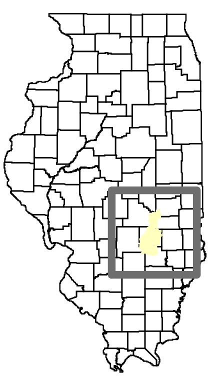
Illinois
Environmental
Protection Agency

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

June 2008

IEPA/BOW/08-014

LITTLE WABASH RIVER I WATERSHED TMDL REPORT



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TMDL Development for the Little Wabash River I 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) Implementation Plan Report

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

SEP 20 2007

REPLY TO THE ATTENTION OF:

WW-16J

RECEIVED
SEP 27 2007
Watershed Management Section
BUREAU OF WATER

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

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Loads (TMDL) for the Little Wabash River watershed including supporting documentation and follow up information. On August 31, 2007 Illinois Environmental Protection Agency (IEPA) submitted TMDL reports for the Little Wabash River Watershed.

Based on this review, U.S. EPA has determined that the following eight Illinois TMDLs which will address 12 impairments meet the requirements of Section 303(d) of the Clean Water Act and U.S. EPA's implementing regulations:

- TMDLs for Little Wabash River C-19 for Manganese, Fecal coliform, and Atrazine;
- TMDLs for Little Wabash River C-21 for Manganese, and Fecal coliform;
- TMDL for Lake Paradise RCG for Total Phosphorus addressing pH impairment;
- TMDL for Lake Mattoon RCF for Total Phosphorus addressing Total Suspend Solids impairment; and
- TMDLs for Lake Sara RCE for Total Phosphorus and Manganese addressing Total Suspended Solids impairment.

This report also addressed waters which IEPA will be proposing to delist in the 2008 Integrated Report based on collection of new data during the develop of this TMDL. These waters are as follows:

- Little Wabash River C-19 for pH;
- Dieterich Creek COC-10 for Silver, Copper, and Manganese;
- First Salt Creek CPC-TU-C1 for Manganese;
- Second Salt Creek for CPD-03 for Silver; and
- East Branch Green Creek CSB-08 for Manganese.

Therefore, U.S. EPA hereby approves Illinois's eight TMDL addressing 12 impairments for the Little Wabash River watershed. The statutory and regulatory requirements for approval, and U.S. EPA's review of Illinois's compliance with each requirement, are described in the enclosed

Final Stage 1 Progress Report

Prepared for Illinois Environmental Protection Agency

September 2006

Little Wabash Watershed

Little Wabash River (C19, C21),
Paradise Lake (RCG), Lake Mattoon (RCF),
First Salt Creek (CPC-TU-C1),
Second Salt Creek (CPD 01, CPD 03, CPD 04),
Salt Creek (CP-EF-C2, CP-TU-C3), Lake Sara (RCE),
East Branch Green Creek (CSB 07, CSB 08) and
Dieterich Creek (COC 10)

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Table of Contents

First Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

April 2006

Little Wabash Watershed

Little Wabash River (C19, C21),

Lake Paradise (RCG), Lake Mattoon (RCF),

First Salt Creek (CPC-TU-C1),

Second Salt Creek (CPD 01, CPD 03, CPD 04),

Salt Creek (CP-EF-C2, CP-TU-C3), Lake Sara (RCE),

East Branch Green Creek (CSB 07, CSB 08),

Dieterich Creek (COC 10), and Clay City Side Channel Reservoir (RCU)

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TABLE OF CONTENTS

List of Tables

List of Figures

EXECUTIVE SUMMARY

This is the first in a series of status reports documenting work completed on the Little Wabash River project watershed. The objective of this report is to provide a summary of Stage 1 work that will ultimately be used to support Total Maximum Daily Load (TMDL) development in the project watershed.

Background

Section 303(d) of the 1972 Clean Water Act requires States to define impaired waters and identify them on a list, which is referred to as the 303(d) list. The State of Illinois has issued the 2006 303(d) list, which is available on the web at: http://www.epa.state.il.us/water/tmdl/303d-list.html. . The Clean Water Act requires that a TMDL be completed for each pollutant listed for an impaired waterbody. A TMDL is a report that is submitted by the States to the EPA. In the TMDL report, a determination is made of the greatest amount of a given pollutant that a waterbody can receive without violating water quality standards and designated uses, considering all known and potential sources. The TMDL also takes into account a margin of safety, which reflects scientific uncertainty, as well as the effects of seasonal variation.

As part of the TMDL process, the Illinois Environmental Protection Agency (IEPA) and several consultant teams have compiled and reviewed data and information to determine the sufficiency of available data to support TMDL development. As part of this review, the data were used to confirm the impairments identified on the 303(d) list and to further identify potential sources causing these impairments. The results of this review are presented in this first quarterly status report.

Next, IEPA, with assistance from consultants, will recommend an approach for the TMDL, including an assessment of whether additional data are needed to develop a defensible TMDL.

Finally, IEPA and consultants will conduct the TMDLs and will work with stakeholders to implement the necessary controls to improve water quality in the impaired waterbodies and meet water quality standards. It should be noted that the controls for nonpoint sources (e.g., agriculture) will be strictly voluntary.

Methods

The effort completed in the first quarter included: 1) watershed characterization; 2) development of a water quality database and data analyses; and 3) synthesis of the watershed characterization information and the data analysis results to confirm the sufficiency of the data to support both the listing decision and the sources of impairment that are included on the 2006 303(d) list.

Results

Based on Stage 1 work, the project team has drawn the following conclusions:

- For **Little Wabash River (Segment C 19)**, data are sufficient to support the listings for manganese, pH, dissolved oxygen, fecal coliform, and atrazine on the 2006 303(d) list, and TMDLs are warranted. The low dissolved oxygen may be related to high water temperatures and low flows, animal operations, failing septic systems, cropland runoff, wildlife, and permitted dischargers. Potential sources of manganese are natural background sources, release from river bottom sediments, and oil well operations. Naturally acidic soils in the watershed are a potential source of the low in-stream pH. Potential sources of fecal coliform include livestock, private sewage systems, wildlife, and permitted point sources. Atrazine is used as an herbicide in the watershed.

- For **Little Wabash River (Segment C 21)**, data are sufficient to support the listings for manganese and fecal coliform on the 2006 303(d) list, and TMDLs are warranted. A potential source of manganese is natural background soils. Potential sources of fecal coliform include livestock, private sewage systems, wildlife, and permitted point sources.
- For **Lake Paradise (Coles) (Segment RCG),** data are sufficient to support the listings for phosphorus and pH on the 2006 303(d) list, and TMDLs are warranted. Runoff from cropland and pastureland is a potential source of phosphorus to the lake. Other sources include release from bottom sediments, failing septic systems, and shoreline erosion. A potential cause of the high pH observed in July 2004 is algal production due to the phosphorus enrichment.
- For **Lake Mattoon (Segment RCF)**, data are sufficient to support the listing for phosphorus, and a TMDL is warranted. Potential phosphorus sources include cropland runoff, release from sediments under anoxic conditions, and failing septic systems.
- For **First Salt Creek (Segment CP-TU-C1)**, data are sufficient to support the listings for manganese and dissolved oxygen on the 2006 303(d) list, and TMDLs are warranted. Naturally high levels of manganese in soils in the watershed are potential sources of manganese. Municipal point sources, livestock operations, and wildlife are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Second Salt Creek (Segment CPD 04),** data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Intensive livestock operations and wildlife are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Second Salt Creek (Segment CPD 03),** data are sufficient to support the listings for dissolved oxygen and silver on the 2006 303(d) list, and TMDLs are warranted. Intensive livestock operations and wildlife are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow. Sources of silver are unknown.
- For **Second Salt Creek (Segment CPD 01)**, data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Intensive livestock operations and wildlife are potential sources contributing to low dissolved

oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.

- For **Salt Creek (Segment CP-TU-C3),** data are sufficient to support the listing for manganese on the 2006 303(d) list, and a TMDL is warranted. Potential sources of manganese are watershed soils naturally enriched in manganese.
- For **Salt Creek (Segment CP-EF-C2)**, data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Municipal point sources and urban runoff/storm sewers likely contribute to low dissolved oxygen in the creek. Wildlife are another potential source. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Lake Sara (Segment RCE)**, data are sufficient to support the listings for phosphorus and manganese on the 2006 303(d) list, and TMDLs are warranted. Potential sources of phosphorus include runoff from golf courses and agricultural lands, failing private sewage disposal systems, and release from sediments under hypolimnetic anoxic conditions. The observed manganese concentrations in the lake likely reflect natural background conditions (soils in the watershed are naturally high in manganese) and release from lake bottom sediments under anoxic conditions.
- For **East Branch Green Creek (Segment CSB 08),** data are sufficient to support the listings for manganese and dissolved oxygen on the 2006 303(d) list, and TMDLs are warranted. Naturally high levels of manganese in soils in the watershed and release from stream bottom sediments under anoxic conditions are potential sources of manganese. Wildlife and runoff from agricultural land (including livestock operations) are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **East Branch Green Creek (Segment CSB 07)**, data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Intensive animal feeding operations, wildlife and low dissolved oxygen upstream of this segment likely contribute to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Dieterich Creek (Segment COC 10),** data are sufficient to support the listings for manganese, copper, and silver on the 2006 303(d) list. Naturally high levels of manganese in soils in the watershed are potential sources of manganese. No obvious sources of copper and silver were identified through the watershed characterization process and review of available data. Based on the age of the data and the limited dataset, it is recommended that IEPA consider re-sampling this stream for silver and copper to determine if the listings are still warranted.
- For **Clay City Side Channel Reservoir (Segment RCU)**, data were sufficient to support the listing for manganese on the 2006 303(d) list, and a TMDL would be warranted if the reservoir were still used for water supply. However, the water withdrawal has been eliminated, which has eliminated the need for a TMDL. No TMDL is being prepared.

INTRODUCTION

This Stage 1 report describes initial activities related to the development of TMDLs for impaired waterbodies in the Little Wabash River watershed. Stage 1 efforts included watershed characterization activities and data analyses to confirm the causes and sources of impairments in the watershed. This section provides some background information on the TMDL process, and Illinois assessment and listing procedures. The specific impairments in waterbodies of the Little Wabash River watershed are also described.

TMDL Process

Section 303(d) of the 1972 Clean Water Act requires States to define impaired waters and identify them on a list, which is called the 303(d) list. The State of Illinois has issued the 2006 303(d) list (IEPA 2004), which is available on the web at: http://www.epa.state.il.us/water/watershed/reports/303d-report/2006/303d-report.pdf. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and instream conditions. This allowable loading represents the maximum quantity of the pollutant that the waterbody can receive without exceeding water quality standards. The TMDL also takes into account a margin of safety, which reflects scientific uncertainty, as well as the effects of seasonal variation. By following the TMDL process, States can establish water quality-based controls to reduce pollution from both point and nonpoint sources, and restore and maintain the quality of their water resources (USEPA, 1991).

As part of the TMDL process, the Illinois Environmental Protection Agency (IEPA) and several consultant teams have compiled and reviewed data and information to determine the sufficiency of available data to support TMDL development. As part of this review, the data were used to confirm the impairments identified on the 303(d) list and to further identify potential sources causing these impairments. The results of this review are presented in this first quarterly status report.

Next, the Illinois EPA, with assistance from consultants, will recommend an approach for the TMDL, including an assessment of whether additional data are needed to develop a defensible TMDL.

Finally, Illinois EPA and consultants will conduct the TMDLs and will work with stakeholders to implement the necessary controls to improve water quality in the impaired waterbodies and meet water quality standards. It should be noted that the controls for nonpoint sources (e.g., agriculture) will be strictly voluntary.

Illinois Assessment and Listing Procedures

Water quality assessments in Illinois are based on a combination of chemical (water, sediment and fish tissue), physical (habitat and flow discharge), and biological (macroinvertebrate and fish) data. Illinois EPA conducts its assessment of water bodies using a set of seven designated uses: aquatic life, aesthetic quality, indigenous aquatic life (for specific Chicago-area waterbodies), primary contact (swimming), secondary contact (recreation), public and food processing water supply, and fish consumption (IEPA, 2006). For each water body, and for each designated use applicable to the water body, Illinois EPA's assessment concludes one of two possible "use-support" levels:

- Fully Supporting (the water body attains the designated use); or
- Not Supporting (the water body does not attain the designated use).

Water bodies assessed as Not Supporting any designated use are identified as "impaired." Waters identified as impaired based on biological (macroinvertebrate, macrophyte, algal and fish), chemical (water, sediment and fish tissue), and/or physical (habitat and flow discharge) monitoring data are placed on the 303(d) list. Potential causes and sources of impairment are also identified for impaired waters (IEPA, 2006).

Following the U.S. EPA regulations at 40 CFR Part 130.7(b)(4), the Illinois Section 303(d) list was prioritized on a watershed basis. Illinois EPA watershed boundaries are based on the USGS ten-digit hydrologic units, to provide the state with the ability to address watershed issues at a manageable level and document improvements to a watershed's health (IEPA, 2006).

List of Identified Watershed Impairments

The impaired waterbody segments included in the project watershed are listed in Table 1, along with the parameters they are listed for, and the use impairments as identified in the 2006 303(d) list (IEPA, 2006). TMDLs are currently only being developed for pollutants that have numerical water quality standards. These pollutants are indicated in Table 1 in boldface type. Causes that are listed for pollutants that exceed statistical guidelines or have non-numeric criteria are not subject to TMDL development at this time (IEPA, 2006). Table 1 provides information on the targeted waterbodies, including size, causes of impairment, and use support (full support, nonsupport). Those impairments that are the focus of this report are shown in bold font.

The remaining sections of this report include:

- Watershed characterization: *discussion of methods for information compilation and a detailed characterization of the watershed*
- Database development and data analysis: *discussion of data sources and methods of data analysis*
- Confirmation of causes and sources of impairment: *assessment of sufficiency of data to support the listing and identification of potential sources contributing to the impairment*
- Conclusions

Table 1. Impaired Waterbodies in the Little Wabash River Watershed

Waterbody Segment	Waterbody Name	Size (miles/acres)	Listed for[1]	Use Support[2]
C 19	Little Wabash River	57.17	**Manganese, pH, dissolved oxygen, fecal coliform, atrazine,** sedimentation/siltation, fish passage barriers, total suspended solids, total phosphorus (statistical guideline)	Aquatic Life (N), Fish Consumption (F), Primary Contact Recreation (N), Public & Food Processing Water Supply (N)
C 21	Little Wabash River	31.12	**Manganese, fecal coliform**	Aquatic Life (F), Fish Consumption (F), Primary Contact Recreation (N), Public & Food Processing Water Supply (N)
RCG	Paradise (Coles) Lake	176	**Phosphorus, pH,** unspecified nutrients, total nitrogen as N, sedimentation/siltation, excess algal growth	Aquatic Life (N), Fish Consumption (F), Public & Food Processing Water Supply (F), Aesthetic Quality (N)
RCF	Lake Mattoon	765	**Total phosphorus**, total suspended solids, excess algal growth,	Aquatic Life (F), Fish Consumption (F), Public & Food Processing Water Supply (F), Aesthetic Quality (N)
CPC-TU-C1	First Salt Creek	1.45	**Manganese, dissolved oxygen**, total phosphorus (statistical guideline)	Aquatic Life (N)
CPD 04	Second Salt Creek	2.92	**Dissolved oxygen,** sedimentation/siltation, total suspended solids, total phosphorus (statistical guideline)	Aquatic Life (N)
CPD 03	Second Salt Creek	1.39	**Dissolved oxygen, silver**, sedimentation/siltation, total suspended solids, total phosphorus (statistical guideline)	Aquatic Life (N)
CPD 01	Second Salt Creek	2.67	**Dissolved oxygen**, sedimentation/siltation, total suspended solids, total phosphorus (statistical guideline)	Aquatic Life (N)
CP-TU-C3	Salt Creek	0.82	**Manganese**, total phosphorus (statistical guideline)	Aquatic Life (N)
CP-EF-C2	Salt Creek	2.34	**Dissolved oxygen**, total nitrogen as N, total phosphorus (statistical guideline)	Aquatic Life (N)

Waterbody Segment	Waterbody Name	Size (miles/acres)	Listed for[1]	Use Support[2]
RCE	Lake Sara	765	**Phosphorus, manganese**, total suspended solids, excess algal growth	Aquatic Life (F), Public & Food Processing Water Supply (N), Aesthetic Quality (N)
CSB 08	E. Branch Green Creek	5.64	**Dissolved oxygen, manganese**, total phosphorus	Aquatic Life (N)
CSB 07	E. Branch Green Creek	3.23	**Dissolved oxygen**, sedimentation/siltation, total suspended solids, total phosphorus	Aquatic Life (N)
COC 10	Dieterich Creek	8.2	**Copper, manganese, silver**, sedimentation/siltation, total suspended solids, total phosphorus	Aquatic Life (N)
RCU	Clay City SCR	6	**Manganese**, total suspended solids, excess algal growth, total phosphorus	Aquatic Life (F), Public & Food Processing Water Supply (N), Aesthetic Quality (N)

[1] Bold font indicates cause will be addressed in this report. Other potential causes of impairment listed for these waterbodies do not have numeric Water Quality Standards and are not subject to TMDL development at this time.
[2]F = Full, N = Nonsupport

WATERSHED CHARACTERIZATION

The purpose of watershed characterization was to obtain information describing the watershed to support the identification of sources contributing to impairments shown in bold in Table 1. Watershed characterization activities were focused on gaining an understanding of key features of the watershed, including topography, geology and soils, climate, hydrology, land cover, urbanization and growth, and point source discharges and septic systems. The methods used to characterize the watershed, and the findings are described below.

Methods

Watershed characterization was conducted by compiling and analyzing data and information from various sources, including several reports. Where available, data were obtained in electronic or Geographic Information System (GIS) format to facilitate mapping and analysis. Calls were placed to local agencies to develop a better understanding of land management practices in the watershed. Additionally, a meeting was held on December 11, 2003 with Regional and State-level IEPA staff and a site visit was conducted on November 15, 2005.

The first step in watershed characterization was to delineate the watershed boundaries for the impaired waterbodies (Table 1) in GIS using topographic and stream network (hydrography) information. Other relevant information obtained and processed for mapping and analysis purposes included:

- current land cover;
- current cropland;
- State and Federal lands;
- soils;
- point source dischargers;
- public water supply intakes;
- roads;
- railroads;
- state, county and municipal boundaries;
- landfills;
- oil wells;
- coal mines;
- dams;
- data collection locations; and
- location of 303(d) listed lakes and streams.

To better describe the watershed and obtain information related to active local watershed groups, data collection efforts, agricultural practices, and septic systems, calls were placed to county-level officials at the Natural Resources Conservation District (NRCS), Soil and Water Conservation District (SWCD) and County Health Department. Several valuable reports used in this effort were *An Intensive Survey of the Little Wabash River Basin, 1993, the Phase I Diagnostic/Feasibility Study Lake Paradise, and Sedimentation Survey of Lake Paradise and Lake Mattoon, Mattoon, Illinois, 2003*. Other information compiled for this task related to climate, population growth and urbanization. A list of data sources and calls is included in Appendix A.

Little Wabash River Watershed Characterization

The Little Wabash River is located in Southeastern Illinois, flowing southward to the Wabash River. The river's headwaters are located in southwestern Coles County. From there, the Little Wabash flows approximately 237 miles south and east to its confluence with the Wabash River near New Haven, a point approximately 13 miles upstream from the Ohio River (IEPA, 1993).

The impaired waterbodies addressed in this report are all located within the portion of the Little Wabash River watershed shown in Figure 1. The watershed shown is delineated to the most downstream listed segment (C19), not the mouth of the Little Wabash River, which is located approximately 123 miles downstream of segment C19. Portions of the study area watershed lie in nine counties: Clay, Effingham, Shelby, Coles, Cumberland, Fayette, Marion, Jasper and Moultrie (only 0.02%). The study area watershed, as shown in Figure 1, is approximately 515,000 acres (805 square miles) in size and the mainstem of the Little Wabash River, from its headwaters to the downstream end of segment C 19, is approximately 114 miles long. Major tributaries to the portion of the Little Wabash River located in the study area include: West Branch, Green Creek, Blue Point Creek, Second Creek, Big Creek North, Fulfer Creek, Salt Creek, Bishop Creek, Lucas Creek, Dismal Creek, Crooked Creek, Panther Creek, and Buck Creek. Fourteen of the fifteen impaired segments that are addressed in this report are located in the upper two thirds of the watershed. Figure 1 shows a map of the watershed, and includes some key features such as waterways, impaired waterbodies, public water intakes and other key features. The map also shows the locations of point source discharges that have a permit to discharge under the National Pollutant Discharge Elimination System (NPDES).

The following sections provide a broad overview of the characteristics of the Little Wabash River watershed, as delineated in Figure 1. Specific information about the smaller subwatersheds for impaired waterbodies follows the general overview.

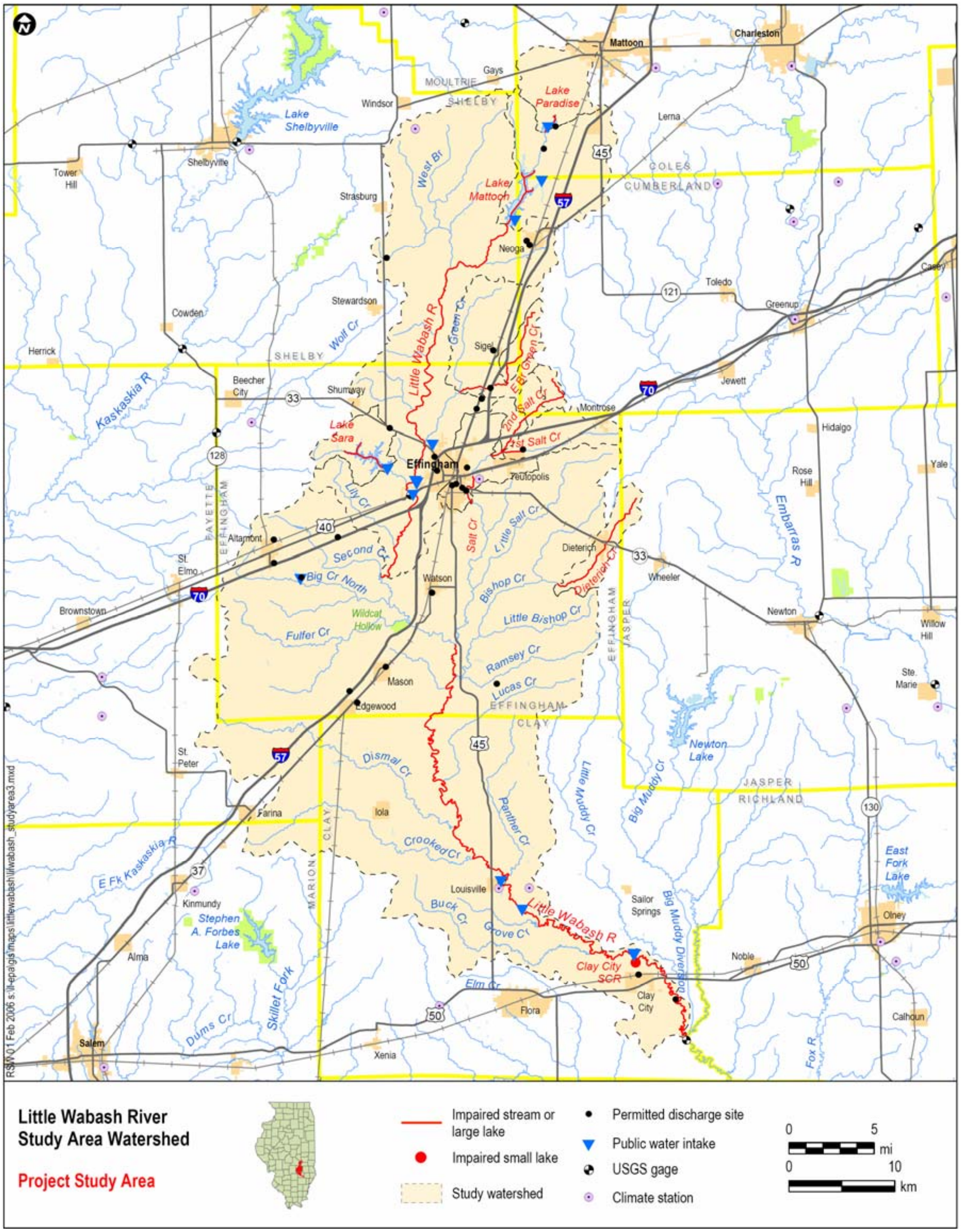

Figure 1. Base Map of Little Wabash River Watershed

Topography

An understanding of topography helps with stream characterization; this information may be used in later stages of this work to support model development. Additionally, knowing the topography of an area helps with developing an understanding of factors affecting instream quality. Topographic information was obtained from the National Elevation Dataset (NED), made available by the U.S. Geological Survey at http://ned.usgs.gov/. As described on the USGS website, "the USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best quality elevation data available across the United States into a seamless raster format. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous U.S. and 1:63,360-scale DEM data for Alaska. The dataset provides seamless coverage of the United States, HI, AK, and the island territories. NED is a living dataset that is updated bimonthly to incorporate the "best available" DEM data."

Based on an analysis of the topographic information, the elevation in the Little Wabash watershed ranges from 778 feet above mean sea level (AMSL) at the highest point in the watershed, in Coles County, near I-57 in far southern Mattoon, to 404 feet in Clay County, at the downstream terminus of segment C 19. The change in elevation of the Little Wabash River itself, between its headwaters and the most downstream portion of segment C 19, is 362.7 feet, over this approximately 114-mile stretch.

Geology and Soils

The portion of the Little Wabash River watershed upstream of segment C19 lies primarily within the Springfield Plain physiographic region. This region covers Effingham and Jasper Counties, the northern half of Clay County, and the southern half of Shelby County. This area was covered by the Kansan Period of glaciation, and is distinguished by its relative flatness and the shallow entrenchment of its drainage (Knapp and Myers, 2001). The headwater region of the Little Wabash River watershed and Lake Paradise, lie within the Bloomington Ridged Plain (IEPA, 2004b). This is the southernmost extent of the Wisconsinan glaciation in Illinois and this southern boundary is marked by a broad prominent ridge known as the Shelbyville moraine (IEPA, 2004b).

The general geology of the Little Wabash River basin consists of a mantle of unconsolidated glacial deposits overlying bedrock. Sands, gravels and sandy till of the Illinoian Glasford formation cover most of the basin except for parts of Coles and Shelby Counties where the sandy till of the Wisconsinan Wedron Formation is present. Unconsolidated deposits range in thickness from zero at places of exposed bedrock to several hundred feet in some areas near the northern edge of the basin (Flemal, 1981; Zuehls, 1987, as cited in IEPA, 1993).

Information on geology and soils was compiled to understand whether the soils are a potential source of manganese and to identify the dominant hydrologic soil group and the susceptibility of the soils to erosion. This information is available through the Natural Resource Conservation Service (NRCS).

Figure 2 shows the major soil associations in the Little Wabash River watershed. Each association has a distinctive pattern of soils, relief, and drainage. The STATSGO soils information was used to identify the predominant soil associations in the Little Wabash River watershed. Note that SSURGO soils information is only available for a small portion of the watershed (Cumberland and Moultrie Counties). The Little Wabash River watershed is comprised primarily of soils from the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory soil associations, with these two associations underlying 85% of the watershed area. The frequency of occurrence of different soil associations is presented in Table 2. Characteristics of the two primary soil associations are discussed in additional detail below.

The Cisne-Hoyleton-Darmstadt association underlies 48% of the study area. The soil series comprising this association are described as follows in the Marion County soil survey (Miles, 1996). The Cisne series consists of poorly drained, very slowly permeable soils on the broad, nearly level parts of the Illinoian till plain. At depths of 8 to 30 and 50 to 60 inches, medium and fine rounded dark accumulations of iron and manganese oxide are noted. The Cisne soil series is also described as being strongly to very strongly acid. The Hoyleton series consists of somewhat poorly drained, slowly permeable soils on knolls and low ridges or on short side slopes along drainageways on the Illinoian till plain. Common medium irregular dark stains of iron and manganese oxide are noted at depths of 30-50 inches and these soils are neutral to very strongly acid. The Darmstadt series consists of somewhat poorly drained, very slowly permeable soils on low ridges or on short side slopes along drainageways on the Illinoian till plain. Common fine and medium rounded dark nodules of iron and manganese oxide are noted at all depths of the Darmstadt series and the pH in these soils varies from strongly alkaline to medium acid. The K-factor for this association ranges from 0.32 to 0.43. K-factors reflect the erodibility of a soil to sheet and rill erosion by water. Values of K range from 0.02 to 0.69, with higher values meaning the soil is more susceptible to sheet and rill erosion by water. The hydrologic soil groups for this association are C, D and C/D indicating these soils have slow infiltration rates and high runoff potential. The Cisne and Hoyleton soils are poorly suited to use as sites for septic tank absorption fields (USDA, 1998).

The Bluford-Ava-Hickory Association underlies 37% of the study area. Bluford soils are nearly level and gently sloping and somewhat poorly drained. Ava soils are gently and moderately sloping and moderately well drained. The Hickory soils are moderately steep to very steep and moderately well drained to well drained and formed in glacial till. The Bluford, Ava and Hickory soils are all described as being strongly to very strongly acidic. The K-factor for this association ranges from 0.37 to 0.43. The hydrologic soil groups for this association are C and D. The Bluford, Ava and steeply sloping Hickory soils are poorly suited to use as sites for septic tank absorption fields. Moderately sloping Hickory soils are moderately suited for septic tank absorption fields. The Bluford, Ava and Hickory soils are all described as having iron and manganese oxides or nodules throughout the soil profile (USDA, 1998).

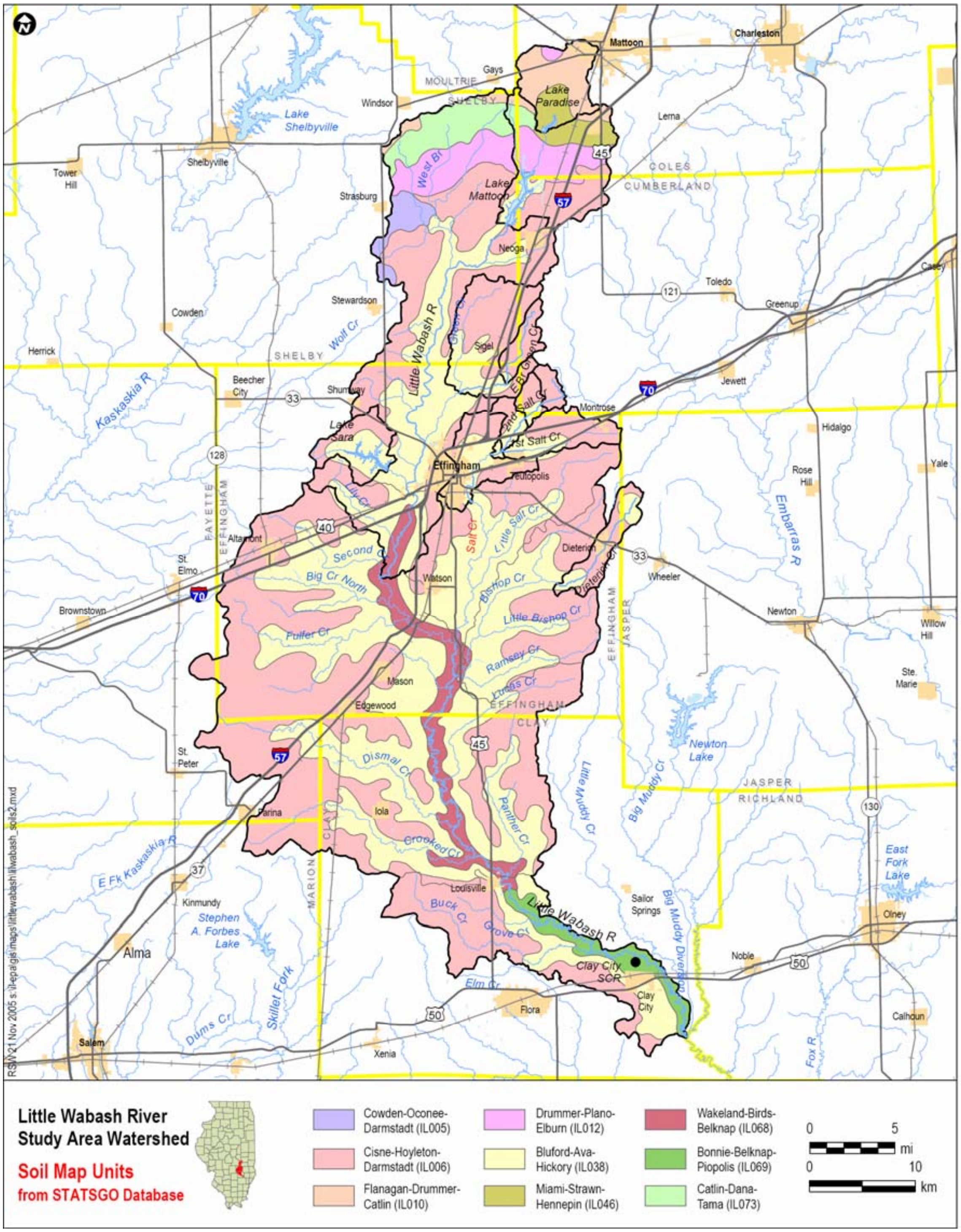

Figure 2. Soil Associations in Little Wabash River Watershed

Table 2. Watershed soils (Source: STATSGO)

Soil Map Units (MUID)	Percentage in study area
COWDEN-OCONEE-DARMSTADT (IL005)	1%
CISNE-HOYLETON-DARMSTADT (IL006)	48%
FLANAGAN-DRUMMER-CATLIN (IL010)	2%
DRUMMER-PLANO-ELBURN (IL012)	3%
BLUFORD-AVA-HICKORY (IL038)	37%
MIAMI-STRAWN-HENNEPIN (IL046)	1%
WAKELAND-BIRDS-BELKNAP (IL068)	4%
BONNIE-BELKNAP-PIOPOLIS (IL069)	2%
CATLIN-DANA-TAMA (IL073)	2%

Figure 3 shows the locations of active oil wells in the Little Wabash River watershed. Although this information is from the 1990s, this figure illustrates that oil fields are located throughout the study area, but are found in the highest density in the southern portion of the study area. According to the Intensive Survey of the Little Wabash Watershed (IEPA, 1993), the Little Wabash basin contains the largest concentration of oil and gas producing areas in the State. As noted in this report, "crude oil and saline water are often found together underground. Brine is also often pumped into oil wells to aid in the extraction process. Therefore the mixture of the two must be run through a separator to yield oil in a useable form. The brine by-product is then either pumped back into the ground, stored in ponds, or discharged to local water courses." According to the Clay County NRCS, some sections of Clay County and Marion Co. soils have been damaged from pumping of salt water into oil wells to increase production. When brine water reaches the surface, it prevents vegetation from growing, and increased erosion results.

Climate

Climate information was obtained and summarized to support the watershed characterization and gain an understanding of runoff characteristics for this study area. The National Weather Service (NWS) maintains a weather station in Effingham, in the middle of the watershed. Two nearby weather stations are located just outside the watershed, to the north (Mattoon) and south (Flora). The station at Effingham was deemed an adequate representation of the climate in the watershed. Climate summaries are available through the Illinois State Climatologist Office website (http://www.sws.uiuc.edu/atmos/statecli/Summary/Illinois.htm).

The Little Wabash River watershed has a temperate climate with cold, snowy winters and hot summers. The average long-term precipitation (1971-2000) recorded at Effingham (Station 112687) is approximately 42 inches. The maximum annual precipitation is 65.18 inches (1927) and the minimum annual precipitation is 18.47 inches (1894). On average there are 110 days with precipitation of at least 0.01 inches and 10.9 days with precipitation greater than 1 inch. Average snowfall is approximately 20.7 inches per year.

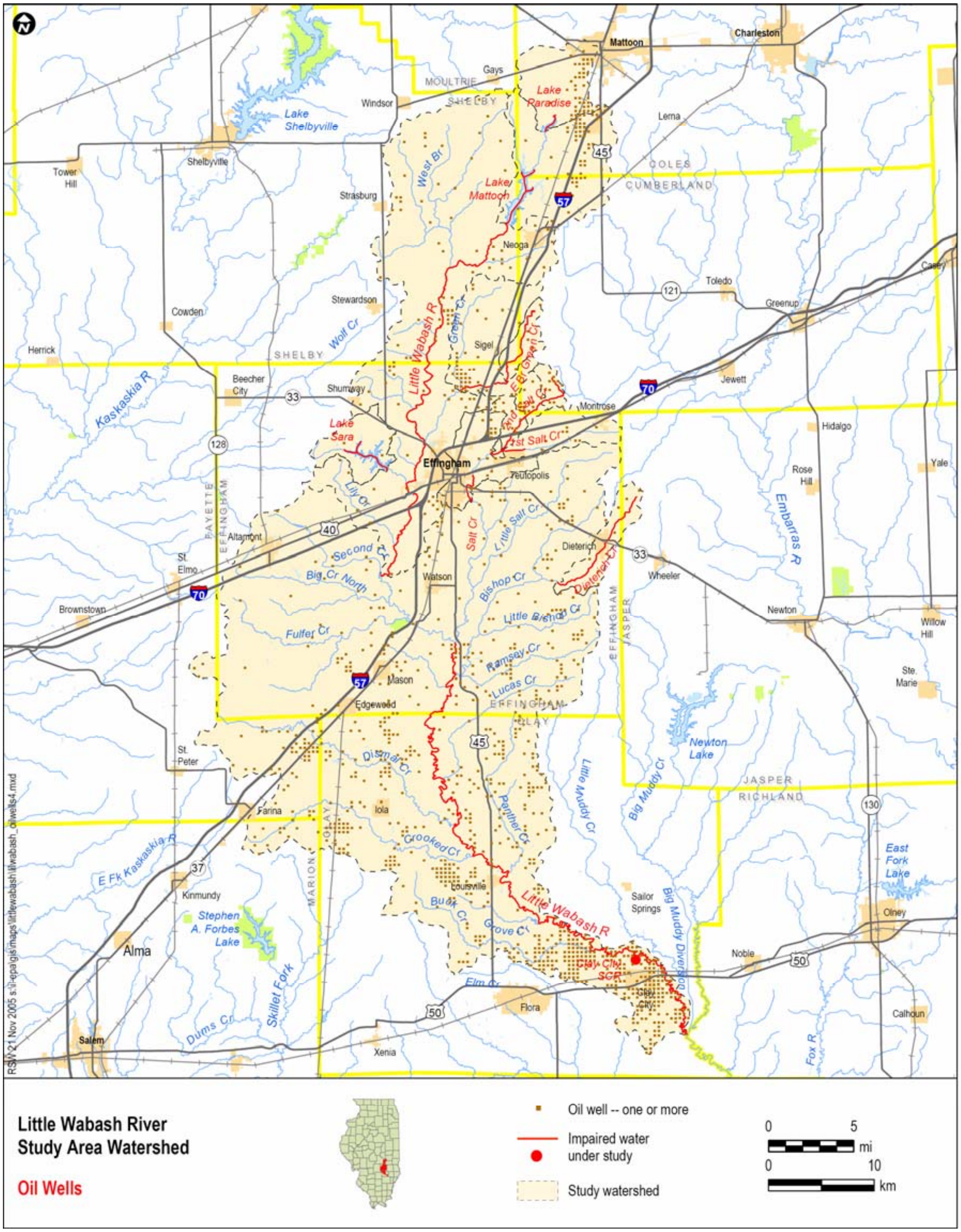

Figure 3. Oil Wells in the Little Wabash River Watershed

Average minimum and maximum temperatures recorded at Effingham (Station 112687) are 17.8 °F and 34.8 °F, in January and 65.7 °F and 86.9 °F in July. This is based on measurements collected between 1971 and 2000. The average temperature recorded in January is 26.3 °F and the average temperature recorded in July is 76.3 °F.

Hydrology

An understanding of hydrology helps with understanding the importance of different watershed transport and instream processes. There are two active USGS streamflow gages in the Little Wabash study area watershed. One is located near Effingham, IL (gage 03378635), near the middle of the study area. The drainage area at this gage is 240 square miles. Daily discharge measurements are available from October of 1966 to the present. The second gage is located below Clay City, IL (gage 03379500), near the southern end of the watershed. Daily discharge measurements are available for this station from August 1914 to present. The 7-day, 10-year low flow (7Q10) is 0.00 ft^3/s at the Effingham gage location and 1.8 ft^3/s at the Clay City gage location (ISWS, 2002). The average monthly flow at the gage near Effingham ranges from 52 cfs to 379 cfs. The average monthly flow at the gage below Clay City ranges from 213 cfs to 1731 cfs. Monthly average flows are presented in Figure 4.

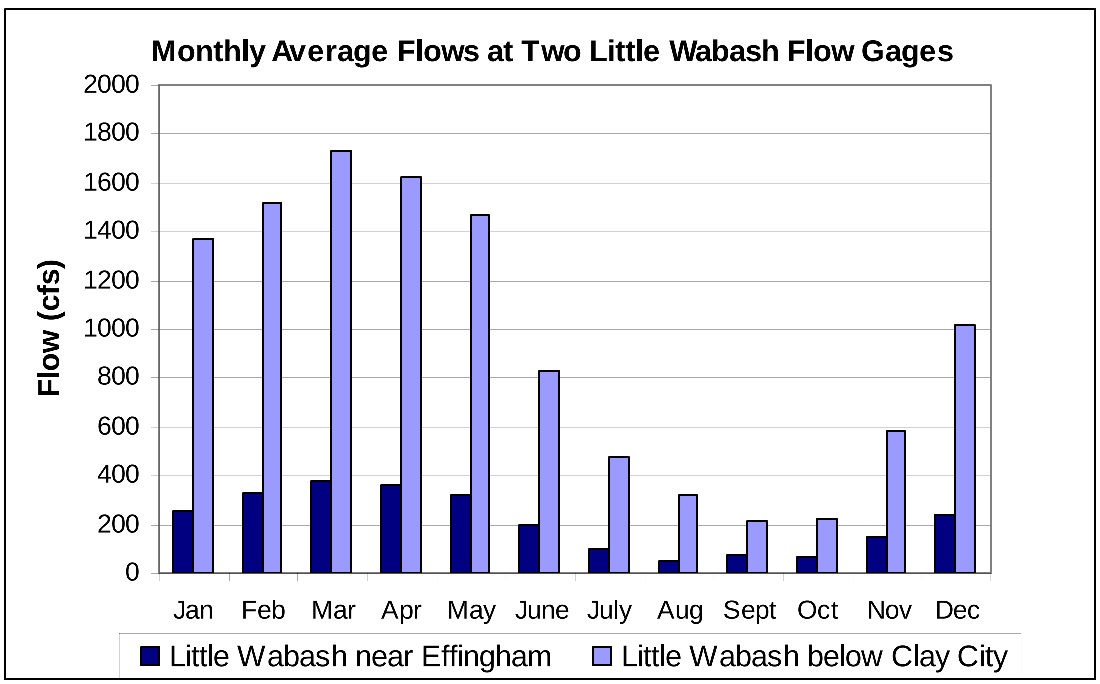

Figure 4. Little Wabash River Monthly Average Flows

Land Cover

Runoff from the land surface contributes pollutants to nearby receiving waters. To understand sources contributing to receiving water impairments, it was necessary to characterize land cover in the watershed. Land cover in the Little Wabash River watershed is shown in Figure 5, and listed in Table 3. The predominant land cover in the watershed is agriculture, shown in yellow on the map. Approximately 69% of the watershed is cropland. Grassland (e.g., pasture) constitutes 7% of the watershed area. The second highest land cover is forest, which covers approximately 19% of the watershed. Developed areas constitute only 3% of the watershed area.

As shown in the land cover maps, land use in the watershed is mostly agricultural. Primary crops grown are soybeans and corn, with lesser amounts of wheat, hay and other small grains. Cropland is fertilized with nitrogen, phosphorus and potassium.

A recent report by the Illinois Department of Agriculture (2004) reports tillage practices by crop type and county. Tillage practices in the watershed range from no-till to conventional tillage, with conventional tillage most commonly used. The statistics for the Little Wabash River watershed, shown below in Table 4, are an area-weighted average of the data from the counties in the watershed.

