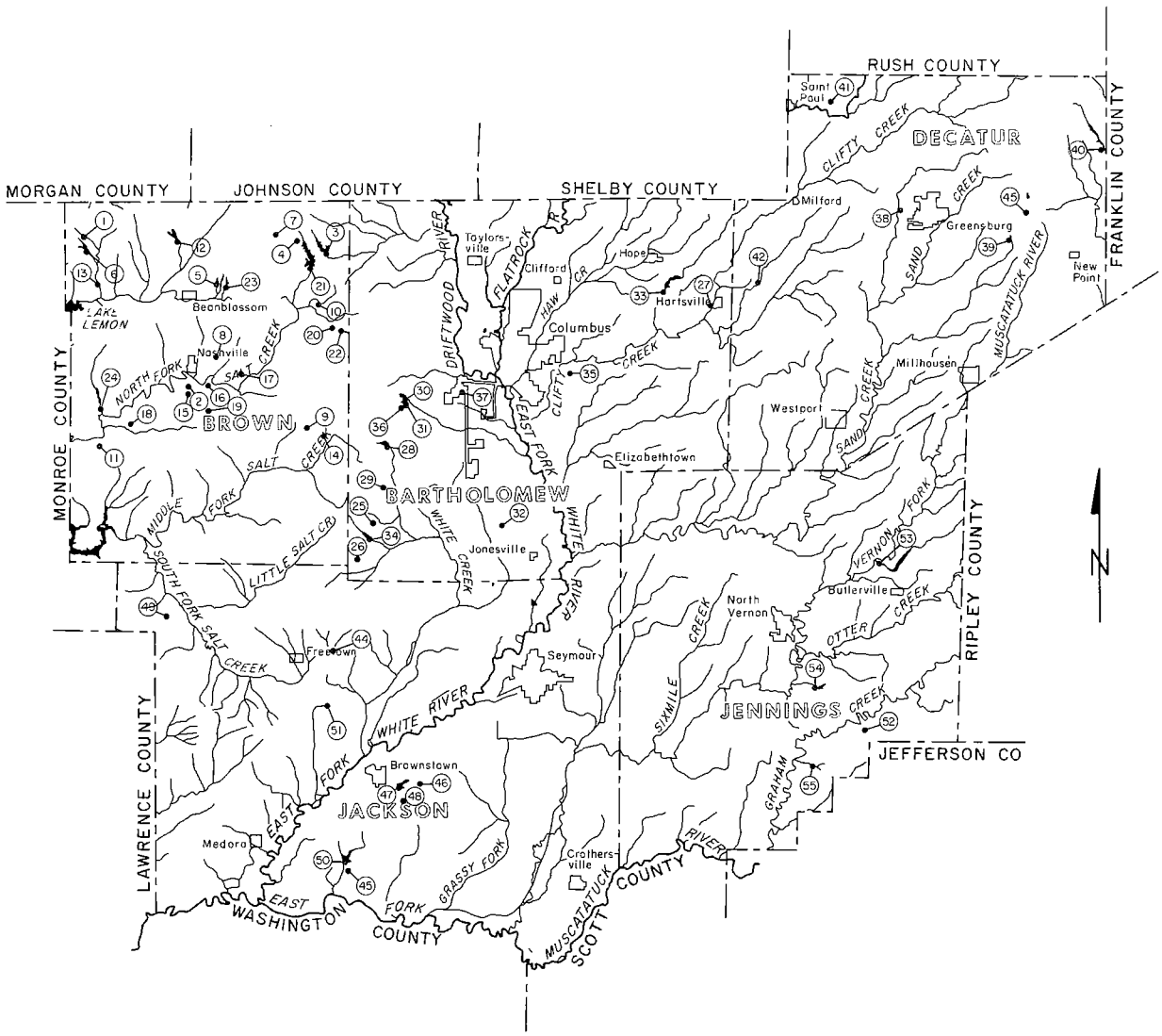


Figure 195
Map of Region Eleven showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

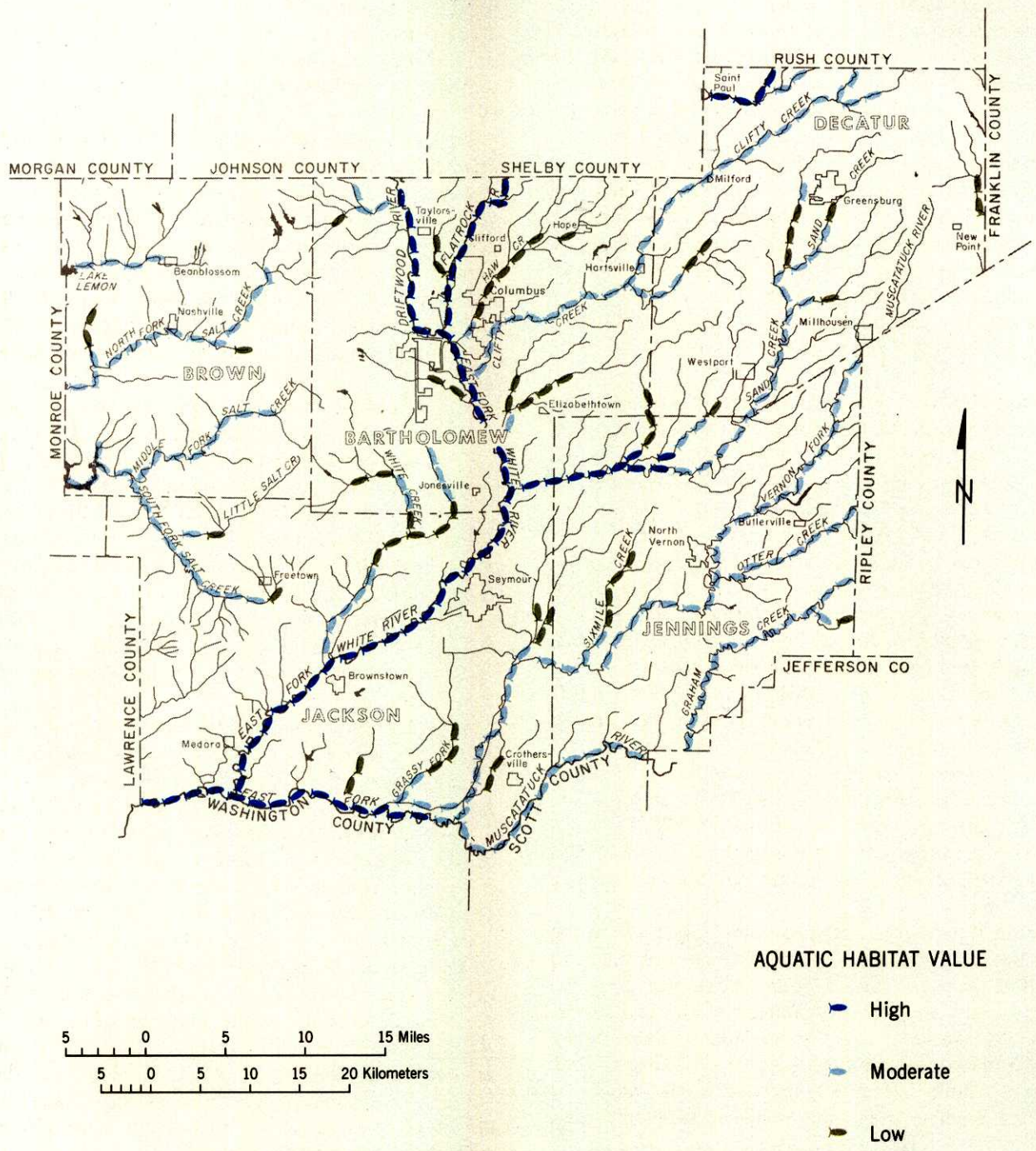


Figure 196
Map of Region Eleven showing the quality of the fisheries habitat.

warmwater fish. Brush Creek Lake is noted for excellent sunfish populations and Starve Hollow Lake offers northern pike sunfish and catfish.

State-owned public fishing sites are available on the East Fork of the White River, Driftwood River, and the East Fork and Vernon Fork of the Muscatatuck River. Other state properties offering fishing access are Greensburg Lake, Grouse Ridge, Cypress Lake and Brownstown Fishing Areas, Brush Creek, and Crosby Fish and Wildlife Areas, Brown County State Park, and Yellowwood and Jackson-Washington State Forests. The Muscatatuck National Wildlife Refuge and Hoosier National Forest offer additional public fishing areas. According to estimates, the existing water acreage meets only fifty-four percent of the current demand for fishing water by residents of the region.

Riparian Habitat The quality of the riparian habitat associated with lakes and streams is indicated in Figure 197. The streams that have not been channelized, such as Big Graham Creek, Vernon Fork Muscatatuck River, and the Fall Fork of Clifty Creek, provide very good wildlife habitat. Ninevah Creek in Camp Atterbury has excellent habitat, which has been undisturbed for nearly forty years. Streams in agricultural areas that are channelized and farmed to their edge have low wildlife value. Other channelized streams, such as Grassy Fork, Grassy, Mutton, and Storm Creeks (in Jackson County) have higher values for wildlife habitat due to revegetated banks. A variety of wildlife use the riparian habitat including furbearers, upland game, shorebirds, songbirds, and waterfowl. The less developed lakes in the region, especially on state and federal properties, provide good to excellent wildlife habitat. Most lakes are surrounded by hardwoods and are frequented by upland game species and various birds.

The most extensive wetlands in the region are in the Muscatatuck National Wildlife Refuge and the wet woods at the upper end of Monroe Lake. Wetlands also occur in the older oxbows. Waterfowl and furbearers, especially muskrat, use the wetland habitat. Public hunting in riparian habitat is permitted at Muscatatuck National Wildlife Refuge, Crosby and Brush State Creek Fish and Wildlife Areas, and Yellowwood State Forest.

Withdrawal Uses

Public Water Supplies Bartholomew, Brown, Decatur, Jackson, and Jennings Counties are served by twenty-seven public water utilities. Approximately 78,500 residents of Region Eleven were served by a public utility in 1975. Approximately 32,800 residents of Bartholomew County are served by public water utilities. At sixty-four percent, Jackson County has the highest percentage of population served.

Fifteen of the public water utilities have service areas consisting primarily of a single urban area. Figure 198 indicates the service areas and withdrawals by public water utilities in Region Eleven. The Columbus system, the largest single public water utility in the region, served approximately 27,500 customers in 1975 and withdrew an average of 5.3 million-gallons-per-day. Other large urban systems include Seymour, providing 13,700 customers with 1.3 mgd; Greensburg, providing 8,500 customers with 1.4 mgd; and North Vernon, providing 4,500 customers with 1.3 mgd. The Freeman Field Utility withdraws an average of 630,000 gallons-per-day primarily for an industrial park, but also supplies approximately 700 persons in adjacent areas.

The remaining twelve public water utilities are primarily rural water systems, which consist of a source of supply and miles of small diameter pipe running along the county roads in the area. The largest rural water system, the Jackson County Water Utility, withdraws approximately 0.5 mgd. Two large systems serve Bartholomew County and several smaller systems radiate out from North Vernon in Jennings County. There are no rural systems in Decatur County, due to a slightly better ground water resource and lack of an adequate supply source for a rural system within the county.

In 1975, public water utilities withdrew an average of 12.4 mgd. Bartholomew County accounted for 5.8 mgd, Jackson County 3.2 mgd, Decatur County 1.7 mgd, Jennings County 1.4 mgd, and Brown County withdrew 0.3 mgd. Not all the water used in the region is withdrawn within the five counties. Some is imported into the region from the Batesville Reservoir, Monroe Reservoir, and from well fields along the Ohio River.

Ground-water sources provide raw water to several of the systems in Region Eleven. All of the utilities in Bartholomew County obtain their water from wells in the East Fork of the White River and Flatrock River aquifers. Crothersville obtains its water from an aquifer within the city limits. Greensburg has developed several wells in less productive aquifers in the area, and from an intake on Flatrock River about six miles from town. Hope, St. Paul, and Edinburgh all use local well fields. Well water is imported into Brown County from the north, and a small amount of well water from along the Ohio River is now being imported into southern Jennings County.

Rural systems that depend on ground water include those in Brownstown and Jackson Counties, which tap into aquifers in the valleys of the East Fork of the White River and the Flatrock River. A well field is being developed in the northeast corner of Jackson County

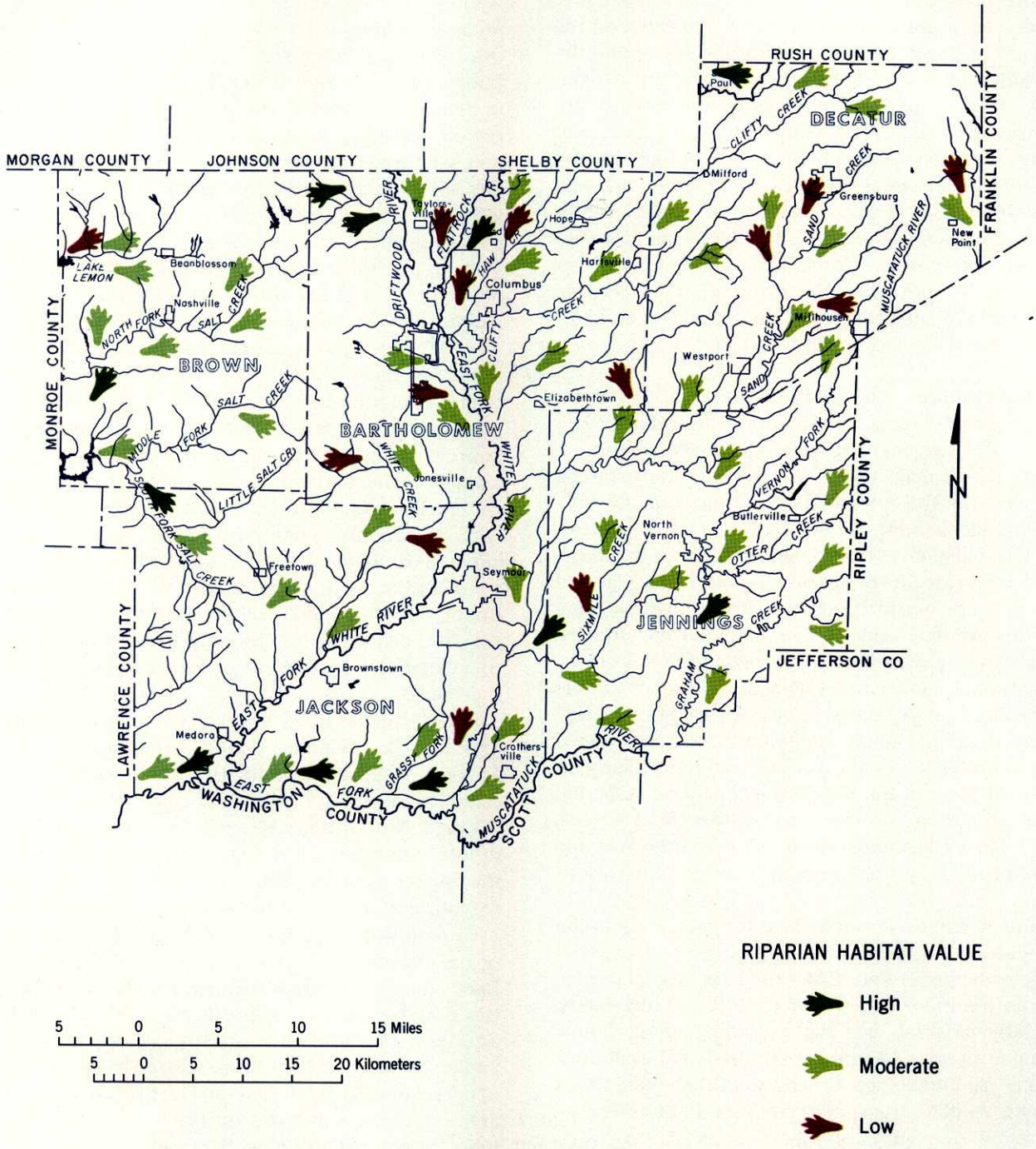


Figure 197
Map of Region Eleven showing the quality of the riparian habitat.

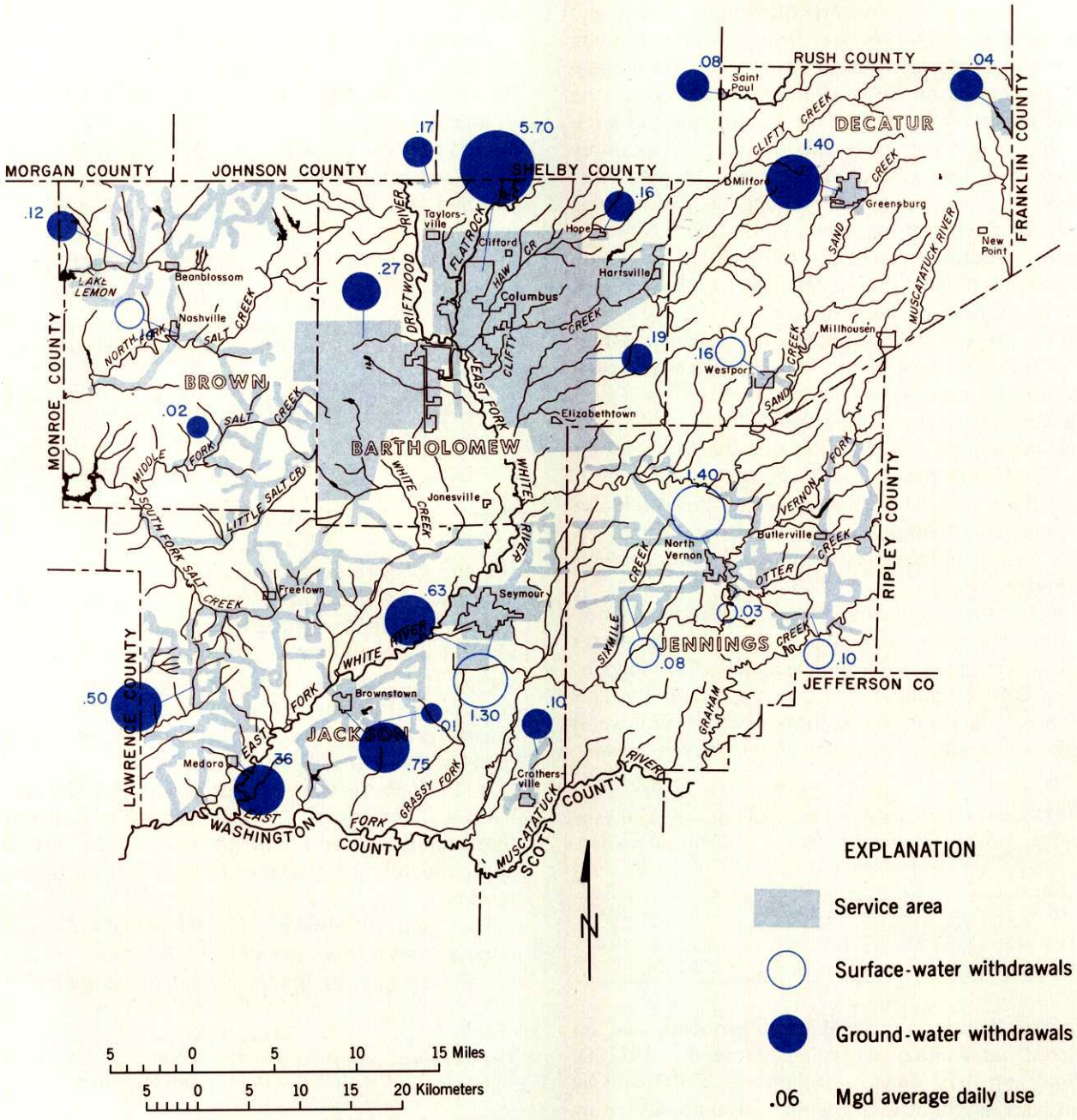


Figure 198
Map of Region Eleven showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

to supply some of the rural systems in northcentral Jennings County.

Surface water is used widely in Jennings County and is also used to supply parts of Brown County, the city of Seymour, and the town of Westport. The surface water distributed in Brown County is withdrawn from Monroe Reservoir by way of the Bloomington municipal utility. Water from Ogle Lake in the Brown County State Park is being sold to the town of Nashville. Westport has a surface-water intake on Sand Creek, with two surface storage ponds within the city limits. Seymour withdraws water from the East Fork of White River, despite the fact that Seymour is located just east of the White River bottom aquifer.

The city of North Vernon primarily withdraws water from the Vernon Fork of the Muscatatuck River, supplemented by releases as necessary from the Brush Creek Reservoir. Brush Creek was built by the State of Indiana as a joint water supply for the Muscatatuck State School and the city of Vernon. This property is also used for fish and wildlife purposes, but it remains as the secondary supply for North Vernon. North Vernon, in turn, supplies Vernon and rural water systems in Jennings County.

Projections of public water supply withdrawals indicate that withdrawals by the region's public water supplies may increase to approximately 19.4 mgd by the year 2000, as indicated in the following table. This projection is based on the assumption that rural water systems will continue to expand their service areas.

Table 158

The 1977 and projected withdrawal and consumption rates for public water supplies by the year 2000, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	12.3	13.1	16.2	19.4
Consumption	2.9	3.0	3.7	4.5

Industrial Water Industrial establishments had an estimated water intake averaging 12.0 mgd in 1977. Of the total industrial intake, 4.9 mgd was withdrawn by the industries themselves while 7.1 mgd was purchased from public utilities.

Ground water is the major source of industrial water supplies. A number of industries develop at least a part of their own water supply from company-owned well fields. Most of the industries relying on wells for significant quantities of water are confined between the communities of Edinburgh, Columbus, Seymour, and Brownstown along the East Fork of the White River.

The largest water-using industry groups include food processors and the manufacturers of transportation equipment. Other industries that use significant amounts of water include manufacturers of rubber and plastic products, furniture, and primary metal products.

Industrial production for the year 2000 is expected to be 112 percent above the 1977 value (U.S. Water Resource Council). In spite of this predicted increase in industrial output, total industrial water intake is expected to decrease slightly to 11.8 mgd by 2000, due to increased plant efficiency. Of this total, approximately 5.0 mgd will be withdrawn directly by the industries. Industrial self-supplied withdrawals during 1977 and projections for future use are now presented.

Table 159

The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supplied	*1977*	*1980*	*1990*	*2000*
Withdrawal	4.9	4.8	4.8	5.0
Consumption	1.1	1.2	1.5	1.9

Rural Self-Supplied Water An estimated 69,100 persons lived in homes provided with some type of self-supplied water source in 1975. It is estimated that about 4.1 mgd was withdrawn for residential purposes in that year. By the year 2000, an estimated 79,700 residents will depend on their own supplies for household water. These people, along with the anticipated general rise in the standard of living, are expected to increase rural residential water use to approximately 6.2 mgd by the year 2000.

In 1975, there were an estimated 304,000 head of livestock and about 1,613,000 chickens. Collectively, these animals used about 2.0 mgd. By the year 2000, approximately 2.6 mgd may be required for these animals.

The total withdrawal of rural self-supplied water may increase from the current 6.3 mgd to approximately 8.8 mgd by the year 2000, as presented here.

Table 160

The 1977 and projected withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.3	6.6	7.7	8.8
Consumption	6.3	6.6	7.7	8.8

Irrigation Water Soil associations with irrigation potential are located along the terraces of the East Fork of the White River or on the windblown sands along the rivers in Bartholomew and Jackson Counties. Figure 199 shows the potential irrigation areas within the region.

Based upon the survey of irrigated croplands, approximately 1,120 acres were irrigated in the region,

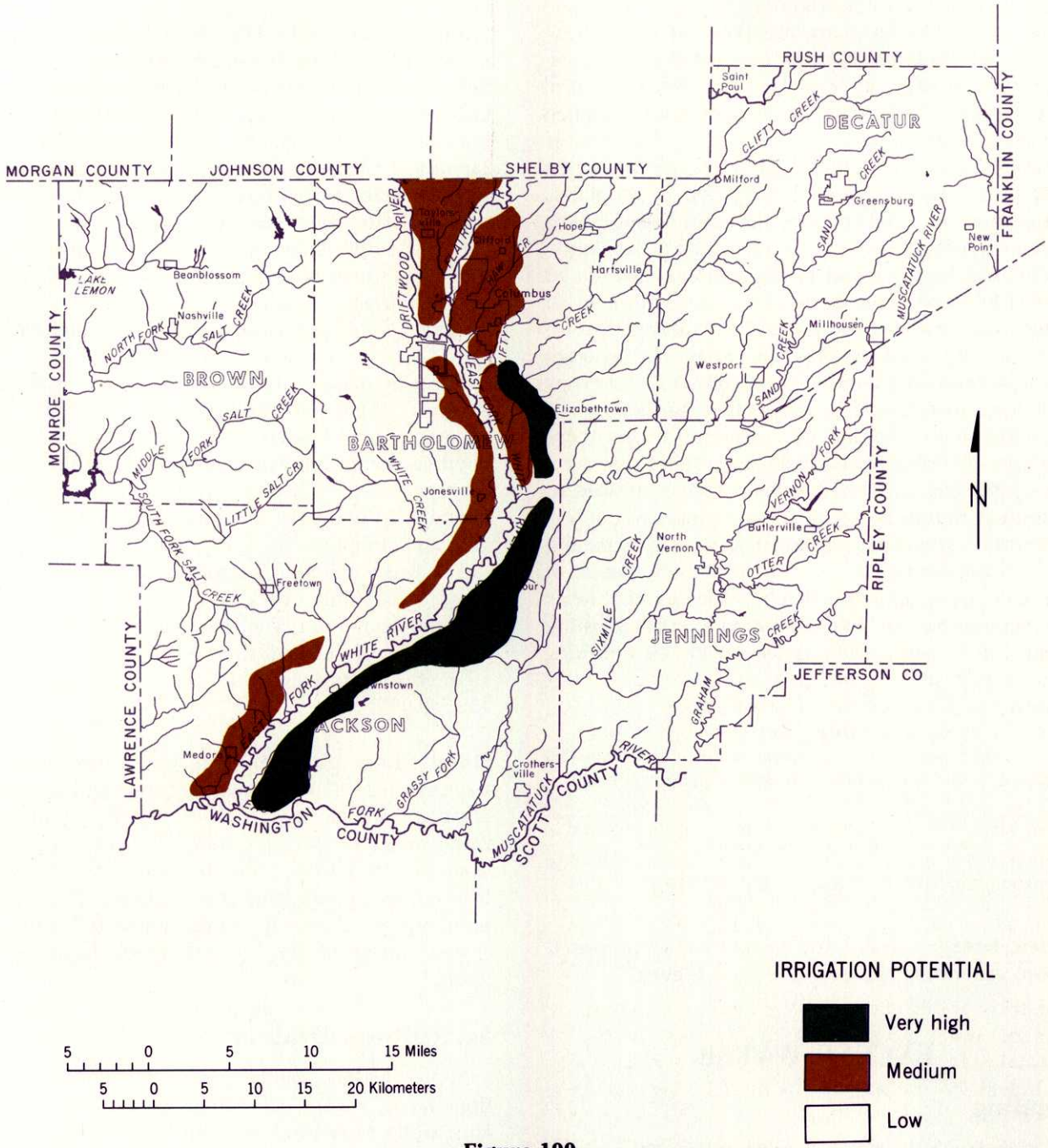


Figure 199

Map of Region Eleven showing the location of the soil associations that appear to possess an economic potential for the irrigation of croplands.

1,100 acres in Bartholomew County and 20 acres in Jackson County. Crops irrigated include corn, soybeans, vegetables, and tobacco.

Assuming 1977 as a normal growing year, these crops required about 2.9 mgd during the peak irrigation period of July and August. About sixty percent of the water used in the region for irrigation was supplied from ground water.

It is estimated that about 23,000 acres in the region could be profitably irrigated. Irrigation of croplands may increase to 5,600 acres by the year 2000. This expansion of croplands may increase the peak July–August irrigation demand in an "average" season to about 14.7 mgd. The average season increase in ground-water withdrawals for crops is expected to increase to 12.1 mgd by the year 2000. The average season increase in ground-water withdrawals for crops is expected to reach 12.1 mgd by the year 2000.

In addition to irrigation for agricultural use, there are about 221 acres of irrigated fairways and greens on the region's golf courses. About 0.7 mgd is applied to these areas during the peak July–August period.

The total withdrawal for irrigation of croplands and golf courses during the average irrigation season of 1977 was approximately 3.6 mgd. These withdrawals may increase to 15.6 mgd during an average growing season by the year 2000, as shown in the following table.

Table 161
The 1977 and projected withdrawal of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	3.6	5.1	10.4	15.6
Consumption	3.6	5.1	10.4	15.6

Electric Energy There are no existing or proposed electric generating stations in Region Eleven.

EXCESS WATER

Flooding

It is estimated that approximately 104,000 acres of the region are subject to flooding. The major flood plains are shown in Figure 200. Figure 201 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $6.5 million of which some eighty-two percent occurred in rural areas.

Virtually all of the streams are subject to flooding. Flash flooding on streams in the area is common due to the steepness of the topography. The East Fork of the White River, the major waterway in the region, is subject to long flood durations.

Flood Control The U.S. Army Corps of Engineers, under the Flood Control Act of 1954, removed drift and debris from a section of the Muscatatuck River on the border between Jennings and Scott Counties near Tobias Bridge. The project was completed in 1968. In January, 1969, the project was transferred to the Jennings and Scott Counties Board of Commissioners for operation and maintenance.

Under authority of the 1948 Flood Control Act, the U.S. Army Corps of Engineers constructed channel improvement of a portion of Grassy Creek in Jackson County. The work consisted of cleaning and straightening 24,150 feet of the existing channel.

The U.S. Army Corps of Engineers is conducting a study to determine the economic feasibility, public acceptance, and advisability of providing additional flood protection improvements on the Driftwood, Flatrock, and East Fork of the White Rivers at and in the vicinity of Columbus. The study was initiated in 1975 and was completed in 1979.

The Federal Flood Control Act of 1965 authorized a reservoir on Clifty Creek for the purposes of flood control and recreation. The dam site is located 1.5 miles southwest of Hartsville in Bartholomew County. In 1976, the estimated total cost of the project was $36,540,000.

Flood Plain Management Columbus, Jonesville, Greensburg, Brownstown, Crothersville, Medora, Seymour, and North Vernon as well as the unincorporated areas of Bartholomew, Decatur, and Jackson Counties are participating in the emergency phase of the National Flood Insurance Program. Nashville and unincorporated Brown County, are participating in the regular phase of the National Flood Insurance Program.

Agricultural Drainage

Approximately twenty percent of the soil associations have "severe," seventeen percent have "moderate," while sixty-three percent have "slight" wetness characteristics. Locations of the soil associations with these wetness characteristics are shown in Figure 202. There are approximately 270 miles of legal drains within the region.

Soil Erosion

The erosion potential of soil associations is shown in Figure 203. Thirty percent of the 1,274,800 acres within the region are rated as having a "high" potential erosion hazard. Twenty-four percent are rated as

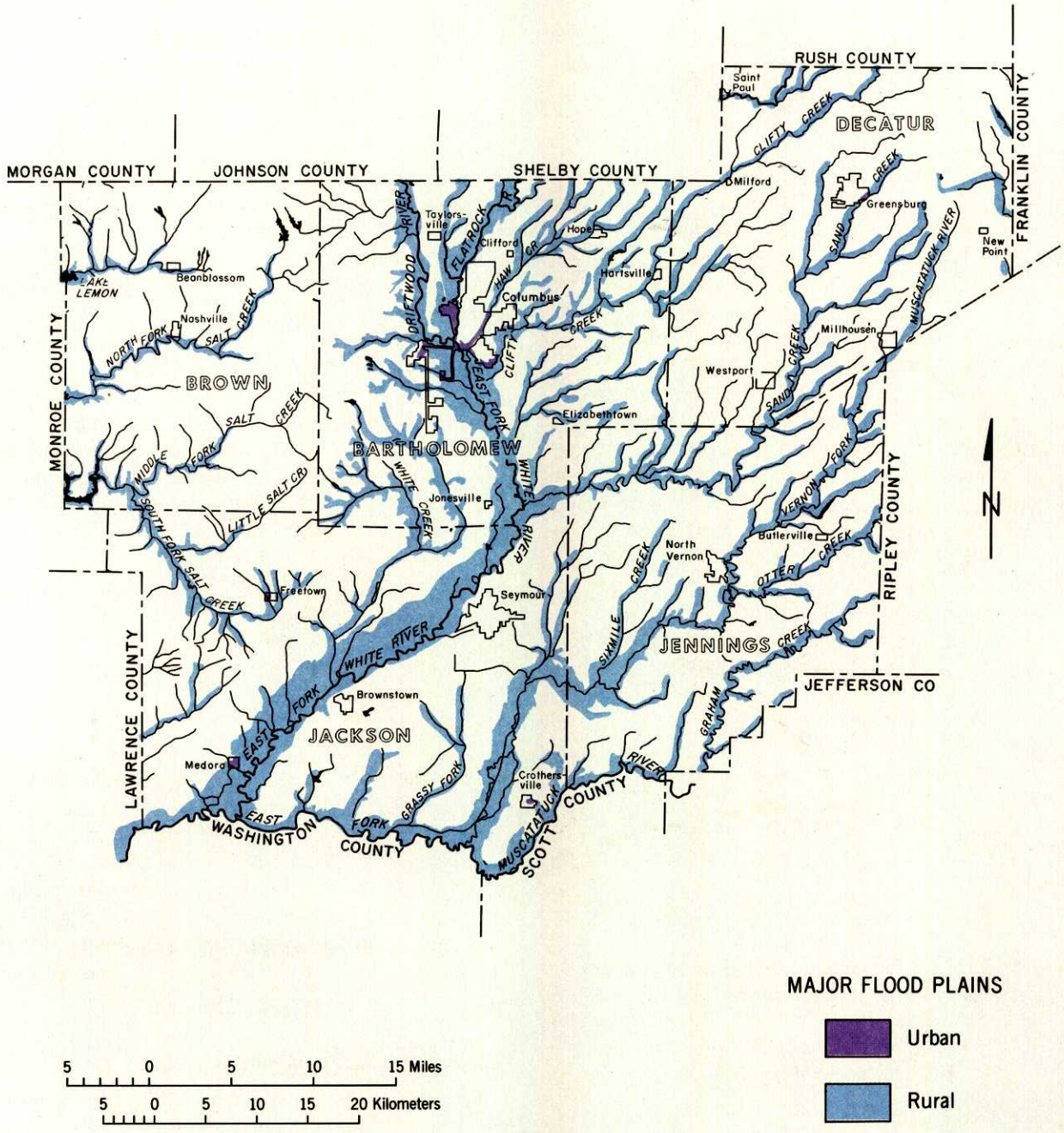


Figure 200
Map of Region Eleven showing the major flood plains.

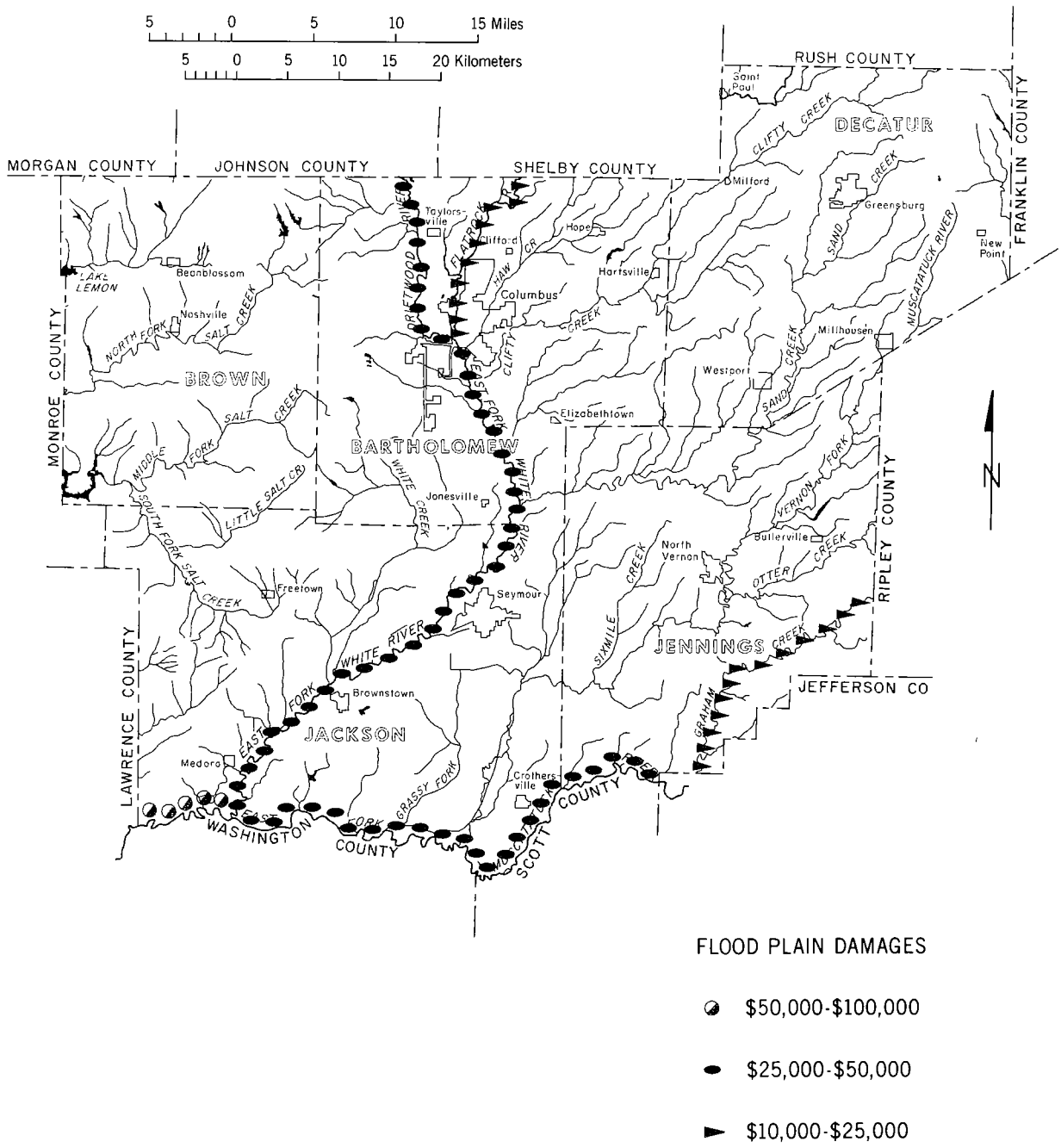


Figure 201
Map of Region Eleven showing the estimated average annual flood damages per mile along selected streams.

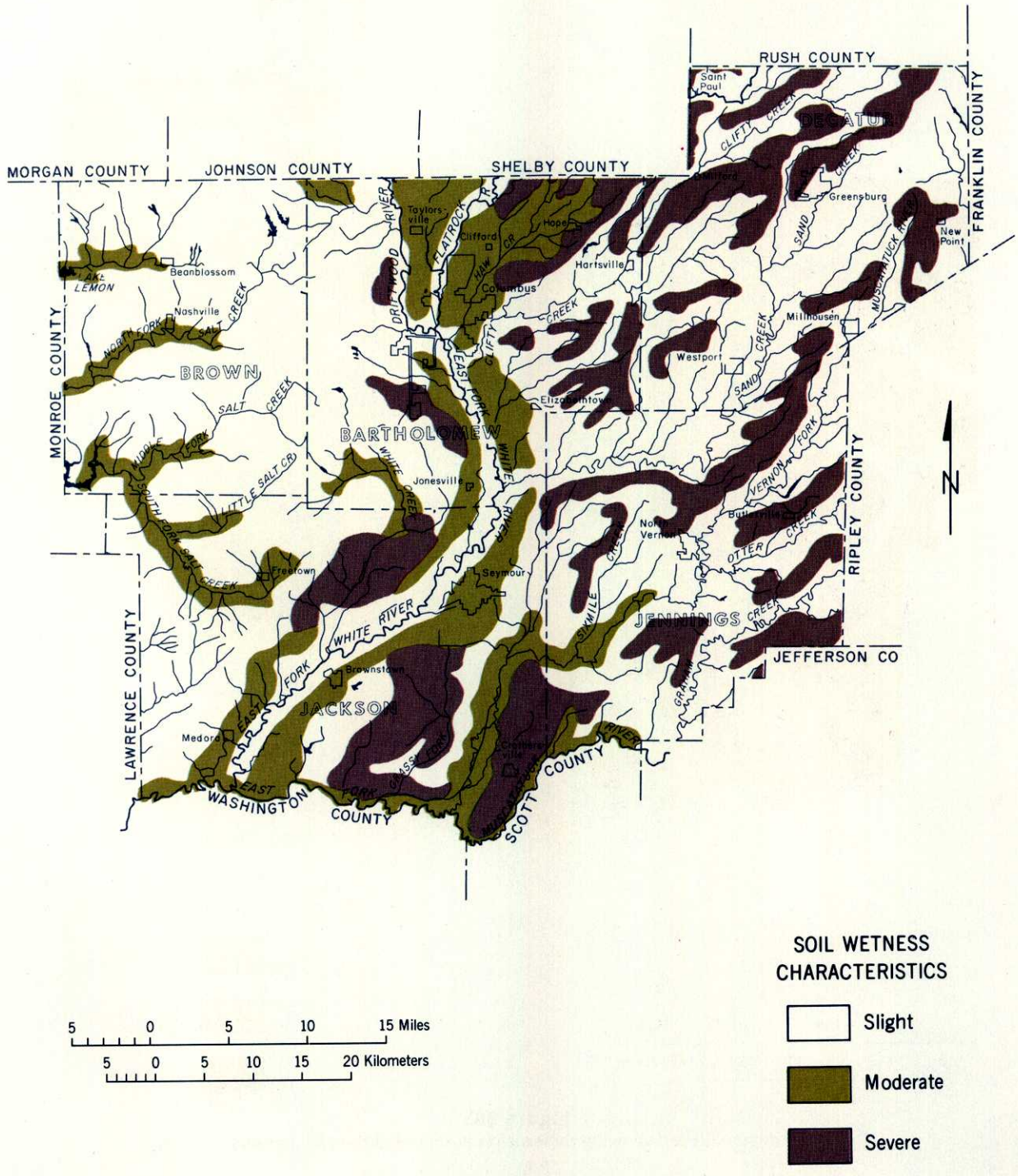


Figure 202
Map of Region Eleven showing the location of the wetness characteristics of soil associations.

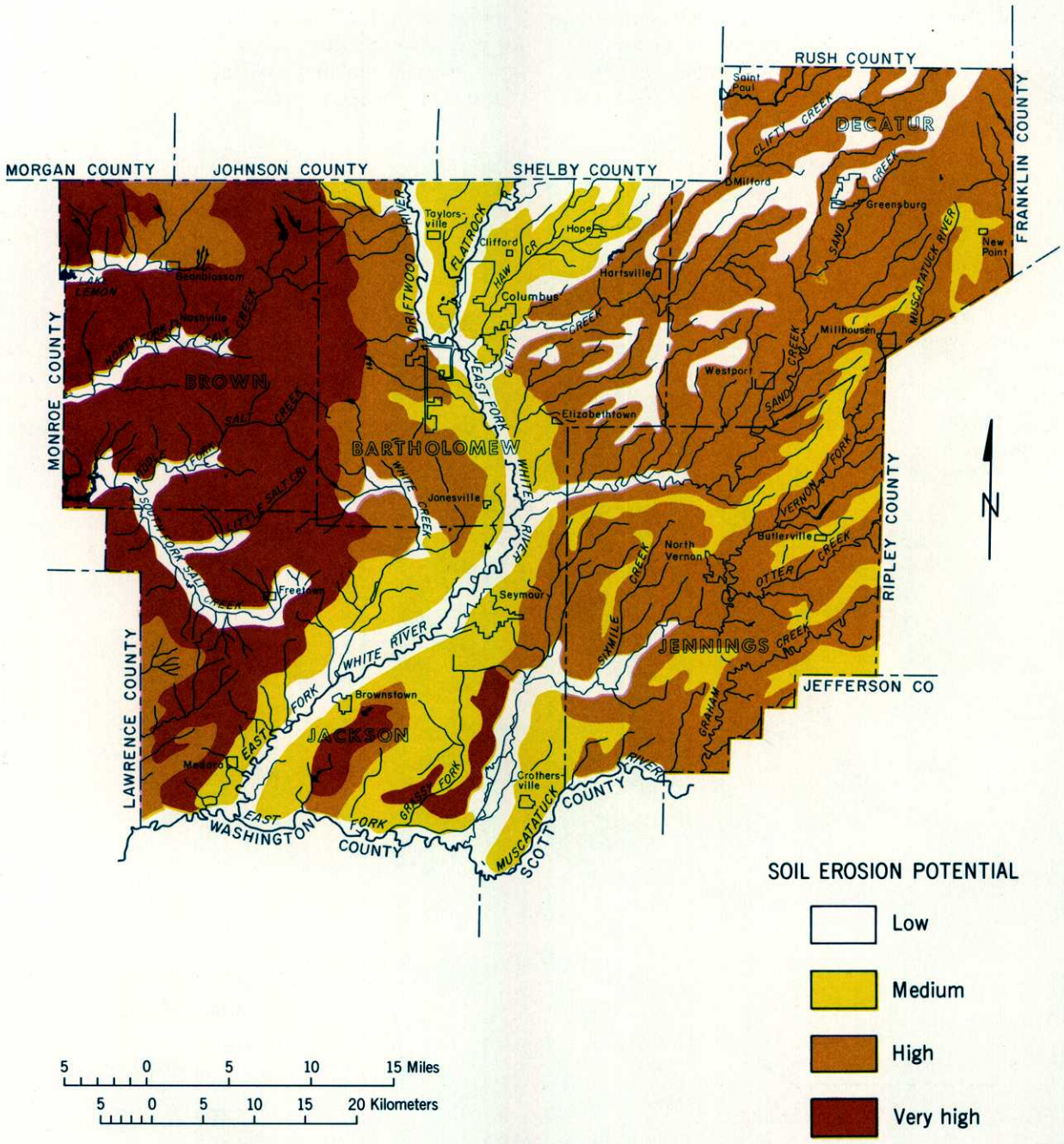


Figure 203
Map of Region Eleven showing the erosion potential of the soil associations.

having a "very high" potential. These are areas of relatively steep slope which require the protective cover of woodland and grassland if erosion is to be prevented. Twenty percent of the areas have a "medium" erosion hazard potential, while the remaining twenty-six percent have a "low" erosion potential for land left in a fallow state.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the East Fork of the White River, the Muscatatuck River, and Salt Creek. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

Water samples from the East Fork of the White River indicated the dissolved oxygen and temperature levels met the state standards. However, concentrations of fecal coliform bacteria frequently violated the criteria for partial body contact. Total coliform bacteria levels near Seymour violated the standard set for a supply of raw drinking water.

A total of five fish kills within the region have been reported to the Indiana State Board of Health in the period 1974 to 1977. Two were in Brown County near Nashville and resulted from a discharge of inadequately treated sewage to Salt Creek and a sewage bypass to Salt Creek. An industrial discharge to Little Sand Creek in Bartholomew County resulted in a fish kill. The largest fish kill occurred in Decatur County near Greensburg and resulted from a sewage bypass to an unnamed stream. Only one fish kill of undetermined magnitude has been reported from Jennings County and was caused by misapplication of pesticide to an area near Six Mile Creek.

Region Twelve

Dearborn, Jefferson, Ohio, Ripley, and Switzerland Counties, located in southeastern Indiana, form Region Twelve. The region contains approximately 1,425 square miles and is bounded by Decatur and Franklin Counties to the north; Ohio to the east; the Ohio River to the south; and Scott and Jennings Counties to the west, as shown in Figure 204.

The 1975 population was 92,753 of which thirty-three percent resided in Dearborn County. The official Indiana Population Projections indicate the region's population will increase by twenty-six percent by the year 2000, with the major growth occurring in Dearborn and Jefferson Counties. The 1975 population and the projections for each county are presented below.

Table 162
The 1975 and projected populations for Region Twelve.

County	*1975*	*1980*	*1990*	*2000*
Dearborn	31,184	32,400	35,100	37,800
Jefferson	27,622	29,000	31,700	34,200
Ohio	4,628	5,200	6,100	7,200
Ripley	22,549	23,800	26,700	29,700
Switzerland	6,770	6,900	7,200	7,400
Total	92,753	97,300	106,800	116,300

The major population centers are Aurora and Lawrenceburg in Dearborn County, Madison in Jefferson County, Rising Sun in Ohio County, Batesville in Ripley County, and Vevay in Switzerland County. These urban centers accounted for thirty-seven percent of the region's 1975 population.

Agriculture is the dominant land use with more than sixty-five percent of the area devoted to farming.

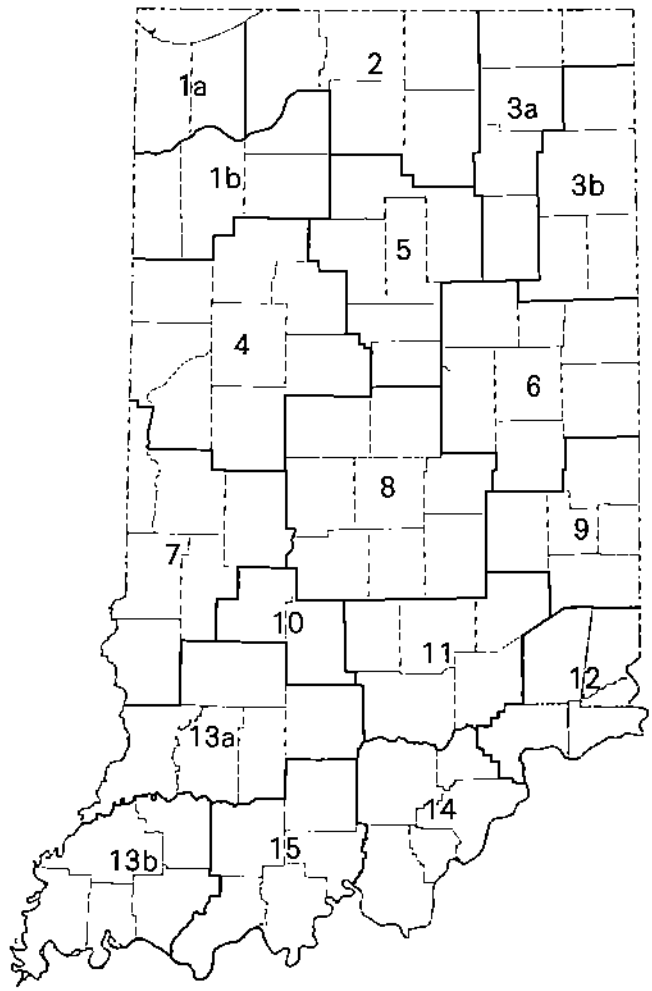


Figure 204
Map of Indiana showing the location of Region Twelve.

Approximately twenty-four percent of the land is forested while eleven percent comprises urban and miscellaneous uses. The region is characterized by a highly rolling, dissected topography.

Although agriculture is by far the major land use, it is not the major source of employment. Manufacturing employs over forty-eight percent of the total work force. Nonmanufacturing employment, including wholesale and retail trade, employs an additional twenty-two percent of the work force.

Average annual precipitation for the region is approximately 41.0 inches. This varies from a high of 4.3 inches in March to a low of 2.5 inches in October. Of the 41.0 inches falling annually, approximately 14.5 inches appear as streamflow while approximately 26.5 inches are consumed through evapotranspiration.

Average temperatures range from 31°F. in January to 75°F. in July. The average annual temperature is 53.5°F. Data from Cincinnati and Covington, Ohio, indicates the annual prevailing wind is from the south to southwest at approximately nine miles per hour.

THE WATER RESOURCE

Ground Water

Glacial deposits left by the Illinoian and older glacial advances consist predominantly of glacial till. Contained within the till are a few scattered lenses of water-bearing sand and gravel. Beneath the thin glacial deposits, usually 10 to 40 feet in thickness, is found layered bedrock, which ranges in age from Ordovician through Devonian. The interbedded shale and limestone bedrock in Dearborn, Ohio, and Switzerland Counties is an extremely poor water-bearing source. "Dry holes" and limited sources of ground water are common. A combination of Dolomitic limestone and shale occurs in the bedrock in Jefferson and Ripley Counties. The Silurian dolomitic bedrock aquifer may yield up to ten gallons-per-minute (gpm) to properly constructed wells. In western Jefferson County the black shale and limestone of the Devonian period are present and have only limited ground-water potential. The black, New Albany shale and the Ordovician shale and limestone bedrock are nonwater-bearing under most conditions. Deeper wells in these deposits often obtain highly mineralized or saline water, if any at all.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In this region, ground-water sources are minimal as shown in Figure 205. Major ground-water sources in the region are often confined to the Whitewater and Ohio River valley aquifers. Wells in these sand and gravel deposits range from 250 to 1,500 (gpm). Moderately productive wells have been obtained in Ripley County, with the exception of Sunman. Elsewhere, only limited, to essentially nonexistent, ground-water withdrawals are possible.

Major aquifers in the sand and gravel deposits of the Ohio and Whitewater River valleys usually contain water of good quality, although it is hard, containing 330 to 460 parts-per-million (ppm). Manganese concentrations may be locally high. However, iron contents are low and no removal is required in many instances. Hydrogen sulfide is present in the limestone aquifers below the New Albany shale.

Surface Water

Streamflow Most streams are in the Ohio River basin. Next to Lake Michigan, in extreme northern Indiana, the Ohio River offers the largest supply of surface water within Indiana. The region is predominantly drained in a northwest to southeast direction by the Laughery Creek system and by many small tributaries to the Ohio River.

The seven day, once in ten year (Q7-10), one day, once in thirty year (Q1-30) and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations are tabulated below.

Table 163
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Whitewater River at Brookville*	1,224	804	56	43
Laughery Creek near Farmers Retreat	248	180	0	0
Muscatatuck River near Deputy	293	220	0	0

*Flow characteristics recorded prior to the construction of Brookville Lake.

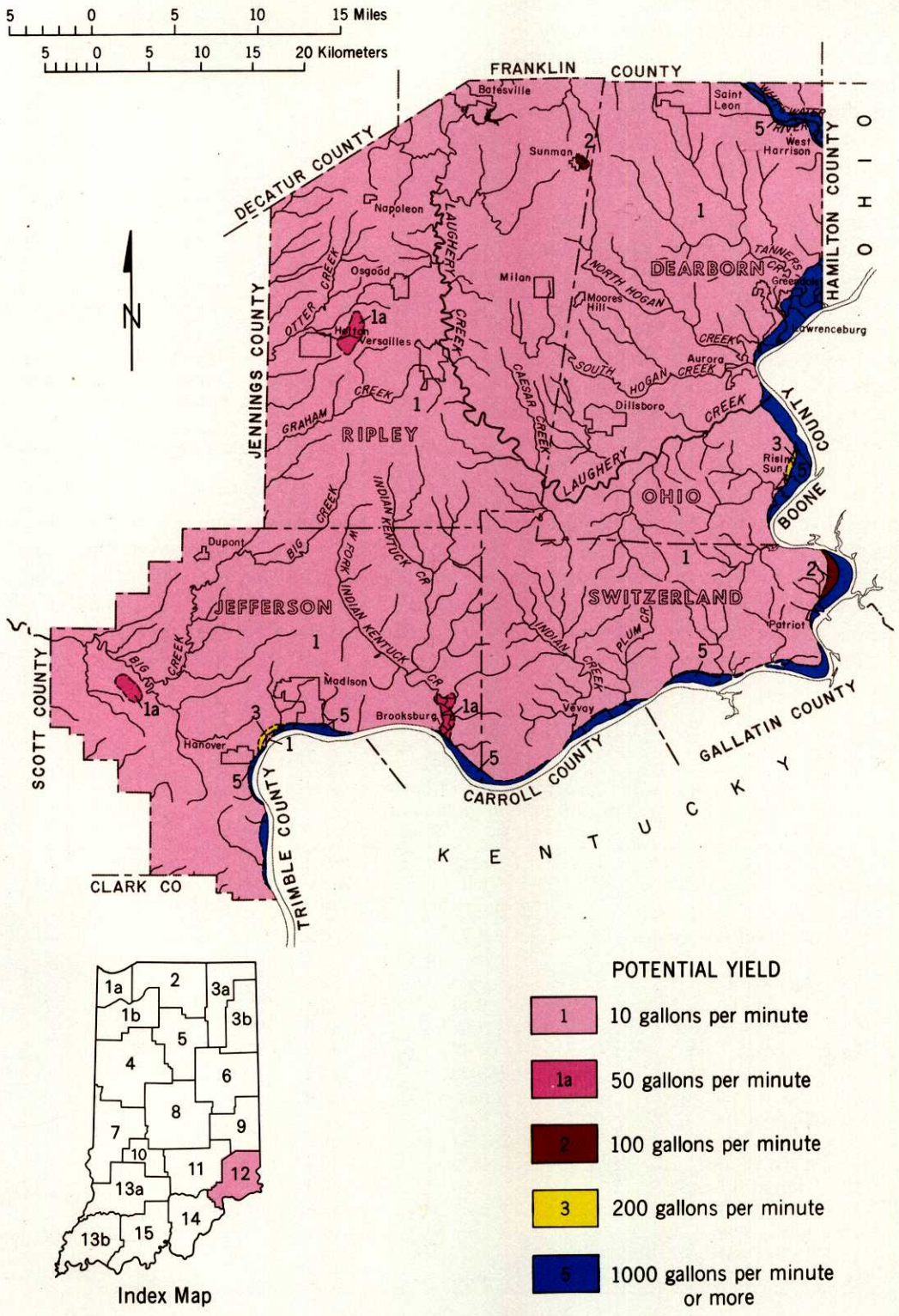


Figure 205

Map of Region Twelve showing the location and potential yield of ground water from properly constructed large diameter wells.

Analysis of the low-flow characteristics of surface streams within the region, indicates that the largest and most reliable streamflows are those in the Ohio River. The Ohio River is the largest surface stream in the state, with an average flow at Cincinnati in excess of 62 billion-gallons-per-day. The flow of the Ohio River is increased downstream of Cincinnati by the discharge of the Great Miami River at the Indiana and Ohio state line and from the Kentucky River at Carrollton, Kentucky.

Prior to the construction of Brookville Lake, Whitewater River had an average discharge at Brookville of 804 mgd. The minimum release from Brookville Lake is 25.9 mgd.

With the exception of the Ohio River and the Whitewater River, streams draining the region run dry with great regularity. Flow in Laughery Creek can be characterized as a trickle or less at least five percent of the time. This is true of all the streams that drain into the Ohio such as both forks of Tanners and Hogan Creeks as well as the streams that drain westwardly into the Muscatatuck River such as Big Creek, Graham Creek, and Otter Creek.

The flow duration curve for Laughery Creek near Farmers Retreat, as shown in Figure 206, has a steep slope indicating a lack of ground-water contribution to streamflow. The curve also indicates that the stream

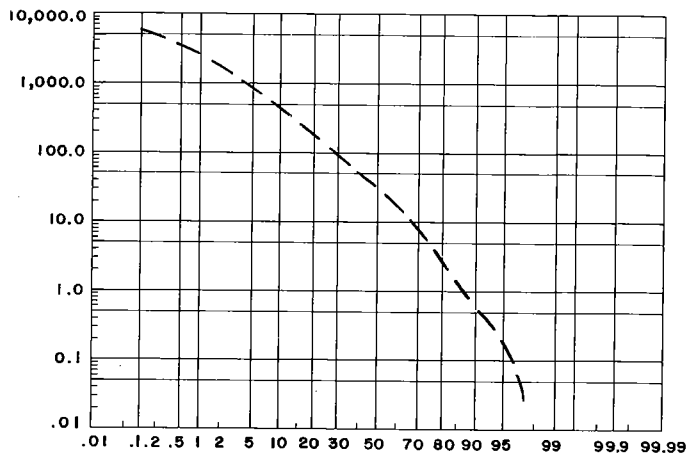


Figure 206
The flow duration curve for the Laughery Creek near Farmers Retreat.

will have a dependable flow of 0.7 mgd ninety percent of the time.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are listed in Table 164, and are located on Figure 207. These sixteen lakes have a combined surface area of approximately 841 acres and a gross storage capacity of 5,550 million gallons.

Table 164
Lakes at least 50.0 acres in size or having a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Bischoff Reservoir	4.53	200.0	625
2	Hahn Reservoir	na	9.4	32
3	LaSarre Lake	na	14.8	97
4	Mullenkramer Lake	6.46	32.8	325
5	Oser Reservoir	na	11.9	39
6	Tall Oak Lake	1.45	52.0	158
7	Versailles Lake	168.00	232.0	967
8	Wood Lake	na	12.0	130
9	Bar-K-Lake	na	na	97
10	Hidden Valley Lake	2.94	166.0	2,593
11	Lake Dilldear	na	16.7	123
12	Hereford Lake	2.50	38.4	110
13	Jefferson Lake	na	15.6	81
14	Edwin Pray Lake	na	na	32
15	Lake Geneva	na	26.1	65
16	Lake Livingston	0.38	13.7	84

na: not available.

