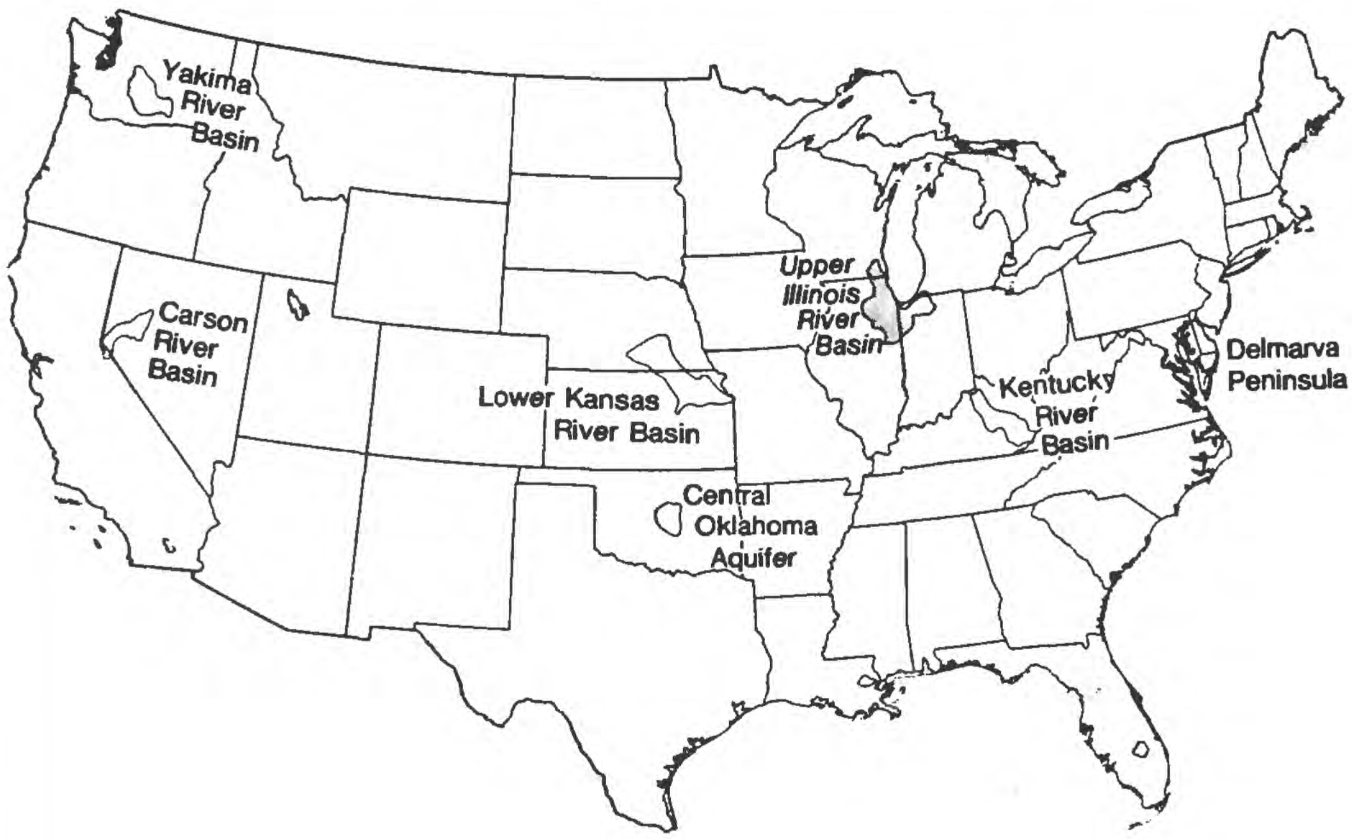
SURFACE-WATER-QUALITY ASSESSMENT OF THE UPPER ILLINOIS RIVER BASIN IN ILLINOIS, INDIANA, AND WISCONSIN: CROSS-SECTIONAL AND DEPTH VARIATION OF WATER-QUALITY CONSTITUENTS AND PROPERTIES IN THE UPPER ILLINOIS RIVER BASIN, 1987–88

by Donna C. Marron and Stephen F. Blanchard



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CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot per second (ft/s)	0.3048	meter per second

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

$$°F = 1.8(°C) + 32$$

Abbreviated water-quality units used in this report:

milligrams per liter (mg/L)
micrograms per liter (µg/L)
microsiemens per centimeter at 25° Celsius (µS/cm)
colonies per 100 milliliters (col/100 mL)

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

Surface-Water-Quality Assessment of the Upper Illinois River Basin in Illinois, Indiana, and Wisconsin: Cross-Sectional and Depth Variation of Water-Quality Constituents and Properties in the Upper Illinois River Basin, 1987-88

By Donna C. Marron *and* Stephen F. Blanchard

Abstract

Data on water velocity, temperature, specific conductance, pH, dissolved oxygen concentration, chlorophyll concentration, suspended sediment concentration, fecal-coliform counts, and the percentage of suspended sediment finer than 62 micrometers were collected at 3–25 verticals at each of 8 river cross sections in the upper Illinois River Basin from March 1987 through September 1988. Cross-sectional coefficients of variation of temperature, specific conductance, and pH ranged up to 6 percent; cross-sectional coefficients of variation of the concentration of dissolved oxygen and the percentage of suspended sediment finer than 62 micrometers ranged up to 21 percent; and cross-sectional coefficients of variation of the concentrations of suspended sediment, fecal coliform, and chlorophyll ranged from 7 to 115 percent. Midchannel measurements of temperature, specific conductance, and pH were within 5 percent of mean cross-sectional values of these properties at the eight sampling sites, most of which appear well mixed because of the effect of dams and reservoirs. Measurements of the concentration of dissolved oxygen at various cross-section locations and at variable sampling depths are required to obtain a representative value of this constituent at these sites. The large variability of concentrations of chlorophyll and suspended sediment, and fecal-coliform counts at the eight sampling sites indicates that composite rather than midchannel or mean values of these constituents are likely to be most representative of the channel cross section.

INTRODUCTION

Agencies responsible for the evaluation of water quality in rivers commonly must choose between the thoroughness of width-depth-integrated flow-weighted sampling and the cost effectiveness of point or grab sampling. Point or grab sampling does not account for spatial variations in water quality within channel cross sections. Such variations are likely because of cross-sectional variations in water velocity. Other factors affecting water quality include shade, channel geometry, and location with respect to point sources of water with a distinct chemical composition. The importance of width-depth-integrated flow-weighted sampling in some situations and the widespread use of point or grab sampling have been documented by Childress and others (1989).

