Volume 2

Water Resources

Fox River Area Assessment

FOX RIVER AREA ASSESSMENT

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For more information about CTAP, call (217) 524-0500 or e-mail at ctap2@dnrmail.state.il.us; for information on the Ecosystems Program call (217) 782-7940 or e-mail at ecoprog@dnrmail.state.il.us.

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About This Report

The Fox River Area Assessment examines an area situated along the Fox River which spans eleven counties in north-eastern Illinois. Because significant natural community and species diversity is found in the area, it has been designated a state Resource Rich Area.

This report is part of a series of reports on areas of Illinois where a public-private partnership has been formed. These assessments provide information on the natural and human resources of the areas as a basis for managing and improving their ecosystems. The determination of resource rich areas and development of ecosystem-based information and management programs in Illinois are the result of three processes -- the Critical Trends Assessment Program, the Conservation Congress, and the Water Resources and Land Use Priorities Task Force.

Background

The Critical Trends Assessment Program (CTAP) documents changes in ecological conditions. In 1994, using existing information, the program provided a baseline of ecological conditions.[1] Three conclusions were drawn from the baseline investigation:

1. the emission and discharge of regulated pollutants over the past 20 years has declined, in some cases dramatically,
2. existing data suggest that the condition of natural ecosystems in Illinois is rapidly declining as a result of fragmentation and continued stress, and
3. data designed to monitor compliance with environmental regulations or the status of individual species are not sufficient to assess ecosystem health statewide.

Based on these findings, CTAP has begun to develop methods to systematically monitor ecological conditions and provide information for ecosystem-based management. Five components make up this effort:

1. identify resource rich areas,
2. conduct regional assessments,
3. publish an atlas and inventory of Illinois landcover,
4. train volunteers to collect ecological indicator data, and
5. develop an educational science curriculum which incorporates data collection

At the same time that CTAP was publishing its baseline findings, the Illinois Conservation Congress and the Water Resources and Land Use Priorities Task Force were presenting their respective findings. These groups agreed with the CTAP conclusion that the state's

[1] See *The Changing Illinois Environment: Critical Trends*, summary report and volumes 1-7.

ecosystems were declining. Better stewardship was needed, and they determined that a voluntary, incentive-based, grassroots approach would be the most appropriate, one that recognized the inter-relatedness of economic development and natural resource protection and enhancement.

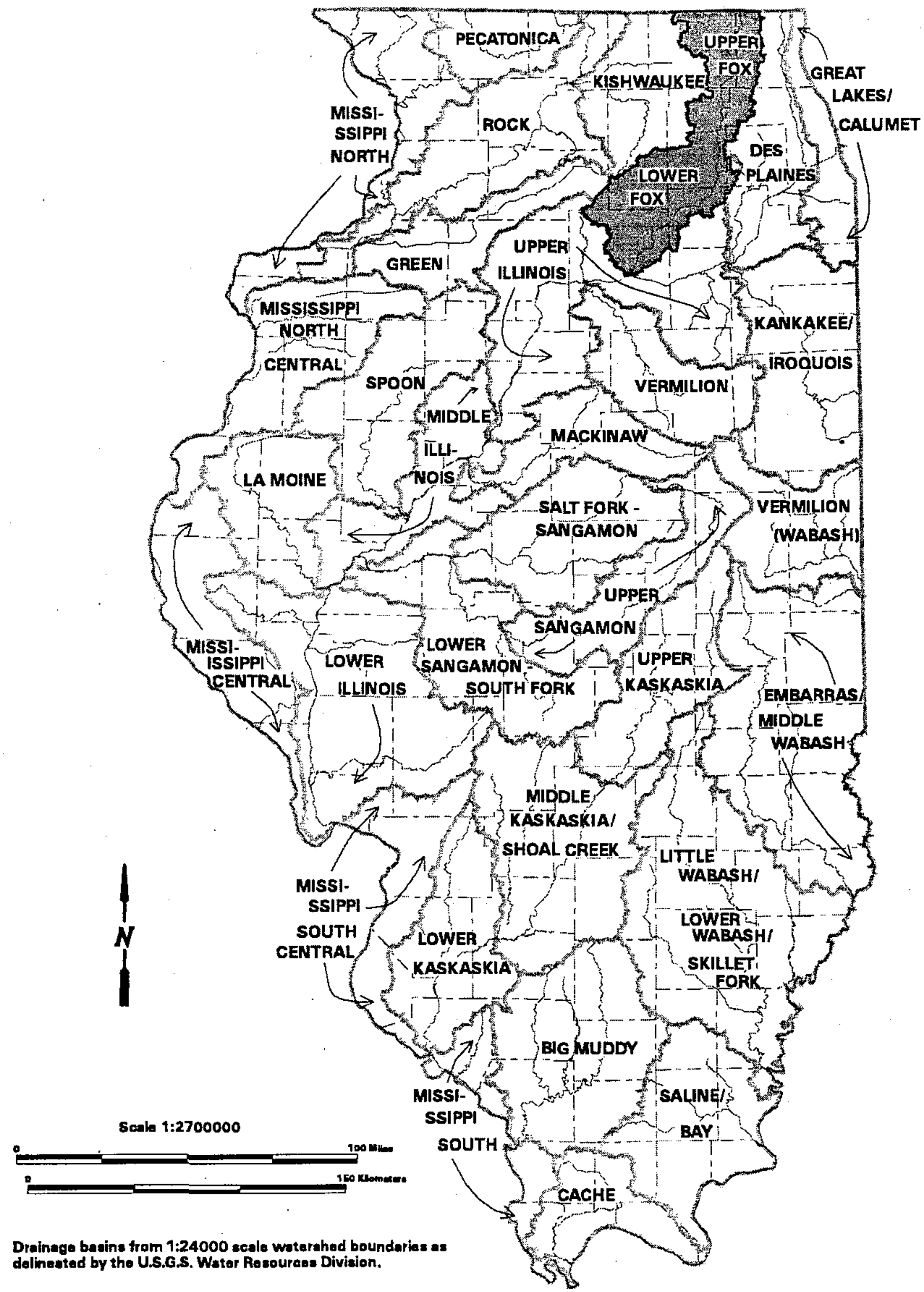
From the three initiatives was born Conservation 2000, a six-year program to begin reversing ecosystem degradation, primarily through the Ecosystems Program, a cooperative process of public-private partnerships that are intended to merge natural resource stewardship with economic and recreational development. To achieve this goal, the program will provide financial incentives and technical assistance to private landowners. The Rock River and Cache River were designated as the first Ecosystem Partnership areas.

At the same time, CTAP identified 30 Resource Rich Areas (RRAs) throughout the state. In RRAs where Ecosystem Partnerships have been formed, CTAP is providing an assessment of the area, drawing from ecological and socio-economic databases to give an overview of the region's resources -- geologic, edaphic, hydrologic, biotic, and socio-economic. Although several of the analyses are somewhat restricted by spatial and/or temporal limitations of the data, they help to identify information gaps and additional opportunities and constraints to establishing long-term monitoring programs in the partnership areas.

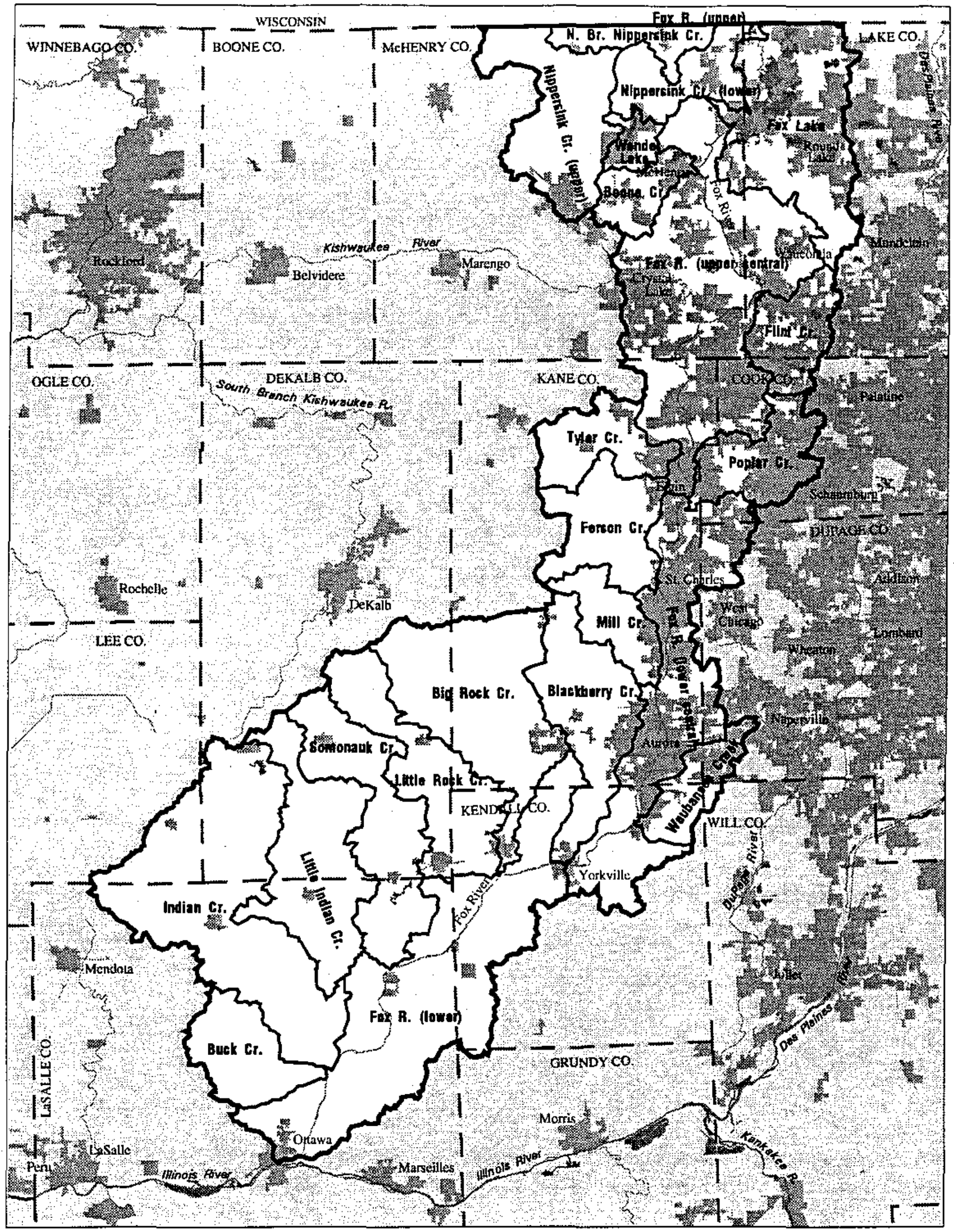
The Fox River Area Assessment

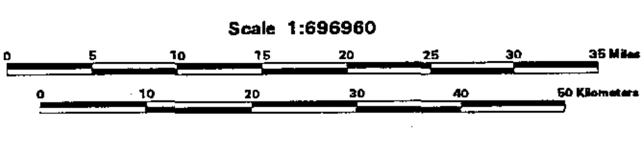
The Fox River assessment covers an area of approximately 1,720 mile (1,092,874 acres) spanning eleven counties in north-eastern Illinois, including parts of Lake, McHenry, Kane, Cook, Kendall, DeKalb, and LaSalle counties, and small parts of Lee, DuPage, Will, and Grundy counties. The boundaries of the assessment area coincide with the boundaries of the Illinois portion of the Fox River Basin. This area encompasses 22 subbasins of the Fox River watershed (identified by the Illinois Environmental Protection Board), from the Illinois-Wisconsin border to the confluence of the Fox and Illinois Rivers at Ottawa, Illinois. This is a distance of 115 miles along the river. The northernmost eight subbasins, totaling 285,844 acres, have been designated as a "Resource Rich Area" because they contain significant natural community diversity. The Fox River Ecosystem Partnership was subsequently formed around this core area of high quality ecological resources.

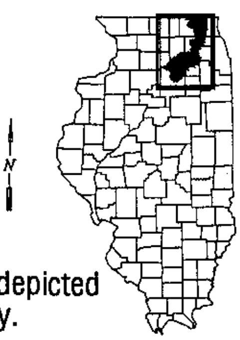
This assessment is comprised of five volumes. In Volume 1, *Geology* discusses the geology, soils, and minerals in the assessment area. Volume 2, *Water Resources*, discusses the surface and groundwater resources and Volume 3, *Living Resources*, describes the natural vegetation communities and the fauna of the region. Volume 4 contains three parts: Part I, *Socio-Economic Profile*, discusses the demographics, infrastructure, and economy of the area, focusing on the six counties with the greatest



Major Drainage Basins of Illinois and Location
of the Fox River Assessment Area







Subbasins in the Fox River assessment area. Subbasin boundaries depicted are those determined by the Illinois Environmental Protection Agency.

amount of land in the area -- DeKalb, Kane, Kendall, Lake, LaSalle, and McHenry counties; Part II, *Environmental Quality*, discusses air and water quality, and hazardous and toxic waste generation and management in the area; and Part III, *Archaeological Resources*, identifies and assesses the archaeological sites, ranging from the Paleo-Indian (B.C. 10,000) to the Postwar Industrial (A.D. 1946), known in the assessment watershed. Volume 5, *Early Accounts of the Ecology of the Fox River Area*, describes the ecology of the area as recorded by historical writings of explorers, pioneers, early visitors and early historians.

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Introduction

The Fox River is located in the northeastern corner of Illinois and southeastern corner of Wisconsin. The river flows south from its headwaters near Waukesha, Wisconsin, to Ottawa, Illinois, where it joins the Illinois River. The Fox River basin (Figure 1) has a total area of approximately 2,658 square miles, 938 of which are in Wisconsin, and includes parts of four Wisconsin counties--Kenosha, Racine, Walworth, and Waukesha--and 11 Illinois counties--Cook, De Kalb, Du Page, Grundy, Kane, Kendall, Lake, La Salle, Lee, McHenry, and Will. The basin is about 130 miles long, from north to south, and rarely exceeds 25 miles in width.

The Fox River basin is one of the most unique and most studied watersheds in Illinois. One of its unique characteristics is the number of glacially formed lakes in the northern part of the basin, most notably the Fox Chain of Lakes in northwestern Lake County. Water quality in these lakes and along the Fox River has long been a concern, primarily because of the dense growth of algae in the lakes during the summer (Kothandaraman et al., 1977; Singh et al., 1995). Flood control and water-level stabilization in the Fox Chain of Lakes has also been a concern (U.S. Army Corps of Engineers, 1984; Northeastern Illinois Planning Commission, 1991; Knapp and Ortel, 1992).

Urban development along the western fringe of the Chicago metropolitan area has placed additional pressure on water quality, especially from construction practices and urban drainage. But the most notable impacts of urbanization are the increased need for river water for public water supply and the use of the river for assimilation of treated wastewaters (Broeren and Singh, 1987; Knapp, 1988; Singh et al., 1995).

Much of the material included here on the general hydrology of the Fox River basin was taken from Knapp (1988).

Rivers and Streams

The Illinois portion of the Fox River basin contains approximately 2,300 river miles, as measured from 1:100,000 topographic mapping. Due to the linear shape of the basin, there are only four large tributaries to the Fox River, three of which are in Illinois: Indian, Big Rock, and Nippersink Creeks. In addition to these major tributaries, there are a number of medium-sized tributaries, with drainage areas ranging from 40 to 100 square miles. These tributaries are listed in Table 1.

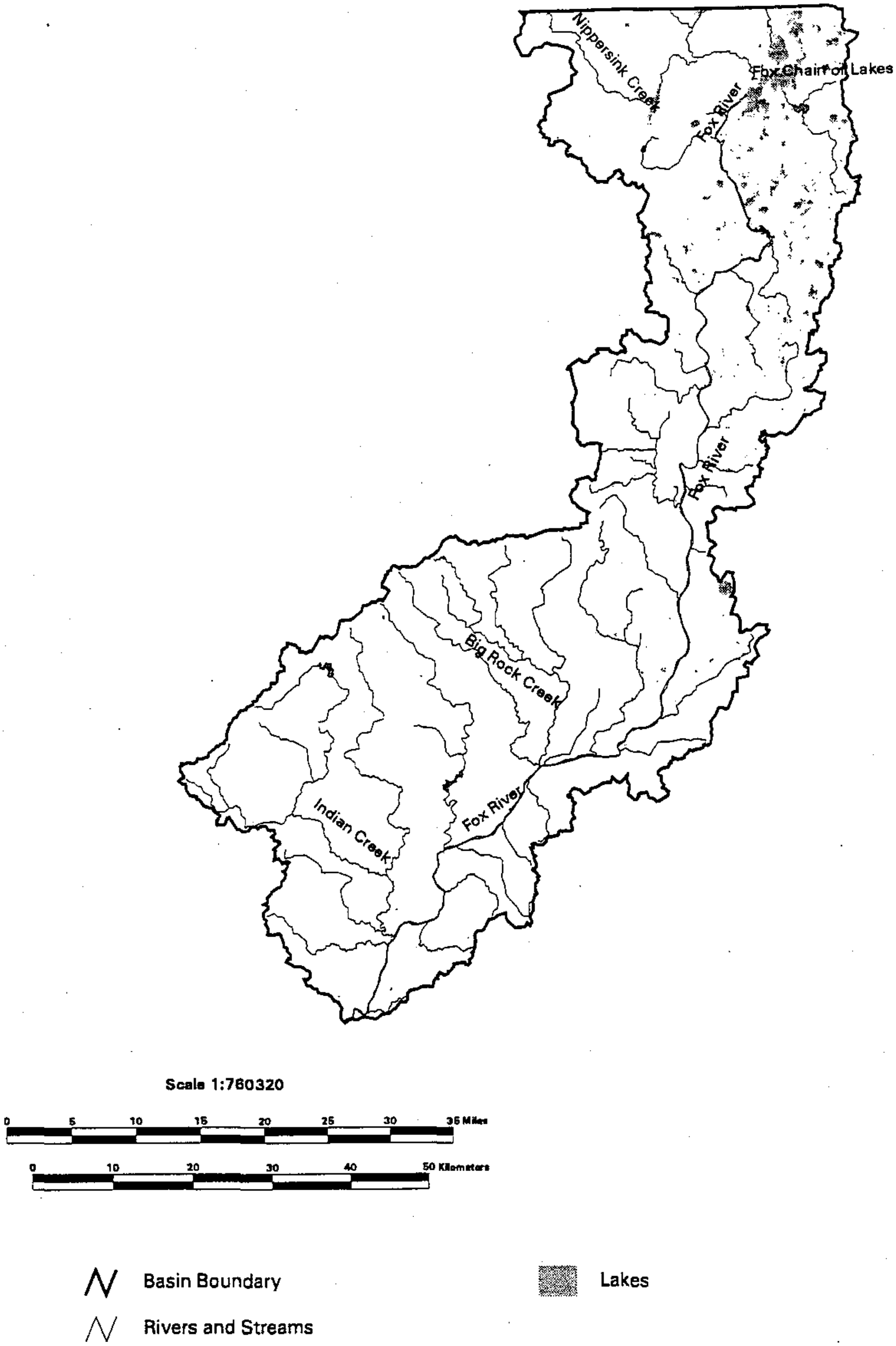


Figure 1. Rivers, Streams, and Lakes in the Fox River Basin

Table 1. Selected Tributaries to the Fox River Basin in Illinois

Stream name	Counties	Drainage area (square miles)
Buck Creek	La Salle	41
Indian Creek	La Salle, De Kalb	264
Somonauk Creek	La Salle, De Kalb	88
Big Rock Creek	Kendall, Kane, De Kalb	194
Blackberry Creek	Kendall, Kane	73
Ferson Creek	Kane	54
Poplar Creek	Cook	44
Tyler Creek	Kane	40
Flint Creek	Lake	37
Nippersink Creek	McHenry	205
Squaw Creek	Lake	46

Figure 2 shows a profile view of the Fox River from its headwaters to its confluence. The profile of the Fox River is atypical of most rivers in that its channel slopes are greatest in the downstream reaches of the stream. The total length of the river is approximately 185 miles, and the total fall from headwaters to confluence is about 460 feet, for an average slope of 2.46 feet per mile.

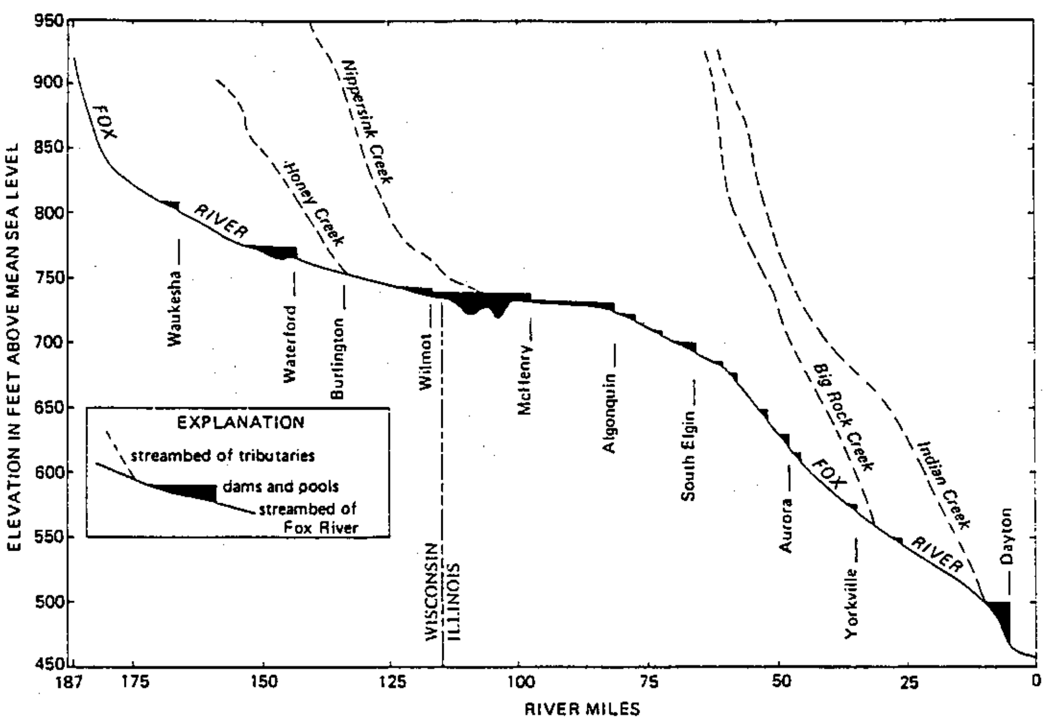


Figure 2. Stream Profile of the Fox River and Major Tributaries (from Knapp, 1988)

In the 50-mile reach between Burlington, Wisconsin, and Algonquin, Illinois, the slope of the river is very flat, averaging less than 0.5 feet per mile. The mild slope and low-lying areas create many wetlands and marshes along this reach. Downstream of Algonquin, the slope of the river increases as the river starts down-cutting through several layers of limestone bedrock. Most of the tributaries in the Fox River basin have moderately steep channel slopes, averaging 5 to 10 feet per mile.

Roughly 34% of the stream miles in the Fox River basin have been channelized, mainly in nearly level, poorly drained upland areas (Mattingly and Herricks, 1991). Drainage tiles are typically needed in these areas to promote field drainage.

Lakes

The Fox River basin in Illinois has 406 lakes, as measured from 1:100,000 topographic mapping. The largest lakes are listed in Table 2. Lake and McHenry Counties, in particular, contain many natural lakes caused by depressions in the glacial deposition.

Table 2. Significant Lakes and Reservoirs in the Fox River Basin in Illinois

Name	County	Origin	Surface area (acres)
Bangs Lake	Lake	Natural	297
Bluff Lake *	Lake	Natural	86
Lake Catherine *	Lake	Natural	147
Cedar Lake	Lake	Natural	285
Channel Lake *	Lake	Natural	318
Crystal Lake	McHenry	Natural	228
East Loon Lake	Lake	Natural	170
Fox Lake*	Lake	Natural	1,709
Grass Lake*	Lake	Natural	1,478
Griswold	McHenry	Natural	141
Highland	Lake	Natural	110
Lake Holiday	La Salle	Man-made	326
Long Lake	Lake	Natural	335
Lake Marie *	Lake	Natural	516
McCullom	McHenry	Natural	245
Nippersink *	Lake	Natural	383
Petite *	Lake	Natural	165
Pistakee *	Lake	Natural	2,048
Round	Lake	Natural	229
Shabbona	De Kalb	Man-made	318
Slocum	Lake	Natural	215
West Loon Lake	Lake	Natural	163
Wonder Lake	McHenry	Man-made	830
Wooster	Lake	Natural	100
Lake Zurich	Lake	Natural	228

Note: All of these lakes and reservoirs are used primarily for recreation.
* Part of the Fox Chain of Lakes.