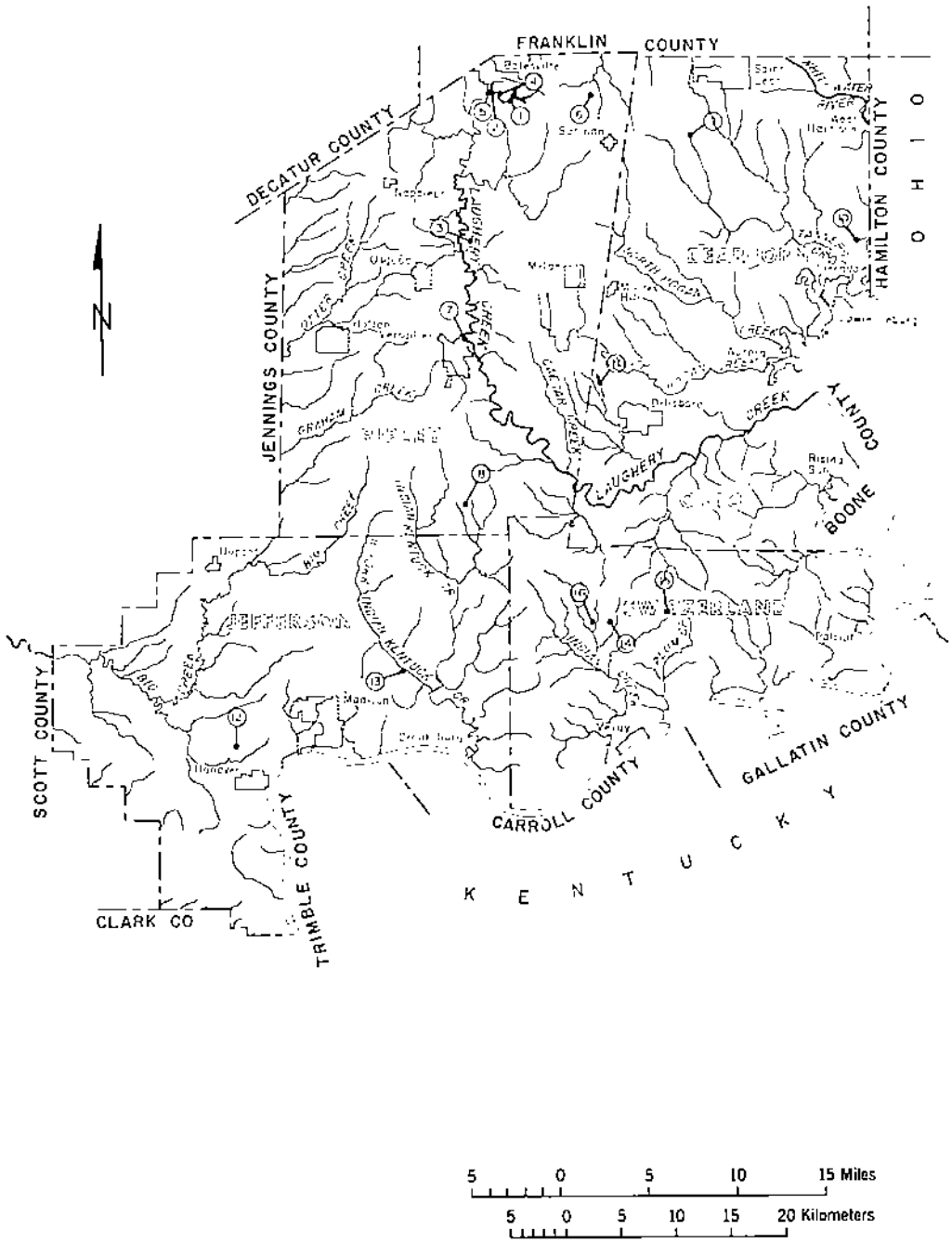


Figure 207
Map of Region Twelve showing the location of lakes that are at least 50.0 acres in size or that have a storage capacity of 32.5 million gallons or more.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Twelve are presented in Table 165. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing Boating opportunities are available on the Ohio River, on some of the reservoirs, and on many streams in the region. The Ohio River provides excellent boating, particularly since the construction of Markland Dam. The current supply of water suitable for waterskiing exceeds the current and projected demand through the year 2000. The Ohio River provides excellent waterskiing opportunities which will also exceed the demand through the year 2000. Waterskiing is not allowed on any of the inland lakes.

Table 165
The outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guideline*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	18	19.6 boats/acre/year	11,800 acres[a]	100+	100+	100+
Waterskiing	5	34.4 skiers/acre/year	10,400 acres[b]	100+	100+	100+
Canoeing	7	585 canoes/mile/year	15 miles	100+	100+	100+
Swimming	39	76,600 swimmers/acre/year	3 acres[c]	60	50	50
Ice-Skating	5	6,678 skaters/acre/year	1 acre	17	17	17
Fishing	49	66 persons/acre/year	21,200 acres[d]	100+	100+	100+

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands by residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.
[a]Includes 8,700 acres of the Ohio River and 3,100 acres of inland waters.
[b]Includes 8,700 acres of the Ohio River and 1,700 acres of inland waters.
[c]Does not include the Ohio River.
[d]Includes 8,700 acres of the Ohio River and 12,500 acres of inland waters.

Canoeing The only river recommended for canoeing is the fifteen-mile section of the Whitewater River which passes through the northeastern corner of Dearborn County. Other streams in the region, such as Laughery Creek, may at times provide canoeing opportunities. The demand for canoeing opportunities in the region is one of the lowest in the state. The minimal supply of canoeing opportunities should meet the projected demands of canoeists through the year 2000.

Swimming and Ice-Skating There is a deficiency of both swimming and ice-skating opportunities within the region. It is estimated that only sixty percent of the needed swimming acreage is currently available, while only seventeen percent of the needed ice-skating facilities are available. These shortages are projected to continue through the year 2000.

Fishing The quality of the fisheries habitat is indicated in Figure 208. The streams generally have good aquatic habitat, the best being located on Laughery Creek and the Ohio River. The Ohio River supports a good warmwater fish population that is used for sport and commercial fishing. The McAlpine and Markland dams on the Ohio River increase the elevation of water in the tributaries, creating excellent habitat. During dry seasons, low flows limit the fisheries resource. Faster-flowing streams, such as Middle Fork, Graham, Big, and Grant Creeks are well known for good smallmouth bass and crappie fishing. Other streams support populations of sunfish, catfish, and various rough and forage fish. The pools and riffles caused by the rocky beds of upland streams increases their importance for fish production.

Although there are no natural public lakes in the region, several of the man-made lakes provide good aquatic habitat. Fisheries in the Versailles Lake and the Batesville Reservoirs are managed by the Indiana Department of Natural Resources. Feller Lake has a well-balanced warmwater fishery, whereas Bischoff and Liberty Park Lakes are rated lower for their aquatic habitats.

Public access is available at Laughery Creek, the Batesville Reservoirs, and Versailles Lake. The U.S. Army Corps of Engineers maintains public access sites to the Ohio River at Vevay, Patriot, and Bryants Creek. A Kentucky fishing license is required for boat fishing on the Ohio River. Other fishery access may be

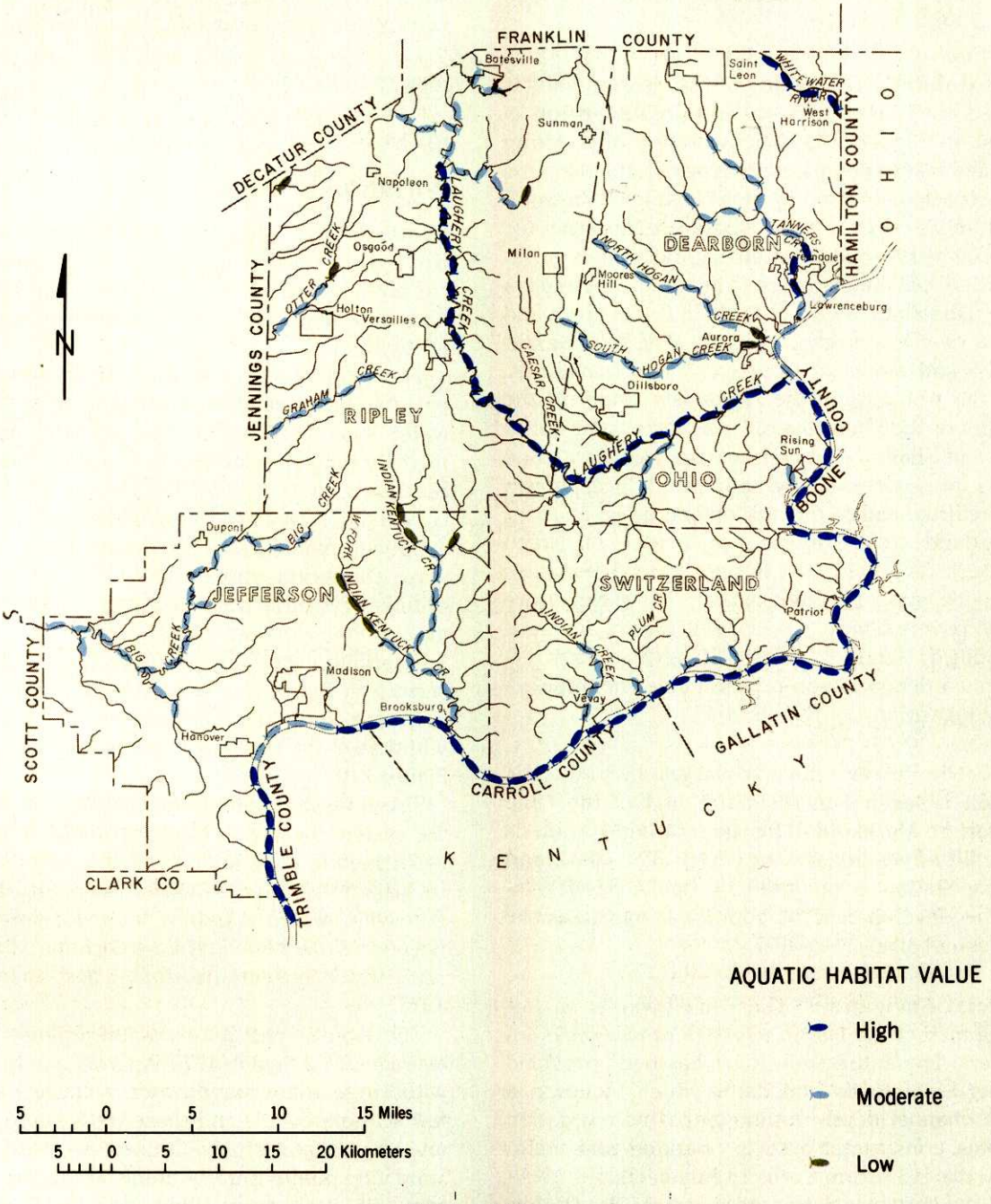


Figure 208
Map of Region Twelve showing the quality of the fisheries habitat.

provided by local governments and where roads cross surface streams.

The supply of public fishing waters exceeds the demand and is projected to exceed the demand through the year 2000.

Riparian Habitat The quality of the riparian habitat associated with lakes and streams in the region is indicated in Figure 209. The wooded hills along streams and lakes support many types of upland game and are occasionally used by waterfowl such as wood ducks. Laughery Creek is especially notable for stretches of very good riparian habitat that is vegetated with trees and shrubs. The poorest riparian habitat occurs along the Ohio River in urban areas and where the river has eroded its banks. The best habitat is to be found along small streams and tributaries. Most of the wetlands in the region are found in the backwaters of the Ohio River. These deepwater shrub swamps and shallower marshes offer abundant food and cover for waterfowl, especially wood ducks, muskrats, shorebirds, and frequently upland game animals. Small wetland areas can also be located on North Hogan Creek. The Batesville Reservoirs and Versailles Lake provide good riparian habitat. Their banks are primarily covered with woody vegetation. Because public hunting lands in Region Twelve are scarce, hunters must depend upon private landowners for access to hunt within the region.

Hydroelectric Power Indiana's largest hydroelectric installation is located in the north end of the Ohio River Dam at Markland. This generating station is rated at fifty-five megawatts (mw). The Markland Generating Station is operated by Public Service Indiana. The development of additional hydroelectric facilities is not likely.

Commercial Navigation The Ohio River is an important branch of the nation's system of navigable, inland waters. The entire Ohio River has been provided with a series of locks and dams which maintain a minimum channel depth of nine feet. This navigation system was constructed and is operated and maintained by the U.S. Army Corps of Engineers.

One of the large navigation dams across the Ohio is located at Markland in Switzerland County. This structure was completed in 1964 and passed an estimated thirty million tons of cargo in 1975. Below the Kentucky River (opposite Lamb in Switzerland County) the Ohio River carried about thirty-five million tons of cargo in 1975.

Many Ohio River communities have some port facilities on the river bank. Such port facilities are found in Madison, Vevay, Aurora, and Lawrenceburg.

Studies by the Ohio River Basin Commission show that the Markland locks and dam should be adequate to carry projected cargoes of eighty million tons by the year 2000. There are three key components of the Ohio River system outside the region which affect the overall system efficiency and, therefore, the future volume of traffic on the waterway. These are the locks on the dam at Gallipolis upriver and the two older dams (locks 52 and 53) downriver in Illinois.

Withdrawal Uses

Public Water Supplies Dearborn, Jefferson, Ohio, Ripley, and Switzerland Counties are served by twenty-nine public water utilities. In 1975, an estimated 62,900 persons were served by a public water utility.

These public water utilities are classified as municipal utilities, supplying adjacent rural areas, and rural water systems. The utilities serving only their immediate municipal areas are Madison, Batesville, Lawrenceburg, Vevay, Versailles, Milan, Osgood, Sunman, Greendale, Rising Sun, and West Harrison. The utilities supplying municipal and adjacent rural areas are Aurora, Dillsboro, and Patriot. The remaining fifteen utilities are rural water systems. These systems provide service along most of the rural roads in Dearborn, Switzerland, Ohio and Jefferson Counties. Rural water service in Ripley County is limited to the eastern and southern sections. The service areas and rates of withdrawal for the public water utilities are shown in Figure 210.

The largest water utility operating in the region is the system located in Madison. It withdrew an average of 2.1 mgd in 1975, and supplied an additional 0.4 mgd to adjacent utilities. Other large utilities include Batesville, which withdrew 0.8 mgd; Aurora, 0.7 mgd; Greendale, 0.6 mgd; and Lawrenceburg, 0.5 mgd. Most rural water systems distributed less than 0.2 mgd in 1975.

The twenty-nine public water utilities pumped an average of 7.5 mgd in 1975. Approximately 6.4 mgd was withdrawn from ground water. With the exception of a few scattered wells and those wells supplying Sunman and Osgood in Ripley County, all production wells supplying public water systems are located in the narrow belt of alluvium along the Ohio River. Sunman's water supply is obtained from a local geological anomaly in the form of a "sand pocket" which has been tapped to furnish a reasonably productive well field.

Systems utilizing ground water radiate from the Ohio River and up the hills to the north and west. Ground-water sources along the Ohio River have not been utilized to any extent in Ripley County because the population is too small to support the cost of new, long diameter supply lines.

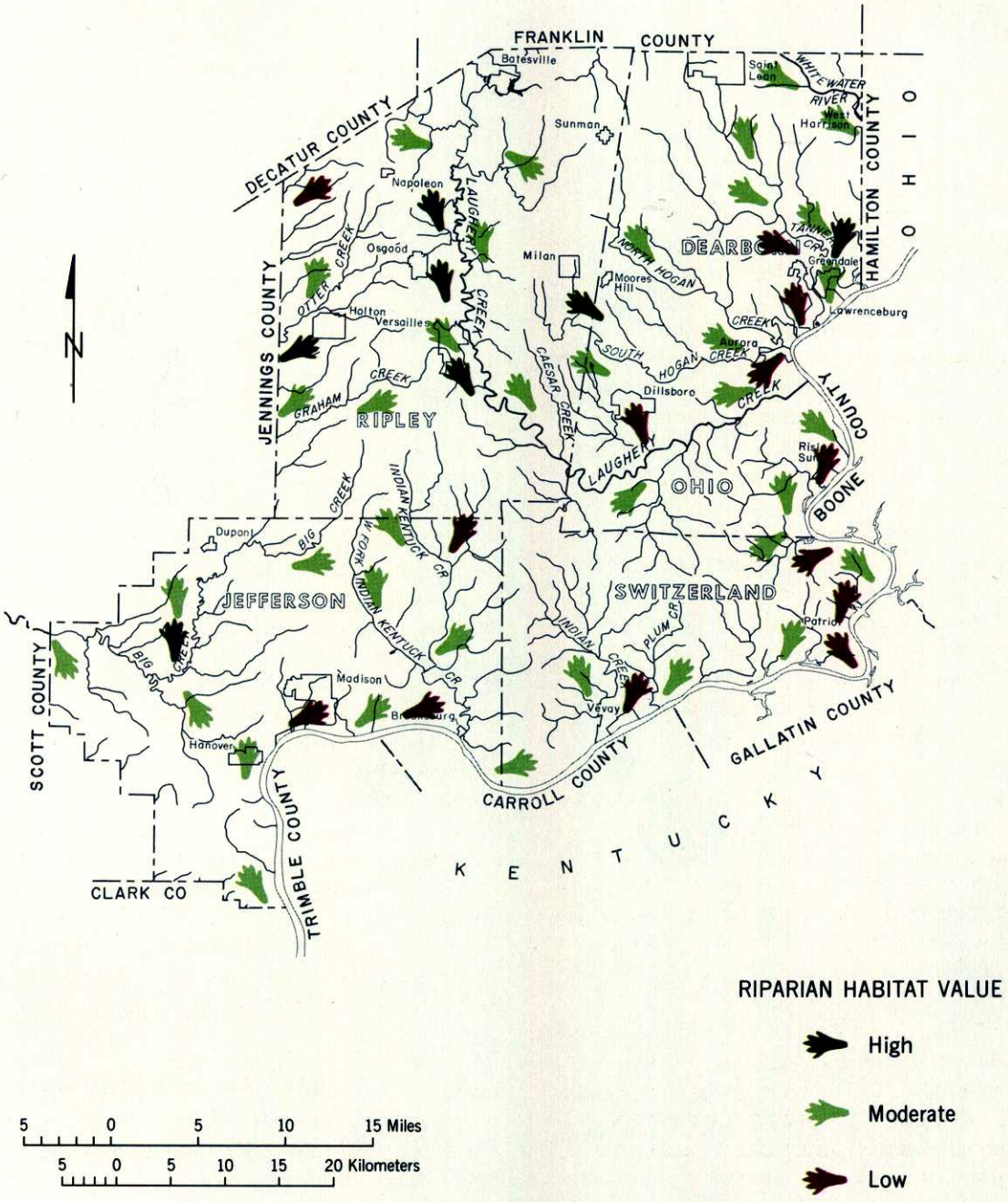


Figure 209
Map of Region Twelve showing the quality of the riparian habitat.

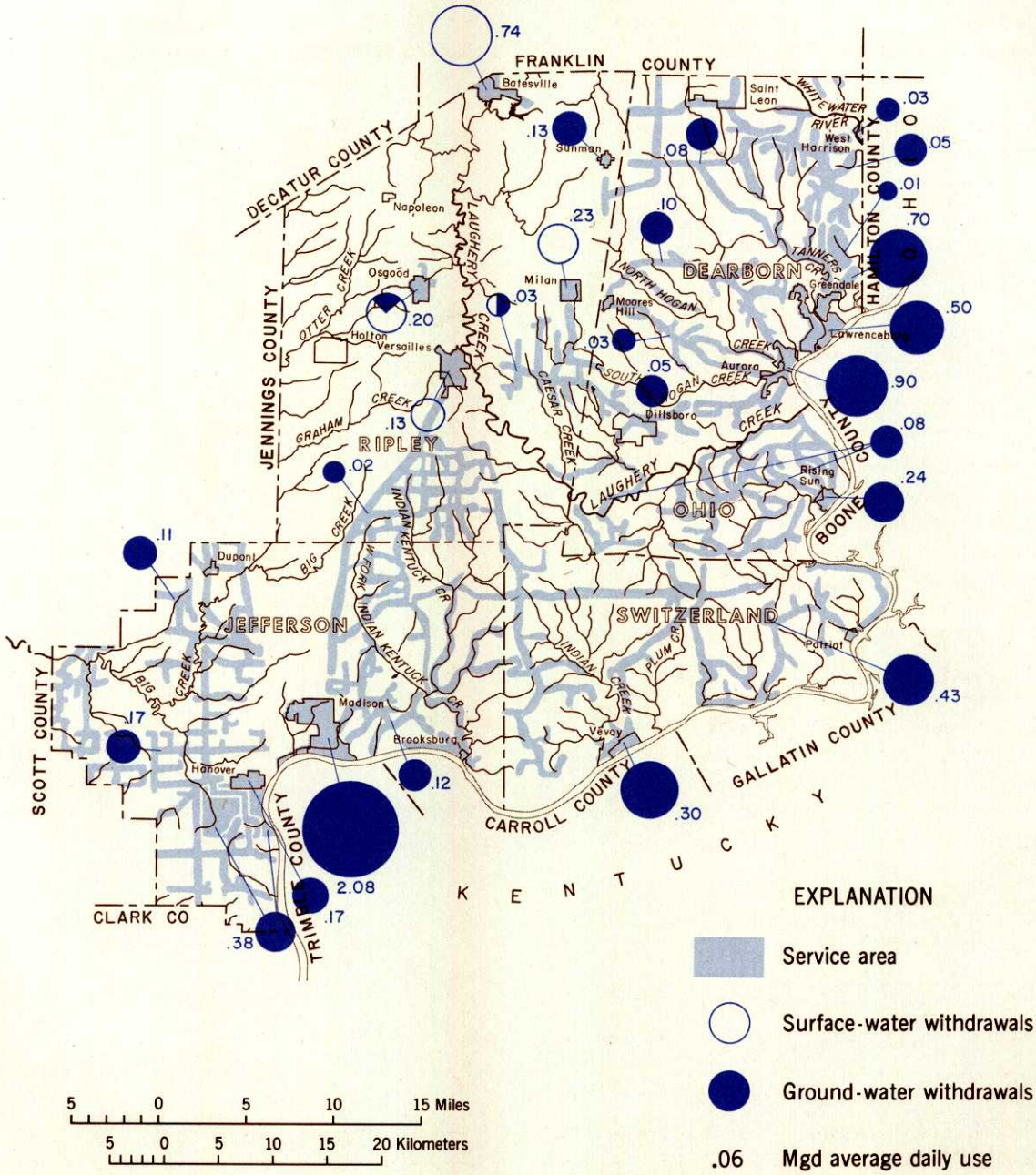


Figure 210
Map of Region Twelve showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Projections of public water utilities indicate that withdrawals for water supplies should increase to approximately 11.6 mgd by the year 2000. The 1977 and projected water withdrawal and consumption rates by public water utilities are shown below.

Table 166
The 1977 and projected withdrawal and consumption rates for public water supplies by the year 2000, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	7.5	7.9	9.7	11.6
Consumption	2.2	2.4	2.9	3.5

Industrial Water Industrial establishments had a water intake averaging 8.2 mgd in 1977. Of the total industrial intake, over sixty percent is purchased from the region's public water utilities, while the remainder is developed by the industries themselves. Usually, self-supplied industries obtain their water from wells in the Ohio River alluvium.

Industrial production for the year 2000 is expected to increase ninety percent above the 1977 value (U.S. Water Resources Council). Although industrial output is expected to increase, total industrial water intake is expected to decrease initially due to plant efficiency and then rise slowly as output increases. Water withdrawals are expected to increase by only six percent to approximately 8.7 mgd, by the year 2000. Data for the current and projected industrial self-supplied water withdrawals and rates of consumption is now presented.

Table 167
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	3.2	3.2	3.1	3.1
Consumption	0.3	0.3	0.4	0.5

Rural Self-Supplied Water Most rural, self-supplied water is withdrawn from ground-water sources. An estimated 29,300 persons lived in homes supplied by individual wells in 1975.

Within the five-county region, 13,600 of these persons lived in Ripley County, 10,500 in Dearborn County, 3,300 in Jefferson County, 900 in Switzerland County, and 1,500 in Ohio County. It is estimated that 2.5 mgd was withdrawn for residential purposes in 1975. By the year 2000, rural water systems are expected to expand, resulting in a ten percent decrease in rural, self-supplied water for residential demands.

In 1975 an estimated 190,000 head of livestock and 508,000 chickens consumed 1.6 mgd of self-supplied, rural water. A slight increase in water withdrawals is expected for these animals by the year 2000. Much of this water is withdrawn from farm ponds.

The total rural, self-supplied water withdrawals are expected to remain constant at approximately 4.1 mgd through the year 2000.

Table 168
The 1977 and projected withdrawal and consumption rates for rural, self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	4.1	4.1	4.1	4.1
Consumption	4.1	4.1	4.1	4.1

Irrigation Water Region Twelve contains a few soil associations that would profitably respond to irrigation. As a consequence only an estimated sixty-four acres are currently irrigated. Crops irrigated include vegetables and tobacco.

Assuming 1977 as a normal growing year, the vegetables and tobacco irrigated would have required about 0.2 mgd during the "average" irrigation season of July and August.

In addition to the irrigation for agricultural use, there are about 100 acres of irrigated fairways and greens on the region's golf courses. About 1.2 mgd is applied to these areas during the peak July–August irrigation season. It is estimated that irrigation withdrawals for both cropland and golf courses will increase to 0.7 mgd by the year 2000 as presented in the following table.

Table 169
The 1977 and projected withdrawals of irrigation water for croplands and golf courses, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.3	0.4	0.5	0.7
Consumption	0.3	0.4	0.5	0.7

Electric Energy The region contains two fossil-fueled electric generating plants and one hydroelectric plant. The fossil-fueled plants are Clifty Creek at Madison, which is owned and operated by the Indiana-Kentucky Electric Corporation, and the Tanners Creek Generating Station at Lawrenceburg, which is owned and operated by the Indiana and Michigan Electric Company. Both of these plants employ once-through cooling. No significant water withdrawals are required by the hydroelectric plant, located at Markland Dam.

There are two additional plants located immediately outside the boundaries of the region on the Ohio River. One of these plants, Miami Fort, is in Ohio, slightly upstream of the Indiana–Ohio state line. It is

owned and operated by the Cincinnati Gas and Electric Company. The Ghent plant is located in Kentucky, across the Ohio River from Vevay Indiana. It is owned and operated by the Louisville Gas and Electric Company.

Clifty Creek was the largest generating facility in Indiana for a number of years. It is rated at 1,304 mw. The energy generated in this plant is used in a nuclear processing facility in Pike County, Ohio. The Tanners Creek Station is rated at 1,066 mw and serves the areas of Fort Wayne, South Bend, Marion, and Muncie.

The generating capacity of the two fossil-fueled plants within the region, and that of the two plants immediately outside the region boundaries, totals 4,489 mw. The hydroelectric plant adds 55 mw to this capacity.

The Indianapolis Power and Light Company has announced plans for the construction of a major new generating station on the Ohio River just upstream from Patriot in an area known as the Mexico Bottoms. The station will be known as the Patriot Generating Station and will be rated at 1,950 mw. The cooling-water cycle will use mechanical draft cooling towers with make-up water withdrawn from the Ohio River.

Public Service Indiana plans to construct the Marble Hill nuclear plant along the Ohio River in Jefferson County, downstream from Madison. The planned capacity of 2,380 mw is expected to consume thirty-six mgd from the Ohio River.

The Cincinnati Gas & Electric Company has announced plans for the construction of another large plant on the Kentucky shore at East Vend, across and just upstream from the Patriot Station. In addition, the Louisville Gas & Electric Company plans to build a new plant in Kentucky across from the Jefferson–Clark County Line to be known as the Trimble County Station. The American Electric Power Company has another site across from Madison under consideration for development as an electric generating facility.

Water withdrawals for energy in the region during 1977 were approximately 2,547 mgd, but they are expected to decrease to 689 mgd by the year 2000, as shown below.

Table 170
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	2,547.0	2,547.0	2,675.0	689.5
Consumption	0	0	62.0	62.0

EXCESS WATER

Flooding

Approximately 7,000 acres of the region, or about one percent of the total area, are subject to flooding. The major flood plains are shown in Figure 211. Figure 212 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be over $750,000.

Virtually all of the streams in Region Twelve are subject to flooding. Flash flooding on streams in the area is commonly due to the steepness of the slope on tributaries of the Ohio River. The Ohio River is the major watershed in the region. It is subject to long flood durations.

Flood Control The city of Lawrenceburg is protected by a major levee. This project was constructed in cooperation with the U.S. Army Corps of Engineers. It protects the city of Lawrenceburg against a flood equal in magnitude to that of January 1937 on the Ohio River.

The federal government had at one time authorized the construction of levees at Rising Sun, Vevay, Patriot, and Madison, but all of these projects were eventually judged as economically infeasible. In the early 1970s, the U.S. Army Corps of Engineers was asked to investigate an extension to the Lawrenceburg floodwall in order to provide protection for a proposed industrial park. That extension was also found to be infeasible.

In addition to the protective works at Lawrenceburg, the U.S. Army Corps of Engineers has constructed fifty-six major reservoirs on tributaries of the Ohio River upstream from Region Twelve. These dams reduce, but do not eliminate, flooding problems on the river. In addition to these federal dams, several large floodwater-retarding dams in the Miami River basin provide a minor degree of flood protection on the Ohio River.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include all the unincorporated areas of the five counties as well as Brooksburg in Jefferson County; Greendale, Lawrenceburg, and West Harrison in Dearborn County; Rising Sun in Ohio County; and Patriot and Vevay in Switzerland County. Aurora in Dearborn County and Hanover and Madison in Jefferson County are participating in the regular phase of the program. Residents in these areas may purchase insurance against property losses due to flooding.

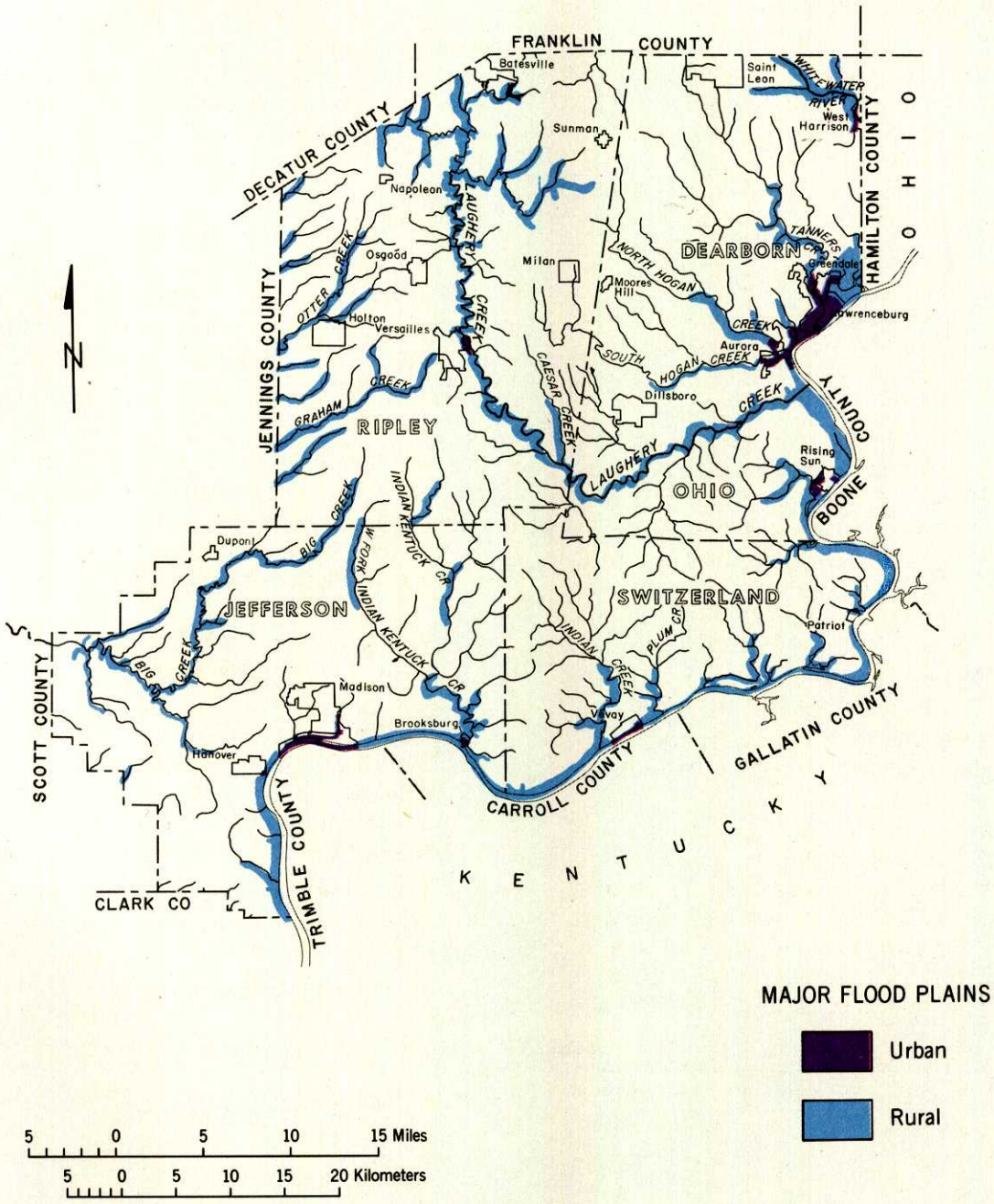


Figure 211
Map of Region Twelve showing the major flood plains.

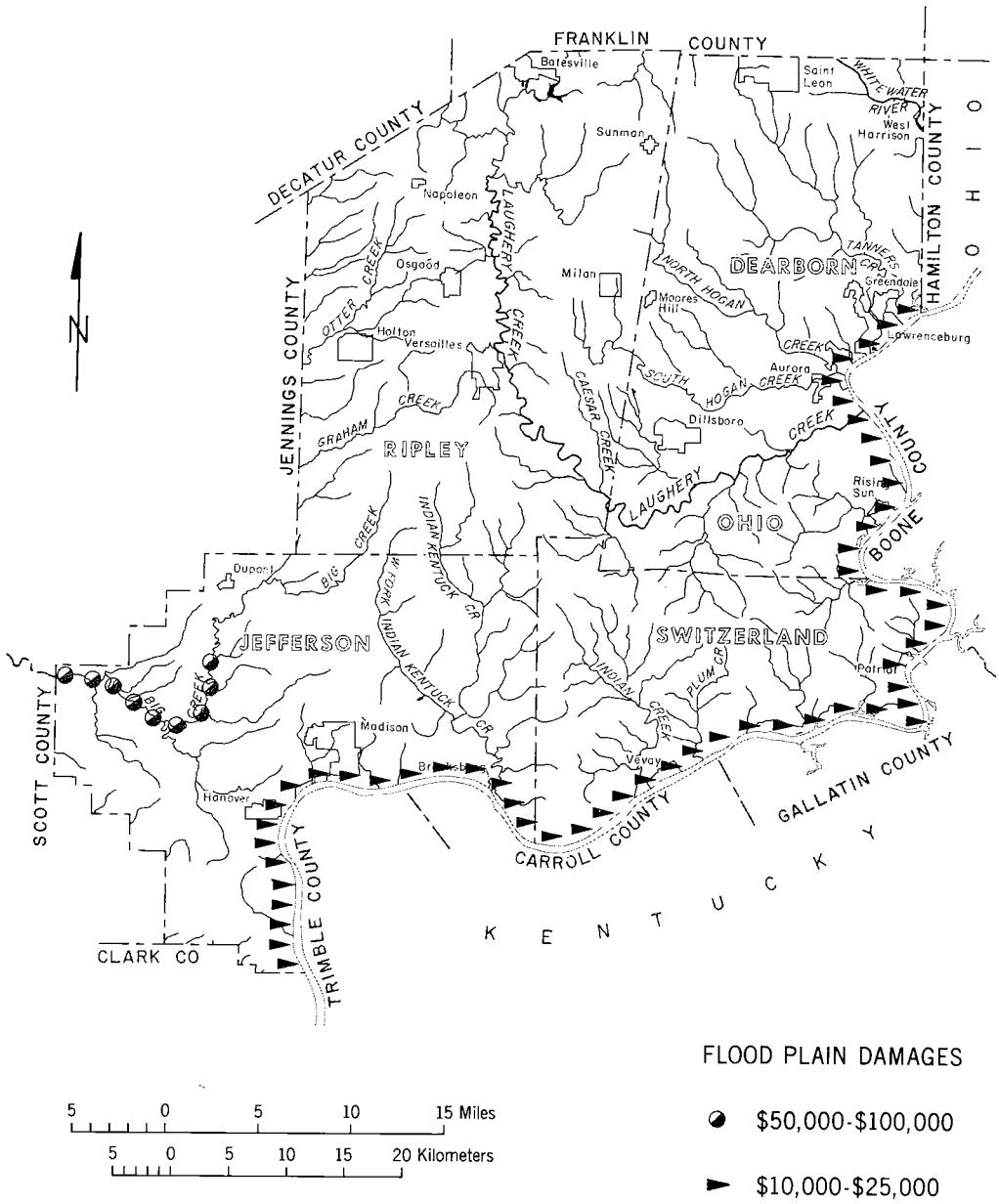


Figure 212
Map of Region Twelve showing the estimated average annual flood damages per mile along selected streams.

Agricultural Drainage

Approximately twenty percent of the soil associations in the region have "severe," two percent have "moderate," while seventy-eight percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics are shown in Figure 213.

There are only twelve miles of legal drains in the region which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of these systems of legal drains is the responsibility of the local county drainage boards or, in a limited number of cases, of conservancy districts.

Soil Erosion

The erosion potential of soil associations are shown in Figure 214. Forty-eight percent of the region is rated as having a "high" potential hazard. These areas need a good protective cover of trees and grasslands. Vegetative cover is extremely difficult to reestablish on the severely eroded sites. Twenty-four percent of the area has a "medium" potential and the remaining four percent is classified as having a "low" erosion hazard potential for land left in a fallow state.

WATER QUALITY

The surface streams within Region Twelve routinely surveyed for water quality by the Indiana State Board of Health are the Ohio River and Laughery Creek. Water quality standards are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

Water samples from Laughery Creek indicate the concentration of dissolved oxygen, and pH values were in compliance with state regulations.

Water quality conditions of the Ohio River at Markland in 1977 indicated that dissolved oxygen, temperature, and pH values were in compliance with state standards.

Five fish kills have been recorded between 1974 and 1977. Three have occurred in Ripley County, two near Batesville in Little Laughery Creek and one near Sunman in Ripley Creek. One of the fish kills in Little Laughery Creek was caused by an industrial spill and the cause of the other was not determined. The fish kill in Ripley Creek was caused from inadequate sewage treatment. An undetermined number of fish were killed in each of these occurrences. Another fish kill occurred in Tanner's Creek near Lawrenceburg in Dearborn County, but the cause and numbers of fish killed were not determined. The other fish kill occurred in Harbert's Creek near Wirts in Jefferson County. Approximately one hundred fish were killed by an unknown cause.

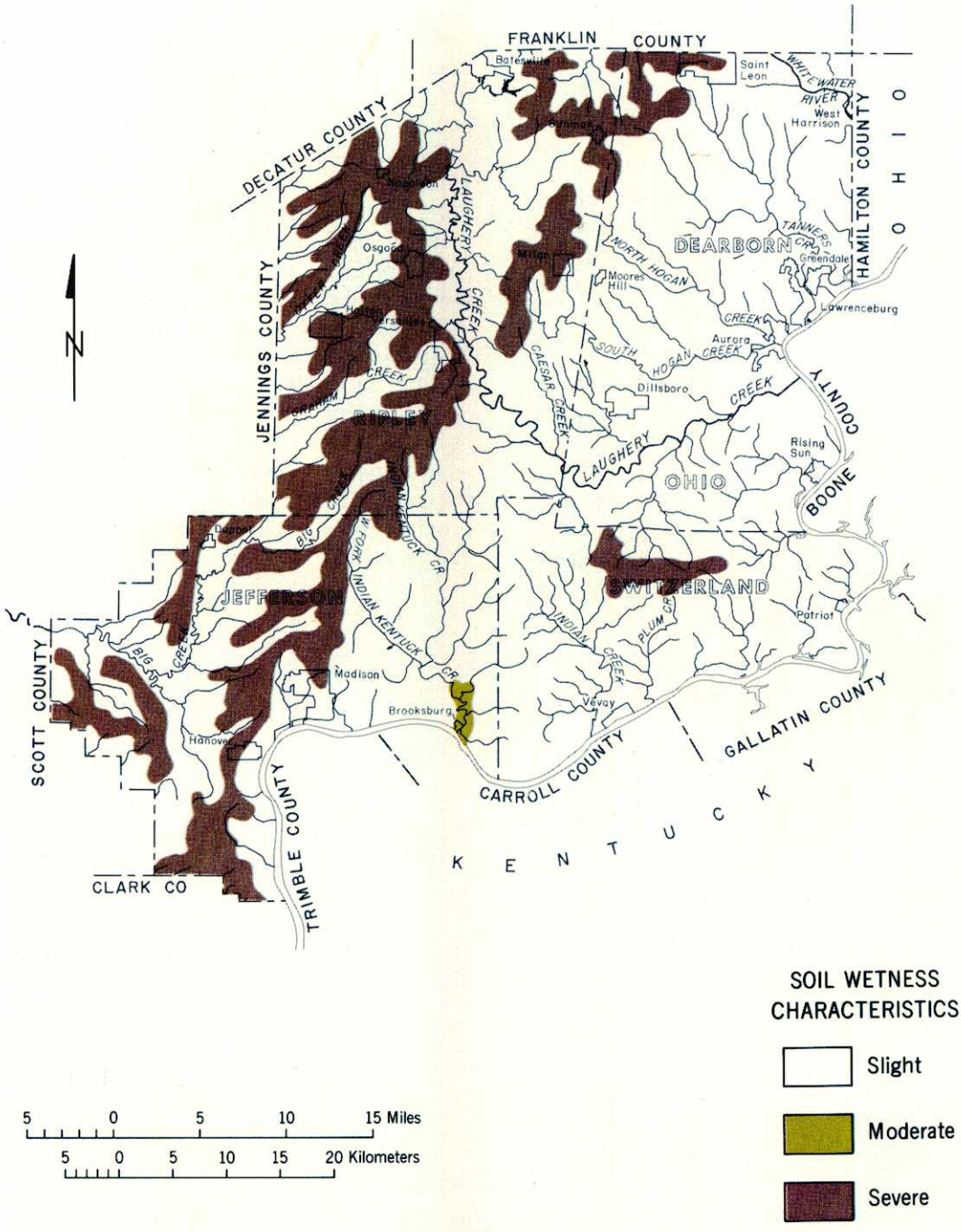


Figure 213
Map of Region Twelve showing the location of the wetness characteristics of soil associations.

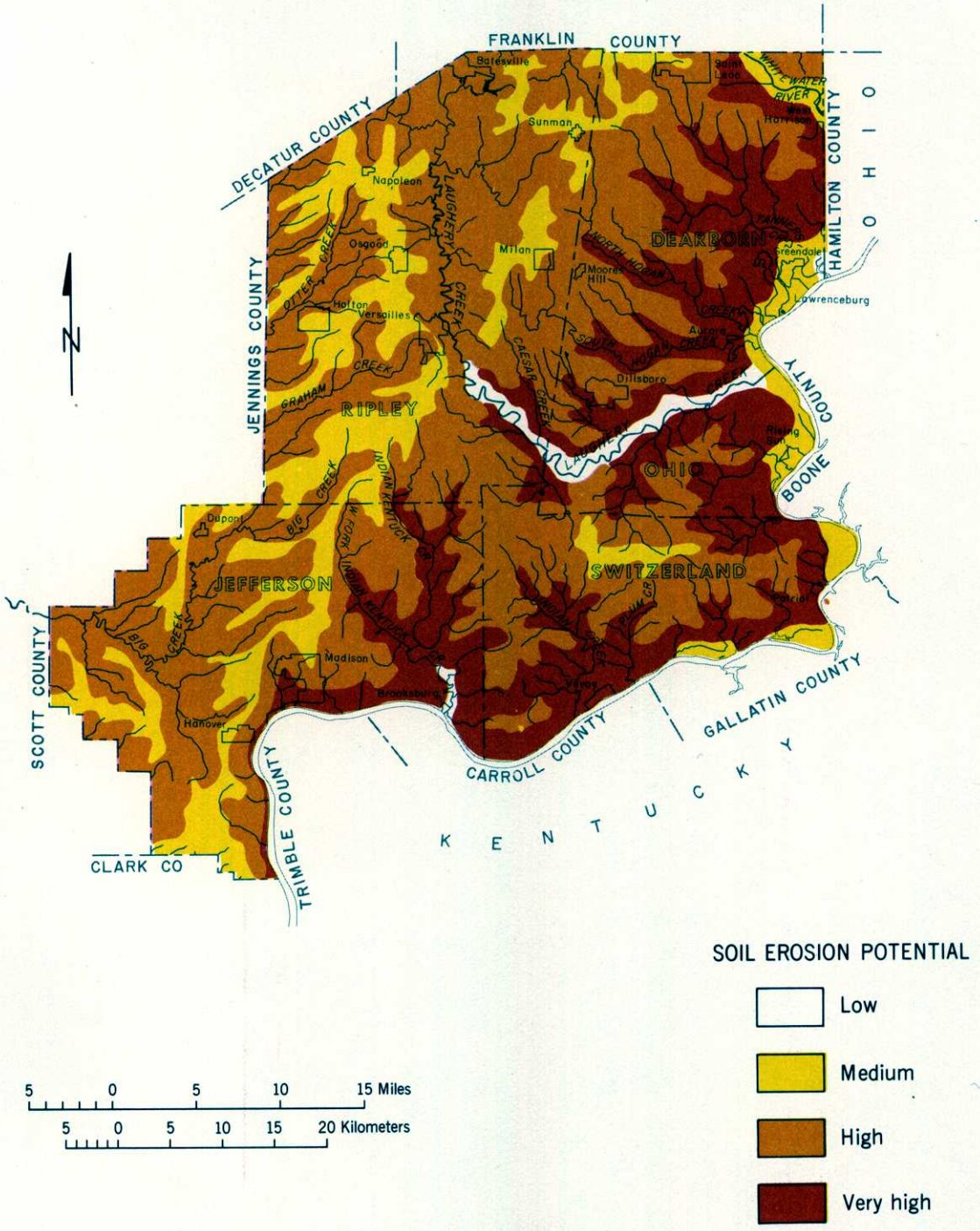


Figure 214
Map of Region Twelve showing the erosion potential of the soil associations.

Region Thirteen-A

Daviess, Greene, Knox, Lawrence, and Martin Counties located in southwestern Indiana form Region Thirteen-A. The region contains approximately 2,300 square miles and is bounded by Sullivan, Clay, Owen, and Monroe Counties to the north; Jackson and Washington Counties to the east; Orange, Dubois, Pike, and Gibson Counties to the south; and Illinois to the west, as shown in Figure 215.

The population in 1975 was 145,721, with fifty-five percent residing in Knox and Lawrence Counties. The official Indiana County Population Projections indicate the region's population may increase eleven percent, by the year 2000, with the major growth occurring in Lawrence County. The 1975 population and projections by county are presented below.

Table 171
The 1975 and projected populations for Region Thirteen-A.

County	*1975*	*1980*	*1990*	*2000*
Daviess	26,127	27,200	27,600	27,500
Greene	28,156	29,700	32,500	35,600
Knox	39,943	40,200	38,500	36,600
Lawrence	40,377	44,200	49,400	53,800
Martin	11,118	11,100	11,000	10,700
Total	145,721	152,400	159,000	164,200

The major population centers are Washington in Daviess County, Linton in Greene County, Vincennes in Knox County, and Bedford in Lawrence County. These urban centers accounted for thirty-six percent of the region's 1975 population.

Agriculture is the dominant land use with more than sixty-one percent of the area devoted to farming.

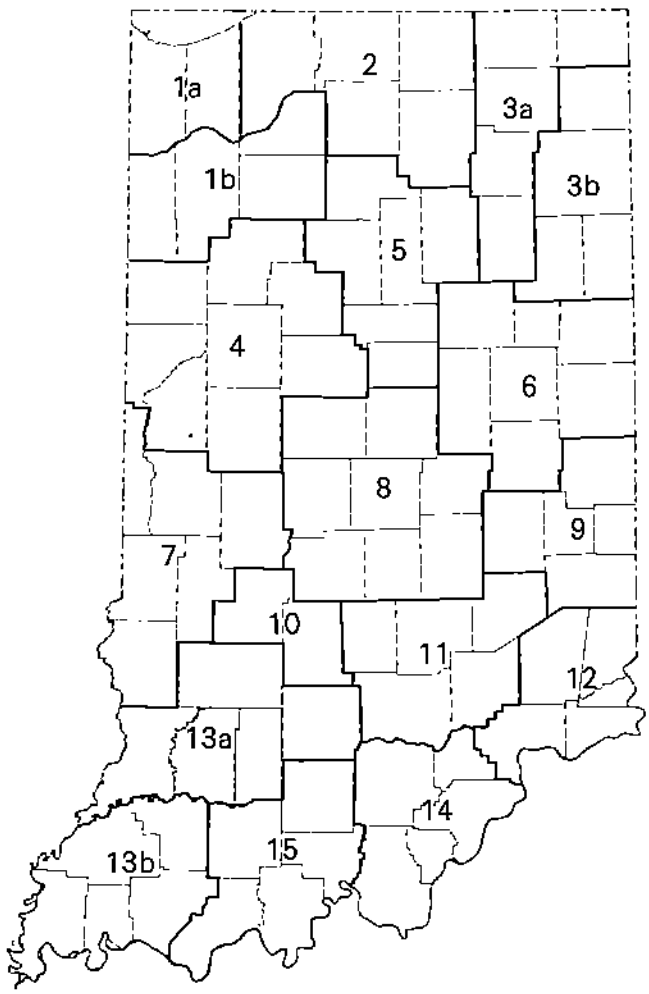


Figure 215
Map of Indiana showing the location of Region Thirteen-A.

Approximately twenty-five percent of the land is forested while the remaining fourteen percent represents urban and miscellaneous uses.

Although agriculture is by far the major land use, it is not the major source of employment. Manufacturing employs over thirty-seven percent of the work force, and wholesale and retail trade employs nearly thirty-six percent.

Average annual precipitation for the region is approximately 43.0 inches, with average monthly values ranging from a high of 4.7 inches in June to a low of 2.5 inches in October. Of the 43.0 inches of annual precipitation, approximately 29.0 inches are consumed through evapotranspiration. Average temperatures range from 31°F. in January to 77°F. in July. The average annual temperature is 55°F. Prevailing winds are from the southwest at 9 miles per hour.

THE WATER RESOURCE

Ground Water

The unconsolidated deposits found in Region Thirteen-A include weathered bedrock residuum, lake clays, wind-blown silt and sand, and outwash sand and gravel. Illinoian age glacial drift occurs in Knox, Daviess, and western Greene Counties. In other unglaciated areas there is very little cover over the underlying bedrock. Extensive sand and gravel deposits associated with the Wabash and White Rivers represent the most significant glacial aquifer within the region.

The bedrock formations are composed of Pennsylvanian sandstones, shales, limestones, and coals in Knox, Daviess, and the western portions of Martin and Greene Counties, while Mississippian age limestones, shales, and sandstones occur in Lawrence County and western Martin and Greene Counties. In general, the bedrock is of low permeability and is not a significant source of ground water.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. There is a pronounced variability in ground-water occurrence in the region, as shown in Figure 216 (page 395).

In general the valleys of the Wabash, East Fork, West Fork, and main stem of the White River contain thick deposits of sand and gravel capable of yielding over 1,000 gallons-per-minute (gpm) to properly constructed wells. Away from the major stream valleys, well yields are generally less than fifty gpm, and in most of the region well yields of less than ten gpm are possible from a fine sand deposit located in a buried valley north and east of Vincennes. Up to fifty gpm may be produced from fine sand and lake deposits in southwestern Greene County.

The quality of ground water is normally acceptable for most domestic, municipal, and commercial uses. Hardness levels range from 40 to 490 parts-per-million (ppm) with locally soft water being associated with deeper wells in the Pennsylvanian sandstone aquifers. The Pennsylvanian rocks also produce "soda water" in portions of Daviess and Greene Counties. Iron concentrations range from 0.1 to 7.3 ppm. The higher iron concentrations are associated with the aquifers bordering the West Fork of the White River through Greene, Knox, and Daviess Counties. The areas of low iron and manganese concentrations are located along the Wabash River in Knox County.

Surface Water

Streamflow The Wabash, White, and East Fork of the White River form the boundaries of portions of three of the five counties composing Region Thirteen-A. These streams, in addition to the Eel, Salt Creek, and West Fork White River, are the major drainage ways in the region and are served by a multitude of radiating tributary streams which extend into the strongly dissected upland areas. These stream systems drain in a southwesterly direction into the Wabash River basin.

The seven day, once in ten year (Q7-10), one day, once in thirty year (Q1-30), and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations within the region are presented in Table 172.

The low-flow characteristics indicate that the largest and most reliable streamflows are those in the Wabash and White Rivers. The one day, once in thirty year low flows for the Wabash River at Vincennes reveal that the river will have a sustained flow of at least 580 mgd, while the average annual flow exceeds 7,000 mgd.

The flow duration curve for the East Fork of the White River near Bedford has a minimal slope, as shown in Figure 217. The curve indicates that the stream will have a dependable flow of 280 mgd ninety

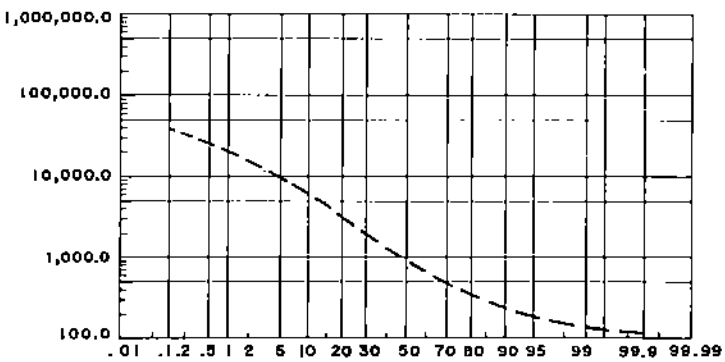


Figure 217
The flow duration curve for the East Fork of the White River near Bedford.

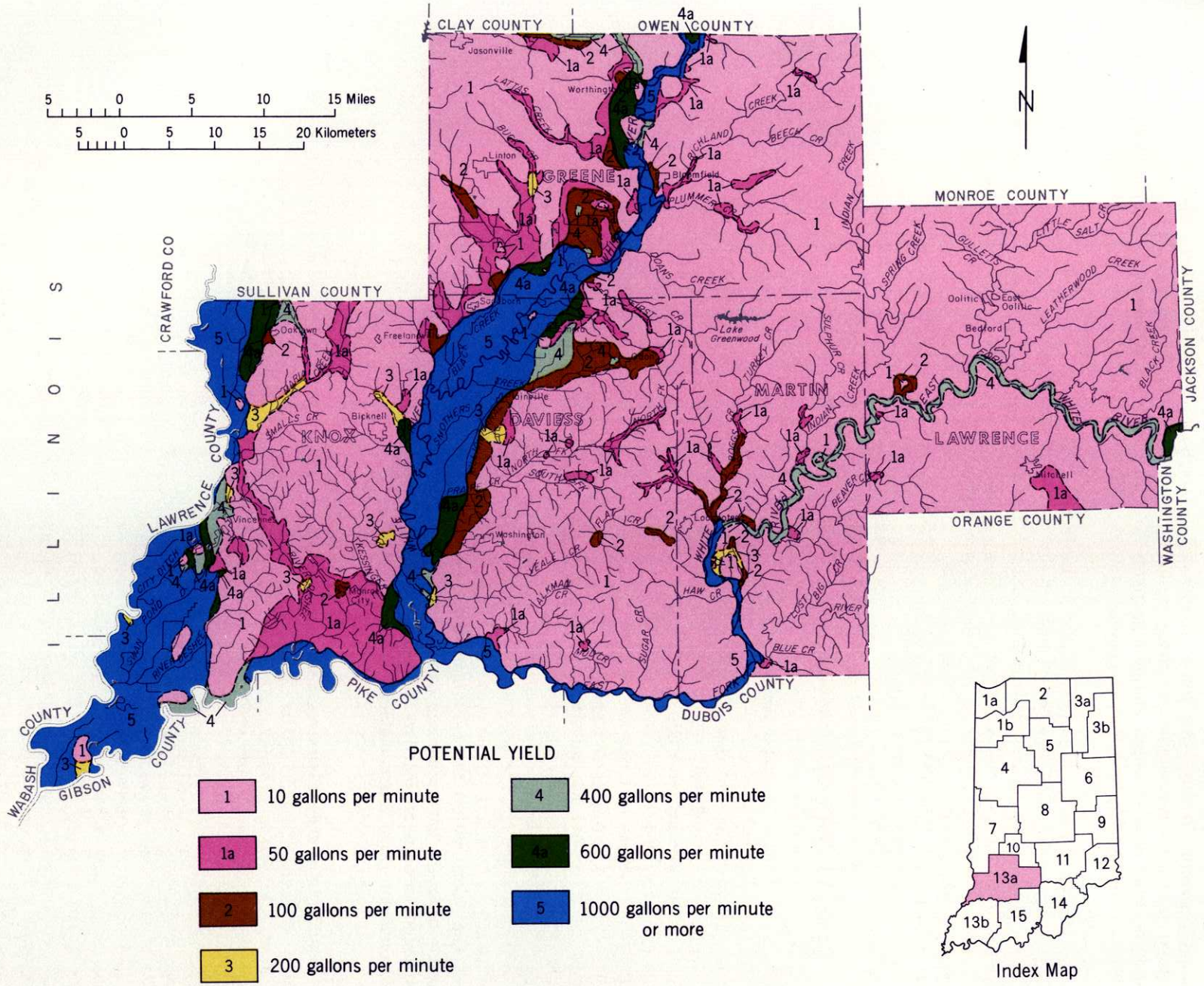


Figure 216

Map of Region Thirteen-A showing the location and potential yield of ground water from properly constructed large diameter wells.

percent of the time. The slope also indicates that the East Fork of the White River drainage basin contains aquifers which provide significant ground-water contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs at the Bedford gaging station, representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to thirty-six, thirty-six, and twenty-eight percent for dry, average, and wet years, respectively. Conversely, from sixty-four to seventy-two percent of the flow, depending on the year, is due directly to surface runoff from runoff-producing precipitation events or from snowmelt.

Table 172
Flow characteristics of streams within Region Thirteen-A.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
East Fork River at Shoals	4,927	3,400	160.0	76.0
West Fork River at Newberry	4,688	2,900	204.0	160.0
White River at Petersburg	11,125	7,300	490.0	370.0
Wabash River at Vincennes	13,706	7,400	760.0	580.0
Salt Creek near Peerless	573	420	1.0	0.4
Indian Creek near Trinity Springs*	172	31	0.1	na
Prairie Creek near Washington*	120	10	0.06	na
Richland Creek near Bloomfield*	954	15	0.32	na
Maria Creek near Emison*	88	10	0.19	na
East Fork of the White River near Bedford	3,861	2,300	160.0	102.0

*Flow characteristics estimated from stream gaging stations with short periods of record.
na: not available.

Lakes The lakes within the region are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are listed in Table 173, and are located on Figure 218. These eighteen lakes have a combined surface area of approximately 3,325 acres and a gross storage capacity of approximately 20,900 million gallons.

Table 173
Lakes at least 50.0 acres in size or having a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Beechwood Lake	na	18.0	130
2	Lake Lenape	1.69	60.3	107
3	Moses Lake	0.95	29.9	224
4	Singer Ditch Lake	4.40	78.0	107
5	White Oak Lake	na	25.5	65
6	Dogwood Lake	13.90	1,313.0	6,647
7	Montgomery Lake	0.44	24.0	62
8	Prairie Creek Structure No. A-2-3	3.80	55.3	47
9	Prairie Creek Structure No. A-4-1	13.20	61.6	128
10	Prairie Creek Structure No. B-2-1	1.98	31.0	88

Table 173 (continued)

Lake Number	Lake Name	Drainage Area (square miles)	Surface Area (acres)	Gross Storage (million gallons)
11	Prairie Creek Structure No. B-4-7	12.80	101.0	117
12	Boggs Creek Lake	na	na	62
13	Greenwood Lake	na	na	7,299
14	Lake Greenwood	14.80	829.0	2,606
15	Seed Tick Lake	na	na	66
16	West Boggs Creek Lake	13.30	622.0	2,531
17	Ken-Ray Lake	1.88	74.0	544
18	Spring Mill Park Lake	na	27.6	74

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of the region are presented in Table 174. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Boating and Waterskiing Portions of the Wabash River and East and West Forks of the White River are used for boating and waterskiing. West Boggs Lake in Daviess County and Lake Sullivan in Knox County, and some of Greene County's strip mine lakes are available for boating and waterskiing. The supply of boating and waterskiing opportunities meets the current and projected demand for boating and waterskiing through the year 2000.

Canoeing The Wabash and the East and West Forks of the White River are available for canoeing. Other streams may also be canoed but are not as accessible and may not have a dependable flow. A total of 363 miles of canoeing streams is available in the region, which exceeds the demand for canoeing opportunities. This surplus of supply is expected to continue through the year 2000.

Table 174
The outdoor recreation demand and supply.

Activity	Percent of Population Participating	Density Guideline	Approximate Supply	Existing Supply as a Percentage of Projected Demand		
				1980	1990	2000
Boating	25	19.6 boats/acre/year	11,000 acres	100+	100+	100+
Waterskiing	10	34.4 skiers/acre/year	1,200 acres	80	75	75
Canoeing	4	585 canoes/mile/year	363 miles	100+	100+	100+
Swimming	33	76,600 swimmers/acre/year	9 acres	100	100	90
Ice-Skating	5	6,678 skaters/acre/year	3 acres	33	33	33
Fishing	52	66 persons/acre/year	14,300 acres	64	61	60

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands by residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.

Swimming and Ice-Skating The available supply of swimming opportunities is enough to meet the current and projected demand. The current and projected demand for ice-skating opportunities exceed the available supply.

