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FOX RIVER BASIN STREAMFLOW ASSESSMENT MODEL: HYDROLOGIC ANALYSIS

by

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1. INTRODUCTION

The management of potential conflicts in the use of streamflow requires both an understanding of present streamflow conditions and the effects of varying water use practices on those conditions. Sufficient information to evaluate these types of water resources questions is seldom available in a usable form, consequently a gap exists between the hydrologic expertise required to evaluate a situation and the actual decision-making process. The Illinois Streamflow Assessment Model, *[ILSAM]* (Knapp et al., 1985a) was developed to help bridge this gap and supply needed processed hydrologic information to a wide range of water resources planners and managers.

ILSAM is a computer program that produces estimates of long-term streamflow conditions for any location in a watershed. The model provides algorithms necessary to estimate the impacts of potential changes in water use and sources for water supply, and translates the effects of these modifications to other sites along the stream. *ILSAM* operates on a micro-computer and thus is available for use by a potentially large number of water resources planners and engineers. The model is being developed for individual watersheds throughout Illinois. With this report, two watersheds have been completed: the Sangamon River and Fox River basins (Fig. 1). Model development has been initiated for the Kaskaskia and Kankakee River basins. *ILSAM* is available from the State Water Survey on two 5 1/4" floppy diskettes for use on an IBM-PC/AT** or compatible computer having a minimum random access memory (RAM) of 512 K (kilobytes).

The Streamflow Assessment Model development has two dimensions: 1) creation of the hydrologic algorithms used to estimate streamflow statistics for any location along a stream, and 2) application of the computer program used to perform the algorithms and interact with the user to present the desired streamflow information. The purpose of this report is to present the first scope, that being the development of the algorithms that describe the variation of streamflow statistics in the Fox River Basin. Although the streamflow estimation algorithms presented in this report can be applied without use of the computer program, doing so is not advised because in many cases a great number of flow components are involved.

The modeling process associated with the Streamflow Assessment Model is a dynamic one in that the model algorithms and the implementation program are undergoing continual improvements. The Fox River study represents a second-generation approach to the modeling. Major improvements in the model include: 1) better definition of the watershed factors affecting streamflow variability; 2) a description of the effects of reservoir size and operation on the downstream flow variability; and 3) an improved referral system for geographic locations within the

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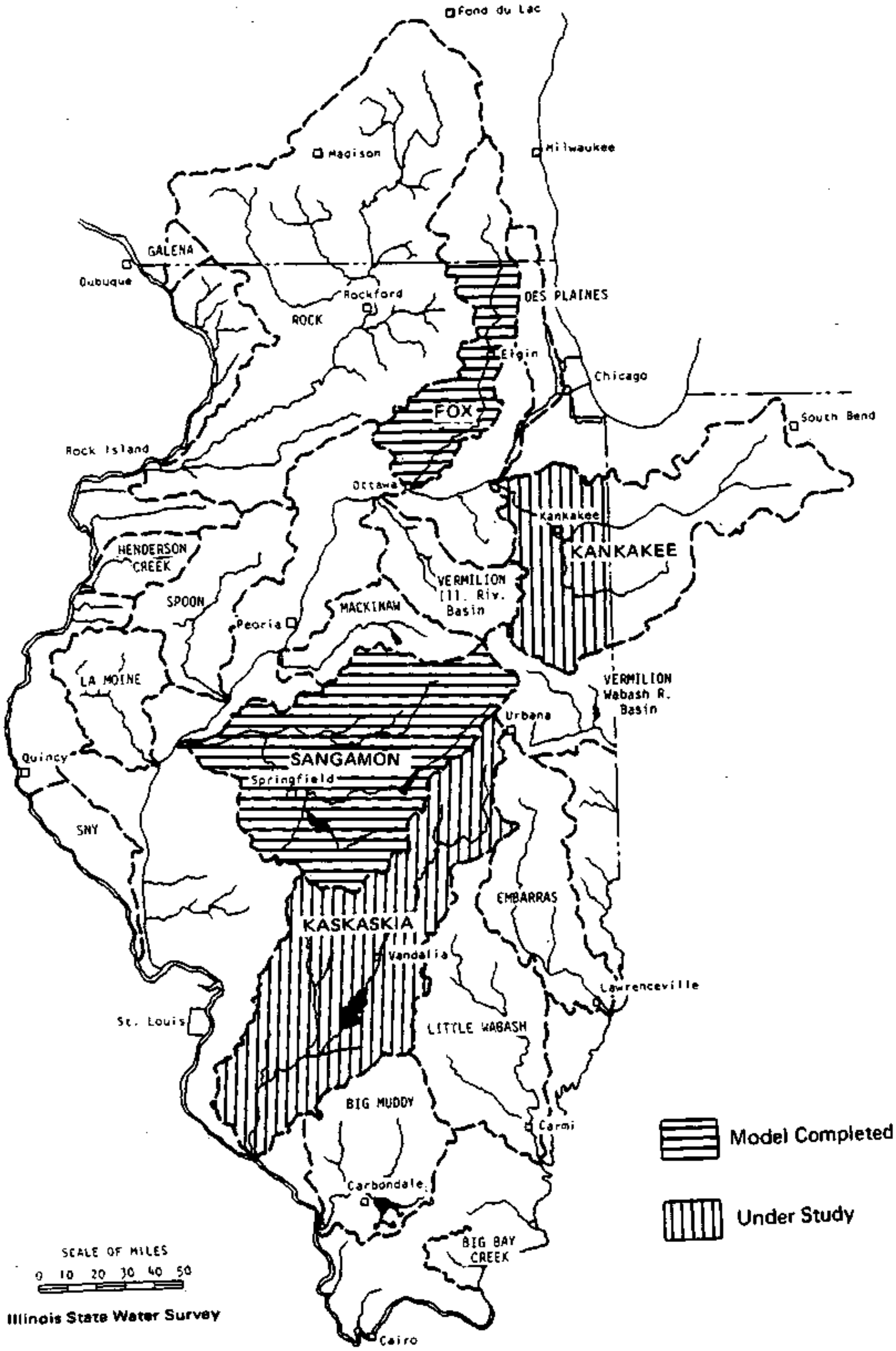

Figure 1. Location of the river basins for which the Streamflow Assessment Model is developed

watershed. Thorough and progressive hydrologic analyses have been applied to define the geographic variability of water resources, not only in the immediate study area, but also for other regions in the state with a similar hydrologic character. Useful by-products of the hydrologic analysis used in the model development, are the evaluations of the low-flow operation and outflow for McHenry Lock and Dam (Fox Chain of Lakes) and the effects on downstream flow conditions of limited modifications to the operation of the dam's outlet structures. The latter evaluation is presented in a subsequent circular.

General Use of the Model

ILSAM produces information on 154 selected flow parameters, including flow duration (flow versus percentage-of-duration) relationships as well as low flows for various durations and expected return intervals. The 154 flow parameters produced by the model are as follows:

Annual Flow-Duration Values (percent probability of exceedance,
for example Q02 = the flow exceeded only 2% of the time) --
Qmean (mean flow), Q99, Q98, Q95, Q90, Q85, Q75, Q60, Q50,
Q40, Q25, Q15, Q05, Q02, Q01

Monthly Flow Duration Values (Probability of exceedance, for
each month of the year) --
Qmean, Q98, Q90, Q75, Q50, Q25, Q10, Q02

Low Flows (annual series, average flow rate over the given duration) --
Durations: 1-day, 7-day, 15-day, 31-day, 61-day, 91-day;
Return Intervals: 2 years, 10 years, 25 years, 50 years

Drought Flows (average flow rate) --
Durations: 6-month, 9-mo., 12-mo., 18-mo., 30-mo., 54-mo.;
Return Intervals: 10 years, 25 years, 50 years

The flow parameters are presented for both present flow conditions and virgin (natural or unaffected) conditions. The concept of virgin flow is described later. In addition, the model's user may introduce a hypothetical (or potential) withdrawal/discharge and estimate its effect on the specified flow parameters. This introduces a third type of flow termed "altered flow". Flow conditions may be estimated for any gaged or ungaged site in the watershed with a drainage area of at least ten square miles.

A Brief Description of Typical Applications. A major concern along the Fox River is that sufficient flow exists in the river to both act as a water supply source and to provide dilution for some of the large effluent discharges into the river. For example, a large withdrawal of water in the upstream portions of the basin could reduce low flows at both Elgin and Aurora. In such a situation the river's capacity to provide both water supply and effluent dilution could be strained. Water quantity information, not included in *ILSAM is* also required for such an evaluation.

For the evaluation of the water quantity situation, the model's user should first locate and quantify the withdrawal at the upstream site. The model will request that the user supply the following:

1. the streamflow parameter(s) desired as model output;

2. the location of the point of interest in the basin (i.e., the point at which the hypothetical modification to the flow is to occur) as identified by the river mile along the stream;

3. information on the type of modification to the flow that is to be analyzed, for example: the amount of an effluent discharge or the size of a new reservoir (this step may be neglected in an ordinary application if the user is interested in only the virgin or present flow conditions; and

4. the locations downstream of interest (identified by river mile) that are potentially affected by the modification.

For example, after locating the new withdrawal, the user could request the altered 7-day, 10-year low flow (Q7,10) at either Elgin or Aurora, thereby evaluating the effects of the upstream withdrawal on the dilution ratio in the stream required for the effluent discharges at these sites.

Acknowledgments

This study was supported by the Illinois Department of Transportation, Division of Water Resources, with Gary Clark as project coordinator. William Rice of the Division of Water Resources was helpful in supplying data on both streamgaging and the operation of McHenry Dam. The investigation was conducted at the Illinois State Water Survey under the overall guidance of Richard G. Semonin, Chief; Richard J. Schicht, Assistant Chief; and Michael Terstriep, Head of the Surface Water Section. Krishan P. Singh, Assistant Head of the Surface Water Section, provided general supervision and helpful advice. Magne Wathne, a visiting scientist from the Norwegian Hydrotechnical Laboratory in Trondheim, analyzed much the hydrology of the Fox Chain of Lakes and McHenry Dam. Jorge Luis Alba and Charles LeCrone, students at the University of Illinois, were instrumental in processing the data. John Brother, Lynn Weiss, and Cheri Chenowith prepared the illustrations, and Mary Giles edited the report.

Part I. Background Information

2. DESCRIPTION OF THE FOX RIVER BASIN

The Fox River is located in the northeastern corner of Illinois and southeastern corner of Wisconsin (Fig. 2). The Fox River watershed has a total area of approximately 2,658 square miles, 938 of which are in Wisconsin. The watershed possesses a linear character, having a total length greater than 130 miles and a width rarely exceeding 25 miles. As a result of the shape of the watershed, there are few large tributaries into the Fox River. The major tributaries are Indian Creek (264 square miles), Big Rock Creek (194 square miles), Nippersink Creek (205 square miles), and Honey Creek (270 square miles). No other tributaries have drainage areas in excess of 100 square miles.

Figure 3 shows a profile of the Fox River from its headwaters in Waukesha County, Wisconsin to its confluence with the Illinois River at Ottawa. The profile of the Fox River is atypical of most rivers in that its channel slopes are greatest in the downstream reaches of the stream. The total length of the river is approximately 185 miles, and the total fall from headwater to confluence is about 460 feet; an average slope of 2.46 feet per mile. In the 50-mile reach between Burlington, Wisconsin and Algonquin, Illinois, the slope of the river is very flat, averaging less than 0.5 feet per mile. Downstream of Algonquin the slope of the river increases as the river starts down-cutting through several layers of limestone bedrock. All of the four major tributaries to the Fox River have moderate gradients, averaging approximately 5 feet per mile (Fig. 3).

Watershed Physiography and Soils

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

Wheaton Morainal Country. In the Wheaton Morainal region the glacial deposition is discontinuous, and moraines frequently occur close together. A variety of "elongated hills, mounds, basins, sags, and valleys" exist (Leighton, et al., 1948), which result in a complex and varied topography. A considerable amount of area is also the result of the deposition of sandy and gravelly material associated with glacial outwash. The region has a number of deep, natural lakes that resulted from the varied pattern of glacial deposition. This heterogeneity throughout the region is shown by the difference in soil properties. Soil permeabilites in the northern portion of the watershed

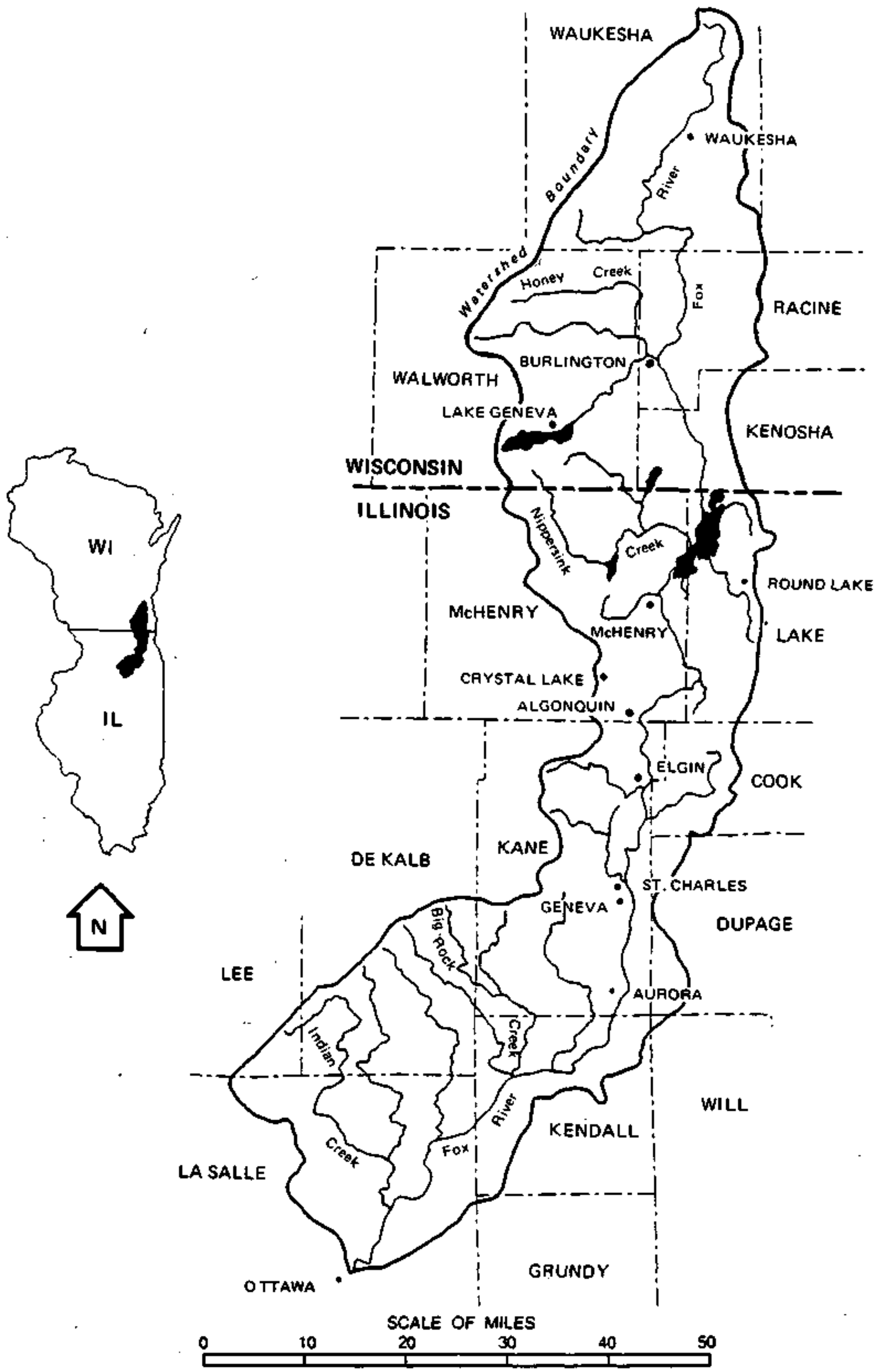

Figure 2. Location of the Fox River Basin in Illinois and Wisconsin

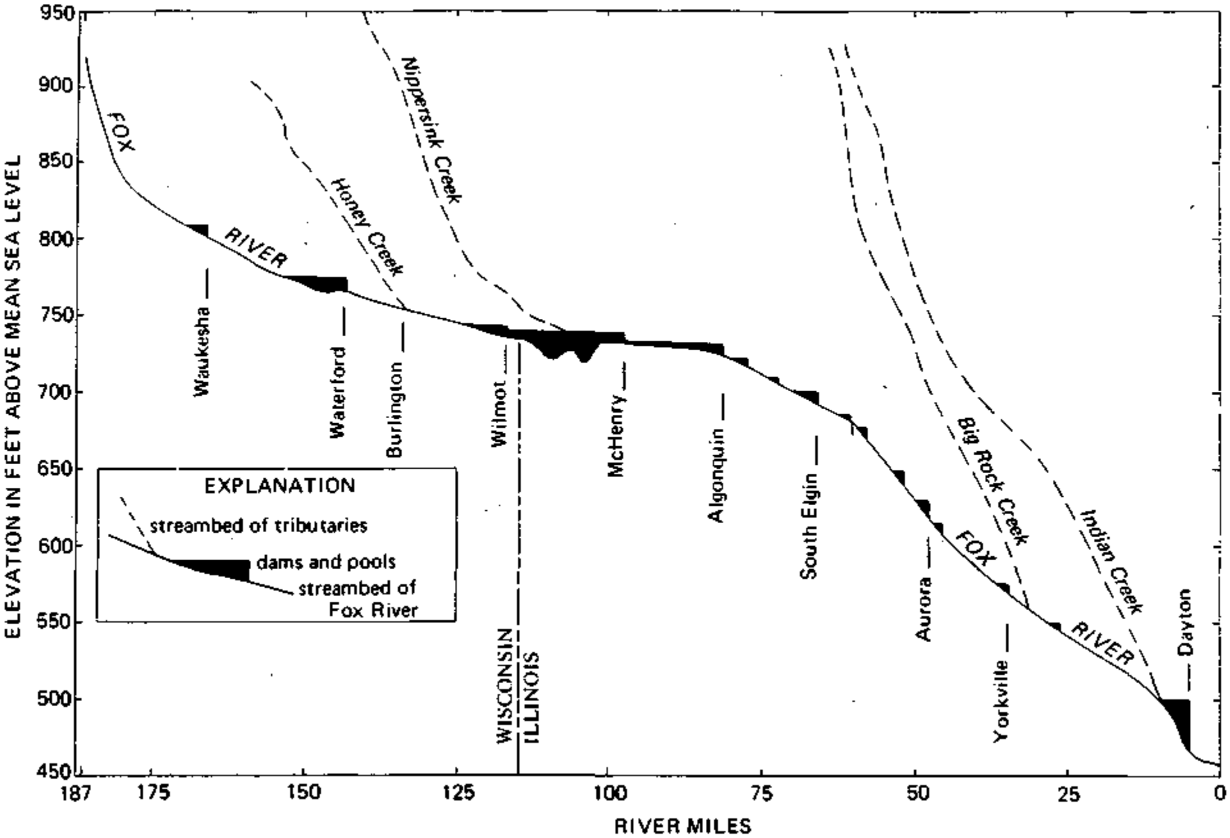

Figure 3. Stream profile of the Fox River and major tributaries

(Fig. 4) vary from moderately slow (less than 0.6 inches per hour) to rapid (greater than 20 inches per hour).

Bloomington Ridged Plain. The Bloomington Ridged Plain, which covers the southern half of the watershed, has moraines that are typically smooth and expansive. The region is relatively homogeneous, having wide stretches of flat or gently rolling uplands broken only by stream valleys. The soils that have developed from this depositional pattern maintain this uniform characteristic. The uniformity in soil characteristics throughout this part of the basin is illustrated in Figure 4. The location and permeabilities of soils shown in Figure 4 were obtained from Fehrenbacher et al. (1984) and various county soil surveys. This portion of the basin has soils of moderate permeability, that is, the substratum has a permeability of between 0.6 and 2.0 inches per hour.

Influence of Soils on Hydrology. Soil type and permeability are of considerable importance in the evaluation of watershed hydrology because they have a great influence on the distribution of flow to the stream. Sandy soils, for example, will have a much higher proportion of precipitation infiltrating

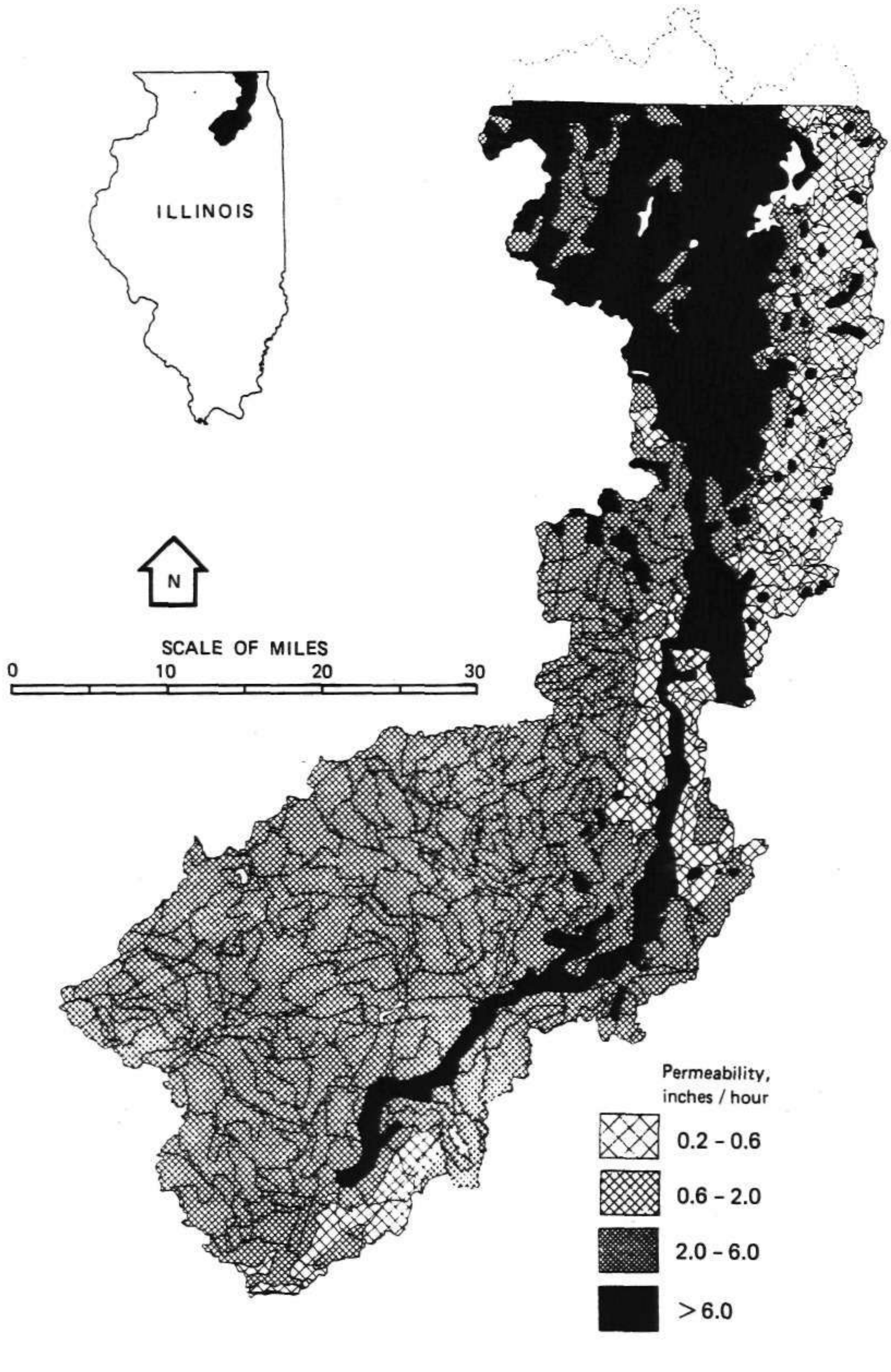

Figure 4. Range of soil permeabilities In the Fox River Basin

into the soil and the lower strata. This reduces the amount of water flowing overland directly to the stream and thereby reduces the magnitude of storm runoff. A large portion of the water that infiltrates is temporarily stored as shallow groundwater and is discharged to the stream later in the year. This allows sandy areas to have a greater amount of baseflow during dry periods.

Land Slopes. An additional difference between the two physiographic subdivisions is the general slope of the land. Table 1 provides the average distribution of overland slopes of the two regions, estimated from data in Runge et al. (1969). More than 25% of the Wheaton Morainal Country has slopes in excess of a 4% slope. On the other hand, less than 10% of the Bloomington Ridged Plain has slopes that steep, and a majority of the area has less than a 2% slope. This difference is illustrated by mesh plots of ground-surface elevations for two areas typical of the respective subdivisions (Figs. 5a and 5b). Each of these plots represents a total surface area of 1.5 square miles. The terrain for the area in the Wheaton Morainal region show both a greater relief (80 feet) and greater variety in surface features than does that of the Bloomington Ridged Plain (total relief = 25 feet).

Table 1. Distribution of Overland Slopes in the Subdivisions of the Fox River Basin

Overland Slope (percent)	Percent of Watershed Area: Wheaton Morainal Country	Percent of Watershed Area: Bloomington Ridged Plain
0- 2	43.	58.
2- 4	31.	33.
4- 7	17.	7.
7-12	6.	1.0
12-18	2.7	0.6
18-30	0.3	0.3
>30	0.0	0.1

Lakes. Dams, and Reservoirs In the Fox River Basin

The northern half of the Fox River Basin contains a number of natural lakes caused by depressions in the glacial deposition. The location of some of the larger lakes in northeastern Illinois is shown in Figure 6. Most conspicuous are the Chain of Lakes in northern Lake and McHenry counties and Lake Geneva in Wisconsin. The Fox Chain of Lakes, comprised of nine interconnected lakes, is of special interest because it has some effect on the flow of the Fox River, which enters the lakes from the north. The Chain of Lakes has a total surface area of 6,850 acres and a total storage

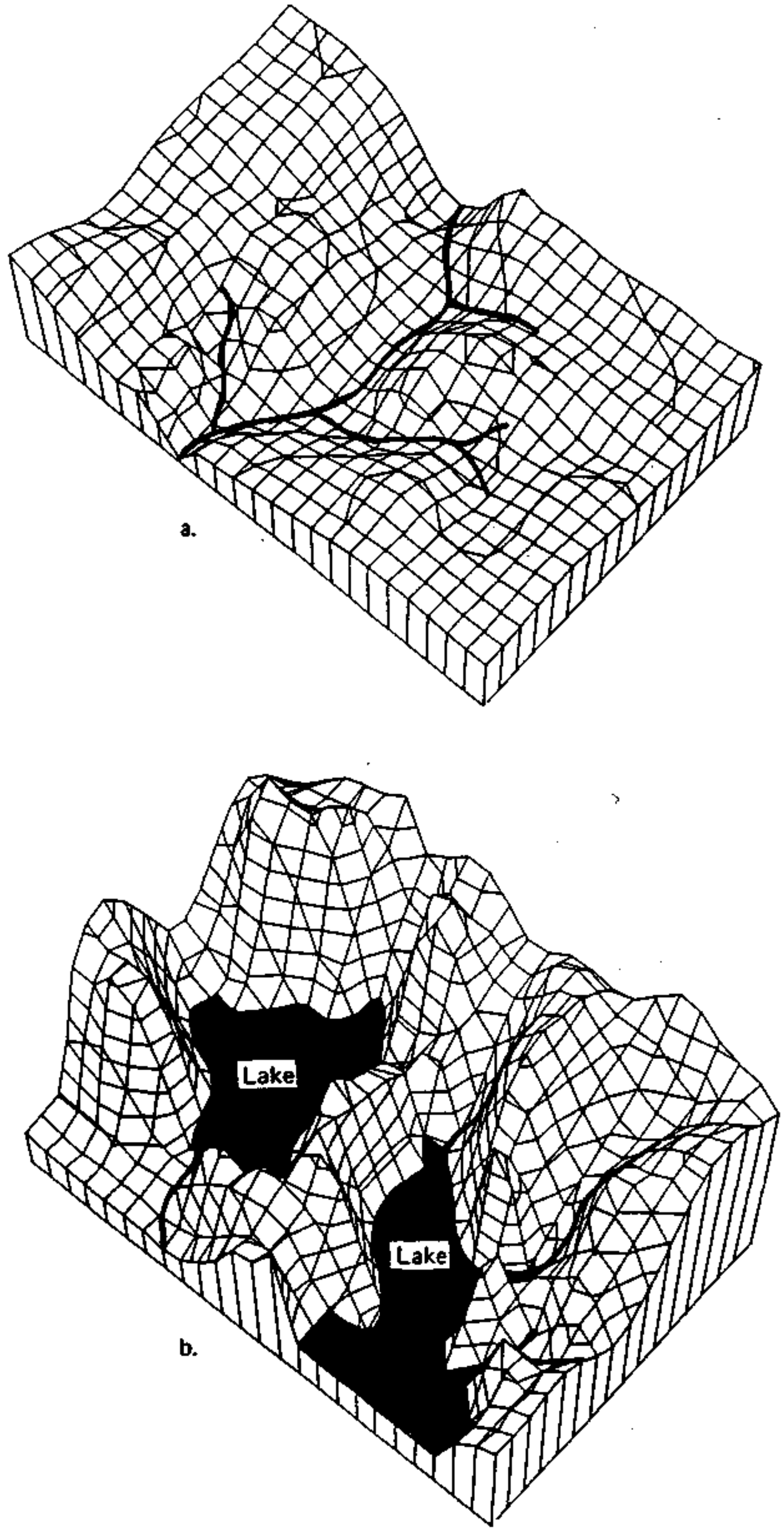

Figure 5. Mesh plots of ground-surface elevation: (a) Sutphens Run (Bloomington Ridged Plain and (b) near Wauconda (Wheaton Morainal Country)

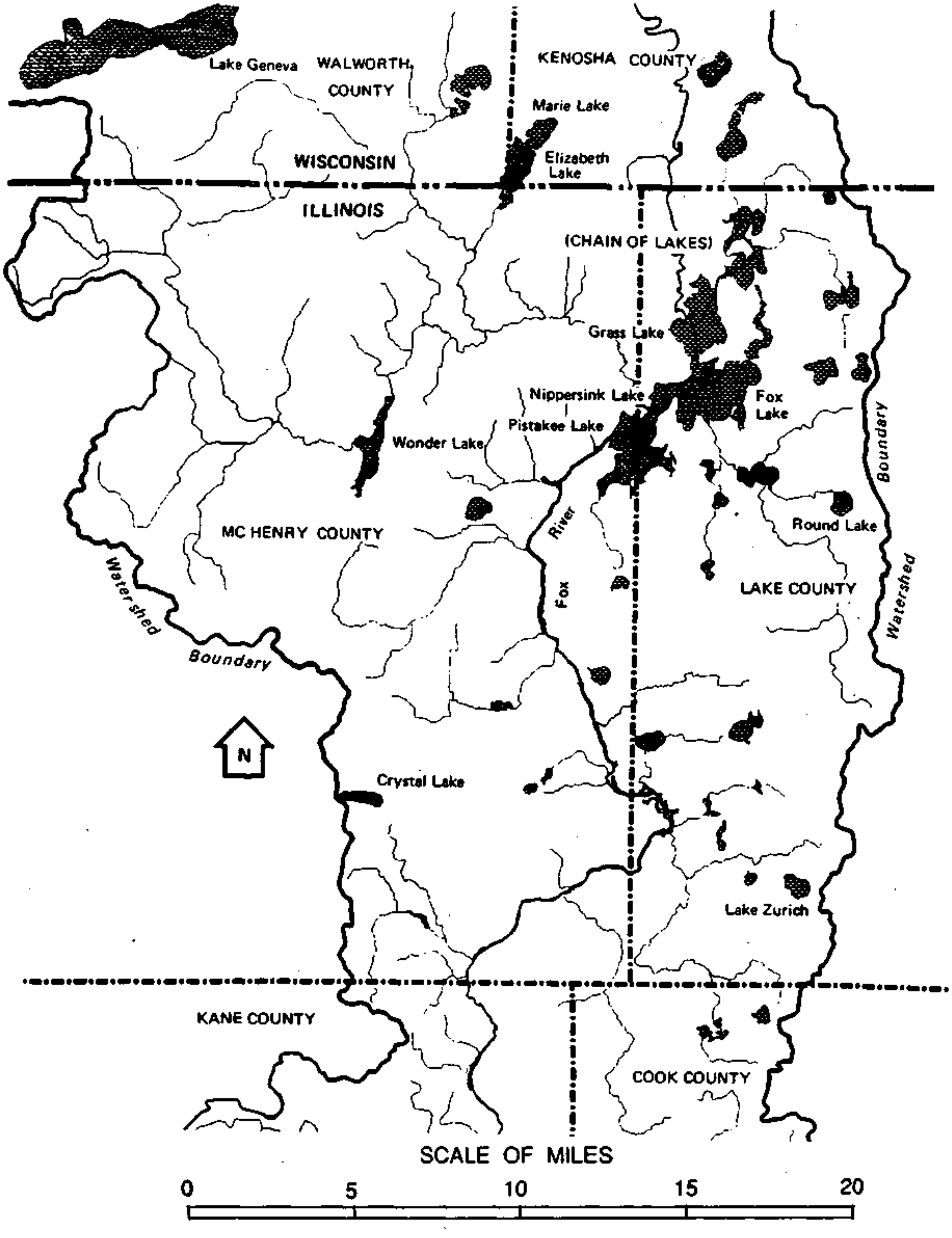

Figure 6. Location of lakes and reservoirs In Lake and McHenry counties

of 37,000 acre-feet. The outflow from the lake is partially controlled by McHenry Dam, which is located on the Fox River, 6 miles downstream of the lakes.

The distribution of lakes shown in Figure 6 is typical of much of the Wisconsin portion of the basin. Many additional small natural lakes and wetlands exist that have surface areas less than 100 acres. These lakes play an important role in the hydrology of the area because they introduce an additional factor of storage within the watershed. This storage tends to reduce the range of variation for dry and wet periods in the basin.

Although most of the lakes in the Fox River Basin have their origins as natural lakes, all but a few have had impounding structures installed at the lake outfall. The impounding structures are used to reduce the variability of stage and prevent the lake level from dropping too low. These structures have caused most of the natural lakes in the region to behave much like man-made lakes. The differences between the effects of a natural lake versus those of a man-made lake are described in the section on "Flow Conditions Downstream of Lakes and Reservoirs" (pages 56-63).

In addition to the lakes and reservoirs described above, nineteen low-level dams exist on the Fox River (Table 2, also shown in Fig. 3), fifteen of which are in Illinois. A majority of the dams were originally built in the period 1830-50 to provide power for saw mills and flour mills, and typically are only seven or eight feet high. Over the years the dams were improved and replaced, and they continued to provide power through the early part of the twentieth century (Illinois Rivers and Lakes

Table 2. Dams on the Fox River

Location	Mileaae	Primary Use	Surface Area (acres)
Dayton	5.7	Hydroelectric	199
Yorkville	36.5	Recreation	111
Montgomery	46.8	Recreation	48
Aurora	48.4	Recreation	67
Aurora	48.9	Recreation	33
North Aurora	52.6	Recreation	133
Batavia	54.9	Recreation	74
Batavia	56.3	Recreation	68
Geneva	58.7	Recreation	89
St. Charles	60.7	Recreation	295
South Elgin	68.2	Recreation	192
Elgin	71.9	Recreation	314
Carpentersville	78.2	Recreation	140
Algonquin	82.6	Recreation	849
McHenry	98.9	Recreation	6850
Wilmot, WI	116.2	Recreation	135
Rochester, WI	139.1	Recreation	46
Waterford, WI	141.3	Recreation	1240
Waukesha, W)	177.2	Recreation	23

Commission, 1915). The Dayton Dam, at the downstream end of the Fox River, is the only one that currently produces electricity. The others are used primarily for recreation and to retain accustomed high pool levels. Downstream of South Elgin the channel bottom of the Fox River is mostly bedrock, and without the heightened pool levels offered by these dams the flow would frequently be shallow (less than 3 feet) and inhibit recreational boating. With the exception of McHenry Dam, the dams do little to alter the river's flow pattern. However, the increase in the normal pool levels does cause flood levels to also be higher (U.S. Army Corps of Engineers, 1984).

Hydrologic Budget (Precipitation. Evapotranspiration. Streamflow. and Monthly Differences)

Precipitation. The 30-year annual average precipitation (1951-80) for the Fox River Basin varies from approximately 35 inches in the DeKalb County area to just under 30 inches in the northern portions of the basin in Wisconsin. A smoothed geographical distribution of the annual average precipitation within Illinois is shown in Figure 7a. This figure is similar to other published values of mean precipitation (Wendland et al., 1985), but the values have been smoothed in order to provide for greater continuity with estimated values of evapotranspiration and streamflow.

Annual totals of precipitation for the Illinois portion of the Fox River Basin have varied from less than 23 inches in 1901 and 1956 to more than 48 inches in 1902 and 1972. Table 3 lists the periods since 1900 having the greatest cumulative deficit in precipitation from the average. Most of these precipitation droughts typically last for a period extending over two summers.

Evapotranspiration. Evapotranspiration for the watershed was estimated as the difference between the 1951-80 precipitation and average streamflow from selected gaging stations for the

Table 3. Precipitation Deficits in the Fox River Basin, 1901-85

Date of Drought	Duration (months)	Cumulative Deficit (inches)
Jun 1933-Aug 1934	15	20.1
Mar 1962-Dec 1964	24	17.0
Feb 1910-Jul 1911	17	14.7
Apr 1922-Jul 1923	15	13.4
Jan 1901 -Jan 1902	13	12.8
Nov 1955-Dec 1956	14	11.2
Aug 1917-Sep 1918	14	11.7
Nov 1970-Nov 1971	13	11.0
Aug 1952-Nov 1953	16	10,9
Extended Droughts		
Aug 1929 -Aug 1934	61	30.5
Aug 1952- Dec 1958	77	20.3

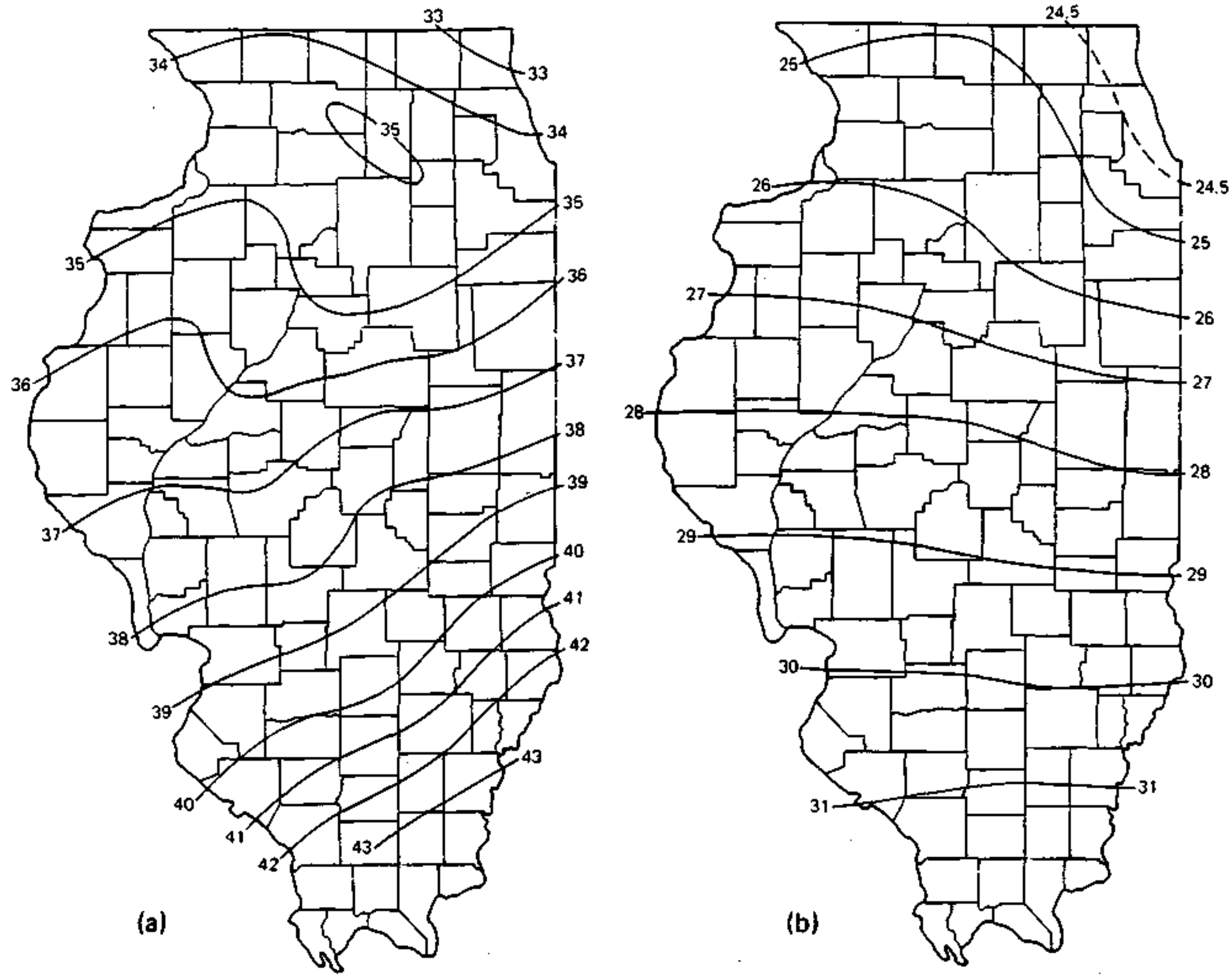

Figure 7. Geographic distribution of average annual (a) precipitation and (b) evapotranspiration in Illinois [inches], 1951-80

same period. This methodology is similar to that used by Jones (1966), with the exception that concurrent records were used for all computations. Average evapotranspiration follows a latitudinal distribution but displays less geographical variation than precipitation (Fig. 7b). Within the Fox River Basin, the average evapotranspiration varies from not quite 26 inches in the southern extreme of the basin to approximately 24 inches in Wisconsin (Cotter et al., 1969). Although the average evapotranspiration follows a geographic pattern, differences in vegetation and soil type can cause local variation in the average evapotranspiration for a region. In particular, watersheds that have sandy soils usually will have lesser amounts of total evapotranspiration; this lower evapotranspiration rate results from a decreased amount of plant-available moisture existing in the shallow layers of these soils. For use in streamflow assessment, this relationship between average evapotranspiration and soil characteristics has been approximated by the following equation:

$$ET = ETo - 0.8 \log (K/1.2) \qquad (1)$$

where ETo is the regional amount of evapotranspiration as shown in Figure 6, and K is the permeability of the soil in inches per hour. If K is less than 1.2 in/hr, ET is equal to ETo.

Streamflow. The average annual streamflow for a watershed is equal to the difference between the average precipitation and the average evapotranspiration, that is P - ET, where ET is determined by Equation 1. This methodology was used to estimate the average streamflow for 62 streamgaging stations in Illinois with records for 1951-80. The standard error of this estimated flow from the amount measured at the gaging stations is 0.46 inches, or an approximate 5% error.

The estimated average streamflow over the Fox River Basin is approximately 8.5 inches, with sub-watershed values ranging from 6 inches near the headwaters in Wisconsin to more than 9.5 inches near the southern part of the basin. Smoothed estimates of the average annual streamflow in Illinois are presented in Figure 8.