This report presents the results of a study to document the cross-sectional and depth variations of selected water-quality constituents and properties in rivers in the upper Illinois River Basin in Illinois, Indiana, and Wisconsin (fig. 1). The report was prepared as part of the pilot phase of the National

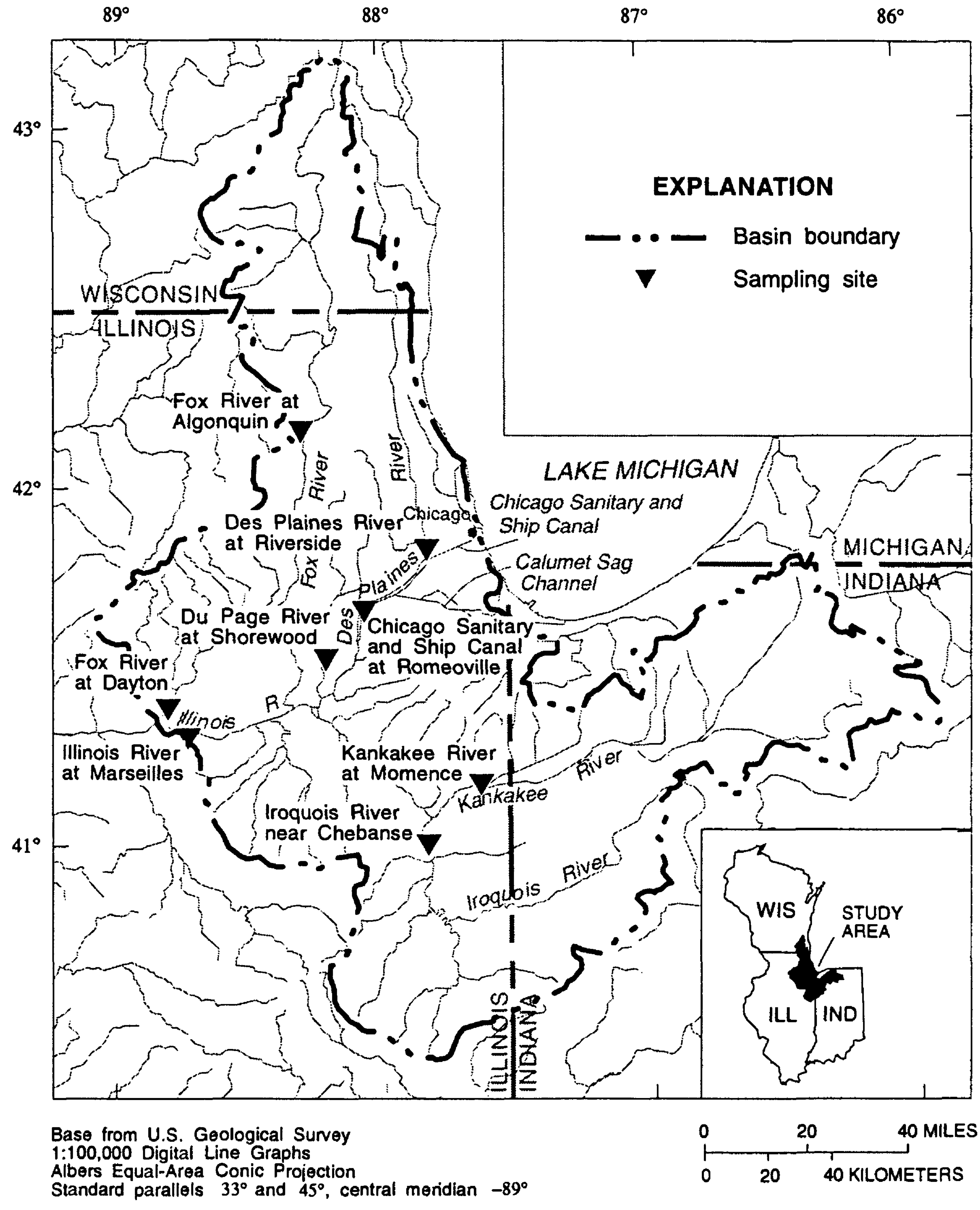

Figure 1. Location of the study area in Illinois, Indiana, and Wisconsin and water-quality sampling sites.

Water-Quality Assessment program of the U.S. Geological Survey (USGS).

The report also presents an evaluation of the comparative accuracies of single-point and width-depth-integrated sampling in the evaluation of water quality in the study area. Data on cross-sectional variations in water-quality constituents and properties were collected at 3–25 verticals at each of 8 river cross sections at sampling sites (fig. 1) from March 1987 through September 1988. The data are published in the USGS annual data reports for Illinois (Fitzgerald and others, 1988; Coupe and others, 1989). Data were collected for eight sampling periods during different seasons and over a range of stream discharges. Data on flow velocity, water temperature, specific conductance, dissolved oxygen concentration, pH, chlorophyll concentration, suspended sediment concentration, and the percentage of suspended sediment finer than 62 micrometers were collected at all eight sites, although not all of these constituents and properties were measured during each sampling period. Fecal-coliform counts were measured during one sampling period at four of the sampling sites.

Previous Work

Cross-sectional variation of suspended-sediment concentrations in river channels has been recognized for decades. Data presented by Colby (1963) and Culbertson and others (1972) demonstrate that fine particles, in particular, can be distributed unevenly across channel cross sections. Horowitz and others (1989) showed that depth-integrated and pumped or point samples contain substantially different suspended sediment concentrations. On the basis of such findings, the USGS utilizes depth-integrated flow-weighted sampling at multiple verticals within a channel cross section to measure the concentration of suspended sediment (Edwards and Glysson, 1988).

Marked cross-sectional variations in water chemistry because of incomplete mixing of tributary waters also have been well documented (Anderson and Faust, 1973). Calculated mixing lengths can range from several miles for small, fast-flowing streams to hundreds of miles for larger rivers (Childress and others, 1989). Cross-sectional variations in the concentrations of pesticide residues associated with sediment particles (Feltz and Culbertson, 1972) and trace elements associated with sediment particles (Horowitz and others, 1989) have been noted. Britton and Greeson (1989) recognize the likelihood that bacteria will be clumped or patchy distributed in the fluvial environment.

A sample of river water for analysis of water-quality constituents and properties should be representative of the channel cross section where it is collected. Publications on the evaluation of water quality in rivers, however, commonly devote more attention to sample preservation and analysis than to the collection of a representative sample (U.S. Environmental Protection Agency, 1982; American Public Health Association and others, 1971; Fishman and Friedman, 1989). Commonly, single-point sampling is utilized at sites that are not immediately downstream from tributaries or point sources of effluents, and that appear, in the field, to be "well-mixed." Hem (1985), however, suggests the use of width-depth-integrated flow-weighted sampling except in situations where the uniformity of stream composition can be demonstrated in the field at all flow conditions.

Description of Study Area

The sites at which data were collected are upstream from the confluence of the Illinois and Fox Rivers in northern Illinois (fig. 1). The climate in the upper Illinois River Basin is classified as continental, with hot, humid summers and cold winters. Average annual precipitation during 1951–80 in the area ranged from 32 to 40 in. (Balding, 1986, p. 217). The predominant land uses in the upper Illinois River Basin are agricultural, urban, and industrial. Streamflow in the area is strongly affected by low-head dams. Streamflow at most of the sampling stations is augmented by irrigation return flow and (or) point-source discharges, such as those from wastewater-treatment facilities.

