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Fox River Watershed Investigation: Stratton Dam to the Illinois River

Phase II Hydrologic and Water Quality Simulation Models


Part 3

Validation of Hydrologic Model Parameters, Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek Watersheds

**by
Alena Bartosova, Jaswinder Singh, Mustafa Rahim, and Sally McConkey**

**Prepared for the
Fox River Study Group, Inc.**

September 2007



Illinois State Water Survey
Center for Watershed Science
Champaign, Illinois

A Division of the Illinois Department of Natural Resources
and an affiliated agency of the University of Illinois

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Report presented to the
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Abstract

This report describes development of watershed loading models for five watersheds contributing to the Fox River: Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek watersheds. These five tributary watersheds were used to validate model parameters previously developed for the Blackberry Creek and Poplar Creek pilot watersheds to different conditions within the Fox River watershed. Several aspects of model uncertainty and confidence are evaluated. Preceding reports describe methodology, procedures, and data used in the model development, as well as results of calibration and validation of the pilot watersheds. Subsequent reports will present the development of models for the remainder of the study area.

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Any opinions, findings, conclusion, or recommendations expressed in this report are those of the authors and do not necessarily reflect those of the Fox River Study Group or the Illinois State Water Survey.

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Introduction

The Fox River watershed is located in Wisconsin and Illinois. The Illinois State Water Survey (ISWS) is participating in a study of the Fox River watershed within Illinois, below Stratton Dam to the confluence of the Fox River with the Illinois River. This report is one of a series of reports on the Fox River Watershed Investigation prepared by the ISWS. Model preparation is part of an ongoing investigation of water quality issues identified by the Illinois Environmental Protection Agency (IEPA). This work is being conducted for and in consultation with the Fox River Study Group, Inc. (FRSG).

Project Overview

The Fox River in northeastern Illinois is the focal point of many communities along the river, providing an aesthetically pleasing area and opportunities for fishing, canoeing, and boating. The Fox River is also a working river. Two major cities, Elgin and Aurora, withdraw water for public water supply, and the river serves as a receptor for stormwater and treated waste water. This highly valued river, however, has been showing increasing signs of impairment.

In response to local concerns about the Fox River water quality the Fox River Study Group (FRSG) organized in 2001. The FRSG is comprised of a diverse group of stakeholders representing municipalities, county government, water reclamation districts, and environmental and watershed groups from throughout the watershed. The goal of the FRSG is to address water quality issues in the Fox River watershed and assist with implementing activities to improve and maintain water quality. The FRSG has initiated activities to more accurately characterize the water quality of the Fox River: data collection and preparation of comprehensive water quality models.

The IEPA in their *Illinois Water Quality Report 2000* (IEPA, 2000) listed parts of the Fox River in McHenry and Kane Counties and part of Little Indian Creek as impaired. The 2002 IEPA report (IEPA, 2002) listed the entire length of the Fox River in Illinois as impaired, as well as Nippersink, Poplar, Blackberry, and Somonauk Creeks, and part of Little Indian Creek. The IEPA has included the Fox River and these tributaries on their list of impaired waters, commonly called the 303(d) list (IEPA, 2003). The latest report (IEPA, 2006) lists the entire length of the Fox River, Nippersink Creek, Tyler Creek, Crystal Lake outlet, Poplar Creek, Ferson Creek, and Blackberry Creek as impaired. The most prevailing potential sources for listing were hydromodification and flow regulation, urban runoff, and combined sewer overflows. The most prevailing potential causes for listing were flow alterations, habitat, sedimentation/siltation, dissolved oxygen, suspended solids, excess algal growth, fecal coliform bacteria, and PCBs. A suite of water quality models has been envisioned to characterize the various sources and causes of impairment.

Reporting Structure

The Phase I report (McConkey et al., 2004) reviews the available literature and data for the study area and includes recommendations for development of a suite of models to simulate hydrology and water quality in the watershed targeted to key water quality issues identified in the watershed. The Hydrological Simulation Program FORTRAN version 12 (HSPF, Bicknell et al., 2001) model was selected to simulate watershed loading and delivery and routing of nonpoint and point sources of pollution from the entire watershed. The QUAL2 model was selected to model dissolved oxygen diurnal processes during steady state low flow conditions along the mainstem Fox River. These models are referred to as watershed loading and receiving stream models, respectively.

The report *Overview of Recommended Phase II Water Quality Monitoring, Fox River Watershed Investigation* (Bartosova et. al., 2005) outlines a plan for monitoring to collect data for improved model calibration.

The Part 1 report (Singh et al., 2007) describes the structure of the HSPF hydrology and water quality model and methods used in developing the watershed loading models, discusses sources of uncertainty in these models and data assimilation conducted in preparation of watershed loading models for the study area, and identifies statistical and graphical methods used in evaluating confidence in the model. It serves as a guide for model development, parameterization, calibration, and validation of the watershed loading models for all tributary watersheds and the Fox River mainstem.

The Part 2 report (Bartosova et al., 2007) presents the specific development of watershed loading models (HSPF) for two pilot watersheds (Blackberry and Poplar Creek) in the Fox River watershed. These pilot watersheds represent contrasting land use and different soil conditions. The HSPF models were calibrated to simulate daily streamflow and selected water quality constituents.

This report (Part 3) describes validation of hydrologic model parameters. Model parameters developed for pilot watersheds were transferred to five tributary watersheds with flow data available for at least part of the study period: Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek. These tributary watersheds were not used in the calibration process but were used to test transferability of model parameters to other watersheds. This report provides background on these five watersheds and compares HSPF hydrologic component simulation results with observed discharges.

The hydrologic model for the Fox River mainstem and remaining tributary watersheds currently is under development and will be addressed in a separate report. Development of water quality components of the HSPF model as well as development of the receiving water quality model (QUAL2) is planned to begin subsequently.

Validation of Hydrologic Components

Simulating movement of water through the watershed, from precipitation to streamflow, is the foundation for water quality modeling. Hydrologic processes must be calibrated before attempting to model generation, transformation, and transport of any water quality constituents. The goal of hydrologic modeling is to simulate daily flow values as closely as possible, particularly medium to low flows.

This report describes five watersheds in the Fox River watershed (Brewster Creek, Ferson Creek, Flint Creek, Mill Creek and Tyler Creek) and development of HSPF models for them. The framework for these models was created using Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) version 3.0, a multipurpose environmental analysis system developed by the U.S. Environmental Protection Agency (USEPA, 2001). The BASINS system enables users to prepare watershed scale hydrologic and water quality simulation models using a Geographic Information System (GIS). Singh et al. (2007) describe HSPF model development for the Fox River watershed, including calibration and validation procedures.

Blackberry Creek and Poplar Creek watersheds, also in the Fox River watershed, were the subjects of a pilot study to calibrate HSPF model parameters (Bartosova et al., 2007). Calibration of HSPF model hydrology components requires long-term simulation (at least 10 years). Water years (WY) 1991-2003 represent the most current time period available at study initiation and were selected as the study period, which then was divided into respective calibration and validation periods. A Water Year is the 12-month period from October 1 through September 30 and is designated by the calendar year in which it ends. Blackberry and Poplar Creek watersheds were selected for parameter calibration as they represent contrasting land uses and also have long-term flow records and some water quality data spanning the calibration and validation periods.

In addition to Blackberry Creek and Poplar Creek watersheds Brewster Creek, Ferson Creek, Flint Creek, Mill Creek and Tyler Creek watersheds are the only other tributaries in the Fox River watershed with streamflow data available from U.S. Geological Survey (USGS) gaging stations, although not all these USGS streamflow gages have been operational for the entire study period.

Available precipitation, land use, soils, hydrography, and elevation datasets pertaining to each of the five watersheds were used to prepare the HSPF models and define hydrologic response units (HRUs) in each watershed. An HRU, a building block of the HSPF model, represents a unique combination of land use, soil type, and slope category. A unique set of parameters characterizes each HRU type.

The five watersheds have varying distributions of land use and soil types, with fraction of impervious area ranging from 4% to 12% of total area. Imperviousness was estimated from land use categories, assuming 35% and 75% imperviousness for urban low/medium density and urban high density areas, respectively. During the validation process, models were run on an hourly basis. Average daily flows were computed from the simulated hourly streamflows and compared with available observed daily streamflow data.

The description of each of the five tributary watersheds is provided, including land area, land use, soil, and slope. An assessment of representativeness of climate and streamflow data is given. Various steps, issues, and resolutions in preparation of the HSPF models are described. Finally, simulated and observed flows are compared, and results are discussed.

These models were prepared using HSPF model parameters for unique HRU types determined from the pilot calibration study of Blackberry Creek and Poplar Creek. The premise of this method of model preparation is that parameters developed for each unique HRU type may be transferred to the same HRU (i.e., same land use, soil, and slope) in a nearby watershed.

These five watersheds were used to validate the set of calibration parameters developed for HRUs in the Blackberry Creek and Poplar Creek watersheds. Validation results provide insights on applicability of this model development approach, but other factors such as quality and availability of precipitation and streamflow data must be taken into consideration when interpreting results. Calibration parameters may be modified further based on validation results and also during completion of the models for remaining study area based on simulation results in the Fox River mainstem.

Watershed Characteristics

Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek watersheds are part of a group of 31 tributary watersheds that drain into the Fox River below Stratton Dam in Illinois, as shown in Figure 1. The Fox River originates in Wisconsin, flows from Wisconsin through northeastern Illinois, and joins the Illinois River at Ottawa. Land uses in the Fox River watershed include agriculture, industry, grassland, forest, and urban areas. The Fox River and its tributaries carry stormwater and receive permitted discharges from wastewater treatment plants, combined sewers, and industry. In Illinois, the population of Fox River watershed by 2020 is expected to increase dramatically (about 30%) from the 2000 totals, with much of the growth in McHenry and Kane Counties.

Reported drainage areas of watersheds were calculated based on the watershed boundary delineated for the HSPF model. The USGS National Hydrography Dataset (NHD) was used to define flow paths and measure stream lengths (USGS, 2004). Singh et al. (2007) fully describe spatial datasets used to define physical characteristics of the watersheds.

Land Use

Land cover for Illinois from the Illinois Interagency Landscape Classification Project or IILCP (IDOA, 2003) was the most recent, high-resolution dataset available at the time of study. It was used to determine and specify different land use categories throughout the watersheds. Land use classifications and their distribution in Brewster, Ferson, Flint, Mill, and Tyler Creek watersheds are shown (Table 1). Fox River, Poplar Creek, and Blackberry Creek watersheds are included for comparison.

Ferson Creek, Mill Creek, and Tyler Creek watersheds include significant percentages of row crops and low percentages of urban land uses. The proportion of these land uses is similar to that in Blackberry Creek watershed. Rural grassland is also present in a significant area, especially in Ferson Creek watershed (37%). Brewster Creek watershed, the most urbanized watershed of the five validation watersheds, has land use similar to that of Poplar Creek watershed but contains 11% of rural grassland that is absent in the Poplar Creek watershed. Flint Creek watershed is quite unique, with dominant land uses being forest (34%) and urban open space (30%).

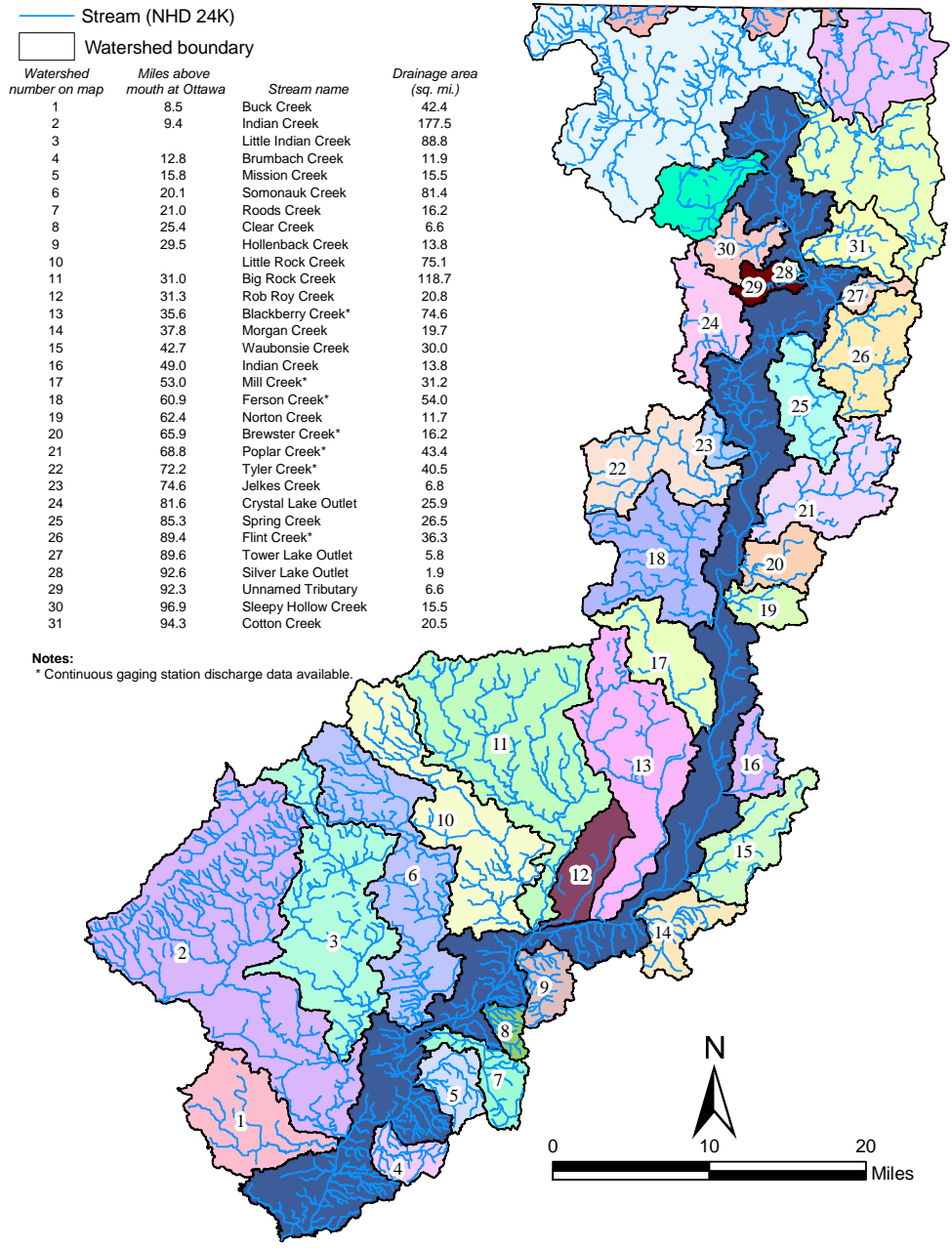


Figure 1. Fox River watershed in Illinois and 31 major tributary watersheds.

Table 1. Major Land Use Classes in Study Watersheds

<i>Model classification</i>	<i>Percent watershed area</i>							
	<i>Fox River*</i>	<i>Poplar Creek</i>	<i>Blackberry Creek</i>	<i>Brewster Creek</i>	<i>Ferson Creek</i>	<i>Flint Creek</i>	<i>Mill Creek</i>	<i>Tyler Creek</i>
Corn	27	4	29	6	18	1	17	28
Soybeans	25	2	25	2	18	1	20	24
Rural Grassland	13	0	19	11	37	11	29	20
Forest	10	14	8	16	13	34	7	9
Urban High Density	2	7	2	8	2	1	2	2
Urban Low/Medium Density	9	30	8	19	7	15	12	11
Urban Open Space	10	38	9	38	5	30	13	7
Wetland	2	3	1	1	0	4	0	0
Water	2	3	1	0	0	3	0	0

Notes: Values are rounded, and 0 represents less than 1%.

*Illinois portion of watershed only.

Soils

Hydrologic soil groups and the estimated percentage area they represent in Blackberry, Poplar, Brewster, Ferson, Flint, Mill, and Tyler Creek watersheds were estimated using the higher resolution Soil Survey Geographic or SSURGO (NRCS, 2003a) data when available. The lower resolution State Soil Geographic or STATSGO (NRCS, 2003b) data were used for the Fox River watershed, as some counties still do not have SSURGO data (Table 2). Both STATSGO and SSURGO data represent generalized categories. Soil components in one map unit (polygon) are not necessarily in the same hydrologic soil group. Because the exact location of an individual soil component within a map unit is not specified and map units had to be adjusted (clipped) to watershed boundaries, percentages of the various soil types were estimated assuming uniform representation of soil components in a given map unit. Given the composition of the soil data, the only option was to assume a constant ratio of individual soil components throughout a map unit. Singh et al. (2007) and Bartosova et al. (2007) present a detailed description of these datasets. Hydrologic soil groups classify soils as A, B, C, or D based on the infiltration rate (Soil Survey Division Staff, 1993). Soils of hydrologic soil group A have a high infiltration rate (e.g., sand) while soils of hydrologic soil group D have a very low infiltration rate (e.g., clay). Dual hydrologic soil groups describe soils with different infiltration rates under natural conditions or when artificially drained. Soils classified as A/D have a low infiltration rate under natural conditions and would be classified as hydrologic soil group D; when artificially drained (e.g., tile drainage on agricultural land), these soils would behave and be classified as hydrologic soil group A, however.

Table 2. Representation of Hydrologic Soil Groups in the Study Watersheds

<i>Hydrologic soil group</i>	<i>Percent watershed area</i>							
	<i>Fox River</i>	<i>Blackberry Creek</i>	<i>Poplar Creek</i>	<i>Brewster Creek</i>	<i>Ferson Creek</i>	<i>Flint Creek</i>	<i>Mill Creek</i>	<i>Tyler Creek</i>
A	2	3	<1	<1	1	<1	<1	<1
A/D	2	0	4	3	2	6	1	3
B	59	80	17	33	56	11	44	58
B/D	21	4	20	8	26	7	19	32
C	14	6	43	34	9	56	23	<1
C/D	<1	0	<1	6	3	9	11	<1
D	1	<1	<1	2	<1	4	0	2
Not specified (impervious surface)	<1	6	16	14	2	7	2	3

Source STATSGO STATSGO SSURGO SSURGO SSURGO SSURGO SSURGO SSURGO

The best soil spatial datasets available for each county were used to develop the HSPF models for the five watersheds. Brewster Creek watershed is located in Kane, Cook, and DuPage Counties, and SSURGO data are available for Kane County and DuPage County. The SSURGO data for Cook County were not available during model development, though the data became available in March 2007. Instead, the County Soil Association Map (CSAM), which provides similar detailed information, was used for the portion of Brewster Creek watershed in Cook County. Ferson Creek, Mill Creek, and Tyler Creek watersheds are located in Kane County so published SSURGO data are available. Flint Creek watershed is primarily located in Lake County and Cook County with a very small part (less than 0.5%) crossing into McHenry County. The CSAM was used for Cook County soils in Brewster Creek watershed. The SSURGO data are available for both Lake County and McHenry County.

Ferson Creek and Tyler Creek watersheds predominantly contain hydrologic soil group B, similarly to Blackberry Creek watershed. Mill Creek watershed also is dominated by hydrologic soil group B, but it also contains a significant area with hydrologic soil group C (23%). Brewster Creek watershed has a fairly even distribution of both hydrologic soil groups B and C. Flint Creek watershed is dominated by hydrologic soil group C. Ferson Creek, Mill Creek, and Tyler Creek watersheds also contain a significant area with dual hydrologic soil groups B/D and/or C/D. As mentioned earlier, dual soil groups represent different hydrologic behavior under natural conditions and with artificial drainage. For example, soils of hydrologic soil group A/D behaves like soils of hydrologic soil group D under normal conditions but like soils of hydrologic soil group A when drained (e.g., agriculture soils with tile drainage). Dual

soils were assigned a single hydrologic soil group based on land use later in model development. Agricultural land always was considered artificially drained when dual soils were present.

Topography

Watershed slope was derived from National Elevation Dataset (NED), a digital elevation dataset distributed by the USGS and described in Singh et al. (2007). The average slope is calculated by BASINS for each subwatershed during automatic watershed delineation. Subwatersheds were categorized based on the following criteria: slope less than or equal to 2%, slope more than 2% but less than or equal to 4%, and slope more than 4%. Figure 2 shows the distribution of watershed slopes in Blackberry Creek, Poplar Creek, Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek watersheds. Poplar Creek, Blackberry Creek, and Flint Creek watersheds include relatively more area with steeper slope than the other watersheds. For example, while 50% of Poplar Creek watershed has a slope greater than 2%, the same slope category occurs in 36% of Flint Creek watershed, 27% of three watersheds (Brewster Creek, Ferson Creek, and Mill Creek watersheds), and 18% of Tyler Creek watershed.

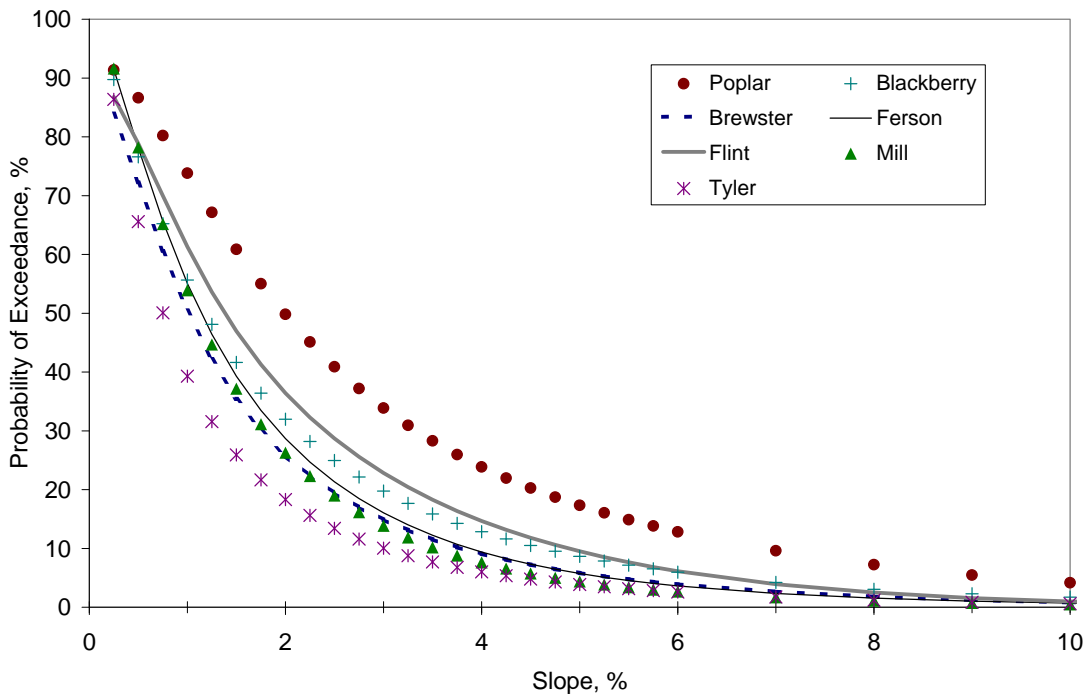


Figure 2. Distribution of land slope in the simulated watersheds.

Summary

Brewster Creek Watershed

The 16-square-mile Brewster Creek watershed is located in Kane, Cook, and DuPage Counties, Illinois. The Brewster Creek mainstem, a 6-mile-long stream originating south of Bartlett in northwestern DuPage County, drains to the Fox River near Valley View in east-central Kane County. Row crops such as corn and soybeans cover nearly 10% of Brewster Creek watershed. Urban high or urban low/medium density impervious areas cover 27%, and urban open space covers nearly 38% of the watershed. Forest and rural grassland cover approximately 16% and 11% of Brewster Creek watershed, respectively. Soils of hydrologic soil groups B (33%) and C (34%) dominate the watershed. Average land surface slope of subwatersheds ranges from 0.25% to 2%. About 91% of the watershed has slope less than 4%, and 50% of the watershed has slope less than 1.1%.

Ferson Creek Watershed

The 54-square-mile Ferson Creek watershed is located in Kane County, Illinois. The Ferson Creek mainstem, a 15-mile-long stream originating north of Elburn in central Kane County, drains to the Fox River near St. Charles in Kane County. Row crops such as corn and soybeans cover nearly 36% of Ferson Creek watershed. Urban high or urban low/medium density impervious areas cover less than 9%, and urban open space cover only 5% of the watershed. Forest and rural grassland cover approximately 13% and 37% of Ferson Creek watershed, respectively. Soils of hydrologic soil groups B and B/D cover 56% and 26% of the watershed, respectively. Average land surface slope of subwatersheds ranges from 0.5% to 2.8%. About 91% of the watershed has slope less than 4%, and 50% of the watershed has slope less than 1.2%.

Flint Creek Watershed

The 36-square-mile Flint Creek watershed is primarily located in Lake County and Cook County, Illinois, but a very small part (less than 0.5%) crosses into McHenry County. The Flint Creek mainstem, an 11-mile-long stream originating in Hawthorn Lake southwest of Barrington in northwestern Cook County, drains to the Fox River near the Village of Lake Barrington in Lake County. Row crops such as corn and soybeans cover only 3.1% of Flint Creek watershed. Urban high or urban low/medium density impervious areas cover 7% and urban pervious open space covers nearly 39% of the watershed. Forest, rural grassland, and wetlands cover approximately 31%, 10%, and 5% of Flint Creek watershed, respectively. Soils of hydrologic soil group C (56%) dominate the watershed. Average land surface slope of subwatersheds ranges from 0.5% to 2.8%. About 85% of the watershed has slope less than 4%, and 50% of the watershed has slope less than 1.4%.

Mill Creek Watershed

The 31-square-mile Mill Creek watershed is located in Kane County, Illinois. The Mill Creek mainstem, a 15-mile-long stream originating north of Elburn in central Kane County, drains to the Fox River near the Village of North Aurora in southeast Kane County. Row crops such as corn and soybeans cover nearly 40% of the Mill Creek watershed. Urban high or urban low/medium density impervious areas cover 14% and urban open space covers nearly 13% of the watershed. Forest and rural grassland cover 7% and 29% of Mill Creek watershed, respectively. Soils of hydrologic soil group B dominate the watershed (44%), followed by hydrologic soil groups C (23%) and B/D (19%). The average land surface slope of subwatersheds ranges from 0.5% to 2%. About 92% of the watershed has slope less than 4%, and 50% of the watershed has slope less than 1.1%.

