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Kankakee River Basin Streamflow Assessment Model: Hydrologic Analysis

by H. Vernon Knapp
Office of Surface Water Resources & Systems Analysis

Prepared for the
Illinois Department of Transportation, Division of Water Resources

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Illinois State Water Survey
Hydrology Division
Champaign, Illinois

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INTRODUCTION

The Illinois Streamflow Assessment Model *(.ILSAM)* is a computer program for water resources management, which provides statistical information on streamflow quantity, primarily for low and medium flows. *ILSAM* combines processed data from streamgage records and recent information on water use withdrawals and effluent discharges to provide its users with a quantitative assessment of the changes in flow variability for all stream locations throughout a watershed. *ILSAM* can also simulate the potential effects of hypothetical water resources projects to provide its users with a quantitative estimate of future streamflow conditions. The model can also translate these effects to other locations downstream. This information can be useful for evaluating the water supply for potable and irrigation use, potential conflicts in water use, wastewater effluent dilution standards, the design of reservoirs, and environmental impacts of water resources projects.

This study analyzes the available hydrologic data for the Kankakee River watershed (located in northeastern Illinois and northwestern Indiana) to estimate the streamflow conditions in the Illinois portion of the watershed. These estimates of streamflow are then processed for use in *ILSAM.* The report is the fourth in a series of studies dealing with hydrologic evaluations for the *ILSAM* models. In prior studies, streamflow estimates were developed for three other watersheds in Illinois: the Sangamon, Fox, and Kaskaskia River basins. The location of all four watersheds is shown in figure 1. Many of the algorithms used to estimate the effects of water use practices on streamflow quantity were presented in earlier reports (Knapp et al., 1985; Knapp, 1988; Knapp, 1990). The operation of the model is further described in the *ILSAM User's Guide* (Mills and Knapp, 1991).

ILSAM is available from the Illinois State Water Survey on 3-1/2 inch or 5-1/4 inch floppy diskettes for use on an IBM-PC/AT* or compatible computer having a minimum random access memory (RAM) of 640 K (kilobytes).

Streamflow Information Produced by the Model

ILSAM produces estimates of 154 selected streamflow parameters, including flow-duration (flow versus percentage of duration) relationships, low flows for various durations, and expected return intervals. The 154 parameters are described in detail in the following paragraphs. All parameter values are given in units of cubic feet per second (cfs).

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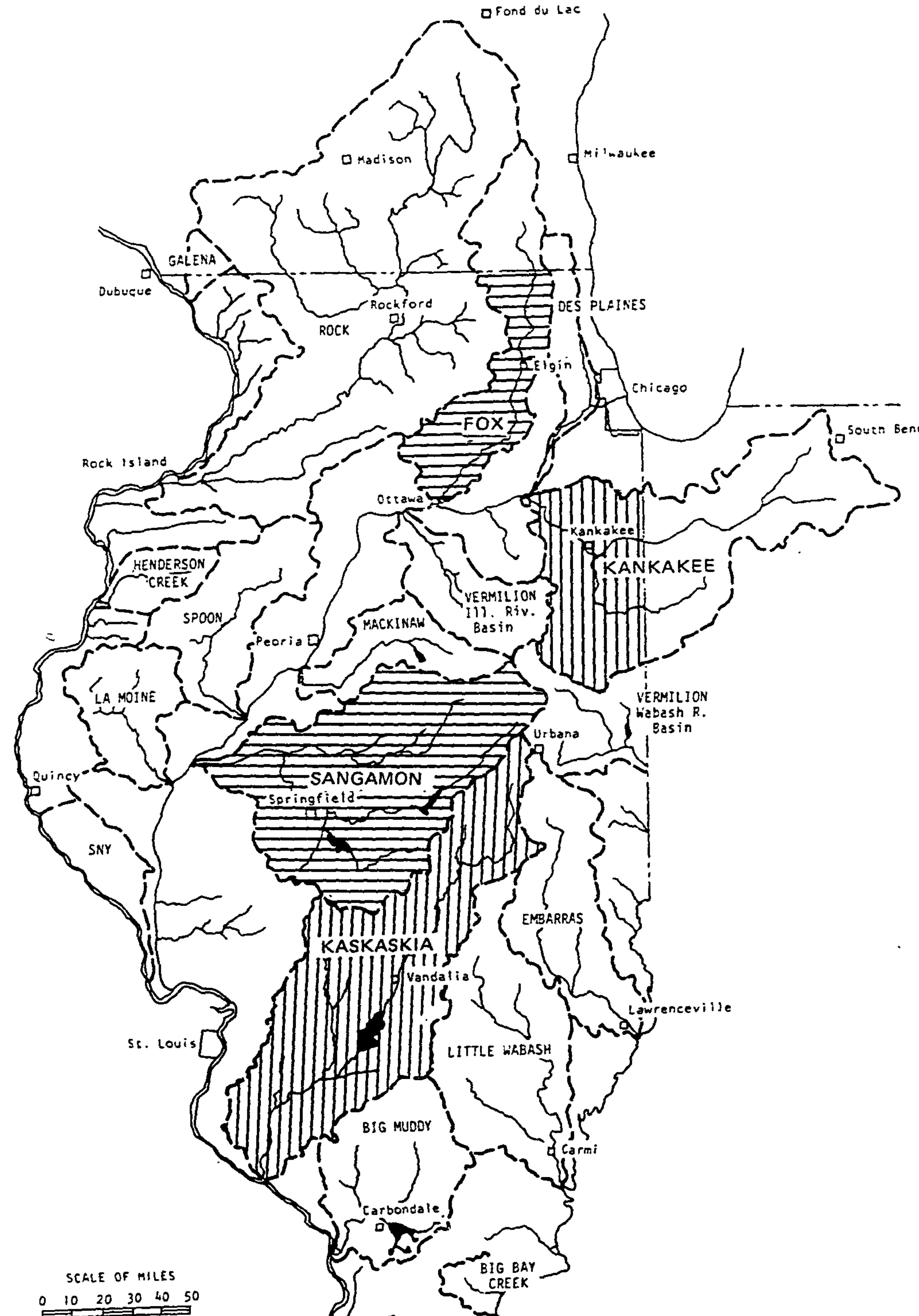

Figure 1. Location of river basins for which the Illinois Streamflow *Assessment* Model has been developed

Estimates of all flow parameters are presented for both present and virgin (natural or unaffected) flow conditions. In addition, *ILSAM* users may introduce a hypothetical (or potential) flow modification and have the model estimate its effect on the specified flow parameters; the resulting flow is called the altered flow. Flow conditions may be estimated for any gaged or ungaged site in the watershed with a drainage area of at least 10 square miles.

Annual Flow-Duration Values

For a gaging station with a record of continuous daily discharge, the 2 percent flow (Q2) is the streamflow volume that is exceeded on exactly 2 percent of the days during that period of record. By definition, the 1 percent flow (Q_1) is a larger volume because it is exceeded less often.

PARAMETERS: Q_{99}, Q_{98}, Q_{95}, Q_{90}, Q_{85}, Q_{75}, Q_{60}, Q_{50}, Q_{40}, Q_{25}, Q_{15}, Q_{10}, Q_5, Q_2, Q_1, AND Q_{MEAN}

Monthly Flow-Duration Values

The monthly flow-duration values are just like the annual flow-duration values, except that they are determined using only those daily discharges that fall within a certain month of the year. For example, in a 30-year streamflow record, there are exactly 900 daily values for the month of April. The value for Q_{10} is the flow that is exceeded exactly 10 percent of the time, or on 90 days.

PARAMETERS: Q_{98}, Q_{90}, Q_{75}, Q_{50}, Q_{25}, Q_{10}, Q_2, AND Q_{MEAN}

Low-Flow Values

Each low-flow parameter is defined by a duration in consecutive days and a recurrence interval in years. A 7-day low flow for a given year is the lowest average flow that occurred for any seven consecutive days within that year. The 7-day, 10-year low flow is the 7-day low flow that occurred *on average* only once in ten years. Low flows with a recurrence interval of more than 10 years will be lower in magnitude than the 10-year low flow. The 2-year low flow is the value expected to occur during an "average" year.

DURATIONS: 1-DAY, 7-DAY, 15-DAY, 31-DAY, 61-DAY, AND 91-DAY
RECURRENCE INTERVALS: 2 YEARS, 10 YEARS, 25 YEARS, AND 50 YEARS

Drought Flows

Drought flows are similar to low flows, except that the duration of the period is defined in months instead of days. The values are average low flows developed from monthly records (as opposed to daily records). These values are useful in determining reservoir yields for which drought severity over a lengthy period is a critical parameter.

DURATIONS: 6-MONTH, 9-MONTH, 12-MONTH, 18-MONTH, 30-MONTH, AND 54-MONTH
RECURRENCE INTERVALS: 10 YEARS, 25 YEARS, AND 50 YEARS

ILSAM Concepts for Estimating Streamflow

All watersheds in Illinois have some level of water use or water resources developments that modify the streamflow condition. In many cases these modifications disturb the consistency in the flow regime that might otherwise exist along a stream or between the different streams within that watershed.

For any location along a stream *ILSAM* defines three different types of flow conditions: 1) virgin flow, 2) present flow, and 3) altered flow. Virgin flow is the flow condition that would naturally exist in the stream if no water resources projects affected its flow. Present flow is the streamflow condition given the present level of water use and water resource developments in the watershed. Altered flow is the streamflow condition that would exist if a specific, new water resource project were added in the watershed.

ILSAM accounts for water resources developments that cause the present flow to differ from virgin flow conditions: withdrawals from streams, discharges to streams, and reservoirs. The effects of urbanization on streamflow are not yet accounted for in the model, but only because the model has not yet been applied to a heavily urbanized watershed. The model also does not account for other potential modifications to the flow such as channelization, drainage improvements, and agricultural changes. These latter modifications are not expected to cause significant changes to the streamflows, nor is there sufficient gaging information available to identify the quantity of the changes in flow if these modifications indeed have an impact.

Summary of the Hydrologic Analyses Used To Develop Model Parameters

Considerable hydrologic analysis is conducted to estimate the streamflow conditions that exist at all spots within each watershed. The three basic steps in the analysis are listed below. Each of these steps is examined in further detail later in this report.

1) *Analysis of Individual Flow Modifications.* This step includes estimating the present and past levels of each major discharge and withdrawal, and relating the daily variations in these modifications to corresponding flow levels in the stream. Also estimated are the changes in streamflow induced by reservoirs. The impact of each modification to the streamflow is estimated not only at the point of modification, but also further downstream.

2) *Analysis of Streamflow Records for Estimating Flow Frequency.* This step involves examining the consistency of flow records between different streamgages, including adjustments to account for differences in their periods of record. For each gage, the frequency of occurrence for all flow values is estimated, as are the recurrence intervals for infrequent events such as droughts.

3) *Development of Equations for Ungaged Sites.* Equations are developed for each of the model's 154 flow parameters to estimate flow statistics at ungaged sites. The equations use watershed characteristics (drainage area and soil types) to identify naturally occurring variations in flow quantity. Equations are examined to ensure that consistency is maintained between all flow parameters for any site in the watershed.

Acknowledgments

This study was supported by the Illinois Department of Transportation, Division of Water Resources, with Gary R. Clark as project coordinator. The report was prepared under the general supervision of Dr. Krishan P. Singh. Jehng-Jung Kao conducted much of the statistical analysis for determination of streamflow parameters. Cheri Chenowith developed stream location information for the Kankakee River watershed. David Cox prepared the illustrations, and Eva Kingston edited the report. John LaTour, U.S. Geological Survey, Illinois District, provided data on return flows to streams. David Finley and Siavash E. Beik, Indiana Department of Natural Resources, provided information on irrigation water use in Indiana.

DESCRIPTION OF THE KANKAKEE RIVER BASIN

The Kankakee River is located in the northeastern portion of Illinois and the northwestern portion of Indiana. The watershed has a total area of approximately 5,800 square miles (mi^2) and encompasses portions of 22 counties in both states, as shown in figure 2. The Kankakee River originates near South Bend, IN (see figure 3). The river generally flows west, for about 140 miles, until its confluence with the Des Plaines River in Will County, IL, to form the Illinois River. By far the largest tributary to the Kankakee River is the Iroquois River, with a drainage area of 2,137 mi^2. Other major streams in the Illinois portion of the watershed are Forked Creek (135 mi"), Horse Creek (128 mi^2), Rock Creek (120 mi^2), Singleton Ditch (252 mi^2), Beaver Creek (185 mi^2), Langan Creek (106 mi^2), Spring Creek (288 mi^2), Sugar Creek (556 mi^2), and Mud Creek (282 mi^2). Locations of these streams are shown in figure 3.

Watershed Physiography, Soils, and Land Use

For physiographic and hydrologic description, three regions in the Kankakee River watershed are defined: 1) the Kankakee River upstream of its confluence with the Iroquois River, 2) the Iroquois River watershed, and 3) the Kankakee River watershed below the Iroquois River. Characteristics of these regions are described below. For other descriptions of the watershed, see Barker et al. (1967), and the Indiana Department of Natural Resources (1976, 1990).

Kankakee River above Kankakee

The most prominent physiographic feature in the watershed is the Kankakee Marsh, a natural swampland that once extended most of the length of the Kankakee River upstream of Momence, IL. Before it was dredged and drained in the period 1886 to 1917, the marsh

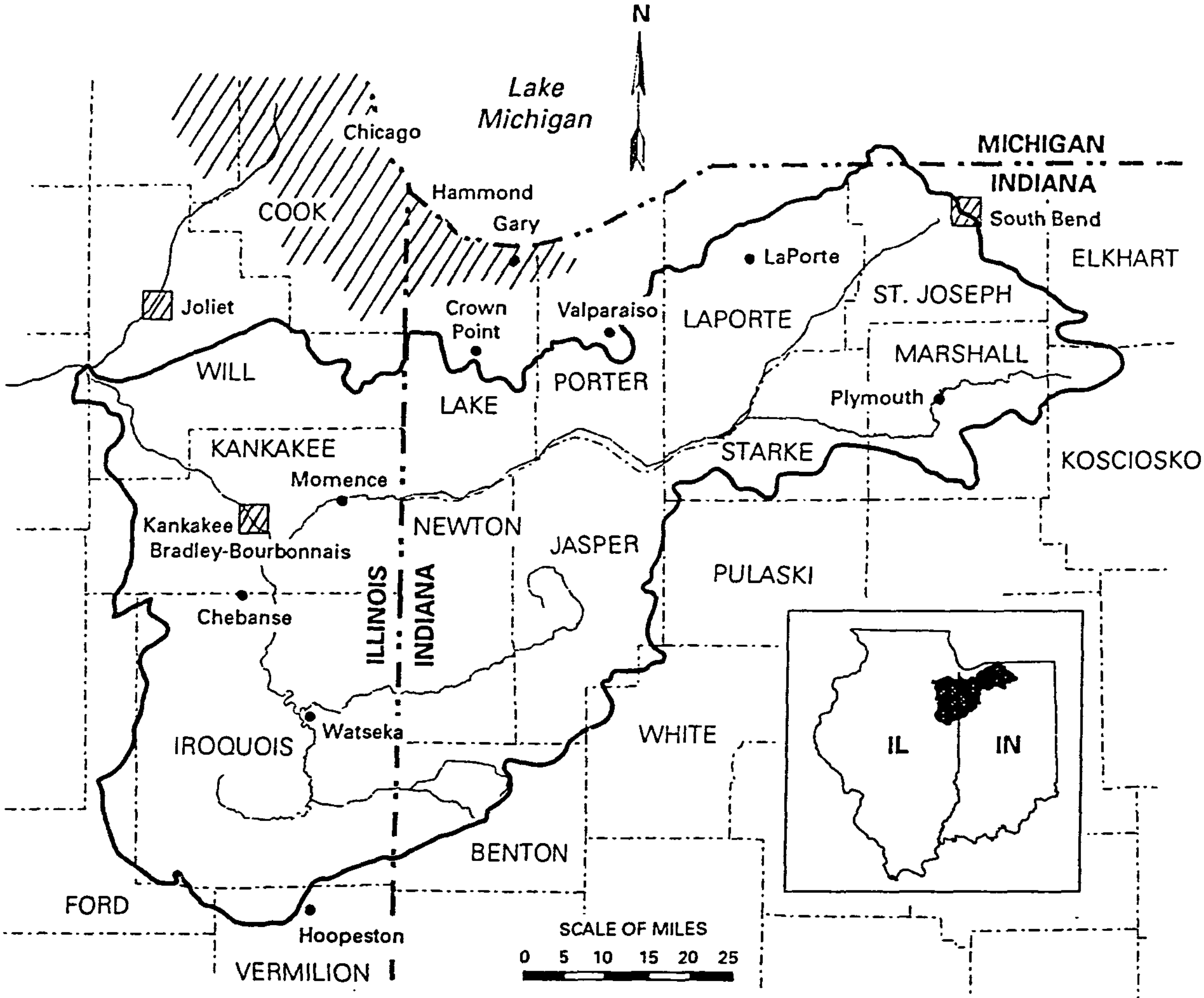

Figure 2. Location of the Kankakee River basin in Illinois and Indiana

encompassed 500,000 acres, or more than one-third of the total watershed area upstream of Momence (IDNR, 1976). The marsh was over 10 miles wide, with a water depth ranging from 1 to 4 feet for eight or nine months of the year (Bhowmik et al., 1980). The channel of the Kankakee River meandered through the swamp and together with the marsh has been described as "all interconnected swamps, ponds, bayous, marshes, and very low islands" (IDPW, 1954), and "240 miles of a marshy, sandy maze of meanders, oxbows, and sloughs that were teeming with a variety of wildlife" (Bhowmik et al., 1980). Much of the watershed upstream of the Kankakee Marsh also originally had poor drainage and very low gradients (in addition to the marsh). There were few well-defined streams in the watershed, the exceptions being in the hillier eastern edge of the watershed and a few of the larger tributaries that entered the marsh.

In the 1880s, channelization of some of the tributaries to the Kankakee River was begun in an attempt to make the land more suitable for agriculture. When this failed to alleviate drainage

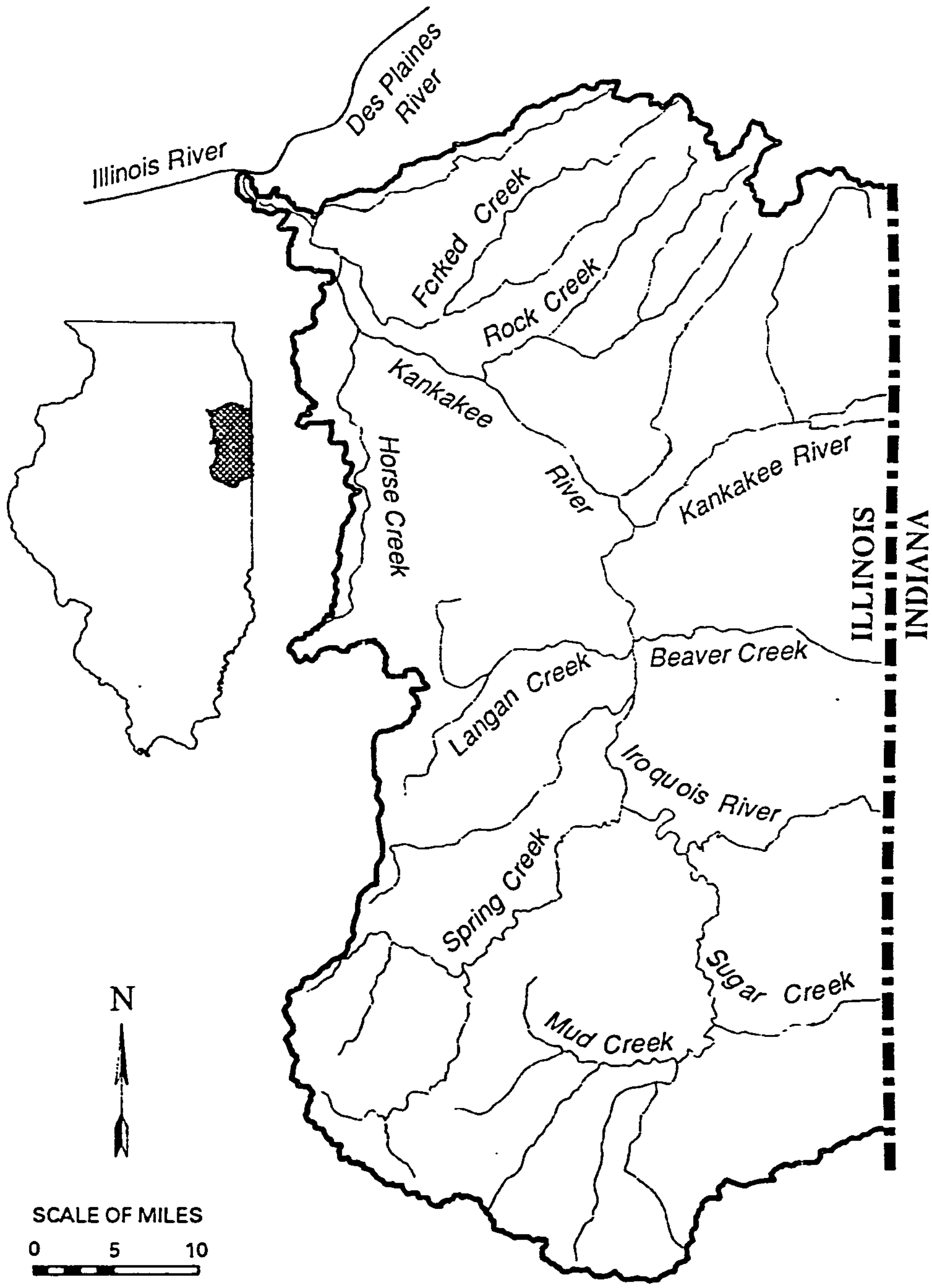

Figure 3. Location of major streams in the Kankakee River basin

problems, channelization continued further downstream. It was thought that one key to adequate drainage was the lowering or removal of the limestone rock ledge in the channel bottom which constricted flow in the Kankakee River just upstream of Momence. In 1893 the rock ledge was cut down several feet by the state of Indiana (IDPW, 1954). Except for this work on the rock ledge, the Illinois portion of the river remains unchanged.

Complete channelization of the entire Kankakee River in Indiana to the state line was completed in 1917. The old channel in Indiana was replaced by a channel 82 miles long (from near South Bend downstream to the Illinois-Indiana state line). Even with channelization and shortening of the river, the channel gradient along this portion of the river is very mild, averaging less than 1 foot per mile. A profile of the entire river is shown in figure 4. The poorly defined tributaries were also modified into a network of drainage ditches, to the extent that less than *1%* of the stream network in the watershed is in its natural condition (IDNR, 1990).

Despite the extensive drainage modifications, overbank flooding throughout the original marsh area still occurs about three times a year (IDNR, 1976). Flooding occurs over 222,000 acres, or about 40% of the original marsh. Even when overbank flooding does not occur, excess water in

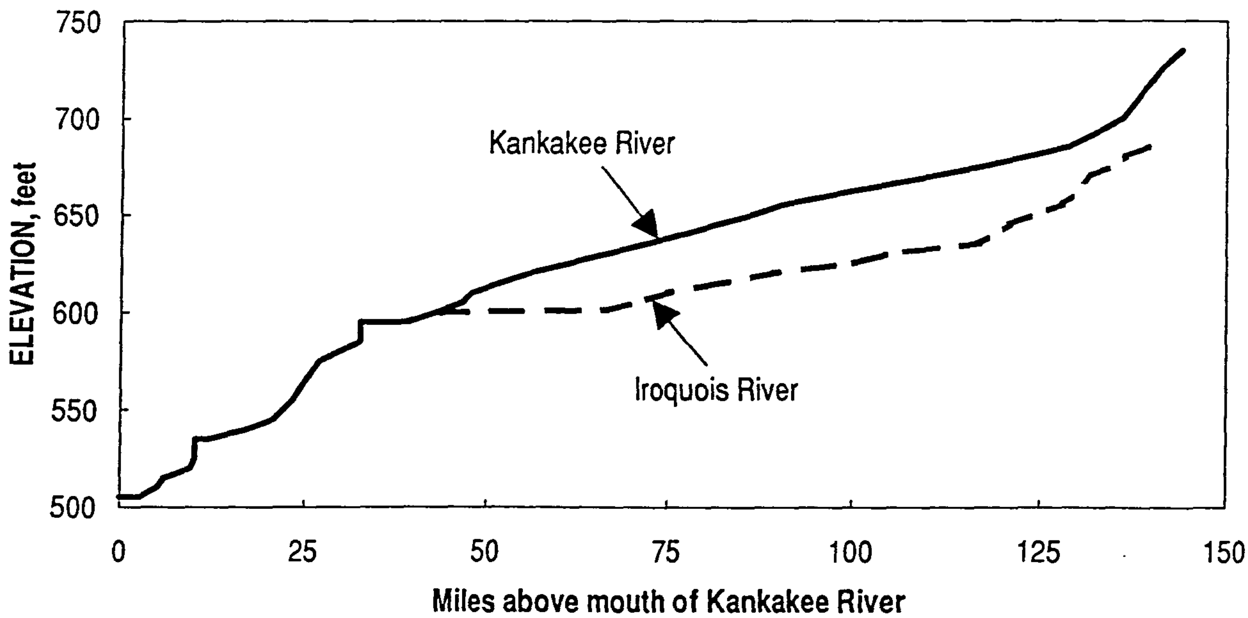

Figure 4. Channel profiles of the Kankakee and Iroquois Rivers

the river often impairs the drainage throughout the lowlands adjacent to the streams. Of the 1,340,000 acres of cropland in the Indiana portion of the watershed, about 851,500 acres, or 64%, have excess water problems (IDNR, 1976).

The Kankakee Marsh is underlain with unconsolidated sands and gravels deposited from the outwash of a glacial lake that had its outlet near South Bend. The outwash flowed west through the present Kankakee River valley. The sand and gravel deposits form a large shallow aquifer, having a saturated thickness ranging from approximately 30 feet near the Illinois border to over 100 feet at several locations in LaPorte and St. Joseph Counties in Indiana (IDNR, 1976). The aquifer and the surface waters are very closely interconnected, and much of the streamflow originates from the ground water. Low-flow characteristics are a direct reflection of this shallow ground-water storage; the Kankakee River has substantial low flow even during the most severe droughts.

Iroquois River

Much of the Iroquois River portion of the watershed was originally prairie, having nearly level to gently sloping topography, and poor drainage. Much of the region is an old glacial lake bed (Lake Watseka). The distribution of land slopes for Iroquois County in Illinois, given in table 1, provides an example of the predominantly flat topography. Broad moraines, deposited by the receding glaciers, add gently rolling features. The materials in these deposits are typically a heterogeneous mix of silts or clays, although local deposits of sand are present in the Indiana portion of the watershed and in northern Iroquois County.

The Iroquois River is approximately 94 miles long. For the lower 80 miles of the river, the average slope is only 0.50 feet per mile (see figure 4). A rock outcrop near Chebanse creates a nearly level pool for more than 20 miles upstream. Other than the major streams, most of the watercourses in the watershed are low-gradient drainage ditches, constructed in the late 1800s.

Table 1. Distribution of Overland Slopes in Iroquois County

Overland slope (%)	*Percentage of land area*
0 - 2	74.5
2 - 4	19.9
4 - 7	4.2
7 -12	0.8
12-18	0.3
18-30	0.2
> 30	0.1

Note:
Values are estimated from data in Runge et al. (1969)

There is only minor entrenchment of both these ditches and the Iroquois River into the landscape. As a result, there is frequent flooding along the Iroquois River, typically two or three times a year. An estimated 50,000 acres are typically flooded along the river in Illinois, and flooding inhibits the drainage for an additional 100,000 acres (Barker et al., 1967).

Dry-season and drought flows in the Iroquois River and its tributaries are fairly typical of similarly sized streams in east-central Illinois, but are considerably lower than those observed in the Kankakee River watershed. Most of the sustained low flow in the Iroquois River originates from the sandy regions in the eastern part of the watershed, where shallow ground-water aquifers contribute to streamflow.

Kankakee River below Kankakee

The confluence of the Kankakee and Iroquois Rivers is directly upstream of the city of Kankakee in the six-mile pool formed by the 12-foot high Kankakee dam. Below Kankakee the character of the river changes dramatically and begins to flow through a relatively narrow, entrenched valley. Relatively little flood damages occur along this portion of the river because of the small amount of lowland areas. The average channel gradient in this lower portion of the river increases to over 2.5 feet per mile, and the slope averages 4 feet per mile in a 10 mile stretch near Kankakee State Park. The tributaries to this portion of the Kankakee River have comparatively steep gradients, consistently greater than 5 feet per mile. The upland areas of these tributaries slope gently to moderately. Drainage ditches are still used to improve local drainage. Much of the area in southwestern Kankakee County has sandy soils, ordinarily associated with significant low flows in streams, which here provide only a small contribution of flow to the streams during dry periods because of their topographic position. The extreme western portion of the watershed contains some surface-mined land, which may modify the ground-water table and flow patterns in nearby streams.