Topographic relief in the upper Illinois River Basin is low to moderate. Most bedrock in the area is covered by glacial sediments. Characteristics of sampling sites are listed in table 1 (all tables are at end of report). Drainage areas of the sampling sites range from 324 to 8,259 mi^2. The mean annual discharges (through 1988) at the sites range from 268 to 10,709 ft^3/s.

Study Methods

Field measurements of temperature, specific conductance, the concentration of dissolved oxygen, and pH were measured with a Series 4000 Hydrolab[1] (Model 4041). At most of the sampling sites, field measurements were made at a single depth at each vertical along the cross section. Most measurements were made 1 ft below the water surface, although measurement depths at sites where measurements were made at only one depth ranged from 0.2 to 2.5 ft. At two of the sampling sites, field measurements were made at more than one depth at some or all of the verticals along the cross section. The field instrument was calibrated to known standards before use. After use, the instrument was checked with the known standards to determine if the instrument had drifted from calibration. If substantial drift resulted, the measurements were corrected for the instrument drift. The mean water velocity at a vertical was determined from a velocity measurement at 0.6 of the stream depth or from the average of velocity measurements taken at 0.2 and 0.8 of the stream depth. Velocity measurements were made with a Price type AA meter with a metal bucket wheel.

Depth-integrated flow-weighted water samples were collected at specific verticals within channel cross sections for the analysis of suspended sediment concentration, percentage of suspended sediment finer than 62 micrometers, and chlorophyll concentration. The equal-width-increment method, described by Edwards and Glysson (1988), was utilized to collect composite samples from at least 10 verticals within a given cross section. Depth-integrating samplers, as described by Edwards and Glysson (1988), were utilized to collect the samples at each vertical. Chlorophyll samples were immediately frozen until analyzed by chromatography, as described by Britton and Greeson (1989). Water samples for the analysis of fecal-coliform concentration were collected within a foot of the water surface at specific verticals within channel cross sections. The concentration of fecal coliform was determined within 6 hours of sample collection utilizing the method described by Britton and Greeson (1988).

[1]Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

WATER-QUALITY CONSTITUENTS AND PROPERTIES

Summaries of data collected at the eight sampling sites are presented in tables 2–9. Midchannel values of constituents and properties are the values at the vertical closest to the midpoint of the cross section. Where the midpoint of the cross section was equidistant from two verticals, values of water-quality constituents at these verticals were averaged to obtain the midchannel value. Composite values of the concentration of suspended sediment and the percentage of suspended sediment finer than 62 micrometers were obtained by analyzing width-depth-integrated samples for these constituents. An example of the variation observed in the cross-sectional water-quality data is shown in figure 2.

Cross-Sectional Variability

Cross-sectional variations in temperature, specific conductance, and pH were minimal at all of the sampling sites during all of the sampling periods. Coefficients of variation are shown in tables 2–9. The maximum coefficient of variation for temperature and pH was 5 percent and for specific conductance, 6 percent. Coefficients of variation were less than 3 percent for 92 percent of the sets of temperature measurements, 78 percent of the sets of specific-conductance measurements, and 97 percent of the sets of pH measurements. Cross-sectional variations in the concentration of dissolved oxygen were more extreme; the maximum coefficient of variation of the concentration of dissolved oxygen was 19 percent, and the coefficient of variation of the concentration of dissolved oxygen was 3 percent or less for only 50 percent of the sets of measurements analyzed.

Although the coefficients of variation for temperature, specific conductance, pH, and dissolved oxygen were commonly low for a given sampling period, these properties usually varied in an orderly manner by consistently increasing or decreasing across channel cross sections (fig. 2). Specific patterns of properties at particular sampling sites sometimes occurred during more than one sampling period but never were consistent during all of the sampling periods. Similarly, parallel or opposite patterns of variation of particular properties commonly resulted during two or more sampling periods

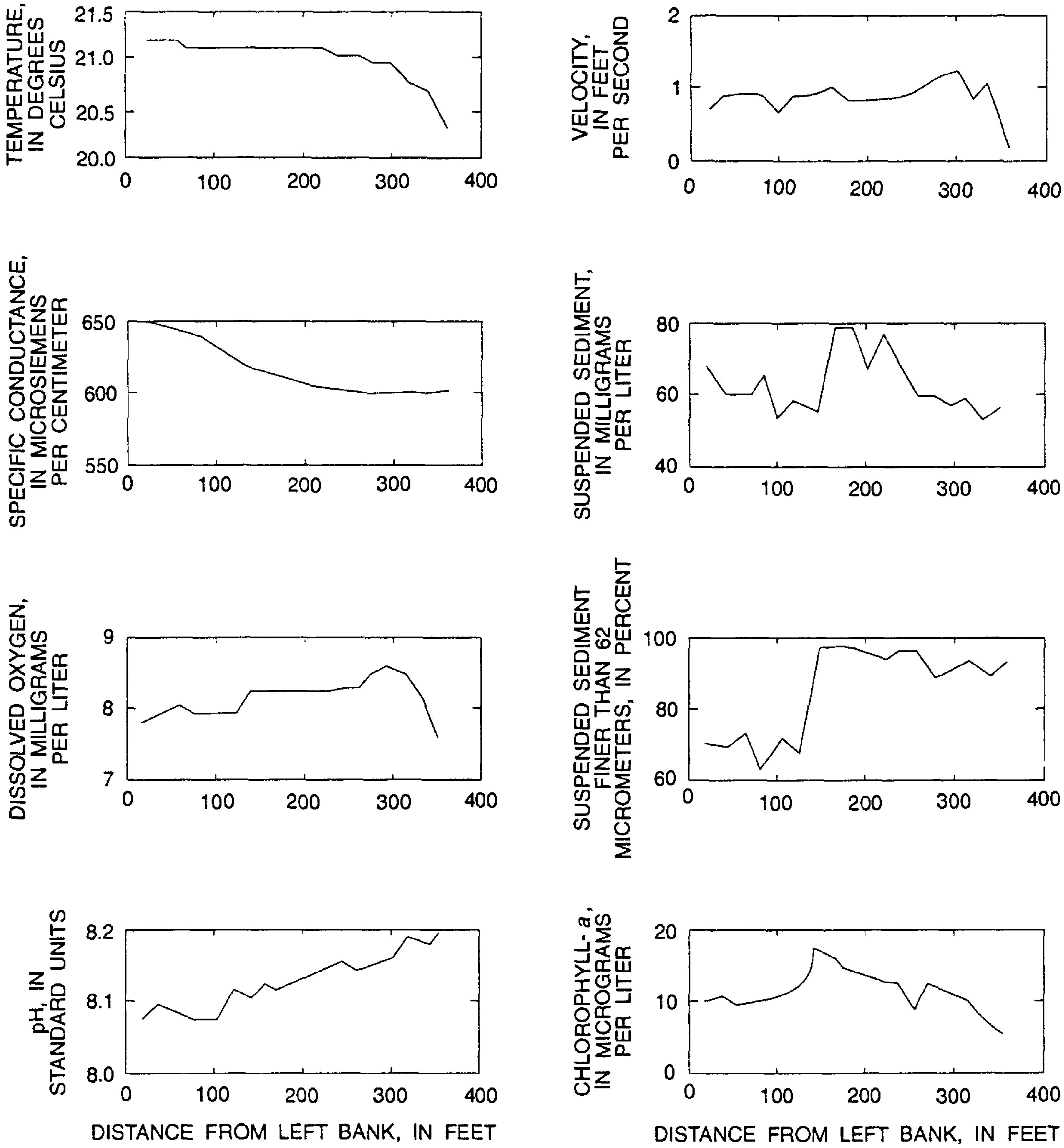

Figure 2. Water-quality data collected at the Kankakee River at Momence, Ill., September 13, 1988.