Fishing The quality of the fisheries habitat is indicated on Figure 219. Larger streams, such as the Wabash River, East and West Fork of the White River, and Indian Creek, have enough diversity of stream bed, sufficient water quality, and vegetation to provide excellent aquatic habitat. The Wabash and White Rivers offer abundant warmwater fisheries for sport fishing

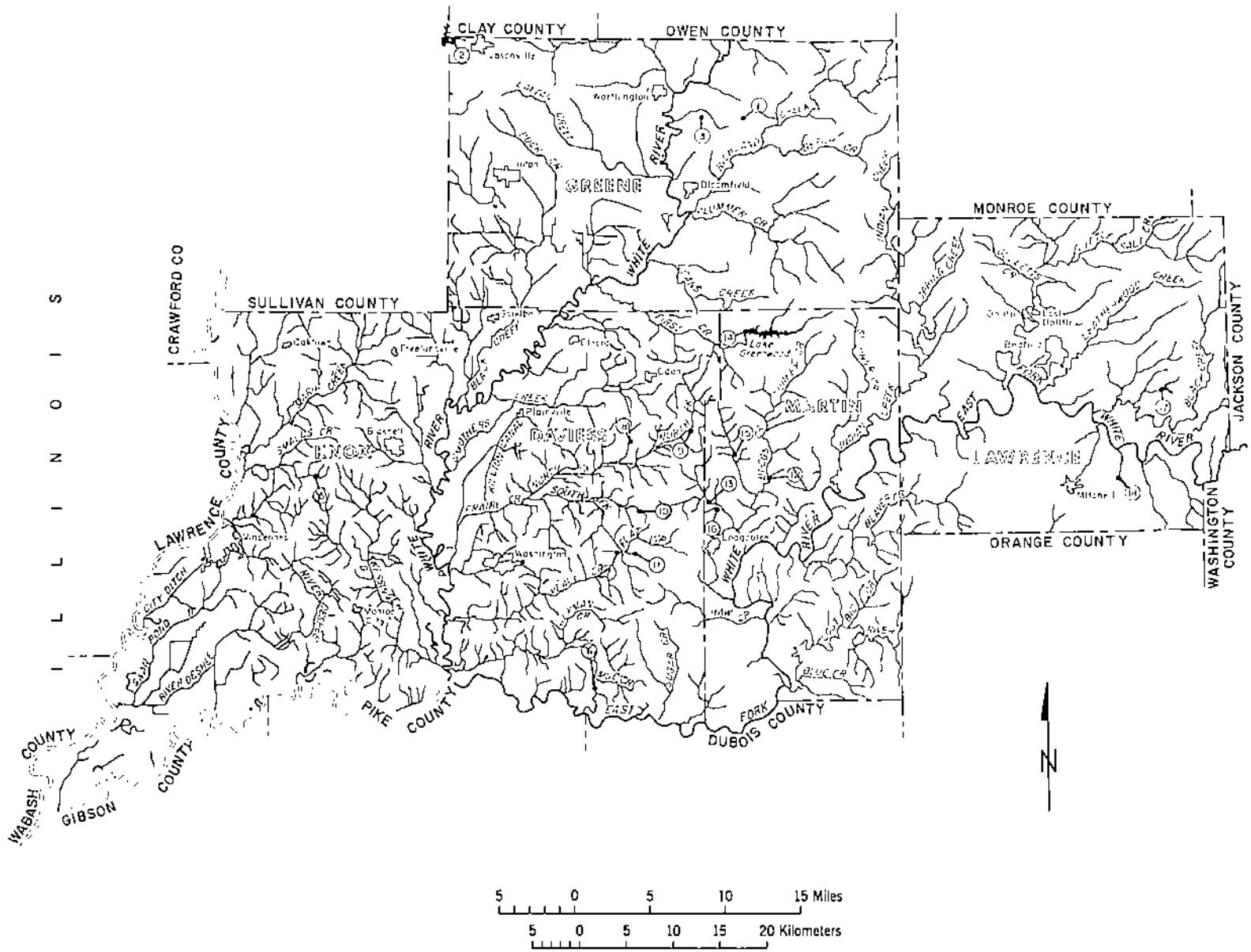


Figure 218
Map of Region Thirteen-A showing the location of lakes that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more.

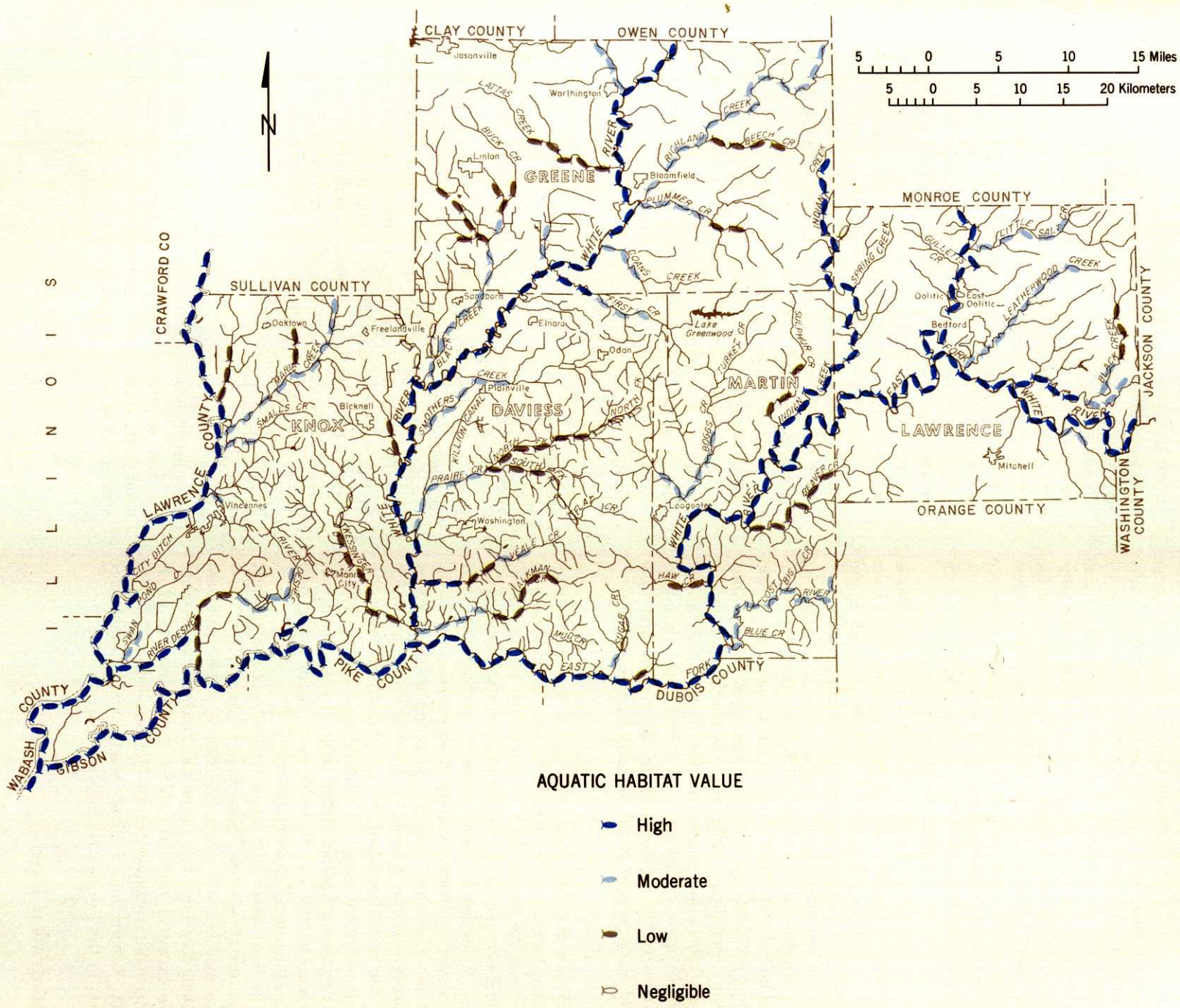


Figure 219
Map of Region Thirteen-A showing the quality of the fisheries habitat.

and commercial fishing. Indian Creek is noted for good smallmouth bass fishing. Aquatic habitat on many smaller streams, such as Lattas Creek in Greene County, has been reduced by channelizatin. Other small streams do not have enough water during dry seasons to support a game fishery.

Except for the oxbow lakes of the White and Wabash Rivers, most lakes in the region are man-made. Dogwood Lake, Spring Mill Lake, West Boggs Lake, and the strip mine lakes of Greene and Sullivan State Forest are known for good fishing. The fish in these lakes are predominantly warmwater species typical of Indiana. Wampler and Graveyard Lakes are stocked with walleye. Airline Pit is stocked with trout.

Public access to the West Fork of the White River is provided in Daviess and Greene Counties and to the East Fork of the White River in Daviess, Lawrence, and Martin Counties. Access to the Wabash River is provided in Vincennes. State-owned access for lake fishing is available in Glendale Fish and Wildlife Area, Greene-Sullivan State Forest, Shakamak State Park, Spring Mill State Park, and at White Oak Lake in Knox County. West Boggs Lake is also available to the public as are lakes contained in the Hoosier National Forest.

The supply of fishing waters will meet sixty-four percent of the demand within the region, and may meet sixty percent of the demand by the year 2000.

Riparian Habitat The quality of the riparian or wildlife habitat associated with streams and lakes is indicated on Figure 220. The region's best riparian habitat is found along the Wabash River and both forks of the White River. These streams offer sufficient food and cover to attract a variety of waterfowl, shorebirds, and other wildlife. The habitat along these rivers is improved by the seasonally flooded wetlands, which are the most abundant in this region. Some of the smaller streams, such as Guthrie and Julian Creeks, offer excellent habitat. Other small streams have less valuable habitat due to inadequate cover associated with agricultural channelization.

The least developed lakeshores attract the greatest diversity of wildlife. West Boggs Lake is the most developed but still offers fair habitat. Other lakes, especially those on state properties, and strip mine lakes have excellent riparian habitat. Public hunting of riparian habitat is allowed on the Glendale Fish and Wildlife Area, Greene and Sullivan Martin State Forests and parts of the Hoosier National Forest.

Withdrawal Uses

Public Water Supplies Daviess, Greene, Knox, Lawrence, and Martin Counties are served by forty-five public water utilities. An estimated 98,000 persons were served by a public utility in 1975. Approximately 31,200 persons were served in Lawrence County; 10,300 in Martin County; 27,100 in Knox County; 14,800 in Daviess County; 14,600 in Greene County; and 10,300 were served by a public water utility in Martin County.

Twenty-one of the utilities have service areas confined to a single municipal area, while four water utilities serve a single subdivision. The remaining twenty public water utilities are rural water systems. The service areas and rates of withdrawal for the public water utilities are shown in Figure 221.

The City of Vincennes Water Department served approximately 19,400 persons in 1975. In 1977, it supplied an average of 3.5 million-gallons-per-day. Bedford withdrew 4.0 mgd in 1977. Bedford sells approximately 0.7 mgd to surrounding communities. Other large utilities in the region include Washington, withdrawing 2.5 mgd; Loogootee, 1.13 mgd; Linton, 0.8 mgd; Mitchell, 0.8 mgd; and Bloomfield, 0.5 mgd. In 1975, these public water utilities pumped an estimated 15.8 mgd.

Rural systems are clustered in a rather dense pattern in Lawrence County and Martin County outside of Crane Naval Ammunition Depot. Rural systems are also located in Eastern Greene County, southern Daviess County and in central and north central Knox County.

A few small utilities in northern Martin County are supplied by surface water from the Crane Naval Depot. Mitchell withdraws water from the East Fork of the White River and Salt Creek. The flows of Salt Creek are augmented by releases from Lake Monroe. The water supply of Lake Monroe is owned by the State of Indiana, which, under contract, provides the City of Bedford with up to 5.0 mgd.

Public utilities rely heavily on ground water withdrawals. Almost all are supplied by well fields located in the West and East Forks of the White River and Wabash River valleys. Several communities rely on ground water even though they are located several miles from the well field. The city of Linton, for example, withdraws water from a well field nine miles from town, near Elnora.

Projections of public water supply withdrawals indicate that they should increase to about 21.1 mgd by the year 2000 as presented in the following table. This increase is projected in part on the assumption that rural water systems will continue to expand both their service areas and number of customers.

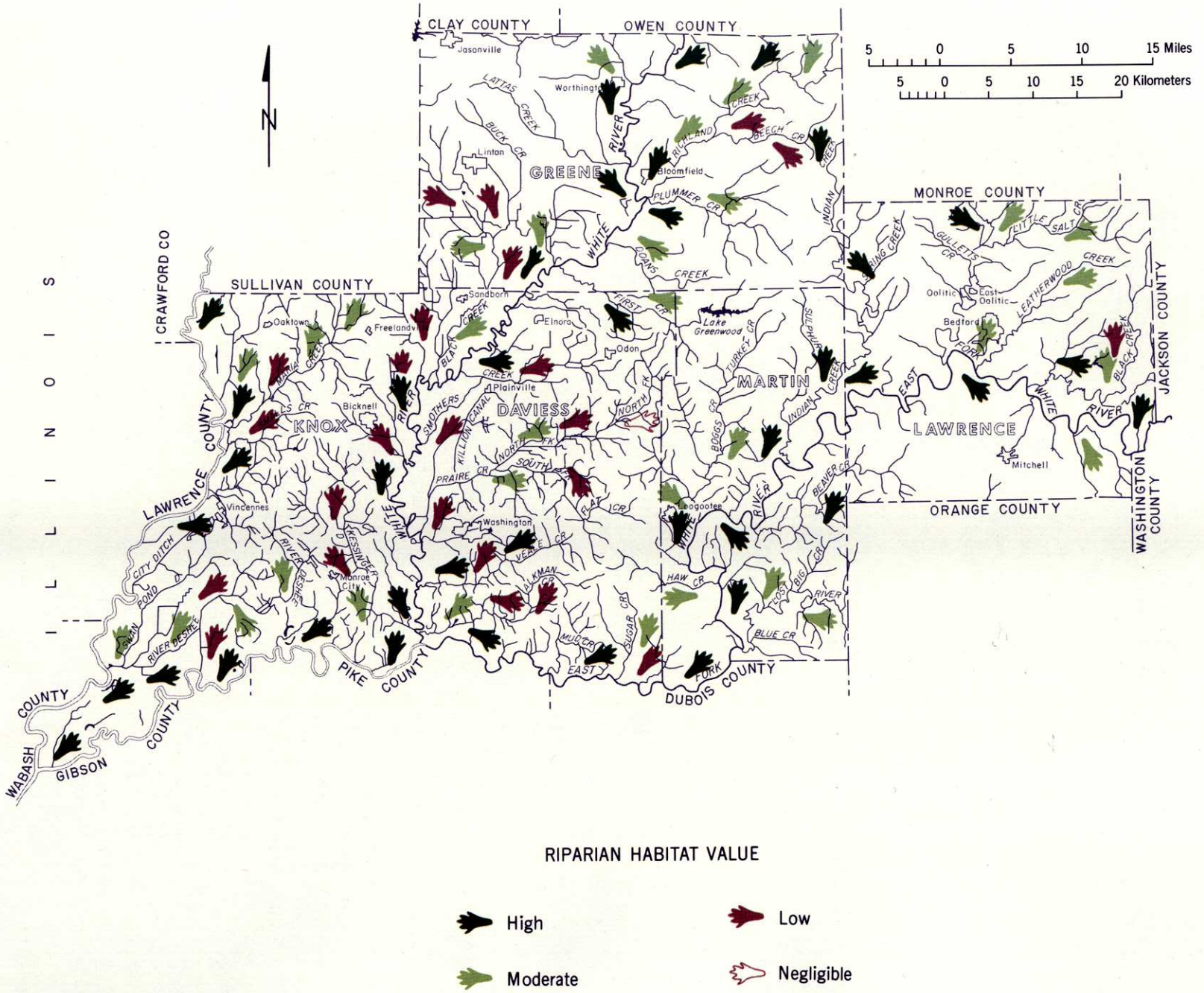


Figure 220
Map of Region Thirteen-A showing the quality of the riparian habitat.

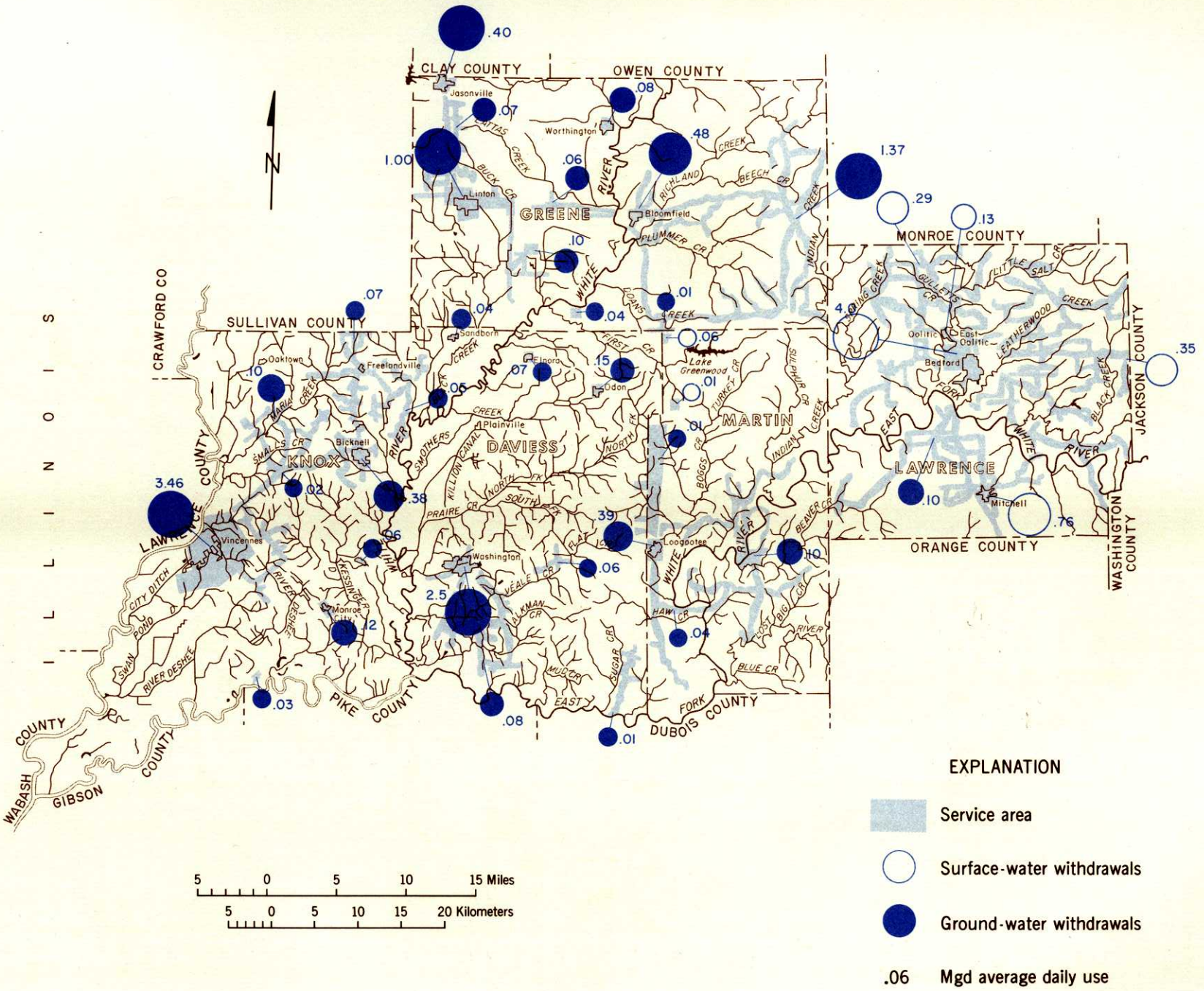


Figure 221
Map of Region Thirteen-A showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Table 175
The 1977 and projected water withdrawal and consumption rates of public water supplies, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	15.8	16.7	19.0	21.1
Consumption	3.3	3.5	4.0	4.1

Industrial Water Industrial establishments had a water intake averaging 21.2 mgd in 1977. Of the total industrial intake, 12.5 mgd was self-supplied by the industries while 8.6 mgd was purchased from the region's public utilities. Ground-water is the source for most of the self-supplied industrial water.

The largest water-using industry group is the stone, clay, and glass group. Most of the water used by these establishments is withdrawn from strip mine lakes and abandoned quarries on company property. Other industries using significant quantities of water include the primary metals group and manufacturers of electrical machinery.

Although industrial output is expected to increase, total industrial water intake is expected to decrease initially, due to plant efficiency, and to rise slowly as ouput increases.

Industrial production by the year 2000 is expected to increase one hundred and eighteen percent above the 1977 value (U.S. Water Resources Council). By the year 2000, total industrial intake is expected to be 24.6 mgd. Of this projected usage, approximately 15.1 mgd may be self-supplied. The current and projected industrial self-supplied withdrawals and rates of consumption are now presented.

Table 176
The 1977 and projected self-supplied withdrawals and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	12.5	12.4	13.7	15.1
Consumption	1.7	1.9	2.6	3.5

Rural Self-Supplied Water Most rural self-supplied water is withdrawn from ground-water sources. In 1975 an estimated 50,000 persons lived in homes supplied by individual sources of water. It is estimated that these people used about 2.8 mgd for residential purposes in that year. By the year 2000, the number using their own water supply is expected to decrease to 47,300 persons. This decrease is a reflection of expansion in the region's public water supplies and, in particular, the expansion of the rural systems. Although fewer will be using self-supplied water, the anticipated general use in the standard of living is expected to increase their withdrawal demands to 3.6 mgd by the year 2000.

In 1975 there were an estimated 386,600 head of livestock, 313,000 chickens, and 128,300 turkeys. Collectively, these animals used about 3.2 mgd. By the year 2000, these animals may require 3.5 mgd. This water is withdrawn from wells, farm ponds, and springs.

The total withdrawal of rural self-supplied water may increase from the current 6.1 mgd to approximately 7.0 mgd by the year 2000, as shown here.

Table 177
The 1977 and projected water withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.1	6.2	6.6	7.0
Consumption	6.1	6.2	6.6	7.0

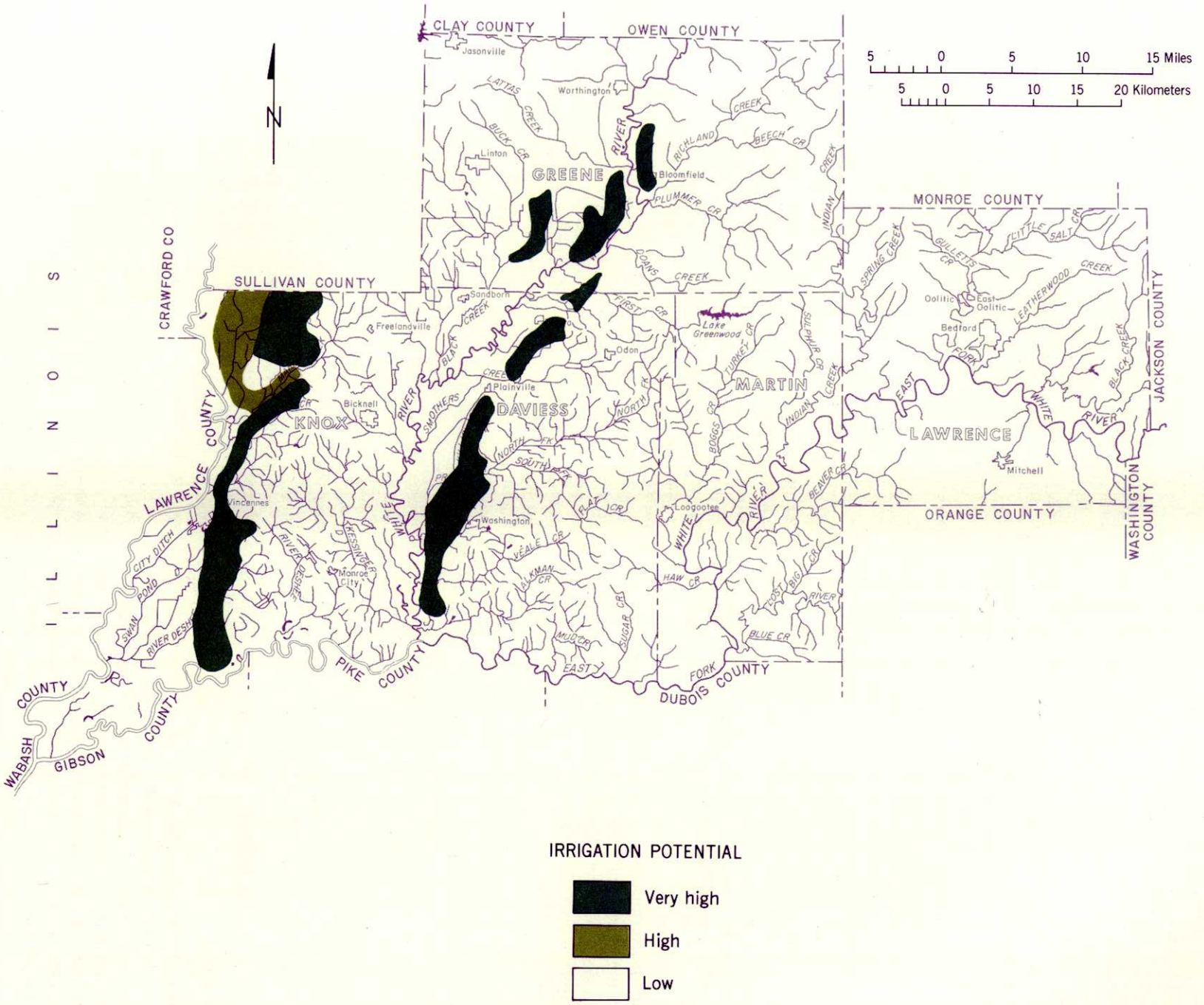
Irrigation Water Soil associations with irrigation potential are located on the Wabash River terraces in Knox County and on windblown sands in Knox, Daviess, and Greene Counties. Figure 222 shows the potential irrigation areas within the region.

Based upon the survey of irrigated croplands, approximately 6,190 acres were irrigated in the region: 6,000 in Knox County and 190 in Daviess County. Corn, soybeans, and other vegetables were the principle crops irrigated in 1977. Other crops irrigated were potatoes, hay, and pasture. Assuming 1977 as a normal growing season, these crops would have required about 16.3 mgd during the peak irrigation season of July and August.

It is estimated that about 15,500 acres of croplands may be profitably irrigated. Today's 6,190 acres may increase to 9,200 acres by the year 2000. Almost all of this additional acreage will be located in Knox County. This expansion of irrigation is expected to increase the peak July and August irrigation demand in an "average" season to about 24.1 mgd to 32.2 mgd by the year 2000.

In addition to the irrigation for agricultural use, there are approximately 124 acres of irrigated fairways and greens on the region's golf courses. About 0.4 mgd was applied to these areas during the peak July to August irrigation period of 1977.

The total withdrawal for irrigation of croplands and golf courses during the "average" irrigation season of 1977 was approximately 16.7 mgd. These withdrawals may increase to 24.5 mgd during the "average" growing season by the year 2000 as presented in Table 178.



IRRIGATION POTENTIAL

- Very high
- High
- Low

Figure 222
Map of Region Thirteen-A showing the general location of the soil association that appear to possess an economic potential for the irrigation of croplands.

Table 178
The current and projected withdrawal of irrigation water for croplands and golf courses, during an average growing season, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	16.7	17.6	21.1	24.5
Consumption	16.7	17.6	21.1	24.5

Electric Energy The region contains one electric generating station, located at Edwardsport on the West Fork of the White River. It is owned and operated by Public Service Indiana. A once-through cooling system is utilized at this plant. Edwardsport is rated at 175 megawatts for the three units currently in operation. Intake requirements are 202 mgd. This is an older station, and at least one of the operating units was installed during World War II. Public Service Indiana expects to retire this station during the next decade.

Water withdrawals for energy during 1977 were approximately 202 mgd. No water is expected to be withdrawn for the generation of electricity by the year 1990, as presented below.

Table 179
The 1977 and projected water withdrawals and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	202	202	0	0
Consumption	0	0	0	0

Coal Conversion: Coal conversion is a process whereby coal is converted to a gaseous or liquid hydrocarbon. Withdrawal demands for coal conversion range from 17 to 32 mgd. If coal conversion should economically be feasible by the end of the century, Region Thirteen-A would be a prime candidate for siting because it contains available water supplies in close proximity to abundant supplies of coal.

EXCESS WATER

Flooding

Approximately 365,000 acres of the region are subject to flooding. The major flood plains are shown in Figure 223. Figure 224 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $7.6 million of which some eighty-three percent would occur in rural areas.

Flood Control There are three completed flood control projects in the region which are sponsored by a local conservancy district in cooperation with the U.S. Soil Conservation Service. Boggs Creek watershed includes two floodwater-retarding structures and 8.2 miles of channel improvements. The project is designed to reduce floodwater damages on 1,565 acres in the watershed.

Lattas Creek watershed includes 4.1 miles of flood prevention channels and 18.3 miles of multipurpose flood prevention and drainage channels. The project is designated to reduce floodwater damage to crops and pastures by ninety percent.

Prairie Creek watershed includes thirteen floodwater retention dams, 33.5 miles of channel improvements, 15.4 miles of levees, and twelve major stabilization structures for flood protection. The project is designed to reduce floodwater damages in the watershed by sixty-eight percent.

The West Boggs Creek small watershed project is authorized for construction. The structural measures of this project consist of one multi-purpose flood prevention and recreation structure which has been completed, and 4.6 miles of flood prevention channel improvement. The project as planned will reduce floodwater damages by eighty-six percent.

An application was made for the Snapp-Kelso Creek watershed.

The U.S. Army Corps of Engineers has constructed five, major, flood protection projects within the region. One of these is the Niblack Levee, which is located on the Wabash River in Knox and Sullivan Counties. It was approved by the Flood Control Act of 1946 and was completed in April 1965. The project consists of eighteen miles of earth levees which have prevented flood damages amounting to more than $2.5 million since their completion.

The Vincennes local protection project is located on the Wabash River at Vincennes in Knox County. The project was authorized by the Flood Control Act of 1946, and construction was completed in June 1962. It consists of concrete walls, including new construction, and enlargement of some existing works, alteration of three railroad bridges, and facilities necessary to the project. Ramps and openings are provided in the levee to permit unobstructed traffic movement during nonflood periods. Work on a section of levee across the south side of Vincennes is currently suspended. Railroad bridge alterations, however, are complete. The degree of protection currently afforded is limited to that provided by the Brevoort Levee. Flood damages prevented by the project amount to more than $23 million.

The Brevoort Levee project is located in Knox County, between the Wabash and White Rivers at their confluence. The project includes a system of earth levees extending from Vincennes downstream along the east bank of the Wabash River and upstream along

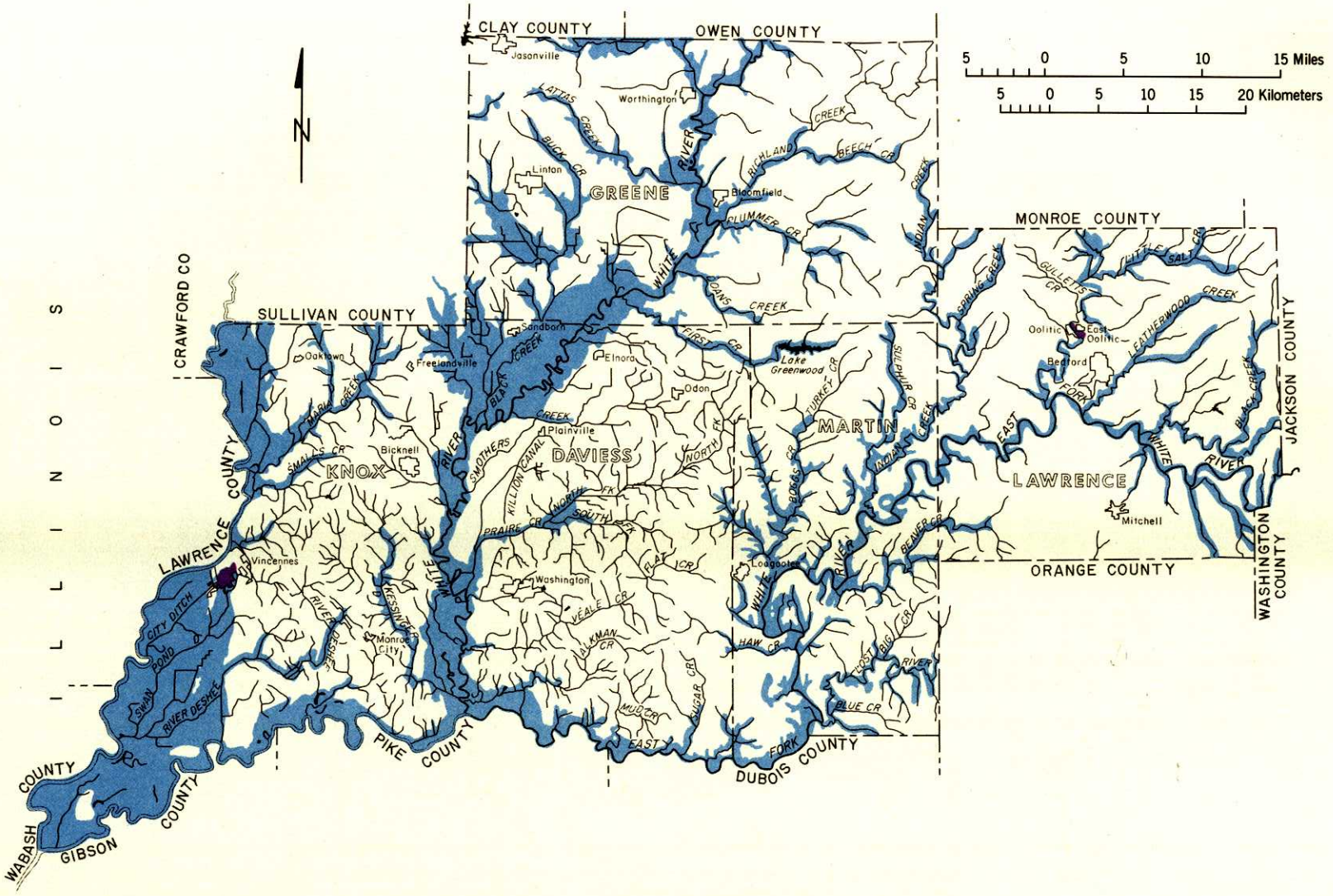


Figure 223
Map of Region Thirteen-A showing the major floodplains.

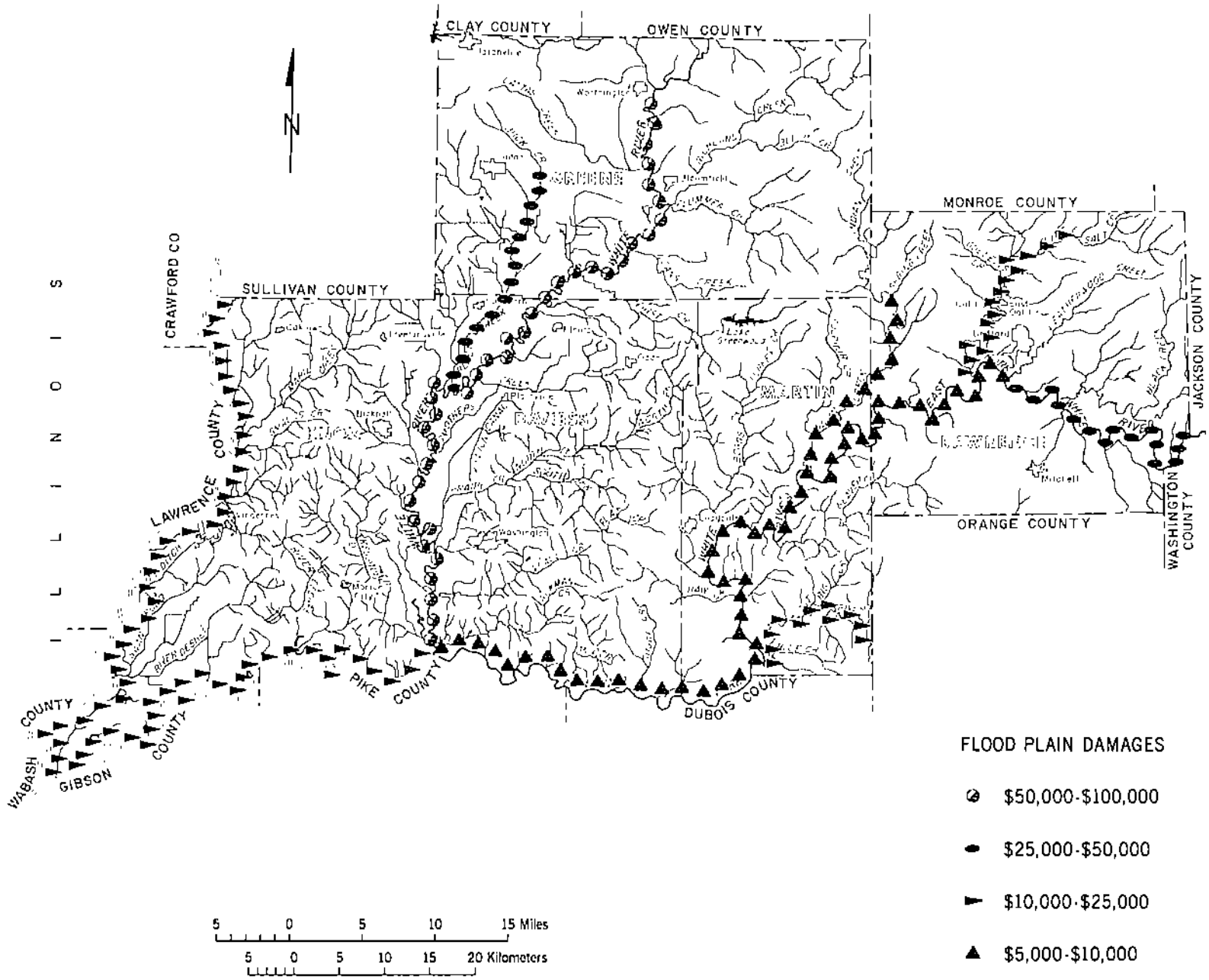


Figure 224
Map of Region Thirteen-A showing the estimated average annual flood damages per mile along selected streams.

the west bank of the White River. Pumping facilities are provided to dispose of drainage from the protected area. The project was authorized by the Flood Control Act of June 1936 and completed in 1947. It is estimated that the project has prevented over $27 million in flood damages since completion.

Levee Unit Eight is located on the left bank of the West Fork of the White River near Plainville in Daviess County. The project consists of a system of earth levees and pumping facilities to dispose of drainage from the protected area. It was completed in 1942 and provides agricultural protection for 13,400 acres.

The Edwardsport project consists of the construction of a pilot channel through a narrow neck in the West Fork of the White River to eliminate caving of river banks.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include Elnora and Washington in Daviess County; Worthington in Greene County; Decker, unincorporated, and Vincennes in Knox County; Bedford and Mitchell in Lawrence County; and Loogootee and Shoals in Martin County. Participants in the regular phase of the National Flood Insurance Program include Plainville in Daviess County and Edwardsport in Knox County.

Agricultural Drainage

Approximately fourteen percent of the soil associations have "severe," twenty-five percent have "moderate," while sixty-one percent have "slight" wetness characteristics. The location of soil associations with these wetness characteristics are shown in Figure 225.

There are approximately 411 miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of these systems is the responsibility of the local county drainage boards, or, in a limited number of cases, of conservancy districts. There is no legal entity responsible for maintaining drainage of the other streams in the region.

Soil Erosion

The erosion potential of soil associations within the region is shown in Figure 226. Thirty-four percent of the 1,473,900 acres in the region are rated as having a "high" potential erosion hazard. These areas need the protective covers of grassland and trees in order to prevent severe erosion. Seven percent are classified as having a "medium" erosion hazard potential, while the remaining thirty-two percent are ranked as having a "low" erosion potential for land left in a fallow state.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the West and East Forks of the White River, the White River, and the Wabash River. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana, and SPC-3, the standard for coal mine wastes and drainage.

Water samples for the East Fork of the White River indicated that temperature, dissolved oxygen, and pH values were in compliance with the state standards. The fecal coliform levels exceeded the water quality standards for streams designated for partial body contact.

Water quality samples from the West Fork of the White River indicated that the temperature and dissolved oxygen levels were in compliance with the state standards. Maximum pH values have been recorded in November which exceeded the state standard. The fecal coliform levels sometimes violated the standard for partial body contact recreation.

The West and East Forks join to form the mainstem of the White River. Generally, the water quality of the White River met temperature, dissolved oxygen, and pH standards of the state. Fecal coliform levels sometimes exceeded maximum standards for partial body contact recreation.

Recently, there has been some concern over the PCB levels found in the water and fish in the East Fork of the White River near Bedford. These types of pollutants are quite persistent in the environment and they may continue to be detected for some time at this location.

Only three fish kills have been reported to the Indiana State Board of Health from Region Thirteen-A in the period 1974 to 1977. One was a fish kill of undetermined size and origin in the Wabash River in Knox County near Vincennes. Another was in Latta's Creek near Switz City in Greene County, which resulted from a misapplication of a pesticide. The third fish kill occurred in Lawrence County, near Williams, in Sulfur Creek and resulted from an industrial discharge.

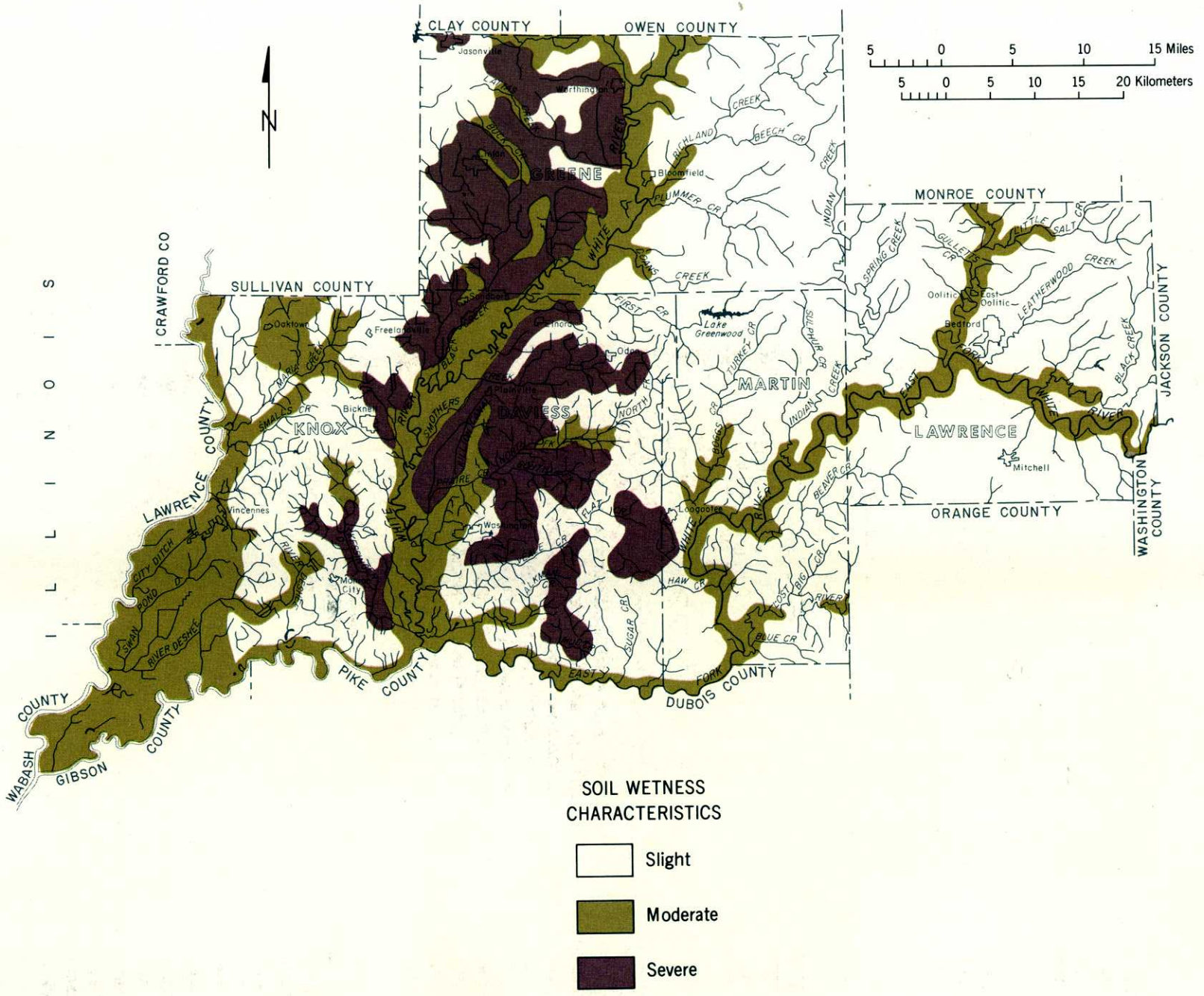


Figure 225
Map of Region Thirteen-A showing the general location of the wetness characteristics of soil associations.

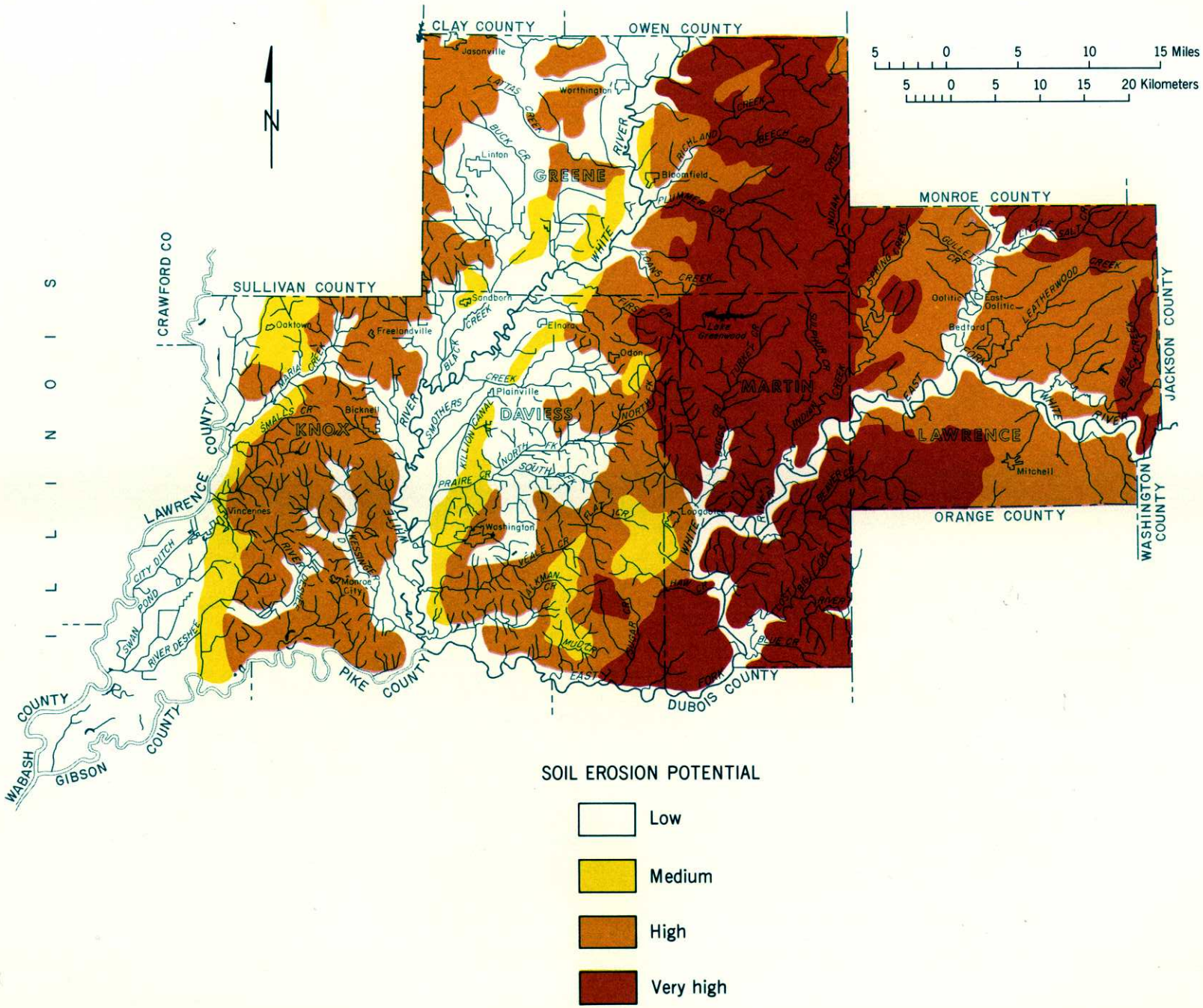


Figure 226
Map of Region Thirteen-A showing the erosion potential of the soil associations.

Region Thirteen-B

Gibson, Pike, Posey, Vanderburgh, and Warrick Counties, located in the extreme southwestern corner of Indiana, form Region Thirteen-B. The region contains approximately 1,879 square miles and is bounded by the East Fork of the White River and Knox and Daviess Counties to the north; Dubois and Spencer Counties to the east; the Ohio River and Kentucky to the south; and the Wabash River to the west, as shown in Figure 227.

The 1975 population was 263,100. The official Indiana Population Projections indicate the region's population will increase to 303,000 by the year 2000, with the major growth in Warrick County. The 1975 population and projections for each county are presented in the following table.

Table 180
The 1975 and projected populations for Region Thirteen-B.

County	*1975*	*1980*	*1990*	*2000*
Gibson	31,400	32,800	34,700	36,400
Pike	12,100	12,100	11,900	11,900
Posey	22,800	24,500	28,100	32,400
Vanderburgh	162,800	159,900	153,400	144,400
Warrick	34,000	41,000	57,000	77,900
Total	263,100	270,300	285,100	303,000

Vanderburgh County, with the city of Evansville, is by far the most populous county in the region. Other major urban areas include Mt. Vernon in Posey County, Princeton in Gibson County, and Booneville in Warrick County.

Agriculture is the dominant land use within the re-

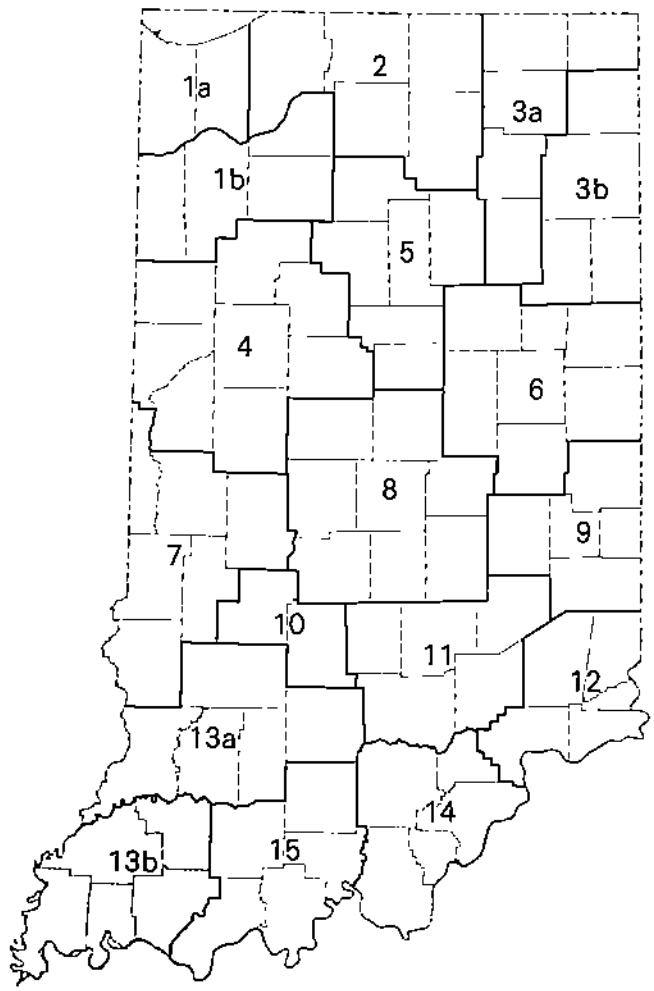


Figure 227
Map of Indiana showing the location of Region Thirteen-B.

gion, comprising more than sixty-six percent of the area. Approximately twenty-one percent of the land is forested while the remaining thirteen percent represents urban and miscellaneous uses.

Nonmanufacturing businesses along with the manufacturing industry employ the greatest numbers of the region's work force. The largest employer in the nonmanufacturing sector is wholesale and retail trade followed by services and construction. The three leading industries in the manufacturing sector are transportation, furniture, and fabricated metals. Vanderburgh County and the city of Evansville consitute the leading employment center.

Average annual precipitation for the region is approximately 43.0 inches, with average monthly values ranging from a high in March of 4.5 inches and a low in October of 2.4 inches. Of the 43.0 inches of precipitation, approximately 28.0 inches are consumed through evapotranspiration while 15.0 inches appear as streamflow. Average temperatures range from 33°F. in January to 78°F. in July. The average annual temperature is 56°F. The average annual prevailing wind at the Evansville Dress Regional Airport is from the south to southwest at 8.3 miles per hour.

THE WATER RESOURCE

Ground Water

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In this region there is a pronounced variability in ground-water occurrence, as shown in Figure 228. The region can be divided into two broad areas based on geology and the resulting ground water occurrence. The first area is composed primarily of glacial outwash sand and gravel that is present in the Ohio River, Wabash River, and the White River valleys. These sand and gravel deposits are capable of producing over 1,000 gallons-per-minute (gpm) from large diameter wells and they comprise the major groundwater resource in the region.

The second area consists of rolling plains underlain by deposits of glacial till, lake clays, outwash sand and gravel, loess, and bedrock. The unconsolidated deposits located outside of the river valleys range in thickness from less than five to over 125 feet and are capable of producing from 50 to 400 gpm. Bedrock deposits consist of Pennsylvanian sandstone, shale, coal, and limestone. Because of the generally low permeabilities of these rocks the bedrock is a limited source of water, usually producing less than ten gpm. The Inglefield sandstone, which is present in Gibson, Posey, and Vanderburg Counties, may produce from 25 to 50 gpm.

Water hardness values vary considerably from 205 parts-per-million (ppm) for Booneville to 690 ppm at Fort Branch. Soft water, below 180 ppm, occurs in parts of Warrick and Pike Counties. "Soda" water, with a pH of between eight and ten, occurs in parts of Warrick County.

Iron content levels range between 0.1 to 3.0 ppm. More than half of the municipalities provide iron removal facilities. Manganese contents reach higher levels than normal along the White River in northern Pike County and along the Ohio River and Little Pigeon Creek in Warrick County. The sand and gravel deposits contained in the Wabash River valley show both low iron and manganese levels.

Surface Water

Streamflow Region Thirteen-B is bordered on the south by the westward flowing Ohio River, on the north by the westward flowing White River, and on the west by the southward flowing Wabash River. Drainage within the region is affected primarily by the Patoka River, Pigeon Creek, Little Pigeon Creek, Big Creek, and their tributaries. Generally, streams flowing westward are part of the Wabash River basin, and the southward flowing streams enter directly into the Ohio River.

The seven day, once in ten year (Q7-10), one day, once in thirty year (Q1-30) and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations within Region Thirteen-B are shown in Table 181.

The low-flow characteristics indicate that the largest and most reliable streamflows are those in the Ohio River. Flows in the Ohio River are modified by reservoirs built by the U.S. Army Corps of Engineers upstream in the Ohio River basin, resulting in a reduction in flood flows and an increase in low flows. Likewise, the reservoirs built by the U.S. Army Corps of Engineers in the Wabash River basin modify flows in the White and Wabash Rivers.

The Patoka River near Princeton has an average flow of 620 mgd. The flow duration curve, as presented in Figure 229, indicates the stream will have a dependable flow of at least ten mgd ninety percent of the time. The flow duration curve indicates the Potoka River contains aquifers that provide minimal groundwater contribution to streamflow. To verify this, the technique of hydrograph separation was applied to three annual hydrographs representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to seventeen, fourteen, and five percent for dry, average, and wet years, respectively. Conversely, from eighty-three to ninety-five percent of the flow, depending on the year, is due to direct surface runoff from runoff-producing precipitation events or from snowmelt.

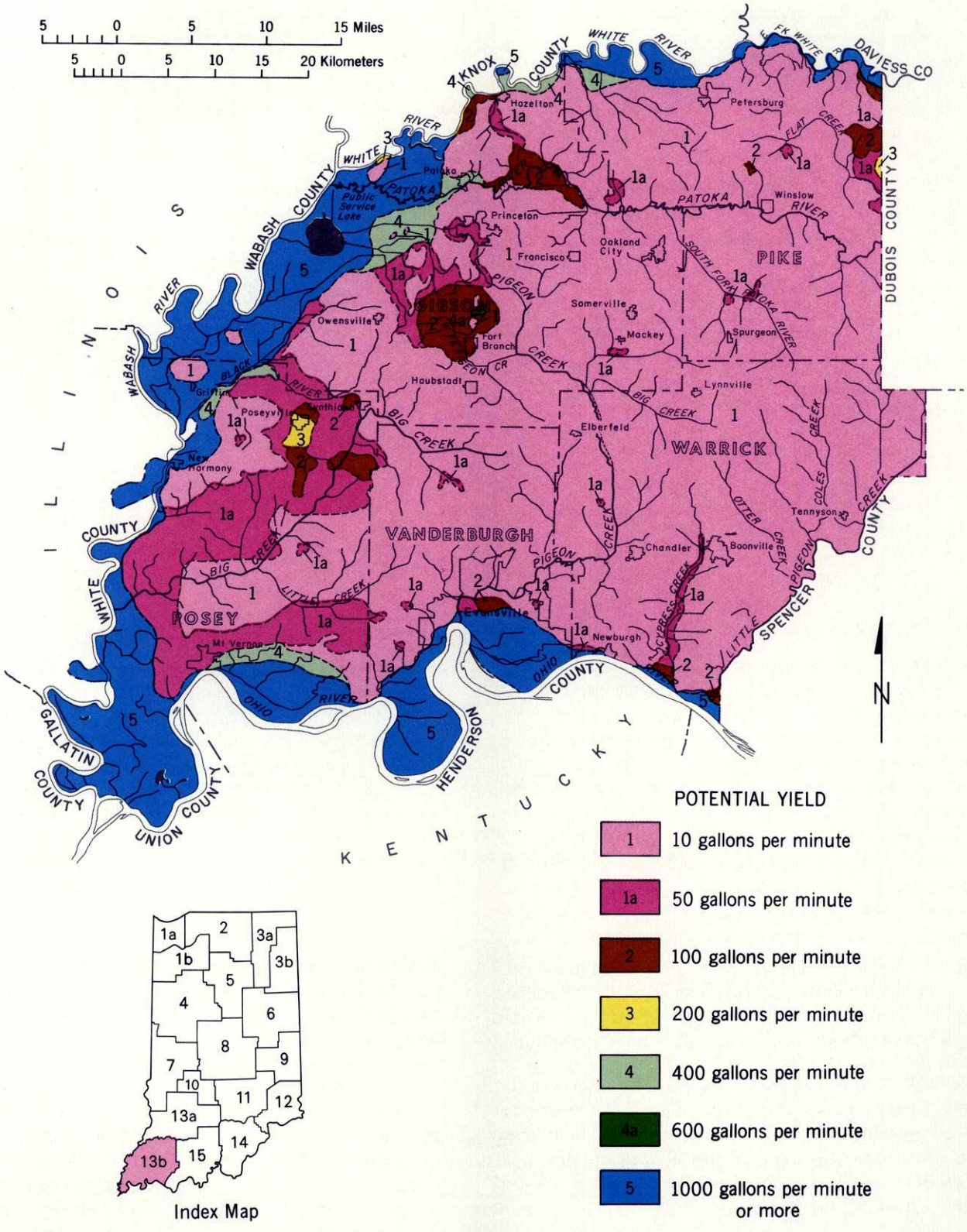


Figure 228
Map of Region Thirteen-B showing the general location and potential yield of ground water from properly constructed large diameter wells.

Table 181
Flow characteristics of streams

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Ohio River at Evansville	107,000	133,300	10,650.0	na
Patoka River near Princeton	822	620	1.1	0.1
Patoka River at Winslow	603	430	0.7	0.2
Pigeon River at Evansville	326	133	0.0	na
Wabash River at Mt. Carmel, Illinois	28,600	17,000	1,500	1,100
White River at Petersburg	11,125	7,300	490	370

na: not available.

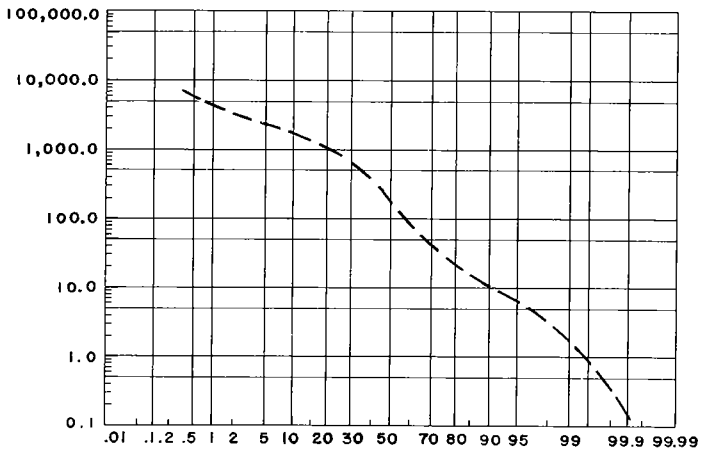


Figure 229
The flow duration curve for the Patoka River near Princeton.

Lakes The lakes within the region of at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more are listed in Table 182 and are located in Figure 230. These twenty-six lakes have a combined surface area of approximately 982 acres and a gross storage capacity of approximately 13,832 million gallons.