The most conspicuous of these lakes are the Fox Chain of Lakes in northeastern Lake County. The Chain of Lakes comprise nine interconnected lakes, with a combined surface area of 6,850 acres and a storage capacity of approximately 37,000 acre-feet at the winter pool level. During the summer recreational pool, the surface area of the lakes increases to 7,700 acres and the storage increases to 44,000 acre-feet. The lake level and outflow for the Chain of Lakes are partially controlled by Stratton Dam (formerly McHenry Dam), which is located on the Fox River six miles downstream of the lakes.

Although most of the lakes in the Fox River basin originated as natural lakes, all but a few have had impounding structures installed at the lake outfall to reduce the variability of stage and prevent the lake level from dropping too low. These structures have caused most of the natural lakes in the region to behave much like man-made lakes.

Channel Dams

In addition to lakes and reservoirs, there are 15 low channel dams on the Fox River in Illinois (Table 3). Most of these dams were built during 1830-1850 to provide power for saw mills and flour mills, and they are typically only 7 or 8 feet high. Over the years, these dams were improved and replaced, and they continued to provide power throughout the early part of the twentieth century (Illinois Rivers and Lakes Commission, 1915).

Table 3. Fox River Dams in Illinois

Name	Location (river mile)	Type/function
Stratton	98.9	Navigation, pool control
Algonquin	82.6	Channel
Carpentersville	78.8	Channel
Elgin	71.9	Channel (old hydropower)
South Elgin	68.2	Channel (old hydropower)
St. Charles	60.6	Channel
Geneva	58.7	Channel
North Batavia	56.3	Channel
South Batavia	54.9	Channel
North Aurora	52.6	Channel/reaeration
Stolp Island, Aurora	48.9	Channel
Hurds Island, Aurora	48.4	Channel
Montgomery	46.8	Channel/reaeration
Yorkville	36.5	Channel
Dayton	5.6	Hydropower

The Dayton Dam, which is located at the downstream end of the Fox River and has a height of 30 feet, is the only dam that currently produces electricity. The other dams on the river are used primarily for recreation and to retain customary high pool levels. Downstream of South Elgin, the channel bottom of the Fox River is mostly bedrock, and without the heightened pool levels provided by these dams the water depth would frequently be shallow (less than 3 feet) and inhibit recreational boating.

With the exception of Stratton Dam, these dams do little to alter the river's flow pattern. However, the increase in normal pool levels does cause flood levels to be higher as well (U.S. Army Corps of Engineers, 1984).

Wetlands

Wetlands are an important part of our landscape because they provide critical habitat for many plants and animals and serve an important role in mitigating the effects of storm flow in streams. They are also government-regulated landscape features under Section 404 of the Clean Water Act. In general, wetlands are a transition zone between dry uplands and open water; however, open-water areas in many upland depressional wetlands are dry at the surface for significant portions of the year.

The Fox River basin has about 4.9% (53,401 acres) of its total area in wetlands (Table 4). However, wetlands are not distributed evenly across the watershed, either in acreage or by wetland type. (For wetland categories, see the table describing wetland and deepwater habitat in Volume 3: Living Resources.)

Table 4. Wetlands in the Fox River Basin

	Subbasin		Wetlands		
Subbasin name	Acres	% of area	Acres	% of subbasin	% of total wetlands
Big Rock Cr.	74,143	6.8	830.83	1.1	1.6
Blackberry Cr.	46,571	4.3	1,868.97	4.0	3.5
Boone Cr.	15,649	1.4	1,206.93	7.7	2.3
Buck Cr.	28,029	2.6	97.79	0.3	0.2
Ferson Cr.	34,575	3.2	1,629.89	4.7	3.1
Flint Cr.	23,919	2.2	2,330.40	9.7	4.4
Fox Lake	70,434	6.4	15,643.72	22.2	29.3
Fox R. (lower central)	85,340	7.8	3,666.12	4.3	6.9
Fox R. (lower)	123,595	11.3	1,746.06	1.4	3.3
Fox R. (upper central)	129,809	11.9	10,463.78	8.1	19.6
Fox R. (upper)	734	0.1	89.63	12.2	0.2
Indian Cr.	112,191	10.3	965.90	0.9	1.8
Little Indian Cr.	56,543	5.2	310.51	0.5	0.6
Little Rock Cr.	48,813	4.5	451.05	0.9	0.8
Mill Cr.	19,698	1.8	586.51	3.0	1.1
N. Br. Nippersink Cr.	13,549	1.2	1,775.93	13.1	3.3
Nippersink Cr. (lower)	25,104	2.3	1,745.39	7.0	3.3
Nippersink Cr. (upper)	50,345	4.6	2,856.36	5.7	5.3
Poplar Cr.	28,551	2.6	1,757.28	6.2	3.3
Somonauk Cr.	52,884	4.8	947.82	1.8	1.8
Tyler Cr.	25,689	2.4	1,442.83	5.6	2.7
Waubansee Creek	18,806	1.7	544.82	2.9	1.0
Wonder Lake	7,886	0.7	442.40	5.6	0.8
Total	1,092,857	100.0	53,400.92	-	100.0

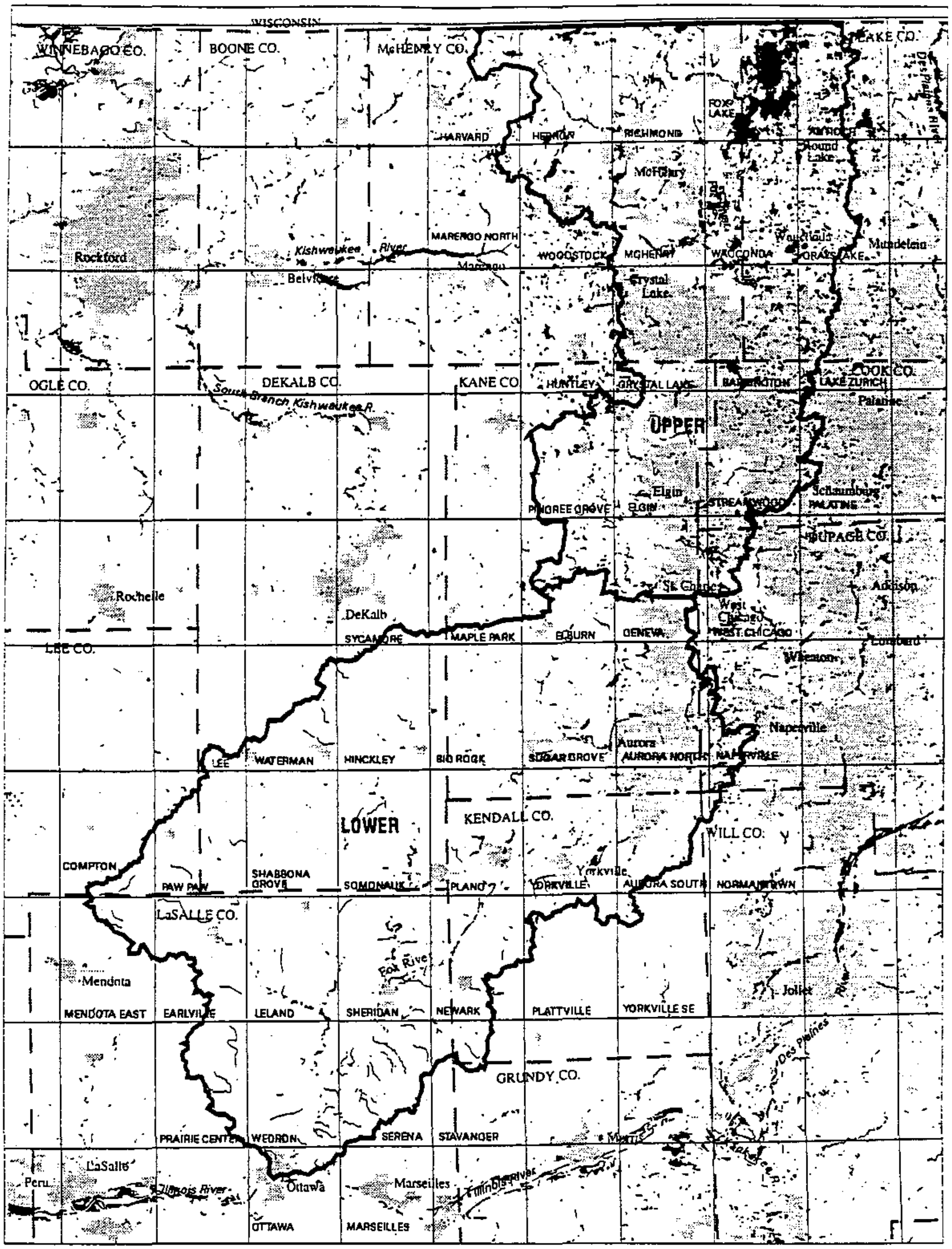
If the basin is divided into upper and lower portions (Figure 3), the differences in acreage and type become more obvious, as shown in Table 5. Approximately 81% (43,087 acres) of the total wetland acreage (53,401 acres) occurs in the area shown as the Upper Fox River basin. As described in Volume 3, the percentages of shallow marsh/wet meadow, deep marsh, and shallow lake wetlands are considerably higher than the state averages. Bottomland forested wetlands only make up 12.9% of wetland areas in the basin, while the state average is 60.9%. The difference is more pronounced if considered on the basis of the upper and lower basins: 7.5% for the upper and 35% for the lower basin.

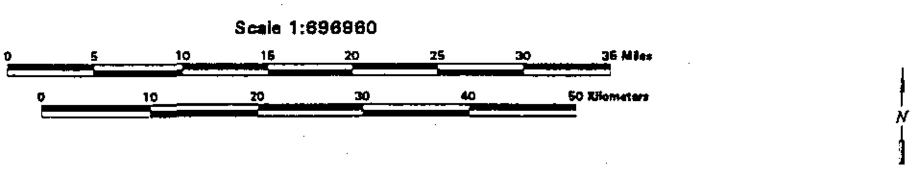
Table 5. Wetlands in the Upper and Lower Fox River Basins
(Based on data from the Illinois Wetlands Inventory)

	Upper Fox River Basin			Lower Fox River Basin		
Category	Acreage	% of total wetlands	% of total land area	Acreage	% of total wetlands	% of total land area
Palustrine Wetlands						
Shrub-Scrub Wetlands	1,554.91	3.6	0.3	407.61	4.0	0.1
Forested Wetlands						
Bottomland Forest	3,230.54	7.5	0.7	3,679.63	35.7	0.6
Swamp	2.32	0.0	0.0	1.03	0.0	0.0
Emergent Wetlands						
Shallow Marsh/Wet Meadow	19,770.96	45.9	4.4	4,134.32	40.1	0.6
Deep Marsh	7,903.38	18.3	1.7	293.47	2.8	0.0
Open Water Wetlands	4,391.03	10.2	1.0	1,453.01	14.1	0.2
Subtotal Palustrine*	36,853.14	85.5	8.2	9,969.07	96.7	1.6
Lacustrine Wetlands						
Shallow Lake	6,226.51	14.5	1.4	62.51	0.6	0.0
Lake Shore	6.00	0.0	0.0	0.29	0.0	0.0
Emergent Lake	0.00	0.0	0.0	0.00	0.0	0.0
Subtotal Lacustrine	6,232.51	14.5	1.4	62.80	0.6	0.0
Riverine Wetlands						
Perennial Riverine	0.00	0.0	0.0	9.90	0.1	0.0
Intermittent Riverine	1.17	0.0	0.0	272.40	2.6	0.0
Subtotal Riverine	1.17	0.0	0.0	282.30	2.7	0.0
Total Wetlands	43,086.82	100.0	9.5	10,314.17	100.0	1.6

Note: Total area is 451,736 acres for the Upper Fox River basin and 641,132 acres for the Lower Fox. * Subtotal of shrub-scrub, forested, emergent, and open water wetlands.

The differences in wetland area and type can be largely attributed to differences in glacial activity in these two areas, which resulted in differences in surface landforms and subsurface materials. During the later phases of the Wisconsin glacial episode, thick debris-rich ice piled up and stagnated on the bedrock in the northern Fox River valley. During melting of this debris-rich ice, glacial meltwaters deposited material in rivers and lakes that formed in contact with the stagnant ice; this produced a chaotic landscape of very hummocky terrain when the sediment collapsed as the ice melted. The combination





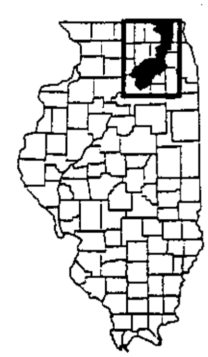


Figure 3. Wetlands from the National Wetlands Inventory and quadrangle map boundaries for the Fox River assessment area. The inset area is depicted in the following figure.

of materials and ice movement produced a surface more prone to lakes and marshes than the area to the south containing the lower basin, where linear moraines formed along the margins of the glacier, producing a landscape of more clearly defined uplands and lowlands. In this landscape, bottomland forested wetlands are more likely to be the dominant wetland type since human activities favor filling and draining the upland depressional wetland type.

The hydrogeology of wetlands allows water to accumulate in them longer than in the surrounding landscape, with far-reaching consequences for the natural environment. Wetland sites become the locus of organisms that require or can tolerate moisture for extended periods of time, and the wetland itself becomes the breeding habitat and nursery for many organisms that require water for early development. Plants that can tolerate moist conditions (hydrophytes) can exist in these areas, whereas upland plants cannot successfully compete for existence. Given the above conditions, the remaining wetlands in our landscape are refuges for many plants and animals that were once widespread but are now restricted to existing wetland areas.

The configuration of wetlands enables them to retain excess rainwater, extending the time the water spends on the upland area. The effect of this retention on the basin is to delay the delivery of water to the main stream. This decreases the peak discharges of storm flow or floods, thus reducing flood damages and the resulting costs. It is important to realize that the destruction of wetland areas has the opposite effect, increasing peak flood flows and thereby increasing flood damages and costs.

The location of wetlands affects many day-to-day decisions because wetlands are considered "Waters of the United States" (Clean Water Act) and are protected by local, state, and federal legislation (for example, the Rivers and Harbors Act of 1899, Section 10; the Clean Water Act; and the Illinois Interagency Wetlands Act of 1989). Activities by government, private enterprise, and individual citizens are subject to regulations administered by the U.S. Army Corps of Engineers. Under a Memorandum of Agreement between federal regulatory agencies with jurisdiction over wetlands, the Natural Resources Conservation Service takes the lead in regulating wetland issues for agricultural land, and the U.S. Army Corps of Engineers takes the lead for all nonagricultural lands.

In contexts where wetland resources are an issue, the location and acreage of a wetland will be information required by any regulatory agency, whether local, state, or federal. Currently, there are two general sources of wetland location information for Illinois: the National Wetland Inventory (NWI), completed in 1980, and *Illinois Land Cover, an Atlas* (*ILCA*) by the Illinois Department of Natural Resources (1996). The State of Illinois used the NWI information to publish the *Wetland Resources of Illinois: An Analysis and Atlas* (Suloway and Hubbell, 1994). While this atlas is not of suitable scale for landowners or government agencies to use for individual wetland locations, it can be used by agencies or groups that consider wetlands in an administrative or general government manner and focus on acreage and not individual wetland boundaries.

The NWI program involved identifying wetlands on aerial photographs of 1:58,000 scale and publishing maps of this information using USGS 1:24,000-scale topographic quadrangle maps as the base. NWI quadrangle maps for the Fox River basin are shown in Figure 3. Individual quadrangles can be purchased from:

Center for Governmental Studies
Wetland Map Sales
Northern Illinois University
De Kalb, IL 60115
Telephone: (815) 753-1901

Digital data by quadrangle are available from the NWI Web site: www.nwi.fws.gov.

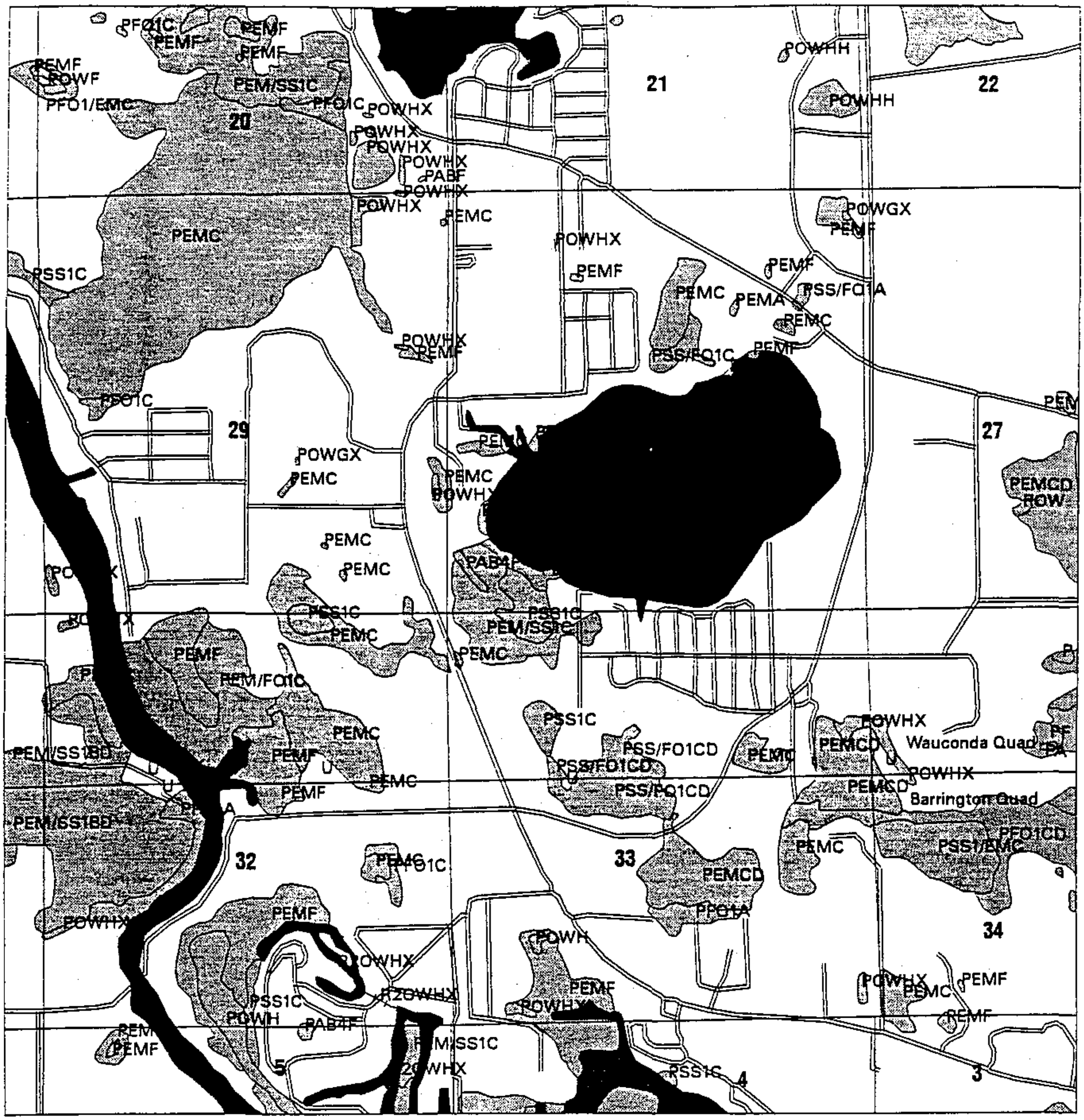
The ILCA inventory used Landsat Thematic Mapper satellite data as the primary source for interpretation. National Aerial Photography Program photographs verified the land cover classification and helped ensure consistency from area to area within Illinois. The ILCA and companion compact disc can be purchased from:

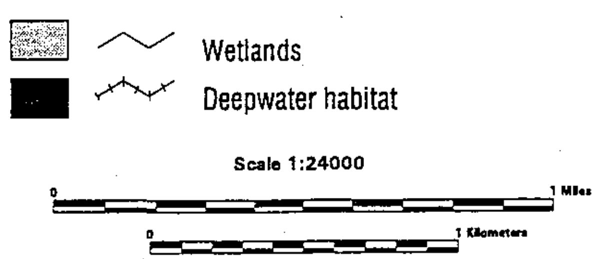
Illinois Department of Natural Resources
524 South Second Street
Lincoln Tower Plaza
Springfield, IL 62701-1787
Telephone: (217) 524-0500
E-mail: ctap2@dnrmail.state.il.us
Web site: http://dnr.state.il.us/ctap/ctaphome.htm

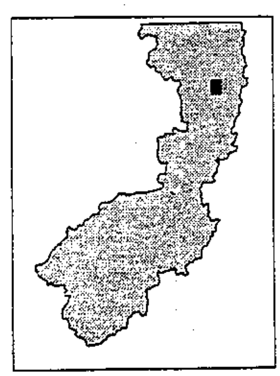
Although the ILCA and NWI programs were not meant for regulatory purposes, they are the only state or regional wetland map resources available and are the logical sources for beginning a wetland assessment. The presence or absence of wetlands as represented by the wetland maps is not certified by either the ILCA or the NWI mapping program. Figure 4, taken from the Wauconda and Barrington Quadrangles in the Fox River basin, exemplifies the information that can be expected from NWI maps.

In some areas with intense economic development and significant wetland acreage, the NWI maps have been redone or updated for use in designating or locating wetland areas. Whatever the source of wetland map information, the user should be aware that this information is a general indication of wetland locations, and the boundaries and exact locations should be field-verified by persons trained or certified in wetland delineation.

Given the limitations of most existing wetland maps, more complete information can be obtained by comparing mapped wetlands with other regional attributes such as shallow aquifers, subsurface geology, and placement in the landscape. When these comparisons show consistent regional patterns (for example, placement in the landscape or correlation with a particular geologic material), any parcels of land with similar landscape positions or geologic materials can be considered potential wetland sites even if maps do not show them as wet.







Fox River AA

Figure 4. National Wetlands Inventory information from the Wauconda and Barrington 7.5-minute quadrangle maps showing wetlands, deepwater habitats, and NWI codes.

Physiography

The topography of the Fox River basin was formed as a result of the deposition of glacial till that occurred during the Wisconsin glacial period. Two major physiographic subdivisions can be identified: the Wheaton Morainal Country, which covers the northern half of the basin including areas in Wisconsin, and the Bloomington Ridged Plain (Leighton et al., 1948). The two regions are separated by the Marengo Ridge, which crosses the Fox River basin near Geneva in central Kane County. In both physiographic subdivisions, the terrain is the result of glacial deposition by terminal and recessional moraines; however, the characteristics of the regions differ greatly.

Wheaton Morainal Country

Glacial deposition is discontinuous in this region, and smaller moraines frequently occur in close proximity to each other. A variety of "elongated hills, mounds, basins, sags, and valleys" exist, which result in a complex and varied topography (Leighton et al., 1948). A considerable amount of the land contains pockets of sandy and gravely material, originating from glacial outwash. The varied pattern of glacial deposition in the region has also created a number of depressions in which lakes are formed.

Bloomington Ridged Plain

The southern part of the basin is within the Bloomington Ridged Plain, with depositional plains of low relief underlain by thick till from Wisconsin-age glaciation. This region is relatively homogeneous, crossed by low and expansive moraines and having wide stretches of flat or gently sloping uplands. The upland areas are broken only by stream valleys, which are generally poorly developed and only moderately incised into the landscape.

Elevations and Land Slopes

Elevations in the basin range from more than 1,100 feet above mean sea level (msl) in northern McHenry County and southern Walworth County to 460 feet msl at the Fox's confluence with the Illinois River. Elevations are generally greatest along the entire western edge of the basin and decrease to the east and south.