Tyler Creek Watershed

The 41-square-mile Tyler Creek watershed is located in Kane County, Illinois. The Tyler Creek mainstem, a 16-mile-long stream originating northwest of the Village of Pingree Grove in northwestern Kane County, drains to the Fox River near Elgin in Kane County. Row crops such as corn and soybeans cover about 52% of Tyler Creek watershed. Urban high or urban low/medium density impervious areas cover 6% and urban open space covers 7% of the watershed. Forest and rural grassland cover approximately 9% and 20% of Tyler Creek watershed, respectively. Soils of hydrologic soil groups B and B/D dominate the watershed with 58% and 32%, respectively. Average land surface slope of subwatersheds ranges from 0.25% to 1.5%. About 94% of the watershed has slope less than 4%, and 50% of the watershed has slope less than 0.8%.

Climate and Streamflow

Most precipitation stations in and near the study area provide daily precipitation values; but a few stations collect hourly data. The Thiessen polygon method was applied across the Fox River watershed to assign precipitation stations to individual tributary watersheds and their subwatersheds. Statistics were computed from available datasets to compare long-term values and values representative of the study period (WY 1991-2003) or as available. Data from nearby stations were used to supplement missing data in the time series.

A few climate stations collect data on various climate conditions in addition to precipitation, e.g., temperature, dew point, or cloud cover. Data from these stations supply the needed climate data for a greater number of precipitation stations.

Daily streamflow data are available for one location in each of the five validation watersheds, but the period of record varies. Details are discussed for individual watersheds. Hourly climate and streamflow data ideally would be used for each watershed for the entire study period, but many stations have only limited records. All streamflow data available during the study period were considered for model validation runs.

Brewster Creek Watershed

Two climate stations were identified for Brewster Creek watershed. One climate station is located in Streamwood (ID 118324) and the other at the DuPage Airport in West Chicago (Weather Bureau-Army-Navy 94892). The Streamwood station has daily data from year 1994 to present. The DuPage airport station has hourly data for the period 1997-2006. Brewster Creek watershed and station locations are shown (Figure 3).

Mean annual precipitation recorded at Streamwood for WY 1995-2003 is 35.7 inches. The highest precipitation occurs from May to August. Precipitation recorded at the Streamwood station for WY 1995-2003 is shown (Figure 4). Daily precipitation data from the Streamwood station were disaggregated into hourly data using the Data Disaggregation Tool in the Watershed Data Management Utility of the HSPF model.

The USGS gage at Valley View (USGS ID 05551030), the only streamflow gage in Brewster Creek watershed (Figure 3), is located approximately one mile upstream from the mouth of Brewster Creek, and the watershed has a drainage area of 14 square miles. Daily streamflow records are available for this station from June 2002 to present. Given the short record of streamflow data in the study period, only average monthly flows for WY 2003-2004 are shown (Figure 5). The highest average streamflow occurs from March to June.

Precipitation and streamflow statistics for the Streamwood station and Valley View gage, respectively, are shown (Table 3).

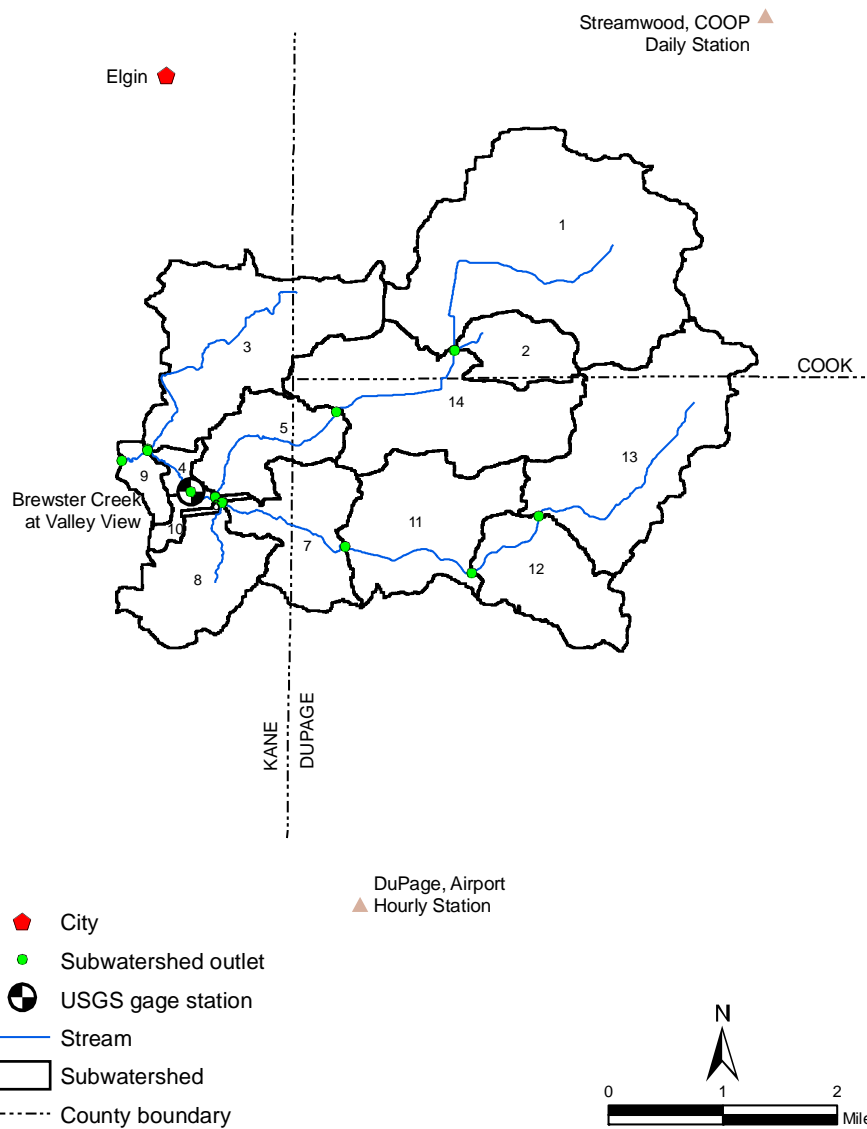


Figure 3. Delineation of Brewster Creek watershed and location of precipitation and streamflow gages.

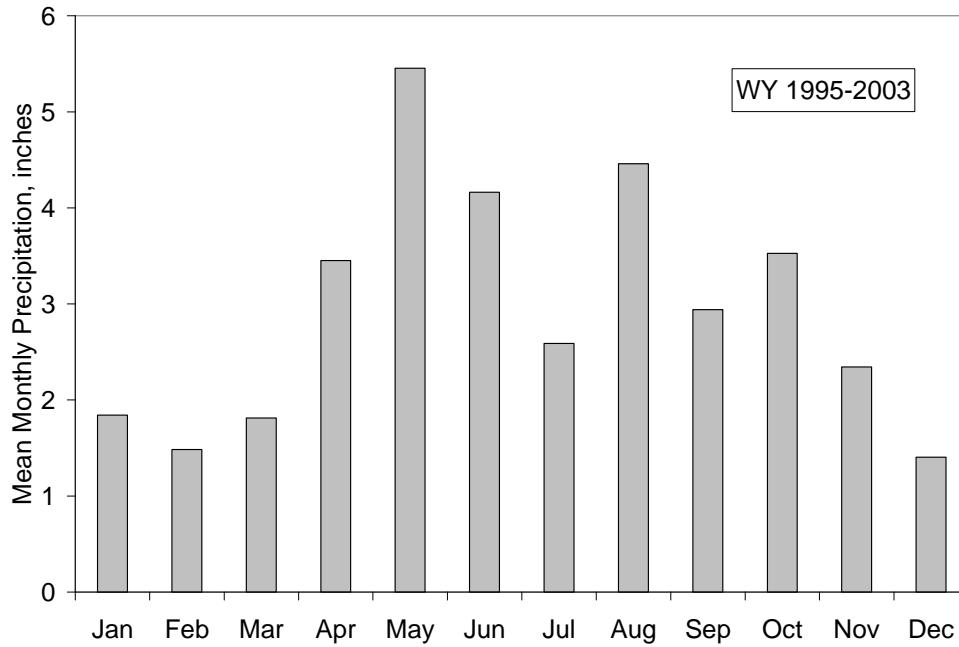


Figure 4. Mean monthly precipitation at Streamwood (Brewster Creek watershed).

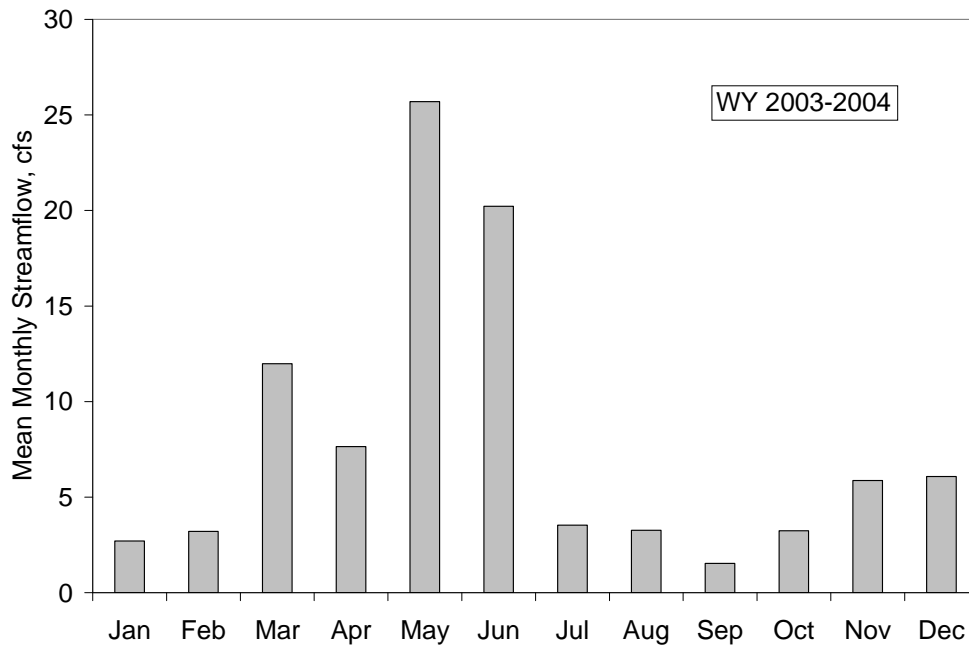


Figure 5. Mean monthly streamflow, Brewster Creek at Valley View (USGS 05551030).

Table 3. Precipitation and Streamflow in Brewster Creek Watershed

<i>Station/ Parameter</i>	<i>Time period (WY)</i>	<i>Mean annual value</i>	<i>High (WY)</i>	<i>Low (WY)</i>
Streamwood (ID 118324) Precipitation (inches)	1995-2003	35.7	42.8 (1995)	25.8 (2003)
Valley View (USGS 05551030) Streamflow (cfs)	2002-2003	7.9	10.1 (2003)	5.8 (2002)
Streamflow (inches on drainage area)	2002-2003	7.7	9.8 (2003)	5.6 (2002)

Ferson Creek Watershed

Five precipitation stations are in or near Ferson Creek watershed: Elgin (ID 112736, 1898-present), Elburn (ID 112709, 1999-present), Hampshire (ID 113782, 1996-1998), St. Charles (ID 117586, 2003-present), and St. Charles Illinois Climate Network or ICN station (ID STC, 1988-present). Only the St. Charles ICN station has hourly data; daily summaries are available for the other stations. Ferson Creek watershed and station locations are shown (Figure 6).

At this stage of the project, only the Elgin station, which has the longest consistent record, was used to provide precipitation and other climate data. Climate data were supplemented with hourly data from the St. Charles ICN station. Other stations were not used in the model for one or more reasons: insufficient record length (Hampshire station, St. Charles COOP station), minimal influence on subwatersheds (Elburn station), or data were being revised by the network operator (St. Charles ICN station).

Observed annual precipitation at Elgin for WY 1963-2003 ranges from 20.2 inches in 1984 to 49.9 inches in 1972, with a long-term mean value of 35.9 inches. Annual precipitation at the Elgin station during the study period was compared with the long-term mean (Figure 7). Five of the 13 years in the study period are wetter than the long-term mean, three years are very close to the long-term mean, and five years are drier. A plot of mean monthly precipitation over the study period (Figure 8) shows that more than half of the annual precipitation occurs between April and August.

The USGS streamflow gage (USGS ID 05551200) at Ferson Creek near St. Charles is located approximately 2.5 miles upstream from the mouth of Ferson Creek at the Fox River and has a drainage area of 52 square miles. This station has a streamflow record from December 1960 to present. Observed mean annual streamflows at the St. Charles gage range from 8.7 cubic feet per second (cfs) in 1977 to 76.7 cfs in 1993, with a long-term mean value of 40.0 cfs for the period of record, WY 1961-2003. Annual mean streamflows for the study period WY 1991-2003 and mean streamflows for WY 1963-2003 (41.9 cfs) are compared (Figure 9) to identify relatively wet, dry, and average streamflow years in the study period. Mean monthly streamflows over the long-term period (WY 1963-2003) and over the study period are illustrated (Figure 10).

Higher streamflows occur between February and June. High streamflows during winter months (February and March) when precipitation is low partially can be attributed to snowmelt.

Table 4 lists precipitation and streamflow statistics for the precipitation station at Elgin and the USGS streamflow gage at St. Charles, respectively.

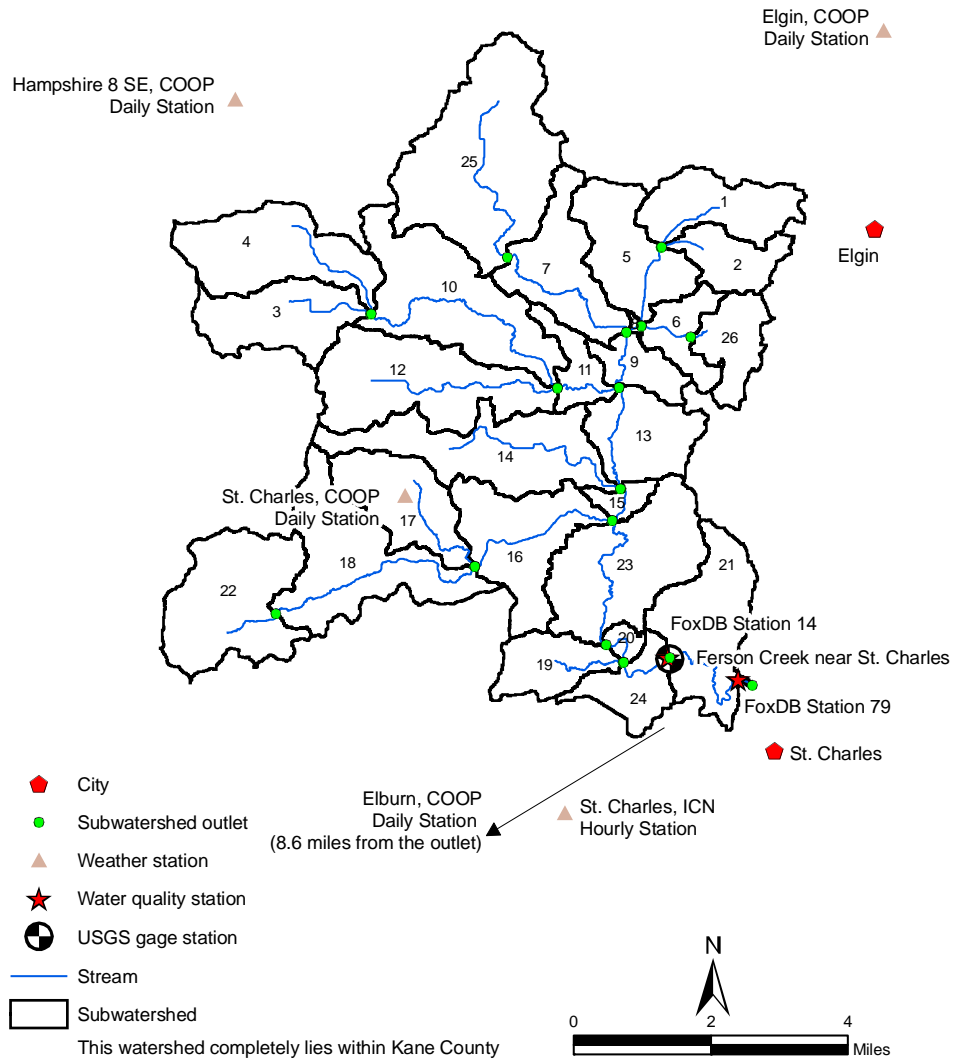


Figure 6. Delineation of Ferson Creek watershed and location of precipitation and streamflow gages.

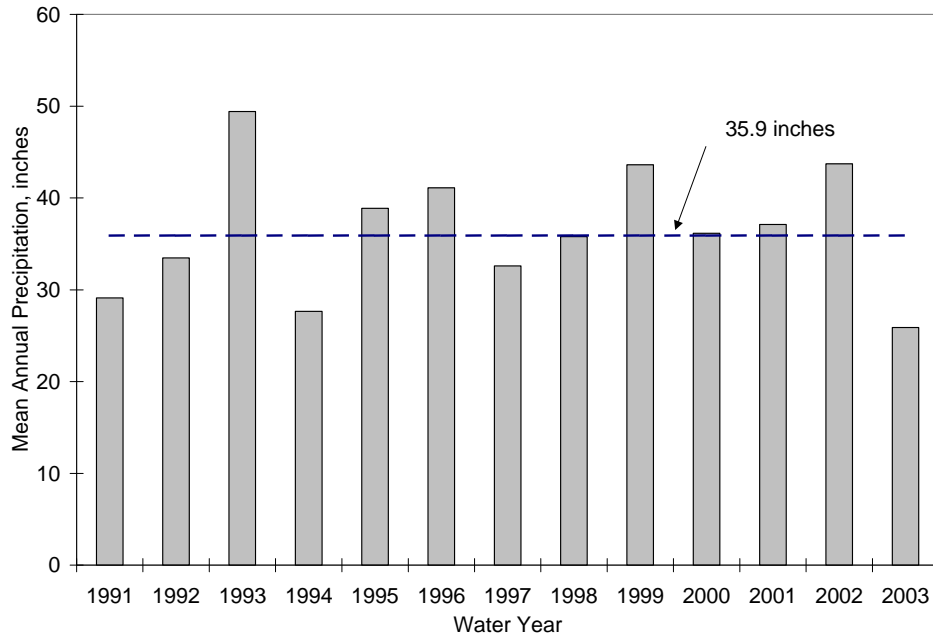


Figure 7. Mean annual precipitation at Elgin and long-term average (WY 1963-2003).

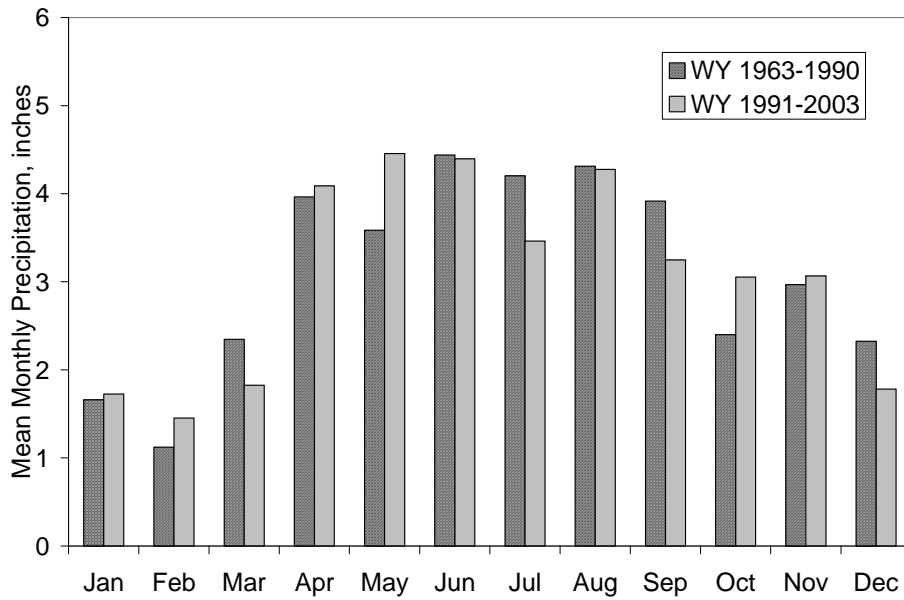


Figure 8. Mean monthly precipitation at Elgin (Ferson Creek watershed).

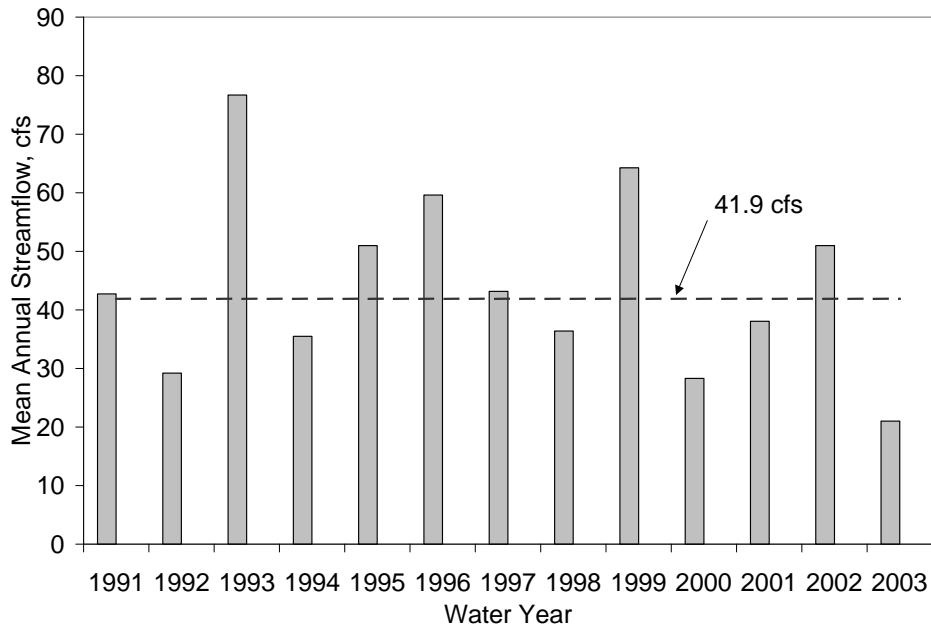


Figure 9. Mean annual streamflow, Ferson Creek at St. Charles, and long-term average (WY 1963-2003).

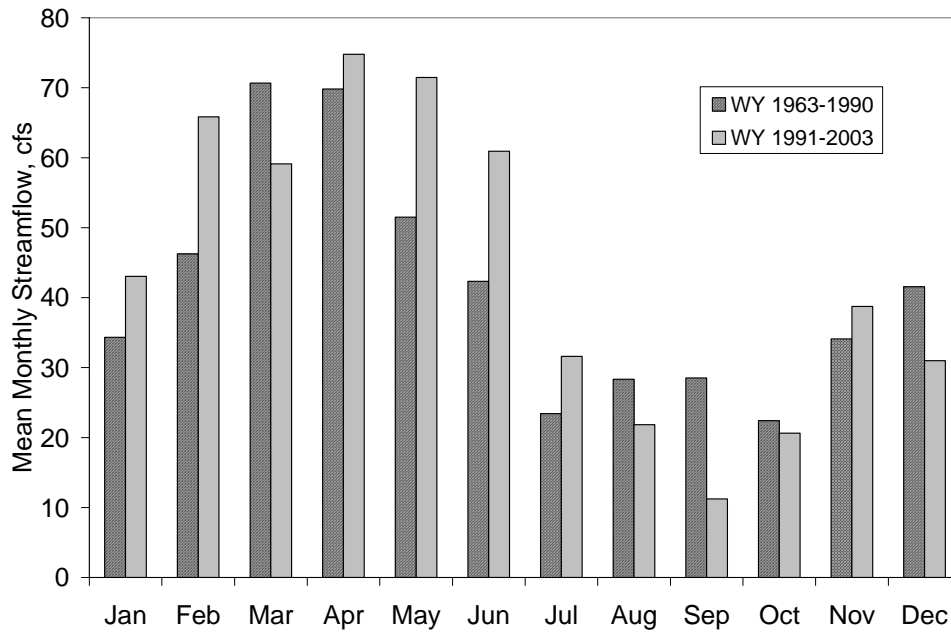


Figure 10. Mean monthly streamflow, Ferson Creek at St. Charles.

Table 4. Precipitation and Streamflow in Ferson Creek Watershed

<u>Station/Parameter</u>	<u>Time period</u> <u>(WY)</u>	<u>Mean annual</u> <u>value</u>	<u>High</u> <u>(WY)</u>	<u>Low</u> <u>(WY)</u>
Elgin (ID 112736)				
Precipitation (inches)	1963-2003	35.9	49.9 (1972)	20.2 (1984)
	1963-1990	35.7	49.9 (1972)	20.2 (1984)
	1991-2003	36.5	49.4 (1993)	25.9 (2003)
St. Charles (USGS 05551200)				
Streamflow (cfs)	1963-2003	41.9	76.7 (1993)	8.7 (1977)
	1963-1990	40.7	72.3 (1973)	8.7 (1977)
	1991-2003	44.4	76.7 (1993)	21.0 (2003)
Streamflow (inches on drainage area)	1963-2003	11.0	20.1 (1993)	2.3 (1977)
	1963-1990	10.7	19.0 (1973)	2.3 (1977)
	1991-2003	11.7	20.1 (1993)	5.5 (2003)

Note: Missing values in precipitation series may affect total precipitation values.

Flint Creek Watershed

Flint Creek watershed is within the influence of two precipitation stations: Barrington (ID 110442, 1962-present) and Mundelein (ID 115961, 1999-present). Ferson Creek watershed and station locations are shown (Figure 11). The Barrington station influences 15 subwatersheds and the Mundelein station nine subwatersheds. At this stage of the project, only the Barrington station was used for model simulations due to the longer record.