Table 3. Land Cover in Little Wabash River Watershed

Land Cover Type	Area (acres)	Percent of Watershed Area
Agriculture[1]	356,256	69%
Forest	99,188	19%
Grassland	33,665	7%
Urban	14,404	3%
Water	3,847	1%
Wetland	7,512	1%
Barren Land	312	0%
Totals[2]	**515,185**	**100**

Source: Illinois Department of Agriculture, 1999-2000 land cover

[1]The primary crops are soybeans (48%), corn (38%) and winter wheat, other small grains and hay (14%)

[2] Total acreage and percentage may not sum as expected due to rounding.

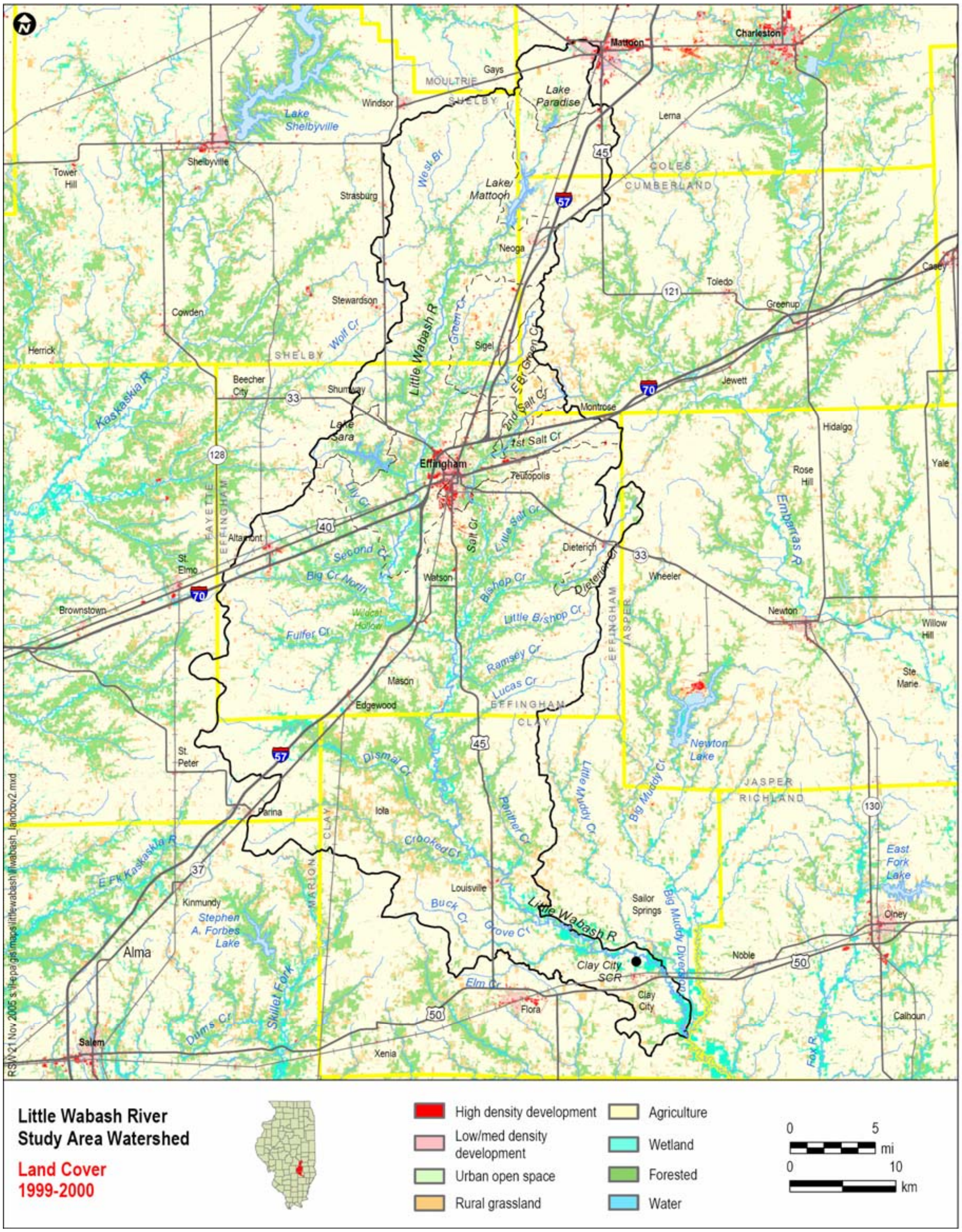

Figure 5. Land Cover in Little Wabash River Watershed 1999-2000

Table 4. Percent of Fields, by Crop, with Indicated Tillage Practice[1]

	Conventional Till[2]	Reduced-Till[3]	Mulch-Till[4]	No-Till[4]
Corn	81	5	3	11
Soybean	42	16	8	34
Small grain	57	12	10	21

Source: Illinois Department of Agriculture (2004)
[1]Total percentage for each crop may not equal 100% due to rounding.
[2] Residue level 0 – 15%
[3] Residue level 16-30%
[4] Residue level > 30%

Animal statistics are summarized in Table 5. This information was obtained from the 2002 Census of Agriculture (USDA, 2002). Additional information on animal operations was obtained through calls to local health department and SWCD officials. Cattle operations are located throughout Effingham County, especially around Bishop and Second Salt Creek. Some cattle have access to the streams, but this is not widespread. In Clay County, livestock operations were identified as a likely source of fecal coliform to the Little Wabash River, segment C 19. Specifically identified as potential sources were cattle in pastures and manure spread on farm fields as fertilizer. Figure 6 shows the location of cattle and hog operations in the Little Wabash River watershed.

Table 5. 2002 Animal Statistics by County for the Little Wabash River Watershed

County	Percent of County within Watershed[1]	Number of Head in County (rounded to nearest 100)		
		Hogs & Pigs	Cattle and Calves	Any poultry - layers ≥ 20 weeks
Clay	41%	34,389	8,687	378
Coles	8%	3,058	8,267	629
Cumberland	10%	49,362	11,882	331
Effingham	82%	82,513	27,885	608
Fayette	4%	11,208	16,862	602
Jasper	1%	88,901	10,332	553
Marion	1%	8,601	11,285	(D)
Moultrie	0.05%	9,346	4,146	1,061
Shelby	15%	56,285	20,247	461

Source: 2002 Census of Agriculture
(D) – withheld to avoid disclosing data for individual farms
[1]Total percentage for the watershed may not equal 100% due to rounding.

The dark green areas on Figure 5 show forested lands (approximately 19% of the watershed), which are both upland (generally oak-hickory) and floodplain (mixed composition). Also shown on the map (in red) are areas of low/medium and high-density development (approximately 3% of the watershed). These areas indicate the locations of the towns and residential communities in the watershed. Effingham is the largest urban area in the study area watershed.

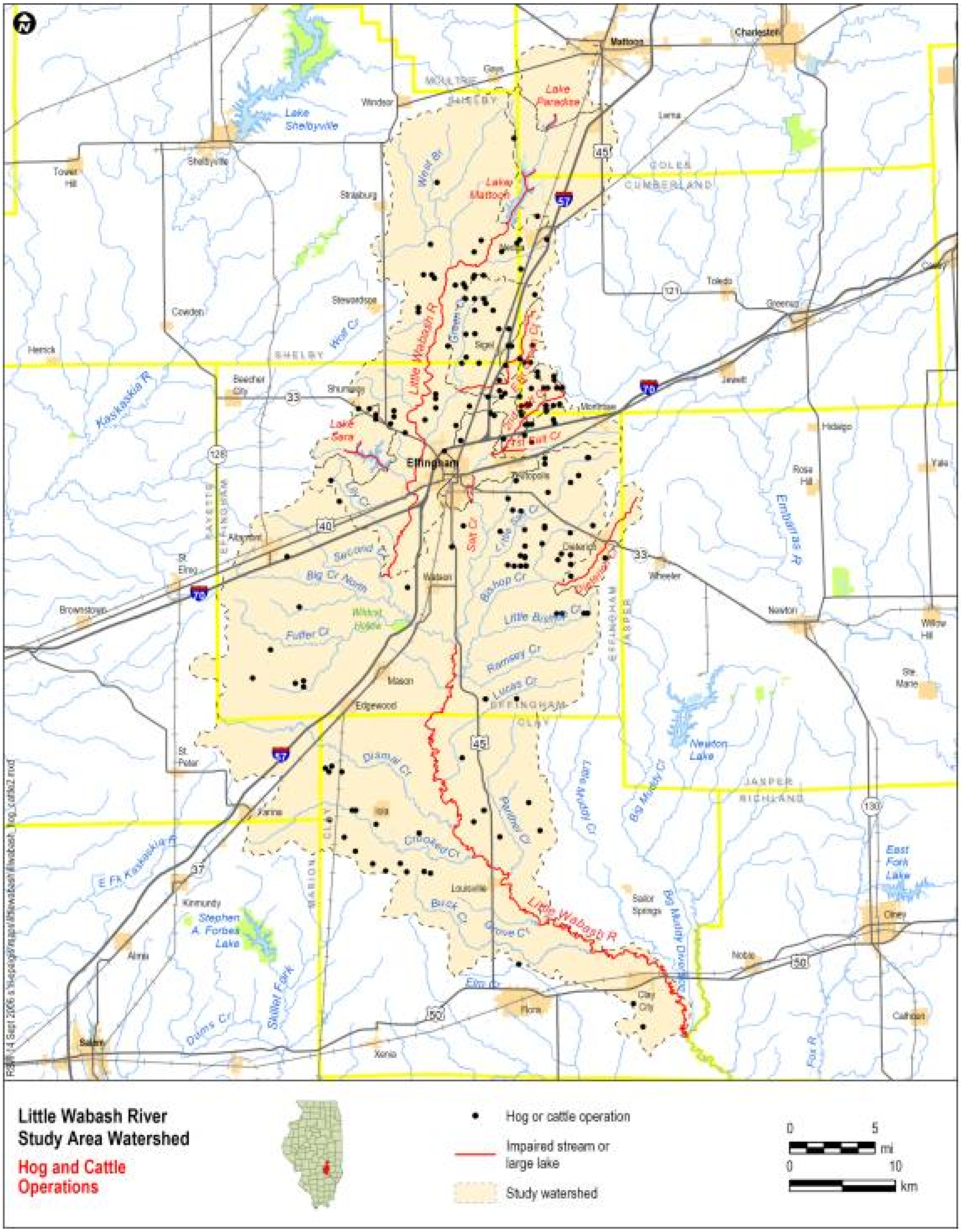

Figure 6. Hog and Cattle Operations

Urbanization and Growth

Urbanization and growth are two factors that can affect the amount and quality of runoff from land surfaces and which also affect the demand on water and sewage treatment facilities. The study area watershed encompasses portions of nine counties (Clay, Coles, Cumberland, Effingham, Fayette, Jasper, Marion, Moultrie, and Shelby) and eleven communities. These communities are: Altamont, Clay City, Dieterich, Edgewood, Effingham, Iola, Louisville, Mason, Sigel, Teutopolis and Watson. Portions of the communities of Neoga, Shumway, Montrose, Mattoon, Farina and Strasburg also lie within the watershed. Effingham is the largest urbanized area entirely within the watershed with 12,384 residents. (Census 2000 website, http://factfinder.census.gov/home/saff/main.html?_lang=en). Population data are shown by county in Table 6.

The State of Illinois Population Trends Report (State of Illinois, 1997) provides projected population trends by county. Illinois Population Trends (State of Illinois, 1997) predicts a decrease in population in Marion, Fayette, Clay and Effingham Counties, and an increase in population in Moultrie, Shelby, Cumberland, Jasper and Coles Counties.

Table 6. Population Summary

County	1990[1]	2000[1]	2010[2]	2020[2]	% of County in Watershed	% of Watershed in County
Clay	14,460	14,560	12,878	12,319	40.89%	23.58%
Coles	51,644	53,196	56,523	58,483	7.55%	4.74%
Cumberland	10,670	11,253	11,963	12,428	9.63%	4.10%
Effingham	31,704	34,264	33,927	33,817	81.66%	48.18%
Fayette	20,893	21,802	19,562	18,860	4.27%	3.80%
Jasper	10,609	10,117	11,005	11,777	0.55%	0.33%
Marion	41,561	41,691	39,328	38,261	1.31%	0.93%
Moultrie	13,930	14,287	14,288	14,562	0.05%	0.02%
Shelby	22,261	22,893	23,443	25,087	15.16%	14.31%

[1]U.S. Census Bureau
[2]State of Illinois, 1997

Point Source Discharges and Septic Systems

Twenty-three entities were identified that are permitted to discharge treated wastewater to the Little Wabash or its tributaries. Ten of these are municipal discharges, four are non-municipal small sewage treatment plants, three are water treatment plants, two are gas or oil company operations, one is a car wash, one is for groundwater treatment, one is for stormwater and one is for fueling area washdown. Figure 1 shows the locations of these discharges, and Table 7 provides information about these dischargers.

One other NPDES-permitted discharger (Shell Pipeline – Clay City, # IL0076074) was also identified in the watershed, however, it is currently thought to be inactive. However, if information showing otherwise becomes available, it will be included in later stages of this project.

Information on sewage and septic systems was obtained from the Clay County Health Department and the Effingham SWCD. In the community of Iola, private surface systems are used to handle sewage. It was noted that raw sewage from these systems is draining to streams. “The Ridge” in northern Clay County was also identified as having a lot of trash and sewage problems. In Effingham County, it was noted that there are many houses located around the shore of Lake Sara and they are all served by septic systems. Depending on the age and condition of these systems, they may be a potential source of phosphorus to Lake Sara.

Watershed Activities

Local agencies and institutions with an interest in watershed management will be important for successful implementation of this TMDL. State agencies currently active in the Little Wabash watershed are Illinois Department of Natural Resources (IDNR), and the Illinois Environmental Protection Agency (IEPA). The discussion that follows summarizes activities identified in the watershed, by area.

Entire Watershed

The Upper Little Wabash Ecosystem Partnership is currently active in the watershed. The Partnership is working with a consultant to prepare a strategic plan that will address concerns that have been identified through a series of public meetings. These concerns include oil wells, flooding and wildlife habitat. They have also calculated erosion rates for the watershed and have compiled locational information on livestock operations. A technical committee has also been formed and they are gathering information on water quality in the watershed, which will be included in the strategic plan.

Lake Paradise

As described later in this report, a Phase I Diagnostic/Feasibility Study has been recently completed for Lake Paradise (IEPA, 2004b). This is a comprehensive study of the lake and its watershed and not only describes the lake, but also identifies concerns and recommended actions for addressing those concerns. A copy of a sedimentation survey of Lake Paradise is also included with the Phase I Diagnostic/Feasibility Study.

The city of Mattoon was awarded federal funding to restore a total of 12 acres of wetland adjacent to Lake Paradise to reduce erosion and nonpoint source pollution and improve water quality. This project implements recommendations of the Lake Paradise Phase I Diagnostic/Feasibility Study (IEPA, 2004b).

Lake Mattoon

A Phase I Diagnostic /Feasibility Study is currently being finalized for this lake. This report will provide a comprehensive description of the lake and its watershed, and will serve as a useful document for later stages of this TMDL work. A sedimentation basin is also being constructed for Lake Mattoon.

Table 7. NPDES Discharges and Parameters

NPDES ID	Facility Name	Average design flow (MGD)	Monitored for	Permit expiration date
IL0020974	CLAY CITY WWTP	0.12	$CBOD_5$, total residual chlorine, DO, pH, TSS, fecal coliform	05-31-09
IL0025429	IL DOT-FAI 70 REST AREA	0.035	BOD5, $CBOD_5$, fecal coliform, ammonia N, pH, TSS, total residual chlorine	10-31-09
IL0028622	EFFINGHAM STP	3.75	$CBOD_5$, BOD_5, total residual chlorine, total fluoride, total nickel, ammonia, DO, pH, TSS, fecal coliform	5-31-09
IL0030091	NEOGA STP	0.37	$CBOD_5$, BOD_5, total residual chlorine, pH, TDS, TSS, fecal coliform	11-30-05
ILG582024	TEUTOPOLIS STP	0.372	$CBOD_5$, total residual chlorine, pH, TSS	6-30-05
IL0045268	RUSHCO SHELL	0.025	$CBOD_5$, total residual chlorine, fecal coliform, ammonia, DO, pH, TSS	10-31-10
IL0047244	WALTER SCOTT CAMP & LEARNING CTR	0.0015	$CBOD_5$, total residual chlorine, DO, pH, TSS	7-31-08
IL0052060	MIDWAY COUNTRY VILLAGE, INC.	0.015	$CBOD_5$, total residual chlorine, pH, TSS	3-31-08
IL0055093	EQUILON ENTERPRISES LLC	0.01	Benzene, benzene-ethyl benzene-toluene-xylene comb., ethyl benzene, oil and grease, Polynuclear aromatics, toluene, xylene, pH, TSS	9-30-10
IL0055701	STEWARDSON-STRASBURG HS	0.05	$CBOD_5$, total residual chlorine, ammonia, DO, pH, TSS	9-30-04
IL0056197	CLEAR WATER SERVICE CORP WTP	0.025	Total residual chlorine, total iron, pH, TSS	7-31-04
IL0060208	IL DOT-I57 EFFINGHAM COUNTY	0.0111	$CBOD_5$, total residual chlorine, fecal coliform, pH, TSS	12-31-07
IL0062286	MASON STP	0.0525	$CBOD_5$, total residual chlorine, fecal coliform, pH, TSS	7-31-05
IL0069931	TA OPERATING CORP	0.0001	3,4, benzofluoran, acenaphthene, acenaphthylene, anthracene, benzene, benzo(a)anthracene, Benzo(a)pyrene, Benzo(GHI)perylene, Benzo(k)fluoranthene, chrysene, dibenzo (A,H) Anthracene, ethylbenzene, fluoranthene, fluorine, indeno(1,2,3-CD) Pyrene, naphthalene, oil and grease, pH, phenanthrene, pyrene, toluene, xylene	5-31-03
IL0074527	MATTOON WTP	0.030	Total residual chlorine, pH, TSS	2-28-05
IL0075922	MEYER OIL-L. SARA CAR WASH	0.004	BOD_5, oil and grease, pH, TSS	2-28-07
ILG580024	SIGEL STP	0.06	$CBOD_5$, total residual chlorine, pH, TSS	12-31-07
ILG580056	WATSON STP	0.1	$CBOD_5$, total residual chlorine, pH, TSS	12-31-07
ILG580070	EDGEWOOD STP	0.0615	$CBOD_5$, total residual chlorine, pH, TSS	12-31-07
ILG580133	ALTAMONT SOUTH WWTP	0.196	$CBOD_5$, total residual chlorine, pH, TSS	12-31-07
ILG580152	ALTAMONT NORTH STP	0.102	$CBOD_5$, total residual chlorine, pH, TSS	12-31-07
ILG640048	ALTAMONT WTP	0.03	Total residual chlorine, pH, TSS	7-1-98
ILG910100	HARPER OIL CO. – EFFINGHAM	0.0015	Benzene, Benzene-thylbenzene-toluene- xylene comb, ethyl benzene, oil and grease, polynuclear aromatics, total agg conc. #1, xylene	7-1-97

Little Wabash River (Segment C 19) Watershed Characterization

Little Wabash Segment C 19 is 57.17 miles in length and its watershed is 515,185 acres (805 mi^2) in size. This segment begins at the confluence of the Little Wabash River and Salt Creek and ends at the confluence of Big Muddy Creek with the main stem of the Little Wabash River. Tributaries to this segment include Second Creek, Lucas Creek, Dismal Creek, Crooked Creek, Panther Creek, and Buck Creek. The subwatershed for Segment C 19 is the entire Little Wabash River watershed that is the focus of this study, and the previous general discussion of the project study area applies to this segment of the Little Wabash River. Land cover, population and point source information was provided previously in Table 3 (land cover), Table 6 (population) and Table 7 (permitted point source dischargers). Several communities, including Flora and Louisville, have public water supply intakes on this segment of the Little Wabash (water supply intakes were shown in Figure 1). Photos are provided in Appendix B.

Little Wabash (Segment C 21) Watershed Characterization

Little Wabash River Segment C 21 is 31.12 miles in length and its subwatershed is 166,792 acres (261 mi^2) in size. This segment begins just downstream of Lake Mattoon and ends at the confluence of Second Creek with the main stem of the Little Wabash River. This segment is used as a public water supply for the City of Effingham. Other tributaries draining to this segment include West Branch Little Wabash River, Blue Point Creek, and Green Creek. This segment is located within Shelby and Effingham Counties and flows past Effingham. The communities of Mattoon, Neoga, Sigel, Effingham, and Shumway are also in this subwatershed. Sixty-nine percent of the soils in this segment's subwatershed are comprised of the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups B through D are found within this segment's subwatershed, with the majority falling into categories C and D. The K-factors range from 0 to 0.43 with most of the soils having K-factors that are 0.32 or higher. Land cover for the Little Wabash C 21 subwatershed is listed in Table 8. Approximately 73% of the land is used for agriculture and approximately 14% is forest. Grasslands and developed areas constitute 6% and 4%, respectively. Numerous livestock operations are located in this watershed (Figure 6).

Eleven permitted point sources discharge within this segment's subwatershed. These are: 1) the Mattoon Water Treatment Plant (treated filter backwash), 2) CWS Corp. Water Treatment Plant (treated iron filter backwash), 3) IL-DOT I-57 Effingham County (STP outfall), 4) Sigel sewage treatment plant (STP outfall), 5) Effingham STP (CSO-Rolling Hills Lift Station), 6) Neoga sewage treatment plant (STP outfall, emergency STP outfall and two SSOs), 7) Midway Country Village, Inc. (STP outfall), 8) Equilon Enterprises LLC (stormwater), 9) Stewardson-Strasburg High School (STP outfall), 10) TA Operating Corp (fueling area washdown), and 11) Meyer-oil – Lake Sara car wash (car wash effluent).

Table 8. Land Cover in Segment C 21 Little Wabash River Subwatershed

Land Cover	Area (acres)	Percent
Agriculture[1]	122,025	73%
Forest	23,913	14%
Grassland	9,290	6%
Urban	5,968	4%
Water	2,454	1%
Wetland	3,051	2%
Barren land	91	0%
Total	**166,792**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (45%), corn (43%) and winter wheat, other small grains and hay (12%)

Lake Paradise (Segment RCG) Watershed Characterization

Lake Paradise, Segment RCG, is 176 acres in size and its subwatershed is 11,494 acres. This lake is also referred to as Old Lake Mattoon. In this report, it will be referred to as Lake Paradise. The description that follows was obtained from a recently completed Phase I Diagnostic/Feasibility Study of Lake Paradise (IEPA, 2004b). This lake was constructed in 1909 by impounding a portion of the Little Wabash River. In 1931 a second dam was built, enlarging the lake to its current size. The lake has a maximum depth of 19 feet, an average depth of 7.5 feet, and a storage capacity of 1,252 acre-feet. The hydraulic retention time of the lake is 0.11 years. In 1995, the City of Mattoon installed one Baker style lake destratifier in the southern portion of the lake near the water intake tower. This was installed to aid in the prevention of taste and odor problems occurring from high algal populations. Temperature and dissolved oxygen data indicate the water column is well mixed thermally, but due to an inadequate amount of dissolved oxygen, anoxic conditions still exist near the water/sediment interface, allowing continued reduction of nutrients and metals from the sediment surface.

Lake Paradise served as the sole source of potable water for the City of Mattoon until the new Lake Mattoon was constructed in the 1950s (IEPA, 2004b). This lake continues to serve as a drinking water source for the City of Mattoon, Illinois, which is partially located within the watershed for this lake. Lake Mattoon now serves as an auxiliary water supply for the City of Mattoon. Raw water can be pumped directly from Lake Paradise and Lake Mattoon to the treatment plant. Water can also be pumped from Lake Mattoon to Lake Paradise. Under normal operating procedures, water is pumped from Lake Mattoon to Lake Paradise only as needed, since it is more economical to pump from Lake Paradise to the treatment plant. Other uses of the lake include fishing and boating. There is also a picnic area available to the public.

Lake Paradise is located primarily within Coles County, near the City of Mattoon. In addition to the Little Wabash River, tributaries to the lake include several small, unnamed streams. The topography of the watershed is relatively flat, with over 87 percent of the land in the watershed having a slope between 0 and 2%. Steep slopes (>15%) exist only along creek banks and eroded sections of the lake shoreline (IEPA, 2004b). Soils in the watershed are predominantly silty clay loam and silt loams. Land use in the watershed is predominantly agricultural (77%), with 9% of the watershed classified as urban, as shown in Table 9. Approximately 420 acres of the cropland have a whole-field subsurface drainage system (IEPA, 2004b).

The Mattoon Water Treatment Plant is the only point source discharge in the Lake Paradise watershed. The effluent from the plant is discharged directly to the lake, west of the water treatment plant. There are over 100 houses located on or near the shore of the lake that use septic tanks to treat their wastewater. Many of the residences are over 50 years old. Although no information is available on the septic systems, it is believed that many of these systems may not adequately treat these effluents prior to discharging them to the lake (IEPA, 2004b).

Nonpoint phosphorus loads were estimated by the Coles County Soil and Water Conservation District (USDA, 2000 in IEPA, 2004b). As shown in Table 10, cropland is the primary nonpoint source of phosphorus in the watershed; it is also the primary land use within the watershed, as shown in Table 9. During the site visit it was observed that at least one farm property extends to the shoreline of Lake Paradise. There are no large livestock operations in the watershed; however, small numbers of livestock are found in the small fields through out the watershed (IEPA, 2004b). During the site visit, cows were observed in a small creek that flows into Lake Paradise.

Table 9. Land Cover in Segment RCG Lake Paradise Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	8,895	77%
Forest	800	7%
Grassland	466	4%
Urban	988	9%
Water	205	2%
Wetland	135	1%
Barren land	4	0%
Total[2]	**11,494**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (55%), corn (42%) and winter wheat, other small grains and hay (3%)
[2] Total acreage and percentage may not sum as expected due to rounding.

Table 10. Estimated Nonpoint Phosphorus Loading Rates[1]

Land Use	Total Phosphorus Load (lbs/yr)
Cropland	3,350
Pasture and Hayland	40
Forest/Woodland	95
Urban	58
Roads and Railroads	0
Water	0
Total	**3,543**

[1] USDA, Coles County Soil and Water Conservation District, 2000, as cited in IEPA, 2004b.

The Diagnostic/Feasibility Study identifies several concerns for Lake Paradise; these include storage loss due to sedimentation, excessive nutrients, low dissolved oxygen at depths below 10 feet in the summer, low quality fishery and a high percentage of shoreline unprotected. Sources identified include excessive erosion during flood events, stream bank and shoreline erosion, sediment resuspension, over-fertilization of cropland, poor pasturing practices near the lake, improperly maintained septic systems along the shoreline, summer hypolimnetic deoxygenation, poor aquatic plant density and diversity, and poor habitat for aquatic fauna, including sport fish (IEPA, 2004b). This report also identifies potential and recommended restoration measures, which will be very useful for the implementation stages of this TMDL.

Lake Mattoon (Segment RCF) Watershed Characterization

Lake Mattoon, Segment RCF was formed in 1959 by an impoundment of the Little Wabash River. The lake is 765 acres in size, having a 55.5-mile shoreline and an average depth of 10.5 feet (maximum depth = 35 feet) (Mattoon Chamber of Commerce, website). Sedimentation has reduced the potential capacity of Lake Mattoon from 13,293 acre-feet in 1958 to 11,588 acre-feet in 2001 (Bogner, 2003). An analysis of sedimentation rates for two different time periods (1958-1980 and 1980-2001) indicates a significant reduction in the sedimentation rate between the two survey periods (Bogner, 2003). The subwatershed for the lake is 35,140 acres and is primarily agricultural land use (81%) as shown in Table 11. The land in the immediate vicinity surrounding the lake is forested, with many residential developments. Photos are provided in Appendix B.

The lake has a capacity of 2.6 billion gallons and is used for boating and fishing, and also serves as a drinking water supply for the City of Mattoon. Since June 2001, Reliant Energy has operated a peaker power plant that has withdrawn water from Lake Mattoon for cooling systems (Bogner, 2003). Lake Mattoon is located downstream of Lake Paradise and traverses three counties: Shelby, Cumberland and Coles. Tributaries to the lake include the Little Wabash River, Clear Creek, and Brush Creek. Forty-six percent of the soils in the Lake Mattoon subwatershed are comprised of the Cisne-Hoyleton-Darmstadt and Flanagan-Drummer-Catlin associations. Hydrologic soil groups B through D are found within this segment's subwatershed, with the majority falling into category B (moderate runoff potential). The K-factors range from 0 to 0.43 with most of the soils having K-factors between 0.28 and 0.37. The City of Mattoon is the only urban area located within this subwatershed, however, there are developments along the shoreline including many houses. Discharges from both the Mattoon water treatment plant and Clear Water Service Corps water treatment plant are located within the Lake Mattoon subwatershed, although neither discharge directly to the lake.

Table 11. Land Cover in Segment RCF, Lake Mattoon Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	28,301	81%
Forest	2,046	6%
Grassland	1,447	4%
Urban	1,608	5%
Water	1,418	4%
Wetland	311	1%
Barren land	8	0%
Total[2]	**35,140**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover

[1]The primary crops are soybeans (49%), corn (47%) and winter wheat, other small grains and hay (4%)

[2] Total acreage and percentage may not sum as expected due to rounding.

First Salt Creek (Segment CPC-TU-C1) Watershed Characterization

First Salt Creek Segment CPC-TU-C1 is 1.45 miles in length and its subwatershed is 7,694 acres in size. This creek originates near Montrose and flows westward past Teutopolis. During the site visit in November 2005, the creek was shallow and slow moving, with some forested banks. The portion of this creek that appears on the 303(d) list begins just upstream of Teutopolis and ends at its confluence with Second Salt Creek. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within this segment's subwatershed, with an almost equal percent found in each of these categories. The K-factors range from 0.32 to 0.43 with most of the soils having K-factors that are 0.37 or above. Land cover for the First Salt Creek Segment CPC-TU-C1 subwatershed is listed in Table 12. Approximately 79% of the land is used for agriculture, approximately 7% is forest and approximately 7% is grassland. Figure 6 shows the location of livestock operations in the watershed. The only point source discharge in this watershed is the Teutopolis sewage treatment plant, which discharges to the listed segment. A photo of First Salt Creek is provided in Appendix B.

Table 12. Land Cover in Segment CPC-TU-C1 First Salt Creek Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	6,077	79%
Forest	525	7%
Grassland	547	7%
Urban	425	6%
Water	26	0%
Wetland	86	1%
Barren land	8	0%
Total	**7,694**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (40%) and corn (45%).

Second Salt Creek (Segments CPD 04, CPD 03 and CPD 01) Watershed Characterization

Second Salt Creek has been divided into three segments that have been identified as being impaired on the IEPA 303(d) list. Second Salt Creek originates in Cumberland County and flows southwest to its confluence with First Salt Creek. The most upstream segment (CPD 04) is 2.92 miles long and is listed solely for low dissolved oxygen. This reach of the creek winds through open fields and the bank vegetation is grassy with low vegetation. The watershed for segment CPD 04 is 1,943 acres. The middle segment (CPD 03) is 1.39 miles long and is listed for both dissolved oxygen and silver impairments. The watershed for segment CPD 03 is 4,080 acres. The downstream segment (CPD 01) is 2.67 miles long and is listed for dissolved oxygen impairments. The watershed for segment CPD 01 is 6,451 acres. Photos of Second Salt Creek are provided in Appendix B.

There are no point source dischargers, mines or incorporated municipalities within the subwatershed boundaries. However, based on a call with the Effingham SWCD, it was noted that cattle operations are located in the Second Salt Creek watershed and that some cattle have access to the creek. Hog and cattle operations are shown in Figure 6. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within subwatershed for these segments, with a slightly higher frequency of hydrologic soil group D (high runoff potential). The K-factors range from 0.32 to 0.43 with the K-factor of 0.37 occurring most frequently. Land cover for each of the Second Salt Creek segment subwatersheds is listed in Table 13. Agriculture, grassland and forest are the predominant land uses within the Second Salt Creek watershed.

Table 13. Land Cover in the Second Salt Creek Subwatershed (Segments CPD 04, CPD 03 and CPD 01)

Segment	Land Cover Type	Area (acres)	Percent
CPD 04	Agriculture[1]	1,640	84%
	Forest	37	2%
	Grassland	243	13%
	Urban	23	1%
	Water	0	0%
	Wetland	0	0%
	Barren land	0	0%
	Total	**1,943**	**100%**
CPD 03	Agriculture[2]	3,262	80%
	Forest	125	3%
	Grassland	623	15%
	Urban	59	1%
	Water	4	0%
	Wetland	6	0%
	Barren land	0	0%
	Total[4]	**4,080**	**100%**
CPD 01	Agriculture[3]	4,643	72%
	Forest	677	10%
	Grassland	855	13%
	Urban	167	3%
	Water	16	0%
	Wetland	91	1%
	Barren land	3	0%
	Total[4]	**6,451**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (30%), corn (54%) and winter wheat, other small grains and hay (16%)
[2]The primary crops are soybeans (25%), corn (48%) and winter wheat, other small grains and hay (27%)
[3]The primary crops are soybeans (29%), corn (44%) and winter wheat, other small grains and hay (27%)
[4] Total acreage and percentage may not sum as expected due to rounding.

Salt Creek (Segment CP-TU-C3) Watershed Characterization

Salt Creek Segment CP-TU-C3 is 0.82 miles in length and its subwatershed is 14,473 acres in size. This segment originates at the confluence of First Salt Creek and Second Salt Creek, both of which appear on the section 303(d) list as impaired and which were previously described in this report. Segment CP-TU-C3 appears on the 303(d) list as impaired due to manganese. First Salt Creek, which flows into Salt Creek, is also listed for manganese impairments.

The communities of Teutopolis and Montrose are located in the watershed draining to this segment. There are no point sources discharging directly to this segment of Salt

Creek, however, the Teutopolis STP, which discharges to First Salt Creek, is located upstream of the listed segment. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within this subwatershed, with an almost equal frequency of occurrence. The K-factors range from 0.32 to 0.43 with the K-factor of 0.37 occurring most frequently. Land cover for the Salt Creek CP-TU-C3 subwatershed is listed in Table 14. Approximately 75% of the land is used for agriculture, approximately 10% is grassland and approximately 9% is forest.

Table 14. Land Cover in Segment CP-TU-C3 Salt Creek Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	10,838	75%
Forest	1,359	9%
Grassland	1,414	10%
Urban	603	4%
Water	46	0%
Wetland	203	1%
Barren land	11	0%
Total[2]	**14,473**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (35%), corn (44%) and winter wheat, other small grains and hay (20%)
[2] Total acreage and percentage may not sum as expected due to rounding.

Salt Creek (Segment CP-EF-C2) Watershed Characterization

Salt Creek Segment CP-EF-C2 is 2.34 miles in length and its subwatershed is 24,197 acres in size. This segment of Salt Creek is listed due to low dissolved oxygen levels and is located just east of Effingham. Five of the segments previously described in this report are located upstream of this Salt Creek segment (CPD 04, CPD 03, CPD 01, CPC-TU-C1 and CP-TU-C3).

Teutopolis, Montrose and Effingham are all located in the watershed draining to this segment. There are two point sources discharging directly to this segment of Salt Creek. These are the Effingham sewage treatment plant and the Harper Oil Company. The Effingham outfalls that discharge to this segment are described as being the STP outfall (0010), treated CSO outfall (O0020), CSO at 3rd and Wabash (C0030) and CSO-East Temple Lift Station (C0070). The Teutopolis STP is also located in this segment's subwatershed, but the discharge is located several miles upstream of this segment, on First Salt Creek. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within this subwatershed, with an almost equal frequency of occurrence. The K-factors range from 0.32 to 0.43 with the K-factor of 0.37 occurring most frequently. Land cover for the Salt Creek CP-EF-C2 subwatershed is listed in Table 15. Approximately 64% of the land is used for agriculture and approximately 13% is urban. 12% of the land in this watershed is forest. During the November 2005 site visit, the creek was shallow and slow moving.

The banks are covered in grass and low vegetation, with some trees. Photos of the creek are provided in Appendix B.

Table 15. Land Cover in Segment CP-EF-C2 Salt Creek Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	15,418	64%
Forest	3,016	12%
Grassland	2,041	8%
Urban	3,163	13%
Water	70	0%
Wetland	446	2%
Barren land	43	0%
Total[2]	**24,197**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (37%), corn (42%) and winter wheat, other small grains and hay (21%)
[2] Total acreage and percentage may not sum as expected due to rounding.

Lake Sara (Segment RCE) Watershed Characterization

Lake Sara is located in Effingham County, approximately 5 miles northwest of Effingham. This lake was constructed 1957 by impounding Blue Point Creek, a tributary to the Little Wabash River. The lake is 765 acres in size and serves many uses, including water supply, boating, fishing, and swimming. Its watershed is 7,777 acres. There are no municipalities or permitted point source dischargers in this subwatershed; however, the shoreline is very developed, with many houses located on the lake. These homes are all served by septic systems. There are also several golf courses located near the lake, as well as two marinas. This lake is currently listed as being impaired due to excess phosphorus and manganese. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within this subwatershed, with hydrologic soil group C occurring most frequently. The K-factors range from 0.32 to 0.43 with the K-factor of 0.43 occurring most frequently. Land use is primarily agriculture (58%) and forest (21%). Land use is summarized in Table 16. There is extreme bank erosion in some areas of Lake Sara. Photos of the lake are provided in Appendix B.

Table 16. Land Cover in Segment RCE Lake Sara Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	4,519	58%
Forest	1,623	21%
Grassland	524	7%
Urban	165	2%
Water	559	7%
Wetland	384	5%
Barren land	3	0%
Total	**7,777**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (49%), corn (31%) and winter wheat, other small grains and hay (20%)

East Branch Green Creek (Segment CSB 08) Watershed Characterization

East Branch Green Creek Segment CSB 08 is 5.64 miles in length, and its subwatershed is 3,662 acres in size. This segment of East Branch Green Creek is listed due to low dissolved oxygen and elevated manganese levels. This segment originates at the headwaters of East Branch Green Creek and is immediately upstream of segment CSB 07, which is also listed for dissolved oxygen impairments. The land use in the Segment CSB 08 subwatershed is primarily agriculture (85%) and grassland (9%). Land cover is summarized in Table 17. Figure 6 shows the location of livestock operations in the watershed. There are no municipalities or point sources located in this segment's subwatershed. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within this subwatershed, with hydrologic soil group D occurring most frequently. The K-factors range from 0.32 to 0.43 with the K-factor of 0.37 occurring most frequently.

Table 17. Land Cover in Segment CSB 08 East Branch Green Creek Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	3,129	85%
Forest	114	3%
Grassland	324	9%
Urban	78	2%
Water	7	0%
Wetland	10	0%
Barren land	0	0%
Total[2]	**3,662**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (45%), corn (45%) and winter wheat, other small grains and hay (10%)
[2] Total acreage and percentage may not sum as expected due to rounding.

East Branch Green Creek (Segment CSB 07) Watershed Characterization

East Branch Green Creek Segment CSB 07 is 3.23 miles in length and its subwatershed is 20,633 acres in size. This segment of East Branch Green Creek is listed due to low dissolved oxygen. This segment originates immediately downstream of Segment CSB 08 and ends at the confluence of East Branch Green Creek with Green Creek. Segment CSB 08 is also listed for dissolved oxygen impairments. The land use in the Segment CSB 07 subwatershed is primarily agriculture (76%), forest (10%) and grassland (9%). Land cover is summarized in Table 18. Livestock operations are shown in Figure 6. The community of Sigel is located in this segment's subwatershed, as are the Sigel STP and an STP outfall for the Illinois DOT I-57 Effingham County facility. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within this subwatershed, with hydrologic soil group D occurring more frequently. The K-factors range from 0.32 to 0.43 with the K-factor of 0.37 occurring most frequently.

Table 18. Land Cover in Segment CSB 07 East Branch Green Creek Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	15,688	76%
Forest	2,020	10%
Grassland	1,946	9%
Urban	651	3%
Water	48	0%
Wetland	261	1%
Barren land	18	0%
Total[2]	**20,633**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (39%), corn (40%) and winter wheat, other small grains and hay (21%)
[2] Total acreage and percentage may not sum as expected due to rounding.

Dieterich Creek (Segment COC 10) Watershed Characterization

Dieterich Creek Segment COC 10 is 8.2 miles in length and its subwatershed is 6,633 acres in size. This segment is listed due to copper, manganese, and silver impairments. This segment originates at the headwaters of Dieterich Creek, flows through Dieterich and ends at the confluence with a small, unnamed tributary, 8.2 miles from the headwaters. The land use in the Segment COC 10 subwatershed is primarily agriculture (72%) and forest (18%). Land cover is summarized in Table 19. There are no NPDES permitted facilities that discharge to Dieterich Creek. One hundred percent of the soils in this subwatershed are described by the Cisne-Hoyleton-Darmstadt and Bluford-Ava-Hickory associations, which were described previously. Hydrologic soil groups C through D are found within this subwatershed, with an almost equal occurrence of hydrologic soil groups C and D. The K-factors range from 0.32 to 0.43 with the K-factor of 0.37 occurring most frequently. The banks of the creek are forested, as shown in the photos in Appendix B.

Table 19. Land Cover in Segment COC 10 Dieterich Creek Subwatershed

Land Cover Type	Area (acres)	Percent
Agriculture[1]	4,807	72%
Forest	1,179	18%
Grassland	292	4%
Urban	275	4%
Water	10	0%
Wetland	67	1%
Barren land	3	0%
Total[2]	**6,633**	**100%**

Source: Illinois Department of Agriculture, 1999-2000 land cover
[1]The primary crops are soybeans (50%), corn (38%) and winter wheat, other small grains and hay (12%)
[2] Total acreage and percentage may not sum as expected due to rounding.

Clay City Side Channel Reservoir (Segment RCU) Watershed Characterization

The Clay City Side Channel Reservoir (Clay City SCR) is located just north of Clay City near Little Wabash River segment C 19. It is a 6-acre reservoir created by diverting a portion of the flow from the Little Wabash River. It was once a drinking water source for the residents of Clay City, and as such had been listed on the 303(d) list due to manganese impairment. However, recent communications with the Village of Clay City (February 2006) indicated that the village now purchases potable water from the EJ Water Corporation, and neither the river nor the SCR is used for drinking water. Therefore, no TMDL is needed for this waterbody.

DATABASE DEVELOPMENT AND DATA ANALYSIS

A water quality database was developed and the data were analyzed to confirm the sufficiency of the data to support both the listing decision and the sources of impairment that are included on the 2006 303(d) list.

Data Sources and Methods

All readily available existing data to describe water quality in the impaired waterbodies were obtained. IEPA data included IEPA ambient water quality monitoring data, IEPA Intensive Basin Survey data, Facility Related Stream Surveys and IEPA NPDES monitoring data. All available and relevant data were then compiled in electronic format along with sample location and collection information, in a project database. A list of data sources is included in Appendix A.

The water quality data were analyzed to confirm the causes of impairment for each waterbody and, in combination with the watershed characterization data, an assessment was made to confirm the sufficiency of the data to support the listing decision and the sources of impairment that are included on the 2006 303(d) list. Once data were compiled, basic statistics for each parameter were computed. The data were then compared to relevant numeric water quality standards based on designated use. Related parameters were also analyzed to understand sources of impairment (e.g., total phosphorus, ammonia, temperature and flow data were reviewed for waterbodies with dissolved oxygen impairments).

A summary of readily available water quality data for the watershed is presented in Table 20 below. Sampling station locations are shown in Figure 7.

CONFIRMATION OF CAUSES AND SOURCES OF IMPAIRMENT

Water quality data were evaluated to confirm the cause of impairment for each waterbody in the Little Wabash River watershed, and in combination with the watershed characterization data, the sufficiency of the data were assessed to support the listing decision and the sources of impairment that are included on the 2006 303(d) list. Table 21 lists the impaired waterbodies, the applicable water quality criteria for listing a cause on the 303(d) list, and the number of samples exceeding the criteria. (Note that the number of samples listed in Table 21 may differ from the values listed in Table 20; while Table 20 summarizes the available data set, Table 21 includes only the data used in the listing decision, typically only the last three to five years of data.) The results summarized in Table 21 are discussed by waterbody in the following sections.

