Illinois Environmental Protection Agency

Total Maximum Daily Load Development for Fox River

April 2004

Draft Final Report

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LIST OF ABBREVIATIONS AND ACRONYMS

µg/L	Microgram per liter
40 CFR	Title 40 of the *Code of Federal Regulations*
7Q10	10-year, 7-day low-flow
AWQMN	Ambient Water Quality Monitoring Network
BASINS	"Better Assessment Science Integration Point and Nonpoint Sources"
BMP	Best management practice
BOD	Biochemical oxygen demand
Ch-a	Chlorophyll-a
COE	U.S. Army Corps of Engineers
CO_2	Carbon dioxide
CRP	Conservation Reserve Program
CWA	Clean Water Act
CWP	Center for Watershed Protection
DAP	Diammonium phosphate
DO	Dissolved oxygen
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FRSS	Facility-Related Stream Survey
ft^3/s	Cubic foot per second
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program – Fortran
HUC	Hydrologic Unit Code
IBS	Intensive Basin Survey
IEPA	Illinois Environmental Protection Agency
ISWS	Illinois State Water Survey
JEQ	*Journal of Environmental Quality*
MBI	Macroinvertebrate biotic index
mg/L	Milligram per liter
MOS	Margin of safety
MGD	Million gallons per day
MRCC	Midwest Regional Climate Center
NCDC	National Climate Data Center
NH_3-N	Ammonia-nitrogen
NO_2	Nitrite
NO_3	Nitrate
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
QUAL2E	Enhanced Stream Water Quality
SHAP	Stream habitat assessment procedure
SOD	Sediment oxygen demand
STP	Sewage treatment plant
TDS	Total dissolved solids
TMDL	Total maximum daily load
TP	Total phosphorus
TSI	Tropic State Index
TSS	Total suspended solids
USGS	U.S. Geological Survey
UV	Ultraviolet
USDA	U.S. Department of Agriculture
VLMP	Volunteer Lake Monitoring Program
WTP	Water treatment plant

EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act (CWA) establishes the process for determining total maximum daily loads (TMDL) to provide more stringent water-quality based controls when technology-based controls are not sufficient to achieve state water quality standards. Title 40 of the *Code of Federal Regulations* (40 CFR), Part 130, provides the federal regulations governing TMDLs.

Under Section 303(d) of the CWA (hereafter referred to as the "303(d) list"), the Fox River (ILCH02-1998) is listed by the Illinois Environmental Protection Agency (IEPA) for impairment of its designated uses resulting from dissolved oxygen (DO) concentrations and pH levels that do not meet state water quality standards. Olney East Fork Lake (ILRCC1-1998) is listed for impairment of its designated uses resulting from total phosphorus (TP) concentrations that exceed Illinois water quality standards and from low DO concentrations. Borah Lake (ILRCB-1998) is listed for the impairment of its designated uses resulting from pH and TP concentrations that exceed Illinois water quality standards. The three water bodies are located in the Fox River watershed, which drains directly to the Little Wabash River (Hydraulic Unit Code [HUC] 05120114).

This report establishes TMDLs for (1) biochemical oxygen demand (BOD) and ammonia-nitrogen (NH_3-N) in the listed Fox River segment, (2) TP and BOD in Olney East Fork Lake, and (3) TP in Borah Lake. The TMDLs were determined using the Hydrological Simulation Program-Fortran (HSPF) model. The pollutant loading in each water body was established for the critical period of May through October and for November through April. As part of TMDL process, the HSPF model was used to investigate seasonal variations and to estimate maximum allowable pollutant loads that water bodies can assimilate without violating water quality standards. The Enhanced Stream Water Quality (QUAL2E) model was used to evaluate the probability of DO concentrations exceeding the water quality standard under low-flow conditions in the Fox River.

The water quality goal of the TMDL for the Fox River is to maintain an average DO concentration of 6 milligrams per liter (mg/L) or more. To achieve this standard, BOD and NH_3-N loads in the river must be reduced. The TMDL for BOD is 588 pounds per day (lb/day) for the critical season from May to October and 2,054 lb/day for November through April. The TMDL for NH_3-N is 28 lb/day for the critical season and 83 lb/day for November through April. Loads from nonpoint sources were established as the estimated average concentration times the average seasonal flow. The point source loads and margin of safety (MOS) allowances make up the balance of the allocation. The MOS was determined as 20 percent of the total load to account for uncertainties, unknown factors, and errors involved in TMDL development. The selected MOS percentage has been used to develop TMDLs for other Illinois water bodies.

The numeric water quality standard used as the TMDL endpoint in Olney East Fork Lake is an average TP concentration under 0.05 mg/L and an average DO concentration above 6 mg/L. The TMDL for TP is 21 lb/day for the critical season and 162 lb/day for November through April. The TMDL for BOD is 60 lb/day for the critical season and 188 lb/day for November through April. Loads from nonpoint sources were established as the estimated average concentration times the average seasonal inflow to the lake. No point sources exist in the Olney East Fork Lake drainage basin; therefore, the MOS allowances make up the balance of the allocations.

The numeric water quality used as the TMDL endpoint in Borah Lake is an average TP concentration under 0.05 mg/L. The TP load needs to be reduced to achieve this endpoint and to reduce Chlorophyll a (Ch-a) concentrations that result in pH levels exceeding the Illinois water quality standard of 6.5 to 9. The TMDL for TP is 11 lb/day for the critical season and 39 lb/day for November through April. Loads from nonpoint sources were established as the estimated average concentration times the average seasonal inflow to the lake. No point sources exist in the Borah Lake drainage basin; therefore, the MOS allowances make up the balance of the allocations. TP is used as a surrogate measure for pH because the correlation between TP and Ch-a concentrations has been observed in Borah Lake. A TMDL for pH is therefore incorporated within the established TMDL for TP.

Best management practices (BMP) are proposed for implementation in order to achieve the TMDLs. Finally, a monitoring plan was developed to assess the efficiency of BMPs in meeting the TMDLs. The monitoring plan is intended to gather flow and water quality data to supplement the limited data available for TMDL development and to verify assumptions made during TMDL development.

1 INTRODUCTION

This report develops total maximum daily load (TMDL) requirements for the Fox River watershed. Under Section 303(d) of the Clean Water Act (CWA) (hereafter referred to as the "303(d) list"), the following segments of the Fox River watershed are not meeting water quality standards and therefore require TMDLs:

- Fox River
- Olney East Fork Lake
- Borah Lake

The Illinois Environmental Protection Agency (IEPA) ranks the priority of TMDL development for these listed water bodies as No. 12.

The following subsections present background information on TMDLs, the segments of the Fox River watershed that are of concern, and the organization of this report.

1.1 TMDL Background Information

Section 303(d) of the CWA establishes the process for determining TMDLs to provide more stringent, water-quality based controls when technology-based controls are not sufficient to achieve state water quality standards. Title 40 of the *Code of Federal Regulations* (40 CFR), Part 130, provides the federal regulations governing TMDLs.

TMDLs ascertain the amount of pollutants from both point and nonpoint sources that can be loaded into a water body without the water body exceeding water quality standards. States determine TMDLs and submit them to the U.S. Environmental Protection Agency (EPA) for approval. TMDLs must meet the following eight regulatory requirements specified in 40 CFR Part 130 in order to be approved by EPA:

- Be designed to implement applicable water quality criteria
- Include a total allowable load as well as individual waste load allocations
- Consider the impacts of background pollutant contributions
- Consider critical environmental conditions

- Consider seasonal environmental variations
- Include a margin of safety (MOS)
- Be subject to public participation
- Have reasonable assurance that the TMDL can be met

In general, TMDLs are developed in accordance with the following relationship:

$$\mathrm{TMDL} = \mathrm{WLA} + \mathrm{LA} + \mathrm{MOS} \tag{1-1}$$

where

TMDL = Total maximum daily load
WLA = Waste load allocation (point source)
LA = Load allocation (nonpoint source)
MOS = Margin of safety (scientific uncertainty)

1.2 Segments of Concern in Fox River Watershed

The State of Illinois prepared the 303(d) list for waters that are not meeting state water quality standards. This list, which was reviewed and approved by EPA in 1998, identifies the following segments of the Fox River watershed:

- Fox River
- Olney East Fork Lake
- Borah Lake

The Fox River Watershed is a sub-watershed of the Little Wabash River watershed (Hydrologic Unit Code [HUC] 05120114). Figure 1-1 shows the locations of these impaired segments.

The portion of the Fox River that is of concern (ILCH02-1998 in the 303[d] list) begins at the mouth of the Fox River at its confluence with the Little Wabash River in Edwards County and extends upstream approximately 17.63 miles to its confluence with the Little Fox Creek in Richland County. The Fox River is included in Illinois' 1998 303(d) list for impairments of designated uses resulting from dissolved oxygen (DO) content and pH levels lower than water quality standards. Although the Fox River segment is impaired because of low pH levels, a TMDL for pH was not developed. Low pH levels in the Fox River were determined to have resulted from acid rain and acidic soils with low buffering capacity. Appendix A presents evidence that shows that the low pH level of the Fox River is caused by acid rain, mining activities, and acid soils rather than pollutant loads to the river. For this reason, a pH TMDL was not developed. for the listed segment of the Fox River.

Although the low river pH is not a result of pollutant loads, some fertilizers can acidify soil; therefore, nutrient management plans with fertilizer application guidelines are included in the list of best management practices (BMP) discussed in Chapter 8.

Olney East Fork Lake, which is identified as ILRCC1-1998 in the 303(d) list, is located on the East Fork Fox River in Richland County. The lake is on the 303(d) list for impairments of designated uses resulting from total phosphorous (TP) concentrations that exceed Illinois water quality standards and low DO concentrations.

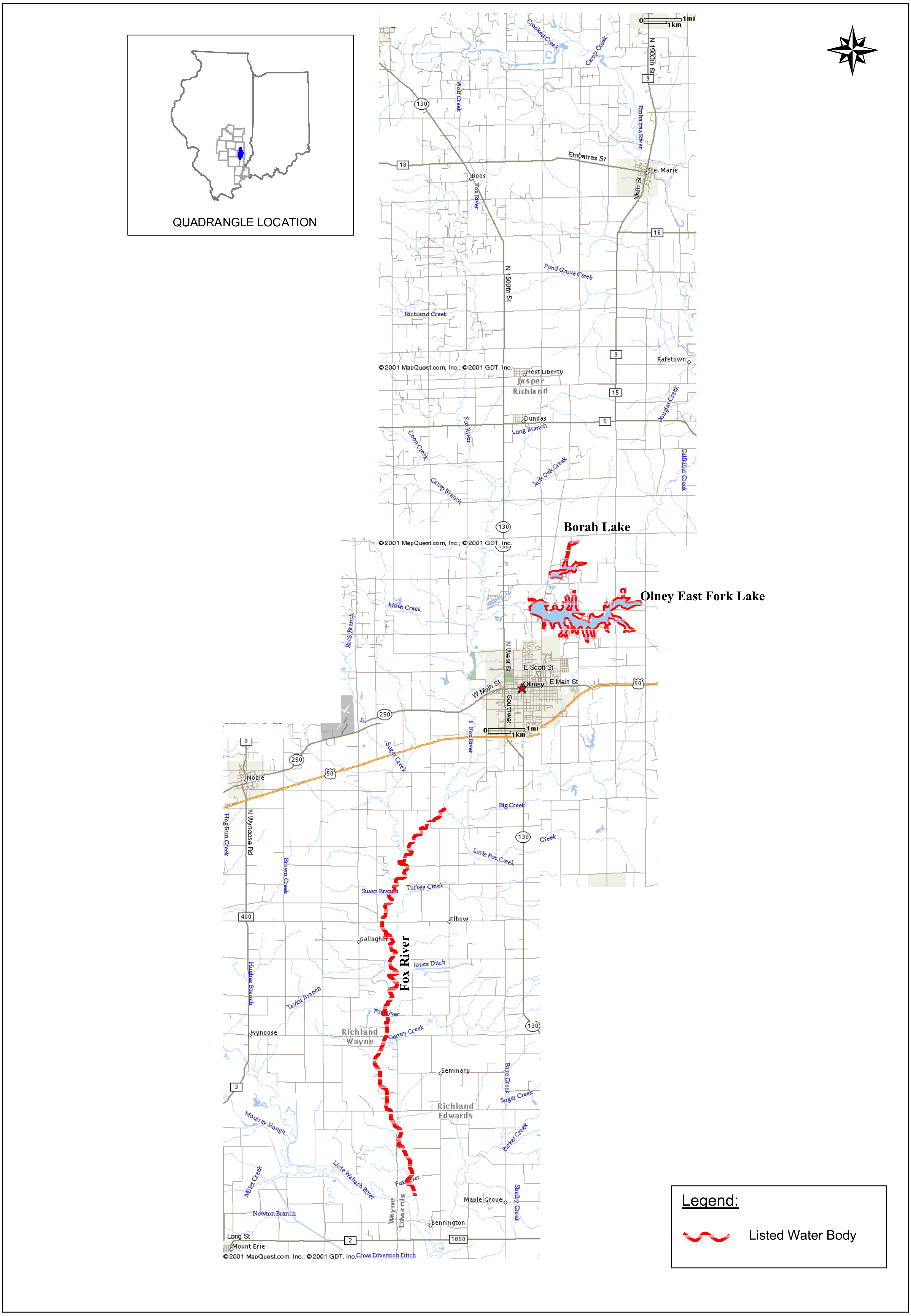
Borah Lake, identified as ILRCB-1998 in the 303(d) list, is located on a tributary of East Fork Fox River in Richland County. The lake is on the 303(d) list for impairments of designated uses resulting from TP concentrations and pH levels that exceed Illinois water quality standards.

1.3 Report Organization

Following this introduction, this TMDL report is organized in the following chapters:

- Chapter 2, Watershed Characteristics
- Chapter 3, Applicable Water Quality Standards and Numeric Water Quality Targets
- Chapter 4, Modeling Approach
- Chapter 5, Fox River TMDLs and Load Allocations
- Chapter 6, Olney East Fork Lake TMDLs and Load Allocations
- Chapter 7, Borah Lake TMDLs and Load Allocations
- Chapter 8, BMP Implementation
- Chapter 9, Monitoring Plan
- Chapter 10, Public Participation

FIGURE 1-1. FOX RIVER WATERSHED SEGMENTS ON 303(d) LIST



References used to prepare this report document are cited at the end of the text. Appendix A provides justification for not developing a pH TMDL for the Fox River by presenting data that indicate that low pH levels in the Fox River are caused by acid rain and acidic soils, not pollutant loads. Appendix B includes a separate report that discusses hydrologic and water quality modeling of the listed segments of the Fox River watersheds. Appendix C presents a table that lists federal funding sources available to support the measures discussed in this report for improving the water quality of the Fox River, Olney East Fork Lake, and Borah Lake.

2 WATERSHED CHARACTERISTICS

The portion of the Fox River studied in this report is about 17.6 miles from the mouth of the Fox River at its confluence with the Little Wabash River to its confluence with Little Fox Creek, which is about 3 miles southwest of the City of Olney. The Fox River's confluence with the Little Wabash River is about 34 miles from the headwaters of the Fox River, and the river drains approximately 205 square miles. The Fox River is a second-order tributary of the Little Wabash River located in southeast Illinois. From north to south, it flows through Jasper, Richland, Wayne, and Edwards Counties, with a major portion in Richland County (see Figure 2-1). The HUC of the Little Wabash River is 05120114. The confluence of the Fox and Little Wabash Rivers is located in northeast Edwards County near Wayne County.

Olney East Fork Lake is located on the East Fork Fox River in Richland County, Illinois, near the City of Olney. It is owned and managed by the City of Olney. East Fork Fox River is a tributary to the Fox River. Olney East Fork Lake was built in 1970 for recreational use and to replace Borah Lake as the primary drinking water resource for the City of Olney (IEPA 1998a). It drains a 10.4-square-mile area, covers 935 acres, and has a normal water storage capacity of 12,460 acre-feet (4 billion gallons) (COE 1978a).

Borah Lake is located on a tributary of the East Fork Fox River in Richland County, Illinois, near the City of Olney (see Figure 2-1) and is also owned and managed by the City of Olney, Illinois. The lake was constructed in 1953 to replace Vernon Lake as a water source for the City of Olney. Borah Lake was in turn replaced by Olney East Fork Lake as a drinking water source. Borah Lake is currently designated for general use. It drains 3.6 square miles, covers about 137 acres, and has a normal reservoir storage capacity of 1,540 acre-feet (0.5 million gallons) (IEPA 1998b; COE 1978b).

This chapter discusses general characteristics of the Fox River watershed, including climate, soils, land use, hydrology, growth trends in the watershed, biological information, pollutants of concern, surrogate measures used as TMDL endpoints, and point and nonpoint sources in the watershed. Table 2-1 summarizes characteristics of the entire watershed, including listed and unlisted segments. Figures 2-1 and 2-2 show the locations of the Fox River watershed and points of interest, respectively.

FIGURE 2-1. FOX RIVER WATERSHED LOCATION

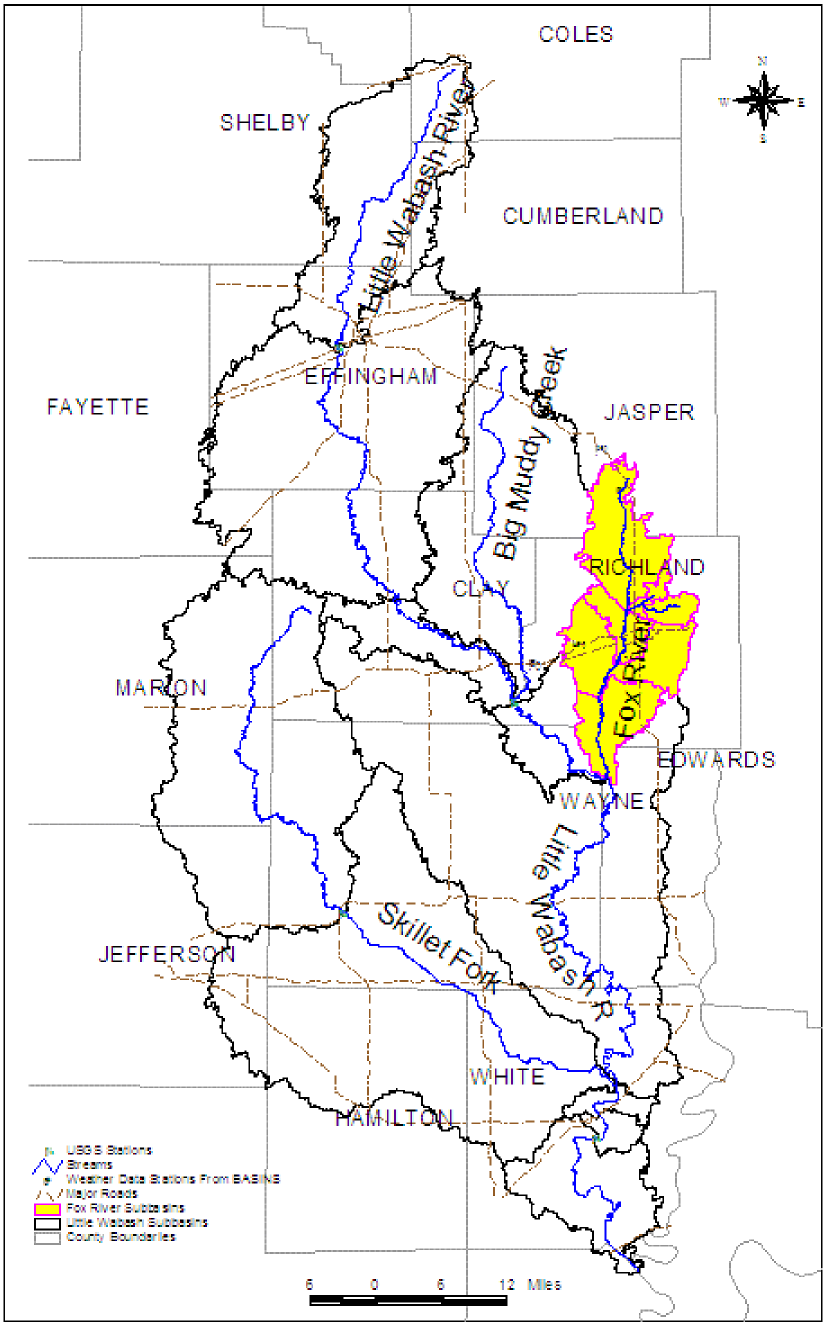
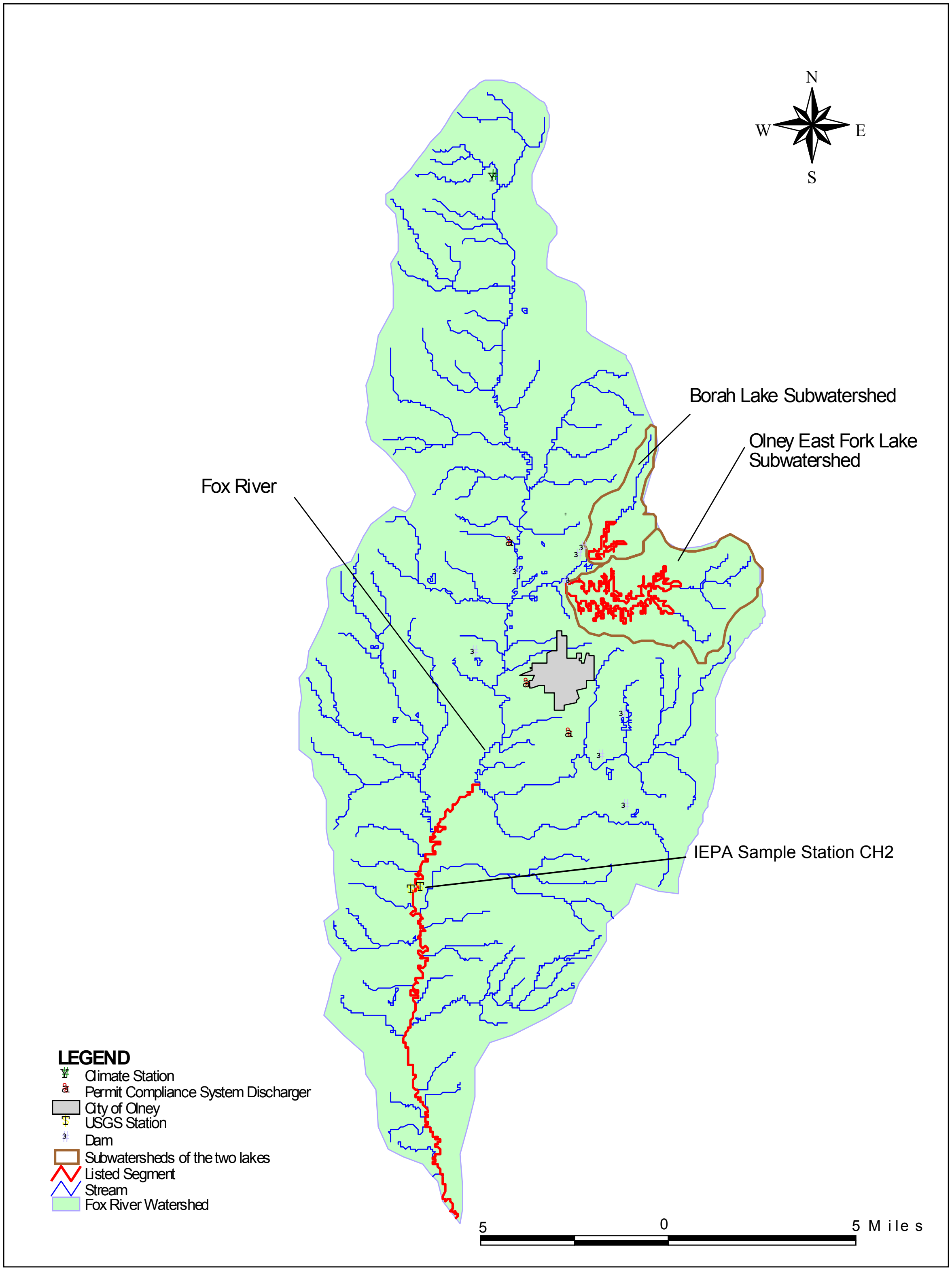


TABLE 2-1. FOX RIVER WATERSHED CHARACTERISTICS

Characteristic	Value
Rivers and streams in watershed (first-order tributaries)	44
Reservoirs in the watershed	6
Area of watershed	205 square miles
Bedrock depth below ground surface	60 inches
Fox River reach length	34 miles

Source: EPA 1998

FIGURE 2-2. FOX RIVER WATERSHED POINTS OF INTEREST



2.1 Climate

The entire Fox River watershed incorporates portions of Jasper, Edwards, Richland, and Wayne Counties in southeastern Illinois, but most of the watershed lies within Richland County; therefore, climate information from this county has been used to represent the entire watershed's climate. The climate in Richland County is temperate continental. The average annual precipitation at the National Climate Data Center (NCDC) Olney station (Identification No. 116446) in Richland County is approximately 43 inches. Monthly precipitation averages 3.55 inches annually (MRCC 2001). Monthly precipitation averages nearly 4 inches from March through July and only about 2.5 inches for the normally driest months of October and February. The maximum and minimum annual precipitations have been 70 and 25 inches, respectively (USDA 1972). On average, annually, 103.6 days have precipitation of at least 0.01 inch, 28.9 days with at least 0.5 inch, and 10.9 days with over 1 inch (MRCC 2001). Severe droughts are infrequent, but prolonged dry periods during part of the growing season are not unusual. Such periods usually cause reduced crop yields (USDA 1972). Most summer showers and thunderstorms are brief. A single thunderstorm often produces more than 1 inch of rain and occasionally is accompanied by hail and damaging winds. More than 4.5 inches of rain has fallen within a 24-hour period, and nearly 15 inches has fallen during a month. Some fall and winter months have had less than 0.25 inch of precipitation (USDA 1972).

The average annual temperature for at the NCDC Olney station is approximately 54 °F. The maximum and minimum average temperatures are 65.5 and 43.9 °F, respectively. The maximum and minimum temperatures are 112 °F (1936) and -24 °F (1994)(MRCC 2001).

Section 2.1 in Appendix B presents additional climate data used for modeling.

2.2 Soils

The Fox River watershed consists mostly of soil types in the Cisne-Hoyleton (30 percent), Bluford-Ava-Blair (50 percent), and Belknap-Bonnie-Peetrolia (20 percent) Associations. The Cisne-Hoyleton Association soils are nearly level to moderately sloping, distributed on upland ridge areas, and poorly to somewhat poorly drained. These soils form in loess and glacial till. Soils of the Bluford-Ava-Blair Association are nearly level to moderately sloping on uplands and somewhat poorly to moderately well-drained. Belknap-Bonnie-Peetrolia Association soils are nearly level on bottomlands near rivers and somewhat poorly to poorly drained (USDA 1972). These soils formed in silt loam and silty clay loam sediments.

The Natural Resources Conservation Service (NRCS) classifies most of the Fox River watershed as hydrologic soil group C and the remainder as group D, which implies that the land has a low potential for infiltration and a high potential to create overland runoff. Soil erodibility (average soil loss) ranges from 0.385 to 0.394 in ton per year per unit of area for soil in cultivated, continuous, fallow land with an arbitrarily selected slope length of 72.6 feet and slope steepness of 9 percent. Thus, the erosion potential of soils in the Fox River watershed is relatively high. The permeability of soils ranges from 0.24 to 1.27 inches per hour (USDA 1972). In general, soils along Fox River and its tributaries exhibit higher erodibility and permeability than those located far from the channelized reaches.

The acidity of the soils in the watershed was evaluated because the Fox River and Borah Lake are on the 303(d) list for pH. Soil acidity data were obtained from the NRCS's official soil descriptions, which provide general and detailed information for each recognized soils series in the United States. Based on an Ava series soil profile from Richland County, soils in the Little Wabash Watershed are very strongly acidic to up 60 inches below ground surface. Soil series present throughout the Little Wabash Watershed are also acidic but to varying degrees (USDA 2002).

2.3 Land Use

Land use in the Fox River watershed is primarily agricultural (83.2 percent), followed by forest (13.7 percent) and urban (2.2 percent). Urban area consists of residential, industrial, commercial, utility, and mixed-urban build-up areas. The remaining 0.8 percent of the watershed consists of water and strip mines. Most of the agricultural land consists of row crops. Corn, soybeans, and wheat are the main crops in Richland County (EPA 1998).

Land use in the Olney East Fork and Borah Lake areas is also predominantly agriculture. The Olney East Fork Lake watershed consists of 64.7 percent cropland and pasture, 20 percent deciduous forest, 15 percent reservoir, and 0.3 percent animal feedlots. The Borah Lake watershed consists of 94 percent cropland and pasture and 6 percent reservoir (EPA 1998).

2.4 Hydrology

The Fox River drains a 204.5-square-mile, predominantly level area with low potential for infiltration and high potential for overland runoff. The low potential for infiltration is due to soil characteristics. Only about 2 percent of the area is covered by the impervious land use type. The Fox River is a shallow stream with a width ranging from less than 5 feet during low flow to greater than 30 feet during high flow. The mean width-to-depth ratio is about 50 feet to 9 feet (NRCS 2002). No U.S. Geological Survey (USGS) gauge stations record flow in Fox River; therefore, flows for the Fox River are based on estimates and vary from source to source. For example, the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) database estimated the 10-year, 7-day low-flow (7Q10) at 0.88 cubic foot per second (ft^3/s) (EPA 1998), and the Illinois State Water Survey (ISWS) estimates the 7Q10 rate at 2 ft^3/s (ISWS 1988). Although the accuracy of the estimated Fox River flow is uncertain, extreme fluctuations are evident. In 1989 and 1994, IEPA measured flows along the Fox River as part of Olney sewage treatment plant (STP) related surveys and verified extreme fluctuations. According to IEPA measurements, the measured flow was less than 4 ft^3/s during low-flow conditions in 1989 and greater than 140 ft^3/s after a storm event in 1994 (IEPA 1989 and 1995).

Olney East Fork Lake drains a 10.4-square-mile area that is gently rolling, with some flat areas. All areas in the lake basin are well-vegetated, and the basin appears to be well-drained. Impervious areas are negligible in the Olney East Fork Lake Watershed. The lake reservoir covers 935 acres, has a normal water storage capacity of 12,460 acre-feet (4 billion gallons), and has a maximum storage capacity of 22,680 acre-feet (7.4 billion gallons) (COE 1978a). As a public water supply system, the lake outflow is controlled by a zoned, earth-fill dam considered a high hazard because residences are located directly downstream of the dam. Water supply withdrawals average 1.56 million gallons per day (MGD) and remain fairly constant throughout the water quality monitoring season (Olney STP 2001). The lake reservoir also has a concrete-lined service spillway on its left abutment and an earth channel emergency spillway on its right abutment. The outlet conduit is plugged with a bulkhead; therefore, reservoir water surface levels cannot be regulated (COE 1978a). No USGS gauging stations are located along this tributary to the Fox River, and no staff gauge readings were taken. Bottom seepage rates are unknown and are therefore assumed to be negligible.

Borah Lake drains 3.60 square miles of gently rolling hills with some flat areas. The lake basin is well-vegetated and well-drained with negligible impervious cover. Several relatively short tributaries that appear to be intermittent streams flow into the reservoir. The tributaries have shallow beds and steep banks (COE 1978b). The lake reservoir covers about 137 acres, has a normal reservoir storage capacity of 1,540 acre-feet (0.5 million gallons), and has a maximum storage capacity of 2,274 acre-feet (0.7 million gallons) (IEPA 1998b; COE 1978b). A zoned, earth-fill dam controls outflow. The reservoir has a concrete and granite spillway approximately 120 feet southeast of its left abutment and the spillway has an uncontrolled crest. However, the intake and 12-inch-diameter pipe tower designed for water supply can function as outlet works, thereby providing a limited means of regulating the reservoir water level. If the valve of the intake tower were open, water would flow through the pipe beneath the dam and then by gravity through the natural channel to the Fox River. A COE 1978 inspection report concludes that the Borah Lake reservoir and spillway are capable of passing and holding a 100-year flood (COE 1978b). However, because of the extremely deteriorated condition of the spillway, it is possible that any appreciable amount of flow could cause a total spillway failure as well as erosion of the natural channel both upstream and downstream of the lake. In addition, the top of the spillway guide wall is only 2 feet above the spillway crest. If flow over the spillway were to over-reach the top of guide wall, severe erosion could result in further damage or loss of the spillway. Evidence of seepage at the downstream toe of the dam has been noted. It was believed that water was entering the water supply intake tower and seeping out through the embankment. This seepage could contribute flow to the Fox River (COE 1978b). Other than potential seepages, discharges occur only when lake levels rise above the elevation of the spillway (469.5 feet above mean sea level).

Because of lack of UGSG gauging stations throughout the Fox River watershed, a hydrologic model was developed for the entire Little Wabash River watershed, which has USGS gauging stations. TMDL development for the Fox River is based on the assumption that the Little Wabash River watershed hydrologic model accurately predicts flows in the Fox River. Appendix B provides details on the Little Wabash River hydrologic model development.

2.5 Growth Trends in the Watershed

Growth trends in the Fox River watershed are assumed to be the same as growth trends in Richland County. Since a population peak of about 17,587 around 1980, the population in Richland County has been steadily decreasing. The estimated population of Richland County was 16,545 in 1990 and 16,149 in 2000, which results in a growth change of - 2.4 percent. The population estimate predicted for 2001 is 16,042, which indicates that the population is expected to continue to decrease but at a slower rate (U.S. Census Bureau 2002). For purposes of this study, the population in the Fox River Watershed was assumed to remain relatively constant in the near future.

2.6 Biological Information

Biological information, including information on macroinvertebrate communities and habitat data, was collected along the listed segment of the Fox River but not from the listed lakes. IEPA collected biological samples and calculated the macroinvertebrate biotic index (MBI) at two stations along the Fox River downstream of the Olney STP in 1988 and 1994. An MBI reflects the degree of tolerance of a macroinvertebrate community to oxygen-demanding and other contaminants. MBI values reflect aquatic community impairment as follows:

- Less than 6.0: Good
- 6.0 through 7.5: Fair
- 7.6 through 8.9: Poor
- Greater than or equal to 9.0: Very Poor

In 1988 and 1994, MBI values for the Fox River ranged from 5.3 to 5.6, indicating that general water quality conditions were good downstream of the Olney STP. More recent MBI values have not been calculated (IEPA 1989 and 1995).

IEPA also evaluated the habitat along the listed segment of the Fox River using the stream habitat assessment procedure (SHAP) as part of the 1999 intensive basin survey of the Little Wabash River watershed. SHAP is a scoring system that takes into account 15 parameters relating to substrate and instream cover, channel morphology and hydrology, and riparian and bank features. SHAP ratings reflect habitat quality as follows:

- Greater than or equal to 142: Excellent
- 100 to 142: Good
- 59 to 100: Fair
- Less than 59: Poor

IEPA calculated a SHAP rating of 99 for the listed segment of the Fox River, indicating that habitat is fair. Factors that lowered the overall SHAP rating included low substrate quality, poor bank stability and vegetation, and low sinuosity. Factors that increased the overall SHAP rating included good pool quality, pool variability, and canopy cover (IEPA 2002b).

2.7 Pollutants of Concern

This section discusses the pollutants of concern for the Fox River watershed. For convenience and the purposes of this report, the term "pollutant of concern" is used to indicate conditions that cause the impairment of the water body's designated uses. The following sections discuss the chemical and biological processes affecting the pollutants of concern and water quality monitoring results that explain why these pollutants of concern were identified for each water body.

2.7.1 DO in Fox River

DO is the primary pollutant of concern in the Fox River. IEPA monitoring data have shown that the DO level of the Fox River does not meet state water quality standards in the summer dry season. . Biochemical oxygen demand (BOD), nutrients such as TP and ammonia-nitrogen (NH_3-N), and temperature are not pollutants of concern but affect DO and are therefore discussed below. In addition, total suspended solids (TSS) is not a pollutant of concern but is modeled because it is a source of TP.

BOD affects DO because BOD concentrations reflect the amount of organic matter in the water column that can be decomposed. The process of organic decomposition involves DO consumption as shown in the following equation:

$$\text{Organic matter} + \text{Bacteria} + O_2 \rightarrow CO_2 + H_2O + \text{More Bacteria} + \text{Energy} \qquad (2\text{-}1)$$

where

O_2 = Oxygen
CO_2 = Carbon dioxide
H_2O = Water

Further, decomposition of organic matter occurs in the sludge bed. Sediment oxygen demand (SOD) supplements the depletion of DO in the water. SOD primarily results from the aerobic decay of organic materials that settle to the bottom of the stream. The organic materials can come from decaying algae, dead leaves, and other debris washed into the river system from land and upper portions of the watershed during storm events. SOD can indirectly account for the effects of high stream-flow events because it captures the effects of decaying organic material deposited during the storm events.

Nutrients affect DO concentrations in two ways: (1) excess nutrient loads can stimulate excess plant growth, which is source of organic matter that can undergo decomposition, and (2) nitrogen-based nutrients undergo nitrification after entering surface water, which involves DO consumption as ammonia (NH_3) is reduced to nitrite (NO_2), which is reduced to nitrate (NO_3). The diurnal DO effect results from photosynthesis and respiration of algae. The chlorophyll within algae, which absorb solar energy to convert the water and carbon dioxide into glucose, and release oxygen, drives the photosynthesis process. Because the photosynthesis process is dependent on solar light, the production of oxygen happens only during the daylight time. Meanwhile, the blooming algae respire oxygen. As a result, lowest minimum values of DO concentration usually occur in the early morning predawn when the algae have been in the no-light dark condition for the longest period of a day. On the other hand, highest DO level usually occur in the early afternoon. The diurnal variation may be large, and if the daily mean DO level is low, the minimum DO concentration during a day may approach zero, which could result in fish kills.

Temperature increases also affect DO concentrations by decreasing the DO saturation level and increasing decay and nitrification rates, which increases DO consumption. Although temperature is not associated with a load and is not a cause of impairment, simulation of temperature in model development is key in understanding DO fluctuations. Nutrients and BOD are causes of impairment in the Fox River. If these parameters are controlled, DO concentrations should not drop below 6.0 milligrams per liter (mg/L) even at elevated temperatures. As shown in Appendix B, the modeling approach takes the temperature's effect on DO into account.

Reaeration can increase DO concentrations that have dropped because of BOD and nutrient loads and temperature, but the reaeration rate in the Fox River has not been measured. Chapter 4 of Appendix B discusses assumed values for reaeration for model development.

From 1997 through 2000, IEPA collected monthly water quality and sediment samples from Station CH 2 (which is the same as USGS Station 03379560) on the Fox River, 7 miles south-southwest of the City of Olney (see Figure 2-2). In addition, from 1972 through 1990, water quality samples were collected from the Fox River from IEPA Stations CH 3 (located a few miles upstream of CH 2) and CH 11 (located near CH 2), but these data are outdated and were not used for TMDL development (EPA 2001b). Table B.2-5 in Appendix B provides Fox River water quality sampling results.

In samples collected by IEPA from 1997 through 2000, DO concentrations less than 6.0 mg/L were detected in 10 of 18 samples collected , usually between May and October (IEPA 1999 and 2001). Most sampling occurred at 6:00 a.m., when the DO concentrations are expected to be lowest. NH_3-N concentrations exceeded the IEPA guideline of 0.41 mg/L three times (IEPA 1998a), which supports the theory that excess nutrient loads contribute to low DO concentrations in the river. As expected, low DO concentrations also correlate to elevated temperatures.

2.7.2 TP and DO in Olney East Fork Lake

Pollutants of concern in Olney East Fork Lake are high TP and low DO levels. Low DO and high TP levels, NH_3-N, Chlorophyll-a (Ch-a), and Carlson Trophic Status Index (TSI) values all indicate excess nutrient loads to the lake. The physical, chemical, and biological processes and relationships between these parameters are discussed below.

Phosphorous is carried to surface water by eroded particles such as TSS that are carried in runoff. When particulate phosphorous enters a lake, it settles out of the water column to the lake bottom and is bound to lake bottom sediment. This phosphorus generally is not available for aquatic plant growth and is not a water quality problem. However, anoxic (free oxygen-depleted) conditions at the lake bottom can result in re-release of the bound phosphorus. Anoxic conditions can be created when lakes stratify and DO is not replenished because of lack of mixing. In the Midwest, lakes are typically stratified because of temperature differences in deeper water bodies. In the summertime, warm surface water “floats” on top of colder, denser, deep water. In the wintertime, freezing surface water also “floats” on top of warmer deep water because ice is less dense than water. When these situations occur, the layers of water essentially separate, creating a thermal resistance to the mixing of water and chemicals. Anoxic conditions can also be created if there is highly active decomposition at the lake bottom in nutrient-rich waters during warm weather when decomposition rates are accelerated. During active decomposition, DO is simply being used faster than it can be replenished.

If there is no mixing of the water column, the particulate phosphorus will remain at the lake bottom; however, mixing can occur from wind action, fish activity, or spring and fall lake turnover following winter and summer thermal stratification. Spring turnover occurs when frozen surface waters melt and sink to the bottom. Fall turnover occurs when warm surface water quickly cools and sinks to the bottom. In either case, particulate phosphorus is brought up to the surface where it is available for algal uptake and growth. If turnover occurs when aquatic plants such as algae are not actively growing (such as late fall), then the dissolved phosphorus released as a result of anoxic conditions does not contribute to water quality problems. If turnover occurs during the active growing season, the dissolved phosphorus can accelerate aquatic plant growth, resulting in nuisance algal blooms. Excess algal bloom conditions are indicated by elevated Ch-a concentrations. When algal blooms decay, oxygen (O_2) is consumed and DO concentrations decrease.

Nitrogen is another essential nutrient for plant growth; however, it is often so abundant that algae growth is not limited. Some species of algae can also “fix” their own atmospheric nitrogen; therefore, they do not need another nitrogen source. With abundant nitrogen availability, the presence of limiting nutrients such as TP results in rapid algal growth. Although nitrogen is not as much of a concern as TP in Olney East Fork Lake, NH_3-N trends are important to consider when estimating nutrient loads.

Along with nutrient, DO, and Ch-a concentrations, Carlson TSI values are used to measure the nutrient enrichment status of lake ecosystems (EPA 2001b; Carlson 1977) Carlson TSI is the measure of a lake's trophic (or "fertility") status. Higher trophic status is associated with more nutrient availability and higher productivity. Figure B.2-7 and Table B.2-10 in Appendix B present the relationship of TSI to lake fertility and the Illinois water quality standards for lakes, respectively Excessive nutrient loads can result in nuisance algal blooms and excessive turbidity. Very low nutrient status also can limit the support of aquatic life. Carlson TSIs are based on TP concentration, Ch-a concentration, or Secchi depth. The individual indices are often averaged to calculate an overall TSI. However, in general, TP is considered the best indicator of *potential* trophic status (Hutchinson 1959).

From 1978 to 1998 as part of the Volunteer Lake Monitoring Program, IEPA collected water quality samples from Stations RCC1, RCC2, and RCC3 within Olney East Fork Lake. The samples were collected from the surface (1 foot below water surface) only except at Station RCC1, where an additional bottom sample was collected. Table B.2-8 in Appendix B summarizes the most recent values for the pollutants of concern (April to October 1998).

The data show that TP exceeded the IEPA guideline of 0.05 mg/L in 13 samples. In addition, according to the IEPA "Water Quality Report 2000," 11 of these measurements classified TP levels as slightly elevated and 2 as high (IEPA 1998a and 2000a). TP is especially high along the lake bottom during the late part of the summer, with measurements of 0.62 mg/L on August 10 and 1.23 mg/L on October 13, 1998. As a result of elevated TP concentrations, Olney East Fork Lake is considered to be eutrophic, with a Carlson TSI value of 60.7 according to 1998 sampling results (IEPA 1998a). Elevated Ch-a concentrations also reveal nutrient enrichment in the lake. Ch-a concentrations exceeded the IEPA water quality guideline of 20 micrograms per liter (μg/L) in six out of nine samples collected during 1998.

Surface DO measurements generally remained above 6 mg/L except in the sample collected on October 13, 1998. DO profiles show anoxic conditions at the bottom of the lake at Station RCC 1, as shown in Table B.2-8.

2.7.3 TP and pH in Borah Lake

The pollutants of concern in Borah Lake are TP and pH. The water quality parameters affecting TP in Borah Lake include NH_3-N, Ch-a, and Carlson TSI values just as for Olney East Fork Lake (see Section 2.7.2). Water quality parameters affecting pH in Borah Lake are discussed below.

