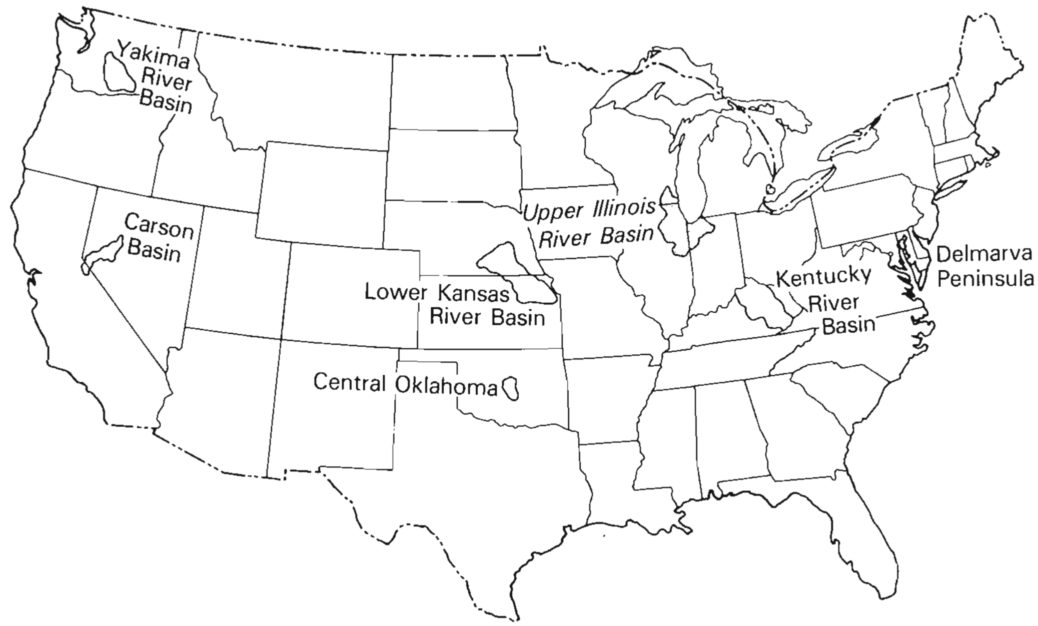
SURFACE-WATER-QUALITY ASSESSMENT OF THE UPPER ILLINOIS RIVER BASIN IN ILLINOIS, INDIANA, AND WISCONSIN: PROJECT DESCRIPTION

by D.M. Mades



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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC (INTERNATIONAL SYSTEM) UNITS

Multiply inch-pound unit	By	To obtain metric unit
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

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

$$°F = 1.8 \times °C + 32$$

SURFACE-WATER-QUALITY ASSESSMENT OF THE UPPER ILLINOIS RIVER BASIN IN ILLINOIS, INDIANA, AND WISCONSIN: PROJECT DESCRIPTION

by Dean M. Mades

ABSTRACT

In 1986, the U.S. Geological Survey began a National Water-Quality Assessment program to (1) provide nationally consistent descriptions of the current status of water quality for a large, diverse, and geographically distributed part of the Nation's surface- and ground-water resources; (2) define, where possible, trends in water quality; and (3) identify and describe the relations of both status and trends in water quality to natural factors and the history of land use and land- and waste-management activities. The program is presently in a pilot phase that will test and modify, as necessary, concepts and approaches in preparation for possible full implementation of the program in the future.

The upper Illinois River basin is one of four basins selected to test the concepts and approaches of the surface-water-quality element of the national program. The basin drains 10,949 square miles of Illinois, Indiana, and Wisconsin. Three principal tributaries are the Kankakee and Des Plaines Rivers that join to form the Illinois River and the Fox River. Land use is predominantly agricultural; about 75 percent of the basin is cultivated primarily for production of corn and soybeans. About 13 percent of the basin is urban area, most of which is located in the Chicago metropolitan area. The population of the basin is about 7 million. About 6 million people live in the Des Plaines River basin.

Many water-quality issues in the upper Illinois River basin are related to sediment, nutrients, potentially toxic inorganic and organic constituents, and to water-management practices. Occurrence of sediment and the chemical constituents in the rivers and lakes within the basin has the potential to adversely affect the water's suitability for aquatic life, recreation, or, through the consumption of fish, human health.

The upper Illinois River basin project consists of five major activities. The first activity--analysis of existing information and preparation of a report that describes recent water-quality conditions and trends--is currently underway. The second activity--fixed-station water-quality sampling at eight stations--began in April 1987 and will last at least 3 years. Water-quality data collected at these stations will be used to determine the frequency of occurrence of constituent concentrations, their annual and seasonal loads, and time trends in concentrations for a selected number of constituents. The third activity will be synoptic water-quality studies. Each study will involve sampling many sites at specific flow conditions and for selected water-quality

constituents. Information gained from these studies will supplement information gained from fixed-station sampling. A synoptic study of streambed sediments is tentatively planned for the summer of 1987 to describe the occurrence and distribution of trace elements in the basin. The fourth activity will consist of one or more topical subbasin or river-reach studies. The purpose of such studies is to better define certain water-quality conditions in specific areas and gain an understanding of the processes affecting the observed conditions. The fifth activity is the preparation of reports that will describe results from each of the first four activities.

Quality assurance and coordination are being provided at both the national and pilot-project levels. A technical quality-assurance plan that addresses all aspects of sample collection, analysis, and reporting is being prepared at the national level. This plan will be appended as needed at the pilot-project level. A National Coordinating Work Group that functions under the auspices of the Interagency Advisory Committee on Water Data and the Advisory Committee on Water Data for Public Use has been established at the national level. A local liaison committee consisting of representatives from Federal, State, and local agencies has been established to enhance communication and to ensure that the scientific information produced by the upper Illinois River basin project is relevant.

INTRODUCTION

Background

Public awareness of the importance of water quality has increased greatly in the past two decades. The Congress has passed major pieces of legislation such as the Federal Water Pollution Control Act Amendments of 1972, the Safe Drinking Water Act of 1974, the Resource Conservation Recovery Act of 1976, and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980. State and local governments and industry also have made significant commitments to water-pollution abatement.

Through these combined efforts, the quality of many of the Nation's rivers and streams has improved significantly, even though industrial activity and population have increased with corresponding increases in water use and in the volume of wastewater discharged. For example, 15 years ago, low dissolved oxygen levels were common in rivers and streams because of the discharge of large volumes of oxygen-demanding carbonaceous and nitrogenous substances. Today (1987), as a result of the construction of new wastewater treatment plants and the upgrading of existing plants, this is no longer true (Association of State and Interstate Water Pollution Control Administrators, 1984).

Despite significant progress, several water-quality issues still remain. Among them are the possible contamination of surface and ground water from nonpoint-source discharges, acid precipitation, and the disposal of hazardous waste. Cost-effective solutions to many of these potential problems may be difficult because onsite treatment solutions may not be feasible and may involve changes in industrial processes or land-use practices. Additional progress in water-quality improvement will require increased knowledge of the nature and extent of these potential problems, as well as the physical, chemical, and biological processes that affect water quality in streams and aquifers.

National Water-Quality Assessment Program

In 1986, the U.S. Geological Survey began a National Water-Quality Assessment program to (1) provide nationally consistent descriptions of the current status of water quality for a large, diverse, and geographically distributed part of the Nation's surface- and ground-water resources; (2) define, where possible, trends in water quality that have occurred over recent decades and provide a baseline for evaluating future trends in water quality; and (3) identify and describe the relations of both the status and the trends in water quality to the relevant natural factors and the history of land use and land- and waste-management practices. This information will be useful for examining the likely consequences of future management actions.

For the surface-water-quality assessments, project areas will be hydrologic subregions, of which there are 222 in the Nation (Seaber and others, 1984). The program will focus on about 90 of these subregions that account in aggregate for more than 80 percent of the surface-water withdrawals in the Nation.

At the proposed full-implementation level, the surface-water-quality assessment program would be conducted on a rotational basis, with about one-third of the designated project areas undergoing intense data acquisition and study at any one time. For any given project area, there would be a 3-year period of concentrated data acquisition and interpretation. At the conclusion of the 3-year period, reports would be written and published that will assess the quality of the water resource. Following this intensive phase, data collection in each project area would be maintained at a smaller scale for 6 years to document large changes in water quality that may occur. While 60 areas are studied at a smaller scale, major efforts would be concentrated in the other 30 project areas, and thus the level of national effort would remain constant. In any given year, the array of project areas being intensively studied would be dispersed around the Nation.

At present (1987), the National Water-Quality Assessment (NAWQA) program is in a pilot phase that will be used to verify and modify, as necessary, assessment concepts and approaches in preparation for possible full implementation of the program. The pilot phase also provides an opportunity to evaluate the potential benefits and costs of a fully-implemented program.

Seven studies have been started. Surface-water-quality assessments were started in the upper Illinois River basin in Illinois, Indiana, and Wisconsin; the lower Kansas River basin in Kansas and Nebraska; the Kentucky River basin in Kentucky; and the Yakima River basin in Washington. Ground-water quality assessments were started in the Carson basin in Nevada and California; the Central Oklahoma aquifer in Oklahoma; and the Delmarva Peninsula of Delaware, Maryland, and Virginia.

Upper Illinois River Basin Project

The upper Illinois River basin in Illinois, Indiana, and Wisconsin is a surface-water quality project area. The upper Illinois River basin was selected as a project area because of its diverse land use that includes the Chicago metropolitan area, in which about 5 percent of the Nation's population resides, and productive agricultural areas. A National plan of study has been adapted to the hydrologic and land-use conditions of the upper Illinois River basin to achieve the goals and objectives of the NAWQA program.

Specific objectives of the upper Illinois River basin project are to (1) define existing surface-water quality; (2) define trends in surface-water quality; (3) calculate average annual constituent transport; and (4) evaluate the impacts of different land uses on stream-water quality and identify stream reaches where water quality is adversely impacted by natural processes or human activities.

Purpose and Scope

This is the first report from the study of the upper Illinois River basin. The purpose and scope of this report are to (1) describe the upper Illinois River basin; (2) summarize the general surface-water quality based on existing reports; (3) depict major water-quality issues; and (4) describe the upper Illinois River basin project.

DESCRIPTION OF THE UPPER ILLINOIS RIVER BASIN

The upper Illinois River basin is the area drained by the Illinois River at a point just downstream from the mouth of the Fox River near Ottawa, Illinois (fig. 1). The basin coincides with hydrologic subregion 0712 as defined by the U.S. Water Resources Council (Seaber and others, 1984). The upper Illinois River drains 10,949 square miles (mi^2) in parts of northeastern Illinois, northwestern Indiana, southeastern Wisconsin, and southwestern Michigan (Healy, 1979). The percentages of total basin drainage area in those States are 62, 28, 10, and less than 1 percent, respectively. For expediency, the part of the upper Illinois River basin in Michigan will not be mentioned.