Monthly Differences. A typical distribution of precipitation, evapotranspiration, and streamflow for each month of the year is shown in Table 4. The evapotranspiration and streamflow do not total the precipitation in any one month due to the effect of subsurface (soil and groundwater) storage of water. For any one month, the average addition to this subsurface storage (AS) is estimated as the remainder between the precipitation (P), evapotranspiration (ET), and

Table 4. Typical Monthly Distribution of Precipitation, Evapotranspiration, Streamflow, and Subsurface Storage

(all units in inches)

Month	P	ET	Q	AS
January	1.8	0.2	0.6	+1.0
February	1.5	0.4	0.7	+0.4
March	2.6	0.9	1.4	+0.3
April	3.7	1.5	1.5	+0.7
May	3.6	2.7	1.1	-0.2
June	4.1	4.3	0.9	-1.1
July	3.8	5.7	0.6	-2.5
August	3.1	4.6	0.4	-1.9
September	3.3	2.8	0.4	+0.1
October	2.6	1.2	0.5	+0.9
November	2.2	0.6	0.5	+1.1
December	2.0	0.2	0.6	+1.2
TOTAL	34.3	25.1	9.2	0.0

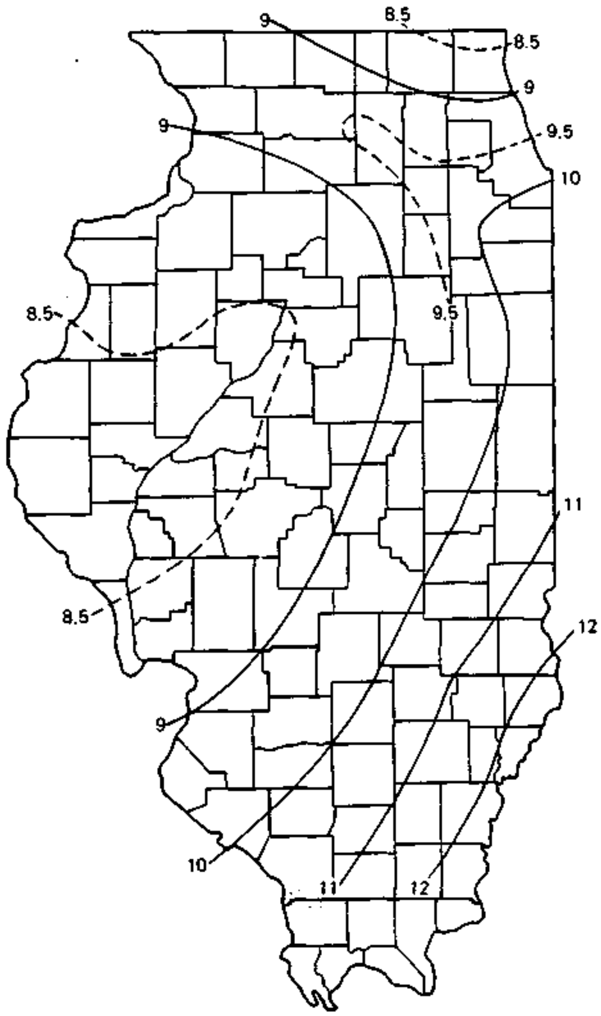

Figure 8. Geographic distribution of average annual streamflow In Illinois [inches], 1951-80

streamflow (Q): $\Delta S = P - ET - Q$. The total streamflow, Q, is the sum of both direct surface runoff and the baseflow which originates from the subsurface storage.

Monthly estimates of evapotranspiration were developed using a soil moisture budget model which was developed at the State Water Survey for use in watershed modeling (Durgunoglu, et al., 1987). Evapotranspiration is noticeably greater than precipitation during the height of the growing season, June through August, when the greatest reduction in subsurface storage of water occurs. The lowest streamflow rates are expected near the end of the growing season (September through November), when soil moisture and groundwater are at their annual minimums. In contrast, average runoff is highest in March, April, and May, when the soil is frequently saturated. In watersheds with large amounts of subsurface storage (resulting from sand and gravel substrata), the seasonal variability in streamflow is often reduced.

Population

The Fox River is located along the western fringe of the metropolitan areas of Chicago and Milwaukee. Figure 9 indicates the extent of urban growth in northeastern Illinois and its proximity to the Fox River. The three major urban areas in the watershed are centered around Aurora (81,000), Elgin (64,000), and Waukesha, Wisconsin (53,000). In 1980, the total population within the Fox River Basin was approximately 950,000, which represents more than a 27% increase since 1970. The 1980 population within the Illinois portion of the basin was approximately 675,000. Population projections by the Illinois Bureau of the Budget show an expected 39% increase in population in the Illinois portion of the basin during the period 1980-2010 (Table 5). Independent projections by the Northeastern Illinois Planning Commission suggest a 59% increase in population over this period. A 41% population increase is expected in Wisconsin.

Table 5. Population Data for Counties within the Fox River Basin

County	Population in thousands (population within the Fox River Basin in parentheses) 1970	1980	2010*
Illinois			
Cook	5488 (42)	5223 (76)	5713(122)
DeKalb	72 (12)	75 (12)	75 (12)
DuPage	492 (8)	658 (10)	843 (64)
Kane	251(245)	278 (272)	358 (352)
Kendall	26 (23)	37 (34)	37 (34)
Lake	383 (67)	440(110)	525(168)
LaSalle	111 (38)	109 (37)	97 (32)
McHenry	112 (91)	148(123)	182(156)
Wisconsin			
Kenosha	118 (12)	123 (16)	123 (20)
Racine	171 (28)	173 (31)	172 (36)
Walworth	63 (31)	72 (38)	90 (50)
Waukesha	231 (148)	280 (189)	378 (280)
TOTAL	(745)	(949)	(1326)

* projection for counties by the Illinois Bureau of the Budget and Southeastern Wisconsin Regional Planning Commission

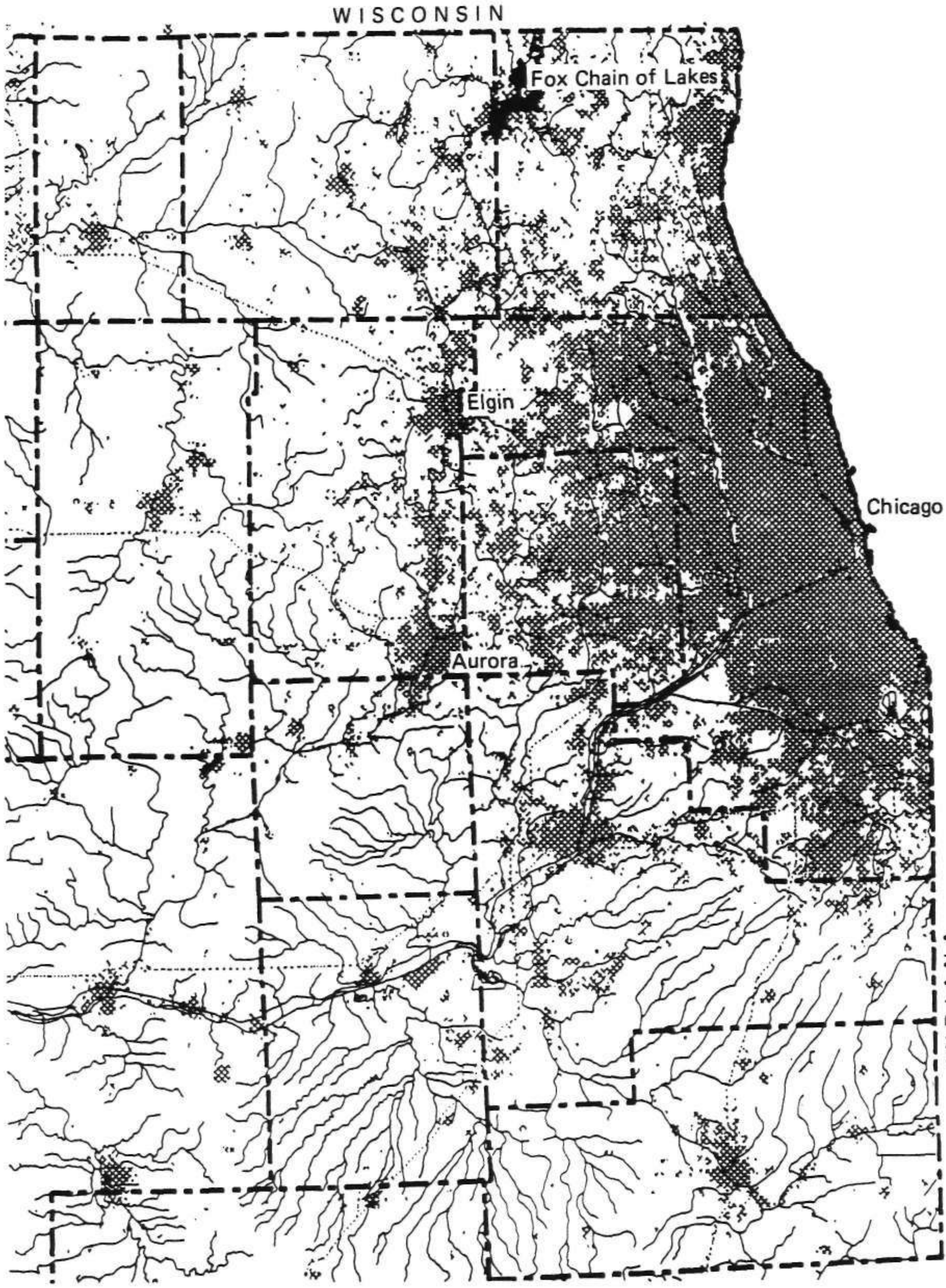

Figure 9. Urban development near the Fox River Basin

A significant proportion of the increase between 1970-80 and the projected increase came from two major areas within the Illinois portion of the basin: 1) the major urbanized area bordering the Fox River in Kane County (Aurora to Elgin), and 2) the suburban communities in the western Lake County and eastern McHenry County area (e.g., Round Lake, McHenry, and Crystal Lake). These two areas are expected to have continued growth through the year 2010. Waukesha County in Wisconsin is an additional area within the watershed that is expected to see significant population growth in the next twenty years.

Urbanization can affect the flow in the watershed in two manners. First, high flows and low flows from urban areas tend to be increased whereas medium flows are decreased. The increase in high flows and decrease in medium flows result from reductions in the infiltration capacity of the land surface and the resulting loss in subsurface storage which is the source of most medium flows. Low flows, however, are increased because of cumulative effect of small discharges to the streams from light industry and storm sewers. The effect of these small discharges is not considered in the Streamflow Assessment Model. The second manner in which urbanization changes flow is the addition of effluent discharges which originate from public and industrial water use. These discharges are discussed in the following section of this report. Population growth in the Fox River Basin has caused a significant increase in these large effluent discharges which therefore has increased low streamflow amounts. The water use and effluent discharge situation is analyzed in the following section.

3. WATER USE AND WATER SUPPLY IN THE FOX RIVER BASIN

The total water use within the Fox River Basin is approximately 33 billion gallons per year, equivalent to 93 million gallons per day (mgd). The water use within the Illinois portion of the basin is approximately 75 mgd. More than half of the Illinois portion is concentrated along the Kane County reach of the Fox River (Aurora north to Carpentersville).

Groundwater is the primary source of water supply for public and industrial use in the Fox River Basin. Only about 7 mgd of the total water usage in the Illinois portion of the watershed comes from surface water sources. Most of the larger withdrawals have been, and continue to be, pumped from the Ironton-Galesville sandstone formation of the Cambrian-Ordovician system. Individual wells in this aquifer typically pump 1,000 gallons per minute (gpm) from an average depth of 1,200 to 1,400 feet below the ground surface. This aquifer is also used extensively for industrial water use throughout the Chicago metropolitan area, and as a result of heavy usage, the aquifer has experienced significant drawdown. Elgin and Aurora, the two largest areas of water use in the basin, use this aquifer and have cones of depression that result from heavy use (Sasman et al., 1982).

Associated with the drawdowns that are occuring in the Cambrian-Ordovician system has been an increase in the barium content of the water being pumped. Many municipalities have been or will be faced with the alternative of treating their water supply for its barium content or finding a different water supply source. The Fox River is the primary alternative source for large amounts of water, although shallow sand and gravel aquifers are also available as sources of water for many communities along the Fox River and other limited areas of the basin. St. Charles, Geneva, and Batavia are all considering shallow sands and gravels as a supplementary source for their water supply systems.

In 1983, Elgin began withdrawing water from the Fox River. By 1986 this withdrawal, with an average rate of 8.1 mgd (12.6 cfs), served 85% of the public water needs for the city. At present, Elgin and the Fermi National Accelerator Laboratory (an average use of 1.16 mgd) are the only significant users of surface water in the Fox River Basin. However, Aurora has developed plans to use the Fox River as a future water supply source. These plans indicate a maximum potential withdrawal of 15 mgd (23.2 cfs), and therefore Aurora may likely become the largest user of surface water in the basin.

<u>Effect of Water Use on Streamflow</u>. Because most of the withdrawals for water use in the Fox River Basin come from groundwater supplies, there are few withdrawals directly from the streams. The major surface withdrawal in the basin (Elgin) is primarily nonconsumptive, which means that the water is returned after use (via the Elgin Sanitary Treatment Plant) to the Fox River just a few mile downstream. In addition, this withdrawal is discontinued during low-flow periods when the potential impact of the withdrawal on streamflow would be greatest.

Existing groundwater withdrawals have a limited impact on streamflow. For this reason streamflow is primarily affected by the addition of flow quantity from many the wastewater treatment plants which continually discharge municipal and industrial effluent water into streams (Figure 10). Because much of this water originates from groundwater sources, the total volume of streamflow in the Fox River has been increased through human use of water in the watershed. Water quality is affected by these discharges, and the ability of the river to assimilate the effluents has been a environmental concern since the early part of this century (Illinois Rivers and Lakes Commission, 1915). However, over the past several decades improvements in effluent treatment have led to a significant visual improvement in the quality condition of the Fox River.

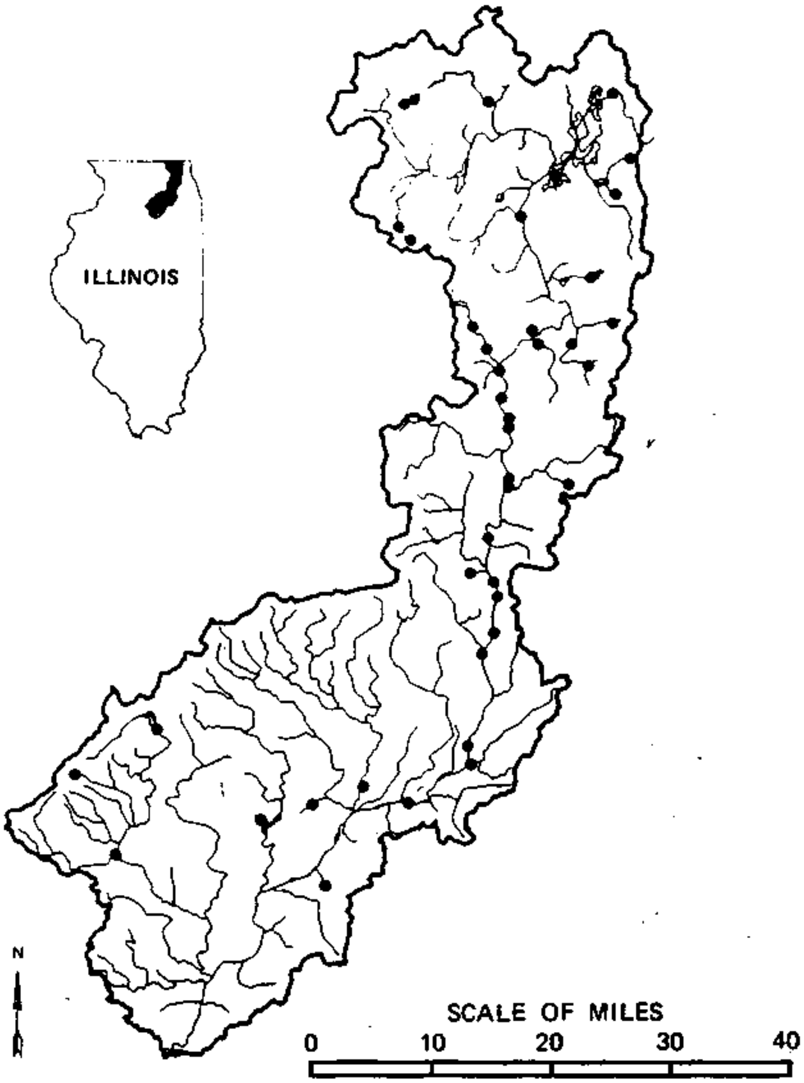

Figure 10. Location of effluent discharges In the Fox River Basin

Withdrawals from shallow sand and gravel aquifers may impact low flows by reducing the groundwater flow to streams. This is a potential concern along the Fox River near Carpentersville and East Dundee, where total withdrawals from shallow alluvium exceed 3 mgd. The variability in baseflow accretion to the Fox River near this area was studied by Broeren and Singh (1987). The results of this study identify reaches along the river where the net flow of groundwater to the stream is negative, and suggests that the withdrawals from existing wells may have some influence on flows in the streams. However, the channel losses given by Broeren and Singh are substantially greater than groundwater withdrawals in the area and for this reason may instead identify reaches of natural negative accretion to the stream. The findings of their analysis are not quantitatively conclusive, and for this reason were not adopted for the evaluation of low flow along the Fox River.

Estimation of Effluent Discharges

The hydrologic evaluations used in the development of the Streamflow Assessment Model require separating the effects of these effluents from the daily streamflow record for each of the streamgaging sites. In order to accomplish this, a time series of daily effluent discharges must be developed. This involves an evaluation of 1) long-term changes in the amount of average discharge at the water treatment sites over the period of record of the streamgages, and 2) an estimation of the short-term, day-to-day variation in the discharge amount.

Long-term changes in average effluent discharges since the early 1900s were estimated from water supply records kept at the Illinois State Water Survey. An example of the estimated water-use patterns developed from this data for Kane County, 1900-80, is shown in Figure 11.

Flow Duration Curves for Effluent Discharges. The day-to-day variations in effluent discharge from the average annual value can be estimated from selected monthly and daily records of discharge from wastewater treatment plants. Monthly totals of discharge were obtained from the Illinois Environmental Protection Agency for 1982-85 for all of the major wastewater treatment plants in the Fox River Basin. For example, monthly effluent discharges from the wastewater treatment plant in Aurora (1982-84) are presented in Figure 12. Daily discharge data were also available for several treatment plants for selected months in 1970-71. A graphical representation of these daily effluent data at Aurora for August 1971 is presented in Figure 13. The daily data show a cyclical response because effluent discharges are usually greater on weekdays than on weekends.

From the type of information shown in Figures 12 and 13, frequency relationships of daily effluent discharges were developed for each of the treatment plants in the Illinois portion of the Fox River watershed. When these frequency curves are made nondimensional (by dividing all flows by the mean discharge of the treatment plant), the curves show great similarity for most sites. These nondimensional curves were averaged, and the resulting probability relationship of daily effluent discharge ratios is given in Table 6.

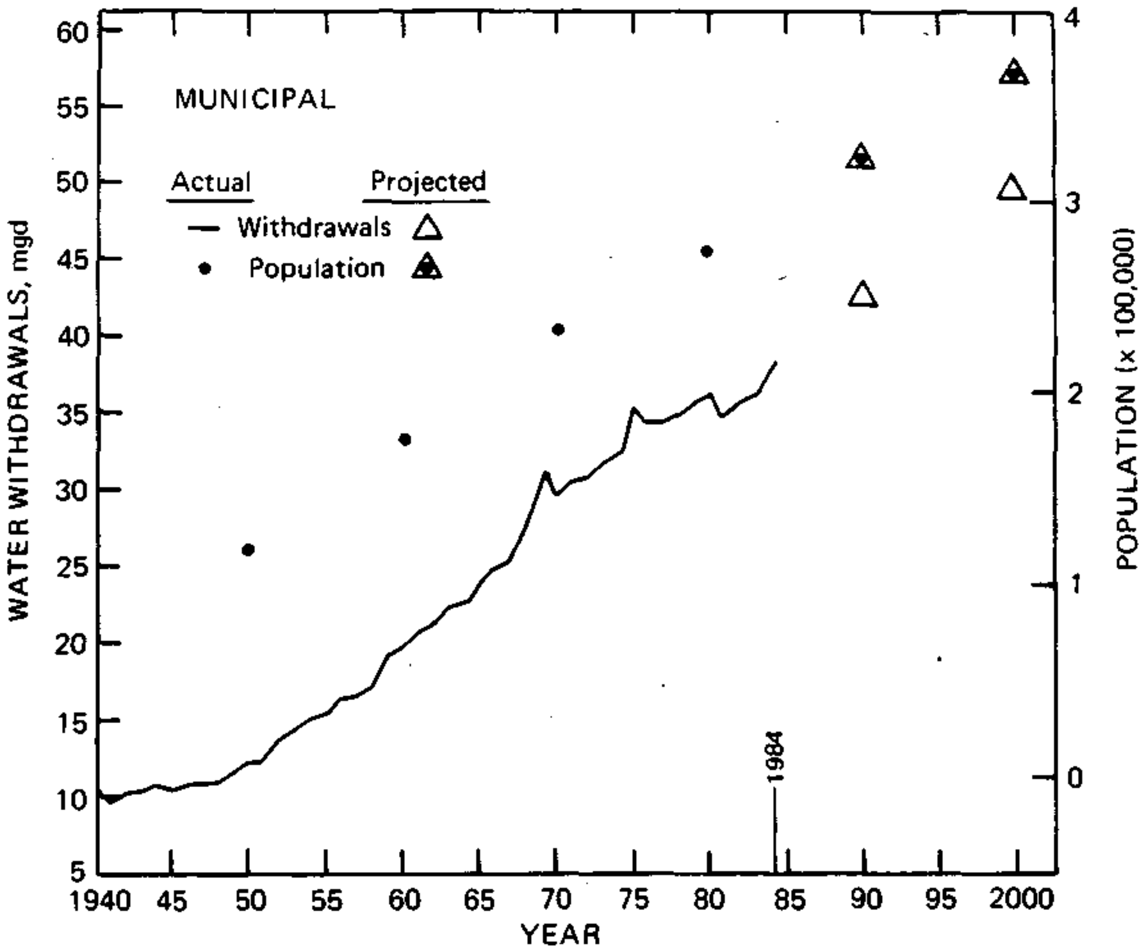

Figure 11. Water use and population patterns In Kane County, 1900-80 (from Broeren and Singh, 1987)

Relationship of the Effluent Discharges to the Corresponding Streamflow. In order to separate the effluent discharges from the daily streamflow record, an estimate of the total effluent amount for each day must be made. Most of the municipal discharges in the basin are from combined systems for which the water treatment plant processes both sewage and storm runoff. For this reason, the periods of the record that have a high rate of effluent discharge will usually occur during periods of high stream runoff. From an examination of Figure 12 it is reasonable to expect this concurrence, for example (on average) an effluent discharge with a frequency of exceedance of 90% will occur when the flow frequency in the stream is near 90%.

However, this relationship is complicated by the observed day-to-day discharges (Figure 13) that show considerable variation. As shown in this figure, the days of lowest effluent discharge tend to occur only on certain days (primarily on weekends). This is in contrast to days of low flow in

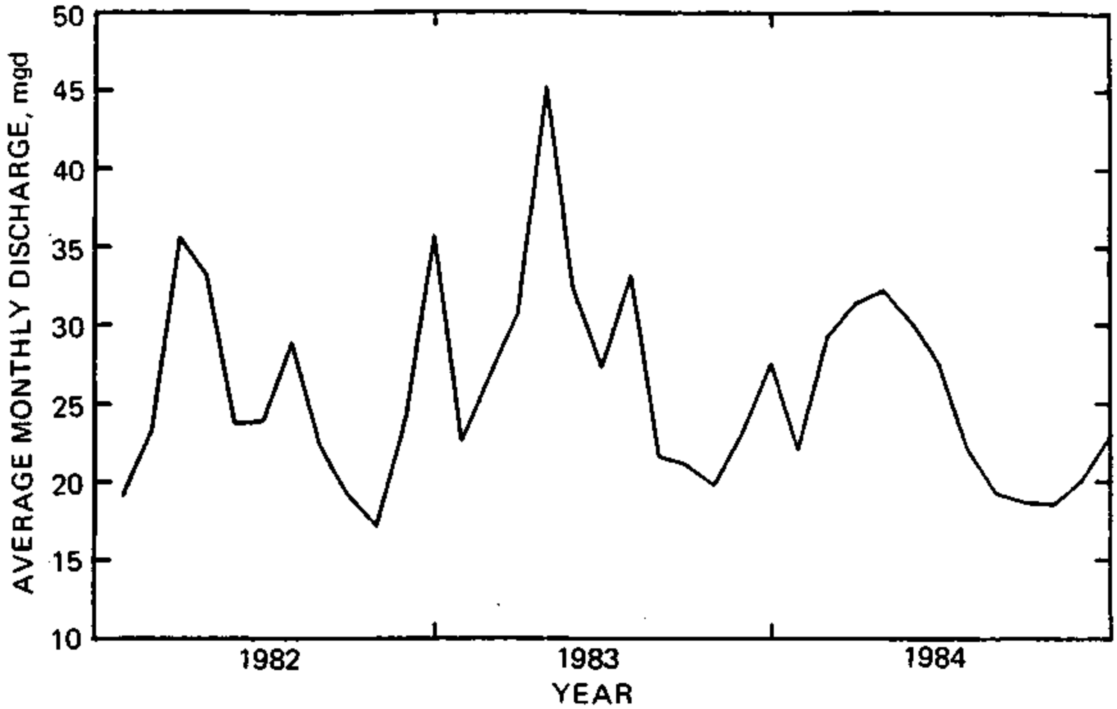

Figure 12. Monthly effluent discharges for Aurora, 1982-84

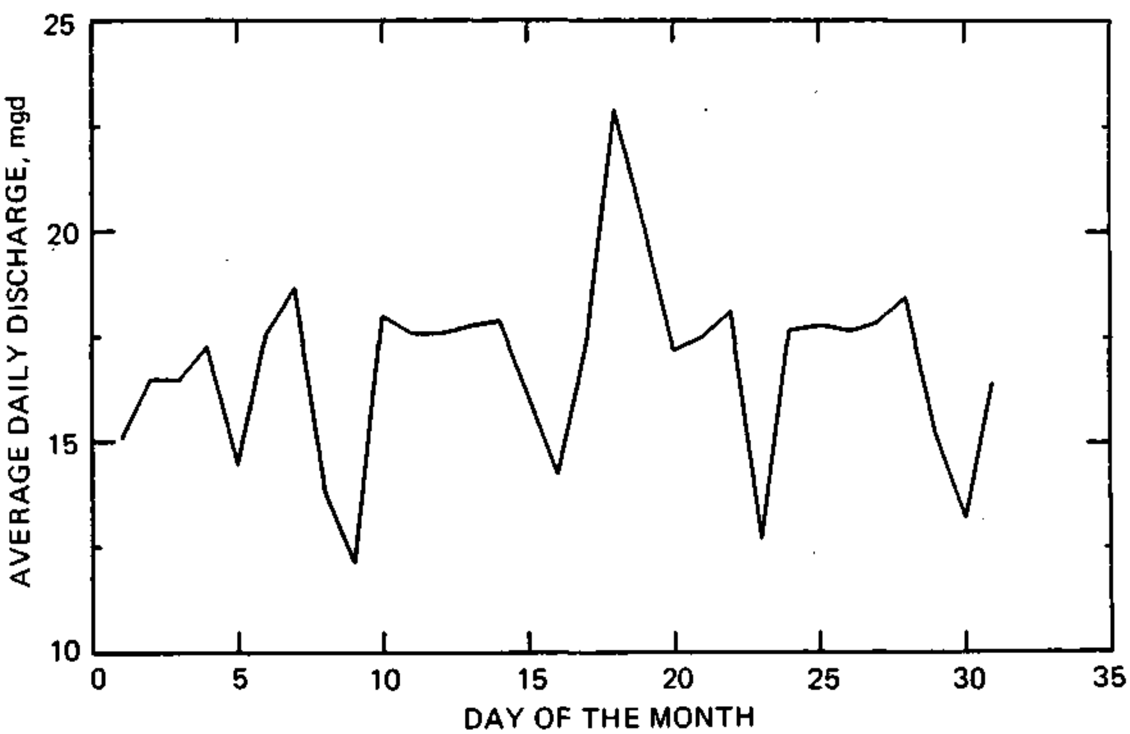

Figure 13. Daily effluent discharges for Aurora, August 1971

Table 6. Relationship Between Flow Frequency, Effluent Discharge Ratio (Ratio to the Mean Discharge), and the Ratio which Contributes to Streamf low

Probability of exceedance (%)	Daily Effluent Discharae Ratio (EDR)	EDR Contributing to Streamflow
1	1.78	1.52
2	1.62	1.40
5	1.45	1.26
10	1.30	1.18
15	1.22	1.12
25	1.11	1.06
40	1.00	1.00
50	0.96	0.97
60	0.91	0.94
75	0.84	0.88
85	0.78	0.84
90	0.72	0.80
95	0.66	0.76
98	0.56	0.70
99	0.50	0.64
99.5	0.47	0.60
99.9	0.40	0.45

streams, which occur consecutively. For this reason, the lowest effluent discharges will not always occur on the same days that have the lowest streamflow. In order to produce an additive relationship between streamflow and effluent volume, the effluent discharges must be averaged to represent the variability of their serial nature. The final column in Table 6, produced through analyses of available daily effluent information, represents the relative discharge amounts that on average correspond to the streamflow (for a given probability of exceedance). Flow rates were computed for each of the model's 154 streamflow parameters at all effluent discharge in the basin. These estimated effluent amounts are given in Appendix B.

Future Water Use and Effluent Discharges

The determination of future streamflow conditions requires an estimation of the future withdrawals for water use, sources for these withdrawals (streamflow versus groundwater), and effluent discharges within the basin. The major changes in water use (and also the changes that are most predictable) are expected to be associated with increases in population, that is, a municipality experiencing an increase in population can expect a similar increase in water use. Figure 11 illustrates the relationship between population and total water use in the Kane County portion of the Fox River Basin. In recent decades, the amount of water use per capita has remained relatively stable; little change is expected in the near future.

Water Supply Sources. The water supply source for each user in the basin is not projected to change during this 1984-2010 period, with the exception of the Aurora, which is expected to begin withdrawing water from the Fox River. The Fox River is expected to supply approximately 50% of the total water needs for that city. Ample flow in the Fox River exists to provide the large quantities of water needed by Aurora and Elgin, as well as by other potential users. These withdrawals of water will not significantly alter flow conditions of the river, with the possible exception of extreme drought conditions. However, supplemental use of the Ironton-Galesville sandstone and other groundwater sources during such low-flow conditions can eliminate the need to withdraw water from the Fox River. If groundwater withdrawals are used for supply during dry periods, Elgin and Aurora's use of Fox River water would not be expected to affect flows in the Fox River significantly.

With the increased use of Fox River water for water supply, the total withdrawal from the deep sandstone aquifers will decline. In addition, by the early 1990s many of the cities directly to the east of the Fox River Basin in DuPage County will begin to receive large amounts of water piped from Lake Michigan, which will reduce pumping from groundwater. Lake Michigan water could eventually be made available to cities along the Fox River, but that would be unlikely while Fox River water is considered in ample supply. As population growth continues into the western portion of the basin, shallow groundwater (sands and gravels in the glacial drift) will supply an increasing amount of water.

Future Effluent Discharges. Estimates of effluent discharge for the year 2010 were developed using population projection figures from the Illinois Bureau of the Budget and the Southeastern Wisconsin Regional Planning Commission (Table 5). The average amount of water use per capita over this period was taken as a constant, therefore in most cases the estimated percentage increase in water use over the period 1984-2010 is equal to the projected rate of population growth. In Table 7, increases in water use estimated by this procedure are given for major municipalities. For certain cities with a substantial industrial water use (e.g., Aurora and Elgin), the estimated increase in water use is based on only that portion of total water use which is related to public supply. Self-supplied industrial water use in the basin has not increased since 1965 and is not projected to increase.

Relationship of Effluents to Low Flows in the Fox River. At present, the 7-day, 10-year effluent discharges from the wastewater treatment plants at both Elgin (south plant) and Aurora are approaching 20% of the 7-day, 10-year low flow in the Fox River. At each of these sites, low flows in the Fox River will increase because of the increased volume of effluents added upstream. However, the increased rate of streamflow is not expected to keep pace with the growth rate of the effluent

Table 7. Present (Year 1984) and Estimated Future (Year 2010) Effluent Discharges in the Fox River Basin

Location	1984 Average (cfs)	1984 Q7.10 (cfs)	2010 Average (cfs)	2010 Q7.10 (cfs)	1984-2010 Population Growth (%)
Upstream of McHenry Dam					
Waukesha, WI	22.9	13.3	33.9	19.7	48
Burlington, WI	3.0	1.9	3.5	2.2	17
Woodstock	2.7	1.8	3.9	2.6	46
Fox Lake Regional	8.4	5.4	13.2	8.5	58
McHenry	3.0	1.9	5.5	3.5	84
Antioch	1.3	1.0	2.1	1.6	65
others	55	4.1	7.5	5.6	36
	46.8	29.4	69.6	43.7	49
Between McHenry and Algonquin					
Cary	1.6	1.1	3.6	2.5	126
Barrington	4.3	2.6	5.5	3.3	27
Lake Zurich	1.5	0.8	2.6	1.4	70
Fox River Grove	1.0	0.9	1.8	1.6	84
others	2.1	0.8	3.0	1.4	43
	10.5	6.2	16.5	10.2	57
Between Algonquin and South Elgin					
Crystal Lake	5.2	3.4	9.5	6.2	83
Lake in the Hills	0.9	0.5	1.0	0.6	15
Algonquin	1.6	0.8	3.6	1.8	128
Carpentersville	4.3	2.3	5.8	3.1	35
East Dundee	0.9	0.5	2.4	1.2	161
West Dundee	1.4	0.8	2.9	1.6	105
Elgin	27.0	20.9	34.6	24.8	**32
	41.5	29.2	59.8	39.3	44
Between South Elgin and Aurora					
St. Charles	6.3	4.6	11.9	8.7	89
Geneva	3.6	2.3	6.9	4.4	93
Batavia	3.5	1.9	6.0	3.2	70
Aurora	37.9	26.6	63.9	43.3	**95
	51.3	35.4	86.7	59.6	69
Downstream of Aurora					
Oswego	0.5	0.3	1.0	0.6	95
Yorkille	1.2	0.8	1.9	1.2	55
Elburn	0.9	0.5	1.9	1.1	**404
others	2.2	1.2	2.2	1.2	0
	4.8	2.8	7.0	4.1	46

** increase in effluent amount is based on that portion of the total discharge which is estimated to result from public water use discharges at either Elgin or Aurora. These observations have three major implications for both the present and future:

1. At present, neither Elgin nor Aurora should withdraw water from the Fox River during extreme low-flow conditions. Otherwise the treatment plant for that city's sanitary district would be in violation of the one-to-five (1:5) dilution ratio required for the discharge of secondary-treated effluents.

2. As growth continues, expected amounts of discharges from each of these plants will exceed the 1:5 dilution ratio. Each of these treatment plants would then need to examine alternative methods of treating or disposing their effluent.

3. Approximately half of the low flows in the river upstream of these plants originated as effluent discharges from other facilities. Under these circumstances, the capacity of the Fox River to assimilate the additional effluents should be of concern.

Part II. Streamflow Assessment

4. STREAMFLOW ANALYSIS FOR GAGED SITES

The objective described in this chapter is to develop estimates of virgin and present streamflow conditions (for the set of streamflow parameters used in the model) at the gage sites in the basin. The first steps involved in this analysis are 1) the separation of the flow record into the two elements of virgin flow and the composite effect of the flow modifiers, and 2) the resulting aggregation of virgin streamflow and present-condition modifiers to compute a streamflow record indicative of present flow. The estimation of each of the 154 flow parameters also involves 3) the interpretation of the record in terms of differences in the period of record at the station of interest as well as the types of analyses used to estimate the recurrence interval of extreme events. The approaches taken for all of these analytical problems are described below.

Hydrologic Concepts of the Streamflow Assessment Model

The characteristics of streamflow in any moderately developed watershed will, over time, vary from earlier conditions because of the cumulative effect of human activities in the region. The degree to which the flow regime has been changed may vary greatly from one stream to another. Generally, the greatest amount of streamflow modification results from water use and water resource projects including: 1) reservoirs; 2) withdrawals from the stream for either irrigation or for industrial and municipal water needs; and 3) effluent discharges, primarily from the municipal and industrial uses of water. These developments, which may have an estimable effect on the streamflow, are termed "flow modifiers."

More subtle modifications to the hydrology of the basin, such as climatic change and changes in land use and urbanization, may have significant effects on changes in the streamflow but these changes are generally indeterminable. For this reason these other effects have not been included as flow modifiers. Because land use changes are not evaluated, the virgin flow should be viewed as representative of the average land use conditions that existed during the period of streamflow record.

By isolating the effects of the flow modifiers and removing the effects from the available streamflow records, estimates can be made describing what the streamflow would be under unmodified conditions. The computation of the unmodified flow, which is termed "virgin flow," can be represented by the equation:

$$Qv = Qp - \Sigma \Delta Qmod(i) \qquad (2)$$

in which: Qv = virgin flow estimate

Qp = measured or "present" flow

Δ Qmod(i) = the change in flow due to the presence of flow modifier " i "

The virgin flows, produced by eliminating the effects of the flow modifiers, have much greater regional homogeneity than do the present flow conditions. Thus, the accuracy of the methods used to transfer the available streamflow records to ungaged sites in the basin may be vastly improved. After estimating the virgin flow (for a given streamflow parameter) for an ungaged site, the present flow can be computed by 1) locating the flow modifiers that affect that site; 2) estimating the effect of the flow modifiers on the streamflow parameter of interest; and 3) reapplying Equation 2, this time to compute the present flow condition. These final steps are an important part of the streamflow assessment model because each flow modifier must be evaluated separately and have a list of its possible effects stored within the model.

Because the effect of each of the flow modifiers is independently derived, it becomes a relatively simple process for the model's user to introduce additional (proposed or hypothetical) flow modifiers. By adding a hypothetical modification (which represents a potential water resources project) to the present conditions, a water resource planner may receive an evaluation of the expected impact of that project on the water supply of the stream system.

Available Streamflow Information

Information on streamflow is put into two categories: 1) daily records from continuous recording streamgages; and 2) miscellaneous discharge measurements at partial record streamgages. Locations of these streamgages and measurement sites are given in Figure 14.

USGS Continuous Recording Gages. Table 8 lists the 11 U.S. Geological Survey (USGS) streamgages in the Fox River Basin for which continuous daily streamflow data are available. Several of these stations do not have records for the mid-1950s and early-1960s and therefore lack much information concerning severe droughts. For these stations, an adjustment is made in the statistics from the gaging record to reflect expected drought conditions (see the section on "Effect of Period of Record", page 34). The first three stations listed in Table 8, all in Wisconsin (outside the area of study), were not analyzed.

IDOT Continuous Recording Gages. In addition to the continuous recording gages operated by the USGS, ten gages exist (Table 8) that are operated by the Illinois Department of Transportation (Division of Water Resources). Four stations lack a rating curve and were therefore unusable in this study. An evaluation of the remaining six gaging stations, all on the Fox River, is presented in Appendix D. The flow records at McHenry Dam and Geneva are of best quality, and these two stations were fully analyzed along with all of the USGS stations.

USGS Miscellaneous Discharge Measurements. In addition to the continuous recording stations, the USGS also has sites at which discharge measurements are taken periodically for varying reasons. However, these measurements, when made at random, are relatively ineffective at describing flow relationships along a stream (Mitchell, 1957). The greatest applicability of discharge

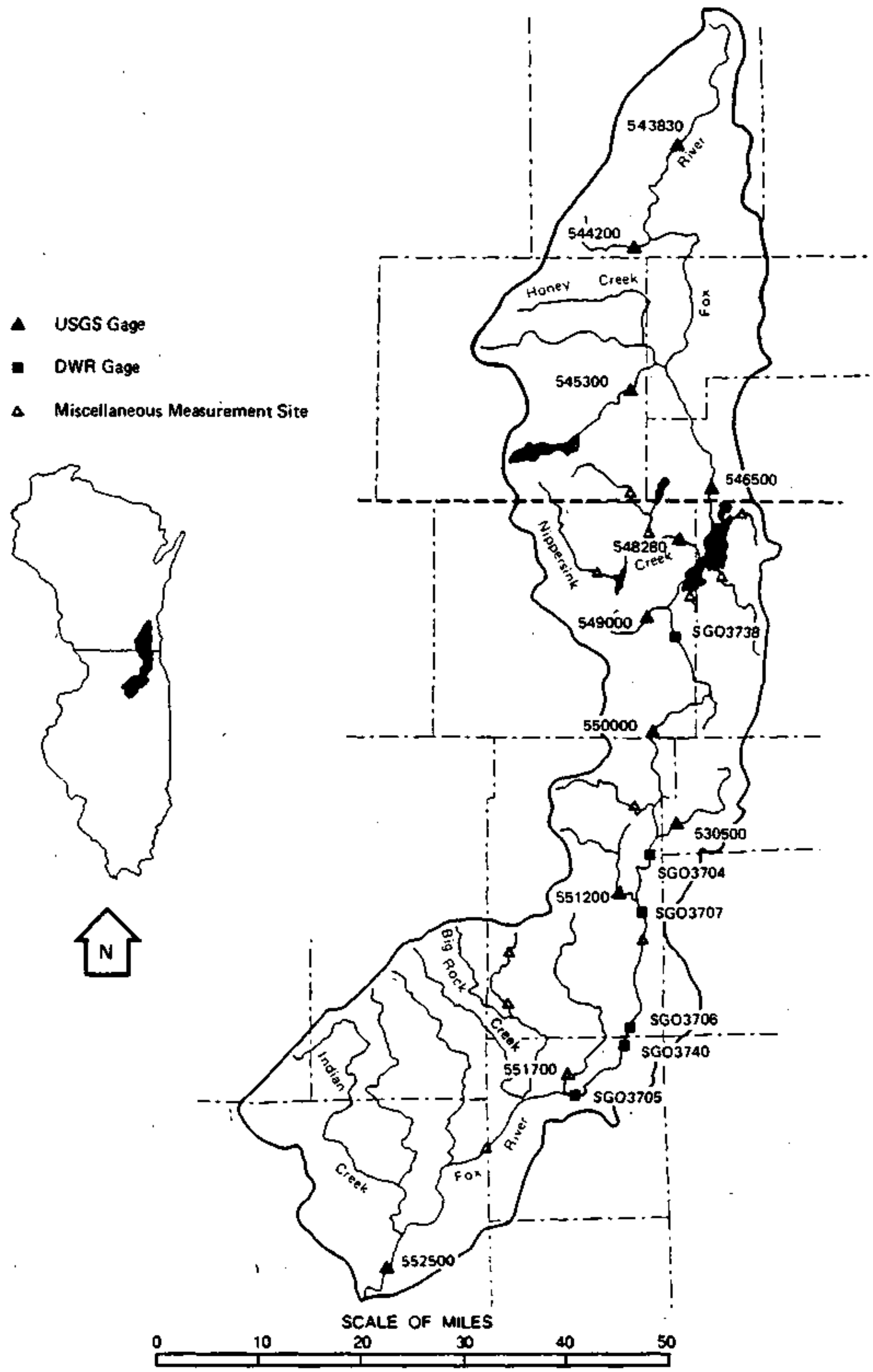

Figure 14. Location of streamgages and miscellaneous measurement sites in the Fox River Basin

Table 8. List of Streamgaging Stations in the Fox River Basin

USGS Continuous Recording Gages

Station name	Gage#	Years of Record	Area (mi^2)
Fox River at Waukesha, WI	05-543830	(1963-1985)	126.
Mukwonago R at Mukwonago, WI	05-544200	(1973-1985)	74.1
White R near Burlington, WI	05-545300	(1973-1982)	97.5
Fox River at Wilmot	05-546500	(1939-1985)	868.
Nippersink Cr near Spring Grove	05-548280	(1966-1985)	192.
Boone Creek near McHenry	05-549000	(1948-1982)	15.5
Fox River at Algonquin	05-550000	(1915-1985)	1403.
Poplar Creek at Elgin	05-550500	(1951-1985)	35.2
Ferson Cr near St. Charles	05-551200	(1960-1985)	51.7
Blackberry Cr near Yorkville	05-551700	(1960-1985)	70.2
Fox River at Dayton	05-552500	(1925-1985)	2642.