Table 20. Water Quality Data Summary for the Little Wabash Watershed

Waterbody Segment	Parameter	Sampling Station	Period of Record (#)	Minimum	Maximum	Average[1]
Little Wabash C 19	Dissolved Oxygen (mg/L)	C 19	1/91 – 1/04 (111 samples)	2.1	20.0	7.7
	Manganese (ug/L)	C 19	1/91 – 6/04 (86 samples)	100	1,100	339
	Fecal coliform (cfu/100 ml)	C 19	1/91 – 6/05 (109 samples)	4	47,600	1,600
	pH (S.U.)	C 19	1/91 – 1/04 (114 samples)	6.0	8.4	7.3
	Atrazine (ug/L)	C 19	1/91 – 10/05 (88 samples)	<0.05	20	2.2
Little Wabash C 21	Manganese (ug/L)	C 21	1/91 – 1/04 (117 samples)	26	1,900	306
	Fecal coliform (cfu/100 mll)	C 21	1/91 – 8/05 (107 samples)	2	20,000	1,261
Lake Paradise RCG	Phosphorus (mg/L)	RCG-1	5/91 – 5/01 (52 samples)	0.01	0.28	0.14
		RCG-2	8/93 – 5/01 (16 samples)	0.01	0.32	0.14
		RCG-3	5/91 – 5/01 (25 samples)	0.08	0.39	0.23
	pH (S.U.)	RCG-1	8/93 – 10/04 (37 samples)	7.2	9.19	8.09
		RCG-2	8/93 – 10/04 (17 samples)	7.5	9.25	8.45
		RCG-3	4/95 – 10/04 (15 samples)	7.6	8.9	8.39
Lake Mattoon RCF	Phosphorus (mg/L)	RCF-1	5/92 – 10/01 (43 samples)	0.03	0.65	0.16
		RCF-2	5/92 – 10/01 (22 samples)	0.03	0.18	0.10
		RCF-3	6/95 – 10/01 (17 samples)	0.12	0.33	0.21
		RCF-4	5/92 – 6/92 (2 samples)	0.17	0.18	0.18
First Salt Creek CPC-TU-C1	Dissolved Oxygen (mg/L)	CPC-TU-A1	9/99 (1 sample)	3.1	3.1	3.1
		CPC-TU-C1	9/99 – 9/01 (2 samples)	2.8	3.1	2.95
		CPC-TU-C2	9/99 (1 sample)	2.8	2.8	2.8
	Manganese (ug/L)	CPC-TU-A1	9/99 (1 sample)	400	400	400
		CPC-TU-C1	9/99 – 9/01 (2 samples)	280	650	465
		CPC-TU-C2	9/99 (1 sample)	2,000	2,000	2,000

Waterbody Segment	Parameter	Sampling Station	Period of Record (#)	Minimum	Maximum	Average[1]
Second Salt Creek CPD 04	Dissolved Oxygen (mg/L)	CPD 06	4/91 – 10/91 (3 samples)	0.5	3.9	2.03
		CPD 05	10/91 (1 sample)	2.6	2.6	2.6
		CPD 04	4/91 – 10/91 (2 samples)	1.9	5.1	3.5
Second Salt Creek CPD 03	Dissolved Oxygen (mg/L)	CPD 03	4/91 – 10/91 (2 samples)	0.6	5.8	3.2
	Silver (ug/l)	CPD 03	4/91 – 10/91 (3 samples)	<3	7	4.3
Second Salt Creek CPD 01	Dissolved oxygen (mg/L)	CPD 02	4/91 – 10/92 (2 samples)	3.5	6	4.75
		CPD 01	4/91 – 10/92 (2 samples)	4.2	8.5	6.35
Salt Creek CP-TU-C3	Manganese (ug/L)	CP-TU-C3	9/99 (1 sample)	1,300	1,300	1,300
Salt Creek CP-EF-C2	Dissolved oxygen (mg/l)	CP-EF-C2	9/99 (1 sample)	2.4	2.4	2.4
Lake Sara RCE	Total Phosphorus (mg/L)	RCE-1	5/91 – 8/02 (63 samples)	0.016	1.25	0.205
		RCE-2	4/92 – 8/02 (24 samples)	0.017	0.075	0.038
		RCE-3	5/91 – 8/02 (29 samples)	0.020	0.087	0.045
	Manganese (ug/L)	RCE-1	4/01 – 10/04 (14 samples)	51	3,200	1,104
E. Br. Green Creek CSB 08	Dissolved oxygen (mg/l)	CSB 08	4/91 – 10/91 2 samples	0.6	7.5	4.05
	Manganese (ug/l)	CSB 08	4/91 – 10/91 3 samples	162	1,687	697
E. Br. Green Creek CSB 07	Dissolved oxygen (mg/l)	CSB 07	4/91 – 10/91 2 samples	3.1	6.6	4.85
Dieterich Creek COC 10	Copper, total (ug/l)	COC 10	4/91 – 10/91 3 samples	< 5	28	12.7
	Manganese, total (ug/l)	COC 10	4/91 – 10/91 3 samples	193	2,844	1,179
	Silver (ug/l)	COC 10	4/91 – 10/91 3 samples	< 3	8	4.7
Clay City SCR RCU	Manganese (ug/l)	RCU	4/01 - 10/01 5 samples	180	380	254

[1] Values less than detection were set at detection level for purposes of calculating an average of the data.

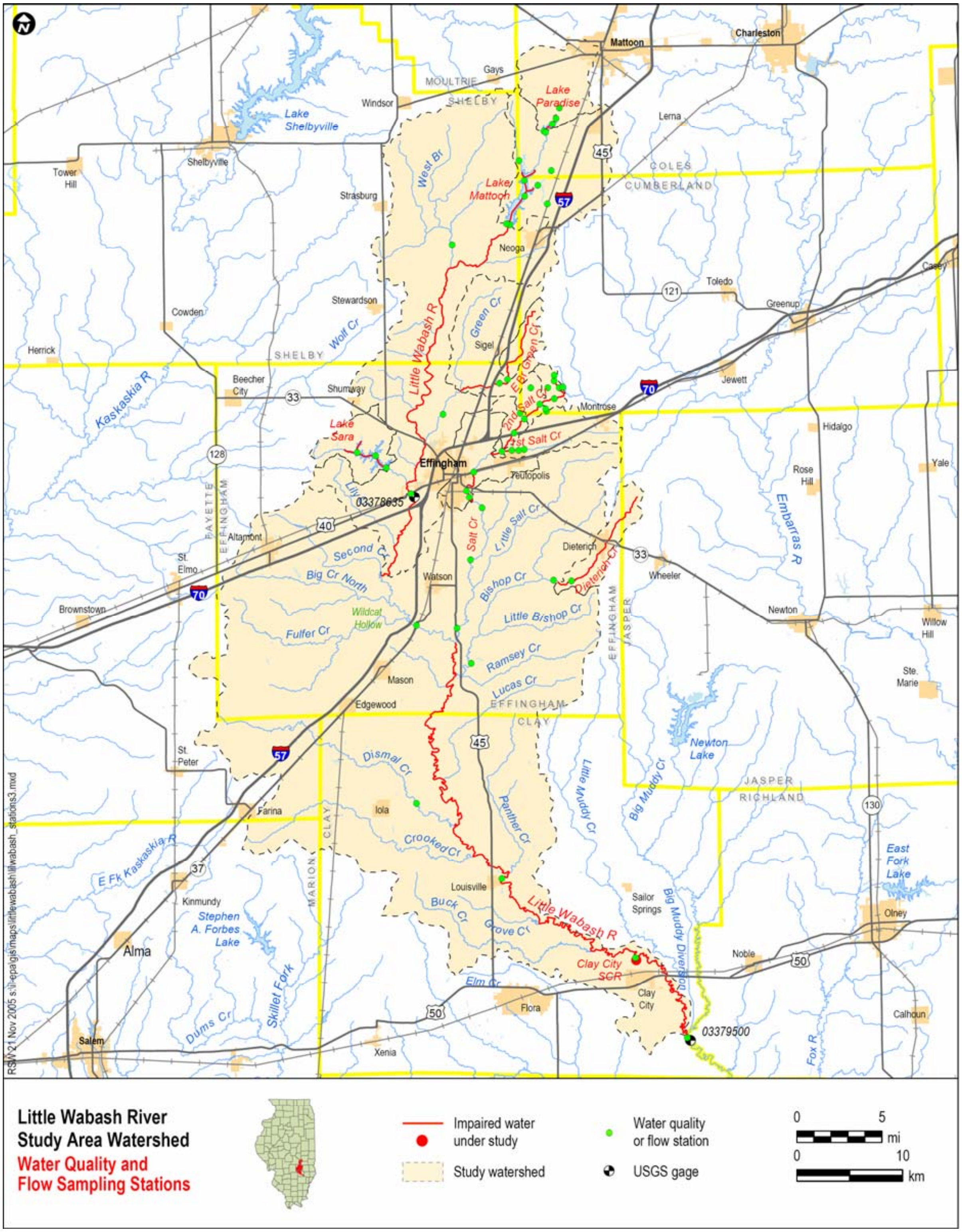

Figure 7. Sampling stations in the Little Wabash River watershed

Table 21. Water Quality Standards and Number of Exceedances

Sample Location/ Cause of Impairment	Applicable Illinois Nonspecific Use Designation	Water Quality Criterion	Number of Samples Exceeding Criterion
Little Wabash (C 19)			
Dissolved oxygen	Aquatic Life	5 mg/l minimum	2 of 30 samples < criterion
Manganese	Public & Food Processing Water Supply	150 ug/l	14 of 14 samples collected since 1999 > criterion
Fecal coliform	Primary contact (swimming)	400 cfu/100ml in < 10% of samples Geomean < 200 cfu/100 ml	11 of 34 samples > criterion Geomean = 194 cfu/100 ml
pH	Aquatic Life	> 6.5 and < 9.0 S.U.	1 of 31 samples < 6.5 S.U.
Atrazine	Aquatic Life	82 ug/l (acute) 9 ug/l chronic	3 of 54 samples > chronic criterion
Little Wabash (C 21)			
Manganese	Public & Food Processing Water Supply	150 ug/l	22 of 28 samples collected in 2001 or more recently > criterion
Fecal coliform	Primary contact (swimming)	400 cfu/100ml in < 10% of samples Geomean < 200 cfu/100 ml	9 of 31 samples > criterion Geomean = 131 cfu/100 ml
Lake Paradise (RCG)			
Total Phosphorus	Aquatic Life	0.05 mg/l	14 of 14 surface samples collected in 2001 > criterion
pH	Aquatic Life	> 6.5 and < 9.0 S.U.	2 of 25 samples collected in 2004 > 9 S.U.
Lake Mattoon			
Total Phosphorus	Aquatic Life	0.05 mg/l	25 of 26 surface samples collected in 2001 > criterion
First Salt Creek (CPC-TU-C1)			
Manganese	Aquatic Life	1,000 ug/l	1 of 4 samples > criterion
Dissolved oxygen	Aquatic Life	5 mg/l minimum	4 of 4 samples < criterion
Second Salt Creek (CPD 04)			
Dissolved oxygen	Aquatic Life	5 mg/l minimum	5 of 6 samples < criterion
Second Salt Creek (CPD 03)			
Dissolved oxygen	Aquatic Life	5 mg/l minimum	1 of 2 samples < criterion
Silver (total)	Aquatic Life	5 ug/l	1 of 3 samples > criterion
Second Salt Creek (CPD 01)			
Dissolved oxygen	Aquatic Life	5 mg/l minimum	2 of 4 samples < criterion

Sample Location/ Cause of Impairment	Applicable Illinois Nonspecific Use Designation	Water Quality Criterion[1]	Number of Samples Exceeding Criterion
Salt Creek (CP-TU-C3)			
Manganese	Aquatic Life	1,000 ug/l	1 of 1 sample > criterion
Salt Creek (CP-EF-C2)			
Dissolved oxygen	Aquatic Life	5 mg/l minimum	1 of 1 sample < criterion
Lake Sara (RCE)			
Total Phosphorus	Aquatic Life	0.05 mg/l	1 of 12 surface samples collected in 2002 > criterion
Manganese	Public & Food Processing Water Supply	150 ug/l	13 of 14 samples collected in 2001 or more recently > criterion
E. Branch Green Creek (CSB 08)			
Dissolved oxygen	Aquatic Life	5 mg/l minimum	1 of 2 samples < criterion
Manganese	Aquatic Life	1,000 ug/l	1 of 3 samples > criterion
E. Branch Green Creek (CSB 07)			
Dissolved oxygen	Aquatic Life	5 mg/l minimum	1 of 2 samples < criterion
Dieterich Creek (COC 10)			
Copper (total)[1]	Aquatic Life – acute	Exp[-1.464+ 0.9422*ln(hard)]*0.96	1 of 3 samples > criterion
	Aquatic Life - chronic	Exp[-1.465+ 0.8545*ln(hard)]*0.96	1 of 3 samples > criterion
Manganese	Aquatic Life	1,000 ug/l	1 of 3 samples > criterion
Silver (total)	Aquatic Life	5 ug/l	1 of 3 samples > criterion
Clay City Side Channel Reservoir (RCU)			
Manganese	Aquatic Life	1,000 ug/l	0 of 1 sample > criterion
	Public & Food Processing Water Supply	150 ug/l	5 of 5 samples collected in 1999 or more recently > criterion

[1] Copper criteria are for dissolved copper. Total copper data were converted to dissolved using a conversion factor of 0.96 and then comparisons to criteria were made.

The following sections also discuss potential sources of impairments. The Illinois EPA (IEPA, 2006) defines potential sources as known or suspected activities, facilities, or conditions that may be contributing to impairment of a designated use. The impairments and sources identified by IEPA in the 305(b) report are listed in Table 22. Potential sources identified through the Stage 1 work are summarized in Table 23. These potential sources were identified through the watershed characterization activities previously discussed and analysis of available data as described in the following section.

Table 22. Waterbody Impairment Causes and Sources (from IEPA, 2006) for the Little Wabash River Watershed

Waterbody	Cause of impairments	Potential Sources (from 305(b) Report)
Little Wabash (C 19)		
	Dissolved oxygen	Source unknown
	Manganese	Source unknown
	Fecal coliform	Source unknown
	pH	Source unknown
	Atrazine	Non-irrigated crop production
Little Wabash (C 21)		
	Manganese	Source unknown
	Fecal coliform	Source unknown
Lake Paradise (RCG)		
	Phosphorus pH	Municipal sources, Agriculture, Crop-related sources, Non-irrigated crop production, Hydromodification, Flow regulation/modification, Forest/grassland/parkland
Lake Mattoon (RCF)		
	Phosphorus	Agriculture, Crop-related sources, Non-irrigated crop production, Habitat modification (other than hydromodification), Bank or shoreline modification/destabilization, Recreation and tourism activities, Forest/grassland/parkland
First Salt Creek (CPC-TU-C1)		
	Manganese	Municipal point source
	Dissolved oxygen	Municipal point source
Second Salt Creek (CPD 04)		
	Dissolved oxygen	Intensive animal feeding operations
Second Salt Creek (CPD 03)		
	Dissolved oxygen	Intensive animal feeding operations
	Silver	Source unknown
Second Salt Creek (CPD 01)		
	Dissolved oxygen	Grazing-related sources, Pasture grazing-Riparian and/or upland, Intensive animal feeding operations
Salt Creek (CP-TU-C3)		
	Manganese	Municipal point sources
Salt Creek (CP-EF-C2)		
	Dissolved oxygen	Municipal point sources, Urban runoff/storm sewers
Lake Sara (RCE)		
	Manganese Phosphorus	Agriculture; Crop-related sources; Non-irrigated crop production; Source unknown
East Branch Green Creek (CSB 08)		
	Dissolved oxygen Manganese	Agriculture, Non-irrigated crop production, Intensive animal feeding operations
East Branch Green Creek (CSB 07)		
	Dissolved oxygen	Intensive animal feeding operations
Dieterich Creek (COC 10)		
	Copper	Source unknown
	Manganese	Source unknown
	Silver	Source unknown
Clay City SCR (RCU)		
	Manganese	Agriculture, Crop-related sources, Non-irrigated crop production, source unknown

Table 23. Other Potential Sources for Causes of Impairment in the Impaired Little Wabash River Watershed

Waterbody	Cause of impairments	Potential Sources
Little Wabash (C 19)		
	Dissolved oxygen	Animal operations, septic systems, municipal point sources, cropland runoff, wildlife, exacerbated by high temperature and low flows
	Manganese	Natural background sources, release from river bottom sediments under anoxic conditions, brine from oil wells
	Fecal coliform	Livestock, private sewage systems, permitted sewage treatment plants, wildlife
	pH	Naturally acidic soils/background conditions
	Atrazine	Cropland runoff and groundwater
Little Wabash (C 21)		
	Manganese	Natural background sources
	Fecal coliform	Livestock, private sewage systems, permitted sewage treatment plants, wildlife
Lake Paradise (RCG)		
	Phosphorus	Cropland and pastureland runoff, improperly functioning septic systems, release from lake bottom sediments under anoxic conditions, shoreline erosion
	pH	Excess algal production resulting from nutrient loading from failing private sewage disposal systems (septic and surface discharge systems), runoff from agricultural land and livestock
Lake Mattoon (RCF)		
	Phosphorus	Cropland runoff, release from lake bottom sediments under anoxic conditions, septic systems
First Salt Creek (CPC-TU-C1)		
	Dissolved oxygen	Municipal STP, animal feeding operations, exacerbated by high temperature and low flows
	Manganese	Natural background
Second Salt Creek (CPD 04)		
	Dissolved oxygen	Animal operations, wildlife, exacerbated by high temperature and low flows
Second Salt Creek (CPD 03)		
	Dissolved oxygen	Animal operations, wildlife, exacerbated by high temperature and low flows
	Silver	No obvious sources
Second Salt Creek (CPD 01)		
	Dissolved oxygen	Animal operations, wildlife, exacerbated by high temperature and low flows
Salt Creek (CP-TU-C3)		
	Manganese	Natural background
Salt Creek (CP-EF-C2)		
	Dissolved oxygen	Municipal point sources, urban runoff, wildlife, exacerbated by high temperature and low flows
Lake Sara (RCE)		
	Manganese	Release from lake bottom sediments under anoxic conditions, natural background
	Phosphorus	Agricultural runoff, golf course runoff, septic systems, shoreline erosion, lake bottom sediments

Waterbody	Cause of impairments	Potential Sources
East Branch Green Creek (CSB 08)		
	Dissolved oxygen	Agricultural lands, animal operations, wildlife, exacerbated by high temperature and low flows
	Manganese	Sediment release under anoxic conditions; natural background
East Branch Green Creek (CSB 07)		
	Dissolved oxygen	Animal operations, wildlife, exacerbated by high temperature and low flows
Dieterich Creek (COC 10)		
	Copper	No obvious sources
	Manganese	Natural background
	Silver	No obvious sources
Clay City SCR (RCU)		
	Manganese	Natural background, release from lake bottom sediments under anoxic conditions, oil well brine and streambank erosion. Note that this reservoir is no longer a drinking water source, and will be removed from the 303(d) list. No TMDL will be prepared.

Little Wabash (Segment C 19)

Listed for: Dissolved Oxygen, Manganese, Fecal Coliform, pH and Atrazine

Dissolved oxygen, manganese, fecal coliform, pH and atrazine data were collected at station C 19, which is located near Louisville, Illinois. These data were collected under the ambient water quality monitoring program and the IEPA intensive basin survey between January 1991 and June 2004.

Dissolved Oxygen

The IEPA guidelines (IEPA, 2006) for identifying dissolved oxygen as a cause of impairment in streams state that dissolved oxygen is a potential cause of impairment if there is at least one excursion of the applicable standard (5.0 mg/L) or known fish kill resulting from dissolved oxygen depletion. The guidelines indicate that for identifying potential causes of impairment in streams, the most recent three years of data, and the most recent intensive basin survey are used. For the most recent three years of data and the most recent intensive basin survey, 2 of 30 dissolved oxygen measurements (7%) were below the aquatic life water quality criterion of 5 mg/L. Excursions of 1 mg/L below the criterion occurred in 2001 and 2003, with the most recent observed occurrence in May 2003. The data compared to the aquatic life criterion are shown in Figure 8. These data are considered representative of water quality in this segment, as the sampling station is located near the middle of the listed segment. Therefore, the data are sufficient to support the listing of this segment of the Little Wabash River for dissolved oxygen on the 303(d) list.

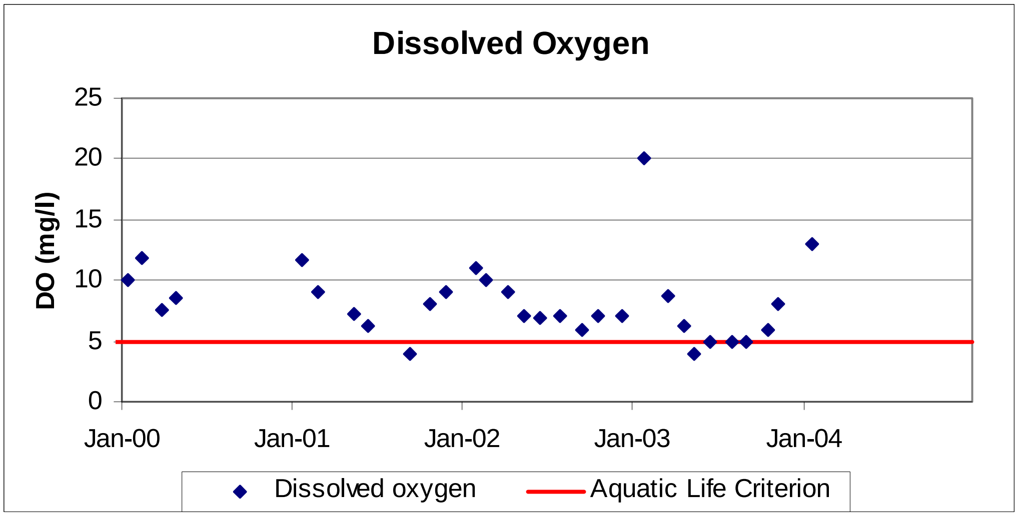

Figure 8. Little Wabash (C 19) Dissolved Oxygen Data Compared to Aquatic Life Criterion

A review of the data show that dissolved oxygen concentrations in this segment are inversely related to water temperature. Many of the low dissolved oxygen readings were concurrent with water temperature above 20 degrees Celsius; indicating water temperature is likely one factor contributing to low dissolved oxygen. A similar pattern is seen with flows, with low dissolved oxygen generally being related to low stream flows, although there are a few exceptions. Animal operations, failing septic systems, cropland runoff, wildlife and permitted dischargers are potential sources of oxygen demanding substances (e.g., ammonia and BOD).

Manganese

The IEPA guidelines (IEPA, 2006) for identifying manganese as a cause of impairment of the public and food processing water supply use in streams state that manganese is a potential cause if, in untreated water, more than 10% of the observations exceed the applicable standard (150 ug/l), or if there is any violation of the applicable maximum contaminant level (also 150 ug/l). Public and food processing water supply use assessments for streams are generally based on data from 2001 and later (IEPA, 2006). For station C 19, none of the available data were collected in 2001 or more recently. However, fourteen of the manganese samples were collected in 1999 or later, consistent with the data set used for assessing uses in lakes. These 14 samples were therefore used in this evaluation. All of the 14 manganese measurements exceeded the public water supply criterion. Exceedances ranged from 10 to 770 ug/l over the criterion.

These data were collected at a station located near the middle of the segment and are considered representative of water quality in this segment. Based on this review of the data, the listing of this segment for manganese is warranted.

Manganese is a naturally occurring element that is a component of over 100 minerals. Of the heavy metals, it is surpassed in abundance only by iron (ATSDR, 1997). Because of the natural release of manganese into the environment by the weathering of manganese-rich rocks and sediments, manganese occurs ubiquitously at low levels in soil, water, air, and food (USEPA, 2003).

As described previously in the Watershed Characterization portion of this report, many of the soils in the Little Wabash River watershed contain naturally-occurring manganese concretions or accumulations and most soils in the watershed are also acidic (pH < 6.6). The low pH could result in the manganese moving into solution and being transported through baseflow and/or runoff. Another potential source of manganese is release from river-bottom sediments under anoxic conditions. A review of available manganese and dissolved oxygen data revealed an inverse relationship between dissolved oxygen and both total and dissolved manganese. As dissolved oxygen concentrations dropped, both total and dissolved manganese concentrations increased. This indicates that release of manganese from river bottom sediments is a potential source of manganese. A third potential source is oil well operations. As shown in Figure 3, there are numerous oil wells in the segment C 19 watershed. In the past, the process of extracting the oil included pumping out brine water, which is typically high in manganese, and dumping it on the surface or storing it in lagoons that drained to surface waters.

The observed levels of manganese are likely due largely to the natural geochemical environment and most likely reflect natural background conditions. For this reason, the manganese standard may be difficult to attain.

Fecal Coliform

The IEPA guidelines (IEPA, 2006) for identifying fecal coliform as a cause of impairment in streams state that fecal coliform is a potential cause of impairment of the primary contact use if the geometric mean of all samples collected during May through October (minimum five samples) is greater than 200/100 ml, or if greater than 10% of all samples exceed 400/100 ml. The most recent five years of data are used in this assessment. Between January 2001 and June 2005, 34 fecal coliform measurements were collected. Of these samples, 11 (32%) were greater than 400 cfu/100 ml. The geometric mean of the samples from this data set is 194 cfu/100 ml). These data are considered representative of water quality in this segment, and the data are considered sufficient to support the listing of this segment of the Little Wabash River for fecal coliform on the 303(d) list, based on exceedances of the 400 cfu/100 ml criterion.

Potential sources of fecal coliform include livestock, private sewage systems, permitted point source dischargers and wildlife. These are discussed in more detail below.

Livestock and animal feeding operations were identified as potential sources of fecal coliform to Segment C 19 (personal communication, Clay County Health Department). Livestock locations were compiled by the Upper Little Wabash Ecosystem Partnership and are shown in Figure 6. Additionally, private surface sewage disposal systems are used to handle sewage in the community of Iola and according to a local official (personal communication, Clay County Health Department), raw sewage from these systems may be draining to streams. In terms of permitted dischargers, twenty-three entities were identified that are permitted to discharge treated wastewater to the Little Wabash River or its tributaries. Ten of these are municipal sewage treatment plant discharges and four are non-municipal small sewage treatment plants. All of these are potential sources of fecal coliform. In addition, wildlife, including waterfowl and terrestrial animals, can be significant sources of coliform bacteria.

pH

The IEPA guidelines (IEPA, 2006) for identifying pH as a cause of aquatic life impairment in streams state that pH is a potential cause if there is at least one excursion of the applicable standards (greater than 6.5 and less than 9.0 S.U.). The guidelines indicate that for identifying potential causes of impairment in streams, the most recent three years of data, and the most recent intensive basin survey are used; in this case, the 2000 intensive basin survey and the ambient water quality monitoring data for 2001-2004 were used. One of the 31 samples measured at station C 19 between January 2000 and January 2004 was less than the minimum pH criterion. The data compared to the aquatic life criterion are shown in Figure 9. These data are considered representative of water quality in this segment and are considered sufficient to support the listing of this segment of the Little Wabash River for pH on the 2006 303(d) list.

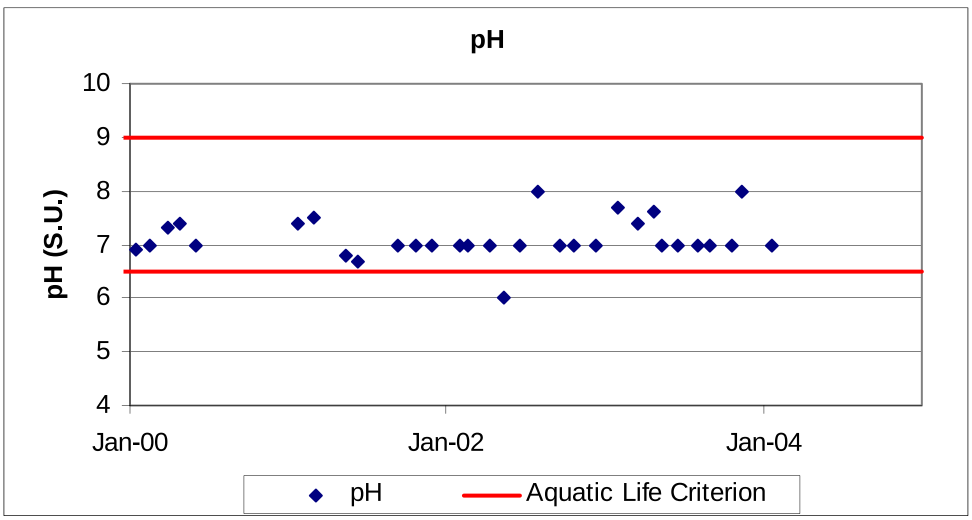

Figure 9. Little Wabash (C 19) pH Data Compared to Aquatic Life Criterion.

Naturally acidic soils in the watershed are a potential source contributing to the low pH. Soils are discussed in more detail in the *Geology and Soils* section of this report.

Atrazine

The IEPA guidelines (IEPA, 2006) for identifying atrazine as a cause of impairment in streams state that atrazine is a potential cause of impairment if there is at least one exceedance of either the acute (82 ug/l) or the chronic (9 ug/L) criterion. The guidelines indicate that for identifying potential causes of impairment in streams, the most recent three years of data, and the most recent intensive basin survey are used. For segment C-19, IEPA ambient water quality monitoring data from January 2003 through October 2005 were used, supplemented by data from the most recent intensive basin survey in 1999 and additional data collected at the City of Flora water intake as part of an annual study conducted by Syngenta. Additional data from the Syngenta study are available and will be incorporated as TMDL activities move forward. In total, 54 samples were used to confirm the listing of segment C-19 for atrazine. Of these 54 samples, three of them (6%) exceeded the chronic criterion for atrazine. The data are consistent and support the listing of this segment for atrazine.

Atrazine is used as an herbicide, primarily for corn, to control grass and broadleaf weeds. It is usually applied to fields by tank just before or just after corn has emerged (IDPH, 2006). There are several pathways that atrazine can be transported from a field to a stream, including surface runoff (transport of the soil particles from the field to the river during a rain event), and migration to groundwater and subsequent outflow to a receiving water.

Little Wabash (Segment C 21)

Listed for: Manganese and Fecal Coliform

The Little Wabash River Segment C 21 is listed due to manganese concentrations exceeding the public and food processing water supply use and fecal coliform levels exceeding primary contact use criteria. This site is monitored regularly, and data were available for the period January 1991 through August 2005.

Manganese

The IEPA guidelines (IEPA, 2006) for identifying manganese as a cause of impairment of the public and food processing water supply use in streams state that manganese is a potential cause if, in untreated water, more than 10% of the observations exceed the applicable standard (150 ug/l), or if there is any violation of the applicable maximum contaminant level (also 150 ug/l). Public and food processing water supply use assessments for streams are generally based on data from 2001 and later (IEPA, 2006). Of the 117 measurements available for manganese for one station (C 21) in this segment, 28 were collected in 2001 or more recently. Twenty-two (22) of the 28 measurements (79%) exceed 150 ug/l. Therefore, the data are considered sufficient to support manganese being listed as a potential cause on the 2006 303(d) list.

Soils naturally enriched in manganese are a potential source of manganese. A discussion of background sources of manganese is provided previously under Segment C 19 of the Little Wabash River. As manganese is ubiquitous in this region, the public water supply standards may be difficult to obtain. It should be noted that manganese does not present any human health hazards, but may be responsible for offensive tastes and appearances in drinking water, as well as staining laundry and fixtures.

Fecal Coliform

The IEPA guidelines (IEPA, 2006) for identifying fecal coliform as a cause of impairment in streams state that fecal coliform is a potential cause of impairment of the primary contact use if the geometric mean of all samples collected during May through October (minimum five samples) is greater than 200/100 ml, or if greater than 10% of all samples exceed 400/100 ml. The most recent five years of data are used in this assessment. Between January 1991 and August 2005, 107 fecal coliform measurements were collected, 31 of which were collected in the most recent five-year period (2001-2005). Of these 31 samples, 9 (29%) were greater than 400 cfu/100 ml. The geometric mean of the data collected in May through October equals 191 cfu/100 ml._ These data are considered representative of water quality in this segment, and the data are considered sufficient to support the listing of this segment of the Little Wabash River for fecal coliform on the 303(d) list, based on exceedances of the 400 cfu/100 ml criterion.

Potential sources of fecal coliform include livestock, private sewage systems, permitted point source dischargers and wildlife. These are discussed in more detail below.

Livestock and animal feeding operations are located throughout Effingham County (personal communication, Effingham County Soil and Water Conservation District), and are potential sources of fecal coliform to Segment C 21. Locations of livestock operations are shown in Figure 6. Additionally, private surface systems are common in the area, given that many of the soil associations in the watershed are poorly suited for use as septic tank absorption fields (USDA, 1998). Such systems, if not properly maintained, can release untreated sewage to local waterways. It has been estimated that, statewide, between 20 and 60 percent of surface discharging systems are failing or have failed (IEPA, 2004c), suggesting that such systems may be a significant source of pollutants. In terms of permitted dischargers, seven entities were identified that are permitted to discharge treated wastewater to this segment of the Little Wabash River. These include several municipal wastewater discharges that are potential sources of fecal coliform. In addition, wildlife, including waterfowl and terrestrial animals, can be significant sources of coliform bacteria.

Lake Paradise (Segment RCG)

Listed for: Total Phosphorus and pH

Lake Paradise is a 176-acre lake used for recreation and as a public water supply. Water quality measurements are available at three locations in the lake, stations RCG-1 (near the dam), RCG-2 (mid-lake), and RCG-3 (near the headwaters of the lake). Both phosphorus and pH were measured at these three locations. Station locations are shown in Figure 7. The depth of the lake at station RCG-1 is approximately 19 feet, at station RCG-2, approximately 15 feet and at station RCG-3, approximately 3.5 feet.

Total Phosphorus

IEPA considers phosphorus a potential cause of impairment of the aquatic life and aesthetic quality uses in lakes greater than 20 acres in size if there is at least one exceedance of the applicable standard (0.05 mg/L) in surface samples during the monitoring year (IEPA, 2006). A total of 17 total phosphorus measurements were collected in 2001, the most recent year for which monitoring data are available. Of these, 13 samples were collected within one foot of the surface. All of these samples exceeded the water quality criterion of 0.05 mg/L, indicating that the aquatic life and aesthetic quality uses are not fully supported. Exceedances ranged from 0.019 mg/L to 0.184 mg/L above the criterion in surface samples. A comparison of the 2001 phosphorus data to the water quality criterion is shown in Figure 10.

Based on this review of the data, the listing of Lake Paradise for total phosphorus is warranted, and the aquatic life and aesthetic quality uses are not fully supported.

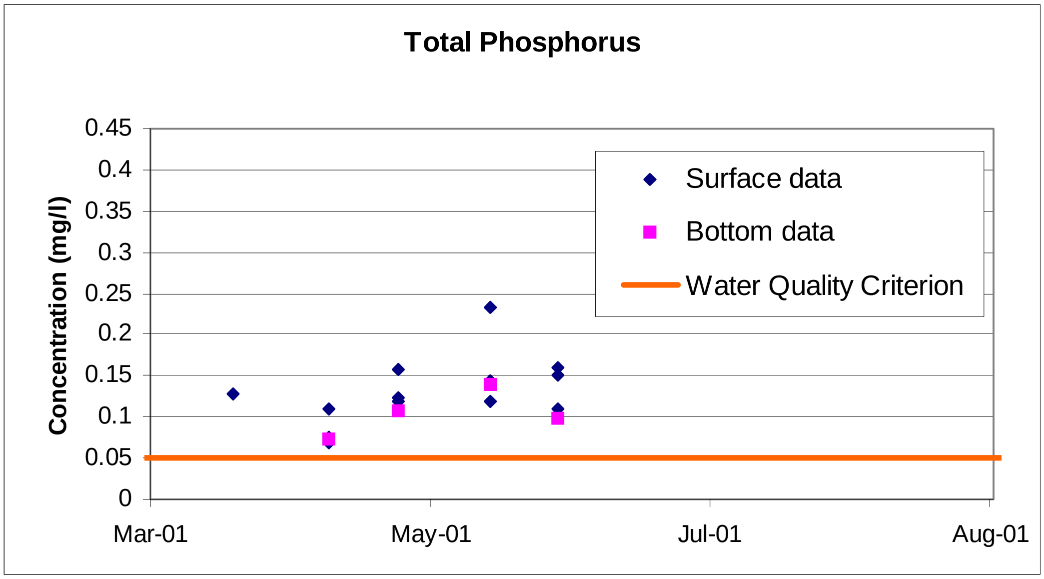

Figure 10. Lake Paradise (RCG) Total Phosphorus Data Compared to the Water Quality Criterion

Phosphorus sources were discussed in the Lake Paradise Diagnostic/Feasibility Study (IEPA, 2004b). Cropland was identified as contributing 95% of the nonpoint source phosphorus to the lake. Poor pasturing practices were also mentioned. Forest, urban and pasture/hayland were all estimated to contribute much less phosphorus. Improperly functioning septic systems near the lake were also identified as a potential source of phosphorus. The release of phosphorus from lake bottom sediments is also a continuing source, in spite of the installation of a lake destratifier in 1995. Finally, shoreline erosion is another potential phosphorus source. Based on the watershed characterization conducted for this study, potential phosphorus sources identified agree with those identified in the Lake Paradise study.

pH

The IEPA guidelines (IEPA, 2006) for identifying pH as a cause of aquatic life impairment in streams state pH is a potential cause if there is at least one excursion of the applicable standards (greater than 6.5 and less than 9.0 S.U.). The guidelines indicate that for identifying potential causes of impairment in inland lakes, the most recent year of monitoring data is used; in this case, data were available from 2004. Available data for Lake Paradise are shown compared to the aquatic life criteria in Figure 11. A total of 25 pH measurements were made in the lake between May and October 2004. None of the pH measurements were less than 6.5 S.U.; however, two were greater than 9.0 S.U., and therefore the listing of this lake for pH is warranted. Both excursions of the pH criteria were recorded on the same day in July 2004, at different monitoring locations in the lake.

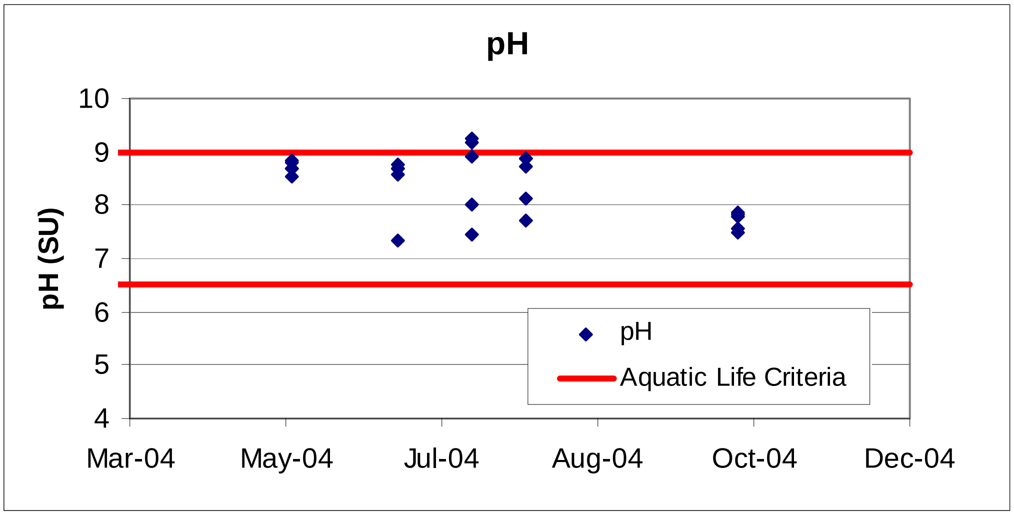

Figure 11. Comparison of pH Data in Lake Paradise to Aquatic Life Criteria

A potential cause of the two high pH values in July 2004 is algal production in the lake because photosynthetic uptake of carbonic acid during periods of algal blooms can raise pH. There are no chlorophyll data for the July 2004 period to confirm this cause, but it is supported by data from other periods of high pH. For example, on June 6 1995, a pH of 9 was measured and the corresponding chlorophyll-a concentration was very high (102.85 ug/l). The water temperature on June 6 was also very high (25^{o}C), a factor in that would have supported the occurrence of algal blooms in the lake. Potential phosphorus sources contributing to algal growth in the lake are discussed above.

Lake Mattoon (Segment RCF)

Listed for: Total Phosphorus

Lake Mattoon is a 765-acre lake used for recreation and as a public water supply. It is listed as impaired for the aesthetic quality use, with total phosphorus as a cause. There are five monitoring stations located within the lake, and four stations located on tributaries. Total phosphorus data were available at four of the five lake stations. These data were collected between 1992 and 2001. Station locations are shown in Figure 7. The depth of the lake varies significantly from station to station; the depth at station RCF-1 is approximately 31 feet, at station RCF-2, approximately 27 feet, at station RCF-3, approximately 5 feet, at station RCF-4, approximately 13 feet, and at station RCF-5, approximately 26 feet.

Total Phosphorus

IEPA considers phosphorus a potential cause of impairment of the aesthetic quality use in lakes greater than 20 acres in size if there is at least one exceedance of the applicable standard (0.05 mg/L) in surface samples during the monitoring year (IEPA, 2006).

A total of 30 total phosphorus measurements were collected at various depths in Lake Mattoon in 2001, the most recent monitoring year. Of these samples, 26 were collected within one foot of the surface; 25 of these (96%) exceeded the aesthetic quality criterion of 0.05 mg/L, indicating that the aesthetic quality use is not fully supported. Excursions ranged from 0.002 mg/L to 0.284 mg/L above the criterion. A comparison of the available phosphorus data to the aesthetic quality criterion is shown in Figure 12. Based on this review of the data, the listing of Lake Mattoon for total phosphorus is warranted, and the aesthetic quality use is not fully supported.

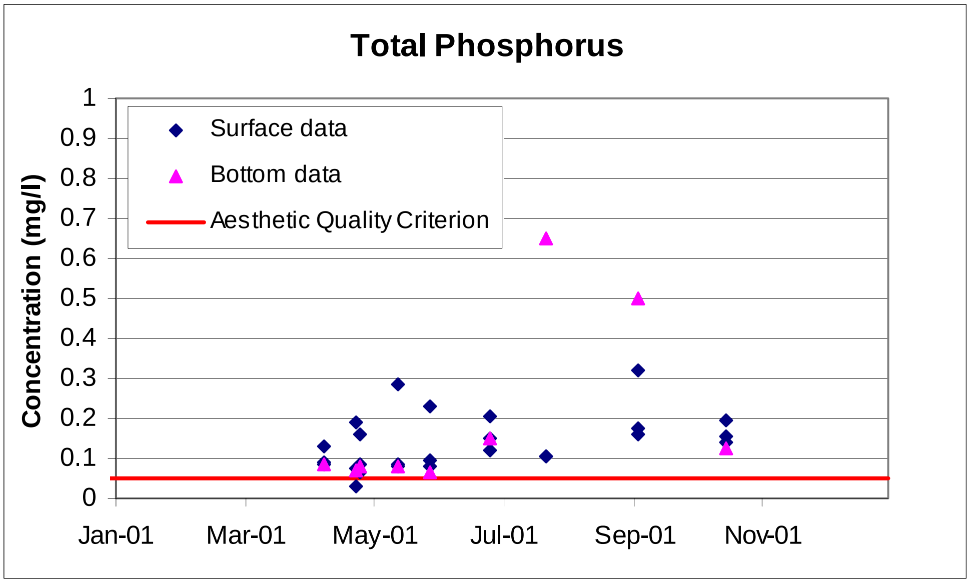

Figure 12. Lake Mattoon (RCF) Total Phosphorus Data Compared to the Aesthetic Quality Criterion

Available in-lake and tributary data were used to help identify potential phosphorus sources. Dissolved oxygen data were available at depth for three stations. Dissolved oxygen profiles were analyzed to determine whether this lake becomes anoxic at depth. Dissolved oxygen levels approached zero in the summer at stations RCF-1 and RCF-2 (Figure 13). The water column remained well-mixed at station RCF-3, which is the shallowest station. Based on a review of these profiles, and phosphorus concentrations measured at surface and bottom depths at station RCF-1, sediment phosphorus release under anoxic conditions is suspected to be a source of phosphorus to Lake Mattoon.

Total phosphorus concentrations appear consistently higher in the upper part of the lake (station RCF-3) than mid-lake or near the dam. In addition, the tributary data indicate higher total phosphorus concentrations in the tributaries than in the lake. Both of these observations suggest that the watershed is a significant source of phosphorus to the lake. Specific sources may include septic systems from shoreline development and cropland runoff (agriculture comprises 81% of the watershed).