The basin is drained by three principal rivers--the Kankakee, Des Plaines, and Fox Rivers. The Kankakee and Des Plaines Rivers join near Morris, Illinois, to form the Illinois River. The Fox River discharges to the Illinois River at the southwestern boundary of the basin near Ottawa, Illinois.

The largest part of the basin is drained by the Kankakee River. Its headwaters begin in northwestern Indiana in St. Joseph County from which the river flows westward 130 miles to its confluence with the Des Plaines River. The Kankakee River drains 5,165 mi^2, or 47.2 percent, of the project area.

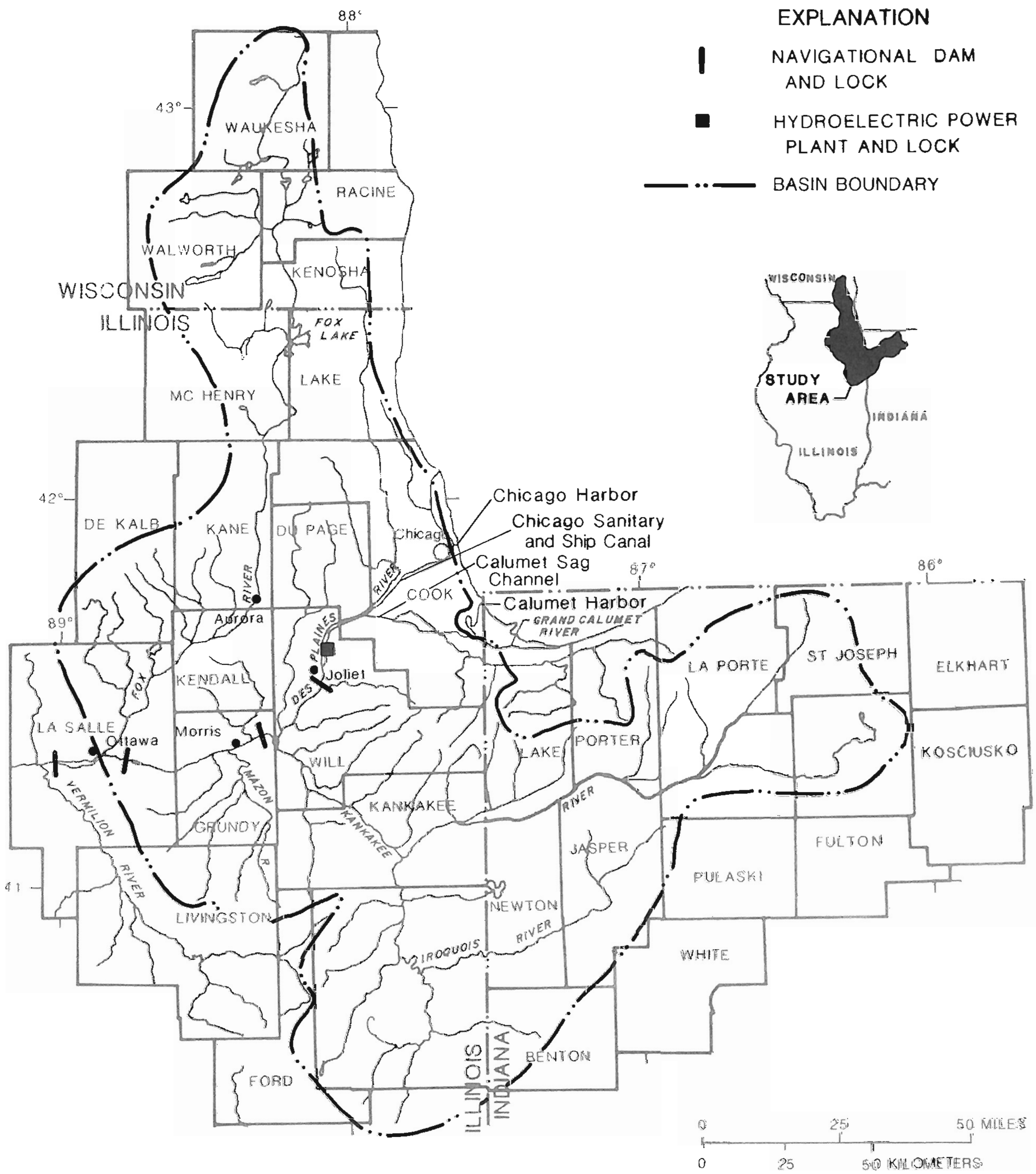

Figure 1.--Location of the upper Illinois River basin.

The Fox River drains the second largest part of the basin. From its headwaters in southeastern Wisconsin in Waukesha County, the Fox River flows southward 180 miles to the Illinois River. The Fox River drains 2,658 mi^2 or 24.3 percent of the upper Illinois River basin.

The third largest part of the basin is drained by the 130-mile long Des Plaines River. It flows southward from its headwaters in Wisconsin near the Illinois-Wisconsin border to its confluence with the Kankakee River. The Des Plaines River drains 2,111 mi^2, or 19.3 percent of the project area, and includes 673 mi^2 that originally drained to Lake Michigan through the Chicago and Calumet Rivers. Locks and controlling works at Chicago Harbor and a navigation dam 7 river miles inland from Calumet Harbor (fig. 1) now form the drainage divide between the Lake Michigan and Illinois River basins. The project-area boundary also crosses several tributaries to the Calumet River system near the Illinois-Indiana border where the natural drainage divide is so low that reversals in streamflow commonly occur during storms.

The combined drainage areas of the Kankakee, Des Plaines, and Fox Rivers comprise 90.8 percent of the project area. The remaining 9.2 percent, or 1,015 mi^2, is drained by tributaries that discharge to the 33-mile long main stem of the Illinois River between Morris and Ottawa, Illinois. From Ottawa, the Illinois River flows west and southwest 240 miles to the Mississippi River.

The Illinois River, lower Des Plaines River, and two canal systems in the Chicago metropolitan area provide a navigable link between Lake Michigan and the Mississippi River. A minimum channel depth of 9 feet is created by 5 dams in the project area (fig. 1) and 3 dams on the Illinois River downstream from the project area. The Chicago Sanitary and Ship Canal links the Chicago River and Des Plaines River. The entrance to this canal system is at Chicago Harbor at Chicago (fig. 1). A second canal, the Calumet Sag Channel, links the Chicago Sanitary and Ship Canal to the Calumet River which can be entered at Calumet Harbor near the Illinois-Indiana border (fig. 1).

Physiography and Geology

The upper Illinois River basin lies in what was originally a prairie plain. Most of the underlying bedrock surface is covered by deposits of glacial material (glacial drift). Advances and recessions of glaciers during five major glacial periods modified deposits laid down during preceding periods. The present land forms in the study area are a result of the last major glaciation during the Wisconsinan Stage and subsequent erosion by wind and rain.

Land forms in the basin were first characterized by Fenneman (1938) who described two physiographic regions, the Great Lakes section and Till Plains section (fig. 2). Leighton and others (1948) later subdivided each of the Illinois part of these sections into two subsections. The Great Lakes section was subdivided into the Chicago Lake Plain and Wheaton Morainal Country subsections. The Till Plains section was subdivided into the Kankakee Plains and the Bloomington Ridged Plain subsections.

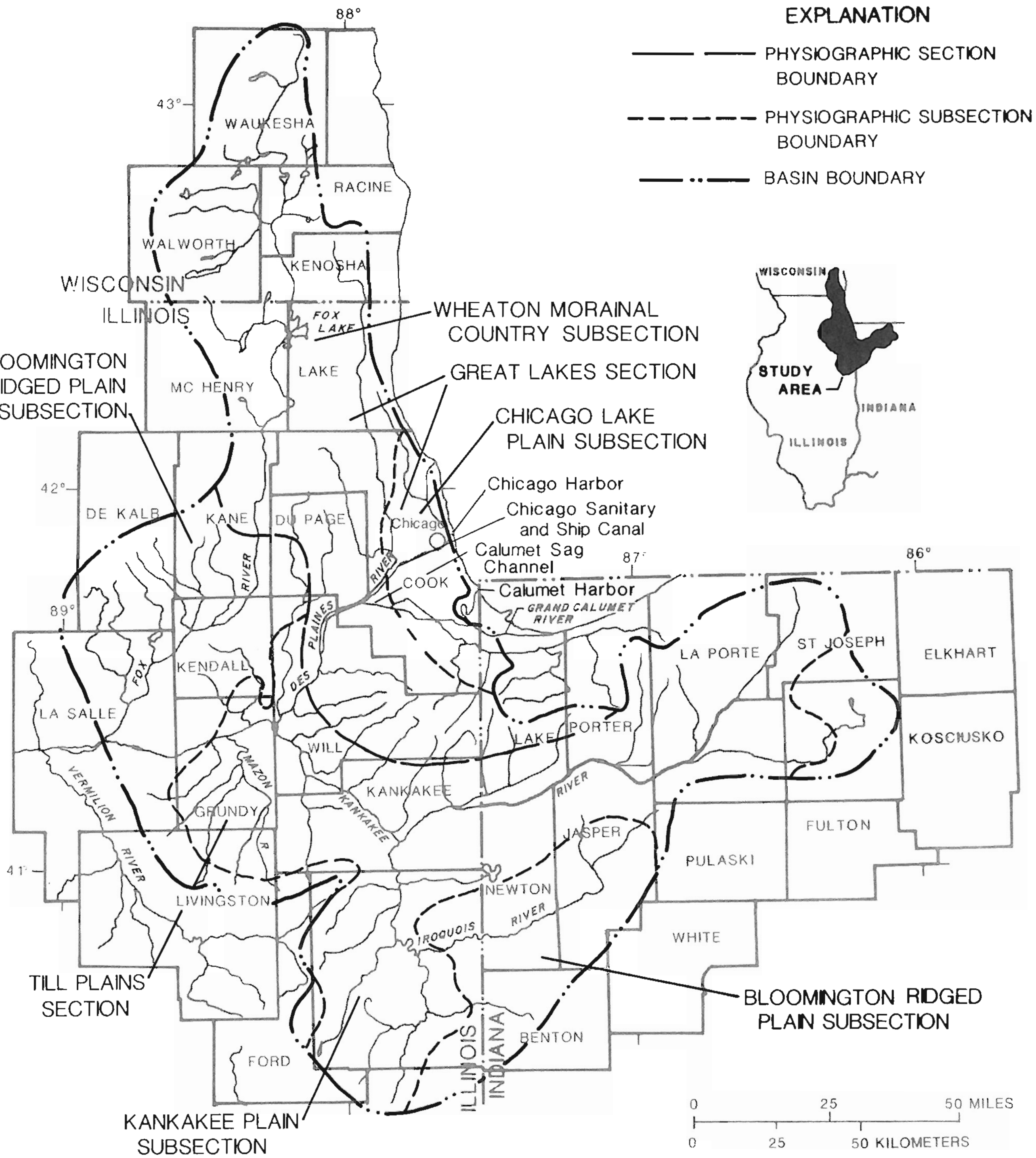

Figure 2.--Physiographic divisions of the upper Illinois River basin. (Modified from Fenneman, 1938, and Leighton and others, 1948)

Much of the metropolitan Chicago area lies in the Chicago Lake Plain subsection, an area that was originally swampy and poorly drained. Surface drainage in the area is to the middle third of the Des Plaines River and the Chicago Sanitary and Ship Canal (fig. 2). The Chicago Lake Plain is low and flat, with local relief less than 50 feet, and has a few low ridges, one of which originally formed a divide between drainage to Lake Michigan and drainage to the Illinois River. Extensive urbanization of this area has nearly eradicated this divide.

