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Kane County Water Resources Investigations: Surface Water Accounting for Water Supply Planning in Kane County

by
H. Vernon Knapp, Amy M. Russell,
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Prepared for the
Kane County Development and
Resources Management Department

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Illinois State Water Survey
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Champaign, Illinois

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Abstract

The Kane County Surface Water Accounting Model (KC-SWAM) was developed to provide the Kane County Development and Resources Management Department with a water supply planning tool that describes the effects of water use on availability of flow quantity in the Fox River and other streams in the Kane County region. By incorporating algorithms that explain present and past human effects on streamflow amount, the model is capable of projecting potential flow changes in upcoming decades based on user-supplied scenarios of water use growth. The model does not simulate sequences of streamflow amounts associated with individual climatic events, but, instead, estimates the probability of occurrence of present and future streamflow amounts as affected by various natural and human-induced factors. As a water supply planning tool, the focus of KC-SWAM model preparation and analyses was on low flows and drought periods.

KC-SWAM is an extension of an existing water resources computer model, the Illinois Streamflow Assessment Model (ILSAM), developed for major watersheds in the Kane County area and other regions of Illinois. In addition to ILSAM capabilities, KC-SWAM has three major functions that improve its use as a water supply planning tool: 1) an interactive map interface assists users in identifying and selecting stream locations and water facilities using point-and-click features; 2) effects of existing water withdrawal and discharge facilities can be modified to simulate future scenarios of water use development; and 3) results of scenarios can be saved, shared with other users, and used as foundations for additional scenario development.

Although extensive computer programming code was prepared in KC-SWAM construction, this report focuses on defining hydrologic inputs to the model and on describing factors that affect flow magnitude of streams in and near the Kane County region. The primary hydrologic data used to develop streamflow estimates in KC-SWAM include U.S. Geological Survey (USGS) daily streamflow data, Illinois Environmental Protection Agency (IEPA) wastewater effluent data, and Illinois State Water Survey (ISWS) water use data. The KC-SWAM databases contain flow frequency statistics computed from these hydrologic data, and processed information on effects of major water withdrawals, discharges, and reservoirs. Flow estimates at ungaged stream locations also are based on regional regression equations developed from USGS daily streamflow data. Low flows measured by the ISWS during the 2005 drought also were used to calibrate low streamflow estimates for tributary streams in Kane County.

Several factors have definable impacts on flow availability in the Fox River and other Kane County streams, including 1) climate variability, 2) wastewater discharges, 3) water use withdrawals, and 4) reservoir operation, particularly the operation of Stratton Dam on the Fox River downstream of the Fox Chain of Lakes. Wastewater released to the Fox River in Kane County also has a sizeable effect on low flows in the river. Although water supply withdrawals at Elgin and Aurora decrease low flows locally, the collective impact of Kane County's water use (discharges and withdrawals) increases low flows in the river. Increases in population growth and expected associated increases in water use likely will magnify the effects of treated wastewater discharged to the Fox River. It is expected that growth in water use will be supplied from various sources yet to be determined, much of it from groundwater, but also with the

potential for additional withdrawals from the Fox River. Local effects on low flows will depend on types of water supply sources being used, and location and magnitude of specific wastewater discharges and river withdrawals. KC-SWAM only identifies potential effects on streamflow magnitude, not stream water quality, another factor that must be examined when determining practicality of future growth scenarios.

Contents

Introduction

An essential element in water supply planning is the ability to evaluate effects of existing and future water use activities on water availability at other sites as well as overall effects on sustainability of regional water supply resources. Surface water and groundwater are connected resources, but water resource planners often must address different issues when evaluating each resource. Surface water resources in Illinois are highly replenishable at most times, but water availability may be limited during periods of low flows caused by severe drought. Thus, whereas groundwater supply planning often may focus on maintaining a sustainable supply over the course of multiple decades, surface water supply planning traditionally has focused on providing an adequate supply during drought and low flow periods typically measured in durations of months or days.

Some of the worst droughts on record in the Kane County region occurred between the 1930s and 1950s. Although there are streamflow records from the Fox River during these severe droughts, many changes over the past 50 years have altered flow amount in the river. The most obvious changes have been the growth of communities located in the region, associated increases in wastewaters discharged to the river, and, to a lesser extent but of essential consideration, water supply withdrawals from the river. As a result, even if identical climate conditions of the 1930s and 1950s occurred again, the flow in the river would not be the same as that observed during these historical droughts. For water supply planning, it is necessary to identify, as best as possible, future flow modifications to the river for use in projecting potential impacts on streamflow quantities in future droughts.

The Kane County Surface Water Accounting Model (KC-SWAM) described in this report was developed to provide a water supply planning tool that describes the effects of water use on quantity of flow in the Fox River and other streams in the Kane County region, one that can be used to assess effects of future water use development on these streams. By developing algorithms that explain past flow modifications, the model is capable of estimating impacts of various potential changes in upcoming decades; for example, changes that may be expected with continued population growth. The model does not simulate sequences of streamflow amounts associated with individual climatic events, but, instead, estimates frequency of present and future streamflow amounts with effects of natural and human-induced factors. Because KC-SWAM is a water supply planning tool, emphasis is placed on examination of streamflow conditions during low flows and drought periods.

Estimates of streamflow frequency were developed in this study not only for the Fox River, but also for many tributary streams in both the Fox and Kishwaukee River watersheds (Figure 1). Although tributary streams in the Kane County region do not have sufficient baseflows during drought periods to serve as water supply sources; as with the Fox River, natural flows are needed to maintain environmental quality, meet needs of fish and wildlife, and, in some cases, provide opportunities for recreation. Low flows in tributary streams typically originate from local shallow groundwater and thus are also likely to show initial effects if there is prolonged overuse of nearby shallow aquifers for water supply.

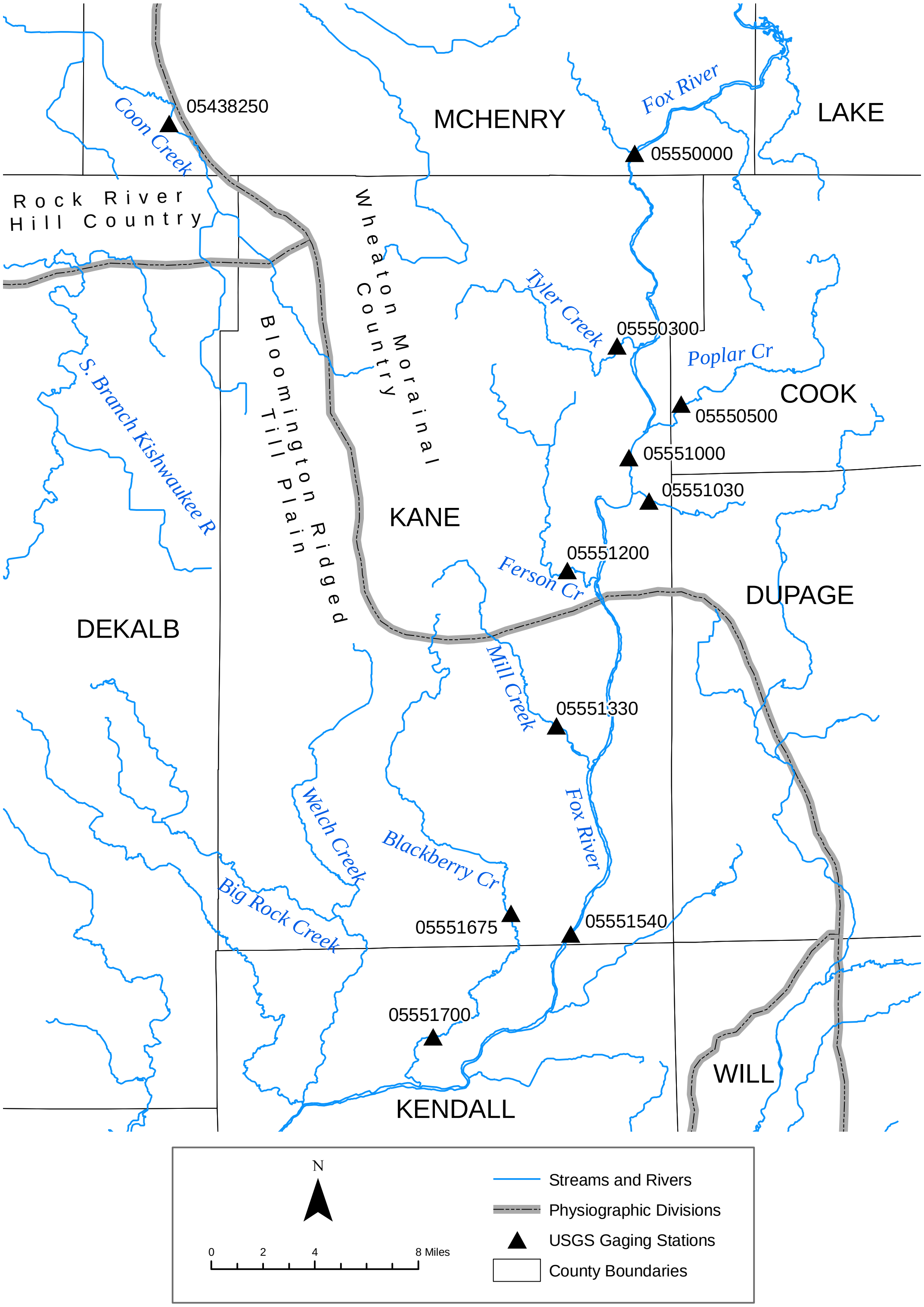

Figure 1. Location of major streams, physiographic divisions, and USGS streamgaging stations in the Kane County region

In the process of analyzing frequency of streamflow amounts in both the Fox River and tributary streams, three primary categories of analytical steps were undertaken: 1) analysis of human influences on flow conditions; 2) analysis of impact of climate variability and period of record on flow conditions; and 3) regional analysis to estimate unaltered flows at ungaged sites. Descriptions of analyses in each category comprise major chapters in this report.

Most analytical steps presented in this report initially were developed for use with the Illinois Streamflow Assessment Model (ILSAM), which was previously applied to the Fox River watershed and other major watersheds covering more than half of Illinois. Thus, KC-SWAM, an extension of ILSAM, produces similar numerical flow estimates. Hydrologic analyses for the Fox River were updated from previous ILSAM applications (Knapp, 1988; Knapp, 1999). Several improvements to ILSAM were developed in preparation of KC-SWAM, as described in the following section.

Acknowledgments

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Kane County Surface Water Accounting Model

The Kane County Surface Water Accounting Model (KC-SWAM) developed for this study is an extension of an existing water resources computer model, the Illinois Streamflow Assessment Model (ILSAM), previously developed by the Illinois State Water Survey (ISWS) for the two major watersheds in Kane County — the Fox and Rock-Kishwaukee River watersheds (Knapp, 1988; Knapp and Myers, 1999; Knapp and Russell, 2004) — and other regions of Illinois. ILSAM is primarily a streamflow information tool: users provide a stream location of interest and obtain a statistical summary of expected long-term flow conditions at that location. As a water planning tool, however, ILSAM can be used to predict potential changes in flow conditions associated with a single modification of flow — for example, a new withdrawal or wastewater treatment facility, a change in an existing facility, construction of a reservoir, etc.

KC-SWAM provides three major improvements over ILSAM:

1. *Interactive Graphics*. An interactive map interface assists users in identifying locations of interest and selecting items using point-and-click features. Map layers provided from Geographic Information System (GIS) coverages identify streams and other major features, such as municipal boundaries, highways, and roads. Icons identify existing water withdrawal and wastewater treatment facilities.
2. *Update/Modify Flow Amounts at Multiple Facilities*. Modifications of discharges or withdrawals at existing facilities can be performed individually or *en masse*. Modifications of this type can be used either to update the model to reflect ongoing changes in water use throughout the county or to examine various potential future changes. New facilities also can be added using point-and-click features.
3. *Scenario Building*. To change existing conditions, the user is required to provide a scenario name to identify proposed water resource changes. For example, if changes in water planning represent one particular vision of the county's water use in 2030, the user could name the scenario "Scenario 2030-A." The model not only allows the user to create new scenarios, but also to build on existing scenarios; for example, the user could make additional changes to Scenario 2030-A and either replace that scenario or save it with a new name.

KC-SWAM was developed using the VB.NET programming language, with a mapping interface developed primarily using MapWinGIS controls. MapWinGIS provides the capability to add custom map features to independent software applications (http://www.mapwindow.org/, accessed December 3, 2007). Several mapping components were evaluated before MapWinGIS eventually was selected based on availability of features, unlimited free redistribution, and access to the source code. Extensive original programming code also was developed for the new model. The internal computation process and data model were redesigned to improve processing speed and make it possible to add several new features, including:

- Allowing evaluation of more than one modification within a single application.
- Creating scenarios that store flow modifications at one or more points.

- Inserting nodes and new modification points along the Fox River.
- Viewing results of multiple scenarios on the same graph or in the same table.
- Saving scenarios, including all modifications and calculations for later access or to share with others.

This report does not focus on details of computer program development, but instead on hydrologic information used in model databases and descriptions of model computations. Additional background information is provided to aid in understanding surface water resource issues that likely will be vital to water supply planning in the Kane County region in upcoming decades.

Streamflow Information Produced by KC-SWAM

Although water supply planning typically focuses on low flows during drought, KC-SWAM development kept the same broad range of flow conditions as previously had been prepared for ILSAM. A total of 154 different streamflow parameters, described in the following paragraphs, were included. All flows are given in units of cubic feet per second (cfs).

Average Flow Values

Parameters: Average Annual Flow (Q_{mean}) and Average Monthly Flows

Annual Flow Duration Values

Description: Flow duration values give a percentage ranking (from high to low) of daily flows expected to occur in a stream over a long period, independent of the actual sequence of daily flows. The 2 percent flow (Q_2), for example, is the daily streamflow rate exceeded on exactly 2 percent of all days, typically computed over a base period or hydrologic record covering many years. The 1 percent flow (Q_1) by necessity is a higher flow rate because it is exceeded less frequently.

Parameters: Q_1, Q_2, Q_5, Q_{10}, Q_{15}, Q_{25}, Q_{40}, Q_{50}, Q_{60}, Q_{75}, Q_{85}, Q_{90}, Q_{95}, Q_{98}, and Q_{99}.

Monthly Flow Duration Values

Description: Monthly flow duration values are defined in the same manner as annual flow-duration values, except that they are determined using only those daily discharges that fall within a certain month of the year.

Parameters for each calendar month: Q_2, Q_{10}, Q_{25}, Q_{50}, Q_{75}, Q_{90}, and Q_{98}.

Low Flows

Description: Each low flow parameter is defined by a duration in consecutive days and a recurrence interval in years. A 7-day low flow for a given year is the lowest average flow within a 7-day consecutive period during that year. The 7-day, 10-

year low flow is the 7-day low flow that occurs on average only once in 10 years. A 2-year low flow is expected to be exceeded once every 2 years, and thus represents an “average” year.

Low Flow Durations: 1, 7, 15, 31, 61, and 91 days.

Recurrence Intervals: 2, 10, 25, and 50 years.

Drought Flows

Description: Drought flows are similar to low flows, except that duration of the period is longer and is defined in months instead of days, and average low flows are developed from monthly records. Drought durations usually are not defined on an annual basis, because a drought period typically encompasses multiple years.

Drought Flow Durations: 6, 9, 12, 18, 30, and 54 months.

Recurrence Intervals: 10, 25, and 50 years.

Basic Hydrologic Concepts in KC-SWAM

Flow in a stream is treated as having two separate components: 1) unaltered or “virgin” flow conditions as influenced primarily by weather and climate phenomena as well as topography, hydrogeology, and prevailing land use conditions in the watershed, and 2) altered flow conditions from human activity that produces a direct quantifiable change in flow from the watershed. Modifications to flow conditions include direct additions to or subtractions from flow in the stream, such as from effluent discharges or water supply withdrawals, or large changes in water stored within the watershed, such as from a major reservoir. Indirect modifications to flow amount, such as from urbanization or other land use changes, also may be recognized; but, based on currently available studies, effects of these alterations on flow amounts may be difficult to predict. There are also no data available to predict past flow conditions in the watershed prior to land cultivation and drainage modifications that occurred in the 1800s.

Two distinguishing features of KC-SWAM (and the parent ILSAM) are: 1) ability to integrate effects of water use facilities and other direct alterations of flow with regional hydrologic equations for estimating streamflow characteristics at any watershed location, and 2) maintenance of consistent flow estimates between any two streamflow parameters or between any two watershed locations. Consistency of flow estimates in these models was defined by the following characteristics:

- Flow estimates represent the same base hydrologic period. There is no situation in which the models define flow characteristics for one stream using streamflow records collected during a period of dry years and for a neighboring stream a using flow records collected during a different period of wet years. Flow extension techniques are used for short-term records so that all streams have flow estimates that represent composite hydrologic conditions as expected over a longer base period.

- Flow equations used in the models are additive in nature, such that sources of low flows in a stream essentially can be traced to particular watershed locations, and that there are no unexpected jumps in flow quantity at tributary confluences. Knapp (1988) explains the concept of variable contribution of base flows from different parts of the watershed, as related to hydrogeologic factors, in more detail. To achieve the additive trait of streamflow estimates, it is necessary to avoid exponentially based equations commonly used in other types of regional hydrologic applications.
- Equations prepared maintain a sensible relationship between any two flow parameters regardless of where in the watershed equations are applied. For example, in most unaltered flow conditions the ratio between 1-day and 7-day low flows should be roughly similar regardless of stream location. To achieve this, it is often necessary to smooth coefficient values in the equations developed to estimate both 1-day and 7-day low flows.

Steps in Hydrologic Analyses

Regional Analyses

One of the first steps in the hydrologic analyses for KC-SWAM was development of regional regression equations for use in estimating unaltered flow conditions at ungaged sites. In this process, hydrologic regions were identified that share common hydrologic traits. Although similarity in streamflow traits can be identified solely using statistical comparisons, hydrologists typically search for physical characteristics that distinguish different hydrologic regions. Most often for Illinois, physiographic divisions as defined by Leighton et al. (1948) have proved to be reliable indicators of differences in regional low flow characteristics. Leighton et al. (1948) defined three physiographic divisions: the Bloomington Ridged Till Plain, situated in southern Kane County; the Wheaton Morainal Country, in northern Kane County; and the Rock River Hill Country, covering a small area in the northwestern corner of Kane County (Figure 1). The Marengo Ridge, which runs through the center of Kane County, separates the Bloomington Ridged Till Plain from the Wheaton Morainal Country. Most of the Kishwaukee River watershed in western Kane County and the Fox River watershed south of St. Charles fall within the Bloomington Ridged Till Plain.

Regional equations for estimating streamflow characteristics within these two physiographic regions previously were developed for ILSAM use in models for the Fox and Rock-Kishwaukee River watersheds. Existing sets of equations in these models were examined and considered applicable for use in KC-SWAM. Specific equations adopted for KC-SWAM were the same as used for the Bloomington Ridged Till Plain (Knapp and Russell, 2004) and for the Wheaton Morainal Country (Knapp and Myers, 1999).

Development of equations for each region in these previous studies used long-term flow records (generally with periods of record of 50 years or more) from streams with negligible or relatively minor impacts from direct human modification — such that they reasonably represent unaltered streamflow conditions within each region. Shorter gaging records (20-35 years of record) were extended to account for differences in period of record. Where long-term records were unavailable — typically for smaller watersheds — regional analysis used extended short-term flow records. Knapp and Russell (2004) present methods for estimating flow frequency of streamflow records, and Knapp (1988) describes the method used for extending short-term records. In development of regional equations, several watershed characteristics were examined as independent variables for estimating streamflow. Independent variables previously used in regional equations for the Bloomington Ridged Till Plain and Wheaton Morainal Country are watershed drainage area, average soil permeability from the deepest soil layers, and average annual net precipitation (precipitation minus evapotranspiration). Deep soil permeability was considered a surrogate value for permeability of shallow groundwater layers that contribute to baseflows in the region's streams.

Once watershed characteristics (independent variables) for regional equations were identified, it was necessary to develop a database of these characteristics for all streams in the region. Previously developed tables of watershed characteristics from existing ILSAM databases for the Fox and Rock-Kishwaukee River watersheds were altered for KC-SWAM use, with the following improvements: 1) values of soil permeability for each watershed were updated using newly available, higher-resolution soils data, and 2) the number of stream locations available within KC-SWAM was increased above that previously used by ILSAM. These steps are explained in greater detail in "Data Used in Hydrologic Analyses: Watershed Characteristics."

Identification and Characterization of Flow Alterations

In developing streamflow estimates for KC-SWAM, it is necessary to identify external human factors expected to alter streamflow noticeably in the Kane County area. Most direct types of human alterations can be classified as: 1) water use withdrawals or other water diversions, 2) effluent discharges or other returns to streams, and 3) reservoirs that retain water for later release. In many cases, the magnitude and effect of such alterations have changed over time. When examining historical streamflow records for KC-SWAM use, it is also necessary to characterize historical trends in alterations, particularly with regard to withdrawals and discharges. Analyses of historical records of water use and effluent discharge are discussed in more detail in "Data Used in Hydrologic Analyses: Water Use Records and Effluent Discharge Records."

An examination of effects of reservoirs on inflow-outflow relationships typically requires application of a hydrologic routing technique such as level-pool (i.e., modified Puls) routing. Based on results of numerous modified Puls routing simulations, Knapp (1988) developed a generic algorithm that predicted flow frequency characteristics downstream of a reservoir using inflow frequency characteristics and selected physical dimensions of a reservoir and its outlet structure. Knapp (1988) showed that the reservoir's surface area and spillway width have a greater influence on its outflow characteristics than other physical dimensions when primary reservoir outflow is from a spillway with vertical side walls. Both ILSAM and KC-SWAM use this algorithm to estimate outflow characteristics for moderate- to large-sized reservoirs in the Fox and Rock-Kishwaukee River watersheds. Outflows from very small reservoirs were not examined in model development, nor were the negligible effects on outflow quantity of the many low-head channel dams along the Fox River.

Stratton Dam, the outlet for the Fox Chain of Lakes, presents a more complex example in estimating the effect of a reservoir on downstream flow conditions. The Chain of Lakes is a collection of nine glacially formed and interconnected lakes near the Wisconsin border in Lake and McHenry Counties. The Fox River flows through four of these lakes. Stratton Dam (previously named McHenry Dam) originally was constructed in 1907 to raise and regulate the pool level in these lakes for navigation by motor boats (Illinois Rivers and Lakes Commission, 1915). The dam included flashboards that could raise the pool an additional 3 feet. Stratton Dam was reconstructed in 1942 in its current form with adjustable gates to control outflow. It has been owned and operated by the State of Illinois since that time. No known records of dam operation prior to 1942 exist, but it is expected that operation of flashboards affected low flows in the Fox River downstream, just as operation of the gates since 1942 has also affected low flows.

Even without Stratton Dam, storage in these natural lakes would considerably modify flows in the Fox River. Knapp (1988) developed a level-pool reservoir routing model of the Chain of Lakes to simulate: 1) outflow under present operating conditions at Stratton Dam, and 2) outflow from the Chain of Lakes without Stratton Dam. The “present condition” simulation was calibrated with recent outflow records, and the “no dam” simulation used a steady-state hydraulic model of the downstream Fox River channel to estimate the relationship between lake elevation and outflow. That analysis estimated that, without the effect of Stratton Dam, the Chain of Lakes would have little overall impact on low flows in the river, but would have decreased high flows. Results of the Knapp (1988) modeling analysis were used to estimate unaltered flow conditions for the Fox River in all subsequent versions of ILSAM and the present KC-SWAM. Present flow frequency estimates downstream of Stratton Dam were adjusted from the original estimate in Knapp (1988) based on intervening years of flow records.

Estimating Virgin and Present Flow Conditions for Gaging Records

Once effects of individual flow alterations in the watershed were identified, their effects were separate from unaltered or “virgin” flow conditions in analyses of streamgage records. For each gaging record, determination of the composite effect of all alterations affecting flows over the period of record included analysis of historical changes in water use, influences of reservoirs, and other possible factors. Where trends in these alterations reasonably could be estimated over the gage’s period of record, estimated effects then were subtracted from observed flows at the gage to produce the unaltered flow condition. For the Fox River immediately downstream of Stratton Dam, the “no dam” simulation was accepted as the virgin flow condition, because the composite of alterations to streamflow was sufficiently complex to make simple subtraction of their effects unfeasible. When analyzing flow alterations from water withdrawals and effluent discharges, the focus was on determining low flow impacts and the virgin low flow condition, because the relative effect of these types of facilities on high flow conditions is typically small.

Statistical estimates of flow frequency were computed for the virgin flow. Knapp and Russell (2004) provide methods for flow frequency analyses. For shorter gaging records that do not reflect long-term climate conditions, flow frequency characteristics of virgin flow were extended to account for differences in period of record relative to the base hydrologic period. Knapp (1988) describes the method used for extending short-term records. In general, gaging records that do not date back to the 1950s were extended to approximate severe drought conditions typically lacking in flow records from the past 40 years, but necessary for accurate estimates of drought flow frequency and magnitude.

