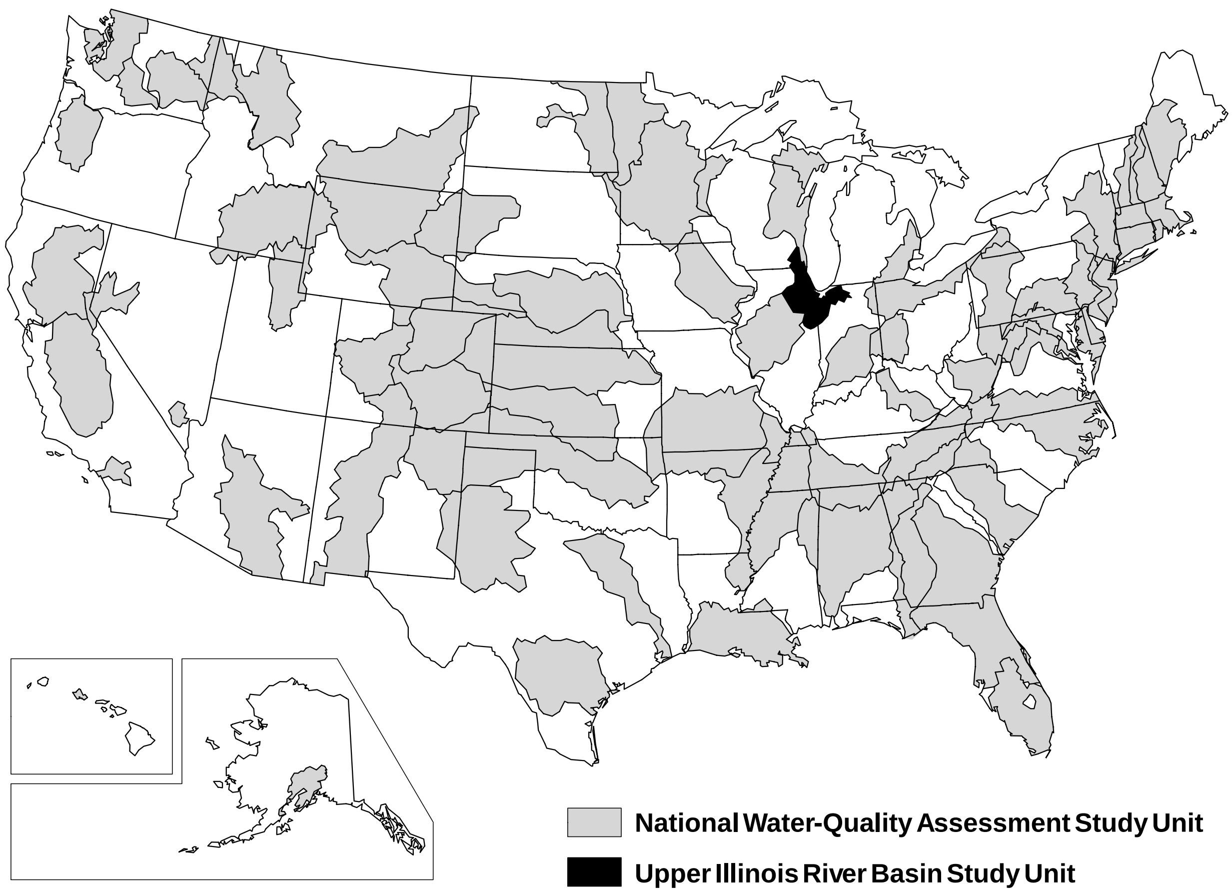
Environmental Setting of the Upper Illinois River Basin and Implications for Water Quality



Water-Resources Investigations Report 98–4268

National Water-Quality Assessment Program

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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By Terri L. Arnold, Daniel J. Sullivan, Mitchell A. Harris, Faith A. Fitzpatrick, Barbara C. Scudder, Peter M. Ruhl, Dorothea W. Hanchar, and Jana S. Stewart

Water-Resources Investigations Report 98–4268

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch per year (in/yr)	25.4	millimeter per year
	Mass	
ton per day (ton/d)	0.9072	metric ton per day

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

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

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations used in this report:.

APC	Areas of Probable Concern
BSC	Biological Stream Characterization
IBI	Index of Biotic Integrity
IEPA	Illinois Environmental Protection Agency
INHS	Illinois Natural History Survey
LIRB	Lower Illinois River Basin
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
NAWQA	National Water-Quality Assessment Program
TARP	Tunnel and Reservoir Plan
UIRB	Upper Illinois River Basin
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

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Abstract

The upper Illinois River Basin (UIRB) is the 10,949 square mile drainage area upstream from Ottawa, Illinois, on the Illinois River. The UIRB is one of 13 studies that began in 1996 as part of the U.S. Geological Survey's National Water-Quality Assessment program. A compilation of environmental data from Federal, State, and local agencies provides a description of the environmental setting of the UIRB. Environmental data include natural factors such as bedrock geology, physiography and surficial geology, soils, vegetation, climate, and ecoregions; and human factors such as land use, urbanization trends, and population change. Characterization of the environmental setting is useful for understanding the physical, chemical, and biological characteristics of surface and ground water in the UIRB and the possible implications of that environmental setting for water quality. Some of the possible implications identified include depletion of dissolved oxygen because of high concentrations of organic matter in wastewater, increased flooding because of suburbanization, elevated arsenic concentrations in ground water because of weathering of shale bedrock, and decreasing ground-water levels because of heavy pumping of water from the bedrock aquifers.

INTRODUCTION

The National Water-Quality Assessment (NAWQA) program of the U.S. Geological Survey (USGS) was designed to provide a national view of the status and trends of the Nation's water resources (Hirsch and others, 1988). On this national scale, consistent monitoring of water-quality conditions over time and a nationally comparable description of water resources are provided. Concerns for the unique hydrologic systems of individual drainage basins are balanced with nationally consistent design criteria. The program utilizes an interdisciplinary approach to study basin ecosystems by incorporating ground- and surface-water hydrology and biology. Results from NAWQA studies will help in understanding how natural and human factors affect water quality.

The building blocks of the NAWQA program are approximately 60 major surface-water drainage basins, called study units (fig. 1). The number of study units varies with changes in priority and funding for the NAWQA program. These drainage basins include about one-half of the area of the conterminous United States, supply water to approximately 65 percent of the population that uses public water supplies, and represent a variety of natural and manmade settings and water-quality issues. The study units are divided into three groups that operate on a 10-year rotational schedule. This schedule is designed to provide periods of initial planning and analysis of available data, intensive data collection and interpretation, report writing, and low-level monitoring activities (fig. 2). (Gilliom and others, 1995).

In 1986, the upper Illinois River Basin (UIRB) was selected as one of seven study units to participate in the pilot phase of the National Water-Quality Assessment program. The UIRB pilot study focused on surface water (Mades, 1987), but the study that began in 1996 includes surface-water, ground-water, and

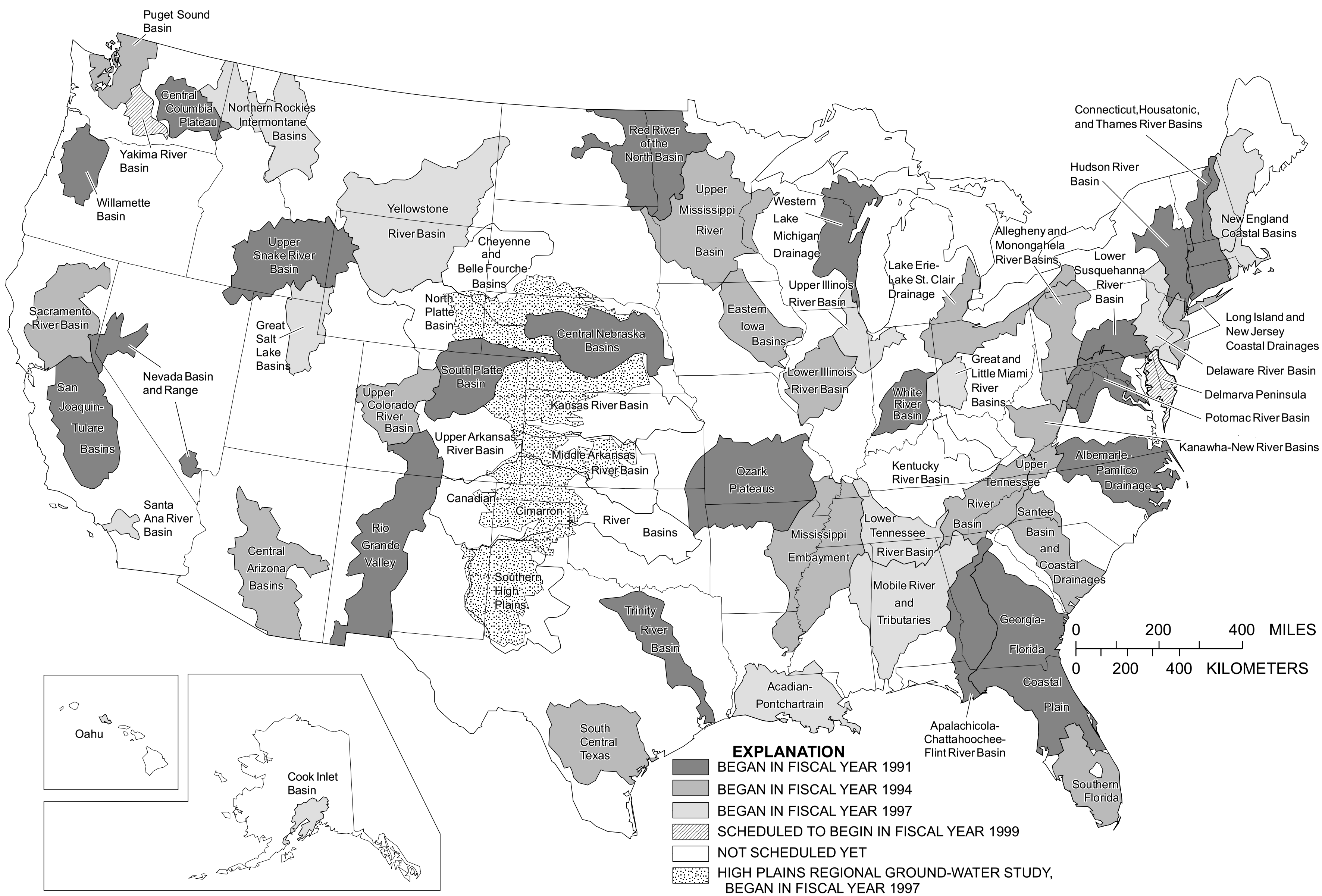


Figure 1. Location of National Water-Quality Assessment program study units and their proposed implementation dates.

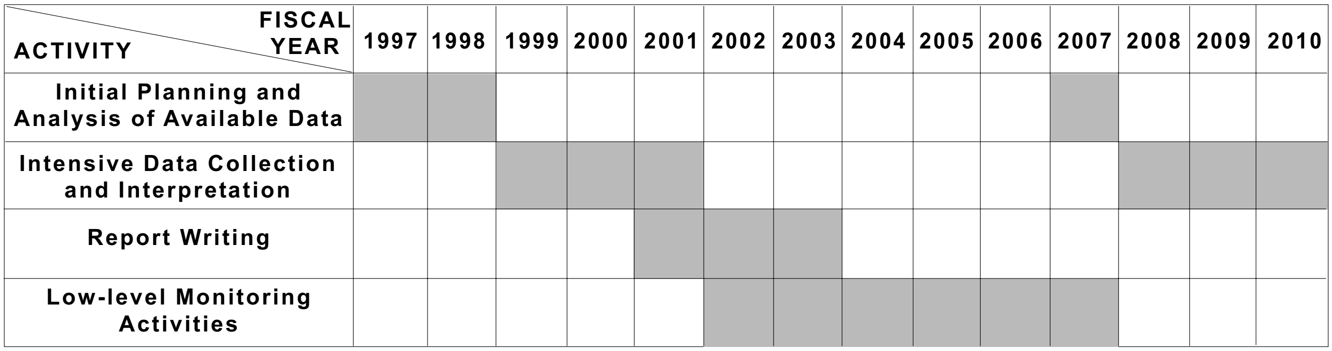


Figure 2. Rotation schedule for activities in the upper Illinois River Basin study unit as part of the National Water-Quality Assessment program, 1997–2010.

biology studies (Friedel, 1998). Fourteen U.S. Geological Survey reports and several journal articles were published as a result of the pilot study. A bibliography of the USGS reports that were published as part of the UIRB NAWQA pilot study are listed in appendix 1 of this report. The lower Illinois River Basin (LIRB) study unit of the NAWQA program is currently assessing the surface- and ground-water quality and biology for the drainage area of the Illinois River downstream from the UIRB (Warner, 1998).

Purpose and Scope

This report describes the environmental setting of the UIRB study unit and the possible implications of that setting for water quality. The environmental setting comprises the natural and human factors that define the hydrologic characteristics of the basin. Natural factors include bedrock geology, physiography and surficial geology, soils, vegetation, climate, and ecoregions. Human factors include land use, urbanization trends, and population change. Each of the natural and human factors affects the physical, chemical, and biological characteristics of surface and ground water. The interrelatedness of these factors and characteristics must be considered when determining the implications for water quality in the UIRB. The information contained in this report is a compilation of data collected from Federal, State, and local agencies that will facilitate selection of monitoring sites and interpretation of water quality in the basin.

Location and Extent of the Study Area

The upper Illinois River Basin includes parts of 16 counties in northeastern Illinois (62 percent of the basin), 13 counties in northwestern Indiana (28 percent of the basin), 7 counties in southeastern Wisconsin (10 percent of the basin), and 1 county in southwestern Michigan (less than 0.1 percent of the basin). Because the part of the basin that is in Michigan is small, it will not be specifically discussed in this report. The drainage area of the UIRB is 10,949 mi^2 upstream from Ottawa, Illinois, on the Illinois River and contains the following major subbasins (hydrologic units): Kankakee River, Iroquois River, Fox River, Des Plaines River, Chicago River, and Illinois River (fig. 3).

The Kankakee River Basin (hydrologic unit 07120001) drains the largest part of the UIRB, 27.6 percent. The Kankakee River flows from Indiana towards Illinois in a general northeast to southwest trend and turns northwestward at the confluence with the Iroquois River about 4.8 miles upstream from Kankakee, Illinois (fig. 3). The Kankakee River joins the Des Plaines River to form the Illinois River near the Grundy and Will County line in Illinois.

The Iroquois River Basin (hydrologic unit 07120002) lies to the south of the Kankakee River Basin and makes up 19.6 percent of the UIRB. The Iroquois River flows from Indiana into Illinois from northeast to southwest, turns northwestward at Watseka, Illinois, and joins the Kankakee River near Kankakee, Illinois (fig. 3). Because the Iroquois River is a tributary to the Kankakee River, it is often included in discussions of the Kankakee River Basin.

The upper Fox River Basin (hydrologic unit 07120006) and the lower Fox River Basin (hydrologic unit 07120007) make up the Fox River Basin, which is 24.3 percent

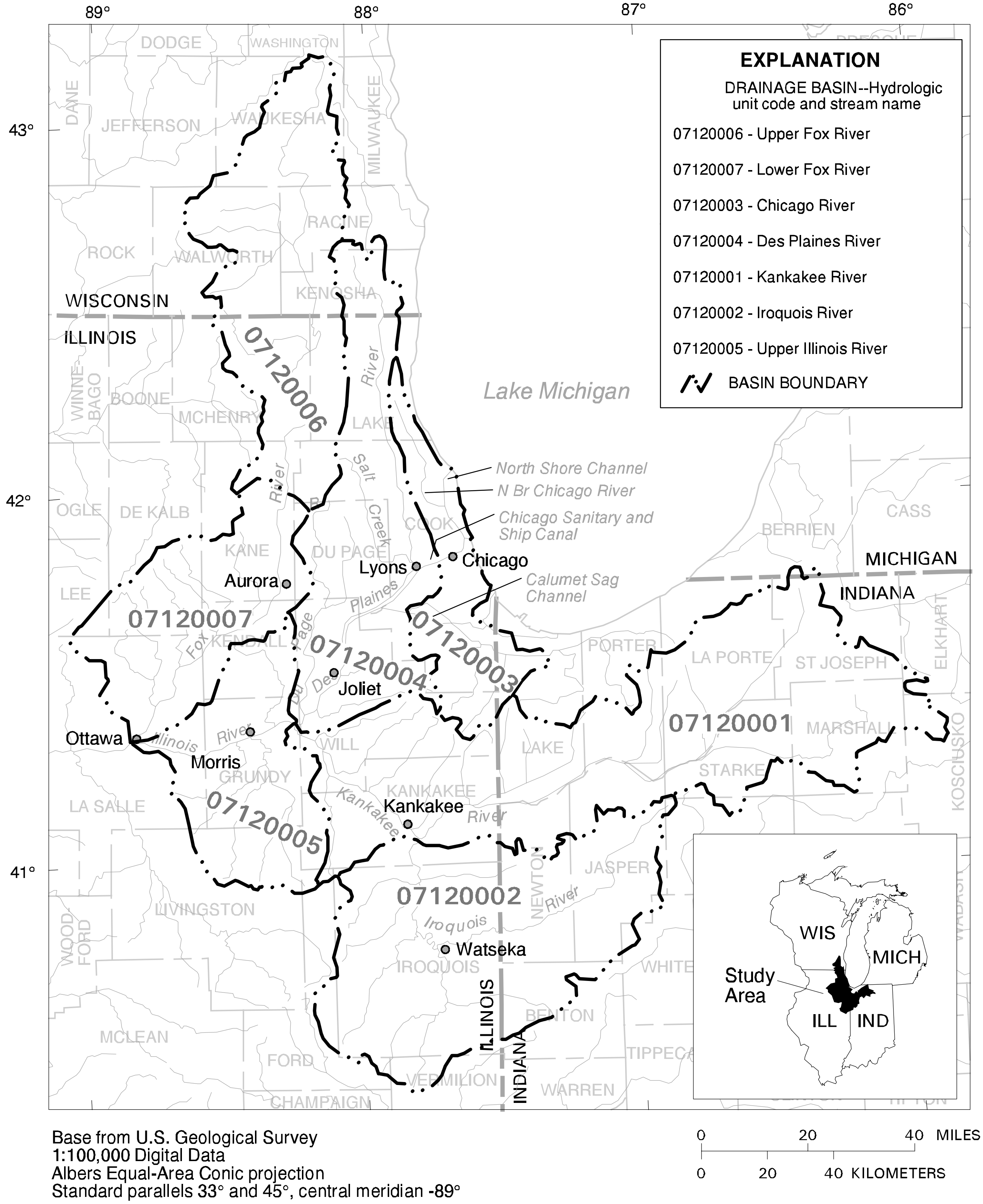


Figure 3. Drainage basins in the upper Illinois River Basin (modified from Seaber and others, 1984).

of the UIRB. The Fox River flows north to south from Wisconsin into Illinois, turns to the southwest at Aurora, Illinois, and joins the Illinois River at Ottawa, Illinois, near the terminus of the UIRB (fig. 3).

The Des Plaines River Basin (hydrologic unit 07120004) is 13.3 percent of the UIRB. The Des Plaines River flows north to south from Wisconsin into Illinois, turns southwest at Lyons, Illinois, follows the Chicago Sanitary and Ship Canal, and joins the Illinois River at the confluence of the Illinois and Kankakee Rivers near the Grundy and Will County line (fig. 3). The Des Plaines River drainage area includes 673 mi^2 that originally drained to Lake Michigan through the Chicago and Calumet Rivers.

The Chicago River Basin (hydrologic unit 07120003) is the smallest part of the UIRB, 6 percent. The Chicago River, which flowed into Lake Michigan prior to the early 1900's, now flows from north to south through Lake and Cook Counties in Illinois and joins the Chicago Sanitary and Ship Canal near Chicago, Illinois. The canal flows into the Des Plaines River at Joliet, Illinois (fig. 3). As a tributary of the Des Plaines River, the Chicago River is often included in discussions of the Des Plaines River Basin.

The Illinois River (hydrologic unit 07120005) is 9.2 percent of the UIRB. The mainstem flows from the confluence of the Des Plaines and Kankakee Rivers westward towards Ottawa, Illinois (fig. 3). The Illinois River, lower reaches of the Des Plaines River, and two canal systems in the Chicago metropolitan area provide a navigable link between Lake Michigan and the Mississippi River.

Acknowledgments

Assistance and data provided by members of the UIRB NAWQA liaison committee and their affiliated agencies are recognized as an integral part of this report. Committee members represent Federal, State, local, and private agencies with interest in the upper Illinois River Basin.

ENVIRONMENTAL SETTING

Natural Factors

Natural factors are those natural environmental characteristics such as bedrock geology, physiography and surficial geology, soils, vegetation, climate, and ecoregions. These factors can affect the hydrologic characteristics of the UIRB, and descriptions of these factors provide the basis for understanding the environmental setting of the UIRB study area.

Bedrock Geology

The composition of bedrock (consolidated) materials affects the flow, transport properties, and chemistry of surface and ground water in the UIRB. Structural features, such as joints and faults, influence ground-water storage and enhance or reduce the potential for water movement.

The entire UIRB is underlain by Precambrian granitic rocks at depths ranging from about 1,000 ft below land surface in the northern part of the basin to about 7,000 ft in the southeastern part. The Precambrian rocks are overlain by sedimentary rocks of the Cambrian System. These sedimentary rocks are predominately sandstone and include three of the most heavily used aquifers in the study area. The Cambrian rocks range in thickness from about 1,000 ft in the northern part of the study area to about 5,000 ft in the southeastern part and are entirely below land surface in the UIRB. Ordovician-aged rocks overlie the Cambrian rocks and are composed predominately of limestone and dolomite but also include some sandstone and shale. The Ordovician rocks are less than 1,000 ft thick in the northern and western parts of the UIRB, where they are exposed in heavily eroded areas, and about 1,500 ft thick in the southeastern part (Willman and others, 1975). Where present, the Maquoketa Shale confines the Cambrian-Ordovician bedrock aquifer.

The uppermost bedrock units of the Kankakee River Basin are predominately Silurian-Devonian dolomite and limestone, and shale (fig. 4a). In Indiana, the limestone and dolomite are part of the Muscatatuck Group and Wabash Formation (Gray and others, 1987). The shale units in Indiana are the Ellsworth, Antrim, and New Albany shales (table 1). In Illinois, the limestone and dolomite are undifferentiated, and the shale is the Maquoketa Shale (Willman and others, 1975) (table 1).

The uppermost bedrock units of the Iroquois River Basin are predominately Silurian-Devonian dolomite and limestone, and shale; Mississippian siltstone; and Pennsylvanian sandstone. In

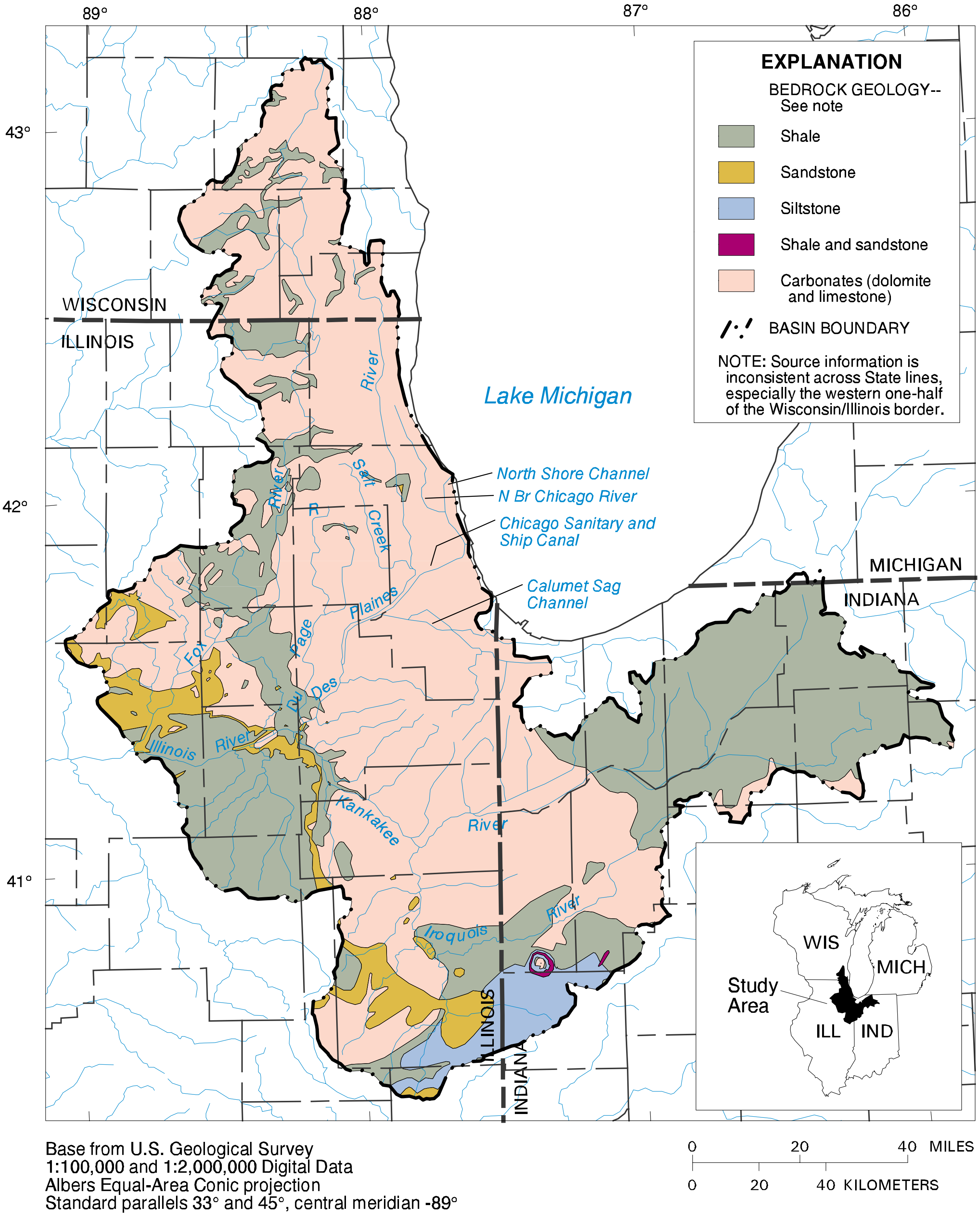


Figure 4. (A) Generalized uppermost bedrock geology in the upper Illinois River Basin (modified from Willman and others, 1975; Gray and others, 1987; and Wisconsin Geological and Natural History Survey, 1981).