Surface drainage in the Wheaton Morainal Country subsection is to the Kankakee, Des Plaines, and Fox Rivers (fig. 2). Local relief in the subsection is typically less than 100 feet. Upland areas are characterized by rolling, elongated hills (moraines) that parallel Lake Michigan. The headwater areas of the Des Plaines and Fox Rivers and lowlands in the subsection have numerous lakes and swamps. Fox Lake (fig. 2) is characteristic of many lakes in the subsection that were formed during glacial recession when large blocks of buried ice melted leaving water filled depressions.

The two subsections of the Till Plains section represent two distinctly different landforms. The Kankakee Plain subsection is fairly level with gently rolling uplands. Surface drainage in this subsection is to the Kankakee, Iroquois, and Mazon Rivers (fig. 2). Unlike the Chicago Lake Plain, the Kankakee Plain has large quantities of sand (glacial outwash) that were deposited by glacial floods. Local relief in the subsection is typically less than 100 feet.

Surface drainage in the Bloomington Ridged Plain subsection is to the lower Fox River and the upper Iroquois River. Upland areas are generally flat or rolling. Terrain along the Fox and Illinois Rivers is hilly and rugged in places with local relief up to 300 feet. Tributaries to these rivers are deeply incised and have steep gradients.

The geology of the project area consists of a deep granitic basement rock that is consecutively overlain by consolidated sedimentary rock and unconsolidated glacial deposits (Willman and others, 1975). Precambrian basement rocks underlie the entire project area at depths ranging from about 1,000 feet below land surface in the northern part to about 7,000 feet in the southeastern part.

The oldest strata of sedimentary rock in the area, the Cambrian System, is predominantly sandstone and contains three of the most heavily used water-bearing formations in the project area. The Mount Simon Sandstone, Elmhurst Sandstone Member of the Eau Claire Formation, and Ironton and Galesville Sandstones (Willman and others, 1975) are important sources of freshwater north of the Kankakee River. The Cambrian System thickens from about 1,000 feet in the northern part of the project area to about 5,000 feet in the southeastern part and is subsurface throughout the entire project area.

The Ordovician System, the next oldest system, overlies the Cambrian System and underlies all of the project area. The system is composed mostly of limestone and dolomite and has lesser amounts of shale and sandstone. Ordovician rocks are exposed along the Illinois River valley. The thickness of the Ordovician System ranges from less than 1,000 feet in the northern and western parts of the project area where it has been heavily eroded to about 1,500 feet in the southeastern part.

The bedrock throughout most of the project area is consolidated deposits (from oldest to youngest age) of Ordovician, Silurian, Devonian, Mississippian, or Pennsylvanian age (fig. 3). Limestones, dolomites, and shales of the Mississippian, Devonian, and Silurian Systems underlie most of the Des Plaines River and Kankakee River basins. Coals, shales, and limestones of the Pennsylvanian System underlie the intervening area south of the Illinois River and between the confluence of the Kankakee and Des Plaines Rivers and the mouth of the Fox River. The lower Fox River basin is underlain by shales, dolomites, and sandstones of the Ordovician System. The bedrock surface is exposed along the Kankakee River in Kankakee County and along valley walls of the lower Fox and Illinois Rivers. Much of the Chicago Sanitary and Ship Canal is an excavated-bedrock channel.

Unconsolidated glacial deposits cover all of the bedrock surface except where the bedrock surface is exposed. The thickness of these deposits in the Kankakee River basin increases eastward and southward from a bedrock outcrop in Kankakee County to about 400 to 500 feet along the southern and eastern boundaries of the basin. The Fox and Des Plaines River basins are also underlain by glacial deposits that thicken to the north from the Illinois River, where bedrock is exposed, to about 400 feet along the northern boundary of the project area.

Land Use

The land-use categories described in this section are generalizations of the land-use and land-cover classification system described by Anderson and others (1976). Urban and industrial areas are areas of intensive use with much of the land covered by structures. An urban area is defined as residential land use that may range from high density, with multiple-unit structures, to low density, where houses are on lots of more than 1 acre. Industrial areas include an array of land uses from light to heavy manufacturing plants, commercial and service areas, transportation routes, and utilities. An agricultural area is land that is used primarily for the production of food and fiber.

Land use (fig. 4) in the upper Illinois River basin includes areas typical of large metropolitan areas and agricultural areas in the midwestern United States. Agriculture accounts for about 75 percent of the land use in the basin. The remaining 25 percent is accounted for by urban areas (13 percent), forest (7 percent), and industrial areas (5 percent). Corn is the principal crop followed by soybeans.

Land use in the Kankakee River basin is predominantly agricultural. About 90 percent of the basin is devoted to growing cultivated crops, principally corn and soybeans. In Indiana, the Kankakee River and many of its tributaries were dredged and straightened, beginning in the 1850's, to expedite drainage

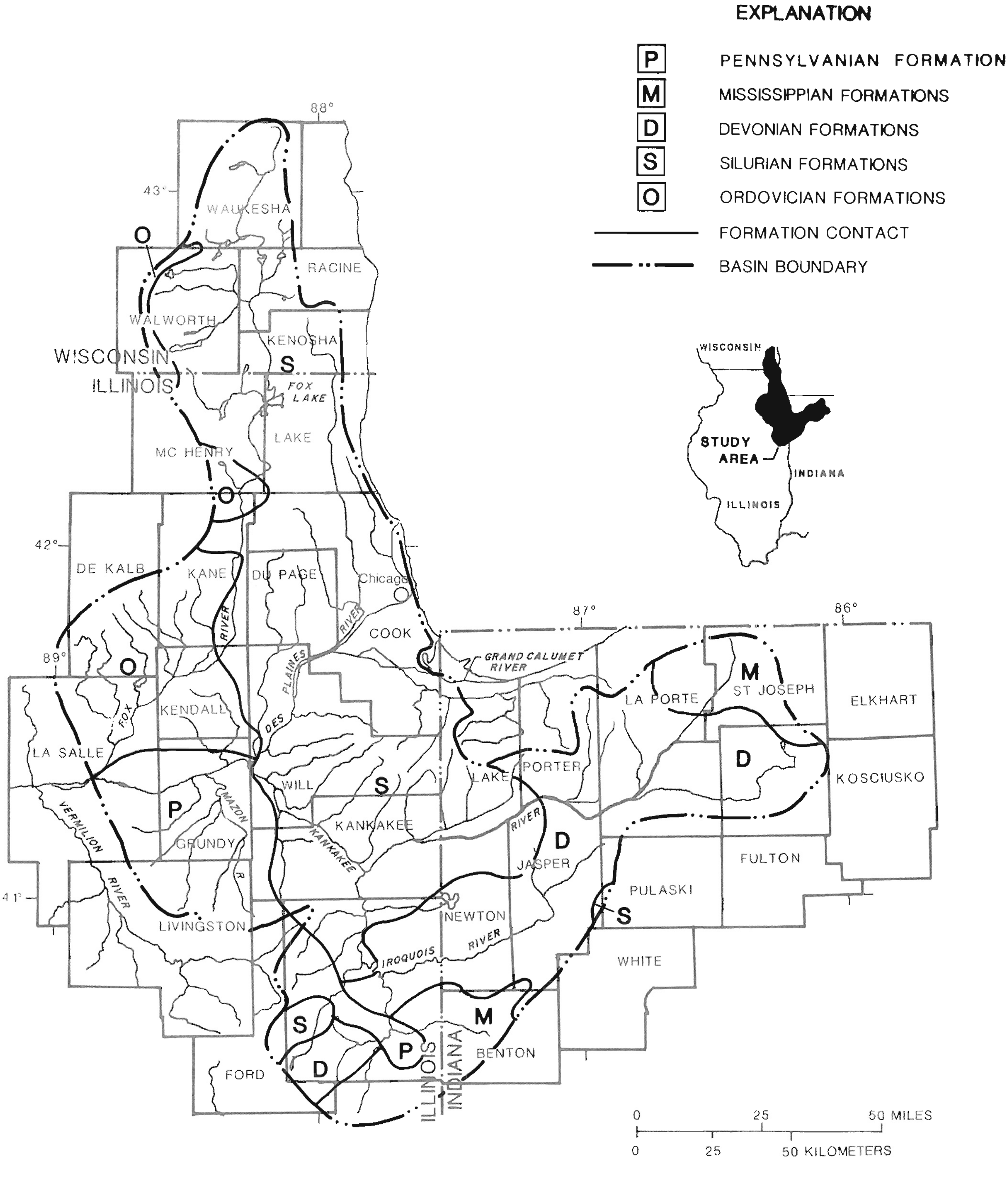

Figure 3.--General bedrock geology of the upper Illinois River basin. (Modified from U.S. Geological Survey, 1970)