Observed annual precipitation for WY 1963-2003 at Barrington ranges from 8.8 inches (WY 1991), a sum affected by missing data, to 48.3 inches (WY 1983), with a mean annual value of 32.4 inches. Annual precipitation at the Barrington station during the study period is compared with the long-term mean (Figure 7). Six of the 13 years in the study period are wetter than the long-term mean, five years are drier, and one year has no recorded data. A plot of mean monthly precipitation over the study period shows the highest precipitation from April to August (Figure 13).

The USGS streamflow gage (USGS ID 05549850) is located approximately one mile upstream from the mouth of Flint Creek at the Fox River and has a reported drainage area of 37 square miles. Based on watershed boundary delineation, discussed in detail later in this report, existing conditions show that only 36 square miles drain to the Fox River via Flint Creek. This station has a record of streamflow data from 1989 to 1996. Observed mean annual streamflow ranges from 21.1 cfs (WY 1994) to 51.2 cfs (WY 1993) with a long-term value of 34.1 cfs (WY 1990-1996). Observed monthly streamflow was higher between March and May than the rest of the year (Figure 14). High streamflows during March when precipitation is low partially can be attributed to snowmelt. Precipitation and streamflow statistics are shown (Table 5).

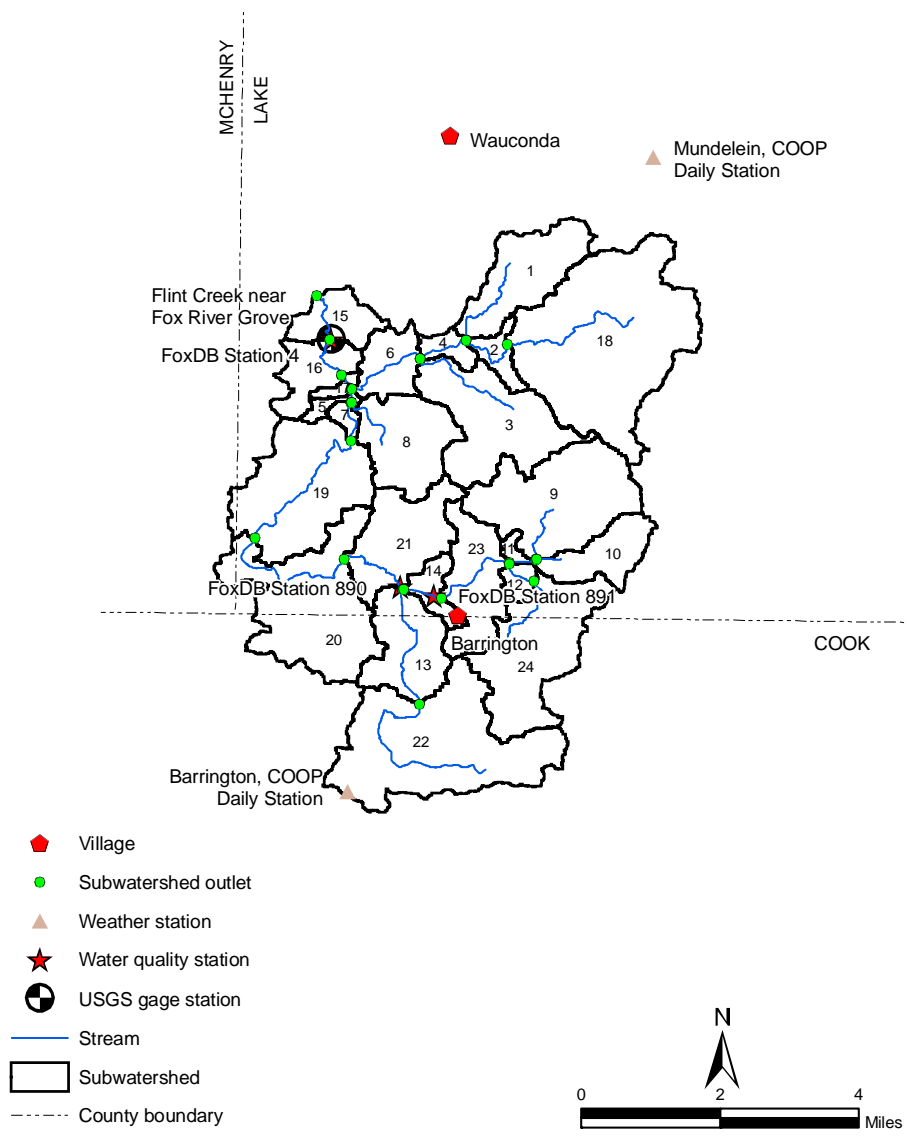


Figure 11. Delineation of Flint Creek watershed and location of precipitation and streamflow gages.

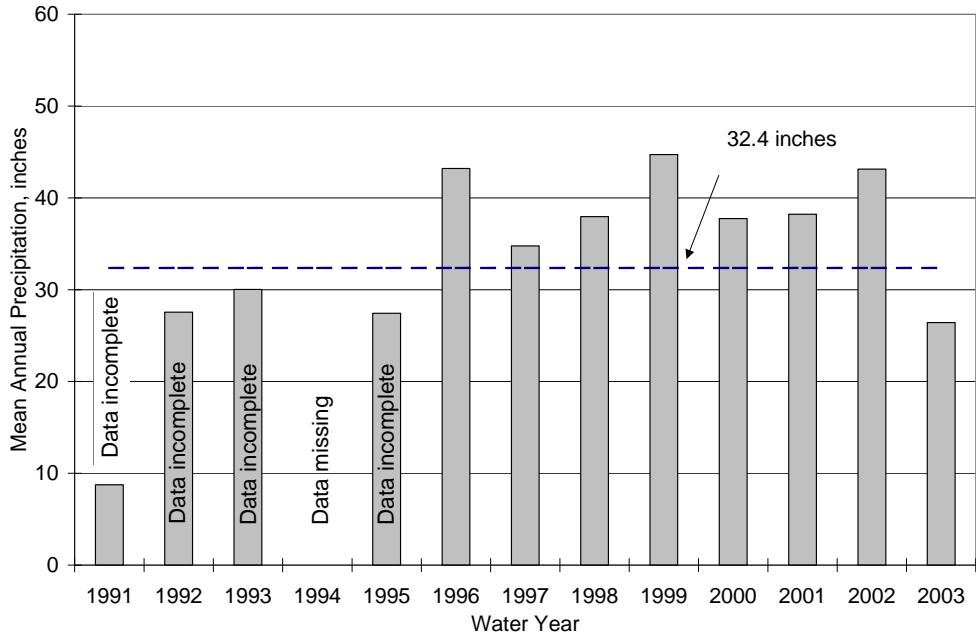


Figure 12. Mean annual precipitation at Barrington and long-term average (WY 1963-2003).

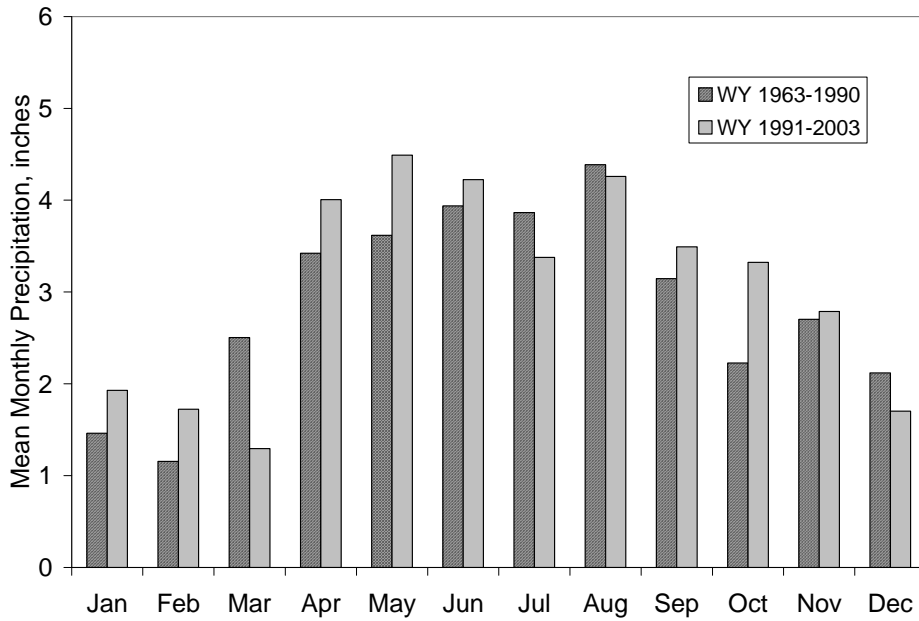


Figure 13. Mean monthly precipitation at Barrington (Flint Creek watershed).

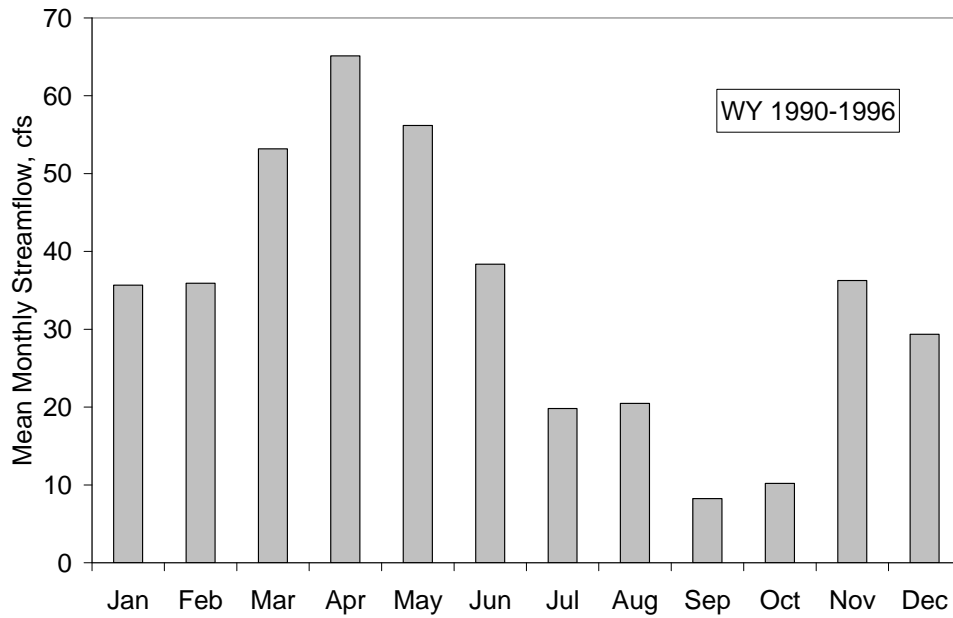


Figure 14. Mean monthly streamflow, Flint Creek near Fox River Grove (WY 1990-1996).

Table 5. Precipitation and Streamflow in Flint Creek Watershed

<u>Station/Parameter</u>	<u>Time period (WY)</u>	<u>Mean annual value</u>	<u>High (WY)</u>	<u>Low (WY)</u>
Barrington (ID 110442)				
Precipitation (inches)	1963-2003	32.2	48.3 (1983)	8.8 (1991)
	1963-1990	31.7	48.3 (1983)	13.1 (1971)
	1991-2003	32.2	44.7 (1999)	8.8 (1991)
Fox River Grove (USGS 05549850)				
Streamflow (cfs)	1991-1996	34.1	51.2 (1993)	21.1 (1994)
Streamflow (inches on drainage area)	1991-1996	12.5	18.8 (1993)	7.7 (1994)

Mill Creek Watershed

The Thiessen polygon method assigned three climate stations to the watershed: Aurora (ID 110338, 1887-present), St. Charles (ID 117586, 2003-present), and St Charles ICN (ID STC, 1988-present). The Charles ICN station has hourly data; only daily summaries are available for the other stations. Watershed and station locations are shown (Figure 15).

The St. Charles ICN station affects the largest part of Mill Creek watershed. Although record length is sufficient, this station was not used in the model simulation as the network operator was revising precipitation totals in hourly data. The St. Charles COOP station affects subwatershed 10 only and the record starts in 2003, the end of the study period. Thus, the Aurora station was used exclusively to supply precipitation and other climate data for the watershed. Climate data were supplemented with hourly data from the St. Charles ICN station.

Observed annual precipitation at the Aurora station for WY 1963-2003 ranges from 25.8 inches (WY 1971) to 51.0 inches (WY 1996), with a long-term mean of 37.4 inches. Annual precipitation at the Aurora station during the study period is compared with the long-term mean (Figure 16). Five of the 13 years in the study period are wetter than the long-term mean, three years are very close to the long-term mean, and five years are drier. A plot of mean monthly precipitation shows the highest values occur between April and September (Figure 17).

The USGS streamflow gage (USGS ID 05551330) near Batavia is located approximately 2.8 miles upstream from the mouth of Mill Creek at the Fox River and drains over 28 square miles. This station has daily streamflow data from May 1998 to present. Mean annual streamflow for the period of record ranges from 10.4 cfs (WY 2003) to 32.5 cfs (WY 1999), with a mean value of 19.8 cfs. The period of record is not sufficient to establish a long-term mean. Mean monthly streamflows over the study period are illustrated (Figure 18). Streamflow is highest from February to June. High streamflows during winter months of February and March when precipitation is low partially can be attributed to snowmelt. Streamflow statistics are reported with precipitation statistics (Table 6).

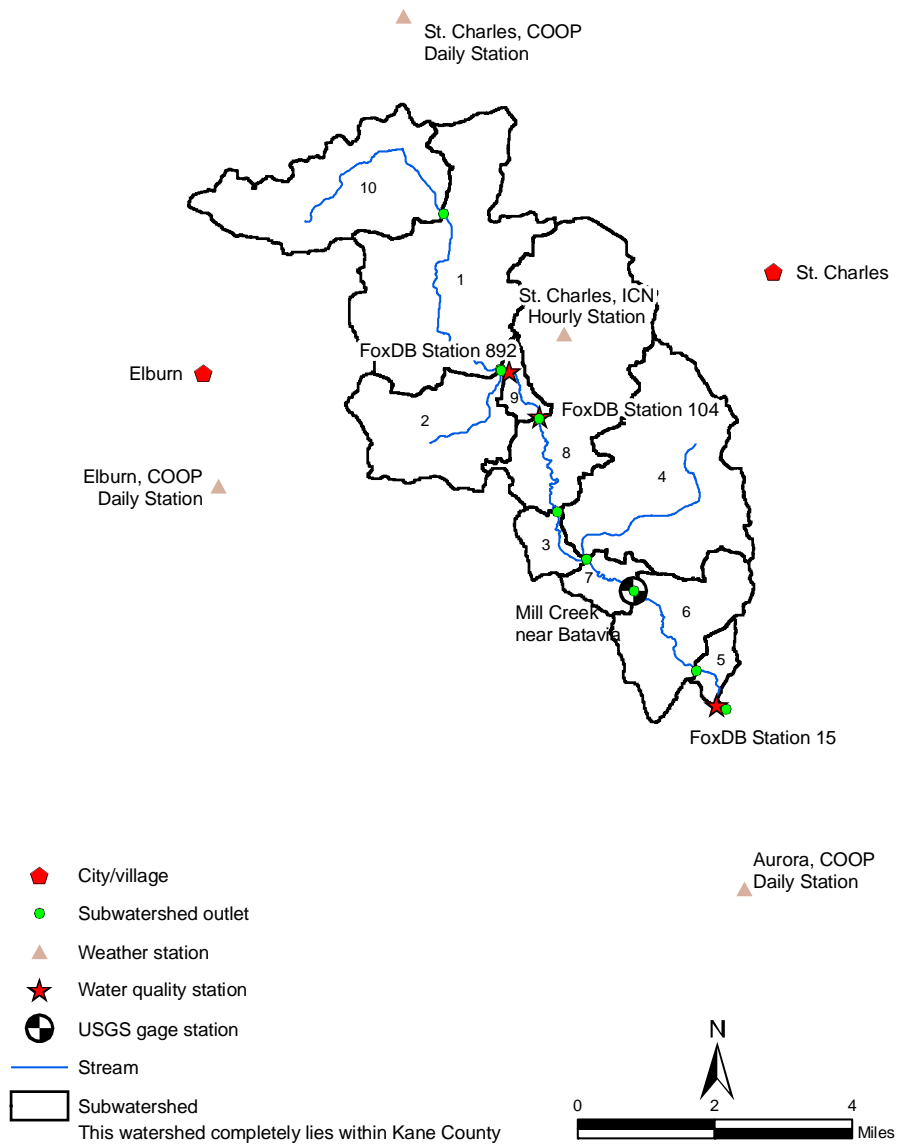


Figure 15. Delineation of Mill Creek watershed and location of precipitation and streamflow gages.

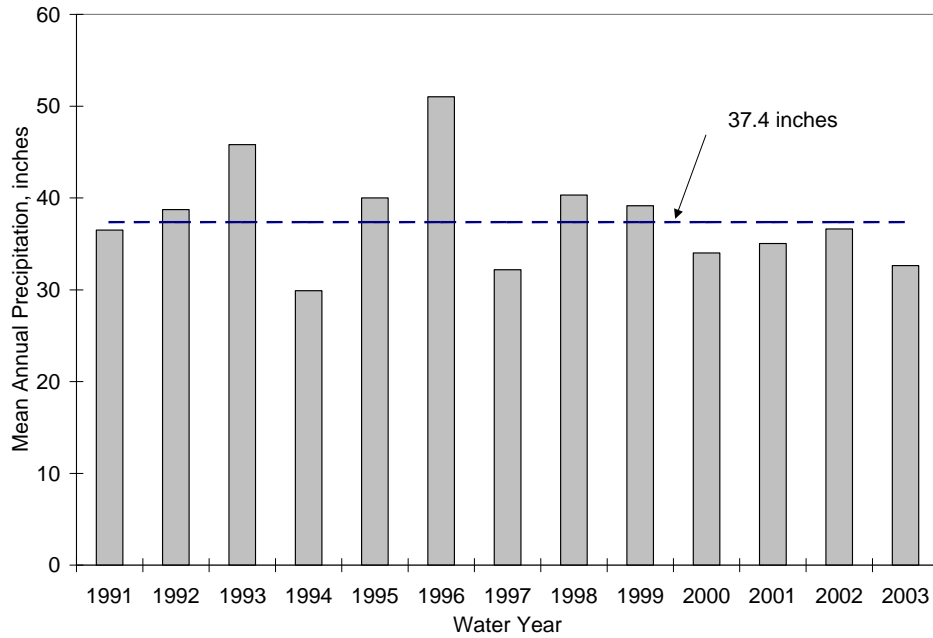


Figure 16. Mean annual precipitation at Aurora and long-term average (WY 1963-2003).

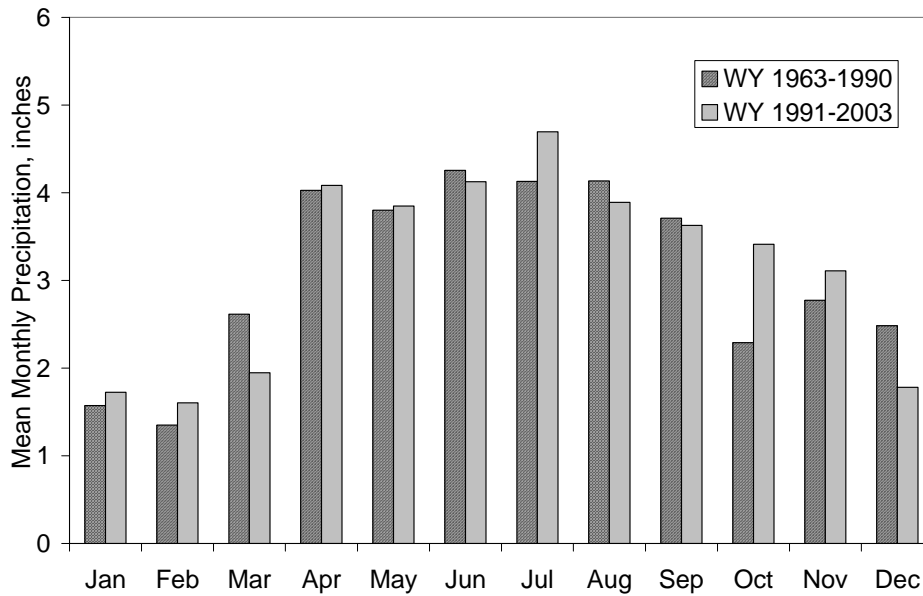


Figure 17. Mean monthly precipitation at Aurora (Mill Creek watershed).

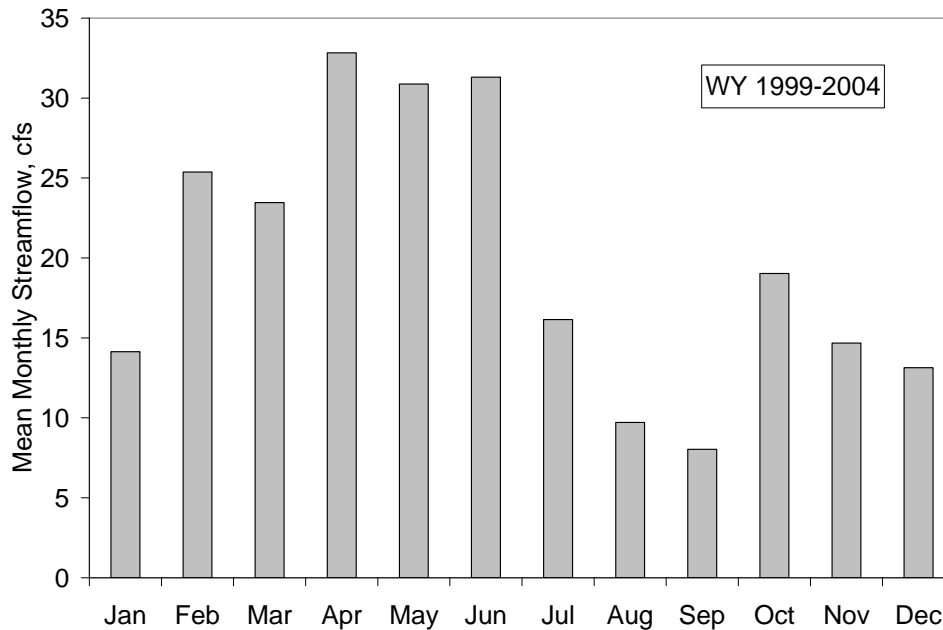


Figure 18. Mean monthly streamflow, Mill Creek near Batavia.

Table 6. Precipitation and Streamflow in Mill Creek Watershed

<u>Station/Parameter</u>	<u>Time period (WY)</u>	<u>Mean annual value</u>	<u>High (WY)</u>	<u>Low (WY)</u>
Aurora (ID 110338)				
Precipitation (inches)	1963-2003	37.4	51.0 (1996)	25.8 (1971)
	1963-1990	37.1	49.6 (1972)	25.8 (1971)
	1991-2003	37.9	51.9 (1996)	29.9 (1994)
Batavia (USGS 05551330)				
Streamflow (cfs)	1999-2004	19.8	32.5 (1999)	10.4 (2003)
Streamflow (inches on drainage area)	1999-2004	9.7	16.0 (1999)	5.1 (2003)

Tyler Creek Watershed

Tyler Creek watershed is within the influence of two climate stations: Hampshire (COOP 113782, 1996-1998) and Elgin (COOP 112736, 1898-present). Watershed and station locations are shown (Figure 19). Hampshire station influences nine subwatersheds and Elgin station 11 subwatersheds. At this stage of model development, only the Elgin station was used due to insufficient record length at the Hampshire station. Figure 7 and Figure 8 show the mean annual and monthly precipitation at Elgin. Statistics for the Elgin station are described in detail in the section on Ferson Creek watershed.

The USGS streamflow gage (USGS ID 05550300) at Tyler Creek at Elgin is located approximately 1.5 miles upstream from the mouth of Tyler Creek at the Fox River and drains about 39 square miles. This station has a record of streamflow data from June 1998 to present. Mean annual streamflow ranges from 11.8 cfs (WY 2003) to 44.6 cfs (WY 1999), with a long-term mean value of 31.1 cfs. Streamflow at the Elgin USGS gage is higher during the period February to May for WY 1990-2003 (Figure 20). High streamflows during February and March when precipitation is low partially can be attributed to snowmelt. Streamflow statistics are reported with precipitation statistics (Table 7).

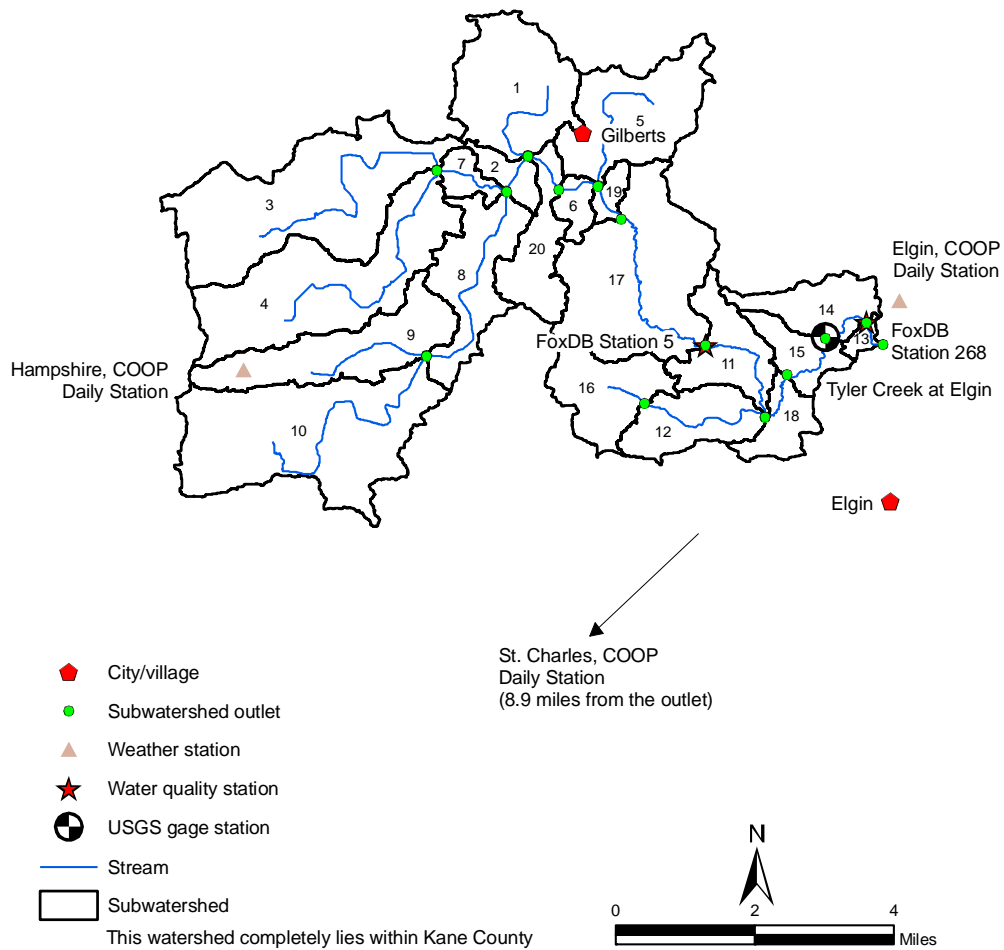


Figure 19. Delineation of Tyler Creek watershed and location of precipitation and streamflow gages.