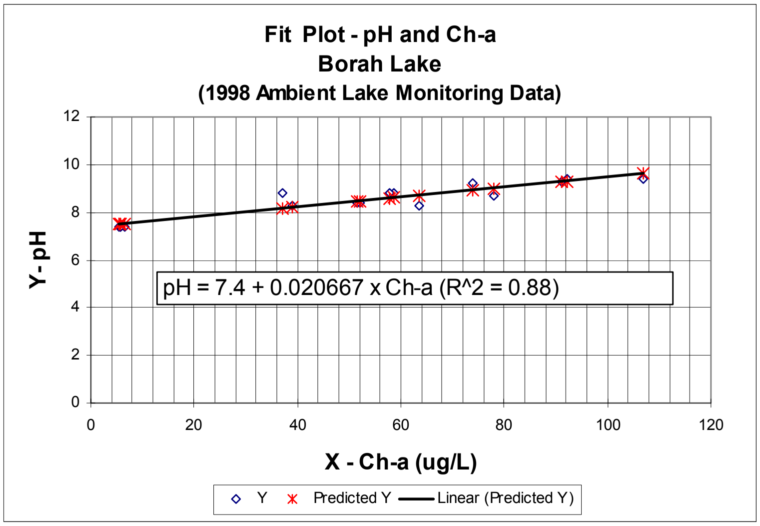
Algal blooms, which are the result of excess TP loads, are reflected by elevated Ch-a concentrations and can cause increased pH values, especially in shallow waters. Algae use carbon dioxide (CO_2) as a carbon source during photosynthesis. CO_2 affects pH because it combines with water to form carbonic acid. When CO_2 is consumed, carbonic acid concentrations decrease, lake acidity decreases, and pH concentrations increase. Similar to CO_2 consumption during daylight hours as a result of photosynthesis, CO_2 is produced during nighttime hours as a result of respiration; therefore, pH diurnal variations are possible.

From 1981 through 1998 as part of the Volunteer Lake Monitoring Program, IEPA collected water quality samples from Stations RCB1, RCB2, and RCB3 in Borah Lake. The stations are identified as RCB1, RCB2, and RCB3. The samples were collected from the surface (1 foot below water surface) only except at Station RCB1, where an additional bottom sample was collected. Table B-2-13 in Appendix B summarizes the most recent values for the pollutants of concern (April to October 1998).

These data show that TP exceeded the water quality standard of 0.05 mg/L in all 15 surface samples. In addition, according to IEPA's "Water Quality Report 2000," the measurements classified TP levels as moderate to high (IEPA 1998b). Like Olney East Fork Lake, TP is especially high along the lake bottom during the late part of the summer, with measurements of 1.04 mg/L on August 11 and 0.233 mg/L on October 14, 1998. Elevated TP concentrations result in a TSI value of 64.2 based on 1998 Volunteer Lake Monitoring Program data, indicating that the lake is eutrophic. Total NH_3-N concentrations did not exceed the IEPA guideline in any of the samples collected in 1998.

Based on 1998 data, pH levels exceeded the water quality standard five times (IEPA 1998b). Likewise, Ch-a concentrations exceeded the IEPA guideline in most of the samples collected. Figure 2-3 shows the correlation between Ch-a concentrations and pH levels.

FIGURE 2-3. LINEAR REGRESSION OF pH AND Ch-a



An R^2 value of 0.88 strongly suggests that elevated concentrations of pH in Borah Lake are the result of excess algal growth. The R^2 value is a fraction between 0.0 and 1.0. A value of 0.0 indicates that no relationship between coordinates "x" and "y," and a value of 1.0 indicates that "x" and "y" are perfectly correlated. Therefore, a value of 0.88 indicates that pH and Ch-a are strongly correlated. Furthermore, Ch-a is closely related to TP level, so reducing TP concentrations can lower elevated pH levels in Borah Lake.

2.8 Surrogate Measures Used as TMDL Endpoints

As discussed in Section 2.7, phosphorus is the limiting nutrient for algae growth in lakes. Because Ch-a as an indicator of algae growth is closely correlated with pH in Borah Lake, phosphorus is then used as a surrogate measure for pH in Borah Lake. Reducing phosphorus loads in Borah Lake will therefore limit algae growth, which in turn will lower the lake's pH to achieve the water quality standard. However, NH_3-N, BOD, temperature, Ch-a, and TSS are each measurable parameters that affect the pollutants of concern (see Section 2.7). Consequently, NH_3-N, BOD, temperature, Ch-a and TSS are modeled and serve as additional water quality indicators that can be used to assess water quality improvements after TMDL implementation.

2.9 Point and Nonpoint Sources

This section describes the point and nonpoint sources that contribute to the impairment of the Fox River and the nonpoint sources that contribute to impairment of the Olney East Fork and Borah Lakes. No point sources are located in the Olney East Fork or Borah Lake watersheds.

2.9.1 Fox River Point and Nonpoint Sources

Three National Pollutant Discharge Elimination System (NPDES) dischargers are located within the Fox River watershed (see Table 2-2).

TABLE 2-2. ACTIVE PERMITTED POINT SOURCES IN THE FOX RIVER WATERSHED

NPDES No.	SIC No.	Facility Name	Location	Receiving Water Body
IL0048755	4952	Olney STP	Southwest Olney, Richland County	Unnamed ditch to Fox River
IL0004146	3751	Roadmaster Corporation treatment plant	Olney, Richland County	Unnamed ditch to Big Creek
ILG551065	6515	Kincade Acres Mobile Home Park	Olney, Richland County	Unnamed tributary to Fox River

Source: EPA 2001a

Notes:

MGD	Million gallons per day
NPDES	National Pollutant Discharge Elimination System
SIC	Standard Industrial Code
STP	Sewage treatment plant

Roadmaster Corporation is no longer involved with manufacturing and has not discharged since December 2001 (Tetra Tech 2002b). Before then, its discharge was less than 0.01 MGD (Tetra Tech 2001). Kincade Acres Mobile Home Park has a discharge of less than 0.01 MGD. Its discharge contains BOD concentrations, but the BOD load contributed to the Fox River is insignificant compared to the Olney STP and surface runoff (Kincade Acres Mobile Home Park 2001). Based on the mean monthly effluent BOD concentration of 1.1 mg/L and the mean flow of 1.8 MGD, approximately 15 pounds of BOD is discharged into Fox River daily.

The Olney STP is the major discharger in the Fox River watershed. The STP's average design discharge rate is 2.2 MGD, and the maximum design flow is 5.5 MGD. The sewer collection system consists of approximately 45 miles of sewer lines ranging in diameter from 8 to 36 inches. The city currently has 19 sewers lift stations (Olney City Government 2001). The storm and sanitary sewer systems were separated between 1987 and 1989, but infiltration and inflow between the two systems still exist as evidenced by fluctuations in plant flow after storm events. In 1994, a storage lagoon was installed to help control excess flows (Tetra Tech 2002d).

The monitored BOD loading to the STP is 5,142 pounds per day, and the TSS loading is 4,792 pounds per day (Olney City Government 2001). From October 1999 to June 2001, the maximum BOD effluent concentration was only 2.5 mg/L, compared to the limit of 20 mg/L. Effluent concentrations of BOD, pH, and NH_3-N never exceeded their NPDES limits (Olney STP 2001; EPA 2001a).

The Little Wabash River is considered to have a potentially high level of impact to water quality from nitrogen runoff from farm fields (EPA 1999). Fox River watershed soils have a relatively low permeability of 0.5 inch per hour, resulting in lower rainfall infiltration and high overland flow and subsequently large nutrient and sediment runoff into streams and lakes. The 303(d) list identifies the nonpoint sources of impairments to the Fox River as agricultural irrigation and nonirrigation crop production and resource extraction. However, nonpoint sources of impairment identified as part of this TMDL study include row crop agriculture (including manure application), animal feedlots, pasture land, septic system failures, and infiltration and inflow between sanitary and storm sewers.

Pollutants from oils wells were also evaluated because 744 oil wells are located in the Fox River watershed (IEPA 2002a). However, leaks from oil wells do not impact DO concentrations in surface water. Salt water and oil are the two possible pollutant loads that can leak from an oil well, but neither can contribute to low DO concentrations in surface water. Saltwater has the potential to increase chloride and total dissolved solid (TDS) concentrations but does not affect DO. Oil breaks down to hydrocarbons very quickly before reaching a water body (Tetra Tech 2002). In addition, saltwater and oil spills are rare in the Fox River watershed. Only nine spills were reported from June 1999 through June 2002 (IDNR 2002).

Most nonpoint sources of nutrient and BOD loads in the Fox River result from row-crop agriculture. Manure, which has a high nutrient content, is commonly applied to agricultural fields in Richland County. Urea and diammonium phosphate (DAP) are the primary manufactured fertilizers applied to row crops in Richland County, Illinois (Tetra Tech 2002a). Urea is a water-soluble organic form of nitrogen that rapidly hydrolyzes to ammonium. Dissolved forms of nitrogen can reach the Fox River through surface water runoff and groundwater. DAP is primarily a source of phosphorous but is also a source of nitrogen. Phosphorous seldom leaches from soils but can reach the Fox River when soil particles containing phosphorous are carried to surface water through runoff.

Animal feedlots and pastureland are other land uses that contribute significantly to nutrient and BOD loads to the Fox River. About 10 livestock producers are located in the Fox River watershed. However, information on the number of confined versus unconfined feeding lots and the number and types of animals was unavailable (NRCS 2002). Grazing on pastureland containing small tributaries could damage streambanks and riparian vegetation and erode streambanks, which would transport soil particles potentially containing phosphorous to the Fox River.

Failing septic systems and infiltration and inflow between sanitary and storm sewers are other potential sources of nutrient and BOD loads to the Fox River. More than 300 septic systems are located in the Fox River watershed (Illinois Department of Public Health 2002; Tetra Tech 2002f). In 2000 and 2001, only five septic system failures in Richland County were reported to the regional health department. The actual number of septic system failures is most likely greater than five because failures are not always reported and septic systems are not regularly inspected in the watershed because of limited resources (Illinois Department of Public Health 2002; Tetra Tech 2002e and 2002f). Richland County does not have a health department. Infiltration and inflow between storm and sanitary sewers in the Olney Sanitary District is evidenced by Olney STP flow fluctuations that correspond to precipitation fluctuations (Tetra Tech 2002d). Infiltration and inflow between sewer systems is also evidenced by an increase in Olney STP flow and a corresponding decrease in population and water production rates (Olney STP 2001b; U.S. Census Bureau 2002; Olney WTP 2001).

2.9.2 Lake Nonpoint Sources

Potential nonpoint sources of impairment to the Olney East Fork and Borah Lakes are listed in Table 2-3 below.

TABLE 2-3. PROPOSED NONPOINT SOURCES TO OLNEY EAST FORK AND BORAH LAKES

Source of Impairment	Olney East Fork Lake	Borah Lake
Nonirrigated crop production	√	
Irrigated crop production	√	√
Construction and land development	√	
Animal feedlots	√	
Pastureland	√	
Infiltration and inflow between sanitary and stormsewers	√	√
Urban runoff and storm sewers	√	√
Land disposal such as on-site wastewater systems	√	√
Recreational and tourist activities	√	√

Source: IEPA 2000

Nonpoint sources of impairment of the lakes include row crop agriculture (including manure application), animal feedlots, pastureland, septic system failures, and infiltration and inflow between sanitary and storm sewer systems (see Section 2.9.1). In addition, runoff from residential land is a potential source of nutrient loading to the lakes, and significant portions of the lakes' shorelines are lined with residential properties. Fertilizer and other lawn care applications can result in nutrient loading to the lakes if not managed appropriately.

For the Olney East Fork and Borah Lake watersheds, cropland and pasture makes up a majority of the watershed; therefore, row crop agriculture and pastureland are the primary sources of nutrient and BOD loads to the lake. Residential land does not cover a large area of the watershed, but the proximity of residential properties to the lakes makes residential use a significant contributor to nutrient loads. Animal feedlots are not identified as a land use type in the Borah Lake watershed; however, as discussed in Section 2.9.1, the number and locations of all animal feedlots throughout the Fox River watershed are unknown (see Figure 2-8 and Table 2-13 in Appendix B for land use distribution in the Olney East Fork Lake and Figure 2-11 and Table 2-17 for land use distribution in the Borah Lake watershed.)

The degree of septic system failures and infiltration and inflow between the sanitary and storm sewer systems in the watershed is unknown, but it is known that these are potential sources of nutrient and BOD loads to Olney East Fork and Borah Lakes.

3 APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY TARGETS

All waters of Illinois are assigned one of the following four designations: general use waters, public and food processing water supplies, Lake Michigan, and secondary contact and indigenous aquatic life waters. Illinois waters must meet general use water quality standards unless they are subject to another specific designation (CWA Section 302.201). The general use standards protect the state's water for aquatic life (except as provided in CWA Section 302.213), wildlife, agricultural use, and secondary contact use (such as recreational and most industrial uses) and ensure the aesthetic quality of the state's aquatic environment. General use standards also protect waters whose physical configuration permits primary contact use such as swimming. Unless otherwise specifically provided for and in addition to general use standards, waters of the state must meet the public and food processing water quality standards at the points of water withdrawal for treatment and distribution as a potable supply or for food processing (CWA Section 302.301).

The Fox River is designated as a general use water body and is protected for aquatic life, fish consumption, and swimming. Olney East Fork Lake is designated as a public use and food processing water supply because it is used as the drinking water supply for the City of Olney. Borah Lake is designated as a general use water body and is protected for aquatic life, recreation, and swimming (IEPA 2000a).

This chapter describes applicable Illinois water quality standards that apply to the designated uses of the Fox River and the two lakes. This chapter also (1) explains IEPA's evaluation of impairment based on these guidelines and (2) standards and identifies numeric water quality targets that are used as TMDL endpoints for each water body.

3.1 Illinois Water Quality Standards

This section discusses applicable Illinois water quality standards for the three water bodies. Illinois water quality standards are based on minimal conditions needed to ensure that the water body meets its designated uses. Illinois water quality standards are enforceable and are used to determine which water bodies require TMDLs. aesthetic quality of water bod Illinois water quality standards for the Fox River and the lakes are discussed below.

3.1.1 River Water Quality Standards

The Fox River is listed on IEPA's 303(d) list for DO (organic enrichment) and pH. DO and pH can be measured directly for a water body. Section 2.7.1 explains how nutrients affect DO in a river. Table 3-1 lists applicable Illinois water quality standards for the causes of impairment of the Fox River.

TABLE 3-1. ILLINOIS WATER QUALITY STANDARDS

Parameter	Standard
TP	Not applicable
NH_3-N	Not applicable
pH	6.5 to 9.0 S.U.
DO	Shall not be less than 6 mg/L during at least 16 hours of any 24-hour period nor less than 5.0 mg/L at any time

Sources: IEPA 1999 and 2000

Notes:

DO	Dissolved oxygen
mg/L	Milligram per liter
NH_3-N	Ammonia-nitrogen
S.U.	Standard unit
TP	Total phosphorus

Illinois water quality standards require that the DO concentration in a river not be lower than 6 mg/L in 16 hours of any 24-hour period nor lower than 5 mg/L at any time; however, monitoring events were not long enough to allow an accurate assessment of the conditions specified in the DO standard. In addition, DO standards are not stated in statistical terms, and continuous monitoring data are usually not available; one violation at any time will result in the listing of a water body. Therefore, given the diurnal variation of DO in rivers, this study uses the average DO standard of 6 mg/L as an end point. In this way, the lower DO limit of not less than 5.0 mg/L will be automatically satisfied. The modeling approach used in this report calculates the daily average DO concentration in the Fox River. The calculated average endpoint is therefore higher than the minimum DO concentration during a 24-hour period.

3.1.2 Lake Water Quality Standards

Olney East Fork Lake is listed on IEPA's 303(d) list for impairment resulting from high TP and DO levels. Borah Lake is listed for DO and pH. DO, pH, and TP can be measured directly in the lakes and have water quality standards. Sections 2.7.2 and 2.7.3 discuss relationships between DO, pH, TP, NH_3-N, and Ch-a. Table 3-2 summarizes applicable Illinois water quality standards for the lakes.

TABLE 3-2. ILLINOIS WATER QUALITY STANDARDS FOR LAKES

Parameter	Standard
NH_3-N	Not applicable
TP	Shall not exceed 0.05 mg/L in any reservoir or lake with a surface area of 8.1 hectares (20 acres) or more or in any stream at the point where it enters any such reservoir or lake
DO	Shall not be less than 6 mg/L during at least 16 hours of any 24-hour period nor less than 5.0 mg/L at any time
Excessive Algal Growth/ Ch-a	Not applicable
pH	6.5 to 9.0 S.U.

Source: IEPA 1999 and 2000

Notes:

Ch-a	Chlorophyll-a
DO	Dissolved oxygen
IEPA	Illinois Environmental Protection Agency
mg/L	Milligram per liter
NH_3-N	Ammonia-nitrogen
S.U.	Standard unit
TP	Total phosphorus

3.2 Impairment Evaluation

IEPA's evaluation of impairment is determined based on (1) the quantity by which a numeric standard was exceeded and (2) the cumulative effect of all standards that were exceeded. Specific steps taken to determine level of impairment are as follows (IEPA 2000a):

1. Assigning points to various pollutants or indicators of water quality based on whether the impairment caused by the particular pollutant or environmental indicator is high, moderate, or slight

2. Assigning impairment support classifications (full, partial, or nonsupport) to each individual use designation based on the sum of the points assigned in Step 1

3. Averaging all individual use impairment classifications to obtain an overall use classification for the overall designated use of the water body

A water body can exceed a particular standard once but still be considered to fully support its overall designated use. TMDLs are required for water bodies that exceed particular standards. Table 3-3 summarizes designated uses and the support status of each water body in the Fox River watershed.

TABLE 3-3. DESIGNATED USES AND SUPPORT STATUS OF IMPAIRED SEGMENTS

Designated Use	**Support Status**		
	Fox River	**Olney East Fork Lake**	**Borah Lake**
Recreation	Not applicable	Partial Support	Partial Support
Aquatic life	Partial support	Full support	Full support
Fish consumption	Full support	Not assessed	Not assessed
Swimming	Partial support	Partial support	Partial support
Drinking water supply	Not applicable	Full	Not assessed
Overall use	**Partial support**	**Partial support**	**Partial support**

Source: IEPA 2000

3.3 TMDL Endpoints

TMDL endpoints are the numeric target values for pollutants and parameters for a water body that represent conditions that will result in the attainment of water quality standards so as to restore the water body to its designated uses. The most stringent water quality standards were chosen as the endpoints for the TMDL analysis. Usually, if an applicable numeric water quality standard violation is the basis for 303(d) listing, the numeric criterion was selected as the TMDL endpoint. As discussed in Section 3.1.1, Table 3-4 does not list an endpoint for pH because the endpoint for TP applies to pH as well. According to the linkage established between pH, Ch-a, and TP in Section 2.7.2, reducing TP levels to below 0.05 mg/L will achieve pH levels between 6.5 and 9.0. Table 3-4 summarizes the TMDL endpoints that will be used to guide the selection of pollutant load reduction allocations for the three water bodies.

TABLE 3-4. TMDL ENDPOINTS

Cause of Impairment	TMDL Endpoint			Indicator
	Fox River	Olney East Fork Lake	Borah Lake	
pH (S.U.)	6.5 to 9.0	6.5 to 9.0	6.5 to 9.0	Direct measurement
TP (mg/L)	Not applicable	<0.05	<0.05	Direct measurement
DO (mg/L)	>6.0	>6.0	Not applicable	Direct measurement

Notes:

DO	Dissolved oxygen
mg/L	Milligram per liter
S.U.	Standard unit
TP	Total phosphorus
TMDL	Total maximum daily load

4 MODELING APPROACH

This chapter presents a general description of the modeling approach used to estimate existing pollutant loads and develop TMDLs for the Fox River, Borah Lake, and Olney East Fork Lake in order to meet Illinois water quality standards. Appendix B presents a detailed description of the models used, the modeling approach, and modeling results. Modeling results are also discussed in Chapters 5 through 7. In addition, to account for seasonal variations, flow and water quality of the Fox River, Olney East Fork Lake, and Borah Lake were modeled using the HSPF model continuously around the year, including dry conditions from April through October and wetter conditions during the rest of the year. In addition, EPA's Enhanced Stream Water Quality (QUAL2E) model was used to determine sensitivity of the Fox River's water quality to the loading from point sources during 7Q10 low-flow conditions from April through October. This chapter discusses the models used; modeling conducted to account for seasonal variations; and modeling assumptions, uncertainties, and MOS.

4.1 Models Used

In Chapters 5 through 7, the modeling approach analyzes and synthesizes the relationship between causes of water impairment and sources to allow the prediction of water body response and comparison of various management plans. Scientific linkage between water quality and pollutant source load allocation using the models allows evaluation of management options and selection of the option that will achieve the desired source load reductions. In Chapters 5 through 7, causes of impairment are linked with sources by characterizing human activities in the watershed. The relative load allocations of nutrients are then assessed for the different sources.

The primary modeling framework for predicting loads for the Fox River watershed is HSPF. HSPF is a very sophisticated and versatile program capable of continuously simulating hydrology and water quality in a watershed and in water bodies. HSPF provides an integrated approach for modeling contaminant fate and transport in surface water and consists of a hydrology module and a water quality module. The model can be used in studies of BOD, DO, nutrients, eutrophication, and organic chemicals. EPA's BASINS geographic information system (GIS) framework was used to extract data and initiate the HSPF model.

Essentially, load is the product of flow and the concentrations of constituents in the water. In order to compute pollutant loads correctly, the model must be calibrated and validated. Unfortunately, the Fox

River watershed has no available flow records for the HSPF model calibration; therefore, modeling began with development of the HSPF model for the Little Wabash River watershed, which is the parenting watershed of the Fox River watershed. The Little Wabash River HSPF model was calibrated using flow data collected at four gauge stations by the USGS between 1990 and 1995. Meteorological data used was obtained from the BASINS database and the NCDC for Illinois. Calculations in HSPF were performed using a time interval of 1 hour.

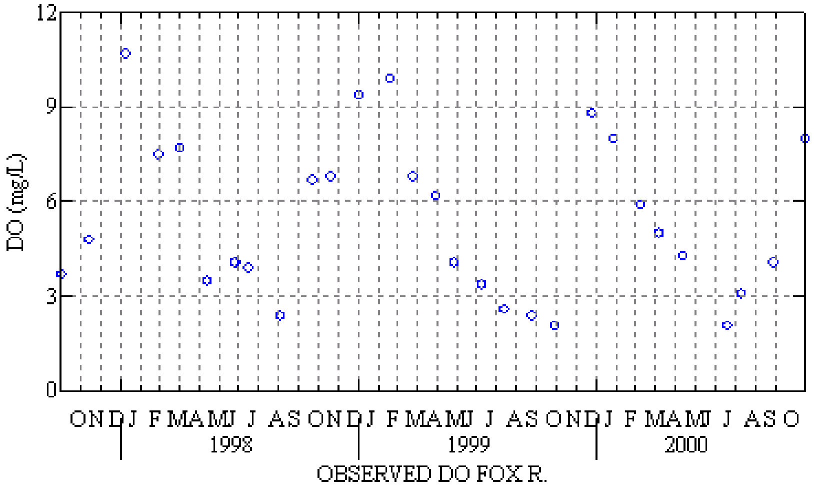
Based on the assumption that the hydrologic setting of Fox River watershed is similar to that of the Little Wabash River watershed, the Fox River watershed HSPF model was obtained from the calibrated HSPF model for the Little Wabash River watershed. The hydrologic parameters were kept unchanged. This model was used to generate a flow series for 1998 to 2000 because water quality data are available for this period. The water quality module of the HSPF model was then calibrated and tested for the Fox River, Borah Lake, and Olney East Fork Lake. The calibrated model was used to estimate nutrient loads to the Fox River and the two lakes as a function of land use and pollutant discharge, and the module was used to predict pollutant concentrations and other responses in the river and lakes. Chapters 5 through 7 discuss model results and Appendix B discusses modeling details.

EPA's QUAL2E model was also used to predict the Fox River's in-stream water quality response to point source load when the Olney STP effluent is the primary source of flow. This steady-state, in-stream water quality model was specifically developed to determine whether DO is a problem in the Fox River during low-flow conditions from April through October and whether NH_3-N and BOD loads from the Olney STP affect the DO concentration in the river. The QUAL2E model is a one-dimensional model applicable to dendritic, well-mixed streams. It assumes that the major pollutant transport mechanisms of advection and dispersion are significant only along the main direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. It can compute the dilution flow augmentations required to meet any prespecified DO level.

4.2 Modeling To Account For Seasonal Variations

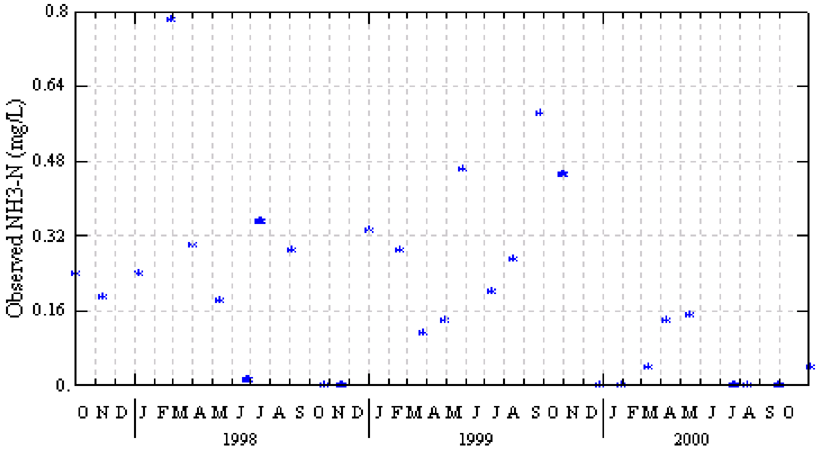
Climactic and hydrologic changes result in seasonal variations of water quality indicators in the Fox River watershed. Figure 4-1 illustrates observed seasonal variations for DO content in the Fox River.

FIGURE 4-1. OBSERVED DO SEASONAL VARIATIONS IN FOX RIVER



The figure indicates that DO is lowest from April to October when flows in Fox River are low and water temperature is high. In addition, as Figure 4-2 shows, NH_3-N concentrations in Fox River are highest from April to October.

FIGURE 4-2. OBSERVED NH_3-N SEASONAL VARIATIONS IN FOX RIVER



In this study, the period from April to October is therefore considered a critical period for TMDL development.

The period from May through October in the watershed is characterized by periodic smaller storms and base flow conditions. The small storm washoffs (or "first flush" storms) tend to generate high BOD and NH_3 concentrations. An analysis of low-flow conditions for the Fox River established a 7Q10 rate of 2.7 ft^3/s. 7Q10 conditions occur when there is no rainfall in the watershed for a long period during which the Olney STP is the only source of water to the river. This condition is included in the continuous hydrology HSPF model simulation described in Appendix B. The 7Q10 conditions of the Fox River were also evaluated using the QUAL2E model to determine the sensitivity of the Fox River's water quality to the low-flow loading from point sources.

The Fox River HSPF model was also used to simulate settling and resuspension processes continuously for the modeling period so that seasonal variations are taken into account. The settling and resuspension of cohesive sediments is determined by the shear stress exerted on the bed surface. The shear stress is calculated for a reach based on slope and hydraulic radius. TMDLs are developed in Chapters 5 though 7 for low-flow and yearly average conditions in order to achieve water quality standards. From November to April, the Fox River generally has low temperatures and higher flows that are unlikely to result in low DO concentrations or elevated NH_3-N concentrations. This period is not considered critical; however, this period indirectly contributes to dry season conditions because a significant amount of wet season nutrients and BOD washoff reach water bodies and settle to the bottom, resulting in high SOD concentrations. When the flow is lower and the water temperature is higher, elevated SOD conditions deplete DO content in the water. The winter loads increase the accumulation of nutrients and organic materials at the bottom of the water body and nutrients and organic matters can be reintroduced into the water column through hydraulic disturbance and animal activities, resulting in high nutrient concentrations; therefore, load reduction is considered for both the critical period and the whole year. Although monitoring data for Olney East Fork and Borah Lakes are only available for Summer 1998, seasonal variations of lake water quality follow the same trend as the Fox River because the runoff into the lakes is generated by the same storm events; therefore, the HSPF model was also used to evaluate lake load reductions during the dry season and all year.

4.3 Modeling Assumptions, Uncertainties, and MOS

The calibrated HSPF model was used to determine pollutant loads from nonpoint sources. The development of the model involved using uncertain inputs and making assumptions and simplifications that could introduce errors in the predicted loads. The main sources of error and their effects are summarized below.

1. No flow data are available for the Fox River watershed for hydrology calibration. Instead, flow data were interpolated using the calibrated Little Wabash River watershed HSPF model and used in subsequent water quality simulations. Errors can result from the assumption that the hydrologic setting of the Fox River watershed is similar to that of the Little Wabash River watershed.

2. HSPF model is sensitive to meteorological input. The lack of evenly distributed precipitation data introduces errors into the predictions.

3. HSPF model calibration and validation were based on data from 1998 to 2000. The load calculation is based on the average load of this period. It was assumed that the average of the 3-year period represents typical yearly water quality trends in the river and lakes. This assumption introduces errors if climate conditions in future years differ from that of the past 3 years that were used to derive the loads.

4. Calibration of flow and pollutant concentrations was based on single-point observations that may not be representative of complete flow or pollutant concentrations for the watershed. The load predictions are affected by the quality of the available concentration data along the river channel.

5. The water quality data are based on grab samples. The data therefore do not represent average daily conditions used to calibrate the water quality module. The instantaneous water quality concentrations in the grab samples are assumed to represent the hourly average used in model calibration.

6. The HSPF model uses various semi-empirical relations that may not accurately represent real-world conditions. For example, an empirical equation is used to calculate the sediment settling rate.

7. No BOD and SOD data for the Fox River are available for water quality module calibration. Instead, DO data were used for calibration.

An MOS of 20 percent is therefore included in the TMDLs to account for the uncertainties and assumptions discussed above (IEPA 2002c). A lower MOS is not recommended because the margin of error in the flow calibration is also the order of 20 percent. The MOS is intended to make load reduction determinations conservative, practical, and achievable. The MOS can be included implicitly in the calculation of the load allocations or explicitly for each separate value. The 20 percent value should be reasonable because of a 20 percent MOS is consistent with other TMDLs approved by EPA that have similar data limitations and model calibration uncertainties (EPA and IEPA 2002).

5 FOX RIVER TMDLs AND LOAD ALLOCATIONS

This chapter describes the development of BOD and NH_3-N TMDLs for the Fox River and loading allocations from nonpoint and point sources. Section 5.1 describes the linkage between water quality and pollutant sources. Section 5.2 discusses the assimilative load capacity and reductions needed to achieve the water quality targets. Section 5.3 summarizes the Fox River TMDLs and load allocations for the sources.

5.1 Linkage of Water Quality and Pollutant Sources

Land in the Fox River watershed is used for cropland, urban land, and forest land. The calibrated HSPF model generates pollutant loadings to the water bodies from each land use. The HSPF model's water quality modules for the Fox River and the two lakes (considered well-mixed reservoirs) evaluated the water quality response to corresponding pollutant loads. Because the HSPF model performed continuous simulation of both hydrology and water quality, seasonal variations were taken into account for the modeling period (see Section 4.2).

The model scenarios show that the DO standard is more frequently exceeded during low-flow conditions, when water temperatures are warmer and flows are lower. The model also shows that the DO standard is not expected to be violated from November through April. A sensitivity analysis was performed to evaluate the dependence of DO on BOD, NH_3-N, SOD, and TP. The HSPF model indicates that BOD is the most sensitive constituent influencing DO concentrations in the Fox River. Reducing BOD loads during the low-flow and high-flow seasons will decrease SOD concentrations and increase DO levels. NH_3-N is the second most sensitive constituent whose reduction would increase DO concentrations. Reducing TP has no noticeable effect on DO concentrations in the river; therefore, TP reduction is not an effective way to achieve the DO standard.

It should be noted that the BOD discussed in this report represents carbonaceous BOD. The HSPF model simulated nitrogen as a separate variable; therefore, the consumption of DO by nitrogenous BOD is accounted for in the model.

5.2 Load Capacity and Percent Reductions

The critical season for DO was determined to be from May to October. During the critical season, the Fox River is poorly flushed, resulting in slow-moving, warm water prone to excessive algae growth and low DO concentration less than 5 mg/L. As discussed in Section 4.2, a TMDL is needed for the critical period to protect water quality. A TMDL is also needed for November through April to maintain water quality because loads during wet conditions also affect DO concentrations during low-flow conditions.

The assimilative load capacity is the maximum allowable load that the listed segment of the Fox River can receive without violating the Illinois DO standard. Multiple pollutants contribute to the low DO conditions in the Fox River, especially BOD and NH_3-N. The HSPF model in-stream water quality module was used to assess loading capacity. The load capacity for each period was determined by multiplying the seasonal average flows and the pollutant concentrations corresponding to the endpoints. Table 5-1 summarizes the existing loads, maximum seasonal load allowable load capacity of each pollutant of concern for the listed segment of the Fox River, and the percentage reductions needed to meet the water quality standards.

TABLE 5-1. FOX RIVER MAXIMUM ALLOWABLE LOADS AND PERCENT REDUCTIONS

Pollutant Load	**May through October (Critical)**		**November to April**	
	cBOD	**NH_3-N**	**cBOD**	**NH_3-N**
Existing (lb/day)	2,352	112	6,846	277
Maximum Allowable (lb/day)	588	28	2,054	83
Percent Reduction (%)	75	75	70	70

Notes:

BOD	Biochemical oxygen demand
lb/day	Pound per day
NH_3-N	Ammonia-nitrogen

The loadings are higher during the November through April season because the higher storm runoff volumes transport higher loads from the watershed even though pollutant concentrations may be higher than during low-flow conditions.

5.3 TMDLs and Load Allocations

By definition, a TMDL is defined as the maximum load that a water body can receive without violating a water quality standard. It is a sum of individual waste load allocations for point sources and load allocations for nonpoint sources and an MOS as described in Equation 1-1 of Section 1.1. As discussed in Section 2.9.1, the major point source in the Fox River watershed is the Olney STP. The load contribution from the Kincade Acres Mobile Home Park is negligible (0.01 MGD, compared to 1.8 MGD from the Olney STP). Modeling results for low flow conditions indicate that the current loads from the Olney STP alone do not cause DO level to drop below the water quality standards; therefore, no additional load reductions are needed for the Olney STP. Waste load allocations for the Olney STP are therefore maintained by the existing NPDES permit limits. The proposed load reductions consequently apply only to nonpoint sources. Based on modeling uncertainties and natural background loads, the MOS was set at 20 percent of the maximum allowable load.

Section 4.3 presents a more detailed discussion of model uncertainties. The load allocation for nonpoint sources was then calculated using the TMDL equation (Equation 1-1). Table 5-2 summarizes the calculated TMDLs and load allocations for the Fox River.

TABLE 5-2. FOX RIVER TMDLs AND LOAD ALLOCATIONS

Pollutant	Season	From Nonpoint Source (LA) (lb/day)	From Point Source (WLA) (lb/day)	MOS (20%)	TMDL (lb/day)
BOD	May – October	440	30	118	588
NH_3-N		17	5	6	28
BOD	November – April	1,614	30	410	2,054
NH_3-N		61	5	17	83

Notes:

BOD	Biochemical oxygen demand
LA	Load allocation (see Equation 1)
lb/day	Pound per day
MOS	Margin of safety
NH_3-N	Ammonia-nitrogen
TMDL	Total maximum daily load
WLA	Waste load allocation (see Equation 1-1)

In Table 5-2, each TMDL is, by definition, equal to the calculated limit presented in Table 5-1. The load allocations for each pollutant (LA) are therefore determined as follows:

- WLA = NPDES permit limit
- MOS = 20 percent of maximum allowable load
- LA = Maximum allowable load–WLA (point sources)–MOS

6 OLNEY EAST FORK LAKE TMDLs AND LOAD ALLOCATIONS

This chapter describes the development of the TP and BOD TMDLs for Olney East Fork Lake to attain the DO water quality standard. Section 6.1 describes the linkage between water quality and pollutant sources. Section 6.2 discusses the load capacity and reductions needed to achieve the water quality targets. Section 6.3 summarizes the Olney East Fork Lake TMDLs and load allocations for the sources.

6.1 Linkage of Water Quality Targets and Pollutant Sources

The in-lake water quality module in the HSPF model was used to link water quality targets and pollutant sources and model the effects of loads and load reductions on lake water quality. Within the Fox River HSPF model, the sub-basin that drains into Olney East Fork Lake was delineated. Runoff from cropland and residential areas around the watershed carry loads to Olney East Fork Lake. Modeling results show that runoff volume from November through April is greater than from May through October. Higher pollutant loads are carried to the lake from November through April. Water withdrawn by the Olney water plant and spillway discharge during large storms remove some dissolved and suspended pollutants from the lake. The HSPF model considered pollutants released through these processes through continuous simulation.

As monitoring data indicate, DO concentrations in the lake fell below the 6-mg/L standard only once during the monitoring period (April to October) on October 13, 1998, during the low-flow period consistent with the HSPF model results. This suggests that the critical period for the lake appears to be during the dry or low-flow period. Under IEPA's 303(d) list criterion, this observation is sufficient to be identified as an impairment of the lake's designated uses. If nonpoint source loads increase in the future and as more residences are developed around the lake, it is possible that DO violations could increase in both severity and frequency.

6.2 Load Capacity and Percent Reductions

The load capacity was assessed using HSPF model's in-lake module. TP and BOD loads were adjusted until the endpoints for TP and DO were met. Load reductions necessary to achieve compliance with the TP and DO water quality standards in Olney East Fork Lake were calculated by determining the percent reduction in in-lake concentrations required to meet the TP and DO endpoints. These percent reductions were then applied to the total input loads to determine the necessary load reductions. Table 6-1 below summarizes the existing loads, maximum seasonal allowable load capacity of each pollutant of concern, and the percent reductions needed to meet the water quality standards.

TABLE 6-1. OLNEY EAST FORK LAKE MAXIMUM ALLOWABLE LOADS AND PERCENT REDUCTIONS

Pollutant Load	**May through October (Critical)**		**November to April**	
	TP	**cBOD**	**TP**	**cBOD**
Existing (lb/day)	83	110	650	342
Maximum Allowable (lb/day)	21	60	162	188
Percent Reduction (%)	75	45	75	45

Notes:

BOD	Biochemical oxygen demand
lb/day	Pound per day
TP	Total phosphorus

The existing pollutant loads were calculated based on existing conditions by the HSPF model continuously for each season and for a simulation period of 3 years, from January 1998 to December 2001 (The average loads for each season for the 3 years calculated). The maximum allowable loads were determined by trial and error. The existing input loads (from the first row) were reduced by a certain percentage. The model was then run to determine DO levels. If the DO levels were below the TMDL endpoints, a further load reduction was applied. This step was repeated until the input load resulted in a DO level above the TMDL endpoint.

6.3 TMDLs and Load Allocations

The sources of pollutant loads to Olney East Fork Lake are nonpoint overland runoff, atmospheric deposition (considered in the MOS), and septic systems. No point sources contribute to Olney East Fork Lake in the watershed. Because background loads are contributed from many different sources, they could not be calculated by the model. . Background loads are therefore considered within the MOS.

The pollutant loads to the lake were determined through the input stream loads and concentrations that would not result in violations of the applicable water quality standards during critical and noncritical seasons. The concentrations were determined using the calibrated lake water quality model. Table 6-2 summarizes the calculated TMDLs and load allocations for Olney East Fork Lake.

TABLE 6-2. OLNEY EAST FORK LAKE TMDLs AND LOAD ALLOCATIONS

Season	Pollutant (lb/day)	From Nonpoint Source (LA) (lb/day)	From Point Source (WLA) (lb/day)	MOS (20%)	TMDL (lb/day)
May – October	TP	17	0	4	21
	cBOD	48	0	12	60
November – April	TP	130	0	32	162
	cBOD	150	0	38	188

Notes:

cBOD	Carbonaceous biochemical oxygen demand
LA	Load allocation (see Equation 1-1)
lb/day	Pound per day
MOS	Margin of safety
TMDL	Total maximum daily load
WLA	Waste load allocation (see Equation 1-1)

7 BORAH LAKE TMDLs AND LOAD ALLOCATIONS

This chapter describes the development of the TP TMDL for Borah Lake and loading allocations from nonpoint sources. Section 7.1 describes the linkage between water quality and pollutant sources. Section 7.2 discusses the load capacity and reductions needed to achieve the water quality target. Section 7.3 summarizes the Borah Lake TMDLs and load allocations for the sources.

7.1 Linkage of Water Quality Targets and Pollutant Sources

Based on 1998 monitoring data, TP concentrations in Borah Lake have exceeded the Illinois water quality standard of 0.05 mg/L, especially in late summer. Elevated TP concentrations have caused eutrophication of the lake system and algae blooms, which result in low DO and high pH. Levels of DO in Borah Lake, however, have not been observed to drop below the DO standard of 5 mg/L. Algae blooms consume DO through respiration and CO_2 through photosynthesis. The growth of algae blooms in the lake was indicated by high Ch-a concentrations, which result in a pH level exceeding, 9.0, the upper limit of the water quality standard for pH.

The in-lake water quality module of the HSPF model was used to link water quality targets and pollutant sources and model the effects of load and load reductions on lake water quality. Within the Fox River HSPF model, the sub-basin of the Fox River watershed that drains into Borah Lake was delineated. Runoff and interflow from cropland and residential areas around the watershed to the lake were simulated. The HSPF model identified Borah Lake as phosphorus-limiting. The calibrated HSPF model predicted the TP concentration and phosphorus load from nonpoint sources in the Borah Lake watershed. The linkage between TP and high pH was established by the relationships between TP and Ch-a and between Ch-a and pH. These two relationships were derived based on observed TP, Ch-a, and pH data for Borah Lake (see Section 6.2.3 of Appendix B). A TMDL for pH is therefore incorporated into the TMDL for TP. TP was simulated as a surrogate for pH. Because the lake is phosphorus-limiting, the reductions in TP specified below should be sufficient to achieve the pH endpoints.

7.2 Load Capacity and Percent Reductions

The TP load capacity is the maximum allowable load that Borah Lake can assimilate without exceeding the TP water quality standard of 0.05 mg/L. The TP allowable load will also enable Borah Lake to achieve compliance with the pH water quality standard of 6.5 to 9.0. The calibrated model was run while reducing the input loads until the average TP concentration in the lake was closer to 0.05 mg/L. The maximum allowable load was determined by multiplying the seasonal average inflow to the lake and concentrations generated by the final model run. The calibrated model was also used to estimate existing loads based on existing inflow and concentration. The percentage reductions were computed as the load reduction divided by the existing load (expressed as a percentage).

TABLE 7-1. BORAH LAKE MAXIMUM ALLOWABLE LOADS AND PERCENT REDUCTIONS

TP Load	May through October (Critical)	November to April
Existing (lb/day)	41	154
Maximum Allowable (lb/day)	11	39
Percent Reduction (%)	75	75

Notes:

lb/day	Pound per day
TP	Total phosphorus

7.3 TMDLs and Load Allocations

The sources of pollutant loads to Borah Lake include nonpoint overland runoff, atmospheric deposition (considered in the MOS), and septic systems. Nonpoint source allocation is calculated to include all sources as gross allotment. No point sources are located in the Borah Lake drainage basin. Background loads cannot be distinguished from other nonpoint source loads because of the lack of sufficient information. Background loads are therefore considered within the MOS component. Table 7-2 summarizes the calculated TMDLs and load allocations for Borah Lake.

TABLE 7-2. BORAH LAKE TMDLs AND LOAD ALLOCATIONS WITH MOS

Season	TP from Nonpoint Source (LA) (lb/day)	TP from Point Source (WLA) (lb/day)	MOS (20%)	TMDL (lb/day)
May – October	9	0	2	11
November – April	31	0	8	39

Notes:

LA	Load allocation (see Equation 1-1)
lb/day	Pound per day
MOS	Margin of safety
TMDL	Total maximum daily load
TP	Total phosphorus
WLA	Waste load allocation (see Equation 1-1)

8 IMPLEMENTATION ACTIVITIES

The implementation activities recommended below would reduce nonpoint source loads to the Fox River and Olney East Fork and Borah Lakes. Although Olney STP is a point source that contributes the overall nutrient and BOD loads, its contribution is insignificant (less than 3 percent) compared to nonpoint source loads. Furthermore, concentrations of Olney STP effluent are well below the plant's NPDES permit limits. The BMPs discussed below were selected based on criteria such as effectiveness and feasibility. Section 9.1 focuses on the effectiveness or "technical merits" of each BMP, and Section 9.2 provides reasonable assurance that the recommended BMPs can and will be implemented.

8.1 Best Management Practices

BMP selection was based on reducing nutrient and total BOD loads from row-crop agriculture, animal feedlots, pastures, failing septic systems, and infiltration and inflow between the sanitary and sewer systems. Table 8-1 below lists BMPs proposed for implementation in the Fox River watershed and identifies which sources each BMP will reduce.