IDOT Continuous Recording Gages

Station name	Gage#	Years of Record	Area (mi^2)
Fox River at McHenry Darn	SG03738	(1942-1985)	1250.
Fox River at South Elgin Dam	SGO3704	(1962-1985)	1556.
Fox River at Geneva	SGO3707	(1962-1985)	1652.
Fox River at Montgomery	SGO3706	(1969-1985)	1732.
Fox River near Aurora	SGO3740	(1947-1979)	1735.
Fox River at Yorkville	SGO3705	(1962-1985)	1804.
Nippersink Cr near Solon Mills (no rating)	SG03735	(1962-1966)	185.
Nippersink Cr at Spring Grove (no rating)	SG03736	(1952-1960)	199.
Blackberry Cr near Elburn (no rating)	SG03741	(1965-1969)	6.0
Blackberry Cr near Sugar Grove (no rating)	SG03742	(1965-1979)	29.6

USGS Miscellaneous Measurement Sites

Station name	Number of Measure-ments	Years	Area (mi^2)
Fox River at South Elgin	84	(1978-1985)	1556.
Fox River at Batavia	33	(1969-1972)	1661.
Fox River at Montgomery	83	(1961-1962, (1975-1985)	1732.
Fox River at Millington	7	(1961-62,1975)	2107.
North Br Nippersink Cr near Genoa City, WI	31	(1961-67,1972)	13.6
North Br Nippersink Cr near Richmond	7	(1961-1963)	69.3
Nippersink Creek at Greenwood	6	(1961-1963)	88.9
Nippersink Creek at Spring Grove	7	(1961-1963)	199.
Sequoit Creek at Antioch	8	(1975)	13.7
Squaw Creek at Fox Lake	9	(1975)	38.6
Lily Lake Drain near Johnsburg	10	(1975)	5.87
Tyler Creek at Elgin	6	(1961-1962)	39.1
East Br Big Rock Cr near Troxel	4	(1977)	6.93
East Br Big Rock Cr near Big Rock	6	(1961-1962)	31.5

measurements appears to lie in the estimation of low-flow conditions at the measurement site. But for miscellaneous discharge measurements to be used in such a manner, the following conditions should hold: 1) a gaging station must exist nearby with which a regressive relationship with a high percentage of explained variance can be developed, and 2) the discharge measurements should include extreme events (greater than a 5-year recurrence) so that the derivation of flow parameters does not require extrapolation much outside of the range of the regressive relationship. The four discharge measurements sites for Nippersink Creek and the North Branch Nippersink Creek were most useful in this regard because the measurements included the extremely dry conditions experienced in 1963.

Estimation of Virgin and Present Conditions

In order to separate the effect of the flow modifiers from the daily streamflow records of the gages in question, the flow-duration relationship for each effluent discharge was modified to represent conditions concurrent with the flow-duration of the streams into which the discharge occurs. The magnitude of effluent discharges to the stream varies over the period of recorded streamflow, therefore the relationship established for 1982-85 needed to be extended to the remainder of the flow record. This was done by examining the State Water Survey's historic records of water use and establishing a trend represented by a time-dependent multiplying factor, f_t. The multiplying factor changes Equation 2 to the form:

$$Qv = Qr - \Sigma f_t \, \Delta \, Qmod(i) \qquad (3)$$

where the term Qr, represents recorded streamflow (as opposed to present flow). If the value of f_t = 1.0 represents the present state of the flow modifier (1985), then for most cases f_t takes on a value less than 1.0 for previous years. In addition, the value for f_t is usually linearly related to time (the number of years before present). As a result of these operations, not only can the record of virgin daily streamflow be estimated, but also a historical series of daily flow modification from a given flow modifier can also be created.

Because the magnitude of modifications to the streamflow varies over the span of years, the flow parameters from a gaging station's daily record will usually differ from both the virgin flow and present flow parameters. Therefore, the present flow conditions must be estimated by reconstructing the gaging record by adding the virgin flow record to a series of the daily flow modifications based on present conditions (f_t = 1.0 in Equation 3). The present flow conditions will normally have higher discharge values than the period of record because of increases in effluent discharges. Selected examples of the differences between flow estimates from the period of record and both the virgin and present flow conditions are presented on page 43 following a description of the analyses related to period of record and frequency characteristics.

Effect of Period of Record

The years included in a gage's record have an important effect on the estimation of the value of a streamflow parameter, especially on the estimated value of extreme events such as low flows and droughts. Long-term streamflow records in northeastern Illinois indicate that the worst droughts in this area occurred in the 1930s, 1940s, and 1950s. Many of the gaging records for the smaller watersheds in the Fox River Basin were initiated in the 1960s and therefore do not cover significant droughts.

A primary consideration in the development of the flow estimates in this study is that a consistent relationship be maintained between different locations. For this reason it becomes necessary to find base periods to which frequency estimates could be related. Considerations include both 1) finding a period that includes a representative number of extreme low flows, and 2) finding a period for which many stations have records. For stations along the Fox River a base period of 1942-85 was established. For long-term records such as for the Fox River at both Algonquin and Dayton, this means that only the latter part of the record is used in estimating the frequency relationships. For tributaries within the Fox River watershed, the period 1951-85 was established as the base period for flow frequency estimates. Many of the gaging stations on smaller creeks have shorter records and therefore required some amount of adjustment in the frequency estimates of their streamflow values.

Adjustment for Period of Record. For each gaging record that needs adjustment because of period of record, an index station is identified whose record includes both the base period (1942-85 for the Fox River and 1951-1985 for its tributaries), and the period of record of the gaging station of interest. An example of the type of adjustment made for a flow duration value to account for the period of record is shown in Figure 15. This example is taken from the streamflow assessment analyses done for the Sangamon River Basin (Knapp et al., 1985b).

In Figure 15, each flow value for the index station (Sangamon River at Mahomet) has a different frequency of occurrence depending upon the period of record. To define the long-term frequency for flow values at the station of interest (Goose Creek near Deland), each flow should be paired with the flow in the index station (Mahomet) that has the same frequency of occurrence for the shorter period of record, 1951-59. A new, or "adjusted," frequency for the longer period of record at Goose Creek is then found by making the same "shift" in frequency in the Goose Creek record as is observed between the different curves for the index station. Frequency adjustments for low flows follow this same process. This hydrograph shift technique, Maintenance of Variance Extension (Hirsch, 1982), keeps the relationship between the relative frequencies involved from one period of record to another.

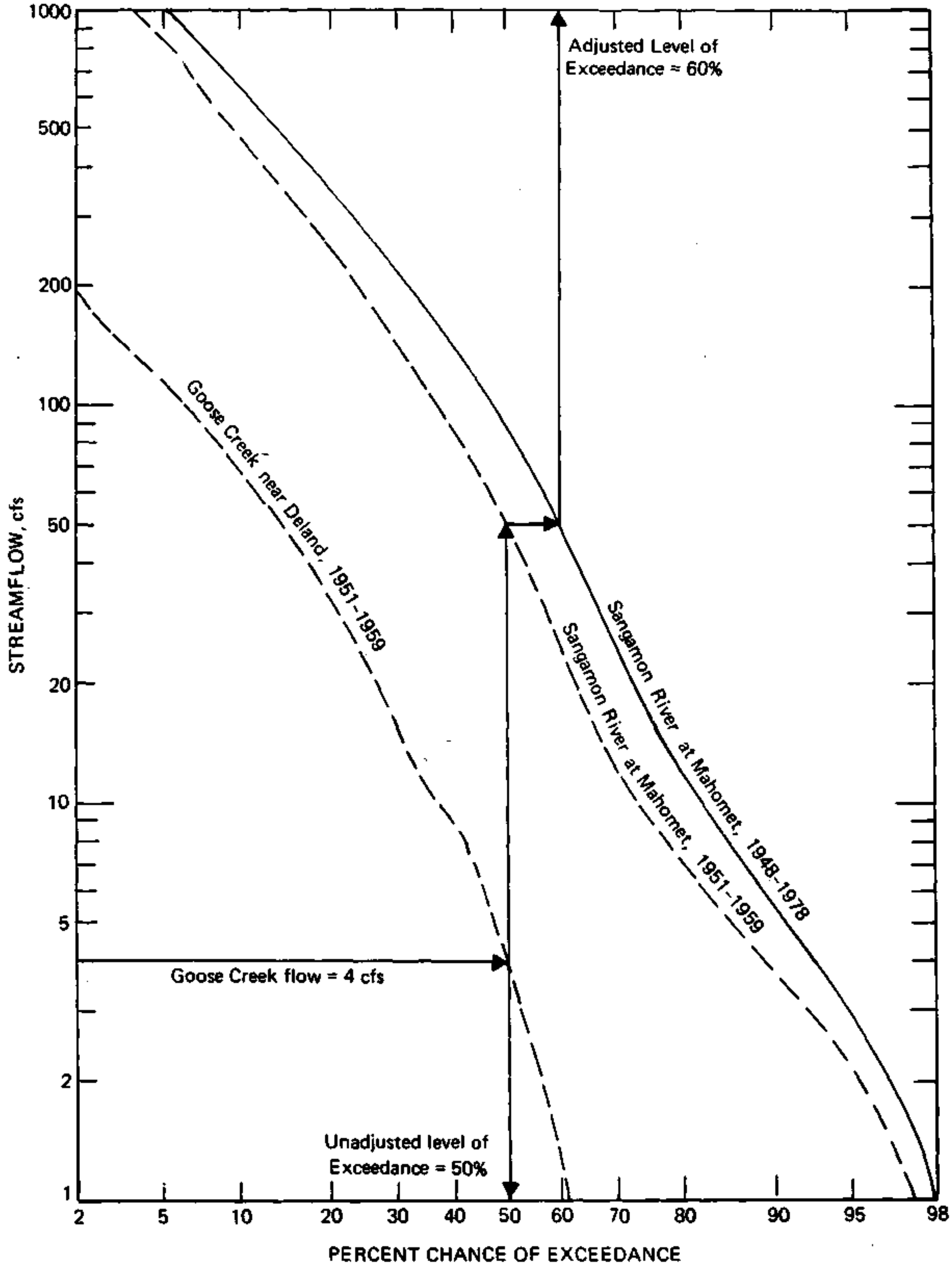

Figure 15. Adjustment In flow frequency for the effects of period of record, Goose Creek near Deland (Sangamon River Basin)

Defining Frequency Characteristics of Low Flows and Droughts

Many streamflow parameters can be computed directly from analysis of the daily streamflow records. However, when dealing with events of infrequent occurrence such as low flows and drought flows, estimates of the associated discharges must generally result from a frequency analysis of the annual series of the streamflow parameter involved. When applicable, it is recommended that the data from the annual series be fitted to a theoretical probability distribution. The fitting of a probability function is preferred for two reasons: 1) it provides an unbiased objective manner of evaluating the data, and 2) the methodology can be automated to reduce the total effort involved with the analysis. However, the probability distribution is only an approximation of the frequency relationship of the flow events. The theoretical distribution will always deviate from the data from the annual series, and it is of value to understand the manner in which these deviations occur.

Three theoretical distribution functions ~ the 1) Gumbel extreme value, 2) Pearson Type III, and 3) Log-Pearson Type III distributions -- were evaluated for their ability to fit the populations of the annual low flows in the Fox River Basin. The first two of these distributions proved to have serious shortcomings for many different sets of data; this is illustrated by one example in Figure 16. In this example, both the Gumbel extreme value and Pearson Type III estimate substantial negative flows for low frequency events.

For most cases, the Log-Pearson Type III distribution performs adequately in fitting the measured data. Nevertheless, there appear to exist systematic deviations between the fitted Log-Pearson Type III distributions and the data from the annual low-flow series. The annual series of low flows for the streamflow gaging stations within the Fox River Basin, when ranked and plotted on a normal probability scale, all show a "terracing" effect in which the change in the low flows from one probability to another is less than that suggested by the distribution function. This terracing effect can be seen in Figure 16 between the probabilities of 10% and 50%. Over these probabilities the general slope of the plotted points is not as steep as the Log-Pearson Type III, creating a poor fitting between the plotted points and the distribution. The misfit causes the distribution to overestimate the low flow for probabilities exceeding 30% and underestimate conditions between the probabilities of 10% and 20%. The plotted points also show localized clusters, which look like smaller "terraces" but do not suggest a systematic deviation between the measured values and the distribution.

The terracing characteristic in low flow distributions occurs commonly, regardless of the period of record for the stations and geographic location, and frequently is more dominant than for the example shown in Figure 16. The characteristic can be observed in the low-flow probabilities for most locations throughout Illinois (for additional examples, see Lara, 1970). It is believed that this characteristic is related to the interdependency between low flows from one year to the next, in that a discontinuity will usually occur between low flows that result from a short annual dry period and the

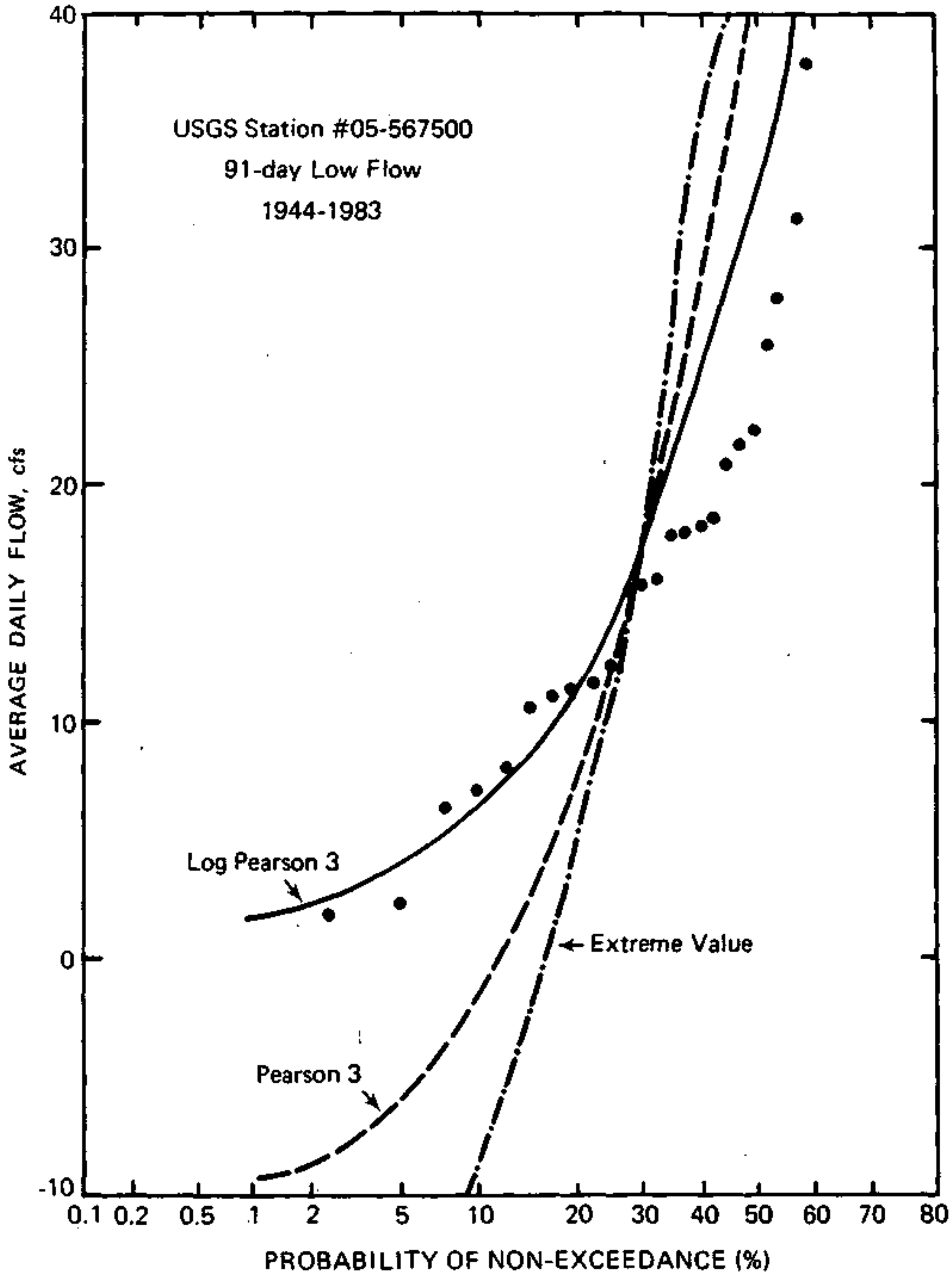

Figure 16. Comparison of three distribution functions with the historical record of the annual 91-day low flow, Mackinaw River at Congerville (1944-83)

more severe droughts caused by the composite effects of several consecutive years of low precipitation.

The Log-Pearson Type III distribution is unable to represent this terracing effect, therefore in some cases its use may cause a misrepresentation in the frequency estimates of both low flows and drought flows. In these cases, a discontinuity in the annual low flows will occur between a probability of 5% and 10% (between the 20-year and 10-year drought). The Log-Pearson Type III distribution will typically overestimate the magnitude of flows in droughts more extreme than the probability at which this discontinuity occurs and underestimate the flows for less severe droughts. Because of these possible errors, it is suggested that the application of the use of any probability distribution function for low flows not be applied without a graphical verification of the fit of the distribution function and possible adjustment for systematic deviations of the data from the distribution. The methodology used to establish low flow and monthly drought frequencies in this study involves a graphical adjustment to the Log-Pearson Type III distribution.

An additional problem in the use of the Log-Pearson Type III distribution is the application for streams that have zero low flow. For these cases the frequency distribution is applied by predetermining the maximum frequency for which the zero flow will occur, and then analyzing the distribution for the remainder of the sample that is non-zero.

Selected Examples of Results from the Analyses

Estimates of the 154 flow parameters were developed for five of the gaging stations on the Fox River and five of the gaging stations for tributaries to the Fox River. The gaging stations upstream of the Fox River at Wilmot were not analyzed. Selected flow parameters for the virgin and present conditions and the period of record are presented for each of the ten stations in Table 9. In addition, recent flow conditions are presented which describe the flow occuring prior to the change in the low flow operation of McHenry Dam, which took place in 1988. Because of this change in operation, the low flow values listed for present conditions are considerably greater than previously published values, such as those in Singh (1983).

A complete list of the estimated values for the 154 streamflow parameters for each streamgaging station is given in Appendix A. Only the gaging stations on Boone Creek and Poplar Creek have statistics from the period of record that are indicative of the established virgin and present conditions. Two additional stations (Ferson Creek and Blackberry Creek) have noticeable differences, but these are all due to adjustments in frequency because of the period of record. The differences that occur at the remaining gaging stations are explained in the following paragraphs.

Table 9. Selected Flow Parameters of Virgin Flow, Present Flow, Recent Flow*, and the Period of Record

	Q7.10	Q90	Q75	Qmean	Q01
Fox River at Wilmot					
Record (1939-1985)	67	114	176	536	2770
Virgin	60	108	168	516	2720
Present	73	125	185	544	2820
Fox River near McHenry					
Record (1961-1984)	53	169	301	810	3694
Virgin	87	159	248	730	3480
Recent	56	148	248	779	3866
Present	94	147	242	779	3866
Fox River at Algonquin					
Record (1915-1985)	50	170	286	850	4090
Virgin	102	187	294	838	3860
Recent	77	184	303	897	4260
Present	115	183	297	897	4260
Fox River at Geneva					
Record (1962-1984)	126	273	465	1212	5232
Virgin	119	227	345	1019	4615
Recent	128	248	382	1111	5065
Present	166	247	376	1111	5065
Fox River at Dayton					
Record (1924-1985)	171	345	537	1717	8725
Virgin	195	355	539	1743	8725
Recent	239	417	621	1886	9205
Present	277	416	615	1886	9205
Nippersink Creek at Spring Grove					
Record (1966-1985)	23.0	42.4	64	155	924
Virgin	15.4	32.1	51	137	856
Present	15.5	34.8	55	141	827
Boone Creek near McHenry					
Record (1948-1982)	3.7	5.6	7.3	13.1	55
Virgin=Present	3.7	5.6	7.3	13.1	55
Poplar Creek at Elgin					
Record (1951-1985)	0.24	0.98	2.7	24.4	207
Virgin=Present	0.22	0.96	2.6	23.5	206
Ferson Creek near St. Charles					
Record (1961-1985)	0.36	3.2	8.7	40.8	336
Virgin=Present	0.23	1.8	6.2	36.2	275
Blackberry Creek near Yorkville					
Record (1960-1985)	4.1	9.1	15.6	52.5	376
Virgin=Present	3.4	7.1	12.4	47.0	363

* Recent flow describes the flow condition on the Fox River prior to the 1988 change in the low flow operation of McHenry Dam.

Fox River at Wilmot. Differences between the station record and both the virgin and present flows are due to changes in the amount of effluents entering the watershed over the period of record.

Fox River at McHenry. The low flow operation of McHenry dam at the Fox Chain-of-Lakes caused the low flows for the observed record and recent flow to be considerably less than the virgin flow condition. With the change in low flow operation, the present flow condition is more similar to the virgin flow condition. The effect of the dam also reduces flood storage and in so doing increases high flows along the river. The effect of McHenry dam on flows is further discussed in the section on "The Effect of McHenry Dam," on pages 64-70. Any further modifications to the operating policy will change the estimated values for the present flow condition.

Fox River at Algonquin. The major differences between the virgin, recent, and present flows are caused by the operation of McHenry Dam, 16 miles upstream. For example, most of the lowest flows observed at Algonquin occurred during periods when very little flow was being released from McHenry Dam. Flow statistics given for the period of record are lower than that given for McHenry Dam because the period contains a greater number of years which had below average flow conditions.

Fox River at Geneva. The present flow condition includes a large amount of effluent discharges, including the large discharge from the city of Elgin. The period of record is short and contains a large precentage of years having above-average streamflow.

Fox River at Dayton. The present flow has become much greater than the virgin flow due to the addition of effluent discharges. During low flow conditions, the total amount of effluents in the watershed exceeds 70 cfs (or 53 mgd). Like the Algonquin station, the low flows for the period of record are small due to flow conditions originating at the Fox Chain-of-Lakes and McHenry Dam. A great portion of the high flows measured at Dayton have originated in the downstream portion of the basin (downstream of the Geneva gage).

Nippersink Creek at Spring Grove. Low flows in Nippersink Creek are reduced slightly because of the evaporation which occurs at Wonder Lake. For this reason the present flow is less than the virgin flow for low flow conditions. Wonder Lake also slightly reduces the high flows of Nippersink Creek.

5. ESTIMATING FLOW AT UNGAGED SITES: REGRESSION ANALYSIS

The estimation of flow characteristics at an ungaged location involves two specific steps. The first step, dealt with in this section, is the estimation of the virgin flow conditions using equations developed with regression analyses. The second step, discussed later, analyzes the factors that may cause the virgin flow condition and/or the present flow condition to deviate from the value produced by these equations.

Variations from one watershed to another in the behavior of the virgin flow regime are theoretically associated with physical (topographic, geologic, and climatic) characteristics of the basin. In practice, however, the effect of watershed properties on differences between sites may be difficult to explain.

One of the methods used to avoid the difficulty of explaining these physiographic and climatic effects is to segment the available data (the processed information from gaging stations) into smaller groups that appear to possess homogeneous characteristics. Each smaller group (subsample) is then analyzed separately. This method is called regionalization because the separation of data is usually associated with geographic location. The major assumption associated with regionalization is that the statistical parameters (mean, standard error, etc.) of all of the gaging stations in each sub-sample are fixed in relation to the independent variables used in the regression analysis (Matalas and Gilroy, 1968). Typically, the use of regionalization reduces the number of gaging stations in each sample to a relatively small amount. However, as the population of the subsample is reduced, the assumption of fixed statistics becomes less valid.

An examination of the flow duration curves from gaging stations on tributaries to the Fox River (Fig. 17) indicates that the hydrologic response within the basin is quite varied. Several of these watersheds are in close geographic proximity, yet have flow duration curves that show significantly different character (such as the slope of the flow duration curve). Because this sample of gaging stations shows relatively little homogeneity, if a regionalization approach is used the validity of its major assumption (the fixed response from each watershed) would be highly suspect. For this reason, it is essential that the analysis for ungaged sites in this study attempt to describe the variation in watershed response resulting from physiographic and climatic influences without the use of regionalization.

Review of Earlier Regression Analyses

Three previous studies (Holmstrom, 1978; Singh, 1983; and Allen and Cowan, 1985) have been conducted that provide for the estimation of flow characteristics at ungaged sites in the vicinity of the Fox River Basin. All of these studies deal with low-flow conditions, specifically with the estimation of the 7-day, 10-year (07,10) low flow, and in Holmstrom and Allen-Cowan also with the

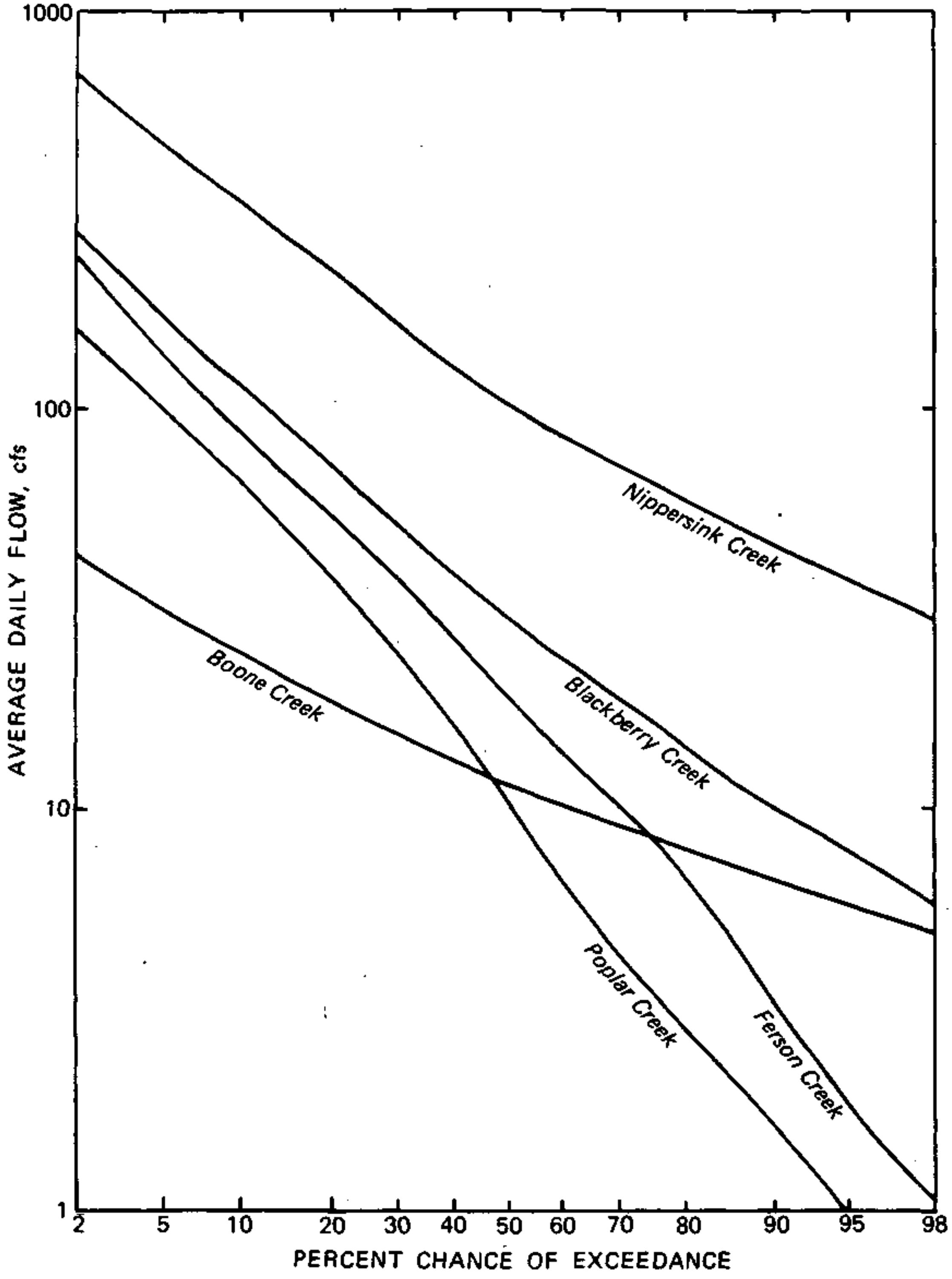

Figure 17. Flow duration curves for streamgages on tributaries to the Fox River (1962-82)

7-day, 2-year (Q7,2) low flow. Singh uses a regression analysis in which the cubic roots of the Q7.10 and the drainage area of the watershed are linearly related. The other two studies use a multi-regression approach with two watershed parameters (similar in both studies) as the independent variables in the estimation equations. The Holmstrom equations use drainage area and the average hydraulic conductivity of the glacial material underlying the watershed to estimate the low flows. The Allen-Cowan equations use drainage area and a streamflow recession index related to the amount of sand and gravel underlying the watershed. In each case, the second parameter attempts to describe the contributing effect of the substratum material to low flow in the stream. The form of the estimating equations used in both studies is a power function:

$$Q = a\, X^{b}\, Y^{c} \qquad (4)$$

where X and Y are the two independent variables and a, b, and c are constants.

The equations from each Holmstrom and Allen-Cowan were applied to several gaged sites in the Illinois portion of the Fox River Basin to determine their applicability. The two sets of equations proved to be inadequate when used in the Fox River Basin. This is apparently the case because the equations were developed using a relatively small range of physiographic conditions and are not applicable to the extrapolated conditions (as present in the Fox Basin). This may occur in part because the form of the equations used (a log-linear approach) is not truly representative of the causative hydrologic relationships expected between the flow and the watershed parameters used in the equation. The regression analysis used in this report attempts to avoid these problems by using gaging stations from watersheds having a wider range of characteristics and by adopting a regression formula that has greater descriptive ability.

Conceptual Models for Low and Medium Flows

Two simple conceptual models were evaluated to determine their applicability for modeling low and medium flows in the Fox River Basin. The first of these models is based on the evaluation of flow at the interface between the stream and the adjacent subsurface water (soil water and groundwater), the latter being the source of flow during low-flow or base-flow conditions. According to Darcian flow theory, the physical factors that should control the base flow to the stream (Qbase) are: 1) the total slope of the groundwater table toward the stream (the head differential); 2) the permeability (K) of the porous substratum of the soil; and 3) the total cross-sectional area of the flow. A modified version of the Darcy equation was used in which the slope of the water table is represented by the total entrenchment of the stream (E), and the cross-sectional area is taken as constant over a unit length of the stream-groundwater interface. Therefore:

$$Q_{base} = c_d \Sigma\, E\, K\, L \qquad (5)$$

where c_d is a constant and L is the total length of each stream segment. The product of E, K, and L were summed for all tributaries within the basin having watershed areas greater than ten square miles. The summation term shown in Equation 5 was computed for a number of stations in northeastern and central Illinois to examine its correlation with low-flow values. The correlation produced by this methodology is lower than a simple correlation between the low flows and the total watershed area. Therefore, the use of Equation 5 was abandoned.

A Variable-Source Conceptual Model. Even though the interface between the stream and the groundwater is very localized, studies such as Kilpatrick (1964) and Bingham (1982) indicate that the total seepage to the stream (base flow) appears to be contributed by the entire watershed. In fact, as base flow recedes (overtime), the upland areas of the watershed appear to have sustained contribution to the total flow. One implication of these studies is that, in modeling base flow, the effect of drainage area on base flow is more likely to be arithmetic (additive) than geometric (as expressed by a power function).

Several other observations should also influence the form of an estimation equation for base flow. First, as evidenced by many watersheds in southern Illinois, large areas can exist that frequently have zero base-flow conditions. These areas typically have very low soil permeabilites, suggesting that there may exist a threshold level (defined by the hydraulic conductivity of the substratum) below which the estimated base flow becomes zero. In these cases the area of the watershed having such low permeability no longer contributes to the total streamflow.

The concept is illustrated in Figure 18, in which a watershed contains areas of varying soil permeabilities. Each sub-watershed contributes a different rate of flow to the stream. If the rate of flow from a given sub-watershed (j) to the stream is assumed to be a linear function of the substratum permeability (K), then the base flow of the entire watershed may be estimated by the equation:

$$Q_{base} = \sum_{j=1}^{J} c_1 \, Qmean_j \quad \max [(K_j - c_2), 0] \tag{6}$$

where J is the total number of sub-watersheds, c_1 and c_2 are constants, and c_2 represents the threshold permeability below which the area involved becomes noncontributing. The mean flow of the sub-watershed (Qmean) is computed from the area of the sub-watershed (A_j) and the average annual precipitation (P) and evapotranspiration (ET) as follows:

$$Qmean = c_3 \; A_j \, (P\text{-}ET) \tag{7}$$

When the watershed area is given in square miles, P and ET are in inches, and Qmean is in cubic feet per second (cfs), then the constant $c_3 = 0.0738$.

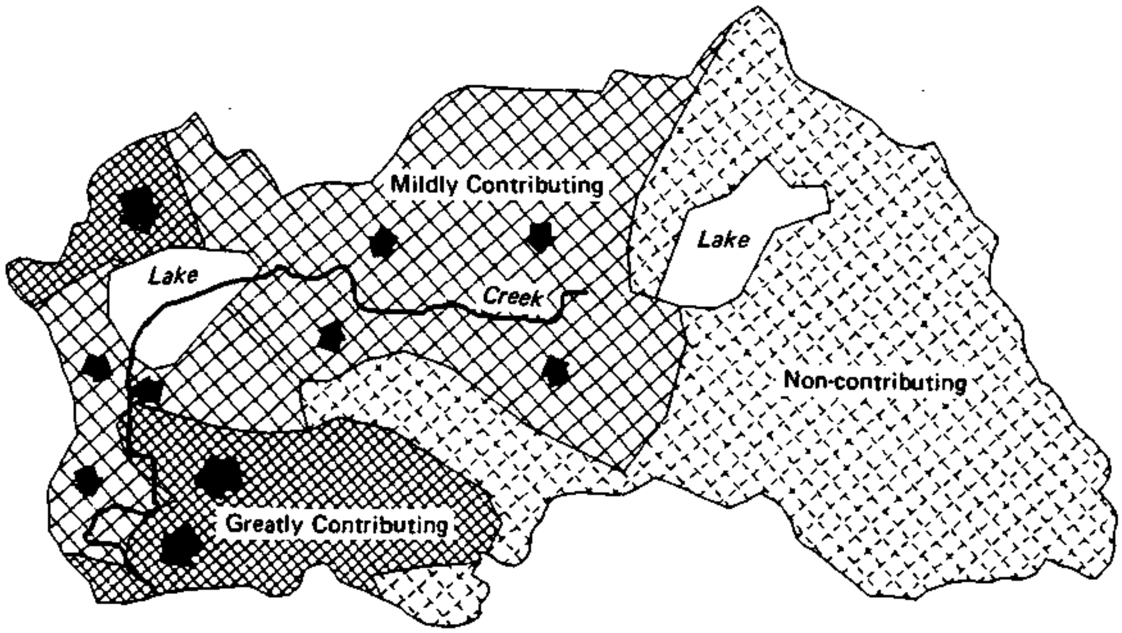

Figure 18. Illustration of variable sources of base flow In a watershed

A second observation affecting the form of equations estimating base flows is that small watersheds frequently have periods of zero flow, even during what would be considered normal flow conditions. The primary reason for this is because of the amount of incision that a stream must have in order for its channel to intersect the water table. A base-flow equation should contain some factor that allows the estimated flow level for small streams to be equal to (or less than) zero. For the present analysis this is accomplished by simply adding on a negative constant to Equation 6. When rewritten with this additonal constant (c), Equation 6 then becomes:

$$Q_{base} = \max \{ [\sum_{j=1}^{J} (a\ Qmean_j + b\ Qmean_j K_j) + c] , 0 \} \tag{8}$$

in which the constants a = - C_1C_2 and b = c_1. When the permeabilities of all the sub-watersheds exceed the threshold value, C_2 (or exceed -a/b), then the average values of Qmean and K for the entire watershed may be used:

$$Q_{base} = \max [a\ Qmean + b\ Qmean\ K , 0] + c \tag{9}$$

Equation 9 will always be equivalent to Equation 8 whenever the coefficient a is a positive number.

Equation 8 is considered flexible enough to also serve as an equation for estimating medium-level flows. During periods of medium flow in which surface runoff and flow from the shallow layers of the soil are also major factors in the total streamflow volume, the additional contribution of any one watershed area to the flow will be primarily associated with the average annual flow ($Q_{med} = C_4$ Qmean). However, in areas having a greater soil permeability, the contribution may be less because of a greater portion of available water infiltrating into the soil. Therefore, $Q_{med} = (C_4 - C_5 K)$ Qmean (which is a form of Equation 8).

Model Estimation (Virgin Flow Equations)

Equation 8 was used to estimate the flow values for ungaged sites of all the 154 streamflow parameters used in the streamflow assessment model. Thirteen USGS gaging stations in northern and central Illinois (Table 10) were selected as the sample population from which the equations were developed. These stations were selected from a list of all USGS stations in Illinois located within the Wisconsin glacial area, and whose period of record included the years 1951-85 (the period analyzed in creating the equations). This period was chosen to maximize the number of stations that could be included in the analysis while still retaining a predominant portion of the total available record. Several stations in the original list were removed from the analysis because their record included significant influence from reservoirs, major effluent discharges, or other anthropogenic influences. Therefore the records used represent the virgin flow (or unaffected) conditions of regional streams. Of the thirteen stations used, three stations have flow records that extend only to 1982.

Table 10. List of USGS Gaging Stations Used in the Regression Analysis of Virgin Flow Conditions; Period of Record = 1951-85.

USGS Station #	Station Name	Area (mi^2)	Substrate Permeability (in/hr)
05-439500	South Br Kickapoo Cr near Fairdale	387	1.08
05-525500	Sugar Creek at Milford	446	1.45
05-537500	Long Run near Lemont	20.9	0.40
05-546500	Fox River at Wilmot, WI	868	3.74
05-550500	Poplar Creek near Elgin	35.2	1.16
05-554500	Vermilion River near Pontiac	579	0.60
05-566500*	East Br Panther Cr near El Paso	28.8	0.60
05-567500	Mackinaw River near Congerville	675	0.73
05-572000	Sangamon River at Monticello	550	0.71
05-579500	Lake Fork near Comland	214	1.05
05-580000	Kickapoo Creek near Waynesville	227	0.77
05-591500*	Asa Creek near Sullivan	8.0	0.60

* for these stations the period of record used is 1951 -82

Coefficients for the virgin flow equations developed from regression analysis of values from these gaging stations are listed in Table 11. The analysis employed a least-squares regression procedure. However, for many parameters the least-squares equations were modified to fix the constant c. In so doing, a slightly higher error of estimate was accepted in order to provide for a smooth transition between the estimates of related parameters [for example, it is essential that the estimate of the 7-day, 25-year flow ($Q_{7,25}$) always fall between the values of the $Q_{7,10}$ and $Q_{7,50}$]. These equations should be used only for watersheds between 10 mi^2 and 1000 mi^2.

Error in the Regression Model. The regression relationship between the flow and watershed characteristics explains a high amount of the flow variance which exists between the thirteen gaging stations in the sample. This is indicated by the high correlation coefficients given in Table 11. The standard error of estimate for the virgin flow equations (S_e), in cfs, is estimated as the product of the coefficient of error given in Table 11 (C_e) and the computed mean flow at the point of interest (Qmean):

$$s_e = C_e Qmean \qquad (10)$$

Equation 10 is a simplified estimate of error as presented by the regression analysis. In actuality, the larger streams and watersheds with a lower average soil permeability will have less variation than that suggested in Equation 10. Conversely, smaller basins with high average soil permeability will show greater variation.

Because the regression analysis was performed on an arithmetic scale, the coefficient of error increases as the magnitude of the flow parameter increases. This may be compared to the usual log-linear regression where the standard error is independent of flow magnitude. For this reason the coefficient of error, as presented in Table 11, may appear to be large for flows such as the 1% level of exceedance (Q01) when the actual percentage of error is rather small. Typically, the standard error will be approximately 25% for estimates of very low flow (such as Q99) and less than 8% for estimates at the high end of the flow duration curve.