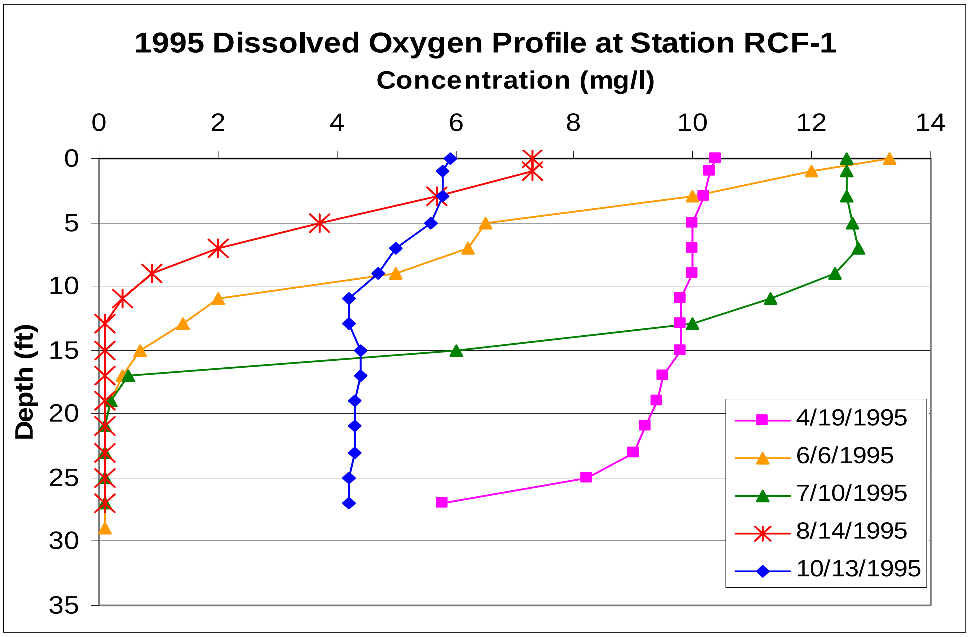

Figure 13. Lake Mattoon Dissolved Oxygen Profile at Station RCF-1

First Salt Creek (Segment CPC-TU-C1)

Listed for: Dissolved Oxygen and Manganese

First Salt Creek Segment CPC-TU-C1 is listed for dissolved oxygen and manganese impairments. The data analyzed for this investigation were collected between September 1999 and September 2001 at three stations within the 303(d)-listed segment. One monitoring station is upstream of the Teutopolis sewage treatment plant (STP) outfall, and two are downstream.

Dissolved Oxygen

The four dissolved oxygen measurements collected in this segment were compared to the aquatic life water quality criterion of 5.0 mg/L. All of the four values were less than the criterion, with the most recent excursion occurring in 2001. Dissolved oxygen concentrations less than the criterion were observed at all three monitoring stations, both upstream and downstream of the Teutopolis STP.

Illinois EPA identified municipal point sources (IEPA, 2006) as the source of low dissolved oxygen in this segment. While the data indicate that the Teutopolis STP is a possible source contributing to low dissolved oxygen levels, it is not the sole source, as the concentration upstream of the STP was also below the dissolved oxygen criteria. One location upstream in this segment's watershed was sampled as part of a livestock survey to better characterize runoff from animal operations. The data collected from this site and observations during the November 2005 site visit indicate that animal operations are also a potential source contributing to low dissolved oxygen in First Salt Creek.

Livestock location information compiled by the Upper Little Wabash Ecosystem Partnership also point to livestock as a potential source (Figure 6). Wildlife are another potential source. Low flows and high temperatures exacerbate low oxygen levels.

Manganese

Four measurements are available for manganese for First Salt Creek for the period between September 1999 and September 2001. One of the four observations exceeded the aquatic life criterion of 1,000 ug/L, supporting the listing of this segment for manganese. This manganese measurement was collected downstream of the Teutopolis STP and was twice the aquatic life criterion for manganese.

Illinois EPA identified municipal point sources (IEPA, 2006) as the source of manganese in this segment. However, the soils in this watershed are naturally enriched in manganese and natural background concentrations are a likely source of manganese in the creek.

Second Salt Creek (Segment CPD 04)

Listed for: Dissolved Oxygen

Second Salt Creek Segment CPD 04 is listed for low dissolved oxygen. The data analyzed for this investigation were collected between April and October 1991 at three stations located along the length of this segment.

Dissolved Oxygen

Six (6) dissolved oxygen measurements collected in this segment were compared to the aquatic life water quality criterion of 5.0 mg/L. Five of the six values were less than the criterion, with excursions observed at each of the three stations. Excursions ranged from 1.1 to 4.5 mg/L below the criterion. These data, while not collected recently, support the listing of this segment for dissolved oxygen.

Illinois EPA identified intensive animal feeding operations as a potential source of low dissolved oxygen. Based on a review of the available data, including a livestock survey conducted in 1991, and livestock locations compiled by the Upper Little Wabash Ecosystem Partnership, animal feeding operations do appear to a potential source of the low dissolved oxygen observed in 1991. A review of available instream data showed extremely high concentrations of BOD, ammonia and fecal coliform measured concurrently with the low dissolved oxygen. This watershed still contains a high number of cattle operations, so these remain a potential source contributing to low instream dissolved oxygen. Wildlife are another potential source. Low flow and high temperatures potentially exacerbate the low dissolved oxygen.

Second Salt Creek (Segment CPD 03)

Listed for: Dissolved Oxygen, Silver

Second Salt Creek Segment CPD 03 is listed for dissolved oxygen and silver. The data analyzed for this investigation were collected at a single location, between April and October 1991.

Dissolved Oxygen

Two dissolved oxygen measurements collected in this segment were compared to the aquatic life water quality criterion of 5.0 mg/L. One of the two values was less than the criterion, with the excursion occurring in October 1991. This measurement was 4.4 mg/l below the criterion. Because only one excursion of the criterion is required in the IEPA guidelines for identifying impairment, the data support the listing of this segment for dissolved oxygen.

Illinois EPA identified intensive animal feeding operations as a potential source of low dissolved oxygen (IEPA, 2006). Based on a review of the available data, including a livestock survey conducted in 1991, and a map of livestock locations recently developed by the Upper Little Wabash Ecosystem Partnership, animal feeding operations do appear to be a potential source of the low dissolved oxygen observed in 1991. A review of available instream data showed extremely high concentrations of BOD, ammonia and fecal coliform measured concurrently with the low dissolved oxygen. This watershed still contains a high number of cattle operations, so these remain a potential source contributing to low instream dissolved oxygen. Wildlife are another potential source. Low flow and high temperatures potentially exacerbate the low dissolved oxygen concentrations.

Silver

Three silver measurements are available for Second Salt Creek for the period between April and October 1991. One of these observations exceeds the aquatic life criterion of 5 ug/l. The criterion is exceeded by 2 ug/l. The other two silver measurements were less than the detection limit of 3 ug/l. Because the IEPA guidelines state that one exceedance of the silver criterion is sufficient to identify silver as a cause of impairment, the data are considered sufficient to support silver being listed on the 2006 303(d) list.

The source of silver to this segment is not known (IEPA, 2006). No obvious sources of silver were identified through the watershed characterization or data review. There are no mines or permitted point source dischargers in the watershed. Based on a conversation with the IDNR office of mines and minerals, it was noted that glacial erratics (pieces of rock carried by glacial ice) occasionally contain silver and therefore natural background sources may be a potential source. The presence of silver-containing erratics in this watershed was not confirmed.

Second Salt Creek (Segment CPD 01)

Listed for: Dissolved Oxygen

Second Salt Creek Segment CPD 01 is listed due to low dissolved oxygen. The data analyzed for this investigation were collected between April and October 1991, at two stations located in this segment.

Dissolved Oxygen

Four dissolved oxygen measurements collected in this segment were compared to the aquatic life water quality criterion of 5.0 mg/L. Two of the four values were less than the criterion, and ranged from 0.8 mg/L to 1.5 mg/L below the criterion. These both occurred in October. Because only one excursion of the criterion is required in the IEPA guidelines for identifying impairment, the data, though extremely limited and not collected recently, support the listing of this segment for dissolved oxygen.

Illinois EPA identified intensive animal feeding operations, grazing related sources, and pasture grazing (riparian and/or upland), as a potential source of low dissolved oxygen. Based on a review of the available data, including a livestock survey conducted in 1991, and a map of hog and cattle operations that was recently completed by the Upper Little Wabash Ecosystem Partnership, animal operations do appear to be a potential source of the low dissolved oxygen observed in 1991. A review of available instream data showed extremely high concentrations of BOD, ammonia, total phosphorus and fecal coliform measured concurrently with the low dissolved oxygen. This watershed still contains a high number of cattle operations, so these remain a potential source contributing to low instream dissolved oxygen. Wildlife are another potential source. Low flow and high temperatures potentially exacerbate the low dissolved oxygen.

Salt Creek (Segment CP-TU-C3)

Listed for: Manganese

Salt Creek Segment CP-TU-C3 is listed for manganese, based on data collected in September 1999 as part of a facility-related stream survey. The data were collected at a sampling station located just downstream of the confluence of First Salt Creek and Second Salt Creek.

Manganese

One manganese measurement is available for Salt Creek. This sample was collected in September 1999 and it exceeded the aquatic life criterion of 1,000 ug/l by 300 ug/l. Excursions of the manganese criterion were also noted on the same day in First Salt Creek.

Illinois EPA identifies the source of the manganese as municipal point sources (IEPA, 2006). Based on the watershed characterization for this segment, natural background soils are a more likely source, as the watershed soils are naturally enriched in manganese.

Salt Creek (Segment CP-EF-C2)

Listed for: Dissolved Oxygen

Salt Creek Segment CP-EF-C2 is listed due to low dissolved oxygen. This segment was sampled in 1999 as part of a facility-related stream survey. Within the 303(d) listed segment, one dissolved oxygen measurement was recorded (Station CP-EF-C2).

Dissolved Oxygen

One dissolved oxygen measurement collected in this segment was compared to the aquatic life water quality criterion of 5.0 mg/L. This measurement of 2.4 mg/l was less than the criterion and was recorded on a day when the water temperature was greater than 20^{o}C. Because only one excursion of the criterion is required in the IEPA guidelines for identifying impairment, the data, though extremely limited, support the listing of this segment for dissolved oxygen.

Illinois EPA identified municipal point sources and urban runoff/storm sewers as the source of low dissolved oxygen. Based on the watershed characterization and a review of the facility-related stream survey, it appears that the Effingham STP potentially contributes to the low dissolved oxygen in this stream. Urban runoff from the city of Effingham and wildlife are also potential sources. Low flows and high temperatures may exacerbate low dissolved oxygen concentrations.

Lake Sara (Segment RCE)

Listed for: Total Phosphorus, Manganese

Lake Sara is a 765-acre lake that is used for both recreation and as a public water supply. Water quality is measured at eight locations in Lake Sara through the volunteer monitoring program and the ambient lake monitoring program. The phosphorus, manganese and dissolved oxygen data used for this analysis were collected only through the ambient lake monitoring program at three stations in the lake. Phosphorus data were collected at three locations between May 1991 and August 2002. Manganese data are available at one location (station RCE-1) for the period April 2001 to October 2004. Station locations are shown in Figure 7. The depth of the lake at station RCE-1 is approximately 49 feet, at station RCE-2, approximately 35 feet and at station RCE-3, approximately 22 feet.

Total Phosphorus

IEPA considers phosphorus a potential cause of impairment of the aquatic life and aesthetic quality uses in lakes greater than 20 acres in size if there is at least one exceedance of the applicable standard (0.05 mg/L) in surface samples during the monitoring year (IEPA, 2006). A total of 116 total phosphorus measurements have been made at various depths over the indicated sampling period. Twelve surface samples were collected during the most recent monitoring year (2002). One of the 12 surface phosphorus samples, collected in April 2002, exceeded the criterion of 0.05 mg/L by 0.008 mg/l. Since IEPA guidelines require only a single surface sample to exceed the criterion, these data indicate the aquatic life and aesthetic quality uses are not fully supported. A comparison of the available data to the criterion is shown in Figure 14.

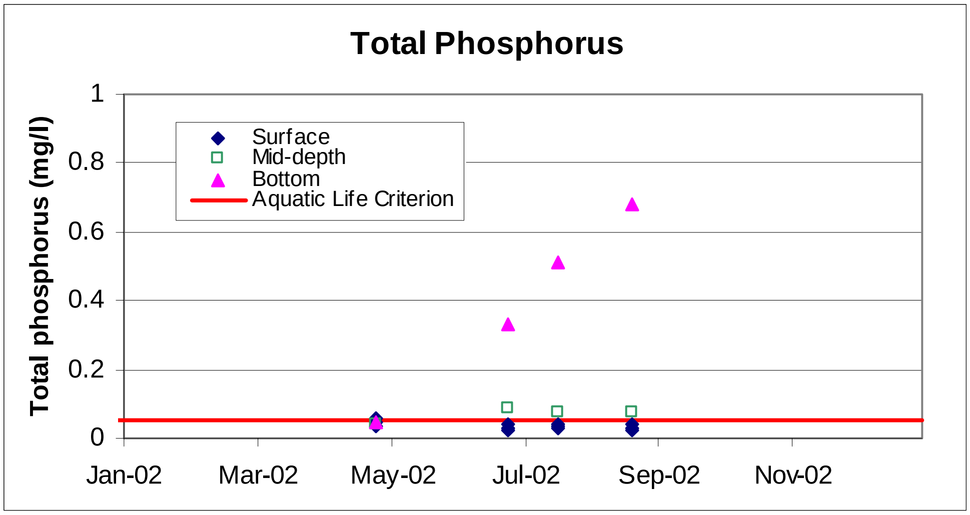

Figure 14. Lake Sara (RCE) Total Phosphorus Data Compared to the Water Quality Criterion

As seen in Figure 14, total phosphorus concentrations are higher at depth. This is consistent with the release of phosphorus from lake bottom sediments under anoxic conditions and consistent with dissolved oxygen data for the lake that show the lake going anoxic at depth during the summer months. Other sources of phosphorus to the lake were identified through the watershed characterization. These include septic systems from lakeside homes (the shoreline of this lake is very developed), golf courses, and agricultural runoff.

Manganese

Manganese was measured at approximately mid-depth at one location in the lake (RCE-1) between April 2001 and October 2004. These data are considered representative of water quality in the reservoir.

The IEPA guidelines (IEPA, 2006) for identifying manganese as a cause of impairment of the public and food processing water supply use in inland lakes state that manganese is a potential cause if, in untreated water, more than 10% of the observations exceed the applicable standard (150 ug/l), or if there is any violation of the applicable maximum contaminant level (also 150 ug/l), for water samples collected in 1999 or later. Thirteen of the fourteen (93%) manganese samples were above 150 ug/l, supporting the listing of this lake for manganese.

Dissolved oxygen levels below 13 feet deep in Lake Sara approach zero during summer months at all three stations (RCE-1, RCE-2 and RCE-2), and a review of sediment data found that all four sediment manganese measurements at station RCE-1 would be classified as being elevated (Mitzelfelt, 1996) for manganese. Therefore, one potential source of manganese is release from lake bottom sediments under anoxic conditions.

Additionally, the soils in this watershed are naturally enriched in manganese, and so natural background sources such as watershed runoff, lakeshore erosion and groundwater are other potential sources of manganese to this lake.

East Branch Green Creek (Segment CSB 08)

Listed for: Dissolved Oxygen and Manganese

East Branch Green Creek Segment CSB 08 is listed for dissolved oxygen and manganese.

Segment CSB 08 was monitored for manganese and dissolved oxygen at a single location in 1991. Two dissolved oxygen and three total manganese measurements were recorded between April and October 1991.

Dissolved Oxygen

The two dissolved oxygen measurements collected in this segment were compared to the aquatic life water quality criterion of 5.0 mg/L. One of the two values was less than the criterion. The dissolved oxygen concentration recorded in 1991 was 0.6 mg/l. This single excursion of the criteria warrants the inclusion of segment CSB 08 on the 303(d) list.

Illinois EPA identified agriculture, nonirrigated crop production, and intensive animal feeding operations (IEPA, 2006) as sources for this segment. Based on the results of the watershed characterization and a review of available data, these seem to be potential sources. Wildlife are another potential source. Low flows and high temperatures exacerbate low dissolved oxygen levels.

Manganese

Three water column measurements are available for manganese for this segment for the period between April 1991 and October 1991. One of these three observations exceeded the aquatic life criterion of 1,000 ug/L. This measurement exceeded the criterion by 687 ug/l. The available water column data support the listing of segment CSB 08 for manganese.

The highest manganese concentration in the water column was observed on the same day as the lowest dissolved oxygen concentration. Although the single measurement of manganese in the sediment (694 mg/kg) would be classified as non-elevated based on IEPA classifications (Mitzelfelt, 1996), the release of manganese from stream bottom sediments under anoxic conditions is nevertheless a potential source of manganese. Soils naturally enriched in manganese are also a potential source of manganese.

East Branch Green Creek (Segment CSB 07)

Listed for: Dissolved Oxygen

East Branch Green Creek Segment CSB 07 is listed for dissolved oxygen. Segment CSB 07 was monitored for dissolved oxygen at a single location in 1991. Two dissolved oxygen measurements were recorded between April and October 1991.

Dissolved Oxygen

The two dissolved oxygen measurements collected in this segment were compared to the aquatic life water quality criterion of 5.0 mg/L. One of the two values was less than the criterion, with a value of 3.1 mg/l. The listing of this segment for low dissolved oxygen is therefore warranted based on this excursion.

The low dissolved oxygen measurement of 3.1 mg/l was recorded in this segment on the same day as a value of 0.6 mg/l DO was recorded in the upstream creek segment (CSB 08). The dissolved oxygen measured in the downstream segment is higher than the upstream segment, indicating that dissolved oxygen concentrations are increasing as the creek flows downstream. Segment (CSB 07) was monitored just 20 minutes prior to the upstream segment (CSB 08).

Illinois EPA identified intensive animal feeding operations (IEPA, 2006) as sources for this segment. Based on the results of the watershed characterization and a review of available data, these appear to be potential sources. Highly elevated levels of fecal coliform, BOD, and total phosphorus were also measured on the same day as the low dissolved oxygen measurement. Low dissolved oxygen levels in the upstream segment (CSB 08) also appear likely to influence concentrations in this segment. This monitoring station is located upstream of all permitted point source dischargers to this segment, so these are not suspected sources. Wildlife, however, are a potential source. Low flows and high temperatures may exacerbate low dissolved oxygen concentrations.

Dieterich Creek (Segment COC 10)

Listed for: Copper, Manganese, Silver

Dieterich Creek Segment COC 10 is listed for copper, manganese, and silver. Segment COC 10 was monitored at a single location in 1991, downstream of the town of Dieterich. Three measurements each of total copper, total manganese, and total silver were recorded between April and October 1991.

Copper

Three measurements are available for copper for this segment for the period between April and October 1991. These were all total copper measurements. Because the criteria are written for dissolved copper, the total copper data were converted to dissolved using the conversion factor of 0.960. This is the same conversion factor used in the water quality standards (Title 35 Subpart B Section 302.208).

Only one of the three copper observations was higher than the 5 ug/l detection level. This total copper observation was analyzed to determine whether the listing of this stream was warranted. The analysis consisted of converting the total copper measurement to dissolved copper and comparing this to both the chronic and acute criteria for dissolved copper. The concentration exceeded both the chronic and acute aquatic life copper criteria by 16 ug/l and 10 ug/l, respectively. IEPA guidelines for listing copper are “at least one violation of the applicable acute or chronic standards for any metal.” Therefore, the data, while limited, support the listing of this stream for copper.

Illinois EPA identified “source unknown”(IEPA, 2006) as the source of copper for this segment. No obvious sources of copper were identified through the watershed characterization process and review of available data. Based on the age of the data, the limited dataset, and the fact that total copper, instead of dissolved copper was measured, it is recommended that IEPA consider resampling this stream to determine if the listing is still warranted.

Manganese

Three measurements are available for manganese for this segment for the period between April and October 1991. One of the three observations exceeded the aquatic life criterion of 1,000 ug/L, supporting the listing of this segment for manganese. This measurement exceeded the aquatic life criterion by 1,844 ug/l. Total manganese and total suspended solids concentrations are positively correlated, suggesting that manganese may be entering the stream attached to sediment.

Illinois EPA identified “source unknown” (IEPA, 2006) as the source of manganese for this segment. Based on the results of the watershed characterization and a review of available data, the source of the manganese is likely natural background levels in the soils.

Silver

Three measurements are available for silver for this segment for the period between April and October 1991. One of the three measurements exceeded the aquatic life criterion of 5 ug/L. The other two measurements were less than the detection level of 3 ug/l. The data, while limited, support the listing of this stream for silver.

Illinois EPA identified “source unknown”(IEPA, 2006) as the source of silver for this segment. No obvious sources of silver were identified through the watershed characterization process and review of available data. Based on a conversation with the IDNR office of mines and minerals, it was noted that glacial erratics occasionally contain silver and therefore natural background sources may be a potential source. The presence of silver-containing erratics in this watershed was not confirmed. Based on the age of the data and the limited dataset, it is recommended that IEPA consider re-sampling this stream to determine if the listing is still warranted.

Clay City Side Channel Reservoir (Segment RCU)

Listed for: Manganese

The Clay City Side Channel Reservoir (Clay City SCR) is a 6-acre reservoir formerly used for supplying drinking water, along with the Little Wabash River, to Clay City. Water quality in the reservoir was monitored in 2001 at one station, with results exceeding the water supply criterion. However, the water withdrawal has been eliminated (Village of Clay City, 2006). This water body can no longer be considered impaired for the public and food processing water supply use, and no TMDL is needed.

CONCLUSIONS

Based on Stage I work, the project team has concluded that TMDLs are warranted for nine of the ten impaired waterbodies in this targeted watershed. Specifically:

- For **Little Wabash River (Segment C 19)**, data are sufficient to support the listings for manganese, pH, dissolved oxygen, fecal coliform, and atrazine on the 2006 303(d) list, and TMDLs are warranted. The low dissolved oxygen may be related to high water temperatures and low flows, animal operations, failing septic systems, cropland runoff, wildlife, and permitted dischargers. Potential sources of manganese are natural background sources, release from river bottom sediments, and oil well operations. A potential source of low pH is the naturally acidic soils in the watershed. Potential sources of fecal coliform include livestock, private sewage systems, wildlife, and permitted point sources. Atrazine is used as an herbicide in the watershed.
- For **Little Wabash River (Segment C 21)**, data are sufficient to support the listings for manganese and fecal coliform on the 2006 303(d) list, and TMDLs are warranted. A potential source of manganese is natural background soils. Potential sources of fecal coliform include livestock, private sewage systems, wildlife, and permitted point sources.
- For **Lake Paradise (Coles) (Segment RCG),** data are sufficient to support the listings for phosphorus and pH on the 2006 303(d) list, and TMDLs are warranted. Runoff from cropland and pastureland is a potential source of phosphorus to the lake. Other sources include release from bottom sediments, failing septic systems, and shoreline erosion. A potential cause of the high pH observed in July 2004 is algal production due to the phosphorus enrichment.
- For **Lake Mattoon (Segment RCF)**, data are sufficient to support the listing for phosphorus, and a TMDL is warranted. Potential phosphorus sources include cropland runoff, release from sediments under anoxic conditions, and failing septic systems.
- For **First Salt Creek (Segment CP-TU-C1)**, data are sufficient to support the listings for manganese and dissolved oxygen on the 2006 303(d) list, and TMDLs are warranted. Naturally high levels of manganese in soils in the watershed are potential sources of manganese. Municipal point sources, livestock operations, and wildlife are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Second Salt Creek (Segment CPD 04),** data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Intensive livestock operations and wildlife are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Second Salt Creek (Segment CPD 03),** data are sufficient to support the listings for dissolved oxygen and silver on the 2006 303(d) list, and TMDLs are warranted. Intensive livestock operations and wildlife are potential sources contributing to low

dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow. Sources of silver are unknown.

- For **Second Salt Creek (Segment CPD 01)**, data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Intensive livestock operations and wildlife are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Salt Creek (Segment CP-TU-C3),** data are sufficient to support the listing for manganese on the 2006 303(d) list, and a TMDL is warranted. Potential sources of manganese are watershed soils naturally enriched in manganese.
- For **Salt Creek (Segment CP-EF-C2)**, data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Municipal point sources and urban runoff/storm sewers likely contribute to low dissolved oxygen in the creek. Wildlife are another potential source. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Lake Sara (Segment RCE)**, data are sufficient to support the listings for phosphorus and manganese on the 2006 303(d) list, and TMDLs are warranted. Potential sources of phosphorus include runoff from golf courses and agricultural lands, failing private sewage disposal systems, and release from sediments under hypolimnetic anoxic conditions. The observed manganese concentrations in the lake likely reflect natural background conditions (soils in the watershed are naturally high in manganese) and release from lake bottom sediments under anoxic conditions.
- For **East Branch Green Creek (Segment CSB 08),** data are sufficient to support the listings for manganese and dissolved oxygen on the 2006 303(d) list, and TMDLs are warranted. Naturally high levels of manganese in soils in the watershed and release from stream bottom sediments under anoxic conditions are potential sources of manganese. Wildlife and runoff from agricultural land, including livestock areas, are potential sources contributing to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **East Branch Green Creek (Segment CSB 07)**, data are sufficient to support the listing for dissolved oxygen on the 2006 303(d) list, and a TMDL is warranted. Intensive animal feeding operations, wildlife and low dissolved oxygen upstream of this segment likely contribute to low dissolved oxygen in this segment. Low dissolved oxygen may also be exacerbated by high temperatures and low flow.
- For **Dieterich Creek (Segment COC 10),** data are sufficient to support the listings for manganese, copper, and silver on the 2006 303(d) list. Naturally high levels of manganese in soils in the watershed are potential sources of manganese. No obvious sources of copper and silver were identified through the watershed characterization process and review of available data. Based on the age of the data and the limited dataset, it is recommended that IEPA consider re-sampling this stream for silver and copper to determine if the listings are still warranted.

- For **Clay City Side Channel Reservoir (Segment RCU)**, data were sufficient to support the listing for manganese on the 2006 303(d) list, and a TMDL would be warranted if the reservoir were still used for water supply. However, the water withdrawal has been eliminated, which has eliminated the need for a TMDL. No TMDL is being prepared.

NEXT STEPS

In the upcoming quarter, methods, procedures and models that will be used to develop TMDLs for the project watershed will be identified and described. This description will include documentation of any important assumptions underlying the recommended approach (methods, procedures and models) and a discussion of data needed to support the development of a credible TMDL.

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APPENDIX A. DATA SOURCES AND LOCAL CONTACTS

Table A-1. Data sources

Data description	Agency	Website
Climate summaries	Illinois State Water Survey	http://www.sws.uiuc.edu/atmos/statecli/index.htm
NPDES permit limits	United States Environmental Protection Agency	http://www.epa.gov/enviro/html/pcs/pcs_query.html
Aerial photography	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/webdocs/doqs/graphic.html
Cattle and hog operations	Upper Little Wabash Ecosystem Partnership	http://www.informpro.com/littlewabash/
Coal mines: active and abandoned - polygons part 1	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Coal mines: active and abandoned - polygons part 2	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Coal mines: active and abandoned – points	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Coal mine permit boundaries	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
County boundaries	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Cropland	United States Department of Agriculture, National Agricultural Statistics Service, via Illinois Department of Agriculture	http://www.agr.state.il.us/gis/pass/nassdata/
Dams	National Inventory of Dams (NID)	http://crunch.tec.army.mil/nid/webpages/nid.cfm
Elevation	United States Geological Survey	http://seamless.usgs.gov/viewer.htm
Federally-owned lands	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Hydrologic cataloging units	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Hydrography	United States Geological Survey	http://nhd.usgs.gov/
Impaired lakes	Illinois Environmental Protection Agency	http://maps.epa.state.il.us/website/wqinfo/
Impaired streams	Illinois Environmental Protection Agency	http://maps.epa.state.il.us/website/wqinfo/
Land cover	Illinois Department of Agriculture	http://www.agr.state.il.us/gis/
Landfills	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Municipal boundaries	U.S. Census Bureau	
Municipal boundaries	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
National Pollutant Discharge Elimination System (NPDES) permitted sites	United States Environmental Protection Agency	
Nature preserves	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Oil wells	United States Geological Survey	http://energy.cr.usgs.gov/oilgas/noga/
Railroads	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Roads	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/

Data description	Agency	Website
Roads – state highways	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Roads – U.S. highways	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Roads- detailed road network	U.S. Census Bureau	http://www.census.gov/geo/www/tiger/tigerua/ua_tgr2k.html
Survey-level soils	United States Department of Agriculture Natural Resources Conservation Service	http://www.il.nrcs.usda.gov/technical/soils/ssurgo.html
State-level soils	United States Department of Agriculture Natural Resources Conservation Service	http://www.il.nrcs.usda.gov/technical/soils/statsgo_inf.html - statsgo8
State boundary	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State conservation areas	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State forests	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State fish and wildlife areas	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State parks	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Topographic map quadrangle index	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Topographic map quadrangles	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
USGS stream gages	Illinois State Water Survey	
Watersheds	Illinois Environmental Protection Agency	http://maps.epa.state.il.us/website/wqinfo/
Water supply – Public water supply intakes	Illinois State Water Survey	
Water Quality Data	Illinois Environmental Protection Agency	
Water Quality Data	USEPA Legacy and Modern STORET databases	http://www.epa.gov/storet/
Water Quality and Hydraulic	United States Geological Survey (USGS)	http://water.usgs.gov/

Table A-2. Local and State Contacts

Contact	Agency/ Organization	Contact Means	Contact #	Subject
Tony Antonacci	Marion Co. NRCS	Telephone	618-548-2230 x3	BMPs, farming practices and pesticides
Laurie King	Clay Co. NRCS	Telephone	618-665-3327 x3	Acidic soils
Melissa Mallow	Marion Co. Health Dept.	Telephone	618-548-3878	Discussed septic systems and pathogens
Burke Davies	Marion County SWCD	Telephone	618-548-2230 x3	Farming and fertilization practices, BMPs. Potential sources of iron and manganese
Sue Ebetsch	Illinois State Data Center	Telephone	217-782-1381	Provided Illinois Population Trends report
Ted LaBelle	CMT, Inc.	Telephone	217-787-8050	Provided Lake Paradise Phase I Diagnostic/Feasibility Study report
Bill Bogner		Telephone	217-333-9546	Discussed Lake Paradise and Lake Mattoon Reports
Jeff Steiner	IDNR	Telephone	217-782-6791	Copper and silver mining
Mike Falter	IDNR	Telephone	217-782-6791	Copper and silver mining
Joe Pelc	IDNR	Telephone	217-782-0357	Abandoned mines
Doug	IDNR	Telephone	217-782-7756	Oil and gas wells
Roger Jansen	Effingham SWCD	Telephone	217-347-7107 ext.3	Watershed characterization
Fred Walker	Upper Little Wabash Ecosystem Partnership	Telephone	618-548-4234	Asked about the Partnership
Hall Healy	Facilitated Solutions International	Telephone	(847) 373-7770	Strategic plan for the Upper Little Wabash Ecosystem Partnership
	Clay City	Telephone	618-676-1441	Switching water supply to groundwater
Bill Bruce	Clay County Health Department	Telephone	618-665-3327 ext. 3	Fecal coliform sources
Laura Biewick	U.S. Geological Survey	Telephone	303-236-7773	GIS data for oil & gas wells
Kathy Brown	Illinois State Water Survey	Telephone	217-333-6778	USGS gage locations; water supply intakes
Don Pitts	United States Department of Agriculture Natural Resources Conservation Service	Telephone	217-353-6642	Potential sources of iron and manganese in south-central Illinois surface waters.
Tony Meneghetti	IEPA	Telephone and e-mail	217-782-3362 Anthony.Meneghetti@epa.state.il.us	Lake data and SWAPs
Bruce Yurdin	IEPA	Telephone	217-782-3362	Data for Lake Sara, Lake

Contact	Agency/ Organization	Contact Means	Contact #	Subject
		and e-mail		Paradise and Clay City SCR
Jim Hefley	IEPA	Telephone	217/786-6892	Facility related stream surveys and monitoring station locations
Sandy Nickel	IEPA	Telephone	(217) 785-6938	L. Paradise and L. Sara sampling stations; Clay City SCR manganese data
Dave Muir	IEPA Marion Regional office	Personal visit	618-993-7200	Assessment data used in 303(d) and 305(b) reports; Intensive Survey of L. Wabash R. report, station locations
Jeff Mitzelfelt	IEPA	e-mail	jeff.mitzelfelt@epa.state.il.us	Websites for GIS information

APPENDIX B. PHOTOGRAPHS

Lake Paradise (Segment RCG)

Lake Paradise (Segment RCG)

Lake Mattoon (Segment RCF)

Lake Mattoon Beach (Segment RCF)

Lake Sara (Segment RCE). Severe bank erosion (IEPA photo)

Lake Sara near boat launch. Eurasian watermilfoil (*Myriophyllum spicatum* L.)

Little Wabash River

Little Wabash River

Little Wabash River

Little Wabash River Bridge

Salt Creek

Salt Creek

Dieterich Creek.

Second Salt Creek

Second Salt Creek

Typical Land Use, Soybean Field, Little Wabash River Watershed

Animal Feeding Operation, Little Wabash River Watershed

Second Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

May 2006

Little Wabash Watershed

Little Wabash River (C19, C21),
Paradise Lake (RCG), Lake Mattoon (RCF),
First Salt Creek (CPC-TU-C1),
Second Salt Creek (CPD 01, CPD 03, CPD 04),
Salt Creek (CP-EF-C2, CP-TU-C3), Lake Sara (RCE),
East Branch Green Creek (CSB 07, CSB 08) and
Dieterich Creek (COC 10)

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Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

This is the second in a series of quarterly status reports documenting work completed on the Little Wabash project watershed. The objective of this report is to provide a summary of Stage 1 work that will ultimately be used to support Total Maximum Daily Load (TMDL) development in the project watershed.

Background

Section 303(d) of the 1972 Clean Water Act requires States to define impaired waters and identify them on a list, which is referred to as the 303(d) list. The State of Illinois recently issued the 2006 303(d) list (IEPA, 2006), which is available on the web at: http://www.epa.state.il.us/water/tmdl/303d-list.html. The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be completed for each pollutant listed for an impaired water body. TMDLs are prepared by the States and submitted to the U.S. EPA. In developing the TMDL, a determination is made of the greatest amount of a given pollutant that a water body can receive without exceeding water quality standards and designated uses, considering all known and potential sources. The TMDL also takes into account a margin of safety, which reflects scientific uncertainty, as well as the effects of seasonal variation.

As part of the TMDL process, the Illinois Environmental Protection Agency (IEPA) and several consultant teams have compiled and reviewed data and information to determine the sufficiency of available data to support TMDL development. As part of this review, the data were used to confirm the impairments identified on the 303(d) list and to further identify potential sources causing these impairments. The results of this review were presented in the first quarterly status report.

The intent of this second quarterly status report is to:

- Identify and briefly describe the methodologies/procedures/models to be used in the development of TMDLs,
- Document important assumptions underlying the recommended methodologies, and
- Identify the data needs for the methodologies to be used in TMDL development, including an assessment of whether additional data are needed to develop credible TMDLs.

In future phases of this project, Illinois EPA and consultants will develop the TMDLs and will work with stakeholders to implement the necessary controls to improve water quality in the impaired water bodies and meet water quality standards. It should be noted that the controls for nonpoint sources (e.g., agriculture) would be strictly voluntary.

Methods

The effort completed in the second quarter included: 1) summarizing potentially applicable model frameworks for TMDL development, 2) Recommending specific model frameworks for application to the fourteen listed waterbodies in the Little Wabash River watershed, and 3) Making a determination whether sufficient data exist to allow development of a credible TMDL. Selection of specific model frameworks was based upon consideration of three separate factors, consistent with the guidance of DePinto et al (2004):

- **Site-specific characteristics:** The characteristics define the nature of the watershed and water bodies. For the **Little Wabash (C 19)** watershed, the relevant site-specific characteristics include a watershed with predominantly agricultural and forest lands, containing numerous oil wells, animal feeding operations and areas with septic and sewage problems, soils naturally enriched in manganese, twenty-three permitted dischargers (sixteen of which are sewage treatment plants), and a river impaired by manganese, pH, low dissolved oxygen, fecal coliform and atrazine. For the **Little Wabash (C 21)** watershed, the relevant site-specific characteristics include a watershed with predominantly agricultural and forest lands, eleven permitted dischargers (six of which are sewage treatment plants), soils containing manganese, and a creek impaired by manganese and fecal coliform. For the **Lake Paradise (RCG)** watershed, the relevant site-specific characteristics include a watershed with predominantly agricultural land use, a single permitted discharger, improperly functioning septic systems, a reservoir with shoreline erosion and anoxic conditions at depth that is impaired by phosphorus and pH. For the **Lake Mattoon (RCF)** watershed, the relevant site-specific characteristics include a watershed with predominantly agricultural land use, two permitted water treatment plant discharges and a reservoir with anoxic conditions at depth, which is impaired by total phosphorus. For the **First Salt Creek (CPC-TU-C1)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use containing the community of Teutopolis and animal feeding operations, one sewage treatment plant, soils containing manganese, and a creek impaired by manganese and low dissolved oxygen. For the **Second Salt Creek (CPD 04)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use and grasslands containing animal operations, no point source dischargers and a creek impaired due to low dissolved oxygen. For the **Second Salt Creek (CPD 03)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use and grasslands containing animal feeding operations, no point source dischargers and a creek impaired due to low dissolved oxygen and silver. For the **Second Salt Creek (CPD 01)** watershed, the site-specific characteristics include a watershed with predominantly agricultural, grasslands and forest lands containing animal feeding operations, no point source dischargers, and a creek impaired due to low dissolved oxygen. For the **Salt Creek (CP-TU-C3)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use and grasslands, soils containing manganese, a single sewage treatment plant discharge, and a creek impaired due to manganese. For the **Salt Creek (CP-EF-C2)** watershed, the site-specific characteristics include a watershed with predominantly agricultural, urban and forest lands, three permitted sewage treatment plants, one of which has combined sewer overflows, and a creek impaired due to low dissolved oxygen. For the **Lake Sara (RCE)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use, forest and grasslands containing golf courses, no municipalities or permitted dischargers, and improperly functioning septic systems and a reservoir that has shoreline erosion and anoxic conditions at depth, which is impaired due to manganese and total phosphorus. For the **East Branch Green Creek (CSB 08)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use and forest, soils containing manganese, no municipalities or permitted dischargers and a creek impaired due to low dissolved oxygen and manganese. For the **East Branch Green Creek (CSB 07)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use, forest and grasslands containing animal operations, the community of Sigel, two sewage treatment plants and a creek impaired due to low dissolved oxygen. For the **Dieterich Creek (COC 10)** watershed, the site-specific characteristics include a watershed with predominantly agricultural land use and forests, soils containing manganese, the community of Dieterich, no permitted dischargers and a creek impaired due to manganese, silver and copper.

- **Management objectives:** These objectives consist of the specific questions to be addressed by the model. For this application, the management objective is to develop a credible TMDL.
- **Available resources:** This corresponds to the amount of time and data available to support TMDL development. Water quality data currently exist for all fourteen listed water bodies in the Little Wabash watershed. One aspect of this work is to define whether or not the existing data are sufficient to allow development of a credible TMDL.

Results

Several modeling frameworks potentially applicable for developing TMDLs were identified, spanning a range of detail from simple to complex. Selection of a specific modeling framework is complicated by the fact that the definition of a “credible” TMDL depends upon the level of detail to be contained in the implementation plan. If the goal of the TMDL implementation plan is to define the primary sources of impairment and quickly identify the general level of reduction required, relatively simple models can be used to develop a credible TMDL. If the goal of the TMDL implementation plan is to explicitly define the specific levels of controls required, more detailed models (and additional data) are required to develop a credible TMDL. Specific recommendations are provided which correspond to the level of detail provided in other Illinois TMDL implementation plans conducted to date.

Because of the wide range of impairment types and water bodies in the Little Wabash watershed, a range of modeling approaches is required. They are summarized here by individual water body segment and grouped together as appropriate.

The recommended modeling approach for the Little Wabash River Segment C 19 consists of using the water quality model QUAL2E to address dissolved oxygen problems. Watershed loads for this segment will be defined using an empirical approach. Manganese and pH impairments will be addressed via empirical load capacity calculations. For this same segment, development of a load-duration curve is recommended to address atrazine and fecal coliform impairments. This will allow for determination of the degree of impairment under different flow conditions. Results from the load-duration curve can also be used to identify the approximate level of source control needed under each set of flow conditions.

The recommended modeling approach for First Salt Creek segment CPC-TU-C1, Salt Creek segment CP-EF-C2 and East Branch Green Creek segments CSB 07 and CSB 08 consists of using the water quality model QUAL2E to address dissolved oxygen problems. Watershed loads for these segments will be defined using an empirical approach. Manganese impairments in Segment CPC-TU-C1 and CSB 08 will be addressed via empirical load capacity calculations calculations.

The recommended modeling approach for Salt Creek (CP-TU-C3) and the Little Wabash River (C 21) consists of addressing manganese impairments via empirical load capacity calculations. For segment C 21, development of a load-duration curve is recommended to address fecal coliform impairments.

The recommended modeling approach for Dieterich Creek segment COC 10 consists of addressing manganese, silver and copper impairments via empirical load capacity calculations.

The recommended approach for modeling dissolved oxygen in Second Salt Creek segments CPD 04, CPD 03, and CPD 01 consists of using spreadsheet calculations. This approach is recommended because there are no permitted point source dischargers in the Second Salt Creek watershed. Watershed loads will be defined using an empirical approach. Silver impairments will be addressed via a load capacity calculation.

The recommended modeling approach for Lake Paradise, Lake Mattoon and Lake Sara would focus on determining the pollutant loading capacity of the lakes, using BATHTUB. BATHTUB would be developed and applied to predict the relationship between the phosphorus load and resulting in-lake phosphorus, dissolved oxygen concentrations and pH (Lake Paradise only), as well as the resulting potential for manganese release from sediments in Lake Sara. Watershed modeling is not recommended. Instead, determination of existing loading sources and prioritization of restoration alternatives could be conducted by local experts as part of the implementation process.

Alternative model frameworks are also provided in the event a different level of detail is desired for the implementation plans. Some alternative approaches require no additional data collection; however, others have significantly greater data requirements, and their use would require additional data collection.

INTRODUCTION/PURPOSE

This Stage 1 report describes intermediate activities related to the development of TMDLs for the fourteen 303(d)-listed water bodies in the Little Wabash watershed. Earlier Stage 1 efforts included watershed characterization activities and data analyses, to confirm the causes and sources of impairments in the watershed.

The remaining sections of this report include:

- **Identification of potentially applicable methodologies to be used in TMDL development:** This section describes the range of potentially applicable watershed loading and water quality methodologies that could be used to conduct the TMDL, and identifies their strengths and weaknesses.
- **Model selection process:** This section describes how management objectives, available resources and site-specific conditions in the Little Wabash watershed affect the recommendation of specific methodologies.
- **Selection of specific methodologies and future data requirements:** This section provides specific recommendation of methodologies for the fourteen listed waterbodies in the Little Wabash watershed, along with the data needed to support application of the methodologies.

IDENTIFICATION OF POTENTIALLY APPLICABLE MODELS AND PROCEDURES TO BE USED IN TMDL DEVELOPMENT

Development of TMDLs requires: 1) a method to estimate the amount of pollutant load being delivered to the water body of interest from all contributing sources, and 2) a method to convert these pollutant loads into an in-stream (or in-lake) concentration for comparison to water quality targets. Both of these steps can be accomplished using a wide range of methodologies, ranging from simple calculations to complex computer models. This section describes the methodologies that are potentially applicable for the fourteen waterbodies in the Little Wabash watershed, and is divided into separate discussions of watershed methodologies and receiving water quality model frameworks.

Watershed Methodologies and Modeling Frameworks

Numerous methodologies exist to characterize watershed loads for TMDL development. These include:

- Empirical Approaches
- Unit Area Loads/Export Coefficients
- Universal Soil Loss Equation
- Watershed Characterization System (WCS) Sediment Tool
- Generalized Watershed Loading Functions (GWLF) Model
- Agricultural Nonpoint Source Pollution Model (AGNPS)
- Hydrologic Simulation Program - Fortran (HSPF)
- Better Assessment Science Integrating point and Nonpoint Sources (BASINS)/ Nonpoint Source Model (NPSM)
- Storm Water Management Model (SWMM)
- Soil & Water Assessment Tool (SWAT)

This section describes each of the model frameworks and their suitability for characterizing watershed loads for TMDL development. Table 1 summarizes some important characteristics of each of the models relative to TMDL application.