Table 6 shows the average distribution of land slopes in the two physiographic subdivisions, estimated from data in Runge et al. (1969). More than 25% of the Wheaton Morainal Country is moderately rolling to steeply sloping (slopes greater than 4%). Conversely, less than 10% of the Bloomington Ridged Plain has slopes that steep, and most of the land is nearly level (less than 2% slope). The terrain in the Wheaton Morainal Country generally has greater relief and variety in surface features than that of the Bloomington Ridged Plain.

Table 6. Distribution of Land Slopes in the Fox River Basin
(Source: Runge et al., 1969)

	Percent of land	
Slope, %	Wheaton Morainal Ctry.	Bloomington Ridged Plain
0–2	43.	58.
2–4	31.	33.
4–7	17.	7.
7–12	6.	1.0
12–18	2.7	0.6
18–30	0.3	0.3
>30	0.0	0.1

Soils

The Wheaton Morainal Country contains a mixture of soil types, including 1) the Casco-Fox association, which is developed on glacial outwash and has moderately rapid to rapid permeability; 2) the moderately permeable and well-drained upland soils developed on sandy and silty loams, represented by the Kidder-McHenry and Griswold-Ringwood associations; and 3) the poorly to moderately drained silty-clay upland soils such as the Drummer-Saybrook association. A fourth soil group, the Morley-Markham-Houghton association, occurs in the lowland areas on the eastern side of the Fox River. This group has moderately slow to very slow permeability and, in the case of the Houghton soils, very poor drainage.

Most of the upland soils in the Bloomington Ridged Plain are generally very similar and have somewhat poor to moderate drainage. A typical soil association in this region is the Drummer-Saybrook-Catlin. Soils in the Fox River basin are well drained with rapid permeability, as typified by the Fox-Casco-Dresden association.

Land Use

Agriculture is a major land use in the nine major counties (Cook, De Kalb, Du Page, Kane, Kendall, La Salle, Lake, Lee, and McHenry) within the Fox River basin. Illinois Agricultural Statistics (IAS) data indicate that in 1995 agriculture acreage (479,701) accounted for approximately 44% of the total watershed area. This acreage has remained virtually the same since 1925, averaging around 507,700. Figure 5 shows changes in selected crop acreage in the Fox River basin from 1925 to 1995.

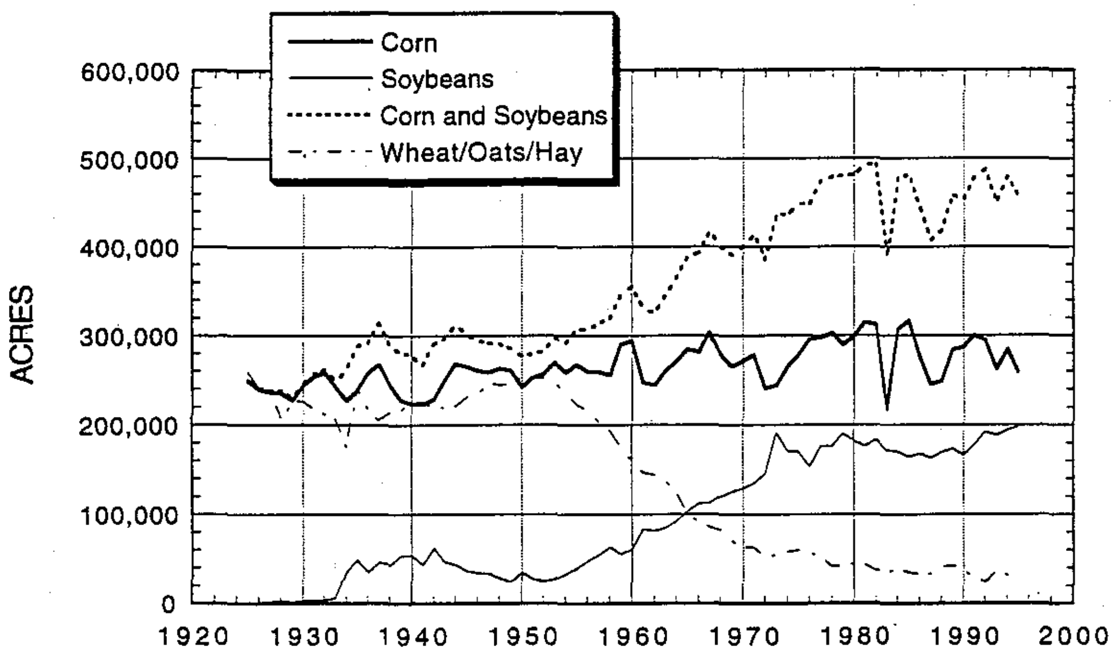


Figure 5. Acreages of Selected Crops in the Fox River Basin Based on IAS Data

In 1925 the dominant crops were corn and wheat, oats, and hay (grassy crops), accounting for 93% of the agricultural crops grown in the basin (249,000 acres for corn and 260,000 for grassy crops). However, starting in the 1950s, soybeans increased while grassy crops decreased. This inverse relationship between soybeans and grassy crops continued through 1995, with soybean acreage increasing to 197,800 and grassy crop acreage decreasing to 23,800, near the soybean acreage during the 1930s. Soybean acreage moderated its increasing trend in 1973 and remained relatively steady through 1995. Grassy crop acreage was nearly that of corn from 1925 through 1952. Corn has remained steady over time, averaging 264,000 acres and increasing only slightly to levels above 300,000 acres in the early 1980s.

Climate and Trends in Climate

This chapter reviews climate trends in and around the Fox River basin since the turn of the century. Climate parameters examined include: annual mean temperature, the number of days with highs above or equal to 90°F, the number of days with lows below or equal to 32°F, the number of days with lows below or equal to 0°F, annual precipitation, the number of days with measurable precipitation, annual snowfall, and the number of days with measurable snowfall. Extreme weather events--tornadoes, hail, and thunderstorms--are also examined in this report.

The Fox River basin in northern Illinois occupies portions of McHenry, Lake, Cook, Kane, Du Page, De Kalb, Lee, La Salle, Kendall, Grundy, and Will Counties. The climate of this area is typically continental, as shown by its changeable weather and the wide range of temperature extremes. Summer maximum temperatures are generally in the 80s or low 90s, with lows in the 50s or 60s, while daily high temperatures in winter are generally in the 20s or 30s, with lows in the teens or 20s. Based on the latest 30-year average (1961-1990), the average first occurrence of 32°F in the fall is October 8, and the average last occurrence in the spring is May 3.

Precipitation is normally heaviest during the growing season and lightest in midwinter. Thunderstorms and associated heavy showers are the major source of growing season precipitation, and they can produce gusty winds, hail, and tornadoes. The months with the most snowfall are December, January, February, and March. However, snowfalls have occurred as early as September and as late as May. Heavy snowfalls have rarely exceeded 12 inches.

The climate data used in the following discussions originate at Aurora, Illinois (Kane County), the National Weather Service (NWS) Coop site with the longest record (1901-1996), located within the central portion of the basin. Supportive data and analyses for nearby Illinois sites can be found in reports by the Illinois Department of Energy and Natural Resources (1994) and Changnon (1984).

Temperature

The mean January maximum temperature is 29°F and the minimum is 11°F, whereas the mean July maximum and minimum temperatures are 84°F and 62°F, respectively (Table 7). The mean annual temperature at Aurora is 48.4°F. The warmest year of record since 1901 was 1921, with an average of 53.5°F, while the coldest was 1917, with an average of 45.1°F.

Table 7. Temperature Summary for Aurora, Illinois
(Averages are from 1961-1990 and extremes are from 1901-1996. Temperatures are in°F)

	Avg. high	Avg. low	Record high (year)	Record low (year)	# of days with high ≥90°F	# of days with low ≤32°F	# of days with low ≤ 0°F
January	28.7	10.7	66 (1909)	-26 (1985)	0.0	29.0	6.0
February	33.6	14.8	70 (1976)	-25 (1905)	0.0	26.0	3.9
March	45.7	26.9	83 (1986)	-15 (1943)	0.0	23.0	0.3
April	59.6	37.5	92 (1930)	8 (1982)	0.1	9.5	0.0
May	71.3	47.5	104 (1934)	21 (1966)	0.7	1.1	0.0
June	81.0	57.2	106 (1934)	34 (1929)	4.3	0.0	0.0
July	84.2	61.8	111 (1936)	40 (1907)	7.6	0.0	0.0
August	82.0	59.8	105 (1934)	37 (1915)	5.3	0.0	0.0
September	75.1	52.0	103 (1939)	25 (1928)	1.8	0.5	0.0
October	63.3	40.4	90 (1954)	11 (1925)	0.0	6.2	0.0
November	48.0	29.9	81 (1950)	-11 (1947)	0.0	19.0	0.1
December	33.7	17.2	67 (1982)	-25 (1914)	0.0	27.0	3.3

Although there is a great deal of year-to-year variability, mean annual temperatures at Aurora show a warming trend from 1901 to 1940, followed by a cooling trend until 1980, before leveling off in the 1980s and 1990s (Figure 6).

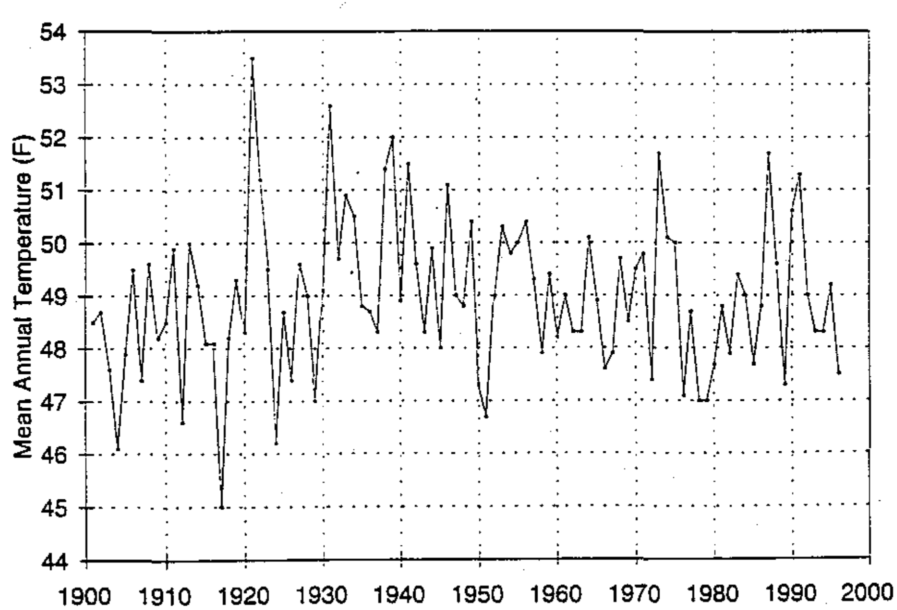


Figure 6. Mean Annual Temperature for Aurora, 1901-1996

Examination of mean temperatures over time is one way to clarify trends. The NWS has adopted 30-year averages, ending at the beginning of the latest new decade, to represent climate "normals." These averages were adopted to filter out some of the smaller scale features and yet retain the character of the longer term trends. Consecutive, overlapping "normals" for the last seven 30-year periods at Aurora are presented in Table 8. The consecutive means demonstrate the warming trend through the 1931-1960 period, followed by the cooling trend through the 1961-1990 period.

Table 8. Average Annual Temperature during Consecutive 30-Year Periods

Averaging period	Average temperature (°F)
1901-1930	48.5
1911-1940	49.1
1921-1950	49.5
1931-1960	49.5
1941-1970	49.0
1951-1980	48.8
1961-1990	48.8

The frequency of extreme events sometimes conveys a clearer picture of trends than mean values. The annual number of days with temperatures equal to or above 90°F is shown in Figure 7. Not too surprisingly, the time series bears little resemblance to that of annual temperature (Figure 6), because the number of days with temperatures above 90°F represents only the high summer temperature extremes. Figure 7 shows an upward trend from 1901 to 1930, followed by a decline through 1980. The latest period, 1981-1996, exhibits a much higher degree of variability than any previous period.

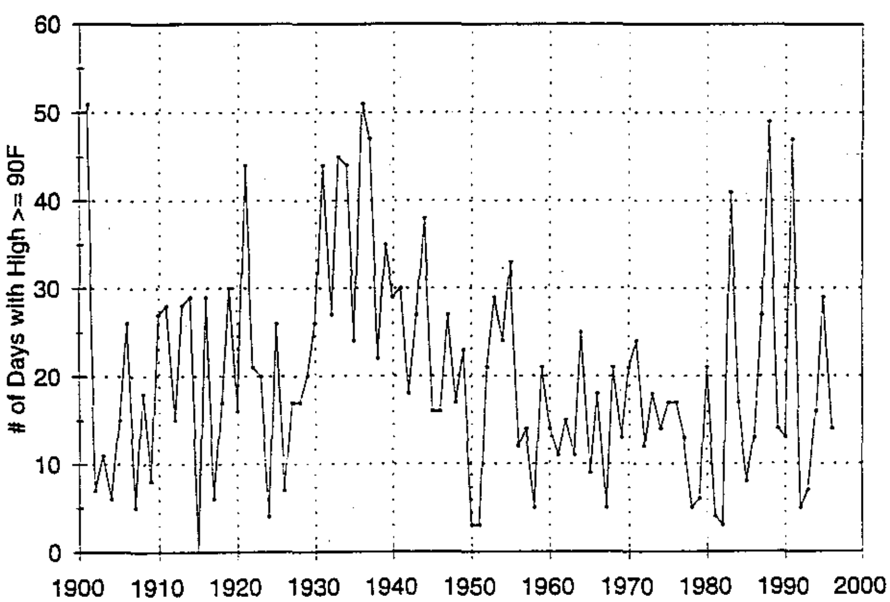


Figure 7. Annual Number of Days with Maximum Temperatures Equal to or Above 90°F at Aurora, 1901-1996

Figure 8 shows the frequency of daily minimum temperatures equal to or below 32°F. There are no long-term trends, although the 1960s and 1980s show less variability than any other decades. Figure 9 shows the frequency of daily minimum temperatures equal to or below 0°F, beginning in 1901-1902. There is great year-to-year variability.

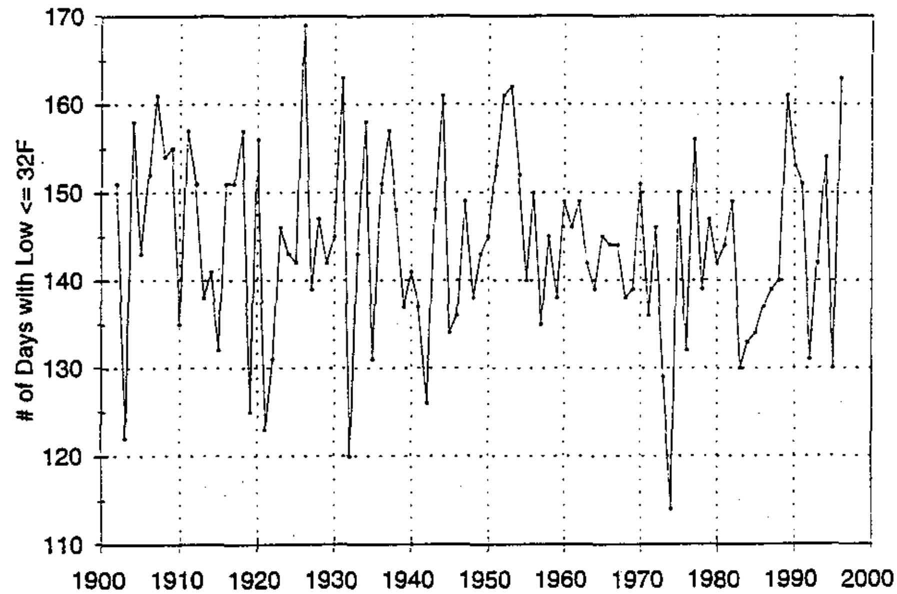


Figure 8. Annual Number of Days with Minimum Temperatures Equal to or Below 32°F at Aurora, Winters 1901-1902 to 1995-1996

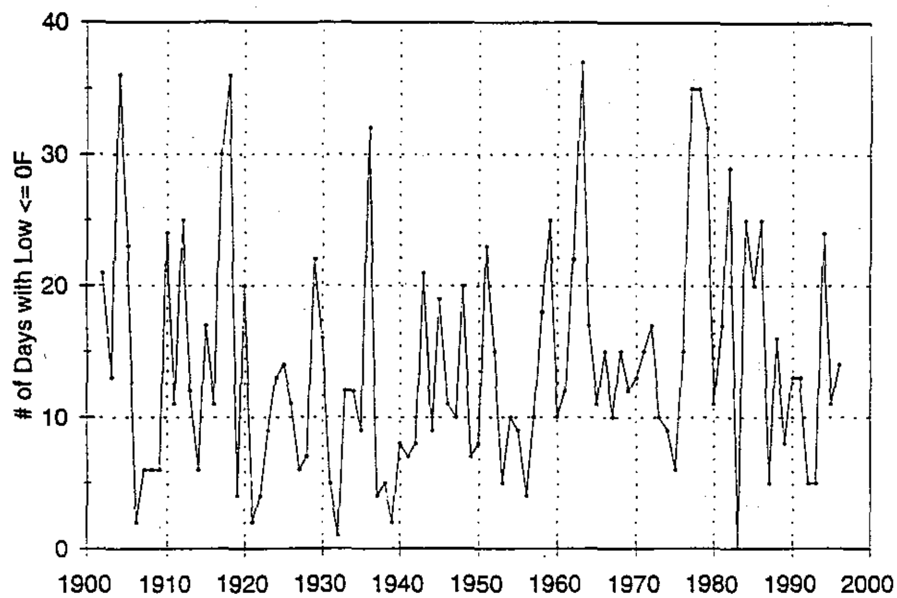


Figure 9. Annual Number of Days with Minimum Temperatures Equal to or Below 0°F at Aurora, Winters 1901-1902 to 1995-1996

Precipitation

Mean annual precipitation is 36.88 inches, with more rainfall in the spring and summer than in fall and winter (Table 9). Late spring, summer, and early fall precipitation is primarily convective in nature, often associated with thunderstorms, with an average duration of 1 to 2 hours. During the remainder of the year, precipitation is of longer duration and associated with synoptic-scale weather systems (cold fronts, occluded fronts, and low pressure systems).

The wettest year of record since 1901 at Aurora was 1972 (51.50 inches). The driest year was 1956 (22.09 inches).

Table 9. Precipitation Summary for Aurora, Illinois

(Averages are from 1961-1990 and extremes are from 1901-1996. Precipitation is in inches.)

	Avg. precip.	Record high (year)	Record low (year)	Largest one-day amount (year)	Snow-fall	# of days w/ precip.
January	1.56	4.80 (1916)	0.07 (1981)	2.91 (1960)	8.6	9
February	1.34	3.86 (1908)	0.00 (1987)	3.26 (1997)	7.6	8
March	2.57	6.12 (1920)	0.33 (1994)	3.51 (1948)	3.7	10
April	3.83	8.38 (1909)	0.39 (1901)	3.52 (1959)	1.1	11
May	3.78	8.62 (1915)	0.56 (1934)	3.59 (1990)	0	10
June	4.25	13.19 (1902)	0.48 (1922)	4.38 (1994)	0	9
July	4.11	21.50 (1996)	0.41 (1937)	16.91 (1996)	0	9
August	3.86	14.49 (1972)	0.35 (1919)	7.12 (1972)	0	9
September	3.84	10.97 (1961)	0.00 (1979)	6.10 (1978)	0	9
October	2.49	14.86 (1954)	0.24 (1964)	10.48 (1954)	0.2	8
November	2.82	7.89 (1985)	0.06 (1904)	2.74 (1995)	1.2	9
December	2.43	6.31 (1949)	0.32 (1930)	2.83 (1982)	8.2	10

Annual precipitation at Aurora is shown in Figure 10. Note the downward trend in the first two decades followed by a period of little change from 1920 to 1970. Since 1970, annual precipitation has increased on the order of 5 inches.

The number of days per year with measurable precipitation (i.e., more than a trace) is shown in Figure 11. A downward trend is evident from 1901 to 1920. From 1920 to 1985, the number of days with precipitation has increased dramatically, from 80 days per year to 130 days per year. In the last ten years of record (1987-1996), the number has declined somewhat to 105 days per year. Precipitation in Aurora is more frequent during summer than during winter.

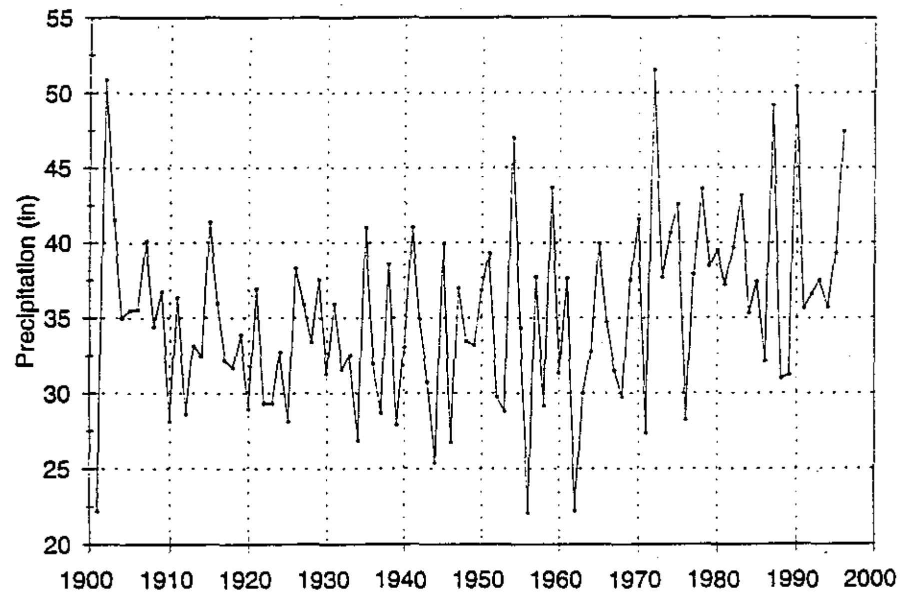


Figure 10. Annual Precipitation at Aurora, 1901-1996

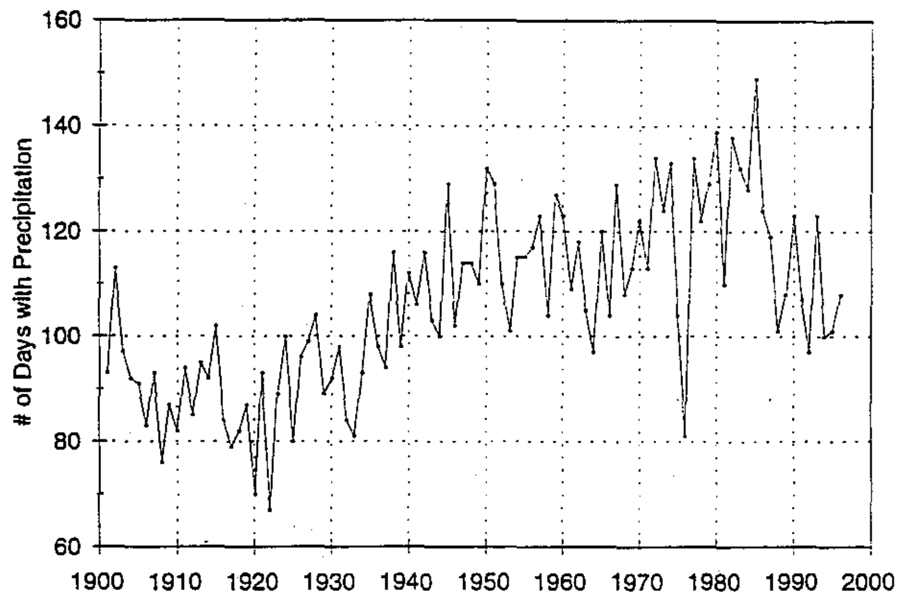


Figure 11. Annual Number of Days with Measurable Precipitation at Aurora, 1901-1996

Average winter snowfall at Aurora is 29.7 inches, but there is great year-to-year variability. The most snowfall during any one winter in Aurora was 62.4 inches during 1951-1952, whereas the least was only 5.7 inches during 1920-1921. Snowfall from the 1901-1902 winter season through the 1995-1996 season is shown in Figure 12, which indicates no long-term trends in snowfall amount.