Once virgin flow characteristics were computed, present flow conditions were estimated by adding present effects of flow alterations to the virgin flow. If there was little trend in flow alterations over the historical record, then present flow characteristics and those in the gaging record were essentially identical. In most cases, however, continuing growth in both population and water increased the magnitude of flow alterations. In typical cases of low flows in streams augmented by growing amounts of effluent discharges, low flow magnitudes associated with present flow conditions were often considerably higher than when estimated directly from the historical record.

Database Components

Analytical steps presented in the previous section result in four primary datasets used by KC-SWAM to compute streamflow characteristics for all locations in the region. All datasets were imported into a Microsoft Access database for direct access by KC-SWAM.

1) *Estimates of 154 flow parameters at gaging stations within the watershed.* In addition to streamgage estimates, flow frequency estimates also were computed and entered into the database for selected other watershed locations where such computations are useful to model operation. Examples include locations downstream of reservoirs or upstream and downstream of major river confluences. Appendix A lists basic streamflow frequency data for 20 watershed locations.
2) *A dataset of all flow modifiers in the watershed (withdrawals, diversions, and effluent discharges).* This includes estimated impacts of each modification on each of the 154 flow parameters produced by KC-SWAM.
3) *A table of watershed characteristics for 200 locations in Kane County and hundreds of other nearby locations in the Fox and Rock-Kishwaukee River watersheds.* Watershed characteristics include stream mileage, drainage area, soils information, and locations of gaging stations, water use projects, reservoirs, and other points of interest in the watershed. Appendix B lists this stream network data for selected stream locations in and near Kane County.
4) *The set of regional regression equations used to estimate virgin flow conditions for each of the 154 flow parameters at ungaged sites in the watershed.* Preparation of these regional equations was discussed in “Kane County Surface Water Accounting Model: Steps in Hydrologic Analysis.”

Model Operation

KC-SWAM can be used either as an information tool to produce streamflow estimates for selected locations or as a planning tool that projects effects on streamflow quantity from new water facilities or changes in capacities of existing water facilities. A description of general types of operations typically used in the model follows. The model's menu provides a user manual that describes examples and specific map functions, menus, and steps to follow for model use.

As an information tool, the following steps may be used to produce streamflow estimates:

- Utilities in the mapping interface may be used to locate and view points of interest, such particular streams or locations. Figure 2 shows the opening screen of KC-SWAM with the navigation toolbox and pull-down menus shown in the upper left corner and the Kane County region highlighted on the right side of the screen.

- The user may select any number or combination of locations to calculate streamflow estimates (Figure 3). At any given stream location, the user has the option of selecting flow calculations for:

  – The selected location only

  – All points on that stream

  – All locations downstream of the selected point (to the mouth of the Fox River)

- Tables and graphs of calculated values appear in a separate window of the model and may be viewed at the user's convenience (Figure 4).

There are only a select number of locations, such as at streamgaging stations, for which flow statistics have been pre-calculated and stored in KC-SWAM databases. When the model is instructed to calculate flows for any other location, two processes occur. First, the model estimates virgin flow at the location. For an ungaged stream, virgin flow is computed from regional regression equations. For a stream with a gage, results of regional regression equations are adjusted to conform to virgin flows at the gage, as estimated from the gage record. Second, model algorithms search for all identified modifications located upstream of the selected point; then, in an upstream to downstream direction, algorithms calculate changes in streamflow caused by those modifications. At certain midpoints, composite effects of modifications already may have been calculated and stored in model databases, making it unnecessary for the model to search further upstream. Typical midpoints include locations of streamgages and confluences where tributary streams flow into the main stem of a stream.

When KC-SWAM is used as a planning tool, the user typically follows these steps:

- *Create a new scenario*. This is a required step whenever the user wants to add a new facility or change an existing facility.

- *Change/update the flow modification amount for existing facilities*. Changes may be made for individual facilities, but it is also possible to update water discharges and withdrawals for all facilities in the Fox or Rock-Kishwaukee River watersheds — a process called "batch update." This process is particularly useful for developing scenarios of future conditions, when water use growth may be expected to affect most facilities in the region.

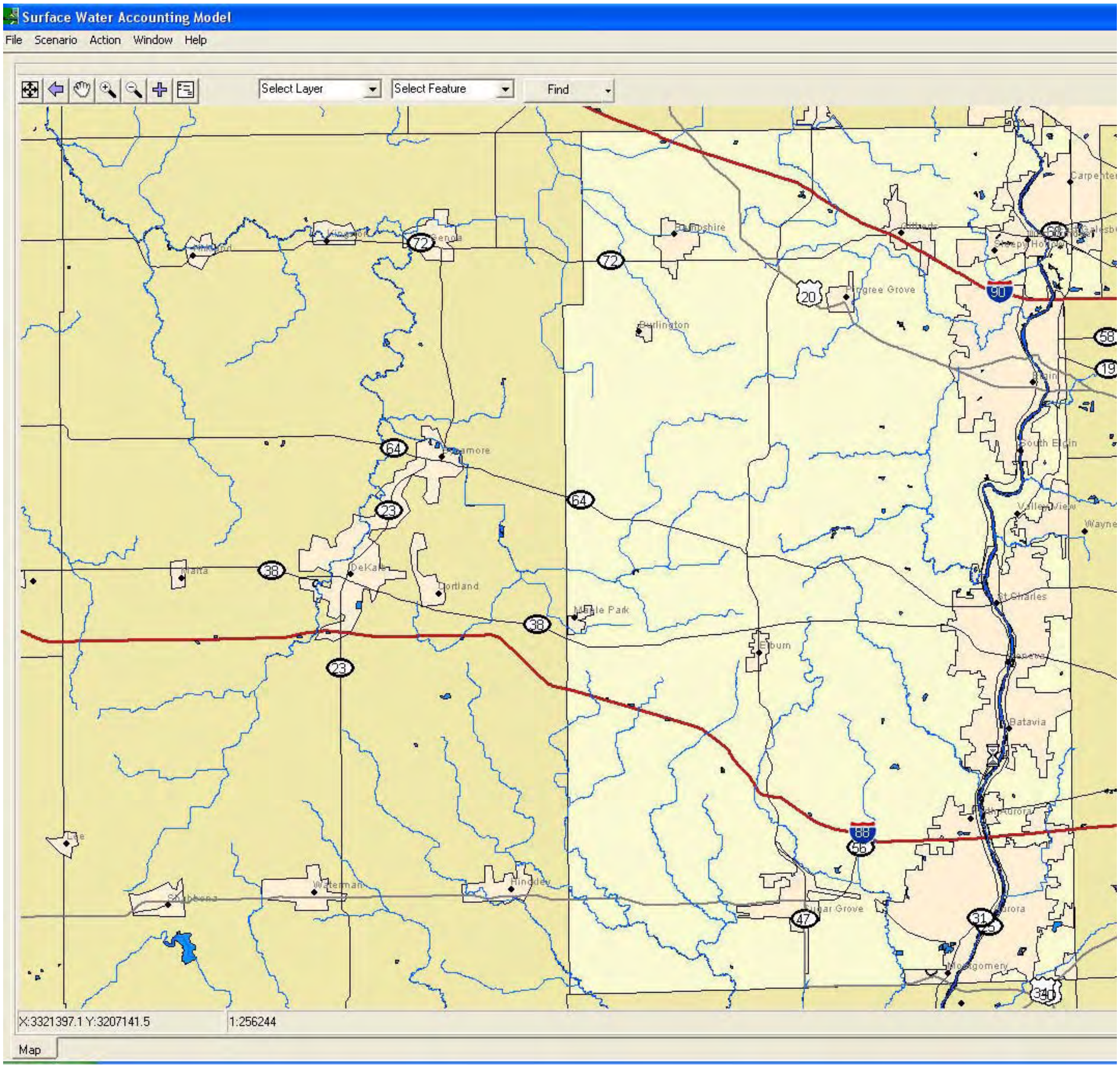


Figure 2. Opening screen of KC-SWAM

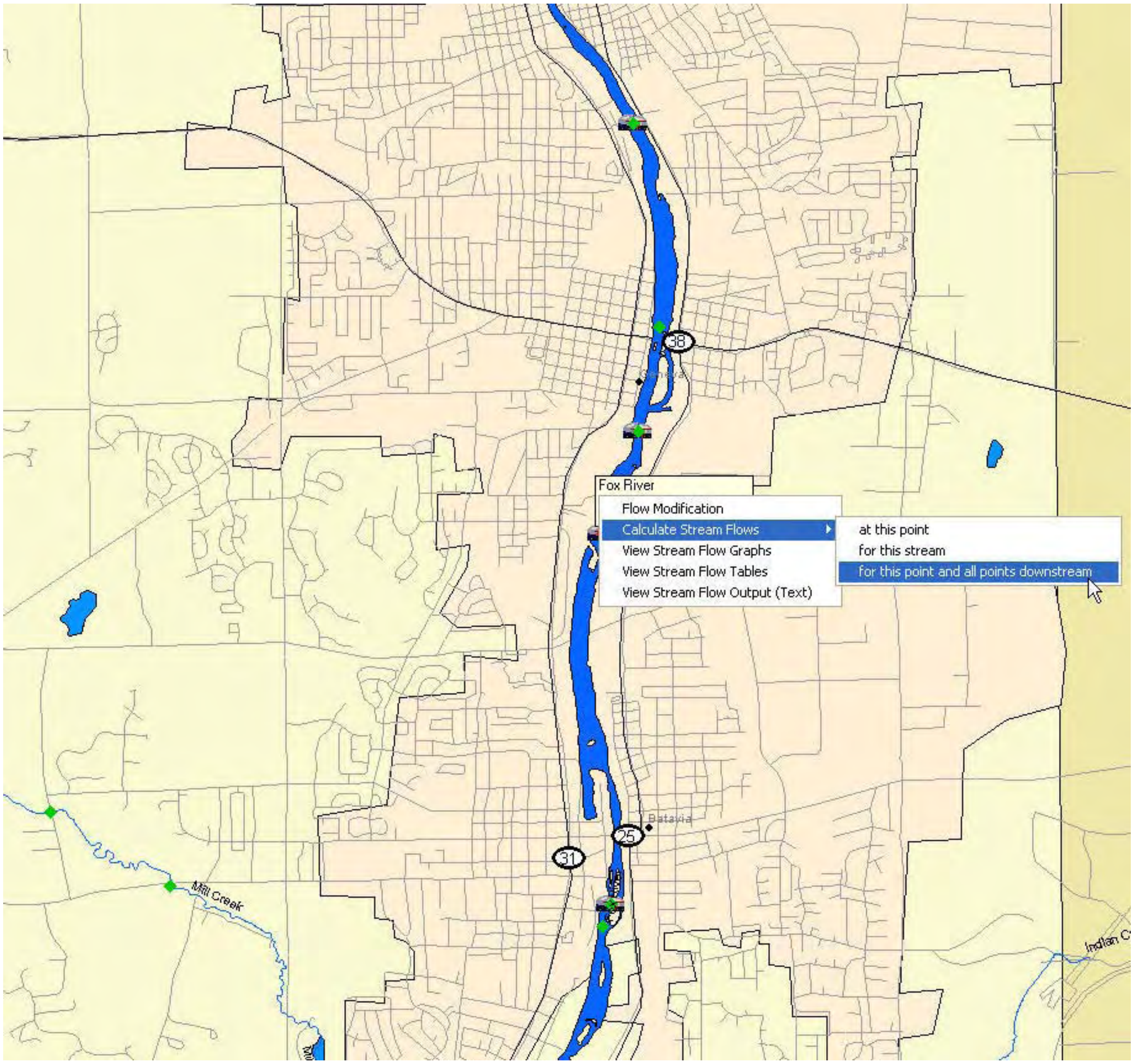
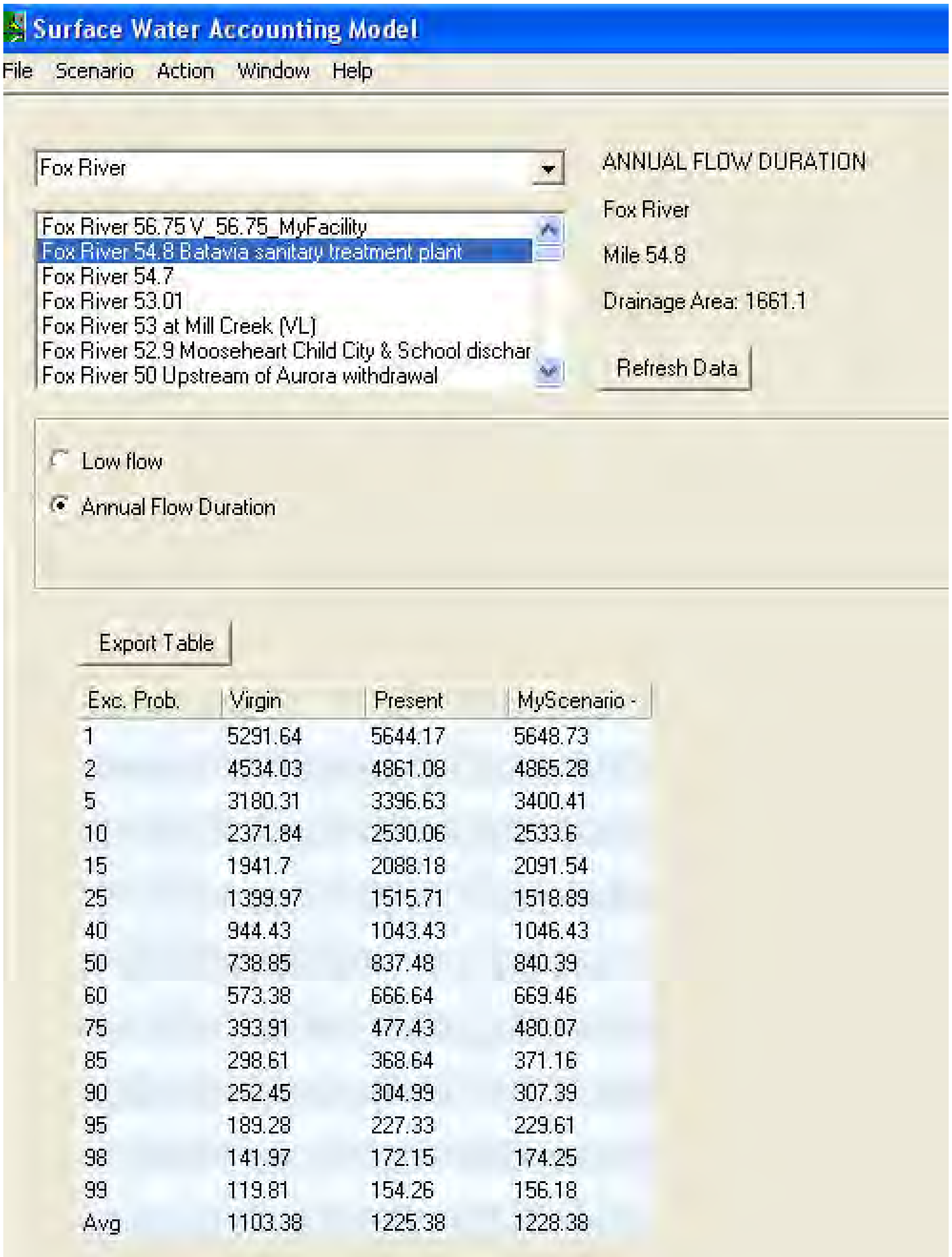


Figure 3. Screen of KC-SWAM showing options available for making flow calculations



Fox River

Fox River 56.75 V_56.75_MyFacility
Fox River 54.8 Batavia sanitary treatment plant
Fox River 54.7
Fox River 53.01
Fox River 53 at Mill Creek (VL)
Fox River 52.9 Mooseheart Child City & School dischar
Fox River 50 Upstream of Aurora withdrawal

ANNUAL FLOW DURATION
Fox River
Mile 54.8
Drainage Area: 1661.1

○ Low flow
● Annual Flow Duration

Exc. Prob.	Virgin	Present	MyScenario -
1	5291.64	5644.17	5648.73
2	4534.03	4861.08	4865.28
5	3180.31	3396.63	3400.41
10	2371.84	2530.06	2533.6
15	1941.7	2088.18	2091.54
25	1399.97	1515.71	1518.89
40	944.43	1043.43	1046.43
50	738.85	837.48	840.39
60	573.38	666.64	669.46
75	393.91	477.43	480.07
85	298.61	368.64	371.16
90	252.45	304.99	307.39
95	189.28	227.33	229.61
98	141.97	172.15	174.25
99	119.81	154.26	156.18
Avg	1103.38	1225.38	1228.38

Figure 4. Screen of KC-SWAM showing tabular output of flow characteristics

- *Input a new node into the model*. A new facility (effluent discharge or withdrawal) may be added. Note that KC-SWAM may restrict the user's ability to add new facilities on tributary streams so that scenarios are consistent with Kane County water planning goals — for example, planning goals may indicate that effluents should be piped to the Fox River instead of building wastewater treatment facilities on tributary streams.
- *Select stream locations for computation*. The flow computation will include not only virgin and present flows for selected locations, but also the altered flow condition based on changes made to existing and new facilities in the scenario.
- *View tables/graphs of virgin, present and altered flow characteristics.* For each selected stream location and set of flow parameters, a KC-SWAM table or graph compares virgin and present flows to the respective flows from each planning scenario.
- *Save the scenario for later use*.
- *Load a previously saved scenario*.

Once a scenario is saved, the model automatically computes and saves values for all database components affected by that change. When the model is instructed to calculate flows after the user has introduced one or more changes in facilities, model algorithms again will search for all identified modifications located upstream of the point of interest. In this case, however, new facilities or changes to existing facilities are identified and included in calculations.

Data Used in Hydrologic Analyses

USGS Daily Streamflow Records

Table 1 lists 14 streamgages in the Fox and Kishwaukee River watersheds within and near Kane County that have been operated by the U.S. Geological Survey (USGS). Figure 1 shows locations of most of these gages. Daily streamflow records from these gages provide primary data for analyses of flow characteristics for this study.

An understanding of uncertainties in daily flow records is necessary for reliable water supply planning and management, both to identify if flow estimates accurately represent available water in the stream and to evaluate significance of changes in low flow frequency and magnitude. Streamflows at a gage usually are estimated from a continuous measurement of the

Table 1. USGS Streamflow Gaging Stations on Streams Flowing through or from Kane County with at Least 4 Years of Continuous Discharge Records

USGS gage #	*Station name*	*Drainage area (mi^2)*	*Record length (years)*	*Period of record*
05438250	Coon Creek near Riley	85.1	21	1961-1982
05438500	Kishwaukee River at Belvidere	538	68	1939-present
05439500	South Branch Kishwaukee River near Fairdale	387	68	1939-present
05550000	Fox River at Algonquin	1493	92	1915-present
05550300	Tyler Creek at Elgin	38.9	9	1998-present
05550500	Poplar Creek at Elgin	35.2	56	1951-present
05551000	Fox River at South Elgin	1556	9	1989-1998
05551030	Brewster Creek at Valley View	14	4	2002-2006
05551200	Ferson Creek near St. Charles	51.7	47	1960-present
05551330	Mill Creek near Batavia	27.6	9	1998-present
05551540	Fox River at Montgomery	1732	5	2002-present
05551675	Blackberry Creek near Montgomery	55	9	1998-present
05551700	Blackberry Creek at Yorkville	70.2	47	1960-present
05552500	Fox River at Dayton*	2642	93	1914-present

Notes:

Present records extend through the end of September 2007. The period of record after September 2005 was not available during hydrologic analyses.

* Prior to 1925, this gage was located upstream near Wedron. Flow records from both gaging locations are considered to be equivalent.

stream's stage (water depth). Stage is converted to discharge using a stage-discharge relationship (rating curve) that must be calibrated using periodic measurements of flow amount. Flow measurements at each gage normally are considered good if within 5 percent of the actual flow amount, and, in themselves, usually are not considered a significant source of error in estimation of daily streamflows. The USGS flow measurements typically are scheduled at 6 to 8 week intervals, and the stage-discharge relationship can vary or shift between measurements. The amount of shift depends on flow condition and character of the stream channel, and is typically caused by either accumulated debris in the channel and floodplain or by scour and deposition of streambed materials. For estimating flows between two field measurements, a gradual change in shift over time often is assumed; however, there is usually no information to determine when shift changes actually occurred, or whether it was gradual or related to a single flow event.

Table 2 shows information on rating curve shift for selected gages, compiled from field measurements available on the USGS Waterwatch Web site (http://water.usgs.gov/waterwatch/). The shift, expressed in units of feet, indicates the amount of stage that should be added to a gage's standard rating curve to reflect streamflow at the time of measurement. Three computed statistics are presented in Table 2: 1) average shift change between successive measurements, 2) standard deviation in shift amount during the lowest 5 percent of measured flow conditions, and 3) average bias (difference from zero) in shift amount during the lowest 5 percent of measured flow conditions. Because of the water supply focus of this study, the emphasis was on field measurements collected during low flows. Note that, for most stations, the shift change from one

Table 2. Average Shifts in Rating Curves during Field Measurements at Selected Streamgages

Streamgage	*Average shift change between successive measurements, ft**	*Standard deviation of low flow shifts, ft*	*Bias in low flow shifts (difference in average shift from zero), ft*
Tyler Creek at Elgin	0.09	0.20	0.00
Poplar Creek at Elgin	0.12	0.13	-0.07
Ferson Creek near St. Charles	0.17	0.27	-0.14
Mill Creek near Batavia	0.35	0.06	-0.07
Blackberry Creek near Montgomery	0.24	0.43	-0.40
Blackberry Creek at Yorkville	0.22	0.22	-0.12
Fox River at Algonquin	0.06	0.03	-0.01
Fox River at Montgomery	0.05	0.03	-0.02
Fox River at Dayton	0.02	0.06	-0.03

Note:
* The average shift between successive measurements was computed from all 2003-2006 measurements at a site.

measurement to the next is comparable in magnitude to the standard deviation in shift amounts, indicating relatively little continuation or serial correlation in shift amount between measurements.

For large stable streams, such as the Fox River, shift amount tends to be small (less than 0.05 feet), particularly directly upstream of dams that control the rating. During most flow conditions, measured flows differ less than 5 percent from the standard rating curve. Only during the very lowest flow conditions do shifts at Fox River gages cause more than a 10 percent difference in estimated flow conditions.

A shift in the stage-discharge relationship of ± 0.1 to 0.2 foot is not unusual for smaller tributary streams such as those in Kane County. During high flow conditions, this shift amount usually does not affect flow estimates by more than 5 percent. During normal (median) flow conditions, the shift may affect flow estimates by about 20 percent. During low flows such as those occurring during drought conditions, however, shifts in the rating curve potentially can create more than a 50 percent error in flow estimates on these tributary streams. In addition, as noted in Table 2, there appears to be a negative bias in rating curve shift at many gages during lowest flow conditions. This suggests that, unless a field measurement during lowest flow conditions identifies this bias, actual flow in the stream would tend to be lower than the amount estimated using normal procedures.

2005 Low Streamflow Measurements and Observations

The 2005 drought provided a unique opportunity to observe the effect of drought on streamflows at ungaged streams throughout Kane County. During summer and fall 2005, four field trips to Kane County and nearby locations documented low flows. Without measurements and observations on smaller ungaged streams recorded during these trips, estimates of low flow frequency on these streams would have been based entirely on regional regression equations developed using data from USGS gages in north-central Illinois. Although there have been other miscellaneous flow measurements in the past at certain ungaged locations in the region, they typically have not been during the driest years that are necessary for accurate representation of drought conditions.

Table 3 lists ISWS flow measurements and approximations during the 2005 drought for stream locations in Kane County and downstream locations on streams that originate in the county. Flow approximations (estimates of flow by visual observation), provided in the latter part of Table 3, were made in lieu of flow measurements for locations with very low flow amounts (less than 0.1 cfs), where channel accessibility or other physical factors made flow measurement unfeasible, or where an approximation was considered sufficient for general flow characterization of the stream. Such flow approximations contain errors often as large as 50 percent. Low flow measurements and approximations were used as calibration guides in modeling shallow groundwater resources of the county.