Table 1 Summary of Potentially Applicable Models for Estimating Watershed Loads

Model	Data Needs	Output Timescale	Potential Accuracy	Calibration	Applicability for TMDL
Empirical Approach	High	Any	High	N/A	Good for defining existing total load; less applicable for defining individual contributions or future loads
Unit Area Loads	Low	Annual average	Low	None	Acceptable when limited resources prevent development of more detailed model
USLE	Low	Annual average	Low	Requires data describing annual average load	Acceptable when limited resources prevent development of more detailed model
WCS Sediment Tool	Low	Annual average	Low	Requires data describing annual average load	Acceptable when limited resources prevent development of more detailed model
GWLF	Moderate	Monthly average	Moderate	Requires data describing flow and concentration	Good for mixed use watersheds; compromise between simple and more complex models
SWMM	Moderate	Continuous	Moderate	Requires data describing flow and concentration	Primarily suited for urban watersheds
AGNPS	High	Continuous	High	Requires data describing flow and concentration	Primarily suited for rural watersheds; highly applicable if sufficient resources are available
HSPF	High	Continuous	High	Requires data describing flow and concentration	Good for mixed use watersheds; highly applicable if sufficient resources are available
SWAT	High	Continuous	High	Requires data describing flow and concentration	Primarily suited for rural watersheds; highly applicable if sufficient resources are available

Empirical Approaches

Empirical approaches estimate pollutant loading rates based upon site-specific measurements, without the use of a model describing specific cause-effect relationships. Time series information is required on both stream flow and pollutant concentration.

The advantage to empirical approaches is that direct measurement of pollutant loading will generally be far more accurate than any model-based estimate. The approach, however, has several disadvantages. The empirical approach provides information specific to the storms that are monitored, but does not provide direct information on conditions for events that were not monitored. Statistical methods (e.g., Preston et al., 1989) can be used to integrate discrete measurements of suspended solids concentrations with continuous flow records to provide estimates of solids loads over a range of conditions.

The primary limitation of empirical techniques is their inability to separate individual contributions from multiple sources. This problem can be addressed by collecting samples from tributaries serving single land uses, but most tributary monitoring stations reflect multiple land uses. The EUTROMOD and BATHTUB water quality models described below contain routines that apply the empirical approach to estimating watershed loads.

Unit Area Loads/Export Coefficients

Unit area loads (also called export coefficients) are routinely used to develop estimates of pollutant loads in a watershed. An export coefficient is a value expressing pollutant generation per unit area and unit time for a specific land use (Novotny and Olem, 1994).

The use of unit areal loading or export coefficients has been used extensively in estimating loading contributions from different land uses (Beaulac 1980, Reckhow et al. 1980, Reckhow and Simpson 1980, Uttormark et al. 1974). The concept is straightforward; different land use areas contribute different loads to receiving waters. By summing the amount of pollutant exported per unit area of land use in the watershed, the total pollutant load to the receiving system can be calculated.

These export coefficients are usually based on average annual loads. The approach permits estimates of current or existing loading, as well as reductions in pollutant export for each land use required to achieve a target TMDL pollutant load. The accuracy of the estimates is dependent on good land use data, and appropriate pollutant export coefficients for the region. EUTROMOD is a spreadsheet-based modeling procedure for estimating phosphorus loading and associated lake trophic state variables, which can estimates phosphorus loads derived from watershed land uses or inflow data using approaches developed by Reckhow et al. (1980) and Reckhow and Simpson (1980). The FLUX module of the BATHTUB software program estimates nutrient loads or fluxes to a lake/reservoir and provides five different algorithms for estimating these nutrient loads based on the correlation of concentration and flow. In addition, the potential errors in loading estimates are quantified.

Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE), and variations of the USLE, are the most widely used methods for predicting soil loss. When applied properly, the USLE can be used as a means to estimate loads of sediment and sediment-associated pollutants for TMDLs. The USLE is empirical, meaning that it was developed from statistical regression analyses of a large database of runoff and soil loss data from numerous watersheds. It does not describe specific erosion processes. The USLE was designed to predict long-term average annual soil erosion for combinations of crop systems and management practices with specified soil types, rainfall patterns, and topography.

Required model inputs to the USLE consist of:

- Rainfall erosivity index factor
- Soil-erodibility factor
- Slope length factor reflecting local topography
- Cropping-management factor
- Conservation practice factor

Most of the required inputs for application of the USLE are tabulated by county Natural Resources Conservation Service (NRCS) offices.

There are also variants to the USLE: the Revised USLE (RUSLE) and the Modified USLE (MUSLE). The RUSLE is a computerized update of the USLE incorporating new data and making some improvements. The basic USLE equation is retained, but the technology for evaluating the factor values has been altered and new data introduced to evaluate the terms for specific conditions. The MUSLE is a modification of USLE, with the rainfall energy factor of the USLE replaced with a runoff energy factor. MUSLE allows for estimation of soil erosion on an event-specific basis.

While the USLE was originally designed to consider soil/sediment loading only, it is also commonly used to define loads from pollutants that are tightly bound to soils. In these situations, the USLE is used to define the sediment load, with the result multiplied by a pollutant concentration factor (mass of pollutant per mass of soil) to define pollutant load.

The USLE is among the simplest of the available models for estimating sediment and sediment-associated loads. It requires the least amount of input data for its application and consequently does not ensure a high level of accuracy. It is well suited for screening-level calculations, but is less suited for detailed applications. This is because it is an empirical model that does not explicitly represent site-specific physical processes. Furthermore, the annual average time scale of the USLE is poorly suited for model calibration purposes, as field data are rarely available to define erosion on an annual average basis. In addition, the USLE considers erosion only, and does not explicitly consider the amount of sediment that is delivered to stream locations of interest. It is best used in situations where data are available to define annual loading rates, which allows for site-specific determination of the fraction of eroded sediment that is delivered to the surface water.

Watershed Characterization System (WCS) Sediment Tool

The Watershed Characterization System (WCS) Sediment Tool was developed by EPA Region 4. The Watershed Characterization System is an ArcView-based application used to display and analyze GIS data including land use, soil type, ground slope, road networks, point source discharges, and watershed characteristics. WCS has an extension called the Sediment Tool that is specifically designed for sediment TMDLs. For each grid cell within the watershed, the WCS Sediment Tool calculates potential erosion using the USLE based on the specific cell characteristics. The model then calculates the potential sediment delivery to the stream grid network. Sediment delivery can be calculated using one of the four available sediment delivery equations: a distance-based equation, a distance slope-based equation, an area-based equation, or a Water Erosion Prediction Project (WEPP)-based regression equation.

The applicability of WCS for estimating sediment loads for TMDLs is similar to that of the USLE in terms of data requirements and model results; i.e., it is relatively simple to apply but has the potential to be inaccurate. It provides three primary enhancements over the USLE: 1) Model inputs are automatically incorporated into the model through GIS coverages; 2) Topographic factors are calculated in the model based on digital elevation data; and 3) The model calculates the fraction of eroded sediment that is delivered to the surface water. It is only applicable to sediment TMDLs whose target represents long-term loading conditions. Because its predictions represent average annual conditions, it is not suitable for predicting loads associated with specific storm events. Like the USLE, it is does not lend itself to model calibration unless data are available to define annual loading rates.

Generalized Watershed Loading Functions Model (GWLF)

The Generalized Watershed Loading Functions Model (GWLF) simulates runoff and sediment loadings from mixed-use watersheds. It is a continuous simulation model (i.e., predicts how concentrations change over time) that uses daily time steps for weather data and water balance calculations. Sediment results are provided on a monthly basis. GWLF requires the user to divide the watershed into any number of distinct groups, each of which is labeled as rural or urban. The model does not spatially distribute the source areas, but simply aggregates the loads from each area into a watershed total; in other words, there is no spatial routing. Erosion and sediment yield for rural areas are estimated using monthly erosion calculations based on the USLE (with monthly rainfall-runoff coefficients). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are then applied to the calculated erosion to determine how much of the sediment eroded from each source area is delivered to the watershed outlet. Erosion from urban areas is considered negligible.

GWLF provides more detailed temporal results than the USLE, but also requires more input data. Specifically, daily climate data are required as well as data on processes related to the hydrologic cycle (e.g., evapotranspiration rates, groundwater recession constants). By performing a water balance, it has the ability to predict concentrations at a watershed outlet as opposed to just loads. It lacks the ability to calculate the sediment delivery ratio that is present in the WCS sediment tool, however, a delivery ratio can be specified by the user. Because the model performs on a continuous simulation basis, it is more amenable to site-specific calibration than USLE or the WCS sediment tool.

Agricultural Nonpoint Source Pollution Model (AGNPS)

The Agricultural Nonpoint Source Pollution Model (AGNPS) is a joint USDA-Agricultural Research Service and -Natural Resources Conservation Service system of computer models developed to predict nonpoint source pollutant loadings within agricultural watersheds. The sheet and rill erosion model internal to AGNPS is based upon RUSLE, with additional routines added to allow for continuous simulation and more detailed consideration of sediment delivery.

AGNPS was originally developed for use in agricultural watersheds, but has been adapted to allow consideration of construction sources.

AGNPS provides more spatial detail than GWLF and is therefore more rigorous in calculating the delivery of eroded sediment to the receiving water. This additional computational ability carries with it the cost of requiring more detailed information describing the topography of the watershed, as well as requiring more time to set up and apply the model.

Hydrologic Simulation Program – Fortran (HSPF)

The Hydrologic Simulation Program – Fortran (HSPF) uses continuous rainfall and other meteorologic records to compute stream flow hydrographs and pollutographs. HSPF is well suited for mixed-use (i.e., containing both urban and rural land uses) watersheds, as it contains separate sediment routines for pervious and impervious surfaces. HSPF is an integrated watershed/stream/reservoir model, and simulates sediment routing and deposition for different classes of particle size. HSPF was integrated with a geographical information system (GIS) environment with the development of Better Assessment Science Integrating point and Nonpoint Sources (BASINS). Although BASINS was designed as a multipurpose analysis tool to promote the integration of point and nonpoint sources in watershed and water quality-based applications, it also includes a suite of water quality models. One such model is Nonpoint Source Model (NPSM). NPSM is a simplified version of HSPF that is linked with a graphical user interface within the GIS environment of BASINS. HSPC is another variant of the HSPF model, consisting of the equations used by HSPF recoded into the C++ programming language.

HSPF provides a more detailed description of urban areas than AGNPS and contains direct linkage to a receiving water model. This additional computational ability carries with it the cost of requiring more detailed model inputs, as well as requiring more time to set up and apply the model. BASINS software can automatically incorporate existing environmental databases (e.g., land use, water quality data) into HSPF, although it is important to verify the accuracy of these sources before using them in the model.

Storm Water Management Model (SWMM)

The Storm Water Management Model (SWMM) is a comprehensive computer model for analysis of quantity and quality problems associated with urban runoff. SWMM is designed to be able to describe both single events and continuous simulation over longer periods of time. SWMM is commonly used to simulate urban hydraulics, although its sediment transport capabilities are not as robust as some of the other models described here.

Soil & Water Assessment Tool (SWAT)

The Soil & Water Assessment Tool (SWAT) is a basin-scale, continuous-time model designed for agricultural watersheds. It operates on a daily time step. Sediment yield is calculated with the Modified Universal Soil Loss Equation. It contains a sediment routing model that considers deposition and channel erosion for various sediment particle sizes. SWAT is also contained as part of EPA's BASINS software.

SWAT is a continuous time model, i.e., a long-term yield model. The model is not designed to simulate detailed, single-event flood routing. SWAT was originally developed strictly for application to agricultural watersheds, but it has been modified to include consideration of urban areas.

Water Quality Methodologies and Modeling Frameworks

Numerous methodologies exist to characterize the relationship between watershed loads and water quality for TMDL development. These include:

- Spreadsheet Approaches
- EUTROMOD
- BATHTUB
- WASP5
- CE-QUAL-RIV1
- CE-QUAL-W2
- EFDC

This section describes each of the methodologies and their suitability for defining water quality for TMDL development. Table 2 summarizes some important characteristics of each of the models relative to TMDL application.

Table 2. Summary of Potentially Applicable Models for Estimating Water Quality

Model	Time scale	Water body type	Spatial scale	Data Needs	Pollutants Simulated	Applicability for TMDL
Spreadsheet approaches	Steady State	River or lake	0- or 1-D	Low	DO, nutrients, algae, metals	Good for screening-level assessments
EUTROMOD	Steady State	Lake	0-D	Low	DO, nutrients, Algae	Good for screening-level assessments
BATHTUB	Steady State	Lake	1-D	Moderate	DO, nutrients, algae	Good for screening-level assessments; can provide more refined assessments if supporting data exist
QUAL2E	Steady State	River	1-D	Moderate	DO, nutrients, algae, bacteria	Good for low-flow assessments of conventional pollutants in rivers
WASP5	Dynamic	River or lake	1-D to 3-D	High	DO, nutrients, metals, organics	Excellent water quality capability; simple hydraulics
CE-QUAL-RIV1	Dynamic	River	1-D	High	DO, nutrients, algae	Good for conventional pollutants in hydraulically complex rivers
HSPF	Dynamic	River or lake	1-D	High	DO, nutrients, metals, organics, bacteria	Wide range of water quality capabilities, directly linked to watershed model
CE-QUAL-W2	Dynamic	Lake	2-D vertical	High	DO, nutrients, algae, some metals	Good for conventional pollutants in stratified lakes or impoundments
EFDC	Dynamic	River or lake	3-D	High	DO, nutrients, metals, organics, bacteria	Potentially applicable to all sites, if sufficient data exist

Spreadsheet Approaches

A wide range of simple methods are available to describe the relationship between pollutant loads and receiving water quality, for a variety of situations including rivers and lakes. These methods are documented in Mills et al. (1985). These approaches do not require specific computer software, and are designed to be implemented on a hand calculator or computer spreadsheet. These approaches have the benefit of relatively low data requirements, as well as being easy to apply. Because of their simplistic nature, these approaches are best considered as screening procedures incapable of producing highly accurate results. They do provide good initial estimates of the primary cause-effect relationships.

EUTROMOD

EUTROMOD is a spreadsheet-based modeling procedure for estimating phosphorus loading and associated lake trophic state variables, distributed by the North American Lake Management Society (Reckhow 1990). The modeling system first estimates phosphorus loads derived from watershed land uses or inflow data using approaches developed by Reckhow et al. (1980) and Reckhow and Simpson (1980). The model accounts for both point and nonpoint source loads. Statistical algorithms are based on regression analyses performed on cross-sectional lake data. These algorithms predict in-lake phosphorus, nitrogen, hypolimnetic dissolved oxygen, chlorophyll, and trihalomethane precursor concentrations, and transparency (Secchi depth). The model also estimates the likelihood of blue-green bacteria dominance in the lake. Lake morphometry and hydrologic characteristics are incorporated in these algorithms. EUTROMOD also has algorithms for estimating uncertainty associated with the trophic state variables and hydrologic variability and estimating the confidence interval about the most likely values for the various trophic state indicators.

BATHTUB

BATHTUB is a software program for estimating nutrient loading to lakes and reservoirs, summarizing information on in-lake water quality data, and predicting the lake/reservoir response to nutrient loading (Walker 1986). It was developed, and is distributed, by the U.S. Army Corps of Engineers. BATHTUB consists of three modules: FLUX, PROFILE, and BATHTUB (Walker 1986). The FLUX module estimates nutrient loads or fluxes to the lake/reservoir and provides five different algorithms for estimating these nutrient loads based on the correlation of concentration and flow. In addition, the potential errors in loading estimates are quantified. PROFILE is an analysis module that permits the user to display lake water quality data. PROFILE algorithms can be used to estimate hypolimnetic oxygen depletion rates, area-weighted or mixed layer average constitutent concentrations, and similar trophic state indicators. BATHTUB is the module that predicts lake/reservoir responses to nutrient fluxes. Because reservoir ecosystems typically have different characteristics than many natural lakes, BATHTUB was developed to specifically account for some of these differences, including the effects of non-algal turbidity on transparency and algae responses to phosphorus.

BATHTUB contains a number of regression equations that have been calibrated using a wide range of lake and reservoir data sets. It can treat the lake or reservoir as a continuously stirred, mixed reactor, or it can predict longitudinal gradients in trophic state variables in a reservoir or narrow lake. These trophic state variables include in-lake total and ortho-phosphorus, organic nitrogen, hypolimnetic dissolved oxygen, metalimnetic dissolved oxygen, chlorophyll concentrations, and Secchi depth (transparency).

Uncertainty estimates are provided with predicted trophic state variables. There are several options for estimating uncertainty based on the distribution of the input and in-lake data. Both tabular and graphical displays are available from the program.

QUAL2E

QUAL2E is a one-dimensional water quality model that assumes steady-state flow, but allows simulation of diurnal variations in dissolved oxygen and temperature. It is supported by the U.S. EPA Center for Exposure Assessment Modeling (CEAM) in Athens, Georgia. The model simulates the following state variables: temperature, dissolved oxygen, biochemical oxygen demand, ammonia, nitrate, organic nitrogen, inorganic phosphorus, organic phosphorus, algae, and conservative and non-conservative substances. QUAL2E also includes components that allow implementation of uncertainty analyses using sensitivity analysis, first-order error analysis, or Monte Carlo simulation. QUAL2E has been used for wasteload allocation purposes throughout the United States. QUAL2E is also linked into EPA's BASINS modeling system.

The primary advantages of using QUAL2E include its widespread use and acceptance, and ability to simulate all of the conventional pollutants of concern. Its disadvantage is that it is restricted to one-dimensional, steady-state analyses.

WASP5

WASP5 is EPA's general-purpose surface water quality modeling system. It is supported by the U.S. EPA Center for Exposure Assessment Modeling (CEAM) in Athens, Georgia. The model can be applied in one, two, or three dimensions and is designed for linkage with the hydrodynamic model DYNHYD5. WASP5 has also been successfully linked with other one, two, and three dimensional hydrodynamic models such as RIVMOD, RMA-2V and EFDC. WASP5 can also accept user-specified advective and dispersive flows. WASP5 provides separate submodels for conventional and toxic pollutants. The EUTRO5 submodel describes up to eight state variables in the water column and bed sediments: dissolved oxygen, biochemical oxygen demand, ammonia, nitrate, organic nitrogen, orthophosphate, organic phosphorus, and phytoplankton. The TOXI5 submodel simulates the transformation of up to three different chemicals and three different solids classes.

The primary advantage of using WASP5 is that it provides the flexibility to describe almost any water quality constituent of concern, along with its widespread use and acceptance. Its primary disadvantage is that it is designed to read hydrodynamic results only from the one-dimensional RIVMOD-H and DYNHYD5 models. Coupling of WASP5 with multi-dimensional hydrodynamic model results will require extensive site-specific linkage efforts.

CE-QUAL-RIV1

CE-QUAL-RIV1 is a linked hydrodynamic-water quality model, supported by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi. Water quality state variables consist of temperature, dissolved oxygen, carbonaceous biochemical oxygen demand, ammonia, nitrate, organic nitrogen, orthophosphate, coliform bacteria, dissolved iron, and dissolved manganese. The effects of algae and macrophytes can also be included as external forcing functions specified by the user.

The primary advantage of CE-QUAL-RIV1 is its direct link to an efficient hydrodynamic model. This makes it especially suitable to describe river systems affected by dams or experiencing extremely rapid changes in flow. Its primary disadvantage is that it simulates conventional pollutants only, and contains limited eutrophication kinetics. In addition, the effort and data required to support the CE-QUAL-RIV1 hydrodynamic routines may not be necessary in naturally flowing rivers.

HSPF

HSPF (Hydrological Simulation Program - FORTRAN) is a one-dimensional modeling system for simulation of watershed hydrology, point and non-point source loadings, and receiving water quality for both conventional pollutants and toxicants (Bicknell et al, 1993). It is supported by the U.S. EPA Center for Exposure Assessment Modeling (CEAM) in Athens, Georgia. The water quality component of HSPF allows dynamic simulation of both conventional pollutants (i.e. dissolved oxygen, nutrients, and phytoplankton) and toxics. The toxics routines combine organic chemical process kinetics with sediment balance algorithms to predict dissolved and sorbed chemical concentrations in the upper sediment bed and overlying water column. HSPF is also linked into EPA’s BASINS modeling system.

The primary advantage of HSPF is that it exists as part of a linked watershed/receiving water modeling package. Nonpoint source loading and hydrodynamic results are automatically linked to the HSPF water quality submodel, such that no external linkages need be developed.

CE-QUAL-W2

CE-QUAL-W2 is a linked hydrodynamic-water quality model, supported by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi. CE-QUAL-W2 simulates variations in water quality in the longitudinal and lateral directions, and was developed to address water quality issues in long, narrow reservoirs. Water quality state variables consist of temperature, algae, dissolved oxygen, carbonaceous biochemical oxygen demand, ammonia, nitrate, organic nitrogen, orthophosphate, coliform bacteria, and dissolved iron.

The primary advantage of CE-QUAL-W2 is the ability to simulate the onset and breakdown of vertical temperature stratification and resulting water quality impacts. It will be the most appropriate model for those cases where these vertical variations are an important water quality consideration. In un-stratified systems, the effort and data required to support the CE-QUAL-W2 hydrodynamic routines may not be necessary.

EFDC

EFDC (Environmental Fluid Dynamics Code) is a three-dimensional hydrodynamic and water quality model supported by the U. S. EPA Ecosystems Research Division. EFDC simulates variations in water quality in the longitudinal, lateral and vertical directions, and was developed to address water quality issues in rivers, lakes, reservoirs, wetland systems, estuaries, and the coastal ocean. EFDC transports salinity, heat, cohesive or noncohesive sediments, and toxic contaminants that can be described by equilibrium partitioning between the aqueous and solid phases. Unique features of EFDC are its ability to simulate wetting and drying cycles, it includes a near field mixing zone model that is fully coupled with a far field transport of salinity, temperature, sediment, contaminant, and eutrophication variables. It also contains hydraulic structure representation, vegetative resistance, and Lagrangian particle tracking. EFDC accepts radiation stress fields from wave refraction-diffraction models, thus allowing the simulation of longshore currents and sediment transport.

The primary advantage of EFDC is the ability to combine three-dimensional hydrodynamic simulation with a wide range of water quality modeling capabilities in a single model. The primary disadvantages are that data needs and computational requirements can be extremely high.

MODEL SELECTION

A wide range of watershed and water quality modeling tools is available and potentially applicable to develop TMDLs for the fourteen waterbodies in the Little Wabash watershed. This chapter presents the general guidelines used in model selection process, and then applies these guidelines to make specific recommendations.

General Guidelines

A wide range of watershed and water quality modeling tools is available and potentially applicable to develop TMDLs. This section provides the guidelines to be followed for the model selection process, based upon work summarized in DePinto et al. (2004). Three factors will be considered when selecting an appropriate model for TMDL development:

- **Management objectives:** Management objectives define the specific purpose of the model, including the pollutant of concern, the water quality objective, the space and time scales of interest, and required level or precision/accuracy.
- **Available resources:** The resources available to support the modeling effort include data, time, and level of modeling effort
- **Site-specific characteristics:** Site-specific characteristics include the land use activity in the watershed, type of water body (e.g. lake vs. river), important transport and transformation processes, and environmental conditions.

Model selection must be balanced between competing demands. Management objectives typically call for a high degree of model reliability, although available resources are generally insufficient to provide the degree of reliability desired. Decisions are often required regarding whether to proceed with a higher-than-desired level of uncertainty, or to postpone modeling until additional resources can be obtained. There are no simple answers to these questions, and the decisions are often made using best professional judgment.

The required level of reliability for this modeling effort is one able to “support development of a credible TMDL”. The amount of reliability required to develop a credible TMDL depends, however, on the degree of implementation to be included in the TMDL. TMDL implementation plans that require complete and immediate implementation of strict controls will require much more model reliability than an implementation plan based upon adaptive management which allows incremental controls to be implemented and includes follow-up monitoring of system response to dictate the need for additional control efforts.

The approach to be taken here regarding model selection is to provide recommendations which correspond to the level of detail provided in other Illinois TMDL implementation plans conducted to date. Alternative methodologies are also provided that will support the development of differing levels of TMDL implementation plans. For each approach, the degree of implementation that can be supported to produce a credible TMDL will be provided. Specific recommendations are provided which correspond to the level of detail provided in other Illinois TMDL implementation plans conducted to date.

Model Selection for Waterbodies in the Little Wabash Watershed

Tables 1 and 2 summarized the characteristics of the various watershed and water quality methodologies with potential applicability to TMDL development. Model selection will consider site-specific characteristics of the systems and the data available to support the modeling. Site characteristics and available data have been previously discussed in the Little Wabash River Watershed First Quarterly Status Report (LTI, 2006). The available data are sufficient to confirm the presence of water quality impairment, but not sufficient to support development of a rigorous watershed or water quality model. Specific items lacking in this data set include tributary flow and loading data for most stream segments and Lake Sara, and sediment oxygen demand and chlorophyll a data for the streams to better define the processes controlling dissolved oxygen.

This section provides recommended approaches for the Little Wabash River watershed modeling. Data needs, assumptions, and the level of TMDL implementation supported are provided for each of the recommended approaches.

Recommended Approaches

This section provides recommendations for specific modeling approaches to be applied for the stream and lake segments in the Little Wabash Watershed. Recommended and alternate approaches are provided (where appropriate) in Tables 3, 4, 5, 6 and 7 for the stream segments, and in Table 8 for the three reservoirs, with each approach having unique data needs and resulting degree of detail.

Table 3. Recommended Modeling Approaches for Little Wabash Segment C 19

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Dissolved oxygen	Empirical approach	QUAL2E	Low flow stream surveys	Identify primary sources to be controlled and approx. level of control needed
	Manganese, pH	None	Empirical load capacity calculation	None	Define allowable load
	Atrazine	None	Load duration curve	None	Identify magnitude of problem under different flow conditions; and identify approximate level of control needed
	Fecal coliform	None	Load duration curve	None	Identify whether sources occur during dry or wet weather; and identify approximate level of control needed
Alternative					
	Fecal coliform	HSPF	HSPF	Tributary flow and coliform concentrations at multiple locations	Define specific sources of bacteria and detailed control strategies

The recommended modeling approach for Little Wabash segment C 19 consists of using the water quality model QUAL2E to address dissolved oxygen problems. Watershed loads for this segment will be defined using an empirical approach. Manganese and pH impairments will be addressed via an empirical load capacity calculation. QUAL2E was selected for dissolved oxygen modeling because it is the most commonly used water quality model for addressing low flow conditions. Because problems appear to be restricted to low flow conditions, watershed loads are not expected to be significant contributors to the impairment. For this reason, an empirical approach was selected for determining watershed loads. Two stream surveys are recommended to define the processes controlling dissolved oxygen. Development of a load-duration curve is recommended to address atrazine and fecal coliform impairments. The atrazine source is believed to be runoff from agricultural lands, for which implementation of controls will be voluntary.

A load-duration curve is a graphical representation of observed pollutant load compared to maximum allowable load over the entire range of flow conditions. Such a graph can be developed by 1) developing a flow duration curve by ranking the daily flow data from lowest to highest, calculating the percent of days these flows were exceeded, and graphing the results as shown in Figure 1; 2) translating the flow duration curve into a load duration curve by multiplying the flows by the water quality standard as shown in Figure 2; and 3) plotting observed pollutant loads (measured concentrations times stream flow) on the same graph as shown in Figure 3.

% Exceed	Flow
99	694.2
95	803.3
90	920.2
85	1213.3
80	1629.7
75	2081.3
70	2692.9
65	3130.3
60	3583.3
55	4177.9
50	5092.2
45	6074.7
40	7068.8
35	8398.1
30	9801.8
25	11617.5
20	13838.5
15	17136.8
10	22281.1

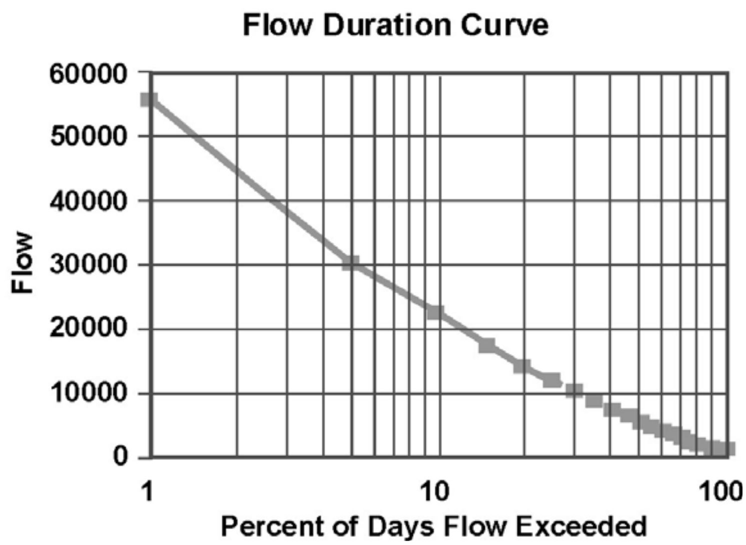

Figure 1. Calculation of a Flow Duration Curve (from Freedman et al., 2003)

% Exceed	Flow	Atrazine (lbs/day)
99	694.2	11.50
95	803.3	13.31
90	920.2	15.25
85	1213.3	20.10
80	1629.7	27.00
75	2081.3	34.49
70	2692.9	44.62
65	3130.3	51.87
60	3583.3	59.38
55	4177.9	69.23
50	5092.2	84.38
45	6074.7	100.66
40	7068.8	117.13
35	8398.1	139.16
30	9801.8	162.42
25	11617.5	192.50
20	13838.5	229.30
15	17136.8	283.96
10	22281.1	369.20
5	30245.9	501.17
1	55562.3	920.67

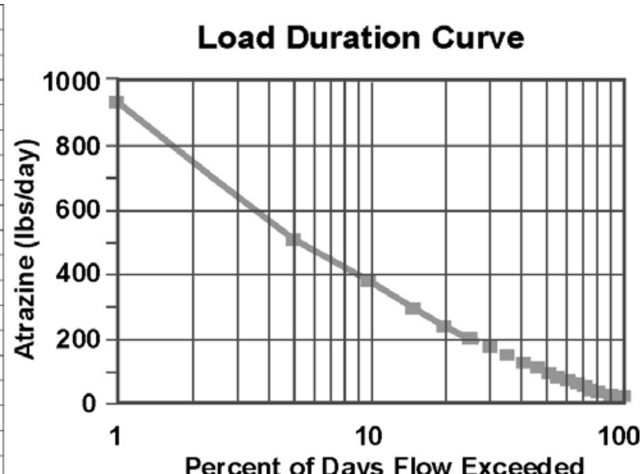

Figure 2. Calculation of a Load Duration Curve (from Freedman et al., 2003)

% Exceed	Flow	Atrazine (lbs/day)	Atrazine Load
99	694.2	11.50	4.33
95	803.3	13.31	
90	920.2	15.25	
85	1213.3	20.10	12.92
80	1629.7	27.00	
75	2081.3	34.49	
70	2692.9	44.62	122.91
65	3130.3	51.87	
60	3583.3	59.38	95.87
55	4177.9	69.23	
50	5092.2	84.38	
45	6074.7	100.66	
40	7068.8	117.13	
35	8398.1	139.16	
30	9801.8	162.42	
25	11617.5	192.50	
20	13838.5	229.30	
15	17136.8	283.96	154.43
10	22281.1	369.20	804.32
5	30245.9	501.17	
1	55562.3	920.67	

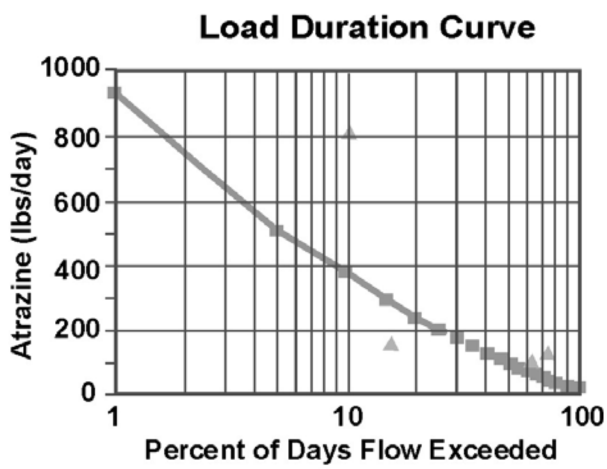

Figure 3. Load Duration Curve with Observed Loads (from Freedman et al., 2003)

The load duration curve provides information to:

- Help identify the issues surrounding the problem and differentiate between point and nonpoint source problems, as discussed immediately below;
- Address frequency of deviations (how many samples lie above the curve vs. those that plot below), and duration (potentially how long the deviation is present) questions; and
- Aid in establishing the level of implementation needed, by showing the magnitude by which existing loads exceed standards for different flow conditions.

The location of loads that plot above the load duration curve is meaningful. Loads which plot above the curve in the area of the plot defined as being exceeded 85-99 percent of the time are considered indicative of point source influences on the water quality. Those loads plotting above the curve over the range of 10-70 percent exceedence likely reflect nonpoint source load contributions. NPS loads are pollution associated with runoff or snowmelt from numerous, dispersed sources over an extended area. Some combination of the two source categories lies in the transition zone of 70-85 percent exceedence. Those loads plotting above the curve at exceedences less than 10 percent or more than 99 percent reflect extreme hydrologic conditions of flood or drought (Freedman et al, 2003).

The load duration curve approach will identify broad categories of coliform and atrazine sources and the extent of control required from these sources to attain water quality standards.

The alternative approach for fecal coliform in the Little Wabash River (C 19) consists of applying the HSPF model to define watershed loads for all fecal coliform sources and using the water quality component of this model to simulate in-stream concentrations and water quality response. This approach, coupled with intensive monitoring, would define specific sources of bacteria and identify detailed control strategies necessary to attain water quality standards.

Table 4. Recommended Modeling Approaches for First Salt Creek (CPC-TU-C1), Salt Creek (CP-EF-C2) and East Branch Green Creek (CSB 07 and CSB 08)

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Dissolved oxygen	Empirical approach	QUAL2E	Two stream surveys at low and moderate flows	Identify primary sources to be controlled and approx. level of control needed
	Manganese (CPC-TU-C1 and CSB 08 only)	None	Empirical load capacity calculation	None	Defines allowable load

The recommended modeling approach for First Salt Creek segment CPC-TU-C1, Salt Creek segment CP-EF-C2 and East Branch Green Creek segments CSB 07 and CSB 08 consists of using the water quality model QUAL2E to address dissolved oxygen problems. Watershed loads for this segment will be defined using an empirical approach. Two stream surveys are recommended to define the processes controlling dissolved oxygen.

Manganese impairments in segment CPC-TU-C1 and CSB 08 will be addressed via empirical load capacity calculations.

Table 5. Recommended and Alternative Modeling Approaches for Salt Creek (CP-TU-C3) and Little Wabash River (C 21)

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Manganese	None	Empirical load capacity calculation	None	Defines allowable load
	Fecal coliform (C 21 only)	None	Load duration curve	None	Identify whether sources occur during dry or wet weather; and identify approximate level of control needed
Alternative					
	Fecal coliform (C 21 only)	HSPF	HSPF	Tributary flow and coliform concentrations at multiple locations	Define specific sources of bacteria and detailed control strategies

The recommended modeling approach for Salt Creek (CP-TU-C3) and Little Wabash River (C 21) consists of addressing manganese impairments in these two segments via empirical load capacity calculations. Development of a load-duration curve is recommended to address fecal coliform impairments in segment C 21. This will allow for determination of the degree of impairment under different flow conditions. Results from the load-duration curve can also be used to identify the approximate level of source control needed under each set of flow conditions.

The alternative approach for fecal coliform in the Little Wabash River (C 21) consists of applying the HSPF model to define watershed loads for all fecal coliform sources and using the water quality component of this model to simulate in-stream concentrations and water quality response. This approach, coupled with intensive monitoring, would define specific sources of bacteria and identify detailed control strategies necessary to attain water quality standards.

Table 6. Recommended Modeling Approaches for Dieterich Creek (COC 10)

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Silver Copper	None	Empirical load capacity calculation	Two surveys at low and moderate flow	Defines allowable load
	Manganese	None	Empirical load capacity calculation	None	Defines allowable load

The recommended modeling approach for Dieterich Creek segment COC 10 consists of addressing manganese, silver and copper impairments via empirical load capacity calculations. Two surveys to collect additional silver and copper data are recommended to verify the appropriateness of the listing (Dieterich Creek has not been sampled since 1991) and also to support the recommended approach. Additional manganese data collection is not recommended, as the source of the manganese is believed to be naturally occurring manganese in the soils.

Table 7. Recommended Modeling Approaches for Second Salt Creek (CPD 01, CPD 03, CPD 04)

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Dissolved oxygen	Empirical approach	Spreadsheet approach	Two surveys at low and moderate flow	Identify approximate level of control needed
	Silver (CPD 03 only)	None	Empirical load capacity calculation	Two surveys at low and moderate flow	Defines allowable load

The recommended approach for modeling dissolved oxygen in Second Salt Creek segments CPD 04, CPD 03 and CPD 01 consists of using spreadsheet calculations. This approach is recommended because there are no point source dischargers in the Second Salt Creek watershed. Watershed loads will be defined using an empirical approach.

Silver impairments will be addressed via a load capacity calculation. Two stream surveys to collect additional silver data are recommended to verify the appropriateness of the listing (available data were collected in 1991) and also to support the recommended approach. Two stream surveys are also recommended to define the processes controlling dissolved oxygen.

Table 8. Recommended Modeling Approaches for Lake Paradise (RCG), Lake Mattoon (RCF) and Lake Sara (RCE)

Modeling Approach	Waterbody	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended						
	L. Paradise, L. Mattoon, L. Sara	Total phosphorus	None	BATHTUB	None	Identify approximate level of control needed
	L. Sara	Manganese				
	L Paradise	pH				
Alternative						
	L. Paradise, L. Mattoon, L. Sara	Total phosphorus	GWLF	BATHTUB	None	Identify primary sources to be controlled; and approximate level of control needed
	L. Sara	Manganese				
	L. Paradise	pH				

The recommended modeling approach for Lake Paradise, Lake Mattoon and Lake Sara would not include any watershed modeling, but would focus only on determining the pollutant loading capacity of the lakes. BATHTUB would then be developed and applied for all three lakes to predict the relationship between phosphorus load and resulting in-lake phosphorus, dissolved oxygen concentrations and pH (Lake Paradise only), as well as the resulting potential for manganese release from sediments in Lake Sara. Determination of existing loading sources and prioritization of restoration alternatives may be conducted by local experts as part of the implementation process. Based upon their recommendations, a voluntary implementation plan can be developed that includes both accountability and the potential for adaptive management.

The alternative approach would involve applying the GWLF watershed model to calculate phosphorus loads to the reservoirs over a time scale consistent with their respective nutrient residence times. BATHTUB would then be developed and applied for all three lakes to predict the relationship between phosphorus load and resulting in-lake phosphorus, dissolved oxygen concentrations and pH (Lake Paradise only), as well as the resulting potential for manganese release from sediments in Lake Sara. This relationship will be used to define the dominant sources of phosphorus to the lakes, and the extent to which they must be controlled to attain water quality standards for phosphorus and manganese. The BATHTUB model was selected because it does not have extensive data requirements (and can therefore be applied with existing data), yet still provides the capability for calibration to observed lake data. GWLF was selected as the watershed model because it can provide loading information on the time-scale required by BATHTUB, with moderate data requirements that can be satisfied by existing data.

Assumptions Underlying the Recommended Methodologies

The recommended approach is based upon the following assumptions:

- The only controllable source of manganese to Lake Sara is that which enters from lake sediments during periods of low dissolved oxygen; this source can be (partially) controlled by reducing phosphorus loads and increasing hypolimnetic dissolved oxygen concentrations.
- A credible TMDL implementation plan can be developed based upon relatively simple models

LTI believes that these assumptions are appropriate.

DATA NEEDS FOR THE METHODOLOGIES TO BE USED

The recommended modeling approaches for Lake Paradise, Lake Mattoon and Lake Sara can be applied without collection of any additional data. Follow-up monitoring is strongly recommended after controls are implemented, to verify their effectiveness in reducing loads and documenting lake response. The alternative approach for these reservoirs can also be applied with the available data.

Application of the recommended approaches for the stream segments in the Little Wabash watershed will require conduct of additional field sampling to support TMDL development. The existing data, while sufficient to document impairment, are not sufficient to define the cause-effect relationships. Two low- to medium-flow surveys are recommended to synoptically measure sources and receiving water concentrations of oxygen demanding substances (segments C 19, CPD 04, CPD 03, CPD 01, CP-EF-C2, CPC-TU-C1, CSB 08 and CSB 07), silver (segments COC 10 and CPD 03), and copper (segment COC 10), to support dissolved oxygen, silver, and copper modeling.

Application of the recommended approach for atrazine will not require conduct of additional field sampling to support TMDL development, as the existing data are sufficient for development of a load-duration curve for the Little Wabash River segment C 19. Additional data can be collected, should a higher confidence be desired for calculating the percent load reduction needed.

Should the recommended approach be selected for the Little Wabash River segment C 19, additional data would not be required. Should the alternative approach for fecal coliform be selected for the Little Wabash River segment C 19 or C 21, extensive data collection efforts would be required in order to calibrate the watershed and water quality models. The purpose of the detailed data collection is as follows:

1) define the distribution of specific loading sources throughout the watershed, and
2) define the extent to which these loads are being delivered to the river.

To satisfy objective one for Little Wabash Segments C 19 and C 21, wet weather event sampling of fecal coliform at multiple tributary and mainstem locations in the watershed will be needed. To satisfy objective two, routine monitoring of loads to the river will be needed. Flows could be estimated using the USGS gages on the Little Wabash River at Clay City, and Effingham, Illinois (03379500 and 03378635, respectively). However, because of the size of the watershed, the flows at these gages may not be reflective of precipitation patterns in other portions of the watershed, especially small streams. Therefore, it is recommended that flows be measured on several tributaries to reflect watershed-specific flow conditions. Water quality sampling and analyses would be required for several wet and dry weather events for Little Wabash (C 19 and C 21) for total suspended solids and fecal coliform.

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Third Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

June 2006

Little Wabash Watershed

Little Wabash River (C19, C21),
Paradise Lake (RCG), Lake Mattoon (RCF),
First Salt Creek (CPC-TU-C1),
Second Salt Creek (CPD 01, CPD 03, CPD 04),
Salt Creek (CP-EF-C2, CP-TU-C3), Lake Sara (RCE),
East Branch Green Creek (CSB 07, CSB 08), and
Dieterich Creek (COC 10)

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Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

This is the third in a series of quarterly status reports documenting work completed on the Little Wabash project watershed. The objective of this report is to provide a summary of Stage 1 work that will ultimately be used to support Total Maximum Daily Load (TMDL) development in the project watershed.

Background

Section 303(d) of the 1972 Clean Water Act requires States to define impaired waters and identify them on a list, which is referred to as the 303(d) list. The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be completed for each pollutant listed for an impaired water body. TMDLs are prepared by the States and submitted to the U.S. EPA. In developing the TMDL, a determination is made of the greatest amount of a given pollutant that a water body can receive without exceeding water quality standards and designated uses, considering all known and potential sources. The TMDL also takes into account a margin of safety, which reflects scientific uncertainty, as well as the effects of seasonal variation.

As part of the TMDL process, the Illinois Environmental Protection Agency (IEPA) and several consultant teams have compiled and reviewed data and information to determine the sufficiency of available data to support TMDL development. As part of this review, the data were used to confirm the impairments identified on the 303(d) list and to further identify potential sources causing these impairments. The results of this review were presented in the first quarterly status report.

In a second quarterly status report, the methodologies/procedures/models to be used in the development of TMDLs were identified and described and models were recommended for application to the project watershed.

The intent of this third quarterly status report is to:

- Identify the amount of data needed to support the modeling (if additional data collection is recommended);
- Provide a general data collection plan; and
- Identify, to the extent possible, the responsible parties for additional data collection.

In future phases of this project, Illinois EPA and consultants will develop the TMDLs and will work with stakeholders to implement the necessary controls to improve water quality in the impaired water bodies and meet water quality standards. It should be noted that the controls for nonpoint sources (e.g., agriculture) would be strictly voluntary.

Methods

The effort completed in the third quarter included summarizing additional data needs to support the recommended methodologies/procedures/models to be used in the development of TMDLs, and where needed, providing general information related to the data collection.

