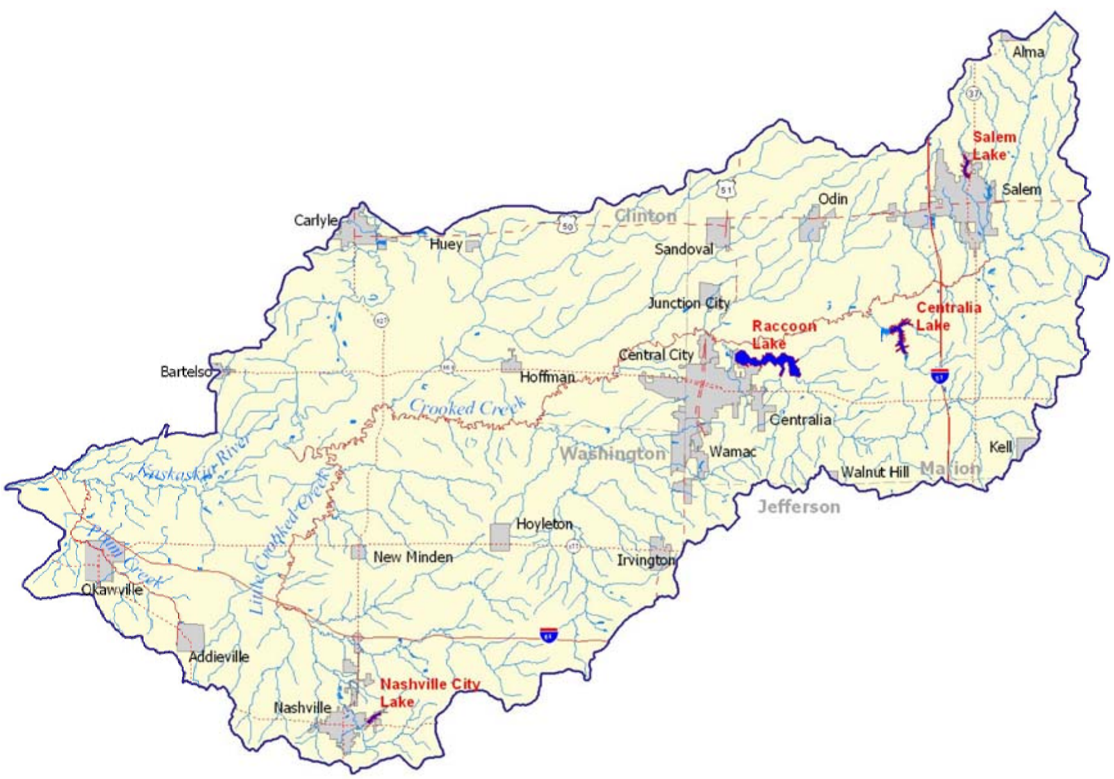
Illinois
Environmental
Protection Agency

Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

June 2008

IEPA/BOW/08-006

Crooked Creek Watershed TMDL Report



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TMDL Development for Crooked Creek Watershed, Illinois

This file contains the following documents:

1) U.S. EPA Approval letter for Stage Three TMDL Report

2) Stage One Report: Watershed Characterization and Water Quality Analysis

3) Stage Two Report: Data Report

4) Stage Three Report: TMDL Development

5) IP Report: Implementation Plan

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

AUG 14 2008

REPLY TO THE ATTENTION OF:

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BUREAU OF WATER
BUREAU CHIEF'S OFF

Marcia Willhite, Chief
Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

Dear Ms. Willhite:

The U. S. Environmental Protection Agency has reviewed the final Total Maximum Daily Loads from the Illinois Environmental Protection Agency for the Crooked Creek Watershed in Illinois. The TMDLs are for Atrazine, Manganese, and Total Phosphorus, and address the recreational use and aquatic life impairments in this watershed.

Based on this review, EPA has determined that Illinois' TMDLs for Atrazine, Manganese, and Total Phosphorus meet the requirements of Section 303(d) of the Clean Water Act and EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, EPA hereby approves eight TMDLs addressing seven impairments in the Crooked Creek Watershed in Illinois. The statutory and regulatory requirements, and EPA's review of Illinois' compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois' effort in submitting this TMDL and look forward to future TMDL submissions by the State of Illinois. If you have any questions, please contact Kevin Pierard, Chief of the Watersheds and Wetlands Branch, at 312-886-4448.

Sincerely yours,

Timothy C. Henry
Acting Director, Water Division

Enclosure
cc: Dean Studer, IEPA
Michael Eppley, IEPA

CDM

Illinois Environmental
Protection Agency

Crooked Creek Watershed TMDL
Stage One
Third Quarter Draft Report

May 2006

Draft Report

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Acronyms

°F	degrees Fahrenheit
BMP	best management practice
CWA	Clean Water Act
DMR	Discharge Monitoring Reports
DO	dissolved oxygen
ft	Foot or feet
GIS	geographic information system
HUC	Hydrologic Unit Code
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
IL-GAP	Illinois Gap Analysis Project
ILLCP	Illinois Interagency Landscape Classification Project
Illinois EPA	Illinois Environmental Protection Agency
INHS	Illinois Natural History Survey
IPCB	Illinois Pollution Control Board
LA	load allocation
LC	loading capacity
lb/d	pounds per day
mgd	Million gallons per day
mg/L	milligrams per liter
MOS	margin of safety
MUID	Map Unit Identification
NA	Not applicable
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NED	National Elevation Dataset
NPDES	National Pollution Discharge Elimination System
NRCS	National Resource Conservation Service
PCS	Permit Compliance System
ppb	Parts per billion
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic
STORET	Storage and Retrieval
STP	Sanitary Treatment Plant

TMDL	total maximum daily load
ug/L	Micrograms per liter
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	waste load allocation
WTP	Water Treatment Plant

Section 1
Goals and Objectives for Crooked Creek Watershed (0714020208, 0714020209, 0714020207)

1.1 Total Maximum Daily Load (TMDL) Overview

A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. TMDLs are a requirement of Section 303(d) of the Clean Water Act (CWA). To meet this requirement, the Illinois Environmental Protection Agency (Illinois EPA) must identify water bodies not meeting water quality standards and then establish TMDLs for restoration of water quality. Illinois EPA lists water bodies not meeting water quality standards every two years. This list is called the 303(d) list and water bodies on the list are then targeted for TMDL development.

In general, a TMDL is a quantitative assessment of water quality problems, contributing sources, and pollution reductions needed to attain water quality standards. The TMDL specifies the amount of pollution or other stressor that needs to be reduced to meet water quality standards, allocates pollution control or management responsibilities among sources in a watershed, and provides a scientific and policy basis for taking actions needed to restore a water body.

Water quality standards are laws or regulations that states authorize to enhance water quality and protect public health and welfare. Water quality standards provide the foundation for accomplishing two of the principal goals of the CWA. These goals are:

- Restore and maintain the chemical, physical, and biological integrity of the nation's waters
- Where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water

Water quality standards consist of three elements:

- The designated beneficial use or uses of a water body or segment of a water body
- The water quality criteria necessary to protect the use or uses of that particular water body
- An antidegradation policy

Examples of designated uses are recreation and protection of aquatic life. Water quality criteria describe the quality of water that will support a designated use. Water quality criteria can be expressed as numeric limits or as a narrative statement.

Antidegradation policies are adopted so that water quality improvements are conserved, maintained, and protected.

1.2 TMDL Goals and Objectives for Crooked Creek Watershed

The Illinois EPA has a three-stage approach to TMDL development. The stages are:

- Stage 1 – Watershed Characterization, Data Analysis, Methodology Selection
- Stage 2 – Data Collection (optional)
- Stage 3 – Model Calibration, TMDL Scenarios, Implementation Plan

This report addresses Stage 1 TMDL development for the Crooked Creek watershed. Stage 2 and 3 will be conducted upon completion of Stage 1. Stage 2 is optional as data collection may not be necessary if additional data are not required to establish the TMDL.

Following this process, the TMDL goals and objectives for the Crooked Creek watershed will include developing TMDLs for all impaired water bodies within the watershed, describing all of the necessary elements of the TMDL, developing an implementation plan for each TMDL, and gaining public acceptance of the process. Following are the impaired water body segments in the Crooked Creek watershed for which a TMDL will be developed:

- Crooked Creek (OJ 07)
- Crooked Creek (OJ 08)
- Lake Centralia (ROI)
- Raccoon Lake (ROK)
- Salem Reservoir (ROR)
- Plum Creek (OZH-OK-A2)
- Plum Creek (OZH-OK-C2)
- Plum Creek (OZH-OK-C3)
- Little Crooked Creek (OJA 01)
- Nashville City Reservoir (ROO)

These impaired water body segments are shown on Figure 1-1. There are 10 impaired segments within the Crooked Creek watershed. Table 1-1 lists the water body segment, water body size, and potential causes of impairment for the water body.

Table 1-1 Impaired Water Bodies in Crooked Creek Watershed

Water Body Segment ID	Water Body Name	Size	Causes of Impairment with Numeric Water Quality Standards	Causes of Impairment with Assessment Guidelines
OJ 07	Crooked Creek	30.84 miles	pH, dissolved oxygen	Total phosphorus
OJ 08	Crooked Creek	21.5 miles	pH, dissolved oxygen	Total nitrogen, sedimentation/siltation, total suspended solids (TSS), total phosphorus
ROI	Lake Centralia	450 acres	Manganese, total phosphorus	TSS, excess algal growth, total phosphorus
ROK	Raccoon Lake	925 acres	Manganese, total phosphorus, pH, dissolved oxygen, atrazine	Sedimentation/siltation, TSS, excess algal growth
ROR	Salem Reservoir	74.2 acres	Manganese, total phosphorus, dissolved oxygen	TSS, excess algal growth, total phosphorus
OZH-OK-A2	Plum Creek	6.73 miles	Manganese, dissolved oxygen	Sedimentation/siltation, habitat alterations (streams), total phosphorus
OZH-OK-C2	Plum Creek	1.85 miles	Dissolved oxygen	Habitat alterations (streams), total phosphorus
OZH-OK-C3	Plum Creek	2.04 miles	Manganese, dissolved oxygen	Sedimentation/siltation, habitat alterations (streams), total phosphorus
OJA 01	Little Crooked Creek	16.64 miles	Manganese, dissolved oxygen	Total phosphorus
ROO	Nashville City Reservoir	42 acres	Manganese, total phosphorus	TSS, excess algal growth

Illinois EPA is currently only developing TMDLs for parameters that have numeric water quality standards, and therefore the remaining sections of this report will focus on the pH, dissolved oxygen, atrazine, manganese, and total phosphorus (numeric standard) impairments in the Crooked Creek watershed. For potential causes that do not have numeric water quality standards as noted in Table 1-1, TMDLs will not be developed at this time. However, in the implementation plans completed during Stage 3 of the TMDL, many of these potential causes may be addressed by implementation of controls for the pollutants with water quality standards.

The TMDL for the segments listed above will specify the following elements:

- Loading Capacity (LC) or the maximum amount of pollutant loading a water body can receive without violating water quality standards
- Waste Load Allocation (WLA) or the portion of the TMDL allocated to existing or future point sources
- Load Allocation (LA) or the portion of the TMDL allocated to existing or future nonpoint sources and natural background
- Margin of Safety (MOS) or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality

These elements are combined into the following equation:

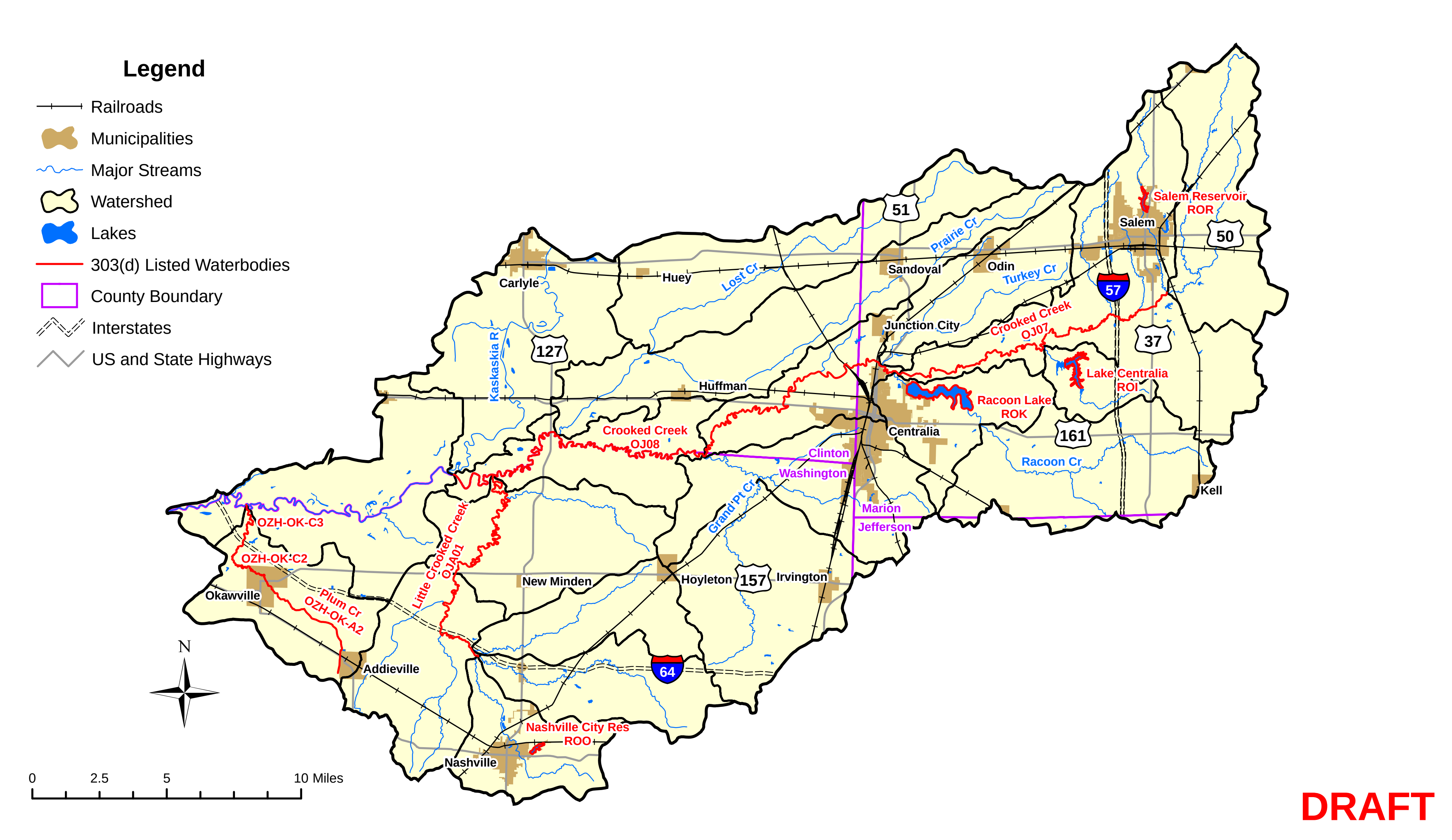
$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

The TMDL developed must also take into account the seasonal variability of pollutant loads so that water quality standards are met during all seasons of the year. Also, reasonable assurance that the TMDL will be achieved will be described in the implementation plan. The implementation plan for the Crooked Creek watershed will describe how water quality standards will be attained. This implementation plan will include recommendations for implementing best management practices (BMPs), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and timeframe for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Crooked Creek Watershed Characteristics** provides a description of the watershed's location, topography, geology, land use, soils, population, and hydrology
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development
- **Section 4 Crooked Creek Watershed Water Quality Standards** defines the water quality standards for the impaired water body
- **Section 5 Crooked Creek Watershed Characterization** presents the available water quality data needed to develop TMDLs, discusses the characteristics of the impaired reservoirs in the watershed, and also describes the point and non-point sources with potential to contribute to the watershed load.
- **Section 6 Approach to Developing TMDL and Identification of Data Needs** makes recommendations for the models and analysis that will be needed for TMDL development and also suggests segments for Stage 2 data collection.



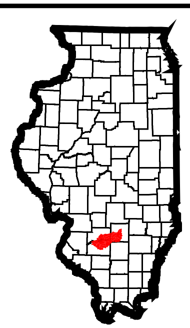


Figure 1-1
Crooked Creek Watershed

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Section 2
Crooked Creek Watershed Description

2.1 Crooked Creek Watershed Location

The Crooked Creek watershed (Figure 1-1) is located in southern Illinois, flows in a west-southwesterly direction, and drains approximately 362,000 acres within the state of Illinois. The watershed covers land within Washington, Jefferson, Clinton, and Marion Counties.

2.2 Topography

Topography is an important factor in watershed management because stream types, precipitation, and soil types can vary dramatically by elevation. National Elevation Dataset (NED) coverages containing 30-meter grid resolution elevation data are available from the USGS for each 1:24,000-topographic quadrangle in the United States. Elevation data for the Crooked Creek watershed were obtained by overlaying the NED grid onto the GIS-delineated watershed. Figure 2-1 shows the elevations found within the watershed.

Elevation in the Crooked Creek watershed ranges from 647 feet above sea level in the headwaters of Crooked Creek to 394 feet in the Kaskaskia River in the west end of the watershed. The absolute elevation change is 221 feet over the approximately 64-mile stream length of Crooked Creek, which yields a stream gradient of approximately 3.6 feet per mile.

2.3 Land Use

Land use data for the Crooked Creek watershed were extracted from the Illinois Gap Analysis Project (IL-GAP) Land Cover data layer. IL-GAP was started at the Illinois Natural History Survey (INHS) in 1996, and the land cover layer was the first component of the project. The IL-GAP Land Cover data layer is a product of the Illinois Interagency Landscape Classification Project (IILCP), an initiative to produce statewide land cover information on a recurring basis cooperatively managed by the United States Department of Agriculture National Agricultural Statistics Service (NASS), the Illinois Department of Agriculture (IDA), and the Illinois Department of Natural Resources (IDNR). The land cover data were generated using 30-meter grid resolution satellite imagery taken during 1999 and 2000. The IL-GAP Land Cover data layer contains 23 land cover categories, including detailed classification in the vegetated areas of Illinois. Appendix A contains a complete listing of land cover categories. (Source: IDNR, INHS, IDA, USDA NASS's 1:100,000 Scale Land Cover of Illinois 1999-2000, Raster Digital Data, Version 2.0, September 2003.)

The land use of the Crooked Creek watershed was determined by overlaying the IL-GAP Land Cover data layer onto the GIS-delineated watershed. Table 2-1 contains the land uses contributing to the Crooked Creek watershed, based on the IL-GAP land cover categories and also includes the area of each land cover category and percentage of the watershed area. Figure 2-2 illustrates the land uses of the watershed.

The land cover data reveal that approximately 275,00 acres, representing nearly 76 percent of the total watershed area, are devoted to agricultural activities. Corn and soybean farming account for 20 percent and 32 percent of the watershed area, respectively; winter wheat and winter wheat/soybeans farming account for approximately 5 percent and 9 percent, respectively; and rural grassland accounts for nearly 8 percent. Wetlands and upland forests occupy approximately 10 and 8 percent, respectively. Other land cover categories represent less that 5 percent of the watershed area.

Table 2-1 Land Use in Crooked Creek Watershed

Land Cover Category	**Area (Acres)**	**Percentage**
Corn	72,786	20.1%
Soybeans	114,189	31.6%
Winter Wheat	18,730	5.2%
Other Small Grains & Hay	4,613	1.3%
Winter Wheat/Soybeans	33,410	9.2%
Other Agriculture	3,360	0.8%
Rural Grassland	27,434	7.6%
Upland	27,353	7.6%
Forested Areas	3,369	0.9%
High Density	4,724	1.3%
Low/Medium Density	7,976	2.2%
Urban Open Space	3,600	1.0%
Wetlands	37,695	10.4%
Surface Water	2,017	0.6%
Barren & Exposed Land	578	0.2%
Total	**361,834**	100%

1. Forested areas include partial canopy/savannah upland.
2. Wetlands include shallow marsh/wet meadow, deep marsh, seasonally/temporally flooded, floodplain forest, and shallow water.

2.4 Soils

General soils data and map unit delineations for the entire state are provided as part of the State Soil Geographic (STATSGO) database. Soil maps for the database are produced by generalizing detailed soil survey data. The mapping scale for STATSGO is 1:250,000.

The Crooked Creek watershed falls within Washington, Jefferson, Clinton, and Marion Counties. Figure 2-3 displays the STATSGO soil map units in the Crooked Creek watershed. Attributes of the spatial coverage can be linked to the STATSGO database, which provides information on various chemical and physical soil characteristics for each map unit. Of particular interest for TMDL development are the hydrologic soil groups as well as the K-factor of the Universal Soil Loss Equation. The following sections describe and summarize the specified soil characteristics for the Crooked Creek watershed.

2.4.1 Crooked Creek Watershed Soil Characteristics

Table 2-2 contains the STATSGO Map Unit IDs (MUIDs) for the Crooked Creek watershed along with area, dominant hydrologic soil group, and K-factor range. Each of these characterizations is described in more detail in the following paragraphs. The predominant soil type in the watershed are soils categorized as a fine-grained and made up of silts and clays with a liquid limit of less than 50 percent that tend toward a lean clay.

Hydrologic soil groups are used to estimate runoff from precipitation. Soils are assigned to one of four groups. They are grouped according to their infiltration rates under saturated conditions during long duration storm events. Hydrologic soil groups B, C, and D are found within the Crooked Creek watershed with the majority of the watershed falling into category C. Category C soils are defined as "soils having a slow infiltration rate when thoroughly wet." C soils consist "chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture." These soils have a slow rate of water transmission (NRCS 2005).

A commonly used soil attribute is the K-factor. The K-factor:

> *Indicates the susceptibility of a soil to sheet and rill erosion by water.* (The K-factor) *is one of six factors used in the Universal Soil Loss Equation (USLE) to predict the average annual rate of soil loss by sheet and rill erosion. Losses are expressed in tons per acre per year. These estimates are based primarily on percentage of silt, sand, and organic matter (up to 4 percent) and on soil structure and permeability. Values of K range from 0.02 to 0.69. The higher the value, the more susceptible the soil is to sheet and rill erosion by water (NRCS 2005).*

The distribution of K-factor values in the Crooked Creek watershed range from 0.17 to 0.43.

Table 2-2: Crooked Creek Watershed Soil Characteristics

STATSGO Map Unit ID	Acres	Percent of Watershed	Dominant Hydrologic Soil Group	K-factor Range
IL005	56651	16%	D	0.28-0.43
IL006	126703	35%	C/D	0.32-0.43
IL037	16851	5%	C	0.28-0.43
IL038	109745	30%	C	0.24-0.43
IL051	7649	2%	C	0.24-0.43
IL064	3560	1%	C	0.17-0.43
IL068	40572	11%	C	0.28-0.43
TOTAL	**361731**	**100%**		

2.5 Population

Population data were retrieved from Census 2000 TIGER/Line Data from the U.S. Bureau of the Census. Geographic shape files of census blocks were downloaded for every county containing any portion of the watersheds. The block files were clipped to each watershed so that only block populations associated with the watershed would be counted. The census block demographic text file (PL94) containing population data were downloaded and linked to each watershed and summed. City populations were taken from the U.S. Bureau of the Census. For municipalities that are located across watershed borders, the population was estimated based on the percentage of area of municipality within the watershed boundary.

Approximately 57,000 people reside in the watershed. The municipalities found within the Crooked Creek watershed are shown in Figure 1-1. The city of Centralia is the largest population center in the watershed and contributes an estimated 14,000 people to total watershed population.

2.6 Climate and Streamflow

2.6.1 Climate

Southern Illinois has a temperate climate with hot summers and cold, snowy winters. Monthly precipitation and temperature data from the Salem station (station id. 7636) in Marion County were extracted from the NCDC database. Precipitation data were available from 1948-2004 while temperature data were available beginning in 1958. Salem, Illinois is located within the basin and was chosen to be representative of meteorological conditions throughout the Crooked Creek watershed.

Table 2-3 contains the average monthly precipitation along with average high and low temperatures for the period of record. The average annual precipitation is approximately 42 inches.

Table 2-3 Average Monthly Climate Data in Salem, IL

Month	Total Precipitation (inches)	Maximum Temperature (degrees F)	Minimum Temperature (degrees F)
January	2.5	38	20
February	2.6	44	25
March	3.7	55	34
April	3.9	67	44
May	4.5	77	54
June	4.3	85	62
July	3.9	89	67
August	3.3	87	64
September	3.2	81	57
October	3.0	69	45
November	3.7	55	35
December	3.2	42	25
Total	**41.9**		

2.6.2 Streamflow

Analysis of the Crooked Creek watershed requires an understanding of flow throughout the drainage area. Two USGS gages within the watershed have relevant data (Figure 2-4). Table 2-4 summarizes the stations along with their respective information.

Table 2-4 Streamflow Gages in the Crooked Creek Watershed

Gage Number	Name	POR
05593520	Crooked Creek near Hoffman, Illinois	1975-1998
05593575	Little Crooked Creek near New Minden, Illinois	1968-2004

USGS gage 05593520 is located on the OJ 08 segment of Crooked Creek, downstream of the confluence with Grand Point Creek, and south of Huffman, Illinois. The average monthly flows recorded at the Crooked Creek near Hoffman, Illinois gage range from 45 cfs in August to 510 cfs in March with a mean annual monthly flow of 240 cfs (Figure 2-5).

USGS gage 05593575 is located on the OJA 01 segment of Little Crooked Creek approximately 5 and one half miles upstream of Crooked Creek. The average monthly flows recorded at the Little Crooked Creek near New Minden, Illinois gage range from 13 cfs in August to 137 cfs in March with a mean annual monthly flow of 72 cfs (Figure 2-5).

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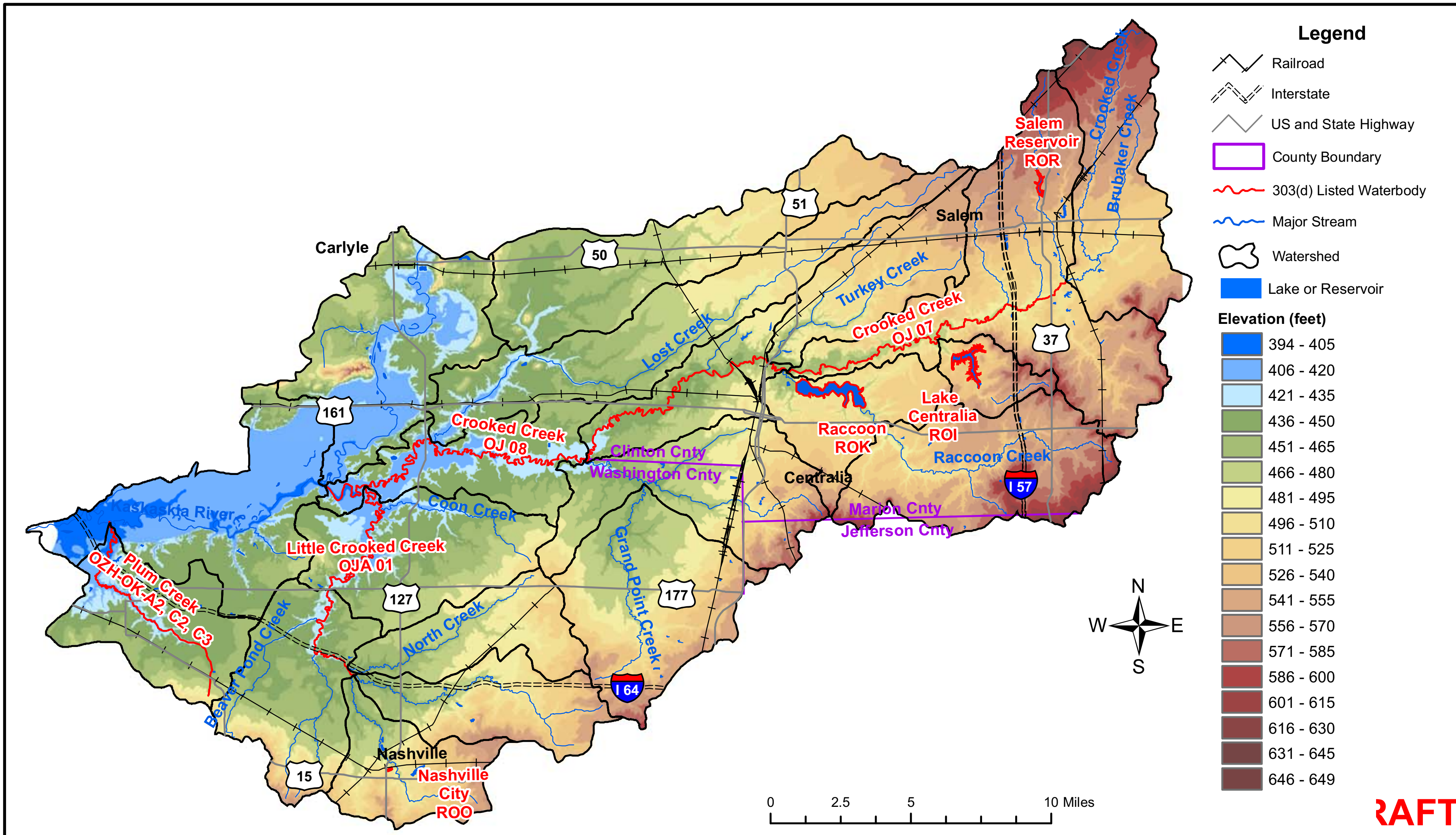

Figure 2-1
Crooked Creek Watershed
Elevation

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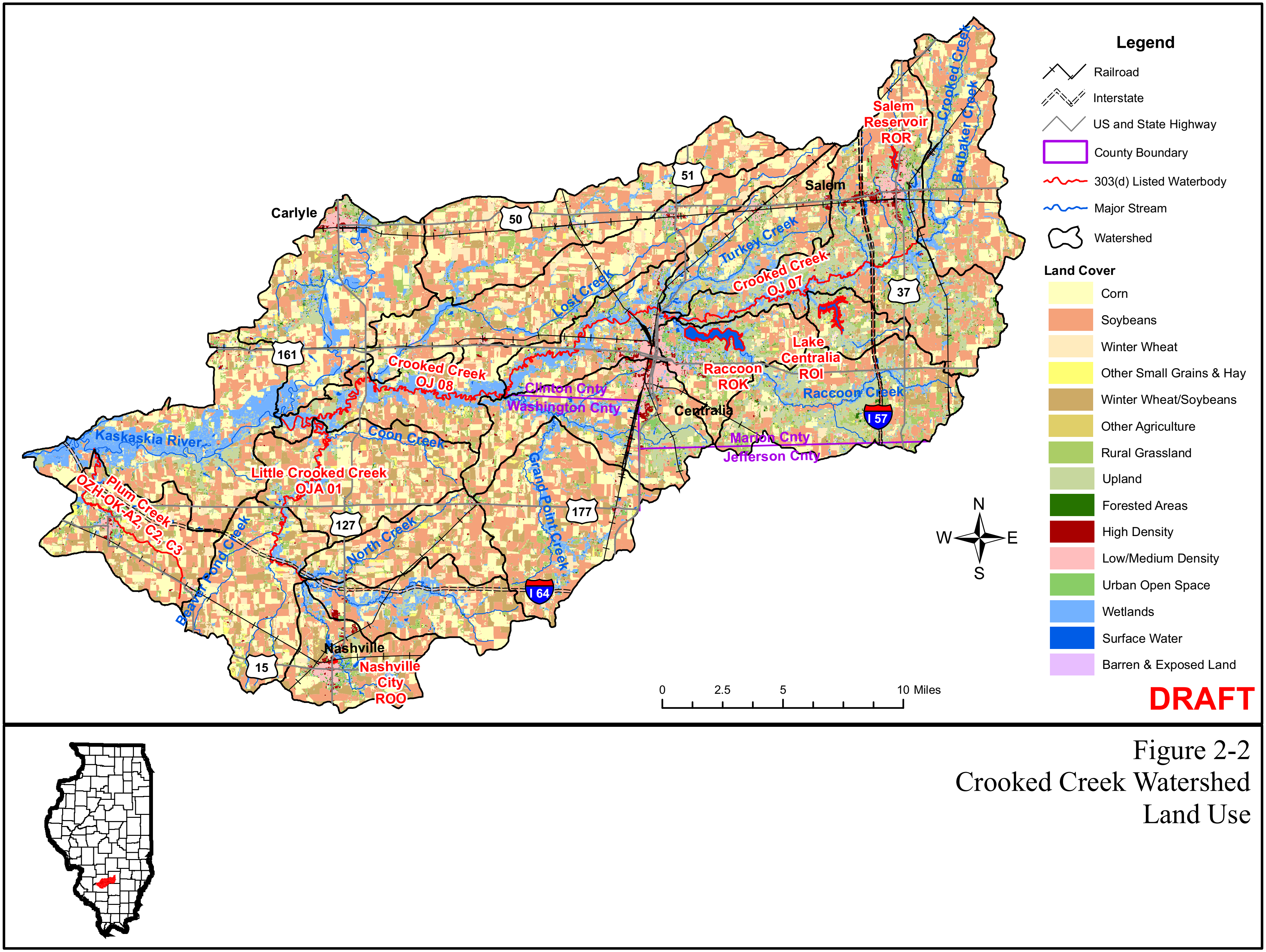

Figure 2-2
Crooked Creek Watershed
Land Use

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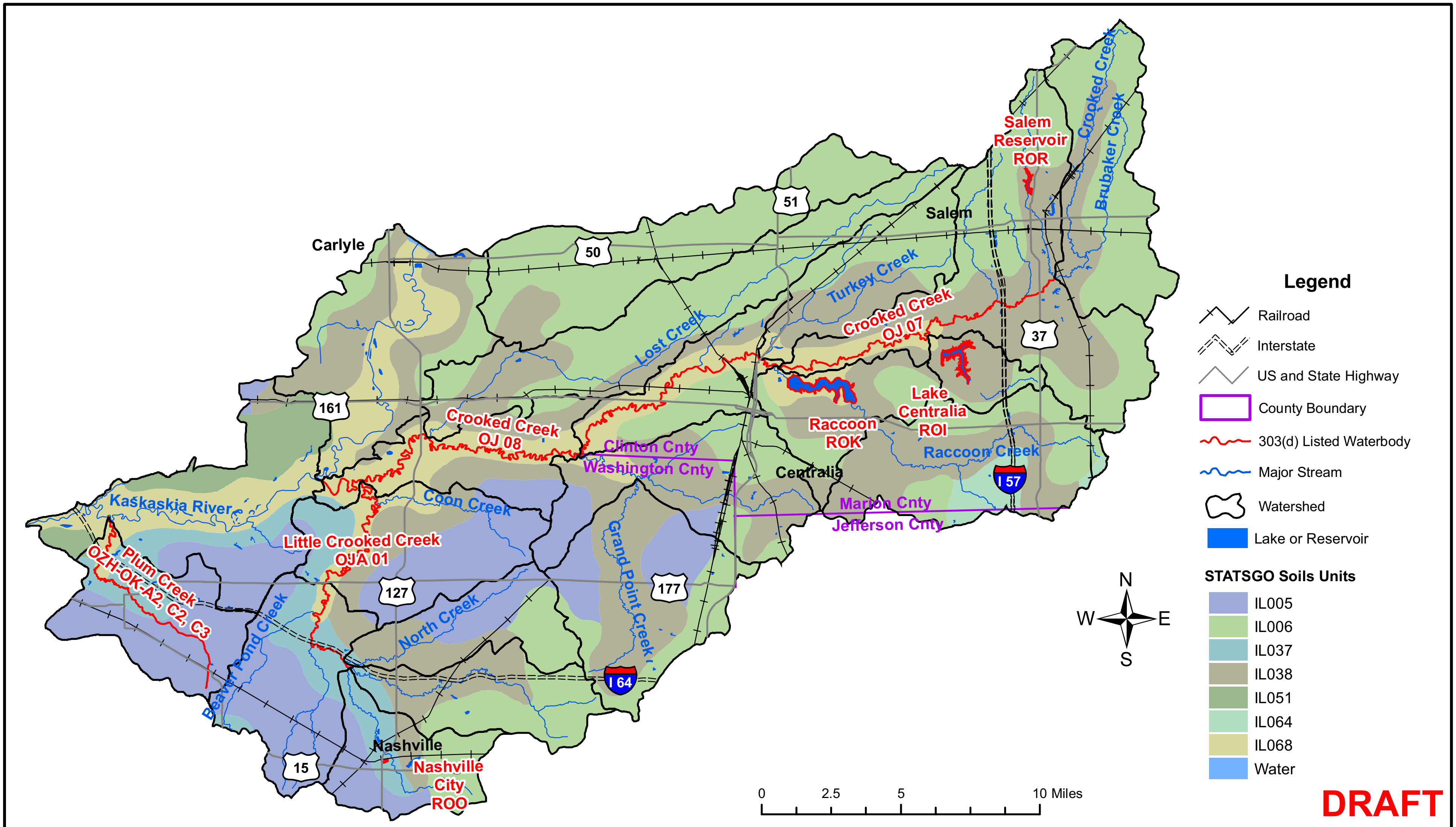

Figure 2-3
Crooked Creek Watershed
Soils

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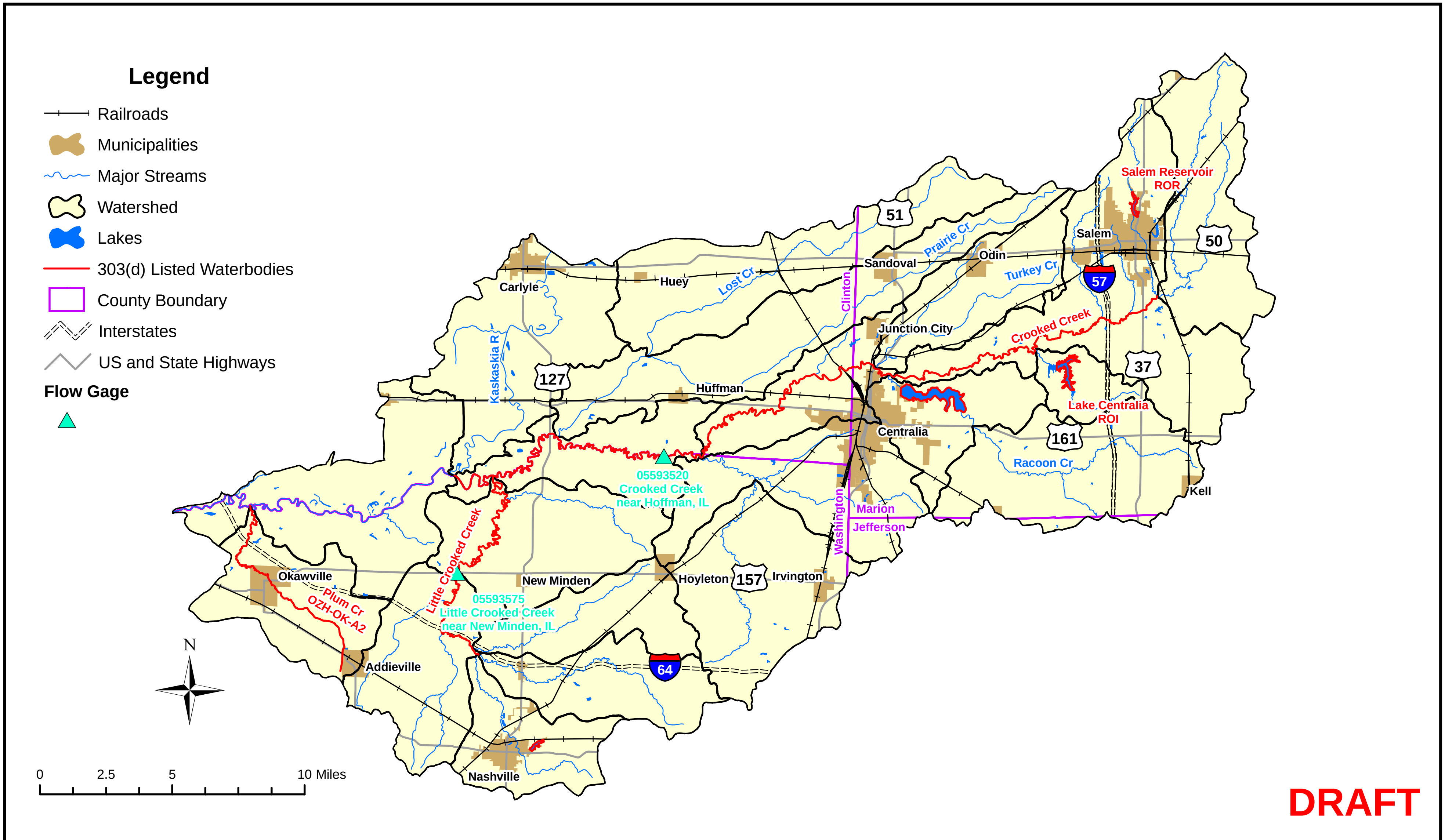

Figure 2-4: USGS Gages
Crooked Creek Watershed

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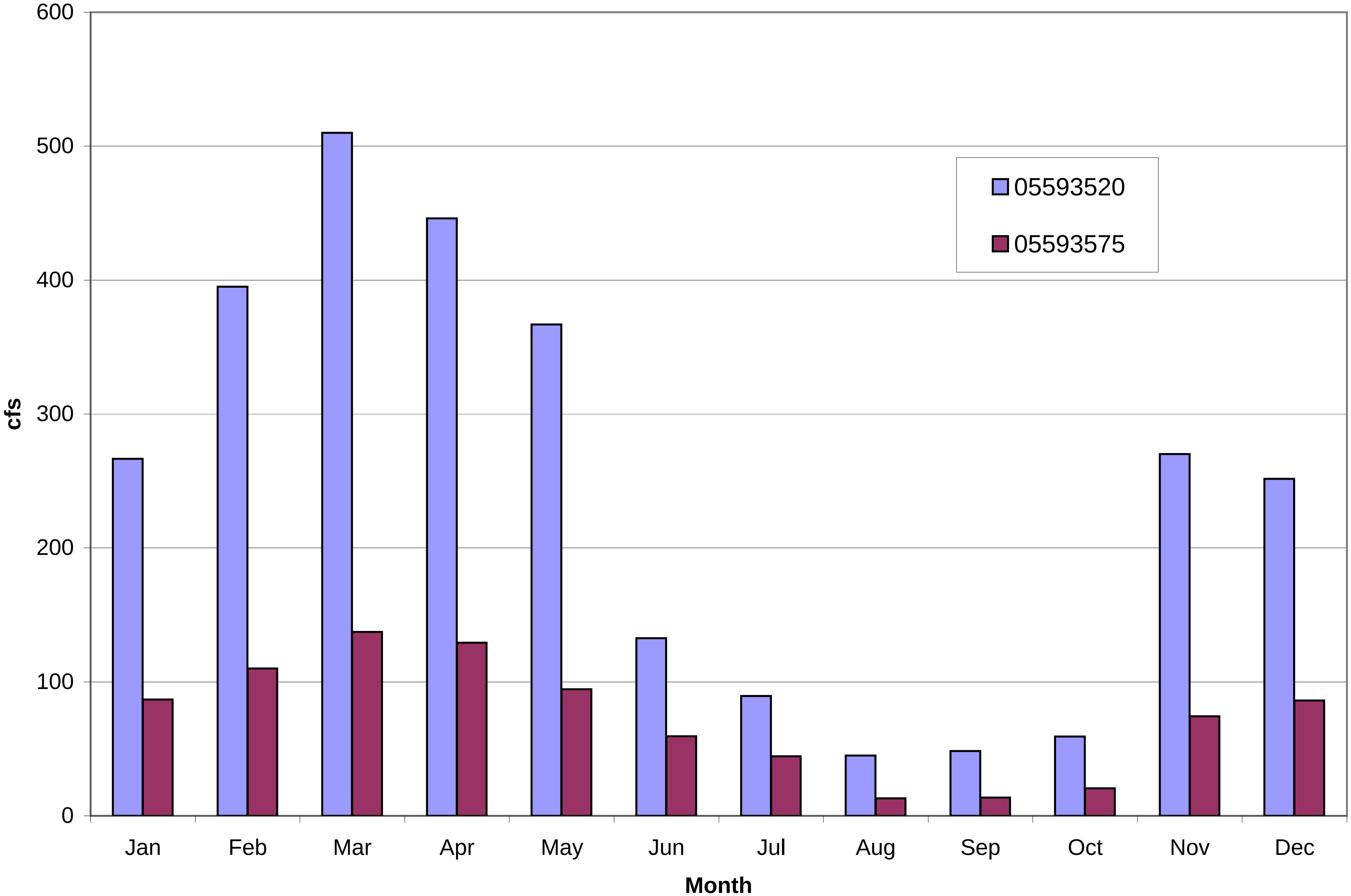

Figure 2-5
Streamflow at USGS Gages 05593720 and 00559375
Crooked Creek near Hoffman, IL
and Little Crooked Creek near New Minden, IL

CDM

T:\GIS\3 Crooked Creek\Data\crookedcreek-precip-temp-flow.xlscrooked flow 2

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Section 3
Public Participation and Involvement

3.1 Crooked Creek Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It is important to involve the public as early in the process as possible to achieve maximum cooperation and counter concerns as to the purpose of the process and the regulatory authority to implement any recommendations.

Illinois EPA, along with CDM, will hold up to four public meetings within the watershed throughout the course of the TMDL development. This section will be updated once public meetings have occurred.

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Section 4
Crooked Creek Watershed Water Quality Standards

4.1 Illinois Water Quality Standards

Water quality standards are developed and enforced by the state to protect the "designated uses" of the state's waterways. In the state of Illinois, setting the water quality standards is the responsibility of the Illinois Pollution Control Board (IPCB). Illinois is required to update water quality standards every three years in accordance with the CWA. The standards requiring modifications are identified and prioritized by Illinois EPA, in conjunction with USEPA. New standards are then developed or revised during the three-year period.

Illinois EPA is also responsible for developing scientifically based water quality criteria and proposing them to the IPCB for adoption into state rules and regulations. The Illinois water quality standards are established in the Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards.

4.2 Designated Uses

The waters of Illinois are classified by designated uses, which include: General Use, Public and Food Processing Water Supplies, Lake Michigan, and Secondary Contact and Indigenous Aquatic Life Use (Illinois EPA 2005). The designated uses applicable to the Crooked Creek watershed are the General Use and the Public and Food Processing Water Supplies Use.

4.2.1 General Use

The General Use classification is defined by IPCB as standards that "will protect the state's water for aquatic life, wildlife, agricultural use, secondary contact use and most industrial uses and ensure the aesthetic quality of the state's aquatic environment." Primary contact uses are protected for all General Use waters whose physical configuration permits such use.

4.2.2 Public and Food Processing Water Supplies

The Public and Food Processing Water Supplies Use is defined by IPCB as standards that are "cumulative with the general use standards of Subpart B and must be met in all waters designated in Part 303 at any point at which water is withdrawn for treatment and distribution as a potable supply or for food processing."

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations for aquatic life uses, Illinois EPA first collects biological data and if this data suggests that an impairment to aquatic life exists, a comparison of available water quality data with water quality standards will then occur. For public and food processing water supply waters, IEPA compares available data with water quality standards to make impairment determinations. Table 4-1 and 4-2 present the water quality standards of the potential causes of impairment for both lakes and streams in the Crooked Creek watershed. Only constituents with numeric water quality standards will have TMDLs developed at this time.

Table 4-1 Summary of Water Quality Standards for Potential Crooked Creek Watershed Lake Impairments

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies
Atrazine	mg/L	Acute standard[(1)] = 82 Chronic standard[(2)] = 9	No numeric standard
Excess Algal Growth	NA	No numeric standard	No numeric standard
Manganese (total)	µg/L	1,000	150
Oxygen, Dissolved	mg/L	5.0 minimum	No numeric standard
pH		6.5 minimum 9.0 maximum	No numeric standard
Sedimentation/Siltation	NA	No numeric standard	No numeric standard
Total Phosphorus	mg/L	0.05[(3)]	No numeric standard
Total Phosphorus - Statistical Guideline	NA	No numeric standard	No numeric standard
Total Suspended Solids	NA	No numeric standard	No numeric standard

µg/L = micrograms per liter

mg/L = milligrams per liter

NA = Not Applicable

[(1)] Not to be exceeded except as provided in 35 Ill. Adm. Code 302.208(d).

[(2)] Not to be exceeded by the average of at least three samples collected over peak atrazine application periods (Spring, Summer, and Fall)

[(3)] Standard applies in particular inland lakes and reservoirs (greater than 20 acres) and in any stream at the point where it enters any such lake or reservoir

Table 4-2 Summary of Water Quality Standards for Potential Crooked Creek Watershed Stream Impairments

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies
Habitat Alteration (streams)	NA	No numeric standard	No numeric standard
Manganese (total)	µg/L	1,000	150
Oxygen, Dissolved	mg/L	5.0 minimum	No numeric standard
pH		6.5 minimum 9.0 maximum	No numeric standard
Sedimentation/Siltation	NA	No numeric standard	No numeric standard
Total Nitrogen as N	NA	No numeric standard	No numeric standard
Total Phosphorus - Statistical Guideline	NA	No numeric standard	No numeric standard
Total Suspended Solids	NA	No numeric standard	No numeric standard

µg/L = micrograms per liter

mg/L = milligrams per liter

NA = Not Applicable

(1) Not to be exceeded except as provided in 35 Ill. Adm. Code 302.208(d).

(2) Not to be exceeded by the average of at least three samples collected over peak atrazine application periods (Spring, Summer, and Fall)

4.4 Potential Pollutant Sources

In order to properly address the conditions within the Crooked Creek watershed, potential pollution sources must be investigated for the pollutants where TMDLs will be developed. The following is a summary of the potential sources associated with the listed causes for the 303(d) listed segments in this watershed. They are summarized in Table 4-3.

Table 4-3 Summary of Potential Sources for Crooked Creek Watershed

Segment ID	Segment Name	Potential Causes	Potential Sources
OJ 07	Crooked Creek	pH, dissolved oxygen, total phosphorus	Municipal point sources, agriculture, crop-related sources, nonirrigated crop production, source unknown
OJ 08	Crooked Creek	Total nitrogen as N, pH, sedimentation/siltation, dissolved oxygen, total suspended solids, total phosphorus	Municipal point sources, agriculture, crop-related sources, nonirrigated crop production, urban runoff/storm sewers, source unknown
ROI	Lake Centralia	Manganese, total phosphorus, total suspended solids, excess algal growth, total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, urban runoff/storm sewers, land disposal, onsite wastewater systems (septic tanks), habitat modification (other than hydromodification), bank or shoreline modification/ destabilization, source unknown
ROK	Raccoon Lake	Manganese, total phosphorus, pH, sedimentation/siltation, dissolved oxygen, atrazine, total suspended solids, excess algal growth	Agriculture, crop-related sources, nonirrigated crop production, urban runoff/storm sewers, land disposal, onsite wastewater systems (septic tanks), habitat modification (other than hydromodification), bank or shore
ROR	Salem Reservoir	Manganese, total phosphorus, dissolved oxygen, total suspended solids, excess algal growth, total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, urban runoff/storm sewers, waterfowl, source unknown
OZH-OK-A2	Plum Creek	Manganese, sedimentation/siltation, dissolved oxygen, habitat alterations (streams), total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, habitat modification (other than hydromodification), bank or shoreline modification/ destabilization, sources unknown
OZH-OK-C2	Plum Creek	Dissolved oxygen, habitat alterations (streams), total phosphorus	Municipal point sources, habitat modification (other than hydromodification), bank or shoreline modification/destabilization
OZH-OK-C3	Plum Creek	Manganese, sedimentation/siltation, dissolved oxygen, habitat alterations (streams), total phosphorus	Municipal point sources, urban runoff/storm sewers
OJA 01	Little Crooked Creek	Manganese, dissolved oxygen, total phosphorus	Municipal point sources, agriculture, crop-related sources, nonirrigated crop production
ROO	Nashville City Reservoir	Manganese, total phosphorus, total suspended solids, excess algal growth	Agriculture, crop-related sources, nonirrigated crop production, urban runoff/storm sewers, forest/ grassland/parkland, source unknown

Section 5
Crooked Creek Watershed Characterization

Data were collected and reviewed from many sources in order to further characterize the Crooked Creek watershed. Data have been collected in regards to water quality, reservoirs, and both point and nonpoint sources. This information is presented and discussed in further detail in the remainder of this section.

5.1 Water Quality Data

There are 23 historic water quality stations within the Crooked Creek watershed that were used for this report. Figure 5-1 shows the water quality data stations within the watershed that contain data relevant to the impaired segments.

The impaired water body segments in the Crooked Creek watershed were presented in Section 1. Refer to Table 1-1 for impairment information specific to each segment. The following sections address both stream and lake impairments. Data are summarized by impairment and discussed in relation to the relevant Illinois numeric water quality standard. Data analysis is focused on all available data collected since 1990. The information presented in this section is a combination of USEPA Storage and Retrieval (STORET) database and Illinois EPA database data. STORET data are available for stations sampled prior to January 1, 1999 while Illinois EPA data (electronic and hard copy) are available for stations sampled after that date. The following sections will first discuss Crooked Creek watershed stream data followed by Crooked Creek watershed lake/reservoir data.

5.1.1 Stream Water Quality Data

The Crooked Creek watershed has three impaired streams within its drainage area that are addressed in this report. There are 10 active water quality stations on impaired segments (see Figure 5-1). The data summarized in this section include water quality data for impaired constituents as well as parameters that could be useful in future modeling and analysis efforts. All historic data are available in Appendix B.

5.1.1.1 Dissolved Oxygen

The following stream segments in the Crooked Creek watershed are 303(d) listed for use impairments caused by low dissolved oxygen: Crooked Creek segments OJ07 and OJ08; Little Crooked Creek segments OJA01 and OJA02; and Plum Creek segments OZH-OK-A2, OZH-OK-C2, and OZH-OK-C3. Table 5-1 summarizes the available historic DO data since 1990 for the impaired stream segments (raw data contained in Appendix B). The table also shows the number of violations for each segment. A sample was considered a violation if the concentration was below 5.0 mg/L. The average DO concentration is below the standard (5.0 mg/L instantaneous minimum) on three of the six impaired segments. Minimum values for all segments are below the DO standard. Figure 5-2 shows the instantaneous DO concentrations over time on Crooked Creek segments OJ07 and OJ08. There was not enough data available on the remaining segments for time series plots.

Table 5-1 Existing DO Data for Crooked Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Illinois WQ Standard (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Crooked Creek Segment OJ 07; Sample Locations OJ07						
DO	5.0[1]	1990-2003; 124	7.58	15.6	2.1	33
Crooked Creek Segment OJ 08; Sample Location OJ08						
DO	5.0[1]	1990-2003; 123	6.8	15.6	2	44
Little Crooked Creek Segment OJA01; Sample Location OJA01						
DO	5.0[1]	1996-2002; 5	3.6	6.1	1.3	4
Plum Creek Segment OZH-OK-A2; Sample Location OZH-OK-A2						
DO	5.0[1]	2002; 1	2.2	2.2	2.2	1
Plum Creek Segment OZH-OK-C2; Sample Locations OZH-OK-C2 and OZH-OK-E2						
DO	5.0[1]	2002; 1	4.8	4.8	4.8	1
Plum Creek Segment OZH-OK-C3; Sample Location OZH-OK-C3						
DO	5.0[1]	2002; 1	1.2	1.2	1.2	1

(1) Instantaneous Minimum

Table 5-2 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for DO TMDL development. Where available, all nutrient, biological oxygen demand, and total organic carbon data has been collected for possible use in future analysis.

Table 5-2 Data Availability for DO Data Needs Analysis and Future Modeling Efforts

Sample Location and Parameter	Available Period of Record Post 1990	Number of Samples
Crooked Creek Segment OJ07; Sample Locations OJ07 and OJ12		
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1990-1998	80
Ammonia, Unionized (mg/L as N)	1990-1998	80
Carbon, Total Organic (mg/L as C)	1990-2002	105
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-2002	113
Nitrogen, Ammonia, Total (mg/L as N)	1990-2002	113
Nitrogen, Kjeldahl, Total (mg/L as N)	1996-2000	7
Phosphorus, Dissolved (mg/L as P)	1990-2002	113
Phosphorus, Total (mg/L as P)	1990-2002	113
Nitrogen Kjeldahl Total Bottom Dep Dry Wt mg/kg	1996-2002	4
Phosphorus, Total, Bottom Deposit (mg/kg-P Dry Wgt)	1996	1
Crooked Creek Segment OJ08; Sample Location OJ08		
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1990-1998	81
Ammonia, Unionized (mg/L as N)	1990-1998	81
Carbon, Total Organic (mg/L as C)	1990-2002	104
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-2001	112
Nitrogen, Ammonia, Total (mg/L as N)	1990-2002	112
Nitrogen, Kjeldahl, Total (mg/L as N)	1996-2000	7
Phosphorus, Dissolved (mg/L as P)	1990-2002	112
Phosphorus, Total (mg/L as P)	1990-2002	112
Nitrogen Kjeldahl Total Bottom Dep Dry Wt mg/kg	1996	1
Phosphorus, Total, Bottom Deposit (mg/kg-P Dry Wgt)	1996	1

Table 5-2 Data Availability for DO Data Needs Analysis and Future Modeling Efforts (continued)

Sample Location and Parameter	Available Period of Record Post 1990	Number of Samples
Little Crooked Creek Segment OJA01; Sample Locations OJA01 and OJA02		
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1996	2
Ammonia, Unionized (mg/L as N)	1996	2
Carbon, Total Organic (mg/L as C)	1996	2
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1996	2
Nitrogen, Ammonia, Total (mg/L as N)	1996	2
Nitrogen, Kjeldahl, Total (mg/L as N)	1996	2
Phosphorus, Dissolved (mg/L as P)	1996	2
Phosphorus, Total (mg/L as P)	1996	2
Plum Creek Segment OZH-OK-A2; Sample Location OZH-OK-A2		
BOD, Carbonaceous	2002	1
BOD	2002	1
Nitrogen, Ammonia (NH3), Total mg/L	2002	1
Nitrogen, Nitrite (NO2) + Nitrate (NO3), Total mg/L	2002	1
Phosphorus as P, Total mg/L	2002	1
Plum Creek Segment OZH-OK-C2; Sample Locations OZH-OK-C2 and OZH-OK-E2		
BOD	2002	2
BOD, Carbonaceous	2002	2
Nitrogen, Ammonia (NH3), Total mg/L	2002	2
Nitrogen, Nitrite (NO2) + Nitrate (NO3), Total mg/L	2002	2
Phosphorus as P, Total mg/L	2002	2
Plum Creek Segment OZH-OK-C3; Sample Location OZH-OK-C3		
Nitrogen, Ammonia (NH3), Total mg/L	2002	1
Nitrogen, Nitrite (NO2) + Nitrate (NO3), Total mg/L	2002	1
Phosphorus as P, Total mg/L	2002	1
BOD, Carbonaceous	2002	1
BOD	2002	1

5.1.1.2 pH

Crooked Creek segments OJ07 and OJ08 are both on the 303(d) list for pH. Table 5-3 summarizes the available historic pH data since 1990 for the impaired stream segments (raw data contained in Appendix B). The table also shows the number of violations for each segment. A sample was considered a violation if the value was not within the 6.5 to 9.0 pH range. The average pH value was within the standard range for both segments and each segment had no more than five violations. There were no violations above 9.0. All occurred when pH levels dropped below 6.5. Figure 5-3 shows pH values recorded over time. The graphic shows that all violations have occurred since 1996.

Table 5-3 Existing pH Data for Crooked Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Illinois WQ Standard (su)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Crooked Creek Segment OJ 07; Sample Locations OJ07						
pH	6.5-9.0	1990-2003; 122	7.3	8.5	6.1	3
Crooked Creek Segment OJ 08; Sample Location OJ08						
pH	6.5-9.0	1990-2003; 123	7.3	8.5	6.2	5

5.1.1.3 Manganese

Little Crooked Creek and Plum Creek segments OZH-OK-A2 and OZH-OK-C3 are listed as impaired for manganese. The applicable water quality standard is a maximum total manganese concentration of 1,000 µg/L for general use and 150 µg/L for public water supply. Neither stream is a source of public water. Table 5-4 summarizes the available historic manganese data since 1990 for the impaired stream segments. This includes dissolved manganese samples where available. The table also shows the number of violations for each segment. There is limited manganese data for each impaired segment. Both Plum Creek segments have only one data point.

Table 5-4 Existing Manganese Data for Crooked Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Illinois WQ Standard (µg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Little Crooked Creek Segment OJA01; Sample Locations OJA01 and OJA02						
Total Manganese	General Use: 1000	1996 - 2002; 5	854	1,400	230	2
Dissolved Manganese	NA		764	1,300	190	NA
Plum Creek Segment OZH-OK-A2; Sample Location OZH-OK-A2						
Total Manganese	General Use: 1000	2002; 1	1,400	1,400	1,400	1
Plum Creek Segment OZH-OK-C3; Sample Location OZH-OK-C3						
Total Manganese	General Use: 1000	2002; 1	1,800	1,800	1,800	1

5.1.2 Lake and Reservoir Water Quality Data

The Crooked Creek watershed has four impaired lakes within its drainage area that are addressed in this report. There are 14 active water quality stations on or tributary to the impaired water bodies (see Figure 5-1). The data summarized in this section include water quality data for impaired constituents as well as parameters that could be useful in future modeling and analysis efforts. All historic data are available in Appendix B.

5.1.2.1 Lake Centralia

There are three active stations on Lake Centralia. The lake is listed as impaired for manganese and total phosphorus. An inventory of all available manganese and phosphorus data at all depths is presented in Table 5-5.

Table 5-5 Lake Centralia Data Inventory for Impairments

Lake Centralia Segment ROI; Sample Locations ROI-1, ROI-2, and ROI-3		
ROI-1	**Period of Record**	**Number of Samples**
Total Phosphorus	1990 - 2001	53
Dissolved Phosphorus	1992 - 2001	50
Total Phosphorus in Bottom Deposits	1992 - 1995	3
Total Manganese	2001	5
Manganese in Bottom Deposits	1992 - 2001	5
ROI-2		
Total Phosphorus	1990 - 2001	26
Dissolved Phosphorus	1992 - 2001	22
Total Phosphorus in Bottom Deposits	1992 - 1995	3
Manganese in Bottom Deposits	1992 - 2001	5

Table 5-6 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for total phosphorus and manganese. DO at varying depths as well as chlorophyll "a" data has been collected where available.

Table 5-6 Lake Centralia Data Availability for Data Needs Analysis and Future Modeling Efforts

Lake Centralia Segment ROI; Sample Locations ROI-1, ROI-2, and ROI-3		
ROI-1	**Period of Record**	**Number of Samples**
Chlorophyll-a Corrected	1992 - 2001	22
Chlorophyll-a Uncorrected	1992 - 2001	22
DO	1998 - 2001	106
ROI-2		
Chlorophyll-a Corrected	1992 - 2001	22
Chlorophyll-a Uncorrected	1992 - 2001	22
DO	1998 - 2001	87
ROI-3		
Chlorophyll-a Corrected	1992 - 2001	22
Chlorophyll-a Uncorrected	1992 - 2001	22
DO	1998 - 2001	50

5.1.2.1.1 Total Phosphorus

Compliance with the total phosphorus standard is based on samples collected at a one-foot depth from the lake surface. The average total phosphorus concentrations at a one-foot depth for each year of available data at each monitoring site on Lake Centralia are presented in Table 5-7. The water quality standard for total phosphorus is a concentration less than or equal to 0.05 mg/L.

Table 5-7 Average Total Phosphorus Concentrations (mg/L) in Lake Centralia at One-Foot Depth

	ROI-1		ROI-2		ROI-3		Lake Average	
Year	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average
1990	4; 2	0.07	NS	NS	4; 3	0.09	8; 5	0.08
1992	3; 0	0.03	3; 0	0.03	3; 2	0.06	9; 2	0.04
1995	5; 3	0.05	5; 2	0.05	5; 3	0.07	15; 8	0.06
1998	9; 7	0.08	8; 8	0.1	9; 9	0.14	26; 24	0.11
2001	5; 2	0.07	5; 3	0.08	5; 3	0.09	15; 8	0.08

The annual averages for total phosphorus at all three sites as well as the lake average are greater than the 0.05 mg/L standard except in 1992 at sites ROI-1 and ROI-2, which brought the lake average below the standard that year as well. The majority of the samples taken at ROI-3 have been above the standard. Figure 5-4 shows the average values by year. Average concentrations were highest at all sites in 1998.

5.1.2.1.2 Manganese

The applicable water quality standard for manganese is a maximum concentration of 1,000 µg/L for general use and 150 µg/L for public water supplies. Table 5-8 summarizes available manganese data for Lake Centralia. Four out of five samples taken in 2001 violated the public water supply standard. All samples were collected at a depth of 11 feet.

Table 5-8 Average Total Manganese Concentrations in Lake Centralia

Year	ROI-1			
	Water Quality Standard (µg/L)	Data Count	Number of Violations	Average
2001	General Use: 1,000	5	0	187
	Public Water Supply: 150		4	

5.1.2.2 Raccoon Lake

There are three active stations on Raccoon Lake and two tributary stations. The lake is listed for impairments caused by manganese, total phosphorus, pH, DO, and atrazine. An inventory of all available manganese, phosphorus, DO, and pH data at all depths is presented in Table 5-9. Atrazine data is further discussed in Section 5.1.2.2.5.

Table 5-9 Raccoon Lake Data Inventory for Impairments

Raccoon Lake Segment ROK; Sample Locations ROK-1, ROK-2, ROK-3, ROK-4, and ROK-5		
ROK-1	**Period of Record**	**Number of Samples**
DO	1990-1998	250
Total Phosphorus	1990-2001	97
Dissolved Phosphorus	1990-1998	63
Total Phosphorus in Bottom Deposits	1990-1995	4
Total Manganese	2001	5
Total Manganese in Bottom Deposits	1990-2001	6
pH	1990-2001	63
ROK-2		
DO	1990-2001	157
Total Phosphorus	1990-2001	76
Dissolved Phosphorus	1990-1998	33
pH	1990-2001	32
ROK-3		
DO	1990-2001	95
Total Phosphorus	1990-2001	72
Dissolved Phosphorus	1990-1998	33
Total Phosphorus in Bottom Deposits	1990-1995	4
Total Manganese in Bottom Deposits	1990-2001	6
pH	1990-2001	33
ROK-4 (tributary)		
DO	2001	4
Total Phosphorus	2001	26
Dissolved Phosphorus	2001	4
pH	2001	4
ROK-5 (tributary)		
DO	2001	3
Total Phosphorus	2001	25
Dissolved Phosphorus	2001	3
pH	2001	3

Table 5-10 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for total phosphorus, DO, and manganese. Nutrient, biological oxygen demand, total organic carbon, and chlorophyll-"a" data has been collected where available.

Table 5-10 Raccoon Lake Data Availability for Data Needs Analysis and Future Modeling Efforts

Raccoon Lake Segment ROK; Sample Locations ROK-1, ROK-2, ROK-3, ROK-4, and ROK-5		
ROK-1	**Period of Record**	**Number of Samples**
Chlorophyll-a Corrected	1990-2001	45
Chlorophyll-a Uncorrected	1990-2001	45
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1990-1998	32
Ammonia, Unionized (mg/L as N)	1990-1998	32
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-2001	97
Nitrogen Kjeldahl Total Bottom Dep Dry Wt mg/kg	1990-1995	4
Nitrogen, Ammonia, Total (mg/L as N)	1990-2001	96
TKN	1990-2001	69
TOC	1998	1
TOC Sediment	2001	1
Carbon, Total Organic (UV Oxid.), Dry Wt, Sediment %	1995	1
ROK-2		
Chlorophyll-a Corrected	1990-2001	39
Chlorophyll-a Uncorrected	1990-2001	39
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1990-1998	18
Ammonia, Unionized (mg/L as N)	1990-1998	18
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-2001	76
Nitrogen, Ammonia, Total (mg/L as N)	1990-2001	76
TKN	1990-2001	55
ROK-3		
Chlorophyll-a Corrected	1990-2001	39
Chlorophyll-a Uncorrected	1990-2001	39
Ammonia, Unionized (Calc Fr Temp pH-NH4) (mg/L)	1990-1998	19
Ammonia, Unionized (mg/L as N)	1990-1998	19
Ammonia-N, Total	1998	1
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-2001	72
Nitrogen Kjeldahl Total Bottom Dep Dry Wt mg/kg	1990-1995	4
Nitrogen, Ammonia, Total (mg/L as N)	1990-2001	71
TKN	1990-2001	57
TOC	1998	1
Carbon, Total Organic (UV Oxid.), Dry Wt. Sediment %	1995	1
ROK-4 (tributary)		
TKN	2001	21
Total Ammonia	2001	26
Total Nitrate & NO2	2001	26
ROK-5 (tributary)		
TKN	2001	20
Total Ammonia	2001	25
Total Nitrate & NO2	2001	25

5.1.2.2.1 pH

Table 5-11 summarizes the available historic pH data collected since 1990 from Raccoon Lake (raw data contained in Appendix B). The table also shows the number of violations recorded at each site. A sample was considered a violation if the pH value was not between 6.5 and 9.0 standard units.

Table 5-11 Average pH Values (s.u.) in Raccoon Lake at One-Foot Depth

	ROK-1		ROK-2		ROK-3		Lake Average	
Year	**Data Count; Number of Violations**	**Average**	**Data Count; Number of Violations**	**Average**	**Data Count; Number of Violations**	**Average**	**Data Count; Number of Violations**	**Average**
1998	10; 0	7.4	4; 1	7	5; 1	7.0	19; 2	7.1
2001	15; 1	8.2	9; 1	7.9	8; 0	7.6	30; 2	7.9

The average pH concentration was within the standard range at all locations. Two of the violations occurred when pH values where sampled below 6.5. Both of these samples were collected in 1998. The remaining violations occurred when samples were collected that were above 9.0. These instances occurred in 2001.