at the sampling sites, but no property had a consistently parallel or inverse relation with any other property at any of the sites during all of the sampling periods. No consistent relations could be determined for the coefficients of variation of temperature, specific conductance, pH, and dissolved oxygen concentration with discharge at any of the sampling sites.

Concentrations of chlorophyll, suspended sediment, and fecal-coliform counts were considerably more variable within the sampled cross sections than the field measurements. Coefficients of variation of chlorophyll concentration ranged from 22 to 103 percent at the sampling site on the Iroquois River near Chebanse and from 11 to 31 percent at the other seven sampling sites. Coefficients of variation of fecal-coliform concentration ranged from 36 to 47 percent, and of suspended sediment concentration from 7 to 115 percent. The coefficient of variation of the percentage of suspended sediment finer than 62 micrometers ranged from less than 1 to 21 percent. Unlike the variations of the properties measured with the Hydrolab, variations in the concentrations of chlorophyll, fecal coliform, and suspended sediment, and the percentage of suspended sediment finer than 62 micrometers, tended to be sporadic across channel cross sections (fig. 2). No consistent relation between the coefficient of variation of these properties and discharge at the specific sampling sites could be determined.

Cross-sectional variations of water-quality constituents and properties measured during this study fall into two general categories. The first category includes properties not associated with particulates such as temperature, specific conductance, and pH, and typically have small cross-sectional variation. The second category includes constituents such as chlorophyll, fecal coliform, and suspended sediment, which are particulates and typically have considerably larger variations than the nonparticulate constituents.

Properties in the first category are maximally affected by chemical reactions and processes and are minimally affected by variations in velocity. The relatively low variability in temperature, specific conductance, and pH at the sampling sites results from the generally well-mixed nature of water at those sampling sites. The larger variability of the concentration of dissolved oxygen, which also is strongly affected by chemical reactions and biologic processes, possibly results from the partial shading of channels or by the production or consumption of dissolved oxygen by aquatic plants. The lack of systematic relations between the properties in the first category indicate that at least some lack of variability results from incomplete mixing of waters with chemical compositions that vary from sampling period to sampling period. Ground-water seepage into streams and local point sources of effluent can introduce water of variable composition into streams in the study area.

Constituents in the second category are strongly affected by the transport of inorganic or organic particles. Sediment is particulate by definition; stream algae commonly grow attached to solid objects or as thin films on clay and silt (Hynes, 1970); and bacteria, such as fecal coliform, commonly are present in clumps or as thin films on clay and silt (Odum, 1971). Although the distribution of sediment particles in river channels has been shown to be affected by water velocity in some river channels (Culbertson and others, 1972), the lack of consistently well-defined relations between any of the constituents in the second category and velocity suggests that other factors, such as turbulence, also affect the distribution of particles at the eight sampling sites.

The cross-sectional variation, when expressed as the coefficient of variation in percent, is generally a small number for many of the constituents and properties examined; however, the variation could be significant if compared to water-quality criteria or annual variation. For example, dissolved oxygen concentration at Des Plaines River at Riverside on September 12, 1988, ranged from 4.3 to 5.3 mg/L along the cross section (table 4). The Illinois water-quality criterion for dissolved oxygen concentration is 5.0 mg/L (Illinois Water Pollution Control Board, 1988). The observed concentrations of dissolved oxygen indicate water samples at a site could either meet or not meet the criteria depending on where the concentration was measured. Similarly, the cross-sectional variation also can be large if compared to the annual variation at a site. The observed concentrations of dissolved oxygen emphasize the importance of making multiple measurements and (or) collecting a representative water sample.

Depth Variability

Temperature, specific conductance, dissolved oxygen concentration, and pH were measured at multiple depths during two out of four sampling periods at the Fox River at Algonquin and during all five sampling periods at the Chicago Sanitary and Ship Canal at Romeoville (fig. 1 and table 10). Measurements were made at two depths at the site on the Fox River and at two to five depths at the site on the Chicago Sanitary and Ship Canal. Only verticals in the deeper parts of channel cross sections were sampled at multiple depths.

Temperature, dissolved oxygen concentration, and pH generally decreased with depth, although these characteristics did increase or remain the same with depth during some of the sampling periods (table 10). Specific conductance does not appear to be related to water depth. Depth-related changes in temperature, pH, and specific conductance were small in relation to cross-sectional mean values of these properties during the different sampling periods (table 10). In contrast, average depth-related changes in the concentration of dissolved oxygen at the two sampling stations commonly exceeded the cross-sectional mean by more than 10 percent (table 10).

Midchannel, Composite, and Mean Values

Differences between midchannel and composite values of the concentration of suspended sediment at the different sampling sites (tables 2–9) indicate that midchannel values generally are not acceptable substitutes for composite values of this constituent. Midchannel values range from 56 to 169 percent of composite values of the concentration of suspended sediment. The largest differences between midchannel and composite measures of the concentration of suspended sediment resulted where concentrations were high (Des Plaines River at Riverside, September 12, 1988) and low (Chicago Sanitary and Ship Canal at Romeoville, April 21, 1987). Midchannel values of the percentage of suspended sediment finer than 62 micrometers ranged from 92 to 112 percent of composite values of this constituent.

Composite samples were not measured for temperature, specific conductance, dissolved oxygen concentration, pH, chlorophyll concentration, and fecal-coliform count. The relation of midchannel to mean values of these properties and constituents, however, corresponds to their variability along channel cross sections. Midchannel values of temperature, pH, and specific conductance are 95 to 103 percent of the mean values of these properties. Midchannel values of the concentration of dissolved oxygen are 93 to 123 percent of the mean values of this constituent. Midchannel values of fecal-coliform count and chlorophyll concentration are 81 to 130 percent and 33 to 136 percent, respectively, of the mean values of these constituents.