Table 3. ISWS Low Flow Measurements and Approximations during the 2005 Drought

Location	*Date*	*Flow (cfs)*
Low Flow Measurements		
Tyler Creek at McCornack Road near Gilberts	7/14/05	0.05
	10/18/05	0.00
Big Rock Creek at West County Line Road near Hinckley	7/14/05	0.00
Big Rock Creek at Hinckley Road near Big Rock	7/14/05	0.00
Big Rock Creek at Granart Road near Big Rock	8/10/05	0.11
Big Rock Creek at Jericho Road	8/10/05	0.22
Big Rock Creek at Henning Road near Plano	7/14/05	3.6
Big Rock Creek at E. Main Street in Plano	8/28/03*	4.9
	8/10/05	6.5
Big Rock Creek immediately above Little Rock Creek near Plano	8/10/05	11.5
	10/19/05	10.3
Blackberry Creek at Main Street	10/18/05	0.89
Blackberry Creek at Finley Road near Sugar Grove	7/14/05	1.7
Blackberry Creek at Ka-de-ka Road near Spring Grove	10/18/05	1.57
Blackberry Creek at USGS Gage 05551700 at Yorkville	10/17/05	0.65
Bowes Creek at Corron Road near Bowes	8/11/05	0.00
Brewster Creek at Route 25 near Valley View	8/11/05	0.00
Coon Creek at New Lebanon Road in New Lebanon	10/18/05	0.27
Coon Creek at Base Line Road	10/18/05	0.00
Coon Creek at West Anthoney Road near Riley	10/18/05	4.9
East Branch of the South Branch Kishwaukee River at Brickville Road at Sycamore	10/19/05	0.99
East Run at Hankes Road near Sugar Grove	8/10/05	0.00
Ferson Creek at Burr Road near St. Charles	8/11/05	0.00
Fitchie Creek at Nestler Road	8/11/05	0.00
Hampshire Creek at State Street in Hampshire	10/18/05	0.00
Hampshire Creek at Allen Road near Hampshire	10/18/05	0.46
Hampshire Creek at Walker Road near Hampshire	7/14/05	3.9
Harmony Creek at West County Line Road	10/18/05	0.00
Little Rock Creek at Creek Road near Plano	8/10/05	0.00
	10/19/05	0.00
Little Rock Creek at US Hwy 34 near Sandwich	10/19/05	1.5
Little Rock Creek at mouth at Millhurst Road in Plano	8/28/03*	4.8
	8/10/05	5.4
Little Rock Creek at mouth at Millhurst Road in Plano	10/19/05	3.9
Mill Creek at Bride Creek Drive at Fox Mills	10/17/05	0.00
Norton Creek at Route 25 near Fox River Estates	8/11/05	0.00
Otter Creek near Waterford Drive near Elgin	10/18/05	0.21
Otter Creek at Happs Road	10/18/05	2.75
Poplar Creek at Sutton Road near Streamwood	8/11/05	0.00
Rob Roy Creek at Blackhawk Road near Plano	8/28/03*	1.34
	8/10/05	1.55

Table 3. (Concluded)

Location	*Date*	*Flow (cfs)*
South Branch Kishwaukee River at Highbridge Road near Union	9/9/05	0.10
Stony Creek at Crawford Road in Plato TWP	7/14/05	0.14
Stony Creek at Burr Road near South Elgin	8/11/05	0.00
	10/17/05	0.00
Union Ditch No. 3 at County Line Road near Maple Park	7/14/05	4.0
	10/19/05	0.7
Union Ditch No. 3 at Meredith Road near Virgil	10/19/05	0.12
Virgil Ditch No. 1 at Beith Road near Maple Park	10/19/05	0.00
Virgil Ditch No. 2 at Welter Road near Virgil	7/15/05	0.26
Virgil Ditch No. 2 at I.C. Trail near Virgil	7/14/05	0.21
	10/19/05	0.00
Virgil Ditch No. 3 at Winters Road near Virgil	7/15/05	0.30
	10/19/05	0.27
Welch Creek at Main Street near Kaneville	7/15/05	0.61
	10/19/05	0.09
Welch Creek at Granart Road near Big Rock	8/10/05	0.09
	10/19/05	0.00
Youngs Creek at Lasher Road near Hinckley	7/14/05	0.00
Low Flow Approximations (visually estimated flows)		
Big Rock Creek at Galena Road	7/14/05	0.5
Bowes Creek at Muirhead Road near Bowes	7/14/05	0.2
Burlington Creek at New Lebanon Road	10/18/05	1.0-1.5
Ferson Creek at Corron Road in Campton TWP	7/14/05	0.05
Fitchie Creek at Nestler Road	7/14/05	0.05
Fitchie Creek at Bowes Road	7/14/05	0.2
Indian Creek at Rural Street in Aurora	8/10/05	0.1
Lake Run at Hankes Road near Sugar Grove	8/10/05	0.1-0.2
Mill Creek at Brundige Road near Geneva	10/17/05	0.1
Mill Creek at Route 31 at Mooseheart	8/11/05	0.2
Otter Creek at Bowes Road near Elgin	8/11/05	0.5-1.0
Pingree Creek at Highland Avenue near Pingree Grove	7/15/05	0.01
Poplar Creek at Evanston-Elgin Road near Elgin	8/11/05	0.1
Poplar Creek at Route 25 in Elgin	8/11/05	5-8
Rob Roy Creek south of Jericho Road (culvert measurement)	8/10/05	0.6
	10/17/05	0.6
South Branch Kishwaukee River at Kruetzer Road near Huntley	7/15/05	0.01
Tyler Creek at Damisch Road near Gilberts	7/15/05	0.05

Note:
* Three discharge measurements from August 2003, included here, provided supplementary data for the hydrologic analyses

For many streams, 2005 low flow measurements and approximations listed in Table 3 are the only available data only for describing low flows. In most cases, these flow amounts were reasonably similar to (within 50 percent of) previously developed regional equations for a 10-year low flow condition (Knapp and Myers, 1999). In other cases, these flow amounts were noticeably different than regional flow estimates, indicating a need to modify regional estimates based on observations.

Water Use Records

Kane County and the Fox River watershed annual water use were obtained from the ISWS' Illinois Water Inventory Program (IWIP) for the period since 1980. Additional ISWS historical files contain periodic reports that include water use information for many communities dating back as early as 1900.

Figure 5 shows consistent growth in water use in Kane County since the late 1940s based on IWIP data. Over the 20-year 1984-2004 period, average water use in the county rose from about 35 million gallons per day (mgd) to more than 55 mgd, an increase exceeding 57 percent. Water use during the 2005 drought year exceeded 58 mgd.

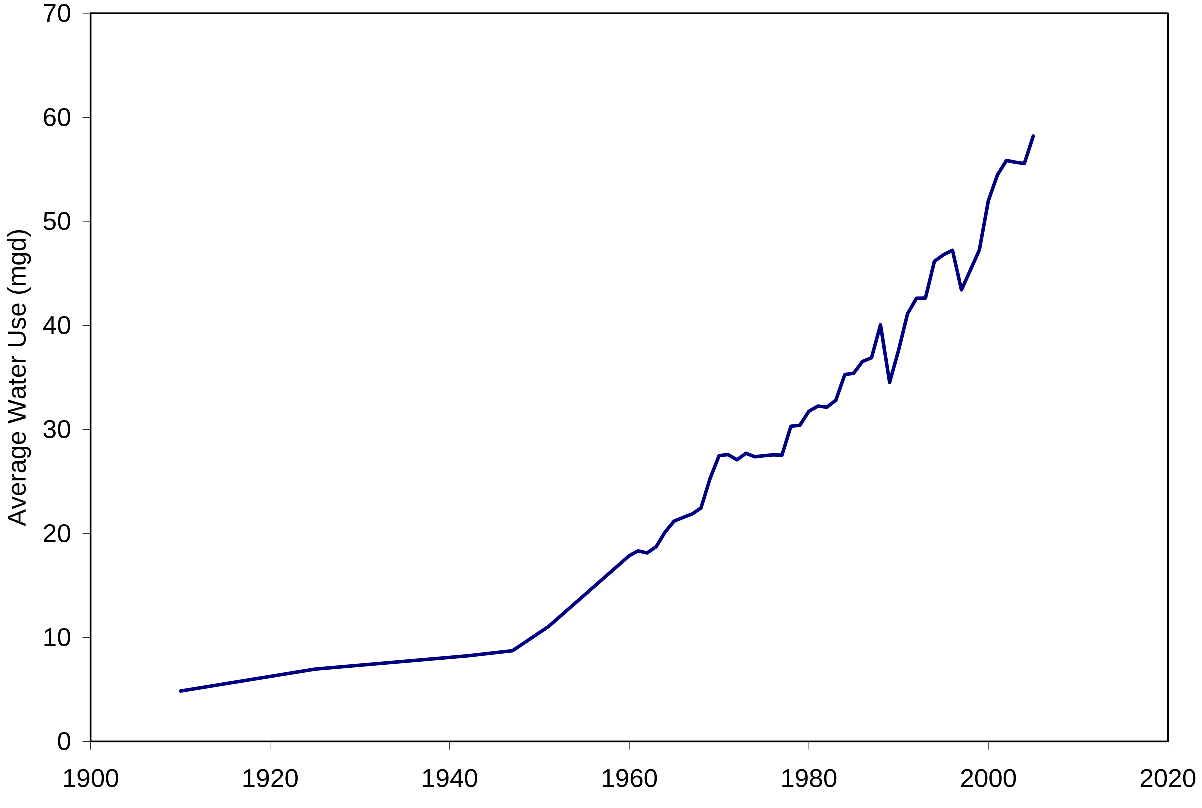


Figure 5. Historical trends in water use in Kane County

Table 4. Water Use for Aurora and Elgin

	Aurora water use (mgd)		*Elgin water use (mgd)*	
Year	*Fox River*	*Groundwater*	*Fox River*	*Groundwater*
1985	0.00	10.50	8.10	1.43
1993	6.70	6.75	10.69	0.95
1994	9.42	5.86	11.33	1.22
1995	9.88	5.69	11.86	1.05
1996	9.62	5.77	11.58	1.11
1997	9.31	6.06	12.23	0.98
1998	8.85	6.83	12.61	0.57
1999	8.78	7.28	12.39	0.78
2000	9.32	7.34	11.74	1.11
2001	10.99	6.85	11.90	1.27
2002	9.72	8.10	10.63	2.05
2003	10.20	7.51	12.50	0.65
2004	8.20	10.90	11.40	0.45
2005	7.46	11.65	12.93	0.45
2006	8.34	9.38	13.04	0.55

Water used in the region historically has been groundwater. But beginning in 1983, the City of Elgin began withdrawing from the Fox River, and most of that city's water now is obtained from the river (Table 4). Aurora began withdrawing water from the Fox River in 1993. Prior to 2004, the river supplied, on average, almost 60 percent of water used by Aurora, an amount reduced to slightly less than 50 percent in recent years. The total amount of Fox River withdrawals for the two water supplies has been fairly steady over the past 12 years, with an average of 21.4 mgd. Fermi National Accelerator Laboratory in Batavia also withdraws water, but this withdrawal is not continuous and ceases when the Fox River drops below 300 cfs.

In addition to annual water use, monthly and daily water use records were provided by three communities along the Fox River: Aurora, Elgin, and St. Charles. Water use from these communities provided sample data used to characterize seasonal and expected water use during drought and low flow periods.

Community water use in Illinois typically follows a well-defined seasonal cycle, as illustrated for the City of St. Charles (Figure 6). For six months of the year, November–April, community water use typically shows little variation. This base level of water use is also fairly consistent from year to year for most communities. As shown in Figure 6, monthly water use typically begins to rise in May, usually reaches a maximum monthly amount in July, and recedes into the fall season. Although various warm-season activities cause water use to rise in summer months, lawn and landscape watering (or irrigation) is expected to be the most influential factor. Summer water use also may vary considerably from year to year, with higher amounts during periods of low precipitation. For most communities in Kane County, the highest water use rates on record occurred during the 2005 drought.

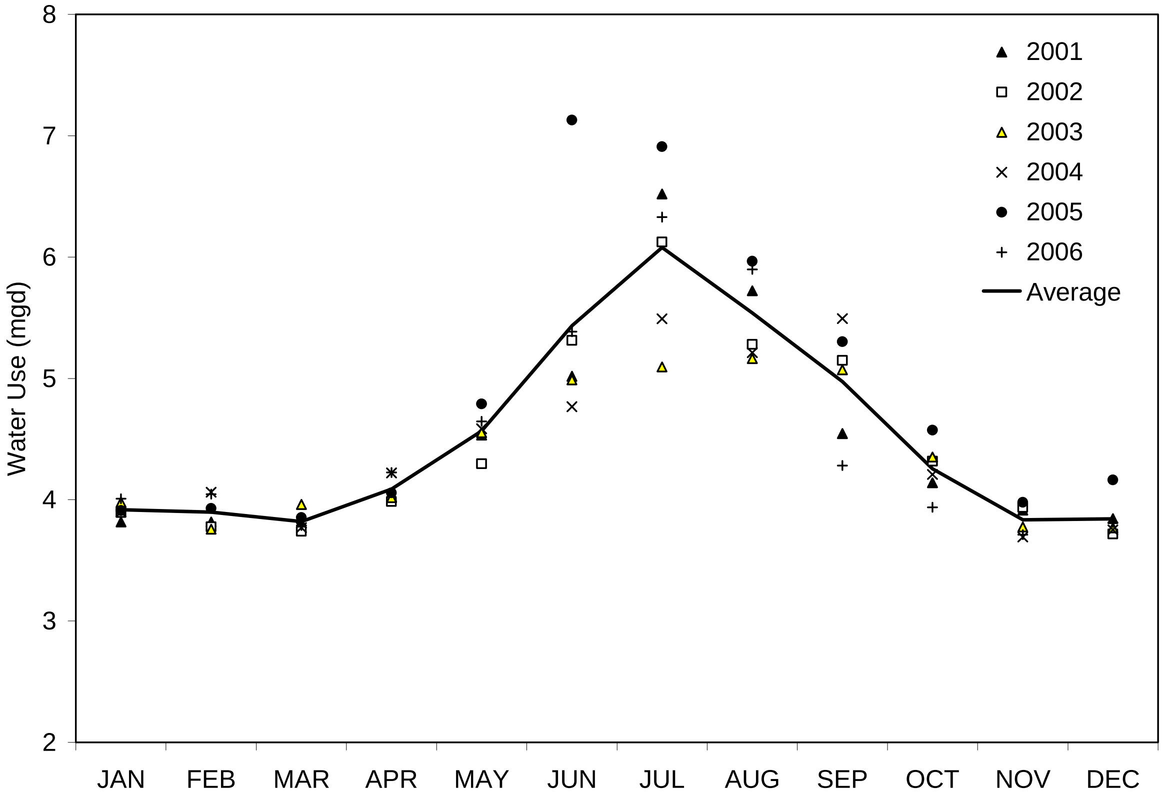


Figure 6. Seasonal differences in water use, St. Charles, Illinois

Table 5 compares total water use in July 2005 to average annual use and average July use for the three communities. For both Aurora and St. Charles, July 2005 usage was more than 20 percent higher than for an average July. Most commercial and industrial uses of water do not show the same seasonal variability; thus, communities with a strong industrial base may have a smaller percentage increase in water use during summer months. The amount of water used for lawn watering may be particularly great in newer subdivisions that lack mature landscaping.

Table 5. Water Use for Three Fox River Communities

Location	*Average annual use (mgd)*	*Average July use (mgd)*	*July 2005 use (mgd)*
Aurora	17.6	21.0	25.1
Elgin	13.0	15.5	16.8
St. Charles	4.5	6.0	7.1

Note:
Average annual and average July use computed using 2002-2006 data

Effluent Discharge Records

Monthly effluent discharge data for the 52 largest effluent discharges in the Fox River watershed in Illinois (those with an average discharge of at least 0.01 mgd) were obtained from the Illinois Environmental Protection Agency (IEPA) for 1998-2006. Table 6 lists effluent discharges, primarily from municipal wastewater treatment plants. Many of these plants are located outside Kane County in the Fox River watershed upstream and affect flow in the Fox River as it passes through the county. The average discharge of all effluents listed in Table 6 is 165 cfs (106 mgd). An additional average effluent of 55 cfs (35.5 mgd), not presented in Table 6, originates from the Wisconsin portion of the Fox River watershed, primarily from treated

Table 6. Estimated Effluent Discharges in the Fox River Watershed and Average Annual Discharge as Estimated using Data through 2006

Facility name	*Annual discharge (cfs)*	*Facility name*	*Annual discharge (cfs)*
Algonquin	4.38	Lake Barrington Homeowners	0.62
Antioch	2.23	Lake Holiday Utilities	0.04
Barrington	4.36	Lake in the Hills	4.93
Batavia	4.92	McHenry Central	3.47
Baxter Health Care-Round Lake	0.60	McHenry South	1.26
Carpentersville	3.64	Modine Manufacturing- McHenry	0.35
Cary	2.50	Montgomery	0.05
Crystal Lake #2	5.60	Mooseheart Child City & School	0.15
Crystal Lake #3	1.05	Morton Interntational-Ringwood	1.81
Earlville	0.47	Newark	0.19
East Dundee	0.78	Northern Moraine WRD	1.95
Elburn	0.88	Paw Paw	0.13
Ferson Creek Utilities	0.20	Plano	0.84
Fox Lake NW Regional	11.10	Quaker Oats Company	0.24
Fox Lake Tall Oaks	0.17	Richmond	0.39
Fox Metro WRD (Aurora)	48.24	Sandwich	0.96
Fox River Grove	1.40	Shabbona	0.15
Fox River WRD North (Elgin)	8.05	Sheridan	0.15
Fox River WRD South (Elgin)	24.32	Somonauk	0.19
Fox River WRD West (Elgin)	2.94	St. Charles-East Side	7.30
Geneva	5.90	St. Charles-West Side	0.52
Gilberts	0.16	Surgipath Medical Industries	0.09
Hinckley	0.30	Waterman	0.22
IL American Water-Terra Cotta	0.04	Wauconda	2.17
IL American Water-Valley Marina	0.40	Woodstock North	2.91
Intermatic Inc.	0.60	Yorkville-Bristol	1.89

Note: WRD = Water Reclamation District.

wastewaters originating from Waukesha, Wisconsin, and surrounding communities. Kane County's only major source of effluent discharge in the Kishwaukee River watershed is the Hampshire Sanitary Treatment Plant, with an average discharge of 0.72 cfs (0.46 mgd).

Table 7 lists changes in effluent discharge over the past 20 years from the 12 largest treatment plants in Illinois. The average effluent amount and effluents during low flow periods have increased by about 30 percent in the last 20 years.

In addition to collecting wastewaters from domestic, commercial, and industrial uses, sanitary sewers also accumulate water during wet periods, primarily as a result of groundwater leaks and stormwater inflow. Thus, the highest effluent discharges from wastewater treatment plants do not occur in summer when water use is highest, but instead during wet periods, typically occurring in spring months. Figure 7 shows monthly effluent discharge amounts for 2001-2004 at the St. Charles East Side sanitary treatment plant. Although average annual effluent discharge from the plant (4.7 mgd or 7.3 cfs) is very similar to average annual water use for St. Charles (4.5 mgd), seasonal differences between water use (Figure 6) and effluent discharge (Figure 7) indicate no direct correspondence between the two values. Only seasonal base levels in water use and effluent discharge (such as occurring for both in late fall), less than 4 mgd, represent comparable quantities.

Table 7. Comparison of Average and Q7,10 Effluent Discharges at the Largest Illinois Treatment Plants, Fox River Watershed

	Average discharge (cfs)			*Q7,10 discharge (cfs)*		
Location	*1984*	*1997*	*2006*	*1984*	*1997*	*2006*
Fox Metro WRD (Aurora)	37.9	44.4	48.2	26.6	30.6	32.0
Fox River WRD (Elgin)	27.0	30.0	35.3	20.9	19.9	27.5
Fox Lake NW Regional	8.4	10.3	11.1	5.4	5.4	7.6
St. Charles	6.3	7.5	7.3	4.6	4.6	4.9
Crystal Lake	5.2	6.9	6.7	3.4	3.4	4.4
Geneva	3.6	4.1	5.9	2.3	2.3	3.8
Lake in the Hills	0.9	3.0	4.9	0.5	2.4	3.6
Batavia	3.5	4.7	4.9	1.9	1.9	3.0
McHenry	3.0	4.2	4.7	1.9	1.9	3.3
Barrington	4.3	4.2	3.8	2.6	2.6	2.0
Carpentersville	4.3	4.0	3.6	2.3	2.3	2.6
Woodstock	2.7	3.8	2.9	2.8	1.8	2.0
Total (12 largest facilities)	107.1	126.1	139.3	75.2	79.1	96.7
Total (52 largest facilities)			165.6			111.0

Note: WRD = Water Reclamation District.

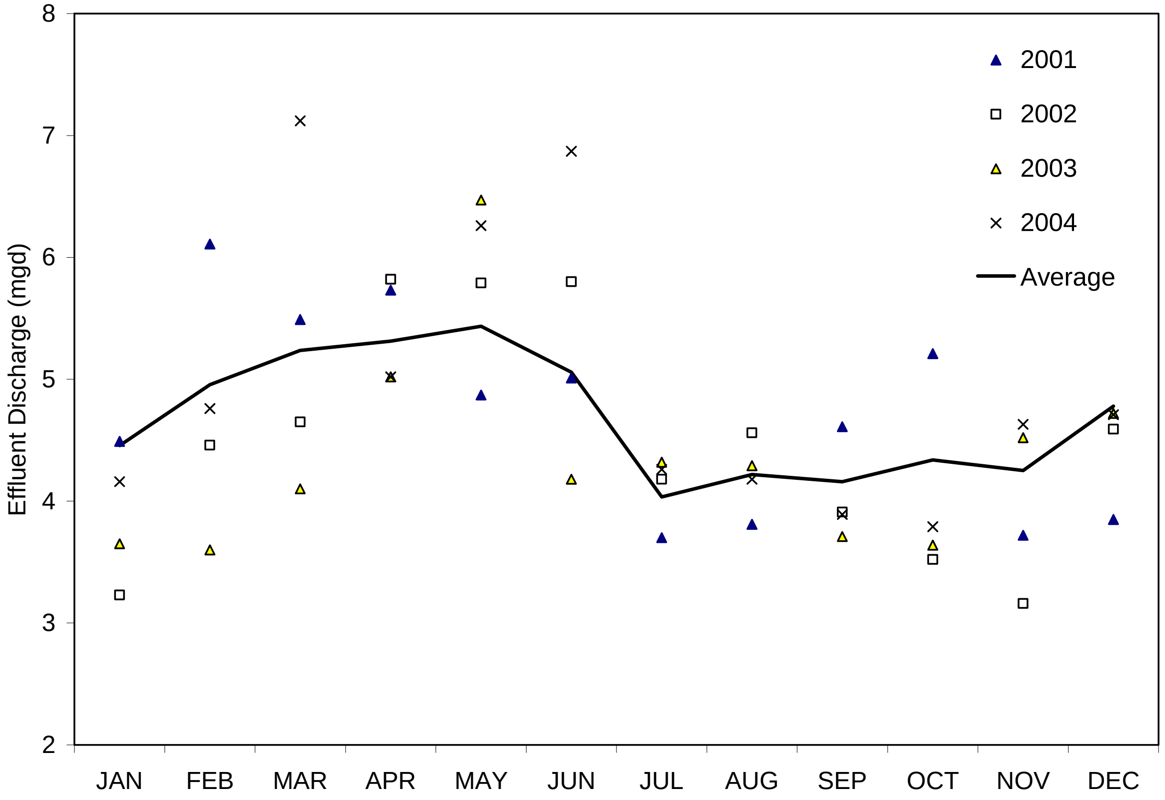


Figure 7. Seasonal differences in wastewater effluent discharge, St. Charles, Illinois

Climate Records

Annual precipitation data used to characterize climate variability primarily were obtained from the Midwestern Regional Climate Center (http://mrcc.sws.uiuc.edu/). Precipitation records selected to characterize long-term trends in the Fox and upper Illinois River watersheds had gaging periods of more than 80 years, with many records dating to the late 1800s. Long-term gaging locations selected for the Fox River watershed include Antioch, Aurora, and Ottawa in Illinois, and Burlington and Waukesha in Wisconsin. Additional gage locations for evaluating precipitation trends in the upper Illinois River watershed include Chicago, Galesburg, Griggsville, Peoria, Springfield, Watseka, and White Hall. The oldest precipitation records during the 19th Century were extracted from early climate summaries published by the U.S. Weather Bureau (1933).

Watershed Characteristics

Regional equations previously developed in ILSAM studies, beginning with Knapp (1988), have used an approach with three watershed characteristics in regional equations: drainage area, subsoil permeability, and average annual net precipitation (precipitation minus evapotranspiration). Databases for ILSAM in models for the Fox and Rock River watersheds already contained these measured attributes for many hundreds of locations in these watersheds, including about 150 locations in Kane County. In developing KC-SWAM, drainage area and net precipitation estimates from previous ILSAM versions were used. These attributes also were measured for an additional 57 locations in the Fox River watershed, specifically to improve the density of location information for streams in and near Kane County. To estimate drainage areas, watershed areas were delineated and digitized from USGS topographic maps and their areas computed using a GIS utility. Over several decades, volumes of average annual net precipitation and average annual streamflow are essentially equivalent in watersheds with no substantial influx or outflux of groundwater. Regional contours of net precipitation were developed for all locations using a combination of computed average annual streamflow from long-term records, average annual precipitation data, and regional estimates of average annual evaporation.

County soil surveys provide the most useful information for characterizing subsoil permeability within the watershed. For each soil type, permeability of the lowest soil layer is used to estimate subsoil permeability. If, for example, the permeability of the lowest soil layer is listed in the range of 0.2-0.6 inches per hour, a logarithmic mean value of 0.35 is used as the subsoil permeability. The logarithmic mean is used because soil permeability groups are classified based on a logarithmic scale, with the following typical class intervals: 0.06-0.2, 0.2-0.6, 0.6-2.0, and 2.0-6.0 inches per hour.