5.1.2.2.2 Total Phosphorus

The water quality standard for total phosphorus is a concentration less than or equal to 0.05 mg/L. Compliance is assessed at a one-foot depth from the lake surface. The average total phosphorus concentrations at a one-foot depth for each year of available data at each monitoring site in Raccoon Lake are presented in Table 5-12.

Table 5-12 Average Total Phosphorus Concentrations (mg/L) in Raccoon Lake at One-Foot Depth

	ROK-1		ROK-2		ROK-3		Lake Average	
Year	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average
1990	5; 5	0.09	5; 5	0.13	5; 5	0.2	15; 15	0.13
1991	5; 5	0.19	5; 5	0.22	NA	NA	10; 10	0.21
1992	5; 5	0.12	5; 5	0.17	5; 5	0.2	15; 15	0.16
1993	5; 5	0.17	5; 5	0.18	5; 5	0.23	15; 15	0.19
1995	5; 5	0.18	5; 5	0.22	5; 5	0.25	15; 15	0.22
1996	4; 4	0.1	NA	NA	NA	NA	4; 4	0.10
1998	9; 9	0.19	9; 9	0.27	9; 9	0.36	27; 27	0.27
2001	17; 16	0.23	41; 41	0.16	41; 41	0.46	99; 98	0.28

Only one sample collected from Raccoon Lake since 1990 has been at or below the 0.05 mg/L total phosphorus standard. Figure 5-5 shows the annual average total phosphorus concentrations for each sampling location as well as for the entire lake.

Tributary data were collected in 2001. There is no numeric standard for total phosphorus in streams; however, the lake standard does apply to streams at the point at which it enters the lake or reservoir. All samples collected on Raccoon Lake tributaries have total phosphorus concentrations above the lake standard of 0.05 mg/L (Table 5-13).

Table 5-13 Total Phosphorus Concentrations (mg/L) in Raccoon Lake Tributaries 2001

	ROK-4	ROK-5	Combined Tributary Data
# of samples	26	25	51
minimum	0.10	0.06	0.06
average	0.65	0.38	0.52
maximum	1.88	0.85	1.88

5.1.2.2.3 Dissolved Oxygen

The average DO concentrations at a one-foot depth for each year of available data at each monitoring site in Raccoon Lake are presented in Table 5-14. The water quality standard for DO is an instantaneous minimum concentrations of 5.0 mg/L. Compliance is assessed at a one-foot depth from the lake surface. No violations were recorded between 1992 and 1998. Figure 5-6 shows the DO concentrations in the lake over time.

Table 5-14 Average DO Concentrations (mg/L) in Raccoon Lake at One-Foot Depth

Year	ROK-1		ROK-2		ROK-3		Lake Average	
	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average
1990	6; 1	8.75	4; 1	7.5	5; 0	8.0	15; 2	8.1
1992	5; 0	8	5; 0	8.9	5; 0	8.0	15; 0	8.3
1993	11; 0	8.1	11; 0	8.5	11; 0	8.3	33; 0	8.3
1995	4; 0	9.3	6; 0	9.1	5; 0	9.9	15; 0	9.4
1998	10; 0	7	12; 0	7.2	8; 0	7.9	30; 0	7.4
2001	NA	NA	3; 3	3.2	4; 4	3.1	7; 7	3.2

5.1.2.2.4 Manganese

The applicable water quality standard for manganese is 1,000 µg/L for general use and 150 µg/L for public water supplies. Table 5-15 summarizes available manganese data for Raccoon Lake. Four out of five samples taken in 2001 violated the public water supply standard. All samples were taken seven feet below the lake surface.

Table 5-15 Average Total Manganese Concentrations in Raccoon Lake

Year	ROK-1			
	Water Quality Standard (µg/L)	Data Count	Number of Violations	Average
2001	General Use: 1,000	5	0	199
	Public Water Supply: 150		4	

5.1.2.2.5 Atrazine

As mentioned above, Raccoon Lake is a source of public water. Atrazine data have recently been collected to assist in public water supply assessments. In order to determine atrazine compliance, this data, coupled with any IEPA ambient atrazine samples were first organized into quarters (Jan-March, April-June, July-Sept, Oct-Dec). An average and running average was then performed on the organized data. If any four quarter average was over 3.0 ppb, the lake was considered impaired. Table 5-16 contains the quarterly average concentration of atrazine data collected at the Centralia raw water intake. The average for data collected in the second quarter of 2003 exceeded 3 ppb and was subsequently listed as impaired. There have been no violations calculated since that quarter.

Table 5-16 Quarterly Average Atrazine Concentrations at Centralia Water Intake

Quarter	Average Atrazine Concentration (ppb)	
	2003	2004
Jan-Mar	0.6	0.5
Apr-June	**4.7**	2.30
July-Sept	1.7	1.68
Oct-Dec	1.4	0.3

5.1.2.3 Salem Reservoir

There are three active stations on Salem Reservoir. The lake is listed for impairments caused by manganese, total phosphorus, and DO. An inventory of all available manganese, phosphorus, and DO data at all depths is presented in Table 5-17.

Table 5-17 Salem Reservoir Data Inventory for Impairments

Salem Reservoir Segment ROR; Sample Locations ROR-1, ROR-2, and ROR-3		
ROR-1	**Period of Record**	**Number of Samples**
DO	1990-1999	96
Total Phosphorus	1990-1999	42
Dissolved Phosphorus	1990-1999	32
Total Phosphorus in Bottom Deposits	1990-1995	2
Total Manganese	1999	5
Total Manganese in Bottom Deposits	1990-1995	3
ROR-2		
DO	1990-1999	54
Total Phosphorus	1990-1999	15
Dissolved Phosphorus	1990-1999	15
ROR-3		
DO	1990-1999	28
Total Phosphorus	1990-1999	25
Dissolved Phosphorus	1990-1999	15
Total Phosphorus in Bottom Deposits	1990-1995	2
Total Manganese in Bottom Deposits	1990-1999	3

Table 5-18 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for total phosphorus, DO, and manganese. Nutrient, biological oxygen demand, total organic carbon, and chlorophyll-"a" data has been collected where available.

Table 5-18 Salem Reservoir Data Availability for Data Needs Analysis and Future Modeling Efforts

Salem Reservoir Segment ROR; Sample Locations ROR-1, ROR-2, and ROR-3		
ROR-1	**Period of Record**	**Number of Samples**
TOC	1999	1
Carbon, Total Organic (UV Oxid.), Dry Wt, Sediment %	1995	1
Chlorophyll-a Corrected	1990-1999	14
Chlorophyll-a Uncorrected	1990-1999	14
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1990-1995	12
Ammonia, Unionized (mg/L as N)	1990-1995	12
Total Ammonia	1990-1999	42
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-1999	42
TKN	1990-1999	32
Nitrogen Kjeldahl Total Bottom Dep Dry Wt mg/kg	1990-1995	2
ROR-2		
Chlorophyll-a Corrected	1990-1999	14
Chlorophyll-a Uncorrected	1990-1999	14
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1990-1995	9
Ammonia, Unionized (mg/L as N)	1990-1995	9
Total Ammonia	1990-1999	15
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-1999	15
TKN	1990-1999	15

Table 5-18 Salem Reservoir Data Availability for Data Needs Analysis and Future Modeling Efforts (continued)

Salem Reservoir Segment ROR; Sample Locations ROR-1, ROR-2, and ROR-3		
ROR-3	**Period of Record**	**Number of Samples**
TOC	1999	1
Carbon, Total Organic (UV Oxid.), Dry Wt, Sediment %	1995	1
Chlorophyll-a Corrected	1990-1999	14
Chlorophyll-a Uncorrected	1990-1999	14
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1990-1995	8
Ammonia, Unionized (mg/L as N)	1990-1995	8
Total Ammonia	1990-1999	25
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1990-1999	25
TKN	1990-1999	15
Nitrogen Kjeldahl Total Bottom Dep Dry Wt mg/kg	1990-1995	2

5.1.2.3.1 Total Phosphorus

The average total phosphorus concentrations at a one-foot depth for each year of available data at each monitoring site in Salem Reservoir are presented in Table 5-19. The water quality standard for total phosphorus is a concentration less than or equal to 0.05 mg/L. Compliance is assessed at a one-foot depth from the lake surface.

Table 5-19 Average Total Phosphorus Concentrations (mg/L) in Salem Reservoir at One-Foot Depth

	ROR-1		ROR-2		ROR-3		Reservoir Average	
Year	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average
1990	5; 5	0.19	5; 5	0.21	5; 5	0.25	15; 15	0.22
1991	6; 6	0.17	NA	NA	6; 6	0.22	12; 12	0.20
1993	4; 4	0.26	NA	NA	4; 4	0.27	8; 8	0.27
1995	5; 5	0.26	5; 5	0.28	5; 5	0.31	15; 15	0.28
1999	4; 4	0.14	5; 5	0.16	5; 5	0.17	14; 14	0.16

Since 1990, there have been no samples collected at a one-foot depth that are below the 0.05 mg/L total phosphorus standard. Figure 5-7 shows the yearly average total phosphorus concentration at each sampling location as well as average values for the reservoir.

5.1.2.3.2 Dissolved Oxygen

The average DO concentrations at a one-foot depth for each year of available data at each monitoring site in Salem Reservoir are presented in Table 5-20. The water quality standard for DO is a 5.0 mg/L instantaneous minimum. Compliance is determined at a one-foot depth from the lake surface.

Table 5-20 Average DO Concentrations (mg/L) in Salem Reservoir at One-Foot Depth

Year	ROR-1		ROR-2		ROR-3		Reservoir Average	
	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average
1990	5; 2	6.9	5; 1	8	4; 1	8.6	14; 4	7.8
1993	1; 0	8.1	NA	NA	4; 0	8	5; 0	8.1
1995	4; 0	8.6	4; 0	8.9	NA	NA	8; 0	8.8
1999	5; 0	7.5	5; 0	7.4	5; 0	7.4	15; 0	7.4

Figure 5-8 shows the DO concentrations sampled over time at Salem Reservoir locations. The annual averages for DO at all three sites as well as the lake average are not in violation of the DO standard at a one-foot depth during any sampling year. However, four DO measurements have been recorded below 5.0 mg/L. All occurred in 1990.

5.1.2.3.3 Manganese

The applicable water quality standard for manganese is 1,000 µg/L for general use and 150 µg/L for public water supplies. Table 5-21 summarizes available manganese data for Salem Reservoir. Four out of five samples taken in 1999 violated the public water supply standard. Samples were collected between 5 and 6 feet below the lake surface.

Table 5-21 Average Total Manganese Concentrations in Salem Reservoir

Year	ROR-1			
	Water Quality Standard (mg/L)	Data Count	Number of Violations	Average
1999	General Use: 1,000	5	0	244
	Public Water Supply: 150		4	

5.1.2.4 Nashville City Reservoir

There are three active water quality stations on Nashville City Reservoir. The reservoir is listed for impairments caused by manganese and total phosphorus. An inventory of all available manganese and phosphorus data at all depths is presented in Table 5-22.

Table 5-22 Nashville City Reservoir Data Inventory for Impairments

Nashville City Reservoir Segment ROO; Sample Locations ROO-1, ROO-2, and ROO-3		
ROO-1	**Period of Record**	**Number of Samples**
Total Phosphorus	1990-2000	66
Dissolved Phosphorus	1992-1998	30
Total Phosphorus in Bottom Deposits	1992-1993	3
Total Manganese in Bottom Deposits	1992-1998	4
ROO-2		
Total Phosphorus	1993-2000	43
Dissolved Phosphorus	1993-1998	14
ROO-3		
Total Phosphorus	1993-2000	23
Dissolved Phosphorus	1993-1998	14
Total Phosphorus in Bottom Deposits	1993	2
Total Manganese in Bottom Deposits	1993-1998	3

Table 5-23 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for total phosphorus and manganese. DO sampled at various depths, as well as chlorophyll-"a" data, has been collected where available.

Table 5-23 Nashville City Reservoir Data Availability for Data Needs Analysis and Future Modeling Efforts

Nashville City Reservoir Segment ROO; Sample Locations ROO-1, ROO-2, and ROO-3		
ROO-1	**Period of Record**	**Number of Samples**
Chlorophyll-a Corrected	1998-2000	9
Chlorophyll-a Uncorrected	1998-2000	9
DO	1992-2000	139
ROO-2		
Chlorophyll-a Corrected	1998-2000	11
Chlorophyll-a Uncorrected	1998-2000	11
DO	1993-2000	107
ROO-3		
Chlorophyll-a Corrected	1998-2000	11
Chlorophyll-a Uncorrected	1998-2000	11
DO	1993-2000	49

5.1.2.4.1 Total Phosphorus

The water quality standard for total phosphorus is a concentration less than 0.05 mg/L. Compliance is assessed at a one-foot depth from the lake surface. The average total phosphorus concentrations at a one-foot depth for each year of available data at each monitoring site in Nashville City Reservoir are presented in Table 5-24.

Table 5-24 Average Total Phosphorus Concentrations (mg/L) in Nashville City Reservoir at One-Foot Depth

Year	ROOI-1		ROO-2		ROO-3		Reservoir Average	
	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average	Data Count; Number of Violations	Average
1990	7; 7	0.89	NA	NA	NA	NA	7; 7	0.89
1992	1; 1	2.27	NA	NA	NA	NA	1; 1	2.27
1993	8; 8	1.49	11; 11	1.53	7; 7	1.5	26; 26	1.51
1997	6; 6	0.69	NA	NA	NA	NA	6; 6	0.69
1998	14; 14	0.77	9; 9	0.75	9; 9	0.77	32; 32	0.76
1999	1; 1	0.63	NA	NA	NA	NA	1; 1	0.63
2000	6; 6	0.23	19; 19	0.75	9; 8	0.17	34; 33	0.38

Figure 5-9 shows the annual average total phosphorus concentration at each sampling location. Since 1992, the annual average total phosphorus within the reservoir has been declining, but as of 2000, it was still well above the average. Only one sample collected since 1990 was below 0.5 mg/L.

5.1.2.4.2 Manganese

The applicable water quality standard for manganese is 1,000 µg/L for general use and 150 µg/L for public water supplies. Table 5-25 summarizes manganese data for Nashville City Reservoir. Sediment samples taken at ROO-1 and ROO-3 are the only manganese data available for the reservoir.

Table 5-25 Manganese in Bottom Deposits in Nashville City Reservoir

Sample Location	Sampling Date	(µg/kg)
ROO-1	8/3/1992	2,000
ROO-1	6/21/1993	1,700
ROO-1	6/21/1993	1,600
ROO-1	8/4/1998	1,400
ROO-3	6/21/1993	393
ROO-3	6/21/1993	384
ROO-3	8/4/1998	460

5.2 Reservoir Characteristic

There are four impaired reservoirs in the Crooked Creek watershed. Reservoir information that can be used for future modeling efforts was collected from GIS analysis, the U.S. Army Corps of Engineers, the Illinois EPA, and USEPA water quality data. The following sections will discuss the available data for each reservoir.

5.2.1 Lake Centralia

Constructed in 1910, Lake Centralia has a surface area of 450 acres with approximately 13 miles of shoreline. Lake Centralia, along with Raccoon Lake, serves as a drinking water source for the Centralia Community Water Supply (Source Water Assessment Program, Illinois EPA 2002). Located in Marion County northeast of Carlyle, Lake Centralia is located on Martin Branch, which is tributary to Crooked Creek. Table 5-26 contains U.S. Army Corps of Engineers dam data.

Table 5-26 Lake Centralia Dam Information (U.S. Army Corps of Engineers)

Dam Length	270 feet
Dam Height	27 feet
Maximum Discharge	1,025 cfs
Maximum Storage	162 acre-feet
Normal Storage	101 acre-feet
Spillway Width	53 feet
Outlet Gate Type	U

Table 5-27 contains depth information for each sampling location. The average maximum depth in Lake Centralia is 21.8 feet.

Table 5-27 Average Depths (ft) for Lake Centralia for Segment ROI (Illinois EPA 2002 and USEPA 2002a)

Year	ROI-1	ROI-2	ROI-3
1990	21.4	15.5	7.55
1991	21.5	15.4	7.59
1992	21.4	14.9	7.71
1995	21.8	15.7	8.50
1998	22.9	15.2	8.43
2001	21.8	16.0	8.61
Average	**21.8**	**15.5**	**8.1**

5.2.2 Raccoon Lake

Raccoon Lake is located northeast of Centralia in Marion County. The lake was created in 1943 by damming Raccoon Creek. The lake has a surface area of 925 acres. Along with Lake Centralia, Raccoon Lake serves as the drinking water source for the Centralia Community Water Supply. An average of 3.9 million gallons are pumped daily from the reservoirs to approximately 7,500 service connections and an estimated population of 14,274 people in Marion, Clinton, and Washington Counties (Source Water Assessment Program, Illinois EPA 2002). Table 5-28 contains U.S. Army Corps of Engineers dam data.

Table 5-28 Raccoon Lake Dam Information (U.S. Army Corps of Engineers)

Dam Length	720 feet
Dam Height	31 feet
Maximum Discharge	5,183 cfs
Maximum Storage	4,165 acre-feet
Normal Storage	2,772 acre-feet
Spillway Width	150 feet
Outlet Gate Type	T

Table 5-29 contains depth information for each sampling location on the lake. The maximum water depth is 12.1 feet.

Table 5-29 Average Depths (ft) for Raccoon Lake Segment ROK (Illinois EPA 2002 and USEPA 2002a)

Year	ROK-1	ROK-2	ROK-3
1990	11.9	5.9	3.1
1991	10.7	4.9	2.4
1992	12.2	6.1	3.0
1993	12.8	7.0	4.2
1994	12.1	6.3	3.4
1995	12.8	6.8	3.6
1996	11.9	6.2	3.1
1997	12.1	6.1	3.4
1998	12.0	5.2	2.9
2001	12.0	5.2	3.4
Average	**12.1**	**6.0**	**3.2**

5.2.3 Salem Reservoir

Salem Reservoir is located in Marion County,
northeast of Centralia, and has a surface area of 74 acres. The City of Salem is supplied by the Salem Community Water Supply, which draws water from Carlyle Lake and Salem Reservoir (Source Water Assessment Program, Illinois EPA 2002). Table 5-30 contains U.S. Army Corps of Engineers dam data.

Table 5-30 Salem Reservoir Dam Information (U.S. Army Corps of Engineers)

Dam Length	775 feet
Dam Height	21 feet
Maximum Discharge	3,000 cfs
Maximum Storage	900 acre-feet
Normal Storage	388 acre-feet
Spillway Width	60 feet
Outlet Gate Type	U

Table 5-31 contains depth information for each sampling location on the lake. The average maximum depth in Salem Reservoir is 10.4 feet.

Table 5-31 Average Depths (ft) for Salem Reservoir Segment ROR (Illinois EPA 2002 and USEPA 2002a)

Year	ROR-1	ROR-2	ROR-3
1990	11.9	5.93	2.80
1991	10.4	6.45	3.05
1992	10.6	6.38	3.69
1993	11.8	7.90	4.60
1994	8.56	4.69	2.69
1995	11.2	6.17	2.97
1996	9.83	6.75	3.17
1997	9.94	6.19	3.25
1998	9.56	6.31	3.00
1999	10.3	5.72	2.60
Average	**10.4**	**6.2**	**3.2**

5.2.4 Nashville City Reservoir

Nashville City Reservoir is located in Washington County on the north side of Nashville and has a surface area of approximately 43 acres. It was created in 1931 by damming Nashville Creek. In conjunction with Washington County Lake, the Nashville City Reservoir serves as a drinking water supply to the City of Nashville. Table 5-32 contains U.S. Army Corps of Engineers dam data.

Table 5-32 Nashville City Reservoir Dam Information (U.S. Army Corps of Engineers)

Dam Length	740 feet
Dam Height	26 feet
Maximum Discharge	9,710 cfs
Maximum Storage	701 acre-feet
Normal Storage	400 acre-feet
Spillway Width	180 feet
Outlet Gate Type	U

Table 5-33 contains depth information for each sampling location. The average maximum depth in Nashville City Reservoir is 12.4 feet.

Table 5-33 Average Depths (ft) for Nashville City Reservoir Segment ROO (Illinois EPA 2002 and USEPA 2002a)

Year	ROO-1	ROO-2	ROO-3
1990	14.1	10.9	4.3
1991	11.4	10.0	3.3
1992	12.3	10.6	3.9
1993	13.2	10.9	4.6
1995	13.0	9.6	4.4
1996	12.2	8.9	3.1
1997	11.9	9.6	4.1
1998	13.5	10.9	4.2
2000	10.4	8.0	2.5
Average	**12.4**	**9.9**	**3.8**

5.3 Point Sources

Point sources for the Crooked Creek watershed have been separated into municipal/ industrial sources and mining discharges. Available data have been summarized and are presented in the following sections.

5.3.1 Municipal and Industrial Point Sources

Permitted facilities must provide Discharge Monitoring Reports (DMRs) to Illinois EPA as part of their NPDES permit compliance. DMRs contain effluent discharge sampling results, which are then maintained in a database by the state. There are approximately 30 point sources located within the Crooked Creek watershed. Figure 5-10 shows all facilities with available DMR data found in the basin. In order to assess point source contributions to the watershed, the data has been examined by receiving water and then by the downstream impaired segment that has the potential to receive the discharge. Receiving waters were determined through information contained in the USEPA Permit Compliance System (PCS) database. Maps were used to determine downstream impaired receiving water information when PCS data were not available. The impairments for each segment or downstream segment were considered when reviewing DMR data. Data have been summarized for any sampled parameter that is associated with a downstream impairment (i.e., all available nutrient and biological oxygen demand data were reviewed for segments that are impaired for DO). This can assist in future model selection as well as source assessment and load allocation.

5.3.1.1 Crooked Creek Segments OJ 07 and OJ 08

There are 18 point sources within the subbasins for Crooked Creek segments OJ 07 and OJ 08. Segments OJ 07 and OJ 08 are listed for impairments caused by pH and DO. Table 5-34 contains a summary of available and pertinent DMR data for these point sources.

Table 5-34 Effluent Data from Point Sources Discharging Upstream of or Directly to Crooked Creek Segments OJ 07 and OJ 08 (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Illinois Central RR-Centralia 1995-2004 IL0000779	Fulton Creek/Crooked Creek Segments OJ 07	Average Daily Flow	0.011 mgd	NA
		pH	7.51 su	—
Centralia WTP 1994-2005 IL0001252	Crooked Creek/Crooked Creek Segments OJ 07	Average Daily Flow	0.216 mgd	NA
		pH	7.28 su	—
Salem STP 1989-2005 IL0023264	Town Creek/Crooked Creek Segments OJ 07	Average Daily Flow	1.67 mgd	NA
		BOD, 5-Day	128.7 mg/L	—
		CBOD, 5-Day	34.2 mg/L	31.5
		Nitrogen, Ammonia	0.113 mg/L	0.95
		pH	7.50 su	
Central City STP 1989-2004 IL0024899	NA/Crooked Creek Segments OJ 07	Average Daily Flow	0.304 mgd	NA
		BOD, 5-Day	158.1 mg/L	28.8
		CBOD, 5-Day	14.5 mg/L	33.4
		pH	7.63	
Centralia STP 1989-2005 IL0027979	Sewer Creek/Crooked Creek Segments OJ 07	Average Daily Flow	3.15 mgd	NA
		BOD, 5-Day	114.6 mg/L	2,095
		CBOD, 5-Day	27.7 mg/L	335
		Nitrogen, Ammonia	0.253 mg/L	3.32
		pH	7.31 su	—

Table 5-34 Effluent Data from Point Sources Discharging Upstream of or Directly to Crooked Creek Segments OJ 07 and OJ 08 (Illinois EPA 2005) (continued)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Centralia-Kaskaskia College 1992-2005 IL0029335	Prairie Creek/Crooked Creek Segments OJ 08	Average Daily Flow	0.125 mgd	NA
		BOD, 5-Day	75.1 mg/L	
		CBOD, 5-Day	4.30 mg/L	1.14
		Nitrogen, Ammonia	0.918 mg/L	0.229
		pH	7.62 su	
Sandoval STP 1992-2005 IL0030961	Prairie Creek/Crooked Creek Segments OJ 08	Average Daily Flow	0.18 mgd	NA
		BOD, 5-Day	51.8 mg/L	
		CBOD, 5-Day	5.85 mg/L	9.52
		pH	7.50 su	
Radiac Abrasives Inc-Salem 1994-2005 IL0059382	Crooked Creek/Crooked Creek Segments OJ 07	Average Daily Flow	0.123 mgd	NA
Il Doc-Centralia Correctional 1995-2005 IL0061344	Unnamed tributary of Prairie Creek/Crooked Creek Segments OJ 08	Average Daily Flow	0.176 mgd	NA
		BOD, 5-Day	293.7mg/L	
		CBOD, 5-Day	4.36 mg/L	6.57
		Nitrogen, Ammonia	2.75 mg/L	3.96
		pH	7.33 su	
United Parcel Service 1996-2005 IL0071242	Tributary to Fulton Branch of Sewer Creek/Crooked Creek Segments OJ 07	Average Daily Flow	0.0005 mgd	NA
		BOD, 5-Day	7.51 mg/L	0.030
		pH	7.54 su	
Junction City STP 2002-2004 IL0073784	Prairie Creek/Crooked Creek Segments OJ 08	Average Daily Flow	0.060 mgd	NA
		BOD, 5-Day	301.5 mg/L	
		CBOD, 5-Day	15.6 mg/L	3.7
		pH	8.64 su	
Woodlawn MHP 1999-2004 ILG551054	NA/Crooked Creek Segments OJ 07	Average Daily Flow	0.019 mgd	NA
		BOD, 5-Day	168.8 mg/L	
		CBOD, 5-Day	21.9 mg/L	2.00
		pH	8.17 su	
Country School MHP 1999-2005 ILG551055	South Creek /Crooked Creek Segments OJ 07	Average Daily Flow	0.0024 mgd	NA
		BOD, 5-Day	183.1 mg/L	
		CBOD, 5-Day	17.3 mg/L	1.88
		pH	7.39 su	
Irvington SD WWTF 1993-2005 ILG580006	Grand Point Creek/Crooked Creek Segments OJ 08	Average Daily Flow	0.093 mgd	NA
		BOD, 5-Day	164.4 mg/L	
		CBOD, 5-Day	65.7mg/L	16.2
		pH	7.85 su	
Wamac STP 1996-2005 ILG580144	Fulton Branch/Crooked Creek Segments OJ 08	Average Daily Flow	0.15 mgd	NA
		BOD, 5-Day	159.4 mg/L	
		CBOD, 5-Day	31.9 mg/L	45.2
		pH	8.14 su	
Odin STP 1997-2005 ILG580187	Turkey Creek /Crooked Creek Segments OJ 07	Average Daily Flow	0.195 mgd	NA
		BOD, 5-Day	110.4 mg/L	
		CBOD, 5-Day	5.67 mg/L	5.63
		pH	7.99 su	
Hoffman STP 1998-2005 ILG580205	Prairie Creek/Crooked Creek Segments OJ 08	Average Daily Flow	0.06 mgd	NA
		BOD, 5-Day	130.9 mg/L	
		CBOD, 5-Day	19.0 mg/L	10.1
		pH	7.57 su	
Salem WTP 1994-2005 ILG640031	Town Creek/Crooked Creek Segments OJ 07	Average Daily Flow	0.039 mgd	NA
		pH	7.84 su	

5.3.1.2 Little Crooked Creek Segment OJA 01

There are five permitted facilities whose discharges have the potential to reach Little Crooked Creek segment OJA 01. Segment OJA 01 is listed for impairments caused by manganese and DO. Table 5-35 contains a summary of available DMR data for these point sources. No manganese data were available because it is unlikely that manganese sampling is required by the discharge permits.

Table 5-35 Effluent Data from Point Sources Discharging Upstream of or Directly to Little Crooked Creek Segment OJA01 (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Nashville STP 1992-2005 IL0027081	Nashville Creek/ Little Crooked Creek Segment OJA 01	Average Daily Flow	0.5 mgd	NA
		BOD, 5-Day	141.4 mg/L	
		CBOD, 5-Day	8.62 mg/L	37.5
		Oxygen, Dissolved	7.75 mg/L	-
Nascote Industries-Nashville 1992-2005 IL0068136	Middle Creek via drainage ditch/ Little Crooked Creek Segment OJA 01	Average Daily Flow	0.006 mgd	NA
		BOD, 5-Day	7.66 mg/L	
		Nitrogen, Ammonia	1.86 mg/L	
Ameren Energy-Pinckneyville 2002-2005 IL0075906	Tributary to Walnut Creek/ Little Crooked Creek Segment OJA 01	Average Daily Flow	0.054 mgd	NA
		Phosphorus, Total	1.4 mg/L	
Nascote Industries Inc 2003-2005 IL0076686	NA/ Little Crooked Creek Segment OJA 01	Average Daily Flow	0.000053 mgd	NA
Hoyleton STP 1994-2005 ILG580016	North Creek/ Little Crooked Creek Segment OJA 01	Average Daily Flow	0.059 mgd	NA
		BOD, 5-Day	154.4 mg/L	
		CBOD, 5-Day	60.8 mg/L	15.4

5.3.1.3 Plum Creek Segments OZH-OK-A2, OZH-OK-C2, and OZH-OK-C3

There are three point sources with the potential to contribute discharge to Plum Creek segments OZH-OK-A2 and OZH-OK-C2 directly or through tributaries. Segments OZH-OK-A2, OZH-OK-C2, and OZH-OK-C3 are listed as for impairments caused by DO. Segments OZH-OK-A2 and OZH-OK-C2 also have manganese listed as a cause. Table 5-36 contains a summary of available DMR data for these point sources. Again, no manganese data were available because manganese sampling is not required by the discharge permits.

Table 5-36 Effluent Data from Point Sources Discharging to Plum Creek Segments OZH-OK-A2 and OZH-OK-C2 (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Addieville STP 1989-2005 IL0049140	Plum Creek/Plum Creek Segment OZH-OK-A2	Average Daily Flow	0.033 mgd	NA
		BOD, 5-Day	133.2 mg/L	
		CBOD, 5-Day	10.3 mg/L	3.06
Okawville STP 2000-2005 IL0074179	NA/Plum Creek Segment OZH-OK-A2	Average Daily Flow	0.025 mgd	NA
		BOD, 5-Day	204.9 mg/L	
		CBOD, 5-Day	5.6 mg/L	7.23
Dalee Oil Company 2000-2005 IL0074608	NA/Plum Creek Segment OZH-OK-A2	Average Daily Flow	0.0216 mgd	NA

5.3.1.4 Raccoon Lake Segment ROK

There is one point source that discharges upstream of Raccoon Lake Segment ROK. Raccoon Lake has been 303(d) listed with manganese, total phosphorus, pH, DO, and atrazine standard violations. Table 5-37 contains a summary of available DMR data.

Table 5-37 Effluent Data from Point Sources Discharging Upstream of Raccoon Lake Segment ROK (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Raccoon Consolidated School 1992-2005 IL0052981	Unnamed Tributary to Raccoon Creek/Raccoon Lake Segment ROK	Average Daily Flow	0.0125 mgd	NA
		BOD, 5-Day	276.8 mg/L	—
		CBOD, 5-Day	4.81 mg/L	0.104
		Nitrogen, Ammonia	0.788 mg/L	0.013
		pH	7.80 su	

5.3.1.5 Nashville City Reservoir Segment ROO

There is one point source that discharges to Nashville City Reservoir segment ROO. Segment ROO has been listed for impairments caused by manganese and total phosphorus. Table 5-38 contains a summary of available DMR data.

Table 5-38 Effluent Data from Point Sources Discharging to Nashville City Lake Segment ROO (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Nashville WTP 1994-2005 IL0069701	Nashville Creek/ Nashville Reservoir Segment ROO	Average Daily Flow	0.056 mgd	NA

5.3.1.6 Other Impaired Segments and Lakes

There are no permitted facilities that discharge directly or through tributaries to Centralia Lake segment ROI and Salem Lake segment ROR.

5.3.2 Mining Discharges

There are no known permitted mine sites or recently abandoned mines within the Crooked Creek watershed.

5.4 Nonpoint Sources

There are many potential nonpoint sources of pollutant loading to the impaired segments in the Crooked Creek watershed. This section will discuss site-specific cropping practices, animal operations, and area septic systems. Data were collected through communication with local NRCS, Soil and Water Conservation District (SWCD), Public Health Department, and County Tax Department officials.

5.4.1 Crop Information

The majority of the land found within the Crooked Creek watershed is devoted to crops. Corn and soybean farming account for approximately 20 percent and 32 percent of the watershed respectively. Tillage practices can be categorized as conventional till, reduced till, mulch-till, and no-till. The percentage of each tillage practice for corn, soybeans, and small grains by county are generated by the Illinois Department of Agriculture from County Transect Surveys. The most recent survey was conducted in 2004. Data specific to the Crooked Creek watershed were not available; however, the Washington, Jefferson, Clinton, and Marion County-wide practices were available and are shown in the following tables.

Table 5-39 Tillage Practices in Washington County

Tillage System	Corn	Soybean	Small Grain
Conventional	37%	12%	6%
Reduced - Till	37%	16%	75%
Mulch - Till	2%	16%	16%
No - Till	24%	55%	3%

Table 5-40 Tillage Practices in Jefferson County

Tillage System	Corn	Soybean	Small Grain
Conventional	25%	19%	18%
Reduced - Till	21%	12%	6%
Mulch - Till	17%	14%	17%
No - Till	37%	55%	59%

Table 5-41 Tillage Practices in Clinton County

Tillage System	Corn	Soybean	Small Grain
Conventional	30%	30%	10%
Reduced - Till	4%	4%	0%
Mulch - Till	26%	26%	62%
No - Till	40%	40%	28%

Table 5-42 Tillage Practices in Marion County

Tillage System	Corn	Soybean	Small Grain
Conventional	85%	21%	80%
Reduced - Till	3%	10%	0%
Mulch - Till	1%	17%	4%
No - Till	11%	51%	16%

Estimates on tile drainage were provided by the Clinton County NRCS office. It is estimated that farms near waterways have an average of 1,000 feet of tile drains. The total drainage for Clinton County in the Crooked Creek watershed is estimated to be 10,000 feet. Watershed specific information from the remaining counties was not available. As more data becomes available, it will be incorporated into TMDL development.

5.4.2 Animal Operations

Watershed specific animal numbers were not available for the Crooked Creek Watershed. Data from the National Agricultural Statistics Service were reviewed and are presented in the following tables to show countywide livestock numbers.

Table 5-43 Washington County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	25,960	26,581	2%
Beef	4,333	4,482	3%
Dairy	7,854	7,834	0%
Hogs and Pigs	47,626	62,113	30%
Poultry	NA	396	NA
Sheep and Lambs	1,043	359	-66%
Horses and Ponies	NA	101	NA

Table 5-44 Jefferson County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	15,248	16,120	6%
Beef	6,438	7,660	19%
Dairy	546	628	15%
Hogs and Pigs	9,511	9,972	5%
Poultry	961	424	-56%
Sheep and Lambs	393	781	99%
Horses and Ponies	NA	1,119	NA

Table 5-45 Clinton County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	37,735	36,849	-2%
Beef	5,095	2,242	-56%
Dairy	14,830	15,080	2%
Hogs and Pigs	93,190	177,880	91%
Poultry	552,992	514,945	-7%
Sheep and Lambs	473	430	-9%
Horses and Ponies	NA	402	NA

Table 5-46 Marion County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	15,580	11,285	-28%
Beef	6,987	5,238	-25%
Dairy	527	226	-57%
Hogs and Pigs	12,711	8,601	-32%
Poultry	NA	NA	NA
Sheep and Lambs	252	331	31%
Horses and Ponies	NA	834	NA

Communications with local NRCS officials have provided more watershed-specific animal information. Clinton County indicated that within the Clinton County portion of the watershed, 10 dairies, 15 beef farms, and between 7 and 15 hog operations exist. It is estimated that the dairies have an average of 75 to 100 cows while the beef farms range from 25 to 50 head. The hog operations in the area are all likely associated with Mashoff Port Production. Watershed specific information from the remaining counties was not available. As data becomes available, it will be incorporated into TMDL development.

5.4.3 Septic Systems

Many households in rural areas of Illinois that are not connected to municipal sewers make use of onsite sewage disposal systems, or septic systems. There are many types of septic systems, but the most common septic system is composed of a septic tank draining to a septic field, where nutrient removal occurs. However, the degree of nutrient removal is limited by soils and system maintenance.

Information on septic systems was obtained for the three major counties within the Crooked Creek watershed. Information on sewered and septic municipalities was obtained from the Washington and Marion County health departments and the Clinton County tax assessor. For each county, the tax assessor was contacted to provide estimates of the number of existing residences located in areas known to be served by septic systems. Table 5-47 is a summary of the available septic system data in the Crooked Creek watershed.

Table 5-47 Estimated Septic Systems in the Crooked Creek Watershed

County	Estimated No. of Septic Systems	Source of Septic Areas/ No. of Septic Systems
Clinton	839	Tax Assessor
Washington	1,900	Health Department/Tax Assessor
Marion	0	Health Department
Jefferson	negligible	
Total	**2,739**	

There are approximately 2,700 septic systems in the watershed. In Marion County, where the impaired Salem Reservoir, Raccoon Reservoir, and Lake Centralia are located, the municipalities and the surrounding rural areas are served by sewers. In Clinton and Washington counties, rural residences are served by septic systems.

5.5 Watershed Studies and Other Watershed Information

The extent of previous planning efforts within the Crooked Creek watershed is not known. It is assumed that this information will become available through public meetings within the watershed community. In the event that other watershed-specific information becomes available, it will be reviewed and all applicable data will be incorporated during Stages 2 and 3 of TMDL development.

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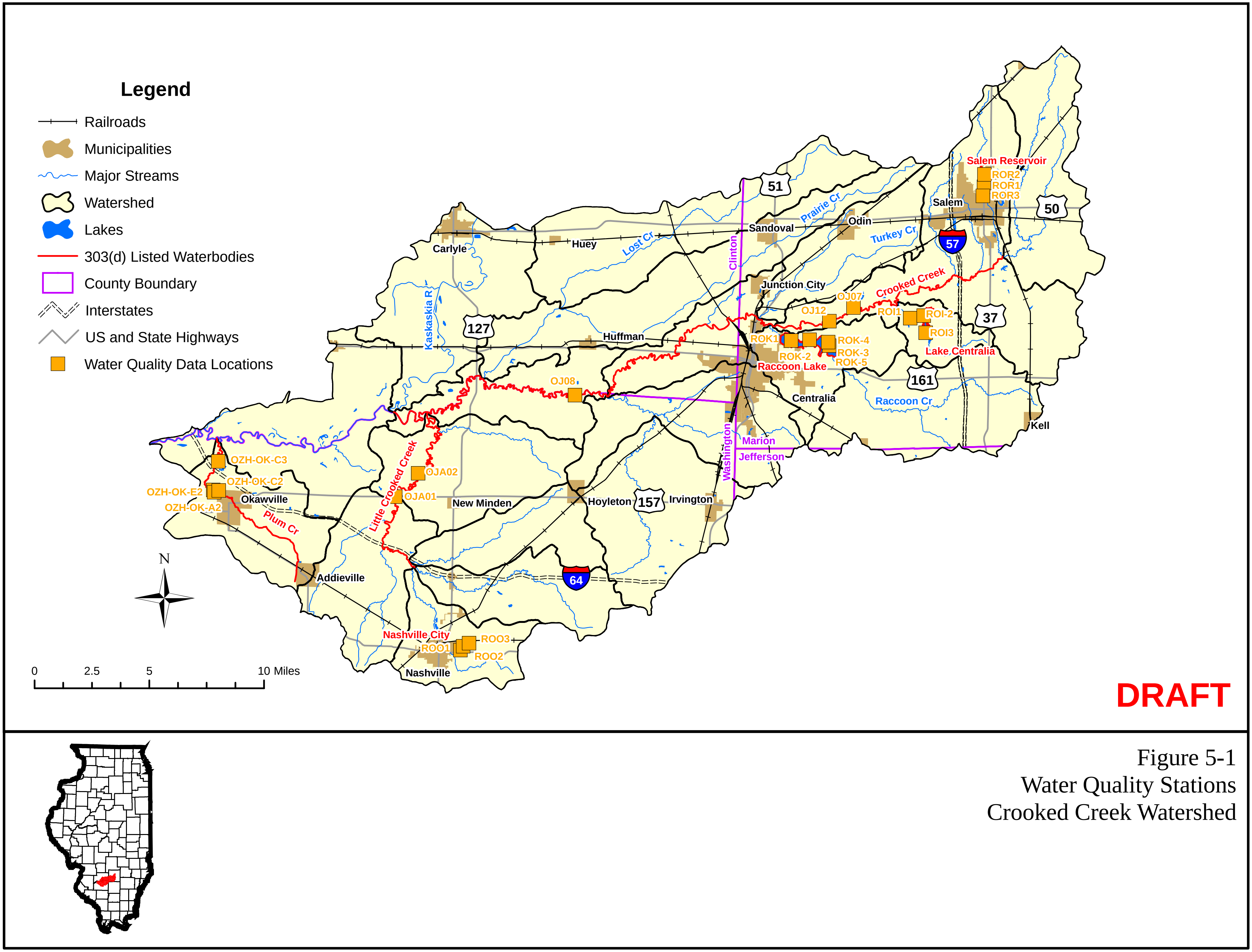

Figure 5-1
Water Quality Stations
Crooked Creek Watershed

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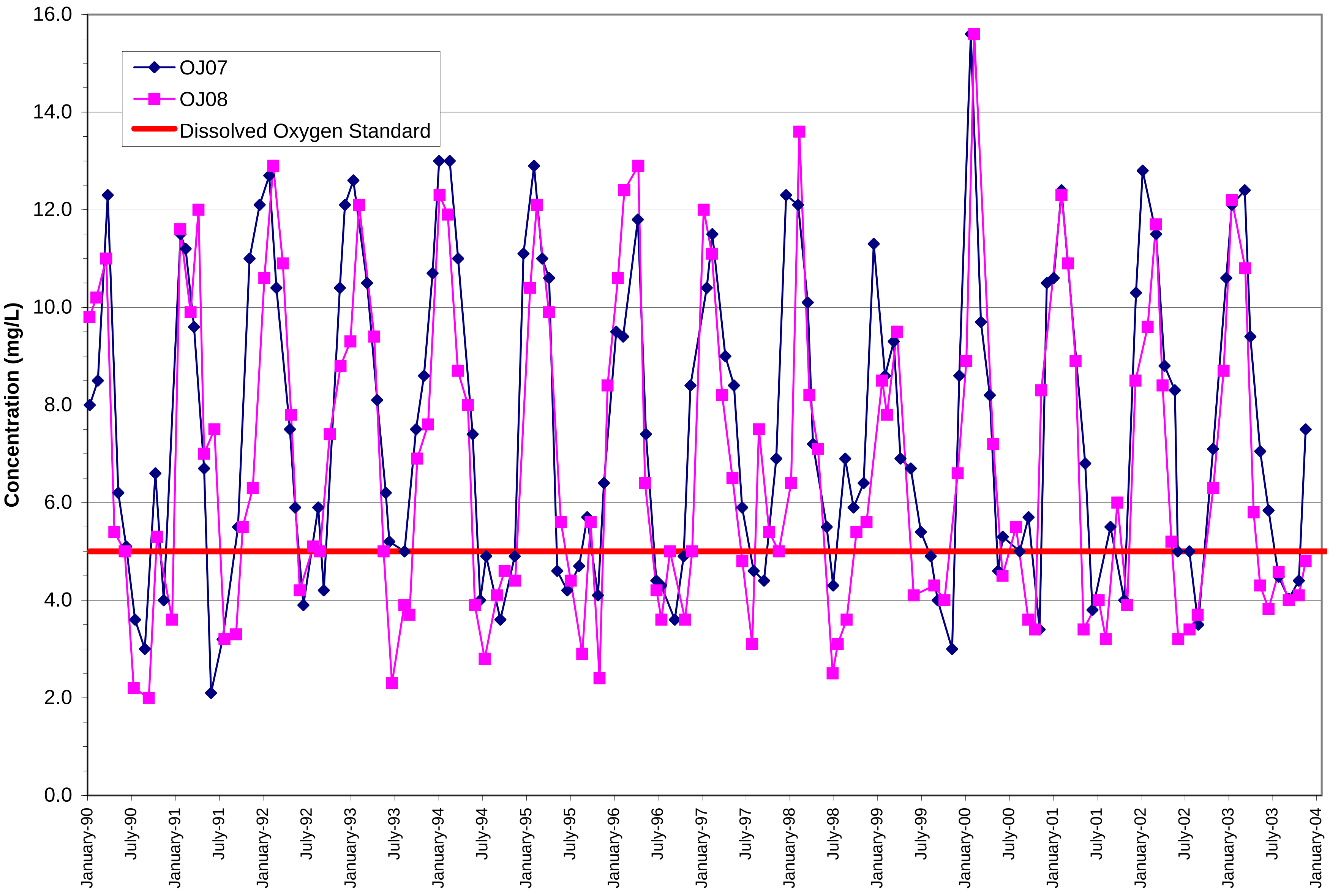

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Figure 5-2:
Crooked Creek Segments OJ07 and OJ08
Instantaneous DO Concentrations

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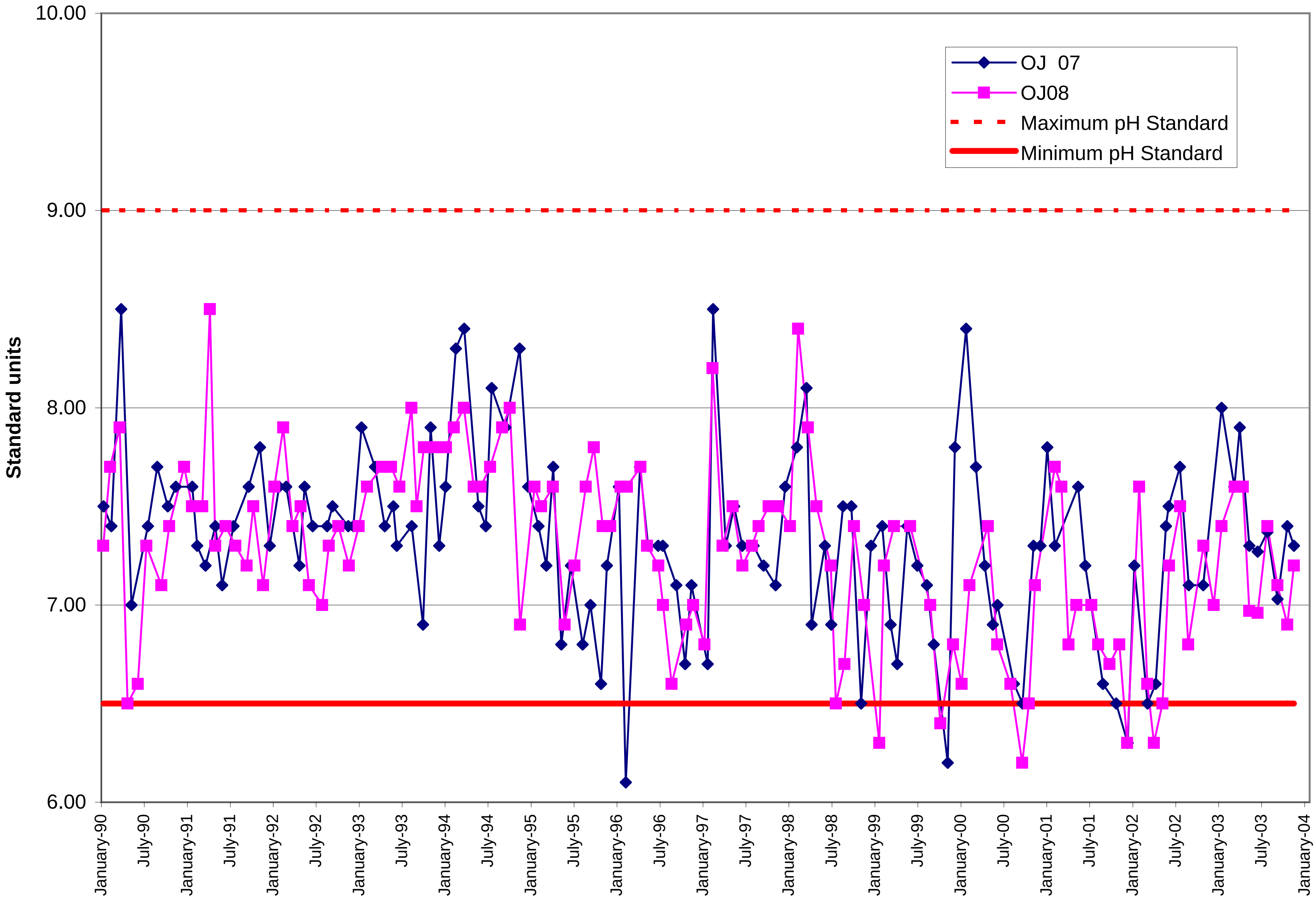

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Figure 5-3:
Crooked Creek Segments OJ07 and OJ08
pH Samples

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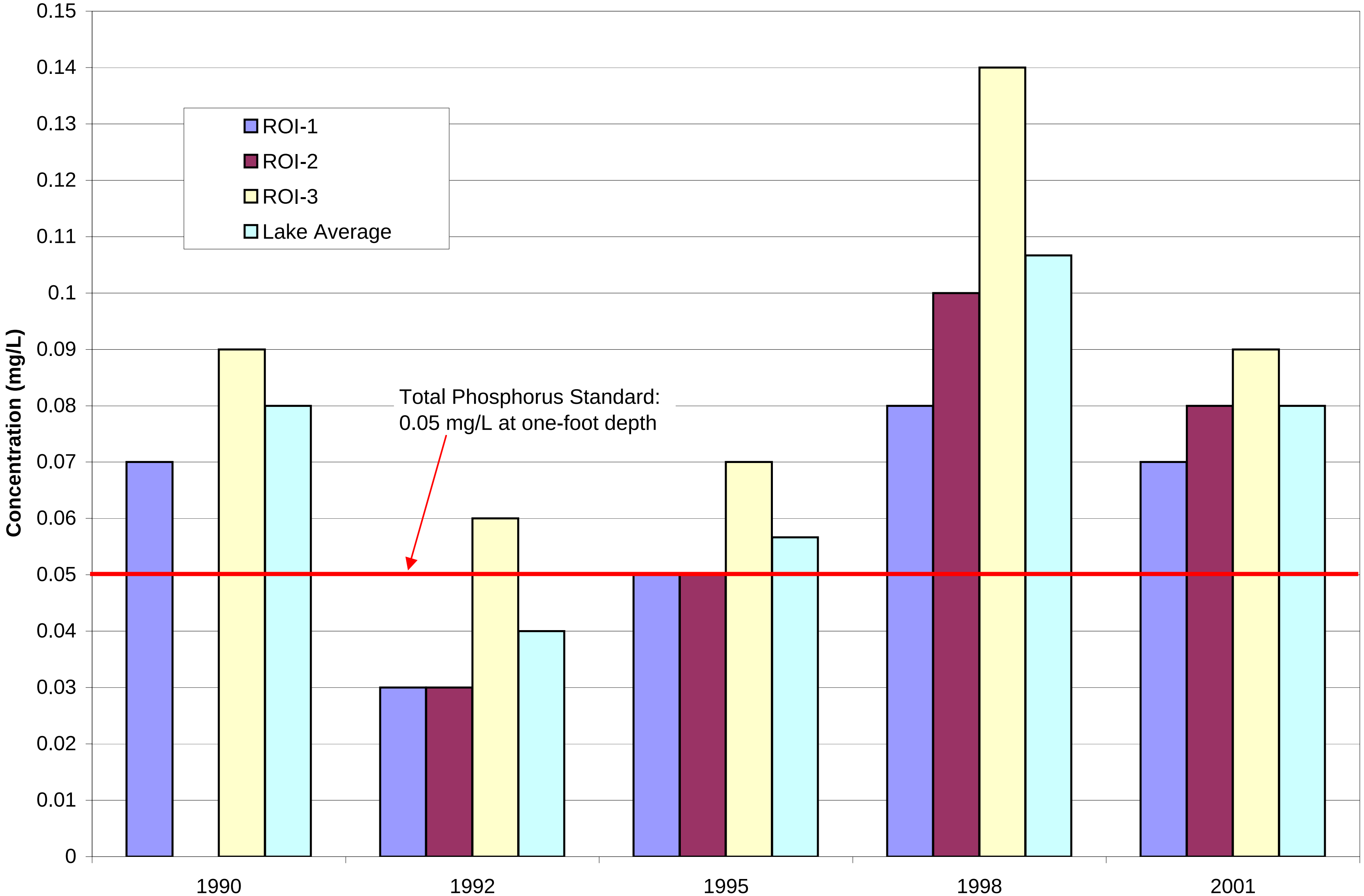

Figure 5-4:
Lake Centralia
Average Annual Total Phosphorus Concentrations
at One-Foot Depth

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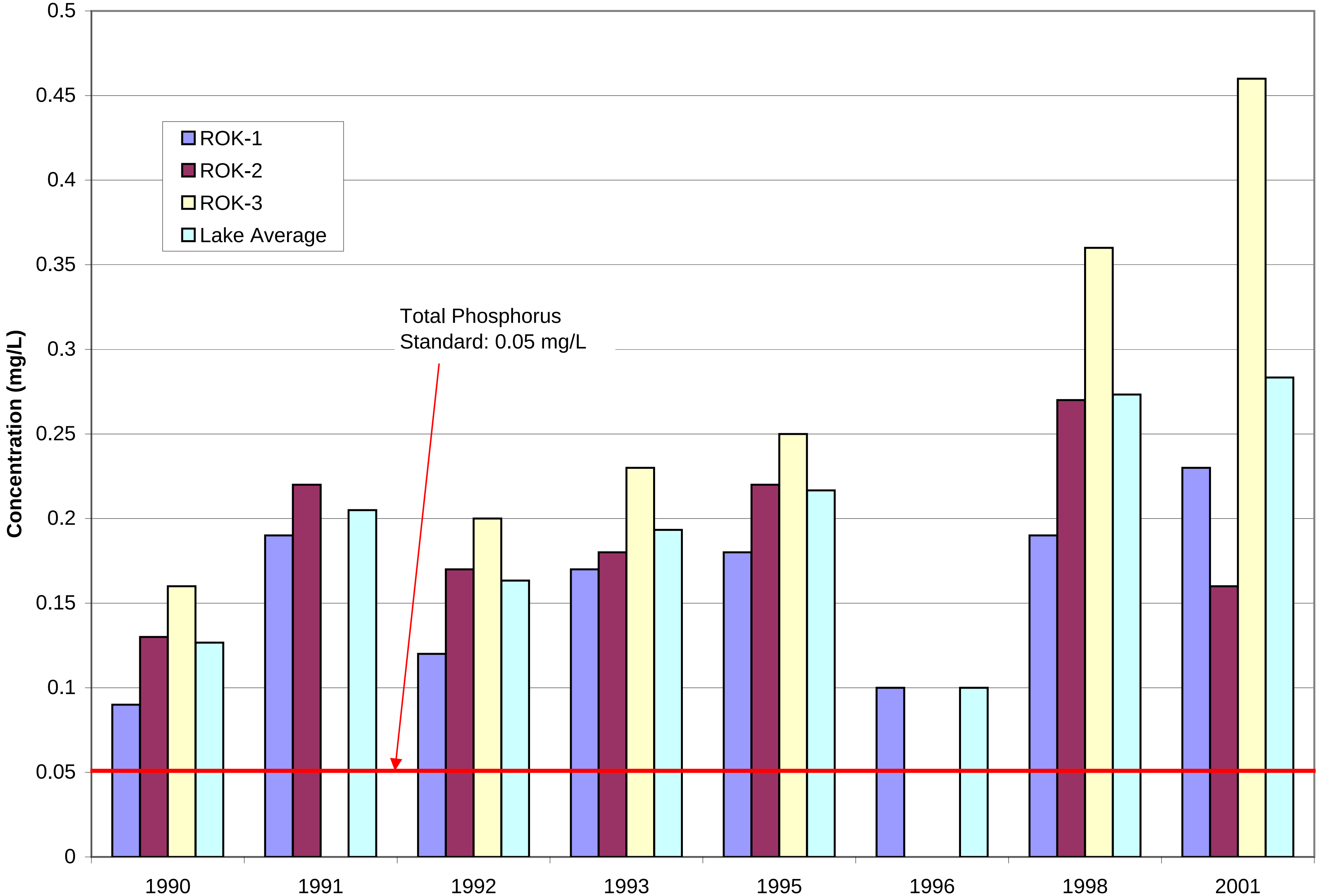

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Figure 5-5:
Raccoon Lake
Annual Average Total Phosphorus Concentrations
at One Foot Depth

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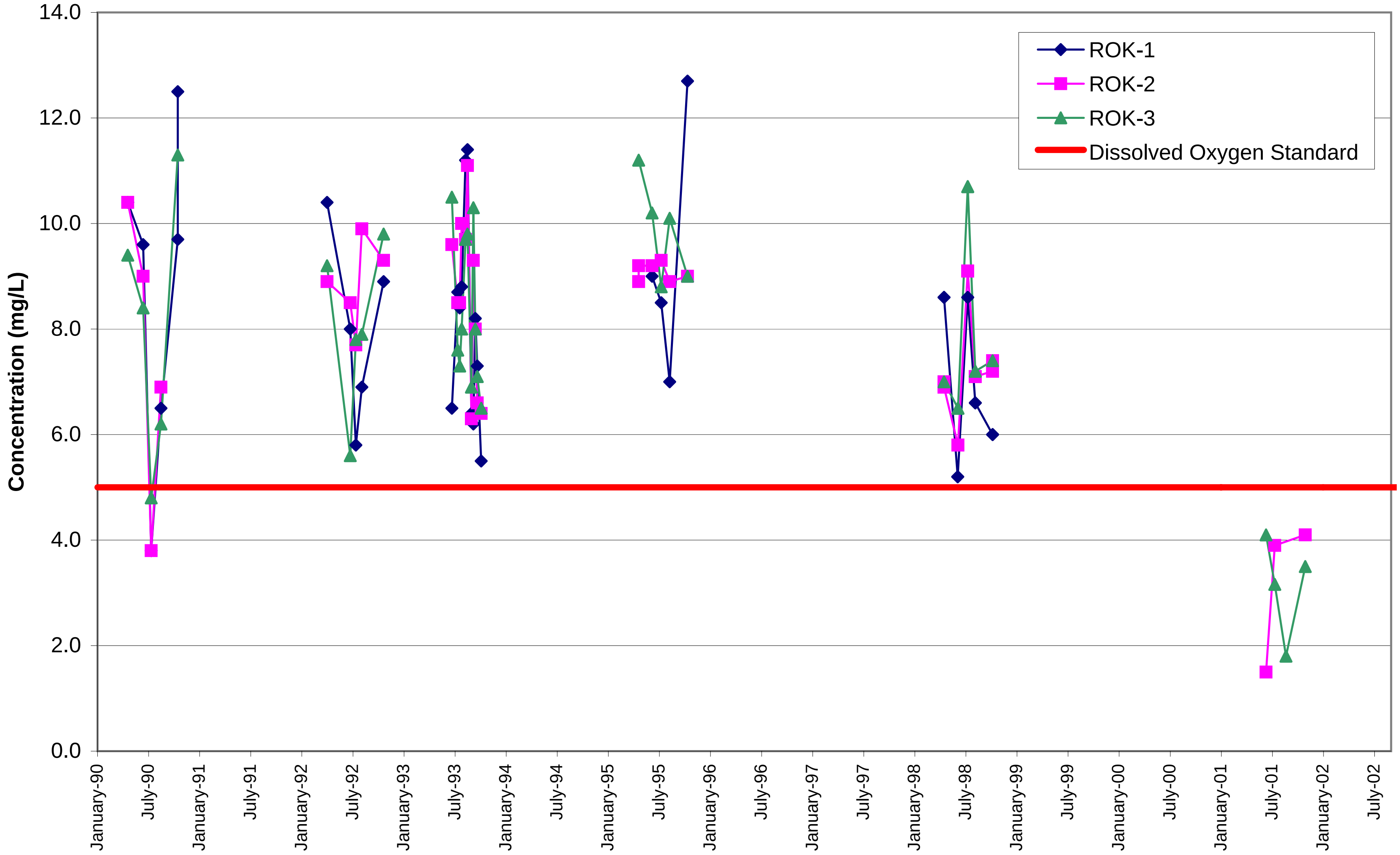

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Figure 5-6:
Raccoon Lake
DO Concentrations

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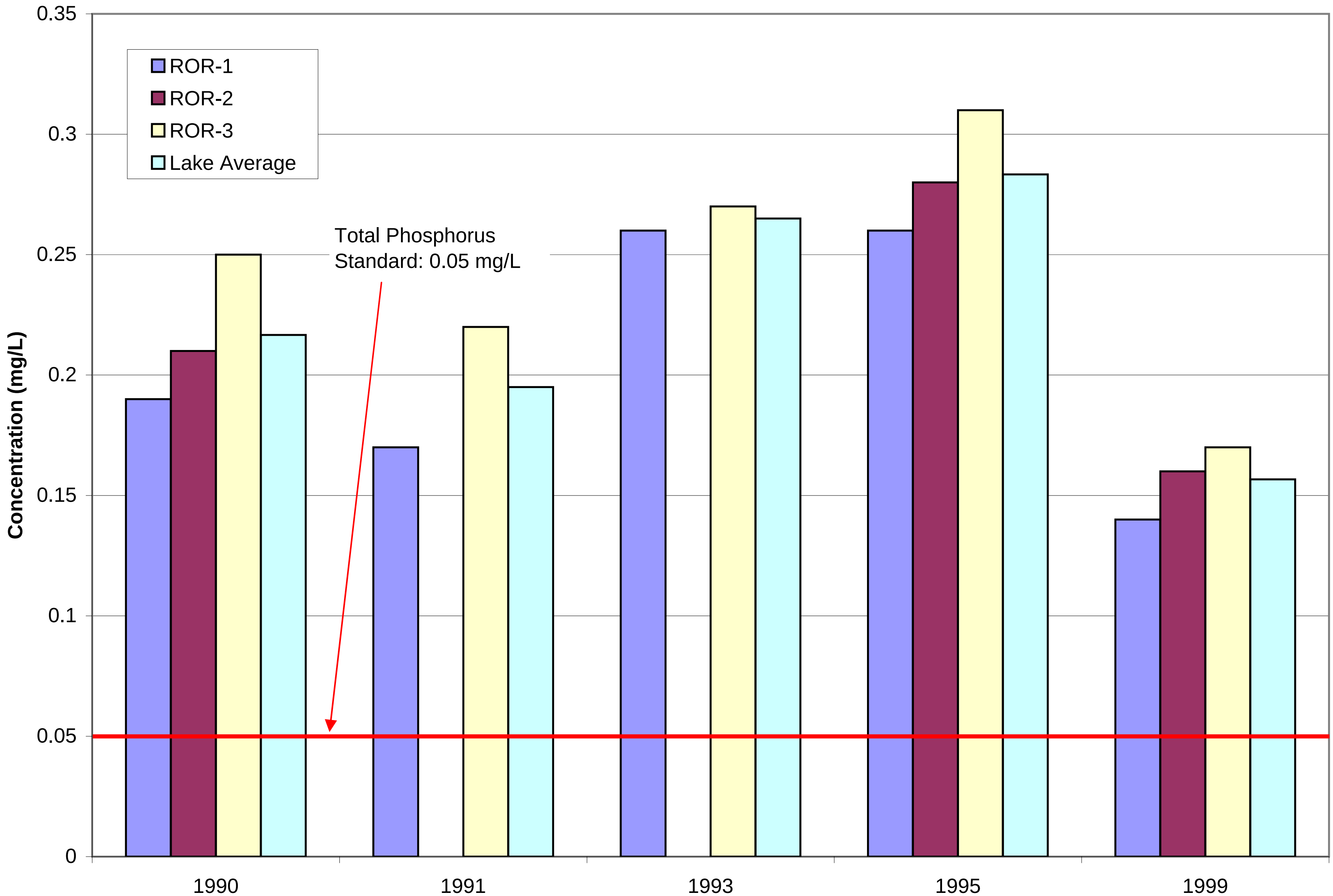

Figure 5-7:
Salem Reservoir
Annual Average Total Phosphorus Concentration
at One-Foot Depth

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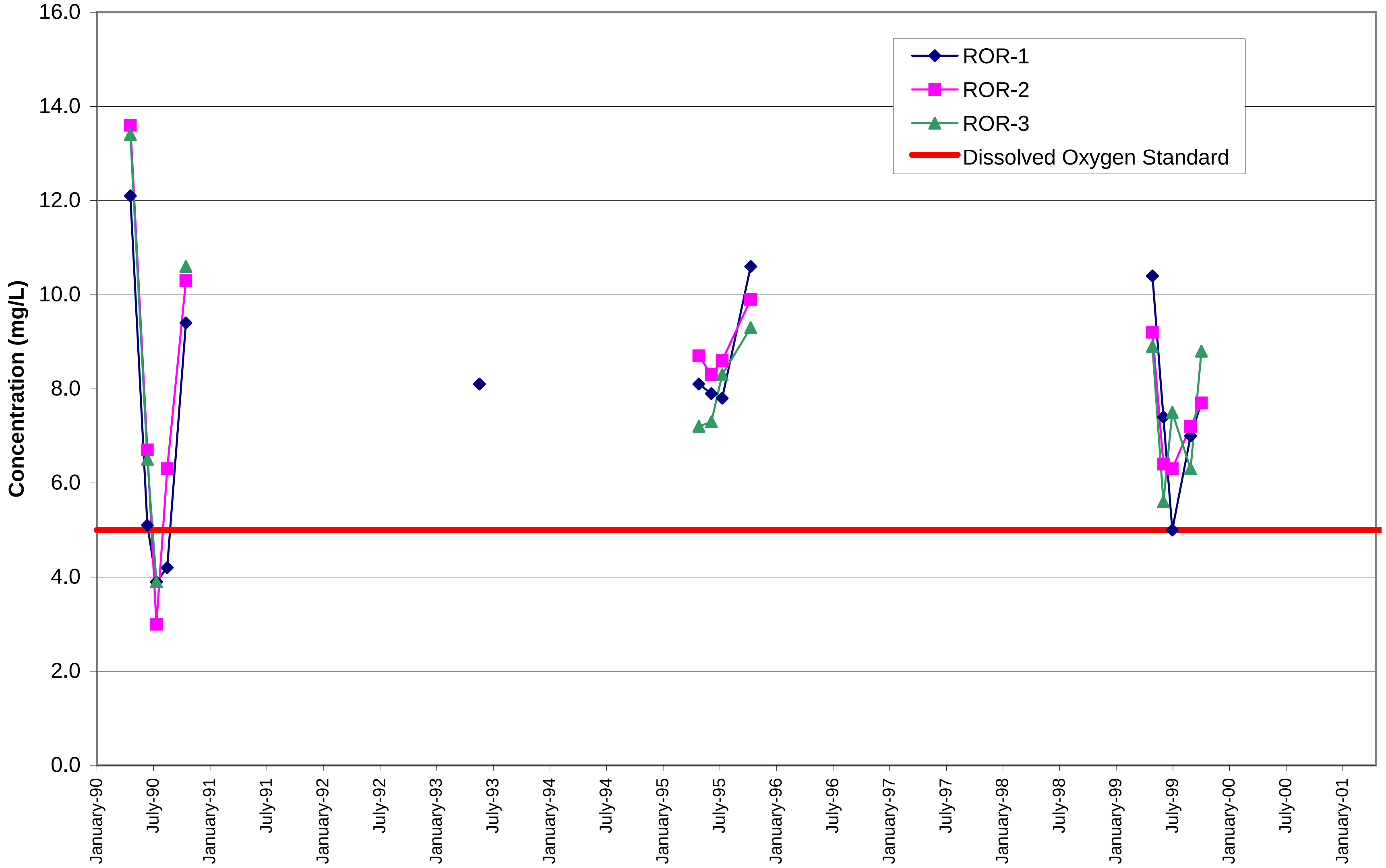

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Figure 5-8:
Salem Reservoir
DO Concentrations

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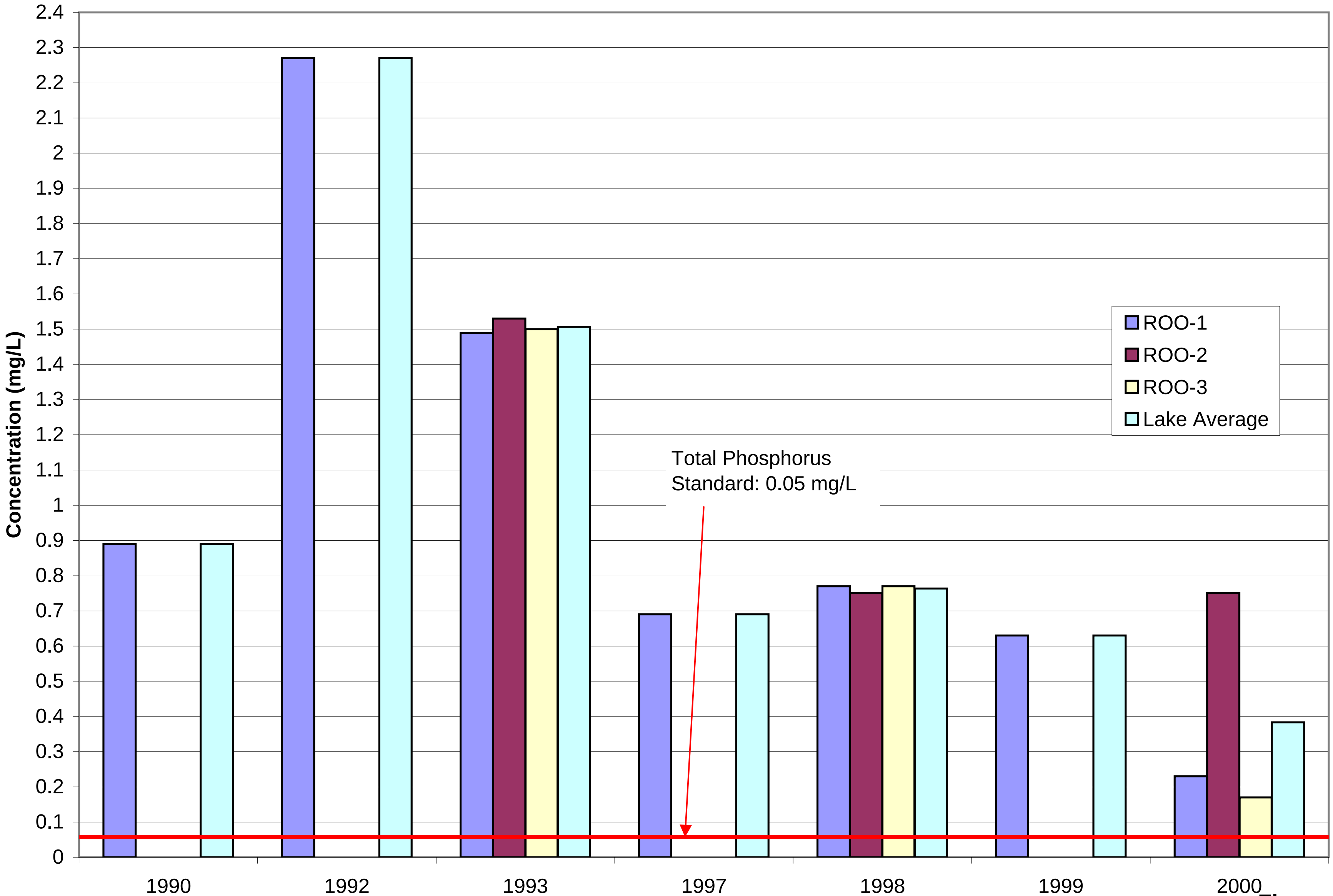

Figure 5-9:
Nashville City Reservoir
Annual Total Phosphorus Concentrations
at One Foot Depth

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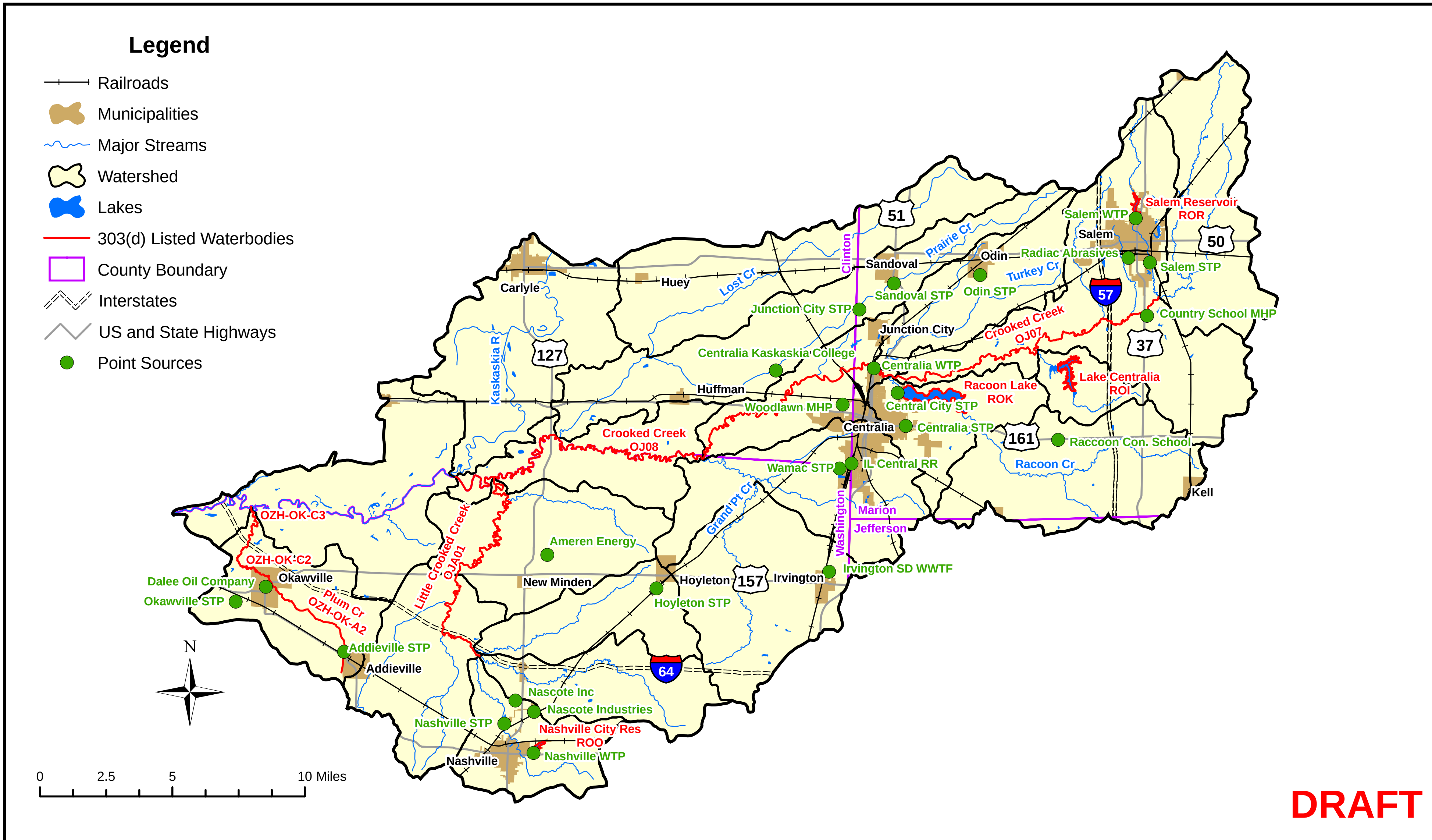

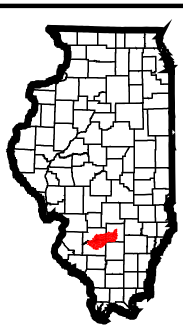

Figure 5-10:
Point Sources
Crooked Creek Watershed

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Section 6
Approach to Developing TMDL and Identification of Data Needs

Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Of the pollutants impairing stream segments in the Crooked Creek watershed, DO, pH and manganese are the only parameters with numeric water quality standards. For lakes, total phosphorus, manganese, pH, atrazine, and DO are the parameters with numeric water quality standards. Refer to Table 1-1 for all segments and associated impairments within the Crooked Creek watershed. Illinois EPA believes that addressing these impairments should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. Recommended technical approaches for developing TMDLs for streams and lakes are presented in this section. Additional data needs are also discussed.