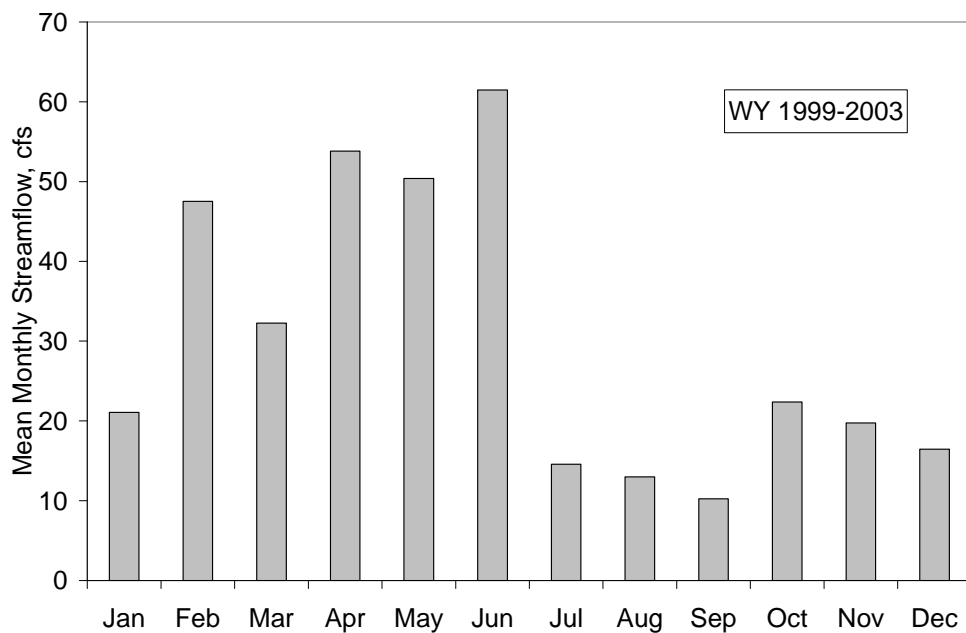


Figure 20. Mean monthly streamflow, Tyler Creek at Elgin (05550300).

Table 7. Precipitation and Streamflow in Tyler Creek Watershed

<u>Station/Parameter</u>	<u>Time period (WY)</u>	<u>Mean annual value</u>	<u>High (WY)</u>	<u>Low (WY)</u>
Elgin (ID 112736)				
Precipitation (inches)	1963-2003	35.9	49.9 (1972)	24.8 (1971)
	1963-1990	35.7	49.9 (1972)	24.8 (1971)
	1991-2003	36.5	49.4 (1993)	25.9 (2003)
Elgin (USGS 05550300)				
Streamflow (cfs)	1999-2003	31.1	44.6 (1999)	11.8 (2003)
Streamflow (inches on drainage area)	1999-2003	10.8	15.5 (1999)	4.1 (2003)

Summary

A comparison of the long-term precipitation record (WY 1963-1990) and the study period (WY 1991-2003) indicates that the study period had somewhat more precipitation, on average, than the prior 27 years. The lowest precipitation occurs January-March, and most precipitation occurs April-September. A comparison of streamflows recorded in the five watersheds shows consistently highest streamflows April-June and lowest ones in September during the study period. A long-term record of discharge data is only available for Ferson Creek at St. Charles. A comparison of the long-term streamflow record (WY 1963-1990) and the study period indicates that the study period had somewhat higher flows, on average, than the prior 27 years. The same is true for Blackberry Creek and Poplar Creek streamflows (Bartosova et al., 2007). Table 8 lists precipitation stations and streamflow gages providing input and calibration data for the modeled watersheds, respectively. Only data during the study period (WY 1991-2003) were used in simulation.

Table 8. Precipitation and Streamflow Stations Used in Modeling

<u>Watershed</u>	<u>Area</u> <u>(mi²)</u>	<u>Precipitation station</u>		<u>USGS streamflow gage</u>		
		<u>Name (ID)</u>	<u>Period of</u> <u>record</u>	<u>Name (ID)</u>	<u>Area*</u> <u>(mi²)</u>	<u>Period of</u> <u>record</u>
Brewster Creek	16	Streamwood (ID 118324)	WY 1995 - 2003	Brewster Creek at Valley View (05551030)	14	5/3/02 - present*
Ferson Creek	54	Elgin (ID 112736)	WY 1991 - 2003	Ferson Creek near St. Charles (05551200)	52	12/1/1960 - present
Flint Creek	36	Barrington (ID 110442)	WY 1991 - 2003	Flint Creek near Fox River Grove (05549850)	37	WY 1990 - 1996
Mill Creek	31	Aurora (ID 110338)	WY 1991 - 2003	Mill Creek near Batavia (05551330)	28	5/27/98 - present
Tyler Creek	41	Elgin (ID 112736)	WY 1991 - 2003	Tyler Creek at Elgin (05550300)	39	5/28/98 - present

Notes: *Area contributing to the USGS gage reported by the USGS does not necessarily reflect watershed area as delineated for purposes of this study.

The Valley View station may be discontinued soon (USGS, 2007).

HSPF Model Development

This section describes various aspects of developing HSPF models for the five validation watersheds: Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek watersheds. Models were developed using the BASINS system (USEPA, 2001). BASINS helps to define model structure using spatial information. Watershed and subwatershed boundaries were delineated, information on stream reaches was extracted, and input files for the HSPF model were created. Default model parameters then were replaced with parameters developed for the Blackberry Creek and Poplar Creek pilot watersheds (Bartosova et al., 2007). Discussion of specifics for each of the five validation watersheds follows.

Watershed Boundary Issues

The BASINS Automatic Delineation Tool was used to define watershed boundaries and to divide study watersheds into smaller subwatersheds. These subwatersheds were divided into HRUs based on land use, soil type, and slope category as specified in Singh et al. (2007) and Bartosova et al. (2007). Each subwatershed also is associated with a stream reach and an outlet that can be specified as a calculation point. The model will output results only for outlets specified as calculation points. Calculation points defined were at locations of USGS streamflow gages.

Within the BASINS framework, spatial analysis tools (GIS tools) are used with digital elevation data (in this case, the NED) to delineate watershed boundaries. Automation of the procedure is time-efficient, but results must be reviewed carefully and the NED often modified to correct the delineation. Accuracy of digital elevation data is crucial when delineating watershed boundaries. One test of autodelineation is to compare boundaries with watershed boundaries that are commonly accepted, such as the Hydrologic Unit Code (HUC-12) boundaries (NRCS, 2003c). HUC-12 boundaries are available for all of Illinois.

Circumstances when autodelineated watershed boundaries significantly differ from the HUC-12 boundaries in delineation of the Fox River tributary watersheds fall into four classes: flat areas and marsh lands, urban residential areas, near elevated roads, and artificial change of natural drainage pattern (e.g., multiple outfalls from a single structure draining to different watersheds). All discrepancies involving 5% or more tributary watershed area were classified as significant and resolved individually. Singh et al. (2007) discuss these problems and their resolution in detail.

Watershed boundaries generated in the BASINS framework facilitate model preparation. In general, when BASINS-delineated boundaries did not correspond with other reliable information, the NED was modified along problem areas to force the model to generate the correct boundary.

Assignment of Calibration Parameters

The HSPF models of Blackberry Creek and Poplar Creek watersheds were calibrated as the pilot watersheds for the HSPF model of the study area, the Fox River watershed from Stratton Dam to Illinois River (Bartosova et al., 2007). The pilot watersheds represent two contrasting land use and soil conditions, both typical for various areas of the Fox River watershed.

Each unique combination of land use, soil type, and slope is represented by a unique HRU in the prepared HSPF models. Each physiographically unique HRU can be assigned a set of parameter values determined through model calibration to define runoff characteristics and loading of various constituents from the HRU. The maximum number of unique HRUs is a product of the number of land use categories, soil types, and land slope categories used. The actual number of unique HRUs in a given watershed is expected to be smaller because not all combinations are necessarily present. Singh et al. (2007) give a detailed description of HRU determination. There are 22 and 53 unique HRU types in the Blackberry Creek and Poplar Creek watershed models, respectively, together accounting for 65 unique HRU types (some present in both watersheds). The five watersheds used for validating hydrology account for 99 unique HRU types, of which 50 types are present in the pilot watersheds.

Major HRU Types

Blackberry Creek watershed includes 22 unique HRU types. Four unique HRU types account for nearly 60% of watershed area, four others for about 20%, and the remaining 14 unique HRU types are distributed over 20% of watershed area. The four dominant HRU types include: corn, soybeans, urban open space, and rural grassland, all on hydrologic soil group B with slope less than 2%. Four other HRU types account for more than 4% of watershed area: forest on hydrologic soil group B with slope less than 2%, and corn, soybeans, and rural grassland on hydrologic soil group B with slope 2-4%. Changing model parameters during the calibration process for the four dominant HRU types has the biggest influence on simulated streamflows. On the other hand, even drastic change in model parameters for one of the 14 minor HRU types is unlikely to result in a significant change in simulated streamflows as each of those HRUs represents less than 3% of watershed area.

Composition of Poplar Creek watershed is even more diverse. Seven unique HRU types account for 62% of watershed area: forest, urban open space, and urban low/medium density on hydrologic soil group C with slope 2-4%, urban open space on hydrologic soil B with slope 2-4%, urban open space on hydrologic soil group D with slope 2-4%, and effective and noneffective impervious urban low/medium density with slope 2-4%. No HRU type is dominant in both Poplar Creek and Blackberry Creek watersheds. The remaining 46 unique HRU types, each contributing less than 4% watershed area, are distributed over 38% of Poplar Creek watershed.

Those 15 HRU types contributing at least 4% of watershed area were classified as major (Table 9). Major HRU types contribute 82.7% and 65.7% of watershed area for Blackberry Creek and Poplar Creek, respectively. Unique HRU types identified as major in Blackberry

Table 9. Major HRU Types Identified in Pilot Watersheds

<u>Land use</u>	<u>Hydrologic soil group</u>	<u>Slope, %</u>	<u>HRU Code</u>	<u>Percent watershed area</u>	
				<u>Blackberry Creek</u>	<u>Poplar Creek</u>
Corn	B	<2	COR21	20.9	0.5
Corn	B	2-4	COR22	5.1	0.9
Forest	B	<2	FOR21	4.6	0
Forest	C	2-4	FOR32	0	6.9
Soybeans	B	<2	SOY21	17.7	0.8
Soybeans	B	2-4	SOY22	5.8	0.6
Urban low/medium density	C	2-4	ULM32	0	12.4
Urban low/medium density (effective)	*	2-4	ULMIe2	0.5	4.2
Urban low/medium density (non-effective)	*	2-4	ULMIn2	0	4.2
Urban open space	B	<2	UOS21	9	0.9
Urban open space	B	2-4	UOS22	2.7	4.8
Urban open space	C	2-4	UOS32	0	22.1
Urban open space	D	2-4	UOS42	0	7.4
Rural grassland	B	<2	RGR21	10.9	0
Rural grassland	B	2-4	RGR22	5.5	0
			<u>Total</u>		
			Major	79.5	62.0
			Minor	3.2	3.7
			All	82.7	65.7

Notes: Major HRU types (more than 4%) are marked in bold for each watershed.

* Hydrologic soil group is not determined for impervious surfaces.

Creek watershed comprise only 3.7% of Poplar Creek watershed, however. Similarly, unique HRU types identified as major in Poplar Creek watershed comprise only 3.2% of Blackberry Creek watershed. Model parameters for the 15 major HRU types were assigned directly during parameterization of other tributary watersheds.

Minor HRU Types

During calibration of pilot watersheds, only major HRU types were calibrated consistently across watersheds. It would be nearly impossible to determine a unique set of calibration parameters for each minor HRU type that could be directly transferable to other watersheds because each one represents only a small area of watershed (less than 4%). Consequently, HRU types not identified as major (Table 9) cannot be considered properly calibrated.

Nine unique HRU types are present in both watersheds in addition to major HRU types. These nine HRU types combined contribute to 8.2% and 9.1% of watershed area for Blackberry Creek and Poplar Creek, respectively (Table 10). Due to time and resource constraints, the difference in parameter values for minor HRU types between Blackberry Creek and Poplar

Table 10. Minor HRU Types Identified in Both Pilot Watersheds

<u>Land use</u>	<u>Hydrologic soil group</u>	<u>Slope, %</u>	<u>HRU Code</u>	<u>Percent watershed area</u>	
				<u>Blackberry Creek</u>	<u>Poplar Creek</u>
Forest	B	2-4	FOR22	2.3	3.1
Surface water	B	2-4	SWA22	0.2	0.5
Wetlands and marshes	B	2-4	SWM22	0.2	0.2
Urban high density (effective)	*	<2	UHD1e1	0.7	0.3
Urban high density (effective)	*	2-4	UHD1e2	0.2	3.1
Urban high density (effective)	*	>4	UHD1e3	0.2	0.1
Urban low/medium density (effective)	*	<2	ULM1e1	1.8	0.8
Urban low/medium density (effective)	*	>4	ULM1e3	0.4	0.3
Urban open space	C	<2	UOS31	2.2	0.7
			<i>Total</i>	8.2	9.1

Note: *Hydrologic soil group is not determined for impervious surfaces.

Creek watershed models was not resolved. Identifying a proper set of calibration parameters for HRU types present in such a small percentage in either watershed would involve major effort but would not improve confidence in the model or its parameters adequately. This difference will be resolved during model development for the Fox River mainstem and all remaining tributaries. It can be expected that other unique HRU types will become important (major) in other tributary watersheds. Major HRU types then will be calibrated to streamflows on the Fox River mainstem during the next stage of the project.

Parameters for minor HRU types identified in both pilot watersheds were transferred from the watershed in which the respective land use or hydrologic soil group (in that order) was dominant. This means that model parameters for HRU types with hydrologic soil group B were transferred from corresponding HRUs in the Blackberry Creek watershed model, while model parameters for impervious urban HRU types and urban open space on hydrologic soil group C were transferred from corresponding HRUs in the Poplar Creek watershed model.

A similar method was used to assign parameters to HRU types not present in the pilot watersheds. Priority was given (in this order) to land use, hydrologic soil group, and slope category (Table 11). Land use was omitted from Table 11 as all land uses are represented in pilot watersheds, even if in low percentages. Each HRU type in the validation watersheds then was assigned the closest HRU type from the pilot watershed in which respective land use or hydrologic soil group (in this order) was dominant. For example, values for forest on hydrologic soil group B with slope less than 2% were taken from forest on hydrologic soil group B with slope 2-4% in Blackberry Creek watershed. Another example when hydrologic soil group could not be matched is for forest on hydrologic soil group A with slope less than 2%; the values were taken from forest on hydrologic soil group B with slope less than 2% in Blackberry Creek watershed. Table 11 shows the order of individual components in which the most similar HRUs were selected.

Table 11. Matching New HRU Types with HRU Types in Pilot Watersheds in Preference Order for Assignment of Model Parameters

<u>New HRU type</u>			<u>Matching HRU type from pilot watersheds</u>					
<u>Land use</u>	<u>Soils</u>	<u>Slope</u>	<u>Land use</u>	<u>Soils</u>				<u>Slope</u>
				(1)	(2)	(3)	(4)	
Any	A	Any	Same	A	B	C	D	See below
Any	B	Any	Same	B	C	A	D	See below
Any	C	Any	Same	C	D	B	A	See below
Any	D	Any	Same	D	C	B	A	See below

<u>New HRU Type</u>	<u>Matching HRU type from pilot watersheds</u>		
<u>Slope</u>	(1)	(2)	(3)
<2%	<2%	2-4%	>4%
2-4%	2-4%	<2%	>4%
>4%	>4%	2-4%	<2%

Specifics for the Study Watersheds

Brewster Creek Watershed

Brewster Creek watershed was subdelimited into 14 hydrologically connected subwatersheds. A calculation point defined at the outlet of subwatershed 6 corresponds to the location of the USGS streamflow gage at Valley View (05551030). Subwatershed numbers (Figure 3) correspond to those listed in Appendix A that summarizes information on the total area of each subwatershed and area of pervious and impervious land use.

Subwatershed size ranges from 23 acres (subwatershed 6) to 2381 acres (subwatershed 1), as listed in Appendix A. The fraction of impervious area within a subwatershed is 0-30.2%. Impervious surface (combined from urban high and urban low/medium density together) covers nearly 12% of watershed area. Unique combinations of land use, soil type, and slope categories in the Brewster Creek watershed result in 53 different HRU types (Appendix B).

Watershed boundary issues were examined and resolved for Brewster Creek watershed. Most discrepancies were related to very small watershed surface slope in some areas. A significant discrepancy occurred at the southeast corner of the watershed, which had new development since publication of topographic maps used as an NED source. Pre-existing smaller ponds were combined into a larger pond, as identified by using recent aerial photographs. An autodelimited boundary crossed through the modified pond. The NED was modified to re-route autodelimited boundary through the official HUC-12 boundary. Figure 21 shows HUC-12 boundary, NED-delineated boundary, and final watershed boundary.

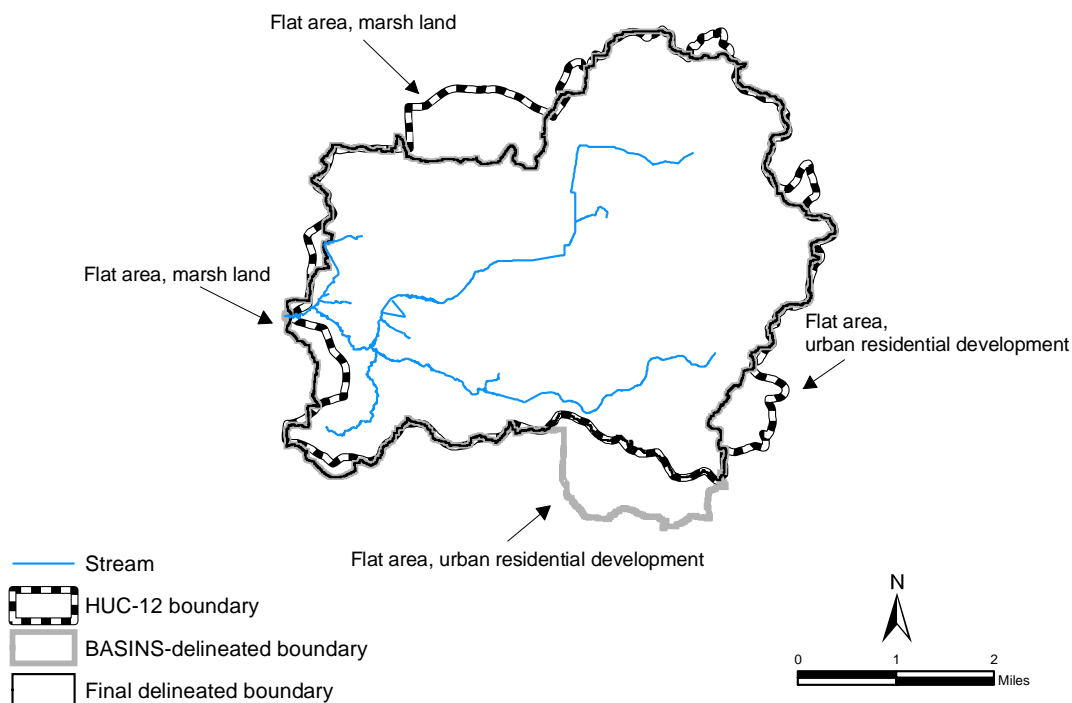


Figure 21. Boundary issues during delineation of Brewster Creek watershed.

Ferson Creek Watershed

Ferson Creek watershed was subdelineated into 26 hydrologically connected subwatersheds. A calculation point defined at the outlet of subwatershed 24 corresponds to the location of the USGS streamflow gage at St. Charles (05551200). Subwatershed numbers (Figure 6) correspond to those listed in Appendix A that summarizes the information on the total area of each subwatershed and area of pervious and impervious land use.

Subwatershed size ranges from 30 acres (subwatershed 8) to 3362 acres (subwatershed 25), as listed in Appendix A. The fraction of impervious area within a subwatershed is 0-27.2%. Impervious surface (combined from urban high and urban low/medium density together) covers only 3.6% of watershed area. Unique combinations of land use, soil type, and slope categories in Ferson Creek watershed result in 60 different HRU types (Appendix B).

Watershed boundary issues were examined and resolved for Ferson Creek watershed. Most discrepancies were related to very small watershed surface slope in some areas. A significant discrepancy at the south boundary shared with Mill Creek watershed is related to elevated road in the area. The change in elevation is extensive enough to be reflected in the 10-meter NED. The original NED was modified to counteract the effect of this elevated structure. Figure 22 shows HUC-12 boundary, NED-delineated boundary, and final model watershed boundary.

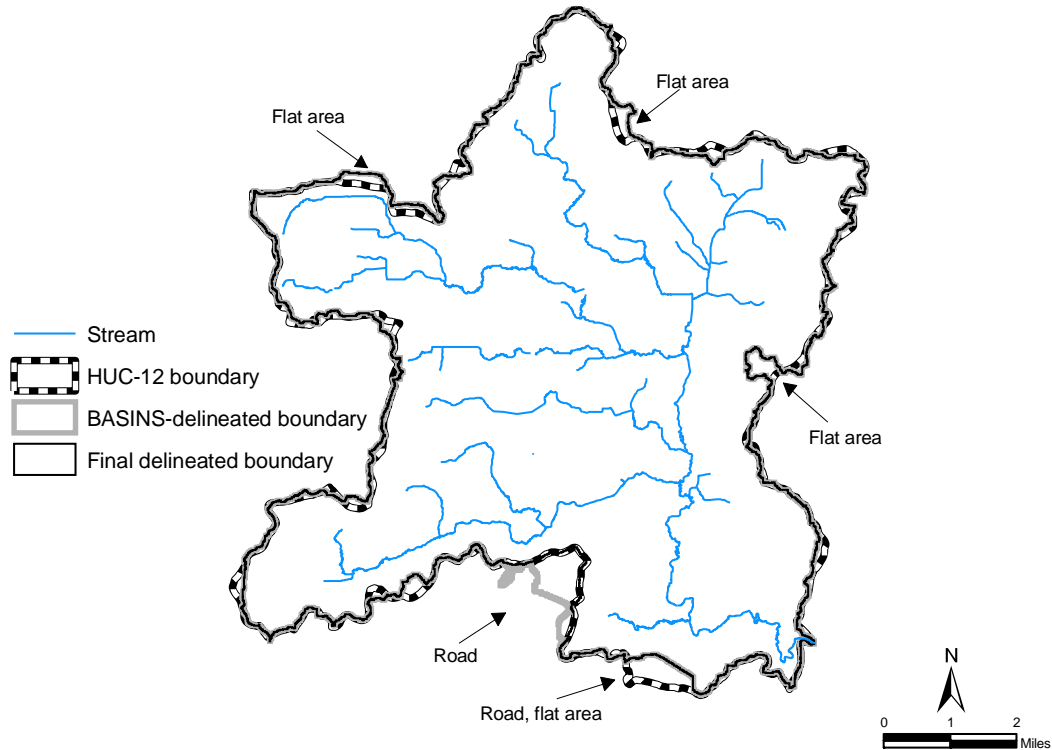


Figure 22. Boundary issues during delineation of Ferson Creek watershed.

Flint Creek Watershed

Flint Creek watershed was subdivided into 24 hydrologically connected subwatersheds. A calculation point defined at the outlet of subwatershed 16 corresponds to the location of the USGS streamflow gage at Fox River Grove (05549850). Subwatershed numbers (Figure 11) correspond to those listed in Appendix A that summarizes the information on the total area of each subwatershed and area of pervious and impervious land use.

Subwatershed size ranges from 78 acres (subwatershed 11) to 3379 acres (subwatershed 18), as shown in Appendix A. The fraction of impervious area within a subwatershed is 0-28.1%. Impervious surface (combined from urban high and low/medium density together) covers 6% of watershed area. Unique combinations of land use, soil type, and slope categories in the Flint Creek watershed result in 66 different HRU types (Appendix B).

Watershed boundary issues were examined and resolved for Flint Creek watershed. Most discrepancies were related to very small watershed surface slope in some areas. A significant boundary difference was observed between the HUC-12 and the autodelineated boundary, particularly along the common boundary with Tower Lake watershed to the north. This northern part of the watershed has residential development as well as marshes and the area is naturally flat. According to the Hawthorn Village authority, the area in concern contributes outside the Flint Creek watershed into the Tower Lake Outlet watershed (Lee M. Fell, Christopher B. Burke Engineering, personal communication, October 2005). The autodelineated boundary reflects this fact. Figure 23 shows HUC-12 boundary, NED-delineated boundary, and final watershed boundary.