Table 182
Lakes at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	Lake Name	Drainage Area (square miles)	Surface Area (acres)	Gross Storage (million gallons)
1	Gibson Public Service Lake	na	na	9,351

Table 182 (continued)

Lake Number	Lake Name	Drainage Area (square miles)	Surface Area (acres)	Gross Storage (million gallons)
2	Lake Gibson	na	9.0	35
3	New Lake	na	60.0	391
4	Old Lake	na	12.0	52
5	Augusta Lake	na	65.2	224
6	Ends Lake	na	10.0	78
7	Forest Homes Lake	0.90	34.0	81
8	Grey Lake	na	15.1	65
9	Lake Helmerich	1.82	75.0	162
10	Prides Creek Structure No. 4	0.79	90.0	367
11	Seven Lakes	na	na	104
12	Hovey Lake	6.36	253.0	na
13	Patoka Camp Lake	na	14.6	84
14	Bell Conservation Lake	na	13.0	65
15	Edgewater Lake	na	13.0	84
16	Harold Mann Lake	na	na	368
17	Lake Talahi	0.14	27.0	97
18	Lloyd Hahn Lake	na	na	130
19	Matre Dei Provinial Lake	na	na	169
20	Schnake Lake	na	15.0	65
21	Woodland Lake	na	23.0	156
22	Hendrickson Lake	na	13.0	52
23	Refuse Reservoir	0.63	89.0	870
24	Scales Lake	na	66.0	169
25	Washing-recirculating Reservoir	na	60.0	547
26	Yellow Bank Lake	0.38	25.8	66

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of the region are presented in Table 183. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Table 183
Outdoor recreation demand and supply analysis.

Activity	Percent of Population Participating	Density Guideline	Approximate Supply	Existing Supply as a Percentage of Projected Demand		
				1980	1990	2000
Boating	23	19.6 boats/acre/year	27,000 acres[a]	100+	100+	100+
Waterskiing	9	34.4 skiers/acre/year	19,700 acres[b]	100+	100+	100+
Canoeing	3	585 canoes/mile/year	145 miles	100+	100+	100+
Swimming	34	76,600 swimmers/acre/year	14 acres[c]	100	100	100
Ice-Skating	1	6,678 skaters/acre/year	0 acres	0	0	0
Fishing	37	66 persons/acre/year	39,300 acres[d]	100+	100+	100+

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of non-residents considered.
[a]Includes 17,100 acres of the Ohio River and 9,900 acres of inland waters.
[b]Includes 17,100 acres of the Ohio River and 2,600 acres of inland waters.
[c]Does not include the Ohio River.
[d]Includes 17,100 acres of the Ohio River and 22,200 acres of inland waters.

Boating and Waterskiing The recreational lakes and the acreage available in the Ohio, Wabash, and White Rivers constitutes the major boating and waterskiing resources in the region. This available supply will meet the projected demand for boating and waterskiing through the year 2000.

Canoeing There are approximately 145 miles of free-flowing streams with sufficient base flow to provide opportunity for canoeing. This available supply will meet the projected demand for canoeing mileage through the year 2000.

Swimming and Ice-Skating Estimates for 1980 indicate that the demand for swimming opportunities is approximately equal to the available supply. Projections indicate that by the year 2000 the demand may slightly exceed the supply of swimming opportunities. The lack of ice-skating opportunities does not approach supplying the current or projected demands.

Fishing The quality of the fisheries habitat is shown on Figure 231. The Ohio, Wabash, and White Rivers, have excellent fisheries habitat. The Ohio and Wabash Rivers offer drum, catfish, and buffalo for commercial fishing, and all three rivers contain warmwater gamefish. Water quality and channelization have adversely affected the aquatic habitat on other streams. Low flow during dry seasons limits the fishery in some of the small streams. Warmwater fish found in the streams include sunfish, catfish, and various rough and forage fish.

Sport fishing is best in the lakes. Warmwater fish, including sunfish and catfish, abound in the lakes, many of which are abandoned coal strip mine lakes. Bethel Pit, in the Patoka Fish and Wildlife Area is stocked with trout in addition to the native, warmwater fish.

Public fishing sites for streams, are located at the Harmonie State Recreation Area, Dogtown Ferry, and New Harmony for the Wabash River. Pike State Forest offers fishing access to the Patoka River. Lake fishing is available at the Patoka Fish and Wildlife Area, Hovey Lake, Scales Lake, and Prides Creek Reservoir. Bridge crossings provide another means of public access for fishing in streams. The demand for fishing waters generated by residents of the region are adequately met and may continue to be met through the year 2000.

Riparian Habitat The quality of the riparian or wildlife habitat associated with streams and lakes is indicated on Figure 232. Riparian habitat along the Ohio, Wabash, White, and Patoka Rivers is very good. The wooded banks and wetlands associated with these rivers provide excellent habitat for waterfowl, shorebirds, furbearers, and most upland wildlife. Although most smaller streams have been channelized in this region, some have recovered with enough vegetation to offer fairly good habitat. Others, such as Big Creek, lack sufficient bank vegetation to provide good wildlife habitat.

Since the lakes have little development, most supply good riparian habitat. Hovey Lake, in particular, attracts a great number of migratory and resident waterfowl. Other lakes, especially the strip mine lakes, provide habitat attractive to most upland game, furbearers, and birds.

Hunting in riparian areas is permitted at Hovey Lake and Patoka State Fish and Wildlife Area as well as the Pike State Forest. Limited public access for hunting is also available on county and private land with permission of the landowners.

Hydroelectric Power Due to the limitations of topography and streamflow characteristics there are no commercial hydroelectric installations here. However, the best opportunity for future developments are the U.S. Army Corps of Engineers' dam projects on the Ohio River at Newburgh and Uniontown.

Commercial Navigation The region contains two lock and dam systems. Uniontown Dam is located in Posey County. Newburgh Dam is located in Warrick County. In 1974 these structures passed forty-five million tons and thirty-five million tons of cargo, respectively. The Ohio River Basin Commission projects Newburgh and Uniontown Dams, respectively, may pass ninety and one hundred and ten million tons of cargo by the year 2000.

The three components of the Ohio system outside the region that affect the overall system efficiency and, therefore, the future volume of traffic on the waterway are the three locks on the dam near Gallipolis, Illinois.

The Southwind Maritime Center located near Mount Vernon in Posey County consists of a river port, a marina, and terminal facilities to accommodate water, rail, and truck transportation. Construction began in 1971 and is still under way although the port is accepting cargo. Between 1976 and 1977 the port handled approximately 156,000 tons of cargo. Projections from the Indiana Port Commission indicate an increase in cargo over the next five years ranging from four to six million tons.

Withdrawal Uses

Public Water Supplies Gibson, Pike, Posey, Vanderburgh, and Warrick Counties are served by twenty-eight public water utilities. Twenty-one of these utilities are municipal systems, six are rural systems,

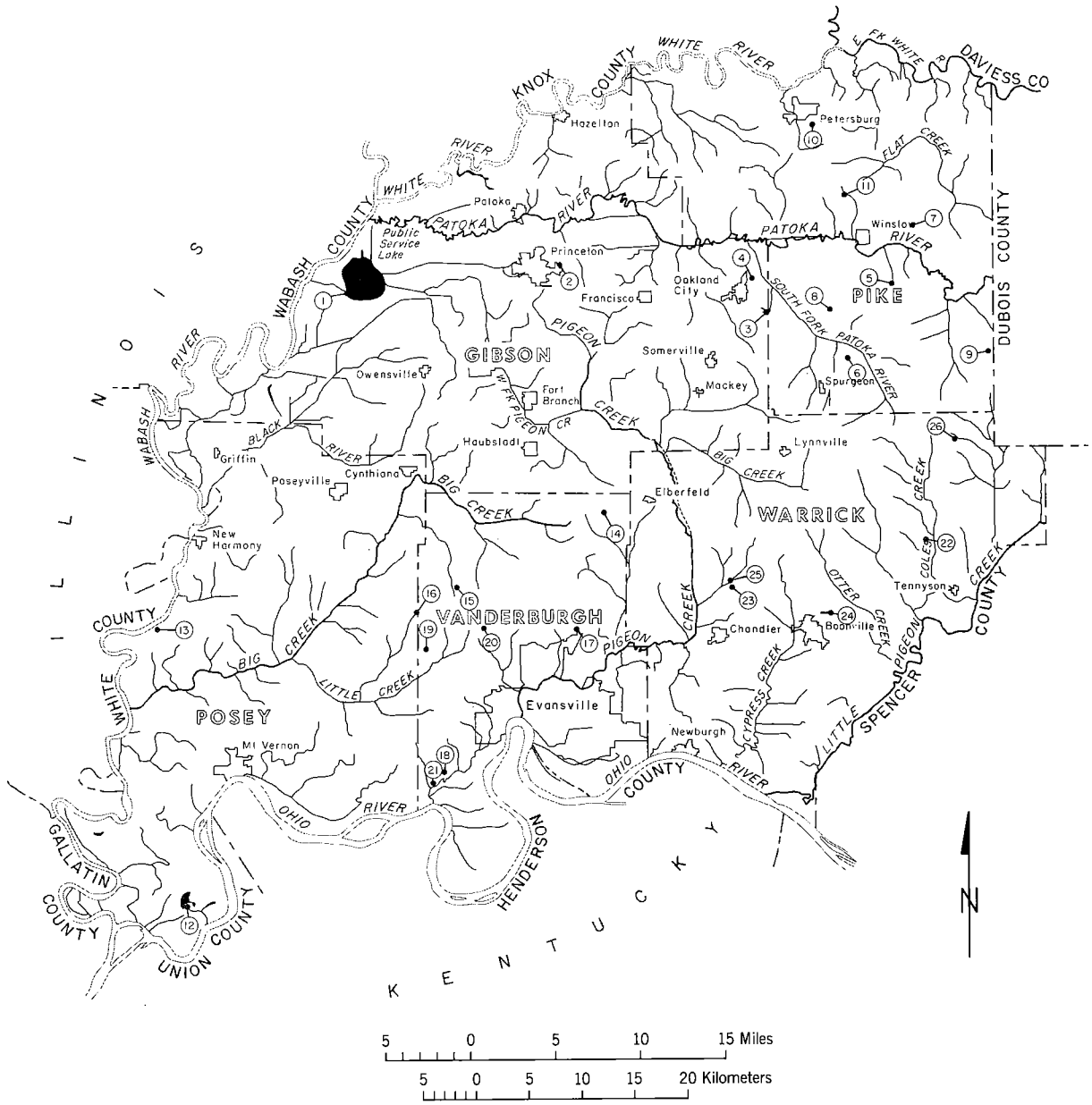


Figure 230
Map of Region Thirteen-B showing the location of lakes that are at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

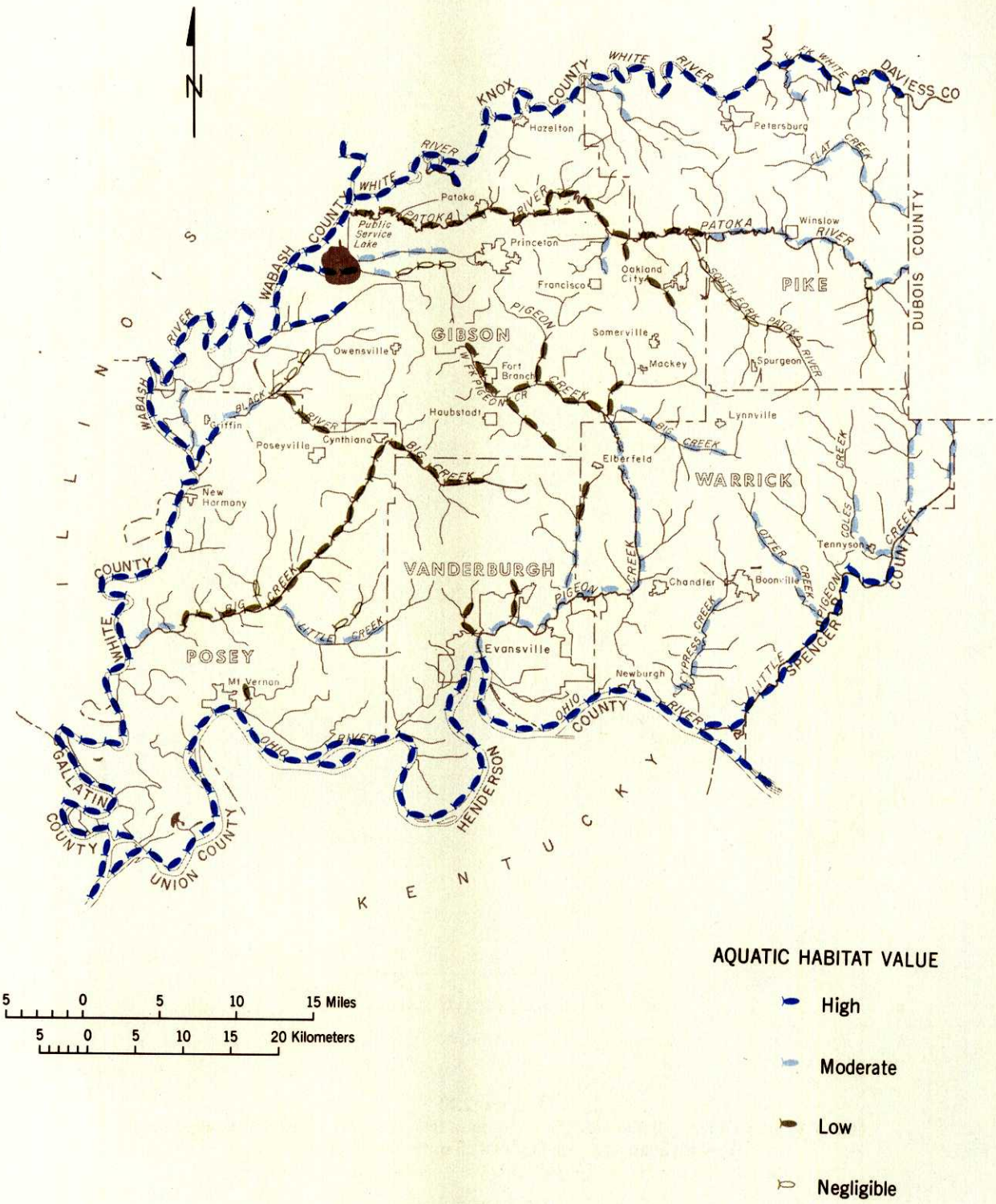


Figure 231
Map of Region Thirteen-B showing the quality of the fisheries habitat.

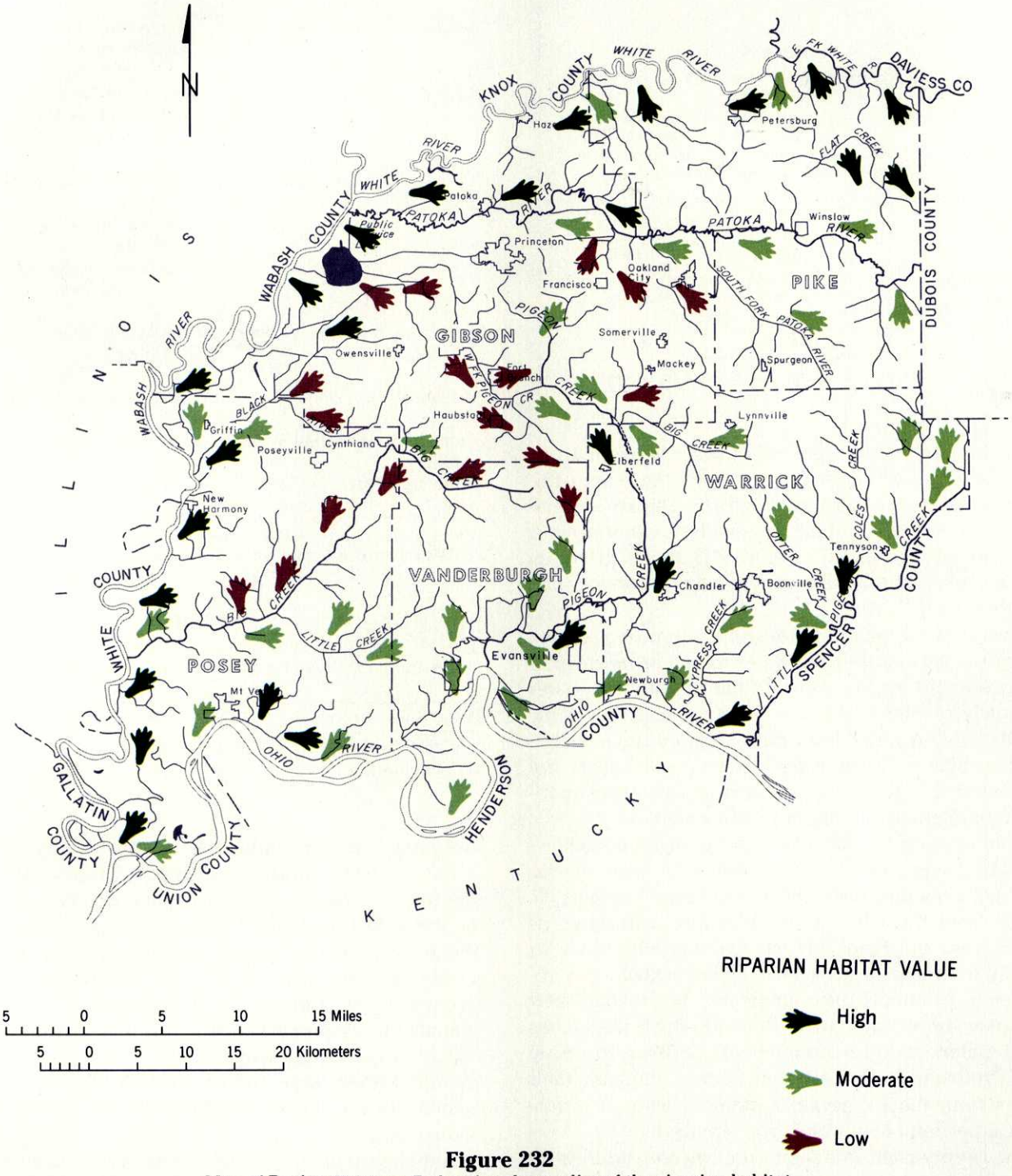


Figure 232
Map of Region Thirteen-B showing the quality of the riparian habitat.

and one is a subdivision system in Evansville. Information on the public water utilities in the region is presented in the following table.

Table 184
The public water supply systems as of 1975.

Counties	*Number Systems*	*Service Population*	*Average Daily Withdrawals in Million-Gallons-Per-Day*
Gibson	9	17,400	2.70
Pike	6	7,800	1.37
Posey	4	9,900	2.34
Vanderburgh	3	134,700	29.56
Warrick	7	14,100	2.20
Total	29*	184,000	38.07

*Because of multi-county systems, the county totals do not add up to the regional total.

The largest, county-wide use of water is by the three systems in Vanderburgh County. These systems withdrew an average of 29.6 mgd in 1975. The six systems in Pike County account for the smallest withdrawals of water at 1.4 mgd in 1975. Figure 233 shows the water service areas and water withdrawals of public water utilities.

Several of the public water utilities not only supply their own systems, but sell water to one or more other utilities in the region. Most of the utilities use water originally obtained within a county of use, but some utilities obtain water from out-of-county utilities. The relationships between system sellers and buyers are presented in Table 185. There is at least one multi-county system, extending into two counties.

Eight systems in the region, including some sellers and purchasers, utilize surface water to some extent. Evansville obtains most, and Mount Vernon obtains all, water from the Ohio River. Winslow withdraws its water from the Patoka River, Lynville withdraws its supply from a strip mine lake, while Oakland City relies on water supply impoundments. The Stendal Water Company buys water from Holland which also relies on a water supply impoundment. German Township and Cynthiana in Vanderburgh County purchase their water from the Evansville system. Newburgh purchases a portion of its water from Evansville.

The twenty-eight utilities in the region withdrew an average of 38.1 mgd in 1975. Approximately twenty percent was withdrawn from surface water sources while eighty percent was withdrawn from groundwater sources.

Projections of public water utilities indicate that withdrawals may increase to approximately 48.1 mgd by the year 2000, as shown in Table 186.

Table 185
Public water system sellers and purchasers.

Sellers	*Purchasers*
Boonville Water Works	Tennyson Water Utility Gentryville Water Utility[b]
Chandler Water	Elberfield Water Indiana Cities Water Corp., Newburgh
Evansville Water Department	German Township Water District Indiana Cities Water Corp., Newburgh Cynthiana Water Works, via German Twp.
Fort Branch Municipal Water Utility	Haubstadt Municipal Water Utility
Holland Water Works[a]	Stendal Water Corporation
Petersburg Municipal Water Utility	Pike-Gibson, Inc.
Princeton Water Works	Patoka Corporation

[a]This seller is located outside of the region.
[b]This purchaser is located outside the region.

Table 186
The 1977 and projected water withdrawal and consumption rates for public water supplies, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	38.1	38.7	43.3	48.1
Consumption	4.2	4.3	4.8	5.3

Industrial Water Industrial establishments had an estimated water intake averaging 27.3 mgd in 1977. Of the total industrial intake, 12.0 mgd was self-supplied by the industries while 15.3 mgd was purchased from the region's public water utilities. The self-supplied water is withdrawn from both surface-water and ground-water sources and is consumed during the manufacturing process at the rate of 1.4 mgd.

The largest water-using industry group is primary metals. Other large industrial water users include manufacturers of rubber and plastics and the electrical industries.

Although industrial output is expected to increase, total industrial water intake is expected to decrease initially due to plant efficiency and then rise slowly as output increases.

Water supplied by public utilities to industries is expected to decrease to 14.1 mgd by the year 2000, while the self-supplied water withdrawals may increase to 14.6 mgd by the year 2000. The 1977 and projected

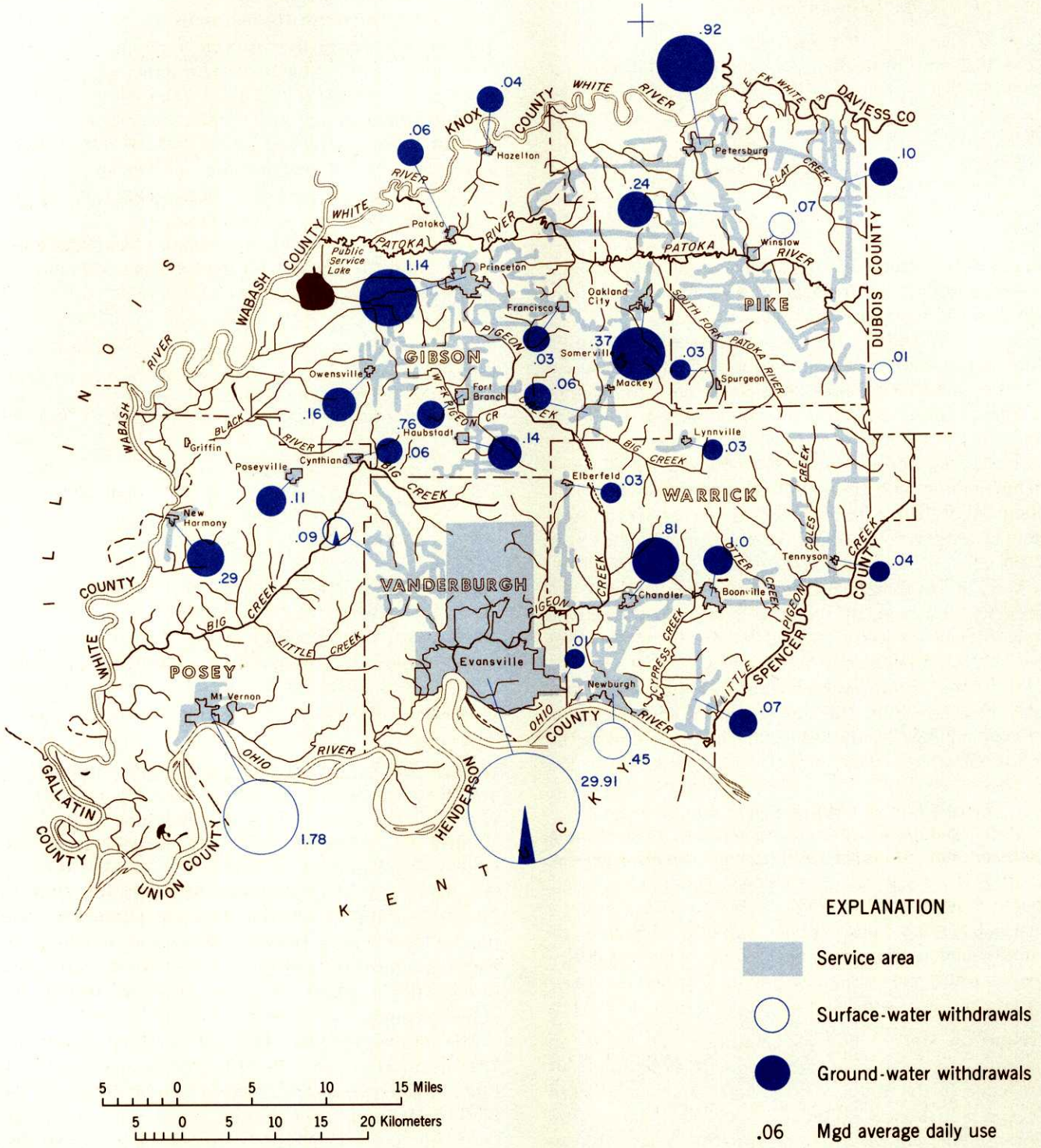


Figure 233
Map of Region Thirteen-B showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

industrial self-supplied withdrawals and rates of consumption are presented in Table 187.

Table 187
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	12.0	11.7	12.8	14.6
Consumption	1.5	1.5	2.1	2.9

Rural Self-Supplied Water Most rural, self-supplied water is withdrawn from ground-water sources, farm ponds, cisterns, and water haulers.

An estimated 79,100 persons lived in homes supplied by individual water sources in 1975. It is estimated that these people used about 4.7 mgd for residential purposes in that year. An estimated 15,600 additional residents of the region may depend on their own wells for household water by the year 2000. These people, along with the anticipated general rise in the standard of living, are expected to increase rural, residential water use to approximately 7.1 mgd by the year 2000.

In 1975, rural, self-supplied water for livestock approached 1.2 mgd. By the year 2000, this withdrawal may increase to about 1.5 mgd. Water for livestock frequently is supplied from farm ponds.

The total withdrawal of rural, self-supplied water may increase from the current 6.1 mgd to approximately 8.7 mgd by the year 2000, as presented in the following table.

Table 188
The 1977 and projected water withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.1	6.4	7.6	8.7
Consumption	6.1	6.4	7.6	8.7

Irrigation Water Soil associations with irrigation potential are located in loess deposits along the eastern edge of the Wabash River flood plain in western Gibson and Posey Counties. Figure 234 shows the potential irrigation areas within the region. Based upon the survey of irrigated lands, approximately six acres were irrigated in the region.

Assuming 1977 as a normal growing year, agricultural land would have required about 0.02 mgd during the peak irrigation period of July and August. All the water used for irrigation was derived from surface water sources.

It is estimated that about 4,500 acres in the region could be profitably irrigated. Irrigation of cropland is expected to increase to 600 acres by the year 2000. This may increase the peak July–August irrigation demand in an "average" year to about 1.6 mgd. The average year increase in ground-water withdrawal may reach 0.9 mgd by the year 2000.

In addition to irrigation for agricultural use, fairways and greens on the region's golf courses are irrigated. About 1.0 mgd is applied to these areas during the peak July–August irrigation period.

The total withdrawal of irrigation water may increase from the current 1.0 mgd to approximately 3.0 mgd by the year 2000, as shown below.

Table 189
The current and projected withdrawals of irrigation water for croplands and golf courses, during an average growing season, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	1.0	1.6	2.2	3.0
Consumption	1.0	1.6	2.2	3.0

Expansion of irrigated areas will depend in part on proximity to water sources. Ground water is limited in some areas which contain soils that could be profitably irrigated. The availability to irrigation water may be a major constraint to any appreciable irrigation practices in the region.

Electric Energy Six major electric generating plants are located in the region. The Petersburg and Hoosier Energy plants are located along the White River in Pike County. The Gibson facility is located along the Wabash River in Gibson County. The Warrick and Culley plants are sited along the Ohio River in Warrick County, and the Ohio River plant is located in Vanderburgh County along the Ohio River. These plants employ once-through cooling systems with the exception of the Gibson plant, which employs a closed-cycle cooling system.

The Petersburg plant has a generating capacity of 754 megawatts (mw), the Hoosier Energy station is rated at 255 mw, and the Gibson plant is rated at 1,370 mw. The Warrick plant is rated at 732 mw and the Culley plant has a generating capacity of 412 mw. The Ohio River facility is rated at 128 mw. Intake requirements from the White River for Petersburg and Hoosier Energy amount to 611 million-gallons-per-day. The Gibson plant withdraws an average of 16 mgd from the Wabash River. The Warrick, Culley, and Ohio River plants withdraw approximately 921 mgd from the Ohio River.

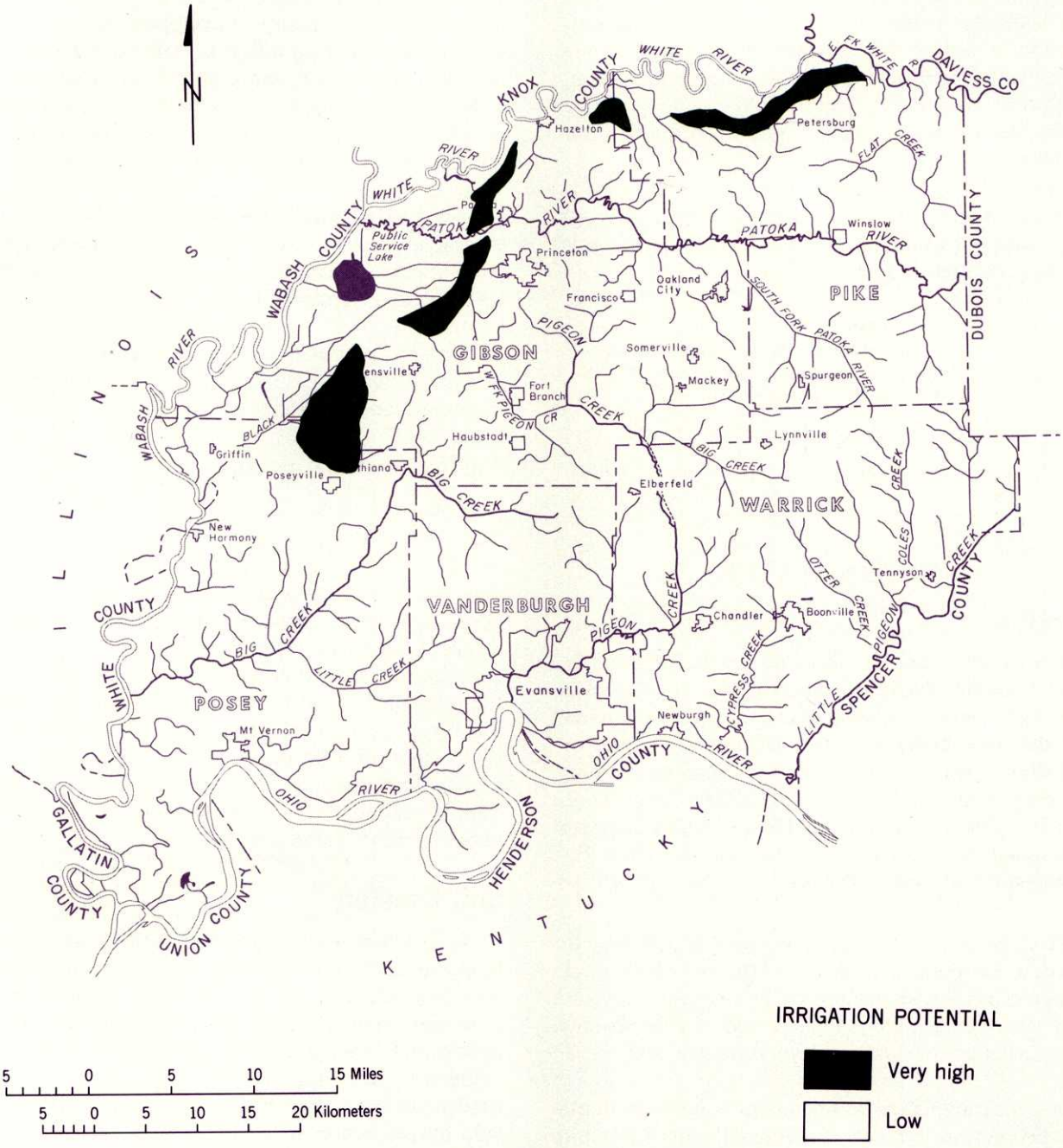


Figure 234
Map of Region Thirteen-B showing the general location of the soil association that appear to possess an economic potential for the irrigation of croplands.

Plans have been announced to expand generating facilities in the region. Additions to the Petersburg plant will increase its consumption requirements to 6.2 mgd of water from the White River by the year 2000. Additions at the Gibson plant will increase consumption of Wabash River water by 25.3 mgd. A new power plant, the Brown facility, will be located along the Ohio River in Posey County, and consumption requirements will reach approximately 3.6 mgd by the year 2000.

Water withdrawals for the generation of energy in the region during 1977 was approximately 1,560 mgd but is expected to decrease to 1,485 mgd by the year 2000 as presented below.

Table 190
The 1977 and projected water withdrawals and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	1,560.8	1,580.1	1,586.1	1,485.1
Consumption	17.9	39.0	5.3	73.3

EXCESS WATER

Flooding

Approximately 242,073 acres of the region are subject to flooding. The major flood plains are shown in Figure 235. Figure 236 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be $963,000 for urban areas and $5,674,000 for rural areas. Most of these damages occur along the Patoka, White, Wabash, and Ohio Rivers, and Big and Pigeon Creeks.

Flood Control There are a number of existing or ongoing flood control projects in the region. A small watershed project, sponsored by Prides Creek Conservancy District, is under construction in Pike County and is designed for flood control, drainage, and recreation.

The U.S. Army Corps of Engineers is constructing a local protection project at Evansville on the Ohio River and Pigeon Creek. The system consists of earth levees, concrete walls, pumping facilities, and provisions for traffic during nonflood periods. When completed, the project will afford protection to the city of Evansville encompassing about 6,740 acres. It has been estimated that completed portions of the project have prevented flood damages amounting to approximately $11,620,000 to date.

The U.S. Army Corps of Engineers has also completed in agricultural levee protection project, Levee Unit 5, in Gibson and Posey Counties along the Wabash River. This project consists of an earth levee which protects a 43,200 acre agricultural area and the communities of Griffin, Skelton, and Lyles against a flood which could be expected to occur on an average of seven times in a one hundred-year period. It is estimated that the project has prevented flood damages amounting to $5,231,000. The U.S. Army Corps of Engineers has also carried out emergency bank protection projects at Mount Vernon, Newburgh, and New Harmony.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program include Princeton, Petersburg, Winslow, Mount Vernon, New Harmony, unincorporated Posey County, Evansville, unincorporated Vanderburgh County, Chandler, Newburgh, and unincorporated Warrick County. Griffin participates in the regular phase of the National Flood Insurance Program.

Agricultural Drainage

Approximately seven percent of the soil associations have "severe," thirty-eight percent have "moderate," while fifty-five percent have "slight" wetness characteristics. The general location of the soil associations with these wetness characteristics are shown in Figure 237.

There are approximately 854 miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards. There is no legal entity that is responsible for maintaining drainage for the other streams in the region.

Soil Erosion

The erosion potential of soil associations is shown in Figure 238. Approximately fifty-two percent of the soil associations are classified as having a "high" potential erosion hazard. These lands are fairly well distributed throughout the region, but generally exclude the river and stream valleys. Another eighteen percent of the region have a "medium" potential erosion hazard, while thirty percent are classified as having a "low" erosion hazard potential for land left in a fallow state.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the Patoka, East Fork White, White, Wabash, and Ohio Rivers. Water quality standards for the region are established by the Stream Pollution Control Board

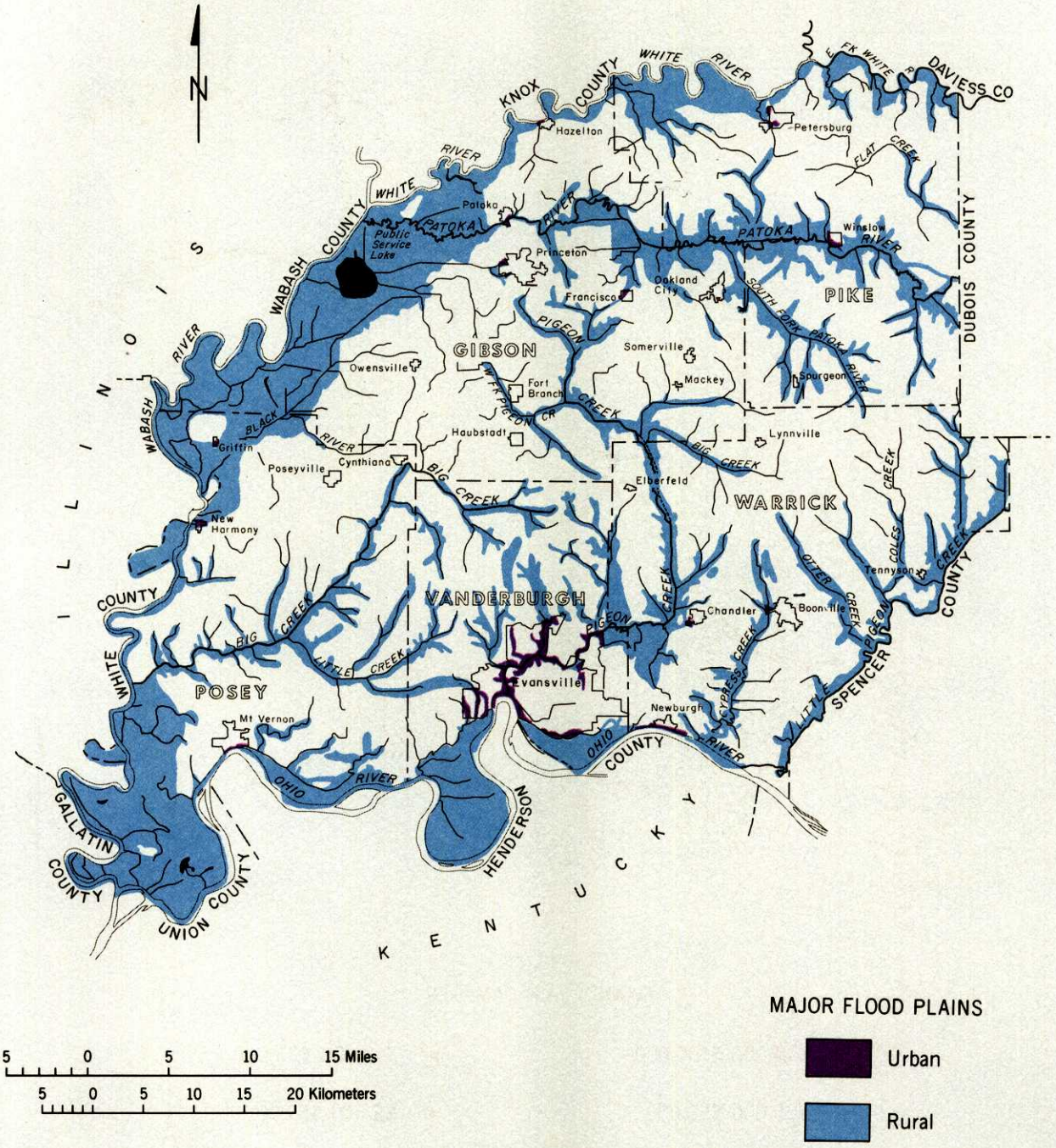
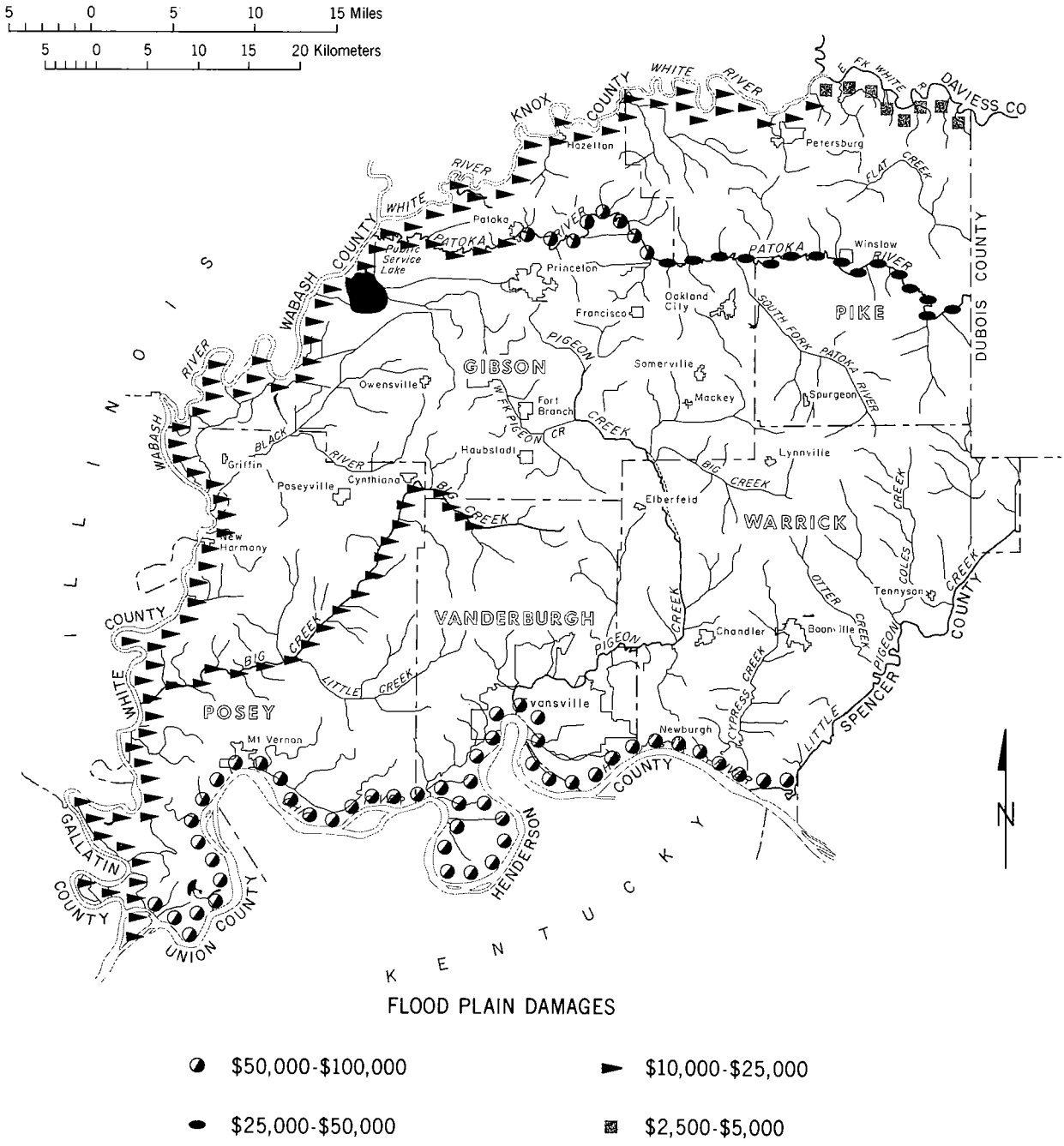


Figure 235
Map of Region Thirteen-B showing the major flood plains.



FLOOD PLAIN DAMAGES

- \$50,000-\$100,000
- \$10,000-\$25,000
- \$25,000-\$50,000
- \$2,500-\$5,000

Figure 236
Map of Region Thirteen-B showing the estimated average annual flood damages per mile along selected streams.

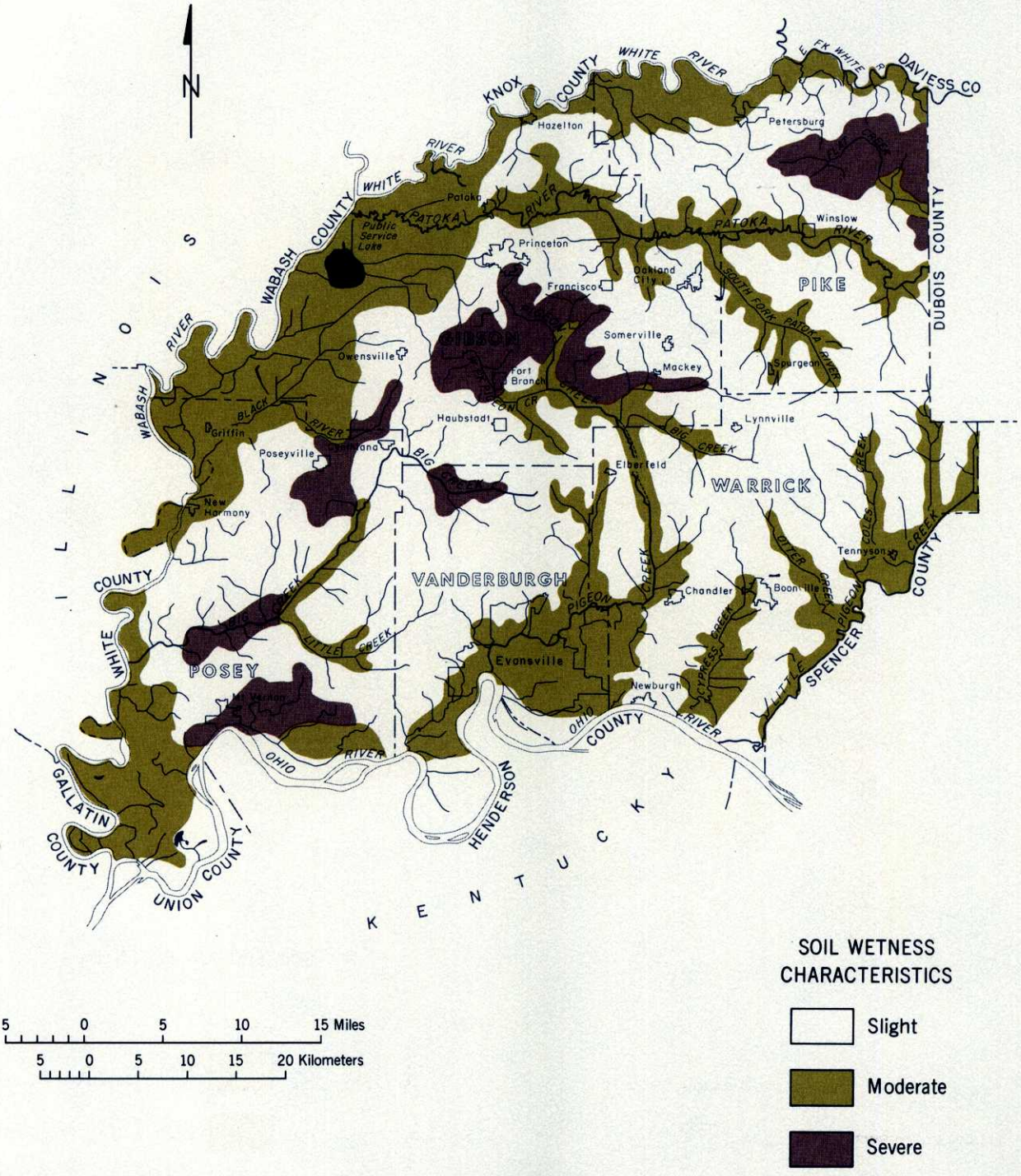


Figure 237
Map of Region Thirteen-B showing the general location of the wetness characteristics of soil associations.

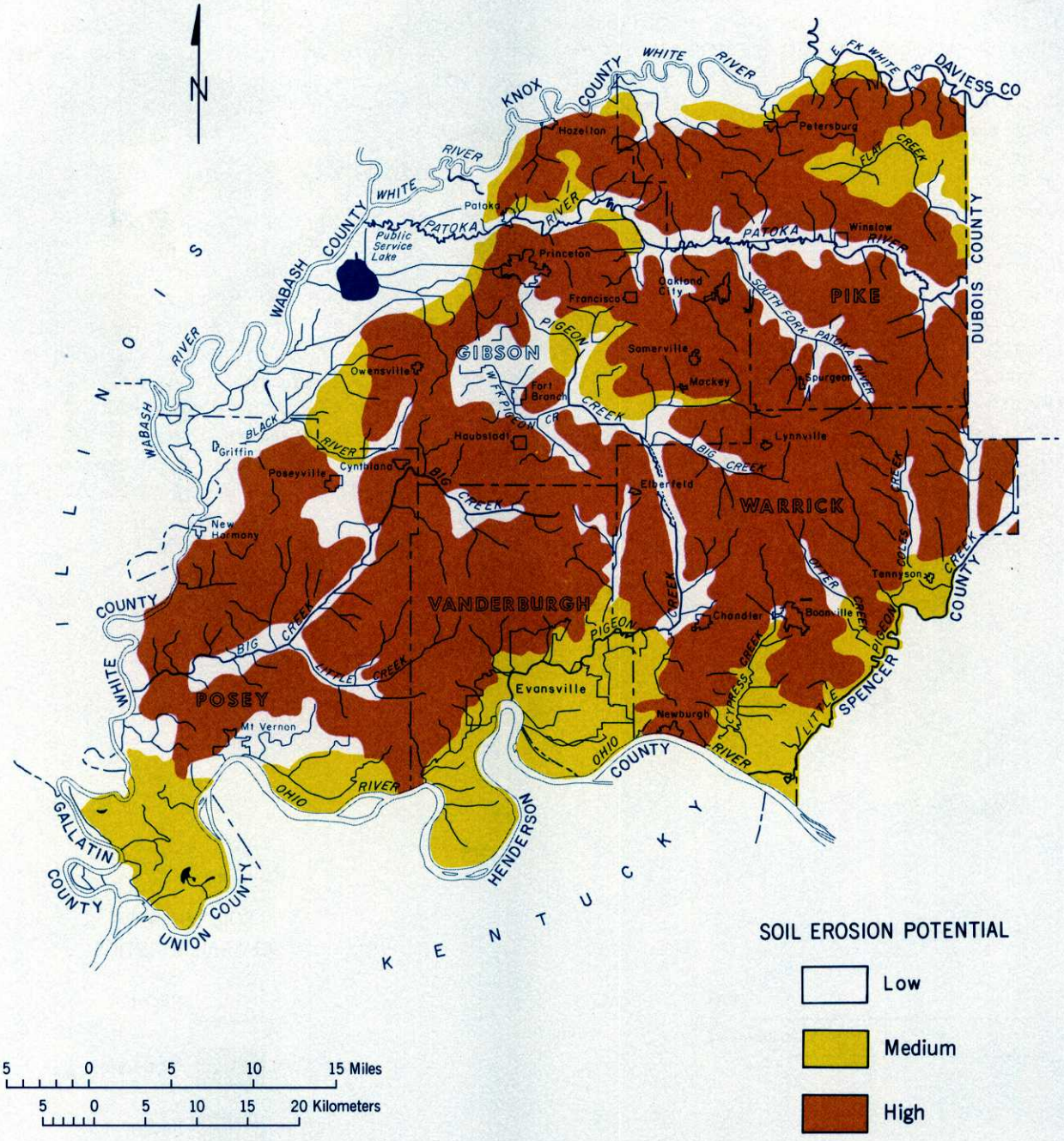


Figure 238
Map of Region Thirteen-B showing the erosion potential of the soil associations.

regulation SPC IR-4, the Water Quality Standards for the State of Indiana, and SPC-3 the coal mine waste and drainage regulations.

Samples of the Patoka River near Princeton and Oakland City indicated that the temperature and pH complied with state standards, and the biochemical oxygen demand was at a satisfactory level. The concentrations of dissolved oxygen occasionally violated the standards. The fecal coliform levels sometimes violated partial body contact standards.

Data from the East Fork of the White River indicated that temperature, dissolved oxygen, nitrate, and pH values were within desirable limits. The values for fecal coliform occasionally were in violation of the standards.

The water quality of the White River near Petersburg met temperature, dissolved oxygen, and pH standards. The only standard violated was the fecal coliform bacteria standard for partial body contact recreation.

Assessment of water quality on the Ohio River near Evansville showed that temperature, the biochemical oxygen demand, nitrate, and pH values all fell within acceptable levels. However, dissolved oxygen levels occasionally violated the standards. Total coliform bacteria levels for drinking water were met at Evansville and Mount Vernon water intakes.

The Wabash River near New Harmony exhibited temperature, nitrate, and pH values within state standards in 1977. The levels of biochemical oxygen demand and dissolved oxygen occasionally were not satisfactory in this part of the Wabash. Fecal coliform bacteria counts were in violation of standards used to designate streams for whole and partial body contact recreation at some times.

Four fish kills have been reported to the Indiana State Board of Health from the region in the period 1974 to 1977. One occurred in Pond Flat Ditch near Haubstadt in Gibson County when a hog waste discharge killed approximately fifty fish. Another, in Posey County near Mount Vernon, resulted in an undetermined number of fish killed from an industrial spill in McFadden Creek. There have been two fish kills reported during this time from the Evansville area in Pigeon Creek. One resulted from a sewer bypass and killed approximately fifty fish, and the other was from an industrial spill which killed an undetermined number of fish.

Region Fourteen

Clark, Floyd, Harrison, Scott, and Washington Counties, located in the southwestern corner of Indiana, form Region Fourteen. The region contains approximately 1,720 square miles and is bounded by Jackson and Jennings Counties to the north; Jefferson County to the east; the Ohio River to the south; and Crawford, Orange, and Lawrence Counties to the west, as shown in Figure 239.

The 1975 population was 202,200. The official Indiana Population Projections indicate the region's population may increase by thirty-nine percent by the year 2000. The 1975 population and the projections for each county are tabulated below.

Table 191
The 1975 and projected populations for Region 14.

County	*1975*	*1980*	*1990*	*2000*
Clark	81,700	88,500	103,600	119,100
Floyd	58,100	60,800	66,000	70,100
Harrison	23,600	27,000	33,800	41,300
Scott	18,900	20,700	24,100	27,100
Washington	19,900	20,600	22,200	24,000
Total	202,200	217,600	249,700	281,600

The major urban areas are Salem in Washington County; Scottsburg in Scott County; Charlestown, Clarksville, and Jeffersonville in Clark County; and New Albany in Floyd County. The New Albany and Jeffersonville area has the region's highest concentration of population.

Agriculture is the dominant land use comprising more than fifty percent of the Region. Approximately

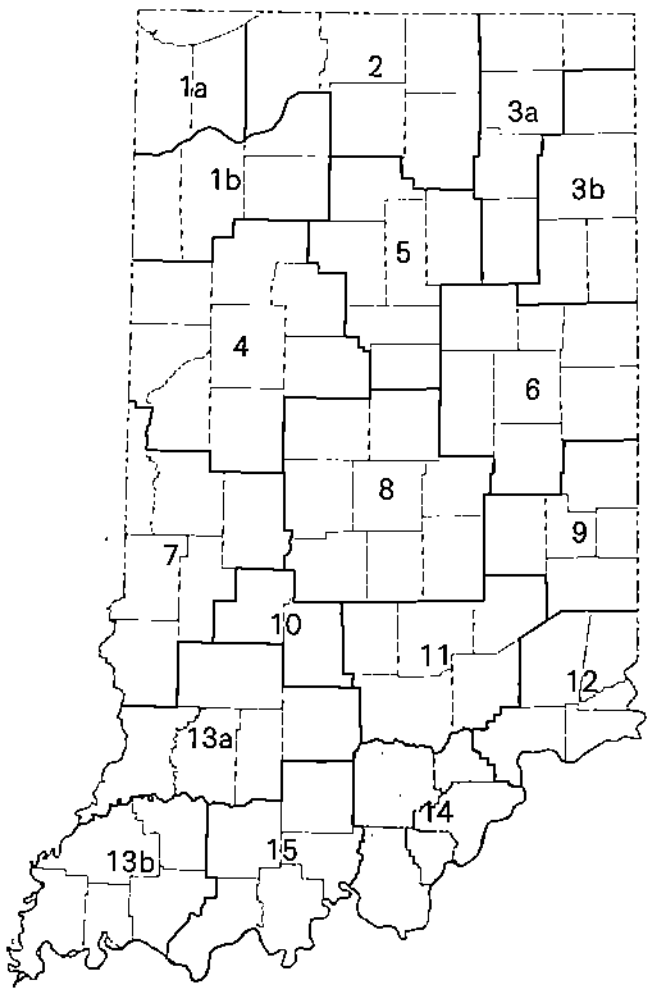


Figure 239
Map of Indiana showing the location of Region Fourteen.

forty percent of the land is forested while the remaining ten percent is devoted to urban and miscellaneous uses.

Manufacturing employs approximately thirty-nine percent of the work force within the region and the wholesale and retail trade employs about thirty-one percent. Other employers include construction, transportation, communication, finance, agriculture, and government. Approximately seventy-five percent of the region's employment is in Clark and Floyd Counties. Louisville, Kentucky, located directly across the Ohio River from New Albany and Jeffersonville, is a major center of employment.

The topography is quite varied, ranging from the high rolling knobs and rugged hills of Floyd, Clark, and Scott Counties to the sink-hole dotted limestone plain of Harrison and Washington Counties. To the east, the glaciated portions of Clark and Scott Counties are more subdued, and flat lakebed deposits of clay and silt are present in much of northwestern Scott County.

Average annual precipitation is approximately 44.0 inches, varying from a high of 4.9 inches in March to a low in October of 2.5 inches. Of the 44.0 inches received yearly, approximately 16.0 inches appear as streamflow while 28.0 inches are consumed through evapotranspiration.

Average temperatures range from 33°F. in January to 78°F. in July. The average annual temperature is 56°F. Information from Louisville, Kentucky indicates that the prevailing wind is from the south at 8.4 miles per hour.

THE WATER RESOURCE

Ground Water

Much of the region occurs within the "driftless" portion of Indiana which was untouched by continental glaciation. Glacial deposits are present in portions of Clark and Scott Counties and flat lakebed deposits of clay and silt are present in much of northwestern Scott County.

Beneath the glacial deposits and surficial overburden of the eastern portion of the region are a variety of bedrock formations. Alternating shale and limestone units are present near the Ohio River in eastern Clark County. These units are covered by dolomitic limestones, black carbonaceous shale, and finally by the tight shales and siltstones of the Borden Group, which forms the "knobs" areas. In Harrison and Washington Counties, thick deposits of limestone are present which are locally capped by shale and sandstone.

The availability of ground water is associated with the nature and type of aquifer materials present in a given area. In this region, there is a pronounced variability in ground-water occurrence, as shown in Figure 240.

Ground-water availability is quite limited in much of the region with a substantial number of "dry holes" being reported in the eastern portions of Scott, Clark, and Floyd Counties. Locally, domestic supplies of water, less than ten gallons-per-minute (gpm), are available from the limestone units. In the western portion of this region, where thicker limestone units are present, well yields are greater and more consistent. Some areas in eastern Washington County are capable of producing over 100 gpm from large diameter wells. Above average yields are also possible from the limestone aquifer system in the Blue River valley of Harrison County.

Major ground-water sources occur in the thick deposits of sand and gravel in the Ohio River valley. Wells commonly yield in excess of 1,000 gpm. A locally anomalous area is present near New Washington where a small sand and gravel deposit is capable of yielding up to 200 gpm.

Water quality in the Ohio River valley sand and gravel deposits is generally good, with hardness levels ranging from 240 to 320 parts-per-million (ppm). Manganese levels in Sellersburg, Charlestown, and Jeffersonville may be sufficiently high to require some form of treatment or removal. Above average nitrate levels occur in Ohio River deposits. Occasional wells in Sellersburg exhibit nitrate levels around 6.0 ppm.

In a number of localities away from the Ohio River valley, water quality is quite questionable and mineralized and "sulfurous" waters are frequently encountered. In the eastern portions of the area mineralized waters are commonly associated with limestone formations, and hydrogen sulfide is present in aquifers overlain by the New Albany shale in Scott and Clark Counties. In Harrison and Washington Counties high hardness and sulfate levels are present near Ramsey and Campbellsburg.

Surface Water

Streamflow Region Fourteen is drained generally from the northeast to the southwest. The Ohio River and the Blue River flow to the southwest. Flowing from east to west is the Muscatatuck River which is a tributary of the East Fork of the White River.

The seven day, once in ten year (Q7-10), one day, once in thirty year, and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations within or near the region are presented in Table 192.