6.1 Simple and Detailed Approaches for Developing TMDLs

The range of analyses used for developing TMDLs varies from simple to complex. Examples of simple approaches include mass-balance, load-duration, and simple watershed and receiving water models. Detailed approaches incorporate the use of complex watershed and receiving water models. Simple approaches typically require less data than detailed approaches and therefore these are the analyses recommended for the Crooked Creek watershed except for stream segments with major point sources whose NDPES permit may be affected by the TMDL's WLA. Establishing a link between pollutant loads and resulting water quality is one of the most important steps in developing a TMDL. As discussed above, this link can be established through a variety of techniques. The objective of the remainder of this section is to recommend approaches for establishing these links for the constituents of concern in the Crooked Creek watershed.

6.2 Approaches for Developing TMDLs for Stream Segments in Crooked Creek Watershed

Stream segments with major point sources in the Crooked Creek watershed are OJ 07 and OJ 08 of Crooked Creek and OJA 01 of Little Crooked Creek. Plum Creek Segments OZH-OK-A2, OZH-OK-C2, and OZH-OK-C3 do not have major point sources discharging to them. Approaches for developing TMDLs for areas with and without major point sources are described below.

6.2.1 Recommended Approach for DO TMDLs for Stream Segments without Major Point Sources

Plum Creek segments OZH-OK-A2, OZH-OK-C2, and OZH-OK-C3 do not have major point sources discharging to them. The data for these segments are limited to one violating sample on each segment collected in 2002. It is first recommended that more data be collected. Once more data has been collected which confirms the dissolved oxygen impairment, a simplified approach that involves simulating pollutant oxidation and stream reaeration only within a spreadsheet model would be recommended for DO TMDL development. This model simulates steady-state stream DO as a function of carbonaceous and nitrogenous pollutant oxidation and atmospheric reaeration. The model allows for non-uniform stream hydraulics, hydrology, and pollutant loadings at any level of segmentation. It is also free of numerical dispersion as it relies on well-known analytical solutions rather than numerical approximations of the fundamental equations. The model assumes plug flow (no hydrodynamic dispersion), which is likely an acceptable assumption for most small to medium sized streams. The model also does not incorporate the impacts of stream plant life, which generally require site-specific data for meaningful parameterization. A watershed model will not be used for these segments. Using the spreadsheet model iteratively, the BOD loads estimated to cause the DO impairments and to maintain a DO of 5.0 mg/L will be calculated. These calculated loads will become the basis for recommending TMDL reductions if necessary.

6.2.2 Recommended Approach for DO TMDLs for Segments with Major Point Sources

Crooked Creek segments OJ 07 and OJ 08 and Little Crooked Creek segment OJA 01 have point sources discharging to them. In most cases, the recommendation for these segments would be a more complicated approach that would also incorporate the impacts of stream plant activity, and possibly sediment oxygen demand (SOD), and would require a more sophisticated numerical model and an adequate level of measured data to aide in model parameterization. However, both Crooked Creek segments OJ07 and OJ08 have significant amounts of DO data available for TMDL development and therefore, the approach for these segments will more closely follow those described above for segments without major dischargers.

This is not the case for Little Crooked Creek segment OJA01. There are only five DO samples available for Little Crooked Creek. It is suggested that additional data collection occur for this segment. Specific data requirements include a synoptic (snapshot in time) water quality survey of this reach with careful attention to the location of the point source discharger. This survey should include measurements of flow, hydraulics, DO, temperature, nutrients, and CBOD. The collected data will be used to support the model development and parameterization and will lend significant confidence to the TMDL conclusions.

This newly collected data could then be used to support the development and parameterization of a more sophisticated DO model for this stream and therefore, the use of the QUAL2E model (Brown and Barnwell 1985) could be utilized to accomplish the TMDL analysis Little Crooked Creek. QUAL2E is well-known and USEPA-supported. It simulates DO dynamics as a function of nitrogenous and carbonaceous oxygen demand, atmospheric reaeration, SOD, and phytoplankton photosynthesis and respiration. The model also simulates the fate and transport of nutrients and BOD and the presence and abundance of phytoplankton (as chlorophyll-a). Stream hydrodynamics and temperature are important controlling parameters in the model. The model is essentially only suited to steady-state simulations.

In addition to the QUAL2E model, a simple watershed model such as PLOAD, Unit Area Loads or the Watershed Management Model is recommended to estimated BOD and nutrient loads from non-point sources in the watershed. This model will allow for allocation between point and nonpoint source loads and provide an understanding of percentage of loadings from point sources and nonpoint sources in the watershed.

6.2.3 Recommended Approach for pH TMDLs

Crooked Creek segments OJ07 and OJ08 are both listed for pH impairments. The numbers of impairments are few in relation to the amount of data collected for these segments. In addition, resource extraction that could be a source of impairment is not present in the watershed. It is recommended that a spreadsheet approach be utilized, which takes into account natural conditions such as acid rain and soil buffering capacity.

6.2.4 Recommended Approach for Manganese TMDLs

Little Crooked Creek and Plum Creek segments OZH-OK-A2 and OZH-OK-C3 are impaired for manganese. No apparent sources of manganese have been identified to date and data are very limited. It is recommended that more data be collected. Once data confirms the manganese impairment, an empirical loading and spreadsheet analysis would be utilized to calculate this TMDL.

6.3 Approaches for Developing TMDLs for Lake Segments in Crooked Creek Watershed

Recommended TMDL approaches for lakes within the Crooked Creek watershed will not be separated into those lakes with or without major point source discharges. It is assumed that for the lakes in the watershed, enough data exists to develop a simple model for use in TMDL development.

6.3.1 Recommended Approach for Atrazine TMDLs

As discussed in Section 5.1.2.2.5, recent data collected for public water supply assessments has indicated non-compliance with the atrazine standard. It is recommended that the atrazine TMDL will be calculated using a conservative mass-balance approach using spreadsheet analyses of the available data.

6.3.2 Recommended Approach for Total Phosphorus, Dissolved Oxygen, and pH TMDLs

Lake Centralia, Raccoon Lake, Salem Reservoir, and Nashville City Reservoir are all listed for impairments caused by elevated total phosphorus. Raccoon Lake and Salem Reservoir have also experienced low DO concentrations. Additionally, the Racoon Lake impairment has pH listed as a cause. The BATHTUB model is recommended for all lake phosphorus and DO assessments in this watershed. The BATHTUB model performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. The model relies on empirical relationships to predict lake trophic conditions and subsequent DO conditions as functions of total phosphorus and nitrogen loads, residence time, and mean depth. (USEPA 1997). Oxygen conditions in the model are simulated as meta and hypolimnetic depletion rates, rather than explicit concentrations.

Watershed loadings to the lakes will be based on empirical data or tributary data available in the lake watersheds. In addition, pH will be addressed empirically. It is likely that control of phosphorus concentrations will address pH impairments within Raccoon Lake.

6.3.3 Recommended Approach for Manganese TMDLs

All four lakes in the watershed have manganese impairments. The applicable water quality standard for manganese is 150 µg/L. It is assumed that the only controllable sources of manganese to the lakes are those which enter from lake sediments during periods of low dissolved oxygen. It is thought that the manganese in the lake sediments can be (partially) controlled by reducing phosphorus loads and increasing hypolimnetic DO concentrations. Each lake has had the sediment sampled for manganese levels. The results of these samples can be used as a screening tool to determine if the assumptions made about manganese sources are plausible. If this is determined to be the case, it is assumed that development of the phosphorus TMDLs described above will, in turn, control the manganese concentrations. Therefore, the manganese target is maintenance of hypolimnetic DO concentrations above zero which would prevent manganese bound in the sediment from entering the water column. The lack of DO in lake bottom waters is presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding materials to the lake. For this reason, attainment of the total phosphorus standard is expected to result in oxygen concentrations that will reduce sediment manganese flux to natural background levels. The TMDL target for manganese is set as a total phosphorus concentration of 0.050 mg-P/l. The recommended approach for the lake phosphorus TMDL was discussed above.

CDM

Illinois Environmental
Protection Agency

Stage 2 Data Report

March 2007

Final Report

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Contents

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Figures

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Tables

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Section 1
Introduction

The Illinois Environmental Protection Agency (Illinois EPA) has a three-stage approach to total maximum daily load (TMDL) development. The stages are:

Stage 1 – Watershed Characterization, Data Analysis, Methodology Selection

Stage 2 – Data Collection (optional)

Stage 3 – Model Calibration, TMDL Scenarios, Implementation Plan

This report addresses data collection associated with Stage 2 TMDL development for the following watersheds:

- Bay Creek
- Cahokia Creek/Holiday Shores Lake
- Cedar Creek/Cedar Lake
- Crab Orchard Creek/Crab Orchard Lake
- Crooked Creek
- Little Wabash River
- Mary's River/North Fork Cox Creek
- Sangamon River/Lake Decatur
- Shoal Creek
- South Fork Saline River/Lake of Egypt
- South Fork Sangamon River/Lake Taylorville

Sampling has been completed based on the recommendations presented in Section 6 of each watershed's Stage 1 TMDL report and the sampling plan described within the quality assurance project plan (QAPP). The Stage 2 data will supplement existing data collected and assessed as part of Stage 1 of TMDL development and will support the development of TMDLs under Stage 3 of the process. Where adequate supporting data exist, data collected during Stage 2 activities may also be used to support the delisting of certain parameters from the state 303(d) list.

The remaining sections of this report contain:

- **Section 2 Field Activities** includes information on sampling locations as well as field parameter, grab sample and continuous monitoring data
- **Section 3 Quality Assurance Review** discusses changes in the sampling plan from the original QAPP, data verification and validity, and conformance to the data quality objectives
- **Section 4 Conclusions** summarizes the Stage 2 work and makes recommendations for moving forward

Section 2
Field Activities

TMDL streams were sampled by CDM twice during the fall of 2006 to collect data needed to support water quality modeling and TMDL development. The first round of Stage 2 data collection took place between August 28 and September 29, 2006. The second round of Stage 2 data collection took place between October 16 and November 17, 2006. In addition, three segments within the Little Wabash River watershed were sampled by Illinois EPA between April and August of 2006. Over the course the sampling project, 32 streams (out of a possible 33) and one lake were sampled within the eleven Stage 2 watersheds. Table 2-1 contains data collection dates for each watershed.

Table 2-1: Stage 2 Data Collection Field Dates

Watershed	First Round Dates (2006)	Second Round Dates (2006)
Bay Creek	9/25-9/29	10/30-11/6
Cahokia Creek/Holiday Shores Lake	8/28-9/6	10/16-10/20
Cedar Lake	9/5-9/14	10/30-11/6
Crab Orchard Lake	9/5-9/14	10/30-11/6
Crooked Creek	9/5-9/14	10/16-10/20
South Fork Saline River/Lake of Egypt	9/25-9/29	10/30-11/6
Little Wabash River - CDM	9/5-9/14	10/30-11/16
Little Wabash River – Illinois EPA	4/18-8/8	
Mary's River	9/5-9/14	10/16-10/20
Sangamon River/Lake Decatur	8/28-9/6	10/30-11/3
Shoal	8/28-9/6	10/16-10/20
South Fork Sangamon River/Lake Taylorville	8/28-9/6	10/30-11/3

Sampling was conducted in accordance with the QAPP by CDM personnel at stream and lake locations with sufficient water and access. When time permitted, alternate locations were investigated if water and/or access were limited at original locations. Figures 2-1 through 2-11 show sampling locations used for Stage 2 data collection for each watershed. Refer to section 3.1 for further information related to sampling location changes from the original QAPP. Appendix A contains pictures of each sampling location. The sampling and analysis activities conducted at each sampling location included:

- In-stream field parameterization
- Grab samples for laboratory analysis
- Continuous monitoring
- Stream gaging

2.1 Instream field parameters

Water quality measurements for pH, temperature, dissolved oxygen (DO), conductivity, and turbidity were taken at each accessible sampling location where water was present using an In-Situ 9500 Profiler water quality meter. In-Situ 9500 Profilers were calibrated each morning of field activity. Water quality readings were taken at each accessible site with adequate water at the center of flow and values were recorded in field books. These values are presented in Table 2-2. Table 2-2 also contains sample location latitude and longitude as well as explanatory information as to why a limited number of sites were not sampled.

At each site with adequate and safely wadeable streamflow, flow measurements were recorded using a Marsh McBirney 2000 flow meter. Appendix B contains flow meter data and stream discharge analysis for these sites.

2.2 Grab Samples

Grab samples were collected based on the causes of impairment identified in the 303(d) list as well as data needed to support TMDL development under Stage 3. Samples collected on Owl Creek and South Fork Sangamon River were analyzed by Prairie Analytical Laboratories in Springfield, IL and all other samples collected by CDM were analyzed by ARDL, Inc in Mt. Vernon, IL. Samples were delivered in person to the laboratory or exchanged with laboratory personnel in the field. Select segments in the Little Wabash watershed (Elm River segment CD01, and Little Wabash River segments C09 and C33) were sampled by Illinois EPA and analyzed by the Illinois EPA Laboratory in Champaign, IL.

Table 2-3 contains data collected at each location associated with impairment status. Values shown in bold face with gray background violated the applicable water quality standard. All data analyzed by the laboratories are contained in Appendix C. This appendix includes the data shown in Table 2-3 as well as all other parameters that were sampled in order to support Stage 3 TMDL development. In addition, Appendix C shows data qualifiers as well as detection limits for all samples.

2.3 Continuous Monitoring

In-Situ 9500 Professional XP multi-parameter data-logging sondes were used for continuous data measurements on streams impaired by low DO and/or pH. The sondes were calibrated prior to deployment then deployed for at least 3 days at select locations with adequate water and access. DO, pH, conductivity and temperature data were recorded at 15 minute intervals during sonde deployment, after which the sonde was removed and data were downloaded to a laptop computer. The continuous data associated with impairment causes are presented in Appendix D. Because sondes were not field checked at the time of retrieval, there is a possibility that some experienced times of drying or build-up of sedimentation during deployment. A column was added to the data presented in Appendix D to estimate acceptable or “suspect” data. Data were deemed suspect when low conductivity or high temperature values indicate that the meter was likely out of the water or also at times when field log books indicated that the sonde had not yet been deployed or had been pulled from the stream. The data that were deemed acceptable were plotted on Figures D-1 through D-26. The charts are grouped by watershed and show data collected during the first and second round of sampling at each location.

Violations of the instantaneous DO standard (5.0 mg/L minimum) were not recorded during either monitoring period on the following segments that are currently listed for impairment caused by low DO:

- Cedar Creek AJF16 (Figure D-1)
- Big Muddy River N99 (Figure D-4)
- Shoal Creek OI05 (Figures D-22 and D-23)
- South Fork Saline River ATH08 (Figure D-24)

According to Table B-2 of the Illinois Integrated Water Quality Report (2006), the aquatic life use may also be impaired if DO concentrations are below 6.0 mg/L for more than 16 hours of any 24 hour period. Appendix D also contains this analysis for the segments that did not violate the instantaneous minimum standard. The number of values recorded below 6.0 mg/L during any 24 hour period were counted and if any count was above 64 (64 values equates to 16 hours worth of data), the stream was considered to be potentially impaired by low DO. The following segments did not experience a violation of either the 5.0 mg/L instantaneous standard or the 6.0 mg/L standard as described above:

- Cedar Creek AJF16 (Figure D-1)
- Shoal Creek OI05 (Figures D-22 and D-23)
- South Fork Saline River ATH08 (Figure D-24)

Violations of the pH standard (6.5 minimum, 9.0 maximum) were not recorded during either monitoring period on the following segments that are currently listed for impairment caused by pH:

- Crab Orchard Creek ND12 (Figure D-5)
- Briers Creek ATHS01 (Figure D-25)

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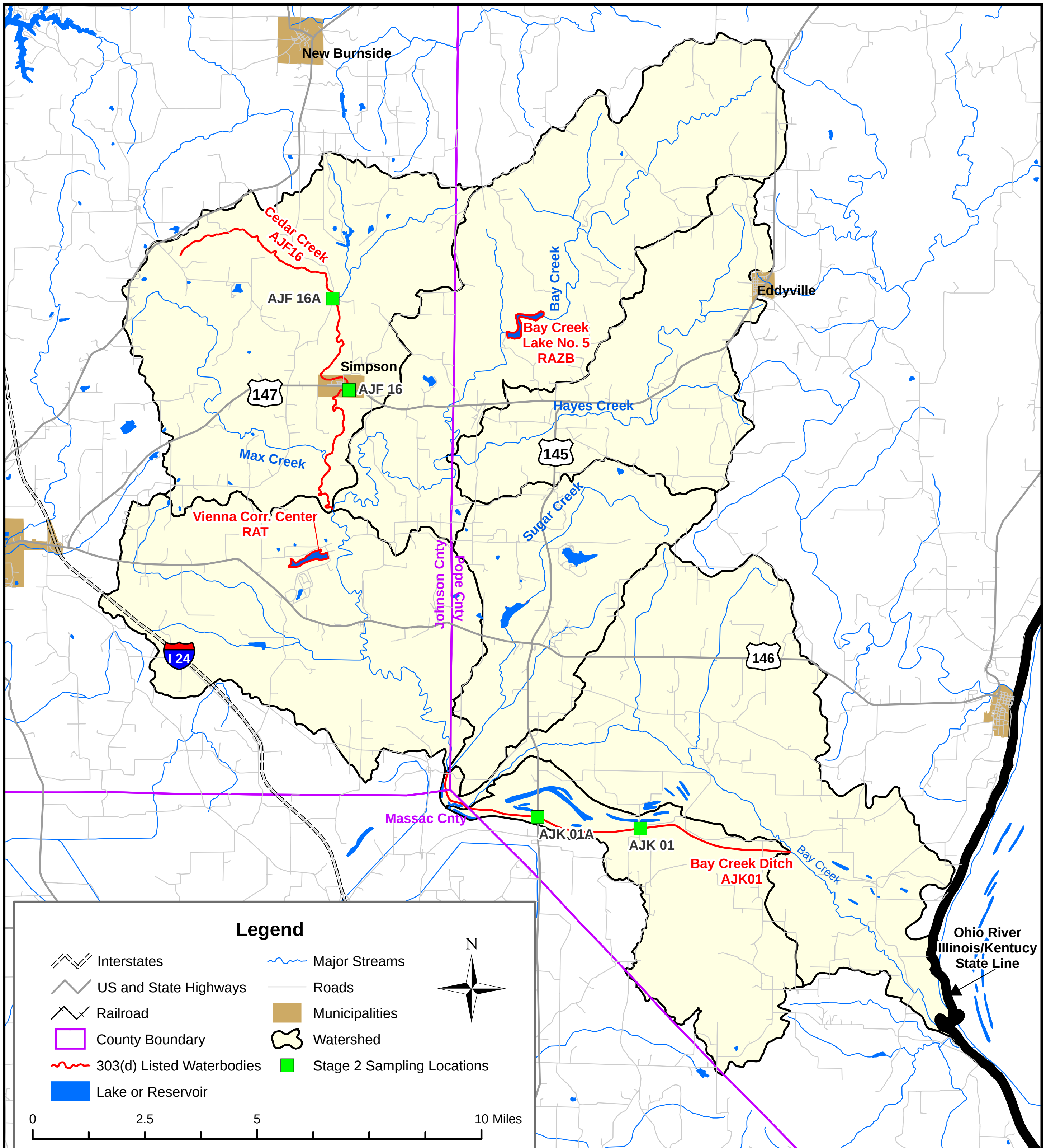

Figure 2-1
Stage 2 Sampling Locations
Bay Creek Watershed

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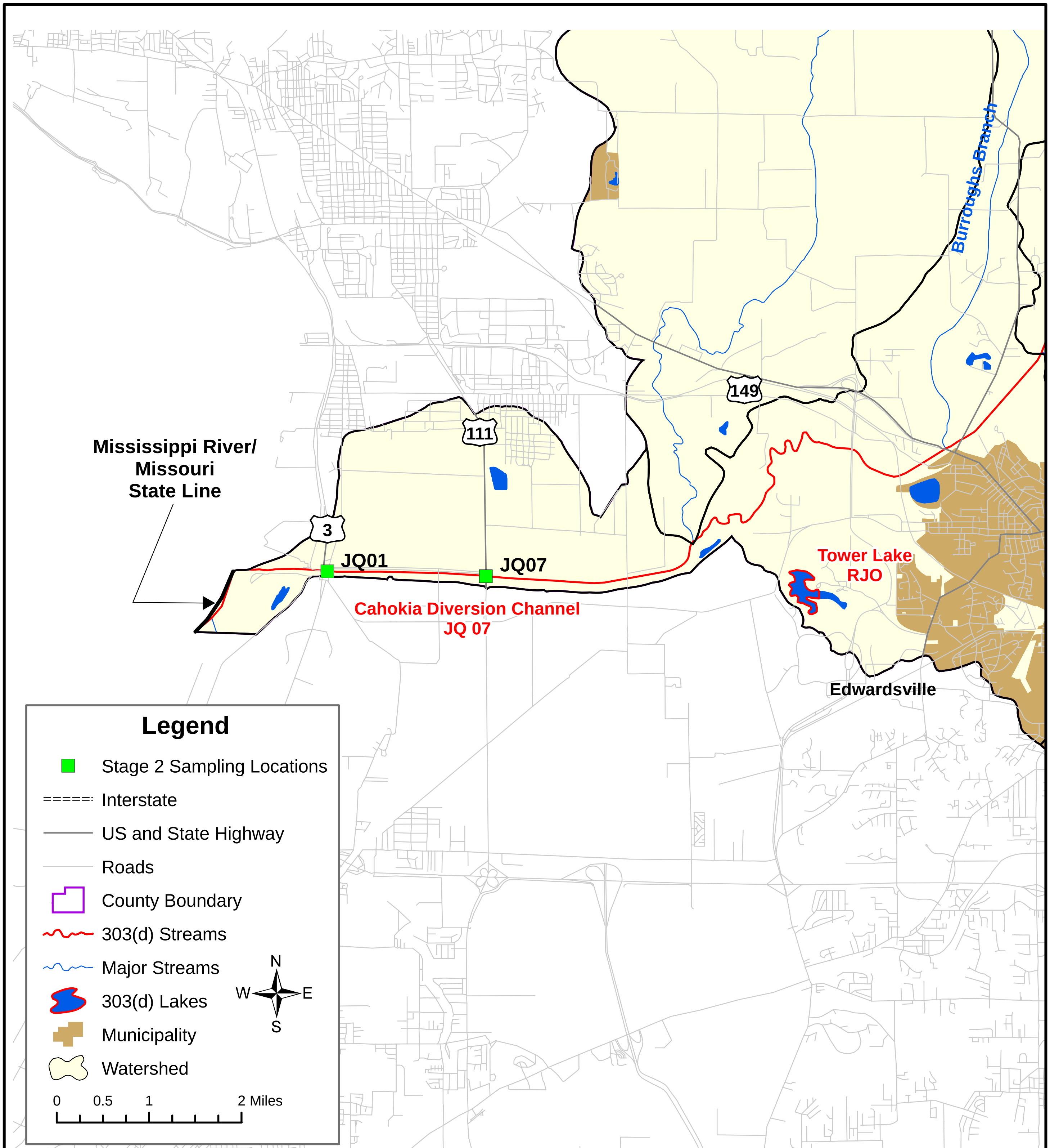

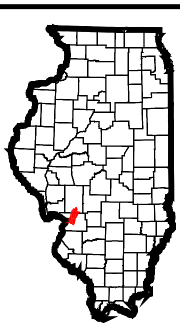

Figure 2-2:
Stage 2 Sampling Locations
Cahokia Creek/Holiday Shores Lake Watershed

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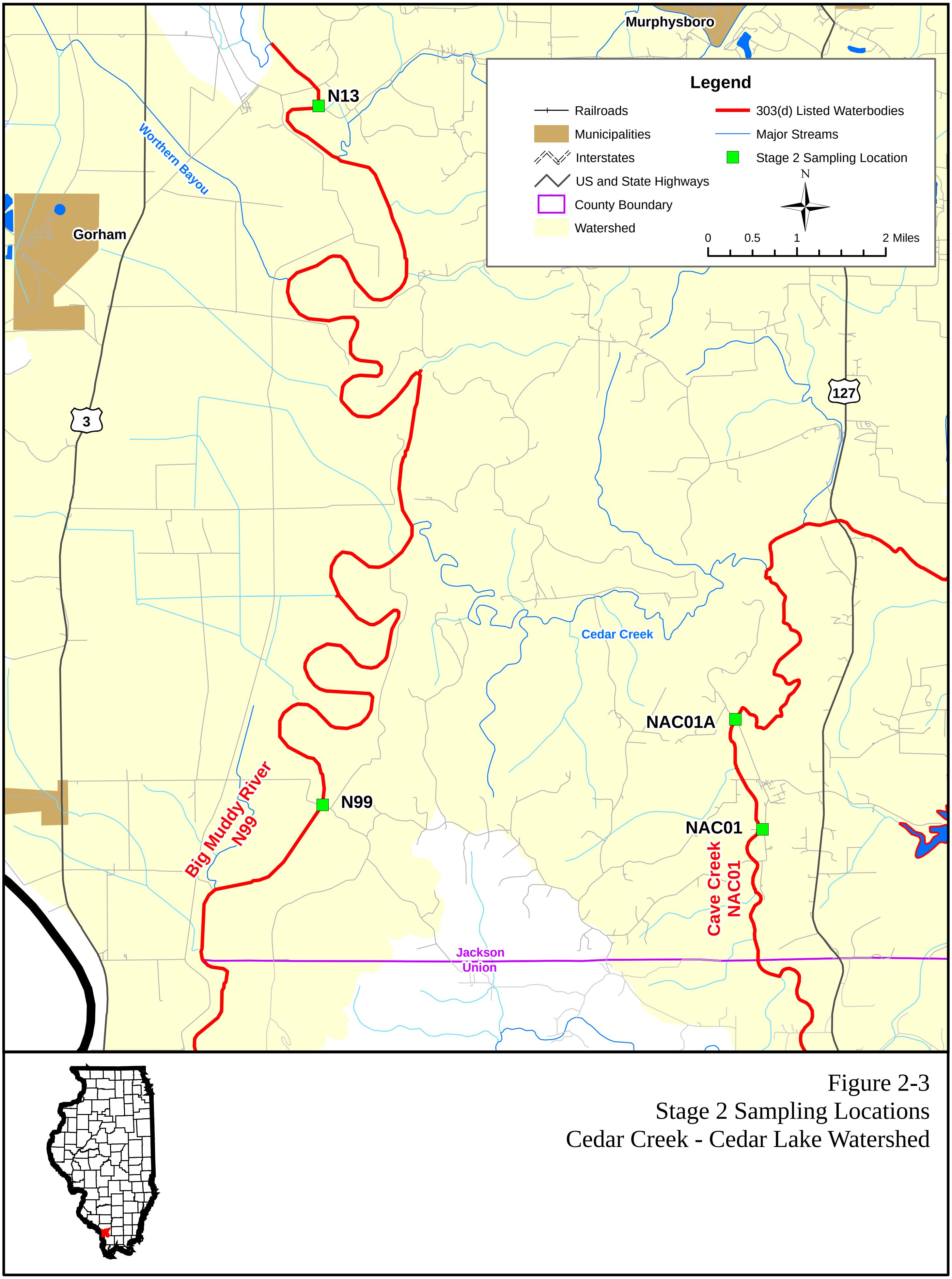

Figure 2-3
Stage 2 Sampling Locations
Cedar Creek - Cedar Lake Watershed

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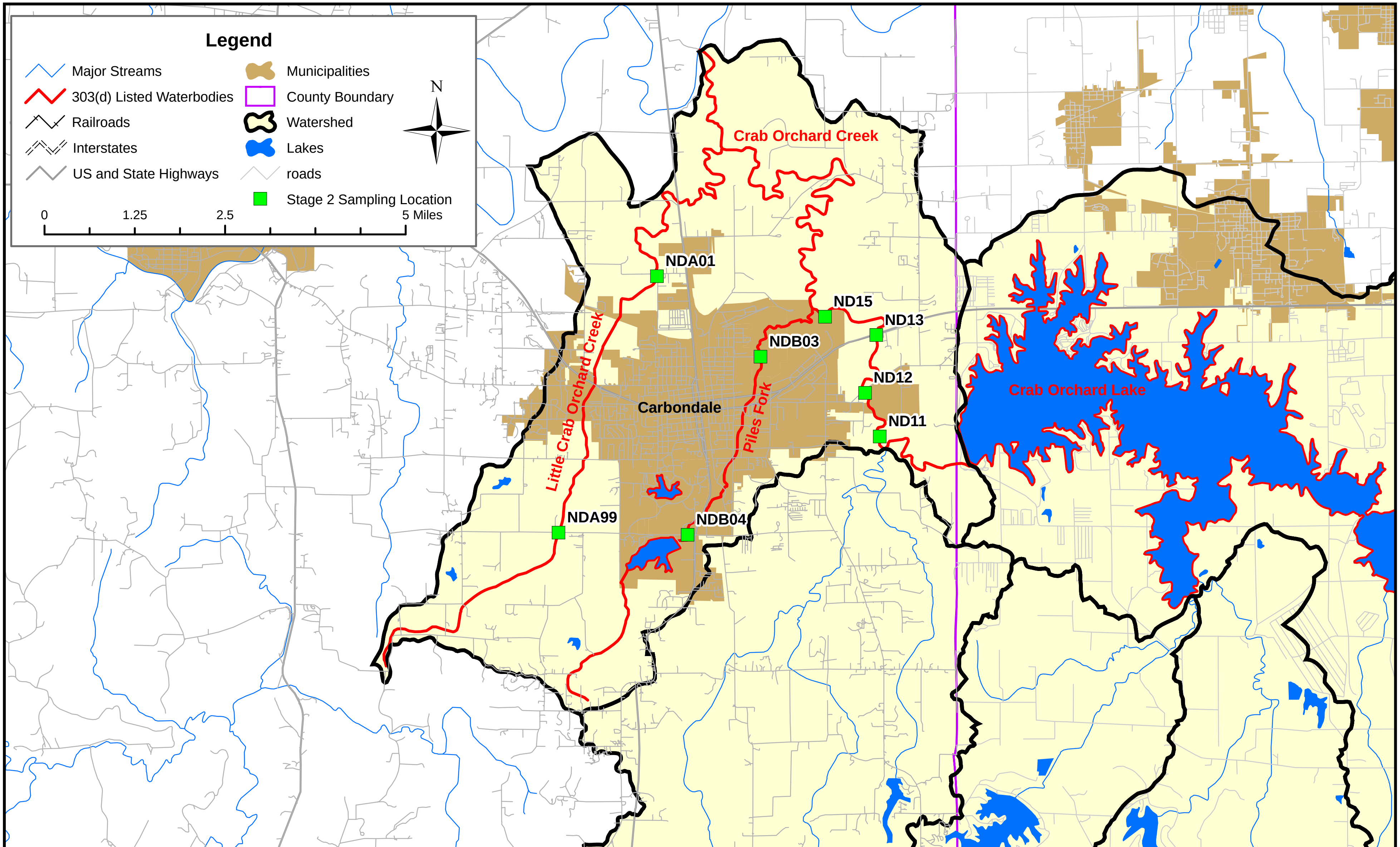

Figure 2-4:
Stage 2 Sampling Locations
Crab Orchard Creek Watershed

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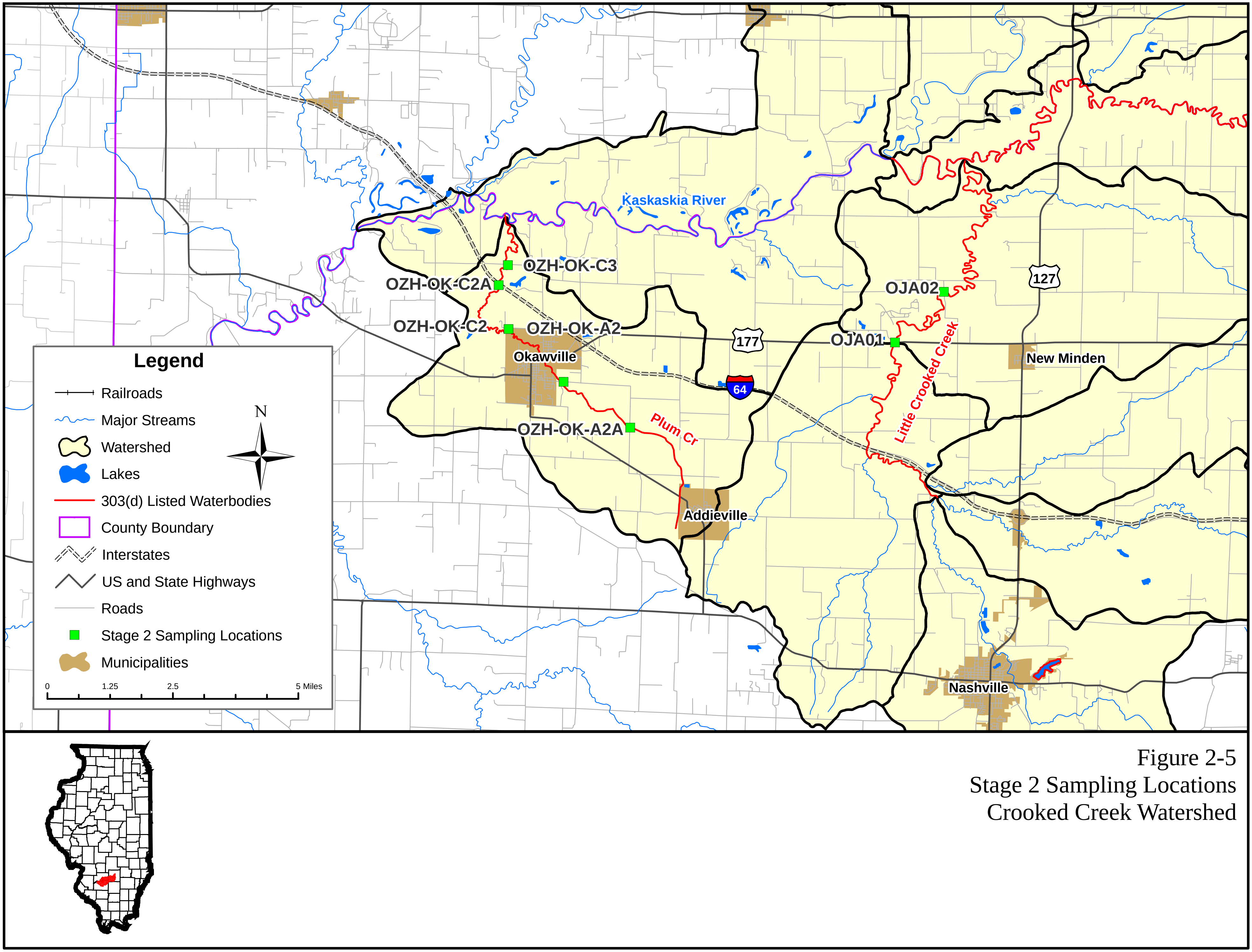

Figure 2-5
Stage 2 Sampling Locations
Crooked Creek Watershed

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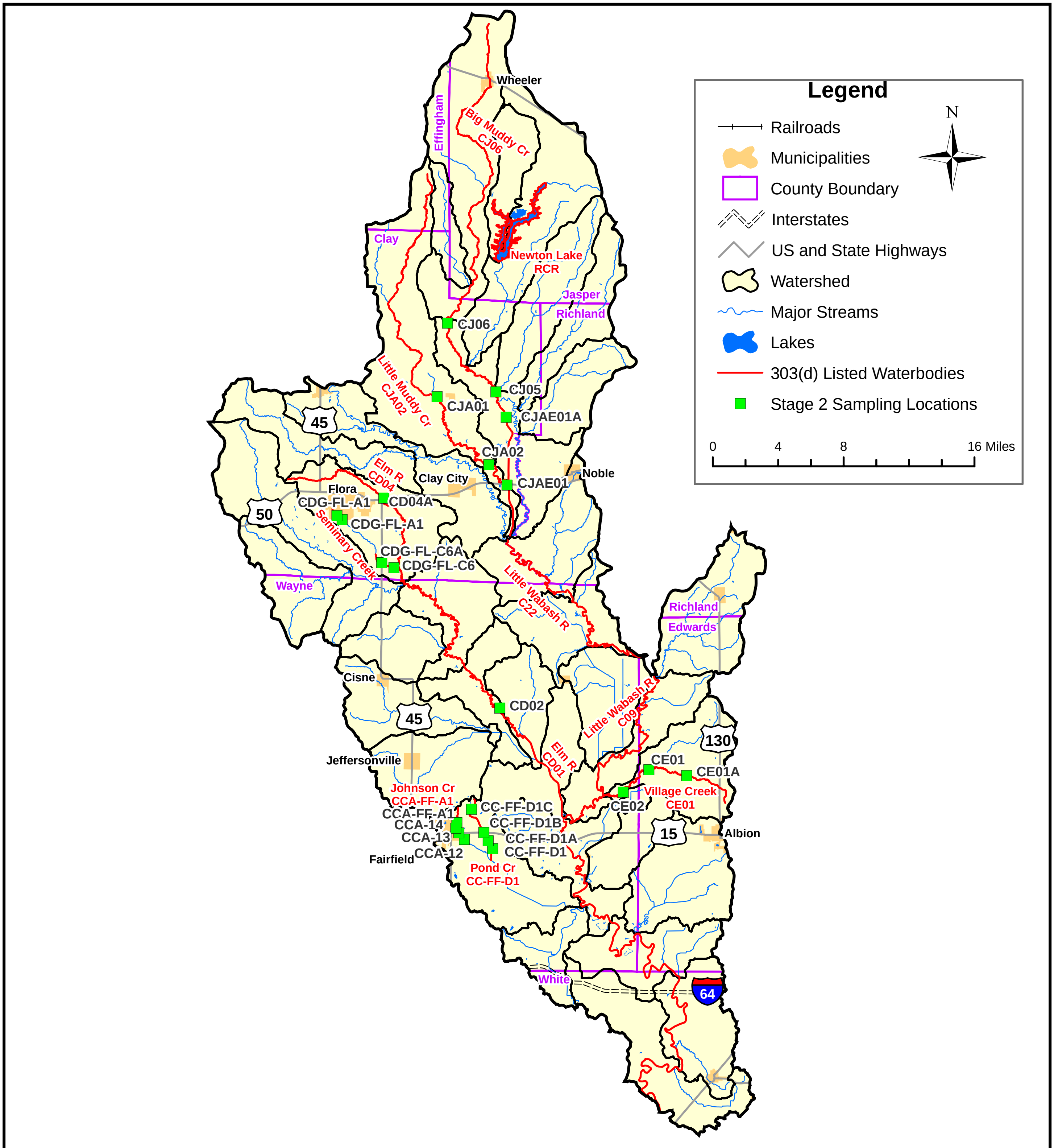

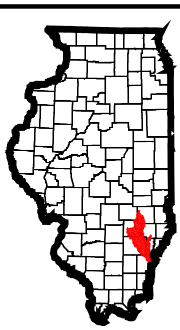

Figure 2-6:
Stage 2 Sampling Locations
Little Wabsash River Watershed

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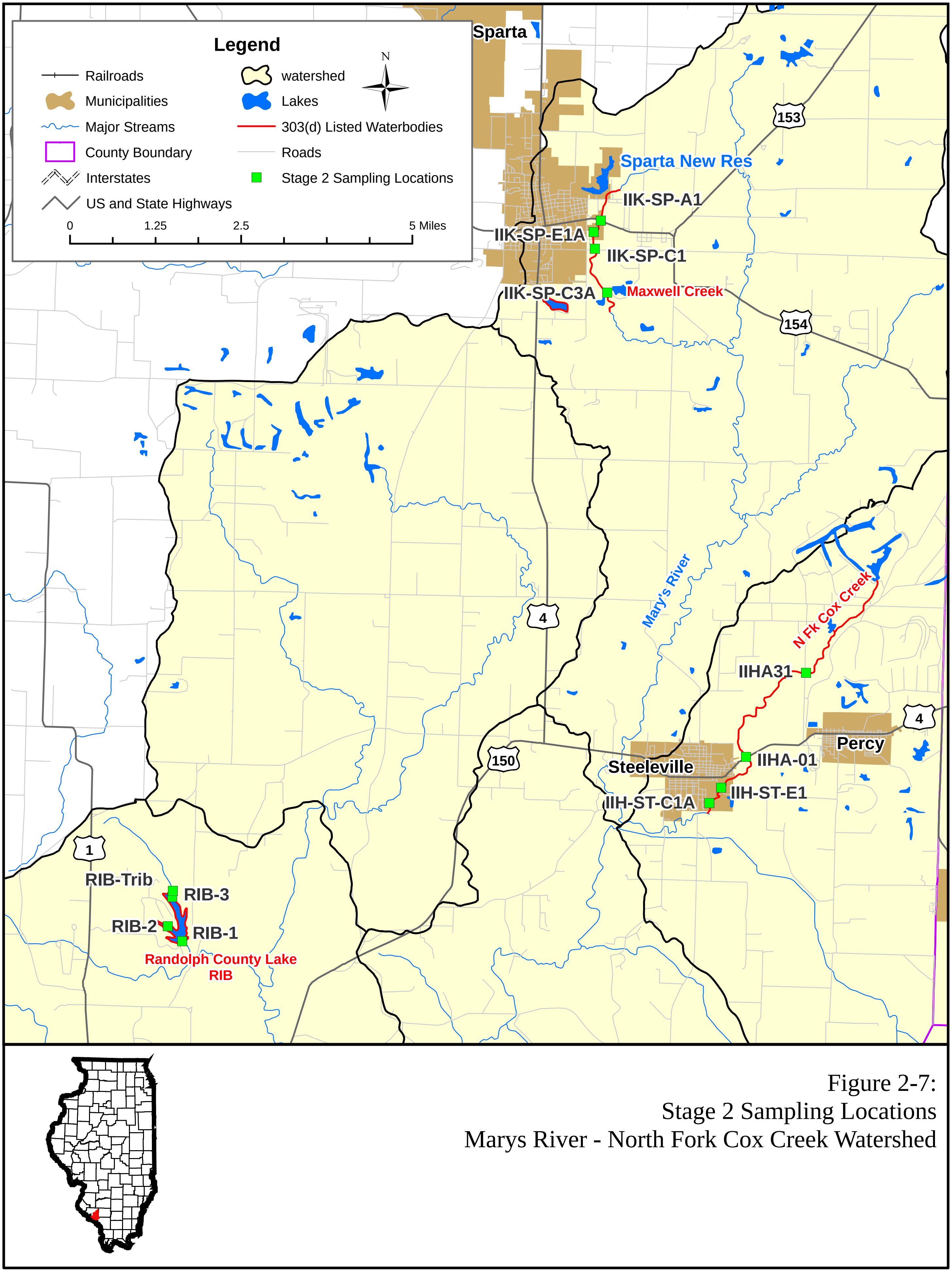

Figure 2-7:
Stage 2 Sampling Locations
Marys River - North Fork Cox Creek Watershed

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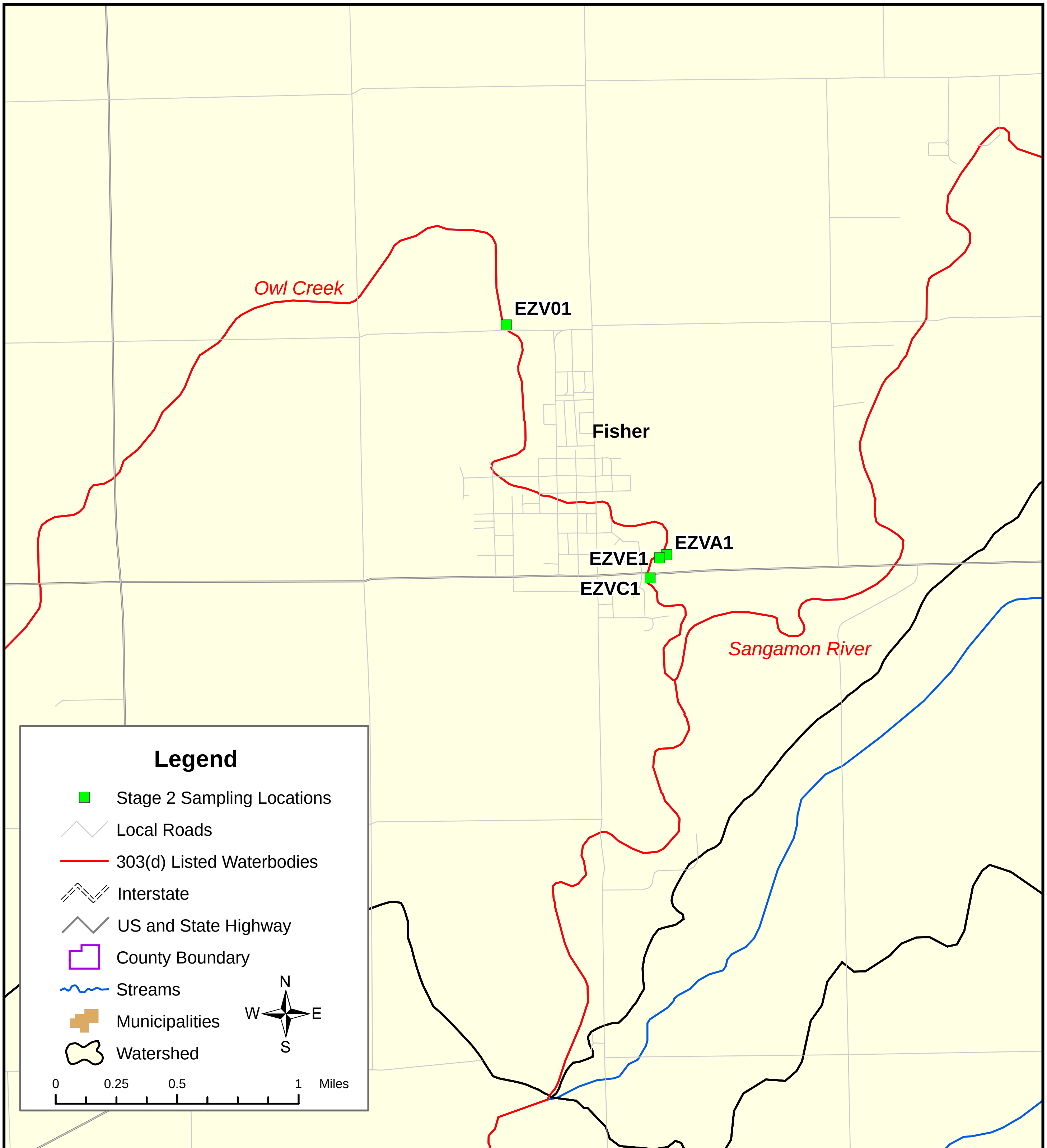

Figure 2-8:
Stage 2 Sampling Locations
Sangamon River - Lake Decatur Watershed

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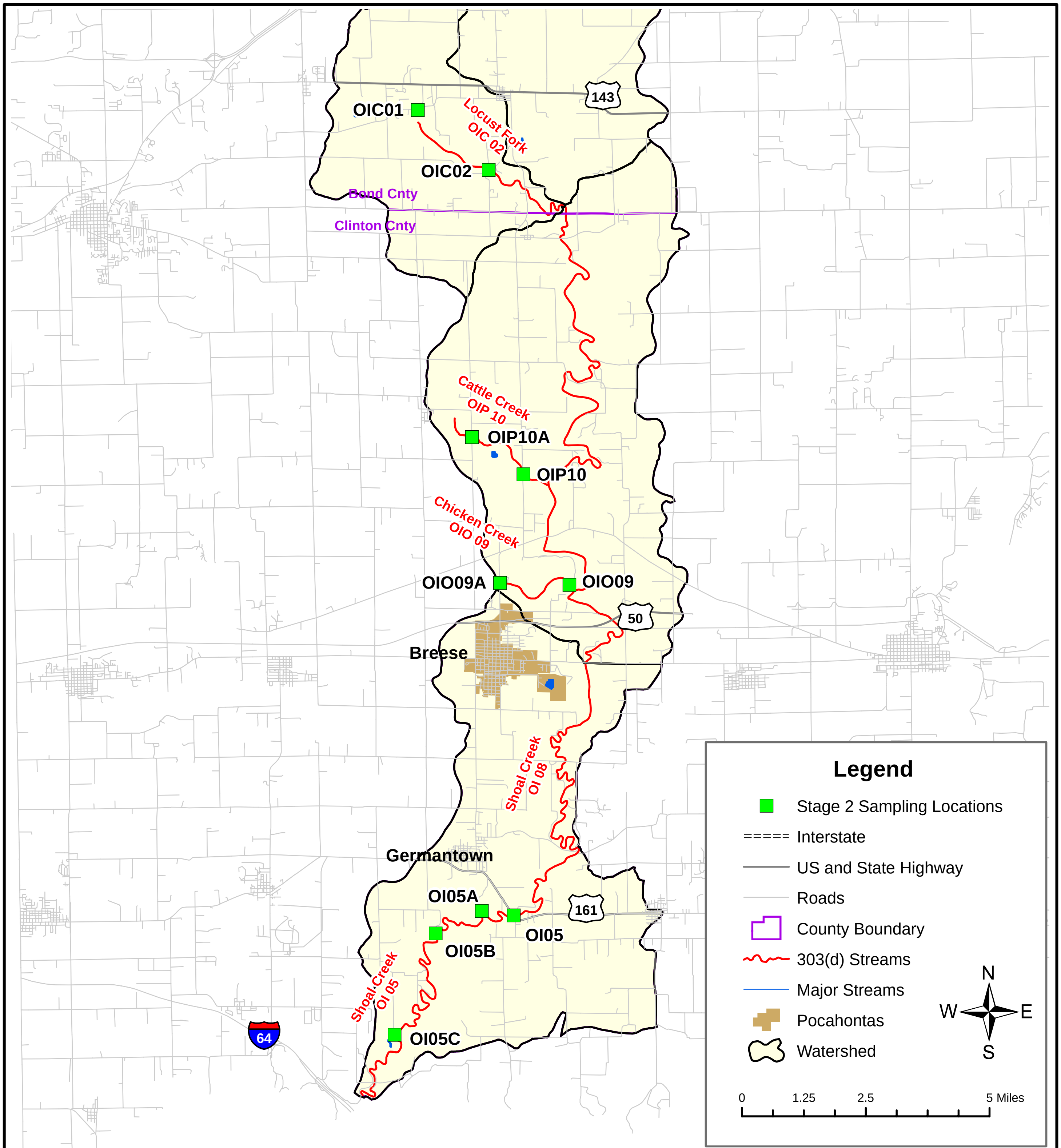

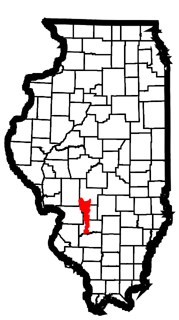

Figure 2-9:
Stage 2 Sampling Locations
Shoal Creek Watershed

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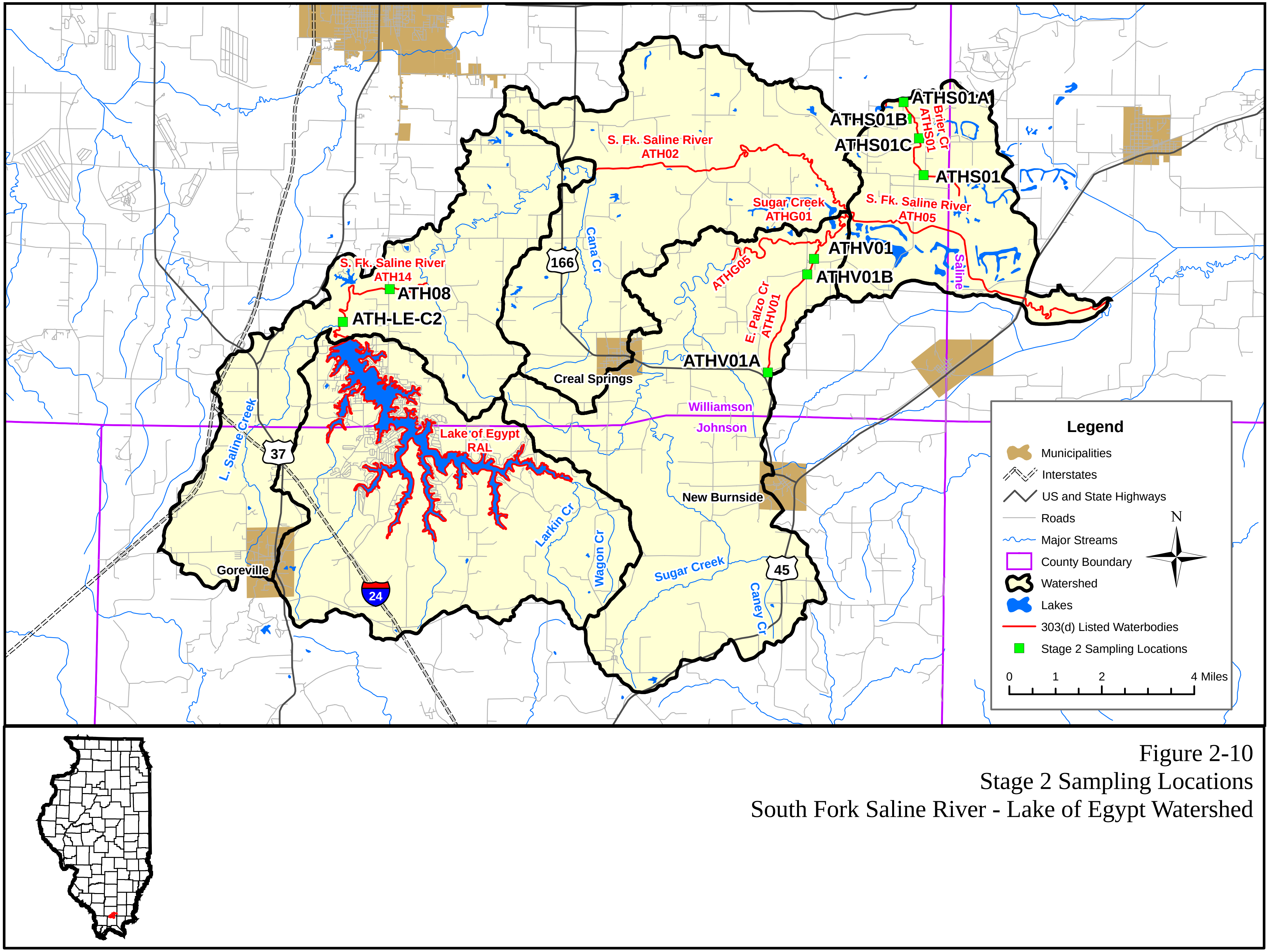

Figure 2-10
Stage 2 Sampling Locations
South Fork Saline River - Lake of Egypt Watershed

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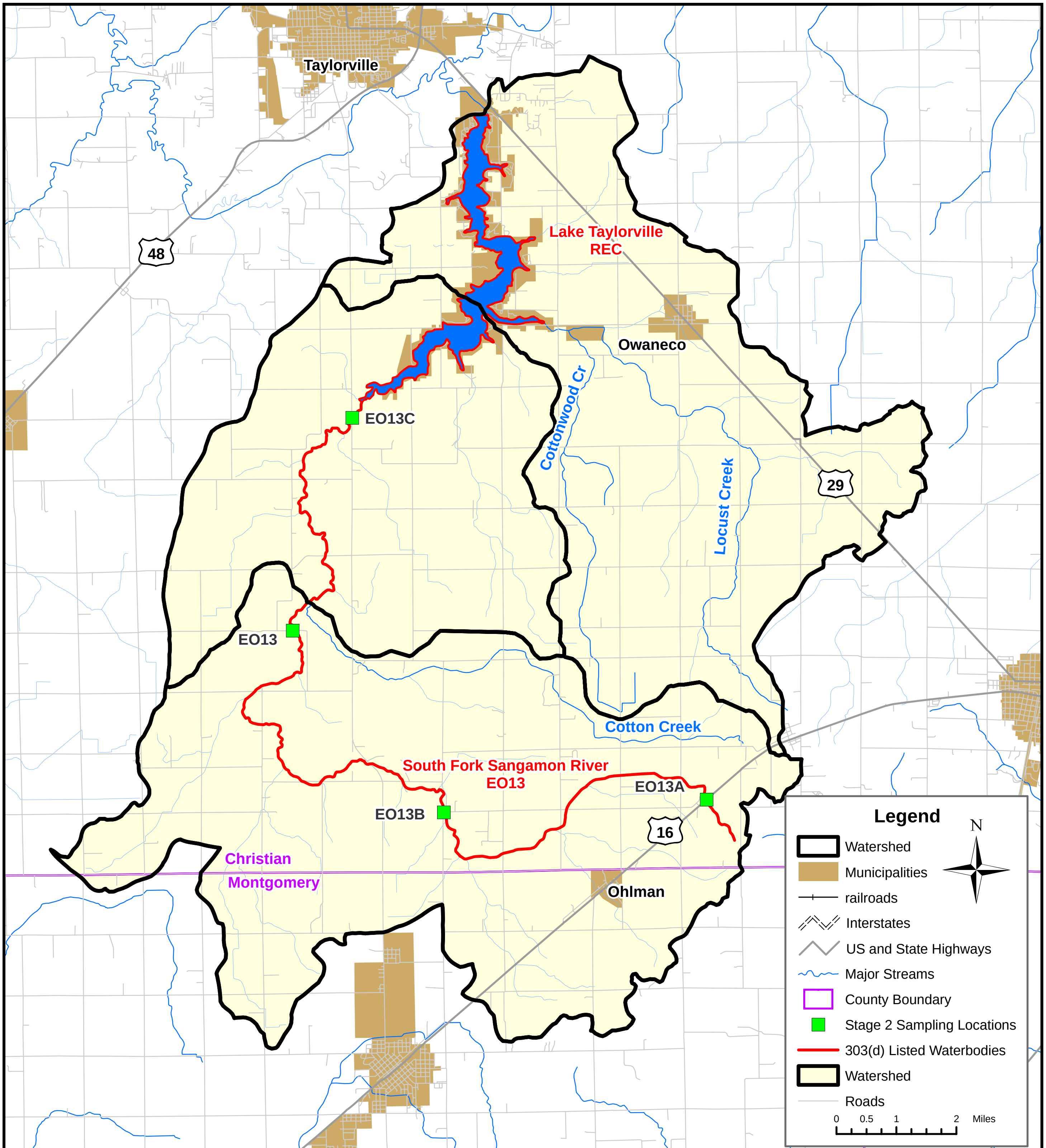

Figure 2-11:
Stage 2 Sampling Locations
South Fork Sangamon River - Lake Taylorville Watershed