Figure 13 shows the number of days each winter with snowfall, from 1901-1902 through 1995-1996. Annual frequencies remained steady from the early 1900s to 1930, before increasing from 1931 to 1960. After 1960, the number of days decreased to levels typical of those at the beginning of the century. A snowfall of more than 6 inches occurs only once every two to three years. Snow cover is frequently experienced at Aurora, typically lasting from a few days at a time to up to three months.

Precipitation Deficits and Excesses

Following are the driest years in the Fox River basin in terms of annual precipitation shortfall, starting with the driest: 1956, 1901, 1962, 1944, 1946, 1934, 1971, 1939, 1910, and 1925. Driest summer seasons (June, July, and August) in the basin include: 1991, 1922, 1927, 1919, 1910, 1936, 1962, 1973, 1944, and 1967. Much above average precipitation fell at Aurora in 1975, 1983, 1978, 1959, 1954, 1996, 1987, 1990, 1902, and 1972. No single decade was dominant in terms of years with excessive precipitation.

Severe Weather

Tornadoes

Although tornadoes are not uncommon in Illinois, most people do not expect to be affected directly by one, even if they live in the state for a lifetime. This is because tornadoes are generally only one-quarter mile in diameter, travel at roughly 30 miles per hour for only 15-20 minutes, and then dissipate, directly affecting a total area less than 2 square miles. Since Illinois observes an average of 28 tornadoes a year (though the actual number has varied from fewer than ten to about 100 during the last 35 years), the total area directly affected by tornadoes annually is only about 55 square miles, 0.1% the total area of the state. Even with 96 tornadoes reported in Illinois in 1974 (the greatest number reported in the last 30 years), the affected area was only about 0.3% the total area of the state. These numbers do not diminish the effect on those experiencing property damage, injury, or worse, but they demonstrate the extremely low probability of direct impact at any given location.

Regular reporting of tornadoes in Illinois began in 1959. From that time through May 1995, 42 tornadoes were recorded in the Fox River basin with no apparent trend in frequency or intensity. On average, the basin experiences slightly more than one tornado per year. The maximum number of tornadoes reported per year is 4 (1959, 1965, 1972, and 1974), with 15 of the last 36 years experiencing no tornado activity.

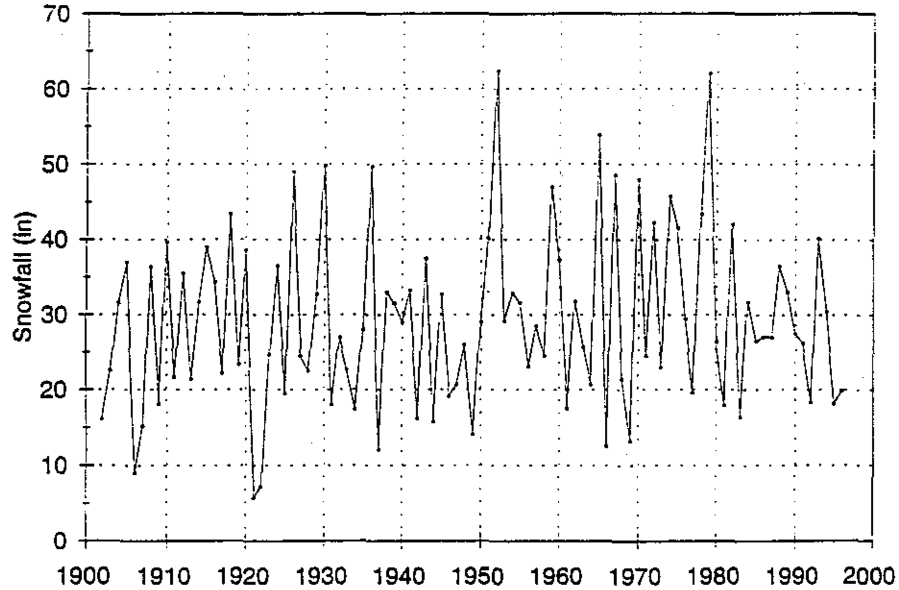


Figure 12. Annual Snowfall at Aurora,
Winters 1901-1902 to 1995-1996

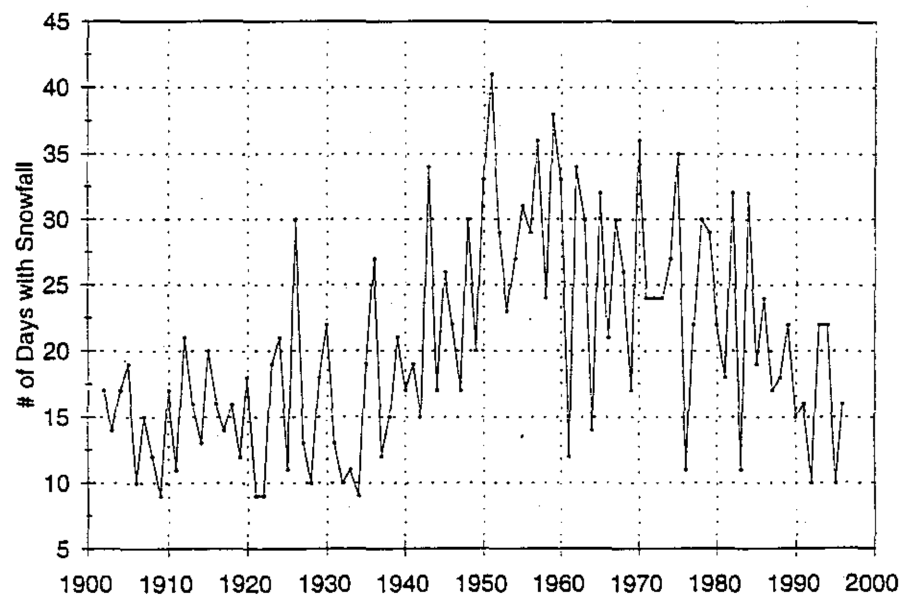


Figure 13. Annual Number of Days with Measurable Snowfall
at Aurora, Winters 1901-1902 to 1995-1996

Hail

Hail events are somewhat rare and typically affect a very small area (from a single farm field up to a few square miles). Unfortunately, very few NWS Coop sites measure hail. The combination of small, infrequent events being measured by a sparse climate network makes for very few reliable, long-term records of these events, particularly for large areas. According to Changnon (1995), the Fox River basin experiences about two hail days per year. The most active year was 1947, which had ten days with hail activity. There are no persistent upward or downward trends based on records from 1905 to the present.

Thunderstorms

On average, the Fox River basin experiences about 32 days with thunderstorms each year. The annual number of days with thunder over the Fox River basin since 1949 is shown in Figure 14, which is composed of data from Rockford (1949-1995). There is substantial year-to-year variation in thunderstorm days, with as many as 47 in 1954 to as few as 18 in 1966, and no significant trend over the 1949-1995 period. (Note: Data were missing for the period 1955-1959.)

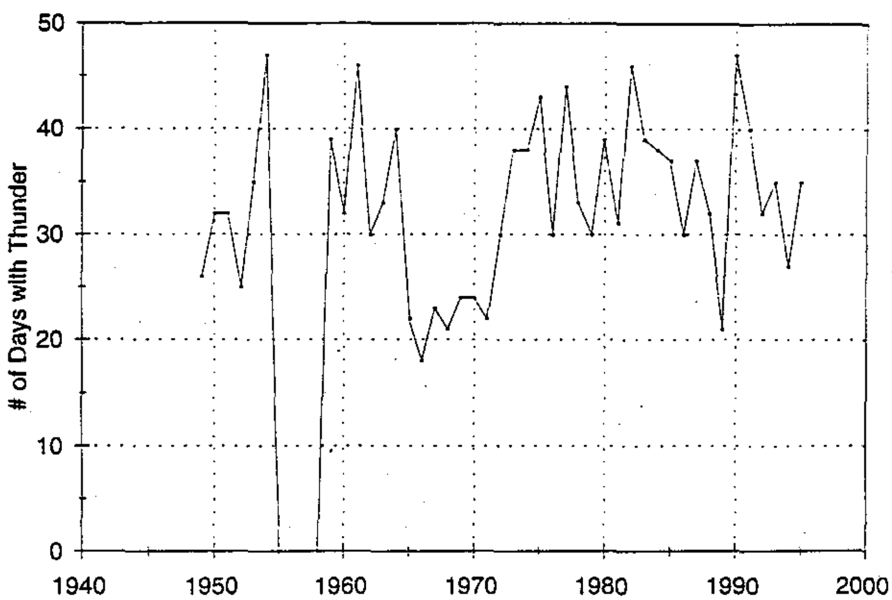


Figure 14. Annual Number of Days with Thunderstorms at Rockford, 1949-1995

Summary

The mean annual temperature for Aurora shows a warming trend through 1940, followed by a cooling trend until the early 1980s before leveling off. The number of days with temperatures above or equal to 90°F shows an upward trend through 1930, followed by a decline through 1980. There are no trends in the number of days with temperatures below or equal to 32°F or the number of days with temperatures below or equal to 0°F.

In terms of annual total precipitation, there is a downward trend from 1901 to 1920, followed by a period of no change until 1970. After 1970, an upward trend is evident. The number of days with measurable precipitation shows a downward trend through 1920, followed by a period of increase through 1985. The last ten years of record show a downward trend. While there is no long-term trend in snowfall amount, the number of days with snow remained steady through 1930, increased through 1960, and then decreased to earlier levels.

Records extending back to 1905 show no clear trends in hail events. Similarly, there are no apparent trends in tornado events, although records date only to 1959. The number of days with thunderstorms has been recorded since 1949 with no significant trends.

Streamflow

Surface water resources are an essential component of any ecosystem because they provide different types of habitats for aquatic and terrestrial biota. In addition to their natural functions, they are sources of water supply for domestic, industrial, and agricultural use. Changes in natural and human factors, such as climate, land and water use, and hydrologic modifications, can greatly affect the quantity, quality, and distribution (both in space and time) of surface waters in a river basin.

There are at least 2,300 miles of rivers and streams in the Fox River basin. The status of these rivers and streams is monitored by stream gaging stations, which measure the flow of water over a period of time, providing information on the amount and distribution of surface water passing the station. Since it is not feasible to monitor all streams in a basin, gaging stations are established at selected locations, and the data collected are transferred to other parts of the watershed by applying hydrologic principles. Streamflow records are used to evaluate the impacts of changes in climate, land use, and other factors on the water resources of a river basin. A more complete analysis of streamflows in the basin and the factors influencing these flows can be found in Knapp (1988).

Stream Gaging Records

Ten U.S. Geological Survey (USGS) gaging stations in the Fox River basin in Illinois have five or more years of continuous daily flow data. These stations are listed in Table 10, and their locations shown in Figure 15. Also listed is the Fox River gaging station near New Munster, Wisconsin (formerly at Wilmot), which measures flow in the river immediately north of the Illinois-Wisconsin line. Nine of the stations listed are active.

Table 10. USGS Stream Gaging Stations with Continuous Discharge Records

USGS ID	Station name	Drainage area (mi^2)	Record length (years)	Period of record
05545750	Fox River near New Munster	868.0	57	1939-1996
05547755	Squaw Creek at Round Lake	17.2	7	1989-1996
05548280	Nippersink Creek near Spring Grove	192.0	30	1966-1996
05549000	Boone Creek near McHenry	15.5	34	1948-1982
05549850	Flint Creek near Fox River Grove	37.0	7	1989-1996
05550000	Fox River at Algonquin	1403.0	81	1915-1996
05550500	Poplar Creek at Elgin	35.2	46	1951-1996
05551000	Fox River at South Elgin	1516.0	7	1989-1996
05551200	Ferson Creek near St. Charles	51.7	36	1960-1996
05551700	Blackberry Creek near Yorkville	70.2	36	1960-1996
05552500	Fox River at Dayton	2642.0	71	1925-1996

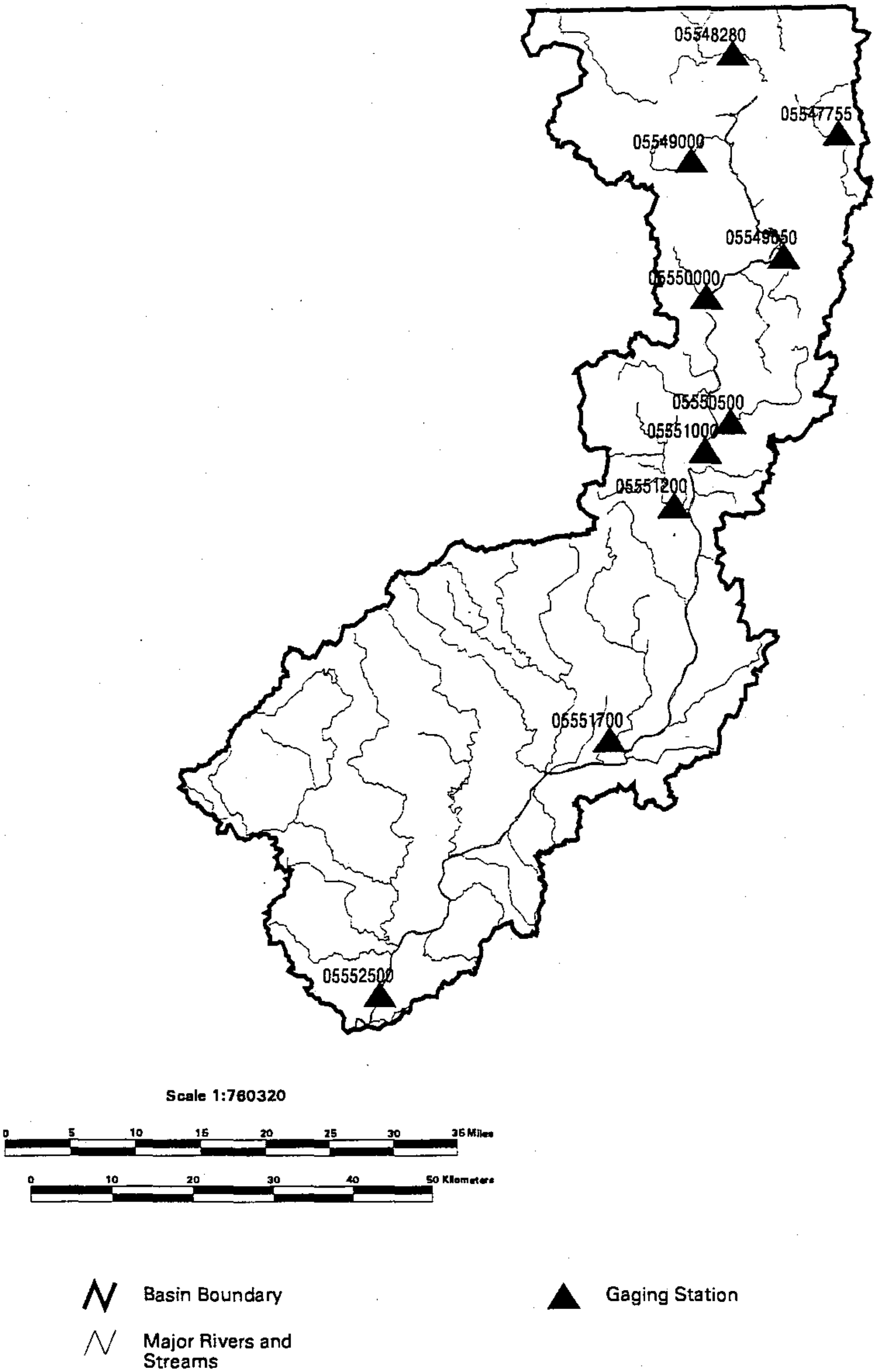


Figure 15. Stream Gaging Stations in the Fox River Basin

Human Impacts on Streamflow

The characteristics of streamflow in any moderately developed watershed will, over time, vary from earlier conditions because of the cumulative effect of human activities in the region. Certain modifications to the watershed, such as point withdrawals and discharges to the streams and the construction and operation of reservoirs, may have readily definable impacts on streamflows. Other more gradual effects, such as changes in agricultural practices, drainage and removal of wetland areas, the impacts of urbanization on downstream flows, and climate variability, are more difficult to quantify.

Of the human modifications in the basin, water use has the greatest impact on flows in the Fox River. The total 1995 water use in the basin was more than 85 million gallons per day, and virtually all of this water was discharged to the Fox River after being used and treated. During low flow conditions, more than one-third of the Fox River flow in the Kane County area and farther downstream can be attributed to wastewater effluents.

To a lesser degree, the operation of Stratton Dam near McHenry has an impact on flows. Figure 16 shows the annual 7-day low flows measured on the Fox River at Dayton and at Algonquin, which is located 17 miles downstream of Stratton Dam. In the past, gates at the dam were closed to reduce the amount of flow and retain water in the Fox Chain of Lakes during dry summer periods. Since 1970 the low flow releases from the dam have been noticeably greater. This is due in part to the wetter climatic conditions over this time and the increase in wastewater effluents to the river, but also comes as a result of a change in operating policy at the dam, which now attempts to maintain a minimum flow of 94 cubic feet per second (cfs) from the dam.

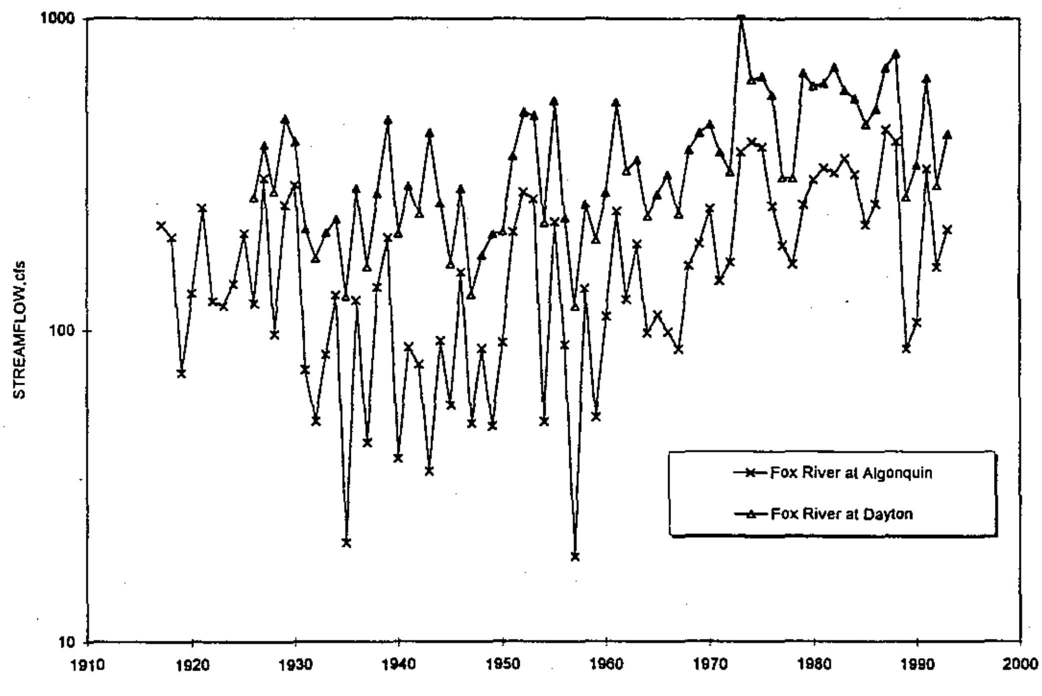


Figure 16. Seven-Day Low Flows for the Fox River at Algonquin and Dayton

Under medium and high flow conditions, the outflow from the dam is generally similar to what would be expected if the dam were not present. Thus, the main impact and benefit of the dam is to keep a consistent, higher water level in the Chain of Lakes for recreational use. Because of the higher water level, the peak discharge from moderate floods is slightly higher than might be expected if the dam were not present. However, the peak discharge from major flood events is generally unaffected (Knapp and Ortel, 1992).

Annual Streamflow Variability

Average streamflow varies greatly from year to year, and can also show sizable variation between decades. Figure 17 shows the annual series of average streamflow for the stream gage records in the Fox River basin. As shown in this figure, the average flow during any given year is similar for all stations. Over the 81 years of record, the annual flows on the Fox River have ranged from a high of around 20 inches in 1973 and 1993 to a low of about 2 inches in the drought year of 1934. The long-term average flow in the Fox River basin is approximately 9 inches per year. Prior to 1969, the average annual flow was less than 8 inches, but since then has averaged 12 inches. This increase in streamflow corresponds to a coincident increase in average precipitation.

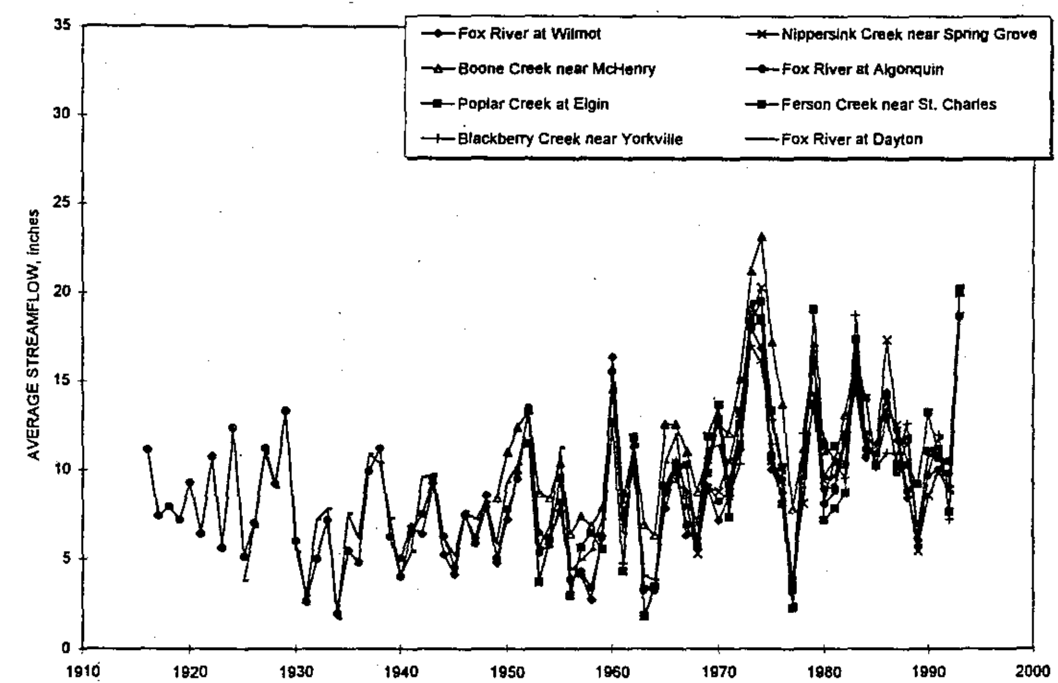


Figure 17. Average Annual Streamflow for Gaging Stations in the Fox River Basin

Figure 18 shows the 11-year moving averages of streamflow and precipitation in the northern Fox River basin (north of the Algonquin gage) for the period 1920-1995. The moving average (MA) streamflow is the average flow for 11 consecutive years; for example, the 11-year MA for 1968 is the average flow for the period 1963-1973.

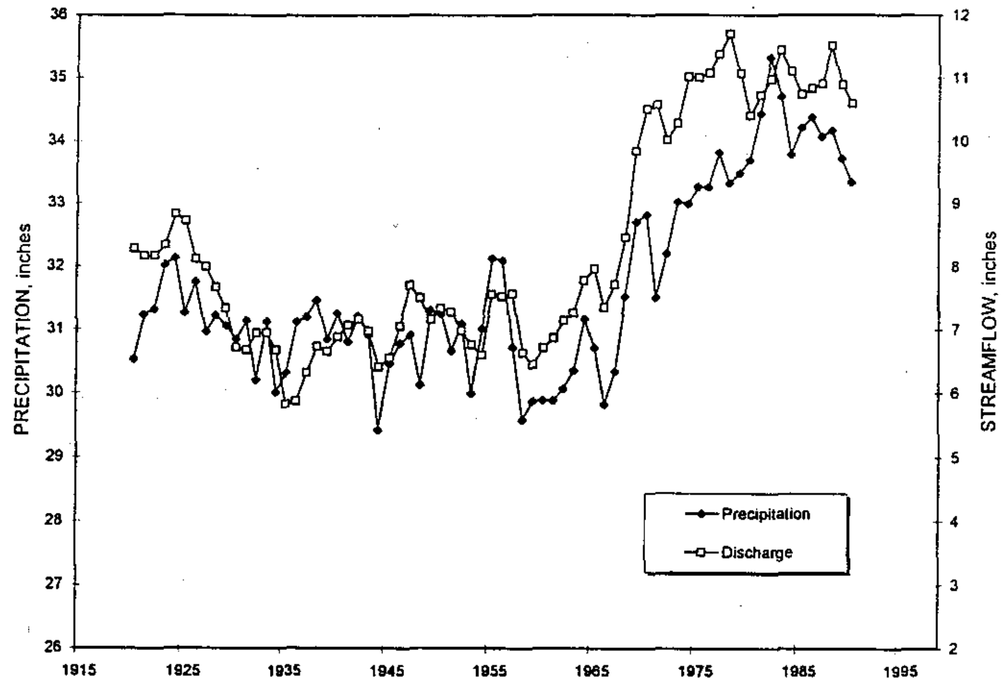


Figure 18. Eleven-Year Moving Averages for Streamflow and Precipitation; Northern Fox River Basin, 1920-1995

The precipitation MA ranged from a high of 35.3 inches in 1977-1987 to a low of 29.4 inches in 1939-1949. The streamflow MA ranged from 11.7 inches in 1973-1983 to 5.8 inches in 1930-1940. As shown in Figure 18, average streamflow is strongly related to average precipitation during that time. The correlation coefficient between these two moving averages is 0.893, indicating that most of the variation in average flow over the period of record can be explained by coincident changes in precipitation.