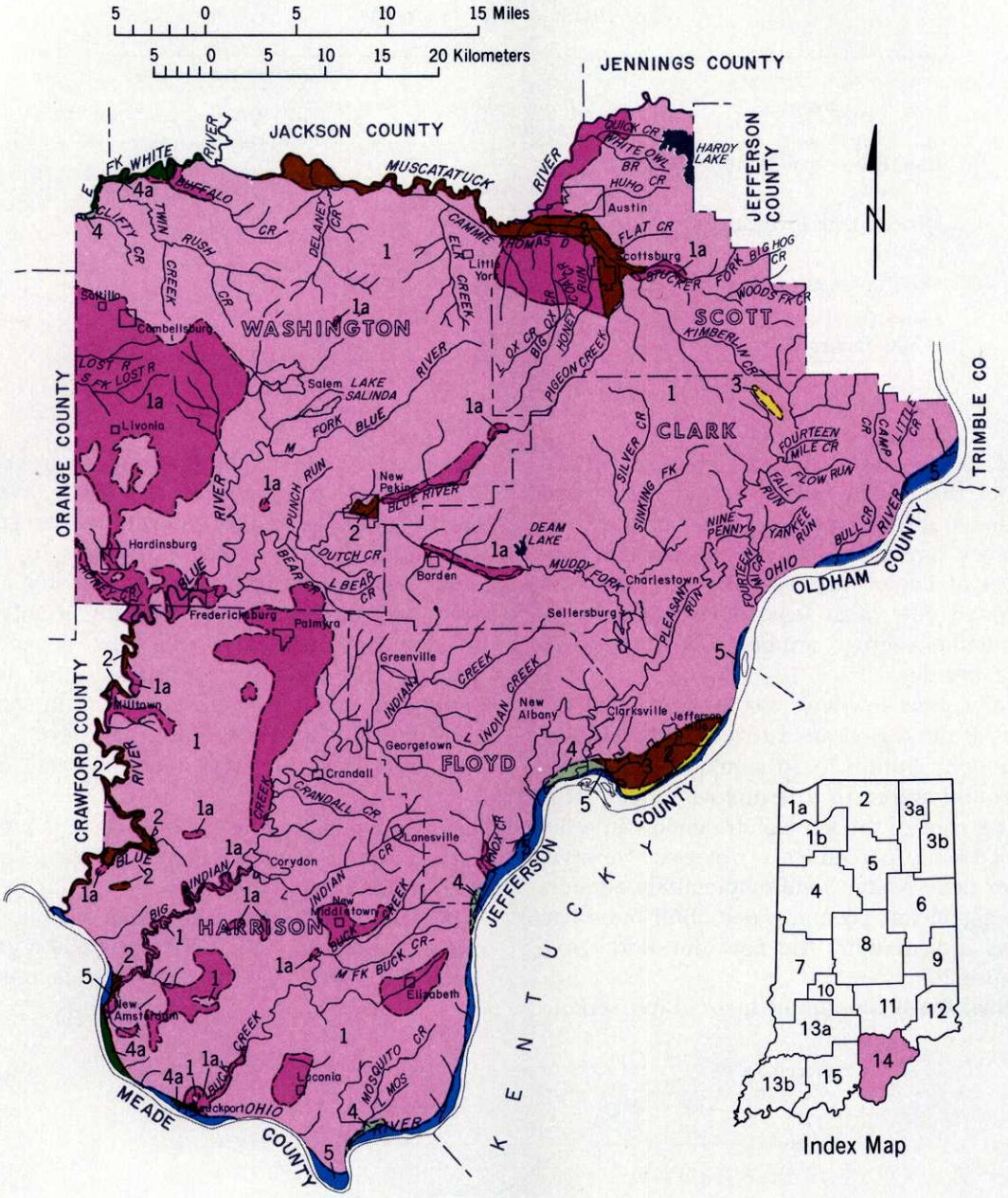


Figure 240
Map of Region Fourteen showing the general location and potential yield of ground water from properly constructed large diameter wells.

Table 192
Flow characteristics of streams.

Stream	Drainage Area (square miles)	Million-Gallons-Per-Day		
		Average Annual	Q7-10	Q1-30
Blue River near White Cloud	476	400	8.4	6.2
Muscatatuck River near Austin	359	250	0.6	0.1
Ohio River at Louisville	91,170	113,600	8,240.0	na
Silver Creek near Sellersburg	189	140	0	0

na: not available.

Analysis of the low-flow characteristics of surface streams within the region indicates that the largest and most reliable streamflows are those in the Ohio River. The seven day, once in ten year low flows for the Ohio River at Louisville reveal that the river will have a sustained flow of at least 53 billion-gallons-per-day, while the average annual flow exceeds 73 billion-gallons-per-day.

The generally poor low-flow characteristics of the other streams in the region are a reflection of minimal ground-water contribution to streamflow. The contribution of ground water to streamflow ranges from about thirty percent of the annual streamflow in a dry year to about twenty percent in a wet year. However the Blue River near White Cloud may contain aquifers that provide significant ground-water contribution to streamflow as indicated by the flow duration curve shown in Figure 241.

To verify this, the technique of hydrograph separation was applied to three annual hydrographs at the gaging station, representing "dry," "average," and "wet" years. The results indicate that the ground-water contribution to streamflow amounts to seventy-two, sixty-four, and thirty-two percent for dry, average, and wet years, respectively. Conversely, from twenty-eight to sixty-eight percent of the flow, depending on the year, is due directly to surface runoff from runoff-producing precipitation events or from snowmelt. The Blue River near White Cloud will have a dependable flow of at least 20.1 mgd, ninety percent of the time.

Lakes The lakes that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are presented in Table 193, and are located on Figure 242. These thirty-four lakes have a combined surface area of approximately 3,760 acres and a gross storage capacity in excess of 8,400 million gallons.

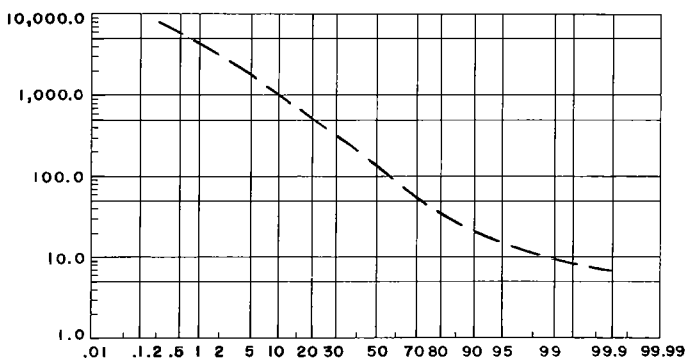


Figure 241
The flow duration curve for the Big Blue River near White Cloud.

Table 193
Lakes at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Delaney Creek Structure No. 1	3.00	27.3	71
2	Delaney Creek Structure No. 2	2.34	25.0	68
3	Elk Creek Structure No. 2	1.21	15.0	35
4	Elk Creek Structure No. 6	0.61	8.0	34
5	Elk Creek Structure No. 9	2.45	47.5	168
6	John Hay Lake	na	na	993
7	Lake Salinda	5.50	85.0	335
8	Palmyra Lake	na	8.0	35
9	Peek-A-Boo Lake	na	na	86
10	Twin Rush Creek Structure No. 3	4.69	14.8	36
11	Arthur S. Klingman Lake	0.12	5.0	37
12	David Garriott Lake	na	12.0	55
13	Hamilton & Rilden Lake	na	12.0	55
14	Lake Hardy	12.00	na	3,897
15	Leroy Smith Lake	na	15.0	48
16	Marysville Lake	7.11	23.0	89
17	Pine Lake	na	16.0	52
18	Scottsburg Reservoir	3.12	1,250.0	194
19	Stucker Fork Structure No. 5	11.20	30.0	33
20	Stucker Fork Structure No. 9	5.69	37.0	72
21	Thomas J. Miller Lake	0.63	15.5	62
22	Borden Reservoir	na	na	145
23	Country Lake	na	14.0	78
24	Deam Lake		1,890.0	928
25	Lake Hideaway	na	22.0	58
26	Schlamm Lake	na	19.0	130
27	Southern Hills Lake	na	52.5	260
28	Stumbler Lake	na	9.0	52
29	Buffalo Trace Lake	0.55	29.4	52
30	Corydon Water Works Dam No. 2	148.00	38.0	38
31	Lanesville Reservoir	0.65	13.5	42
32	St. Peters Lake	na	13.0	65
33	Georgetown Lake	na	10.7	38
34	Mt. St. Francis Proseminary Lake	na	11.0	130

na: not available.

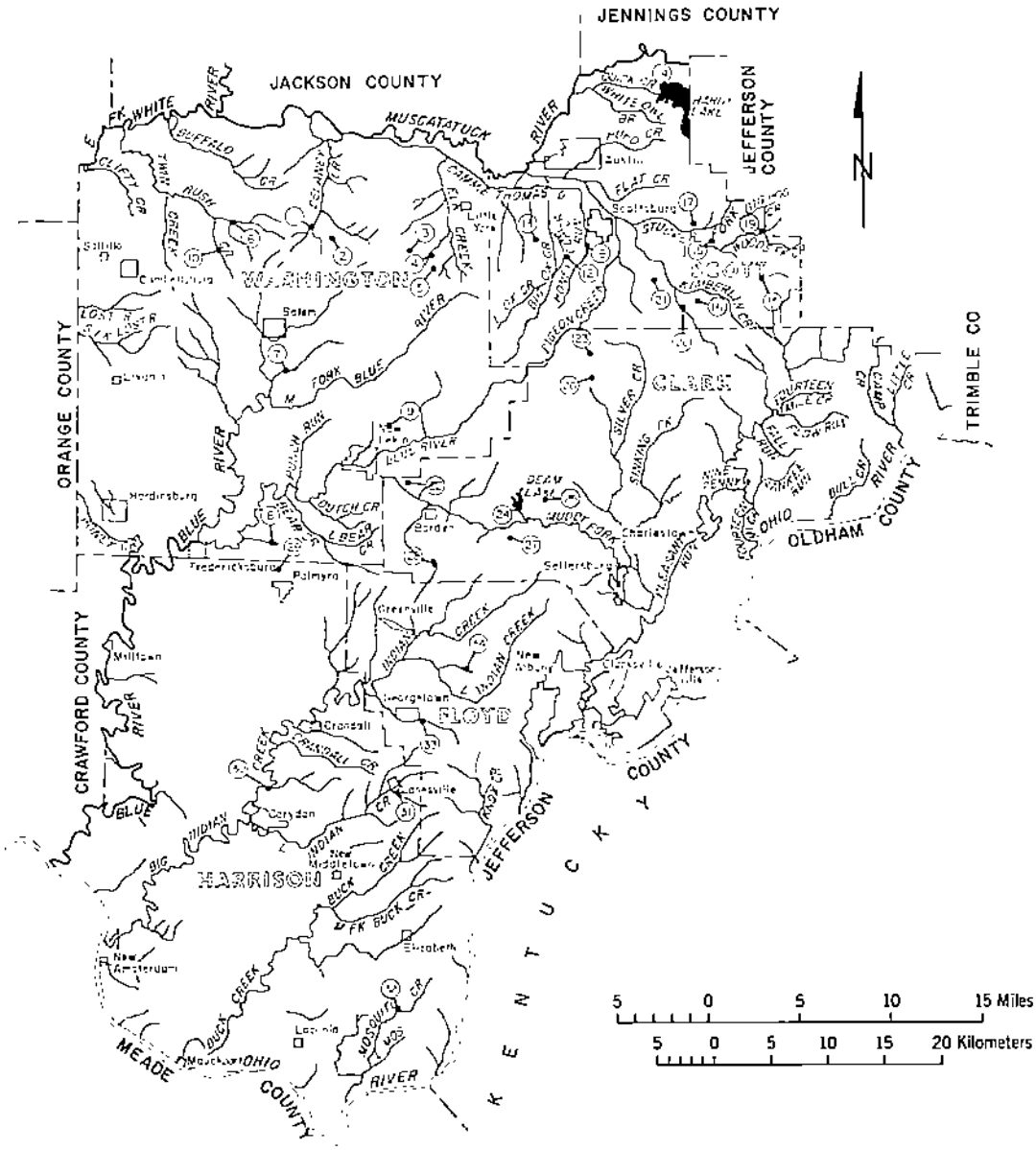


Figure 242
Map of Region Fourteen showing the location of lakes that are at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by the residents of Region Fourteen is presented in Table 194. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Table 194
Outdoor recreation demand and supply analysis.

Activity	*Percent of Population Participating*	*Density Guidelines*	*Approximate Supply*	*Existing Supply as a Percentage of Projected Demand*		
				1980	*1990*	*2000*
Boating	23	19.6 boats/acre/year	14,500 acres[a]	100+	100+	100+
Waterskiing	8	34.4 skiers/acre/year	12,000 acres[b]	100+	100+	100+
Canoeing	5	585 canoes/mile/year	104 miles	100+	100+	100+
Swimming	7	76,600 swimmers/acre/year	0 acres	0	0	0
Ice-Skating	38	6,678 skaters/acre/year	7 acres[c]	54	54	50
Fishing	52	66 persons/acre/year	25,700 acres[d]	100+	100+	100+

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.
[a]Includes 11,500 acres of the Ohio River and 3,000 acres of inland waters.
[b]Includes 11,500 acres of the Ohio River and 500 acres of inland waters.
[c]Does not include the Ohio River.
[d]Includes 11,500 acres of the Ohio River and 14,200 acres of inland waters.

Boating and Waterskiing The recreational lakes contained in the region and the acreage available in the Ohio River constitute the major boating and waterskiing resources. It is estimated the available water acreage will meet the region's demand for boating and waterskiing through the year 2000.

Canoeing There are approximately 104 miles of free-flowing streams that have a sufficient base flow to provide opportunity for canoeing. Included in this figure are approximately fifty-eight miles of Blue River, fourteen miles of the East Fork of the White River, and fourteen miles of the Muscatatuck River. This supply of canoeable streams is expected to meet the demand through the year 2000.

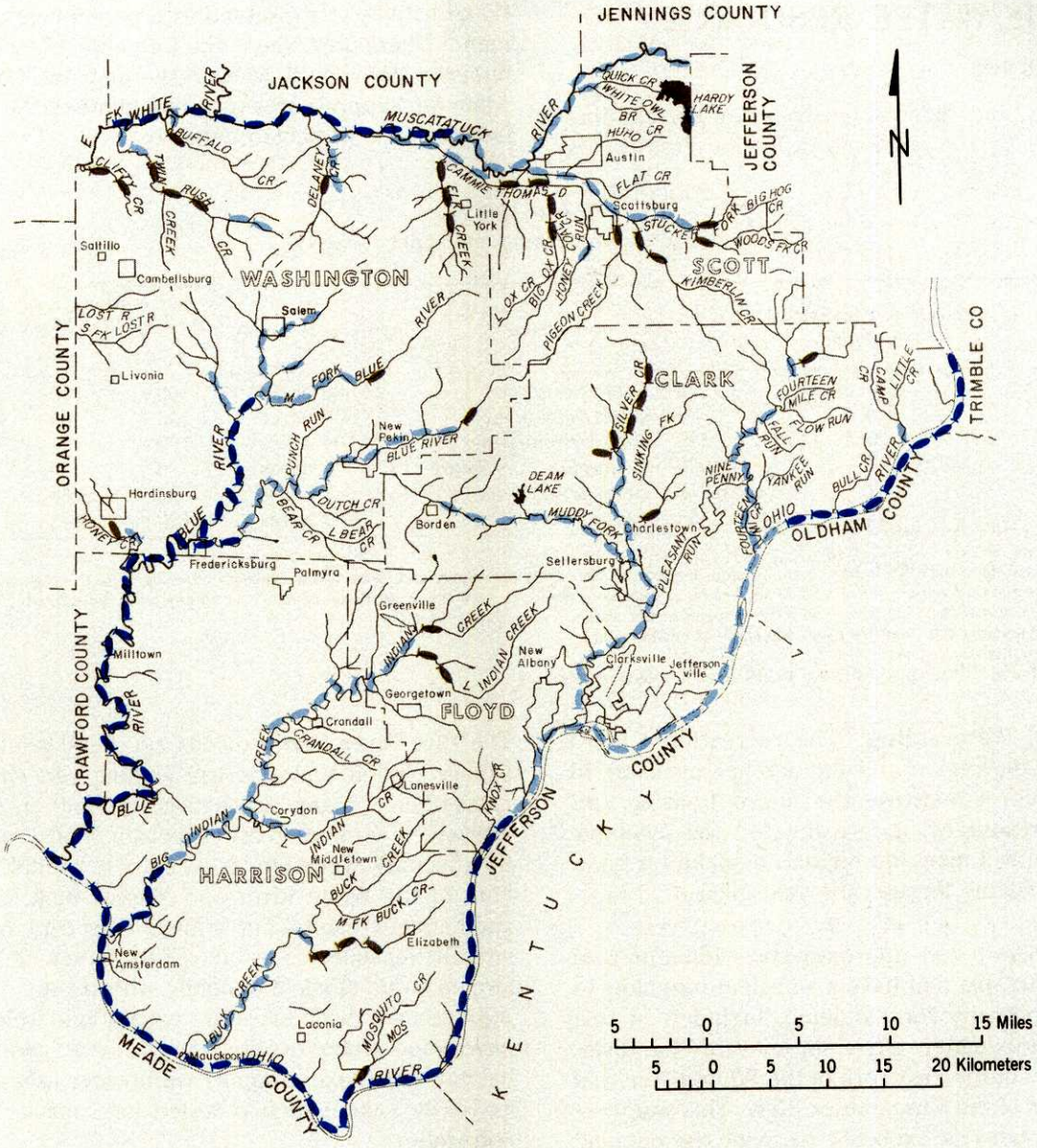
Swimming and Ice-skating The demand for both swimming and ice-skating acreage exceeds the supply. There are no ice-skating facilities in the region. The demand for swimming and ice-skating is expected to exceed the supply through the year 2000.

Fishing The quality of the fisheries habitat is shown on Figure 243. Warmwater fish, including sunfish and catfish, are located in most of the region's streams and lakes. Except for dams along the Blue River, Indian Creek, Silver Creek, and the Ohio River, the streams in the southern counties are relatively unaltered. The Ohio still provides excellent fisheries habitat and is used for commercial fishing as well as sport fishing. The Blue River also provides excellent habitat for its fishery, which includes the endangered Ohio River muskellunge. Many channelized streams in the more intensively farmed areas, especially Scott County, lack the diversity needed for good aquatic habitat. The East Fork of the White River and Muscatatuck River have good aquatic habitat but some of their tributaries have very little fisheries value. Clifty Creek is the only stream to be stocked annually with trout.

Since man-made lakes are usually undeveloped and have good water quality, they provide good aquatic habitat. Most lakes support warmwater fisheries, such as Hardy Lake, which is noted for sunfish, bullhead, and walleye.

Public fishing sites are available at the confluence of the East Fork White River and East Fork of the Muscatatuck River, on the mainstream of the Muscatatuck River, the Ohio River, in the Harrison-Crawford State Forest and on Elk Creek in Washington County. Sharps Mill Pond provides access to the Blue River. Indian Creek is accessible from the Indian Creek Dam Number 3. Hardy Lake, Dean Lake State Recreation Areas, and Clark State Forest also offer public access for fishing. City or county parks and bridges may provide public access for fishing. The region has a surplus of fishing water which is projected to continue through the year 2000.

Riparian Habitat The quality of the wildlife habitat associated with streams and lakes is shown on Figure



AQUATIC HABITAT VALUE

- High
- Moderate
- Low

Figure 243
Map of Region Fourteen showing the quality of the fisheries habitat.

244. The rugged terrain of the southern part of the region promotes riparian habitat of high value. Habitat along some streams passing through the intensively farmed areas has been reduced by channelization. Other areas are revegetated by young and intermediate age hardwoods which increase their wildlife value. Upland and woodland game animals utilize the wooded streambanks as well as furbearers and some waterfowl. Wetlands created by the backwaters of the Ohio River provide excellent wood duck nesting habitat and are also used by migrating waterfowl, other birds, and various furbearers and other wildlife.

Many of the lakes are located on state-owned property and are relatively undeveloped, providing very good wildlife habitat. The habitat around nonstate-owned lakes is generally good, although Buffalo Trace Lake, Georgetown Lake, and Iola Lake have low habitat values due to insufficient cover. A shallow marsh at Hardy Lake provides good waterfowl habitat. Public hunting is permitted on the Jackson-Washington, Harrison, Crawford, and Clark State Forests.

Hydroelectric Power Due to limitations of topography and streamflow characteristics, there are no current commercial hydroelectric installations here. However, the best potential for future sites is on the Ohio River at the U.S. Army Corps of Engineers dam projects.

Commercial Navigation The Ohio River is an important branch of the nation's system of navigable inland waters. McAlpine Dam, a large dam and lock system, is located near Jeffersonville in Clark County. This structure was redesigned in 1965 and passed an estimated thirty million tons of cargo in 1974. Studies by the Ohio River Basin Commission indicate the McAlpine locks and dam may reach their cargo capacity by the year 2000. The commission has recommended that the U.S. Army Corps of Engineers conduct a preliminary investigation of the need for modification of the locks and dam to accommodate increased cargo.

There are three components of the Ohio system outside the region that affect the overall system efficiency and, therefore, the future volume of traffic on the waterway. These are the locks on the dam at Gallipolis upriver and the two older dams (locks 52 and 53) downriver in Illinois.

Application for a permit for dock facilities to be used in conjunction with a proposed industrial port was made to the U.S. Army Corps of Engineers by the Indiana Port Commission in April of 1974 for the Clark County Maritime Center. This project was planned on the Ohio River upstream from Jeffersonville, Indiana. The port facilities will require about two hundred acres of land and will be built on the flood plain of the Ohio River behind Six Mile Island.

Withdrawal Uses

Public Water Supply Clark, Floyd, Harrison, Scott, and Washington Counties are served by forty public water utilities. Thirteen of these are municipal systems, twenty-two are rural systems, and five are subdivision systems. Information for these public water utilities is presented in the following table.

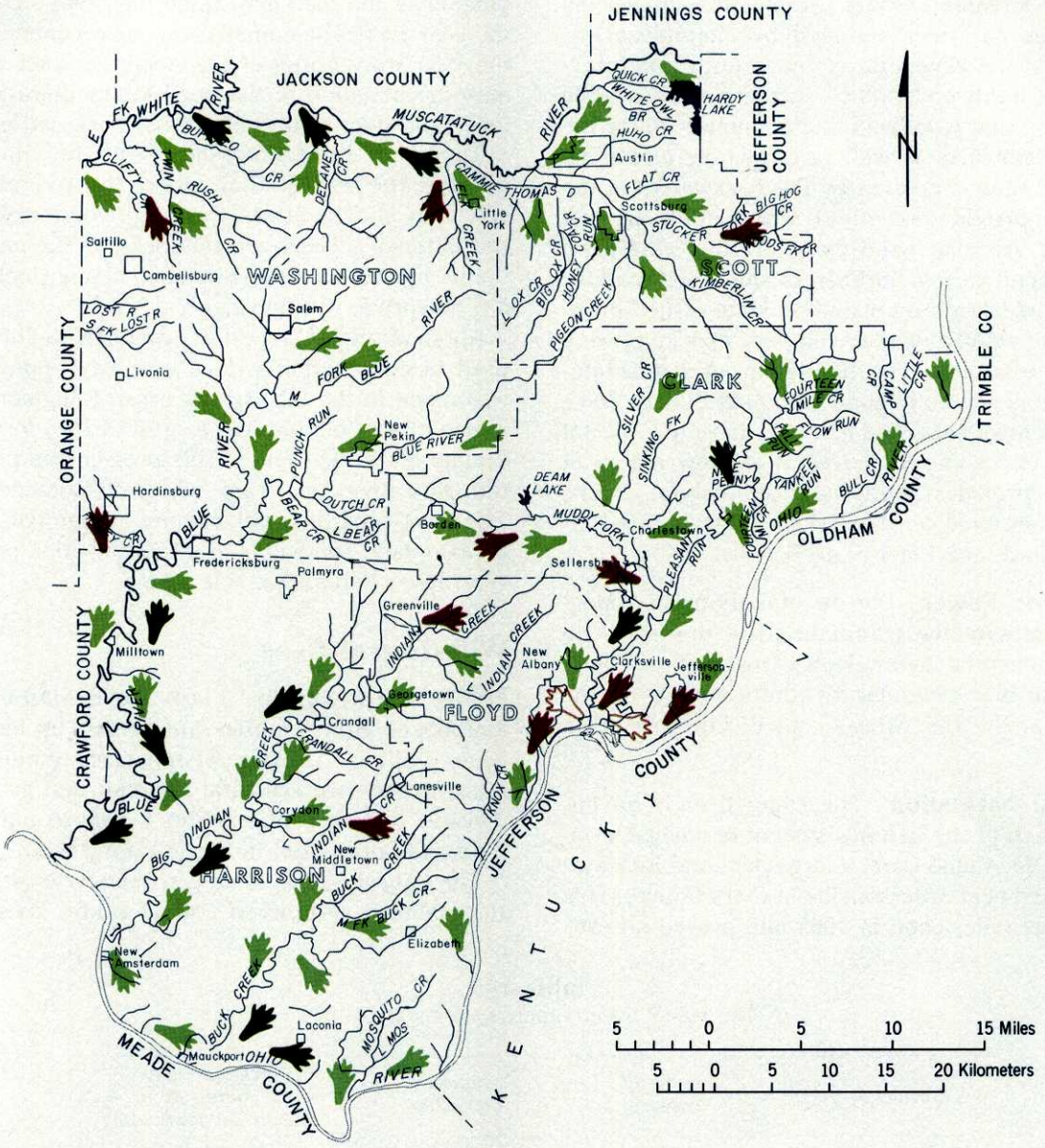
The largest county-wide use of water is attributed to the eighteen systems in Clark County. These utilities served about 61,160 persons in 1975 and supplied an average of 7.7 mgd. The eight systems in Washington County had the smallest county-wide use of water in the region. They served 7,800 persons and supplied an average of 0.8 mgd. Figure 243 shows the water service areas and the rate of water withdrawals by public water utilities.

Table 195
The public water supply systems as of 1975.

Counties	*Number of Systems*	*Service Population*	*Average Daily Withdrawals in Million-Gallons-Per-Day*
Clark	18	61,160	7.7
Floyd	9	45,600	5.3
Harrison	11	9,000	1.3
Scott	6	15,200	1.4
Washington	9	7,800	.8
Total	53*	138,700	16.5

*Regional total does not equal sum of county totals due to several multi-county systems.

Several of the systems in the region not only supply their own water but also sell water to one or more other systems in the region. The relationship between system sellers and buyers is presented in Table 196. Several are multi-county systems extending into two or more counties. As a result, some utilities export and import water from one county to another.



RIPARIAN HABITAT VALUE

High

Low

Moderate

Negligible

Figure 244
Map of Region Fourteen showing the quality of the riparian habitat.

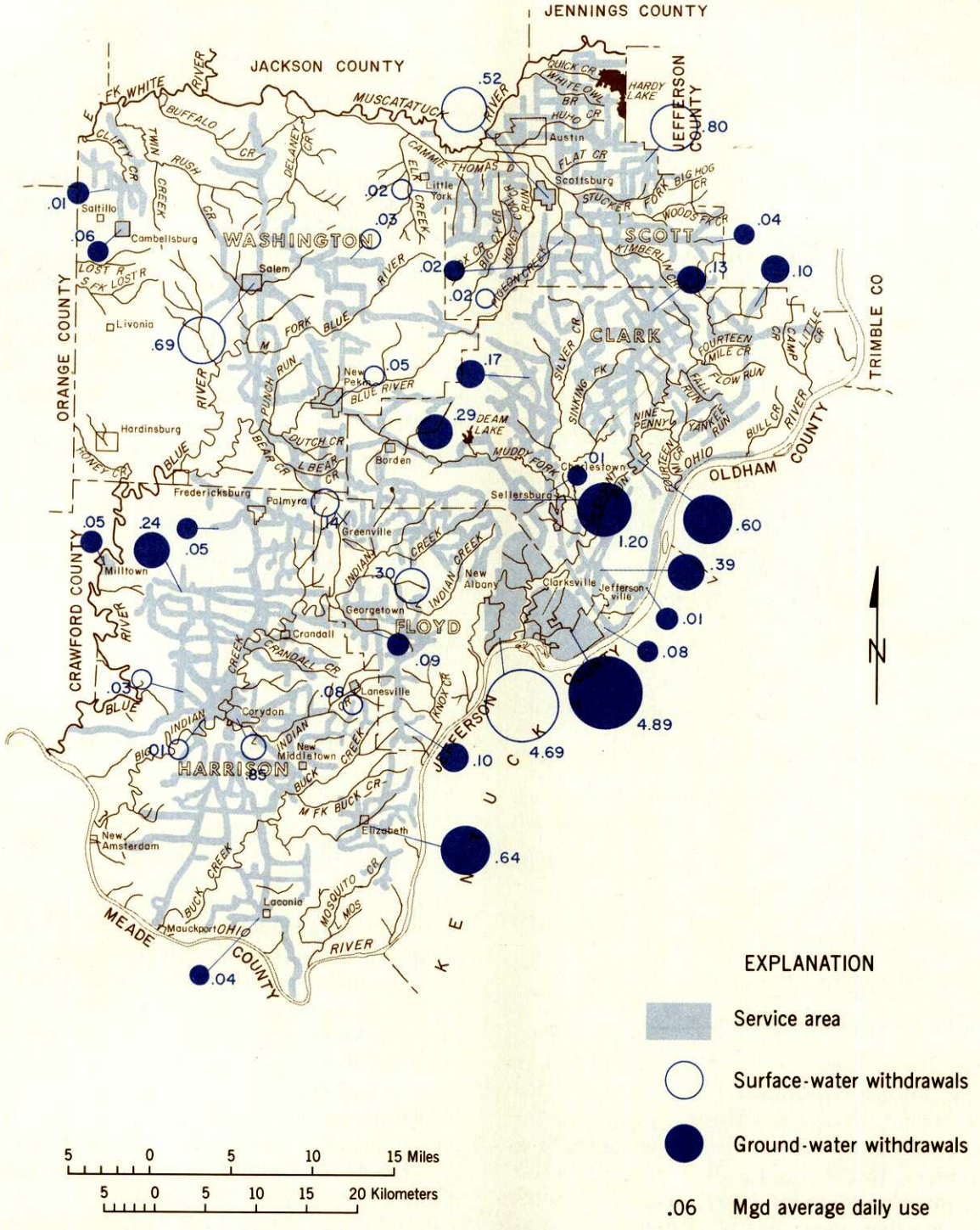


Figure 245
Map of Region Fourteen showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

Table 196
Public water system sellers and purchasers.

Sellers	*Purchasers*
Campbellsburg Water Works	North Brown Water Corporation
Corydon Water Utility	East Harrison Water Company West Harrison Water Corporation
Charlestown Water Department	Marysville-Ostisco-Nabb Water Utility
Edwardsville Water Corporation	Elizabeth Water Company
Madison Water Department*	Kent Water Company
Ramsey Water Company, Inc.	Floyd's Knobs Water Company Georgetown Water Department Greenville Water Utility Palmyra Water Company West Harrison Water Company
Riverside Water Company, Inc.	Oak Park Conservancy District
Salem Water Works	East Washington Rural Water Corporation Pekin Municipal Water Utility
Scottsburg Water Department	Underwood Water Company Vienna Water Company, Inc.
Sellersburg Water Department	Rural Membership Water Corporation Silver Creek Water Corporation
Stucker Fork Water Utility	Kent Water Company

*Madison Water Department is located outside the region.

The utilities serving Louisville, Corydon, Salem, Scottsburg, Borden Tri-County Regional Water District, New Albany, Georgetown, Greenville, and Stucker Conservancy District withdraw their water supply from surface sources. The utilities that withdraw their water supply from ground water locate their well fields within or near their respective service areas.

The forty utilities in the region withdrew an average of 16.5 mgd in 1975. Approximately fifty percent is withdrawn from groundwater sources while fifty percent is withdrawn from surface water supplies. Projections of public water utilities indicate that withdrawals may increase to approximately 29.5 mgd by the year 2000, as presented here.

Table 197
The 1977 and projected water withdrawals and consumption rates of public water supplies, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	16.5	18.1	23.6	29.5
Consumption	3.8	4.2	5.4	6.8

Industrial Water Industrial establishments had a water intake averaging 14.7 mgd in 1977. Of the total industrial intake, 9.6 mgd was self-supplied by the industries while 5.1 was consumed through the manufacturing process. Most of the self-supplied water is withdrawn from ground-water sources.

The largest water-using industry group is comprised of small industries. Others that use large amounts of water include the chemical, food processing, and steel industries.

Industrial production is expected to increase by the year 2000; however, due to increased plant efficiency, water withdrawals are projected to rise only moderately, to 20.2 mgd. Withdrawals of self-supplied water are estimated to increase by 14.0 mgd in the year 2000, as indicated in the following table. Use of water supplied by public utilities is projected to increase to approximately 6.2 mgd.

Table 198
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	9.6	10.3	12.0	14.0
Consumption	2.0	2.4	3.5	4.9

Rural Self-Supplied Water Most of the rural self-supplied water is withdrawn from ground-water sources. An estimated 63,500 persons lived in homes supplied by individual water sources in 1975. It is estimated that these people used about 3.6 mgd for residential purposes in that year. An estimated 9,800 additional persons will depend on their own supplies for household water by the year 2000. These people, along with the anticipated general rise in the standard of living, are expected to increase rural residential water use to about 4.2 mgd by the year 2000.

In 1975, use of rural self-supplied water for farm animals amount to 2.3 mgd. By the year 2000, this use may increase to 2.6 mgd. Water for livestock is usually withdrawn from ponds, streams, and springs.

The total withdrawal of rural self-supplied water may increase from the current 6.0 mgd to approximately 6.9 mgd by the year 2000, as shown in Table 199.

Table 199
The 1977 and projected water withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.0	6.2	6.5	6.9
Consumption	6.0	6.2	6.5	6.9

Irrigation Water Based upon the survey of irrigated lands, approximately 230 acres of agricultural lands were irrigated during 1977. By the year 2000, about 250 acres may be irrigated. Assuming 1977 as a normal growing year, about 0.6 mgd of water could have been applied during the "average" irrigation period of July and August. Water withdrawal for crops by the year 2000 may approach 1.2 mgd during an "average" irrigation season.

In addition to irrigation for agricultural use, about 0.3 mgd was applied to golf courses during the peak July and August irrigation period in 1977. Irrigation withdrawals for golf courses is expected to increase to 0.6 mgd by the year 2000.

The total withdrawal for irrigation of croplands and golf courses during the irrigation season of 1977 was approximately 0.9 mgd. These withdrawals may increase to 1.2 mgd during the "average" growing season by the year 2000, as tabulated here.

Table 200
The current and projected withdrawals of irrigation water for croplands and golf courses during an average growing season, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.9	1.0	1.1	1.2
Consumption	0.9	1.0	1.1	1.2

Electric Energy Region Fourteen contains one electric generating facility, the Gallagher plant. It is owned and operated by Public Service Indiana, and is located on the Ohio River in Floyd County. The facility is fossil-fueled and utilizes a once-through cooling system. It has a generating capacity of 680 megawatts and withdraws 488 mgd from the Ohio River. These withdrawals will end as the plant is retired by the year 2000.

There are four additional power plants in Kentucky across the Ohio River as well as many other existing and planned facilities both upstream and downstream of the region's borders along the river.

Water withdrawals for the production of electricity were approximately 488 mgd during 1977. These withdrawals are expected to end by the year 2000, as presented in the following table.

Table 201
The 1977 and projected water withdrawals and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	488.0	488.0	488.0	0.0
Consumption	0.0	0.0	0.0	0.0

EXCESS WATER

Flooding

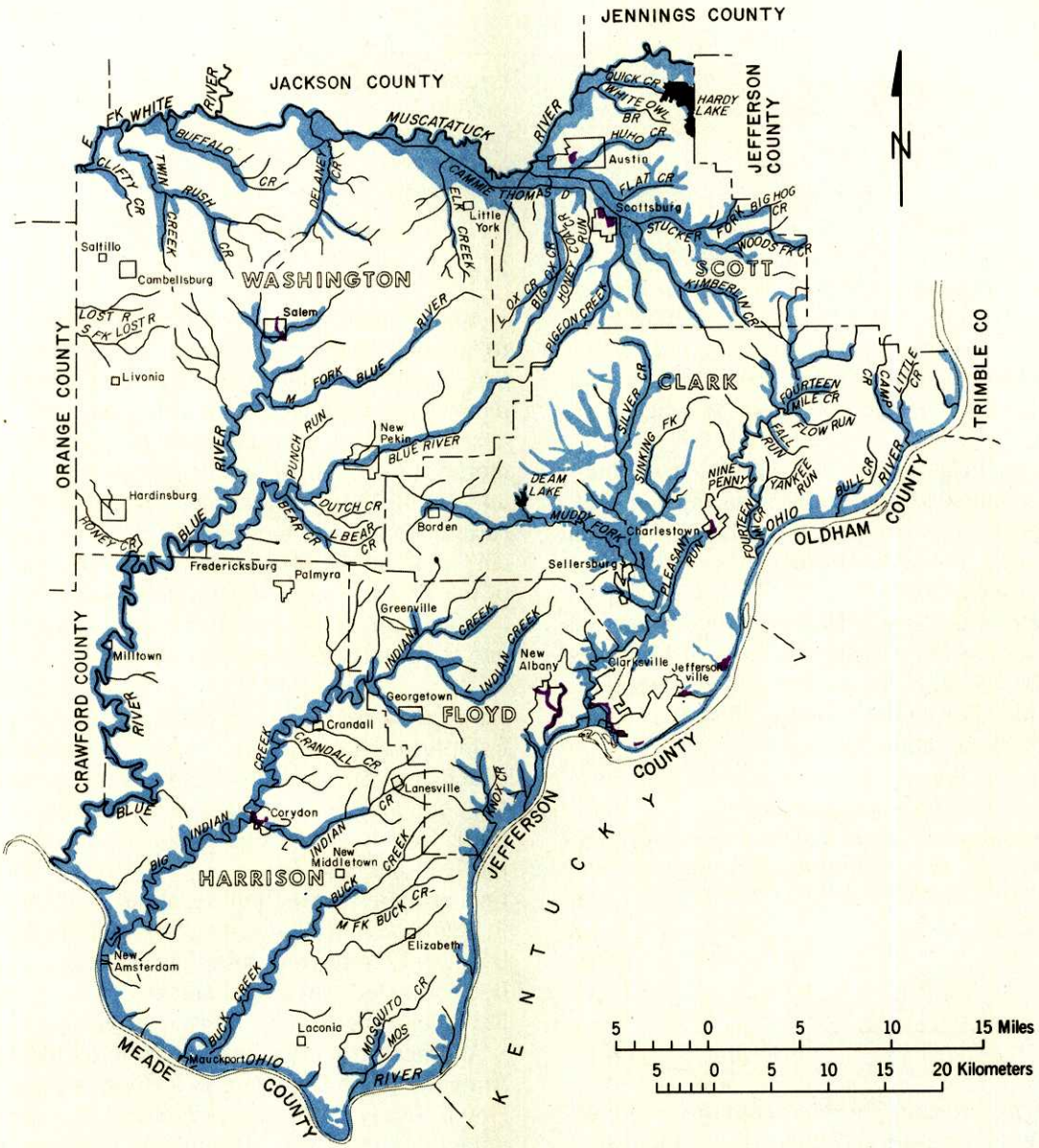
Approximately 84,247 acres of the region are subject to flooding. The major flood plains are shown in Figure 246. Figure 247 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be about $480,000 for urban areas and $1,800,000 for rural areas. Over half of the region's rural damages and one-third of the urban damages occurred along the Muscatatuck River and the East Fork of the White River. The Ohio River accounts for about fourteen percent of the urban damages and less than one percent of the rural damages.

Flood Control The U.S. Army Corps of Engineers has completed three local protection projects, one of which is located on the right bank of the Ohio River at the contiguous cities of Jeffersonville and Clarksville in Clark County. The project, consisting of a system of earth levees and concrete walls with pumping facilities, provides protection for about 4,190 acres of land in Jeffersonville, Clarksville, the community of Claysburg, and contiguous suburban and agricultural areas. It is estimated that flood damages amounting to almost $21 million have been averted by the project to date.

Another protection project constructed by the U.S. Army Corps of Engineers is located at New Albany in Floyd County. This project consists of a system of 2.8 miles of earth levee, 0.7 miles of concrete walls, and six pumping facilities. The project protects about 1,500 acres in the city of New Albany from Ohio River floods equal in magnitude to the 1937 flood, which is the maximum flood on record at this location. It is estimated that flood damages amounting to $3,028,000 have been averted by the project.

Another U.S. Army Corps of Engineers' protection project is located at Corydon in Harrison County. The work consists of channel modifications extending through Corydon on Indian and Little Indian Creeks and continues about 2.5 miles below thier junction. The work provides for the enlargement of about 3.3 miles of Indian Creek and 1.1 miles of Little Indian Creek.

The Elk Creek Small Watershed project is located in



MAJOR FLOOD PLAINS

Urban

Rural

Figure 246
Map of Region Fourteen showing the major flood plains.

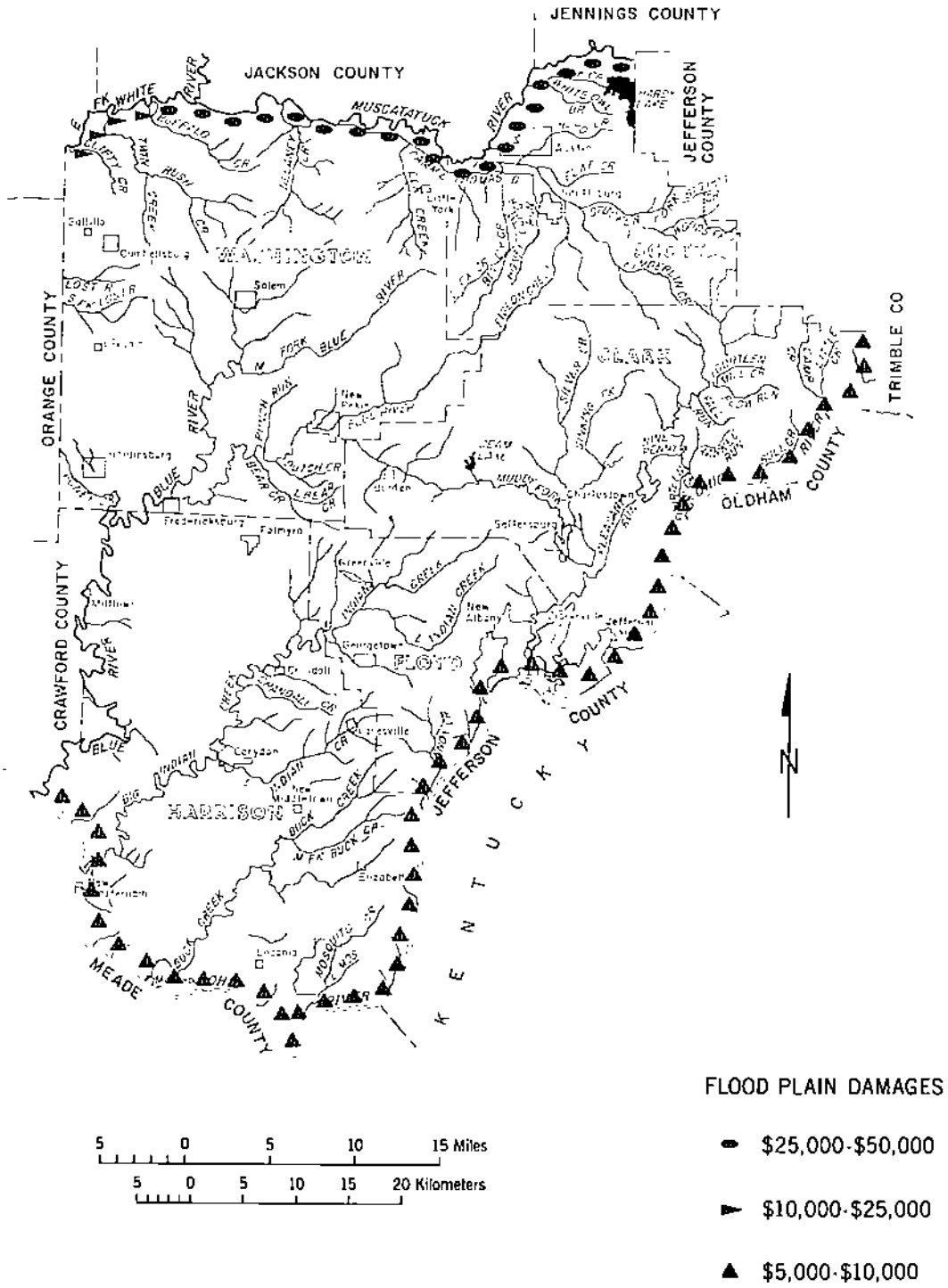


Figure 247
Map of Region Fourteen showing the estimated average annual flood damages per mile along selected streams.

Region Fourteen. The Twin Rush Creek, Delaney Creek, Stucker Fork and Muddy Fork of Silver Creek small watershed projects are under construction.

Flood Plain Management Communities participating in the emergency phase of the National Flood Insurance Program are listed in the following table. New Albany and Salem are participating in the regular phase of the program.

Table 202
Communities participating in the emergency phase of the National Flood Insurance Program.

Austin	Georgetown
Clark County, unincorporated	Harrison County, unincorporated
Clarksville	Jeffersonville
Charlestown	Lanesville
Corydon	Mauckport
Crandall	New Amsterdam
Floyd County, unincorporated	Scottsburg
Fredericksburg	Sellersburg

Agricultural Drainage

Approximately five percent of the soil associations have "severe," twelve percent have "moderate," and eighty-three percent have "slight" wetness characteristics as shown in Figure 248. There are approximately forty-three miles of legal drains in the region, which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards or, in a limited number of cases, the conservancy districts. There is no legal entity that is responsible for maintaining drainage for other streams in the region.

Soil Erosion

The erosion potential of soil associations is shown in Figure 249. Seventy-seven percent of the 1,101,000 acres in Region Fourteen is rated as having a "high" soil erosion hazard potential. Ten percent is classified as having a "medium" potential erosion hazard, and the remaining thirteen percent is rated as having a "low" erosion potential for land in a fallow state.

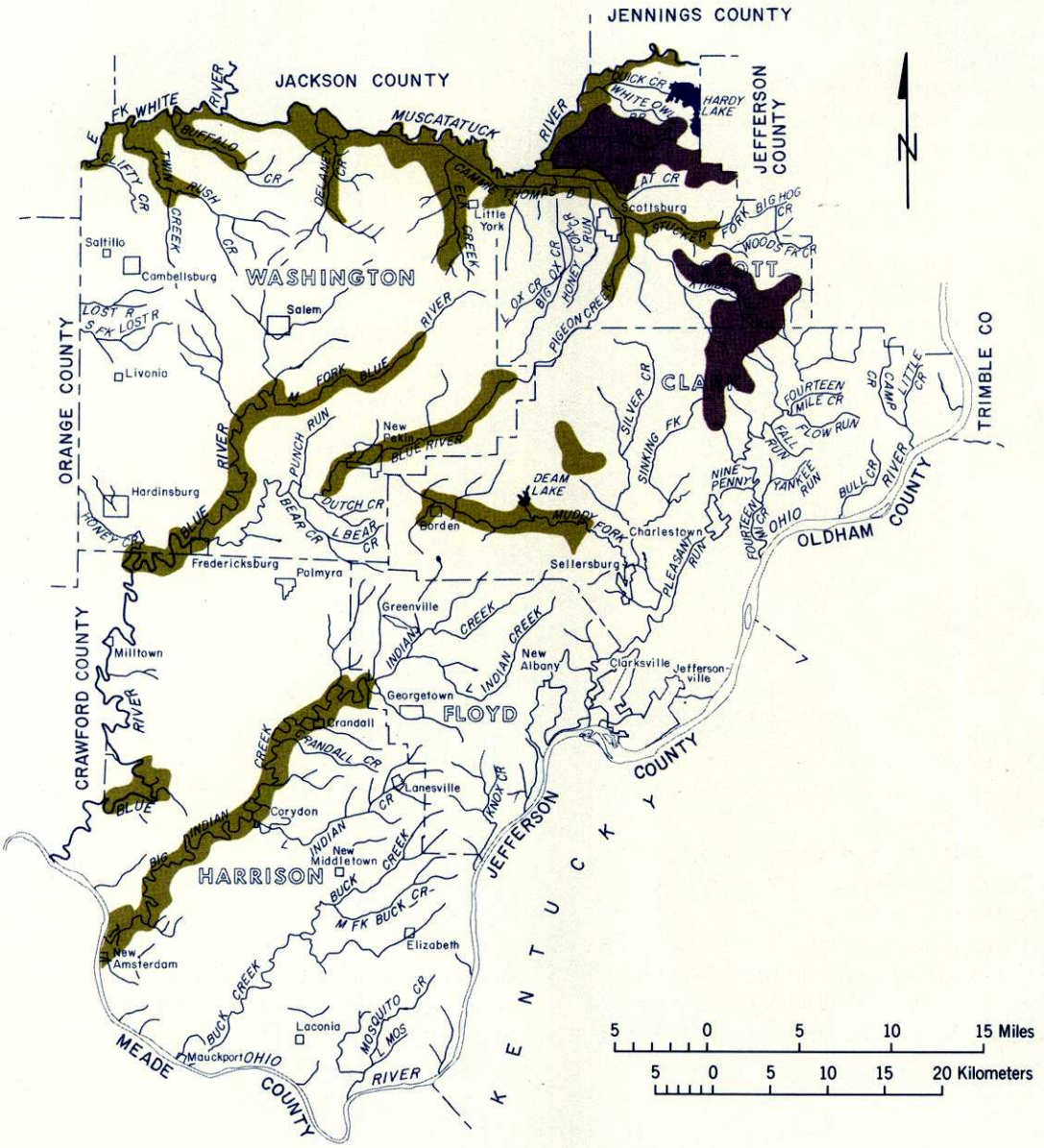
WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the Blue, Muscatatuck, and Ohio Rivers. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana.

Samples of the Blue River near Fredricksburg indicated that the temperature, dissolved oxygen, and maximum and minimun values of pH were in compliance with state standards. Nitrate levels and the biochemical oxygen demand were also within recommended levels.

The Muscatatuck River exhibited temperature and pH values that were in compliance with state standards. Levels of dissolved oxygen occasionally fell below the water quality standard, although the biochemical oxygen demand concentrations seemed to be at acceptable levels.

The Ohio River is degraded by the combined impacts of municipal and industrial discharges from cities in Indiana and Kentucky. Fecal coliform bacteria often exceeded limits established by the state. This is particularly true at times of low flow and when temperature increased in the stream.



SOIL WETNESS CHARACTERISTICS

- Slight
- Moderate
- Severe

Figure 248
Map of Region Fourteen showing the general location of the wetness characteristics of soil associations.

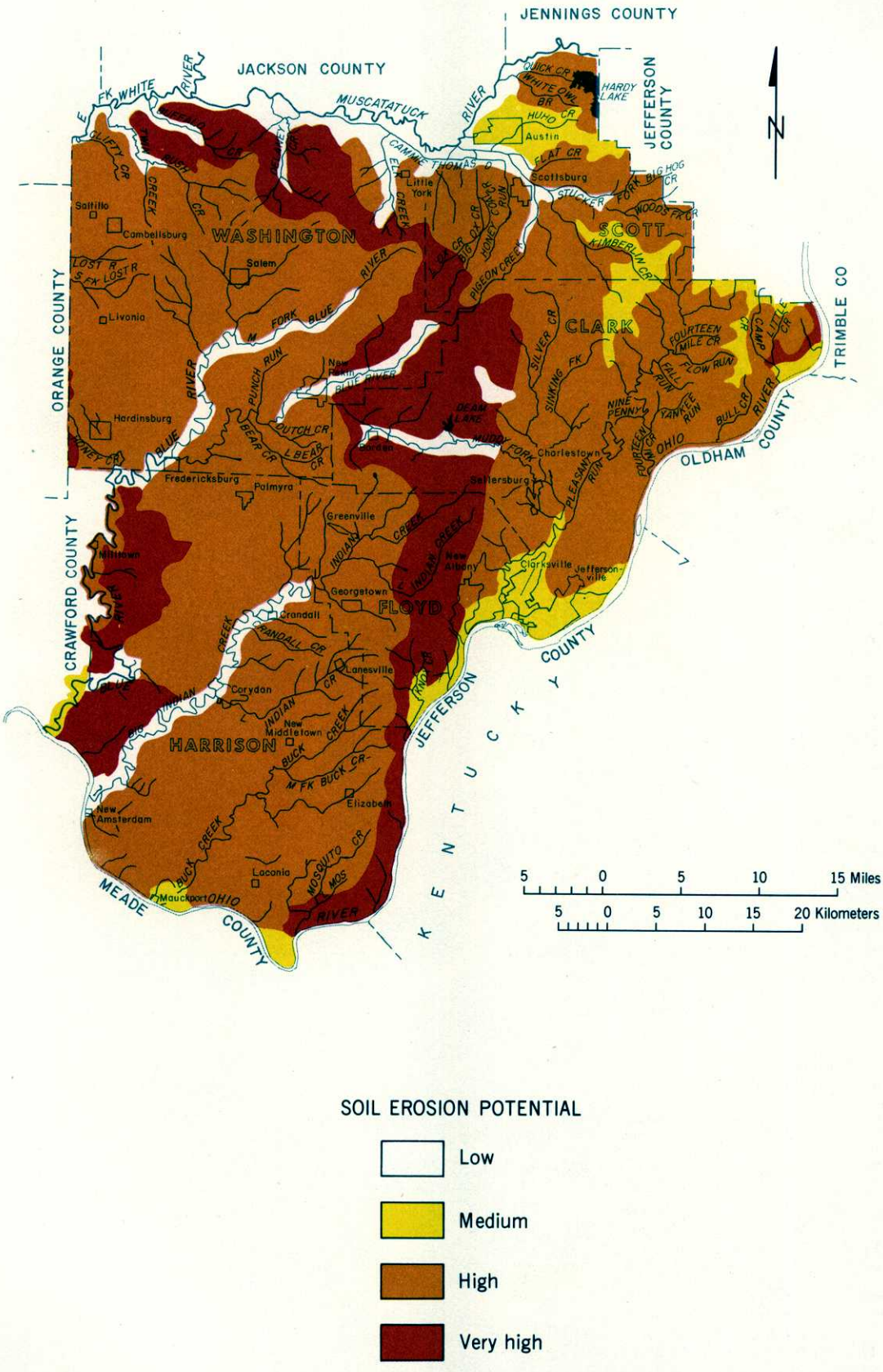


Figure 249
Map of Region Fourteen showing the erosion potential of the soil associations.

Region Fifteen

Crawford, Dubois, Orange, Perry, and Spencer Counties, located in south-central Indiana, form Region Fifteen. The region encompasses approximately 1,930 square miles and is bounded by Daviess, Martin, and Lawrence Counties to the north; Washington and Harrison to the east; the Ohio River to the south; and Warrick and Pike Counties to the west as indicated in Figure 250.

The 1975 population was approximately 95,000 of which thirty-four percent resided in Dubois County. The official Indiana Population Projections indicate the region's population will increase by nineteen percent by the year 2000. The 1975 population and the projections for each county are presented below. The major population centers within the region are Jasper in Dubois County and Tell City in Perry County.

Table 203
The 1975 and projected populations for Region Fifteen.

County	*1975*	*1980*	*1990*	*2000*
Crawford	8,700	9,400	10,300	11,100
Dubois	32,000	33,300	36,500	39,500
Orange	17,400	17,900	18,600	18,900
Perry	19,100	19,200	19,700	20,200
Spencer	17,800	18,700	20,600	22,600
Total	95,000	98,500	105,700	112,300

Agriculture is the dominant land use within the region with more than fifty-one percent of the area devoted to that purpose. Approximately thirty-seven percent of the land is forested while the remaining twelve percent represents urban and miscellaneous uses. The

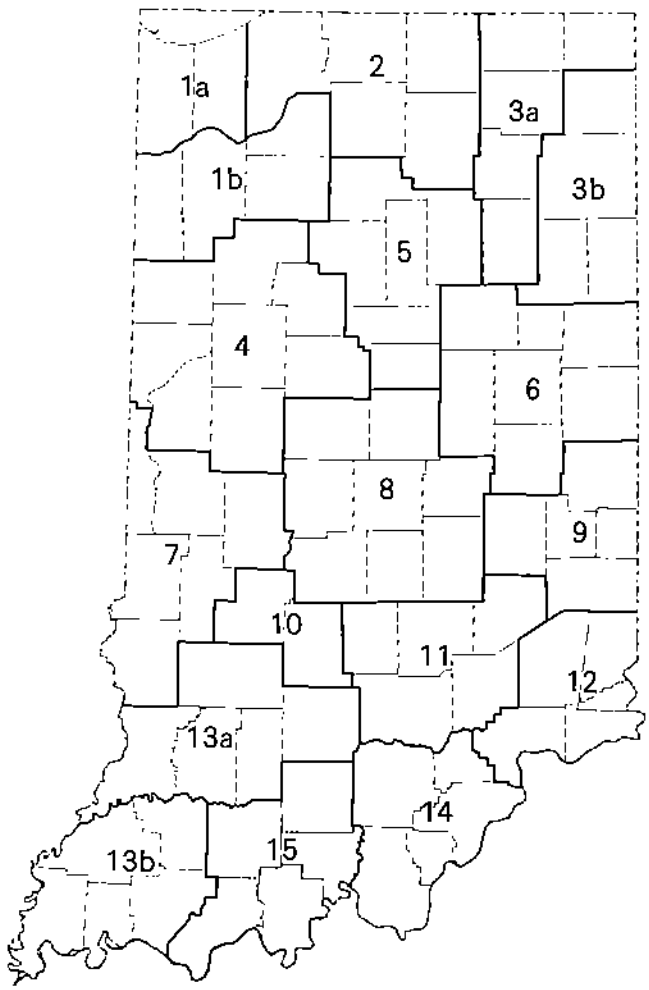


Figure 250
Map of Indiana showing the location of Region Fifteen.

topography of the region is characterized by slightly rolling to hilly terrain.

Approximately fifty-two percent of the work force is employed by the manufacturing sector with the lumber and furniture industries providing a large percentage of the jobs. The nonmanufacturing sector provides about forty-two percent of employment opportunities with wholesale and retail trade leading this sector. Over half of the employment opportunities are in Dubois County.

Average annual precipitation for the region is approximately 45.0 inches. This varies from a high in March of 4.7 inches to a low in October of 2.5 inches. Of the 45.0 inches of average annual precipitation approximately 27.0 inches are consumed through evapotranspiration while 18.0 inches appear as streamflow. Average temperatures range from 33°F. in January to 77°F. in July. The average annual temperature is 56°F. Prevailing winds are from the south to southwest at 8.3 miles per hour.

THE WATER RESOURCE

Ground Water

Ground-water availability is usually considered poor except for sand and gravel deposits along the Ohio River and a few isolated areas in western Dubois and southwestern Spencer Counties, as shown in Figure 251.

Bedrock is usually shallow in depth with layers of thin, weathered and broken rock overlying it. The bedrock consists of shales, sandstones, and limestones which yield limited amounts of water. Wells in these bedrock deposits normally yield less than ten gallons-per-minute (gpm). Higher yields up to one hundred gpm are possible from limestones in northeastern Orange County. Areas bordering Crawford County along the Blue River can also be expected to produce above average well yields from bedrock sources.

Large ground-water yields in the region are only available along the Ohio River and the East Fork of the White River where thick sand and gravel deposits are present. Properly constructed, large-diameter wells can be expected to produce over 1,000 gpm from these deposits. Other areas of higher ground-water yields are limited to western Dubois County, where sand and gravel deposits are capable of producing up to two hundred gpm, and to southwestern Spencer County, where depostis contained in an old Ohio River channel can yield up to six hundred gpm.

Water hardness varies considerably with maximum values of 700 parts-per-million (ppm) occurring in eastern Orange and Crawford Counties. The limestones also exhibit lower than normal values of iron at 2.0 ppm, higher than normal nitrates at 5.0 ppm, fluoride at 1.7 ppm and sulfate levels above 500 ppm.

Wells in sand and gravel deposits along the Ohio River yield fairly hard water of 320 to 550 ppm, iron as much as 5.4 ppm, and high sulfates and nitrates ranging from 3.0 to 4.0 ppm.

Surface Water

Streamflow Region Fifteen is bordered on the south by the westward flowing Ohio River, on the north by the westward flowing East Fork of the White River, on the east by the southward flowing Blue River, and on the west by southward flowing Little Pigeon Creek. Drainage within the region is affected primarily by the Anderson, Patoka, Lost, and Little Blue Rivers and their tributaries. Generally, the streams flowing westward are part of the Wabash River basin, and the southward flowing streams enter directly into the Ohio River.

The seven day, once in ten year (Q7-10), one day, once in thirty year (Q1-30) and the average annual flow in million-gallons-per-day (mgd) for streams with gaging stations within Region 15 are tabulated below.

Table 204
Flow characteristics of streams.

Stream	*Drainage Area (square miles)*	*Million-Gallons-Per-Day*		
		Average Annual	*Q7-10*	*Q1-30*
Lost River near West Baden Springs[a]	287	na	1.7	na
Middle Fork Anderson River at Bristow	42	34	0.0	0.0
Patoka River near Ellsworth	171	130	0.1	0.0
Patoka River at Jasper[b]	262	230	0.5	0.0

na: not available.
[a]Flow characteristics estimated from stream gaging stations with a short period of record.
[b]Flow recorded prior to the construction of Patoka Lake.