Soil Types and Their Influence on Streamflow Hydrology

Soil type and permeability are of considerable importance in the evaluation of watershed hydrology because they have a great influence on the rainfall-runoff process and the eventual distribution of flow to the stream. Soils with high sand content generally allow a much higher proportion of precipitation to infiltrate the soil, reducing the amount of water flowing overland directly to the stream and the magnitude of storm runoff. A large portion of the water that infiltrates is usually stored as shallow ground water and may be discharged to the stream later in the year during dry periods. Soils having high clay content usually produce greater runoff during storm periods and less streamflow during dry periods.

The Kankakee River basin has a large range in variability of soil types. Average soil permeabilities range from moderately slow (0.2 to 0.6 inch per hour) in the clayey and silty soils prevalent in the Illinois portion of the Iroquois River watershed to rapid (6 to 20 inches per hour) in the sandy areas of the Kankakee Marsh. The geographic distribution of average soil permeabilities in the Illinois portion of the watershed, based on Fehrenbacher et al. (1984), is shown in figure 5. Average permeability estimates are taken from county soil surveys (Kiefer, 1982; Paschke, 1979).

Land Use

Agriculture is the major land use and economic activity in the Kankakee River watershed. Farming accounts for 71% and 94% of the total acreage in Kankakee and Iroquois Counties, respectively, and over 75% of the total acreage in the Indiana portion of the watershed (IDNR, 1990; Kiefer, 1982; Paschke, 1979). Field corn and soybeans are the predominant crops, comprising over 80% of the agricultural acreage. Minor crops include wheat, hay, vegetables, sod grass, and flowers (primarily gladioli). Irrigated cropland (further discussed in the section on water use) accounts for 5% of the total agricultural acreage. The major nonagricultural land uses are woodlands (9%), urban land (8%), and water, wetlands, and barren land (IDNR, 1990).

Population

The Kankakee River basin is a predominantly rural watershed, with a total 1990 population of approximately 376,000. The largest cities located entirely within the watershed are Kankakee-Bradley-Bourbonnais, IL (population 52,300), and LaPorte, IN (21,500). Small portions of three other major Indiana cities are also contained in the watershed: South Bend (105,500), Valparaiso (24,400), and Crown Point (17,700). No other cities in the watershed exceed a population of 10,000. The metropolitan areas of Chicago, IL, and Gary-Hammond, IN, begin about 10 miles north of the watershed. Despite the proximity of these metropolitan areas, little population growth in the Kankakee River basin is expected in the next 30 years.

The 1990 population for each county partially or wholly contained within the watershed is given in table 2. The total 1990 population for the watershed is roughly 12% greater than that in 1970. Between 1970 and 1990, the Illinois portion of the watershed experienced only a 1% increase in population. Projections, using Illinois Bureau of the Budget data, indicate little or no population growth in the Illinois portion of the watershed over the next 30 years.

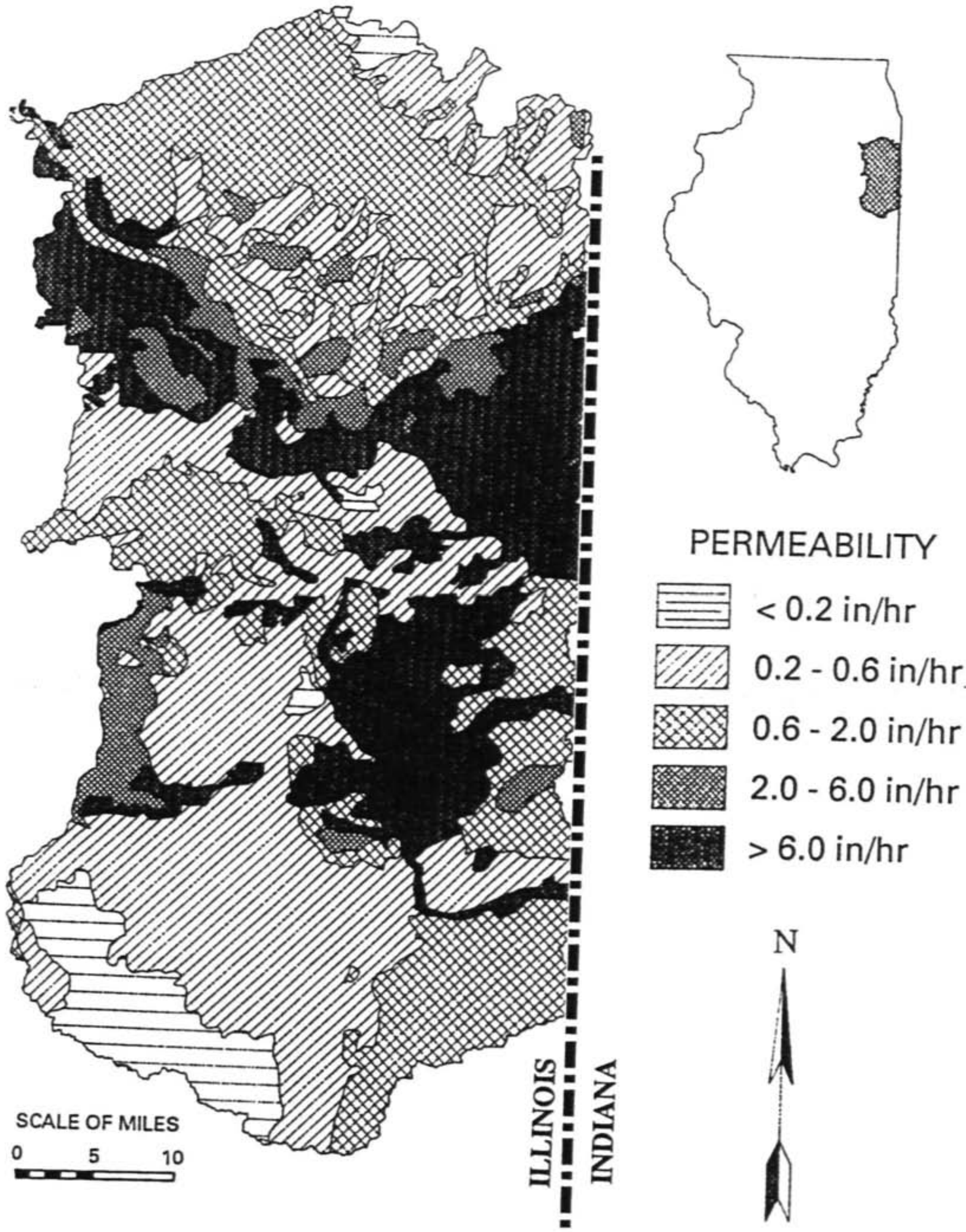

Figure 5. Average soil permeabilities for the Illinois portion of the Kankakee River basin

Table 2. Population Data for Kankakee River Basin Counties
(in thousands)

County	*1970*	*1990*	*2000*	*2020*
	(estimated population within the Kankakee River basin in parentheses)			
Illinois				
Iroquois	34(34)	31(31)	31(31)	30(30)
Kankakee	97(96)	96(95)	93(92)	92(91)
Vermilion	97 (1)	88 (1)	86 (1)	81 (1)
Will	249(20)	357(26)	355(27)	389(29)
Indiana				
Benton	11 (5)	9(4)	(4)	
Jasper	20(20)	25(25)	(26)	
Kosciosko	48 (3)	65 (2)	(2)	
Lake	546(30)	476(41)	(44)	
LaPorte	105(34)	107(38)	(37)	
Marshall	35(27)	42(32)	(34)	
Newton	12(12)	14(14)	(14)	
Porter	87(11)	129(23)	(28)	
St. Joseph	245(25)	247(25)	(25)	
Starke	19(17)	23(19)	(19)	
TOTAL	1605(335)	1703(376)	(384)	

Notes:
The following counties have less than 1,000 population falling within the watershed: Ford (IL), Elkhart (IN), Pulaski (IN), White (IN), and Berrien (MI).

Population projections for Illinois counties are from the Illinois Bureau of the Budget (1987). Population projections for Indiana counties are from IDNR (1990).

Estimates of the population of each county within the Kankakee watershed are based on township data from the 1970 and 1990 Censuses of Population (U.S. Bureau of the Census, 1970; 1990) and IDNR (1990).

AVAILABLE HYDROLOGIC DATA

Precipitation Records

The average annual precipitation for the Kankakee watershed for the 30-year period, 1961-1990, is approximately 38 inches, ranging from over 40 inches along the northern side of the watershed in Indiana, to less than 36 inches on the western portion nearest Joliet. The 1961-1990 averages for 13 stations in and near the watershed are shown in figure 6. Eight of these precipitation gages have over 80 years of record. These precipitation stations and their periods of record are: Delphi, IN (1885-1990); Kankakee, IL (1911-1990); Joliet, IL (1893-1990); LaPorte, IN (1901-1990); Hoopeston, IL (1903-1990); Watseka, IL (1885-1890, 1892-1893, 1895-1916, 1921-1988); Valparaiso, IN (1901-1906, 1915-1990); and Plymouth, IN (1906-1988).

The maximum recorded annual (calendar-year) rainfall in the watershed was 71 inches in 1954 for LaPorte, IN. The greatest annual precipitation, averaged over the watershed, was observed in 1990, with a basinwide annual average of approximately 53 inches (15 inches above normal). The driest calendar year on record was 1925, when the average watershed precipitation was 27 inches (11 inches below normal). The minimum recorded annual rainfall, also from 1925, was 21.44 inches for Kankakee, IL.

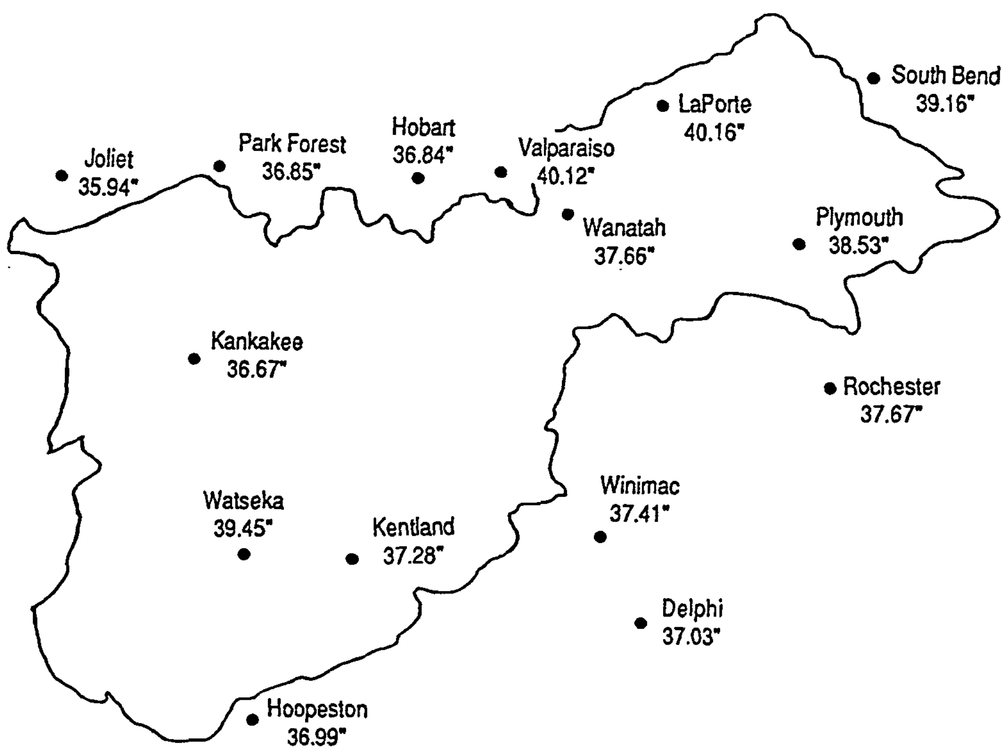

Figure 6. Average annual precipitation for gaging stations in and near the Kankakee River basin, 1961-1990

Annual precipitation for the Kankakee, Hoopeston, and LaPorte gages is plotted in figure 7 for the years 1900-1990. Also plotted in figure 7 are the 1900-1990 average precipitation amounts for each station and an 11-year moving average of the annual values. These series of annual values indicate the large natural variability in rainfall, not only year to year but also at different locations within the watershed. The moving averages shown in figure 7 indicate several major wet and dry periods. The Kankakee precipitation record (figure 7a) shows a period of high average rainfall between 1965 and 1985. High average rainfall for this same period is also present in the records at Watseka, Kentland, Valparaiso, Lowell, and South Bend gages. The LaPorte record (figure 7c) shows a significant increase in precipitation between 1940 and 1960. Changnon (1968) credited this "LaPorte anomaly" to urban effects from the Chicago-Gary-Hammond metropolitan area. This pattern is not evident at any other gaging stations. The authenticity of the LaPorte anomaly has been both supported and questioned by numerous studies (IDNR, 1990).

Droughts

The eight precipitation gages in and near the Kankakee watershed, having continuous records over 80 years in length, were chosen to provide long-term information on precipitation droughts. The cumulative precipitation deficit is one indicator of a hydrologic drought (a drought that is likely to impact streamflows). Tables 3 and 4 list the drought periods for these eight gages during which significantly below-average precipitation amounts were observed. The watershed has experienced several brief, but intense, drought periods lasting from four to six months. By far, the five worst brief droughts were those of 1895, 1925, 1934, 1936, and 1988 (see table 3). Most of these short, intense drought periods occurred within a prolonged drought period, though 1988 is a noticeable exception. The more prolonged droughts listed in table 4 have durations ranging from 8 to 38 months. An analysis of streamflow records, provided in the next section, indicates that the short intense droughts are as likely to be responsible for extremely low flows in the Kankakee River as are the more prolonged droughts.

Table 3. Precipitation Deficits (cumulative inches) for Short, Intense Drought Periods: Kankakee River Basin, 1885-1990

		Average basin-wide precipitation deficit, inches	
Year	*Rank*	*4 month droughts*	*6 month droughts*
1934	#1	9.6	10.5
1936	#2	9.2	10.3
1988	#3	8.6	9.4
1895	#4	8.1	9.2
1925	#5	7.6	8.8

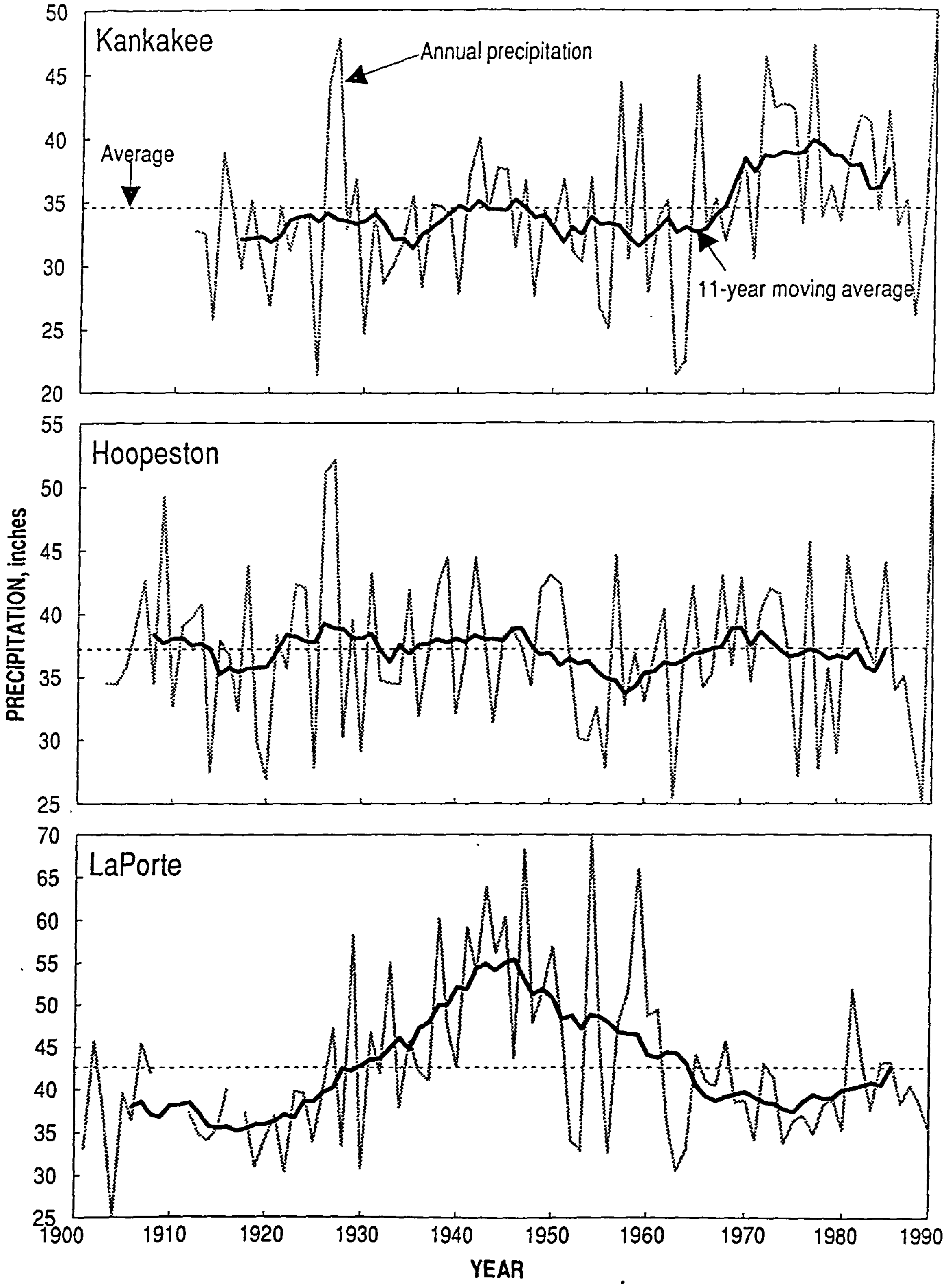

Figure 7. Annual precipitation, 11-year moving average of annual precipitation, and long-term average precipitation, 1900-1990: Kankakee, Hoopeston, and LaPorte

Table 4. Precipitation Deficits (cumulative inches) and Historical Drought Ranking: Kankakee River Basin, 1885-1990

Gaging Stations and Periods of Record:

1) Joliet, IL (1893-1990)
2) Kankakee, IL (1911-1990)
3) Watseka, IL (1885-1890; 1892-1893; 1895-1916; 1921-1988)
4) Hoopeston, IL (1903-1990)
5) Valparaiso, IN (1901-1906; 1915-1990)
6) LaPorte, IN (1901-1990)
7) Plymouth, IN (1906-1988)
8) Delphi, IN (1885-1990)

Gaging Stations

Drought period (duration) *1* *2* *3* *4* *5* *6* *7* *8*

Drought period (duration)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
May 1893-Oct 1895	26.0	------	31.*	------	------	------	------	26.0
(29 months)	#1		#1					#1
Dec 1898-Jan 1902	19.5	------	23.3	------	------	------	------	------
(38 months)	#4		#3					
Jun 1913 -Jun 1915	22.0	17.5	24.5	14.2	------	20.6	11.6	20.0
(25 months)	#3	#2	#2	#4		#2		#3
Jan 1917-Aug 1918	9.4	5.0	------	1.5	15.2	15.1*	13.4	6.8
(20 months)					#5	#6	#5	
Oct 1924-Aug 1925	14.1	15.7	17.0	9.7	11.1	10.8	14.1	11.9*
(11 months)		#3	#7				#3	
Feb 1930-Apr 1931	7.5	13.2	16.9	15.9	14.5	18.7	12.8	15.0
(15 months)			#8	#2	#6	#4	#6	#6
Nov 1933-Jul 1934	16.0	12.6	17.4	12.3	15.4	14.0	14.1	16.3
(9 months)	#5		#6		#4	#7	#4	#5
Dec 1935 - Jul 1936	12.1	11.1	11.2	10.8	12.4	15.0	10.8	9.1
(8 months)						#7		
Aug 1939-Aug 1941	15.8	17.8	19.9	13.4	9.8	8.0	18.9	23.8
(25 months)	#6	#1	#4	#5			#1	#2
Jul 1952-Jan 1954	8.9	9.1	7.0	12.5	15.8	17.8	11.5	9.2
(19 months)					#3	#5		
Nov 1955-Mar 1957	10.0	13.9	13.5	14.9	11.2	13.3	9.8	12.8
(17 months)		#5		#3				
Aug 1962-Feb 1964	22.8	14.3	19.6	18.3	18.6	22.7	7.7	17.5
(19 months)	#2	#4	#5	#1	#1	#1		#4
Apr 1988-Sep 1988	12.4	11.6	12.5	10.7	7.5	9.1	5.0	10.8
(6 months)	#6							

* Precipitation for some months during this period was estimated from adjacent gages.

Note:
Drought Ranks: #1 = the drought with the greatest precipitation deficit at the location, #2 = the drought with the second greatest deficit, etc.

Streamflow Records

Table 5 provides a list of the 27 streamgage records in the Kankakee watershed that have continuous records of average daily discharge for a period greater than 5 years. The locations of these gaging stations are provided in figure 8. Twenty of the 27 USGS gaging stations listed in table 5 have operated for more than 30 years. Sixteen of these gages have periods of record greater than 40 years, which typically include the years 1949-1989. These gages provide good coverage of continuous streamflow throughout the watershed for use in determining long-term flow conditions.

The average runoff over the Kankakee River basin is approximately 10.25 inches, ranging from less than 9.5 inches on the western edge of the watershed to 11.0 inches on the northeastern edge. The streamflow records for the Kankakee River indicate that since 1965 there has been a

Table 5. Selected Stream Discharge Records for the Kankakee River Basin

USGS gages with daily flow records

Station name	*Gage #*	*Years of record*	*Drainage area (mi^2)*
Kankakee River near North Liberty, IN	05-515000	(1951-1989)	174
Kingsbury Creek near LaPorte, IN	05-515400	(1971-1986)	7.1
Kankakee River at Davis, IN	05-515500	(1925-1989)	537
Yellow River near Breman, IN	05-516000	(1956-1973)	135
Yellow River at Plymouth, IN	05-516500	(1949-1989)	294
Yellow River at Knox, IN	05-517000	(1944-1989)	435
Kankakee River at Dunns Bridge, IN	05-517500	(1949-1989)	1,352
Kankakee River near Kouts, IN	05-517530	(1975-1989)	1,376
Cobb Ditch near Kouts, IN	05-517890	(1968-1989)	30.3
Kankakee River at Shelby, IN	05-518000	(1923-1989)	1,779
Singleton Ditch at Schneider, IN	05-519000	(1948-1989)	123
West Creek near Schneider, IN	05-519500	(1948-1951; 1954-1972)	54.7
Singleton Ditch at Illinoi, IL	05-520000	(1945-1978)	220
Kankakee River at Momence, IL	05-520500	(1915-1989)	2,294
Iroquois River at Rosebud, IN	05-521000	(1949-1989)	35.6
Iroquois River near North Marion, IN	05-522000	(1949-1989)	144
Iroquois River at Rensellaer, IN	05-522500	(1949-1989)	203
Bice Ditch near South Marion, IN	05-523000	(1949-1989)	21.8
Slough Creek near Collegeville, IN	05-523500	(1949-1982)	83.7
Carpenter Creek at Egypt, IN	05-524000	(1949-1982)	44.8
Iroquois River near Foresman, IN	05-524500	(1949-1989)	449
Iroquois River at Iroquois, IL	05-525000	(1945-1989)	686
Sugar Creek at Milford, IL	05-525500	(1949-1989)	446
Iroquois River near Chebanse, IL	05-526000	(1923-1989)	2,091
Terry Creek near Custer Park, IL	05-526500	(1950-1975)	12.1
Kankakee River at Custer Park, IL	05-527000	(1915-1933)	4,810
Kankakee River near Wilmington, IL	05-527500	(1934-1989)	5,150

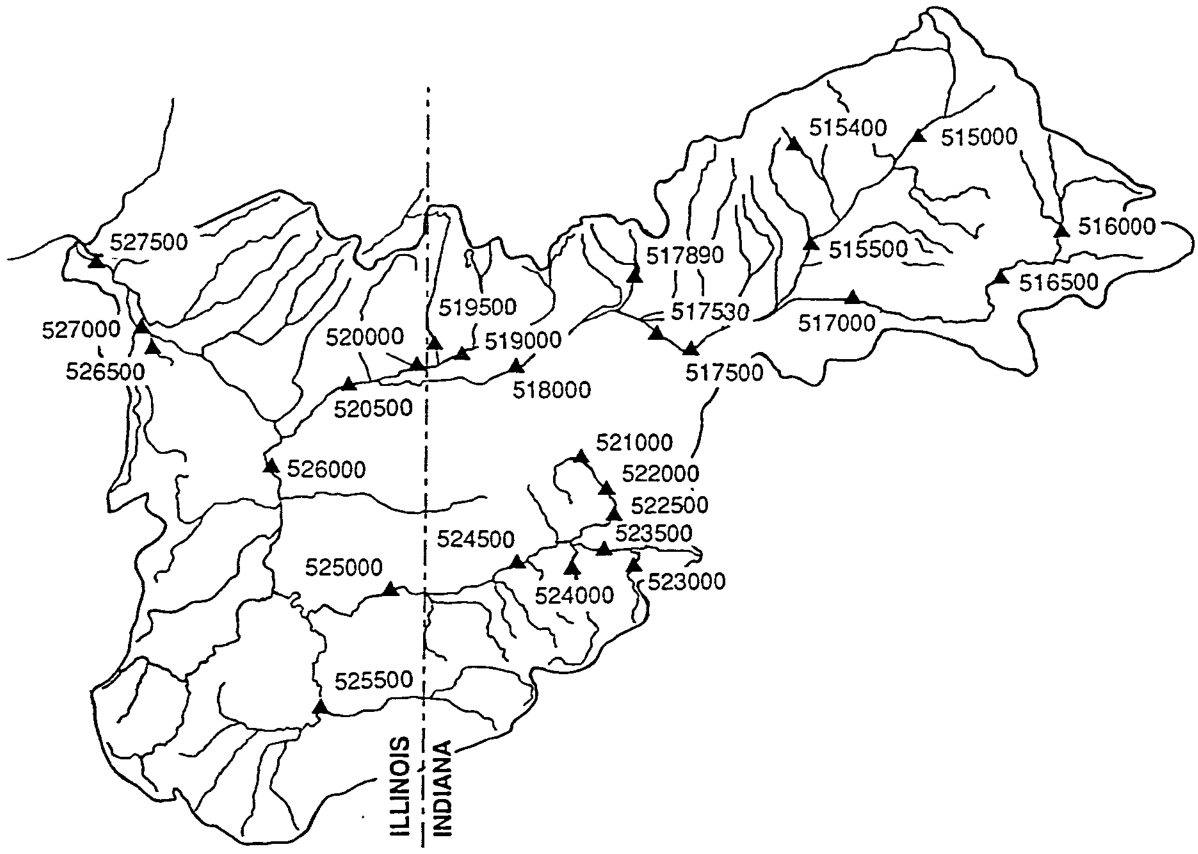

Figure 8. Location of continuous-recording streamgages in the Kankakee River basin

definite increase in the average runoff rate, as well as increases in both low flows and high flows. There also appears to be a slight increase in the flow conditions on the Iroquois River at Chebanse. These increases can be seen in plots of the mean annual flows between 1915 and 1990, shown in figure 9 for the Momence, Wilmington, and Chebanse gages. [Flow values listed for the Wilmington gage prior to 1934 are actually taken from the Custer Park gage, and are assumed to be equivalent.] The increased flows observed in recent decades are most likely associated with climatic factors, particularly the higher rainfalls observed at many precipitation gages in the watershed since the mid-1960s. This precipitation increase is a recent phenomenon, and there is no substantial evidence to suggest that it represents a continuing trend. Thus the average long-term conditions are believed to be the best estimate of future conditions in the watershed. It is possible that additional factors, particularly large water uses such as irrigation, may also be causing hydrologic modification in the watershed (discussed later in the section). If such modification exists, however, it is masked by the impacts of normal climatic and hydrologic variability.