Results

The recommended modeling approach for the Little Wabash River (C 19) consists of using the water quality model QUAL2E to address dissolved oxygen problems. Watershed loads for this segment will be defined using an empirical approach. Manganese and pH impairments will be addressed via empirical load capacity calculations. For this same segment, development of a load-duration curve is recommended to address atrazine and fecal coliform impairments.

The recommended modeling approach for First Salt Creek (CPC-TU-C1), Salt Creek (CP-EF-C2) and East Branch Green Creek (CSB 07 and CSB 08) consists of using the water quality model QUAL2E to address dissolved oxygen problems. Watershed loads for these segments will be defined using an empirical approach. Manganese impairments in First Salt Creek (CPC-TU-C1) and East Branch Green Creek (CSB 08) will be addressed via empirical load capacity calculations.

The recommended modeling approach for Salt Creek (CP-TU-C3) and the Little Wabash River (C 21) consists of addressing manganese impairments via empirical load capacity calculations. Little Wabash River (C21) fecal coliform impairments will be addressed via a load duration curve.

The recommended modeling approach for Dieterich Creek segment COC 10 consists of addressing manganese, silver and copper impairments via empirical load capacity calculations.

The recommended approach for modeling dissolved oxygen in Second Salt Creek (CPD 04, CPD 03, and CPD 01) consists of using spreadsheet calculations. This approach is recommended because there are no permitted point source dischargers in the Second Salt Creek watershed. Watershed loads will be defined using an empirical approach. Silver impairments will be addressed via a load capacity calculation.

The recommended modeling approach for Lake Paradise, Lake Mattoon and Lake Sara would focus on determining the pollutant loading capacity of the lakes, using BATHTUB. BATHTUB can be developed and applied to predict the relationship between the phosphorus load and resulting in-lake phosphorus, dissolved oxygen concentrations and pH (Lake Paradise only), as well as the resulting potential for manganese release from sediments in Lake Sara. Watershed modeling is not recommended. Instead, determination of existing loading sources and prioritization of restoration alternatives would be conducted by local experts as part of the implementation process.

INTRODUCTION/PURPOSE

This Stage 1 report describes intermediate activities related to the development of TMDLs for impaired water bodies in the Little Wabash watershed. Earlier Stage 1 efforts included watershed characterization activities and data analyses, to confirm the causes and sources of impairments in the watershed, and the recommendation of models to support TMDL development.

The remaining sections of this report include:

- **Description of additional data collection, if any, to support modeling:** This section describes the amount (temporal and spatial) of data to be collected, and also includes a general description of a data collection plan. Potential parties that may be responsible for additional data collection are also identified.
- **Next steps**

DESCRIPTION OF ADDITIONAL DATA COLLECTION TO SUPPORT MODELING

Modeling recommendations have previously been documented in the Second Quarterly Progress Report for the Little Wabash watershed (LTI, 2006), and have also been summarized in the Executive Summary of this report.

Application of the recommended approaches for dissolved oxygen, manganese, silver and copper in the stream segments in the Little Wabash River watershed will require conduct of additional field sampling to support TMDL development. The existing data, while sufficient to document impairment, are not sufficient to define the cause-effect relationships for these parameters. Two low- to medium-flow surveys are recommended to synoptically measure sources and receiving water concentrations of oxygen demanding substances (segments C 19, CPC-TU-C1, CP-EF-C2, CSB 07, CSB 08, CPD 01, CPD 03, and CPD 04), manganese (segments C19, CPC-TU-C1, CP-TU-C3, CSB-08 and COC 10), silver (segments COC 10 and CPD 03) and copper (segment COC 10) to support dissolved oxygen, silver and copper modeling.

Data Collection Plan

The data collection plan outlined in general terms below, will support development of the recommended approaches for TMDL development. Two stream surveys are recommended to synoptically measure sources and receiving water concentrations of oxygen-demanding substances at 23 stations located within and upstream of the eight stream segments listed for dissolved oxygen impairments. These stations are shown in Figures 1 and 2. Two low- to medium-flow surveys are recommended to synoptically measure receiving water concentrations of copper and silver in Dieterich Creek (segment COC 10), silver in Second Salt Creek (segment CPD 03), and manganese in Little Wabash River (segment C19), First Salt Creek (segment CPC-TU-C1), Salt Creek (segment CP-TU-C3), East Branch Green Creek (segment CSB-08), and Dieterich Creek (segment COC 10).

Sample collection

Twenty-five monitoring stations are shown and described in Figures 1 and 2. It is recommended that these stations be sampled during low- to medium-flow conditions to support model development and application. Twenty-three of these stations are identified for collecting information on dissolved oxygen or oxygen-demanding substances. In addition, one station is identified for copper sampling, two for silver sampling and five for manganese sampling.

Two low to medium flow surveys are recommended to provide data to support model development and calibration. At each of the stations shown in Figures 1 and 2, it is recommended that the measurements shown in Table 1 be collected on the same day.

Table 1. Sampling recommendations

Measurement	Number of surveys recommended*	Segment (number of stations)
Dissolved oxygen	2	23 stations as follow: Segment C 19 (10); Segment CPC-TU-C1 (3); Segment CP-EF-C2 (3); Segment CPD 01 (1); Segment CPD 03 (1); Segment CPD 04 (1); Segment CSB 07 (3); Segment CSB 08 (1)
Water temperature	2	
Biochemical oxygen demand (BOD)	2	
Ammonia	2	
Channel morphometry	2	
Total silver	2	2 stations as follow: Segment CPD 03 (1) Segment COC 10 (1)
Total Manganese	2	5 stations as follow: Segment C19 (1) Segment CPC-TU-C1 (1) Segment CP-TU-C3 (1) Segment CSB-08 (1) Segment COC 10 (1)
Dissolved copper	2	1 station as follows: Segment COC 10 (1)

*Surveys should be conducted at low to medium flow conditions

In addition, it is recommended that depth and velocity be measured at 12 of the stations at the same time as the water quality sampling, to support flow calculation.

Also, for those segments listed for low dissolved oxygen, it is recommended that sediment oxygen demand (SOD) be measured, in addition to either continuous dissolved oxygen measurements or dissolved oxygen measurements collected in the morning and afternoon. These SOD measurements should be collected at stations determined to be representative of each segment (7 total), based on a field survey. The purpose of these dissolved oxygen measurements is to assess the effect of algae on instream dissolved oxygen concentrations. The SOD only needs to be measured during one survey.

Potential parties that may be responsible for additional data collection

Both Baetis Environmental Services, Inc. and Limno-Tech, Inc. are qualified to conduct the recommended data collection in the Little Wabash watershed.

NEXT STEPS

A public meeting will be scheduled and held in the watershed to present the conclusions and recommendations of Stage 1 work to local stakeholders and to obtain feedback on the work completed to date.

REFERENCES

Illinois Environmental Protection Agency (IEPA), 2006. *Illinois Integrated Water quality Report and Section 303(d) List – 2006.* Clean Water Act Sections 303(d), 305(b) and 314. Water Resource Assessment Information and Listing of Impaired Waters. Bureau of Water. [online] http://www.epa.state.il.us/water/tmdl/303d-list.html

Limno-Tech, Inc., 2006. Second Quarterly Status Report Little Wabash Watershed. May 2006.

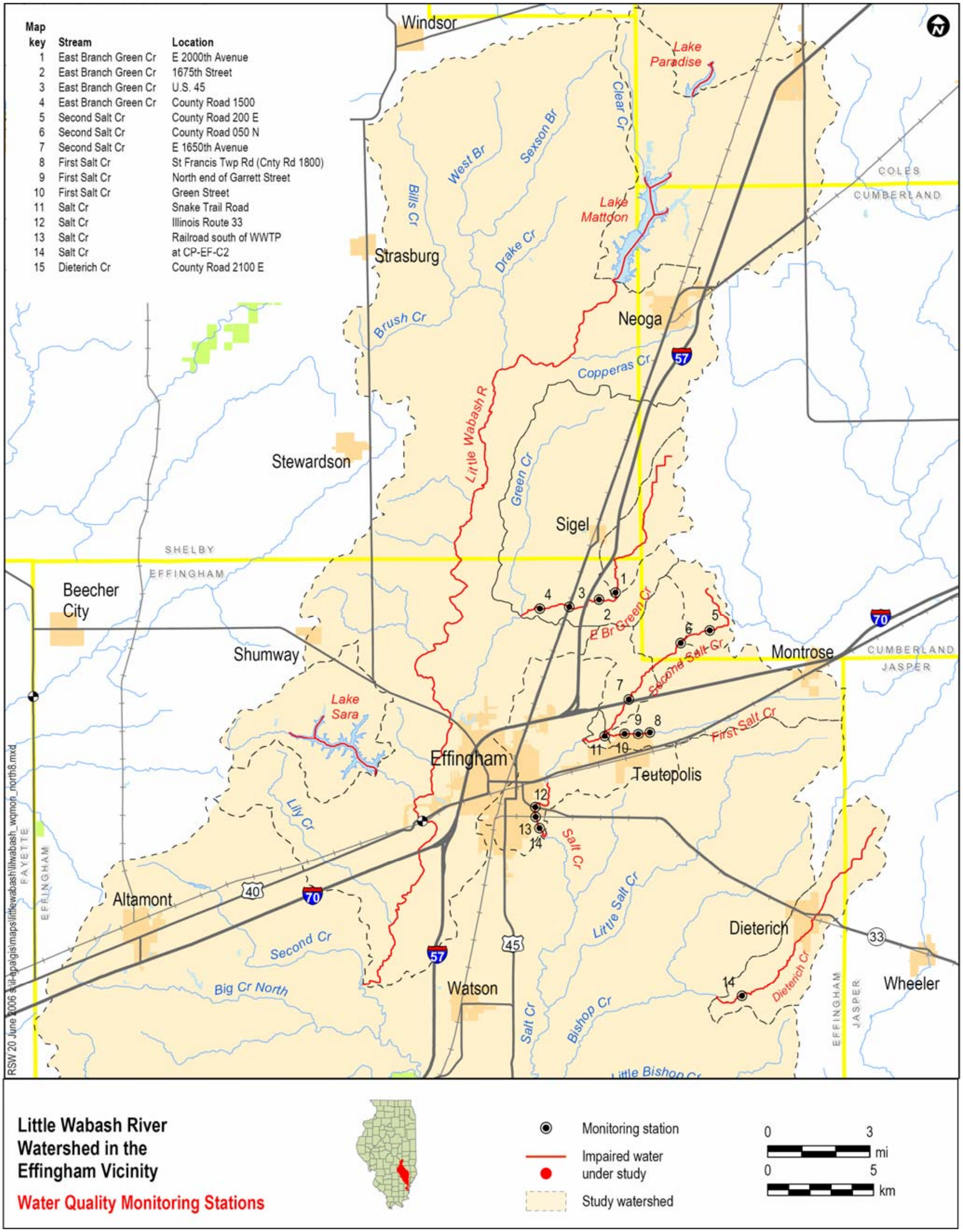

Figure 1. Recommended Stage 2 Sampling Locations (Northern)

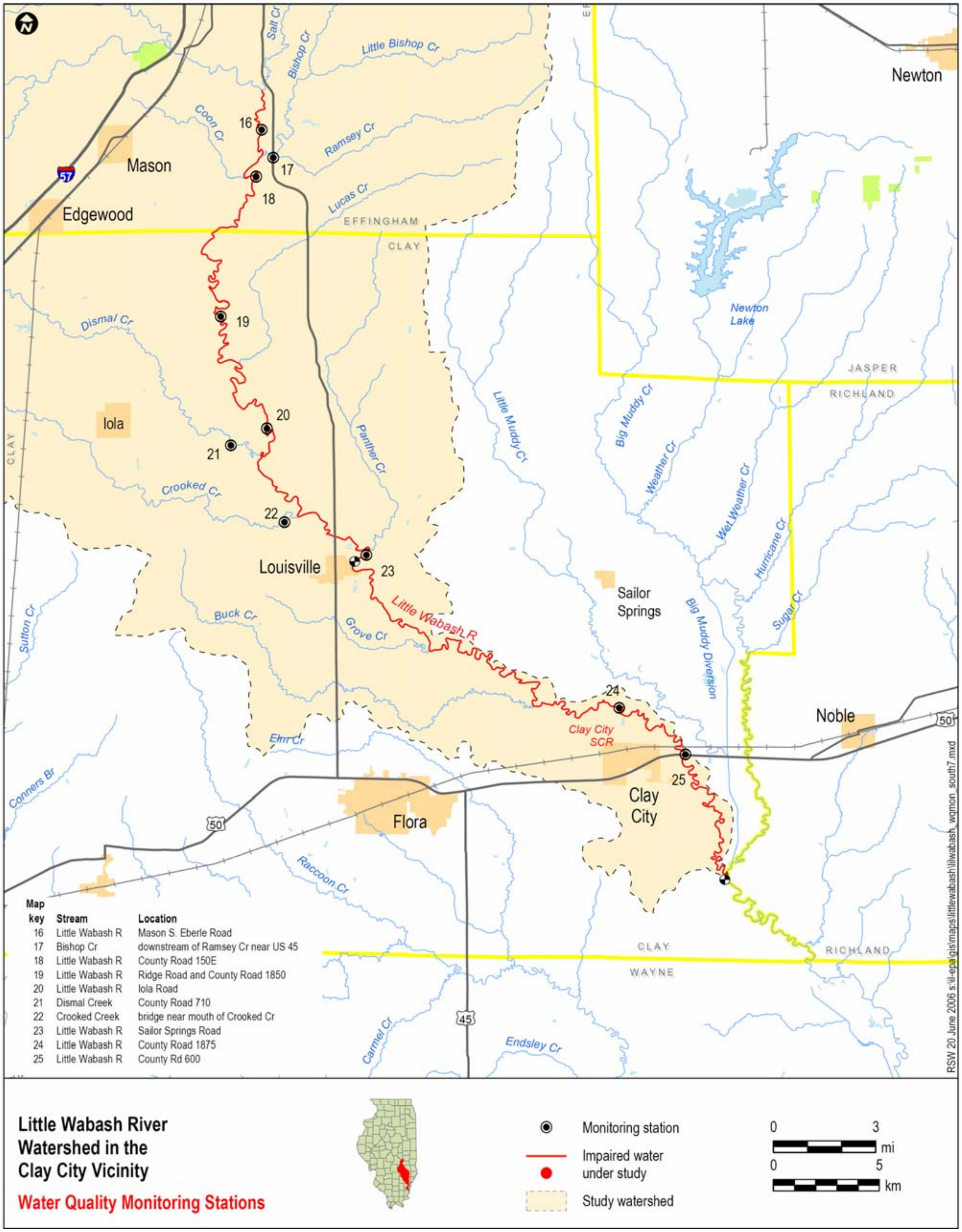

Figure 2. Recommended Stage 2 Sampling Locations (Southern)

Fourth Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

September 2006

Little Wabash Watershed

Little Wabash River (C19, C21),
Paradise Lake (RCG), Lake Mattoon (RCF),
First Salt Creek (CPC-TU-C1),
Second Salt Creek (CPD 01, CPD 03, CPD 04),
Salt Creek (CP-EF-C2, CP-TU-C3), Lake Sara (RCE),
East Branch Green Creek (CSB 07, CSB 08) and
Dieterich Creek (COC 10)

Limno-Tech, Inc.
www.limno.com

PUBLIC PARTICIPATION

Stage One included opportunities for local watershed institutions and the general public to be involved. The Agency and its consultant met with local municipalities and agencies in June 2004 to initiate Stage One. As quarterly progress reports were produced, the Agency posted them to their website. The draft Stage One Report (LTI, 2006) for this watershed was available to the public for review beginning in June 2006.

In July 2006, a public meeting was announced for presentation of the Stage One findings. This announcement was mailed to everyone on the previous TMDL mailing list and published in local newspapers. Copies of the report were sent to three local libraries. The public meeting was held at 6:00 pm on Tuesday, August 1, 2006 in Effingham, Illinois at Lake Land College's Kluthe Center for Higher Education and Technology. In addition to the meeting's sponsors, approximately 15 individuals attended the meeting. Attendees registered and listened to an introduction to the TMDL Program from Illinois EPA and a presentation on the Stage One findings by Limno-Tech, Inc. This was followed by a general question and answer session. Comments, questions and concerns from the public were noted and the Stage 1 Report has been modified to address them.

This is the fourth in a series of quarterly status reports documenting work completed on the Little Wabash River project watershed. The objective of this report is to provide a summary of Stage 1 work that will ultimately be used to support Total Maximum Daily Load (TMDL) development in the project watershed.

REFERENCES

Limno-Tech, Inc., 2006. Little Wabash River TMDL Stage 1 Public Draft Report. June 2006.

FINAL

November 2006

Little Wabash River Watershed

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Limno-Tech, Inc. (LTI) completed surface water sampling in the summer of 2006 to support Total Maximum Daily Load (TMDL) development for impaired water bodies in the Little Wabash River watershed, Illinois. This report describes the field investigations and results of this sampling program. This report is divided into sections describing:

- Field investigation overview
- Water sample collection and field measurements
- Discharge measurements
- Sediment oxygen demand and continuous dissolved oxygen monitoring
- Quality assurance review
- Data analysis

FIELD INVESTIGATION OVERVIEW

The Little Wabash River and its tributaries were sampled during the summer of 2006 to collect data needed to support water quality modeling and TMDL development. Sampling locations are listed in Table 1 and shown in Figures 1 and 2.

Data were collected during two low-flow periods in accordance with an Illinois EPA-approved Quality Assurance Project Plan (QAPP) (LTI, 2006; see Appendix 1). Table 1 presents a summary of the sampling completed and field observations.

The sampling and analysis activities included:

- collection of water samples for laboratory analysis;
- measurement of in-stream water quality and channel morphology parameters;
- stream discharge measurements;
- continuous dissolved oxygen (DO) monitoring; and
- sediment oxygen demand (SOD) measurements.

Water samples and stream measurements were collected from all of the selected locations during both events. Discharge measurements, SOD and 24-hour continuous DO measurements were conducted at a subset of locations in each watershed. In accordance with the QAPP, sample collection and field measurement activities (water quality, morphometry and discharge) were conducted during two separate dry weather periods and continuous DO and SOD monitoring were conducted only during one dry weather period.

Following the completion of field investigation and laboratory analysis activities, the generated data were compiled and a quality assurance review was conducted to assess data quality and usability.

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Table 1. Sampling Summary

Site ID	IEPA Segment ID	IEPA Station ID	Station Description	DO, NH_3, BOD_5, Water Temp, channel morphometry		Flow (depth & velocity)		SOD & diurnal DO	Dissolved Copper		Total Silver		Total Manganese		Round 1 Notes	Round 2 Notes
				Round 1	Round 2	Round 1	Round 2	Round 1	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2		
Little Wabash River Watershed															**8/26/05-9/1/05**	**10/12/2005**
LWAB-1	CSB08	CSB 08	East Br. Green Ck at E 2000th Avenue	✓	✓	✓	✓	✓					✓	✓	Water present; Sampled u.s. side of bridge	Dry under bridge; pooled water ~15' u.s. of bridge and ~30' d.s. of bridge; Sampled u.s. side
LWAB-2	CSB07	CSB 07	East Br. Green Ck at N. 1675th Street	✓	✓										Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-3	CSB07		East Br. Green Ck at U.S. 45	✓	✓										Water present, flowing beneath cobble under bridge; Sampled d.s. side of bridge	Same as Round 1
LWAB-4	CBS07		East Br. Green Ck at N. 1500th St	✓	✓	✓	✓	✓							Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-5	CPD04	CPD 04	Second Salt Creek at road 200 E	✓	✓	✓	✓								Water present; Sampled d.s. side of bridge	Same as Round 1
LWAB-6	CPD03	CPD 03	Second Salt Creek at road 050 N	✓	✓	✓	✓				✓	✓			Water present; Sampled u.s. side of bridge; Wind appears to blow surface water u.s.	Similar to Round 1
LWAB-7	CPD01	CPD 01	Second Salt Creek at E 1650th Avenue	✓	✓	✓	✓	✓							Water present	Same as Round 1
LWAB-8	CPC-TU-C1		First Salt Creek at St Francis Twp Rd/N 1800th St.	✓	✓										Water present; sampled u.s. side of bridge	Same as Round 1
LWAB-9	CPC-TU-C1		First Salt Creek at north of end of Garrett Street	✓	✓			✓							Water present	Same as Round 1
LWAB-10	CPC-TU-C1		First Salt Creek at Green Street	✓	✓	✓	✓						✓	✓	Water present; Sampled d.s. side of bridge	Same as Round 1
LWAB-11	CP-TU-C3		Salt Creek at Snake Trail			✓	✓						✓	✓	Water present; Sampled d.s. side of bridge	Same as Round 1
LWAB-12	CP-EF-C2	CP-14	Salt Creek at Illinois Route 33	✓	✓			✓							Water present; sampled ~12' u.s. of bridge	Same as Round 1
LWAB-13	CP-EF-C2		Salt Creek at railroad south of WWTP	✓	✓										Water present; sampled ~30 d.s. of R.R. bridge	Similar to Round 1
LWAB-14	CP-EF-C2	CP-EF-C2	Salt Creek, one-half mile downstream of WWTP	✓	✓	✓	✓								Water present; sampled by large Maple tree on W. bank that is ~300' d.s. of confluence with small tributary at W. bank and near d.s. end of a landfill located along E. bank; channel is about twice as wide as stream	Same as Round 1
LWAB-15	COC10	COC 10	Dieterich Creek at N 2100th St			✓	✓		✓	✓	✓	✓	✓	✓	Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-16	C19		Little Wabash River at Mason S. Eberle Road	✓	✓										Water present	Same as Round 1
LWAB-17	C19		Ramsey Creek, downstream of U.S. 45 and confluence of Bishop and Ramsey	✓	✓	✓	✓								Water present	Same as Round 1

Site ID	IEPA Segment ID	IEPA Station ID	Station Description	DO, NH_3, BOD_5, Water Temp, channel morphometry		Flow (depth & velocity)		SOD & diurnal DO	Dissolved Copper		Total Silver		Total Manganese		Round 1 Notes	Round 2 Notes
				Round 1	Round 2	Round 1	Round 2	Round 1	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2		
Little Wabash River Watershed															**8/26/05-9/1/05**	**10/12/2005**
			Creeks													
LWAB-18	C19		Little Wabash River at road 150E	✓	✓										Water present; no usable bridge for morphometry measurements which were collected by wading	Same as Round 1
LWAB-19	C19		Little Wabash River at Ridge Road and road 1850 N	✓	✓			✓							Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-20	C19	C 10	Little Wabash River at Iola Road	✓	✓										Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-21	C19	CM 01	Dismal Creek at road 710 E	✓	✓	✓	✓								Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-22	C19		Crooked Creek at bridge near mouth of Crooked Creek	✓	✓	✓	✓								Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-23	C19	C 19	Little Wabash River at Sailor Springs Road	✓	✓								✓	✓	Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-24	C19	C 07	Little Wabash River at road 1875 E	✓	✓			✓							Water present; Sampled u.s. side of bridge	Same as Round 1
LWAB-25	C19		Little Wabash River at road 600 N	✓	✓										Water present; Sampled u.s. side of bridge	Same as Round 1

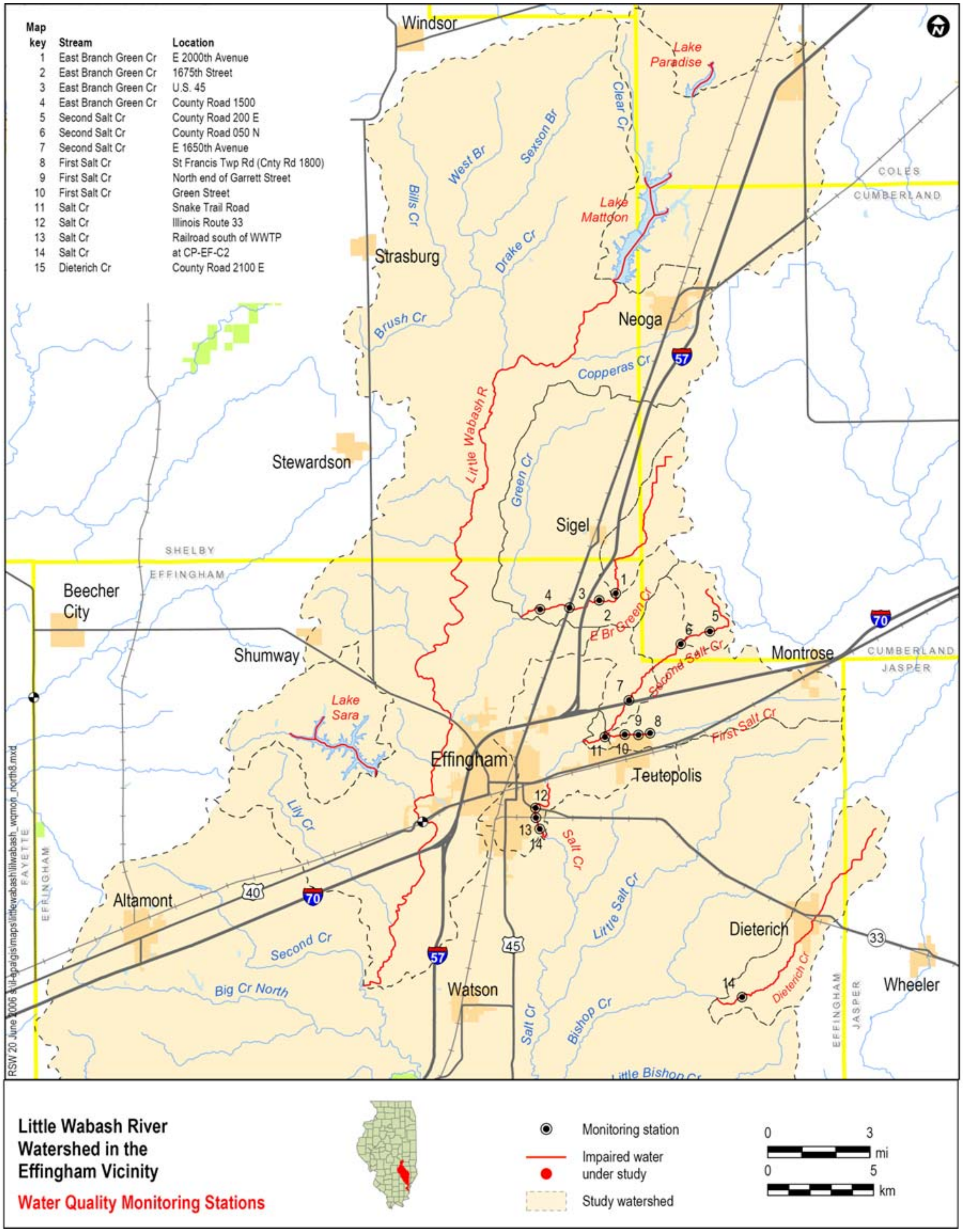

Figure 1. Little Wabash River Watershed Sampling Locations (Northern Watershed)

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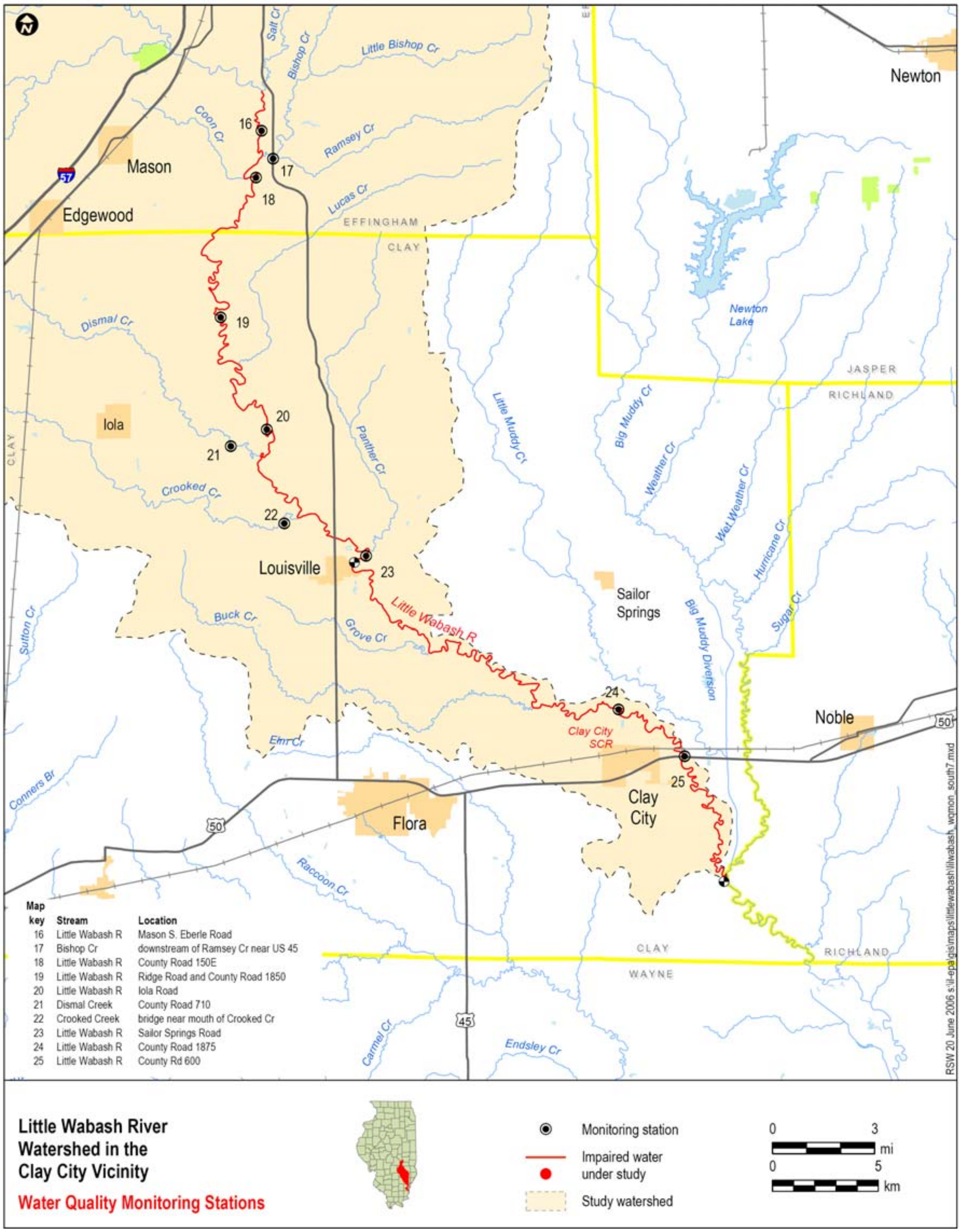

Figure 2. Little Wabash River Watershed Sampling Locations (Southern Watershed)

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WATER SAMPLE COLLECTION AND FIELD MEASUREMENTS

Sampling activities were conducted in accordance with the QAPP during low flow conditions on two separate occasions (Round 1 and Round 2), as noted in Table 1. Surface water samples and field measurements were collected by LTI at 25 stream locations in the Little Wabash River watershed. During the Round 2 sampling event at one location, East Br. Green Ck at E 2000th Avenue (LWAB-1), there was no water observed in the channel underneath the bridge, but water was observed downstream and upstream. Samples were collected upstream of the dry area under the bridge. Water level conditions observed in the field are noted in Table 1.

Table 1 presents a summary of the parameters analyzed at each location. Analytes were based on the causes of impairment identified in the 303(d) list. Field instruments were used to measure in-situ water quality parameters, and Brighton Analytical, Inc. conducted all laboratory analyses. At 23 of the 25 sampling locations, water samples were collected for laboratory analysis of ammonia and 5-day biochemical oxygen demand (BOD_5), while field measurements included dissolved oxygen (DO), water temperature (T), and channel morphometry (water depth and width). In addition, samples for analysis of dissolved copper, total silver and total manganese were collected at one, two and five locations, respectively.

The analytical and field measurement results for Round 1 and Round 2 sampling are presented in Tables 2 through 4.

Table 2. Round 1 Laboratory and Field Measurement Results

Segment ID	Sample ID	Collection Date/Time	Ammonia (mg/L)	BOD_5 (mg/L)	Tot. Ag (mg/L)	Diss. Cu (mg/L)	Tot. Mn (mg/L)	Temp (degC)	DO* (mg/L)
CSB08	LWAB-1	8/24/2006 13:30	<0.01	<2.0			0.09	24.33	9.64
CSB07	LWAB-2	8/24/2006 13:45	0.13	<2.0				22.5	6.05
CSB07	LWAB-3	8/24/2006 14:00	0.22	<2.0				23.74	4.39
CSB07	LWAB-4	8/24/2006 14:20	<0.01	<2.0				23.89	7.21
CPD04	LWAB-5	8/24/2006 13:05	5.4	<33				21.34	0.27
CPD04	LWAB-5	8/24/2006 13:05	5.6	<33					
CPD03	LWAB-6	8/24/2006 12:20	1.3	<20	<0.0002			22.85	0.47
CPD01	LWAB-7	8/24/2006 10:40	0.34	<20				20.98	2.19
CPC-TU-C1	LWAB-8	8/24/2006 10:20	<0.01	<20				20.93	2.52
CPC-TU-C1	LWAB-9	8/24/2006 10:05	3	12				22.78	3.79
CPC-TU-C1	LWAB-10	8/24/2006 9:50	1.3	8.2			0.44	21.43	3.51
CP-TU-C3	LWAB-11	8/24/2006 9:30					0.2		
CP-EF-C2	LWAB-12	8/24/2006 9:10	0.09	2.6				21.42	3.11
CP-EF-C2	LWAB-13	8/24/2006 8:42	0.03	2.1 J				23.72	5.77
CP-EF-C2	LWAB-14	8/24/2006 8:00	0.04	2.1 J				22.36	5.07
COC10	LWAB-15	8/24/2006 16:30			<0.0002	0.004	0.08	24.35	11.07
COC10	LWAB-15 Dup	8/24/2006 16:30			<0.0002	<0.004			
C19	LWAB-16	8/24/2006 15:35	<0.01	2.1 J				25.11	8.51
C19	LWAB-17	8/24/2006 15:10	0.02	<2.0				23.82	7.27
C19	LWAB-18	8/24/2006 14:30	<0.01	2.1 J				26.02	8.43
C19	LWAB-19	8/24/2006 13:45	<0.01	<2.0				24.33	6.72
C19	LWAB-20	8/24/2006 12:55	<0.01	<2.0				23.95	6.26
C19	LWAB-21	8/24/2006 12:20	<0.01	<2.0				23.53	6.93
C19	LWAB-22	8/24/2006 11:45	<0.01	<2.0				22.56	6.65
C19	LWAB-23	8/24/2006 10:55	<0.01	3.4			0.2	24.32	5.62
C19	LWAB-23 Dup	8/24/2006 10:55	<0.01	3			0.2		
C19	LWAB-24	8/24/2006 8:15	<0.01	2.4 J				24.58	4.9
C19	LWAB-25	8/24/2006 9:40	<0.01	2.3 J				25.56	4.46
	LWAB-RB1	8/24/2006 6:30	<0.01	<2.0					
	LWAB-RB2	8/24/2006 6:30	<0.01	<2.0	<0.0002	0.009	<0.02		

Notes:

J Value is considered estimated based on quality control/quality assurance deficiencies. The nature of the deficiency and its significance are discussed in the QA section of this report.

< The analyte was not present at or above the detection limit reported.

* Dissolved oxygen sensor (on Hydrolab Quanta data sonde) is based on a standard Clark Cell design, which is U.S.EPA approved; Range: 0 to 50 mg/L; Accuracy: +/- 0.2 mg/L for 20 mg/L or less, +/- 0.6 mg/L for over 20 mg/L; Resolution: 0.01 mg/L

Table 3. Round 2 Laboratory and Field Measurement Results

Segment ID	Sample ID	Collection Date/Time	Ammonia (mg/L)	BOD_5 (mg/L)	Tot. Ag (mg/L)	Diss. Cu (mg/L)	Tot. Mn (mg/L)	Temp (degC)	DO* (mg/L)
CSB08	LWAB-1	9/7/2006 10:30	0.06	<2.0			0.69	19.99	3.50
CSB07	LWAB-2	9/7/2006 10:45	0.22	<2.0				17.77	4.26
CSB07	LWAB-3	9/7/2006 10:55	23	17				19.08	4.03
CSB07	LWAB-4	9/7/2006 11:15	1.3	3				20.37	10.36
CPD04	LWAB-5	9/7/2006 10:10	17	14				18.50	0.36
CPD03	LWAB-6	9/7/2006 9:45	1.5	2.7	<0.0002			19.42	0.62
CPD03	LWAB-6 Dup	9/7/2006 9:45	1.5	2.7	<0.0002				
CPD01	LWAB-7	9/7/2006 9:20	0.14	<2.0				17.34	4.11
CPC-TU-C1	LWAB-8	9/7/2006 9:05	0.04	<2.0				18.12	5.87
CPC-TU-C1	LWAB-9	9/7/2006 8:50	5.2	7.2				19.60	2.28
CPC-TU-C1	LWAB-10	9/7/2006 8:40	2.5	6.6			0.41	18.15	2.95
CP-TU-C3	LWAB-11	9/7/2006 8:20					0.14	17.87	5.11
CP-EF-C2	LWAB-12	9/7/2006 8:00	0.05	<2.0				18.25	5.80
CP-EF-C2	LWAB-13	9/7/2006 7:30	0.06	<2.0				21.47	6.71
CP-EF-C2	LWAB-14	9/7/2006 7:00	0.05	<2.0				20.84	6.30
COC10	LWAB-15	9/7/2006 14:00			<0.0002	0.005	0.03	20.79	9.71
C19	LWAB-16	9/7/2006 13:25	<0.01	<2.0				21.60	9.38
C19	LWAB-17	9/7/2006 13:10	0.07	<2.0				20.27	6.26
C19	LWAB-18	9/7/2006 12:30	0.01	2.3 J				21.92	7.90
C19	LWAB-19	9/7/2006 11:30	<0.01	2.5				21.08	6.38
C19	LWAB-20	9/7/2006 10:45	0.02	2.7				20.52	5.06
C19	LWAB-21	9/7/2006 10:20	<0.01	<2.0				19.68	6.46
C19	LWAB-22	9/7/2006 9:45	<0.01	<2.0				19.30	6.77
C19	LWAB-23	9/7/2006 9:15	0.03	2.1 J			0.44	21.07	4.74
C19	LWAB-23 Dup	9/7/2006 9:15	0.02	2.9			0.37		
C19	LWAB-24	9/7/2006 8:10	0.03	<2.0				21.35	5.28
C19	LWAB-25	9/7/2006 7:30	0.07	2				21.81	5.13
	LWAB-RB1	9/7/2006 5:40	<0.01	<2.0			<0.02		
	LWAB-RB2	9/7/2006 5:40	<0.01	<2.0		<0.004	<0.02		

Notes:

J Value is considered estimated based on quality control/quality assurance deficiencies. The nature of the deficiency and its significance are discussed in the QA section of this report.

< The analyte was not present at or above the detection limit reported.

* Dissolved oxygen sensor (on Hydrolab Quanta data sonde) is based on a standard Clark Cell design, which is U.S.EPA approved; Range: 0 to 50 mg/L; Accuracy: +/- 0.2 mg/L for 20 mg/L or less, +/- 0.6 mg/L for over 20 mg/L; Resolution: 0.01 mg/L

Table 4. Stream Morphometry Results

		Round 1 - 8/24/2006			Round 2 - 9/7/2006		
Segment ID	Site ID	Time	River Width (ft)	Avg. Water Depth (ft)	Time	River Width (ft)	Avg. Water Depth (ft)
CSB08	LWAB-1	13:30	13.5	0.91	10:30	10	0.42
CSB07	LWAB-2	13:45	12.5	0.60	10:45	11	0.45
	LWAB-3	14:00	13	0.59	10:55	13	0.38
	LWAB-4	14:20	22	0.81	11:15	19	0.85
CPD04	LWAB-5	13:05	8	0.69	10:10	8	0.64
CPD03	LWAB-6	12:20	25	1.94	9:45	16	1.64
CPD01	LWAB-7	10:40	14	0.23	9:20	14	0.21
CPC-TU-C1	LWAB-8	10:20	15	0.43	9:05	12	0.46
	LWAB-9	10:05	17	0.15	8:50	16	0.31
	LWAB-10	9:50	13	0.25	8:40	11	0.28
CP-TU-C3	LWAB-11	9:30	18	0.87	8:20	15.5	0.85
CP-EF-C2	LWAB-12	9:10	24	0.84	8:00	22	0.93
	LWAB-13	8:42	34	0.89	7:30	34	0.83
	LWAB-14	8:00	13	0.34	7:00	15.5	0.32
COC10	LWAB-15	16:30	10	0.39	13:55	8	0.30
C19	LWAB-16	15:45	24	2.48	13:25	22	2.53
	LWAB-17	14:50	5	0.30	13:10	2.8	0.13
	LWAB-18	14:30	46	0.60	12:30	44	0.55
	LWAB-19	13:45	61	1.29	11:32	58	0.92
	LWAB-20	13:05	76	5.03	10:45	78	4.37
	LWAB-21	12:30	23.5	0.28	10:20	23	0.32
	LWAB-22	11:45	17	0.96	9:45	19	1.39
	LWAB-23	10:55	96	9.86	8:45	94	10.37
	LWAB-24	8:55	82	4.02	8:10	79	3.49
	LWAB-25	9:50	76	4.04	7:30	72	3.03

DISCHARGE MEASUREMENTS

Discharge measurements were conducted at a subset of locations representative of the waterbodies in each watershed. Discharge measurements were recorded using standard USGS techniques employing an electromagnetic point velocity meter (Marsh–McBirney Flo-Mate 2000) and a bridgeboard or a wading rod. Information supporting flow calculation was recorded in field notebooks and included:

- Site location,
- Date and time,
- Measurement monitoring point,
- Distance between measurement points,
- Depth at each measurement point,
- Velocities at each measurement point,

- Angle of flow at each measurement point,
- Angle of bridge with respect to river channel (where measurements were conducted from bridges), and
- Any significant observations of monitoring procedures or river conditions

The discharge measurement results are presented in Table 5.

Table 5. Discharge Results

	Date:	8/24/06		9/7/06	
Segment	**Site ID**	**Time**	**Q (cfs)[a]**	**Time**	**Q (cfs)[a]**
CSB08	LWAB-1	13:30	0.07	10:30	0[b]
CSB07	LWAB-4	14:20	0.17	11:15	0.37
CPD04	LWAB-5	13:05	0.01	10:10	0.02
CPD03	LWAB-6	12:20	0.19	9:45	0.07
CPD01	LWAB-7	10:40	0[b]	9:20	0[b]
CPC-TU-C1	LWAB-10	9:50	0.28	8:40	0.14
CP-TU-C3	LWAB-11	9:30	0.42	8:20	0.63
CP-EF-C2	LWAB-14	8:00	1.77	7:00	1.77
COC10	LWAB-15	16:30	0.04	13:55	0.01
Trib. to C19	LWAB-17	14:50	0.24	13:10	0.02
Trib. to C19	LWAB-21	12:30	0.43	10:20	0.11
Trib. to C19	LWAB-22	11:45	0.54	9:45	7.93

[a]Q (cfs) = stream discharge in cubic feet per second

[b]No observable and/or measured downstream current

[c]Segment C19 flow was not measured because flows from an active USGS gage are available

SEDIMENT OXYGEN DEMAND AND CONTINUOUS DO MONITORING

Sediment oxygen demand and continuous dissolved oxygen were measured at select locations representative of river conditions in each watershed. SOD respirometer chambers were installed in accordance with the QAPP, and DO measurements during SOD testing were manually recorded in the field notes for a period of 2 hours or until DO dropped by 2 mg/L or to zero mg/L. The data were used to calculate SOD rates for use in the DO modeling activities. The SOD rate results are presented in Table 6.

In-Situ Mini-Troll multi-parameter data-logging sondes were used for continuous DO measurements. The sondes were deployed for at least 24 hours at each of the selected locations. Calibration of the sondes for DO using the Winkler titration method was conducted before deployment and again after deployment to check the system for drift in DO values over time. Calibration and drift-check results were recorded in the field notes and are presented in Table 7. DO 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 DO and temperature data are presented in Figures 3 through 9 and in Appendix 2.