The most detailed soil information available in electronic form is the Soil Survey Geographic (SSURGO) database, produced by the Natural Resources Conservation Service. The SSURGO datasets are completed on a county scale and match the detail of the original county soil surveys. The SSURGO maps are linked to an attribute database that provides permeability of each soil layer and percentage of different component soils comprising each map unit. The SSURGO map units for this region typically contain a single predominant component. For those units consisting of 2-3 components a weighted average permeability is computed.

For development of the Fox River watershed model, eight counties in that watershed had SSURGO data completed: Cook, Lake, McHenry, Kane, DuPage, DeKalb, Will, and Lee Counties. For the remainder of the watershed, soil associations were digitized from the general soils map found in county soil surveys, and weighted average permeability values then were computed for each soil association.

Effect of Climate Variability on Streamflow

Climate and hydrologic records from the past 100 years in Illinois show considerable long-term variability. Figure 8 shows average precipitation and streamflow for the Fox River watershed since 1900, as expressed as moving 10-year average values. Precipitation and streamflow values plotted in Figure 8 represent the approximate midpoint of the 10 years being averaged; for example, the value for 1995 represents the average for 10 years from 1990-1999, the value for 1996 represents the average for the 10 years 1991-2000, and so forth. Streamflow values in Figure 8 from the Fox River gage at Dayton are expressed in inches of water spread uniformly over the entire watershed, such that average streamflow can be compared directly with precipitation for the concurrent period. Figure 8 shows that precipitation and streamflow in the Fox River watershed since 1970 have been considerably higher than at any other time in the 20th Century. Clearly, 10-year average streamflow is related very closely to concurrent precipitation, with a correlation coefficient (*r*) of 0.922. Precipitation and streamflow trends shown in Figure 8 are consistent with regional trends that affect northern Illinois and much of the upper Midwest (Knapp, 2005).

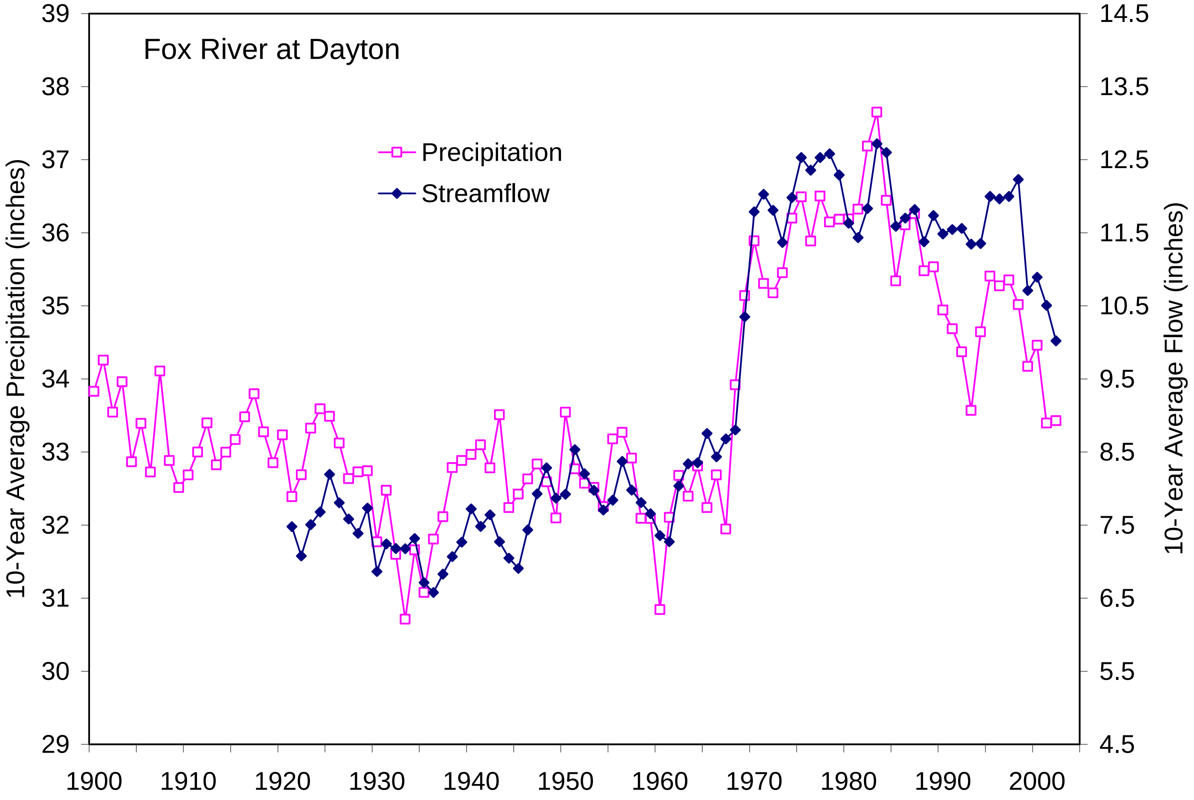


Figure 8. Comparison of 10-year average annual precipitation in the Fox River watershed (1900-2006) and streamflow measured for the Fox River at Dayton (1915-2006)

Table 8. Comparison of Average Precipitation and Average Streamflow for Four Selected Periods of Record, Fox River Watershed

Years	*Average Precipitation (inches/year)*	*Average Streamflow (inches/year)*
1915-2006	33.6	9.3
1930-1964	31.9	7.3
1970-1996	35.9	12.1
1948-2006	34.2	10.3

Table 8 compares average precipitation and streamflow for four separate periods of record at the Dayton gage: 1915-2006, the period of record for the gage; 1930-1964, an extended period of low precipitation and streamflow; 1970-1996, an extended period of high precipitation and streamflow; and 1948-2006, a base period often used by the ISWS for streamflow analyses because many long-term gages have records dating back to about 1948. For all periods, the difference between average precipitation and streamflow is about 24 inches per year, which is the average amount of water returned to the atmosphere through evaporation and plant transpiration. Average streamflow during the wettest period, 1970-1996, is 66 percent greater than during the driest period, 1930-1964. Average streamflow during the 1948-2006 base period is about 10 percent greater than for the entire 91-year gaging record, 1915-2006.

Figure 9 compares precipitation and streamflow for the upper portion of the Illinois River watershed, which covers much of northeastern Illinois and areas as far south as Peoria. For the larger Illinois River watershed, the relationship between precipitation and corresponding streamflow (Figure 9) appears to be even stronger, with *r* equal to 0.958. Prior to 1895, precipitation for the Illinois River watershed is estimated by precipitation records from seven individual gages that date back to 1870. These precipitation records show that averages during a decade of high precipitation in the late 1870s and early 1880s were of similar magnitude but shorter duration than high precipitation amounts during 1970-1995.

An examination of the three longest precipitation records for the Upper Mississippi River watershed (St. Louis, Missouri; St. Paul, Minnesota; and Prairie du Chien, Wisconsin), dating back to 1840, indicates another wet period in the 1840s and 1850s may have been comparable to 1970-1995 conditions. When viewed in this longer context, as shown in Figure 10, there is considerable variability in the precipitation record, but no overall long-term trend (Knapp, 2005). Because there is such a strong correlation between average precipitation and streamflow over historical records, it is reasonable to assume that the mid-1800s experienced high streamflow amounts. Therefore, increases in streamflow observed in the Fox River watershed (and much of the Upper Midwest) during the 20th Century, may not be an apparent long-term trend if available streamflow records also extended into the mid-1800s.

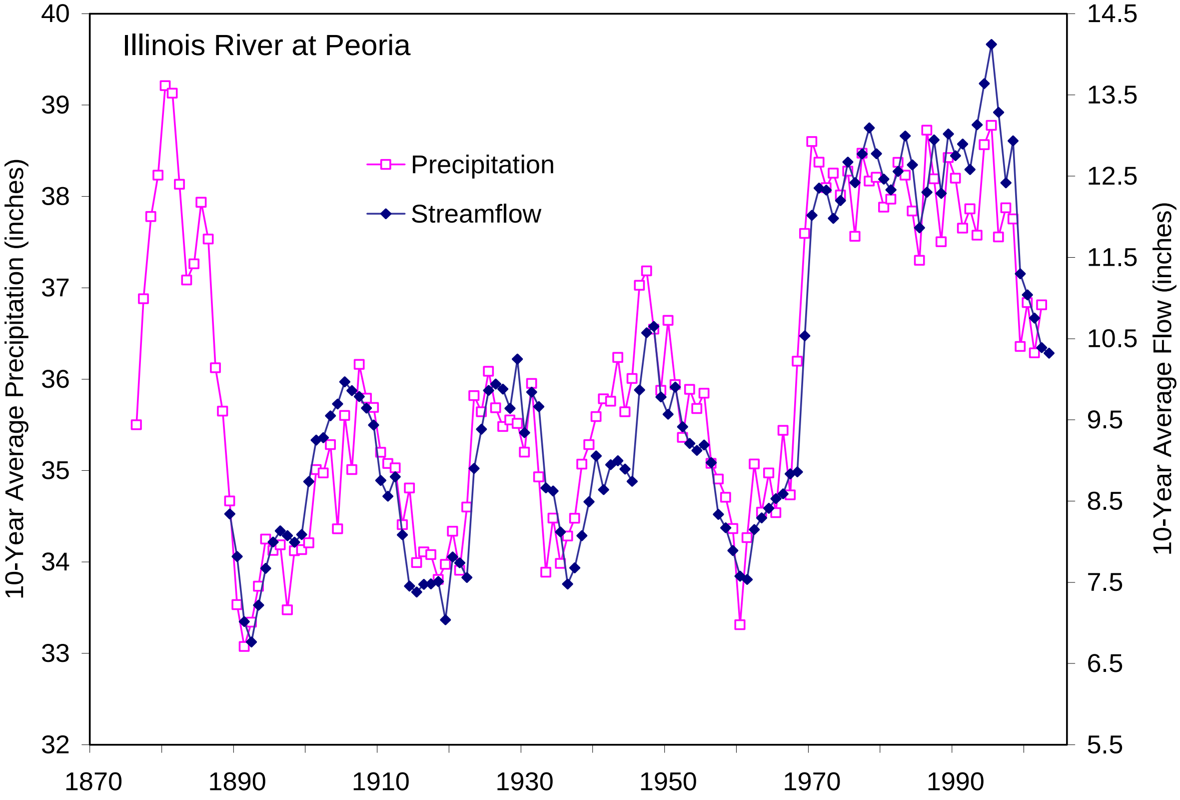


Figure 9. Comparison of 10-year average annual precipitation in the Upper Illinois River watershed (1870-2006) and streamflow measured for the Illinois River at Peoria and Kingston Mines (1884-2006)

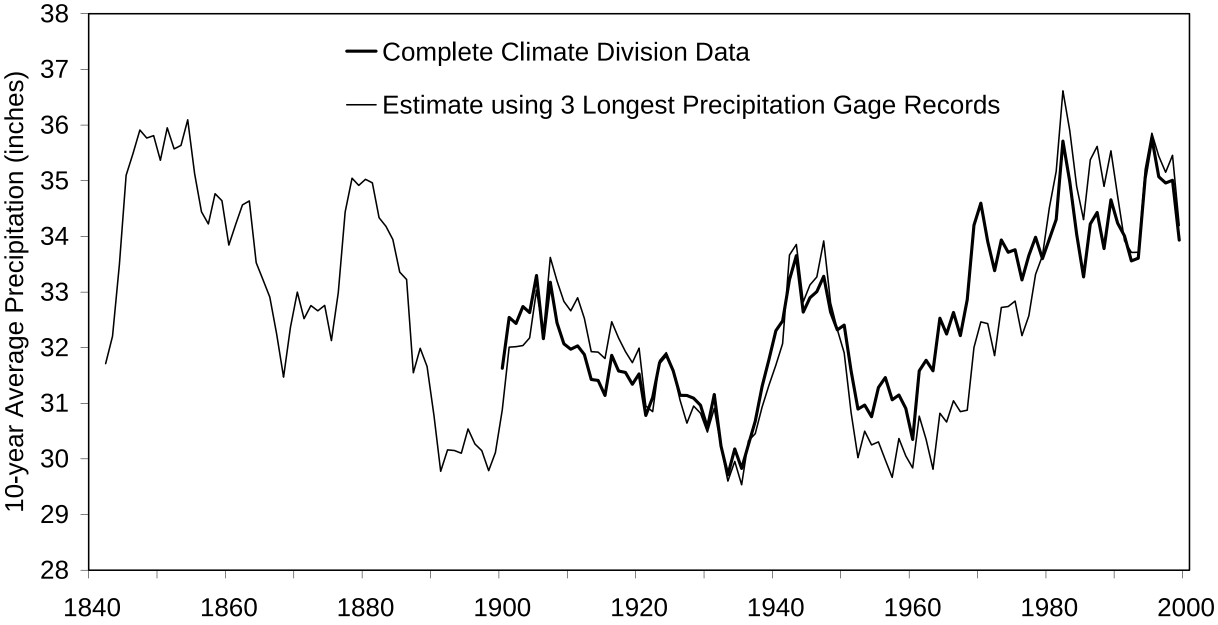


Figure 10. Estimated 10-Year average watershed precipitation, Upper Mississippi River watershed, 1840-2000 (from Knapp, 2005)

Figure 11. Locations of long-term streamflow gages (at least 89 years of record) showing statistically significant trends in mean annual flow in the eastern United States (from Knapp, 2005)

Locations of long-term gaging stations in the eastern United States with statistically significant trends in average streamflow are shown (Figure 11). Streamflow increases observed in the Fox River watershed over the past 100 years are part of a regional pattern covering northern Illinois and extending into Iowa, Minnesota, and parts of Wisconsin. Almost all flow records that have increases in mean flows also show proportional increases in normal (median) and low flow ranges (Knapp, 2005). Thus, if there is an increase in average precipitation, chances are very good that there also will be increases in low and median flows unless these flows are otherwise altered by human activity. Nearly all long-term flow records studied in Illinois, including that for the Fox River at Algonquin, have changes in annual maximum flows that are also proportional to coincident changes in mean flows (Knapp, 2005).

For defining frequency of events such as drought, the hydrologic record often is considered to be stationary in nature, i.e., no change in overall long-term conditions. As already shown, the hydrologic record is not stationary when viewed from one decade to another. But when viewed over the course of very long time periods, such as 150 years, it is unclear whether or not there is substantial change in long-term conditions. There is no certainty that future hydrologic conditions (not accounting for human modifications) would be substantially different than events in the historical record. For water supply planning purposes, if the hydrologic record is relatively stationary, severe droughts similar to those in the 1930s and 1950s would be expected to occur again in the future.

High 1970-1995 precipitation and streamflow amounts in northeastern Illinois have led many to speculate that climate change is causing an increasing trend in these variables that will continue into the 21st Century. There is widespread acceptance within the scientific community that global warming is occurring, and that Illinois probably will experience an undetermined temperature increase as a result. Effects of climate change, however, likely will not be uniform for all locations. For example, while global average temperature has increased during the last century, there are no trends in average temperatures in Illinois and a decreasing trend in temperatures for the southeastern United States (http://sws.uiuc.edu/atmos/statecli/Climate_change/ustrends-maps.htm). Quite possibly, high precipitation and streamflow amounts over the past 30 years may represent a regional effect of climate change, but it is also possible that these conditions are instead the results of normal climate variability that potentially could mask more subtle long-term trends related to climate change. Some global climate models predict a precipitation increase for the Midwest during the 21st Century, whereas other models predict precipitation decreases.

Scientists are not yet able to predict climate conditions for upcoming decades. The analysis of potential climate change impacts on water resources only can be understood by modeling expected hydrologic effects resulting from a wide range of potential climate change scenarios. Continuous-simulation watershed models can simulate potential impacts of such scenarios on streamflow conditions, such as for the Fox River (Knapp et al., 2004); however, most watershed models do not have sufficient physical basis for describing potential changes in groundwater-surface water interactions that contribute to low flows in streams under different climate conditions. Refining climate models to describe future climate scenarios and coupling of groundwater and surface water modeling are both necessary to develop a more complete understanding of potential impacts of climate change on water resources.

From both Figures 8 and 9, there appears to be a downturn in precipitation and streamflow amounts since 1995, perhaps suggesting an end to the previous period of high precipitation. Average precipitation and streamflow since 1995 is closer to the 100-year average condition than to high amounts from the previous 25 years. Despite the expectation that climatic and hydrologic conditions may not be stationary in the future, there is still a practical need to continue to use historical records from the past 100 years to determine sensitivity of surface water supplies to drought.

Human Factors Directly Affecting Streamflow Amounts

Three basic factors considered that directly affect streamflow amounts: 1) direct withdrawals from streams, 2) discharges into streams, and 3) reservoirs or other storage that detain and release streamflows. Other human factors that indirectly affect flow amounts, such as land use changes, are discussed in the next section of this report.

Factors Affecting Low Flows in the Fox River

In addition to the substantial effects of climate variability on natural low flow levels, discussed previously, three primary human factors affect the quantity of low flows in the Fox River: 1) operation of Stratton Dam in McHenry County, 2) substantial amounts of effluents discharged into the river and its tributaries, and 3) water supply withdrawals from the river. These factors are discussed below.

Stratton Dam Operations

Prior to 1965, summer pool elevations at Stratton Dam normally were kept at 0.1 foot above the dam's spillway level, or 0.3 foot below the current target level. As such, there was little surcharge storage (lake storage above spillway level) that provided for flow over the spillway during dry periods. Therefore dry-weather outflow from the dam typically was limited to releases from gates at the dam. From 1942 to 1958, there were six dry years when low flows fell to 50 cfs or below. In all these instances, water level at the dam fell at least 0.2 foot below the spillway. In 1956, the water level in the Chain of Lakes fell to 0.5 foot below the spillway, and, in response, most gates at the dam were closed in October, resulting in a daily flow release of as little as 3 cfs. At other times in the 1940s and 1950s, it is possible that low flows observed downstream of the dam at the Algonquin gage partially may have been from debris jams in the Stratton Dam gates, when the gate opening was as little as 0.05 foot.

Since the summer target pool was raised about 0.4 foot in 1965, there have been only a few instances, each lasting no more than a few days, when summer pool fell below the dam's spillway level. In 1988, the operation policy at the dam adopted a minimum gate opening of 0.10 foot (up from the previous policy level of 0.05 foot), providing a minimum flow release of about 94 cfs. The USGS flow record at Algonquin indicates that 7-day flows at the gage fell below this 94 cfs release level only two times since 1965 (see Table 9).

Knapp (1988) used a reservoir routing model (modified Puls method) to simulate outflow from the Chain of Lakes under the hypothetical condition of no dam downstream of the lakes. The estimated 10-year minimum flow under such circumstances would be about 85 cfs. For a 50-year drought, the estimated minimum flow would be about 46 cfs. Examination of Table 9 indicates that low flows between 1942 and 1965 at Algonquin, 17 miles downstream of Stratton Dam, were markedly lower than this estimate of "no dam" (or virgin) conditions. It is concluded that dam operation during this period suppressed downstream low flows in the Fox River. In contrast, the present minimum flow release of 94 cfs exceeds the 10-year virgin low flow at the dam. During severe droughts, in particular, the present operation policy of the dam is expected

Table 9. Lowest 7-day, 31-day, 91-day, and 6-month Flows, Fox River at Algonquin

Rank	*Year*	*7-day flow (cfs)*	*Year*	*31-day flow (cfs)*	*Year*	*91-day flow (cfs)*	*Year*	*6-month flow (cfs)*
Prior to 1965								
1	1956	19	1934	31	1934	47	1934	108
2	1934	21	1956	32	1946	79	1939	153
3	1942	35	1936	52	1958	93	1958	176
4	1939	44	1939	56	1931	97	1946	178
5	1936	49	1931	63	1948	106	1956	181
6	1948	50	1958	66	1936	108	1944	181
7	1946	51	1948	70	1932	118	1963	183
8	1953	52	1946	70	1956	121	1948	198
9	1931	57	1944	85	1963	128	1932	203
10	1958	73	1918	92	1939	131	1953	212
Since 1965								
1	1988	87	1965	115	2005	156	1966	265
2	1966	87	1966	121	1988	162	2005	286
3	1965	99	2003	126	1966	172	1976	308
4	2003	102	1988	128	1971	220	1971	311
5	2005	115	2005	134	1977	244	1988	335
10-year		106		130		154		234
50-year		84		96		108		180

to augment flows in the river above the "no dam" condition. Since 1965, flow amounts for the lowest 7- and 31-day events at the Fox River at Algonquin were all comparable; for example the five lowest 31-day flows since 1965 (Table 9) ranged from 115 to 134 cfs. These consistent flow amounts occurred as a result of low flow operation of the dam (from both summer pool level and minimum flow release). Whereas differences in drought severity do not affect minimum flow amount, they do affect the duration of minimum dam releases. During a 10-year drought, the minimum release may occur over a 4- to 6-week period before inflows allow lake levels to rebound. In contrast, flow levels during a 50-year drought may remain low for up to 4 months.

Although dam operation is the main factor determining amount of low flows downstream, the ability to maintain minimum flow releases over the course of a longer 25- or 50-year drought is only possible because of increased inflows into the Chain of Lakes. As a result of groundwater use in the Wisconsin portion of the watershed and subsequent release of treated wastewaters into the Fox River, primarily from Waukesha and nearby communities, low flows in the Fox River are currently augmented by 30-35 cfs. Without this additional inflow into the Chain of Lakes, normal pool level could not be maintained during a severe drought, which would be a hardship for the boating and recreation industry of the lakes.

Withdrawals and Wastewater Discharges

Lowest flow amounts in the Fox River typically are observed in late summer and early fall. Although water use is highest during mid-summer, it is also typically above normal during August and September low flow periods, such that river withdrawals during low flow periods often exceed those during normal periods. Figure 12 illustrates the relationship between monthly water use at Elgin and concurrent monthly flow rates in the river. During months when average flow in the Fox River is less than 300 cfs, average water use at Elgin is 14.45 mgd, about 11 percent higher than average annual water use at Elgin. In most cases, it can be anticipated that there will be above normal water demand during low flows and that projected impacts of withdrawals on low flows thus also will be greater than during normal periods. Although the overall water demand for Aurora during the 2005 drought period also was above normal, a greater amount of the water used was provided by groundwater. During September 2005, taste and odor problems related to algal growth in the river prompted Aurora to withdraw an average of only 6.1 mgd from the Fox River, less than one-third of the total water use for that month. Thus, in the case of Aurora, it cannot be concluded that greater water use at times of low flows will necessarily lead to corresponding increases in river withdrawals.

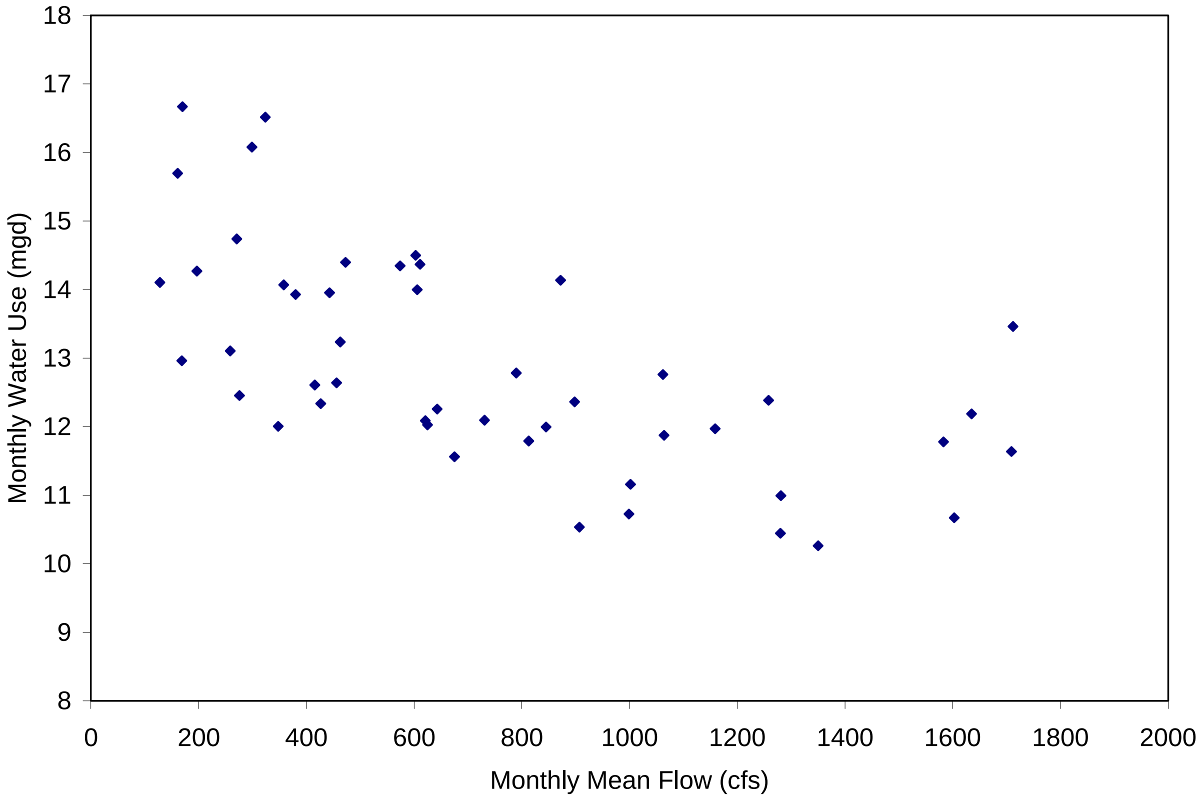


Figure 12. A comparison of monthly river withdrawals at Elgin and coincident flow upstream at Algonquin

Figure 13 shows changes in the 7-day, 10-year low flow on the Fox River from upstream of Algonquin Dam (north of Kane County) to near Yorkville (south of Kane County). Also shown is an estimate of the unaltered 7-day, 10-year flow, that being the condition withno withdrawals, discharges, or dams in the watershed. As the Fox River flows downstream from Algonquin to Yorkville its flow increases, and more than half of the gain is from addition of effluent discharges. Noticeable increases in present low flow amounts on the river occur with effluent discharges downstream of Elgin (Fox River Water Reclamation District South Plant) and Aurora (Fox Metro Water Reclamation District). Downstream of Yorkville, the gain in flow is almost entirely from natural tributary flows, with the biggest inflow from Big Rock Creek (not shown). Figure 13 shows two locations where the Fox River loses flow, these being for Elgin and Aurora water supply withdrawals.