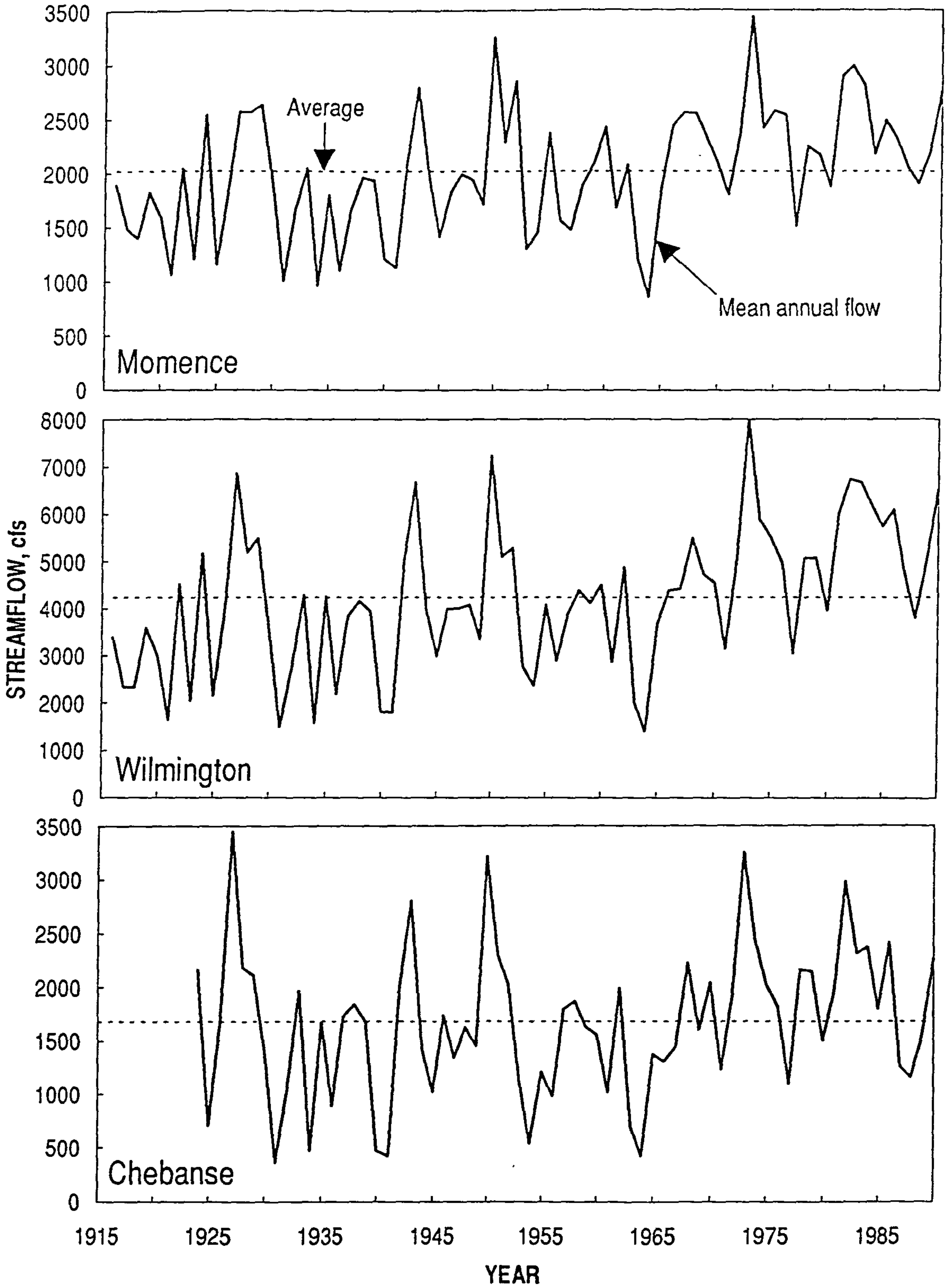

Figure 9. Annual series of mean flow rate, 1915-1990: Kankakee River at Momence, Kankakee River near Wilmington, and Iroquois River near Chebanse

Low Flows

Table 6 lists the low flow amounts experienced during the most severe streamflow droughts at the four long-term gages in the watershed: Kankakee River at Momence, Kankakee River at Shelby, Iroquois River near Chebanse, and Kankakee River at Wilmington. The lowest flows at Wilmington generally occur during the same years as those at Momence and Shelby. The lowest flows at Chebanse also occur in many of the same years, but with less regularity. Low flows at all four gaging stations generally occur in August or September.

The rank of each low flow year differs from station to station. But five drought periods show consistent lower flows: 1934, 1936, 1941, 1962-1964, and 1988. These periods include both the short, intense precipitation droughts noted in table 3 and the highest-ranking extended droughts given in table 4. From this comparison it can be inferred that the 1895 and 1915 droughts (which had high precipitation deficits) also produced some of the lowest flows in the last 100 years.

During dry years, most of the flow in the Kankakee River originates upstream in Indiana. Both the streamgages at Shelby, IN (located 10 miles upstream of the state line in Indiana) and Momence have similar low flows, even though there is a 500 mi^2 difference in their watershed areas. Though the magnitudes of the low flows at these two stations are similar, the arithmetic difference between the recorded flows at the two gages is inconsistent. During the 1988 drought, the difference between the concurrent 31-day flows at the Momence and Shelby gages was -25 cfs, and during the 1963 drought the difference was -32 cfs. This suggests a loss in flow between the two stations. During the 1964 and 1941 droughts, however, the differences were +45 and +68 cfs, respectively. There is no explanation why such a variation in the differences would occur between years -- other than normal measurement error at the gages. It would be of great interest if flow decreases actually occur, particularly if caused by increased water use in the watershed. But given the current amount of data and the existence of normal measurement error, it is difficult to quantify these possible impacts or to decisively conclude that any impacts exist.

Table 6. Magnitude of the Ten Lowest 31-day Low Flows and Year of Occurrence: Kankakee River Basin, 1923-1989

Rank	*Wilmington (cfs)*	*Momence (cfs)*	*Shelby (cfs)*	*Chebanse (cfs)*
#1	1936 - 378.4	1988 - 351.2	1941 - 356.2	1936 - 22.3
#2	1988-412.2	1941-424.8	1988-376.0	1956-23.2
#3	1941-480.1	1934-425.2	1962-406.8	1934-23.4
#4	1964-481.9	1963-428.9	1934-410.7	1944-24.0
#5	1963-513.6	1964-433.7	1964-435.2	1941-25.8
#6	1956-520.5	1962-451.3	1953-446.6	1964-27.8
#7	1953-525.7	1936-455.1	1936-453.9	1925-28.8
#8	1934-540.0	1925-457.2	1956-459.2	1963-30.8
#9	1925-549.6	1953-468.4	1939-460.0	1966-31.6
#10	1962-606.8	1956-493.2	1963-461.4	1940-33.8

WATER USE IN THE KANKAKEE RIVER BASIN

Public Water Supply

Approximately 5.3 billion gallons (bg) per year, equivalent to an average 14.5 million gallons per day (mgd), are used for public water supply in the Illinois portion of the Kankakee watershed. Of the 33 public water-supply systems in Illinois (listed in table 7), only two use surface water as their major source: the Consumers Illinois Water Company and the city of Wilmington. The Consumers Illinois Water Company (formerly the Kankakee Water Company), which supplies the cities of Kankakee, Bradley, and Bourbonnais, began withdrawing from the Kankakee River in 1886. This one system accounts for over 75% of the total public water supply in the Illinois portion of the watershed. The city of Wilmington used ground-water resources until 1990 when it began withdrawing water from the Kankakee River. All public water supplies in the Indiana portion of the watershed are obtained from ground water.

The total use for the public water systems in the Illinois portion of the Kankakee River watershed is not expected to increase over the next 30 years (Singh et al., 1988a). However, the city of Joliet (population 76,800), located outside the watershed in Will County, has begun to evaluate using water from the Kankakee River for a large portion of its water supply.

Table 7a. Public Water Supply from Ground-Water Sources (Illinois Portion of the Watershed)

Aroma Park	Gilman	Onarga
Ashkum	Grant Park	Peotone
Beaverville	Herscher	Rankin
Beecher	Loda	Roberts
Buckley	Manhattan	St. Anne
Chebanse	Manteno	Sheldon
Cissna Park	Martinton	Symerton
Clifton	Milford	Thawville
Crescent City	Momence	Watseka
Danforth	Monee	Woodland
Donovan		

Table 7b. Public Water Supply from Surface Water Sources (Illinois Portion of the Watershed)

System	*Source of water*	*Communities served*
Consumers Illinois Water Company	Kankakee River (direct withdrawal)	Kankakee Bradley Bourbonnais
Wilmington	Kankakee River (direct withdrawal)	Wilmington

Industrial and Cooling Water Supply

Most of the commercial and industrial water use in the Illinois portion of the watershed occurs within the Kankakee-Bradley-Bourbonnais area and is provided from the Consumers Illinois Water Company (LaTour, 1991). The remaining self-supplied industrial water use is small (less than 0.2 mgd) and obtained by ground water, with the exception of the Commonwealth Edison electric-generating plant at Braidwood. The Braidwood facility withdraws approximately 30 mgd from the Kankakee River near Custer Park for cooling water. The facility is required to discontinue pumping during periods of low flow, whenever either the streamflow falls below 450 cfs (slightly lower than the 7-day, 10-year low flow) or when the withdrawal would otherwise cause the streamflow to fall below 450 cfs. The Braidwood plant also continuously returns water to the Kankakee River from its cooling pond. The R.M. Schahfer electric-generating plant in Jasper County, IN, also withdraws water from the Kankakee River for cooling purposes.

Irrigation

The development of irrigation in the Kankakee River basin reportedly began as early as 1926 (Cravens et al., 1990). However, the first large-scale use of irrigation in the Kankakee River basin did not begin until after World War II. By 1949, over 4000 acres were being irrigated, primarily in Jasper County, IN (table 8). Since then the amount of irrigated acres has continued to increase, roughly doubling every ten years. In the latest agricultural census (USDA, 1987), the number of irrigated acres in the major ten counties in the watershed was 76,000 acres, or approximately 5% of the total cropland in the watershed. Irrigation acreage in the Indiana portion of the watershed is expected to increase to 109,000 acres by the year 2000 (IDNR, 1990).

Field corn, the most frequently irrigated crop, accounts for approximately 60% of the irrigated acreage (Cravens et al., 1990; USDA, 1987). Farming of vegetables, melons, potatoes, and flowers accounts for an additional 25-30% of the acres. Sod farming, which accounts for about 10% of the total irrigated acreage, requires a large amount of irrigation applications and can account for over 25% of the total irrigation water withdrawals (Cravens et al., 1990).

In 1987, the total water use for irrigation in the watershed was approximately 11.6 billion gallons (bg). Of this total, 9.5 bg were used in Indiana and 2.1 bg were used in Illinois. The water use in 1987 is typical of an average year. Total water use during the 1988 drought year increased to 28 bg (22.4 bg in Indiana, 5.6 bg in Illinois). During this drought year, the number of irrigated acres in Illinois increased by almost 20% (Cravens et al., 1990). The 1987 water use is equivalent to 5.5 inches of water applied to every irrigated acre in the watershed; the 1988 water use, accounting for a 20% increase in acreage, is equivalent to approximately 11 inches of applied water.

In Illinois, virtually all water used for irrigation is withdrawn from the dolomite bedrock aquifer (Cravens et al., 1990). In Indiana, approximately 57% of the irrigation withdrawals are

Table 8. Number of Irrigated Acres for Counties in the Kankakee River Basin, 1949-1987

County	*1949*	*1959*	*1969*	*1978*	*1987*
Iroquois, IL	-----	2	947	1,000	1,221
Kankakee, IL	-----	727	6,280	8,445	9,057
Jasper, IN	2,822	4,113	5,594	5,257	9,138
Lake, IN	134	122	596	1,760	5,524
LaPorte,IN	18	485	2,147	5,650	15,607
Marshall, IN	2	759	232	469	4,086
Newton, IN	49	65	3,931	2,430	9,874
Porter, IN	-----	386	75	1,317	3,618
St. Joseph, IN*	595	727	2,541	5,853	10,632
Starke, IN	582	1,106	2,244	2,245	8,650
TOTAL	4,202	8,491	24,607	34,361	77,407

Source: U.S. Census of Agriculture (various years, 1944-1987)

Note:
The listed number of irrigated acres is a total for the entire county. Some of the reported irrigated acres in Lake, Porter, LaPorte, Marshall, and Starke Counties may be located outside the Kankakee River basin, although most of the irrigated acres in each county falls within the basin. A major portion of the irrigated acres in St. Joseph County is located outside the Kankakee River basin.

taken from surface water sources (primarily the Kankakee River), and many of these appear to be discharged into ditches, which then flow adjacent to the irrigated fields. A majority of the ground-water withdrawals in Indiana take water from the unconsolidated sand-and-gravel aquifer that underlies much of the Kankakee watershed. However, in Jasper and Newton Counties, those closest to Illinois, the dolomite bedrock is the major source of ground water.

Table 9 presents data on the total amount of water withdrawn for irrigation from ground- and surface water sources for each county in the watershed. The amount of irrigation water is given in terms of the total water pumped (in acre-feet), and the equivalent depth if this water were evenly spread over each irrigated acre in each county (using the 1987 number irrigated acres). In 1986, the average water use per acre ranged from 1.2 to 18.2 inches; but most counties had an average use between 4 and 6 inches, which is considered to be normal. During 1988, the amount of irrigation withdrawals more than doubled, ranging from 3.9 to 36.6 inches. Most counties, however, had an average use of 9 to 11 inches, which is the estimated amount of irrigation water (above precipitation) that can be consumed by most crops during such a drought year.

Table 9. Annual Irrigation Water Withdrawal within the Kankakee River Watershed, by County

County	*1986*	*1987*	*198S*	*19S6*	*1987*	*1988*
		(mgd)			(inches*)	
Iroquois & Kankakee, IL	-----	2125	5658	-----	7.6	20.3
Jasper, IN	1622	2494	6248	6.5	10.1	25.2
Lake, IN	2735	1601	3988	18.2	10.7	26.6
LaPorte, IN	2465	1932	4010	5.8	4.6	9.5
Marshall, IN	130	216	457	1.2	1.9	4.1
Newton, IN	1471	1094	2429	5.5	4.1	9.1
Porter, IN	614	490	1110	6.2	5.0	11.3
St. Joseph, IN	1368	1362	3140	4.7	4.7	10.9
Starke, IN	396	320	915	1.7	1.4	3.9

* Average irrigation use in inches is computed by dividing the total volume of irrigation withdrawals (in the portion of the county contained within the Kankakee watershed) by the number of acres irrigated in the entire county (1987 acreage). Because some of the acreage in each county may occur outside of the watershed, the actual rate in inches may exceed the value listed.

The amount of water withdrawn for irrigation in Jasper and Lake Counties is greater per acre than what is observed for other counties, and generally exceeds the amount of water that could be consumed by crops. One factor that may contribute to the withdrawal rate in these two counties is the irrigation of sod farms. Sod grass must be irrigated frequently to keep the upper soil layers moist at all times. Data from Cravens et al. (1990) indicate that, during the summer of 1988 in the Illinois portion of the basin, irrigation to both sod and gladioli exceeded 2 inches per week, with applications as frequently as every other day. Annual applications to sod often exceed 40 inches. In contrast, the annual evapotranspiration rate (consumption rate) is normally about 25 inches (Cravens et al., 1990; IDNR, 1990). Any excess water will infiltrate the soil and recharge the shallow ground water, and a large portion of this recharge likely will move laterally into the streams (Morel-Seytoux et al., 1987; Peters and Renn, 1988). Another possible explanation for the larger withdrawal rate is that some of the water may not be applied to the fields. In both counties there are several large water withdrawals from the Kankakee River that, by appearance, may be pumped into lateral ditches. These ditches can serve as a source of irrigation water for farms located along their banks, but all unused water in the ditch will flow back to the Kankakee River. Regardless of the mechanism, the excess irrigation withdrawal remains unused and most eventually returns to the stream, either directly or by lateral ground-water flow.

ESTIMATING HUMAN-INDUCED IMPACTS ON STREAMFLOW

Three activities have significantly changed the variability of streamflow in the Kankakee River over the last 100 years: 1) draining of the Kankakee Marsh, 2) channelization of the Kankakee River, and 3) use of river water, primarily for irrigation. There is little gaging information from which to estimate the streamflow regime prior to the drainage and channelization. Because the Kankakee Marsh provided significant storage of water, it can be inferred that the original streamflow rates were less variable than at present. It is probable that flood discharges are now higher and drought flows are lower than they were prior to drainage and channelization. Further discussion of the impacts of drainage and channelization is provided in IDNR (1990).

Because there are no early flow records, the virgin flow conditions estimated for *ILSAM* are based on conditions that existed in the watershed in the 1920s after drainage and channelization. The major human-induced impacts to streamflow since then are associated with water use: municipal and industrial withdrawals, effluent discharges, and irrigation.

The hydrologic evaluations used in the development of ILSAM require analytical removal of the effects of surface water withdrawals, effluent discharges, and irrigation from the streamflow record for each streamgage. The effects of each different flow modifier are quantified for present and past conditions, and then subtracted from the recorded streamflow statistics record to produce an estimate of the virgin flow. Estimation of the effects of the flow modifiers are described in the following paragraphs.

Impacts of Public Water Supply and Industrial Withdrawals on Streamflow

Two major withdrawals in the Illinois portion of the Kankakee watershed were analyzed: 1) water-supply withdrawal by Consumers Illinois Water Company for the cities of Kankakee, Bradley, and Bourbonnais; and 2) cooling water withdrawal for the Braidwood power plant. A third withdrawal for the city of Wilmington is relatively small and does not significantly impact flows on the Kankakee River.

LaTour (1991) evaluated the variation in the withdrawal rates for the Consumers Illinois Water Company. The greatest variation is associated with seasonal changes in domestic water use. Summer withdrawals by the Consumers Illinois Water Company in 1984 were typically 10-15% higher than the winter base rate (LaTour, 1991). Withdrawals for domestic water use in drier, hotter summers can cause water use to exceed the base rate by as much as 50%. Quantitative estimates of the effect of present withdrawal rates on streamflow are provided in appendix B. Long-term changes in water use and withdrawals were also evaluated for determining changes in flow over the period of record for each streamgage. This was accomplished by examining the Water Survey's records of water use and identifying historical trends.

The Braidwood power plant withdraws approximately 30 mgd from the Kankakee River near Custer Park for cooling water. The facility is required to discontinue pumping during periods of low flow when the streamflow falls below 450 cfs (the $Q_{7,10}$ when the facility was being planned) or when the withdrawal would otherwise cause the streamflow to fall below 450 cfs. The Braidwood plant also continuously returns water to the Kankakee River from its cooling pond. In the period 1988-1990, the average return to the Kankakee River was 19 mgd. Ordinarily, the withdrawal is considerably larger than the cooling water discharge, but when the withdrawal ceases during low flow, the Braidwood system provides a net discharge to the Kankakee River. During July and August 1988, when the flow in the Kankakee River was at its lowest in 50 3-ears, the discharge from the Braidwood facility provided a 13 cfs net increase of flow in the river. The R.M. Schahfer electric-generating plant in Jasper County, IN also withdrawals water from the Kankakee River for cooling purposes. The net mean withdrawal rate of this facility during the August 1988 low-flow period was approximately 21 cfs (IDNR, 1990).

Impacts of Effluent Return Flows on Streamflow

There are 17 major effluent return flows (having an average discharge of over 0.05 mgd) to streams in the Illinois portion of the Kankakee watershed. They are listed in table 10. Eleven of the return flows are from public wastewater treatment facilities. In almost all cases, because the wastewater systems use combined sanitary-storm sewers, discharges from these systems are significantly greater after storms and during wet periods of the year. Variations in these effluent discharges are analyzed in the following paragraphs, and the expected flow amounts resulting from this analysis are given in appendix B.

Variations in Effluent Flows

Monthly data on effluent return flows were collected for the facilities listed in table 10 for the period 1983-1990. The monthly discharges for the combined total effluent of the Kankakee, Bradley, and Bourbonnais discharges, given in table 11, provide an example of the variation that occurs with combined systems. The variation in the monthly discharge can most closely be

Table 10. Major Return Flows to Streams in the Illinois Portion of the Watershed

Wastewater treatment effluents		*Other return flows*
Kankakee	Bradley	Commonwealth Edison Co. (Braidwood plant)
Bourbonnais	Momence	Joliet Arsenal
Watseka	Wilmington	Manteno Limestone Quarry
Peotone	Gilman	Lehigh Rock Quarry
Beecher	Herscher	Momence Quarry
Cissna Park		Armstrong World Industries

Table 11. Total Monthly Discharge (mgd) for the Kankakee, Bradley, and Bom-bonnais Wastewater Treatment Plants, 1983-1990

	J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
1983	11.1	12.1	11.8	17.0	15.4	10.2	9.0	9.7	8.7	*8.8*	9.0	12.9
1984	8.3	13.1	15.7	12.6	13.6	10.7	*8.8*	*8.6**	8.0	8.7	9.6	9.7
1985	11.1	12.1	17.7	15.5	10.7	10.0	9.5	10.5	9.8	9.8	15.2	14.0
1986	10.2	11.3	13.5	10.1	10.9	11.3	12.9	8.7	9.3	13.2	11.3	12.3
1987	10.5	12.8	10.4	11.3	11.9	12.0	9.5	10.0	9.3	8.2	9.0	13.5
1988	11.4	11.6	11.3	12.7	9.8	9.9	9.1	9.3	9.2	9.7	10.7	10.2
1989	9.2	8.3	10.3	11.0	9.1	12.4	10.6	9.7	15.5	9.5	9.4	8.6
1990	10.8	16.6	17.1	12.4	16.6	10.7	12.0	10.9	9.1	12.5	15.0	18.2
Average	*10.3*	*12.2*	*13.5*	*12.8*	*12.2*	*10.9*	*10.2*	*9.7*	*9.7*	*9.8*	*11.2*	*12.4*

* Estimated average discharge during Q7,10 low flows = 80% x 8.6 mgd = 6.9 mgd = 10.7 cfs.

associated with 1) increases caused by storm runoff from combined sewers, and 2) seasonal changes in domestic water use. Because most municipal discharges come from combined systems, the analysis also indirectly estimates some impacts of urbanization on streamflow.

The amount of increased flow due to storm runoff can most easily be evaluated by correlating the monthly effluent returns to the coinciding runoff from a nearby gaged watershed. For example, in figure 10, the total monthly effluents for Kankakee, Bradley, and Bourbonnais are compared to the runoff from Hickory Creek in Joliet. The gage at Joliet was chosen because there are no small gaged watersheds near Kankakee. Though the linear relationship shown in figure 10 has significant scatter, it provides an average expected return flow during the various flow conditions. Most municipalities also show a seasonal change in effluents (with a slightly greater return flow during summer) which were also evaluated. However, this seasonal change is not evident in the Kankakee return flows, primarily because much of the city's water use is industrial rather than domestic.

The return flows during the drought summer of 1988 are fairly typical of the minimum that would be expected during any other year. Using guidelines established by Singh et al. (1988b), the amount of effluent during a 7-day, 10-year drought flow is estimated as 80% of the expected minimum monthly flow. The minimum monthly flow shown in table 11 that occurs during a summer month is 8.6 mgd. Thus the effluent during $Q_{7,10}$ conditions is estimated as 80% of 8.6 mgd, or *6.9* mgd (10.7 cfs). Return flows corresponding to other low-flow statistics were estimated based on ratios to the 7-day 10-year return and average return rate, which were established in previous studies (see Knapp, 1990). The estimated return flow values are given in appendix B.

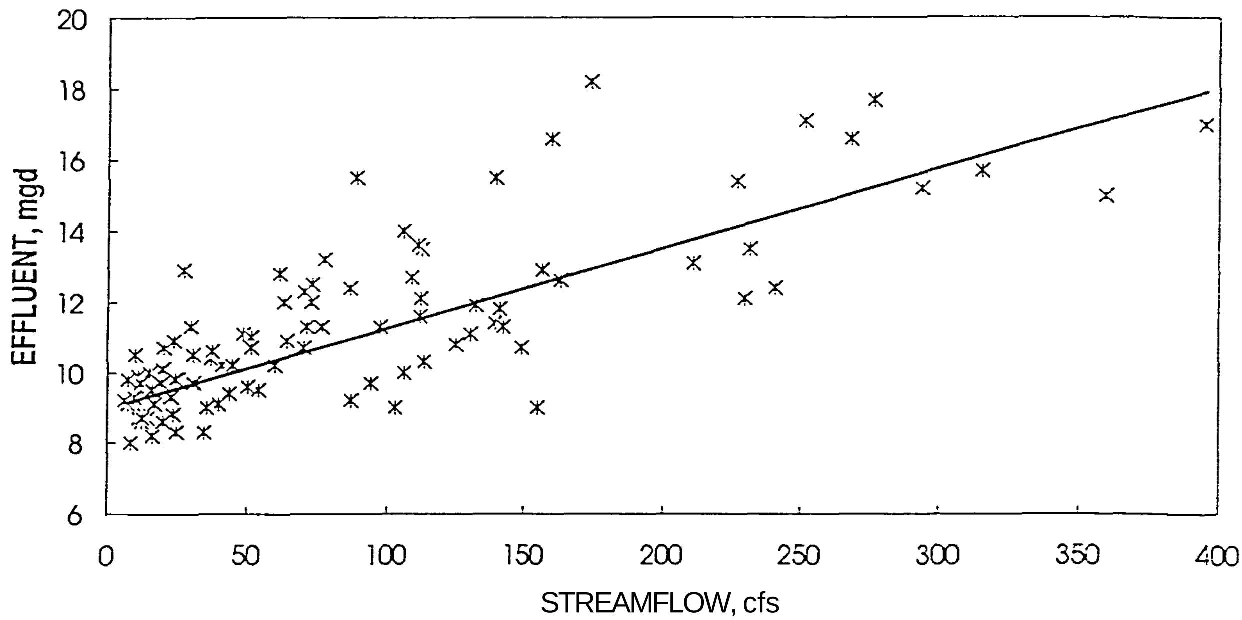

Figure 10. Relationship between the total monthly effluent for Kankakee, Bradley, and Bourbonnais, and the average monthly streamflow for Hickory Creek at Joliet, 1983-1990

Effluents Discharged into Dry Streams

When a discharge is made into a dry stream (zero flow), some of the discharged flow will be lost as the flow moves downstream by way of evaporation and infiltration into the streambed. The expected loss from evaporation and infiltration is computed by the following equation:

$$\text{Loss (in cfs)} = 0.00814\ L\ W \qquad (1)$$

where L is the length of the stream reach in miles, and W is the width of the stream in feet -- estimated from the flow amount, Q (cfs), and the drainage area, A (mi^2), by:

$$\log_{10} W = 0.328 \log_{10} Q + 0.720 \log_{10} A + 0.127 \qquad (2)$$

Equation 2 is an adaptation of the hydraulic geometry relationships for the Kankakee River basin given in Stall and Fok (1968). The coefficient in equation 1 was estimated through the examination of six gaging stations in central Illinois that exist downstream of an effluent into a dry stream. The value was judged to be applicable to the Kankakee watershed. The implementation of equations 1 and 2 is usually completed in successive intermediate steps proceeding downstream from the location of the modifier to the site of interest. If the stream becomes wet naturally at one of these intermediate locations, the reduction of the effect of the discharge ceases.

Evaluation of the Impact of Irrigation Withdrawals and Returns on Streamflow

There is insufficient data to conduct a complete quantitative assessment of the impacts of irrigation on streamflows. Most of the irrigation withdrawals are generally outside the scope of this study because they occur in Indiana. A brief assessment of the overall expected impact of irrigation on the Kankakee River, as it enters Illinois, however, is provided. Reference is made to irrigation use in August 19SS, the month having the lowest average streamflow in the last 50 years.

Withdrawals

The most obvious impact is the reduction in streamflow by withdrawal directly from the streams, in which case the reduction in streamflow equals the withdrawal rate. But the reduction in streamflow caused by pumping from the shallow sand-and-gravel aquifers, which are hydraulically connected to the stream, is expected to be only 25-35% of the withdrawal rate, based on results from Peters and Renn (1988). Withdrawals from the dolomite bedrock have no perceived impact on streamflow.

The average rate of surface water withdrawals for irrigation in the Kankakee River basin during August 1988 was 181 cfs. The rate of water withdrawn from shallow sand-and-gravel aquifers is estimated to be 48 cfs. The total impact of all withdrawals on streamflow is therefore about 195 cfs, assuming the net impact of the ground-water pumping is 30% of the withdrawal rate.

Return Flows to Streams

If the water withdrawn for irrigation were a totally consumptive use, then its impact could reduce the streamflow during the driest months by 195 cfs (computed above). A portion of the irrigation withdrawals can return to the stream, however. Return flows to stream may occur in three ways: 1) direct return flows when water diverted from the Kankakee River is not directly applied to irrigated fields; 2) induced runoff to the streams (via ground-1water seepage) whenever the irrigation application rate exceeds the potential evapotranspiration rate; and 3) increased baseflow in the stream because of the raised water table and increased soil moisture storage. None of these return flows can be directly computed without considerable monitoring, but the sum of the first two returns may be roughly estimated as the difference between the amount of water available for irrigation (precipitation and withdrawals) and the potential evapotranspiration rate:

Approximate Irrigation Water Balance for Jasper County, August 1988

Precipitation	+2.3 inches
Withdrawals (all sources)	+7.6 inches
Potential evapotranspiration	- 6.0 inches
Surplus for return flows	+3.9 inches

The total return flows for the Kankakee River watershed upstream of Momence, computed in this manner for each county for August 1988, amount to about 115 cfs. This should not be interpreted as an exact value, but rather as an indicator of the general magnitude of return flows.

In addition to these surplus flows, is the baseflow that accretes to the stream from the high ground-water levels. The baseflow contribution from an irrigated area should be similar to the baseflow that occurs during normal conditions when precipitation replenishes the moisture lost through evapotranspiration. An examination of the streamflow record at Momence indicates that the 31-day low flow during a wet year is about 1000 cfs, or 0.44 cfs/mi^2. By contrast, the 31-day, 10-year low flow is estimated to be 454 cfs, or 0.20 cfs/mi^2. The difference, 0.24 cfs/mi^2, is an estimate of the baseflow increase induced by each square mile of irrigated land during dry years. The 1987 amount of irrigated land in the basin is 121 mi^2, thus the expected increase in baseflow due to irrigation is about 30 cfs.