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Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Bay Creek	Cedar Creek	AJF16	37.4661	88.7508	9/25/2006	18:00	6.5	117.0	7.8	8.9	63.9	NA
	Cedar Creek	AJF16	37.4661	88.7508	11/3/2006	11:05	7.2	164.5	8.6	11.0	7.0	NA
	Cedar Creek	AJF16A	37.4954	88.7592	9/25/2006	18:15	6.6	81.0	15.6	9.4	64.0	NA
	Cedar Creek	AJF16A	37.4954	88.7592	11/2/2006	13:30	7.3	101.8	5.4	11.6	9.2	NA
	Bay Creek Ditch	AJK01	37.3245	88.6337	9/25/2006	15:58	6.3	74.0	17.2	5.6	66.6	NA
	Bay Creek Ditch	AJK01	37.3245	88.6337	10/31/2006	8:15	7.2	91.6	20.4	8.2	12.8	NA
	Bay Creek Ditch	AJK01A	37.3282	88.6747	9/25/2006	NOT SAMPLED *Site flooded over banks into surrounding fields with no access/alternate site not located*						NA
	Bay Creek Ditch	AJK01A	37.3282	88.6747	10/31/2006	8:45	7.1	91.1	44.5	6.1	13.2	NA
Cahokia Creek/Holiday Shores Lake	Cahokia Diversion Ditch	JQ01	38.8054	90.1023	8/31/2006	13:40	7.4	606.7	62.3	3.4	23.9	NA
	Cahokia Diversion Ditch	JQ01	38.8054	90.1023	10/17/2006	14:45	8.3	459.8	92.9	9.6	12.6	NA
	Cahokia Diversion Ditch	JQ07	38.8050	90.0673	8/31/2006	14:45	7.4	498.6	68.0	5.3	23.0	NA
	Cahokia Diversion Ditch	JQ07	38.8050	90.0673	10/17/2006	14:15	8.3	427.0	115.8	9.4	12.8	NA
Cedar Creek	Big Muddy River	N13	37.7392	89.4284	9/7/2006	11:15	7.6	646.1	45.5	8.1	29.9	NA
	Big Muddy River	N13	37.7392	89.4284	11/1/2006	10:45	7.1	319.1	258.5	8.2	11.2	NA
	Big Muddy River	N99	37.6252	89.4284	9/7/2006	12:15	7.7	749.5	40.2	10.1	23.6	NA
	Big Muddy River	N99	37.6252	89.4284	11/1/2006	9:45	7.4	333.4	188.4	7.8	11.5	NA
	Cave Creek	NAC01	37.6154	89.3395	9/11/2006	11:45	7.8	288.4	N/A	7.6	20.4	NA
	Cave Creek	NAC01	37.6154	89.3395	11/1/2006	11:45	7.8	213.2	24.0	10.6	9.8	NA
	Cave Creek	NAC01A	37.6380	89.5660	9/11/2006	11:15	7.5	330.3	N/A	4.9	20.5	NA
	Cave Creek	NAC01A	37.6380	89.5660	11/1/2006	12:15	7.7	227.7	20.6	10.1	10.2	NA
Crab Orchard Creek	Crab Orchard Creek	ND11	37.7198	89.1717	9/6/2006	12:15	7.3	385.9	N/A	5.2	20.1	NA
	Crab Orchard Creek	ND11	37.7198	89.1717	11/1/2006	14:00	7.7	229.6	26.7	10.1	11.7	NA
	Crab Orchard Creek	ND12	37.7286	89.1753	9/6/2006	13:15	7.3	502.7	N/A	6.4	24.2	NA
	Crab Orchard Creek	ND12	37.7286	89.1753	11/1/2006	15:00	7.7	233.4	52.2	10.4	11.7	NA
	Crab Orchard Creek	ND13	37.7402	89.1723	9/6/2006	15:00	7.4	494.1	N/A	6.0	22.2	NA
	Crab Orchard Creek	ND13	37.7402	89.1723	11/1/2006	15:45	7.3	234.7	19.0	11.1	11.8	NA
	Crab Orchard Creek	ND15	37.7440	89.1852	9/6/2006	16:30	7.0	470.0	N/A	6.8	22.4	NA
	Crab Orchard Creek	ND15	37.7440	89.1852	11/1/2006	NOT SAMPLED *Site located behind Walmart parking lot and not accessible due to large chain link fence/no available alternate sites*						NA
	Little Crab Orchard Creek	NDA01	37.7525	89.2276	9/6/2006	18:00	7.3	242.5	N/A	2.1	19.2	NA
	Little Crab Orchard Creek	NDA01	37.7525	89.2276	11/2/2006	8:30	7.0	225.5	30.4	8.2	6.3	NA
	Little Crab Orchard Creek	NDA99	37.7011	89.2531	9/9/2006	NOT SAMPLED *Site dry and road crossings in the vacinity of site were also dry*						NA
	Little Crab Orchard Creek	NDA99	37.7011	89.2531	11/2/2006	10:30	8.7	190.5	17.0	12.3	5.5	NA
	Piles Fork	NDB03	37.7361	89.2016	9/7/2006	10:00	7.3	404.0	7.4	1.6	18.5	NA
	Piles Fork	NDB03	37.7361	89.2016	11/2/2006	9:15	7.7	240.7	25.5	10.3	7.3	NA
	Piles Fork	NDB04	37.7004	89.2205	9/9/2006	7:40	7.7	753.7	7.8	3.6	17.6	NA
	Piles Fork	NDB04	37.7004	89.2205	11/2/2006	11:00	8.1	154.9	56.5	11.5	10.2	NA
Crooked Creek	Little Crooked Creek	OJA-01	38.4416	89.4170	9/7/2006	17:45	7.0	274.0	22.5	3.7	20.3	NA
	Little Crooked Creek	OJA-01	38.4416	89.4170	10/19/2006	14:05	7.5	335.4	84.1	4.7	12.0	NA
	Little Crooked Creek	OJA-02	38.4564	89.3992	9/8/2006	11:15	7.0	284.8	20.2	3.1	19.7	NA
	Little Crooked Creek	OJA-02	38.4564	89.3992	10/19/2006	14:35	7.3	332.5	48.1	3.8	12.4	NA
	Plum Creek	OZH-OK-A2	38.4290	89.5387	9/8/2006	14:00	7.9	663.3	10.4	6.8	23.9	NA
	Plum Creek	OZH-OK-A2	38.4290	89.5387	10/19/2006	10:50	7.6	390.6	51.8	5.3	11.2	NA
	Plum Creek	OZH-OK-A2A	38.4160	89.5140	9/8/2006	16:45	7.8	503.2	56.9	8.5	22.3	NA
	Plum Creek	OZH-OK-A2A	38.4160	89.5140	10/19/2006	11:20	7.8	341.6	74.7	9.0	9.8	NA
	Plum Creek	OZH-OK-C2	38.4441	89.5592	9/8/2006	12:45	7.3	367.1	11.2	1.1	18.8	NA
	Plum Creek	OZH-OK-C2	38.4441	89.5592	10/19/2006	10:15	7.4	361.7	66.4	2.5	12.0	NA
	Plum Creek	OZH-OK-C2A	38.4568	89.5630	9/8/2006	17:30	7.8	977.9	13.4	4.6	20.7	NA
	Plum Creek	OZH-OK-C2A	38.4568	89.5630	10/19/2006	13:40	7.7	433.1	48.8	3.2	11.5	NA
	Plum Creek	OZH-OK-C3	38.4626	89.5598	9/8/2006	15:00	7.7	983.2	38.5	4.1	21.2	NA
	Plum Creek	OZH-OK-C3	38.4626	89.5598	10/19/2006	9:35	7.5	384.1	556.5	5.2	11.7	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Little Wabash	Little Wabash River	C09	38.4407	88.2581	1/25/2005	14:00	7.3	415	42	12.1	1.1	NA
	Little Wabash River	C09	38.4407	88.2581	3/17/2005	8:00	8.3	700	23	14.9	7	NA
	Little Wabash River	C09	38.4407	88.2581	4/19/2005	14:30	7.8	535	50	7.3	18.8	NA
	Little Wabash River	C09	38.4407	88.2581	5/9/2005	10:30	7.3	738	60	6.7	19.7	NA
	Little Wabash River	C09	38.4407	88.2581	6/23/2005	7:30	7.7	690	47	5.1	26	NA
	Little Wabash River	C09	38.4407	88.2581	8/23/2005	13:00	7.2	290	70	4.2	27.1	NA
	Little Wabash River	C09	38.4407	88.2581	9/27/2005	16:00	7.8	533	25	7.5	24.6	NA
	Little Wabash River	C09	38.4407	88.2581	10/27/2005	14:00	7.8	550	11	8.7	11.7	NA
	Little Wabash River	C09	38.4407	88.2581	12/6/2005	13:00	7.6	375	70	11.8	1.6	NA
	Little Wabash River	C09	38.4407	88.2581	2/1/2006	13:00	7.6	390	200	9.3	6.8	NA
	Little Wabash River	C09	38.4407	88.2581	3/15/2006	10:00	6.6	150	130	6.2	12.4	NA
	Little Wabash River	C09	38.4407	88.2581	4/18/2006	16:00	7.9	572	40	8.1	20.1	NA
	Little Wabash River	C09	38.4407	88.2581	4/26/2006	10:00	7.8	580	59	7.2	17.7	NA
	Little Wabash River	C09	38.4407	88.2581	5/1/2006	9:45	7.5	543	75	6.4	16.2	NA
	Little Wabash River	C09	38.4407	88.2581	5/10/2006	10:00	7.4	475		6.2	18.5	NA
	Little Wabash River	C09	38.4407	88.2581	5/17/2006	11:00	7.4	421	70	7.4	14.7	NA
	Little Wabash River	C09	38.4407	88.2581	5/24/2006	9:45	7.5	473		6.6	18.9	NA
	Little Wabash River	C09	38.4407	88.2581	5/31/2006	10:20	7.2	352		4	25.3	NA
	Little Wabash River	C09	38.4407	88.2581	6/7/2006	10:15	7.2	345		4.3	23.3	NA
	Little Wabash River	C09	38.4407	88.2581	6/15/2006	8:50	7.4	536	55	5.2	23.9	NA
	Little Wabash River	C09	38.4407	88.2581	6/22/2006	10:05	7.5	608	65	4.4	28.4	NA
	Little Wabash River	C09	38.4407	88.2581	6/27/2006	10:40	7.44	462	64	4.9	24.17	NA
	Little Wabash River	C09	38.4407	88.2581	7/5/2006	10:30	7.2	321		4.4	27.5	NA
	Little Wabash River	C09	38.4407	88.2581	7/12/2006	10:30	7.3	456		3.8	25.3	NA
	Little Wabash River	C09	38.4407	88.2581	7/20/2006	10:00	7.4	372		4.8	29.4	NA
	Little Wabash River	C09	38.4407	88.2581	7/27/2006	10:00	7.2	239		4.8	26.4	NA
	Little Wabash River	C09	38.4407	88.2581	8/1/2006	8:30	7.3	306	65	4.5	30.3	NA
	Little Wabash River	C09	38.4407	88.2581	8/8/2006	11:05	7.3	392	55	4.75	28.4	NA
	Little Wabash River	C33	38.2699	88.1377	4/18/2006	11:00	7.1	418	35	4.4	19.8	NA
	Little Wabash River	C33	38.2699	88.1377	4/26/2006	12:15	7.7	607	56	6	19	NA
	Little Wabash River	C33	38.2699	88.1377	5/1/2006	11:45	7.7	597	58	6.8	16.8	NA
	Little Wabash River	C33	38.2699	88.1377	5/10/2006	12:20	7.3	409		5.3	18.7	NA
	Little Wabash River	C33	38.2699	88.1377	5/17/2006	14:00	7.4	462	90	7.2	15.5	NA
	Little Wabash River	C33	38.2699	88.1377	5/24/2006	12:15	7.4	494		6.4	19.9	NA
	Little Wabash River	C33	38.2699	88.1377	5/31/2006	12:40	7.2	449		3.9	25.4	NA
	Little Wabash River	C33	38.2699	88.1377	6/7/2006	12:30	6.8	286		3	23.01	NA
	Little Wabash River	C33	38.2699	88.1377	6/15/2006	11:05	7.5	511	45	8.1	25.1	NA
	Little Wabash River	C33	38.2699	88.1377	6/22/2006	12:00	7.2	546	38	3	29.8	NA
	Little Wabash River	C33	38.2699	88.1377	6/27/2006	11:50	7.4	548	61	4.8	26.17	NA
	Little Wabash River	C33	38.2699	88.1377	7/5/2006	13:00	7.3	334		5.8	29	NA
	Little Wabash River	C33	38.2699	88.1377	7/12/2006	12:30	7.1	326		3.4	25.3	NA
	Little Wabash River	C33	38.2699	88.1377	7/20/2006	12:20	6.9	247		3.4	29.9	NA
	Little Wabash River	C33	38.2699	88.1377	7/27/2006	12:10	7.5	308		6.4	27.4	NA
	Little Wabash River	C33	38.2699	88.1377	8/1/2006	10:30	7.3	296	40	4.7	30.8	NA
	Little Wabash River	C33	38.2699	88.1377	8/8/2006	13:30	7.3	361	40	4.9	29.8	NA
	Johnson Creek	CCA12	38.3732	88.3449	9/9/2006	13:05	8.2	1402.0	13.4	14.2	28.4	NA
	Johnson Creek	CCA12	38.3732	88.3449	11/14/2006	9:45	7.5	651.4	645.5	7.7	7.0	NA
	Johnson Creek	CCA13	38.3789	88.3511	9/9/2006	14:30	8.6	1517.0	3.1	14.9	25.4	NA
	Johnson Creek	CCA13	38.3789	88.3511	11/14/2006	10:15	7.7	649.4	19.0	12.8	8.1	NA
	Johnson Creek	CCA14A	38.3830	88.3546	9/9/2006	15:25	7.6	836.0	3.6	5.7	21.6	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Little Wabash (cont.)	Johnson Creek	CCA14A	38.3830	88.3546	11/14/2006	10:25	7.7	694.2	2.4	12.5	8.0	NA
	Johnson Creek	CCAFFA1A	38.3881	88.3535	9/10/2006	10:50	7.4	788.0	5.9	3.8	19.8	NA
	Johnson Creek	CCAFFA1A	38.3881	88.3535	11/14/2006	10:45	7.4	789.8	4.3	12.3	7.5	NA
	Pond Creek	CCFFD1	38.3648	88.3130	9/9/2006	10:30	7.7	576.0	8.6	7.1	19.5	NA
	Pond Creek	CCFFD1	38.3648	88.3130	10/31/2006	10:10	7.6	8719.7	29.2	8.2	3.8	NA
	Pond Creek	CCFFD1A	38.3720	88.3181	9/9/2006	NOT SAMPLED *Site Dry/no available alternate sites*						NA
	Pond Creek	CCFFD1A	38.3720	88.3181	11/9/2006	12:15	7.3	742.5	9.1	11.2	13.6	NA
	Pond Creek	CCFFD1B	38.3793	88.3230	9/9/2006	11:45	7.5	784.0	10.0	8.6	22.9	NA
	Pond Creek	CCFFD1B	38.3793	88.3230	11/9/2006	11:35	7.3	827.9	4.1	12.1	12.7	NA
	Pond Creek	CCFFD1C	38.3999	88.3370	9/10/2006	12:10	8.0	3941.0	17.8	11.9	19.3	NA
	Pond Creek	CCFFD1C	38.3999	88.3370	10/31/2006	11:20	8.8	1394.0		14.4	4.4	NA
	Elm River	CD01	38.5184	88.1320	1/26/2005	13:00	7.1	388	36	9.1	1.4	NA
	Elm River	CD01	38.5184	88.1320	3/15/2005	11:30	8.4	950	7.2	14.6	6.2	NA
	Elm River	CD01	38.5184	88.1320	4/20/2005	11:30	7.4	670	60	6.7	20.1	NA
	Elm River	CD01	38.5184	88.1320	5/5/2005	13:00	7.5	625	27	7.6	13.8	NA
	Elm River	CD01	38.5184	88.1320	6/23/2005	10:00	7.5	1050	22	5.2	24.7	NA
	Elm River	CD01	38.5184	88.1320	8/18/2005	11:00	7.6	730	34	3.6	24.6	NA
	Elm River	CD01	38.5184	88.1320	9/29/2005	11:30	7.6	700	17	3.6	18.5	NA
	Elm River	CD01	38.5184	88.1320	10/18/2005	11:30	7.5	680	8.2	5.9	15	NA
	Elm River	CD01	38.5184	88.1320	12/8/2005	10:30	7.4	321	65	9.6	0.3	NA
	Elm River	CD01	38.5184	88.1320	2/1/2006	15:00	7.5	430	80	9.1	7	NA
	Elm River	CD01	38.5184	88.1320	3/1/2006	13:30	7.4	840	42	10.2	9.1	NA
	Elm River	CD01	38.5184	88.1320	4/6/2006	11:00	7.3	440	90	8.6	13.5	NA
	Elm River	CD01	38.5184	88.1320	4/18/2006	14:30	7.3	670	40	5.6	20.9	NA
	Elm River	CD01	38.5184	88.1320	4/26/2006	11:15	7.5	860		6.2	15.9	NA
	Elm River	CD01	38.5184	88.1320	5/1/2006	11:00	7.4	958		5.9	15.2	NA
	Elm River	CD01	38.5184	88.1320	5/10/2006	11:10	7.2	489		5	18.2	NA
	Elm River	CD01	38.5184	88.1320	5/17/2006	9:30	7.1	484	35	7	13.8	NA
	Elm River	CD01	38.5184	88.1320	5/24/2006	11:20	7.2	594		5.7	18.5	NA
	Elm River	CD01	38.5184	88.1320	5/31/2006	11:30	7.2	605		3.8	25.7	NA
	Elm River	CD01	38.5184	88.1320	6/7/2006	11:25	7	346		4.5	23.4	NA
	Elm River	CD01	38.5184	88.1320	6/15/2006	9:50	7.1	622		4.6	22.5	NA
	Elm River	CD01	38.5184	88.1320	6/22/2006	11:15	7.1	443		4.6	27.9	NA
	Elm River	CD01	38.5184	88.1320	6/27/2006	9:15	6.77	229	91	5	21.95	NA
	Elm River	CD01	38.5184	88.1320	7/5/2006	11:50	7.2	588		3.6	26.6	NA
	Elm River	CD01	38.5184	88.1320	7/12/2006	11:30	7.2	569		4.2	23.9	NA
	Elm River	CD01	38.5184	88.1320	7/20/2006	11:15	7	285		2.8	28.2	NA
	Elm River	CD01	38.5184	88.1320	7/27/2006	11:05	7.1	346		3.5	25.8	NA
	Elm River	CD01	38.5184	88.1320	8/1/2006	9:20	7.3	382		4	27.8	NA
	Elm River	CD01	38.5184	88.1320	8/8/2006	12:20	7.1	425		4.1	26.3	NA
	Elm River	CD02	38.6751	88.4362	9/8/2006	17:45	7.5	344.0	15.9	8.1	23.2	NA
	Elm River	CD02	38.6751	88.4362	11/8/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	Elm River	CD02A	38.4894	88.3051	9/12/2006	12:51	7.2	404.0	15.7	3.8	22.0	NA
	Elm River	CD02A	38.4894	88.3051	11/8/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	Seminary Creek	CDFGLC6	38.6180	88.4384	9/8/2006	12:25	7.7	708.0	4.2	6.6	19.5	NA
	Seminary Creek	CDFGLC6	38.6180	88.4384	11/8/2006	17:00	7.5	527.6	17.5	10.5	12.4	NA
	Seminary Creek	CDFGLC6A	38.6135	88.4245	9/8/2006	11:10	7.7	720.0	201.2	7.0	20.1	NA
	Seminary Creek	CDFGLC6A	38.6135	88.4245	11/8/2006	16:45	7.3	561.7	15.1	12.0	13.5	NA
	Seminary Creek	CDGFLA1	38.6561	88.4832	9/8/2006	15:40	7.9	558.0	7.0	10.0	22.0	NA
	Seminary Creek	CDGFLA1	38.6561	88.4832	11/8/2006	14:45	7.3	385.0	12.5	14.3	12.7	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Little Wabash (cont.)	Seminary Creek	CDGFLA1A	38.6595	88.4890	9/8/2006	13:45	7.4	362.0	22.7	2.6	19.0	NA
	Seminary Creek	CDGFLA1A	38.6595	88.4890	11/8/2006	15:50	7.2	429.8	16.8	15.1	12.7	NA
	Village Creek	CE01	38.4348	88.1369	9/6/2006	17:30	8.1	610.0	11.4	9.9	24.9	NA
	Village Creek	CE01	38.4348	88.1369	11/14/2006	8:45	7.5	697.9	8.0	10.6	6.8	NA
	Village Creek	CE01A	38.4294	88.0943	9/12/2006	17:05	7.2	327.0	145.2	5.8	22.6	NA
	Village Creek	CE01A	38.4294	88.0943	11/9/2006	13:45	7.2	607.2	8.7	11.2	14.2	NA
	Village Creek	CE02	38.4150	88.1659	9/6/2006	15:20	7.8	568.0	15.7	7.9	25.0	NA
	Village Creek	CE02	38.4150	88.1659	11/9/2006	12:55	7.5	587.4	14.1	10.7	13.1	NA
	Big Muddy Creek	CJ05	38.7693	88.3093	9/7/2006	16:45	8.2	63.1	11.4	10.5	23.6	NA
	Big Muddy Creek	CJ05	38.7693	88.3093	11/8/2006	11:30	7.4	457.0	32.5	12.4	8.3	NA
	Big Muddy Creek	CJ06	38.8298	88.3642	9/7/2006	18:10	7.5	588.0	34.6	4.9	21.8	NA
	Big Muddy Creek	CJ06	38.8298	88.3642	11/8/2006	11:00	7.3	455.1	15.8	11.6	10.6	NA
	Little Muddy Creek	CJA01	38.7647	88.3760	9/12/2006	10:20	7.0	321.0	9.5	3.4	20.9	NA
	Little Muddy Creek	CJA01	38.7647	88.3760	11/13/2006	12:00	7.0	267.9	113.2	10.1	7.4	NA
	Little Muddy Creek	CJA02	38.7047	88.3174	9/7/2006	14:20	6.8	554.0	45.9	2.8	20.4	NA
	Little Muddy Creek	CJA02	38.7047	88.3174	11/8/2006	12:30	7.0	497.0	35.8	9.3	10.4	NA
	Big Muddy Diversion Ditch	CJAE01	38.6865	88.2967	9/7/2006	12:10	7.1	1946.0	26.9	9.1	22.2	NA
	Big Muddy Diversion Ditch	CJAE01	38.6865	88.2967	11/8/2006	13:05	7.3	478.2	30.8	10.8	11.7	NA
	Big Muddy Diversion Ditch	CJAE01A	38.7467	88.2977	9/7/2006	15:45	8.1	908.0	6.5	10.3	24.3	NA
	Big Muddy Diversion Ditch	CJAE01A	38.7467	88.2977	11/13/2006	12:30	7.6	452.9	37.8	9.8	8.2	NA
Mary's River/North Fork Cox Creek	North Fork Cox Creek	IIHA01	38.0114	89.6460	9/9/2006	17:40	7.9	2073.0	N/A	10.0	22.0	NA
	North Fork Cox Creek	IIHA01	38.0114	89.6460	10/18/2006	14:25	8.3	2995.0	13.5	8.1	15.4	NA
	North Fork Cox Creek	IIHA31	38.0293	89.6303	9/9/2006	17:10	8.2	3491.0	N/A	9.6	23.9	NA
	North Fork Cox Creek	IIHA31	38.0293	89.6303	10/18/2006	14:45	8.4	3215.0	8.5	8.6	15.5	NA
	North Fork Cox Creek	IIHA-STC1	38.0015	89.6557	9/9/2006	16:15	7.8	3019.0	N/A	7.1	21.9	NA
	North Fork Cox Creek	IIHA-STC1	38.0015	89.6557	10/18/2006	14:00	8.1	1990.0	20.0	7.0	14.9	NA
	North Fork Cox Creek	IIHA-STE1	38.0048	89.6526	9/9/2006	15:45	7.8	3422.0	N/A	6.9	20.7	NA
	North Fork Cox Creek	IIHA-STE1	38.0048	89.6526	10/18/2006	13:40	8.0	2505.0	16.3	6.0	14.7	NA
	Maxwell Creek	IIKSPA1	38.1242	89.6870	9/7/2006	NOT SAMPLED						NA
	Maxwell Creek	IIKSPA1	38.1242	89.6870	10/17/2006	*Site dry during both visits/available alternate locations also dry*						NA
	Maxwell Creek	IIKSPC1	38.1182	89.6885	9/7/2006	15:30	7.3	968.1	4.8	2.0	24.3	NA
	Maxwell Creek	IIKSPC1	38.1182	89.6885	10/17/2006	8:20	7.1	561.5	22.3	20.2	18.4	NA
	Maxwell Creek	IIKSPC3A	38.1090	89.6850	9/7/2006	15:00	7.5	997.0	4.4	2.6	21.6	NA
	Maxwell Creek	IIKSPC3A	38.1090	89.6850	10/17/2006	8:45	7.5	457.8	19.2	6.5	15.4	NA
	Maxwell Creek	IIKSPE1A	38.1218	89.6889	9/7/2006	NOT SAMPLED						NA
	Maxwell Creek	IIKSPE1A	38.1218	89.6889	10/17/2006	*Site dry during both visits/available alternate locations also dry*						NA
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:00	9.1	279.7	N/A	13.9	25.6	1
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:02	9.1	279.5	N/A	13.9	24.9	2
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:04	9.1	279.2	N/A	13.8	24.7	3
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:06	9.1	278.8	N/A	13.9	24.6	4
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:08	9.0	279.3	N/A	13.2	24.4	5
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:10	9.0	279.7	N/A	12.6	24.3	6
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:12	8.9	280.4	N/A	11.8	24.2	7
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:14	8.2	286.0	N/A	6.2	23.9	8
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:16	7.8	287.4	N/A	4.4	23.7	9
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:18	7.6	288.9	N/A	2.5	23.5	10
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:20	7.3	290.3	N/A	0.3	23.1	11
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:22	7.3	296.0	N/A	0.1	22.7	12
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:24	7.1	317.6	N/A	0.0	21.2	13
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:26	7.1	332.7	N/A	0.0	18.5	14
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:28	7.1	330.3	N/A	0.0	17.1	15

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Mary's River/North Fork Cox Creek (cont.)	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:30	7.1	329.6	N/A	0.0	16.1	16
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:32	7.1	329.9	N/A	0.0	14.7	17
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:34	7.1	330.0	N/A	0.0	13.6	18
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:36	7.1	332.4	N/A	0.0	12.4	19
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:38	7.1	335.4	N/A	0.0	11.8	20
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:40	7.1	341.7	N/A	0.0	11.3	21
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:42	7.1	347.9	N/A	0.0	10.9	22
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:44	7.1	350.1	N/A	0.0	10.8	23
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:46	7.1	352.6	N/A	0.0	10.6	24
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:48	7.0	363.8	N/A	0.0	10.2	25
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	8.0	306.1	5.6	7.1	15.8	0
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.8	305.0	6.7	5.4	15.7	3.28
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.8	304.9	5.9	5.4	15.7	6.56
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.8	303.6	6.6	5.3	15.6	9.84
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.7	303.5	7.1	5.3	15.6	13.12
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.6	304.0	11.9	4.5	13.3	16.4
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.5	371.4	9.8	0.6	12.7	19.68
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.6	392.9	8.3	0.5	10.9	22.96
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.5	435.0	63.4	0.3	10.1	26.24
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:00	9.0	286.4	N/A	13.3	27.0	1
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:02	9.0	282.2	N/A	13.8	26.8	2
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:04	9.1	279.7	N/A	14.7	25.0	3
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:06	9.0	280.2	N/A	14.3	24.7	4
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:08	8.9	282.2	N/A	12.5	24.4	5
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:10	8.6	286.3	N/A	9.0	24.1	6
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:12	8.1	290.2	N/A	6.0	24.0	7
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:14	7.8	292.2	N/A	4.0	23.9	8
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:16	7.7	292.7	N/A	3.1	23.8	9
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	8.0	304.9	10.3	7.1	16.0	0
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	7.9	304.5	7.0	6.7	15.9	3.28
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	7.8	304.5	6.6	6.4	15.9	6.56
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	7.8	304.5	6.3	6.3	15.8	9.84
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:00	9.0	283.0	N/A	13.2	26.4	1
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:02	9.0	283.3	N/A	12.9	26.5	2
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:04	9.0	281.0	N/A	12.8	25.8	3
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:06	9.0	280.4	N/A	12.9	25.0	4
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:08	9.0	279.7	N/A	12.9	24.6	5
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:10	9.0	279.7	N/A	12.6	24.5	6
	Randolph County Lake	RIB-3	37.9800	89.7990	10/18/2006	11:15	8.0	305.0	8.8	7.9	16.0	0
	Randolph County Lake	RIB-3	37.9800	89.7990	10/18/2006	11:15	7.9	304.7	8.7	7.1	16.0	3.28
	Randolph County Lake	RIB-3	37.9800	89.7990	10/18/2006	11:15	7.8	304.7	10.4	6.7	16.0	6.56
	Randolph County Lake Tributary	RIB-Trib	37.9813	89.7988	9/9/2006	13:20	9.0	284.0	N/A	12.9	28.4	NA
	Randolph County Lake Tributary	RIB-Trib	37.9813	89.7988	10/18/2006	11:45	8.1	341.7	46.3	8.3	16.2	NA
Sangamon River/Lake Decatur	Owl Creek	EZV01	40.3254	88.3531	8/30/2006	12:50	7.4	669.0	50.8	8.5	21.2	NA
	Owl Creek	EZV01	40.3254	88.3531	11/2/2006	9:25	8.2	856.7		12.2	5.1	NA
	Owl Creek	EZVA1	40.3115	88.3409	8/30/2006	11:05	7.7	606.9	52.3	6.5	19.0	NA
	Owl Creek	EZVA1	40.3115	88.3409	11/2/2006	10:33	8.2	856.3		11.8	4.7	NA
	Owl Creek	EZVC1	40.3101	88.3423	8/30/2006	10:25	7.3	1450.0	25.6	5.0	21.0	NA
	Owl Creek	EZVC1	40.3101	88.3423	11/2/2006	12:20	8.1	990.7		11.7	6.0	NA
	Owl Creek	EZVE1	40.3113	88.3415	8/30/2006	10:45	7.5	1497.0	20.3	11.1	21.5	NA
	Owl Creek	EZVE1	40.3113	88.3415	11/2/2006	12:59	8.3	859.8		12.5	6.1	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Shoal Creek	Shoal Creek	OI05	38.5361	89.5213	9/1/2006	12:35	7.5	563.4	38.7	9.1	22.9	NA
	Shoal Creek	OI05	38.5361	89.5213	10/17/2006	11:30	7.9	604.4	39.7	8.5	12.0	NA
	Shoal Creek	OI05A	38.5370	89.5330	9/1/2006	NOT SAMPLED						NA
	Shoal Creek	OI05A	38.5370	89.5330	10/17/2006	*Site located at end of private road with chained fence/alternate location not located*						NA
	Shoal Creek	OI05B	38.5333	89.5496	9/1/2006	14:20	7.8	542.2	43.0	10.8	26.2	NA
	Shoal Creek	OI05B	38.5333	89.5496	10/17/2006	11:15	7.9	542.4	72.7	8.7	12.3	NA
	Shoal Creek	OI05C	38.5020	89.5661	9/1/2006	15:40	7.8	535.3	43.5	10.2	23.5	NA
	Shoal Creek	OI05C	38.5020	89.5661	10/16/2006	10:30	8.0	578.9	46.0	9.4	12.1	NA
	Locust Fork	OIC01	38.7715	89.5556	8/31/2006	NOT SAMPLED *Site dry/no other road crossings on segment*						NA
	Locust Fork	OIC01	38.7715	89.5556	10/19/2006	12:20	7.8	401.1	24.3	3.8	10.0	NA
	Locust Fork	OIC02	38.7536	89.5288	8/31/2006	17:50	8.0	499.6	23.2	9.4	24.2	NA
	Locust Fork	OIC02	38.7536	89.5288	10/17/2006	13:00	7.7	422.2	26.9	5.2	14.2	NA
	Chicken Creek	OIO09	38.6407	89.5025	9/1/2006							NA
	Chicken Creek	OIO09	38.6407	89.5025	10/17/2006	NOT SAMPLED						NA
	Chicken Creek	OIO09A	38.6373	89.5260	9/1/2006	*Sites dry during both visits/sites located at only two road crossings on segment*						NA
	Chicken Creek	OIO09A	38.6373	89.5260	10/17/2006							NA
	Cattle Creek	OIP10	38.6649	89.5170	8/31/2006	NOT SAMPLED *Site dry/no other road crossings on segment*						NA
	Cattle Creek	OIP10	38.6649	89.5170	10/17/2006	12:05	7.9	928.0	105.6	2.0	14.2	NA
	Cattle Creek	OIP10A	38.6744	89.5359	8/31/2006	NOT SAMPLED						NA
	Cattle Creek	OIP10A	38.6744	89.5359	10/17/2006	*Site dry/no other road crossings on segment*						NA
South Fork Saline River/Lake of Egypt	South Fork Saline River	ATH08	37.6399	88.9281	9/26/2006	10:20	7.1	165.0	0.6	8.7	23.6	NA
	South Fork Saline River	ATH08	37.6399	88.9281	10/31/2006	11:15	6.6	213.1	10.0	8.8	19.0	NA
	South Fork Saline River	ATH14	NA	NA	9/26/2006							NA
	South Fork Saline River	ATH14	NA	NA	10/31/2006	NOT SAMPLED						NA
	South Fork Saline River	ATHLEC1	NA	NA	9/26/2006	*Sites located on private property and/or not accessible by roads No other road crossings available on segment*						NA
	South Fork Saline River	ATHLEC1	NA	NA	10/31/2006							NA
	South Fork Saline River	ATHLEC2	37.6295	88.9465	9/26/2006	9:45	6.6	81.0	15.6	9.4	18.1	NA
	South Fork Saline River	ATHLEC2	37.6295	88.9465	10/31/2006	12:00	6.8	137.7	11.6	9.6	17.1	NA
	Briers Creek	ATHS01	37.6766	88.7178	9/11/2006	11:30	7.6	1997.0	2.0	9.1	21.3	NA
	Briers Creek	ATHS01	37.6766	88.7178	9/27/2006	9:00	7.3	1392.0	3.4	10.2	15.5	NA
	Briers Creek	ATHS01	37.6766	88.7178	10/30/2006	16:30	7.1	1281.0	19.6	9.4	13.7	NA
	Briers Creek	ATHS01	37.6766	88.7178	11/15/2006	10:25	7.0	700.1	185.3	4.6	9.4	NA
	Briers Creek	ATHS01A	37.6995	88.7257	9/11/2006	10:00	7.1	765.0	5.6	9.7	17.9	NA
	Briers Creek	ATHS01A	37.6995	88.7257	9/27/2006	11:30	7.5	817.0	1.9	9.7	17.0	NA
	Briers Creek	ATHS01A	37.6995	88.7257	11/2/2006	12:00	8.0	862.8	3.0	8.5	9.5	NA
	Briers Creek	ATHS01A	37.6995	88.7257	11/15/2006	11:10	6.8	226.1	36.3	5.4	10.2	NA
	Briers Creek	ATHS01B	37.6943	88.7245	9/11/2006	10:25	7.2	507.0	6.2	9.5	17.8	NA
	Briers Creek	ATHS01B	37.6943	88.7245	9/27/2006	10:35	6.7	500.0	0.5	9.7	17.3	NA
	Briers Creek	ATHS01B	37.6943	88.7245	11/2/2006	12:20	7.4	726.7	2.9	9.9	9.5	NA
	Briers Creek	ATHS01B	37.6943	89.7640	11/15/2006	11:30	6.8	198.9	69.1	4.0	10.0	NA
	Briers Creek	ATHS01C	37.6882	88.7195	9/11/2006	12:55	6.8	2071.0	21.5	6.3	19.0	NA
	Briers Creek	ATHS01C	37.6882	88.7195	9/27/2006	9:30	7.0	1571.0	2.2	9.8	15.1	NA
	Briers Creek	ATHS01C	37.6882	88.7195	10/31/2006	14:30	7.4	1296.0	4.5	9.4	12.0	NA
	Briers Creek	ATHS01C	37.6882	88.7195	11/15/2006	10:45	7.0	848.6	90.7	8.8	9.5	NA
	East Palzo Creek	ATHV01	37.6502	88.7608	9/11/2006	10:40	6.9	375.0	16.4	6.7	22.7	NA
	East Palzo Creek	ATHV01	37.6502	88.7608	9/27/2006	NOT SAMPLED *Site flooded over road with no safe access/no other road crossings on segment*						NA
	East Palzo Creek	ATHV01	37.6502	88.7608	10/31/2006	13:40	6.5	490.6	14.2	7.6	12.4	NA
	East Palzo Creek	ATHV01	37.6502	88.7608	11/15/2006	10:00	6.3	554.5	200.0	5.1	9.4	NA
	East Palzo Creek	ATHV01A	37.6143	88.7788	9/11/2006	8:25	7.2	1878.0	1.7	6.6	18.8	
	East Palzo Creek	ATHV01A	37.6143	88.7788	9/27/2006	NOT SAMPLED						NA
	East Palzo Creek	ATHV01A	37.6143	88.7788	10/31/2006	*Site dry/no other road crossings on segment*						NA
	East Palzo Creek	ATHV01A	37.6143	88.7788	11/15/2006	9:05	6.8	158.9	81.9	9.0	9.4	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	9/11/2006	8:55	6.9	481.0	28.8	6.0	19.1	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	9/26/2006	12:30	6.2	405.0	4.6	10.9	17.4	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	10/31/2006	13:00	6.4	498.2	23.8	8.7	12.4	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	11/15/2006	9:35	6.1	435.0	243.8	5.6	9.4	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
South Fork Sangamon River/ Lake Taylorville	South Fork Sangamon River	EO13	39.4072	89.3164	8/30/2006	18:10	7.3	719.3	7.2	6.3	20.4	NA
	South Fork Sangamon River	EO13	39.4072	89.3164	11/2/2006	16:50	7.7	528.5		6.5	6.1	NA
	South Fork Sangamon River	EO13A	39.2700	89.1880	8/30/2006	19:55	7.3	754.7	7.6	9.7	21.6	NA
	South Fork Sangamon River	EO13A	39.2700	89.1880	11/2/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	South Fork Sangamon River	EO13B	39.3630	89.2700	8/30/2006	19:25	7.6	1112.0	60.1	8.3	21.6	NA
	South Fork Sangamon River	EO13B	39.3630	89.2700	11/2/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	South Fork Sangamon River	EO13C	39.4590	89.2970	8/30/2006	18:55	7.0	56.9	96.0	3.8	21.1	NA
	South Fork Sangamon River	EO13C	39.4590	89.2970	11/2/2006	16:25	8.2	954.1		5.8	6.4	NA

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Table 2-3: Data Associated with Impairment Status

					Causes of Impairment												
Watershed	**Water body**	**Sample Site**	**Date**	**Time**	**pH[1]**	**DO[1]**	**Total Mn**	**Sulfates**	**TDS**	**Total Boron**	**Dissolved Zinc [6]**	**Dissolved Iron**	**Total Silver**	**Dissolved Copper [6]**	**TP**	**Atrazine [5]**	**Ammonia**
					s.u.	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**ug/L**	**mg/L**
Bay Creek	Cedar Creek	AJF16	9/25/2006	18:00		8.9	0.25										
			11/3/2006	11:05		11.0	0.12										
		AJF16A	9/25/2006	18:15		9.4	0.23										
			11/2/2006	13:30		11.6	0.08										
	Bay Creek Ditch	AJK01	9/25/2006	15:58		5.6	0.16										
			10/31/2006	8:15		8.2	0.05										
		AJK01A	10/31/2006	8:45		6.1	0.06										
Cahokia Creek/Holiday Shores Lake	Cahokia Diversion Ditch	JQ07	10/4/2006	16:35		5.3								ND			
			10/17/2006	14:15		9.4								ND			
		JQ01	10/4/2006	16:20		**3.4**								ND			
			10/17/2006	14:45		9.6								ND			
Cedar Creek	Big Muddy River	N99	9/7/2006	12:15		10.1		186									
			11/1/2006	9:45		7.8		75									
		N13	9/7/2006	11:15		8.1		144									
			11/1/2006	10:45		8.2		68									
	Cave Creek	NAC01	9/11/2006	11:45		7.6											
			11/1/2006	11:45		10.6											
		NAC01A	9/11/2006	11:15		**4.9**											
			11/1/2006	12:15		10.1											
Crab Orchard Lake	Crab Orchard Creek	ND11	9/6/2006	12:15	7.3	5.2	1.00										
			11/1/2006	14:00	7.7	10.1	0.26										
		ND12	9/6/2006	13:15	7.3		0.17										
			11/1/2006	15:00	7.7		ND										
		ND13	9/6/2006	15:00		6.0											
			11/1/2006	15:45		11.1											
		ND15	9/6/2006	16:30		6.8											
	Little Crab Orchard Creek	NDA01	9/6/2006	18:00		**2.1**	**2.00**										
			11/2/2006	8:30		8.2	0.20										
		NDA99	11/2/2006	10:30		12.3	0.03										
	Piles Fork	NDB03	9/7/2006	10:00		**1.6**											
			11/2/2006	9:15		10.3											
		NDB04	9/9/2006	7:40		**3.6**											
			11/2/2006	11:00		11.5											
Crooked Creek	Plum Creek	OZH-OK-A2	9/8/2006	14:00		6.8	0.65										
			10/19/2006	10:50		5.3	0.33										
		OZH-OK-A2A	9/8/2006	16:25		8.5	0.20										
			10/19/2006	11:20		9.0	0.22										
		OZH-OK-C2	9/8/2006	12:45		**1.1**											
			10/19/2006	10:15		**2.5**											
		OZH-OK-C2A	9/8/2006	17:30		**4.6**											
			10/19/2006	13:40		**3.2**											
		OZH-OK-C3	9/9/2006	15:00		**4.1**	0.30										
			10/19/2006	9:35		5.2	0.77										
	Little Crooked Creek	OJA-01	9/7/2006	17:45		**3.7**	0.14										
			10/19/2006	14:05		**4.7**	0.17										
		OJA-02	9/8/2006	11:15		**3.1**	0.14										
			10/19/2006	14:35		**3.8**	0.17										

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH(1)	DO(1)	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc (6)	Dissolved Iron	Total Silver	Dissolved Copper (6)	TP	Atrazine (5)	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Little Wabash	Village Creek	CE01	9/6/2006	17:30		9.9	0.17										
			11/14/2006	8:45		10.6	0.10										
		CE02	9/6/2006	15:20		7.9	0.80										
			11/9/2006	12:55		10.7	0.11										
		CE01A	9/12/2006	17:05		5.8	0.41										
			11/9/2006	13:45		11.2	0.08										
	Johnson Creek	CCAFFA1A	9/10/2006	10:50		**3.8**											
			11/14/2006	10:45		12.3											
		CCA12	9/9/2006	13:05		14.2											
			11/14/2006	9:45		7.7											
		CCA13	9/9/2006	14:30		14.9											
			11/14/2006	10:15		12.8											
		CCA14A	9/9/2006	15:25		5.7											
			11/14/2006	10:25		12.5											
	Pond Creek	CCFFD1	9/9/2006	10:30		7.1											
			10/31/2006	10:10		8.2											
		CCFFD1A	11/9/2006	12:15		11.2											
		CCFFD1B	9/9/2006	11:45		8.6											
			11/9/2006	11:35		12.1											
		CCFFD1C	9/10/2006	12:10		11.9											
			10/31/2006	11:20		14.4											
	Seminary Creek	CDGFLA1	9/8/2006	15:40		10.0											
			11/8/2006	14:45		14.3											
		CDGFLA1A	9/8/2006	13:45		**2.6**											
			11/8/2006	15:50		15.1											
		CDFGLC6	9/8/2006	12:25		6.6											
			11/8/2006	17:00		10.5											
		CDFGLC6A	9/8/2006	11:10		7.0											
			11/8/2006	16:45		12.0											
	Big Muddy Creek	CJ06	9/7/2006	18:10		**4.9**	0.54										
			11/8/2006	11:00		11.6	0.39										
		CJ05	9/7/2006	16:45		10.5	0.04										
			11/8/2006	11:30		12.4	0.07										
	Little Muddy Creek	CJA02	9/7/2006	4:20		**2.8**	**1.30**										
			11/8/2006	12:30		9.3	0.39										
		CJA01	9/12/2006	10:20		**3.4**	**1.30**										
			11/13/2006	12:00		10.1	0.17										
	Big Muddy Diversion Ditch	CJAE01	9/7/2006	12:10		9.1											
			11/8/2006	13:05		10.8											
		CJAE01A	9/7/2006	15:45		10.3											
			11/13/2006	12:30		9.8											

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH(1)	DO(1)	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc (6)	Dissolved Iron	Total Silver	Dissolved Copper (6)	TP	Atrazine (5)	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Little Wabash	Elm River	CD02A	9/12/2006	12:51		**3.8**											
		CD02	9/8/2006	17:45		8.1											
		CD01	4/18/2006	14:30												0.12	
			4/26/2006	11:15												0.16	
			5/1/2006	11:00												0.27	
			5/17/2006	9:30												**19.00**	
			5/24/2006	11:20												**15.00**	
			5/31/2006	11:30												8.30	
			6/7/2006	11:25												5.70	
			6/15/2006	9:50												2.80	
			6/22/2006	11:15												1.20	
			6/27/2006	9:15												4.20	
			7/5/2006	11:50												2.40	
			7/12/2006	11:30												0.92	
			7/20/2006	11:15												2.40	
			7/27/2006	11:05												2.60	
			8/1/2006	9:20												2.60	
			8/8/2006	12:20												1.60	
	Little Wabash River	C33 (4)	4/18/2006	11:00												0.55	
			4/26/2006	12:15			**0.35**									1.10	
			5/1/2006	11:45			**0.50**									0.71	
			5/10/2006	12:20			**0.41**										
			5/17/2006	14:00												**19.00**	
			5/24/2006	12:15			**0.38**									8.10	
			5/31/2006	12:40			**0.37**									**13.00**	
			6/7/2006	12:30			**0.44**									6.30	
			6/15/2006	11:05												5.30	
			6/22/2006	12:00			**0.76**									2.60	
			6/27/2006	11:50												2.50	
			7/5/2006	13:00			**0.50**									1.70	
			7/12/2006	12:30			**0.54**									1.00	
			7/20/2006	12:20			**0.46**									2.30	
			7/27/2006	12:10												0.64	
			8/1/2006	10:30												0.66	
			8/8/2006	13:30												0.50	

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH[1]	DO[1]	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc [6]	Dissolved Iron	Total Silver	Dissolved Copper [6]	TP	Atrazine [5]	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Little Wabash	Little Wabash River	C09	3/17/2005	8:00		14.9											
			4/19/2005	14:30		7.3											
			5/9/2005	10:30		6.7											
			6/23/2005	7:30		5.1											
			8/23/2005	13:00		**4.2**											
			9/27/2005	16:00		7.5											
			10/27/2005	14:00		8.7											
			12/6/2005	13:00		11.8											
			2/1/2006	12:30		9.3											
			3/15/2006	10:00		6.2											
			4/18/2006	16:00												0.27	
			4/26/2006	10:00									ND			0.62	
			5/1/2006	9:45									ND			0.59	
			5/10/2006	10:00									ND				
			5/17/2006	11:00									ND			**20.00**	
			5/24/2006	9:45									ND			6.30	
			5/31/2006	10:20									ND			**24.00**	
			6/7/2006	10:15									ND			4.20	
			6/15/2006	8:50									ND			1.80	
			6/22/2006	10:05									ND			1.20	
			6/27/2006	10:40									ND			1.50	
			7/5/2006	10:30									ND			1.20	
			7/12/2006	10:30									ND			0.96	
			7/20/2006	10:00									ND			1.60	
			7/27/2006	10:00									ND			0.72	
			8/1/2006	8:30									ND			0.63	
			8/8/2006	11:05									ND			0.40	
			8/18/2006	16:00									ND				
Mary's River/North Fork Cox Creek	North Fork Cox Creek	IIHA31	9/9/2006	17:10				**1610**	**3110**								
			10/18/2006	14:45				**1830**	**2830**								
		IIHA01	9/9/2006	17:40				**1850**	**3090**								
			10/18/2006	14:25				**1630**	**2540**								
		IIHA-STE1	9/9/2006	15:40					**3090**								
			10/18/2006	13:40					**1340**								
		IIHA-STC1	9/9/2006	16:15					**2530**								
			10/18/2006	14:00					**1400**								
	Maxwell Creek	IIKSPC1	9/7/2006	15:30		**2.0**											
			10/17/2006	8:20		20.2											
		IIKSPC3A	9/7/2006	15:00		**2.6**											
			10/17/2006	8:45		6.5											
	Randolph County Lake	RIB-1[3]	9/9/2006	12:00											0.04		
			10/18/2006	10:45											**0.130**		
		RIB-2 [3]	9/9/2006	14:00											0.04		
			10/18/2006	12:05											**0.053**		
		RIB-3 [3]	9/9/2006	13:00											0.04		
			10/18/2006	11:15											**0.100**		

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH[1]	DO[1]	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc [6]	Dissolved Iron	Total Silver	Dissolved Copper [6]	TP	Atrazine [5]	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Sangamon River/ Lake Decatur	Owl Creek	EZV01	8/30/2006	12:50		8.5											
			11/2/2006	9:25		12.2											
		EZVA1	8/30/2006	11:05		6.5											
			11/2/2006	10:33		11.8											
		EZVE1	8/30/2006	10:45		11.1											
			11/2/2006	12:59		12.5											
		EZVC1	8/30/2006	10:25		**5.0**											
			11/2/2006	12:20		11.7											
Shoal Creek	Shoal Creek	OI05	9/1/2006	12:35		9.1											
			10/17/2006	11:30		8.5											
		OI05B	9/1/2006	14:20		10.8											
			10/17/2006	11:15		8.7											
		OI05C	9/1/2006	15:40		10.2											
			10/16/2006	10:30		9.4											
	Locust Fork	OIC01	10/19/2006	12:20		**3.8**	0.18										
		OIC02	8/31/2006	17:50		9.4	0.35										
			10/17/2006	13:00		5.2	0.08										
	Cattle Creek	OIP10	10/17/2006	12:05		**2.0**			928[2]					0.021			5.8
South Fork Saline River/ Lake of Egypt	Briers Creek	ATHS01	9/11/2006	11:30	7.6	9.1	0.65	**1250**	**1960**		0.020	0.310	ND				
			9/27/2006	9:00	7.3	10.2	**2.00**	**951**	**1490**		0.022	ND	ND				
			10//2006	11:30							ND	ND					
			10/30/2006	16:30			**1.50**	**656**	**1120**		0.035	ND	ND				
			11/15/2006	10:25			**1.40**	281	469		0.028	**1.10**	ND				
		ATHS01A	9/27/2006	11:30	7.5	9.7	0.10	294	678		ND	**1.10**	ND				
			10/4/2006	10:50							ND	ND					
			11/2/2006	12:00	8.0	8.5	0.11	219	597		0.012	ND	ND				
			11/15/2006	11:10	6.8	5.4	0.12	65	213		ND	**1.40**	ND				
		ATHS01B	9/13/2006	10:40			0.18	143	418			ND	ND				
			9/27/2006	10:35	6.7	9.7	0.17	196	414		ND	ND	ND				
			10/4/2006	11:05							0.013	ND					
			11/2/2006	12:20	7.4	9.9	0.22	373	608		0.018	ND	ND				
			11/15/2006	11:30	6.8	**4.0**						**2.10**					
		ATHS01C	9/11/2006	12:55			**8.70**	**1290**	**2150**			**5.00**	ND				
			9/27/2006	9:30	7.0	9.8	**4.10**	**1100**	**1660**		ND	0.78	ND				
			10/4/2006	11:20							ND	**2.20**					
			10/31/2006	14:30	7.4	9.4	**1.90**	**691**	**1190**		ND	0.17	ND				
			11/15/2006	10:45	7.0	8.8	0.93	338	667		ND	0.470	ND				

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH(1)	DO(1)	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc (6)	Dissolved Iron	Total Silver	Dissolved Copper (6)	TP	Atrazine (5)	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
South Fork Saline River/ Lake of Egypt	East Palzo Creek	ATHV01A	9/11/2006	10:40	6.9	6.7	**1.40**		**1560**			ND					
			10/31/2006	13:40	6.5	7.6	**1.80**		375			0.160		ND			
			11/15/2006	10:00	**6.3**	5.1	0.09		211			**2.60**		ND			
		ATHV01	9/11/2006	10:40	6.9	6.7	0.38		262			ND					
			10/4/2006	12:30								0.13		ND			
			10/31/2006	13:40	6.5	7.6	**1.80**		375			0.16		ND			
			11/15/2006	10:00	**6.3**	5.1	**2.10**		324			0.340		ND			
		ATHV01B	9/11/2006	8:55	6.9	6.0	0.41		388			ND					
			9/26/2006	12:30	**6.2**	10.9	1.00		323			ND		ND			
			10/4/2006	11:50								ND		ND			
			10/31/2006	13:00	**6.4**	8.7	**1.60**		341			ND		ND			
			11/15/2006	9:35	**6.1**	5.6	**1.60**		225			0.100		ND			
	South Fork Saline River	ATHLEC2	9/26/2006	9:45		9.4											
			10/31/2006	12:00		9.6											
		ATH08	9/26/2006	10:20		8.7											
			10/31/2006	11:15		8.8											
South Fork Sangamon River/ Lake Taylorville	South Fork Sangamon River	EO13A	8/30/2006	19:55		9.7	0.61			0.05							
		EO13	8/30/2006	18:10		6.3	0.49			0.20							
			11/2/2006	16:50		6.5	0.33			0.08							
		EO13B	8/30/2006	19:25		8.3	**1.18**			0.20							
		EO13C	8/30/2006	18:55		**3.8**	**5.49**			0.27							
			11/2/2006	16:25		5.8	0.38			0.13							

Shaded cells indicate exceedances of the applicable water quality standard

1 pH and DO values in this table represent field parameters sampled using the In-Site 9500 Profiler. Continuous DO and pH data are available in Appendix D.

2 Value shown is for conductivity. TDS standard corresponds to 1667 uS/cm specific conductance

3 Values shown were collected at one-foot depth.

4 Segment C33 is a source of public water. Therefore the applicable manganese standard is 150 ug/L.

5 Chronic criteria for atrazine is 9 ug/L and a single exceedance of this value indicates a potential cause of impairment

6 Corresponding hardness values were used to calculate standards. Analytical data can be found in Appendix C.

Section 3
Quality Assurance Review

A review was conducted to assess the quality and usability of data generated from Stage 2 work activities and to review compliance with the original sampling plan and objectives developed for the QAPP. Field and laboratory methods were deemed in accordance with the QAPP. Minor deviations from the original plan occurred and all are discussed below.

3.1 Deviations from original Sampling Plan (QAPP)

The following issues and/or concerns developed during the sampling events:

- Sampling during the week of September 25th followed a heavy precipitation event which resulted in high stream flows and flooding at Bay Creek Ditch segment AJK01A and East Palzo Creek segment ATHV01.
- In-field filtering was not performed for dissolved phosphorus or dissolved metal samples. Illinois EPA requested additional information on this procedure. CDM along with ARDL, Inc drafted text for Illinois EPA to validate this sampling practice. Total versus dissolved samples are discussed further in section 3.2.2.
- All locations on Chicken Creek (OIO09) were dry during both sample periods; therefore no samples were collected for this segment.
- The following sites had no water during either sampling event: Maxwell Creek IIKSPA1 and IIKSPE1A, and Cattle Creek OIP10A. Alternate locations were not found.
- Access was not available to the following sites during either sampling event: Shoal Creek OIO5A, South Fork Saline River sites ATH14 and ATHLEC1. Alternate locations were not found.
- Site EZVA1 on Owl Creek was moved from the location proposed in the QAPP to the intersection of Owl Creek and County Road 3100 due to better stream flow.
- Only one round of sampling was conducted at the following sites due to access or water volume issues (refer to Table 2-2 for specific dates and issues): Locust Fork OIC01, Cattle Creek OIP10, Crab Orchard Creek ND15, Little Crab Orchard Creek NDA99, Pond Creek CCFFD1A, East Palzo Creek ATHV01 and ATHV01A, and Bay Creek Ditch AJK01A.
- Due to field crew error only one round of sampling was conducted at South Fork Sangamon River EO13A and EO13B and Elm River locations CD02 and CD02A.

3.2 Data Verification and Validation

A data quality review was performed on all laboratory data. The review consisted of an evaluation of laboratory QC and field QC samples. Laboratory QC included an evaluation of method blanks, matrix spikes, matrix spike duplicates, laboratory control samples and holding times. Field QC included an evaluation of field duplicates. No decontamination rinsate blanks were collected.

No laboratory violation resulted in the qualification of CDM collected data. While some matrix spikes had percent recoveries outside of the established limits, all other QC associated with the samples were acceptable. When a matrix spike was reported outside of the control limits, the laboratory control samples had percent recoveries within the established control limits, indicating a matrix effect on the sample analysis and no need to qualify the data. All samples were analyzed within the control limits.

An evaluation of the phosphorus data (total versus dissolved) was performed to determine the effects of filtering the samples immediately versus waiting up to 48 to 64 hours. All samples were received by the laboratories on ice and at 4^0C (+/-). A total of 161 samples have been analyzed for both total and dissolved phosphorus by method 365.2. Of the 161 samples, a total of 10 samples sets had a phosphorus concentration of greater than 1 mg/L (100 times higher than the reporting limit and considered significant when controlling based on RPDs). One of these samples had relative percent difference (RPD) between the total and dissolved fraction of the sample of greater than 100. Precision values of less that 25 % RPD are considered acceptable for sample results reported significantly above the reporting limit. Sample EO13C had total phosphorus measured at 2.09 mg/L and dissolved phosphorus measured at 0.52 mg/L. The TSS measured in this sample was 159 mg/L. The suspended solids contained in this sample may have absorbed the available phosphorus, but all other results in samples with phosphorus concentrations above 1mg/L show that this reaction is not taking place. Sampling or analytical variations may explain the elevated RPD between the sample and the duplicate. Total phosphorus and dissolved phosphorus results for samples with phosphorus concentrations above 1 mg/L are not significantly different.

Looking at all other results, there does not appear to be a correlation between the difference of total and dissolved phosphorus and the TSS concentration. Suspended solids absorbing dissolved phosphorus would be the likely mechanism for lowering the dissolved phosphorus concentrations. Based on the lack of this correlation, dissolved phosphorus concentration would not be significantly different if the samples were filtered immediately versus filtering at the laboratory 48-hours after collection.

Finally, field and laboratory quality control data were collected to assess bias associated between field and laboratory methods. Positive sample results and relative percent difference (RPD) are presented in Table 3-1.

3.3 Data Quality Objectives

The data generated during the Stage 2 investigation conformed to the data quality objectives established in the QAPP. A completeness criterion of 90% was established and easily achieved. No data have been qualified that were collected by CDM personnel and analyzed by ARDL, Inc or Prairie Analytical laboratories. Data qualifiers were applied to some of the data collected by Illinois EPA personnel. All qualifiers are included with the laboratory data contained in Appendix C.

Table 3-1: Duplicate Pair Sample Results

SampleLocation	Parameter	Result	Units	Collection Date	RPD(%)
AJK01-DUP	Solids, total suspended	24.2	MG/L	9/25/2006	
AJK01	Solids, total suspended	25	MG/L	9/25/2006	3.252033
ATHS01A-DUP	Hardness (CA/MG)	435.1	MG CACO3/L	11/2/2006	
ATHS01A	Hardness (CA/MG)	445	MG CACO3/L	11/2/2006	2.249744
ATHS01A-DUP	Solids, total dissolved	604	MG/L	11/2/2006	
ATHS01A	Solids, total dissolved	597	MG/L	11/2/2006	-1.1657
ATHS01A-DUP	Chloride	5.13	MG/L	9/27/2006	
ATHS01A	Chloride	5.1	MG/L	9/27/2006	-0.64556
ATHS01A-DUP	Solids, total dissolved	675	MG/L	9/27/2006	
ATHS01A	Solids, total dissolved	678	MG/L	9/27/2006	0.443459
ATHS01A-DUP	Sulfate	290.63	MG/L	9/27/2006	
ATHS01A	Sulfate	294	MG/L	9/27/2006	1.154242
ATHS01C-DUP	Chloride	5.38	MG/L	9/11/2006	
ATHS01C	Chloride	5.4	MG/L	9/11/2006	0.388903
ATHS01C-DUP	Sulfate	1297.83	MG/L	9/11/2006	
ATHS01C	Sulfate	1290	MG/L	9/11/2006	-0.60514
ATHS01-FIELDDUP	Alkalinity	113	MG/L	10/30/2006	
ATHS01	Alkalinity	108	MG/L	10/30/2006	-4.52489
ATHS01-FIELDDUP	Chloride	4.9	MG/L	10/30/2006	
ATHS01	Chloride	4.9	MG/L	10/30/2006	0
ATHS01-FIELDDUP	Hardness (CA/MG)	673	MG CACO3/L	10/30/2006	
ATHS01	Hardness (CA/MG)	668	MG CACO3/L	10/30/2006	-0.74571
ATHS01-FIELDDUP	Iron	68200	MG/KG	10/30/2006	
ATHS01	Iron	93800	MG/KG	10/30/2006	31.60494
ATHS01-FIELDDUP	Manganese	1130	MG/KG	10/30/2006	
ATHS01	Manganese	1480	MG/KG	10/30/2006	26.81992
ATHS01-FIELDDUP	Manganese	1.5	MG/L	10/30/2006	
ATHS01	Manganese	1.5	MG/L	10/30/2006	0
ATHS01-FIELDDUP	Nitrate-Nitrite	0.06	MG/L	10/30/2006	
ATHS01	Nitrate-Nitrite	0.06	MG/L	10/30/2006	-11.9658
ATHS01-FIELDDUP	Phosphorus, diss	0.05	MG/L	10/30/2006	
ATHS01	Phosphorus, diss	0.05	MG/L	10/30/2006	8.163265
ATHS01-FIELDDUP	Phosphorus, total	0.04	MG/L	10/30/2006	
ATHS01	Phosphorus, total	0.03	MG/L	10/30/2006	-26.8657
ATHS01-FIELDDUP	Solids, total	69.7	%	10/30/2006	
ATHS01	Solids, total	74.5	%	10/30/2006	6.65742
ATHS01-FIELDDUP	Solids, total dissolved	1040	MG/L	10/30/2006	
ATHS01	Solids, total dissolved	1070	MG/L	10/30/2006	2.843602
ATHS01-FIELDDUP	Solids, total suspended	4.3	MG/L	10/30/2006	
ATHS01	Solids, total suspended	5.6	MG/L	10/30/2006	26.26263
ATHS01-FIELDDUP	Sulfate	662	MG/L	10/30/2006	
ATHS01	Sulfate	604	MG/L	10/30/2006	-9.16272
ATHS01-FIELDDUP	Zinc	106	MG/KG	10/30/2006	
ATHS01	Zinc	116	MG/KG	10/30/2006	9.009009
ATHS01-FIELDDUP	Zinc, diss	0.02	MG/L	10/30/2006	
ATHS01	Zinc, diss	0.03	MG/L	10/30/2006	8.333333
ATHS01-DUP	Alkalinity	60.9	MG/L	11/15/2006	
ATHS01	Alkalinity	56.8	MG/L	11/15/2006	-6.96686
ATHS01-DUP	Hardness (CA/MG)	340.14	MG CACO3/L	11/15/2006	
ATHS01	Hardness (CA/MG)	337	MG CACO3/L	11/15/2006	-0.92743
ATHS01-DUP	Solids, total dissolved	481	MG/L	11/15/2006	

Table 3-1: Duplicate Pair Sample Results (continued)

SampleLocation	Parameter	Result	Units	Collection Date	RPD(%)
ATHS01	Solids, total suspended	151	MG/L	11/15/2006	-104.43
ATHS01-DUP	Hardness (CA/MG)	1035.17	MG CACO3/L	9/27/2006	
ATHS01	Hardness (CA/MG)	1030	MG CACO3/L	9/27/2006	-0.50069
ATHV01B-DUP	Alkalinity	15.3	MG/L	9/26/2006	
ATHV01B	Alkalinity	15.3	MG/L	9/26/2006	0
ATHV01B-DUP	Solids, total	72.5	%	9/26/2006	
ATHV01B	Solids, total	71.9	%	9/26/2006	-0.83102
CCFFD1-DUP	Chlorophyll	5.5	MG/CU.M.	9/9/2006	
CCFFD1	Chlorophyll	5	MG/CU.M.	9/9/2006	-9.52381
CE01A-DUP	Solids, total suspended	134	MG/L	9/12/2006	
CE01A	Solids, total suspended	137	MG/L	9/12/2006	2.214022
CJA02-DUP	Biological Oxygen Demand	4	MG/L	11/8/2006	
CJA02	Biological Oxygen Demand	3.7	MG/L	11/8/2006	-7.79221
EO13-DUP	Biological Oxygen Demand	6.3	MG/L	11/2/2006	
EO13	Biological Oxygen Demand	6.3	MG/L	11/2/2006	0
EO13-DUP	Solids, total suspended	8.4	MG/L	11/2/2006	
EO13	Solids, total suspended	7.6	MG/L	11/2/2006	-10
IIAA01-DUP	Chloride	21.71	MG/L	9/9/2006	
IIAA01	Chloride	21.7	MG/L	9/9/2006	-0.0258
IIAA01-DUP	Sulfate	1832.11	MG/L	9/9/2006	
IIAA01	Sulfate	1850	MG/L	9/9/2006	0.971725
IIHA01-DUP	Chloride	21.71	MG/L	9/9/2006	
IIHA01	Chloride	21.7	MG/L	9/9/2006	-0.0258
IIHA01-DUP	Sulfate	1832.11	MG/L	9/9/2006	
IIHA01	Sulfate	1850	MG/L	9/9/2006	0.971725
IIHA31-DUP	Hardness (CA/MG)	1290.87	MG CACO3/L	9/9/2006	
IIHA31	Hardness (CA/MG)	1300	MG CACO3/L	9/9/2006	0.704783
IIHA31-DUP	Hardness (CA/MG)	1306.27	MG CACO3/L	10/18/2006	
IIHA31	Hardness (CA/MG)	1280	MG CACO3/L	10/18/2006	-2.0315
IIHA31-DUP	Chloride	19.5	MG/L	10/18/2006	
IIHA31	Chloride	19.4	MG/L	10/18/2006	-0.51363
IIHA31-DUP	Solids, total dissolved	2850	MG/L	10/18/2006	
IIHA31	Solids, total dissolved	2830	MG/L	10/18/2006	-0.70423
IIHA31-DUP	Sulfate	1783.35	MG/L	10/18/2006	
IIHA31	Sulfate	1830	MG/L	10/18/2006	2.582091
IIHA-STE1-DUP	Solids, total dissolved	3100	MG/L	9/9/2006	
IIHA-STE1	Solids, total dissolved	3090	MG/L	9/9/2006	-0.3231
IIKSPC3A-DUP	Biological Oxygen Demand	11	MG/L	9/7/2006	
IIKSPC3A	Biological Oxygen Demand	11	MG/L	9/7/2006	0
JQ01-DUP	Chlorophyll	11.8	MG/CU.M.	8/31/2006	
JQ-01	Chlorophyll	13.2	MG/CU.M.	8/31/2006	11.2
JQ01-DUP	Hardness (CA/MG)	221.3	MG CACO3/L	8/31/2006	
JQ-01	Hardness (CA/MG)	221	MG CACO3/L	8/31/2006	-0.13565
ND11-DUP	Solids, total suspended	16.2	MG/L	11/1/2006	
ND11	Solids, total suspended	15	MG/L	11/1/2006	-7.69231
ND11-DUP	Alkalinity	90.2	MG/L	9/6/2006	
ND11	Alkalinity	90.2	MG/L	9/6/2006	0
NDA01-DUP	Solids, total suspended	18.2	MG/L	9/6/2006	
NDA01	Solids, total suspended	16.6	MG/L	9/6/2006	-9.1954
NDB04-DUP	Chlorophyll	26.9	MG/CU.M.	11/2/2006	
NDB04	Chlorophyll	25.7	MG/CU.M.	11/2/2006	-4.56274
OI05C-DUP	Biological Oxygen Demand	4.6	MG/L	9/1/2006	
OI05C	Biological Oxygen Demand	5.1	MG/L	9/1/2006	10.30928
OIC02-DUP	Solids, total suspended	14	MG/L	8/31/2006	
OIC02	Solids, total suspended	13.7	MG/L	8/31/2006	-2.16606
OIC02-DUP	Solids, total suspended	18.5	MG/L	10/17/2006	

Table 3-1: Duplicate Pair Sample Results (continued)

SampleLocation	Parameter	Result	Units	Collection Date	RPD(%)
OIC02	Solids, total suspended	16.8	MG/L	10/17/2006	-9.63173
OIP10-DUP	Hardness (CA/MG)	278.52	MG CACO3/L	10/17/2006	
OIP10	Hardness (CA/MG)	286	MG CACO3/L	10/17/2006	2.650039
OZH-OK-A2A-DUP	Chlorophyll	155.4	MG/CU.M.	9/8/2006	
OZH-OK-A2A	Chlorophyll	126	MG/CU.M.	9/8/2006	-20.8955

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Section 4
Conclusions

Data collected during Stage 2 have been deemed adequate and usable for Stage 3 TMDL development (see discussion in Section 3). Table 4-1 contains information for each segment sampled during Stage 2 with regards to its impairment status. The table contains information on the number of historic samples available prior to Stage 2 data collection, the number of historic violations as well as the date of the last recorded violation. The intention of this table is to assist any future determination on the impairment status of the Stage 2 stream segments.

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Table 4-1: Impairment Status

Watershed	Stream Name	Segment	Parameter of Concern	Historic Data Count	Number of Historic Violations	Date of Last Recorded Violation	Stage 2 Data Count	Number of Violations	Suggested Status
Bay Creek	Cedar Creek	AJF16	Dissolved Oxygen	1	1	2000	Continuous	0	Delist
			Manganese	1	0	-	4	0	Delist
	Bay Creek Ditch	AJK01	Dissolved Oxygen	3	3	1987	Continuous	Multiple	Impaired
			Manganese	3	3	1987	3	0	Delist
Cahokia Creek/ Holiday Shores Lake	Cahokia Diversion Ditch	JQ07	Dissolved Oxygen	147	130	2005	Continuous	Multiple	Impaired
			Copper	5	1	1998	4	0	Delist
Cedar Creek	Big Muddy River	N99	Dissolved Oxygen	3	1	2002	Continuous	*	Impaired
			Sulfates	3	0	-	4	0	Delist
	Cave Creek	NAC01	Dissolved Oxygen	2	1	1995	Continuous	1	Impaired
Crab Orchard Lake	Crab Orchard Creek	ND11	Dissolved Oxygen	2	1	2000	Continuous	Multiple	Impaired
			Manganese	2	2	2000	2	0	Delist
			pH	3	2	2004	Continuous	Multiple	Impaired
	Crab Orchard Creek	ND12	pH	3	1	2004	Continuous	0	Delist
			Manganese	2	1	2000	2	0	Delist
	Crab Orchard Creek	ND13	Dissolved Oxygen	4	4	2000	Continuous	Multiple	Impaired
	Little Crab Orchard Creek	NDA01	Dissolved Oxygen	2	1	1995	Continuous	Multiple	Impaired
			Manganese	2	1	1995	3	1	Impaired
	Piles Fork	NDB03	Dissolved Oxygen	2	1	1995	Continuous	Multiple	Impaired
Crooked Creek	Plum Creek	OZH-OK-A2	Dissolved Oxygen	1	1	2002	Continuous	Multiple	Impaired
	Plum Creek		Manganese	1	1	2002	4	0	Delist
	Plum Creek	OZH-OK-C2	Dissolved Oxygen	1	1	2002	Continuous	Multiple	Impaired
	Plum Creek	OZH-OK-C3	Dissolved Oxygen	1	1	2002	Continuous	Multiple	Impaired
	Plum Creek		Manganese	1	1	2002	2	0	Delist
	Little Crooked Creek	OJA-01	Dissolved Oxygen	5	4	2002	Continuous	Multiple	Impaired
			Manganese	5	2	2002	4	0	Delist

Table 4-1: Impairment Status

Watershed	Stream Name	Segment	Parameter of Concern	Historic Data Count	Number of Historic Violations	Date of Last Recorded Violation	Stage 2 Data Count	Number of Violations	Suggested Status
Little Wabash	Little Wabash River	C09	Dissolved Oxygen	43	7	2003	Continuous	Multiple	Impaired
			Silver	43	1	2002	18	0	Delist
			Atrazine	2	1	1991	16	2	Impaired
		C33	Dissolved Oxygen	5	3	2002	Continuous	Multiple	Impaired
			Manganese	5	5	2002	10	10	Impaired
			Atrazine	NA	NA	NA	16	2	Impaired
	Village Creek	CE01	Dissolved Oxygen	1	0	NA	Continuous	Multiple	Impaired
			Manganese	1	1	2002	6	0	Delist
	Johnson Creek	CCAFFA1	Dissolved Oxygen	1	1	1997	Continuous	Multiple	Impaired
	Pond Creek	CCFFD1	Dissolved Oxygen	1	1	1997	Continuous	Multiple	Impaired
	Elm River	CD01	Atrazine	8	3	2002	16	2	Impaired
		CD02	Dissolved Oxygen	3	2	2003	Continuous	Multiple	Impaired
	Seminary Creek	CDGFLA1	Dissolved Oxygen	1	1	1998	Continuous	Multiple	Impaired
	Seminary Creek	CDFGLC6	Dissolved Oxygen	1	1	1998	Continuous	Multiple	Impaired
	Big Muddy Creek	CJ06	Dissolved Oxygen	3	1	2002	Continuous	Multiple	Impaired
			Manganese	2	1	2002	6	0	Delist
	Little Muddy Creek	CJA02	Dissolved Oxygen	4	3	2002	Continuous	Multiple	Impaired
			Manganese	4	3	2002	4	2	Impaired
	Big Muddy Diversion Ditch	CJAE01	Dissolved Oxygen	1	0	2000	Continuous	Multiple	Impaired
Mary's River/ North Fork Cox Creek	North Fork Cox Creek	IIHA31	Sulfates	2	2	1995	4	4	Impaired
			TDS	2	2	1995	4	4	Impaired
	North Fork Cox Creek	IIHA-STC1	TDS	1	1	1995	4	2	Impaired
	Maxwell Creek	IIKSPC1A	Dissolved Oxygen	2	2	19999	Continuous	Multiple	Impaired
	Randolph County Lake	RIB	Total Phosphorus	11	3	1993	6	2	Impaired
Sangamon River/ Lake Decatur	Owl Creek	EZV	Dissolved Oxygen	3	1	1998	Continuous	Multiple	Impaired

Table 4-1: Impairment Status

Watershed	Stream Name	Segment	Parameter of Concern	Historic Data Count	Number of Historic Violations	Date of Last Recorded Violation	Stage 2 Data Count	Number of Violations	Suggested Status
Shoal Creek	Shoal Creek	OI05	Dissolved Oxygen	3	1	2002	Continuous	0	Delist
	Locust Fork	OIC01	Dissolved Oxygen	3	1	1991	Continuous	Multiple	Impaired
			Manganese	3	1	1991	2	0	Delist
	Chicken Creek	OIO09	Dissolved Oxygen	2	1	1991	0	0	No Water
	Cattle Creek	OIP10	Dissolved Oxygen	3	2	1991	Continuous	Multiple	Impaired
			Ammonia	3	1	1991	1	0	Delist
			TDS	3	1	1991	1	0	Delist
South Fork Saline River/ Lake of Egypt	Briers Creek	ATHS01	Zinc	2	2	1993	13	0	Delist
			Iron	3	3	1993	16	3	Impaired
			Manganese	3	3	1993	8	4	Impaired
			Silver	3	1	1993	12	0	Delist
			Sulfates	3	3	1993	16	6	Impaired
			TDS	2	1	1993	16	9	Impaired
			pH	3	3	1993	Continuous	0	Delist
			Dissolved Oxygen	2	1	1993	Continuous	1	Impaired
	East Palzo Creek	ATHV01	Copper	3	2	1993	5	0	Delist
			Iron	3	3	1993	7	1	Impaired
			Manganese	3	3	1993	7	3	Impaired
			TDS	0		-	7	1	Impaired
			pH	3	3	1993	Continuous	Multiple	Impaired
	South Fork Saline River	ATH14	Dissolved Oxygen	8	1	2000	Continuous	0	Delist
South Fork Sangamon/ Lake Taylorville	South Fork Sangamon River	EO13	Dissolved Oxygen	1	1	1989	Continuous	Multiple	Impaired
			Boron	1	1	1989	6	0	Delist
			Manganese	1	1	1989	6	2	Impaired

* Continuous data did not violate the 5.0 mg/L instantaneous DO standard, however, continuous data collected at site N13 experienced more than 16 hours below 6.0 mg/L in a 24 hour period

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For Appendices, please contact Jennifer Clarke at the Illinois EPA for information.