The present 10-year low flow along the entire reach of the Fox River is consistently higher than the estimated unaltered low flow condition, even at Elgin and Aurora withdrawal locations, because of addition of wastewater effluents from communities. Thus, the overall impact of discharges and withdrawals is to increase low flows in the river, with the overall increase of 47 cfs in the 7-day, 10-year low flow at the mouth of the river. Withdrawals for community supplies (Elgin and Aurora) have reduced low flows slightly in the river since the early 1980s.

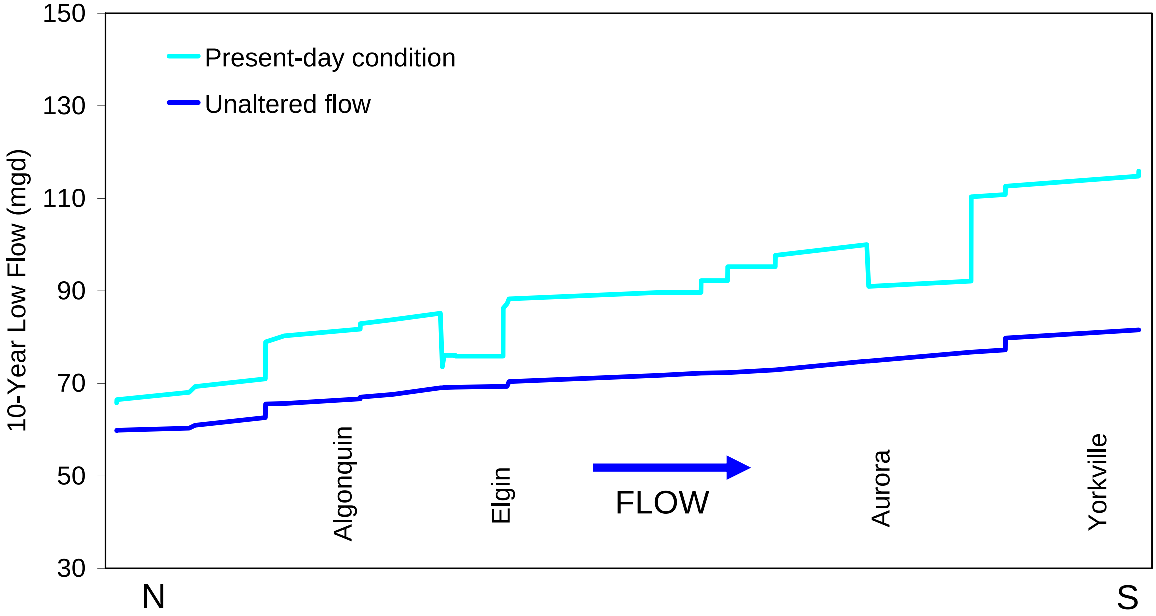


Figure 13. Profile view (north to south) of 7-day 10-year low flows on the Fox River in the Kane County region

Future Changes in Direct Human Effects on Flows

Dziegelewski et al. (2005) forecast that average water use in Kane County will increase over the next 20 years by about 30 mgd, an increase of 47 percent over the year 2000 water use amount. Most of the projected increase is associated with public water supply in response to population growth. It is expected that growth in water use will be supplied from various sources yet to be determined, much of it from groundwater, but also with the potential for additional withdrawals from the Fox River. Most treated wastewater associated with this water use growth is expected to be discharged to the Fox River. As a result, it is likely that the overall amount of flow in the Fox River will increase over time, although local effects on low flows will depend on location and magnitude of specific wastewater discharges and potential water supply withdrawals. KC-SWAM provides a planning tool for pre-examining potential effects of various future growth scenarios on low flows — scenarios that can examine effects of both the potential expansion of existing facilities and potential locations for new facilities. The model only identifies potential effects on flow magnitude, not water quality, another factor that must be examined when determining practicality of future growth scenarios. Future viability of the Fox River and its tributaries for environmental and recreational uses also must be considered when evaluating additional direct withdrawals from the Fox River.

Human Factors Indirectly Affecting Streamflow Amounts

Human factors that modify hydrologic processes that generate runoff and baseflow into streams are considered to have indirect effects on streamflow amounts because these factors do not directly add or subtract flow from the stream. Such factors potentially include: 1) groundwater pumpage within a watershed, particularly from shallow wells near a stream; 2) land cover changes, including urbanization, afforestation/deforestation, and changes in agricultural practices; and 3) development of recharge zones and stormwater detention facilities and other practices that affect runoff and infiltration. Primary concerns regarding indirect human impacts often are related to urban and residential development.

Whereas the impact of land use and runoff detention on flood magnitudes often is calculated using hydrologic models, those cause-and-effect relationships for low flow conditions are more difficult to determine. In an extensive review of literature on low flow hydrology, Smakhtin (2001) found no relevant studies about effects of agricultural practices on low flows. In reviewing urban impacts on low flow trends, Hejazi and Moglen (2006) indicated that available studies are a “mixed bag,” with urban streams in some studies having decreased low flows while other studies have streams with increased flows or no trend. For example, Smakhtin (2001) cited three studies indicating that urbanization is expected to reduce low flows in streams (by decreasing infiltration to shallow groundwater); but Meyer (2005) indicated that the lowest flows in urban streams in northeastern Illinois tend to be greater than for similar rural watersheds in surrounding areas. In many suburban areas, for example, lawn watering artificially increases soil moisture, which ultimately affects infiltration and recharge of shallow groundwater, and thus could increase low flows.

In concept, indirect effects on streamflow conditions (both high and low flows) are more likely to be observed in smaller watersheds where individual impacts are concentrated, as opposed to larger watersheds potentially affected by a greater variety of factors, for which individual impacts may be difficult to distinguish. Regardless of watershed scale, however, effects of climate variability also must be considered in analyses of indirect human impacts on low flows, as climate typically is the dominant source of flow variability in streams and often can mask effects of other factors (Knapp, 1994).

Any analysis of indirect effects of human factors on low flows also should avoid using watersheds already experiencing direct impacts of withdrawals, discharges, or reservoirs. For tributary streams in Kane County, there are no known withdrawals and relatively few wastewater discharges. The three largest wastewater discharges in tributary streams are at the Villages of Elburn and Hampshire into Welch and Hampshire Creeks, respectively, and the St. Charles West Side treatment plant at Fox Mill (Mill Creek).

Three gaging records on tributary streams with 45 or more years of record (Poplar Creek at Elgin, Ferson Creek near St. Charles, and Blackberry Creek at Yorkville) were examined to determine any noticeable changes in flow regime over the period of record. Two 10-year periods within each flow record were selected that had about the same average flow amount, in an effort to minimize effects related to climate variability. The first period selected was near the start of the gaging record, and the second was near the end of the gaging record. The two 10-year periods selected for this comparison were 1965-1974 and 1996-2005 for the Poplar Creek record; and 1964-1973 and 1996-2005 for the Ferson and Blackberry Creek records. Flow statistics from those earlier and later periods (Table 10) were compared to identify systematic changes in flow characteristics. The Poplar Creek flow record did not provide an ideal comparison because during much of the 1965-1974 period there was a wastewater treatment plant upstream at Streamwood. It was, however, this was the only 10-year period with similar overall flow amounts to the later period. Urbanization was most extensive in the Poplar Creek watershed. In addition to having less development, the Ferson and Blackberry Creek watersheds also have comparatively greater natural baseflows.

In general, frequency characteristics of daily streamflow in Table 10 were similar for the two time periods in the medium flow range between 30 and 70 percent exceedence levels. The very highest flows (1 percent exceedence and above) were noticeably greater at all three gages during 1996-2005. These observations are consistent with an analysis of causes of increasing trends in flooding in northeastern Illinois streams that identified urbanization and increases in magnitude and frequency of heavy precipitation events as contributing factors in these trends (Markus and McConkey, 2007).

Table 10. Comparison of Flow Statistics between Two 10-year Periods, At Poplar, Ferson, and Blackberry Creek Streamgages

	Poplar Creek		*Ferson Creek*		*Blackberry Creek*	
Flow statistic (all flows in cfs)	*1965-1974**	*1996-2005*	*1964-1973*	*1996-2005*	*1964-1973*	*1996-2005*
Average flow	30.3	30.6	38.5	41.0	50.2	51.5
Minimum daily flow	0.7	0.5	0.2	1.1	2.5	0.32
99% exceedence	1.0	0.7	0.8	1.7	4.6	1.1
95% exceedence	1.9	1.3	1.6	3.7	7.1	5.4
90% exceedence	2.5	2.0	2.4	5.7	9.0	9.4
80% exceedence	3.2	3.5	5.4	8.7	13	13
70% exceedence	5.8	5.9	9.3	11	17	17
60% exceedence	9.3	8.7	14	15	22	22
50% exceedence	14	13	19	20	28	28
40% exceedence	21	18	26	27	36	38
30% exceedence	32	26	37	36	51	48
20% exceedence	46	37	52	50	72	65
10% exceedence	75	68	86	85	110	102
5% exceedence	110	127	126	140	159	153
1% exceedence	212	306	332	371	321	380
2nd highest peak	797	882	1700	1990	1300	2040
Highest peak flow	896	1180	1970	2580	1320	5510

Note: * Wastewater effluent affected low flows

The three gaging records show considerably different responses in low flow conditions between the two time periods. For Blackberry Creek, flows in the lowest 10 percent of the 1996-2005 record were substantially lower compared to those in 1964-1973. Lower flows in the 1996-2005 period cannot just be attributed to the 2005 drought, as low flows also occurred in 1997, 2001, and 2003. These observations suggest that there may be a decreasing trend caused by human factors, although there is no firm evidence to that effect.

In contrast, the 1996-2005 period at the Ferson Creek gage showed substantially higher low flows than the earlier 1964-1973 period. The source of this increase in low flows was not obvious, but residential and commercial development in southwest Elgin partially may be responsible. For example, irrigation of lawns in new residential developments significantly can increase water use during dry periods. Given that the comparative increase covers a broad range of flow conditions, with exceedence probabilities greater than 70 percent, lawn irrigation may not be the sole or primary factor involved in this increase.

For the Poplar Creek flow record, low flow characteristics for 1996-2005 were fairly similar to those for 1965-1974. Despite the similarity in flow amount, there was at least one difference between the two periods, however. In the late 1960s and early 1970s, a wastewater treatment plant at Streamwood was discharging approximately 2 cfs into the South Branch of Poplar Creek. During dry periods, some of that wastewater would have been expected to infiltrate into the streambed, resulting in lower flows at the gage downstream. Nevertheless, it is likely that “unaltered” low flows for 1965-1974 (without wastewater) would have been noticeably lower than those shown in Table 10. Thus, it is not unreasonable to assume that unaltered low flows for 1965-1974 were lower than those for 1996-2005, although specific estimates cannot be provided.

Meyer (2005) studied baseflow levels at several northeastern Illinois streams and concluded that, while there were no widespread trends in base flows, there did appear to be an increase in lowest flow conditions. The flow comparison for Poplar Creek, the most urban of three watersheds examined, appears to be most consistent with those findings. In contrast, the Ferson and Blackberry Creek comparisons are widely different, with Ferson Creek displaying a substantial increase in low flows and Blackberry Creek displaying a substantial decrease. These trends must be revisited in the future with additional supportive data, particularly the Blackberry Creek trend that potentially could identify a reduction in groundwater contribution for that stream.

In analyzing potential trends associated with these records, it also must be recognized that estimates of low flow quantity have considerable uncertainty and potential biases as discussed in “Data Used in Hydrologic Analyses: USGS Daily Streamflow Data.” At any individual gaging location, these uncertainties and biases could invalidate or reduce the significance of apparent trends in low flows. Thus, collaborative evidence from several other locations should be used to verify potential trends. For the interim, however, analysis of available data does not provide conclusive results for estimating urban impacts on low flow amounts. Therefore, KC-SWAM does not adjust flow estimates to account for potential urbanization impacts.

Additional Flow Characteristics of Kane County Streams

This section provides general descriptions of selected streamflow characteristics in Kane County without specific regard to flow modifications and other analytical procedures included in KC-SWAM. Descriptions presented provide the reader with a basic understanding of flow character in the region. These observations of flow characteristics at USGS streamgaging records are reflected in streamflow frequency and exceedence probability values computed by KC-SWAM for those gages.

Annual Variability in Streamflow

Figure 8 illustrated that there potentially can be more than a 50 percent difference between average streamflow observed during two different 10-year periods. On an annual or seasonal basis, however, streamflow differences between any two time periods are typically considerably greater. Figure 14 shows annual streamflow (runoff) for the two gages on the Fox River in Illinois at Algonquin and Dayton. Long-term average streamflow for the Fox River watershed is 9.3 inches per year, but annual runoff has ranged from a low of 1.7 inches in 1934 to a high of 20 inches in 1993.

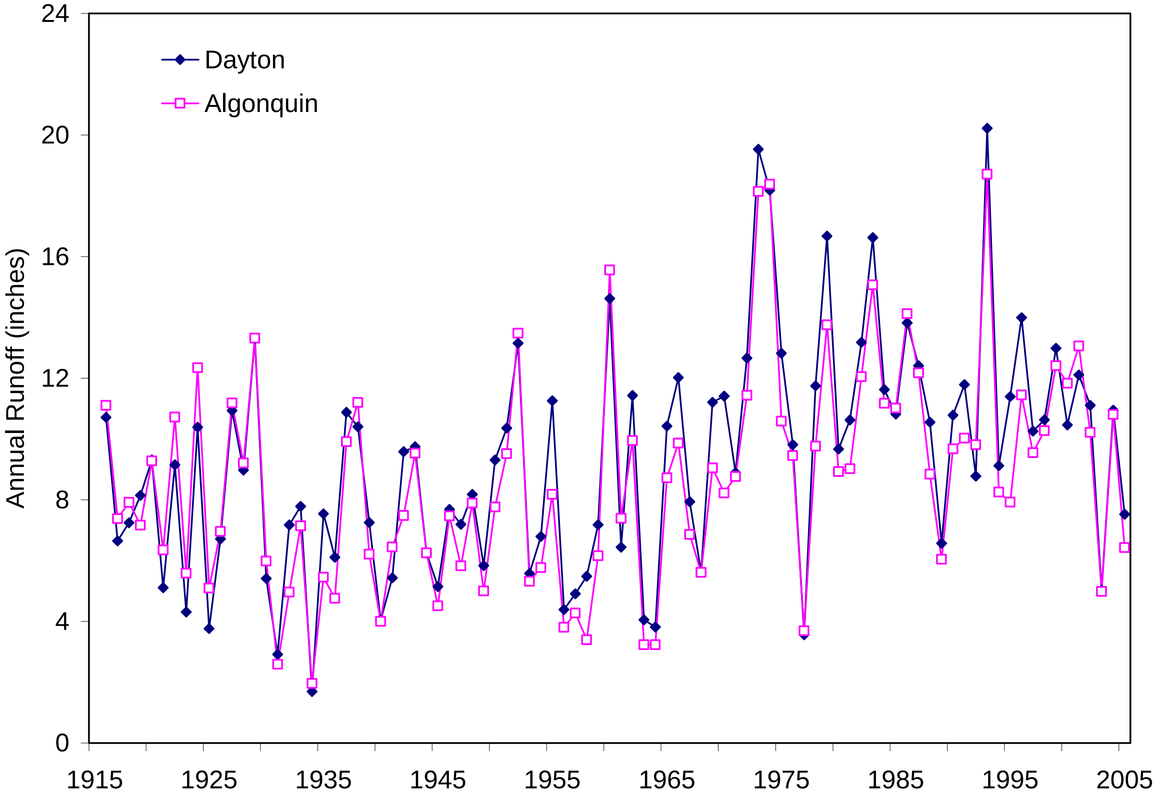


Figure 14. Annual runoff for the Fox River measured at the Algonquin and Dayton gages, 1916-2005

Figure 15 compares exceedence probabilities of daily streamflow characteristics for the Fox River at Dayton for four separate years of record: 1) 1934, the driest year on record; 2) 1993, the wettest year on record; 3) 1994, a "normal" year with total runoff of 9.1 inches; and 4) 2005, the year of the recent drought with a total runoff of 7.5 inches. Also shown are composite flow frequency values for the 90-year Dayton flow record (1915-2005). Flow rankings and percentiles used in Figure 15 and throughout this report were computed from highest to lowest flow values, such that the lowest 1 percent of daily flow values (that occur only 3.65 days during the year) have a 99 percent chance of exceedence.

A comparison of the 1934 and 1993 flow frequency curves in Figure 15 shows that the highest flows during the 1934 drought were of similar magnitude to the lowest flows during 1993, the wettest year. The composite flow exceedence curve is similar to the 1994 "normal" year except for low flows (with exceedence probabilities greater than 90 percent), which tend to be clustered in drought years and do not generally occur in normal years.

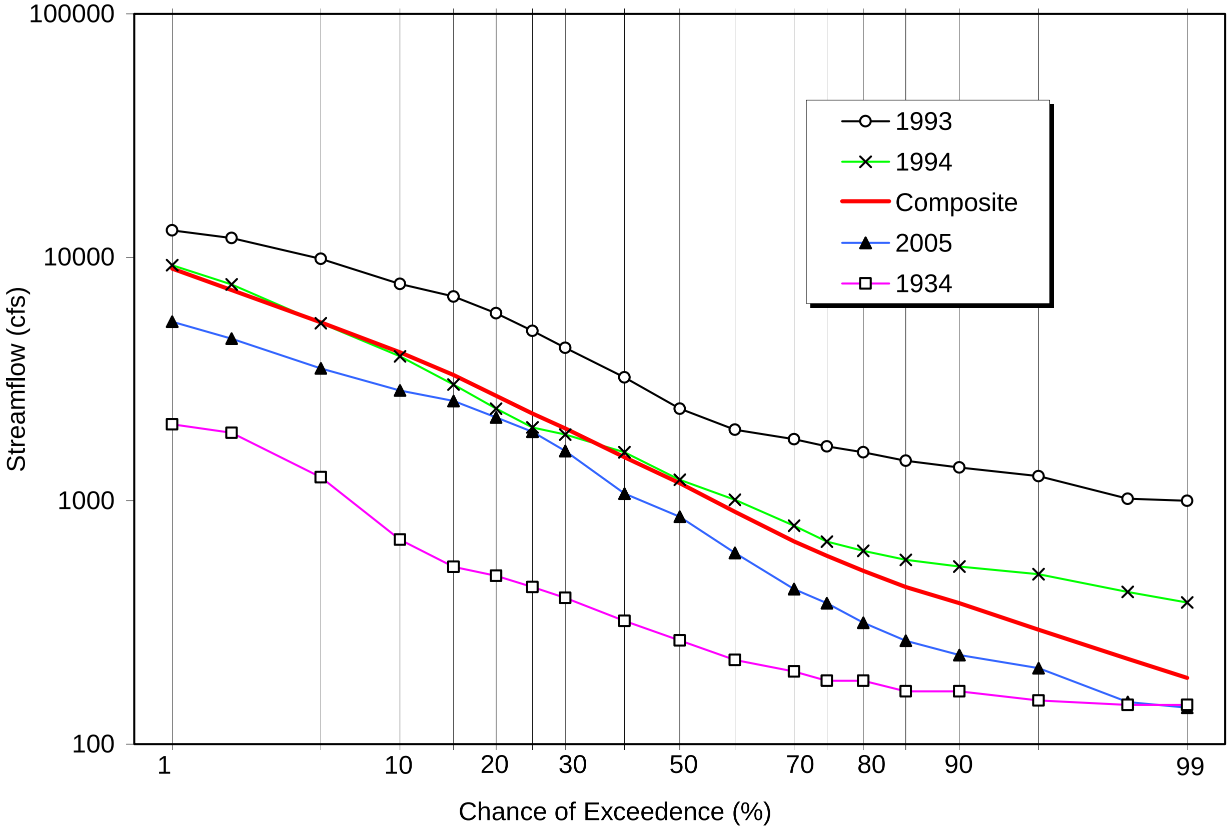


Figure 15. Exceedence probabilities of daily streamflows, Fox River at Dayton, 1916-2005 period of record (composite frequency) and four individual years of record

The 2005 year included a short period during which daily flows were estimated to be as low as those experienced in 1934, but the 1934 low flows occurred for several months that year. Flows in much of 2005 were typical of those during normal years. Because there can be considerable differences between dry years and most typical years, or between severe and moderate droughts, it is important that hydrologic analyses for water supply include the entire range of years experienced over long hydrologic records.

Figure 16 shows variability of annual runoff for the five gaged tributaries to the Fox River in Kane County: Blackberry, Ferson, Mill, Poplar and Tyler Creeks. The Mill and Tyler Creek gaging records began in 1998. Annual runoff varied from a low of less than 3 inches in 1963 to a high of 20 inches in 1993. The sequence of annual flows is similar for all tributaries, but there can be noticeable variation in runoff between gaging locations for any individual year. Over multiple years, however, differences in runoff between locations tend to diminish. Over the 7-year record (1998-2005), average runoff for most tributary streams is within 10 percent of the 5-station average (Table 11). Over the last 45 years (1961-2005), average annual runoff between the Blackberry, Ferson and Poplar Creek gages is within 4 percent of the 3-station average (Table 11). Comparatively small regional variability over the long-term hydrologic record permits accurate estimation of long-term average flow conditions for ungaged sites.

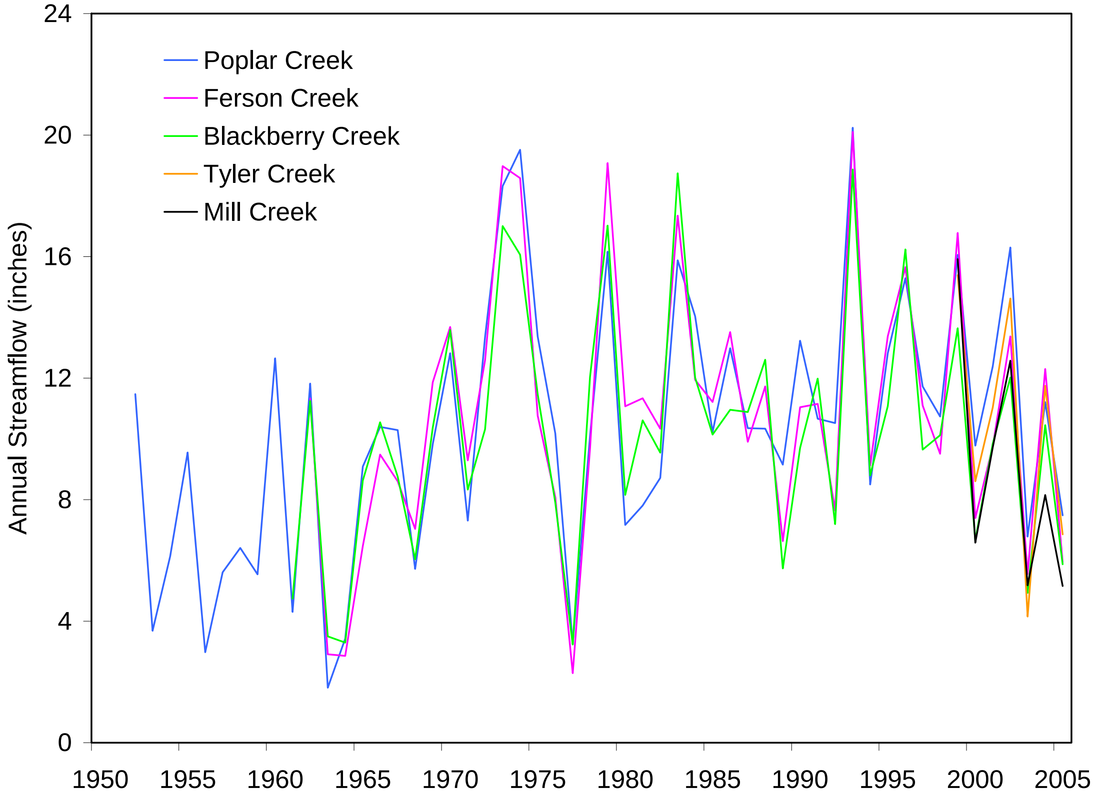


Figure 16. Annual runoff for Fox River tributary gages in and near Kane County

Table 11. Average Annual Runoff for Fox River Tributary Gages for Different Periods of Record

Location	*1951-2005*	*1960-2005*	*1998-2005*
Poplar Creek at Elgin	10.3	11.1	11.4
Ferson Creek near St. Charles	—	10.9	10.2
Blackberry Creek at Yorkville	—	10.4	9.1
Tyler Creek at Elgin	—	—	10.3
Mill Creek near Batavia	—	—	9.0
Average of all gages	10.3	10.8	10.0

Figure 17 compares exceedence probabilities of daily streamflow for 7-year flow records (1998-2005) at Mill Creek and Tyler Creek, 45-year records (1960-2005) at Blackberry Creek and Ferson Creek, and the 54-year record (1951-2005) for Poplar Creek. In comparing flow probabilities at locations, differences in streamflow magnitude primarily relate to watershed size at each respective gage; for example, the Blackberry Creek gage at Yorkville is on the largest watershed, and the Mill Creek gage near Batavia is on the smallest watershed.