Composite Impact of all Water Use

The combined impacts on the Kankakee River flows due to irrigation withdrawals, return flows, and increased baseflow is estimated to reduce low flows by about 50 cfs. Other factors impacting the present low-flow conditions upstream of Momence are the level of low-flow effluent discharges (+20 cfs). The net withdrawal of the R.M. Schahfer electric-generating plant in Jasper County is -21 cfs, but this amount was not included in the development of present flow estimates. Therefore the difference between virgin flow conditions and present flow conditions at the Illinois-Indiana state line is estimated by *ILSAM* to be -30 cfs. Note that this overall amount was evaluated by using standard hydrologic principles ~ the actual amount of the impact cannot be adequately verified given the accuracy of the available streamgage records. Irrigation and other water uses also affect flows in the Iroquois River, but to a much smaller degree, and in the development of present flow their total impact was assumed to be zero.

ESTIRIATING STREAMFLOW PARAMETERS AT GAGED SITES

This section describes the development of flow frequency estimates for the virgin and present flow conditions, which were computed using the methodologies described in the previous section. Two primary considerations in the development of the flow frequency estimates were that these estimates reasonably represent long-term conditions in the watershed and that a consistent relationship was maintained between different locations.

Long continuous discharge records are needed for determining reliable estimates of the streamflow parameters used in *ILSAM.* The streamgages listed in table 5 have records that cover a varying set of years, and the differences in their periods of record affect the frequency estimates for each gage. For gages having records less than 30 years, the length of the record may be insufficient to cover a wide range of hydrologic conditions. Estimates of streamfiow frequency derived from shorter records were adjusted to reflect expected conditions for the longer period 1949-1989, described below, or they were not included in the analysis. One of two adjustments, depending on the type of streamfiow parameter being estimated, was made to account for these differences in record length.

The streamfiow parameters estimated by *ILSAM* can be divided into two broad categories: 1) flow duration statistics that are computed independent of the sequence of daily flow values, and 2) estimates of low-flow frequency that relate average conditions during a sequence of daily flows with an expected frequency of occurrence. For the first category, the flow frequency represents the percent probability that a flow value *will be exceeded on any one day.* For the second category, the frequency of occurrence represents the chance that the average flow value *will not be exceeded in any one year.*

Flow Duration Adjustments for Differences in Period of Record

To maintain consistent frequency estimates between different locations, it is necessary to define **a** set period of years, or "base" period, to which estimates of the annual and monthly flow duration can be related. Considerations in defining this base period require choosing **a** period: 1) that includes representative low-flow and high-flow conditions, and 2) for which many stations have concurrent records. Using these guidelines, the period 1949-1989 was established as the base period for the analysis of flow duration relationships in the Kankakee watershed. The frequency of flow computed from gage records covering a different period were adjusted from their observed values to reflect streamflow conditions during the base period. This adjustment technique involves modifying the frequency with which each particular flow is expected to occur. The adjustment in frequency (or "frequency shift") is determined by comparing the changes in flow frequency that occur for different years at nearby gaging stations that have long-term records. This method is described in greater detail in Knapp (1988).

Defining Recurrence Intervals for Low Flows and Drought Flows

The recurrence interval (RI) for a drought or low flow is normally estimated by the formula,

$$RI = n/(N+1) \quad (3)$$

where N represents the number of years of the streamflow record, and n represents the rank of the drought in the flow record (n=1 represents the worst drought on record, n=2 is the second worst drought on record, etc.). This estimate of recurrence interval is unbiased and assumes no further knowledge of flow frequency other than what occurs in the N-year record. However, when the period of record between two gaging stations is significantly different, this method will not yield consistent estimates of low flow and drought frequency. In these cases, the recurrence interval of a given drought event for the shorter record may be assumed to be equal to the recurrence interval for that same drought computed using the longer station. A graphical fit to the data at each gaging station is then made using log-probability graph paper. Graphical fits of frequency require a somewhat subjective evaluation of the data, but they are generally superior to the use of theoretical probability distributions for describing low-flow frequency (Task Committee, 1980; Knapp, 1988).

Selected Results from Analyses

Estimates of the 154 flow parameters were developed for 19 gaging stations in the Kankakee watershed. A list of the estimated values for the 154 streamflow parameters for gages in or near the Illinois portion of the watershed is given in appendix A. With the exception of stations on the Kankakee River, the long-term virgin flow conditions, present conditions, and flow estimates from the period of record for the gages are similar. These estimates are presented for the Kankakee River gages at Momence and Wilmington in table 12. The flow estimates from the period of record are slightly lower than those for virgin and present flow, primarily because the latter estimates neglect the flow records from 1916 to 1922, which are atypically low when compared to the remainder of the records.

Table 12. Selected Flow Parameters of Virgin Flow, Present Flow, and the Period of Record

Gaging station	*Q7.10*	*Q90*	*Q75*	*Qmean*	*Q01*
Kankakee River at Momence					
Virgin	431.	669.	914.	2032.	6850.
Present	404.	662.	910.	2026.	6853.
Record (1915-1989)	380.	646.	900.	2021.	6850.
Kankakee River at Wilmington					
Virgin	496.	830.	1301.	4279.	22296.
Present	453.	803.	1285.	4273.	22324.
Record (1915-1989*)	463.	796.	1250.	4239.	22296.

* The analysis for Wilmington incorporates the Custer Park gaging record (1915-1933)

ESTIMATING STREAMFLOW PARAMETERS AT UNGAGED SITES

The estimation of virgin flow characteristics at an ungaged location involves two specific steps: 1) the estimation of the virgin flow conditions using equations developed with regression analyses, discussed earlier, and 2) adjustment of this estimate when flow statistics are available from records at gaging stations on the same stream. The present flow conditions are estimated from the virgin flow by evaluating of effects of flow modifiers, i.e., withdrawals and return flows.

Virgin Flow Equations

Variations in the virgin flow from one watershed to another are theoretically associated with a number of physical (topographic, geologic, and climatic) characteristics of the basin. In the following analysis, three of these watershed characteristics are used to define differences in streamflow: 1) total drainage area of the stream, 2) average permeability of the subsoil, and 3) annual average excess precipitation (precipitation minus evapotranspiration).

The basic equation used to estimate the virgin flow values for ungaged sites of all 154 streamflow parameters used in the streamflow assessment model is:

$$Q_x = \min \{ Qmean [a + b K + c DA] -0.05 , 0\} \qquad (4)$$

where Q_x (cfs) is any flow parameter estimated in the model, Qmean (cfs) is the mean flow at the location, K (inches per hour) is the average subsoil permeability of the watershed, DA (square miles) is the total drainage area, and a, b, and c are coefficients determined by calibration. The mean flow can be determined from estimates of the average annual values for precipitation, P (inches), and evapotranspiration, ET (inches) over the watershed:

$$Qmean = 0.0738 DA (P-ET) \qquad (5)$$

Two sets of the coefficients in equation 4 (a, b, and c) were calibrated using a least squares regression procedure. The first set of coefficients was developed using streamflow data from fifteen U.S. Geological Survey (USGS) gaging stations located in and near the Kankakee River basin (data set 1). The second set of coefficients was developed using streamflow data from 14 gaging stations (data set 2) across the Bloomington Ridged Plain, the physiographic region of which most of the Kankakee watershed in Illinois is a part (Leighton et al., 1948). The gaging stations used for both data sets are listed in table 13. One of the major differences in the two data sets is that the soil permeabilities of the watersheds in data set 1 are generally greater than those in data set 2.

The stations presented in table 13 were selected from a list of all USGS stations located within their respective regions, and whose period of record included the major portion of the years 1949-1989. Several other stations, not listed, fit these criteria but were not used in the analysis

Table 13. USGS Gaging Stations Used in the Regression Analysis of Virgin Flow

a) Vicinity of the Kankakee Watershed (gage data set #1)

USGS station #	*Station name*	*Drainage area (mi^2)*	*Subsoil permeability (in/hr)*	*Mean annual runoff (in)*
05-515000	Kankakee River near North Liberty, IN*	174.	9.2	12.02
05-515500	Kankakee River at Davis, IN*	537.	10.6	12.85
05-516500	Yellow River at Plymouth, IN*	294.	4.0	11.96
05-517000	Yellow River at Knox, IN*	435.	5.9	12.42
05-517890	Cobb Ditch near Kouts, IN	30.3	4.4	14.83
05-519000	Singleton Ditch at Schneider, IN	123.	2.7	12.14
05-521000	Iroquois River at Rosebud, IN	35.6	2.8	10.41
05-522000	Iroquois River near North Marion, IN	144.	2.5	12.64
05-522500	Iroquois River at Rensselaer, IN	203.	1.9	11.37
05-552300	Bice Ditch near South Marion, IN	21.8	1.2	10.84
05-523500	Slough Creek near Collegeville, IN	83.7	1.6	11.37
05-524000	Carpenter Creek at Egypt, IN	44.8	0.5	11.61
05-524500	Iroquois River near Foresman, IN	449.	1.6	11.70
05-525500	Sugar Creek at Milford	446.	1.1	11.00
05-537500	Long Run near Lemont	20.9	0.4	10.80

* Portions of these watersheds do not contribute directly to surface runoff.

b) Bloomington Ridged Plain, Illinois (gage data set #2)

USGS station #	*Station name*	*Drainage area (mi)*	*Subsoil permeability (in/hr)*	*Mean annual runoff (in)*
05-439500	South Br Kickapoo Cr near Fairdale	387.	1.08	9.10
05-525500	Sugar Creek at Milford	446.	1.10	11.00
05-537500	Long Run near Lemont	20.9	0.40	10.80
05-546500	Fox River at Wilmot, WI	868.	3.74	6.95
05-550500	Poplar Creek near Elgin	35.2	1.16	9.10
05-554500	Vermilion River near Pontiac	579.	0.60	9.10
05-566500	East Br Panther Cr near El Paso	28.8	0.60	9.00
05-567500	Mackinaw River near Congerville	675.	0.73	10.20
05-572000	Sangamon River at Monticello	550.	0.71	10.00
05-579500	Lake Fork near Cornland	214.	1.05	9.80
05-580000	Kickapoo Creek near Waynesville	227.	0.77	9.60
05-590000	Kaskaskia Ditch near Bondville	12.4	0.77	10.45
05-591500	Asa Creek near Sullivan	8.0	0.77	10.45
05-592000	Kaskaskia River at Shelbyville	1054.	0.54	10.48

because their records included significant influence from reservoirs, major effluent discharges, or other anthropogenic influences. Therefore the flows at these stations represent the virgin (or near-virgin) flow conditions of regional streams.

Coefficients for the virgin flow equations (a, b, and c), developed from regression analysis of flow values from these gaging stations, are listed in table 14. Some of the least-squares estimates of coefficients a, b, and c were modified so that a smooth transition might exist between estimates of related flow parameters. For example, the estimate of the 7-day, 25-year low flow ($Q_{7,25}$) must always fall between the values of the $Q_{7,10}$ and $Q_{7,50}$. In these cases a higher error of estimate was accepted to achieve the proper relationships between flow parameters. In general, the values of the coefficients for data sets 1 and 2 are remarkably similar in magnitude, which indicates that each set of equations will produce reasonably similar values. But the coefficient of error (c_e) for data set 2 is significantly less. This should be expected since most of the gaging stations used in data set 2 come from watersheds with similar characteristics, particularly with respect to soil permeability.

Application of the Virgin Flow Equations

It is desirable to use the equations from data set 2 because they have a lower error, *but* these equations should only be applied to watersheds having similar soil permeabilities to those shown for data set 2 in table 13. It is recommended that the equations from data set 1 be applied whenever the average soil permeability of the watershed *exceeds 1.5 inches per hour.* Application of the equations should also be limited to watershed areas similar to those used in developing each set of equations. Specifically, these equations should only be used for watersheds *between 10 and 1,000 mi*^{2}.

The application of the equations is illustrated by the following example. Assume that a watershed exists with the following characteristics: drainage area = 100 mi^2, average annual precipitation = 36 inches, average soil permeability = 2.0 inches per hour, and average annual evapotranspiration = 25 inches. The virgin flow coefficients for data set 1 (found in table 14) are used to estimate the following values of the annual flow duration: the mean flow (Qmean), Q98, Q90, Q75, Q50, Q25, Q10, and Q02:

Qmean = .0738 (100) (36-25) = 81.2 cfs

Q98 = 81.2 [- 0.01488 - 0.00002 (100) + 0.03961 (2.0)] - 0.05 = 5.0 cfs

Q90 = 81.2 [- 0.00573 - 0.000032 (100) + 0.04798 (2.0)] - 0.05 = 7.0 cfs

Q75 = 81.2 [0.06664 - 0.000046 (100) + 0.05564 (2.0)] - 0.05 = 14.0 cfs

Q50 = 81.2 [0.30486 + 0.0000791 (100) + 0.05175 (2.0)] - 0.05 = 33.7 cfs

Q25 = 81.2 [0.94596 + 0.000293 (100) + 0.01773 (2.0)] - 0.05 = 82 cfs

Q10 = 81.2 [2.4966 + 0.000604 (100) - 0.08938 (2.0)] - 0.05 = 193 cfs

Q02 = 81.2 [7.62119 - 0.0017 (100) - 0.44896 (2.0)] - 0.05 = 532 cfs

Table 14. Coefficients for Virgin Flow Equations (equations 4 and 5)

$$Qmean = 0.0738\ DA\ (P\text{-}ET)$$

$$Q_x = \min \{ Qmean\ [\ a + b\ DA + c\ K\ ]\ -0.05\ ,\ 0\ \}$$

	Data set 1 (Vicinity of the Kankakee Watershed)				*Data set 2 (Bloomington Ridged Plain, Illinois)*			
	a	*b*	*c*	*Error (c_e)*	*a*	*b*	*c*	*Error (c_e)*
Flow Duration								
Q01	10.55491	-0.00357	-0.64874	1.3163	11.37308	-0.00118	-1.44505	0.8389
Q02	7.62119	-0.00170	-0.44896	0.8605	7.78878	-0.00074	-0.80458	0.4752
Q05	4.31349	0.0000982	-0.21941	0.4202	4.21772	0.0000246	-0.29777	0.2523
Q10	2.49660	0.000604	-0.08938	0.2063	2.40866	0.000266	-0.08557	0.1349
Q15	1.70181	0.000477	-0.03177	0.1590	1.63600	0.000218	0.00803	0.0927
Q25	0.94596	0.000293	0.01773	0.1269	0.90690	0.000179	0.05760	0.0645
Q40	0.47728	0.000118	0.04470	0.1012	0.42365	0.000102	0.07891	0.0577
Q50	0.30486	0.0000791	0.05175	0.0849	0.23094	0.0000731	0.09085	0.0495
Q60	0.17956	0.0000302	0.05521	0.0531	0.09932	0.0000437	0.09550	0.0398
Q75	0.06664	-0.000046	0.05564	0.0437	-0.00634	0.0000114	0.08830	0.0224
Q85	0.02409	-0.000041	0.05079	0.0376	-0.02532	0.0000112	0.07129	0.0140
Q90	-0.00573	-0.000032	0.04798	0.0320	-0.02705	0.0000104	0.06112	0.0118
Q95	-0.00741	-0.000028	0.04402	0.0290	-0.02661	0.0000075	0.05094	0.0092
Q98	-0.01488	-0.000020	0.03961	0.0275	-0.02410	0.0000046	0.04183	0.0074
Q99	-0.02118	-0.0000098	0.03748	0.0252	-0.02282	0.0000037	0.03685	0.0065
Low Flows								
$Q_{1,2}$	-0.01200	-0.000015	0.05000	0.0447	-0.02423	0.0000055	0.05223	0.0110
$Q_{1.10}$	-0.01700	-0.000015	0.03400	0.0413	-0.01993	0.0000042	0.03045	0.0056
$Q_{1,25}$	-0.01900	-0.000008	0.03000	0.0427	-0.01774	0.0000034	0.02497	0.0045
$Q_{1,50}$	-0.02200	-0.000005	0.02900	0.0432	-0.01569	0.0000044	0.01910	0.0038
$Q_{7,2}$	-0.00700	-0.000020	0.05100	0.0485	-0.02511	0.0000039	0.05874	0.0121
$Q_{7,10}$	-0.01500	-0.000020	0.03600	0.0449	-0.02263	0.0000042	0.03568	0.0065
$Q_{7,25}$	-0.01800	-0.000012	0.03200	0.0482	-0.01967	0.0000044	0.02810	0.0048
$Q_{7,50}$	-0.02100	-0.000007	0.03098	0.0494	-0.01712	0.0000052	0.02150	0.0038
$Q_{15,2}$	-0.00200	-0.000025	0.05200	0.0511	-0.02619	0.0000034	0.06562	0.0128
$Q_{15,10}$	-0.01300	-0.000025	0.03744	0.0466	-0.02416	0.0000039	0.04020	0.0078
$Q_{15,25}$	-0.01600	-0.000018	0.03395	0.0495	-0.02050	0.0000038	0.03100	0.0058
$Q_{15,50}$	-0.01900	-0.000013	0.03273	0.0517	-0.01820	0.0000044	0.02500	0.0042
$Q_{31,2}$	0.00600	-0.000030	0.05300	0.0525	-0.02565	0.0000001	0.07326	0.0142
$Q_{31,10}$	-0.01100	-0.000030	0.03975	0.0479	-0.02420	0.0000025	0.04434	0.0087
$Q_{31,25}$	-0.01400	-0.000023	0.03600	0.0510	-0.02070	0.0000026	0.03506	0.0067
$Q_{31,50}$	-0.01700	-0.000018	0.03450	0.0535	-0.01840	0.0000035	0.02800	0.0047
$Q_{61,2}$	0.02000	-0.000050	0.05500	0.0504	-0.02273	0.0000002	0.08503	0.0175
$Q_{61,10}$	-0.00900	-0.000035	0.04293	0.0481	-0.02436	0.0000030	0.04851	0.0090
$Q_{61,25}$	-0.01200	-0.000028	0.03800	0.0509	-0.02157	0.0000027	0.03834	0.0072
$Q_{61,50}$	-0.01500	-0.000023	0.03600	0.0531	-0.01852	0.0000035	0.03072	0.0054
$Q_{91,2}$	0.04000	-0.000060	0.06000	0.0565	-0.01224	-0.0000064	0.09576	0.0202
$Q_{91,10}$	-0.00500	-0.000040	0.04500	0.0466	-0.02687	0.0000054	0.05407	0.0102
$Q_{91,25}$	-0.00800	-0.000035	0.04000	0.0512	-0.02309	0.0000043	0.04221	0.0077
$Q_{91,50}$	-0.01200	-0.000030	0.03800	0.0542	-0.01836	0.0000043	0.03279	0.0060

Table 14. Concluded

	Data set 1				Data set 2			
	a	*b*	*c*	*Error* (c_e)	*a*	*b*	*c*	*Error* (c_e)
<u>Drought Flows</u>								
$M_{6,10}$	0.00500	-0.000040	0.05100	0.0477	-0.02025	0.0000126	0.06140	0.0269
$M_{6,25}$	-0.00200	-0.000035	0.04800	0.0494	-0.02578	0.0000134	0.05318	0.0199
$M_{6,50}$	-0.00600	-0.000025	0.04500	0.0522	-0.02708	0.0000112	0.04929	0.0170
$M_{9,10}$	0.13000	-0.000020	0.04600	0.0481	0.05645	0.000043	0.04913	0.0692
$M_{9,25}$	0.07000	-0.000010	0.04500	0.0407	0.01053	0.0000042	0.05574	0.0392
$M_{9,50}$	0.03000	-0.000005	0.04600	0.0429	-0.00277	-0.0000013	0.05299	0.0280
$M_{12,10}$	0.33701	0.000065	0.03445	0.0461	0.21441	0.0000233	0.05117	0.1559
$M_{12,25}$	0.21717	-0.000052	0.03936	0.0376	0.09882	-0.000021	0.06497	0.0945
$M_{12,50}$	0.15462	-0.000015	0.03986	0.0510	0.05853	-0.000037	0.06243	0.0674
$M_{18,10}$	0.48129	0.000013	0.02601	0.0496	0.30235	0.0000773	0.02324	0.1973
$M_{18,25}$	0.30444	-0.000070	0.03314	0.0411	0.13603	0.0000199	0.04706	0.1129
$M_{18,50}$	0.17138	0.000016	0.03885	0.0616	0.08595	-0.000018	0.05623	0.0858
$M_{30,10}$	0.67427	-0.000021	0.01759	0.0518	0.57779	0.0000312	0.01697	0.3370
$M_{30,25}$	0.41247	-0.000076	0.03260	0.0460	0.28821	0.000074	0.02383	0.1933
$M_{30,50}$	0.24356	0.000060	0.03870	0.0630	0.20469	-0.000020	0.04028	0.1382
$M_{54,10}$	0.90350	-0.000061	0.00688	0.0569	0.82105	-0.0000035	0.02720	0.4707
$M_{54,25}$	0.53204	-0.000018	0.02855	0.0534	0.46537	0.0000271	0.03804	0.2908
$M_{54,50}$	0.44628	-0.000054	0.02859	0.0730	0.32438	-0.0000061	0.04610	0.2116
<u>January Flows</u>								
Jan-02	8.46155	-0.002010	-0.53524	1.3314	8.25623	0.000282	-1.38139	1.2030
Jan-10	2.50880	0.000471	-0.07303	0.4344	2.06431	0.001110	-0.42050	0.3917
Jan-25	0.92643	0.000071	0.02672	0.1577	0.72872	0.000597	-0.14009	0.1719
Jan-50	0.37228	0.000060	0.05134	0.1123	0.22011	0.000232	0.00668	0.0760
Jan-75	0.13536	-0.000066	0.05524	0.0583	0.00531	0.0000419	0.06118	0.0191
Jan-90	0.02067	-0.000062	0.05145	0.0456	-0.02721	0.0000128	0.05269	0.0106
Jan-98	0.00120	-0.000088	0.04239	0.0497	-0.02804	0.0000083	0.04232	0.0085
JANAVG	1.04928	-0.000047	0.00100	0.1119	0.88842	0.00031	-0.12603	0.1175
<u>February Flows</u>								
Feb-02	10.24468	-0.00181	-0.68343	1.3079	9.28448	-0.00074	-1.28014	1.0674
Feb-10	3.59316	0.00054	-0.16765	0.4135	2.98910	0.000841	-0.48225	0.4091
Feb-25	1.47814	0.000389	-0.01480	0.1645	1.27979	0.000500	-0.20344	0.2485
Feb-50	0.55826	0.000135	0.04115	0.1272	0.39966	0.000239	-0.02031	0.1236
Feb-75	0.20631	-0.000030	0.05692	0.0876	0.09329	0.0000907	0.03700	0.0479
Feb-90	0.06449	-0.000072	0.05128	0.0467	-0.02533	0.0000489	0.05759	0.0139
Feb-98	0.00927	-0.000061	0.04381	0.0520	-0.02987	0.0000156	0.04998	0.0098
FEBAVG	1.43926	0.000116	-0.02853	0.1073	1.25872	0.000229	-0.16287	0.1879
<u>March Flows</u>								
Mar-02	10.31250	-0.00494	-0.48757	1.4102	10.19418	-0.00148	-0.71963	1.3390
Mar-10	4.68235	-0.00102	-0.19797	0.5283	3.94080	-0.00034	0.13784	0.5570
Mar-25	2.38920	-0.000014	-0.05587	0.2445	1.79299	0.000244	0.21239	0.2611
Mar-50	1.16923	0.000042	0.01464	0.1242	0.80366	0.000162	0.15612	0.1055
Mar-75	0.57074	-0.000041	0.04300	0.0972	0.31649	0.000173	0.08655	0.0721
Mar-90	0.29569	-0.000028	0.05442	0.0942	0.12243	0.0000955	0.07008	0.0501
Mar-98	0.08743	0.000011	0.05723	0.0419	-0.00969	0.0000468	0.07026	0.0270
MARAVG	2.04521	-0.000390	-0.03987	0.1819	1.72251	-0.00003	0.07040	0.1702

	Data set 1				Data set 2			
	a	*b*	*c*	*Error* (c_e)	*a*	*b*	*c*	*Error* (c_e)
April Flows								
Apr-02	10.42997	-0.00382	-0.61137	1.1391	11.21738	0.001142	-1.82310	1.2877
Apr-10	4.91823	-0.00062	-0.23147	0.5386	4.57544	0.000853	-0.53006	0.6603
Apr-25	2.53936	0.000453	-0.07789	0.2826	2.35265	0.000548	-0.12227	0.2950
Apr-50	1.20243	0.000276	0.01102	0.1606	1.12176	0.000191	0.07607	0.1683
Apr-75	0.58126	0.000076	0.04206	0.1116	0.51502	0.0000397	0.10793	0.0849
Apr-90	0.31922	0.0000485	0.05032	0.0643	0.23084	0.0000814	0.07838	0.0613
Apr-98	0.16562	-0.000011	0.05370	0.0623	0.03372	0.0000406	0.07416	0.0402
APRAVG	2.10523	-0.000083	-0.05577	0.1593	2.07532	0.000248	-0.12209	0.2123
May Flows								
May-02	8.15090	-0.00076	-0.50491	0.7884	9.59296	-0.00047	-1.62335	1.4765
May-10	3.01631	0.000655	-0.13235	0.2304	3.18388	0.000928	-0.43881	0.3242
May-25	1.33098	0.000476	-0.01143	0.1582	1.47506	0.000610	-0.11808	0.1741
May-50	0.64432	0.000196	0.03565	0.0991	0.73953	0.000271	-0.00660	0.1025
May-75	0.34172	0.000155	0.04793	0.0858	0.38646	0.000148	0.02281	0.0633
May-90	0.20711	0.0000862	0.04938	0.0670	0.22235	0.0000858	0.02546	0.0384
May-98	0.09034	0.0000533	0.04645	0.0490	0.07839	0.0000291	0.03031	0.0375
MAYAVG	1.35673	0.000155	-0.02053	0.1028	1.55688	0.000261	-0.16939	0.0986
June Flows								
Jun-02	9.17498	-0.00303	-0.61635	1.5822	10.91530	-0.00161	-1.89561	1.7579
Jun-10	2.48811	0.001133	-0.14257	0.3987	3.16795	0.000485	-0.43261	0.4487
Jun-25	0.90402	0.000551	0.00369	0.1284	1.25134	0.000416	-0.11455	0.1973
Jun-50	0.39632	0.000148	0.04395	0.0995	0.49775	0.000183	-0.00025	0.0985
Jun-75	0.20912	0.0000583	0.04896	0.0625	0.22252	0.000101	0.02485	0.0590
Jun-90	0.10868	0.0000030	0.04853	0.0625	0.10236	0.0000482	0.03529	0.0420
Jun-98	0.03500	-0.000040	0.04500	0.0492	0.01802	0.0000220	0.04506	0.0275
JUNAVG	1.19180	0.0000149	-0.02470	0.1434	1.47677	0.0000147	-0.16798	0.2120
July Flows								
Jul-02	4.62780	0.000643	-0.30866	0.8249	5.95937	-0.00090	-0.61420	0.9058
Jul-10	0.97221	0.001159	-0.02307	0.1652	1.41917	0.000327	-0.05925	0.2643
Jul-25	0.35201	0.000404	0.03798	0.0935	0.53224	0.000230	0.02455	0.1362
Jul-50	0.15438	0.000102	0.05209	0.0852	0.18523	0.000138	0.03742	0.0683
Jul-75	0.07386	-0.0000062	0.04986	0.0593	0.05286	0.0000588	0.04572	0.0368
Jul-90	0.02200	-0.000020	0.04600	0.0516	0.00403	0.0000224	0.04475	0.0205
Jul-98	-0.00700	-0.000010	0.04000	0.0485	-0.00858	0.0000132	0.03148	0.0106
JULAVG	0.54703	0.000185	0.01599	0.0902	0.73114	0.0000116	-0.01921	0.0948
August Flows								
Aug-02	1.67347	0.003151	-0.11684	0.6770	4.39597	-0.00099	-0.35585	0.9775
Aug-10	0.38973	0.000357	0.04133	0.1334	0.51588	0.0000056	0.18036	0.1606
Aug-25	0.15651	0.0000096	0.05572	0.0615	0.08561	0.0000401	0.14258	0.0642
Aug-50	0.06688	-0.000055	0.05416	0.0610	0.00366	0.0000234	0.08964	0.0340
Aug-75	0.01100	-0.000015	0.00490	0.0577	-0.01262	0.0000109	0.05886	0.0180
Aug-90	-0.01100	-0.000008	0.04150	0.0516	-0.01516	0.0000069	0.04372	0.0115
Aug-98	-0.02200	-0.000007	0.03650	0.0478	-0.01444	0.0000040	0.03077	0.0068
AUGAVG	0.22803	0.0000985	0.03816	0.0728	0.37171	-0.000074	0.06242	0.0830