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TMDL Development for the Crooked Creek Watershed, Illinois

FINAL REPORT

May 29, 2008

Submitted to:
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62702

Submitted by:
Tetra Tech

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1.0 INTRODUCTION

A total maximum daily load (TMDL) is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. A TMDL is also required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. The overall goals and objectives in developing TMDLs for the listed waterbodies in the Crooked Creek watershed include:

- Assess the water quality of the impaired waterbodies and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science and available data to determine the maximum load the waterbodies can receive and fully support all of their designated uses.
- Use the best available science and available data to determine current loads of pollutants to the impaired waterbodies.
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.
- Identify feasible and cost-effective actions that can be taken to reduce loads.
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used.
- Submit a final TMDL report to U.S. EPA for review and approval.

The Illinois Environmental Protection Agency (IEPA) has a three-stage approach to TMDL development. The stages are:

1) Stage 1 for the Crooked Creek watershed was completed by the consulting firm Camp Dresser & McKee (CDM) in January 2007 and involved characterization of the watershed, assessment of the available water quality data, identification of additional data needs for the development of credible TMDLs and recommendation of potential technical approaches for TMDL development (Appendix D).
2) Stage 2 was completed by CDM in March 2007 and involved the collection of additional chemical water quality and continuous dissolved oxygen data as well as channel morphology and discharge measurements at twenty-three monitoring locations.
3) This report addresses Stage 3 of the project which involves modeling, TMDL development, and preparation of a project implementation plan.

Several segments have been de-listed since the Stage 1 report due to newer ambient data or Stage 2 Data. A summary of the de-listed segments is provided below and included in Table 1.

- Plum Creek segment OZH-OK-A2 was originally listed as impaired for manganese. However, additional data collected in 2006 indicated no exceedances of the manganese water quality standard (Table 1) and this segment will be recommended for de-listing in the 2008 Integrated Report. No TMDL has therefore been developed.
- Plum Creek segment OZH-OK-C3 was originally listed as impaired for manganese. However, additional data collected in 2006 indicated no exceedances of the manganese water quality

standard (Table 1) and this segment will be recommended for de-listing in the 2008 Integrated Report. No TMDL has therefore been developed.

- Little Crooked Creek segment OJA-01 was originally listed as impaired for manganese. However, additional data collected in 2006 indicated no exceedances of the manganese water quality standard and this segment will be recommended for de-listing in the 2008 Integrated Report. No TMDL has therefore been developed.

Table 1. De-listed Crooked Creek Watershed Segments.

Segment and Segment ID	Parameter	Water Quality Standard	Original Listing Violation # exceed/#sample	Original Violation Value (µg/l)	2006 Stage 2 Data Count	Number of Violations
Plum Creek (OZH-OK-A2)	Manganese	1,000 µg/l	1 of 1 (2002)	1400	4	0
Plum Creek (OZH-OK-C3)	Manganese	1,000 µg/l	1 of 1 (2002)	1800	2	0
Little Crooked Creek (OJA-01)	Manganese	1,000 µg/l	2 of 6 (2002)	1400	4	0

2.0 BACKGROUND

The Crooked Creek watershed is located in south-western Illinois flowing south-west to the Kaskaskia River (Figure 1). The portion of the watershed addressed in this report has an area of 560 square miles and encompasses four counties with Washington County covering 39 percent of the watershed followed by Marion (35%), Clinton (25%) and Jefferson (1%). The entire watershed has a drainage area of approximately 1680 square miles and spans one 8 digit hydrologic unit code (07140202) as defined by the US Geological Survey (USGS).

The Crooked Creek watershed includes a portion of the Kaskaskia River as well as the 303 (d) listed Plum Creek. Crooked Creek originates near the city of Alma and flows approximately 52 miles south and west to its confluence with the Kaskaskia River. Major tributaries to Crooked Creek include Grand Point Creek, Little Crooked Creek, Lost Creek, and Raccoon Creek. Plum Creek drains to the Kaskaskia River approximately 12 miles downstream of the Crooked Creek and Kaskaskia River confluence.

Approximately 57,000 people reside in the watershed. The city of Centralia is the largest population center in the watershed and contributes an estimated 14,000 people to total watershed population. Agriculture is the dominant land use in the watershed (Figure 2) and additional information on the characteristics of the watershed (e.g., soil types, topography, hydrology) can be found in Appendix D.

Table 2 identifies the impaired segments in the Crooked Creek watershed, including the causes of impairment addressed by TMDLs in this report. IEPA is currently developing TMDLs for pollutants that have numeric water quality standards. IEPA believes that addressing the impairments with numeric water quality standards should lead to an overall improvement in water quality due to the interrelated nature of other listed pollutants. Pollutants can be interrelated because they originate from the same source or are transported together. For example, Lake Centralia is listed for both phosphorus and total suspended solids, but IEPA only has numeric lake water quality standards for phosphorus. However, phosphorus binds to sediment and therefore some of the management measures taken to reduce phosphorus loads (e.g., buffer strips, reducing streambank erosion) should also result in reduced loads of suspended solids.

Table 2. 2006 303(d) List Information for the Crooked Creek Watershed. Bold font indicates cause will be addressed by a TMDL in this report.

Waterbody Name	Waterbody Segment	Segment Length (miles) and Lake Area (acres)	Cause of Impairment	Impaired Designated Use
Crooked Creek	OJ-07	30.84	**Dissolved Oxygen**	Aquatic Life
			pH	Aquatic Life
			Total Phosphorus	Aquatic Life
Crooked Creek	OJ-08	21.5	**Dissolved Oxygen**	Aquatic Life
			Total Nitrogen	Aquatic Life
			pH	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Little Crooked Creek	OJA-01	16.64	**Dissolved Oxygen**	Aquatic Life
			Manganese*	Aquatic Life
			Total Phosphorus	Aquatic Life
Plum Creek	OZH-OK-A2	6.73	**Dissolved Oxygen**	Aquatic Life
			Manganese*	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
Plum Creek	OZH-OK-C2	1.85	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
Plum Creek	OZH-OK-C3	2.04	**Dissolved Oxygen**	Aquatic Life
			Manganese*	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
Centralia Lake	ROI	450	**Manganese**	Public Water Supplies
			Total Phosphorus	Aesthetic Quality
			Total Suspended Solids	Aesthetic Quality
Raccoon Lake	ROK	925	**Atrazine**	Aquatic Life
			Dissolved Oxygen	Aquatic Life
			Manganese	Public Water Supplies
			pH	Aquatic Life
			Total Phosphorus	Aesthetic Quality
				Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aesthetic Quality
				Aquatic Life
Nashville City Lake	ROO	42	**Manganese**	Public Water Supplies
			Total Phosphorus	Aesthetic Quality
			Total Suspended Solids	Aesthetic Quality
Salem Lake	ROR	74.2	**Dissolved Oxygen**	Aquatic Life
			Manganese	Public Water Supplies
			Total Phosphorus	Aesthetic Quality
				Aquatic Life
			Total Suspended Solids	Aesthetic Quality
				Aquatic Life

*Recommended for de-listing (see Section 1).

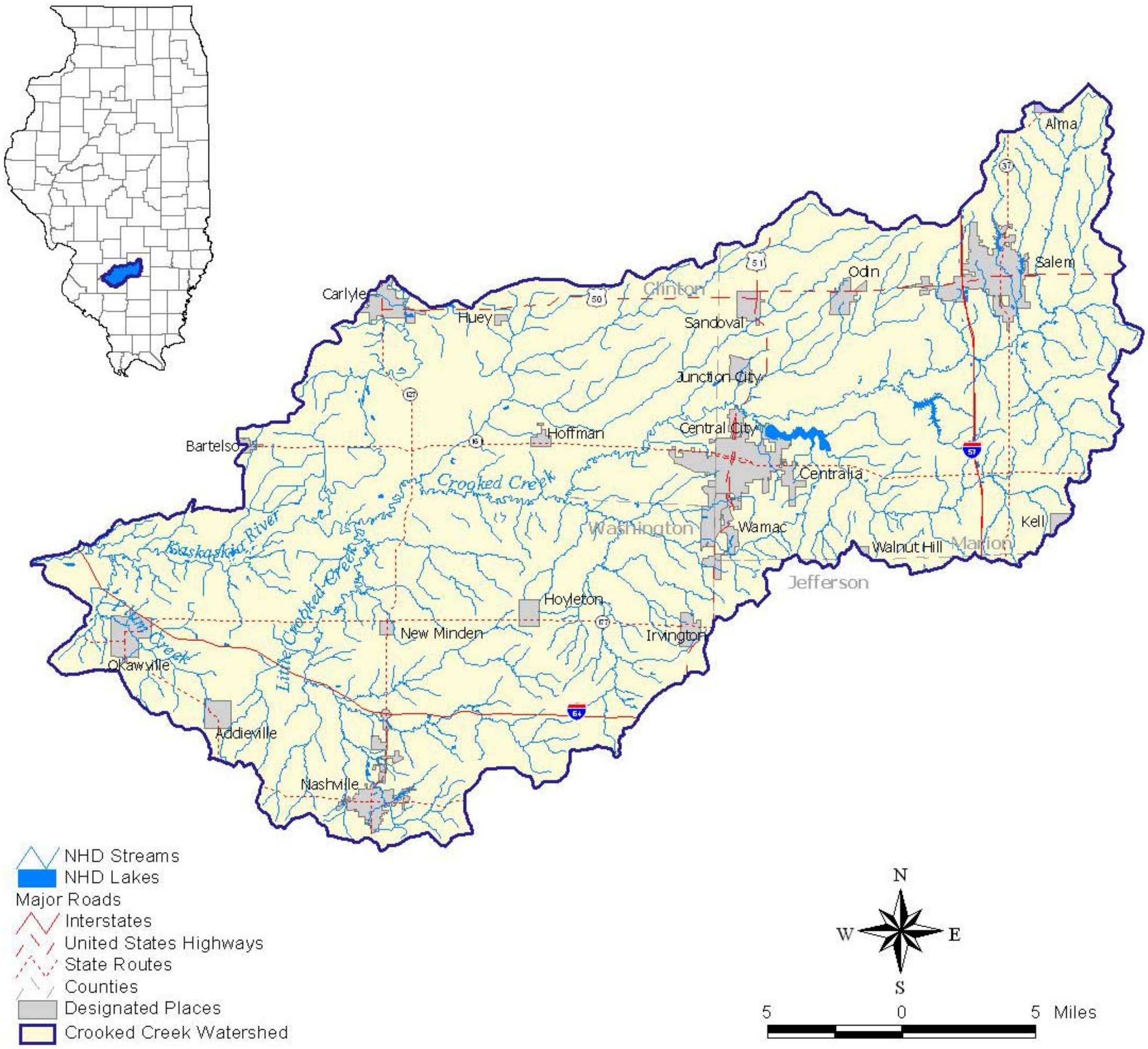

Figure 1. Location of the Crooked Creek Watershed

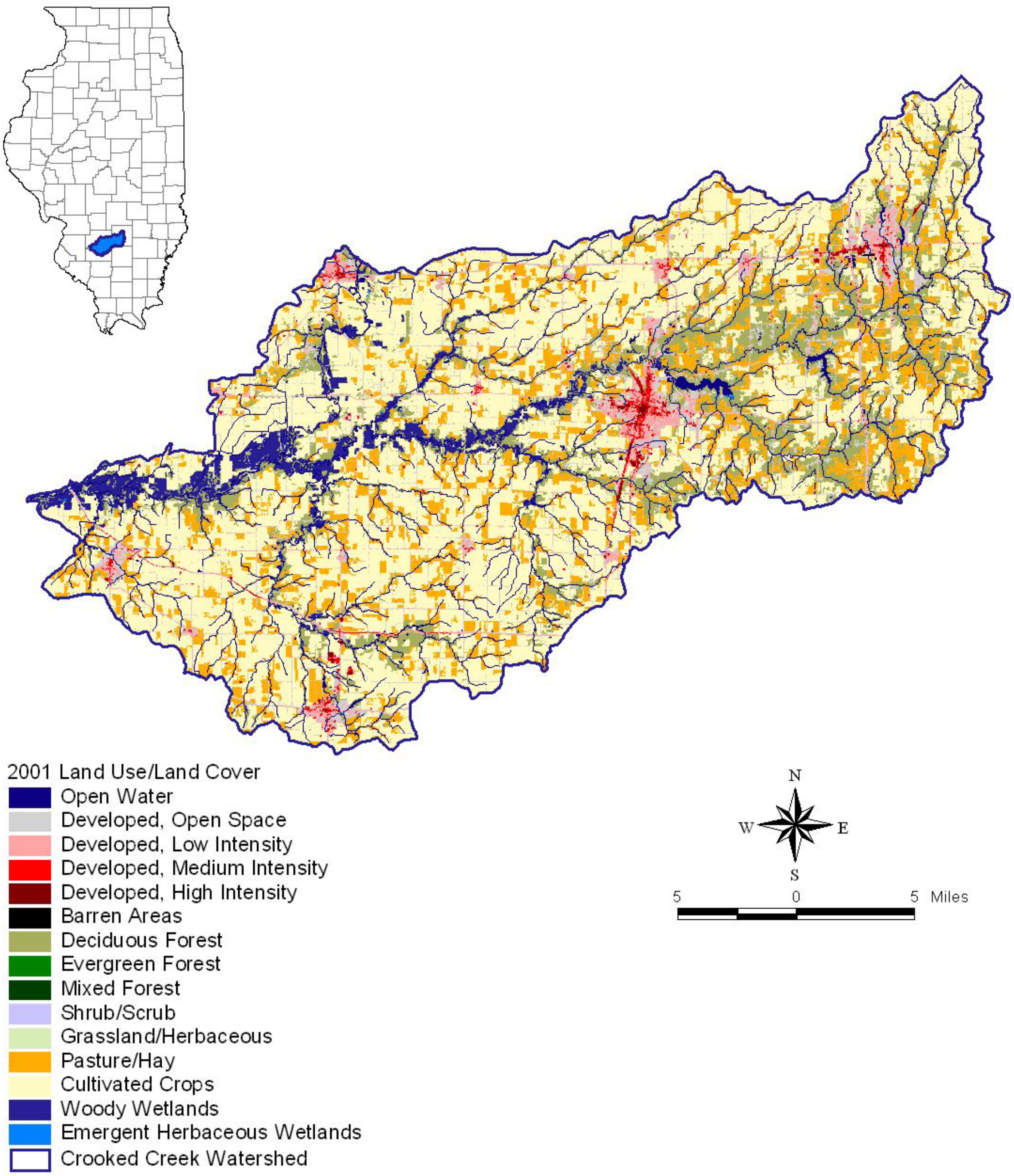

Figure 2. Land Use in the Crooked Creek Watershed

3.0 APPLICABLE WATER QUALITY STANDARDS

The purpose of developing a TMDL is to identify the pollutant loading that a waterbody can receive and still achieve water quality standards. Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of three components: designated uses, numeric or narrative criteria, and an antidegradation policy. A description of the water quality standards that apply to this TMDL is presented below and detailed comparisons of the available water quality data to the standards are provided in Appendix D and Appendix E.

3.1 Use Support Guidelines

IEPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB) to assess the designated use support for Illinois waterbodies. The following are the use support designations provided by the IPCB that apply to water bodies in the Crooked Creek watershed:

General Use Standards - These standards protect for aquatic life, wildlife, agricultural, primary contact (where physical configuration of the waterbody permits it, any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing), secondary contact (any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating, and any limited contact incident to shoreline activity), and most industrial uses. These standards are also designed to ensure the aesthetic quality of the state's aquatic environment.

Public and food processing water supply standards – These standards are cumulative with the general use standards and apply to waters of the state at any point at which water is withdrawn for treatment and distribution as a potable supply to the public or for food processing.

Water quality standards used for TMDL development in the Crooked Creek watershed are listed below for lakes (Table 3) and streams (Table 4). The exact language of the standards is available from the Illinois Pollution Control Board, Title 35, Chapter I, Part 302 at the following Web site:

http://www.ipcb.state.il.us/documents/dsweb/Get/Document-33354/

Table 3. Summary of Water Quality Standards for the Crooked Creek Watershed Lake Impairments.

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies	Section for Regulatory Citation[a]
Atrazine	µg/L	Acute= 82[b]	3	302.601 to 302.669
		Chronic= 9[c]		
Dissolved Oxygen	mg/L	5.0 instantaneous minimum	No numeric standard	General use: 302.206
		6.0 minimum during at least 16 hours of any 24 hour period		
Manganese	µg/L	1,000	150	General use: 302.208 Public Water Supply: 302.304
pH	S.U.	> 6.5 and <9.0	No numeric standard	General Use: 302.204
Total Phosphorus	mg/L	0.05[d]	No numeric standard	302.205

[a]All IEPA water quality standards are published by the Illinois Pollution Control Board under Title 35: Environmental Protection Subtitle C: Water Pollution Chapter I: Pollution Control Board. Part 302. Water Quality Standards. Subpart A: General Water Quality Provisions.
[b] Not to be exceeded except as provided in 35 Ill. Adm. Code 302.208(d)
[c] Not to be exceeded by the average of at least three samples collected over peak atrazine application periods (Spring, Summer, and Fall)
[d] Standard only applies in lakes/reservoirs that are greater than 20 acres in surface area and in any stream at the point where it enters such a lake/reservoir.

Table 4. Summary of Water Quality Standards for the Crooked Creek Watershed Stream Impairments.

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies	Section for Regulatory Citation[a]
Dissolved Oxygen	mg/L	5.0 instantaneous minimum	No numeric standard	General use: 302.206
		6.0 minimum during at least 16 hours of any 24 hour period		

[a]All IEPA water quality standards are published by the Illinois Pollution Control Board under Title 35: Environmental Protection Subtitle C: Water Pollution Chapter I: Pollution Control Board. Part 302. Water Quality Standards. Subpart A: General Water Quality Provisions.

3.2 Relationship Between Lake Total Phosphorus, Dissolved Oxygen, and pH Impairments

Several of the lakes in the Crooked Creek watershed are listed as impaired for total phosphorus, dissolved oxygen, and pH. These listings are all assumed to be related because increasing the amount of phosphorus in a lake tends to cause an increase in algae and macrophyte production (assuming all other variables remain the same). Sources of phosphorus include wastewater treatment plants, runoff from fertilized lands, failing septic systems, and a variety of other sources. When excessive phosphorus loads enter a lake, the growth of algae and macrophytes is stimulated, which in turn produces and consumes oxygen in water. During daylight hours, oxygen is produced by photosynthesis. Plants and algae then consume oxygen from the water column at night (respiration). Oxygen depletion occurs when the balance between oxygen consumption and production is altered, either causing excessive oxygen consumption or reduced oxygen production. The dissolved oxygen concentration in a waterbody becomes too low, thereby threatening oxygen breathing aquatic life and impairing the designated use.

Plants also utilize carbon dioxide during photosynthesis (removing it from the water) which causes alkaline carbonates and bicarbonates to predominate in the water and the pH to rise. The opposite occurs at night. In the case of heavy algae blooms, the pH of the water can fluctuate quite dramatically through a 24 hour period. While many large fish can survive these fluctuations, small fish can become quite stressed by rapid pH changes. The result is an impairment to the designated aquatic life use.

4.0 POLLUTANT SOURCES

The Crooked Creek watershed contains waterbodies listed for impairments due to total phosphorus, dissolved oxygen, manganese, atrazine, and pH. Both point and nonpoint sources contribute to the impairments. This section describes each major source category as well as the impacts and contributions to pollutant loading in this watershed.

4.1 Point Source Dischargers

There are 26 facilities regulated by the National Pollutant Discharge Elimination System (NPDES) that are allowed to discharge industrial or municipal wastewater to waterbodies located in the Crooked Creek watershed. Information on these dischargers is shown in Table 5. Blank cells in the table indicate that permit information was not available for that parameter.

Table 5. Wastewater Treatment Plants Discharging to Impaired Streams within the Crooked Creek Watershed.

Facility Name	Permit Number	Outfall	Receiving Stream/Downstream Impaired Waterbody	Design Average Flow (MGD)	Design Maximum Flow (MGD)
Illinois Central Rr-Centralia	IL0000779	001	Fulton Creek/Crooked Creek Segments OJ 07	0.011	N/A
		002 - 004		Overflow	
Centralia WTP	IL0001252	001	Crooked Creek/Crooked Creek Segments OJ 07	0.216	0.333
		002	Unnamed Tributary to Crooked Creek		
Salem STP	IL0023264	001	Town Creek/Crooked Creek Segments OJ 07	1.672	3.762
		001		2.508	7.023
		A01		Excess Flow Discharge	
Nashville STP	IL0027081	001	Nashville Creek/ Little Crooked Creek Segment OJA 01	0.5	1.7
Centralia STP	IL0027979	001	Sewer Creek/Crooked Creek Segments OJ 07	3.15	4.5
		A01		Excess Flow Discharge (Flows Over 4.50 MGD)	
Centralia-Kaskaskia College	IL0029335	001	Prairie Creek/Crooked Creek Segments OJ 08	0.125	0.312
Sandoval STP	IL0030961	001	Prairie Creek/Crooked Creek Segments OJ 08	0.18	0.45
Addieville STP	IL0049140	001	Plum Creek/Plum Creek Segment OZH-OK-A2	0.033	0.083
Raccoon Consolidated School	IL0052981	001	Unnamed Tributary to Raccoon Creek/Raccoon Lake Segment ROK	0.0125	0.031
Radiac Abrasives Inc-Salen	IL0059382	001	Crooked Creek/Crooked Creek Segments OJ 07	0.123	1.06
		002-004		Overflow	
Il Doc-Centralia Correctional	IL0061344	001	Unnamed tributary of Prairie Creek/Crooked Creek Segments OJ 08	0.234	0.343
Nascote Industries-Nashville	IL0068136	001	Middle Creek via drainage ditch/ Little Crooked Creek Segment OJA 01	0.006	2
		002		0.006	2
Nashville WTP	IL0069701	001	Nashville Creek/ Nashville Reservoir Segment ROO	0.056	0.963
		002		0.056	0.963
United Parcel Service	IL0071242	001	Tributary to Fulton Branch of Sewer Creek/Crooked Creek Segments OJ 07	0.0005	0.0012
Ameren Energy-	IL0075906	001	Tributary to Walnut	0.054	N/A

Facility Name	Permit Number	Outfall	Receiving Stream/Downstream Impaired Waterbody	Design Average Flow (MGD)	Design Maximum Flow (MGD)
Pinckneyville		002	Creek/ Little Crooked Creek Segment OJA 01	0.017	N/A
Woodlawn MHP	ILG551054	001	Unnamed Tributary to Crooked Creek/ Crooked Creek Segment OJ 07	0.019	0.038
Country School MHP	ILG551055	001	South Creek /Crooked Creek Segments OJ 07	0.0024	0.0006
Irvington Sd WWTF	ILG580006	001	Grand Point Creek/Crooked Creek Segments OJ 08	0.093	0.33
Hoyleton STP	ILG580016	001	North Creek/ Little Crooked Creek Segment OJA 01	0.059	0.159
Wamac STP	ILG580144	001	Fulton Branch/Crooked Creek Segments OJ 08	0.15	0.6
Odin STP	ILG580187	001	Turkey Creek /Crooked Creek Segments OJ 07	0.195	1.8
Hoffman STP	ILG580205	001	Prairie Creek/Crooked Creek Segments OJ 08	0.06	0.15
Central City STP	ILG580265	001	NA/Crooked Creek Segments OJ 07	0.304	1.267
Junction City STP	ILG580277	001	Prairie Creek/Crooked Creek Segments OJ 08	0.06	0.15
Okawville STP	ILG580268	001	NA/Plum Creek Segment OZH-OK-A2	0.25	0.877
Salem WTP	ILG640031	001	Town Creek/Crooked Creek Segments OJ 07	0.039	N/A

Notes: N/A = Not Available; MGD = Million Gallons per Day

4.1.1 Phosphorus

None of the point source dischargers in the watershed are required to monitor for total phosphorus so it is not possible to accurately estimate the existing load from point sources. Four lakes are currently listed for phosphorus. The Raccoon Consolidated Schools facility is the only point source that discharges upstream of any of the lakes. It is not likely that the Raccoon Consolidated Schools facility is contributing a significant fraction of the total load, however, because average flows from this facility are only 0.0125 million gallons per day.

4.2 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) are not typically a significant source of pollutant loading if they are operating as designed. However, if the failure rates of systems in this watershed are high, then the loading from this source may be significant. At this time, there is limited information with which to estimate levels of performance.

Pollutant loading rates from properly functioning onsite wastewater systems are typically insignificant. However, if systems are placed on unsuitable soils, not maintained properly, or are connected to subsurface drainage systems, loading rates to receiving waterbodies may be relatively high. It is suggested that each system in the watershed be inspected to accurately quantify the loading from this source. Systems older than 20 years and those located close to the lakes or streams should be prioritized for inspection.

4.2.1 Phosphorus

In a properly functioning septic system, wastewater effluent leaves the septic tank and percolates through the system drainfield. Phosphorus is removed from the wastewater by adsorption to soil particles. Plant uptake by vegetation growing over the drainfield is assumed negligible since all of the phosphorus is removed in the soil treatment zone. Failing systems that either short circuit the soil adsorption field or cause effluent to pool at the ground surface are assumed to retain phosphorus through plant uptake only (average annual uptake rate of 0.2 g/capita/day). Direct discharge systems that intentionally bypass the drainfield by connecting the septic tank effluent directly to a waterbody or other transport line (such as an agricultural tile drain) do not allow for soil zone treatment or plant uptake.

4.3 Crop Production

The majority of land in the Crooked Creek watershed (52 percent) is used for production of corn, soybeans, wheat, and other small grains. Due to application of commercial fertilizer, manure, and pesticides, as well as increased rates of erosion, pollutant loads from croplands are relatively high compared to other land uses.

4.3.1 Phosphorus

Agriculture is a primary land use throughout the Crooked Creek watershed with approximately 185,000 acres of land are used to grow corn, soybeans, wheat, and other grains. Based on data presented by Gentry et al. (2007), phosphorus loading rates from tiled agricultural fields in east-central Illinois range from 0.5 to 1.5 lb/ac/yr. Using these values the phosphorus loads to the Crooked Creek watershed from crop production areas may range from 92,500 to 277,500 lb/yr assuming that all of the fields are artificially drained.

4.3.2 Manganese

Impairments due to manganese occur in Centralia Lake, Raccoon Lake, and Salem Lake. Manganese is found naturally in the environment in groundwater and soils and any land disturbing activities can result in loading of manganese to local waterbodies. Because crop production tends to increase rates of erosion, the sediment bound manganese loads tend to increase from this land use. In addition, much of the land farmed in this watershed is classified as highly erodible.

Typical concentrations of manganese in Southern Illinois range from 4 to 200 milligrams of manganese per kilogram of soil (mg/kg) with an average value of 23 mg/kg (Ebelhar, 2007). Based on data presented by Czapar et al. (2006), conventional chisel plow crop production activities in Midwestern states result in sediment loads of 7.5 tons/ac/yr. Approximately 185,000 acres of land are used for crop production in the

Crooked Creek watershed. Assuming a manganese concentration of 23 mg/kg percent yields an estimated loading rate from this source of 32 tons/yr.

4.3.3 Atrazine

Atrazine is a commonly used herbicide for controlling broadleaf and grassy weeds. Raccoon Lake is impaired due to atrazine and the sole source is crop production. Because many herbicides are available for use, it is not possible to quantify the load to waterbodies in the watershed without site specific application data.

4.4 Animal Operations

Pollutant loading from animal operations can be a problem in both confined and pasture-based systems. Though the exact location of animal operations in the watershed is not known, countywide statistics indicate that a large number of livestock, swine, and poultry may exist. Agricultural animal operations are a potentially large source of pollutant loading if adequate best management practices (BMPs) are not in place to protect surface waters.

4.4.1 Phosphorus

Census estimates of animals in Washington and Marion County were area weighted to estimate the number of animals the watershed of each lake (Table 6). Large animals produce more fecal matter per animal compared to smaller animals, so the concept of animal unit is used to normalize loading from various operations. The phosphorus load from these animals might be significant and is discussed in more detail in the Implementation Plan.

Table 6. Estimated Number of Livestock and Poultry in the Crooked Creek Lake Watersheds.

Animal	Centralia Lake	Raccoon Lake	Salem Lake	Nashville City Lake
Poultry	0	0	0	1
Beef cattle	56	435	36	12
Dairy cattle	2	19	2	22
Hogs and pigs	93	714	59	171
Sheep and lambs	4	27	2	1

4.5 Streambank and Lake Shore Erosion

Excessive erosion of streambanks and lake shores quickly degrades water quality and habitat. Both phosphorus and manganese contribute to the overall composition of sediment and once this sediment reaches a waterbody, these elements may be released through biological and chemical transformations. Release of phosphorus may increase rates of algal and plant growth (eutrophication), which leads to issues with dissolved oxygen concentrations, water treatability, and aesthetics. Manganese also effects water treatment operations and is detrimental to aquatic life at high concentrations.

In addition to the release of phosphorus and manganese, erosion will also reduce the stability of streambanks by undercutting the roots of established vegetation and altering the channel geometry. Loss of vegetative canopy and widening of a stream channel will allow more sunlight to reach the water column which may 1) increase rates of eutrophication, 2) increase water temperatures, and 3) decrease the amount of dissolved oxygen the water can hold.

Without quantitative estimates of streambank and shoreline erosion, it is not possible to estimate the phosphorus or manganese loading from this source or the impacts on dissolved oxygen. Fortunately several of the BMPs described in the Implementation Plan that control pollutant loads and runoff volumes will also help control streambank and lakeshore erosion.

4.6 Internal Loading from Lake Bottom Sediments

Four lakes in the Crooked Creek watershed are listed for pollutants that may be released from bottom sediments under anoxic conditions. Centralia, Raccoon, Salem, and Nashville City Lake are listed for both phosphorus and manganese. Because the Nashville City Lake listing was based on sediment samples and could not be compared to the water quality standards, a manganese TMDL was not developed for this lake.

Both manganese and phosphorus may be released internally from lake sediments when oxygen concentrations near the bottom of the lake reach low levels. Low dissolved oxygen in lakes may be caused by degradation of organic material or respiration of algae in the absence of sunlight. Conditions for low dissolved oxygen are most severe during the summer months when the water temperatures are higher and the water is able to contain less oxygen.

Each of the lakes is monitored at several stations for dissolved oxygen. The data suggest that anoxic conditions are sometimes present in Raccoon Lake in the lower depths. Based on this dataset, releases of phosphorus and manganese from bottom sediments is a potential concern. Dissolved oxygen concentrations in Lake Centralia are generally lower than in Lake Raccoon and anoxic conditions are prevalent. Release of phosphorus and manganese from bottom sediments is more likely in this lake, though quantitative estimates cannot be made without additional data. Monitoring data collected in Lake Salem do not indicate anoxic conditions at the sediment-water interface, so releases of phosphorus and manganese from bottom sediments are not likely. Dissolved oxygen concentrations in Lake Nashville sometimes approach zero, but are not expected to cause significant releases of phosphorus or manganese.

4.7 Domestic Pets and Wildlife Populations

Domestic pets such as cats and dogs and wildlife animals such as deer, geese, ducks, etc., can be significant sources of loading in watersheds that have high densities of urban populations or rural communities with relatively undisturbed land use patterns. In the Crooked Creek watershed, where the majority of land is used for agricultural production, these sources are likely not significant relative to the loading from other sources.

5.0 TECHNICAL ANALYSIS

This section of the report describes the technical approaches that were used to calculate TMDLs within the Crooked Creek watershed. The QUAL2K model was used to assess instream dissolved oxygen concentrations and the BATHTUB model was used to assess lake water quality. Table 7 presents the listed water bodies and the corresponding modeling approach used to address each TMDL.

Table 7. 303(d) List Information and Modeling Approaches for the Crooked Creek Watershed.

Waterbody Name	Segment	Cause of Impairment	Modeling Approach
Crooked Creek	OJ-07	Dissolved Oxygen	QUAL2K
Crooked Creek	OJ-08	Dissolved Oxygen	QUAL2K
Little Crooked Creek	OJA-01	Dissolved Oxygen	QUAL2K
Plum Creek	OZH-OK-A2	Dissolved Oxygen	QUAL2K
Plum Creek	OZH-OK-C2	Dissolved Oxygen	QUAL2K
Plum Creek	OZH-OK-C3	Dissolved Oxygen	QUAL2K
Centralia Lake	ROI	Manganese	BATHTUB
		Total Phosphorus	BATHTUB
Raccoon Lake	ROK	Atrazine	BATHTUB
		Dissolved Oxygen	BATHTUB
		Manganese	BATHTUB
		pH	BATHTUB
		Total Phosphorus	BATHTUB
Nashville City Lake	ROO	Manganese	BATHTUB
		Total Phosphorus	BATHTUB
Salem Lake	ROR	Dissolved Oxygen	BATHTUB
		Manganese	BATHTUB
		Total Phosphorus	BATHTUB

5.1 QUAL2K Model

The QUAL2K water quality model was selected to assess the dissolved oxygen impairments in the Crooked Creek watershed. QUAL2K is supported by U.S. EPA and has been used extensively for TMDL development and point source permitting issues across the country, especially for issues related to dissolved oxygen concentrations. QUAL2K has also been used previously by Illinois EPA for TMDL development. QUAL2K is well accepted within the scientific community because of its proven ability to simulate the processes important to dissolved oxygen conditions within streams. The QUAL2K model is suitable for simulating the hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics. Six QUAL2K models were set up for each of the following impaired streams (Figure 3) to address low dissolved oxygen conditions:

- Crooked Creek (Segment OJ 07 and OJ 08)
- Little Crooked Creek (Segment OJ A01_01)
- Little Crooked Creek (Segment OJ A01_02)

- Plum Creek (Segment OZH OK C3)
- Plum Creek (Segment OZH OK C2)
- Plum Creek (Segment OZH OK A2)

Illinois' water quality standard requires a minimum dissolved oxygen concentration of 5 mg/L at all times and a 6.0 minimum during at least 16 hours of any 24 hour period. Once the model was setup and calibrated for each stream, a series of scenarios were run to evaluate the most likely cause of the observed low dissolved oxygen. These results are summarized in Section 7.0 and a detailed discussion of the QUAL2K model is included in Appendix B.

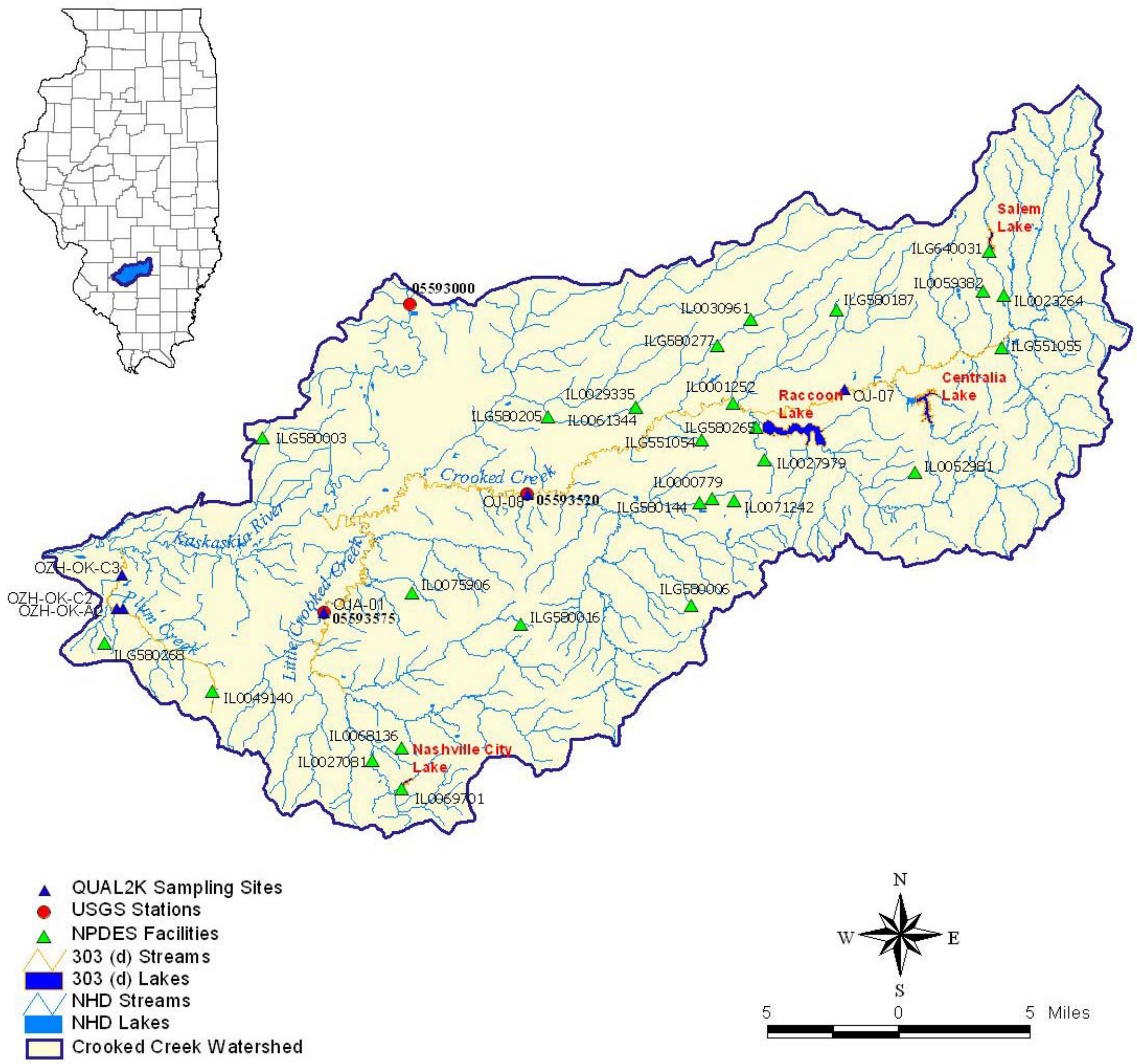

Figure 3. USGS, QUAL2K Sampling Sites, and NPDES facilities in the Crooked Creek Watershed

5.2 BATHTUB Model

The USACE BATHTUB model was selected for modeling water quality in Centralia Lake, Raccoon Lake, Nashville City Lake, and Salem Lake. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network, which accounts for pollutant transport and sedimentation. In addition, the BATHTUB model incorporates internal phosphorus loadings into its calculations. Eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker, 1987). Manganese can also be simulated as a conservative substance. BATHTUB was determined to be appropriate because it addresses the primary parameters of concern (phosphorus and manganese) and has been used previously for reservoir TMDLs in Illinois and elsewhere. U.S. EPA also recommends the use of BATHTUB for phosphorus TMDLs (U.S. EPA, 1999). A detailed discussion for each of the individual BATHTUB models is included in Appendix C.

Typically, watershed loads are input to the BATHTUB model and used to simulate average in-lake pollutant concentrations. However, for Centralia Lake, Raccoon Lake, Nashville City Lake, and Salem Lake, watershed and tributary data are not available to estimate loads to the lake. A “reverse” BATHTUB model was therefore developed where average inlake concentrations were used to estimate the load required given annual flow volume and lake bathymetry data. No adjustment of the calibration factors were needed with this simulation because the loads were set by year to match average observed concentrations (i.e., calibration factors were left to the BATHTUB default settings). Lake bathymetry data were available from the Stage 1 report and are summarized in Table 8. Maps of the IEPA monitoring stations for each lake are shown in Figure 4, Figure 5, and Figure 6.

Table 8. Bathymetry Data for the Crooked Creek Watershed Lakes.

Lake	Parameter	Value
Centralia Lake	Normal Pool Volume (ac-ft)	2,550
	Normal Pool Surface Area (ac)	254
	Maximum Depth (ft)	23.5
	Mean Depth (ft)	10.04
Raccoon Lake	Normal Pool Volume (ac-ft)	2,772
	Normal Pool Surface Area (ac)	925
	Maximum Depth (ft)	13
	Mean Depth (ft)	3.0
Nashville City Lake	Normal Pool Volume (ac-ft)	400
	Normal Pool Surface Area (ac)	42
	Maximum Depth (ft)	15.5
	Mean Depth (ft)	9.5
Salem Lake	Normal Pool Volume (ac-ft)	388
	Normal Pool Surface Area (ac)	74.2
	Maximum Depth (ft)	11
	Mean Depth (ft)	5.2

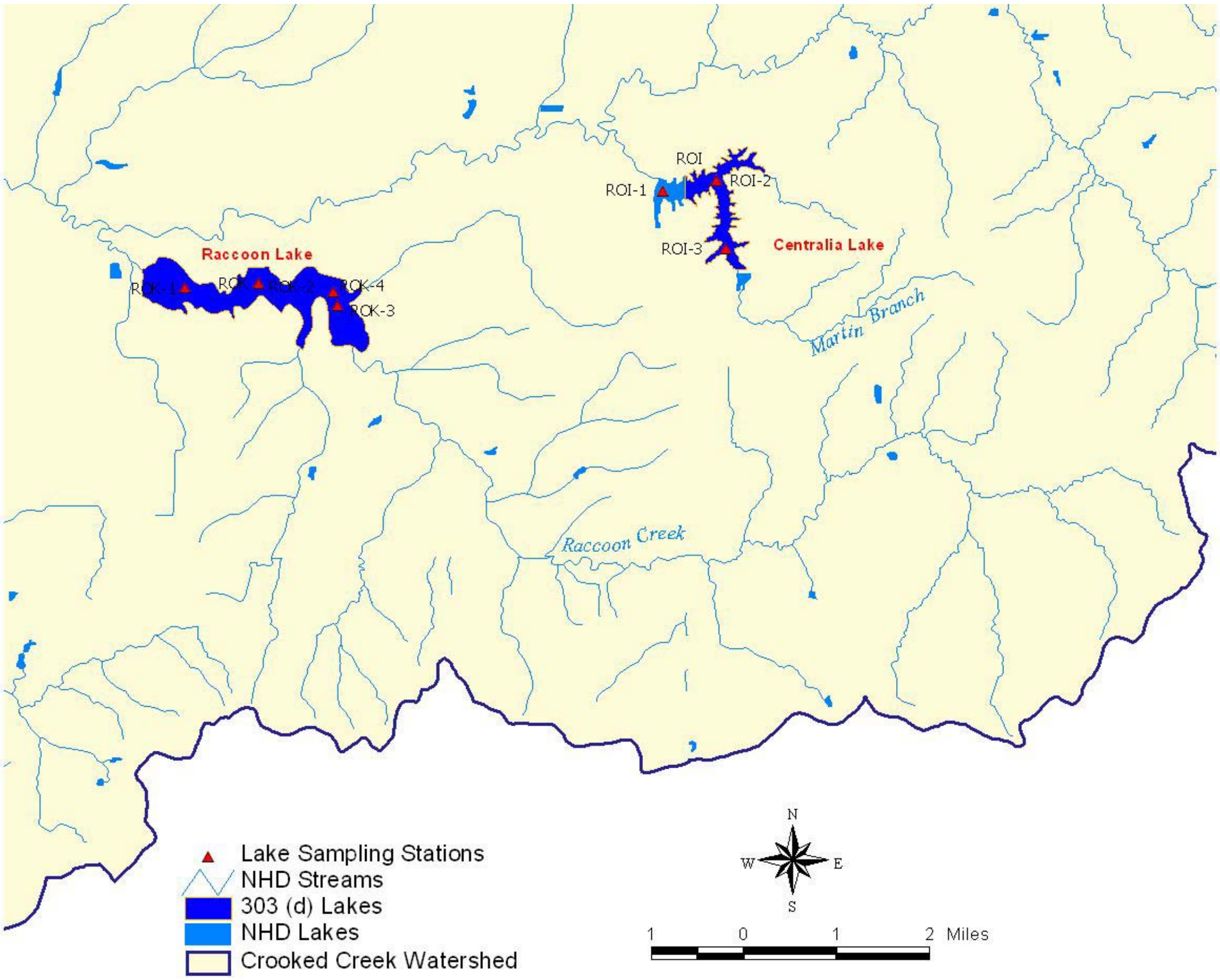

Figure 4. Centralia Lake and Raccoon Lake Monitoring Stations

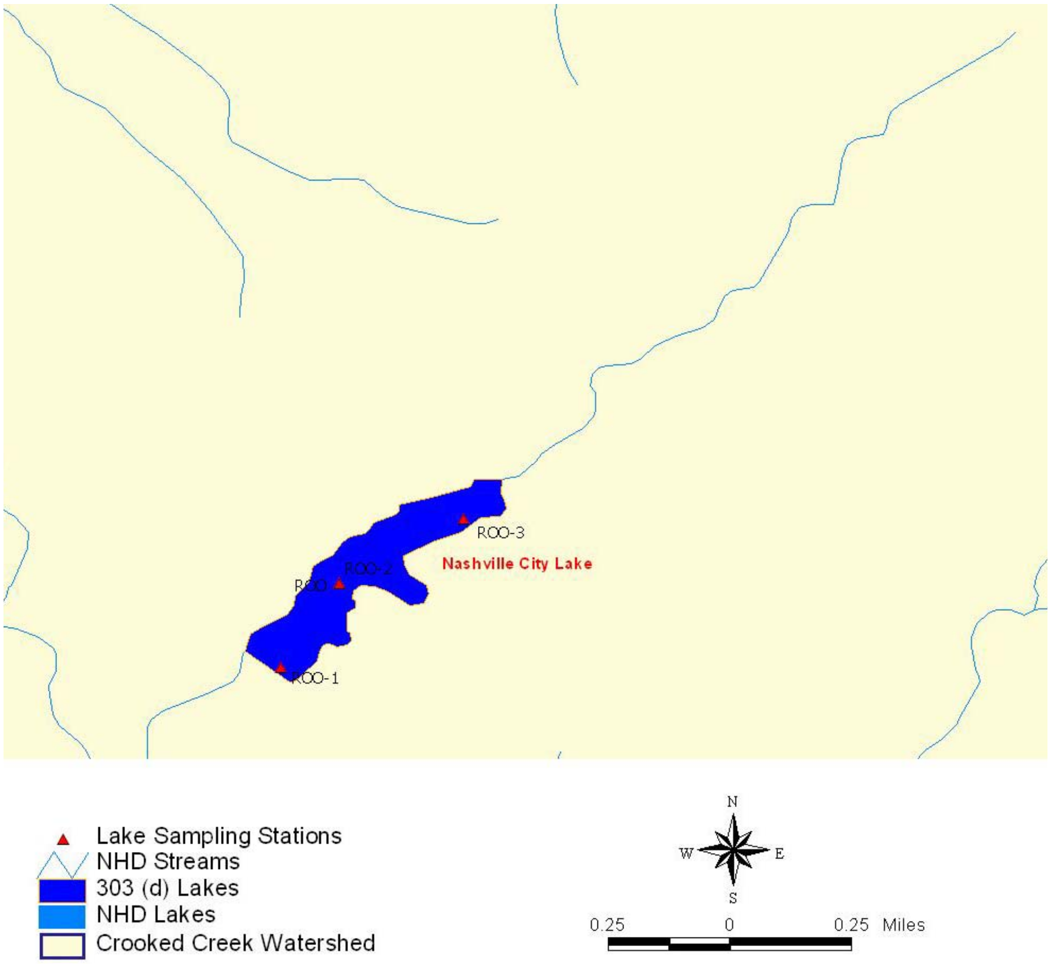

Figure 5. Nashville City Lake Monitoring Stations

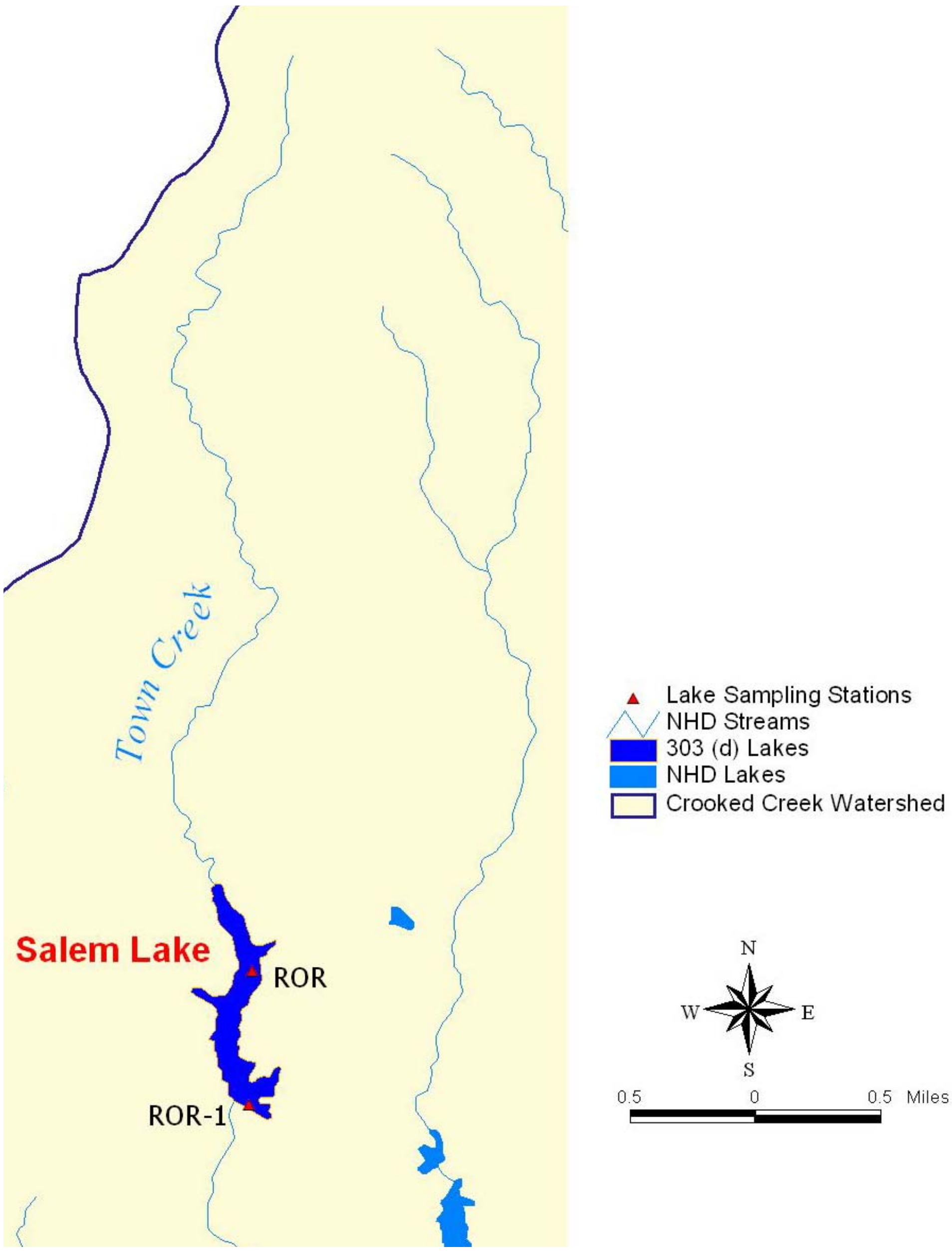

Figure 6. Salem Lake Monitoring Stations

BATHTUB was set up to simulate phosphorus and manganese response in the lakes for years corresponding with the available water quality data. The estimated watershed loads and total flow volumes to these lakes are summarized by year in Table 9. Stream flows are displayed in million gallons (MG) per year.

Table 9. Annual Watershed Flows and Loads to the Crooked Creek Watershed Lakes.

Lake	Year	Volume of Inflow	Manganese Existing Load	Total Phosphorus Existing Load
Centralia Lake	1998	1,697 million gallons/year	No Data Available	2904 kg/yr 6404 lb/yr
	2001	615 million gallons/year	436 kg/yr 961 lb/yr	977 kg/yr 2154 lb/yr
Raccoon Lake	1998	11,772 million gallons/year	No Data Available	34,020 kg/yr 75,001 lb/yr
	2001	3,429 million gallons/year	2,583 kg/yr 5,695 lb/yr	20,630 kg/yr 45,481 lb/yr
Nashville City Lake	1998	444 million gallons/year	No Data Available	23,780 kg/yr 52,425 lb/yr
	1999	346 million gallons/year	No Data Available	14,150 kg/yr 31,195 lb/yr
	2000	315 million gallons/year	No Data Available	7,520 kg/yr 16,579 lb/yr
Salem Lake	1999	839 million gallons/year	776 kg/yr 1,711 lb/yr	1,520 kg/yr 3,351 lb/yr

6.0 TMDLS DEVELOPED WITHIN THE CROOKED CREEK WATERSHED

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources (including natural background levels). In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this is defined by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

A summary of the TMDL allocations for the Crooked Creek watershed is presented in this section of the report, organized according to pollutants and modeling analysis.

6.1 Loading Capacity for Lakes in the Crooked Creek Watershed

As described in Section 5.2, the BATHTUB model was used to simulate atrazine, total phosphorus, and manganese concentrations in the impaired lakes in the Crooked Creek watershed. After the models were set up as described in Appendix C, the TMDLs were determined by identifying the load reductions needed to achieve the water quality standards as average conditions for all modeled years. Loading capacities were then calculated by multiplying the needed load reduction by the average existing load for as many years as which data were available. This was considered appropriate because data were primarily available for 1998 (a wet year) and 2001 (a dry year). The loading capacity thus represents the typical load of pollutants to each lake that will result in meeting water quality standards.

The following sections summarize the resulting TMDLs for Centralia Lake, Raccoon Lake, Nashville City Lake, and Salem Lake.

6.1.1 Centralia Lake Loading Capacity

Centralia Lake is listed as impaired for manganese, total phosphorus, and total suspended solids. Of these, IEPA only has numeric criteria for manganese and total phosphorus and so TMDLs were only developed for these two pollutants.

The total phosphorus target for Centralia Lake is 0.05 mg/L. To meet the target, a 74 percent reduction of phosphorus load is required. The total manganese target for Centralia Lake is 150 µg/L. To meet the target, a 20 percent reduction of manganese load is required. Table 10 shows the resulting average concentrations if these reductions are implemented and Table 11 presents the existing load, loading capacity, margin of safety and load allocation for Centralia Lake. Existing loads were estimated by using a reverse BATHTUB model where incoming loads were estimated to match observed concentrations assuming model default parameters for settling, re-suspension, etc. (Appendix C).

Table 10. Average Total Manganese and Total Phosphorus Concentrations in Centralia Lake with recommended TMDL Reductions in Loading

Year	Predicted Post-TMDL Manganese (µg/L)	Predicted Post-TMDL Total Phosphorus (mg/L)
1998	No Data Available	0.0493
2001	149.76	0.0389

Table 11. TMDL Summary for Centralia Lake.

Pollutant	Existing Load	Reduction	Loading Capacity	Wasteload Allocation	Margin of Safety (5%)	Load Allocation
Manganese (kg/yr)	436	20%	348	0	17	331
Manganese (kg/day)	1.195	20%	0.953	0	0.047	0.907
Total Phosphorus (kg/yr)	1,941	74%	505	0	25	480
Total Phosphorus (kg/day)	5.318	74%	1.384	0	0.069	1.315

6.1.2 Raccoon Lake Loading Capacity

Raccoon Lake is listed as impaired for atrazine, dissolved oxygen, manganese, pH, total phosphorus, sedimentation/siltation, and total suspended solids. Of these, IEPA only has numeric criteria for atrazine, dissolved oxygen, manganese, pH and total phosphorus. Furthermore, the dissolved oxygen and pH impairments are believed to be related to the total phosphorus impairment (see Section 3.2) and therefore a total phosphorus TMDL was prepared to address these three inter-related parameters.
The total phosphorus target for Raccoon Lake is 0.05 mg/L. To meet the target during all years, a 96 percent reduction of phosphorus load is required. IEPA believes that attaining the total phosphorus target of 0.05 mg/L will result in shifting plant production back to natural levels, which in turn will result in dissolved oxygen and pH meeting water quality standards. When excessive phosphorus loads enter a lake, the growth of algae and macrophytes is stimulated, which in turn produces and consumes oxygen in water. Oxygen depletion occurs when the balance between oxygen consumption and production is altered, either causing excessive oxygen consumption or reduced oxygen production. Plants utilize carbon dioxide during photosynthesis and oxygen consumption, which causes pH to fluctuate (see Section 3.2 for more details). The details of the Raccoon Lake BATHTUB total phosphorus modeling are available in Appendix C.

The total manganese target for Raccoon Lake is 150 µg/L. To meet the target during all years, a 25 percent reduction in the manganese load to the lake is required. Table 12 shows the predicted average concentrations in the lake for years with available data if this level of reduction is achieved and Table 13 shows the existing load, loading capacity, wasteload allocation, margin of safety and load allocation. The details of the Raccoon Lake BATHTUB manganese modeling are available in Appendix C.

The atrazine target for Raccoon Lake is 3 µg/L. To meet the target during the two years that were modeled, a 31 percent reduction of atrazine load is required. Table 12 shows the average summer (May-September) atrazine concentrations if a 31 percent reduction is assumed. The existing load, loading capacity, wasteload allocation, margin of safety, and load allocations are shown in Table 13. The details of the modeling are available in Appendix C.

Table 12. Average total Manganese, total phosphorus, and atrazine concentrations in Raccoon Lake with recommended TMDL reductions in loading.

Year	Raccoon Lake Manganese (µg/L)	Raccoon Lake Total Phosphorus (mg/L)	Raccoon Lake Atrazine (µg/L)
1998	N/A	0.0271	N/A
2001	149.3	0.0475	N/A
2003	N/A	N/A	2.97
2004	N/A	N/A	1.31

Table 13. TMDL Summary for Raccoon Lake.

Pollutant	Existing Load	Reduction	Loading Capacity	Wasteload Allocation	Margin of Safety (5%)	Load Allocation
Atrazine (kg/summer)	445	31%	307	0	15	292
Atrazine (kg/day)	2.96	31%	2.04	0	0.10	1.95
Manganese (kg/yr)	2,583	25%	1937	0	97	1840
Manganese (kg/day)	7.07	25%	5.31	0	0.27	5.04
Total Phosphorus (kg/yr)	27,325	96%	1093	69	55	969
Total Phosphorus (kg/day)	74.86	96%	2.99	0.19	0.15	2.65

6.1.3 Nashville City Lake Loading Capacity

Nashville City Lake is listed as impaired for manganese, total phosphorus, and total suspended solids and, of these, IEPA only has numeric criteria for manganese and total phosphorus. Because insufficient data were available to develop a manganese TMDL, no TMDL is presented here. However, the manganese impairment may be related to the phosphorus impairment in that excessive phosphorus loadings are leading to anoxic (no dissolved oxygen) conditions in the bottom of the lake. These anoxic conditions, in turn, can lead to the release of manganese from the bottom sediments of the lake.

The total phosphorus target for Nashville City Lake is 0.05 mg/L. To meet the target during all years, a 99 percent reduction of phosphorus loads is required. Table 14 shows the resulting average concentrations if these reductions are implemented. Table 15 presents the existing load, loading capacity, margin of safety and load allocation for Nashville City Lake. Existing loads were estimated by using a reverse BATHTUB model where incoming loads were estimated to match observed concentrations assuming model default parameters for settling, re-suspension, etc. (Appendix C).

Table 14. Average Expected Total Phosphorus Concentration in Nashville City Lake with 99 Percent Reduction in Phosphorus Loading

Year	Nashville City Lake Total Phosphorus (mg/L)
1998	0.0390
1999	0.0472
2000	0.0278

Table 15. TMDL Summary for Nashville City Lake.

Pollutant	Existing Load	Reduction	Loading Capacity	Wasteload Allocation	Margin of Safety (5%)	Load Allocation
Total Phosphorus (kg/yr)	15,150	99%	151	0	8	143
Total Phosphorus (kg/day)	41.51	99%	0.41	0	0.02	0.39

6.1.4 Salem Lake Loading Capacity

The total phosphorus target for Salem Lake is 0.05 mg/L. To meet the target during all years, a 83 percent reduction of phosphorus load is required. The total manganese target for Salem Lake is 150 µg/L. To meet the target during all years, a 39 percent reduction of manganese load is required. Table 16 shows the resulting average concentrations if these reductions are implemented. Table 17 presents the existing load, loading capacity, margin of safety and load allocation for Salem Lake. Existing loads were estimated by using a reverse BATHTUB model where the user inputs loads to match observed concentrations (Appendix C).

Table 16. Average Total Manganese and Total Phosphorus Concentrations in Salem Lake with recommended TMDL Reductions in Loading

Year	Salem Lake Manganese (µg/L)	Salem Lake Total Phosphorus (mg/L)
1999	148.9	0.0499

Table 17. TMDL Summary for Salem Lake.

Pollutant	Existing Load	Reduction	Loading Capacity	Wasteload Allocation	Margin of Safety (5%)	Load Allocation
Manganese (kg/yr)	1520	39%	927	0	46	881
Manganese (kg/day)	4.16	39%	2.54	0	0.13	2.41
Total Phosphorus (kg/yr)	776	83%	132	0	7	125
Total Phosphorus (kg/day)	2.13	83%	0.36	0	0.02	0.34

6.1.5 Waste Load Allocations

There are no permitted dischargers of manganese to any of the Crooked Creek watershed lakes, so wasteload allocations for manganese are set to zero. The Raccoon Consolidated Schools facility has one outfall that discharges to an unnamed tributary that eventually flows into Raccoon Lake. The facility is not required to monitor for total phosphorus in its effluent so actual loads are unknown. Loads of total phosphorus from the STP outfall was estimated by multiplying the design average flow by a literature value phosphorus concentration of value of 4 mg/L (Litke, 1999). The resulting wasteload allocations are included in Table 18.

Table 18. WLA Summary for Raccoon Consolidated Schools (Permit IL0052981).

Outfall	Design Average Flow (million gallons per day)	TP Concentration (mg/L)[1]	TP Load (Kg/day)	TP Load (Kg/year)
001	0.0125	4 mg/L	0.189	69

[1]Literature value from Litke, 1999.

6.1.6 Load Allocation

The load allocations for the Crooked Creek Watershed Lake TMDLs are summarized in Table 11, Table 13, Table 15, and Table 17. The existing loads were determined using a reverse BATHTUB simulation in which loads were back calculated for each year based on observed inlake water quality concentrations. The loading capacity was calculated based on the percent reduction of existing loads required to simulate concentrations at or below the water quality standard for each parameter. The load allocations were set equal to the loading capacities minus any wasteload allocations and the margin of safety.

6.1.7 Margin of Safety

Section 303(d) of the Clean Water Act and U.S. EPA's regulations at 40 CFR 130.7 require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (U.S. EPA, 1991).

A five percent explicit margin of safety has been incorporated into the Crooked Creek watershed Lake TMDLs by reserving a portion of the loading capacity. A relatively low margin of safety was applied because existing loads were calculated by using a reverse BATHTUB model where incoming loads were set to match observed concentrations assuming model default parameters for settling, re-suspension, etc. No calibration of the model was therefore required as the predicted lake concentrations matched the observed concentrations.

In addition, the manganese modeling also incorporates an internal margin of safety by assuming the manganese sedimentation rate is zero.

6.1.8 Critical Conditions and Seasonality

Section 303(d)(1)(C) of the Clean Water Act and U.S. EPA's regulations at 40 CFR 130.7(c)(1) require that a TMDL be established that addresses seasonal variations normally found in natural systems. Lake nutrients are typically highest during the summer and the BATHTUB User's manual suggests modeling summer months from May through September. However, for all Crooked Creek lakes, the annual simulation was chosen because 1) the summer period simulation did not meet the nutrient turnover criteria for phosphorus, 2) the annual model was more conservative in terms of required reductions, and 3) the annual model made use of all of the limited data. For all of the lakes, it is expected that the reductions required for the annual simulations will protect water quality during all seasons.

6.1.9 Reasonable Assurance, Monitoring, and Implementation

A detailed Implementation Plan has been developed to outline steps that can be taken to implement the Crooked Creek TMDLs described in this report. The Implementation Plan identifies the most likely sources of each pollutant, describes controls that can be used to reduce loadings, provides information on available funding resources, and presents follow-up monitoring recommendations. The Key Findings of the Implementation Plan were as follows:

> *The results of a TMDL study for the Crooked Creek watershed indicate that significant reductions of total phosphorus and manganese are needed to attain water quality standards in four lakes in the drainage area. In addition, reductions of atrazine loads to Raccoon Lake are required to achieve water quality standards.*
>
> *The largest potential sources of pollutant loading in the watershed are agricultural practices. Manure from animal operations contributes nutrients, pathogens, and biodegradable organic material. In addition, animals with access to stream channels can deposit nutrients directly into or near the stream and erode the banks as they climb in and out. This erosion leads to increased loads of sediment and manganese, a metal common in soils. The BMPs most likely to control loading from animal operations are 1) proper handling, storage, and final disposal practices for manure, 2) vegetative controls*

such as grassed waterways, filter strips, and constructed wetlands, 3) manure composting, and 4) restoration of riparian buffers.

Crop production in the watershed results in loadings of nutrients, sediment, manganese, and pesticides to the watershed. Application of fertilizers and pesticides contributes phosphorus and atrazine to the waterbodies when rain events wash pollutants into nearby streams or through underlying tile drain systems. Increased rates of erosion result in excessive sediment and manganese loads. The most cost-effective management strategy that addresses all pollutants of concern is conservation tillage. Other effective practices include grass waterways, filter strips, fertilizer and pesticide management, and restoration of riparian buffers.

Pollutant loads from point sources in the watershed may be significant, but the actual loads are difficult to estimate because several of the facilities are not required to monitor for the TMDL pollutants. Given that most of these facilities provide at least a secondary level of wastewater treatment, it is not likely that IEPA will require them to upgrade their plants to reduce nutrient or organic loading. The State may request that facilities submit TMDL pollutant data to verify that water quality standards are being met.

The density of onsite wastewater treatment systems in the watershed is relatively sparse and loading from this source is likely not significant relative to the other sources. However, failing onsite systems may cause localized water quality impacts as well as risks to human health. Identifying these systems through a routine inspection program and encouraging proper maintenance and upkeep will minimize these impacts.