Parallel flow exceedence curves for these five streams are indicative of regional homogeneity in stream hydrology. There are greater differences in curve shapes for the lower ends of the flow spectrum, however. If the lower tail of a flow exceedence curve slopes downward (Mill Creek), there is less sustained baseflow in the stream during drought periods, generally indicating a weaker hydrologic connection between shallow groundwater and the stream. A flattening of curvature in the lower tail (Tyler Creek) or an overall low gradient in the lower flow range (Blackberry Creek) is generally indicative of a stronger groundwater-baseflow relationship. In these latter cases, the connection between groundwater and the stream either could be localized or distributed throughout the watershed. On a regional scale, groundwater-baseflow relationships and the controlling near-surface geology often are related to physiographic divisions (Figure 1). But there is enough variability in the Kane County near-surface geology to obscure boundaries of these physiographic divisions, and observed low flow amounts in tributary streams appear to be more closely related to local variations in near-surface geology and local deposits of shallow sands and gravels.

Another factor that can affect shapes of flow exceedence curves is the period of record for each gage. Exceedence probabilities of daily streamflow records collected during a wet or dry period may not be representative of expected long-term stream conditions. Even if flow records are otherwise representative of normal conditions, the lower tail of the flow exceedence curve may not reflect expected long-term conditions if there is not a drought within the period of record.

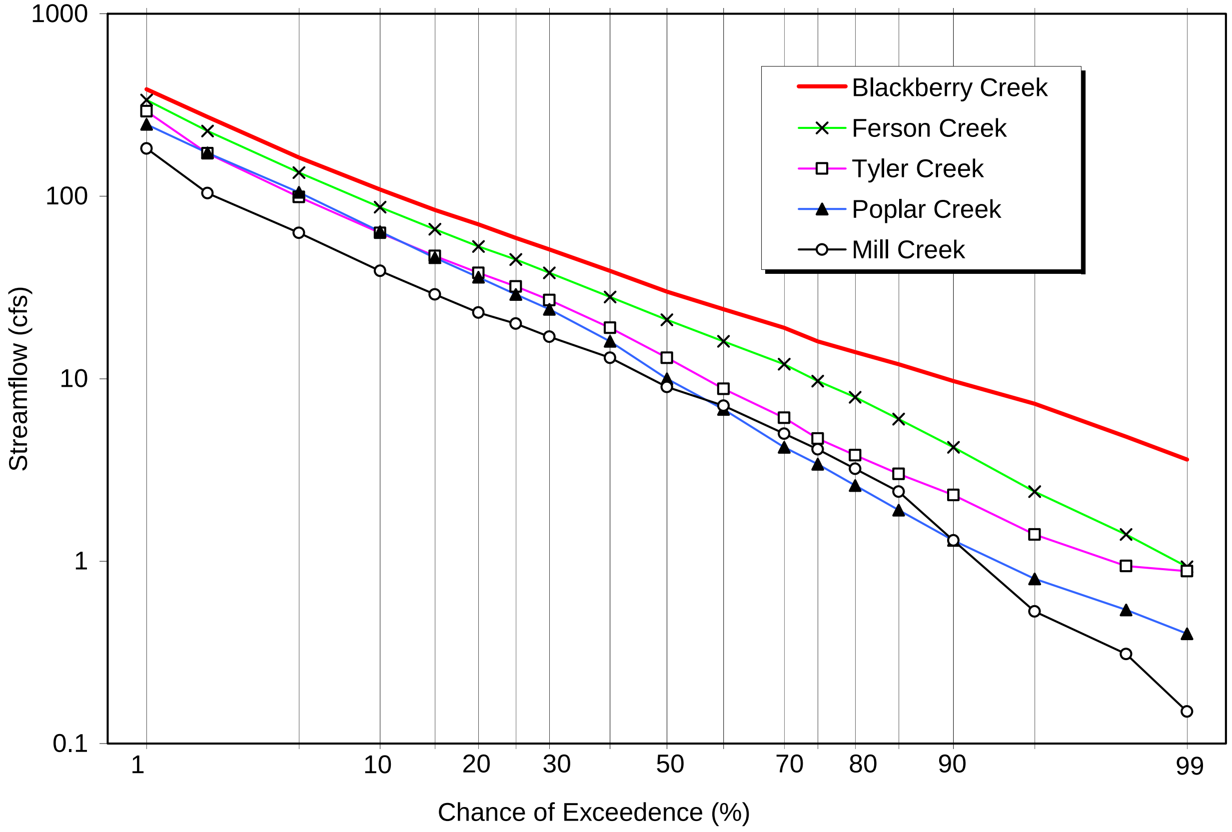


Figure 17. Exceedence probability of daily streamflows for the period of record at five Fox River tributary gages

Table 12 compares selected flow characteristics for three gages (Poplar Creek at Elgin, Ferson Creek near St. Charles, and Blackberry Creek at Yorkville) using different periods of record. For comparison to the composite record at each gage, flow characteristics were computed also for separate 7-year and 8-year periods within the flow record. The standard deviation of mean flow rate between various 7- and 8-year periods is about 20 percent between 1960 and 2005, but increases to 25 percent for Poplar Creek when the 1951-1959 drought period is included. Note that variation of average runoff from one period to the next is noticeably greater than variation from stream to stream during a given time period (Table 11). This suggests that, for characterizing streamflow conditions throughout a region, it is very important to: 1) use the same period of record when comparing flows between two different gages, and 2) maintain hydrologic records that have long periods of record to understand the variability of flows between different periods. The period of gage operation is just as important as selection of gage records used in determining regional low flow characteristics.

Table 12. Sensitivity of Flow Frequency Estimates to the Period of Gaging Record for Three Tributary Gages

		Flow exceedence							
Poplar Creek record	*Average*	*1%*	*10%*	*50%*	*80%*	*90%*	*95%*	*99%*	*Minimum*
1951-1959	14.8	166	43	4.5	0.8	0.6	0.4	0.2	0.10
1959-1967	20.7	214	54	6.6	1.3	1.0	0.8	0.5	0.30
1968-1975*	32.5	215	79	17	4.5	3.2	2.6	1.9	0.93
1976-1983	25.7	260	59	9.5	2.9	2.0	1.2	0.65	0.52
1984-1991	29.5	276	67	12	3.7	2.0	1.0	0.43	0.16
1991-1998	33.3	271	75	16	5.2	2.8	1.9	0.80	0.77
1998-2005	29.7	320	65	11	3.1	1.8	1.2	0.63	0.51
Composite 1951-2005	26.7	248	64	10	2.6	1.3	0.8	0.40	0.10
Composite 1960-2005	28.5	260	67	12	3.2	1.7	1.1	0.60	0.16

Note:
* Period during which there was a wastewater treatment plant upstream of the gage at Streamwood, from 1968-1977.

		Flow exceedence							
Ferson Creek record	*Average*	*1%*	*10%*	*50%*	*80%*	*90%*	*95%*	*99%*	*Minimum*
1960-1967	25.3	236	58	10	3.0	1.7	1.2	0.4	0.10
1968-1975	49.0	370	105	27	10	5.9	3.9	0.93	0.22
1976-1983	42.5	349	91	22	9.6	5.0	2.3	0.65	0.31
1984-1991	41.6	301	84	26	9.7	5.8	3.8	1.8	0.69
1991-1998	47.2	398	94	25	10	6.0	4.2	2.5	1.2
1998-2005	38.8	345	82	19	8.2	5.1	3.0	1.7	1.1
Composite 1960-2005	41.0	337	87	21	7.9	4.2	2.4	0.93	0.10

		Flow exceedence							
Blackberry Creek record	*Average*	*1%*	*10%*	*50%*	*80%*	*90%*	*95%*	*99%*	*Minimum*
1960-1967	37.5	270	80	20	9.1	7.1	5.8	4.0	2.5
1968-1975	60.3	388	128	34	17	14	10	6.7	5.2
1976-1983	56.5	439	111	32	17	12	7.3	4.3	3.7
1984-1991	54.4	381	108	33	16	11	8.0	4.1	1.6
1991-1998	60.7	420	117	35	17	12	9.6	5.8	2.8
1998-2005	46.9	340	98	26	12	8.5	4.2	0.87	0.32
Composite 1960-2005	53.0	386	109	30	14	9.7	7.3	3.6	0.32

For each of the three gaging records in Table 12, most of the lowest flows on record occurred within a single 7- or 8-year period. For the Poplar Creek gage, for example, almost all flows less than 0.4 cfs occurred in the 1951-1959 drought years. Flows equal to or less than 0.4 cfs occurred 5 percent of the time in 1951-1959, but less than 1 percent of the time in all other time periods. Thus, the low flow frequency estimate can be substantially different if a drought period having the lowest flows is not available for use in flow frequency analysis. A comparison between the 1951-2005 and 1960-2005 statistics for Poplar Creek from Table 12 shows a 0.2 cfs (or 33 percent) decrease in the estimate of the 99 percent flow exceedence when the 1951-1959 period is added to the analysis. While the absolute difference (0.2 cfs) is comparatively small, a similar 33 percent decrease in low flow estimates of other larger streams could be substantial. It can be expected that flow records that extend back to the 1950s or earlier will have comparatively lower flow estimates.

In a similar manner, most of the lowest flows observed in the Ferson Creek record occurred during the first 7 years of record, 1960-1967. In contrast, most of the lowest flows in the Blackberry Creek record occurred in the last 7 years of record, 1998-2005. These observations further support the hypothesis that low flows in Poplar Creek and Ferson Creek have been increasing, but that the Blackberry Creek low flows have decreased.

Seasonal Differences in Flow Characteristics

As with all other locations in Illinois, streams in the Fox River watershed display a well-defined seasonal cycle. Figures 18 and 19 shows the probability of daily flow rates computed for each month using the periods of record for two gages, Poplar Creek at Elgin and the Fox River at Algonquin. These gages were selected to provide a sample of representative conditions throughout the region. Despite differences in sizes of streams and their watersheds, these monthly flow exceedence characteristics of the Fox River and Poplar Creek are similar. Although high flows and flooding can occur at any time of the year, such flows most often occur during the spring, March-May. Conversely, low flow conditions that may affect water supply availability never have occurred during the spring, and instead are most likely to occur between mid-summer (July) and late winter (February). Lowest flows typically occur in August, September, and October.

Drought and Low Flows

Low Flows during the 2005 Drought

Kane County and much of north-central Illinois received very low March-October precipitation in 2005; amounts were 13-15 inches below normal, depending on location. Dry conditions produced low flows in streams that for some locations had not occurred in 40 years. In June 2005, Governor Blagojevich declared a drought emergency and enacted the State's Drought Response Task Force. Although drought concerns extended to central and western Illinois, the worst impacts were in north-central Illinois. Many drought impacts of greatest concern were over by the end of the summer, including those on agriculture and water use restrictions; however, low streamflow conditions continued through October.

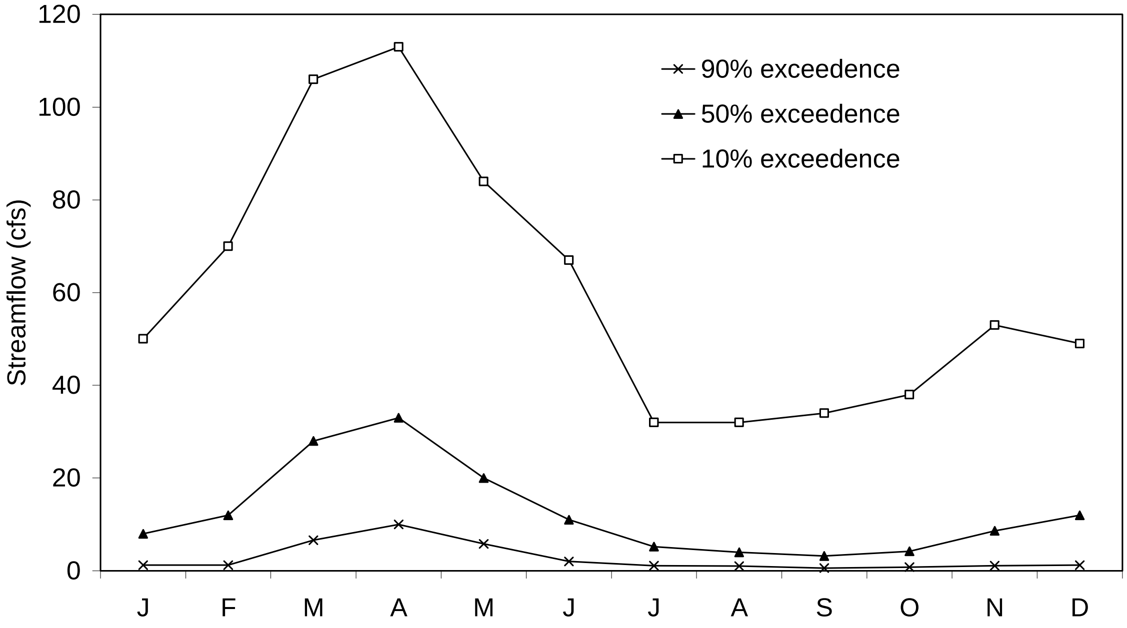


Figure 18. Monthly flow exceedence characteristics for Poplar Creek at Elgin

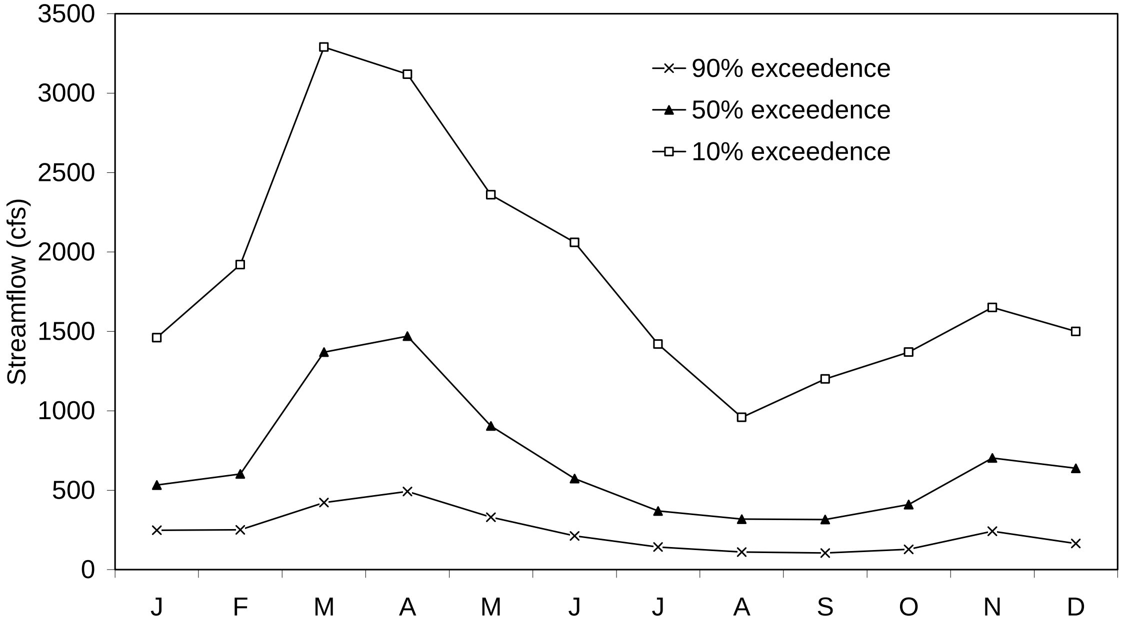


Figure 19. Monthly flow exceedence characteristics for Fox River at Algonquin

Figures 20 and 21 show flow hydrographs during the 2005 drought for the three Fox River gages and selected tributary gaging stations in and near Kane County. As can be seen, low flows occurred over several periods throughout summer and fall, with flows rising after rain events and then receding again to low values. There was noticeable variation in the response of individual streams during the drought. For Tyler Creek, Ferson Creek, and the Fox River at Algonquin and Montgomery, flows stayed generally low from July through mid-October. For Blackberry Creek and the Fox River at Dayton, the lowest flow conditions occurred primarily in September and October. Although the 7-day low flow for all three Fox River gages occurred in early September, the minimum daily flow for the Algonquin and Montgomery gages occurred in mid-July. At the Dayton gage the period of lowest flows lasted only 12 days, from September 4-15, which was unique compared to upstream gages at Algonquin and Montgomery where lowest flows lingered for several months. Low flows that occurred in the first half of September at the Dayton and Montgomery gages were lower than 50-year low flows for these gages as previously estimated by ILSAM (Knapp and Myers, 1999).

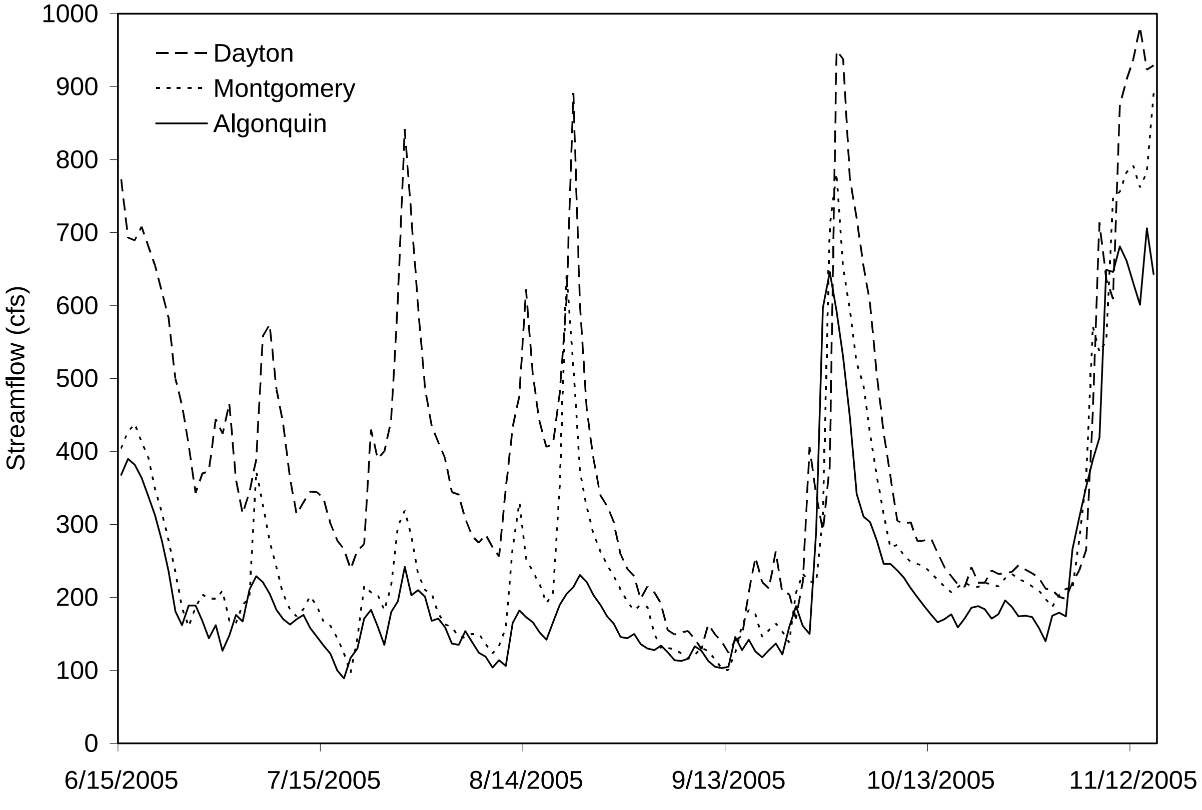


Figure 20. Flow hydrograph during the 2005 drought for Fox River gages at Algonquin, Montgomery, and Dayton

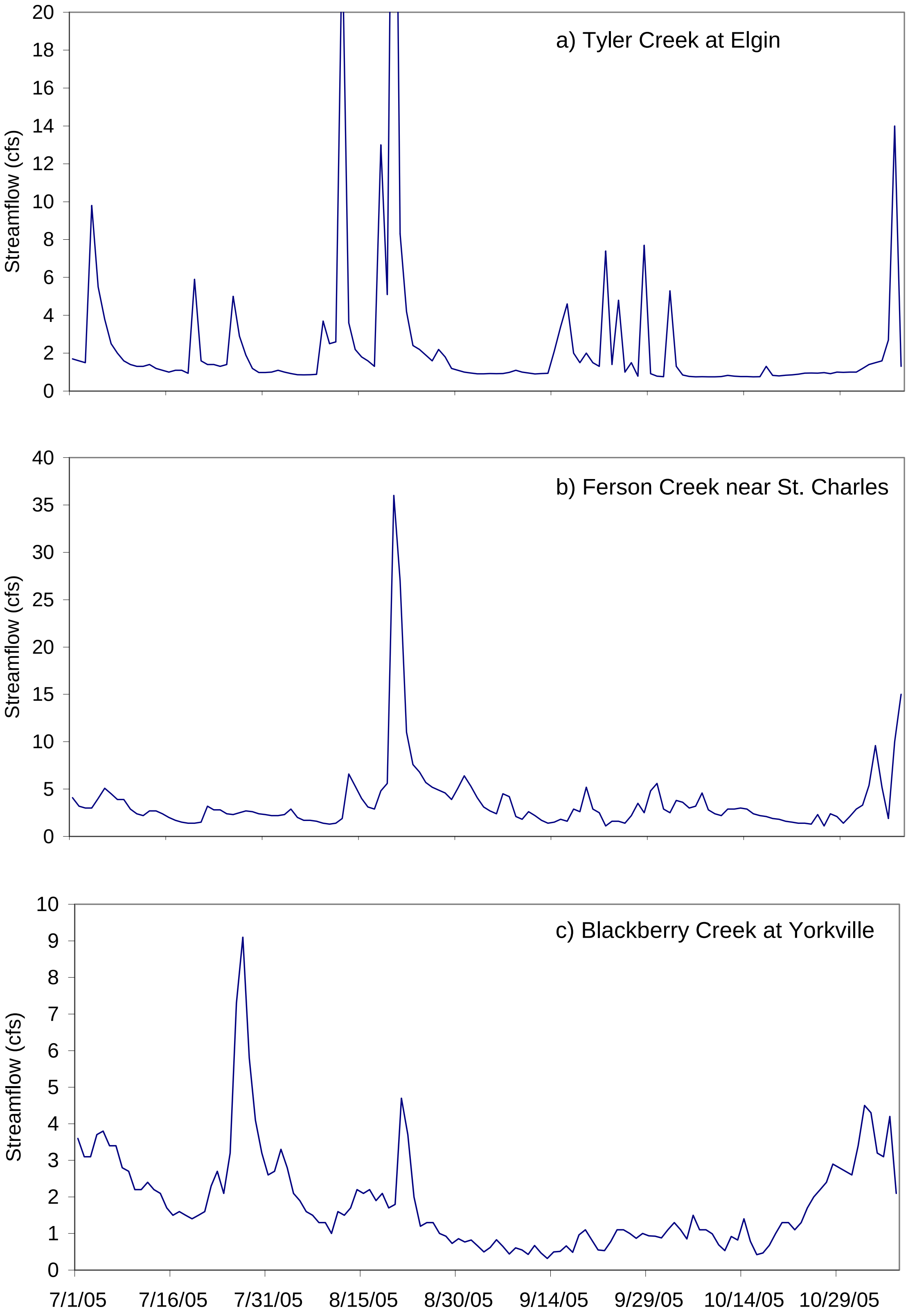


Figure 21. Flow hydrograph during the 2005 drought for three Fox River tributaries

Table 13. Low Flows at USGS Gages during the 2005 Drought, including Rank in the Historical Record

	Years of Record	*7-day flow (cfs)*	*Rank*	*91-day flow (cfs)*	*Rank*
Tyler Creek at Elgin	8	0.77	2	1.57	1
Ferson Creek near St. Charles	46	1.60	10	3.67	9
Poplar Creek at Elgin	55	0.51	12	2.08	11
Mill Creek near Batavia	8	0.04	1	0.22	1
Blackberry Creek	46	0.49	1	1.29	1
Fox River near New Munster	64	87	20	134	15
Fox River at Algonquin	91	115	29	156	16
Fox River at Montgomery	4	106	1	200	1
Fox River at Dayton	91	141	4	315	13

Table 13 lists values of 7-day and 91-day low flows observed at USGS gages during the 2005 drought. Flows were the lowest on record for most short-term gages. However, the 2005 drought did not consistently rate within the top ten events on record for many gages with flow records of at least 40 years. Although the drought produced the lowest flows on record for Blackberry Creek at Yorkville, 7-day low flows at the Ferson Creek and Poplar Creek gages were only the 10th and 12th lowest on record, respectively. For the Fox River gage at Dayton, the 7-day low flow was the 4th lowest on record, not adjusting for effects of wastewater effluents on historical flow amounts.