Table 14. Concluded

	Data set 1				Data set 2			
	a	*b*	*c*	*Error* (c_e)	*a*	*b*	*c*	*Error* (c_e)
September Flows								
Sep-02	3.79263	-0.00152	-0.21099	0.8451	4.06000	-0.00085	-0.24500	1.5610
Sep-10	0.57221	-0.00028	0.03816	0.1534	0.44585	-0.000037	0.23617	0.3236
Sep-25	0.12000	-0.00010	0.05729	0.0635	0.01076	0.0000195	0.14930	0.0712
Sep-50	0.02000	-0.00004	0.05600	0.0594	-0.03539	0.0000034	0.10176	0.0247
Sep-75	-0.00500	-0.000025	0.04S00	0.0542	-0.03059	0.0000079	0.06149	0.0127
Sep-90	-0.01200	-0.000023	0.04100	0.0543	-0.02485	0.0000055	0.04283	0.0084
Sep-98	-0.02300	-0.000008	0.03572	0.0488	-0.01945	0.0000040	0.02915	0.0061
SEPAVG	0.32027	-0.00022	0.03399	0.0500	0.33055	-0.000094	0.07743	0.1099
October Flows								
Oct-02	2.69550	0.000504	-0.05888	0.8500	3.74951	-0.00098	-0.13493	0.8482
Oct-10	0.81008	-0.000016	0.03375	0.1765	0.76678	0.0000512	0.15624	0.2924
Oct-25	0.27157	-0.00023	0.06371	0.1118	0.11210	0.0000028	0.18260	0.1447
Oct-50	0.06448	-0.00013	0.06120	0.0600	-0.03232	-0.0000021	0.10654	0.0267
Oct-75	0.00500	-0.00005	0.05311	0.0595	-0.03464	0.0000066	0.06865	0.0124
Oct-90	-0.01000	-0.00003	0.04597	0.0537	-0.02957	0.0000014	0.05162	0.0087
Oct-98	-0.02500	-0.000008	0.03800	0.0578	-0.02461	0.0000009	0.03825	0.0069
OCTAVG	0.35392	-0.00016	0.04575	0.1062	0.36037	-0.000094	0.08168	0.1237
November Flows								
Nov-02	3.98976	0.000094	-0.18044	0.8126	3.91240	-0.00071	-0.30011	0.6226
Nov-10	1.32858	-0.000067	0.02501	0.2334	1.09762	0.0000194	0.12568	0.3098
Nov-25	0.51178	-0.00014	0.05834	0.1213	0.27637	-0.0000070	0.19316	0.1791
Nov-50	0.16620	-0.00017	0.06181	0.0728	-0.01876	0.0000042	0.15342	0.0523
Nov-75	0.04753	-0.000097	0.05760	0.0574	-0.04706	0.0000175	0.09212	0.0175
Nov-90	0.00500	-0.000060	0.05000	0.0518	-0.04239	0.0000111	0.06914	0.0130
Nov-98	-0.01400	-0.000025	0.04050	0.0543	-0.03462	0.0000073	0.05068	0.0104
NOVAVG	0.54237	-0.00014	0.03934	0.1012	0.35071	-0.0000048	0.10102	0.1065
December Flows								
Dec-02	7.12090	-0.0010	-0.45565	1.1606	6.80638	-0.00014	-1.16873	1.1576
Dec-10	2.48900	0.000573	-0.09259	0.2761	1.79465	-0.0000051	-0.09807	0.3902
Dec-25	0.99538	0.000041	0.02986	0.1579	0.62957	-0.000015	0.06041	0.1730
Dec-50	0.40659	-0.00016	0.05807	0.1091	0.12361	0.0000055	0.10328	0.0990
Dec-75	0.11408	-0.00016	0.06072	0.0719	-0.02192	0.0000081	0.08007	0.0199
Dec-90	0.00300	-0.000040	0.05317	0.0680	-0.03241	0.0000141	0.05693	0.0106
Dec-98	-0.01800	-0.000025	0.04578	0.0670	-0.03051	0.0000111	0.04412	0.0085
DECAVG	1.04012	-0.00013	0.00407	0.0717	0.74290	-0.000023	-0.00911	0.1270

Error in the Regression Model

The regression relationship between the flow and watershed characteristics explains a high amount of the variance that exists between the gaging stations in the sample. The standard error of estimate (s_e) for the virgin flow equations, in cfs, is estimated as the product of the coefficient of error given in table 14 (c_e) and the computed mean flow at the point of interest (Qmean):

$$s_e = c_e \text{ Qmean} \qquad (6)$$

Computation of the standard error of estimate for the above application is provided as follows:

s_e (Q98) = 81.2 * 0.0275 = 2.2 cfs
s_e (Q90) = 81.2 * 0.0320 = 2.6 cfs
s_e (Q75) = 81.2 * 0.0437 = 3.5 cfs
s_e (Q50) = 81.2 * 0.0849 = 6.9 cfs
s_e (Q25) = 81.2 * 0.1269 = 10.3 cfs
s_e (Q10) = 81.2 * 0.2063 = 16.8 cfs
s_e (Q02) = 81.2 * 0.8605 = 70 cfs

Inclusion of Information from Nearby Gaged Sites

The virgin flows computed at gaged sites will generally not be the same values as those estimated by the virgin flow equations; the computed value is always considered superior to that produced by the equations. For ungaged sites located on the same stream as a gage, the estimates of virgin flow should use the better information offered at the gage. In these cases the following methodologies are used to modify the virgin flow estimate.

Three different types of adjustments exist, depending upon location of the ungaged site with respect to that of the gaged sites on the stream: 1) when a gage exists both upstream and downstream of the site; 2) when a gage exists only upstream of the site; and 3) when a gage exists only downstream of the site. Let the values estimated by the equations at the site of interest, the gage upstream, and the gage downstream be represented by qvi, qvu, and qvd, respectively. Also, let the difference between the virgin flow computed at the gage and the value estimated by the equations be represented by Aqu (nearest upstream gage) and Aqd (nearest downstream gage). Then the adjustments made to compute the virgin flow, Q, are as follows:

For gages both upstream and downstream:

$$Q = qvi + \Delta qd - (\Delta qd - \Delta quXqvd - qvi)/(qvd - qvu) \qquad (7)$$

For upstream gages:

$$Q = qvi + \Delta qu \qquad (8)$$

For downstream gages:

$$Q = qvi\ (1 + \Delta qd/qvd) \qquad (9)$$

MODEL OPERATION

ILSAM has three basic data components: 1) control points (gaging stations and other locations for which a full set of flow statistics is precomputed); 2) virgin flow equations, to estimate the undisturbed flow at ungaged sites; and 3) flow modifiers (primarily effluent discharges) that are added to the flow. Methods for determining these components have been described in this report. A list of the locations and estimated flow for the control points and flow modifiers are given in appendices A and B, respectively. The location of all of these points and the drainage area and permeability information needed as independent variables in the virgin flow equations are included in a "network" component, the data for which are given in appendix C.

As the model user requests flow information at a particular site, the following series of computations is performed to provide the streamflow estimate:

1. Locate point and collect information on permeability and drainage area (from the network component).
2. Compute the mean flow (equation 5).
3. Compute the virgin flow estimates (equation 4, table 14); search upstream of the point of interest (using the network component) to identify the total area contributing to the low flow and compute subwatersheds independently.
4. Adjust virgin flow estimates using information from gaging stations along the same stream (equations 7-9).
5. Add all flow modifiers between the point of interest and any upstream control points (add all flow modifiers in the basin if no upstream control points exist).
6. Compute loss of flow when an effluent is discharged into a dry stream (equations 1-2).
7. Add in the effect of user-supplied modifications to produce the altered flow condition.

The preceding steps are duplicated for any additional downstream locations for which the user requests flow information.

Uncertainties of Flow Estimation

Every step in the computation of flow conditions includes some degree of uncertainty. For example, even at the most basic level, using data from streamgaging, some measurement error and uncertainty in the accuracy of the gage's rating curve must be accepted. The error in streamgaging is typically considered to be 10% to 15%. Additional uncertainties are associated with the development of the hydrologic information presented in *ILSAM*. At gaged sites, errors may be expected in 1) the adjustment for period of record (a function of the total number of years extended and the correlation between the gage in question and the index station used for adjustment), and 2) the errors in estimating the frequency of low flows. An additional uncertainty is associated with 3) the separation of virgin flow and the flow modifiers. All of these errors differ from station to station. At ungaged sites, errors are associated with 4) the accuracy of the virgin flow equations and 5) uncertainties in the model's algorithms that concern the effect of flow modifications on downstream sites. In this report, only the fourth error term is addressed (table 14), primarily because it is the only error term that is both quantifiable and universally applicable to all locations within the watershed.

The streamflow statistics represented in this model may be changed over time. Adjustments in flow values may occur because water-use practices will change, and additional years of gaging may provide additional information concerning long-term streamflow conditions. However, long-term virgin streamflow conditions in the future are expected to be similar to those of the past. Proper verification that the virgin flow in the past 40 years is typical of long-term conditions would require many years of additional streamgage records. The greatest amount of uncertainty in the model output lies with the geographic limitation of the available data. For this reason, future improvement in the model's data depends on the continued procurement of flow data (additional streamgaging, low-flow discharge measurements at additional sites, or additional measurement of withdrawals and discharges).

CONCLUSION

This report has presented the major analytical steps used to prepare the hydrologic data available for the Illinois portion of the Kankakee River basin for use in *ILSAM*. The three basic steps involved in estimating flow at any site in the basin are: 1) use of virgin flow equations; 2) adjustments in the virgin flow because of the proximity of gaging stations that have more precise information; and 3) adjustment for the effects of modifications to the flow from effluent discharges, withdrawals, and reservoirs. Streamflow information is supplied in appendices A and B, and the watershed network that describes the relative location of these streamflow elements is provided in appendix C. This information will allow the user to follow these steps to estimate the flow statistics at any location in the basin (with drainage area greater than 10 mi^2). However, the user will likely want to use *ILSAM* because the number of computations could be great. Readers are referred to the *Illinois Streamflow Assessment Model: Version 3.2 User's Guide* (Mills and Knapp, 1991) for a detailed description of how the model works. *ILSAM is* available from the Illinois State Water Survey on floppy diskettes for use on an IBM-PC/AT or compatible computer having a minimum random access memory of 640 K.

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Appendix A. Control Points: Location and Estimated Flow (cfs)

Name of control point	Flow type (virgin or present)	Stream code	River mile
1) Kankakee River at Shelby (USGS Gage # 5518000)	Virgin	Y	67.90
2 Kankakee River at Shelby (USGS Gage # 5518000)	Present	Y	67.90
3) Kankakee River at Momence (USGS Gage # 5520500)	Virgin	Y	47.90
4) Kankakee River at Momence (USGS Gage # 5520500)	Present	Y	47.90
5) Kankakee River above confluence with Iroquois River	Virgin	Y	37.01
6) Kankakee River above confluence with Iroquois River	Present	Y	37.01
7) Kankakee River below confluence with Iroquois River	Virgin	Y	37.00
8) Kankakee River below confluence with Iroquois River	Present	Y	37.00
9) Kankakee River near Wilmington (USGS Gage # 5527500)	Virgin	Y	5.70
10) Kankakee River near Wilmington (USGS Gage # 5527500)	Present	Y	5.70
11) Iroquois River near Foresman (USGS Gage # 5524500)	*	YG	72.70
12) Iroquois River at Iroquois (USGS Gage # 5525000)	*	YG	50.40
13) Iroquois River near Chebanse (USGS Gage # 5526000)	*	YG	6.50
14) Sugar Creek at Milford (USGS Gage # 5525500)	*	YGI	23.90
15) Terry Creek near Custer Park (USGS Gage # 5526500)	*	YD3	0.30
16) Singleton Ditch at Illinoi (USGS Gage # 5520000)	*	YI	5.60
17) Sugar Creek above confluence with Mud Creek	*	YGI	23.91
18) Mud Creek at mouth	*	YGIK	0.00

* Virgin flow = present flow

a The stream code is used by *ILSAM* to uniquely identify all streams in the watershed. The code for each stream is given in appendix C.

Appendix A. Continued

Flow Type	Location (11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Drought Flows-Cont								
$Q_{54.10}$	354.95	543.43	1075.00	311.63	9.57	175.19	115.54	191.S4
$Q_{54.25}$	203.67	303.56	909.00	198.35	4.27	110.00	70.31	113.36
$Q_{54.50}$	170.00	268.00	877.00	164.94	4.08	94.00	51.99	79.46
January Flows								
Q_{02}	2124.00	3266.00	9670.00	3190.00	60.00	1350.00	877.45	1763.62
Q_{10}	977.00	1500.00	4660.00	940.00	24.00	588.50	227.81	500.31
Q_{25}	440.00	680.00	2140.00	300.00	10.00	257.75	86.55	190.75
Q_{50}	215.00	295.00	840.00	122.00	5.00	105.00	35.97	66.38
Q_{75}	92.00	125.00	300.00	45.00	1.60	50.75	12.54	10.79
Q_{90}	33.00	40.00	100.00	13.00	0.90	30.00	5.95	1.34
Q_{98}	15.00	19.00	35.00	4.00	0.11	19.00	3.89	0.34
Q_{mean}	390.64	582.99	1759.00	379.10	9.50	224.60	104.42	210.37
February flows								
Q_{02}	3114.00	4500.00	13620.00	3528.00	69.32	1391.00	1012.61	1945.65
Q_{10}	1350.00	2180.00	6200.00	1380.00	25.00	652.60	336.81	688.88
Q_{25}	698.00	1060.00	3040.00	520.00	13.00	325.50	147.15	304.11
Q_{50}	299.00	446.00.	1370.00	205.00	5.50	177.00	55.59	105.19
Q_{75}	141.50	180.00	450.00	66.00	2.35	83.00	21.15	31.50
Q_{90}	56.00	68.00	160.00	20.00	1.20	38.00	7.87	3.78
Q_{98}	22.60	24.00	64.00	8.00	0.40	20.00	5.17	0.87
Q_{mean}	562.S3	548.54	2508.00	537.43	11.32	280.34	146.06	286.67
March Flows								
Q_{02}	2680.00	4282.00	12670.00	2864.00	57.52	1320.00	1219.71	2170.19
Q_{10}	1500.00	22S0.00	6920.00	1500.00	30.40	646.00	550.45	901.43
Q_{25}	937.00	1360.00	4000.00	790.00	19.00	390.25	2S5.58	452.35
Q_{50}	523.00	750.00	1940.00	378.00	11.00	237.00	140.61	213.64
Q_{75}	287.00	395.00	966.00	163.00	6.30	142.00	62.02	93.S5
Q_{90}	170.00	228.00	521.00	S4.00	3.50	94.90	31.07	42.29
Q_{98}	76.00	91.00	233.00	40.00	1.61	45.00	12.21	S.68
Q_{mean}	717.76	1057.35	3010.00	635.58	14.86	326.55	245.25	402.21
April Flows								
Q_{02}	2420.00	3630.00	12000.00	3240.00	80.00	1544.00	1217.53	2451.41
Q_{10}	1590.00	2450.00	7370.00	1630.00	38.00	795.00	542.82	1048.53
Q_{25}	1140.00	1640.00	4480.00	881.00	22.00	422.00	308.47	563.53
Q_{50}	560.00	859.00	2240.00	415.00	13.00	237.00	170.04	279.04
Q_{7S}	283.50	406.00	970.00	202.00	6.80	143.50	89.82	132.98
Q_{90}	172.00	242.00	610.00	117.00	3.70	SS.OO	46.98	67.25
Q_{98}	112.80	140.00	375.00	62.00	2.00	62.00	18.64	18.75
Q_{mean}	763.37	1138.43	3221.00	711.27	17.90	359.19	264.87	480.69
May Flows								
Q_{02}	2501.60	3802.00	12900.00	2810.00	77.40	1270.40	998.44	1995.79
Q_{10}	1240.00	1800.00	6080.00	1270.00	25.00	477.10	372.78	743.38
Q_{25}	686.50	1030.00	3300.00	576.00	14.00	263.50	191.84	366.24
Q_{50}	317.50	511.00	1480.00	259.00	8.30	156.00	104.75	187.48
Q_{75}	188.00	290.00	776.00	147.00	5.00	99.00	59.51	101.15
Q_{90}	130.10	185.00	436.00	92.00	2.80	70.90	36.41	59.62
Q_{98}	72.00	104.80	206.00	50.80	2.00	44.00	16.57	23.33
Q_{mean}	545.10	822.04	2628.00	526.60	16.63	242.52	186.39	356.43
June Flows								
Q_{02}	2126.00	3510.00	8830.00	3030.00	93.80	1076.00	1104.17	2195.26
Q_{10}	1190.00	1800.00	4660.00	1190.00	30.00	291.00	361.88	711.77
$Q_{\cdot 25}$	473.00	757.00	2140.00	425.00	13.00	158.00	158.05	301.93
Q_{50}	225.00	340.00	970.00	165.00	5.90	105.00	71.29	126.44
Q_{75}	126.00	193.00	484.00	94.00	3.40	74.00	36.73	60.50
Q_{90}	76.00	110.00	225.00	45.00	1.90	58.00	21.15	30.63
Q_{98}	34.60	40.00	86.00	20.00	1.00	34.40	10.90	10.61
Q_{mean}	448.69	689.01	2855.00	469.53	14.11	170.45	170.04	321.55

Appendix A. Continued

Location

Flow Type	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Q_{01}	4900.00	4900.00	6850.00	6S53.00	7123.	7131.	19040.	19046.	22300.00	22324.00
Q_{02}	4450.00	4450.00	6090.00	6093.00	6336.	6339.	15498.	15503.	18000.00	18020.00
Q_{05}.	3880.00	3880.00	5060.00	5063.00	5262.	5265.	11592.	11597.	13000.00	13017.00
Q_{10}	3270.00	3268.00	4210.00	4211.00	4376.	4377.	8796.	8799.	9930.00	9943.00
Q_{15}	2800.00	2800.00	3620.00	3623.00	3761.	3764.	7128.	7133.	8070.00	8084.00
Q_{25}	2130.00	2128.00	2710.00	2711.00	2813.	2814.	4916.	4919.	5533.00	5539.00
Q_{40}	1550.00	1546.00	1900.00	1899.00	196S.	1967.	3088.	3089.	3500.00	3499.00
Q_{50}	1300.00	1295.00	1550.00	1548.00	1604.	1602.	2384.	2384.	2700.00	2695.00
Q_{60}	1080.00	1074.00	1240.00	1237.00	1280.	1277.	1783.	1781.	1990.00	1981.00
Q_{75}	828.00	821.00	914.00	910.00	941.	937.	1161.	1158.	1300.00	1285.00
Q_{85}	685.00	677.00	750.00	745.00	770.	765.	892.	888.	962.00	942.00
Q_{90}	620.00	610.00	669.00	662.00	685.	678.	774.	768.	828.00	803.00
Q_{95}	542.00	530.00	586.00	577.00	598.	589.	655.	647.	689.00	658.00
Q_{98}	480.00	462.00	495.00	480.00	502.	487.	549.	535.	568.00	526.00
Q_{99}	450.00	420.00	460.00	433.00	464.	437.	506.	480.	524.00	464.00
Q_{mean}	1631.00	1622.00	2032.00	2026.00	2106.	2100.	3769.	3765.	4279.00	4273.00
Low Flows										
$Q_{1,2}$	549.00	534.00	592.00	580.00	605.	593.	666.	655.	643.00	598.00
$Q_{1,10}$	396.00	370.00	404.00	381.00	409.	386.	431.	409.	412.00	380.00
$Q_{1,25}$	338.00	295.00	354.00	314.00	357.	317.	370.	331.	350.00	316.00
$Q_{1,50}$	295.00	270.00	310.00	2S8.00	311.	289.	318.	297.	298.00	282.00
$Q_{7,2}$	579.00	566.00	620.00	610.00	634.	624.	705.	696.	716.00	687.00
$Q_{7,10}$	422.00	392.00	431.00	404.00	435.	408.	472.	446.	492.00	453.00
$Q_{7,25}$	345.00	318.00	360.00	336.00	363.	339.	379.	356.	385.00	370.00
$Q_{7,50}$	328.00	299.00	339.00	313.00	341.	315.	358.	333.	360.00	343.00
$Q_{15,2}$	603.00	593.00	654.00	647.00	670.	663.	750.	744.	772.00	747.00
$Q_{15,10}$	440.00	418.00	458.00	439.00	463.	444.	499.	481.	516.00	472.00
$Q_{15,25}$	373.00	346.00	382.00	358.00	385.	361.	403.	380.	408.00	394.00
$Q_{15,50}$	350.00	320.00	356.00	329.00	358.	331.	374.	348.	377.00	359.00
$Q_{31,2}$	635.00	626.00	688.00	682.00	705.	699.	806.	801.	852.00	830.00
$Q_{31,10}$	452.00	432.00	471.00	454.00	479.	462.	506.	490.	524.00	479.00
$Q_{31,25}$	408.00	383.00	425.00	403.00	431.	409.	456.	435.	475.00	447.00
$Q_{31,50}$	380.00	363.00	395.00	381.00	400.	386.	421.	408.	437.00	433.00
$Q_{61,2}$	686.00	678.00	752.00	747.00	772.	767.	920.	916.	975.00	956.00
$Q_{61,10}$	480.00	462.00	495.00	480.00	504.	489.	544.	530.	547.00	507.00
$Q_{61,25}$	453.00	434.00	464.00	448.00	472.	456.	510.	495.	512.00	468.00
$Q_{61,50}$	420.00	395.00	430.00	408.00	436.	414.	472.	451.	474.00	445.00
$Q_{91,2}$	759.00	752.00	847.00	843.00	871.	867.	1078.	1075.	1205.00	1190.00
$Q_{91,10}$	517.00	501.00	543.00	530.00	554.	541.	615.	603.	651.00	616.00
$Q_{91,25}$	485.00	464.00	505.00	487.00	514.	496.	558.	541.	578.00	533.00
$Q_{91,50}$	461.00	438.00	479.00	459.00	487.	467.	527.	508.	545.00	496.00
Drought Flows										
$Q_{6,10}$	617.00	617.00	662.00	665.00	678.	681.	767.	771.	835.00	823.00
$Q_{6,25}$	572.00	572.00	603.00	606.00	617.	620.	702.	706.	740.00	724.00
$Q_{6,50}$	558.00	558.00	583.00	586.00	596.	599.	660.	664.	697.00	679.00
$Q_{9,10}$	751.00	751.00	863.00	866.00	888.	891.	1232.	1236.	1380.00	1373.00
$Q_{9,25}$	706.00	706.00	771.00	774.00	792.	795.	977.	981.	1016.00	1006.00
$Q_{9,50}$	675.00	685.00	725.00	738.00	744.	757.	867.	881.	888.00	885.00
$Q_{12,10}$	931.00	931.00	1126.00	1129.00	1162.	1165.	1893.	1898.	2077.00	2076.00
$Q_{12,25}$	848.00	848.00	927.00	930.00	954.	957.	1316.	1320.	1422.00	1416.00
$Q_{12,50}$	798.00	798.00	890.00	893.00	916.	919.	1205.	1209.	1267.00	1258.00
$Q_{18,10}$	1012.00	1012.00	1129.00	1132.00	1165.	1168.	1931.	1936.	2118.00	2119.00
$Q_{18,25}$	875.00	875.00	984.00	987.00	1014.	1017.	1442.	1446.	1535.00	1531.00
$Q_{18,50}$	811.00	811.00	901.00	904.00	927.	930.	1277.	1281.	1350.00	1343.00
$Q_{30,10}$	1238.00	1238.00	1495.00	1498.00	1546.	1549.	2719.	2724.	3103.00	3107.00
$Q_{30,25}$	1050.00	1050.00	1227.00	1230.00	1267.	1270.	1840.	1845.	2008.00	2008.00
$Q_{30,50}$	899.00	899.00	1102.00	1105.00	1137.	1140.	1671.	1675.	1774.00	1770.00

Appendix A. Continued

Flow Type	Location (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Drought Flows-Cont										
$Q_{54,10}$	1481.00	1481.00	1839.00	1842.00	1905.	1908.	3671.	3676.	4109.00	4116.00
$Q_{54,25}$	1242.00	1242.00	1521.00	1524.00	1573.	1576.	2461.	2466.	2741.00	2743.00
$Q_{54,50}$	1161.00	1161.00	1359.00	1362.00	1404.	1407.	2321.	2326.	2507.00	2507.00
January Flows										
Q_{02}	4035.00	4035.00	5655.00	5658.00	5S82.	5S85.	15150.	15156.	17100.00	17122.00
Q_{10}	3345.00	3345.00	4360.00	4363.00	4532.	4535.	8952.	8957.	9600.00	9615.00
Q_{25}	2225.00	2225.00	2940.00	2943.00	3052.	3055.	5252.	5257.	5800.00	5808.00
Q_{50}	1470.00	1470.00	1800.00	1803.00	1864.	1867.	2707.	2712.	3200.00	3201.00
Q_{75}	948.00	948.00	1070.00	1073.00	1103.	1106.	1495.	1499.	1700.00	1692.00
Q_{90}	710.00	710.00	700.00	703.00	718.	721.	S2S.	832.	900.00	885.00
Q_{98}	450.00	450.00	490.00	493.00	499.	502.	545.	549.	560.00	538.00
Q_{mean}	1719.00	1719.00	2159.00	2162.00	2238.	2241.	3997.	4002.	4462.00	4470.00
February Sows										
Q_{02}	4378.00	4378.00	6226.00	6229.00	6477.	64S0.	19952.	19968.	23104.00	23127.00
Q_{10}	3410.00	3410.00	4560.00	4563.00	4741.	4744.	10647.	10652.	11800.00	11816.00
Q_{25}	2490.00	2490.00	3250.00	3253.00	3375.	3378.	6433.	6438.	7200.00	7213.00
Q_{50}	1706.00	1706.00	2170.00	2173.00	2250.	2253.	3790.	3795.	4055.00	4058.00
Q_{75}	1150.00	1150.00	1300.00	1303.00	1343.	1346.	1923.	1927.	2100.00	2094.00
Q_{90}	769.00	769.00	810.00	813.00	832.	835.	1002.	1006.	1141.00	1130.00
Q_{98}	500.00	500.00	540.00	543.00	551.	554.	648.	652.	747.00	730.00
Q_{mean}	1917.00	1917.00	2461.00	2464.00	2553.	2556.	5055.	5070.	5678.00	5589.00
March Flows										
Q_{02}	5341.00	5341.00	7323.00	7326.00	7621.	7624.	19235.	19241.	23600.00	23624.00
Q_{10}	3990.00	3990.00	5275.00	5278.00	5486.	5489.	11771.	11776.	13300.00	13317.00
Q_{25}	3130.00	3130.00	3973.00	3976.00	4129.	4132.	8359.	8364.	9200.00	9215.00
Q_{50}	2330.00	2330.00	3035.00	3038.00	3151.	3154.	5241.	5246.	5910.00	5918.00
Q_{75}	1690.00	1690.00	2020.00	2023.00	2093.	2096.	3143.	3148.	3500.00	3502.00
Q_{90}	1230.00	1230.00	1520.00	1523.00	1572.	1575.	2160.	2164.	2320.00	2317.00
Q_{98}	822.00	822.00	932.00	935.00	959.	962.	1214.	1218.	1366.00	1354.00
Q_{mean}	2515.00	2515.00	3242.00	3245.00	3367.	3370.	6377.	6382.	7240.00	7254.00
April Flows										
Q_{02}	5480.00	5480.00	7420.00	7423.00	7722.	7725.	18622.	18628.	21000.00	21024.00
Q_{10}	4320.00	4320.00	5830.00	5833.00	6065.	6068.	12925.	12930.	14200.00	14217.00
Q_{25}	3680.00	3680.00	4630.00	4633.00	4814.	4817.	9329.	9334.	10500.00	10515.00
Q_{50}	2650.00	2650.00	3430.00	3433.00	3563.	3566.	6203.	6208.	7000.00	7010.00
Q_{75}	1700.00	1700.00	2130.00	2133.00	2208.	2211.	3276.	3281.	3775.00	3778.00
Q_{90}	1346.00	1346.00	1600.00	1603.00	1656.	1659.	2331.	2336.	2660.00	2660.00
Q_{98}	1108.00	1108.00	1280.00	1283.00	1322.	1325.	1756.	1760.	1960.00	1950.00
Q_{mean}	2781.00	2781.00	3576.00	3579.00	3715.	3718.	6938.	6943.	7844.00	7858.00
May Flows										
Q_{02}	4886.00	4886.00	6684.00	6687.00	6955.	6958.	19783.	19789.	24624.00	24648.00
Q_{10}	3910.00	3907.00	5134.00	5134.00	5339.	5339.	10715.	10717.	12400.00	12413.00
Q_{25}	3005.00	3000.00	3885.00	3883.00	4037.	4035.	7352.	7352.	8290.00	8297.00
Q_{50}	2000.00	1995.00	2560.00	2558.00	2656.	2654.	4376.	4376.	4830.00	4831.00
Q_{75}	1390.00	1382.00	1720.00	1715.00	1781.	1776.	2693.	2690.	3020.00	3014.00
Q_{90}	1133.00	1123.00	1306.00	1299.00	1349.	1342.	1924.	1919.	2030.00	2019.00
Q_{98}	790.00	777.00	932.00	922.00	959.	949.	1165.	1156.	1150.00	1126.00
Q_{mean}	2285.00	2278.00	2930.00	2926.00	3042.	3038.	5684.	5682.	6504.00	6509.00
June Flows										
Q_{02}	4274.00	4270.00	5826.00	5825.00	6060.	6059.	14014.	14016.	17000.00	17020.00
Q_{10}	2900.00	2890.00	3660.00	3653.00	3803.	3796.	8623.	8618.	9930.00	9936.00
Q_{25}	2000.00	1988.00	2550.00	2541.00	2646.	2637.	4926.	4919.	5690.00	5689.00
Q_{50}	1470.00	1458.00	1800.00	1791.00	1864.	1855.	2941.	2934.	3330.00	3321.00
Q_{7S}	1100.00	1082.00	1280.00	1265.00	1322.	1307.	1920.	1907.	2180.00	2162.00
Q_{90}	852.00	828.00	928.00	907.00	955.	934.	1238.	1218.	1290.00	1261.00
Q_{98}	579.00	541.00	628.00	593.00	643.	608.	735.	701.	790.00	740.00
Q_{mean}	1695.00	1680.00	2106.00	2094.00	2183.	2171.	4053.	4043.	4677.00	4672.00