Application of the Regression Equations. As an example, assume that a watershed exists with the following characteristics:

drainage area = 68 square miles
average soil permeability = 1.2 inches per hour
average annual precipitation = 35.1 inches
average annual evapotranspiration = 25.0 inches (using Equation 1, page 15)

and that the following estimates of the annual flow duration are desired: Q98, Q90, Q75, Q50, Q25, Q10, and Q02. The virgin flow coefficients are taken from Table 11 and are used in the following

Table 11. Regression Coefficients for Virgin Flow Equations (Using Equations 7,8, and 9)

$$Qmean = c_3 \; A_j \; (P\text{-}ET)$$

$$Q_X = \sum_{j=1}^{J} \{ \max [(a \; Qmean_j + b \; Qmean_j \; K_j) \; , 0] \} + c$$

or $$Q_x = a \; Qmean + b \; Qmean \; K + c, \;\; \text{when } K > -a/b$$

Flow Duration	a	b	c	r (correlation)	Ce (error)
Q99	-0.0165	0.0277	-0.2	0.997	0.0047
Q98	-0.0148	0.0293	-0.2	0.988	0.0050
Q95	-0.0126	0.0362	-0.2	0.995	0.0046
Q90	-0.0089	0.0446	-0.3	0.999	0.0047
Q85	-0.0074	0.0538	-0.35	0.999	0.0073
Q75	0.0177	0.0626	-0.5	0.997	0.0158
Q60	0.1633	0.0657	-1.0	0.991	0.0274
Q50	0.3241	0.0590	-1.25	0.992	0.0406
Q40	0.5723	0.0523	-1.8	0.994	0.0744
Q25	0.9758	0.0258	-2.2	0.998	0.1040
Q15	1.7176	-0.0207	-0.8	0.998	0.1159
Q10	2.4719	-0.0766	0.0	0.998	0.1398
Q05	4.1612	-0.2198	0.0	0.999	0.1919
Q02	7.3893	-0.5147	0.0	0.996	0.5088
Q01	10.7340	-0.8492	0.0	0.993	0.9569
Low Flows					
$Q_{1,2}$	-0.00893	0.0353	-0.2	0.989	0.0067
$Q_{7,2}$	-0.00693	0.0380	-0.2	0.983	0.0088
$Q_{15,2}$	-0.00436	0.0408	-0.2	0.978	0.0108
$Q_{31,2}$	-0.00160	0.0445	-0.2	0.975	0.0144
$Q_{61,2}$	0.00591	0.0497	-0.2	0.967	0.0183
$Q_{91,2}$	0.02209	0.0537	-0.2	0.982	0.0224
$Q_{1,10}$	-0.01309	0.0206	-0.2	0.977	0.0048
$Q_{7,10}$	-0.01259	0.0226	-0.2	0.963	0.0068
$Q_{15,10}$	-0.01362	0.0254	-0.2	0.976	0.0072
$Q_{31,10}$	-0.01413	0.0290	-0.2	0.989	0.0069
$Q_{61,10}$	-0.01028	0.0306	-0.2	0.985	0.0083
$Q_{91,10}$	-0.00901	0.0341	-0.2	0.984	0.0092
$Q_{1,25}$	-0.01362	0.0185	-0.2	0.990	0.0027
$Q_{7,25}$	-0.01492	0.0206	-0.2	0.986	0.0037
$Q_{15,25}$	-0.01525	0.0226	-0.2	0.979	0.0048
$Q_{31,25}$	-0.01752	0.0261	-0.2	0.994	0.0034
$Q_{61,25}$	-0.01547	0.0278	-0.2	0.992	0.0041
$Q_{91,25}$	-0.01544	0.0312	-0.2	0.996	0.0041

Table 11 Continued

Low Flows	a	b	c	r (correlation)	Ce (error)
Q1,50	-0.01432	0.0175	-0.2	0.998	0.0010
Q7.50	-0.01608	0.0195	-0.2	0.999	0.0015
Q15,50	-0.01653	0.0213	-0.2	0.998	0.0019
Q31,50	-0.01920	0.0249	-0.2	0.997	0.0025
Q61,50	-0.01853	0.0265	-0.2	0.993	0.0035
Q91,50	-0.01895	0.0298	-0.2	0.978	0.0054
Drouaht Flows					
$Q_{6,10}$	-0.00349	0.0512	-0.4	0.991	0.0093
$Q_{9,10}$	0.08394	0.0489	-0.6	0.975	0.0256
$Q_{12,10}$	0.23324	0.0413	-0.4	0.990	0.0365
$Q_{18,10}$	0.34075	0.0320	-0.4	0.990	0.0565
$Q_{30,10}$	0.60437	0.0126	-0.2	0.999	0.0203
$Q_{54,10}$	0.83163	0.0110	0.0	0.999	0.0491
$Q_{6,25}$	-0.01158	0.0469	-0.4	0.980	0.0085
$Q_{9,25}$	0.02381	0.0475	-0.3	0.985	0.0178
$Q_{12,25}$	0.10236	0.0511	-0.6	0.979	0.0390
$Q_{18,25}$	0.14313	0.0460	-0.6	0.975	0.0399
$Q_{30,25}$	0.28918	0.0371	-0.4	0.989	0.0477
$Q_{54,25}$	0.46754	0.0252	-0.1	0.988	0.0791
$Q_{6,50}$	-0.01383	0.0456	-0.4	0.959	0.0104
$Q_{9,50}$	0.00204	0.0464	-0.2	0.973	0.0131
$Q_{12,50}$	0.04883	0.0539	-0.4	0.982	0.0270
$Q_{18,50}$	0.07518	0.0506	-0.4	0.970	0.0360
$Q_{30,50}$	0.17562	0.0467	-0.4	0.983	0.0427
$Q_{54,50}$	0.33036	0.0350	-0.1	0.982	0.0725
January Flows					
Qmean	0.9213	-0.0150	0.0	0.993	0.0368
Q98	-0.02283	0.0425	-0.2	0.992	0.0040
Q90	-0.01804	0.0501	-0.2	0.983	0.0047
Q75	0.03220	0.0583	-0.4	0.976	0.0073
Q50	0.29459	0.0548	-1.5	0.972	0.0186
Q25	0.88096	0.0161	-2.0	0.977	0.0557
Q10	2.2850	-0.1181	-0.8	0.991	0.1039
Q02	8.1573	-0.5827	0.0	0.986	0.3915
February Flows					
Qmean	1.2500	-0.0323	0.0	0.992	0.0507
Q98	-0.01203	0.0399	-0.2	0.951	0.0052
Q90	0.00235	0.0472	-0.2	0.971	0.0077
Q75	0.12463	0.0510	-0.6	0.968	0.0128
Q50	0.47807	0.0381	-1.5	0.972	0.0325
Q25	1.3420	-0.0265	0.0	0.992	0.0550
Q10	3.0052	-0.1574	0.0	0.996	0.0793
Q02	8.6409	-0.4900	0.0	0.985	0.3905

Table 11 Continued

March Flows	a	b	c	r (correlation)	C_e (error)
Qmean	1.8155	-0.0200	0.0	0.995	0.0603
Q98	0.04594	0.0579	-0.6	0.956	0.0095
Q90	0.17760	0.0556	-0.8	0.982	0.0136
Q75	0.41829	0.0579	-1.0	0.988	0.0256
Q50	1.0194	0.0264	-2.0	0.992	0.0484
Q25	2.1151	-0.0241	-2.0	0.991	0.1003
Q10	4.1214	-0.1247	0.0	0.991	0.1855
Q02	9.8355	-0.5859	0.0	0.991	0.3940
April Flows					
Qmean	2.1779	-0.0648	0.0	0.996	0.0638
Q98	0.06184	0.0707	-0.8	0.941	0.0128
Q90	0.30709	0.0567	-1.0	0.987	0.0177
Q75	0.64168	0.0436	-1.5	0.996	0.0233
Q50	1.3329	0.0121	-2.0	0.995	0.0440
Q25	2.5581	-0.0640	-1.25	0.994	0.0853
Q10	4.6777	-0.2440	-0.4	0.992	0.1868
Q02	11.3578	-0.8381	0.0	0.993	0.3809
May Flows					
Qmean	1.5981	-0.0535	0.0	0.998	0.0333
Q98	0.09644	0.0446	-0.8	0.990	0.0078
Q90	0.26645	0.0425	-0.8	0.987	0.0128
Q75	0.47347	0.0369	-1.25	0.991	0.0193
Q50	0.88128	0.0229	-2.0	0.995	0.0294
Q25	1.6486	-0.0171	-2.0	0.996	0.0512
Q10	3.3781	-0.1412	-2.0	0.997	0.0848
Q02	9.0226	-0.7627	0.0	0.984	0.4263
June Flows					
Qmean	1.4220	-0.0557	0.0	0.989	0.0654
Q98	0.02591	0.0398	-0.4	0.942	0.0073
Q90	0.13516	0.0378	-0.6	0.981	0.0136
Q75	0.27307	0.0394	-1.0	0.985	0.0186
Q50	0.58130	0.0363	-1.75	0.982	0.0294
Q25	1.3467	-0.0183	0.0	0.986	0.0657
Q10	3.1924	-0.1521	0.0	0.989	0.1357
Q02	10.0360	-0.7958	0.0	0.967	0.6230
July Flows					
Qmean	0.6983	0.0196	0.0	0.994	0.0250
Q98	-0.00707	0.0414	-0.4	0.946	0.0049
Q90	0.02067	0.0475	-0.4	0.983	0.0063
Q75	0.09252	0.0563	-0.8	0.971	0.0091
Q50	0.26315	0.0625	-1.5	0.965	0.0155
Q25	0.64708	0.0617	-2.0	0.988	0.0292
Q10	1.5283	0.0094	-2.0	0.991	0.0682
Q02	5.4460	-0.3065	0.0	0.988	0.2600

Table 11 Concluded

August Flows	a	b	c	r (correlation)	C_e (error)
Qmean	0.3802	0.0435	0.0	0.985	0.0246
Q98	-0.02048	0.0391	-0.2	0.952	0.0045
Q90	-0.01117	0.0458	-0.2	0.996	0.0041
Q75	0.00904	0.0525	-0.4	0.990	0.0041
Q50	0.04552	0.0705	-0.6	0.992	0.0065
Q25	0.16644	0.0870	-1.0	0.991	0.0164
Q10	0.65099	0.0912	-2.0	0.986	0.0425
Q02	4.1538	-0.2192	0.0	0.976	0.3036
September Flows					
Qmean	0.2884	0.0582	0.0	0.941	0.0317
Q98	-0.02927	0.0388	-0.2	0.958	0.0050
Q90	-0.02341	0.0457	-0.2	0.999	0.0048
Q75	-0.01386	0.0526	-0.2	0.982	0.0052
Q50	0.00463	0.0700	-0.4	0.982	0.0091
Q25	0.06785	0.0874	-0.6	0.985	0.0183
Q10	0.48751	0.1180	-1.75	0.951	0.0746
Q02	3.8257	-0.0849	0.0	0.880	0.4710
October Flows					
Qmean	0.3389	0.0498	0.0	0.969	0.0320
Q98	-0.03190	0.0436	-0.2	0.995	0.0043
Q90	-0.02664	0.0498	-0.2	0.993	0.0046
Q75	-0.01660	0.0572	-0.2	0.985	0.0055
Q50	0.00570	0.0752	-0.4	0.956	0.0096
Q25	0.16920	0.0790	-0.8	0.963	0.0336
Q10	0.83096	0.0614	-2.0	0.971	0.0736
Q02	3.3060	-0.1339	0.0	0.842	0.3175
November Flows					
Qmean	0.3590	0.0641	0.0	0.976	0.0304
Q98	-0.02629	0.0478	-0.4	0.983	0.0061
Q90	-0.01961	0.0566	-0.4	0.953	0.0072
Q75	-0.00648	0.0681	-0.4	0.924	0.0095
Q50	0.05760	0.0894	-0.8	0.952	0.0199
Q25	0.35005	0.0894	-1.5	0.940	0.0516
Q10	1.1516	0.0453	-2.0	0.965	0.0988
Q02	3.2833	-0.1483	0.0	0.967	0.2468
December Flows					
Qmean	0.7193	0.0175	0.0	0.988	0.0336
Q98	-0.02322	0.0453	-0.4	0.994	0.0051
Q90	-0.02067	0.0556	-0.4	0.992	0.0054
Q75	0.00043	0.0675	-0.4	0.971	0.0059
Q50	0.12107	0.0708	0.0	0.929	0.0233
Q25	0.57274	0.0521	0.0	0.987	0.0339
Q10	1.7370	-0.0384	0.0	0.984	0.0904
Q02	6.4040	-0.4738	0.0	0.981	0.3271

computations. Equation 7 and Equation 9 (applicable because the coefficient a is positive for all flow parameters) are used to determine the mean flow and flow duration values, respectively.

Qmean = 0.0738 (68) (35.1-25.0) = 50.7 cfs

Q98 = - 0.0148 (50.7) + 0.0293 (50.7) (1.2) - 0.2 = 0.83 cfs

Q90 = - 0.0089 (50.7) + 0.0446 (50.7) (1.2) - 0.3 = 1.96 cfs

Q75 = 0.0177 (50.7) + 0.0626 (50.7) (1.2) - 0.5 = 4.2 cfs

Q50 = 0.3241 (50.7) + 0.0590 (50.7) (1.2) -1.25 = 18.8 cfs

Q25 = 0.9758 (50.7) + 0.0258 (50.7) (1.2) - 2.2 = 49 cfs

Q10 = 2.4719 (50.7) - 0.0766 (50.7) (1.2) = 121 cfs

Q02 = 7.3893 (50.7) - 0.5147 (50.7) (1.2) = 343 cfs

Comparison of the Virgin Flow Equations with Recorded Values

The true value of a regression equation lies in its ability to produce a good estimate not only for the stations used in the regression analysis but also for stations outside of the population for which it was calibrated. To evaluate this capability, flow duration values were estimated using the regression equations and compared with the flow record for all of the gaging stations for tributaries to the Fox River. These comparisons are shown in Table 12.

The one station given in Table 12 that does not reasonably estimate the flow duration values is Boone Creek near McHenry. Because of its topographic situation, it is believed that this station has a large amount of groundwater flowing into the basin from nearby watersheds. A consistent addition to the basef low of the stream of approximately 1.7 cfs would explain not only the station's high mean flow, but also the differences between the estimated and observed values for all of the flow duration curve. Poplar Creek, the other station used in the gaging analysis, displays an excellent agreement between the estimated and observed values.

The remaining three stations (Nippersink Creek, Ferson Creek, and Blackberry Creek) have short-term records and for this reason were not used for the regression analysis described earlier. The values of flow estimated by the virgin flow equations are compared with the flow estimates using the short-term records of the stations and applying an adjustment for period of record (Table 12). In general, the equations perform well in estimating the flow conditions at the stations. For high flows with a probability of exceedance less than 10%, the equations overestimate the flow duration values at these three locations. This overestimation does not appear to be systematic for all watersheds.

Table 12. Estimation of Flow Duration Curves for Gaging Stations on Tributaries to the Fox River

	Poplar Creek at Elgin		Boone Creek near McHenry	
	regression equation	period of record	regression equation	period of record
Qmean	23.6	23.5	11.8	13.1
Q99	0.17	0.23	2.2	4.2
Q98	0.25	0.41	2.4	4.6
Q95	0.49	0.67	3.0	5.1
Q90	0.71	0.96	3.8	5.6
Q85	0.94	1.35	4.6	6.0
Q75	1.6	2.6	5.6	7.3
Q60	4.6	5.3	7.1	8.8
Q50	8.0	8.6	8.1	9.8
Q40	13.1	13.0	9.8	11.3
Q25	21.4	26.0	11.7	14.7
Q15	39.	44.	17.5	18.8
Q10	56.	60.	22.0	22.5
Q05	92.	95.	28.6	29.5
Q02	160.	155.	39.	43.
Q01	229.	206.	47.	55.

	Nippersink Creek at Sprina Grove		Ferson Creek near St. Charles		Blackberry Creek near Yorkville	
	regression eauation	extended record	regression eauation	extended record	regression equation	extended record
Qmean	137.6	137.2	36.6	36.2	51.8	47.0
Q99	17.1	15.5	0.89	0.23	3.5	3.3
Q98	18.4	18.4	1.05	0.48	3.8	4.0
Q95	23.6	24.5	1.56	0.90	5.1	5.2
Q90	30.	32.	2.1	1.8	6.5	7.1
Q85	37.	38.	2.7	3.1	8.1	8.6
Q75	46.	51.	4.0	6.2	10.7	12.4
Q60	68.	69.	9.1	12.0	18.3	19.0
Q50	86.	84.	14.5	17.0	25.	25.
Q40	115.	106.	22.8	23.0	37.	34.
Q25	150.	155.	37.	38.	54.	52.
Q15	224.	223.	62.	61.	86.	76.
Q10	294.	283.	87.	82.	118.	101.
Q05	441.	414.	142.	125.	187.	152.
Q02	709.	628.	247.	200.	315.	250.
Q01	969.	856.	354.	275.	445.	363.

More accurate estimation of high flows would require another form of equation that introduces additional independent variables to the regression analysis. This analysis was not pursued.

The error in estimation that exists between the regression equations and recorded values does not carry over to the Streamflow Assessment Model. In the model the recorded value supercedes all equation values. In addition, all ungaged locations along the stream are adjusted to allow for a smooth transition between these sites and the gaged location. This adjustment is described in the section "Inclusion of Information from Nearby Gaged Sites" on page 55.

In addition to the comparison made in Table 12, the virgin flow equations were also tested on two watersheds in portions of Illinois outside the physiograpic region used for the regression. The virgin flow equations results are compared to the flow values for the recorded streamflow for the Kishwaukee River at Belvidere (immediately to the west of the Fox River Basin) and Shoal Creek near Breese (in southwestern Illinois) in Table 13. These basins represent two completely different flow regimes. The virgin flow equations perform well in describing the flow duration of the Kishwaukee River, and do well in describing the low flows and high flows of Shoal Creek. However, the equations overestimate the medium flows that occur at Shoal Creek. Application of the model in this southern portion of Illinois would require calibrating a new set of flow equations.

Table 13. Estimation of Flow Duration Curves for Gaging Stations Outside the Area of the Regression Analysis

	Kishwaukee River at Belvidere		Shoal Creek near Breese	
	regression equation	period of record	regression eauation	period of record
Qmean	354.	349.	542.	541.
Q99	30.0	36.4	0.80	0.82
Q98	32.7	41.4	1.62	2.91
Q95	42.5	52.4	4.6	7.3
Q90	55.	67.	9.2	11.4
Q85	67.	82.	13.0	15.9
Q75	87.	113.	29.2	28.8
Q60	142.	166.	109.	63.
Q50	190.	205.	193.	100.
Q40	269.	263.	325.	170.
Q25	379.	408.	537.	407.
Q15	581.	610.	924.	764.
Q10	776.	800.	1315.	1311.
Q05	1189.	1220.	2184.	2591.
Q02	1951.	1958.	3838.	4266.
Q01	2703.	2571.	5542.	6386.

6. ESTIMATING FLOW AT UNGAGED SITES: ADDITIONAL CONSIDERATIONS

The use of the virgin flow equations presented in the preceding chapter is only a preliminary step in the estimation of flow conditions at the site of interest. The best estimate of the virgin flow may at times be different than that produced by the equations, depending on the availability of information at gaging sites. In addition, the present flow conditions at the site of interest can vary greatly from the estimated virgin flow because of the flow modifiers present upstream. This section will deal with the major aspects of applying this additional information for computating the present flow conditions at the point of interest.

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 which are located on the same stream as a gage, the estimates of virgin flow need to take advantage of 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 where the ungaged site is located with respect to the gaged sites on the stream: 1) when a gage exists both upstream and downstream of the site; 2) when a gage exists only on the upstream side of the site; and 3) when a gage exists only on the downstream side 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 for the nearest upstream gage and Aqd for the nearest downstream gage. Then the adjustments made to compute the virgin flow, Q, are as follows:

For gages both upstream and downstream:

$$Q = qvi + \Delta qd - (\Delta qd - \Delta qu)\,(qvd - qvi)/(qvd - qvu) \qquad (11)$$

For gages only on the upstream side:

$$Q = qvi + \Delta qu \qquad (12)$$

For gages only on the downstream side:

$$Q = qvi\ (1 + \Delta qd/qvd) \qquad (13)$$

Effect of Flow Modifiers on Downstream Sites

Once the virgin flow has been computed, the estimation of present flow conditions for an ungaged site involves accounting for the effects of all of the flow modifiers upstream of that site. An entire list of major flow modifiers in the Fox River Basin is supplied in Appendix B. The estimated effect of each of these flow modifications in determining the present flow at the location of the flow modifiers is also given in Appendix B. These values represent the AQmod(i) term presented earlier in Equation 2. Further downstream, at the site of interest, the effect of the modifier is judged to be exactly the same value as what is given in Appendix B, with one major exception. When a discharge is made into a stream that is dry (has zero flow), the volume of the discharged flow will be decreased through evaporation and infiltration into the streambed as the flow progresses downstream. The expected loss is computed in the streamflow assessment model by the following equation:

$$\text{Loss (in cfs)} = 0.00814\ L\ W \tag{14}$$

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:

$$\log_{10} W = 0.117 \log_{10} Q + 0.508 \log_{10} A + 0.255 \tag{15}$$

Equation 15 is an adaptation of the hydraulic geometry relationships for the Fox River Basin given in Stall and Fok (1968). The calibration of the coefficient in Equation 14 was estimated through the examination of six gaging stations in central Illinois that exist downstream of an effluent into a dry stream, and was judged to be applicable to the Fox River Basin.

The implementation of Equations 14 and 15 is usually completed in successive intermediate steps proceeding downstream from the location of the modifier to the site of interest. If the natural condition of the stream becomes wet or has flow at one of these intermediate locations, the reduction of the effect of the discharge ceases.

Flow Conditions Downstream of Lakes and Reservoirs

Major lakes and reservoirs will produce considerable changes in the flow characteristics of the streams on which they are located. Peak flows and daily high flows will usually be diminished - the extent of this effect depends on the storage-outflow relationship of the reservoir. The frequency of medium-level flows will be increased by a reservoir. The low flows from a lake can be either increased or greatly decreased, depending on whether the lake is naturally occuring or has a man-made outlet (and also if the lake with the man-made outlet has a minimum release policy).

Many of the lakes in the Fox River Basin occur naturally. However, over the years almost all of these have been given an impounding structure, thereby causing the lake to behave similar to a man-made reservoir. The difference in the hydrologic effects of a natural lake versus a man-made lake is related to the lake's storage-outflow relationship. The natural lake generally has a greater volume of storage that is used to both sustain low flows and reduce peak flows. Under dry conditions, a natural lake will often continue to have outflow at or above the level of a natural stream.

Unless a man-made lake has an outflow structure that is used to augment flow over the spillway, it will always have lower dry-weather flow than either a natural stream or a natural lake existing under similar conditions. Even when minimum flows are released, the duration of the period of lowest flows is extended.

In order to examine the effects of lakes and reservoirs on the streamflow conditions, information was collected on the storage-outflow relationships. The primary sources for this information were a number of Dam Safety Reports published by the U.S. Army Corps of Engineers and files located at the Illinois State Water Survey. Estimates of net lake evaporation were compiled using climatological data from the U.S. Weather Service station at Rockford and applying the evaporation formula given in Roberts and Stall (1967).

Conceptual Reservoir Model. Figure 19 represents a conceptual model of a reservoir with a rectangular spillway and a linear stage/surface area relationship. The net groundwater seepage to and from the reservoir is assumed to be zero. If the discharge from the outlet works (Qo) is zero, then four characteristics of the reservoir can conceptually affect the inflow-outflow relationship: 1) the total surface area of the reservoir, A_r; 2) the width of the spillway, W; 3) the spillway coefficient, c_S; and 4) the slope of the stage/surface area relationship, SL.

A sensitivity analysis was performed on the four variables listed above, using a modified-Puls reservoir routing method on several daily inflow series from streams in northern and central Illinois. The results of these simulations indicate that the variables that most greatly affect the inflow/outflow

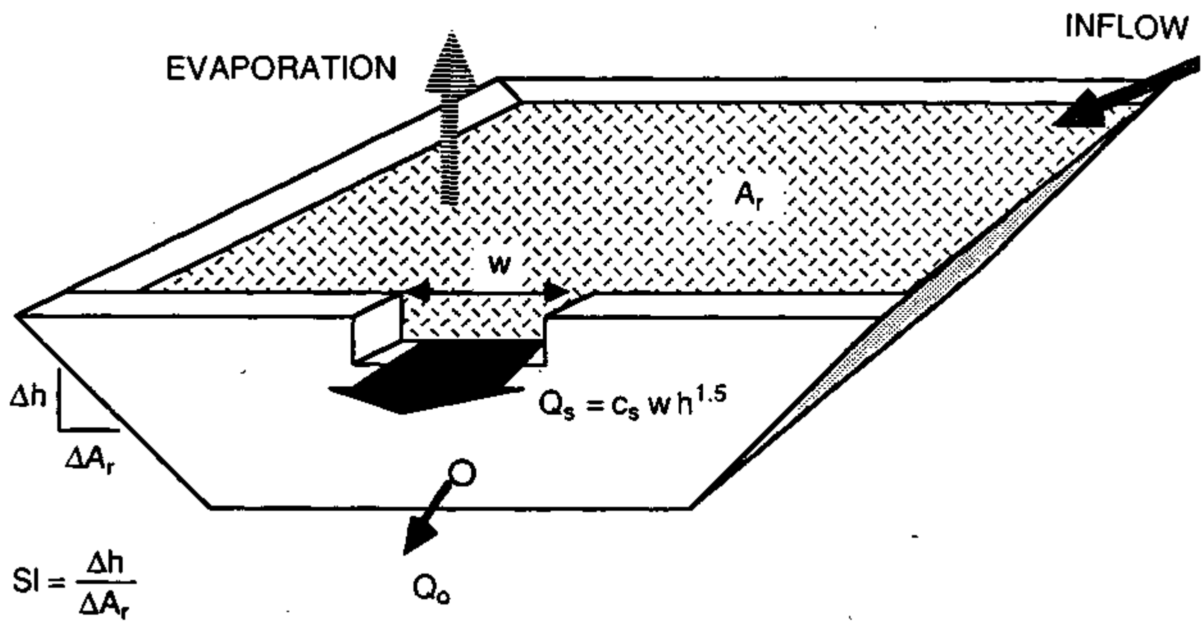

Figure 19. Simple conceptual model of a reservoir and factors affecting outflow

relationship of the reservoir are the surface area of the reservoir and the width of the spillway. The surface area of the lake determines the total evaporative loss of the reservoir. The spillway width is the primary variable affecting the storage-outflow relationship of the reservoir, and in this manner determines to what extent storage will either augment or diminish outflow from the reservoir. The other two factors listed above, c_s and SL, have less significant effects on the inflow/outflow relationship.

Effects of Storage on Reducing High Flows. Detention storage acts to attenuate the magnitude of flood peaks and high flows. When detention storage is significant (that occurs with either a large reservoir or when the reservoir's spillway is of narrow to moderate width), the attenuation of the larger flows can affect the entire flow duration curve. Figure 20 illustrates the reduction of the upper portions of the flow duration curve. The volume of flow resulting from the reduction of high flows is detained in the reservoir and is subsequently released during periods of medium and low flows.

An analysis of reservoir routing simulations suggests that the total volume of flow that is detained during high flows may be estimated using 1) the variability and total volume of high flows (expressed by the slope of the upper portion of the flow duration curve: Q1-Q2, in cfs); 2) the mean flow entering the reservoir (Qmean, in cfs); 3) the reservoir surface area (A_r, in mi^2); and 4) the width of the reservoir spillway (W, in feet). The volume of flow detention, V_{det}. expressed as an average flow (cfs) over the entire flow period, is estimated by the empirical formula:

$$V_{det} = (Q1-Q2)\,(a\,A_r^{\,b}+c) \qquad (16)$$

in which:

$$a = 5\,W^{-0.5}\,(Q_{mean} + 500\,W^{-0.5})^{-0.8}$$

$$b = 1.08 - 160\,(100 + Q_{mean})^{-1.2}$$

$$c = -Q_{mean} / 125{,}000$$

The flow volume detained during periods of high flow is redistributed throughout the remaining flow record, particularly during medium flows. The changes in the flow duration curve that result from the redistribution of V_{det} are given by the following set of equations:

$$\begin{aligned} Q01' &= Q01 - 27.0V_{det} \qquad (17)\\ Q02' &= Q02 - 15.0V_{det}\\ Q05' &= Q05 - 2.0V_{det}\\ Q10' &= Q10 + 2.0\,V_{det}\\ Q15' &= Q15 + 2.5\,V_{det}\\ Q25' &= Q25 + 2.5\,V_{det}\\ Q40' &= Q40 + 1.5\,V_{det}\\ Q50' &= Q50 + 1.0\,V_{det}\\ Q60' &= Q60 + 0.75\,V_{det}\\ Q75' &= Q75 + 0.25\,V_{det} \end{aligned}$$

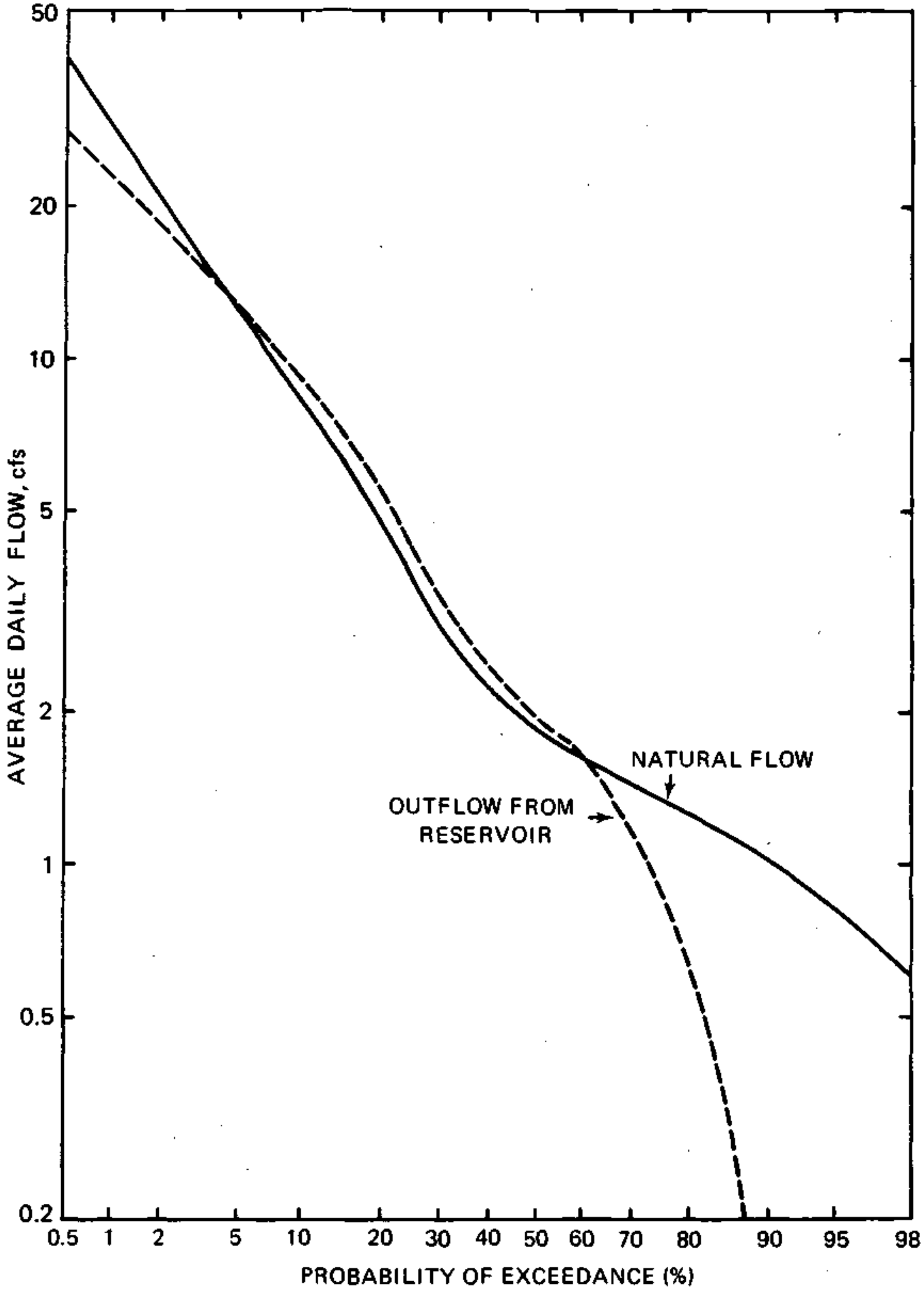

Figure 20. Effect of reservoir storage and evaporation on the outflow of Crystal Lake

The effect of detention storage on other flow variables, such as the monthly flow durations, is estimated by a transformation of these variables from the annual flow duration curve.

Reduction of Low Flows. The volume of net evaporation resulting from the lake surface area is the major factor affecting the reduction of outflow by reservoirs. The reduction in flow by a unit amount of surface area (for example one square mile) will vary depending on both the inflow characteristics and the width of the spillway opening of the reservoir. If the width of the spillway is considered to be infinitely large, then the impact of the reservoir storage on the outflow is minimal and the effect of inflow characteristics can be studied.

Figure 21 illustrates the effect that surface area has on the simulated low flow leaving a reservoir. For a particular flow parameter such as the 95% flow duration (Q95), the rate of reduction in flow magnitude increases as the surface area increases. A maximum reduction slope, Smax (Fig. 21), of flow versus surface area is reached at the point at which the particular flow parameter is reduced to zero. Smax appears to be approximately the same for all streamflow parameters of a given inflow record. In fact, Smax will vary for different inflow records and is larger for those flow records that display more persistent low flows. This tends to include flow records from watersheds

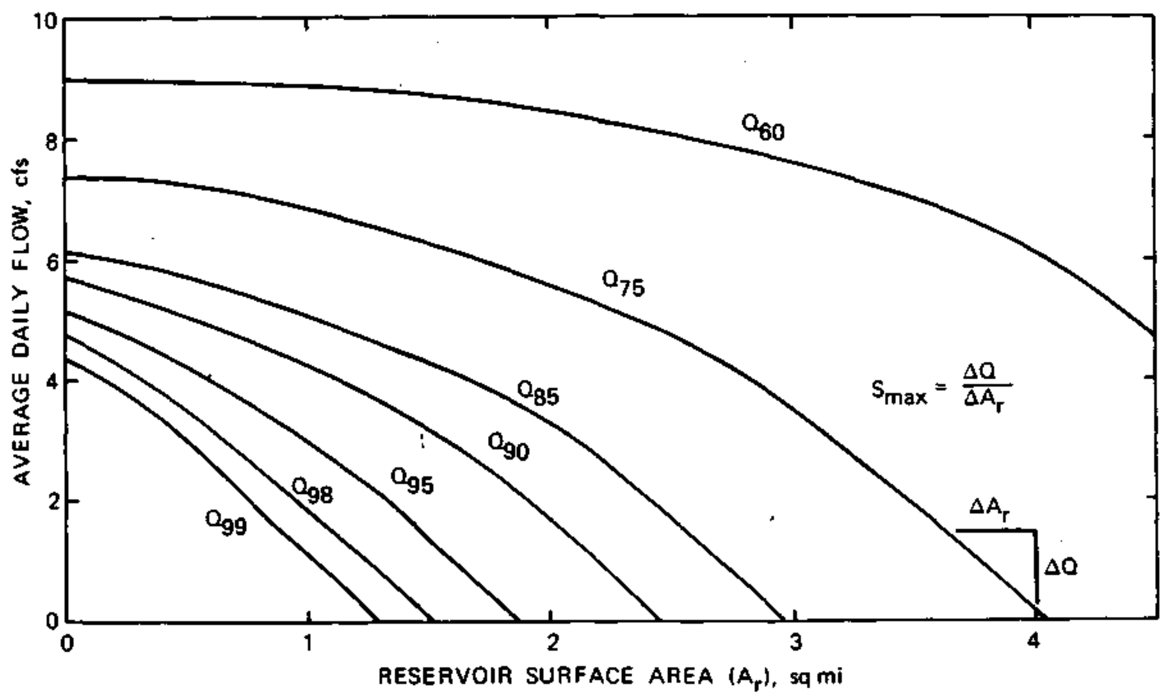

Figure 21. Relationship between reservoir surface area and flow duration values of daily flow; Boone Creek near McHenry

that have either a larger area or have soil types that reduce the variability in flow. An empirical relationship between Smax and the watershed characteristics of mean flow and average soil permeability is given in the equation:

$$S_{max} = 1.4 + 0.0034 \ Qmean + \ln(K + 0.4) \quad (18)$$

The total surface area needed to reduce a given flow parameter to zero (Areao) is a function of Smax, the total flow magnitude (Q), and the frequency of that parameter (f):

$$Area_0 = (S_{max}^{-1} \ Q + 0.025 \ Q^2) + 0.6 \ Q \ (1-f) \quad (19)$$

in which the area is in square miles, Q is in cfs, and f is a fraction (0.98 for the 98% flow duration). The total reduction in flow, Q_{loss} (cfs), because of a given reservoir surface area, A_r (mi^2), is:

$$Q_{loss} = 20 \ [(s^2 + 0.1 \ A_{loss})^{0.5} - s] \quad (20)$$

where: $A_{loss} = [A_r - 0.6 \ Q \ (1-f)]$

$s = S_{max}^{-1}$

Equation 20 is applicable when the reservoir's spillway is very wide. If the reservoir has a narrow spillway (relative to the reservoir size) the greater amount of detention storage will act to augment the low flow during dry periods. For such cases the reduction of the low-flow condition will not be as great as the amount given in Equation 20. The modified reduction in flow under the condition of detention storage (Qioss') is described by the empirical equation:

$$Q_{loss}' = Q_{loss} \ (1.0 - e^{-\gamma w}) \quad (21)$$

in which w is the width of the spillway in feet, and γ is a coefficient related to the surface area of the reservoir: $\gamma = 0.0433125 \ A_r$.

Losses due to evaporation will cause the mean flow downstream of the reservoir to be reduced. The mean flow downstream of the reservoir (Qmeand) is computed as a function of the mean inflow (Qmean) and reservoir surface area as follows:

$$Qmean_d = Qmean - 0.3 \ A_r \quad (22)$$

<u>Example</u>. Wonder Lake, located on Nippersink Creek in McHenry County, is the largest man-made lake in the Fox River Basin. The total storage of the lake is 8,000 acre-feet, and the normal surface area of the lake is 728 acres (or 1.138 mi^2). The width of the rectangular spillway is 150 feet. The dam has an outlet structure, but records indicate that it has rarely, if ever, been used. The estimated mean flow of the inflow into the lake is 71.5 cfs, and the average permeability of the basin

Table 14. Inflow into Wonder Lake and the Effect of Storage and Evaporation on Outflow

	Inflow	Effect Of storage on outflow	Net effect of evaporation and storage on outflow
Q99	9.0	9.0	6.3
Q98	10.1	10.1	7.6
Q95	12.3	12.3	10.4
Q90	14.3	14.3	13.5
Q85	17.5	17.5	17.5
Q75	22.0	22.3	22.3
Q60	31.4	32.3	32.3
Q50	40.	41.	41.
Q40	56.	58.	58.
Q25	84.	87.	87.
Q15	124.	127.	127.
Q10	154.	156.	156.
Q05	227.	225.	225.
Q02	351.	332.	332.
Q01	483.	448.	448.

is 2.04 inches/hour. The flow duration curve of the inflow into Wonder Lake is given in the first column of Table 14.

The total flow volume of the flow duration curve affected by the lake storage of Wonder Lake can be estimated using Equation 16:

$$a = 5\,(150)^{-0.5}\,[\,71.5 + 500\,(150)^{-0.5}\,]^{-0.8} = 0.009344$$

$$b = 1.08 - 160(100 + 71.5)^{-1.2} = 0.7466$$

$$c = -\,Qmean/1250 = -\,71.5/1250 = -\,0.000572$$

$$Vdet = (483-351)\,[0.009344\,(1.138)^{0.7466} - 0.000572] = 1.282$$

Equation 17 can then be used to estimate the adjusted flow values because of lake storage effects. For example, the estimation of the discharge having an probability of exceedance of 1% (Q01) is as follows:

$$Q01' = 483 - 27\,(1.282) = 448 \text{ cfs}$$

The adjusted values for the entire flow duration curve are shown in the second column of Table 14.

The effect of net evaporation on reducing the low flows and mean flow leaving Wonder Lake is estimated using Equations 18, 20, and 21. For example, the flow with probability of exceedance equal to 0.99 (Q99) is computed as follows:

$$S_{max} = 1.4 + 0.0034\ (71.5) + \ln\ (3.25 + 0.4) = 2.94$$

$$s = Smax^{-1} = 0.34$$

$$A_{loss} = [\ 1138 - 0.6\ (9.0)\ (1.0 - 0.99)\ ] = 1.084$$

$$Q_{loss} = 20\ \{[\ 0.34^2 + 0.1\ (1.084)\ ]^{0.5} - 0.34\ \} = 2.66 \text{ cfs}$$

$$Qloss' = 2.66\ [\ 1.0 - e^{-00433125}\ (150)\ ] = 2.656 \text{ cfs}$$

$$Q99' = Q99 - Q_{loss}' = 90 - 2.7 = 6.3 \text{ cfs}$$

The resulting estimated flow-duration relationship for the outflow from Wonder Lake is shown in the third column of Table 14. The mean outflow is computed using Equation 22:

$$Qmean_d = 71.5 - 0.3\ (1.138) = 71.2$$

7. EFFECT OF McHENRY DAM ON FOX RIVER FLOWS

McHenry Dam is the structure that controls the outflow of water from the Fox Chain of Lakes in McHenry County. It is the only location in the Fox River Basin in Illinois where the flow is regulated. The operation of the dam and resulting flow conditions are a concern in streamflow assessment because of the potential effect of the dam on water supply conditions downstream on the Fox River.

McHenry dam was originally constructed in 1907 to regulate the level of water in the Fox Lake region to permit navigation by power boats. Over the years, the dam has been rebuilt and has undergone several changes in its operation policy. The last major change in operation policy occurred in about 1965. In 1965 the target for the summer pool elevation has been increased to from 0.1 to 0.4 feet above the spillway crest (the crest elevation is 736.76 above mean sea level). Since that time the summer pool level has never fallen below the spillway level for a period of more than a few days. With this pool level, the minimum gate opening of 0.05 feet allows for a constant minimum flow from the gates of 45 cfs. An average of 4 cfs is added to the minimum flow from the gates because of lockages (the passing of boats through the dam's lock).

Due to the findings in this section, the minimum gate opening at McHenry Dam was increased to 0.10 feet, which allows a minimum flow from the gates of 90 cfs. The estimated flow resulting from lockages remains unchanged. The gates were operated using the increased minimum gate opening throughout the drought year of 1988. During this operation there was no significant drawdown in the lake below the spillway crest.

Inflows into the Fox Chain of Lakes. The urbanization and industrialization of the Fox River Basin upstream of the Chain of Lakes during the last fifty years have increased the level of low flows entering the lakes during dry periods. In particular, low-flow effluent discharges from Waukesha, Wisconsin presently exceed 12 cfs. Additional low-flow discharges upstream of the lakes total another 16 cfs and are steadily increasing over time. For this reason, the water supply status of the Fox River is continually changing. In order to account for the changes, all records of streamflow for the following analysis were modified (increased) to represent 1985 low-flow conditions.

Effect of McHenry Dam and Its Operation on Low Flows Before the original McHenry Dam was built, the storage in the Fox Chain of Lakes had only a slight effect on the outflows into the Fox River. An estimate of the inflow and outflow flow duration curves assuming this pre-dam condition of the lakes is given in Table 15. The outflow from the lake under these conditions was estimated using a reservoir routing model (modified Puls method), where net lake evaporation was estimated using Roberts and Stall (1967) and the storage-outflow relationship of the lakes was developed from a

Table 15. Comparison of Flow Values for: a) Total Inflow Into the Lakes; b) Flow In the Fox River with the Absence of the Dam; c) Flow before the Recent Change in the Minimum Gate Opening; and d) Flow for the Present Minimum Gate Opening at McHenry Dam

Estimated Streamflow (cfs)

	a) Inflow	b) No Dam	c) Recent	d) Present
Q99	94.	97.	71.	96.
Q98	107.	111.	94.	99.
Q95	132.	137.	119.	119.
Q90	165.	170.	148.	147.
Q85	198.	204.	173.	171.
Q75	260.	269.	248.	242.
Q60	378.	390.	363.	360.
Q50	475.	498.	451.	447.
Q40	637.	665.	620.	618.
Q25	973.	999.	948.	947.
Q15	1462.	1444.	1483.	1483.
Q10	1743.	1715.	1773.	1773.
Q05	2221.	2136.	2264.	2264.
Q02	3127.	2953.	3131.	3131.
Q01	3828.	3577.	3866.	3866.

HEC-2 analysis using the channel of the Fox River between McHenry and Johnsburg as a control on the outflow. From this methodology it is estimated that, prior to dam construction, the Chain of Lakes had little effect on low-flows and slightly decreased high flows. Even during extremely dry conditions, it is estimated the lake storage was great enough to allow for sustained low flows. In the case of high flows, the storage under these conditions was greater than at present because the lake level was able to fluctuate to a greater degree.

Table 15 also provides the estimated outflow based on dam operation. The values provided describe flow conditions both prior to and following the recent change in the minimum gate opening. Much of the flow duration curve appears to be unaffected by the dam operation. However, under the smaller minimum gate opening (0.05 feet) the low flows from the lakes are estimated to be reduced by as much as 25 cfs. High volume flows from the dam estimated by this routing method are not significantly different than the volume of inflows. High flows from the dam do not appear to be reduced because the lake storage is not used for active detention of flood flows.

Minimum Gate Opening. Lake outflows are regulated by several aspects of the operation policy: 1) the minimum gate opening; 2) summer and winter target levels; and 3) the raising of the lake level during the spring. Of these the minimum gate opening has the greatest effect on the low flows from the lake and the resulting effect on drawdown levels in the lake during drought conditions.

In order to analyze the effect of the gate opening on lake storage and outflow, the computer model for reservoir routing was modified to simulate the changes in gate openings at McHenry Dam. Gate opening decisions were based on lake level, change in lake level, and the amount of inflow expected in the next 24-hours (for anticipation of flood flows). Decisions in determining the gate openings were calibrated until both the gate openings and outflow could replicate the operating policy for the last twenty years of record at the dam. The simulations do not account for the effect of wind on the pool level at the dam. Evaporation over the Fox Chain of Lakes was estiated using Roberts and Stall (1967). The effect of the minimum gate opening is presented below.