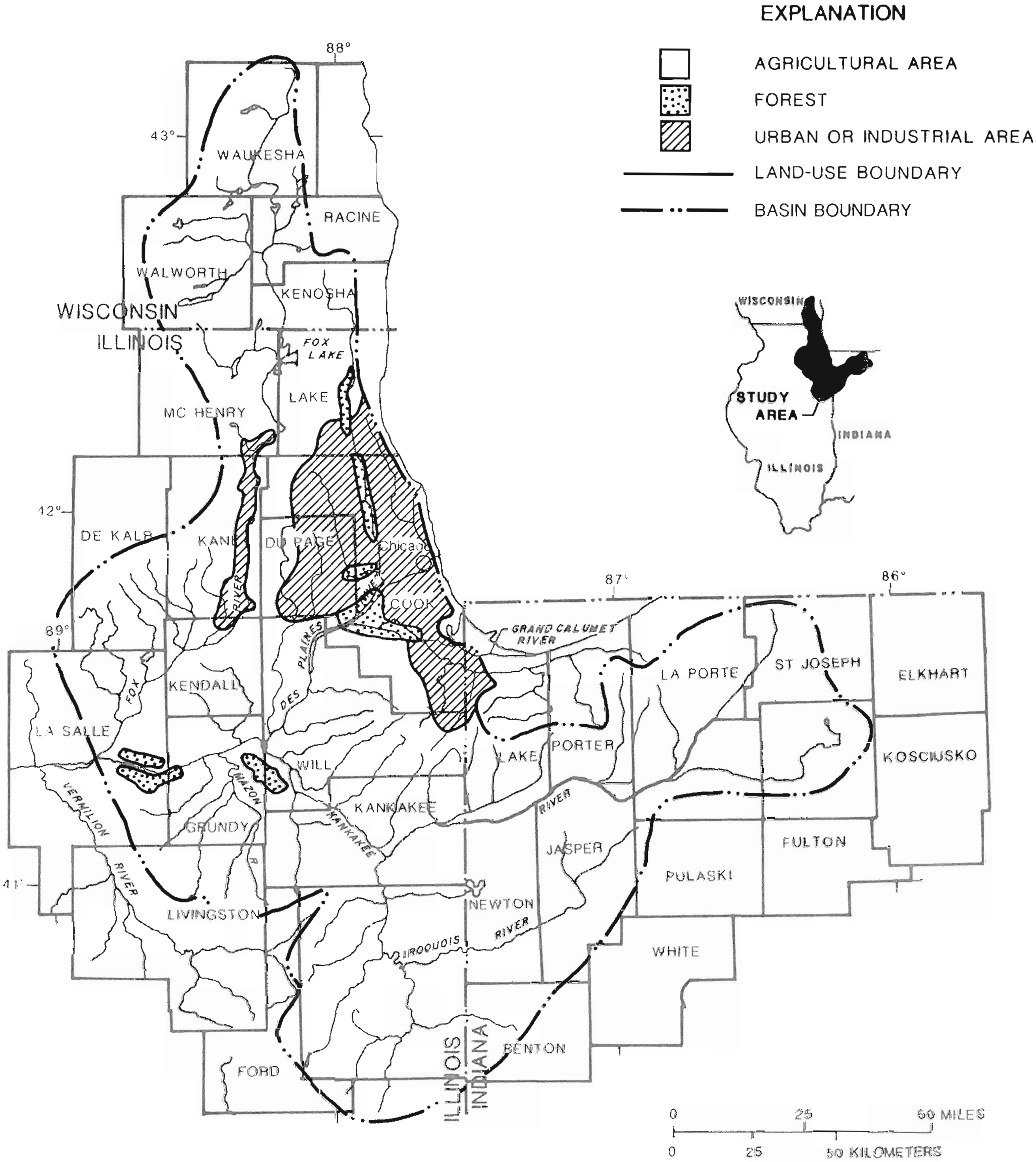

Figure 4.--Land use in the upper Illinois River basin, 1970. (Modified from U.S. Geological Survey, 1970)

of wetlands typical of the Wheaton Morainal Country and Kankakee Plain (fig. 2) for agricultural purposes. Large acreages of crops are irrigated in the Indiana part of the Kankakee Plain where sandier soils, topography, and ground-water availability are well suited for irrigation. The remaining 10 percent of the Kankakee River basin is urban area (5 percent) and forest (5 percent). The largest urban area in the Kankakee River basin is Kankakee, Illinois, that together with its surrounding suburbs had a 1980 population of about 55,000.

About 60 percent of the Des Plaines River basin is urban or industrial area and the remaining 40 percent is agricultural land and forest. Approximately 6 million people, or 86 percent of the 7 million populating the upper Illinois River basin, live in the urban area. Three million people live in the city of Chicago. Most of the agricultural area is drained by tributaries entering the upper and lower thirds of the Des Plaines River. At present, the most rapid expansion of the Chicago metropolitan area is in a westerly and northwesterly direction from Chicago towards the Fox River.

Approximately 85 percent of the Fox River basin is agricultural area and forest; 15 percent is urban or industrial. The urban areas, with a 1980 population of approximately 500,000, are generally located along the Fox River between Fox Lake and Aurora, Illinois (fig. 4). The upland areas along this corridor of urban development and the areas that drain to the Fox River downstream from Aurora are cultivated for the production of corn and soybeans. The area drained by the Fox River upstream from Fox Lake is mixed cropland and pasture.

Climate

The climate of the upper Illinois River basin is classified as continental. Great variations in precipitation and temperature may occur in any year because the basin is far from large physical features such as oceans or mountain ranges that modify regional weather patterns.

In general, summers are hot and humid, and winters are cold. Summer temperatures exceeding 39°C and winter temperatures below -26°C have occurred. July is normally the warmest month and January is normally the coldest. The 1941-70 average July and January temperatures were 23°C and -6°C, respectively [National Oceanic and Atmospheric Administration (NOAA), 1981]. The average annual temperature, 9°C, varied less than 1°C during this period of time.

The period of time, in days, between the last spring temperature of 0°C, or lower, and the first fall temperature of 0°C, or lower, is a measure of the growing season. Changnon (1984) reported a trend in length of the growing season from 1901 to 1980 at Aurora, Illinois (fig. 1). Ten-year average values of the growing season at Aurora have increased from 149 days during the period 1921-30 to 162 days during the period 1971-80. This increase was considered to possibly be attributed to increased urbanization around Aurora. The last spring freeze normally occurs in late March or early April, and the first fall freeze normally occurs in mid-October (Changnon, 1984). Records from NOAA indicate that the length of growing season in rural areas throughout the upper Illinois River basin varied during 1980 from 145 days in the western and northern parts of the basin to 165 days in the eastern part.

Average annual precipitation for 1951-80 ranged from 32 inches in the north at the headwaters of the Des Plaines and Fox Rivers to 40 inches in the east at the headwaters of the Kankakee River (Moody and others, 1986). Records of the National Weather Service indicate there was no extreme variability in annual precipitation throughout the upper Illinois River basin during this period.

About 50 percent of the average annual precipitation, or 16 to 20 inches, occurs during the growing season from May through mid-October. Extremes of average monthly precipitation during 1951-80 ranged from lows of 1.5 to 2.0 inches in February to highs of 3.5 to 4.5 inches in April, May, or June.

An estimated 70 percent of the average annual precipitation on the study area is returned to the atmosphere via evapotranspiration. Based on this percentage, average annual evapotranspiration varies from about 25 inches in the north to 28 inches in the east. An estimated 75 percent of the average annual evapotranspiration occurs during the growing season (U.S. Geological Survey, 1970). During the growing season, evapotranspiration normally exceeds precipitation by about 1 to 2 inches and depletes available soil moisture. During the nongrowing season, precipitation exceeds evapotranspiration by about 11 inches and replenishes soil moisture and recharges ground-water systems.

Streamflow

The discharge of the upper Illinois River basin consists of runoff and return flow. Runoff is that part of precipitation that appears in streams. The two principal sources of runoff are overland flow, which is rainwater or snowmelt that flows over the land surface toward stream channels, and ground-water runoff, which is ground water that discharges into a stream channel from a spring or as seepage. Return flow is water that has been released from some facility. Typical examples of return flow are discharges from industrial and municipal wastewater treatment facilities.

Variations in the streamflow characteristics throughout the project area can be generally described by comparing flow-duration characteristics. Listed in table 1 is selected information for eight stream-gaging stations for which flow-duration characteristics were determined. Streamflow associated with the 90-, 50-, and 10-percent exceedance frequencies, the percentage of time the indicated streamflow is equaled or exceeded, are listed in table 1 in units of cubic feet per second (ft^3/s). Equivalent values are also presented in units of cubic feet per second per square mile [$(ft^3/s)/mi^2$] to facilitate comparison of streamflow characteristics for different size basins. The streamflow with a 50-percent exceedance frequency is the median streamflow. The ratio of streamflows at the 10- and 90-percent exceedance frequencies is a measure of variability. Smaller ratios are attributable to a larger amount of storage available within a basin, which reduces streamflow variability, or to large amounts of return flow that sustain a higher-than-natural streamflow during low-flow periods.

Table 1.--Flow-duration characteristics for selected gaging stations in the upper Illinois River basin

[Flow-duration characteristics based on records collected prior to 1986 water year; exceedance frequency is percentage of time that indicated streamflow is equaled or exceeded]

Station No.	Station name	Drainage area, in square miles	Period of record	Streamflow, in cubic feet per second — Exceedance frequency, in percent: 90	50	10	Streamflow, in cubic feet per second per square mile — Exceedance frequency, in percent: 90	50	10	Index of variability[1]
05520500	Kankakee River at Momence, Ill.	2,294	1914 - present	643	1,500	4,200	0.28	0.65	1.83	6.5
05526000	Iroquois River near Chebanse, Ill.	2,091	1923 - present	74.2	678	4,600	.04	.32	2.20	62
05532500	Des Plaines River at Riverside, Ill.	630	1943 - present	28.0	237	1,270	.04	.38	2.02	45
05540500	Du Page River at Shorewood, Ill.	324	1940 - present	42.3	141	594	.13	.43	1.83	14
05542000	Mazon River near Coal City, Ill.	455	1939 - present	1.4	82.1	851	.003	.18	1.87	610
05543500	Illinois River at Marseilles, Ill.	8,259	1919 - present	4,570	9,070	19,300	.55	1.10	2.34	4.2
05550000	Fox River at Algonquin, Ill.	1,403	1915 - present	176	546	1,980	.12	.39	1.41	11
05552500	Fox River at Dayton, Ill.	2,642	1914 - present	349	1,080	4,060	.13	.41	1.54	12

[1] Index of variability is the ratio of streamflows at the 10- and 90-percent exceedance frequencies.

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 Kankakee River, the Iroquois River, and the upper Fox River (table 1). The drainage areas for gaging stations on the Kankakee and Iroquois Rivers are similar in size, but the more sandy soils in the upper Kankakee River basin cause increased infiltration that results in higher low flow and lower high flow than occurs in the Iroquois River basin. This characteristic is readily apparent from the index of variability that ranges from 6.5 for the Kankakee River at Momence to 62 for the Iroquois River near Chebanse.

The large percentage of low, poorly drained land and numerous lakes in the upper Fox River provide natural storage that affects streamflow in a manner similar to the sandy soils of the upper Kankakee River basin. The per-square-mile streamflow for the Fox River at Algonquin varies from 0.12 to 1.41, a range of 1.29 $(ft^3/s)/mi^2$. This gaging station has the smallest range of any of the stations in table 1.

Streamflow characteristics for the Illinois River at Marseilles indicate large amounts of return flow, principally from municipal wastewater treatment facilities and utilities in the Chicago metropolitan area. Its 90-percentile streamflow (per square mile) is at least twice the values determined for all other gaging stations except the Kankakee River at Momence (table 1). The two major sources of water that is withdrawn, used, and discharged as return flow are Lake Michigan and ground water, both of which are major sources of water that is diverted into the Illinois River basin.

Relation Between Surface Water and Ground Water

Low-flow characteristics for the upper Kankakee River and Fox River (table 1) indicate that substantial quantities of ground water are discharged to streams throughout much of the study area. The quality of surface water is affected by the quality and quantity of ground water that enters streams or lakes.