7.0 ASSESSMENT OF DISSOLVED OXYGEN ISSUES IN THE CROOKED CREEK WATERSHED

Three streams in the Crooked Creek watershed are listed as impaired due to low dissolved oxygen concentrations:

- Crooked Creek (segments OJ 07 and OJ 08)
- Little Crooked Creek (segment OJA 01)
- Plum Creek (segments OZH OK A2, OZH OK C2, and OZH OK C3)

No TMDLs are being developed for these streams at this time due to the considerations described below.

7.1 Dissolved Oxygen Analysis for Crooked Creek (OJ 07)

Crooked Creek segment OJ 07 is listed as impaired due to low dissolved oxygen. The original listing was made based on 33 of 124 (27%) dissolved oxygen measurements being below the aquatic life water quality criterion of 5 mg/L (refer to the Stage 1 report for details). The QUAL2K model was setup and calibrated to 2002 sampling data to further investigate the dissolved oxygen issues as explained in Section 5.1. Details of the QUAL2K modeling are provided in Appendix B.

To further investigate the cause of the low dissolved oxygen in Crooked Creek, three separate analyses were conducted:

- Point and nonpoint source loads were reduced until both components of the dissolved oxygen water were met.
- The average dissolved oxygen re-aeration coefficient derived from the QUAL2K calibration was increased until both components of the dissolved oxygen water quality standard were met.
- The sediment oxygen demand derived from the QUAL2K calibration was decreased (while maintaining existing point and nonpoint source loads) until both components of the dissolved oxygen water quality standard were met.

The results of this analysis indicate that even complete removal of carbonaceous biochemical oxygen demand (CBOD) and total ammonia loads from both nonpoint and point sources are not enough to achieve the 6 mg/L component of the standard. CBOD measures the rate of oxygen uptake by micro-organisms in a sample of water and is an indication of the amount of biodegradable carbon in organic matter. Total ammonia is the sum of ammonia (NH_3) and ammonium (NH_4+) and is significant because the conversion of ammonium to nitrate by bacteria consumes dissolved oxygen. It is infeasible to completely remove loads of CBOD and ammonium from a natural stream system, given that at least a portion of this load is associated with natural background sources. For example, leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like swamps and bogs are all natural sources of material that consume oxygen.

The modeling analysis also suggests that the 6 mg/L water quality standard cannot be met even with the complete elimination of sediment oxygen demand (some of which is also expected to be natural). Although the water quality standards could be met if the average re-aeration rate is increased from 2.01 per day to 7.5 per day, increasing aeration in the stream would be technically difficult and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDL will be developed at this time and instead methods to reduce pollutant loadings and increase in-stream re-aeration will be outlined in the Implementation Plan.

7.2 Dissolved Oxygen Analysis for Other Streams in the Crooked Creek Watershed

Similar analyses were conducted for the other streams in the Crooked Creek that are impaired due to low dissolved oxygen:

- Crooked Creek (OJ 08)
- Little Crooked Creek (OJA 01)
- Plum Creek (OZH OK A2, OZH OK C2, and OZH OK C3)

The results are summarized in Table 19 and indicate that meeting the dissolved oxygen water quality standards would require very large (potentially infeasible) reductions from point and nonpoint sources or sediment oxygen demand. Although the water quality standards could be met with increased re-aeration rates, increasing aeration in the streams would be technically difficult and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDLs will be developed at this time and instead methods to reduce pollutant loadings and increase in-stream re-aeration are outlined in the Implementation Plan.

Table 19. Summary of dissolved oxygen QUAL2K analysis for streams in the Crooked Creek watershed impaired due to low dissolved oxygen.

Segment	Listing Rationale	Load Reduction Results	SOD Reduction Results	Re-aeration Increase Results
Crooked Creek (OJ 08)	Original listing made based on 44 of 123 (36%) measurements below 5 mg/L; (see Appendix D)	Complete removal of point and nonpoint source CBOD and total ammonia loads does not achieve 6mg/l component of the WQS	Complete removal of SOD does not achieve WQS	Average re-aeration rate would need to be increased from 0.6 per day to 3.0 per day to achieve WQS
Little Crooked Creek (OJA 01)	Original listing made based on 4 of 5 (80%) measurements below 5 mg/L; impairment confirmed based on continuous Stage 2 sampling (see Appendix E)	WQS would be met with an 85 percent reduction of CBOD and total ammonia loads from point sources and nonpoint sources	Complete removal of SOD does not achieve WQS	Average re-aeration rate would need to be increased from 1.12 per day to 4.75 per day to achieve WQS
Plum Creek (OZH OK A2)	Original listing made based on one dissolved oxygen measurement that was below 5 mg/L in 2002; impairment confirmed based on continuous Stage 2 sampling (see Appendix E)	Complete removal of point and nonpoint source CBOD and total ammonia loads would not achieve the WQS	Complete removal of SOD will not achieve the 6 mg/L component of the WQS	Average re-aeration rate would need to be increased from 2.7 per day to 7 per day to achieve WQS
Plum Creek (OZH OK C2)	Original listing made based on one dissolved oxygen measurement that was below 5 mg/L in 2002; impairment confirmed based on continuous Stage 2 sampling (see Appendix E)	Complete removal of point and nonpoint source CBOD and total ammonia loads would not achieve the WQS	Complete removal of SOD will not achieve the 6 mg/L component of the WQS	Average re-aeration rate would need to be increased from 2.63 per day to 9.0 per day
Plum Creek (OZH OK C3)	Original listing made based on one dissolved oxygen measurement that was below 5 mg/L in 2002; impairment confirmed based on continuous Stage 2 sampling (see Appendix E)	Complete removal of point and nonpoint source CBOD and total ammonia loads would not achieve the WQS	Complete removal of SOD will not achieve the 6 mg/L component of the WQS	Average re-aeration rate would need to be increased from 2.94 per day to 5.5 per day to achieve WQS

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Appendix A. : Dissolved Oxygen Data for QUAL2K Analysis

Table A-1. Available Dissolved Oxygen Data for Segment OJ 07

Date	Dissolved Oxygen (mg/L)
2/2/1999	8.6
3/10/1999	9.3
4/7/1999	6.9
5/20/1999	6.7
7/1/1999	5.4
8/11/1999	4.9
9/9/1999	4
11/8/1999	3
12/8/1999	8.6
1/25/2000	15.6
3/7/2000	9.7
4/13/2000	8.2
5/17/2000	4.6
6/6/2000	5.3
8/15/2000	5
9/21/2000	5.7
11/6/2000	3.4
12/6/2000	10.5
1/4/2001	10.6
2/5/2001	12.4
5/15/2001	6.8
6/14/2001	3.8
8/28/2001	5.5
10/24/2001	4
12/12/2001	10.3
1/9/2002	12.8
3/6/2002	11.5
4/10/2002	8.8
5/23/2002	8.3
6/4/2002	5
7/22/2002	5
8/28/2002	3.5
10/29/2002	7.1
12/23/2002	10.6
1/15/2003	12.1
3/10/2003	12.4
4/2/2003	9.4

Date	Dissolved Oxygen (mg/L)
5/13/2003	7.05
6/17/2003	5.84
7/29/2003	4.48
9/9/2003	4.03
10/21/2003	4.4
11/18/2003	7.5

Table A-2. Available Dissolved Oxygen Data for Segment OJ 08

Date	Dissolved Oxygen (mg/L)
1/21/1999	8.5
2/10/1999	7.8
3/24/1999	9.5
6/1/1999	4.1
8/26/1999	4.3
10/7/1999	4
12/1/1999	6.6
1/6/2000	8.9
2/8/2000	15.6
4/27/2000	7.2
6/5/2000	4.5
7/31/2000	5.5
9/20/2000	3.6
10/18/2000	3.4
11/13/2000	8.3
2/5/2001	12.3
3/5/2001	10.9
4/5/2001	8.9
5/8/2001	3.4
7/10/2001	4
8/9/2001	3.2
9/26/2001	6
11/6/2001	3.9
12/10/2001	8.5
1/30/2002	9.6
3/5/2002	11.7
4/2/2002	8.4

Date	Dissolved Oxygen (mg/L)
5/9/2002	5.2
6/6/2002	3.2
7/23/2002	3.4
8/26/2002	3.7
10/30/2002	6.3
12/12/2002	8.7
1/15/2003	12.2
3/12/2003	10.8
4/16/2003	5.8
5/13/2003	4.3
6/17/2003	3.82
7/29/2003	4.58
9/9/2003	4
10/21/2003	4.1
11/18/2003	4.8

Table A-3. Available Dissolved Oxygen data for Segment OJA 01

Date	Dissolved Oxygen (mg/L)
6/20/2002	3.6
7/22/2002	1.3
8/26/2002	2.5
9/7/2006	3.7
10/19/2006	4.7

Table A-4. Available Dissolved Oxygen Data for Segment OZH OK A2

Date	Dissolved Oxygen (mg/L)
8/22/2002	2.2
9/8/2006	6.8
10/19/2006	5.3

Table A-5. Available Dissolved Oxygen Data for Segment OZH OK C2

Date	Dissolved Oxygen (mg/L)
8/22/2002	4.8
9/8/2006	1.1
10/19/2006	2.5

Table A-6. Available Dissolved Oxygen Data for Segment OZH OK C3

Date	Dissolved Oxygen (mg/L)
8/22/2002	1.2
9/8/2006	4.1
10/19/2006	5.2

Appendix B. : QUAL2K Modeling

B.0 Dissolved Oxygen Model (QUAL2K)

The QUAL2K water quality model was selected to assess water quality conditions for the dissolved oxygen impaired streams in the Crooked Creek watershed. QUAL2K is supported by U.S. EPA and has been used extensively for TMDL development and point source permitting issues across the country, especially for issues related to dissolved oxygen concentrations. The QUAL2K model is suitable for simulating hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics. Three QUAL2K models were set up for each impaired stream to address the low dissolved oxygen conditions. The impaired streams were Plum Creek, Little Crooked Creek, and Crooked Creek.

The impaired streams were segmented into a series of stream reaches in the QUAL2K model and the stream reaches were further divided into cells (or “elements”). Flow and mass balance calculations are performed within each cell for each time step that the user specifies. The specifications of reach and element lengths for each QUAL2K model were determined based on the hydrogeometry of the streams, tributary locations, point and nonpoint source locations, and the flow and water quality sampling points.

QUAL2K models require hourly weather data to simulate temperature and other biochemical reactions. The hourly weather data for air temperature, dew point temperature, wind speed, and cloud cover were retrieved from the National Climatic Data Center (NCDC) web site and the available weather data for the Effingham County Memorial Airport was selected for all of the QUAL2K models.

Each model required two different sets of calibrations: (1) flow and (2) water quality. To be conservative, the date of the calibration was set to match the date of the lowest observed dissolved oxygen data (and where sufficient data were available for calibration). If observed flow data from the impaired segments were available, they were used during the calibration. When the observed flow data were not available, USGS data from gage 05593520 and 05593575 were used to estimate flow rates at each calibration location. The estimated flows were derived using the area weighted estimation method.

Flows from NPDES facilities were incorporated using monthly averaged reported flow data during the flow calibration period. After the calibrations were completed, the baseline conditions for flows from NPDES facilities were set using each facility’s design averaged flow. After inputting flows for headwaters, tributaries, and point sources, flow was calibrated by either subtracting or adding nonpoint source flows. Table B-1 shows the flows used to set up the baseline conditions for the models.

Table B-1. Baseline conditions for NPDES flow discharges

Facility Name	Permit Number	Receiving Stream	Discharge point(km)*	Flow (m^3/s)
Addieville STP	IL0049140	Plum CR(OZH-OK-A2)	16.10	0.0006
American Energy	IL0075906	Little Crooked CR(OJA01)	9.00	0.0031
Central City STP	ILG580265	Crooked CR(OJ07)	59	0.0133
Centralia STP	IL0027979	Crooked CR(OJ07)	59	0.1378
Centralia WTP	IL0001252	Crooked CR(OJ07)	57.5	0.0095
Centralia-Kaskaskia College	IL0029335	Crooked CR(OJ08)	18	0.0055
Country School MHP	ILG551055	Crooked CR(OJ07)	83.3	0.0001
Hoffman STP	ILG580205	Crooked CR(OJ08)	18	0.0026
Hoyleton STP	ILG580016	Little Crooked CR(OJA01)	24.80	0.0026
Il Doc-Centralia Correctional	IL0061344	Crooked CR(OJ08)	18	0.0102
Illinois Central Rr-Centralia	IL0000779	Crooked CR(OJ08)	33	0.0005
Irvington SD WWTF	ILG580006	Crooked CR(OJ08)	33	0.0041
Junction City STP	ILG580277	Crooked CR(OJ08)	18	0.0026
Nascote Industries	IL0068136	Little Crooked CR(OJA01)	24.80	0.0003
Nashville STP	IL0027081	Little Crooked CR(OJA01)	24.80	0.0219
Odin STP	ILG580187	Crooked CR(OJ07)	57.5	0.0085
Okawville STP	ILG580268	Plum CR(OZH-OK-C2)	6.00	0.0026
Radiac Abrasives Inc-Salen	IL0059382	Crooked CR(OJ07)	83.3	0.0054
Salem STP	IL0023264	Crooked CR(OJ07)	85.5	0.1829
Salem WTP	ILG640031	Crooked CR(OJ07)	85.5	0.0017
Sandoval STP	IL0030961	Crooked CR(OJ08)	18	0.0079
United Parcel Service	IL0071242	Crooked CR(OJ08)	33	0.0000
Wamac STP	ILG580144	Crooked CR(OJ08)	33	0.0066
Woodlawn MHP	ILG551054	Crooked CR(OJ07)	50	0.0008

* The stream outlet location is 0 km.

Each QUAL2K model was calibrated to the following observed parameters (pending availability of the observed data):

a. temperature
b. dissolved oxygen (daily average and diel)
c. carbonaceous biochemical oxygen demand
d. nitrate
e. total ammonia
f. inorganic phosphorus
g. phytoplankton
h. total phosphorus
i. total kjeldahl nitrogen

When available, the observed water quality boundary concentrations were used to input as inflow loadings to the impaired segments. Sensitivity analyses were then conducted to determine the input loadings of the parameters from nonpoint sources by adjusting the loads during the calibration period. The reaction rates for nutrients and related eutrophication process were selected within the range of the literature values (Brown and Barnwell, 1986). In addition to nutrients and floating algae, sediment oxygen demand (SOD) was also incorporated in the models.

After the water quality calibrations were completed, the baseline for parameters concentrations from NPDES facilities were selected from either daily averaged or monthly averaged concentrations, depending on the permit. Table B-2 shows the baseline concentrations for NPDES facilities included in the models.

Table B-2. Baseline conditions for NPDES water quality concentrations

Facility Name	Permit Number	Receiving Stream	Discharging point(km)*	CBOD5 (mg/L)	Total Ammonia (ug/L)
Addieville STP	IL0049140	Plum CR(OZH-OK-A2)	16.10	4.0	-
American Energy	IL0075906	Little Crooked CR(OJA01)	9.00	-	-
Central City STP	ILG580265	Crooked CR(OJ07)	59	25.0	-
Centralia STP	IL0027979	Crooked CR(OJ07)	59	10.0	1500
Centralia WTP	IL0001252	Crooked CR(OJ07)	57.5	-	-
Centralia-Kaskaskia College	IL0029335	Crooked CR(OJ08)	18	10.0	1500
Country School MHP	ILG551055	Crooked CR(OJ07)	83.3	25.0	-
Hoffman STP	ILG580205	Crooked CR(OJ08)	18	25.0	-
Hoyleton STP	ILG580016	Little Crooked CR(OJA01)	24.80	3.8	-
Il Doc-Centralia Correctional	IL0061344	Crooked CR(OJ08)	18	10.0	2800
Illinois Central Rr-Centralia	IL0000779	Crooked CR(OJ08)	33	-	-
Irvington SD WWTF	ILG580006	Crooked CR(OJ08)	33	25.0	-
Junction City STP	ILG580277	Crooked CR(OJ08)	18	25.0	-
Nascote Industries	IL0068136	Little Crooked CR(OJA01)	24.80	-	-
Nashville STP	IL0027081	Little Crooked CR(OJA01)	24.80	3.8	-
Odin STP	ILG580187	Crooked CR(OJ07)	57.5	25.0	-
Okawville STP	ILG580268	Plum CR(OZH-OK-C2)	6.00	2.0	-
Radiac Abrasives Inc-Salen	IL0059382	Crooked CR(OJ07)	83.3	10.0	-
Salem STP	IL0023264	Crooked CR(OJ07)	85.5	20.0	3000
Salem WTP	ILG640031	Crooked CR(OJ07)	85.5	-	-
Sandoval STP	IL0030961	Crooked CR(OJ08)	18	25.0	-
United Parcel Service	IL0071242	Crooked CR(OJ08)	33	10.0	-
Wamac STP	ILG580144	Crooked CR(OJ08)	33	25.0	-
Woodlawn MHP	ILG551054	Crooked CR(OJ07)	50	25.0	-

* The stream outlet location is 0 km.

The following figures show the model calibration results.

References

Brown and Barnwell. 1987. The Enhanced Stream Water Quality Models QUAL2E and Qual2E-UNCAS: Documentation and user manual, Linfield C. Brown and Thomas O. Barnwell, Jr. Department of Civil Engineering Tufts University, MA, 1987

Appendix C. : BATHTUB Model

C.0 Estimating Existing Loads and Flows to the Crooked Creek Watershed Lakes

The ACOE BATHTUB model (Walker, 1987) was set up to simulate nutrient concentrations in the impaired lakes in the Crooked Creek watershed using the second order nutrient response model. In a separate application, the model was altered to simulate manganese concentrations using the fixed sedimentation option.

C.1 Centralia Lake Watershed Loading

Annual flow rates to Centralia Lake were estimated by area weighting flows observed at USGS gage 05593575 on Little Crooked Creek near New Minden, Il. The Centralia Lake drainage area is approximately 6.28 square miles and the drainage area to the Little Crooked Creek gage is 84.30 square miles. Daily average flow rates at the gage were scaled down by 0.074 (6.28/84.30) to estimate daily flows to the lake.

There are no permitted facilities discharging upstream of Centralia Lake (either directly into the lake or into tributaries of the lake), however the Centralia Community Water Supply withdraws a portion of its drinking water supply from Centralia Lake. The Centralia Community Water Supply has intakes in both Centralia Lake and Raccoon Lake, and the average daily pumpage for both lakes combined is 3.9 MGD. About 0.028 MGD are withdrawn from Centralia Lake, for an annual total of around 10.25 million gallons (personal communication with Perry White at the Centralia Water Treatment Plant, 11/13/07). This annual withdrawal was subtracted from the estimated flow rate to Centralia Lake.

C.1.1 Centralia Lake Sedimentation and Internal Loading

The “reverse” BATHTUB model was altered to simulate manganese concentrations in Centralia Lake using the fixed sedimentation option. For a conservative estimate, the sedimentation rate was set to zero. The model was then used to back calculate the loads required to simulate the observed concentrations. The resulting load is equivalent to the external watershed load plus the net load resulting from sedimentation and release from bottom sediments. Sufficient data to estimate the internal load separately are not currently available.

C.1.2 Summary of Centralia Lake Inlake Water Quality Data

Typically, watershed loads are input to the BATHTUB model and average inlake concentration is output. However, watershed and tributary data are not available to estimate loads to the lake. A limited number of inlake observations of total manganese concentration have been collected across 5 months in 2001 at one sampling location (ROI-1) and a limited number of inlake observations of total phosphorus concentrations have been collected during 1998 and 2001 at three stations. A “reverse” BATHTUB model was therefore applied where average inlake concentrations were used to estimate the load required given annual flow volume and lake bathymetry data. No adjustment of the calibration factor was needed with this simulation because the loads were set by year to match average observed concentrations. Table C-1 summarizes the total manganese data by year, and Table C-2 summarizes the total phosphorus data by year.

Table C-1. Total Manganese Observations in Centralia Lake (µg/L)

Year	Minimum	Average	Maximum
2001	87	187	290

Table C-2. Total Phosphorus Observations in Centralia Lake (mg/L)

Year	Minimum	Average	Maximum
1998	0.052	0.108	0.266
2001	0.035	0.078	0.175

The total manganese loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-3. The total phosphorus loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-4. An annual simulation was required for this lake to meet BATHTUB's turnover ratio criteria.

Table C-3. Annual Flows and Estimated Total Manganese Loads to Centralia Lake

Year	Flow (MG)	Manganese Load (lb)
2001	615	961

Table C-4. Annual Flows and Estimated Total Phosphorus Loads to Centralia Lake

Year	Flow (MG)	Phosphorus Load (lb)
1998	1,697	6,404
2001	615	2,154

C.1.3 Centralia Lake BATHTUB Modeling Results

Once the existing manganese loads were determined for Centralia Lake, an iterative process was used to determine the load reductions required to meet the water quality standard for this lake. The model predicts that reducing loads by 20 percent will likely meet the water quality target. Once the total phosphorus loads were determined for each modeling year, the BATHTUB model was used to determine the reduction in loading required to meet the phosphorus water quality standard. A reduction of 74 percent results in simulated concentrations below the target in each modeling year.

C.2 Raccoon Lake Watershed Loading

Annual flow rates to Raccoon Lake were estimated by area weighting flows observed at USGS gage 05593575 on Little Crooked Creek near New Minden, Il. The Raccoon Lake drainage area is approximately 48.45 square miles and the drainage area to the Little Crooked Creek gage is 84.30 square miles. Daily average flow rates at the gage were scaled down by 0.574 (48.45/84.30) to estimate daily flows to the lake.

One NPDES permitted facility, the Raccoon Consolidated School (# IL0052981), discharges to an Unnamed Tributary that eventually flows into Raccoon Lake. The facility's design average flow is 0.0125 MGD, and this value was multiplied by 365 days and added to the estimated annual flows to Raccoon Lake to account for the additional flow.

Additionally, the Centralia Community Water Supply withdraws a portion of its drinking water supply from Raccoon Lake. The Centralia Community Water Supply has intakes in both Raccoon Lake and Centralia Lake, and the average daily pumpage for both lakes combined is 3.9 MGD. The Raccoon Lake withdrawal accounts for 3.839 MGD of the total pumpage (an average of the 2004-2006 annual Raccoon Lake withdrawals obtained through personal communication with Perry White of the Centralia Water Treatment Plant, 11/13/07). This value was multiplied by 365 days and subtracted from the total inflow from the watershed to account for the public water supply withdrawal.

C.2.1 Raccoon Lake Sedimentation and Internal Loading

The "reverse" BATHTUB model was altered to simulate manganese and atrazine concentrations in Raccoon Lake using the fixed sedimentation option. For a conservative estimate, the sedimentation rate was set to zero for both parameters. The model was then used to back calculate the loads required to simulate the observed concentrations. The resulting load is equivalent to the external watershed load plus the net load resulting from sedimentation and release from bottom sediments. Sufficient data to estimate the internal load separately are not currently available.

C.2.2 Summary of Raccoon Lake Inlake Water Quality Data

Typically, watershed loads are input to the BATHTUB model and average inlake concentration is output. However, watershed and tributary data are not available to estimate loads to the lake. The available inlake total phosphorus, manganese, and atrazine observations were therefore used in a "reverse" BATHTUB modeling application. Table C-5 summarizes the total manganese data by year, Table C-6 summarizes the total phosphorus data by year, and Table C-7 summarizes the atrazine data by year.

Table C-5. Total Manganese Observations in Raccoon Lake (µg/L)

Year	Minimum	Average	Maximum
2001	87	187	290

Table C-6. Total Phosphorus Observations in Raccoon Lake (mg/L)

Year	Minimum	Average	Maximum
1998	0.052	0.108	0.266
2001	0.035	0.078	0.175

Table C-7. Summer (May-September) Atrazine Observations in Raccoon Lake (μg/L)

Year	Minimum	Average	Maximum
2003	0.23	4.25	23.95
2004	0.05	1.93	3.75

Notes: A limited number of inlake observations of atrazine concentration have been collected in 2001 by the IEPA at one sampling location (ROK-1), and in 2003 and 2004 as part of the Centralia Community Water Supply's water intake sampling. Due to very low estimated inflows to Raccoon Lake during the summer of 2001, only the 2003 and 2004 data were used.

The total manganese loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-8. The total phosphorus loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-9. An annual simulation for manganese and phosphorus was required for this lake to meet BATHTUB's turnover ratio criteria.

Table C-8. Annual Flows and Estimated Total Manganese Loads to Raccoon Lake

Year	Flow (MG)	Manganese Load (lb)
2001	3,429	5,695

Table C-9. Annual Flows and Estimated Total Phosphorus Loads to Raccoon Lake

Year	Flow (MG)	Phosphorus Load (lb)
1998	11,772	75,001
2001	3,429	45,481

The atrazine loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-10. Summer loads were used during the analysis because they were the critical period for atrazine (i.e., the annual average loads did not result in an exceedances of the water quality standard).

Table C-10. Summer Flows and Estimated Atrazine Loads to Raccoon Lake

Year	Summer Flow (MG)	Atrazine Load (lb)
2003	5,299	1,900
2004	3,842	61

C.2.3 Raccoon Lake BATHTUB Modeling Results

Once the existing loads were determined for Raccoon Lake, an iterative process was used to determine the load reductions required to meet the water quality standards. The model predicts that reducing loads by 25 percent for manganese, 96 percent for phosphorus, and 31 percent for atrazine will likely meet the water quality standards.

C.3 Nashville City Lake Watershed Loading

Annual flow rates to Nashville City Lake were estimated by area weighting flows observed at USGS gage 05593575 on Little Crooked Creek near New Minden, Il. The Nashville City Lake drainage area is approximately 1.56 square miles and the drainage area to the Little Crooked Creek gage is 84.30 square miles. Daily average flow rates at the gage were scaled down by 0.019 (1.56/84.30) to estimate daily flows to the lake.

One NPDES permitted facility, the Nashville Water Treatment Plant (# IL0069701), discharges to Nashville Creek that eventually flows into Nashville City Lake. The facility's design average flow is 0.056 MGD, and this value was multiplied by 365 days and added to the estimated annual flows to Nashville City Lake to account for the additional flow. Additionally, the Nashville Community Water Supply withdraws a portion of its drinking water supply from Nashville City Lake. The Nashville Community Water Supply has one intake in the Nashville City Lake, however to maintain lake levels, water is withdrawn from Washington County Lake and the Kaskaskia River and pumped into Nashville City Lake (Personal communication, Blaine Middleton of the Nashville Water Treatment Plant, 11/13/07). The overall result is a net water loss of zero, therefore no withdrawals were subtracted from the annual flows to the lake.

C.3.1 Nashville City Lake Sedimentation and Internal Loading

The "reverse" BATHTUB model was altered to simulate manganese concentrations in Nashville City Lake using the fixed sedimentation option. For a conservative estimate, the sedimentation rate was set to zero. The model was then used to back calculate the loads required to simulate the observed concentrations. The resulting load is equivalent to the external watershed load plus the net load resulting from sedimentation and release from bottom sediments. Sufficient data to estimate the internal load separately are not currently available.

C.3.2 Summary of Nashville City Lake Inlake Water Quality Data

Table C-11 summarizes the total phosphorus data by year resulting from the reverse BATHTUB application of Nashville City Lake.

Table C-11. Total Phosphorus Observations in Nashville City Lake (mg/L)

Year	Minimum	Average	Maximum
1998	0.334	0.754	0.992
1999	0.626	0.626	0.626
2000	0.032	0.466	1.480

The total phosphorus loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-12. An annual simulation was required for this lake to meet BATHTUB's turnover ratio criteria.

Table C-12. Annual Flows and Estimated Total Phosphorus Loads to Nashville City Lake

Year	Flow (MG)	Phosphorus Load (lb)
1998	444	52,425
1999	346	31,195
2000	315	16,579

C.3.3 Nashville City Lake BATHTUB Modeling Results

Once the total phosphorus loads were determined for each modeling year, the BATHTUB model was used to determine the reduction in loading required to meet the phosphorus water quality standard. A reduction of 99.3 percent results in simulated concentrations below the target in each modeling year.

C.4 Salem Lake Watershed Loading

Annual flow rates to Salem Lake were estimated by area weighting flows observed at USGS gage 05593575 on Little Crooked Creek near New Minden, Il. The Salem Lake drainage area is approximately 4.03 square miles and the drainage area to the Little Crooked Creek gage is 84.30 square miles. Daily average flow rates at the gage were scaled down by 0.048 (4.03/84.30) to estimate daily flows to the lake.

There are no permitted facilities discharging upstream of Salem Lake (either directly into the lake or into tributaries of the lake), however the Salem Community Water Supply withdraws a portion of its drinking water supply from Salem Lake. The Salem Community Water Supply has intakes in both Salem Lake and Carlyle Lake, and the average daily pumpage for both lakes combined is 1.72 MGD. Because lake-specific pumpage data were not available, the withdrawals from Salem Lake were estimated by calculating its proportion of the total drainage area of both Salem Lake and Carlyle Lake combined, then multiplying that ratio by the total pumpage of 1.72 MGD for both lakes. Salem Lake makes up about 0.15 percent of the total drainage area, and the resulting fraction of the total pumpage is 0.0016 MGD. This value was multiplied by the averaging period (365 days) and subtracted from the total inflow from the watershed to account for the public water supply withdrawal.

C.4.1 Salem Lake Sedimentation and Internal Loading

The “reverse” BATHTUB model was altered to simulate manganese concentrations in Salem Lake using the fixed sedimentation option. For a conservative estimate, the sedimentation rate was set to zero. The model was then used to back calculate the loads required to simulate the observed concentrations. The resulting load is equivalent to the external watershed load plus the net load resulting from sedimentation and release from bottom sediments. Sufficient data to estimate the internal load separately are not currently available.

C.4.2 Summary of Salem Lake Inlake Water Quality Data

A limited number of inlake observations of total manganese concentration have been collected across 5 months in 1999 at one sampling location (ROR-1). The “reverse” BATHTUB model was therefore used to estimate existing loads based on observed conditions within the lake. Table C-13 summarizes the total manganese data by year, and Table C-14 summarizes the total phosphorus data by year.

Table C-13. Total Manganese Observations in Salem Lake (µg/L)

Year	Minimum	Average	Maximum
1999	12	244	440

Table C-14. Total Phosphorus Observations in Salem Lake (mg/L)

Year	Minimum	Average	Maximum
1999	0.080	0.157	0.234

The total manganese loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-15. The total phosphorus loads required to simulate the observed concentrations with the BATHTUB model are listed in Table C-16. An annual simulation was required for this lake to meet BATHTUB's turnover ratio criteria.

Table C-15. Annual Flows and Estimated Total Manganese Loads to Salem Lake

Year	Flow (MG)	Manganese Load (lb)
1999	839	1,711

Table C-16. Annual Flows and Estimated Total Phosphorus Loads to Salem Lake

Year	Flow (MG)	Phosphorus Load (lb)
1999	839	3,351

C.4.3 Salem Lake BATHTUB Modeling Results

Once the existing manganese loads were determined for Salem Lake, an iterative process was used to determine the load reductions required to meet the water quality standard for this lake. Reducing loads by 39 percent will likely meet the water quality target. Once the total phosphorus loads were determined for each modeling year, the BATHTUB model was used to determine the reduction in loading required to meet the phosphorus water quality standard. A reduction of 83 percent results in simulated concentrations below the target in each modeling year.

Appendix D. : Stage 1 Report

Appendix E. : Stage 2 Report

Appendix F. : Responsiveness Summary

Crooked Creek Watershed TMDL Implementation Plan

FINAL REPORT

February 2008

Submitted to:
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62702

Submitted by:
Tetra Tech

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KEY FINDINGS

The results of a TMDL study for the Crooked Creek watershed indicate that significant reductions of total phosphorus and manganese are needed to attain water quality standards in four lakes in the drainage area. In addition, reductions of atrazine loads to Raccoon Lake are required to achieve water quality standards.

The largest potential sources of pollutant loading in the watershed are agricultural practices. Manure from animal operations contributes nutrients, pathogens, and biodegradable organic material. In addition, animals with access to stream channels can deposit nutrients directly into or near the stream and erode the banks as they climb in and out. This erosion leads to increased loads of sediment and manganese, a metal common in soils. The BMPs most likely to control loading from animal operations are 1) proper handling, storage, and final disposal practices for manure, 2) vegetative controls such as grassed waterways, filter strips, and constructed wetlands, 3) manure composting, and 4) restoration of riparian buffers.

Crop production in the watershed results in loadings of nutrients, sediment, manganese, and pesticides to the watershed. Application of fertilizers and pesticides contributes phosphorus and atrazine to the waterbodies when rain events wash pollutants into nearby streams or through underlying tile drain systems. Increased rates of erosion result in excessive sediment and manganese loads. The most cost-effective management strategy that addresses all pollutants of concern is conservation tillage. Other effective practices include grass waterways, filter strips, fertilizer and pesticide management, and restoration of riparian buffers.

Pollutant loads from point sources in the watershed may be significant, but the actual loads are difficult to estimate because several of the facilities are not required to monitor for the TMDL pollutants. Given that most of these facilities provide at least a secondary level of wastewater treatment, it is not likely that IEPA will require them to upgrade their plants to reduce nutrient or organic loading. The State may request that facilities submit TMDL pollutant data to verify that water quality standards are being met.

The density of onsite wastewater treatment systems in the watershed is relatively sparse and loading from this source is likely not significant relative to the other sources. However, failing onsite systems may cause localized water quality impacts as well as risks to human health. Identifying these systems through a routine inspection program and encouraging proper maintenance and upkeep will minimize these impacts.

1.0 INTRODUCTION

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters identified as impaired on the Section 303(d) lists. Several waterbodies in the Crooked Creek watershed are listed on Illinois' 2006 303(d) list as described in Table 1-1 and shown in Figure 1-1.

Table 1-1. 2006 303(d) List Information for the Crooked Creek Watershed.

Waterbody Name	Waterbody Segment	Segment and Lake Size (Segment Length in Miles, Lake Area in Acres)	Cause of Impairment	Impaired Designated Use
Crooked Creek	OJ-07	30.84	Dissolved Oxygen	Aquatic Life
			pH	Aquatic Life
			Total Phosphorus	Aquatic Life
Crooked Creek	OJ-08	21.5	Dissolved Oxygen	Aquatic Life
			Total Nitrogen	Aquatic Life
			pH	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Little Crooked Creek	OJA-01	16.64	Dissolved Oxygen	Aquatic Life
			Manganese*	Aquatic Life
			Total Phosphorus	Aquatic Life
Plum Creek	OZH-OK-A2	6.73	Dissolved Oxygen	Aquatic Life
			Manganese*	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
Plum Creek	OZH-OK-C2	1.85	Dissolved Oxygen	Aquatic Life
			Total Phosphorus	Aquatic Life
Plum Creek	OZH-OK-C3	2.04	Dissolved Oxygen	Aquatic Life
			Manganese*	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
Centralia Lake	ROI	450	Manganese	Public Water Supplies

Waterbody Name	Waterbody Segment	Segment and Lake Size (Segment Length in Miles, Lake Area in Acres)	Cause of Impairment	Impaired Designated Use
			Total Phosphorus	Aesthetic Quality
			Total Suspended Solids	Aesthetic Quality
Raccoon Lake	ROK	925	Atrazine	Aquatic Life
			Dissolved Oxygen	Aquatic Life
			Manganese	Public Water Supplies
			pH	Aquatic Life
			Total Phosphorus	Aesthetic Quality
				Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aesthetic Quality
				Aquatic Life
Nashville City Lake	ROO	42	Manganese	Public Water Supplies
			Total Phosphorus	Aesthetic Quality
			Total Suspended Solids	Aesthetic Quality
Salem Lake	ROR	74.2	Dissolved Oxygen	Aquatic Life
			Manganese	Public Water Supplies
			Total Phosphorus	Aesthetic Quality
				Aquatic Life
			Total Suspended Solids	Aesthetic Quality
				Aquatic Life

*Recommended for de-listing (see Section 1).

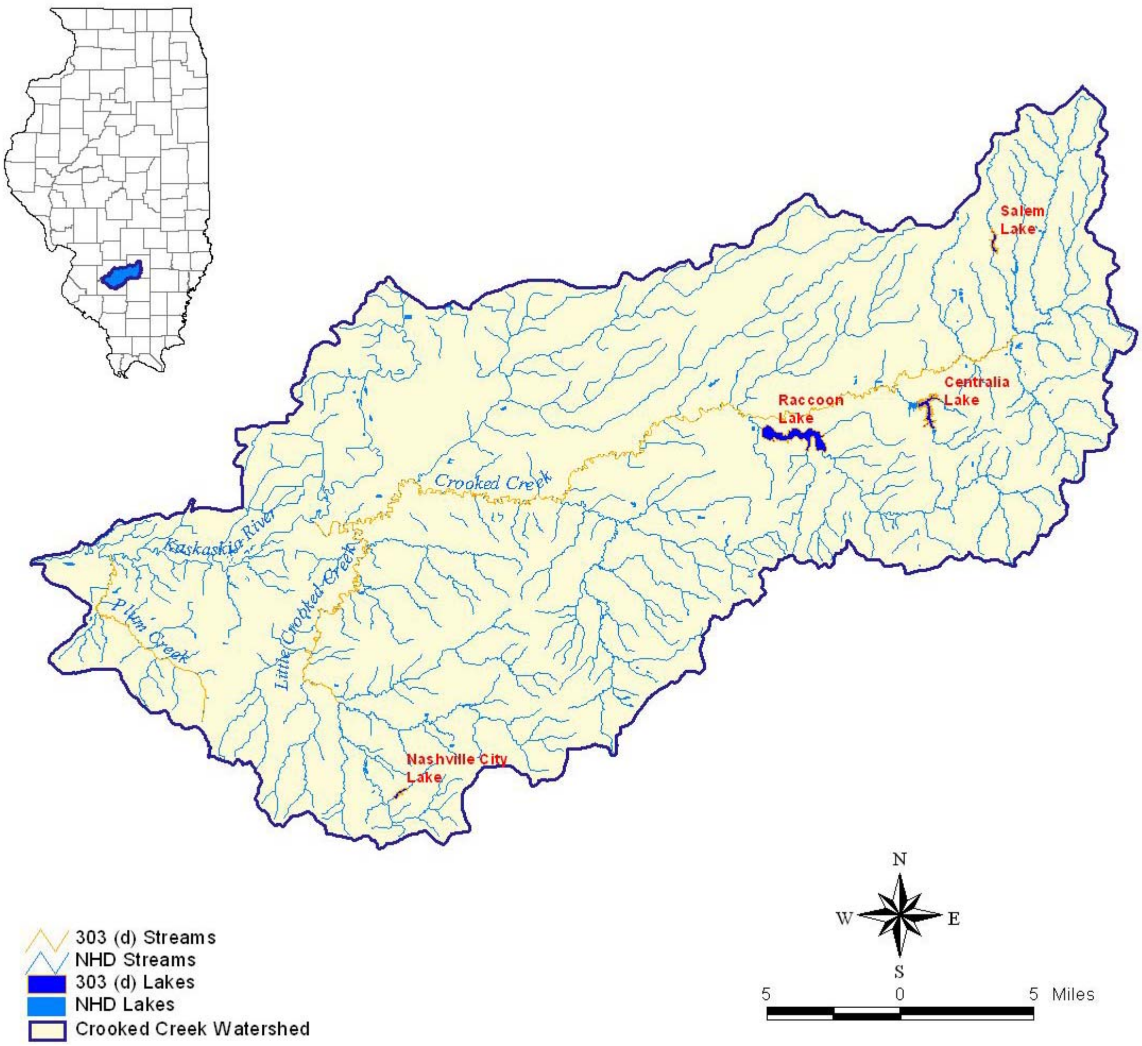

Figure 1-1. 303(d) Listed Waterbodies in the Crooked Creek Watershed.

IEPA is currently developing TMDLs for pollutants that have numeric water quality standards. Of the pollutants impairing waterbodies in the Crooked Creek watershed, total phosphorus, dissolved oxygen, manganese, atrazine, and pH have numeric water quality standards. IEPA believes that addressing these impairments should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. For example, reducing loads of phosphorus should result in less algal growth and some of the management measures taken to reduce phosphorus loads (e.g., reducing agricultural erosion) should also reduce loads of suspended solids.

This project is being initiated in three stages. Stage One was completed in the spring of 2006 and involved the characterization of the watershed, an assessment of the available water quality data, and identification of potential technical approaches. Stage Two involves additional data collection for waters where a TMDL could not yet be developed (i.e., Little Crooked Creek and Plum Creek). The first part of Stage Three involved modeling and TMDL analyses; the final component of Stage Three is this implementation plan, outlining how the TMDL reductions will be achieved.

The TMDLs for the waterbodies in the Crooked Creek watershed were developed using the QUAL2K and BATHTUB models. Due to the number of listed segments in the watershed, this report will not detail the TMDL process. Readers interested in the details of each TMDL may refer to the Stage Three report which is available online at:

http://www.epa.state.il.us/water/tmdl/

2.0 DESCRIPTION OF WATERBODY AND WATERSHED CHARACTERISTICS

The purpose of this section of the report is to provide a brief background of the Crooked Creek watershed. More detailed information on the soils, topography, land use/land cover, climate, and population are available in the Stage One Watershed Characterization Report.

Soils in the watershed are primarily IL006 (Cisne-Hoyleton-Darmstadt), IL038 (Bluford-Ava-Hickory), and IL005 (Cowden-Oconee-Darmstadt) (Figure 2-1). Soil erodibility factors reported for these soils in the STATSGO database range from 0.352 to 0.4174, indicating moderate soil erodibility. Soils identified by STATSGO as highly erodible generally have slopes greater than 5 percent and represent 23 percent of the total watershed area (Figure 2-2). Most of the highly erodible soils are currently on lands used for crop production or pasture.

The depths to the water table reported in the STATSGO database for soils in the Crooked Creek watershed range from 0.38 feet to 4.04 feet. Tile drainage systems are usually placed 3 to 4 feet below the soil surface to lower the depth. The use of tile drains may be common in the watershed.

Land use/land cover in the watershed is largely crop production (52 percent) based on satellite imagery collected around 2001 (INHS, 2003) (Figure 2-3). Additional land use/land cover includes pasture/hay (17.7 percent), forest (14.4 percent), urban areas (11.3 percent), and wetlands (3.6 percent).

The Crooked Creek watershed is part of the Kaskaskia watershed addressed by the Kaskaskia Watershed Association, Inc. (Appendix A). This partnership includes the entire Kaskaskia watershed in the Midwest/Northern High Plains Region of Illinois. In 2002, the association developed a comprehensive watershed management strategy whose goal is to develop, enhance and protect the ecological and socio ecological values of the natural resources within the Kaskaskia River Watershed.

http://www.swircd.org/swircd/projects/Kaskaskia-Basin-Plan.htm

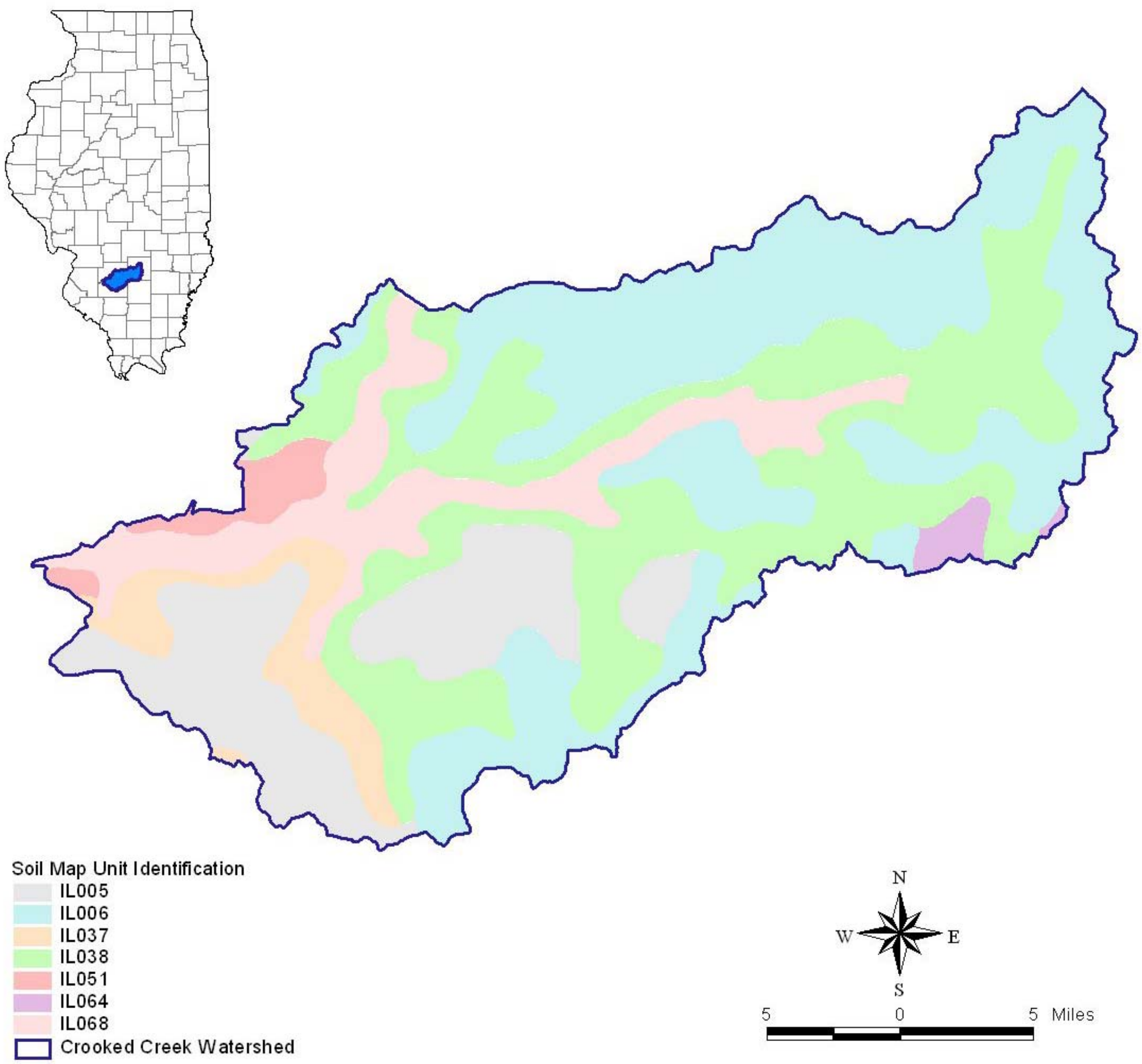

Figure 2-1. Soil Types in the Crooked Creek Watershed.

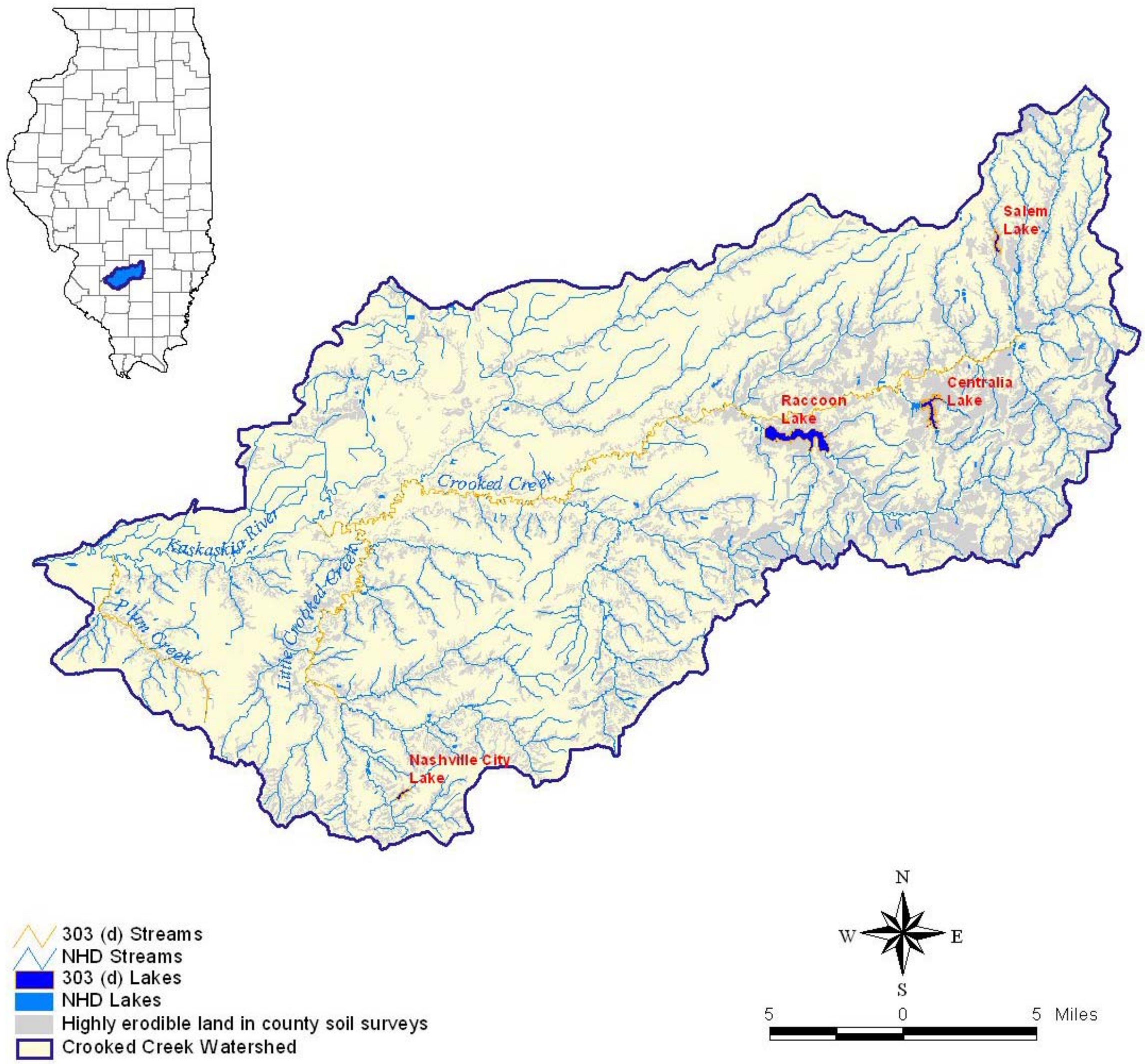

Figure 2-2. Highly Erodible Soils in the Crooked Creek Watershed.

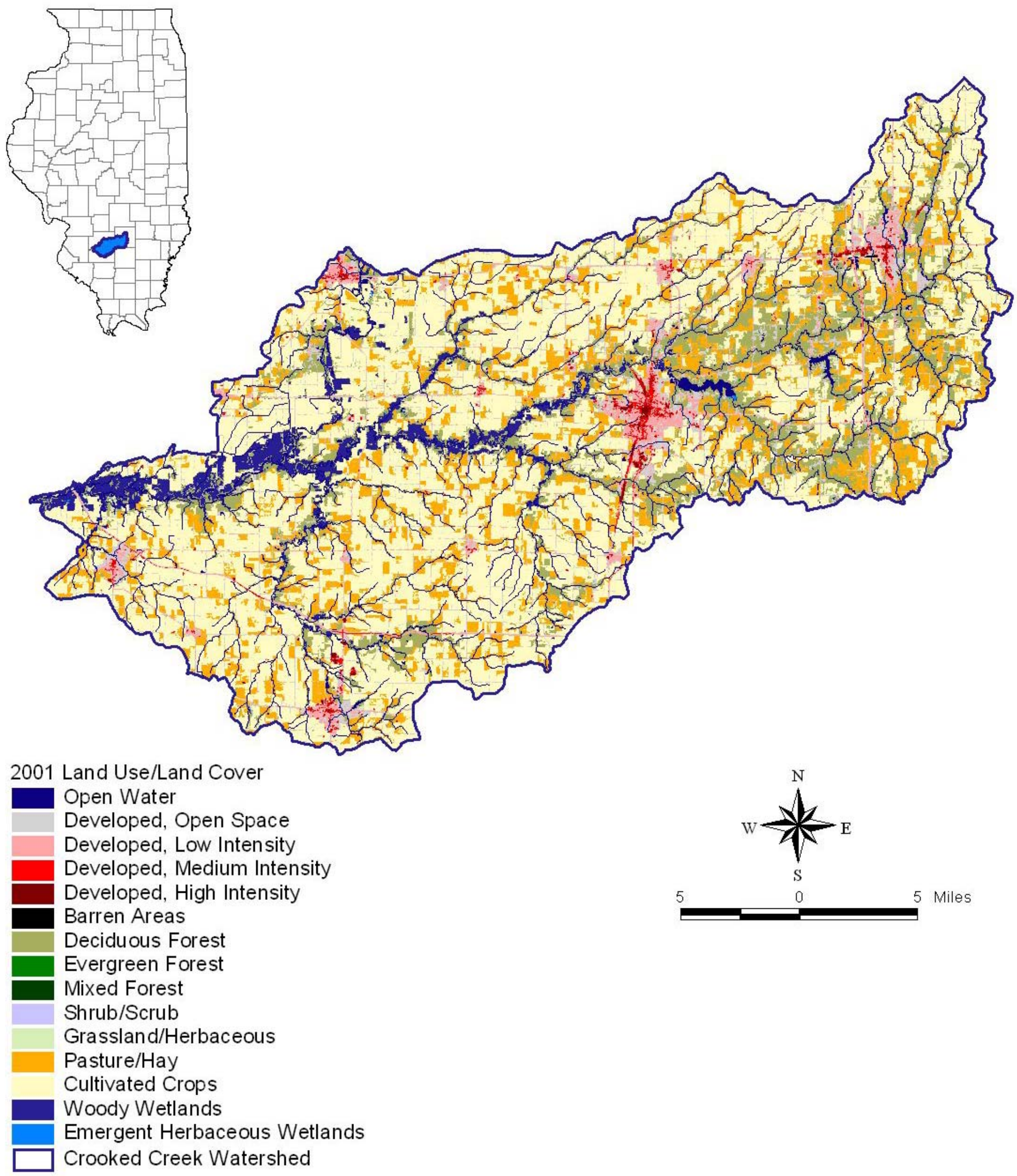

Figure 2-3. Land Use/Land Cover in the Crooked Creek Watershed (Year 2001 NLCD Data).

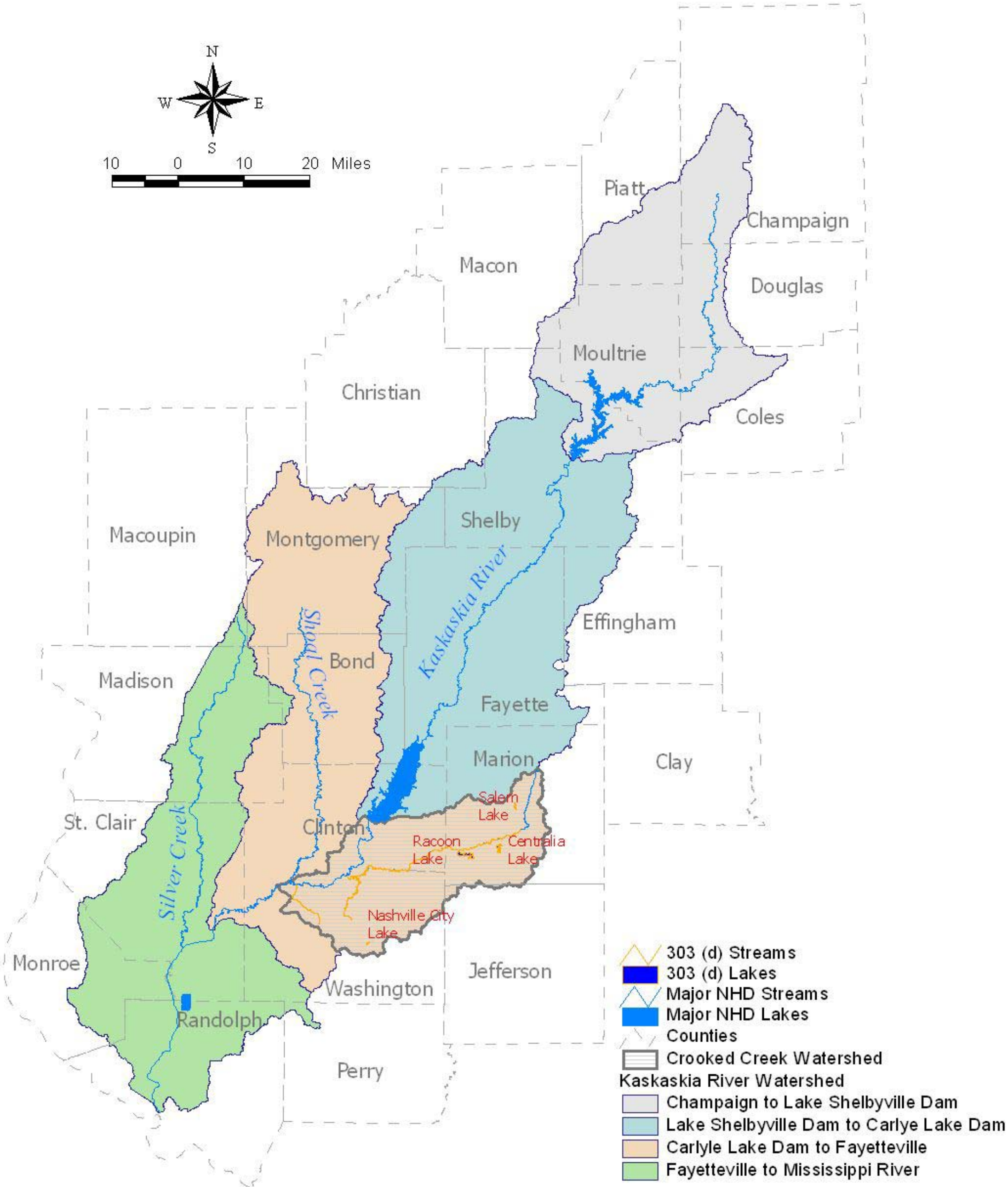

Figure 2-4. Kaskaskia River Watershed.

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3.0 WATER QUALITY DATA, IMPAIRMENTS, AND TMDL ALLOCATIONS

Waters in the Crooked Creek watershed are currently listed for several impairments. Those that have numeric water quality standards (total phosphorus, dissolved oxygen, manganese, atrazine, and pH) are addressed in this implementation plan. This section presents the applicable water quality standards for each parameter and a summary of the listed reaches and TMDL allocations in the watershed. More detailed discussions of the available water quality data and TMDL development are presented in the Stage One Watershed Characterization Report and Stage Three TMDL Development Report, respectively. For the purposes of this report, which is targeted for stakeholders in the watershed, loads for mass-based pollutants are expressed in pounds per day or pounds per year. The TMDL report expressed loads in kilograms because the simulation models run and generate output in metric units.

To assess the designated use support for Illinois waterbodies, the IEPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB). The following are the use support designations applicable in the Crooked Creek watershed:

General Use Standards - These standards protect for aquatic life, wildlife, agricultural use, primary contact recreation (where physical configuration of the waterbody permits it), secondary contact recreation, and most industrial uses. Primary contact recreation includes any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing. Secondary contact recreation includes any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating, and any limited contact incident to shoreline activity. These standards are also designed to ensure the aesthetic quality of the state's aquatic environment.

Public and Food Processing Water Supply Standards – These standards are cumulative with the general use standards and apply to waters of the state at any point at which water is withdrawn for treatment and distribution as a potable supply to the public or for food processing.

3.1 Total Phosphorus

3.1.1 Water Quality Standards

The numeric water quality standard for total phosphorus requires that concentrations at one foot from the water surface remain at or below 0.05 mg/L in lakes with a surface area of at least 20 ac. The standard also applies to streams at the point that they enter a lake or reservoir.

3.1.2 Impairments in the Crooked Creek Watershed

Centralia Lake, Raccoon Lake, Nashville City Lake, and Salem Lake are all in violation of the numeric phosphorus standard. Table 3-1 summarizes the total phosphorus data collected in these lakes; Figure 3-1 shows the location of these waterbodies listed for total phosphorus in the watershed.

Table 3-1. Summary of Total Phosphorus Data Collected in Newton Lake.

Waterbody Name (Segment ID)	Number of Samples	Average TP (mg/L)	Exceedance (percent)
Centralia Lake (ROI)	73	0.074	64
Raccoon Lake (ROK)	200	0.195	99.5
Nashville City Lake (ROO)	107	1.019	99
Salem Lake (ROR)	64	0.226	100

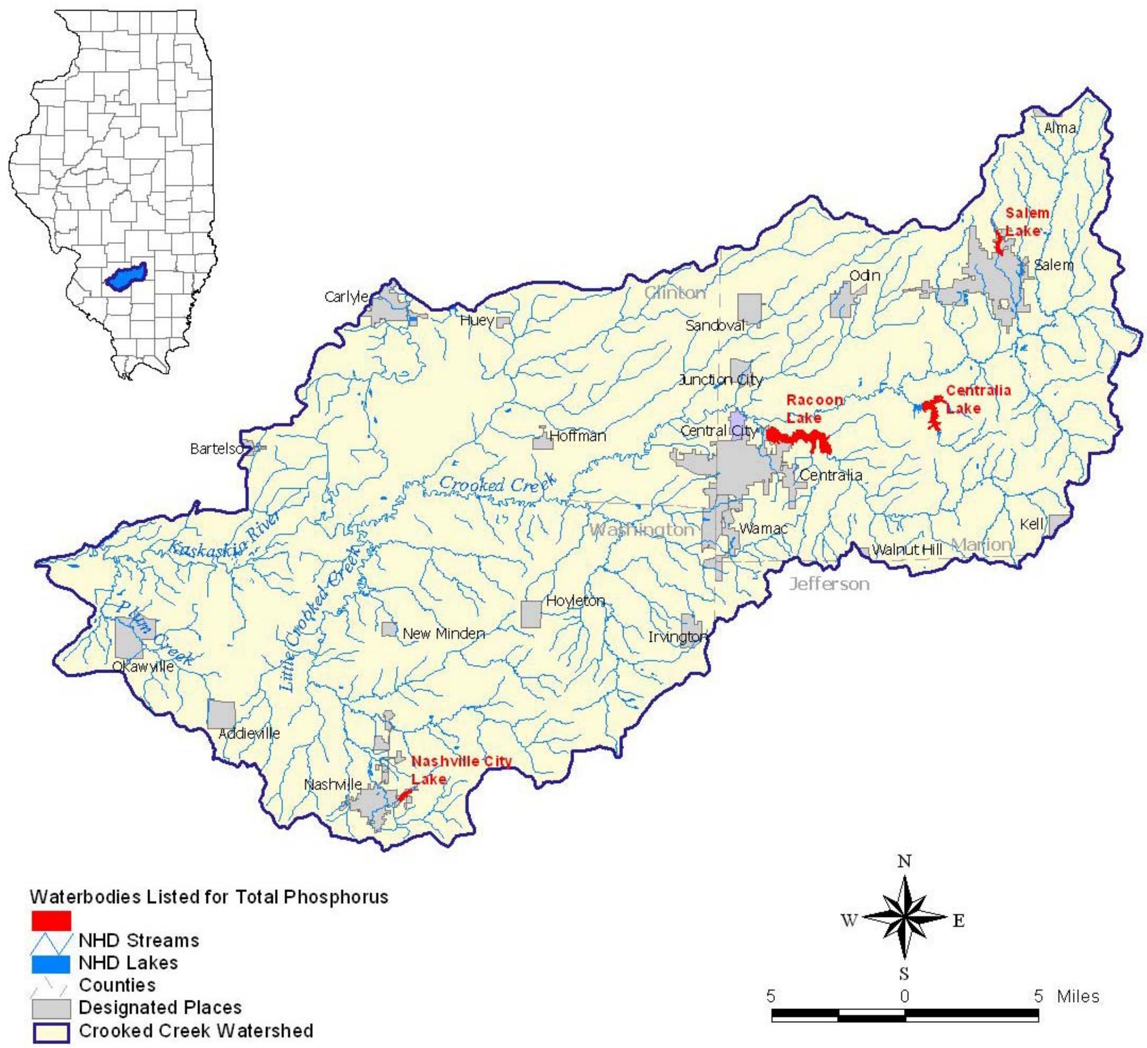

Figure 3-1. Waterbodies Listed for Phosphorus Impairment in the Crooked Creek Watershed.

3.1.3 TMDL Allocations

The phosphorus TMDLs for the listed lakes require reductions in phosphorus loading of 74 to 99 percent. The allocations are summarized in Table 3-2.

Table 3-2. Phosphorus TMDL Allocations

Lake	Category	Phosphorus (lb/yr)	Phosphorus (lb/d)
Centralia Lake (ROI)	Existing Load	4,279	11.7
	Loading Capacity	1,058	2.9
	Wasteload Allocation	0	0.0
	Margin of Safety	55	0.2
	Load Allocation	1,003	2.7
Nashville City Lake (ROO)	Existing Load	33,400	91.5
	Loading Capacity	223	0.6
	Wasteload Allocation	n/a	n/a
	Margin of Safety	11	0.0
	Load Allocation	212	0.6
Raccoon Lake (ROK)	Existing Load	60,241	165.0
	Loading Capacity	2,288	6.3
	Wasteload Allocation	152	0.4
	Margin of Safety	121	0.3
	Load Allocation	2,015	5.5
Salem Lake (ROR)	Existing Load	3,351	9.2
	Loading Capacity	540	1.5
	Wasteload Allocation	0	0.0
	Margin of Safety	29	0.1
	Load Allocation	511	1.4

3.2 Dissolved Oxygen

No loading allocations were defined for the dissolved oxygen impairments in the Crooked Creek watershed. QUAL2K modeling of each impaired reach determined that load reductions of degradable material from point and nonpoint sources would not achieve the water quality targets. The strategy for improving dissolved oxygen conditions in these waterbodies will be to focus on reducing pollutant load reductions to the extent practicable, implement stream protection measures, and increase canopy cover where necessary. In some cases, stream restoration to improve reaeration may be needed.

3.3 Manganese

3.3.1 Water Quality Standards

The general use water quality standard for manganese is 1,000 µg/L, and the public and food processing water supply standard is 150 µg/L.

3.3.2 Impairments in the Crooked Creek Watershed

Four waterbodies designated for public water supply are impaired for manganese. Because insufficient data were available to develop a manganese TMDL for Nashville City Lake, no data are presented here.

Table 3-3 summarizes the manganese data collected in the impaired segments. Figure 3-2 shows the location of the lakes in the watershed listed for manganese.

Table 3-3. Summary of Manganese (Mn) Data Collected in the Listed Reaches of the Crooked Creek Watershed.

Waterbody Name (Segment ID)	Number of Samples	Minimum Mn (µg/L)	Average Mn (µg/L)	Maximum Mn (µg/L)	Exceedance (percent)
Centralia Lake (ROI)	5	87	187	290	60
Raccoon Lake (ROK)	5	95	199	290	80
Salem Lake (ROR)	5	12	244	440	60

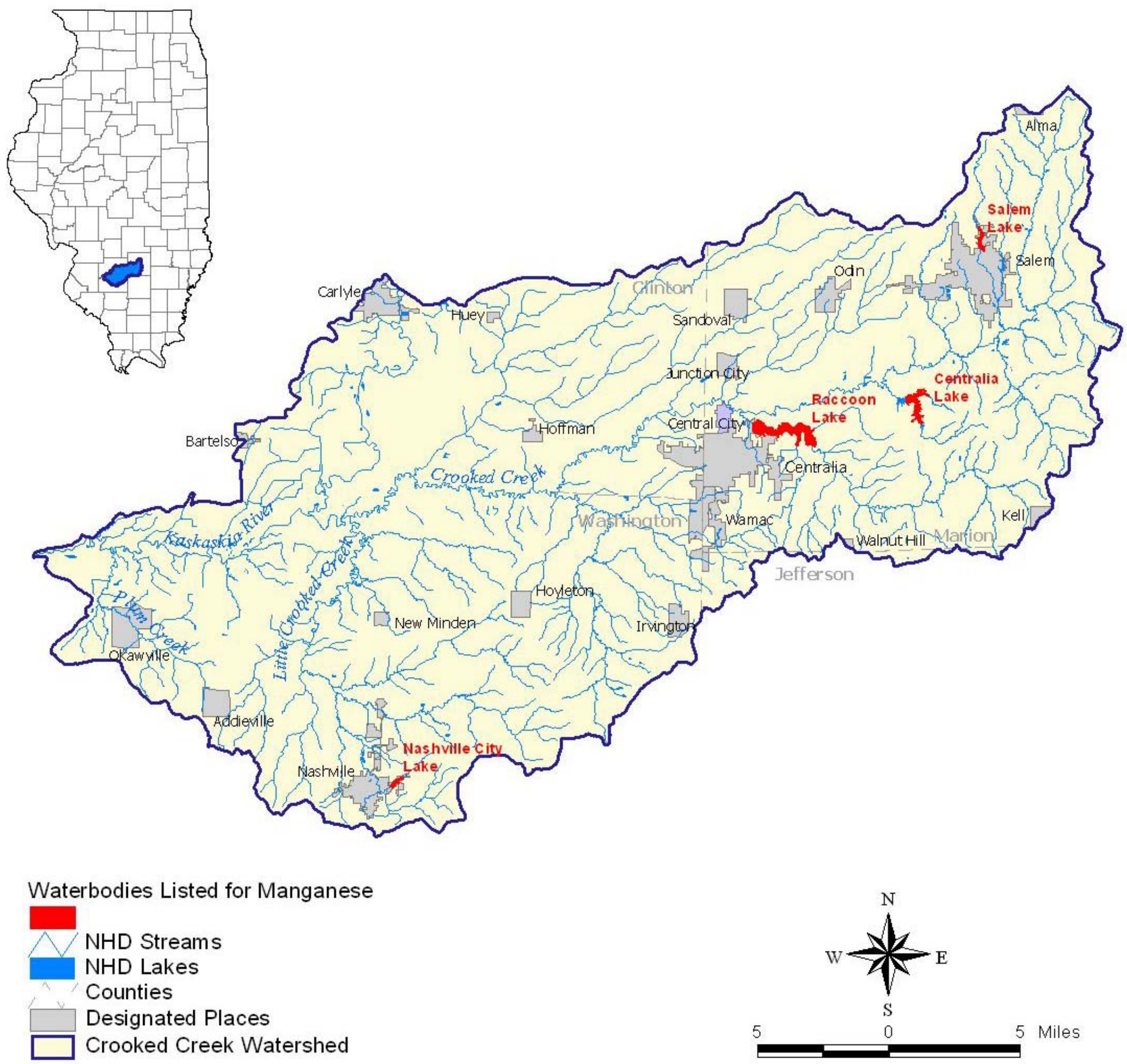

Figure 3-2. Waterbodies Listed for Manganese Impairment in the Crooked Creek Watershed.