Appendix A. Continued

Location

Flow Type	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(S)	(9)	(10)
July Flows										
Q_{02}	3042.00	3032.00	3760.00	3753.00	3907.	3900.	11308.	11303.	11816.00	11825.00
Q_{10}	1874.00	1856.00	2354.00	2339.00	2442.	2427.	5033.	5020.	5620.00	5616.00
Q_{25}	1380.00	1359.00	1670.00	1652.00	1729.	1711.	2925.	2909.	3325.00	3309.00
Q_{50}	1040.00	1016.00	1210.00	1189.00	1249.	1228.	1752.	1733.	1980.00	1957.00
Q_{75}	825.00	795.00	929.00	902.00	956.	929.	1222.	1196.	1350.00	1314.00
Q_{90}	638.00	600.00	694.00	659.00	711.	676.	838.	804.	900.00	851.00
Q_{98}	458.00	396.00	478.00	419.00	486.	427.	516.	458.	487.00	406.00
Q_{mean}	1189.00	1161.00	1414.00	1389.00	1462.	1437.	2583.	2560.	2912.00	2890.00
August Flows										
Q_{02}	2120.00	2110.00	2751.00	2744.00	2855.	2S48.	6111.	6106.	6981.00	6988.00
Q_{10}	1390.00	1374.00	1610.00	1597.00	1666.	1653.	2623.	2612.	2994.00	2985.00
Q_{25}	1010.00	992.00	1170.00	1155.00	1207.	1192.	1632.	1619.	1880.00	1862.00
Q_{50}	786.00	766.00	900.00	883.00	926.	909.	1134.	1118.	1260.00	1233.00
Q_{75}	625.00	600.00	710.00	688.00	728.	706.	849.	828.	890.00	854.00
Q_{90}	530.00	498.00	594.00	565.00	607.	578.	669.	641.	680.00	633.00
Q_{98}	408.00	362.00	424.00	381.00	430.	387.	458.	416.	468.00	431.00
Q_{mean}	896.00	874.00	1032.00	1013.00	1064.	1045.	1499.	1482.	1683.00	1664.00
September Flows										
Q_{02}	2274.00	2274.00	2972.00	2975.00	3086.	3089.	7814.	7819.	8500.00	8515.00
Q_{10}	1230.00	1228.00	1540.00	1541.00	1593.	1594.	2545.	2548.	2810.00	2810.00
Q_{25}	885.00	881.00	1020.00	1019.00	1051.	1050.	1332.	1332.	1560.00	1550.00
Q_{50}	689.00	693.00	745.00	752.00	765.	772.	861.	869.	956.00	949.00
Q_{75}	570.00	564.00	620.00	617.00	634.	631.	692.	690.	724.00	703.00
Q_{90}	501.00	494.00	540.00	536.00	551.	547.	593.	590.	608.00	582.00
Q_{98}	405.00	396.00	422.00	416.00	428.	422.	453.	448.	478.00	468.00
Q_{mean}	813.00	808.00	934.00	932.00	962.	960.	1416.	1416.	1601.00	1595.00
October Flows										
Q_{02}	3452.00	3452.00	4219.00	4222.00	4385.	4388.	8003.	8003.	9451.00	9467.00
Q_{10}	1690.00	1690.00	2310.00	2313.00	2396.	2399.	4021.	4026.	4440.00	4446.00
Q_{25}	1110.00	1110.00	1260.00	1263.00	1301.	1304.	1857.	1861.	2160.00	2157.00
Q_{50}	794.00	794.00	870.00	873.00	895.	898.	1063.	1067.	1200.00	1189.00
Q_{75}	640.00	640.00	687.00	690.00	704.	707.	786.	790.	848.00	833.00
Q_{90}	555.00	555.00	580.00	583.00	593.	596.	648.	652.	678.00	656.00
Q_{98}	455.00	455.00	460.00	463.00	467.	470.	506.	510.	520.00	497.00
Q_{mean}	1009.00	1009.00	1183.00	1186.00	1221.	1224.	1834.	1839.	2060.00	2061.00
November Flows										
Q_{02}	3680.00	3680.00	4660.00	4663.00	4845.	4848.	9155.	9160.	11300.00	11317.00
Q_{10}	2150.00	2150.00	2680.00	2683.00	2781.	2784.	4961.	4966.	5380.00	5388.00
Q_{25}	1490.00	1490.00	1800.00	1803.00	1864.	1867.	2801.	2806.	3205.00	3206.00
Q_{50}	1020.00	1020.00	1110.00	1113.00	1145.	1148.	1599.	1603.	1800.00	1793.00
Q_{75}	784.00	784.00	850.00	853.00	874.	877.	1023.	1027.	1110.00	1097.00
Q_{90}	605.00	605.00	668.00	671.00	684.	687.	762.	766.	845.00	826.00
Q_{98}	505.00	505.00	484.00	487.00	492.	495.	534.	538.	600.00	570.00
Q_{mean}	1249.00	1249.00	1468.00	1471.00	1518.	1521.	2360.	2365.	2759.00	2760.00
December Flows										
Q_{02}	4025.00	4025.00	5930.00	5933.00	6169.	6172.	15638.	15643.	17870.00	17910.00
Q_{10}	2994.00	2994.00	3840.00	3843.00	3990.	3993.	8175.	8180.	9390.00	9404.00
Q_{25}	1940.00	1940.00	2400.00	2403.00	2490.	2493.	4090.	4095.	4800.00	4803.00
Q_{50}	1290.00	1290.00	1520.00	1523.00	1572.	1575.	2254.	2258.	2600.00	2596.00
Q_{75}	912.00	912.00	960.00	963.00	989.	992.	1259.	1263.	1400.00	1389.00
Q_{90}	713.00	713.00	731.00	734.00	750.	753.	861.	865.	950.00	933.00
Q_{98}	540.00	540.00	578.00	581.00	590.	593.	649.	653.	700.00	675.00
Q_{mean}	1569.00	1569.00	1945.00	1948.00	2015.	2018.	3523.	3528.	4110.00	4114.00

Appendix A. Continued

	Location							
Flow Type	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Q_{01}	2565.30	3999.00	12900.00	3419.00	75.85	15S4.26	1255.68	2379.47
Q_{02}	2100.61	3290.00	10100.00	2598.01	55.00	1197.00	S94.S9	1654.62
Q_{05}	1470.00	2210.00	4660.00	1620.00	32.00	689.86	518.84	939.58
Q_{10}	1040.00	1550.00	3440.00	985.00	21.00	437.71	316.10	562.44
Q_{15}	780.00	1170.00	2050.00	657.50	16.00	316.71	227.81	391.31
Q_{25}	454.25	694.00	1090.00	361.00	10.00	211.60	137.34	226.72
Q_{40}	252.00	366.00	735.00	174.00	6.20	130.50	73.5S	113.36
Q_{50}	178.00	254.00	465.00	115.00	4.40	100.33	49.05	68.13
Q_{60}	120.00	166.00	166.00	70.00	3.00	75.83	31.39	36.41
Q_{75}	59.00	73.00	187.00	25.00	1.70	50.48	15.15	9.19
Q_{85}	37.00	42.00	107.00	14.00	1.10	36.47	9.50	3.25
Q_{90}	26.00	31.00	80.00	10.00	0.74	29.71	7.43	1.99
Q_{95}	19.00	21.00	55.00	7.00	0.40	21.82	5.61	1.18
Q_{98}	14.00	15.00	38.00	5.00	0.20	17.49	4.26	0.68
Q_{99}	11.40	12.00	28.00	4.10	0.06	14.62	3.52	0.41
Q_{mean}	382.40	568.90	1657.00	365.20	9.40	194.39	135.16	229.99
Low Flows								
$Q_{1,2}$	20.00	26.00	57.00	7.00	0.33	23.50	6.11	1.52
$Q_{1,10}$	8.90	9.60	20.00	3.27	0.00	13.00	2.78	0.23
$Q_{1,25}$	7.40	7.90	12.50	2.66	0.00	6.56	2.0S	0.02
$Q_{1,50}$	6.30	7.00	10.50	2.50	0.00	6.00	1.33	0.00
$Q_{7,2}$	22.40	28.29	61.00	8.74	0.40	25.08	7.13	1.91
$Q_{7,10}$	10.00	10.60	24.00	3.62	0.04	14.00	3.35	0.34
$Q_{7,25}$	8.26	8.70	16.00	3.21	0.00	7.30	2.40	0.07
$Q_{7,50}$	7.30	7.80	14.00	2.89	0.00	6.70	1.58	0.00
$Q_{15,2}$	24.70	29.47	69.00	11.65	0.56	27.62	8.20	2.33
$Q_{15,10}$	10.60	11.80	27.00	3.81	0.08	14.80	3.95	0.53
$Q_{15,25}$	8.66	9.80	18.00	3.66	0.02	8.40	2.79	0.20
$Q_{15,50}$	7.80	8.70	16.30	3.44	0.00	7.60	2.05	0.00
$Q_{31,2}$	28.23	34.87	87.00	12.97	0.82	31.16	9.57	2.95
$Q_{31,10}$	12.43	14.00	33.00	4.40	0.14	16.57	4.64	0.83
$Q_{31,25}$	10.60	11.50	24.00	3.95	0.04	11.00	3.47	0.48
$Q_{31,50}$	9.44	10.40	22.00	3.95	0.01	9.88	2.53	0.19
$Q_{61,2}$	36.00	46.67	117.00	16.38	1.43	40.06	1Z10	4.68
$Q_{61,10}$	14.50	16.50	37.00	5.69	0.23	17.10	5.38	1.16
$Q_{61,25}$	11.69	12.30	33.00	4.89	0.09	13.96	3.93	0.65
$Q_{61,50}$	10.30	11.62	30.00	4.63	0.05	12.00	3.01	0.40
$Q_{91,2}$	51.92	67.68	172.00	23.42	1.80	49.48	15.26	7.71
$Q_{91,10}$	16.57	18.50	45.00	6.72	0.28	21.50	6.08	1.36
$Q_{91,25}$	13.28	15.11	41.00	5.84	0.17	16.13	4.46	0.82
$Q_{91,50}$	11.45	12.79	38.00	5.72	0.12	14.76	3.41	0.59
Drought Flows								
$Q_{6,10}$	27.30	34.75	105.00	17.66	0.60	28.24	8.45	3.30
$Q_{6,25}$	22.18	30.65	72.00	11.08	0.30	23.55	6.25	1.55
$Q_{6,50}$	20.50	27.21	60.00	8.62	0.29	21.03	5.33	1.06
$Q_{9,10}$	92.92	138.59	288.00	57.34	1.39	56.51	17.33	21.26
$Q_{9,25}$	59.00	98.00	190.00	45:16	0.62	36.11	11.45	8.93
$Q_{9,50}$	43.40	76.00	141.00	22.02	0.59	29.76	9.01	5.20
$Q_{12,10}$	166.77	237.47	587.00	151.53	2.83	79.18	38.59	56.57
$Q_{12,25}$	104.00	152.00	390.00	84.94	1.35	54.00	24.53	28.67
$Q_{12,50}$	76.00	120.00	298.00	76.87	1.30	40.72	18.20	18.09
$Q_{18,10}$	234.74	326.61	679.00	178.74	4.35	111.64	46.76	77.17
$Q_{18,25}$	134.00	184.00	442.00	97.89	1.41	65.46	27.25	37.82
$Q_{18,50}$	100.00	152.00	349.00	73.68	1.19	47.00	21.26	24.96
$Q_{30,10}$	290.95	414.59	857.00	250.01	6.71	150.74	81.86	137.34
$Q_{30,25}$	16400	23459	626.00	131.00	2.37	91.37	44.80	73.79
$Q_{30,50}$	120.00	184.00	536.00	119.97	1.82	63.33	34.44	50.36

Appendix A. Concluded

Flow Type	Location (11)	(12)	(13)	(14)	(15)	(16)	(17)	(IS)
July Flows								
Q_{02}	1400.00	2418.00	8090.00	2000.00	40.00	540.50	677.98	1244.78
Q_{10}	522.00	1040.00	2650.00	620.00	14.00	194.00	188.57	341.17
Q_{25}	187.00	338.00	1110.00	221.00	6.60	118.00	81.42	140.61
Q_{50}	93.00	140.00	408.00	93.00	3.40	76.00	34.66	55.81
Q_{75}	53.75	75.00	174.00	42.00	2.00	52.00	16.57	21.04
Q_{90}	33.00	42.00	85.00	17.00	1.30	37.00	8.97	7.38
Q_{98}	18.00	20.00	37.00	9.16	0.70	25.00	4.70	2.45
Q_{mean}	215.33	382.96	1112.00	276.20	7.74	114.83	95.81	166.77
Au prist Plows								
Q_{02}	531.00	746.80	3270.00	1214.00	15.00	332.04	510.12	907.97
Q_{10}	175.00	293.00	1000.00	182.00	5.70	113.00	102.13	139.52
Q_{25}	89.00	131.00	349.00	60.00	3.20	73.00	37.93	38.37
Q_{50}	46.00	62.00	152.00	27.00	1.70	48.00	17.00	12.43
Q_{75}	30.00	37.00	84.00	14.00	0.90	33.00	8.99	4.52
Q_{90}	20.00	23.00	50.00	8.50	0.40	24.00	5.85	1.87
Q_{98}	11.00	11.00	26.00	5.20	0.15	16.00	3.58	0.87
O_{mean}	87.40	128.71	431.50	109.57	2.90	71.88	59.84	87.75
September Flows								
Q_{02}	1214.00	1520.00	5220.00	1210.00	21.40	405.20	487.23	852.38
Q_{10}	257.00	283.00	926.00	119.00	5.00	134.00	101.70	126.44
Q_{25}	67.00	75.00	213.00	31.00	2.00	59.00	28.56	20.49
Q_{50}	35.00	40.00	96.00	15.00	1.10	34.00	13.41	4.20
Q_{75}	20.00	24.00	52.00	7.80	0.40	26.00	6.97	1.58
Q_{90}	15.00	16.00	36.00	5.10	0.15	18.00	4.36	0.69
Q_{98}	9.86	9.60	20.00	3.70	0.02	9.20	2.61	0.17
Q_{mean}	120.10	135.56	456.10	100.80	2.56	67.55	56.46	78.70
October Flows								
Q_{02}	890.00	1392.00	4690.00	850.40	18.50	485.50	462.16	784.80
Q_{10}	330.00	524.00	1600.00	256.00	8.80	209.50	132.98	197.29
Q_{25}	135.00	186.00	452.00	46.00	4.97	90.75	47.85	46.54
Q_{50}	54.00	58.00	133.00	18.00	1.70	43.00	14.61	4.93
Q_{75}	25.00	29.00	72.00	10.00	1.00	27.00	7.66	1.68
Q_{90}	17.00	16.00	46.00	6.40	0.23	17.00	5.20	0.80
Q_{98}	9.40	11.00	28.00	4.20	0.01	13.00	3.47	0.27
Q_{mean}	132.36	191.36	613.00	91.82	3.64	91.08	61.26	86.11
November Flows								
Q_{02}	1249.60	1860.00	5270.00	1640.00	25.40	527.90	461.07	820.77
Q_{10}	553.10	790.00	2140.00	483.00	12.00	249.60	171.13	268.14
Q_{25}	237.50	327.00	900.00	158.00	6.70	128.25	71.72	84.91
Q_{50}	97.00	107.00	271.00	36.00	2.50	48.00	24.96	13.19
Q_{75}	54.00	63.00	140.00	16.00	1.10	34.00	10.42	2.36
Q_{90}	24.00	28.00	76.00	8.00	0.60	22.00	6.80	0.93
Q_{98}	14.00	16.00	42.00	5.60	0.40	15.42	4.47	0.25
Q_{mean}	218.56	305.56	842.50	193.56	5.02	108.78	65.40	91.78
December Flows								
Q_{02}	1942.20	3002.00	10070.00	2665.99	42.88	932.06	709.59	1426.81
Q_{10}	1042.00	1580.00	4170.00	1000.00	15.00	339.00	225.63	402.21
Q_{25}	487.00	712.00	1580.00	328.00	7.80	160.00	95.70	150.42
Q_{50}	219.00	289.00	615.00	103.00	3.90	88.00	35.21	40.44
Q_{76}	74.75	81.00	210.00	27.00	1.60	45.00	11.45	4.77
Q_{90}	32.90	38.00	100.00	9.00	0.76	27.00	6.04	0.32
Q_{98}	18.00	20.00	42.00	4.80	0.21	13.96	3.93	0.00
Q_{mean}	397.72	569.21	1508.00	366.17	7.51	155.48	98.43	168.95

Appendix B. Discharges and Withdrawals: Location and Estimated Flow (cfs)

Name of discharge or withdrawal		Stream code[a]	River mile
1)	Wilmington discharge	Y	9.2
2)	Commonwealth Edison (Braidwood Power Plant)	Y	14.1
3)	Bourbonnais discharge	Y	29.6
4)	Bradley discharge	Y	30.5
5)	Kankakee discharge	Y	30.8
6)	Kankakee withdrawal (Consumers Illinois Water Co.)	Y	33.6
7)	Momence discharge	Y	47.7
8)	Joliet Arsenal discharge	YB	4.5
9)	Herscher discharge	YD	17.5
10)	Lehigh Quarry	YDN	5.9
11)	Manteno discharge	YEG	5.9
12)	Peotone discharge	YEGN	3.4
13)	Armstrong World Industries	YF	2.0
14)	Manteno Limestone Quarry	YF	7.8
15)	Watseka discharge	YG	35.4
16)	Gilman discharge	YGGEC	5.0
17)	Cissna Park discharge	YGIKP	3.1
18)	Beecher discharge	YH9	13.1
19)	Momence Quarry	YI	3.4

a The stream code is used by *ILSAM* to uniquely identify all streams in the watershed. The code for each stream is given in appendix C.

Appendix B. Continued

Flow Type	Location (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Q_{01}	1.54	0.00	2.43	3.77	20.55	-19.56	2.69	1.40	0.20	4.50
Q_{02}	1.3S	0.00	2.16	3.39	18.90	-19.56	2.43	1.22	0.18	4.50
Q_{05}	1.20	0.00	1.86	2.95	16.99	-19.56	2.14	1.01	0.16	4.50
Q_{10}	1.09	0.00	1.68	2.70	15.89	-19.56	1.97	0.89	0.15	4.50
Q_{15}	1.01	-0.40	1.55	2.51	15.07	-19.56	1.85	0.80	0.15	4.50
Q_{25}	0.94	-4.40	1.42	2.32	14.25	-19.56	1.72	0.71	0.14	4.50
Q_{40}	0.S6	-8.40	1.29	2.13	13.43	-19.56	1.60	0.62	0.13	4.50
Q_{50}	0.82	-10.40	1.22	2.04	13.02	-19.56	1.53	0.57	0.13	4.50
Q_{60}	0.78	-12.40	1.16	1.94	12.61	-19.56	1.47	0.53	0.13	4.50
Q_{75}	0.70	-16.40	1.03	1.75	11.79	-19.56	1.34	0.44	0.12	4.50
Q_{85}	0.64	-19.01	0.94	1.63	11.24	-19.56	1.26	0.38	0.11	4.50
Q_{90}	0.59	-21.68	0.85	1.50	10.69	-19.56	1.18	0.32	0.11	4.50
Q_{95}	0.54	-24.35	0.76	1.38	10.14	-19.56	1.09	0.26	0.10	4.50
Q_{98}	0.46	-28.36	0.63	1.19	9.32	-19.56	0.97	0.17	0.10	4.50
Q_{99}	0.38	-32.37	0.50	1.00	8.50	-19.56	0.84	0.08	0.09	4.50
Q_{mean}	0.S6	-8.33	1.29	2.13	13.43	-19.56	1.60	0.62	0.13	4.50
Low Flows										
$Q_{1,2}$	0.36	-32.79	0.48	0.96	8.14	-19.56	0.80	0.08	0.09	4.50
$Q_{1,10}$	0.31	-6.69	0.41	0.83	7.04	-19.56	0.70	0.07	0.07	4.50
$Q_{1,25}$	0.31	8.12	0.40	0.81	6.38	-19.56	0.68	0.06	0.07	4.50
$Q_{1,50}$	0.30	8.03	0.40	0.80	6.80	-19.56	0.67	0.06	0.07	4.50
$Q_{7,2}$	0.58	-22.22	0.83	1.48	10.58	-19.56	1.16	0.31	0.11	4.50
$Q_{7,10}$	0.38	-11.47	0.50	1.00	8.50	-19.56	0.84	0.08	0.09	4.50
$Q_{7,25}$	0.37	9.74	0.49	0.97	8.25	-19.56	0.82	0.08	0.09	4.50
$Q_{7,50}$	0.36	9.61	0.48	0.96	8.14	-19.56	0.80	0.08	0.09	4.50
$Q_{15,2}$	0.60	-21.15	0.37	1.53	10.80	-19.56	1.19	0.33	0.11	4.50
$Q_{15,10}$	0.42	-24..96	0.57	1.09	8.91	-19.56	0.90	0.12	0.09	4.50
$Q_{15,25}$	0.38	9.91	0.49	0.99	8.39	-19.56	0.83	0.08	0.09	4.50
$Q_{15,50}$	0.37	9.78	0.49	0.97	8.29	-19.56	0.32	0.08	0.09	4.50
$Q_{31,2}$	0.63	-19.81	0.91	1.59	11.07	-19.56	1.23	0.36	0.11	4.50
$Q_{31,10}$	0.45	-28.76	0.62	1.17	954	-19.56	0.95	0.16	0.10	4.50
$Q_{31,25}$	0.38	-5.47	0.50	1.00	8.50	-19.56	0.34	0.08	0.09	4.50
$Q_{31,50}$	0.38	9.91	0.49	0.99	8.39	-19.56	0.33	0.08	0.09	4.50
$Q_{61,2}$	0.66	-18.51	0.96	1.67	11.40	-19.56	1.58	0.40	0.12	4.50
$Q_{61,10}$	0.50	-26.36	0.70	1.58	9.73	-19.56	1.03	0.51	0.10	4.50
$Q_{61,25}$	0.42	-28.46	0.57	1.09	8.91	-19.56	0.90	0.12	0.09	4.50
$Q_{61,50}$	0.40	-7.17	0.53	1.04	8.66	-19.56	0.37	0.10	0.09	4.50
$Q_{91,2}$	0.70	-16.34	1.03	1.75	11.79	-19.56	1.34	0.44	0.12	4.50
$Q_{91,10}$	0.54	-24.35	0.76	1.38	10.14	-19.56	1.09	0.56	0.10	4.50
$Q_{91.25}$	046	-28.36	0.63	1.19	9.32	-19.56	0.97	0.17	0.10	4.50
$Q_{91,50}$	0.44	-29.56	0.59	1.13	9.07	-1936	0.93	0.14	0.10	4.50
Drought Flows										
$Q_{6,10}$	0.64	-19.01	0.94	1.63	11.54	-19.56	1.26	0.38	0.11	4.50
$Q_{6,25}$	0.38	-22.52	0.33	1.48	10.58	-19.56	1.16	0.31	0.11	4.50
$Q_{6,50}$	0.35	-23.32	0.78	1.40	10.55	-19.56	1.11	057	0.11	4.50
$Q_{9,10}$	0.72	-15.14	1.06	1.31	12.03	-19.56	1.38	0.47	0.12	4.50
$Q_{9,25}$	0.67	-17.68	0.98	1.69	11.51	-19.56	1.30	0.41	0.12	4.50
$Q_{9,50}$	0.63	-19.55	0.92	1.60	11.13	-19.56	1.24	0.37	0.11	430
$Q_{12,10}$	0.30	-11.33	1.19	1.99	12.31	-19.56	1.50	0.55	0.13	4.50
$Q_{12,25}$	0.74	-14.34	1.09	1.85	12.50	-19.56	1.41	0.48	0.12	4.50
$Q_{12,50}$	0.69	-16.61	1.02	1.74	11.73	-19.56	1.33	0.43	0.12	4.50
$Q_{18,10}$	0.32	-9.93	1.54	2.06	13.10	-19.56	1.54	0.58	0.13	4.50
$Q_{18,25}$	0.77	-12.73	1.14	1.92	12.32	-19.56	1.46	0.52	0.13	4.50
$Q_{18,50}$	0.72	-15.14	1.06	1.31	12.03	-19.56	1.38	0.47	0.12	4.50
$Q_{30,10}$	0.86	-7.93	1.30	2.15	13.31	-19.56	1.61	0.63	0.13	4.50
$Q_{30,25}$	0.31	-10.73	1.21	2.02	12.94	-19.56	1.52	0.57	0.13	4.50
$Q_{30.50}$	0.77	-12.73	1.14	1.92	12.52	-19.56	1.46	0.52	0.13	4.50

Appendix B. Continued

Flow Type	Location (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	q_0)
Drought Flows-Cont										
$Q_{54,10}$	0.92	-5.12	1.39	2.28	14.09	-19.56	1.70	0.69	0.14	4.50
$Q_{54,25}$	0.84	-9.33	1.26	2.08	13.22	-19.56	1.56	0.60	0.13	4.50
$Q_{54,50}$	0.81	-10.73	1.21	2.02	12.94	-19.56	1.52	0.57	0.13	4.50
January Flows										
Q_{02}	1.43	0.00	2.24	3.50	19.40	-19.56	2.51	1.27	0.19	4.50
Q_{10}	1.09	0.00	1.68	2.70	15.89	-19.56	1.97	0.89	0.15	4.50
Q_{25}	0.94	-4.32	1.42	2.32	14.25	-19.56	1.72	0.71	014	4.50
Q_{50}	0.62	-10.33	1.22	2.04	13.02	-19.56	1.53	0.57	0.13	4.50
Q_{75}	0.70	-16.34	1.03	1.75	11.79	-19.56	1.34	0.44	0.12	4.50
Q_{90}	0.59	-21.68	0.85	1.50	10.69	-19.56	1.18	0.32	0.11	4.50
Q_{98}	0.50	-26.36	0.70	1.28	9.73	-19.56	1.03	0.21	0.10	4.50
Q_{mean}	0.94	-4.32	1.42	2.32	14.25	-19.56	1.72	0.71	0.14	4.50
February Flows										
Q_{02}	1.50	0.00	2.35	3.65	20.05	-19.56	2.61	1.34	0.19	4.50
Q_{10}	1.15	0.00	1.77	2.82	16.44	-19.56	2.06	0.95	0.16	4.50
Q_{25}	1.00	-1.11	1.52	2.47	1451	-19.56	1.82	0.78	0.15	4.50
Q_{50}	0.86	-8.33	1.29	213	13.43	-19.56	1.60	0.62	0.13	4.50
Q_{75}	0.74	-14.34	1.09	1.85	12.20	-19.56	1.41	0.48	0.12	4.50
Q_{90}	0.66	-18.48	0.96	1.65	11.35	-19.56	1.28	0.39	0.11	4.50
Q_{98}	0.57	-22.75	0.82	1.45	10.47	-19.56	114	0.30	0.11	4.50
Q_{mean}	0.98	-2.32	1.49	2.41	14.66	-19.56	1.78	0.75	0.14	4.50
March Flows										
Q_{02}	1.54	0.00	2.43	3.77	20.55	-19.56	2.69	1.40	0.20	4.50
Q_{10}	1.20	0.00	1.86	2.95	1659	-19.56	214	1.01	0.16	4.50
Q_{25}	1.05	0.00	1.60	2.58	15.40	-19.56	1.90	0.83	0.15	4.50
Q_{50}	0.94	-4.32	1.42	2.32	14.25	-19.56	1.72	0.71	0.14	4.50
Q_{75}	0.84	-9.33	1.26	2.08	13.22	-19.56	1.56	0.60	0.13	4.50
Q_{90}	0.78	-12.33	116	1.94	12.61	-19.56	1.47	0.53	0.13	4.50
Q_{98}	0.64	-19.01	0.94	1.63	11.24	-19.56	1.26	0.38	0.11	4.50
Q_{mean}	1.01	-0.31	1.55	2.51	15.07	-1936	1.85	0.80	0.15	4.50
April Flows										
Q_{02}	1.54	0.00	2.43	3.77	20.55	-19.56	2.69	1.40	0.20	4.50
Q_{10}	1.20	0.00	1.36	2.95	1659	-19.56	214	1.01	0.16	4.50
Q_{25}	1.08	0.00	1.66	2.66	15.73	-19.56	155	0.37	0.15	4.50
Q_{50}	0.96	-3.12	1.46	2.38	14.50	-1936	1.76	0.74	0.14	4.50
Q_{75}	0.36	-8.33	1.29	2.13	13.43	-19.56	1.60	0.62	0.13	4.50
Q_{90}	0.31	-10.73	1.21	2.02	1254	-1936	132	0.57	0.13	4.50
Q_{98}	0.67	-17.68	0.98	1.69	11.51	-1936	130	0.41	0.12	4.50
Q_{mean}	1.04	0.00	1.59	2.57	1532	-1936	138	0.33	0.15	4.50
May Flows										
Q_{02}	1.54	0.00	2.43	3.77	20.35	-19.36	2.69	1.40	0.20	4.50
Q_{10}	1.15	0.00	1.77	2.82	16.44	-19.56	2.06	0.55	0.16	4.50
Q_{25}	0.98	-1.91	1.30	2.43	14.74	-19.56	1.30	0.76	0.14	4.50
Q_{50}	0.90	-6.32	1.35	2.23	13.34	-19.56	1.66	0.66	0.14	4.50
Q_{75}	0.84	-9.33	1.26	2.08	13.22	-19.56	1.36	0.60	0.13	4.50
Q_{90}	0.30	-1133	1.19	1.99	12.31	-1936	1.30	0.55	0.13	4.50
Q_{98}	0.66	-18.48	0.96	1.65	11.35	-19.56	1.28	0.39	0.11	4.50
Q_{mean}	0.99	-1.51	1.51	2.45	14.32	-19.56	1.31	0.77	0.15	4.50
June Flows										
Q_{02}	1.54	0.00	2.43	3.77	2035	-19.56	2.69	1.40	0.20	4.50
Q_{10}	1.15	0.00	1.77	2.32	16.44	-19.56	2.06	0.55	0.16	4.50
Q_{25}	0.37	-2.72	1.47	2.40	14.58	-19.56	1.77	0.74	0.14	4.50
Q_{50}	0.36	-8.33	1.29	2.13	13.43	-19.56	1.60	0.62	0.13	4.50
Q_{75}	0.30	-10.93	1.20	2.01	12.39	-1936	1.51	0.56	0.13	4.50
Q_{90}	0.75	-13.54	1.12	1.39	12.36	-19.56	1.43	0.30	0.12	4.50
Q_{98}	0.64	-19.01	0.94	1.63	11.24	-19.56	1.26	0.38	0.11	4.50
Q_{mean}	0.96	-3.12	1.46	2.38	14.30	-19.56	1.76	0.74	0.14	4.50