Concentrations of dissolved solids in ground water from the glacial drift in the upper Illinois River basin range from about 400 to 600 milligrams per liter (mg/L) of which calcium and bicarbonate are the major constituents (Gibb and O'Hearn, 1980). Water from the shallow dolomite and limestone aquifers that underlie most of the study area has somewhat higher concentrations of dissolved solids. Concentrations typically range from about 400 to 1,000 mg/L, and calcium, bicarbonate, and sulfate are the major constituents in these waters.

Little is known about the characteristics of the hydraulic connection between long reaches of streams in the study area and nearby ground-water systems and the related effects on surface- and ground-water quality. The Northeastern Illinois Planning Commission has calibrated hydrologic models for many of the streams in northeastern Illinois (G. C. Schaefer, Northeastern Illinois Planning Commission, written commun., 1987). Such models may aid in interpreting existing water-quality data.

Proper interpretation of the relation between surface water and ground water and the attendant water-quality effects is possible only if detailed information concerning both systems is available. Results of a study (Sasman and others, 1981) in Du Page County are briefly described to emphasize this point.

Prior to ground-water development, ground-water levels in the shallow dolomite aquifer underlying Du Page County (fig. 1) were generally higher than water levels in nearby streams, and ground water was discharged to these streams. Ground-water levels have since declined in response to increasing ground-water withdrawal, and ground-water discharge to streams has reportedly decreased. Areal trends in ground-water quality are now apparent as increasingly higher concentrations of dissolved solids now occur in ground water near areas where the bedrock aquifer has been nearly dewatered. These areas also correspond to high-density urban development where large amounts of road salt are used in the winter.

The authors indicate that it is difficult to interpret the chemical data because the present ground-water quality is the result of both the effects of human activities and natural geochemical processes, and long-term records of surface- and ground-water quality are lacking. Sasman's work indicates that further investigation may be necessary to fully understand the relation between surface- and ground-water quality in Du Page County.

Water Use

Average daily water use in the upper Illinois River basin totaled 13,920 ft^3/s in 1985. The amounts of water withdrawn, according to source of supply, were 2,600 ft^3/s from Lake Michigan, 10,670 ft^3/s from surface waters other than Lake Michigan, and 650 ft^3/s from aquifers. The 3,250 ft^3/s combined withdrawal from Lake Michigan and aquifers represents imported water that upon release, after use, contributes to the large amount of return flow discussed in the previous section on streamflow.

The major use of water was for power generation--6,280 ft^3/s or 45 percent of total use was withdrawn for cooling thermoelectric (steam turbine) power generation, and 4,070 ft^3/s or 29 percent of total use was used for hydroelectric power generation. All of this use was supplied by surface-water sources other than Lake Michigan.

Public water supply accounted for 2,170 ft^3/s or 16 percent of total water use. Of this amount, 1,660 ft^3/s was from Lake Michigan, 420 ft^3/s was from aquifers, and 90 ft^3/s was from streams or lakes in the basin. Ground-water withdrawals were greatest in the Des Plaines River basin in which 280 ft^3/s was withdrawn for public water supply.

An estimated 930 ft^3/s, or 7 percent, was supplied by diversion of Lake Michigan water for navigational purposes and other discretionary uses by the Metropolitan Sanitary District of Greater Chicago.

The remaining 3 percent of total water use was for domestic water supply in rural areas, commercial and industrial water supply, and irrigation. The combined withdrawals of water for these uses was 470 ft^3/s. The respective amounts of water withdrawn for these uses are 120, 290, and 60 ft^3/s. All of the domestic water supply and 83 percent of the irrigation water was from aquifers. Of the 290 ft^3/s in commercial and industrial uses, 10 ft^3/s was from Lake Michigan, 60 ft^3/s was from aquifers, and 220 ft^3/s was from surface waters other than Lake Michigan.

WATER QUALITY IN THE UPPER ILLINOIS RIVER BASIN

A considerable amount of information on surface-water quantity, quality, and related topics has been provided by previous studies. A list of bibliographic citations is provided in the "Selected References" section of this report. Studies of streamflow and water-quality characteristics for large parts of the upper Illinois River basin and other studies more limited in scope are important sources of background information for this project.

Following is a very general description of five major changes that have affected water quantity and water quality in the upper Illinois River basin. The remainder of this section is a brief description of the general characteristics of surface-water quality within the project area. A more detailed analysis of recent existing water-quality data for the project area is currently underway.

Water-Quality Conditions

Society has made five major changes in the upper Illinois River basin that have undoubtedly changed the quality of surface waters a great deal--construction of navigational waterways, diversion of Lake Michigan water, construction of wastewater-treatment facilities, drainage of wetlands, and agricultural activities.

Chicago began to replace St. Louis as the major center of commerce for Illinois River valley trade when the Illinois and Michigan Canal was opened to traffic in 1848 (Illinois Department of Public Works and Buildings, 1969). The 96-mile long canal connected the Illinois River 14 miles downstream from Ottawa (fig. 1) with Lake Michigan at Chicago. Parts of the canal still exist along the Illinois and Des Plaines Rivers and the Chicago Sanitary and Ship Canal. Chicago quickly began to grow with the migration of people from the northeastern States via steamboats along the Erie Canal and the Great Lakes. Competition from railroads, a more economical means of transportation, led to further improvements in the Illinois River for navigational purposes. The present navigable waterway was completed in 1939.

Increasing amounts of untreated domestic sewage and industrial wastes were discharged to Lake Michigan, the principal public water supply, as Chicago grew during the latter half of the 19th century. These discharges were made directly to the Lake and indirectly through tributaries such as the Chicago River. The concurrent increasing incidence of typhoid-related deaths and illnesses during this period of time was attributed to contaminated Lake water and led to a proposal to divert the flow of the Chicago River from Lake Michigan to the Illinois River basin.

The Chicago River was diverted by constructing the Chicago Sanitary and Ship Canal and diverting Lake Michigan water via the Chicago River to this channel. Construction of the Main Channel was begun in 1892 and completed in 1907 when the Lockport Power House near Joliet (fig. 1) was put in operation.

Lake Michigan diversions were begun in 1900 at a rate of 3,000 ft^3/s. Of this amount, about 1,200 ft^3/s was withdrawn for water supply and 1,800 ft^3/s was diverted primarily to dilute domestic and industrial wastes discharged to the Chicago Sanitary and Ship Canal. By 1917, the diversion rate had increased to 8,200 ft^3/s (fig. 5). The U.S. Supreme Court has since authorized the State of Illinois and the Metropolitan Sanitary District of Greater Chicago to divert Lake Michigan water according to schedules outlined in Decrees dated 1930 and 1967. The most recent schedule, outlined in a 1980 amendment to the 1967 Decree, limits 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).

The Lake Michigan diversion had two significant impacts. Water-quality conditions along the Chicago area lakefront improved, and water-quality conditions in the lower Des Plaines River and Illinois River declined. By 1912, all fish and mussels from the lower Des Plaines River and Illinois River upstream from Morris (fig. 1) were eliminated and the Nation's second-largest fresh-water fishery, supported by the Illinois River, had collapsed (Forbes and Richardson, 1913). Increasing amounts of oxygen-demanding wastes were discharged to the upper Illinois River system as the Chicago-area population rapidly grew during the World War I era. A study of dissolved oxygen concentrations in the Illinois River reach between La Salle (near Ottawa) and Beardstown, 136 miles downstream, documented anaerobic conditions as far as 146 miles downstream from Lake Michigan (Greenfield, 1924). Greenfield concluded, "Such conditions of course would make impossible the existence of fish or other forms of higher life in these portions of the river. This conclusion is confirmed by observation of the fishing activities."

Water-quality conditions have been in various states of recovery since wastewater-treatment practices were begun in the early 1900's. An inventory of Illinois sewerage systems in the early 1920's documented that domestic waste from a combined population of only approximately 100,000 people was receiving primary treatment by 27 wastewater treatment facilities in the project area (Weinhold and others, 1924). The Metropolitan Sanitary District of Greater Chicago began a study of sewage-treatment processes in 1909 and put its first treatment facility, the Des Plaines River Sewage Treatment Plant, in operation in 1922 (Metropolitan Sanitary District of Greater Chicago, 1982). In 1982, the Sanitary District served an area of 870 mi^2, including Chicago and 124 communities in Cook County, and treated a domestic wastewater load of 5.1 million persons and an industrial load equivalent to 4.5 million persons. The return flow from its treatment operations averaged 2,200 ft^3/s.

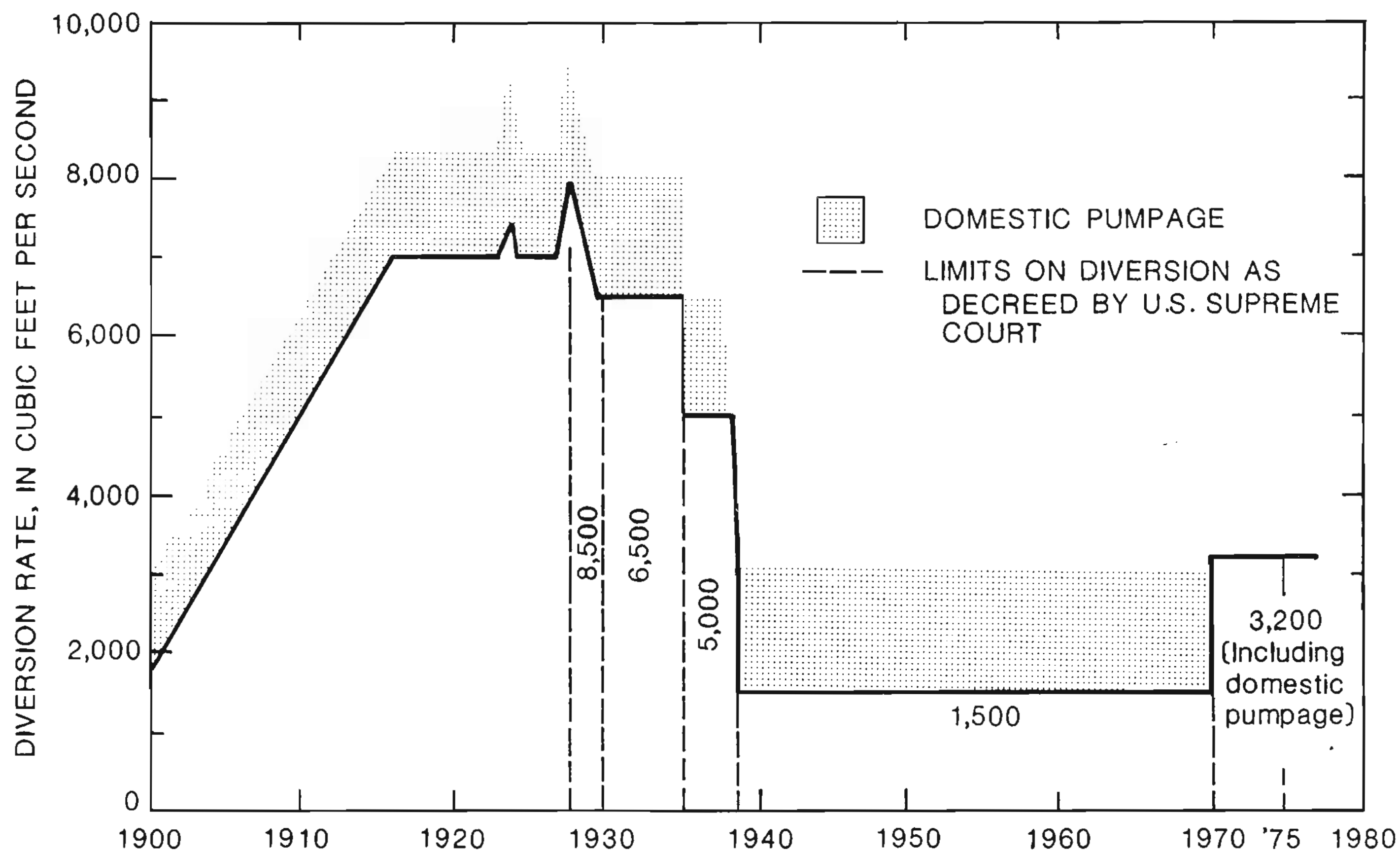

Figure 5.--Historic rate of diversion of water from Lake Michigan at Chicago. (Modified from Espey and others, 1981)