Table 6. Sediment Oxygen Demand Results

Date	Segment ID	Site ID	<=SOD, g/m2/day @ 20° C
8/22/2006	CSB08	LWAB-1	1.04
8/22/2006	CSB07	LWAB-4	1.51
8/22/2006	CPD01	LWAB-7	0.57
8/21/2006	CPC-TU-C1	LWAB-9	1.39
8/23/2006	CP-EF-C2	LWAB-12	0.73
8/23/2006	C19	LWAB-19	1.14
8/23/2006	C19	LWAB-24	1.07

Table 7. Continuous DO Sonde Calibration Values and Drift Check Results

		Pre-Deployment Calibration	Post-Deployment Drift Check						
Segment ID	Site ID	Winkler DO (mg/L)	Water Sample DO (mg/L)	Winkler DO (mg/L)	DO Drift (mg/L)	DO Drift (%)	Hours Deployed	Average Drift/hr (mg/L)	Average Drift/hr (%)
CSB08	LWAB-1	5.3	7.18	6.65	0.53	7.7%	25.25	0.021	0.30%
CSB07	LWAB-4	5.95	7.59	6.65	0.94	13.2%	26.25	0.0358	0.50%
CPD01	LWAB-7	4.15	3.61	3.85	-0.24	-6.4%	24.75	-0.0097	-0.26%
CPC-TU-C1	LWAB-9	5.7	7.31	8	-0.69	-9.0%	21	-0.0329	-0.43%
CP-EF-C2	LWAB-12	4.65	4.23	5	-0.77	-16.7%	23.75	-0.0324	-0.70%
C19	LWAB-19	7.5	6.58	7.45	-0.87	-12.4%	19.5	-0.0446	-0.64%
C19	LWAB-24	4.8	5.68	4.95	0.73	13.7%	23.5	0.0311	0.58%

Notes: Sonde deployed was Hydrolab MiniSonde 4a

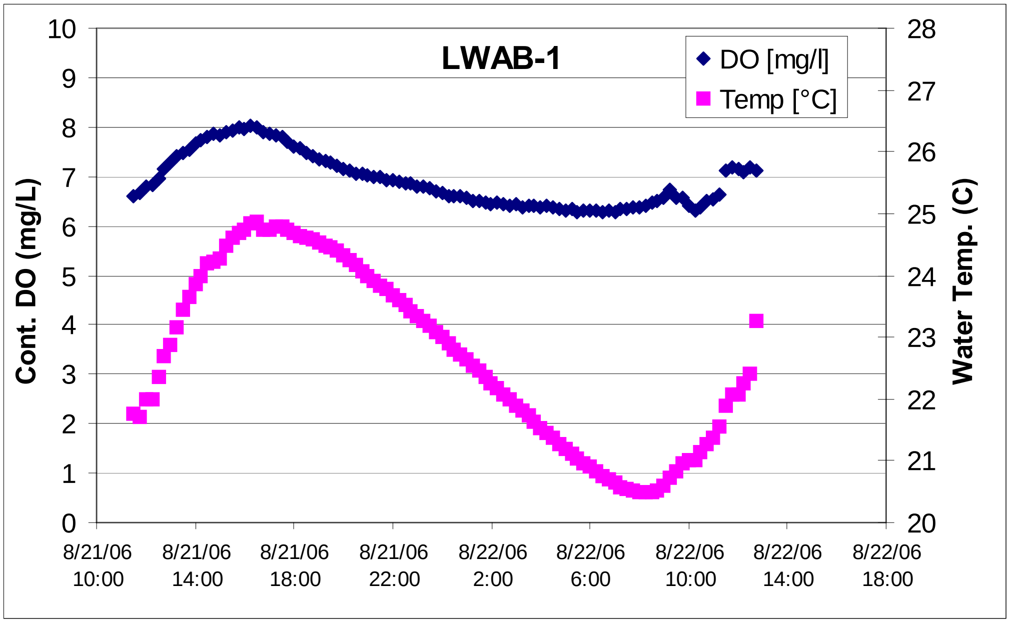

Figure 3. East Branch Green Creek Station LWAB-1 (Segment CSB08): Continuous DO and Water Temperature

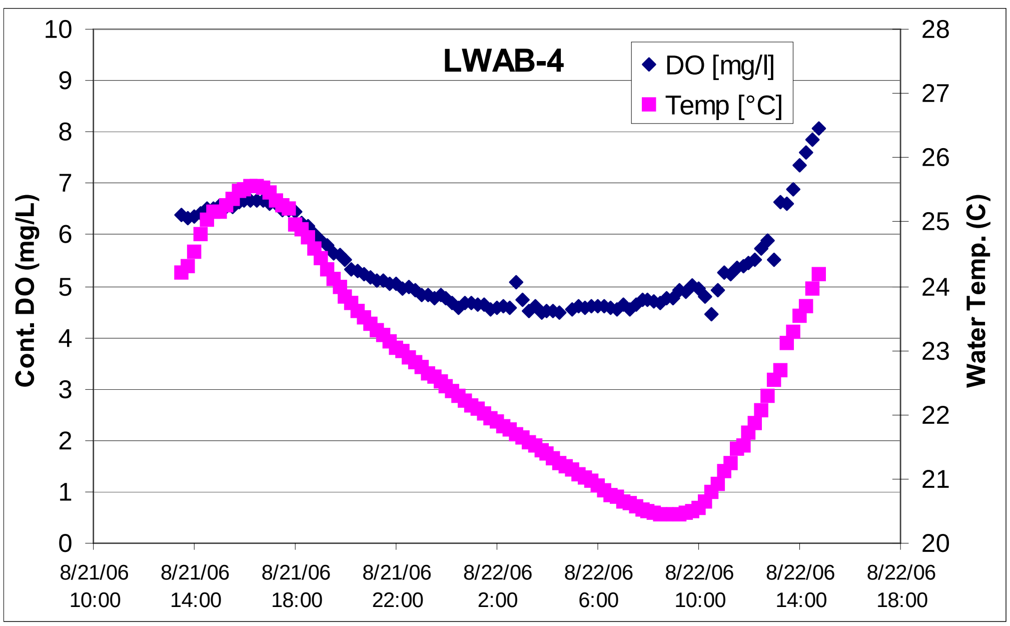

Figure 4. East Branch Green Creek Station LWAB-4 (Segment CSB07): Continuous DO and Water Temperature

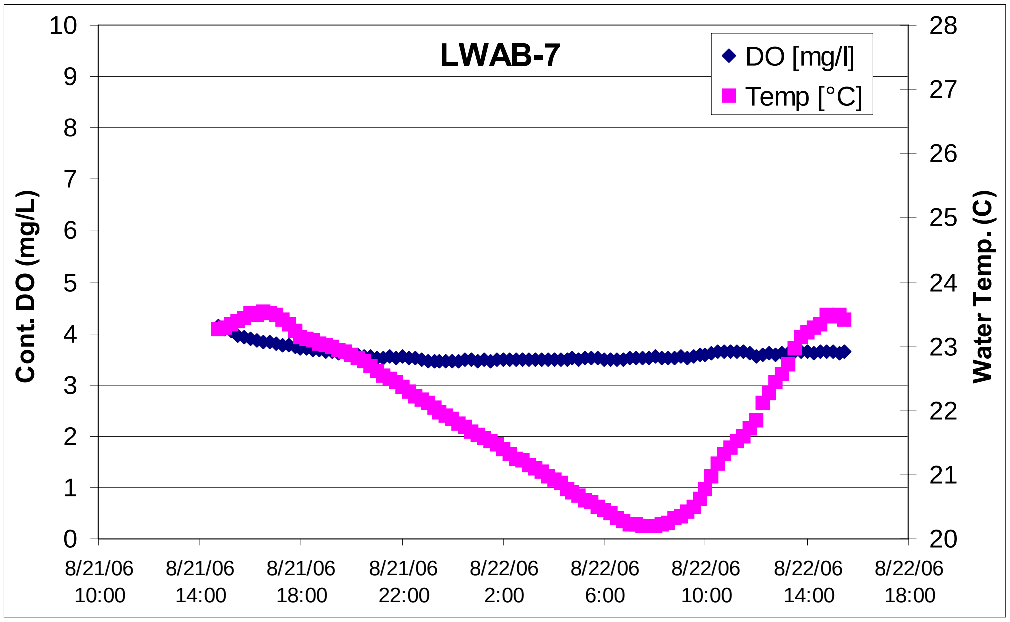

Figure 5. Second Salt Creek Station LWAB-7 (Segment CPD01): Continuous DO and Water Temperature

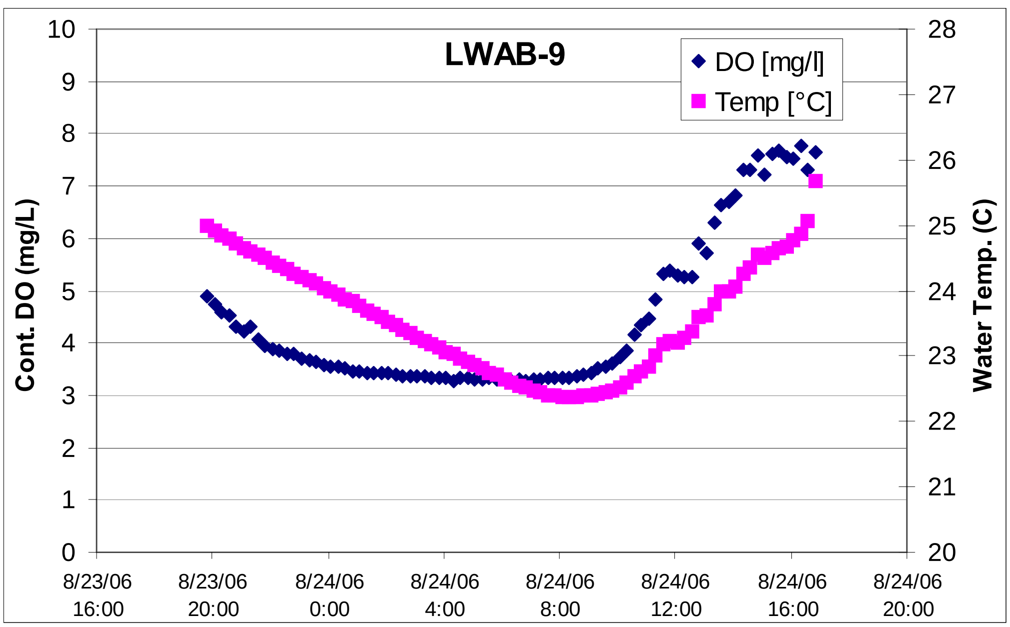

Figure 6. First Salt Creek Station LWAB-9 (Segment CPC-TU-C1): Continuous DO and Water Temperature

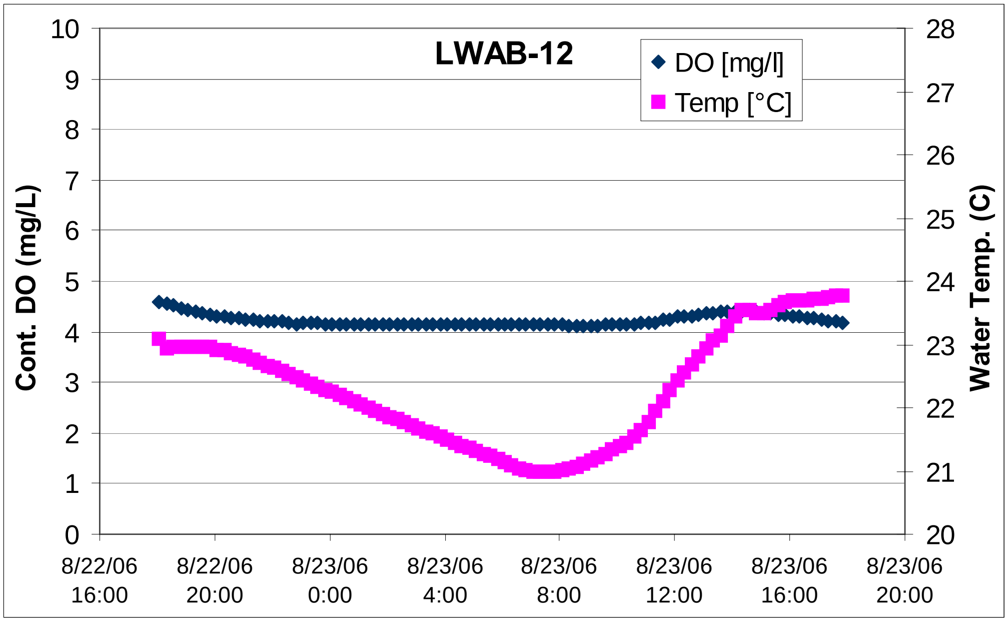

Figure 7. Salt Creek Station LWAB-12 (Segment CP-EF-C2): Continuous DO and Water Temperature

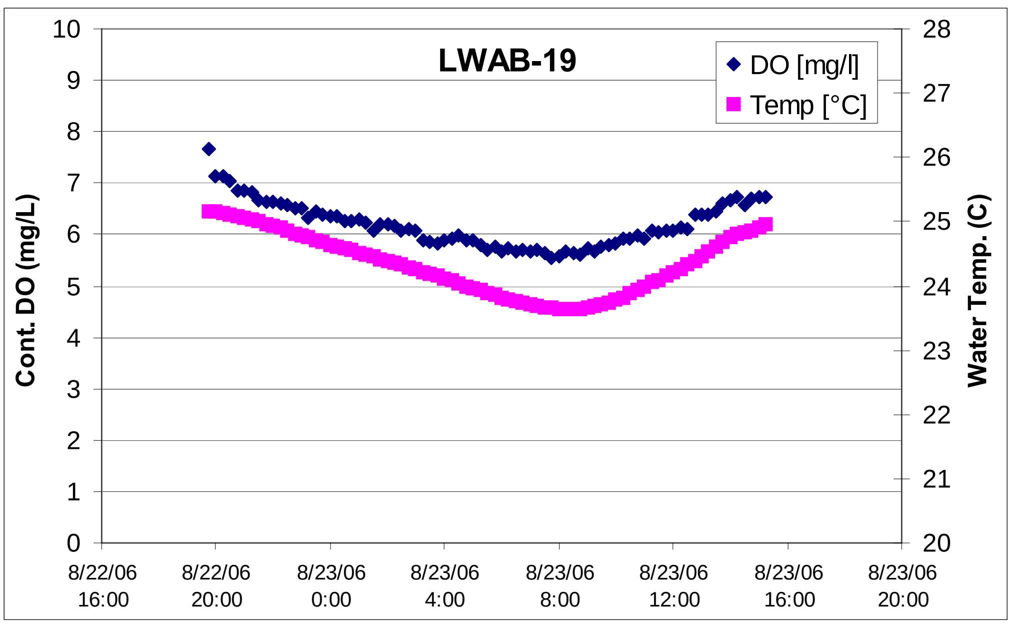

Figure 8. Little Wabash River Station LWAB-19 (Segment C19): Continuous DO and Water Temperature

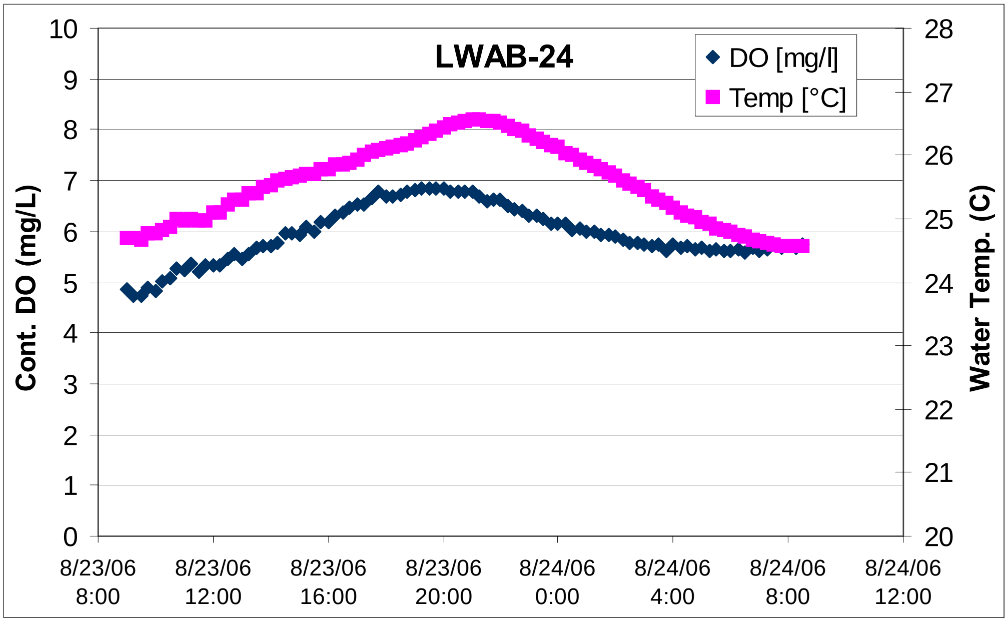

Figure 9. Little Wabash River Station LWAB-24 (Segment C19): Continuous DO and Water Temperature

QUALITY ASSURANCE REVIEW

A review was conducted to assess the quality and usability of data generated from implementation of the work activities and to assess adherence to protocols specified in the QAPP. Field and laboratory methods were reviewed and found to be in accordance with the QAPP. Field measurement data and laboratory analytical data were verified and validated in accordance with the QAPP.

Overall, the data generated are of satisfactory quality and suitable for the intended uses, which include stream characterization and modeling for TMDL development. Some of the data, though acceptable for use, are qualified because of deficiencies in field or laboratory quality control procedures or conditions. Other data, though not specifically flagged with a data qualifier, are associated with uncertainties that prompt caution in their use. These are discussed in this section.

The following subsections of this document present the deviations, deficiencies and cautions associated with the data generated during the investigations. These subsections include the sampling plan changes implemented during the course of the investigation and the results of the data verification and data validation activities.

Data Verification and Validation

The data generated are of overall good quality and acceptable for use with some qualifications as discussed below.

Discharge data. There is uncertainty associated with discharge values generated from flow data for some locations. Results that are very near zero accurately represent the fact that little to no downstream discharge was present, but should be used with caution in terms of defining a specific magnitude of flow. Field observations of "no apparent flow" were common. Uncertainties in the data may be associated with the following:

- Recorded water velocities that were very low may have been below the sensitivity of the velocity meter (±0.05 feet per second),
- Stream flow may have been insufficient to overcome measurement system inertia and accurately orient the velocity sensor in the direction of flow, resulting in inaccurate recordings of flow angle when using a bridgeboard, and
- Stream flow may have been insufficient to overcome water currents induced by the presence of sampling personnel when measuring velocities while wading in the stream.

The knowledge that little to no downstream discharge was present will be sufficient to satisfy modeling requirements.

Laboratory data. There is uncertainty associated with some of the laboratory data based on results of quality control procedures that are outside of control limits. These data were qualified as estimated (J flag), and are described in additional detail below.

- ***BOD_5 method blanks*** **–** Internal laboratory method blanks showed the presence of BOD_5 when, ideally, there should be none. Where sample results are less than five times the associated method blank concentration, these values are considered to be estimated and are flagged with the "J" qualifier in the data tables. The samples affected are presented below.
  - ➢ Round 1 samples: LWAB-13, LWAB-14, LWAB-16, LWAB-18, LWAB-24, and LWAB-25
  - ➢ Round 2 samples: LWAB-18 and LWAB-23

  The BOD_5 results for these samples are usable and are considered sufficient to support model and TMDL development.

- ***BOD_5 detection limits*** **–** Detection limits were elevated for five BOD_5 samples with non-detect results from the Round 1 sampling event. The laboratory analyst observed these samples to be turbid and, based upon professional judgment that turbid samples frequently have higher BOD_5, diluted the samples prior to analysis. This action resulted in the elevated detection limits. The samples affected are presented below.
  - ➢ Round 1 samples: LWAB-5, LWAB-5 Dup, LWAB-6, LWAB-7, and LWAB-8

  The BOD_5 results for these samples are usable and, in conjunction with the Round 2 sampling results provide information that is considered sufficient to support model and TMDL development.

Field QC data. Field quality control (QC) samples were collected to assess bias associated with field and laboratory methods. The field QC samples included four field duplicate sample pairs and four rinse blank samples. The results of these analyses are presented below.

- ***Dissolved copper contamination in one rinse blank*** – Dissolved copper was detected in one rinse blank (LWAB-RB2) analyzed from the Round 1 sampling event. No qualifications were made to the sample results based on the presence of rinse blank contamination. This is because the samples analyzed for dissolved copper (from station LWAB-15 only) were collected from the stream directly into the sample bottle. No intermediate sample collection container was used at this location and, therefore the rinse blank result has no significance regarding the quality of the sample result.

- ***Field Duplicates*** **–** Four field duplicate pairs were analyzed with the monitoring data. Positive sample results and relative percent differences (RPD) are presented in Table 8 along with the criteria for precision (relative percent difference values). All duplicate recoveries were within acceptable ranges.

Table 8. Field Duplicate Pair Sample Results

Sample ID	Ammonia (mg/L)	BOD_5 (mg/L)	Total Silver (mg/L)	Dissolved Copper (mg/L)	Total Mn (mg/L)
Round 1 Results					
LWAB-5	5.4	33 U			
LWAB-5 Dup	5.6	33 U			
RPD (%)	**0.9 b**				
LWAB-15			0.0002 U	0.004	0.08
LWAB-15 Dup			0.0002 U	0.004 U	
RPD (%)				**0.0 a**	
LWAB-23	0.01 U	3.4			0.2
LWAB-23 Dup	0.01 U	3			0.2
RPD (%)		**3.1 b**			**0.0 a**
Round 2 Results					
LWAB-6	1.5	2.7	0.0002 U		
LWAB-6 Dup	1.5	2.7	0.0002 U		
RPD (%)	**0.0 b**	**0.0 b**			
LWAB-23	0.03	2.1 J			0.44
LWAB-23 Dup	0.02	2.9			0.37
RPD (%)	**10.0 b**	**8.0 b**			**4.3 a**

Notes:

J Value is considered estimated based on quality control/quality assurance deficiencies. The nature of the deficiency and its significance are discussed in the QA section of this report.

U The analyte was not present at or above the detection limit reported.

a Acceptable metal duplicate; sample results are within +/- the laboratory reporting limit or <= 20% RPD (for aqueous samples).

b Acceptable organic duplicate; sample results are within +/- the laboratory reporting limit or <= 20% RPD (for aqueous samples) or the difference is < a factor of 5X in the concentration.

*RPD= |S-D| x100 / (S+D)/2 where S: original sample; D: Duplicate sample

Conformance to Data Quality Objectives. Overall, the data generated during the investigation conformed to the project data quality objectives (DQOs) and are suitable for their intended uses. The monitored parameters were evaluated in terms of minimum measurement criteria, minimum measurement objectives, required detection limits, accuracy, precision and completeness using the DQOs presented in the project QAPP. Table 9 summarizes the results of the DQO quality assurance (QA) check.

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Table 9. Measurement Objectives and Criteria Check

Parameter	Minimum Measurement Criteria	Minimum Measurement Objectives	Method*; MDL[1]	QA check	MS/MSD * Accuracy (% recovery)	QA check	Precision (RPD)	QA check	LCS * Accuracy (% recovery)	QA check	Completeness Criteria	QA check
Dissolved Oxygen	NA	0.1 mg/l [s]	Field; NA	S	NA	NA	NA	NA	NA	NA	90%	S (100%)
Water Temperature	NA	0.1 degree C [s]	Field; NA	S	NA	NA	NA	NA	NA	NA	90%	S (100%)
pH	NA	0.1 pH unit[s]	Field; NA	S	NA	NA	NA	NA	NA	NA	90%	S (100%)
Ammonia	15.0 mg/l[G]	3.0 mg/l	EPA 350.1/ 350.3; 0.01/0.03 mg/l	S	80-120%	S	20%	S	80-120%	S	90%	S (100%)
BOD_5	No Standard	No Standard	EPA 405.1/ SM 5210 B; 2 mg/l	S	NA	NA	20%	S	NA	NA	90%	S (100%)
Copper, Dissolved	0.011 mg/l[G, 2]	0.005 mg/l	EPA 200.8; 0.0004 mg/l	S	70-130%	S	20%	S	80-120%	S	90%	S (100%)
Silver, Total	0.005 mg/l[G]	0.005 mg/l	EPA 200.8 0.0002 mg/l	S	70-130%	S	20%	S	80-120%	S	90%	S (100%)
Manganese, Total	1 mg/l[G]	0.2 mg/l	EPA 200.8 0.02 mg/l	S	70-130%	S	20%	S	80-120%	S	90%	S (100%)

<u>Notes</u>

1 Method Detection Limit (MDL) from SM and EPA.
2 Calculated acute standard based on a minimum water hardness of 100 mg/L as CaCO3
* Limits are subject to change based upon capabilities of contract labs
G State of Illinois General Use Water Quality Standard
s Required sensitivity
EPA U.S. EPA Methods for Chemical Analysis of Water and Wastes, March 1983
NA Not Applicable
SM Standard Methods of the Examination of Water and Wastewater, 20th Edition
S QA check is satisfactory, criteria met

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DATA ANALYSIS

Data presented in this memo were collected in August and September 2006 during low flow conditions, to support TMDL model development and to assess whether the stream segments meet or violate water quality standards for the parameters monitored. Table 10 presents a summary of the data compared to the appropriate water quality criteria, for each sampled segment. As shown in Table 10, recent data did not violate applicable water quality criteria for the segments and parameters listed below.

- East Branch Green Creek (CSB08) – manganese
- Second Salt Creek (CPD03) – silver
- Dieterich Creek (COC10) – silver, copper, manganese
- First Salt Creek (CPC-TU-C1) – manganese.
- Salt Creek (CP-TU-C3) – manganese

It is worth noting that the 303(d) listings for the first three segments above were based on data collected in 1991. The listings for First Salt Creek and Salt Creek for manganese were based on more recent data collected in 2001 and 1999, respectively.

Water quality violations were observed during at least one survey in the following eight stream segments:

- East Branch Green Creek (CSB08) – Dissolved oxygen violations
- East Branch Green Creek (CSB07) – Dissolved oxygen violations
- Second Salt Creek (CPD01) – Dissolved oxygen violations
- Second Salt Creek (CPD03) – Dissolved oxygen violations
- Second Salt Creek (CPD04) – Dissolved oxygen violations
- First Salt Creek (CPC-TU-C1) – Dissolved oxygen violations
- Salt Creek (CP-EF-C2)- Dissolved oxygen violations
- Little Wabash River (C19) – Total manganese and dissolved oxygen violations

As shown in Table 10, dissolved oxygen violations are noted at five of the seven locations where continuous dissolved oxygen monitoring was conducted. The continuous dissolved oxygen data are presented in Figures 3 through 9 and in Appendix 2.

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Table 10. Summary of Data Compared to Applicable Water Quality Criteria

Waterbody	Site ID	Applicable Water Quality Criterion	Round 1 Sampling[1]	Round 2 Sampling[2]	Continuous DO[3]
East Branch Green Creek (CSB08)					
Dissolved Oxygen	LWAB-1	5 mg/l minimum	OK	DO<5 mg/l	OK
Manganese, total	LWAB-1	1 mg/l	OK	OK	
East Branch Green Creek (CSB07)					
Dissolved Oxygen	LWAB-2	5 mg/l minimum	OK	DO<5 mg/l	
	LWAB-3		DO<5 mg/l	DO<5 mg/l	
	LWAB-4		OK	OK	48 of 102 DO measurements < 5 Avg. hourly DO<6 for 17 of 24 hrs
Second Salt Creek (CPD04)					
Dissolved Oxygen	LWAB-5	5 mg/l minimum	DO < 5 mg/l	DO < 5 mg/l	
Second Salt Creek (CPD03)					
Dissolved Oxygen	LWAB-6	5 mg/l minimum	DO < 5 mg/l	DO < 5 mg/l	
Silver, total	LWAB-6	5 ug/l	OK	OK	
Second Salt Creek (CPD01)					
Dissolved Oxygen	LWAB-7	5 mg/l minimum	DO < 5 mg/l	DO < 5 mg/l	100 of 100 DO measurements < 5 Avg. hourly DO<6 for 24 of 24 hrs
First Salt Creek (CPC-TU-C1)					
Dissolved Oxygen	LWAB-8	5 mg/l minimum	DO<5 mg/l	OK	
	LWAB-9		DO<5 mg/l	DO<5 mg/l	96 of 96 DO measurements < 5 Avg. hourly DO<6 for 16 of 22 hrs
	LWAB-10		DO<5 mg/l	DO<5 mg/l	
Manganese, total	LWAB-10	1 mg/l	OK	OK	
Salt Creek (CP-TU-C3)					
Manganese, total	LWAB-11	1 mg/l	OK	OK	

Waterbody	Site ID	Applicable Water Quality Criterion	Round 1 Sampling[1]	Round 2 Sampling[2]	Continuous DO[3]
Salt Creek (CP-EF-C2)					
Dissolved Oxygen	LWAB-12	5 mg/l minimum	DO<5 mg/l	OK	63 of 85 DO measurements < 5 Avg. hourly DO<6 for 24 of 24 hrs
	LWAB-13		OK	OK	
	LWAB-14		OK	OK	
Dieterich Creek (COC10)					
Silver, total	LWAB-15	5 ug/l	OK	OK	
Copper, dissolved[4]	LWAB-15	Exp[-1.465+ 0.8545*ln(hard)]*0.96	OK	OK	
Manganese, total	LWAB-15	1 mg/l	OK	OK	
Little Wabash River (C19)[5]					
Dissolved Oxygen	LWAB-16	5 mg/l minimum	OK	OK	
	LWAB-18		OK	OK	
	LWAB-19		OK	OK	OK
	LWAB-20		OK	OK	
	LWAB-23		OK	DO<5 mg/l	
	LWAB-24		DO<5 mg/l	OK	5 of 95 DO measurements < 5 Avg. hourly DO is OK
	LWAB-25		DO<5 mg/l	OK	
Manganese, total	LWAB-23	0.15 mg/l	Mn >.15 mg/l	Mn >.15 mg/l	

Notes:
1. First sampling round, conducted 8/24/06
2. Second sampling round, conducted 9/7/06
3. Continuous DO sampling conducted the week beginning 8/21/06
.
4. Chronic criteria for copper is presented, as it is lower than the acute criteria.
5. Only data collected on the mainstem of the Little Wabash are included in this analysis.
OK- data collected and water quality criteria were not violated
Blank cells indicates data were not collected during this sampling effort

APPENDIX 1.
Quality Assurance Project Plan

Available Upon Request

Contact Illinois EPA at 217-782-3362

APPENDIX 2.
Continuous Dissolved Oxygen Data

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Continuous Dissolved Oxygen (DO) Data - Little Wabash River Watershed

LWAB-1			LWAB-4			LWAB-7			LWAB-9		
Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]
8/21/2006 11:30	21.77	6.61	8/21/2006 13:30	24.22	6.4	8/21/2006 14:45	23.26	4.13	8/23/2006 19:50	24.98	4.89
8/21/2006 11:45	21.72	6.67	8/21/2006 13:45	24.31	6.31	8/21/2006 15:00	23.29	4.08	8/23/2006 20:05	24.92	4.74
8/21/2006 12:00	22	6.79	8/21/2006 14:00	24.54	6.34	8/21/2006 15:15	23.34	4.04	8/23/2006 20:20	24.85	4.58
8/21/2006 12:15	21.99	6.82	8/21/2006 14:15	24.81	6.42	8/21/2006 15:30	23.4	3.95	8/23/2006 20:35	24.79	4.52
8/21/2006 12:30	22.35	6.96	8/21/2006 14:30	25.04	6.52	8/21/2006 15:45	23.43	3.94	8/23/2006 20:50	24.73	4.3
8/21/2006 12:45	22.7	7.14	8/21/2006 14:45	25.17	6.52	8/21/2006 16:00	23.51	3.9	8/23/2006 21:05	24.66	4.22
8/21/2006 13:00	22.87	7.27	8/21/2006 15:00	25.16	6.56	8/21/2006 16:15	23.5	3.87	8/23/2006 21:20	24.6	4.32
8/21/2006 13:15	23.17	7.4	8/21/2006 15:15	25.25	6.54	8/21/2006 16:30	23.55	3.83	8/23/2006 21:35	24.54	4.06
8/21/2006 13:30	23.44	7.49	8/21/2006 15:30	25.37	6.55	8/21/2006 16:45	23.52	3.83	8/23/2006 21:50	24.49	3.95
8/21/2006 13:45	23.66	7.55	8/21/2006 15:45	25.49	6.62	8/21/2006 17:00	23.48	3.8	8/23/2006 22:05	24.43	3.89
8/21/2006 14:00	23.86	7.68	8/21/2006 16:00	25.52	6.68	8/21/2006 17:15	23.42	3.78	8/23/2006 22:20	24.37	3.85
8/21/2006 14:15	24	7.75	8/21/2006 16:15	25.57	6.68	8/21/2006 17:30	23.34	3.76	8/23/2006 22:35	24.32	3.79
8/21/2006 14:30	24.19	7.79	8/21/2006 16:30	25.55	6.67	8/21/2006 17:45	23.25	3.74	8/23/2006 22:50	24.26	3.79
8/21/2006 14:45	24.21	7.86	8/21/2006 16:45	25.53	6.68	8/21/2006 18:00	23.15	3.72	8/23/2006 23:05	24.21	3.71
8/21/2006 15:00	24.27	7.82	8/21/2006 17:00	25.46	6.59	8/21/2006 18:15	23.11	3.71	8/23/2006 23:20	24.15	3.68
8/21/2006 15:15	24.48	7.91	8/21/2006 17:15	25.33	6.59	8/21/2006 18:30	23.08	3.69	8/23/2006 23:35	24.1	3.65
8/21/2006 15:30	24.62	7.94	8/21/2006 17:30	25.25	6.48	8/21/2006 18:45	23.05	3.68	8/23/2006 23:50	24.03	3.59
8/21/2006 15:45	24.68	7.98	8/21/2006 17:45	25.2	6.49	8/21/2006 19:00	23.02	3.66	8/24/2006 0:05	23.99	3.54
8/21/2006 16:00	24.73	7.97	8/21/2006 18:00	24.97	6.46	8/21/2006 19:15	22.99	3.65	8/24/2006 0:20	23.93	3.54
8/21/2006 16:15	24.84	8.04	8/21/2006 18:15	24.88	6.22	8/21/2006 19:30	22.95	3.62	8/24/2006 0:35	23.87	3.53
8/21/2006 16:30	24.86	7.98	8/21/2006 18:30	24.76	6.16	8/21/2006 19:45	22.92	3.61	8/24/2006 0:50	23.83	3.47
8/21/2006 16:45	24.73	7.91	8/21/2006 18:45	24.58	6.01	8/21/2006 20:00	22.87	3.59	8/24/2006 1:05	23.77	3.45
8/21/2006 17:00	24.74	7.86	8/21/2006 19:00	24.44	5.9	8/21/2006 20:15	22.81	3.58	8/24/2006 1:20	23.69	3.43
8/21/2006 17:15	24.8	7.84	8/21/2006 19:15	24.27	5.78	8/21/2006 20:30	22.76	3.55	8/24/2006 1:35	23.65	3.42
8/21/2006 17:30	24.79	7.79	8/21/2006 19:30	24.12	5.63	8/21/2006 20:45	22.69	3.55	8/24/2006 1:50	23.59	3.41
8/21/2006 17:45	24.73	7.71	8/21/2006 19:45	23.99	5.6	8/21/2006 21:00	22.62	3.52	8/24/2006 2:05	23.52	3.41
8/21/2006 18:00	24.68	7.6	8/21/2006 20:00	23.84	5.5	8/21/2006 21:15	22.55	3.53	8/24/2006 2:20	23.47	3.39
8/21/2006 18:15	24.64	7.56	8/21/2006 20:15	23.73	5.34	8/21/2006 21:30	22.49	3.54	8/24/2006 2:35	23.41	3.36
8/21/2006 18:30	24.61	7.47	8/21/2006 20:30	23.61	5.3	8/21/2006 21:45	22.43	3.52	8/24/2006 2:50	23.35	3.36
8/21/2006 18:45	24.57	7.41	8/21/2006 20:45	23.51	5.24	8/21/2006 22:00	22.36	3.54	8/24/2006 3:05	23.29	3.36
8/21/2006 19:00	24.53	7.35	8/21/2006 21:00	23.41	5.18	8/21/2006 22:15	22.29	3.52	8/24/2006 3:20	23.23	3.36
8/21/2006 19:15	24.49	7.32	8/21/2006 21:15	23.31	5.12	8/21/2006 22:30	22.22	3.51	8/24/2006 3:35	23.19	3.32
8/21/2006 19:30	24.45	7.28	8/21/2006 21:30	23.23	5.1	8/21/2006 22:45	22.17	3.49	8/24/2006 3:50	23.13	3.33
8/21/2006 19:45	24.39	7.23	8/21/2006 21:45	23.15	5.06	8/21/2006 23:00	22.11	3.46	8/24/2006 4:05	23.07	3.32
8/21/2006 20:00	24.32	7.15	8/21/2006 22:00	23.05	5.06	8/21/2006 23:15	22.04	3.46	8/24/2006 4:20	23.03	3.27
8/21/2006 20:15	24.25	7.13	8/21/2006 22:15	22.98	4.96	8/21/2006 23:30	21.98	3.47	8/24/2006 4:35	22.97	3.32
8/21/2006 20:30	24.16	7.07	8/21/2006 22:30	22.89	4.98	8/21/2006 23:45	21.92	3.46	8/24/2006 4:50	22.91	3.32
8/21/2006 20:45	24.07	7.05	8/21/2006 22:45	22.81	4.93	8/22/2006 0:00	21.87	3.46	8/24/2006 5:05	22.87	3.3
8/21/2006 21:00	23.99	7.02	8/21/2006 23:00	22.74	4.84	8/22/2006 0:15	21.8	3.47	8/24/2006 5:20	22.82	3.3
8/21/2006 21:15	23.91	6.98	8/21/2006 23:15	22.65	4.82	8/22/2006 0:30	21.74	3.48	8/24/2006 5:35	22.75	3.32
8/21/2006 21:30	23.84	7	8/21/2006 23:30	22.59	4.76	8/22/2006 0:45	21.68	3.48	8/24/2006 5:50	22.71	3.29
8/21/2006 21:45	23.77	6.94	8/21/2006 23:45	22.51	4.82	8/22/2006 1:00	21.62	3.47	8/24/2006 6:05	22.65	3.3
8/21/2006 22:00	23.68	6.92	8/22/2006 0:00	22.44	4.76	8/22/2006 1:15	21.57	3.49	8/24/2006 6:20	22.6	3.28
8/21/2006 22:15	23.61	6.9	8/22/2006 0:15	22.37	4.68	8/22/2006 1:30	21.51	3.47	8/24/2006 6:35	22.55	3.3
8/21/2006 22:30	23.52	6.86	8/22/2006 0:30	22.3	4.59	8/22/2006 1:45	21.46	3.48	8/24/2006 6:50	22.52	3.28
8/21/2006 22:45	23.43	6.85	8/22/2006 0:45	22.22	4.66	8/22/2006 2:00	21.39	3.48	8/24/2006 7:05	22.46	3.3
8/21/2006 23:00	23.35	6.79	8/22/2006 1:00	22.15	4.67	8/22/2006 2:15	21.33	3.49	8/24/2006 7:20	22.44	3.29
8/21/2006 23:15	23.27	6.78	8/22/2006 1:15	22.09	4.63	8/22/2006 2:30	21.25	3.49	8/24/2006 7:35	22.4	3.33
8/21/2006 23:30	23.18	6.75	8/22/2006 1:30	22.02	4.64	8/22/2006 2:45	21.22	3.48	8/24/2006 7:50	22.39	3.34
8/21/2006 23:45	23.09	6.71	8/22/2006 1:45	21.94	4.55	8/22/2006 3:00	21.15	3.49	8/24/2006 8:05	22.38	3.32
8/22/2006 0:00	23	6.67	8/22/2006 2:00	21.89	4.58	8/22/2006 3:15	21.09	3.49	8/24/2006 8:20	22.37	3.34
8/22/2006 0:15	22.9	6.61	8/22/2006 2:15	21.81	4.61	8/22/2006 3:30	21.04	3.5	8/24/2006 8:35	22.38	3.36
8/22/2006 0:30	22.8	6.6	8/22/2006 2:30	21.76	4.57	8/22/2006 3:45	20.98	3.49	8/24/2006 8:50	22.39	3.39
8/22/2006 0:45	22.71	6.6	8/22/2006 2:45	21.69	5.08	8/22/2006 4:00	20.91	3.5	8/24/2006 9:05	22.4	3.44
8/22/2006 1:00	22.63	6.57	8/22/2006 3:00	21.64	4.74	8/22/2006 4:15	20.86	3.5	8/24/2006 9:20	22.43	3.53
8/22/2006 1:15	22.54	6.5	8/22/2006 3:15	21.58	4.52	8/22/2006 4:30	20.78	3.5	8/24/2006 9:35	22.45	3.56
8/22/2006 1:30	22.45	6.51	8/22/2006 3:30	21.51	4.6	8/22/2006 4:45	20.73	3.51	8/24/2006 9:50	22.48	3.61
8/22/2006 1:45	22.35	6.47	8/22/2006 3:45	21.45	4.5	8/22/2006 5:00	20.68	3.5	8/24/2006 10:05	22.53	3.73
8/22/2006 2:00	22.26	6.44	8/22/2006 4:00	21.39	4.51	8/22/2006 5:15	20.61	3.53	8/24/2006 10:20	22.59	3.86
8/22/2006 2:15	22.17	6.47	8/22/2006 4:15	21.33	4.53	8/22/2006 5:30	20.57	3.52	8/24/2006 10:35	22.69	4.16
8/22/2006 2:30	22.08	6.45	8/22/2006 4:30	21.24	4.5	8/22/2006 5:45	20.5	3.53	8/24/2006 10:50	22.77	4.34
8/22/2006 2:45	21.99	6.42	8/22/2006 4:45	21.2	35.57	8/22/2006 6:00	20.46	3.49	8/24/2006 11:05	22.83	4.46
8/22/2006 3:00	21.9	6.44	8/22/2006 5:00	21.14	4.55	8/22/2006 6:15	20.39	3.5	8/24/2006 11:20	23	4.84
8/22/2006 3:15	21.81	6.38	8/22/2006 5:15	21.07	4.62	8/22/2006 6:30	20.33	3.48	8/24/2006 11:35	23.17	5.31
8/22/2006 3:30	21.73	6.4	8/22/2006 5:30	21.01	4.59	8/22/2006 6:45	20.28	3.48	8/24/2006 11:50	23.22	5.39
8/22/2006 3:45	21.64	6.41	8/22/2006 5:45	20.96	4.6	8/22/2006 7:00	20.22	3.52	8/24/2006 12:05	23.21	5.29
8/22/2006 4:00	21.54	6.36	8/22/2006 6:00	20.9	4.6	8/22/2006 7:15	20.22	3.53	8/24/2006 12:20	23.28	5.25
8/22/2006 4:15	21.45	6.4	8/22/2006 6:15	20.83	4.61	8/22/2006 7:30	20.21	3.51	8/24/2006 12:35	23.37	5.25
8/22/2006 4:30	21.36	6.36	8/22/2006 6:30	20.76	4.57	8/22/2006 7:45	20.21	3.51	8/24/2006 12:50	23.59	5.9
8/22/2006 4:45	21.28	6.33	8/22/2006 6:45	20.72	4.54	8/22/2006 8:00	20.21	3.54	8/24/2006 13:05	23.61	5.72
8/22/2006 5:00	21.2	6.31	8/22/2006 7:00	20.66	4.63	8/22/2006 8:15	20.23	3.52	8/24/2006 13:20	23.78	6.31
8/22/2006 5:15	21.11	6.35	8/22/2006 7:15	20.62	4.56	8/22/2006 8:30	20.26	3.52	8/24/2006 13:35	23.99	6.64
8/22/2006 5:30	21.04	6.29	8/22/2006 7:30	20.58	4.64	8/22/2006 8:45	20.32	3.52	8/24/2006 13:50	23.98	6.71
8/22/2006 5:45	20.97	6.32	8/22/2006 7:45	20.53	4.75	8/22/2006 9:00	20.36	3.55	8/24/2006 14:05	24.07	6.83
8/22/2006 6:00	20.9	6.32	8/22/2006 8:00	20.51	4.74	8/22/2006 9:15	20.43	3.53	8/24/2006 14:20	24.25	7.3
8/22/2006 6:15	20.83	6.31	8/22/2006 8:15	20.47	4.69	8/22/2006 9:30	20.51	3.56	8/24/2006 14:35	24.36	7.3
8/22/2006 6:30	20.75	6.27	8/22/2006 8:30	20.45	4.68	8/22/2006 9:45	20.62	3.57	8/24/2006 14:50	24.54	7.58
8/22/2006 6:45	20.7	6.31	8/22/2006 8:45	20.44	4.76	8/22/2006 10:00	20.78	3.59	8/24/2006 15:05	24.5	7.21
8/22/2006 7:00	20.64	6.27	8/22/2006 9:00	20.45	4.76	8/22/2006 10:15	20.97	3.61	8/24/2006 15:20	24.58	7.62
8/22/2006 7:15	20.58	6.34	8/22/2006 9:15	20.44	4.91	8/22/2006 10:30	21.17	3.63	8/24/2006 15:35	24.66	7.68
8/22/2006 7:30	20.54	6.35	8/22/2006 9:30	20.47	4.89	8/22/2006 10:45	21.31	3.65	8/24/2006 15:50	24.68	7.54
8/22/2006 7:45	20.52	6.36	8/22/2006 9:45	20.51	5.02	8/22/2006 11:00	21.41	3.64	8/24/2006 16:05	24.77	7.53
8/22/2006 8:00	20.5	6.38	8/22/2006 10:00	20.56	4.94	8/22/2006 11:15	21.51	3.65	8/24/2006 16:20	24.88	7.77
8/22/2006 8:15	20.49	6.41	8/22/2006 10:15	20.65	4.8	8/22/2006 11:30	21.6	3.64	8/24/2006 16:35	25.07	7.31
8/22/2006 8:30	20.5	6.48	8/22/2006 10:30	20.8	4.45	8/22/2006 11:45	21.72	3.61	8/24/2006 16:50	25.68	7.66
8/22/2006 8:45	20.53	6.52	8/22/2006 10:45	20.92	4.91	8/22/2006 12:00	21.84	3.56			
8/22/2006 9:00	20.6	6.56	8/22/2006 11:00	21.12	5.25	8/22/2006 12:15	22.11	3.58			
8/22/2006 9:15	20.72	6.72	8/22/2006 11:15	21.25	5.22	8/22/2006 12:30	22.26	3.6			
8/22/2006 9:30	20.83	6.57	8/22/2006 11:30	21.47	5.37	8/22/2006 12:45	22.43	3.58			
8/22/2006 9:45	20.95	6.56	8/22/2006 11:45	21.51	5.38	8/22/2006 13:00	22.56	3.6			
8/22/2006 10:00	21	6.4	8/22/2006 12:00	21.71	5.46	8/22/2006 13:15	22.72	3.61			
8/22/2006 10:15	21	6.3	8/22/2006 12:15	21.88	5.5	8/22/2006 13:30	22.97	3.65			
8/22/2006 10:30	21.15	6.36	8/22/2006 12:30	22.06	5.74	8/22/2006 13:45	23.14	3.64			
8/22/2006 10:45	21.28	6.52	8/22/2006 12:45	22.29	5.9	8/22/2006 14:00	23.22	3.63			
8/22/2006 11:00	21.38	6.53	8/22/2006 13:00	22.55	5.52	8/22/2006 14:15	23.28	3.62			
8/22/2006 11:15	21.55	6.64	8/22/2006 13:15	22.7	6.65	8/22/2006 14:30	23.34	3.63			
8/22/2006 11:30	21.89	7.13	8/22/2006 13:30	23.11	6.59	8/22/2006 14:45	23.49	3.66			
8/22/2006 11:45	22.06	7.18	8/22/2006 13:45	23.3	6.87	8/22/2006 15:00	23.47	3.66			
8/22/2006 12:00	22.06	7.16	8/22/2006 14:00	23.54	7.34	8/22/2006 15:15	23.48	3.61			
8/22/2006 12:15	22.24	7.09	8/22/2006 14:15	23.69	7.59	8/22/2006 15:30	23.42	3.66			
8/22/2006 12:30	22.41	7.19	8/22/2006 14:30	23.97	7.84						
8/22/2006 12:45	23.27	7.13	8/22/2006 14:45	24.19	8.06						