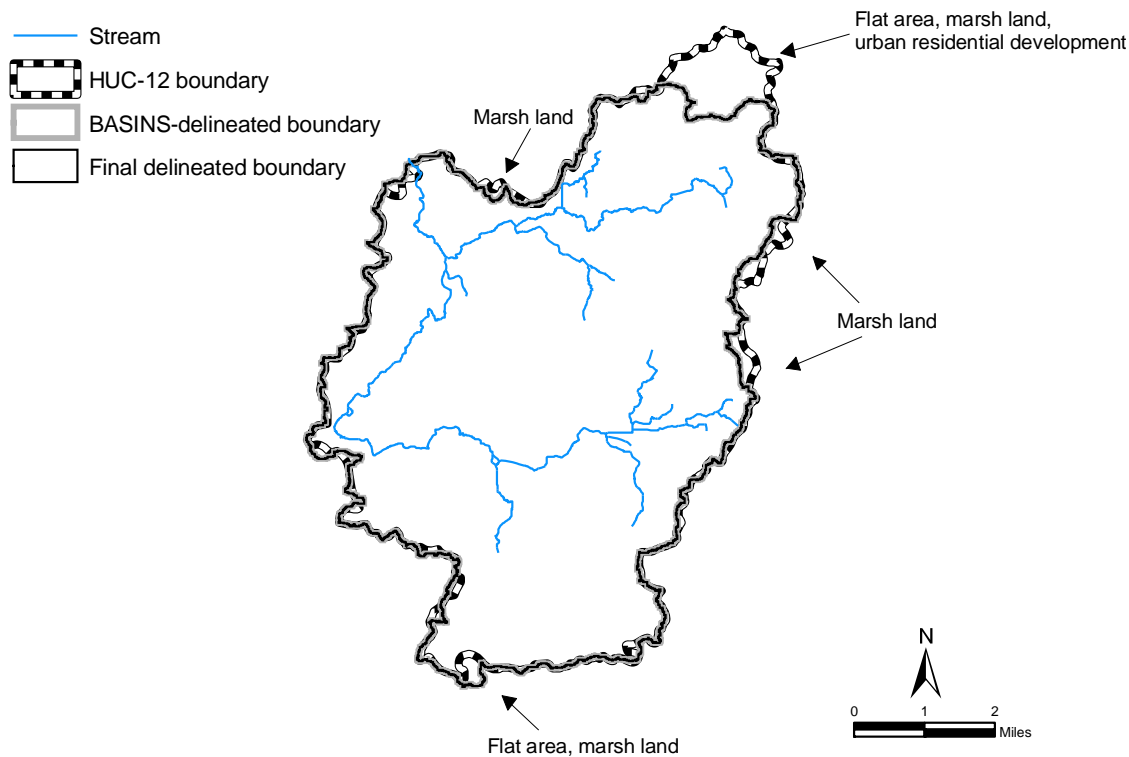


Figure 23. Boundary issues during delineation of Flint Creek watershed.

Mill Creek Watershed

Mill Creek watershed was subdelineated into 10 hydrologically connected subwatersheds. A calculation point defined at the outlet of subwatershed 7 corresponds to the location of the USGS streamflow gage at Batavia (05551330). Subwatershed numbers (Figure 15) correspond to those listed in Appendix A that summarizes the information on the total area of each subwatershed and area of pervious and impervious land use.

The subwatershed size ranges from 305 acres (subwatershed 9) to 4264 acres (subwatershed 1), as shown in Appendix A. The fraction of impervious area within a subwatershed is 0-18.1%. Impervious surface (combined from urban high and urban low/medium density together) covers 5.6% of watershed area. Unique combinations of land use, soil type, and slope categories in the Mill Creek watershed result in 49 different HRU types (Appendix B).

Watershed boundary issues were examined and resolved for the Mill Creek watershed. The discrepancy along the northeast boundary, shared with Ferson Creek watershed, is caused by the elevated road structure as discussed above. The same NED modification was used to counteract the effect of the structure. Figure 24 shows HUC-12 boundary, NED-delineated boundary, and final watershed boundary.

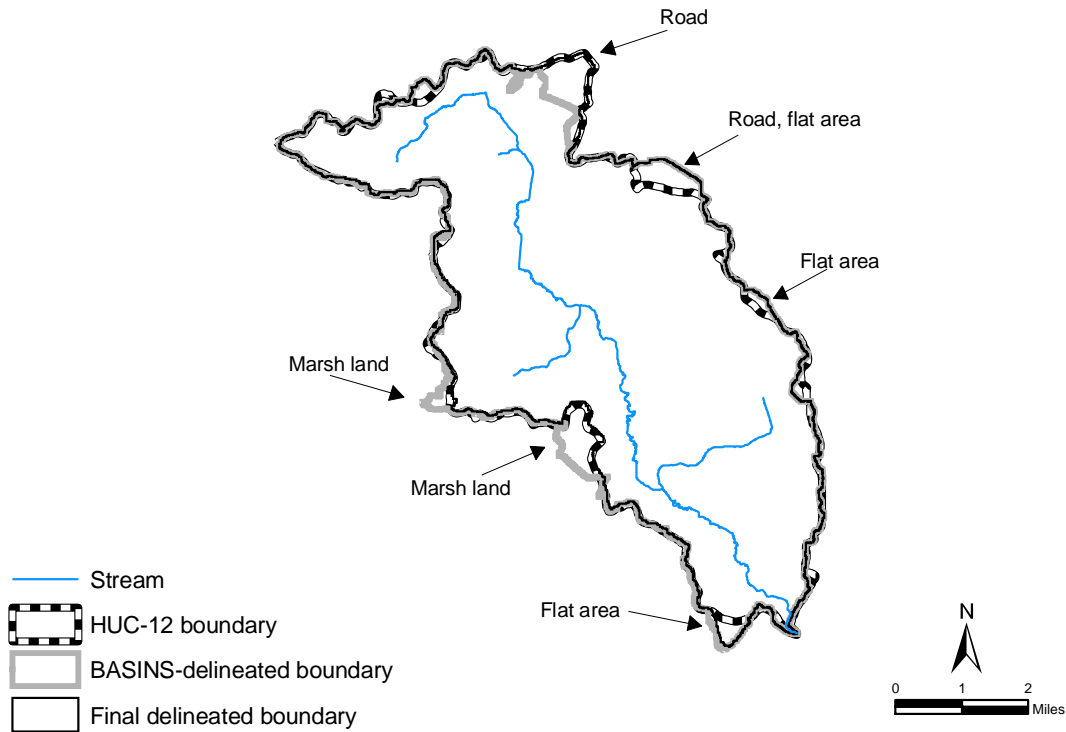


Figure 24. Boundary issues during delineation of Mill Creek watershed.

Tyler Creek Watershed

Tyler Creek watershed was subdelineated into 20 hydrologically connected subwatersheds. A calculation points defined at the outlet of subwatershed 15 corresponds to the location of the USGS streamflow gage at Elgin (05550300). Subwatershed numbers (Figure 19) correspond to those listed in Appendix A that summarizes the information on the total area of each subwatershed and area of pervious and impervious land use.

The subwatershed size ranges from 113 acres (subwatershed 13) to 3411 acres (subwatershed 10), as shown in Appendix A. The fraction of impervious area within a subwatershed is 0-35.5%. Impervious surface (combined from urban high and urban low/medium density together) covers 5.2% of watershed area. Unique combinations of land use, soil type, and slope categories in the Tyler Creek watershed result in 45 different types of HRUs (Appendix B).

Watershed boundary issues were examined and resolved for the Tyler Creek watershed. Most discrepancies were related to very small watershed surface slope in some areas. The NED was modified along the discrepancy at the east-central boundary to follow the HUC-12 boundary as the autodelineated boundary went through one of the ponds located at the roadside. The HUC-12 boundary keeps all ponds in this area in the Jelkes Creek watershed. Figure 25 shows HUC-12 boundary, NED-delineated boundary, and final watershed boundary.

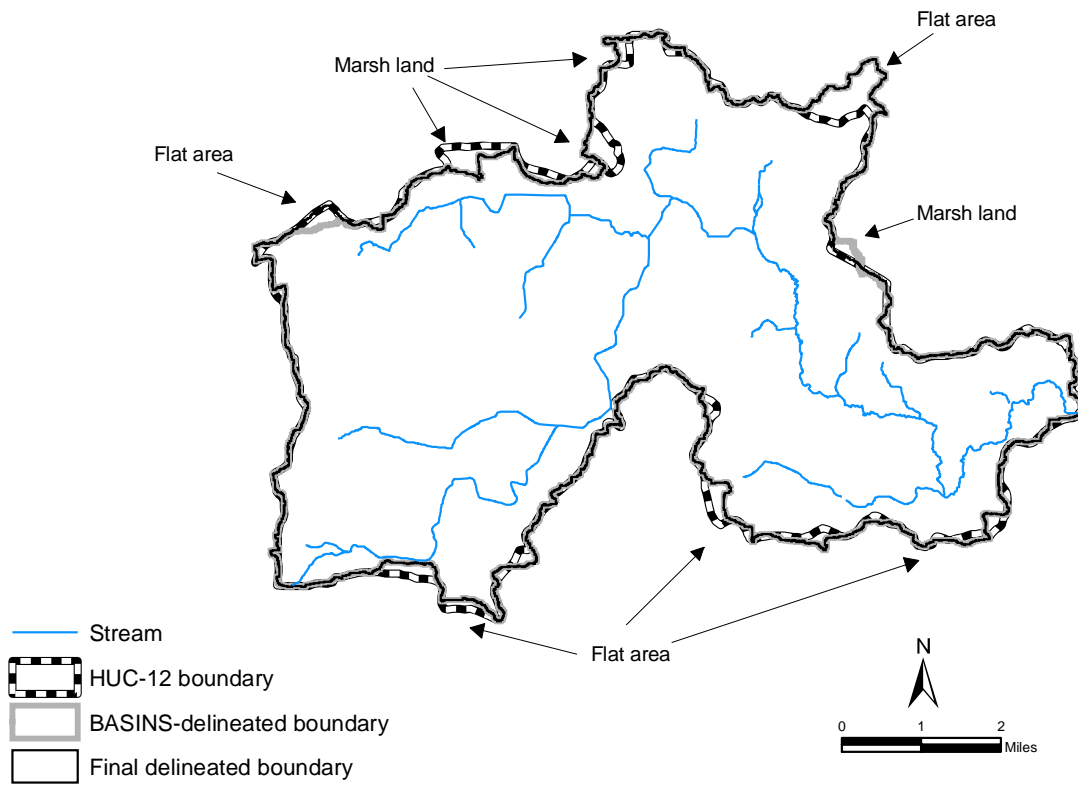


Figure 25. Boundary issues during delineation of Tyler Creek watershed.

Validation of Model Parameters

Criteria

Validation of hydrology on five additional watersheds tests transferability of model parameters outside calibrated watersheds. The hydrologic component of the HSPF model was calibrated to best simulate observed streamflow recorded at USGS streamflow gages at Blackberry Creek and Poplar Creek pilot watersheds (Bartosova et al., 2007). Both statistical and graphical tools were used to evaluate quality of fit between simulated (S) and observed (O) streamflows. Statistics provide an objective measure of fit, whereas graphs can depict trends and biases in a simple way. Parameter values determined through calibration of HSPF models for Blackberry Creek and Poplar Creek watersheds were used in HSPF models for the other five watersheds as described previously. The same comparisons for goodness of fit were used in this report as when evaluating models for pilot watersheds.

Three statistical measures of fit between simulated values and observations were calculated. For the overall, annual, and monthly comparisons, percentage errors in streamflow volumes (Dv, %) were calculated. Donigian et al. (1984) state that annual and monthly fit in HSPF simulations is very good when the absolute Dv is less than 10%, good between 10% and 15%, and fair between 15% and 25%. Annual, monthly, and daily flows also were compared statistically by calculating model efficiency (Nash-Sutcliffe Efficiency of model fit, NSE) and coefficient of correlation (r) between observed and simulated flows. The NSE indicates how consistently observed data match simulated values following a linear best-fit line. Both NSE and r values equal to one indicate perfect fit. Higher scatter around S=O line would result in lower r value.

Simulated and observed data also were compared graphically. A scatter plot of observed and simulated mean flows was used to identify any bias in terms of consistent overestimation or underestimation of flows for annual, monthly, and daily averages. Fit between daily observed and simulated streamflows also was checked by plotting flow duration curves. General agreement between observed and simulated flow duration curves indicates adequate calibration over the range of flow conditions simulated.

Bartosova et al. (2007) report results of calibrating the hydrologic component of HSPF models for Blackberry Creek and Poplar Creek watersheds. Statistical results of model calibration for Blackberry Creek and Poplar Creek also are given (Table 12 and Table 13, respectively).

Table 12. Statistics for Model Calibration and Validation Periods at Yorkville and Montgomery Gages, Blackberry Creek Watershed (Bartosova et al., 2007)

<u>Statistic</u>	<u>Yorkville gage</u>		<u>Montgomery gage</u>	
	<u>Calibration</u>	<u>Validation 1</u>	<u>Validation 2</u>	<u>Validation 3</u>
<u>Period of analysis</u>	<u>WY 1993-2000</u>	<u>WY 1991-1992</u>	<u>WY 2001-2003</u>	<u>WY 2000-2003</u>
<i>Long-term mean</i>				
Observed, cfs	61.6	49.7	46.3	36.2
Simulated, cfs	61.9	57.5	43.6	35.5
Dv, %	0.6	15.8	-5.8	-1.9
<i>Annual</i>				
NSE	0.82	0.59	0.66	0.72
r	0.92	1.00	0.88	0.92
Years with Dv within $\pm 10\%$	5	0	2	2
Years with Dv within $\pm 25\%$	8	2	2	4
<i>Monthly</i>				
NSE	0.74	0.63	0.75	0.77
r	0.92	0.85	0.88	0.93
Months with Dv within $\pm 10\%$	27	5	5	13
Months with Dv within $\pm 25\%$	56	13	14	22
<i>Daily</i>				
NSE	0.55	0.52	0.64	0.59
r	0.72	0.75	0.78	0.80

Note: Dv = Error in simulated and observed streamflow volumes for a given time period.

Table 13. Statistics for Model Calibration and Validation Periods at Elgin Gage, Poplar Creek Watershed (Bartosova et al., 2007)

<u>Statistic</u>	<u>Elgin</u>	
	<u>Calibration</u> <u>April 1991-WY 1999</u>	<u>Validation</u> <u>WY 2000-2003</u>
<i>Long-term mean</i>		
Observed, cfs	33.7	29.4
Simulated, cfs	33.6	27.0
Dv, %	<0.1	-8.2
<i>Annual</i>		
NSE	0.95	0.89
r	0.98	0.98
Years with Dv within $\pm 10\%$	7	3
Years with Dv within $\pm 25\%$	9	4
<i>Monthly</i>		
NSE	0.87	0.88
r	0.93	0.95
Months with Dv within $\pm 10\%$	26	12
Months with Dv within $\pm 25\%$	61	27
<i>Daily</i>		
NSE	0.76	0.67
r	0.87	0.82

Note: Dv = Error in simulated and observed streamflow volumes for a given time period.

Brewster Creek Watershed

Table 14 presents model validation statistics for the USGS gage at Valley View. The volume error between observed and simulated streamflows was -7.5% over the validation period (June 2002-WY 2003), indicating very good overall fit. This error was within 10% both years (Figure 26). Mean annual streamflows were simulated with NSE=0.88.

Mean monthly streamflows were simulated with NSE=0.84 (Table 14), indicating good correlation with observed data. This is also shown in a scatter plot of observed and simulated mean monthly flows (Figure 27). The volume error between observed and simulated mean monthly streamflows was within 25% (fair simulation) in five months of the 16-month validation period.

Statistics show poor agreement between observed and simulated daily streamflows for the validation period (NSE=-0.31 and r=0.69). The scatter plot (Figure 28) and flow duration curves (Figure 29) of observed and simulated daily streamflows show that the model simulated the high range of daily streamflows within 25% of observed values but significantly underestimated streamflows with observed values less than 8 cfs.

Table 14. Statistics for Model Validation Periods at Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek Watersheds

<u>Statistics</u>	<u>Brewster Creek</u> <u>6/2002-9/2003</u>	<u>Ferson Creek</u> <u>WY 1991-2003</u>	<u>Flint Creek</u> <u>WY 1991-1996</u>	<u>Mill Creek</u> <u>6/1998-WY 2003</u>	<u>Tyler Creek</u> <u>6/1998-WY 2003</u>
<i>Long-term mean</i>					
Observed, cfs	7.11	44.2	33.9	20.5	29.8
Simulated, cfs	6.58	37.8	27.1	17.9	29.3
Dv, %	-7.5	-14.4	-20.1	-12.3	-1.6
<i>Annual</i>					
NSE	0.88	0.64	0.25	0.67	0.97
r	1.0	0.91	0.87	0.87	0.997
Years with Dv within $\pm 10\%$	2	4	2	2	4
Years with Dv within $\pm 25\%$	2	10	5	5	4
<i>Monthly</i>					
NSE	0.84	0.77	0.73	0.57	0.89
r	0.94	0.90	0.89	0.77	0.95
Months with Dv within $\pm 10\%$	0	31	11	6	16
Months with Dv within $\pm 25\%$	5	79	27	16	34
<i>Daily</i>					
NSE	-0.30	0.52	0.39	0.37	0.72
r	0.69	0.73	0.67	0.61	0.86

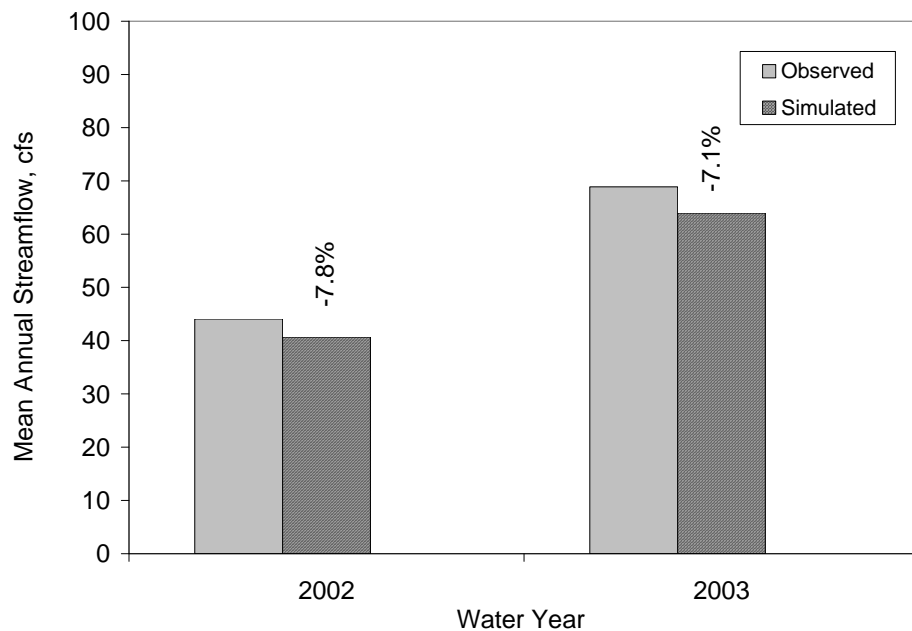


Figure 26. Observed and simulated mean annual streamflows, Brewster Creek.

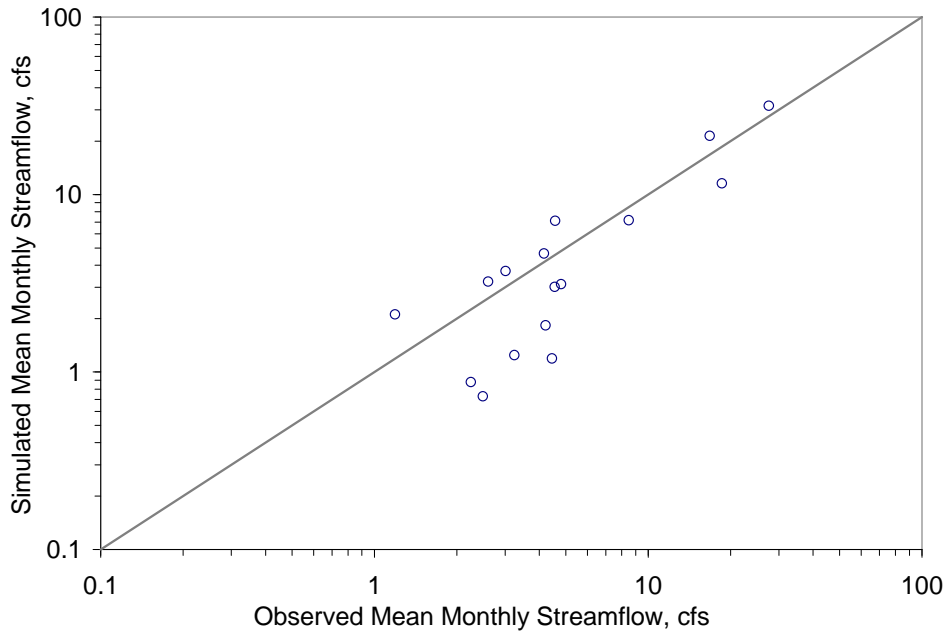


Figure 27. Observed and simulated mean monthly streamflows, Brewster Creek.

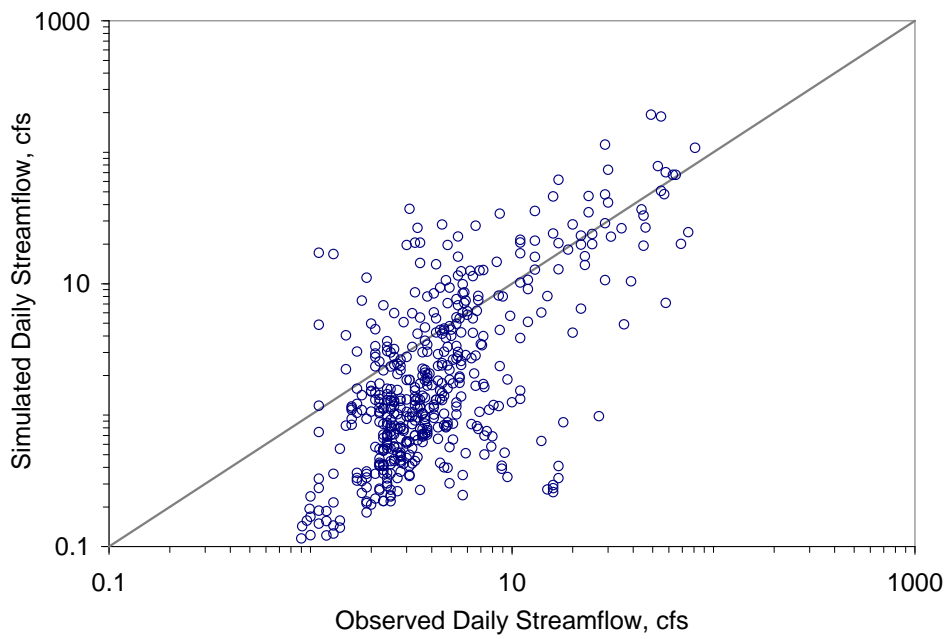


Figure 28. Observed and simulated daily streamflows, Brewster Creek.

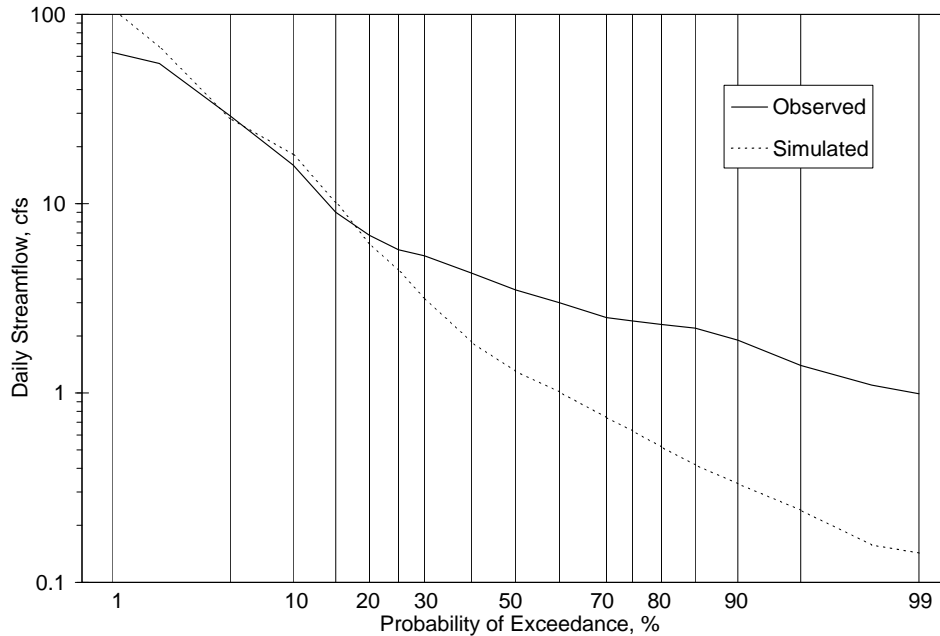


Figure 29. Flow duration curve for observed and simulated daily streamflows, Brewster Creek.

Natural streamflows plotted on probabilistic scale of flow duration curve typically approximate a straight line. Observed streamflows in Brewster Creek form two distinct segments with a breakpoint around 8 cfs (Figure 29), indicating a change in flow regime. The change can be attributed to a dam located just upstream of the USGS gage and constructed in 1929. The dam was lowered gradually between June 2003 and February 2004 (Kane County, 2007) during a stream restoration process and is no longer functional. Hydraulic properties of a reach in the HSPF model are specified in input files in FTABLES. The BASINS framework creates FTABLES for each reach automatically, assuming natural conditions. Any FTABLES for impounded reaches would need to be modified accordingly to reflect changed conditions. This was not done for the reach affected by the impoundment. Flood Insurance Study (FIS) models were not available for Brewster Creek, or any of the other four creeks evaluated in this study. The dam and impoundment are the past conditions, so any future scenarios should be evaluated without the dam, which is how the model is set up.

Ferson Creek Watershed

Table 14 presents model validation statistics at the USGS gage near St. Charles. The volume error between observed and simulated streamflows was -14.4% over the validation period (WY 1991-2003), indicating good overall fit. On a yearly basis, the volume error was within $\pm 10\%$ (very good simulation) in four years and within $\pm 25\%$ (fair simulation) in ten years (Figure 30). The model overestimated annual streamflows in three years and underestimated them in eight years. Mean annual streamflows were simulated with NSE=0.64.