On average, the difference between precipitation and streamflow in Figure 18 is 23.5 inches per year, equivalent to the average annual rate of evapotranspiration for the northern Fox River basin. The estimated average annual evapotranspiration was about 24 inches during 1925-1960, decreasing to about 23 inches during the 1970s, 1980s, and 1990s. This decline is most likely related to the general decrease in air temperatures that has been experienced over this period, as reported elsewhere in this volume.

The variability of precipitation and streamflow in the southern part of the Fox River basin (south of the Algonquin gage) is almost identical to that shown in Figure 18. Average annual precipitation and evapotranspiration are several inches greater for the southern part of the basin, and there is a slight increase in the average streamflow.

Statistical Trend Analysis

Trend coefficients were estimated for the annual flow record at selected stations, and are presented in Table 11. All gaging stations with records greater than 30 years show a significant increasing trend, which is directly related to increases in average precipitation since 1969. Stream gage records since 1969 show no additional increase in flow.

Table 11. Trend Correlations for Annual and Seasonal Flows

	Kendall trend correlation				
	Annual	Fall	Winter	Spring	Summer
Full Streamflow Record					
Boone Creek near McHenry	0.294	0.269	0.102	0.223	0.326
Fox River at Algonquin	0.212	0.172	0.213	0.081	0.208
Poplar Creek at Elgin	0.315	0.295	0.266	0.135	0.135
Ferson Creek near St. Charles	0.184	0.230	0.269	0.080	0.098
Fox River at Dayton	0.318	0.262	0.240	0.210	0.293
Streamflow Record since 1969					
Nippersink Creek near Spring Grove	0.098	0.138	0.158	0.025	-0.310
Fox River at Algonquin	-0.031	0.128	0.151	-0.066	-0.208
Poplar Creek at Elgin	0.043	0.168	0.168	-0.094	-0.071
Ferson Creek near St. Charles	-0.083	0.094	0.088	-0.009	-0.140
Fox River at Dayton	-0.094	0.185	0.105	-0.077	-0.214

Geographic Variability in Streamflow

Figure 19 plots the flow duration curves for three gages on the Fox River and six tributary gages. The flow duration curve provides an estimate of the frequency with which given flows are exceeded. As shown in the figure, flows for all of the streams can vary significantly; however, the total range is significantly smaller than for most regions of Illinois and generally ranges from one-tenth to ten times the stream's average flow.

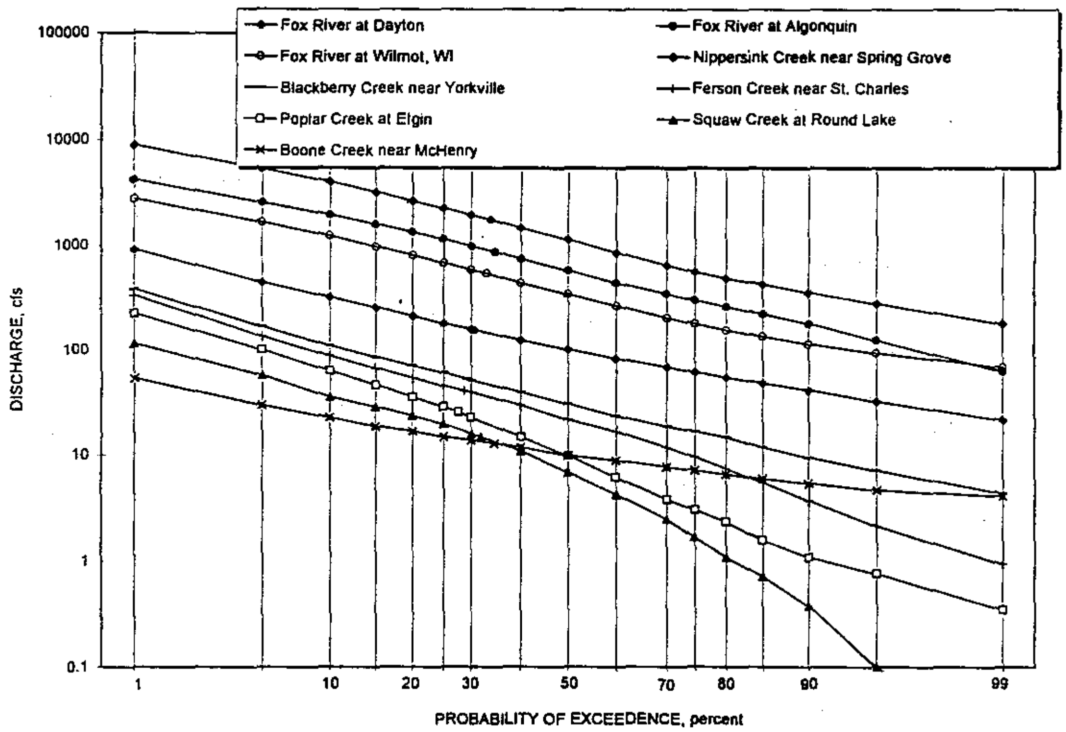


Figure 19. Flow Duration Curves (Discharge Versus Probability)

Of the Fox River tributaries shown in Figure 19, Squaw Creek and Poplar Creek display greater variability of flows, as indicated by the steeper gradient in the flow duration curve. This is especially apparent for low flow conditions (flows with a probability of exceedence greater than 70%). Boone Creek, on the other hand, has a particularly small range in flow conditions. The small gradient on the Boone Creek curve indicates that relatively more precipitation is retained in its soil and substrata following a storm event, and more baseflow is released to the streams during low and medium flow conditions. These flow characteristics are directly related to the soil permeability in the respective watersheds of the tributaries. Both Squaw Creek and Poplar Creek are located on the eastern side of the Fox River basin, where the soils are less variable and have lower permeability.

As shown in Figure 19, all the Fox River gaging records exhibit the same general range of flow variability. The overall magnitude of the flows increases further downstream, and is greatest at the Dayton gage. There is a relative decrease in the extreme low flows (99% probability of exceedence) between the Wilmot and Algonquin gages. This decrease is caused by the evaporation that occurs in the Chain of Lakes during dry periods.

Seasonal Variability in Streamflow

As in all other locations in Illinois, streams in the Fox River basin display a well-defined seasonal cycle. Figure 20 shows the average monthly flow rate for Boone Creek, Poplar Creek, and the Fox River at Algonquin. As shown, flows are greatest during the spring months, March–May, while lower flows are more common in late summer and autumn.

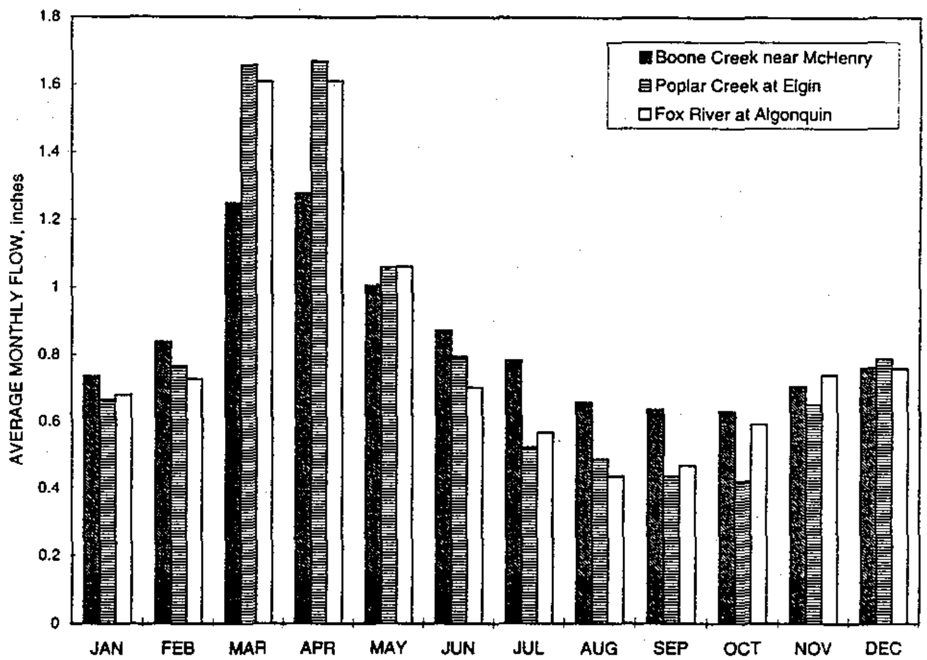


Figure 20. Average Monthly Flows for Selected Stations in the Fox River Basin

The variability in soil characteristics throughout the basin also influences the seasonal characteristics of runoff. A major difference between the monthly flows for these three gages is the variability between the spring high flows and the late summer low flows. The variability in the Fox River displays the composite effect of flows coming from the various types of tributaries.

Table 11 gives the results of trend analysis for each season. All of the longer gaging records show an increasing trend for all seasons, similar in magnitude to the observed increase in average annual flows. Over the past 30 years, however, there has been only a slight increase in fall and winter flows, and a more significant decrease in summer flows. Spring flows, generally the largest flows, show no trend over the 30-year period.

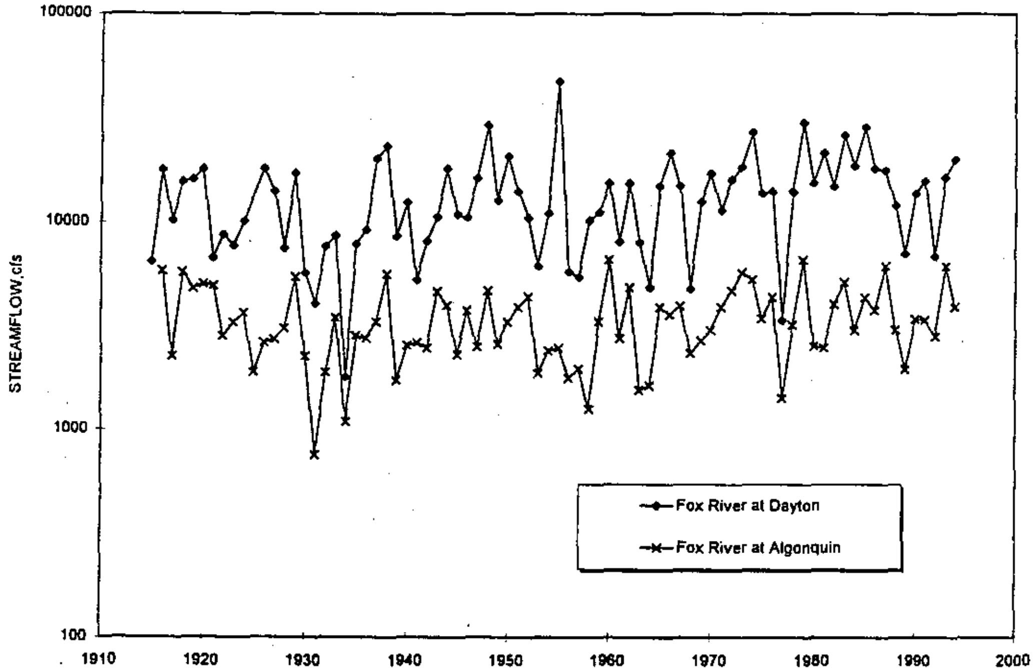
Flooding and High Flows

Figure 21 shows the annual series of peak flood discharges for the Fox River and three tributaries. For most gaging records it appears that while moderate flooding has been more frequent in the last 25 years, the frequency of the highest flood events has not changed appreciably over time. The increase in moderate floods is related to the increase in average precipitation over the last 25 years. Only the flood record for Poplar Creek shows an obvious increase in the magnitude of flood peaks over time, and urbanization or other human-induced factors probably contribute to this increase.

Table 12 gives results from the statistical trend analysis of the flood records. Over the full period of record, most stations display a low positive trend correlation, which is probably related to the increased frequency of moderate-sized floods. Only two gages, Poplar Creek at Elgin and Fox River at Dayton, have a statistically significant increase in flood peaks and flood volumes. There has been no further increase in the flood peaks at Dayton over the last 25 years. However, Poplar Creek continues to show an increase in flood volumes over this time, and Ferson Creek shows a decrease in the magnitude of flood peaks and volumes.

Table 12. Trend Correlations for Flood Volume and Peak Flow

Stream gaging station	Period of record	Kendall trend correlation: Flood volume	Kendall trend correlation: Peak flow
Nippersink Creek near Spring Grove	1966-1995	-0.005	-0.042
Boone Creek near McHenry	1948-1982	0.066	-0.040
Fox River at Algonquin	1915-1995	0.090	0.074
	1969-1995	-0.009	-0.040
Poplar Creek at Elgin	1951-1995	0.296	0.393
	1969-1995	0.157	0.219
Ferson Creek near St. Charles	1960-1995	-0.066	0.054
	1969-1995	-0.191	-0.168
Fox River at Dayton	1925-1995	0.270	0.202
	1969-1995	-0.086	0.003



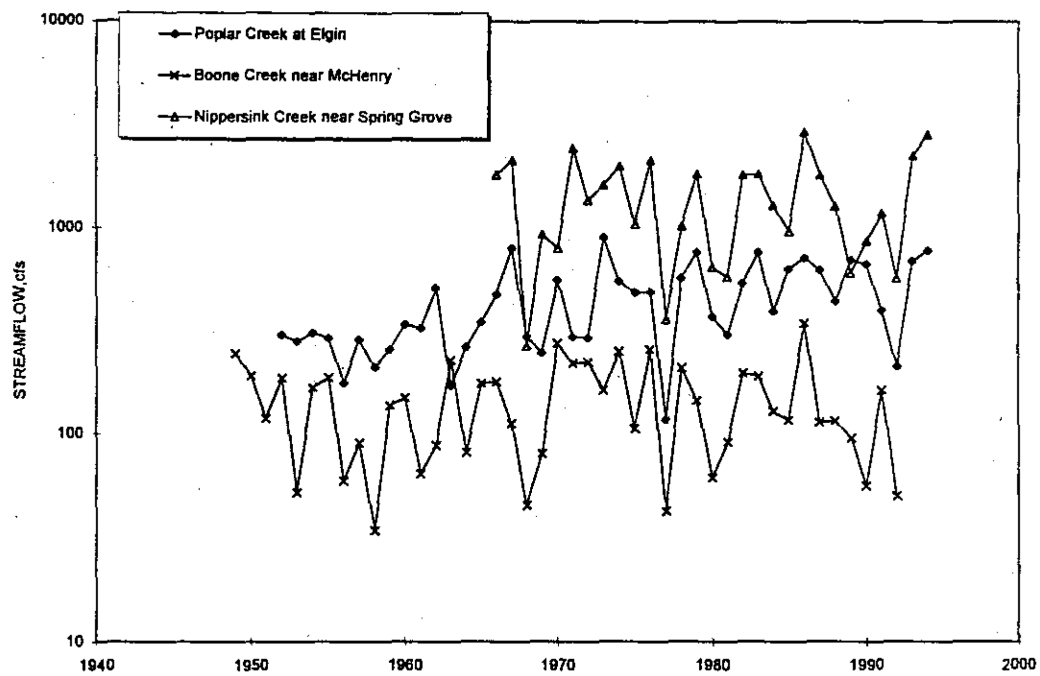


Figure 21. Annual Peak Discharges for Gaging Stations in the Fox River Basin

Table 13 presents the monthly distribution of the top 25 flood events for five gaging stations. In the northern part of the basin, represented by the Spring Grove and Algonquin gages, major flooding occurs predominantly in late winter and early spring. Many of the largest flood events during this season are caused by a combination of snowmelt and rainfall.

For tributaries in the southern part of the basin, flooding occurs during any season; in addition to the normal spring flood season, summer flooding caused by locally heavy rainfall is common. Flooding on the downstream reaches of the Fox River, such as at the Dayton gage, is occasionally caused by these heavy summer rains. Major floods at Dayton are most common in spring, but have occurred in all seasons.

Table 13. Monthly Distribution of Top 25 Flood Events

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nippersink Creek near Spring Grove	0	6	5	6	2	1	1	0	2	1	0	1
Fox River at Algonquin	0	1	13	7	2	0	1	0	1	1	0	0
Poplar Creek at Elgin	1	2	7	3	2	3	2	3	0	0	1	1
Ferson Creek near St. Charles	2	4	4	2	1	4	2	3	2	0	0	2
Fox River at Dayton	1	4	7	4	2	1	0	1	1	1	1	2

Drought and Low Flows

Two flow parameters are used here to describe dry period flows: the 7-day low flow and the 18-month drought flow. The 7-day low flow is representative of the minimum streamflows that are measured during any given year, whereas the 18-month minimum flow is specifically estimated for drought periods and represents the persistence of a drought and its resulting impact on reservoir supplies. All of the major surface water supplies in the Fox River basin are direct withdrawals from streams; therefore, the 7-day low flow is the more important value for assessing impacts in this region.

Figure 16 gives the computed 7-day low flows for the Fox River at Algonquin and Dayton. Figure 22 presents the 7-day low flows computed for stream gages on the tributaries to the Fox River. Low flows on the tributaries show little if any trend. Increases and decreases in the low flows on Poplar Creek are caused by changes in the amount of treated wastewater released to that stream.

Low flows on the Fox River show significant increases, especially during the last 30 years. Three major factors contribute to this increase: 1) the increase in average precipitation that has occurred since the mid-1960s, 2) the continuing increase in wastewater effluents to the river, and 3) the change in operation policy for Stratton Dam (albeit to a lesser degree).

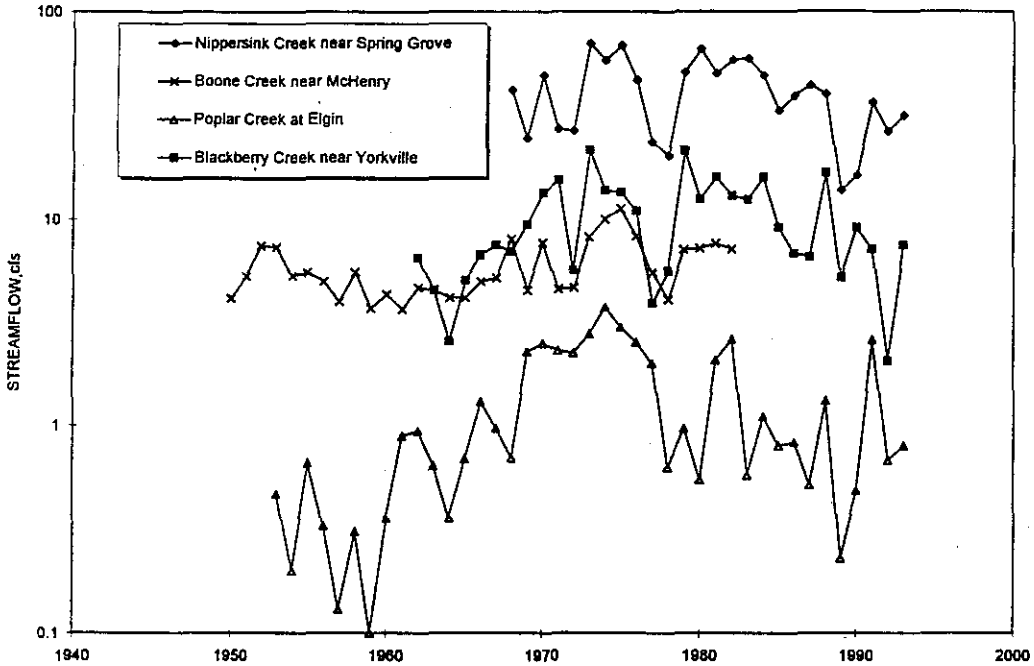


Figure 22. Seven-Day Low Flows for Fox River Tributaries

The 7-day, 10-year low flow for the Fox River ranges from 73 cfs at the Wisconsin border to 260 cfs at its confluence with the Illinois (Singh and Ramamurthy, 1993). More than 64 cfs of treated wastewater is discharged to the middle reach of the river, in the vicinity of Kane County, where the 10-year low flow increases from 122 to 206 cfs. All of the major Fox River tributaries have sustained low flows during a 10-year drought. Low flows from tributaries in the northwestern part of the basin (McHenry County) have particularly high sustained flows during drought.

Table 14 lists the 7-day low flow and 18-month flows for 11 major droughts for the Fox River at Algonquin and Dayton. The lowest 7-day flows occurred during the droughts of 1933-1934 and 1953-1954, and the lowest 18-month flows occurred during 1933-1934. Although it is most common for the lowest 7-day flows to occur in the midst of an extended drought, they can also occur during any abnormally dry, hot summer, such as in 1936, 1946, and 1991.

Table 14. Low Flows and Drought Flows Experienced during Major Droughts
(in cubic feet per second, cfs)

	18-month drought flows		7-day low flows	
Drought years	Algonquin	Dayton	Algonquin	Dayton
1930-1931	272	603	51	171
1933-1934	238	433	21	129
1939-1940	359	688	39	206
1944-1945	445	954	57	164
1947-1948	406	902	49	175

Table 14. Concluded

	18-month drought flows		7-day low flows	
Drought years	Algonquin	Dayton	Algonquin	Dayton
1953-1954	454	884	51	224
1955-1956	321	698	19	120
1957-1958	317	880	52	196
1963-1964	286	649	98	234
1976-1977	407	795	164	312
1988-1989	521	1,039	87	269

Summary

Streamflow records for the Fox River basin show a significant increase in both average and low flows around 1970. These increases are directly related to a coincident increase in average annual precipitation. Additional human factors contribute to the increase in low flows; specifically, the increase in the amount of treated wastewater discharged to the Fox River and, to a lesser degree, changes in the low flow operation of Stratton Dam.

Only two gaging records in the basin, Poplar Creek at Elgin and Fox River at Dayton, display statistically significant increases in flood peaks and flood volumes. The increase for the Dayton gage coincides with the increase in average annual precipitation and streamflow that occurred about 1970; no additional increase for this location has been identified in the last 25 years. The flood magnitudes for Poplar Creek have continued to increase, and are probably related to urbanization.

Erosion and Sedimentation

Instream Sediment Load

Instream sediment load is the component of soil eroded in the watershed and from the streambanks that is transported to and measured at a gaging station. It indicates the actual amount of soil generated upstream of the gaging station and eventually transported to downstream reaches of the river. Given the complex dynamic process of soil erosion, sediment transport, and deposition, it is very difficult to quantify how much of the soil eroded from uplands and streambanks actually moves to downstream reaches.

The sediment transported by a stream is a relatively small percentage of the total erosion in the watershed. However, the amount of sediment transported by a stream is the most reliable measure of the cumulative results of soil erosion, bank erosion, and sedimentation in the watershed upstream of a monitoring station.

There are three gaging stations in the Fox River basin where instream sediment was monitored for some time. As shown in Figure 23, two of these stations are located on the Fox River and the third on Ferson Creek. Table 15 summarizes information about the monitoring stations.