3.3.3 TMDL Allocations

The lake manganese TMDLs were developed based on an annual BATHTUB simulation and are summarized in Table 3-4. Values presented in the tables are given in pounds per day (lb/d) with the exception of the TMDL reductions which are given as percentages.

For the lakes, a reverse BATHTUB model was used to estimate the required reductions based on samples of manganese collected in the water column. A reduction in loading of 20 to 39 percent is required to maintain the water quality standard.

Table 3-4. Manganese TMDL Allocations for the listed Crooked Creek Lakes.

Lake	Category	Manganese (lb/yr)	Manganese (lb/d)
Centralia Lake (ROI)	Existing Load	961	2.6
	Loading Capacity	732	2.0
	Wasteload Allocation	0	0.0
	Margin of Safety	37	0.1
	Load Allocation	694	1.9
Raccoon Lake (ROK)	Existing Load	5,697	15.6
	Loading Capacity	4,059	11.1
	Wasteload Allocation	0	0.0
	Margin of Safety	214	0.6
	Load Allocation	3,845	10.5
Salem Lake (ROR)	Existing Load	1,711	4.7
	Loading Capacity	990	2.7
	Wasteload Allocation	0	0.0
	Margin of Safety	53	0.1
	Load Allocation	937	2.6

3.4 Atrazine

3.4.1 Water Quality Standards

For waters designated as public water supply, the running annual average concentration of atrazine must not exceed 3 µg/L and the instantaneous concentrations should not exceed 9 µg/L. If any four quarter average exceeds 3 µg/L, the waterbody is considered impaired.

3.4.2 Impairments in the Crooked Creek Watershed

One lake in the watershed is listed for violation of the atrazine standards. Table 3-5 summarizes the atrazine data collected in Raccoon Lake. Raccoon Lake is designated as public water supply and has 8 samples that exceeded the criteria of 9 µg/L. The average for data collected in the second quarter of 2003 also exceeded 3 µg/L.

Table 3-5. Summary of Atrazine Data Collected in Raccoon Lake.

Waterbody Name (Segment ID)	Number of Samples	Minimum Atrazine (µg/L)	Average Atrazine (µg/L)	Maximum Atrazine (µg/L)	Exceedance (percent)
Raccoon Lake (ROK)	73	0.05	2.12	23.95	2.5

3.4.3 TMDL Allocations

The atrazine TMDL for Raccoon Lake is summarized in Table 3-6. A reduction in loading of 31 percent is required to maintain the water quality standard.

Table 3-6. Atrazine TMDL Allocations for Raccoon Lake.

Lake	Category	Atrazine (lb/yr)	Atrazine (lb/d)
Raccoon Lake (ROK)	Existing Load	981	2.65
	Loading Capacity	677	1.85
	Wasteload Allocation	0	0.00
	Margin of Safety	33	0.09
	Load Allocation	644	1.76

3.5 pH

3.5.1 Water Quality Standards

The water quality standard for pH is a range with a minimum of 6.5 and maximum of 9.0. The pH parameter is listed as a cause of less than full support use attainment in waterbodies if there is at least one violation from the most recent basin survey or facility survey data.

3.5.2 Impairments in the Crooked Creek Watershed

Raccoon Lake is listed for pH. Table 3-7 summarizes the pH data collected in Raccoon Lake. Table 3-7 shows the location of the segments in the watershed listed for pH.

Table 3-7. Summary of PH Data Collected in the Listed Reaches of the Crooked Creek Watershed.

Waterbody Name (Segment ID)	Number of Samples	Minimum pH (µg/L)	Average pH (µg/L)	Maximum pH (µg/L)	Exceedance (percent)
Raccoon Lake (ROK)	100	5	7.5	9.1	8

3.5.3 TMDL Allocations

Because the pH impairment is believed to be related to the total phosphorus impairment (see Section 3.2 of Stage Three report, no separate allocations were identified for the pH TMDL.

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4.0 POLLUTANT SOURCES IN THE CROOKED CREEK WATERSHED

The Crooked Creek watershed contains waterbodies listed for impairments due to total phosphorus, dissolved oxygen, manganese, atrazine, and pH. Both point and nonpoint sources contribute to the impairments. This section describes each major source category as well as the impacts and contributions to pollutant loading in this watershed.

4.1 Point Source Dischargers

There are 26 facilities regulated by the National Pollutant Discharge Elimination System that are allowed to discharge industrial or municipal wastewater to waterbodies located in the Crooked Creek watershed. Information on these dischargers is shown in Table 4-1. Blank cells in the table indicate that permit information was not available for that parameter.

Table 4-1. Wastewater Treatment Plants Discharging to Impaired Streams within the Crooked Creek Watershed.

Facility Name	Permit Number	Outfall	Receiving Stream/Downstream Impaired Waterbody	Design Average Flow (MGD)	Design Maximum Flow (MGD)	Daily PH Limit	Daily CBOD Limit (mg/L)	Daily Ammonia Limit (mg/L)
Illinois Central Rr-Centralia	IL0000779	001	Fulton Creek/Crooked Creek Segments OJ 07	0.011	N/A	6 to 9		
		002 - 004		Overflow				
Centralia WTP	IL0001252	001	Crooked Creek/Crooked Creek Segments OJ 07	0.216	0.333	6 to 9		
		002	Unnamed Tributary to Crooked Creek			6 to 9		
Salem STP	IL0023264	001	Town Creek/Crooked Creek Segments OJ 07	1.672	3.762	6 to 9	20	April - October 1.5 November - March 3.9
		001		2.508	7.023	6 to 9	10	April - October 1.5 November - February 3.9 March 3.5
		A01		Excess Flow Discharge		6 to 9	30	
Nashville STP	IL0027081	001	Nashville Creek/ Little Crooked Creek Segment OJA 01	0.5	1.7	6 to 9	25	
Centralia STP	IL0027979	001	Sewer Creek/Crooked Creek Segments OJ 07	3.15	4.5	6 to 9	10	April - October 1.5 November - March 3.6
		A01		Excess Flow Discharge (Flows Over 4.50 MGD)		6 to 9	30	

Facility Name	Permit Number	Outfall	Receiving Stream/Downstream Impaired Waterbody	Design Average Flow (MGD)	Design Maximum Flow (MGD)	Daily PH Limit	Daily CBOD Limit (mg/L)	Daily Ammonia Limit (mg/L)
Centralia-Kaskaskia College	IL0029335	001	Prairie Creek/Crooked Creek Segments OJ 08	0.125	0.312	6 to 9	10	April- October 1.5 November - March 3.6
Sandoval STP	IL0030961	001	Prairie Creek/Crooked Creek Segments OJ 08	0.18	0.45	6 to 9	25	
Addieville STP	IL0049140	001	Plum Creek/Plum Creek Segment OZH-OK-A2	0.033	0.083	6 to 9	25	
Raccoon Consolidated School	IL0052981	001	Unnamed Tributary to Raccoon Creek/Raccoon Lake Segment ROK	0.0125	0.031	6 to 9	10	April - October 1.5 November - March 3.5
Radiac Abrasives Inc-Salen	IL0059382	001	Crooked Creek/Crooked Creek Segments OJ 07	0.123	1.06	6 to 9	10	
		002-004		Overflow				
Il Doc-Centralia Correctional	IL0061344	001	Unnamed tributary of Prairie Creek/Crooked Creek Segments OJ 08	0.234	0.343	6 to 9	10	April – May/ September -October 2.8 June - August 2.8 November - February 4.0 March 3.9
Nascote Industries-Nashville	IL0068136	001	Middle Creek via drainage ditch/ Little Crooked Creek Segment OJA 01	0.006	2	6 to 9		
		002		0.006	2	6 to 9		

Facility Name	Permit Number	Outfall	Receiving Stream/Downstream Impaired Waterbody	Design Average Flow (MGD)	Design Maximum Flow (MGD)	Daily PH Limit	Daily CBOD Limit (mg/L)	Daily Ammonia Limit (mg/L)
Nashville WTP	IL0069701	001	Nashville Creek/ Nashville Reservoir Segment ROO	0.056	0.963	6 to 9		
		002		0.056	0.963	6 to 9		
United Parcel Service	IL0071242	001	Tributary to Fulton Branch of Sewer Creek/Crooked Creek Segments OJ 07	0.0005	0.0012	6 to 9	10	
Ameren Energy-Pinckneyville	IL0075906	001	Tributary to Walnut Creek/ Little Crooked Creek Segment OJA 01	0.054	N/A	6 to 9		
		002		0.017	N/A	6 to 9		
Woodlawn MHP	ILG551054	001	Unnamed Tributary to Crooked Creek/ Crooked Creek Segment OJ 07	0.019	0.038	6 to 9	25	
Country School MHP	ILG551055	001	South Creek /Crooked Creek Segments OJ 07	0.0024	0.0006	6 to 9	25	
Irvington Sd WWTF	ILG580006	001	Grand Point Creek/Crooked Creek Segments OJ 08	0.093	0.33	6 to 9	25	
Hoyleton STP	ILG580016	001	North Creek/ Little Crooked Creek Segment OJA 01	0.059	0.159	6 to 9	25	
Wamac STP	ILG580144	001	Fulton Branch/Crooked Creek Segments OJ 08	0.15	0.6	6 to 9	25	
Odin STP	ILG580187	001	Turkey Creek /Crooked Creek Segments OJ 07	0.195	1.8	6 to 9	25	
Hoffman STP	ILG580205	001	Prairie Creek/Crooked Creek Segments OJ 08	0.06	0.15	6 to 9	25	
Central City STP	ILG580265	001	NA/Crooked Creek Segments OJ 07	0.304	1.267	6 to 9	25	

Facility Name	Permit Number	Outfall	Receiving Stream/Downstream Impaired Waterbody	Design Average Flow (MGD)	Design Maximum Flow (MGD)	Daily PH Limit	Daily CBOD Limit (mg/L)	Daily Ammonia Limit (mg/L)
Junction City STP	ILG580277	001	Prairie Creek/Crooked Creek Segments OJ 08	0.06	0.15	6 to 9	25	
Okawville STP	ILG580268	001	NA/Plum Creek Segment OZH-OK-A2	0.25	0.877	6 to 9	25	
Salem WTP	ILG640031	001	Town Creek/Crooked Creek Segments OJ 07	0.039	N/A	6 to 9		

Notes: N/A = Not Available; MGD = Million Gallons per Day

4.1.1 Phosphorus

None of the point source dischargers in the watershed are required to monitor for total phosphorus so it is not possible to accurately estimate the existing load from point sources. Four lakes are currently listed for phosphorus. The Raccoon Consolidated Schools facility is the only point source that discharges upstream of any of the lakes. It is not likely that the Raccoon Consolidated Schools facility is contributing a significant fraction of the total load. Approximate average flows from this facility are 0.0125 MGD. Assuming a total phosphorus concentration of 4 mg/L from the effluent based on literature values (Litke, 1999) yields an approximate daily load of 152 lb/yr compared to the allowable load of 2,218 lb/yr.

4.2 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) are not typically a significant source of pollutant loading if they are operating as designed. However, if the failure rates of systems in this watershed are high, then the loading from this source may be significant. At this time, there is limited information with which to estimate levels of performance.

Pollutant loading rates from properly functioning onsite wastewater systems are typically insignificant. However, if systems are placed on unsuitable soils, not maintained properly, or are connected to subsurface drainage systems, loading rates to receiving waterbodies may be relatively high. It is suggested that each system in the watershed be inspected to accurately quantify the loading from this source. Systems older than 20 years and those located close to the lakes or streams should be prioritized for inspection.

4.2.1 Phosphorus

Centralia Lake, Raccoon Lake, Salem Lake, and Nashville Lake are all listed for total phosphorus. To approximate the phosphorus loading rate from onsite wastewater systems in the drainage areas of these lakes, a rough calculation based on the population density of the Counties they lay in, the area of the watershed, and net loading rates reported in the Generalized Watershed Loading Function (GWLF) User's manual were assumed.

Though a watershed model was not developed for the lakes in the Crooked Creek watershed, the GWLF user's manual (Haith et al., 1992) reports septic tank effluent loading rates and subsequent removal rates based on the use of phosphate detergents. Though phosphates have been banned from laundry detergents, dish detergents often contain between 4 and 8 percent phosphate by weight. The GWLF model assumes a septic tank effluent phosphorus loading rate for households using phosphate detergent of 2.5 g/capita/day. The model assumes a plant uptake rate of 0.4 g/capita/day of phosphorus during the growing season and 0.0 g/capita/day during the dormant season. Assuming a 6-month growing season (May through October), the average annual plant uptake rate is 0.2 g/capita/day.

In a properly functioning septic system, wastewater effluent leaves the septic tank and percolates through the system drainfield. Phosphorus is removed from the wastewater by adsorption to soil particles. Plant uptake by vegetation growing over the drainfield is assumed negligible since all of the phosphorus is removed in the soil treatment zone. Failing systems that either short circuit the soil adsorption field or cause effluent to pool at the ground surface are assumed to retain phosphorus through plant uptake only (average annual uptake rate of 0.2 g/capita/day). Direct discharge systems that intentionally bypass the drainfield by connecting the septic tank effluent directly to a waterbody or other transport line (such as an agricultural tile drain) do not allow for soil zone treatment or plant uptake.

1992 and 1998 Census data indicate that there are approximately 5,500 onsite wastewater treatment systems present in Marion County and 3,100 onsite wastewater treatment systems present in Washington County. Centralia, Raccoon, and Salem Lakes are all in Marion County, Nashville Lake lies in Washington County. Based on the drainage areas of the lakes and assuming a uniform density of homes throughout the rural portions of the counties results in an estimated 1,310 people served by onsite systems upstream of the lakes.

The USEPA Onsite Wastewater Treatment Systems Manual (2002b) estimates that septic systems fail (do not perform as designed) at an average rate of 7 percent across the nation; failure rates in the Crooked Creek watershed are unknown. Phosphorus loading rates under four scenarios were therefore calculated to show the range of loading from this source. System failures were distributed evenly over the three failure types: short circuiting, ponding, and directly discharging. Table 4-2 shows the phosphorus load if 0, 7, 15, 30, and 60 percent of systems in the watershed are failing.

Table 4-2. Failure Rate Scenarios and Resulting Phosphorus Loads to Lakes in the Crooked Creek Watershed.

Failure Rate[1] (%)	Average Annual Phosphorus Load (lb/yr)			
	Centralia Lake	Raccoon Lake	Salem Lake	Nashville Lake
0	0	0	0	0
0.58	1.6	12.2	1.0	0.2
7[2]	19.1	147.8	12.4	2.7
15	41	316.8	26.6	5.9
30	81.9	633.6	53.3	11.8
60	163.9	1267.1	106.5	23.5

[1] Failures are assumed distributed evenly over short-circuiting, ponded, and directly discharging systems.
[2] This is the average annual failure rate across the nation.

4.3 Crop Production

The majority of land in the Crooked Creek watershed (52 percent) is used for production of corn, soybeans, wheat, and other small grains. Due to application of commercial fertilizer, manure, and pesticides, as well as increased rates of erosion, pollutant loads from croplands are relatively high compared to other land uses. This section of the implementation plan describes the mechanisms of pollutant loading from farmland for each of the TMDL pollutants causing impairments in the watershed.

4.3.1 Phosphorus

Agriculture is a primary land use throughout the Crooked Creek watershed. Phosphorus impairments, are only present in Centralia Lake, Raccoon Lake, Salem Lake, and Nashville City Lake. In this watershed, approximately 185,000 acres of land are used to grow corn, soybeans, wheat, and other grains. Based on data presented by Gentry et al. (2007), phosphorus loading rates from tiled agricultural fields in east-central Illinois range from 0.5 to 1.5 lb/ac/yr. Based on this data, the phosphorus loads to the Crooked Creek watershed from crop production areas may range from 92,500 to 277,500 lb/yr assuming that all of the fields are artificially drained. If a significant amount of the farmland is not artificially drained, these values may underestimate the loading from this source. Table 4-3 details the potential phosphorus loads from crop production in each listed lakes drainage area based on the Gentry et al. (2007) phosphorus loading rates and acres of crop production.

Table 4-3. Potential Phosphorus Loads from Crop Production in the Crooked Creek Lake Watersheds.

Lake	Phosphorus Load (lb/yr)
Centralia Lake	541 to 1,623
Raccoon Lake	5,446 to 16,338
Salem Lake	710 to 2,130
Nashville City Lake	350 to 1,052

4.3.2 Manganese

Impairments due to manganese occur in Centralia Lake, Raccoon Lake, and Salem Lake. Manganese is found naturally in the environment in groundwater and soils and any land disturbing activities can result in loading of manganese to local waterbodies. Because crop production tends to increase rates of erosion, the sediment bound manganese loads tend to increase from this land use. In addition, much of the land farmed in this watershed is classified as highly erodible (Figure 2-2).

Typical concentrations of manganese in Southern Illinois range from 4 to 200 milligrams of manganese per kilogram of soil (mg/kg) with an average value of 23 mg/kg (Ebelhar, 2007). Based on data presented by Czapar et al. (2006), conventional chisel plow crop production activities in Midwestern states result in sediment loads of 7.5 tons/ac/yr. Approximately 185,000 acres of land are used for crop production in the Crooked Creek watershed. Assuming a manganese concentration of 23 mg/kg percent yields an estimated loading rate from this source of 32 tons/yr. Table 4-4 estimates the potential manganese loads from crop production in each of the listed lakes drainage areas.

Table 4-4. Potential Manganese Loads from Crop Production in the Crooked Creek Lake Watersheds.

Lake	Manganese Load (lb/yr)
Centralia Lake	373
Raccoon Lake	3,758
Salem Lake	490

4.3.3 Atrazine

Atrazine is a commonly used herbicide for controlling broadleaf and grassy weeds. Raccoon Lake is impaired due to atrazine and the sole source is crop production. Because many herbicides are available for use, it is not possible to quantify the load to waterbodies in the watershed without site specific application data.

4.4 Animal Operations

Pollutant loading from animal operations can be a problem in both confined and pasture-based systems. Though the exact location of animal operations in the watershed is not known, countywide statistics indicate that a large number of livestock, swine, and poultry may exist. Agricultural animal operations are a potentially large source of pollutant loading if adequate best management practices (BMPs) are not in place to protect surface waters. Figure 4-1 shows an example of poorly managed animal wastes that may contaminate nearby surface waters.

(Photo courtesy of USDA NRCS.)

Figure 4-1. Example of Poorly Managed Animal Waste.

4.4.1 Phosphorus

Census estimates of animals in Washington and Marion County were area weighted to estimate the number of animals the watershed of each lake (Table 4-5). Large animals produce more fecal matter per animal compared to smaller animals, so the concept of animal unit is used to normalize loading from various operations. Total phosphorus loading rates are usually given as pounds per animal unit per day. Table 4-6 lists the number of animals equivalent to one animal unit (IDA, 2001) for each of the livestock and poultry classes likely present in the watershed, as well as the total phosphorus loading rate (USEPA, 2002a) from one animal unit. In addition, the table lists the total number of animal units in the watershed and resulting total phosphorus load.

Table 4-5. Estimated Number of Livestock and Poultry in the Crooked Creek Lake Watersheds.

Animal	Centralia Lake	Raccoon Lake	Salem Lake	Nashville City Lake
Poultry	0	0	0	1
Beef cattle	56	435	36	12
Dairy cattle	2	19	2	22
Hogs and pigs	93	714	59	171
Sheep and lambs	4	27	2	1

Table 4-6. Animal Unit Data and Total Phosphorus Loading Rates for the Listed Lake Watersheds in the Crooked Creek Watershed.

Lake	Animal	Number of Animals in One Animal Unit	Number of Animal Units in Watershed	Total Phosphorus Load (lb/au/d)	Total Phosphorus Load (lb/yr)
Centralia Lake	Poultry	50	0	0.32	0
	Beef cattle	1	56	0.16	9
	Dairy cattle	0.71	3	0.14	0
	Hogs and pigs	2.5	285	0.13	37
	Sheep and lambs	10	0	0.05	0
	Total Phosphorus Load from Agricultural Animals in the Centralia Lake Watershed				**46**
Raccoon Lake	Poultry	50	0	0.32	0
	Beef cattle	1	435	0.16	70
	Dairy cattle	0.71	26	0.14	4
	Hogs and pigs	2.5	285	0.13	37
	Sheep and lambs	10	3	0.05	0
	Total Phosphorus Load from Agricultural Animals in the Raccoon Lake Watershed				**110**
Salem Lake	Poultry	50	0	0.32	0
	Beef cattle	1	36	0.16	6
	Dairy cattle	0.71	2	0.14	0
	Hogs and pigs	2.5	24	0.13	3
	Sheep and lambs	10	0	0.05	0
	Total Phosphorus Load from Agricultural Animals in the Salem Lake Watershed				**9**
Nashville City Lake	Poultry	50	0	0.32	0
	Beef cattle	1	12	0.16	2
	Dairy cattle	0.71	30	0.14	4
	Hogs and pigs	2.5	69	0.13	9
	Sheep and lambs	10	0	0.05	0
	Total Phosphorus Load from Agricultural Animals in the Nashville City Lake Watershed				**15**

4.5 Streambank and Lake Shore Erosion

Excessive erosion of streambanks and lake shores quickly degrades water quality and habitat. Both phosphorus and manganese contribute to the overall composition of sediment. Once sediment reaches a waterbody, these elements may be released through biological and chemical transformations.

In addition to the release of phosphorus and manganese, erosion will also reduce the stability of streambanks by undercutting the roots of established vegetation and altering the channel geometry. Loss of vegetative canopy and widening of a stream channel will allow more sunlight to reach the water column which may 1) increase rates of eutrophication, 2) increase water temperatures, and 3) decrease the amount of dissolved oxygen the water can hold.

The Illinois Department of Natural Resources (IDNR) has begun an inventory of streams in the State for inclusion in the Illinois Stream Information System (ISIS). So far, all reaches in the state draining at least 10 square miles are included in the database.

For those stream channels and lake shores that have not yet been inventoried by IDNR, the most cost-effective way to assess erosion is to visually inspect representative reaches of each channel or lake and rank the channel stability using a bank erosion index. Banks or shorelines ranked moderately to severely eroding could be targeted for stabilization efforts. A more time and resource intensive method is to determine the rate of erosion by inserting bank pins and measuring the rate of recession. Once soil loss estimates are obtained, reaches can be prioritized for restoration and protection.

Without quantitative estimates of streambank and shoreline erosion, it is not possible to estimate the phosphorus or manganese loading from this source or the impacts on dissolved oxygen. Fortunately several of the BMPs described in Section 5.0 that control pollutant loads and runoff volumes will also help control streambank and lakeshore erosion.

4.6 Internal Loading from Lake Bottom Sediments

Four lakes in the Crooked Creek watershed are listed for pollutants that may be released from bottom sediments under anoxic conditions. Centralia, Raccoon, Salem, and Nashville City Lake are listed for both phosphorus and manganese. Because the Nashville City Lake listing was based on sediment samples and could not be compared to the water quality standards, a manganese TMDL was not developed for this lake.

Both manganese and phosphorus may be released internally from lake sediments when oxygen concentrations near the bottom of the lake reach low levels. Low dissolved oxygen in lakes may be caused by degradation of organic material or respiration of algae in the absence of sunlight. Conditions for low dissolved oxygen are most severe during the summer months when the water temperatures are higher and the water is able to contain less oxygen.

Each of the lakes is monitored at several stations for dissolved oxygen. The following graphs show the measurements collected at all stations relative to depth. Figure 4-3 shows the measurements collected in Lake Raccoon and indicates that anoxic conditions may sometimes occur in the lower depths. Based on this dataset, releases of phosphorus and manganese from bottom sediments is a potential concern. Dissolved oxygen concentrations in Lake Centralia are generally lower than in Lake Raccoon and anoxic conditions are prevalent (Figure 4-2). Release of phosphorus and manganese from bottom sediments is more likely in this lake, though quantitative estimates cannot be made without additional data. Monitoring data collected in Lake Salem (Figure 4-4) do not indicate anoxic conditions at the sediment-water interface, so releases of phosphorus and manganese from bottom sediments are not likely. Dissolved oxygen concentrations in Lake Nashville sometimes approach zero, but are not expected to cause significant releases of phosphorus or manganese.

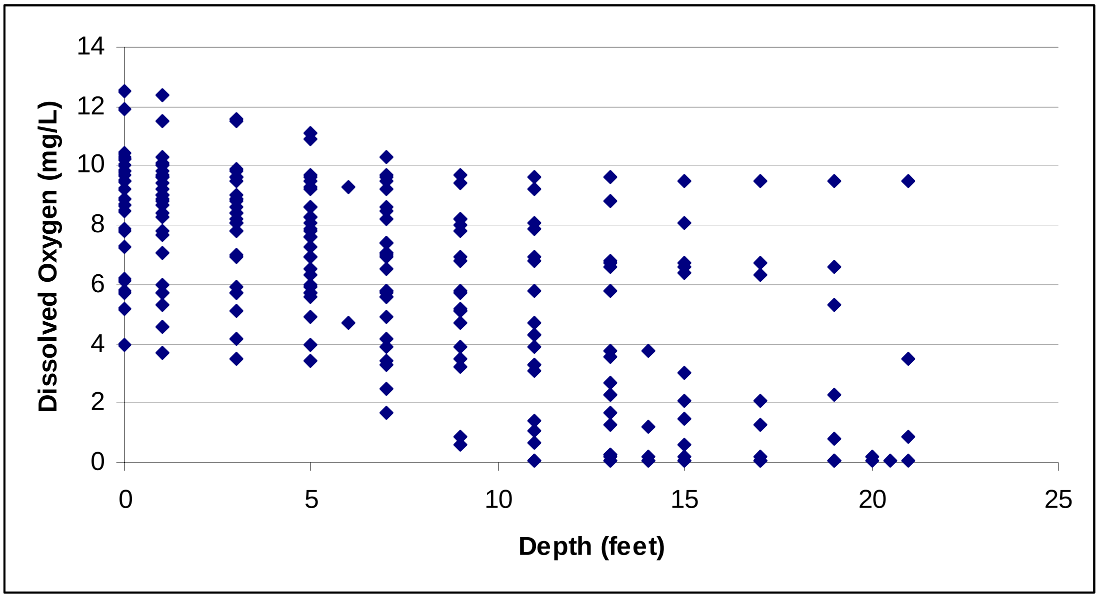


Figure 4-2. Dissolved Oxygen Profile for Centralia Lake.

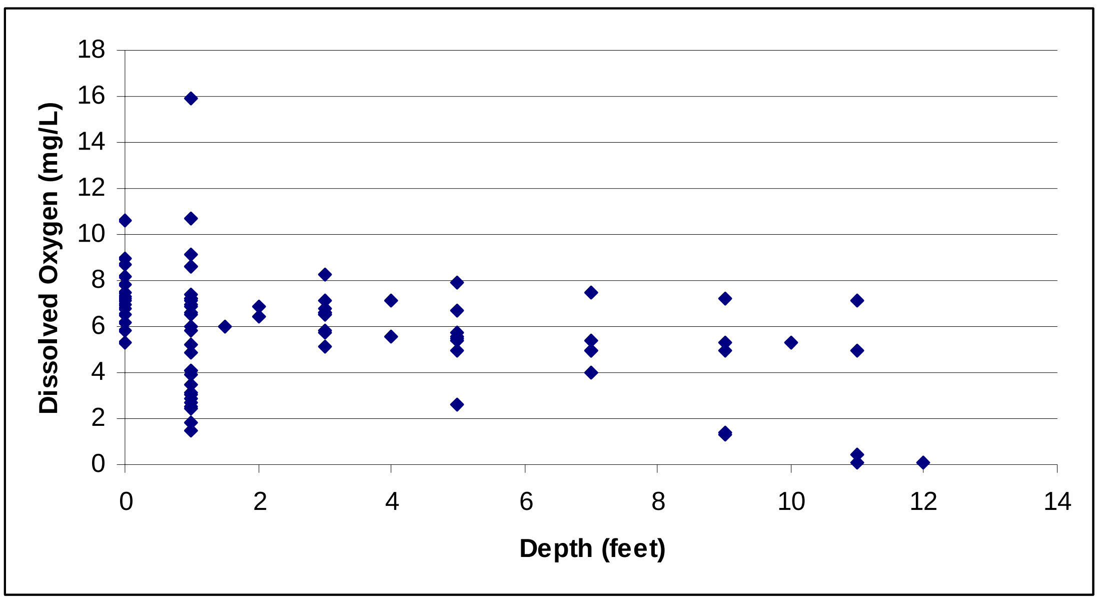


Figure 4-3. Dissolved Oxygen Profile for Raccoon Lake.

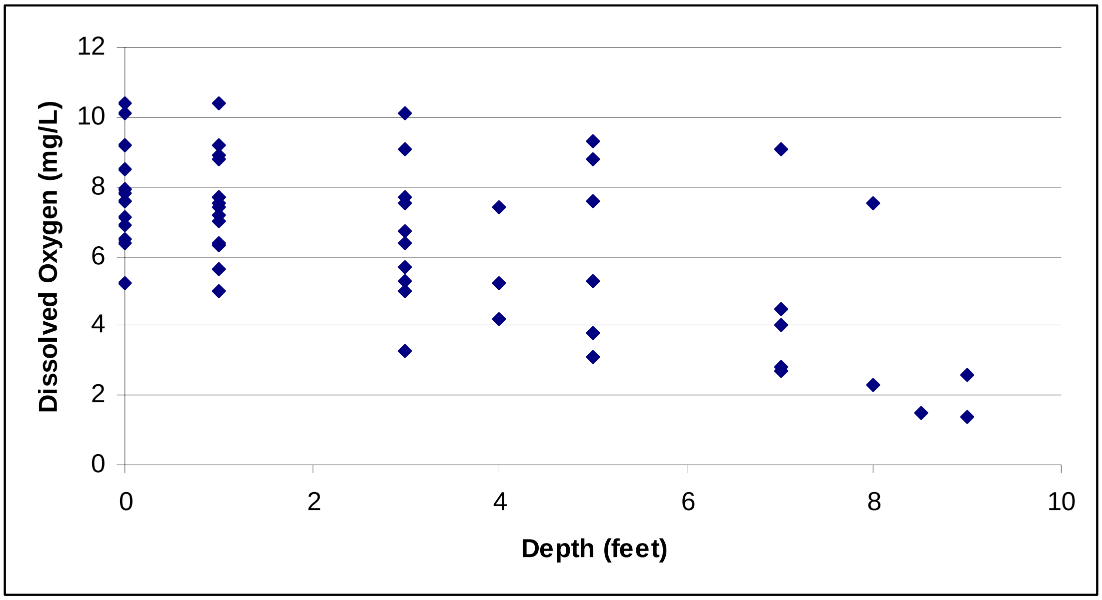


Figure 4-4. Dissolved Oxygen Profile for Salem Lake.

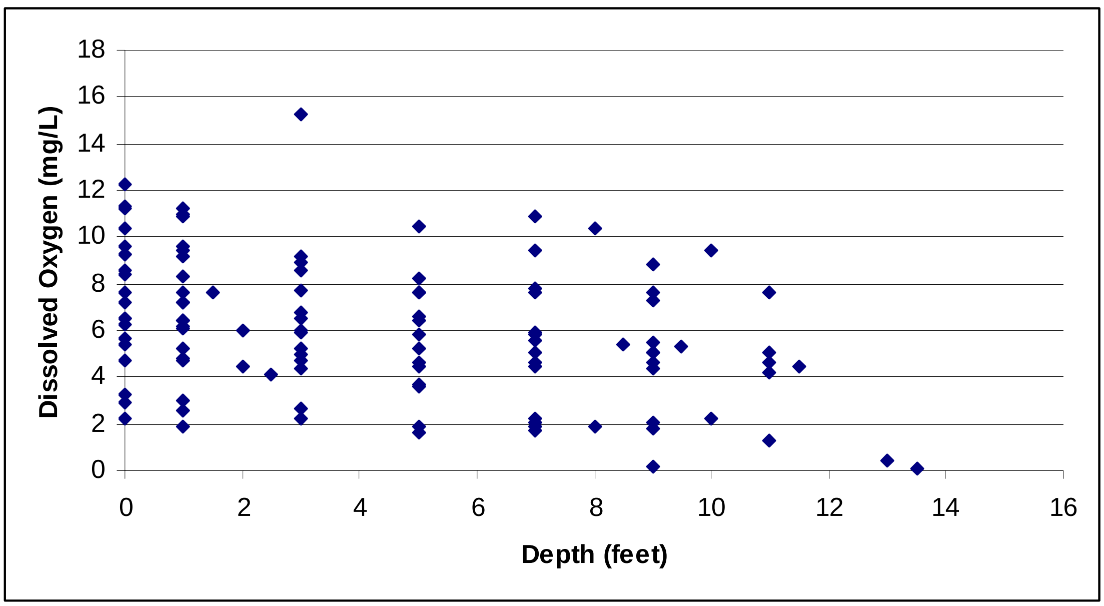


Figure 4-5. Dissolved Oxygen Profile for Nashville City Lake.

4.6.1 Phosphorus

Four lakes in the Crooked Creek watershed are listed for phosphorus impairments. Estimating the fraction of phosphorus in the water column that originates from re-suspended sediment stores is difficult with the current data. With the exception of Centralia Lake, the dissolved oxygen profiles do not indicate that phosphorus releases from bottom sediments are a significant source. In addition, the average depths and residence times of Raccoon, Salem, and Nashville City Lake are relatively low, further supporting the assumption that internal loading is not significant. Centralia Lake, on the other hand, has an average depth of 10 ft and a much longer residence time. These factors along with anoxic conditions near the lake bottom may stimulate significant releases of phosphorus from the bottom sediments.

More intensive water quality studies of these lakes and their tributaries will be required to estimate the significance of internal loading. Inlake management strategies are discussed in Section 5.0. In addition, BMPs that reduce phosphorus and BOD_5 loads in the watershed will also mitigate the dissolved oxygen conditions that stimulate releases from bottom sediments.

4.6.2 Manganese

Centralia, Raccoon, and Salem Lake are also impaired by manganese; Nashville City Lake is also listed but no water column samples are available to confirm the impairment.

As with phosphorus releases, conditions in Centralia Lake may be favorable for releases of manganese from bottom sediments, but this is likely not a significant fraction of the total load in Raccoon, Salem, or Nashville City Lake. Collection of additional manganese data in the lakes and their tributaries will allow for quantitative estimates from this source. If internal loading is deemed a significant source, then the inlake management measures may be necessary.

4.7 Domestic Pets and Wildlife Populations

Domestic pets such as cats and dogs and wildlife animals such as deer, geese, ducks, etc., can be significant sources of loading in watersheds that have high densities of urban populations or rural communities with relatively undisturbed land use patterns. In the Crooked Creek watershed, where the majority of land is used for agricultural production, these sources are likely not significant relative to the loading from other sources.

5.0 BEST MANAGEMENT PRACTICES

Controlling pollutant loading to the waterbodies in the Crooked Creek watershed will require implementation of various BMPs depending on the pollutant(s) of concern and major sources of loading. This section describes BMPs that may be used to reduce loading from onsite wastewater treatment systems, agricultural operations, inlake resuspension, and streambank erosion.

The net costs associated with the BMPs described in this plan depend on the cost of construction (for structural BMPs), maintenance costs (seeding, grading, etc.), and operating costs (electricity, fuel, labor, etc.). In addition, some practices require that land be taken out of farm production and converted to treatment areas, which results in a loss of income from the cash crop. On the other hand, taking land out of production does save money on future seed, fertilizer, labor, etc., and this must be accounted for as well. This section describes how the various costs apply to each BMP, and presents an estimate of the annualized cost spread out over the service life. Incentive plans and cost share programs are discussed separately in Section 8.0.

The costs presented in this section are discussed in year 2004 dollars because this was the latest year for which gross income estimates for corn and soybean production were available when this Implementation Plan was prepared. Market prices can fluctuate significantly from year to year based on supply and demand factors, so applying straight rates of inflation to convert crop incomes from one year to the next is not appropriate. The cost to construct, maintain, and operate the BMPs is assumed to follow a yearly inflation rate of 3 percent since these components are not as dependent on such factors as weather and consumer demand. Therefore, all prices for BMP costs have been converted to year 2004 dollars to develop a net cost for each BMP. Inflated prices are rounded to the nearest quarter of a dollar since most of the costs were reported in whole dollars per acre, not dollars and cents.

Gross 2004 income estimates for corn and soybean in Illinois are $510/ac and $473/ac, respectively (IASS, 2004). Accounting for operating and ownership costs results in net incomes from corn and soybean farms of $140/ac and $217/ac (USDA-ERS, 2005). The average net annual income of $178/ac was therefore used to estimate the annual loss from BMPs that take a portion of land out of farm production. The average value is considered appropriate since most farms operate on a 2-year crop rotation.

5.1 Proper Maintenance of Onsite Systems

The most effective BMP for managing loads from septic systems is regular maintenance. Unfortunately, most people do not think about their wastewater systems until a major malfunction occurs (e.g., sewage backs up into the house or onto the lawn). When not maintained properly, septic systems can cause the release of pathogens and excess nutrients into surface water. Good housekeeping measures relating to septic systems are listed below (Goo, 2004; CWP, 2004):

- Inspect system annually and pump system every 3 to 5 years, depending on the tank size and number of residents per household.
- Refrain from trampling the ground or using heavy equipment above a septic system (to prevent collapse of pipes).
- Prevent septic system overflow by conserving water, not diverting storm drains or basement pumps into septic systems, and not disposing of trash through drains or toilets.

Education is a crucial component of reducing pollution from septic systems. Many owners are not familiar with USEPA recommendations concerning maintenance schedules. Education can occur through public meetings, mass mailings, and radio and television advertisements.

The USEPA recommends that septic tanks be pumped every 3 to 5 years depending on the tank size and number of residents in the household. Annual inspections, in addition to regular maintenance, ensure that systems are functioning properly. An inspection program would help identify those systems that are currently connected to tile drain systems. All tanks discharging to tile drainage systems should be disconnected immediately.

Some communities choose to formally regulate septic systems by creating a database of all the systems in the area. This database usually contains information on the size, age, and type of system. All inspections and maintenance records are maintained in the database through cooperation with licensed maintenance and repair companies. These databases allow the communities to detect problem areas and ensure proper maintenance.

5.1.1 Effectiveness

The reductions in pollutant loading resulting from improved operation and maintenance of all systems in the watershed depends on the wastewater characteristics and the level of failure present in the watershed. Reducing the level of failure to 0 percent may result in the following load reductions:

- Phosphorus loads to Centralia Lake may be reduced by 1.58 to 164 lb/d.
- Phosphorus loads to Raccoon Lake may be reduced by 12.23 to 1265 lb/d.
- Phosphorus loads to Salem Lake may be reduced by 1.03 to 106 lb/d.
- Phosphorus loads to Nashville City Lake may be reduced by 0.23 to 24 lb/d.
- BOD_5 loads in the Crooked Creek watershed may be reduced by 5 to 698 lb/d.

5.1.2 Costs

Septic tanks are designed to accumulate sludge in the bottom portion of the tank while allowing water to pass into the drain field. If the tank is not pumped out regularly, the sludge can accumulate and eventually become deep enough to enter the drain field. Pumping the tank every three to five years prolongs the life of the system by protecting the drain field from solid material that may cause clogs and system backups.

The cost to pump a septic tank ranges from $250 to $350 depending on how many gallons are pumped out and the disposal fee for the area. If a system is pumped once every three to five years, this expense averages out to less than $100 per year. Septic tanks that are not maintained will likely require replacement which may cost between $2,000 and $10,000.

The cost of developing and maintaining a watershed-wide database of the onsite wastewater treatment systems in the watershed depends on the number of systems that need to be inspected. Based on Census data collected in 2000, there are approximately 4,230 households in the watershed with onsite wastewater treatment systems. After the initial inspection of each system and creation of the database, only systems with no subsequent maintenance records would need to be inspected. A recent inspection program in South Carolina found that inspections cost approximately $160 per system (Hajjar, 2000).

Education of home and business owners that use onsite wastewater treatment systems should occur periodically. Public meetings, mass mailings, and radio, newspaper, and TV announcements can all be used to remind and inform owners of their responsibility to maintain their systems (Table 5-1).

The costs associated with education and inspection programs will vary depending on the level of effort required to communicate the importance of proper maintenance and the number of systems in the area.

Table 5-1. Costs Associated with Maintaining and Replacing an Onsite Wastewater Treatment System.

Action	Cost per System	Frequency	Annual Cost per System
Pumping	$250 to $350	Once every 3 to 5 years	$70 to $85
Inspection	$160	Initially all systems should be inspected, followed by 5 year inspections for systems not on record as being maintained	Up to $32, assuming all systems have to be inspected once every five years, which is not likely
Replacement	$2,000 to $10,000	With proper maintenance, system life should be 30 years	$67 to $333
Education	$1	Public reminders should occur once per year	$1

5.2 Nutrient Management Plans

The majority of nutrient loading from farmland occurs from fertilization with commercial and manure fertilizers (USEPA, 2003). In heavily fertilized areas, soil phosphorus content has increased significantly over natural levels. Parties responsible for reducing loads due to excessive fertilization include farmers and local agricultural service agencies that provide fertilization guidelines.

The primary BMP for reducing phosphorus loading from excessive fertilization is the development of a nutrient management plan. The plan should address fertilizer application rates, methods, and timing. Initial soil phosphorus concentrations are determined by onsite soil testing, which is available from local vendors. Losses through plant uptake are subtracted, and gains from organic sources such as manure application or industrial/municipal wastewater are added. The resulting phosphorus content is then compared to local guidelines to determine if fertilizer should be added to support crop growth and maintain current phosphorus levels. In some cases, the soil phosphorus content is too high, and no fertilizer should be added until stores are reduced by crop uptake to target levels.

Soil phosphorus tests are used to measure the phosphorus available for crop growth. Test results reported in parts per million (ppm) can be converted to lb/ac by multiplying by 2 (USDA, 2003). Based on a survey of state soil testing laboratories in 1997, 64 percent of soils in Illinois had high soil phosphorus test concentrations (> 50 ppm). By 2000, the percentage of soils testing high decreased to 58 percent (USDA, 2003). Guidelines in the Illinois Agronomy Handbook (IAH) recommend maintaining soil test phosphorus content in southeastern Illinois at 25 ppm (50 lb/ac). Soils that test at or above 35 ppm (70 lb/ac) should not be fertilized until subsequent crop uptake decreases the test to 25 ppm (50 lb/ac) (IAH, 2002). Soil phosphorus tests should be conducted once every three or four years to monitor accumulation or depletion of phosphorus (USDA, 2003).

Table 5-2 and Table 5-3 show buildup, maintenance, and total application rates for various starting soil test concentrations for sample corn and soybean yields, respectively. For a complete listing of buildup and maintenance rates for the three inherent availability zones and varying yields of corn, soybeans, oats, wheat, and grasses, see Chapter 11 of the IAH.

Starting Soil Test Phosphorus	***Fertilization Guidelines***
Less than 25 ppm:	*Buildup plus maintenance*
Between 25 and 35 ppm:	*Maintenance only*
Greater than 35 ppm:	*None*

Table 5-2. Suggested Buildup and Maintenance Application Rates of P_2O_5 for Corn Production in the Low Inherent Phosphorus Availability Zone (IAH, 2002).

Starting Soil Test P ppm (lb/ac)	Buildup P_2O_5 (lb/ac)[1]	Maintenance P_2O_5 (lb/ac)[2]	Total P_2O_5 (lb/ac)
10 (20)	68	71	139
15 (30)	45	71	116
20 (40)	22	71	93
25 (50)	0	71	71
30 (60)	0	71	71
35 (70) or higher	0	0	0

[1] Rates based on buildup for four years to achieve target soil test phosphorus of 25 ppm (50 lb/ac).
[2] Maintenance rates assume a corn yield of 165 bushels per acre. The IAH lists maintenance rates discretely for yields of 90 to 200 bushels per acre.

Table 5-3. Suggested Buildup and Maintenance Application Rates of P_2O_5 for Soybean Production in the Low Inherent Phosphorus Availability Zone (IAH, 2002).

Starting Soil Test P ppm (lb/ac)	Buildup P_2O_5 (lb/ac)[1]	Maintenance P_2O_5 (lb/ac)[2]	Total P_2O_5 (lb/ac)
10 (20)	68	51	119
15 (30)	45	51	96
20 (40)	22	51	73
25 (50)	0	51	51
30 (60)	0	51	51
35 (70) or higher	0	0	0

[1] Rates based on buildup for four years to achieve target soil test phosphorus of 25 ppm (50 lb/ac).
[2] Maintenance rates assume a soybean yield of 60 bushels per acre. The IAH lists maintenance rates discretely for yields of 30 to 100 bushels per acre.

Nutrient management plans also address methods of application. Fertilizer may be applied directly to the surface, placed in bands below and to the side of seeds, or incorporated in the top several inches of the soil profile through drilled holes, injection, or tillage. Surface applications that are not followed by incorporation may result in accumulation of phosphorus at the soil surface and increased dissolved phosphorus concentrations in surface runoff (Mallarino, 2004).

Methods of phosphorus application have shown no impact on crop yield (Mallarino, 2004). The Champaign County Soil and Water Conservation District (CCSWCD) reports that deep placement of phosphorus in bands next to the seed zone requires only one-third to one-half the amount of phosphorus fertilizer to achieve the same yields and that on average, fertilizer application rates were decreased by 13 lb/ac (Stikkers, 2007). Thus, deep placement will not only reduce the amount of phosphorus available for transport, but will also result in lower fertilizer costs. Figure 5-1 shows the deep placement attachment used by the CCSWCD.

The NRCS provides additional information on nutrient management planning at:
http://efotg.nrcs.usda.gov/references/public/IL/590.pdf

The Illinois Agronomy Handbook may be found online at:
http://iah.aces.uiuc.edu/

(Photo Courtesy of CCSWCD)

Figure 5-1. Deep Placement Phosphorus Attachment Unit for Strip-till Toolbar.

For corn-soybean rotations, it is recommended that phosphorus fertilizer be applied once every two years, following harvest of the corn crop if application consists of broadcast followed by incorporation (UME, 1996). Band placement should occur prior to or during corn planting, depending on the type of field equipment available. Fertilizer should be applied when the chance of a large precipitation event is low. Application to frozen ground or snow cover should be strongly discouraged. Researchers studying loads from agricultural fields in east-central Illinois found that fertilizer application to frozen ground or snow followed by a rain event could transport 40 percent of the total annual phosphorus load (Gentry et al., 2007).

Recent technological developments in field equipment allow for fertilizer to be applied at varying rates across a field. Crop yield and net profits are optimized with this variable rate technology (IAH, 2002). Precision farming typically divides fields into 1- to 3-acre plots that are specifically managed for seed, chemical, and water requirements. Operating costs are reduced and crop yields typically increase, though upfront equipment costs may be high.

5.2.1 Effectiveness

The effectiveness of nutrient management plans (application rates, methods, and timing) in reducing phosphorus loading from agricultural land will be site specific. The following reductions are reported in the literature:

- 35 percent average reduction of total phosphorus load reported in Pennsylvania (USEPA, 2003).
- 20 to 50 percent total phosphorus load reductions with subsurface application at agronomic rates (HWRCI, 2005).
- 60 to 70 percent reduction in dissolved phosphorus concentrations and 20 percent reduction in total phosphorus concentrations when fertilizer is incorporated to a minimum depth of two inches prior to planting (HWRCI, 2005).
- 60 to 70 percent reduction in dissolved phosphorus concentrations and 20 to 50 percent reduction in total phosphorus with subsurface application, such as deep placement (HWRCI, 2005).
- 60 percent reduction in runoff concentrations of phosphorus when the following precipitation event occurred 10 days after fertilizer application, as opposed to 24 hours after application (HWRCI, 2005).
- Nutrient management plans will also reduce the dissolved oxygen impairments in the watershed by reducing the nutrients available to stimulate eutrophication.

5.2.2 Costs

A good nutrient management plan should address the rates, methods, and timing of fertilizer application. To determine the appropriate fertilizer rates, consultants in Illinois typically charge $6 to $18 per acre, which includes soil testing, manure analysis, scaled maps, and site specific recommendations for fertilizer management (USEPA, 2003). The CCSWCD (2003) estimates savings of approximately $10/ac during each plan cycle (4 years) by applying fertilizer at recommended rates. Actual savings (or costs) depend on the reduction (or increase) in fertilizer application rates required by the nutrient management plan as well as other farm management recommendations.

Placing the fertilizer below and to the side of the seed bed (referred to as banding) reduces the required application by one third to one half to achieve the same crop yields. In Champaign County, phosphorus application rates were reduced by approximately 13 lb/ac with this method. The equipment needed for deep placement costs up to $113,000 (Stikkers, 2007). Alternatively the equipment can be rented or the entire process hired out. The Heartland Regional Water Coordination Initiative lists the cost for deep placement of phosphorus fertilizer at $3.50/ac per application (HRWCI, 2005).

Table 5-4 summarizes the assumptions used to develop the annualized cost for this BMP.

Table 5-4. Costs Calculations for Nutrient Management Plans.

Item	Costs and Frequency	Annualized Costs (Savings)
Soil Testing and Determination of Rates	Costs $6/ac to $18/ac Every four years	$1.50/ac/yr to $4.50/ac/yr
Savings on Fertilizer	Saves $10/ac Every four years	($2.50/ac/yr)
Deep Placement of Phosphorus	Costs $3.50/ac Every two years	$1.75/ac/yr
Average Annual Costs		**$0.75/ac/yr to $3.75/ac/yr**

5.3 Conservation Tillage

Conservation tillage practices and residue management are commonly used to control erosion and surface transport of pollutants from fields used for crop production. The residuals not only provide erosion control, but also provide a nutrient source to growing plants, and continued use of conservation tillage results in a more productive soil with higher organic and nutrient content. Increasing the organic content of soil has the added benefit of reducing the amount of carbon in the atmosphere by storing it in the soil. Researchers estimate that croplands and pasturelands could be managed to trap 5 to 17 percent of the greenhouse gases produced in the United States (Lewandrowski et al., 2004).

Several practices are commonly used to maintain the suggested 30 percent cover:

- No-till systems disturb only a small row of soil during planting, and typically use a drill or knife to plant seeds below the soil surface.
- Strip till operations leave the areas between rows undisturbed, but remove residual cover above the seed to allow for proper moisture and temperature conditions for seed germination.
- Ridge till systems leave the soil undisturbed between harvest and planting: cultivation during the growing season is used to form ridges around growing plants. During or prior to the next planting, the top half to two inches of soil, residuals, and weed seeds are removed, leaving a relatively moist seed bed.
- Mulch till systems are any practice that results in at least 30 percent residual surface cover, excluding no-till and ridge till systems.

The NRCS provides additional information on these conservation tillage practices:
no-till and strip till: **http://efotg.nrcs.usda.gov/references/public/IL/329a.pdf**
ridge till: http://efotg.nrcs.usda.gov/references/public/IL/329b.pdf
mulch till: http://efotg.nrcs.usda.gov/references/public/IL/329c.pdf

Tillage system practices are not available specifically for the Crooked Creek watershed; however, countywide tillage system surveys are performed by the Illinois Department of Agriculture every two years. It is assumed that the general tillage practice trends measured in the counties is applicable to the watershed and the results of the 2006 surveys are presented in Table 5-5. Mulch till and no-till are considered conservation tillage practices: reduced till practices do not maintain 30 percent ground cover.

In 2006, the use of conservation tillage practices on corn fields occurred on less than 55 percent of the fields surveyed. Only 29 and 32 percent of corn fields in Marion and Clinton County, respectively, employ conservation tillage practices. It is more common for soybean fields to use conservation practices. At least 71 percent of soybean fields in each county use some form of conservation tillage. Practices on small grain fields vary widely from county to county with 97 percent of fields in Jefferson County using conservation tillage practices but less than 40 percent of fields employing these practices in Marion County.

Table 5-5. Percentage of Agricultural Fields Surveyed with Indicated Tillage System in 2006.

Crop Field Type	Tillage Practice				Conservation Tillage
	Conventional Till	Reduced-till	Mulch Till	No Till	
Clinton County					
Corn	68	5	19	8	**32**
Soybean	29	5	26	40	**71**
Small Grain	15	0	62	23	**85**
Jefferson County					
Corn	45	20	15	20	**55**
Soybean	25	13	15	47	**75**
Small Grain	3	2	88	7	**97**
Marion County					
Corn	71	10	0	19	**29**
Soybean	16	18	4	62	**84**
Small Grain	60	20	1	19	**40**
Washington County					
Corn	49	23	3	25	**51**
Soybean	12	15	21	52	**88**
Small Grain	10	72	11	7	**90**

Source: IDA, 2006.

Corn residues are more durable and capable of sustaining the required 30 percent cover required for conservation tillage. Soybeans generate less residue, the residue degrades more quickly, and supplemental measures or special care may be necessary to meet the 30 percent cover requirement (UME, 1996). Figure 5-2 shows a comparison of ground cover under conventional and conservation tillage practices.

Figure 5-2. Comparison of Conventional (left) and Conservation (right) Tillage Practices.

Though no-till systems are more effective in reducing sediment loading from crop fields, they tend to concentrate phosphorus in the upper two inches of the soil profile due to surface application of fertilizer and decomposition of plant material (IAH, 2002; UME, 1996). This pool of phosphorus readily mixes with precipitation and can lead to increased concentrations of dissolved phosphorus in surface runoff. Chisel plowing may be required once every several years to reduce stratification of phosphorus in the soil profile.

5.3.1 Effectiveness

Czapar et al. (2006) summarize past and present tillage practices and their impacts on erosion control and nutrient delivery. Historically, the mold board plow was used to prepare the field for planting. This practice disturbed 100 percent of the soil surface and resulted in basically no residual material. Today, conventional tillage typically employs the chisel plow, which is not as disruptive to the soil surface and tends to leave a small amount of residue on the field (0 to 15 percent). Mulch till systems were classified as leaving 30 percent residue; percent cover was not quantified for the no-till systems in this study. The researchers used WEPP modeling to simulate changes in sediment and nutrient loading for these tillage practices. Relative to mold board plowing, chisel plowing reduced phosphorus loads leaving the field by 38 percent, strip tilling reduced loads by 80 percent, and no-till reduced loads by 85 percent. If chisel plowing is now considered conventional, then the strip till and no-till practices are capable of reducing phosphorus loads by 68 percent and 76 percent, respectively (Czapar et al., 2006).

The IAH (2002) defines conservation tillage as any tillage practice that results in at least 30 percent coverage of the soil surface by crop residuals after planting. Tillage practices leaving 20 to 30 percent residual cover after planting reduce erosion by approximately 50 percent compared to bare soil. Practices that result in 70 percent residual cover reduce erosion by approximately 90 percent (IAH, 2002). Manganese reductions will be similar since this pollutant is primarily sediment bound.

USEPA (2003) reports the findings of several studies regarding the impacts of tillage practices on pesticide loading. Ridge till practices reduced pesticide loads by 90 percent and no-till reduced loads by an average of 67 percent. In addition, no-till reduced runoff losses by 69 percent, which will protect streambanks from erosion and loss of canopy cover (USEPA, 2003).

The reductions achieved by conservation tillage reported in these studies are summarized below:

- 68 to 76 percent reduction in total phosphorus.
- 50 percent reduction in sediment, and likely manganese, for practices leaving 20 to 30 percent residual cover.
- 90 percent reduction in sediment, and likely manganese, for practices leaving 70 percent residual cover.
- 90 percent reduction in pesticide loading for ridge till practices.
- 67 percent reduction in pesticide loading for no-till practices.
- 69 percent reduction in runoff losses for no-till practices.

5.3.2 Costs

Conservation tillage practices generally require fewer trips to the field, saving on labor, fuel, and equipment repair costs, though increased weed production may result in higher pesticide costs relative to conventional till (USDA, 1999). In general, conservation tillage results in increased profits relative to conventional tillage (Olson and Senjem, 2002; Buman et al., 2004; Czapar, 2006). The HRWCI (2005) lists no additional costs for conservation tillage.

Depending on the type of equipment currently used, replacing conventional till equipment with no-till equipment can either result in a net savings or slight cost to the producer. Al-Kaisi et al. (2000) estimate that converting conventional equipment to no-till equipment costs approximately $1.25 to $2.25/ac/yr, but that for new equipment, purchasing no-till equipment is less expensive than conventional equipment. Other researchers report a net gain when conventional equipment is sold to purchase no-till equipment (Harman et al., 2003).

Table 5-6 summarizes the available information for determining average annual cost for this BMP.

Table 5-6. Costs Calculations for Conservation Tillage

Item	Costs and Frequency	Annualized Costs (Savings)
Conversion of Conventional Equipment to Conservation Equipment	Costs presented in literature were already averaged out to yearly per acre costs: $1.25/ac/yr to $2.25/ac/yr	$1.25/ac/yr to $2.25/ac/yr
Operating Costs of Conservation Tillage Relative to Conventional Costs	$0/ac/yr	$0/ac/yr
Average Annual Costs		**$1.25/ac/yr to $2.25/ac/yr**

5.4 Cover Crops

Grasses and legumes may be used as winter cover crops to reduce soil erosion and improve soil quality (IAH, 2002). These crops also contribute nitrogen to the following crop, reducing fertilizer requirements. Grasses tend to have low seed costs and establish relatively quickly, but can impede cash crop development by drying out the soil surface or releasing chemicals during decomposition that may inhibit the growth of a following cash crop. Legumes take longer to establish, but are capable of fixing nitrogen from the atmosphere, thus reducing nitrogen fertilization required for the next cash crop. Legumes, however, are more susceptible to harsh winter environments and may not have adequate survival to offer sufficient erosion protection. Planting the cash crop in wet soil that is covered by heavy surface residue from the cover crop may impede emergence by prolonging wet, cool soil conditions. Cover crops should be killed off two or three weeks prior to planting the cash crop either by application of herbicide or mowing and incorporation, depending on the tillage practices used. Use of cover crops is illustrated in Figure 5-3.

(Photo Courtesy of NRCS)

Figure 5-3. Use of Cover Crops.

The NRCS provides additional information on cover crops at:
http://efotg.nrcs.usda.gov/references/public/IL/340.pdf

5.4.1 Effectiveness

The effectiveness of cover crops in reducing pollutant loading has been reported by several agencies. In addition to these benefits, the reduction in runoff losses will reduce erosion from streambanks, further reducing manganese loads and allowing for the establishment of vegetation and canopy cover. The reported reductions are listed below:

- 50 percent reduction in soil and runoff losses with cover crops alone. When combined with no-till systems, may reduce soil loss by more than 90 percent (IAH, 2002). Manganese reductions will likely be similar.
- 70 to 85 percent reduction in phosphorus loading on naturally drained fields (HRWCI, 2005).
- Reduction in fertilizer and pesticide requirements (OSUE, 1999).
- Useful in conservation tillage systems following low-residue crops such as soybeans (USDA, 1999).

5.4.2 Costs

The National Sustainable Agriculture Information Service recommends planting ryegrass after corn harvest and hairy vetch after soybeans (Sullivan, 2003). Both seeds can be planted at a depth of ¼ to ½ inch at a rate of 20 lb/ac or broadcast at a rate of 25 to 30 lb/ac (Ebelhar and Plumer, 2007; OSUE, 1990).

Researchers at Purdue University estimate the seed cost of ryegrass and hairy vetch at $12 and $30/ac, respectively. Savings in nitrogen fertilizer (assuming nitrogen fertilizer cost of $0.30/lb (Sample, 2007)) are $3.75/ac for ryegrass and $28.50/ac for hairy vetch. Yield increases in the following crop, particularly during droughts, are reported at 10 percent and are expected to offset the cost of this practice (Mannering et al., 1998). Herbicide application is estimated to cost $14.25/ac.

Accounting for the seed cost, herbicide cost, and fertilizer offset results in an average net cost of approximately $19.25/ac assuming that cover crop planting recommendations for a typical 2-year corn/soybean rotation are followed (Mannering et al., 1998). These costs do not account for yield increases which may offset the costs completely. Table 5-7 summarizes the costs and savings associated with ryegrass and hairy vetch.

Table 5-7. Costs Calculations for Cover Crops.

Item	Ryegrass	Hairy Vetch
Seed Costs	$12/ac	$30/ac
Nitrogen Fertilizer Savings	($3.75/ac)	($28.50/ac)
Herbicide Costs	$14.25/ac	$14.25/ac
Annual Costs	$22.50/ac	$15.75/ac
Average Annual Cost Assuming Ryegrass Follows Corn and Hairy Vetch Follows Soybeans: $19.25/ac		

5.5 Filter Strips

Filter strips are used in agricultural and urban areas to intercept and treat runoff before it leaves the site. If topography allows, filter strips may also be used to treat effluent from tile drain outlets. For small dairy operations, filter strips may also be used to treat milk house washings and runoff from the open lot (NRCS, 2003).

Filter strips will require maintenance, including grading and seeding, to ensure distributed flow across the filter and protection from erosion. Periodic removal of vegetation will encourage plant growth and uptake and remove nutrients stored in the plant material. Filter strips are most effective on sites with mild slopes of generally less than 5 percent, and to prevent concentrated flow, the upstream edge of a filter strip should follow one elevation contour (NCDENR, 2005). A grass filter strip is shown in Figure 5-4.

(Photo Courtesy of NRCS)

Figure 5-4. Grass Filter Strip Protecting Stream from Adjacent Agriculture.

The NRCS provides additional information on filter strips at:
http://efotg.nrcs.usda.gov/references/public/IL/393.pdf

Filter strips also serve to reduce the quantity and velocity of runoff. Filter strip sizing is dependent on site specific features such as climate and topography, but at a minimum, the area of a filter strip should be no less than 2 percent of the drainage area for agricultural land (OSUE, 1994). The minimum filter strip width suggested by NRCS (2002a) is 30 ft. The strips are assumed to function properly with annual maintenance for 30 years before requiring replacement of soil and vegetation.

5.5.1 Effectiveness

Filter strips have been found to effectively remove pollutants from agricultural runoff. The following reductions are reported in the literature (USEPA, 2003; Kalita, 2000; Woerner et al., 2006):

- 65 percent reduction in total phosphorus
- 11 to 100 percent reductions for atrazine

- 65 percent reductions for sediment (and likely manganese)
- Slows runoff velocities and may reduce runoff volumes via infiltration

5.5.2 Costs

Filter strips cost approximately $0.30 per sq ft to construct, and the system life is typically assumed to be 20 years (Weiss et al., 2007). Assuming that the required filter strip area is 2 percent of the area drained (OSUE, 1994), 870 square feet of filter strip are required for each acre of agricultural land treated. The construction cost to treat one acre of land is therefore $261/ac. The annualized construction costs are $13/ac/yr. Annual maintenance of filter strips is estimated at $0.01 per sq ft (USEPA, 2002c), for an additional cost of $8.70/ac/yr of agricultural land treated. In addition, the area converted from agricultural production to filter strip will result in a net annual income loss of $3.50. Table 5-8 summarizes the costs assumptions used to estimate the annualized cost to treat one acre of agricultural drainage with a filter strip.

Table 5-8. Costs Calculations for Filter Strips Used in Crop Production.

Item	Costs Required to Treat One Acre of Agricultural Land with Filter Strip
Construction Costs	$0.30
Annual Maintenance Costs	$0.01
Construction Costs	$261
System Life (years)	20
Annualized Construction Costs	$13
Annual Maintenance Costs	$8.70
Annual Income Loss	$3.50
Average Annual Costs	**$25/ac treated**

Filter strips used in animal operations typically treat contaminated runoff from pastures or feedlot areas or washings from the milk houses of small dairy operations (NRCS, 2003). The NRCS (2003) costs for small dairy operations (75 milk cows) assume a filter strip area of 12,000 sq ft is required. For the pasture operations, it is assumed that a filter strip area of 12,000 sq ft (30 ft wide and 400 ft long) would be required to treat runoff from a herd of 50 cattle (NRCS, 2003). The document does not explain why more animals can be treated by the same area of filter strip at the dairy operation compared to the pasture operation.

For animal operations, it is not likely that land used for growing crops would be taken out of production for conversion to a filter strip. Table 5-9 summarizes the capital, maintenance, and annualized costs for filter strips per head of animal.

Table 5-9. Costs Calculations for Filter Strips Used at Animal Operations.

Operation	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Small dairy (75 milking cows)	$48 per head of cattle	$1.50 per head of cattle	$4 per head of cattle
Beef or other (50 cattle)	$72 per head of cattle	$2.50 per head of cattle	$6 per head of cattle

5.6 Grassed Waterways

Grassed waterways are stormwater conveyances lined with grass that prevent erosion of the transport channel. They are often used to divert clean up-grade runoff around contaminated feedlots and manure storage areas (NRCS, 2003). In addition, the grassed channel reduces runoff velocities, allows for some infiltration, and filters out some particulate pollutants. A grassed waterway providing surface drainage for a corn field is shown in Figure 5-5.

(Photo Courtesy of NRCS)

Figure 5-5. Grassed Waterway.

The NRCS provides additional information on grassed waterways at:
http://efotg.nrcs.usda.gov/references/public/IL/412.pdf

5.6.1 Effectiveness

The effectiveness of grass swales for treating agricultural runoff has not been quantified. The Center for Watershed Protection reports the following reductions in urban settings (Winer, 2000):

- 30 percent reduction in total phosphorus
- 68 percent reduction of total suspended solids (similar reduction likely for manganese)

In addition, grassed waterways that allow for water infiltration may reduce atrazine loads by 25 to 35 percent (Kansas State University, 2007).

5.6.2 Costs

Grassed waterways cost approximately $0.50 per sq ft to construct (USEPA, 2002c). These stormwater conveyances are best constructed where existing bare ditches transport stormwater, so no income loss from land conversion is expected with this practice. It is assumed that the average area required for a grassed waterway is approximately 0.1 to 0.3 percent of the drainage area, or between 44 and 131 sq ft per acre. The range is based on examples in the Illinois Drainage Guide, information from the NRCS Engineering Field Handbook, and a range of waterway lengths (100 to 300 feet). Waterways are assumed to remove phosphorus effectively for 20 years before soil, vegetation, and drainage material need to be replaced (Weiss et al., 2007). The construction cost spread out over the life of the waterway is thus $2.25/yr for each acre of agriculture draining to a grassed waterway. Annual maintenance of grassed waterways is estimated at $0.02 per sq ft (Rouge River, 2001) for an additional cost of $1.75/ac/yr of agricultural land treated. Table 5-10 summarizes the annual costs assumptions for grassed waterways.

Table 5-10. Costs Calculations for Grassed Waterways Draining Cropland.

Item	Costs Required to Treat One Acre of Agricultural Land
Costs per Square Foot	
Construction Costs	$0.50
Annual Maintenance Costs	$0.02
Costs to Treat One Acre of Agricultural Land (assuming 44 to 131 sq ft of filter strip)	
Construction Costs	$22 to $65.50
System Life (years)	20
Annualized Construction Costs	$1 to $3.25
Annual Maintenance Costs	$1 to $2.75
Annual Income Loss	$0
Average Annual Costs	**$2 to 6/ac treated**

Grassed waterways are primarily used in animal operations to divert clean water away from pastures, feedlots, and manure storage areas. Table 5-11 summarizes the capital, maintenance, and annualized costs of this practice per head of cattle as summarized by NRCS (2003).

Table 5-11. Costs Calculations for Grassed Waterways Used in Cattle Operations.

Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
$0.50 to $1.50	$0.02 to $0.04	$0.05 to $0.12

5.7 Riparian Buffers

Riparian corridors, including both the stream channel and adjacent land areas, are important components of watershed ecology. The streamside forest slowly releases nutrients as twigs and leaves decompose. These nutrients are valuable to the fungi, bacteria, and invertebrates that form the basis of a stream's food chain. Tree canopies of riparian forests also cool the water in streams which can affect the composition of the fish species in the stream, the rate of biological reactions, and the amount of dissolved oxygen the water can hold. Channelization or widening of streams moves the canopy farther apart, decreasing the amount of shaded water surface, increasing water temperatures, and decreasing dissolved oxygen concentrations.

Preserving natural vegetation along stream corridors can effectively reduce water quality degradation associated with human disturbances. The root structure of the vegetation in a buffer enhances infiltration of runoff and subsequent trapping of nonpoint source pollutants. However, the buffers are only effective in this manner when the runoff enters the buffer as a slow moving, shallow "sheet"; concentrated flow in a ditch or gully will quickly pass through the buffer offering minimal opportunity for retention and uptake of pollutants.

Even more important than the filtering capacity of the buffers is the protection they provide to streambanks. The rooting systems of the vegetation serve as reinforcements in streambank soils, which help to hold streambank material in place and minimize erosion. Riparian buffers also prevent cattle access to streams, reducing streambank trampling and defecation in the stream. Due to the increase in stormwater runoff volume and peak rates of runoff associated with agriculture and development, stream channels are subject to greater erosional forces during stormflow events. Thus, preserving natural vegetation along stream channels minimizes the potential for water quality and habitat degradation due to streambank erosion and enhances the pollutant removal of sheet flow runoff from developed areas that pass through the buffer. A riparian buffer protecting the stream corridor from adjacent agricultural areas is shown in Figure 5-6.