Until 1988 the operation policy for McHenry Dam listed a minimum gate opening of 0.05 feet during low flow periods. Under this policy, if the level of the lakes drops below the spillway level, the minimum expected outflow from the gates and lock is approximately 49 cfs. However, the reservoir routing simulation suggests it is unlikely that the lake level will ever recede below the spillway elevation for more than a few days. For this reason the 7-day, 10-year low flow for this condition is estimated to be greater than 49 cfs, or about 56 cfs. The average 7-day summer pool elevation associated with this ten-year event is estimated to be 736.82 feet msl.

Table 16 lists the simulated effects of increasing the minimum gate opening on the lake level and minimum outflow. Increasing the minimum gate opening has two effects: 1) the minimum flow level downstream would be increased, and 2) the pool elevation behind the reservoir would be lowered. The pool level is lowered because some of the lake storage would be used to supplement the low flow release from the reservoir. The relationship to pool elevation is further illustrated in Figure 22.

The optimal minimum gate opening is one that maintains a high level of minimum outflows from the lake yet still maintains an acceptable lake level during drought conditions. An opening of 0.10 feet may be most acceptable, in that this opening allows for low-flow releases similar in magnitude to lake inflows and yet results in only a few inches of drawdown during the dryest years.

As mentioned previously, increasing effluent discharges into the Fox River are continually increasing the inflows entering the lakes. For this reason the effects of the minimum gate openings will be different in the future than they are presently. These differences are illustrated by Table 17, in which the values presented are based on projected increases in water use for the year 2010. The expected increase in low flows is 13 cfs above the present conditions. Though the magnitude of the low flows is not affected much by the simulated increase of inflow into the lakes, the drawdown in the lake level is decreased. This occurs because less of the lake storage is used to supplement the low flow release from the dam. Since the potential drawdown will decrease, an additional increase in the minimum gate opening (for example from 0.10 to 0.125 feet) may be acceptable sometime in the future.

Table 16. Effects of Minimum Gate Opening on Outflow and Minimum Summer Elevations

Spillway Elevation = 736.76

Minimum Opening	7-day, 10-year Low Flow	Minimum Summer Pool (simulated year of occurrence)
0.050 ft	56.0 cfs	736.61 (1958)
		736.79 (1946)
0.075 ft	77.0 cfs	736.56 (1958)
		736.60 (1946)
		736.78 (1949)
0.100 ft	94.0 cfs	736.35 (1946)
		736.42 (1958)
		736.72 (1948)
		736.73 (1949)
		736.74 (1963)
0.125 ft	113.0 cfs	736.05 (1946)
		736.10 (1958)
		736.55 (1948)
		736.59 (1944)
		736.61 (1963)
0.150 ft	130.0 cfs	735.78 (1958)
		735.78 (1946)
		736.35 (1963)
		736.36 (1948)
		736.37 (1944)

Table 17. Simulated Effects of Minimum Gate Opening on Outflow and Minimum Summer Elevations (Year = 2010)

Minimum Opening	7-day, 10-year Low Flow	Minimum Summer Pool (simulated year of occurrence)
0.050 ft	80.0 cfs	736.71 (1958)
		736.83 (1946)
0.100 ft	97.0 cfs	736.58 (1958)
		736.60 (1946)
		736.79 (1949)
		736.80 (1948)
		736.81 (1963)
0.125 ft	113.0 cfs	736.25 (1946)
		736.31 (1958)
		736.68 (1948)
		736.72 (1949)
		736.74 (1944)
0.150 ft	130.0 cfs	735.99 (1946)
		736.03 (1958)
		736.51 (1948)
		736.55 (1944)
		736.56 (1963)

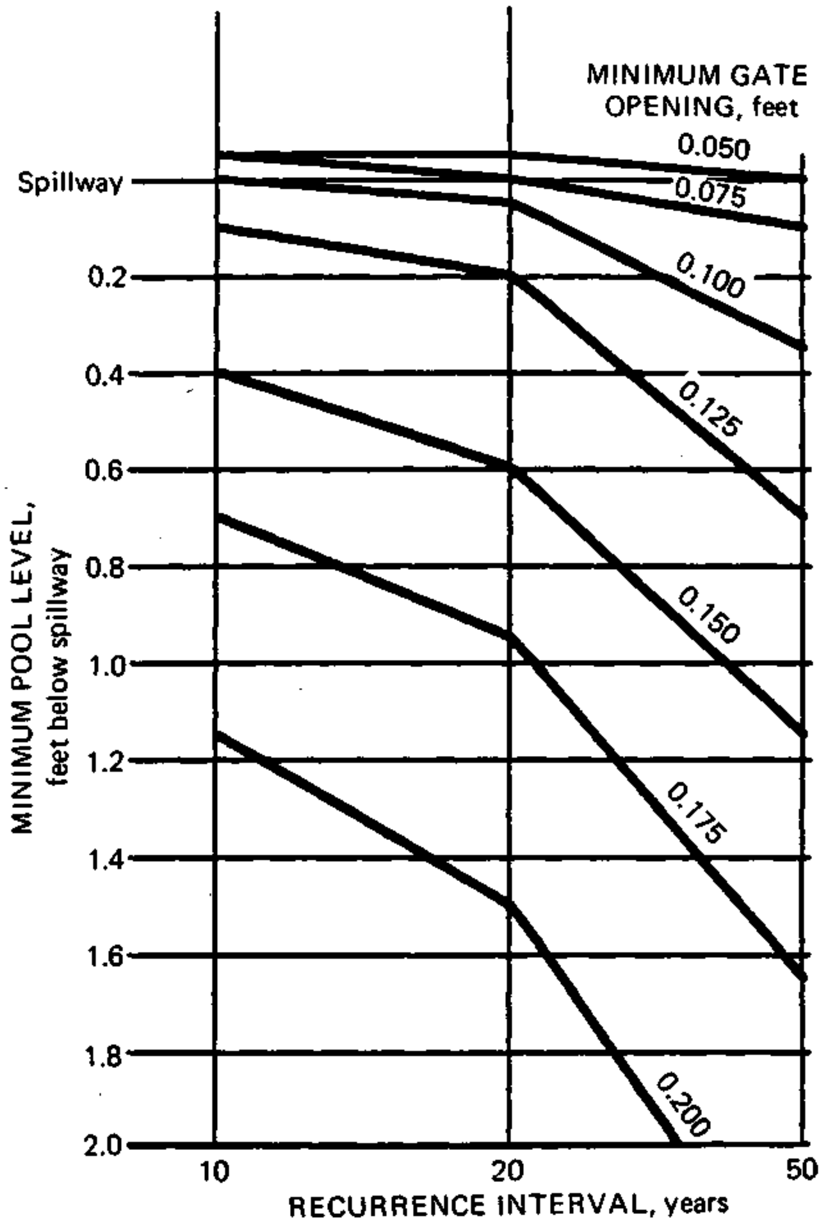

Figure 22. Relationship between the minimum gate opening and drawdown at McHenry Dam

8. MODEL OPERATION

The Streamflow Assessment Model has three basic components, the determination of which were all described earlier in this report: 1) control points (gaging stations and other locations for which a full set of flow statistics is pre-computed); 2) virgin flow equations, used to estimate the undisturbed flow at ungaged sites; and 3) flow modifiers (primarily effluent discharges), that are added to the flow. A list of the locations and estimated flow for the control points and flow modifiers is given in Appendixes A and B. Flow conditions at reservoirs (that would ordinarily be considered flow modifiers) are provided in the list of control points. 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 of which is 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 (Equations 1 and 7);
3. compute the virgin flow estimates (Equation 8, Table 12); search upstream of the point of interest (using the network component) to identify the total area contibuting to the low flow and compute sub-watersheds independently;
4. adjust virgin flow estimates using information from gaging stations along the same stream (using Equations 11-13);
5. add all flow modifiers between point of interest and any upstream control points (add all flow modifiers in the basin if no upstream control points exist);
6. add in the effect of user-supplied modifications to produce the altered flow condition.

The preceding steps will be 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 has some amount of uncertainty associated with it. For example, even at the most basic level involving data from streamgaging, some measurement error and uncertainty in the accuracy of the gage's rating curve must be accepted. Additional uncertainties associated with the development of the hydrologic information presented in the streamflow assessment model are enumerated in the following. At gaged sites, expected errors are 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. There exists an additional uncertainty 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 presented, primarily because it is the only error term that is both estimable and universally applicable to all locations within the watershed.

The development of this model represents an exhaustive evaluation of the streamflow data available for the Fox River Basin. Therefore further data do not exist for total verification of the model results. The greatest amount of uncertainty in the model output generally lies with the geographic limitation of the available data. For this reason, future improvement in the model's data, as well as verification of the present output, is dependent on the procurement of flow data (additional streamgaging or low-flow discharge measurements at additional sites).

9. CONCLUSION

This report has presented the major analytical steps used to prepare the hydrologic data available in the Fox River Basin for use in the Illinois Streamf low Assessment Model *(ILSAM).* The three basic steps involved in estimating flow at any site in the basin are: 1) use of the virgin flow regression equations; 2) adjustments in the virgin flow because of the proximity of gaging stations that have more precise information; and 3) the accounting of the effects of modifications to the flow from effluent discharges, withdrawals, and reservoirs. Streamflow information is supplied in Appendixes 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 a 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 the Streamflow Assessment Model because the number of computations could be great. Readers are referred to the Streamflow Assessment Model User's Manual (Knapp et al., 1985a, and forthcoming revisions) for a detailed description of how the model works. *ILSAM* is available from the State Water Survey on two 5 1/4" floppy diskettes for use on an IBM-PC/AT** or compatible computer having a minimum random access memory (RAM) of 512 K (kilobytes).

The following items highlight some of the results extending from the analysis used for model development.

1. The Fox River Basin has varied topographic and soil characteristics that result from the pattern of glacial deposition. This variety produces a broad range of hydrologic responses between watersheds from within the basin.

2. Groundwater is the primary source of water supply in the Fox River Basin. Since few surface water withdrawals exist, the greatest impact of water use on streamflow quantity results from effluent discharges that add flow to the streams.

3. Streamflow parameters that describe long-term flow conditions can be estimated for ungaged sites throughout the basin using a set of regression equations that **were** developed in this study. The equations employ information on the size of the watershed, permeability of the soil substratum, average annual precipitation, **and** average annual evapotranspiration.

4. A methodology is developed that estimates the effect of reservoirs on downstream flow conditions. The effects of reservoir storage and evaporation on outflow is primarily a function of the surface area of the reservoir and the spillway width at the dam.

5. A change in the minimum gate opening at McHenry Dam can be used to augment low flows along the Fox River. Although large increases in the minimum gate opening will result in a lowering of the lake level during dry periods, smaller increases have no significant effects on drawdown.

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Appendix A. Control Points, Location and Estimated Flow

	Name of Control Point	Location Code	Location Mile
1)	Fox River at Wilmot, WI	V	116.6
2)	Fox River at McHenry Dam	V	97.8
3)	Fox River at Algonquin	V	81.6
4)	Fox River at South Elgin	V	67.3
5)	Fox River at Geneva	V	57.9
6)	Fox River near Montgomery	V	44.49
7)	Fox River at Dayton	V	5.4
8)	Nippersink Cr at Wonder Lake	VX	16.7
9)	Nippersink Cr at Spring Grove	VX	7.0
10)	Boone Creek near McHenry	VW	4.8
11)	Poplar Creek at Elgin	VP	2.3
12)	Ferson Creek near St. Charles	VN	2.2
13)	Blackberry Cr near Yorkville	VI	3.3
14)	Somonauk Cr at Lake Holiday	VF	9.3
15)	Indian Creek at Lake Shabbona	VC	41.2
16)	Crystal Creek at Crystal Lake	VS	7.5

The 154 streamflow parameters are given for each control point on the following pages

Appendix A, continued. Control Points

Location Flow Type	(1) Virgin	(1) Present	(2) Virgin	(2) Present	(3) Virgin	(3) Present	(4) Virgin	(4) Present	(5) Virgin	(5) Present	(6) Virgin	(6) Present	(7) Virgin	(7) Present
Qmean	516.	544.	730.	779.	838.	897.	946	1032.	1019.	1111.	1079.	1217.	1743.	1886.
Q99	62.	74.	89.	96.	104.	117.	117.	158.	121.	167.	128.	206.	194.	275.
Q98	71.	85.	102.	99.	119.	123.	134.	163.	138.	172.	145.	213.	220.	291.
Q95	88.	102.	125.	119.	146.	148.	174.	194.	179.	204.	188.	249.	285.	349.
Q90	108.	125.	159.	147.	187.	183.	217.	232.	227.	247.	238.	296.	355.	416.
Q85	128.	143.	188.	171.	223.	214.	254.	265.	264.	281.	276.	343.	418.	479.
Q75	168.	185.	248.	242.	294.	297.	332.	357.	345.	376.	360.	432.	539.	615.
Q60	246.	266.	369.	360.	436.	436.	513.	538.	544.	575.	567.	642.	828.	909.
Q50	315.	336.	477.	447.	557.	537.	655.	661.	700.	712.	730.	787.	1104.	1167.
Q40	403.	430.	631.	618.	741.	738.	849.	873.	902.	932.	945.	1021.	1416.	1499.
Q25	640.	674.	956.	947.	1138.	1140.	1283.	1314.	1367.	1405.	1437.	1523.	2240.	2336.
Q15	933.	978.	1425.	1483.	1579.	1650.	1783.	1886.	1910.	2020.	2012.	2173.	3217.	3387.
Q10	1174.	1230.	1680.	1773.	1955.	2060.	2207.	2345.	2370.	2515.	2500.	2698.	3981.	4188.
Q05	1625.	1685.	2150.	2364.	2436.	2665.	2763.	3027.	2985.	3257.	3160.	3488.	5200.	5531.
Q02	2230.	2310.	2860.	3131.	3243.	3530.	3644.	3970.	3880.	4214.	4130.	4526.	7170.	7549.
Q01	2720.	2820.	3480.	3866.	3860.	4260.	4274.	4715.	4615.	5065.	4920.	5436.	8725.	9205.
Low Flows														
Q1,2	90.	104.	133.	134.	142.	149.	163.	182.	170.	194.	182.	236.	226.	282.
Q7,2	101.	115.	139.	139.	161.	169.	185.	212.	192.	224.	204.	274.	288.	361.
Q15,2	113.	127.	151.	154.	174.	185.	201.	231.	209.	244.	222.	295.	309.	385.
Q31,2	126.	140.	165.	171.	189.	200.	216.	250.	224.	266.	238.	317.	357.	440.
Q61,2	150.	165.	183.	209.	202.	233.	234.	289.	244.	305.	259.	360.	392.	497.
Q91,2	172.	188.	224.	252.	252.	280.	287.	346.	299.	364.	316.	422.	467.	577.
Q1,10	51.	64.	85.	89.	94.	103.	103.	136.	106.	143.	115.	177.	143.	207.
Q7.10	60.	73.	87.	94.	102.	115.	115.	157.	119.	166.	128.	207.	195.	277.
Q15,10	67.	80.	92.	96.	108.	119.	125.	163.	130.	173.	140.	.216.	217.	296.
Q31.10	75.	88.	101.	100.	116.	122.	135.	167.	141.	178.	151.	222.	228.	302.
Q61,10	83.	97.	110.	106.	125.	128.	147.	172.	153.	183.	164.	229.	248.	316.
Q91,10	93.	107.	123.	116.	139.	139.	165.	183.	173.	196.	185.	244.	264.	326.
Q1,25	42.	55.	62.	87.	68.	97.	74.	126.	75.	131.	84.	165.	100.	183.
Q7,25	48.	61.	64.	88.	74.	104.	87.	145.	90.	153.	99.	193.	143.	240.
Q15,25	55.	68.	69.	89.	79.	105.	92.	147.	96.	156.	105.	196.	159.	253.
Q31,25	59.	72.	74.	90.	85.	107.	102.	153.	107.	163.	117.	205.	173.	264.
Q61,25	65.	78.	83.	94.	94.	112.	120.	165.	121.	171.	131.	214.	201.	287.
Q91.25	72.	85.	92.	105.	105.	125.	132.	177.	140.	190.	151.	235.	234.	321.
Q1,50	36.	48.	46.	85.	50.	93.	57.	123.	58.	128.	66.	160.	77.	173.
Q7.50	40.	53.	48.	85.	54.	97.	65.	136.	68.	144.	77.	183.	117.	226.
Q15,50	45.	58.	52.	86.	59.	99.	70.	138.	74.	147.	83.	187.	134.	241.
Q31,50	49.	62.	57.	87.	64.	100.	74.	139.	78.	148.	87.	188.	144.	248.
Q61,50	52.	65.	64.	88.	74.	104.	90.	149.	95.	159.	105.	201.	178.	277.
Q91,50	56.	69.	72.	90.	86.	111.	106.	158.	113.	170.	123.	213.	216.	309.

Appendix A, continued. Control Points

Drought Flows	(1) Virgin	(1) Present	(2) Virgin	(2) Present	(3) Virgin	(3) Present	(4) Virgin	(4) Present	(5) Virgin	(5) Present	(6) Virgin	(6) Present	(7) Virgin	(7) Present
Q6,10	114.	128.	152.	159.	173.	188.	203.	238.	212.	253.	221.	302.	362.	447.
Q9.10	144.	159.	184.	207.	208.	240.	246.	301.	261.	322.	275.	378.	430.	537.
Q12.10	218.	236.	290.	268.	335.	323.	387.	400.	411.	430.	432.	495.	675.	743.
Q18.10	240.	260.	335.	310.	386.	371.	445.	456.	475.	492.	501.	563.	820.	887.
Q30,10	340.	361.	450.	460.	523.	543,	602.	649.	647.	700.	684.	783.	1064.	1168.
Q54.10	475.	500.	660.	690.	755.	795.	861.	929.	921.	996.	971.	1094.	1477.	1605.
Q6.25	96.	110.	129.	145.	148.	172.	174.	217.	182.	230.	190.	276.	318.	407.
Q9,25	116.	130.	148.	164.	165.	190.	195.	241.	206.	258.	216.	308.	390.	486.
Q12.25	171.	187.	235.	237.	276.	287.	317.	351.	334.	374.	349.	431.	563.	649.
Q18,25	179.	195.	250.	245.	294.	298.	338.	366.	356.	390.	373.	450.	623.	705.
Q30,25	235.	254.	310.	300.	359.	359.	415.	440.	442.	473.	465.	540.	770.	850.
Q54,25	330.	350.	440.	465.	510.	545.	580.	641.	618.	685.	650.	762.	1145.	1262.
Q6,50	87.	100.	113.	129.	128.	152.	153.	195.	160.	207.	167.	251.	296.	383.
Q9,50	101.	114.	130.	149.	145.	172.	172.	219.	181.	234.	189.	281.	366.	461.
Q12.50	137.	151.	202.	188.	240.	235.	277.	294.	291.	314.	304.	368.	533.	601.
Q18,50	153.	167.	220.	218.	262.	269.	300.	330.	315.	351.	329.	407.	593.	675.
Q30.50	181.	196.	255.	260.	300.	314.	348.	386.	369.	413.	387.	474.	663.	755.
Q54,50	255.	273.	350.	360.	410.	430.	469.	514.	499.	550.	524.	619.	966.	1066.
January Flows														
Qmean	373.	393.	610.	653.	669.	723.	753.	836.	804.	894.	848.	986.	1350.	1494.
Q98	76.	88.	106.	129.	116.	146.	142.	193.	149.	205.	163.	254.	223.	317.
Q90	99.	117.	146.	140.	197.	199.	236.	257.	248.	274.	269.	333.	380.	447.
Q75	145.	160.	206.	202.	293.	298.	355.	382.	377.	410.	395.	469.	526.	604.
Q50	240.	263.	351.	339.	489.	487.	560.	584.	592.	622.	622.	697.	908.	988.
Q25	392.	414.	570.	607.	806.	854.	929.	1006.	999.	1083.	1045.	1177.	1556.	1693.
Q10	760.	803.	1130.	1200.	1435.	1517.	1644.	1759.	1785.	1907.	1886.	2061.	3128.	3309.
Q02	1800.	1855.	2130.	2715.	2290.	2890.	2565.	3206.	2766.	3415.	2953.	3665.	5333.	6053.
February Flows														
Qmean	458.	484.	650.	730.	752.	843.	871.	992.	945.	1073.	1006.	1183.	1723.	1905.
Q98	93.	106.	137.	130.	161.	162.	199.	218.	211.	235.	227.	288.	326.	390.
Q90	127.	137.	162.	143.	227.	216.	271.	281.	285.	301.	313.	369.	475.	534.
Q75	171.	197.	232.	247.	356.	380.	413.	460.	437.	490.	457.	552.	622.	722.
Q50	289.	310.	395.	368.	545.	528.	636.	646.	683.	699.	727.	789.	1168.	1235.
Q25	530.	558.	710.	713.	916.	930.	1085.	1129.	1189.	1240.	1279.	1380.	2324.	2431.
Q10	1010.	1065.	1290.	1460.	1520.	1702.	1826.	2042.	2034.	2257.	2173.	2451.	3878.	4162.
Q02	2060.	2095.	2280.	3150.	2350.	3325.	2794.	3722.	3100.	4037.	3381.	4383.	6855.	7864.
March Flows														
Qmean	1101.	1147.	1449.	1485.	1648.	1695.	1843.	1921.	1961.	2046.	2064.	2200.	3248.	3390.
Q98	159.	173.	194.	144.	287.	245.	345.	323.	366.	350.	403.	427.	667.	695.
Q90	257.	278.	326.	275.	431.	389.	493.	476.	519.	508.	551.	584.	834.	872.
Q75	441.	469.	551.	453.	811.	723.	901.	839.	944.	888.	992.	981.	1452.	1445.
Q50	835.	861.	1035.	1025.	1353.	1354.	1528.	1558.	1626.	1663.	1716.	1801.	2690.	2780.
025	1515.	1555.	2000.	1950.	2420.	2380.	2671.	2663.	2822.	2821.	2938.	2989.	4275.	4332.
Q10	2310.	2390.	2940.	3015.	3400.	3490.	3776.	3900.	4015.	4147.	4182.	4370.	6147.	6341.
Q02	3630.	3820.	4180.	4590.	4450.	4875.	4944.	5415.	5288.	5768.	5653.	6199.	10192.	10750.

Appendix A, continued. Control Points

	(1) Virgin	(1) Present	(2) Virgin	(2) Present	(3) Virgin	(3) Present	(4) Virgin	(4) Present	(5) Virgin	(5) Present	(6) Virgin	(6) Present	(7) Virgin	(7) Present
April Flows														
Qmean	1042.	1087.	1543.	1507.	1745.	1720.	1951.	1957.	2081.	2094.	2195.	2259.	3549.	3619.
Q98	184.	202.	324.	163.	473.	321.	540.	410.	564.	440.	599.	515.	836.	756.
Q90	316.	327.	467.	272.	644.	459.	714.	554.	746.	592.	791.	681.	1208.	1103.
Q75	515.	545.	733.	571.	962.	810.	1055.	930.	1103.	984.	1155.	1082.	1692.	1624.
Q50	862.	897.	1292.	1105.	1689.	1513.	1853.	1706.	1948.	1808.	2045.	1954.	3118.	3032.
Q25	1325.	1380.	1940.	1820.	2563.	2455.	2801.	2725.	2950.	2881.	3082.	3066.	4622.	4612.
Q10	1925.	2010.	2730.	2725.	3440.	3450.	3827.	3872.	4090.	4143.	4271.	4380.	6498.	6613.
Q02	3285.	3355.	4240.	4510.	4800.	5085.	5297.	5625.	5665.	6002.	6005.	6408.	10360.	10770.
May Flows														
Qmean	661.	694.	1057.	1058.	1175.	1187.	1326.	1368.	1423.	1472.	1508.	1607.	2516.	2621.
Q98	114.	125.	185.	163.	243.	229.	294.	302.	314.	328.	338.	392.	527.	585.
Q90	206.	223.	320.	257.	417.	364.	476.	448.	504.	482.	534.	556.	822.	849.
Q75	322.	342.	493.	402.	640.	559.	715.	660.	753.	704.	791.	767.	1187.	1188.
Q50	516.	540.	750.	656.	1019.	935.	1142.	1086.	1210.	1160.	1274.	1271.	1973.	1975.
Q25	838.	872.	1140.	1130.	1555.	1556.	1762.	1793.	1887.	1925.	1995.	2083.	3235.	3329.
Q10	1290.	1340.	1730.	1795.	2240.	2317.	2537.	2648.	2732.	2850.	2890.	3063.	4779.	4958.
Q02	2120.	2185.	3560.	3335.	4240.	4030.	4719.	4553.	5090.	4933.	5385.	5294.	9243.	9159.
June Flows														
Qmean	488.	515.	708.	727.	819.	849.	955.	1014.	1043.	1109.	1156.	1271.	1940.	2060.
Q98	109.	124.	166.	131.	200.	173.	233.	226.	244.	243.	260.	299.	367.	410.
Q90	147.	162.	220.	193.	269.	251.	314.	319.	333.	344.	353.	407.	525.	583.
Q75	214.	231.	324.	293.	405.	384.	480.	484.	516.	526.	547.	601.	851.	910.
Q50	349.	370.	516.	430.	707.	631.	806.	757.	858.	815.	911.	914.	1468.	1476.
Q25	624.	657.	872.	844.	1175.	1158.	1355.	1367.	1431.	1450.	1516.	1584.	2494.	2567.
Q10	1035.	1085.	1734.	1849.	2190.	2317.	2439.	2600.	2605.	2773.	2749.	2972.	4505.	4734.
Q02	1600.	1670.	2920.	2040.	3560.	2695.	3964.	3143.	4270.	3458.	4556.	3810.	8261.	7522.
July Flows														
Qmean	356.	379.	502.	509.	575.	592.	657.	702.	703.	754.	746.	844.	1215.	1317.
Q98	63.	79.	101.	104.	120.	131.	147.	176.	156.	190.	170.	240.	250.	322.
Q90	100.	114.	149.	126.	179.	165.	209.	216.	219.	232.	238.	291.	364.	420.
Q75	139.	154.	197.	164.	251.	227.	310.	309.	333.	338.	353.	400.	505.	556.
Q50	223.	243.	322.	279.	416.	383.	491.	483.	524.	522.	558.	601.	857.	905.
Q25	415.	442.	549.	501.	776.	738.	880.	869.	932.	927.	981.	1023.	1469.	1516.
Q10	754.	789.	1050.	990.	1415.	1366.	1576.	1558.	1669.	1658.	1746.	1786.	2603.	2649.
Q02	1615.	1670.	1690.	2170.	1840.	2333.	2263.	2794.	2555.	3094.	2745.	3343.	5097.	5702.
August Flows														
Qmean	294.	315.	371.	384.	446.	469.	510.	560.	541.	597.	571.	673.	863.	969.
Q98	55.	66.	79.	98.	94.	120.	116.	167.	122.	178.	133.	223.	189.	282.
Q90	81.	94.	111.	105.	134.	136.	158.	179.	165.	191.	181.	245.	278.	345.
Q75	113.	131.	159.	144.	192.	185.	235.	249.	249.	269.	266.	326.	373.	436.
Q50	187.	207.	257.	245.	324.	321.	381.	401.	401.	427.	343.	411.	578.	650.
Q25	346.	366.	453.	432.	603.	592.	684.	698.	716.	736.	752.	816.	1045.	1114.
Q10	630.	653.	813.	754.	1088.	1040.	1250.	1230.	1327.	1314.	1396.	1431.	2065.	2106.
Q02	1250.	1340.	1440.	1815.	1635.	2025.	1806.	2231.	1922.	2355.	2022.	2511.	3255.	3750.

Appendix A, continued. Control Points

September Flows	(1) Virgin	(1) Present	(2) Virgin	(2) Present	(3) Virgin	(3) Present	(4) Virgin	(4) Present	(5) Virgin	(5) Present	(6) Virgin	(6) Present	(7) Virgin	(7) Present
Qmean	299.	319.	383.	419.	458.	504.	534.	605.	568.	645.	603.	724.	929.	1054.
Q98	51.	66.	65.	94.	73.	108.	99.	161.	106.	173.	117.	216.	168.	270.
Q90	76.	69.	100.	103.	115.	126.	145.	174.	153.	187.	165.	235.	223.	296.
Q75	111.	125.	142.	143.	166.	175.	207.	235.	220.	253.	233.	304.	310.	384.
Q50	186.	205.	243.	244.	304.	314.	364.	396.	383.	421.	400.	478.	501.	582.
Q25	306.	325.	409.	372.	544.	516.	634.	629.	666.	667.	696.	739.	906.	953.
Q10	667.	707.	856.	884.	1140.	1180.	1365.	1431.	1465.	1537.	1552.	1670.	2346.	2469.
Q02	1415.	1440.	1700.	2250.	1960.	2525.	2407.	3005.	2684.	3289.	2883.	3541.	5206.	5869.
October Flows														
Qmean	338.	360.	432.	466.	523.	567.	600.	670.	636.	712.	674.	795.	1046.	1172.
Q98	65.	78.	85.	96.	93.	110.	114.	158.	120.	169.	126.	205.	151.	232.
Q90	89.	104.	115.	110.	134.	136.	160.	183.	167.	195.	180.	243.	250.	316.
Q75	123.	141.	148.	159.	183.	202.	221.	259.	232.	275.	247.	328.	321.	405.
Q50	197.	218.	271.	277.	330.	345.	384.	421.	402.	445.	423.	506.	543.	630.
Q25	426.	456.	584.	517.	784.	726.	883.	850.	923.	896.	973.	990.	1383.	1405.
Q10	750.	793.	998.	1025.	1252.	1290.	1439.	1505.	1535.	1607.	1614.	'1733.	2429.	2553.
Q02	1420.	1530.	1710.	2045.	1855.	2202.	2224.	2604.	2465.	2852.	2619.	3060.	4464.	4911.
November Flows														
Qmean	405.	429.	514.	644.	604.	744.	687.	853.	726.	898.	762.	979.	1106.	1328.
Q98	89.	99.	116.	102.	139.	131.	165.	184.	173.	197.	186.	242.	250.	308.
Q90	124.	138.	149.	148.	188.	195.	220.	245.	229.	259.	244.	310.	327.	396.
Q75	171.	184.	217.	264.	270.	325.	328.	404.	346.	428.	276.	397.	449.	574.
Q50	302.	320.	394.	460.	494.	569.	559.	657.	582.	686.	608.	754.	797.	947.
Q25	522.	556.	691.	836.	839.	994.	972.	1153.	1030.	1217.	1071.	1303.	1440.	1677.
Q10	875.	927.	1200.	1440.	1443.	1695.	1624.	1905.	1722.	2010.	1782.	2118.	2425.	2767.
Q02	1295.	1375.	1660.	2090.	1830.	2275.	2090.	2570.	2262.	2749.	2389.	2932.	3926.'	4475.
December Flows														
Qmean	379.	403.	541.	736.	648.	853.	740.	972.	791.	1029.	820.	1104.	1138.	1427.
Q98	80.	95.	128.	142.	138.	159.	168.	215.	176.	228.	188.	274.	244.	333.
Q90	105.	129.	165.	229.	199.	271.	234.	324.	244.	339.	253.	385.	302.	437.
Q75	152.	172.	215.	368.	283.	444.	341.	524.	359.	548.	371.	600.	445.	678.
Q50	274.	293.	395.	614.	478.	706.	590.	842.	633.	891.	653.	954.	804.	1110.
Q25	464.	500.	627.	801.	804.	988.	945.	1156.	1016.	1233.	1060.	1323.	1501.	1769.
Q10	771.	799.	986.	1350.	1227.	1605.	1404.	1813.	1514.	1930.	1560.	2027.	2133.	2606.
Q02	1410.	1465.	1630.	2210.	1850.	2445.	2186.	2821.	2435.	3078.	2591.	3296.	4588.	5301.

Appendix A, continued. Control Points

Location Flow Type	(8) Virgin	(8) Present	(9) Virgin	(9) Present	(10) Vir=Pre	(11) Vir=Pre	(12) Vir=Pre	(13) Vir=Pre	(14) Present	(15) Present	(16) Present
Qmean	67.8	71.4	137.2	141.2	13.1	23.5	36.2	47.0	43.7	12.7	4.32
Q99	5.2	5.0	15.5	15.6	4.2	0.28	0.35	3.3	0.0	0.0	0.0
Q98	6.4	6.5	18.4	18.9	4.6	0.41	0.48	4.0	0.0	0.0	0.0
Q95	8.9	9.8	24.5	25.8	5.1	0.67	0.90	5.2	0.09	0.0	0.0
Q90	11.3	13.6	32.1	34.8	5.6	0.96	1.8	7.1	0.63	0.0	0.01
Q85	13.7	18.2	38.2	43.	6.0	1.35	3.1	8.6	1.3	0.0	0.38
Q75	18.7	22.4	51.	55.	7.3	2.6	6.2	12.4	3.4	0.0	0.94
Q60	27.9	32.5	69.	74.	8.8	5.3	12.0	19.0	10.0	2.0	1.75
Q50	36.1	41.	84.	90.	9.8	8.6	17.0	25.0	16.8	4.0	2.1
Q40	52.	58.	106.	112.	11.3	13.0	23.0	34.	27.4	6.8	2.5
Q25	80.	87.	155.	163.	14.7	26.	38.	52.	52.	13.9	3.8
Q15	118.	126.	223.	231.	18.8	44.	61.	76.	83.	24.4	7.5
Q10	149.	156.	283.	291.	22.5	60.	62.	101.	117.	35.	9.4
Q05	222.	224.	414.	417.	29.5	95.	125.	152.	181.	53.	12.6
Q02	345.	326.	628.	609.	43.	155.	200.	250.	316.	93.	18.3
Q01	477.	447.	856.	827.	55.	206.	275.	363.	451.	132.	23.8
Low Flows											
Q1,2	9.0	9.9	22.2	23.5	5.0	0.70	2.4	7.6	0.48	0.0	0.0
Q7,2	10.0	12.0	25.4	27.8	5.3	0.90	3.0	8.6	0.75	0.0	0.0
Q15.2	11.1	13.8	32.2	35.4	5.6	1.1	3.5	9.5	1.1	0.0	0.02
Q31.2	12.3	16.2	36.	40.	6.0	1.5	4.8	10.6	1.5	0.0	0.2
Q61,2	13.9	18.2	42.	47.	6.6	2.0	7.5	12.8	2.2	0.0	0.6
Q91,2	17.0	20.7	51.	55.	7.2	2.8	10.5	15.5	3.4	0.3	1.0
Q1,10	4.0	3.0	13.5	12.8	3.5	0.14	0.20	3.1	0.0	0.0	0.0
Q7,10	4.6	4.3	15.4	15.5	3.7	0.22	0.36	3.4	0.0	0.0	0.0
Q15,10	5.3	5.2	18.5	18.8	4.0	0.28	0.45	3.7	0.0	0.0	0.0
Q31.10	6.8	6.9	21.0	21.5	4.4	0.40	0.80	4.0	0.0	0.0	0.0
Q61,10	7.7	8.2	24.1	25.0	4.6	0.62	1.4	4.9	0.15	0.0	0.0
Q91,10	9.1	10.0	27.2	28.5	4.9	0.83	1.9	6.2	0.42	0.0	0.0
Q1,25	3.3	2.1	9.8	8.9	3.3	0.07	0.12	2.3	0.0	0.0	0.0
Q7.25	3.8	3.3	11.5	11.3	3.5	0.11	0.21	2.5	0.0	0.0	0.0
Q15,25	4.4	4.0	14.8	14.7	3.7	0.15	0.30	2.8	0.0	0.0	0.0
Q31,25	5.6	5.3	17.2	17.3	4.1	0.22	0.60	3.1	0.0	0.0	0.0
Q61,25	5.7	6.3	21.0	21.3	4.3	0.36	1.1	3.8	0.0	0.0	0.0
Q91,25	7.8	7.9	23.5	23.9	4.7	0.50	1.5	4.7	0.0	0.0	0.0
Q1,50	2.9	1.6	8.5	7.5	3.2	0.05	0.08	2.0	0.0	0.0	0.0
Q7.50	3.4	2.8	9.5	9.2	3.4	0.08	0.15	2.2	0.0	0.0	0.0
Q15,50	3.9	3.4	12.9	12.7	3.6	0.11	0.23	2.5	0.0	0.0	0.0
Q31,50	5.1	4.7	14.2	14.1	4.0	0.16	0.50	2.8	0.0	0.0	0.0
Q61,50	5.7	5.4	18.5	18.6	4.2	0.25	1.0	3.4	0.0	0.0	0.0
Q91,50	7.0	7.0	21.0	21.3	4.6	0.36	1.4	4.3	0.0	0.0	0.0

Appendix A, continued. Control Points

Location Drought Flows	(8) Virgin	(8) Present	(9) Virgin	(9) Present	(10) Vir=Pre	(11) Vir=Pre	(12) Vir=Pre	(13) Vir=Pre	(14) Present	(15) Present	(16) Present
Q6,10	13.5	18.0	38.	43.	5.6	1.1	3.0	8.4	1.2	0.0	0.2
Q9.10	20.2	24.2	47.	51.	6.4	2.9	7.2	13.6	5.3	0.5	0.6
Q12.10	27.8	32.7	61.	66.	7.7	7.5	14.2	19.8	11.7	3.0	1.8
Q18.10	33.5	38.8	72.	78.	8.0	7.2	17.2	23.5	16.0	4.3	2.1
Q30,10	47.	53.	93.	100.	10.3	14.5	24.0	33.	26.9	7.7	2.9
Q54.10	61.	67.	124.	131.	12.1	21.0	31.0	41.	37.	10.8	4.0
Q6,25	11.7	13.7	33.5	36.	5.0	0.7	1.6	7.2	0.50	0.0	0.0
Q9,25	14.5	18.6	40.	45.	5.5	1.7	5.1	9.8	2.8	0.0	0.4
Q12.25	21.8	26.0	51.	56.	6.8	4.6	8.9	14.7	6.2	0.9	0.9
Q18.25	23.6	28.1	54.	59.	7.0	4.0	10.5	16.0	7.8	1.6	1.0
Q30.25	31.0	36.0	66.	71.	8.0	8.0	15.7	21.8	14.0	3.7	2.0
Q54,25	40.	45.	84.	90.	9.0	14.8	20.9	28.4	21.6	6.2	2.7
Q6.50	11.1	12.2	31.	33.	4.7	0.5	1.3	6.9	0.31	0.0	0.0
Q9,50	12.7	16.8	36.	40.	5.2	1.4	3.3	8.2	1.5	0.0	0.3
Q12,50	19.0	22.8	45.	49.	6.5	3.7	7.0	12.8	4.2	0.2	0.8
Q18,50	20.1	24.1	47.	51.	6.6	2.8	8.0	13.6	5.2	0.7	0.8
Q30,50	25.0	29.5	57.	62.	7.3	5.7	12.2	17.9	9.4	2.3	1.8
Q54,50	32.4	37.4	71.	76.	8:2	11.5	17.3	23.7	16.0	4.5	2.4
January Flows											
Qmean	59.	66.	98.	106.	11.2	17.5	27.3	34.	40.	11.7	3.6
Q98	9.3	9.8	19.6	20.5	4.5	0.6	1.4	3.8	0.0	0.0	0.0
Q90	12.1	14.4	33.5	36.	5.5	0.9	3.5	8.1	0.57	0.0	0.4
Q75	18.8	22.5	43.	47.	6.9	2.2	8.7	13.4	3.7	0.6	1.0
Q50	33.	38.	63.	69.	9.0	5.6	15.9	21.0	13.9	2.9	1.4
Q25	64.	71.	103.	111.	11.8	14.6	26.1	34.	37.	9.5	2.4
Q10	128.	135.	161.	169.	17.2	44.	53.	72.	94.	27.4	5.9
Q02	335.	316.	416.	398.	40.	158.	199.	240.	332.	99.	19.1
February Flows											
Qmean	78.	86.	139.	147.	13.9	23.7	38.	46.	53.	15.8	4.6
Q98	9.6	11.4	20.5	22.6	4.4	0.7	2.1	5.6	0.33	0.0	0.0
Q90	12.6	17.0	28.5	33.	5.4	1.0	4.5	9.2	1.6	0.0	0.4
Q75	23.0	27.2	41.	46.	7.1	2.6	9.0	14.3	7.2	1.5	1.0
Q50	42.	48.	66.	72.	9.6	8.2	17.4	25.8	21.2	5.1	1.7
Q25	86.	94.	138.	146.	14.6	26.4	43.	59.	58.	17.0	5.2
Q10	155.	160.	273.	279.	23.0	64.	91.	107.	125.	37.	8.7
Q02	378.	353.	698.	673.	58.	161.	194.	277.	357.	106,	23.9
March Flows											
Qmean	119.	127.	233.	241.	19.0	48.	65.	80.	79.	23.2	7.5
Q98	19.2	23.6	31.	36.	6.7	1.3	7.4	13.4	4.1	0.0	0.5
Q90	26.8	31.4	56.	61.	8.1	4.8	14.3	21.3	9.5	2.1	1.6
Q75	43.	48.	94.	100.	10.3	10.9	24.3	33.	20.0	5.0	2.6
Q50	74.	81.	161.	169.	14.1	27.4	44.	56.	44.	11.4	3.3
Q25	130.	138.	279.	287.	21.6	62.	80.	100.	90.	25.0	6.7
Q10	226.	228.	473.	476.	34.	112.	158.	182.	175.	52.	14.6
Q02	421.	391.	1010.	980.	60.	251.	363.	427.	405.	121.	26.4

Appendix A, continued. Control Points

Location	(8)	(8)	(9)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
April Flows	Virain	Present	Virqin	Present	Vir=Pre	Vir=Pre	Vir=Pre	Vir=Pre	Present	Present	Present
Qmean	133.	141.	263.	271.	20.1	53.	67.	86.	93.	27.4	7.8
098	23.0	27.1	56.	61.	8.4	2.5	9.5	14.9	5.1	0.2	1.5
Q90	35.	40.	95.	100.	9.5	10.1	19.7	25.6	15.1	3.6	2.0
Q75	56.	62.	135.	141.	11.7	18.6	34.	41.	28.7	7.2	2.6
050	92.	100.	195.	203.	16.4	36.	54.	73.	57.	15.3	4.3
025	145.	152.	309.	317.	23.0	65.	89.	117.	108.	31.	8.2
Q10	235.	237.	499.	502.	32.	114.	141.	185.	194.	57.	13.2
Q02	455.	425.	1001.	972.	60.	246.	302.	367.	460.	138.	25.8
Mav Flows											
Qmean	97.	105.	175.	183.	15.3	33.	48.	72.	68.	20.0	5.5
098	19.8	24.2.	37.	42.	5.9	3.0	6.5	15.5	5.5	0.3	0.9
Q90	29.9	34.8	55.	60.	7.7	6.3	11.3	21.3	12.8	3.1	1.6
Q75	42.	47.	75.	81.	9.3	10.3	20.2	30.	21.2	5.2	1.9
Q50	64.	71.	117.	124.	12.2	19.9	35.	54.	38.	9.6	2.6
Q25	106.	114.	199.	207.	17.0	42.	62.	89.	70.	19.1	4.8
Q10	178.	183.	335.	341.	25.6	75.	101.	158.	140.	40.	8.8
Q02	354.	332.	744.	723.	43.	151.	237.	353.	361.	108.	17.6
June Flows											
Qmean	84.	92.	151.	159.	13.7	26.2	43.	58.	60.	17.5	4.7
Q98	12.1	16.6	25.4	30.3	4.7	0.9	1.3	9.1	2.3	0.0	0.0
Q90	21.0	25.4	41.	46.	5.7	2.0	4.2	13.6	7.1	1.2	0.3
Q75	29.5	34.4	68.	73.	7.4	4.2	10.5	22.3	12.8	2.9	0.9
Q50	50.	56.	107.	113.	10.3	11.0	23.8	40.	25.4	6.1	1.9
Q25	88.	96.	172.	180.	15.3	28.8	48.	67.	58.	17.2	5.4
Q10	155.	163.	328.	336.	23.8	66.	98.	126.	133.	40.	9.7
Q02	306.	292.	551.	538.	43.	168.	324.	335.	404.	121.	21.1
July Flows											
Qmean	52.	59.	100.	107.	11.9	15.2	23.0	37.	31.	8.9	3.7
098	9.1	10.0	18.0	19.3	4.4	0.5	0.7	6.6	0.0	0.0	0.0
Q90	13.8	18.0	31.	36.	5.5	1.1	2.0	9.2	2.2	0.0	0.1
Q75	22.0	26.1	46.	51.	7.1	2.5	7.5	15.4	5.8	0.5	0.4
Q50	33.	38.	71.	77.	9.3	6.1	14.8	25.8	12.9	2.5	1.3
Q25	59.	65.	111.	118.	13.6	15.1	24.0	41.	29.2	7.0	2.7
Q10	104.	112.	234.	242.	18.9	33.	43.	69.	66.	17.8	5.1
Q02	265.	259.	416.	410.	35.	114.	135.	180.	225.	67.	15.2
August Flows											
Qmean	35.4	41.2	89.	95.	10.0	8.3	21.4	23.0	18.1	5.0	3.0
098	8.4	8.6	15.6	16.1	4.2	0.5	0.4	4.4	0.0	0.0	0.0
090	11.0	13.4	23.4	26.2	5.0	0.9	1.6	6.8	0.3	0.0	0.0
Q75	14.4	18.7	36.	41.	5.8	1.7	4.0	10.0	1.6	0.0	0.3
Q50	21.9	25.9	58.	62.	7.9	3.5	8.8	17.0	4.3	0.2	1.2
Q25	32.	37.	89.	94.	11.2	7.1	19.1	28.7	10.1	2.1	2.3
Q10	65.	72.	175.	183.	16.9	18.5	52.	48.	31.	7.4	3.6
Q02	209.	211.	394.	397.	29.5	66.	172.	109.	172.	51.	12.0