Appendix B. Continued

Flow Type	Location (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<u>July Flows</u>										
Q_{02}	1.29	0.00	2.01	3.17	17.95	-19.56	2.29	1.11	0.17	4.50
Q_{10}	1.01	-0.31	1.55	2.51	15.07	-19.56	1.85	0.80	0.15	4.50
Q_{25}	0.88	-7.12	1.33	2.19	13.67	-19.56	1.63	0.65	0.14	4.50
Q_{50}	0.82	-10.33	1.22	2.04	13.02	-19.56	1.53	0.57	0.13	4.50
Q_{75}	0.73	-14.74	1.08	1.83	12.11	-19.56	1.39	0.48	0.12	4.50
Q_{90}	0.67	-17.94	0.97	1.68	11.46	-19.56	1.29	0.40	0.12	4.50
Q_{98}	0.54	-24.35	0.76	1.38	10.14	-19.56	1.09	0.26	0.10	4.50
Q_{mean}	0.90	-6.32	1.35	2.23	13.84	-19.56	1.66	0.66	0.14	4.50
<u>August Flows</u>										
Q_{02}	1.20	0.00	1.86	2.95	16.99	-19.56	2.14	1.01	0.16	4.50
Q_{10}	0.92	-5.12	1.39	2.28	14.09	-19.56	1.70	0.69	0.14	4.50
Q_{25}	0.80	-10.93	1.20	2.01	12.89	-19.56	1.51	0.56	0.13	4.50
Q_{50}	0.72	-1514	1.06	1.81	12.03	-19.56	1.38	0.47	0.12	4.50
Q_{75}	0.66	-18.21	0.96	1.67	11.40	-19.56	1.28	0.40	0.12	4.50
Q_{90}	0.59	-21.68	0.85	1.50	10.69	-19.56	1.18	0.32	0.11	4.50
Q_{98}	0.46	5.04	0.63	1.19	9.32	-19.56	0.97	0.17	0.10	4.50
Q_{mean}	0.85	-8.73	1.27	2.11	13.35	-19.56	1.58	0.61	0.13	4.50
<u>September Flows</u>										
Q_{02}	1.09	0.00	1.68	2.70	15.89	-19.56	1.97	0.89	0.15	4.50
Q_{10}	0.84	-8.93	*127*	2.10	13.30	-19.56	1.58	0.61	0.13	4.50
Q_{25}	0.73	-14.74	1.08	1.83	12.11	-19.56	1.39	0.48	0.12	4.50
Q_{50}	0.67	-17.94	0.97	1.68	11.46	-19.56	1.29	0.40	012	4.50
Q_{75}	0.60	-21.15	0.87	1.53	10.80	-19.56	11.9	0.33	0.11	4.50
Q_{90}	0.54	-24.35	0.76	1.38	10.14	-19.56	1.09	0.26	0.10	4.50
Q_{99}	0.38	-3.97	0.50	1.00	8.50	-19.56	0.84	0.08	0.09	4.50
Q_{mean}	0.80	-11.33	1.19	1.99	12.81	-19.56	1.50	0.55	0.13	4.50
<u>October Flows</u>										
Q_{02}	113	0.00	1.73	2.77	16.22	-19.56	2.02	0.92	0.16	4.50
Q_{10}	0.90	-6.32	1.35	2.23	13.84	-19.56	1.66	0.66	0.14	4.50
Q_{25}	0.78	-11.93	117	1.96	12.69	-19.56	1.48	0.54	0.13	4.50
Q_{50}	0.67	-17.94	0.97	1.68	11.46	-19.56	1.29	0.40	0.12	4.50
Q_{75}	0.59	-21.68	0.85	1.50	10.69	-19.56	1.18	0.32	0.11	4.50
Q_{90}	0.50	-26.36	0.70	1.28	9.73	-19.56	1.03	0.21	0.10	4.50
Q_{98}	0.36	-25.39	0.48	0.96	8.14	-19.56	0.80	0.08	0.09	4.50
Q_{mean}	0.82	-10.33	1.22	2.04	13.02	-19.56	1.53	0.57	0.13	4.50
<u>November Flows</u>										
Q_{02}	1.18	0.00	1.82	2.90	16.77	-19.56	2.11	0.98	0.16	4.50
Q_{10}	0.54	-4.32	1.42	2.32	14.25	-19.56	1.72	0.71	0.14	4.50
Q_{25}	0.82	-9.93	1.24	2.06	13.10	-1956	1.54	0.58	0.13	4.50Q
Q_{50}	0.72	-15.14	1.06	1.81	12.03	-19.56	1.38	0.47	0.12	4.50
Q_{75}	0.63	-19.55	0.52	1.60	11.13	-19.56	1.24	0.37	0.11	4.50
Q_{90}	0.54	-24.35	0.76	1.38	10.14	-19.56	1.09	0.26	010	4.50
Q_{98}	0.38	-32.37	0.50	1.00	8.50	-19.56	0.84	0.08	0.09	4.50
Q_{mean}	0.82	-10.33	1.22	2.04	13.02	-19.56	1.53	0.57	0.13	4.50
<u>December Flows</u>										
Q_{02}	1.38	0.00	216	3.39	1850	0.00	2.43	1.22	0.18	4.50
Q_{10}	1.01	-0.31	1.55	2.51	15.07	-19.56	1.85	0.80	0.15	4.50
Q_{25}	0.86	-8.33	1.29	2.13	13.43	-19.56	1.60	0.62	0.13	4.50
Q_{50}	0.76	-13.13	113	1.91	12.44	-19.56	1.44	0.51	0.12	4.50
Q_{75}	0.66	-18.48	0.96	1.65	11.35	-19.56	1.28	0.39	0.11	4.50
Q_{90}	0.57	-23.02	031	1.44	10.42	-19.56	1.13	0.29	0.11	4.50
Q_{98}	0.44	-29.16	0.61	1.15	9.16	-19.56	0.54	0.15	0.10	4.50
Q_{mean}	0.87	-7.52	1.31	2.17	13.59	-19.56	1.62	0.64	0.13	4.50

Appendix B. Continued

Flow Type	Location (11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Q_{01}	1.04	0.S6	0.97	6.78	2.57	0.92	0.15	0.51	2.60
Q_{02}	0.95	0.78	0.85	6.06	2.32	0.81	0.13	0.45	2.60
Q_{05}	0.85	0.6S	0.72	5.22	2.04	0.68	0.12	0.39	2.60
Q_{10}	0.79	0.63	0.64	4.74	1.87	0.60	0.11	0.35	2.60
Q_{15}	0.75	0.59	0.59	4.38	1.75	0.55	010	0.33	2.60
Q_{25}	0.70	0.55	0.53	4.02	1.63	0.49	0.09	0.30	2.60
Q_{40}	0.66	0.50	0.47	3.66	1.50	0.44	0.09	0.27	2.60
Q_{50}	0.64	0.48	0.44	3.48	1.44	0.41	0.08	0.26	2.60
Q_{60}	0.62	0.46	0.41	3.30	1.38	0.38	0.08	0.25	2.60
Q_{75}	0.57	0.42	0.36	254	1.26	0.33	0.07	0.22	2.60
Q_{85}	0.55	0.40	0.32	2.70	1.18	0.29	0.06	0.20	2.60
Q_{90}	0.52	0.37	0.28	2.46	1.10	0.26	0.06	0.18	2.60
Q_{95}	0.49	0.34	0.24	2.22	1.01	0.22	0.05	0.17	2.60
Q_{98}	0.44	0.30	0.19	1.56	0.89	0.17	0.05	0.14	2.60
Q_{99}	0.40	0.26	0.13	1.50	0.77	0.11	0.04	0.11	2.60
Q_{mean}	0.66	0.50	0.47	3.66	1.50	0.44	0.09	0.27	2.60
Low Flows									
$Q_{1,2}$	0.38	0.25	012	1.44	0.74	011	0.04	0.11	2.60
$Q_{1,10}$	0.33	0.22	011	1.24	0.64	0.09	0.03	0.09	2.60
$Q_{1,25}$	0.32	0.21	Oil	1.21	0.62	0.09	0.03	0.09	2.60
$Q_{1,50}$	0.32	0.21	010	1.20	0.62	0.09	0.03	0.09	2.60
$Q_{7,2}$	0.51	0.36	0.27	2.41	1.08	0.25	0.06	018	2.60
$Q_{7,10}$	0.40	0.26	013	1.50	0.77	0.11	0.04	0.11	2.60
$Q_{7,25}$	0.39	0.25	0.13	1.46	0.75	0.11	0.04	0.11	2.60
$Q_{7,50}$	0.38	0.25	012	1.44	0.74	0.11	0.04	0.11	2.60
$Q_{15,2}$	0.52	0.37	0.29	2.51	1.11	0.26	0.06	0.19	2.60
$Q_{15,10}$	0.42	0.28	016	1.68	0.83	014	0.04	0.13	2.60
$Q_{15,25}$	0.39	0.26	0.13	1.48	0.76	0.11	0.04	0.11	2.60
$Q_{15,50}$	0.39	0.25	013	1.46	0.75	0.11	0.04	0.11	2.60
$Q_{31,2}$	0.54	0.39	031	2.63	115	0.28	0.06	0.20	2.60
$Q_{31,10}$	0.44	030	0.18	1.82	0.88	016	0.05	0.14	2.60
$Q_{31.25}$	0.40	0.26	0.13	1.50	0.77	0.11	0.04	0.11	2.60
$Q_{31,50}$	0.39	0.26	0.13	1.48	0.76	0.11	0.04	0.11	2.60
$Q_{61,2}$	0.55	0.40	0.33	2.77	1.20	0.30	0.07	0.21	2.60
$Q_{61,10}$	0.47	0.32	0.22	2.04	0.95	0.19	0.05	0.15	2.60
$Q_{61,25}$	0.42	0.28	016	1.68	0.83	0.14	0.04	0.13	2.60
$Q_{61,50}$	0.41	0.27	014	1.57	0.79	0.12	0.04	0.12	2.60
$Q_{91,2}$	0.57	0.42	0.36	2.94	1.26	0.33	0.07	0.22	2.60
$Q_{91,10}$	0.49	0.34	0.24	2.22	1.01	0.22	0.05	0.17	2.60
$Q_{91.25}$	0.44	0.30	0.19	1.86	0.59	0.17	0.05	0.14	2.60
$Q_{91,50}$	0.43	0.29	0.17	1.75	0.86	0.15	0.05	0.13	2.60
Drought Flows									
$Q_{6,10}$	0.55	0.40	0.32	2.70	118	0.29	0.06	0.20	2.60
$Q_{6,25}$	0.51	0.36	0.27	2.41	1.08	0.25	0.06	0.18	2.60
$Q_{6,50}$	0.49	0.35	0.25	2.27	1.03	0.23	0.06	0.17	2.60
$Q_{9,10}$	0.59	0.44	0.38	3.05	130	0.35	0.07	0.23	2.60
$Q_{9,25}$	0.56	0.41	0.34	2.32	1.22	0.31	0.07	0.21	2.60
$Q_{9,50}$	0.54	0.39	0.31	2.65	116	0.29	0.06	0.20	2.60
$Q_{12,10}$	0.63	0.47	0.43	3.39	1.41	0.40	0.08	0.25	2.60
$Q_{12,25}$	0.60	0.44	0.39	3.12	1.32	0.36	0.07	0.23	2.60
$Q_{12,50}$	0.57	0.42	0.35	2.51	1.25	0.33	0.07	0.22	2.60
$Q_{18,10}$	0.64	0.49	0.45	3.51	1.46	0.42	0.08	0.26	2.60
$Q_{18,25}$	0.61	0.46	0.41	3.26	1.37	0.38	0.08	0.24	2.60
$Q_{18,50}$	0.59	0.44	0.38	3.05	1.30	0.35	0.07	0.23	2.60
$Q_{30,10}$	0.67	0.51	0.48	3.69	1.52	0.45	0.09	0.28	2.60
$Q_{30.25}$	0.63	0.48	0.44	3.44	1.43	0.41	0.08	0.26	2.60
$Q_{30.50}$	0.61	0.46	0.41	3.26	1.37	0.38	0.08	0.24	2.60

Appendix B. Continued

Flow Type	Location (11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Drought Flows-Cont.									
$Q_{54,10}$	0.70	0.54	0.52	3.95	1.60	0.48	0.09	0.30	2.60
$Q_{54,25}$	0.65	0.49	0.46	3.57	1.47	0.43	0.08	0.27	2.60
$Q_{54,50}$	0.63	0.48	0.44	3.44	1.43	0.41	0.08	0.26	2.60
January Flows									
Q_{02}	0.98	0.80	0.S9	6.27	2.40	0.84	0.14	0.47	2.60
Q_{10}	0.79	0.63	0.64	4.74	1.87	0.60	0.11	0.35	2.60
Q_{25}	0.70	0.55	0.53	4.02	1.63	0.49	0.09	0.30	2.60
Q_{50}	0.64	0.48	0.44	3.48	1.44	0.41	0.08	0.26	2.60
Q_{75}	0.57	0.42	0.36	2.94	1.26	0.33	0.07	0.22	2.60
Q_{90}	0.52	0.37	0.28	2.46	1.10	0.26	0.06	0.18	2.60
Q_{98}	0.47	0.32	0.22	2.04	0.95	0.19	0.05	0.15	2.60
Q_{meaa}	0.70	0.55	0.53	4.02	1.63	0.49	0.09	0.30	2.60
February Flows									
Q_{02}	1.01	0.83	0.93	6.56	2.49	0.88	0.15	0.49	2.60
Q_{10}	0.82	0.65	0.68	4.98	1.95	0.64	0.11	0.37	2.60
Q_{25}	0.74	0.58	0.57	4.31	1.73	0.54	0.10	0.32	2.60
Q_{50}	0.66	0.50	0.47	3.66	1.50	0.44	0.09	0.27	2.60
Q_{75}	0.60	0.44	0.39	3.12	1.32	0.36	0.07	0.23	2.60
Q_{90}	0.55	0.40	0.33	2.75	1.19	0.30	0.07	0.21	2.60
Q_{98}	0.50	0.36	0.27	2.36	1.06	0.24	0.06	0.18	2.60
Q_{mean}	0.73	0.57	0.56	4.20	1.69	0.52	0.10	0.31	2.60
March Flows									
Q_{02}	1.04	0.86	0.97	6.78	2.57	0.92	0.15	0.51	2.60
Q_{10}	0.85	0.68	0.72	5.22	2.04	0.68	0.12	0.39	2.60
Q_{25}	0.77	0.60	0.61	4.52	1.80	0.57	0.10	0.34	2.60
Q_{50}	0.70	0.55	0.53	4.02	1.63	0.49	0.09	0.30	2.60
Q_{75}	0.65	0.49	0.46	3.57	1.47	0.43	0.08	0.27	2.60
Q_{90}	0.62	0.46	0.41	3.30	1.38	0.38	0.08	0.25	2.60
Q_{98}	0.55	0.40	0.32	2.70	1.18	0.29	0.06	0.20	2.60
Q_{mean}	0.75	0.59	0.59	4.38	1.75	0.55	0.10	0.33	2.60
April Flows									
Q_{02}	1.04	0.86	0.97	6.78	2.57	0.92	0.15	0.51	2.60
Q_{10}	0.85	0.68	0.72	5.22	2.04	0.68	0.12	0.39	2.60
Q_{25}	0.78	0.62	0.63	4.67	1.85	0.59	0.11	0.35	2.60
Q_{50}	0.72	0.56	0.55	4.13	1.66	0.51	0.09	0.31	2.60
Q_{75}	0.66	0.50	0.47	3.66	1.50	0.44	0.09	0.27	2.60
Q_{90}	0.63	0.48	0.44	3.44	1.43	0.41	0.08	0.26	2.60
Q_{98}	0.56	0.41	0.34	2.82	122	0.31	0.07	0.21	2.60
Q_{mean}	0.76	0.60	0.60	4.49	1.79	0.57	0.10	0.34	2.60
May Flows									
Q_{02}	1.04	0.86	0.97	6.78	2.57	0.92	0.15	0.51	2.60
Q_{10}	0.82	0.65	0.68	4.98	1.95	0.64	0.11	0.37	2.60
Q_{25}	0.73	0.57	0.56	4.23	1.70	0.53	0.10	0.32	2.60
Q_{50}	0.68	0.53	0.50	3.84	1.57	0.47	0.09	0.29	2.60
Q_{75}	0.65	0.49	0.46	3.57	1.47	0.43	0.08	0.27	2.60
Q_{90}	0.63	0.47	0.43	3.39	1.41	0.40	0.08	0.25	2.60
Q_{98}	0.55	0.40	0.33	2.75	1.19	0.30	0.07	0.21	2.60
Q_{mean}	0.73	0.57	0.57	4.27	1.71	0.53	0.10	0.32	2.60
June Flows									
Q_{02}	1.04	0.86	0.37	6.78	2.57	0.92	0.15	0.51	2.60
Q_{10}	0.82	0.65	0.68	4.98	1.95	0.64	0.11	0.37	2.60
Q_{25}	0.72	0.56	0.55	4.16	1.68	0.52	0.10	0.31	2.60
Q_{50}	0.66	0.50	0.47	3.66	1.50	0.44	0.09	0.27	2.60
Q_{75}	0.63	0.48	0.43	3.42	1.43	0.40	0.08	0.26	2.60
Q_{90}	0.60	0.45	0.40	3.19	1.35	0.37	0.08	0.24	2.60
Q_{98}	0.55	0.40	0.32	2.70	1.18	0.29	0.06	0.20	2.60
Q_{mean}	0.72	0.56	0.55	4.13	1.66	0.51	0.09	0.31	2.60

Appendix B. Continued

Flow Type	Location (11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
July Flows									
Q_{02}	0.90	0.73	0.79	5.64	2.18	0.74	0.13	0.42	2.60
Q_{10}	0.75	0.59	0.59	4.38	1.75	0.55	0.10	0.33	2.60
Q_{25}	0.67	0.52	0.49	3.77	1.54	0.46	0.09	0.28	2.60
Q_{50}	0.64	0.48	0.44	3.48	1.44	0.41	0.08	0.26	2.60
Q_{75}	0.59	0.44	0.38	3.08	1.31	0.35	0.07	0.23	2.60
Q_{90}	0.56	0.41	0.34	2.79	1.21	0.31	0.07	0.21	2.60
Q_{98}	0.49	0.34	0.24	2.22	1.01	0.22	0.05	0.17	2.60
Q_{mean}	0.68	0.53	0.50	3.84	1.57	0.47	0.09	0.29	2.60
August Flows									
Q_{02}	0.85	0.68	0.72	5.22	2.04	0.68	0.12	0.39	2.60
Q_{10}	0.70	0.54	0.52	3.95	1.60	0.48	0.09	0.30	2.60
Q_{25}	0.63	0.48	0.43	3.42	1.43	0.40	0.08	0.26	2.60
Q_{50}	0.59	0.44	0.38	3.05	1.30	0.35	0.07	0.23	2.60
Q_{75}	0.55	0.40	0.33	2.77	1.20	0.30	0.07	0.21	2.60
Q_{90}	0.52	0.37	0.28	2.46	1.10	0.26	0.06	0.18	2.60
Q_{98}	0.44	0.30	0.19	1.86	0.89	0.17	0.05	0.14	2.60
Q_{mean}	0.66	0.50	0.47	3.62	1.49	0.43	0.08	0.27	2.60
September Flows									
Q_{02}	0.79	0.63	0.64	4.74	1.87	0.60	0.11	0.35	2.60
Q_{10}	0.65	0.50	0.46	3.60	1.49	0.43	0.08	0.27	2.60
Q_{25}	0.59	0.44	0.38	3.08	1.31	0.35	0.07	0.23	2.60
Q_{50}	0.56	0.41	0.34	2.79	1.21	0.31	0.07	0.21	2.60
Q_{75}	0.52	0.37	0.29	2.51	1.11	0.26	0.06	0.19	2.60
Q_{90}	0.49	0.34	0.24	2.22	1.01	0.22	0.05	0.17	2.60
Q_{98}	0.40	0.26	0.13	1.50	0.77	0.11	0.04	0.11	2.60
Q_{mean}	0.63	0.47	0.43	3.39	1.41	0.40	0.08	0.25	2.60
October Flows									
Q_{02}	0.81	0.64	0.67	4.88	1.92	0.63	0.11	0.37	2.60
Q_{10}	0.68	0.53	0.50	3.84	1.57	0.47	0.09	0.29	2.60
Q_{25}	0.62	0.47	0.42	3.33	1.39	0.39	0.08	0.25	2.60
Q_{50}	0.56	0.41	0.34	2.79	1.21	0.31	0.07	0.21	2.60
Q_{75}	0.52	0.37	0.28	2.46	1.10	0.26	0.06	0.18	2.60
Q_{90}	0.47	0.32	0.22	2.04	0.95	0.19	0.05	0.15	2.60
Q_{98}	0.38	0.25	0.12	1.44	0.74	0.11	0.04	0.11	2.60
Q_{mean}	0.64	0.48	0.44	3.48	1.44	0.41	0.08	0.26	2.60
November Flows									
Q_{02}	0.84	0.67	0.70	5.12	2.00	0.66	0.12	0.38	2.60
Q_{10}	0.70	0.55	0.53	4.02	1.63	0.49	0.09	0.30	2.60
Q_{25}	0.64	0.49	0.45	3.51	1.46	0.42	0.08	0.26	2.60
Q_{50}	0.59	0.44	0.38	3.05	1.30	0.35	0.07	0.23	2.60
Q_{75}	0.54	0.39	0.31	2.65	1.16	0.29	0.06	0.20	2.60
Q_{90}	0.49	0.34	0.24	2.22	1.01	0.22	0.05	0.17	2.60
Q_{98}	0.40	0.26	0.13	1.50	0.77	0.11	0.04	0.11	2.60
Q_{mean}	0.64	0.48	0.44	3.48	1.44	0.41	0.08	0.26	2.60
December Flows									
Q_{02}	0.95	0.78	0.85	6.06	2.32	0.31	0.13	0.45	2.60
Q_{10}	0.75	0.59	0.59	4.38	1.75	0.55	0.10	0.33	2.60
Q_{25}	0.66	0.50	0.47	3.66	1.50	0.44	0.09	0.27	2.60
Q_{50}	0.61	0.46	0.40	3.23	1.36	0.37	0.08	0.24	2.60
Q_{75}	0.55	0.40	0.33	2.75	1.19	0.30	0.07	0.21	2.60
Q_{90}	0.50	0.36	0.26	2.34	1.06	0.24	0.06	0.18	2.60
Q_{98}	0.43	0.29	0.18	1.79	0.87	0.15	0.05	0.13	2.60
Q_{mean}	0.67	0.51	0.48	3.73	1.53	0.45	0.09	0.28	2.60

Appendix C. NETWORK File Describing the Location of All Streams, Control Points, Withdrawals, and Discharges in the Kankakee River Basin, Illinois Portion

DA(u) = Drainage area upstream of location (sq mi)
DA(d) = Drainage area downstream oflocation (sq m
K = Average soil subpermeability (in/hr)
P-ET = Net excess precipitation for the watershed (i

ID = 0 Basic watershed information
= 1 Tributary inflow
= 2 Effluent discharge
= 3 Water supply withdrawal
= 6 Control point (full set of flow information)

Stream (code)[a]	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Kankakee River	67.90	1779.0	1779.0	7.60	10.30	6	USGS Gage 0551S000 Shelby
(Y)	58.50	1920.0	1920.0	7.08	10.30	0	ILLINOIS-INDIANA State Line
	56.10	1920.8	1939.0	7.02	10.30	0	at Williams Ditch-Dike Ditch
	50.80	1946.0	2197.6	6.56	10.30	1	at Singleton Ditch (YD
	50.30	2198.0	2261.6	6.39	10.30	1	at Trim Creek (YH9)
	48.80	2262.0	2288.6	6.32	10.30	1	Kankakee River tributary YH7
	47.90	2294.0	2294.0	6.31	10.30	6	USGS Gage 05525000 Momence
	47.70	2294.1	2294.1	6.31	10.30	2	Momence Discharge
	46.60	2295.5	2314.3	6.25	10.30	1	at Tower Creek (YH4)
	43.80	2321.4	2331.0	6.22	10.30	0	at Farr Creek (YH)
	42.10	2334.5	2334.5	6.22	10.30	0	ILRT 17
	38.40	2347.8	2375.4	6.16	10.30	1	at Spring Creek (YG4)
	37.01	2378.0	2378.0	6.16	10.30	6	upstream of Iroquois River
	37.00	2378.0	4515.0	3.68	10.22	6	at Iroquois River (YG)
	34.90	4521.0	4563.9	3.67	10.22	1	at Baker Creek (YF6)
	34.S0	4564.0	4564.0	3.67	10.22	0	Interstate HWY 57
	33.80	4566.6	4592.4	3.66	10.22	1	at Gar Creek Ditch (YF4)
	33.60	4592.5	4592.5	3.66	10.22	3	Consumer Illinois Withdrawal
	31.81	4597.2	4597.2	3.66	10.22	0	ILRT 17
	31.80	4597.2	4623.7	3.65	10.22	1	at Soldier Creek (YF)
	30.80	4624.8	4624.8	3.65	10.22	2	Kankakee Discharge
	30.50	4625.0	4625.0	3.65	10.22	2	Bradley Discharge
	29.60	4627.8	4627.8	3.65	10.22	2	Bourbonnais Discharge
	28.30	4630.2	4637.7	3.65	10.22	0	at Davis Creek
	26.70	4637.4	4644.6	3.65	10.22	0	at Wiley Creek
	23.01	4653.7	4653.7	3.65	10.21	0	upstream of Rock Creek
	23.00	4653.7	4774.0	3.62	10.21	1	at Rock Creek (YE)
	21.60	4774.8	4779.5	3.62	10.21	0	Will-Kankakee County Line
	16.50	4793.6	4805.9	3.62	10.21	1	at Terry Creek (YD3)
	14.60	4807.9	4807.9	3.62	10.21	0	N & W RR at Custer Park
	14.30	4808.0	4938.4	3.62	10.20	1	at Horse Creek (YD)
	1410	4938.5	4938.5	3.62	10.20	3	Commonwealth Edison Withdrawal
	9.90	4952.5	4952.5	3.62	10.20	0	IL RT 53
	9.40	4952.8	5089.3	3.58	10.20	1	at Forked Creek (YC)
	9.20	5089.4	5089.4	3.58	10.20	2	Wilmington Discharge
	6.11	5098.3	5098.3	3.58	10.20	0	upstream of Prairie Creek
	6.10	5098.3	5149.8	3.57	10.20	1	at Prairie Creek (YB)
	5.70	5150.0	5150.0	3.57	10.20	6	USGS Gage 05527500 Wilmington
	5.40	5150.3	5150.3	3.57	10.20	0	Interstate HWY 55
	0.00	5155.0	5155.0	3.57	10.20	0	at mouth near Dresden Island
Prairie Creek	19.30	8.8	8.8	0.55	10.00	0	
(YB)	17.00	11.0	21.2	0.53	10.00	1	tributary YBQ
	11.90	26.4	26.4	0.54	9.97	0	near Manhattan
	7.70	39.8	39.8	0.58	9.96	0	
	4.50	43.8	43.8	0.68	9.95	2	Joliet Arsenal discharge
	4.00	44.6	44.6	0.70	9.95	0	IL RT 53
	0.00	50.6	50.6	0.85	9.94	0	