SUMMARY AND CONCLUSIONS

The degree to which water-quality constituents and properties vary across channel cross sections affects the design of sampling programs for evaluating water quality in streams. However, published data on cross-sectional variations in water-quality constituents and properties in different fluvial environments are limited. The data presented in this report were collected to enhance this limited data base, particularly, as the data pertains to streams in urbanized and agricultural areas in the upper Illinois River Basin. The report was prepared as part of the pilot phase of the National Water-Quality Assessment program of the U.S. Geological Survey.

The cross-sectional variability of water-quality constituents and properties fell into two categories. In one category, the variability of properties, such as temperature, specific conductance, and pH, which are not associated with particulates, is low (coefficients of variation do not exceed 6 percent); in the second category, the variability of the constituents, such as suspended sediment, fecal coliform, and chlorophyll, which represent particulate substances, are high (coefficients of variation range from 7 to 115 percent). Properties in the first category are generally affected by chemical reactions and biologic processes, whereas constituents in the second category are strongly affected by the transport of organic or inorganic particles. Depth-related variations of properties in the first category are small in relation to cross-sectional mean values of these properties. An exception is the concentration of dissolved oxygen, which appears to be depth-related and which commonly exceeded the cross-sectional mean value of this constituent by more than 10 percent.

Small coefficients of variation of temperature, specific conductance, and pH across channel cross sections result in midchannel values of these properties within 5 percent of the mean cross-sectional values of these properties at the eight sampling sites. The effect of dams and reservoirs on most of these sites may limit the transfer value of this observation to streams unaffected by dams. The larger variability of the concentration of dissolved oxygen, both across channels and with depth at the sampling sites, indicates the need for multiple measurements to obtain a representative concentration for this constituent.

Differences between midchannel and composite values of suspended sediment concentration at the different sampling sites indicate that midchannel concentrations generally are not acceptable substitutes for composite concentrations. This observation probably also applies to other particulate material, such as fecal coliform and chlorophyll, on the basis of the variability observed from this study. These results indicate that width-depth-integrated flow-weighted sampling is the best method for obtaining representative samples of suspended and particulate substances.

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TABLES 1–10

Table 1. Characteristics of water-quality sampling sites in the upper Illinois River Basin
[USGS, U.S. Geological Survey; mi^2, square mile; ft^3/s, cubic feet per second; ft, feet; mi, mile]

Site name	USGS station number	Drainage area (mi^2)	Mean annual discharge (ft^3/s)	Period of discharge record	Average depth at mean-annual discharge (ft)	Channel width (ft)	Comments
Kankakee River at Momence, Ill.	05520500	2,294	1,985	1914–88	2.5	500	Double channel, two dams within 0.5 mi upstream from site.
Iroquois River near Chebanse, Ill.	05526000	2,091	1,657	1923–88	4.0	310	Tributary enters channel at right bank within 0.12 mi upstream from site.
Des Plaines River at Riverside, Ill.	05532500	630	503	1943–88	3.2	220	Dam within 0.25 mi upstream from site. Point source discharge enters channel at left bank between dam and site.
Chicago Sanitary and Ship Canal at Romeoville, Ill.	05536995	739	3,778	1984–88	25.0	160	Oil refinery outflow enters channel at left bank within 1.5 mi upstream from site. Barge traffic mixes water.
Du Page River at Shorewood, Ill.	05540500	324	268	1940–88	1.4	115	Dam within 0.12 mi upstream from site. Reach is riffled.
Illinois River at Marseilles, Ill.	05543500	8,259	10,709	1919–88	3.1	575	Double channel; only right one measured. Dam within 0.5 mi upstream from site. Diversion channel enters main channel at right bank between dam and site.
Fox River at Algonquin, Ill.	05550000	1,403	864	1915–88	6.2	295	Dam within 0.25 mi downstream from site. Site is in backwater of dam.
Fox River at Dayton, Ill.	05552500	2,642	1,744	1914–88	3.7	175	Dam within 0.25 mi upstream from site. Dam outlet enters channel at right bank between dam and site.

Table 2. Summary of water-quality data collected at Kankakee River at Momence, Ill.

[ft/s, feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (µS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (µg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (80154)	Suspended sediment finer than 62 micrometers (percent) (70331)
April 8, 1987; discharge = 1,470 ft^3/s; 19 verticals									
Mean	--	12.9	647	12.2	8.4	--	--	--	--
Coefficient of variation (percent)	--	1	5	4	1	--	--	--	--
Minimum	--	12.8	616	11.6	8.4	--	--	--	--
Maximum	--	13.1	702	13.0	8.5	--	--	--	--
Midchannel value	--	12.8	635	11.7	8.4	--	--	--	--
Composite value	--	--	--	--	--	--	--	--	--
July 21, 1987; discharge = 1,490 and 940 ft^3/s; 10 to 20 verticals									
Mean	1.3	29.2	686	9.0	8.4	--	195	38	80
Coefficient of variation (percent)	13	1	4	2	<1	--	47	33	9
Minimum	1.0	28.9	648	8.7	8.4	--	46	16	62
Maximum	1.7	29.7	723	9.4	8.5	--	360	57	90
Midchannel value	1.1	29.1	680	8.9	8.4	--	158	54	84
Composite value	--	--	--	--	--	--	--	--	--
March 8, 1988; discharge = 2,400 ft^3/s; 19 to 23 verticals									
Mean	--	7.8	658	9.6	7.7	3.9	--	36	83
Coefficient of variation (percent)	--	3	4	6	1	19	--	21	11
Minimum	--	7.5	621	8.6	7.6	1.2	--	27	64
Maximum	--	8.0	700	10.2	7.8	5.0	--	47	97
Midchannel value	--	7.5	657	9.7	7.7	3.7	--	37	87
Composite value	--	--	--	--	--	--	--	--	--
June 9, 1988; discharge = 752 ft^3/s; 17 to 19 verticals									
Mean	1.2	21.3	644	8.3	8.1	--	--	59	90
Coefficient of variation (percent)	26	1	3	3	<1	--	--	17	8
Minimum	.5	21.0	615	8.0	8.0	--	--	35	68
Maximum	1.8	21.5	675	8.9	8.1	--	--	78	99
Midchannel value	.9	21.4	645	8.2	8.1	--	--	74	92
Composite value	--	--	--	--	--	--	--	--	--
September 13, 1988; discharge = 574 ft^3/s; 18 verticals									
Mean	.9	21.0	611	8.2	8.1	11.1	--	63	85
Coefficient of variation (percent)	27	1	3	4	1	27	--	12	14
Minimum	.3	20.3	592	7.5	8.1	4.7	--	53	63
Maximum	1.3	21.2	648	8.7	8.2	17.0	--	78	97
Midchannel value	.8	21.1	604	8.3	8.1	13.5	--	72	95
Composite value	--	--	--	--	--	--	--	69	85

Table 3. Summary of water-quality data collected at Iroquois River near Chebanse, Ill.