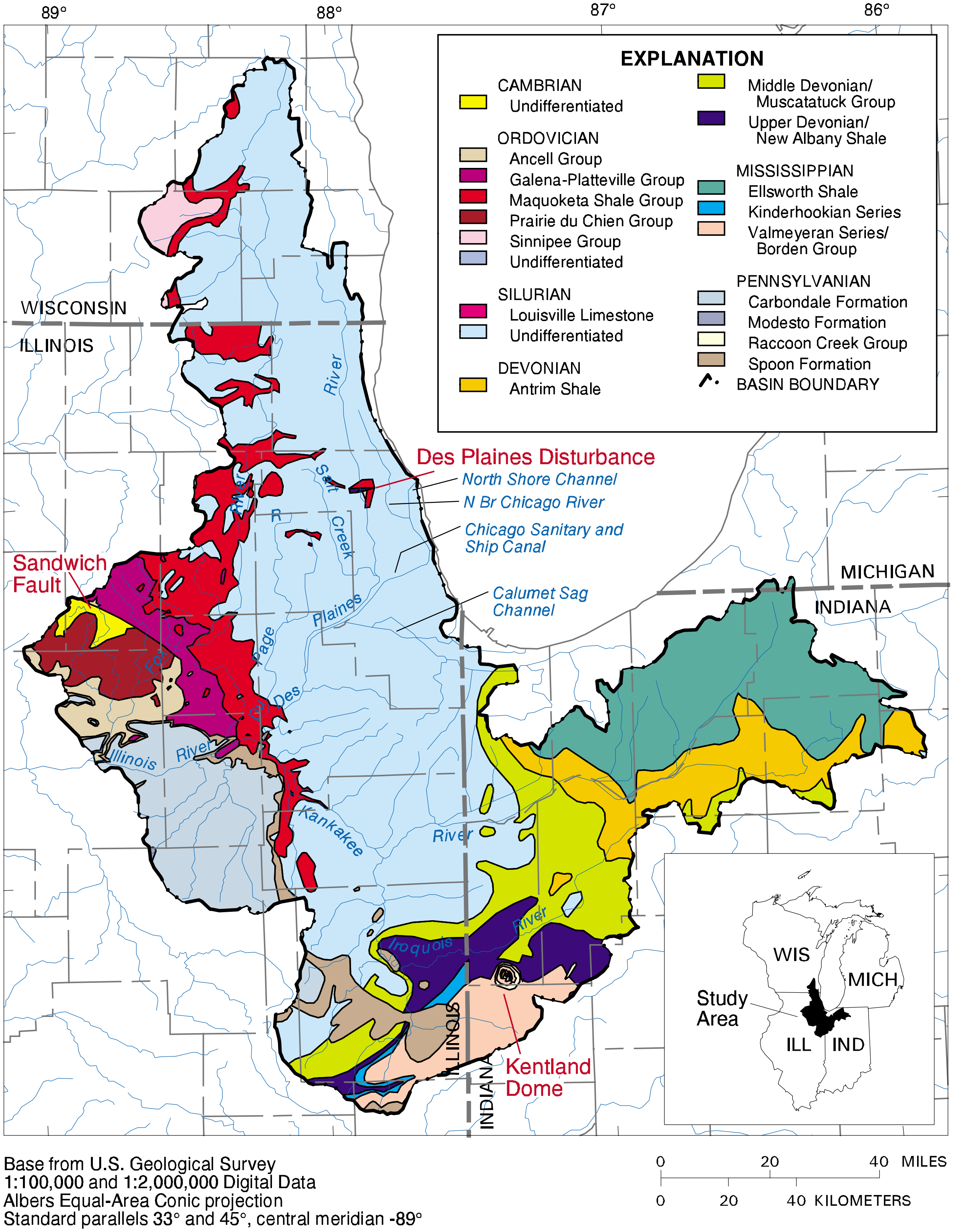


Figure 4. (B) Uppermost bedrock geology in the upper Illinois River Basin (modified from Willman and others, 1975; Gray and others, 1987; and Wisconsin Geological and Natural History Survey, 1981).

Table 1. Uppermost bedrock stratigraphy of the upper Illinois River Basin

[modified from Willman and others, 1975; Gray and others, 1987; and Wisconsin Geological and Natural History Survey, 1981]

	Illinois		Indiana		Wisconsin	
Period	Geologic unit	Lithology	Geologic unit	Lithology	Geologic unit	Lithology
Pennsylvanian	Carbondale Formation	Grey shale, subgraywackes sandstone, grey argillaceous limestone, and coal	Not present as uppermost bedrock		Not present as uppermost bedrock	
Pennsylvanian	Modesto Formation	Grey shale, thin argillaceous limestone, and thin coal beds	Not present as uppermost bedrock		Not present as uppermost bedrock	
Pennsylvanian	Not present as uppermost bedrock		Raccoon Creek Group	Mostly shale and sandstone; thin beds of limestone, clay, and coal	Not present as uppermost bedrock	
Pennsylvanian	Spoon Formation	Well developed sandstone, coal, and limestone	Not present as uppermost bedrock		Not present as uppermost bedrock	
Mississippian	Not present in study area		Ellsworth Shale	Green shale; some black shale in lower part	Not present as uppermost bedrock	
Mississippian	Valmeyeran Series	Siltstone and limestone	Borden Group	Siltstone with lenses of limestone in lower part	Not present as uppermost bedrock	
Mississippian	Kinderhookian Series	Shale with thin limestone	Not present as uppermost bedrock		Not present as uppermost bedrock	
Devonian	Upper	Black and grey shale of the New Albany Shale	New Albany Shale	Black and greenish-grey shale	Not present as uppermost bedrock	
Devonian	Middle	Limestone	Muscatatuck Group	Limestone and dolomite	Not present as uppermost bedrock	
Devonian	Not present as uppermost bedrock		Antrim Shale	Black shale, grey shale and limestone in lower part	Not present as uppermost bedrock	
Silurian	Not present as uppermost bedrock		Louisville Limestone	Limestone	Not present as uppermost bedrock	
Silurian	Undifferentiated	Limestone and dolomite	Wabash Formation	Limestone, dolomite, and argillaceous dolomite	Undifferentiated	Dolomite
Ordovician	Ancell Group	Sandstone, argillaceous and sandy limestone, and dolomite. St. Peter Sandstone and Glenwood formation	Not present as uppermost bedrock		Not present as uppermost bedrock	
Ordovician	Galena-Platteville Group	Limestone and dolomite	Not present as uppermost bedrock		Not present as uppermost bedrock	
Ordovician	Maquoketa Shale Group	Shale and limestone	Maquoketa Group	Not present as uppermost bedrock	Maquoketa Formation	Shale and dolomite
Ordovician	Prairie du Chien Group	Cherty dolomite with interbedded sandstone	Not present as uppermost bedrock		Prairie du Chien Group	Dolomite with some sandstone and shale
Ordovician	Not present as uppermost bedrock		Not present as uppermost bedrock		Sinnipee Group	Dolomite with some limestone and shale
Cambrian	Undifferentiated	Sandstone and dolomite	Not present as uppermost bedrock		Not present as uppermost bedrock	

Indiana, the limestone and dolomite compose the Muscatatuck Group, Wabash Formation, and Louisville Limestone; the shale is the New Albany shale; the siltstone is part of the Borden Group; and the sandstone is part of the Raccoon Creek Group (Gray and others, 1987). In Illinois, the limestone and dolomite is undifferentiated, the shale is part of the Upper Devonian and the Mississippian Kinderhookian Series, the siltstone is part of the Valmeyeran Series, and the sandstone is the Spoon Formation (fig. 4; table 1). The Kentland Dome, a small structural feature (approximately 5 mi^2), is in southern Newton County, Indiana (fig. 4b). This feature is represented by dipping Ordovician and Silurian rocks that have been uplifted approximately 2,000 ft (Fenelon and others, 1994).

The uppermost bedrock units of the upper Fox River Basin are predominately undifferentiated Silurian-Devonian dolomite and limestone, and Ordovician shale of the Maquoketa Shale Group in Illinois; and the Maquoketa Formation and Sinnipee Groups in Wisconsin (fig. 4; table 1). The uppermost bedrock units of the lower Fox River Basin are predominately undifferentiated Silurian-Devonian dolomite and limestone, Ordovician limestone of the Galena-Platteville Group, Ordovician dolomite of the Prairie du Chien Group, Ordovician shale of the Maquoketa Shale Group, and Cambrian-Ordovician sandstone. The Prairie du Chien Group is exposed along the Fox River Valley (Willman and others, 1975) (fig. 4). The Sandwich Fault is evident in southern De Kalb County in Illinois where Cambrian rocks are adjacent to Ordovician rocks (fig. 4b).

The uppermost bedrock units of the Chicago and Des Plaines River Basins are predominately undifferentiated Silurian-Devonian dolomite and limestone, and Ordovician shale of the Maquoketa Shale Group (fig. 4). The Des Plaines Disturbance fault, unexposed at the surface, is in northern Cook County, Illinois, near the Des Plaines and Chicago River Basin drainage divide (fig. 4b). The origin of the fault has been explained as being from either volcanic activity or from meteoric impact (Willman and others, 1975).

The uppermost bedrock units of the Illinois River Basin are predominately Pennsylvanian shale of the Carbondale Formation, Ordovician shale of the Maquoketa Shale Group, and Ordovician limestone and dolomite of the Galena-Platteville Formation (fig. 4) (Willman and others, 1975). The Carbondale Formation contains coal seams and is a source for mining in the UIRB (fig. 5).

Physiography and Surficial Geology

Studying the physiography provides a generalized description of the natural characteristics of an area by aggregating areas that were formed under similar conditions and have similar surficial geology. A description of these factors is an important part of the environmental setting because the composition and origin of surficial deposits affect soil composition and water chemistry. When water flows through the interstitial spaces of surficial deposits, its chemical composition and/or the minerals in the surficial deposits can be changed by processes like ion exchange. The surficial sand, and sand and gravel deposits form the important unconsolidated aquifers in the basin. Surficial geologic materials are broken down by weathering processes and form the parent material for most soils in the UIRB. Most of the unconsolidated surficial deposits in the basin are of glacial, fluvial, or aeolian origin.

Surficial geologic materials were deposited and land-surface features were formed in the UIRB during five major glacial periods. With each glacial advance and retreat, succeeding glaciers modified the deposits left during previous periods. The most recent period of glaciation, called the Wisconsinan period, occurred about 17,000–12,000 years ago (Willman and Frye, 1970; Gilbert, 1980). The Lake Michigan, Saginaw, and Huron-Erie glacial lobes once covered the UIRB (fig. 6). Typical glacial features such as till and outwash plains, moraines, kettles, kames, and drumlins are found in various parts of the basin, but moraines are the most prevalent glacial feature (fig. 7). Bedrock has been exposed in places along the Illinois, Des Plaines, and Kankakee River valleys by glacial processes such as meltwater floods (Illinois State Geological Survey, 1973). Except for these bedrock exposures in major river valleys, unconsolidated glacial (Quaternary) deposits cover most of the study area (fig. 8).

In recent times, glacial deposits and features have been modified by wind and water erosion (Piskin and Bergstrom, 1975). The glacial and erosional processes are the sources of the present-day landforms in the UIRB; these landforms are the

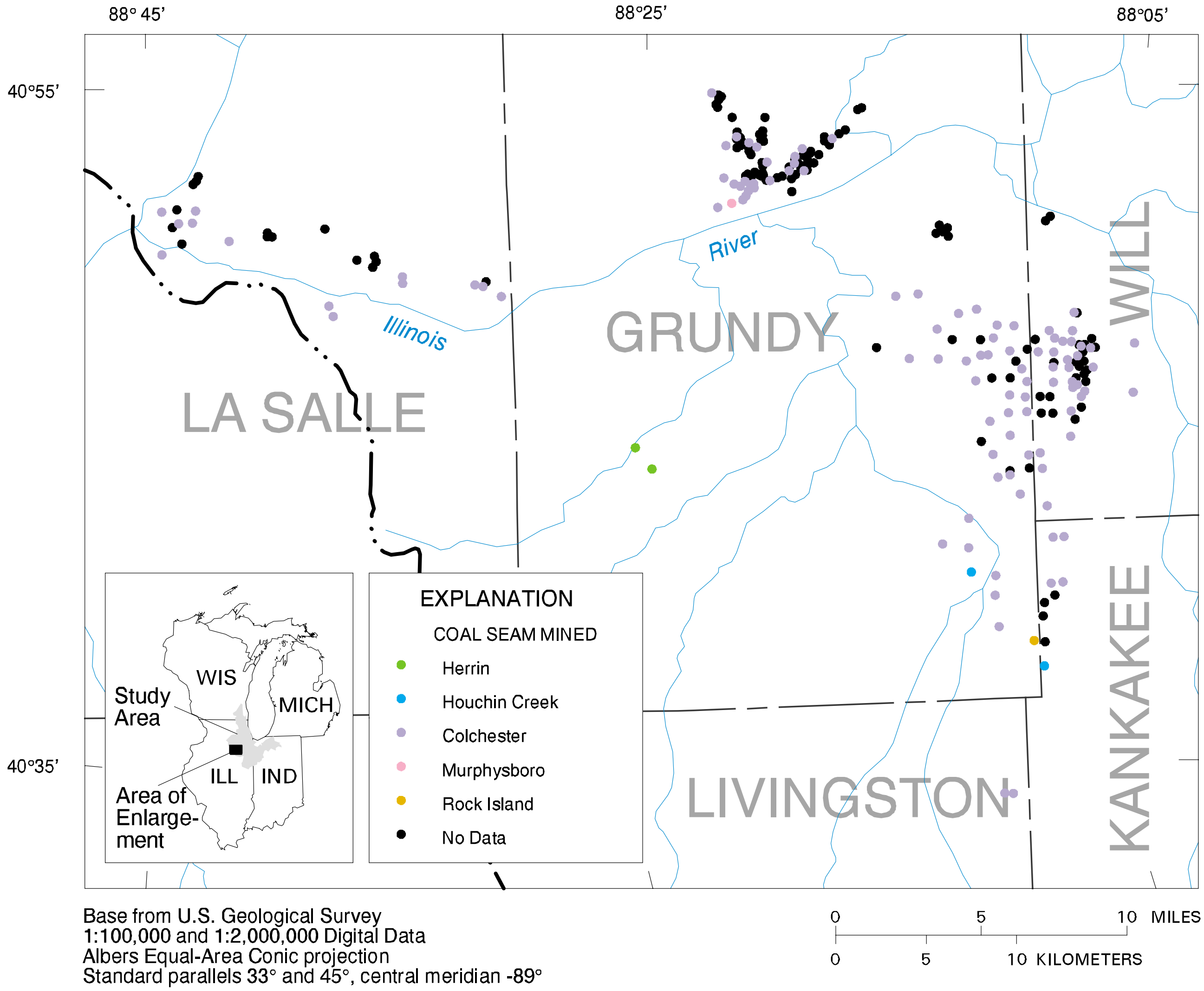


Figure 5. Coal seams mined in the upper Illinois River Basin (from Illinois State Geological Survey, 1991).

basis for the following physiographic definitions. Overall, topography in the UIRB varies from 443 ft above sea level in the Chicago River Basin and the western parts of the Kankakee River Basin to 1,250 ft above sea level in the northern extremes of the upper Fox River Basin (fig. 9).

The UIRB lies in the Central Lowlands physiographic province and is divided into two physiographic sections: the Great Lake Section and the Till Plains Section (Fenneman, 1938). Leighton and others (1948) divided the Illinois part of these sections into two subsections each. In the Illinois part of the UIRB, the Great Lake Section was divided into the Chicago Lake Plain and the Wheaton Morainal Plain, whereas the Till Plains Section was divided into the Kankakee Till Plain and the Bloomington Ridged Plain. For the Indiana part of the UIRB, Schneider (1966) subdivided the Great Lake and the Till Plains physiographic sections into the Northern Moraine and Lake Region and the Tipton Till Plain. In the area of the UIRB, the Northern Moraine and Lake Region subsection was further divided into the Valparaiso Morainal Area, the Kankakee Outwash and Lacustrine Plain, and the Steuben Morainal Lake Area (Schneider, 1966).

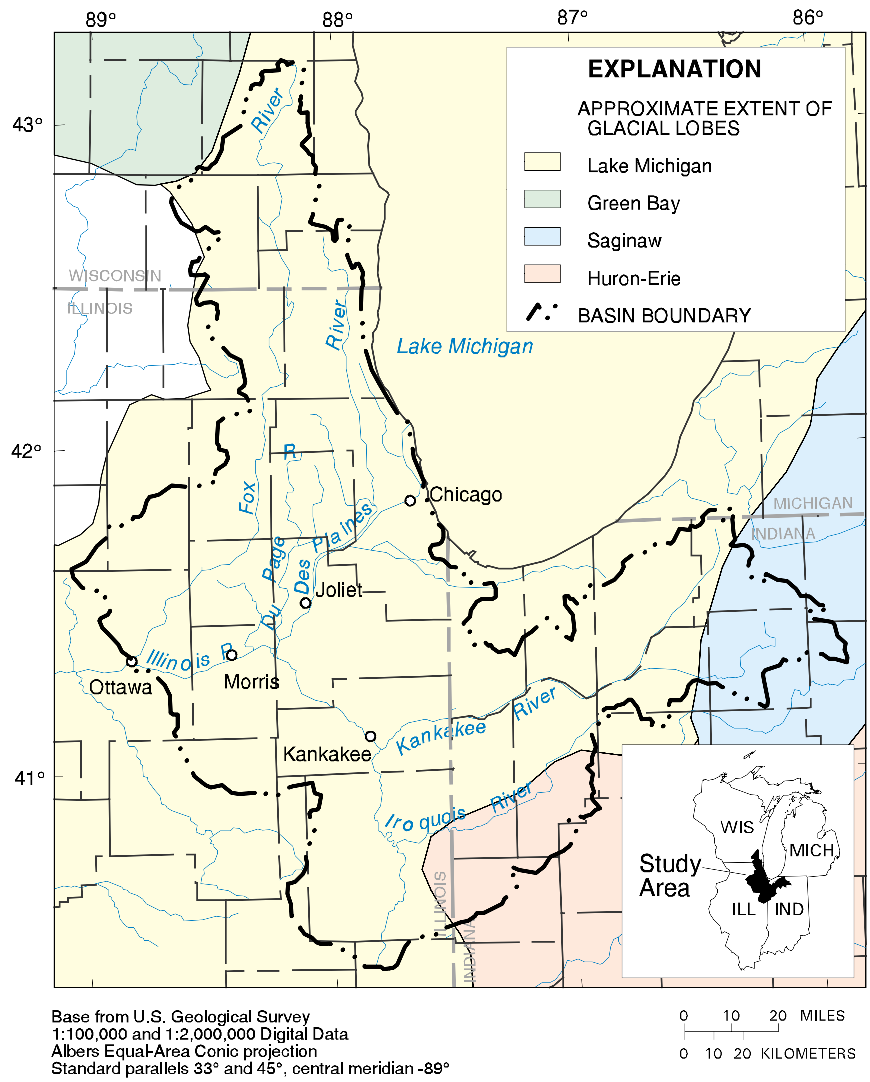


Figure 6. Approximate historical extent of glacial lobes in the upper Illinois River Basin (modified from Hansel and Johnson, 1996).

Although the physiography has been delineated and named in various ways, defining characteristics of the physiographic sections correspond well across State lines. The Valparaiso Morainal Area in Indiana corresponds to the Wheaton Morainal Plain in Illinois. The Kankakee Outwash and Lacustrine Plain in Indiana corresponds to the Kankakee Till Plain in Illinois. The Tipton Till Plain in Indiana corresponds to the Bloomington Ridged Plain in Illinois. For the purpose of this report, the Illinois terms will be used when describing physiography that corresponds across Illinois, Indiana, and Wisconsin State lines. (fig. 10)

The Chicago Lake Plain (4.7 percent of the basin) is approximately the area that is now metropolitan Chicago in the Chicago River Basin. The plain is a relatively flat, glacio-lacustrine deposit formed by the slow moving waters of glacial Lake Chicago. Glacial Lake Chicago was formed when meltwater accumulated behind the Wisconsinan glacier's Valparaiso moraine. The meltwater eventually broke through a low spot in the moraine and drained back into the present day Lake Michigan Basin (Horsley, 1986). The Chicago Lake Plain consists of poorly drained lake clay and silt overlying the limestone of the Niagara Formation (Mayer and Wade, 1969) and lake sand and gravel (fig. 8). These deposits are the Carmi and Dolton Members of the Equality/Atherton Formation. Clayey till of the Wedron Formation (Wadsworth Till Member) also is present and is deposited as moraines (table 2). Surficial deposits in the Chicago Lake Plain generally are less than 200 ft thick with areas of less than 50 ft thick near the Des Plaines River, Chicago River, Calumet Sag Channel, and Lake Michigan shore (fig. 11). Local topography typically varies less than 50 ft with a minimum elevation of 580 ft and a maximum elevation of 699 ft above sea level.

The Wheaton Morainal Plain (32 percent of the basin) is approximately the area of the upper Fox River Basin and the northern part of the Kankakee River Basin (fig. 10). This area is characterized by gently rolling Wisconsinan-age moraines that are approximately parallel to the Lake Michigan shoreline. The Wheaton Morainal Plain is predominately clayey till of the Wadsworth Till Member/Oak Creek Formation, and sandy and loamy till, and sand and gravel of the Haeger Till Member/New Berlin Formation (fig. 8, table 2). Other surficial deposits in this area include lake clay and silt, and alluvium. Bedrock is exposed along the downstream reaches of the Des Plaines River and along parts

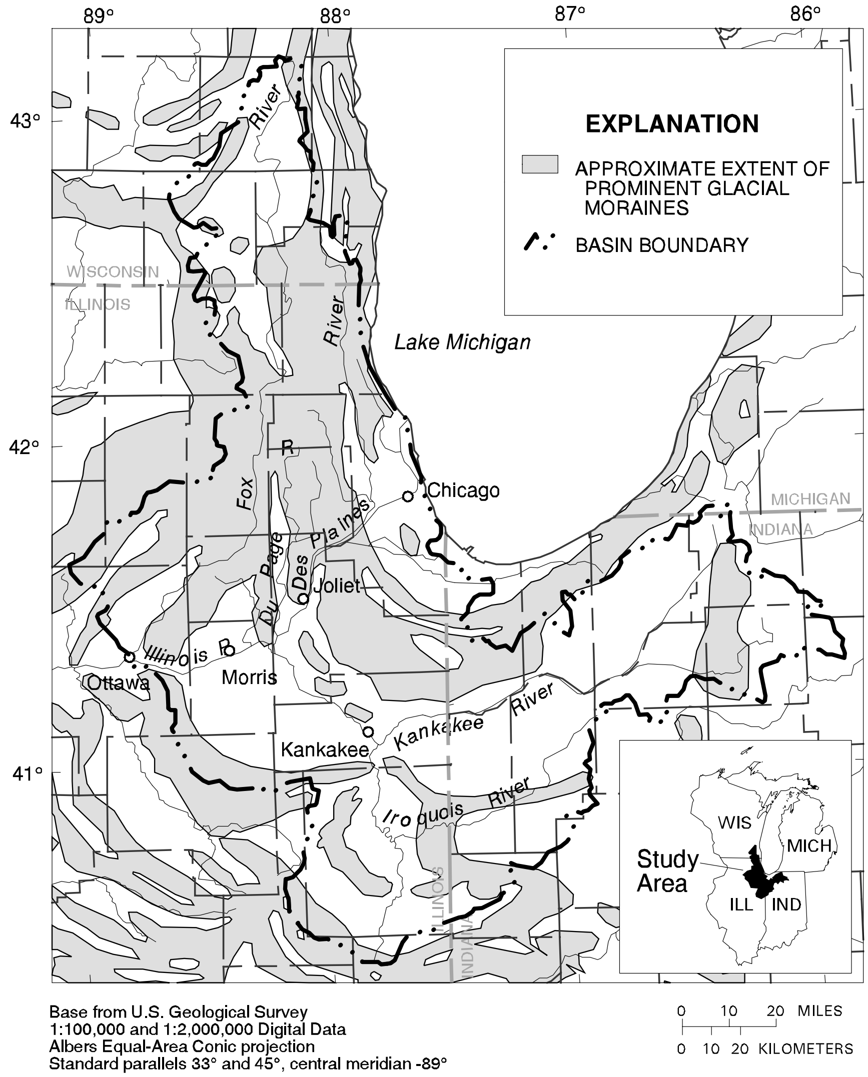


Figure 7. Prominent glacial moraines in the upper Illinois River Basin (modified from Sugden and John, 1976).

of the Fox River. Surficial deposits in the Wheaton Morainal Plain are generally between 50 and 200 ft thick; however, deposits in some northern areas of the UIRB are less than 50 ft thick, and deposits in many southern areas are greater than 200 ft thick (fig. 11). Relief generally is less than 100 ft with a minimum elevation of 505 ft and a maximum elevation of 1,188 ft above sea level (fig. 9). As the Wisconsinan glacier retreated through the upper Fox River Basin, many lakes (kames) and some swamps were formed by isolated buried ice blocks melting in depressions made by the glacier (Mades, 1987).

The Kankakee Till Plain (37 percent of the basin) is approximately the area covered by the western three-quarters of the Kankakee River Basin, the Illinois River Basin, and the western part of the Iroquois River Basin (fig. 10). The Kankakee Till Plain is an outwash plain formed by the variable gradient, variable volume, and variable velocity of glacial floods (Mickelson and others, 1984). Surficial deposits are predominately outwash sand and gravel of the Henry/Atherton Formation (Mackinaw and Batavia Members in Illinois, undifferentiated in Indiana) (fig. 8, table 2) but also include alluvium and fill materials. Bedrock is exposed along the downstream reaches of the Kankakee River. Surficial deposits generally are less than 200 ft thick; however, some deposits in the Kankakee River lowland are less than 50 ft thick, and some deposits in the upland are greater than 200 ft thick (fig. 11). Local changes in elevation generally are less than 100 ft with a minimum elevation of 482 ft and a maximum elevation of 899 ft above sea level (fig. 9).

The Bloomington Ridged Plain (22 percent of the basin) is approximately the area of the lower Fox River Basin and the southern part of the Iroquois River Basin (fig. 10). Surficial deposits in this area are mostly loamy till (Malden Till Member) and clayey till (Yorkville Till Member) of the Wedron Formation (fig. 8, table 2) deposited as moraines by the Lake Michigan glacial lobe (fig. 6). The lower Fox River Basin has well developed rolling moraines, whereas the southern part of the Iroquois River Basin has lower and more gently rolling moraines. In the Iroquois River Basin, the Bloomington Ridged Plain is mostly loamy till (unnamed in Illinois; Trafalgar Formation in Indiana), and lake clay and silt (Carmi Member of the Equality Formation) deposited by the Huron-Erie glacial lobe (fig. 6). Surficial deposits generally are less

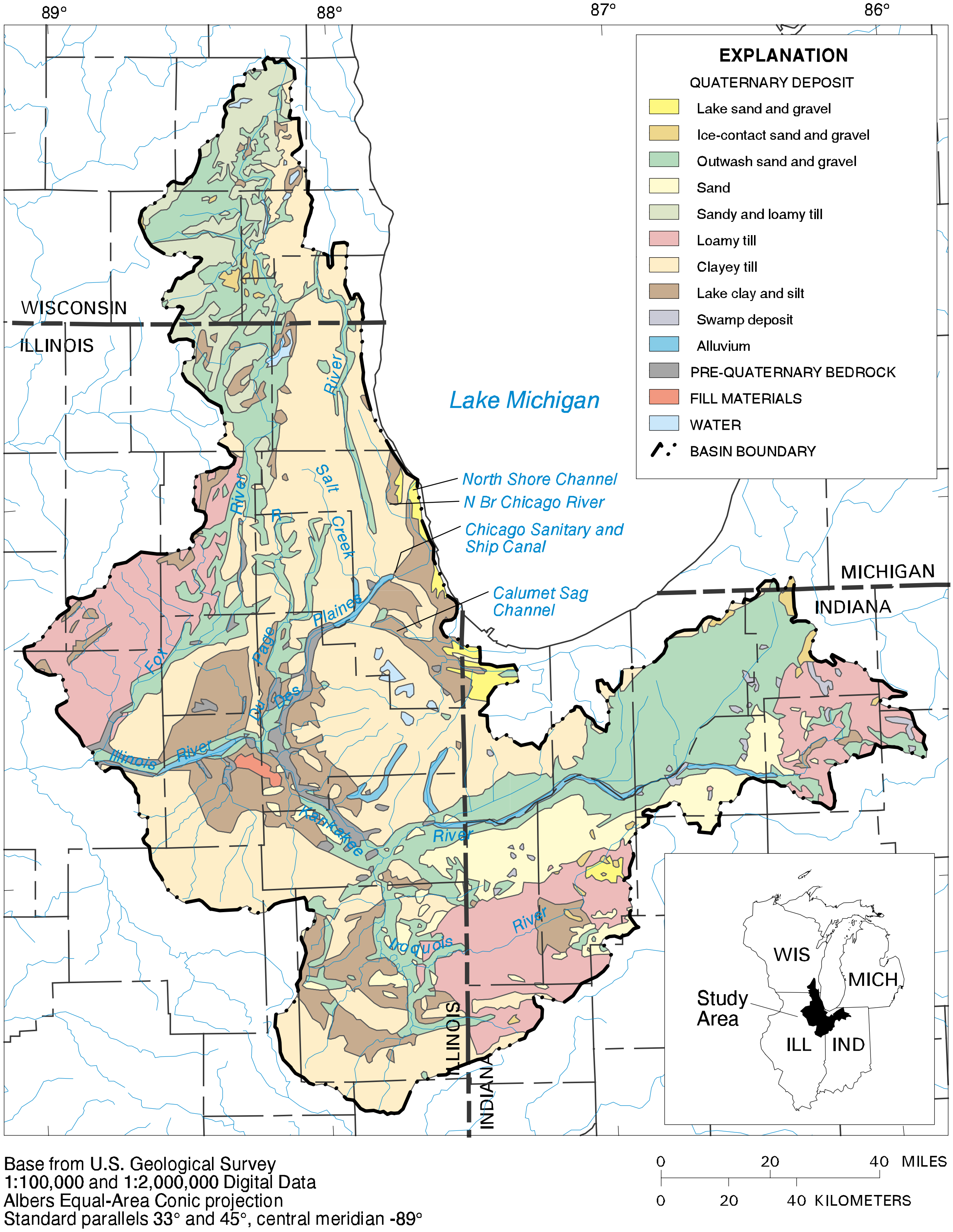


Figure 8. Quaternary deposits in the upper Illinois River Basin (modified from Lineback and others, 1983) (Quaternary Geologic Map of the Chicago 4°x6° Quadrangle, United States).