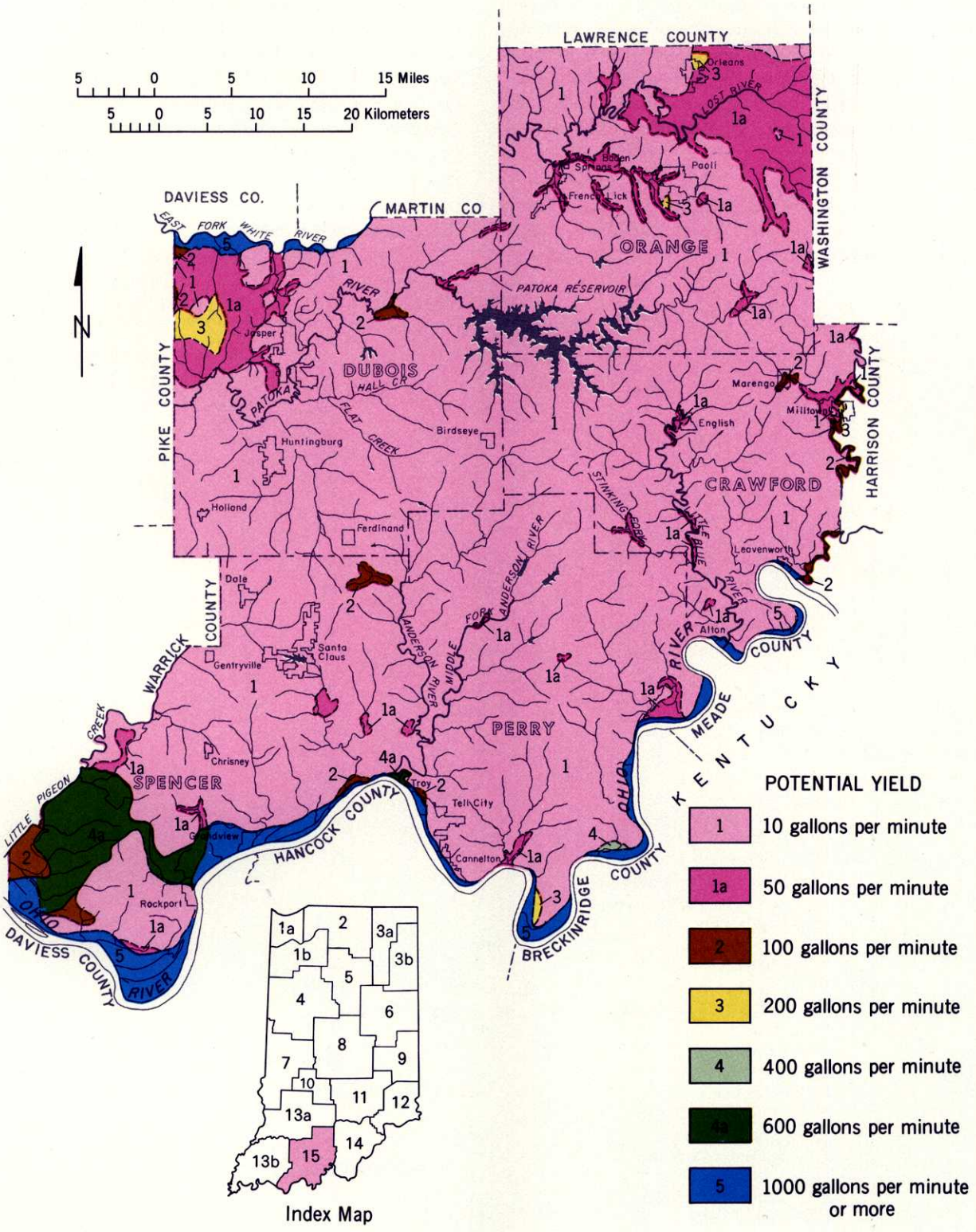


Figure 251
Map of Region Fifteen showing the general location and potential yield of ground water from properly constructed large diameter wells.

The Ohio River bordering Region Fifteen has an average flow of 73,400 mgd, as measured at Louisville, Kentucky. Other than the Ohio River the Patoka River at Jasper has the most reliable streamflow because its zero flows occur the most infrequently. This stream has a flow of 1.6 mgd ninety percent of the time. Ground-water contribution to streamflow is minimal in the region as indicated by the frequency of zero low flows.

Lakes The lakes within the region that are at least 50.0 acres in size or have a storage capacity of 32.5 million gallons or more are listed in Table 205 and are located on Figure 252. These thirty-seven lakes have a combined surface area of approximately 11,500 acres and a gross storage capacity in excess of sixty-seven billion gallons.

The soon-to-be functional Patoka Reservoir is located on the Patoka River in Crawford, Dubois, and Orange Counties. This joint state-federal facility was designed for flood control, water supply, water quality control, recreation, and fish and wildlife. The reservoir has a water supply pool surface area of 8,880 acres and a gross storage of 58,829 million gallons; of which sixty-three mgd have been allocated as a water supply.

Table 205

Lakes at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

Lake Number	*Lake Name*	*Drainage Area (square miles)*	*Surface Area (acres)*	*Gross Storage (million gallons)*
1	Beaver Creek Lake	3.87	190.0	772
2	Calumet Lake	na	9.0	32
3	City Lake	1.84	180.0	651
4	Ferdinand Old Lake	na	na	65
5	Ferdinand Reservoir	0.50	10.5	36
6	Ferdinand State Forest Lake	na	24.0	312
7	Holland Lake	0.57	23.5	58
8	Huntingburg Conservation Club Lake	na	na	na
9	Izaak Walton Lakes	na	na	91
10	Lottes Lakes	na	na	39
11	Olinger Lake	0.56	59.0	84
12	Patoka Lake	168.00	8,880.0	58,829
13	Ruxer Lake		37.0	114
14	St. Anthony Conservation Lake	na	10.0	65
15	Schneilville Conservation Lake	na	na	65
16	Buzzard Creek Structure No. F-3	na	na	109
17	French Lick Creek Structure No. F-7	6.98	141.0	549
18	English Reservoir	1.90	33.0	160
19	Wyandotte Lake	na	12.0	39
20	Christmas Lake	2.47	200.0	716
21	Dale Reservoir	0.40	20.0	32
22	Fishers Cedar Crest Lake	na	10.0	71
23	Lake Holly		14.5	39
24	Lincoln Park Lake	na	58.0	169
25	Noel Lake	0.27	20.0	59
26	St. Meinrad North Lake	na	9.0	65
27	St. Meinrad South Lake	na	5.0	45
28	Santa Claus Lake	na	10.0	40
29	Celina Lake	na	na	1,258
30	Indian Lake	na	na	556
31	Little Sulphur Creek Structure No. 2	na	na	179
32	Middle Fork Structure No. 7	11.80	39.0	32

Table 205 (continued)

Lake Number	Lake Name	Drainage Area (square miles)	Surface Area (acres)	Gross Storage (million gallons)
33	Mill Lake	7.18	39.6	35
34	Russell Byrds Echo Lake	0.80	11.0	43
35	Saddle Lake	3.53	40.8	159
36	Salinda Lake	na	na	1,171
37	Tipsaw Lake	9,000.00	1,420.00	593

na: not available.

UTILIZATION OF THE WATER RESOURCE

Instream Uses

The supply and demand analysis for recreational uses of water by residents of the region are presented in Table 206. The existing supply for recreational activity is expressed as a percentage of the demand. Therefore, when this percentage exceeds one hundred the supply exceeds the demand. Conversely, when the supply is less than one hundred the supply is less than the projected demand.

Table 206
Outdoor recreation demand and supply analysis.

Activity	Percent of Population Participating	Density Guidelines	Approximate Supply	Existing Supply as a Percentage of Projected Demand		
				1980	1990	2000
Boating	29	19.6 boats/acre/year	12,600 acres[a]	100+	100+	100+
Waterskiing	10	34.4 skiers/acre/year	10,400 acres[b]	100+	100+	100+
Canoeing	6	585 canoes/mile/year	47 miles	100+	100+	100+
Swimming	41	76,600 swimmers/acre/year	12 acres[c]	100+	100+	100+
Ice-Skating	5	6,678 skaters/acre/year	1 acre	25	25	25
Fishing	58	66 persons/acre/year	17,000 acres[d]	100+	100+	100+

This table is based upon the 1979 Indiana State Outdoor Recreation Plan. Only the supply and recreational demands of residents of the region are displayed. The available recreational opportunities outside the region are not considered, nor are the recreational demands of nonresidents considered.
[a]Includes 9,800 acres of the Ohio River and 2,800 acres of inland waters.
[b]Includes 9,800 acres of the Ohio River and 600 acres of inland waters.
[c]Does not include the Ohio River or Patoka Reservoir.
[d]Includes 9,800 acres of the Ohio River and 7,200 acres of inland waters.

Boating and Waterskiing Inland lakes and the Ohio River make up the major recreational sites in the region and constitute the primary boating and waterskiing resources. The Patoka Reservoir, which is the second largest lake in Indiana, adds to the available acreage and contributed even more when its normal pool was reached in 1979. These combined resources easily supply the region's demands for boating and waterskiing opportunities. This adequate supply is expected to continue well into the next century.

Canoeing There are approximately sixty miles of canoeing streams. These consist of approximately forty-five miles of Blue River and fifteen miles of the East Fork of the White River. This abundant supply of canoeable streams is expected to supply the demand through the year 2000.

Swimming and Ice-Skating Swimming areas, both beach and pool acreage, exceed the demand. It is estimated that the surplus will continue through the year 2000, with no shortage of swimming opportunities.

A deficiency of ice-skating opportunities exists in the region. Only twenty-five percent of the current demand is estimated to be met by existing facilities. This shortage is expected to continue to the year 2000. Patoka Lake, not included in the supply and demand analysis, should substantially increase the available supply for both swimming and ice-skating.

Fishing The quality of the fisheries habitat is shown in Figure 253. Warmwater fish, including largemouth and smallmouth bass, bluegill, crappie, and other sunfish, together with rough and forage fish, are commonly found in the streams and lakes. Streams in the southeastern part of the region are generally fast.

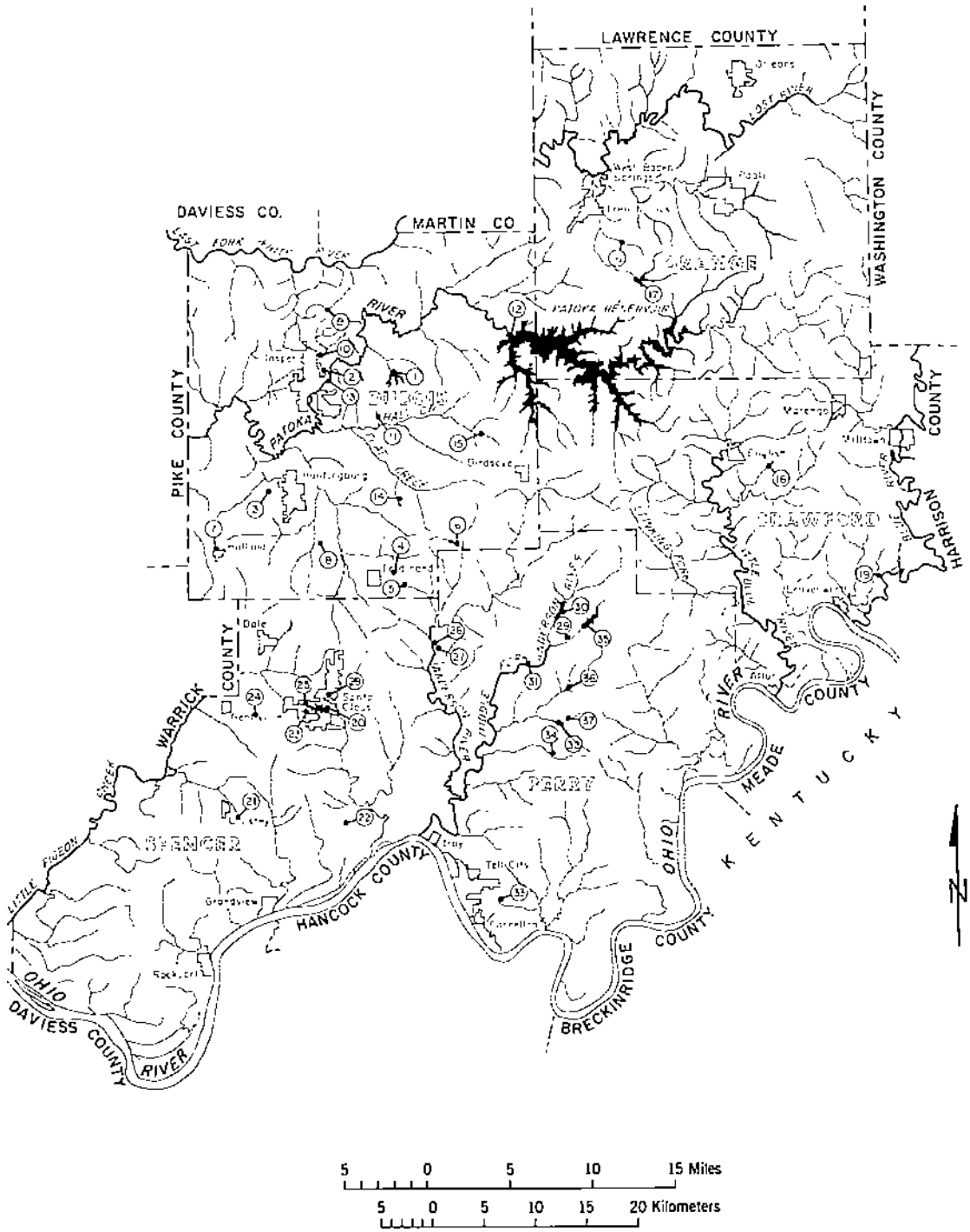


Figure 252
Map of Region Fifteen showing the location of lakes that are at least 50.0 acres in size or with a storage capacity of 32.5 million gallons or more.

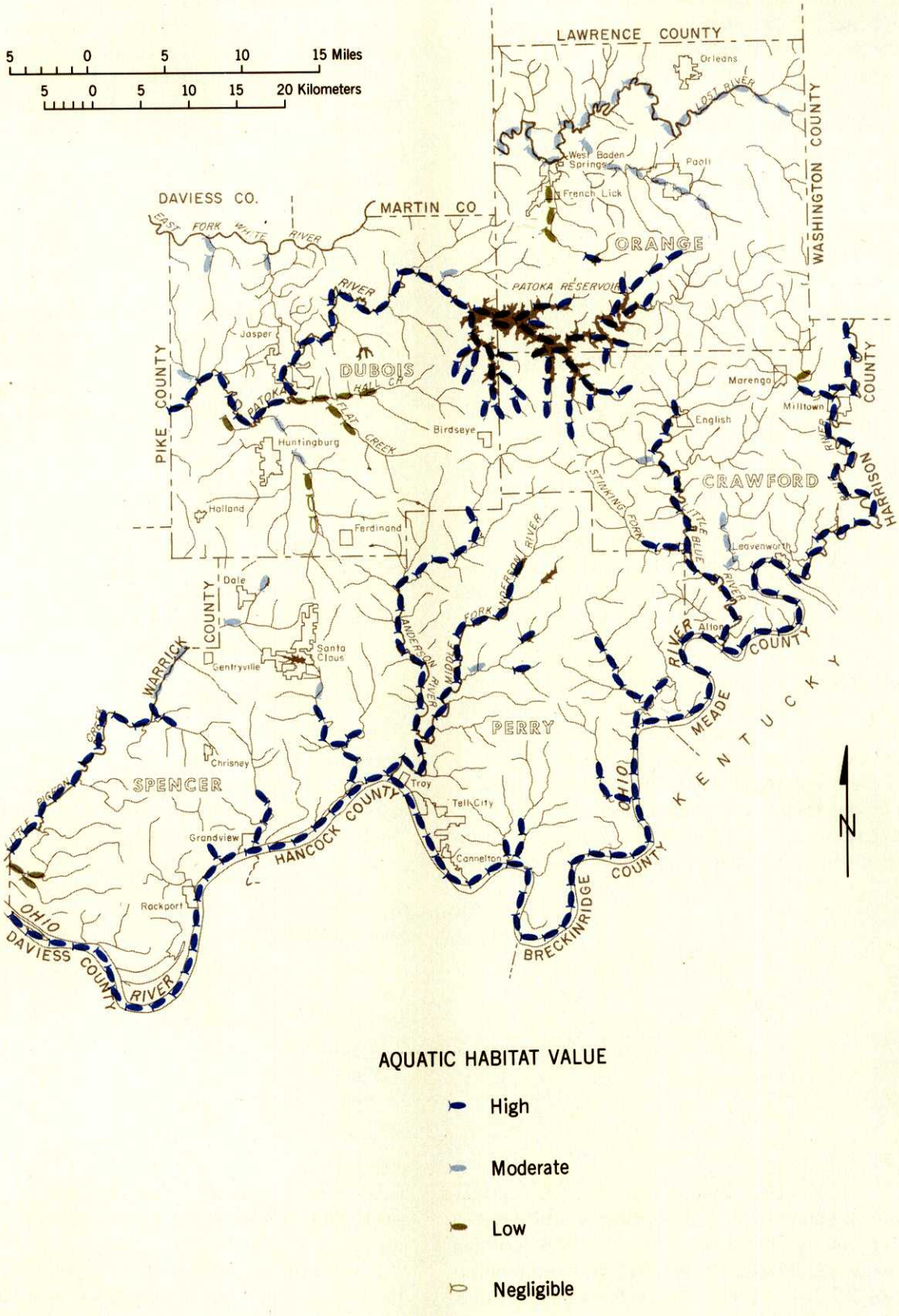


Figure 253
Map of Region Fifteen showing the quality of the fisheries habitat.

flowing with sand and gravel bottoms while northwestern streams are characteristically channelized with mud and silt bottoms. Sport fishing is popular along the larger streams with very good fisheries habitat such as the Little Blue River, Little Pigeon Creek, Anderson River, and Patoka River. The Ohio River is used for both sport and commercial fishing. During dry seasons, many of the smaller streams do not contain enough water to support good fish populations.

Lakes in the region are man-made and offer very good sport fishing, highlighted by Patoka Lake. Patoka Lake is stocked with walleye, largemouth bass, bluegill, redear, and channel catfish. Other lakes, including Indian, Celina, Tipsaw, Saddle, Springs Valley, and Ferdinand Forest Lakes, contain similar warmwater fisheries.

Besides fishing areas available in the Hoosier National Forest, the state provides fishing at Springs Valley Fishing Area, Harrison-Crawford and Ferdinand State Forests, Lincoln State Park, and Patoka Lake. Other public access sites are available on the Patoka and the Ohio Rivers. Bridge crossings and city-county parks may also provide access. The surplus of fishing water for the demand is expected to continue through the year 2000.

Riparian Habitat The quality of the wildlife habitat associated with streams and lakes is indicated on Figure 254. Wetlands are located mainly in the floodplain and backwaters of the Ohio River and also along Little Pigeon Creek and the Patoka River. Many types of wildlife utilize these wetlands, especially furbearers and waterfowl. Hardwood and other woody vegetation line streambanks and many lakes creating excellent habitat for upland wildlife, some furbearers, waterfowl, and shorebirds. Smaller streams, such as some tributaries to the Patoka River, supply little valuable wildlife habitat due to loss of vegetation from channelization. Excellent habitat is found along the Ohio, Patoka, Little Blue, and Anderson Rivers, and along Little Pigeon Creek as well as Patoka Lake and most other lakes.

Hunting is permitted on Harrison-Crawford and Ferdinand State Forests. Other riparian hunting opportunities are available only on private land with permission.

Hydroelectric Power Due to the limitations of topography and streamflow characteristics, there are no current commercial hydroelectric installations in the region. However, the best opportunity for future expansion lies in additional hydroelectric development at the U.S. Army Corps of Engineers Cannelton structure on the Ohio River.

Commercial Navigation A large dam and lock system located near Cannelton in Perry County passed an estimated thirty-five million tons of cargo in 1974. Studies by the Ohio River Basin Commission indicate that the Cannelton locks and dams should be adequate to carry 105 million tons by the year 2000.

Withdrawal Uses

Public Water Supplies Crawford, Dubois, Orange, Perry, and Spencer Counties are served by thirty-seven public water utilities. Twenty-two of these are municipal systems while fifteen are rural systems. Data for public water utilities are presented in the following table.

Table 207
Public water supply systems as of 1975.

Counties	*Number of Systems*	*Service Population*	*Average Daily Withdrawals in Million-Gallons-Per-Day*
Crawford	8	3,300	0.4
Dubois	12	22,800	2.7
Orange	4	8,000	1.1
Perry	4	12,200	1.4
Spencer	9	8,900	0.9
Total	37	55,224	6.5

The largest county-wide use of water is attributed to the twelve systems in Dubois County. These utilities served about 22,800 persons in 1975 and supplied an average of 2.7 mgd. The eight systems in Crawford County account for the smallest county-wide use of water in the region. These systems served 3,300 persons in 1975 and sitributed 0.4 mgd. The service areas and water withdrawals for public water utilities are shown in Figure 255.

Several of the utilities in the region not only supply their own water but also sell water to one or more utilities in the region. Most of the region's systems distribute water originally withdrawn from the county of use. However some systems buy and distribute water

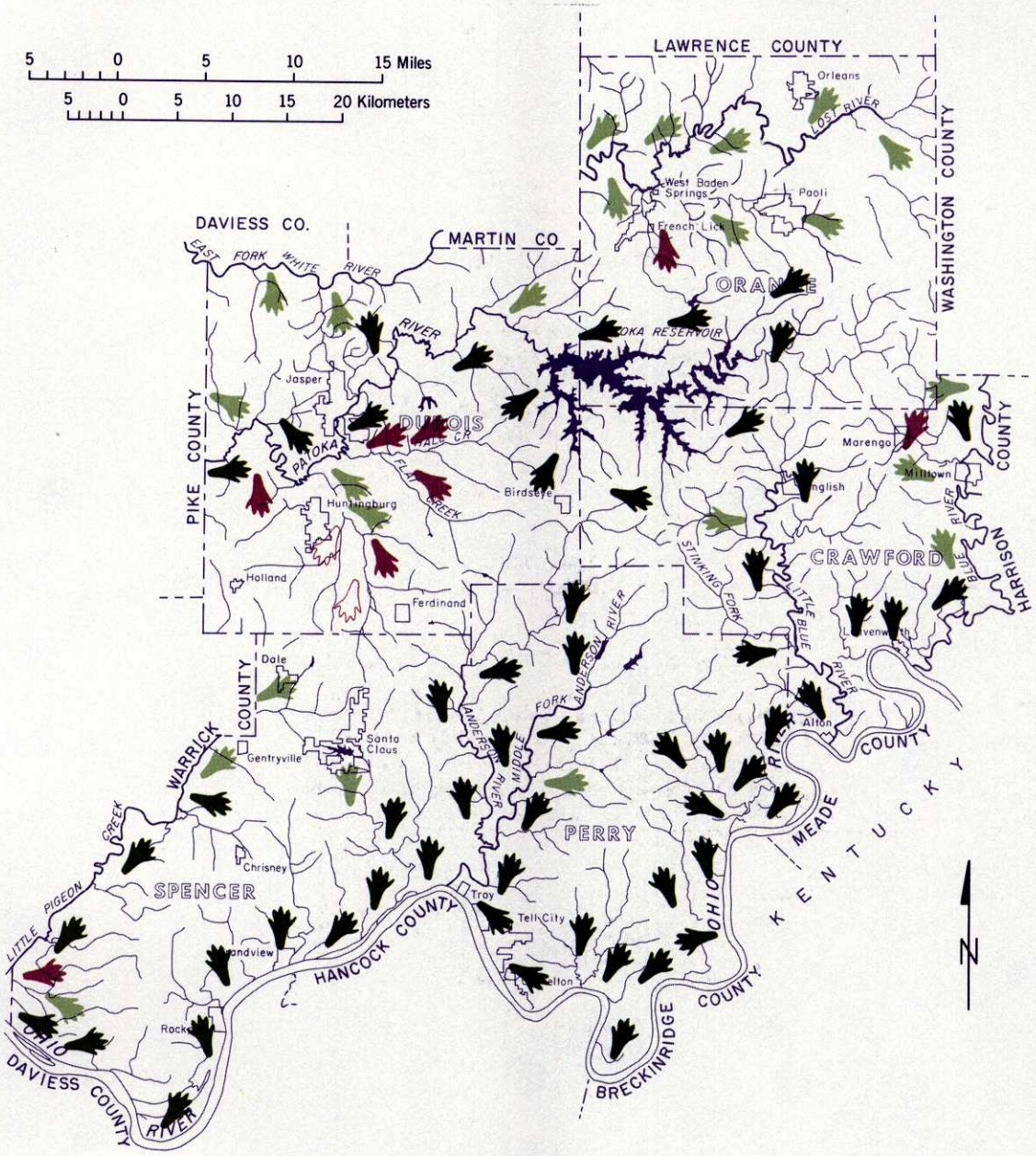


Figure 254
Map of Region Fifteen showing the quality of the riparian habitat.

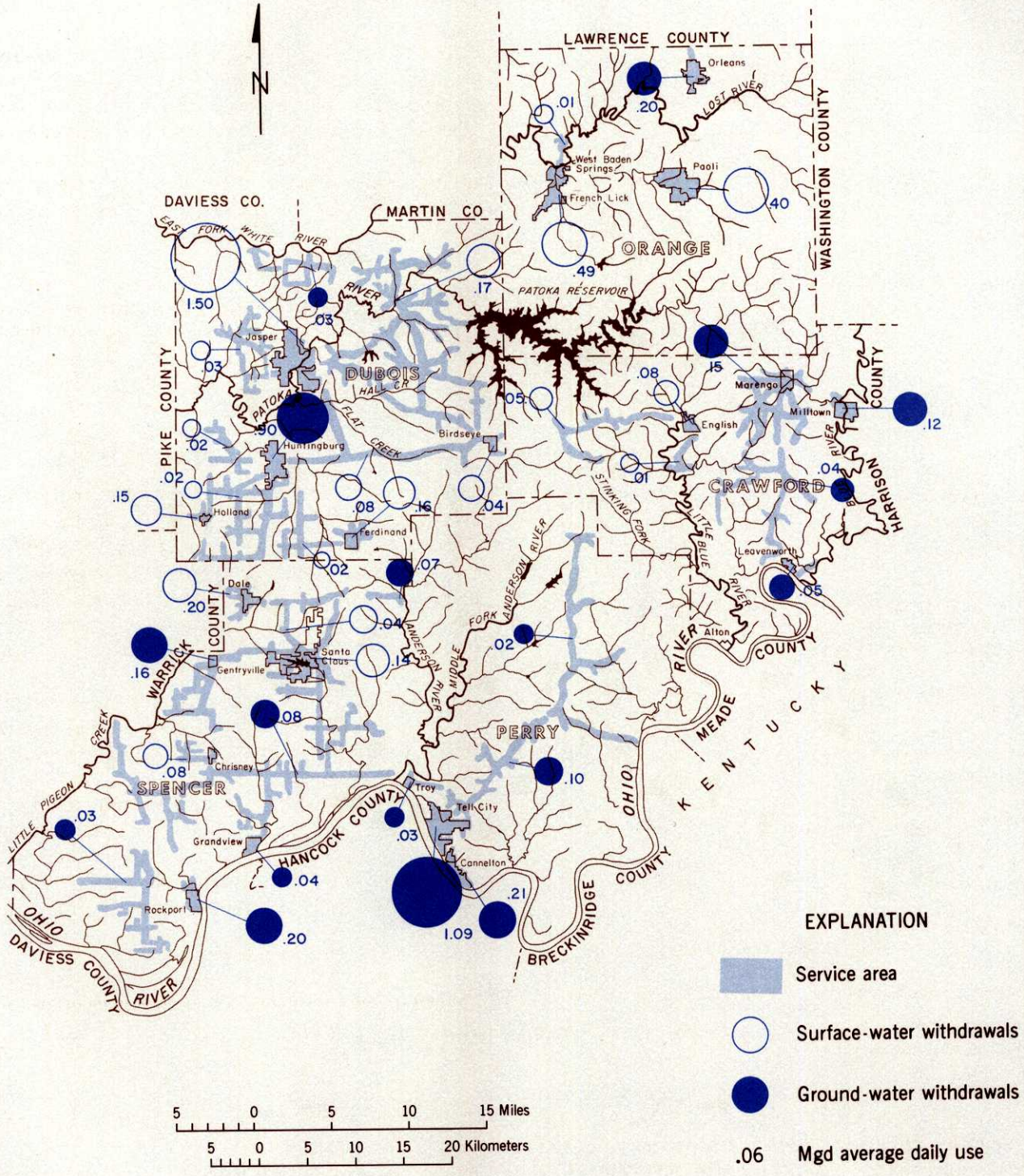


Figure 255
Map of Region Fifteen showing the service areas of the public water utilities and average daily use in million-gallons-per-day.

withdrawn outside the county and region. Sellers and buyers are listed below. A few of the utilities are multi-county systems extending into two or more counties.

Table 208
Public water system sellers and purchasers.

Sellers	*Purchasers*
Dale Water Works	Santa LaHill, Inc.
English Municipal Water Works	Grantsburg Water Company Patoka Water Company
Ferdinand Municipal Water Works	St. Henry Water Corporation
Grandview	Finch Newton Water Corporation
Haysville Water Utility	Alfordsville Water Works
Holland	Sendal Water Corporation[a]
Huntingburg Water Department	Birdseye Water System Duff Water Corporation St. Anthony Water Utilities St. Henry Water Corporation
Indiana Cities Water Corporation (French Lick– West Baden)	New Prospect Rural Water Company
Jasper Municipal Water Utility	Dubois Water Utilities, Inc. Ireland Utilities, Inc.
Leavenworth Water Company	Crawford County Water Corporation
Mitchell Water Department[b]	Orleans Water Works
Santa Claus Water Department	Santa LaHill, Inc.
Tell City Water Department	And-Tro, Inc. North Perry Water, Inc.
Tennyson Water Utility	Gentryville Water Utility

[a]This purchaser is located mostly outside the region.
[b]This seller is located outside the region.

Most public water systems in the region rely on surface water. Surface water is utilized by systems in the communities of English, Holland, Huntingburg, Ireland, Jasper, Ferdinand, French Lick, West Baden, Paoli, Chrisney, Dale, Santa Claus, and the newly formed Patoka Lake Regional Water and Sewer District. The Patoka Lake Regional Water and Sewer District will withdraw its supply from Patoka Lake to supply at least eleven of the region's existing utilities as well as certain rural areas. In addition, several systems in the region are undertaking expansions as a result of development of the regional water and sewer district. Utilization of Patoka Lake as a water supply will allow the phasing out of several of the small water supply reservoirs.

The thirty-seven public water utilities in the region distributed an average of 6.5 mgd in 1975. Approximately sixty-one percent was derived from surface sources, while thirty-nine percent was withdrawn from ground-water sources. Projections of public water utilities indicate that withdrawals may increase to approximately 10.3 mgd by the year 2000, as indicated here.

Table 209
The 1977 and projected water withdrawal and consumption rates of public water supplies, in million-gallons-per-day.

Public Water Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	6.5	6.9	8.5	10.3
Consumption	1.1	1.2	1.4	1.8

Industrial Water Industrial establishments had an estimated water intake averaging 9.7 mgd in 1977. Of the total industrial intake 4.7 mgd was self-supplied by the industries themselves while 5.0 mgd was purchased from public water utilities. About 1.8 mgd was consumed through the manufacturing process. Most of the self-supplied water is withdrawn from ground-water sources.

The largest water-using industry group is comprised of small industries. Other industries that use large amounts of water include food processors and furniture manufacturers.

Industrial production is expected to increase by the year 2000. Total industrial water intake is expected to increase from 9.7 mgd to 11.5 mgd. Industrial self-supplied water withdrawals may increase to 6.0 mgd, as presented in the following table.

Table 210
The 1977 and projected self-supplied withdrawal and consumption rates for industries, in million-gallons-per-day.

Industrial Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	4.7	4.7	5.3	6.0
Consumption	.9	1.0	1.4	1.9

Rural Self-Supplied Water Rural self-supplied water is withdrawn from wells, cisterns (particularly in Perry County), ponds, streams, springs, and water haulers. Ground-water withdrawals ar generally limited to the smaller valleys.

An estimated 39,800 persons lived in homes supplied by individual water sources in 1975. It is estimated that 2.4 mgd was used for residential pur-

poses. The number of people depending on their own water supplies may decrease by the year 2000, due to the expansion of rural water systems. The anticipated general increase in the standard of living, however, may increase rural self-supplied water withdrawals for residential purposes to 2.6 mgd by the year 2000.

In 1975, rural water use for animals accounted for approximately 2.8 mgd. By the year 2000, this figure may increase to 3.3 mgd. Water for animals is generally supplied from ponds, streams, and springs.

The total withdrawal of rural, self-supplied water may increase from the current 5.0 mgd to approximately 5.9 mgd by the year 2000, as shown here.

Table 211
The 1977 and projected water withdrawal and consumption rates for rural self-supplied water, in million-gallons-per-day.

Rural Self-Supply	*1977*	*1980*	*1990*	*2000*
Withdrawal	5.0	5.1	5.5	5.9
Consumption	5.0	5.1	5.5	5.9

Irrigation Water Based upon the survey of irrigated lands, approximately 120 acres, all in Dubois County, were irrigated. Assuming 1977 as a normal growing year, approximately 0.3 mgd was applied during the peak irrigation period of July and August. In addition to the irrigation for agricultural use, golf courses are irrigated. About 0.5 mgd is applied to golf courses during the peak July and August irrigation period.

Because of the lack of soil associations which can be profitably irrigated the amount of water withdrawn for croplands and golf courses is expected to remain constant at 0.8 mgd as presented below.

Table 212
The current and projected withdrawal of irrigation water for croplands and golf courses during an average growing season, in million-gallons-per-day.

Irrigation	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.8	0.8	0.8	0.8
Consumption	0.8	0.8	0.8	0.8

Electric Energy Region Fifteen contains one electric generating facility, the Jasper plant, which utilizes a cooling system that requires approximately 0.2 mgd. This water is withdrawn from an impoundment on the Patoka River. Water returned to the river after the cooling process approaches 0.05 mgd. This facility is rated at 14.5 megawatts.

The Indiana and Michigan Electric Company has announced plans to construct a power plant along the Ohio River near Rockport in Spencer County. This plant is designed to have a generating capacity of 2,600 megawatts and is expected to consume 32.0 mgd of water from the Ohio River. The facility may become operational in the 1980s. Water withdrawals for the generation of electricity are expected to increase to 65.2 mgd by the year 2000, as presented in Table 213.

In addition to these facilities, there are several existing and proposed generating stations on the Ohio River both upstream and downstream from Region Fifteen.

Table 213
The 1977 and projected water withdrawal and consumption rates for the production of energy, in million-gallons-per-day.

Energy	*1977*	*1980*	*1990*	*2000*
Withdrawal	0.2	0.2	65.2	65.2
Consumption	0.2	0.1	32.4	32.4

EXCESS WATER

Flooding

Approximately 83,300 acres are subject to flooding. The major flood plains are shown in Figure 256. Figure 257 delineates the average annual flood damages along selected streams within the region. The average annual damages due to flooding were estimated in 1977 to be approximately $737,200 in urban areas and $4,233,900 in rural areas. Losses in the Lost River watershed in Orange County account for thirty-six percent of the region's urban damages and thirteen percent of the rural damages. Approximately twenty-eight percent of the region's urban damages and thirty-one percent of the rural damages occur in the Patoka River watershed. Less than one percent of the flood damages occur along the Ohio River.

Flood Control The small watershed projects that are completed include French Lick and Middle Fork of the Anderson River. A small watershed project for the Anderson River has been approved for construction.

The U.S. Army Corps of Engineers has completed two local protection projects in the region. Both are in Perry County at Tell City and Cannelton.

The Tell City project is located along the Ohio River at Tell City, and consists of a system of earth levees and a concrete wall with pumping facilities to dispose of sewage and drainage from the protected area during floods. The project protects an area of about 200 acres from a flood equal in magnitude to the 1937 flood, the maximum flood of record for that area. Since its completion in 1943, it is estimated that this project has averted flood damages at Tell City in an amount of about $8,085,000.

The Cannelton Local Protection Project, which was completed in 1952, consists of a system of earth levees

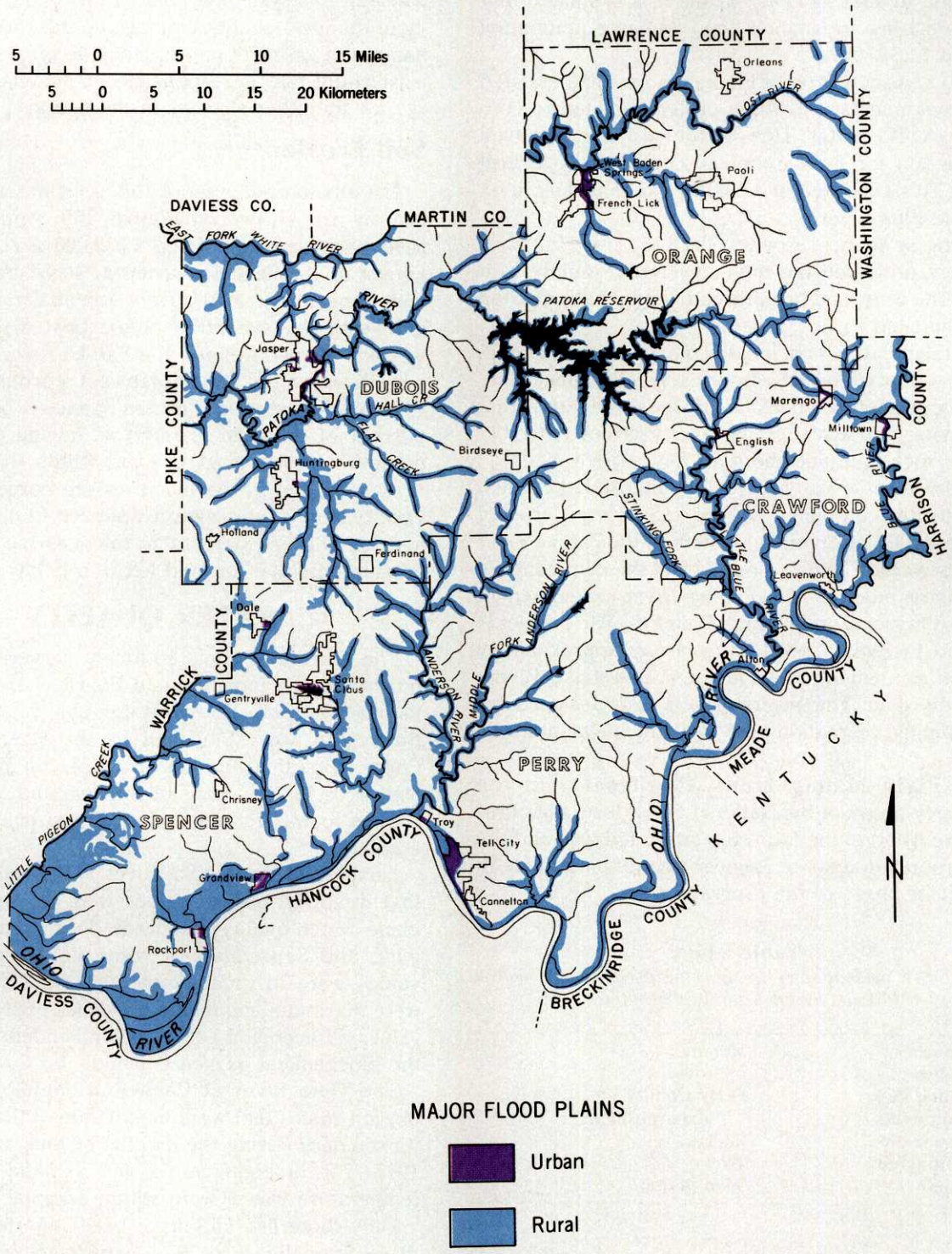


Figure 256
Map of Region Fifteen showing the major flood plains.

and concrete walls with pumping facilities. It provides protection to about 400 acres, and it is estimated that this project has forestalled flood damages amounting to about $1,840,000.

The U.S. Army Corps of Engineers has also assisted local governments with three projects related to control of excess water. One of the projects involved construction for flood relief at English in Crawford County. This consisted of 3.4 miles of channel work on the Little Blue River.

At Troy in Spencer County, the U.S. Army Corps of Engineers protected the municipal water supply with riprap. The wells had been threatened by bank erosion along the Ohio River.

The third project is located at Rockport, also in Spencer County. The U.S. Army Corps of Engineers repaired a segment of bank along the Ohio River that was caving and endangering a city street lying between a rock bluff and the river.

Flood control is also provided by Patoka Lake which was recently completed by the U.S. Army Corps of Engineers. The reservoir is located on the Patoka River near Ellsworth in Dubois County, and the dam controls 168 square miles of the Patoka River watershed in Dubois, Crawford, and Orange Counties. The project is designed to reduce flood damages by approximately fourteen percent on the Patoka and Wabash Rivers below the dam. The reservoir was also designed for water supply, recreation, and low-flow augmentation.

Flood Plain Management Participants in the emergency phase of the National Flood Insurance Program are listed in the following table. Tell City and the unincorporated areas of Spencer County participate in the regular phase of the program.

Table 214
Communities participating in the emergency phase of the National Flood Insurance Program.

Cannelton	Marengo
English	Milltown
French Lick	Perry County, unincorporated
Gentryville	Rockport
Grandview	Troy
Huntingburg	West Baden
Jasper	

Agricultural Drainage

Approximately three percent of the soil associations have "severe," eighteen percent have "moderate," while seventy-nine percent have "slight" wetness characteristics as shown in Figure 258.

There are approximately sixty miles of legal drains in the region which serve as the main collectors and outlets for on-farm drainage systems. The maintenance of this system of legal drains is the responsibility of the local county drainage boards, or in a limited number of cases, of conservancy districts. There is no legal entity that is responsible for maintaining drainage for the other streams in the region.

Soil Erosion

The erosion potential of soil associations within the region are shown in Figure 259. Approximately seventy-six percent of the 1,235,000 acres in Region Fifteen is classified as having a "high" potential erosion hazard. This area covers essentially all of the region with the exception of the Lost River valley in western Orange County, the Patoka River and Anderson River valley, the northwest corner of Dubois County, and extreme southern Spencer County. Eleven percent of the land is rated as having a "medium" potential erosion hazard. Land within this classification is located in the nc thwestern corner of Dubois County and southwestern Spencer County. The remaining thirteen percent is rated as having a "low" erosion potential for land left in a fallow state.

WATER QUALITY

The surface streams routinely surveyed for water quality by the Indiana State Board of Health are the Patoka and Ohio Rivers. Water quality standards for the region are established by the Stream Pollution Control Board regulation SPC IR-4, the Water Quality Standards for the State of Indiana, and SPC-3, which applies to wastes and drainage from coal mining operations.

Samples of the Patoka River near Jasper indicated that dissolved oxygen values were in violation of Indiana water quality standards during June, July, August, and September of some years. Temperature values were in compliance with state standards, as were maximum and minimum values of pH. The nitrate values all averaged below recommended levels as did the biochemical oxygen demand.

The Ohio River at Cannelton exhibited dissolved oxygen values that were in violation of the water quality standard during the months of June and August in 1977. The biochemical oxygen demand, nitrate and temperature values were within acceptable levels.

Only three fish kills have been reported to the Indiana State Board of Health from the region in the period 1974 to 1977, and all were in Orange County. One occurred in Lick Creek near Paoli and resulted in approximately one hundred fish killed from an industrial spill. The other two occurred near French Lick, one from hog waste discharge into Sulphur Creek which killed ten fish, and another from a sewer bypass into French Lick Creek which killed 1,230 fish.

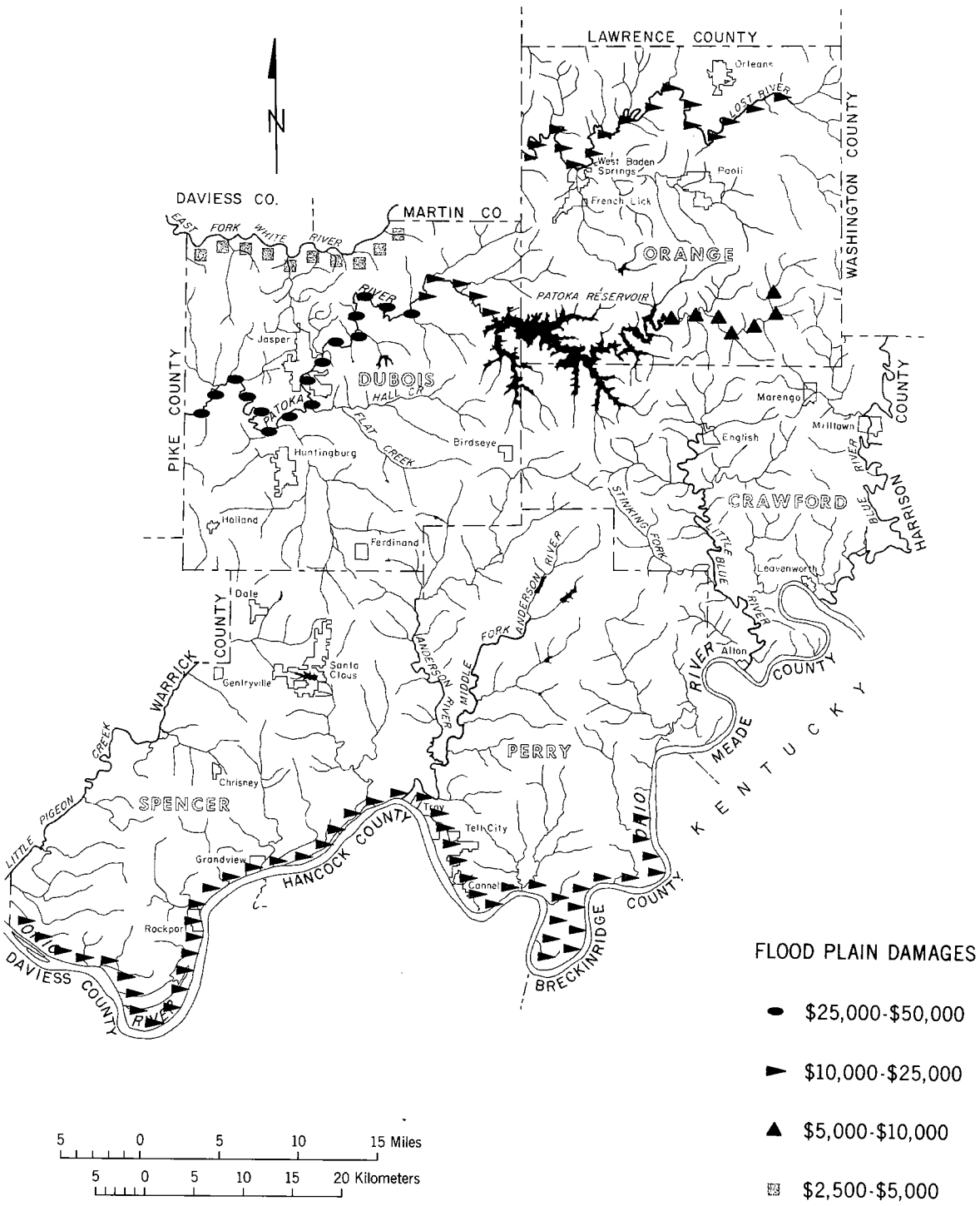


Figure 257
Map of Region Fifteen showing the estimated average annual flood damages per mile along selected streams.

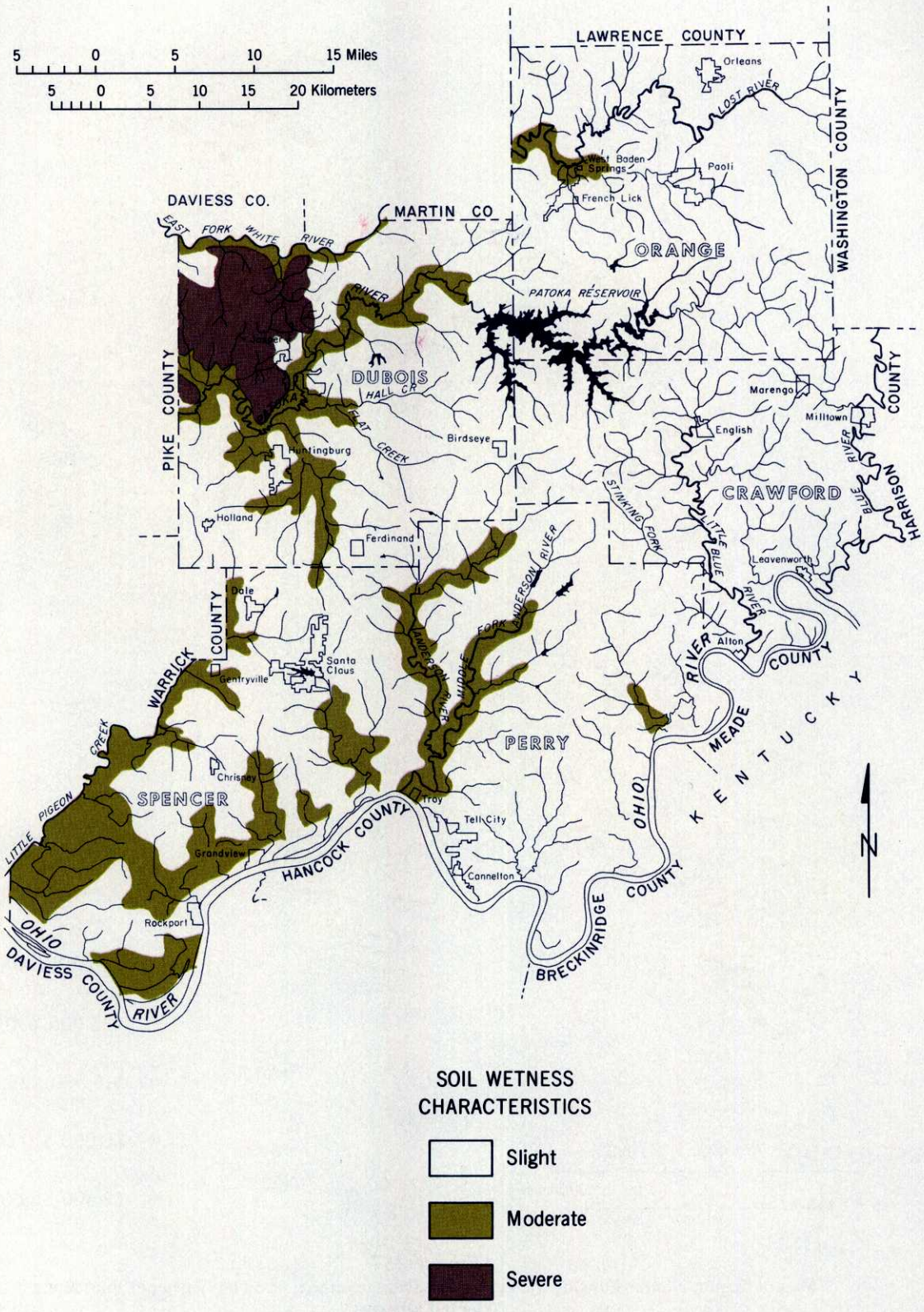


Figure 258
Map of Region Fifteen showing the general location of the wetness characteristics of soil associations.

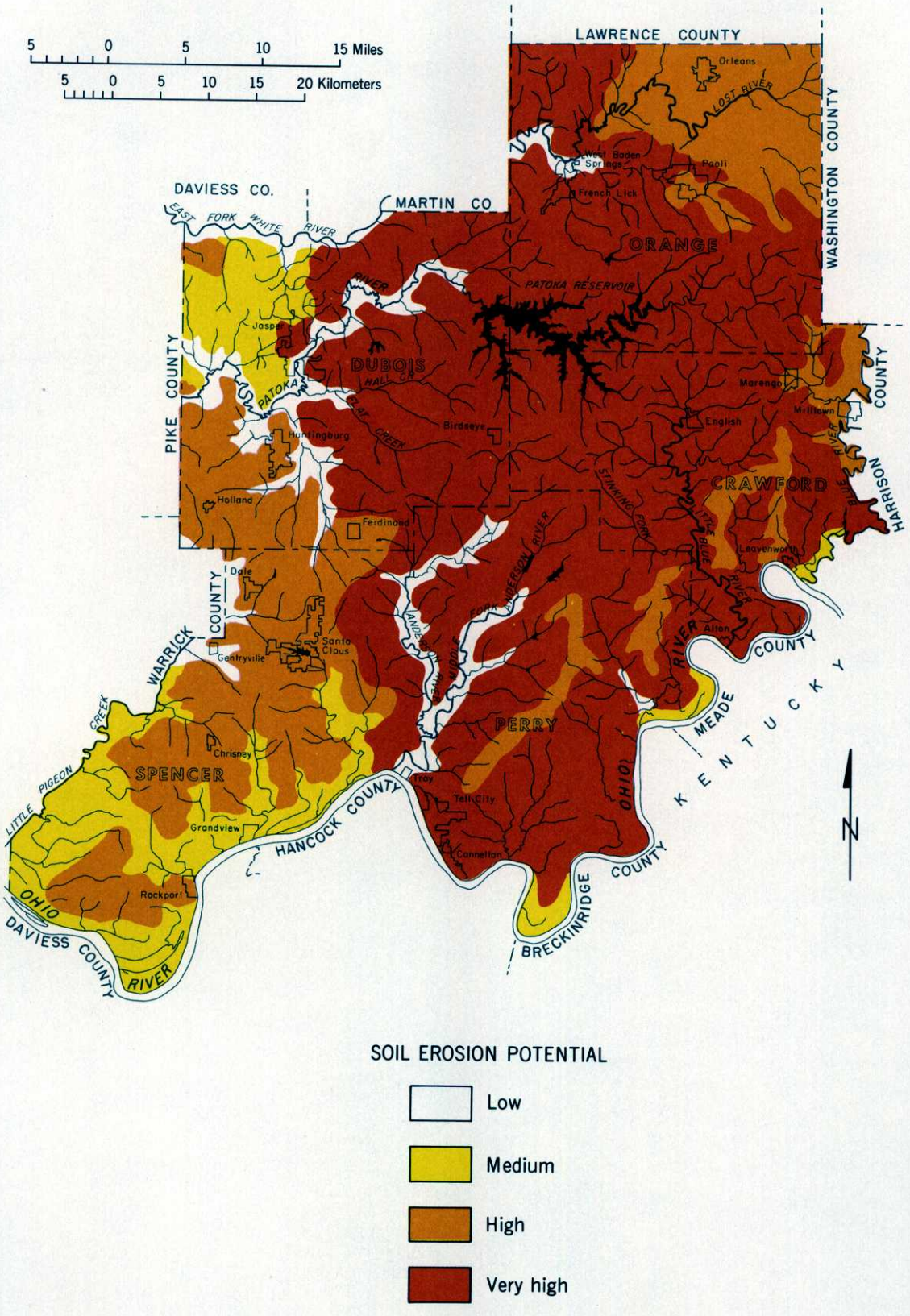


Figure 259
Map of Region Fifteen showing the erosion potential of the soil associations.


Appendixes

Appendix One

PUBLIC WATER SUPPLIES

Inventory

Average Daily Use—Water Sources The Indiana State Board of Health has from time to time published data on Indiana public water supplies. These appear as "Bulletin SE-10, Data on Indiana Public Water Supplies." Issues of this bulletin have been published in 1957, 1960, and 1968. This bulletin contains data on the population served, source of supply, rated plant capacity, average and maximum daily use, treatment, and physical and chemical water characteristics for each public water supply in the state.

The data on average daily use (and maximum daily use) and water sources came from an in-house update of the 1968 SE-10 which is maintained in the offices of the Indiana State Board of Health. This in-house update generally reflects 1975 use data. It was necessary in some instances to use additional outside data, usually from the utility itself.

Population Served It has been the practice of the Board of Health to assume that all persons living in an incorporated area are served by the public utility in that community. Therefore, census data has been used to establish served populations. It should be noted that very few utilities have any data on populations served. They do maintain files on the number of service connections, but this is not directly related to population served.

Although the 1975 in-house SE-10 contains population estimates for 1975, this data was discarded in favor of Indiana "Population Estimates and Projections" (Series P-25, No. 662, issued May 1977) by the Bureau of the Census which contains 1975 population estimates. Where service areas did not coincide with a political boundary, as in a rural water system, the board of health population estimates were used. The population-served figure for the Indianapolis Water Company was established by an analysis of census tract data from the 1970 census.

Service Areas The service area maps were drawn from maps furnished by the utilities in a questionnaire survey conducted in the spring of 1978 and from the data the Farmers Home Administration and several of the regional planning and development offices. A follow-up field interview was conducted in the fall of 1978 to obtain data from those utilities that failed to respond to the spring mail survey.

Projections

Population Projections The county population projections used were taken from *Indiana County Population Projections, 1975–2000* prepared by the Division of Research, School of Business, Indiana University and published by the Indiana State Board of Health in 1976. These projections were recommended for all types of ongoing state planning by the State Planning Services Agency. Population values for 1975, however, were taken from the Series P-25, No. 662 census report.

Shortly after the initial publication of this study, the Board of Health published revised population estimates under the title "Indiana County Population Projections, 1980–2000." It was not possible to incorporate these values into this study, but the following estimates of the population in each region in the year 2000 are furnished for purposes of comparison.

Table 215
Comparison of estimated regional population projections for the year 2000.

Region	*Projections Published In 1976*	*Projections Published In 1978*
One-A	767,000	735,600
One-B	98,200	81,400
Two	694,100	609,000
Three-A	200,300	173,700
Three-B	493,800	462,700
Four	292,200	269,000
Five	283,300	250,000
Six	527,000	487,900
Seven	221,900	214,300
Eight	1,531,100	1,440,700
Nine	170,700	151,900
Ten	133,000	123,200
Eleven	192,400	185,000
Twelve	116,300	102,400
Thirteen-A	164,200	139,500
Thirteen-B	303,000	276,600
Fourteen	281,600	258,900
Fifteen	112,300	99,000
Total	6,582,400	6,061,000

Population Served In order to estimate the probable future populations that will be served by public water utilities, the histories of all utilities now serving over one thousand persons were constructed using the published SE-10 data. Population data was taken from the 1950, 1960, and 1970 census and the aforementioned 1975 estimates. These individual utility histories were combined to form a series of county historical data summaries. In order to

establish the population served, estimates to coincide with the SE-10 water data years (or vice versa), mathematical growth curves were constructed through the data points. In all but a few cases, extremely high correlation coefficients were achieved. It was then possible to compute the percentage of population served (by larger systems) in any given county and to establish past trends of growth or decline in the percentage of the population served.

Detailed analysis of the past service characteristics was made for seventeen counties scattered across the state. There were three distinct growth patterns revealed in the study. In the majority of counties, the percent served was stable over the study period, but there were a few cases where percent served was declining and in a few more cases the percent served was rising.

This percentage served was stable in the large urban counties such as Lake and Marion, where the bulk of the population lived in urban areas served by public water systems. It was also stable in smaller counties where the ground-water availability map indicated that wells yielding from under 50 to 800 gallons-per-minute (gpm) could be developed.

The percent served figure was declining only in those few counties where ground water was abundant, such as Elkhart County. The trend line analysis showed a modest decline in percent served, on the order of about seven percent by the year 2000. There were no rural water systems in these counties.

There were two classes of counties experiencing growth in terms of percent population served. These were the rapidly growing suburban counties such as Hamilton and Porter, and the counties with poor ground-water conditions and rural water systems. When a growth trend was found, it was usually strong. The composite growth trend line for the counties analyzed showed an 11.5 percent growth in population served by the year 2000.

The population served by public water supplies in the future was calculated by: (1) computing the percent population served in that county in 1975; (2) determining by inspection whether that percentage will decrease, remain the same or increase, as outlined above; (3) making appropriate adjustments to this percentage for the years 1980, 1990, and 2000; and finally (4) multiplying these adjusted percentages by the future estimated total county population.

It should be noted that the water used for all of the future population not served by a public water supply appears as "Rural Self-Supplied Water," so the water use for all future residents in the state has been accounted for.

Per Capita and Estimated Water Use Three different per capita use projections were made for this study. These can be identified as the constant per capita method, the regional trend method, and the thirteen cities method. The total population served and its water use are given in the following table.

Table 216
The 1975 water use in gallons-per-capita-per-day.

Region	*Population Served*	*Average Daily Use (million gallons)*	*GCD*
One-A	572,570	77.35	135
One-B	20,770	2.57	124
Two	345,810	61.30	178
Three-A	50,520	6.85	136
Three-B	258,840	38.03	147

Table 216 (continued)

Region	*Population Served*	*Average Daily Use (million gallons)*	*GCD*
Four	157,960	25.27	160
Five	132,180	27.37	207
Six	306,290	50.77	166
Seven	127,340	15.99	126
Eight	883,480	120.24	136
Nine	91,180	17.31	190
Ten	67,020	12.06	180
Eleven	78,530	12.35	157
Twelve	62,950	7.54	120
Thirteen-A	98,040	15.82	161
Thirteen-B	183,980	38.07	207
Fourteen	140,280	16.48	117
Fifteen	54,080	6.40	118
Total	3,631,820	551.77	152

Future water use figures were computed by assuming that the regional per capita figure would remain constant and by multiplying that figure by the projected population served for that region.

The second, the regional trend, method involved compiling the historical data for all public utilities now serving over one thousand persons. This data was then added together to obtain regional per capita use going back to 1950. A least squares linear equation was then fit through the data and projected out to the year 2000. Because the data in a few regions appeared to be rising at an unreasonable rate, the 1990 use was "capped" at 250 gallons-per-capita-per-day (gcd) and the 2000 figure was "capped" at 260 gcd. The computed values for future per capita use from this analysis are listed below.

Table 217
Future water use in gallons-per-capita-per-day.

Region	*1980*	*1990*	*2000*	*Region*	*1980*	*1990*	*2000*
One-A	141	152	163	Eight	137	139	141
One-B	136	160	183	Nine	207	243	260
Two	187	205	224	Ten	191	213	236
Three-A	148	172	196	Eleven	163	174	186
Three-B	154	170	185	Twelve	126	138	150
Four	183	215	247	Thirteen-A	169	186	202
Five	231	250	260	Thirteen-B	221	250	260
Six	173	188	202	Fourteen	130	148	168
Seven	133	147	160	Fifteen	123	131	139

The future water use was then computed by multiplying these per capita uses by the estimated population served for the appropriate year.

At is meeting on June 22, 1978, several of the commissioners expressed the view that the per capita use of the larger systems was rising slowly, not at the higher rates shown in the regional trend method. These commissioners suggested that the projected growth (in per capita use) trend from the larger, more stable public water supplies would furnish the best method of forecasting future per capita use for the state as a whole.

Accordingly, the histories of the larger cities in the state were reviewed and the following thirteen cities were chosen: Anderson, Columbus, Evansville, Fort Wayne, Hammond, Kokomo, Lafayette, Madison, Muncie, Richmond, Terre Haute, Valparaiso, and Vincennes. The Indianapolis Water Company

and the Gary-Hobart Water Company were not used because of the difficulty in establishing past-population-served data.