Table 15. Suspended Sediment Monitoring Stations within the Fox River Basin

Station name	USGS station number	Drainage area (sq. mi.)	Period of record
Fox River at Algonquin	05550000	1,403	Oct. 1980–Sept. 1982
Fox River at Dayton	05552500	2,642	Oct. 1980–Sept. 1981
Ferson Creek near St. Charles	05551200	52	Oct. 1980–Sept. 1982

Data were collected by the Illinois State Water Survey (ISWS) for two water years (1981 and 1982) at the Fox River at Algonquin, one water year (1981) at the Fox River at Dayton, and two water years (1981 and 1982) at Ferson Creek near St. Charles. The sediment data collected by the ISWS were instantaneous weekly samples. Therefore, only instantaneous sediment loads can be calculated, not average daily or annual sediment loads. Figures 24-26 show the variability of instantaneous suspended sediment concentrations for the three stations.

For the Fox River at Algonquin (Figure 24), concentrations varied from 10 milligrams per liter (mg/l) to 446 mg/l. Because most of the data were collected during a single water year, it is difficult to assess trends in the data. For the Fox River at Dayton (Figure 25), concentrations varied from 6 mg/l to 260 mg/l. Data at this station were collected sparingly for only one water year.

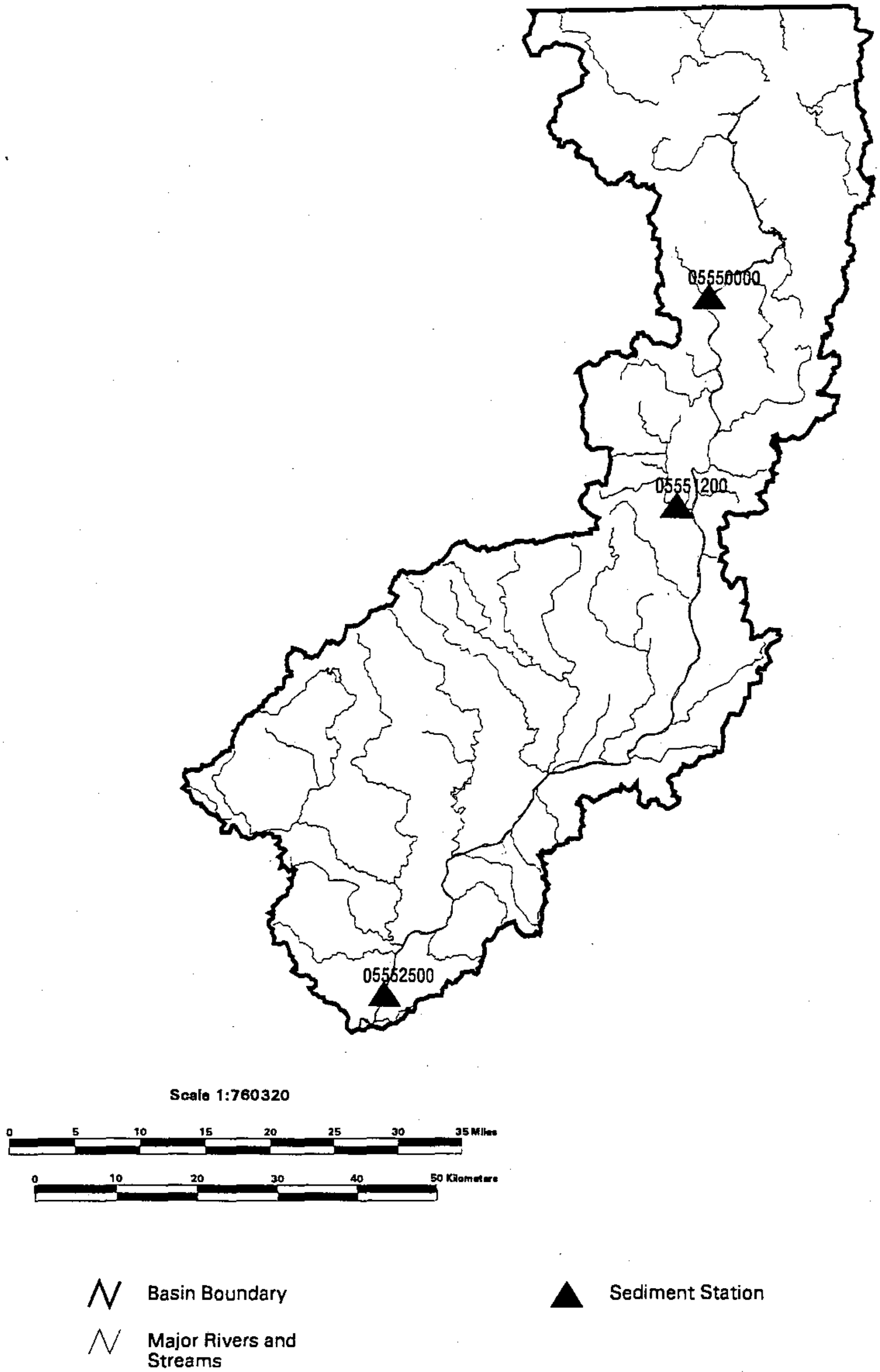


Figure 23. Sediment Monitoring Stations in the Fox River Basin

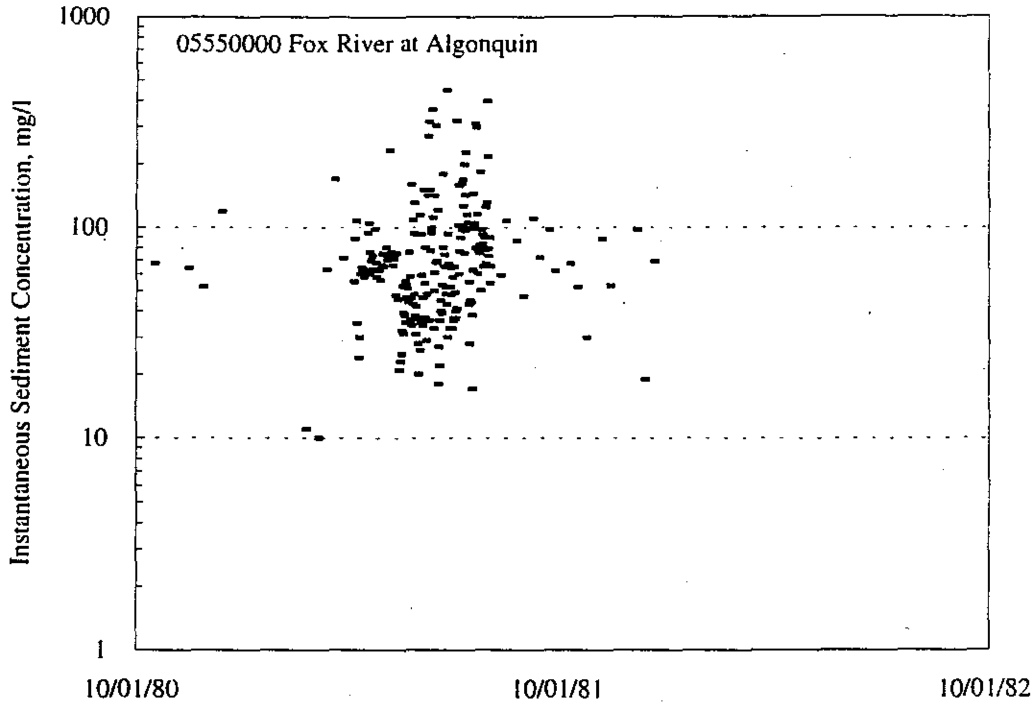


Figure 24. Variability of Instantaneous Suspended Sediment Concentrations for the Fox River at Algonquin

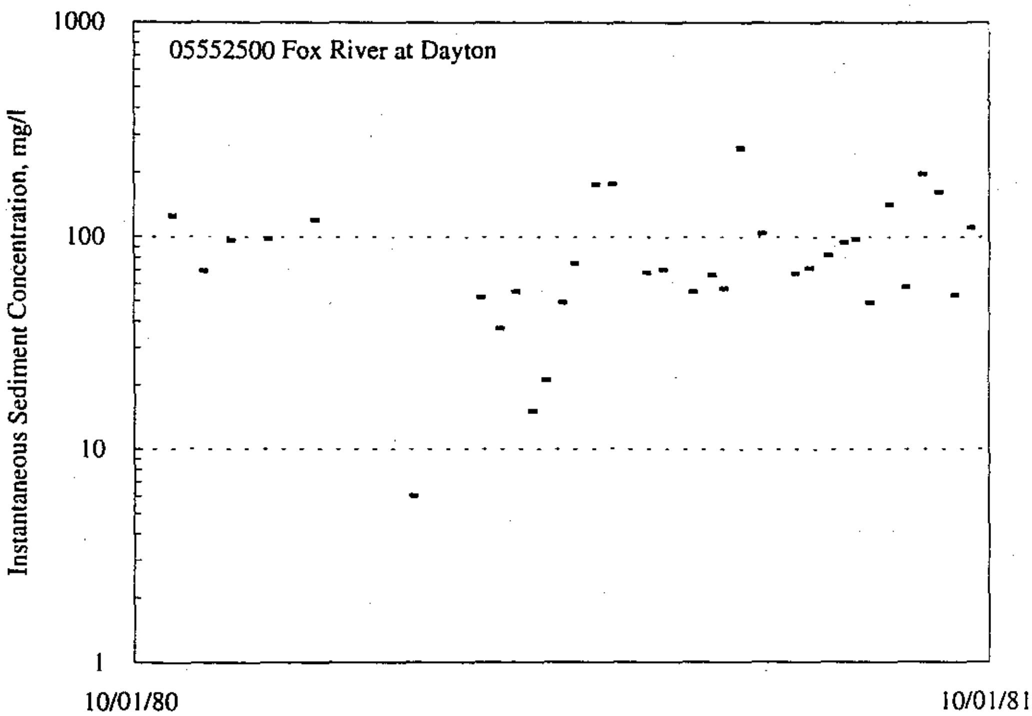


Figure 25. Variability of Instantaneous Suspended Sediment Concentrations for the Fox River at Dayton

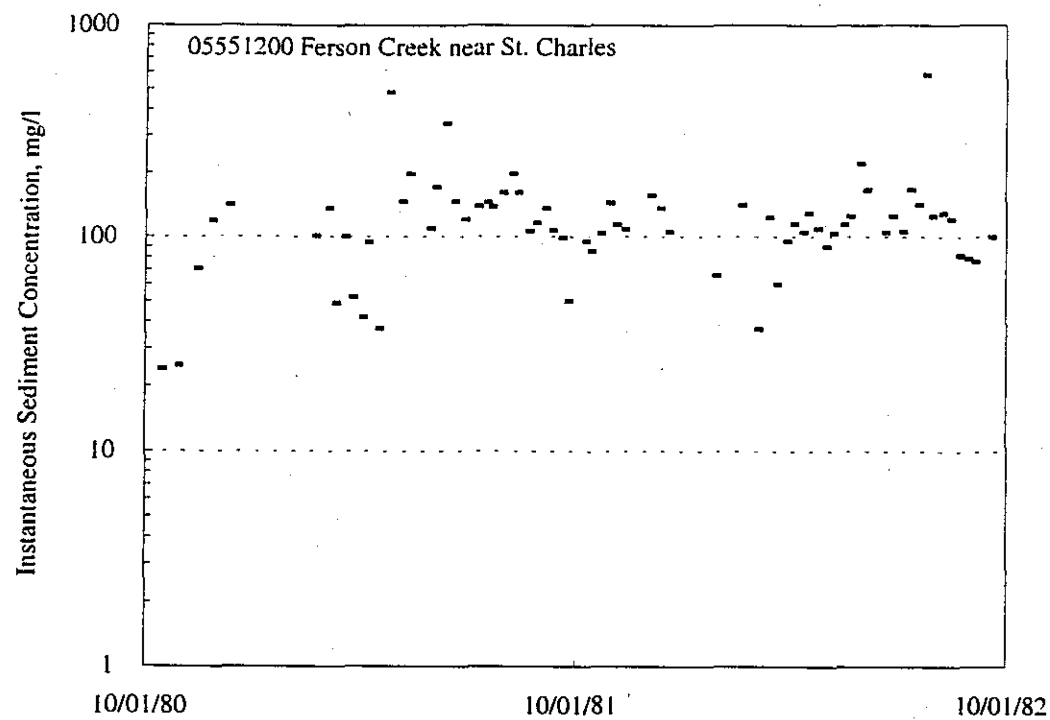


Figure 26. Variability of Instantaneous Suspended Sediment Concentrations for Ferson Creek near St. Charles

For Ferson Creek near St. Charles (Figure 26), concentrations varied from a low of 24 mg/l to a high of 585 mg/l over the two-year period. There are no significant trends in average concentrations.

Figures 27-29 show instantaneous sediment concentrations and loads for the three stations for each water year monitored. The figures show the variability of streamflow (Q_w), suspended sediment concentration (C_s), and suspended sediment load (Q_s). Water years start on October 1 and end on September 30. Therefore, day 1 on the time scale is October 1 of the previous year. To provide values in tons per day, sediment load was computed by multiplying the daily water discharge by the instantaneous sediment concentrations and applying the proper unit conversion factors. Since these calculations are based on weekly instantaneous sediment samples, it was not possible to compute average daily and annual sediment loads. However, sediment load provides a range of values to compare variability of sediment from year to year and from station to station.

For the Fox River at Algonquin (Figure 27), the sediment load varied from 20 to 888 tons per day. For the Fox River at Dayton (Figure 28), the sediment load varied from 21 to 4,181 tons per day. For Ferson Creek (Figure 29), the sediment load varied from 2.2 to 473 tons per day. It should be noted that sediment load depends on the size of the drainage area; therefore, a station with a larger drainage area will generally have a higher sediment load than one with a smaller drainage area under similar conditions. For this reason, the Fox River at Dayton has the highest sediment load of the three stations.

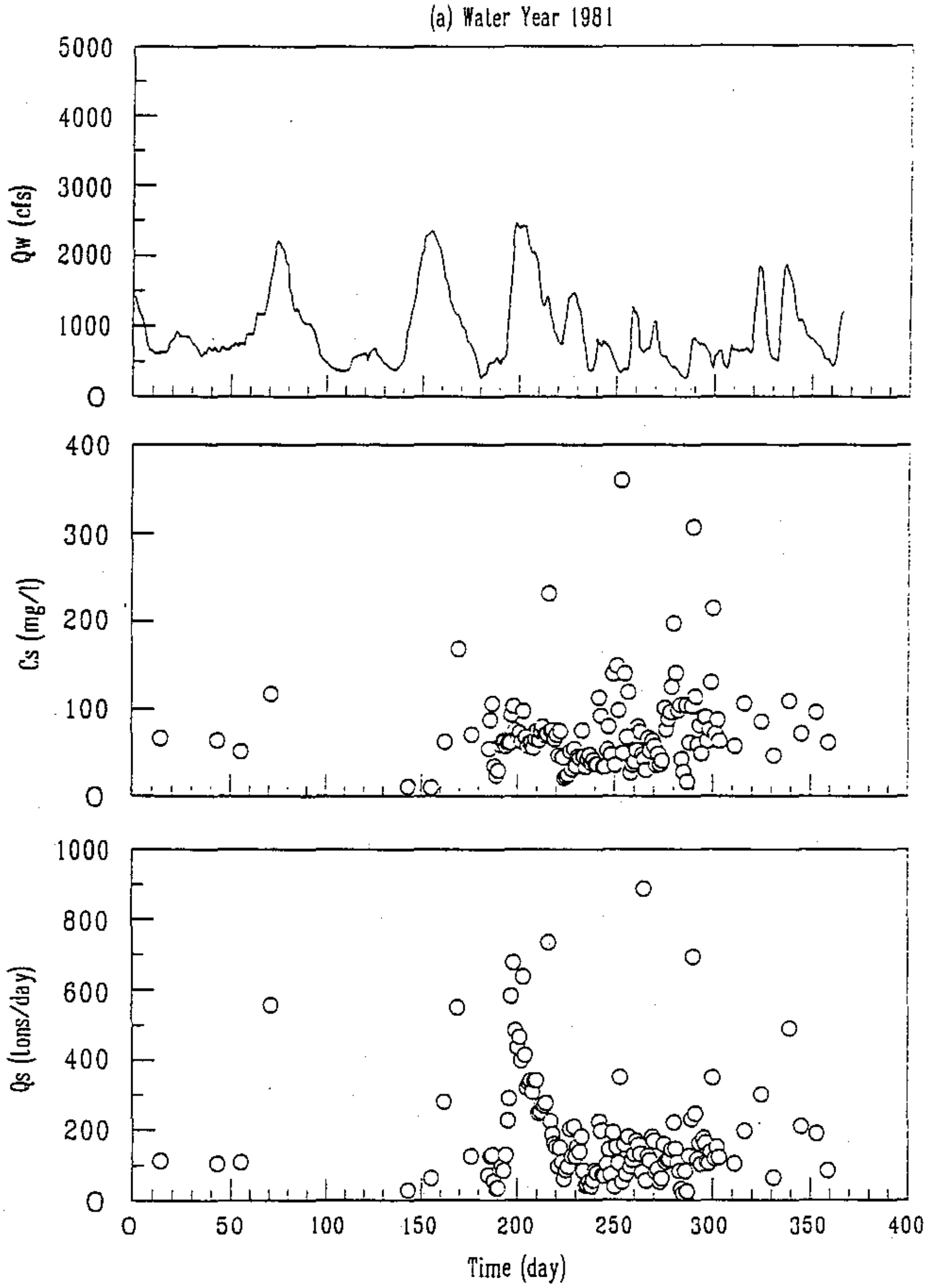


Figure 27. Instantaneous Suspended Sediment Load for the Fox River at Algonquin, (a) Water Year 1981 and (b) Water Year 1982

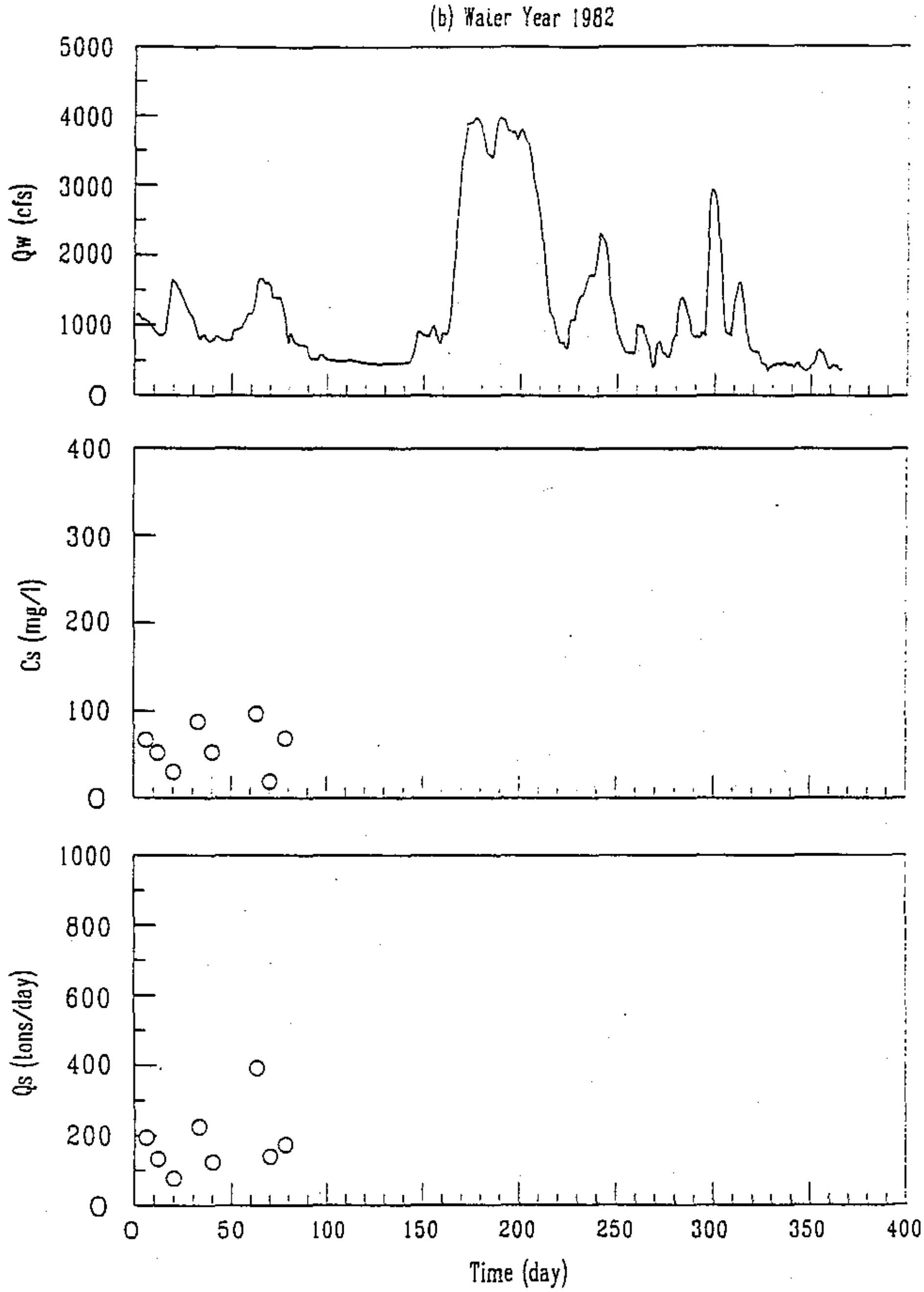


Figure 27. Concluded

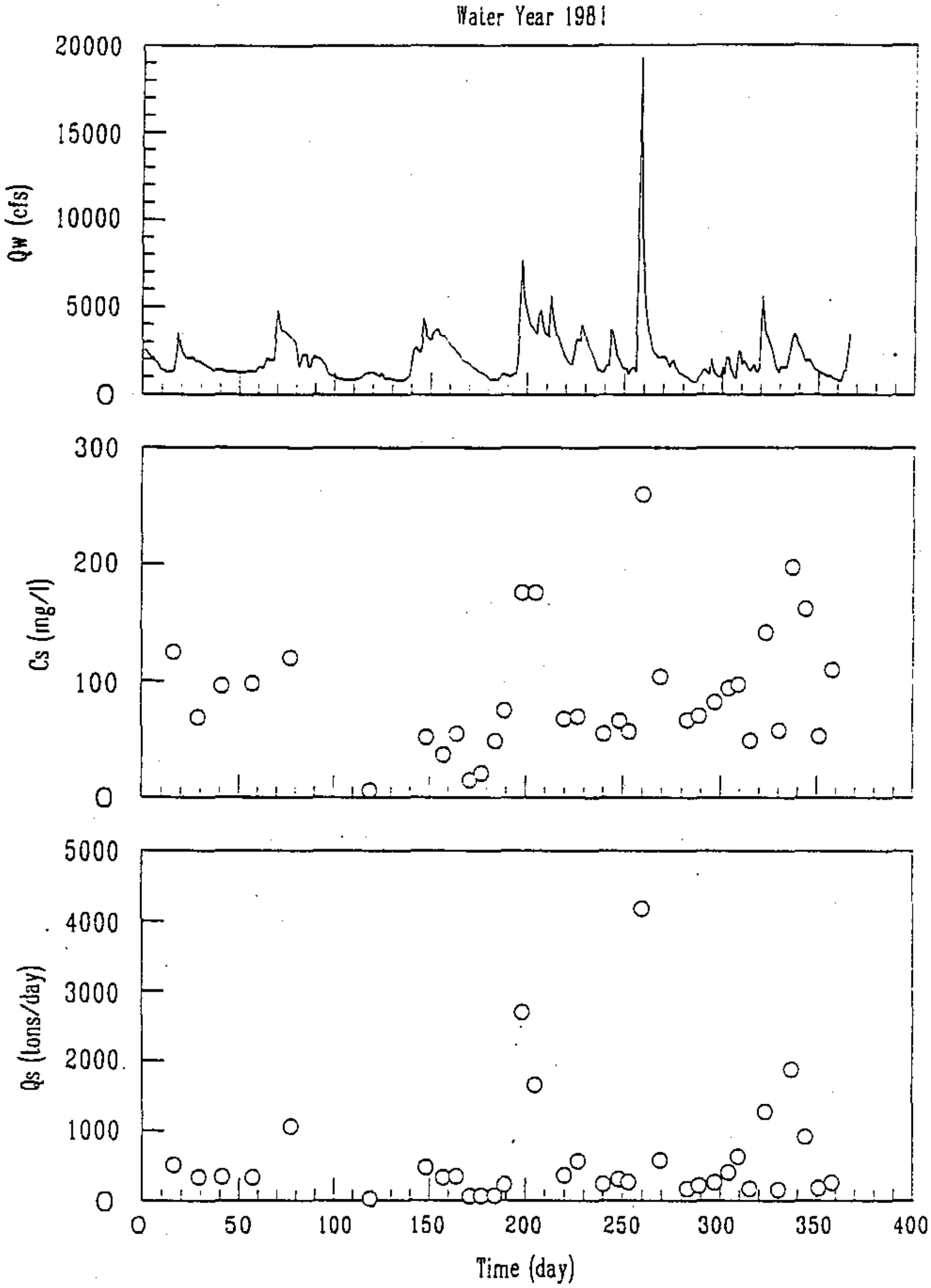


Figure 28. Instantaneous Suspended Sediment Load for the Fox River at Dayton, Water Year 1981