TABLE 8-1. BMPs FOR FOX RIVER WATERSHED

BMP	Row-Crop Agriculture	Animal Feedlots	Pastures	Lake and Residential Property Management	Failing Septic Systems	Infiltration and Inflow
Nutrient management plans	√	√	√			
Buffer and filter strips	√	√	√	√		
Conservation tillage	√					
Construction of wetlands in tiled areas	√	√	√			
Prevention of animal waste runoff		√				
Pasture management			√			
Lake and residential property management				√		
Septic system management					√	
Identification and remediation of infiltration and inflow between sanitary and storm sewer systems						√
Use of outlet works in Borah Lake to increase flow to Fox River[a]						

Notes:

BMP Best management practice

[a] No source is checked because increasing the flow to Fox River would not reduce loads from identified sources but would increase DO content through increased turbulence and reaeration.

Each of these nonpoint sources contributes to loads to the Fox River, Borah Lake, and Olney East Fork Lake; therefore, the BMPs listed in Table 8-1 apply to the entire Fox River watershed. BMPs that are more applicable to a specific water body are indicated as such. Most of the BMPs focus on reducing nutrient and BOD loads from row-crop agriculture because its runoff contributes the most to overall nutrient and BOD loads. Some of the BMPs listed in Table 8-1 are already being implemented (see Section 8.2).

Sections 8.1.1 through 8.1.9 present detailed descriptions of each BMP. Descriptions focus on factors that affect BMP effectiveness such as applicability and performance. Expected reduction percentages for BMPs to reduce nonpoint source pollutant loads are difficult to predict because (1) BMP effectiveness is site-specific and (2) BMPs are usually implemented in groups so that the effectiveness of one BMP cannot be quantified. Measured results of successful BMP activities are provided when available. Follow-up monitoring of the Fox River and the lakes, which is described in Chapter 9, is crucial in BMP implementation because of the uncertainty in BMP effectiveness.

8.1.1 Nutrient Management Plans

Nutrient management plans can reduce loads to the listed segments. Nutrient management involves managing the source, rate, form, timing, and placement of each nutrient source, including manure and commercial fertilizers. If implemented correctly, this can be the most effective BMP. Nutrient management can be one component of a conservation management system used in conjunction with conservation tillage and buffer and filter strips to reduce the amount of nutrients and other organic matter that reaches the listed segments.

The objectives of nutrient management are to effectively and efficiently use scarce nutrient resources to adequately supply soils and plants to produce food, forage, fiber, and cover while achieving environmental goals. Nutrient management is applicable to all lands where plant nutrients and soil amendments are applied. It is recommended that nutrient management practices follow NRCS's conservation practice standard for nutrient management, Code 590 (NRCS 2002a) and the University of Illinois Agronomy Handbook (University of Illinois 2001).

Typical nutrient management components of conservation plans may include the following information:

- Field and soil maps
- Crop rotation or sequence

- Results of soil, water, plant, and organic sample analysis
- Expected yield
- Sources of nutrients to be applied
- Nutrient budget, including nutrient credits available
- Recommended nutrient rates, form, timing, and method of application
- Locations of designated sensitive areas
- Guidelines for plan operation and maintenance

General nutrient management considerations may consider the following:

- Testing of soils, plants, water, and organic material for nutrient content
- Realistic yield goals
- Nutrient application in accordance with soil test recommendations
- Nutrient credits from all sources
- Effects of drought or excess moisture on quantities of available nutrients
- Water budgeting to guide timing of nutrient applications
- Use of cover crops and green manure whenever possible to recover and retain residual nitrogen and other nutrients between cropping periods
- Use of split applications of nitrogen fertilizer for greater nutrient efficiency

Guidelines for plan operation and maintenance are summarized below.

- Review the nutrient management component of the conservation plan annually, and make adjustments when needed.
- Calibrate application equipment to ensure uniform distribution and accurate application rates.
- Protect nutrient storage areas from weather to minimize runoff and leakage.
- Avoid unnecessary human exposure to fertilizer and organic wastes, and wear protective clothing when necessary.
- Observe setback distances required for nutrient applications adjacent to water bodies, drainage ways, and other sensitive areas.
- Maintain records of nutrient application.
- Clean up residual material from nutrient application equipment and dispose of properly.

A nutrient management plan also includes an assessment of site-specific potential environmental risks. For example, a nutrient management plan should include an assessment of potential risks if nitrogen and phosphorus impact water quality. Areas that may have high levels of nutrients (produced or applied) and thus may contribute to environmental degradation must be considered, and appropriate conservation practices and management techniques must be implemented to mitigate unacceptable risks.

8.1.2 Buffer and Filter Strips

Buffer strips are transitional areas around streams, lakes, and wetlands that are designated to be left in their natural, usually vegetative state to improve water quality by reducing sediment, organic, and other contaminant loads in runoff. Filter strips are generally narrow and long and slow the runoff rate, allowing sediments, organic matter, and other pollutants conveyed in the runoff to be removed. Buffer and filter strips also reduce erosion and resulting stream pollution. Buffer and filter strips have been implemented throughout the watershed, especially along the listed lakes and the Fox River. Buffer and filter strips are also important along first-order streams that drain into the Fox River and the lakes. Installation of filter strips in upland areas further from the water bodies should also be evaluated because nutrient build-up along the banks and shorelines can eventually migrate to the water body.

The case studies summarized below illustrate the effectiveness of buffer strips.

- In Missouri, a study compared nutrient and erosion reductions from grass buffer strips to grass buffer strips with trees. Results after 3 years of are summarized below.

Pollutant	Grass Buffer Strip	Grass Buffer Strip with Trees
Total phosphorous	10 percent	20 percent
Total nitrogen	20 percent	20 percent
Erosion	20 percent	Not available

Source: JEQ On-Line 2002

- In Arkansas, two studies concluded that sediment and nutrients in runoff (including nitrogen and phosphorus) from poultry- and swine-manured fields were significantly reduced in the first 10 feet of an area where a tall fescue grass buffer was grown on Captina silt loam soil. Further lengthening of the buffer strip beyond 30 feet did not significantly reduce the contaminant load of the runoff water (USDA 1999).
- In Montana, the trapping efficiency and nutrient uptake of four grasses in a buffer strip were measured to treat dairy manure in runoff. Orchard grass and meadow bromegrass were effective at both entrapping the nutrients in the runoff and absorbing the nitrogen into the plant biomass within the upper 20 feet of the buffer (USDA 1999).
- According to research compiled by the American Society of Civil Engineers, removal efficiencies of buffer strips applied in urban areas are as follows (ASCE 2001):

Pollutant	Grass Filter Strip (20 feet wide)	Forested Filter Strip (100 feet wide)
Total Phosphorous	Greater than 20 percent	40 to 60 percent
Total Nitrogen	Greater than 20 percent	40 to 60 percent
Biological oxygen demand	Greater than 20 percent	60 to 80 percent

The effectiveness of buffer strips depends on many parameters. The key parameters include overland flow velocity and depth, vegetation, and width. The choice of vegetation should be based on climate conditions, intended functions of the buffer, desired by-products, and soil characteristics. Based on field experience, ideal slopes for buffer strips range from 2 to 6 percent. For preliminary design purposes, the required widths of buffer strips can be estimated from Table 8-2

TABLE 8-2. BUFFER STRIP WIDTH BASED ON LAND SLOPES[a]

Percent Slope	Width (Feet)	
	Minimum	Maximum
0.5	36	72
1.0	54	108
2.0	72	144
3.0	90	180
4.0	108	216
5.0 or more	117	234

Source: NRCS 1999

Note:

[a] Proposed buffer strip widths will achieve a minimum water flow-through time of 15 and 30 minutes at a 0.5-inch flow depth.

Ongoing studies at the University of Illinois Urbana-Champaign involve the use of buffer strips to filter outflow from drain tiles in agricultural areas. No results are available to date regarding the effectiveness of this technique. If successful, the technique would be applied to areas contiguous to the Fox River and the lakes. Currently, water sediment control basins and grassways along tile drains are used to control sediment and nutrient loads (Tetra Tech 2002g).

In addition to reducing the amount of nutrients, buffer and filter strips provide the additional benefits listed below.

- Buffer and filter strips can contribute to landscape aesthetics by providing contrasting colors and textures.
- Wildlife habitat is enhanced when some part of the cropland area is converted to permanent vegetation. Besides providing shelter, nesting sites, and a food source, buffer and filter strips also create corridors for wildlife movement.
- Permanent vegetation along watercourses and drainage ways helps stabilize the adjacent area. The width of buffer and filter strips provides distance from the edge of the watercourse so that equipment does not damage the area.
- Companion legumes in buffer and filter strips have value and can be harvested. Alfalfa is an example of a companion legume that can have different uses such as commercial hay, various types of livestock operations, and other uses.

8.1.3 Conservation Tillage

Conventional tilling practices typically involve plowing a field to eliminate surface soil residue and prepare a seedbed. Bare and unprotected soil left after conventional tilling is easily eroded. Consequently, phosphorous particles from fertilizer that adsorbed to the soil can end up in surface water runoff. A variety of conservation tillage practices have been developed to limit erosion and the transport of phosphorous particles to surface water.

Examples of conservation tillage practices include no-till, mulch till, and reduced till. No-till or reduced till practices leave the soil fairly undisturbed from harvest to planting except for possible nutrient injection. Mulch till practices disturb the soil prior to planting only. No-till drilling requires drills designed to uniformly place seeds through heavy residue and into firm, moist soil. In addition, fertilizers applied to fields where conservation tillage is practiced should be injected to prevent runoff.

Conservation tillage was implemented in the Saginaw Bay watershed in Michigan in 1996 as part of a 319 project Grant. Results show that soil erosion was reduced by about 70 percent (EPA 2002).

8.1.4 Construction of Wetlands in Tiled Areas

Areas of the Fox River watershed have been tiled since the 1950s. Currently, water sediment control basins and grassways along tile drains are used to control nutrient and sediment loads (Tetra Tech 2002). An additional BMP to control nutrient and sediment loads from tile drains involves breaking up the tile drains and constructing a wetland in these naturally saturated areas. Identification and confirmation of tile drain locations in the Fox River watershed is the first step in implementing this BMP. Constructed wetlands can reduce pollutant loads, provide erosion control, provide wildlife habitat, and offer natural aesthetic qualities. Although the effectiveness of constructed wetland varies and is difficult to quantify because of uniqueness of each wetland, research has shown that wetlands are efficient filters for suspended solids and organic matter, are effective transformers of nitrogen, and have the ability to store phosphorous, depending on soil adsorption and chemistry. Measured removal efficiencies of a 15-acre wetland constructed in Tampa, Florida, are as follows (ASCE 2001):

- NH_3: 79 percent
- Total organic nitrogen: 29 percent
- Nitrite plus nitrate: 94 percent
- TP: 70 percent

Although results are not available, wetlands are being constructed in watersheds in Illinois and Iowa. The University of Illinois is breaking up tile drains and constructing a wetland in the Cedar Creek watershed in Illinois. Future results from constructed wetlands in the region should be evaluated before a wetland is constructed in the Fox River watershed.

In conjunction with wetland construction, continual preservation of existing wetlands is recommended. The 1983 through 1987 National Wetland Inventory maps and 1998 aerial photographs show that a variety of wetlands seem undisturbed in the Fox River watershed (Illinois Geospatial Data Clearinghouse 2002; USGS 1998). A field survey to identify the functionality of the identified wetland sites could also identify opportunities for protecting and enhancing these wetlands in the future.

8.1.5 Prevention of Animal Waste Runoff

Although about 10 livestock producers are located in the Fox River watershed, information about the number of confined versus unconfined feeding lots and the number and types of animals is not available (NRCS 2002b). Based on the approximate number of livestock producers and size of the watershed, animal feedlots are not prevalent throughout the watershed. Some of the larger livestock producers already developed livestock waste facility management plans around 1995 that included solid waste holding facilities and settling basins (Tetra Tech 2002g). Consequently, BMPs for large livestock producers are not included in this implementation plan. Instead, BMPs applicable to smaller-scale feeding operations are recommended, such as constructing roofs, diversion dikes, walls, or curbs to redirect precipitation and runoff from animal wastes. Constructing a roof, dikes, walls, or curbs over the area where animal wastes are stored can prevent precipitation from contacting the waste and transporting it to the water bodies in runoff.

8.1.6 Pasture Management

Animals that graze near water bodies can cause erosion and increase the potential for animal wastes to be directly input into the water bodies. Management practices applicable to grazing pastures along the Fox River and tributaries include fencing and rotational grazing. Grazing does not occur along the lake shorelines (Tetra Tech 2002g). Fencing along river shorelines prevents animals from grazing along riverbanks and protects riparian areas that act as filters. Rotational grazing involves designating smaller rotational areas for grazing instead of continual grazing over an entire field. Rotational grazing can reduce erosion.

8.1.7 Lake and Residential Property Management

Management of the lakes and the residential properties surrounding Borah and Olney East Fork Lakes is key in reducing nutrient concentrations in the lakes. In-lake management practices include restrictions on heavy boat activity. Large boats with large motors can erode soils that potentially contain phosphorous and mix deeper, more concentrated waters with shallower less concentrated waters.

Lawn management is the most important consideration for residential properties surrounding the lakes. Incorrect application of pesticides and fertilizers on residential properties can contribute to runoff to the lakes. The University of Idaho Cooperative Extension System has developed BMPs for lawn care that are applicable to residential properties surrounding Olney East Fork and Borah Lakes. (University of Idaho, 2002).

Fertilizer management practices require knowledge of the nutrients used in fertilizers. Generally, lawns need addition of only four nutrients: nitrogen, phosphorus, potassium, and sulfur. Improper use of nitrogen and phosphorus fertilizers on lawns can negatively impact water quality. Proper fertilizer management BMPs for lawns are summarized below.

1. Base fertilizer application rates on a sound scientific strategy such as the following:

    - Determine the length of the lawn-growing season (in months).
    - Base nitrogen application on the lawn growing season length.
    - Base phosphorus, potassium, and sulfur applications on the ratio to nitrogen: 1,000 square feet of lawn requires 0.5 pound of nitrogen per month of active growth. The ratio by weight is 3 nitrogen to 1 phosphorus to 2 potassium to 1 sulfur. Buy fertilizer with as

close to a 3:1:2:1 ratio as possible or mix different fertilizers together to achieve the desired ratio.

2. Correctly time fertilizer applications and apply fertilizer when the lawn needs it. Use split applications (divide the total nutrient application by four) as follows:

    - 1/4 in early spring (Easter)
    - 1/4 in late spring (Memorial Day)
    - 1/4 in late summer (Labor Day)
    - 1/4 in fall (Halloween)

3. Use slow-release nitrogen fertilizers to improve nitrogen use efficiency and reduce leaching. Look for fertilizers with the word “WIN” on the bag. “WIN” stands for “water insoluble nitrogen,” a slow-release fertilizer.

4. Use water wisely. Water lawns at optimal times and deeply (to 6 inches below the soil surface) twice a week instead of shallowly every day or every other day.

8.1.8 Septic System Management

Septic systems are a potential source of nutrient and BOD loads to the listed water bodies. There are more than 300 septic systems in the Fox River watershed (Illinois Department of Public Health 2002; Tetra Tech 2002f). Almost 30septic systems are located around the lakes alone. In 2000 and 2001, a total of only five septic system failures in Richland County were reported to the regional health department. The actual number of septic system failures is most likely much greater than five because septic system failures are not always reported and septic systems are not regularly inspected in the watershed due to limited resources (Illinois Department of Public Health 2002; Tetra Tech 2002e and 2002f).

Typically the county health department inspects and manages septic systems, but there is no health department in Richland County. Instead the City of Olney water department and the Regional Health Department share septic system management duties. The City of Olney is responsible for inspecting and responding to complaints about septic systems around the lakes and in the City of Olney. The city’s goal is to inspect septic systems under the City of Olney’s responsibilities every 5 years, but all septic systems have not been inspected in 10 years (Tetra Tech 2002f). The Regional Health Department’s primary responsibilities in Richland County are to issue permits and track new septic systems, log complaints, and respond to complaints passed on by the City of Olney. Because of the lack of resources devoted to septic system management in Richland County, the city and county rely on the septic system manufacturers to maintain new septic systems and educate residents through 5-year maintenance agreements (Tetra Tech 2002e).

A local management unit is recommended to take on the above-mentioned responsibilities and provide the services below to residents in Richland County:

- Educate residents with septic systems, especially those with older septic systems who do not have educational materials from the manufacturer.
- Develop a complaint-response system that is tracked electronically, and encourage the reporting of septic system problems so that assistance can be provided.
- Monitor septic systems that currently receive little attention because they are outside the City of Olney area but inside Richland County.

8.1.9 Identification and Remediation of Infiltration and Inflow Between Sanitary and Storm Sewer Systems

In the Olney Sanitary District, combined sewers were separated between 1985 and 1987, but infiltration and inflow between storm and sanitary sewers still exists and is evidenced by Olney STP flow fluctuations that correspond precipitation fluctuations (Tetra Tech 2002d). Infiltration and inflow between sewer systems is also evidenced by an increase in Olney STP flow and a decrease in population and water production rates (Olney STP 2001b U.S. Census Bureau 2002; and Olney WTP 2001). In 1994, a storage lagoon was installed to help control excess flows. Watertight manholes have also been installed to reduce the infiltration and inflow problems and inspections are conducted to identify inappropriate roof drain and gutter connections by conducting smoke tests (Tetra Tech 2002d). It is recommended that additional efforts be made to identify and remediate the biggest infiltration and inflow problem areas.

8.1.10 Use of Outlet Works in Borah Lake to Increase Flow to Fox River

Although nutrient loads to the Fox River cause DO concentrations to drop, low turbulence and reaeration are also responsible for low DO content in the Fox River; therefore, increasing the flow (which would increase turbulence and reaeration) could increase DO concentrations in the river. Flows could come from Borah Lake through the outlet works that already exists. The Borah Lake outlet works is actually the intake and 12-inch-diameter pipe tower designed for water supply. If the valve of the intake tower were open, water would flow through the pipe beneath the dam and then by gravity through the natural channel to the Fox River (COE 1978b). Timing of the release from Borah Lake would be critical and would need to be further assessed before this BMP is implemented.

8.2 Reasonable Assurance

Reasonable assurance that the BMPs will be implemented is necessary for IEPA to determine if implementation of the TMDLs will result in the Fox River, Borah Lake, and Olney East Fork Lake meeting water quality standards. Reasonable assurances may be nonregulatory, regulatory, or incentive-based, consistent with applicable laws and programs. This section discusses why the recommended BMPs likely will be implemented.

In general, farmers in Richland County are proactive in implementing agricultural BMPs (Tetra Tech 2002g). The limiting factor for implementing BMPs is usually funding. Appendix C provides a list of federal government funding sources because funding is such a key factor in implementing these BMPs. Most funding used by Richland County for watershed BMPs is provided through the U.S. Department of Agriculture's (USDA) continuous Conservation Reserve Program (CRP).

As indicated in the following sections, several BMPs have already been implemented, some for a few years. Because BMPs are implemented gradually, their full benefits might not be realized until several years later. As a result, water quality violations may still occur after the BMPs are implemented. The effectiveness of BMPs in addressing water quality problems is best evaluated by water quality monitoring. Monitoring for BMP effectiveness is discussed in Chapter 9.

8.2.1 Nutrient Management Plans

Nutrient management plans are not currently a cost-sharable practice in Richland County but are expected to be by February 2003. Once funding is available, nutrient management plans will be a focus in Richland County because most other agricultural BMPs have already been implemented (Tetra Tech 2002g). Guidance for nutrient management in Illinois is readily available. NRCS's conservation practice standard for nutrient management in Illinois (Code 590) is available on-line at http://www.il.nrcs.usda.gov/resources/fotg/section4/590/590.pdf. The *Illinois Agronomy Handbook* is available on-line at http://web.aces.uiuc.edu/aim/IAH/

8.2.2 Buffer and Filter Strips

Buffer and filter strips currently line most of the Fox River and portions of lake shoreline that are also lined by agricultural land. Funding programs for buffer and filter strip implementation have been available since 1980s, and farmers in Richland County have taken advantage of the financial assistance. Continuous CRP cost sharing is available for implementing buffer and filter strips along agricultural lands that line first-order streams that are tributaries to the Fox River and possible upland areas.

Implementation of buffer and filter strips along residential properties requires the support of residents. After residents are educated about the link between lawn management and water quality, they likely will be supportive.

8.2.3 Conservation Tillage

As shown in Table 8-3 below, most farmers in the watershed already practice conservation tillage.

TABLE 8-3. CROPLAND TILLAGE IN RICHLAND COUNTY

Crop	Conventional Till (Percent)	Reduced Till (Percent)	Mulch Till (Percent)	No Till (Percent)
Corn	37	0	6	57
Beans	10	0	11	79
Wheat	42	0	25	33

Source: NRCS 2002b

Some farmers have been practicing conservations tillage since 1985. No-till practices were promoted in Richland County when the Illinois Soil and Water Conservation District (SWCD) purchased a no-till drill that was available for rent to farmers. This drill is no longer used because farmers in the county have their own drills. Although most farmers already use no-till practices, it is also recommended that deeper fertilizer injection be practiced. Injecting fertilizers deeper into the soil is often done along with conservation tillage and should be easy to implement.

8.2.4 Construction of Wetlands in Tiled Areas

As mentioned in Section 8.1, the University of Illinois is breaking up tile drains and constructing a wetland in the Cedar Creek watershed in Illinois. Depending on this project’s effectiveness, techniques used in the Cedar Creek watershed could be applied to the Fox River watershed. Funding for such projects is available through several agencies and grant opportunities as described in Appendix C. In addition, the U.S. Fish and Wildlife Service in Richland County supports BMP efforts that focus on improving and increasing wildlife habitat.

8.2.5 Prevention of Animal Waste Runoff

Some larger livestock producers already developed livestock waste management plans since about 1995 that include solid waste holding facilities and settling basins (Tetra Tech 2002g). Federal cost-share money is available for livestock producers (see Appendix C). In addition, IEPA established a "Tax Certification Program for Livestock Waste Management Facilities" in August 2000. A livestock producer can become certified as a pollution control facility by implementing various livestock BMPs, including constructing roof and other structures or devices specifically to divert runoff from waste storage areas. Once IEPA has certified the facility as a pollution control facility, IEPA submits a copy of the certification to the Illinois Department of Revenue, which assumes authority from the county tax assessment office to assess the value of the certified facility. Ultimately, the livestock producers' property tax can be reduced (IEPA 2000b).

8.2.6 Pasture Management

As mentioned in Section 8.1.5, pasture management plans that include tips on seeding, timing of cutting, and timing of fertilizers have been implemented in Richland County since around 1995 (Tetra Tech 2002g). Pastureland management plans that focus on animal grazing and include techniques on fencing and rotational grazing have not yet been implemented, but cost-share funding is available through the Environmental Quality Incentive Program (EQIP) (see Appendix C).

8.2.7 Lake and Residential Property Management

Placing restrictions on the size of boats and motors used in the listed lakes is recommended. Currently, boating permits are required for Borah and Olney East Fork Lakes. Permits range from $10 for non-powered boats to $50 for boats with motors greater than 75 horsepower (Olney City Government 2001). The City of Olney could use the system in place to evaluate and possibly revise current boating regulations to better protect the lakes' water quality.

The first step in developing residential property BMPs is educating residents on the link between lawn care and water quality. According to the Center for Watershed Protection (CWP), in Prince William

County, Virginia, most residents were at least aware and concerned about the link between lawn care and water quality but did not have much time to learn about lawn care BMPs. The idea of "neighborhood demonstration lawns" provided a practical public education program. When this idea was implemented, surveys indicated that homeowners significantly changed both their attitudes and actual lawn practices as a result of participating in the demonstration program (CWP 1994). A similar approach would most likely result in effective lawn management practices around the listed lakes.

8.2.8 Septic System Management

Establishment of a county health department requires approval by the County Board; therefore, establishment of a county health department is feasible if residents in the county see the benefit of a local management system. The potential county health department or other local management system should focus on the needs of Richland County residents. Assistance could include providing educational materials on proper maintenance of septic systems, which could prevent expensive future septic system problems. A local system could also provide a means for the Regional Health Department to provide funding to Richland County residents.

8.2.9 Identification and Remediation of Infiltration and Inflow Between Sanitary and Storm Sewer Systems

As discussed in Section 8.1.8, the City of Olney has historically been committed to addressing problems with sanitary and storm sewer systems. With funding, the City of Olney would be able to devote more resources to identifying and remediating infiltration and inflow problems. Currently, personnel from the Olney STP have responsibilities that would be eliminated with the development of a county health department. If a county health department were developed, Olney STP personnel could focus on infiltration and inflow problems.

8.2.10 Use of Outlet Works in Borah Lake to Increase Flow to Fox River

Periodically releasing flows from Borah Lake to the Fox River is implementable because the intake and 12-inch-diameter pipe tower designed for water supply still exist and could function as an outlet works. However, implementation of this BMP requires a thorough evaluation of the impacts of releasing water from Borah Lake to the river.

9 MONITORING PLAN

To ensure that the selected controls will achieve expected load reductions, water quality monitoring after BMP implementation is needed. Recommended monitoring of the Fox River, Olney East Fork Lake, and Borah Lake are described below.

9.1 Fox River Monitoring Plan

IEPA will continue to monitor NH_3-N, other nutrients, and DO levels in the listed segment of the Fox River as part of the Ambient Water Quality Monitoring Network (AWQMN), the Intensive Basin Survey (IBS) of the Little Wabash watershed, and Facility Related Stream Survey (FRSS) of the Olney STP. Samples are collected upstream and downstream of the Olney STP as part of the FRSS program when needed.. In addition, the flow measurement will be taken for sampling events, which can be used to verify the Fox River flow estimate in the TMDL development. Water quality sampling as part of each of these programs is determined to be sufficient by IEPA to evaluate possible threats to public health and aquatic life and to determine progress in meeting the TMDLs. The water body will remain listed until the water quality standards are achieved and further load reductions are no longer needed.

9.2 Olney East Fork and Borah Lakes Monitoring Plan

IEPA will continue to monitor TP and other nutrients, pH, DO, and Ch-a, as part of the Volunteer Lake Monitoring Program (VLMP). Samples are collected from 1 foot below the water surface from three locations in each lake. An additional sample from the lake bottom is collected at one of the three locations. Historically, samples have been collected almost once a month from May through October each year. If resources are available, it is recommended that samples be collected twice a month every year, which is the goal of VLMP (IEPA 2002b). Water quality sampling as part this program is determined to be sufficient by IEPA to evaluate possible threats to public health and aquatic life and to determine progress in meeting the TMDLs. The water bodies will remain listed until the water quality standards are achieved and further load reductions are no longer needed.

10 PUBLIC PARTICIPATION

Illinois provides public participation consistent with the requirements in 40 CFR Section 130.7 (c) (1) (ii). Furthermore, Illinois provides for meaningful public involvement in the TMDL development process through two public meetings and one public hearing that allow public comment.

The Fox River watershed TMDL development process included two public meetings and a public hearing held in Olney, Illinois. The first meeting was held on February 28, 2002, in Springfield, Illinois, and included a general description of the TMDL process and reasons for listing the Fox River, Olney East Fork Lake, and Borah Lake on the 303(d) list. The second meeting was held in conjunction with a workshop on November 20, 2002, in Olney, Illinois. During this meeting and workshop, the modeling approach was presented including discussion of initial load allocation. IEPA published notice of the commencement of its solicitation of comments from this public hearing in January 2003. Prior to the public hearing, a draft TMDL document was placed at the Olney Public Library. IEPA responses to the public's comments will be addressed in a separate document that will be appended to the final TMDL report.

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APPENDIX A

JUSTIFICATION FOR NOT DEVELOPING pH TMDL FOR THE FOX RIVER

(Five Pages)

APPENDIX A

JUSTIFICATION FOR NOT DEVELOPING pH TMDL FOR FOX RIVER

The Fox River was listed on Illinois' 1998 303(d) list for low pH. Section 302.204 of Illinois Water Quality Standards states that pH shall be within the range of 6.5 to 9.0 except for natural causes. The pH data and soil acidity information available throughout the watershed and for other Illinois watersheds was evaluated to determine whether nonpoint sources, low buffering capacity (or acidic soils), and /or acid rain caused the low pH level. The findings of this evaluation were used to determine if it was necessary to develop total maximum daily loads (TMDL) from nonpoint sources to the Fox River. The methodology, findings, and conclusions of this evaluation are discussed below.

METHODOLOGY

The pH analysis involved the following steps:

1. Evaluate soil survey classifications throughout Illinois, and identify watersheds with acidic soils (low buffering capacity) and watersheds with alkaline soils (high buffering capacity)
2. Collect precipitation pH data from stations closest to the watersheds identified in Step 1.
3. Collect pH data for tributaries in the watersheds identified in Step 1.
4. Compare soil classifications, precipitation pH data, and tributary pH data, and determine whether any correlations exist

Soil classification data for Illinois counties were obtained from the Natural Resources Conservation Service's official soil classification descriptions available on-line (USDA 2002). Based on preliminary review, counties in the Little Wabash River watershed contain acidic soils and counties in the Apple-Plum and Pecatonica watersheds contain alkaline soils. Data collection focused on these three watersheds because they cover the spectrum of soil buffering capacities in Illinois soils. Soil classification data were also available for two counties within the Little Wabash watershed: Effingham County in the northern half of the watershed and Edwards County in the middle portion of the watershed closest to the Fox River. In Effingham County, the uppermost surface soil layer is slightly alkaline. All surface soil layers in Edwards County are at least slightly acidic. Consequently, precipitation and stream pH data for specific areas within the Little Wabash watershed were also collected and evaluated (USDA 2002).

Precipitation pH data were obtained from the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) on-line database (NADP 2001). Five sampling stations are located in the vicinity of the three focus watersheds. NADP/NTN stations IL 11, IN 22, and IL 99 are in the vicinity of the Little Wabash watershed and NADP/NTN stations IA 08 and IL 18 are in the vicinity of the Apple-Plum and Pecatonica watersheds. For each station, monthly precipitation-weighted mean concentrations were downloaded from 1990 through 2001 (NADP 2001).

Most pH data for tributaries in these watersheds were obtained through the U.S. Environmental Protection Agency's (EPA) STORage and RETrieval Database (STORET) (EPA 2002). Because of the large volume of pH data for these watersheds, only pH data from the counties where the soil classification samples were collected were downloaded. In addition, pH data for Fox River were obtained from Illinois Environmental Protection Agency (IEPA) personnel preparing the 1999 Intensive Basin Survey for the Little Wabash River watershed (IEPA 2001).

After the data were collected, the average tributary pH values for each watershed were calculated to identify correlations between tributary acidity and rain and soil acidity. For consistency, only tributary pH data from 1989 and 1990 were compared because those years are the only years when pH was measured in each of the focus areas. Data ranges and averages from 1989 and 1990 were then compared with averages and ranges from 1989 through 2000 to confirm that 1989 and 1990 data are representative of current trends. For example, for the Fox River, which has the most complete set of data available, the 1989 and 1990 pH values averaged 6.8 and the 1989 through 2001 pH values averaged 6.9.

FINDINGS

Table A.1 shows the stream pH values for the three watersheds and three areas within the Little Wabash River watershed. The pH values ranged from 6.2 to 7.8, with an average of 7.0 in tributaries in the Little Wabash River watershed, where soils are strongly acidic and acid rain is prevalent. The pH values ranged from 6.8 to 8.3, with an average of 7.8, in tributaries in the Plum-Apple and Pecatonica watersheds, where soils are alkaline and rain is less acidic than in the Little Wabash River watershed. Within the Little Wabash River watershed, the pH values in tributaries in Effingham County are slightly higher than pH values in other tributaries in the Little Wabash River watershed, where soils are slightly more acidic. The1999 Little Wabash River watershed Intensive Basin Survey also shows a slight increase in pH in tributaries near Effingham County compared to counties closer to the Fox River.

TABLE A.1 pH DATA USED TO DETERMINE THE CAUSE OF LOW pH VALUES

Watershed	Surface Soil Acidity (less than 5 feet deep) (Range/Average)	Monthly Average Precipitation pH from 1990 through 2001 (S.U.)[a]	Tributary pH in 1989 and 1990[b] (S.U.) (Range/Average)
Little Wabash River	Slightly alkaline to extremely acidic/ strongly acidic	4.5	6.2 to 7.8/7.0
Fox River (in Richland County)	Slightly to very strongly acidic/strongly acidic[c]	4.5	6.6 to 7.0/6.8
Near Fox River (in Clay and Wayne Counties)	Slightly to very strongly acidic/strongly acidic[c]	4.5	6.2 to 7.8/7.0
North of Fox River (in Effingham County)	Slightly alkaline to extremely acidic/strongly acidic	4.5	6.6 to 7.7/7.2
Apple-Plum (in Jo Daviess County)	Mildly alkaline	4.9	6.9 to 8.1/7.8
Pecatonica (in Stephenson County)	Mildly alkaline to slightly acidic/neutral	4.9	6.8 to 8.3/7.7

Notes:

S.U. Standard Unit

[a] Precipitation pH values for the Little Wabash River watershed are the averages of monthly pH values for precipitation samples collected at NADP/NTN stations IL 11, IN 22, and IL 99. Precipitation pH values in the Apple-Plum and Pecatonica watersheds are the averages of monthly pH values for precipitation samples collected at NADP/NTN stations IA 08 and IL 18.

[b] The pH values represent the ranges and averages of pH values in tributaries in the watershed, not the main stem.

[c] Surface soil classifications are based on the classifications for Edwards County (USDA 2002).

CONCLUSIONS

Based on the findings described above, acid rain and low buffering capacity of the soils in the Fox River watershed contribute to low pH values in the Fox River. The relative impact of the buffering capacity compared to the acidity of the rain cannot be distinguished, but the combination of both conditions affect tributary pH values. In any case, the nonpoint sources in the watershed contribute only very minimally to the low pH values detected in the Fox River compared to acid rain and the soils' low buffering capacity; therefore, pH TMDLs were not developed for nonpoint sources to the Fox River.

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APPENDIX B

HYDROLOGIC AND WATER QUALITY MODELING OF THE FOX RIVER WATERSHED

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LIST OF ABBREVIATIONS AND ACRONYMS

μg/L	Microgram per liter
40 CFR	Title 40 of the *Code of Federal Regulations*
7Q10	10-year, 7-day low-flow
AWQMN	Ambient Water Quality Monitoring Network
BASINS	“Better Assessment Science Integration Point and Nonpoint Sources”
BMP	Best management practice
BOD	Biochemical oxygen demand
Btu/ft^2-hr	British thermal unit per square-feet hour
Ch-a	Chlorophyll-a
COE	U.S. Army Corps of Engineers
CO_2	Carbon dioxide
CRP	Conservation Reserve Program
CWA	Clean Water Act
CWP	Center for Watershed Protection
DAP	Diammonium phosphate
DO	Dissolved oxygen
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FRSS	Facility-Related Stream Survey
ft^3/s	Cubic foot per second
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program – Fortran
HUC	Hydrologic Unit Code
HSPFEXP	HSPF Expert System
IBS	Intensive Basin Survey
IEPA	Illinois Environmental Protection Agency
ISWS	Illinois State Water Survey
JEQ	*Journal of Environmental Quality*
MBI	Macroinvertebrate biotic index
mg/L	Milligram per liter
MOS	Margin of safety
MGD	Million gallons per day
MRCC	Midwest Regional Climate Center
NCDC	National Climate Data Center
NH_3-N	Ammonia-nitrogen
NO_2	Nitrite
NO_3	Nitrate
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
QUAL2E	Enhanced Stream Water Quality
SHAP	Stream habitat assessment procedure
SIC	Standard Industrial Code
SOD	Sediment oxygen demand
STP	Sewage treatment plant
TDS	Total dissolved solids
TMDL	Total maximum daily load
TP	Total phosphorus
TSI	Tropic State Index
TSS	Total suspended solids
USGS	U.S. Geological Survey
UV	Ultraviolet
USDA	U.S. Department of Agriculture
VLMP	Volunteer Lake Monitoring Program
WARM	Water and Atmospheric Resource Monitoring
WDM	Watershed Data Management
WTP	Water treatment plant

1 INTRODUCTION

This appendix discusses the development of a water quality model to simulate conditions in the Fox River Watershed to determine the load reductions necessary to support designated uses of the Fox River, Olney East Fork Lake, and Borah Lake. The appendix is part of the documentation required to support development of total maximum daily loads (TMDL) for these three water bodies. The modeling background and appendix organization are discussed below.

1.1 Modeling Background

Segment ILCH02-1998 of the Fox River is listed on Illinois' 303(d) list for not meeting Illinois Environmental Protection Agency (IEPA) numeric standards for dissolved oxygen (DO) content and pH. In addition to DO, ammonia-nitrogen (NH_3-N), total phosphorous (TP), and biochemical oxygen demand (BOD), which impact DO content, and total suspended solids (TSS), which is a source of TP, are modeled in the Fox River. Although the listed segment of the Fox River is impaired because its pH levels are lower than water quality standards, a pH TMDL for Fox River was not developed. As Appendix A shows, low pH levels in the Fox River result from acid rain and acidic soils with low buffering capacity. Therefore, a pH TMDL was not developed for the river. Some fertilizers can acidify soil; therefore, nutrient management plans with fertilizer application guidelines are included in the list of best management practices (BMP) discussed in Chapter 9 of the TMDL report. The specific endpoint used as a modeling goal to determine allocations for the Fox River is a DO concentration of 6.0 milligrams per liter (mg/L). The water quality standard requires DO concentrations to remain above 5.0 mg/L at all times and above 6.0 mg/L during any consecutive 16-hour period; therefore, using a modeling goal of 6.0 mg/L will ensure that the water quality standard for DO is not violated (IEPA 1999).

Olney East Fork Lake, which is identified as ILRCC1-1998 in Illinois' 303(d) list, is impaired because it does not meet Illinois water quality standards for TP and DO. DO and TP are therefore the primary constituents modeled for Olney East Fork Lake. In addition, NH_3-N, chlorophyll-a (Ch-a), and TSS are modeled because of their relationship to DO and TP. The specific endpoints used as modeling goals used to determine allocations for Olney East Fork Lake are a DO concentration of 6.0 mg/L and a TP concentration of 0.05 mg/L. As mentioned above, the DO water quality standard requires that DO concentrations always be above 5.0 mg/L and above 6.0 mg/L during any consecutive 16-hour period. The water quality standard for TP is 0.05 mg/L for lakes with surface areas greater than or equal to 20 acres.

Borah Lake, which is identified as ILRCB-1998 in Illinois' 303(d) list, is impaired because it does not meet Illinois water quality standards for TP and pH. TP is the primary constituent modeled for Borah

Lake. TP loads result in excess algae growth, which in turn leads to elevated pH values. NH_3-N, Ch-a, and TSS are also modeled for Borah Lake because of their relationship to TP and algae growth. The specific endpoint used as a modeling goal is a TP concentration of 0.05 mg/L, which is the water quality standard for lakes with surface areas greater than or equal to 20 acres. When lake concentrations of TP are less than 0.05 mg/L, algae growth will decrease, and pH values will decrease to less than 9.0 but greater than 6.0 standard units (S.U.), which is IEPA's pH water quality standard. Although the correlation between algae growth (represented as Ch-a) and pH is evident in Borah Lake water quality monitoring, future monitoring is necessary to confirm whether or not pH values decrease as TP loads and algae growth decrease.

Before water quality models for each listed water body were developed, a hydrologic model was developed for the entire Little Wabash River watershed, which includes the Fox River watershed. This hydrologic model was developed because no flow data are available for the Fox River. Flow data are key in model development and essential for predicting accurate pollutant loads. The TMDLs developed for each water body is based on the assumption that the flows predicted by the Little Wabash River watershed hydrologic model are the actual flows for the Fox River. Because of the unavailability of key data for model development, the Fox River and lakes should be monitored as part of TMDL implementation to validate modeling results.

The U.S. Environmental Protection Agency's (EPA) "Better Assessment Science Integration Point and Nonpoint Sources" (BASINS) was used as the modeling framework to support TMDL development. BASINS is embedded in a Geographic Information System (GIS) to integrate watershed and water quality studies. This framework correlates key spatial and analytical data (EPA 1998). The Hydrologic Simulation Program – Fortran (HSPF) is a component of BASINS that was used to model watershed hydrology, pollutant sources, and pollutant transport processes in the river and lakes. The Enhanced Stream Water Quality (QUAL2E) model was also used to evaluate the Fox River during low flow when the HSPF hydrologic model is not applicable because runoff is contributing to flow in the Fox River.

1.2 Appendix Organization

Besides this introduction, this appendix consists of the chapters below.

- Chapter 2, Watershed Characteristics Data Used for Model Development, discusses general characteristics of the watershed such as climate, soils, land use, and biological information, and water body-specific data such as physical characteristics, pollutants of concern, and pollution sources.
- Chapter 3, Hydrologic Modeling Using HSPF Model, discusses the use of the model set-up of the entire Little Wabash River watershed and the Fox River watershed. In addition to model design and development, this chapter discusses hydrologic calibration and validation.
- Chapter 4, Water Quality Modeling Using HSPF Model, discusses simulation of water quality parameters that contribute to impairment of the listed water bodies.
- Chapter 5, DO Modeling Using QUAL2E Model, discusses the QUAL2E model and values used to simulate DO conditions in the Fox River during low-flow conditions.
- Chapter 6, Pollutant Load Estimation and TMDL Allocation, discusses how modeling results were translated to load allocations and TMDLs for each water body.
- Chapter 7, Summary, summarizes the crucial load reductions needed to achieve Illinois water quality standards and guidelines.

In addition, this appendix has two attachments. Attachment A presents the input files for the HSPF model, and Attachment B provides both the input and output files for the QUAL2E model. Because of the large volume of the HSPF model output, output results are not included. These results will be submitted to IEPA electronically.

2 WATERSHED CHARACTERISTICS DATA USED FOR MODEL DEVELOPMENT

The Fox River watershed is located within the Little Wabash River watershed in southeast Illinois (see Figure B.2-1). Table B.2-1 summarizes characteristics of the entire Fox River watershed, including both the listed and unlisted segments. Figure B.2-2 shows points of interest within the watershed, including climate stations, permit compliance system dischargers, the City of Olney, water quality monitoring stations, dams, listed segments of the river and lakes, streams, and watershed boundaries.

TABLE B.2-1. FOX RIVER WATERSHED CHARACTERISTICS

Characteristic	Value
Rivers and streams in watershed (first-order tributaries)	44
Reservoirs in the watershed	6
Area of watershed	204.5 square miles
Bedrock depth	60 inches
Fox River reach length	34 miles
Habitats	Forest riparian habitat (<25%) and agricultural/urban riparian habitat (>50%)

Source: EPA 1998

This chapter describes the general watershed characteristics such as climate, soils, land use, and biological information for the entire Fox River watershed, followed by discussion of water body-specific information such as physical characteristics, water quality, and pollution sources. The chapter ends with a discussion of background sources of nutrients and BOD in the watershed. Data presented in this chapter were used to develop the model described in Chapters 3 and 4 of the appendix.