Comparison of 2005 Observed Low Flows to Regional Equation Estimates

Prior to the 2005 drought, estimates of low flow frequency on ungaged tributary streams, including that provided in ISWS estimates of the 7-day, 10-year low flow, were based on regional flow equations without availability of local data. Low flow measurements and observations on tributary streams conducted during the 2005 drought, listed in Table 3, provided valuable data used to verify or adjust low flow frequency estimates for these ungaged sites. Below is a summary of notable information on tributary streams gained from these measurements:

- Observed flows for Big Rock Creek in Kane County were much lower than estimated by previously developed regional equations. Between the Kane-Kendall county line and the creek’s confluence with the Fox River, however, there was a tremendous increase in low flows that apparently was provided by shallow groundwater. The low flows of Big Rock Creek at its mouth exceeds that of any other tributary to the Fox River downstream of the Chain of Lakes.
- Welch Creek, a tributary to Big Rock Creek, was a “losing stream” during drought conditions, meaning that flow in the stream will be lost through a combination of streambed infiltration and evaporation. Treated wastewater from the Village of Elburn

was discharged into the upper reach of Welch Creek, but there was no flow in the downstream portion of the creek during latter stages of the 2005 drought (in October).

- Groundwater contribution to low flows in middle reaches of Blackberry Creek (west of Batavia near Main Street) was greater than previously predicted. Flows measured between Main Street and Bliss Woods Forest Preserve (Ka-De-Ka Road) were noticeably higher than flows recorded and measured farther downstream at the USGS gage in Yorkville, suggesting that the creek had lost flow over this lower reach. The amount of loss (approximately 1 cfs) may not have been easily detectable except during severe low flow conditions, but may be indicative of a groundwater-surface water interaction requiring further investigation.
- Although Poplar Creek has a fairly small low flow amount for most of its reach, considerable flow (roughly estimated to be 5 to 8 cfs) was observed at Illinois Route 25 immediately downstream of the Bluff Springs Nature Preserve and a nearby quarry.
- Although previous regional estimates for Tyler Creek were generally good, the primary zone of baseflow accretion to the stream appeared to be its downstream reaches (near Tyrell and Randall Roads), not distributed upstream as previously estimated.
- Brewster and Norton Creeks were dry for substantial periods during the drought.
- Regional equations were generally reliable for the Kishwaukee River watershed, but no flow was observed in Burlington Creek upstream of Hampshire Creek. Low flows also appeared to be somewhat greater at a few locations where sod farms or nurseries were being irrigated.
- Observed low flow amounts in tributary streams appeared not to relate directly to the respective physiographic regions in the region, but instead to local variations in near-surface geology.

Historical Low Flows and Droughts

Drought periods by their nature are extended events containing short-term variations in their intensity, depending on weather patterns. Even with similar weather patterns, the response of different streams may vary as a result of hydrogeologic differences in watersheds. For example, watersheds with considerable subsurface storage may not respond immediately to short intense periods of hot, dry weather but instead may be influenced more by cumulative effects of precipitation deficits. Low flows in streams from the same region may not occur at the same time within a drought period, and the ranking of droughts may differ, depending on drought duration or gaging location. Lowest flows during a fairly short time period, such as seven days, also may not necessarily coincide with the worst overall drought conditions that have an extended duration. This is why no single streamflow statistic typically is used to rank or compare historical droughts. Comparison of historical drought periods often includes evaluations of low flow periods of various durations. In general, the ranking of low flows with longer durations is considered more representative for comparing area wide drought impacts, whereas comparison of low flows with shorter durations is reflective of acute conditions in that particular stream as they may affect direct water use withdrawals, water quality, and biological concerns.

Annual low flow statistics presented in this report were computed over the 365 days between May 1 of one year and April 30 of the next calendar year, instead of the water year (October-September) typically used for other annual statistics. This is done to avoid artificially subdividing individual dry periods that typically extend from summer into fall and winter.

Tributary Streams

Of the gages on tributary streams in the Kane County area, only three records are longer than eight years. The Poplar Creek gage at Elgin has the longest record, beginning in 1951, whereas gages on Ferson Creek at St. Charles and Blackberry Creek at Yorkville have records extending back to 1960. Table 14 gives the 10 lowest flow events for annual 7-day and 91-day flows for these flow records.

An analysis of low flows at the Poplar Creek gage indicated that a majority of the 10 lowest years on record occurred during the 1950s. This also can be seen in a plot of 7-day low flows for the period of record of the Poplar Creek gage (Figure 22). Also evident in Figure 22 is the influence of the 1968-1977 Streamwood wastewater discharge upstream of the Poplar Creek gage. Trend analysis of 7-day low flows for the 1951-2005 Poplar Creek gaging record indicated an increasing trend, with a Kendall tau-b coefficient of 0.204. (The Kendall tau-b statistical test provides a quantitative measure of trend, with a coefficient value of 0 indicating no trend and a value of 1 indicating an absolute increasing trend. For the 54-year Poplar Creek flow record, a value of 0.204 indicates an increasing trend at a 98 percent confidence level.) On the other hand, if the 1951-1959 portion of the Poplar Creek record is removed from the analysis, the remaining 46-year record showed no significant trend, regardless of whether or not 1968-1977 low flows affected by wastewater discharge are included. The 2005 drought had the 15th lowest annual 7-day low flow on record, and the 7th lowest such flow since 1960.

Low flow records from the Ferson Creek and Blackberry Creek gages showed considerably different tendencies. For the Ferson Creek gage, 8 of the 10 lowest flows on record occurred during the first 17 years of record, 1961-1977, including the lowest 5 events (Table 14 and Figure 22). In contrast, 6 of the 10 lowest flows at the Blackberry Creek gages occurred after 1977, including 4 of the 5 lowest 7-day events (Table 14 and Figure 22). The 2005 drought resulted in the worst low flows on record for the Blackberry Creek gage, but only the 10th lowest on record for the Ferson Creek gage. Kendall tau-b trend analysis indicated that neither record had a low flow trend; but from Figure 22 it also appears that the magnitude of lowest events is increasing for Ferson Creek and decreasing for Blackberry Creek.

Fox River

For most reaches of the Fox River in Kane County, the 2005 drought produced the lowest flows since 1963. Tables 9 and 15 list lowest flows recorded at the Algonquin and Dayton gages on the Fox River for four separate annual flow statistics: 7-day, 31-day, 91-day, and 6-month low flows. Low flows and their rankings are divided into two periods, before and after 1965. This division is based on a change in operation policy at Stratton Dam, which controls low flow releases from the Chain of Lakes in McHenry County. Effects of this operation change were

Table 14. Lowest 7-day and 91-day Low Flows on Record for Long-term Fox River Tributary Gages

Poplar Creek at Elgin

Rank	*Year*	*7-day flow (cfs)*	*Year*	*91-day flow (cfs)*
1	1958	0.10	1956	0.41
2	1956	0.13	1953	0.53
3	1953	0.20	1963	0.87
4	1988	0.23	1952	0.98
5	1951	0.29	1962	1.04
6	1957	0.31	1958	1.11
7	1955	0.33	1955	1.16
8	1959	0.36	1960	1.24
9	1963	0.36	1959	1.41
10	1952	0.47	1964	1.77
15	2005	0.58	----	----
18	----	----	2005	3.00
10-year		0.27		0.95

Blackberry Creek at Yorkville

Rank	*Year*	*7-day flow (cfs)*	*Year*	*91-day flow (cfs)*
1	2005	0.49	2005	1.9
2	2003	1.7	1976	5.5
3	1991	2.1	1963	5.5
4	1963	2.5	1991	6.5
5	1997	3.0	1962	7.0
6	1976	3.9	1971	8.0
7	2001	4.4	1988	8.2
8	1962	4.5	1997	8.8
9	1964	5.0	1964	10.8
10	1988	5.2	2001	10.8
10-year		2.5		6.2

Ferson Creek near St. Charles

Rank	*Year*	*7-day flow (cfs)*	*Year*	*91-day flow (cfs)*
1	1961	0.23	1963	1.7
2	1971	0.33	1964	1.8
3	1977	0.36	1961	2.2
4	1976	0.59	1971	2.2
5	1964	0.60	1976	2.5
6	1991	0.76	1966	2.7
7	1963	1.00	1991	3.5
8	1965	1.41	1977	3.5
9	1966	1.51	1962	3.8
10	2005	1.57	2005	3.8
10-year		0.6		2.4

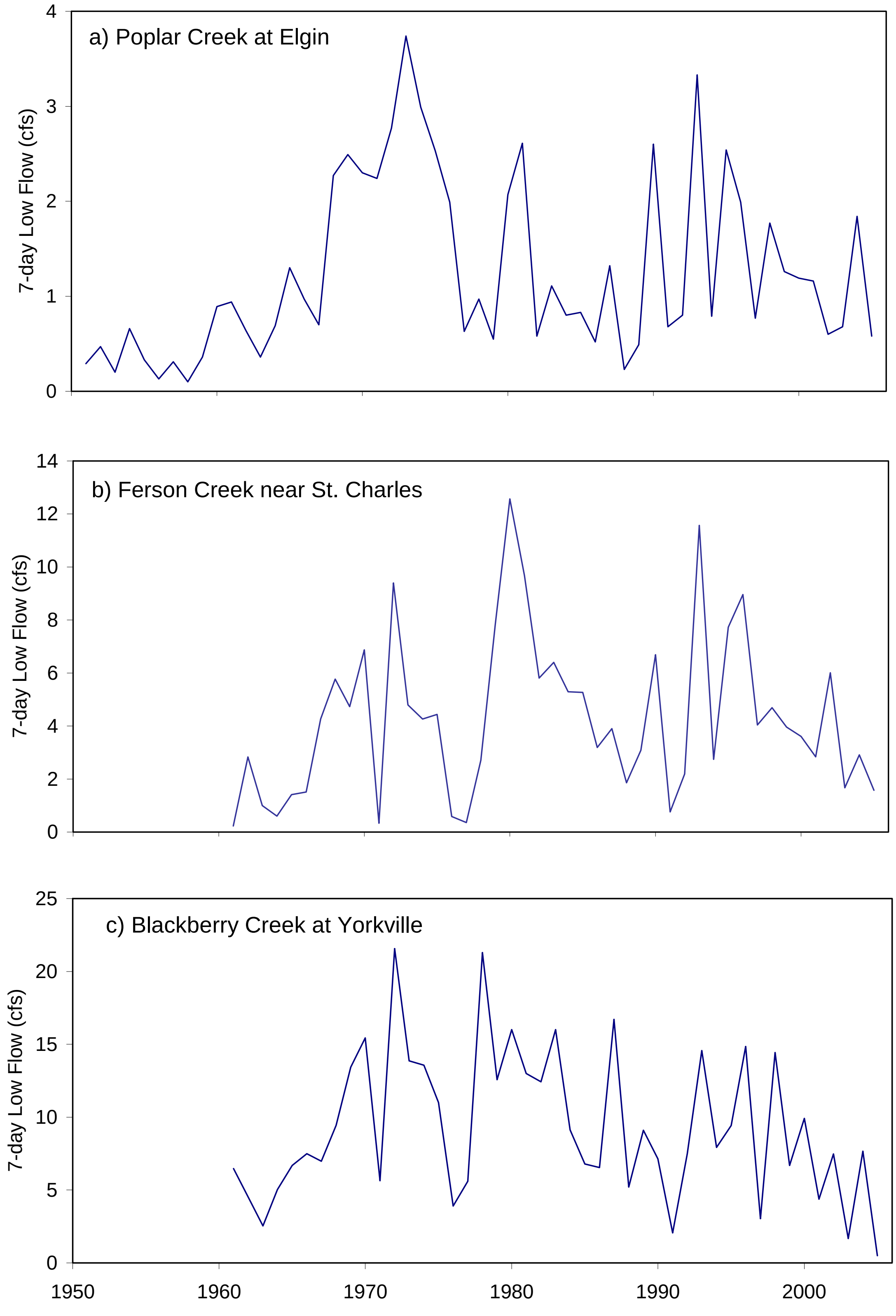


Figure 22. Seven-day low flows for the Poplar, Ferson, and Blackberry Creek gages

discussed in more detail in the previous section "Human Impacts on Streamflow." As can be seen in both tables, differences in low flow magnitudes between the two time periods are substantial, particularly for the Algonquin gage 17 miles downstream of Stratton Dam. Some of this difference is caused by human factors, including operation changes at Stratton Dam, but there are also considerable climate differences between the two time periods, as discussed previously. In general, a greater proportion of differences in shorter (7-day) flows are expected to be caused by human factors, and a greater proportion of differences in longer (6-month) flows are expected to be caused by climate factors.

The short-term drop in flow amounts at the Dayton gage on September 4-15, 2005, is particularly unusual when compared to other droughts. Table 16 examines the ratio between 7- and 31-day low flow amounts for 15 of the most severe low flow events on the Fox River at Dayton over three time periods: 1915-1939, 1940-1964, and 1965-2005. Within each period, events are listed by drought magnitude, with the most severe drought (lowest flows) listed first. There is a general decrease in the ratio of the 7-day low flow to 31-day low flow over time, perhaps indicating a reduction in stability of the river's baseflow conditions. The 7- day to 31-day ratio for the 2005 event is by far the lowest for all droughts listed. It is not known, however,

Table 15. Lowest 7-day, 31-day, 91-day, and 6-month Flows, Fox River at Dayton

Rank	*Year*	*7-day flow (cfs)*	*Year*	*31-day flow (cfs)*	*Year*	*91-day flow (cfs)*	*Year*	*6-month flow (cfs)*
Prior to 1965								
1	1956	120	1956	138	1934	178	1934	300
2	1934	129	1934	153	1946	234	1944	319
3	1946	131	1936	169	1931	239	1939	351
4	1936	161	1946	173	1956	243	1956	355
5	1944	164	1944	191	1936	250	1946	373
6	1931	171	1931	191	1944	257	1963	394
7	1947	175	1947	221	1949	272	1933	398
8	1918	194	1932	231	1932	277	1930	413
9	1958	196	1958	233	1953	291	1953	414
10	1923	204	1939	235	1948	292	1949	426
Since 1965								
1	2005	141	2005	200	2005	316	2005	471
2	2003	228	2003	287	1988	390	1976	494
3	1966	239	1966	307	1971	398	1971	524
4	1988	269	1988	332	1966	419	1988	644
5	1991	294	1976	339	1976	431	2002	693
10-year		245		288		331		496
50-year		141		200		294		410

Table 16. Ratio of 7-day low flows to 31-day low flows on the Fox River at Dayton

Year	*Ratio*	*Year*	*Ratio*	*Year*	*Ratio*
1934	0.843	1956	0.858	2005	0.705
1931	0.895	1946	0.792	2003	0.794
1936	0.953	1944	0.775	1966	0.779
1918*	0.752	1947	0.870	1988	0.810
1923*	0.846	1958	0.841	1991	0.808
Average	0.858	Average	0.827	Average	0.779

Notes:
Drought events are sorted by low flow magnitude, starting with the most severe drought (lowest flow amount).
*The 1918 and 1923 low flows preceded construction of the Dayton Dam in 1925.

whether this low ratio represents effects of water use practices on the river or some other factor. No discharge measurements were taken at the gage during the period of lowest flows, and it is possible that a shift in stage-discharge relationship used to estimate flow amounts could produce uncertainty in the flow estimate. Whereas a relatively common shift of ±0.1 foot in the gage’s stage-discharge relationship may produce only a 5 percent discharge error under normal flow conditions, during lowest flow conditions it could result in a 30 percent change in the flow estimate.

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Comparison of KC-SWAM Hydrologic Results and Earlier ILSAM Results

Appendix A lists flow duration and low flow values estimated from hydrologic analyses for 10 locations in and near Kane County. These values are used as part of the input into KC-SWAM to update the hydrology from the previous version of the Fox River ILSAM (Knapp and Myers, 1999). Flow characteristics from newer USGS gages, such as on Tyler Creek, Mill Creek, and Blackberry Creek near Montgomery, were not used because their flow records were not long enough to compute long-term flow probabilities. The KC-SWAM flow values for the portion of Kane County within the Kishwaukee River watershed remain unchanged from the previous ILSAM model, as presented in Knapp and Russell (2004).

Table 17 compares KC-SWAM flow estimates and those from previous ILSAM versions for nine locations in the Fox River watershed. Knapp and Myers (1999) provided a previous comparison of flow values for these same nine locations, which include some locations not included in Appendix A outside of the immediate vicinity of Kane County. All locations are at current or discontinued USGS gaging stations except for the location upstream of the Fox Metro Water Reclamation District (WRD). Values for eight flow parameters range from high flows (Q_1) to low flows ($Q_{7,10}$). Whereas substantial changes in flow magnitudes were identified between the 1988 and 1999 ILSAM versions, differences between the 1999 ILSAM and the 2007 KC-SWAM are relatively minor, with most KC-SWAM flow parameters having less than 5 percent change from 1999 values.

As discussed in “Effect of Climate Variability on Streamflow,” climate and streamflow conditions in the Fox River watershed over the last decade are relatively close to long-term average conditions; such that with the most recent 8 years of data, one does not expect to see a substantial shift in flows caused by climate factors. Several locations, however, appear to have differences in low flow frequency. For the lower Fox River, in particular, 7-day low flows during the 2005 drought were some of the lowest on record, and the dry year of 2003 also produced a 10-year low flow in the river. The most recent analysis also indicates an increase in low flow magnitude on Ferson Creek and a decrease on Blackberry Creek, as noted earlier in this report. In general, changes in low flow frequency related to climate influences have overshadowed concurrent effects of increased effluent discharges. Only for the Fox River gage near New Munster, Wisconsin (relocated in 1993 from a site at Wilmot), was there a noticeable increase in low flow frequency related to effluent discharges. However, the effect of wastewater effluents from the Waukesha, Wisconsin, area on lowest flow conditions at the New Munster gage appear to have been underestimated by the 1999 ILSAM.

Table 17. Comparison of 1988, 1999, and 2007 Estimates of Present Flow Conditions

	*Selected flow parameter**							
Year of hydrologic analysis	Q_{mean}	Q_1	Q_{10}	Q_{50}	Q_{75}	Q_{90}	Q_{98}	$Q_{7,10}$
Fox River near New Munster, WI								
1988	544	2820	1230	336	185	125	85	73
1999	588	2930	1312	381	210	138	92	73
2007	592	2920	1310	387	219	143	95	84
Fox River at Algonquin								
1988	897	4260	2060	537	294	187	119	115
1999	967	4340	2150	688	352	208	118	115
2007	1008	4330	2190	692	377	223	123	106
Fox River at South Elgin								
1988	1032	4715	2345	661	357	232	163	157
1999	1122	5098	2368	776	435	273	154	142
2007	1143	5110	2380	782	440	277	157	135
Fox River upstream of Fox Metro WRD								
1988	1179	5382	2654	750	398	264	185	180
1999	1268	5923	2624	855	482	305	167	151
2007	1286	5925	2623	855	483	306	168	143
Fox River at Dayton								
1988	1886	9205	4188	1167	615	416	291	277
1999	2081	9860	4462	1314	689	458	283	251
2007	2093	9760	4450	1310	706	468	288	245
Blackberry Creek near Yorkville								
1988	47.0	363	101	25.0	12.4	7.1	3.0	3.4
1999	50.4	390	113	29.0	14.7	8.6	5.2	4.4
2007	50.0	371	106	29.1	14.4	8.4	3.9	2.5
Nippersink Creek near Spring Grove								
1988	141	827	291	90	55	35	19.0	15.5
1999	146	896	314	96	56	36	20.0	16.6
2007	134	808	287	91	53	31	19.2	17.0
Ferson Creek near St. Charles								
1988	36.2	275	82	17.0	6.2	1.8	0.48	0.36
1999	38.2	337	88	19.0	7.6	2.3	0.60	0.45
2007	39.0	325	84	20.5	8.5	3.2	0.98	0.60
Poplar Creek at Elgin								
1988	23.5	206	60	8.6	2.6	0.96	0.41	0.22
1999	26.1	227	64	10.0	3.3	1.2	0.45	0.27
2007	26.1	248	65	11.0	3.4	1.3	0.45	0.27

Notes:

The 1988 and 1999 analyses were for the Fox River ILSAM. The 2007 analysis was for KC-SWAM.

* Q_{mean} is the mean flow at the location; Q_1, Q_{10}, Q_{50}, Q_{75}, Q_{90}, and Q_{98} are flow duration exceedence parameters; $Q_{7,10}$ is the 7-day, 10-year low flow

Summary

The Kane County Surface Water Accounting Model (KC-SWAM), developed for this study, is a planning tool for use in evaluating streamflow impacts related to various proposed water use scenarios. KC-SWAM has capabilities of the pre-existing ILSAM but also three major improvements: 1) an interactive map interface developed to assist users in identifying and selecting stream locations and water facilities using point-and-click features; 2) updates or modifications to the amount of water discharged or withdrawn at existing facilities can be performed individually or *en masse*, and multiple new water facilities and stream nodes can be inserted into the model; and 3) users can create entire water use scenarios that can be saved, shared, and used as a foundation for additional scenario development.

For any stream location in a watershed, KC-SWAM can compute the magnitude of 154 different streamflow parameters, covering a broad range of hydrologic conditions. Of these, parameters of greatest interest for water supply planning are typically the stream's low flow characteristics. Not only does KC-SWAM compute flow magnitudes for present-day conditions, but also altered flow conditions that may result from changes in water use as proposed by the model user. The virgin, or unaltered, flow condition for the stream also is estimated. Present-day conditions represent current water use practices but account for the probability of recurring droughts and/or wet periods similar to those over a base period covering the past 60 years.

Primary hydrologic data used to develop KC-SWAM streamflow estimates include USGS daily streamflow data, IEPA wastewater effluent data, and ISWS water use data. The KC-SWAM databases contain flow frequency statistics computed from these hydrologic data, and processed information on effects of major water withdrawals, discharges, and reservoirs. Flow estimates at ungaged stream locations also are based on regional regression equations developed from USGS daily streamflow data. Low flow measurements taken by the ISWS during the 2005 drought also were used to calibrate and validate low streamflow estimates for tributary streams in Kane County.

Climate and hydrologic records from the past 100 years in Illinois show considerable long-term variability, part of a regional pattern observed throughout much of the Upper Midwest. Average annual 1930-1964 precipitation over the Fox River watershed was less than 32 inches. In contrast, average annual 1970-1996 precipitation was almost 36 inches, an increase of more than 12 percent. The effect of these precipitation differences on streamflow is magnified, such that average annual streamflow (measured in equivalent inches of runoff over the watershed) increased from 7.3 inches in 1930-1964 to 12.2 inches in 1970-1996. In the decade since 1996, average annual streamflow of 10.0 inches is much closer to the long-term historical average. Interdecadal trends in medium and low flows tend to follow these rises and falls in average flow. It is possible that high precipitation and streamflow amounts in 1970-1996 included a regional component of climate change. But unless a specific pattern in climate change can be identified, it is necessary to consider patterns in the historical record as part of natural variability and that severe droughts similar to those in the 1930s and 1950s will occur again in the future. Thus, water supply planning must address vulnerability of water supply systems to these severe historical droughts, if not also the possibility of a more severe drought.

Prior to 1965, annual low flows for the Fox River were often much lower than they are today. Although effects of climate variability have increased average low flow levels over the last 40 years, low flows also have been increased by 1) changes in the operation of Stratton Dam in McHenry County and 2) increases in wastewater amounts discharged into the river. Two changes in operation policy of Stratton Dam that have increased low flows are increases in the summer pool level in 1965 and the minimum flow release in 1988. Also, maintaining minimum flow releases from the dam over the course of a longer 25- or 50-year drought, without bringing hardship for the boating and recreation industry of the lakes, is only possible because of flow augmentation from wastewater discharges in urban areas near Waukesha, Wisconsin.

Wastewater released to the Fox River in Kane County also has a sizeable effect on low flows in the river. Although water supply withdrawals at Elgin and Aurora cause local decreases in low flows, the collective impact of Kane County's water use (discharges and withdrawals) is to increase low flows in the river by about 30 cfs (or 19 mgd). Average water use in Kane County is projected to increase over the next 20 years by about 30 mgd. Most treated wastewater associated with this water use growth probably will be discharged to the Fox River. This growth in water use will be supplied from various sources, mainly groundwater, but also potentially from additional withdrawals from the Fox River. Local effects on low flows will depend on types of water supply sources being used, and location and magnitude of specific wastewater discharges and river withdrawals.