Mean monthly streamflows were simulated with NSE=0.77 (Table 14), indicating fair correlation with observed data. Figure 31 indicates that simulated monthly streamflows generally

followed the same trend as observed values, but the model slightly overestimated lower flows and slightly underestimated higher flows. The volume error between observed and simulated monthly streamflows was within $\pm 10\%$ in 31 months and within $\pm 25\%$ in 79 months.

Statistics show fair agreement between observed and simulated daily streamflows (NSE=0.52 and $r=0.73$). The scatter plot (Figure 32) and flow duration curves (Figure 33) of the observed and simulated daily streamflows for the validation period show that the model slightly overestimated low daily streamflows and underestimated high daily streamflows.

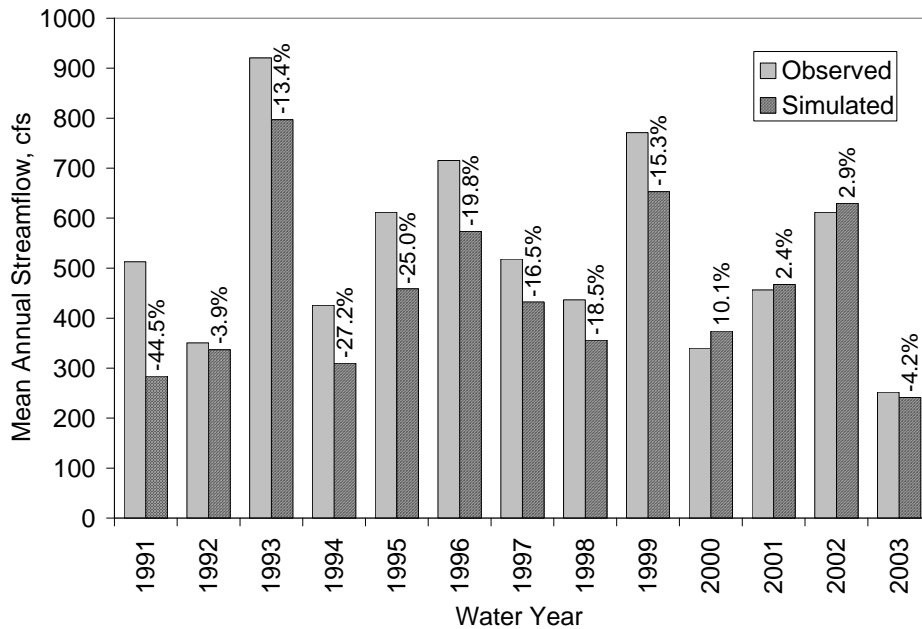


Figure 30. Observed and simulated mean annual streamflows, Ferson Creek.

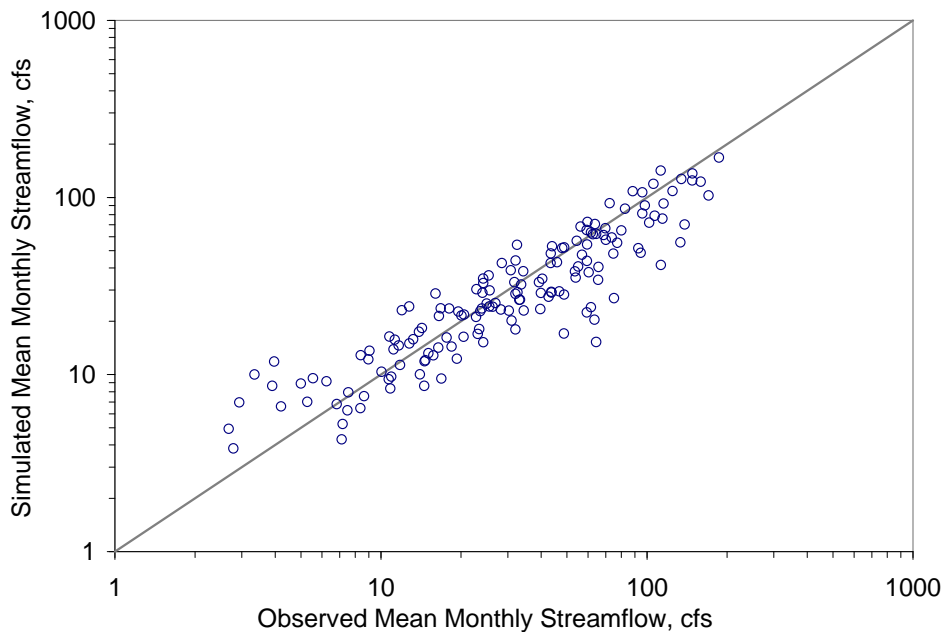


Figure 31. Observed and simulated mean monthly streamflows, Ferson Creek.

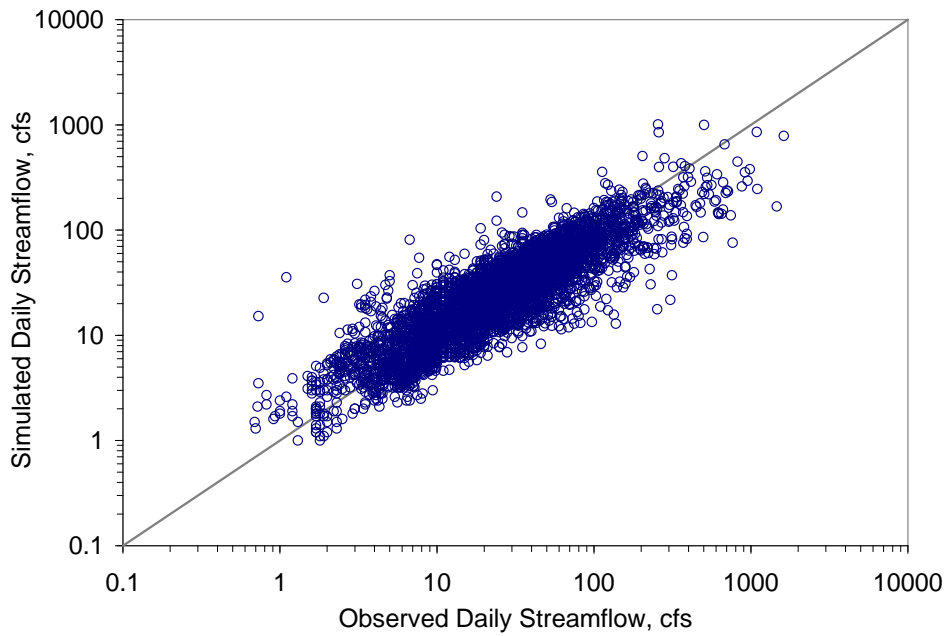


Figure 32. Observed and simulated daily streamflows, Ferson Creek.

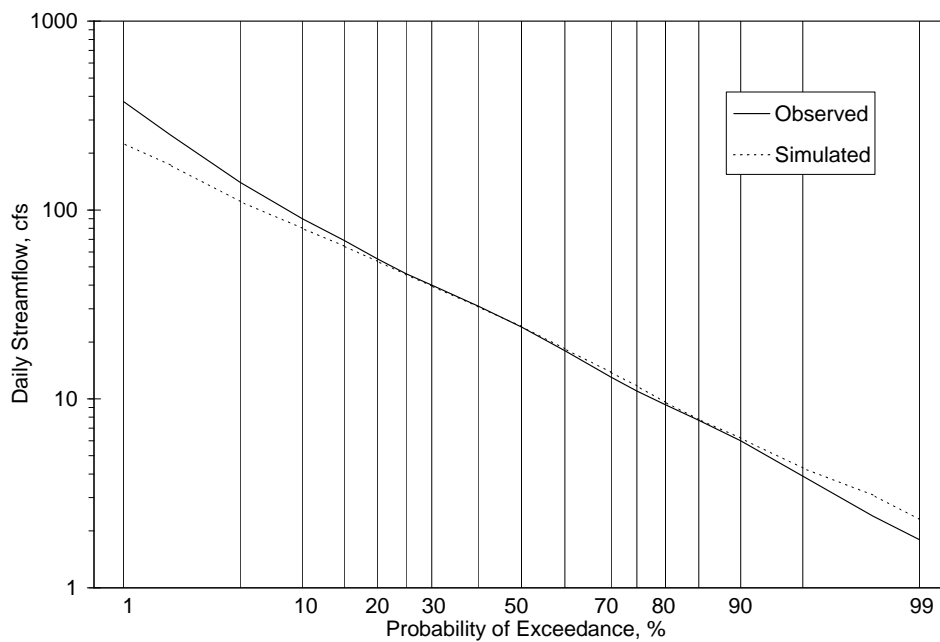


Figure 33. Flow duration curve for observed and simulated daily streamflows, Ferson Creek.

Flint Creek Watershed

Table 14 presents model validation statistics for the USGS gage near Fox River Grove. The volume error between observed and simulated annual streamflows was -20.1% over the calibration period (WY 1991-1996), indicating fair overall fit. The volume error was within $\pm 10\%$ (very good simulation) in two years and within $\pm 25\%$ (fair simulation) in five years (Figure 34). The model underestimated streamflows in all six years (by -8.4% to -54%). Mean annual streamflows were simulated with NSE=0.25. The low NSE is driven by a large difference between simulated and observed streamflows during the first year of simulation, WY 1991. Excluding first-year data greatly improves the statistic to NSE=0.80. Unknown initial conditions necessitate a substantial period (in some cases more than a year) before the model stabilizes and achieves proper balance of various hydrologic processes. Thus, the simulation period always starts before the calibration or validation period. In this case, the simulation period started January 1, 1990. A longer stabilization period may be needed.

Mean monthly streamflows were simulated with NSE=0.73 (Table 14), indicating good correlation with observed data. Excluding the first year improves all statistics (Table 15). The scatter plot (Figure 35) shows simulated monthly streamflows generally followed the same trend as observed streamflows, but the model slightly overestimated lower flows and slightly underestimated higher flows. The volume error between observed and simulated mean monthly streamflows was within $\pm 10\%$ in 11 months and within $\pm 25\%$ in 27 months.

Statistics show fair agreement between observed and simulated daily streamflows for the validation period (NSE=0.39 and $r=0.67$). The scatter plot (Figure 36) and flow duration curves (Figure 37) of the observed and simulated daily streamflows show that the calibrated model slightly underestimated daily streamflows.

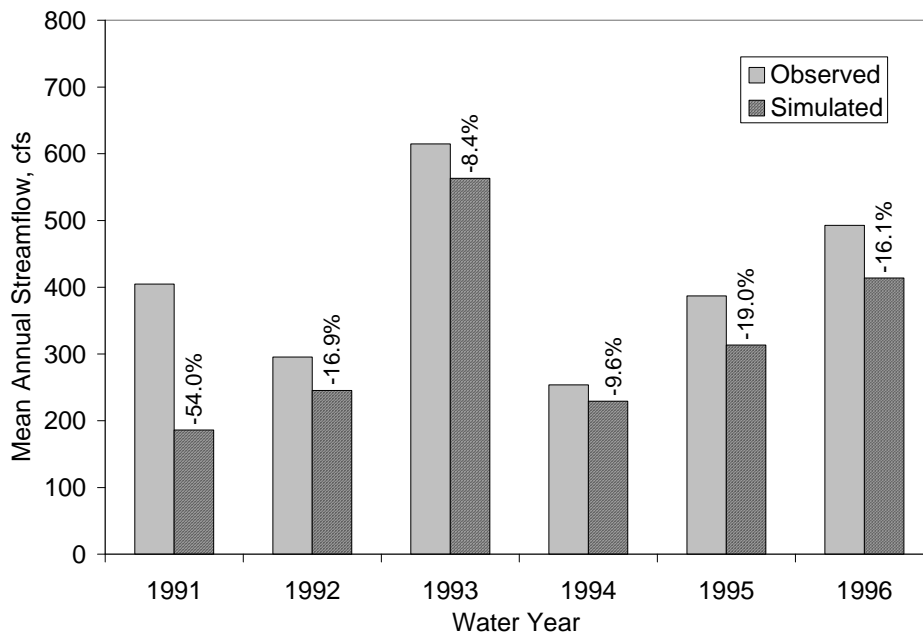


Figure 34. Observed and simulated mean annual streamflows, Flint Creek.

Table 15. Statistics for the Model Validation Period at Flint Creek Watershed

<u>Statistics</u>	<u>Flint Creek</u>	
	<u>WY 1991-</u> <u>1996</u>	<u>WY 1992-</u> <u>1996</u>
<i>Long-term mean</i>		
Observed, cfs	33.9	34.0
Simulated, cfs	27.1	29.4
Dv, %	-20.1	-13.5
<i>Annual</i>		
NSE	0.25	0.80
r	0.87	0.99
Years with Dv within $\pm 10\%$	2	2
Years with Dv within $\pm 25\%$	5	5
<i>Monthly</i>		
NSE	0.73	0.81
r	0.89	0.92
Months with Dv within $\pm 10\%$	11	10
Months with Dv within $\pm 25\%$	27	23
<i>Daily</i>		
NSE	0.39	0.41
r	0.67	0.68

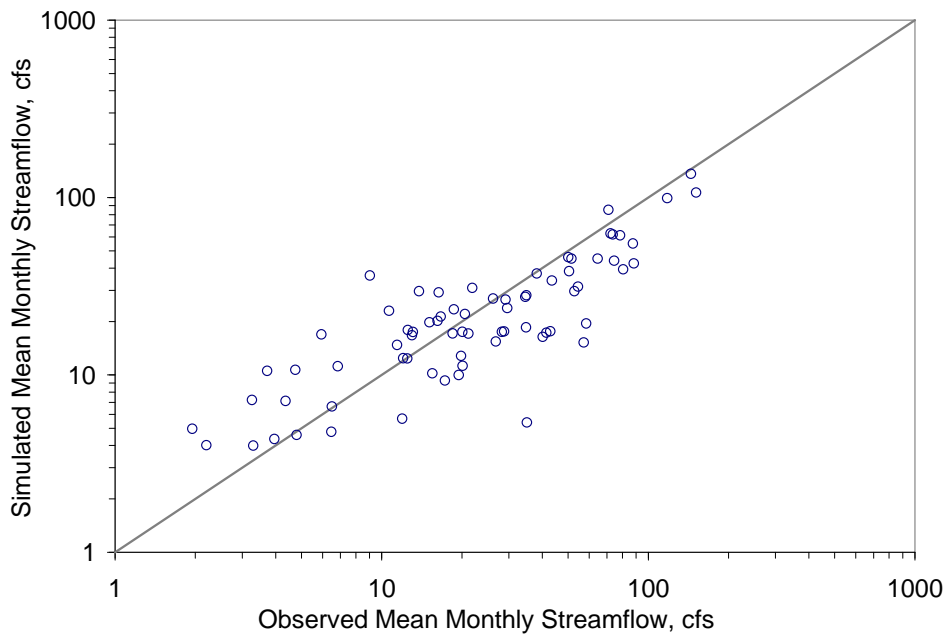


Figure 35. Observed and simulated mean monthly streamflows, Flint Creek.

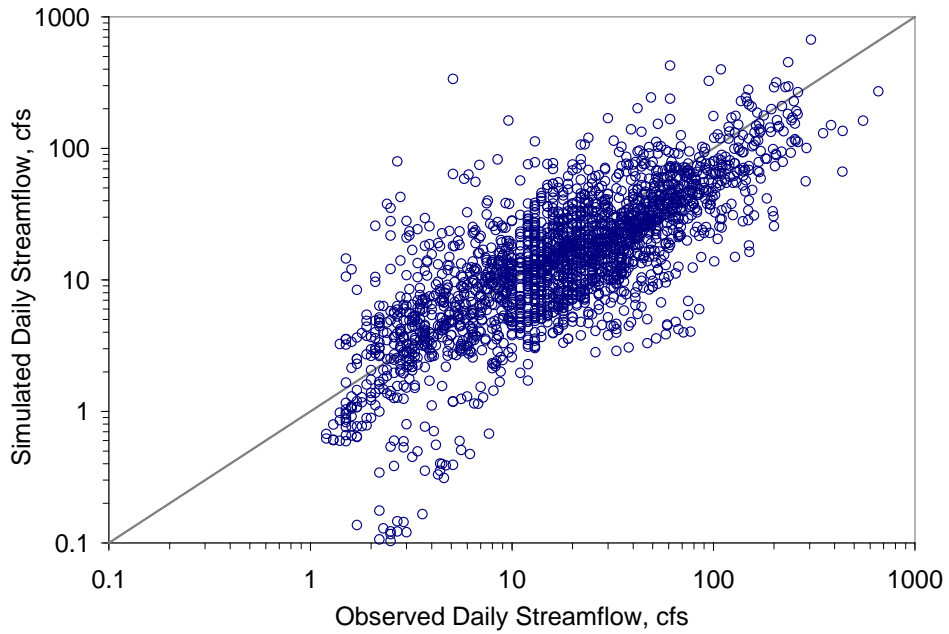


Figure 36. Observed and simulated daily streamflows, Flint Creek.

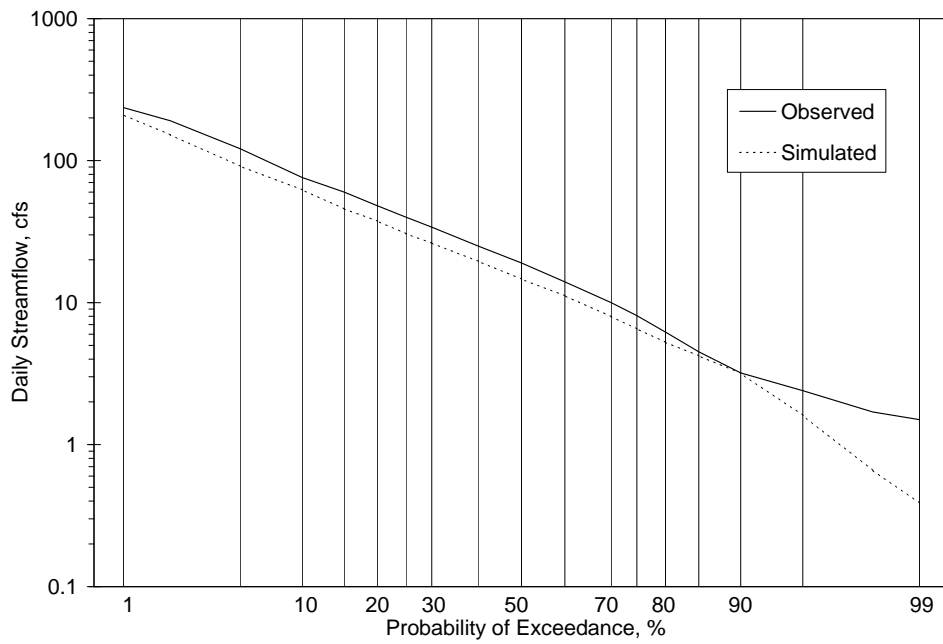


Figure 37. Flow duration curve for observed and simulated daily streamflows, Flint Creek.

Mill Creek Watershed

Table 14 presents model validation statistics at the USGS gage near Batavia. The volume error between observed and simulated streamflows was -12.3% over the validation period (June 1998-WY 2003), indicating good overall fit. The volume error was within $\pm 10\%$ (very good simulation) in two years and within $\pm 25\%$ (fair simulation) in five years (Figure 38). The model overestimated streamflows in four years and underestimated them in two years. Mean annual streamflows were simulated with $NSE=0.67$.

Mean monthly streamflows were simulated with $NSE=0.57$ (Table 14), indicating fair correlation with observed data. Figure 39 indicates that simulated monthly streamflows generally followed the same trend as observed values. The volume error between observed and simulated monthly streamflows was within $\pm 10\%$ in six months and within $\pm 25\%$ in 16 months.

Statistics reported show fair agreement between observed and simulated daily streamflows ($NSE=0.37$ and $r=0.61$). The scatter plot (Figure 40) and flow duration curves (Figure 41) of observed and simulated daily streamflows for the validation period show the model slightly underestimated streamflows.

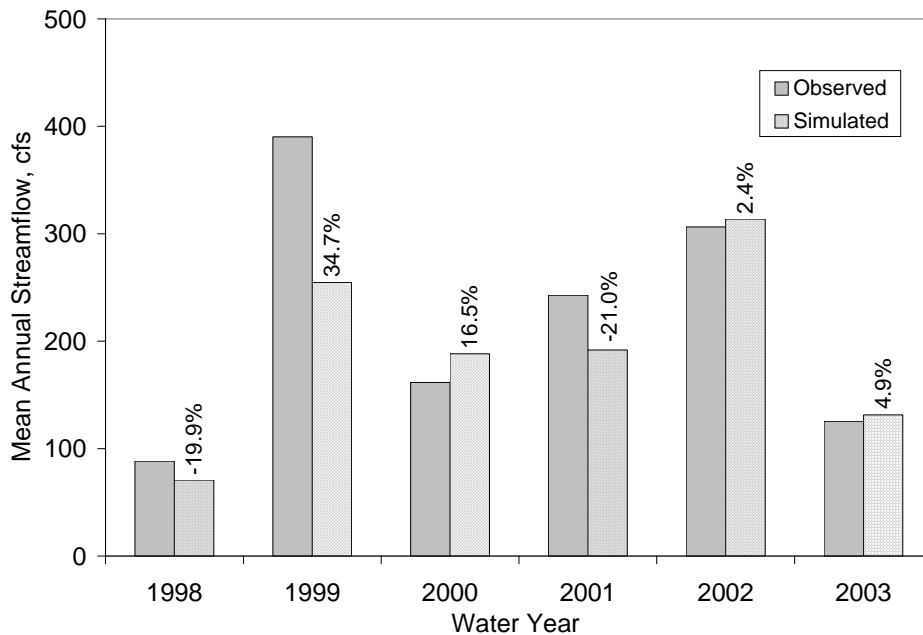


Figure 38. Observed and simulated mean annual streamflows, Mill Creek.

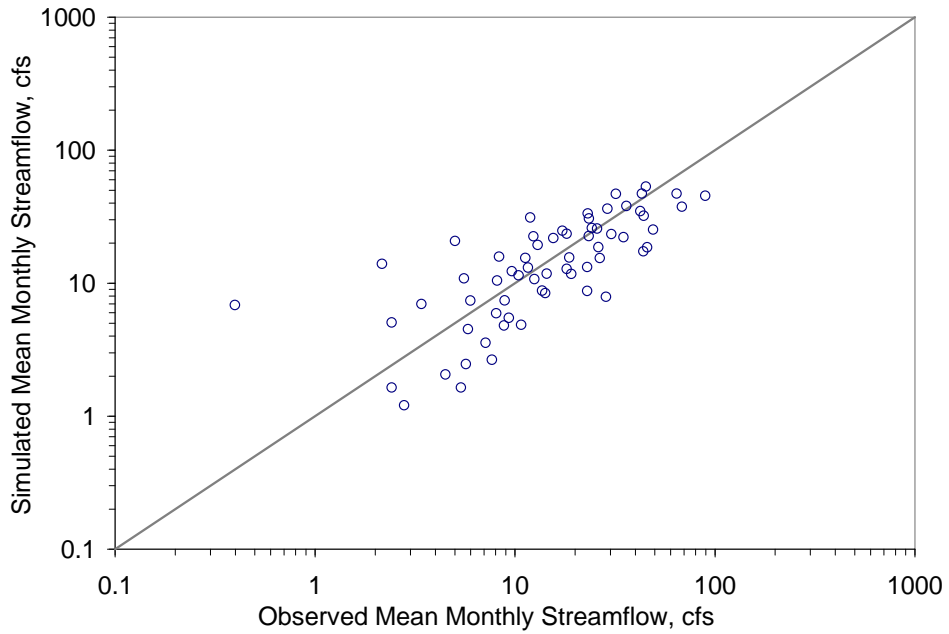


Figure 39. Observed and simulated mean monthly streamflows, Mill Creek.

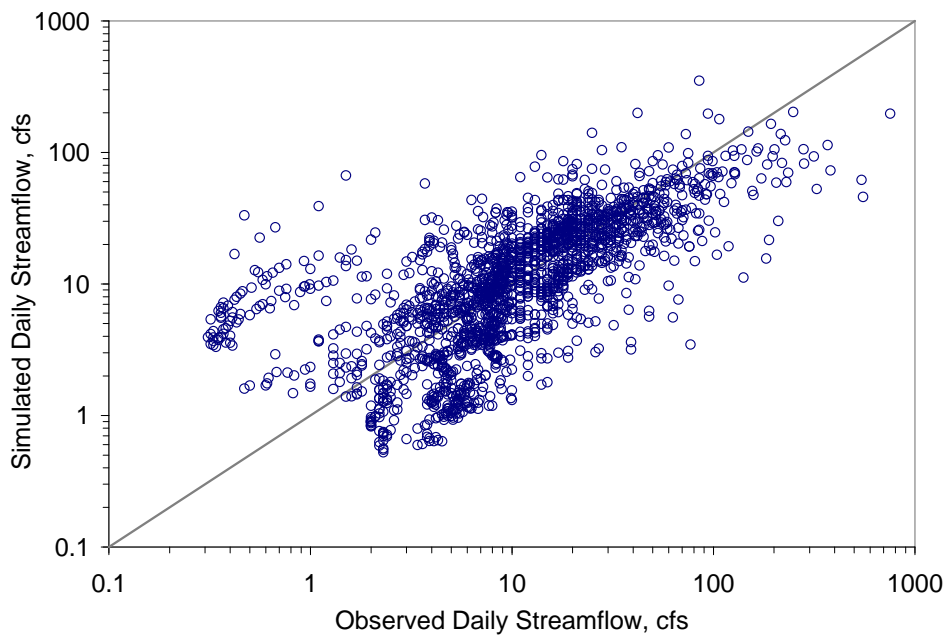


Figure 40. Observed and simulated daily streamflows, Mill Creek.