Development of the Chicago metropolitan area and farmland in the flat areas of the Kankakee Plain and Chicago Lake Plain subdivisions (fig. 2) was made possible by the drainage of large areas of wetlands that existed prior to the 1850's. Invention of farm implements such as the steel plow, reaper, binder, and barbed wire; fertile land; and development of an extensive railway system contributed to the demand to drain wetlands for agricultural purposes (Illinois Department of Public Works and Buildings, 1969). The "Grand Marsh" in the central Indiana part of the Kankakee River basin is one of the largest drained freshwater wetlands in North America. Approximately 400,000 acres of Kankakee River wetlands were drained for agricultural purposes (Bellrose, 1976).

The impacts of such extensive drainage activities on the hydrology and quality of surface waters in the project area cannot be quantified because most of the drainage occurred before water-data-collection programs were established. However, the functions and values of these early wetlands can be inferred from reports by Kusler (1983) and Sather and Smith (1984).

Agricultural practices in the lower Fox and Des Plaines River basins and the Kankakee River basin changed appreciably during the 1940's and 50's, nearly a century after these areas 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. Increasing amounts of commercial fertilizers and pesticides were used to increase crop yields and profits. The practice of crop rotation decreased, and fall plowing increased. Irrigation, particularly in the Indiana part of the Kankakee River basin, has steadily increased.

The impacts of intensification in agricultural practices on water quality are difficult to quantify. 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). Increased sedimentation and water turbidity caused, in part, by agricultural activities has reduced the food supply for fish (Bellrose and others, 1977). 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 to measures of agricultural activity such as fertilizer application rates (Smith and others, 1987). A declining trend in the percentages of water samples in which the pesticides chlordane and dieldrin were detected throughout Illinois was attributed to U.S. Environmental Protection Agency restrictions on their use (Illinois Environmental Protection Agency, 1986). However, long-term information about newer generation pesticides such as organophosphates and carbamates is lacking.

Biennial reports prepared by the Illinois Environmental Protection Agency (1986), Indiana Department of Environmental Management (1986), and Wisconsin Department of Natural Resources (Schreiber, 1986) provide general descriptions of recent surface-water quality in the project area. Surface-water monitoring programs administered by each of these agencies provide information concerning water chemistry, sediment chemistry, and biological conditions. Streams have been designated for particular uses, and numerical limits for selected constituents (water-quality standards) have been set to protect the designated uses. Each agency assesses the degree to which stream-water quality is impaired by comparing observed water-chemistry conditions to the appropriate standards. In 1983, the Illinois Environmental Protection Agency began including fishery and macroinvertebrate data and instream habitat characteristics in its assessments of the degree to which designated stream use is supported.

Streams in the Kankakee River and Fox River basins reportedly have the least number of water-quality problems. Water quality throughout these basins appears good on the basis of biological and chemical information. According to the Indiana Department of Environmental Management (1986), headwaters of the Kankakee River are excellent stream fisheries; the Little Kankakee River in La Porte County is a put-and-take trout fishery. All of the assessed streams in Illinois except Blackberry Creek in Kendall County were described as being highly valued or unique aquatic resources that provide good fisheries for species such as walleye, smallmouth and largemouth bass, northern pike, crappie, or catfish (Illinois Environmental Protection Agnecy, 1986). Fecal coliform density and iron concentration were the only water-quality characteristics that frequently exceeded Illinois water-quality standards during 1985. Total iron concentrations exceeded the 1,000 mg/L standard in 51 percent of the combined samples collected at 5 Kankakee River basin stations and 27 percent of the combined samples collected at 10 Fox River basin stations. Fecal coliform counts exceeded the State standard of 200 colonies per 100 mL in 41 and 51 percent of the samples collected from the respective basins.

The Illinois Environmental Protection Agency (1986) reported that the Des Plaines River basin had more severe water-quality problems than any other basin in the State. In general, streams draining the urban and industrial areas within the basin (fig. 4) were assessed as moderately or severely impaired in their ability to support aquatic life. Few if any fish were found in the Chicago Sanitary and Ship Canal and the Calumet Sag Channel. Carp were the predominant fish species found in the streams assessed moderately impaired. Only the upper Des Plaines River in Lake County and the main stem of the Du Page River in Will County were assessed as highly valued aquatic resources that supported sport fisheries described for the Kankakee and Fox River basins. In general, iron; copper; silver; ammonia; dissolved oxygen; fecal coliform; and fats, oils, and greases are the characteristics that more frequently exceeded State water-quality standards (Metropolitan Sanitary District of Greater Chicago, 1984; Illinois Environmental Protection Agency, 1986).

Streambed sediments can serve as a long-term integrator of water quality. Kelly and Hite (1984) summarized the collection and analysis of about 800 sediment samples that were collected at 551 sites throughout Illinois during the period 1974 through 1980. About 20 percent of the sites sampled are in the upper Illinois River basin. Samples were analyzed for chemical oxygen demand, total kjeldahl nitrogen, total phosphorus, 8 trace elements, and 10 organochlorine compounds.

In general, the highest measured concentrations were in the Des Plaines River basin. The reported mean total-phosphorus concentration for the basin was 2,640 milligrams per kilogram (mg/kg). Mean concentrations for samples collected from the Kankakee and Fox River basins were 458 and 725 mg/kg, respectively. The mean lead concentration of 477 mg/kg for the Des Plaines

River basin was about an order-of-magnitude higher than mean concentrations in the Fox River basin (59.7 mg/kg) and the Kankakee River basin (28.7 mg/kg). Sediments collected from the Des Plaines River basin also had some of the highest measured concentrations of chlordane, which ranged from 10 to 50 micrograms per kilogram (μg/kg), total DDT (20 to 940 μg/kg), and PCB's (500 to 10,000 μg/kg).

The quality of five inland lakes in the project area is periodically assessed by the Illinois Environmental Protection Agency (1986) on the basis of chemical monitoring. Skokie Lagoons, in Cook County, was assessed as being severely impaired by runoff from urban land and return flows from municipal and industrial wastewater treatment facilities. Lake Catherine, Channel Lake, and Long Lake, near Fox Lake (fig. 1), were assessed as being partially impaired by runoff from urban and industrial lands and municipal return flows. Lake Shabbona, in De Kalb County, was assessed as being partially impaired by agricultural runoff. Chlordane and PCB's were detected in 31 and 77 percent of 13 samples of fish flesh collected during 1984 and 1985 from three lakes in Lake County. However, none of the detected concentrations exceeded U.S. Food and Drug Administration tolerance levels. An earlier study of lake-sediment chemistry in 63 lakes throughout Illinois showed that mean concentrations of total kjehldahl nitrogen, chemical oxygen demand, arsenic, lead, mercury, and zinc in sediments from nine glacial lakes in the project area were higher than mean concentrations for other groups of lakes throughout the State (Kelly and Hite, 1981). The sampled glacial lakes were located in Lake County (seven), Cook County (one), and McHenry County (one).

The presence of trace organic constituents in some fish has been documented by the Illinois Environmental Protection Agency (1986) and Indiana Department of Environmental Management (1986). Fish-consumption advisories exist for the reach from the Des Plaines River near Joliet to the Illinois River at Starved Rock Dam near Ottawa and for the Grand Calumet River in Indiana (fig. 1). The advisories inform that concentrations of PCB's in carp exceed U.S. Food and Drug Administration tolerance levels and advise limited consumption of that fish.

Water-Quality Issues

The following discussion includes only the major regional water-quality issues in the upper Illinois River basin that were previously identified by a group of officials from Federal, State, and local agencies. It is not intended to include all of the existing or potential water-quality issues in the basin.

Surface-water-quality issues in the upper Illinois River basin are primarily related to constituents such as sediment, nutrients, trace inorganic and organic constituents, and to water-resource planning and management. Sediment, nutrients, and trace constituents are transported to rivers and lakes in the project area primarily via return flow from municipal and industrial wastewater treatment facilities, surface runoff, and ground-water runoff. Hydrology, land use, and wastewater-treatment practices affect their transport and fate within the surface-water system.

Typical sources of sediment in the upper Illinois River basin are soils eroded from the land surface, lake shorelines, and stream banks. Other sources include decomposed organic material such as algae and vegetation, industrial waste, and abraded construction material such as concrete and asphalt.

Sediment affects water quality in several ways. Suspended sediment reduces the transparency of water and depth to which light penetrates. Reduced transparency inhibits photosynthesis and can limit the potential productivity of surface waters. Sediment also serves as a vehicle for the transport of phosphorus, metals, and hydrophobic organic compounds. Many of these constituents can remain on sediment or enter the solution phase depending on factors such as temperature, pH, and dissolved oxygen.

Transport of constituents associated with sediment discharge is viewed by Federal, State, and local agencies as an important water-quality issue in the basin. Fisheries biologists have found evidence of poor health in bottom-feeding fish, such as carp and catfish, principally in the Illinois River and rivers in the Chicago metropolitan area (J. Arbise, Illinois Departement of Conservation, written commun., 1986; D. C. Hudak, U.S. Fish and Wildlife Service, written commun., 1986; and T. A. Butts, Illinois State Water Survey, written commun., 1986). The U.S. Army Corps of Engineers (Army Corps) performs dredging operations to maintain a navigable waterway and must consider the effects that dredging may have on water quality (G. E. Johnson and M. O'Connor, U.S. Army Corps of Engineers, written commun., 1986). In addition, the Army Corps must consider the effects that placement of dredge spoil may have on the surrounding environment.