2.1 Climate

The entire Fox River watershed incorporates portions of Jasper, Edwards, Richland, and Wayne Counties in southeastern Illinois, but most of the watershed lies within Richland County; therefore, climate information from this county has been used to represent the entire watershed’s climate. The climate in Richland County is temperate continental. The average annual precipitation at the National Climate Data Center (NCDC) Olney station (Identification No. 116446) in Richland County is approximately 43 inches. Monthly precipitation averages 3.55 inches annually (MRCC 2001). Monthly precipitation averages nearly 4 inches from March through July and only about 2.5 inches for the normally driest

FIGURE B.2-1. FOX RIVER WATERSHED LOCATION

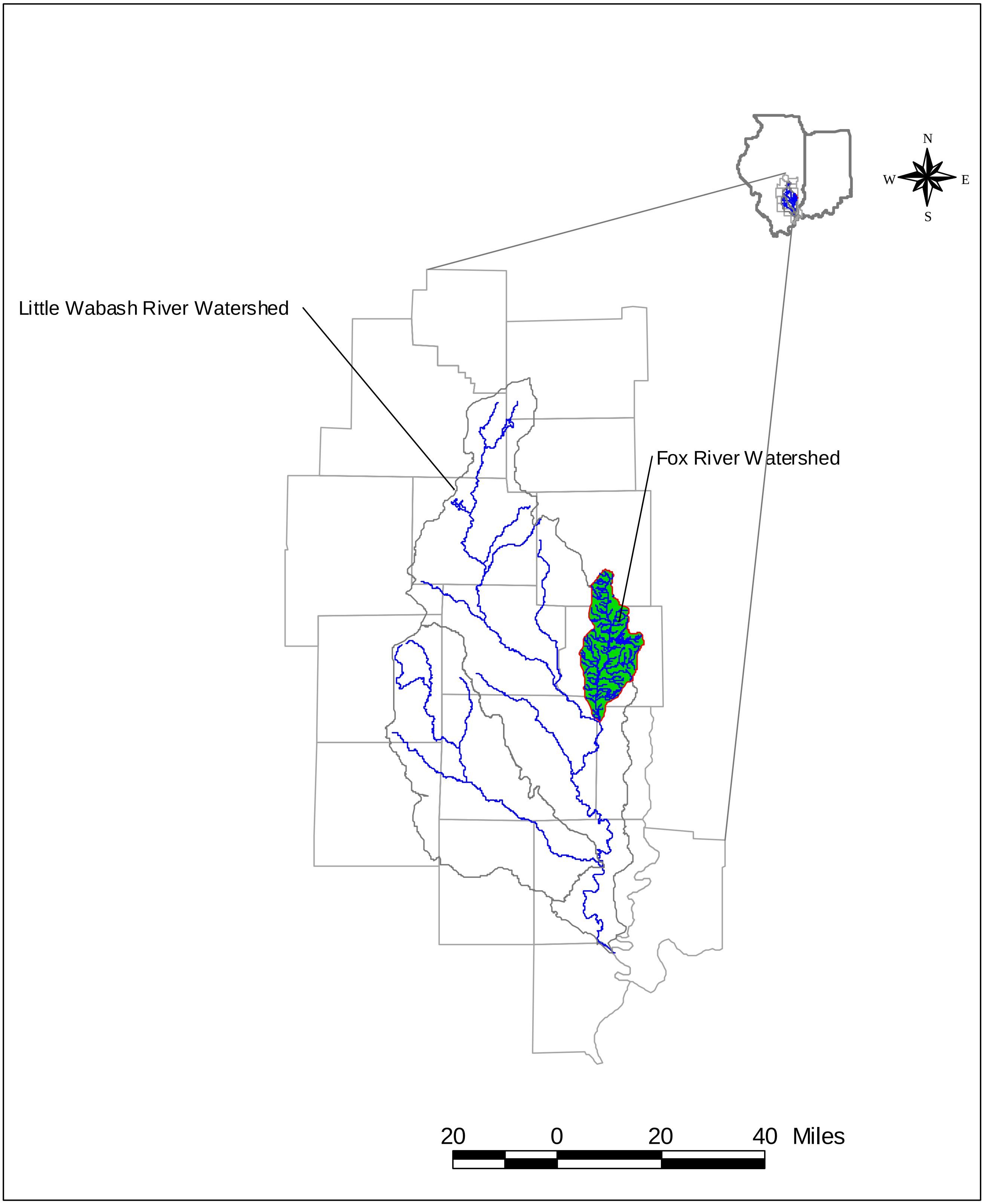
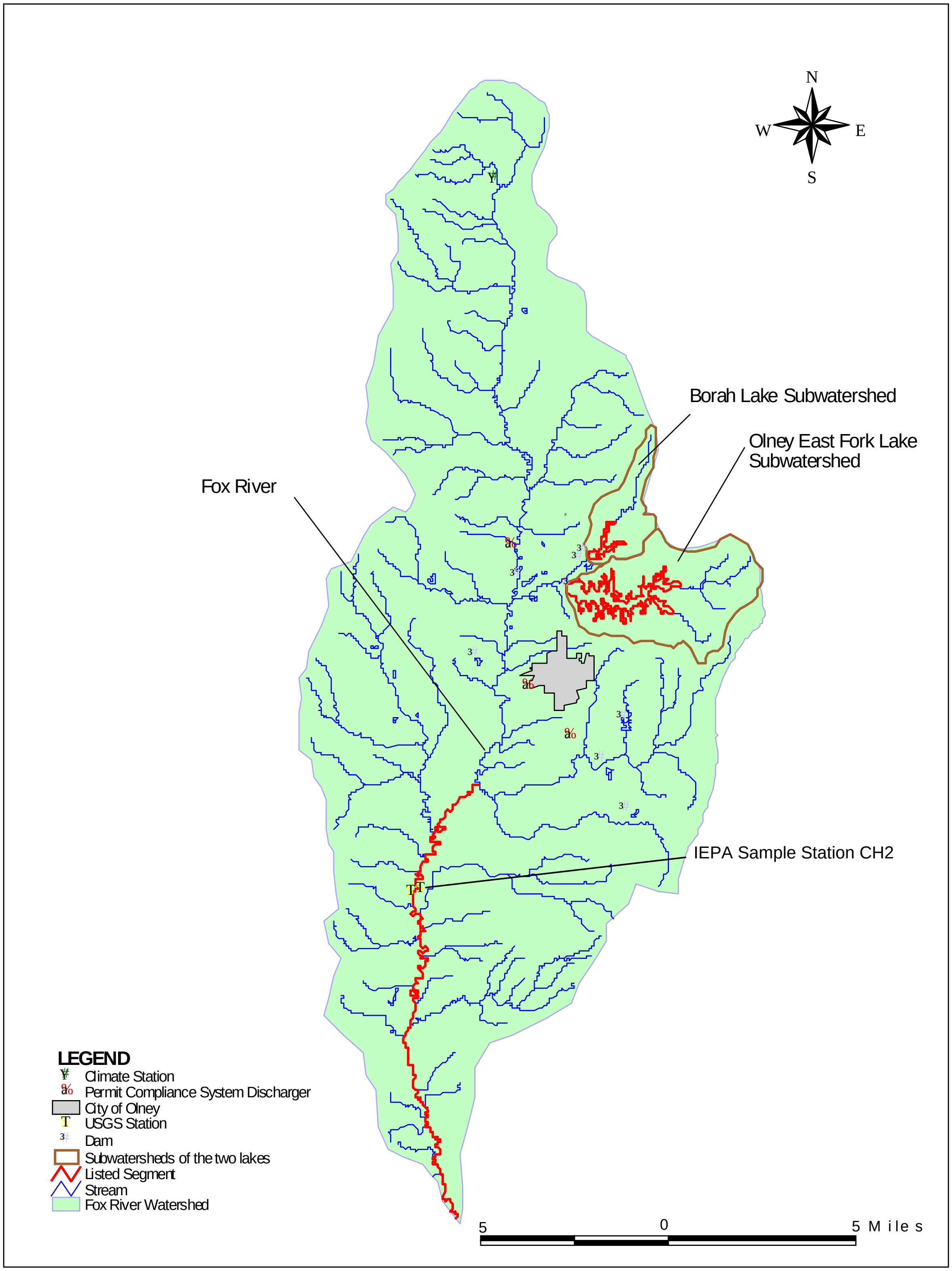


FIGURE B.2-2. FOX RIVER WATERSHED POINTS OF INTEREST



months of October and February. The maximum and minimum annual precipitations have been 70 and 25 inches, respectively (USDA 1972). On average, annually, 103.6 days have precipitation of at least 0.01 inch, 28.9 days with at least 0.5 inch, and 10.9 days with over 1 inch (MRCC 2001). Severe droughts are infrequent, but prolonged dry periods during part of the growing season are not unusual. Such periods usually cause reduced crop yields (USDA 1972). Most summer showers and thunderstorms are brief. A single thunderstorm often produces more than 1 inch of rain and occasionally is accompanied by hail and damaging winds. More than 4.5 inches of rain has fallen within a 24-hour period, and nearly 15 inches has fallen during a month. Some fall and winter months have had less than 0.25 inch of precipitation (USDA 1972).

The average annual temperature for at the NCDC Olney station is approximately 54 °F. The maximum and minimum average temperatures are 65.5 and 43.9 °F, respectively. The maximum and minimum temperatures are 112 °F (1936) and -24 °F (1994)(MRCC 2001).

Meteorological data were obtained from the Water and Atmospheric Resource Monitoring (WARM) station in Olney, Illinois. The average wind speed from 1999 and 2000 was 8.51 feet per second, the average barometric pressure was 29.55 inches of mercury, and the average solar radiation was 56 British thermal units per square feet-hour (BTU/ft^2-hr) (ISWS 2001).

2.2 Soils

The Fox River watershed consists mostly of soil types in the Cisne-Hoyleton (30 percent), Bluford-Ava-Blair (50 percent), and Belknap-Bonnie-Peetrolia (20 percent) Associations. The Cisne-Hoyleton Association soils are nearly level to moderately sloping, distributed on upland ridge areas, and poorly to somewhat poorly drained. These soils form in loess and glacial till. Soils of the Bluford-Ava-Blair Association are nearly level to moderately sloping on uplands and somewhat poorly to moderately well-drained. Belknap-Bonnie-Peetrolia Association soils are nearly level on bottomlands near rivers and somewhat poorly to poorly drained (USDA, 1972). These soils formed in silt loam and silty clay loam sediments

Figures B.2-3 and B.2-4 show the permeability and erodibility of soils within the Fox River watershed. The Natural Resources Conservation Service NRCS classifies most of the Fox River watershed as hydrologic soil group C and the remainder as group D, which implies that the land has a low potential for infiltration and a high potential to create overland runoff (USDA 1972). According to BASINS, the Fox River watershed has a low average bedrock depth of 60 inches below ground surface, which also contributes to high overland runoff (EPA 1998). Soil erodibility ranges from 0.385 to 0.394 in tons per year per unit of area for soil in cultivated, continuous, fallow land with an arbitrarily selected slope length of 72.6 feet and slope steepness of 9 percent. Thus, the erosion potential of soils in the Fox River watershed is relatively high. The permeability of soils ranges from 0.24 to 1.27 inches per hour (USDA 1972).

2.3 Land Use

Land use in the Fox River Watershed is primarily agricultural (83.2 percent), followed by forest (13.7 percent) and urban (2.2 percent), according to the BASINS file. Table B.2-2 summarizes land use distributions in the watershed, and Figure B.2-5 shows the watershed's land-use distribution. Corn, soybeans, and wheat are the main crops in Richland County (EPA 1998). The Fox River watershed land-use distributions from IEPA's 1999 Intensive Basin Survey of the Little Wabash River watershed are consistent with 1998 BASINS land-use distributions, which were used for model development (IEPA 2002).

TABLE B.2-2. LAND-USE DISTRIBUTIONS IN FOX RIVER WATERSHED

Land Use	Area (acres)	Area (square miles)	% of Total
Agricultural	108,928	170.2	83.20
Forest	17,984	28.1	13.73
Residential	1,856	2.9	1.43
Commercial and services	576	0.9	0.46
Industrial	64	0.1	0.06
Pavement and utility	192	0.3	0.15
Mixed urban or built-up	192	0.3	0.15
Water	1,024	1.6	0.79
Strip mine	64	0.1	0.03
TOTAL	130,880	204.5	100

Source: EPA 1998

FIGURE B.2-3. FOX RIVER WATERSHED SOIL PERMEABILITY MAP

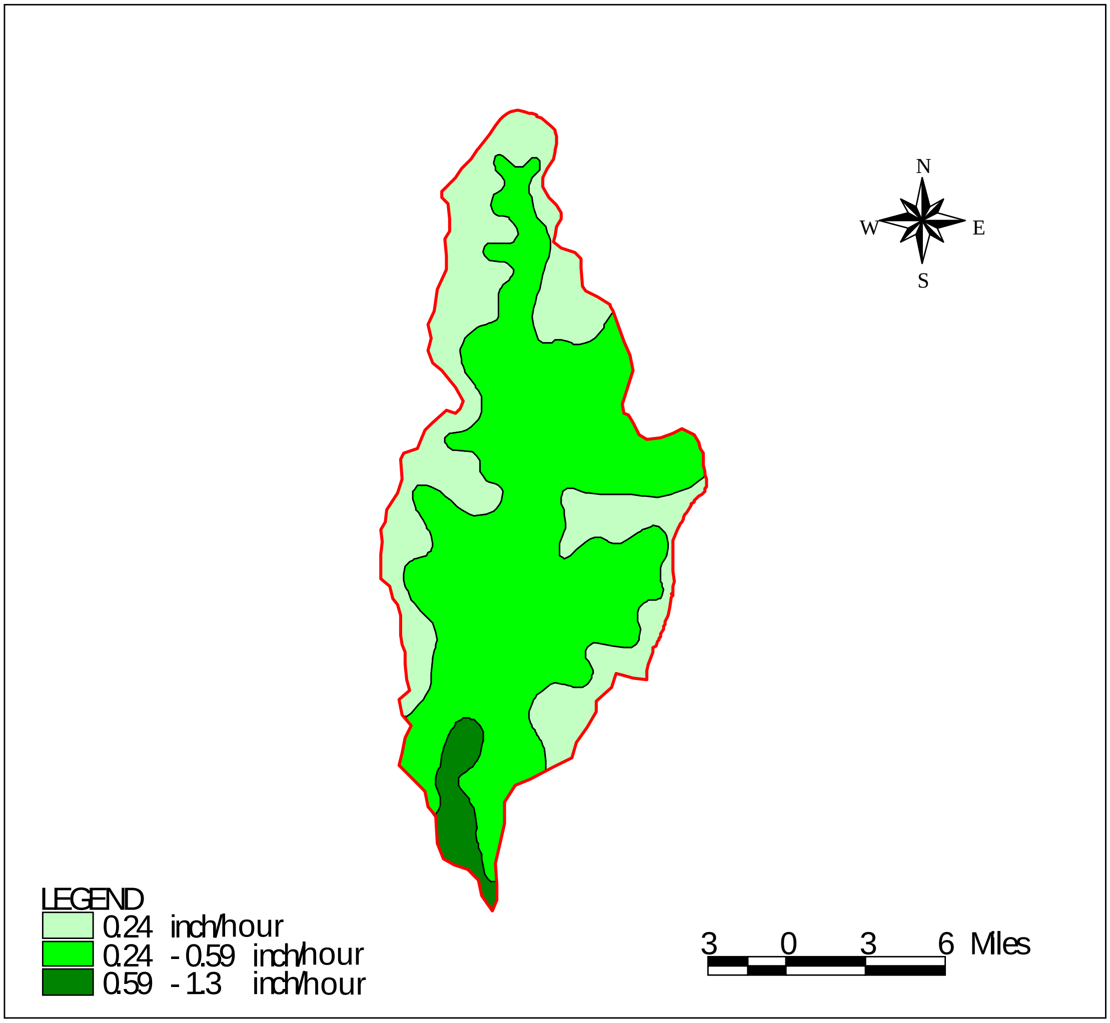


FIGURE B.2-4. FOX RIVER WATERSHED SOIL ERODIBILITY MAP

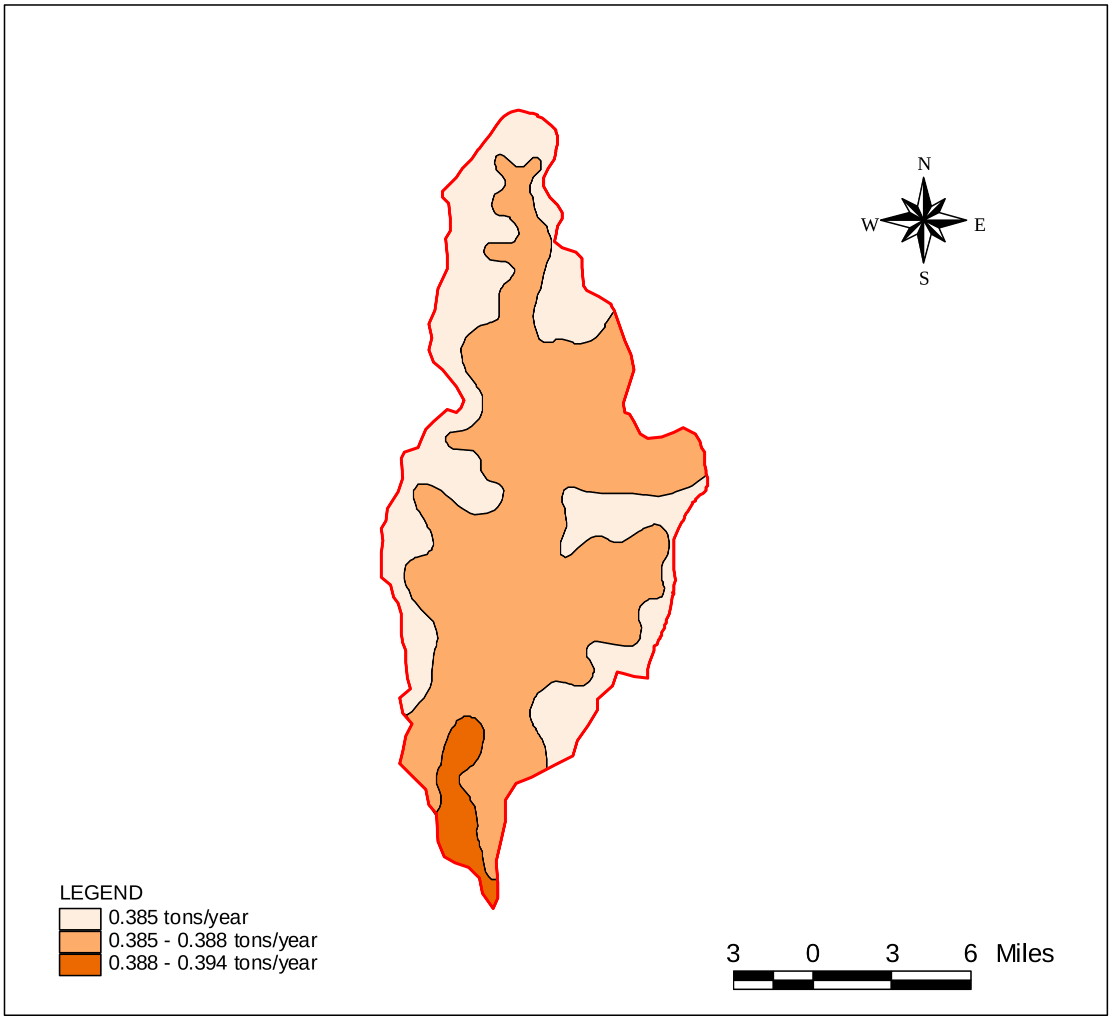
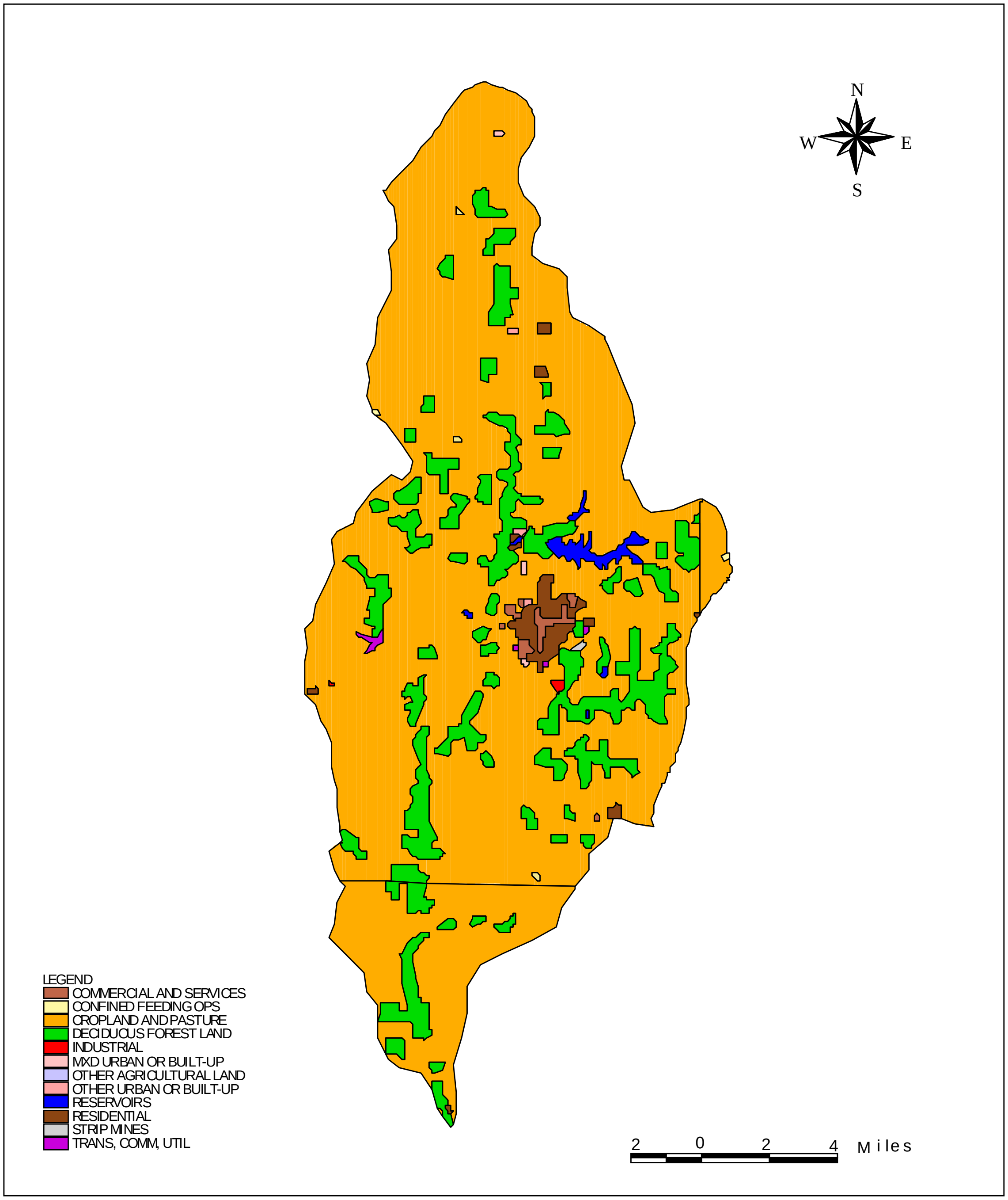


FIGURE B.2-5. FOX RIVER WATERSHED LAND USE MAP



2.4 Biological Information

Biological information, including information on macroinvertebrate communities and habitat data, was collected along the listed segment of the Fox River but not from the listed lakes. IEPA collected biological samples and calculated the macroinvertebrate biotic index (MBI) at two stations along the Fox River downstream of the Olney STP in 1988 and 1994. An MBI reflects the degree of tolerance of a macroinvertebrate community to oxygen-demanding and other contaminants. MBI values reflect aquatic community impairment as follows:

- Less than 6.0: Good
- 6.0 through 7.5: Fair
- 7.6 through 8.9: Poor
- Greater than or equal to 9.0: Very Poor

In 1988 and 1994, MBI values for the Fox River ranged from 5.3 to 5.6, indicating that general water quality conditions were good downstream of the Olney STP. More recent MBI values have not been calculated (IEPA 1989 and 1995).

IEPA also evaluated the habitat along the listed segment of the Fox River using the stream habitat assessment procedure (SHAP) as part of the 1999 intensive basin survey of the Little Wabash River watershed. SHAP is a scoring system that takes into account 15 parameters relating to substrate and instream cover, channel morphology and hydrology, and riparian and bank features. SHAP ratings reflect habitat quality as follows:

- Greater than or equal to 142: Excellent
- 100 to 142: Good
- 59 to 100: Fair
- Less than 59: Poor

IEPA calculated a SHAP rating of 99 for the listed segment of the Fox River, indicating that habitat is fair. Factors that lowered the overall SHAP rating included low substrate quality, poor bank stability and vegetation, and low sinuosity. Factors that increased the overall SHAP rating included good pool quality, pool variability, and canopy cover (IEPA 2002).

2.5 Fox River Characteristics

The Fox River is a second-order tributary of the Little Wabash River located in southeast Illinois. From north to south, the Fox River flows 34 miles through southern Jasper, Richland, Wayne, and Edwards Counties, with a major portion in Richland County and drains approximately 204.5 square miles (see Figure 2-1). The 17.63-mile segment studied in this report extends from its mouth at its confluence with the Little Wabash River to its confluence with Little Fox Creek, which is about 3 miles southwest of the City of Olney (EPA 1998). The Fox River's physical characteristics and flow, pollutants of concern, water quality sampling, and point and nonpoint sources are discussed below.

2.5.1 Physical Characteristics and Flow

The Fox River is a shallow stream with a width ranging from less than 5 feet during low flow to greater than 30 feet during high flow. The mean width to depth ratio of the Fox River is about 50 foot to 8.6 foot (NRCS 2002). Based on BASINS file data for the entire length of the Fox River, other characteristics of the river are listed in Table B.2-3 below.

TABLE B.2-3. FOX RIVER CHARACTERISTICS FROM BASINS

Characteristic	Value
10-year, 7-day low-flow	0.88 cubic foot per second
Low-flow mean velocity	0.28 foot per second
Mean flow	230.73 cubic feet per second
Mean velocity	1.36 feet per second
Bottom of reach elevation	387 feet above mean sea level
Mean width-to-depth ratio	50 to 8.6 feet
Manning's coefficient	0.05

Sources: EPA 1998 and NRCS 2002

No U.S. Geological Survey (USGS) gauge stations record flow in the Fox River watershed; therefore, flows for the Fox River are based on estimates and vary from one source to another. For example, the BASINS file estimates a 10-year, 7-day low-flow (7Q10) of 0.88 cubic feet per second (ft^3/s) (EPA 1998), and the Illinois State Water Survey (ISWS) estimates a 7Q10 flow of 2 ft^3/s (ISWS 1988). Although the accuracy of estimated Fox River flows is uncertain, extreme fluctuations in flow are evident. Flows along the Fox River were measured in 1989 and 1994 as part of Olney sewage treatment plant (STP) related surveys conducted by IEPA. Findings verified extreme fluctuations. The measured flow was less than 4 ft^3/s during low-flow conditions in 1989 and greater than 140 ft^3/s after a storm event in 1994 (IEPA 1989 and 1995).

The availability of flow data is a decisive factor in developing TMDLs; therefore, the first step of the modeling effort was focused on estimating the flow for the Fox River. Although no continuous flow data are recorded for the Fox River, USGS stations that record continuous flow are located in the Little Wabash River watershed, which is hydrologically similar to the Fox River watershed. Four USGS gauge stations are located in the Little Wabash River watershed: Station 03378635 in Effingham County, Stations 03378900 and 03379500 in Clay County, and Station 03381500 in White County. These stations have relatively long records (1966 to about 1996) of flow and water quality. Consequently, a hydrologic model was developed for the entire Little Wabash River watershed, and the hydrologic model for the Fox River is actually a subpart of the calibrated model for the larger watershed.

Although flow characteristics of the Fox River are based on hydrologic modeling results of the entire Little Wabash River watershed, the hydrologic model accounts for characteristics unique to the Fox River watershed. For example, point dischargers in the Fox River watershed were incorporated into the hydrologic model because the Olney STP is a significant source of flow to the Fox River, especially during low-flow conditions. The average flow of 2.78 ft^3/s from the Olney STP was determined to be a reasonable estimate of the 7Q10 low flow at the upstream end of the listed Fox River segment because the flow for the Fox River segment upstream of the Olney STP discharge point appears negligible. At times there is no flow upstream of the Olney STP. More details on hydrologic model development are discussed in Chapter 3 of this appendix.

2.5.2 Pollutants of Concern

This section discusses the pollutants of concern for the Fox River. For convenience and the purposes of this appendix, the term “pollutant of concern” is used to indicate a condition that caused the impairment of the water body’s designated uses. Low DO content is the primary pollutant of concern in the Fox River, and low pH is also a pollutant of concern according to the 303(d) list; however, low pH in the river is a result of acidic soils and acid rain, not pollutant loads (see Appendix A). A pH TMDL for the Fox River was therefore not developed. BOD; nutrients such as TP, NH_3-N, and total nitrogen; and temperature are not pollutants of concern but affect DO content and are therefore discussed below. In addition, TSS is not a pollutant of concern but is modeled because it is a source of TP, BOD, and NH_3-N.

A discussion on understanding DO is presented below.

BOD affects DO because BOD concentrations reflect the amount of organic matter in the water column that can be decomposed. The process of organic decomposition involves DO consumption as shown in the following equation:

$$\text{Organic Matter} + \text{Bacteria} + O_2 \rightarrow CO_2 + H_2O + \text{More Bacteria} + \text{Energy} \tag{B-2-1}$$

where

O_2 = Oxygen
CO_2 = Carbon dioxide
H_2O = Water

BOD measures the quantity of oxygen consumed by microorganisms during decomposition of organic matter. BOD is the most commonly used parameter for determining the oxygen demand of a water body receiving municipal or industrial discharge. BOD can also be used to evaluate the efficiency of treatment processes and is an indirect measure of biodegradable organic compounds in water.

Particulate BOD materials from overland runoff and point source discharge settle down to the bottom of the river to increase benthic deposit, whose decomposition causes the depletion of DO in the water. Oxygen demand by benthic sediment and organisms, usually referred as Sediment oxygen demand (SOD) represent a large fraction of oxygen consumption in surface water. Benthic deposit is the result of the transportation and deposition of BOD organic materials. It is reported that the steady-state SOD should be equal to about 130% of the downward flux of ultimate BOD (Chapra, 1997). The benthic deposit also release organic matter to the water column and increases the pool of BOD present in the water and exerts a demand on the dissolved oxygen concentration at a rate determined by the BOD decomposition kinetics.

Typical nonpoint BOD sources include agricultural runoff, urban runoff, and livestock operations. If not properly regulated and controlled, both point and nonpoint sources can contribute significantly to oxygen demand in a lake or stream. Major point sources of high BOD levels include wastewater treatment facilities, and natural sources, such as leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas such as swamps and bogs. Leaves and dead vegetation, which are composed of organic matter, are readily degraded by a variety of microorganisms. Aerobic (oxygen-requiring) bacteria and fungi use oxygen as they break down organic components into simpler, more stable products such as CO_2, water, phosphate and nitrate. Because the organisms consume oxygen, the DO level decreases.

If elevated BOD levels lower the DO concentration in a water body, there is a potential for profound effects on the water body itself and the resident aquatic life. When the DO concentration falls below 6 mg/L standard, species intolerant of low oxygen levels become stressed. The lower the DO concentration, the greater the stress. Eventually, species sensitive to low DO levels are replaced by species more tolerant of adverse conditions, significantly reducing the diversity of aquatic life in a given body of water. If the DO levels fall below 2 mg/L for more than even a few hours, fish kills can result. At levels below 1 mg/L, anaerobic bacteria (which live in habitats devoid of oxygen) replace aerobic bacteria. As the anaerobic bacteria break down organic matter, foul-smelling hydrogen sulfide can be produced.

BOD is typically divided into carbonaceous BOD and nitrogenous BOD. Carbonaceous BOD results from the breakdown of organic molecules such cellulose and sugars, CO_2, and water. Nitrogenous BOD results from the breakdown of proteins, which contain sugars linked to nitrogen. After the nitrogen is "broken off" a sugar molecule, it is usually in the form of NH_3, which is readily converted to nitrate in the environment. The conversion of NH_3 to nitrate requires more than four times the amount of oxygen as the conversion of an equal amount of sugar to CO_2 and water. Because the HPSF model accounts for nitrogen components, the term “BOD” refers to carbonaceous BOD.

Nutrients affect DO concentrations in two ways: (1) excess nutrient loads can stimulate excess plant growth, which is source of organic matter that can undergo decomposition, and (2) nitrogen-based nutrients undergo nitrification after entering surface water, which involves DO consumption as NH_3 is reduced to nitrite (NO_2), which is reduced to nitrate (NO_3).

Increases in temperature also affect DO concentrations by (1) decreasing the DO saturation level and (2) increasing the decay and nitrification rates, which increases DO consumption. Although temperature is not associated with a load, simulation of temperature in model development is key in understanding DO fluctuations in the river.

Reaeration can increase DO concentration decreases resulting from BOD, nutrient loads, and high temperature, but the reaeration rate in the Fox River has not been calculated. Chapter 4 of this appendix discusses assumed values for reaeration for model development.

Aquatic life cannot survive when DO concentrations are too low. Consequently, Illinois has set a standard and guidelines for DO concentrations in rivers listed in Table B.2-4 below.

Because of the relationship between nutrients and DO, IEPA has also set guidelines for TP and NH_3-N, which are shown in the table as well. These guidelines can be used for understanding the causes of impairment in a water body, but are not enforceable standards. TMDLs are not required for water bodies that don't meet applicable water quality guidelines; only those that do not meet applicable water quality standards.

TABLE B.2-4. IEPA NUTRIENT AND DO STANDARDS AND GUIDELINES FOR RIVERS

Parameter	Standard	Guideline
TP	Not applicable	Shall not exceed 0.61 mg/L in any sample in 3 years
NH_3-N	Not applicable	Total NH_3-N shall not exceed 0.41 mg/L in any sample in 3 years
DO	Shall not be less than 6 mg/L during at least 16 hours of any 24-hour period nor less than 5.0 mg/L at any time	At least one violation of general use standards in 3 years results in 303(d) listing

Sources: IEPA 1999 and 2000

Notes:

DO	Dissolved oxygen
mg/L	Milligrams per liter
NH_3-N	Ammonia Nitrogen
TP	Total phosphorus

2.5.3 Water Quality Sampling

From January 1999 to December 2000, IEPA collected monthly water quality and sediment samples at Station CH 2 (which is the same as USGS Station 03379560) on the Fox River 7 miles south-southwest of the City of Olney (see Figure B.2-2). IEPA collected samples from CH 2 in 1997 and 1998 as well. Results are consistent with 1999 and 2000 sampling results. In addition, water quality samples were collected from the Fox River from IEPA Stations CH 3 (located a few miles upstream of CH 2) and CH 11 (located near CH 2) from 1972 through 1990, but these data are outdated and were not used for TMDL development (EPA 2001b).

Table B.2-5 indicates values for conditions of interest. These data, along with sampling results from 1998, were used in water quality model calibration and verification as discussed in Chapter 4. DO concentrations less than 6.0 mg/L were detected in over half of the samples collected from 1999 to 2000, usually between May and October (IEPA 1999 and 2001). TP concentrations did not exceed the IEPA guideline, but NH_3-N concentrations exceeded the IEPA guideline of 0.41 mg/L three times. The lowest DO concentrations detected in fall of 1999 correspond to elevated NH_3-N concentrations. In addition, low DO concentrations correlate to elevated river temperatures.

TABLE B.2-5. FOX RIVER WATER QUALITY DATA AT IEPA STATION CH2

Date	**Total NH_3-N (mg/L)**	**TP (mg/L)**	**pH**	**DO (mg/L)**	**Temperature (°C)**	**Total Nitrogen (mg/L)**
12/05/00	0.05	0.18	6.9	8.0	3.3	1.17
10/17/00	0.01	0.28	6.7	**4.1**	15.9	0.97
08/29/00	0.01	0.26	**6.1**	**3.1**	24.8	0.32
08/08/00	0.01	0.23	**6.2**	**2.1**	25.3	0.35
05/31/00	0.16	0.40	7.0	**4.3**	20.6	3.00
04/25/00	0.15	0.30	7.4	**5.0**	14.4	0.84
03/28/00	0.05	0.27	7.4	**5.9**	16.1	1.14
02/15/00	0.01	0.48	6.5	8.0	4.8	1.44
01/13/00	0.01	0.20	7.0	8.8	6.3	0.48
11/16/99	**0.46**	0.44	6.9	**2.1**	13.2	0.01 (outlier)
10/13/99	**0.59**	0.38	6.9	**2.4**	19.8	0.51
08/31/99	0.28	0.23	7.3	**2.6**	26.2	3.90
07/28/99	0.21	0.31	7.2	**3.4**	29.0	1.32
06/15/99	**0.47**	0.43	**6.4**	**4.1**	23.5	1.95
05/18/99	0.15	0.28	6.9	6.2	23.3	1.22
04/13/99	0.12	0.20	7.0	6.8	14.8	0.38
03/09/99	0.30	0.26	6.9	9.9	4.4	0.71
01/20/99	0.34	0.38	**6.0**	9.4	3.0	1.30
Mean	0.19	0.31	6.8	5.3	16.0	1.17
Maximum	0.59	0.48	7.4	9.9	29.0	0.01
Minimum	0.01	0.18	6.0	2.1	3.0	3.90
Standard Deviation	0.18	0.09	0.4	2.6	8.7	0.98

Source: IEPA 1999, 2000, and 2001

Notes:

Bolded values exceed Illinois water quality standards (IEPA 1999) or water quality guidelines (IEPA 2000).

DO	Dissolved oxygen
mg/L	Milligram per liter
NH_3-N	Ammonia-nitrogen
TP	Total phosphorus

2.5.4 Point and Nonpoint Sources

This section describes point and nonpoint sources that contribute to the impairment of use for the Fox River.

Point Sources

Three National Pollutant Discharge Elimination System (NPDES) dischargers are located within the Fox River watershed. Table B.2-6 lists these discharges.

TABLE B.2-6. ACTIVE PERMITTED POINT SOURCE FACILITIES IN THE FOX RIVER WATERSHED

NPDES No.	SIC No.	Facility Name	Location	Receiving Water Body
IL0048755	4952	Olney STP	Southwest Olney, Richland County	Unnamed ditch to Fox River
IL0004146	3751	Roadmaster Corporation treatment plant	Olney, Richland County	Unnamed ditch to Big Creek
ILG551065	6515	Kincade Acres Mobile Home Park	Olney, Richland	Unnamed tributary to Fox River

Source: EPA 2001a

Notes:

NPDES	National Pollutant Discharge Elimination System
SIC	Standard Industrial Code
STP	Sewage treatment plant

Only the Olney STP discharges a significant flow to the Fox River. Roadmaster Corporation is no longer involved with manufacturing and has not discharged since December 2001. Before then, its discharge was less than 0.01 million gallons per day (MGD) (Tetra Tech 2001b). Kincade Acres Mobile Home Park also discharges less than 0.01 MGD. Its discharge contains BOD concentrations, but the BOD load contributed to the Fox River is insignificant compared to the loads contributed by the Olney STP and surface runoff (Kincade Acres Mobile Home Park 2001).

The Olney STP is the major discharger in the Fox River watershed. The STP's average design discharge rate is 2.2 MGD, and its maximum design flow is 5.5 MGD. The monitored BOD loading is 5,142 pounds per day, and the suspended solids loading is 4,792 pounds per day. The sewer collection system consists of approximately 45 miles of sewer lines ranging in diameter from 8 to 36 inches. The city currently has 19 sewer lift stations (Olney City Government 2001). The storm and sanitary sewer systems were separated between 1987 and 1989, but infiltration and inflow between the two systems still exist as evidenced by fluctuations in STP flow after storm events. In 1994, a storage lagoon was installed to help control excess flows (Tetra Tech 2002d). Table B.2-7 summarizes the Olney STP's discharge statistics from October 1999 to June 2001. As the table indicates, no effluent concentrations of constituents of interest exceeded the effluent limits from October 1999 through June 2001.

TABLE B.2-7. OLNEY STP DISCHARGE DATA (OCTOBER 1999 THROUGH JUNE 2001)

Statistic	**Average Flow (MGD)**	**pH (S.U.)**	**DO (mg/L)**	**Carbonaceous 5-Day BOD (mg/L)**	**NH_3-N (mg/L)**
Effluent Limit	NA	6.0 to 9.0	NA	Monthly Average: 10 Monthly Maximum: 20	Monthly Average: 4.0 [a] Monthly Maximum: 8.0/1.0 [a]
Mean	1.8	7.5	7.6	1.1	0.25
Maximum	2.7	8.6	12.0	2.5	4.8[b]
Minimum	1.2	6.3	6.0	0.7	0.02
Standard deviation	0.4	0.3	1.1	0.3	0.76

Sources: Olney STP 2001 and EPA 2001a

Notes:

BOD	Biochemical oxygen demand
DO	Dissolved oxygen
MGD	Million gallons per day
mg/L	Milligram per liter
NA	Not applicable
NH_3-N	Ammonia-nitrogen
STP	Sewage treatment plant
S.U.	Standard unit

[a] The 4.0 and 8.0 mg/L values are the monthly average and maximum limits from November through March, and 1.0 mg/L is the monthly maximum limit from May through October. There is no monthly average limit from May through October.

[b] An NH_3-N concentration of 4.8 mg/L was measured in December when the monthly maximum limit is 8.0 mg/L; therefore, the Olney STP was in compliance. The maximum NH_3-N effluent concentration from the Olney STP from May through October when the limit is 1.0 mg/L was 0.78 mg/L.

Nonpoint Sources

The Little Wabash River is considered to have a potentially high level of impact to water quality from nitrogen runoff from farm fields (EPA 1999). Fox River watershed soils have a relatively low permeability of 0.5 inch per hour, resulting in lower rainfall infiltration and high overland flow and subsequently large nutrient and sediment runoff into streams and lakes. The 303(d) list identifies the nonpoint sources of impairments to the Fox River as agricultural irrigation and nonirrigation crop production and resource extraction. However, nonpoint sources of impairment identified as part of this TMDL study include row crop agriculture (including manure application), animal feedlots, pasture land, septic system failures, and infiltration and inflow between sanitary and storm sewers.

Pollutants from oils wells were also evaluated because 744 oil wells are located in the Fox River watershed (IEPA 2002). However, leaks from oil wells do not impact DO concentrations in surface water. Salt water and oil are the two possible pollutant loads that can leak from an oil well, but neither can contribute to low DO concentrations in surface water. Saltwater has the potential to increase chloride and total dissolved solid (TDS) concentrations but does not affect DO. Crude oil in the watershed has low sulfur content. As a result, the contribution to acidity resulting from the breakdown of sweet oil is negligible. Oil breaks down to hydrocarbons very quickly before reaching a water body (Tetra Tech 2002). In addition, saltwater and oil spills are rare in the Fox River watershed. Only nine spills were reported from June 1999 through June 2002 (IDNR 2002).

Most nonpoint sources of nutrient and BOD loads in the Fox River result from row-crop agriculture. Manure, which has a high nutrient content, is commonly applied to agricultural fields in Richland County. Urea and diammonium phosphate (DAP) are the primary manufactured fertilizers applied to row crops in Richland County, Illinois (Tetra Tech 2002a). Urea is a water-soluble organic form of nitrogen that rapidly hydrolyzes to ammonium. Dissolved forms of nitrogen can reach the Fox River through surface water runoff and groundwater. DAP is primarily a source of phosphorous but is also a source of nitrogen. Phosphorous seldom leaches from soils but can reach the Fox River when soil particles containing phosphorous are carried to surface water through runoff.

Animal feedlots and pastureland are other land uses that contribute significantly to nutrient and BOD loads to the Fox River. About 10 livestock producers are located in the Fox River watershed. However, information on the number of confined versus unconfined feeding lots and the number and types of animals was unavailable (NRCS 2002). Grazing on pastureland containing small tributaries could damage streambanks and riparian vegetation and erode streambanks, which would transport soil particles potentially containing phosphorous to the Fox River.

Failing septic systems and infiltration and inflow between sanitary and storm sewers are other potential sources of nutrient and BOD loads to the Fox River. The Fox River watershed has more than 300 septic systems (Tetra Tech. 2002e). In 2000 and 2001, only five septic system failures were reported in Richland County to the regional health department. The actual number of septic system failures is most likely greater than five because such failures are not always reported and septic systems are not regularly inspected in the watershed because of limited resources (Illinois Department of Public Health 2002; Tetra Tech 2002c and 2002d). Infiltration and inflow between storm and sanitary sewers in the Olney Sanitary District is evidenced by Olney STP flow fluctuations that correspond to precipitation fluctuations (Tetra Tech 2002d).

2.6 Olney East Fork Lake Characteristics

Olney East Fork Lake is located on the East Fork Fox River in Richland County, Illinois, near the City of Olney. The East Fork Fox River is a tributary to the Fox River. The watershed is shown in Figure B.2-6. Olney East Fork Lake was built in 1970 for recreational use and to replace Borah Lake as the primary drinking water resource for the City of Olney (IEPA 1998a). Olney East Fork Lake's physical characteristics, pollutants of concern, water quality sampling, and nonpoint sources of pollution are discussed below.

2.6.1 Physical Characteristics

The Olney East Fork Lake watershed is gently rolling, with some flat areas. The watershed basin is roughly oval, and the lake surface area constitutes less than 15 percent of the watershed. The remainder of the watershed is composed mainly of farmland, rural residential areas, and lightly to heavily forested areas. All areas in the basin are well-vegetated, and the basin appears to be well-drained. Basin slope is fairly uniform throughout the drainage area (COE 1978a). Table B.2-7 summarizes the lake's physical characteristics.