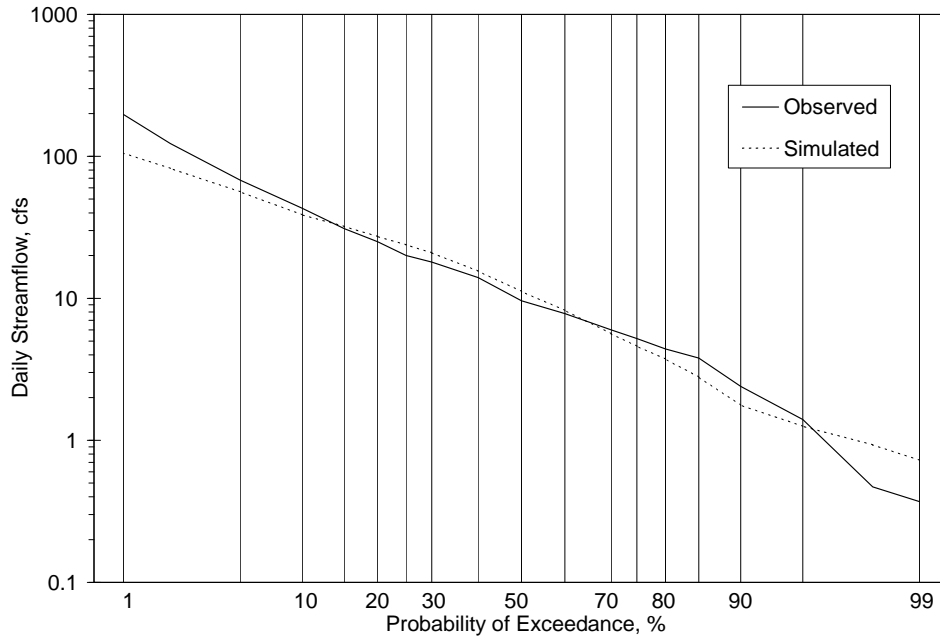


Figure 41. Flow duration curve for observed and simulated daily streamflows, Mill Creek.

Tyler Creek Watershed

Table 14 presents model validation statistics at the USGS gage on Tyler Creek at Elgin. The volume error between observed and simulated annual streamflows was only -1.6% over the validation period (June 1998-WY 2003), indicating very good overall fit. The volume error was within $\pm 10\%$ (very good simulation) in four years (Figure 42). The model overestimated streamflows by 33.7% in WY 1998 and by 31.7% in WY 2003. In the other four years, it underestimated mean annual streamflows between -1.2% and -6.9%. Mean annual streamflows were simulated with $NSE=0.97$.

Mean monthly streamflows were simulated with $NSE=0.89$ (Table 14), indicating very good correlation with observed data. Figure 43 indicates that simulated monthly streamflows generally followed the same trend as observed values, but the model overestimated very low flows (less than 10 cfs). The volume error between observed and simulated mean monthly streamflows was within $\pm 10\%$ in 16 months and within $\pm 25\%$ in 34 months.

Statistics show good agreement between observed and simulated daily streamflows ($NSE=0.72$ and $r=0.86$). The scatter plot (Figure 44) and flow duration curves (Figure 45) of observed and simulated daily streamflows show that the calibrated model simulated observed flows quite well but generally overestimated low flows and underestimated high flows.

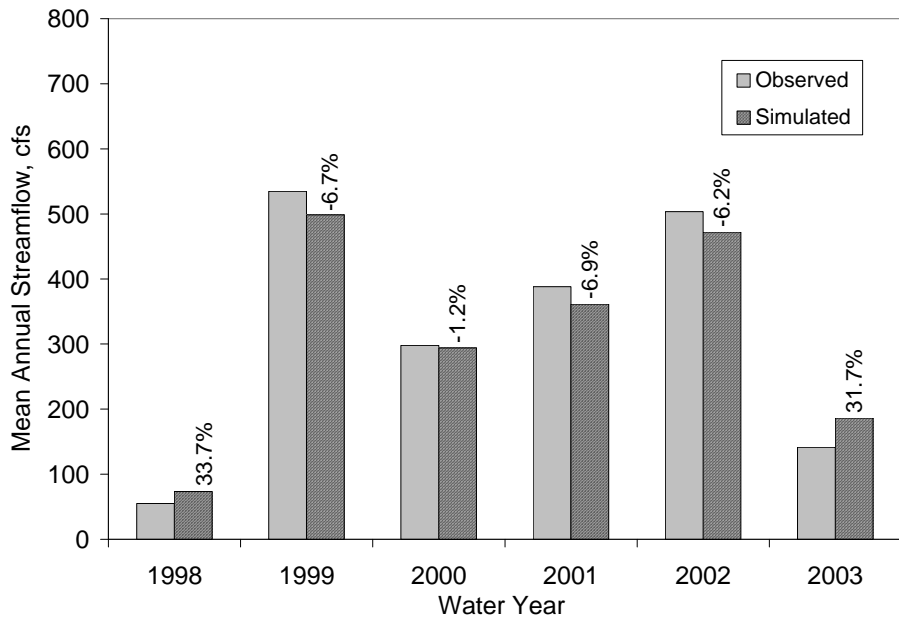


Figure 42. Observed and simulated mean annual streamflows, Tyler Creek.

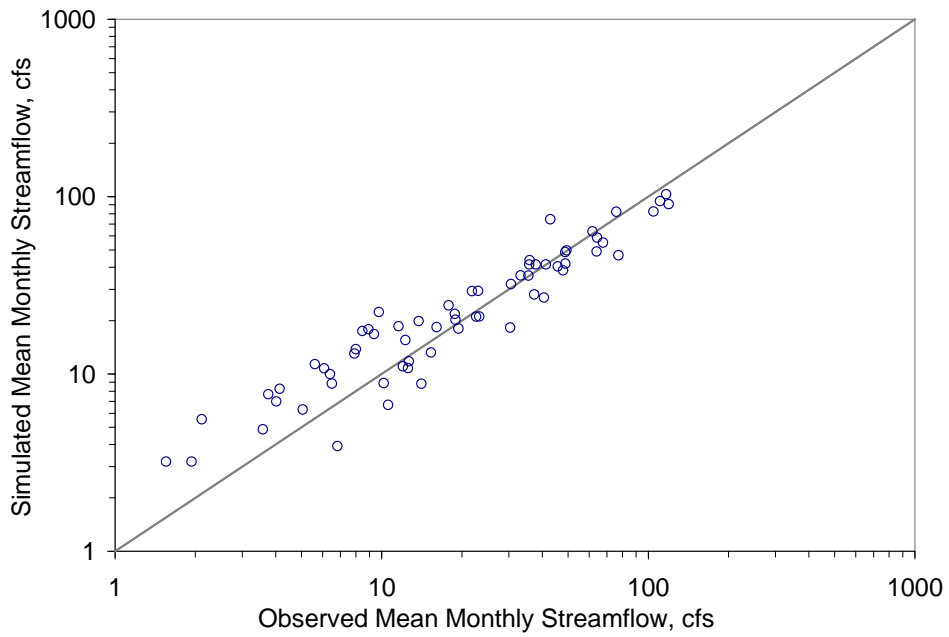


Figure 43. Observed and simulated mean monthly streamflows, Tyler Creek.

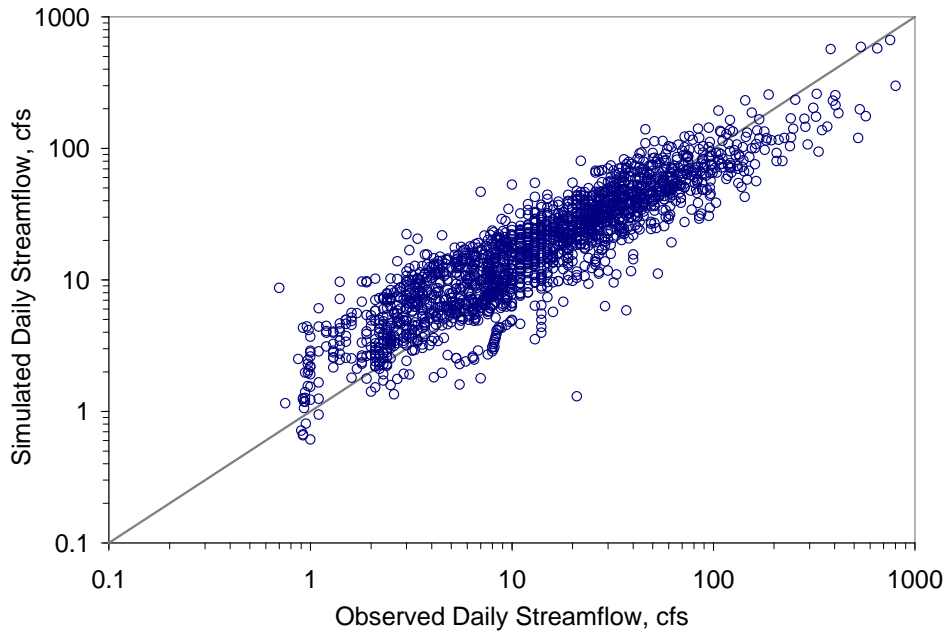


Figure 44. Observed and simulated daily streamflows, Tyler Creek.

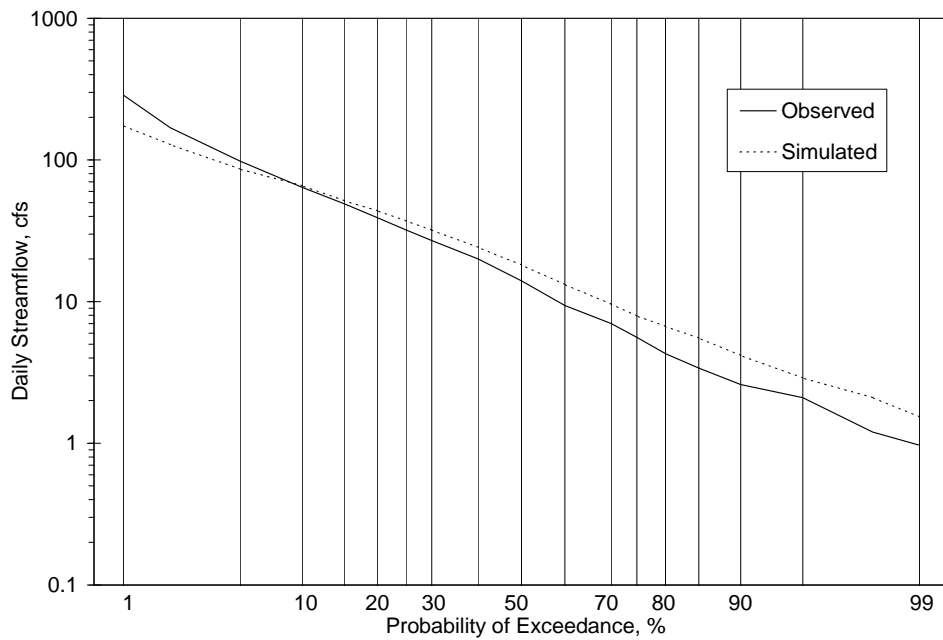


Figure 45. Flow duration curve for observed and simulated daily streamflows, Tyler Creek.

Uncertainty and Confidence in the Model

Results from validation model runs establish confidence in model application outside the calibration watersheds and typical variation between model outputs and measured values. The stepwise calibration process used in this project is designed to develop and test calibration parameters under different conditions. This approach tests the underlying assumption of homogeneous HRUs.

Given the limits of knowledge of natural processes, ability to compose formulas expressing physical conditions, and data accuracy, perfect agreement is not expected. Comparison of simulated and observed values provides insights on model strengths and weaknesses and model performance under different flow conditions, however.

Confidence in the Model

Confidence in the model can be expressed in percentage variation (Dv) of simulated and observed streamflows. This percentage variation for long-term, annual, and monthly means was calculated and discussed earlier (Table 14). Table 16 summarizes the results by converting number of years, months, or days predicted with Dv within $\pm 10\%$ (very good simulation) and within $\pm 25\%$ (fair simulation, acceptable range) into percentages that enable direct comparison across simulation periods of various lengths. Results for Blackberry Creek and Poplar Creek watersheds are included for comparison. Annual means are simulated within 25% of observed means in 67-100% of years. The Poplar Creek and Blackberry Creek models simulate 100% and 92% of years within the acceptable range, respectively. The Brewster Creek watershed model also shows very good fit on an annual basis, despite simulating of only two years. Simulation of monthly means is less accurate: 51% of months were within an acceptable range ($\pm 25\%$) for Ferson Creek and Tyler Creek watersheds, and 38%, 31%, and 24% of months for Flint Creek, Brewster Creek, and Mill Creek watersheds, respectively.

The ability of models to simulate daily flows is even lower. The Ferson Creek and Tyler Creek watershed models simulate daily flows within $\pm 25\%$ for 41% and 36% of days, respectively. The Flint Creek, Mill Creek and Brewster Creek watershed models simulate daily flows within $\pm 25\%$ of observed values for 26%, 24%, and 14% of days, respectively. The Tyler Creek and Ferson Creek watershed models show the overall highest performance based on percentage variation.

Table 17 shows calculated Dv across range of simulated daily flows of selected probability of exceedance (flow duration curve) for the five validation watersheds. High probability of exceedance is associated with low flows and vice versa, e.g., flow with 90% probability of exceedance is exceeded 90% of days. Simulation then is classified as very good (Dv within $\pm 10\%$), good (Dv within 15%), or fair (Dv within $\pm 25\%$). Simulation within $\pm 25\%$ is considered acceptable.

Table 16. Confidence in Simulated Annual, Monthly, and Daily Means Expressed as Percentage of Values Simulated within Specified Limits (Dv)

<u>Statistics</u>	<u>Percent values simulated within specified limits</u>						
	<u>Blackberry Creek</u>	<u>Poplar Creek</u>	<u>Brewster Creek</u>	<u>Ferson Creek</u>	<u>Flint Creek</u>	<u>Mill Creek</u>	<u>Tyler Creek</u>
<u>Years</u>							
Dv=±10%	54	77	100	31	33	33	67
Dv=±25%	92	100	100	77	83	83	67
<u>Months</u>							
Dv=±10%	23	24	0	20	15	9	24
Dv=±25%	53	56	31	51	38	24	51
<u>Days</u>							
Dv=±10%	36	15	7	18	10	9	15
Dv=±25%	88	37	14	41	26	24	36

Table 17. Confidence in Simulated Flow Duration Curve for Validation Watersheds

<u>Probability of exceedance, %</u>	<u>Brewster Creek</u>		<u>Ferson Creek</u>		<u>Flint Creek</u>		<u>Mill Creek</u>		<u>Tyler Creek</u>	
	<u>Dv, %</u>	<u>Fit*</u>	<u>Dv, %</u>	<u>Fit*</u>	<u>Dv, %</u>	<u>Fit*</u>	<u>Dv, %</u>	<u>Fit*</u>	<u>Dv, %</u>	<u>Fit*</u>
99	-86	1	33	1	-74	1	96	<1	59	1
98	-86	1	41	1	-61	1	98	<1	75	1
95	-83	1	17	F	-33	1	-10	VG	38	1
90	-83	2	6	VG	-1	VG	-26	1	60	2
80	-77	2	5	VG	-15	G	-15	G	56	2
70	-70	2	8	VG	-20	F	-6	VG	37	3
60	-66	2	3	VG	-20	F	5	VG	41	4
50	-63	2	1	VG	-23	F	16	F	29	4
40	-57	2	-1	VG	-22	F	11	G	21	F
30	-40	2	-1	VG	-23	F	16	F	19	F
20	-9	VG	-3	VG	-22	F	9	VG	12	G
10	13	G	-13	G	-18	F	-10	VG	3	VG
5	-3	VG	-24	F	-24	F	-17	F	-12	G
2	22	F	-40	77	-21	F	-33	41	-24	F
1	72	45	-64	150	-11	G	-46	92	-39	112

Notes: Number entered for less than fair fit shows absolute difference of simulated and observed streamflows in cfs.
 *VG signifies very good fit (Dv=±10%), G signifies good fit (Dv=±15%), and F signifies fair fit (Dv=±25%).

The Brewster Creek watershed model shows acceptable match with observed data based on Dv for flows exceeded in 2-20% of days. Lower streamflows (exceedance higher than 20%) are underestimated by as much as 86%, but the absolute difference between observed and simulated flows is only 2 cfs or less. As discussed previously, the dam not represented in the HSPF model influenced simulated streamflows in Brewster Creek watershed, particularly low flows.

The Ferson Creek, Flint Creek, and Mill Creek watershed models show acceptable match with observed data based on Dv for flows exceeded in 5-90% of days. The models typically underestimate very high flows (probability of exceedance 2% or less) by 40-64% and overestimate very low flows (probability of exceedance more than 90%) by as much as 74%. The absolute difference between observed and simulated streamflows in this probability range is 1 cfs or less.

The Tyler Creek watershed model shows acceptable match with observed data based on Dv for flows exceeded in 2-40% of days. It underestimates lower streamflows (exceedance higher than 40%) by as much as 75%. The absolute difference between observed and simulated flows is less than 2 cfs for flows exceeded on more than 80% of days and less than 4 cfs for flows exceeded on 50-80% of days.

Major HRU Types in Pilot Watersheds

Efficiency of model parameter transfer from pilot watersheds to validation watersheds largely depends on how well conditions in validation watersheds reflect those in pilot watersheds. Table 18 lists major HRU types identified in pilot watersheds and their representation in validation watersheds. Tyler Creek watershed has the highest percentage of area represented by these HRU types: 40% of area is dominant HRU types (those comprising at least 10% of pilot watershed area) and 76% of area is all major HRU types. The HSPF model for this watershed shows very good simulation results annually, monthly, and daily. Flint Creek watershed has the lowest percentage of area represented by major HRU types (42%) and only 13% by dominant HRU types. The HSPF model for this watershed also shows the lowest long-term and annual performance.

Brewster Creek, Ferson Creek, and Mill Creek watersheds have 60-66% of area represented by major HRU types, comparable to the percentage in Poplar Creek watershed (66%). Dominant HRU types represent 18% of Brewster Creek watershed but only 5% and 6% of Mill Creek and Ferson Creek watershed, respectively. The Brewster Creek watershed model performs the best of those three models annually and monthly, but its daily performance is poor due to the effects of dam.

Mill Creek and Ferson Creek watersheds have very similar representation of both major and dominant HRU types. Although annual performance of models for these two watersheds is very similar, monthly and daily performance of the Ferson Creek watershed model far exceeds that of the Mill Creek watershed model. The difference in model performance is most likely from interaction of multiple causes, including but not limited to HRU types and their representation in watersheds.

Table 18. Representation of Major HRU Types in Validation Watersheds

<i>HRU Code</i>	<i>Percent watershed area</i>						
	<i>Blackberry Creek</i>	<i>Poplar Creek</i>	<i>Brewster Creek</i>	<i>Ferson Creek</i>	<i>Flint Creek</i>	<i>Mill Creek</i>	<i>Tyler Creek</i>
<i>Dominant</i>							
COR21	20.9	0.5	0.6	1.9	0	0.5	16.1
RGR21	10.9	0	0	0	0	0	0
SOY21	17.7	0.8	2.2	1.5	0	0.6	8.6
ULM32	0	12.4	0	2.5	0	0.5	15.5
UOS32	0	22.1	15.5	0.2	12.6	3.2	0
<i>Subtotal</i>	49.5	35.8	18.3	6.1	12.6	4.8	40.2
<i>Other major</i>							
COR22	5.1	0.9	3.5	14.4	0.2	14.0	11.1
FOR21	4.6	0	1.0	0.1	0.1	0	0.9
FOR32	0	6.9	7.8	0.3	11.5	0.4	0
RGR22	5.5	0	0	0	0	0	0
SOY22	5.8	0.6	4.9	22.5	2.5	22.4	9.3
ULMIe2	0.5	4.2	0.8	12.9	0.5	16.3	8.2
ULMIIn2	0	4.2	5.5	0.3	6.4	1.7	0
UOS21	9	0.9	2.3	1.6	0.2	2.8	1.0
UOS22	2.7	4.8	13.3	2.4	3.0	3.3	5.2
UOS42	0	7.4	4.4	0	4.5	0	0.1
<i>Subtotal</i>	33.2	29.9	43.5	54.5	28.9	60.9	35.8
<i>Total</i>	82.7	65.7	61.8	60.6	41.5	65.7	76.0

Note: Numbers greater than 4% are marked in bold for each watershed.

Discussion in this section assumes that other assumptions and inputs incorporated in the models (e.g., assumptions in spatial representation of precipitation and climate data) introduce uncertainty comparable in magnitude across watersheds. This may not necessarily be true. For example, all precipitation stations selected for the model run are outside the studied watersheds. Representativeness of precipitation stations varies depending on the station's actual location, distance and position relative to the watershed, and spatial distribution of precipitation, however. Uncertainty associated with precipitation station data is dictated by the existing network of precipitation and climate stations and can only be described qualitatively.

Other HRU types represent more than 4% of validation watersheds, but they may be present in pilot watersheds in very small percentages or not at all (Table 19 and Table 20). One additional HRU type was identified as significant in Mill Creek watershed: forest on hydrologic soil group B with 2-4% slope. In addition to this HRU type, two HRU types were identified as significant in Ferson Creek watershed: forest and rural grassland, both on hydrologic soil group B with slope more than 4%. Higher performance of the Ferson Creek watershed model than that of the Mill Creek watershed model possibly can be related to the fact that model parameters for rural grassland on hydrologic soil group B with slope greater than 4% were transferred from one of the major HRU types in the Blackberry Creek watershed model.

Table 19. Additional HRU Types Identified in Validation Watersheds as Significant

<u>Land use</u>	<u>Hydrologic soil group</u>	<u>Slope, %</u>	<u>HRU Code</u>	<u>Transferred from HRU</u>	<u>In what watershed</u>	<u>Dominance</u>
Forest	B	2-4	FOR22	FOR22	Blackberry	-
Forest	B	>4	FOR23	FOR22	Blackberry	-
Forest	C	>4	FOR33	FOR33	Poplar	-
Rural grassland	B	>4	RGR23	RGR22	Blackberry	M
Rural grassland	C	2-4	RGR32	RGR31	Blackberry	-
Urban low/medium density	B	2-4	ULM22	ULM22	Poplar	-
Urban open space	C	>4	UOS33	UOS32	Poplar	D

Note: D signifies dominant HRU type, M signifies major HRU type, and - signifies minor HRU type.

Table 20. Representation of Additional HRU Types

<u>HRU Code</u>	<u>Percent watershed area</u>						
	<u>Blackberry Creek</u>	<u>Poplar Creek</u>	<u>Brewster Creek</u>	<u>Ferson Creek</u>	<u>Flint Creek</u>	<u>Mill Creek</u>	<u>Tyler Creek</u>
FOR22	2.3	3.1	5.4	5.5	4.2	5.9	6.5
FOR23	0	0.7	0.2	5.1	1.5	0.2	0
FOR33	0	1.0	0.1	1.5	8.4	0.6	0
RGR23	0	0	0.1	8.2	0.6	0.5	0
RGR32	0	0	2.4	1.4	4.7	2.7	0
ULM22	0	3.3	4.5	1.9	0.8	1.9	6.3
UOS33	0	1.3	0.6	0.3	5.1	0.4	0
<u>Total</u>	2.3	9.5	13.2	23.8	25.5	12.2	12.8

Note: Numbers greater than 4% are marked in bold for each watershed.

Spatial Resolution of Soil Data

The default BASINS' algorithm for creating an HSPF model uses only land use to determine HRU types present in subwatersheds. A more advanced algorithm that considers both land use and soils also included in the BASINS system was used in this study. As explained previously, there are two major sources of soil data (STATSGO and SSURGO) with two basic differences between them. First, the STATSGO dataset has a lower spatial resolution, resulting in larger map units (polygons) when plotted. Although both STATSGO and SSURGO datasets specify soil composition in a polygon by using components that describe the fraction of polygon area, the maximum number of components varies. Each STATSGO polygon can have up to 21 components while SSURGO polygons can have only up to three components. The more detailed SSURGO datasets were used in model development when available (Table 2). As SSURGO datasets are not available for all counties in the Fox River watershed, it is important to understand differences between these datasets and their effects on model development and results.

Table 21 compares representation of hydrologic soil groups in study watersheds calculated using all STATSGO and SSURGO components. Because SSURGO data are not available for portions of the Fox River watershed (including portions of Blackberry Creek watershed), only the five validation watersheds are shown. Ferson Creek, Mill Creek, and Tyler Creek watersheds have similar composition regardless of soil data used, but dual hydrologic soil groups present in the SSURGO dataset seem to be combined in the STATSGO dataset with the hydrologic soil group representing the drained condition. The STATSGO dataset shows a significant portion (42%) of Brewster Creek watershed is composed of hydrologic soil groups A and A/D while SSURGO dataset attributes less than 4% watershed area to these soils. Hydrologic soil groups C and C/D represent less than 7% of Brewster Creek watershed in the STATSGO dataset while the SSURGO dataset attributes 40% watershed area to these soils. A similar relation is found in Flint Creek watershed. Using lower resolution STATSGO data leads to overrepresentation of hydrologic soil groups A and A/D and underrepresentation of hydrologic soil groups C and C/D in Brewster Creek and Flint Creek watersheds.

Soil composition in Table 21 was derived using all components of soil datasets. The BASINS' algorithm, however, uses only the first component, which describes the most dominant hydrologic soil group for each polygon. If soils in the polygon are uniform and the percentage of the dominant soil is high, a reasonable approximation of soil composition in the watershed is achieved even when using only the first component. If soils in the polygon are highly variable and additional components contain a significant percentage of soils, this approximation may result in a significant discrepancy between model representation and actual soil composition represented by soil datasets.

Table 21. Comparison of Soil Composition Using All Components in STATSGO and SSURGO

<i>Hydrologic soil group</i>	<i>Percent watershed area</i>									
	<i>Brewster Creek</i>		<i>Ferson Creek</i>		<i>Flint Creek</i>		<i>Mill Creek</i>		<i>Tyler Creek</i>	
	<i>(1)</i>	<i>(2)</i>	<i>(1)</i>	<i>(2)</i>	<i>(1)</i>	<i>(2)</i>	<i>(1)</i>	<i>(2)</i>	<i>(1)</i>	<i>(2)</i>
A	10	<1	2	1	<1	<1	6	<1	<1	<1
A/D	32	3	0	2	46	6	0	1	0	3
B	16	33	87	56	14	11	67	44	84	58
B/D	36	8	0	26	25	7	0	19	0	32
C	6	34	7	9	13	56	27	23	6	<1
C/D	<1	6	0	3	1	9	0	11	0	<1
D	0	2	<1	<1	0	4	0	0	3	2
Not specified	<1	14	3	2	0	7	0	2	7	3

Notes: (1) signifies STATSGO dataset was used.
(2) signifies SSURGO dataset was used.