Appendix A, concluded. Control Points

Location	(8) Virgin	(8) Present	(9) Virgin	(9) Present	(10) Vir=Pre	(11) Vir=Pre	(12) Vir=Pre	(13) Vir=Pre	(14) Present	(15) Present	(16) Present
September Flows											
Qmean	32.4	37.3	87.	92.	10.0	12.6	25.4	32.5	14.8	4.1	3.0
098	7.2	7.0	13.6	13.7	4.1	0.1	0.3	3.4	0.0	0.0	0.0
Q90	9.9	10.8	20.8	22.1	4.9	0.4	1.0	5.3	0.0	0.0	0.0
075	13.1	15.8	37.	40.	5.7	1.0	3.6	8.0	0.7	0.0	0.4
Q50	19.5	23.7	59.	64.	7.4	2.7	7.7	16.0	1.8	0.0	1.7
025	26.7	30.8	96.	101.	10.2	7.8	21.8	33.	6.2	0.8	2.3
Q10	59.	65.	224.	230.	17.1	31.	70.	85.	24.9	5.8	3.9
Q02	215.	223.	641.	649.	39.	131.	233.	217.	164.	48.	14.5
October Flows											
Qmean	34.0	39.1	91.	97.	9.6	11.0	19.5	27.5	17.1	4.7	3.0
098	8.8	8.3	17.8	17.6	4.6	0.4	0.6	3.7	0.0	0.0	0.0
090	11.0	11.5	27.5	28.4	5.3	0.7	1.5	6.0	0.1	0.0	0.2
Q75	13.9	16.2	39.	42.	6.1	1.2	4.7	9.5	1.1	0.0	0.9
Q50	20.8	25.0	60.	65.	8.0	3.0	12.2	19.1	3.3	0.0	1.8
025	31.	36.	101.	106.	10.4	9.4	26.0	36.	10.2	2.2	2.3
Q10	68.	75.	184.	191.	15.3	31.	50.	64.	37.	9.4	3.5
Q02	177.	183.	346.	353.	27.2	84.	113.	138.	139.	41.	10.7
November Flows											
Qmean	38.	43.	102.	108.	11.1	14.3	25.0	30.3	18.7	5.2	3.5
Q98	10.0	9.7	21.1	21.2	5.0	0.2	0.8	3.8	0.0	0.0	0.0
Q90	13.0	13.9	28.5	30.	5.8	0.7	2.2	8.6	0.6	0.0	0.4
Q75	18.4	22.4	47.	51.	7.2	1.5	8.1	12.7	2.1	0.0	1.6
Q50	26.2	30.2	75.	79.	9.4	5.1	17.1	22.8	5.8	0.4	2.1
Q25	46.	51.	127.	133.	12.8	19.1	38.	40.	17.9	3.9	2.7
Q10	86.	93.	202.	210.	17.5	40.	65.	74.	51.	13.3	4.4
Q02	172.	175.	286.	290.	26.1	80.	120.	124.	137.	41.	10.2
December Flows											
Qmean	53.	59.	132.	139.	11.6	20.1	32.7	40.	32.	9.4	3.7
098	10.3	10.3	29.8	30.	4.7	0.4	1.4	3.0	0.0	0.0	0.0
Q90	13.1	14.7	43.	45.	5.9	0.8	3.4	8.3	0.5	0.0	0.3
Q75	18.7	23.1	63.	68.	7.3	2.5	12.0	17.4	2.5	0.0	1.6
Q50	27.2	31.7	104.	109.	9.5	10.0	21.6	28.4	8.5	2.3	2.6
Q25	54.	60.	148.	154.	13.1	22.0	40.	47.	27.5	7.9	4.1
Q10	109.	117.	229.	237.	18.0	44.	66.	84.	75.	22.0	6.6
Q02	292.	278.	538.	525.	30.0	131.	177.	201.	260.	78.	14.5

Appendix B. Effluent Discharges, Location and Estimated Flow

	Name of Discharger	Location (stream and river mile)
1)	Algonquin	Fox River (V), mile 80.6
2)	Antioch	Sequoit Creek (VZ), mile 1.4
3)	Armour Dial, Inc	Fox River tributary (VJ3), mile 1.4
4)	Aurora	Fox River (V), mile 44.5
5)	Barrington	Flint Creek tributary (VUP), mile 0.5
6)	Batavia	Fox River (V), mile 54.8
7)	Carpentersville	Fox River (V), mile 76.6
8)	Cary	Cary Creek (VT1), mile 0.9
9)	Crystal Lake	Crystal Creek (VS), mile 6.1
10)	Earlville	Indian Creek (VC), mile 22.61
11)	East Dundee	Fox River (V), mile 74.9
12)	Elburn	Welch Creek (VHJ), mile 16.0
13)	Elgin (North)	Fox River (V), mile 72.1
14)	Elgin (South & West)	Fox River (V), mile 69.1
15)	Fox Lake Regional	Fox River (V), mile 104.5
16)	Fox River Grove	Spring Creek (VT), mile 0.6
17)	Geneva	Fox River (V), mile 57.3
18)	Hebron	DeYoung Creek (VXHV), mile 0.5
19)	Island Lake	Cotton Creek (VV), mile 1.7
20)	Lake in the Hills	Crystal Creek (VS), mile 2.5
21)	Lake Villa	Eagle Creek (VYE), mile 3.3
22)	Lake Zurich (NW)	North Br Flint Creek (VUE), mile 4.1
23)	McHenry	Fox River (V), mile 100.1
24)	Morton Chemical Co.	Dutch Creek tributary (VW4J), mile 1.8
25)	Oswego	Fox River (V), mile 42.4
26)	Paw Paw	Paw Paw Run (VCN), mile 8.7
27)	Piano	Big Rock Creek (VH), mile 1.2
28)	Richmond	North Br Nippersink Cr (VXH), mile 5.7
29)	St. Charles	Fox River (V), mile 58.7
30)	Sandwich	Little Rock Cr tributary (VHAD), mile 1.6
31)	Somonauk	Somonauk Creek tributary (VFH), mile 1.4
32)	Travenol Laboratories	Squaw Creek tributary (VYH), mile 2.2
33)	Waterman	Somonauk Creek tributary (VFU), mile 1.8
34)	Wauconda	Bangs Lake Outlet (VU3), mile 4.8
35)	West Dundee	Fox River (V), mile 74.8
36)	Woodstock (East)	Silver Creek (VXP), mile 5.8
37)	Woodstock (West)	Silver Creek tributary (VXPL), mile 2.2
38)	Woodstock Die Casting	Silver Creek (VXP), mile 7.3
39)	Yorkville-Bristol	Fox River (V), mile 35.61

The 154 streamflow parameters are given for each discharge on the following pages

Appendix B, continued. Effluent Discharges

Location	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Qmean	1.70	1.31	0.68	37.90	4.32	3.50	4.30	1.60	5.20	0.26	0.90	0.91	4.75	22.25	8.35	0.99	3.64	0.30	0.36	0.90
Q99	0.98	0.97	0.68	26.60	2.60	1.90	2.30	1.10	3.40	0.12	0.47	0.46	2.90	17.98	5.40	0.87	2.30	0.23	0.29	0.50
Q98	1.10	1.03	0.68	28.48	2.89	2.17	2.63	1.18	3.70	0.14	0.54	0.54	3.21	18.69	5.89	0.89	2.52	0.24	0.30	0.57
Q95	1.22	1.08	0.68	30.37	3.17	2.43	2.97	1.27	4.00	0.17	0.61	0.61	3.52	19.40	6.38	0.91	2.75	0.25	0.31	0.63
Q90	1.30	1.12	0.68	31.62	3.36	2.61	3.19	1.32	4.20	0.18	0.66	0.66	3.72	19.88	6.71	0.92	2.90	0.26	0.32	0.68
Q85	1.38	1.16	0.68	32.88	3.56	2.79	3.41	1.38	4.40	0.20	0.71	0.71	3.93	20.35	7.04	0.94	3.04	0.27	0.33	0.72
Q75	1.46	1.20	0.68	34.13	3.75	2.97	3.63	1.43	4.60	0.21	0.76	0.76	4.13	20.83	7.37	0.95	3.19	0.28	0.34	0.77
Q60	1.58	1.25	0.68	36.02	4.03	3.23	3.97	1.52	4.90	0.24	0.83	0.84	4.44	21.54	7.86	0.97	3.42	0.29	0.35	0.83
Q50	1.64	1.28	0.68	36.96	4.18	3.37	4.13	1.56	5.05	0.25	0.86	0.87	4.60	21.89	8.10	0.98	3.53	0.29	0.35	0.87
Q40	1.70	1.31	0.68	37.90	4.32	3.50	4.30	1.60	5.20	0.26	0.90	0.91	4.75	22.25	8.35	0.99	3.64	0.30	0.36	0.90
Q25	1.82	1.37	0.68	39.78	4.61	3.77	4.63	1.68	5.50	0.28	0.97	0.99	5.06	22.96	8.84	1.01	3.86	0.31	0.37	0.97
Q15	1.94	1.42	0.68	41.67	4.89	4.03	4.97	1.77	5.80	0.31	1.04	1.06	5.37	23.67	9.33	1.03	4.09	0.32	0.38	1.03
Q10	2.06	1.48	0.68	43.55	5.18	4.30	5.30	1.85	6.10	0.33	1.12	1.14	5.68	24.39	9.83	1.05	4.31	0.34	0.40	1.10
Q05	2.22	1.56	0.68	46.06	5.56	4.66	5.74	1.96	6.50	0.36	1.21	1.24	6.09	25.33	10.48	1.08	4.61	0.35	0.41	1.19
Q02	2.50	1.69	0.68	50.46	6.23	5.28	6.52	2.16	7.20	0.42	1.38	1.41	6.81	26.99	11.63	1.12	5.13	0.38	0.44	1.34
Q01	2.74	1.80	0.68	54.22	6.80	5.81	7.19	2.32	7.80	0.46	1.52	1.56	7.42	28.42	12.61	1.16	5.58	0.40	0.46	1.48
Low Flows																				
Q1,2	0.90	0.93	0.68	25.34	2.41	1.72	2.08	1.04	3.20	0.10	0.42	0.41	2.69	17.51	5.07	0.86	2.15	0.22	0.28	0.46
Q7,2	1.28	1.11	0.68	31.37	3.33	2.58	3.14	1.31	4.16	0.18	0.65	0.65	3.68	19.78	6.65	0.92	2.87	0.26	0.32	0.67
Q15,2	1.32	1.13	0.68	31.87	3.40	2.65	3.23	1.33	4.24	0.19	0.67	0.67	3.76	19.97	6.78	0.93	2.93	0.26	0.32	0.69
Q31,2	1.36	1.15	0.68	32.50	3.50	2.74	3.34	1.36	4.34	0.19	0.69	0.70	3.87	20.21	6.94	0.93	3.00	0.27	0.33	0.71
Q61,2	1.40	1.17	0.68	33.25	3.61	2.84	3.48	1.39	4.46	0.20	0.72	0.73	3.99	20.49	7.14	0.94	3.09	0.27	0.33	0.74
Q91,2	1.46	1.20	0.68	34.13	3.75	2.97	3.63	1.43	4.60	0.21	0.76	0.76	4.13	20.83	7.37	0.95	3.19	0.28	0.34	0.77
Q1,10	0.65	0.82	0.68	21.48	1.82	1.18	1.39	0.87	2.59	0.06	0.28	0.26	2.06	16.05	4.06	0.82	1.69	0.20	0.26	0.32
Q7,10	0.98	0.97	0.68	26.60	2.60	1.90	2.30	1.10	3.40	0.12	0.47	0.46	2.90	17.98	5.40	0.87	2.30	0.23	0.29	0.50
Q15,10	1.04	1.00	0.68	27.54	2.74	2.03	2.47	1.14	3.55	0.13	0.51	0.50	3.05	18.34	5.65	0.88	2.41	0.24	0.30	0.53
Q31,10	1.09	1.02	0.68	28.30	2.86	2.14	2.60	1.18	3.67	0.14	0.53	0.53	3.18	18.62	5.84	0.89	2.50	0.24	0.30	0.56
Q61,10	1.16	1.06	0.68	29.43	3.03	2.30	2.80	1.23	3.85	0.16	0.58	0.57	3.36	19.05	6.14	0.90	2.64	0.25	0.31	0.60
Q91,10	1.22	1.08	0.68	30.37	3.17	2.43	2.97	1.27	4.00	0.17	0.61	0.61	3.52	19.40	6.38	0.91	2.75	0.25	0.31	0.63
Q1,25	0.62	0.80	0.68	20.92	1.74	1.10	1.29	0.85	2.50	0.05	0.25	0.23	1.97	15.83	3.92	0.81	1.63	0.19	0.25	0.30
Q7,25	0.92	0.94	0.68	25.72	2.47	1.78	2.14	1.06	3.26	0.11	0.44	0.43	2.76	17.65	5.17	0.86	2.20	0.22	0.28	0.47
Q15,25	0.96	0.96	0.68	26.22	2.54	1.85	2.23	1.08	3.34	0.12	0.46	0.45	2.84	17.84	5.30	0.87	2.26	0.23	0.29	0.49
Q31,25	0.98	0.97	0.68	26.60	2.60	1.90	2.30	1.10	3.40	0.12	0.47	0.46	2.90	17.98	5.40	0.87	2.30	0.23	0.29	0.50
Q61,25	1.04	1.00	0.68	27.54	2.74	2.03	2.47	1.14	3.55	0.13	0.51	0.50	3.05	18.34	5.65	0.88	2.41	0.24	0.30	0.53
Q91,25	1.10	1.03	0.68	28.48	2.89	2.17	2.63	1.18	3.70	0.14	0.54	0.54	3.21	18.69	5.89	0.89	2.52	0.24	0.30	0.57
Q1,50	0.60	0.79	0.68	20.64	1.69	1.06	1.24	0.84	2.45	0.05	0.24	0.22	1.92	15.73	3.84	0.81	1.59	0.19	0.25	0.29
Q7,50	0.90	0.93	0.68	25.34	2.41	1.72	2.08	1.04	3.20	0.10	0.42	0.41	2.69	17.51	5.07	0.86	2.15	0.22	0.28	0.46
Q15,50	0.93	0.95	0.68	25.85	2.49	1.79	2.17	1.07	3.28	0.11	0.44	0.43	2.78	17.70	5.20	0.86	2.21	0.23	0.29	0.47
Q31,50	0.96	0.96	0.68	26.22	2.54	1.85	2.23	1.08	3.34	0.12	0.46	0.45	2.84	17.84	5.30	0.87	2.26	0.23	0.29	0.49
Q61,50	1.00	0.98	0.68	26.98	2.66	1.95	2.37	1.12	3.46	0.12	0.48	0.48	2.96	18.12	5.50	0.87	2.34	0.23	0.29	0.51
Q91,50	1.06	1.01	0.68	27.92	2.80	2.09	2.53	1.16	3.61	0.14	0.52	0.51	3.12	18.48	5.74	0.88	2.46	0.24	0.30	0.55

Appendix B, continued. Effluent Discharges

Drought Flows	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(141	(15)	(16)	(17)	(18)	(19)	(20)
Q6,10	1.38	1.16	0.68	32.88	3.56	2.79	3.41	1.38	4.40	0.20	0.71	0.71	3.93	20.35	7.04	0.94	3.04	0.27	0.33	0.72
Q9.10	1.50	1.21	0.68	34.70	3.83	3.05	3.73	1.46	4.69	0.22	0.78	0.78	4.23	21.04	7.51	0.96	3.26	0.28	0.34	0.79
Q12,10	1.61	1.27	0.68	36.49	4.11	3.30	4.05	1.54	4.98	0.24	0.85	0.85	4.52	21.72	7.98	0.98	3.47	0.29	0.35	0.85
Q18,10	1.65	1.29	0.68	37.15	4.21	3.39	4.17	1.57	5.08	0.25	0.87	0.88	4.63	21.97	8.15	0.98	3.55	0.30	0.36	0.87
Q30,10	1.71	1.32	0.68	38.09	4.35	3.53	4.33	1.61	5.23	0.26	0.91	0.92	4.78	22.32	8.40	0.99	3.66	0.30	0.36	0.91
Q54,10	1.80	1.36	0.68	39.41	4.55	3.71	4.57	1.67	5.44	0.28	0.96	0.97	5.00	22.82	8.74	1.01	3.82	0.31	0.37	0.95
Q6,25	1.28	1.11	0.68	31.37	3.33	2.58	3.14	1.31	4.16	0.18	0.65	0.65	3.68	19.78	6.65	0.92	2.87	0.26	0.32	0.67
Q9,25	1.42	1.18	0.68	33.51	3.65	2.88	3.52	1.41	4.50	0.21	0.73	0.74	4.03	20.59	7.20	0.94	3.12	0.27	0.33	0.74
Q12,25	1.52	1.23	0.68	35.08	3.89	3.10	3.80	1.48	4.75	0.23	0.79	0.80	4.29	21.18	7.61	0.96	3.31	0.28	0.34	0.80
Q18,25	1.57	1.25	0.68	35.83	4.00	3.21	3.93	1.51	4.87	0.23	0.82	0.83	4.41	21.47	7.81	0.97	3.39	0.29	0.35	0.83
Q30,25	1.63	1.28	0.68	36.77	4.15	3.34	4.10	1.55	5.02	0.25	0.86	0.87	4.57	21.82	8.06	0.98	3.51	0.29	0.35	0.86
Q54,25	1.67	1.30	0.68	37.43	4.25	3.43	4.22	1.58	5.13	0.25	0.88	0.89	4.67	22.07	8.23	0.99	3.58	0.30	0.36	0.88
Q6,50	1.24	1.09	0.68	30.62	3.21	2.47	3.01	1.28	4.04	0.17	0.62	0.62	3.56	19.50	6.45	0.91	2.78	0.25	0.31	0.64
Q9,50	1.36	1.15	0.68	32.63	3.52	2.75	3.37	1.37	4.36	0.19	0.70	0.70	3.89	20.26	6.97	0.93	3.01	0.27	0.33	0.71
Q12,50	1.45	1.19	0.68	34.01	3.73	2.95	3.61	1.43	4.58	0.21	0.75	0.76	4.11	20.78	7.33	0.95	3.18	0.28	0.34	0.76
Q18,50	1.50	1.21	0.68	34.70	3.83	3.05	3.73	1.46	4.69	0.22	0.78	0.78	4.23	21.04	7.51	0.96	3.26	0.28	0.34	0.79
Q30,50	1.57	1.25	0.68	35.83	4.00	3.21	3.93	1.51	4.87	0.23	0.82	0.83	4.41	21.47	7.81	0.97	3.39	0.29	0.35	0.83
Q54,50	1.63	1.28	0.68	36.77	4.15	3.34	4.10	1.55	5.02	0.25	0.86	0.87	4.57	21.82	8.06	0.98	3.51	0.29	0.35	0.86
January Flows																				
Qmean	1.82	1.37	0.68	39.78	4.61	3.77	4.63	1.68	5.50	0.28	0.97	0.99	5.06	22.96	8.84	1.01	3.86	0.31	0.37	0.97
Q98	1.16	1.06	0.68	29.43	3.03	2.30	2.80	1.23	3.85	0.16	0.58	0.57	3.36	19.05	6.14	0.90	2.64	0.25	0.31	0.60
Q90	1.30	1.12	0.68	31.62	3.36	2.61	3.19	1.32	4.20	0.18	0.66	0.66	3.72	19.88	6.71	0.92	2.90	0.26	0.32	0.68
Q75	1.46	1.20	0.68	34.13	3.75	2.97	3.63	1.43	4.60	0.21	0.76	0.76	4.13	20.83	7.37	0.95	3.19	0.28	0.34	0.77
Q50	1.64	1.28	0.68	36.96	4.18	3.37	4.13	1.56	5.05	0.25	0.86	0.87	4.60	21.89	8.10	0.98	3.53	0.29	0.35	0.87
Q25	1.82	1.37	0.68	39.78	4.61	3.77	4.63	1.68	5.50	0.28	0.97	0.99	5.06	22.96	8.84	1.01	3.86	0.31	0.37	0.97
Q10	2.06	1.48	0.68	43.55	5.18	4.30	5.30	1.85	6.10	0.33	1.12	1.14	5.68	24.39	9.83	1.05	4.31	0.34	0.40	1.10
Q02	2.57	1.72	0.68	51.59	6.40	5.44	6.72	2.21	7.38	0.43	1.42	1.46	6.99	27.42	11.92	1.14	5.26	0.38	0.44	1.38
February Flows																				
Qmean	1.88	1.40	0.68	40.73	4.75	3.90	4.80	1.73	5.65	0.30	1.01	1.02	5.21	23.32	9.09	1.02	3.98	0.32	0.38	1.00
Q98	1.27	1.11	0.68	31.12	3.29	2.54	3.10	1.30	4.12	0.18	0.64	0.64	3.64	19.69	6.58	0.92	2.84	0.26	0.32	0.66
Q90	1.40	1.17	0.68	33.13	3.59	2.82	3.46	1.39	4.44	0.20	0.72	0.72	3.97	20.45	7.10	0.94	3.07	0.27	0.33	0.73
Q75	1.52	1.23	0.68	35.08	3.89	3.10	3.80	1.48	4.75	0.23	0.79	0.80	4.29	21.18	7.61	0.96	3.31	0.28	0.34	0.80
Q50	1.70	1.31	0.68	37.90	4.32	3.50	4.30	1.60	5.20	0.26	0.90	0.91	4.75	22.25	8.35	0.99	3.64	0.30	0.36	0.90
Q25	1.92	1.41	0.68	41.29	4.84	3.98	4.90	1.75	5.74	0.30	1.03	1.05	5.31	23.53	9.24	1.03	4.04	0.32	0.38	1.02
Q10	2.14	1.52	0.68	44.81	5.37	4.48	5.52	1.S1	6.30	0.35	1.16	1.19	5.88	24.86	10.15	1.06	4.46	0.34	0.40	1.14
Q02	2.67	1.77	0.68	53.09	6.63	5.65	6.99	2.27	7.62	0.45	1.48	1.52	7.24	27.99	12.32	1.15	5.44	0.39	0.45	1.44
March Flows																				
Qmean	1.94	1.42	0.68	41.67	4.89	4.03	4.97	1.77	5.80	0.31	1.04	1.06	5.37	23.67	9.33	1.03	4.09	0.32	0.38	1.03
Q98	1.38	1.16	0.68	32.88	3.56	2.79	3.41	1.38	4.40	0.20	0.71	0.71	3.93	20.35	7.04	0.94	3.04	0.27	0.33	0.72
Q90	1.58	1.25	0.68	36.02	4.03	3.23	3.97	1.52	4.90	0.24	0.83	0.84	4.44	21.54	7.86	0.97	3.42	0.29	0.35	0.83
Q75	1.67	1.30	0.68	37.43	4.25	3.43	4.22	1.58	5.13	0.25	0.88	0.89	4.67	22.07	8.23	0.99	3.58	0.30	0.36	0.88
Q50	1.82	1.37	0.68	39.78	4.61	3.77	4.63	1.68	5.50	0.28	0.97	0.99	5.06	22.96	8.84	1.01	3.86	0.31	0.37	0.97
Q25	1.99	1.45	0.68	42.42	5.01	4.14	5.10	1.80	5.92	0.32	1.07	1.09	5.49	23.96	9.53	1.04	4.18	0.33	0.39	1.06
Q10	2.22	1.56	0.68	46.06	5.56	4.66	5.74	1.96	6.50	0.36	1.21	1.24	6.09	25.33	10.48	1.08	4.61	0.35	0.41	1.19
Q02	2.74	1.80	0.68	54.22	6.80	5.81	7.19	2.32	7.80	0.46	1.52	1.56	7.42	28.42	12.61	1.16	5.58	0.40	0.46	1.48

Appendix B, continued. Effluent Discharges

April Flows	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Qmean	1.98	1.44	0.68	42.23	4.98	4.11	5.07	1.79	5.89	0.31	1.06	1.08	5.46	23.89	9.48	1.04	4.15	0.33	0.39	1.05
Q98	1.42	1.18	0.68	33.51	3.65	2.88	3.52	1.41	4.50	0.21	0.73	0.74	4.03	20.59	7.20	0.94	3.12	0.27	0.33	0.74
Q90	1.63	1.28	0.68	36.77	4.15	3.34	4.10	1.55	5.02	0.25	0.86	0.87	4.57	21.82	8.06	0.98	3.51	0.29	0.35	0.86
Q75	1.70	1.31	0.68	37.90	4.32	3.50	4.30	1.60	5.20	0.26	0.90	0.91	4.75	22.25	8.35	0.99	3.64	0.30	0.36	0.90
Q50	1.86	1.38	0.68	40.35	4.69	3.85	4.73	1.71	5.59	0.29	0.99	1.01	5.15	23.18	8.99	1.02	3.93	0.32	0.38	0.99
Q25	2.04	1.47	0.68	43.17	5.12	4.25	5.23	1.83	6.04	0.33	1.10	1.12	5.61	24.24	9.73	1.05	4.27	0.33	0.39	1.09
Q10	2.22	1.56	0.68	46.06	5.56	4.66	5.74	1.96	6.50	0.36	1.21	1.24	6.09	25.33	10.48	1.08	4.61	0.35	0.41	1.19
Q02	2.74	1.80	0.68	54.22	6.80	5.81	7.19	2.32	7.80	0.46	1.52	1.56	7.42	28.42	12.61	1.16	5.58	0.40	0.46	1.48
May Flows																				
Qmean	1.90	1.41	0.68	41.10	4.81	3.95	4.87	1.74	5.71	0.30	1.02	1.04	5.27	23.46	9.19	1.02	4.02	0.32	0.38	1.01
Q98	1.40	1.17	0.68	33.13	3.59	2.82	3.46	1.39	4.44	0.20	0.72	0.72	3.97	20.45	7.10	0.94	3.07	0.27	0.33	0.73
Q90	1.61	1.27	0.68	36.49	4.11	3.30	4.05	1.54	4.98	0.24	0.85	0.85	4.52	21.72	7.98	0.98	3.47	0.29	0.35	0.85
Q75	1.67	1.30	0.68	37.43	4.25	3.43	4.22	1.58	5.13	0.25	0.88	0.89	4.67	22.07	8.23	0.99	3.58	0.30	0.36	0.88
Q50	1.76	1.34	0.68	38.84	4.46	3.63	4.47	1.64	5.35	0.27	0.94	0.95	4.90	22.61	8.60	1.00	3.75	0.31	0.37	0.93
Q25	1.89	1.40	0.68	40.91	4.78	3.93	4.83	1.73	5.68	0.30	1.01	1.03	5.24	23.39	9.14	1.02	4.00	0.32	0.38	1.01
Q10	2.14	1.52	0.68	44.81	5.37	4.48	5.52	1.91	6.30	0.35	1.16	1.19	5.88	24.86	10.15	1.06	4.46	0.34	0.40	1.14
Q02	2.74	1.80	0.68	54.22	6.80	5.81	7.19	2.32	7.80	0.46	1.52	1.56	7.42	28.42	12.61	1.16	5.58	0.40	0.46	1.48
June Flows																				
Qmean	1.86	1.38	0.68	40.35	4.69	3.85	4.73	1.71	5.59	0.29	0.99	1.01	5.15	23.18	8.99	1.02	3.93	0.32	0.38	0.99
Q98	1.38	1.16	0.68	32.88	3.56	2.79	3.41	1.38	4.40	0.20	0.71	0.71	3.93	20.35	7.04	0.94	3.04	0.27	0.33	0.72
Q90	1.54	1.24	0.68	35.45	3.95	3.15	3.87	1.49	4.81	0.23	0.81	0.81	4.35	21.32	7.71	0.96	3.35	0.28	0.34	0.81
Q75	1.62	1.27	0.68	36.68	4.13	3.33	4.08	1.55	5.01	0.24	0.85	0.86	4.55	21.79	8.03	0.98	3.49	0.29	0.35	0.86
Q50	1.70	1.31	0.68	37.90	4.32	3.50	4.30	1.60	5.20	0.26	0.90	0.91	4.75	22.25	8.35	0.99	3.64	0.30	0.36	0.90
Q25	1.87	1.39	0.68	40.54	4.72	3.87	4.77	1.72	5.62	0.29	1.00	1.02	5.18	23.25	9.04	1.02	3.95	0.32	0.38	0.99
Q10	2.14	1.52	0.68	44.81	5.37	4.48	5.52	1.91	6.30	0.35	1.16	1.19	5.88	24.86	10.15	1.06	4.46	0.34	0.40	1.14
Q02	2.74	1.80	0.68	54.22	6.80	5.81	7.19	2.32	7.80	0.46	1.52	1.56	7.42	28.42	12.61	1.16	5.58	0.40	0.46	1.48
July Flows																				
Qmean	1.76	1.34	0.68	38.84	4.46	3.63	4.47	1.64	5.35	0.27	0.94	0.95	4.90	22.61	8.60	1.00	3.75	0.31	0.37	0.93
Q98	1.22	1.08	0.68	30.37	3.17	2.43	2.97	1.27	4.00	0.17	0.61	0.61	3.52	19.40	6.38	0.91	2.75	0.25	0.31	0.63
Q90	1.41	1.17	0.68	33.38	3.63	2.86	3.50	1.40	4.48	0.20	0.73	0.73	4.01	20.54	7.17	0.94	3.10	0.27	0.33	0.74
Q75	1.51	1.22	0.68	34.89	3.86	3.07	3.77	1.47	4.72	0.22	0.79	0.79	4.26	21.11	7.56	0.96	3.28	0.28	0.34	0.79
Q50	1.64	1.28	0.68	36.96	4.18	3.37	4.13	1.56	5.05	0.25	0.86	0.87	4.60	21.89	8.10	0.98	3.53	0.29	0.35	0.87
Q25	1.74	1.33	0.68	38.47	4.41	3.58	4.40	1.63	5.29	0.27	0.92	0.93	4.84	22.46	8.50	1.00	3.71	0.30	0.36	0.92
Q10	1.94	1.42	0.68	41.67	4.89	4.03	4.97	1.77	5.80	0.31	1.04	1.06	5.37	23.67	9.33	1.03	4.09	0.32	0.38	1.03
Q02	2.36	1.62	0.68	48.26	5.90	4.97	6.13	2.06	6.85	0.39	1.29	1.32	6.45	26.16	11.05	1.10	4.87	0.36	0.42	1.27
Auaust Flows																				
Qmean	1.69	1.30	0.68	37.71	4.29	3.47	4.27	1.59	5.17	0.26	0.89	0.90	4.72	22.18	8.30	0.99	3.62	0.30	0.36	0.89
Q98	1.10	1.03	0.68	28.48	2.89	2.17	2.63	1.18	3.70	0.14	0.54	0.54	3.21	18.69	5.89	0.89	2.52	0.24	0.30	0.57
Q90	1.30	1.12	0.68	31.62	3.36	2.61	3.19	1.32	4.20	0.18	0.66	0.66	3.72	19.88	6.71	0.92	2.90	0.26	0.32	0.68
Q75	1.40	1.17	0.68	33.25	3.61	2.84	3.48	1.39	4.46	0.20	0.72	0.73	3.99	20.49	7.14	0.94	3.09	0.27	0.33	0.74
Q50	1.50	1.21	0.68	34.70	3.83	3.05	3.73	1.46	4.69	0.22	0.78	0.78	4.23	21.04	7.51	0.96	3.26	0.28	0.34	0.79
Q25	1.62	1.27	0.68	36.68	4.13	3.33	4.08	1.55	5.01	0.24	0.85	0.86	4.55	21.79	8.03	0.98	3.49	0.29	0.35	0.86
Q10	1.80	1.36	0.68	39.41	4.55	3.71	4.57	1.67	5.44	0.28	0.96	0.97	5.00	22.82	8.74	1.01	3.82	0.31	0.37	0.95
Q02	2.22	1.56	0.68	46.06	5.56	4.66	5.74	1.96	6.50	0.36	1.21	1.24	6.09	25.33	10.48	1.08	4.61	0.35	0.41	1.19

Appendix B, continued. Effluent Discharges

Sept. Flows	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Qmean	1.61	1.27	0.68	36.49	4.11	3.30	4.05	1.54	4.98	0.24	0.85	0.85	4.52	21.72	7.98	0.98	3.47	0.29	0.35	0.85
Q98	0.98	0.97	0.68	26.60	2.60	1.90	2.30	1.10	3.40	0.12	0.47	0.46	2.90	17.98	5.40	0.87	2.30	0.23	0.29	0.50
Q90	1.22	1.08	0.68	30.37	3.17	2.43	2.97	1.27	4.00	0.17	0.61	0.61	3.52	19.40	6.38	0.91	2.75	0.25	0.31	0.63
Q75	1.32	1.13	0.68	31.87	3.40	2.65	3.23	1.33	4.24	0.19	0.67	0.67	3.76	19.97	6.78	0.93	2.93	0.26	0.32	0.69
Q50	1.41	1.17	0.68	33.38	3.63	2.86	3.50	1.40	4.48	0.20	0.73	0.73	4.01	20.54	7.17	0.94	3.10	0.27	0.33	0.74
Q25	1.51	1.22	0.68	34.89	3.86	3.07	3.77	1.47	4.72	0.22	0.79	0.79	4.26	21.11	7.56	0.96	3.28	0.28	0.34	0.79
Q10	1.68	1.30	0.68	37.62	4.28	3.46	4.25	1.59	5.16	0.26	0.89	0.90	4.70	22.14	8.28	0.99	3.61	0.30	0.36	0.89
Q02	2.06	1.48	0.68	43.55	5.18	4.30	5.30	1.85	6.10	0.33	1.12	1.14	5.68	24.39	9.83	1.05	4.31	0.34	0.40	1.10
October Flows																				
Qmean	1.64	1.28	0.68	36.96	4.18	3.37	4.13	1.56	5.05	0.25	0.86	0.87	4.60	21.89	8.10	0.98	3.53	0.29	0.35	0.87
Q98	0.90	0.93	0.68	25.34	2.41	1.72	2.08	1.04	3.20	0.10	0.42	0.41	2.69	17.51	5.07	0.86	2.15	0.22	0.28	0.46
Q90	1.16	1.06	0.68	29.43	3.03	2.30	2.80	1.23	3.85	0.16	0.58	0.57	3.36	19.05	6.14	0.90	2.64	0.25	0.31	0.60
Q75	1.30	1.12	0.68	31.62	3.36	2.61	3.19	1.32	4.20	0.18	0.66	0.66	3.72	19.88	6.71	0.92	2.90	0.26	0.32	0.68
Q50	1.41	1.17	0.68	33.38	3.63	2.86	3.50	1.40	4.48	0.20	0.73	0.73	4.01	20.54	7.17	0.94	3.10	0.27	0.33	0.74
Q25	1.59	1.26	0.68	36.21	4.06	3.26	4.00	1.53	4.93	0.24	0.84	0.84	4.47	21.61	7.91	0.97	3.44	0.29	0.35	0.84
Q10	1.76	1.34	0.68	38.84	4.46	3.63	4.47	1.64	5.35	0.27	0.94	0.95	4.90	22.61	8.60	1.00	3.75	0.31	0.37	0.93
Q02	2.11	1.50	0.68	44.30	5.29	4.41	5.43	1.88	6.22	0.34	1.14	1.17	5.80	24.67	10.02	1.06	4.40	0.34	0.40	1.13
November Flows																				
Qmean	1.64	1.28	0.68	36.96	4.18	3.37	4.13	1.56	5.05	0.25	0.86	0.87	4.60	21.89	8.10	0.98	3.53	0.29	0.35	0.87
Q98	0.98	0.97	0.68	26.60	2.60	1.90	2.30	1.10	3.40	0.12	0.47	0.46	2.90	17.98	5.40	0.87	2.30	0.23	0.29	0.50
Q90	1.22	1.08	0.68	30.37	3.17	2.43	2.97	1.27	4.00	0.17	0.61	0.61	3.52	19.40	6.38	0.91	2.75	0.25	0.31	0.63
Q75	1.36	1.15	0.68	32.63	3.52	2.75	3.37	1.37	4.36	0.19	0.70	0.70	3.89	20.26	6.97	0.93	3.01	0.27	0.33	0.71
Q50	1.50	1.21	0.68	34.70	3.83	3.05	3.73	1.46	4.69	0.22	0.78	0.78	4.23	21.04	7.51	0.96	3.26	0.28	0.34	0.79
Q25	1.65	1.29	0.68	37.15	4.21	3.39	4.17	1.57	5.08	0.25	0.87	0.88	4.63	21.97	8.15	0.98	3.55	0.30	0.36	0.87
Q10	1.82	1.37	0.68	39.78	4.61	3.77	4.63	1.68	5.50	0.28	0.97	0.99	5.06	22.96	8.84	1.01	3.86	0.31	0.37	0.97
Q02	2.19	1.54	0.68	45.56	5.49	4.58	5.66	1.94	6.42	0.35	1.19	1.22	6.00	25.14	10.35	1.07	4.55	0.35	0.41	1.17
December Flows																				
Qmean	1.72	1.32	0.68	38.28	4.38	3.55	4.37	1.62	5.26	0.26	0.91	0.93	4.81	22.39	8.45	0.99	3.68	0.30	0.36	0.91
Q98	1.08	1.02	0.68	28.11	2.83	2.11	2.57	1.17	3.64	0.14	0.53	0.52	3.15	18.55	5.79	0.89	2.48	0.24	0.30	0.55
Q90	1.26	1.10	0.68	30.99	3.27	2.52	3.08	1.29	4.10	0.17	0.64	0.64	3.62	19.64	6.55	0.92	2.82	0.26	0.32	0.66
Q75	1.40	1.17	0.68	33.13	3.59	2.82	3.46	1.39	4.44	0.20	0.72	0.72	3.97	20.45	7.10	0.94	3.07	0.27	0.33	0.73
Q50	1.56	1.24	0.68	35.64	3.98	3.18	3.90	1.50	4.84	0.23	0.81	0.82	4.38	21.40	7.76	0.97	3.37	0.29	0.35	0.82
Q25	1.70	1.31	0.68	37.90	4.32	3.50	4.30	1.60	5.20	0.26	0.90	0.91	4.75	22.25	8.35	0.99	3.64	0.30	0.36	0.90
Q10	1.94	1.42	0.68	41.67	4.89	4.03	4.97	1.77	5.80	0.31	1.04	1.06	5.37	23.67	9.33	1.03	4.09	0.32	0.38	1.03
Q02	2.50	1.69	0.68	50.46	6.23	5.28	6.52	2.16	7.20	0.42	1.38	1.41	6.81	26.99	11.63	1.12	5.13	0.38	0.44	1.34