Nitrogen and phosphorus significantly influence the potential productivity of surface waters. Highly productive waters are characterized by large populations of aquatic organisms, such as algae and macrophytes, and large hourly variations in dissolved oxygen concentrations. These characteristics can have adverse effects on the suitability of water for aquatic life or recreation.

The Skokie Lagoons, a series of seven interconnected lakes in the Des Plaines River basin in northeastern Cook County, are an example of severe degradation largely caused by excessive nutrient loadings (Illinois Environmental Protection Agency, 1986). Decomposition of algae after periodic die-off depletes oxygen and contributes to winter fish kills and unpleasant appearances and odors during warm weather. A restoration project funded jointly by the U.S. Environmental Protection Agency and the Forest Preserve District of Cook County was begun in 1984 in response to this problem. Four major tasks of the project are the diversion of wastewater treatment facility effluent around the Lagoons, dredging the bottom material, applying limited amounts of aquatic algacides, and controlling shoreline erosion.

Demand for recreational waters will continue to increase as the population of the basin increases. It is expected that nutrient enrichment will continue to be an issue in the upper Illinois River basin and particularly for the lakes and streams in the Des Plaines River and Fox River basins.

Trace elements and organic compounds will continue to be a concern in the upper Illinois River basin for three reasons: (1) Trace organic constituents have already been detected in fish at levels exceeding U.S. Food and Drug

Administration tolerance levels, (2) a large number of potential sources of these constituents exists, and (3) analytical methods for measuring these constituents are improving. The occurrence of trace inorganic and organic constituents may have toxic effects on aquatic life and has the potential for affecting human health. Based on the U.S. Environmental Protection Agency's National Priority List and a second list of known abandoned hazardous-waste sites, there are 666 hazardous-waste sites in the Illinois and Indiana parts of the project area (D. C. Hudak, U.S. Fish and Wildlife Service, written commun., 1986). Agricultural and industrial activities and urbanization of the project area, particularly the Des Plaines and Fox River basins, will continue to provide a source of these constituents. Finally, the ability to measure these constituents in water, on sediment, and in plant and animal tissues with greater precision should change as new laboratory methods and equipment are developed.

Several issues are related to water-quality planning and management. Water-quality standards have been established by State management agencies in Illinois, Indiana, and Wisconsin to allow unimpaired use of water for some predefined set of purposes. Standards are periodically reviewed and changed as more knowledge is gained about water-quality constituents, treatment processes, or effects of constituents on aquatic life or human health. Existing water-quality standards for all streams except the navigable waterways in the project area were established to protect water for aquatic life, agricultural use, fishing, swimming, and most industrial uses.

The Illinois Environmental Protection Agency and the Northeastern Illinois Planning Commission recognize a major conflict between the use of streams in northeastern Illinois for storm drainage and the use for which existing water-quality standards were established (G. C. Schaefer, Northeastern Illinois Planning Commission, written commun., 1987). Hydrologic modifications such as storm sewers, and stream channelization, straightening, and deepening are made to reduce flood damages yet may adversely impact aquatic habitats and surface-water quality.

Water-quality data are needed for use in the process of establishing and reviewing water-quality standards (R. Lanyon, Metropolitan Sanitary District of Greater Chicago, written commun., 1986). The Illinois standard for disinfection, which is based on fecal coliform, a bacteriological indicator, is one example of a standard that is currently under review. The issues in this review center on the possible toxic effects of chlorine on human health and aquatic life and the need to maintain year-round compliance with the disinfection standard for seasonally used recreational waters. The Illinois Pollution Control Board recently eliminated the requirement for disinfecting effluent discharges to water designated for secondary-contact use (incidental or accidental contact), such as the Chicago Sanitary and Ship Canal. The Board has also been asked to consider seasonal disinfection of effluent that is discharged to water designated for general use.

Another issue concerning planning and management is the need to relate change in water quality to methods used to control the quality of runoff and return flow from wastewater treatment facilities (R. Lanyon, Metropolitan Sanitary District of Greater Chicago, written commun., 1986). Three examples of changing management practices in the upper Illinois River basin are the upgrading of wastewater treatment facilities, Chicago's Tunnel And Reservoir Plan (TARP), and the Illinois Soil Erosion and Sediment Control Program.

Wastewater treatment facilities have been and are continuing to be upgraded to reduce the potentially toxic effects that discharges of un-ionized ammonia nitrogen may have on aquatic organisms or to reduce the potential oxygen demand of ammonium that may be discharged. Current treatment processes convert ammonia to nitrite and nitrate nitrogen before the treated effluent is discharged. The discharged nitrogen is then in a form that is less toxic but more readily available as a nutrient for aquatic organisms.

The first of two phases of TARP will address adverse effects on water quality that are presently caused by untreated discharges of combined sewage and stormwater to streams in the Des Plaines River basin. Approximately 85 percent of the storm related organic loading to Chicago-area waterways will be removed in this phase (R. Lanyon, Metropolitan Sanitary District of Greater Chicago, written commun., 1987). Phase I is a system of drop shafts, 110 miles of tunnels (ranging in size from 9 to 33 feet in diameter and 250 to 350 feet below land surface), and pumping stations that will collect combined-sewer discharges and transport the discharge to existing treatment facilities. At present, about one-third of Phase I has been constructed and is in operation. Phase II is a system of another 21 miles of tunnels and several large reservoirs in which floodwater will be temporarily stored. Phase II of TARP primarily addresses flood control; however, water quality will also be further improved to achieve a total reduction in organic loading of 99 percent.

The Soil Erosion and Sediment Control Program requires each of the 98 Soil and Water Conservation Districts in Illinois to prepare erosion guidelines to meet a target soil-loss value, T, that maintains soil productivity. The program was adopted in 1983 and established a 17-year schedule to meet the target levels; the goal of the program is commonly referred to as "T by 2000." This program is 1 of 12 Illinois programs dealing directly or indirectly with nonpoint source contamination that was recently evaluated by the Association of State and Interstate Water Pollution Control Administrators (1985). Indiana and Wisconsin also have implemented erosion and sediment control programs.

Each of these land- and water-management activities has had or may have a significant impact on the quality of surface water in the upper Illinois River basin. Each activity is financed by public funds. It is reasonable to expect that the public, in general, and agencies that administer these activities will want to understand the degree to which quality has been affected.

DESCRIPTION OF UPPER ILLINOIS RIVER BASIN PROJECT

The upper Illinois River basin project will consist of five major activities. The first activity involves compiling and interpreting existing water-quality data. The second and third activities are fixed-station sampling and synoptic studies of present water-quality conditions. The fourth activity consists of one or more subbasin or river-reach studies. The fifth activity is the preparation of reports that will describe results from each of the first four activities. The remainder of this section is a description of the first four activities.

Analysis of Existing Information

The purpose for analyzing existing information is to describe current water-quality conditions and trends and their relation to natural and man-induced factors. Results from such a retrospective analysis will also be useful in developing detailed work plans for future activities in the basin.

The retrospective analysis consists of four steps. The first step is to identify the sources of water-quality data that could be used to describe current water-quality conditions. The second step is to evaluate each available water-quality data base to determine whether the data are suitable for the retrospective analysis. The third step is to analyze the data using exploratory data-analysis techniques and simple statistical methods. Narratives of some information, such as descriptions of biological conditions and their relation to observed water-quality conditions, will be prepared when appropriate. The fourth and final step is to prepare a report that describes the results of the assessment.

The analysis of existing information is currently (1987) underway. Principal agencies that are sources of information include the Illinois Environmental Protection Agency, Northeastern Illinois Planning Commission, Indiana Department of Environmental Management, Metropolitan Sanitary District of Greater Chicago, Illinois State Water Survey, Illinois Department of Conservation, U.S. Fish and Wildlife Service, Wisconsin Department of Natural Resources, and Illinois Natural History Survey. Information provided by members of the upper Illinois River Basin Liaison Committee (described in the "Coordination" section of this report) has been very helpful in this phase of the study.

Fixed-Station Sampling

Fixed-station sampling will be used to determine (1) average annual and seasonal concentrations and loads of selected constituents that will include trace elements, suspended sediment, nitrogen, and phosphorus; and (2) trends in concentrations and loads.

Eight water-quality stations (table 2) have been selected in the upper Illinois River basin (fig. 6). A ninth station, possibly in the headwaters of the Kankakee River basin, may be established to measure baseline water quality. Sampling began in April 1987. Samples are being collected monthly at each station in a cooperative effort with the Illinois Environmental Protection Agency. As many as six additional samples will be collected during special hydrologic conditions such as floods, low flows, or the first snowmelt runoff of the season.

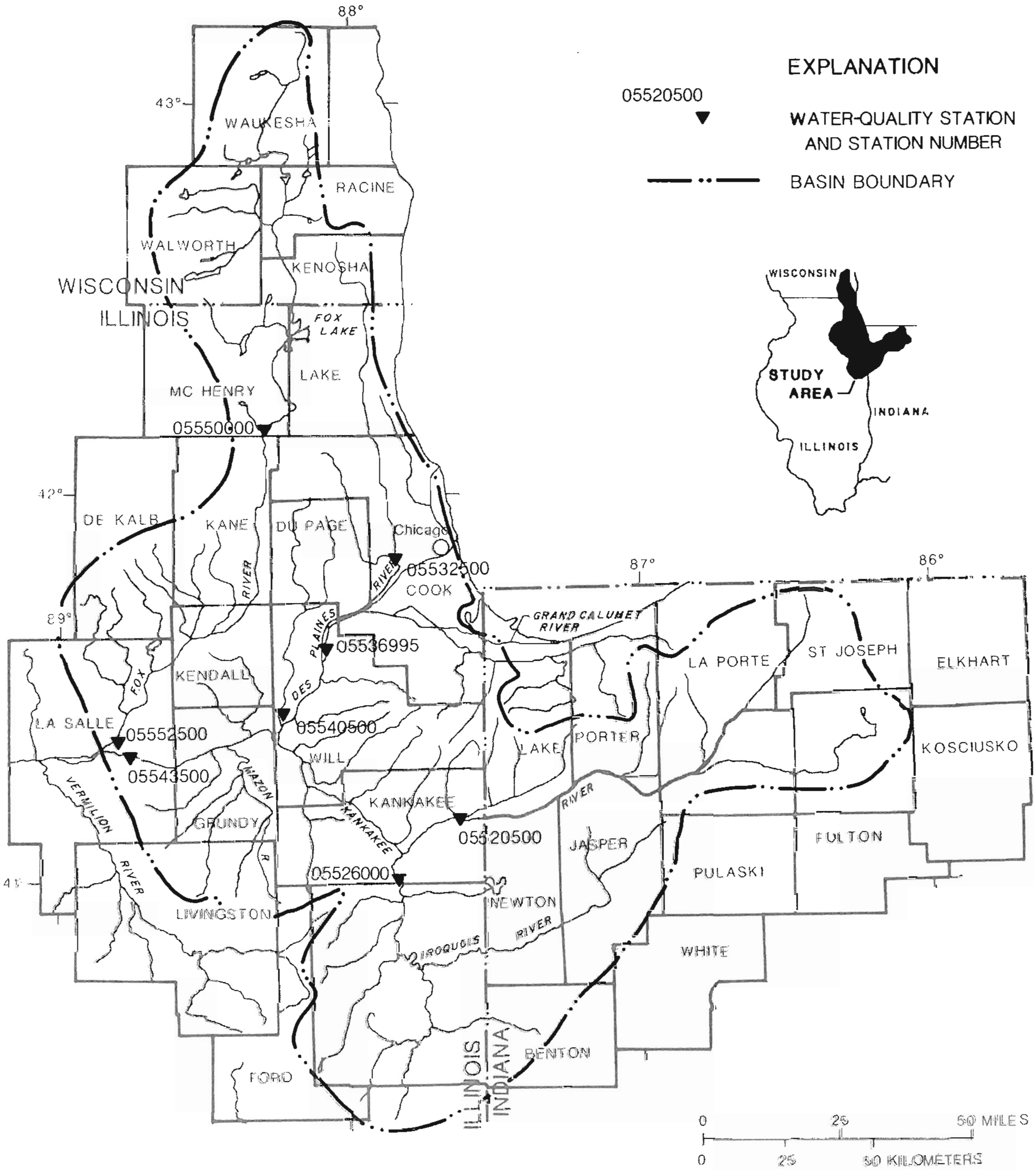

Figure 6.-Location of water-quality stations in the upper Illinois River basin that were selected for fixed-station sampling.