Table 22 shows actual representation of soils in HSPF models using only the dominant component. Although numbers vary from composite percentages given in Table 2, the difference is typically within a few percent. The most notable difference is in hydrologic soil group D, which is typically present in less than 5% watershed area but is represented in up to 14% watershed area in the models due to partial assignment of dual hydrologic soil groups to hydrologic soil group D. Hydrologic soil group B in Mill Creek watershed is represented by 71% in the HSPF model, higher than the combined contribution of hydrologic soil groups B and B/D (Table 21).

As SSURGO data are not available for the whole Fox River watershed, it is important to understand how selection of soil data for model development affects simulation results. Refining soil data from STATSGO to SSURGO resolution in Brewster Creek and Flint Creek watersheds significantly changed proportions of individual hydrologic soil groups. Lower spatial resolution of STATSGO data leads to a shift in soil composition even when using information from all components. The shift is even more pronounced in the HSPF model that uses only one dominant component (Table 23 and Table 24).

Table 22. Actual Representation of Soils in HSPF Model Using Only the Dominant Component

<i>Hydrologic soil group</i>	<i>Fox River</i>	<i>Blackberry Creek</i>	<i>Percent watershed area in HSPF model</i>					
			<i>Poplar Creek</i>	<i>Brewster Creek</i>	<i>Ferson Creek</i>	<i>Flint Creek</i>	<i>Mill Creek</i>	<i>Tyler Creek</i>
A	1	0	0	<1	3	8	<1	3
B	78	86	19	41	85	15	71	90
C	14	10	51	36	9	57	23	0
D	4	<1	14	10	0	14	0	1
Impervious	3	4	15	12	4	6	6	5
<i>Source</i>	STATSGO	STATSGO	SSURGO	SSURGO	SSURGO	SSURGO	SSURGO	SSURGO

Table 23. Comparison of Soil Composition in Brewster Creek Watershed

<i>Hydrologic soil group</i>	<i>Percent watershed area</i>			
	<i>All components</i>		<i>Dominant component (HSPF)</i>	
	<i>STATSGO</i>	<i>SSURGO</i>	<i>STATSGO</i>	<i>SSURGO</i>
A	10	<1	0	<1
A/D	32	3		
B	16	33	0	41
B/D	36	8		
C	6	34	45	36
C/D	<1	6		
D	0	2	43	10
Not specified or impervious	<1	14	12	12

Table 24. Comparison of Soil Composition in Flint Creek Watershed

<i>Hydrologic soil group</i>	<i>Percent watershed area</i>			
	<i>All components</i>		<i>Dominant component (HSPF)</i>	
	<i>STATSGO</i>	<i>SSURGO</i>	<i>STATSGO</i>	<i>SSURGO</i>
A	<1	<1	0	8
A/D	46	6		
B	14	11	6	15
B/D	25	7		
C	13	56	86	57
C/D	1	9		
D	0	4	1	14
Not specified or impervious	0	7	6	6

The difference in representation of soils using only the dominant component is quite significant between STATSGO- and SSURGO-derived models. Hydrologic soil groups A and B are grossly underestimated when using one STATSGO dominant component rather than using all STATSGO components. Using one STATSGO dominant component leads to underrepresentation of hydrologic soil group D in Flint Creek watershed but to its overrepresentation in Brewster Creek watershed. Both STATSGO and SSURGO data were used to test responses of the HSPF model for Brewster Creek and Flint Creek watersheds. Models were parameterized using the procedure described previously with values from pilot watersheds.

Figure 46 and Figure 47 present simulation results for Brewster Creek and Flint Creek watersheds, respectively. The STATSGO-derived model of Brewster Creek watershed generally simulates higher streamflows than the SSURGO-derived model, but the absolute difference between simulated streamflows of given exceedance probability is less than 1 cfs (Table 25). The STATSGO-derived model of Flint Creek watershed simulates lower streamflows in the low-flow range (probability of exceedance 50% or more) and higher flows in the high-flow range (probability of exceedance below 50%) than the SSURGO-derived model. The STATSGO-derived model simulated higher long-term volume over validation periods than the SSURGO-derived model by 5.9% and 13.2% for Brewster Creek and Flint Creek watershed, respectively. The difference is driven by a lack of soils with higher infiltration rate (i.e., hydrologic soil groups A and B) in STATSGO-derived models, leading to increased surface runoff and total volume.

The Blackberry Creek and Poplar Creek pilot watersheds contain mostly hydrologic soil groups B and C with a small percentage of hydrologic soil group D. Blackberry Creek watershed includes significant area of row crops (soybeans and corn), and rural grassland. Poplar Creek watershed includes significant area of urban low/medium density, urban open space, and forest. Values for calibration parameters of HRU types not present in either pilot watershed are supplied with values of calibration parameters of similar HRU types. This means that this comparison is limited by efficiency of parameter transfer. The full effect of soil data resolution on simulation results will be assessed in detail once all significant HRU types are fully calibrated using data from the Fox River mainstem.

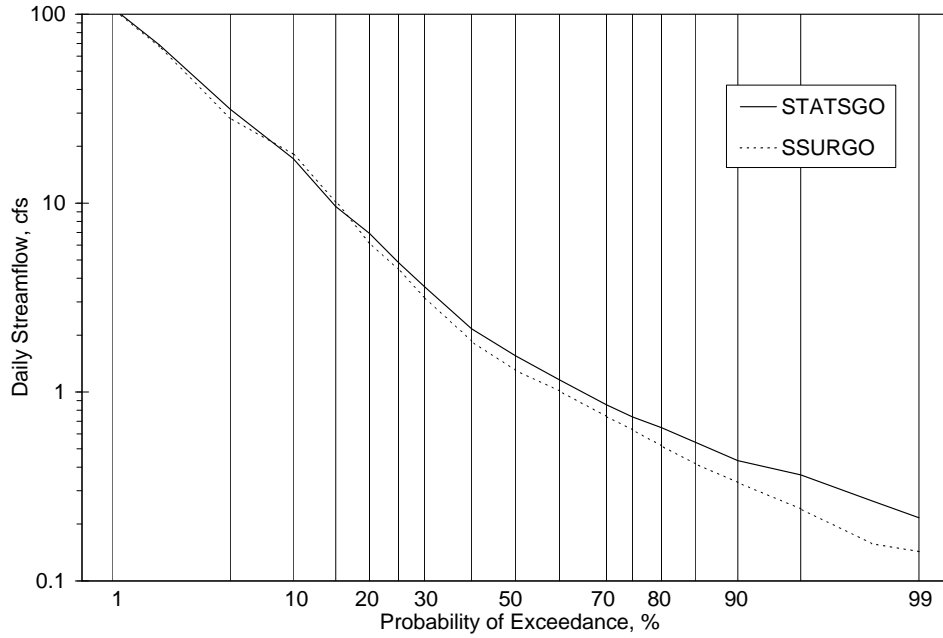


Figure 46. Comparison of flow duration curves simulated from STATSGO- and SSURGO-derived HSPF model of Brewster Creek watershed.

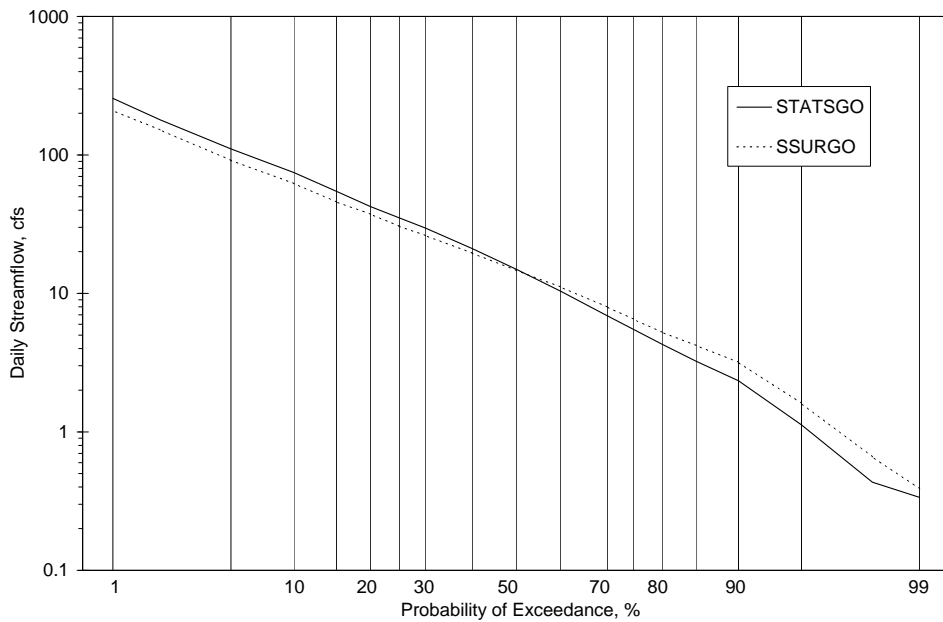


Figure 47. Comparison of flow duration curves simulated from STATSGO- and SSURGO-derived HSPF model of Flint Creek watershed.

Table 25. Variation in Simulated Flow Duration Curve between SSURGO- and STATSGO-derived Models

<i>Probability of exceedance, %</i>	<i>Brewster Creek</i>		<i>Flint Creek</i>	
	<i>Dv, %</i>	<i>cfs</i>	<i>Dv, %</i>	<i>cfs</i>
99	51	<1	-13	<1
98	69	<1	-34	<1
95	51	<1	-30	<1
90	30	<1	-26	<1
80	25	<1	-18	<1
70	15	<1	-13	1
60	15	<1	-7	<1
50	19	<1	2	<1
40	17	<1	8	2
30	14	<1	13	3
20	12	<1	13	5
10	-5	<1	20	12
5	11	3	21	20
2	2	2	18	28
1	1	<1	23	47

Summary and Conclusions

The model parameters developed for the Blackberry Creek and Poplar Creek pilot watersheds were transferred to HSPF models for five watersheds (Brewster Creek, Ferson Creek, Flint Creek, Mill Creek, and Tyler Creek watersheds) using the concept of dominant HRU types. These five watersheds were used to validate model parameters under different conditions outside the pilot watersheds. The USGS measured streamflow at these watersheds for periods of various lengths during the study period (WY 1991-2003).

Model parameters perform well based on performance measures selected for this study. Statistical measures of fit are generally within the range of calibration and validation results for the pilot watersheds. The models generally underestimate long-term average streamflow with percentage variation of -1.6% to -20.1%. Streamflow simulated within $\pm 25\%$ is considered acceptable. Mean annual streamflows were simulated within 25% of observed means for 67-100% of simulated years with $NSE=0.67-0.97$, excluding the first year simulated in Flint Creek watershed. Mean monthly streamflows were simulated within 25% of observed means for 24-51% of simulated months with $NSE=0.57-0.89$ and $r=0.77-0.95$. Mean daily streamflows were simulated within 25% of observed means for 24-41% of simulated days with $NSE=0.61-0.86$ and $r=0.37-0.72$, excluding the Brewster Creek watershed model with $NSE=-0.30$ and $r=0.69$. Performance of the Brewster Creek watershed model is affected by a dam that influences the flow regime. The FTABLEs would need to be modified to account for the attenuation of flow caused by the impoundment, even though the dam has been removed. The model with modified FTABLEs would need to be modified again to simulate any future scenarios, however.

Model performance and efficiency of parameter transfer vary. The HRU types present in validation and calibration watersheds play a significant role in model performance. Validation watersheds with high percentages of area composed of major HRU types found in calibration watersheds performed better than watersheds with lower percentages. Using a variety of conditions in model calibration is crucial for evaluating different management options or land use scenarios. The pilot watersheds represent contrasting land uses and different soil conditions, five additional watersheds are used to evaluate performance of calibration parameters outside the pilot watersheds, and parameters eventually will be fine-tuned on the Fox River mainstem for any remaining HRU types that represent significant portions of tributary watersheds. Future scenarios then can be simulated by substituting HRUs representing existing land use conditions with HRUs representing alternate conditions, such as urban areas replacing agriculture, for major HRU types.

Effects of using STATSGO dataset instead of SSURGO dataset were investigated, as SSURGO data are not available for all counties in the Fox River watershed. Brewster Creek and Flint Creek watersheds were selected for comparison simulation runs. The STATSGO-derived models showed significantly lower representation of soils with higher infiltration rate (hydrologic soil groups A and B) than SSURGO-derived models, resulting in higher total simulated volume. Other watersheds may show different effects, depending on homogeneity of soils.

Comparison of simulated and observed values provides insights on model strengths and weaknesses. Simulation results show that model parameters tend to overestimate low flows and underestimate high flows. This bias must be addressed during calibration of the Fox River mainstem. Although the percentage variation between observed and simulated daily streamflows with high probability of exceedance (i.e., low flows) may be as high as 96%, the absolute difference is typically 2 cfs or less. Flint Creek watershed is unique as the simulated flow duration curve consistently was underestimated across all flows.

Results of validation runs and analyses presented in this report will benefit the next step, calibration of the HSPF model for the Fox River watershed. Model parameters developed during calibration will be transferred to all tributary watersheds and the area contributing directly to the Fox River, and then further modified to simulate flow in the Fox River mainstem.

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Appendix A. Subwatershed Characteristics

Subwa- tershed ID	Brewster Creek			Ferson Creek			Flint Creek			Mill Creek			Tyler Creek							
	<u>Acres</u>	<u>Imp.</u>	<u>%</u>	<u>Acres</u>	<u>Imp.</u>	<u>%</u>	<u>Acres</u>	<u>Imp.</u>	<u>%</u>	<u>Acres</u>	<u>Imp.</u>	<u>%</u>	<u>Acres</u>	<u>Imp.</u>	<u>%</u>					
1	2381	1954	427	17.9	1167	849	318	27.2	1055	987	68	6.4	4264	4186	78	1.8	1825	1753	72	3.9
2	334	233	101	30.2	713	556	157	22.0	235	229	6	2.6	2088	2088	0	0	326	306	20	6.1
3	1283	1086	197	15.4	1348	1348	0	0	1552	1494	58	3.7	686	656	30	4.4	3287	3287	0	0
4	84	72	12	14.3	1791	1791	0	0	192	188	4	2.1	3770	3089	681	18.1	2875	2875	0	0
5	511	454	57	11.2	1369	1331	38	2.8	96	86	10	10.4	306	270	36	11.8	1724	1666	58	3.4
6	23	23	0	0	609	565	44	7.2	500	500	0	0	1790	1642	148	8.3	267	259	8	3.0
7	632	632	0	0	1391	1365	26	1.9	99	93	6	6.1	464	454	10	2.2	287	269	18	6.3
8	603	603	0	0	30	30	0	0	1043	1043	0	0	4041	3877	164	4.1	1360	1330	30	2.2
9	126	99	27	21.4	541	527	14	2.6	1769	1635	134	7.6	305	305	0	0	1662	1662	0	0
10	82	82	0	0	2423	2423	0	0	604	580	24	4.0	2845	2845	0	0	3411	3411	0	0
11	903	903	0	0	502	484	18	3.6	78	76	2	2.6					952	718	234	24.6
12	652	594	58	8.9	2281	2281	0	0	146	124	22	15.1					964	824	140	14.5
13	1425	1281	144	10.1	1147	891	256	22.3	940	868	72	7.7					113	79	34	30.1
14	1332	1092	240	18.0	2073	2073	0	0	267	192	75	28.1					802	579	223	27.8
15					238	230	8	3.4	489	477	12	2.5					541	349	192	35.5
16					1690	1690	0	0	550	538	12	2.2					1093	1067	26	2.4
17					1297	1273	24	1.9	86	82	4	4.7					2873	2759	114	4.0
18					2201	2201	0	0	3379	3063	316	9.4					509	358	151	29.7
19					797	781	16	2.0	1838	1788	50	2.7					201	201	0	0
20					156	156	0	0	2031	2031	0	0					892	866	26	2.9

Notes: Perv. = pervious area, Imp.= impervious area, and % = percent of impervious area in the subwatershed.

Appendix B. Types of Hydrologic Response Units (HRUs) in the Brewster Creek, Ferson Creek, Flint Creek, Mill Creek and Tyler Creek Watersheds

<i>HRU type¹</i>	<i>Brewster Creek</i>		<i>Ferson Creek</i>		<i>Flint Creek</i>		<i>Mill Creek</i>		<i>Tyler Creek</i>	
	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>
COR11	0	0.0	0	0.0	0	0.0	0	0.0	14	0.3
COR12	0	0.0	129	3.1	32	0.3	27	0.5	36	0.8
COR21	58	1.0	654	15.7	0	0.0	97	1.9	4185	89.4
COR22	365	6.2	4974	119.5	57	0.5	2788	54.9	2882	61.6
COR23	0	0.0	100	2.4	0	0.0	0	0.0	0	0.0
COR31	0	0.0	109	2.6	0	0.0	164	3.2	0	0.0
COR32	125	2.1	219	5.3	28	0.3	323	6.4	0	0.0
COR33	0	0.0	13	0.3	0	0.0	0	0.0	0	0.0
COR41	4	0.1	0	0.0	0	0.0	0	0.0	0	0.0
COR42	53	0.9	0	0.0	0	0.0	0	0.0	13	0.3
FOR11	0	0.0	0	0.0	8	0.1	0	0.0	7	0.1
FOR12	0	0.0	45	1.1	417	3.9	0	0.0	239	5.1
FOR13	2	0.0	102	2.5	197	1.9	11	0.2	0	0.0
FOR21	106	1.8	49	1.2	32	0.3	0	0.0	240	5.1
FOR22	564	9.7	1898	45.6	984	9.3	1176	23.2	1676	35.8
FOR23	19	0.3	1766	42.4	352	3.3	33	0.6	0	0.0
FOR24	0	0.0	44	1.1	0	0.0	0	0.0	23	0.5
FOR31	18	0.3	18	0.4	24	0.2	0	0.0	0	0.0
FOR32	808	13.8	94	2.3	2679	25.4	77	1.5	0	0.0
FOR33	6	0.1	505	12.1	1962	18.6	122	2.4	0	0.0
FOR34	0	0.0	102	2.5	0	0.0	0	0.0	0	0.0
FOR41	47	0.8	0	0.0	0	0.0	0	0.0	0	0.0
FOR42	122	2.1	0	0.0	893	8.5	0	0.0	136	2.9
FOR43	0	0.0	0	0.0	336	3.2	0	0.0	0	0.0
RGR11	0	0.0	0	0.0	0	0.0	0	0.0	36	0.8
RGR12	0	0.0	346	8.3	184	1.7	23	0.5	300	6.4
RGR21	229	3.9	506	12.2	11	0.1	123	2.4	2231	47.7
RGR22	507	8.7	7772	186.7	589	5.6	4475	88.1	2405	51.4
RGR23	9	0.2	2836	68.1	138	1.3	94	1.9	0	0.0
RGR24	0	0.0	8	0.2	0	0.0	0	0.0	0	0.0
RGR31	0	0.0	82	2.0	0	0.0	278	5.5	0	0.0
RGR32	245	4.2	480	11.5	1097	10.4	539	10.6	0	0.0
RGR33	0	0.0	716	17.2	320	3.0	106	2.1	0	0.0
RGR34	0	0.0	2	0.0	0	0.0	0	0.0	0	0.0
RGR41	55	0.9	0	0.0	0	0.0	0	0.0	0	0.0
RGR42	71	1.2	0	0.0	94	0.9	0	0.0	107	2.3
RGR43	4	0.1	0	0.0	63	0.6	0	0.0	0	0.0
SOY12	0	0.0	171	4.1	8	0.1	0	0.0	139	3.0
SOY21	0	0.0	851	20.4	2	0.0	109	2.1	4037	86.2
SOY22	84	1.4	4474	107.5	107	1.0	3250	64.0	2142	45.7
SOY23	0	0.0	580	13.9	0	0.0	14	0.3	0	0.0
SOY31	0	0.0	54	1.3	9	0.1	238	4.7	0	0.0

**Appendix B. Types of Hydrologic Response Units (HRUs) in the Brewster
Creek, Ferson Creek, Flint Creek, Mill Creek and Tyler Creek Watersheds
(Continued)**

<i>HRU type¹</i>	<i>Brewster Creek</i>		<i>Ferson Creek</i>		<i>Flint Creek</i>		<i>Mill Creek</i>		<i>Tyler Creek</i>	
	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>
SOY32	122	2.1	131	3.1	86	0.8	352	6.9	0	0.0
SOY42	0	0.0	0	0.0	0	0.0	0	0.0	2	0.0
SWA22	0	0.0	0	0.0	42	0.4	0	0.0	0	0.0
SWA32	0	0.0	0	0.0	557	5.3	0	0.0	0	0.0
SWA33	13	0.2	0	0.0	24	0.2	0	0.0	0	0.0
SWM22	0	0.0	0	0.0	53	0.5	0	0.0	0	0.0
SWM32	0	0.0	0	0.0	313	3.0	0	0.0	0	0.0
SWM33	0	0.0	0	0.0	146	1.4	0	0.0	0	0.0
SWM41	21	0.4	0	0.0	0	0.0	0	0.0	0	0.0
UHD12	0	0.0	0	0.0	11	0.1	1	0.0	0	0.0
UHD21	0	0.0	32	0.8	1	0.0	31	0.6	0	0.0
UHD22	117	2.0	89	2.1	0	0.0	4	0.1	99	2.1
UHD24	0	0.0	0	0.0	0	0.0	0	0.0	7	0.1
UHD31	0	0.0	3	0.1	4	0.0	54	1.1	0	0.0
UHD32	34	0.6	23	0.6	28	0.3	3	0.1	2	0.0
UHD33	15	0.3	0	0.0	0	0.0	0	0.0	0	0.0
UHD42	19	0.3	0	0.0	0	0.0	0	0.0	0	0.0
UHDIe01	0	0.0	79	1.9	12	0.1	193	3.8	0	0.0
UHDIe02	382	6.5	252	6.1	87	0.8	20	0.4	227	4.8
UHDIe03	55	0.9	0	0.0	0	0.0	0	0.0	0	0.0
UHDIe04	0	0.0	0	0.0	0	0.0	0	0.0	15	0.3
UHDIIn01	0	0.0	26	0.6	5	0.0	65	1.3	0	0.0
UHDIIn02	128	2.2	84	2.0	30	0.3	7	0.1	77	1.6
UHDIIn03	18	0.3	0	0.0	0	0.0	0	0.0	0	0.0
UHDIIn04	0	0.0	0	0.0	0	0.0	0	0.0	5	0.1
ULM11	0	0.0	0	0.0	0	0.0	0	0.0	3	0.1
ULM12	0	0.0	0	0.0	210	2.0	0	0.0	14	0.3
ULM21	0	0.0	403	9.7	6	0.1	386	7.6	190	4.1
ULM22	466	8.0	646	15.5	194	1.8	381	7.5	1646	35.2
ULM23	30	0.5	94	2.3	14	0.1	29	0.6	0	0.0
ULM24	0	0.0	0	0.0	0	0.0	0	0.0	27	0.6
ULM31	0	0.0	115	2.8	24	0.2	394	7.8	0	0.0
ULM32	565	9.7	105	2.5	1486	14.1	333	6.6	0	0.0
ULM33	25	0.4	123	3.0	212	2.0	56	1.1	0	0.0
ULM42	158	2.7	0	0.0	165	1.6	0	0.0	14	0.3
ULM43	9	0.2	0	0.0	25	0.2	0	0.0	0	0.0
ULMIe01	0	0.0	140	3.4	8	0.1	210	4.1	52	1.1
ULMIe02	318	5.4	201	4.8	556	5.3	192	3.8	452	9.7
ULMIe03	20	0.3	58	1.4	73	0.7	23	0.5	0	0.0
ULMIe04	0	0.0	0	0.0	0	0.0	0	0.0	7	0.1
ULMIIn01	0	0.0	140	3.4	8	0.1	210	4.1	52	1.1
ULMIIn02	318	5.4	201	4.8	556	5.3	192	3.8	452	9.7

Appendix B. Types of Hydrologic Response Units (HRUs) in the Brewster Creek, Ferson Creek, Flint Creek, Mill Creek and Tyler Creek Watersheds (Concluded)

<i>HRU type¹</i>	<i>Brewster Creek</i>		<i>Ferson Creek</i>		<i>Flint Creek</i>		<i>Mill Creek</i>		<i>Tyler Creek</i>	
	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>	<i>Acres</i>	<i>%*</i>
ULMIn03	20	0.3	58	1.4	73	0.7	23	0.5	0	0.0
ULMIn04	0	0.0	0	0.0	0	0.0	0	0.0	7	0.1
UOS11	0	0.0	75	1.8	7	0.1	0	0.0	0	0.0
UOS12	30	0.5	50	1.2	462	4.4	0	0.0	98	2.1
UOS21	236	4.0	538	12.9	42	0.4	552	10.9	255	5.4
UOS22	1382	23.7	819	19.7	701	6.6	656	12.9	1360	29.0
UOS23	56	1.0	79	1.9	237	2.2	52	1.0	0	0.0
UOS24	0	0.0	0	0.0	0	0.0	0	0.0	22	0.5
UOS31	55	0.9	122	2.9	41	0.4	666	13.1	0	0.0
UOS32	1602	27.4	82	2.0	2933	27.8	638	12.6	8	0.2
UOS33	58	1.0	113	2.7	1196	11.3	85	1.7	0	0.0
UOS41	22	0.4	0	0.0	0	0.0	0	0.0	0	0.0
UOS42	461	7.9	0	0.0	1048	9.9	0	0.0	23	0.5
UOS43	11	0.2	0	0.0	288	2.7	0	0.0	0	0.0

Notes: ¹HRU types is composed of land use indicator (COR=Corn, SOY=Soybean, FOR=Forest, SWA=Surface water, SWM=Wetland, UHD=Urban high density, ULM=Urban low-medium density, UOS=Urban open space, RGR=Rural grassland, I=Impervious, e=effective, and n=noneffective), hydrologic soil group category (1=A, 2=B, 3=C, and 4=D), and slope category (1=slope <2%, 2=2-4%, 3=slope 4-6%, and 4=slope >6%).

*Fraction of total watershed area.

Illinois State **WATER** Survey (1895)



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