The per capita uses for all thirteen utilities were averaged for the years 1950, 1960, 1970, and 1975 and projected forward to the year 2000. The results of these projections are as follows:

Table 218
Thirteen-cities method, past and future uses, in gallons-per-capita-per-day.

Year	*Average Use*	*Projected Use*	*Percentage of 1975 Use*
1950	132		
1960	135		
1970	143		
1975	155		
1980		155	100.0
1990		165	106.5
2000		173	111.6

The anticipated water use was then calculated by: (1) computing the average 1975 per capita use for each region as outlined above; (2) adjusting these per capita figures by the percentages shown in the above table for the years 1980, 1990, and 2000; then (3) multiplying these adjusted figures by the projected population served as previously outlined. The values from this method are the values presented in the main body of this report.

The constant per capita method produced the lowest future water use estimates. With the exception of Region Eight, the regional trend method produced the highest estimate, and the thirteen-cities method produced the midline estimate.

Water Consumed The definition of consumed water as used in this study is water that is extracted from the environment, used, and then not returned to a surface stream. Consumed water is not lost. It could be evaporated, spilled, placed into the soil profile, incorporated into a manufactured product, or otherwise used. This water will eventually work its way back into the hydrologic cycle, but will do so either at some point other than its point of extraction or at some time other than its time of extraction.

Because of the inevitable mix of self-supplied and public-supplied water users in a community and areal differences in water utility and sewer utility service areas, no attempt was made to actually measure the water consumed by public water systems in this study. Instead, it was assumed that ten percent of the water pumped by an urban utility and eighty-five percent of the water pumped by rural water systems are considered consumed water. The eighty-five percent value is a figure commonly assigned to these systems. Since most of the households served by rural water systems utilize septic tanks for wastewater disposal, and these systems do not (it is hoped) return this water to the point of extraction in a timely manner, this value is considered reasonable.

The consumed figures applying in this report reflect the mix of urban and rural systems and their pumpage rates. For the purpose of projecting future consumption rates, this mixture was assumed to remain constant throughout the study period.

Table 219
Public water supplies, projected future withdrawals and consumption in million-gallons-per-day.

Region	*Population Served*	*Low*	*1980 Mid*	*High*	*Population Served*	*Low*	*1990 Mid*	*High*	*Population Served*	*Low*	*2000 Mid*	*High*
One-A												
Withdrawal	593,800	80.22	83.73	83.73	642,900	86.86	92.50	97.72	690,000	93.22	104.03	112.47
Consumed		10.43	10.43	10.69		11.29	12.03	12.48		12.12	13.52	14.37
One-B												
Withdrawal	22,700	2.81	2.81	3.09	25,300	3.13	3.34	4.05	27,800	3.44	3.84	5.09
Consumed		0.28	0.28	0.31		0.31	0.33	0.41		0.34	0.38	0.51
Two												
Withdrawal	355,100	62.96	62.96	66.40	359,900	63.81	67.96	73.78	360,400	63.90	71.31	80.73
Consumed		7.24	7.24	7.63		7.28	7.81	8.47		7.35	8.20	9.27
Three-A												
Withdrawal	52,400	7.11	7.11	7.76	56,200	7.62	8.12	9.67	59,700	8.10	9.03	11.70
Consumed		0.71	0.71	0.78		0.76	0.81	0.97		0.81	0.90	1.17
Three-B												
Withdrawal	273,900	40.24	40.24	42.18	309,100	45.41	48.36	52.54	340,400	50.00	55.81	62.97
Consumed		4.02	4.02	4.22		4.54	4.84	5.25		5.00	5.58	6.30
Four												
Withdrawal	164,000	27.31	27.31	30.01	174,100	28.99	30.87	37.43	181,700	30.25	33.76	44.88
Consumed		2.73	2.73	3.00		2.90	3.09	3.74		3.03	3.38	4.49
Five												
Withdrawal	139,400	28.87	28.87	32.20	150,800	31.23	33.27	37.70	160,800	33.30	37.16	41.81
Consumed		2.89	2.89	3.22		3.12	3.33	3.77		3.33	3.72	4.18
Six												
Withdrawal	316,700	52.51	52.51	54.79	330,800	54.85	58.41	62.19	339,700	56.32	62.86	68.62
Consumed		5.51	5.51	5.74		5.76	6.13	6.52		5.91	6.60	7.19

Table 219 (continued)

Region	Population Served	1980 Low	1980 Mid	1980 High	Population Served	1990 Low	1990 Mid	1990 High	Population Served	2000 Low	2000 Mid	2000 High
Seven												
Withdrawal	130,700	16.48	16.48	17.38	131,200	16.54	17.62	19.29	131,400	16.57	18.49	21.02
Consumed		2.14	2.14	2.27		2.15	2.29	2.52		2.15	2.40	2.75
Eight												
Withdrawal	931,900	126.83	126.83	127.67	1,047,700	142.59	145.63	151.86	1,175,600	160.00	165.76	178.56
Consumed		13.32	13.32	13.37		14.97	15.25	15.95		16.80	17.36	18.75
Nine												
Withdrawal	95,200	18.07	18.07	19.71	102,700	19.49	20.76	24.96	105,600	20.04	22.37	27.46
Consumed		1.99	1.99	2.14		2.14	2.28	2.71		2.20	2.46	2.91
Ten												
Withdrawal	72,700	13.09	13.09	13.89	87,400	15.73	16.18	18.61	101,800	18.32	20.46	24.02
Consumed		2.55	2.55	2.71		3.06	3.27	3.63		3.57	3.99	4.68
Eleven												
Withdrawal	83,300	13.10	13.10	13.58	96,500	15.18	16.17	16.79	110,700	17.41	19.43	20.59
Consumed		3.01	3.01	3.12		3.49	3.76	3.86		4.00	4.47	4.73
Twelve												
Withdrawal	66,400	7.95	7.95	8.37	76,300	9.14	9.73	10.53	86,500	10.36	11.56	12.98
Consumed		2.31	2.31	2.48		2.65	2.92	3.11		3.00	3.47	3.84
Thirteen A												
Withdrawal	103,200	16.66	16.66	17.44	110,300	17.80	18.96	20.52	116,900	18.87	21.06	23.61
Consumed		3.50	3.50	3.67		3.74	3.98	4.32		3.96	4.42	4.97
Thirteen B												
Withdrawal	187,200	38.73	38.73	41.37	196,400	40.60	43.28	49.10	208,300	43.10	48.10	54.16
Consumed		4.26	4.26	4.57		4.47	4.76	5.43		4.74	5.29	5.99
Fourteen												
Withdrawal	153,900	18.08	18.08	20.01	188,200	22.11	23.55	27.85	225,300	26.47	29.50	37.85
Consumed		4.16	4.16	4.59		5.08	5.42	6.39		6.09	6.79	8.68
Fifteen												
Withdrawal	58,200	6.89	6.89	7.16	67,700	8.01	8.53	8.87	77,800	9.20	10.27	10.81
Consumed		1.17	1.17	1.21		1.36	1.45	1.50		1.56	1.75	1.82

Appendix Two

INDUSTRIAL WATER

Inventory

For the purposes of this study the term *industry* is defined as a manufacturing facility engaged in the fabrication of durable and nondurable goods. This term does not include farming, mining, construction, wholesale or retail trade, transportation, utilities, finance, services, or government.

Industrial operations extract water from the environment either by means of their own facilities, from public water supplies, or a combination of both. This water is then used in the manufacturing process. Usually water is reused within the plant, often several times over. Water is finally discarded to the outside environment, either untreated, treated by the industry, discharged into a locally available sanitary sewer, or some combination of the foregoing. It is not the purpose of this study to deal with the water use and reuse within the manufacturing operation, defined as total water use. (This will be a factor in some computations, however.) We are concerned with the water extracted from the environment, labeled water intake, and the difference between water taken into the plant and water discharged, labeled consumptive use. Consumptive use accounts for water spilled, evaporated, incorporated into the product, or occasionally chemically broken down in the process. Future time frames for study purposes are the years 1980, 1990, and 2000.

There is a parallel, ongoing study of anticipated future demands on public water supplies. Some industrial water comes from the public source. Since it is not possible at this time to disaggregate the industrial component from other components of public water supplies, the projections made for future demands on these supplies will account for the publicly supplied industrial water. This study will deal with self-supplied industrial water, although some publicly supplied water will be used for computational purposes.

This study was made by means of a survey of current industrial water use, projections of future levels of economic activity, and projections of future levels of industrial efficiency in the use of water.

There are several assumptions that have been made for the purposes of this study. In all probability none of these assumptions are totally true. All are believed accurate enough to produce the desired results; besides, in the absence of significant amounts of historical data, we have no choice. These assumptions are: (1) industrial water use is directly proportional to production; (2) earnings by industry are directly proportional to production, hence directly proportional to water use, (3) value added by industry is directly proportional to production and water use; (4) the future character of industrial water use will be an extrapolation of past industrial performance; and (5) 1977 (the survey year) does not represent an unusual industrial year.

The Survey The survey represents one hundred percent of all industries in Indiana employing over fifty persons and about a ten percent sample of industries employing less than fifty. The list of industries comes from *The Indiana Industrial Directory, 1976 – 77* published by the Indiana State Chamber of Commerce. Industries are divided by county, employment, and a two-digit standard, industrial classification (SIC) code. The questionnaire contains questions on type of industry (to verify the SIC code), employment, amount of water used in a year, annual operating days, and source of the water. These forms are confidential and will be treated as such. Data from responding industries will be used to "fill in" for nonresponding industries. These predictions require a reasonable and accurate survey.

Projections

Indiana industries, for the most part, function in a national economy, that is to say their activity rises and falls as the national demand for goods and services expands or contracts. Much of Indiana's industrial output is consumed in the state and still more is used within the mid-west, but there seems to be no evidence that the state's economy is independent of the national economy. Projections for future Indiana industrial activity will be more solid if they represent a diaggregation of national projections, rather than an extrapolation of past state activity.

Because of the limitations imposed by available data and the time frame provided for the study, projections will be made on the two-digit SIC code for SIC-20 through SIC-39. Also, an all industry growth curve will be developed for use in those industries with an inadequate data base.

A data base exists for making projections of future industrial growth. Probably the most important component of this base is the census of manufacture which collected data at ten-year intervals from 1809 through 1899 and five-year intervals thereafter.

This and other data have been analyzed, and projections of future economic activity have been made by the U.S. Department of Commerce and U.S. Department of Agriculture acting jointly under contract to the U.S. Water Resources Council. These projections are known as the OBERS Projections (an acronym made from outdated U.S. DOC and USDA agency names) and occur in several series. The latest series is known as the Series E population set and

was published in 1974. Series E is based on a projected national population of 263.8 million in the year 2000 with a total personal income of $2,154,266,000,000. The OBERS projections also are based on a series of assumptions such as no major wars, a decline of 0.35 percent per year in hours worked, a somewhat smaller military establishment, a 2.9 percent per year increase in productivity, and past historical data can be used to project future trends.

These OBERS projections are made in terms of industrial earnings which, for the purposes of this study, must be assumed to be directly proportional to both industrial production and industrial water use.

The OBERS projections were made on a national basis and then disaggregated into several subnational classifications. These classifications are the states, clusters of counties forming a megalopolis (known as Standard Metropolitan Statistical Areas or SMSA's), larger clusters of counties representing substate regions (known as Business and Economic Areas or BEA's), water resource regions, and non SMSA's of BEA's. All of these classifications, with the exception of the states themselves can cross state lines.

Population Adjustment The Indiana State Board of Health has published a document entitled *Indiana County Population Projections 1975–2000* (1976). This document was prepared by the Division of Research, School of Business, Indiana University. These projections have gained general acceptance as the best available estimates of future population patterns in the state and are now being used for most ongoing state-level studies. Because of the quality and overall acceptability of these projections, this study will use these figures as the "most probable" estimates of future populations.

A decision has been made to use OBERS, Series E, as the basis for future industrial projections, because the Series E projections do not quite agree with the Indiana State Board of Health (ISBH) projections. To bring these studies into agreement was necessary to apply an adjustment factor based on population differences to the OBERS projections. These differences can be seen in the following table which compares the ISBH projections with those used as a basis for the OBERS projections.

Table 220
A comparison between the ISBH and OBERS Population Projections.

	1970	*1980*	*1985*	*1990*	*2000*
ISBH	5,193,700	5,575,400	5,828,600	6,086,600	6,582,100
OBERS	5,208,000	5,783,600	6,066,900	6,364,200	6,837,000
Ratio (ISBH/OBERS)	.9973	.9640	.9607	.9564	.9627

The actual adjustments will be made on the basis of the ratio of expected residents of each region to the "closest fit" OBERS area, be it SMSA, BEA, or another. This figure will be labeled γ and will be computed for each region for each time frame.

Industrial Growth and Its Distribution

Growth The statewide industrial growth was taken from the data presented in *Volume 4—States* of the OBERS Series E projections. This data was displayed as an all industry curve for each two digit SIC classification from SIC-20 through SIC-39 with the exceptions of 21, 26, 30, 31, 32, and 38 for which no data exists. A term, labeled (α was computed, defined as the ratio of the industry's 1980 (and 1990 and 2000) earnings to the 1977 earnings. The 1977 earnings were estimated by straight-line interpolation between the 1970 and 1980 values.

Distribution of Growth Industrial growth across the state will not be even, with some regions growing faster than others. In order to take this into account, an all-industry growth curve for each region will be compared to an all-industry growth curve for the state. A factor labeled Ω incorporating this ratio was developed for each region in each time frame. These individual regional growth curves were developed from the "closest fit" OBERS areas, with some values being better than others, mostly because of the fact that some regions fit OBERS areas better.

Note This approach is sound as long as Indiana industries are evenly dispersed around the state, that is, each region has its reasonable "share" of a particular industrial group within its boundaries. An example would be the steel industry along Lake Michigan. Here, the industry growth rates will not be affected by the growth distribution coefficient Ω

Industrial Efficiency Factor An analysis of available data shows two seemingly contradictory pronounced trends in American industry with respect to water. These are: (1) the water taken into the plant, on a per unit of production basis, is dropping; and (2) the total water used in the manufacturing process is increasing. American industry is able to do this by recycling water within the plant, using the same gallon over again instead of discarding that water after a single use. This trend is expected to accelerate because of PL 92-500 and other similar pollution abatement laws. Some industries are more efficient than others. In general, the more abundant the water supply (less cost per unit) the less efficient the industry tends to be. One might expect, for certain industries, this increase in water use efficiency will cause the overall water intake to fall in spite of substantial increase in production.

A coefficient ϕ was computed for each two-digit SIC group. ϕ is defined as the ratio of the water intake in the year 1980 (1990, 2000) to the water intake in 1977, per unit of production. Since census data was used for this computation, it must be assumed that production is directly proportional to value added by industry.

Data Base As hereinbefore noted, the Bureau of the Census has conducted censuses of manufactures since 1809. In the 1954 Census, the bureau first began to ask questions about industrial water use. From 1954 on, a report entitled something like "Water Use in Manufacturing" is available for each census. Industrial censuses are therefore available for the years 1954, 1958, 1963, 1967, and 1972.

There is one serious complication with this data. From the 1958 census on, each industry inventoried was asked, "Do you use twenty million gallons of water per year or more?" If the response was positive, that industry was sent a detailed questionnaire covering water use for the following year. We therefore have water use figures for the years 1954, 1959, 1964, 1968, and 1973. A problem arises because the bureau reported economic activity (as measured by value added by industry) for the census years and water use for the following year. The bureau claimed that its twenty-million-gallon-per-year criteria accounted for ninety-seven percent of the industrial water withdrawn in spite of the fact that only 4.2 percent of the industrial establishments were surveyed in detail.

The bureau published data on total water withdrawn, total water used in the process, total water discharged, how the water was used within the plant, where it came from, how it was treated, and the treatment cost. Of all this information, only the intake, use, discharge, and value added were used in this study. This data is published on the national, state, and major river basin levels. By combining the Great Lakes Basin data with the Ohio River Basin data a "regional" data base can be established. The Indiana State Library carries a full set of necessary census reports.

The Bureau of the Census has been very careful to protect the confidentiality of its respondents. This does lead to gaps in data, particularly at the state and regional levels. Also since this data is presented in terms of billions of gallons, the data at the state (and sometimes the national) level does not contain a sufficient number of significant figures to permit meaningful analysis.

The next problem that must be addressed is placing all the economic data on a common dollar basis. In this case, 1977 was chosen as the survey year. The initial attempt to do this involved the use of the Consumer Price Index published by the Department of Labor. Upon further reflection and research, it was decided that use of the DOL's "Wholesale Prices and Price Indices" would be more realistic. In order to use these indices, two tasks were necessary. The first was to find a "Major Commodity Group" that corresponded to the SIC classifications. The second was to get these wholesale price indices to a common base. In the eighteen years covered by the census surveys, DOL had used three different years for data bases.

The Computation of ϕ Two intermediate values must be computed, these are R, the recirculation ratio, defined as the ratio of water intake to the total water used, and Z, the total water used per dollar of value added. (The value added has been adjusted for inflation by the process described above.) The R factor represents industrial efficiency while the Z represents the actual water used in the process. In all cases, R is decreasing (indicating more efficient use) and in most cases Z is found to be rising. It must be noted that Z is based on the mixed year economic data and hence a weaker value than R which is not so afflicted. Next, a least square fit for a curve following the equation was fit through the data. This data was extrapolated to the year 2000 with intermediate values at 1977, 1980, and 1990 picked off. Also, this data was plotted and, in some cases, visual adjustments were made.

$$(R \text{ or } Z) = ae^{bx}$$

where a and b are constant, x = number of years, and e is the natural logarithm.

National data was plotted in all cases. This has the best data base and should give the best results. Regional and state data were also plotted where the data base was available. In general, state data either agreed with national data, exhibited similar trends but at different levels, or showed movement toward national trends. In some cases the state or regional data was more "regular" than the national and in a few cases the state or regional data was so erratic as to be useless. In general, the data showed:

(1) Indiana industries generally use more water for the same function than national data indicates, probably reflecting the relative abundance of water in Indiana. This is especially true of the primary metal industry.
(2) While Indiana uses more water, it consumes a lesser percentage of that water than national data would indicate.
(3) The most visible and easily verified trend in industrial water use is that R is dropping, showing a pronounced trend toward industrial recycling. In some cases, a linear extrapolation of existing data will pass through zero in the near future.
(4) While recycling is going up, the actual water used per unit of production is also rising. If one trend is strong enough to offset the other, then the intake per unit of production will fall. In all cases, the fall in R was sufficient to offset the increase (if any) in Z.

It was then possible to complete ϕ defined as the ratio of industrial water intake in a given year to the 1977 value per unit of production. The intermediate value, θ, is defined as $(Ry \times Ry) \div R_{1977} = \theta$. This is a somewhat awkward term which is, in effect, the Z for a particular year divided by a constant. Since ϕ, the term sought, is simply a ratio of the θ for a given year to the θ for 1977, this constant dropped out of the equation.

Basic Equations Self-supplied, industrial water use projections will be made for each basic industry group (by two-digit SIC code) by each region for the years 1980, 1990, and 2000.

The basic equation is:

$$[WW_{(YEAR)(SIC)(REGION)}] = [WW_{(1977)(SIC)(REGION)}]\,[\alpha_{(SIC)(YEAR)}]\,[\Omega_{(REGION)(YEAR)}]\,[Y_{(REGION)(YEAR)}]\,[\Phi_{(SIC)(YEAR)}]$$

Where

$WW_{(YEAR)(SIC)(REGION)}$ = Self-supplied industrial water withdrawn for a given industrial group in a given region for a specific future year.

$WW_{(1977)(SIC)(REGION)}$ = Inventoried water withdrawn in 1977.

$\varphi_{(SIC)(YEAR)}$ = The ratio of industrial economic activity (earnings) for the Year to comparable industrial economic activity in 1977.

$\Omega_{(REGION)(YEAR)}$ = Industrial growth adjustment factor to allow for anticipated differences in industrial growth rates in the regions.

$Y_{(REGION)(YEAR)}$ = A factor to adjust the OBERS growth projections to the ISBH projections (strictly a ratio of the populations).

$\Phi_{(SICXYEAR)}$ = Industrial water use efficiency factor which accounts for an anticipated lesser amount of water withdrawal necessary to support a comparable level of industrial activity (value added by industry).

The equation can be simplified to:

$$[WW_{(YEARXSICXREGION)}] = [\Gamma_{(SICXYEAR)}] \quad [\Lambda_{(REGIONXYEAR)}]$$

Where:

$$\Gamma_{(SICXYEAR)} = [\alpha_{(SICXYEAR)}] \quad [\Phi_{(SICXYEAR)}]$$

$$\Lambda_{(REGIONXYEAR)} = [\Omega_{(REGIONXYEAR)}] \quad [\Upsilon_{(REGIONXYEAR)}]$$

It should be noted that these equations represents water withdrawn from the environment and not total water industrial use.

Table 221
Computation of Γ, the factors relating to industrial groups.

Industry Group	SIC	α *1980*	α *1990*	α *2000*	Φ *1980*	Φ *1990*	Φ *2000*	Γ *1980*	Γ *1990*	Γ *2000*
All Industries		1.1025	1.4813	1.9881	.942	.771	.630	1.0386	1.1421	1.2525
Food	20	1.0612	1.2652	1.5241	.924	.713	.549	.9805	.9021	.8367
Tobacco	21	1.1025	1.4813	1.9881	.942	.771	.630	1.0386	1.1421	1.2525
Textiles	22	1.0457	1.1787	1.3879	.942	.771	.630	.9850	.9088	.8744
Apparel	23	1.0872	1.3007	1.5906	.942	.771	.630	1.0241	1.0028	1.0021
Lumber	24	1.0950	1.3799	1.7542	.901	.637	.451	.9866	.8790	.7911
Furniture	25	1.1042	1.4974	2.0260	.901	.637	.451	.9949	.9538	.9137
Paper	26	1.1025	1.4813	1.9881	.943	.774	.635	1.0397	1.1465	1.2624
Printing	27	1.1169	1.5547	2.1502	.942	.771	.630	1.0521	1.1987	1.3546
Chemicals	28	1.1293	1.6984	2.4813	.947	.732	.574	1.0694	1.2432	1.4243
Petrol-Coal	29	1.0838	1.3485	1.6824	.900	.650	.470	.9754	.8765	.7907
Rubber	30	1.1025	1.4813	1.9881	.947	.732	.574	1.0441	1.0843	1.1412
Leather	31	1.1025	1.4813	1.9881	.942	.771	.630	1.0386	1.1421	1.2525
Stone, Glass	32	1.1025	1.4813	1.9881	.898	.626	.437	.9900	.9273	.8688
Pri. Metals	33	1.0675	1.2747	1.5275	.978	.914	.863	1.0440	1.1651	1.3182
Fab. Metals	34	1.0851	1.4706	1.9699	.920	.696	.525	.9983	1.0235	1.0342
Machinery	35	1.0838	1.4104	1.8328	.920	.696	.525	.9971	.9816	.9622
Elect. Mach.	36	1.1536	1.7259	2.5407	.838	.449	.234	.9667	.7749	.5945
Trans.	37	1.0984	1.4648	1.9326	.865	.544	.331	.9501	.7969	.6397
Instruments	38	1.1025	1.4813	1.9881	.942	.771	.630	1.0386	1.1421	1.2525
Misc.	39	1.0866	1.4760	2.0120	.942	.771	.630	1.0236	1.1380	1.2676

Table 222
Computation of Λ, the factors relating to regions.

Region	Ω *1980*	Ω *1990*	Ω *2000*	Υ *1980*	Υ *1990*	Υ *2000*	Λ *1980*	Λ *1990*	Λ *2000*
One-A	.9790	.8937	.8708	.928	.925	.925	.9085	.8267	.7592
One-B	.9994	1.0084	1.0232	1.077	1.081	1.088	1.0764	1.0901	1.1132
Two	.9855	.9619	.9396	1.012	1.020	1.045	.9973	.9811	.9819
Three-A	1.0130	1.0638	1.0986	1.023	1.029	1.064	1.0363	1.0947	1.1689
Three-B	1.0130	1.0638	1.0986	.967	.951	.949	.9796	1.0117	1.0426
Four	1.0035	1.0270	1.0511	1.014	1.019	1.020	1.0175	1.0465	1.0721
Five	1.0118	1.0425	1.0652	.949	.903	.870	.9602	.9414	.9267
Six	.9996	.9415	.9137	.956	.965	.961	.9556	.9085	.8781
Seven	1.0115	1.0757	1.1299	.972	.936	.909	.9832	1.0069	1.0271
Eight	.9934	.9893	.9798	.969	.970	.994	.9626	.9596	.9739
Nine	.9875	.9668	.9506	.959	.928	.909	.9470	.8972	.8641
Ten	1.0118	1.0425	1.0652	.990	.982	.978	1.0017	1.0237	1.0418
Eleven	1.0118	1.0425	1.0652	.971	.960	.970	.9825	1.0008	1.0332
Twelve	.9875	.9668	.9506	1.012	1.022	1.050	.9994	.9881	.9981
Thirteen-A	1.0181	1.0678	1.0994	.942	.911	.901	.9591	.9728	.9906
Thirteen-B	1.0181	1.0678	1.0994	.921	.901	.917	.9377	.9621	1.0081
Fourteen	1.0155	1.1077	1.1756	1.016	1.002	1.014	1.0317	1.1099	1.1921
Fifteen	1.0181	1.0678	1.0994	.952	.948	.964	.9692	1.0123	1.0598

Table 223
The SIC codes.

01	Agricultural Production
07	Agricultural Services and Hunting and Trapping
08	Forestry
09	Fisheries
12	Bituminous Coal and Lignite Mining
13	Crude Petroleum and Natural Gas
14	Mining and Quarrying of Nonmetallic Minerals, Except Fuels
15–17	Contract Construction
19	Ordnance and Accessories
20	Food and Kindred Products
21	Tobacco Manufactures
22	Textile Mill Products
23	Apparel and Other Finished Products Made from Fabrics and Similar Materials
24	Lumber and Wood Products, Except Furniture
25	Furniture and Fixtures
26	Paper and Allied Products
27	Printing, Publishing, and Allied Industries
28	Chemicals and Allied Products
29	Petroleum Refining and Related Industries
30	Rubber and Miscellaneous Plastic Products
31	Leather and Leather Products
32	Stone, Clay, Glass, and Concrete Products
33	Primary Metal Industries
34	Fabricated Metal Products, Except Ordnance Machinery, and Transportation Equipment
35	Machinery, Except Electrical
36	Electrical Machinery, Equipment, and Supplies
37	Transportation Equipment
38	Professional, Scientific, and Controlling Instruments: Photographic and Optical Goods: Watches and Clocks
39	Miscellaneous Manufacturing Industries

Table 224
Consumption of industrial self-supplied water.

	Consumption as a Percentage of Intake	
Year	*Measured Value*	*Projection*
1954	2.43	
1959	1.41	
1964	1.54	
1968	3.019	
1973	3.568	
1977	4.91	4.18
1980		4.55
1990		5.77
2000		6.98

Table 224 indicates the percentage of intake consumed in 1980 will be 1.089 times greater than the 1977 rate, 1990 will be 1.38 times greater, and 2000 will be 1.67 times greater. The industrial consumption figures are computed as follows:

1. The percentage of industrial water consumed in 1977 is computed for each planning region.
2. This factor is multiplied by 1.089 for 1980, 1.38 for 1990 and 1.67 for 2000 (see Table 229).
3. The resulting coefficients are multiplied by the estimated self-supplied industrial water intake for 1980, 1990, and 2000 to obtain the estimated consumption for the respective years.

Table 225
Consumptive use of industrial self-supplied water in million-gallons-per-day.

	1977		*1980*		*1990*		*2000*	
Region	*Intake*	*Consumed*	*Intake*	*Consumed*	*Intake*	*Consumed*	*Intake*	*Consumed*
One-A	3,093.00	89.70	2,920	92.22	2,928	117.18	3,010.00	145.78
One-B	0.59	0.18	0.65	0.22	0.69	0.29	0.74	0.38
Two	53.15	6.38	54.85	7.17	56.23	9.31	59.12	11.85
Three-A	2.76	0.33	2.88	0.37	3.03	0.50	3.25	0.65
Three-B	39.75	6.36	39.93	6.96	43.65	9.64	47.81	12.77
Four	30.00	3.60	31.64	4.13	34.91	5.78	38.54	7.72
Five	15.44	2.47	15.13	2.64	15.46	3.41	15.94	4.26
Six	33.43	4.68	32.35	4.93	31.42	6.07	31.28	7.31
Seven	34.77	6.95	36.01	7.84	41.44	11.43	47.25	15.77
Eight	92.94	16.73	91.57	17.95	95.95	23.85	102.80	30.90
Nine	8.15	0.55	7.98	0.59	8.20	0.76	8.55	0.96
Ten	6.02	1.26	6.18	1.41	6.67	1.93	7.19	2.51
Eleven	4.86	1.12	4.80	1.20	4.83	1.54	5.00	1.92
Twelve	3.20	0.29	3.20	0.32	3.12	0.39	3.15	0.48
Thirteen-A	12.53	1.75	12.44	1.89	13.70	2.64	15.14	3.53
Thirteen-B	12.01	1.44	11.67	1.52	12.83	2.12	14.62	2.93
Fourteen	9.60	2.02	10.27	2.35	12.00	3.48	13.98	4.91
Fifteen	4.74	0.90	4.74	.98	5.32	1.39	5.99	1.90
Total	3,456.94	146.71	3,286.29	154.69	3,317.45	201.71	3,430.35	256.53

Appendix Three

RURAL WATER USE

Inventory

There were no direct inventories of rural water use made for the Commission, but the 1975 livestock population and self-supplied rural populations (the consumers of such water) were measured directly. Water use rates were assigned to livestock populations.

The livestock population was obtained from a statistical series published by Purdue University and the U.S. Department of Agriculture, *Annual Crop and Livestock Summary 1975*. The rural, self-supplied populations were taken as the 1975 county populations as reported by the Bureau of the Census less the populations served by public water systems (see "Methodology: Public Water Supplies," Appendix 2).

Per capita rural water-use rates and livestock-use rates were obtained from estimates published by the Great Lakes Basin Commission, *Great Lakes Basin Framework Study: Water Supply—Municipal, Industrial and Rural, Appendix 6.*

Projections

Projections for the year 2000 were made directly. Since there was only a modest growth in rural water use, values for 1977, 1980, and 1990 were made by straight line interpolation.

The projections for self-supplied, rural residents in the year 2000 were developed by subtracting the estimated population served by public water supplies in the year 2000 from the estimated year 2000 population for each region. Per capita use rates were taken from the Great Lakes Basin Commission report cited above. These rates are somewhat higher than the 1975 rates, which reflect an anticipated growth in income levels.

The projections for future livestock populations were based on the *OBERS Projections of Economic Activity in the United States, Series E* which is the same volume used to estimate future industrial activity. The future livestock population was distributed in proportion to the 1975 population. The 1975 livestock water use rates were projected for the year 2000 livestock populations, in million-gallons-per-day (mgd).

Table 226

Rural residential and livestock water use for the years 1975 and 2000, in million-gallons-per-day.

Region	1975 Population	1975 Residential Water Use (mgd)	1975 Livestock (head)	1975 Poultry (head)	1975 Livestock Water (mgd)	1975 Total Water Use (mgd)	2000 Population	2000 Residential Water Use (mgd)	2000 Livestock (head)	2000 Poultry (head)	2000 Livestock Water (mgd)	2000 Total Water Use (mgd)
One-A	70,515	4.15	56,400	106,000	0.49	4.64	77,000	5.79	60,200	116,700	0.54	6.33
One-B	48,607	2.86	260,000	545,400	1.81	4.68	70,400	5.30	310,700	600,000	2.06	7.36
Two	222,592	13.11	453,500	2,100,900	3.87	16.98	333,700	25.11	493,000	2,310,500	4.06	29.17
Three-A	87,980	5.18	386,100	1,070,500	3.16	8.34	140,600	10.58	417,400	1,179,000	3.30	13.88
Three-B	114,322	6.73	305,800	896,500	2.06	8.79	153,400	11.54	350,500	993,900	2.38	13.92
Four	96,540	5.69	744,700	611,100	3.61	9.30	110,500	8.31	900,800	733,500	5.41	13.72
Five	104,486	6.15	608,900	994,400	3.23	9.38	122,500	9.22	724,600	1,091,100	4.45	13.67
Six	178,661	9.91	492,700	440,400	2.86	12.77	187,300	14.09	575,900	528,800	3.82	17.91
Seven	86,597	5.10	305,700	185,300	1.97	7.07	90,500	6.81	360,100	204,000	2.59	9.40
Eight	255,271	15.03	514,600	383,700	3.04	18.07	355,500	26.75	600,600	461,200	4.13	30.88
Nine	58,788	3.46	497,000	108,100	2.80	6.26	65,100	4.90	591,800	119,000	3.77	8.67
Ten	35,196	2.07	67,900	10,300	0.56	2.63	31,200	2.35	75,900	11,000	0.69	3.04
Eleven	69,577	4.10	304,400	1,613,000	2.01	6.11	81,700	6.15	357,800	1,776,000	2.61	8.76
Twelve	29,806	2.47	190,200	508,000	1.64	4.11	29,800	2.24	211,400	559,000	1.88	4.12
Thirteen-A	47,683	2.81	386,600	441,300	3.16	5.97	47,300	3.56	449,800	466,500	3.49	7.05
Thirteen-B	79,223	4.67	182,100	260,500	1.22	5.89	94,700	7.12	213,100	282,000	1.57	8.69
Fourteen	61,924	3.65	269,400	354,000	2.32	5.97	56,300	4.24	300,900	387,000	2.66	6.90
Fifteen	39,973	2.36	369,000	1,701,600	2.57	4.93	34,500	2.60	432,800	1,789,400	3.30	5.90

Appendix Four

IRRIGATION WATER

A survey was made of identified 1978 irrigators. County agricultural agents, district soil conservationists, and irrigation equipment dealers assisted in this identification.

A survey instrument, with a letter explaining the purpose, was sent to each of the irrigators. On the initial mailing there were 297 sent, with over a seventy-five percent return. The county agents were requested to contact non respondents to determine their status. A second mailing of 139 produced an additional seventy-five returns; however the acreage involved from this second mailing was rather small, indicating that replies from the major irrigators were received on the initial return. The following questions were included on the survey:

1. Total acres irrigated in 1976 _____ acres
   in 1977 _____ acres
2. Do you expect to increase, decrease, or no change in irrigated acres the next five years?
   How many acres change _____?
3. Crops irrigated
   Corn _____ acres Soybeans _____ acres
   Potatoes _____ acres Other (please list)
   _____ acres _____ acres
   _____ acres _____ acres
4. Water Supply
   Well _____ Pond or lake _____
   Stream or River _____ Other _____
5. Power Source
   Gasoline Engine _____ Diesel Engine _____
   L.P. Engine _____ Electric Motor _____
   Farm Tractor _____ Portable _____
6. Type of System
   Portable _____ acres
   Solid Set _____ acres
   Hose Pull _____ acres
   Center Pivot _____ acres
   Other, list _____ acres

Croplands From the survey, irrigated acreages were obtained by crop. When and how much water irrigators apply is dependent on weather, the stage of growth of the crop, and the type of soil on which the crop is grown. Normally water is not metered when irrigating nor does the irrigator keep accurate records of the time or amount applied. Research has shown fairly accurately the total amount of water that plants will transpire during the season. Knowing the rainfall pattern, the irrigation needs can be estimated with reasonable accuracy. Three levels of irrigation are considered in making the estimates: (1) below average rainfall, (2) average rainfall, (3) above average rainfall. Crops vary somewhat in water needs, primarily in the length of their growing season.

Table 227
The estimated irrigation requirements for corn, soybeans, potatoes, and mint.

Month	*Below average Rainfall (inches)*	*Average Rainfall (inches)*	*Above average Rainfall (inches)*
May	0	0	0
June	2	2	1.0
July	4	3	2.5
August	4	3	2.5
September	0	0	0
Total	10	8	6.0

Table 228
The estimated irrigation requirement for hay.

Month	*Below average Rainfall (inches)*	*Average Rainfall (inches)*	*Above average Rainfall (inches)*
June	2	2	1.0
July	4	3	2.5
August	4	3	2.5
September	2	2	1
Total	12	10	7.0

Table 229

The projected total withdrawals and ground-water withdrawals for the years 1980, 1990, and 2000 during the peak July–August cropland irrigation season, in million-gallons-per-day.

Region	1977 Irrigated Acreage	1980 High	1980 Medium	1980 Low	1990 High	1990 Medium	1990 Low	2000 High	2000 Medium	2000 Low	2000 Irrigated Acreage
One-A	2,000										5,500
Total Withdrawal		8.60	6.58	5.38	13.92	10.63	18.70	19.25	14.69	12.03	
Ground-water Withdrawal		1.42	1.08	.88	3.13	2.37	1.94	4.84	3.67	3.01	
One-B	12,050										23,500
Total Withdrawal		47.45	35.59	29.65	64.91	48.70	40.56	82.38	61.80	51.47	
Ground-water Withdrawal		20.98	15.79	13.10	32.93	24.74	20.58	44.87	33.69	28.06	
Two	21,100										45,100
Total Withdrawal		84.86	63.64	47.74	121.31	90.99	73.34	157.76	118.33	98.94	
Ground-water Withdrawal		54.92	41.19	34.36	86.17	64.63	53.99	117.41	88.07	73.62	
Three-A	14,850										23,800
Total Withdrawal		56.16	42.13	33.78	69.94	52.48	38.02	83.72	62.82	42.25	
Ground-water Withdrawal		33.20	24.91	19.82	47.21	35.42	25.50	61.21	45.93	31.19	
Three-B	839										2,000
Total Withdrawal		3.90	2.60	2.16	5.96	3.92	3.26	8.03	5.24	4.36	
Ground-water Withdrawal		.99	.66	.55	2.50	1.65	1.37	4.02	2.63	2.18	
Four	960										11,000
Total Withdrawal		7.94	5.99	4.97	23.22	17.53	14.55	38.50	29.07	24.12	
Ground-water Withdrawal		3.24	2.48	2.03	11.69	8.84	7.32	20.14	15.20	12.61	
Five	1,560										9,200
Total Withdrawal		8.99	7.17	5.57	20.77	16.62	12.78	32.55	26.07	19.98	
Ground-water Withdrawal		3.24	2.54	2.01	9.76	7.79	6.05	16.28	13.04	10.09	
Six	400										3,600
Total Withdrawal		2.99	2.17	1.80	8.30	5.85	4.86	13.60	9.54	7.92	
Ground-water Withdrawal		1.25	.90	.74	4.23	3.01	2.48	7.22	5.11	4.22	
Seven	2,122										10,000
Total Withdrawal		11.00	8.29	6.91	22.94	17.34	14.45	34.88	26.39	21.98	
Ground-water Withdrawal		9.71	7.32	6.10	17.33	13.10	10.92	24.96	18.89	15.74	
Eight	867										26,000
Total Withdrawal		4.35	3.60	2.79	9.02	7.26	5.94	13.69	10.92	9.08	
Ground-water Withdrawal		2.79	2.32	1.73	5.67	4.55	3.41	8.54	6.78	5.08	
Nine	0										29,500
Total Withdrawal		1.51	1.14	.95	6.53	4.95	4.10	11.55	8.75	7.26	
Ground-water Withdrawal		.88	.67	.55	3.82	2.89	2.40	6.76	5.12	4.24	
Ten	130										1,000
Total Withdrawal		.53	.40	.33	.79	.59	.49	1.06	.79	.65	
Ground-water Withdrawal		.05	.04	.03	.24	.18	.15	.42	.32	.26	
Eleven	1,115										23,000
Total Withdrawal		5.89	4.47	3.71	12.57	9.59	7.94	19.25	14.72	12.18	
Ground-water Withdrawal		4.10	3.09	2.59	10.08	7.61	6.37	16.05	12.14	10.16	
Twelve	64										800
Total Withdrawal		.29	.22	.18	.50	.37	.31	.70	.53	.44	
Ground-water Withdrawal		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Thirteen-A	6,188										15,500
Total Withdrawal		23.05	17.28	14.40	27.60	20.69	17.25	32.16	24.10	20.10	
Ground-water Withdrawal		3.56	2.67	2.22	15.41	11.55	9.63	27.27	20.44	17.04	
Thirteen-B	6										600
Total Withdrawal		.30	.22	.18	1.25	.91	.73	2.20	1.59	1.28	
Ground-water Withdrawal		.16	.12	.10	.70	.51	.41	1.24	.91	.73	
Fourteen	233										300
Total Withdrawal		.81	.56	.47	.78	.56	.47	.75	.56	.47	
Ground-water Withdrawal		.07	0.0	0.0	.07	0.0	0.0	.07	0.0	0.0	
Fifteen	120										0
Total Withdrawal		.42	.32	.26	.42	.32	.26	.42	.32	.26	
Ground-water Withdrawal		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
State	64,604										157,300
Total Withdrawal		269.04	202.37	161.23	410.73	309.30	248.01	552.45	416.23	334.77	
Total Ground-water Withdrawal		140.56	105.78	86.81	250.94	188.84	152.52	361.30	271.94	218.23	

*Consumption of irrigation water equals the total withdrawal.

Table 230

The total water withdrawals and ground-water withdrawals for croplands during the July – August irrigation season, in million-gallons-per-day.

Region	Acreage	Amount of Precipitation High	Medium	Low
One-A	2,000			
Total Withdrawal		7.00	5.36	4.38
Ground-water Withdrawal		.91	.69	.56
One-B	12,050			
Total Withdrawal		42.21	31.66	26.38
Ground-water Withdrawal		17.40	13.10	10.86
Two	21,100			
Total Withdrawal		73.92	55.44	40.07
Ground-water Withdrawal		45.55	34.16	28.47
Three-A	14,850			
Total Withdrawal		52.03	39.03	32.51
Ground-water Withdrawal		29.00	21.76	18.11
Three-B	839			
Total Withdrawal		3.28	2.20	1.83
Ground-water Withdrawal		.53	.37	.31
Four	960			
Total Withdrawal		3.36	2.53	2.10
Ground-water Withdrawal		.70	.57	.44
Five	1,560			
Total Withdrawal		5.46	4.34	3.41
Ground-water Withdrawal		1.28	.96	.80
Six	400			
Total Withdrawal		1.40	1.06	.88
Ground-water Withdrawal		.35	.27	.22
Seven	2,122			
Total Withdrawal		7.42	5.58	4.65
Ground-water Withdrawal		7.42	5.58	4.65
Eight	867			
Total Withdrawal		2.96	2.50	1.85
Ground-water Withdrawal		1.93	1.65	1.23
Nine	0.0			
Total Withdrawal		0.0	0.0	0.0
Ground-water Withdrawal		0.0	0.0	0.0
Ten	130			
Total Withdrawal		.46	.34	.28
Ground-water Withdrawal		0.0	0.0	0.0
Eleven	1,115			
Total Withdrawal		3.89	2.93	2.44
Ground-water Withdrawal		2.31	1.73	1.45
Twelve	64			
Total Withdrawal		.23	.17	.14
Ground-water Withdrawal		0.0	0.0	0.0
Thirteen-A	6,188			
Total Withdrawal		21.68	16.26	13.55
Ground-water Withdrawal		0.0	0.0	0.0
Thirteen-B	6			
Total Withdrawal		.02	.02	.01
Ground-water Withdrawal		0.0	0.0	0.0
Fourteen	233			
Total Withdrawal		.82	.56	.47
Ground-water Withdrawal		.07	0.0	0.0
Fifteen	120			
Total Withdrawal		.42	.32	.26
Ground-water Withdrawal		0.0	0.0	0.0
State	64,598			
Total Withdrawal		226.56	170.30	135.21
Ground-water Withdrawal		107.45	80.84	67.10

Golf Courses Golf course irrigation projections are based upon 1977 regional data supplied by the Department of Natural Resources, Division of Outdoor Recreation. This data supplied the number of golf courses, number of holes and the number irrigated, and was forwarded to Purdue University where 1977 irrigation figures were compiled according to region.

After the 1977 golf course irrigation figures were obtained, the Department of Natural Resources, Division of Water, established future growth rates of regional golf courses using Division of Outdoor Recreation projections from the year 1979 to the year 1995. Since values for this report were to be projected to the year 2000, the growth rates for the year 2000 had to be obtained by linear regression. Once the growth rates for 1980, 1990, and 2000 were developed the irrigation rates for those years were solved by multiplying the 1977 regional use by the proper regional growth rate.

It should be noted that irrigation figures reflect medium cropland and golf course irrigation and do not reflect irrigation of parks or cemeteries.

Table 231

Current and projected golf course irrigation from 1977 to 2000, during the average July – August season in million-gallons-per-day.

Region	1977 Withdrawal	1980 Withdrawal	1990 Withdrawal	2000 Withdrawal
One-A	2.01	2.97	3.12	3.32
One-B	.29	.29	.29	.29
Two	4.67	4.67	4.90	5.32
Three-A	.94	.94	.94	.94
Three-B	2.23	2.32	2.63	2.94
Four	1.54	1.54	1.54	1.54
Five	1.26	1.42	1.50	1.61
Six	2.58	2.58	2.58	2.58
Seven	1.19	1.19	1.19	1.19
Eight	5.54	7.65	8.59	10.42
Nine	.70	.70	.70	.70
Ten	.53	.60	.66	.69
Eleven	.68	.68	.80	.86
Twelve	.12	.14	.14	.16
Thirteen-A	.38	.38	.38	.38
Thirteen-B	1.01	1.34	1.34	1.41
Fourteen	.32	.46	.52	.59
Fifteen	.48	.48	.48	.48
Total	26.47	30.35	32.30	35.42

Appendix Five

ENERGY

Inventory

The water used (1) in steam turbine, electric generating stations, (2) to wash the coal mined in southwestern Indiana, and (3) in the future coal gasification or liquefaction was measured by the methodology discussed herein. The water used by refineries, however, is accounted for as industrial water.

Two questionnaires were sent to each utility, municipality, or corporation known to operate electric generating facilities with steam turbines. The first questionnaire (Form A) requested the following specific data for each generating station for the year 1977: (1) plant location; (2) size of plant (mw), both gross and net; (3) fuel, (4) water intake into plant; (5) water discharged from plant; (6) type of condenser cooling; (7) age of units; (8) nominal or projected retirement date for units; and (9) evaporation rate from cooling water system (if known).

The second questionnaire (Form B) requested the following data for each company: (1) net system generating capacity in megawatts (mg); (2) retail sales in Indiana in kilowatt hours (kwh); (3) estimated or projected growth rates in retail sales, both through 1990 and for 1990 to 2000; and (4) a question on future cooling methods.

Data on out-of-state plants came from information provided by the East Central Area Reliability Coordination Agreement (a group of major mid-western utilities) or from the ongoing Ohio River Basin Energy Study.

Historical data on power generation (both state and national) load factors and energy sources came from various issues of the *Statistical Year Book of the Electric Utility Industry*, by the Edison Electric Institute. Data on hydroelectric power came from the Indiana Department of Commerce and other sources. Service area information was obtained from the major utilities.

A questionnaire was sent to all companies operating coal washing facilities in Indiana. These companies were asked to provide data on: (1) location of the plant; (2) tonnage of coal washed in 1976, (3) water used to wash coal; (4) percentage of water recycled from slurry ponds; (5) source of water, (6) method of washing; and (7) the company's estimate of future water needs per ton washed.

Projections

In order to estimate the future shortfall or surplus capacity, it was first necessary to estimate the probable future in-situ generating capacity in Indiana. In order to do this, a retirement-replacement schedule was developed showing the probable retirement of existing units and the anticipated start up of those new generating facilities already announced by the utilities.

Retirement dates were those furnished by the utilities or, in the absence of such data, based on an assumed forty-year life of each unit. Whether these units will be actually retired after forty years will depend on many factors such as the overall system capacity and the cost of operation of that unit. For the purposes of this study, it was assumed that all existing units utilizing once-through cooling facilities would continue to use these facilities until retirement.

Since it requires a minimum of eight years to construct a major generating facility, most utilities announce their plans for new units or new plants well in advance of the proposed start-up dates. Usually in order to secure the necessary permits, an environmental impact statement is prepared. Data on future utility facilities was derived from those announcements or statements available in early 1978.

The load factor is the relationship between the installed electric generating capacity and the total kilowatt hours of energy produced during a given year. Historical data on both national and state load factors was plotted and reviewed. The plot showed that Indiana utilities are more efficient with their equipment use than the national average, that this efficiency has declined somewhat recently and that past performance has gone through distinct cycles. There was no real trend in load factor that could be projected forward with confidence. It was then decided to use the existing load factor of about fifty percent as a reasonable approximation of future utility load factors to the year 2000.

Projecting the growth rate for future electric energy generation is fraught with uncertainty. In the first place, it is no longer possible to isolate the consumption of electric energy from other forms of energy consumption. For example, in the last decade, electric energy has been widely used for space heating, a field traditionally dominated by fossil fuels. Many factors affecting the availability and price of energy now lie outside American control. The political instability of the major energy producing regions in the world is of particular concern. Further, there are a number of federal mandates, often working at cross purposes, which could have a radical impact on the production and consumption of energy. Many believe, however, that in the future, the electric utilities will provide an increasing share of the nation's energy requirements.

Several projection methods were considered. A 1973 study by the Department of Natural Resources suggests that a 6.9 percent growth rate will prevail until 1980, and then a 6.3 percent growth rate will prevail to the end of the century. The growth estimates from the utilities themselves, weighted

to reflect utility size, amount to 5.9 percent through the year 2000. The Ohio River Basin Commission in their 1978 Ohio River Main Stem Study reviewed a number of energy projections and finally selected a growth rate slightly over five percent as the "most representative of the anticipated future conditions." Another method might be based on the recent growth trends in Indiana as shown on the following table.

Table 232
Historical data for electric energy generation.

Year	Total U.S.* Generation (KWH × 10^6)	Moving 5 Year Growth Rate (Percent)	Total Indiana* Generation (KWH × 10^6)	Moving 5 Year Growth Rate (Percent)
1930	91,112	8.20	na	na
1940	141,837	8.28	na	na
1950	329,141	8.15	na	na
1960	753,350	6.61	na	na
1962	852,314	6.18	34,648	na
1964	983,990	6.74	38,968	na
1966	1,144,350	7.64	45,685	6.81
1968	1,329,443	7.72	48,024	5.61
1970	1,531,609	7.74	51,890	3.99
1972	1,747,323	7.55	54,228	4.16
1974	1,866,436	5.29	56,863	1.65
1976	2,036,503	4.78	62,411	3.34

*Source: *Statistical Yearbook of the Electric Utility Industry*, by the Edison ELectric Institute, various issues.
na: not available.

The future, required generating capacity was computed by permitting the 1977 installed generating capacity to grow at the specified growth rate (compounded). The estimated, available capacity came from the retirement replacement schedule described above. The anticipated shortfall in generating capacity is simply the difference between the required and available capacities.

The estimates of future water withdrawals were made for three conditions. First, those generating stations currently in service; the withdrawal and consumption rates shown on the utility questionnaire were assumed to remain constant over the life of the station (or units in that station). Second, withdrawal and consumption rates for those units or stations now under construction or announced for future construction came from published environmental impact statements or other industry sources. Since the location of all of these facilities is known, it is possible to assign the appropriate water use figures to the planning and development regions.

The third condition was the probable future water needed to meet the anticipated shortfall outlined above. This was accomplished by assuming: (1) all unannounced generating facilities will be provided with some form of wet cooling devices; (2) eighty percent of these plants will be coal-fired, consuming 5.8 million-gallons-per-day (mgd) withdrawal per 1000 mw of installed capacity; (3) the remaining twenty percent will be nuclear-fueled plants with require about fifty percent more water intake, and finally (4) fifty percent of the water brought into these stations will not be returned to the source but will be lost through evaporation and drift off of the towers.

Table 233
Steam turbine electric generating stations.

Year	Annual Growth Rate (percent)	Existing Stations			Announced Additional Capacity			Total Required Capacity (mw)	Additional Required Capacity		
		Nameplate Rating (mw)	Intake (mgd)	Consumption (mgd)	Nameplate Rating (mw)	Intake (mgd)	Consumption (mgd)		Nameplate Rating (mw)	Intake (mgd)	Consumption (mgd)
1976		14,761	9,493	48.1							
					Low Range Projection						
1980	3.5	14,620	9,445	47.6	3,357	45.5	30.1	16,300	0	0	0
1990	3.5	14,136	9,063	47.1	12,403	296	158	23,000	0	0	0
2000	3.5	8,812	4,403	43.1	12,935	302	161	32,400	10,653	140	68.2
					Mid Range Projection						
1980	5.0	14,620	9,445	47.6	3,357	45.5	30.1	17,000	0	0	0
1990	5.0	14,136	9,063	47.1	12,403	296	158	27,700	1,161	15.3	7.4
2000	5.0	8,812	4,403	43.1	12,935	302	161	45,100	23,353	308	150
					High Range Projection						
1980	6.5	14,620	9,445	47.6	3,357	45.5	30.1	17,800	0	0	0
1990	6.5	14,136	9,063	47.1	12,403	296	158	33,300	6,761	89.2	43.3
2000	6.5	8,812	4,403	43.1	12,935	302	161	62,600	40,853	539	261

Coal Future water requirements for coal washing were estimated by assuming the growth in coal production will parallel the growth in electrical energy in Indiana.

No estimates were made for future water requirements for processes that convert coal to liquid or gaseous hydrocarbons. At present there are no such facilities operating commercially in Indiana (except for incidental production of gas as part of other industrial uses of coal). No announcements have been made concerning the construction of such facilities.

Most authorities agree that the future construction of these facilities is related closely to the price of gas or liquid hydrocarbons. Because Indiana's coal fields are located near adequate sources of water, Indiana should be considered an attractive location for such facilities.

There are a number of commercial coal conversion practices now in existence. The water requirements for representative processes are shown below.

Table 234

Water requirements for selected coal conversion processes, based on plant capacity of 250 million standard cubic feet per day of gas or 50,000 barrels per day of liquid hydrocarbon.

Process	*Hydrocarbon Produced*	*Water Requirements (mgd)*
BCR Bi–Gas	Gas	24
CO_2 Adapter	Gas	17
H–Coal	Liquid	17
IGT Hygas	Gas	29
Synthane	Gas	24
Synthoil	Liquid	20
SRC Liquid Fuels	Liquid	22

Appendix Six

AREAS WITH IRRIGATION POTENTIAL, AGRICULTURAL DRAINAGE, AND SOIL EROSION

The identification and location of areas with irrigation potential, soil erosion, and wetness characteristics are based upon the soil associations as shown in Figure 8. The map of soil associations provides a broad perspective of the soils and landscapes in Indiana. It provides a basis for comparing the potential and limitations of large areas. Because of the small scale, Figure 8 does not show the kind of soil at a specific site. Thus, it is not suitable for planning the management of a form or field or for selecting a site for a road, building, or other structure.

Irrigation Potential

When mapping irrigable soils, it is necessary to look at the soil associations based on the water holding capacity and the surface texture of the soils. Each state soil association was assigned an irrigation index number based on how profitable it would be to irrigate a particular soil association, as shown below.

Table 235
The relationship between the irrigation index and the response to irrigation.

Irrigation Index Rating of Response to Irrigation	
1. Low	Little or no profitable response
2. Medium	1–2 years in 5.
3. High	3–4 years in 5.
4. Very High	yearly.

Once the irrigation index was determined a percent of potentially irrigable soils within the soil association were grouped as shown on the following table.

Table 236
Potential irrigable soils within soil associations.

Group	*Criteria*
A	100-70 percent of soils have irrigation indices of 2, 3, and 4.
B	69-40 percent of soils have irrigation indices of 2, 3, and 4.

Table 236 (continued)

Group	*Criteria*
C	39-25 percent of soils have irrigation indices of 2, 3, and 4.
D	24 percent or less soils have irrigation indices of 2, 3, and 4.

An additional criterion, greater than fifteen percent of the soils, must be in irrigation classes 3 and 4.

The groups of soil associations that were mapped for potential irrigation were groups A, B, and C. Soil associations having greater than fifty percent, poorly or somewhat poorly drained soils, were dropped one group, e.g., from A to B. The associations which fall within these groupings are shown in the table below.

Table 237
Percent of each soil association with an irrigation potential.

Group	*Soil Association*	*Percent of Association that has Irrigation Potential*
A	Plainfield – Maumee – Oshtemo	90
	Riddles – Tracy – Chelsea	84
	Elston – Shipshe – Warsaw	80
	Oakville – Adrian	73
B	Sebewa – Gilford – Homer	78
	Maumee – Gilford – Oshtemo	73
	Oshtemo – Fox	64
	Tracy – Door – Lydick	56
	Princeton – Bloomfield – Ayrshire	47
	Fox – Ockley – Westland	37
	Fox – Genesee – Eel	32

The irrigation indices for the sixteen regions with irrigation potential are listed below.

Table 238
The potential irrigation acreage by region.

Region	*Irrigation Indexes* 1	2	3	4
One-A	408,800	49,800	75,600	66,500
One-B	604,500	121,100	253,500	118,400
Two	641,800	338,800	254,100	80,400
Three-A	864,600	127,400	147,600	27,900
Three-B	1,068,200	13,900	32,400	3,500
Four	1,923,200	50,300	208,900	30,500

Table 238 (continued)

Region	Irrigation Indexes 1	2	3	4
Five	1,091,600	152,000	102,500	20,600
Six	1,407,200	7,000	45,900	1,100
Seven	1,417,800	32,100	100,200	10,800
Eight	1,843,600	15,400	91,900	2,600
Nine	945,700	7,300	64,500	0
Ten	503,600	200	4,700	–
Eleven	1,213,700	14,400	38,700	5,600
Twelve	906,300	0	3,000	0
Thirteen-A	1,400,300	44,500	15,000	12,800
Thirteen-B	1,170,000	19,200	6,900	5,400

Agricultural Drainage

Natural soil drainage as used in this report includes soil associations with severe, moderate, and slight soil wetness characteristics. A percentage of soils with the same wetness characteristics was calculated in order to determine the classification of a particular soil association. The classification of wetness characteristics of the soil associations is as follows.

Table 239
Classification of soil wetness characteristics.

Wetness Characteristic	Criteria
Slight	Less than 30 out of every 100 acres need drainage in order to maximize crop yields.
Moderate	30 to 69 out of every 100 acres need drainage.
Severe	More than 70 out of every 100 acres need drainage.

These are natural drainage classes and do not reflect the completeness of artificial drainage installed to correct wetness in crop field or in construction.

State soil associations which were mapped as having severe wetness characteristics are shown in the following table.

Table 240
Soil associations with severe wetness characteristics.

Houghton – Adrian	Iva – Vigo
Maumee – Gilford – Sebewa	Brookston – Odell – Corwin
Rensselaer – Darroch – Whitaker	Crosier – Brookston
Sebewa – Gilford – Homer	Crosby – Brookston
Lyles – Ayrshire – Princeton	Blount – Pewamo
Milford – Bono – Rensselaer	Hoyville – Nappanee
Patton – Lyles – Henshaw	Bartle – Peoga – Dubois
Ragsdale – Raub	Avonburg – Clermont
Sable – Ipava	Fincastle – Ragsdale
Reelsville – Ragsdale	

State soil associations mapped as having moderate wetness characteristics are shown in the following table.

Table 241
Soil associatrions with moderate wetness characteristics.

Sloan – Ross – Vincennes – Zipp	Parr – Brookston
Stendal – Haymond – Wakeland – Nolin	Miami – Crosier – Brookston – Riddles
Zipp – Markland – McGary	Miami – Crosby – Brookston
Fox – Ockley – Westland	Markham – Elliott – Pewamo
Oakville – Adrian	Morley – Blount – Pewamo
Plainfield – Maumee – Oshtemo	Weinbach – Wheeling
Princeton – Bloomfield – Ayrshire	

All other state soil associations are mapped as having slight wetness characteristics.

The number of acres included within the wetness characteristics classification system for each region is shown on the following table.

Table 242
The soil wetness characteristics by region.

Region	Wetness Characteristic Slight	Moderate	Severe
One-A	31,000	354,000	215,000
One-B	13,000	214,000	594,000
Two	463,000	755,000	396,000
Three-A	263,000	683,000	222,000
Three-B	77,000	455,000	570,000
Four	613,000	553,000	1,041,000
Five	220,000	496,000	650,000
Six	151,000	429,000	1,136,000
Seven	969,000	161,000	428,000
Eight	404,000	563,000	985,000
Nine	500,000	265,000	253,000
Ten	460,000	27,000	22,000
Eleven	801,000	219,000	252,000
Twelve	706,000	20,000	183,000
Thirteen-A	900,000	371,000	203,000
Thirteen-B	660,000	451,000	84,000
Fourteen	908,000	135,000	57,000
Fifteen	983,000	221,000	35,000
Total	9,128,000	6,372,000	7,326,000

Potential Erosion

In order to map state soil associations with a potential erosion hazard it was necessary to use the Universal Soil Loss Equation. This equation is written A = R K L S C P where:

"A" is the computed soil loss (sheet and rill erosion) in tons-per-acre-per-year;

"R," the rainfall factor, is the number of erosion-index units in a normal year's rain;

"K," the soil-erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated, continuous fallow, on a nine percent slope 72.6 feet long;

"L," the slope length factor, is the ratio of the soil loss from the field slope length to that from a 72.6 foot length on the same soil type and gradient;

"S," the slope-gradient factor, is the ratio of soil loss from the field gradient to that from a nine percent slope;

"C," the cropping management factor, is the ratio of soil loss from a field with specified cropping and

management to that from the fallow condition on which the factor K is evaluated; and

"P," the erosion-control practice factor, is the ratio of soil loss with contouring, strip cropping, or contour irrigated furrows to that with straight-row farming, up-and-down slope.