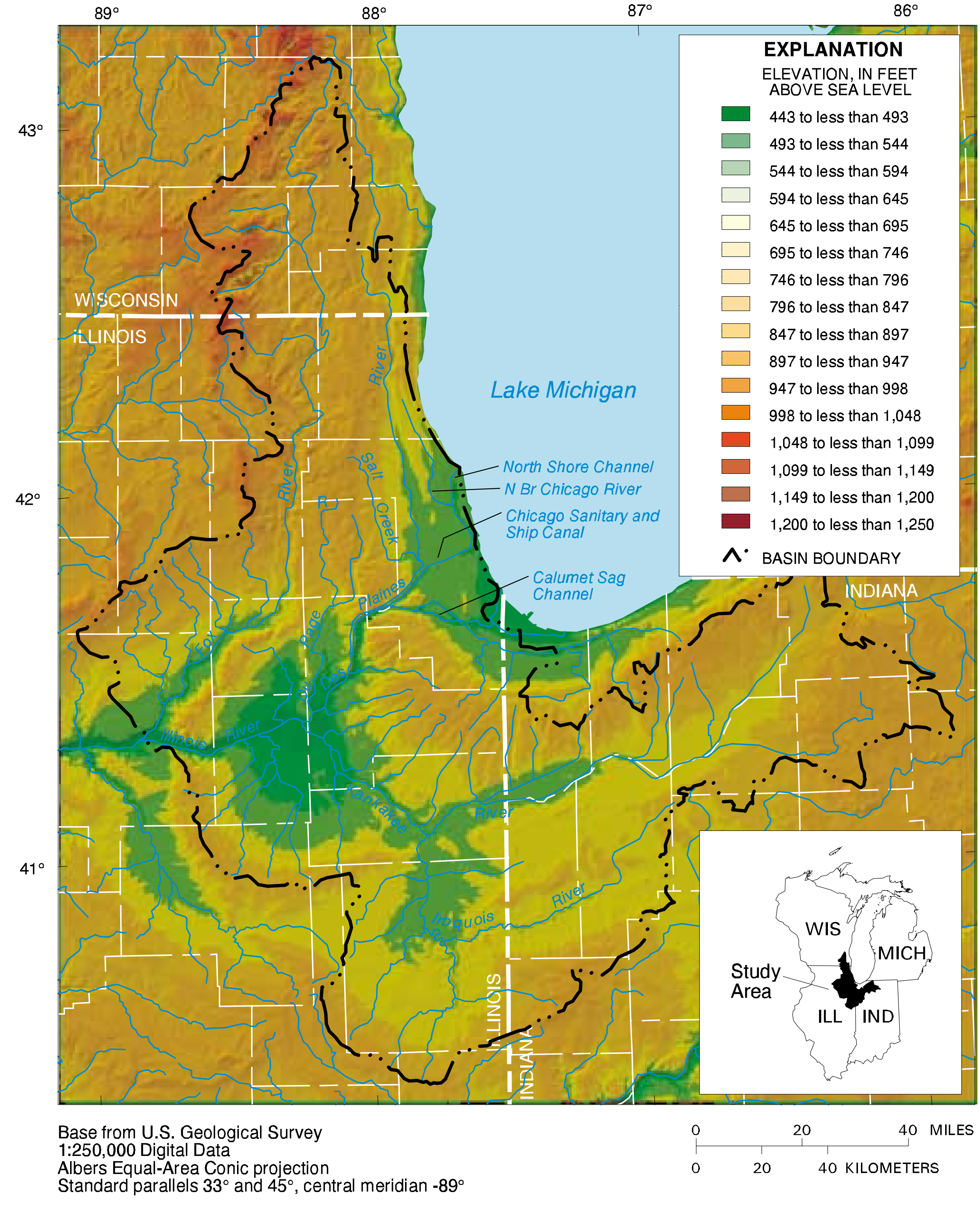


Figure 9. Surface topography of the upper Illinois River Basin (modified from U.S. Geological Survey [undated]).

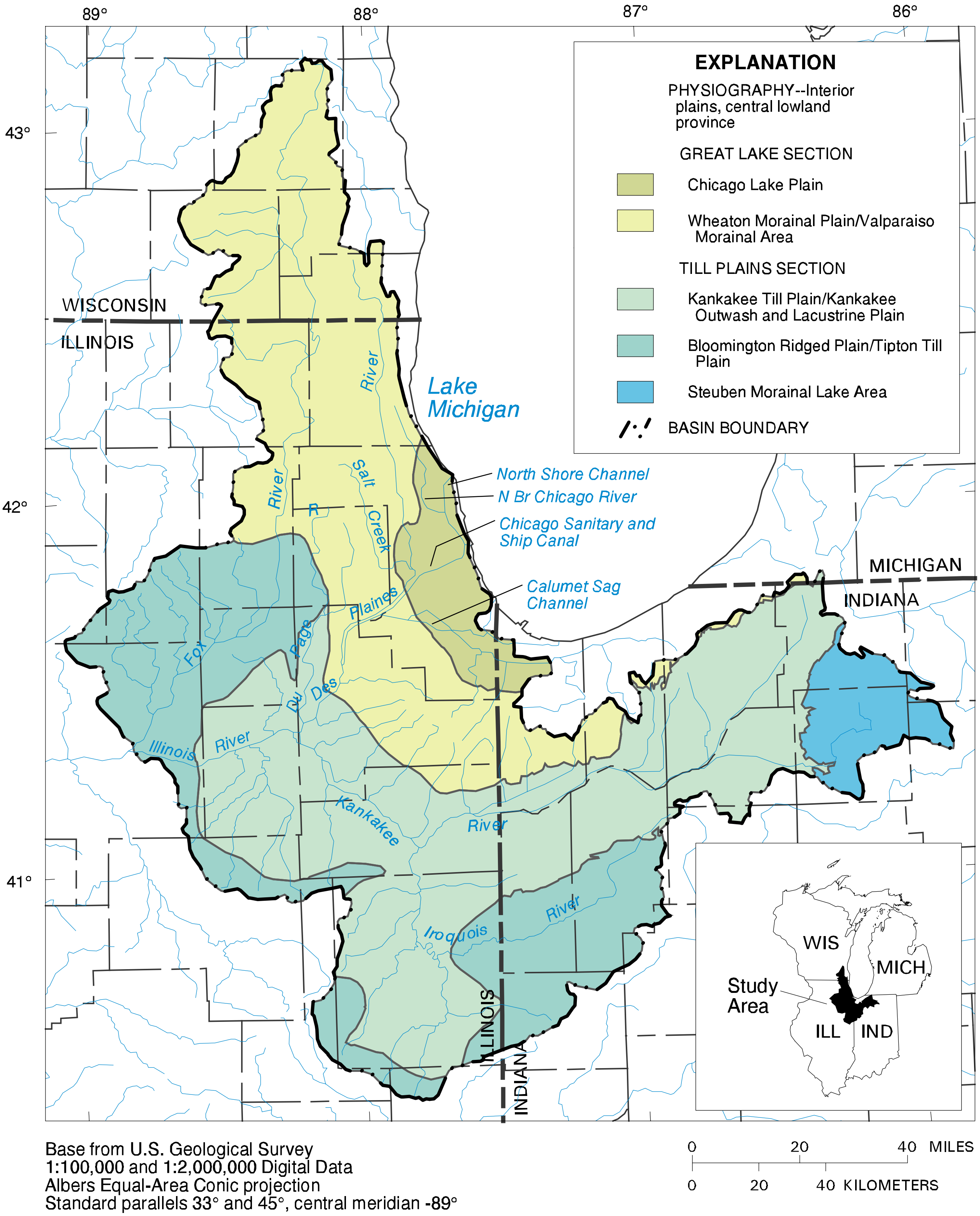


Figure 10. Physiography of the upper Illinois River Basin (modified from Fenneman, 1938; Leighton and others, 1948; and Schneider, 1966).

Table 2. Uppermost Quaternary stratigraphy of the upper Illinois River Basin

[modified from Willman and others, 1975; Gray, 1989; Lineback and others, 1983; and Mickleson and others, 1984]

	Illinois		Indiana		Wisconsin	
Formation	Member	Lithology	Formation	Lithology	Formation	Lithology
Henry	Batavia	Outwash plains: sand, gravel, and silt.	Atherton	Outwash facies: gravel and sand of glacial outwash deposits.	Present, but unnamed	
Henry	Mackinaw	Valley trains: sand, pebbly sand, and gravel; well-sorted.	Atherton	Outwash facies: gravel and sand of glacial outwash deposits.	Present, but unnamed	
Henry	Wasco	Ice contact deposits: sand and gravel in kames, eskers, and deltas.	No information		No information	
Equality	Carmi	Clay, silt, and some sand.	Atherton	Lacustrine facies: silt, sand, and clay of glacial lake sediments.	Present, but unnamed	
Equality	Dolton	Mostly sand with beds of silt and gravel deposited as beaches and sand bars. Best developed in Cook County.	Atherton	Lacustrine facies: silt, sand, and clay of glacial lake sediments.	Not present as uppermost deposit	
Wedron	Tiskilwa Till	Pinkish-tan sand, most extensive member of Wedron Formation.	No information		Tiskilwa	Pink, medium textured till of sand, silt, and clay.
Wedron	Malden Till	Silty, sandy, loamy yellow-gray till with lenses of gravel and sand.	No information		No information	
Wedron	Yorkville Till	Clayey, dark greenish-grey till with small dolomite pebbles.	Trafalgar	Dark grey loam with areas of calcareous till and lenses of silt, sand, and gravel.	New Berlin	Lower unit is proglacial outwash sand and gravel. Upper unit is gravelly sandy loamy till.
Wedron	Haeger Till	Calcareous, gravelly, silty till.	Not present as uppermost deposit		New Berlin	Lower unit is proglacial outwash sand and gravel. Upper unit is gravelly sandy loamy till.
Wedron	Wadsworth Till	Clayey grey tills deposited as moraines.	Present, but unidentified on source maps		Oak Creek	Calcareous fine-grained till and lacustrine clay, silt, and sand deposited as moraines.
Grayslake Peat		Peat, sandy and silty peat, muck and clay.	Present, but unnamed		Not present as uppermost deposit	
Cahokia Alluvium		Silt, clay, and silty sand with lenses of sand and gravel.	Martinsville	Alluvial facies: mud, silt, sand, and gravel of present-day streams.	Not present as uppermost deposit	
Parkland Sand		Windblown sand in dunes and sheet-like deposits.	Atherton	Dune facies: dune sand deposited on the surface of outwash sediments.	Not present as uppermost deposit	

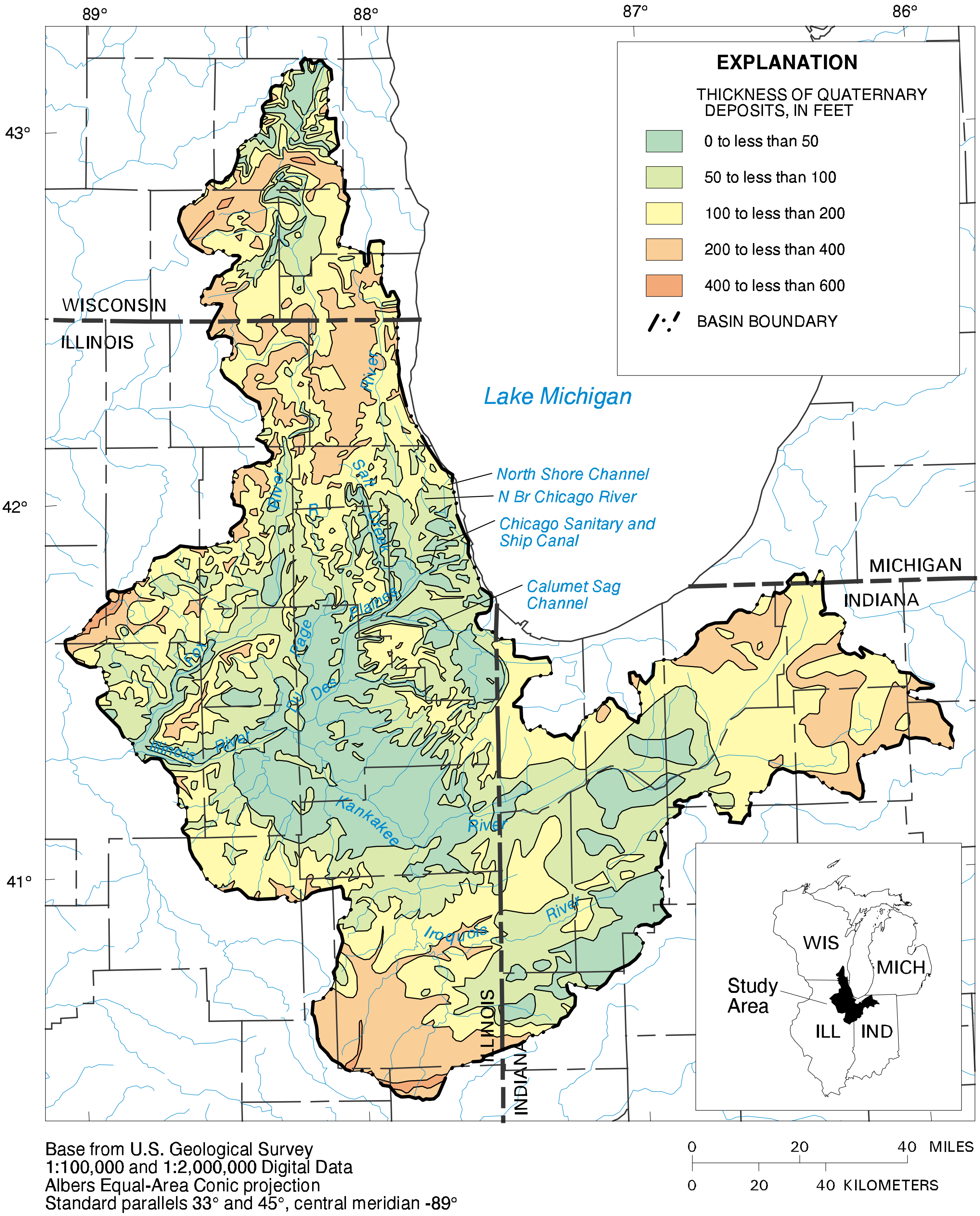


Figure 11. Thickness of Quaternary deposits in the upper Illinois River Basin (from Soller, 1998).

than 200 ft thick; however, there are areas in both basins that are more than 400 feet thick (fig. 11). Topography in upland areas of the Bloomington Ridged Plain is flat or gently rolling. Lowland areas, such as along the Fox and Illinois Rivers, are very hilly and rugged with local relief as great as 300 ft where the rivers are deeply incised and bedrock is exposed (Piskin and Bergstrom, 1975). Topography generally varies less than 300 ft with a minimum elevation of 472 ft and a maximum elevation of 981 ft above sea level (fig. 9).

The Steuben Morainal Lake Area (4.3 percent of the basin) is the eastern-most part of the Kankakee River Basin (fig. 10). This area is characterized by hilly knob and kettle glacial terrain. Knobs are formed when a melting glacier deposits hills of sand and gravel into a depression left by the ice. Kettles are formed when ice blocks from a glacier melt in depressions left by the ice. The kettles form the basins for many kames and peat bogs in the area. Surficial deposits are predominately loamy till of the Trafalgar Formation deposited by the Saginaw glacial lobe (fig. 6) and generally are greater than 200 ft thick (fig. 11). Topography generally is less than 100 ft with a minimum elevation of 721 ft and a maximum elevation of 899 ft above sea level (fig. 9) (Schneider, 1966).

Soils

The texture and composition of soil affects the chemistry and infiltration rate of water. Soil texture and composition predominately is determined by climate, parent material, and vegetation. Temperature and precipitation determine the rate of chemical weathering and the development of soil materials. The more humid the climate, the faster soils can develop. During the Wisconsinan period, when most of the soils in the UIRB formed, the climate was more humid and warmer than at present (Fehrenbacher and others, 1984).

In the UIRB, parent materials of soil are generally the underlying surficial deposits in which the soils are developed. The parent materials can be identified from the map showing Quaternary deposits (fig. 8). Some of the soil along the major river valleys, such as the Illinois River valley, is from decomposition of exposed bedrock (Fehrenbacher and others, 1984), but most of the soil in the UIRB is derived from the glacial surficial deposits discussed earlier in this report.

In addition to glacial materials, alluvium is a prime parent material for younger soils (entisols) around stream banks and flood plains in the UIRB (fig. 12). Entisols generally are light colored and sandy (Fehrenbacher and others, 1984); have poor horizon definition (Muller and Oberlander, 1984); and, on a relative scale, are moderately to highly permeable (fig. 13). Entisols are common in the Kankakee and Illinois River Basins and cover 5 percent of the UIRB.

Soil development also is affected by vegetation because of the organic matter it contributes to the soil. Soils formed under grasslands tend to be dark and high in organic content (mollisols); in contrast, soils formed under forested land tend to be light colored and low in organic content (alfisols) (Fehrenbacher and others, 1984). Mollisols generally contain greater than 1 percent organic matter in their surficial horizon, whereas alfisols generally contain less than 1 percent organic matter. Mollisols cover 59 percent of the UIRB and dominate the Iroquois, Illinois, Chicago, and lower Fox River Basins (fig. 12). Relative soil permeability of mollisols in the UIRB is low to very low (fig. 13). Alfisols cover 33 percent of the UIRB and are common around dry morainal areas and in gently rolling, well drained areas of the Kankakee, Des Plaines, and upper Fox River Basins (fig 12.). Relative soil permeability of alfisols is low to moderate (fig 13).

Histosols, soils from mostly organic parent materials, cover 2 percent of the UIRB and are scattered throughout the Fox, Kankakee, and Iroquois River Basins (fig. 12). Generally, histosols have greater than 20 percent organic content in their surficial horizon and are found in low lying areas that remain wet most of the time (Fehrenbacher and others, 1984). In the UIRB, histosols have relatively very low permeability (fig. 13).

Inceptisols are soils with poorly developed soil horizons. These soils cover approximately 1 percent of the UIRB and are found in the Fox and Des Plaines River Basins (fig. 12). On a relative scale, inceptisols are moderately permeable (fig. 13).

Vegetation

Vegetation is an important part of soil formation and the water cycle. The type and quantity of plant material contributes to the organic content of the soil and the activity of root growth affects breakdown of soil components.

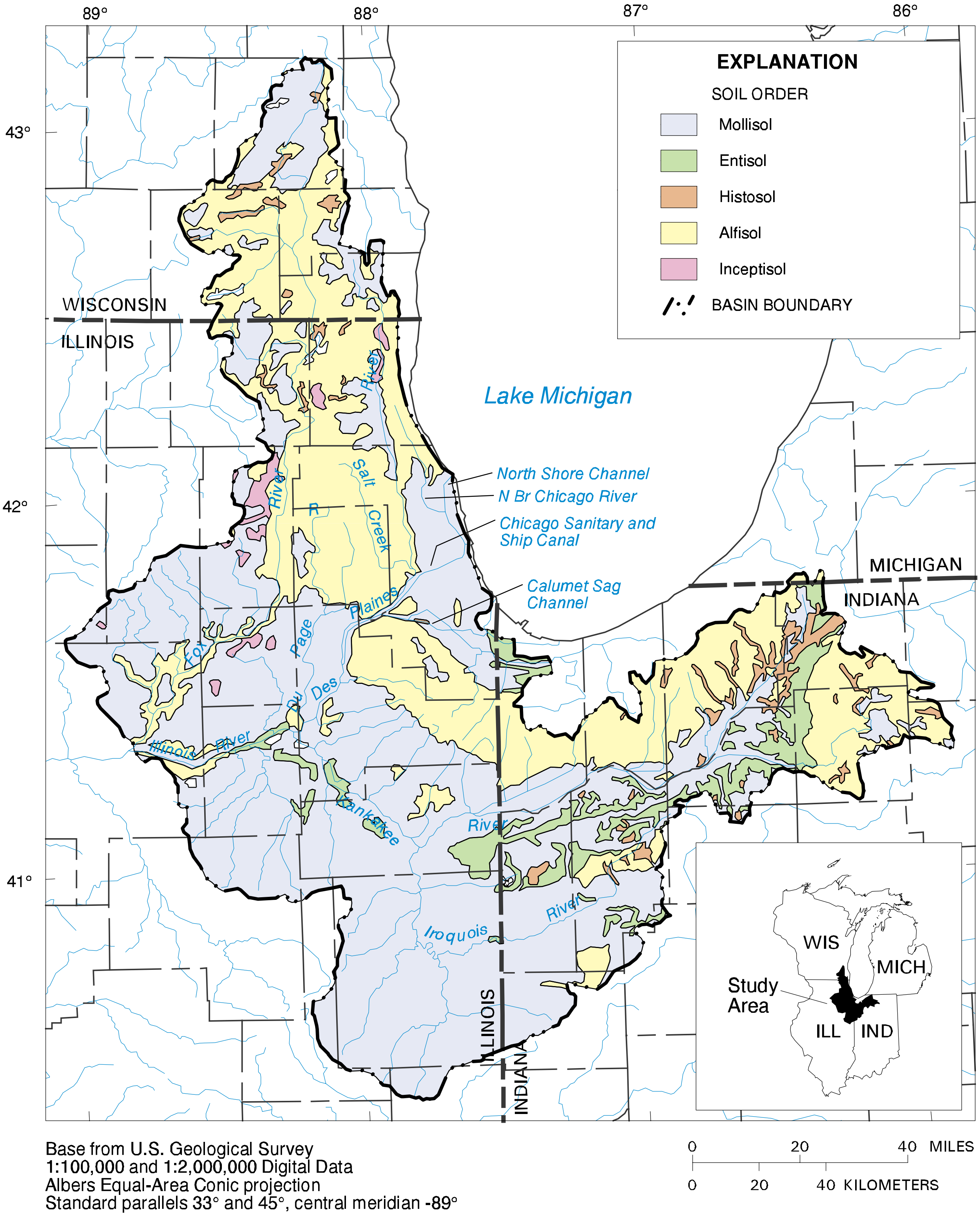


Figure 12. Soil order of the uppermost horizon in the upper Illinois River Basin (from U.S. Department of Agriculture, 1994).

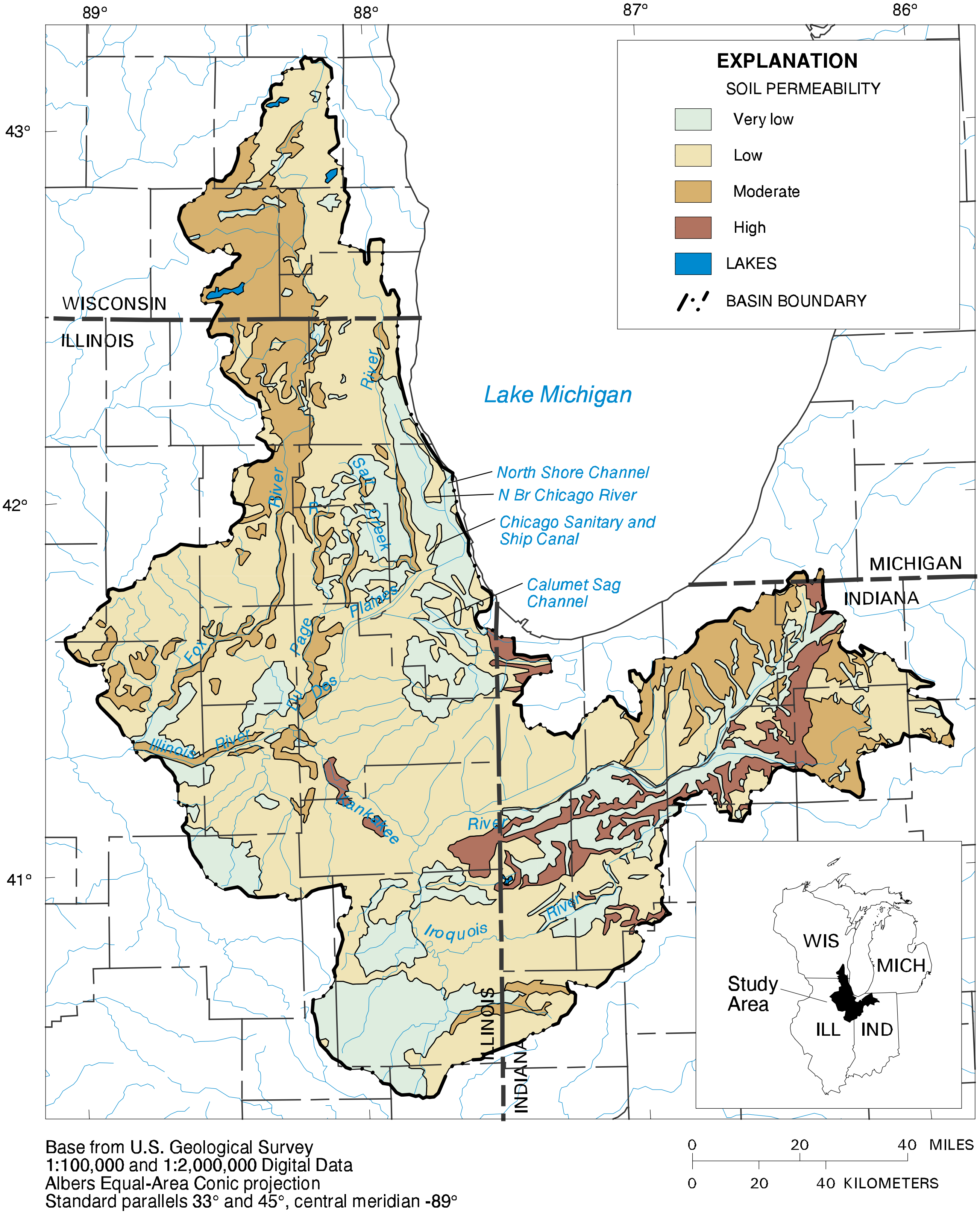


Figure 13. Soil permeability in the upper Illinois River Basin (modified from U.S. Department of Agriculture, 1994).

In addition, vegetation intercepts precipitation and also draws moisture from the soil that could otherwise infiltrate to ground water.