[ft/s, feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (µS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (µg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (80154)	Suspended sediment finer than 62 micrometers (percent) (70331)
March 31, 1987; discharge = 600 ft^3/s; 20 verticals									
Mean	--	7.7	666	11.2	8.6	--	--	--	--
Coefficient of variation (percent)	--	4	4	5	1	--	--	--	--
Minimum	--	7.1	625	10.5	8.6	--	--	--	--
Maximum	--	8.1	692	12.2	8.8	--	--	--	--
Midchannel value	--	7.9	672	11.1	8.6	--	--	--	--
Composite value	--	--	--	--	--	--	--	--	--
July 21, 1987; discharge = 329 ft^3/s; 9 to 25 verticals									
Mean	0.8	27.4	567	6.1	8.1	--	226	111	100
Coefficient of variation (percent)	24	2	<1	3	<1	--	36	7	<1
Minimum	.1	25.8	562	5.9	8.1	--	106	88	98
Maximum	1.0	28.0	571	6.6	8.2	--	345	124	100
Midchannel value	.9	27.7	567	6.0	8.2	--	106	114	100
Composite value	--	--	--	--	--	--	--	--	--
March 8, 1988; discharge = 1,220 ft^3/s; 20 to 21 verticals									
Mean	--	5.7	683	11.5	8.1	2.4	--	65	84
Coefficient of variation (percent)	--	5	4	2	1	72	--	35	10
Minimum	--	5.3	655	11.2	8.0	1.5	--	43	66
Maximum	--	6.1	711	11.8	8.2	9.5	--	130	96
Midchannel value	--	5.4	680	11.7	8.1	2.0	--	57	85
Composite value	--	--	--	--	--	--	--	42	92
June 10, 1988; discharge = 198 ft^3/s; 20 to 24 verticals									
Mean	.6	20.4	714	8.9	8.1	14.9	--	112	91
Coefficient of variation (percent)	25	2	<1	3	1	22	--	14	4
Minimum	.3	20.1	713	8.5	7.8	7.6	--	87	86
Maximum	.8	21.2	718	10.0	8.2	22.5	--	141	97
Midchannel value	.6	20.2	713	8.8	8.1	15.5	--	110	87
Composite value	--	--	--	--	--	--	--	--	--
September 13, 1988; discharge = 32 ft^3/s; 13 verticals									
Mean	--	25.8	516	15.9	8.7	1.2	--	17	97
Coefficient of variation (percent)	--	2	2	10	1	103	--	45	8
Minimum	--	25.2	500	13.4	8.6	.3	--	5	70
Maximum	--	26.9	533	18.5	8.8	4.8	--	26	100
Midchannel value	--	25.3	516	16.8	8.7	.4	--	9	99
Composite value	--	--	--	--	--	--	--	16	100

Table 4. Summary of water-quality data collected at Des Plaines River at Riverside, Ill.

[ft/s, feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (µS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (µg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (80154)	Suspended sediment finer than 62 micrometers (percent) (70331)
April 9, 1987; discharge = 395 ft^3/s; 10 verticals									
Mean	--	12.6	1,046	12.2	8.4	--	--	15	96
Coefficient of variation (percent)	--	1	1	1	<1	--	--	14	4
Minimum	--	12.4	1,039	12.1	8.31	--	--	12	89
Maximum	--	12.8	1,059	12.3	8.41	--	--	18	100
Midchannel value	--	12.6	1,045	12.3	8.41	--	--	13	98
Composite value	--	--	--	--	--	--	--	14	96
July 22, 1987; discharge = 315 ft^3/s; 18 to 20 verticals									
Mean	1.8	26.0	750	5.7	7.4	--	--	18	99
Coefficient of variation (percent)	26	1	<1	2	<1	--	--	96	1
Minimum	1.0	25.7	747	5.3	7.3	--	--	11	96
Maximum	2.4	26.2	752	5.8	7.4	--	--	85	100
Midchannel value	2.1	26.0	749	5.8	7.4	--	--	13	100
Composite value	--	--	--	--	--	--	--	--	--
March 10, 1988; discharge = 848 ft^3/s; 19 to 21 verticals									
Mean	.9	5.6	1,215	10.6	8.4	2.4	--	19	83
Coefficient of variation (percent)	56	3	2	4	1	19	--	56	14
Minimum	.2	5.4	1,171	9.8	8.2	1.9	--	11	57
Maximum	1.7	5.8	1,247	11.2	8.5	3.9	--	60	100
Midchannel value	1.2	5.5	1,225	10.5	8.5	2.5	--	20	76
Composite value	--	--	--	--	--	--	--	--	--
June 6, 1988; discharge = 212 ft^3/s; 15 to 16 verticals									
Mean	1.5	23.5	1,183	8.2	8.0	--	--	29	99
Coefficient of variation (percent)	33	<1	<1	2	1	--	--	11	1
Minimum	.4	23.4	1,177	7.9	7.9	--	--	26	96
Maximum	2.1	23.8	1,188	8.7	8.1	--	--	38	100
Midchannel value	2.0	23.5	1,188	8.2	8.0	--	--	27	98
Composite value	--	--	--	--	--	--	--	--	--
September 12, 1988; discharge = 1,260 ft^3/s; 20 to 22 verticals									
Mean	--	22.5	797	4.9	7.3	24.6	--	429	99
Coefficient of variation (percent)	--	1	1	7	1	31	--	25	1
Minimum	--	22.3	779	4.3	7.2	11.0	--	268	97
Maximum	--	23.0	817	5.3	7.4	36.0	--	557	100
Midchannel value	--	22.5	799	5.1	7.4	33.5	--	477	99
Composite value	--	--	--	--	--	--	--	282	99

Table 5. Summary of water-quality data collected at Chicago Sanitary and Ship Canal at Romeoville, Ill.