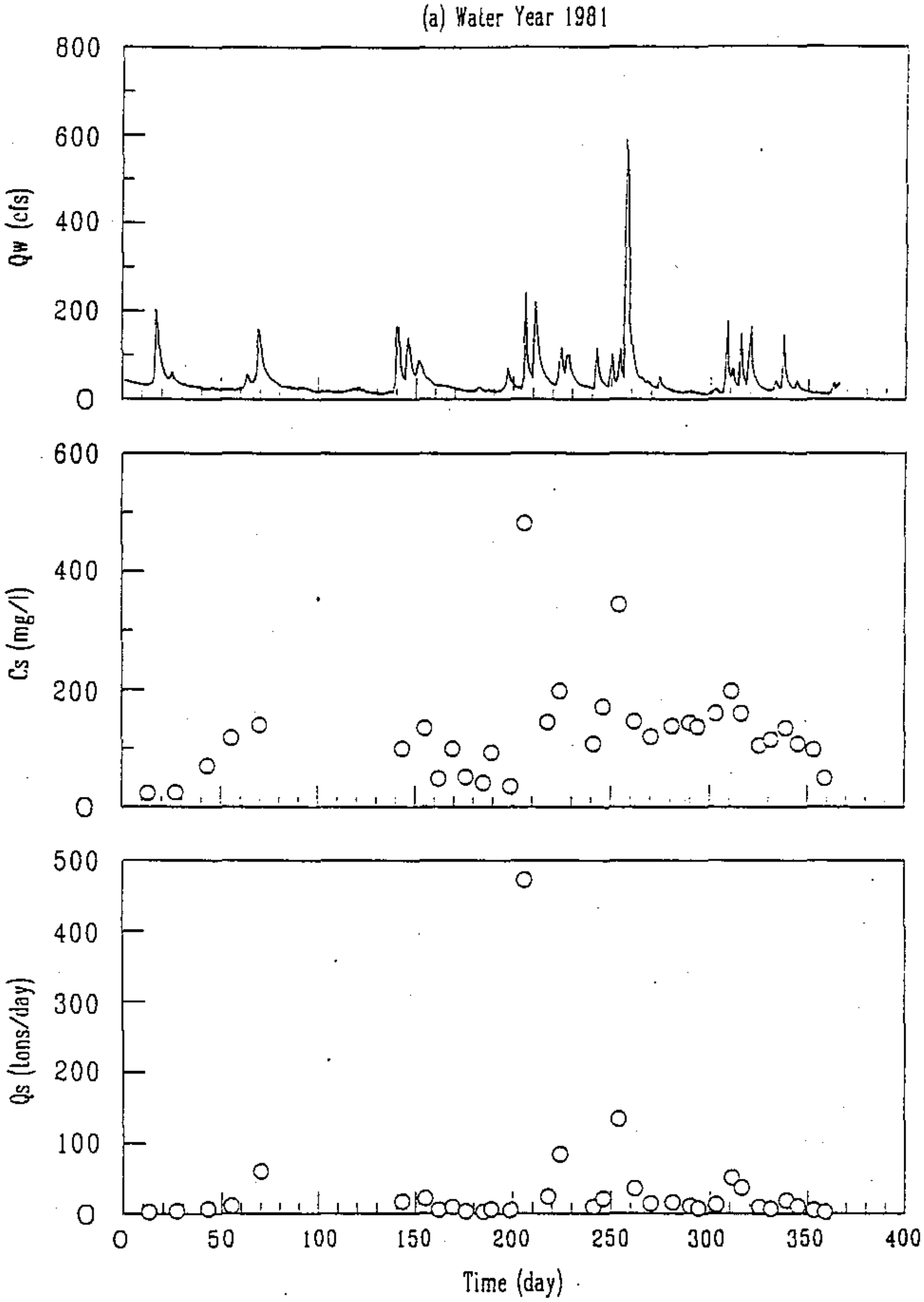


Figure 29. Instantaneous Suspended Sediment Load for Ferson Creek near St. Charles, (a) Water Year 1981 and (b) Water Year 1982

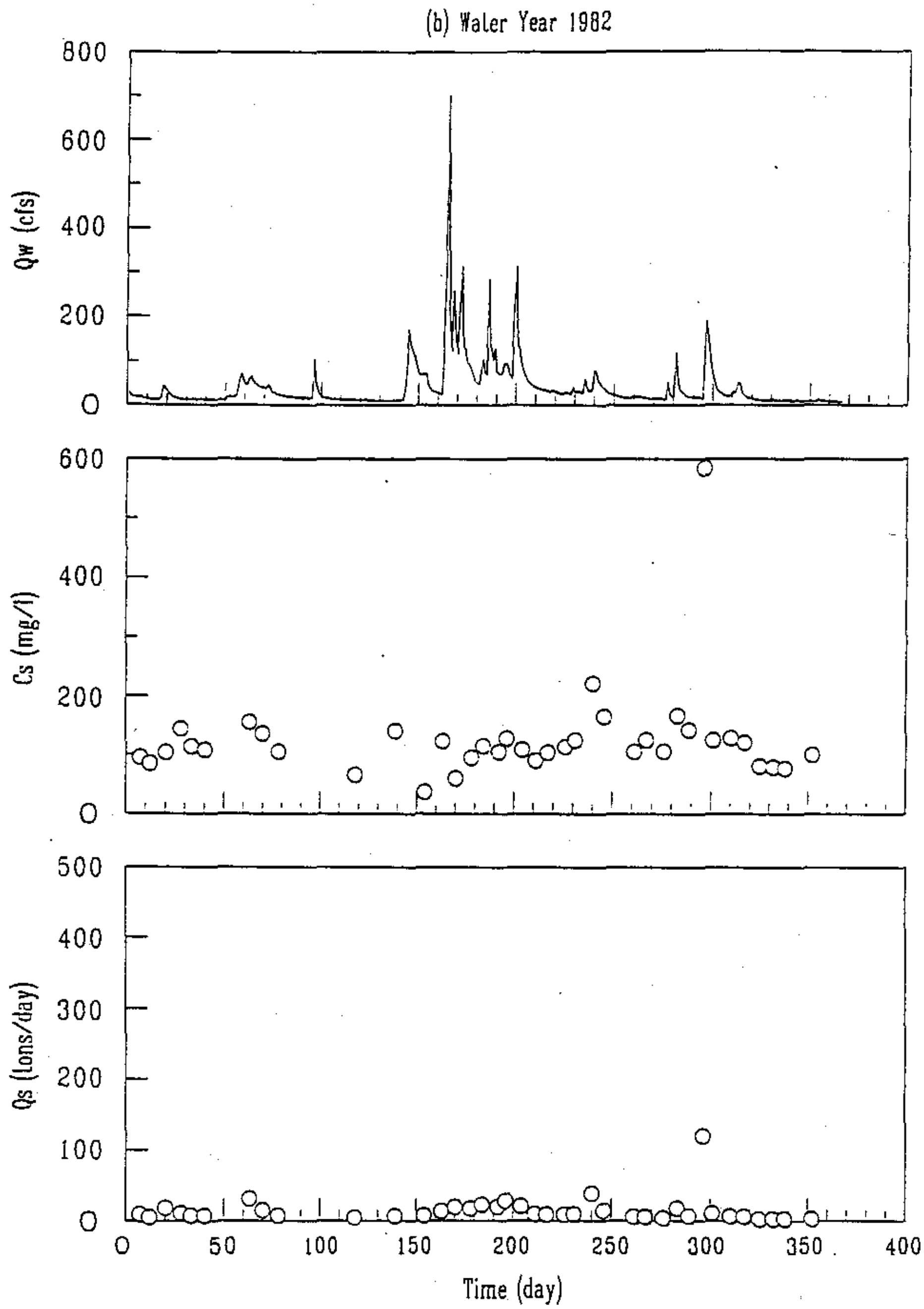


Figure 29. Concluded

Sedimentation

Sedimentation is the process by which eroded soil is deposited in stream channels, lakes, wetlands, and floodplains. In natural systems that have achieved dynamic equilibrium, the rates of erosion and sedimentation are in balance over a long period of time. This results in a stable system, at least until disruption by extreme events. However, in ecosystems where there are significant human activities such as farming, construction, and hydraulic modifications, the dynamic equilibrium is disturbed, resulting in increased rates of erosion in some areas and a corresponding increased rate of sedimentation in other areas.

Erosion rates are measured by estimating soil loss in upland areas and measuring streambank and bed erosion along drainageways. These measurements are generally not very accurate and thus are estimated indirectly, most often through evaluation of sediment transport rates based on instream sediment measurements and empirical equations.

Similarly, measurement of sedimentation rates in stream channels is very difficult and expensive. Lake sedimentation surveys provide the most reliable sedimentation measurements. Since lakes are typically created by constructing dams across rivers, creating a stagnant or slow-moving body of water, they trap most of the sediment that flows into them. The continuous accumulation of eroded soils in lake beds provides a good measure of how much soil has been eroded in the watershed upstream of the lake.

Water Use and Availability

Statewide, water use has increased a modest 27% since 1965 (Illinois Department of Energy and Natural Resources, 1994). Most of that increase is in power generation. PWS use has risen only about 7%, less than the concurrent increase in population. The number of public ground-water supply facilities in Illinois has risen significantly during that time, yet the total amount supplied by ground water remains near 25%.

A dependable, adequate source of water is essential to sustaining existing and potential population demands and industrial uses in Illinois. Modifications to and practical management of both surface and ground-water use have helped make Illinois' water resources reliable. As individual facilities experience increases in water use, innovative alternative approaches to developing adequate water supplies must arise. This is likely to involve conjunctive use of surface and ground waters.

Major metropolitan centers such as the Chicago area, Peoria, and Decatur, as well as smaller communities, have already developed surface and ground-water sources to meet their development needs and to sustain growth. The construction of impounding reservoirs has become and will remain economically and environmentally expensive, making it a less common approach.

Proper management of water resources is necessary to ensure a reliable, high quality supply for the population. Water conservation practices will become increasingly important to reduce total demand and to avoid exceeding available supplies. Both our ground-water resources and surface reservoir storage must be preserved to maintain reliable sources for future generations.

Ground-Water Resources

Ground water provides approximately one-third of Illinois' population with drinking water. The sources of this water can be broken down into three major units: 1) sand and gravel, 2) shallow bedrock, and 3) deep bedrock. Most ground-water resources are centered in the northern two-thirds of Illinois.

Sand-and-gravel aquifers are found along many of the major rivers and streams across the state and also within "buried bedrock valley" systems created by complex glacial and interglacial episodes of surface erosion. There are also many instances of thin sand-and-gravel deposits within the unconsolidated materials above bedrock. These thin deposits are used throughout Illinois to meet the water needs of small towns. Shallow bedrock units are more commonly used in the northern third of Illinois, whereas deep bedrock units are most widely used in the northeastern quarter (in and around the Chicago area). The variety of uses and the volume of water used vary widely throughout the state. This report describes ground-water availability and use within the Fox River basin.

Data Sources

Private Well Information

The Illinois State Water Survey (ISWS) has maintained well construction reports since the late 1890s. Selected information from these documents has been computerized and is maintained within the Private Well Database. These data are easily queried and summarized for specific needs and form the basis of well distribution studies in the area.

Public Well Information

Public Water Supply (PWS) well information has been maintained at the ISWS since the late 1890s. Municipal well books (or files) have been created for virtually all of the reported surface and ground-water PWS facilities in Illinois. Details from these files are assembled within the Public-Industrial-Commercial Database, which was created to house water well and water use information collected by the ISWS.

Ground-Water Use Information

The water use data in this report are from records compiled by the ISWS' Illinois Water Inventory Program (IWIP). This program was developed to document and facilitate planning and management of existing water resources in Illinois. Program information is collected through an annual water use summary mailed directly to each PWS facility.

Data Limitations

Several limitations must be taken into consideration when interpreting these data:

1. Information is reported by drillers and each PWS facility.
2. Data measuring devices are generally not very accurate.
3. Participation in the IWIP is voluntary.

Information assembled from well construction reports and from the IWIP is considered "reported" information. This means that the data are as accurate as the reliability of the individual reporting or as mechanical devices dictate. The quality of the reported information depends upon the skill or budget of the driller or facility, respectively. Moreover, the ISWS estimates that only one-third to one-half of the wells in the state are on file at the Survey, mainly due to the lack of reporting regulations prior to 1976.

Water use measuring devices used by PWS facilities are generally not very accurate. In fact, errors of as much as 10% are not uncommon. Much of the information reported in the IWIP is estimated by the water operator or by program staff.

Participation in the program is not required by the State of Illinois, and each facility voluntarily reports its information through a yearly survey. However, not all facilities know of or respond to the water use questionnaire. After several mail and telephone attempts have been made to gather this information, estimates are made using various techniques. To help reduce errors associated with the program, reported information is checked against usage from previous years to identify any large-scale reporting errors.

Ground-Water Availability

The Fox River basin encompasses portions of 11 counties: Lake, McHenry, Cook, Kane, De Kalb, Du Page, Lee, Will, Kendall, La Salle, and Grundy. The portion of each county within the basin varies from less than 1% (Grundy County) to 74% (Kane County). This section summarizes ground-water availability in the area, taking into consideration only those portions of each county that are actually within the basin.

Domestic and Farm Wells

Available regional information indicates that ground water for domestic and farm use in the basin is mostly obtained from drilled drift wells, although a common practice is to continue these wells into the limestone. East of the Fox River, the dolomite is well creviced and a dependable source of ground water; west of the river, the dolomite is part of a shale and dolomite formation (Maquoketa) and is an important source for small supplies (Bergstrom et al., 1955). Area wells are generally finished at depths between 100 and 300 feet.

Table 16 summarizes the number of reported private wells in the Fox River basin by county and depth.

Table 16. Number of Reported Private Wells within the Fox River Basin
(Source: ISWS Private Well Database)

	Depth range, feet								
County	0-50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	400+
Cook	23	46	81	188	440	325	49	19	32
De Kalb	17	25	80	141	117	57	30	19	48
Du Page	12	35	195	214	55	36	5	1	3
Grundy*			1			1			
Kane	396	927	1,470	1,732	1,165	872	422	295	1,180
Kendall	79	387	421	371	171	167	66	46	340
Lake	148	1,149	1,024	620	376	311	251	31	12
La Salle	26	154	394	374	97	54	32	12	27
Lee*	1		1	4	2	6	17	2	14
McHenry	1,447	3,530	2,294	1,841	1,448	465	121	54	63
Will*			10	3	3		1		
Total	2,149	6,253	5,971	5,488	3,874	2,294	994	479	1,719

*Note: Very small portions of Grundy, Lee, and Will Counties are contained within the basin.

Public Water Supply Wells

Information from the ISWS Public-Industrial-Commercial database indicates that most ground water for PWS use in the basin is obtained from drilled wells finished in either the unconsolidated sand and gravel aquifers, which supply 47.1% of the ground water withdrawn, or the Cambrian-Ordovician aquifers, which supply 42.8%.

Unconsolidated wells range in depth from 37 to 390 feet, while bedrock wells range in depth from 80 to 2,300 feet. A total of 127 public water supplies provide water to a reported 849,578 residents in and around the basin. The average per capita daily water use is 78.4 gallons per day (gpd).

1995 Ground-Water Use

Ground water constitutes a substantial portion of the total water use within the Fox River basin. Total ground-water use in the basin during 1995 was estimated to be 65.23 million gallons per day (mgd): 50.69 mgd for PWS facilities, 5.42 mgd for self-supplied industries, 7.79 mgd for rural/domestic withdrawals, and 1.33 mgd for livestock watering.

Public Water Supply

In 1995, municipal residential ground-water use for 127 communities was reported to be 50.69 mgd, serving a combined reported population of 849,578. The average per capita use of these municipalities was 78.4 gpd.

Self-Supplied Industry

Self-supplied industries are defined as those facilities that meet all or a portion of their water needs from their own sources. Within the Fox River basin, 91 facilities reported total ground-water pumpage of 5.42 mgd during 1995.

Rural/Domestic

There is no direct method for determining rural/domestic water use within the basin. To get a rough estimate for the area, several assumptions were made using existing information. The population served and number of services reported by PWS facilities were used to calculate an average population per service for all PWS facilities within the area. This number was used as an estimate of population per reported domestic well. The average PWS per capita use was then used as a multiplier to determine the total rural/domestic water use from each well.

Since the ISWS Private Well Database contains 29,221 reported wells in the Fox River basin, with an average of 3.4 people per service (well) and 78.4 gpd per person, total rural/domestic water use was estimated at 7.79 mgd.

Livestock Watering

Water withdrawals for livestock use in 1995 were estimated to be 1.33 mgd. Water use estimates for livestock are based on a fixed amount of water use per head for each type of animal. Percentages of the total animal population (Illinois Department of Agriculture, 1995) for the major livestock (cattle and hogs) in the counties were calculated based upon the percentage of county acres within the Fox River basin. Daily consumption rates (beef cattle = 12 gpd, all other cattle = 35 gpd, and hogs = 4 gpd) provided the basis for these calculations.

Ground-Water Use Trends

Ground-water use within the Fox River basin has declined slightly over the last six years. During this period, total ground-water use within the basin has averaged 59.17 mgd and ranged from 54.23 to 65.91 mgd; PWS use has averaged 53.15 mgd and ranged from 48.58 to 58.36 mgd; and SSI use has averaged 6.03 mgd and ranged from 5.34 to 7.55 mgd. Table 17 shows the individual totals per year since 1990. No significant trends are evident in terms of water withdrawals in the basin.

Table 17. Ground-Water Use Trends within the Fox River Basin
(in million gallons per day, mgd)

Year	PWS	SSI	Total
1990	55.36	6.09	61.45
1991	56.57	5.34	61.91
1992	49.33	6.10	55.43
1993	48.58	5.65	54.23
1994	58.36	7.55	65.91
1995	50.69	5.42	56.11
Average	53.15	6.03	59.17

Surface Water Resources

The rivers, streams, and lakes of the Fox River basin serve a wide variety of purposes, including uses for public water supply, recreation (boating, fishing, and swimming), and habitat for aquatic life. The primary focus of this section is on the existing and potential use of surface waters in the basin for supplying public and industrial water systems.

Public Water Supply Use

Throughout most of this century, towns in the Fox River basin have relied almost entirely on ground water for their public water supplies. However, over the past 15 years, seven communities in the basin have begun using surface sources for their water supply.

The cities of Elgin and Aurora, the two largest users of deep aquifers in the basin, have switched to the Fox River as their primary water supply source. This change occurred for two reasons: 1) excessive pumping from deep sandstone aquifers had led to continuous lowering of piezometric levels, and 2) water obtained from the deeper layers of those aquifers contained excessive amounts of barium, which would require costly treatment. Elgin began obtaining a portion of its water from the Fox River in 1983, and more than 90% of the city's present use of 12.9 mgd has been obtained from the river. Aurora has been using the Fox River for its water supply since 1992, and since 1994 withdrawals from the river have been averaging 9.6 mgd, or more than 60% of the city's total use of 15.4 mgd. The use of the Fox River by Elgin and Aurora presently accounts for 30% of the PWS use in basin, and the total use from all surface water sources represents more than 35% of the use in the basin.

Lake Michigan is the source of water for five communities on the eastern edge of the basin: Round Lake, Round Lake Beach, Round Lake Park, Valley View, and Streamwood. In the future, more communities on the eastern fringe of the basin may connect to Lake Michigan if local sources are inadequate or have quality problems.

Self-Supplied Industrial Use

Most of the self-supplied industrial use of surface waters in the Fox River basin is associated with sand-and-gravel and quarry operations. This water is typically reused and not discharged to streams. The Fermi National Accelerator Lab near Batavia also withdraws a small amount of water from the Fox River for cooling purposes. The total amount of water used for all these industrial purposes was 8.1 mgd in 1995.

Future Demands by Public Water Supplies

Singh et al. (1995) estimated that the total use for PWS systems in the Fox River basin will increase to 105 mgd by the year 2010, from the present level of 77 mgd. Most of the increase is likely to occur in Kane and McHenry Counties, which are expected to have the greatest population growth. Much of this growth will be in areas supplied by shallow ground water. It is expected that the Fox River and Lake Michigan will continue to supply more than a third of the basin's total water use. Although net changes in the flow magnitudes on the Fox River as a result of increased water use will be relatively small, the impact of increased effluents on water quality is a concern, as discussed below.

Effluent Discharges to Streams

Most of the water used in the basin is eventually discharged into the Fox River or its tributaries by wastewater treatment facilities. During a normal summer, the cumulative amount of the discharges from the basin can account for more than 20% of the total flow along most of the Illinois portion of the river. During an extreme dry period such as the 7-day 10-year low flow (Q7,10), the percentage of flow originating as effluents can increase to as much as 40%. The volume of effluent to the Fox River during the Q7,10 is expected to increase by about 57% between 1990 and 2010 (Singh et al., 1995).

The ability of the Fox River to assimilate wastewaters discharged into it has been a water quality concern for many decades. The employment of wastewater treatment standards has greatly improved the quality of the river since the early 1960s, reducing phosphorous concentrations and fecal coliform counts. However, excessive algal blooms are still a concern, particularly in the pools behind the numerous low-channel dams situated on the river. High nutrient inputs from wastewater effluents are a primary factor in promoting these algal growths. Singh et al. (1995) indicated that if the treatment of wastewater is not changed in upcoming decades, it is likely that the growing amount of effluents may halt or reverse the declining trends in phosphorous and fecal coliform.

Potential for Development of Additional Surface Water Supplies

Water supply systems in Illinois generally obtain surface water in one of three manners: direct withdrawal from a stream, impoundment of a stream to create a storage reservoir, and creation of an off-channel (side-channel) storage reservoir into which stream water is pumped. The available locations for development of these sources are discussed below.

Direct Withdrawals from Streams and Natural Lakes

To support a continuous direct withdrawal of water, a stream must have sufficient sustained flow during extreme drought conditions. The Fox River has a large amount of sustained flow and presently supplies most of the water for the cities of Elgin and Aurora. The only other streams in the Illinois portion of the basin that have a sufficient natural flow to support a moderate-sized water supply withdrawal are Nippersink Creek, the North Branch of Nippersink Creek, and Boone Creek, all in McHenry County.

Natural lakes in the region are considered valuable biological and recreational resources, and are generally not considered for water supply withdrawals, especially given the number of water supply options available in most parts of the Fox River basin. Potential withdrawals from lakes fed by a major river, such as the Chain of Lakes, which are fed by the Fox River, would be considered a direct stream withdrawal.

Impounding Reservoirs

Dawes and Terstriep (1967) identified 14 potential reservoir sites in the Fox River basin. Reservoirs have since been built at two of these sites: Lake Holiday in La Salle County and Shabbona Lake in De Kalb County. Both of these reservoirs presently are used only for recreational purposes. Most of the remaining 12 sites have a reasonably small potential yield, of a magnitude that could be supplied by nearby ground-water sources or the Fox River. One potential reservoir site, near the headwaters of Nippersink Creek in northern McHenry County, has a relatively large estimated yield of 8 to 9 mgd.

Side-Channel Reservoirs

The construction of a side-channel reservoir is a less expensive alternative to an impounding reservoir for most small- and medium-sized water supply systems. A side-channel reservoir is a potential water supply option along most streams in the basin. However, this option does not realistically provide yields greatly exceeding those that could be provided by regional ground-water sources.