The central part of the UIRB lies in the eastern lobe of the grassland region of central North America and the eastern and northern parts lie in the deciduous forest regions. Prior to European settlement of the area, the UIRB vegetation communities included prairies, savannas, woodlands, and wetlands. Today, only fragments of the presettlement vegetation remain; the dominant modern vegetation is agricultural.

Plant communities that would exist if humans were not present in the basin and a climax plant community were allowed to develop naturally are called potential-natural vegetation. Küchler (1964) classified these potential plant communities on the basis of the one to three (usually two) dominant plant genera present in an area. On a national scale, six potential-natural vegetation types in the UIRB are defined by Küchler (1964): oak-hickory forest, beech-maple forest, maple-basswood forest, oak savanna, bluestem prairie, and mixed bluestem prairie and oak-hickory forest (fig. 14).

Prior to European settlement, the potential-natural vegetation of the central part of the UIRB was mostly a mixture of tallgrass bluestem prairie and oak-hickory forest. In the western part of the basin, tallgrass prairie typically grew as broad expanses on the flat uplands and forests grew on protected slopes, in ravines, and in river valleys. The prairie ecosystem was formed and maintained by a harsh climate, grazing by free-ranging-large animals, and periodic fires. Tallgrass prairie plants typically have extensive deep root systems that build soil fertility. During the midnineteenth century, natural prairie land was converted to agricultural land when the metal plow was introduced and settlers discovered that prairie soils were more productive than forest soils (Illinois Department of Energy and Natural Resources, 1994). As a result, only small fragments of prairie remain in the UIRB.

A national prairie restoration effort is ongoing at the Midewin National Tallgrass Prairie in Will County, Illinois. This 24-mi^2 area was established in 1996 on the grounds of the former Joliet Army Ammunition Plant (1940–96) near the confluence of the Des Plaines and Kankakee Rivers. This prairie is the Nation's first Federally designated tallgrass prairie and, in conjunction with nearby natural areas, forms the 62-mi^2 Prairie Parklands Macrosite, which is a mix of public, private, and corporate lands managed to protect diversity (Midewin National Tallgrass Prairie, 1998).

Further east, in the upper reaches of the Kankakee River Basin, prairie vegetation characteristically decreased and was replaced by oak-hickory and beech-maple forest vegetation. In the upper Fox and Des Plaines River Basins, the tallgrass prairie graded northward into oak savanna and eventually into a maple-basswood forest. Oak savanna is tallgrass prairie with deciduous trees, characteristically Bur oak (*Quercus macrocarpa*), scattered singly or in groves (Küchler, 1964). Similarly, Finley (1976) depicted the original vegetation of the Wisconsin part of the UIRB as a mosaic of oak forest, oak savanna, prairie, maple-basswood-oak forest, and herbaceous and shrub wetlands.

Climate

The climate of the UIRB is classified as humid continental because of the cool, dry winters and warm, humid summers. Both seasons are usually dominated by cool, dry air from Canada (continental polar); warm, moist air from the Gulf of Mexico (maritime tropical); and occasionally warm, dry air from the Pacific Ocean (maritime polar). The combinations of cool, dry and warm, moist air are the sources of most precipitation in the basin. However, any combination of these three air masses can be over the basin at any time. Large daily fluctuations in temperature and precipitation can result from this combination (Muller and Oberlander, 1984).

The average annual temperature for the UIRB (1961–90) ranged from 46° F in the north of the basin to 51° F in the south of the basin. The coolest temperatures occurred during the winter months of December, January, and February; the minimum average monthly temperature occurred in January. During the period of record through 1995, minimum average January temperatures ranged from less than 4° F in the northwestern Wisconsin part of the basin to more than 11° F in the northeastern Indiana and southern Illinois parts of the basin. The average basin-wide January temperature ranged from 18° F to 25° F during the same period (National Oceanic and Atmospheric Administration, 1995).

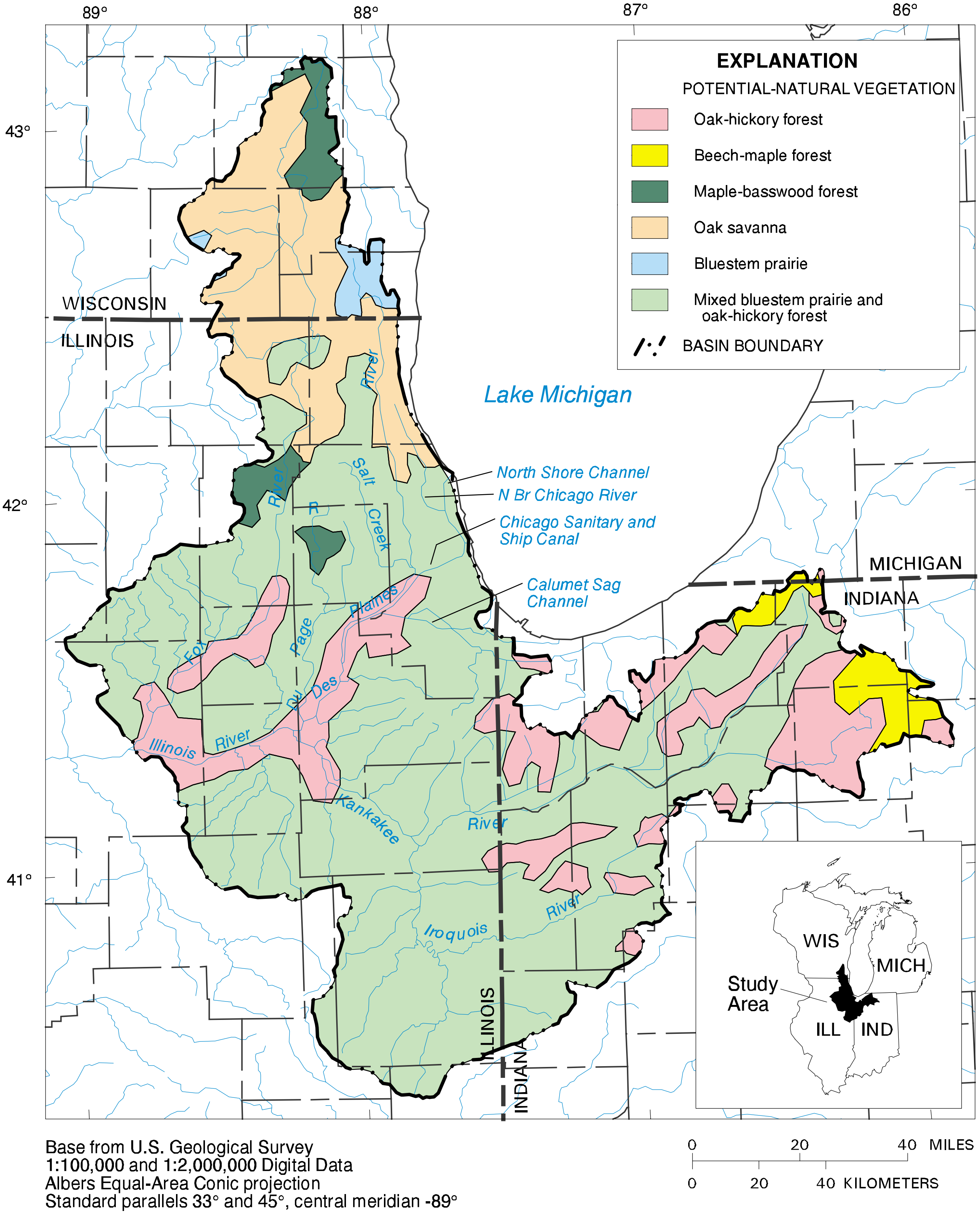


Figure 14. Potential-natural vegetation in the upper Illinois River Basin (modified from Küchler, 1964).

The warmest temperatures in the UIRB (1961–90) occurred during the months of June, July, and August; the maximum average monthly temperature occurred in July. Maximum average July temperatures during the period of record through 1995 ranged from less than 77° F in the northern parts of the basin to greater than 82° F in the southern part of the basin. The average basinwide July temperature ranged from 72° F to 75° F during the same period (National Oceanic and Atmospheric Administration, 1995). Lake Michigan has a moderating effect on temperature near the shoreline because the water in Lake Michigan heats up and cools down more slowly than the surrounding land.

Average annual precipitation, including the liquid equivalent of snowfall, for the period 1961–90 ranged from less than 32 in. in the northern Wisconsin part of the basin to more than 38 in. near the southern and eastern Lake Michigan shoreline in the Indiana part of the basin (fig. 15). During the same period, the minimum mean monthly precipitation occurred in February (1.54 in.), and the maximum mean monthly precipitation occurred in June (3.61 in.) (National Oceanic and Atmospheric Administration, 1995). About 50 percent of the average annual precipitation, approximately 16–18 in., generally occurs during the growing season from May through mid-October.

On average, for the period of record through 1995, annual snowfall (including snow, ice, sleet, and hail) varied from less than 30 in/yr in the southwestern part of the basin in Illinois to greater than 65 in/yr east of Lake Michigan in the extreme northeastern part of the basin in Indiana. West of Lake Michigan, in Wisconsin, average annual snowfall for the same period was less than 50 in/yr. Lake Michigan produces seasonal effects on precipitation in the basin for areas near the shoreline (Changnon, 1968).

Evapotranspiration (moisture released from plants) returns an estimated 70 percent of the average annual precipitation to the atmosphere. Based on this percentage, average annual evapotranspiration ranges from about 22 in. in the northern part of the UIRB to about 27 in. in the eastern part. Approximately 75 percent of the average annual evapotranspiration usually occurs during the growing season (U.S. Geological Survey, 1970). Evapotranspiration normally exceeds precipitation during the growing season and, thereby, depletes available soil moisture. During the nongrowing season, precipitation generally exceeds evapotranspiration and, thereby, replenishes soil moisture and recharges ground-water sources.

Ecoregions

Ecoregions are areas of relatively homogeneous ecological systems or relations between organisms and their environments (Omernik, 1987). Ecoregion classification builds on single-purpose geographical classifications (such as physiography, climate, or soils) to create a framework for understanding regional patterns and managing aquatic and terrestrial resources. Classification of ecoregions can assist environmental planners and decision makers in addressing environmental problems on a regional scale. Based on this regionalization, chemical or biological standards within a region can be established in order to evaluate environmental conditions.

Omernik's (1987) ecoregion classification, which divided the conterminous United States into 76 level-3 ecoregions, is used by the NAWQA program to evaluate regional water-quality patterns. Omernik primarily used maps of land use, potential-natural vegetation, surficial geology, physiography, and climate to develop his classification, which resulted in areas that were relatively homogenous in their characteristics. Omernik and Gallant (1988) defined the "most typical" areas of each level-3 ecoregion for the upper Midwest States. A most typical area of an ecoregion has all characteristics that typify the level-3 ecoregion.

Over 80 percent of the UIRB is classified as the Central Corn Belt Plains ecoregion. Aside from the Chicago metropolitan area, land use in the Central Corn Belt Plains is mostly corn and soybean cultivation for livestock feed crops and some livestock production. The soils are typically mollisols. Historically, vegetation in the Central Corn Belt Plains was a mosaic of bluestem prairie and oak-hickory forest. The prairie typically covered the flat uplands, and the forest typically occupied stream valleys and moraines. High stream turbidity and sedimentation are a problem in the streams of this ecoregion (Omernik and Gallant, 1988).

Parts of the upper Fox and upper reaches of the Des Plaines River Basins, about 10.5 percent of the UIRB, are classified in the Southeastern Wisconsin Till

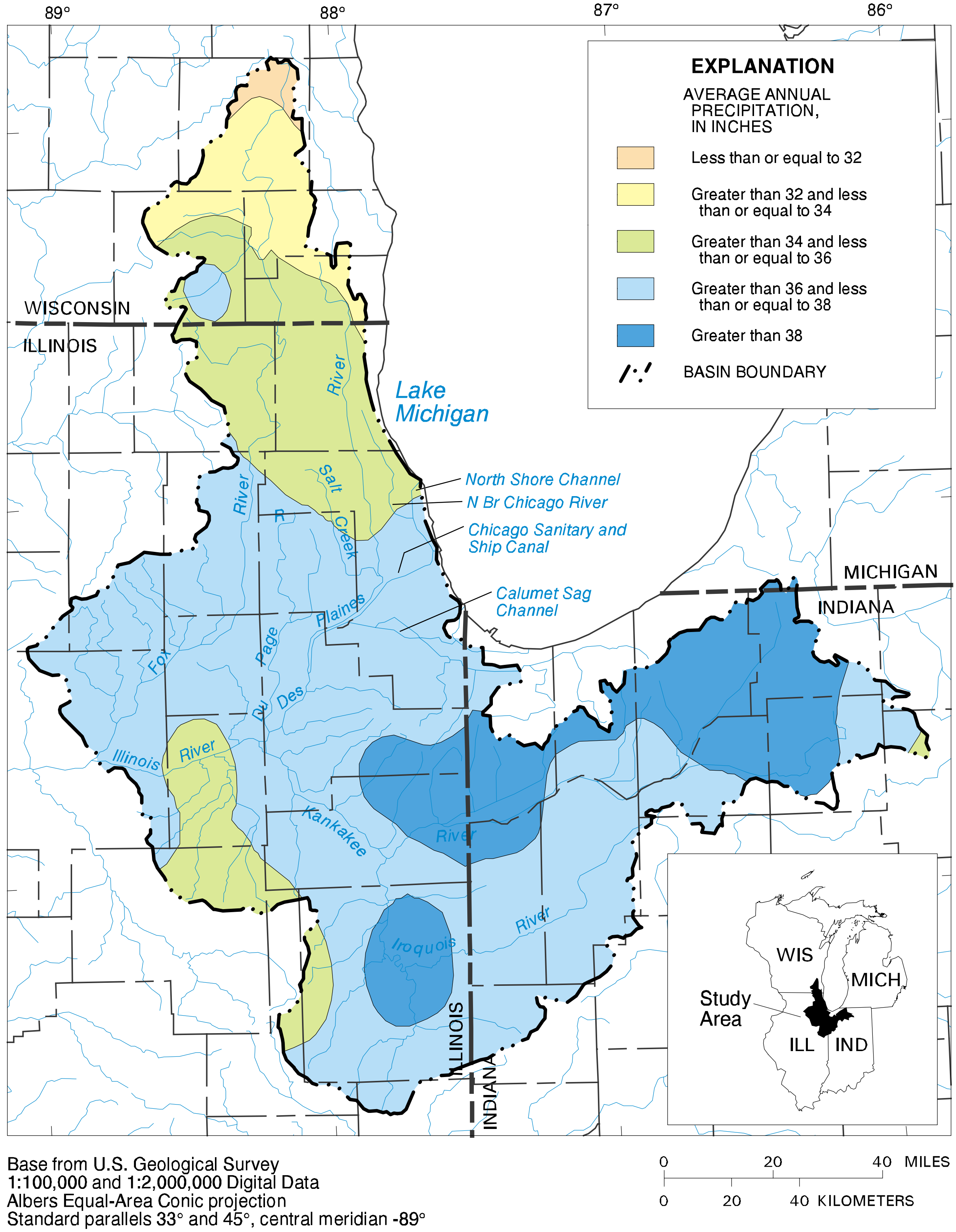


Figure 15. Average annual precipitation for the period 1961–90 in the upper Illinois River Basin (modified from National Oceanic and Atmospheric Administration, 1995).

Plains ecoregion. In contrast to the feed-grain cultivation in the Central Corn Belt Plains, dairy and livestock production are the predominant land use in this ecoregion. Other land uses include cultivation for livestock-feed grain, canning, and truck crops; pasture; and woodlots. Watersheds generally are smaller in the Southeastern Wisconsin Till Plains than in the Central Corn Belt Plains, typically covering from about 386 to 956 mi^2. Approximately 25–30 percent of the streams are intermittent in this ecoregion. The Wisconsin Till Plains ecoregion lies within the Wheaton Morainal Plain physiographic subsection (fig. 10). The soils are typically alfisols and mollisols. The historical vegetation in the Southeastern Wisconsin Till Plains was a mixture of tallgrass prairie to the south, oak savanna to the west, and hardwood forest to the north (Omernik and Gallant, 1988).

The upper reaches of the Kankakee River Basin, 8.5 percent of the UIRB, are classified as less typical areas of the Southern Michigan/Northern Indiana Till Plains ecoregion. This is a transitional region between the hillier regions in northern Michigan and the flatter central and eastern corn belt plains to the south and overlaps the Steuben Morainal Lake Area physiographic subsection (fig. 10). Crop and livestock production are the most extensive land use in the UIRB part of this ecoregion, and gravel quarries are common. Streams tend to be sluggish, often bordered with swampy tracts. Stream channelization is widespread (Omernik and Gallant, 1988).

Human Factors

Human factors that affect the hydrologic characteristics of the UIRB include land use, urbanization, and population change. These human factors have had an appreciable effect on the basin because people reshape the landscape to fit their needs. One of the earliest human activities was the development of transportation corridors. These corridors opened a passageway between the Great Lakes and the Mississippi River, first by using natural waterways and manmade canal systems and later by building railroads. With the ease of transportation came rapid settlement. Population in the basin grew steadily and created urban and industrial growth areas along the Lake Michigan shoreline and along major rivers, such as the Illinois and Des Plaines. Because of rapid urban growth in these areas, wastewater disposal became a serious issue (Mayor and Wade, 1969). Railroads, such as the Illinois Central; Chicago, Burlington, and Quincy; and Chicago, Rock Island, and Pacific Railroads, soon supplemented and nearly replaced waterway transport (Conzen and Morales, 1989). Agriculture also developed as farmers moved into the basin to supply the growing urban areas with food and goods. Some of the earliest traded goods were lumber from Chicago, and coal and stone from the Illinois Valley (Conzen and Morales, 1989).

Manmade features in the UIRB can be grouped into two broad categories that relate to agricultural and urban land use (Mades, 1987). Today, the UIRB receives numerous inputs of contaminants and nutrients from manmade sources that include municipal and industrial releases, urban and agricultural runoff, and atmospheric deposition. Data collected during the UIRB NAWQA pilot study (1986–92) indicated that differences in fish community structure and water quality could be correlated with differences in urban and agricultural land use (Fitzpatrick and others, 1995; Ruhl, 1995; Sullivan and others, 1998).

Land Use

In 1990, agriculture accounted for about 75 percent of the land use in the basin (table 3). Corn was the principal row crop harvested in the basin, followed by soybeans. In 1985, approximately 1.8 million acres of corn were harvested for seed, grain, silage, or sweet corn; and approximately 1.4 million acres of soybeans were harvested for beans (Battaglin and Goolsby, 1995). In 1990, urban areas accounted for about 17 percent of the land use in the basin and were concentrated mainly in the metropolitan areas in and around Chicago. Of this 17 percent, 11 percent was used for low to high density residential purposes, and 6 percent was used for commercial and industrial purposes (Hitt, 1992). The land drained by the Calumet and lower Des Plaines Rivers was some of the most heavily industrialized in the Nation. Along these rivers, petroleum refining and steel manufacturing were the dominant industries (City of Chicago and Illinois Environmental Protection Agency, 1989). In 1990, forests covered about 5 percent of the UIRB and were concentrated in city forest preserves and along large-stream riparian areas (fig. 16)

Table 3. Land use in the upper Illinois River Basin, 1970 and 1990 (modified from Hitt, U.S. Geological Survey, unpublished data, 1992)

Land-use category	Total area in 1970 (percent)	Total area in 1990 (percent)
Agriculture	77	75
Urban	14	17
Forest	6	5
Other	3	3

Since the 1970's, agricultural areas have decreased by 2 percent while urban areas have increased by 3 percent (table 3). Most of the recent urbanization is the result of development of new suburban and residential areas. The effects from converting previously agricultural land to new residential land are not fully known. Some of the possible implications of urbanization on streams include accelerated erosion and channel instability; loss of aquatic habitat; increase in peak flow, duration of peaks, and flood volumes; and loss of base flow from ground-water pumping and change in surface water drainage networks.

Urbanization

Urbanization began in the Chicago area soon after European settlement and was concentrated in the Des Plaines River Basin. In the last few decades, westward urban development of the Chicago and Milwaukee metropolitan areas has affected the Fox and lower reaches of the Kankakee River Basins (fig. 17). Specific areas of urban expansion are indicated by U.S. Geological Survey digital land-use data from approximately 1975–82 (Fegeas and others, 1983; Fitzpatrick-Lins, 1980; Anderson and others, 1976), which was updated using 1990 Census data (Hitt, 1995). This urban expansion land-use category accounts for about 3 percent of the basin and indicates areas with more than 1,000 people per square mile. The updated land-use data indicate that low-density residential land use has increased from 8 percent to 11 percent in approximately a 10-year period from 1980 to 1990. The Northeastern Illinois Planning Commission estimates that from 1970 to 1990 the population of Chicago grew by 4 percent, while the amount of urban land expanded by 51 percent—more than 360,000 acres (Illinois Department of Energy and Natural Resources and the Nature of Illinois Foundation, 1994). Presently, there are no land-use/land-cover data available for the entire basin to quantify the exact amount of expansion, but expansion of suburbs has continued since 1990. Subbasins within the UIRB that are mostly affected by urban expansion include parts of the Des Plaines, Du Page, and Fox River Basins.

Population Change

Out of the approximately 7.6 million people currently living in the UIRB, about 6 million live in the Chicago metropolitan area (3 million people live within the city limits of Chicago). Total population for the UIRB has increased from 7,211,669 in 1970 to 7,602,203 in 1990 (U.S. Bureau of the Census, 1991; Lanfear, U.S. Geological Survey, unpublished data, 1993; Hitt, U.S. Geological Survey, unpublished digital data, 1992). County population data for the years 1970, 1980, and 1990 indicate a similar trend for urban expansion in the counties surrounding Chicago (table 4). Counties with the greatest increases in population from 1970 to 1990 are on the western and southern edge of the Chicago area and include McHenry (39 percent), Du Page (38 percent), Kendall (31 percent), Will (31 percent), Lake (26 percent), Kane (21 percent), and Grundy (18 percent) Counties in Illinois. Other counties in the basin with population growth greater than 10 percent are near smaller urban areas that also are undergoing urban expansion, such as the Counties of Waukesha, Wisconsin and Porter, Indiana. In contrast, many counties that predominately consist of either agricultural or densely-populated urban land have had declines in population from 1970 to 1990 (table 4).

Hydrologic Characteristics

Surface Water

The quantity, distribution, and variability of streamflow has an appreciable effect on the quality of surface water in the UIRB. The quantity of water in a stream can affect the stream's ability to support aquatic life, to assimilate or dilute waste discharges, and to carry suspended sediment. The temporal variability of streamflow is an important cause of the temporal variability of water quality, and knowledge of streamflow is important to understanding the water and ecological dynamics of a watershed.

Human factors have caused four major changes in the UIRB and have significantly affected the quality of surface waters. These changes are the construction of navigable waterways, diversion of Lake Michigan water, construction of wastewater-treatment plants, and agricultural activities. Mades

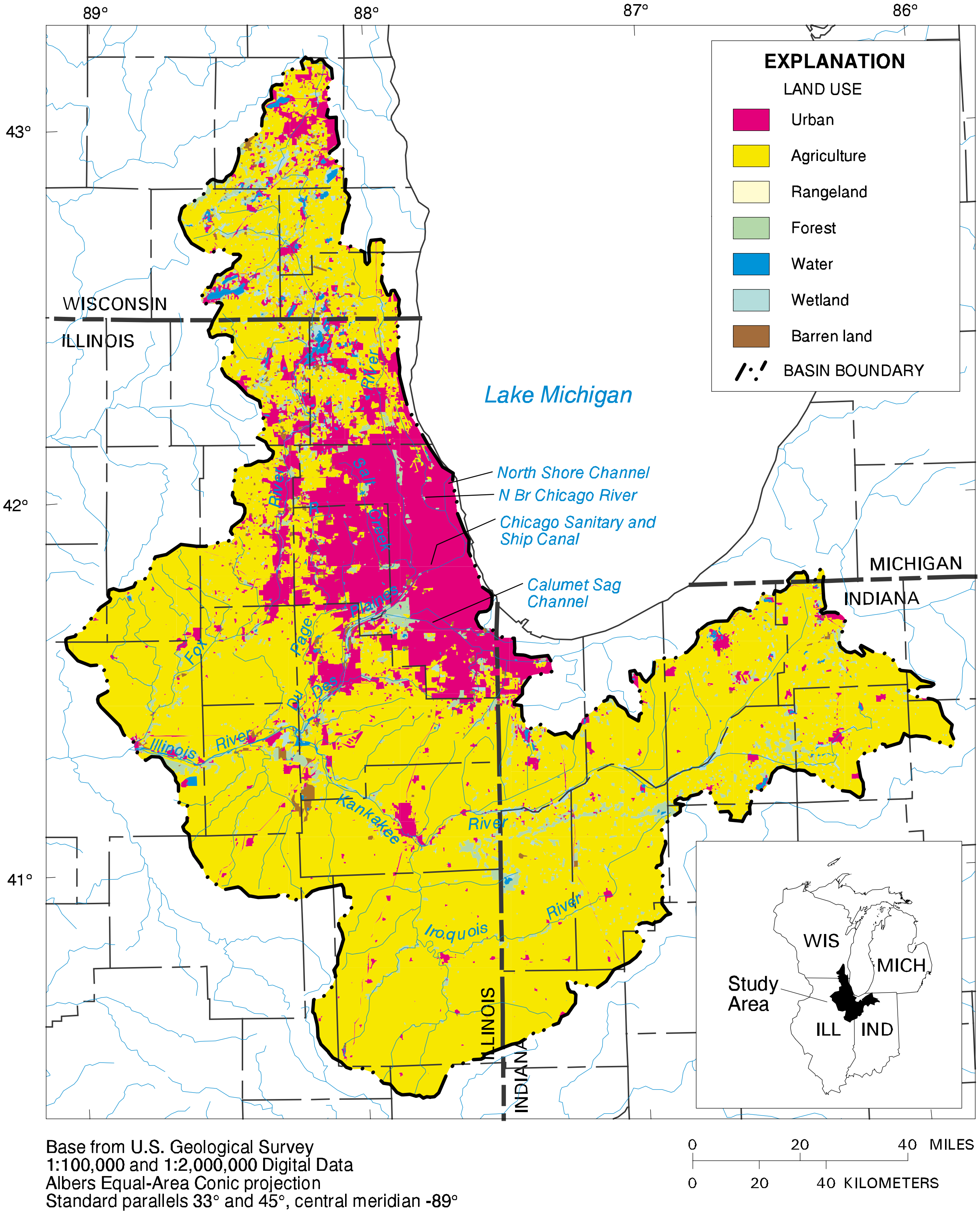


Figure 16. Anderson level-1 land-use classification in the upper Illinois River Basin, 1990 (from Hitt, U.S. Geological Survey, unpublished data, 1992).