[ft/s, feet per second; °C, degrees Celsius; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (μS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (μg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (80154)	Suspended sediment finer than 62 micrometers (percent) (70331)
April 21, 1987; discharge = 3,750 ft^3/s; 10 verticals; depths averaged[1]									
Mean	--	15.2	796	3.1	7.1	--	--	17	89
Coefficient of variation (percent)	--	1	<1	3	<1	--	--	14	7
Minimum	--	15.0	792	2.9	7.0	--	--	14	78
Maximum	--	15.5	800	3.2	7.1	--	--	22	98
Midchannel value	--	15.2	796	3.1	7.1	--	--	21	90
Composite value	--	--	--	--	--	--	--	12	92
August 14, 1987; discharge = 14,750 ft^3/s; 10 verticals; depths averaged[1]									
Mean	--	25.6	565	3.2	7.3	--	--	13	93
Coefficient of variation (percent)	--	1	<1	4	1	--	--	27	5
Minimum	--	25.5	563	3.0	7.3	--	--	8	84
Maximum	--	26.0	566	3.4	7.4	--	--	19	100
Midchannel value	--	25.5	566	3.2	7.3	--	--	12	94
Composite value	--	--	--	--	--	--	--	--	--
March 10, 1988; discharge = 2,170 ft^3/s; 3 to 19 verticals; depths averaged[1]									
Mean	--	8.2	1,101	8.0	7.0	2.4	--	7	97
Coefficient of variation (percent)	--	1	<1	19	1	8	--	20	10
Minimum	--	8.2	1,100	6.9	6.9	2.1	--	5	63
Maximum	--	8.3	1,103	9.8	7.1	2.7	--	10	100
Midchannel value	--	8.2	1,100	9.8	7.0	2.6	--	5	100
Composite value	--	--	--	--	--	--	--	--	--
June 7, 1988; discharge = 4,560 ft^3/s; 3 to 20 verticals; depths averaged[1]									
Mean	--	21.9	760	2.9	6.9	--	--	20	97
Coefficient of variation (percent)	--	1	<1	3	1	--	--	104	4
Minimum	--	21.8	759	2.8	6.9	--	--	9	88
Maximum	--	22.0	762	3.0	7.0	--	--	82	100
Midchannel value	--	22.0	760	2.9	6.9	--	--	13	98
Composite value	--	--	--	--	--	--	--	--	--
September 12, 1988; discharge = 4,150 ft^3/s; 18 to 20 verticals; depths averaged[1]									
Mean	--	21.0	525	4.9	7.8	2.6	--	11	99
Coefficient of variation (percent)	--	<1	<1	2	2	20	--	16	3
Minimum	--	20.9	522	4.8	7.6	1.9	--	8	88
Maximum	--	21.3	528	5.1	8.2	3.9	--	14	100
Midchannel value	--	21.0	526	4.9	7.8	2.9	--	11	98
Composite value	--	--	--	--	--	--	--	--	--

[1]Constituent values measured at more than one depth were averaged at some verticals.

Table 6. Summary of water-quality data collected at Du Page River at Shorewood, Ill.

[ft/s, feet per second; °C, degrees Celsius; μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (μS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (μg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (80154)	Suspended sediment finer than 62 micrometers (percent) (70331)
July 22, 1987; discharge = 200 ft^3/s; 14 to 33 verticals									
Mean	1.5	28.7	1,501	9.5	8.4	--	--	46	96
Coefficient of variation (percent)	55	1	1	2	<1	--	--	51	8
Minimum	.2	28.1	1,474	9.1	8.3	--	--	9	72
Maximum	3.1	29.1	1,537	9.7	8.5	--	--	107	100
Midchannel value	2.7	28.9	1,515	9.3	8.4	--	--	26	100
Composite value	--	--	--	--	--	--	--	--	--
March 10, 1988; discharge = 328 ft^3/s; 17 to 20 verticals									
Mean	1.9	6.4	1,553	10.4	8.1	1.8	--	19	98
Coefficient of variation (percent)	32	3	4	2	1	23	--	101	2
Minimum	.3	6.1	1,284	10.1	7.8	.7	--	12	94
Maximum	2.8	6.7	1,589	10.8	8.2	2.6	--	22	100
Midchannel value	2.8	6.5	1,583	10.4	8.0	2.0	--	18	99
Composite value	--	--	--	--	--	--	--	--	--
June 7, 1988; discharge = 106 ft^3/s; 19 verticals									
Mean	1.3	22.8	1,754	9.4	8.4	--	--	17	97
Coefficient of variation (percent)	35	1	1	4	<1	--	--	21	4
Minimum	.3	22.4	1,690	8.4	8.4	--	--	10	82
Maximum	1.9	23.1	1,779	9.7	8.5	--	--	25	100
Midchannel value	1.9	22.9	1,759	9.7	8.4	--	--	12	100
Composite value	--	--	--	--	--	--	--	--	--
September 11, 1988; discharge = 73 ft^3/s; 19 verticals									
Mean	--	25.9	1,925	12.5	8.8	9.8	--	11	93
Coefficient of variation (percent)	--	<1	<1	4	1	31	--	28	6
Minimum	--	25.5	1,908	11.4	8.5	2.9	--	5	82
Maximum	--	26.0	1,955	13.4	8.8	15.0	--	15	100
Midchannel value	--	25.9	1,923	12.1	8.8	10.0	--	15	90
Composite value	--	--	--	--	--	--	--	13	100

Table 7. Summary of water-quality data collected at Illinois River at Marseilles, Ill.

[ft/s, feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (µS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (µg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (80154)	Suspended sediment finer than 62 micrometers (percent) (70331)
July 23, 1987; discharge = 5,940 ft^3/s; 12 verticals									
Mean	--	30.2	667	6.2	7.6	--	37	21	99
Coefficient of variation (percent)	--	<1	<1	5	<1	--	42	14	2
Minimum	--	30.0	666	5.8	7.5	--	25	17	94
Maximum	--	30.5	670	6.7	7.6	--	70	27	100
Midchannel value	--	30.2	666	6.3	7.6	--	48	24	99
Composite value	--	--	--	--	--	--	--	--	--
March 9, 1988; discharge = 6,720 ft^3/s; 18 to 19 verticals									
Mean	--	6.7	980	--	8.1	3.9	--	15	98
Coefficient of variation (percent)	--	1	2	--	1	17	--	11	3
Minimum	--	6.6	925	--	7.9	3.1	--	12	90
Maximum	--	6.8	1,000	--	8.3	5.1	--	19	100
Midchannel value	--	6.6	972	--	8.0	3.5	--	15	93
Composite value	--	--	--	--	--	--	--	--	--
June 6, 1988; discharge = 3,840 ft^3/s; 19 verticals									
Mean	3.1	25.3	821	6.8	7.8	--	--	15	99
Coefficient of variation (percent)	19	<1	<1	5	1	--	--	8	2
Minimum	2.2	25.1	818	6.4	7.8	--	--	13	90
Maximum	4.2	25.6	823	7.7	8.0	--	--	17	100
Midchannel value	3.5	25.2	821	6.5	7.8	--	--	15	100
Composite value	--	--	--	--	--	--	--	--	--
September 10, 1988; discharge = 4,430 ft^3/s; 11 verticals									
Mean	--	22.2	646	9.5	7.9	48.9	--	27	97
Coefficient of variation (percent)	--	1	6	3	1	11	--	22	2
Minimum	--	21.9	630	9.2	7.9	42.0	--	22	92
Maximum	--	22.3	763	10.1	8.0	59.0	--	42	99
Midchannel value	--	22.2	638	9.7	7.9	53.0	--	28	92
Composite value	--	--	--	--	--	--	--	26	96

Table 8. Summary of water-quality data collected at Fox River at Algonquin, Ill.