FIGURE B.2-6. OLNEY EAST FORK LAKE WATERSHED

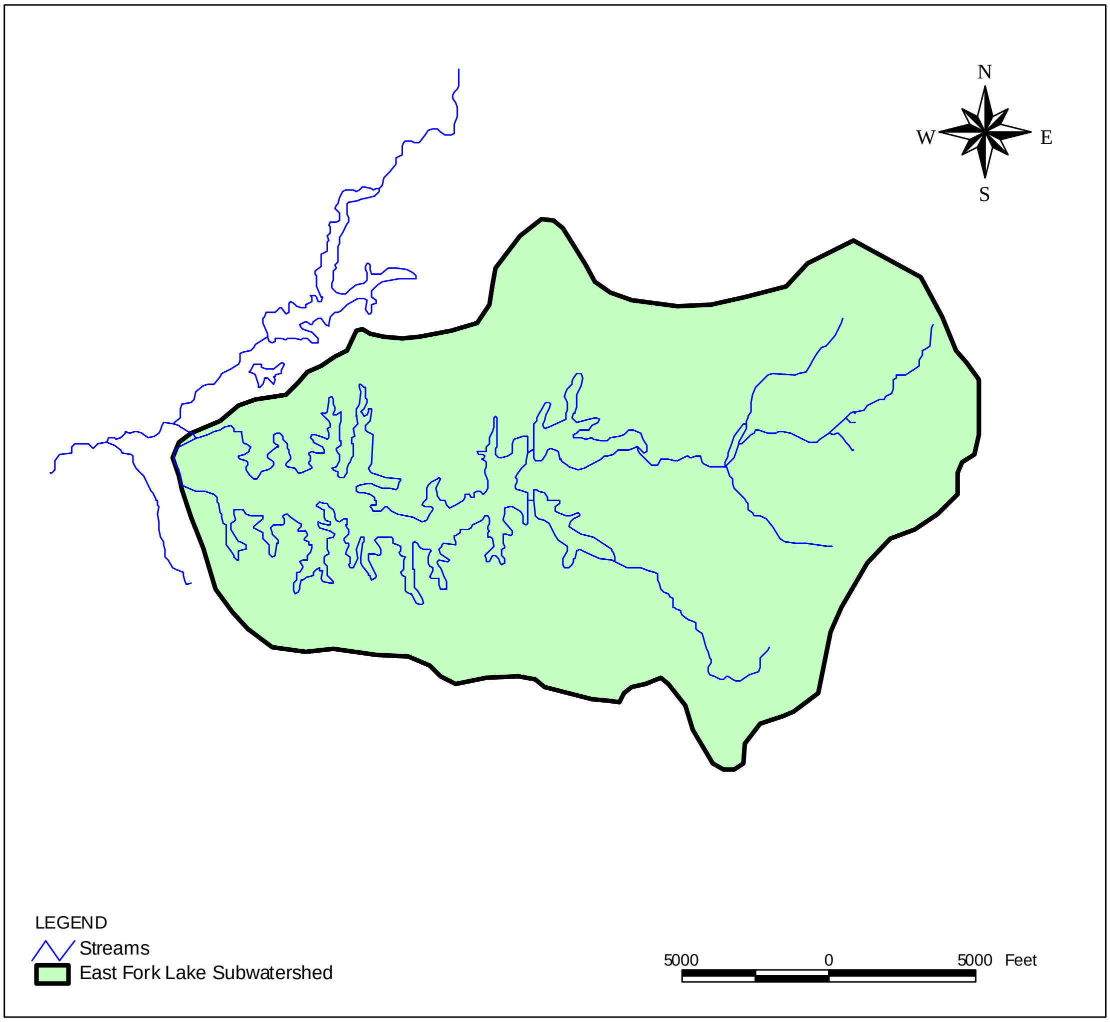


TABLE B.2-8. OLNEY EAST FORK LAKE PHYSICAL CHARACTERISTICS

Characteristic	Value
Drainage area	10.4 square miles[a]
Water surface	935 acres[b]
Service spillway crest elevation	475.0 feet
Emergency spillway elevation	478.0 feet
Maximum storage	22,680 acre-feet
Normal storage	12,460 acre-feet
Maximum pool length	3.4 miles
Annual percentage loss in capacity	0.07 percent[c]
Average depth	15 feet[b]
Maximum depth	44 feet[b]
Potential downstream hazard	Significant
Dam height	84 feet
Dam length	6,500 feet
Designed maximum discharge	11,536 cubic feet per second

Notes:

Unless otherwise indicated, source is COE 1978a

[a] This value is 9,982 acres (or 15.6 square miles) according to IEPA 1998a.
[b] Source: IEPA 1998a
[c] Source: EPA 1998

As a public water supply system, Olney East Fork Lake is owned and managed by the City of Olney. Outflow is controlled by a zoned, earth-fill dam approximately 84 feet high and considered a high hazard because residences are located directly downstream of the dam. The lake drains 10.4 square miles, and its normal storage is 12,460 acre-feet (4 billion gallons). Maximum storage is 22,680 acre-feet (7.4 billion gallons) (COE 1978a). Water supply withdrawals average 1.56 MGD (Olney STP 2001). The total embankment length, including the earth dike, is approximately 6,500 feet. The reservoir also has a concrete-lined service spillway on its left abutment and an earth channel emergency spillway on its right abutment. The outlet conduit is plugged with a bulkhead; therefore, reservoir water surface levels cannot be regulated (COE 1998a). Water withdrawals remain fairly constant throughout the monitoring season. Table B.2-9 lists annual water production values for the Olney STP.

TABLE B.2-9. AVERAGE ANNUAL WATER PRODUCTION OF OLNEY STP

Year	Average Production (MGD)
1995	1.6
1996	1.59
1997	1.57
1998	1.59
1999	1.46
2000	1.42

Source: Olney WTP 2001

Notes:

MGP	Million gallons per day
STP	Sewage treatment plant

No USGS gauging stations are located along this tributary to the Fox River, and no staff gauge readings were taken. Bottom seepage rates are unknown and are therefore assumed to be negligible.

2.6.2 Pollutants of Concern

The pollutants of concern for the Olney East Fork Lake are DO and TP. In addition, NH_3-N, Ch-a, Carlson's Trophic Status Index (TSI), and TSS are closely linked to DO and TP. Lake mechanisms and relationships between these parameters are discussed below. BOD was also modeled for Olney East Fork Lake, and BOD's effect on DO is discussed in Section 2.5.2 above.

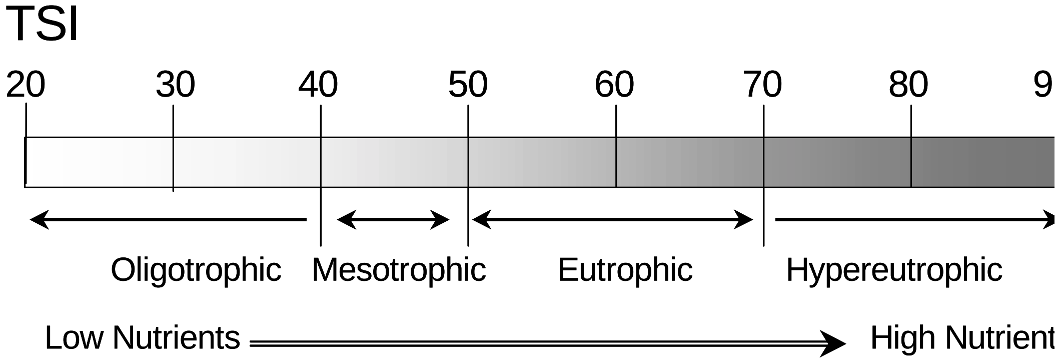
Phosphorous is carried to surface water by eroded particles such as TSS that are carried in runoff. When particulate phosphorous enters a lake, it settles out of the water column to the lake bottom and is bound to lake bottom sediment. This phosphorus generally is not available for aquatic plant growth and is not a water quality problem. However, anoxic (free oxygen-depleted) conditions at the lake bottom can result in re-release of the bound phosphorus. Anoxic conditions can be created when lakes stratify and DO is not replenished because of lack of mixing. In the Midwest, lakes are typically stratified because of temperature differences in deeper water bodies. In the summertime, warm surface water "floats" on top of colder, denser, deep water. In the wintertime, freezing surface water also "floats" on top of warmer deep water because ice is less dense than water. When these situations occur, the layers of water essentially separate, creating a thermal resistance to the mixing of water and chemicals. Anoxic conditions can also be created if there is highly active decomposition at the lake bottom in nutrient-rich waters during warm weather when decomposition rates are accelerated. During active decomposition, DO is simply being used faster than it can be replenished.

If there is no mixing of the water column, the dissolved phosphorus will remain at the lake bottom; however, mixing can occur from wind action, fish activity, or spring and fall lake turnover following winter and summer thermal stratification. Spring turnover occurs when frozen surface waters melt and sink to the bottom. Fall turnover occurs when warm surface water quickly cools and sinks to the bottom. In either case, dissolved phosphorus is brought up to the surface where it is available for algal uptake and growth. If turnover occurs when aquatic plants such as algae are not actively growing (such as late fall), then the dissolved phosphorus released as a result of anoxic conditions does not contribute to water quality problems. If turnover occurs during the active growing season, the dissolved phosphorus can accelerate aquatic plant growth, resulting in nuisance algal blooms. Excess algal bloom conditions are indicated by elevated Ch-a concentrations. When algal blooms decay, oxygen (O_2) is consumed and DO concentrations decrease.

Nitrogen is another essential nutrient for plant growth; however, it is often so abundant that algae growth is not limited. Some species of algae can also “fix” their own atmospheric nitrogen; therefore, they do not need another nitrogen source. With abundant nitrogen availability, the presence of limiting nutrients such as TP results in rapid algal growth. Although nitrogen is not as much of a concern as TP in Olney East Fork Lake, NH_3-N trends are important to consider when estimating nutrient loads.

Along with nutrient, DO, and Ch-a concentrations, Carlson TSI values are used to measure the nutrient enrichment status of lake ecosystems. Carlson TSI is the measure of a lake’s trophic (or “fertility”) status. Higher trophic status is associated with more nutrient availability and higher productivity. Excessive nutrient loads can result in nuisance algal blooms and excessive turbidity. Very low nutrient status also can limit the support of aquatic life. Carlson TSIs are based on TP concentration, Ch-a concentration, or Secchi depth. The individual indices are often averaged to calculate an overall TSI. However, in general, TP is considered the best indicator of *potential* trophic status. Figure B.2-7 depicts the relationship between the TSI, tropic status, and nutrient status.

FIGURE B.2-7. TSI RELATIONSHIP TO LAKE FERTILITY



Olney East Fork Lake is considered to be eutrophic, which corresponds to nutrient-rich conditions. The 1998 Volunteer Lake Monitoring Program report for the Olney East Fork Lake reports a TSI value of 60.7 (IEPA 1998a). Aquatic life cannot survive when DO concentrations are too low. Consequently, IEPA has set standards for DO and TP concentrations (see Table B.2-10 below).

TABLE B.2-10. ILLINOIS WATER QUALITY STANDARDS FOR LAKES

Parameter	Standard
NH_3-N	Not applicable
TP	Shall not exceed 0.05 mg/L in any reservoir or lake with a surface area of 8.1 hectares (20 acres) or more or in any stream at the point where it enters any such reservoir or lake
DO	Shall not be less than 6 mg/L during at least 16 hours of any 24-hour period nor less than 5.0 mg/L at any time
Excessive Algal Growth/ Ch-a	Not applicable
pH	6.5 to 9.0 S.U.

Source: IEPA 1999 and 2000
Notes:

μg/L	Microgram per liter
Ch-a	Chlorophyll-a
DO	Dissolved oxygen
IEPA	Illinois Environmental Protection Agency
mg/L	Milligram per liter
NH_3-N	Ammonia-nitrogen
S.U.	Standard unit
TP	Total phosphorus

Because of the relationship between nutrients, DO, and algae growth, IEPA has also set guidelines for NH_3-N, TP, and chlorophyll-a which are shown in the table as well. These guidelines can be used for understanding the causes of impairment in a water body, but are not enforceable standards. TMDLs are not required for water bodies that don't meet applicable water quality guidelines, only those that do not meet applicable water quality standards.

2.6.3 Water Quality Sampling in Olney East Fork Lake

From 1978 to 1998 as part of the Volunteer Lake Monitoring Program, IEPA collected water quality samples from Stations RCC1, RCC2, and RCC3 within Olney East Fork Lake. The samples were collected from the surface (1 foot below water surface) only except at Station RCC1, where an additional bottom sample was collected. Table B.2-11 summarizes most recent values for the pollutants of concern (April to October 1998). These data were used in water quality model development discussed in Chapter 4.

The data show that TP exceeded the IEPA guideline of 0.05 mg/L in 13 samples. In addition, according to the IEPA "Water Quality Report 2000," 11 of these measurements classified TP levels as slightly elevated and 2 (IEPA 2000). TP is especially high along the lake bottom during the late part of the year, with measurements of 0.615 mg/L on August 10 and 1.23 mg/L on October 13, 1998.

DO profiles show anoxic conditions at the bottom of the lake at Station RCC 1. Surface DO measurements generally remain above 6 mg/L except in the sample collected on October 13, 1998. In addition, Ch-a concentrations exceeded the IEPA guideline in six of the nine samples collected for Ch-a analysis.

2.6.4 Point and Nonpoint Sources of Pollution

This section describes nonpoint sources that contribute to the impairment of the uses of Olney East Fork Lake. No point source discharges are located within the Olney East Fork Lake watershed. Potential nonpoint sources of impairment listed in "IEPA's Water Quality Report 2000" are listed in Table B.2-12 below.

TABLE B.2-11. OLNEY EAST FORK LAKE WATER QUALITY DATA

Date	Station No.	Ch-a (corrected) (μg/L)	Total Ammonia-Nitrogen (mg/L)	Total P (mg/L)	DO[a] (mg/L)
4/28/98	RCC 1	17.50	0.22	0.050	8.3
	RCC 1 (bottom)	-	0.26	0.049	8.1
	RCC 2	18.68	0.39	**0.055**	-
	RCC 3	**26.97**	0.27	**0.063**	-
6/10/98	RCC 1	18.97	0.10	0.045	7.7
	RCC 1 (bottom)	-	0.07	0.049	0.1
	RCC 2	**35.82**	0.06	**0.090**	-
	RCC 3	**53.40**	0.13	**0.136**	-
7/7/98	RCC 1	**27.10**	0.13	**0.051**	8.5
	RCC 1 (bottom)	-	0.10	0.043	0.1
	RCC 2	**30.00**	0.14	**0.063**	-
	RCC 3	**40.90**	0.24	**0.090**	-
8/10/98	RCC 1	-	0.18	0.046	8.4
	RCC 1 (bottom)	-	1.60	0.615	0.1
	RCC 2	-	0.14	0.049	-
	RCC 3	-	0.18	**0.051**	-
10/13/98	RCC 1	-	0.16	**0.114**	**4.3**
	RCC 1 (bottom)	-	4.40	1.230	0.1
	RCC 2	-	0.26	**0.115**	-
	RCC 3	-	0.49	**0.139**	-
Summary Statistics for Surface Samples					
Average		29.93	0.21	0.08	7.4
Minimum		17.50	0.06	0.045	4.3
Maximum		53.40	0.49	0.139	8.5
Standard deviation		11.85	0.11	0.034	1.78

Sources: IEPA 1998a, 1999, and 2000

Notes:

Bolded values exceed Illinois water quality standards (IEPA 1999) or guidelines (IEPA 2000).

μg/L	Microgram per liter	IEPA	Illinois Environmental Protection Agency
-	Not measured	mg/L	Milligram per liter
Ch-a	Chlorophyll-a	NH_3-N	Ammonia-nitrogen
DO	Dissolved oxygen	TP	Total phosphorus

[a] Source: EPA 2001b

TABLE B.2-12. NONPOINT SOURCES OF IMPAIRMENT TO OLNEY EAST FORK LAKE

Sources of Impairment
Agriculture – nonirrigated and irrigated crop production
Construction and land development
Animal Feedlot
Pastureland
Infiltration and inflow between sanitary and storm sewers
Urban runoff and storm sewers
Land disposal – on-site wastewater systems
Recreational and tourist activities

Source: IEPA 2000

Nonpoint sources of impairment include row-crop agriculture (including manure application), animal feedlots, pastureland, urban runoff, construction, and septic system failures (see Section 2.9.1 of the TMDL report). Prevalence of these sources in the Olney East Fork Watershed is based on land use distributions in the Olney East Fork watershed. Figure B.2-8 shows land use within the Olney East Fork watershed, and Table B.2-13 summarizes land-use distribution information used to model the Olney East Fork Lake watershed.

TABLE B.2-13. LAND-USE DISTRIBUTION INFORMATION USED FOR MODELING

Land Use	Acres	% of Total
Cropland and pasture	4,385	64.7
Deciduous forest	1,312	20
Reservoir	935	15
Animal feedlots	24	0.3
Total	6,656	100

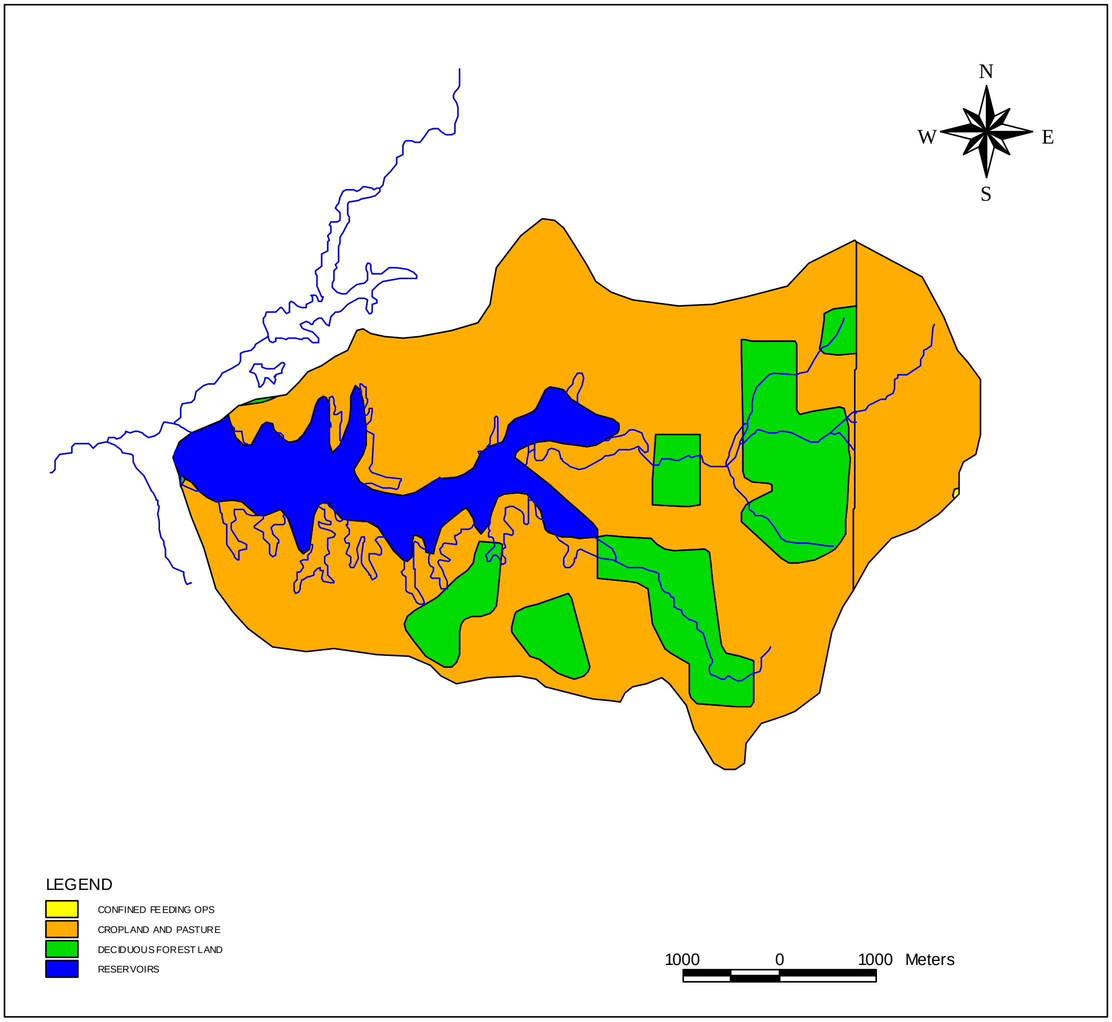
Source: EPA 1998

Cropland and pasture makes up a majority of the watershed; therefore, row-crop agriculture and pastureland are the primary sources of nutrient and BOD loads to the lake. Animal feedlots also exist in the watershed and are a significant source. Although the prevalence of septic system failures in the watershed is unknown, septic system failures are a potential source of nutrient and BOD loads to Olney East Fork Lake.

2.7 Borah Lake Characteristics

Borah Lake, which is owned and managed by the City of Olney, Illinois, is located on a tributary of the East Fork Fox River in Richland County, Illinois, near the City of Olney (see Figure B.2-2). Figure B.2-9 shows the Borah Lake watershed area. The lake was constructed in 1953 to

FIGURE B.2-8. OLNEY EAST FORK LAKE LAND USE



replace Vernor Lake as a water source for the City of Olney. Borah Lake was in turn replaced by Olney East Fork Lake as a drinking water source. Borah Lake is currently designated for general use. Borah Lake's physical characteristics, pollutants of concern, water quality sampling, and nonprofit sources of pollution are discussed below.

2.7.1 Physical Characteristics

The Borah Lake watershed is gently rolling, with some flat areas. The watershed consists mainly of farmland and lightly to heavily forested areas. All areas in the basin are well-vegetated, and the basin appears to be well-drained. Basin slope is fairly uniform throughout the drainage area. No rock outcroppings were observed in the watershed. Paved surfaces, roads, and housing developments are the only impervious areas in the watershed. Several relatively short tributaries that appear to be intermittent streams flow into the lake. The tributaries have shallow beds and steep banks (COE 1978b). Table B.2-14 summarizes Borah Lake's physical characteristics.

TABLE B.2-14. BORAH LAKE PHYSICAL CHARACTERISTICS

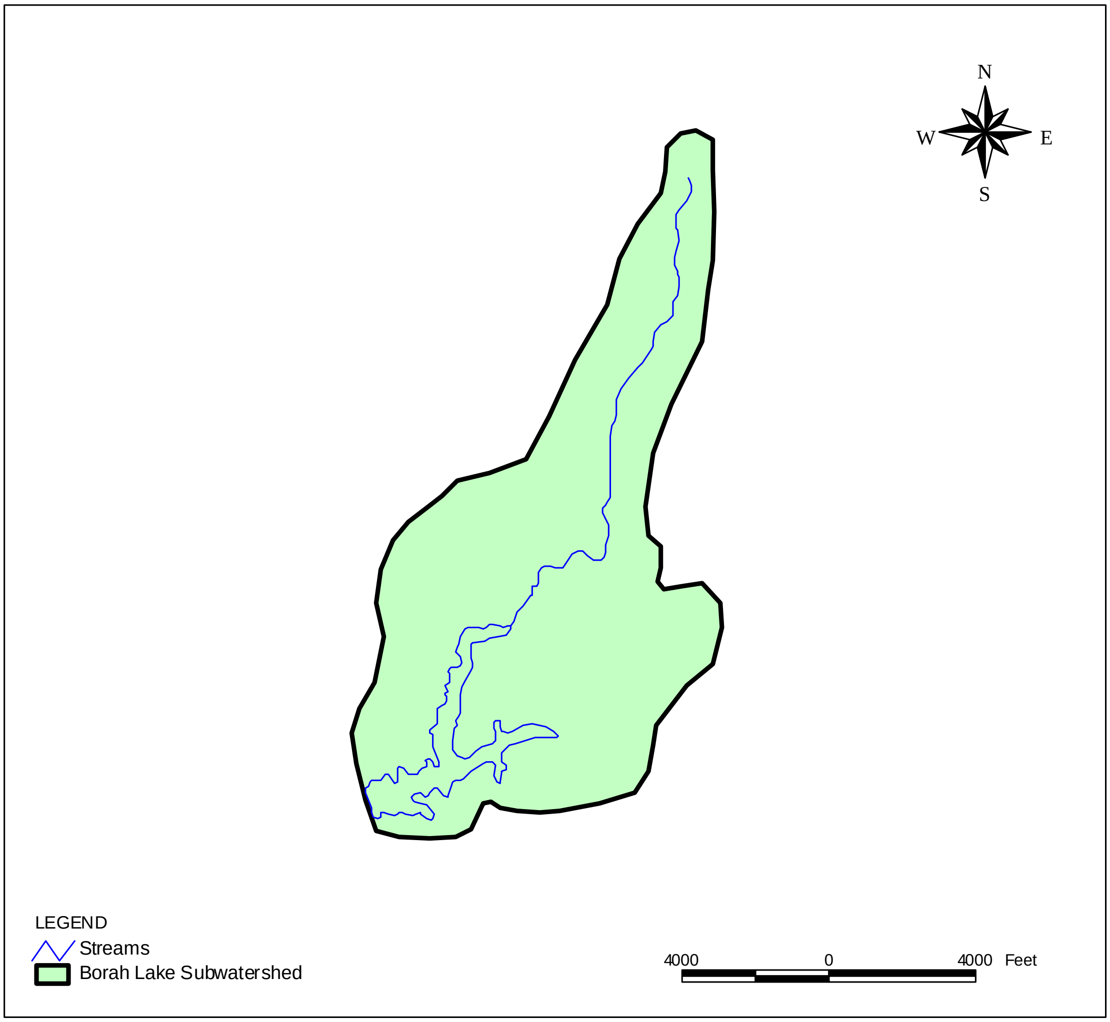
Characteristic	Value
Drainage area	3.61 square miles
Water surface	137 acres[a]
Spillway crest elevation	469.5 feet
Maximum storage	2,274 acre-feet
Normal storage	1,540 acre-feet
Maximum pool length	1.8 miles
Average depth	11 feet[a]
Maximum depth	32 feet[a]
Potential downstream hazard	Significant
Dam height	31 feet
Dam length	960 feet
Designed maximum discharge	6,225 cubic feet per second[b]

Notes:

Unless otherwise indicated, source is COE 1978b

a Source: IEPA 1998b
b Source: EPA 1998

FIGURE B.2-9. BORAH LAKE WATERSHED



Borah Lake is a constructed reservoir on a tributary to the Fox River. A zoned, earth-fill dam controls outflow. The lake reservoir covers about 137 acres and has 3.61 square miles of drainage area (IEPA 1998b; COE 1978b). Normal reservoir storage is 1,540 acre-feet (0.5 million gallons), and maximum storage is 2,274 acre-feet (0.7 million gallons) (COE 1978b). The Borah Lake dam (ILNONAME 313) is approximately 31 feet high and 960 feet long. The reservoir has a concrete and granite spillway approximately 120 feet southeast of its left abutment. The spillway has an uncontrolled crest; however, an intake and 12-inch-diameter pipe tower that was designed for water supply can function as outlet works, thereby providing a limited means of regulating the reservoir. If the valve of the intake tower were open, water would flow through the pipe beneath the dam and then by gravity through the natural channel to the Fox River. Because the purpose of the dam has changed from a drinking water source to recreation only, operational procedures need to be verified. No water is withdrawn from the lake. Discharges occur only when lake levels rise above the elevation of the spillway (469.5 feet above mean sea level).

A COE 1978 inspection report concludes that the Borah Lake reservoir and spillway are capable of passing and holding a 10-year flood (COE 1978b). However, because of the extremely deteriorated condition of the spillway, it is possible that any appreciable amount of flow could cause a total spillway failure, as well as erosion of the natural channel both upstream and downstream of the lake. In addition, the top of the spillway guide wall is only 2 feet above the spillway crest. If flow over the spillway were to over-reach the top of guide wall, severe erosion could result in further damage or loss of the spillway. Evidence of seepage at the downstream toe of the dam has been noted. Water was believed to be entering the water supply intake tower and seeping out through the embankment. These seepages could contribute flow to the Fox River (COE 1978b).

No USGS gauging stations are located along this tributary to the Fox River; therefore, no staff gauge readings were taken. Bottom seepage rates are unknown and are therefore assumed to be negligible.

2.7.2 Pollutants of Concern

The pollutants of concern in Borah Lake are TP and pH. The water quality parameters affecting TP in Borah Lake include NH_3-N, Ch-a, and Carlson TSI values just as for Olney East Fork Lake (see Section 2.7.2). Physical and chemical processes affecting pH in Borah Lake are discussed below.

Algal blooms, which are the result of excess TP loads, are reflected by elevated Ch-a concentrations and can cause increased pH values, especially in shallow waters. Algae use carbon dioxide (CO_2) as a carbon source during photosynthesis. CO_2 affects pH because it combines with water to form carbonic acid. When CO_2 is consumed, carbonic acid concentrations decrease, lake acidity decreases, and pH concentrations increase. Similar to CO_2 consumption during daylight hours as a result of photosynthesis, CO_2 is produced during nighttime hours as a result of respiration; therefore, pH diurnal variations are possible.

Because the pH of a natural water body affects chemical reactions and other constituents in the water, Illinois set a water quality standard for pH of 6.5 to 9.0. A pH of 7.0 is neutral, and levels below 7.0 are acidic and above 7.0 are basic.

2.7.3 Water Quality Sampling in Borah Lake

From 1981 through 1998 as part of the Volunteer Lake Monitoring Program, IEPA collected water quality samples from Stations RCB1, RCB2, and RCB3 in Borah Lake. The stations are identified as RCB1, RCB2, and RCB3. The samples were collected from the surface (1 foot below water surface) only except at Station RCB1, where an additional bottom sample was collected. Table B.2-15 summarizes the most recent values for the pollutants of concern (April to October 1998). These data were used for water quality model calibration and validation as discussed in Chapter 4.

These data show that TP exceeded the water quality standard of 0.05 mg/L in all 15 surface samples. In addition, according to IEPA's "Water Quality Report 2000," the measurements classified TP levels as moderate to high (IEPA 1998b). Like Olney East Fork Lake, TP is especially high along the lake bottom during the late part of the summer, with measurements of 1.04 mg/L on August 11 and 0.233 mg/L on October 14, 1998. Elevated TP concentrations result in a TSI value of 64.2 based on 1998 Volunteer Lake Monitoring Program data, indicating that the lake is eutrophic. Total NH_3-N concentrations did not exceed the IEPA guideline in any of the samples collected in 1998.

TABLE B.2-15. BORAH LAKE WATER QUALITY DATA

Date	Station No.	Total NH_3-N (mg/L)	TP (mg/L)	Ch-a (corrected) (µg/L)	pH (S.U.)
4/28/1998	RCB 1	0.41	**0.126**	6.41	7.4
	RCB 1 (bottom)	0.50	0.128	-	7.1
	RCB 2	0.50	**0.134**	5.66	7.4
	RCB 3	0.49	**0.143**	5.32	7.4
6/9/1998	RCB 1	0.24	**0.112**	**37.15**	8.8
	RCB 1 (bottom)	0.79	0.303	-	6.7
	RCB 2	0.13	**0.097**	**77.96**	8.7
	RCB 3	0.12	**0.164**	**58.74**	8.8
7/7/1998	RCB 1	0.18	**0.145**	**73.80**	**9.2**
	RCB 1 (bottom)	0.17	0.161	-	9.0
	RCB 2	0.17	**0.205**	**107.00**	**9.4**
	RCB 3	0.22	**0.128**	**92.30**	**9.4**
8/11/1998	RCB 1	0.16	**0.059**	-	**9.2**
	RCB 1 (bottom)	4.10	1.040	-	6.7
	RCB 2	0.34	**0.344**	-	9.0
	RCB 3	0.17	**0.207**	-	**9.1**
10/14/1998	RCB 1	0.70	**0.094**	-	7.1
	RCB 1 (bottom)	6.40	0.233	-	6.5
	RCB 2	0.70	**0.096**	-	7.2
	RCB 3	0.59	**0.158**	-	7.2
Summary Statistics for Surface Samples					
Average		0.34	0.147	51.59	8.4
Minimum		0.12	0.059	5.32	7.1
Maximum		0.70	0.34	107	9.4
Standard deviation		0.21	0.07	39.48	0.93

Source: IEPA 1998b

Notes:

Bolded values exceed Illinois water quality standards (IEPA 1999) or guidelines (IEPA 2000).

-	Not measured
Ch-a	Chlorophyll-a
mg/L	Milligram per liter
IEPA	Illinois Environmental Protection Agency
NH_3-N	Ammonia-nitrogen
S.U.	Standard unit
TP	Total phosphorus

[a] Source: EPA 2001b

[b] Dissolved oxygen (DO) was not analyzed for at the bottom depth (22 feet below the water surface), however, samples at 21 and 23 feet below the water surface yielded DO results of 7.1 and 2.5 mg/L respectively.

2.7.4 Nonpoint Sources

This section describes nonpoint sources that contribute to the impairment of the uses of Borah Lake. No point source discharges are located within the Borah Lake watershed. Potential nonpoint sources of impairment listed in IEPA's "Water Quality Report 2000" for Borah Lake are listed in Table B.2-16.

TABLE B.2-16. NONPOINT SOURCES OF IMPAIRMENT TO BORAH LAKE

Sources of Impairment
Agriculture – Irrigated crop production
Infiltration and inflow between sanitary and storm sewers
Urban runoff and storm sewers
Land disposal – on-site wastewater systems
Recreational and tourist activities

Source: IEPA 2000

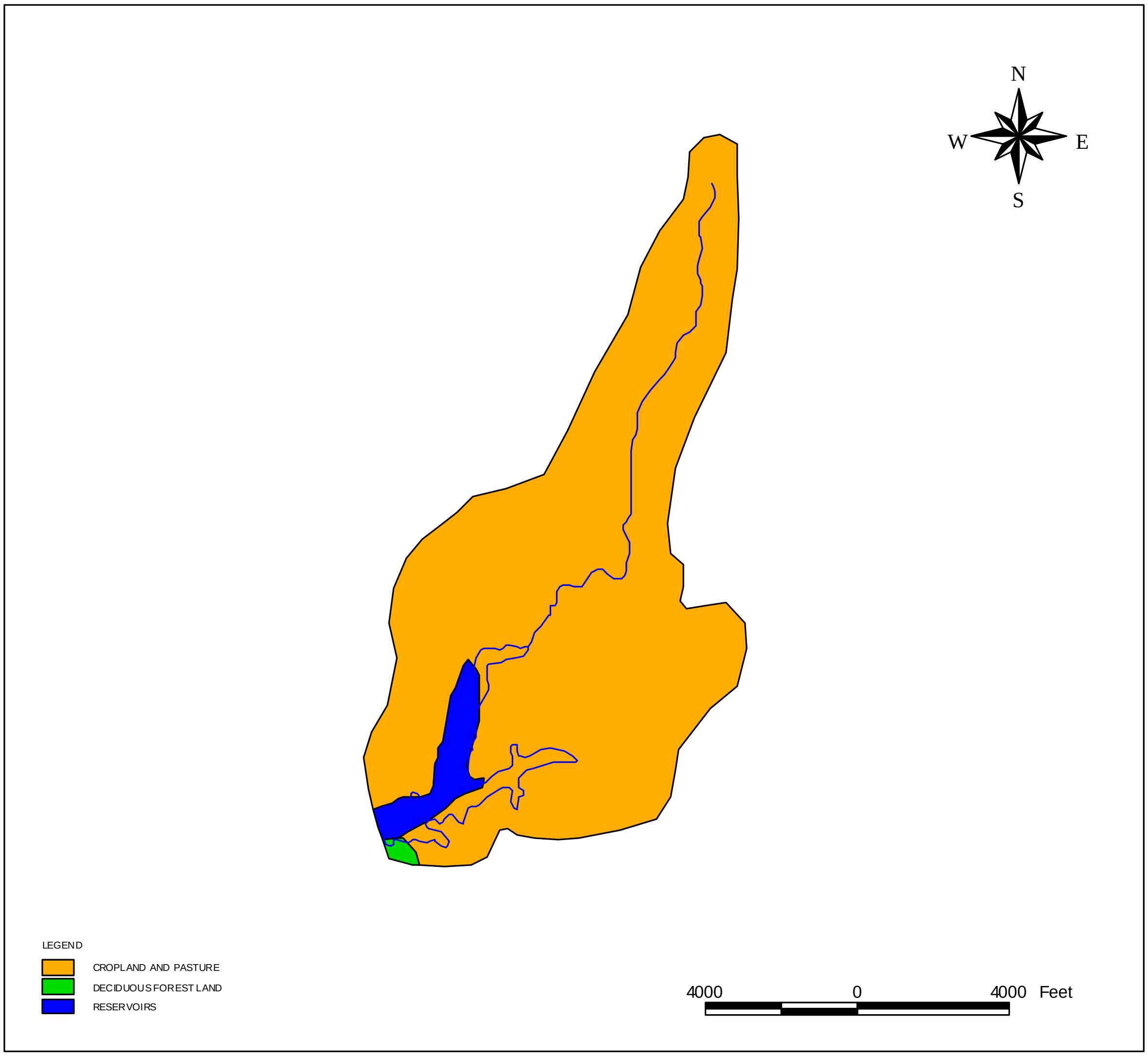
Nonpoint sources of impairment include row-crop agriculture (including manure application), animal feedlots, pastureland, and septic system failures (see Section 2.9.1 of the TMDL report). Prevalence of these sources in the Borah Lake Watershed is based on land-use distributions in the Borah Lake watershed. Figure B.2-10 shows land use within the Borah lake Watershed, and Table B.2-17 shows land-use distribution information used to model the Borah Lake watershed.

TABLE B.2-17. LAND-USE DISTRIBUTION INFORMATION USED FOR MODELING

Land Use	Acres	% of Total
Cropland and pasture	2,165	94
Reservoir	145	6
Total	2,310	100

Source: EPA 1998

FIGURE B.2-10. BORAH LAKE LAND USE



Cropland and pasture makes up a majority of the watershed; therefore, row-crop agriculture and pastureland are the primary sources of nutrient and BOD loads to the lake. Animal feedlots are not identified as a land-use type in the watershed. As discussed in Section 2.6.4, the number and locations of all animal feedlots throughout the Fox River Watershed is unknown; therefore, animal feedlots are potential sources of nutrient and BOD loads to Borah Lake. The frequency of septic system failures in the watershed is also unknown, but septic system failures are another potential source of nutrient and BOD loads to Borah Lake.

2.8 Background Sources in the Watershed

Background sources of nutrients and BOD that are naturally present in a watershed include atmospheric deposition, wildlife, in-stream decomposition of plant materials, and groundwater. Assessment of the load allocation from each background source is not possible without any background information. Therefore, for the purpose of TMDL development, background loading will be included in the MOS component of the TMDL.

3 Hydrologic Modeling

The objective of water quality modeling studies is to link the pollutant sources and water quality targets to predict the impacts of nonpoint and point source loading on surface water bodies. The HSPF model was used to simulate the flow in the Little Wabash and Fox Rivers and water qualities of the Fox River and two lakes. Based on this simulation, the model predicted the loads to the Fox River, Olney East Fork Lake, and Borah Lake. The HSPF model has been used extensively for watersheds around the United States, such as the Chesapeake Bay watershed (Donigian 1992), Minnesota River Basin (Tetra Tech 2001), and Chippewa River watershed (Tetra Tech, Inc. 2001). The HSPF model simulates continuous nonpoint source runoff and pollutant loadings to a watershed, combines these with point source contributions, and performs flow and water quality routing simulation in river reaches and well-mixed impoundments such as lakes. Continuous rainfall and other meteorological records are used to generate stream flow hydrographs and pollutographs. HSPF model can simulates a very large number of hydrologic and water quality process including DO, BOD, nutrients, and algae, which are of interest in th Fox River Watershed. The model can simulate one or many pervious or impervious unit areas discharging to one or many river reaches or reservoirs. The HSPF model is generally used to assess the effects of land-use change, reservoir operations, point or nonpoint source treatment alternatives, and flow diversions.

This chapter discusses the rationale for the modeling approach, background information for the HSPF model, HSPF model setup, hydrologic model calibration and validation, and modeled Fox River flow eata results.

3.1 Rationale for Modeling Approach

The historic reliance on the use of design flows for developing permit limits and for evaluating attainment of water quality standards has not prepared TMDL practitioners in developing TMDLs for water bodies that receive inputs from both point sources (steady, continuous loads) and nonpoint sources (unsteady, discontinuous loads). Episodic discharges from nonpoint sources result from rain or melting snow entering streams whose assimilative capacities (generally approximated as dilution ratios) are not well represented by design flow rates (such as 7Q10) traditionally used to set permit limits for point sources. Although determining allowable load allocations from nonpoint sources based on a design flow is environmentally protective, it also probably unfairly allocates loads to point source dischargers and thus makes the attainment of allowable load allocations through load reductions impossible. Both point and nonpoint sources must be combined for TMDL development. Choice of the HSPF model is therefore intended to overcome this limitation through the simulation of both point and nonpoint sources in a realistic manner.

To estimate integrated loads from point and nonpoint sources, the concentrations of the pollutants of concern in the watershed would have to be continually measured. Sensors would have to be placed at appropriate locations to continuously collect data on chemical concentrations, stream volume flow, temperature, pH, and other properties for several years. With such a database, statistical descriptions could be developed of the distributions of pollutant concentrations resulting from point and nonpoint loadings within the watershed. Unfortunately, this monitoring effort would require decades to evaluate whether water quality criteria (chemical concentrations) were being exceeded more frequently than specified by the state water quality standards.

The next best way to generate the data needed to evaluate attainment of water quality standards is to model the watershed to predict future conditions. By running a continuous simulation model, a database can by synthesized that is analogous to a database from the decades-long monitoring effort described above. The HSPF model was used to simulate daily values for stream volume flow, pollutant loadings, pollutant concentrations and other conditions for a certain period of time. The computer output from this watershed modeling study was subject to the same statistical tests as real monitoring data.

Loadings from point sources were predicted based on information such as permitted releases of chemicals from municipal and industrial facilities (from, for example, EPA's Permit Compliance System database) and monitoring data collected at these facilities (discharge monitoring reports). Loadings from nonpoint sources were estimated using the HSPF model. Loads are dependent on factors such as land use, vegetation cover, and meteorological conditions. Resulting pollutant concentrations were estimated by dividing daily loadings predicted by the model (the total loads from both point and nonpoint sources) to generate daily stream flow data. If in-stream pollutant concentrations predicted by the model exceeded applicable criteria, loads were reduced until the criteria were attained.

Essentially, load is the product of flow and the concentrations of constituents in the water. In order to compute pollutant loads correctly, the model must be calibrated and validated. Unfortunately, the Fox River watershed has no available flow records for the HSPF model calibration; therefore, modeling began with development of the HSPF model for the Little Wabash River watershed, which is the parenting watershed of the Fox River watershed. The Little Wabash River HSPF model was calibrated using flow data collected at four gauge stations by the USGS between 1990 and 1995. Meteorological data used was obtained from the BASINS database and the NCDC for Illinois.

3.2 HSPF Model Background Information

The HSPF model consists of a set of modules arranged hierarchically to permit the continuous simulation of a comprehensive range of hydrologic and water quality processes. The model program is designed around a time series management system operating on direct access principles, which makes continuous simulation possible. The simulation modules draw input from time series storage files and are capable of writing output to the storage files. The modules can be invoked either individually or as a group. The three major modules are associated with pervious land segment (PERLND), impervious land segment (IMPLND), and streams and reservoirs (RCHRES). Each module has submodules that simulate individual water quality processes and conditions. A watershed is divided into pervious and impervious land based on land use. Land that could allow enough infiltration to influence the water budget is considered pervious; all other land is considered impervious. Watershed boundaries are established according to user's needs and the homogeneity of hydrologic characteristics. For modeling purposes, water, sediment, and water quality constituents move laterally downstream to a river reach or reservoir.

In the PERLND module, PWATER is a key component used to calculate water budget, primarily to predict total runoff from pervious area. PWATER simulates interception by land cover, infiltration, surface runoff, evaporation, evapotranspiration, interflow, and groundwater flow. IWATER in the IMPLND module is similar to PWATER; however, IWATER is simpler because infiltration and subsurface processes do not apply. RCHRES simulates processes in a single open or closed channel rach and in a well-mixed lake. Specifically, HYDR in RCHRES simulates hydraulic processes, performs hydraulic routing, and analyzes reservoir behavior. Figure B.3-1 highlights the hydrologic processes modeled by HSPF. More details on each module are presented in the HSPF users' manual (Bicknell and others 2001).

Incoming moisture from precipitation and snow melt flows through a series of stores, including interception storage (storage above the soil surface), surface detention storage, upper zone soil storage, lower zone soil storage, and active groundwater. A significant portion of total incoming moisture re-entered the atmosphere through evaporation and plant transpiration ("evapotranspiration"). Excess moisture at the soil surface becomes surface runoff. Moisture that enters the soil profile is partitioned between interflows and storages that may discharge groundwater (including deep groundwater). In pervious land, surface runoff results from the quick flow storm response, interflow and intermediate time-scale hydrologic response, and groundwater discharge. The interflow is the lateral movement of water through shallow soil. Many parameters are used to describe the movement between the various moisture stores. In general, movement from an upper to a lower store depends on how quickly the lower store fills and rate-limiting parameters, some of which are user-specified. Key rate parameters include the infiltration rate, which controls movement of water from upper to lower soil zones, and interflow inflow rate, which controls movement of water into the interflow. These rates, combined with the available capacity of each store, determine the disposition of water and the resulting shape of the outflow hydrograph.

The WinHSPF model provides a Windows graphical user interface to the HSPF model. WinHSPF provides efficient way to edit input and adjust parameters. In order to successfully apply WinHSPF, meteorological data local to the area being studied are required. These data are stored in the Watershed Data Management (WDM) format, which is used by both BASINS and HSPF. WDM files and the code library that manages them provide a powerful tool for managing and manipulating time-series data. WDMUtil was used to input time-series meteorological data to the model and post-processes the model output.