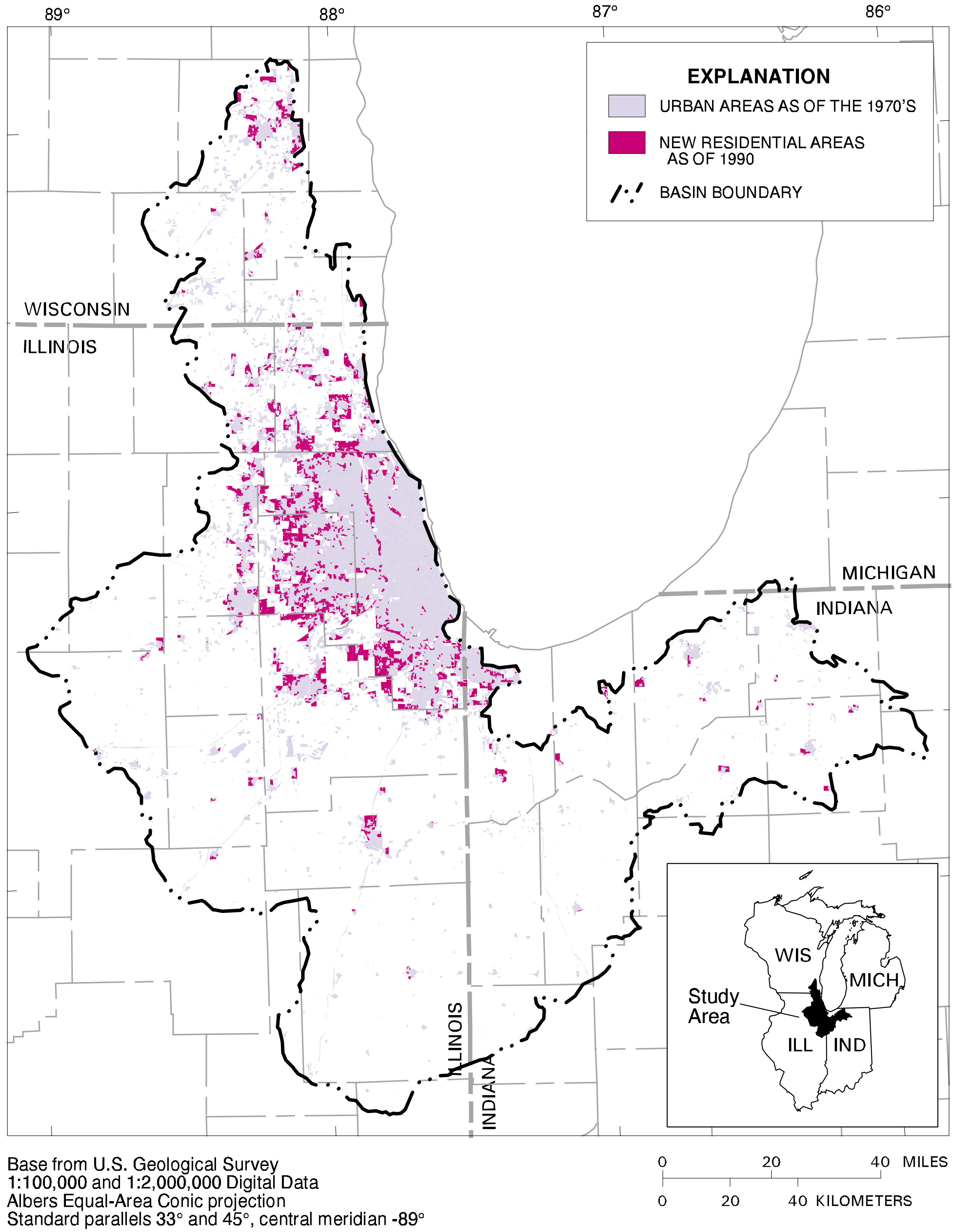


Figure 17. Urbanization in the upper Illinois River Basin (from Hitt, U.S. Geological Survey, unpublished data, 1992).

Table 4. Population change, by county, for the period 1970–90 in the upper Illinois River Basin (modified from Lanfear, U.S. Geological Survey, unpublished data, 1993; and Hitt, U.S. Geological Survey, unpublished data, 1992)

County	County population			Change in population		
	1970	1980	1990	1970 to 1980	1980 to 1990	1970 to 1990
Illinois						
Cook	5,426,286	5,191,233	5,105,067	–235,053	–86,166	–321,219
De Kalb	71,589	74,624	77,932	3,035	3,308	6,343
Du Page	487,578	658,835	781,666	171,257	122,831	294,088
Ford	16,370	15,265	14,275	–1,105	–990	–2,095
Grundy	26,510	30,582	32,337	4,072	1,755	5,827
Iroquois	33,505	32,976	30,787	–529	–2,189	–2,718
Kane	250,806	278,405	317,471	27,599	39,066	66,665
Kankakee	97,161	102,926	96,255	5,765	–6,671	–906
Kendall	26,348	37,202	39,413	10,854	2,211	13,065
Lake	381,781	439,737	516,418	57,956	76,681	134,637
La Salle	111,298	112,033	106,913	735	–5,120	–4,385
Lee	37,918	36,328	34,392	–1,590	–1,936	–3,526
Livingston	40,650	41,381	39,301	731	–2,080	–1,349
McHenry	111,456	147,897	183,241	36,441	35,344	71,785
Vermilion	96,966	95,222	88,257	–1,744	–6,965	–8,709
Will	247,605	324,460	357,313	76,855	32,853	109,708
Indiana						
Benton	11,252	10,218	9,441	–1,034	–777	–1,811
Elkhart	126,436	137,330	156,198	10,894	18,868	29,762
Jasper	20,414	26,138	24,960	5,724	–1,178	4,546
Kosciusko	48,086	59,555	65,294	11,469	5,739	17,208
Lake	545,886	522,872	475,594	–23,014	–47,278	–70,292
La Porte	105,254	108,632	107,066	3,378	–1,566	1,812
Marshall	34,964	39,155	42,182	4,191	3,027	7,218
Newton	11,596	14,844	13,551	3,248	–1,293	1,955
Porter	87,068	119,816	128,932	32,748	9,116	41,864
Pulaski	12,526	13,258	12,643	732	–615	117
St. Joseph	244,652	241,617	247,052	–3,035	5,435	2,400
Starke	19,270	21,997	22,747	2,727	750	3,477
White	20,981	23,867	23,265	2,886	–602	2,284
Michigan						
Berrien	163,819	171,276	161,378	7,457	–9,898	–2,441
Wisconsin						
Jefferson	60,028	66,152	67,783	6,124	1,631	7,755
Kenosha	117,842	123,137	128,181	5,295	5,044	10,339
Milwaukee	1,053,740	964,988	959,275	–88,752	–5,713	–94,465
Racine	170,751	173,132	175,034	2,381	1,902	4,283
Walworth	63,384	71,507	75,000	8,123	3,493	11,616
Washington	63,788	84,848	95,328	21,060	10,480	31,540
Waukesha	231,165	280,326	304,715	49,161	24,389	73,550

(1987) discusses these changes in detail; selected changes are discussed here.

A number of canals were built to enable navigation between Lake Michigan and the Mississippi River. The 96 mi long Illinois and Michigan Canal was opened to traffic in 1848 (Illinois Department of Public Works and Buildings, 1969). This canal connected the Illinois River 14 mi downstream from Ottawa with Lake Michigan at Chicago. Subsequent competition from railroads led to further improvements in the Illinois River for navigational purposes; as a result, Chicago replaced St. Louis as the major center of commerce for the Illinois River Valley trade. The present navigable waterway was completed in 1939.

The city of Chicago has relied on Lake Michigan as a major source of freshwater from the time of its incorporation in 1837 (Schodek, 1987). Waste disposal was accomplished through a sewer system that fed into the Chicago River and then into Lake Michigan. Untreated sewage often would flow into the water-supply intake cribs during floods and create health hazards. During the latter one-half of the 19th century, periodic outbreaks of typhoid fever, amoebic dysentery, and cholera were attributed to contaminated lake water. In an effort to protect their Lake Michigan water supply, the city of Chicago redirected the flow of industrial and domestic wastes to the upper Illinois River system by way of the Chicago Sanitary and Ship Canal (Forbes and Richardson, 1913, 1919; Richardson, 1928). The Chicago Sanitary and Ship Canal links the Chicago River to the Des Plaines River. A second canal, the Calumet Sag Channel, links the Chicago Sanitary and Ship Canal to the Calumet River (Mades, 1987).

Diversion of Lake Michigan water was begun in 1900 at a rate of about 3,000 ft^3/s. Of this amount, about 1,200 ft^3/s was used for water supply and the remainder was used to dilute domestic and industrial wastes. The allowable rate of diversion varied over the years with maximum diversions of about 8,470 ft^3/s occurring during the late 1920’s. Guidelines, outlined in a 1980 amendment to the 1967 Supreme Court Decree, limit the diversion, including withdrawals for water supply, to an average of 3,200 ft^3/s over a 40-year running accounting period (Espey and others, 1981).

Water-quality conditions in the UIRB were dramatically affected by these diversions, but water quality has improved since wastewater-treatment practices were begun. The Metropolitan Sanitary District of Greater Chicago (now called the Metropolitan Water Reclamation District of Greater Chicago, or MWRDGC) began operation of the first large-scale treatment plant in 1922 (Metropolitan Sanitary District of Greater Chicago, 1982). As a result of the Clean Water Act, the U.S. Environmental Protection Agency (USEPA) helped to finance improvements for wastewater treatment in order to reduce municipal and industrial pollution (U.S. Environmental Protection Agency, 1979). In 1982, MWRDGC treatment plants served an area of 870 mi^2, including Chicago and 124 communities in Cook County. These plants treated a domestic wastewater load of 5.1 million persons and an industrial load equivalent to 4.5 million persons (Terrio, 1994). The return flow from these treatment operations averaged 2,200 ft^3/s. In 1983–84, MWRDGC ceased chlorination of wastewater at three treatment plants because chlorination provided limited benefits to the streams receiving the treated wastewater and possibly affected aquatic life. (Terrio, 1994). In addition, implementation of Chicago’s Tunnel and Reservoir Plan (TARP), a series of tunnels and reservoirs that capture overflow from combined sewers and store the water until it can be treated, resulted in improved quality and controlled quantity of effluent discharged from Chicago’s wastewater-treatment plants (Terrio, 1994).

Despite improvements in the effectiveness of wastewater-treatment plants since 1900 (U.S. Environmental Protection Agency, 1979; 1989), point sources in the Chicago area continue to be major sources of nutrients and contaminants in the UIRB. Approximately 196 wastewater-treatment plants discharge wastewater to streams in the UIRB, the majority of which are located in the greater Chicago area (U.S. Environmental Protection Agency, 1997b).

Agricultural practices in the lower Fox, Des Plaines, and Kankakee River Basins changed appreciably during the 1940’s and 1950’s, nearly a century after these basins were first developed for agricultural purposes. Increasing demands for corn and soybeans in domestic and international markets caused an intensification in the cultivation of these row crops. Commercial fertilizers and pesticides were used in larger amounts to increase crop yields and profits. The practice of crop rotation decreased, and fall plowing increased. Irrigation, especially in the Indiana part of the Kankakee River Basin, has steadily increased. A nationwide study of water-quality trends concluded that trends in concentrations of total phosphorus and total nitrate observed from 1974 to 1981 show strong associations with measures of agricultural activity, such as fertilizer application rates (Smith and others, 1987). Because these intensified agricultural practices were effecting water quality negatively at the same time that wastewater-treatment improvements were effecting water quality positively, expected improvements in water quality have not been as dramatic as anticipated.

Streamflow Characteristics

Streamflow in the study area consists of overland flow, ground-water discharge, and point-source return flow. Overland flow is rainwater or snowmelt that flows over the land surface toward stream channels. Ground-water discharge enters stream channels from springs or as seepage. Typically, point-source return flow is previously used water that is discharged to streams from industrial and municipal wastewater-treatment facilities. In the UIRB, the original source of return-flow water is often ground water or Lake Michigan water and, thus, represents water introduced to the surface-water system that may not have been present under natural conditions.

The mean annual flow from the upper Illinois River Basin is estimated at 12,600 ft^3/s, on the basis of streamflow records from gaging stations near the terminus of the basin (fig. 18 and table 5). These stations, the Fox River at Dayton, Ill. (05552500), and the Illinois River at Marseilles, Ill. (05543500), have been in operation since 1915 and 1919, respectively. In 1997, there were 78 active streamflow-gaging stations operated by the USGS in the study area (fig. 19, table 5).

Effects of geology and natural land-surface features on streamflow are indicated by the differences in flow-duration characteristics for rivers that receive little return flow, such as the upper reaches of the Kankakee River, the Iroquois River, and the upper Fox River (table 6). The drainage area size and land use above streamflow-gaging stations on the Kankakee and Iroquois Rivers are similar, but the clayey soils in the Iroquois River Basin result in slower infiltration of precipitation and less ground-water discharge and, thus, greater variations in streamflow. In fact, the index of variability for the Iroquois River station is almost 10 times greater than that for the Kankakee River station (table 6). In the upper Fox River Basin, the large percentage of low, poorly drained land and numerous lakes provide natural storage that affects streamflow in a manner similar to that of the sandy soils of the upper Kankakee River Basin.

Seasonal streamflow characteristics are consistent throughout the study area. The highest mean monthly streamflow of all streams and rivers generally occurs during June or July, and the lowest mean monthly streamflow generally occurs during December or January (fig. 20).

Streamflow data analyzed during the UIRB NAWQA pilot study indicated that flow trends during 1978–86 were above the long-term average at many streamflow-gaging stations (Schmidt and Blanchard, 1997). Presently, these trends are continuing. Regression analyses indicate significant increases in streamflow at a majority of stations for the period 1950–97 (table 7). Analysis of precipitation records for the 1950–90 period showed no significant trend (National Oceanic and Atmospheric Administration, 1995); therefore, increased precipitation probably is not the source of the increased streamflow. For streamflow analysis, three flow regimes were analyzed: 7-day low flow, mean annual flow, and maximum annual flow. Mean annual streamflows increased during the 1950–97 period at all seven stations shown in table 7, which include streamflow in all the major subbasins of the upper Illinois River Basin. The 7-day low flow also increased at five of the seven stations analyzed, while maximum flow increased at three of the seven stations. The most dramatic increases occurred at stations draining urbanized land, although there also were increases at stations draining agricultural land.

The largest increase in mean annual streamflow from 1950 to 1997 was 84 percent at the Des Plaines River at Riverside, Ill. (05532500). However, further analysis of mean annual streamflow data indicate a step increase around 1980. The two major wastewater-treatment plants upstream from this station began operations in 1975 and 1980, and contributed an average of about 32 and 53 ft^3/s, respectively, to the

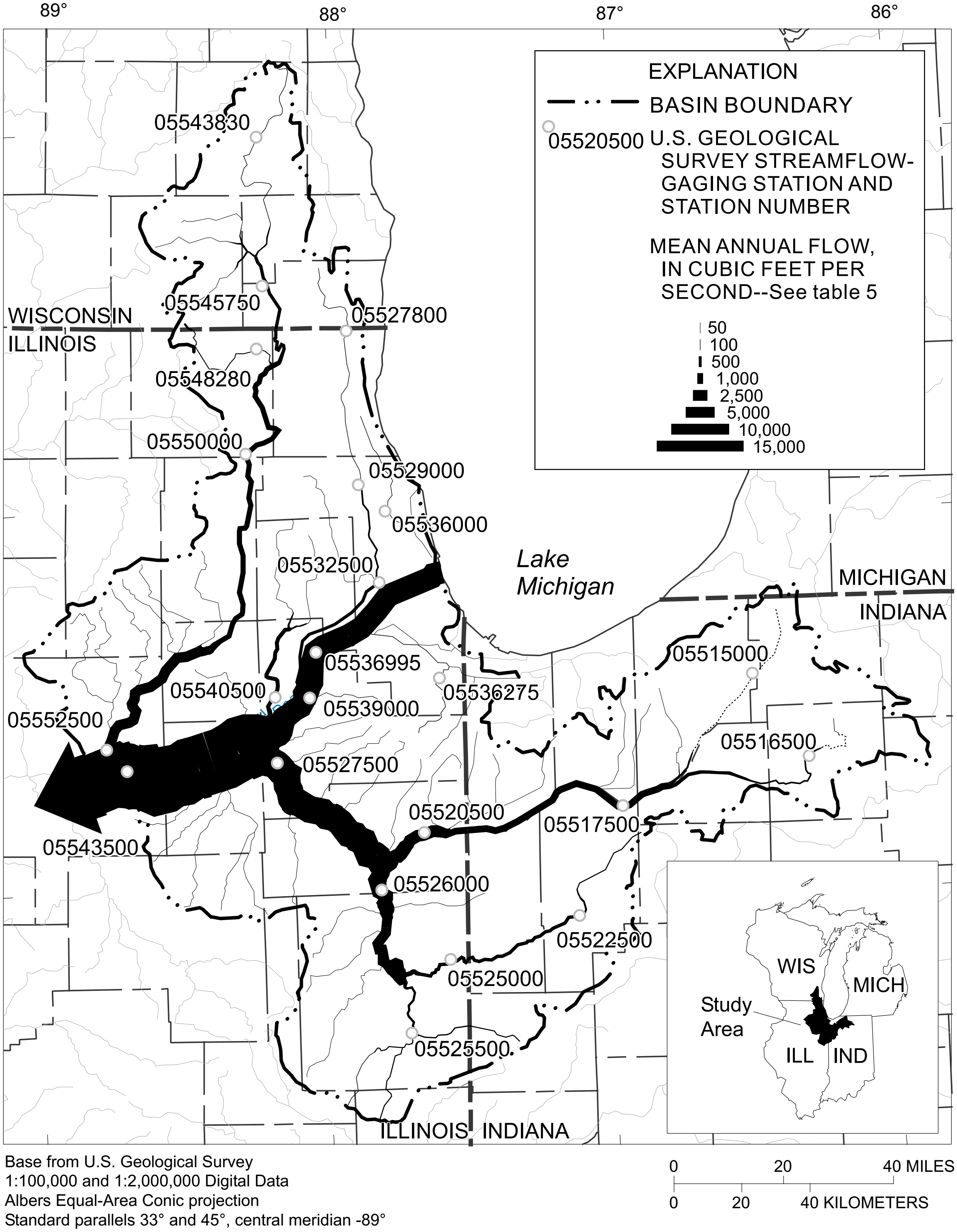


Figure 18. Mean annual streamflows calculated for the upper Illinois River Basin.

Table 5. Active U.S. Geological Survey streamflow-gaging stations in the upper Illinois River Basin, 1997

[USGS, U.S. Geological Survey; mi^2, square mile; ft^3/s, cubic feet per second]

USGS station number (fig. 19)	Site name	Drainage area (mi^2)	Start of record (water year[1])	Mean annual discharge (ft^3/s)
	Illinois River Basin			
05543500	Illinois River at Marseilles, Ill.	8,259	1919	10,820
	Fox River Basin			
05543800	Fox River at Watertown Road near Waukesha, Wis.	77.4	1993	73.2
05543830	Fox River at Waukesha, Wis.	126	1963	104
05544200	Mukwonago River at Mukwonago, Wis.	74.1	1973	55.6
05544385	Muskego Lake Outlet near Wind Lake, Wis.	28.3	1988	17.0
05545750	Fox River near New Munster, Wis.[2]	811	1940	561
05547755	Squaw Creek at Round Lake, Ill.	17.2	1990	15.7
05548105	Nippersink Creek above Wonder Lake, Ill.	84.5	1994	50.5
05548110	Nippersink Creek below Wonder Lake, Ill.	97.3	1994	58.2
05548280	Nippersink Creek near Spring Grove, Ill.	192	1966	152
05550000	Fox River at Algonquin, Ill.	1,403	1916	885
05550500	Poplar Creek at Elgin, Ill.	35.2	1951	26.2
05551000	Fox River at South Elgin, Ill.	1,556	1961	1,290
05551200	Ferson Creek near St. Charles, Ill.	51.7	1961	42.2
05551700	Blackberry Creek near Yorkville, Ill.	70.2	1961	54.2
05552500	Fox River at Dayton, Ill.	2,642	1915	1,792
	Kankakee River Basin			
05515000	Kankakee River near North Liberty, Ind.	[3]174	1951	161
05515500	Kankakee River at Davis, Ind.	[4]537	1905	526
05516500	Yellow River at Plymouth, Ind.	[5]294	1948	272
05517000	Yellow River at Knox, Ind.	[6]435	1905	414
05517500	Kankakee River at Dunns Bridge, Ind.	[7]1,352	1948	1,399
05517530	Kankakee River near Kouts, Ind.	[8]1,376	1975	1,565
05517890	Cobb Ditch near Kouts, Ind.	30.3	1968	34.5
05518000	Kankakee River at Shelby, Ind.	[9]1,779	1923	1,702
05519000	Singleton Ditch at Schneider, Ind.	123	1948	116
05520500	Kankakee River at Momence, Ill.	[10]2,294	1905	2,081
05521000	Iroquois River at Rosebud, Ind.	35.6	1948	28.9
05522500	Iroquois River at Rensselaer, Ind.	203	1948	184
05524500	Iroquois River near Foresman, Ind.	449	1949	409
05525000	Iroquois River at Iroquois, Ill.	686	1945	589
05525500	Sugar Creek at Milford, Ill.	446	1948	380
05526000	Iroquois River near Chebanse, Ill.	2,091	1923	1,741
05527500	Kankakee River near Wilmington, Ill.	5,150	1934	4,709
	Des Plaines River Basin			
05527800	Des Plaines River at Russell, Ill.	123	1967	97.9
05527950	Mill Creek at Old Mill Creek Ill.	61.0	1990	52.4
05528000	Des Plaines River near Gurnee, Ill.	232	1946	237
05528500	Buffalo Creek near Wheeling, Ill.	19.6	1952	18.1
05529000	Des Plaines River near Des Plaines, Ill.	360	1941	289
05529500	McDonald Creek near Mount Prospect, Ill.	7.93	1952	6.15
05530000	Weller Creek at Des Plaines, Ill.	13.2	1951	10.4
05530990	Salt Creek at Rolling Meadows, Ill.	30.5	1974	31.5

Table 5. Active U.S. Geological Survey streamflow-gaging stations in the upper Illinois River Basin, 1997—Continued

USGS station number (fig. 19)	Site name	Drainage area (mi^2)	Start of record (water year[1])	Mean annual discharge (ft^3/s)
Des Plaines River Basin—Continued				
05531300	Salt Creek at Elmhurst, Ill.	91.5	1989	144
05531500	Salt Creek at Western Springs, Ill.	115	1946	128
05532000	Addison Creek at Bellwood, Ill.	17.9	1950	16.5
05532500	Des Plaines River at Riverside, Ill.	630	1944	538
05533000	Flag Creek near Willow Springs, Ill.	16.5	1951	20.9
05533400	Sawmill Creek near Lemont, Ill.	13.0	1986	11.1
05534500	North Branch Chicago River at Deerfield, Ill.	19.7	1952	16.3
05535000	Skokie River at Lake Forest, Ill.	13.0	1952	12.4
05535070	Skokie River near Highland Park, Ill.	21.1	1967	21.6
05535500	West Fork of North Branch Chicago River at Northbrook, Ill.	11.5	1952	13.6
05536000	North Branch Chicago River at Niles, Ill.	100	1951	100
05536105	North Branch Chicago River at Albany Avenue at Chicago, Ill.	113	1990	137
05536179	Hart Ditch at Dyer, Ind.	37.6	1990	47.7
05536190	Hart Ditch at Munster, Ind.	70.7	1942	69.0
05536195	Little Calumet River at Munster, Ind.	90.0	1958	73.6
05536215	Thorn Creek at Glenwood, Ill.	24.7	1949	39.8
05536235	Deer Creek near Chicago Heights, Ill.	23.1	1948	18.9
05536255	Butterfield Creek at Flossmoor, Ill.	23.5	1948	18.4
05536265	Lansing Ditch near Lansing, Ill.	8.84	1948	8.21
05536275	Thorn Creek at Thornton, Ill.	104	1948	106
05536290	Little Calumet River at South Holland, Ill.	208	1948	189
05536340	Midlothian Creek at Oak Forest, Ill.	12.6	1951	12.1
05536357	Grand Calumet River at Hohman Ave. at Hammond, Ind.	Indeterminate	1992	45.7
05536500	Tinley Creek near Palos Park, Ill.	11.2	1951	11.0
05536995	Chicago Sanitary and Ship Canal at Romeoville, Ill.	739	1985	[11]3,493.
05537500	Long Run near Lemont, Ill.	20.9	1951	17.7
05539000	Hickory Creek at Joliet, Ill.	107	1945	88.9
05539900	West Branch Du Page River near West Chicago, Ill.	28.5	1961	36.2
05540060	Kress Creek at West Chicago, Ill.	18.1	1986	16.5
05540091	Spring Brook at Forest Preserve near Warrenville, Ill.	6.83	1992	14.8
05540095	West Branch Du Page River near Warrenville, Ill.	90.4	1969	105
05540130	West Branch Du Page River near Naperville, Ill.	123	1989	152
05540160	East Branch Du Page River near Downers Grove, Ill.	26.6	1990	48.8
05540195	St. Joseph Creek at Route 34 at Lisle, Ill.	11.1	1989	8.72
05540250	East Branch Du Page River at Bolingbrook, Ill.	75.8	1989	108
05540275	Spring Brook at 87th Street near Naperville, Ill.	9.90	1988	10.3
05540500	Du Page River at Shorewood, Ill.	324	1941	286

[1]One water year is from October through September.
[2] Prior to 1993, published as “at Wilmot”, 05546500.
[3] Of the drainage area listed for this site, 58.2 mi^2 is probably noncontributing.
[4] Of the drainage area listed for this site, 137 mi^2 is probably noncontributing.
[5] Of the drainage area listed for this site, 22 mi^2 is probably noncontributing.
[6] Of the drainage area listed for this site, 51 mi^2 is probably noncontributing.
[7] Of the drainage area listed for this site, 192 mi^2 is probably noncontributing
[8] Of the drainage area listed for this site, 194 mi^2 is probably noncontributing.
[9] Of the drainage area listed for this site, 201 mi^2 is probably noncontributing.
[10] Of the drainage area listed for this site, 201 mi^2 is probably noncontributing.
[11] Mean-annual discharge based on period of 1993–96 record.

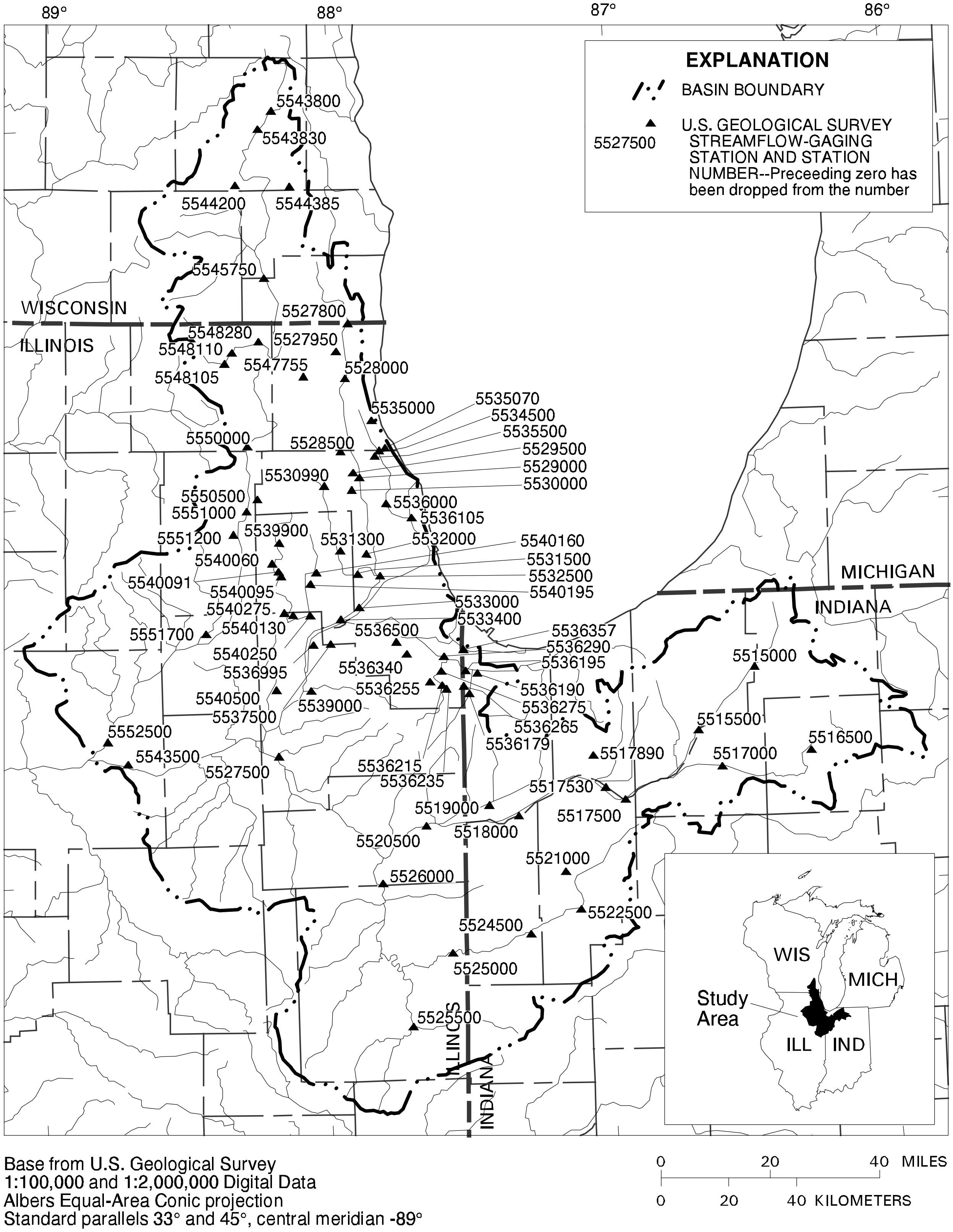


Figure 19. Active U.S. Geological Survey streamflow-gaging stations in the upper Illinois River Basin, 1997.

streamflow at this station during 1978–88 (Terrio, 1994). During the period 1975–97, mean annual streamflow was 682 ft^3/s compared with 565 ft^3/s for the period 1950–97. Although there was an increase above the additional discharge from the wastewater-treatment plants, most of the increase in streamflow at this station is due to effluent return flow. Prior to 1975, effluent from this part of the Chicago area was treated at wastewater-treatment plants that discharged to the Chicago Sanitary and Ship Canal.