Indirect impacts to baseflow levels in streams, including effects of groundwater-surface water interactions and land use, are more difficult to identify and quantify. Many areas depend on shallow groundwater wells for water supply, and these wells potentially can decrease low flows in nearby streams. This may explain observed decreases of low flows in the Blackberry Creek flow record. Changes to baseflow levels in urbanizing areas may vary, although there is evidence that certain urban streams (Poplar Creek and Ferson Creek) have increases in the lowest flow conditions. These trends should be revisited in the future using additional and site-specific supportive data.

This report has focused on defining factors that affect flow magnitude of streams in and near the Kane County region. KC-SWAM, developed from this study, provides a planning tool for pre-examining potential effects of a variety of future growth scenarios on low flows — scenarios that can examine effects of both potential expansion of existing facilities and potential locations for new facilities. KC-SWAM only identifies potential effects on flow magnitude, not water quality, another factor that must be examined when determining practicality of future growth scenarios. Future viability of the Fox River and tributaries for environmental and recreational uses must be considered by additional direct withdrawals from the Fox River. One important water planning issue not directly addressed in this report is instream flow uses that must be considered when determining availability of flows for water withdrawal.

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Appendix A. Flow Duration and Low Flow Estimates for Streamgages and Other Selected Locations

(flows in cubic feet per second)

Location	*Streamflow Parameter**											
	Q_{mean}	Q_1	Q_2	Q_5	Q_{10}	Q_{15}	Q_{25}	Q_{40}	Q_{50}	Q_{60}	Q_{75}	Q_{85}
Fox River Present Flow												
Algonquin (USGS Gage)	995	4330	3710	2850	2190	1810	1290	879	692	546	377	281
Upstream of Elgin PWS	1064	4660	3970	2980	2285	1890	1360	943	748	593	417	318
South Elgin (USGS Gage)	1148	5120	4390	3190	2420	2010	1450	1010	804	640	456	349
Geneva Dam	1238	5620	4850	3410	2560	2125	1540	1075	861	688	495	385
Aurora PWS	1288	5860	5070	3540	2640	2190	1590	1105	887	710	512	400
Fox Metro WRD	1347	6020	5240	3660	2730	2270	1655	1155	934	752	548	433
Dayton (USGS Gage)	2117	9800	8150	5940	4510	3710	2620	1710	1350	1060	732	585
Fox River Virgin Flow												
Algonquin (USGS Gage)	899	4056	3443	2666	2052	1678	1195	793	899	4056	3443	2666
Upstream of Elgin PWS	947	4356	3674	2769	2121	1734	1242	836	947	4356	3674	2769
South Elgin (USGS Gage)	1015	4778	4061	2951	2231	1831	1312	889	1015	4778	4061	2951
Geneva Dam	1098	5266	4510	3161	2362	1937	1394	947	1098	5266	4510	3161
Aurora PWS	1137	5488	4714	3277	2429	1990	1433	966	1137	5488	4714	3277
Fox Metro WRD	1165	5589	4831	3352	2478	2032	1463	985	1165	5589	4831	3352
Dayton (USGS Gage)	1929	9397	7753	5627	4248	3462	2418	1530	1929	9397	7753	5627
Tributary Present Flow												
Poplar Creek at Elgin	26.1	248	173	105	65	47	29	16.0	11.0	6.9	3.4	1.9
Ferson Creek near St. Charles	39.0	325	219	130	84	65	42	27.9	20.5	14.9	8.5	4.8
Blackberry Creek near Yorkville	50.0	371	265	158	106	82	56	38.0	29.1	22.5	14.4	10.2

Appendix A. Continued

	*Streamflow Parameter**											
Location	Q_{90}	Q_{95}	Q_{98}	Q_{99}	$Q_{1,2}$	$Q_{1,10}$	$Q_{1,25}$	$Q_{1,50}$	$Q_{7,2}$	$Q_{7,10}$	$Q_{7,25}$	$Q_{7,50}$
Fox River Present Flow												
Algonquin (USGS Gage)	223	164	123	113	196	94	88	75	208	108	95	83
Upstream of Elgin PWS	258	194	147	134	223	114	103	88	240	128	116	98
South Elgin (USGS Gage)	287	215	162	145	237	120	104	88	264	138	125	100
Geneva Dam	320	237	180	158	258	133	110	94	293	151	139	106
Aurora PWS	333	249	190	168	265	140	118	100	303	162	147	113
Fox Metro WRD	362	274	213	186	284	154	130	110	330	181	164	127
Dayton (USGS Gage)	488	391	301	261	302	188	147	122	392	241	194	141
Fox River Virgin Flow												
Algonquin (USGS Gage)	186	141	108	93	177	82	61	38	185	95	65	42
Upstream of Elgin PWS	205	156	118	101	191	91	65	40	201	102	73	45
South Elgin (USGS Gage)	227	172	129	110	204	98	68	42	219	110	81	46
Geneva Dam	254	189	142	119	221	107	71	45	243	119	91	48
Aurora PWS	259	193	145	123	222	109	74	46	245	124	93	49
Fox Metro WRD	267	198	151	126	227	112	76	47	251	128	96	50
Dayton (USGS Gage)	389	311	235	198	242	143	90	56	308	185	123	61
Tributary Present Flow												
Poplar Creek at Elgin	1.30	0.80	0.45	0.35	0.60	0.20	0.12	0.08	0.80	0.27	0.15	0.10
Ferson Creek near St. Charles	3.20	1.80	0.98	0.62	2.70	0.38	0.20	0.17	3.40	0.60	0.36	0.25
Blackberry Creek near Yorkville	8.40	6.00	3.90	2.90	7.30	2.00	0.90	0.50	7.90	2.50	1.30	0.80

Appendix A. Concluded

	Streamflow Parameter*											
Location	$Q_{31,2}$	$Q_{31,10}$	$Q_{31,25}$	$Q_{31,50}$	$Q_{61,2}$	$Q_{61,10}$	$Q_{61,25}$	$Q_{61,50}$	$Q_{91,2}$	$Q_{91,10}$	$Q_{91,25}$	$Q_{91,50}$
Fox River Present Flow												
Algonquin (USGS Gage)	257	130	105	98	297	142	112	104	348	154	125	108
Upstream of Elgin PWS	293	151	128	116	335	164	138	123	391	179	152	133
South Elgin (USGS Gage)	322	164	141	125	366	176	152	138	429	196	171	149
Geneva Dam	356	178	158	138	404	190	171	156	471	216	193	170
Aurora PWS	365	192	167	146	415	205	182	166	485	229	205	182
Fox Metro WRD	394	213	186	164	447	227	203	187	519	255	227	204
Dayton (USGS Gage)	477	294	247	197	533	315	277	253	628	338	314	290
Fox River Virgin Flow												
Algonquin (USGS Gage)	227	115	74	53	252	128	85	63	294	137	96	74
Upstream of Elgin PWS	246	122	84	58	273	135	97	69	319	147	109	85
South Elgin (USGS Gage)	268	131	95	65	296	143	108	82	346	159	124	98
Geneva Dam	296	140	108	74	328	152	122	96	382	174	141	114
Aurora PWS	297	147	111	76	330	160	126	100	387	179	146	119
Fox Metro WRD	304	151	115	79	338	164	131	105	396	185	151	124
Dayton (USGS Gage)	382	228	173	109	419	248	201	168	499	264	234	206
Tributary Present Flow												
Poplar Creek at Elgin	2.00	0.52	0.28	0.20	3.00	0.85	0.48	0.35	4.40	0.95	0.55	0.40
Ferson Creek near St. Charles	5.50	1.10	0.79	0.64	7.20	1.70	1.40	1.10	11.20	2.40	1.70	1.60
Blackberry Creek near Yorkville	10.10	3.80	2.30	1.50	12.60	5.00	3.40	20.0	14.60	6.20	4.20	2.70

Note:
*Q_{mean} is the mean flow at the location; Q_1 – Q_{99} are flow duration exceedence parameters; $Q_{x,y}$ are low flow values with *x* being the duration in days and *y* being the recurrence interval in years.

Appendix B. Descriptions and Watershed Characteristics of Selected Stream Locations in KC-SWAM

Stream	*River mile*	*Location description*	*Drainage area (sq mi)*	*Permeability* (in/hr)*
Fox River	104.5	Chain of Lakes outlet (near Johnsburg)	1199.2	3.70
	104.4	Fox Lake regional treatment plant	1199.2	3.70
	103.0	USGS Gage #05548500 at Johnsburg	1202.4	3.70
	102.5	at Dutch Creek	1215.3	3.71
	100.3	at Boone Creek	1241.5	3.77
	100.1	McHenry Central treatment plant	1241.6	3.77
	98.9	McHenry South treatment plant	1246.5	3.77
	97.8	Stratton Dam	1247.9	3.77
	96.9	at Sleepy Hollow Creek	1269.1	3.80
	95.1	Burtons Bridge	1276.2	3.81
	94.3	at Mutton Creek	1289.7	3.79
	94.2	Northern Moraine District treatment plant	1289.7	3.79
	92.3	Rawson Bridge	1294.7	3.81
	90.8	at Slocum Lake Outlet	1315.5	3.82
	89.4	at Flint Creek	1359.4	3.72
	86.0	US Highway 14	1364.2	3.73
	85.6	Cary treatment plant	1364.5	3.73
	85.5	at Cary Creek	1368.3	3.75
	85.4	Fox River Grove treatment plant	1368.4	3.75
	85.3	at Spring Creek	1394.5	3.74
	81.6	USGS Gage #05550000 at Algonquin	1401.3	3.76
	81.5	at Crystal Creek	1428.4	3.81
	80.6	Algonquin treatment plant	1432.7	3.81
	76.6	Carpentersville treatment plant	1444.5	3.81
	74.9	East Dundee treatment plant	1448.9	3.82
	74.6	at Jelkes Creek	1458.0	3.82
	73.2	Interstate Highway 90	1462.5	3.81
	72.4	upstream of Elgin withdrawal	1464.2	3.81
	72.3	Elgin Water Supply Withdrawal	1464.2	3.81
	72.2	at Tyler Creek	1504.8	3.81
	71.6	Fox River WRD North treatment plant	1505.4	3.81
	69.1	Fox River WRD South treatment plant	1509.1	3.83
	68.9	Fox River WRD West treatment plant	1509.7	3.83
	68.8	at Poplar Creek	1552.7	3.76
	67.3	USGS Gage #05551000 at South Elgin	1555.1	3.77
	65.9	at Brewster Creek	1574.0	3.77
	62.4	at Norton Creek	1590.6	3.77
	60.9	at Ferson Creek	1646.2	3.72
	59.9	St. Charles Dam	1648.5	3.71
	58.7	St. Charles treatment plant	1652.3	3.70
	57.9	IDNR Gage at Geneva	1654.0	3.70

Appendix B. Continued

Stream	*River mile*	*Location description*	*Drainage area (sq mi)*	*Permeability* (in/hr)*
Fox River	57.3	Geneva treatment plant	1654.4	3.70
	54.8	Batavia treatment plant	1661.1	3.70
	53.0	at Mill Creek	1697.0	3.64
	52.9	Mooseheart Child City & School discharge	1697.2	3.64
	50.0	Upstream of Aurora withdrawal	1703.5	3.63
	49.9	Aurora Water Supply Withdrawal	1703.6	3.63
	49.3	Illinois Avenue in Aurora	1704.4	3.63
	49.0	at Indian Creek	1721.6	3.61
	45.9	Montgomery treatment plant	1730.7	3.62
	44.5	Fox Metro WRD treatment plant	1735.3	3.63
	44.0	IL American - Valley Marina discharge	1735.9	3.63
	42.7	at Waubansee Creek	1768.3	3.60
	42.5	US Highway 34	1768.3	3.60
	37.8	at Morgan Creek	1796.6	3.58
	35.9	IL Route 47 at Yorkville	1802.5	3.57
	35.7	Yorkville-Bristol treatment plant	1802.6	3.57
	35.6	at Blackberry Creek	1876.1	3.52
	31.3	at Rob Roy Creek	1905.9	3.49
	31.0	at Big Rock Creek	2099.9	3.30
	29.5	at Hollenback Creek	2115.5	3.28
	28.6	Rogers Road	2116.6	3.28
	25.4	at Clear Creek	2138.6	3.27
	25.2	La Salle-Kendall County Line	2138.6	3.27
	21.0	at Roods Creek	2166.5	3.25
	20.1	at Somonauk Creek	2250.4	3.16
	19.1	Sheridan treatment plant	2253.9	3.16
	15.8	at Mission Creek	2279.2	3.14
	13.0	at Brumbach Creek	2304.1	3.11
	9.4	at Indian Creek	2577.1	2.88
	8.5	at Buck Creek	2621.7	2.85
	5.6	Dayton Dam	2640.9	2.83
	5.2	USGS Gage #05552500 at Dayton	2641.2	2.83
	4.6	US Highway 80	2644.3	2.83
	1.3	IL Route 71	2656.4	2.82
	0.0	at mouth at Ottawa	2657.7	2.82
Big Rock Creek	26.9	Harter Road	5.7	0.72
	25.7	Perry Road	6.9	0.75
	24.1	Owens Road	9.3	0.76
	21.8	upstream of Youngs Creek	11.9	0.73
	21.7	at Youngs Creek	23.1	0.70
	19.8	Kane-DeKalb County Line	26.2	0.69
	15.7	US Highway 30	32.5	0.68

Appendix B. Continued

Stream	*River mile*	*Location description*	*Drainage area (sq mi)*	*Permeability* (in/hr)*
Big Rock Creek	15.7	US Highway 30	32.5	0.68
	13.8	at West Branch Big Rock Creek	61.5	0.67
	12.9	Price Road	62.0	0.68
	10.4	upstream of Welch Creek	66.6	0.70
	10.3	at Welch Creek	104.8	0.70
	8.0	Kendall-Kane County Line	108.8	0.72
	7.4	Galena Road	110.5	0.85
	2.8	US Highway 34	115.1	2.49
	1.2	Plano treatment plant	116.1	3.00
	0.1	at Little Rock Creek	193.8	3.06
	0.0	at mouth near Plano	193.8	3.06
Little Rock Creek	27.1	McGirr Road	5.5	0.87
	24.0	at Little Rock Creek tributaary	7.8	0.82
	23.5	Lee Road	14.7	0.70
	23.4	at Little Rock Creek tributaary	19.2	0.71
	18.0	Hinckley STP	25.3	0.66
	13.4	at Little Rock Creek tributary #2	40.6	0.62
	9.5	Miller Road	47.4	0.62
	6.1	Creek Road	56.9	0.61
	3.2	upstream of tributary #1	66.5	1.40
	3.2	at Little Rock Creek tributary #1	71.8	1.68
	0.0	at mouth near Plano	75.0	2.24
Little Rock Creek Tributary #1	1.6	Sandwich treatment plant	3.3	0.56
	0.0	at mouth near Sandwich	5.3	0.86
Little Rock Creek Tributary #2	3.3	Somonauk Road	5.0	0.68
	1.0	East Sandwich Road	10.5	0.85
	0.0	at mouth near Little Rock	11.1	0.87
Welch Creek	16.0	Elburn treatment plant	1.4	1.14
	14.8	Rowe Road	3.9	0.90
	13.4	Interstate 88 East-West Tollway	7.9	0.84
	12.0	Dauberman Road at Kaneville	10.0	0.79
	11.2	Main Street Road	11.9	0.78
	7.1	Scott Road	15.5	0.78
	4.9	Dauberman Road	17.0	0.79
	3.2	Grannart Road near Big Rock	22.0	0.79
	2.2	at Duffin Ditch	37.0	0.78
	0.0	at mouth near Big Rock	38.2	0.78

Appendix B. Continued

Stream	*River mile*	*Location description*	*Drainage area (sq mi)*	*Permeability* (in/hr)*
Duffin Ditch	4.2	Scott Road	3.8	2.17
	2.9	Wheeler Road	5.8	2.02
	1.5	Grannart Road	7.4	1.99
	0.0	at mouth near Sugar Grove	14.4	1.95
West Branch Big Rock Creek	10.9	McGirr Road	2.9	0.58
	7.6	upstream of Battle Creek	8.4	0.55
	7.5	at Battle Creek	23.4	0.57
	7.0	Phillips Road	23.7	0.57
	5.6	Pritchard Road at Hinckley	24.7	0.56
	4.1	Kane-DeKalb County Line	25.9	0.56
	2.6	US Highway 30 (west of Big Rock)	26.6	0.57
	0.0	at mouth near Big Rock	28.1	0.60
Battle Creek	7.4	Harter Road	2.4	0.42
	5.9	at Battle Creek tributary	10.2	0.50
	3.3	McGirr Road	12.4	0.53
	0.0	at mouth near Hinckley	15.0	0.58
Youngs Creek	6.7	Schrader Road	2.4	1.02
	4.4	DeKalb-Kane County Line Road	4.5	0.97
	2.2	Owens Road (county line)	6.8	0.83
	0.4	McGirr Road	11.0	0.81
	0.0	at mouth near Kaneville	11.2	0.81
Rob Roy Creek	9.2	Jericho Road	3.9	6.00
	7.8	Galena Road	6.4	4.83
	5.4	C.B.&Q. RR	12.5	3.94
	5.0	Faxon Road	13.0	3.90
	3.0	Schaefer Road	19.0	3.62
	0.0	at mouth near Silver Springs Park	21.0	3.60
Blackberry Creek	31.9	Pouley Road	3.4	0.52
	27.9	Hughes Road	6.0	0.98
	25.4	Main Street	11.4	2.75
	23.1	Finley Road	14.9	2.75
	22.6	Scott Road	20.9	2.79
	21.9	IL Route 47	21.5	2.81
	21.5	Waubonsee Community College	23.1	2.79
	19.8	Ka-De-Ka Road	24.6	2.76
	17.3	Interstate 88 East-West Tollway	29.5	2.46
	17.0	at Lake Run	44.3	1.99
	15.5	at East Run	49.2	1.89

Appendix B. Continued

Stream	*River mile*	*Location description*	*Drainage area (sq mi)*	*Permeability* (in/hr)*
Blackberry Creek	14.3	Prairie Street	51.7	1.85
	13.0	Jericho Road	58.8	1.72
	11.3	Kendall-Kane County Line Road	59.5	1.72
	7.4	Galena Road	63.6	1.74
	3.3	USGS Gage #05551700 near Yorkville	70.2	1.77
	1.8	US Highway 34	71.9	1.77
	0.0	at mouth at Yorkville	73.4	1.78
Lake Run	6.0	Bliss Road (west of Batavia)	2.1	1.46
	4.0	Seavey Road	7.7	1.27
	3.3	Tanner Road	11.1	1.08
	2.0	East-West Tollway	13.0	1.12
	0.0	at mouth near Sugar Grove	14.7	1.29
Morgan Creek	6.7	Douglas Road	1.2	0.86
	4.6	Grove Road	4.1	0.85
	2.9	at Morgan Creek tributary	8.6	1.49
	2.1	Munker Road	16.3	1.25
	1.0	IL Route 71	17.6	1.22
	0.0	at mouth near Yorkville	18.0	1.26
Waubansee Creek	10.5	IL Route 65	2.7	1.33
	9.3	E.J.& E. RR	4.6	1.11
	7.2	Kane-DuPage County Line	9.3	0.91
	5.5	E.J.& E. RR	17.3	0.91
	3.4	Douglas Road	20.1	1.38
	2.1	at Waubansee Creek tributary	23.3	1.50
	1.2	US Highway 34 near Oswego	29.2	1.46
	0.3	IL Route 25	29.5	1.47
	0.0	at mouth at Oswego	29.6	1.47
Indian Creek	5.7	IL Route 56	5.2	1.39
	2.9	Reckinger Road	10.9	1.19
	1.1	Ohio Street in Aurora	16.4	1.00
	0.5	High Sreet in Aurora	16.6	1.00
	0.0	at mouth in Aurora	16.7	1.00
Mill Creek	13.2	Brown Road	2.5	0.42
	10.2	US Alt Highway 30 near Wasco	8.1	0.75
	7.2	Keslinger Road	14.9	0.74
	5.9	St. Charles-West Side treatment plant	20.3	0.72
	5.4	Kaneville Road	20.5	0.72
	4.1	Wenmoth Road	21.4	0.72
	3.0	Main Street	27.4	0.75

Appendix B. Continued

Stream	*River mile*	*Location description*	*Drainage area (sq mi)*	*Permeability* (in/hr)*
Mill Creek	1.0	at Mooseheart Lake	30.6	0.80
	0.2	IL Route 31	31.0	0.84
	0.0	at mouth near Mooseheart	31.0	0.84
Ferson Creek	12.0	Ferson Creek Utility discharge	4.4	0.84
	10.4	Burlington Road at Wasco	6.2	0.85
	8.6	Denker Road	9.3	0.94
	6.6	upstream of Otter Creek	11.5	1.04
	6.5	at Otter Creek	45.9	1.05
	4.5	Bolcum Road	48.6	1.05
	2.2	USGS Gage #05551200 near St. Charles	51.8	1.05
	0.2	IL Route 31	54.6	1.05
	0.0	at mouth at St. Charles	54.6	1.05
Otter Creek	4.4	at Otter Creek tributary	3.9	2.00
	3.9	upstream of Fitchie Creek	7.3	1.40
	3.8	at Fitchie Creek	14.5	1.20
	2.7	at Stony Creek	28.2	1.09
	1.0	Silver Glen Road	29.9	1.07
	0.0	at mouth near Elgin	34.5	1.05
Stony Creek	3.4	Gordon Road	2.1	0.54
	1.3	upstream of Bowes Creek	3.2	0.71
	1.2	at Bowes Creek	11.9	1.01
	0.6	Stevens Road	12.2	1.04
	0.0	at mouth near Elgin	12.3	1.05
Norton Creek	2.6	Dunham Road near Wayne	7.4	6.41
	0.5	IL Route 25	11.5	4.60
	0.0	at mouth near St Charles	11.7	4.58
Brewster Creek	4.2	Illinois Central RR	3.0	0.34
	2.0	Kane-DuPage County Line	6.0	3.66
	0.8	IL Route 25	14.0	3.14
	0.0	at mouth near South Elgin	17.4	3.77
Poplar Creek	14.8	IL Route 62 near Barrington	3.3	0.47
	11.8	IL Route 72 near Bartlett	6.2	0.46
	10.8	upstream of East Branch	8.2	0.52
	10.7	at East Branch Poplar Creek	13.1	0.56
	10.1	IL Route 58	16.5	0.61
	7.5	IL Route 58	23.2	0.66
	4.9	at Streamwood tributary	34.3	0.76
	2.3	USGS Gage #05550500 at Elgin	35.8	1.12

Appendix B. Concluded

Stream	*River mile*	*Location description*	*Drainage area (sq mi)*	*Permeability* (in/hr)*
Poplar Creek	1.0	Kane-Cook County Line	42.1	2.29
	0.0	at mouth at Elgin	43.0	2.47
Tyler Creek	15.5	IL Route 72 at Starks	1.2	1.55
	12.9	IL Route 72	5.3	1.02
	11.7	upstream of Pingree Creek	10.4	0.78
	11.6	at Pingree Creek	21.4	0.61
	9.8	Gilberts STP	25.1	0.61
	9.0	C.& N.W. RR	28.0	0.70
	7.9	Big Timber Road	28.8	0.78
	6.8	CMSTP&P RR	30.6	0.92
	5.6	Randall Road	32.7	0.98
	1.6	Big Timber Road at Elgin	39.0	1.14
	0.0	at mouth at Elgin	40.5	1.14
Pingree Creek	6.4	Illinois Central RR	1.8	1.20
	2.7	US Highway 20	8.4	0.69
	1.4	Highland Ave	9.5	0.68
	0.0	at mouth near Gilberts	11.0	0.65
Jelkes Creek	3.8	Sleepy Hollow Road	2.8	1.34
	0.5	IL Route 31	6.6	1.28
	0.0	at mouth near West Dundee	6.8	1.28
Crystal Creek	7.5	Crystal Lake outlet	5.8	3.05
	6.1	Crystal Lake treatment plant #2	8.4	3.05
	2.5	Lake in the Hills treatment plant	10.9	3.05
	2.1	Cedar Street	11.1	3.05
	1.4	Algonquin Road	11.2	3.05
	1.3	at Woods Creek	20.3	2.31
	0.0	at mouth near Algonquin	27.1	2.31
Woods Creek	3.3	Huntley-Algonquin Road	3.4	1.17
	1.7	Crystal Lake Road	8.3	1.28
	0.4	Huntley-Algonquin Road	8.9	1.37
	0.0	at mouth near Lake in the Hills	9.0	1.38
Spring Creek	10.1	Penny Road	5.6	0.62
	9.0	Dundee Road	7.7	0.53
	8.0	IL Route 62	8.4	0.64
	5.7	Donlea Road	15.6	1.31
	4.6	McHenry-Cook County Line	20.8	1.90
	0.0	at mouth near Fox River Grove	26.1	2.93

Note: *Average permeability of the lowest soil layers throughout the watershed (inches per hour).

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