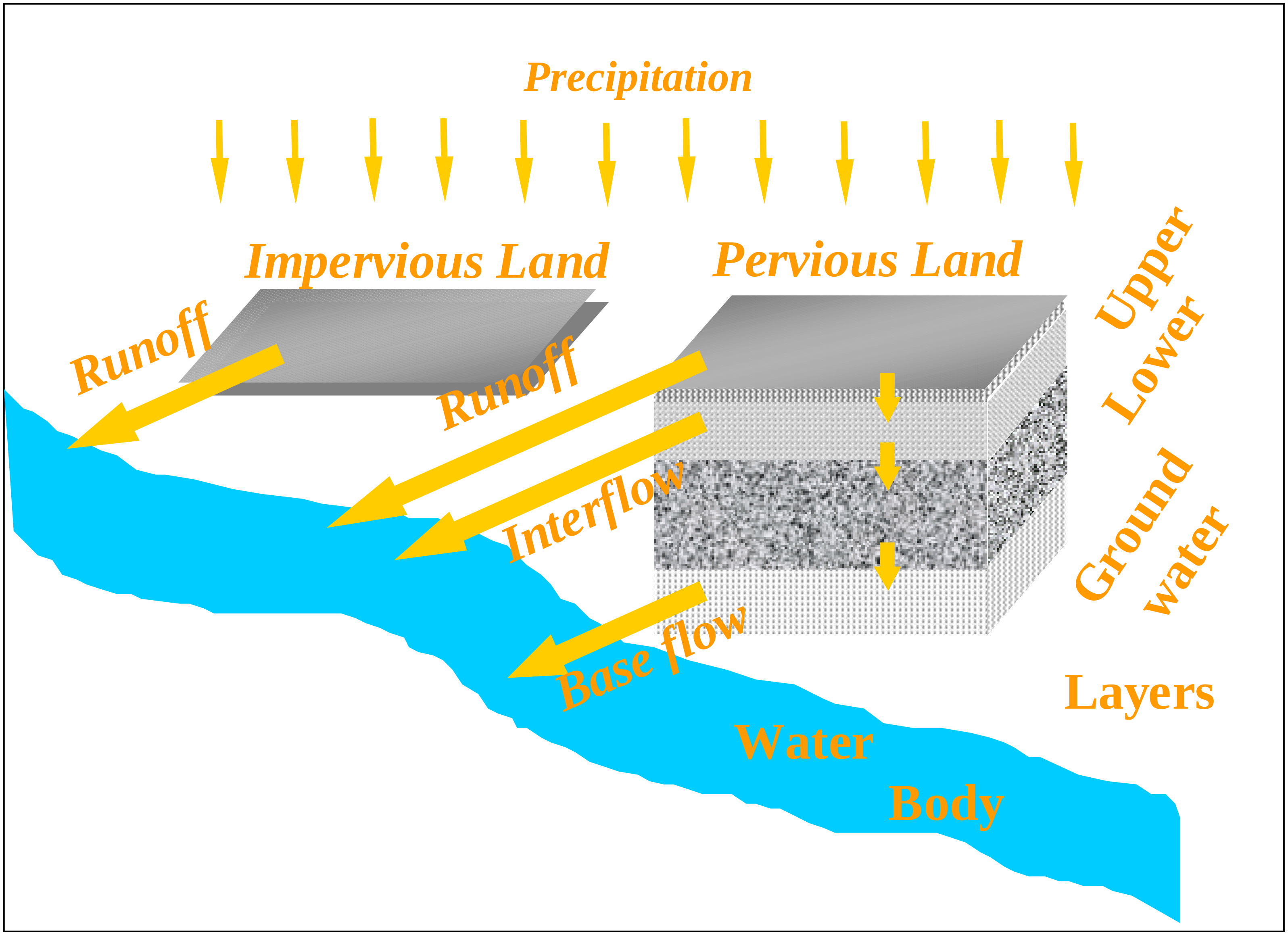
3.3 HSPF Model Setup

This section describes the HSPF model setup, which involved the use of BASINS to create the initial HSPF model, tile drainage simulation, data input, and determination of model parameters.

3.3.1 Use of BASINS to Create Initial HSPF Model

BASINS is a multipurpose environmental analysis system developed by EPA’s Office of Water to help regional, state, tribal, and local agencies perform watershed- and water quality-based studies. BASINS integrates data on water quality and quantity, land uses, and point and nonpoint source loading in the continental United States to allow watershed assessment. From a modeling perspective, BASINS

FIGURE B.3-1.   HSPF MODEL COMPONENTS



provides a starting point for delineating a watershed. BASINS contains information on a watershed's characteristic parameters. The BASINS physiographic data, monitoring data, and associated assessment tools are integrated in a customized GIS environment. The HSPF model simulations were integrated into this GIS environment by generating the data required to build the input files in the ArcView environment and then passing the data directly to the model. The model simulations were run in either Windows or DOS.

The Little Wabash River watershed (HUC 05120114) drains 3,259 square miles, including 1,073 square miles of the Skillet River watershed (HUC 05120115). The main stream of Little Wabash River is 221 miles long. In the HSPF model, the Little Wabash River watershed was divided into 18 sub-basins, including those of the Fox River watershed (see Figure B.3-2). Each sub-basin was assigned an identification number for use in the model. The sub-basins were delineated in a way that properly represented the watershed's spatial variations. An outlet was defined at the each of four model calibration locations, and the sub-basins were defined for the Fox River watershed, including the Olney East Fork and Borah Lake drainage basins. After flow calibration and model validation were complete, an operational Fox River watershed HSPF model was generated to simulate water quality using the QAAL2E model separate from the Little Wabash River watershed (see Chapter 4).

FIGURE B.3-2. SUB-BASINS OF LITTLE WABASH AND FOX RIVER WATERSHEDS

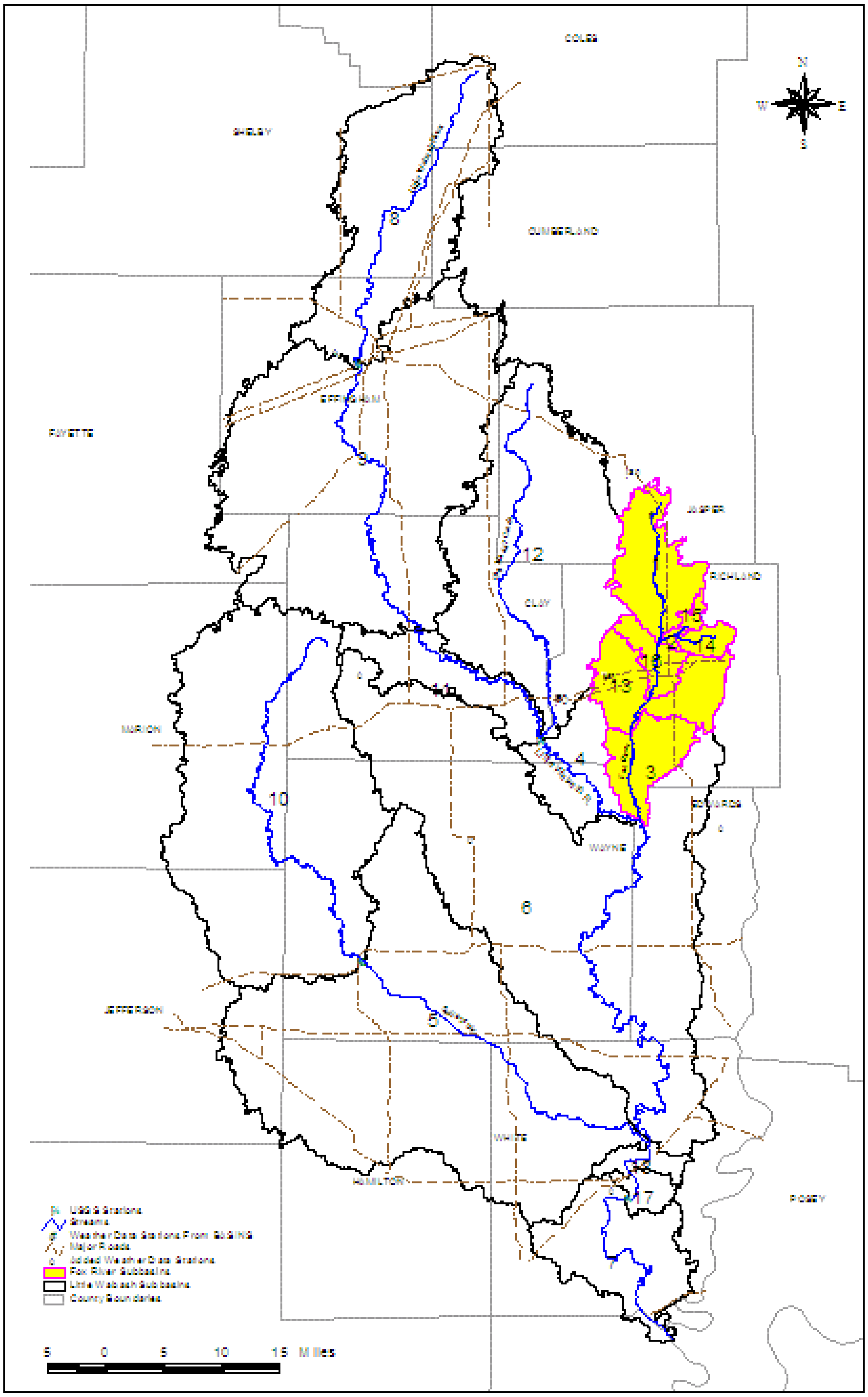
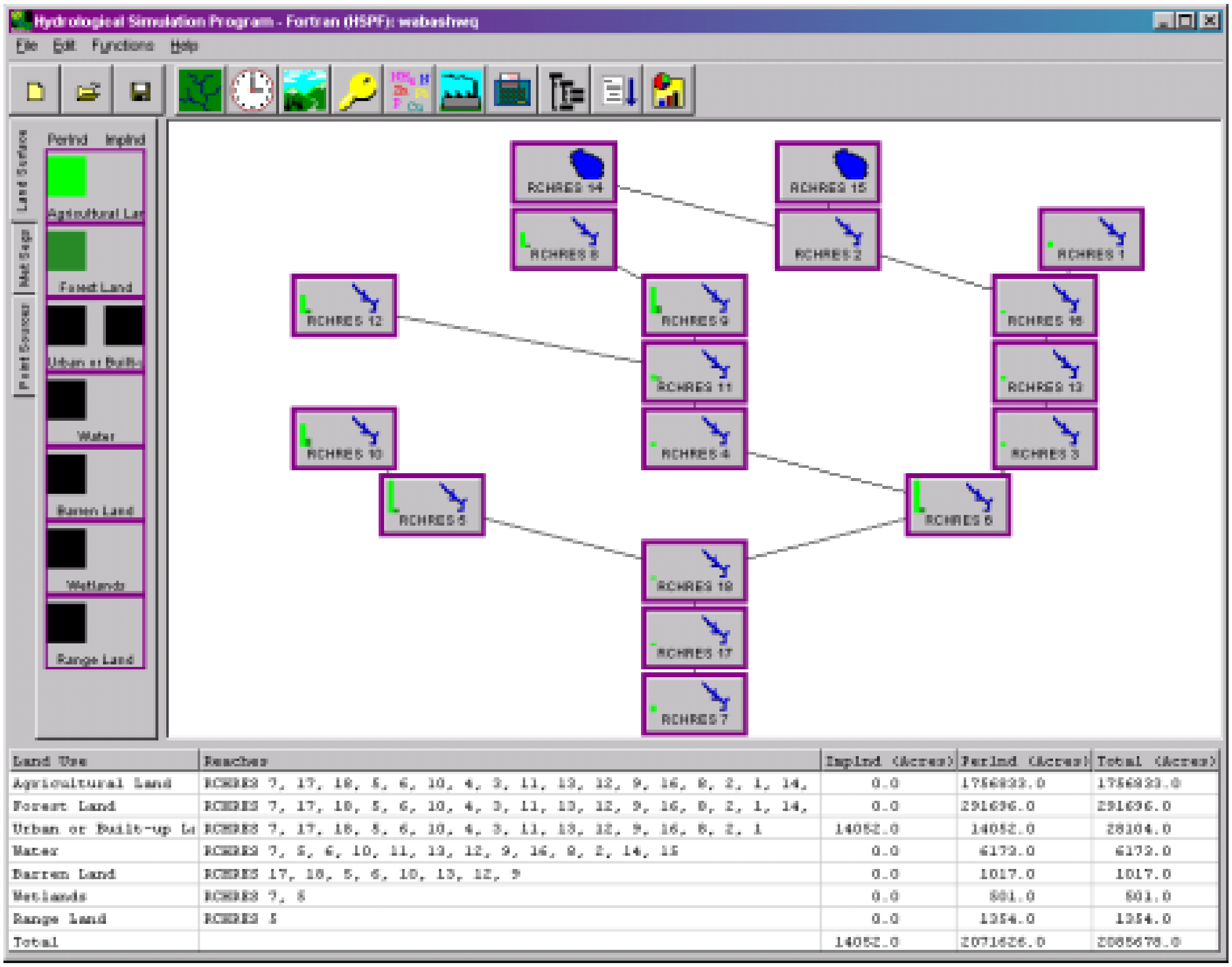


Figure B.3-3 shows the interface of the HSPF model in WinHSPF, including a schematic diagram of the Little Wabash River watershed.

FIGURE B.3-3. WinHSPF INTERFACE SHOWING SCHEMATIC DIAGRAM OF LITTLE WABASH RIVER WATERSHED



Land Use	Reaches	Implnd (Acres)	Perlnd (Acres)	Total (Acres)
Agricultural Land	RCHRES 7, 17, 18, 5, 6, 10, 4, 3, 11, 13, 12, 9, 16, 8, 2, 1, 14,	0.0	1756533.0	1756533.0
Forest Land	RCHRES 7, 17, 18, 5, 6, 10, 4, 3, 11, 13, 12, 9, 16, 8, 2, 1, 14,	0.0	291696.0	291696.0
Urban or Built-up L	RCHRES 7, 17, 18, 5, 6, 10, 4, 3, 11, 13, 12, 9, 16, 8, 2, 1	14052.0	14052.0	28104.0
Water	RCHRES 7, 5, 6, 10, 11, 13, 12, 9, 16, 8, 2, 14, 15	0.0	6173.0	6173.0
Barren Land	RCHRES 17, 18, 5, 6, 10, 13, 12, 9	0.0	1017.0	1017.0
Wetlands	RCHRES 7, 5	0.0	801.0	801.0
Range Land	RCHRES 5	0.0	1354.0	1354.0
Total		14052.0	2071626.0	2085678.0

Each rectangle in the main window represents a sub-basin and its associated stream or reservoir. Generally, each sub-basin may consist of agricultural, forest, urban built-up, barren , or range lands; water bodies; and wetlands. Hydrologic parameters were either assigned to each land-use type based on literature review or calibrated.

3.3.2 Tile Drainage Simulation

On a basin-wide scale, tile drains move water relatively rapidly out of surface storage without direct surface drainage. Accordingly, tile drainage was considered best represented in the HSPF model as an interflow component with a response time somewhat slower than direct surface runoff but faster than groundwater discharge. Tile drainage was therefore represented by a relatively fast recession coefficient.

Tile drainage encompasses a range of different hydrologic response times. The fraction of the net discharge from tile drain surface inlets is a rapid-response component; however, tile drain outflow also contains a slower component of subsurface flow that has percolated through upper soil layers and into the drains through lateral soil flow. As a result, the net tile drainage in the HSPF model was represented as a combination of interflow and groundwater discharge. There are some limitations in representing tile drainage as interflow in the HSPF model. The model determines the rate of interflow inflow is in relation to infiltration, and the rate of interflow discharge depends on the extent to which the lower soil zone capacity is filled. In reality, tile drain discharge depends on the capacity of the tile drains and the hydraulic head at the tile outlets. Actual tile drainage has an upper limit determined by pipe capacity regardless of the extent to which infiltration has filled the lower soil zone. As a result, HSPF model simulations that represent tile drainage discharge under normal conditions are likely to overestimate interflow discharge during large precipitation events with dry antecedent conditions. Available data do not allow direct determination of the interflow inflow parameter to represent tile drainage. This parameter must be determined through calibration.

For the reasons discussed above, the HSPF model cannot be expected to neatly partition all flow that actually moves through tile drains into the interflow compartment: the most rapid-response portion of this flow (surface inlets with short piped runs) appear s as surface runoff, and the slowest-response portion (subsurface inlets with long piped runs) appears as groundwater discharge. The major portion of the storm response should, however, be covered in the simulation by the interflow compartment.

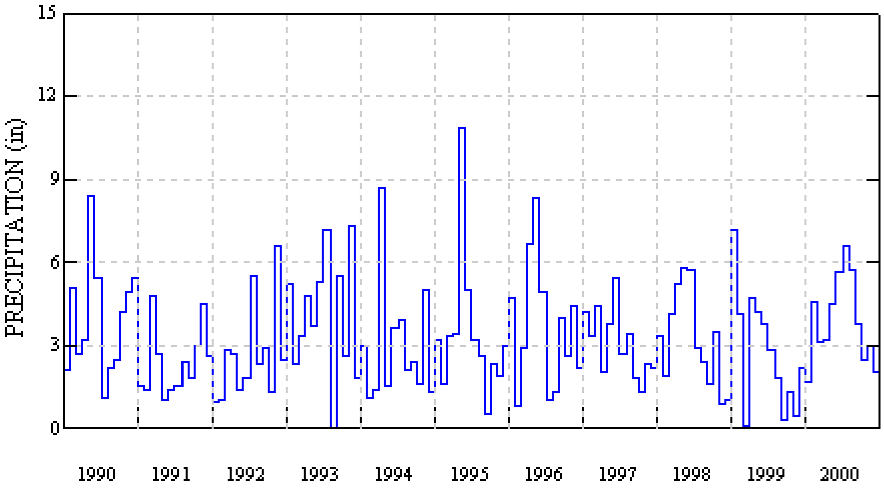
3.3.3 Data

This section describes the primary data used in HSPF model, which included meteorological land-use, and flow data. .

Meteorological Data

The Fox River Watershed has only one precipitation gauge station, IL 6159 Newton 6 SSE, located in the headwater area in Jasper County (see Figure B.3-2). This station contains precipitation data up through 1995. Four additional meteorological stations were identified in the Little Wabash River watershed as being within the study area and having recorded observations during the period of interest. These stations are located at Carmi, Cisne, Effingham, and Flora Cities. Meteorological data for these stations were obtained from the NCDC, and the data for Newton (located at the north end of the Fox River water shed) were extended to 2000. Figure B.3-4 presents the monthly precipitation data recorded at the Newton station from 1990 through 2000.

FIGURE B.3-4. MONTHLY PRECIPITATION FROM 1990 TO 2000 AT NEWTON STATION



The figure indicates that generally the period from November to March has more rainfall than the rest of year.

Land Use Data

The HSPF model was developed using land use/land cover digital data collected by USGS and converted to ARC/INFO by the EPA (EPA, 1998). The dataset was processed using the ArcView GIS embedded BASINS to determine the distribution by subwatershed using the newly delineated watershed boundaries.

The land use was divided into five categories, cropland, urban, forestland, wetland, and water. The loads from each type of land use were simulated using the HSPF model.

Flow Data

The flow data used to calibrate the HSPF model were daily flow data for four stations obtained from USGS (USGS, 2002). For each station, the flow time series from 1990 through 2000 was processed and imported into a WDM file for model calibration.

3.3.4 Determination of Parameters

Tables B.3-1 through B.3-3 summarize the hydrologic parameters used in the HSPF model.

As discussed above, the HSPF model is highly sensitive to the use of simulated meteorological data. For example, the lack of true hourly precipitation data introduces an irreducible component of uncertainty into the model predictions. Results are highly sensitive to several of the many model parameters used. Model predictions for flow are most sensitive to infiltration capacity (which controls the amount of storm runoff) and soil lower zone nominal water storage capacity (LZSN) (which is a key factor in determining the amount of water lost to evapotranspiration). Both these parameters were set in the model based on interpretation of soils data. This approach does not guarantee precise values but should adequately reflect the spatial differences between watersheds.

A number of the parameters used in the HSPF model reflect soil properties. These parameters can be derived from or related to reported soil characteristics. This approach has two important advantages: it (1) reduces the number of unconstrained (or “free”) parameters that must be addressed in calibration, and (2) helps to ensure that variability in parameter values between basins is systematic and based on physical evidence. To simulate hydrology, parameters for infiltration rate (INFILT in inches per hour) and lower zone soil storage (LZSN in inches) can be related to soil parameters and are the two most sensitive parameters. They were calibrated in HSPF model. Other parameters not as sensitive as infiltration capacity and lower zone soil nominal water storage capacity were assigned based on literature review or on the HSPF model used in Midwest regions. Other sensitive parameters assigned to calibrate the model include snow balance parameters that control heat gain and melting of the snowpack. Deep seepage losses to regional groundwater

TABLE B.3-1 HSPF PARAMETERS USED FOR IMPERVIOUS AGRICULTURE LAND SEGMENT – PARM2 IN HSPF INPUT FILE

Parameter Name	Definition	Unit	Range of Values				Determining Factors	Value used	Note
			Typical		Possible				
			Minimum	Maximum	Minimum	Maximum			
FOREST	Fraction of forest cover	None	0	0.5	0	0.95	Forest cover	Various	Impacted by snow melt simulation
LSZN	Lower zone nominal soil moisture storage	Inch	3.0	8.0	2.0	15.0	Soils and climate	4.5	Calibrated
INFILT	Infiltration capacity	Inches/ hour	0.01	0.25	0.001	0.5	Soils and land use	0.075	Calibrated
LSUR	Length of overland slope	Feet	200	500	100	700	Topography	400	Estimated from GIS
SLRUR	Slope of overland plane	None	0.01	0.15	0.001	0.30	Topography	0.01 – 0.02	Estimated from GIS
KVARY	Variable groundwater recession	None	0.1	3.0	0	5.0	Base flow variation	0.3	Estimated from Literature
AGWRC	Base groundwater recession	None	0.92	0.99	0.85	0.999	Base flow recession	0.95	Calibrated

Note:

GIS Geographical Information System

TABLE B.3-2 HSPF PARAMETERS USED FOR IMPERVIOUS AGRICULTURE LAND (PARM3)

Parameter Name	Definition	Unit	Range of Values				Determining Factors	Value Used
			Typical		Possible			
			Minimum	Maximum	Minimum	Maximum		
PETMAX	Temperature below which ET is reduced	° F	35	45	32	48	Climate	45
PETMIN	Temperature below which ET is set to zero	° F	30	35	30	40	Climate	30
INFEXP	Exponent in infiltration equation	None	2	2	1	3.0	Soils variability	2
INFILD	Ration of maximum-to-mean infiltration capacities	None	2	2	1	3.0	Soils variability	3
DEEPFR	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	Geology, GW recharge	0.2
BASEETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	Riparian vegetation	0.05
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	Marsh/wetland extent	0.05

Note:

ET	Evapotranpiration

TABLE B.3-3. HSPF PARAMETERS USED FOR IMPERVIOUS AGRICULTURE LAND (PARM4)

Parameter Name	Definition	Unit	Range of Values				Determining Factors	Value Used	Notes
			Typical		Possible				
			Minimum	Maximum	Minimum	Maximum			
CEPSC	Interception storage	Inch	0.03	0.2	0.01	0.4	Vegetation and land use	Monthly Values used	See input file In Attachment A
NSUR	Manning's roughness coefficient for overland flow	None	0.15	0.35	0.1	0.5	Surface conditions	Monthly Value Used	See input file in Attachment A
UZSN	Upper zone nominal soil moisture storage	Inch	0.10	1.0	0.05	2.0	Surface soil condition	0.1	Near surface retention
INTFW	Interflow inflow parameter	None	1.0	3.0	1.0	10.0	Soil, topography, and land use	Calibration	Monthly value
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	Soil, topography, and land use	0.7	
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	Vegetation type and density and root depth	Calibration	Monthly value

Note:

ET Evapotranpiration

3.4 Model Calibration and Validation

Simulation of the flow of water underlies all aspects of model performance; thus, reasonable hydrologic calibration is essential. During calibration, observed data are used to adjust the initial estimate of parameters so that model predictions closely match the observed data. Prior to water quality calibration, hydrologic parameters were calibrated, and it was determined if the model could reproduce flow hydrographs for given meteorological conditions.

The ability of the model to reproduce observed flow is, however, limited by the accuracy and resolution of available rainfall data. The HSPF model includes a large number of inputs and parameters. Many of the parameters can be specified on a monthly basis, further multiplying the number of adjustments that could be made to achieve calibration. In essence, the HSPF model can be thought of as "over-parameterized," meaning that typically, more parameters need to be specified than can be clearly determined from the data (Tetra Tech, Inc. 2001).

Model calibration and validation are discussed below.

3.4.1 Calibration

Flow was calibrated to USGS data from stations at Effingham, Clay, and Carmi cities along the Little Wabash River and from the station at Wayne on Skillet Creek, a tributary to the Little Wabash River. The flow was calibrated from upstream to downstream and the calibration period was from 1990 through 1992. This period includes a wide range of hydrologic conditions, encompassing both very dry and wet years. The calibration was performed using the HSPF Expert System (HSPEXP) (Lumb and others 1994). The calibration is cross-sectional in nature in that the same parameters are used for a given land use in all watersheds except when known differences in soils and topography justify the use of different parameters.

The major calibration criteria included the following:

- Predict total flow volume over the period of simulation within 10 percent
- Predict the volume of the 10-percent highest flows within 10 percent
- Predict the volume of the 50-percent lowest flows within 15 percent

After each HSPF run, the key parameters (usually the most sensitive ones) were adjusted following expert advice provided in the HSPEXP. This procedure was repeated until all three criteria were met.

Figure B.3-5 shows a typical comparison of the daily series of observed and predicted flows for the Little Wabash River at the Carmi station.

FIGURE B.3-5 SIMULATED AND OBSERVED LITTLE WABASH RIVER HYDROGRAPH AT CARMI STATION

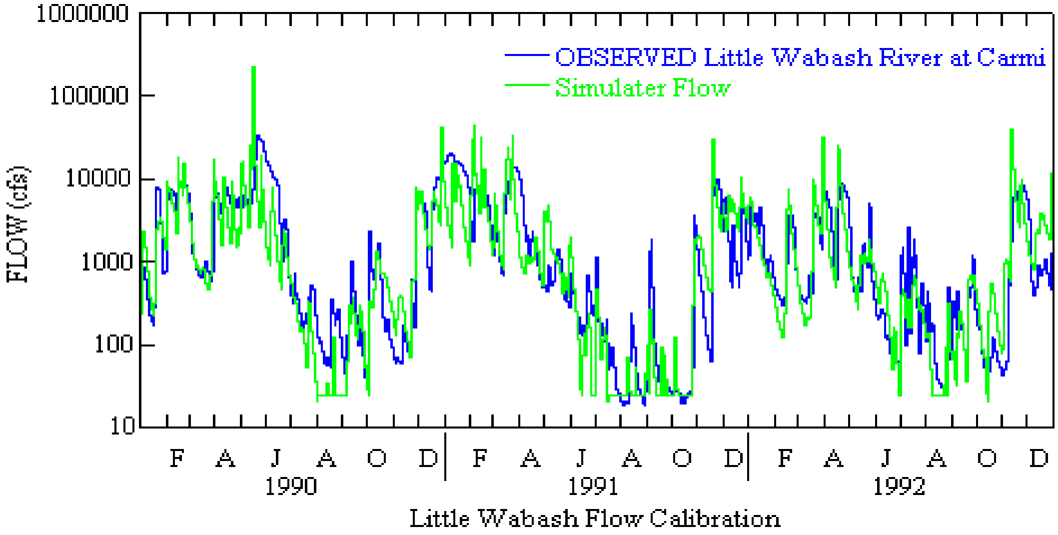


Table B.3-4 presents the model calibration results. It shows that three calibration criteria were achieved.

TABLE B.3-4. SUMMARY OF FLOW CALIBRATION RESULTS IN LITTLE WABASH RIVER.

Outlet Location	USGS Gauge No.	HSPF Sub-basin Code	Total Runoff Volume (inches)		50% Lowest Flow (inches)		10% Highest Flow (inches)	
			Observed	Simulated	Observed	Simulated	Observed	Simulated
Little Wabash River at Effingham Station	03378635	8	29.00	28.70	0.95	0.98	20.70	21.30
Little Wabash River at Clay Station	03379500	11	34.50	34.90	1.10	1.10	22.90	21.30
Skillet Creek at Wayne Station	03380500	5	34.50	34.40	0.43	0.46	26.20	24.52
Little Wabash River at Carmi Station	03381500	17	35.40	35.90	1.40	1.60	17.40	20.60

3.4.2 Validation Results

Validation involves using the calibrated model to generate the data for comparison with a second independent set of information consisting of field measurements of the same type as the data output from the model. If the test results lie within an acceptable limit, the calibrated model is considered valid. Generally, the calibrated Little Wabash River HSPF model was validated by comparing simulated flows with observed flow from four stations at Effingham, Clay, Wayne, and Carmi from 1993 to 1994. Table B.3-5 summarizes the validation statistics. It shows that the calibrated HSPF model predicted flows with an overall accuracy of 15 to 25 percent. This performance is comparable to that of the calibration.

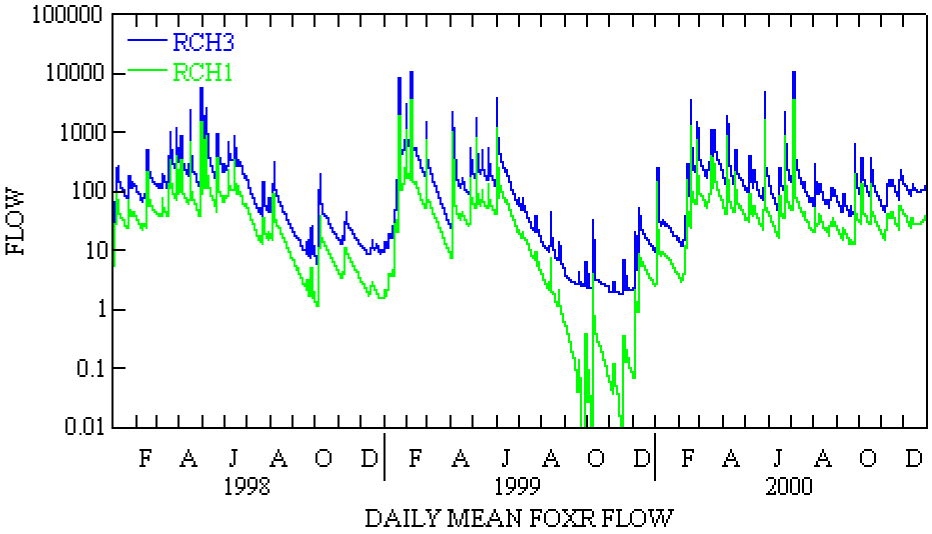
TABLE B-3-5. SUMMARY OF FLOW VALIDATION FOR LITTLE WABASH RIVER FROM 1993 TO 1994

Outlet Location	USGS Gauge No.	HSPF Sub-basin Code	Total Runoff Volume (inches)		50% Lowest Flow (inches)		10% Highest Flow (inches)	
			Observed	Simulated	Observed	Simulated	Observed	Simulated
Little Wabash River at Effingham Station	03378635	8	38.20	30.70	1.10	0.96	26.40	24.40
Little Wabash River at Clay Station	03379500	11	34.00	32.50	1.30	1.60	19.50	21.10
Skillet Creek at Wayne Station	03380500	5	37.70	31.20	0.66	1.03	27.30	22.28
Little Wabash River at Carmi Station	03381500	17	36.30	30.10	1.81	2.41	13.80	18.00

3.5 Modeled Fox River Flow Data Results

The calibrated model was used to generate flow data for the Fox River. Figure B.3-6 shows the simulated flow at the mouth of the Fox River (RCH3) and at the mouth of Sub-basin No. 1 (RCH1) (see Figure B.3-2). No flow data are available to further validate the simulated flow in Fox River. The simulated flow reflects actual flow conditions and seasonal variations given that the Fox River is a first-order tributary to the Little Wabash River. The upstream segment in Sub-basin No. 1 has a flow close to zero in October and November 1999. It was confirmed that the upstream portion of the Fox River is ephemeral during Tetra Tech's site visit. The downstream segment (RCH3) experienced low flow when there was no rainfall in the watershed for a long time. At such times, the Onley STP contributes the primary flow. The model results replicate a low flow close to the Olney STP average discharge rate of 3 cubic feet per second.

FIGURE B.3-6. HSPF MODEL PREDICTED MEAN DAILY FLOWS AT RCH3 AND RCH1



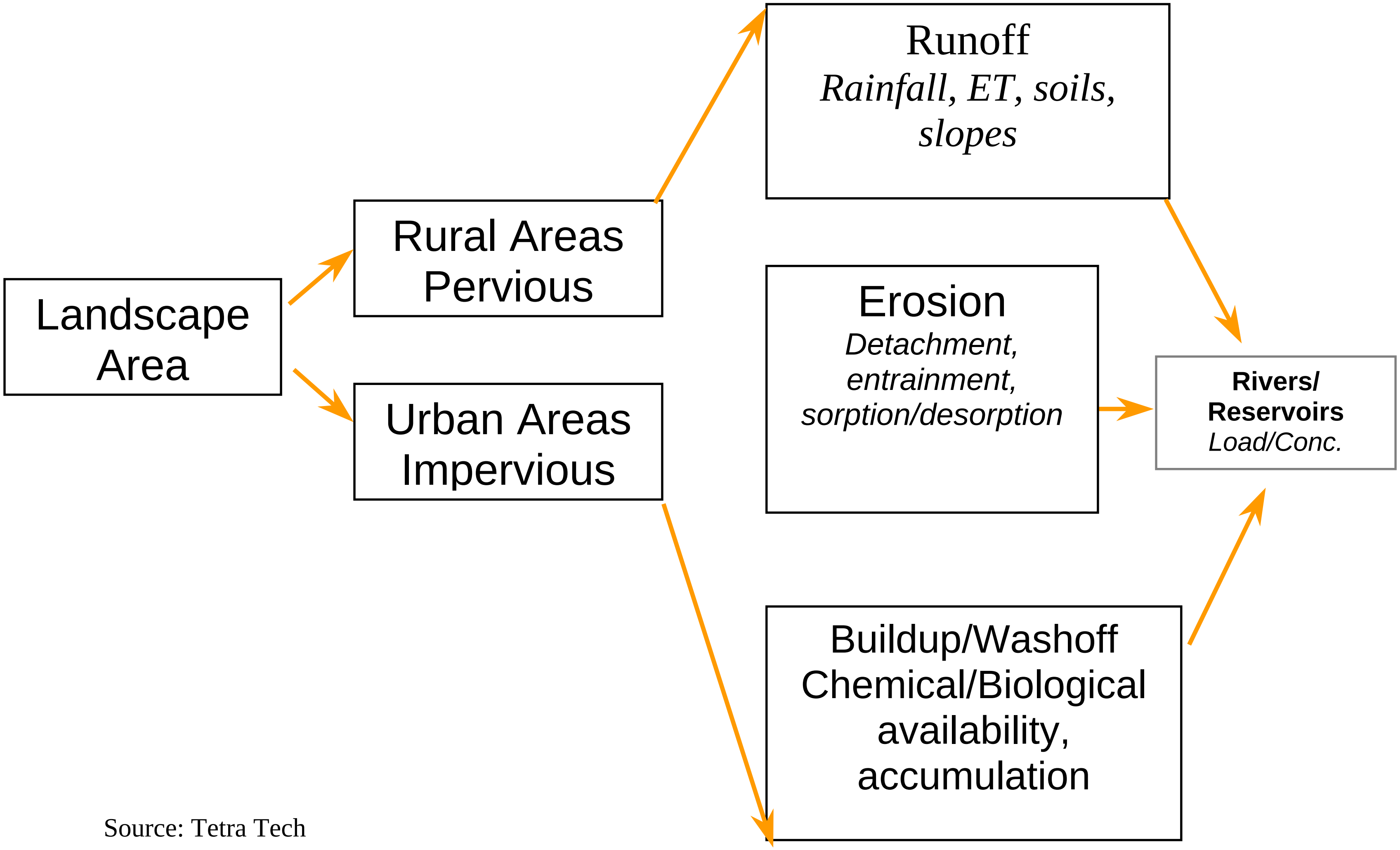
4 Water Quality Modeling

This chapter describes water quality modeling for the three water bodies in the Fox River watershed using the HSPF model based on the HSPF flow modeling of the Little Wabash River watershed described in Chapter 3 of this appendix. The purpose of developing water quality models for the Fox River watershed is to establish the link between pollutant sources and the use impairment of the water bodies. This linkage will be achieved by developing a calibrated model that simulates observed water quality parameters in the water bodies. The model will also help identify critical conditions during which water quality standards are not attained. TMDL development and implementation will focus on such critical conditions.

As discussed in Chapter 3, the hydrologic modules of the HSPF model use rainfall, evaporation, and meteorological data to calculate runoff and subsurface flow for the entire basin's land uses, including agricultural, urban, forest lands. Surface and subsurface flows ultimately drive the nonpoint source submodel, which simulates soil erosion and pollutant loads from land to water bodies such as river and reservoirs. The water body submodel simulates the routing of flow and associated pollutant loads from land through rivers and reservoirs. Figure B.4-1 is a flow chart of the pollutant loading process.

The sub-modules of the HSPF model's PERLND module are SEDMNT, PSTEM, PWTGAS, PQAL, and MSTL. SEDMNT simulates the production and removal of sediment from pervious land. PSTEMP simulates soils temperatures for the surface, upper, and lower layers of a land for use in PWTGAS, which simulates water temperature and concentrations of DO and carbon dioxide (CO_2) in surface, interflow, and groundwater outflows from a land segment. The PQUAL submodule simulates water quality constituents in outflows from pervious land using simple relationships between water and sediment yield. The simulated constituents are phosphorus, NH_3-N, nitrate and nitrite, and BOD. The behavior of a constituent in surface water outflow is considered more complex and dynamic than in subsurface flow. A constituent on the surface can be affected greatly by adhesion to the soil, temperature, light, wind, atmospheric deposition, and direct human influences. PQUAL is able to represent these processes in a general fashion. MSTL simulates the moisture content of soil layers.

FIGURE B.4-1. POLLUTANT LOADING PROCESS



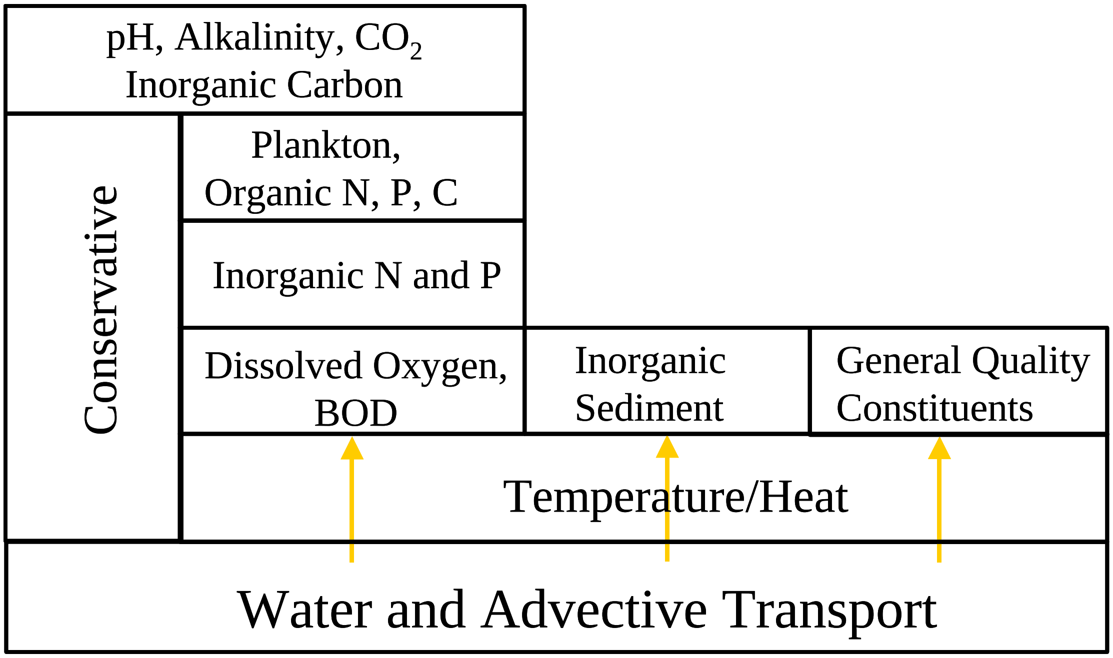
Source: Tetra Tech

The overload flow and load are imported to the water bodies. The RCHRES module simulates the flow and water quality dynamic in the closed river segment or well-mixed reservoir. The flow in the reach is assumed to be one-dimensional. Water and chemical constituents from other river segments and local sources are assumed to enter the reach through its upstream end. The following RCHRES modules were used for the Fox River watershed:

- ADCALC – Calculation of the advection of entered constituents
- CONS – Simulation of behavior of conservative constituents
- ADVECT – Simulation of advection of constituent totally entrained in water
- HTRCH – Simulation of heat exchange and water temperature
- SEDTRN – Simulation of behavior of inorganic sediment
- RQUAL – Simulation of behavior of a generalized quality constituent
- RQUAL – Simulation of behavior of constituents involved in biochemical transformation

Figure B.4-2 shows the simulation structure for in-stream water quality.

FIGURE B.4-2. SIMULATION STRUCTURE OF IN-STREAM WATER QUALITY



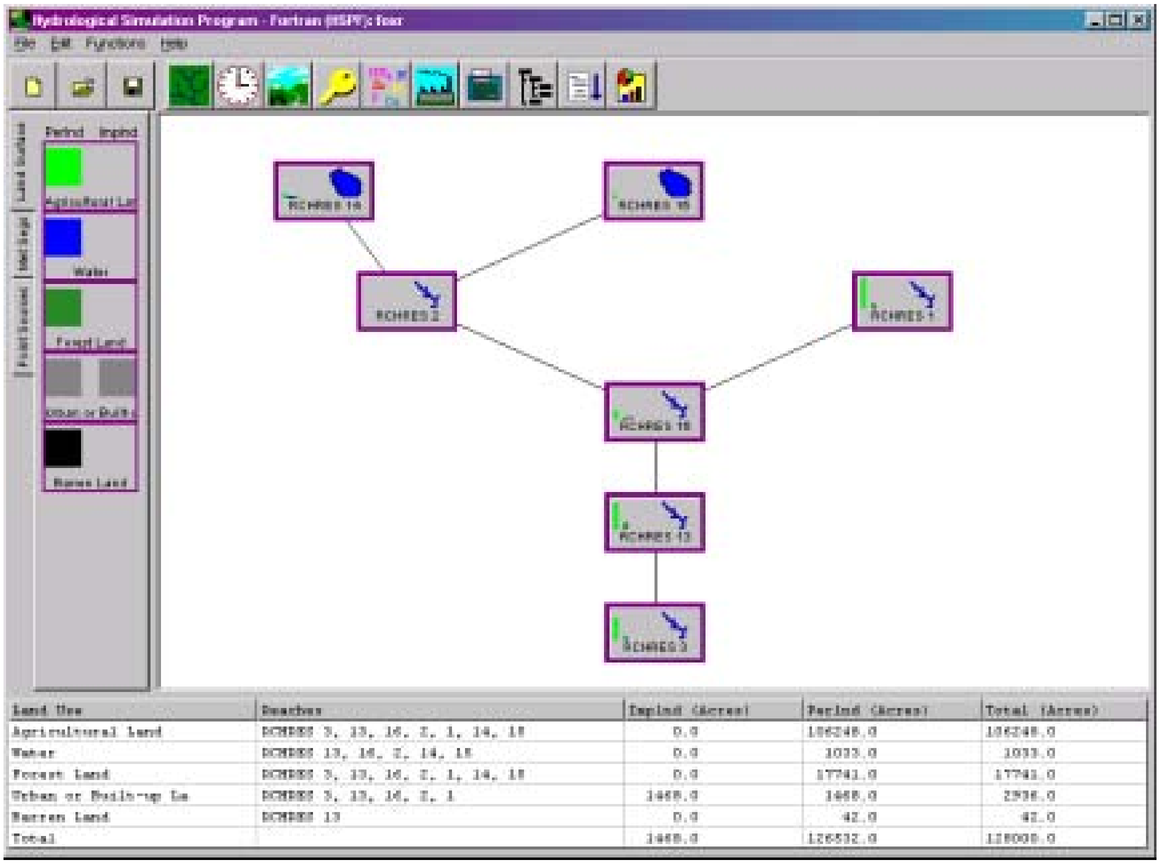
This chapter discusses water quality modeling results. The HSPF model setup is discussed first, followed by discussion of modeling results for the Fox River, Olney East Fork Lake, and Borah Lake.

Attachment A of this appendix presents the input files for the HSPF model. Because of the large volume of the HSPF model output, output results are not included. These results will be submitted to IEPA electronically.