Streamflow data at the other stations shown in table 7 are normally distributed and seem to indicate a more gradual increase in flows. These trends are probably the result of three factors: land-use changes that have resulted in less infiltration and faster runoff of precipitation from the basins; gradually increasing ground-water pumpage and/or use of Lake Michigan waters; and the associated increase in wastewater-treatment plant effluent return flows. In urban areas, less infiltration and faster runoff result from an increase in impervious surfaces including roads, parking lots, and buildings. In agricultural areas, less infiltration and faster runoff result from the trend toward more intensive row-crop production and practices designed to speed drainage, including tile drains and the drainage of wetlands by ditching. In agricultural areas of the basin, an increase in the acreage of irrigated cropland probably also has contributed to increased streamflows as ground water from aquifers is brought to the surface and channeled toward streams through agricultural drainage systems.

Table 6. Flow-duration characteristics at selected streamflow-gaging stations in the upper Illinois River Basin

[Flow-duration characteristics based on records collected prior to 1998 water year; exceedance frequency is percentage of time that indicated streamflow is equaled or exceeded; USGS, U.S. Geological Survey; mi^2, square miles; ft^3/s, cubic feet per second; --, no data]

USGS streamflow-gaging station (fig. 19, table 5)	USGS station name	Period of record[1] (water year[2])	Drainage area (mi^2)	Mean annual flow (ft^3/s)	Flow at exceedance frequency for period of record at indicated percentile (ft^3/s)			Flow at exceedance frequency 1950–97 at indicated percentile (ft^3/s)			Index of variability[3]	90th percentile flow per mi^2 (ft^3/s)
					10	50 (median)	90	10	50 (median)	90		
05520500	Kankakee River at Momence, Ill.	1915–present	[4]2,294	2,066	4,300	1,580	655	4,658	1,850	712	6.5	0.34
05526000	Iroquois River near Chebanse, Ill.	1924–present	2,091	1,735	4,740	735	79	5,044	832	90	56.0	.04
05532500	Des Plaines River at Riverside, Ill.	1943–present	630	535	1,320	290	34	1,385	318	50	27.7	.08
05536995	Chicago Sanitary and Ship Canal at Romeoville, Ill.[5]	1984–present	739	3,536	5,080	3,110	2,140	--	--	--	--	--
05540500	Du Page River at Shorewood, Ill.	1940–present	324	285	618	162	46	650	176	53	12.3	.16
05543500	Illinois River at Marseilles, Ill.	1919–present	[6]8,259	10,810	19,400	9,020	4,590	19,598	7,618	4,392	4.5	.53
05550000	Fox River at Algonquin, Ill.	1915–present	1,403	884	2,000	590	186	2,167	684	224	9.7	.16
05552500	Fox River at Dayton, Ill.	1915–present	2,642	1,790	4,060	1,160	370	4,516	1,376	456	9.9	.17

[1]Continuous record shown.
[2]One water year is from October through September.
[3]Index of variability is the ratio of streamflows at the 10- and 90-percent exceedance frequencies.
[4]201 square miles probably is noncontributing.
[5]Flow statistics for this site were based on 1991–97 data.
[6]Does not include diversion from Lake Michigan through the Chicago Sanitary and Ship Canal, which has occurred since Jan. 17, 1900.

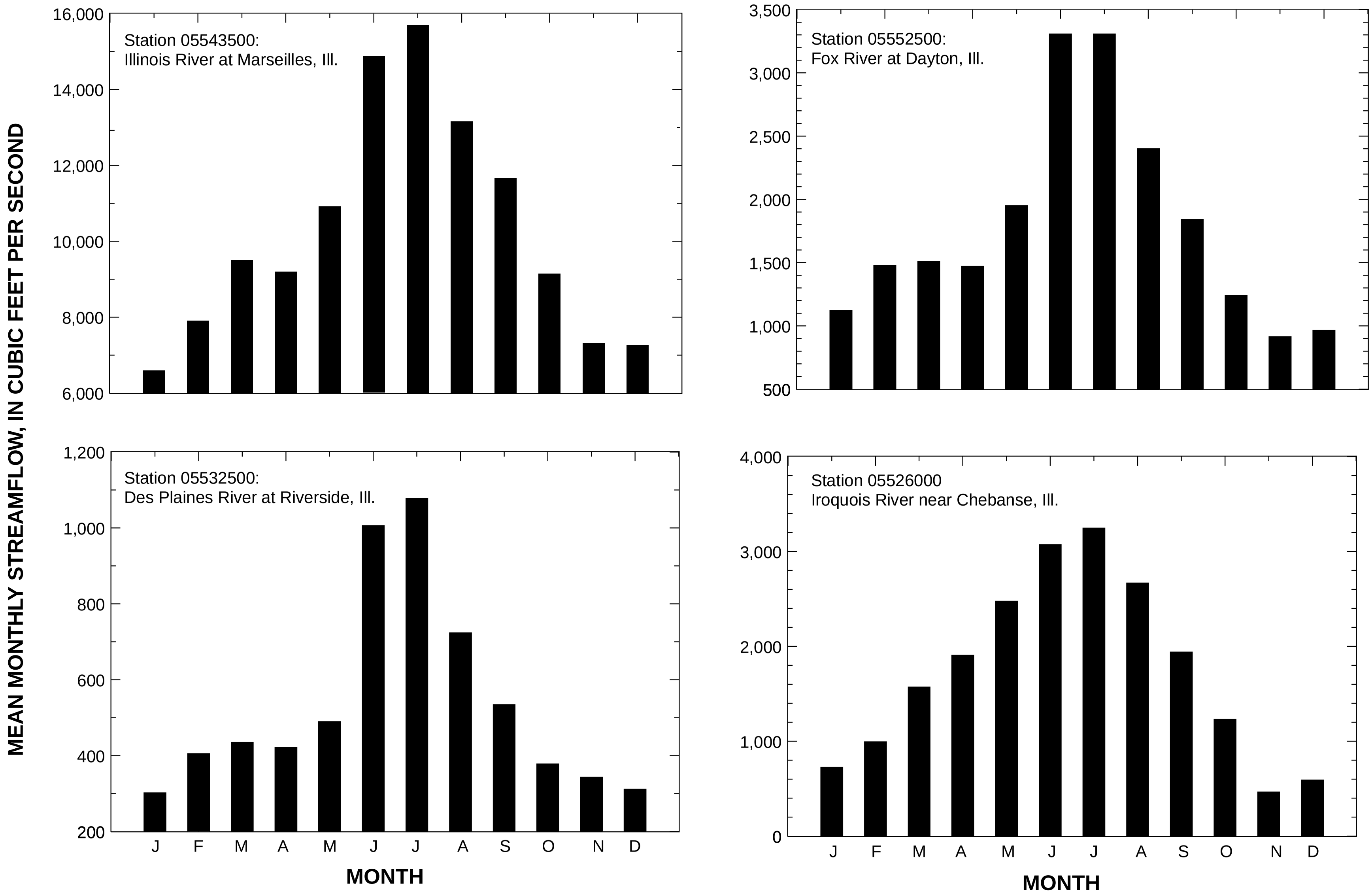


Figure 20. Mean monthly streamflow at four stations in the upper Illinois River Basin, 1950–97.

Table 7. Trends in streamflow at selected streamflow-gaging stations in the upper Illinois River Basin, 1950–97

[Trends are considered significant at $p<0.05$; USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; o, no trend; +, increasing trend; --, not applicable]

USGS streamflow-gaging station (fig. 19, table 5)	Direction of flow trend			Change in flow, in percent[1]		
	7-day low flow	Mean annual flow	Maximum annual flow	7-day low flow (ft^3/s)	Mean annual flow (ft^3/s)	Maximum annual flow (ft^3/s)
05520500	o	+	+	--	39	38
05526000	+	+	o	113	47	--
05532500	+[2]	+	+	237	84	39
05540500	+	+	o	136	72	--
05543500	o	+	o	--	26	--
05550000	+	+	o	85	50	--
05552500	+	+	+	456	48	62

[1]Percent change is defined as the average yearly change divided by the mean annual flow.
[2]Residuals were non-normal because of a step change in the data.

Floods and Droughts

Floods and droughts are caused by climatic conditions and affect surface runoff, soil moisture, stream discharge, and ground water. Local flooding generally is caused by isolated thunderstorms, whereas widespread flooding is caused by more extensive thunderstorms that cover a wide area, by rapid snowmelt in the spring, or by a combination of these factors (U.S. Geological Survey, 1991). Usually, some flooding occurs in the UIRB every year. In some years the floods are minor; in other years, floods are extensive and cause loss of life and property. The most widespread flooding to affect the UIRB was during 1943.

Floods of greater than 100-year recurrence intervals have been experienced in the UIRB a number of times since records have been kept. On July 13, 1957, local rainfall of greater than 6 in. caused 9 deaths and extensive damage in northeastern Illinois. During February and March 1985, rain fell on snow-covered areas in northeastern Illinois and was followed by a second intense rainfall period. Subsequent flooding caused 26 counties to be declared disaster areas with $10 million worth of damage. During a 2-week period from September 20 to October 3, 1986, local rains caused flooding that resulted in 4 deaths and $50 million in damages.

Heavy rainfall on August 13 and 14, 1987, caused severe flooding of urban areas by streams in Cook and Du Page Counties in Illinois. An all-time 24-hour rainfall record was set during the storm, with 9.35 in. falling at O'Hare International Airport (Chicago, Ill.). This record was more than 3 in. greater than the previous 24-hour record. The worst flooding occurred along the Des Plaines River and its tributary, Salt Creek. Record maximum peak streamflows were recorded at 10 streamflow-gaging stations on 8 streams.

Droughts are the result of more persistent climate patterns than those of floods, produce less precipitation than normal, and usually have a duration measured in years (U.S. Geological Survey, 1991). Four droughts have been severe in all or part of the basin: 1930–36, 1952–57,1962–67, and 1975–78. The most severe drought basinwide was around 1957 when precipitation was 64 percent of the average, but less severe droughts have been observed during every decade from 1920 to 1980. The most severe drought in the Midwest, one that resulted in dustbowl conditions, occurred in the 1930's. The drought of 1952–57 was the most severe in terms of deficient streamflow in Illinois and was followed by another drought of almost equal severity only 5 years later (1962–67). The last major drought observed in all or part of the basin was during 1975–78, and this drought was the least severe of the four.

Lakes and Wetlands

Few natural lakes are present in the study area, with the exception of glacial lakes in the upper Fox River Basin in Wisconsin and McHenry County, Illinois. A few small remnant glacial lakes also exist in Lake County, Illinois. There are a number of manmade lakes throughout the basin.

Many wetland types occur in the basin, including marshes and shrub swamps, sedge meadows, fens, and bogs (Sullivan, undated). These wetland types are differentiated by their time of inundation, chemical properties, water depth, place in the landscape, and the plants and animals that occupy them. Wetlands are often located between terrestrial and aquatic systems, and function in hydrological, chemical, and biological roles (Mitsch and Gosselink, 1993). Although wetlands make up a relatively small amount (1 percent) of land cover in the UIRB, a great proportion of species, including endangered and threatened species, are dependent on wetlands (Illinois Department of Energy and Natural Resources, 1994). Alteration of wetlands changes the character of streams and can affect stream water quality (Mitsch and Gosselink, 1993). Wetlands were once a major feature of the basin, but most of the wetlands in the upper Illinois River Basin were drained prior to the 1850's. The effects of such extensive wetland drainage on the hydrology and water quality of the UIRB cannot be quantified because most of the drainage was completed before water-data collection programs were established.

Development of farmland in the Kankakee Till Plain (fig. 10) was made possible by the drainage of wetland areas such as the "Grand Marsh." The Grand Marsh of the Kankakee River Basin was one of the largest wetlands in the interior United States until the early twentieth century (Mitsch and Gosselink, 1993). This marsh and swamp complex covered an area of about 400,000 acres in a corridor 3–5 mi wide on each side of the Kankakee River (Bellrose, 1976; Meyer, 1936). The wetland was a mosaic of various types of grassy wetlands, hardwood swamps, and sandy islands; and supported a rich and diverse variety of fish, wildlife, and plants (Meyer, 1936). During the middle nineteenth century, tributaries to the Kankakee River were channelized and land was cleared and drained for agriculture. Prior to these changes, the area was a prime hunting and fishing region used by Indians, European traders and settlers, and American sportsmen. Channelization of the mainstem Kankakee River began in 1906 and the entire river in Indiana was channelized by 1918. Because of channelization, the length of the Kankakee River in Indiana was reduced from about 250 mi to about 80 mi. Riparian forest wetlands between the Indiana border and Momence, Illinois, are remnants of the Grand Marsh (Ivens and others, 1981; Mitsch and Gosselink, 1993). Presently (1998), the U.S. Fish and Wildlife Service is proposing the re-creation of a 30,000-acre Grand Kankakee Marsh National Wildlife Refuge in the Kankakee River Basin.

Remaining wetlands in the UIRB are mainly in riparian areas, with the largest areas occurring along the Kankakee River on both sides of the Illinois-Indiana border and along the Des Plaines River in Wisconsin. Small wetlands are scattered about the Fox River Basin in Wisconsin and in McHenry County, Illinois, and in the upper reaches of the Kankakee River Basin in Indiana.

Water Chemistry

Information on water-quality conditions in the UIRB is widely available. The NAWQA pilot study (1986–92) produced numerous reports about (1) changes in wastewater-treatment practices and effects on water quality (Terrio, 1994); (2) trace elements in water, sediment, and biota (Fitzpatrick and others, 1995); (3) relations between fish communities and environmental factors (Ruhl, 1995); (4) nutrients, dissolved oxygen, and fecal-indicator bacteria (Terrio, 1995); (5) organic compounds in water, sediment, and biota (Sullivan and others, 1998); and produced a summary report (Schmidt and Blanchard, 1997). In addition, the Illinois Environmental Protection Agency (IEPA) produces a biannual report that summarizes results from their monitoring network (Illinois Environmental Protection Agency, 1996a, 1996b, 1996c).

Results of analyses of historical data indicate that the primary factor affecting water quality in the UIRB is land use (Schmidt and Blanchard, 1997). Distinct chemical signatures are seen in streams that drain urban land compared with streams that drain agricultural land. For trace inorganic constituents, loads were 2–13 times greater from the Chicago metropolitan area, mainly from the Des Plaines to the Illinois River (Schmidt and Blanchard, 1997). Nonagricultural synthetic organic compounds were similarly enriched in urban areas compared to agricultural areas (Sullivan and others, 1998). Although the specific pesticides differed among land use, pesticides were found in both urban and agricultural areas with a few exceptions. The most commonly used herbicide in the Midwest in the 1980's and 1990's, atrazine, was found in concentrations that exceeded USEPA standards in urban and agricultural streams (Sullivan and others, 1998).

As of 1996, IEPA samples 39 stream sites in the UIRB (Illinois Environmental Protection Agency, 1996b). At most sites, samples are analyzed for nutrients and major ions. A number of other constituents may be monitored, depending on the location of the stream and important water-quality issues.

The IEPA reports that overall water quality in the State has steadily improved over the last 26 years (Illinois Environmental Protection Agency, 1996c). The report notes declining trends in many conventional pollutants, as well as increased species diversity in the Illinois River. Much of the mainstem rivers in the upper Illinois River Basin were assessed as having “poor” water quality in 1972; in 1996 most mainstem rivers had been upgraded to “fair” and a few were classified as “good.” Most of the nonmainstem streams were assessed as having “good” water quality in 1996; most nonmainstem streams were not assessed in 1972.

Constituent loads were calculated for selected sites in the UIRB (fig. 21) with IEPA data collected during 1978–97 using the Estimator program (Cohn and others, 1989). In general, nutrient loads, as illustrated by nitrogen and phosphorus, were greatest from the urban center of the Chicago metropolitan area, reflecting the effect of wastewater return flows to the Des Plaines River and Chicago Sanitary and Ship Canal. Total-suspended solids loads were greatest from agricultural areas.

Aquatic Biological Characteristics

Water-quality assessments commonly utilize information about aquatic biology for determining the status of water resources. Perhaps the simplest approach is to use the presence of species with restrictive ecological requirements to indicate particular environmental conditions. For example, because trout require cool water, their presence can indicate that water temperature does not exceed a given threshold. A more complicated approach is to use information about the relative abundance of aquatic species to calculate various numerical indices. The Index of Biotic Integrity (IBI), which is based on the relative abundance of fish species, is one example of a widely used numerical index (Karr and others, 1986).

Although each of these approaches varies in complexity, all require an understanding of biogeography, which is the study of the geographic distribution of plants and animals, and the factors that determine those distributions. These factors fall into two broad categories: (1) ecological factors and (2) historical factors. Ecological factors include structural habitat features, water-chemistry conditions, and biological interactions such as competition and predation. Historical factors include geologic and climatic conditions acting over geologic time scales and recent influences such as introduction of constituents associated with human activities (Gilbert, 1980).

Water-resource assessments usually focus on ecological factors and recent historical influences. Assessments based solely on ecological factors and recent historical influences, however, can be inaccurate or misleading if long-term geologic and climatic factors also are not considered. This result is particularly true at regional scales, where long-term geologic and climatic antecedent conditions can be important factors affecting species distributions (Gilbert, 1980; Jackson and Harvey, 1989).

Early Biogeographic Setting

The dominant long-term geologic and climatic factors affecting presettlement species distributions in the UIRB were the glacial periods. As the Wisconsinan glaciers advanced, aquatic species were either eliminated or displaced to areas where they could exist until the ice retreated. When the glaciers retreated, species reinvaded the glaciated regions. The majority of the present-day aquatic fauna of the UIRB reinvaded by moving north from the lower Mississippi River Basin. Interconnected meltwater lakes at the southern end of the retreating glaciers enhanced this reinvasion by providing avenues for rapid dispersal. The unglaciated (driftless) region of southwest Wisconsin and northwestern Illinois also was a source for reinvasion of the UIRB. Fishes that may have reinvaded from the driftless region include northern brook lamprey (*Ichthyomyzon fossor*), central mudminnow (*Umbra limi*), brassy minnow (*Hybognathus hankinsoni*), pugnose shiner (*Notropis anogenus*), blackchin shiner (*Notropis heterodon*), and common shiner (*Luxilus cornutis*) (Burr and Page, 1986). An outlet between the Great Lakes and the Susquehanna River on the Atlantic Slope provided an invasion pathway for spottail shiner (*Notropis hudsonius*) and banded killifish (*Fundulus diaphanus*). Red shiner (*Cyprinella lutrensis*) and suckermouth minnow (*Phenacobius mirabilis*) probably came from the west through aquatic connections to the Missouri River Basin (Burr and Page, 1986). The red shiner is of particular interest because the range of this plains-adapted species is expanding eastward and this species is displacing other fishes (Burr, 1991). Although the red shiner is not historically widespread in the UIRB, this fish may be expanding its range in the region. In 1990, the red shiner was captured in the Iroquois River

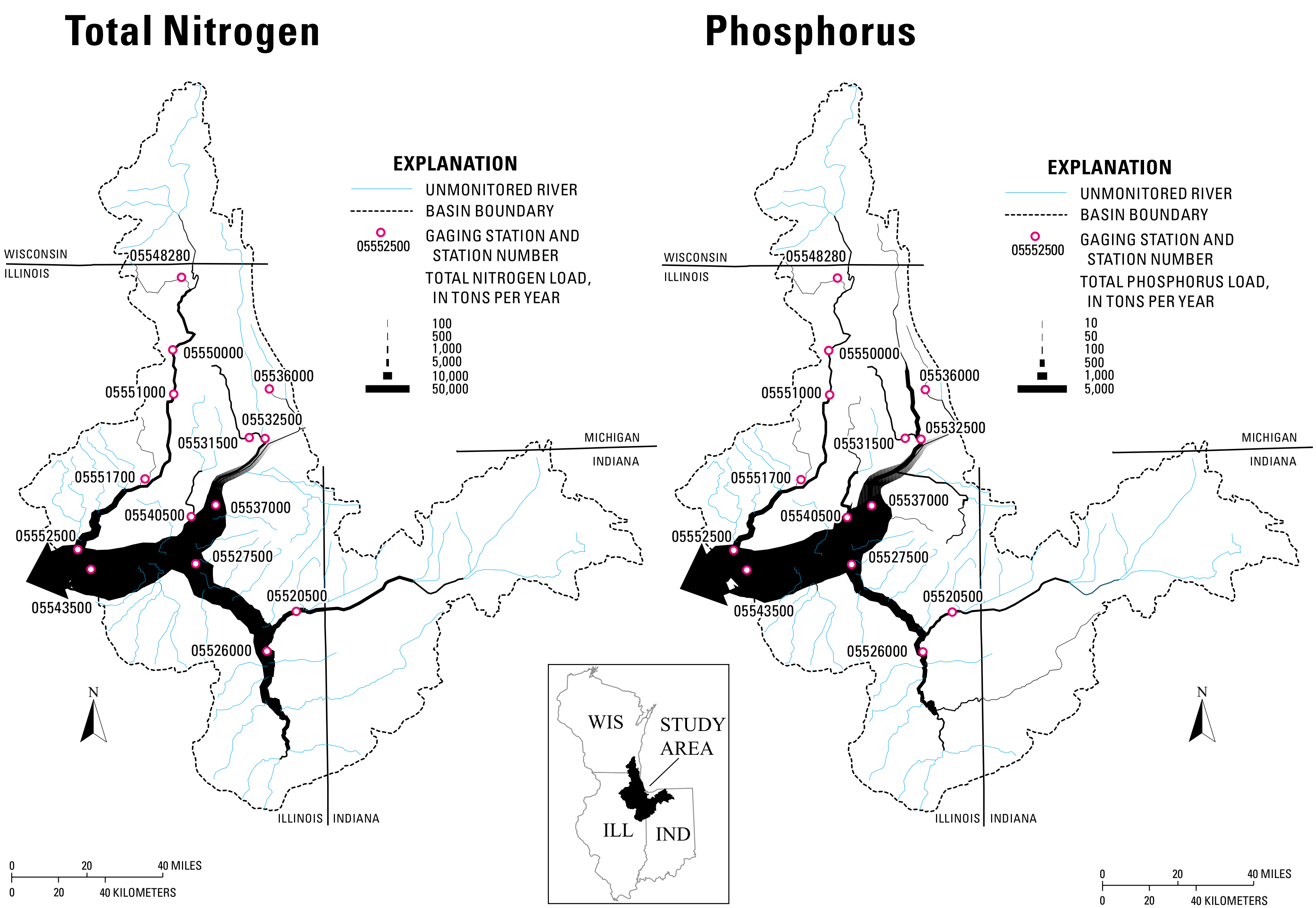


Figure 21. Loads of selected constituents in the upper Illinois River Basin.

Total Suspended Solids

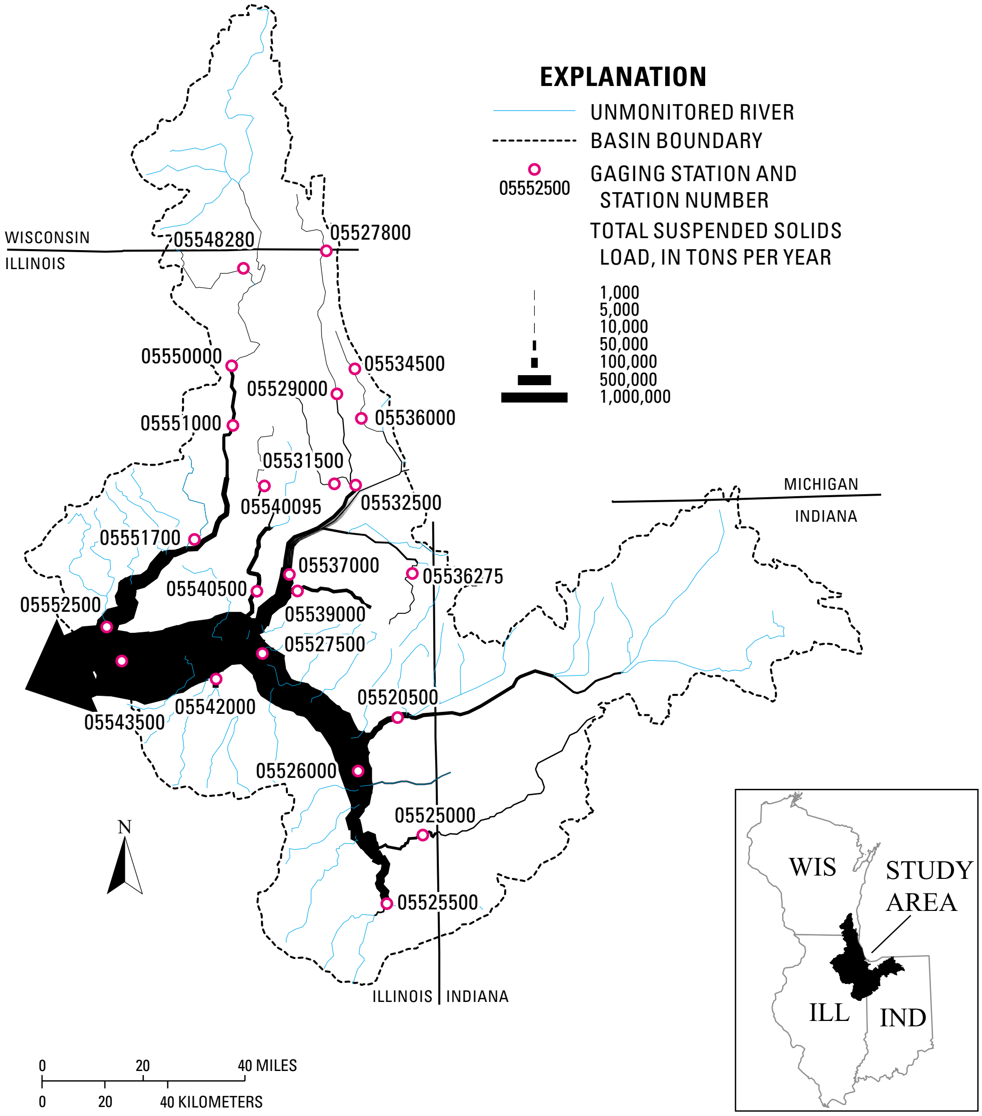


Figure 21. Continued.

Basin at stations in Illinois and Indiana (Simon, 1992).