(Photo Courtesy of NRCS)

Figure 5-6. Riparian Buffer Between Stream Channel and Agricultural Areas.

The NRCS provides additional information on riparian buffers at:
http://efotg.nrcs.usda.gov/references/public/IL/390.pdf *and*
http://efotg.nrcs.usda.gov/references/public/IL/391.pdf

5.7.1 Effectiveness

Riparian buffers should consist of native species and may include grasses, grass-like plants, forbs, shrubs, and trees. Minimum buffer widths of 25 feet are required for water quality benefits. Higher removal rates are provided with greater buffer widths. Riparian corridors typically treat a maximum of 300 ft of adjacent land before runoff forms small channels that short circuit treatment. Buffer widths based on slope measurements and recommended plant species should conform to NRCS Field Office Technical Guidelines. The following reductions are reported in the literature:

- 25 to 30 percent reduction of total phosphorus for 30 ft wide buffers (NCSU, 2002)
- 70 to 80 percent reduction of total phosphorus for 60 to 90 ft wide buffers (NCSU, 2002)
- 62 percent reduction in BOD_5 for 200 ft wide buffers (Wenger, 1999)
- 70 to 90 percent reduction of sediment (and likely manganese) (NCSU, 2002)
- 80 to 90 percent reduction of atrazine (USEPA, 2003)

- Increased canopy cover provides shading which may reduce water temperatures and improve dissolved oxygen concentrations (NCSU, 2002). Wenger (1999) suggests buffer width of at least 30 ft to maintain stream temperatures.
- Increased channel stability will reduce streambank erosion and manganese loads

5.7.2 Costs

Restoration of riparian areas costs approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). Maintenance of a riparian buffer should be minimal, but may include items such as period inspection of the buffer, minor grading to prevent short circuiting, and replanting/reseeding dead vegetation following premature death or heavy storms. Assuming a buffer width of 90 ft on either side of the stream channel and an adjacent treated width of 300 ft of agricultural land, one acre of buffer will treat approximately 3.3 acres of adjacent agricultural land. The cost per treated area is thus $30/ac to construct and $142.50/ac to maintain over the life of the buffer. Assuming a system life of 30 years results in an annualized cost of $59.25/yr for each acre of agriculture land treated (Table 5-12).

Table 5-12. Costs Calculations for Riparian Buffers.

Item	Costs Required to Treat One Acre of Agricultural Land
Costs per Acre of Riparian Buffer	
Construction Costs	$100
Maintenance Costs Over System Life	$475
Costs to Treat One Acre of Agricultural Land (assuming 0.3 ac of buffer)	
Construction Costs	$30
Maintenance Costs Over System Life	$142.50
System Life (Years)	30
Annualized Construction Costs	$1
Annualized Maintenance Costs	$4.75
Annual Income Loss	$53.50
Average Annual Costs	**$59.25/ac treated**

Restoration of riparian areas will protect the stream corridor from cattle trampling and reduce the amount of fecal material entering the channel. The cost of this BMP depends more on the length of channel to be protected, not the number of animals having channel access. The cost of restoration is approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). The costs per length of channel for 30 ft and 200 ft wide buffers restored on both sides of a stream channel are listed in Table 5-13. A system life of 30 years is assumed.

Table 5-13. Costs Calculations for Riparian Buffers per Foot of Channel.

Width	Capital Costs per ft	Annual Operation and Maintenance Costs per ft	Total Annualized Costs per ft
30 ft on both sides of channel	$0.14	$0.02	$0.03
60 ft on both sides of channel	$0.28	$0.04	$0.05
90 ft on both sides of channel	$0.42	$0.06	$0.07
200 ft on both sides of channel	$0.93	$0.13	$0.16

5.8 Constructed Wetlands

Constructed wetlands used to treat animal wastes are typically surface flowing systems comprised of cattails, bulrush, and reed plants. Prior to treating animal waste in a constructed wetland, storage in a lagoon or pond is required to protect the wetland from high pollutant loads that may kill the vegetation or clog pore spaces. After treatment in the wetland, the effluent is typically held in another storage lagoon and then land applied (USEPA, 2002a). Alternatively, the stored effluent can be used to supplement flows to the wetland during dry periods. Constructed wetlands that ultimately discharge to a surface waterbody will require a permit, and the receiving stream must be capable of assimilating the effluent during low flow conditions (NRCS, 2002b). Figure 5-7 shows an example of a lagoon-wetland system.

(Photo courtesy of USDA NRCS.)

Figure 5-7. Constructed Wetland System for Animal Waste Treatment.

The NRCS provides additional information on constructed wetlands at
http://efotg.nrcs.usda.gov/references/public/IL/656.pdf
and
ftp://ftp.wcc.nrcs.usda.gov/downloads/wastemgmt/NEH637Ch3ConstructedWetlands.pdf

5.8.1 Effectiveness

Wetland environments treat wastewater through sedimentation, filtration, plant uptake, biochemical transformations, and volatilization. Reported pollutant reductions found in the literature are listed below:

- 42 percent reduction in total phosphorus (USEPA, 2003)
- 59 to 80 percent reduction in BOD_5 (USEPA, 2002a)
- 53 to 81 percent reduction in total suspended solids (and likely manganese) (USEPA, 2002a)
- 50 percent reduction in atrazine in wetlands with a retention time of 35 days (Moore, 1999)

5.8.2 Costs

Researchers of the use of constructed wetlands for animal waste management generally agree that these systems are a lower cost alternative compared to conventional treatment and land application technologies. Few studies, however, actually report the costs of constructing and maintaining these systems. A Canadian study (CPAAC, 1999) evaluated the use of a constructed wetland system for treating milk house washings as well as contaminated runoff from the feedlot area and manure storage pile of a dairy operation containing 135 head of dairy cattle. The treatment system was comprised of a pond/wetland/pond/wetland/filter strip treatment train that cost $492 per head to construct. Annual operating and maintenance costs of $6.75 per head include electricity to run pumps, maintenance of pumps and berms, and dredging the wetland cells once every 10 years. Reductions in final disposal costs due to reduced phosphorus content of the final effluent were $20.75 per head and offset the costs of constructing and maintaining the wetland in seven years.

Another study evaluated the use of constructed wetlands for treatment of a 3,520-head swine operation in North Carolina. Waste removal from the swine facility occurs via slatted floors to an underlying pit that is flushed once per week. This new treatment system incorporated a settling basin, constructed wetland, and storage pond treatment system prior to land application or return to the pit for flushing.

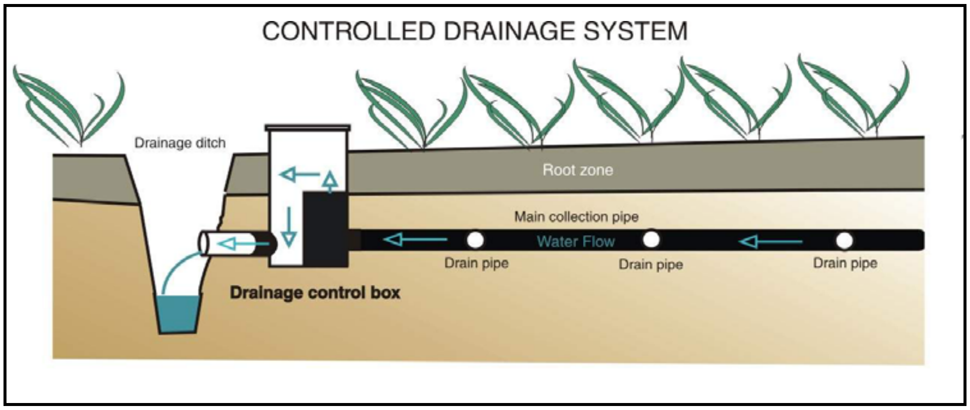
Capital and maintenance costs reported in the literature for dairy and swine operations are summarized per head in Table 5-14. No example studies including costs were available for beef cattle operations, which should generate less liquid waste than the other two operations. It would therefore be expected that constructing a wetland for beef cattle operation would cost less than for a dairy or swine operation.

Table 5-14. Costs Calculations for Constructed Wetlands.

Example	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Dairy farm	$492	-$14	$2.50
Swine operation	$103.75	$1.00	$4.50

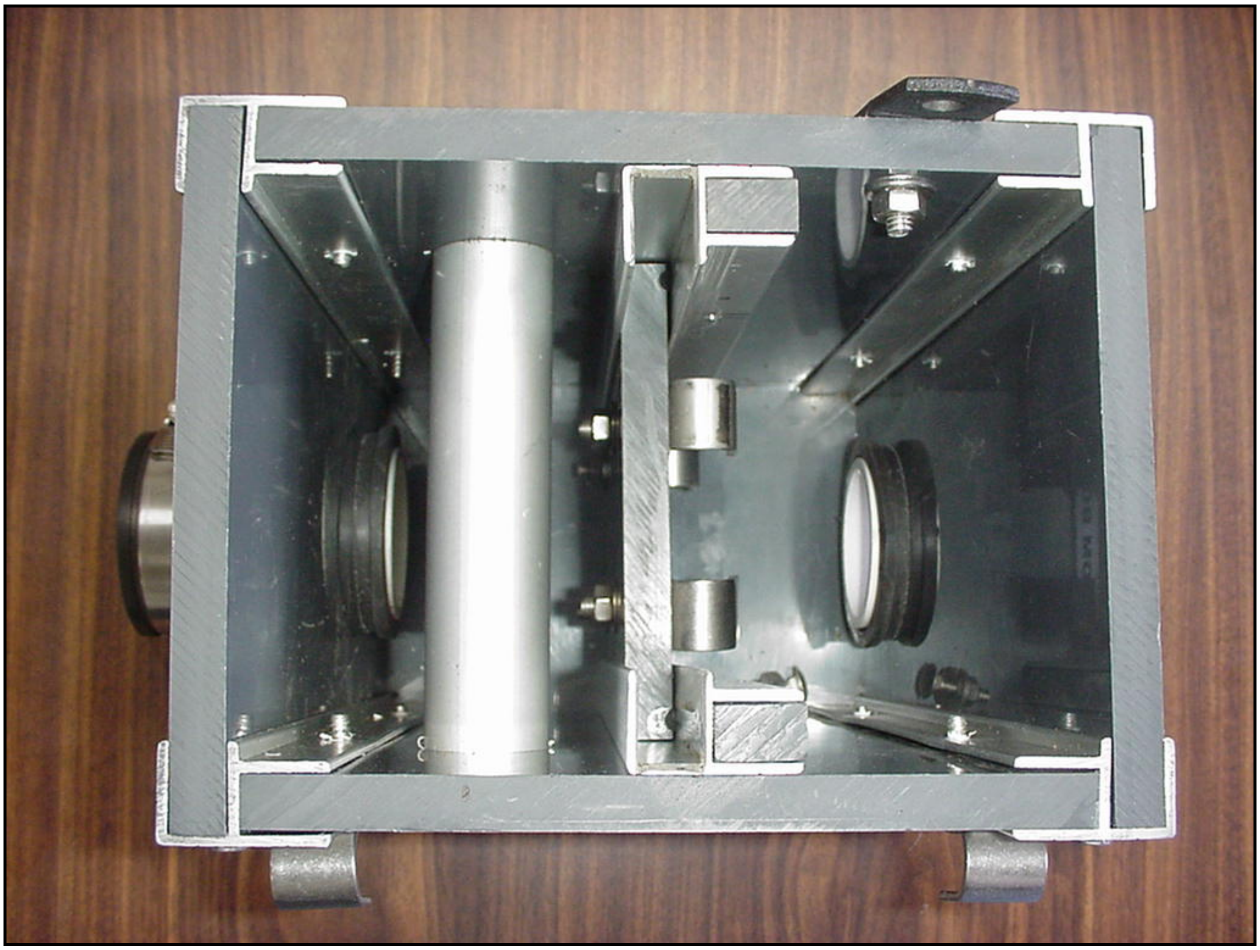
5.9 Controlled Drainage

A conventional tile drain system collects infiltrated water below the root zone and transports the water quickly to a down-gradient surface outlet. Placement of a water-level control structure at the outlet (Figure 5-8 and Figure 5-9) allows for storage of the collected water to a predefined elevation. The stored water becomes a source of moisture for plants during dry conditions and undergoes biological, chemical, and physical processes that result in lower nutrient concentrations in the final effluent.



(Illustration Courtesy of the Agricultural Research Service Information Division)

Figure 5-8. Controlled Drainage Structure for a Tile Drain System.



(Photo Courtesy of CCSWCD)

Figure 5-9. Interior View of a Drainage Control Structure with Adjustable Baffle Height.

The NRCS provides additional information on drainage management at: http://efotg.nrcs.usda.gov/references/public/IL/554.pdf.

5.9.1 Effectiveness

Use of control structures on conventional tile drain systems in the coastal plains has resulted in reductions of total phosphorus loading of 35 percent (Gilliam et al., 1997). Researchers at the University of Illinois also report reductions in phosphorus loading with tile drainage control structures. Concentrations of phosphate were reduced by 82 percent, although total phosphorus reductions were not quantified in this study (Cooke, 2005). Going from a surface draining system to a tile drain system with outlet control reduces phosphorus loading by 65 percent (Gilliam et al., 1997).

Storage of tiled drained water for later use via subsurface irrigation has shown decreases in dissolved phosphorus loading of approximately 50 percent (Tan et al., 2003). However, accumulated salts in reuse water may eventually exceed plant tolerance and result in reduced crop yields. Mixing stored drain water with fresh water or alternating irrigation with natural precipitation events will reduce the negative impacts of reuse. Salinity thresholds for each crop should be considered and compared to irrigation water concentrations.

5.9.2 Costs

The Champaign County Soil and Water Conservation District currently offers tile mapping services for approximately $2.25/ac using color infrared photography to assist farmers in identifying the exact location of their tile drain lines. Similar services are likely available through local vendors in the Crooked Creek watershed. Cooke (2005) estimates that the cost of retrofitting tile drain systems with outlet control structures ranges from $20 to $40 per acre. Construction of new tile drain systems with outlet control is approximately $75/ac. The yield increases associated with installation of tile drain systems are expected to offset the cost of installation (Cooke, 2005). It is assumed that outlet control structures have a system life of 30 years. Cost assumptions for retrofitting and installation of new tile drain systems with outlet control devices are summarized in Table 5-15.

Table 5-15. Costs Calculations for Outlet Control Devices on Tile Drain Systems.

Item	Costs to Retrofit Existing Systems	Costs to Install a New System
Mapping Costs per Acre	$2.25	$0
Construction Costs	$20 to $40/ac	$75/ac
System Life (years)	30	30
Average Annual Costs	**$0.75 to $1.50/ac treated**	**$2.50/ac treated**

5.10 Proper Manure Handling, Collection, and Disposal

Animal operations are typically either pasture-based or confined, or sometimes a combination of the two. The operation type dictates the practices needed to manage manure from the facility. A pasture or open lot system with a relatively low density of animals (1 to 2 head of cattle per acre (USEPA, 2002a)) may not produce manure in quantities that require management for the protection of water quality. If excess manure is produced, then the manure will typically be scraped with a tractor to a storage bin constructed on a concrete surface. Stored manure can then be land applied when the ground is not frozen and precipitation forecasts are low. Rainfall runoff should be diverted around the storage facility with berms or grassed waterways. Runoff from the feedlot area is considered contaminated and is typically treated in a lagoon.

Confined facilities (typically dairy cattle, swine, and poultry operations) often collect manure in storage pits located under slatted floors. Wash water used to clean the floors and remove manure buildup combines with the solid manure to form a liquid or slurry in the pit. The mixture is usually land applied or transported offsite.

Final disposal of waste usually involves land application on the farm or transportation to another site. Manure is typically applied to the land once or twice per year. To maximize the amount of nutrients and organic material retained in the soil, application should not occur on frozen ground or when precipitation is forecast during the next several days.

An example of a waste storage lagoon is shown in Figure 5-10.

(Photo courtesy of USDA NRCS.)

Figure 5-10. Waste Storage Lagoon.

The NRCS provides additional information on waste storage facilities and cover at
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 313 and 367

and on anaerobic lagoons at
http://efotg.nrcs.usda.gov/references/public/IL/IL-365_2004_09.pdf
http://efotg.nrcs.usda.gov/references/public/IL/IL-366_2004_09.pdf

5.10.1 Effectiveness

Though little change in total phosphorus or organic content has been reported, reductions in fecal coliform as a result of manure storage have been documented in two studies:

- 97 percent reduction in fecal coliform concentrations in runoff when manure is stored for at least 30 days prior to land application (Meals and Braun, 2006).
- 90 percent reduction in fecal coliform loading with the use of waste storage structures, ponds, and lagoons (USEPA, 2003).

5.10.2 Costs

Depending on whether or not the production facility is pasture-based or confined, manure is typically deposited in feedlots, around watering facilities, and within confined spaces such as housing units and milking parlors. Except for feedlots serving a low density of animals, each location will require the collection and transport of manure to a storage structure, holding pond, storage pit, or lagoon prior to final disposal.

Manure collected from open lots and watering areas is typically collected by a tractor equipped with a scraper. This manure is in solid form and is typically stored on a concrete pad surrounded by three walls that allow for stacking of contents. Depending on the climate, a roof may be required to protect the manure from frequent rainfall. Clean water from rooftops or up-grade areas should be diverted around waste stockpiles and heavy use areas with berms, grassed channels, or other means of conveyance (USEPA, 2003). Waste storage lagoons, pits, and above ground tanks are good options for large facilities. Methane gas recovered from anaerobic treatment processes can be used to generate electricity.

The NRCS (2003) has developed cost estimates for the various tasks and facilities typically used to transport, store, and dispose of manure. Table 5-16 summarizes the information contained in the NRCS report and lists the capital and operating/maintenance costs reported per head of animal. Annual maintenance costs were assumed 3 percent of capital costs except for gutter downspouts (assumed 10 percent to account for animals trampling the downspouts) and collection and transfer (assumed 15 percent to account for costs associated with additional fuel and labor). The costs presented as a range were given for various sizes of operations. The lower values reflect the costs per head for the larger operations which are able to spread out costs over more animals.

The full NRCS document can be viewed at
http://www.nrcs.usda.gov/Technical/land/pubs/cnmp1.html

The useful life for practices requiring construction is assumed to be 20 years. The total annualized costs were calculated by dividing the capital costs by 20 and adding the annual operation and maintenance costs. Prices are converted to year 2004 dollars.

Table 5-16. Costs Calculations for Manure Handling, Storage, and Treatment Per Head.

Item	Application	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Collection and Transfer of Solid Manure, Liquid/Slurry Manure, and Contaminated Runoff				
Collection and transfer of manure solids (assuming a tractor must be purchased)	All operations with outside access and solid collection systems for layer houses	$130.50 - dairy cattle $92.50 - beef cattle $0 - layer[1] $37.00 - swine	$19.50 - dairy cattle $13.75 - beef cattle $0.04 - layer $5.50 - swine	$26.00 - dairy cattle $18.25 - beef cattle $0.04 - layer $7.25 - swine
Collection and transfer of liquid/slurry manure	Dairy, swine, and layer operations using a flush system	$160 to $200 - dairy cattle $.50 - layer $5.75 to $4.50 - swine	$12.25 - dairy cattle $0.03 - layer $0.25 - swine	$20.25 to 22.25 - dairy cattle $0.05 - layer $0.50 - swine
Collection and transfer of contaminated runoff using a berm with pipe outlet	Fattened cattle and confined heifers	$4 to $9 - cattle	$0.12 to 0.25 - cattle	$0.25 to $0.75 - cattle
Feedlot Upgrades for Cattle Operations Using Concentrated Feeding Areas				
Grading and installation of a concrete pad	Cattle on feed (fattened cattle and confined heifers)	$35 - cattle	$1 - cattle	$2.75 - cattle
Clean Water Diversions				
Roof runoff management: gutters and downspouts	Dairy and swine operations that allow outside access	$16 - dairy cattle $2.25 - swine	$1.60 - dairy cattle $0.25 - swine	$2.50 - dairy cattle $0.50 - swine
Earthen berm with underground pipe outlet	Fattened cattle and dairy operations	$25.25 to $34.50 - cattle	$0.75 to $1.00 - cattle	$2 to $2.75 - cattle
Earthen berm with surface outlet	Swine operations that allow outside access	$1 - swine	$0.03 - swine	$0.08 - swine
Grassed waterway	Fattened cattle and confined heifer operations: scrape and stack system	$0.50 to $1.50 - cattle	$0.02 to $0.04 - cattle	$0.05 to $0.12 - cattle
Storage				
Liquid storage (contaminated runoff and wastewater)	Swine, dairy, and layer operations using flush systems (costs assume manure primarily managed as liquid)	$245 to $267 - dairy cattle $2 - layer $78.50 to $80 - swine	$7.25 - dairy cattle $0.06 - layer $2.50 - swine	$19.50 to $20.50 - dairy cattle $0.16 - layer $6.50 - swine

Item	Application	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Slurry storage	Swine and dairy operations storing manure in pits beneath slatted floors (costs assume manure primarily managed as slurry)	$104 to $127 - dairy cattle $15.50 to $19.50 - swine	$3.25 to $3.75 - dairy cattle $0.50 - swine	$8.25 to $10.25 - dairy cattle $1.25 to $1.50 - swine
Runoff storage ponds (contaminated runoff)	All operations with outside access	$125.50 - dairy cattle $140 - beef cattle $23 - swine	$3.75 - dairy cattle $4.25 - beef cattle $0.75 - swine	$10 - dairy cattle $11.25 - beef cattle $2 - swine
Solid storage	All animal operations managing solid wastes (costs assume 100% of manure handled as solid)	$196 - dairy cattle $129 - beef cattle $1 - layer $14.25 - swine	$5.75 - dairy cattle $3.75 - beef cattle $0.03 - layer $0.50 - swine	$15.50 - dairy cattle $10.25 - beef cattle $0.25 - layer $1.25 - swine
Final Disposal				
Pumping and land application of liquid/slurry	Operations handling manure primarily as liquid or slurry.	Land application costs are listed as capital plus operating for final disposal and are listed as dollars per acre for the application system. The required number of acres per head was calculated for each animal type based on the phosphorus content of manure at the time of application. Pumping costs were added to the land application costs as described in the document.		$19.50 - dairy cattle $0.25 - layer $2.75 - swine
Pumping and land application of contaminated runoff	Operations with outside feedlots and manure handled primarily as solid	Pumping costs and land application costs based on information in NRCS, 2003. Assuming a typical phosphorus concentration in contaminated runoff of 80 mg/L to determine acres of land required for agronomic application (Kizil and Lindley, 2000). Costs for beef cattle listed as range representing variations in number of animals and manure handling systems (NRCS, 2003). Only one type and size of dairy and swine operation were included in the NRCS document.		$4 - dairy cattle $3.75 - beef cattle $4.50 - swine
Land application of solid manure	Operations handling manure primarily as solid	Land application costs are listed as capital plus operating for final disposal and are given as dollars per acre for the application system. The required number of acres per head was calculated for each animal type based on the phosphorus content of manure at the time of application. No pumping costs are required for solid manure.		$11 - dairy cattle $0.25 - layer $1.50 - swine $10.25 - fattened cattle

[1] Costs presented by NRCS (2003) as operating and maintenance only.

5.11 Composting

Composting is the biological decomposition and stabilization of organic material. The process produces heat that, in turn, produces a final product that is stable, free of pathogens and viable plant seeds, and can be beneficially applied to the land. Like manure storage areas, composting facilities should be located on dry, flat, elevated land at least 100 feet from streams. The landowner should coordinate with local NRCS staff to determine the appropriate design for a composting facility based on the amount of manure generated. Extension agents can also help landowners achieve the ideal nutrient ratios, oxygen levels, and moisture conditions for composting on their site.

Composting can be accomplished by simply constructing a heap of the material, forming composting windrows, or by constructing one or more bins to hold the material. Heaps should be 3 feet wide and 5 feet high with the length depending on the amount of manure being composted. Compost does not have to be turned, but turning will facilitate the composting process (University of Missouri, 1993; PSU, 2005). Machinery required for composting includes a tractor, manure spreader, and front-end loader (Davis and Swinker, 2004). Figure 5-11 shows a poultry litter composting facility.

(Photo courtesy of USDA NRCS.)

Figure 5-11. Poultry Litter Composting Facility.

The NRCS provides additional information on composting facilities at
http://efotg.nrcs.usda.gov/references/public/IL/IL-317rev9-04.pdf
and
ftp://ftp.wcc.nrcs.usda.gov/downloads/wastemgmt/neh637c2.pdf

5.11.1 Effectiveness

Composting stabilizes the organic content of manure and reduces the volume that needs to be disposed. In addition, the following reductions in loading are reported:

- 56 percent reduction in runoff volumes and 68 percent reduction in sediment (and likely manganese) as a result of improved soil infiltration following application of composted manure (HRWCI, 2005).

5.11.2 Costs

The costs for developing a composting system include site development costs (storage sheds, concrete pads, runoff diversions, etc.), purchasing windrow turners if that system is chosen, and labor and fuel required to form and turn the piles. Cost estimates for composting systems have not been well documented and show a wide variation even for the same type of system. The NRCS is in the process of developing cost estimates for composting and other alternative manure applications in Part II of the document discussed in Section 5.10.2. Once published, these estimates should provide a good comparison with the costs summarized for the Midwest region in Table 5-16. For now, costs are presented in Table 5-17 based on studies conducted in Wisconsin, Canada, and Indiana.

Researchers in Wisconsin estimated the costs of a windrow composting system using four combinations of machinery and labor (CIAS, 1996). These costs included collection and transfer of excreted material, formation of the windrow pile, turning the pile, and reloading the compost for final disposal. The Wisconsin study was based on a small dairy operation (60 head). Costs for beef cattle, swine, and layer hens were calculated based on animal units and handling weights of solid manure (NRCS, 2003). Equipment life is assumed 20 years. The costs presented in the Wisconsin study are much higher than those presented in Table 5-17 for collection, transfer, and storage of solid manure. However, the Wisconsin study presented a cost comparison of the windrow system to stacking on a remote concrete slab, and these estimates were approximately four and half times higher than the values summarized by NRCS. It is likely that the single data set used for the Wisconsin study is not representative of typical costs.

Two studies have been conducted in Canada regarding the costs of composting. The University of Alberta summarized the per ton costs of windrow composting with a front end load compared to a windrow turner (University of Alberta, 2000). The Alberta Government presented a per ton estimate for a windrow system with turner: this estimate is quite different than the University of Alberta study. These per ton costs were converted to costs per head of dairy cattle, beef cattle, swine, and layer hens based on the manure generation and handling weights presented by NRCS (2003).

In 2001, the USEPA released a draft report titled “Alternative Technologies/Uses for Manure.” This report summarizes results from a Purdue University research farm operating a 400-cow dairy operation. This farm also utilizes a windrow system with turner.

Table 5-17 summarizes the cost estimates presented in each of the studies for the various composting systems. None of these estimates include the final costs of land application, which should be similar to those listed for disposal of solid manure in Table 5-16, as no phosphorus losses occur during the composting process.

Table 5-17. Costs Calculations for Manure Composting.

Equipment Used	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
2004 Costs Estimated from CIAS, 1996 – Wisconsin Study			
Windrow composting with front-end loader	$324.25 - dairy cattle $213.50 - beef cattle $1.75 - layer $23.75 - swine	$179.75 - dairy cattle $118.50 - beef cattle $1 - layer $13.25 - swine	$196 - dairy cattle $129.25 - beef cattle $1 - layer $14.25 - swine
Windrow composting with bulldozer	$266 - dairy cattle $175.25 - beef cattle $1.50 - layer $19.50 - swine	$179.75 - dairy cattle $118.50 - beef cattle $1 - layer $13.25 - swine	$193.25 - dairy cattle $127.25 - beef cattle $1 - layer $14.25 - swine
Windrow composting with custom-hire compost turner	$266 - dairy cattle $175.25 - beef cattle $1.50 - layer $19.50 - swine	$215.25 - dairy cattle $141.75 - beef cattle $1.25 - layer $15.75 - swine	$228.75 - dairy cattle $150.50 - beef cattle $1.25 - layer $16.75 - swine
Windrow composting with purchased compost turner	$617 - dairy cattle $406.25 - beef cattle $3.50 - layer $45.25 - swine	$234.25 - dairy cattle $154.25 - beef cattle $1.25 - layer $17.25 - swine	$265.25 - dairy cattle $174.75 - beef cattle $1.50 - layer $19.50 - swine
2004 Costs Estimated from University of Alberta, 2000			
Windrow composting with front-end loader	Study presented annualized costs per ton of manure composted.		$23.75 to $47.50 - dairy cattle $15.75 to $31.25 - beef cattle $0.13 to $0.25 - layer $1.75 to $3.50 - swine
Windrow composting with compost turner	Study presented annualized costs per ton of manure composted.		$71.25 to $142.50 - dairy cattle $47.00 to $94.00 - beef cattle $0.50 to $0.75 - layer $5.25 to $10.50 - swine
2004 Costs Estimated from Alberta Government, 2004			
Windrow composting with compost turner	Study presented annualized costs per ton of manure composted.		$31.50 - dairy cattle $20.75 - beef cattle $0.25 - layer $2.25 - swine
2004 Costs Estimated from USEPA, 2001 Draft			
Windrow composting with compost turner	Study presented annualized costs per dairy cow.		$15.50 - dairy cattle $10.25 - beef cattle $0.09 - layer $1.25 - swine

5.12 Feeding Strategies

Use of dietary supplements, genetically enhanced feed, and specialized diets has been shown to reduce the nitrogen and phosphorus content of manure either by reducing the quantity of nutrients consumed or by increasing the digestibility of the nutrients. Manure with a lower nutrient content can be applied at higher rates to crop land, thus reducing transportation and disposal costs for excess manure.

Manure typically has high phosphorus content relative to plant requirements compared to its nitrogen content. Nitrogen losses due to ammonia volatilization begin immediately following waste excretion and continue throughout the stabilization process, whereas phosphorus remains conserved. In addition, most livestock animals are not capable of efficiently digesting phosphorus, so a large percentage passes through the animal undigested. Compounding the problem is over-supplementation of phosphorus additives relative to nutritional guidelines, particularly for dairy cattle (USEPA, 2002a).

5.12.1 Effectiveness

Most feeding strategies work to reduce the phosphorus content of manure such that the end product has a more balanced ratio of nitrogen and phosphorus. Reducing the phosphorus content of manure will result in lower phosphorus concentrations in runoff and stream systems. Feeding strategies will indirectly impact dissolved oxygen concentrations by reducing eutrophication in streams and lakes. The USEPA (2002a) reports the following reductions in phosphorus manure content:

- 40 percent reduction in the phosphorus content of swine manure if the animals are fed low-phytate corn or maize-soybean diets or given a phytase enzyme to increase assimilation by the animal.
- 30 to 50 percent reduction in the phosphorus content of poultry manure by supplementing feed with the phytase enzyme.

5.12.2 Costs

Several feeding strategies are available to reduce the phosphorus content of manure. Supplementing feed with the phytase enzyme increases the digestibility of phytate, which is difficult for animals to digest and is the form of phosphorus found in conventional feed products. Supplementing with phytase used to be expensive, but now is basically equivalent to the cost of the dietary phosphorus supplements that are required when animals are fed traditional grains (Wenzel, 2002).

Another strategy is to feed animals low-phytate corn or barley which contains more phosphorus in forms available to the animal. Most animals fed low-phytate feed do not require additional phosphorus supplementation; the additional cost of the feed is expected to offset the cost of supplements. The third strategy is to stop over-supplementing animals with phosphorus. Reducing intake to dietary requirements established by the USDA may save dairy farmers $25 per year per cow (USEPA, 2002a). Final disposal costs for manure will likely also decrease since less land will be required during the application process.

5.13 Alternative Watering Systems

A primary management tool for pasture-based systems is supplying cattle with watering systems away from streams and riparian areas. Livestock producers who currently rely on streams to provide water for their animals must develop alternative watering systems, or controlled access systems, before they can exclude cattle from streams and riparian areas. One method of providing an alternative water source is the development of off-stream watering using wells with tank or trough systems. These systems are often highly successful, as cattle often prefer spring or well water to surface water sources.

Landowners should work with an agricultural extension agent to properly design and locate watering facilities. One option is to collect rainwater from building roofs (with gutters feeding into cisterns) and use this water for the animal watering system to reduce runoff and conserve water use (Tetra Tech, 2006).

Whether or not animals are allowed access to streams, the landowner should provide an alternative shady location and water source so that animals are encouraged to stay away from riparian areas.

Figure 5-12 shows a centralized watering tank allowing access from rotated grazing plots and a barn area.

(Photo courtesy of USDA NRCS.)

Figure 5-12. Centralized Watering Tank.

The NRCS provides additional information on these alternative watering components:

Spring development:
http://efotg.nrcs.usda.gov/references/public/IL/IL-574.pdf,

Well development:
http://efotg.nrcs.usda.gov/references/public/IL/IL-642.pdf,

Pipeline:
http://efotg.nrcs.usda.gov/references/public/IL/516.pdf,

Watering facilities (trough, barrel, etc.):
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 614

5.13.1 Effectiveness

The USEPA (2003) reports the following pollutant load reductions achieved by supplying cattle with alternative watering locations and excluding cattle from the stream channel by structural or vegetative barrier:

- 15 to 49 percent reductions in total phosphorus loading

Some researchers have studied the impacts of providing alternative watering sites without structural exclusions and found that cattle spend 90 percent less time in the stream when alternative drinking water is furnished (USEPA, 2003). Prohibiting access to the stream channels will also prevent streambank trampling, decrease bank erosion, protect bank vegetation, and reduce the loading of organic material to the streams. As a result, dissolved oxygen concentrations will likely increase and manganese loads associated with bank erosion will decrease.

5.13.2 Costs

Alternative drinking water can be supplied by installing a well in the pasture area, pumping water from a nearby stream to a storage tank, developing springs away from the stream corridor, or piping water from an existing water supply. For pasture areas without access to an existing water supply, the most reliable alternative is installation of a well, which ensures continuous flow and water quality for the cattle (NRCS, 2003). Assuming a well depth of 250 ft and a cost of installation of $22.50 per ft, the cost to install a well is approximately, $5,625 per well. The well pump would be sized to deliver adequate water supply for the existing herd size. For a herd of 150 cattle, the price per head for installation was estimated at $37.50.

After installation of the well or extension of the existing water supply, a water storage device is required to provide the cattle access to the water. Storage devices include troughs or tanks. NRCS (2003) lists the costs of storage devices at $23 per head.

Annual operating costs to run the well pump range from $9 to $22 per year for electricity (USEPA, 2003; Marsh, 2001), or up to $0.15 per head. Table 5-18 lists the capital, maintenance, and annualized costs for a well, pump, and storage system assuming a system life of 20 years.

Table 5-18. Costs Calculations for Alternative Watering Facilities.

Item	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Installation of well	$37.50	$0	$2
Storage container	$23	$0	$1
Electricity for well pump	$0	$0.15	$0.15
Total system costs	**$60.50**	**$0.15**	**$3.15**

5.14 Cattle Exclusion from Streams

Cattle manure is a substantial source of nutrient loading to streams, particularly where direct access is not restricted and/or where cattle feeding structures are located adjacent to riparian areas. Direct deposition of feces into streams may be a primary mechanism of pollutant loading during baseflow periods. During storm events, overbank and overland flow may entrain manure accumulated in riparian areas resulting in pulsed loads of nutrients, total organic carbon (TOC), and biological oxygen demand (BOD) into streams. In addition, cattle with unrestrained stream access typically cause severe streambank erosion. The impacts of cattle on stream ecosystems are shown in Figure 5-13 and Figure 5-14.

Figure 5-13. Typical Stream Bank Erosion in Pastures with Cattle Access to Stream.

Figure 5-14. Cattle-Induced Streambank Mass Wasting and Deposition of Manure into Stream.

An example of proper exclusion and the positive impacts it has on the stream channel are shown in Figure 5-15.

(Photo courtesy of USDA NRCS.)

Figure 5-15. Stream Protected from Sheep by Fencing.

The NRCS provides additional information on fencing at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 382

Allowing limited or no animal access to streams will provide the greatest water quality protection. On properties where cattle need to cross streams to have access to pasture, stream crossings should be built so that cattle can travel across streams without degrading streambanks and contaminating streams with manure. Figure 5-16 shows an example of a reinforced cattle access point to minimize time spent in the stream and mass wasting of streambanks.

(Photo courtesy of USDA NRCS.)

Figure 5-16. Restricted Cattle Access Point with Reinforced Banks.

The NRCS provides additional information on use exclusion and controlled access at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 472

5.14.1 Effectiveness

Fencing cattle from streams and riparian areas using vegetative or fencing materials will reduce streambank trampling and direct deposition of fecal material in the streams. As a result, manganese (associated with eroded sediment) and BOD_5 loads will decrease. The USEPA (2003) reports the following reductions in phosphorus loading as a result of cattle exclusion practices:

- 15 to 49 percent reductions in total phosphorus loading

5.14.2 Costs

The costs of excluding cattle from streams depends more on the length of channel that needs to be protected than the number of animals on site. Fencing may also be used in a grazing land protection operation to control cattle access to individual plots. The system life of wire fences is reported as 20 years; the high tensile fence materials have a reported system life of 25 years (Iowa State University, 2005). NRCS reports that the average operation needs approximately 35 ft of additional fencing per head to protect grazing lands and streams. Table 5-19 presents the capital, maintenance, and annualized costs for four fencing materials based on the NRCS assumptions.

Table 5-19. Installation and Maintenance Costs of Fencing Material.

Material	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Woven Wire	$43.50	$3.50	$5.75
Barbed Wire	$33.50	$2.75	$4.50
High Tensile (non-electric) 8-strand	$30.75	$1.75	$3.00
High Tensile (electric) 5-strand	$23.00	$1.50	$2.50

5.15 Grazing Land Management

While erosion rates from pasture areas are generally lower than those from row-crop areas, a poorly managed pasture can approach or exceed a well-managed row-crop area in terms of erosion rates. Grazing land protection is intended to maximize ground cover on pasture, reduce soil compaction resulting from overuse, reduce runoff concentrations of nutrients, and protect streambanks and riparian areas from erosion and fecal deposition. Figure 5-17 shows an example of a pasture managed for land protection. Cows graze the left lot while the right lot is allowed a resting period to revegetate.

(Photo courtesy of USDA NRCS.)

Figure 5-17. Example of a Well Managed Grazing System.

The NRCS provides additional information on prescribed grazing at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 528A

And on grazing practices in general at:
http://www.glti.nrcs.usda.gov/technical/publications/nrph.html

5.15.1 Effectiveness

Maintaining sufficient ground cover on pasture lands requires a proper density of grazing animals and/or a rotational feeding pattern among grazing plots. Increased ground cover will also reduce transport of sediment-bound manganese. Dissolved oxygen concentrations in streams will likely improve as the concentrations of BOD_5 in runoff are reduced proportionally with the change in number of cattle per acre.

The following reductions in loading are reported in the literature:

- 49 to 60 percent reduction in total phosphorus loading

5.15.2 Costs

The costs associated with grazing land protection include acquiring additional land if current animal densities are too high (or reducing the number of animals maintained), fencing and seeding costs, and developing alternative water sources. Establishment of vegetation for pasture areas costs from $39/ac to $69/ac based on data presented in the EPA nonpoint source guidance for agriculture (USEPA, 2003). Annual costs for maintaining vegetative cover will likely range from $6/ac to $11/ac (USEPA, 2003). If cattle are not allowed to graze plots to the point of requiring revegetation, the cost of grazing land protection may be covered by the fencing and alternative watering strategies discussed above.

5.16 Inlake Controls

For lakes experiencing high rates of phosphorus or manganese inputs from bottom sediments, several management measures are available to control internal loading. Hypolimnetic (bottom water) aeration involves an aerator air-release that can be positioned at a selected depth or at multiple depths to increase oxygen transfer efficiencies in the water column and reduce internal loading by establishing aerobic conditions at the sediment-water interface.

Hypolimnetic aeration effectiveness in reducing phosphorus concentration depends in part on the presence of sufficient iron to bind phosphorus in the oxygenated waters. A mean hypolimnetic iron:phosphorus ratio greater than 3.0 is optimal to promote iron phosphate precipitation (Stauffer, 1981). The iron:phosphorus ratio in the sediments should be greater than 15 to bind phosphorus (Welch, 1992). Aeration of bottom waters will also likely inhibit the release of manganese from bottom sediments in lakes.

Phosphorus inactivation by aluminum addition (specifically aluminum sulfate or alum) to lakes has been the most widely-used technique to control internal phosphorus loading. Alum forms a polymer that binds phosphorus and organic matter. The aluminum hydroxide-phosphate complex (commonly called alum floc) is insoluble and settles to the bottom, carrying suspended and colloidal particles with it. Once on the sediment surface, alum floc retards phosphate diffusion from the sediment to the water (Cooke et al., 1993).

Artificial circulation is the induced mixing of the lake, usually through the input of compressed air, which forms bubbles that act as airlift pumps. The increased circulation raises the temperature of the whole lake

(Cooke et al., 1993) and chemically oxidizes substances throughout the water column (Pastorak et al., 1981 and 1982), reducing the release of phosphorus and manganese from the sediments to the overlying water, and enlarging the suitable habitat for aerobic animals.

5.16.1 Effectiveness

If lake sediments are a significant source of phosphorus or manganese in the Crooked Creek watershed, then these inlake controls should reduce the internal loading significantly. Without data to quantify the internal load for each lake, it is difficult to estimate the reduction in loading that may be seen with these controls.

5.16.2 Costs

In general, inlake controls are expensive. For comparison with the agricultural cost estimates, the inlake controls have been converted to year 2004 dollars assuming an average annual inflation rate of 3 percent.

Hypolimnetic aerators may decrease internal loading of both phosphorus and manganese. The number and size of hypolimnetic aerators used in a waterbody depend on lake morphology, bathymetry, and hypolimnetic oxygen demand. Total cost for successful systems has ranged from $170,000 to $1.7 million (Tetra Tech, 2002). USEPA (1993) reports initial costs ranging from $340,000 to $830,000 plus annual operating costs of $60,000. System life is assumed to be 20 years.

Alum treatments are effective on average for approximately 8 years per application and can reduce internal phosphorus loading by 80 percent. Treatment cost ranges from $290/ac to $720/ac (WIDNR, 2003).

Dierberg and Williams (1989) cite mean initial and annual costs for 13 artificial circulation projects in Florida of $440/ac and $190/ac/yr, respectively. The system life is assumed to be 20 years.

Table 5-20 summarizes the cost analyses for the three inlake management measures. The final column lists the annualized cost per lake surface area treated.

Table 5-20. Cost Comparison of Inlake Controls.

Control	Construction or Application Cost	Annual Maintenance Cost	Annualized Costs $/ac/yr
Centralia Lake (254 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$300 to $400
Alum Treatment	$74,000 to $183,000	$0	$36 to $90
Artificial Circulation	$112,000	$48,000	$212
Raccoon Lake (925 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$83 to $110
Alum Treatment	$270,000 to $670,000	$0	$36 to $90
Artificial Circulation	$407,000	$176,000	$212
Salem Lake (74.2 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$1040 to $1400
Alum Treatment	$22,000 to $53,000	$0	$36 to $90
Artificial Circulation	$33,000	$14,000	$212
Nashville City Lake (42 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$1,800 to $2,400
Alum Treatment	$12,000 to $30,000	$0	$36 to $90
Artificial Circulation	$18,000	$8,000	$212

5.17 Atrazine BMPs

Several strategies exist to reduce atrazine migration from corn and grain applications. Similar to nutrient management planning, most of these BMPs rely on rates, methods, and timing of application. Researchers at Kansas State have found that 90 percent of atrazine losses occur in the dissolved form during runoff events (Kansas State University, 2007; University of Nebraska, 1996).

5.17.1 Effectiveness

The effectiveness of the atrazine control strategies are summarized below (Kansas State University, 2007):

- Incorporating atrazine into the top 2 inches of soil will reduce loading by 60 to 75 percent.
- Applying atrazine between November 1 and April 15 when rainfall events are less frequent and intense reduces loading by 50 percent.
- Post emergence applications of atrazine require 60 to 70 percent less applied product than application to soil and result in 50 to 70 percent reductions in atrazine loading. Post emergence applications are also more successful for weed control.
- Reducing the application rates of soil-applied atrazine by one-third may reduce loading by 33 percent. Use of other herbicides or weed control strategies may be necessary to control nuisance growth.
- Applying one-half to two-thirds of the application prior to April 15 and the remainder before or immediately following planting will reduce atrazine loads by 25 percent.
- Using non-atrazine herbicides will reduce atrazine in runoff by 100 percent.
- Integrated pest management strategies employing variable rate herbicide applications, crop rotation, pre-plant tillage, cover crops, row cultivation, hybrid selection, planting techniques, etc., may reduce atrazine loading by 0 to 100 percent.
- Band application of atrazine with ridge till cultivation may reduce loads by 50 to 67 percent.
- Riparian areas and filter strips that allow for water infiltration may reduce loads by 25 to 35 percent.
- Using proper mixing, application, and disposal practices will prevent additional environmental impacts.

5.17.2 Costs

The costs of implementing atrazine BMPs will vary for each farm based on the current application methods and the type of tillage system employed. The BMPs that allow for reduced application rates may lead to a net savings in herbicide costs. Splitting applications may or may not cost more depending on whether or not the savings from reduced application rates offsets the expense of additional trips to the field. Because atrazine typically costs less than other herbicides, offsetting application rates with other products may increase overall costs.

5.18 Streambank and Shoreline Erosion BMPs

Reducing erosion of streambanks and lake shore areas will reduce phosphorus and manganese loading and improve temperature and dissolved oxygen conditions by allowing vegetation to establish. The filter strips and riparian area BMPs discussed in Sections 5.5 and 5.7 and the agricultural BMPs that reduce the quantity and volume of runoff (Sections 5.3, 5.4, 5.6 5.8, and 5.9) or prevent cattle access (Section 5.14) will all provide some level of streambank and lake shore erosion protection.

In addition, the streambanks and lake shores in the watershed should be inspected for signs of erosion. Banks showing moderate to high erosion rates (indicated by poorly vegetated reaches, exposed tree roots, steep banks, etc.) can be stabilized by engineering controls, vegetative stabilization, and restoration of riparian areas. Peak flows and velocities from runoff areas can be mitigated by infiltration in grassed waterways and passage of runoff through filter strips.

5.18.1 Effectiveness

Because the extent of streambank and lake shore erosion has not yet been quantified, the effectiveness of erosion control BMPs is difficult to estimate. The benefits of BMPs that offer stream bank protection and runoff control are therefore underestimated in this report.

5.18.2 Costs

Costs associated with the BMPs that offer secondary benefits to streambank and lake erosion are discussed separately for each BMP in Sections 5.3, 5.4, 5.5, 5.6, 5.7,5.8, 5.9, and 5.14.

5.19 Stream Restoration

Stream restoration activities usually focus on improving aquatic habitat, but can also be used to increase the amount of reaeration from the atmosphere to the water. A proper restoration effort will involve an upfront design specific to the conditions of the reach being restored. Stagnant, slow moving, and deep waters typically have relatively low rates of reaeration. Restorations aimed at increasing reaeration must balance habitat needs (which include pools of deeper water) with sections of more shallow, faster flowing water. Adding structures to increase turbulence and removing excessive tree fall may be incorporated in the restoration plan.

Stream restoration differs from riparian buffer restoration in that the shape or features within the stream channel are altered, not the land adjacent to the stream channel. Of course, a stream restoration may also include restoration of the riparian corridor as well.

The effectiveness and costs of stream restorations are site specific and highly variable. Watershed planners and water resource engineers should be utilized to determine the reaches where restoration will result in the most benefit for the watershed as a whole.

6.0 PRIORITIZATION OF IMPLEMENTATION

The listed reaches in the Crooked Creek watershed require varying degrees of reductions to meet water quality standards. This section briefly summarizes the required reductions for each segment and discusses the BMPs that will likely meet the water quality goals for the waterbody. Costs comparisons for each of the suggested BMPs are included at the end of the section. The Raccoon Lake watershed is part of the Kaskaskia Watershed Association, Inc (KWWAI, 2002) located in Reach III – Carlyle Lake Dam to Fayetteville. The watershed plan developed by the Kaskaskia River Watershed Association, Inc. has goals to improve aquatic habitat, reduce nutrients and sedimentation, and stabilize bank and shorelines along river and lakes. Appendix A includes a copy of this plan. The BMPs suggested below should improve conditions in this watershed and help the association work towards its goals.

6.1.1 Centralia Lake (ROI)

Centralia Lake is impaired for manganese, total phosphorus, and total suspended solids. The lake requires a 74 percent reduction in phosphorus loading to attain water quality standards. The lake requires a 20 percent reduction in manganese loading to attain water quality standards. The majority of phosphorus and manganese loading likely originates from crop production areas. Achieving at least a 74 percent load reduction from crop production areas should focus on source reduction strategies such as conservation tillage or cover crops (cover crops may not achieve the reported reductions on artificially drained fields). Nutrient management planning would offer supplemental reductions (and possibly cost savings) but will likely not achieve the required reductions alone. Attaining the manganese standards may be achieved by conservation tillage practices alone.

Animal operations also contribute to the phosphorus loading. Achieving load reductions from animal operations should focus on combining at least two of the following BMPs: animal feeding strategies, cattle exclusion from streams with alternative watering systems, or grazing land management.

Treatment level BMPs such as filter strip, grassed waterways, constructed wetlands, and restoration of riparian buffers can mitigate phosphorus loads from both animal operations and crop production areas. These BMPs typically treat small drainage areas and are suggested as supplemental measures to be strategically located where needed.

6.1.2 Raccoon Lake (ROK)

Raccoon Lake is listed as impaired for atrazine, dissolved oxygen, manganese, pH, total phosphorus, sedimentation/siltation, and total suspended solids. The dissolved oxygen and pH impairments are believed to be related to the total phosphorus impairment. The lake requires a 96 percent reduction in phosphorus loading, a 25 percent reduction in manganese loading, and a 31 percent reduction in atrazine loading to attain water quality standards. The majority of phosphorus, manganese, and atrazine loading likely originate from crop production areas. Achieving a 96 percent load reduction from crop production areas will be difficult but should focus on source reduction strategies such as conservation tillage or cover crops (cover crops may not achieve the reported reductions on artificially drained fields). Nutrient management planning would offer supplemental reductions (and possibly cost savings) but will likely not achieve the required reductions alone. Attaining the manganese standards may be achieved by conservation tillage practices alone. Reductions in atrazine loading can be attained by altering one or two of the application practices on each farm in the watershed.

Animal operations also contribute to the phosphorus loading. Achieving load reductions from animal operations should focus on combining at least two of the following BMPs: animal feeding strategies, cattle exclusion from streams with alternative watering systems, or grazing land management.

Treatment level BMPs such as filter strip, grassed waterways, constructed wetlands, and restoration of riparian buffers can mitigate phosphorus loads from both animal operations and crop production areas.

These BMPs typically treat small drainage areas and are suggested as supplemental measures to be strategically located where needed.

6.1.3 Salem Lake (ROR)

Salem Lake is impaired for manganese, total phosphorus, and dissolved oxygen. The dissolved oxygen impairments are believed to be related to the total phosphorus impairment. The lake requires an 83 percent reduction in phosphorus loading and a 39 percent reduction in manganese loading to attain water quality standards. The majority of the loading likely originates from crop production areas. Achieving at least an 83 percent load reduction from crop production areas should focus on source reduction strategies such as conservation tillage or cover crops (cover crops may not achieve the reported reductions on artificially drained fields). Nutrient management planning would offer supplemental reductions (and possibly cost savings) but will likely not achieve the required reductions alone. Attaining the manganese standards may be achieved by conservation tillage practices alone.

Achieving load reductions from animal operations should focus on combining at least two of the following BMPs: animal feeding strategies, cattle exclusion from streams with alternative watering systems, or grazing land management.

Treatment level BMPs such as filter strip, grassed waterways, constructed wetlands, and restoration of riparian buffers can mitigate phosphorus loads from both animal operations and crop production areas. These BMPs typically treat small drainage areas and are suggested as supplemental measures to be strategically located where needed.

6.1.4 Nashville City Lake (ROO)

Nashville City Lake is impaired for manganese, total phosphorus, and total suspended solids. The lake requires a 99 percent reduction in phosphorus loading to attain water quality standards. There were not sufficient data available to develop a manganese TMDL and current loads are unknown. The majority of the loading likely originates from crop production areas. Achieving a 99 percent load reduction from crop production areas will be very difficult but should focus on source reduction strategies such as conservation tillage or cover crops (cover crops may not achieve the reported reductions on artificially drained fields). Nutrient management planning would offer supplemental reductions (and possibly cost savings) but will likely not achieve the required reductions alone.

Achieving load reductions from animal operations should focus on combining at least two of the following BMPs: animal feeding strategies, cattle exclusion from streams with alternative watering systems, or grazing land management.

Treatment level BMPs such as filter strip, grassed waterways, constructed wetlands, and restoration of riparian buffers can mitigate phosphorus loads from both animal operations and crop production areas. These BMPs typically treat small drainage areas and are suggested as supplemental measures to be strategically located where needed.

7.0 MEASURING AND DOCUMENTING PROGRESS

Managing impairments in the Crooked Creek watershed will likely involve multiple agricultural BMPs to be used for crop production and animal operations. Continuing to monitor water quality in the waterbodies will determine whether or not managing the other sources of impairments, which may include failing onsite wastewater systems, point source discharges, oil mining operations, and inlake re-suspension, is necessary to bring the watershed into compliance.

The KRWAI (2002) has developed a work plan that documents in excess of 100 BMPs in the Kaskaskia River watershed. The work plan was developed with the intention of being a living document maintained by the Kaskaskia Watershed Association Inc., to provide up-to-date information for legislators and agency personnel, to assist in securing funding to implement listed projects. Tracking the implementation of BMPs while continuing to monitor water quality parameters will assist the stakeholders and public agencies in determining the effectiveness of this plan. If concentrations remain above the water quality standards, further encouragement of the use of BMPs across the watershed through education and incentives will be a priority. It may also be necessary to begin funding efforts for localized BMPs such as riparian buffer restoration.

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8.0 REASONABLE ASSURANCE

USEPA requires that a TMDL provide reasonable assurance that the required load reductions will be achieved and water quality will be restored. For this watershed, use of agricultural BMPs for crop production and animal operations are the primary management strategies to reach these goals. Participation of farmers and landowners is essential to improving water quality, but resistance to change and upfront cost may deter participation. Educational efforts and cost share programs will likely increase participation to levels needed to protect water quality.

Two of the incentive programs discussed below were administered under the 2002 Farm Bill, which expired September 30, 2007. The Conservation Reserve Program will continue to pay out existing contracts, but new enrollments will not be allowed until the bill is reinstated; no official date of reinstatement has been announced. Though the Environmental Quality Incentives Program was also part of the 2002 Farm Bill, it was extended beyond fiscal year 2007 by the Deficit Reduction Act of 2005 (Congressional Research Reports for the People, 2007).

8.1 Environmental Quality Incentives Program (EQIP)

Several cost share programs are available to farmers and landowners who voluntarily implement resource conservation practices in the Crooked Creek watershed. The most comprehensive is the NRCS Environmental Quality Incentives Program (EQIP) which offers cost sharing and incentives to farmers statewide who utilize approved conservation practices to reduce pollutant loading from agricultural lands.

- The program will pay $10 for one year for each acre of farmland that is managed under a nutrient management plan (up to 400 acres per farmer).
- Use of vegetated filter strips will earn the farmer $100/ac/yr for three years (up to 50 acres per farmer).
- The program will also pay 60 percent of the cost to construct grassed waterways, riparian buffers, and windbreaks.
- Use of residue management will earn the farmer $15/ac for three years (up to 400 acres per farmer).
- Installation of drainage control structures on tile outlets will earn the farmer $5/ac/yr for three years for the effected drainage area as well as 60 percent of the cost of each structure.
- The program will pay 75 percent of the construction cost for a composting facility.
- Sixty percent of the fencing, controlled access points, spring and well development, pipeline, and watering facility costs are covered by the program.
- Waste storage facilities and covers for those facilities have a 50 percent cost share for construction.
- Prescribed grazing practices will earn the farmer $10/ac/yr for three years (up to 200 acres per farmer).

In order to participate in the EQIP cost share program, all BMPs must be constructed according to the specifications listed for each conservation practice.

The specifications and program information can be found online at:
http://www.il.nrcs.usda.gov/programs/eqip/cspractices.html.

8.2 Conservation Reserve Program (CRP)

The Farm Service Agency of the USDA supports the Conservation Reserve Program (CRP) which rents land converted from crop production to grass or forestland for the purposes of reducing erosion and protecting sensitive waters. This program is available to farmers who establish vegetated filter strips or grassed waterways. The program typically provides 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years.

More information about this program is available online at:
http://www.nrcs.usda.gov/programs/crp/

8.3 Conservation 2000

In 1995 the Illinois General Assembly passed the Conservation 2000 bill providing $100 million in funding over a 6-year period for the promotion of conservation efforts. In 1999, legislation was passed to extend the program through 2009. Conservation 2000 currently funds several programs applicable to the Crooked Creek watershed through the Illinois Department of Agriculture.

General information concerning the Conservation 2000 Program can be found online at:
http://www.agr.state.il.us/Environment/conserv/

8.3.1 Conservation Practices Program (CPP)

The Conservation Practices Cost Share Program provides monetary incentives for conservation practices implemented on land eroding at one and one-half times or more the tolerable soil loss rate. Payments of up to 60 percent of initial costs are paid through the local SWCDs. Of the BMPs discussed in this plan, the program will cost share cover crops, filter strips, grassed waterways, no-till systems, and pasture planting. Other sediment control options such as contour farming and installation of stormwater ponds are also covered. Practices funded through this program must be maintained for at least 10 years.

More information concerning the Conservation Practices Program can be found online at:
http://www.agr.state.il.us/Environment/conserv/

8.3.2 Streambank Stabilization Restoration Program

Conservation 2000 also funds a streambank stabilization and restoration program aimed at restoring highly eroding streambanks. Research efforts are also funded to assess the effectiveness of vegetative and bioengineering techniques.

More information about this program is available online at:
http://dnr.state.il.us/orep/c2000/grants/proginfo.asp?id=20

8.3.3 Sustainable Agriculture Grant Program (SARE)

The Sustainable Agricultural Grant Program funds research, education, and outreach efforts for sustainable agricultural practices. Private landowners, organizations, educational, and governmental institutions are all eligible for participation in this program.

More information concerning the Sustainable Agricultural Grant Program can be found online at:
http://www.sare.org/grants/

8.4 Nonpoint Source Management Program (NSMP)

Illinois EPA receives federal funds through Section 319(h) of the Clean Water Act to help implement Illinois' Nonpoint Source (NPS) Pollution Management Program. The purpose of the Program is to work cooperatively with local units of government and other organizations toward the mutual goal of protecting the quality of water in Illinois by controlling NPS pollution. The program emphasizes funding for implementing cost-effective corrective and preventative best management practices (BMPs) on a watershed scale; funding is also available for BMPs on a non-watershed scale and the development of information/education NPS pollution control programs.

The maximum federal funding available is 60 percent, with the remaining 40 percent coming from local match. The program period is two years unless otherwise approved. This is a reimbursement program.

Section 319(h) funds are awarded for the purpose of implementing approved NPS management projects. The funding will be directed toward activities that result in the implementation of appropriate BMPs for the control of NPS pollution or to enhance the public's awareness of NPS pollution. Applications are accepted June 1 through August 1.

More information about this program is available online at:
http://www.epa.state.il.us/water/financial-assistance/non-point.html

8.5 Agricultural Loan Program

The Agricultural Loan Program offered through the Illinois State Treasury office provides low-interest loans to assist farmers who implement soil and water conservation practices. These loans will provide assistance for the construction, equipment, and maintenance costs that are not covered by cost share programs.

More information about this program is available online at:
http://www.state.il.us/TREAS/ProgramsServices.aspx

8.6 Illinois Conservation and Climate Initiative (ICCI)

The Illinois Conservation and Climate Initiative (ICCI) is a joint project of the State of Illinois and the Delta Pollution Prevention and Energy Efficiency (P2/E2) Center that allows farmers and landowners to earn carbon credits when they use conservation practices. These credits are then sold to companies or agencies that are committed to reducing their greenhouse gas emissions. Conservation tillage earns 0.5 metric tons (1.1 US ton) of carbon per acre per year (mt/ac/yr), grass plantings (applicable to filter strips and grassed waterways) earn 0.75 mt/ac/yr, and trees planted at a density of at least 250 stems per acre earn somewhere between 3.5 to 5.4 mt/ac/yr, depending on the species planted and age of the stand.

Carbon credits are currently selling at around $2.50 per mt. Current exchange rates are available online at http://chicagoclimatex.com. Administrative fees of $0.14/mt plus 8 percent are subtracted from the sale price.

Program enrollment occurs through the P2/E2 Center which can be found online at http://p2e2center.org/. The requirements of the program are verified by a third party before credits can be earned.

More information about carbon trading can be found online at:
http://illinoisclimate.org/

Table 8-1 and Table 8-2 summarize the cost share programs available for BMPs in the Crooked Creek watershed. Table 8-3 lists the contact information for each local soil and water conservation district (SWCD).

Table 8-1. Summary of Assistance Programs Available for Farmers in the Crooked Creek Watershed.

Assistance Program	Program Description	Contact Information
NSMP	Provides grant funding for educational programs and implementation of nonpoint source pollution controls.	Illinois Environmental Protection Agency Bureau of Water Watershed Management Section, Nonpoint Source Unit P.O. Box 19276 Springfield, IL 62794-9276 Phone: (217) 782-3362
Agricultural Loan Program	Provides low-interest loans for the construction and implementation of agricultural BMPs. Loans apply to equipment purchase as well.	Office of State Treasurer Agricultural Loan Program 300 West Jefferson Springfield, Illinois 62702 Phone: (217) 782-2072 Fax: (217) 522-1217
NRCS EQIP	Offers cost sharing and rental incentives to farmers statewide who utilize approved conservation practices to reduce pollutant loading from agricultural lands. Applies to nutrient management plans, filter strips, grassed waterways, riparian buffers, and conservation tillage.	Contact local SWCD (Table 8-3)
FSA CRP	Offsets income losses due to land conversion by rental agreements. Targets highly erodible land or land near sensitive waters. Provides up to 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years for converted land.	
Conservation 2000 CPP	Provides up to 60 percent cost share for several agricultural BMPs: cover crops, filter strips, grassed waterways.	
Conservation 2000 Streambank Stabilization Restoration Program	Provides 75 percent cost share for establishment of riparian corridors along severely eroding stream banks. Also provides technical assistance and educational information for interested parties.	
SARE	Funds educational programs for farmers concerning sustainable agricultural practices.	
Local SWCD	Provides incentives for individual components of nutrient management planning, use of strip tillage, and restoration of riparian buffers.	
ICCI	Allows farmers to earn carbon trading credits for use of conservation tillage, grass, and tree plantings.	

Table 8-2. Assistance Programs Available for Agricultural BMPs.

BMP	Cost Share Programs and Incentives
Education and Outreach	Conservation 2000 Streambank Stabilization Restoration Program SARE NSMP Local SWCD ULWREP
Nutrient Management Plan	EQIP: $10/ac for one year, 400 ac. max. Local SWCD: up to $30/ac for one year ULWREP: contact agency for individual resource allocations
Conservation Tillage	EQIP: $15/ac for three years, 400 ac. max. ICCI: earns 0.5 mt/ac/yr of carbon trading credit ULWREP: contact agency for individual resource allocations
Cover Crops	CPP: cost share of 60 percent ULWREP: contact agency for individual resource allocations
Filter Strips	EQIP: $100/ac for three years, 50 ac. max. CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Grassed Waterways	EQIP: 60 percent of construction costs CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Land Retirement of Highly Erodible Land or Land Near Sensitive Waters	CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted ULWREP: contact agency for individual resource allocations
Restoration of Riparian Buffers	EQIP: 60 percent of construction of costs CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted ULWREP: contact agency for individual resource allocations

Note: Cumulative cost shares from multiple programs will not exceed 100 percent of the cost of construction.

Table 8-3. Contact Information for Local Soil and Water Conservation Districts.

Organization Name	Address	Contact Numbers
Clinton County SWCD	1780 N. 4th Street Breese, IL 62230	Phone: 618/526-7919 (Ext. 3) Fax: 618/526-8021
Jefferson County SWCD	221 Withers Drive Mt. Vernon, IL 62864	Phone: 618/244-0773 (Ext. 3) Fax: 618/244-5942
Marion County SWCD	1550 E. Main Street Salem, IL 62881	Phone: 618/548-2230 (Ext. 3) Fax: 618/548-2341
Washington County SWCD	424 E. Holzhauer Drive Nashville, IL 62837	Phone: 618/842-7602 (Ext. 3) Fax: 618/842-3332

9.0 IMPLEMENTATION TIMELINE

This implementation plan for the Crooked Creek watershed is based upon a phased approach (Figure 9-1). Ideally, implementing control measures on nonpoint sources of loading will be based on voluntary participation which will depend on 1) the effectiveness of the educational programs for farmers, landowners, and owners of onsite wastewater systems, and 2) the level of participation in the programs. This section outlines a potential schedule for implementing the control measures and determining whether or not they are sufficient to meet the water quality standards.

Phase I of this implementation plan should focus on education of farm owners concerning the benefits of agricultural BMPs on crop yield, soil quality, and water quality as well as cost share programs available in the watershed. It is expected that initial education through public meetings, mass mailings, TV and radio announcements, and newspaper articles could be achieved in less than 6 months. As described in Section 8.0, assistance with educational programs is available through the following agencies: the Illinois Department of Agriculture Conservation 2000 Streambank Stabilization Restoration Program, the Illinois Department of Agriculture Sustainable Agriculture Grant Program (SARE), the Illinois Environmental Protection Agency Nonpoint Source Management Program (NSMP), and the local Soil and Water Conservation Districts.

Phase II of the implementation schedule should involve voluntary participation of landowners in BMPs such as proper management of manure, fertilizers, and pesticides and use of filter strips, composting, constructed wetlands, conservation tillage, and grassed waterways. The local Natural Resources Conservation Service office will be able to provide technical assistance and cost share information for these BMPs. In addition, initial inspections of all onsite wastewater treatment systems and necessary repairs may begin. Continued monitoring of water quality in the watershed should continue throughout this phase, which will likely take one to three years.

If pollutant concentrations measured during Phase II monitoring remain above the water quality standards, Phase III of the implementation plan will be necessary. The load reduction achieved during Phase II should be estimated by 1) summarizing the areas where BMPs are in use, 2) calculating the reductions in loading from BMPs, and 3) determining the impacts on pollutant concentrations measured before and after Phase II implementation. If BMPs are resulting in decreased concentrations, and additional areas could be incorporated, further efforts to include more stakeholders in the voluntary program will be needed. If the Phase II BMPs are not having the desired impacts on pollutant concentrations, or additional areas of incorporation are not available, supplemental BMPs, such as restoration of riparian areas and stream channels will be needed. If required, this phase may last five to ten years.

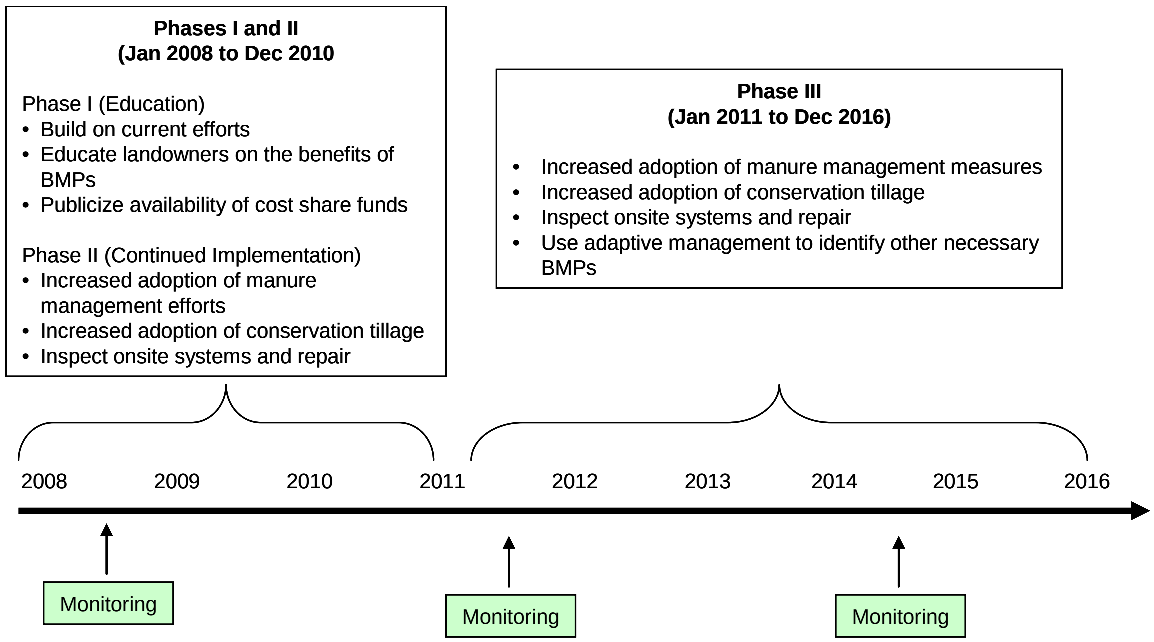

Figure 9-1. Timeline for the Crooked Creek TMDL Implementation Plan.

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APPENDIX A. AN ECOSYSTEM APPROACH TO ISSUES & OPPORTUNTIES