It should be noted that the "C" and "P" factors relating to land use in the Universal Soil Loss Equation have been excluded since the cropping management and erosion control practices are beyond the scope of this study.

After the soil loss was determined for each association, the associations were grouped according to ranges in order to simplify mapping. The ranges for these groups are as shown on the following table.

Table 243
Potential soil loss hazard.

Group	*Potential Soil Loss Hazard*	*Soil Loss Range (tons/acre/year)*
A	Low	0 – 30
B	Medium	31 – 80
C	High	81 – 350
D	Very High	351 – and up

State soil associations that have a very high erosion potential (Group D) are shown on the following table.

Table 244
Soil associations with a very high erosion potential.

Parke – Negley
Welston – Zanesville – Berks
Berks – Gilpin – Weikert
Corydon – Weikert – Berks
Eden – Switzerland

State soil associations that have a high erosion potential (Group C) are shown on the following table.

Table 245
Soil associations with a high erosion potential.

Alford	Cincinnati – Vigo – Ava
Miami – Hennepin – Crosby	Cincinnati – Rossmoyne
Miami – Russell – Fincastle – Ragsdale	Crider – Hagerstown – Lawrence
Russell – Henepin – Fincastle	Crider – Hagerstown – Bedford
Hosmer	Crider – Baxter – Corydon
Zanesville – Wellston – Tilsit	

State soil associations that have a medium soil erosion potential (Group B) are shown on the following table.

Table 246
Soil associations with a medium erosion potential.

Wheeling – Huntington – Lindsdale	Princeton – Bloomfield – Ayrshire
Zipp – Markland – McGary	Miami – Crosier –
Fox – Ockley – Westland	Brookston – Riddles

Table 246 (continued)

Miami – Crosby – Brookston	Bartle – Peoga – Dubois
Markham – Elliot – Pewamo	Weinback – Wheeling
Morley – Blount – Pewamo	Avonburg – Clermont

All other state soil associations are rated as having a low soil erosion potential (Group A).

Table 247
The soil erosion potential in acres for each region.

Region	*Soil Erosion Potential in Acres*			
	Slight	*Moderate*	*High*	*Very High*
One-A	337,000	364,000	0	0
One-B	1,065,000	3,000	0	0
Two	32,000	1,584,000	0	0
Three-A	502,000	666,000	0	0
Three-B	727,000	392,000	0	0
Four	1,417,000	332,000	465,000	0
Five	807,000	493,000	7,000	0
Six	1,110,000	350,000	0	0
Seven	764,000	76,000	702,000	16,000
Eight	1,183,000	592,000	158,000	39,000
Nine	326,000	285,000	356,000	51,000
Ten	71,000	21,000	229,000	188,000
Eleven	332,000	255,000	382,000	306,000
Twelve	37,000	218,000	437,000	218,000
Thirteen-A	472,000	103,000	501,000	398,000
Thirteen-B	361,000	217,000	626,000	0
Fourteen	143,000	110,000	639,000	209,000
Fifteen	160,000	136,000	346,000	593,000

Appendix Seven

STATE WATER LAWS

Instream Uses

Recreation The water in all streams, lakes, and other natural bodies of water in the state is a natural resource and public water subject to the control and regulations for the public welfare (I.C. 13-2-1-2).

In 1973, the general assembly created the Recreational Development Commission with purposes of providing for the health and welfare of the citizens of the state through the acquisition, construction, improvement, and operation of public recreational facilities, and promoting the development and use of parks throughout the state (I.C. 14-3-12-1). Also the Natural Resources Commission has the authority to acquire, maintain, and make available to the public, parks, and other suitable places for recreation (I.C. 14-3-2-9).

The Natural Resources Commission is empowered to lease state-owned lands, which are under its management and control, to any local government; and to contract for the construction and operation of lodging, food, and other outdoor recreation, water resources, or service facilities that the commission deems appropriate (I.C. 14-3-8-2). The commission is also authorized to prepare, maintain, and keep up to date a comprehensive plan for the development of state outdoor recreation resources, and to coordinate its activities with and represent the interest of all agencies of the state, county, city, and other government units (I.C. 14-3-5-1).

The state, municipalities, special taxing districts, and public utilities may acquire reservoir sites to meet present and future needs for storage of water for purposes that include recreational uses (I.C. 13-2-9-1). These reservoir sites must be approved by the board of health and the Natural Resources Commission before condemnation can be used in acquisition of those sites (I.C. 13-2-9-7), and if the dam meets certain criteria it must be inspected annually by the Department of Natural Resources (I.C. 13-2-20-4).

Cities have the authority to regulate, license, and prohibit recreational uses on water courses within their jurisdiction (I.C. 18-1-1.5-9).

Approval must be acquired from the Natural Resources Commission prior to the construction of a channel connecting to streams and rivers, for the purpose of providing access by boat or otherwise to public or private recreational facilities (I.C. 13-2-18.5-3).

Conservancy districts can be established for purposes that include the developing of parks and recreational facilities where feasible in connection with beneficial water management (I.C. 19-3-2-1).

The state has consented to the acquisition by the United States of lands within the state for the establishment, maintenance, and development of fish hatcheries, wildlife or forest preserves, or for agricultural, recreational, or experimental uses (I.C. 4-21-8-1).

Fish and Wildlife The Department of Natural Resources has the responsibility and authority to protect the fish and wildlife resources of the state (I.C. 14-2-1-2). This includes the setting of seasons, limits, methods of taking, selling, transporting, and the proper management of wild animals in any designated water and land areas of the state, and setting aside and designating any lands or waters owned or controlled by the state for conservation purposes as public hunting and fishing areas (I.C. 14-2-3-3). The Natural Resources Commission is to establish and maintain areas for public fishing within all port areas created by the Port Commission (I.C. 8-10-1-7.5).

All wild animals, except those legally owned or held in captivity under license or permit, are property of the people of the state (I.C. 14-2-1-2).

It is illegal to place an obstruction, other than a dam, in a waterway of the state that prevents fish from ascending or descending, and the owner of a dam with a watershed greater than fifty square miles may be required to maintain a downstream discharge, during periods of low flow, equal to the inflow into the impoundment; and he may be required to construct and maintain fish ladders (I.C. 14-2-5-9).

It is unlawful to deposit into the waters of the state any substance deleterious to public health, or that which destroys or jeopardizes any beneficial animal, fish, or vegetable life in the water (I.C. 16-1-26-1). Also, it is unlawful, with certain exceptions, to chemically treat aquatic vegetation in any water of the state without first obtaining a permit from the director of the Department of Natural Resources (I.C. 14-2-5-10).

It is also unlawful to perform construction activities on any floodway of a stream in Indiana that would result in unreasonably detrimental effects upon the fish, wildlife, and botanical resources (I.C. 13-2-22-13).

The United States may acquire land in the state for the establishment, maintenance, and development of fish hatcheries, wildlife, or forest preserves, or for agricultural, recreational, or experimental uses (I.C. 4-21-8-1).

The state, municipalities, special taxing districts, and public utilities may secure needed reservoir sites to meet present and future needs for storage of water for purposes that include power (I.C. 13-2-9-1). Sites for impoundments must be approved by the board of health and the Natural Resources Commission before condemnation can be used in

acquisition of those sites (I.C. 13-2-9-7), and if the dams meet certain criteria they must be inspected annually by the Department of Natural Resources (I.C. 13-2-20-4).

Any person may divert flood waters of any water course for any useful purpose upon the approval of the Natural Resources Commission (I.C. 13-2-1-6). Also any construction activity that would take place in the floodway of any stream in Indiana must be approved by the Natural Resources Commission (I.C. 13-2-22-1).

Commercial Navigation The Indiana Port Commission is authorized and empowered to construct, maintain, and operate, in cooperation with the federal government, modern ports on Lake Michigan or the Ohio or Wabash Rivers with terminal facilities and traffic exchange points for all forms of transportation (I.C. 8-10-1-1).

A municipal corporation, county, or any combination, has the authority to create a port authority (I.C. 8-10-5-1), and the county commissioners upon the petition of twenty-four freeholders of the county in the vicinity of the streams may declare any stream or water course in the county navigable (I.C. 13-2-4-1).

The state, municipalities, special taxing districts, and public utilities may secure needed reservoir sites to meet present and future needs for storage of water for purposes that include transportation (I.C. 13-2-9-1).

Any riparian owner may, in aid of navigation and commerce, build, maintain, and use piers, wharves, docks, or harbors. But these works shall not extend further into the stream than necessary to accommodate navigation, and in no case may these structures obstruct navigation (I.C. 13-2-4-5). Also, prior to the construction of any channel connecting to any river or stream for the purpose of providing access by boat or otherwise, approval must be acquired from the Natural Resources Commission (I.C. 13-2-18.5-3).

Any construction that would occur in the floodway of a stream must first meet the approval of the Natural Resources Commission (I.C. 13-2-22-13).

The state has consented to the acquisition by the United States of any lands, buildings, or other property for the purpose of improvement of any navigable river within or bordering Indiana (I.C. 4-21-3-1). Also, consent is given to the United States to purchase any tract, piece, or parcel of land on the banks of the Ohio or Wabash Rivers within the limits of the state in connection with the improvements of those rivers (I.C. 4-21-4-1).

Noncommercial Navigation The water in all streams, lakes, and other natural bodies in the state is a natural resource and is water subject to control and regulation for the public welfare (I.C. 31-2-1-2).

Full power and control of all public, fresh-water lakes is vested in the state, which shall hold these lakes in trust for the citizens of the state for all purposes, including boating; and no person owning lands bordering such lakes shall have the exclusive right to the use of the water of the lakes (I.C. 13-2-11-1). The citizens of the state have a vested right in the preservation and enjoyment of all public, fresh-water lakes and the use of such waters for recreational purposes (I.C. 13-2-14-1).

The Natural, Scenic, and Recreational Rivers System is administered by the Natural Resources Commission for the purpose of setting aside and preserving rivers of unusual natural, scenic, or recreational significance for the benefit of present and future generations (I.C. 13-2-26-1). Also, the Natural Resources Commission is authorized to establish and participate in river commissions to protect the natural integrity of rivers designated in the system (I.C. 13-2-27-1).

The Natural Resources Commission has general charge of the management of the state's water resources (I.C. 14-3-1-14; I.C. 13-2-22-1 *et seq.*), and cities and towns have exclusive power over water courses within their jurisdiction except when otherwise provided by law (I.C. 18-5-10-4).

County commissions may declare any stream or water course in the county navigable upon the petition of twenty-four freeholders of the county within the vicinity of the stream (I.C. 13-2-4-1).

The state, municipalities, special taxing districts, and public utilities can acquire sites for the storage of water for purposes that include recreation (I.C. 13-2-9-1). Impoundment sites must be approved by the Natural Resources Commission and the board of health (I.C. 13-2-9-7).

Approval must be received from the Natural Resources Commission for the construction of a channel connecting any river or stream to a recreational facility for the purpose of providing access by boat or otherwise (I.C. 13-2-18.5-3). Also, any construction that might occur in the floodway of any stream in the state must be approved by the Natural Resources Commission.

All watercraft in Indiana must be registered with the Department of Natural Resources (I.C. 14-1-2-3).

The owner of a dam with a watershed greater than fifty square miles may be required to maintain a downstream discharge, during periods of low flow, equal to the inflow into the impoundment, and he may be required to construct and maintain a passageway around and over the dam to allow the hand carrying of small boats for the purpose of navigation (I.C. 13-2-5-1 *et seq.*).

Natural Lakes The water in all streams, lakes, and other natural bodies in the state is a natural resource and is water subject to control and regulation for the public welfare (I.C. 13-2-1-2). Also, full power and control of all public fresh-water lakes is vested in the state, which shall hold these lakes in trust for the citizens of the state, and no person owning lands bordering such lakes have the exclusive right to the use of the waters of the lake (I.C. 31-2-11-1).

The public has a right to the preservation, protection, and enjoyment of all public, fresh-water lakes (I.C. 13-2-14-1).

The Natural Resources Commission has the authority to become a party to any drainage proceeding in the courts which might injuriously affect the water levels of any lake, river, or stream in the state (I.C. 13-2-12-3).

Any filling, construction, or other activities affecting the shoreline of a public, fresh-water lake must be approved by the Natural Resources Commission (I.C. 13-2-11-2, I.C. 13-2-14-5).

Sewage disposal facilities for housing developments of five or more houses which are an integral part of any change of a shoreline must be approved by the Stream Pollution Control Board prior to any action by the Natural Resources Commission (I.C. 13-2-11-4 and I.C. 13-2-14-4).

Lake Michigan The water in all streams, lakes, and other natural bodies in the state is a natural resource and is water, subject to the control and regulation for the public welfare (I.C. 13-2-1-2).

The Stream Pollution Control Board has been granted the authority to control and prevent pollution of water in the

state (I.C. 13-1-3-4), and the Department of Natural Resources is empowered to protect the lakes, streams, and springs of the state against impurities or pollution by industrial, municipal, or other sewage waste (I.C. 14-3-1-14) and to protect and properly manage the fish and wildlife resources of the state (I.C. 14-2-1-1).

The Natural Resources Commission has also been given charge and supervision of the navigable waters of the state. Therefore, one must seek the commission's approval prior to performing any construction activities in Lake Michigan (I.C. 14-3-1-14). An owner or owners of land abutting upon the shore of Lake Michigan may fill in or construct any dock or wharf upon the approval of the Natural Resources Commission and the Governor (I.C. 4-18-13-3).

The Indiana Port Commission is authorized to construct, maintain, and operate, in cooperation with the federal government, modern ports on Lake Michigan (I.C. 8-10-1-1), as well as grant private agencies or corporations the privilege, upon application, to establish a foreign trade zone (I.C. 8-10-3-2).

Finally, commercial fishermen are required to have licenses to operate and are required to keep monthly records (I.C. 14-2-5-5) when catching, curing, cleaning, or shipping fish. They are required to pursue their trade in a manner that is sanitary and nonpolluting (I.C. 14-2-5-6).

Reservoirs: Impoundments and Discharges The State of Indiana, municipalities, special taxing districts, and public utilities may secure needed reservoir sites to meet present and future needs for the storage of water (I.C. 13-2-9-1). These sites must be approved by the Natural Resources Commission and the State Board of Health before condemnation can be used in acquisition of those sites (I.C. 13-2-9-7); and any dam that meets certain criteria must be inspected annually by the Department of Natural Resources (I.C. 13-2-20-4).

The Natural Resources Commission may contract to provide minimum quantities of streamflow or sell water directly from impoundments financed by the state (I.C. 13-2-1-7).

Land owners who are adjacent to a water course have the right to impound water after receiving the approval of the Natural Resources Commission (I.C. 13-2-1-3). Also, any person may divert floodwater from any water course for any useful purpose upon the approval of the Natural Resources Commission (I.C. 13-2-1-6). However, the owner of a dam, levee, dike, floodwall, or appurtenance is required to maintain the structure in safe operating condition (I.C. 13-2-20-2).

If a person constructs a dam across a water course with a drainage area greater than fifty square miles, the impoundment should have enough storage head to provide the stream with a minimum flow downstream from the dam. It is unlawful to prevent fish from ascending or descending the waterway, so the construction of a fish ladder may be necessary, and passageways around and over the dam may be required to allow hand carrying of small boats for purposes of navigation (I.C. 14-2-5-9).

The Natural Resources Commission is authorized to prevent and limit flooding by regulating, supervising, and coordinating the construction, operation, and design of flood control works or structures (I.C. 13-2-22-1). This includes the regulation of all construction activities within the floodways of the streams in the state (I.C. 13-2-22-13).

Withdrawal Uses

Ground-Water Withdrawals It is the policy of the state to conserve and protect ground-water resources and provide regulations for their most beneficial use and disposition (I.C. 13-2-2-2); and the Natural Resources Commission is authorized to require reduced flow from water wells to prevent the loss or waste of potable water not being put to beneficial use (I.C. 13-2-3-1).

The Natural Resources Commission can designate "restricted use" areas, so the withdrawal of ground water does not exceed the natural replenishment of that source (I.C. 13-2-2-3).

Water well drilling contractors are required to obtain a renewable, annual license from the Department of Natural Resources (I.C. 25-39-1-1), and are required to keep accurate records of wells and file the drilling logs with the department (I.C. 25-39-1-2).

County commissioners may enact ordinances and regulations to control the location, construction, or repair of all wells within the county. Cities and towns may do the same within their jurisdiction (I.C. 17-2-22-4.5), and any water that is sold or consumed by the public must meet standards established by the Environmental Management Board (I.C. 13-7-14-1).

Surface-Water Withdrawals Water in streams, lakes, and other natural bodies in the state is a natural resource and is water subject to control and regulation for the public welfare (I.C. 13-2-1-2).

Individual riparian land owners have the right to the use of water in quantities necessary to satisfy their needs for domestic purposes, and this shall have priority and be superior to any and all uses. Also, the riparian land owner may impound water from the course after receiving permission from the Natural Resources Commission (I.C. 13-2-1-3). Any construction that would occur in the floodway of a stream requires a permit from the Natural Resources Commission (I.C. 13-2-22-13).

Any person may divert flood waters of any water course for any useful purpose upon the approval of the Natural Resources Commission (I.C. 13-2-1-6).

The state, municipalities, special taxing districts, and public utilities may secure needed reservoir sites to meet present and future needs for storage of water for purposes that include domestic and municipal use (I.C. 13-2-9-1). Sites for water supply storage must meet the approval of the Natural Resources Commission and the board of health before condemnation can be used in acquisition of those sites (I.C. 13-2-9-7), and if the impoundment exceeds certain criteria as to minimum drainage area, volume of storage or height of dam, it must be inspected annually by the Department of Natural Resources (I.C. 13-2-20-4). The state may contract to supply minimum quantities of streamflow or to sell water for supply purposes from impoundments financed by the state (I.C. 13-2-1-7).

Before water can be withdrawn from a navigable stream in Indiana, a permit must be acquired from the Natural Resources Commission (I.C. 14-3-14). Similarly, cities may regulate the withdrawal of water from courses within a distance of ten miles from their corporate limits, but not into a county other than the one in which the city hall is located (I.C. 18-1-15-9).

Concerning ground water, county commissioners may enact ordinances and regulations to control the location, construction, or repair of all wells located within the county,

and cities and towns may do the same within their jurisdiction (I.C. 17-2-22-4.5). The Natural Resources Commission can designate "restricted use areas" so the withdrawal of ground water does not exceed the natural replenishment of that source (I.C. 13-2-2-3).

The Environmental Management Board (EMB) has a broad mandate to develop long-term environmental control programs including standards and regulations for the accomplishment of such programs (I.C. 13-7-1-1). The EMB is to classify all water and wastewater treatment plants as to qualification for their operation (I.C. 3-1-6-1), establish requirements for permits for the construction of public water supply facilities (I.C. 13-7-10-1); approve the plans and specifications prior to the construction of a public water supply facility and require its safe operation (I.C. 13-7-14-1); inspect public water supplies (I.C. 13-7-3-1); require the submission of water supplies for analysis (I.C. 13-7-14-4); and establish and enforce standards for water that is sold or consumed by the public (I.C. 13-7-14-1).

Also, the EMB is to encourage and advise local governmental units in developing facilities or establishing minimum standards for: air, water, odor, and noise pollution control, water or wastewater treatment, water resource development, and solid waste disposal. If local governmental units do not develop plans to meet minimum state requirements, the EMB may order the affected local governmental units to form regional water and sewage districts (I.C. 13-7-15-1).

Any public utility, except in third-class cities engaged in specific activities including the furnishing of water, is authorized and empowered, with the approval of the public service commission, to appropriate and condemn lands or any easements necessary to carry out its objectives (I.C. 8-1-8-1).

Cities, towns, and other municipal corporations can purchase and acquire waterworks (I.C. 19-3-10-1).

Conservancy districts may be established for purposes that include providing water supply, including treatment and distribution for domestic, industrial, and public use (I.C. 19-3-2-1). Also, any area of the state may be organized as a regional water and sewage district for reasons that include providing a water supply for domestic, industrial, and public use to consumers within and without the district (I.C. 19-3-1.1-1).

Industrial Water Supply Water in streams, lakes, and other natural bodies in the state is a natural resource and is water subject to control and regulation for the public welfare (I.C. 13-2-1-2).

The state, municipalities, special taxing districts, and public utilities may secure needed reservoir sites to meet present and future needs for storage of water for purposes that include commercial and industrial use (I.C. 13-2-9-1). Sites for water supply storage must meet the approval of the Natural Resources Commission and the State Board of Health before condemnation can be used in acquisition of those sites (I.C. 13-2-9-7), and if the dam and the impoundment meet certain minimum size criteria they must be inspected annually by the Department of Natural Resources (I.C. 13-2-20-4). The state may contract to provide minimum quantities of streamflow or to sell water for supply purposes from impoundments financed by the state (I.C. 13-2-1-7).

Individual riparian land owners have the right to the use of water in quantities necessary to satisfy their needs for domestic purposes, and this shall have priority over any and all uses. Also, the riparian land owner may impound water from the course after receiving permission from the Natural Resources Commission (I.C. 13-2-1-3). Any construction that would occur in the floodway of a stream must first meet the approval of the Natural Resources Commission (I.C. 13-2-22-13).

Any person may divert flood waters of any course for any useful purpose upon the approval of the Natural Resources Commission (I.C. 13-2-1-6).

Before water can be withdrawn from a navigable stream in Indiana, a permit must be acquired from the Natural Resources Commission (I.C. 14-3-1-14), and cities may regulate the withdrawal of water from courses within a distance of ten miles from their corporate limits, but not into a county other than that in which the city hall is located (I.C. 18-1-1.5-9).

Conservancy districts may be established for purposes that include providing water supply including treatment and distribution for domestic, industrial, and public use (I.C. 19-3-2-1). Also any area of the state may be organized as a regional water and sewage district for reasons that include providing water supply for domestic, industrial, and public use to consumers within and without the district (I.C. 19-3-1.1-1).

Concerning ground water, county commissioners may enact ordinances and regulations to control the location, construction, or repair of all wells located within the county. Cities and towns may also adopt their own ordinances to control the location, construction, or repair of all wells within their jurisdiction (I.C. 17-2-22-4.5). The state Natural Resources Commission can designate "restricted use areas" so the withdrawal of ground water does not exceed the natural replenishment of that source (I.C. 13-2-2-3).

Water that is sold to or consumed by the public must meet standards established by the Environmental Management Board (I.C. 13-7-14-1).

Agricultural Water Water in streams, lakes, and other natural bodies in the state is a natural resource and is water subject to control and regulation for the public welfare (I.C. 13-2-1-2).

The state municipalities, special taxing districts, and public utilities may secure reservoir sites to meet present and future needs for storage of water for purposes such as agricultural uses including irrigation (I.C. 13-2-9-1). The Natural Resources Commission and the State Board of Health must approve the impoundment sites before condemnation can be used in acquisition of those sites (I.C. 13-2-9-7), and if the dam meets certain criteria it must be annually inspected by the Department of Natural Resources (I.C. 13-2-20-4). The state may contract to supply minimum quantities of streamflows or to sell water for supply purposes from impoundments financed by the state (I.C. 13-2-1-7).

Individual riparian land owners have the right to the use of water in quantities necessary to satisfy their needs for domestic purposes, and this shall have priority over any and all uses. Also, the riparian land owner may impound water from the course after receiving permission from the Natural Resources Commission (I.C. 13-2-1-3). Any construction that occurs in the floodway of a stream requires a permit from the Natural Resources Commission (I.C. 13-2-22-13).

Any person may divert flood water of any course for any useful purpose upon the approval of the Natural Resources Commission (I.C. 13-2-1-6).

Before water can be withdrawn from a navigable stream in Indiana a permit must be acquired from the Natural Resources Commission (I.C. 14-3-1-14), and cities may

regulate the withdrawal of water from courses within a distance of ten miles from their corporate limits, but not into a county other than the one in which the city hall is located (I.C. 18-1-1.5-9).

Conservancy districts may be established for purposes that include providing water for irrigation and water supply, including treatment and distribution for domestic, industrial, and public use (I.C. 19-3-2-3). Also, any area of the state may be organized as a regional water and sewage district for reasons that include providing a water supply for domestic uses to consumers within and without the region.

As for ground water and agricultural use, county commissioners may enact ordinances and regulations to control the location, construction, or repair of all wells located within the county (I.C. 17-2-22-4.5).

Water that is sold to or consumed by the public must meet standards established by the Environmental Management Board (I.C. 13-7-14-1).

Production of Energy Surface waters of the state are to be put to beneficial use for the welfare of the people, and all water in natural bodies in the state is a natural resource and is public water (I.C. 13-2-1-1.2).

Land owners contiguous to a public water course may impound water from the course after receiving permission from the Natural Resources Commission (I.C. 13-2-1-3), and any person may divert flood waters of any course for any useful purpose upon the approval of the Natural Resources Commission (I.C. 13-2-1-6).

The state, municipalities, special taxing districts, and public utilities may secure needed reservoir sites to meet present and future needs for storage of water for purposes that include the production of energy (I.C. 13-2-9-1). The impoundment site must be approved by the Natural Resources Commission and the board of health before condemnation can be used in acquisition of those sites (I.C. 13-2-9-7), and if the dam meets certain criteria it must be inspected annually by the Department of Natural Resources (I.C. 13-2-20-4). Also, any construction which would occur in the floodway of a stream must be approved by the Natural Resources Commission (I.C. 12-2-22-13).

Excess Water

Flood Control In 1945 the general assembly determined that it was in the best interest of the citizens of the state to prevent and limit floods by regulating; supervising; coordinating the construction, operation, and design of flood control works and structures; alteration of streams; and keeping floodways free and clear (I.C. 13-2-22-2). The Natural Resources Commission has been given the primary authority concerning flood control activities in the state which includes jurisdiction over all public and private waters of the state and all lands adjacent to these waters necessary for flood control purposes or the prevention of flood damages and the responsibility of establishing a master plan for flood control in all areas. The commission may also construct flood control works. It is illegal to construct any permanent place of residence in a floodway. Any structure, obstruction, deposit, or excavation in the floodway of any stream in the state must first be approved by the Natural Resources Commission; however, approval is not needed when the project will take place within the upper ten miles of the streams or legal open drain in rural access (I.C. 13-2-22-13).

The state has also established minimum standards for the delineation and regulation of all flood hazard areas within the state, and has provided the means by which local units of government, based on these minimum standards, can regulate the flood hazard areas within their jurisdiction (I.C. 13-2-22.5-1 *et seq.*).

No individual, partnership, association, corporation, municipal corporation or political subdivision, of the state may do any work designed to regulate or control the waters for flood control purposes without the approval of the Natural Resources Commission (I.C. 13-2-24-1 and I.C. 13-2-22-15).

The state, municipalities, special taxing districts, and public utilities may secure needed reservoir sites for the storage of surface water for purposes that include flood prevention and control (I.C. 13-2-9-1); and all impoundment sites must be approved by the board of health and the Natural Resources Commission before condemnation can be used in acquisition of those sites (I.C. 13-2-9-7); and if the dam meets certain criteria it must be inspected annually by the Department of Natural Resources (I.C. 13-2-20-4).

The Natural Resources Commission and the State Board of Finance may loan up to $100,000 to any municipality for flood control purposes (I.C. 13-2-23-3).

Cities and towns may petition in the circuit court of the county for specific or general relief for the purpose of lessening or preventing the inundation by flood water (I.C. 19-4-17-1).

Cities of the second, third, fourth, and fifth classes may, by petition to the circuit court of the county, establish districts for the purpose of undertaking flood control and relief projects (I.C. 19-4-18-1). Cities of the first class (Indianapolis) may create a department of flood control (I.C. 19-4-21-1).

Cities of the second, third, fourth, and fifth classes may construct levees when the board of public works or the common council determines that this action is necessary for the protection of the city (I.C. 18-1-10-1).

Any person lawfully authorized to maintain, protect, or repair any levee shall have the right to purchase for the use of the levee whatever ground may be necessary to protect, maintain, or repair the levee (I.C. 13-2-19-1).

The owner(s) of any dam, levee, dike, floodwall, or appurtenance is required to maintain the structure in safe operating condition (I.C. 13-2-20-2); and the Department of Natural Resources is required to conduct annual inspections of these structures (I.C. 13-2-20-4).

Conservancy districts may be established for purposes that include undertaking actions for the prevention and control of flooding (I.C. 19-3-2-1).

Soil and water conservation districts have been established in the state to promote the policy of conserving the state's soil and water resources and for the prevention of, among other things, damages due to flood water (I.C. 13-3-1-1).

Diversions Any person may divert flood waters of any water course for any useful purpose upon the approval of the Natural Resources Commission provided certain conditions are met. This is not limited to contiguous land owners (I.C. 13-2-1-6). Contiguous land owners have the right at all times to the use of water from public water courses in quantities necessary to satisfy domestic needs. They also have the right to impound water from such courses and use the increased flows resulting from releases from the impoundment. The action to impound must be approved by the Natural Resources Commission (I.C. 13-2-1-3).

A permit must be acquired from the Natural Resources Commission prior to withdrawing water from a navigable

stream (I.C. 14-3-1-14), and cities and towns may regulate the withdrawal of water from courses within a distance of ten miles from their corporate limits, but not beyond the county in which the city hall is located (I.C. 18-1-1.5-9).

Agricultural Drainage Each county in Indiana has a county drainage board, of which the county surveyor is an ex-officio member (I.C. 19-4-1-3), which board has the primary responsibility for the construction, reconstruction, and maintenance of all legal drains except in areas where this responsibility has been relinquished to cities, towns, sanitary districts, conservancy districts, and any legal entity responsible for flood control and drainage (I.C. 19-4-1-1 through 19-4-10-5).

It is illegal to undertake any drainage activities that might cause the lowering of the water level in public fresh-water lakes (I.C. 13-2-17-1).

It is unlawful to conduct any activity in the floodway of any water course of the state that will adversely affect the efficiency or restrict the capacity of the floodway, constitute a hazard to the safety of life or property, or have detrimental effects upon fish, wildlife, and botanical resources. Therefore, any person wishing to undertake any construction activities on any floodway must first obtain approval from the Natural Resources Commission; however, approval is not required for reconstruction or maintenance projects on those streams or legal drains in rural areas where the total length of the specific stream or legal drain is ten miles or less (I.C. 13-2-22-13).

Cities have been granted the power to establish, maintain, and control water courses within a distance of ten miles from the corporate limits but not beyond the county line in which the city hall is located. These powers include the ability to dam, widen, straighten, dredge, change the channels of, or remove an obstruction in, any water course (I.C. 18-1-1.5-9).

Fifty-one percent of the frontage land owners bordering on any nonnavigable stream may petition their county commissioners requesting that a portion of the stream between two designated points be cleaned out or improved to provide adequate capacity (I.C. 17-2-29-1).

Conservancy districts can be established to undertake activities for improving drainage (I.C. 19-3-2-1), and soil and water conservation districts have been established in Indiana to promote wise and efficient use of the state's land and water resource (I.C. 13-3-1-2).

Stream Modification It is unlawful to erect any structure, obstruction, deposit, or excavation in the floodway of any water course of the state that will adversely affect the efficiency or unduly restrict the capacity of the floodway, constitute an unreasonable hazard to the safety of life or property, or have unreasonable detrimental effects upon fish, wildlife, and botanical resources. Any person wishing to undertake such activities in any floodway must first obtain approval from the Natural Resources Commission; however, approval is not required for reconstruction or maintenance projects on streams or legal drains in rural areas where the total length of the specific stream or legal drain is ten miles or less, or for bridges in rural areas where the drainage area of the bridge site is fifty square miles or less (I.C. 13-2-22-13).

Cities have been granted the power to establish, maintain, and control water courses within a distance of ten miles from the corporate limits but not beyond the county line in which the city hall is located. This power includes the ability to dam, widen, straighten, dredge, change the channels of, or remove an obstruction in, any water course (I.C. 18-1-1.5-9, I.C. 18-5-10-4).

Fifty percent of the frontage land owners bordering on any nonnavigable stream may petition their county commissioners requesting that a portion of the stream between two designated points be cleaned out or improved to provide adequate capacity (I.C. 17-2-29-1).

Flood Plain Management It is unlawful to conduct any activity in the floodway of any water course of the state which will adversely affect the efficiency or restrict the capacity of the floodway, constitute a hazard to the safety of life or property, or have detrimental effects upon fish, wildlife, and botanical resources. Therefore, any person wishing to undertake any construction activities on any floodway must first obtain approval from the Natural Resources Commission (I.C. 13-2-22-13). Also, the state has established minimum standards for the delineation and regulation of all flood hazard areas within the state and has provided the means by which local units of government, based on the minimum standards, can regulate the flood hazard areas within their jurisdiction (I.C. 13-2-22.5-1 *et seq.*).

Similarly, local units of government have been authorized to establish flood plain commissions which may regulate land uses within identified flood hazard areas (I.C. 18-7-4.5-1).

Soil Erosion With the establishment of soil and water conservation districts throughout the state it has become the policy of the state to promote the conservation of land and water resources (I.C. 13-3-1-1); and to further this policy the state provides funds for soil and water conservation districts as well as small watershed planning in cooperation with the United States Soil and Water Conservation Service (I.C. 13-4-3-2).

The state also regulates the reclamation of lands subject to surface mining for purposes that include the prevention of soil erosion (I.C. 13-4-6-1, I.C. 14-4-2-1).

Conservancy districts can be established for purposes that include preventing the loss of top soil from injurious water erosion (I.C. 19-3-2-3).

Water Research and Data Collection

The Natural Resources Commission is authorized to conduct investigations and measurements of water resources (I.C. 13-2-8-1). Also, the commission is authorized to investigate, compile, and disseminate information and make recommendations concerning the state's natural resources (I.C. 14-3-1-3), and make research data and reports available to public or private institutions or indiciduals (I.C. 14-3-1-4).

The State Board of Health and Natural Resources Commission are authorized to conduct research necessary for beneficial development, use, and management of the state's water resources (I.C. 13-2-7-2).

The United States may obtain land in the state for the development of fish hatcheries, wildlife or forest preserves, or for agricultural, recreational, or experimental uses (I.C. 4-21-8-1).

Water Quality

The Environmental Management Board has a general charge to preserve, protect, and enhance the quality of the state's environment and to develop programs that provide

for the most beneficial use of the resources of the state (I.C. 13-7-1-1). In furtherance of this mandate, the EMB is given the specific duty, among others, to evolve standards and develop regulations to preserve, protect, and enhance the quality of the environment and assure accomplishment of the comprehensive, long-term program it is to develop (I.C. 13-7-3-1).

The Stream Pollution Control Board (SPCB), operating under the general overview of the Environmental Management Board, has been granted the jurisdiction to control and prevent pollution in the waters of the state (I.C. 13-1-3-4). This involves the determination of qualities or properties that indicate pollution and the development of regulations and orders to restrict the discharge of polluting substances into the surface and ground waters of the state (I.C. 13-1-3-7).

In addition to the authority provided by I.C. 13-1-3-7, the Stream Pollution Control Board, as well as the EMB, is empowered to prescribe, by regulation, standards or requirements:(1) to specify the maximum permissible short-term and long-term concentrations of various contaminants in the state's surface and ground water; and (2) for the filling or sealing of abandoned water wells, water holes, and drainage holes to protect ground water against contamination. (I.C. 13-7-7-5; also, I.C. 13-7-5-1).

The discharge (or threatened discharge) of any contaminant is prohibited, either alone or in combination with contaminants from other sources, into the environment in any form that violates (or would violate) regulations, standards — including water quality standards — or discharge requirements of the SPCB or the EMB (I.C. 13-7-4-1).

Any plans, specifications, and so forth, for the abatement or correction of any polluted condition must be approved by the SPCB (I.C. 13-1-3-10, I.C. 13-7-4-1).

The SPCB has been designated as the water pollution agency for the state for purposes of the Federal Water Pollution Act (I.C. 13-7-2-10).

Any person discharging or proposing to discharge or emit contaminants affecting environmental quality must furnish technical reports as the EMB or SPCB may specify (I.C. 13-7-16-7).

Finally, the EMB is to encourage, assist, and advise local governmental units in developing facilities or establishing standards for, among other things, water pollution control, including waste water treatment. If the EMB finds plans to meet minimum state standards have not been developed it may order the affected local governmental units to proceed to form regional water or sewage districts (I.C. 13-7-15-2).

In order to protect the state's ground water for the public's use, the state will provide the means whereby any test hole drilled will be plugged in such a manner as to prevent pollution, impairment, and waste of natural resources (I.C. 13-4-5-1). Similarly, injection wells must be plugged or repaired to prevent leakage of saltwater, oil, gas, or other deleterious substance into freshwater formations (I.C. 13-4-4-1). Also, the Natural Resources Commission has the power to regulate disposal of salt- or sulfur-bearing water and waste liquids produced in the operation of any oil and gas well (I.C. 13-4-7-12).

The proper reclamation of lands subject to mining of minerals is required to protect lakes and streams from pollution (I.C. 13-4-6-1).

Although its authority would appear to be largely superseded by I.C. 13-7, I.C. 13-1-3, and I.C. 16-1-26, the Natural Resources Commission is empowered (by I.C. 14-3-1-14) to protect the lakes, streams, and springs of the state against impurities or pollution by industrial, municipal, or other sewage waste. The Natural Resources Commission is charged with the responsibility of protecting and properly managing the fish and wildlife resources of the state (I.C. 14-2-1-1).

Cities have been authorized to establish, maintain, and control watercourses within a distance of ten miles from their corporate limits. These powers include the power to regulate, license, and prohibit the putting of substances into the water that might endanger public health, safety, or injure property (I.C. 18-1-1.5-9).

The Ohio River Valley Water Sanitation Commission, an interstate compact among Illinois, Indiana, Kentucky, Ohio, West Virginia, New York, and Virginia, develops water quality criteria for use by the signatory states in establishing water quality standards for the Ohio River and its tributary waters which form boundaries between two or more signatory states.

Ground Water Injection It is the policy of the state to conserve and protect the ground-water resource of the state and provide regulations for its most beneficial use and disposition (I.C. 13-2-2-2).

A permit must be acquired from the Natural Resources Commission in order to inject, pump, or otherwise induce potable water into underground formations that contain nonpotable water (I.C. 13-2-3-2).

In order to protect the public, any test hole drilled 200 feet or more in the state will be plugged in such a manner as to prevent pollution, impairment, and waste of natural resources (I.C. 13-4-5-8). Also, injection wells must be plugged or repaired to prevent leakage of saltwater, oil, gas, or other deleterious substances into freshwater formations (I.C. 13-4-4-1).

Independently of its authority under the Environment Management Act (I.C. 13-7), the SPCB is empowered under its enabling act to control and prevent pollution in waters (including underground waters) of the state (I.C. 13-1-3-4) and to require the sealing of mines, oil and gas wells, brine wells, or any other subterranean strata causing, contributing, or about to cause or contribute, to a polluted condition of the waters of this state (I.C. 13-1-3-5).

Waste Disposal In those instances where the SPCB lacks jurisdiction (under I.C. 13-1-3), authority has been transferred to the EMB to enforce I.C. 16-1-26-1 which provides that it is unlawful to deposit any substance into the waters of the state that is deleterious to public health; the prosecution of any industry or lawful occupation, agriculture, floriculture or horticulture, the livestock industry or use for domestic animals; or which lessens, impairs, or materially interferes with the use of the water by the state or any political subdivision of it; or which destroys or jeopardizes any beneficial animal, fish, or vegetable life in the waters (compare with I.C. 13-1-3-8). Also, any person who has suffered, or is threatened with damage, because of pollution of water by any person may bring a suit in a superior or circuit court of the appropriate county (I.C. 16-1-26-2).

The SPCB is mandated to enforce the phosphate detergent law (I.C. 13-1-5.5) which prohibits the disposal into state waters of any nondegradable detergent containing alkyl benzine sulfonate except for limited exceptions which may be granted pursuant to regulations prescribed by the SPCB.

No person shall construct and operate a confined feeding operation unless the SPCB gives its approval based upon a satisfactory water pollution control proposal for the operation (I.C. 13-1-5.7).

Although its authority would appear to be largely superseded by I.C. 13-7, I.C. 13-13, and I.C. 16-1-26-1, the Natural Resources Commission is empowered (by I.C. 14-3-1-14) to protect the lakes, streams, and springs of the state against impurities or pollution by industrial, municipal, or other sewage waste.

Cities have been authorized to establish, maintain, and control watercourses within a distance of ten miles from their corporate limits. This authorization includes the power to regulate, license, and prohibit the putting of substances into the water that might endanger public health, safety, or injure property (I.C. 18-1-1.5-9).

Each city and town is authorized to own, acquire, construct, equip, extend, operate, and maintain—within and without its corporate limits—a sewage treatment plant or plants (I.C. 19-2-5-2). The responsibility is usually charged either to the Board of Public Works and Safety, Board of Sanitation, Board of Trustees (of a town), Utility Service Board, or to any other agency of municipal government.

Conservancy districts can be established for purposes that include the collection, treatment, and disposal of sewage and other liquid waste (I.C. 19-3-2-1).

Any area in the state may be organized as a regional water and sewage district for purposes that include the collection, treatment, and disposal of sewage within and without the district. (I.C. 19-3-1.1).

The Ohio River Valley Water Sanitation Commission, an interstate compact, requires the treatment of sewage discharged or permitted to flow into the Ohio River and its tributary waters that form boundaries between two or more signatory states. It also establishes effluent standards for sewage and industrial waste discharged into tributaries wholly within a signatory state that flow into waters of an interstate stream (I.C. 13-5-5-1). Illinois, Indiana, Kentucky, and Ohio are among the signatory states.

Appendix Eight

FEDERAL WATER LAWS

Instream Uses

Navigation The Constitution of the United States provides Congress with the power to regulate commerce with foreign nations and among the several states, and with Indian tribes.

The secretary of the army is required to prescribe regulations necessary for the use, administration, and navigation of the navigable waters of the United States (33 USC 1).

The creation of any obstruction not authorized by Congress to the navigable capacity of any of the waters of the United States is prohibited (33 USC 403).

Similarly, any structure affecting the navigation of navigable waters in the U.S. must be approved by the secretary of the army (16 USC 797).

The secretary of transportation must approve the location and plans for bridges to be constructed over navigable waters of the United States (33 USC 525 *et. seq.*).

The secretary of the army is authorized to establish harbor lines when he determines it to be necessary for the preservation and protection of a harbor (33 USC 404).

A comprehensive program is authorized to provide for control and progressive eradication of noxious aquatic plant growth from the navigable and allied waters of the United States in the combined interest of navigation, flood control, drainage, agriculture, fish and wildlife conservation, public health and related purposes (33 USC 610).

The secretary of the army is authorized to receive funds from local interest for the prosecution of authorized river and harbor improvements (33 USC 561), and any improvements or other work done on any navigable river must be approved by the secretary of the army (33 USC 565).

Recreation A land and water conservation fund has been created to assist states in planning, acquisition, and development of needed land and water areas and facilities, and to assist in federal acquisition and development of recreational areas (16 USC 460L-4).

Uniform policies and procedures relating to benefits and costs of recreational and enhancement of fish and in connection with federal multipurpose water resource projects have been established through the federal Water Project Recreation Act (16 USC 460L-12 *et. seq.*).

The chief of engineers of the Army Corps of Engineers is authorized to construct, maintain, and operate public park and recreational facilities at water resource development projects (16 USC 460d).

Furthermore, the secretary of agriculture should cooperate with the states and their political subdivisions in the planning and development of works for the utilization and development of water (16 USC 1001).

The Wild and Scenic Rivers Act of 1968 is an effort by Congress to preserve certain selected rivers of the nation in their natural state (16 USC 1271).

Fish and Wildlife In the Fish and Wildlife Act, Congress established a comprehensive policy for fish, shellfish, and wildlife resources for the nation (16 USC 742a). Under this act the secretary of the interior has a broad policy-making role and is authorized to take required steps for the development, management, advancement, and protection of fish and wildlife resources through research, acquisition of refuge lands, development of existing facilities, and other means.

The Fish and Wildlife Coordination Act provides that whenever any federal license or permit impounds, diverts, or otherwise controls any waters, such agency shall consult the United States Fish and Wildlife Service and the head of the state agency having administration over the affected resource (16 USC 662a).

The Federal Water Project Recreation Act (16 USC 460L-12 *et. seq.*) establishes uniform policies and procedures for the evaluation of benefits and costs of federal multipurpose water resource projects.

The secretary of the interior has the authority to conserve fish and wildlife and project species of fish and wildlife that are threatened by extinction (16 USC 668 aa-dd).

The Watershed Protection Act authorizes certain fish and wildlife improvement activities at small watershed projects (16 USC 1001-1009).

Water Withdrawals

Water Supply Primary responsibilities for developing water supplies for domestic, municipal, industrial, and other purposes rests with the states and local interest, but the federal government may participate and cooperate with the states and local interests in developing water supplies (43 USC 390b[a]). Thus, water may be included in multiple purpose reservoirs (43 USC 390b[a]).

The secretary of the army is authorized to receive funds from states and political subdivisions and expend them in connection with funds appropriated by the United States for any authorized flood control work, and modify the plans of any reservoir project to provide additional storage capacity for domestic water supply or other conservation storage (33 USC 701h).

The secretary of the army is also authorized to make contracts with states, municipalities, private concerns, or individuals for domestic and industrial uses for surplus water that may be available at any reservoir under the control of the Department of the Army (33 USC 708).

The secretary of agriculture has broad powers to undertake activities directly or indirectly related to water supplies (16 USC 1001) through conducting investigations and surveys aimed at preserving, protecting, and improving the nation's land and water resources.

Production of Energy The Department of Energy is authorized to issue licenses for production of power on river sites by private companies or by state or municipal agencies (16 USC 791 *et. seq.*). If the proposed structure affects the navigability of any navigable stream it must first be approved by the corps of engineers.

The secretary of the army is authorized, upon his discretion, to provide in the permanent parts of any dam authorized by Congress for the improvement of navigation such foundations, sluices, and other works as may be considered desirable for the future development of its water power.

Furthermore, all examinations and surveys of projects relating to flood control must include data on the possible economic development and utilization of water power (33 USC 701).

Excess Water

Flood Control Authority to deal with federal investigations and improvements of rivers and other waterways for flood control and allied purposes is vested in the Department of the Army (33 USC 701 *et. seq.*).

In order to have any money expended on construction of local protection projects, assurances must be made by states and other nonfederal interests that they will provide land, easements, and rights-of-way; hold and save the United States free from damages due to construction works and maintain and operate the works (33 USC 701c). Construction of any water resources project shall not be commenced until each nonfederal interest has entered into a written agreement with the secretary of the army to furnish its required cooperation for the project (42 USC 1962d 5b).

In the Watershed Protection and Flood Prevention Act the secretary of agriculture is given certain authority with respect to watershed areas not exceeding 250,000 acres and not including any single structure that provides more than 12,500 acre-feet of floodwater detention capacity, and more than 25,000 acre-feet of total capacity (16 USC 1001 *et. seq.*).

The secretary of housing and urban development is authorized to establish and carry out a national flood insurance program. This insurance is to be made available throughout the nation through a cooperative effort of the federal government and the private insurance industry (42 USC 4001 *et. seq.*).

Water Quality The Rivers and Harbors Appropriation Act of 1899 makes it unlawful to discharge or cause to be discharged into the navigable waters of the United States any refuse matter of any kind or description other than that flowing in a liquid state from streets and sewers (33 USC 407). This prohibition extends to any tributary or bank of such tributary if the refuse is likely to be washed into the navigable water.

The Water Pollution Control Act provides that the administrator of the Environmental Protection Agency, in cooperation with others, shall develop or prepare comprehensive programs for preventing, reducing, or eliminating the pollution of navigable and ground waters and improving the sanitary condition of surface and underground waters (33 USC 1252 *et. seq.*). The act calls for the formulation of water quality standards, and the states are encouraged to establish quality criteria and enforcement plans.


Glossary

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Accretion: The gradual or imperceptible increase or extension of land by natural forces acting over a long period of time, as on a beach by the washing up of sand from the sea or on a flood plain by the accumulation of sediment deposited by a stream.

Advanced Waste Treatment: Wastewater treatment beyond the secondary or biological stage that includes removal of nutrients such as phosphorus and nitrogen and a high percentage of suspended solids. Advanced waste treatment, known as tertiary treatment, is the "polishing stage" of wastewater treatment and produces a high quality effluent.

Agricultural Pollution: The liquid and solid waste from all types of farming including runoff from pesticides, fertilizers and feed lots; erosion and dust from plowing, animal manure and carcasses; and crop residues and debris. It has been estimated that agricultural pollution in the U.S. has amounted to more than two and one-half billion tons per year.

Algal Bloom: A proliferation of living algae on the surface of lakes, streams, or ponds. Algae blooms are stimulated by phosphate enrichment.

Alluvial: Pertaining to or composed of alluvium, or deposited by a stream or running water.

Alluvium: A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Ammonia ($NH_3 - N$) and Organic Nitrogen: These are indicators of the freshness of sewage. Waters in which most of the nitrogen is in the form of organic and ammonia nitrogen are often considered to have been recently polluted. The presence of ammonia in municipal water sources is particularly significant because of its marked effect on the amount of chlorine needed to disinfect water properly. Ammonia is also capable of exerting a significant oxygen demand in surface waters. The toxic effect of ammonia on aquatic life increases with increasing pH and temperature.

Aquatic Plants: Plants that grow in water either floating on the surface, or growing up from the bottom.

Aquifer: A body of rock that contains sufficient saturated, permeable material to conduct ground water to wells and springs.

Bacteria: Single-celled microorganisms that lack chlorophyll. Some bacteria are capable of causing human, animal, or plant diseases; others are essential in pollution control because they break down organic matter in the air and in the water.

Basal Ice Load: Debris carried in the lower several meters of glacial ice that typically carries the bulk of the glacial debris.

Base: The bottom or that part of an engineering structure resting upon the subgrade or supporting soil or solid rock.

Base Flow: Sustained or fair-weathered flow of a stream, whether or not affected by the works of man.

BEA: Business And Economic Area.

Bedrock: A general term for the rock, usually solid, that underlies soils or other unconsolidated, superficial material.

Bedrock Aquifer: Saturated consolidated or bedrock formations which yield water in sufficient quantity to be of consequence as a source of supply.

Biochemical Oxygen Demand: A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. Large amounts of organic waste use up large amounts of dissolved oxygen, thus the greater the degree of pollution, the greater the BOD.

BOD: Biochemical Oxygen Demand, biological oxygen demand.

Coliform Bacteria: A group of organisms common to the intestinal tracts of man and of animals. The presence of coliform bacteria in water is an indicator of pollution and of potentially dangerous bacterial contamination.

Cold-Water Fishery: An environment having well oxygenated water (above six parts-per-million) and temperatures between 60 to 62°F. that will support salmonid populations, such as trout and salmon.

Combined Sewers: A sewerage system that carries both sanitary sewage and stormwater runoff. During dry weather, combined sewers carry all wastewater to the treatment plant. During a storm, only part of the flow is intercepted because of plant overloading; the remainder goes untreated to the receiving stream.

Cooling Lake: An artificial lake created to provide cooling water to, and receive discharge water from, an electric generating station.

Cooling Lake Method: Method of dispersing heat generated by electrical power generating stations. Heated water is discharged into a cooling lake where the water naturally cools and is in part recycled through the generating station as coolant water.

Cooling Tower: A structure where warm water from a power plant is cooled by the evaporation process.

Disinfection Facility: Effective killing by chemical or physical processes of all organisms capable of causing infectious disease. Chlorination is the disinfection method

commonly employed in sewage treatment and drinking water treatment facilities.

Dissolved Oxygen: The oxygen dissolved in water or sewage. Adequately dissolved oxygen is necessary for the life of fish and other aquatic organisms and for the prevention of offensive odors. Low dissolved oxygen concentrations generally are due to discharge of excessive organic solids having high BOD, the result of inadequate waste treatment.

Dissolved Solids: The total amount of dissolved material, organic and inorganic, contained in water or wastes. Excessive dissolved solids make water unpalatable for drinking and unsuitable for industrial uses.

Drainage Basin: A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

Drift Sheet: A widespread sheet-like body of glacial drift, deposited, continuously or discontinuously, during a single glaciation, or during a series of closely related glaciations.

Dry Holes: A drill hole in which no water is used for drilling, such as a hole driven upward through rock in a quarry.

Effluent: A discharge of pollutant into the environment, partially or completely treated, or in its natural state. Generally used in regard to discharges into waters.

EMB: Environmental Management Board.

End Moraine: A moraine that is being produced at the front of an actively flowing glacier at any given time; a moraine that has been deposited at the lower or outer end of a glacier.

EPA: U.S. Environmental Protection Agency.

Eutrophication: The normally slow, aging process by which a lake evolves into a bog or marsh and ultimately assumes a completely terrestrial state and disappears. During eutrophication the lake becomes so rich in nutritive compounds, especially nitrogen and phosphorus, that algae and other microscopic plant life become super-abundant, thereby "choking" the lake and causing it eventually to dry up. Eutrophication may be accelerated by many human activities.

Eutrophic Lakes: Shallow lakes, weed choked at the edges and very rich in nutrients. The water is characterized by large amounts of algae, low transparency, low dissolved oxygen, and high BOD.

Evaporation: The process by which water is changed from the liquid or the solid state into the vapor state. In hydrology, evaporation is vaporization that takes place at a temperature below the boiling point.

Evapotranspiration: Loss of water from a land area through transpiration of plants and evaporation from the soil.

Fallow: Cultivated land that is allowed to lie idle during the growing season.

Fecal Coliform Bacteria: A group of organisms common to the intestinal tracts of man and of animals. The presence of fecal coliform bacteria in water is an indicator of pollution and of potentially dangerous bacterial contamination.

Flood: The water of any river or stream which is above the bank and outside the channel.

Flood Frequency: A measure of severity of a flood, commonly expressed in years. Larger floods occur less often and have higher frequencies. Thus the 100 year flood is larger than the ten year flood. A ten year flood is the largest flood that is likely to occur in a ten year period, on the average.

Flood Plain: the low lying lands adjoining a river or stream that have been or may be covered with flood water.

Floodway: The channel of the river and those portions of the flood plain adjoining the channel that are required to carry flood water.

Flow Duration Curve: A cumulative frequency curve that shows the percentage of time that specified discharges are equalled or exceeded. For example, the 90% flow duration curve value is that flow at a specified site on a stream that can be expected to be equalled or exceeded 90% of the time.

GCD: gallons-per-capita-per-day.

Glacial Drift: A general term for drift transported by glaciers or icebergs and deposited directly on land or in the sea.

Glaciation: The formation, movement, and recession of glaciers or ice sheets.

Glacier: A large mass of ice formed, at least in part, on land by the compaction and recrystallization of snow, moving slowly downslope or outward in all directions due to the stress of its own weight, and surviving from year to year.

GPM: gallons-per-minute.

Ground Water: Water in the ground that is in the zone of saturation, from which wells, springs, and ground-water runoff are supplied.

Hard Water: Water containing dissolved minerals such as calcium, iron, and magnesium. The most noticeable characteristic of hard water is its inability to lather soap.

Hydroelectric: The production of electricity by waterpower.

Hydrograph: A graph showing stage, flow, velocity, or other property of water with respect to time.

Hydrograph Separation: A technique for separating a hydrograph into its components of base flow and direct runoff. Base flow is sustained or fair weather flow in a stream and is composed largely of ground-water runoff.

Hydrologic Cycle: The constant circulation of water from the sea, through the atmosphere, to the land and its eventual return to the atmosphere by way of evaporation from the sea and the land surfaces.

Internal Combustion: (for electric power) The generation of electric power from turbines driven by internal combustion engines such as diesel engines.

Inter-till: The material found between till sheets.

Lechates: A liquid solution or product that passes out or through the container or environment in which it was placed.

Legal Drain: A natural or artificial open channel or a tile drain, or a combination of the two, that has been established by the use of any drainage statute of Indiana.

Legal Tile Drain: A tiled channel for the carrying off of surplus water from the land, which channel was established pursuant to, or made subject to, any drainage statute of the State of Indiana.

Lense (water bearing): A geologic deposit bounded by converging surfaces (at least one of which is curved), thick in the middle and thinning out toward the edge, and containing water.

Loess: A widespread, homogeneous, commonly nonstratified, porous, friable, unconsolidated but slightly coherent, usually highly calcareous, fine-grained, blanket deposit of marl or loam, consisting predominantly of silt with subordinate grain sizes ranging from clay to fine sand.

MG: million gallons.

MGD: million-gallons-per-day.

MW: megawatts (1,000,000 watts)

Moraine: A mound, ridge, or other distinct accumulation of unsorted, unstratified glacial drift, predominantly till.

Mutual Drain: A tile or open drain running through the lands of two or more owners and established by their mutual consent and not under any drainage statute.

Nitrate: A mineral compound characterized by a fundamental anionic structure of NO_3.

Nitrate-Nitrogen (NO_3-N): Nitrate-nitrogen is generally present in relatively small quantities in unpolluted surface water. Any significant increase in its concentration indicates that the water characteristics have been altered by industrial, domestic, and agricultural waste. Nitrate-nitrogen is the most highly oxidized form of ammonia; consequently it is the most stable state in the nitrogen cycle. Organic nitrogen is converted to ammonia nitrogen, which then is oxidized to nitrite and consequently to nitrate. When a stream is depleted of dissolved oxygen, it uses the nitrate as an alternated source of oxygen. High concentration of nitrate-nitrogen are reported to cause methemoglobinemia in infants (commonly called "blue babies"). A limit of ten mg/l of nitrate-nitrogen is recommended for drinking water. Nitrates are necessary to complete the normal cycle of aquatic life, which is of particular significance in natural waters. If nitrate is present with phosphorus in excessive amounts, massive growths can be troublesome to municipal water operation and can also cause taste and odor problems. Others can cause unslightly conditions in streams and along shorelines.

Non-Point Source Pollution: A polluted material that has become soluble and has entered the receiving stream through natural drainage patterns. Agricultural pollution is usually considered as a non-point source of pollution.

Nutrients: Elements or compounds essential as raw materials for organism growth and development, for example, carbon, oxygen, nitrogen, and phosphorus.

OBERS: The projections of future economics activity made by the U.S. Department of Commerce and the U.S. Department of Agriculture.

Once-Through Cooling: A method of condensing steam from electric generating stations by withdrawing water from a lake or stream, passing it over condenser coils, and discharging that water back into the lake or stream.

Outwash Plain: A broad, outspread, flat or gently sloping, alluvial sheet of outwash deposited by meltwater streams flowing in front or beyond the terminal moraine of a glacier.

Partial Body Contact: Any contact with water excluding complete submergence.

PCB: Poly chlorinated biphenyl.

PDR: Planning and Development Region.

pH: A measure of the acidity or alkalinity of a substance. pH is represented on a scale of 0 to 14 with 7 representing a neutral state, 0 representing the most acid, and 14 the most alkaline.

Phosphorus: An element that, while essential to life, contributes to the eutrophication of lakes and other bodies of water.

Point Source Pollution: A polluted material that enters the receiving stream at a specific point, such as a conduit or pipe discharging a polluted material into a receiving stream.

Pollution: The presence of matter or of energy whose nature, location or quantity produces undesired environmental effects.

Potable Water: Water suitable for drinking or cooking.

PPM: parts-per-million.

Precipitation: As used in hydrology, precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface.

Put and Take Trout Fishery: The management of a trout fishery where the fish are raised to harvestable size and stocked into the stream when the probability of the trout being caught is highest.

Raw Sewage: Untreated domestic or commercial wastewater.

Recharge: Replenishment of ground water contained in the aquifer primarily by infiltration of precipitation, with minor contribution by lakes and streams.

Riparian: Pertaining to the banks of a stream.

Riparian Owner: One who owns the property on a stream course.

Riprap: A layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment.

Sanitary Sewers: Sewers that carry only domestic or commercial sewage. Stormwater runoff is carried in a separate system.

Secondary Treatment: Wastewater treatment, beyond the primary stage, in which bacteria consume the organic part of the wastes. This biochemical action is accomplished by uses of trickling filters or the activated sludge process. Effective secondary treatment removes virtually all floating and settleable solids and approximately 85% of both BOD and suspended solids. Customarily, disinfection by chlorination is the final stage of the secondary treatment process.

Sewage: The total of organic waste and wastewater generated by residential and commercial establishments.

Sewer: Any pipe or conduit used to collect or carry away sewage or stormwater runoff from the generating source to treatment plants or receiving streams. A sewer that conveys household and commercial sewage is called a sanitary sewer. If it transports runoff from rain or snow, it is called a storm sewer. Often stormwater runoff and sewage are transported in the same system or combined sewers.

Shortfall: A deficiency, a failure to provide for a need.

SIC: Standard industrial classification code.

Siltation: Soil material that has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface.

SMSA: Standard Metroploitan Statistical Area.

Soil Association: A mapping unit used on reconnaissance or generalized soil maps in which two or more defined taxonomic units occurring together in a characteristic pattern are combined because the scale of the map or the purpose for which it is being made does not require delineation of the individual soils.

Soil Erosion: The detachment and movement of soil from the land surface by wind or water.

SPCB: Stream Pollution Control Board.

Storm Sewer: A conduit that collects and transports rain and snow runoff. In some sewerage systems, storm sewers are entirely separate from those carrying domestic and commercial wastewater.

Strip Mine Lakes: Primarily an impoundment created by the final cut of a surface coal mine operation.

Surface Runoff: The runoff that travels over the soil surface to the nearest surface stream.

Surface Water: All waters on the surface of the earth, including fresh and salt water, ice and snow.

Suspended Solids: Small particles of solid pollutants in sewage that can contribute to turbity and that resist separation by conventional means. The examination of suspended solids and the BOD test constitute the two main determinations for water quality performed at wastewater treatment facilities.

Thermal Pollution: Degradation of water quality by the introduction of a heated effluent. Primarily a result of the discharge of cooling waters from industrial processes, particularly from electrical power generation. Even small deviations from normal water temperatures can affect aquatic life. Thermal pollution usually can be controlled by cooling towers.