One of the likely consequences of the Wisconsinan glaciation is that fishes that prefer small, clear streams were favored during the southern dispersal. Because water became tied up in glacial ice, rainfall declined, and the Mississippi River and its tributaries became less turbid, upland and clear-water species were able to utilize the tributaries for dispersal and refuge (Burr and Page, 1986). The pool of species available for reinvading the glaciated regions, thus, included many fishes that were adapted to small, clear streams. This fact suggests that the presettlement fish assemblage of the UIRB may have been particularly sensitive to increases in turbidity and sedimentation.

Another consequence of the Pleistocene glaciation is that the aquatic fauna of the upper midwestern United States, including the UIRB, consists of relatively few endemic species compared to other more stable regions, such as the Tennessee Uplands and the Ozark Plateau. Endemic species are those that are confined to a certain region or area. In general, areas with stable geologic and climatic history will have more endemic species than unstable regions. For example, the Great Lakes area, which also was covered by glaciers during the Pleistocene, has nine endemic fish species, whereas the climatically more stable Tennessee Uplands area has about 50 endemic fish species (Gilbert, 1980).

One of the most notable features of the aquatic biota of the UIRB is the presence of relic populations of species that have current-day distributions centered in the southern coastal plain of the Mississippi River Basin and Gulf Coast. These relic populations include those of the ironcolor shiner (*Notropis chalybaeus*) and the weed shiner (*Notropis texanus*), which are characteristic of southern lowland swamps. Both species are found in the northeastern part of the Kankakee River Basin (Burr and Page, 1986). Other relic populations found in or near the UIRB include the nonparasitic lamprey (*Ichthyomyzon cf. gagei*) and several kinds of plants. *Ichthyomyzon cf. gagei*, which is found in the southeastern United States, also may be found in Wisconsin (Lyons and others, 1997). Several southern Coastal Plain plants are found in the sandplains near Lake Michigan in southwestern Michigan and northern Indiana (Reznicek, 1994).These relic populations probably became established during an unusually warm post-glacial climatic period between 4,000 and 8,000 years ago. Subsequent climatic cooling has reduced the northern range of these populations until they are found in only a few locations in the upper Midwest (Burr and Page, 1986).

Early Aquatic Communities

Landforms created by the Pleistocene glaciations, post-glacial faunal reinvasion, and subsequent climatic variation are important factors for the development of presettlement aquatic communities in the UIRB. Although the productivity and diversity of presettlement aquatic communities were not formally cataloged, accounts of the early explorers and investigations of the late nineteenth and early twentieth century indicate these communities were large and diverse. When the first European explorers entered the Illinois River Basin, they described the area as “teeming” with fish and wildlife. Fish and waterfowl were plentiful, the mainstem of the Illinois River ran clear, and the associated backwaters and bottomland lakes had firm bottoms and luxurious stands of submerged and emergent aquatic macrophytes (Steffeck and Striegl, 1989). In 1900, prior to the opening of the Chicago Sanitary and Shipping Canal, the economic value of the commercial fishery of the Illinois River was ranked third nationally behind the salmon fishery of the Pacific Coast and the Great Lakes fishery (Steffeck and Striegl, 1989). Between 1870 and 1900, at least 38 mussel species were collected from the Illinois River (Starrett, 1971). Smith (1979) recorded 97 fish species that were captured before 1908 in the Illinois part of the UIRB.

Presettlement aquatic communities encompassed warm- to cool-water assemblages adapted to low- to moderate-gradient streams and rivers. Although level-3 ecoregion classification suggests a rather uniform environment, the glacial landforms provided diverse habitats and ecological niches. The Kankakee, upper Fox, and Des Plaines River Basins contained many small lakes, ponds, and wetlands. Some cool-water streams persist in the Little Kankakee River Basin in Indiana and in the northern Fox River Basin in Wisconsin, some of which are capable of supporting stocked trout (Fago, 1984; Robertson, 1979).

Recent Conditions and Trends

During the last 150 years, aquatic communities of the UIRB have been affected by human activities. In the State of Illinois, 7 percent of the fish species have disappeared since the turn of the century, and many more species are in decline (Illinois Department of Energy and Natural Resources, 1994). Smith (1971) listed eight conditions responsible for the extirpation or decimation of many fish populations in Illinois streams. Some of these conditions can be found in the UIRB, including: siltation; drainage of natural lakes, swamps, and prairie marshes; desiccation during drought; species interactions, including competition from nonindigenous fish; industrial, domestic, and agricultural pollution other than siltation; dams and impoundments; and increased water temperature.

One of the most notable human effects occurred between 1900 and 1920 in the Illinois River downstream from Chicago, after the Chicago Sanitary and Shipping Canal opened. The biological repercussions of industrial and domestic wastes being diverted to the upper Illinois River peaked about 1920, when plants, benthic organisms, and fish were practically eliminated from the Illinois River for about 160 mi downstream from Chicago (Richardson, 1928). Since the 1920's, there has been a gradual improvement in this reach of the Illinois River because of the improved wastewater-treatment practices upstream. Monitoring by the Illinois Natural History Survey (INHS) has documented partial recovery of fish communities. Between 1957 and 1992, common carp and goldfish dominated fish communities in the mainstem of the upper Illinois River. By 1993, however, native species had returned to the mainstem of the river and the relative abundance of common carp and goldfish had declined significantly (Sparks and Lerczak, 1993). In contrast, fish life in the bottomland lakes along the lower Illinois River has not increased to the degree anticipated from improvement in dissolved oxygen conditions (Mills and others, 1966; Sparks and Starrett, 1975).

Urban streams in the UIRB tend to have degraded aquatic communities relative to streams in agricultural areas. Studies have consistently shown that fish communities in urbanized areas generally have low IBI scores and relatively low species richness, and are often dominated by tolerant fish species such as green sunfish (*Lepomis cyanellus*) and common carp (Smith, 1971; Bertrand, 1984; Illinois Environmental Protection Agency, 1987, 1988a, 1988b, Ruhl, 1995). During the 1970's, some streams in Chicago were so degraded that no fish could be captured despite repeated sampling attempts (Dennison and others, 1997).

In contrast with urban streams, streams in predominantly agricultural areas generally have higher IBI scores and more diverse fish communities that often include several intolerant fish species (Smith, 1971; Bertrand, 1984; Illinois Environmental Protection Agency, 1987, 1988a, 1988b, Ruhl, 1995). Ruhl (1995) analyzed IEPA fish, habitat, and water-chemistry data and found differences in fish community structure in the Fox, Des Plaines, and Du Page River Basins were strongly related to water-quality gradients associated with differences between agricultural and urban land uses. Differences were only moderately related to habitat structure. Bertrand (1984) also concluded that fish communities in the Calumet, Des Plaines, and Du Page River Basins probably were limited by water quality rather than by habitat.

The contrast between urban and agricultural streams also is reflected in the IEPA's Biological Stream Characterization (BSC) of UIRB streams (Bertrand and others, 1996). The BSC is a system for classifying streams according to the status of the their aquatic biota (table 8). The BSC is based primarily on IBI scores but also is based on game fish and macroinvertebrate information as needed. In the primarily agricultural Kankakee River Basin, 74 percent of the total stream miles were classified as highly valued aquatic resources, and none were classified as limited aquatic resources. In contrast, in the more heavily urbanized Des Plaines River Basin (including the Chicago Waterways and Calumet Basins) only 7 percent of the river miles was classified as highly valued resources and 56 percent was classified as limited aquatic resources (table 9).

There is some evidence that aquatic communities in the Chicago Waterways have improved recently in response to changes in wastewater treatment and implementation of the TARP. Dennison and others (1997) have documented increased fish abundance (from an average of 43 fish per unit effort to 111 per unit effort) and fish species richness (from 41 species to 61 species) at sampling stations downstream from affected areas. They also documented an increase in the proportion of game fish (from 16 percent to 36 percent) found in the MWRDGC monitoring collections.

Nonindigenous Species

Most nonindigenous (also known as exotic, alien, or nonnative) species are regarded as negative indicators of water quality (Karr, 1995) because they often have direct negative effects on the landscape. Many nonindigenous species are able to colonize and become abundant only where water quality has already been negatively affected. Nonindigenous species may alter habitat, prey on native species, compete with native species for food and habitat, or transmit diseases or parasites (Florida Caribbean Science Center, 1998). Nonindigenous species may be introduced by intentional and accidental stocking, release from bait buckets, release of unwanted aquarium fish, escape from aquaculture facilities, and discharge of ballast water.

Nonindigenous fish species in the UIRB include the common carp (*Cyprinus carpio*), goldfish

Table 8. Biological Stream Characterization (BSC) categories

[Adapted from Bertrand and others (1996), table 1]

Stream class	BSC category	Biotic resource quality description
A	Unique aquatic resource	Excellent. Comparable with the best situations without human disturbance.
B	Highly valued aquatic resource	Good. Good fishery for important gamefish species; species richness may be below expectations for stream size or geographic region.
C	Moderate aquatic resource	Fair. Fishery consists predominantly of bullheads (*Ictalurus spp.*), sunfish (*Lepomis spp.*), and carp (*Cyprinus carpio*). Species diversity and number of intolerant fish reduced. Trophic structure skewed with increased frequency of omnivores, green sunfish, or tolerant species.
D	Limited aquatic resource	Poor. Fishery predominantly for carp; fish community dominated by omnivores and tolerant species. Intolerant macroinvertebrates rare or absent; moderate, facultative and tolerant organisms dominate benthic community. Species richness may be notably lower than expected for geographic area, stream size, or available habitat.
E	Restricted aquatic resource	Very Poor. Few fish of any species present; no sport fishery exists. Intolerant macronivertebrates absent; benthic community consists of essentially tolerant species or no aquatic life may be present. Species richness may be restricted to a few oligochaete or chironomid taxa.

Table 9. Summary of Biological Stream Characterization (BSC) of the Des Plaines, Fox, and Kankakee River Basins in Illinois

[Stream miles are shown outside the parentheses, numbers within the parentheses are percentages of the total miles in the basin]

River basin	Stream class					Total miles
	A	B	C	D	E	
Des Plaines	10.2 (1.3)	53.8 (6.7)	254.2 (32)	444 (56)	35.5 (4)	797.7
Fox	16.4 (2.4)	221.9 (32.9)	381.6 (56.6)	54.9 (8.1)	0 (0)	674.8
Kankakee	0 (0)	362.2 (74)	127.5 (26)	0 (0)	0 (0)	489.7

(*Carassius auratus*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), white perch (*Morone americana*), rudd (*Scardinius erythrophthalmus*), oriental weatherfish (*Misgurnus anguillicaudatus*), and round goby (Smith, 1979; Fago, 1984; Page and others, 1992; Sparks and Lerczak, 1993; Steingraeber and others, 1997). The common carp was introduced into the United States over 100 years ago. Today, common carp is one of the most abundant fish in many streams. Common carp is considered a pest because it disturbs habitat by stirring up the stream bottom, which uproots aquatic vegetation and increases turbidity. Goldfish, similar to common carp, are extremely tolerant and can be the most abundant fish species where habitat and water-chemistry conditions are severely degraded.

Rainbow trout and brown trout are intentionally stocked in streams in the upper Fox River Basin in Wisconsin and in the Little Kankakee River Basin in Indiana (Robertson, 1979; Fago, 1984). These basins contain streams that are able to support stocked trout because water temperatures remain relatively cool during summer.

Several additional nonindigenous fish have either recently arrived in the UIRB or have the potential to enter the basin. The round goby (*Neogobius melanostomus*), tubenose goby (*Proterorhinus marmoratus*), and the ruffe (*Gymnocephalus cernuus*) have become established in the Great Lakes and have access to the UIRB through the Chicago Waterways. The round goby, a native of Eurasia, was collected from the Little Calumet River in 1996 (Steingraeber and others, 1997). The round goby has decimated populations of mottled sculpin (*Cottus bairdi*) in the

St. Clair River near Detroit, Michigan (Jude and Crawford, 1995). Breeding populations of the grass carp (*Ctenopharyngodon idella*) and bighead carp (*Hypophthalmichthys nobilis*) are found downstream from the UIRB but may invade UIRB rivers and eventually the Great Lakes (Florida Caribbean Science Center, 1998).

The zebra mussel (*Dreissena polymorpha*) invaded the UIRB from Lake Michigan in 1991 and has spread throughout the Mississippi River Basin (Neves and others, 1996). Zebra mussels can attach to almost any hard surface, and populations can reach densities of greater than 2,000,000 per acre, threatening native mussel species and fouling water pipes.

Other nonindigenous species are of concern in the UIRB. The zooplankter (*Daphnia lumholtzi*), a type of water flea, moved upriver from the Mississippi Basin and has become established in the Illinois River. The behaviorally aggressive rusty crayfish (*Orconectes rusticus*), which first appeared in Illinois in 1973, is now found in all UIRB drainages and has displaced native crayfish species (Taylor and Redmer, 1996). In many UIRB wetlands, purple loosestrife and glossy buckthorn, two plant species originally from northern Europe, have spread rapidly and also have displaced native plants (Illinois Department of Energy and Natural Resources, 1994).

Threatened and Endangered Species

A number of aquatic species of the UIRB are listed by the individual States or by the Federal government as endangered, threatened, of special concern, or extirpated. These species include fish such as the river redhorse (*Moxostoma carinatum*) and greater redhorse (*Moxostoma valenciennesi*), mollusks such as the snuffbox (*Epioblasma triquetra*) and sheepnose (*Plethobasus cyphyus*), and a Federally endangered insect—the Hine's emerald dragonfly (*Somatochlora hineana*) (Illinois Department of Energy and Natural Resources, 1994). Nineteen fish species that historically were found in the UIRB are listed as threatened or endangered by Illinois, Indiana, or Wisconsin (table 10). The river redhorse and greater redhorse are listed by all three States as threatened, endangered, or of special concern

Table 10. Historically recorded fish species found in the upper Illinois River Basin that are listed as threatened, endangered, or of special concern by the States of Illinois, Indiana, or Wisconsin

[Upper Illinois River Basin distribution records from Smith (1979), Becker (1983), Lee and others (1980) and Kwak (1991); E, endangered; --, not applicable T, threatened; SC, special concern]

Scientific name	Common name	Listed by		
		Illinois[1]	Indiana[2]	Wisconsin[3]
Acipenser fulvescens	Lake sturgeon	E	E	--
Etheostoma exile	Iowa darter	E	--	--
Fundulus diaphanus	Banded killifish	--	T	--
Fundulus dispar	Starhead topminnow	--	--	E
Ichthyomyzon fossor	Northern brook lamprey	E	--	--
Lepomis megalotis	Longear sunfish	--	--	T
Lepomis punctatus	Spotted sunfish	T	--	--
Luxilus chrysocephalus	Striped shiner	--	--	E
Lythrurus umbratilis	Redfin shiner	--	--	T
Moxostoma carinatum	River redhorse	T	SC	T
Moxostoma valenciennesi	Greater redhorse	E	E	T
Notropis amblops	Bigeye chub	E	--	--
Notropis amnis	Pallid shiner	E	--	E
Notropis anogenus	Pugnose shiner	E	--	T
Notropis boops	Bigeye shiner	E	--	--
Notropis chalybaeus	Ironcolor shiner	T	--	--
Notropis heterodon	Blackchin shiner	T	--	--
Notropis heterolepis	Blacknose shiner	E	--	--
Notropis texanus	Weed shiner	E	--	--

[1]Illinois listings from http://www.inhs.uiuc.edu/cbd/main/TnE/fishte.html

(table 10). Lists of threatened and endangered species can change as a result of new distributional and life history information. The most up-to-date information can be accessed using the Internet (Illinois Natural History Survey, 1998; Indiana Department of Natural Resources, 1998; Wisconsin Department of Natural Resources, 1998; U.S. Fish and Wildlife Service, 1998).

Ground Water

Aquifers in the UIRB are associated with the Quaternary, Silurian-Devonian, and Cambrian-Ordovician stratigraphic systems. Surficial or unconsolidated aquifers are in the Quaternary system, whereas bedrock or consolidated aquifers are in the Silurian-Devonian or Cambrian-Ordovician systems (Friedel, 1998). Regional ground-water flow is affected by geology and, in the UIRB, is generally from west to east; intermediate and local flow is spatially variable throughout the basin (Friedel, 1998).

Surficial Aquifers

Surficial aquifers are composed of the unconsolidated Quaternary glacial deposits that overlie the bedrock in the basin (fig. 8). These deposits form one of the most productive aquifers in the UIRB and mainly consist of sand, and sand and gravel. Before water suppliers began using Lake Michigan water, the surficial aquifers supplied approximately 10 percent of the water for the urban Chicago area and almost 85 percent of the water for the rural areas in the southeastern part of the basin. Since that time, the importance of the surficial aquifers has increased. Some Chicago suburbs are growing into areas that are too far away to efficiently utilize Lake Michigan water; therefore, the ground water in surficial aquifers is under ever increasing demand (Fitzpatrick and others, 1992). Trilinear plots of water-chemistry data from Illinois indicate that the chemical composition of water from the unconsolidated aquifers is predominately calcium bicarbonate. Where unconsolidated material may be in contact with underlying shale, the chemical composition is predominately calcium sulfate.

Bedrock Aquifers

The Cambrian-Ordovician aquifer is the oldest and deepest aquifer underlying the UIRB (fig. 22). This aquifer consists of numerous alternating layers of sandstone, limestone, and dolomite. On a regional scale, each of the layers of Cambrian and Ordovician strata are hydraulically interconnected and act as a single aquifer (Visocky and others, 1985).

The Mount Simon Sandstone, Elmhurst Sandstone Member of the Eau Claire Formation, and Ironton and Galesville Sandstones (Willman and others, 1975) of the Cambrian system are important sources of freshwater north of the Kankakee River. The Mount Simon aquifer is composed of the Mount Simon Sandstone and the Elmhurst Member of the Eau Claire Formation. Ground water in this aquifer occurs under leaky artesian conditions because of the overlying relatively confining siltstone and shale beds of the Eau Claire Formation (Walton and Csallany, 1962).

The Prairie du Chien Series and Galena-Platteville Group of Ordovician age overlie the Cambrian system and yield small to moderate quantities of water. Where directly underlying drift, solution activity of water has enlarged openings in the dolomite of the Galena-Platteville Group, allowing water to flow more freely (Walton and Csallany, 1962).

The Maquoketa Shale is a confining unit of the Cambrian-Ordovician aquifer. Localized areas of recharge from the shallow, surficial aquifers to the deeper bedrock aquifers suggest that the Maquoketa Shale may not completely confine the Cambrian-Ordovician aquifer (Michael Friedel, U.S. Geological Survey, written, commun., 1998).

Dolomites and limestones of Silurian and Devonian age constitute one of the principal shallow-bedrock aquifers in the UIRB (fig. 22). The Silurian-Devonian aquifer is the uppermost bedrock aquifer and is primarily overlain by unconsolidated glacial deposits. Although the Devonian is absent throughout most of Illinois and Wisconsin, the name “Silurian-Devonian” will be used for comparisons and consistency.

Historically, the Silurian-Devonian aquifer has been heavily pumped in the basin. Pumping of the aquifer has resulted in slowly degrading water quality because heavily mineralized water has migrated upward from the deeper parts of the Elmhurst and Mount Simon sandstones (Visocky, 1997), and water has locally migrated downward from unconsolidated aquifers (Mike Friedel, U.S. Geological Survey, written commun., 1998). Trilinear plots of water chemistry data from Illinois indicate that the chemical

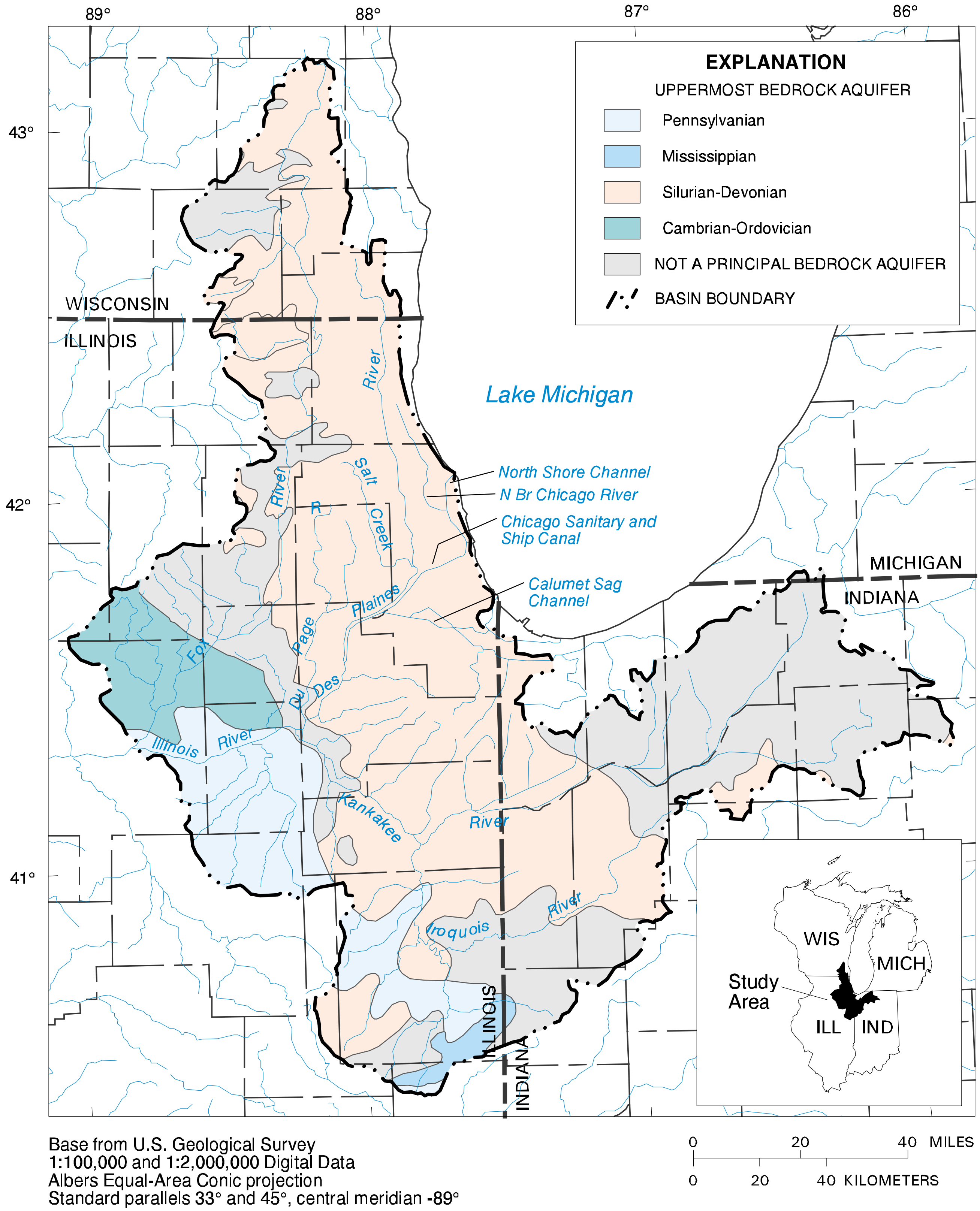


Figure 22. Uppermost bedrock aquifers in the upper Illinois River Basin (from U.S. Geological Survey, 1998).

composition of water from the Silurian-Devonian aquifers is variable and ranges from calcium bicarbonate to sodium chloride.

Over 35 percent of the ground water pumped in the Chicago area is from the Silurian-Devonian aquifer (Kirk, 1987). In 1986, western suburban Chicago heavily pumped the Silurian-Devonian aquifer for domestic, municipal, and industrial use, but a recent trend in suburban Chicago has been to switch to other water supplies including the surficial aquifers and Lake Michigan. Some of the decline in pumpage from the deep aquifer is due to communities complying with the Safe Drinking Water Standards (Visocky, 1997).

Surface-Water and Ground-Water Interactions

As precipitation infiltrates the soil and subsoil, the surficial aquifers are recharged. In areas where sand and gravel surficial aquifers directly overlie principal shallow-bedrock aquifers, water can flow downward through fissures and solution channels to recharge the bedrock aquifers. In these areas, there is good hydraulic connection between the surficial and shallow-bedrock aquifers, and recharge is local and rapid (Hughes and others, 1966). Downward leakage of water through the shallow bedrock system also can recharge deeper bedrock aquifers. The permeability of the soil and surficial deposits partially determines the rate at which infiltration occurs. If precipitation is too heavy and falls too quickly for the soil to absorb the water, runoff results. In this case, runoff directly recharges streams by overland flow.

Streams can recharge aquifers, particularly in areas where ground water is heavily pumped from wells nearby the stream. Heavy pumping can cause a decrease in hydraulic head in and near the well. In these areas, surface water can slowly flow through aquifers toward the pumping source to equalize the difference in hydraulic head (Friedel, 1998). In areas such as the lower Fox River Basin where streams are incised into the productive shallow Galena-Platteville and Ancell bedrock aquifers, ground water discharges to the stream and provides base flow to the river (Visocky and others, 1985). Additional withdrawals from these aquifers near the Fox River may reduce ground-water discharges and base flow (Fitzpatrick and others, 1992).

Water Use

During 1995, an estimated 1,375 Mgal/d was used for public-water supply in the upper Illinois River Basin. Of this total 1,375 Mgal/d used for public-water supply, 196 Mgal/d was supplied by sources of water other than Lake Michigan (table 11). Many communities in the UIRB supplement their water supply with Lake Michigan water, which is a source outside of the basin. In 1995, there were 1,179 Mgal/d withdrawn from Lake Michigan for public supply (13 percent of the total water used), up from an average of 1,070 Mgal/d percent during 1978–86. Excluding withdrawals from Lake Michigan, ground water supplies about 82 percent and surface water supplies about 18 percent of the total public-water supply for the UIRB. Increasing restrictions on the use of Lake Michigan water

Table 11. History of water use in the upper Illinois River Basin

[Mgal/d, million gallons per day]

Water-use category[1]	Source of water: Ground water (Mgal/d)			Source of water: Surface water other than Lake Michigan (Mgal/d)			Total for use category without Lake Michigan diversions (Mgal/d)		
	Average[2] 1978–86	[3]1990	[3]1995	Average[2] 1978–86	[3]1990	[3]1995	Average[2] 1978–86	[3]1990	[3]1995
Cooling/thermoelectric	0	3	3	4,060	7,698	7,668	4,060	7,701	7,671
Public-water supply	270	201	161	60	35	35	330	236	196
Rural (domestic) supply	80	65	48	0	0	0	80	65	48
Industrial and commercial	40	70	58	140	107	100	180	177	158
Irrigation	33	58	52	7	46	33	40	104	85
Total	423	397	322	4,267	7,886	7,836	4,690	8,283	8,158

[1]Mining and livestock water use not considered.
[2]From Schmidt and Blanchard, U.S. Geological Survey, written commun., 1998.
[3]From U.S. Geological Survey, 1995.

indicate that more ground water may be utilized in the future.

Thermoelectric power generation is the single largest use of water in the basin. In 1995, water used to cool electric power generating equipment accounted for 94 percent of the water withdrawn from all sources inside the UIRB. Surface water from inside the UIRB provided almost 100 percent of the water used for this purpose in 1995; less than 1 percent of the water was supplied by ground-water resources (U.S. Geological Survey, 1995).

When all water-supply sources, including Lake Michigan, are considered, ground water accounted for 19 percent and surface water accounted for 81 percent of all water used in 1995 for public and domestic supply, commercial, industrial, mining, livestock, and irrigation in the UIRB. Excluding Lake Michigan water, the percentages increase to 64 percent for ground water and decrease to 36 percent for surface water (U.S. Geological Survey, 1995).