4.1 HSPF Model Setup

Figure B.4-3 shows the schematic diagram of the Fox River watershed representing the sub-basins shown in Figure B.3-2.

FIGURE B.4-3. SCHEMATIC DIAGRAM OF FOX RIVER WATERSHED IN HSPF MODEL



Land Use	Reaches	Implnd (Acres)	Perlnd (Acres)	Total (Acres)
Agricultural Land	RCHRES 3, 13, 18, 2, 1, 14, 15	0.0	106248.0	106248.0
Water	RCHRES 13, 18, 2, 14, 15	0.0	1033.0	1033.0
Forest Land	RCHRES 3, 13, 18, 2, 1, 14, 15	0.0	17741.0	17741.0
Urban or Built-up La	RCHRES 3, 13, 18, 2, 1	1468.0	1468.0	2936.0
Barren Land	RCHRES 13	0.0	42.0	42.0
Total		1468.0	126532.0	128000.0

Seven sub-basins are delineated in the Fox River watershed, including sub-basins draining into Olney East Fork and Borah Lakes. As discussed in Chapter 4 of the TMDL report, the Fox River HSPF model was excerpted from the calibrated Little Wabash River watershed HSPF model discussed in Chapter 3 of this appendix. The hydrologic parameters are the same as those used in the calibrated model for Little Wabash River watershed. The calibrated HSPF model is considered to properly predict Fox River flow.

Water quality modeling using the HSPF model involves a series of integrated submodules that are discussed here as if they were separate. The input file in Attachment A of this appendix includes the water quality modules used, along with corresponding options and parameters. .

The parameters and rates used in the modules were based on site-specific studies and established HSPF applications in the Midwest region. A consistent set of parameters was established for the same land use across all sub-basins and parameters do not vary between basins without a plausible explanation. This approach is designed to achieve a calibrated model that is defensible and consistent with other basin studies. The fact that final model parameters provide rescannable results across multiple basins and monitoring stations also indicates that the parameter set is reasonable and appropriate. The HSPF models created for the Fox River watershed basin simulate nutrient loads from the land surface in four categories: nitrate-nitrite nitrogen (representing both the nitrate and nitrite forms of inorganic nitrogen), NH_3-N (both sorbed and dissolved), "phosphate" (representing TP), and organic matter (partitioned at the water's edge into organic carbon, BOD, organic nitrogen, and organic phosphorus). Pollutant loads from nonpoint sources are associated with various land uses. As discussed in Chapter 3 of this appendix, the watershed is represented by land uses, such as cropland or agricultural land, urban land, and forest lands. Loading coefficients were assigned to each land-use type as constant over year or on monthly basis. These coefficients were adjusted as needed to achieve better calibration results.

Point sources in the Fox River watershed include the Olney STP, Kincade Acres Mobile Home Park, and Roadmaster Corporation treatment plant. The Olney STP and Kincade Acres Mobile Park Home were represented in the model by variable time series developed using discharge monitoring records either provided by the plant or obtained from the NPDES database maintained by EPA. The flow and pollutant loads from the point sources were added to the Fox River segment as external sources.

As noted above, water quality calibration was based on finding a common set of parameters applicable across all major watersheds, with variations between watersheds based on external evidence. The data available for calibration consisted primarily of results for point-in-time grab samples collected from the listed Fox River segments. Data from these points were taken to represent the combined net impact of all upstream loads, as well as interactions in and between the water column and sediment. Few results are available for samples collected from lower order headwater streams. Continuous or event-mean observations are also not available, so it is impossible to clearly distinguish whether the lack of correspondence between model results and external observations is due to bias in the model parameters, mis-timing of temporal events, or random variability in sampling results. Because of the watershed's large spatial scale and limitations on the use of simulated data (such as precipitation data) for the Fox

River watershed, the model is not expected to accurately reproduce individual point-in-time measurements; however, to set load allocations, the model must reproduce long-term trends and averages (particularly average loads) inferred observed data. Model calibration and validation were therefore visually assessed through comparison of model-generated pollutographs to instantaneous monitoring data points. As discussed in Chapter 2 of this appendix, the monthly water quality monitoring data for the three water bodies are from 1998 through 2000. Periodic monitoring data are also available for part of 1997. For modeling purposes, data from 1998 to 1999 were used for model calibration and data from 2000 were used for model validation. In the interests of brevity, the model results and figures presented in the following sections contain both the calibration and validation periods.

4.2 Fox River Water Quality Modeling

This section discusses BOD, DO NH_3-N, and temperature water quality modeling results for the Fox River.

4.2.1 BOD

The HSPF model simulates transport of generic organic matter from the land surface. This generic organic matter is “ translated” at the stream edge into equivalent concentrations of organic nitrogen, organic phosphorus, organic carbon, and BOD. Although crop residue, leaf litter, and other sources contribute to organic matter transport, most readily bioavailable fine, organic matter comes from the land surface is and derived from soil organic matter. The basis for the organic matter simulation is therefore soil organic matter content (weighted average by major watershed), and organic matter washoff from the surface is simulated through a sediment potency factor. Basing gross organic material load calculations on soil organic matter, however, leads to consistent over-estimation of instream organic carbon, nitrogen, phosphorus, and BOD components because the model simulates these constituents only in their dissolved form within the stream. The surface washoff component must therefore address only the dissolved and readily desorbable or decomposable components of organic matter and not large debris or highly refractory compounds. Apparently, reducing the sediment potency factor by an empirical factor of 4 relative to the total organic matter content of soil yields reasonable results for croplands. Although this factor is empirical, the derivation of potency factors from the organic matter content does preserve what appears to be reasonable geographic variations in loading. More refractory components in the land surface washoff can contribute to dissolved organic matter concentrations in-stream through specification of benthic release rates, but these sources are not causally linked in the model to upland loading rates.

Dissolved concentrations of organic matter in interflow and groundwater discharge appear to exhibit a distinct seasonal component, with peaks in the early Spring following snowmelt and in late Summer to early Fall following harvest. No data are available to characterize these components; therefore, values were set through model calibration intended to match observed in-stream DO concentrations. Organic matter concentrations were then inferred from the assumed BOD content of the organic matter. Although the resulting concentrations are empirical estimates, geographic variability was preserved by assuming a constant seasonal pattern that is scaled from watershed to watershed based on soil organic matter content.

The same surface potency factor was assumed for all land uses in a watershed. Interflow and groundwater concentrations of organic matter from nonagricultural land uses were set to values ranging from 0.5 to 2.5 mg/L, consistent with experience in other modeling exercises. Model results are not sensitive to the specification of these parameters. For impervious urban lands, build-up (ACCUM of 0.196 pound per acre per day) and limiting storage (SQOLIM of 2.358 pounds per acre) were set based on data from a 1988 study (Kuo and others 1988).

Although no Illinois water quality standards pertain directly to BOD, effluent limitations for BOD must be restrictive enough to ensure that the receiving water will meet Illinois water quality standards for DO. In order to support aquatic life, Illinois water standards require that DO concentrations in rivers or lakes shall not be less than 6 mg/L during at least 16 hours of a 24-hour period nor less than 5 mg/L at any time.

Table B.4-1 summarizes the BOD values used in the HSPF model for interflow and groundwater flow. Figure B.4-4 shows the monthly mean BOD concentration at RCHRES3.

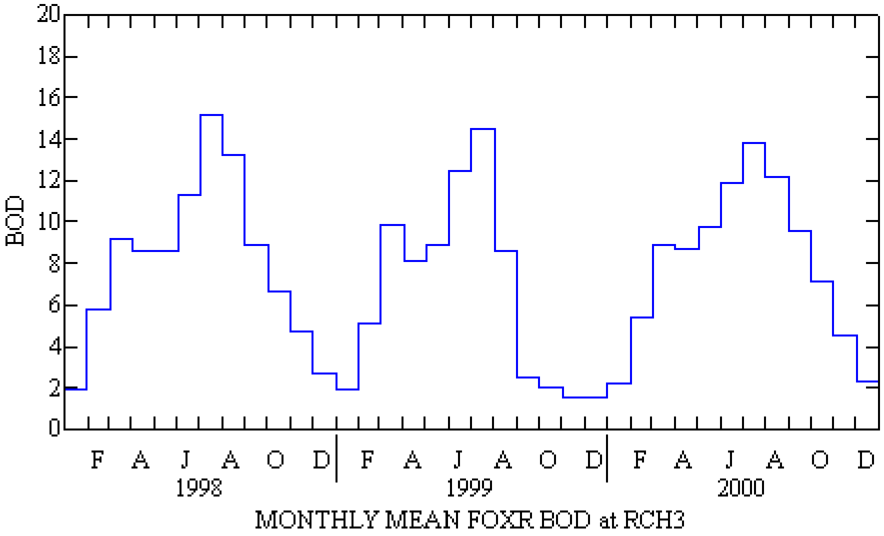
TABLE B.4-1. FOX RIVER VALUES USED IN INTERFLOW AND GROUNDWATER

Flow Component	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Interflow Concentration (lb/ft^3)												
Cropland	9.4	5.9	14	5.9	8.1	14	16.4	18.7	21.1	23.4	21.1	11.7
Urban impervious land	9.5	9.5	9.5	14	14	14	14	14	14	9.5	9.5	9.5
Forest land	1	1	1	1.5	1.5	1.5	1.5	1.5	1.5	2.5	2	1
Groundwater Concentration (lb/ft^3)												
Cropland	1.5	1.5	35	29	29	35	53	53	35	26	18	6
Urban impervious land	9.5	9.5	9.5	14	14	14	14	14	14	9.5	9.5	9.5
Forest land	1	1	1.5	1.5	1.5	1.5	1.5	1.5	2	2	1	1

Note:

lb/ft^3 Pound per cubic foot

FIGURE B.4-4. MONTHLY MEAN BOD CONCENTRATION AT RCHRES3



The figure shows that BOD concentrations are higher during the critical period from April to October than the rest of year.

4.2.2 DO

Many processes influence aquatic DO levels. The decomposition of organic matter in water through BOD consumes DO and lower DO levels. Organic materials in the mud of riverbed or lake bottom demands DO for decomposition, resulting from direct loss of oxygen from the waters. In addition, the benthos releases or resuspends the settled BOD materials, increasing BOD concentrations in water and exerting a demand on DO at a rate determined by BOD decomposition kinetics. Reaeration replenishes oxygen through diffusion from the atmosphere at the air and water interface. The net transfer of oxygen is from the atmosphere and into the water because DO levels in most natural waters are below saturation. In addition, oxygen can come from photosynthesizing algae and water plants that produce oxygen when there is a sufficient light source. During times of insufficient light, these same organisms consume oxygen. These organisms are responsible for the diurnal (daily) cycle of DO levels in lakes and streams. The HSPF model includes module to simulate each of these kinetic process.

In-stream DO concentrations are also influenced by water temperature, which determines the oxygen saturation concentration. As noted in Section 4.2.4 below, the temperature simulation appears fairly accurate. Reaeration rates are estimated using typical values in literature for flow conditions similar to that in Fox River. Algae concentrations may change rapidly over time, and are difficult to predict. Their effect is primarily visible during periods of supersaturation due to algae production. DO conditions are difficult to simulate mainly because it is difficult to predict the oxygen demand components. Oxygen demand is exerted by nonpoint source loads, point loads, and stream sediments. The model uses ultimate carbonaceous BOD as a variable for the water column component. Unfortunately, none of the data collected from the basin during the 1998 through 2000 modeling period include measurements of long-term or ultimate BOD.

In addition, carbonaceous BOD values are not available for wastewater discharges but were estimated from BOD_5 concentrations. The HSPF simulations use typical literature values for the ration of ultimate carbonaceous BOD to BOD_5 of 2.28 for secondary waste discharges and 1.47 for in-stream concentrations. Although these estimates are reasonable, the lack of measured BOD data means that only qualitative data exist for calibration of BOD in the water column.

SOD constitutes a significant portion of total oxygen demand in most rivers and no SOD data have been identified for the Fox River basin; therefore, the SOD value was a calibration parameter. Using the EPA published data as a guide, a value of 180 $mg/m^2/hr$ was determined through calibration (Bowie and others 1985).

In the Fox River watershed HSPF model, submodule OXRX in RCHRES simulates primary processes that determine the DO concentration in a reach or mixed reservoir. OXRX considered the following processes to determine DO concentration

- Longitudinal advection of DO and BOD
- Sinking of BOD material
- Benthic oxygen demand (SOD)
- Benthic release of BOD
- Reaeration through the air-water interface
- Oxygen depletion from decay of organic materials

In addition, NUTRX in the RCHRES module simulates the nitrification of DO and denitrification of BOD. The DO balance was also adjusted to account for photosynthesis and respiration by phytoplankton and benthic algae and respiration by zooplankton. Incremental adjustments were made to the BOD variable in PLANK from the death of plankton and non-refractory organic excretion by zooplankton.

Various methods have been used to calculate atmospheric the reaeration coefficient. The HSPF model has three empirical formula proven accurate for a particular set of hydraulic conditions in a river. One way to calculate reaeration is as a power function of hydraulic depth and velocity. The following general equation was used (Bicknell and others 2001):

$$\mathrm{KOREA} = \mathrm{REAK} \times (\mathrm{AVVELE}^{\mathrm{EXPREV}}) \times (\mathrm{ADVVDEPE}^{\mathrm{EXPRED}}) \times (\mathrm{TCGINV}^{(\mathrm{TW}-20)}) \times \mathrm{DELT60} \qquad \text{(B.4-1)}$$

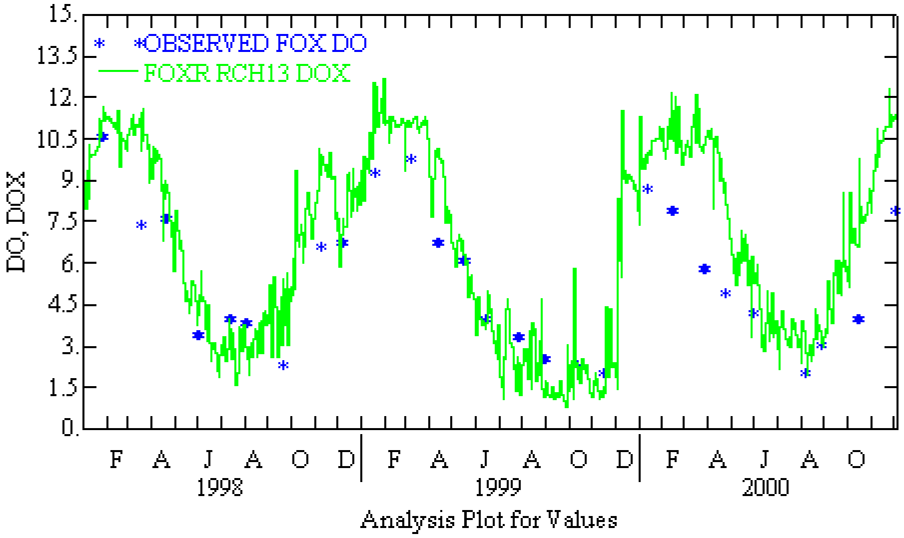
where

KOREA = Reaeration coefficient (per interval)
REAK = Empirical constant for reaeration equation (per hour) (0.538)
AVVELE = Average velocity of water (feet per second)
EXPREV = Exponent to average velocity of water (0.5)
AVDEPE = Average water depth (feet)
EXPRED = Exponent to average depth (-1.5)
TCGINV = Temperature correction coefficient for reaeration (defaulted to 1.047)
TW = Water temperature
DELT60 = Conversion factor

For much of its length, the Fox River is a gradient, pond-like stream with minimal capacity to assimilate nonpoint or point source loads. Equation B.4-1 above was used because it considers lower velocity situations at depths of greater than 2 feet, which correlates to the Fox River hydraulic conditions.

Figure B.4-5 presents the simulated DO levels for the modeling period. As the figure shows, the HSPF model closely replicated DO seasonal variations in the Fox River.

FIGURE B.4-5. FOX RIVER SIMULATED AND OBSERVED DO CONCENTRATIONS



As Figure B.4-5 shows, both the simulated and observed DO data indicate seasonal variations, with high DO levels (above the 6-mg/L standard) from November to April and low DO levels (below 6 mg/L) from May to September. The warm season from May to September is characterized by low flows and high temperatures. During such a period, point sources decrease DO levels even more because of low runoff. BOD reduction does not increase the DO concentration from June through October 1999 because then, the river flow is very low, with small rainfall. SOD then becomes the dominating factor in depleting the river's DO content.

The most extreme case of low flow for the Fox River is when there is no runoff from the watershed and the only flow in the river is contributed by the Olney STP and the Kincade Acres Mobile Home Park. Although the HSPF model simulates point sources well, it does not offer the flexibility to perform more detailed evaluation of low-flow conditions through variation of aeration, SOD, or nutrient loading rates. For this reason, the QUAL2E model was used to examine the low-flow conditions in the Fox River segment. The QUAL2E model is a steady-state water quality model that can not only simulate the DO process similar to the DO module in the HSPF model, but that can also allow a sensitivity analysis of model parameters. A sensitivity analysis is especially useful in this case because most site-specific parameters and coefficients for the listed segment are not available; therefore, rather than developing a calibrated QUAL2E model using highly uncertain model inputs, a Monte Carlo simulation was performed. This approach takes into account uncertain model inputs and develops a probability of the DO level exceeding or falling below a preset value (such as the water quality standard of 6 mg/L). Chapter 5 discusses development of the Monte Carlo simulation and results.

4.2.3 NH_3-N

NH_3-N is a constituent of the total nitrogen loading from most land uses. It is included as a separate constituent in the model primarily because of the potential for elevated NH_3-N loading from manure application, fertilizer application, feedlots, and urban runoff. Nitrification of NH_3-N decreases DO levels in the Fox River.

Internal generation of NH_3-N from the breakdown of organic matter in a stream can also be significant. Based on these considerations, the literature-based parameter values for NH_3-N were used for the Fox River HSPF model. Surface accumulation rates for NH_3-N are expected to be very low because of ammonia's rapid oxidation on the water surface and are essentially nominal values except for manure. Subsurface concentrations of NH_3-N are more important to model simulation than surface loading because tile drains are present in the watershed. Subsurface concentrations specified in the model for a reactive parameter such as ammonia are *not* equivalent to concentrations observed in groundwater because the model simulates only higher order streams and significant nitrification of NH_3-N is expected to occur in lower order feeder streams that are not included in the model. Values that should be specified in the model are therefore not actual groundwater concentrations but rather the *exerted* concentration present when flow reaches a simulated reach. In any case, as noted above, model results are not very sensitive to the nonpoint component of NH_3-N loading, which subsequently causes low DO problems.

Table B.4-2 summarizes the NH_3-N parameters used for the watershed.

4.2.4 Temperature

Temperature increases also affect DO concentrations by decreasing the DO saturation level and increasing decay and nitrification rates, which in turn increases DO consumption. Although temperature is dependent on the atmospheric temperature and not associated with a load and is not a cause of impairment, simulation of temperature in model development is key in understanding DO fluctuations. Nutrients and BOD are causes of impairment in the uses of the Fox River. If these parameters are controlled, DO concentrations should not drop below 6.0 mg/L even at elevated temperatures. The saturated concentration of DO is computed at prevalent atmospheric conditions using the following equation (Bicknell 1997):

$$\mathrm{SATDO} = \left(14.652 + \mathrm{TW} \times \left(-0.41022 + \mathrm{TW} \times \left(0.007991 - 0.7777\mathrm{E} - 4 \times \mathrm{TW}\right)\right)\right) \times \mathrm{CFPRES} \qquad \text{(B-4-2)}$$

where

SATDO = Saturated concentration of dissolved oxygen (mg/L)
TW = Water temperature (° C)
CFPRES = Ratio of site pressure to sea level pressure, dependent on mean elevation input in reaches

Equation B.4-2 shows that the higher the water temperature, the lower the DO saturation level.

The HSPF model demonstrates a good agreement between simulated and observed temperatures in the Fox River. Figure B.4-6 presents the temperature simulation results for the Fox River for the calibration period (1998 through 1999) and the validation period (2000).

FIGURE B.4-6. FOX RIVER SIMULATED AND OBSERVED WATER TEMPERATURE

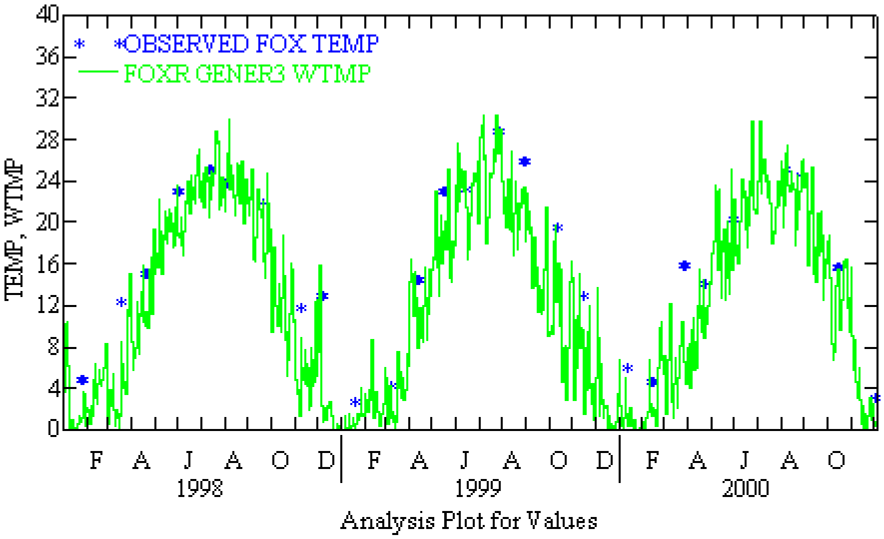


TABLE B.4-2. FOX RIVER NH_3-N VALUES USED FOR PERVIOUS LAND

Flow Component	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Accumulation Rate (lb/acre/day)												
Cropland	0.003	0.003	0.005	0.013	0.02	0.020	0.015	0.014	0.013	0.010	0.005	0.003
Urban impervious land	0.007	0.007	0.008	0.01	0.01	0.01	0.01	0.01	0.01	0.008	0.007	0.006
Forest land	0.003	0.004	0.005	0.012	0.012	0.012	0.012	0.012	0.012	0.008	0.004	0.003
Accumulation Limit (lb)												
Cropland	0.008	0.008	0.013	0.033	0.051	0.051	0.038	0.036	0.033	0.025	0.013	0.008
Urban impervious land	0.027	0.028	0.031	0.039	0.039	0.039	0.039	0.039	0.039	0.031	0.028	0.027
Forest land	0.004	0.005	0.007	0.015	0.015	0.015	0.015	0.015	0.015	0.011	0.005	0.004
Interflow Concentration (lb/ft^3)												
Cropland	0.4	0.4	0.4	0.25	0.25	0.25	0.25	0.25	0.25	0.4	0.4	0.4
Urban impervious land	0.3	0.3	0.3	0.24	0.24	0.24	0.24	0.24	0.24	0.30	0.30	0.30
Forest land	0.12	0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.12	0.12	0.12

Notes:

lb	Pound
lb/ft^3	Pound per cubic foot

4.3 Olney East Fork Lake Water Quality Modeling

Olney East Fork Lake is listed for TP and DO. This section describes the simulations of these two constituents for the lake. The description of loading here applies to both Olney East Fork and Borah Lakes.

4.3.1 TP

The HSPF simulation of TP differs significantly from the simulation of nitrogen because inorganic TP is strongly particle-reactive. The movement of inorganic TP (phosphate) is thus to a large extent controlled by the movement of sediment. In addition, phosphate's strong sorption to soil particles means that phosphate concentrations tend to be more stable over time than nitrogen concentrations and more strongly reflect the characteristics of native soils. As with nitrogen, organic TP loading is simulated separately as a fraction of the loading of generalized organic matter.

The following subsections discuss TP loads used in the model from various land uses expected for Olney East Fork Lake, including TP surface washoff potency factor for agricultural land use, interflow and groundwater TP concentrations for agricultural land use, TP parameters for other land uses, and TP parameters.

TP Surface Washoff Potency Factor for Agricultural Land Uses

The HSPF model simulates surface washoff of inorganic TP using a potency factor approach. In this approach, the TP load is estimated as a fraction of sediment yield (expressed as a potency factor in units of pounds of phosphate per ton of sediment). Because TP movement is a function of sediment movement, the sediment delivery ratio is automatically incorporated into the estimate of TP loading. Further, management practices that reduce sediment yield (such as conservation tillage) are automatically reflected in the TP simulation. The basic approach to establishing surface potency for phosphate from agricultural land is to begin with soil survey data results that reflect inorganic TP characteristics throughout the Fox River watershed.

For simulating sediment-associated washoff, the soil TP concentration is most relevant. It is also clear that washoff of TP exhibits some seasonal patterns in sediment potency as a result of cycles of fertilization, tillage, and cropping, although the seasonality is not as pronounced as for nitrate. Unlike nitrate, USDA's Soil Conservation Service determined that TP losses are highly sensitive to the fertilization cycle, with peaks associated with Spring fertilization (typically about April 20) and, where used, Fall fertilization (first week in October). It was assumed that the average of the corn and soybean results provides a reasonable estimate of seasonal patterns of the TP potency factor for agriculture throughout the basin. The potency estimate for October was adjusted upward to account for seasonal variations. The resulting estimates of TP potency thus account for seasonal variations associated with typical tillage practices. Conventional and conservation tillage both have the same potency factor; however, TP loading from conservation tillage is less because sediment delivery is also reduced.

Interflow and Groundwater TP Concentrations for Agricultural Land Use

Groundwater TP concentrations are generally low and appear to exhibit much less seasonal variability than interflow concentrations. Base flow concentrations in streams suggest that *exerted* P concentrations in streams of the Fox River basin are on the order of 0.05 to 0.15 mg/L. Higher groundwater concentrations are reasonably expected from manure application. For agricultural lands, the groundwater TP concentration was represented as the monthly average of the interflow concentration (0.05 mg/L).

As sediment is transported with interflow, TP is also transported with this sediment. Accordingly, an interflow sediment potency factor is also needed. The physical processes of runoff collection in depressions and entry into surface tile drains is likely to result in considerable sorting of the washoff, with preferential transport of the fine fraction relative to overland erosion processes. Because TP is preferentially associated with the fine fraction of soils, the TP associated with interflow sediment is likely to be enriched. Interflow sediment potencies were therefore calculated using an enrichment factor of 2. 0. Interflow sediment potency was not adjusted for seasonal variations in the model because the representation of sediment transport through surface inlets using the HSPF Special Actions function did does not lend itself easily to the seasonal variation of parameters. Examination of simulation results suggests that varying interflow potency at a scale similar to seasonal variations in surface potency for TP would not result in noticeable changes in simulation results.

TP Parameters for Other Land Uses

Only limited information is available to set TP parameters for nonagricultural land uses. For forestland, pastureland, and urban pervious areas, the surface potency factor was set at a constant (not seasonally varying) value equal to the area-weighted average of soil test results. The TP potency factor for wetland land uses was set to a constant value of 0.18 pound/ton in all basins as specified in the original model. For impervious urban land, build-up (accumulation [ACCUM] of 0.010 pound per acre per day) and limiting storage (SQOLIM of 0.12 pound per acre) values were based on values from a 1988 study of urban land TP loads (Kuo and others 1988).

TP Parameters for Cropland

Although the HSPF model simulates portions of the TP load from the land surface as sediment-associated and portions as dissolved, these components are reassigned for the lakes. Significant transformations of TP are expected to occur in transport in first-order streams that are not included within the HSPF model network. For the reaches with simulated TP values, it was necessary to redivide the total inorganic TP load into absorbed and sediment-associated components. In addition, the in-stream model works with three sediment fractions (sand, silt, and clay), whereas the upland model only simulates generalized sediment. Inorganic TP in surface washoff was empirically partitioned as 10 percent dissolved, 58 percent associated with silt, and 32 percent associated with clay. The subsurface components of TP loading were assigned entirely to the dissolved fraction; however, reactions within the stream reaches are simulated, and further sorption and desorptions in the reaches are accounted for in the model.

Table B.4-3 summarizes the inorganic TP concentrations used for cropland.

Figure B.4-7 presents the simulated phosphorus in Olney East Fork Lake. The Observed records were not long enough to validate the model. It is anticipated that this simulation can be further tested with the data out of TMDL follow-up monitory plan.

FIGURE B.4-7. OLNEY EAST FORK LAKE SIMULATED TP CONCENTRATIONS

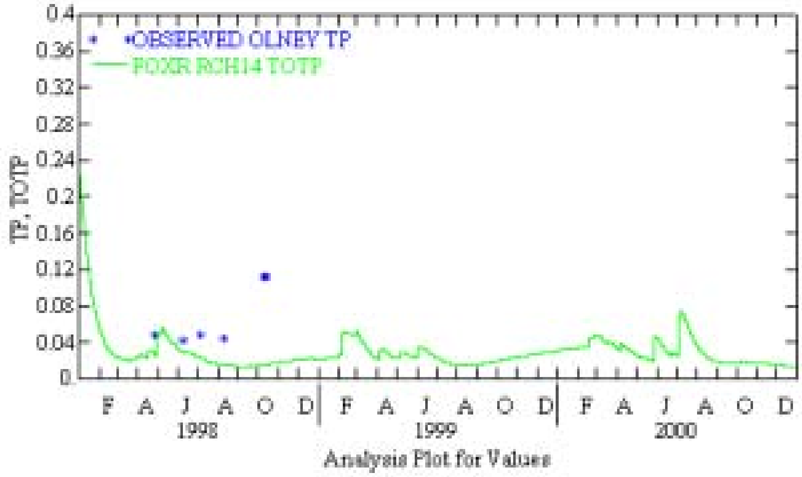


TABLE B.4-3. OLNEY EAST FORK LAKE INORGANIC PHOSPHORUS VALUES USED FOR CROPLAND

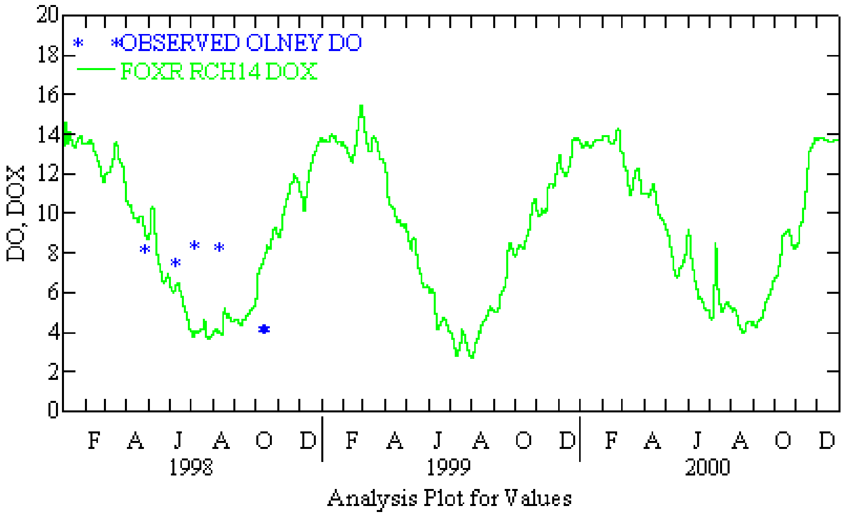
Flow Component	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
TP potency in Surface (no unit)	0.52	0.66	0.93	0.88	1.10	0.98	1.10	1.04	0.95	0.65	0.72	0.52
Interflow Concentration (mg/L)	0.09	0.11	0.15	0.16	0.19	0.17	0.19	0.18	0.17	0.12	0.13	0.09
Groundwater Flow Concentration (mg/L)	0.05	0.06	0.08	0.08	0.09	0.08	0.09	0.09	0.08	0.06	0.07	0.06

4.3.2 DO

When nutrients such as nitrate and phosphate are released into the water, aquatic plant growth is stimulated. Eventually, the increase in plant growth leads to an increase in plant decay and a greater "swing" in the DO level. The result is an increase in microbial populations, higher levels of BOD, and increased oxygen demand by photosynthetic organisms during the dark hours. This reduces DP concentrations, especially just before dawn. All sampling of DO in the Fox River occurred about this time.

The DO processes discussed for the Fox River are applicable and were used to simulate DO levels in Olney East Fork Lake except that in a lake, calculation of reaeration depends on surface area, volume, and wind speed. Surface area and volume are calculated in the hydrologic simulation. The wind speed time series input were based on data obtained from meteorological stations. It was assumed that the Olney East Fork Lake is well mixed. No stratification is considered in the model. Figure B.4-8 shows the simulated DO results for Olney East Fork Lake.

FIGURE B.4-8. OLNEY EAST FORK LAKE SIMULATED DISSOLVED OXYGEN CONCENTRATION



4.4 Borah Lake Water Quality Modeling

Borah Lake is listed for elevated TP and pH. This section presents the modeling results for TP in Borah Lake. Ch-a levels were also simulated to evaluate its correlation with TP.

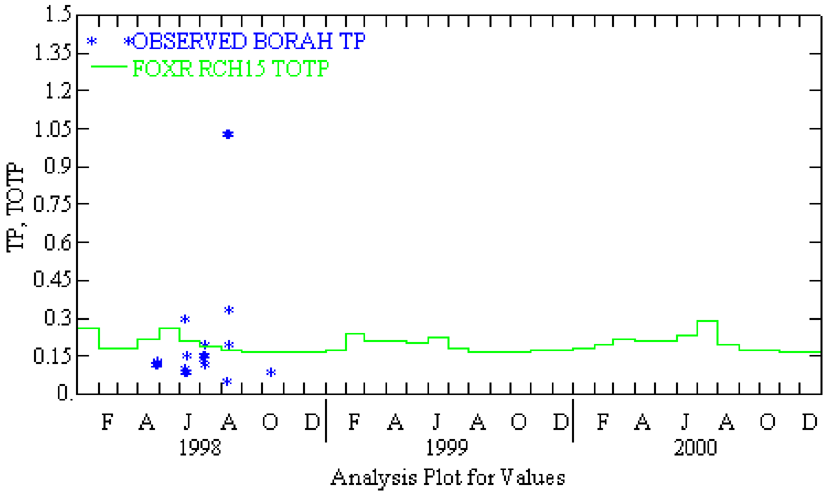
4.4.1 TP

The TP loading mechanism in Borah Lake is similar to that of Olney East Fork Lake. The parameters used for each land-use type for Borah Lake are therefore the same as those shown in Table B.4-4. Figure B.4-0 shows simulated TP concentration.

4.4.2 Ch-a

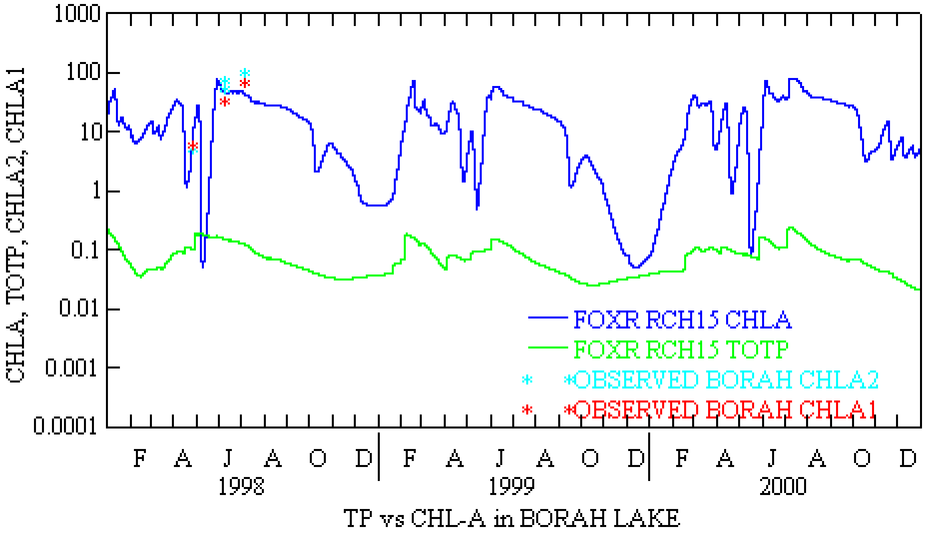
Ch-a is a dominant photosynthetic pigment in algae and is often used as a surrogate for algal density. Although it is not a particularly accurate surrogate for algal density, it is the only parameter related to algae that is regularly monitored in the Fox River basin. Simulation of algae is important because algae (through photosynthesis and respiration) significantly affects the DO balance in lakes. Algae also play a significant role in the cycling of nutrients, taking up inorganic nutrients and converting them to organic forms.

FIGURE B.4-9. BORAH LAKE SIMULATED TP CONCENTRATION



Ch-a generally applies to floating or planktonic algae. In streams and rivers, rooted macrophytes and benthic or periphytic algae also typically affect Ch-a to a significant degree. The HSPF model does not include macrophytes, but their impact was approximated through the benthic algae simulation. No data from the Fox River are available on benthic algae, so this component of the model is essentially a free calibration parameter. The HSPF model simulates the biomass of algae and internally converts this number to an approximate Ch-a concentration. Algal growth is estimated based on light penetration, nutrient availability, and temperature. Algal concentration depends on the balance between growth, death, and advection. Benthic algal growth rates are simulated proportionally to planktonic algal growth. Benthic algae are not advected but can be removed by scouring mechanisms. Observations on Ch-a are limited for the Fox River basin. Algal parameters for the model were thus based primarily on literature values and past experience. The key calibration parameters varied to achieve an approximate correlation to conditions in the Fox River basin were LI TSED (the multiplier on suspended sediment concentration used to estimate light extinction), and CLALDH (the Ch-a concentration above which increased algal death occurs). To comply with the general calibration philosophy adopted for the model, one set of parameters was applied across all basins. Some distinctions were made between lakes, smaller streams, and major rivers. Ch-a parameters for plankton are summarized in Figure B.4-10 below.

FIGURE B.4-10. BORAH LAKE SIMULATED CH-A CONCENTRATIONS



5 DO MODELING USING QUAL2E MODEL

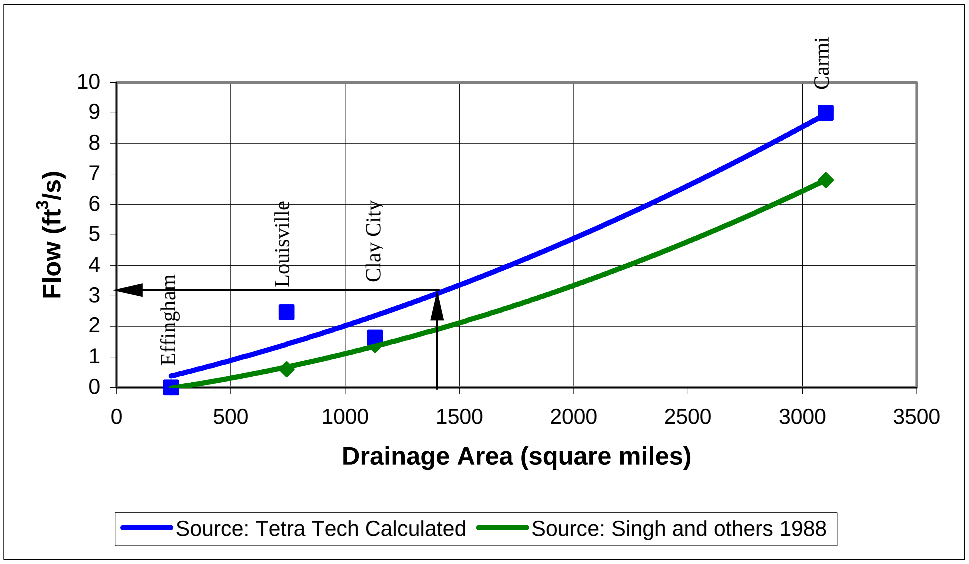
As described in Chapters 3 and 4, the HSPF model was used to simulate hydrologic and water quality conditions in the Fox River watershed. HSFP model development focused on estimating nonpoint source runoff and pollutant loadings for the watershed but did not evaluate low-flow conditions in the Fox River when source runoff does not exist. Instead, the QUAL2E model was used to evaluate the probability that Illinois DO standard would be exceeded during low-flow conditions in the Fox River when Olney STP effluent is the primary source of flow. More specifically, the QUAL2E model was used to determine whether DO is a problem in the Fox River during low-flow conditions from May through October and whether NH_3-N and BOD loads from the Olney STP affect the DO concentrations in the river.

As part of the modeling, full flow-time series for the model periods were generated and used to estimate pollutant loads. For the purposes of this report, the flow data from the four USGS stations were analyzed to derive the 7Q10 flow for the Fox River (ISWS 1988). Figure B.5-1 plots flow against drainage area for the Little Wabash River. The differences between calculated 7Q10 flows and measured 1988 flows may be attributable to the use of an extended flow data series up to 1998. The ISWS flow data extend up to 1988 (ISWS 1988).

The drainage area at the confluence of the Fox and Little Wabash Rivers is 1,394 square miles. According to Figure B.5-1, the corresponding 7Q10 flow at the confluence is 3.1 ft^3/s. The BASINS file for the Little Wabash River lists a 0.88 ft^3/s 7Q10 flow for the Fox River. The basis of this value is unknown (EPA 1998).

Recent data from the major discharger in the Fox River watershed, the Olney STP, indicate an average flow of 1.8 MGD, or 2.78 ft^3/s; therefore, the 7Q10 flow at the confluence consists of both natural hydrologic flow and discharge from the Olney STP. The Olney STP flow of 2.78-ft^3/s plus the hydrologically estimated 7Q10 flow of 0.4 ft^3/s for the Fox River segment equals 3.18 ft^3/s, which is close to the estimate of 3.1 ft^3/s. According to Figure B.5-1, the ISWS estimate from the USGS stations appears to underestimate the 7Q10 flow at the confluence because the flow of 2.0 ft^3/s is less than the Olney STP flow of 2.78 ft^3/s.

FIGURE B.5-1. LITTLE WABASH RIVER 7Q10 FLOW VERSUS DRAINAGE AREA



The QUAL2E model simulated low-flow DO conditions from May through October in the Fox River along an 18.5-mile segment starting at the Olney STP and ending at the river's confluence with the Little Wabash River. Because of limited data, a calibrated QUAL2E model was not developed. Instead, a Monte Carlo simulation using QUAL2E model was developed to estimate the probability that DO concentrations would be less than or equal to 6 mg/L during low-flow conditions. Key steps taken to develop the QUAL2E Monte Carlo simulation included the following:

1. Determining key QUAL2E input parameters that have the greatest impact on DO concentrations
2. Reviewing QUAL2E input parameters that have been collected along the Fox River
3. Assuming values for key input parameters that have the greatest impact on DO and that have not been established for the Fox River
4. Assigning percent variations for key hydraulic, reaction rate, and reaction coefficient input parameters
5. Running three Monte Carlo simulations for average, minimum, maximum Olney STP load conditions

Table B.5-1 shows the key parameters having the greatest impact on DO. The key parameters were selected by performing a basic sensitivity analysis with the steady state QUAL2E. Of the key parameters, BOD, reaeration, and SOD values have the greatest effect on DO concentrations. The data source column in Table B.5-1 distinguishes between actual and assumed values for each key input parameter. In addition, the table specifies the percent variation applied for the hydraulic data and reaction rates and coefficients when conducting the three Monte Carlo simulations. All percent variations were based on QUAL2E model default values except for BOD decay. The default percent variation used for BOD decay was 0.15, but the percent variation used was 0.50 to be conservative because of the high level of uncertainty of the actual BOD decay rate in the Fox River.

As mentioned in Step 5, three separate Monte Carlo simulations were run for the average, minimum, and maximum load conditions. For this analysis, river in-flow was assumed to be the same as Olney STP effluent. Three in-flow or load conditions were defined as follows:

1. Average: Assumed an average DO, BOD, and NH_3-N effluent concentration from the Olney STP from May through October
2. Minimum: Assumed a maximum DO concentration and minimum BOD and NH_3-N effluent concentrations from the Olney STP from May through October
3. Maximum: Assumed a minimum DO concentration and maximum BOD and NH_3-N effluent concentrations from the Olney STP from May through October

Average flow and temperature were assumed for each condition. Average flow was based on the average Olney STP discharge flow, and average temperature was based on the average summer temperatures of Fox River water. Olney STP effluent temperatures are not monitored.

As indicated in Figure B.5-2, QUAL2E Monte Carlo simulations indicate about a 95 percent chance that DO concentrations will fall below 6 mg/L during low-flow conditions from May through October, regardless of Olney STP discharge loads. DO concentrations in Figure B.5-2 represent DO concentrations at the downstream end of the segment, where concentrations are expected to be lowest based on preliminary QUAL2E modeling results.