[ft/s, feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (µS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (µg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (60154)	Suspended sediment finer than 62 micrometers (percent) (70331)
July 28, 1987; discharge = 504 ft^3/s; 13 to 14 verticals; depths averaged[1]									
Mean	--	27.5	623	7.2	8.1	--	--	38	96
Coefficient of variation (percent)	--	1	1	14	3	--	--	20	3
Minimum	--	27.3	613	5.6	7.8	--	--	26	88
Maximum	--	28.0	629	9.8	8.5	--	--	51	99
Midchannel value	--	27.4	624	6.7	8.0	--	--	31	95
Composite value	--	--	--	--	--	--	--	42	97
March 11, 1988; discharge = 1,520 ft^3/s; 18 to 20 verticals; depths averaged[1]									
Mean	0.7	4.1	643	--	9.5	14.7	--	37	75
Coefficient of variation (percent)	26	5	4	--	5	18	--	115	21
Minimum	.4	3.9	572	--	8.7	9.4	--	11	37
Maximum	1.1	4.5	664	--	10.2	19.4	--	185	94
Midchannel value	.6	4.0	659	--	9.4	16.9	--	12	78
Composite value	--	--	--	--	--	--	--	--	--
June 9, 1988; discharge = 350 ft^3/s; 19 to 20 verticals									
Mean	.2	22.0	652	6.7	8.1	44.8	--	48	97
Coefficient of variation (percent)	34	1	1	9	1	21	--	11	3
Minimum	.1	21.5	646	6.1	8.0	16.8	--	38	91
Maximum	.4	22.4	657	8.1	8.2	59.7	--	59	100
Midchannel value	.3	22.0	652	6.6	8.1	44.9	--	43	99
Composite value	--	--	--	--	--	--	--	--	--
September 11, 1988; discharge = 210 ft^3/s; 16 to 17 verticals									
Mean	--	19.7	766	6.8	8.1	66	--	46	99
Coefficient of variation (percent)	--	<1	3	2	1	17	--	11	1
Minimum	--	19.5	750	6.6	8.1	37	--	37	97
Maximum	--	19.8	810	7.0	8.3	81	--	55	100
Midchannel value	--	19.8	751	6.8	8.2	74	--	47	99
Composite value	--	--	--	--	--	--	--	50	97

[1]Constituent values measured at more than one depth were averaged at some verticals.

Table 9. Summary of water-quality data collected at Fox River at Dayton, Ill.

[ft/s, feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; <, less than; --, no data; (00055), WATer Data STOrage and REtrieval System (WATSTORE) parameter code number]

	Velocity (ft/s) (00055)	Temperature (°C) (00010)	Specific conductance (µS/cm) (00095)	Dissolved oxygen (mg/L) (00300)	pH (standard units) (00400)	Chlorophyll (µg/L) (70953)	Fecal coliform (col/100 mL) (31616)	Suspended sediment (mg/L) (80154)	Suspended sediment finer than 62 micrometers (percent) (70331)
May 4, 1987; discharge = 2,960 ft^3/s; 13 verticals									
Mean	--	14.9	636	10.9	8.7	--	--	60	92
Coefficient of variation (percent)	--	1	<1	9	1	--	--	15	7
Minimum	--	14.7	634	9.5	8.6	--	--	48	73
Maximum	--	15.3	643	12.0	8.7	--	--	84	98
Midchannel value	--	14.9	635	11.6	8.7	--	--	54	98
Composite value	--	--	--	--	--	--	--	56	97
July 23, 1987; discharge = 756 ft^3/s; 20 to 22 verticals									
Mean	--	28.4	615	7.6	8.5	--	--	61	98
Coefficient of variation (percent)	--	1	<1	3	<1	--	--	29	4
Minimum	--	28.0	611	7.1	8.5	--	--	19	85
Maximum	--	28.6	621	8.1	8.6	--	--	108	100
Midchannel value	--	28.5	614	7.5	8	--	--	54	98
Composite value	--	--	--	--	--	--	--	--	--
March 9, 1987; discharge = 2,230 ft^3/s; 17 to 19 verticals									
Mean	2.4	5.6	754	10.8	8.4	14.4	--	48	77
Coefficient of variation (percent)	31	1	1	1	1	12	--	69	8
Minimum	1.3	5.5	740	10.5	8.4	11.9	--	29	65
Maximum	3.6	5.7	760	11.0	8.7	17.7	--	165	89
Midchannel value	3.6	5.6	762	10.8	8.4	--	--	30	81
Composite value	--	--	--	--	--	--	--	--	--
June 6, 1988; discharge = 651 ft^3/s; 20 verticals									
Mean	1.7	24.9	597	--	9.1	--	--	41	99
Coefficient of variation (percent)	31	<1	1	--	1	--	--	14	2
Minimum	.8	24.7	591	--	9.0	--	--	27	91
Maximum	2.6	25.1	619	--	9.2	--	--	48	100
Midchannel value	2.1	25.0	596	--	9.0	--	--	43	100
Composite value	--	--	--	--	--	--	--	--	--
September 10, 1988; discharge = 143 ft^3/s; 13 to 18 verticals									
Mean	--	21.9	727	15.0	9.2	44.2	--	46	95
Coefficient of variation (percent)	--	1	<1	7	2	18	--	17	6
Minimum	--	21.7	720	13.2	8.6	31.0	--	34	78
Maximum	--	22.4	730	16.5	9.4	59.0	--	64	99
Midchannel value	--	21.8	729	16.2	9.3	41.0	--	41	97
Composite value	--	--	--	--	--	--	--	53	98

Table 10. Depth-related variations in water-quality constituents and properties in the upper Illinois River Basin
[Average and maximum change refers to the change from the shallowest to the deepest measurement at a sampling station; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; --, no data]

	Temperature (°C)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	pH (units)
Fox River at Algonquin, July 28, 1987; 8 verticals				
Average change	–0.5	8	–1.6	–0.40
Maximum change	–1.0	18	–5.2	–.77
Cross-section mean	27.5	623	7.2	8.1
Fox River at Algonquin, March 11, 1988; 14 verticals				
Average change	.0	–3	--	.02
Maximum change	.0	–17	--	–.10
Cross-section mean	4.1	643	--	9.5
Chicago Sanitary and Ship Canal at Romeoville, April 21, 1987; 11 verticals				
Average change	.1	–2	–.3	–.01
Maximum change	.5	–6	–.4	–.04
Cross-section mean	15.2	796	3.1	7.1
Chicago Sanitary and Ship Canal at Romeoville, August 14, 1987; 10 verticals				
Average change	–.1	0	–.6	–.04
Maximum change	–.5	–4	–.9	–.14
Cross-section mean	25.6	565	3.2	7.3
Chicago Sanitary and Ship Canal at Romeoville, March 10, 1988; 3 verticals				
Average change	–.2	3	1.3	–.03
Maximum change	–.5	10	4.4	–.10
Cross-section mean	8.2	1,101	8.0	7.0
Chicago Sanitary and Ship Canal at Romeoville, June 7, 1988; 3 verticals				
Average change	–.2	1	–.4	–.07
Maximum change	–.5	2	–1.4	–.10
Cross-section mean	21.9	760	2.9	6.9
Chicago Sanitary and Ship Canal at Romeoville, September 12, 1988; 4 verticals				
Average change	–.1	–1	.1	–.06
Maximum change	–.5	–1	.4	–.23
Cross-section mean	21.0	525	4.9	7.8