In 1995, an estimated total of 329 Mgal/d, including water used for thermoelectric, was withdrawn from ground-water sources inside the basin (53 percent from surficial aquifers and 47 percent from bedrock aquifers). These percentages indicate that the amount of ground water used from these two aquifer types is similar and substantiates the decrease in water used from bedrock aquifers and the consequent increase in water used from the surficial aquifers. McHenry County, west of Chicago, relies totally on the surficial sand and gravel aquifer for its water supply. Continued urban expansion of Chicago is likely to increase the total urban use of the surficial aquifer in the near future. In general, there has been a major decline in water use from bedrock aquifers in the UIRB since 1986, but there has been an increase in withdrawals from surficial aquifers.

Forty-one percent of the surface water supplied from within the basin is used for industry; in contrast, only 14 percent of ground water is used for industry. Forty-nine percent of ground water supplied from within the basin is used for public drinking water; in contrast, only 19 percent of the surface water is used for this purpose. A large proportion of surface- and ground-water supply is used for irrigation, 18 percent and 16 percent, respectively (fig. 23).

IMPLICATIONS OF ENVIRONMENTAL SETTING FOR WATER QUALITY

Study Area Stratification by Natural and Human Factors

The quantity and quality of surface waters in the UIRB prior to settlement were undoubtedly much different than at present. Vast areas of wetlands have been drained for agriculture and urban development; Chicago, one of the Nation's largest metropolitan areas, has developed and continues to grow rapidly; the flow of the Chicago River has been reversed; and water diversions from Lake Michigan have been added.

The effect of natural and human factors on surface- and ground-water quantity and quality is one of the many topics studied by scientists in the NAWQA program (Hirsch and others, 1988). Previous sections of this report describe the natural and human factors that make up the general environmental setting of the upper Illinois River Basin. Important natural factors in the UIRB include bedrock geology, physiography and surficial geology, soils, vegetation, and climate. Important human factors in the UIRB include land use, urbanization, and hydrologic modifications.

In an attempt to isolate the effects of the natural and human factors that are thought to be most important in affecting water quantity and quality, an environmental framework called "stratification" was established for the UIRB. This stratification was accomplished by overlaying thematic maps of human and natural environmental factors. A similar approach has been used by other NAWQA study units. Two stratification schemes were developed—one for surface-water and one for ground-water sampling designs. Using the resulting stratification schemes, the study area can be divided into subunits with similar natural characteristics and land use.

Surface-water stratification for the UIRB was based primarily on physiography (fig. 10), with further subdivisions based on surficial geology (fig. 8) and associated soil permeability (fig. 13), and land use/land cover (fig. 16) and associated population density. This stratification, termed level-3 because of the three basic factors used, resulted in 13 subunits of the UIRB: four in the Wheaton Morainal Plain; one in the Chicago Lake Plain; three in the

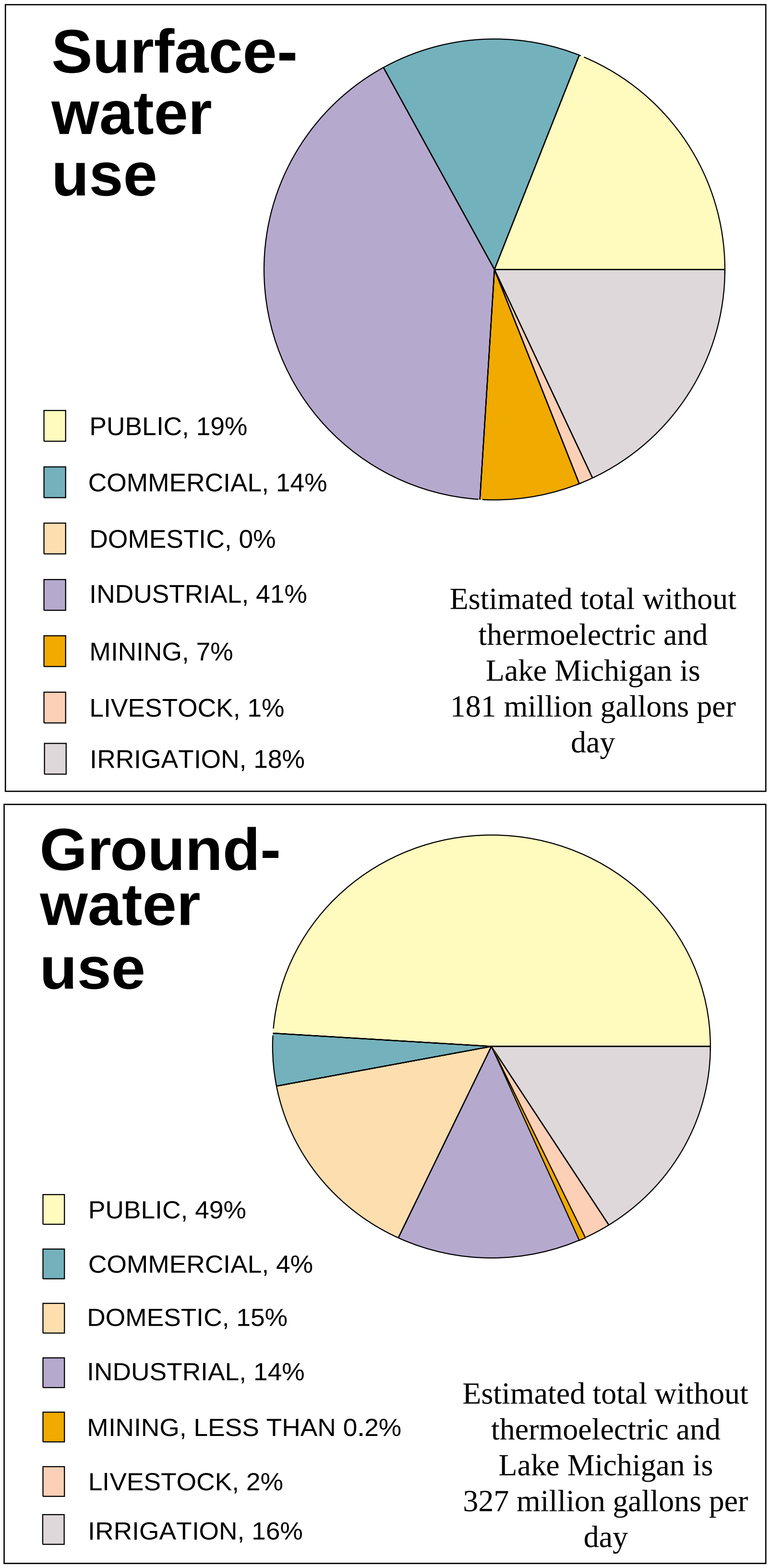


Figure 23. Surface- and ground-water use in the upper Illinois River Basin, 1995 (U.S. Geological Survey, 1995).

Bloomington Ridged Plain; four in the Kankakee Till Plain; and one in the Steuben Morainal Lake Area (fig. 24). Major surface-water issues, mainly related to differences in urban and agricultural land use, in the UIRB will be examined within the stratification scheme. Surface-water issues related to urbanization include point and nonpoint sources of sediment, nutrients, trace elements, and organic compounds; streamflow alterations; and the health and community structure of aquatic biota. Surface-water issues related to agriculture include nonpoint sources of sediment, nutrients, trace elements, and pesticides; drainage modifications; and the health and community structure of aquatic biota.

Ground-water stratification was similar to the surface-water stratification but also included bedrock geology (fig. 4A). The ground-water stratification, termed level-4 because of the four basic factors used, was preliminary and resulted in 23 subunits: six in the Wheaton Morainal Plain, one in the Chicago Lake Plain, eight in the Bloomington Ridged Plain, seven in the Kankakee Till Plain; and one in the Steuben Morainal Lake Area. Major ground-water issues in the UIRB will be examined within the stratification scheme (fig. 25). Ground-water-quality assessments will be conducted where surficial sand, and sand and gravel aquifers overlie principal bedrock aquifers. The surficial aquifers being assessed are those aquifers that underlie areas transitioning from agricultural to urban land use and that overlie the carbonate Silurian-Devonian aquifer in the Great Lakes physiographic section (Wheaton Morainal Plain), and those aquifers that underlie agricultural land use and overlie the carbonate Silurian-Devonian aquifer in the Till Plains physiographic section (Kankakee Till Plain) (fig. 25).

Surface Water and Aquatic Biota

Historical and ongoing urban land-use practices have resulted in a continuing problem of nonpoint and point source contamination of streambed sediment and aquatic biota. In addition to point sources, constituents from urban nonpoint runoff may be derived from residues from gasoline, motor oil, tires, brake linings, galvanized metal, nails, building materials, painted surfaces, pesticides, and fertilizers (Moore and Ramamoorthy, 1984; Striegl and Cowan, 1987; Leed and Belanger, 1981; Kelly and Hite, 1981, 1984). For example, streambed sediments from several urban streams of the UIRB exceeded USEPA National Sediment Inventory reference levels for trace elements (Cd, Cr, Hg, Ni, Pb, Zn) and synthetic organic compounds (heptachlor epoxide, polychlorinated byphenols (PCB's), chlordane, dichloro-diphenyl-trichloroethane (*p,p'*-DDT), dichloro-diphenyl-dichloroethane (*p,p'*-DDD), and dichloro-diphenyl-dichloroethylene (*p,p'*-DDE) (Fitzpatrick and others, 1995; Sullivan and others, 1998; U.S. Environmental Protection Agency, 1994). These reference levels were selected to represent concentrations above which might be an appreciable threat to either aquatic life or human health. The USEPA also identified four urban subbasins in the UIRB (out of 96 nationwide) as Areas of Probable Concern (APC's), on the basis of the National Sediment Inventory data (U.S. Environmental Protection Agency, 1997a). The UIRB subbasins identified as APC's are the Little Calumet, Chicago, Des Plaines, and upper Fox Rivers. Synergistic effects of these constituents on aquatic biota also are of concern because correlations were found among trace organic compounds and Cr, Cu, Hg, and Zn in streambed sediment. Concentrations of *p,p'*-DDE, chlordane, and dieldrin in whole fish from some sites in the UIRB exceeded various guidelines for protection of fish and fish-consuming wildlife and humans (Sullivan and others, 1998). Concentrations in whole fish from sites on the Des Plaines and Illinois Rivers in and downstream from Chicago exceeded U.S. Food and Drug Administration fish flesh consumption advisory levels for PCB's (Sullivan and others, 1998).

The effects of the continued expansion of Chicago suburbs into the Fox and upper Des Plaines River Basins (fig. 17) has raised several issues, including the potential for accelerated erosion and channel instability, increased flooding, increased nonpoint sources of contaminants, and further loss of aquatic habitat and biological integrity. Physical changes in streamflow and channel characteristics are primarily the result of increases in the amount of impervious surface in the drainage basin, which also has a direct effect on biological communities (Schueler, 1995).

Large navigational and hydroelectric dams are located on the Illinois, Fox, Des Plaines, and

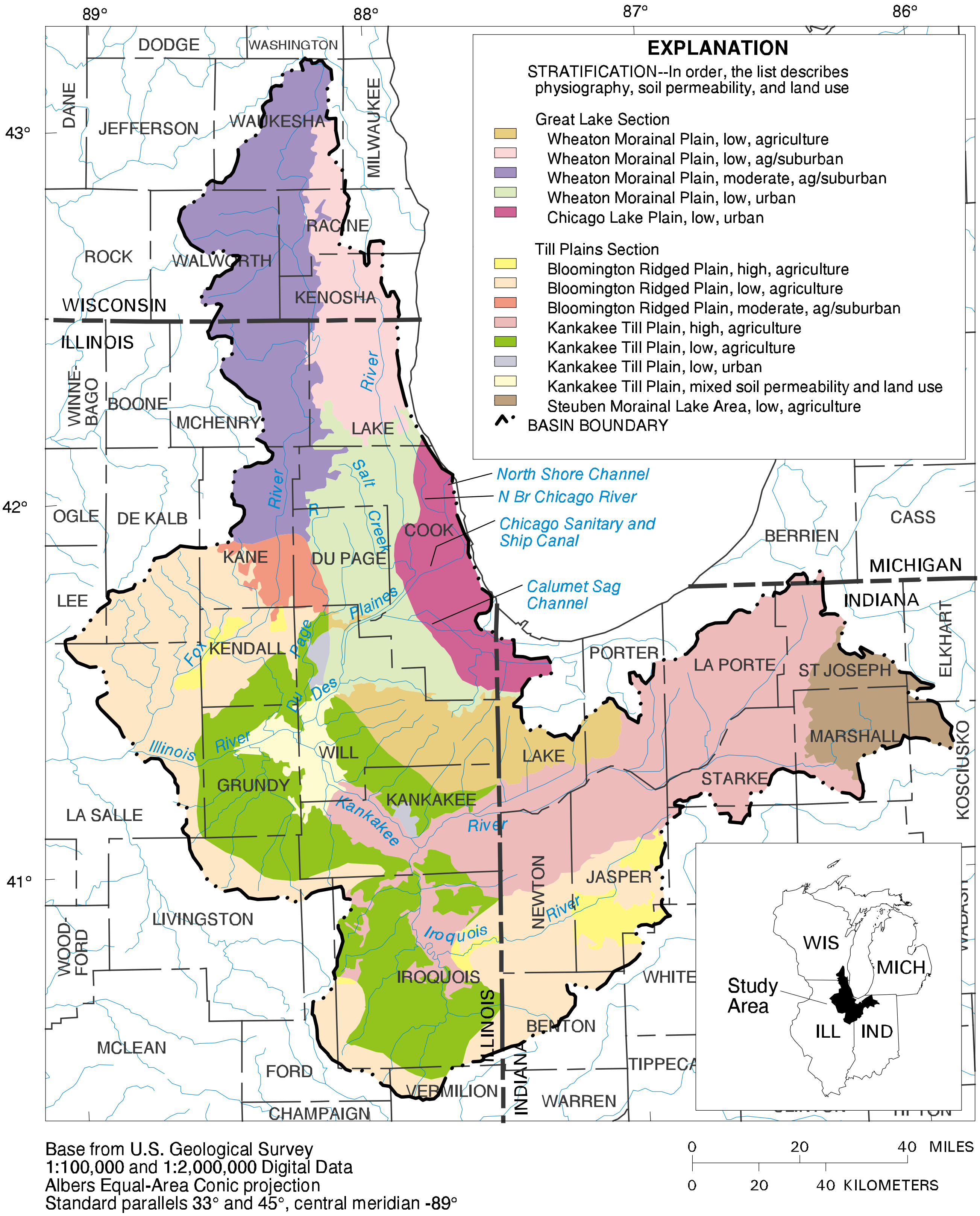
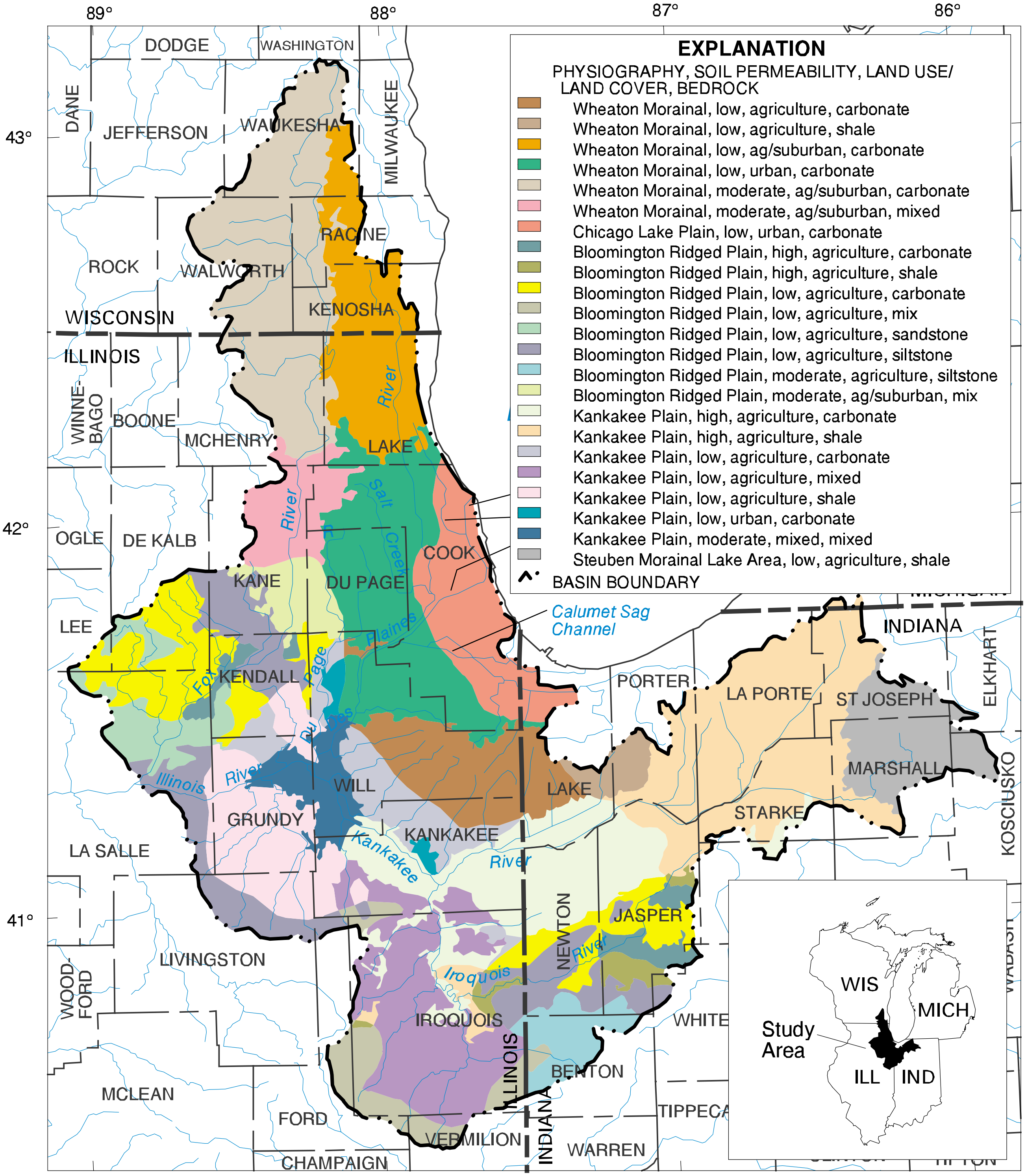


Figure 24. Level-3 surface-water stratification of the upper Illinois River Basin.



Base from U.S. Geological Survey
1:100,000 and 1:2,000,000 Digital Data
Albers Equal-Area Conic projection
Standard parallels 33° and 45°, central meridian -89°

Figure 25. Level-4 ground-water stratification of the upper Illinois River Basin.

Kankakee Rivers. These dams cause unnatural variations in streamflow characteristics and accumulations of fine-grained sediment upstream from the dam (U.S. Army Corps of Engineers, Chicago District, 1987). In addition, fish migrations are restricted by dams, and mussels are affected by sedimentation and by decreases in fish hosts critical to their reproduction.

The effects of agricultural activities on water quality in the UIRB has included changes to hydrologic conditions caused by drainage of wetlands, channelization of streams, and reduction of riparian vegetation. These changes have resulted in increased loads of suspended sediment to streams and associated turbidity caused by runoff from farm fields (fig. 21). Increased sedimentation and water turbidity reduces the food supply for fish (Bellrose and others, 1977), decreases the visibility needed by sight predators to find food, and interferes with reproductive activities (Sparks and Lerczak, 1993). In addition, disruption of the natural hydrologic regime may exacerbate these problems by affecting spawning and rearing habitats associated with backwater lakes along the lower Illinois River. The INHS is currently conducting research that focuses on characterizing relations between hydrologic regime and fish-community composition in the UIRB (Sparks, 1984; Illinois Natural History Survey, oral commun., 1998).

Elevated arsenic concentrations in sediment, fish, and clams in the Kankakee River Basin above the confluence of the Iroquois River (Coleman and Sanzolone, 1991; Fitzpatrick and others, 1995) may be related to multiple and interacting natural and human factors. Agricultural use of arsenical-based chemicals (for example, cacodylic acid) is a potential source; however, elevated arsenic concentrations were not found in the Iroquois River Basin, which is more intensively farmed than the Kankakee River Basin. Highly permeable soils (fig. 13) in the Kankakee River Basin generally require more irrigation than the fine-grained soils of the Iroquois River Basin. Shallow ground water used for irrigation in the Kankakee River Basin generally is enriched in arsenic and may contribute arsenic to streams in that basin (John Winters, Indiana Department of Environmental Management, oral commun., 1992). Weathering of shale bedrock in the region is a potential source of arsenic to ground water (Yarling, 1992; Fenelon and others, 1995).

The effect of channelization on aquatic ecosystems was discussed earlier in this report. Loss of habitat because of channelization, drainage of wetlands, and clearance of riparian vegetation has altered the characteristics of the streams in agricultural areas. The extent of these changes is unknown because agricultural activities began before water-quality conditions were documented.

Ground Water

Ground-water issues in the UIRB include water levels and water quality. Heavy withdrawals in the Chicago area beginning about 1950 caused water levels in the Cambrian-Ordovician aquifer to decline by more than 1,000 ft (Sasman and others, 1982). The effect of water-level declines were noticed as far away as Wisconsin. In 1980, the western Chicago suburbs began switching their water source to Lake Michigan or more shallow bedrock and surficial aquifers, which reduced ground-water withdrawals closer to natural recharge rates (Visocky, 1997). At the current pumpage rate, water levels are expected to recover as much as 650 ft by 2010 (Illinois Department of Energy and Natural Resources and the Nature of Illinois Foundation, 1994).

The water quality of the Silurian-Devonian aquifer is more likely to be affected by increased urbanization than the Cambrian-Ordovician aquifer. The Cambrian-Ordovician aquifer is confined by the Maquoketa Shale and is deeper than the Silurian-Devonian aquifer. Because of this relation, urbanization probably would not affect the Cambrian-Ordovician aquifer as much as it might affect the Silurian-Devonian aquifer. Volatile organic compounds (VOC's) have been detected in water supplies of communities that pump water from the Silurian-Devonian aquifer. In 1994, there was an increase in the amount of VOC and other synthetic organics detected, although the number of wells with VOC detections did not increase (Illinois Environmental Protection Agency, 1994). In addition, water-quality data indicate that the Cambrian-Ordovician aquifer contains concentrations of naturally occurring radium and barium in excess of standards set by USEPA (U.S. Environmental Protection Agency, 1975).

Arsenic in ground water in the UIRB may be considered a problem at a regional scale. Yarling (1992) found arsenic concentrations in ground water near Wakarusa, Indiana (Elkhart County), that were above the USEPA maximum contaminant level (50 ug/L). These high arsenic concentrations were detected in ground water from the deep lower Mahomet aquifer, which is composed of unconsolidated quaternary deposits. Yarling (1992) concluded that the high arsenic concentrations were probably related to chemical weathering of black shales in the area. Extensive areas of these same shale bedrock types are present in parts of the Kankakee River Basin and in east-central Illinois. These shales include the Antrim, New Albany, and Ellsworth Shales (fig. 4B), and they are generally black, enriched in metal content, and were deposited in strongly reducing conditions. Glaciers deposited black shale fragments in proglacial outwash and tills in northern Indiana. A study of aquifers in the St. Joseph River Basin near South Bend, Indiana (immediately adjacent to the headwaters of the Kankakee Basin), showed that arsenic concentrations in the deep aquifer were significantly higher than in the shallow aquifer (Fenelon and others,1995). These higher concentrations were attributed to chemical weathering of shale in the aquifer. In Illinois, Holm and Curtiss (1988) also found high arsenic concentrations in ground water. A study conducted by Warner (U.S. Geological Survey, written commun.,1998) in the LIRB NAWQA study unit found arsenic concentrations above the USEPA maximum contaminant level in some wells in the deep Mahomet aquifer, a major water resource in east-central Illinois. Elevated arsenic concentrations are present in streambed sediment and ground-water discharge areas.

SUMMARY

The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program was established, in part, to assess the status and trends of the Nation's water quality. The program objectives are accomplished through study units that encompass areas that represent a large part of the Nation's surface- and ground-water resources. The upper Illinois River Basin (UIRB) study of the NAWQA program that began in 1996 is an assessment of surface- and ground-water quality and biology. An environmental framework of human and natural factors is used to describe the similarities and differences in the hydrologic characteristics of the UIRB.

The UIRB drains a 10,949 mi^2 area upstream from Ottawa, Illinois, in northeastern Illinois, northwestern Indiana, and southeastern Wisconsin. The following major subbasins are within the UIRB: Kankakee River, Iroquois River, Fox River, Des Plaines River, Chicago River, and Illinois River.

The Silurian-Devonian limestones and dolomites form the principal shallow bedrock aquifer. The underlying Cambrian-Ordovician sandstone forms the dominant deep bedrock aquifer. Ground-water levels in the deep bedrock aquifer have changed over time. In 1986, western suburban Chicago heavily pumped the aquifer for domestic, municipal and industrial use, but a recent trend of suburban Chicago has been to switch to other water supplies such as those of shallow aquifers and Lake Michigan.

The UIRB lies in the Central Lowlands physiographic province which is subdivided into two physiographic sections: the Great Lake Section and the Till Plains Section. The subdivisions of these two sections are based on the geomorphology of the landforms in the basin, which are mostly a result of Wisconsinan glaciation. The surficial unconsolidated sand and gravel deposits form the major surficial aquifers in the UIRB. Surficial deposits are the parent material of most of the soils in the basin.

The climate of the UIRB is humid continental and large daily fluctuations in temperature and precipitation can result throughout the basin. The normalized average annual temperature for the UIRB (1961–90) ranged from 46° F in the northern part of the basin to 51° F in the southern part of the basin. Average annual precipitation for the period 1961–90 ranged from 32 in. to 38 in.

Most of the UIRB is in the Central Corn Belt Plains ecoregion. Parts of the upper Fox and upper reaches of the Des Plaines River Basins are classified in the Southeastern Wisconsin Till Plains ecoregion. The upper reaches of the Kankakee River Basin are classified as Southern Michigan/ Northern Indiana Till Plains ecoregion.

The UIRB contains Chicago, Illinois, one of the largest metropolitan areas in the United States. Urban areas around Chicago have been expanding into previously agricultural and forested areas. Subbasins within the UIRB that are mainly affected by urban expansion from the Chicago area include the Des Plaines, Du Page, and Fox River Basins. The primary crops grown in the agricultural areas of the basin are corn and soybeans.

Five major changes in the upper Illinois River Basin have altered the quality of surface waters. These changes are construction of navigable waterways, diversion of Lake Michigan water, construction of wastewater-treatment plants, drainage of wetlands, and agricultural activities. Results of historical water-quality data analysis indicate that the primary factor affecting water quality in the UIRB is land use. Distinct chemical signatures are found in streams that drain urban land compared with streams that drain agricultural land.

Aquatic biota is affected by the glacial history of the UIRB, land use, manmade modifications to water bodies and streams, and invasion of nonidigenous species. One of the consequences of past glaciation is that aquatic fauna of the UIRB has relatively few endemic species. The original aquatic communities of the UIRB were diverse and productive. During the last 150 years, aquatic communities of the UIRB have been significantly affected by human activities.

In an attempt to isolate the effects of the natural and human factors that are thought to have the most effect on water quantity and quality, an environmental framework called "stratification" was established for the UIRB. The stratification scheme divides the study area into subunits with similar natural characteristics and land use, and will be used during the UIRB study to design a framework for where to collect water and biology samples.

Surface-water issues related to urbanization include point and nonpoint sources of sediment, nutrients, trace elements, and organic compounds; streamflow alterations; and the health and community structure of aquatic biota. Surface-water issues related to agriculture include nonpoint sources of sediment, nutrients, trace elements, and pesticides; drainage modifications; and the health and community structure of aquatic biota. Ground-water issues include declining water levels and degraded water quality, and elevated arsenic concentrations in ground water.

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APPENDIX

APPENDIX 1. BIBLIOGRAPHY OF U.S. GEOLOGICAL SURVEY REPORTS FROM THE UPPER ILLINOIS RIVER BASIN PILOT STUDY OF THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

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