TABLE B.5-1. QUAL2E INPUT PARAMETERS FOR LOW FLOW SIMULATION

Parameter	Value	Percent Variation[a]	Data Source
Hydraulic Data			
Roughness (Manning's coefficient)	0.05	10	BASINS data (EPA 1998)
Side Slopes (ft/ft)	0.15	5	Estimated during site visit
Width (feet)	3	5	Estimated during site visit
Slope (ft/ft)	0.0007	5	BASINS data (EPA 1998)
Reaction Rates and Coefficients			
BOD decay rate (/day)	3	50	Assumed from literature review (EPA 1985)
SOD rate (g/ft2-day)	0.4	20	Assumed from literature review (EPA 1985)
Reaeration Rate (per day)	8 to 12[b]	15	Assumed from literature review (EPA 1985)
Inflow Conditions (Olney STP Effluent)			
Flow (ft^3/s)	2.78	NA	Average effluent flow from Olney STP discharge monitoring reports for 1999 through 2001 (Olney STP 2001)
Temperature (°F)	60	NA	Average in-stream temperature measured by IEPA in 1999 and 2000 (IEPA 2001)
DO concentration (mg/L)	Average 7.1 Minimum 6.0 Maximum 9.5	NA	Value from monthly discharge monitoring reports from 1999 through 2001 (Olney STP 2001)
BOD concentration (mg/L)	Average 1.04 Minimum 1.0 Maximum 2.0	NA	Value from monthly discharge monitoring reports from 1999 through 2001 (Olney STP 2001)
NH_3-N concentration (mg/L)	Average 0.08 Minimum 0.02 Maximum 0.78	NA	Value from monthly discharge monitoring reports from 1999 through 2001 (Olney STP 2001)

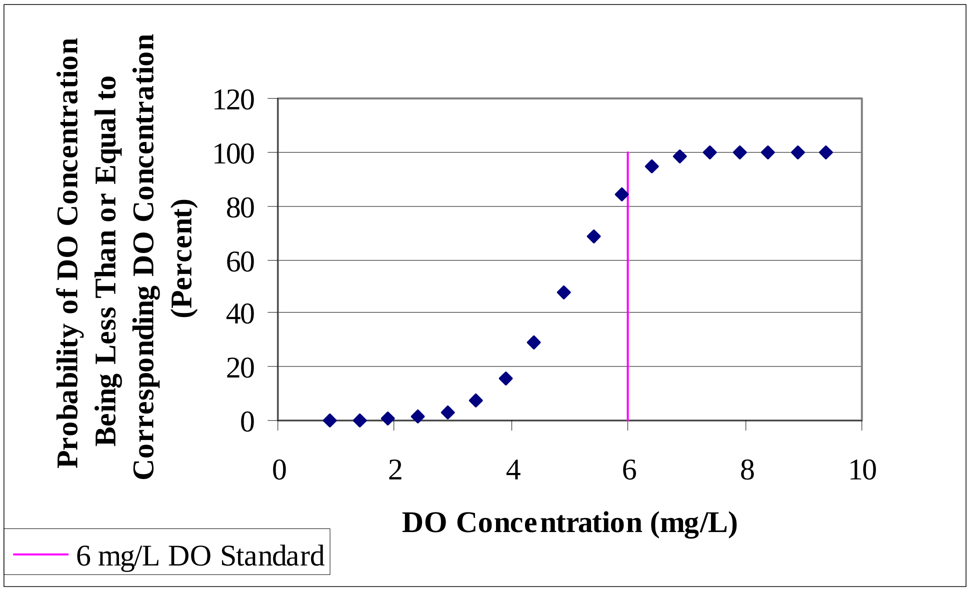
Notes:

BOD	Biological oxygen demand
DO	Dissolved oxygen
ft/ft	Foot per feet
ft^3/s	Cubic foot per second
g/ft2-day	Gram per foot squared-day
mg/L	Milligram per liter
NA	Not applicable
NH_3-N	Ammonia nitrate
SOD	Sediment oxygen demand
STP	Sewage treatment plant

[a] Inflow condition variations were not considered in the Monte Carlo simulation because separate simulations where run for the average, maximum, and minimum inflow conditions.

[b] Reaeration rate is based on the Owens, Edwards, Gibbs, and the Foree equations (EPA 1985). The range reflects the variation in reaeration rates along different portions of the segment.

FIGURE B.5-2. MONTE CARLO SIMULATION RESULTS FOR AVERAGE, MINIMUM, AND MAXIMUM BOD AND NH_3-N LOADS FROM OLNEY STP



A variety of factors could affect the DO levels, and the Monte Carlo simulation did not distinguish the relative impact of each factor; however, this analysis concludes that (1) DO is a problem in the Fox River during low-flow conditions and (2) BOD and NH_3-N loads from the Olney STP have almost no impact on the DO concentrations in the river. Instead, the following significant factors contribute to low DO concentrations during low flow: (1) elevated temperature, which decreases the DO saturation level and increases the BOD decay rate; (2) low reaeration, which results from low turbulence in the river; and (3) high SOD, which results from residual loads of organic material from the point source discharge and nonpoint source runoff. Of these three causes of low DO, high SOD is the only factor linked to a pollutant load, namely, BOD load. Decreasing loads of organic material in runoff and Olney STP effluent lowers SOD. HSPF model development focused on nutrient and BOD loads to the Fox River; therefore, load reductions estimated by the HSPF model to increase DO levels during runoff events will also increase DO levels during low flow.

The QUAL2E model steady-flow analysis indicates that the Olney STP is not necessarily the cause of DO violations during low flow; however, this result was based on very uncertain inputs, such as aerobic coefficients and SOD rates, which have not been measured in the Fox River. A Monte Carlo analysis that included variability of all the most sensitive input values indicated that even when pollutant loads are reduced dramatically, DO violations could still occur because of natural conditions in the river. In particular, the probability of a DO violation during low flow was about 50 percent on an annual basis. It was therefore concluded that the river segment is naturally susceptible to low DO during low-flow periods and that load reductions from the Olney STP will not significantly impact DO levels. The load allocations for the Olney STP should therefore remain at the permitted limits.

6 POLLUTANT LOAD ESTIMATION AND TMDL ALLOCATION

Once the HSPF model was calibrated and validated, the models were used to estimate pollutant loads and determine TMDL allocations for the Fox River, Olney East Fork Lake, and Borah Lake. The allocations were based on estimating seasonal pollutant loads during both the critical period from May to October and from November to April. Specifically, the HSPF model was used to determine loads of BOD and NH_3-N to the listed Fox River segment, TP and BOD loads to Olney East Fork Lake, and TP loads to Borah Lake. The seasonal loads were computed using the calibrated HSPF model based on available data from 1998 to 2000. Percent reductions needed for compliance were calculated by comparing existing seasonal loads and the maximum allowable loads needed to achieve compliance with the water quality standards.

This chapter discusses the estimation of loads to the listed water bodies and determination of load reductions needed to comply with the water quality standards.

6.1 Fox River

This section discusses the load estimation and allocation for listed Fox River segment.

6.1.1 Load Estimation

To calculate seasonal loads to the Fox River, the calibrated HSPF model was run based on available data from 1998 through 2000, which is also the period for model calibration and validation. This period was selected because it represents a typical wet year, dry year, and intermediate year. The information required for continuous simulation were records of precipitation, wind, solar radiation, temperature, and potential evaporation at hourly time intervals. These data were obtained from the USGS gauge station located at the north end of the Fox River watershed (see Figure B.2-2). The HSPF model generated hydrographs and pollutographs for 1998 through 2000 for the Fox River, Olney East Fork Lake, and Borah Lake that were used to determine seasonal average flows and concentrations.

The mean seasonal and daily loads were calculated based on the average seasonal loads from 1998 to 2000. The period from May to October was considered a critical season because periodic water quality monitoring conducted in the Fox River and HSPF model simulation indicate that DO concentrations during this period were below the 6-mg/L standard most of the time. For each modeling year, the seasonal and daily loads for BOD and NH_3-N were computed by multiplying seasonal predicted mean flows and concentrations. Table B.6-1 summarizes the seasonal BOD and NH_3-N loads in the listed Fox River segment.

TABLE B.6-1. SUMMARY OF SEASONAL AND DAILY BOD AND NH_3-N LOADS IN FOX RIVER

Year	May to October (Critical Season)					November to April				
	Mean Flow (ft^3/s)	BOD		NH_3-N		Mean Flow (ft^3/s)	BOD		NH_3-N	
		Total (lb)	Daily Load (lb/day)	Total (lb)	Daily Load (lb/day)		Total (lb)	Daily Load (lb/day)	Total (lb)	Daily Load (lb/day)
1998	49	479,327	2,619	22,825	125	-	-	-	-	-
1999	20	195,644	1,069	9,316	51	179	882,890	4,824	33,581	184
2000	63	616,277	3,367	29,364	160	330	1,627,600	8,894	67,525	370
Mean	44	430,416	2,352	20,496	112	254	1,255,250	6,846	50,553	277

Notes:

-	Complete data for November to April 1998 not available
BOD	Biological oxygen demand
ft3/s	Cubic feet per second
lb/day	Pound per day
NH3-N	Ammonia-nitrogen

6.1.2 Load Reductions

The calibrated HSPF model linked the DO impairment in the Fox River to nonpoint source BOD, SOD, and NH_3-N loads from the Fox River watershed. Occurrences of the low flows and lower reaeration of the river can also result in the low DO concentrations, but these phenomena affect DO not through loads but through natural alluvial geomorphologic process that result in a flatter slope in the river. In addition, high temperature and high SOD rates resulting from residual effects of point and nonpoint source organic materials can contribute to low DO. Low flows and algal respiration also cause extreme diurnal variations in the river, which makes it difficult to maintain a DO concentration above 6.0 mg/L at all times.

The QUAL2E model simulation indicates that during low-flow conditions when there is no runoff from the watershed and only the Olney STP and Kincade Acres Mobile Home Park contribute to flow, the probability of DO violation in the Fox River is about 50 percent. On the other hand, given hydrodynamic conditions in the river, preseason or previous loads can settle to the bottom of the river and cause high SOD rates, which will dominate the DO depletion dynamic during low-flow and high-temperature conditions. Load reductions therefore are needed for both the critical period and during the rest of the year.

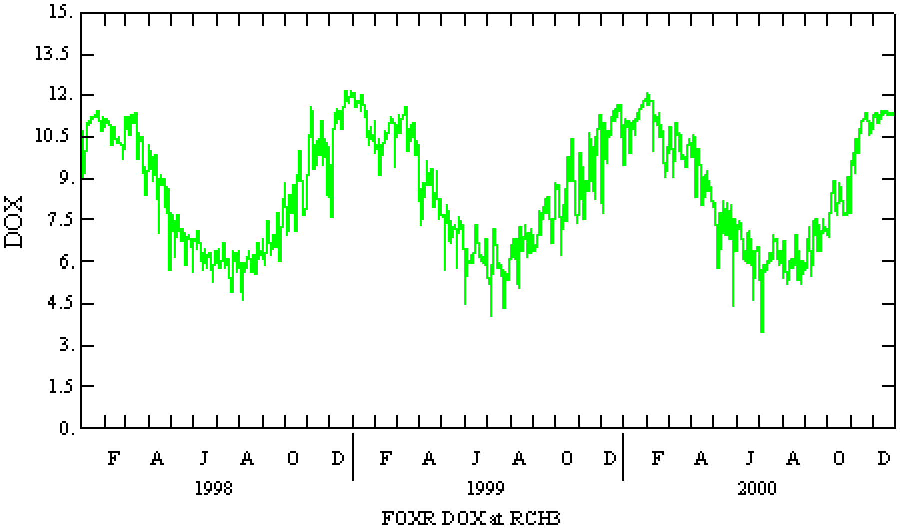
A DO TMDL modeling endpoint of 6.0 mg/L was used to ensure that DO concentrations would exceed 6.0 mg/L during any 16-hour period. Because of diurnal variations in DO concentrations in the Fox River, the average DO concentration was evaluated to compare with the endpoint and determine the DO standard compliance. The calibrated HSPF model revealed that BOD loading from nonpoint and point sources most significantly impacts DO concentrations.

The load capacity is the maximum allowable loads that the Fox River can receive without exceeding the 6.0-mg/L DO endpoint. DO is the indicator of the effect exerted by BOD and NH_3-N loads. The calibrated HSPF model was run under different scenarios combining reductions of BOD and NH_3-N loads. It was found that the combination of reducing BOD and NH_3-N loads by 75 percent during the critical season and by 70 percent from November through April result in the average DO concentrations equal to or higher than 6 mg/L.

DO concentrations are sensitive to SOD which in turn is determined by the amount and composition of BOD loads. Although the organic composition of BOD loads in the Fox River watershed is not known, it can be assumed to vary seasonally and be fairly constant from year to year because no major changes in sources are occurring in the watershed. In general, the relationship between SOD and BOD rates is nonlinear. For the purpose of this analysis, the simplest relationship between SOD and BOD rates can be assumed to be linear because SOD rates tend to increase or decrease along with BOD rates if the organic composition of BOD loads remains unchanged. In the Fox River watershed, reductions in BOD rates were assumed to produce proportional reductions in SOD rates.

The BOD loads contribute to the increase of SOD through organic matter settling, which subsequently decreases the DO concentration. Although there is no measurement to verify the relationship of BOD to SOD reduction, the HSPF model simulated DO concentration based on a 75 percent of reduction of SOD, which resulted in a 75 percent reduction of BOD. Figure B.6-1 presents the resulting DO concentrations and indicates that the average DO concentration complies with the 6-mg/L endpoint.

FIGURE B.6-1. DO CONCENTRATION AFTER BOD LOAD REDUCED BY 75 PERCENT



According to the calibrated HSPF model, the NH_3-N concentrations of the Fox River exceeded the 0.41-mg/L guideline for NH_3-N at 0.47 mg/L on June 15, 1999; 0.59 mg/L on October 13, 1999; and 0.46 mg/L on November 11, 1999. Low DO concentrations were measured on the same days. The HSPF model also determined that the reduction of NH_3-N could increase DO concentration in Fox River, although not as significantly as BOD reduction. Therefore, reductions in BOD in conjunction with NH_3-N loads are needed to meet the DO standard. Table B.6-2 summarizes the proposed seasonal load reductions in the Fox River watershed required to bring the listed segment in compliance with the DO water quality standards.

TABLE B.6-2. BOD AND NH_3-N SEASONAL LOAD REDUCTIONS NEEDED

Pollutant Load	May through October (Critical)		November to April	
	BOD (lb/day)	NH_3-N (lb/day)	BOD (lb/day)	NH_3-N (lb/day)
Existing	2,352	112	6,846	277
Maximum Allowable	588	28	2,054	83
% Reduction	75	75	70	70

Notes:

BOD	Biological oxygen demand
lb/day	Pound per day
NH3-N	Ammonia-nitrogen

6.2 Olney East Fork Lake

This section describes the load estimation and TMDL allocation for Olney East Fork Lake.

6.2.1 Load Estimation

Monitoring data and HSPF model simulations indicate that TP concentrations in Olney East Fork Lake exceeded the 0.05-mg/L standard. The model was also used to assess DO concentrations to evaluate the effect of elevated TP concentrations and elevated BOD loads from watershed runoff. Table B.6-3 summarizes the seasonal TP and BOD loads for each year.

TABLE B.6-3. SUMMARY OF SEASONAL TP AND BOD LOADS IN OLNEY EAST FORK LAKE

Year	May to October (Critical Season)					November to April				
	Mean Inflow (ft^3/s)	TP		cBOD		Mean Inflow (ft^3/s)	TP		cBOD	
		Total (lb)	Daily Load (lb/day)	Total (lb)	Daily Load (lb/day)		Total (lb)	Daily Load (lb/day)	Total (lb)	Daily Load (lb/day)
1998	4.1	18,877	103	25,010	137	-	-	-	-	-
1999	2.0	9,205	50	12,200	67	6	64,882	354	34,137	186
2000	4.9	22,553	123	29,890	163	16	172,935	945	91,034	498
Mean	3.3	15,189	83	20,130	110	11	118,950	650	62,585	342

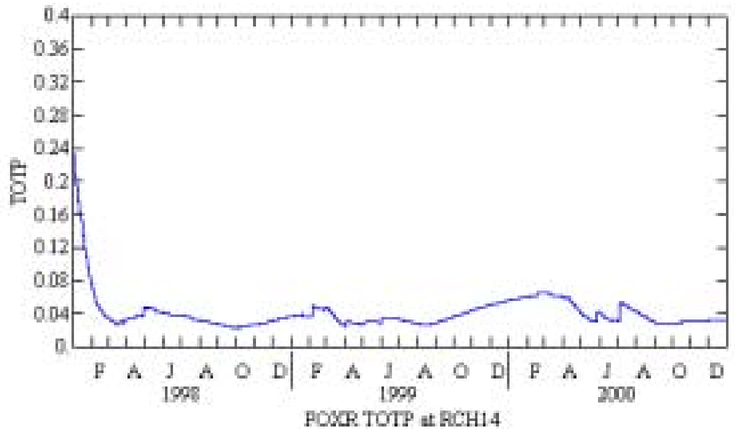
Notes:

-	Complete data for November to April 1998 not available
BOD	Biological oxygen demand
ft3/s	Cubic feet per second
lb/day	Pound per day
NH3-N	Ammonia-nitrogen
TP	Total phosphorus

6.2.2 Load Reductions

TP is a relatively stable constituent in water bodies; therefore, the reduction of TP is proportional to the margin of existing concentrations and the target concentration of 0.05 mg/L. Figure B.6-2 shows the TP concentrations in Olney East Fork Lake after TP loading was reduced by 75 percent.

FIGURE B.6-2. TP CONCENTRATIONS AFTER PHOSPHORUS LOAD REDUCED BY 75 PERCENT



As the figure indicates, the average TP concentration can be brought into compliance with 0.05 mg/L. High TP concentrationsin January resulted from specifying a high initial concentration in the model.

Table B.6-4 summarizes the seasonal load reductions of TP and BOD. The percentage of TP load reduction is equal to the percent reduction of concentration based on the assumption that the loads are proportional to seasonal flow. The available data show only one DO violation observed at the surface of the lake on October 13, 1998. Although it is not known whether the DO violations in the lake are more frequent, a 45 percent BOD reduction along with a 75 percent TP load reduction are expected to bring the lake into compliance with the DO standard.

TABLE B.6-4. TP AND BOD SEASONAL LOAD REDUCTIONS NEEDED

Pollutant Load	**May through October (Critical)**		**November to April**	
	TP (lb/day)	**cBOD (lb/day)**	**TP (lb/day)**	**cBOD (lb/day**
Existing	83	110	650	342
Maximum Allowable	21	60	162	188
% Reduction	75	45	75	45

Notes:

BOD	Biological oxygen demand
lb/day	Pound per day
TP	Total phosphorus

6.3 Borah Lake

This section describes the load estimation and allocation for Borah Lake.

6.3.1 Load Estimation

As both monitoring and simulated data show, elevated TP concentrations in Borah Lake are the primary concern and are directly linked to the TP loads from the watershed. Table B.6-5 summarizes the existing seasonal loads.

TABLE B.6-5. SUMMARY OF SEASONAL AND DAILY TP AND BOD LOADS IN BORAH LAKE

Year	May to October (Critical Season)			November to April		
	Mean Inflow (ft^3/s)	TP		Mean Inflow (ft^3/s)	TP	
		Total (lb)	Daily Load (lb/day)		Total (lb)	Daily Load (lb/day)
1998	1.7	7,972	44	-	-	-
1999	1.0	4,989	26	2.5	16,832	92
2000	2.1	9,847	54	5.7	37,576	205
Mean	1.6	7,503	41	4.1	28,182	154

Notes:

-	Complete data for November to April 1998 not available
BOD	Biological oxygen demand
ft3/s	Cubic feet per second
lb/day	Pound per day
NH3-N	Ammonia-nitrogen

6.3.2 Load Reductions

All monitoring data show the TP concentrations exceeding the 0.05-mg/L standard, which was used as the TMDL endpoint. As discussed in Section 2.7.3, the pH violation in Borah Lake correlates linearly with the TP concentration. The TP endpoint was also used as a surrogate for the pH TMDL. Figure B.6-3 shows that TP concentrations in Borah Lake meet the 0.05-mg/L endpoint after a 75 percent reduction in TP loading.

FIGURE B.6-3. TP CONCENTRATION AFTER TP LOAD REDUCED BY 75 PERCENT

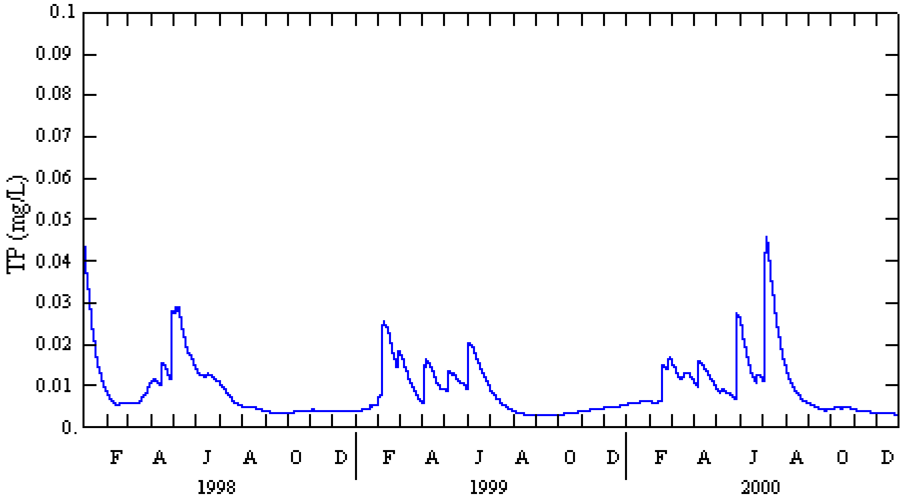


Table B.6-6 summarizes seasonal TP load reductions needed for Borah Lake.

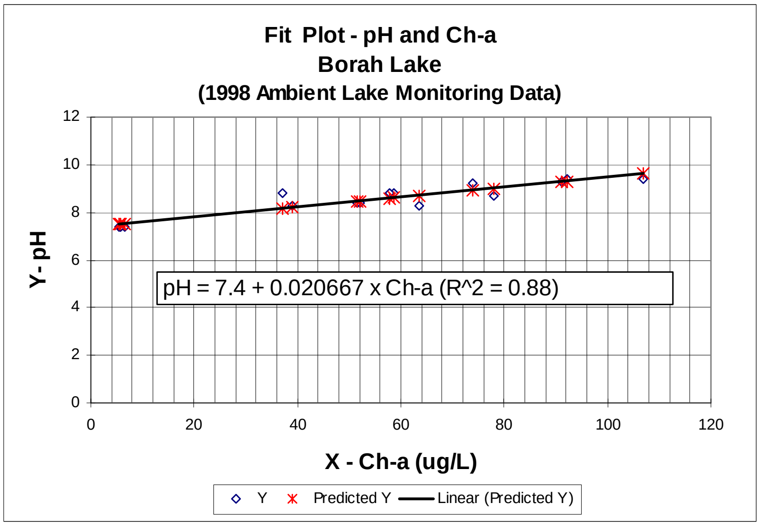
TABLE B.6-6. TP SEASONAL LOAD REDUCTIONS NEEDED

Load	May through October (Critical) (lb/day)	November to April (lb/day)
Existing	41	154
Maximum Allowable	11	39
% Reduction	75	75

As discussed in Section 2.7.3, TP is the primary limiting nutrient causing eutrophication in Borah Lake. After analysis of the monitoring data for the lake, two empirical equations were developed to link the TP concentration to Ch-a and Ch-a to pH. The two equations establish a cause-effect relationship between TP concentration and pH level. These empirical equations were developed as discussed below.

A linear regression was performed on available Ch-a and pH data and results were plotted in Figure B.6-4. Figure B.6-4 shows that pH increases with increases in Ch-a concentration (that is, with algae growth in Borah Lake). An R^2 value of 0.88 strongly suggests that elevated concentrations of pH in Borah Lake are the result of excess algal growth. The R^2 value is a fraction between 0.0 and 1.0. A value of 0.0 indicates no relationship between coordinates “x” and “y,” and a value of 1.0 indicates that “x” and “y” are perfectly correlated.

FIGURE B.6-4. LINEAR REGRESSION OF pH AND Ch-a



The derived empirical equation is as follow:

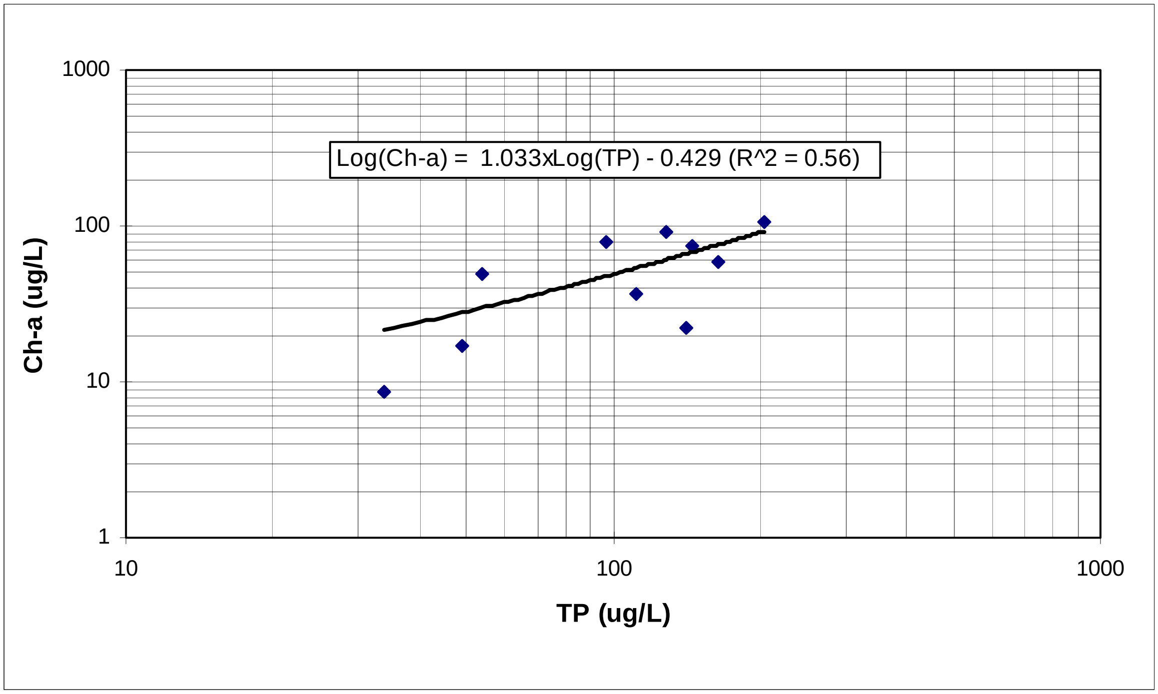
$$pH = 7.4 + 0.020667 \times Ch\text{-}a \qquad (B.6\text{-}1)$$

A data analysis was also preformed to link TP concentration to Ch-a concentration, which is considered a symptom of lake eutrophication. Figure B.6-5 shows a linear regression between observed Ch-a concentration and TP concentration. Although the data show some scatter, an R^2 value of 0.56 indicates that Ch-a and TP concentrations are also correlated and increase of TP concentration increases Ch-a concentration (as observed in algae bloom). The derived empirical equation is as follows:

$$Log(Ch\text{-}a) = 1.033 \times Log(TP) – 0.429 \qquad (B.6\text{-}2)$$

In the equation, both Ch-a and TP are expressed in the unit of μg/L. The coefficients, 1.033 and –0.429 in the equation fall in the range reported by Chapra (1997).

FIGURE B.6-5. CORRELATION BETWEEN CH-A AND TP CONCENTRATIONS IN BORAH LAKE



Equations B.6-1 and B.6-2 were used to determine which endpoint was critical for achieving both phosphorus and pH standards in Borah Lake. The 0.05-mg/L endpoint corresponded to a pH of 7.8 pH, which is within the range of 6.5 to 9 required by the pH standard. In contrast, the pH of 9 corresponded to a TP concentration of 0.175 mg/L, which exceeds the 0.05-mg/L TP standard; therefore, for Borah Lake, the TP endpoint is more stringent than the pH endpoint. A TMDL for TP only is sufficient to enable both TP and pH concentrations in the lake to comply with water quality standards for TP and pH.

The derived empirical equations are subject to sampling errors and uncertainties inherent in the natural process. Such error and uncertainty are incorporated into the MOS when a TMDL is calculated.

7 SUMMARY

In order to develop TMDLs for the Fox River, Olney East Fork Lake, and Borah Lake, the modeling effort focused on simulating BOD, DO, NH_3-N, and TP and related processes in the Fox River watershed on a continuous basis and determining the response of the water bodies to the pollutant loads.

The HSPF model was used to predict BOD, NH_3-N, and TP loads from nonpoint sources and simulate the response of the water bodies. For the river segment, the QUAL2E model was also used to evaluate the sensitivity of water quality in the Fox River to point sources during low-flow conditions. The modeling was based on data collected by USGS, NCDC, and IEPA. The calibrated HSPF model was able to simulate water quality conditions in the three water bodies.

The modeling effort determined that, for the river segment, the BOD loads need to be reduced by 75 percent during the critical period from May through October and by 70 percent from November through April. The NH_3-N loads need to be reduced by 75 percent to meet the DO standard. For Olney East Fork Lake, the TP load needs to be reduced by 70 percent to comply with TP standard, and BOD must be reduced by 45 percent to comply with the DO standard. For Borah Lake, the TP loads need to be reduced by 75 percent to comply with the TP and pH standards. It is determined that meeting TP standard in Borah Lake also results in compliance with pH standard. Various best management practices are proposed in Chapter 8 of the TMDL report to achieve the reductions needed.

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APPENDIX C

FEDERAL FUNDING SOURCES

A variety of funding sources are available to support implementation of the best management practices (BMP) and other management measures addressed in the total maximum daily load (TMDL) report. The table below provides a brief overview of sources available at the federal level. Additional information on these sources is available from the U.S. Environmental Protection Agency (EPA) publication titled "Catalog of Federal Funding Sources for Watershed Protection" (EPA 841-B-99-003). The publication presents information on 69 federal funding sources (grants and loans) that may be used to fund a variety of watershed protection projects. The information below on funding sources is organized by funding agencies, which include the EPA, U.S. Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS), U.S. Forest Service, U.S. Fish and Wildlife Service (USFWS), and U.S. Army Corps of Engineers (COE). More information is also available at http://www.epa.gov/owow/watershed/wacademy/fund.html

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
EPA - PROGRAM GRANTS TO STATES Watersheds and Nonpoint Source Programs Branch, EPA Region 5			
Nonpoint Source Implementation Grants	Formula grants are provided to the states to implement nonpoint source projects programs in accordance with Section 319 of the Clean Water Act.	States and Indian tribes	Grants are awarded to a lead state agency. States and local organizations receiving grants are required to provide 40 percent of program cost.
Water Quality Cooperative Agreements	Grants are provided to support new approaches to meeting storm water, combined sewer outflow, sludge, and pretreatment requirements as well as to enhancing state capabilities. Eligible projects usually include research, investigation, experiment, training, environmental technology demonstration, survey, and study related to the causes, effects, extent, and prevention of pollution.	State water pollution control agencies; interstate agencies; local public agencies; Indian tribes; and nonprofit institutions, organizations, and individuals	Grants are awarded and matching funding is encouraged .
Water Quality Management Planning	Formula grants are awarded to state water quality management agencies to carry out water quality planning. States are required to allocate at least 40 percent of funds to eligible Regional Public Comprehensive Planning Agencies (RPCPO) and Interstate Organizations (IO).	States	States are required to allocate at least 40 percent of funds to eligible RPCPOs and IOs.

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
State Revolving Funds (SRF)	EPA awards grant money to states to establish SRFs. Under the SRF program, Illinois has created revolving loan funds to provide independent and permanent sources of low-cost financing for a range of water quality infrastructure projects. States set loan terms, repayment periods, and other loan features. SRFs are available for a wide variety of water quality projects, including all types of nonpoint source and estuary management projects as well as more traditional wastewater treatment projects.	States	Grants are awarded to a lead agency. Loans are provided to eligible participants.
Capitalization Grants for Clean Water SRFs	EPA awards grants to states to capitalize their Clean Water SRFs. Through the SRF, the states make loans for high-priority water quality activities. Loans are used for water quality management activities.	States, tribes, Puerto Rico, U.S. territories, and DC	Grants are awarded to a lead agency. Loans are provided by the state to eligible participants. States are required to provide 20 percent matching funds.
Capitalization Grants for Drinking Water SRFs	EPA awards grant money to states for Drinking Water SRFs. Through its Drinking Water SRFs, Illinois provides loans for drinking water supply-related projects. Although most loan money is intended for upgrades of infrastructure (public or private drinking water supplies), Illinois also has the option to use some of the funds for source water protection, capacity development, drinking water programs, and operator certification programs. The emphasis is on preventing contamination and enhancing water systems management.	States, territories, U.S. possessions, and Indian tribes	Grants and loans are awarded to drinking water suppliers. States are required to provide 20 percent matching funds.
Water Pollution Control Program Grants	The Water Pollution Control Program authorizes EPA to provide assistance to States and interstate agencies to establish and implement ongoing water pollution control programs. Prevention and control measures supported include permitting, pollution control activities, surveillance, monitoring, and enforcement; advice and assistance to local agencies; and the provision of training and public information. The program helps foster a watershed approach at the state level by examining water quality problems holistically.	States, interstate agencies, and Indian tribes	Funds are allotted among state and interstate water pollution control agencies on the basis of the extent of water pollution problems in the respective state.

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
EPA - PROJECT GRANTS Watersheds and Nonpoint Source Programs Branch, EPA Region 5			
Great Lakes Program	EPA's Great Lakes Program issues awards assistance to projects affecting the Great Lakes Basin or in support of the U.S.-Canada Great Lakes Water Quality Agreement. Project activities include surveillance and monitoring of Great Lakes water quality and land-use activities.	State water pollution control agencies; interstate agencies; and other public or nonprofit agencies, institutions, organizations, and individuals	Assistance can be provided through project grants, provision of property and equipment, provision of specialized services, and dissemination of technical information.
Pollution Prevention Grants Program	This program provides project grants to states to implement pollution prevention projects. The grant program focuses on institutionalizing multimedia pollution prevention (air, water, and land).	States and Indian tribes	Individual grants are awarded based on requests. States are required to provide at least 50 percent of total project costs.
Wetlands Protection Development Grants Program	This program provides financial assistance to States, Indian tribes, and local governments to support wetlands development or augmentation and enhancement of existing programs. Projects must clearly demonstrate a direct link to an increase in the group's ability to protect its wetland resources.	States, Indian tribes, and interstate and intertribal agencies, and local governments	Project grants are used to fund individual projects. States or tribes must provide 25 percent of the total project costs.
USDA AND NRCS			
Conservation Reserve Program (CRP)	The CRP is a voluntary program that offers long-term rental payments and cost-share assistance to establish long-term, resource-conserving cover on environmentally sensitive croplands or, in some cases, marginal pasturelands. The protective cover should reduce soil erosion, improve water quality, and enhance or establish wildlife habitat. Increased rental payments are available on certain land areas. (For example, land within a wellhead protection area may receive an additional 10 percent payment.)	Individuals, partnerships, associations, Indian tribal venture corporations, estates, trusts, other business enterprises or legal entities, states, state political subdivisions, and state or local agencies owning or operating land.	The CRP provides annual rental payments to each participant of up to \$50,000 per fiscal year, up to 50 percent of the cost for establishing cover, or incentive payments for wetland hydrology restoration equal to 25 percent of the cost of restoration.

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
Environmental Quality Incentives Program (EQIP)	EQIP provides technical, financial, and educational assistance, half targeted to livestock-related natural resource concerns and the other half to more general conservation priorities. EQIP applies primarily in priority areas having significant natural resource concerns and objectives.	Non-federal landowners engaged in livestock operations or agricultural productions; eligible land includes croplands, rangelands, pasturelands, forest lands, and other farm and ranch lands	EQIP can provide up to 75 percent of costs of certain conservation practices. Incentive payments can be up to 100 percent for 3 years, paid at a flat rate. The maximum funding limit is $10,000 per person per year and $50,000 over the length of the contract.
Forestry Incentives Program (FIP)	FIP supports good forest management practices on privately owned, nonindustrial forest lands nationwide. FIP is designed to benefit the environment while meeting future demands for wood products. Eligible practices are tree planting, timber stand improvement, site preparation for natural regeneration, and other related activities. FIP's forest maintenance and reforestation provides numerous natural resource benefits, including reduced soil erosion and enhanced water quality and wildlife habitat. Land must be suitable for conversion from nonforest to forest land, for reforestation, or for improved forest management and be capable of producing marketable timber crops.	Private landowner of at least 10 acres and no more than 1,000 acres of nonindustrial forest or other suitable land. Individuals, groups, Indian Tribes, and corporations whose stocks are not publicly traded might be eligible provided they are not primarily manufacturing forest products or providing public utility services.	FIP provides no more than 65 percent of total costs, with a maximum funding limit of $10,000 per person per year.
Small Watershed Program	This program works through local government sponsors and helps participants solve natural resource and related economic problems on a watershed basis. Projects include watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in watersheds of 250,000 or fewer acres. Technical and financial assistance is available for projects that protect, develop, and utilize the land and water resources in small watersheds.	Local or state agencies, counties, municipalities or towns and townships, soil and water conservation districts; flood prevention or flood control district; Indian tribes or tribal organizations, and nonprofit agencies with authority to carry out, maintain, and operate watershed improvement works	Assistance can cover 100 percent of flood prevention construction costs; 50 percent of construction costs related to agricultural water management, recreation, and fish and wildlife; and none of the costs for other municipal and industrial water management. Technical assistance and counseling may also be provided.

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
Wetlands Reserve Program (WRP)	The WRP is a voluntary program to restore and protect wetlands on private property. WRP provides landowners with financial incentives to enhance wetlands in exchange for retiring marginal agricultural land. Landowners may sell a conservation easement or enter into a cost-share restoration agreement. Landowners voluntarily limit future use of the land, yet retain private ownership. Landowners and the NRCS develop a plan for the restoration and maintenance of the wetland.	Easement participant must have owned the land for at least 1 year; owner can be an individual, partnership, association, corporation, estate, trust, business, or other legal entity, a state (when applicable), a political subdivision of a state, or any agency owning private land; land must be restorable and suitable for wildlife benefits	WRP provides the following three options to the landowner: Permanent Easement: USDA purchases easement (price is lesser of land value or payment cap) and pays 100 percent of restoration costs 30-year Easement: Payment is 75 percent of what would be paid for a permanent easement; USDA pays 75 percent of restoration costs Restoration Cost Share Agreement: Minimum 10-year agreement to restore degraded wetland habitat; USDA pays 75 percent of restoration costs
Wildlife Habitat Incentives Program (WHIP)	WHIP is a voluntary program for people who want to develop and improve wildlife habitat on private land. It provides both technical assistance and cost sharing to help establish and improve fish and wildlife habitat. A wildlife habitat plan is developed that describes the landowner's goals for improving wildlife habitat, includes a list of practices and schedule for installing them, and details the steps necessary for maintenance.	Individuals must own or have control of the land under consideration, and cannot have the land already enrolled in programs that have a wildlife focus, such as the WRP, or use the land for mitigation.	USDA will pay up to 75 percent of installation costs and will provide technical assistance for establishing habitat development projects.
Resource Conservation and Development (RC&D) Program	The RC & D Program provides a way for local residents to work together to solve environmental, economic, and social problems facing their communities. Assistance is available for planning and implementing approved projects specified in RC&D Program area plans for land conservation, water management, community development, and environmental enhancement.	Must be an RC&D Program area authorized by the Secretary of Agriculture for assistance	Technical assistance grants (as funding) allows up to 25 percent of total costs not to exceed $50,000; financial assistance has not been available in recent years due to budget constraints; local or state governments must provide 10 percent of total costs and are also responsible for operation and maintenance

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
Watershed Surveys and Planning Program	This program provides planning assistance to federal, state, and local agencies developing coordinated water and related land resources programs in watersheds and river basins. Special priority is given to projects that solve problems of upstream rural community flooding, improve water quality degraded by agricultural nonpoint sources, preserve wetlands, and manage droughts in agricultural and rural communities.	States, federal agencies, Indian tribes, and local agencies	Technical assistance is provided. Each cooperating agency is expected to fund its own project.
Emergency Watershed Protection (EWP) Program	The EWP Program was set up to respond to emergencies created by natural disasters. All EWP Program work must reduce threats to life and property and be economically and environmentally defensible. EWP Program projects work can include a wide variety of measures ranging from reshaping and protecting eroded banks to reseeding damaged areas.	Public and private landowners represented by a project sponsor who must be a public agency	NRCS can fund up to 75 percent of total project costs.
U.S. FOREST SERVICE			
Cooperative Forestry Assistance	The Cooperative Forestry Assistance helps state foresters or equivalent agencies with forest stewardship programs on private, state, local, and other non-federal forest and rural lands, including rural and urban communities. Assistance is provided through the following programs: Forest Stewardship Program, Stewardship Incentive Program, Economic Action Program, Urban and Community Forestry Program, Cooperative Lands Forest Health Protection Program, and Cooperative Lands Fire Protection Program. These programs help attain ecosystem health and sustainability by improving wildlife habitat, conserving forest land, promoting reforestation, improving soil and water quality, preventing and suppressing damaging insects and diseases, providing wildfire protection, expanding economies of rural communities, and improving urban environments.	State forester or equivalent state agencies, which can provide the funds received to owners of non-federal lands; rural communities; urban or municipal governments; nonprofit organizations; and state, local, and private agencies acting through state foresters or the equivalent	Formula grants, project grants, and cost share programs are available as well as use of property and facilities.

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
Stewardship Incentive Program	The Stewardship Incentive Program provides technical and financial assistance to encourage nonindustrial private forest landowners to keep their lands and natural resources productive and healthy. Qualifying land includes rural lands with existing tree cover and land suitable for growing trees owned by a private individual, group, association, corporation, Indian tribe, or other legal private entity.	Landowners owning 1,000 or fewer acres of qualifying land with an approved forest stewardship plan; authorizations for exceptions may be obtained for up to 5,000 acres.	Technical or financial assistance can be provided.
USFWS			
Coastal Wetlands Planning, Protection, and Restoration Act	Under this act, funds are provided to assist states in pursuing coastal wetlands conservation projects. Funds can be used for acquisition of interests in coastal lands or waters, or for restoration, enhancement, or management of coastal wetland ecosystems on a competitive basis with all coastal states.	All states bordering the Atlantic, Gulf and Pacific coasts, Great Lakes, and other U.S. coastal territories	Project grants are provided. The federal share of costs may not exceed 50 percent; but could be increased to 75 percent if a coastal state has established a fund (1) for the acquisition of coastal wetlands, other natural areas, or open spaces, or (2) derived from a dedicated, recurring source of funding.
Partners for Wildlife Habitat Restoration Program	The Partners for Wildlife Program provides technical and financial assistance to private landowners through voluntary cooperative agreements in order to restore formerly degraded wetlands, native grasslands, riparian areas, and other habitats to conditions as natural as feasible. Under cooperative agreements, private landowners agree to maintain restoration projects as specified in the agreement but otherwise retain full control of the land. To date, the Program has restored over 360,000 acres of wetlands; 128,000 acres of prairie grassland; 930 miles of riparian habitat; and 90 miles of in-stream aquatic habitat.	Private landowners (must enter into cooperative agreement for fixed term of at least 10 years)	Project grants (cooperative agreements) are provided. The program's goal is that no more than 60 percent of project costs is paid by federal moneys. The program seeks the remainder of the funds required from landowners and nationally-based and local entities.

PROGRAM	OVERVIEW	ELIGIBILITY	ASSISTANCE PROVIDED
Wildlife Conservation and Appreciation Program	The Wildlife Conservation and Appreciation Program provides grants to fund projects that bring together USFWS, state agencies, and private organizations and individuals. Projects include identification of significant problems that can adversely affect fish and wildlife and their habitats; actions to conserve species and their habitats; actions that will provide opportunities for the public to use and enjoy fish and wildlife resources through nonconsumptive activities; species monitoring, and identification of significant habitats.	State fish and wildlife agencies	Project grants are provided.
North American Wetlands Conservation Act (NAWCA) Grant Program	The NAWCA Grant Program promotes long-term conservation of North American wetland ecosystems. Principal conservation actions supported by the NAWCA include acquisition, enhancement, and restoration of wetlands and wetlands-associated habitats.	Public or private, profit or nonprofit entities or individuals establishing public-private sector partnerships	Project grants (cooperative agreements and contracts) are provided. Cost-share partners must at least match grant funds with non-federal money.
COE			
Planning Assistance to States Program	Under this program, COE assists states, Indian tribes, local governments, and other non-federal entities in preparing comprehensive plans for the development, utilization, and conservation of water and related land resources. The program can encompass many types of studies dealing with water resource issues. Typical studies are only at the planning level of detail. Studies in recent years assessed water quality, flood plain management, environmental conservation, and many other topics.	States, Indian tribes, local governments, and other non-federal entities	Federal allotments for each state or tribe from the nation-wide appropriation are limited to $500,000 annually.