Appendix C. Continued

Stream (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Prairie Cr Tributary	5.20	4.1	4.1	0.52	10.00	0	
(YBQ)	0.00	10.2	10.2	0.52	10.00	0	
Forked Creek	34.41	7.3	7.3	0.16	10.10	0	
(YC)	34.40	7.3	12.1	0.16	1010	0	
	30.00	20.6	20.6	0.32	10.09	0	US HWY 45
	21.90	27.4	27.4	0.45	10.07	0	US HWY 52 at Wilton Center
	19.50	29.9	37.0	0.41	10.07	0	
	16.70	38.8	48.0	0.46	10.05	0	at West Branch Forked Creek
	1410	52.2	52.2	0.47	10.04	0	Will-Kankakee County Line
	11.71	59.5	59.5	0.48	10.04	0	
	11.70	59.5	93.8	0.56	10.06	1	at South Branch Forked Creek (YCI)
	8.70	100.0	100.0	0.58	10.05	0	
	6.20	102.7	102.7	0.58	10.05	0	at Ritchie
	1.61	108.4	108.4	0.60	10.04	0	above Jordan Creek
	1.60	108.4	129.5	0.62	10.02	1	at Jordan Creek (YCB)
	0.00	134.5	134.5	0.64	10.01	0	at mouth in Wilmington
Jordan Creek	6.50	7.8	7.8	0.59	9.90	0	Norfolk and Western RR
(YCB)	3.80	14.0	14.0	0.59	9.90	0	
	0.00	21.1	211	0.72	9.90	0	at mouth near Wilmington
South Branch Forked Cr	15.70	8.1	8.1	0.55	1015	0	
(YCI)	13.00	12.1	12.1	0.55	10.15	0	US HWY 45
	7.90	16.3	16.3	0.60	10.13	0	Kankakee-Will County Line
	5.80	19.4	26.7	0.63	10.12	0	
	0.00	34.3	34.3	0.72	10.10	0	
Horse Creek	18.70	7.0	15.3	0.38	9.85	0	
(YD)	17.50	16.4	16.4	0.38	9.85	2	Herscher discharge
	14.50	24.1	24.1	0.37	9.85	0	3 miles north of Herscher
	11.31	28.0	28.0	0.37	9.85	0	
	11.30	28.0	44.0	0.47	9.87	1	at Lehigh-Raymond Run (YDN)
	9.90	45.1	54.8	0.57	9.88	0	at South Bonfield Branch
	9.10	55.6	70.0	0.61	9.89	1	at North Bonfield Branch (YDK)
	7.91	72.0	72.0	0.61	9.89	0	
	7.90	72.0	103.4	0.60	9.85	1	at West Branch Horse Creek (YDJ)
	4.10	114.4	114.4	0.60	9.85	0	Will-Kankakee County Line
	0.00	128.4	128.4	0.63	9.85	0	at mouth at Custer Park
West Branch Horse Cr	14.40	6.6	6.6	0.42	9.70	0	Kankakee-Ford County Line
(YDJ)	10.90	11.6	11.6	0.42	9.70	0	
	9.30	17.6	17.6	0.42	9.71	0	IL RT 115
	4.40	27.0	27.0	0.40	9.74	0	IL RT 17
	0.00	31.4	31.4	0.40	9.75	0	
North Bonfield Branch	5.90	6.3	6.3	0.91	9.95	0	
(YDL)	3.70	9.6	9.6	0.91	9.95	0	1 mile north of Bonfield
	0.00	14.4	14.4	0.91	9.95	0	
Lehigh-Raymond Run	5.90	3.5	3.5	0.65	9.90	2	Lehigh Quarry
(YDN)	2.40	9.0	9.0	0.65	9.90	0	
	0.40	10.4	15.9	0.65	9.90	0	
	0.00	16.0	16.0	0.65	9.90	0	
Terry Creek	3.00	8.2	8.2	0.85	9.90	0	Will-Kankakee County Line
(YD3)	0.30	121	121	0.85	9.90	5	USGS Gage 05526500 near Custer Park
	0.00	12.3	12.3	0.85	9.90	0	
Rock Creek	20.70	7.8	7.8	0.36	10.15	0	IL RT 50
(YE)	18.80	11.8	11.8	0.36	10.15	0	
	15.00	19.9	19.9	0.51	10.15	0	west of I-57 Peotone exit
	1010	28.9	28.9	0.62	10.15	0	US HWY 45

Appendix C. Continued

Stream (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Rock Creek	6.41	36.3	36.3	0.61	10.15	0	
	6.40	36.3	95.8	0.63	10.20	1	at South Branch Rock Creek (YEG)
	3.90	101.2	113.9	0.62	10.19	1	at tributary YEE
	0.00	120.3	120.3	0.62	10.18	0	
Rock Cr Tributary	7.00	4.0	4.0	0.49	10.10	0	Kankakee-Will County Line
(YEE)	0.00	12.7	12.7	0.49	10.10	0	
South Branch Rock Cr	13.50	9.8	9.8	0.75	10.30	0	Kankakee-Will County Line
(YEG)	10.40	12.6	18.0	0.65	10.28	0	at Marshall Slough
	10.20	18.0	36.5	0.64	10.26	1	at Black Walnut Creek (YEGN)
	7.50	45.8	45.8	0.63	10.25	0	1 mile east of Manteno
	5.90	47.8	47.8	0.63	10.25	2	Manteno discharge
	3.00	55.3	55.3	0.64	10.24	0	US HWY 45
	0.00	59.5	59.5	0.65	10.23	0	
Black Walnut Creek	11.10	5.7	5.7	0.48	10.25	0	at Oflner Road
(YEGN)	5.70	12.0	12.0	0.48	10.25	0	2 miles east of Peotone
	3.40	15.4	15.4	0.55	10.25	2	Peotone discharge
	0.00	18.5	18.5	0.62	10.25	0	
Soldier Creek	7.80	2.7	2.7	0.68	10.20	2	Manteno Limestone Quarry
(YF)	5.40	10.1	10.1	0.68	10.20	0	
	2.00	19.2	19.2	0.71	10.20	2	Kinzie Avenue
	0.00	26.5	26.5	0.74	10.20	0	at mouth in Kankakee
Gar Creek Ditch	8.70	3.6	3.6	0.43	9.95	0	IL RT 115
(YF4)	7.20	10.8	10.8	0.43	9.95	0	
	3.40	18.7	18.7	0.75	9.99	0	Kankakee Airport
	1.90	23.0	23.0	0.93	10.01	0	AOS Industrial discharge
	0.00	24.8	24.8	1.01	10.02	0	at mouth in Kankakee
Baker Creek	18.00	4.7	4.7	0.97	10.30	0	
(YF6)	15.90	10.6	10.6	0.97	10.30	0	
	12.20	16.9	16.9	0.98	10.29	0	Manteno Road
	10.80	18.6	24.1	0.99	10.28	0	at Canavan Slough
	7.80	29.4	29.4	1.00	10.27	0	at St. George
	4.60	36.8	36.8	1.12	10.26	0	at Exline
	0.00	43.9	43.9	1.23	10.25	0	
Iroquois River	55.40	661.0	661.0	1.20	10.90	0	
(YG)	54.80	661.3	672.4	1.20	10.89	1	North Sheldon-South Concord Ditch (YGM)
	50.40	686.6	686.6	1.20	10.S8	5	USGS Gage 05525000 Iroquois
	44.21	700.3	700.3	1.20	10.87	0	
	44.20	700.3	713.7	1.20	10.66	1	at Eastburn Hollow (YGK)
	37.30	723.6	734.7	1.20	10.84	1	at Middleport Ditch No. 1 (YGJ)
	35.40	737.3	737.3	1.20	10.84	2	Watseka discharge
	33.01	739.2	739.2	1.20	10.84	0	above Sugar Creek
	33.00	739.2	1295.3	1.06	10.54	1	at Sugar Creek (YGI)
	21.91	1318.7	1318.7	1.05	10.53	0	
	21.90	1318.7	1606.2	0.95	10.43	1	at Spring Creek (YGG)
	16.51	1620.9	1620.9	0.94	10.43	0	
	16.50	1620.9	1632.9	0.94	10.43	1	at tributary YGF
	13.11	1639.9	1639.9	0.94	10.43	0	
	13.10	1639.9	1690.0	0.93	10.42	1	at Prairie Creek (YGE)
	11.90	1690.5	1759.7	0.92	10.39	1	at Pike Creek (YGD)
	10.30	1767.4	1873.2	0.90	10.36	1	at Langan Creek (YGC)
	9.70	1873.4	2058.6	0.92	10.36	1	at Beaver Creek (YGB)
	6.50	2066.5	2073.3	0.92	10.36	5	USGS Gage 05526000 Chebanse
	6.00	2073.5	20S4.9	0.92	10.36	1	at Trail Creek (YGA6)
	3.20	2088.1	2111.2	0.92	10.36	1	at Minnie Creek (YGA3)
	0.00	2119.4	2119.4	0.92	10.36	0	

Appendix C. Continued

Stream (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Minnie Creek	4.50	8.5	8.5	0.79	10.00	0	
(YGA3)	2.30	16.6	16.6	1.01	10.02	0	Interstate HWY 57
	0.00	23.1	23.1	1.20	10.04	0	
Trail Creek	3.20	5.3	5.3	0.55	10.05	0	US HWY 45
(YGA6)	0.00	11.4	11.4	0.55	10.05	0	
Beaver Creek	21.80	59.4	59.4	1.27	10.50	0	Illinois/Indiana State Line
(YGB)	19.90	67.9	67.9	1.27	10.49	0	
	17.40	73.1	99.6	1.25	10.47	1	at Hooper Branch (YGBN)
	13.10	112.1	112.1	1.18	10.45	0	KBSR Railroad near Beaverville
	8.00	120.2	120.2	1.14	10.44	0	IL RT 1 near Papineau
	7.00	120.5	178.5	1.10	10.41	1	at Little Beaver Creek (YGBF)
	0.00	185.2	185.2	1.09	10.40	0	
Little Beaver Creek	14.90	6.8	6.8	1.31	10.45	0	1 mile south of Hopkins Park Subd.
(YGBF)	13.10	13.4	13.4	1.31	10.45	0	2 miles west of Leesville
	9.40	26.5	26.5	1.25	10.43	0	
	6.70	32.1	32.1	1.15	10.40	0	
	5.10	34.2	45.2	1.04	10.38	1	at tributary YGBFH
	0.00	58.0	58.0	0.94	10.35	0	at mouth near Papineau
Little Beaver Cr Tributary	0.80	4.6	4.6	0.70	10.30	0	
(YGBFH)	0.00	11.0	11.0	0.70	10.30	0	
Hoover Branch	4.10	15.3	15.3	1.19	10.45	0	Illinois-Indiana State Line
(YGBN)	0.00	26.5	26.5	1.19	10.43	0	
Langan Creek	21.60	8.4	8.4	0.62	9.80	0	
(YGC)	19.40	15.2	15.2	0.62	9.80	0	IL RT 116
	18.00	23.4	23.4	0.60	9.80	0	
	13.61	40.5	40.5	0.55	9.80	0	
	13.60	40.5	64.4	0.60	9.80	1	at tributary YGCO
	11.30	73.2	80.4	0.61	9.83	0	
	9.70	83.2	83.2	0.61	9.83	0	US HWY 45 near Clifton
	9.20	83.6	90.4	0.62	9.85	0	
	4.70	94.7	94.7	0.62	9.86	0	US HWY 52
	0.00	105.8	105.8	0.62	9.88	0	
Langan Cr Tributary	5.50	7.8	7.8	0.71	9.80	0	
(YGCO)	3.20	12.5	12.5	0.71	9.80	0	
	2.70	13.2	22.2	0.71	9.80	0	
	0.00	23.9	23.9	0.71	9.80	0	
Pike Creek	12.10	9.2	9.2	1.05	10.30	0	
(YGD)	9.90	14.5	14.5	1.00	10.28	0	2 miles east.of Pittwood
	6.20	21.3	21.3	0.92	10.25	0	IL RT 1
	3.90	28.5	64.8	0.72	10.26	1	at North Martinton Ditch (YGDF)
	0.00	69.2	69.2	0.72	10.25	0	
North Martinton Ditch	2.80	5.8	5.8	0.41	10.25	0	UP Railroad near Martinton
(YGDF)	2.40	7.5	33.8	0.63	10.29	1	at Main Martinton Ditch (YGDFI)
	0.00	36.3	36.3	0.61	10.29	0	
Main Martinton Ditch	6.30	5.9	5.9	0.48	10.35	0	KBSR Railroad
(YGDFI)	4.80	7.3	15.5	0.61	10.35	0	
	1.00	20.0	20.0	0.61	10.31	0	1 mile east of Martinton
	0.00	26.3	26.3	0.61	10.31	0	at mouth near Martinton
Prairie Creek	16.20	2.3	2.3	0.39	9.90	0	US HWY 45 in Danforth
(YGE)	12.10	7.7	7.7	0.39	9.90	0	
	9.90	18.3	18.3	0.37	9.94	0	
	7.40	29.3	29.3	*0.38*	9.96	0	US HWY 45 east of Ashkum

Appendix C. Continued

Stream (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Prairie Creek	5.90	31.8	42.0	0.38	9.97	1	at tributary YGEF
	4.90	42.4	42.4	0.38	9.97	0	US HUTS 52 & 45 near L'Erable
	0.00	50.1	50.1	0.42	9.98	0	
Prairie Cr Tributary	4.90	5.5	5.5	0.39	10.00	0	
(YGEF)	0.00	10.2	10.2	0.39	10.00	0	
Iroquois R Tributary	4.00	3.2	3.2	0.97	10.10	0	
(YGF)	0.00	12.0	12.0	0.97	1010	0	
Spring Creek	60.10	6.6	6.6	0.08	9.70	0	US HWY 45 near Loda
(YGG)	56.80	12.8	12.8	0.08	9.70	0	downstream of Bayles Lake
	56.20	12.8	29.5	0.21	9.64	1	at tributary YGGW
	51.20	33.9	33.9	0.20	9.65	0	US HWY 45 near Buckley
	50.90	33.9	41.4	017	9.67	1	
	45.40	43.9	43.9	017	9.67	0	1 mile east of Buckley
	3810	53.6	76.7	0.21	9.70	1	at Louis Creek (YGGP)
	35.70	77.9	137.4	0.27	9.68	1	at tributary YGGO
	28.50	146.3	151.7	0.28	9.70	1	2 miles east of Onarga
	18.31	161.5	161.5	0.28	9.72	0	above Shavetail Creek
	18.30	161.5	191.5	0.33	9.77	1	at Shavetail Creek (YGGH)
	15.40	194.9	215.3	0.34	9.78	1	at tributary YGGG
	14.90	215.5	215.5	0.34	9.78	0	US HWY 24 west of Crescent City
	9.91	219.6	219.6	0.34	9.78	0	
	9.90	219.6	268.6	0.42	9.S0	1	at tributary YGGE
	7.70	269.4	279.1	0.42	9.S1	0	
	6.40	280.3	280.3	0.42	9.81	0	IL RT 49 near Crescent City
	0.00	287.5	287.5	0.42	9.82	0	
Spring Cr Tributary	14.20	4.1	4.1	1.00	9.70	0	US HWY 24 near LaHogue
(YGGE)	12.90	12.3	12.3	1.00	9.70	0	at LaHogue
	9.70	22.9	22.9	0.96	9.74	0	
	710	28.2	28.2	0.90	9.76	0	
	5.00	36.0	36.0	0.84	9.78	0	US HWY 45 near Gilman
	1.50	38.4	45.8	0.78	9.81	1	at Gilman tributary (YGGEC)
	0.00	49.0	49.0	0.77	9.84	0	
Gilman Tributary	5.00	4.7	4.7	0.51	9.90	2	Gilman discharge
(YGGEC)	0.00	7.4	7.4	0.51	9.90	0	
Spring Cr Tributary	6.50	61	6.1	0.49	9.90	0	US HWY 45 at Gilman
(YGGG)	4.00	11.1	11.1	0.49	9.90	0	
	1.60	16.3	16.3	0.46	9.90	0	at Leonard
	0.00	20.4	20.4	0.45	9.90	0	
Shavetail Creek	5.70	5.6	5.6	0.78	9.90	0	
(YGGH)	4.40	10.3	16.5	0.64	9.90	0	IL RT 49
	2.30	25.3	25.3	0.64	9.90	0	
	0.00	30.0	30.0	0.64	9.90	0	
Spring Cr Tributary	8.90	7.5	7.5	0.27	9.60	0	at Thawville
(YGGO)	6.60	8.6	271	0.27	9.60	1	at tributary YGGOK
	610	36.8	36.8	0.35	9.60	0	IL RT 54 near Ridgeville
	2.70	461	461	0.35	9.62	0	Interstate HWY 57
	1.50	46.6	58.2	0.35	9.64	1	at tributary YGGOC
	0.00	59.5	59.5	0.35	9.64	0	at mouth near Delrey
Tributary YGGOC	2.90	6.5	6.5	0.34	9.80	0	
	0.00	11.6	11.6	0.34	9.80	0	at mouth near Delrey
Tributary YGGOK	5.30	6.6	6.6	0.20	9.60	0	Iroquois-Ford County Line
	4.80	6.7	12.3	0.20	9.60	0	
	0.00	18.5	18.5	0.20	9.60	0	

Appendix C. Continued

Stream (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Louis Creek	9.50	7.7	7.7	0.21	9.70	0	
(YGGP)	4.80	10.9	19.9	0.21	9.70	0	
	3.10	21.2	21.2	0.21	9.70	0	US HWY 45 near Buckley
	0.00	23.1	231	0.21	9.70	0	
Spring Cr Tributary	4.30	8.5	8.5	0.31	9.60	0	
(YGGW)	2.40	15.3	15.3	0.31	9.60	0	Iroquois-Ford County Line
	0.00	16.7	16.7	0.31	9.60	0	
Sugar Creek	38.90	65.1	85.1	1.20	10.50	0	Illinois/Indiana State Line
(YGI)	34.30	92.1	123.8	1.27	10.47	1	at Mud Creek (YGIP)
	29.60	131.7	152.8	1.30	10.46	1	at tributary YGIN
	26.00	158.4	158.4	1.31	10.45	0	IL RT 1 at Milford
	23.91	159.9	159.9	1.32	10.45	5	above Mud Creek (YGK)
	23.90	441.4	441.4	0.83	10.14	5	USGS Gage 05525500 Milford
	16.30	452.8	452.8	0.83	10.14	0	UP Railroad south of Woodland
	1310	454.3	475.4	0.83	10.14	1	at Jefferson Creek (YGIF)
	9.70	4S0.1	527.0	0.86	10.14	1	at Coon Creek (YGIE)
	5.40	542.4	552.5	0.88	10.14	0	at tributary YGIC
	0.00	556.1	556.1	0.88	10.14	0	at mouth near Watseka
Sugar Cr Tributary	3.10	7.2	7.2	0.90	10.10	0	
(YGIC)	0.00	10.1	101	0.90	10.10	0	
Coon Creek	16.80	2.3	2.3	0.89	10.30	0	Llinois/Indian a State Line
(YGIE)	1210	9.0	9.0	0.89	10.30	0	KSBR Railroad
	9.60	14.0	14.0	0.89	10.30	0	
	7.50	22.6	22.6	0.89	10.30	0	
	6.90	22.9	39.4	1.04	10.27	1	at Possum Trot Ditch (YGIEL)
	6.60	39.7	39.7	1.04	10.27	0	IL RT 1
	0.00	46.9	46.9	1.09	10.26	0	at mouth near Woodland
Possum Trot Ditch	4.60	6.6	6.6	1.25	10.25	0	at Darrow
(YGIEL)	0.00	16.5	16.5	1.25	10.25	0	
Jefferson Creek	5.50	7.2	7.2	0.44	10.10	0	
(YGIF)	4.20	10.6	10.6	0.44	10.10	0	
	0.00	21.1	21.1	0.74	10.10	0	
Mud Creek	24.50	6.2	6.2	0.35	10.00	0	
(YGIK)	23.60	11.6	11.6	0.35	10.00	0	
	22.21	19.5	19.5	0.37	10.00	0	
	22.20	19.5	29.8	0.38	10.00	1	at tributary YGIKU
	20.90	33.4	49.0	0.36	10.00	1	at tributary YGIKT
	2010	49.8	49.8	0.36	10.00	0	IL RT 49 near Cissna Park
	17.60	53.7	1181	0.32	10.05	1	at Pigeon Creek (YGDSP)
	15.10	124.8	124.8	0.32	10.06	0	1 mile north of Claytonville
	9.30	131.5	131.5	0.32	10.07	0	UP Railroad near Goodwine
	8.41	131.8	131.8	0.32	10.07	0	
	8.40	131.8	215.5	0.43	10.12	1	at Fountain Creek (YGIKH)
	4.70	219.1	241.0	0.47	10.15	1	at Gay Creek (YGIKE)
	2.50	244.3	279.4	0.53	10.17	1	at tributary YGIKC
	0.00	281.5	281.5	0.53	10.17	5	at mouth near Milford
Mud Cr Tributary	10.70	7.4	7.4	0.80	10.35	0	
(YGIKC)	4.70	14.3	14.3	0.80	10.35	0	
	1.90	18.9	34.0	0.82	10.32	1	IL RT1 / at tributary YGDKCD
	0.00	35.1	35.1	0.90	10.31	0	at mouth near Milford
Tributary YGIKCD	8.40	7.1	7.1	0.80	10.20	0	
	3.40	11.8	11.8	0.80	10.20	0	
	0.00	15.1	15.1	0.83	10.20	0	

Appendix C. Continued

Stream (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Gay Creek	8.10	7.4	7.4	0.80	10.30	0	
(YGIKE)	5.60	14.7	14.7	0.80	10.30	0	2 miles west of Wellington
	0.00	21.9	21.9	0.77	10.30	0	
Fountain Creek	15.80	2.0	2.0	0.44	10.20	0	IL RT 9
(YGIKH)	14.30	9.4	15.0	0.49	10.20	0	at East Lynn
	13.20	15.3	26.5	0.57	10.20	1	at tributary YGIKHR
	9.90	33.4	33.4	0.56	10.20	0	at Fountain Creek
	4.70	42.2	42.2	0.54	10.20	0	at Goodwine
	3.80	42.5	62.0	0.53	10.20	1	at Whiskey Creek (YGIKHF)
	2.50	63.0	82.6	0.60	10.20	1	at tributary YGIKHD
	0.00	83.7	83.7	0.60	10.20	0	
Fountain Cr Tributary	6.70	7.5	7.5	0.80	10.25	0	
(YGIKHD)	3.00	13.1	131	0.80	10.25	0	
	0.00	19.6	19.6	0.80	10.25	0	
Whiskey Creek	11.30	7.9	7.9	0.32	10.15	0	IL RT 9 east of Rankin
(YGIKHF)	8.80	10.8	10.8	0.32	10.15	0	Iroquois-Vermilion County Line
	1.90	17.2	17.2	0.34	10.15	0	at Claytonville
	0.00	19.5	19.5	0.35	1015	0	at mouth near Goodwine
Fountain Cr Tributary	2.30	5.1	5.1	0.70	10.20	0	IL RT 9
(YGIKHR)	0.00	11.2	11.2	0.70	10.20	0	
Pigeon Creek	9.30	4.0	4.0	0.06	10.05	0	Iroquois-Vermilion County Line
(YGIKP)	9.00	4.2	10.5	0.06	10.05	0	
	6.20	12.7	12.7	0.06	10.05	0	IL RT 49
	4.70	13.3	29.0	0.12	10.08	1	at tributary YGIKPK
	3.50	29.9	49.2	0.16	10.07	1	at tributary YGIKPI
	3.10	49.4	49.4	0.16	10.07	2	Cissna Park discharge
	1.90	52.7	62.7	0.20	10.08	1	at tributary YGIKPE
	0.00	64.4	64.4	0.22	10.08	0	
Pigeon Cr Tributary	2.50	7.4	7.4	0.43	1010	0	
(YGIKPE)	0.00	10.0	10.0	0.43	10.10	0	
Pigeon Cr Tributary	5.60	9.8	9.8	0.13	10.05	0	
(YGIKPI)	2.70	11.8	17.3	013	10.05	0	
	0.00	19.3	19.3	013	10.05	0	
Pigeon Cr Tributary	3.20	8.9	8.9	0.20	10.10	0	
(YGIKPK)	0.00	15.7	15.7	0.20	10.10	0	
Mud Cr Tributary	2.90	8.0	8.0	0.34	10.00	0	
(YGDXT)	0.00	15.6	15.6	0.34	10.00	0	
Mud Cr Tributary	2.30	4.5	4.5	0.40	10.00	0	
(YGIKU)	0.00	10.3	10.3	0.40	10.00	0	
Sugar Cr Tributary	10.40	5.2	5.2	0.70	10.40	0	
(YGIN)	7.50	10.2	10.2	0.70	10.40	0	
	3.80	13.8	13.8	0.72	10.40	0	at Stockland
	0.00	21.1	211	0.76	10.40	0	
Mud Creek	5.50	16.0	16.0	1.20	10.45	0	Illinois/Indiana State Line
(YGIP)	2.01	20.5	20.5	112	10.45	0	above Cole Creek
	2.00	20.5	30.3	1.08	10.45	0	at Cole Creek
	0.00	31.7	31.7	1.06	10.45	0	at mouth near Stockland
Middleport Ditch No. 1	2.50	3.7	3.7	0.78	10.20	0	
(YGJ)	0.00	11.1	11.1	0.78	10.20	0	at mouth near Watseka

Appendix C. Continued

Stream (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID	Location description
Eastburn Hollow	3.50	6.5	6.5	1.53	10.30	0	
(YGK)	1.80	11.6	11.6	1.53	10.30	0	US HWY 24
	0.00	13.7	13.7	1.53	10.30	0	
North Sheldon-East	5.20	5.4	5.4	1.53	10.35	0	US HWY 52 at Sheldon
Concord Ditch (YGM)	0.00	11.1	111	1.53	10.35	0	
Spring Creek	6.50	9.9	9.9	1.98	10.35	0	UP Railroad
(YG4)	4.00	15.7	15.7	1.95	10.32	0	ILRT1
	2.10	17.3	24.8	1.90	10.30	0	
	0.00	27.6	27.6	1.90	10.29	0	at mouth near Aroma Park
Farr Creek	2.90	6.5	6.5	0.80	10.30	0	
(YH)	0.00	9.6	9.6	0.80	10.30	0	
Tower Creek	5.10	7.3	7.3	0.61	10.35	0	
(YH4)	2.50	10.2	13.9	0.61	10.35	0	
	0.00	18.8	18.8	0.61	10.35	0	at mouth near Momence
Kankakee R Tributary	4.91	7.8	7.8	2.00	10.45	0	
(YH7)	4.90	7.8	15.8	2.00	10.43	0	
	1.30	24.5	24.5	1.90	10.42	0	IL RT 114
	0.00	25.8	25.8	1.89	10.42	0	at mouth at Momence
	17.50	8.0	8.0	0.83	10.40	0	
Trim Creek	14.90	12.8	12.8	0.83	10.40	0	1 mile east of Beecher
(YH9)	1310	15.2	18.8	0.83	10.40	2	Beecher discharge
	10.90	25.0	25.0	0.78	10.40	0	Kankakee-Will County Line
	6.00	33.0	33.0	0.78	10.40	0	IL RT 1 at Grant Park
	0.80	37.9	63.3	0.70	10.40	1	at Pike Creek (YH9B)
	0.00	63.6	63.6	0.70	10.40	0	at mouth near Momence
Pike Creek	10.30	7.0	7.0	0.38	10.40	0	Kankakee-Will County Line
(YH9B)	6.90	141	141	0.38	10.40	0	
	4.70	19.0	19.0	0.39	10.40	0	IL RT 17
	0.00	25.4	25.4	0.41	10.40	0	
Singleton Ditch	5.60	220.0	220.0	2.70	10.60	5	USGS Gage 05520000 Indiana State Line
(YI)	3.80	220.2	236.2	2.56	10.60	1	at Bull Creek (YID)
	3.40	238.8	238.8	2.56	10.60	2	Momence quarry
	0.00	251.6	251.6	2.50	10.59	0	
Bull Creek	6.00	5.7	5.7	0.81	10.50	0	
(YTD)	3.80	10.2	10.2	0.81	10.50	0	IL RT 17
	0.00	16.0	16.0	0.81	10.50	0	

a The stream code is an alphanumeric set of characters used by *ILSAM* to uniquely identify each stream in the watershed.