Appendix B, continued. Effluent Discharges

Location	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)
Qmean	0.47	1.46	3.00	1.10	0.47	0.29	0.82	0.18	6.26	1.02	0.24	0.65	0.42	1.16	1.38	2.65	0.59	0.63	1.19
Q99	0.23	0.80	1.90	1.10	0.31	0.14	0.70	0.12	4.60	0.52	0.14	0.65	0.14	0.56	0.76	1.40	0.39	0.63	0.80
Q98	0.27	0.91	2.08	1.10	0.34	0.17	0.72	0.13	4.88	0.60	0.16	0.65	0.19	0.66	0.86	1.61	0.42	0.63	0.87
Q95	0.31	1.02	2.27	1.10	0.36	0.19	0.74	0.14	5.15	0.69	0.17	0.65	0.23	0.76	0.97	1.82	0.46	0.63	0.93
Q90	0.34	1.09	2.39	1.10	0.38	0.21	0.75	0.15	5.34	0.74	0.18	0.65	0.26	0.83	1.04	1.96	0.48	0.63	0.97
Q85	0.36	1.17	2.51	1.10	0.40	0.22	0.77	0.15	5.52	0.80	0.20	0.65	0.30	0.89	1.10	2.09	0.50	0.63	1.02
Q75	0.39	1.24	2.63	1.10	0.42	0.24	0.78	0.16	5.71	0.85	0.21	0.65	0.33	0.96	1.17	2.23	0.52	0.63	1.06
Q60	0.43	1.35	2.82	1.10	0.44	0.27	0.80	0.17	5.98	0.94	0.22	0.65	0.37	1.06	1.28	2.44	0.56	0.63	1.13
Q50	0.45	1.41	2.91	1.10	0.46	0.28	0.81	0.18	6.12	0.98	0.23	0.65	0.40	1.11	1.33	2.55	0.57	0.63	1.16
Q40	0.47	1.46	3.00	1.10	0.47	0.29	0.82	0.18	6.26	1.02	0.24	0.65	0.42	1.16	1.38	2.65	0.59	0.63	1.19
Q25	0.51	1.57	3.18	1.10	0.50	0.32	0.84	0.19	6.54	1.10	0.26	0.65	0.47	1.26	1.48	2.86	0.62	0.63	1.26
Q15	0.55	1.68	3.37	1.10	0.52	0.34	0.86	0.20	6.81	1.19	0.27	0.65	0.51	1.36	1.59	3.07	0.66	0.63	1.32
Q10	0.59	1.79	3.55	1.10	0.55	0.37	0.88	0.21	7.09	1.27	0.29	0.65	0.56	1.46	1.69	3.28	0.69	0.63	1.39
Q05	0.64	1.94	3.79	1.10	0.59	0.40	0.91	0.22	7.46	1.38	0.31	0.65	0.62	1.59	1.83	3.55	0.73	0.63	1.47
Q02	0.74	2.19	4.22	1.10	0.65	0.46	0.95	0.25	8.10	1.58	0.35	0.65	0.73	1.83	2.07	4.04	0.81	0.63	1.62
Q01	0.82	2.41	4.59	1.10	0.70	0.51	0.99	0.27	8.66	1.74	0.38	0.65	0.82	2.03	2.28	4.46	0.88	0.63	1.75
Low Flows																			
Q1,2	0.20	0.73	1.78	1.10	0.29	0.12	0.69	0.11	4.42	0.46	0.13	0.65	0.11	0.49	0.69	1.26	0.37	0.63	0.76
Q7,2	0.33	1.08	2.36	1.10	0.38	0.20	0.75	0.15	5.30	0.73	0.18	0.65	0.26	0.81	1.02	1.93	0.47	0.63	0.96
Q15,2	0.34	1.11	2.41	1.10	0.38	0.21	0.76	0.15	5.37	0.75	0.19	0.65	0.27	0.84	1.05	1.98	0.48	0.63	0.98
Q31,2	0.36	1.14	2.47	1.10	0.39	0.22	0.76	0.15	5.47	0.78	0.19	0.65	0.29	0.87	1.08	2.05	0.49	0.63	1.00
Q61,2	0.37	1.19	2.55	1.10	0.40	0.23	0.77	0.16	5.58	0.81	0.20	0.65	0.30	0.91	1.13	2.14	0.51	0.63	1.03
Q91,2	0.39	1.24	2.63	1.10	0.42	0.24	0.78	0.16	5.71	0.85	0.21	0.65	0.33	0.96	1.17	2.23	0.52	0.63	1.06
Q1,10	0.12	0.50	1.40	1.10	0.24	0.07	0.65	0.09	3.85	0.29	0.09	0.65	0.01	0.29	0.48	0.83	0.30	0.63	0.62
Q7,10	0.23	0.80	1.90	1.10	0.31	0.14	0.70	0.12	4.60	0.52	0.14	0.65	0.14	0.56	0.76	1.40	0.39	0.63	0.80
Q15,10	0.25	0.86	1.99	1.10	0.32	0.15	0.71	0.13	4.74	0.56	0.15	0.65	0.16	0.61	0.81	1.50	0.41	0.63	0.83
Q31,10	0.27	0.90	2.07	1.10	0.33	0.16	0.72	0.13	4.85	0.60	0.16	0.65	0.18	0.65	0.85	1.59	0.42	0.63	0.86
Q61,10	0.29	0.97	2.18	1.10	0.35	0.18	0.73	0.14	5.02	0.65	0.17	0.65	0.21	0.71	0.92	1.71	0.44	0.63	0.90
Q91,10	0.31	1.02	2.27	1.10	0.36	0.19	0.74	0.14	5.15	0.69	0.17	0.65	0.23	0.76	0.97	1.82	0.46	0.63	0.93
Q1,25	0.11	0.47	1.35	1.10	0.23	0.06	0.64	0.09	3.77	0.27	0.09	0.65	0.00	0.26	0.45	0.77	0.29	0.63	0.60
Q7,25	0.21	0.75	1.81	1.10	0.30	0.13	0.69	0.12	4.47	0.48	0.13	0.65	0.12	0.51	0.71	1.30	0.37	0.63	0.77
Q15,25	0.22	0.78	1.86	1.10	0.30	0.14	0.70	0.12	4.54	0.50	0.14	0.65	0.13	0.54	0.74	1.36	0.38	0.63	0.79
Q31,25	0.23	0.80	1.90	1.10	0.31	0.14	0.70	0.12	4.60	0.52	0.14	0.65	0.14	0.56	0.76	1.40	0.39	0.63	0.80
Q61,25	0.25	0.86	1.99	1.10	0.32	0.15	0.71	0.13	4.74	0.56	0.15	0.65	0.16	0.61	0.81	1.50	0.41	0.63	0.83
Q91,25	0.27	0.91	2.08	1.10	0.34	0.17	0.72	0.13	4.88	0.60	0.16	0.65	0.19	0.66	0.86	1.61	0.42	0.63	0.87
Q1,50	0.10	0.45	1.32	1.10	0.23	0.06	0.64	0.09	3.72	0.26	0.09	0.65	0.00	0.24	0.43	0.74	0.28	0.63	0.59
Q7,50	0.20	0.73	1.78	1.10	0.29	0.12	0.69	0.11	4.42	0.46	0.13	0.65	0.11	0.49	0.69	1.26	0.37	0.63	0.76
Q15,50	0.21	0.76	1.83	1.10	0.30	0.13	0.69	0.12	4.49	0.49	0.13	0.65	0.12	0.52	0.72	1.32	0.38	0.63	0.77
Q31,50	0.22	0.78	1.86	1.10	0.30	0.14	0.70	0.12	4.54	0.50	0.14	0.65	0.13	0.54	0.74	1.36	0.38	0.63	0.79
Q61,50	0.24	0.82	1.94	1.10	0.32	0.15	0.70	0.12	4.66	0.54	0.14	0.65	0.15	0.58	0.78	1.44	0.40	0.63	0.81
Q91,50	0.26	0.88	2.03	1.10	0.33	0.16	0.71	0.13	4.79	0.58	0.15	0.65	0.17	0.63	0.83	1.55	0.41	0.63	0.85

Appendix B, continued. Effluent Discharges

Drought Flows	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)
Q6,10	0.36	1.17	2.51	1.10	0.40	0.22	0.77	0.15	5.52	0.80	0.20	0.65	0.30	0.89	1.10	2.09	0.50	0.63	1.02
Q9,10	0.40	1.27	2.69	1.10	0.42	0.25	0.79	0.16	5.79	0.88	0.21	0.65	0.34	0.99	1.20	2.30	0.53	0.63	1.08
Q12,10	0.44	1.38	2.86	1.10	0.45	0.27	0.81	0.17	6.05	0.96	0.23	0.65	0.39	1.09	1.30	2.49	0.57	0.63	1.14
Q18,10	0.45	1.42	2.93	1.10	0.46	0.28	0.81	0.18	6.15	0.99	0.23	0.65	0.40	1.12	1.34	2.57	0.58	0.63	1.16
Q30,10	0.47	1.47	3.02	1.10	0.47	0.29	0.82	0.18	6.29	1.03	0.24	0.65	0.42	1.17	1.39	2.67	0.59	0.63	1.20
Q54,10	0.50	1.55	3.15	1.10	0.49	0.31	0.84	0.19	6.48	1.09	0.25	0.65	0.46	1.24	1.46	2.82	0.62	0.63	1.24
Q6,25	0.33	1.08	2.36	1.10	0.38	0.20	0.75	0.15	5.30	0.73	0.18	0.65	0.26	0.81	1.02	1.93	0.47	0.63	0.96
Q9,25	0.38	1.20	2.57	1.10	0.41	0.23	0.77	0.16	5.61	0.83	0.20	0.65	0.31	0.93	1.14	2.16	0.51	0.63	1.04
Q12,25	0.41	1.30	2.73	1.10	0.43	0.25	0.79	0.17	5.85	0.90	0.22	0.65	0.35	1.01	1.23	2.34	0.54	0.63	1.09
Q18,25	0.43	1.34	2.80	1.10	0.44	0.26	0.80	0.17	5.96	0.93	0.22	0.65	0.37	1.05	1.27	2.42	0.55	0.63	1.12
Q30,25	0.45	1.39	2.89	1.10	0.45	0.28	0.81	0.17	6.09	0.97	0.23	0.65	0.39	1.10	1.32	2.53	0.57	0.63	1.15
Q54,25	0.46	1.43	2.95	1.10	0.46	0.2B	0.82	0.18	6.19	1.00	0.24	0.65	0.41	1.14	1.35	2.60	0.58	0.63	1.17
Q6,50	0.32	1.03	2.29	1.10	0.37	0.19	0.74	0.14	5.19	0.70	0.18	0.65	0.24	0.77	0.98	1.84	0.46	0.63	0.94
Q9,50	0.36	1.15	2.49	1.10	0.40	0.22	0.76	0.15	5.49	0.79	0.19	0.65	0.29	0.88	1.09	2.07	0.50	0.63	1.01
Q12,50	0.39	1.23	2.62	1.10	0.41	0.24	0.78	0.16	5.69	0.85	0.21	0.65	0.32	0.95	1.17	2.22	0.52	0.63	1.06
Q18,50	0.40	1.27	2.69	1.10	0.42	0.25	0.79	0.16	5.79	0.88	0.21	0.65	0.34	0.99	1.20	2.30	0.53	0.63	1.08
Q30,50	0.43	1.34	2.80	1.10	0.44	0.26	0.80	0.17	5.96	0.93	0.22	0.65	0.37	1.05	1.27	2.42	0.55	0.63	1.12
Q54,50	0.45	1.39	2.89	1.10	0.45	0.28	0.81	0.17	6.09	0.97	0.23	0.65	0.39	1.10	1.32	2.53	0.57	0.63	1.15
January Flows																			
Qmean	0.51	1.57	3.18	1.10	0.50	0.32	0.84	0.19	6.54	1.10	0.26	0.65	0.47	1.26	1.48	2.86	0.62	0.63	1.26
Q98	0.29	0.97	2.18	1.10	0.35	0.18	0.73	0.14	5.02	0.65	0.17	0.65	0.21	0.71	0.92	1.71	0.44	0.63	0.90
Q90	0.34	1.09	2.39	1.10	0.38	0.21	0.75	0.15	5.34	0.74	0.18	0.65	0.26	0.83	1.04	1.96	0.48	0.63	0.97
Q75	0.39	1.24	2.63	1.10	0.42	0.24	0.78	0.16	5.71	0.85	0.21	0.65	0.33	0.96	1.17	2.23	0.52	0.63	1.06
Q50	0.45	1.41	2.91	1.10	0.46	0.28	0.81	0.18	6.12	0.98	0.23	0.65	0.40	1.11	1.33	2.55	0.57	0.63	1.16
Q25	0.51	1.57	3.18	1.10	0.50	0.32	0.84	0.19	6.54	1.10	0.26	0.65	0.47	1.26	1.48	2.86	0.62	0.63	1.26
Q10	0.59	1.79	3.55	1.10	0.55	0.37	0.88	0.21	7.09	1.27	0.29	0.65	0.56	1.46	1.69	3.28	0.69	0.63	1.39
Q02	0.76	2.26	4.33	1.10	0.66	0.47	0.97	0.25	8.27	1.63	0.36	0.65	0.76	1.89	2.13	4.16	0.83	0.63	1.66
February Flows																			
Qmean	0.53	1.63	3.28	1.10	0.51	0.33	0.85	0.20	6.68	1.15	0.27	0.65	0.49	1.31	1.54	2.96	0.64	0.63	1.29
Q98	0.33	1.06	2.34	1.10	0.37	0.20	0.75	0.14	5.26	0.72	0.18	0.65	0.25	0.80	1.01	1.90	0.47	0.63	0.96
Q90	0.37	1.18	2.54	1.10	0.40	0.23	0.77	0.15	5.56	0.81	0.20	0.65	0.30	0.91	1.12	2.12	0.51	0.63	1.03
Q75	0.41	1.30	2.73	1.10	0.43	0.25	0.79	0.17	5.85	0.90	0.22	0.65	0.35	1.01	1.23	2.34	0.54	0.63	1.09
Q50	0.47	1.46	3.00	1.10	0.47	0.29	0.82	0.18	6.26	1.02	0.24	0.65	0.42	1.16	1.38	2.65	0.59	0.63	1.19
Q25	0.54	1.66	3.33	1.10	0.52	0.34	0.86	0.20	6.76	1.17	0.27	0.65	0.50	1.34	1.57	3.03	0.65	0.63	1.31
Q10	0.62	1.86	3.67	1.10	0.57	0.38	0.89	0.22	7.27	1.33	0.30	0.65	0.59	1.53	1.76	3.41	0.71	0.63	1.43
Q02	0.79	2.35	4.48	1.10	0.69	0.49	0.98	0.26	8.49	1.69	0.37	0.65	0.80	1.97	2.21	4.33	0.86	0.63	1.71
March Flows																			
Qmean	0.55	1.68	3.37	1.10	0.52	0.34	0.86	0.20	6.81	1.19	0.27	0.65	0.51	1.36	1.59	3.07	0.66	0.63	1.32
Q98	0.36	1.17	2.51	1.10	0.40	0.22	0.77	0.15	5.52	0.80	0.20	0.65	0.30	0.89	1.10	2.09	0.50	0.63	1.02
Q90	0.43	1.35	2.82	1.10	0.44	0.27	0.80	0.17	5.98	0.94	0.22	0.65	0.37	1.06	1.28	2.44	0.56	0.63	1.13
Q75	0.46	1.43	2.95	1.10	0.46	0.28	0.82	0.18	6.19	1.00	0.24	0.65	0.41	1.14	1.35	2.60	0.58	0.63	1.17
Q50	0.51	1.57	3.18	1.10	0.50	0.32	0.84	0.19	6.54	1.10	0.26	0.65	0.47	1.26	1.48	2.86	0.62	0.63	1.26
Q25	0.57	1.72	3.44	1.10	0.53	0.35	0.87	0.20	6.92	1.22	0.28	0.65	0.53	1.40	1.63	3.15	0.67	0.63	1.35
Q10	0.64	1.94	3.79	1.10	0.59	0.40	0.91	0.22	7.46	1.38	0.31	0.65	0.62	1.59	1.83	3.55	0.73	0.63	1.47
Q02	0.82	2.41	4.59	1.10	0.70	0.51	0.99	0.27	8.66	1.74	0.38	0.65	0.82	2.03	2.28	4.46	0.88	0.63	1.75

Appendix B, continued. Effluent Discharges

April Flows	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)
Qmean	0.56	1.71	3.42	1.10	0.53	0.35	0.87	0.20	6.90	1.21	0.28	0.65	0.53	1.39	1.62	3.13	0.67	0.63	1.34
Q98	0.38	1.20	2.57	1.10	0.41	0.23	0.77	0.16	5.61	0.83	0.20	0.65	0.31	0.93	1.14	2.16	0.51	0.63	1.04
Q90	0.45	1.39	2.89	1.10	0.45	0.28	0.81	0.17	6.09	0.97	0.23	0.65	0.39	1.10	1.32	2.53	0.57	0.63	1.15
Q75	0.47	1.46	3.00	1.10	0.47	0.29	0.82	0.18	6.26	1.02	0.24	0.65	0.42	1.16	1.38	2.65	0.59	0.63	1.19
Q50	0.52	1.60	3.24	1.10	0.50	0.32	0.85	0.19	6.62	1.13	0.26	0.65	0.48	1.29	1.51	2.92	0.63	0.63	1.27
Q25	0.58	1.77	3.51	1.10	0.54	0.36	0.88	0.21	7.03	1.25	0.29	0.65	0.55	1.44	1.67	3.23	0.68	0.63	1.37
Q10	0.64	1.94	3.79	1.10	0.59	0.40	0.91	0.22	7.46	1.38	0.31	0.65	0.62	1.59	1.83	3.55	0.73	0.63	1.47
Q02	0.82	2.41	4.59	1.10	0.70	0.51	0.99	0.27	8.66	1.74	0.38	0.65	0.82	2.03	2.28	4.46	0.88	0.63	1.75
May Flows																			
Qmean	0.54	1.65	3.31	1.10	0.52	0.33	0.85	0.20	6.73	1.16	0.27	0.65	0.50	1.33	1.56	3.00	0.65	0.63	1.30
Q98	0.37	1.18	2.54	1.10	0.40	0.23	0.77	0.15	5.56	0.81	0.20	0.65	0.30	0.91	1.12	2.12	0.51	0.63	1.03
Q90	0.44	1.38	2.86	1.10	0.45	0.27	0.81	0.17	6.05	0.96	0.23	0.65	0.39	1.09	1.30	2.49	0.57	0.63	1.14
Q75	0.46	1.43	2.95	1.10	0.46	0.28	0.82	0.18	6.19	1.00	0.24	0.65	0.41	1.14	1.35	2.60	0.58	0.63	1.17
Q50	0.49	1.52	3.09	1.10	0.48	0.30	0.83	0.19	6.40	1.06	0.25	0.65	0.44	1.21	1.43	2.75	0.61	0.63	1.22
Q25	0.53	1.64	3.29	1.10	0.51	0.33	0.85	0.20	6.70	1.15	0.27	0.65	0.49	1.32	1.55	2.98	0.64	0.63	1.29
Q10	0.62	1.86	3.67	1.10	0.57	0.38	0.89	0.22	7.27	1.33	0.30	0.65	0.59	1.53	1.76	3.41	0.71	0.63	1.43
Q02	0.82	2.41	4.59	1.10	0.70	0.51	0.99	0.27	8.66	1.74	0.38	0.65	0.82	2.03	2.28	4.46	0.88	0.63	1.75
June Flows																			
Qmean	0.52	1.60	3.24	1.10	0.50	0.32	0.85	0.19	6.62	1.13	0.26	0.65	0.48	1.29	1.51	2.92	0.63	0.63	1.27
Q98	0.36	1.17	2.51	1.10	0.40	0.22	0.77	0.15	5.52	0.80	0.20	0.65	0.30	0.89	1.10	2.09	0.50	0.63	1.02
Q90	0.42	1.32	2.76	1.10	0.44	0.26	0.79	0.17	5.90	0.91	0.22	0.65	0.36	1.03	1.25	2.38	0.55	0.63	1.11
Q75	0.44	1.39	2.88	1.10	0.45	0.27	0.81	0.17	6.08	0.97	0.23	0.65	0.39	1.10	1.31	2.51	0.57	0.63	1.15
Q50	0.47	1.46	3.00	1.10	0.47	0.29	0.82	0.18	6.26	1.02	0.24	0.65	0.42	1.16	1.38	2.65	0.59	0.63	1.19
Q25	0.53	1.61	3.26	1.10	0.51	0.33	0.85	0.19	6.65	1.14	0.26	0.65	0.49	1.30	1.52	2.94	0.64	0.63	1.28
Q10	0.62	1.86	3.67	1.10	0.57	0.38	0.89	0.22	7.27	1.33	0.30	0.65	0.59	1.53	1.76	3.41	0.71	0.63	1.43
Q02	0.82	2.41	4.59	1.10	0.70	0.51	0.99	0.27	8.66	1.74	0.38	0.65	0.82	2.03	2.28	4.46	0.88	0.63	1.75
July Flows																			
Qmean	0.49	1.52	3.09	1.10	0.48	0.30	0.83	0.19	6.40	1.06	0.25	0.65	0.44	1.21	1.43	2.75	0.61	0.63	1.22
Q98	0.31	1.02	2.27	1.10	0.36	0.19	0.74	0.14	5.15	0.69	0.17	0.65	0.23	0.76	0.97	1.82	0.46	0.63	0.93
Q90	0.37	1.20	2.56	1.10	0.41	0.23	0.77	0.16	5.60	0.82	0.20	0.65	0.31	0.92	1.13	2.15	0.51	0.63	1.03
Q75	0.41	1.28	2.71	1.10	0.43	0.25	0.79	0.16	5.82	0.89	0.21	0.65	0.35	1.00	1.21	2.32	0.54	0.63	1.09
Q50	0.45	1.41	2.91	1.10	0.46	0.28	0.81	0.18	6.12	0.98	0.23	0.65	0.40	1.11	1.33	2.55	0.57	0.63	1.16
Q25	0.48	1.49	3.06	1.10	0.48	0.30	0.83	0.18	6.34	1.05	0.25	0.65	0.43	1.19	1.41	2.71	0.60	0.63	1.21
Q10	0.55	1.68	3.37	1.10	0.52	0.34	0.86	0.20	6.81	1.19	0.27	0.65	0.51	1.36	1.59	3.07	0.66	0.63	1.32
Q02	0.69	2.07	4.01	1.10	0.62	0.43	0.93	0.24	7.78	1.48	0.33	0.65	0.68	1.71	1.95	3.80	0.77	0.63	1.55
August Flows																			
Qmean	0.47	1.45	2.98	1.10	0.47	0.29	0.82	0.18	6.23	1.01	0.24	0.65	0.42	1.15	1.37	2.63	0.59	0.63	1.18
Q98	0.27	0.91	2.08	1.10	0.34	0.17	0.72	0.13	4.88	0.60	0.16	0.65	0.19	0.66	0.86	1.61	0.42	0.63	0.87
Q90	0.34	1.09	2.39	1.10	0.38	0.21	0.75	0.15	5.34	0.74	0.18	0.65	0.26	0.83	1.04	1.96	0.48	0.63	0.97
Q75	0.37	1.19	2.55	1.10	0.40	0.23	0.77	0.16	5.58	0.81	0.20	0.65	0.30	0.91	1.13	2.14	0.51	0.63	1.03
Q50	0.40	1.27	2.69	1.10	0.42	0.25	0.79	0.16	5.79	0.88	0.21	0.65	0.34	0.99	1.20	2.30	0.53	0.63	1.08
Q25	0.44	1.39	2.88	1.10	0.45	0.27	0.81	0.17	6.08	0.97	0.23	0.65	0.39	1.10	1.31	2.51	0.57	0.63	1.15
Q10	0.50	1.55	3.15	1.10	0.49	0.31	0.84	0.19	6.48	1.09	0.25	0.65	0.46	1.24	1.46	2.82	0.62	0.63	1.24
Q02	0.64	1.94	3.79	1.10	0.59	0.40	0.91	0.22	7.46	1.38	0.31	0.65	0.62	1.59	1.83	3.55	0.73	0.63	1.47

Appendix B,concluded, Effluent Discharges

Sept. Flows	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)
Qmean	0.44	1.38	2.86	1.10	0.45	0.27	0.81	0.17	6.05	0.96	0.23	0.65	0.39	1.09	1.30	2.49	0.57	0.63	1.14
Q98	0.23	0.80	1.90	1.10	0.31	0.14	0.70	0.12	4.60	0.52	0.14	0.65	0.14	0.56	0.76	1.40	0.39	0.63	0.80
Q90	0.31	1.02	2.27	1.10	0.36	0.19	0.74	0.14	5.15	0.69	0.17	0.65	0.23	0.76	0.97	1.82	0.46	0.63	0.93
Q75	0.34	1.11	2.41	1.10	0.38	0.21	0.76	0.15	5.37	0.75	0.19	0.65	0.27	0.84	1.05	1.98	0.48	0.63	0.98
Q50	0.37	1.20	2.56	1.10	0.41	0.23	0.77	0.16	5.60	0.82	0.20	0.65	0.31	0.92	1.13	2.15	0.51	0.63	1.03
Q25	0.41	1.28	2.71	1.10	0.43	0.25	0.79	0.16	5.82	0.89	0.21	0.65	0.35	1.00	1.21	2.32	0.54	0.63	1.09
Q10	0.46	1.44	2.97	1.10	0.47	0.29	0.82	0.18	6.22	1.01	0.24	0.65	0.41	1.15	1.36	2.62	0.59	0.63	1.18
Q02	0.59	1.79	3.55	1.10	0.55	0.37	0.88	0.21	7.09	1.27	0.29	0.65	0.56	1.46	1.69	3.28	0.69	0.63	1.39
October Flows																			
Qmean	0.45	1.41	2.91	1.10	0.46	0.28	0.81	0.18	6.12	0.98	0.23	0.65	0.40	1.11	1.33	2.55	0.57	0.63	1.16
Q98	0.20	0.73	1.78	1.10	0.29	0.12	0.69	0.11	4.42	0.46	0.13	0.65	0.11	0.49	0.69	1.26	0.37	0.63	0.76
Q90	0.29	0.97	2.18	1.10	0.35	0.18	0.73	0.14	5.02	0.65	0.17	0.65	0.21	0.71	0.92	1.71	0.44	0.63	0.90
Q75	0.34	1.09	2.39	1.10	0.38	0.21	0.75	0.15	5.34	0.74	0.18	0.65	0.26	0.83	1.04	1.96	0.48	0.63	0.97
Q50	0.37	1.20	2.56	1.10	0.41	0.23	0.77	0.16	5.60	0.82	0.20	0.65	0.31	0.92	1.13	2.15	0.51	0.63	1.03
Q25	0.43	1.36	2.84	1.10	0.45	0.27	0.80	0.17	6.01	0.95	0.23	0.65	0.38	1.07	1.29	2.46	0.56	0.63	1.13
Q10	0.49	1.52	3.09	1.10	0.48	0.30	0.83	0.19	6.40	1.06	0.25	0.65	0.44	1.21	1.43	2.75	0.61	0.63	1.22
Q02	0.61	1.83	3.62	1.10	0.56	0.38	0.89	0.21	7.20	1.30	0.30	0.65	0.58	1.50	1.73	3.36	0.70	0.63	1.41
November Flows																			
Qmean	0.45	1.41	2.91	1.10	0.46	0.28	0.81	0.18	6.12	0.98	0.23	0.65	0.40	1.11	1.33	2.55	0.57	0.63	1.16
Q98	0.23	0.80	1.90	1.10	0.31	0.14	0.70	0.12	4.60	0.52	0.14	0.65	0.14	0.56	0.76	1.40	0.39	0.63	0.80
Q90	0.31	1.02	2.27	1.10	0.36	0.19	0.74	0.14	5.15	0.69	0.17	0.65	0.23	0.76	0.97	1.82	0.46	0.63	0.93
Q75	0.36	1.15	2.49	1.10	0.40	0.22	0.76	0.15	5.49	0.79	0.19	0.65	0.29	0.88	1.09	2.07	0.50	0.63	1.01
Q50	0.40	1.27	2.69	1.10	0.42	0.25	0.79	0.16	5.79	0.88	0.21	0.65	0.34	0.99	1.20	2.30	0.53	0.63	1.08
Q25	0.45	1.42	2.93	1.10	0.46	0.28	0.81	0.18	6.15	0.99	0.23	0.65	0.40	1.12	1.34	2.57	0.58	0.63	1.16
Q10	0.51	1.57	3.18	1.10	0.50	0.32	0.84	0.19	6.54	1.10	0.26	0.65	0.47	1.26	1.48	2.86	0.62	0.63	1.26
Q02	0.63	1.91	3.75	1.10	0.58	0.39	0.90	0.22	7.39	1.36	0.31	0.65	0.61	1.57	1.80	3.50	0.73	0.63	1.45
December Flows																			
Qmean	0.48	1.48	3.04	1.10	0.48	0.30	0.82	0.18	6.32	1.04	0.24	0.65	0.43	1.18	1.40	2.69	0.60	0.63	1.20
Q98	0.26	0.89	2.05	1.10	0.33	0.16	0.72	0.13	4.82	0.59	0.15	0.65	0.18	0.64	0.84	1.57	0.42	0.63	0.85
Q90	0.32	1.06	2.33	1.10	0.37	0.20	0.75	0.14	5.25	0.71	0.18	0.65	0.25	0.79	1.00	1.89	0.47	0.63	0.95
Q75	0.37	1.18	2.54	1.10	0.40	0.23	0.77	0.15	5.56	0.81	0.20	0.65	0.30	0.91	1.12	2.12	0.51	0.63	1.03
Q50	0.42	1.33	2.78	1.10	0.44	0.26	0.80	0.17	5.93	0.92	0.22	0.65	0.36	1.04	1.26	2.40	0.55	0.63	1.11
Q25	0.47	1.46	3.00	1.10	0.47	0.29	0.82	0.18	6.26	1.02	0.24	0.65	0.42	1.16	1.38	2.65	0.59	0.63	1.19
Q10	0.55	1.68	3.37	1.10	0.52	0.34	0.86	0.20	6.81	1.19	0.27	0.65	0.51	1.36	1.59	3.07	0.66	0.63	1.32
Q02	0.74	2.19	4.22	1.10	0.65	0.46	0.95	0.25	8.10	1.58	0.35	0.65	0.73	1.83	2.07	4.04	0.81	0.63	1.62

Appendix C. NETWORK file describing the location of all streams, control points, and effluent discharges in the Fox River Basin

DA(u) Drainage area upstream of location
DA(d) Drainage area downstream of location
K Average soil permebaility for the watershed
P-ET Net precipitation for the watershed

ID. =0 Basic watershed information
= 1 Tributary inflow
= 2 Effluent discharge
= 3 Water supply withdrawal
= 6 Control point (full set of flow information)
= 9 Reservoir