Table 2.--Water-quality stations in the upper Illinois River basin that were selected for fixed-station sampling

Station No.	Station name	Drainage area, in square miles	River mile
05520500	Kankakee River at Momence, Ill.	2,294	47.9
05526000	Iroquois River near Chebanse, Ill.	2,091	6.5
05532500	Des Plaines River at Riverside, Ill.	630	44.3
05536995	Chicago Sanitary and Ship Canal at Romeoville, Ill.	739	6.2
05540500	Du Page River at Shorewood, Ill.	324	10.6
05543500	Illinois River at Marseilles, Ill.	8,259	246.5
05550000	Fox River at Algonquin, Ill.	1,403	81.6
05552500	Fox River at Dayton, Ill.	2,642	5.3

All of the stations except Fox River at Algonquin (05550000) were selected primarily for accounting purposes so that mass balances may be attempted. The combined loads measured on the Illinois River at Marseilles (05543500) and Fox River at Dayton (05552500) will represent the yield of the project area. Loads measured at stations on the Kankakee, Iroquois, Des Plaines, and Du Page Rivers and the Chicago Sanitary and Ship Canal will be combined and compared to loads measured on the Illinois River at Marseilles. Information collected at the Kankakee River and Iroquois River stations will be compared to describe effects that geology may have on the quality of water from two subbasins that are similar in size and have the same agricultural land use. The two Fox River stations were selected to determine if effects attributable to urbanization could be measured. The Du Page River station was selected to determine if water-quality trends attributable to the steadily increasing urbanization of the Du Page River basin could be measured.

Additional interstation comparisons of concentrations and loads will be made to infer cause-and-effect relations between water quality and factors such as land use, wastewater-treatment practices, and hydrology. Information gained from such comparisons should be useful in describing the need for subbasin or river-reach studies.

Synoptic Studies

One purpose of synoptic studies is to provide information at a greater degree of resolution than can be provided by fixed-station sampling. Another purpose is to better define the relation between the occurrence of selected constituents and factors such as land use and hydrology that affect occurrence.

Synoptic studies will be done during periods of high flow and extended low flow. Each synoptic study will be limited in scope to the measurement of a particular class of constituents, such as nutrients or organic compounds, and necessary support information such as discharge, water temperature, and pH. These studies may be reconnaissance-type studies to document the presence or absence of selected constituents, or they may be studies of cause and effect.

Water and suspended sediment will be sampled during high-flow periods to determine concentrations of suspended sediment, pesticides and other selected organic compounds, trace elements, nutrients such as nitrogen and phosphorus, and bacteriological indicators such as fecal coliform or Escherichia Coli. Water and streambed sediment will be sampled during low-flow periods. Water will be analyzed to determine concentrations of nutrients, selected trace elements, pesticides, and dissolved oxygen. Sediment will be analyzed to determine concentrations of pesticides and trace elements.

Biological measurements of plants and animals will be made to determine the relative importance of biological processes in controlling dissolved oxygen dynamics; to determine the relation between concentrations of potentially toxic constituents in water, sediments, and aquatic organisms; and to determine the occurrence of a broad array of potentially toxic organic constituents. Bioassay procedures may be used with physical and chemical measurements to provide additional insight as to the presence of potentially toxic substances.

Existing information will be considered in the design of each synoptic study. A general description of one type of design follows. The total number of samples to be collected are separated into three groups. One group of samples would be collected from major rivers such as the Kankakee, Des Plaines, Fox, and Illinois Rivers at intervals of about 50 river miles. A second group would be collected at sites where problems are suspected or known to exist. The third group would be collected from small streams draining areas of homogeneous land use.

Plans are currently being made to do a study to describe the presence of trace inorganic constituents in streambed sediments during the summer of 1987. Information gained from this study will be used to help select the target constituents to be measured at fixed stations.

Subbasin or River-Reach Studies

The purpose of subbasin or river-reach studies is to better define water quality and understand processes that affect water quality. Such studies would be limited in scope to small drainage basins or short river reaches. The studies would primarily address local or regional conditions and issues, or processes that significantly affect the quality of surface water in the upper Illinois River basin.

Three sources of information would be used in the process of selecting a particular subbasin, or reach, and process for intensive study. The analysis of existing information and discussions with members of the project liaison committee should provide direction as to the issues and areas of most concern. Information from the synoptic studies should also be useful in defining the magnitude of water-quality "problems" in the upper Illinois River basin.

At present (1987), specific plans have not been made for any intensive studies. Following is a general description of two studies that are desirable if funding is available. No priority is assigned and potential studies are not limited to these examples.

The temporary storage and subsequent treatment of combined sewer overflows that will be provided by TARP may have a marked effect on the water quality of the lower Des Plaines River and the Illinois River. A study of the Des Plaines River from the northern boundary of Cook County to the mouth of the Des Plaines River could focus on pre-TARP water quality and provide baseline information to which future water quality can be compared. The purpose of the study would be to document the occurrence and transport of selected constituents, such as oxygen-demanding material and metals, and characteristics of runoff from the basin. Chemical analyses of selected size fractions of suspended sediment and streambed sediment and of dissolved constituents could be examined to describe transport processes.

A sediment-chemistry study could be performed in the pools upstream from dams on the Illinois, Des Plaines, and Fox Rivers. Chemical analyses of cores removed from the streambed sediments could be used for two purposes. The first purpose would be to describe the chemistry of sediments that potentially may be resuspended by floods, navigation, or dredging operations. The second purpose would be to describe long-term (about 50 to 90 years) trends in the chemistry of sediments eroded from the upper Illinois River basin. The dams, built in the early 1900's, form reservoirs that act as sediment traps. Sections of cores collected from slackwater areas that have not been disturbed could be analyzed to determine the date of deposition and constituent concentrations. The resulting time series of concentrations would represent long-term trends to which current sediment chemistry could be compared.

Quality Assurance

Variability in analytical results is caused by errors in the sample-collection and analysis process and always occurs, even under rigorously controlled field and laboratory conditions. For example, errors can be introduced into sample results through (1) selection of a sampling location or method that produces a sample that fails to represent the conditions of interest; (2) improper use of instruments; (3) contamination of the sample; and (4) inappropriate methods of analysis. These errors can be so small that they cannot be measured or so large that their presence is obvious.

Quality-assurance programs are used to detect and control errors and to maintain and document the reliability of results. Technical quality-assurance plans are being prepared for the national program and the upper Illinois River basin study. These plans will address all aspects of sample collection, analysis, and reporting needed to produce reliable and verifiable data in a nationally consistent manner. The plans will include existing U.S. Geological Survey quality-assurance methods and practices described in manuals by the Office of Water Data Coordination (1977), Friedman and Erdmann (1982), and others as needed.

Agency Coordination

Coordination between U.S. Geological Survey personnel and other interested scientists and water-management personnel is an important component of the NAWQA program. Liaison committees have been established at the national level and local level to ensure that the scientific information produced by the program is relevant and made available in a timely manner.

A National Coordinating Work Group has been established by the Director of the U.S. Geological Survey to advise the U.S. Geological Survey on the coordination of the NAWQA program. The work group functions under the general auspices of the Interagency Advisory Committee on Water Data and the Advisory Committee on Water Data for Public Use. The general purposes of the work group are to advise the U.S. Geological Survey on (1) water-quality-information needs of non-Federal and Federal communities of water users and (2) coordination procedures for making the data and information stemming from the NAWQA program timely and appropriately available.

The National Coordinating Work Group currently consists of the Chief Hydrologist of the U.S. Geological Survey, eight Federal members, seven non-Federal members, and a member from each of the pilot-study local liaison committees. Organizations represented include the following:

- American Water Resources Association,
- Association of American State Geologists,
- Association of State and Interstate Water Pollution Control Administrators,
- Chemical Manufacturers Association,
- Council on Environmental Quality,
- Interstate Conference on Water Policy,
- National Association of Conservation Districts,
- U.S. Army Corps of Engineers,
- U.S. Bureau of Reclamation,
- U.S. Environmental Protection Agency,
- U.S. Fish and Wildlife Service,
- U.S. Forest Service, and
- U.S. Soil Conservation Service.

Each NAWQA study has a liaison committee. Specific activities of the committees will include (1) exchanging information about local and regional water-quality and water-data management issues; (2) identifying water-quality constituents and study locations of local and regional interest; (3) discussing adjustments of NAWQA, other U.S. Geological Survey, and other agencies' program activities; and (4) reviewing and commenting on planning documents and reports from the basin studies.

Organizations currently represented on the upper Illinois River Basin Liaison Committee include the following:

Northeastern Illinois Planning Commission,
The Metropolitan Sanitary District of Greater Chicago,
Southeastern Wisconsin Regional Planning Commission,
Illinois Department of Conservation,
Illinois Department of Transportation,
Illinois Environmental Protection Agency,
Illinois Institute for Environmental Studies,
Illinois Natural History Survey,
Illinois State Water Survey,
Indiana Department of Environmental Management,
Indiana Department of Natural Resources,
Wisconsin Department of Natural Resources,
University of Wisconsin,
U.S. Army Corps of Engineers, Chicago District,
U.S. Army Corps of Engineers, Rock Island District,
U.S. Environmental Protection Agency, Region V,
U.S. Environmental Protection Agency, Environmental Research Laboratory, Duluth,
U.S. Fish and Wildlife Service,
U.S. Geological Survey, and
U.S. Soil Conservation Service.

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