Ground-Water Quality

This section examines ground-water quality records to determine temporal trends and to provide baseline water quality parameters within the Fox River basin. Increasingly, ground-water contamination is discussed in the news media, and it may seem that the entire ground-water resource has been affected. However, these contamination events are often localized and may not represent widespread degradation of the ground-water resource. By examining the temporal trends in ground-water quality within the area, it may be possible to determine whether large-scale degradation of the ground-water resource has occurred.

The general term "ground-water quality" refers to the chemical composition of ground water. Ground water originates as precipitation that filters into the ground. As the water infiltrates the soil, it begins to change chemically due to reactions with air in the soil and with the earth materials through which it flows. Human-induced chemical changes can also occur. In fact, contamination of ground water is generally the result of human-induced chemical changes and not naturally occurring processes.

As a general rule, local ground-water quality tends to remain nearly constant under natural conditions because of long ground-water travel times. Therefore, significant changes in ground-water quality can often indicate degradation of the ground-water resource.

Data Sources

The ground-water quality data that are used in this report come from two sources: private wells and municipal wells. The private well water quality data are compiled by the Chemistry Division of the Illinois State Water Survey (ISWS) as part of its water testing program and are maintained by the Office of Ground-Water Information in a water quality database. The municipal well data come from ISWS analyses and from the Illinois Environmental Protection Agency (IEPA) laboratories.

The combined database now contains more than 50,000 records of chemical analyses from samples analyzed at the ISWS and IEPA laboratories. Some of these analyses date to the early part of the century, but most are from 1970 to the present. Before 1987, most analyses addressed inorganic compounds and physical parameters. Since then, many organic analyses have been added to the database from the IEPA Safe Drinking Water Act compliance monitoring program. This report presents information for only a portion of the chemical parameters within the ISWS database.

Data Limitations

Several limitations must be understood before meaningful interpretation of the water quality data can begin:

1. Representativeness of the sample
2. Location information
3. Data quality (checked by charge balance)
4. Extrapolation to larger areas

Private well samples are likely not completely representative of regional ground-water quality. In most cases, private well owners submit samples for analysis only when they believe there may be a problem such as high iron or an odd odor or taste. This suggests that while one or more constituents may not be representative, in general the remainder of the chemical information will be accurate and useful. As a result, the composite data may be skewed toward analyses with higher than normal concentrations.

On the other hand, private well information probably gives a better picture of the spatial distribution of chemical ground-water quality than municipal well information because of the larger number of samples spread over a large area. Recent IEPA data from municipal wells will not be skewed because each well is sampled and analyzed on a regular basis. While this produces a much more representative sample overall, samples are generally limited to specific areas where municipalities are located. Therefore, these data may not be good indicators of regional ground-water quality.

Much of the location information for the private wells is based solely on the location provided by the driller at the time the well was constructed. Generally, locations are given to the nearest 10-acre plot of land. For this discussion, that degree of resolution is adequate. However, it is not uncommon for a given location to be in error by as much as 6 miles. To circumvent possible location errors, this report presents results on a watershed basis.

The validity of water quality data was not checked for this report. However, previous charge balance checking of these data was conducted for a similar statewide project (Illinois Department of Energy and Natural Resources, 1994). Charge balance is a simple measure of the accuracy of a water quality analysis. It measures the deviation from the constraint of electrical neutrality of the water by comparing total cations (positively charged ions) with total anions (negatively charged ions). Because many of the early analyses were performed for specific chemical constituents, a complete chemical analysis is not always available from which to calculate a charge balance.

The statewide study searched the water quality database for analyses with sufficient chemical constituents to perform an ion balance. The charge balance checking of those data found that more than 98% of the analyses produced acceptable mass balance, which suggests that the chemical analyses are accurate within the database. Using that assumption for this report, we feel confident that most of the analyses used are accurate and give representative water quality parameters for the Fox River basin. However, this may be true only for large samples, a factor that should be considered when reviewing the results, as this report presents data from ten decades and a wide range of sample sizes.

The question of extrapolation of point value (a well water sample) to a regional description of ground-water quality is difficult and theoretically beyond the scope of this report. However, none of the data provide a uniform spatial coverage. Therefore, it seems best to summarize the data on a watershed basis to ensure an adequate number of values. The private well analyses are more numerous and will likely provide better spatial coverage than the municipal well data, which are concentrated in isolated locations.

Chemical Components Selected for Trend Analysis

In many cases, ground-water contamination involves the introduction into ground water of industrial or agricultural chemicals such as organic solvents, heavy metals, fertilizers, and pesticides. However, recent evidence suggests that many of these contamination occurrences are localized and form finite plumes that extend down gradient from the source. Much of this information is relatively recent, dating back a few decades, but long-term records at any one site are rare.

As mentioned earlier, changes in the concentrations of naturally occurring chemical elements such as chloride, sulfate, or nitrate also can indicate contamination. For instance, increasing chloride concentrations may indicate contamination from road salt or oil field brine, while increasing sulfate concentrations may be from acid wastes such as metal pickling, and increasing nitrate concentrations may result from fertilizer application, feed-lot runoff, or leaking septic tanks. These naturally occurring substances are the major components of mineral quality in ground water and are routinely included in ground-water quality analyses.

Fortunately, the ISWS has maintained records of routine water quality analyses of private and commercial wells that extend as far back as the 1890s. After examination of these records, six chemical constituents were chosen for trend analyses based on the large number of available analyses and because they may be indicators of human-induced degradation of ground-water quality. These components are iron (Fe), total dissolved solids (TDS), sulfate (SO_4), nitrate (NO_3), chloride (Cl), and hardness (as $CaCO_3$).

Aquifer Unit Analysis

Ground water occurs in many types of geological materials and at various depths below the land surface. This variability results in significant differences of natural ground-water quality from one part of Illinois to another and from one aquifer to the next even at the same location. For the purpose of this trend analysis, wells that were finished within the unconsolidated sand and gravel units were grouped together, as were wells finished within the bedrock units. The unconsolidated units are by far the most frequently used within the Fox River basin. Out of the more than 29,221 private wells reported within the basin, only 6,776 indicate penetration into the bedrock units. From the water quality analyses within the ISWS water quality database, 994 of 3,308 wells indicated that the water for the sample came from the bedrock units. Unconsolidated and bedrock aquifers are treated separately in the descriptions of each chemical constituent.

Discussion and Results

Temporal trends in the six chemical constituents from unconsolidated and bedrock materials are summarized in this section. Tables 18 and 19 present the results of decade analyses of each constituent for unconsolidated and bedrock materials, respectively.

Median values are given in the tables by decade, beginning with 1900-1909 (Decade 0), 1910-1919 (Decade 1), and so on through the 1990s (Decade 9). Each decade covers the corresponding ten-year period, except for the partial decade of the 1990s. Median concentrations are given per decade so that temporal trends can be identified within the data set. Median values are the midpoints of a set of data, above which lie half the data points and below which is found the remaining half. These values are used to look at the central tendency of the data set. Although the arithmetic mean would also look at this statistic, it incorporates all data points into its analysis, which can move the mean value in one direction or another based upon maximum or minimum values.

In many data sets, outliers occur. These are extreme values that tend to stand alone from the central values of the data set. They may lead to a false interpretation of the data set, whereas the median values are true values that are central to the data set. By looking at the median we can determine trends in the central portions of the data. However, for data sets with a small number of samples, the median may not necessarily be representative of the water quality in the area.

It is important to recognize that the values included in these tables are reported values. While every attempt to verify the values was made, the *validity* of each value with regard to method error, etc. is not known. For this reason, the tables include every analysis within the database and all analysis results regardless of whether a value seems excessive and regardless of the sample size in the decade.

Table 18. Chemical Constituents Selected for Trend Analysis, Unconsolidated Aquifer Systems

	Decade*									
Chemical constituent	0	1	2	3	4	5	6	7	8	9
Iron (Fe)										
Sample size (N)	8	10	8	99	46	38	81	350	303	71
Minimum (mg/l)	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Maximum (mg/l)	2.5	3.0	2.0	40.0	13.4	4.4	8.3	18.0	6.4	2.8
Mean (mg/l)	1.1	1.1	0.8	1.5	1.7	1.3	1.1	1.3	1.4	1.2
Median (mg/l)	1.0	0.7	0.6	0.9	1.2	1.1	0.9	1.0	1.4	1.5
TDS										
Sample size (N)	8	12	8	99	47	38	79	346	303	69
Minimum (mg/l)	290.0	267.0	216.0	238.0	7.0	283.0	290.0	198.0	242.0	118.0
Maximum (mg/l)	450.0	1585.0	1753.0	1693.0	1599.0	1134.0	878.0	994.0	972.0	841.0
Mean (mg/l)	378.8	463.2	554.4	423.4	458.2	461.8	441.7	448.1	485.9	412.2
Median (mg/l)	375.0	368.0	383.5	373.0	392.0	423.5	424.0	427.5	471.0	429.0
Sulfate (SO_4)										
Sample size (N)	8	11	8	92	24	4	4	229	292	69
Minimum (mg/l)	0.0	0.0	0.0	0.0	0.0	20.0	8.0	0.0	0.1	10.0
Maximum (mg/l)	69.0	1088.0	1103.0	1078.0	1071.0	182.0	318.0	316.0	343.0	333.0
Mean (mg/l)	30.5	121.5	176.8	81.4	119.2	116.2	108.0	67.0	71.3	74.0
Median (mg/l)	24.0	28.0	54.5	37.5	77.0	131.5	53.0	60.0	66.0	74.0
Nitrate (NO_3)										
Sample size (N)	8	11	6	94	15	32	59	322	13	0
Minimum (mg/l)	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Maximum (mg/l)	22.0	8.8	9.7	26.6	25.2	10.7	56.8	30.8	21.3	0.0
Mean (mg/l)	2.8	2.1	2.5	3.1	5.1	1.8	3.0	1.5	2.2	0.0
Median (mg/l)	0.0	0.7	1.3	1.2	1.1	1.0	1.0	0.3	0.5	0.0
Chloride (Cl)										
Sample size (N)	8	12	8	95	47	40	81	349	304	69
Minimum (mg/l)	2.0	2.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Maximum (mg/l)	32.0	6.0	26.0	44.0	89.0	59.0	293.0	175.0	184.0	247.0
Mean (mg/l)	10.2	3.8	8.5	5.6	9.1	9.0	15.5	14.3	23.4	46.4
Median (mg/l)	6.0	3.5	7.0	3.0	6.0	5.0	5.0	6.0	16.0	33.0
Hardness (as $CaCO_3$)										
Sample size (N)	8	9	8	99	47	40	79	337	179	32
Minimum (mg/l)	214.0	152.0	153.0	58.0	194.0	146.0	68.0	12.0	156.0	100.0
Maximum (mg/l)	404.0	957.0	977.0	944.0	910.0	660.0	755.0	715.0	594.0	549.0
Mean (mg/l)	336.8	359.6	392.4	343.6	392.7	376.2	358.5	366.5	377.0	378.4
Median (mg/l)	341.0	322.0	362.5	338.0	367.0	378.0	368.0	367.0	382.0	397.5

*Note: Decade 0=1900-1909, Decade 1=1910-1919, and so on.

Table 19. Chemical Constituents Selected for Trend Analysis, Bedrock Aquifer Systems

Chemical constituent	Decade* 0	1	2	3	4	5	6	7	8	9
Iron (Fe)										
Sample size (N)	17	11	4	37	15	12	58	372	420	170
Minimum (mg/l)	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Maximum (mg/l)	8.4	4.8	2.4	90.0	5.0	10.0	22.0	24.3	17.6	9.1
Mean (mg/l)	1.5	1.3	1.2	9.9	1.6	1.3	2.2	1.1	0.7	0.7
Median (mg/l)	1.0	0.8	1.1	0.6	1.0	0.3	1.1	0.6	0.3	0.3
TDS										
Sample size (N)	17	11	4	37	14	12	58	372	412	158
Minimum (mg/l)	320.0	315.0	323.0	297.0	310.0	301.0	253.0	160.0	53.0	86.0
Maximum (mg/l)	530.0	537.0	373.0	1483.0	868.0	1120.0	739.0	1520.0	1310.0	3032.0
Mean (mg/l)	394.4	386.6	348.0	492.7	439.7	458.7	414.6	450.6	430.9	336.9
Median (mg/l)	380.0	369.0	348.0	442.0	382.5	374.5	395.0	418.0	397.0	337.5
Sulfate (SO_4)										
Sample size (N)	14	11	4	35	6	4	10	323	411	160
Minimum (mg/l)	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	2.0	10.0
Maximum (mg/l)	82.0	97.0	38.0	887.0	125.0	114.0	160.0	1000.0	859.0	551.0
Mean (mg/l)	30.6	23.7	10.0	67.3	42.3	38.5	45.9	86.2	63.6	52.2
Median (mg/l)	27.0	21.0	1.0	11.0	20.5	17.5	10.0	60.0	50.0	37.5
Nitrate (NO_3)										
Sample size (N)	17	10	4	35	6	5	41	322	19	0
Minimum (mg/l)	0.0	0.9	0.0	0.0	0.7	0.3	0.0	0.0	0.2	0.0
Maximum (mg/l)	4.0	29.2	3.0	38.5	4.8	0.7	9.2	63.2	2.2	0.0
Mean (mg/l)	0.6	4.7	1.5	3.6	2.6	0.4	1.1	1.1	0.7	0.0
Median (mg/l)	0.0	1.4	1.4	1.3	2.6	0.3	0.5	0.1	0.6	0.0
Chloride (Cl)										
Sample size (N)	17	11	4	37	14	12	58	386	415	159
Minimum (mg/l)	1.0	2.0	1.0	1.0	1.0	3.0	1.0	0.0	1.0	1.0
Maximum (mg/l)	106.0	27.0	19.0	126.0	24.0	440.0	66.0	615.0	215.0	288.3
Mean (mg/l)	12.7	12.0	7.2	18.8	5.3	51.3	7.2	17.1	16.8	23.0
Median (mg/l)	5.0	5.0	4.5	6.0	2.5	11.0	4.0	5.0	6.2	8.2
Hardness (as $CaCO_3$)										
Sample size (N)	17	11	3	37	15	12	58	364	228	56
Minimum (mg/l)	260.0	164.0	298.0	98.0	91.0	216.0	27.0	1.0	10.0	36.0
Maximum (mg/l)	408.0	368.0	370.0	671.0	505.0	836.0	618.0	796.0	724.0	477.0
Mean (mg/l)	329.9	276.1	331.0	309.6	292.8	346.0	312.6	327.2	302.0	300.9
Median (mg/l)	322.0	270.0	325.0	318.0	312.0	290.5	319.0	326.0	288.0	307.0

*Note: Decade 0=1900-1909, Decade 1=1910-1919, and so on.

Iron (Fe)

Iron in ground water occurs naturally in the soluble (ferrous) state. However, when exposed to air, iron becomes oxidized into the ferric state and forms fine to fluffy reddish-brown particles that will settle to the bottom of a container if allowed to sit long enough. The presence of iron in quantities much greater than 0.1 to 0.3 milligrams per liter (mg/l) usually causes reddish-brown stains on porcelain fixtures and laundry. The drinking water standards recommend a maximum limit of 0.3 mg/l iron to avoid staining (Gibb, 1973).

Unconsolidated Aquifer Systems

Iron concentrations for unconsolidated aquifer systems in the basin are given for each decade in Table 18. Minimum and maximum concentrations for all ten decades are 0.0 and 40.0 mg/l, respectively. These values clearly indicate spatial variability in iron within the basin. The median concentrations range from 0.6 to 1.5 mg/l for all ten decades. While these median values show relatively high concentrations that could cause staining of porcelain fixtures (greater than 0.3 mg/l), they generally pose no threat to human health. The median values are all well above the Class I potable ground-water supply standard of 0.5 mg/l. Table 18 suggests no significant trend in iron concentrations in the area.

Bedrock Aquifer Systems

Iron concentrations for bedrock aquifer systems in the basin are given for each decade in Table 19. Minimum and maximum concentrations for all ten decades are 0.0 and 90.0 mg/l, respectively. These values clearly indicate a great deal of spatial variability in iron within the basin. The median values range from 0.3 to 1.1 mg/l for all ten decades. While these median values show relatively high concentrations that could cause staining of porcelain fixtures (greater than 0.3 mg/l), they generally pose no threat to human health. Table 19 suggests no significant trend in iron concentrations in the area.

Total Dissolved Solids (TDS)

The TDS content of ground water is a measure of the mineral solutes in the water. Water with a high mineral content may taste salty or brackish depending on the types of minerals in solution and their concentrations. In general, water containing more than 500 mg/l TDS will taste slightly mineralized. However, the general public can become accustomed to the taste of water with concentrations of up to 2,000 mg/l. Water containing more than 3,000 mg/l TDS generally is not acceptable for domestic use, and at 5,000 to 6,000 mg/l, livestock may not drink the water. Because TDS concentration is a lumped measure of the total amount of dissolved chemical constituents in the water, it will not be a sensitive indicator of trace-level contamination. However, it is a good indicator of major inputs of ions or cations to ground water.

Unconsolidated Aquifer Systems

TDS concentrations within the unconsolidated aquifer systems in the basin are given for each decade in Table 18. Minimum and maximum concentrations for all ten decades are 7.0 and 1,753.0 mg/l, respectively. Median values range from 368.0 to 471.0 mg/l for all ten decades. Generally, there are no significant trends in TDS concentrations within these aquifer systems in the basin.

Bedrock Aquifer Systems

TDS concentrations for bedrock aquifer systems in the basin are reported for each decade in Table 19. Minimum and maximum concentrations for all ten decades are 53.0 and 3,032.0 mg/l, respectively. Median values range from 337.5 to 442.0 mg/l for all ten decades. Generally, there are no significant trends in TDS concentrations within bedrock aquifer systems in the basin. Any fluctuations from one decade to the next are more likely related to data limitations than to any inherent changes in ground-water quality.

Sulfate (SO_4)

Water with high sulfate concentrations often has a medicinal taste and a pronounced laxative effect on those not accustomed to it. Sulfates generally are present in aquifer systems in one of three forms: as magnesium sulfate (sometimes called Epsom salt); as sodium sulfate (Glauber's salt); or as calcium sulfate (gypsum). They also occur in earth materials in a soluble form that is the source for natural concentrations of this compound. Human sources similar to those for chloride also can contribute locally to sulfate concentrations. Coal mining operations particularly are a common source of sulfate pollution, as are industrial wastes. Drinking water standards recommend an upper limit of 250 mg/l for sulfates. Trends in sulfate concentrations can suggest potential ground-water pollution.

Unconsolidated Aquifer Systems

Sulfate concentrations for unconsolidated aquifer systems in the basin are reported for each decade in Table 18. Minimum and maximum concentrations for all ten decades are 0.0 and 1,103.0 mg/l, respectively. Median values are all well below the drinking water standard, and range from 24.0 to 131.5 mg/l for all ten decades.

Bedrock Aquifer Systems

Sulfate concentrations for bedrock aquifer systems in the basin are reported for each decade in Table 19. Minimum and maximum concentrations for all ten decades are 0.0 and 1,000.0 mg/l, respectively. Median values are all well below the drinking water standard, and range from 1.0 to 60.0 mg/l for all ten decades. Fluctuations from one decade to the next are more likely related to data limitations than to any inherent changes in ground-water quality.

Nitrate (NO_3)

Nitrates are considered harmful to fetuses and children under the age of one when concentrations in drinking water supplies exceed 45 mg/l (as NO_3), or the approximate equivalent of 10 mg/l nitrogen (N). Excessive nitrate concentrations in water may cause "blue baby" syndrome (methmoglobinemia) when such water is used in the preparation of infant feeding formulas. Inorganic nitrogen fertilizer has proven to be a source of nitrate pollution in some shallow aquifers, and may become an even more significant source in the future as ever increasing quantities are applied to Illinois farmlands. Trends in concentrations of nitrate may be a good indication that farm practices in the area are affecting the ground-water environment.

Unconsolidated Aquifer Systems

Nitrate concentrations for unconsolidated aquifer systems in the basin are reported for each decade in Table 18. Minimum and maximum concentrations for all ten decades are 0.0 and 56.8 mg/l, respectively. Median values are all well below the drinking water standards, and range from 0.0 to 1.3 mg/l for all ten decades. However, the ISWS has documented numerous cases of elevated nitrate levels associated with rural private wells (Wilson et al., 1992). The evidence suggests that rural well contamination is associated more with farmstead contamination of the local ground water or well than with regional contamination of major portions of an aquifer from land application of fertilizers. This topic is actively being studied.

Bedrock Aquifer Systems

Nitrate concentrations for bedrock aquifer systems in the basin are reported for each decade in Table 19. Minimum and maximum concentrations for all ten decades are 0.0 and 63.2 mg/l, respectively. Median values are well below the drinking water standards, and range from 0.0 to 2.6 mg/l for all ten decades.

Chloride

Chloride is generally present in aquifer systems as sodium chloride or calcium chloride. Concentrations greater than about 250 mg/l usually cause the water to taste salty. Chloride occurs in earth materials in a soluble form that is the source for normal concentrations of this mineral in water. Of the constituents examined in this report, chloride is one of the most likely to indicate the impacts of anthropogenic activity on ground water. Increasing chloride concentrations may indicate contamination from road salt or oil field brine. The drinking water standards recommend an upper limit of 250 mg/l for chloride. In sand and gravel aquifers throughout most of the state, chloride concentrations are usually less than 10 mg/l.

Unconsolidated Aquifer Systems

Chloride concentrations for unconsolidated aquifer systems in the basin are reported for each decade in Table 18. Minimum and maximum concentrations for all ten decades are 0.0 and 293.0 mg/l, respectively, and median concentrations range from 3.0 to 33.0 mg/l. Although the median values are well below the drinking water standards, it should be noted that an increasing trend appears in the data. This may be the result of increased road de-icing operations, a topic that is currently being investigated in several areas in Illinois.

Bedrock Aquifer Systems

Chloride concentrations for bedrock aquifer systems in the basin are reported for each decade in Table 19. Minimum and maximum concentrations for all ten decades are 0.0 and 615.0 mg/l, respectively. Median values are all well below the drinking water standard, and range from 2.5 to 11.0 mg/l for all ten decades. Table 19 indicates no significant trends in chloride concentrations in the basin. Fluctuations from one decade to the next are more likely related to data limitations than to any inherent changes in groundwater quality.

Hardness (as $CaCO_3$)

Hardness in water is caused by calcium and magnesium. These hardness-forming minerals generally are of major importance to users since they affect the consumption of soap and soap products and produce scale in water heaters, pipes, and other parts of the water system. The drinking water standards do not recommend an upper limit for hardness. The distinction between hard and soft water is relative, depending on the type of water a person is accustomed to. The ISWS categorizes water from 0 to 75 mg/l as soft, 75 to 125 mg/l as fairly soft, 125 to 250 mg/l as moderately hard, 250 to 400 mg/l as hard, and over 400 mg/l as very hard.

Unconsolidated Aquifer Systems

Hardness concentrations for unconsolidated aquifer systems in the basin are reported for each decade in Table 18. Minimum and maximum concentrations for all ten decades are 12.0 and 977.0 mg/l, respectively. Median values range from 322.0 to 397.5 mg/l for all ten decades. The water is considered hard and is typical for shallow unconsolidated materials within Illinois.

Bedrock Aquifer Systems

Hardness concentrations for bedrock aquifer systems in the basin are reported for each decade in Table 19. Minimum and maximum concentrations for all ten decades are 1.0 and 836.0, respectively. Median values range from 270.0 to 326.0 mg/l for all ten decades. The water is considered hard.

Summary

This work was undertaken to examine long-term temporal trends in ground-water quality within the Fox River basin. Data from private and municipal wells were the primary sources of information used to show the trends in six chemical constituents of ground water within the area. These data demonstrate that on a watershed scale, ground water has not been degraded with respect to five of the chemicals examined. However, there appears to be a trend of rising chloride concentrations within the unconsolidated materials in the last few decades, possibly the result of de-icing practices in the basin. More research is required to verify whether such a trend is widespread or localized.

Fluctuations from one decade to the next are more likely related to data limitations than to any inherent changes in ground-water quality. It is also evident that the sample size within each decade can play a role in trend analysis.

Much of the contamination of Illinois' ground water is localized. Nonetheless, this contamination can render a private or municipal ground-water supply unusable. Once contaminated, ground water is very difficult and expensive to clean, and clean-up may take many years to complete. Clearly it is in the best interests of the people of Illinois to protect their ground-water resource through prevention of contamination.

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