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Fox River	116.60	868.0	868.0	3.74	6.95	62	USGS Gage #05546500 at Wilmot
(V)	109.50	894.0	894.0	3.74	7.00	1	Sequoit Creek VZ)
	107.51	931.5	931.5	3.76	7.08	0	
	107.50	931.5	978.0	3.68	7.16	1	Squaw Creek (VY)
	106.31	981.1	981.1	3.68	7.17	0	
	106.30	981.1	1184.6	3.84	7.46	1	Nippersink Creek (VX)
	104.51	1201.0	1201.0	3.89	7.48	2	Fox River Regional sanitary discharge
	104.50	1201.0	1201.0	3.89	7.48	0	Chain of Lakes outlet (near Johnsburg)
	103.00	1204.0	1204.0	3.89	7.48	0	
	102.51	1204.1	1204.1	3.89	7.48	0	
	102.50	1204.1	1216.8	3.91	7.50	1	Dutch Creek (VW4)
	100.31	1219.4	1219.4	3.92	7.50	0	
	100.30	1219.4	1242.7	3.99	7.52	1	Boone Creek (VW)
	101.10	1242.8	1242.8	3.99	7.52	2	McHenry sanitary treatment plant
	97.80	1249.0	1249.0	4.01	7.52	61	DOWR Gage at McHenry Dam
	96.91	1254.0	1254.0	4.03	7.52	0	
	96.90	1254.0	1269.0	4.06	7.54	1	Sleepy Hollow Creek (W4)
	94.31	1276.7	1276.7	4.09	7.55	0	
	94.30	1276.7	1289.1	4.08	7.57	1	Mutton Creek (VV)
	90.81	1302.7	1302.7	4.12	7.58	0	
	90.80	1302.7	1313.2	4.09	7.59	1	Slocum Lake Outlet (VU3)
	89.41	1320.0	1320.0	4.12	7.60	0	
	89.40	1320.0	1356.8	4.08	7.64	1	Flint Creek (VU)
	85.50	1362.7	1366.0	4.11	7.65	1	Cary Creek (VT1)
	85.31	1366.0	1366.0	4.11	7.65	0	
	85.30	1366.0	1391.8	4.08	7.67	1	Spring Creek (VT)
	81.60	1399.0	1399.0	4.10	7.68	62	USGS Gage #05550000 at Algonquin
	81.59	1399.0	1427.2	4.15	7.71	1	Crystal Creek (VS)
	80.60	1431.5	1431.5	4.16	7.71	2	Algonquin sanitary treatment plant
	76.60	1444.7	1444.7	4.18	7.73	2	Carpentersville sanitary treatment plant
	74.90	1451.0	1451.0	4.18	7.73	2	East Dundee sanitary treatment plant
	74.80	1451.1	1451.1	4.18	7.73	2	West Dundee sanitary treatment plant
	74.61	1451.6	1451.6	4.18	7.73	0	
	74.60	1451.6	1458.4	4.18	7.74	1	Jelkes Creek (VQ5)
	72.21	1464.0	1464.0	4.18	7.75	0	
	72.20	1464.0	1504.0	4.19	7.78	1	Tyler Creek (VQ)
	72.10	1504.0	1504.0	4.19	7.78	2	Elgin (north) sanitary treatment plant
	70.70	1507.2	1507.2	4.19	7.78	3	Elgin Water Supply Withdrawal
	69.10	1507.7	1507.7	4.19	7.78	2	Elgin (South & West) treatment plants
	68.81	1507.8	1507.8	4.19	7.78	0	
	68.80	1507.8	1552.1	4.19	7.82	1	Poplar Creek (VP)
	67.30	1555.0	1555.0	4.19	7.83	62	DOWR Gage at South Elgin
	65.91	1557.5	1557.5	4.19	7.83	0	
	65.90	1557.5	1573.0	4.20	7.84	1	Brewster Creek (VO)
	62.41	1577.5	1577.5	4.20	7.84	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Fox River	62.40	1577.5	1589.6	4.18	7.85	1	Norton Creek (VN3)
	60.91	1590.5	1590.5	4.18	7.85	0	
	60.90	1590.5	1644.6	4.09	7.90	1	Ferson Creek (VN)
	59.90	1646.0	1646.0	4.09	7.90	0	
	58.70	1646.8	1650.5	4.09	7.90	2	St. Charles sanitary treatment plant
	57.90	1652.0	1652.0	4.09	7.90	62	DOWR Gage at Geneva
	57.30	1652.5	1652.5	4.09	7.90	2	Geneva sanitary treatment plant
	54.80	1657.9	1657.9	4.09	7.90	2	Batavia sanitary treatment plant
	53.00	1662.7	1693.6	4.03	7.93	1	Mill Creek (VL)
	49.30	1701.6	1701.6	4.03	7.94	0	
	49.00	1701.8	1716.5	4.04	7.96	1	Indian Creek (VK)
	45.90	1726.5	1726.5	4.04	7.97	0	
	44.80	1726.0	1729.0	4.04	7.97	1	Fox River tributary (VJ3)
	44.50	1729.0	1729.0	4.04	7.97	2	Aurora sanitary treatment plant
	44.49	1729.0	1729.0	4.04	7.97	62	
	42.71	1733.7	1733.7	4.04	7.97	0	
	42.70	1733.7	1763.1	4.03	8.00	1	Waubansee Creek (VJ)
	42.40	1763.1	1763.1	4.03	8.00	2	Oswego sanitary treatment plant
	37.81	1766.0	1766.0	4.03	8.00	0	
	37.80	1766.0	1783.0	4.00	8.02	1	Morgan Creek (VI3)
	35.90	1788.7	1788.7	4.00	8.02	0	
	35.61	1789.0	1789.0	4.00	8.02	2	Yorkville-Bristol treatment plant
	35.60	1789.0	1864.0	3.93	8.08	1	Blackberry Creek (VI)
	31.31	1873.0	1873.0	3.93	8.08	0	
	31.30	1873.0	1892.6	3.91	8.10	1	Rob Roy Creek (VH2)
	31.01	1900.3	1900.3	3.91	8.10	0	
	31.00	1900.3	2092.7	3.68	8.23	1	Big Rock Creek (VH)
	29.51	2094.3	2094.3	3.68	8.24	0	
	29.50	2094.3	2109.6	3.67	8.25	1	Hollenback Creek (VG7)
	25.41	2126.5	2126.5	3.67	8.25	0	
	25.40	2126.5	2132.0	3.67	8.25	0	
	21.01	2134.0	2134.0	3.67	8.25	0	
	21.00	2134.0	2150.0	3.66	8.26	1	Roods Creek (VF1)
	20.11	2160.9	2160.9	3.66	8.27	0	
	20.10	2160.9	2243.9	3.56	8.30	1	Somonauk Creek (VF)
	19.00	2247.4	2250.1	3.56	8.30	0	Sheridan
	15.81	2257.2	2257.2	3.56	8.30	0	
	15.80	2257.2	2272.4	3.53	8.31	1	Mission Creek (VE)
	13.01	2285.1	2285.1	3.51	8.31	0	
	13.00	2285.1	2296.8	3.49	8.32	1	Brumbach Creek (VD)
	9.41	2304.4	2304.4	3.48	8.32	0	
	9.40	2304.4	2568.8	3.24	8.43	1	Indian Creek (VC)
	8.51	2572.0	2572.0	3.24	8.43	0	
	8.50	2572.0	2612.9	3.20	8.45	1	Buck Creek (VB)
	5.40	2630.8	2630.8	3.18	8.46	62	USGS Gage #05552500 at Dayton
	0.00	2647.7	2647.7	3.16	8.46	0	
Buck Creek	16.40	0.0	0.0	.87	9.20	0	
(VB)	11.90	6.5	6.5	.87	9.20	0	
	10.40	11.7	11.7	.87	9.20	0	
	9.10	16.3	16.3	.87	9.20	0	
	8.61	17.3	17.3	.87	9.20	0	
	8.60	17.3	29.7	.97	9.20	1	Buck Creek tributary (VBP)
	5.90	30.2	30.2	.97	9.20	0	
	4.52	36.3	36.3	.94	9.20	0	
	4.10	38.0	38.0	.94	9.20	0	
	2.90	40.1	40.1	.93	9.20	0	
	0.00	40.9	40.9	.93	9.20	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Buck Creek	14.00	0.0	0.0	1.11	9.20	0	
tributary (VBP)	6.90	2.7	2.7	1.11	9.20	0	
	5.78	5.6	5.6	1.11	9.20	0	
	3.84	8.5	8.5	1.11	9.20	0	
	1.52	12.1	12.1	1.11	9.20	0	
	.63	13.1	13.1	1.11	9.20	0	
	0.00	13.4	13.4	1.11	9.20	0	
Indian Creek	53.19	0.0	0.0	.81	9.30	0	
(VC)	52.70	2.1	2.1	.81	9.30	0	
	46.10	7.6	7.6	.81	9.30	0	
	44.00	11.8	13.7	.81	9.30	0	
	41.20	18.8	18.8	.81	9.30	91	Lake Shabbona
	36.00	31.8	31.8	.86	9.30	0	
	32.90	36.6	36.6	.87	9.30	0	
	26.81	47.6	47.6	1.00	9.30	0	
	26.80	47.6	59.8	1.06	9.30	1	Paw Paw Run (VCN)
	24.21	68.1	68.1	1.11	9.30	0	
	24.20	68.1	86.0	1.13	9.30	1	Indian Creek tributary (VCM)
	22.61	87.9	87.9	1.13	9.30	2	Eariville sanitary treatment plant
	22.60	87.9	115.6	1.19	9.30	1	Sutphens Run (VCL)
	15.70	125.6	125.6	1.20	9.30	0	
	9.41	138.1	138.1	1.21	9.30	0	
	9.40	138.1	225.3	1.22	9.30	1	Little Indian Creek (VCF)
	4.40	231.5	231.5	1.23	9.30	0	
	1.51	234.1	234.1	1.23	9.30	0	
	1.50	234.1	263.3	1.19	9.30	1	Crooked Leg Creek (VCB)
	0.00	264.4	264.4	1.19	9.30	0	
Crooked Leg Creek	18.81	0.0	0.0	.80	9.30	0	
(VCB)	16.50	5.7	5.7	.80	9.30	0	
	13.00	8.9	8.9	.80	9.30	0	
	12.24	10.6	10.6	.80	9.30	0	
	9.90	15.8	15.8	.80	9.30	0	
	7.50	17.8	17.8	.80	9.30	0	
	6.50	18.7	18.7	.80	9.30	0	
	5.20	21.0	21.0	.80	9.30	0	
	3.10	24.8	24.8	.80	9.30	0	
	0.00	28.7	28.7	.80	9.30	0	
Little Indian Creek	34.70	0.0	0.0	.81	9.30	0	
(VCF)	32.30	3.4	3.4	.81	9.30	0	
	28.90	8.1	8.1	.81	9.30	0	
	27.44	10.8	10.8	.81	9.30	0	
	24.30	16.6	16.6	.81	9.30	0	
	20.70	25.3	25.3	1.05	9.30	0	
	18.70	37.9	37.9	1.21	9.30	0	
	17.00	40.6	40.6	1.23	9.30	0	
	15.60	42.8	42.8	1.24	9.30	0	
	14.03	43.7	43.7	1.23	9.30	0	
	14.02	43.7	51.2	1.27	9.30	0	
	12.10	55.0	55.0	1.26	9.30	0	
	8.81	64.7	64.7	1.24	9.30	0	
	8.80	64.7	73.6	1.22	9.30	0	
	6.40	79.8	79.8	1.23	9.30	0	
	4.10	82.6	82.6	1.24	9.30	0	
	0.00	87.3	87.3	1.24	9.30	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Sutphens Run	15.30	0.0	0.0	1.35	9.30	0	
(VCL)	12.50	3.8	3.8	1.35	9.30	0	
	10.90	7.1	7.1	1.35	9.30	0	
	9.57	9.2	9.2	1.35	9.30	0	
	7.30	12.8	18.1	1.35	9.30	0	
	5.40	19.1	19.1	1.36	9.30	0	
	1.90	26.6	26.6	1.39	9.30	0	
	0.00	27.7	27.7	1.39	9.30	0	
Indian Creek	8.40	0.0	0.0	1.20	9.30	0	
tributary (VCM)	5.60	2.9	2.9	1.20	9.30	0	
	3.30	4.8	4.8	1.20	9.30	0	
	.81	10.2	10.2	1.20	9.30	0	
	.80	10.2	17.7	1.20	9.30	0	
	0.00	18.0	18.0	1.20	9.30	0	
Paw Paw Run	11.10	0.0	0.0	1.31	9.30	0	
(VCN)	8.70	2.4	2.4	1.31	9.30	2	Paw Paw sanitary treatment plant
	5.70	4.5	4.5	1.31	9.30	0	
	3.00	9.2	9.2	1.31	9.30	0	
	1.00	10.9	10.9	1.31	9.30	0	
	0.00	12.2	12.2	1.31	9.30	0	
Brumbach Creek	9.00	0.0	0.0	.25	9.30	0	
(VD)	8.81	.2	.2	.25	9.30	0	
	6.34	4.2	4.2	.25	9.30	0	
	3.60	6.6	6.6	.25	9.30	0	
	1.70	9.4	9.4	.25	9.30	0	
	.60	10.2	10.2	.25	9.30	0	
	0.00	11.7	11.7	.25	9.30	0	
Mission Creek	8.70	0.0	0.0	.97	9.30	0	
(VE)	6.60	2.2	2.2	.97	9.30	0	
	3.70	5.7	5.7	.97	9.30	0	
	1.10	8.7	8.7	.97	9.30	0	
	0.00	15.2	15.2	.97	9.30	0	
Somonauk Creek	35.00	0.0	0.0	.82	9.40	0	
(VF)	30.20	8.9	8.9	.82	9.40	0	
	29.10	12.5	14.1	.82	9.40	1	Somonauk Creek tributary (VFU)
	25.30	21.7	21.7	.82	9.40	0	
	20.40	26.4	26.4	.89	9.40	0	
	14.01	43.3	43.3	1.02	9.40	0	
	14.00	43.3	55.8	1.03	9.40	1	Buck Branch (VFK)
	10.50	59.8	62.8	1.04	9.40	1	Somonauk Creek tributary (VFH)
	9.30	64.0	64.0	1.04	9.40	91	Lake Holiday
	5.30	64.9	64.9	1.05	9.40	0	
	4.71	73.1	73.1	1.12	9.40	0	
	0.00	83.0	83.0	1.18	9.40	0	
Somonauk Creek	1.40	1.9	1.9	1.60	9.40	2	Somonauk sanitary treatment plant
tributary (VFH)	0.00	3.0	3.0	1.60	9.40	0	
Buck Branch	6.10	0.0	0.0	1.05	9.40	0	
(VFK)	3.70	6.7	6.7	1.05	9.40	0	
	2.50	9.0	9.0	1.05	9.40	0	
	.90	12.1	12.1	1.05	9.40	0	
	0.00	12.5	12.5	1.05	9.40	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Somonauk Creek	1.80	0.9	0.9	.82	9.40	2	Waterman sanitary treatment plant
tributary (VFU)	0.00	1.6	1.6	.82	9.40	0	
Roods Creek	12.30	0.0	0.0	2.89	9.40	0	
(VF1)	9.80	1.4	1.4	2.89	9.40	0	
	7.40	5.7	5.7	2.89	9.40	0	
	4.40	11.9	11.9	2.89	9.40	0	
	.90	14.8	14.8	2.89	9.40	0	
	0.00	15.9	15.9	2.89	9.40	0	
Hollenback Creek	8.20	0.0	0.0	2.21	9.40	0	
(VG7)	5.00	5.7	5.7	2.21	9.40	0	
	4.20	8.0	8.0	2.21	9.40	0	
	3.00	11.3	11.3	2.21	9.40	0	
	1.70	13.5	13.5	2.21	9.40	0	
	0.00	15.3	15.3	2.21	9.40	0	
East Branch Big Rock	30.20	0.0	0.0	1.14	9.50	0	
Creek (VH)	26.90	5.7	5.7	1.14	9.50	0	
	25.70	6.9	6.9	1.14	9.50	0	
	24.10	9.1	9.1	1.14	9.50	0	
	21.71	11.2	11.2	1.14	9.50	0	
	21.70	11.4	22.9	1.10	9.50	1	Youngs Creek (VHT)
	19.80	26.9	26.9	1.14	9.50	0	
	15.70	32.6	32.6	1.17	9.50	0	
	13.81	33.1	33.1	1.18	9.50	0	
Big Rock Creek	13.80	33.1	60.9	1.04	9.50	1	West Branch Big Rock Creek (VHM)
(VH)	12.90	62.0	62.0	1.05	9.50	0	
	10.31	64.4	64.4	1.07	9.50	0	
	10.30	64.4	102.7	1.52	9.50	1	Welch Creek (VHJ)
	8.00	108.2	108.2	1.60	9.50	0	
	7.40	109.6	109.6	1.62	9.50	0	
	3.00	114.9	114.9	1.69	9.50	0	
	1.20	115.7	115.7	1.70	9.50	2	Piano sanitary treatment plant
	.11	117.9	117.9	1.73	9.50	0	
	.10	117.9	192.4	1.48	9.50	1	Little Rock Creek (VHA)
	0.00	192.4	192.4	1.48	9.50	0	
Little Rock Creek	30.80	0.0	0.0	.80	9.50	0	
(VHA)	27.10	5.6	5.6	.80	9.50	0	
	24.00	7.6	14.4	.80	9.50	0	
	23.40	14.5	18.9	.80	9.50	0	
	18.00	24.6	24.6	.80	9.50	0	
	13.40	29.2	40.1	.80	9.50	1	Little Rock Creek tributary (VHAL)
	9.50	51.2	51.2	.87	9.50	0	
	4.10	58.6	66.2	.93	9.50	0	
	3.20	66.5	71.4	1.03	9.50	1	Little Rock Creek tributary (VHAD)
	0.00	74.5	74.5	1.09	9.50	0	
Little Rock Creek	1.60	3.0	3.0	2.46	9.50	2	Sandwich sanitary treatment plant
tributary (VHAD)	0.00	4.9	4.9	2.46	9.50	0	
Little Rock Creek	6.60	0.0	0.0	1.09	9.50	0	
tributary (VHAL)	3.30	6.3	6.3	1.09	9.50	0	
	1.00	10.5	10.5	1.09	9.50	0	
	0.00	10.9	10.9	1.09	9.50	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Welch Creek	17.40	0.0	0.0	3.70	9.50	0	
(VHJ)	16.00	2.1	2.1	3.70	9.50	2	Elburn sanitary treatment plant
	14.50	3.8	3.8	3.70	9.50	0	
	12.00	10.0	10.0	3.70	9.50	0	
	10.90	12.0	12.0	3.42	9.50	0	
	7.10	15.6	15.6	3.10	9.50	0	
	4.90	19.3	19.3	2.90	9.50	0	
	3.20	22.1	22.1	2.79	9.50	0	
	2.20	22.4	22.4	2.78	9.50	0	
	2.20	22.4	36.8	2.24	9.50	0	
	0.00	38.3	38.3	2.28	9.50	0	
Welch Creek	7.10	0.0	0.0	1.39	9.50	0	
tributary (VHJD)	4.20	5.5	5.5	1.39	9.50	0	
	2.90	7.7	7.7	1.39	9.50	0	
	1.50	10.2	10.2	1.39	9.50	0	
	0.00	14.4	14.4	1.39	9.50	0	
West Branch Big Rock	13.90	0.0	0.0	.87	9.50	0	
Creek (VHM)	10.90	3.9	3.9	.87	9.50	0	
	7.51	8.4	8.4	.87	9.50	0	
	7.50	8.4	23.2	.89	9.50	1	Battle Creek (VHMO)
	7.00	23.6	23.6	.89	9.50	0	
	5.60	24.8	24.8	.89	9.50	0	
	4.10	25.4	25.4	.89	9.50	0	
	2.60	25.8	25.8	.89	9.50	0	
	.80	26.6	26.6	.88	9.50	0	
	0.00	27.8	27.8	.88	9.50	0	
Battle Creek	10.00	0.0	0.0	.90	9.50	0	
(VHMO)	7.40	3.4	3.4	.90	9.50	0	
	5.90	9.9	9.9	.90	9.50	0	
	3.30	12.6	12.6	.90	9.50	0	
	0.00	14.8	14.8	.90	9.50	0	
Youngs Creek	8.30	0.0	0.0	1.08	9.50	0	
(VHT)	6.70	2.6	2.6	1.08	9.50	0	
	4.40	4.5	4.5	1.08	9.50	0	
	2.20	8.3	8.3	1.08	9.50	0	
	.40	11.0	11.0	1.08	9.50	0	
	0.00	19.8	19.8	1.08	9.50	0	
Rob Roy Creek	10.30	0.0	0.0	2.18	9.50	0	
(VH2)	7.80	7.2	7.2	2.18	9.50	0	
	5.40	13.1	13.1	2.18	9.50	0	
	5.00	14.1	14.1	2.18	9.50	0	
	3.00	17.0	17.0	2.18	9.50	0	
	0.00	19.6	19.6	2.18	9.50	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Blackberry Creek	34.60	0.0	0.0	1.16	9.40	0	
(VI)	31.90	3.5	3.5	1.16	9.40	0	
	27.90	6.0	6.0	1.16	9.40	0	
	25.40	9.2	9.2	1.67	9.40	0	
	22.60	18.7	18.7	2.14	9.40	0	
	21.90	21.1	21.1	2.20	9.40	0	
	19.80	25.2	25.2	2.04	9.40	0	
	17.01	30.7	30.7	1.89	9.40	0	
	17.00	30.7	44.3	1.61	9.40	1	Lake Run (VIN)
	14.30	48.1	48.1	1.81	9.40	0	
	11.30	52.7	52.7	2.01	9.40	0	
	7.40	57.0	57.0	2.17	9.40	0	
	3.30	70.2	70.2	2.53	9.40	52	USGS Gage #05551700 near Yorkville
	1.80	71.7	71.7	2.56	9.40	0	
	0.00	72.9	72.9	2.59	9.40	0	
Lake Run	7.30	0.0	0.0	.98	9.40	0	
(VIN)	6.00	2.1	2.1	.98	9.40	0	
	3.98	8.8	8.8	.98	9.40	0	
	3.30	11.0	11.0	.98	9.40	0	
	2.00	12.5	12.5	.98	9.40	0	
	0.00	13.6	13.6	.98	9.40	0	
Morgan Creek	8.60	0.0	0.0	1.45	9.40	0	
(VI3)	6.70	1.2	1.2	1.45	9.40	0	
	4.60	4.2	4.2	1.45	9.40	0	
	2.90	9.3	15.7	1.45	9.40	0	
	1.00	17.4	17.4	1.45	9.40	0	
	0.00	17.7	17.7	1.45	9.40	0	
Waubansee Creek	12.60	0.0	0.0	2.84	9.40	0	
(VJ)	10.50	1.8	1.8	2.84	9.40	0	
	9.30	3.9	3.9	2.84	9.40	0	
	7.20	14.3	14.3	2.84	9.40	0	
	5.50	17.2	17.2	2.84	9.40	0	
	3.40	20.3	20.3	2.67	9.40	0	
	1.20	28.8	28.8	2.39	9.40	0	
	.30	28.9	28.9	2.39	9.40	0	
	0.00	29.4	29.4	2.38	9.40	0	
Fox River tributary	1.40	2.3	2.3	4.63	9.40	2	Armour Dial industrial discharge
(VJ3)	0.00	2.8	2.8	4.63	9.40	0	
Indian Creek	9.10	0.0	0.0	4.63	9.30	0	
(VK)	5.70	3.1	3.1	4.63	9.30	0	
	2.90	8.9	8.9	4.63	9.30	0	
	1.10	14.2	14.2	4.63	9.30	0	
	.50	14.5	14.5	4.63	9.30	0	
	0.00	14.7	14.7	4.63	9.30	0	
Mill Creek	16.30	0.0	0.0	1.16	9.30	0	
(VL)	13.20	3.6	3.6	1.16	9.30	0	
	10.20	8.0	8.0	1.16	9.30	0	
	7.20	14.7	14.7	1.00	9.30	0	
	5.40	19.8	19.8	.94	9.30	0	
	4.10	23.5	23.5	.92	9.30	0	
	1.00	30.4	30.4	.89	9.30	0	
	.20	30.8	30.8	.89	9.30	0	
	0.00	30.9	30.9	.89	9.30	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Ferson Creek	15.20	0.0	0.0	1.17	9.30	0	
(VN)	12.10	4.8	4.8	1.17	9.30	0	
	10.40	6.1	6.1	1.17	9.30	0	
	8.74	8.4	8.4	1.17	9.30	0	
	6.51	11.4	11.4	1.26	9.30	0	
	6.50	11.4	45.5	1.21	9.30	1	Otter Creek (VNL)
	4.40	47.9	47.9	1.22	9.30	0	
	2.20	53.1	53.1	1.25	9.30	52	USGS Gage #05551200 nr St. Charles
	.20	54.1	54.1	1.25	9.30	0	
	0.00	54.1	54.1	1.25	9.30	0	
Otter Creek	7.20	0.0	0.0	1.20	9.30	0	
(VNL)	4.38	2.5	2.5	1.20	9.30	0	
	3.80	4.7	11.9	1.20	9.30	0	
	2.71	13.9	13.9	1.20	9.30	0	
	2.70	13.9	25.4	1.19	9.30	1	Stony Creek (VNLK)
	1.00	28.9	28.9	1.19	9.30	0	
	0.00	34.1	34.1	1.19	9.30	0	
Stony Creek	6.00	0.0	0.0	1.17	9.30	0	
(VNLK)	3.40	5.0	5.0	1.17	9.30	0	
	1.20	10.8	11.1	1.17	9.30	0	
	.60	11.6	11.6	1.17	9.30	0	
	0.00	11.7	11.7	1.17	9.30	0	
Norton Creek	5.30	0.0	0.0	1.14	9.20	0	
(VN3)	2.60	7.4	7.4	1.14	9.20	0	
	.50	11.5	11.5	1.14	9.20	0	
	0.00	12.1	12.1	1.14	9.20	0	
Brewster Creek	6.80	0.0	0.0	6.53	9.20	0	
(VO)	4.20	4.9	4.9	6.53	9.20	0	
	2.00	7.0	7.0	6.53	9.20	0	
	.80	12.0	12.0	6.53	9.20	0	
	0.00	15.5	15.5	6.53	9.20	0	
Poplar Creek	17.70	0.0	0.0	.74	9.10	0	
(VP)	14.80	3.3	3.3	.74	9.10	0	
	11.80	7.8	7.8	.74	9.10	0	
	10.71	8.2	8.2	.74	9.10	0	
	10.70	8.2	13.3	.74	9.10	1	East Branch Poplar Creek (VPQ)
	10.10	16.6	16.6	.74	9.10	0	
	7.50	21.8	21.8	1.00	9.10	0	
	4.91	26.1	26.1	1.08	9.10	0	
	4.90	26.1	33.2	1.15	9.10	1	Poplar Creek tributary (VPH)
	4.40	34.4	34.4	1.16	9.10	0	
	2.30	35.5	35.5	1.16	9.10	52	USGS Gage #05550500 at Elgin
	1.00	43.4	43.4	2.46	9.10	0	
	0.00	44.3	44.3	2.60	9.10	0	
Poplar Creek	6.48	0.0	0.0	1.38	9.10	0	
tributary (VPH)	1.30	6.0	6.0	1.38	9.10	0	
	0.00	7.2	7.2	1.38	9.10	0	
East Branch Poplar	5.07	0.0	0.0	.74	9.10	0	
Creek (VPQ)	2.70	3.7	3.7	.74	9.10	0	
	0.00	5.1	5.1	.74	9.10	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Tyler Creek	17.70	0.0	0.0	4.00	9.20	0	
(VQ)	15.50	5.2	5.2	4.00	9.20	0	
	11.61	10.1	10.1	4.00	9.20	0	
	11.60	10.1	21.5	3.94	9.20	1	Pingree Creek (VQR)
	9.00	28.0	28.0	4.17	9.20	0	
	7.90	30.7	30.7	4.24	9.20	0	
	6.80	32.2	32.2	4.27	9.20	0	
	5.60	33.8	33.8	4.30	9.20	0	
	3.00	36.9	36.9	4.36	9.20	0	
	1.60	38.4	38.4	4.38	9.20	0	
	0.00	40.0	40.0	4.40	9.20	0	
Pingree Creek	9.00	0.0	0.0	3.89	9.20	0	
(VQR)	6.40	1.9	1.9	3.89	9.20	0	
	2.70	8.4	8.4	3.89	9.20	0	
	1.40	10.0	10.0	3.89	9.20	0	
	0.00	11.4	11.4	3.89	9.20	0	
Jelkes Creek	1.50	0.0	0.0	5.20	9.10	0	
(VQ5)	.50	6.5	6.5	5.20	9.10	0	
	0.00	6.8	6.8	5.20	9.10	0	
Crystal Creek	8.85	0.0	0.0	6.63	9.00	0	
(VS)	7.50	5.8	5.8	6.63	9.00	91	Crystal Lake
	6.10	8.4	8.4	6.63	9.00	2	Crystal Lake sanitary treatment plant
	2.50	9.5	9.5	6.63	9.00	2	Lake in the Hills treatment plant
	2.10	10.4	10.4	6.63	9.00	0	
	1.40	11.4	11.4	6.63	9.00	0	
	1.30	11.4	20.4	6.63	9.00	0	Woods Creek (VSE)
	0.00	27.2	27.2	6.63	9.00	0	
Woods Creek	3.68	0.0	0.0	6.63	9.00	0	
(VSE)	3.30	3.4	3.4	6.63	9.00	0	
	1.70	8.3	8.3	6.63	9.00	0	
	.40	8.9	8.9	6.63	9.00	0	
	0.00	9.0	9.0	6.63	9.00	0	
Spring Creek	12.90	0.0	0.0	3.01	9.00	0	
(VT)	10.10	5.2	5.2	3.01	9.00	0	
	9.30	5.3	5.3	3.01	9.00	0	
	8.00	8.2	8.2	3.01	9.00	0	
	5.70	17.7	17.7	2.80	9.00	0	
	4.60	20.7	20.7	2.78	9.00	0	
	.60	24.8	24.8	2.75	9.00	2	Fox River Grove treatment plant
	0.00	25.8	25.8	2.75	9.00	0	
Cary Creek	0.90	3.0	3.0	6.63	9.00	2	Cary sanitary treatment plant
(VT1)	0.00	3.3	3.3	6.63	9.00	0	
Flint Creek	15.58	0.0	0.0	2.76	9.00	0	
(VU)	15.00	.7	.7	2.76	9.00	0	
	12.10	3.4	3.4	2.76	9.00	0	
	9.90	4.4	4.4	2.76	9.00	0	
	9.30	5.6	13.3	2.76	9.00	1	Flint Creek tributary (VUP)
	5.10	19.8	19.8	2.76	9.00	0	
	4.70	20.4	20.4	2.76	9.00	0	
	2.30	23.9	35.3	2.76	9.00	1	Flint Creek tributary (VUE)
	1.10	36.0	36.0	2.76	9.00	0	
	0.00	36.8	36.8	2.76	9.00	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Flint Creek	6.50	0.0	0.0	2.36	9.00	0	
tributary (VUE)	4.10	5.6	5.6	2.36	9.00	2	Lake Zurich treatment plant
	1.50	8.3	8.3	2.36	9.00	0	
	1.32	8.6	8.6	2.36	9.00	0	
	.30	10.8	10.8	2.36	9.00	0	
	0.00	11.4	11.4	2.36	9.00	0	
Flint Creek	2.00	5.7	5.7	2.76	9.00	0	
tributary (VUP)	0.50	7.5	7.5	2.76	9.00	2	Barrington sanitary treatment plant
	0.00	7.7	7.7	2.76	9.00	0	
Slocum Lake Outlet	9.20	0.0	0.0	1.30	9.00	0	
(VU3)	4.80	4.9	4.9	1.30	9.00	2	Wauconda sanitary treatment plant
	2.00	8.8	8.8	1.30	9.00	0	
	0.00	11.5	11.5	1.30	9.00	0	
Mutton Creek	7.85	0.0	0.0	2.56	9.00	0	
(VV)	6.50	3.9	3.9	2.56	9.00	0	
	3.50	9.0	9.0	2.56	9.00	0	
	2.79	10.4	10.4	2.56	9.00	0	
Cotton Creek	2.60	10.9	10.9	2.56	9.00	0	
(VV)	1.70	11.3	11.3	2.56	9.00	2	Island Lake sanitary treatment plant
	0.00	12.4	12.4	2.56	9.00	0	
Sleepy Hollow Creek	8.00	0.0	0.0	7.28	8.80	0	
(VV4)	5.20	8.6	8.6	7.28	8.80	0	
	1.70	11.4	11.4	7.28	8.80	0	
	0.00	15.0	15.0	7.28	8.80	0	
Boone Creek	12.40	0.0	0.0	8.85	8.80	0	
(VW)	9.70	4.5	4.5	8.85	8.80	0	
	9.00	5.8	5.8	8.85	8.80	0	
	7.30	8.9	8.9	8.85	8.80	0	
	6.89	9.9	9.9	8.85	8.80	0	
	5.42	10.5	14.0	8.85	8.80	0	
	4.80	15.5	15.5	8.85	8.80	52	USGS Gage #05549000 near McHenry
	3.38	17.9	17.9	8.45	8.80	0	
	1.30	22.3	22.3	7.98	8.80	0	
	0.00	23.3	23.3	7.87	8.80	0	
Dutch Creek	4.80	0.0	0.0	5.95	8.80	0	
(VW4)	1.80	3.5	6.4	5.95	8.80	1	Dutch Creek tributary (VW4J)
	.80	7.9	7.9	5.95	8.80	0	
	0.00	12.7	12.7	5.95	8.80	0	
Dutch Creek	1.80	0.6	0.6	5.95	8.80	2	Morton Chemical industrial discharge
tributary (VW4J)	0.00	2.9	2.9	5.95	8.80	0	

Appendix C, continued. NETWORK file

STREAM (code)	Mileage	DAM	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Nippersink Creek	38.00	0.0	0.0	2.13	8.80	0	
(VX)	36.40	2.5	2.5	2.13	8.80	0	
	31.01	8.0	8.0	2.13	8.80	0	
	31.00	8.0	18.4	2.34	8.80	1	Nippersink Creek tributary (VXV)
	30.70	19.3	19.3	2.34	8.80	0	
	27.50	21.7	21.7	2.34	8.80	0	
	24.50	24.7	24.7	2.34	8.80	0	
	22.21	28.3	28.3	2.27	8.80	0	
	22.20	28.3	65.1	2.71	8.80	1	Newman Creek (VXP)
	22.01	65.1	65.1	2.71	8.80	0	
	22.00	65.1	79.9	2.81	8.80	1	VanderKarr Creek (VXO)
	19.30	84.1	84.1	2.93	8.80	0	
	16.70	95.7	95.7	3.25	8.80	91	Wonder Lake
	10.30	115.7	115.7	3.67	8.80	0	
	9.71	116.3	116.3	3.68	8.80	0	
	9.70	116.3	184.6	4.19	8.72	1	North Branch Nippersink Creek (VXH)
	7.00	191.3	191.3	4.35	8.72	62	USGS Gage #05548280 nr Spring Grove
	2.70	201.8	201.8	4.58	8.72	0	
	0.00	203.5	203.5	4.61	8.72	0	
North Br Nippersink	20.10	0.0	0.0	4.08	8.60	0	
Creek (VXH)	16.50	6.1	11.7	4.08	8.60	1	De Young Creek (VXHV)
	14.70	13.6	13.6	4.08	8.60	0	
	10.50	42.7	42.7	4.08	8.60	0	
	9.00	43.9	43.9	4.08	8.60	0	
	8.60	44.3	44.3	4.11	8.60	0	
	5.70	51.7	51.7	4.57	8.60	2	Richmond sanitary treatment plant
	5.01	51.8	51.8	4.57	8.60	0	
	5.00	51.8	64.6	4.94	8.60	1	Elizabeth Lake Drain (VXHG)
	4.30	65.8	65.8	4.98	8.60	0	
	2.40	67.3	67.3	5.03	8.60	0	
	0.00	68.3	68.3	5.06	8.60	0	
Elizabeth Lake Drain	5.40	0.0	0.0	6.42	8.60	0	
(VXHG)	2.30	8.5	8.5	6.42	8.60	0	
	1.90	9.7	9.7	6.42	8.60	0	
	.90	12.4	12.4	6.42	8.60	0	
	0.00	12.8	12.8	6.42	8.60	0	
DeYoung Creek	3.30	0.0	0.0	4.08	8.60	0	
(VXHV)	1.70	1.5	1.5	4.08	8.60	0	
	.50	5.5	5.5	4.08	8.60	2	Hebron sanitary treatment plant
	0.00	5.6	5.6	4.08	8.60	0	
VanderKarr Creek	6.20	0.0	0.0	3.25	8.80	0	
(VXO)	3.70	4.0	4.0	3.25	8.80	0	
	2.85	9.3	9.3	3.25	8.80	0	
	2.50	11.4	11.4	3.25	8.80	0	
	.20	14.8	14.8	3.25	8.80	0	
	0.00	14.8	14.8	3.25	8.80	0	

Appendix C, concluded. NETWORK file

STREAM (code)	Mileage	DA(u)	DA(d)	K	P-ET	ID.	LOCATION DESCRIPTION
Silver Creek	9.80	0.0	0.0	4.06	8.80	0	
(VXP)	7.30	2.7	5.4	4.06	8.80	2	Woodstock Die Casting indust. discharge
	5.80	9.0	9.0	4.06	8.80	2	Woodstock (East) treatment plant
	5.00	9.3	12.2	4.06	8.80	1	Silver Creek tributary (VXPL)
	4.00	15.4	15.4	4.06	8.80	0	
	1.21	18.0	18.0	4.06	8.80	0	
Newman Creek	1.20	180	36.4	3.03	8.80	1	Slough Creek (VXPD)
(VXP)	0.00	36.8	36.8	3.04	8.80	0	
Slough Creek	8.20	0.0	0.0	2.02	8.80	0	
(VXPD)	6.20	3.6	3.6	2.02	8.80	0	
	5.10	7.6	7.6	2.02	8.80	0	
	3.60	8.4	8.4	2.02	8.80	0	
	2.86	11.0	11.0	2.02	8.80	0	
	.90	17.8	17.8	2.02	8.80	0	
	0.00	18.4	18.4	2.02	8.80	0	
Silver Creek	2.20	0.2	0.2	4.06	8.80	2	Woodstock (West) treatment plant
tributary (VXPL)	0.00	2.9	2.9	4.06	8.80	0	
Nippersink Creek	6.90	0.0	0.0	2.51	8.80	0	
tributary (VXV)	5.50	3.7	3.7	2.51	8.80	0	
	2.80	3.1	3.1	2.51	8.80	0	
	0.00	10.6	10.6	2.51	8.80	0	
Squaw Creek	15.30	0.0	0.0	2.45	8.60	0	
(VY)	11.40	7.5	7.5	2.45	8.60	0	
	9.50	12.6	12.6	2.45	8.60	0	
	8.20	16.1	16.1	2.45	8.60	0	
	4.50	18.5	21.7	2.38	8.60	1	Squaw Creek tributary (VYH)
	3.20	23.7	30.9	2.25	8.60	1	Squaw Creek tributary (VYF)
	2.70	31.5	35.6	2.23	8.60	1	Eagle Creek (VYE)
	1.40	37.8	37.8	2.23	8.60	0	
	1.20	38.0	38.0	2.23	8.60	0	
	0.00	46.5	46.5	2.20	8.60	0	
Eagle Creek	4.80	0.0	0.0	2.09	8.60	0	
(WE)	3.30	1.3	1.3	2.09	8.60	2	Lake Villa sanitary treatment plant
	0.00	4.1	4.1	2.09	8.60	0	
Squaw Creek tributary	4.60	0.0	0.0	2.09	8.60	0	
(VYF)	2.70	4.5	4.5	2.09	8.60	0	
	1.50	5.2	5.2	2.09	8.60	0	
	0.00	7.2	7.2	2.09	8.60	0	
Squaw Creek	2.20	1.5	1.5	2.09	8.60	2	Travenol Industries discharge
tributary (VYH)	0.00	3.2	3.2	2.09	8.60	0	
Sequoit Creek	7.50	0.0	0.0	2.13	8.60	0	
(VZ)	5.00	5.2	5.2	2.13	8.60	0	
	3.10	10.4	10.4	2.13	8.60	0	
	1.40	12.8	12.8	2.13	8.60	2	Antioch sanitary treatment plant
	.90	13.4	13.4	2.13	8.60	0	
	0.00	13.7	13.7	2.13	8.60	0	

Appendix D. Hydrologic Evaluation of DOWR Gaging Records

Flow Duration Curves and Mean Flow. One of the analytical methods used to evaluate the appropriateness of the DOWR gaging records on the Fox River was to compare their flow duration curves with the flow duration curves of the USGS gages also on the Fox River. Because great flow disturbances do not exist along the Fox River below McHenry Dam, all gages on that river should display flow duration curves that are roughly similar, especially in the medium-flow range. This is necessary because of the continuity of flow that must exist in the river. The flow duration curves with hydrologic continuity show up as roughly parallel lines when graphed. The flow duration curves for the McHenry, Algonquin, Geneva, and Dayton gages show this characteristic (Fig. D-1).

Although the general character of the flow duration curves for the South Elgin, Aurora, and Yorkville gages (Fig. D-2) is somewhat similar to the curves for the Algonquin and Dayton gages, variations exist in the estimated flows for these stations that should not be expected. For example, the Yorkville flow duration curve displays high estimated values for medium flows, between the 25% and 75% levels of exceedance. As a result, the estimated mean flow for this gage is high (Table D-1). Both the Aurora and South Elgin gages display additional inconsistencies. For the South Elgin gage, medium flows appear to be overestimated and low flows underestimated. High flows are underestimated for the Aurora gage, and the remainder of the flow duration curve at Aurora displays an uncharacteristic sinuosity.

The inconsistencies in the discharge records are primarily attributable to the lack of sufficient discharge measurements, which are needed to develop a good rating curve. The accuracy of the rating curves limits the potential value of these gaging records in the evaluation of water supply. The need for improved ratings at these gages was also suggested in a previous evaluation by the U.S.G.S. Illinois District Office (c. 1979).

Maximum and Minimum Flows. Table D-2 provides observed maximum peak and minimum daily discharges at each of the gages on the Fox River for the period 1963-78. The maximum flows, which were observed in either April 1973 or March 1979, have reasonable agreement between one location on the stream and another. There exists some unexpected variation in the flow magnitude between the Geneva, Aurora, and Yorkville stations. The minimum daily flows, observed in the early- to mid-1960's, show little relationship between stations. Because of the error and uncertainty associated with the low flow estimates at the South Elgin, Geneva, Aurora and Yorkville gages, these records offer limited use for water supply evaluation.

Table D-1. Mean Flows for USGS and DOWR Gages on the Fox River, (1963-82)

Name of Station	Drainage Area(mi^2)	Mean Flow (cfs)	Mean Flow (cfs/mi^2)	
Wilmot	868.	585.	.674	
McHenry	1250.	805.	.644	low
Algonquin	1403.	972.	.697	
South Elgin	1556.	1253.	.805	high
Geneva	1649.	1167.	.708	
Aurora	1706.	1214.	.712	
Yorkville	1804.	1470.	.815	high
Dayton	2642.	2074.	.785	

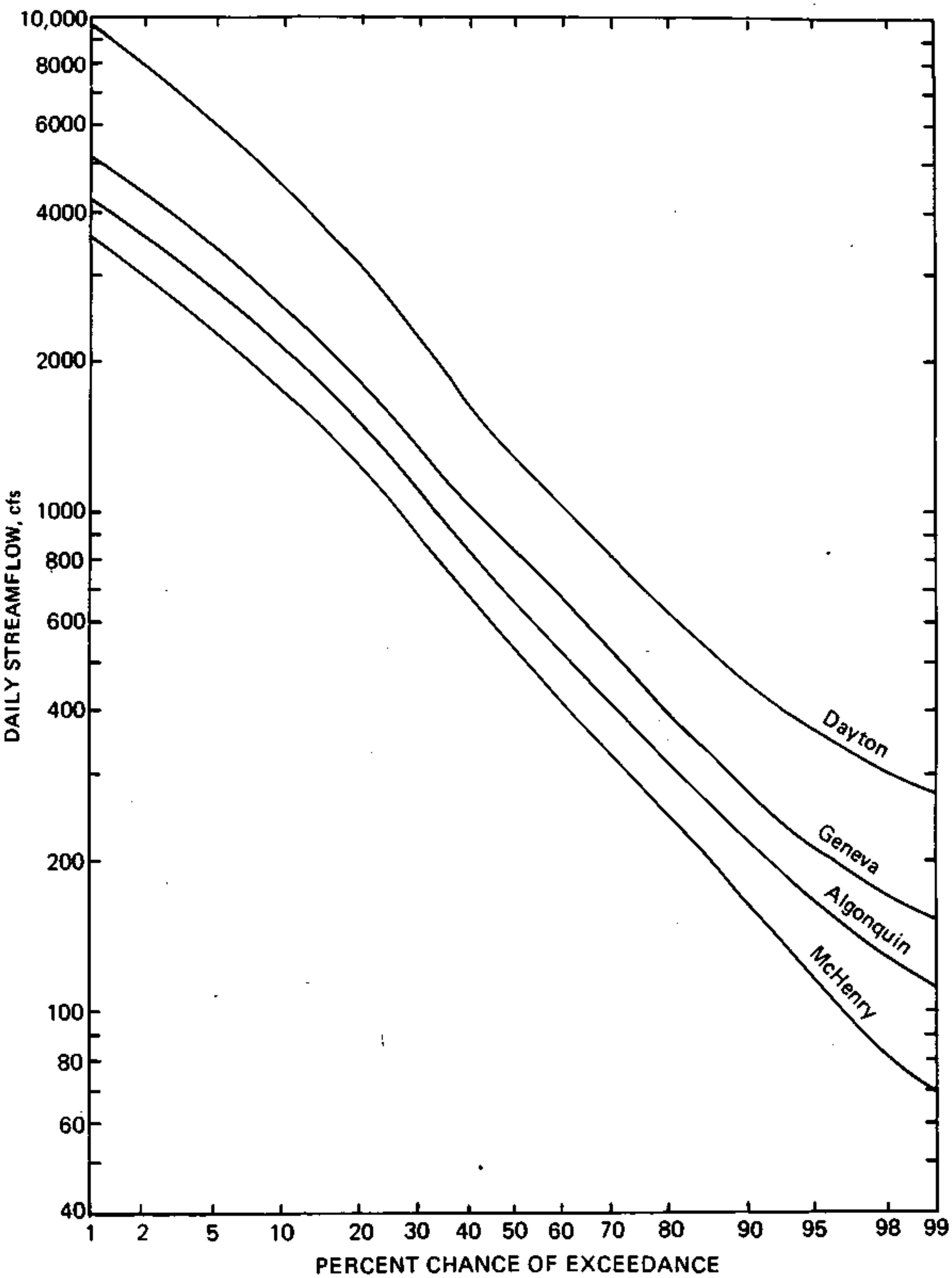

Figure D-1. Flow duration curves for gaging stations on the Fox River showing hydrologlc continuity

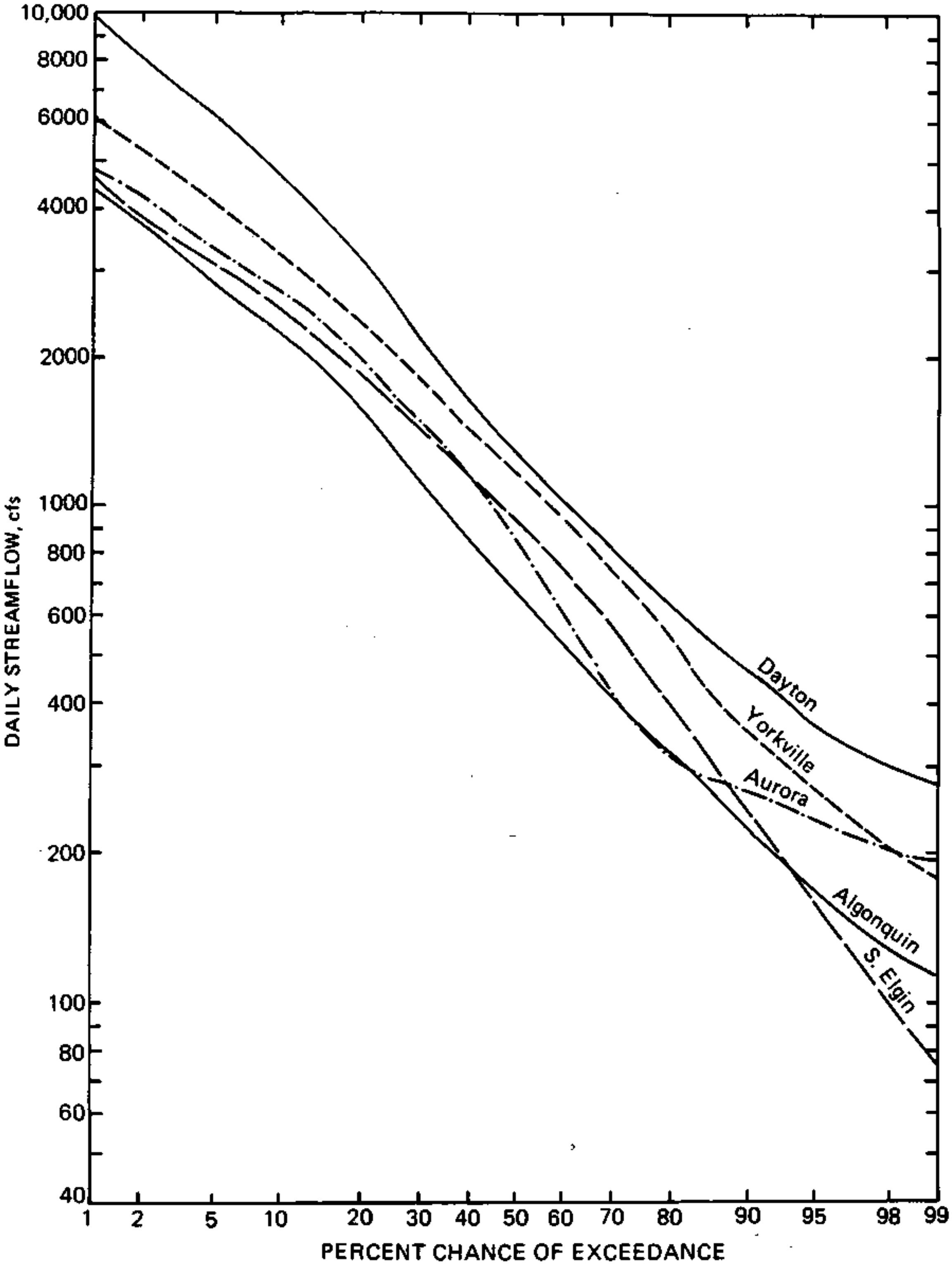

Figure D-2. Flow duration curves for gaging stations on the Fox River lacking acceptable continuity

Table D-2. Maximum Peak and Minimum Daily Flows for USGS and DOWR Gages on the Fox River, (1963-82)

Name of Station	Drainage Area (mi^2)	Maximum Peak Flow (cfs)	Minimum Daily Flow (cfs)
Wilmot	868.	6430.	52.
McHenry	1250.	5595.	39.
Algonquin	1403.	6610.	63.
South Elgin	1556.	7500.	0.
Geneva	1649.	8230.	54.
Aurora	1706.	10260.	174.
Yorkville	1804.	9820.	103.
Dayton	2642.	28900.	157.

Comparison with Independent Discharge Measurements. Miscellaneous discharge measurements taken by the USGS along the Fox River are also useful in the evaluation of the DOWR gage records. For example, discharge measurements taken at Batavia correspond well with the estimated flow at the Geneva gage, thus helping to verify the appropriateness of that gage's rating curve. Discharge measurements taken at the USGS site at Montgomery point out inconsistencies in the estimated discharges at the Aurora gage, which is located just downstream. These measurements at Montgomery show good correlation with the rating curve with the DOWR gage at Montgomery, but this gage is not included in the analysis since it has a short record. An example of the types of differences expected between teh discharge measurements and the rating curves for the DOWR gages is provided in the following paragraph for the South Elgin gage.

Miscellaneous discharge measurements taken by the USGS at South Elgin suggest the rating curve at the DOWR gage underestimates low flows and overestimates medium flows. The differences between the gage rating at South Elgin and discharge measurements at South appear to be minor as plotted in Figure D-3. However, a majority of the points comparing the measured discharge to the gage rating plot above the 45-degree line that indicates equivalence between the two numbers. For example, the rating curve estimate associated with a measured discharge of 1250 cfs is approximately 1500 cfs. On average, the estimated discharge from the rating curve exceeds the measured discharge by 8 to 10 percent. In such cases, the rating curve at the gaging station could be adjusted to reflect the information provided by the miscellaneous discharge measurements. However, the measurements do not include many samples of low-flow or high-flow conditions, which is the portion of the record that needs the greatest amount of verification.

At McHenry Dam, flows through the gates and over the spillway are estimated from hydraulic equations using the reported gate openings and the headwater and tailwater levels at the dam. The estimated flow seems to correspond relatively well with discharge measurements made further downstream at the USGS gage at Algonquin. The discharges estimated for this study indicate that the hydraulic equations underestimate the total flow at the dam. However, the new equations and coefficients of discharge recently developed by Fisk (1988) should, from preliminary examination, improve the estimates of flow past the dam. As a result of the underestimated high flows, the estimated mean flow at the gage is low.

Selective periods in the McHenry Dam records prior to 1956 contain abnormalities in the reported gate openings. Estimated low-flow releases from the dam based on the reported gate openings do not correspond well with discharges measured concurrently at Algonquin. Such

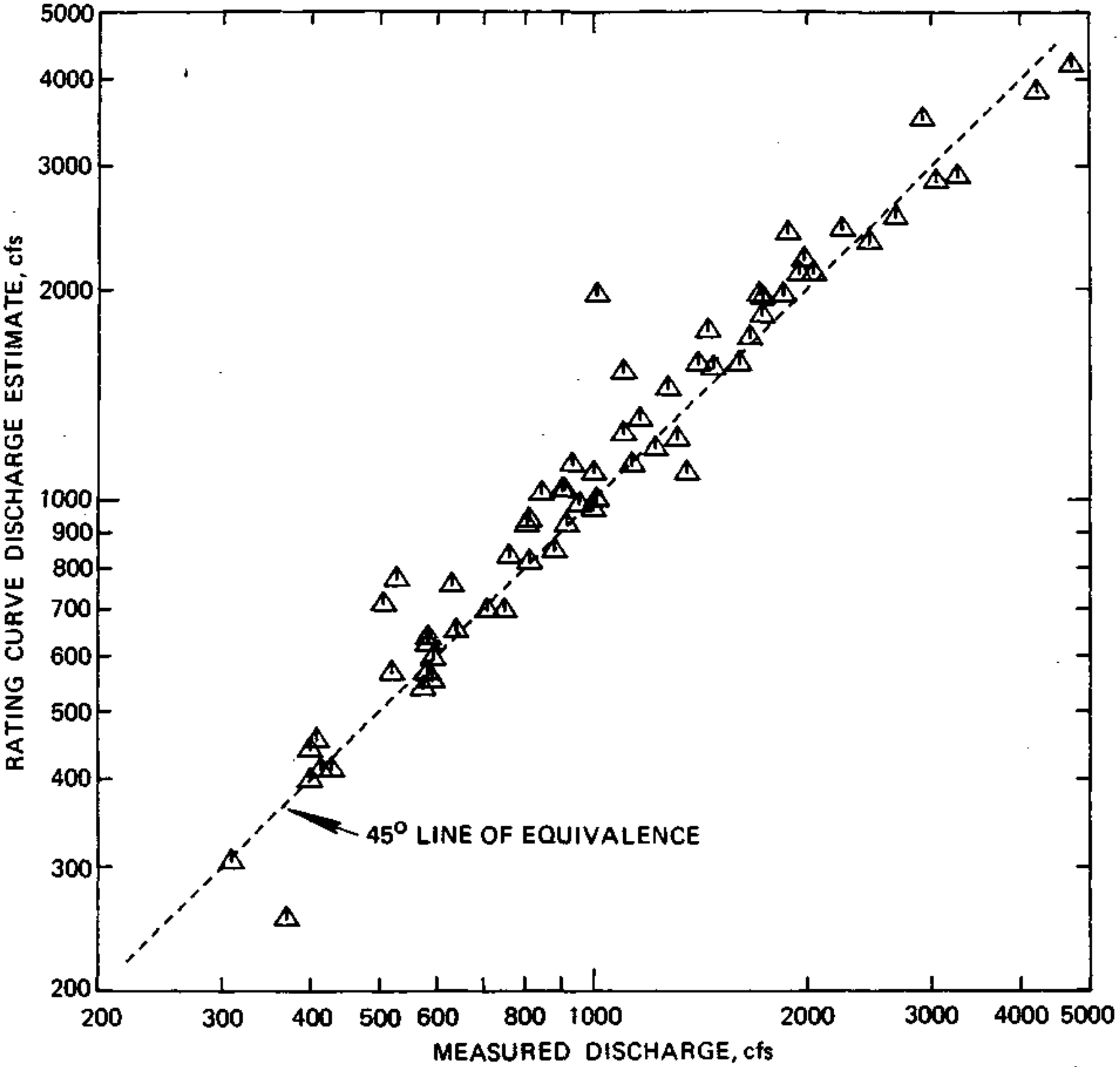

Figure D-3. Comparison of measured discharge versus rating curve estimates, Fox River at South Elgin (1978-85)

differences have only been observed for low flow periods. The estimated low flow for these periods is considerably higher than the discharges observed downstream. Examples are shown in Table D-2. In each of these examples, a loss of from 31 to 47 cfs is reported between McHenry and Algonquin. There are no observed losses of this sort between McHenry and Algonquin in the remainder of the years on record. For this reason it is believed that the reported gate opening are in error. The estimation of discharges at the McHenry Dam for periods prior to 1956 should attempt to reconstruct the gate opening record for these low flow periods.

Table D-2. Comparison of Estimated Discharges at McHenry Dam and Discharges at Algonquin for Selected Low Flow Periods Prior to 1956

Year	Dates	Reported Gate opening (feet)	Estimated Flow at McHenry (cfs)	Average Flow at Algonquin (cfs)
1944	Aug 11 -Aug 17	.10	94.	57.
1946	Aug 4 -Aug 13	.10	94.	52.
	Aug 1 -Oct 31	.10 to .20	122.	79.
1948	Sep 1 -Sep 19	.10 to .20	108.	67.
	Aug 23 - Oct 31	.10 to .30	153.	114.
1953	Nov 12 - Nov 23	.10 to .20	113.	82.

Conclusions. The DOWR gages at McHenry and Geneva provide the most useful records of streamflow along the Fox River, which help augment the USGS gages. The rating curve for the Geneva gage should be verified using additional discharge measurements, especially for low and high flow periods. The stage records at South Elgin and Yorkville appear to be of good quality but the rating curves are not of sufficient accuracy to allow using the station record for any water resource evaluation. Discharges estimated at McHenry Dam using the equations given by Fisk provide valuable information on the hydrology of the Fox Chain of Lakes, however estimation of the discharges prior to 1956 will require an evaluation and reconstruction of the gate opening record for certain periods.

In order to best evaluate water supply, it is desirable to have a quality streamflow record between the Algonquin and Dayton gages, preferably near or downstream of the Aurora Sanitary District treatment plant near Oswego. The DOWR station at Yorkville has the potential for providing this information, but its record should be updated using an appropriate rating curve based on sufficient discharge measurements.

References

Fisk, G.G., 1988. Discharge Ratings for Control Structures at McHenry Dam on the Fox River, Illinois, U.S.G.S. Water Resources Investigations, Open-File Report 78-85,98 p.

U.S.G.S. Illinois District Office, c. 1979. Notes on U.S.G.S. Review of Illinois Division of Water Resources Stream-Gaging Network in Illinois, unpublished.