Continuous Dissolved Oxygen (DO) Data - Little Wabash River Watershed

LWAB-12			LWAB-19			LWAB-24		
Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]
8/22/2006 18:05	23.08	4.59	8/22/2006 19:45	25.15	7.67	8/23/2006 9:00	24.69	4.86
8/22/2006 18:20	22.94	4.55	8/22/2006 20:00	25.16	7.12	8/23/2006 9:15	24.7	4.73
8/22/2006 18:35	22.95	4.52	8/22/2006 20:15	25.13	7.12	8/23/2006 9:30	24.66	4.72
8/22/2006 18:50	22.96	4.46	8/22/2006 20:30	25.11	7.04	8/23/2006 9:45	24.77	4.88
8/22/2006 19:05	22.97	4.42	8/22/2006 20:45	25.08	6.85	8/23/2006 10:00	24.77	4.84
8/22/2006 19:20	22.97	4.39	8/22/2006 21:00	25.06	6.84	8/23/2006 10:15	24.81	5.02
8/22/2006 19:35	22.95	4.36	8/22/2006 21:15	25.03	6.81	8/23/2006 10:30	24.86	5.09
8/22/2006 19:50	22.95	4.34	8/22/2006 21:30	25	6.66	8/23/2006 10:45	24.99	5.26
8/22/2006 20:05	22.92	4.31	8/22/2006 21:45	24.97	6.62	8/23/2006 11:00	24.96	5.25
8/22/2006 20:20	22.9	4.29	8/22/2006 22:00	24.93	6.62	8/23/2006 11:15	24.99	5.35
8/22/2006 20:35	22.87	4.28	8/22/2006 22:15	24.9	6.61	8/23/2006 11:30	24.97	5.22
8/22/2006 20:50	22.83	4.26	8/22/2006 22:30	24.86	6.58	8/23/2006 11:45	24.98	5.33
8/22/2006 21:05	22.8	4.25	8/22/2006 22:45	24.82	6.52	8/23/2006 12:00	25.09	5.34
8/22/2006 21:20	22.76	4.23	8/22/2006 23:00	24.78	6.52	8/23/2006 12:15	25.1	5.32
8/22/2006 21:35	22.72	4.22	8/22/2006 23:15	24.75	6.33	8/23/2006 12:30	25.23	5.47
8/22/2006 21:50	22.67	4.22	8/22/2006 23:30	24.71	6.46	8/23/2006 12:45	25.3	5.56
8/22/2006 22:05	22.63	4.2	8/22/2006 23:45	24.68	6.4	8/23/2006 13:00	25.29	5.47
8/22/2006 22:20	22.57	4.2	8/23/2006 0:00	24.64	6.34	8/23/2006 13:15	25.39	5.55
8/22/2006 22:35	22.53	4.19	8/23/2006 0:15	24.61	6.35	8/23/2006 13:30	25.41	5.69
8/22/2006 22:50	22.47	4.16	8/23/2006 0:30	24.58	6.25	8/23/2006 13:45	25.51	5.72
8/22/2006 23:05	22.43	4.18	8/23/2006 0:45	24.55	6.25	8/23/2006 14:00	25.53	5.71
8/22/2006 23:20	22.38	4.17	8/23/2006 1:00	24.51	6.28	8/23/2006 14:15	25.61	5.77
8/22/2006 23:35	22.34	4.17	8/23/2006 1:15	24.48	6.24	8/23/2006 14:30	25.63	5.96
8/22/2006 23:50	22.28	4.16	8/23/2006 1:30	24.45	6.08	8/23/2006 14:45	25.66	5.95
8/23/2006 0:05	22.25	4.15	8/23/2006 1:45	24.42	6.2	8/23/2006 15:00	25.68	5.94
8/23/2006 0:20	22.19	4.15	8/23/2006 2:00	24.39	6.19	8/23/2006 15:15	25.71	6.08
8/23/2006 0:35	22.15	4.14	8/23/2006 2:15	24.36	6.17	8/23/2006 15:30	25.7	5.98
8/23/2006 0:50	22.1	4.14	8/23/2006 2:30	24.33	6.06	8/23/2006 15:45	25.79	6.19
8/23/2006 1:05	22.05	4.15	8/23/2006 2:45	24.29	6.1	8/23/2006 16:00	25.79	6.19
8/23/2006 1:20	21.99	4.14	8/23/2006 3:00	24.27	6.08	8/23/2006 16:15	25.86	6.3
8/23/2006 1:35	21.95	4.14	8/23/2006 3:15	24.22	5.88	8/23/2006 16:30	25.85	6.36
8/23/2006 1:50	21.9	4.15	8/23/2006 3:30	24.19	5.87	8/23/2006 16:45	25.88	6.47
8/23/2006 2:05	21.86	4.14	8/23/2006 3:45	24.15	5.82	8/23/2006 17:00	25.94	6.54
8/23/2006 2:20	21.82	4.14	8/23/2006 4:00	24.12	5.88	8/23/2006 17:15	26	6.54
8/23/2006 2:35	21.77	4.14	8/23/2006 4:15	24.08	5.93	8/23/2006 17:30	26.05	6.65
8/23/2006 2:50	21.72	4.15	8/23/2006 4:30	24.04	5.99	8/23/2006 17:45	26.09	6.79
8/23/2006 3:05	21.66	4.16	8/23/2006 4:45	24	5.89	8/23/2006 18:00	26.1	6.69
8/23/2006 3:20	21.63	4.15	8/23/2006 5:00	23.97	5.89	8/23/2006 18:15	26.12	6.69
8/23/2006 3:35	21.59	4.14	8/23/2006 5:15	23.93	5.79	8/23/2006 18:30	26.15	6.72
8/23/2006 3:50	21.55	4.14	8/23/2006 5:30	23.9	5.69	8/23/2006 18:45	26.19	6.78
8/23/2006 4:05	21.49	4.15	8/23/2006 5:45	23.86	5.77	8/23/2006 19:00	26.24	6.82
8/23/2006 4:20	21.45	4.14	8/23/2006 6:00	23.82	5.68	8/23/2006 19:15	26.28	6.83
8/23/2006 4:35	21.4	4.15	8/23/2006 6:15	23.79	5.72	8/23/2006 19:30	26.34	6.84
8/23/2006 4:50	21.36	4.16	8/23/2006 6:30	23.76	5.68	8/23/2006 19:45	26.39	6.86
8/23/2006 5:05	21.31	4.16	8/23/2006 6:45	23.73	5.69	8/23/2006 20:00	26.43	6.84
8/23/2006 5:20	21.27	4.16	8/23/2006 7:00	23.71	5.66	8/23/2006 20:15	26.48	6.78
8/23/2006 5:35	21.23	4.15	8/23/2006 7:15	23.69	5.69	8/23/2006 20:30	26.51	6.78
8/23/2006 5:50	21.18	4.15	8/23/2006 7:30	23.67	5.65	8/23/2006 20:45	26.53	6.79
8/23/2006 6:05	21.13	4.16	8/23/2006 7:45	23.66	5.55	8/23/2006 21:00	26.55	6.77
8/23/2006 6:20	21.09	4.15	8/23/2006 8:00	23.64	5.57	8/23/2006 21:15	26.56	6.68
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8/23/2006 6:50	21.02	4.15	8/23/2006 8:30	23.64	5.65	8/23/2006 21:45	26.54	6.64
8/23/2006 7:05	20.99	4.14	8/23/2006 8:45	23.65	5.6	8/23/2006 22:00	26.5	6.62
8/23/2006 7:20	20.98	4.14	8/23/2006 9:00	23.67	5.74	8/23/2006 22:15	26.46	6.49
8/23/2006 7:35	20.98	4.14	8/23/2006 9:15	23.69	5.67	8/23/2006 22:30	26.42	6.45
8/23/2006 7:50	20.98	4.13	8/23/2006 9:30	23.71	5.75	8/23/2006 22:45	26.38	6.4
8/23/2006 8:05	21.01	4.13	8/23/2006 9:45	23.74	5.79	8/23/2006 23:00	26.32	6.3
8/23/2006 8:20	21.04	4.11	8/23/2006 10:00	23.78	5.81	8/23/2006 23:15	26.27	6.3
8/23/2006 8:35	21.07	4.11	8/23/2006 10:15	23.82	5.92	8/23/2006 23:30	26.21	6.24
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8/23/2006 9:05	21.17	4.11	8/23/2006 10:45	23.93	5.97	8/24/2006 0:00	26.12	6.14
8/23/2006 9:20	21.21	4.12	8/23/2006 11:00	23.98	5.93	8/24/2006 0:15	26.04	6.15
8/23/2006 9:35	21.27	4.13	8/23/2006 11:15	24.05	6.07	8/24/2006 0:30	26	6.04
8/23/2006 9:50	21.33	4.13	8/23/2006 11:30	24.09	6.04	8/24/2006 0:45	25.94	6.06
8/23/2006 10:05	21.4	4.15	8/23/2006 11:45	24.15	6.08	8/24/2006 1:00	25.88	6
8/23/2006 10:20	21.45	4.15	8/23/2006 12:00	24.2	6.08	8/24/2006 1:15	25.83	5.98
8/23/2006 10:35	21.55	4.16	8/23/2006 12:15	24.26	6.14	8/24/2006 1:30	25.78	5.94
8/23/2006 10:50	21.65	4.17	8/23/2006 12:30	24.33	6.12	8/24/2006 1:45	25.72	5.94
8/23/2006 11:05	21.78	4.17	8/23/2006 12:45	24.39	6.4	8/24/2006 2:00	25.67	5.89
8/23/2006 11:20	21.94	4.19	8/23/2006 13:00	24.46	6.39	8/24/2006 2:15	25.6	5.85
8/23/2006 11:35	22.1	4.23	8/23/2006 13:15	24.54	6.39	8/24/2006 2:30	25.54	5.76
8/23/2006 11:50	22.29	4.25	8/23/2006 13:30	24.62	6.45	8/24/2006 2:45	25.49	5.76
8/23/2006 12:05	22.43	4.29	8/23/2006 13:45	24.69	6.6	8/24/2006 3:00	25.44	5.73
8/23/2006 12:20	22.55	4.31	8/23/2006 14:00	24.76	6.68	8/24/2006 3:15	25.35	5.71
8/23/2006 12:35	22.68	4.3	8/23/2006 14:15	24.8	6.72	8/24/2006 3:30	25.29	5.74
8/23/2006 12:50	22.82	4.32	8/23/2006 14:30	24.84	6.58	8/24/2006 3:45	25.24	5.62
8/23/2006 13:05	22.94	4.36	8/23/2006 14:45	24.86	6.7	8/24/2006 4:00	25.17	5.73
8/23/2006 13:20	23.07	4.38	8/23/2006 15:00	24.91	6.73	8/24/2006 4:15	25.11	5.68
8/23/2006 13:35	23.15	4.39	8/23/2006 15:15	24.95	6.72	8/24/2006 4:30	25.05	5.72
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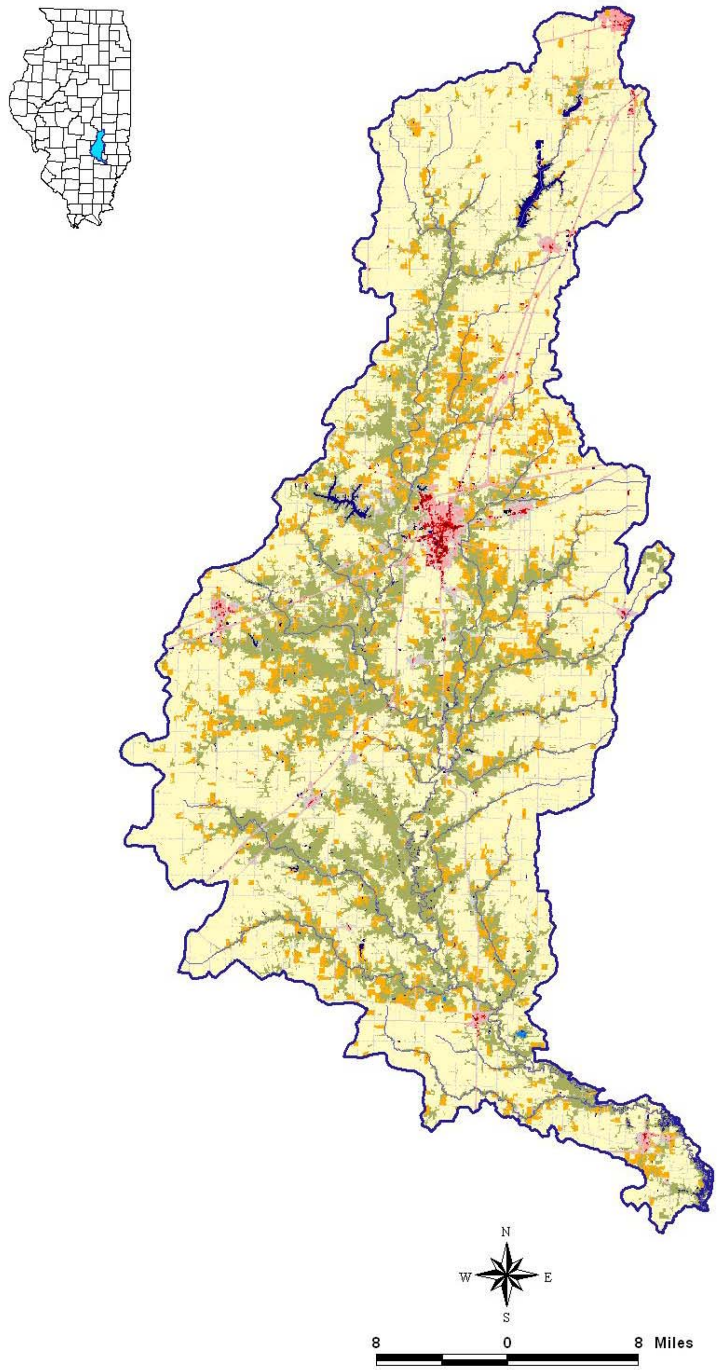
8/23/2006 14:05	23.45	4.4				8/24/2006 5:00	24.95	5.69
8/23/2006 14:20	23.55	4.41				8/24/2006 5:15	24.91	5.61
8/23/2006 14:35	23.54	4.42				8/24/2006 5:30	24.85	5.65
8/23/2006 14:50	23.49	4.39				8/24/2006 5:45	24.82	5.63
8/23/2006 15:05	23.5	4.38				8/24/2006 6:00	24.79	5.61
8/23/2006 15:20	23.55	4.36				8/24/2006 6:15	24.74	5.64
8/23/2006 15:35	23.61	4.33				8/24/2006 6:30	24.72	5.58
8/23/2006 15:50	23.66	4.32				8/24/2006 6:45	24.68	5.67
8/23/2006 16:05	23.69	4.29				8/24/2006 7:00	24.65	5.63
8/23/2006 16:20	23.69	4.3				8/24/2006 7:15	24.63	5.65
8/23/2006 16:35	23.7	4.28				8/24/2006 7:30	24.6	5.74
8/23/2006 16:50	23.72	4.26				8/24/2006 7:45	24.58	5.67
8/23/2006 17:05	23.73	4.23				8/24/2006 8:00	24.56	5.72
8/23/2006 17:20	23.75	4.21				8/24/2006 8:15	24.57	5.68
8/23/2006 17:35	23.77	4.2				8/24/2006 8:30	24.56	5.73
8/23/2006 17:50	23.77	4.19						

TMDL Development for the Little Wabash River Watershed, Illinois

Final Report
August 29, 2007



TETRA TECH

Illinois Environmental Protection Agency

TMDL Development for the Little Wabash River Watershed, Illinois

FINAL REPORT

August 29, 2007

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

Submitted by:
Tetra Tech, Inc.
Water Resources TMDL Center

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TABLE OF CONTENTS

FIGURES

TABLES

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 Little Wabash River 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 was completed by the consulting firm Limno-Tech, Inc. in September 2006 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 F).
2) Stage 2 was completed by Limno-Tech in November 2006 and involved the collection of additional chemical water quality and continuous dissolved oxygen data as well channel morphology and discharge measurements at twenty-five monitoring locations (Figure 1 and **Error! Reference source not found.)**.
3) This report addresses Stage 3 of the project which involves modeling and TMDL analysis of the parameters of concern for the Little Wabash impaired segments. Stage 3 will also include the development of a project implementation plan, to be completed during Fall 2007.

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.

- Little Wabash River segment C-19 is being considered for de-listing for the pH impairment due to newer ambient data that showed no recent violations of the water quality standard. The original listing was made based on one of the 31 samples between January 2000 and January 2004 that was less than the minimum pH criterion.

- East Branch Green Creek was originally listed as impaired for manganese. However, additional data collected in 2006 indicated no exceedances of the manganese water quality standard (**Error! Reference source not found.** and Table 1) and this segment will be recommended for de-listing in the 2008 Integrated Report. No TMDL has therefore been developed.

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

- Dieterich Creek was originally listed as impaired for silver, copper, and manganese. However, additional data collected in 2006 indicated no exceedances of the silver, copper, and manganese water quality standards (Table 1 and Table 2) and this segment will be recommended for de-listing in the 2008 Integrated Report. No TMDL has therefore been developed.

- First Salt Creek 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.

- Salt Creek 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 Little Wabash Segments

Segment and Segment ID	Parameter	Standard	Original Listing Violation # exceed/#sample	Original Violation Value (µg/l)	2006 Stage 2 Data Round 1 (µg/l)	2006 Stage 2 Data Round 2 (µg/l)
E. Branch Green Creek (CSB08)	Manganese	1,000 µg/l	1 of 3 (1991)	1,687	90	690
Second Salt Creek (CPD03)	Silver	5 µg/l	1 of 3 (1991)	7	<0.2 (detection limit)	<0.2 (detection limit)
Dieterich Creek (COC10)	Silver	5 µg/l	1 of 3 (1991)	8	<0.2 (detection limit)	<0.2 (detection limit)
	Copper	acute/chronic see Table 2	1 of 3 (1991)	28	4	5
	Manganese	1,000 µg/l	1 of 3 (1991)	2,844	80	30
First Salt Creek (CPC-TU-C1)	Manganese	1,000 µg/l	1 of 4 (1999)	2,000	440	410
Salt Creek (CP-TU-C3)	Manganese	1,000 µg/l	1 of 1 (1999)	1,300	200	140

Table 2. Copper Samples and Standards

IEPA Station_ID	Date	Parameter	Result (µg/l)	Chronic Copper Criteria (µg/l)	Acute Copper Criteria (µg/l)	Hardness (mg/l)	Hardness notes
COC 10	10/30/1991	Copper, Total	<5	10.0	14.8	86	measured
COC 10	4/19/1991	Copper, Total	<5	21.4	34.2	210	measured
COC 10	8/6/1991	Copper, Total	28	11.4	17.0	100	measured
COC 10	8/24/2006	Copper, Dissolved	4	10.0	14.8	86	Not available; hardness estimated based on most conservative 1991 value
COC 10	9/7/2006	Copper, Dissolved	5	10.0	14.8	86	Not available; hardness estimated based on most conservative 1991 value

2.0 BACKGROUND

The Little Wabash River watershed has a drainage area of approximately 1131 square miles and is an 8 digit hydrologic unit code (05120114) as defined by USGS Geological Survey (USGS). The watershed is located in south-eastern Illinois flowing south to the Wabash River (Figure 1). The portion of the watershed addressed in this report has a drainage area of 805 square miles and encompasses eight counties with Effingham County covering 47.5 percent of the watershed followed by Clay (24%), Shelby (14%), Coles (5%), Cumberland (4%), and Fayette (4%). Small portions of the watershed also lie in Marion (1%) and Jasper (0.5%) counties. The Little Wabash River initiates its journey from south-western Coles County and flows approximately 237 miles south and east to its confluence with the Wabash River near New Haven, a point approximately 13 miles upstream from the Ohio River (IEPA, 1993). Major tributaries to the Little Wabash include West Branch, Green Creek, Second Creek, Big Creek North, Fulfer Creek, Salt Creek, Bishop Creek, Lucas Creek, Dismal Creek, Crooked Creek, Panther Creek, and Buck Creek. Agriculture is the dominant land use in this watershed (Figure 2).

Table 3 identifies the Little Wabash River's impaired segments, 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. For example, several lakes in the watershed are 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 target reductions in loads of suspended solids.

Table 3. 2006 303(d) List Information for the Little Wabash River Watershed. Bold font indicates cause will be addressed by a TMDL in this report

Waterbody Name	Waterbody Segment	Segment and Lake Size (Segment Length in Miles, Lake Area in Acres)	Cause of Impairment	Impaired Designated Use
Little Wabash River	C-19	57.17	**Dissolved Oxygen**	Aquatic Life
			Manganese	Public Water Supplies
			Total Fecal Coliform	Primary Contact Recreation
			Atrazine	Aquatic Life
			pH	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Little Wabash River	C-21	31.12	**Manganese**	Public Water Supplies
			Total Fecal Coliform	Primary Contact Recreation
First Salt Creek	CPC-TU-C1	1.45	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life

Waterbody Name	Waterbody Segment	Segment and Lake Size (Segment Length in Miles, Lake Area in Acres)	Cause of Impairment	Impaired Designated Use
Second Salt Creek	CPD-04	2.92	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Second Salt Creek	CPD-03	1.39	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Second Salt Creek	CPD-01	2.67	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Salt Creek	CP-EF-C2	2.34	**Dissolved Oxygen**	Aquatic Life
			Total Nitrogen	Aquatic Life
			Total Phosphorus	Aquatic Life
East Branch Green Creek	CSB-08	5.64	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
East Branch Green Creek	CSB-07	3.23	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Lake Paradise	RCG	176	**Total Phosphorus**	Aesthetic Quality & Aquatic Life
			pH	Aquatic Life
			Total Nitrogen	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
Lake Mattoon	RCF	1,010[a]	**Total Phosphorus**	Aesthetic Quality
			Total Suspended Solids	Aesthetic Quality
Lake Sara	RCE	765	**Total Phosphorus**	Aesthetic Quality
			Manganese	Public Water Supplies
			Total Suspended Solids	Aesthetic Quality

[a] The surface area for Lake Mattoon has been reported as a variety of values over the years, ranging from 750 acres (Mattoon Public Water Supply) to 1,027 (Bogner, 2003) with IEPA traditionally reporting the surface area as 765 acres. However, IEPA re-calculated the surface area as 1,010 acres for this study using the most recent aerial photo and the Illinois Transmercator geographic information system projection and this value was used for the modeling and TMDL development.

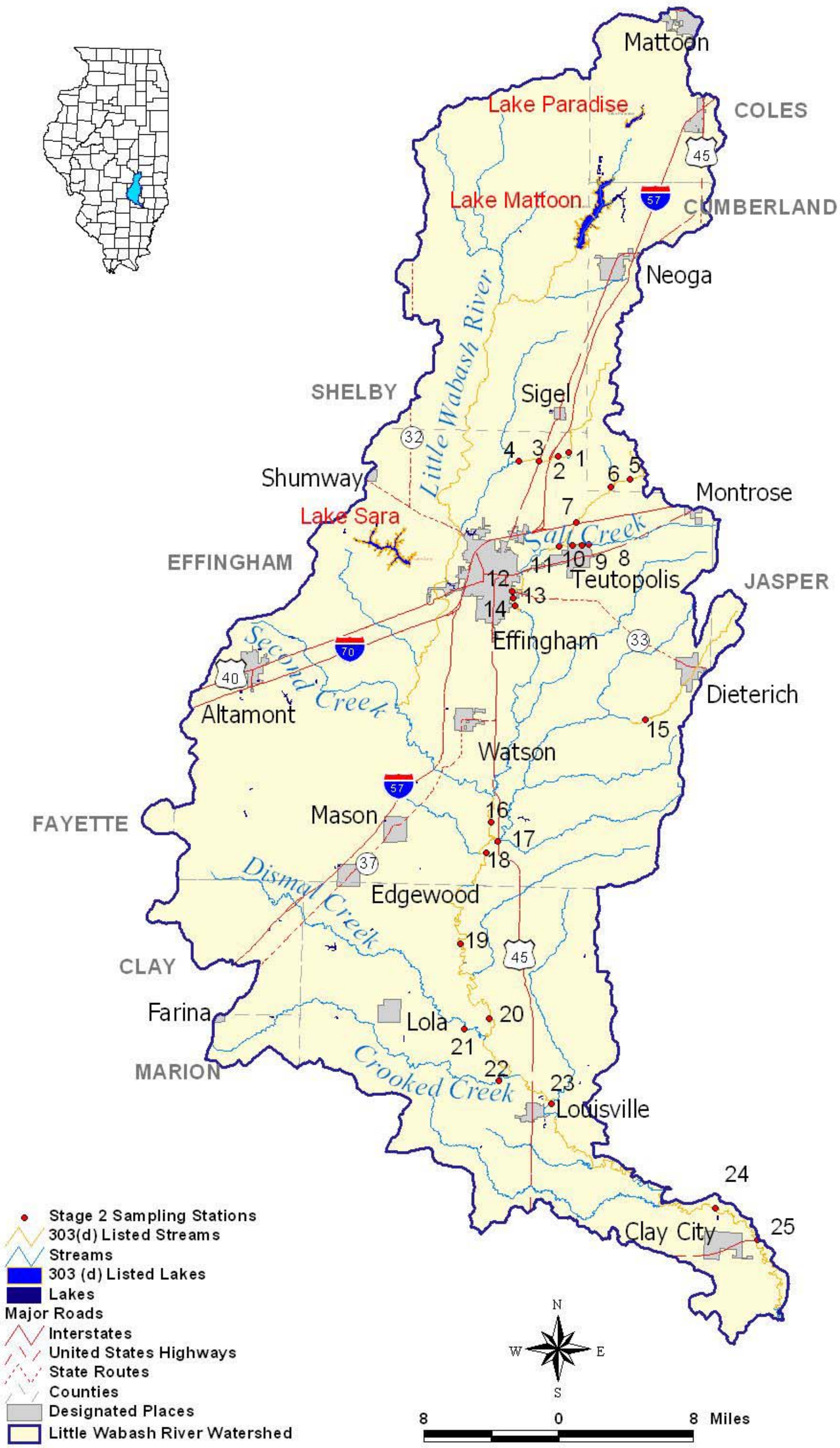

Figure 1. Location of the Little Wabash Watershed

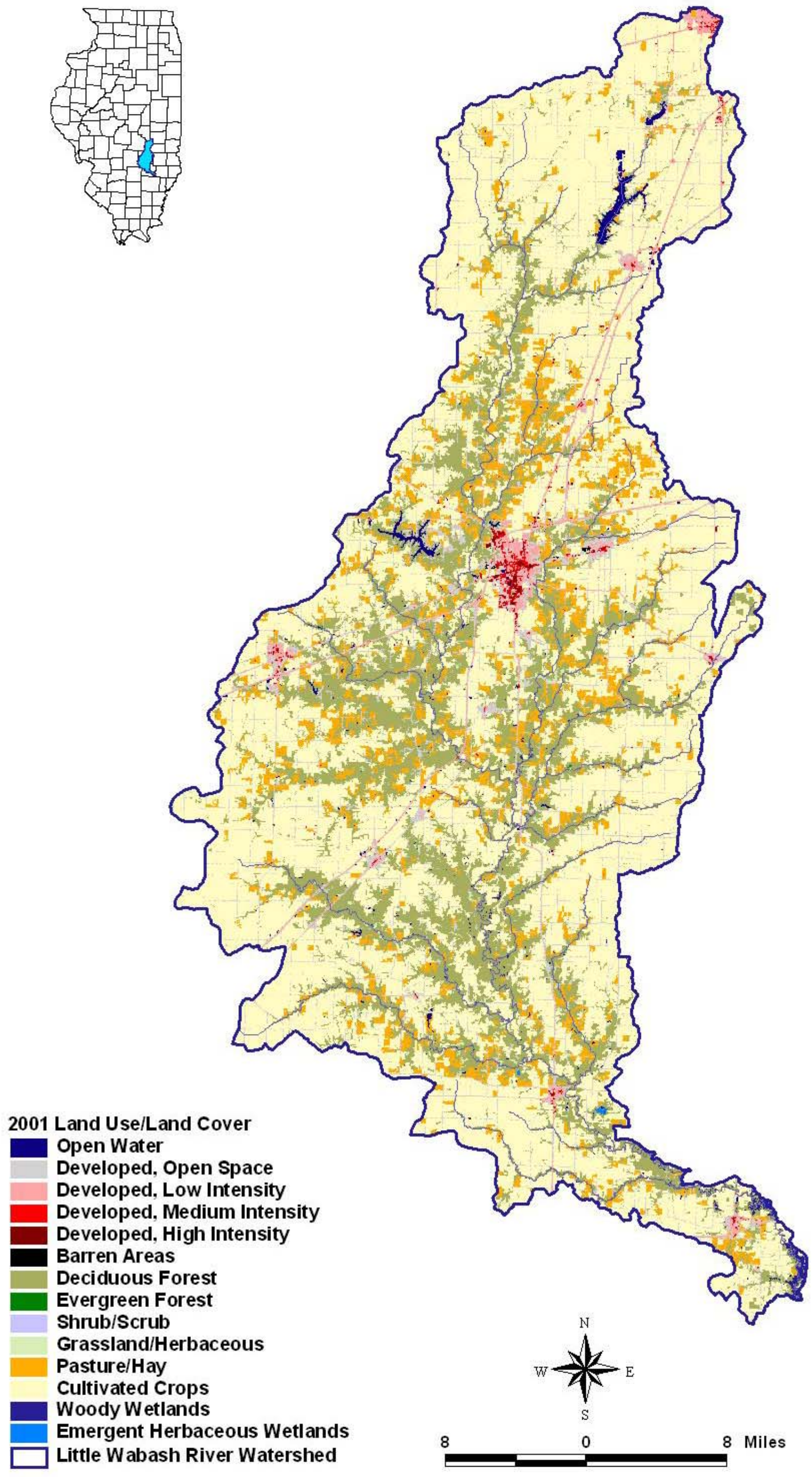

Figure 2. Land Use in the Little Wabash Watershed

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 F and **Error! Reference source not found.**.

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 Little Wabash 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 Little Wabash River watershed are listed below for lakes (Table 4) and streams (Table 5).

Table 4. Summary of Water Quality Standards for the Little Wabash River Watershed Lake Impairments.

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies	Section for Regulatory Citation[b]
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	302.204
Total Phosphorus	mg/L	0.05[a]	No numeric standard	302.205

[a] 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.
[b]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.

Table 5. Summary of Water Quality Standards for the Little Wabash River Watershed Stream Impairments.

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies	Section for Regulatory Citation[f]
Atrazine	µg/L	Acute= 82[a]	3	302.601 to 302.669[g]
		Chronic= 9[b]		
Dissolved Oxygen	mg/L	5.0 instantaneous minimum	No numeric standard	302.206
		6.0 minimum during at least 16 hours of any 24 hour period		
Fecal coliform[c]	#/100 mL	400 in <10% of samples[d]	Geomean[d] <2,000	General use: 302.209 Public Water Supply: 302.306
		Geomean < 200[e]		
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	302.204

[a] Not to be exceeded except as provided in 35 Ill. Adm. Code 302.208(d)
[b] Not to be exceeded by the average of at least three samples collected over peak atrazine application periods (Spring, Summer, and Fall)
[c] Fecal coliform standards are for the recreation season only (May through October)
[d] Standard shall not be exceeded by more than 10% of the samples collected during a 30 day period
[e] Geometric mean based on minimum of 5 samples taken over not more than a 30 day period
[f] 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.
[g] The atrazine criteria are a derived water quality standard. Additional information can be found in the *Illinois Integrated Water Quality Report and Section 303(d) List – 2006* (IEPA, 2006a)

4.0 TECHNICAL ANALYSIS

This section of the report describes the technical approaches that were used to calculate TMDLs within the Little Wabash River watershed. Load duration curves were used to estimate the current and allowable loads of atrazine, fecal coliform, and manganese loads for impaired streams in the Little Wabash watershed; the QUAL2K model was used to assess instream dissolved oxygen concentrations; and the BATHTUB model was used to assess lake water quality. Table 6 presents the listed water bodies and the corresponding modeling approach used to address each TMDL.

Table 6. 303(d) List Information and Modeling Approaches for the Little Wabash Watershed

Waterbody Name	Segment	Cause of Impairment	Modeling Approach
Little Wabash River	C-19	Dissolved Oxygen	QUAL2K
		Manganese	Load Duration Curve
		Total Fecal Coliform	Load Duration Curve
		Atrazine	Load Duration Curve/Mass Balance Analysis
Little Wabash River	C-21	Manganese	Load Duration Curve
		Total Fecal Coliform	Load Duration Curve
First Salt Creek	CPC-TU-C1	Dissolved Oxygen	QUAL2K
Second Salt Creek	CPD-04	Dissolved Oxygen	QUAL2K
Second Salt Creek	CPD-03	Dissolved Oxygen	QUAL2K
Second Salt Creek	CPD-01	Dissolved Oxygen	QUAL2K
Salt Creek	CP-EF-C2	Dissolved Oxygen	QUAL2K
East Branch Green Creek	CSB-08	Dissolved Oxygen	QUAL2K
East Branch Green Creek	CSB-07	Dissolved Oxygen	QUAL2K
Lake Paradise	RCG	Total Phosphorus	BATHTUB
		pH	BATHTUB/Causal Linkage
Lake Mattoon	RCF	Total Phosphorus	BATHTUB
Lake Sara	RCE	Total Phosphorus	BATHTUB
		Manganese	BATHTUB/Causal Linkage

4.1 Load Duration Curves

Load reductions for atrazine, fecal coliform, and manganese were determined through the use of load duration curves. The load duration curve demonstrates the allowable loadings of a pollutant at different flow regimes expected to occur in the impaired segment and still maintain the water quality standard. The following steps are taken:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points.

2. The flow curve is translated into a load duration (or TMDL) curve. To accomplish this, each flow value is multiplied by the water quality standard and by a conversion factor. The resulting points are graphed.

3. Each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected and a conversion factor. Then, the individual loads are plotted on the TMDL graph.

4. Points plotting above the curve represent deviations from the water quality standard and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load.

5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards.

Atrazine, fecal coliform, and total manganese loadings were calculated for Little Wabash River segments C 19 and C 21. Segment C 19 starts at the confluence of Little Wabash River and Salt Creek and ends at the confluence of Big Muddy Creek. Segment C 21 begins at the downstream portion of Lake Mattoon and ends at the confluence of Second Creek with the main stem of the Little Wabash River (Figure 3). Atrazine, fecal coliform, and manganese data from sampling stations C 21 and C 19 (Figure 3) were used to assess fecal coliform and manganese loadings to stream Segments C 21 and C 19, respectively.

The stream flows displayed on a load duration curve may be grouped into various flow regimes to aid with interpretation of the load duration curves. The flow regimes are typically divided into 10 groups, which can be further categorized into the following five "hydrologic zones" (Cleland, 2005):

- High flow zone: stream flows that plot in the 0 to 10-percentile range, related to flood flows.
- Moist zone: flows in the 10 to 40-percentile range, related to wet weather conditions.
- Mid-range zone: flows in the 40 to 60 percentile range, median stream flow conditions;
- Dry zone: flows in the 60 to 90-percentile range, related to dry weather flows.
- Low flow zone: flows in the 90 to 100-percentile range, related to drought conditions.

The load duration approach helps to identify the issues surrounding the impairment and to roughly differentiate between sources. Table 7 summarizes the relationship between the five hydrologic zones and potentially contributing source areas.

The load reduction approach also considers critical conditions and seasonal variation in the TMDL development as required by the Clean Water Act and EPA's implementing regulations. Because the approach establishes loads based on a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions.

Table 7. Relationship Between Load Duration Curve Zones and Contributing Sources.

Contributing Source Area	Duration Curve Zone				
	High	Moist	Mid-Range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
On-site wastewater systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Stormwater: Impervious		H	H	H	
Combined sewer overflow (CSO)	H	H	H		
Stormwater: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	
Bank erosion	H	M			
Note: Potential relative importance of source area to contribute loads under given hydrologic condition (H: High; M: Medium; L: Low)					

4.1.1 Stream Flow Estimates

Daily stream flows are needed to apply the load duration curve. There are two USGS gages with continuous flow data in the Little Wabash watershed (Figure 3). USGS gage 03378635 is located on the Little Wabash River downstream of Lake Sara and near the city of Effingham. USGS gage 03379500 is located on the Little Wabash River near the mouth approximately 29 miles downstream of monitoring station C 19.

Stream flows for monitoring station C 19 were extrapolated from the USGS station 03379500, using a multiplier based upon a comparison of the two drainage areas. The drainage area downstream of Lake Mattoon to the water quality monitoring station C 19 is 744.38 square miles and the drainage area of flow gage 03379500 is 1131 square miles. The drainage area ratio therefore equals 0.658 and the daily flows at the flow gage were multiplied by 0.658 to estimate the daily flows at station C 19. For sampling station C 21, daily stream flows from USGS station 03378635 were directly applied since the gage is co-located with the water quality sampling station.

A further modification to the flow estimates was made to ensure that they accounted for the design flows of any upstream point sources (because the TMDL WLAs are based on design flows). In cases where the minimum estimated flows were less than the cumulative design flows from the point sources, the design flows were added to the flow record.

Figure 3. USGS, Load Duration Sampling Sites, and NPDES facilities in the Little Wabash River Watershed

4.2 QUAL2K Model

The QUAL2K water quality model was selected to assess the dissolved oxygen impairments in the Little Wabash River 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. Five QUAL2K models were set up for each impaired stream to address low dissolved oxygen conditions. The impaired streams are East Brach Green Creek, Second Salt Creek, First Salt Creek, Salt Creek, and Little Wabash River.

Illinois' water quality standard requires a minimum dissolved oxygen concentration of 5 mg/L at all times within the impaired streams and a 6.0 minimum during at least 16 hours of any 24 hour period. Once the model was setup and calibrated, a series of scenarios were run to evaluate the most likely cause of the observed low dissolved oxygen. These results are summarized in Section 0 and a detailed discussion of the QUAL2K model is included in Appendix D.

4.3 BATHTUB Model

BATHTUB was selected for modeling water quality in Lake Paradise, Lake Mattoon, and Lake Sara. BATHTUB performs steady-state water and phosphorus 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). BATHTUB was determined to be appropriate because it addresses the primary parameter of concern (phosphorus) 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 E.

The BATHTUB model requires the following data to configure and calibrate: tributary flows and concentrations, reservoir bathymetry, in-lake water quality concentrations, and global parameters such as evaporation rates and annual average precipitation. Lake bathymetry data were available from Phase 1 of the Clean Lakes Study that was conducted for Lake Paradise and Lake Mattoon in 2000-2001 and are summarized in Table 8. Watershed loads were estimated based on a load duration curve analysis as explained in Section 4.1.

Table 8. Bathymetry Data for the Little Wabash River Watershed Lakes.

Lake	Parameter	Value
Lake Paradise	Normal Pool Volume (ac-ft)	1,193
	Normal Pool Surface Area (ac)	166
	Maximum Depth (ft)	19
	Mean Depth (ft)	7
Lake Mattoon	Normal Pool Volume (ac-ft)	11,588
	Normal Pool Surface Area (ac)	1010[a]
	Maximum Depth (ft)	35
	Mean Depth (ft)	15
Lake Sara	Normal Pool Volume (ac-ft)	13,263
	Normal Pool Surface Area (ac)	765
	Maximum Depth (ft)	49
	Mean Depth (ft)	17

[a] The surface area for Lake Mattoon has been reported as a variety of values over the years, ranging from 750 acres (Mattoon Public Water Supply) to 1,027 (Bogner, 2003) with IEPA traditionally reporting the surface area as 765 acres. However, IEPA re-calculated the surface area as 1,010 acres for this study using the most recent aerial photo and the Illinois Transmercator geographic information system projection and this value was used for the modeling and TMDL development.

In a typical BATHTUB model application, tributary flows and corresponding phosphorus concentrations are input to the model, and simulated inlake concentrations are compared to available water quality samples. During Phase 1 of the Clean Lakes Study program water quality data were collected on the Little Wabash river upstream of Lake Paradise and on four tributaries upstream of Lake Mattoon; however, no tributary sampling data are available for Lake Sara.

Data for the Little Wabash River upstream of Lake Paradise were used to develop load duration curves to estimate nutrient loading to the lake. These regression equations are based on water quality samples collected from March through May 2001 at one water quality station (RCG-T2) in the watershed (Figure 4). Table 9 summarizes the regression equations for each nutrient species monitored at this station. Mattoon tributary data were used to develop load duration curves to estimate nutrient loading to the lake. These regression equations are based on water quality samples collected in April and May 2001 at four water quality stations in the watershed (Figure 4). Table 9 summarizes the regression equations for each nutrient species monitored. Loads and flows estimated to Lake Paradise were scaled down to model Lake Sara based on the ratio of the drainage areas to each lake. The Lake Paradise watershed is approximately 18 square miles and the drainage area to Lake Sara is approximately 12 square miles.

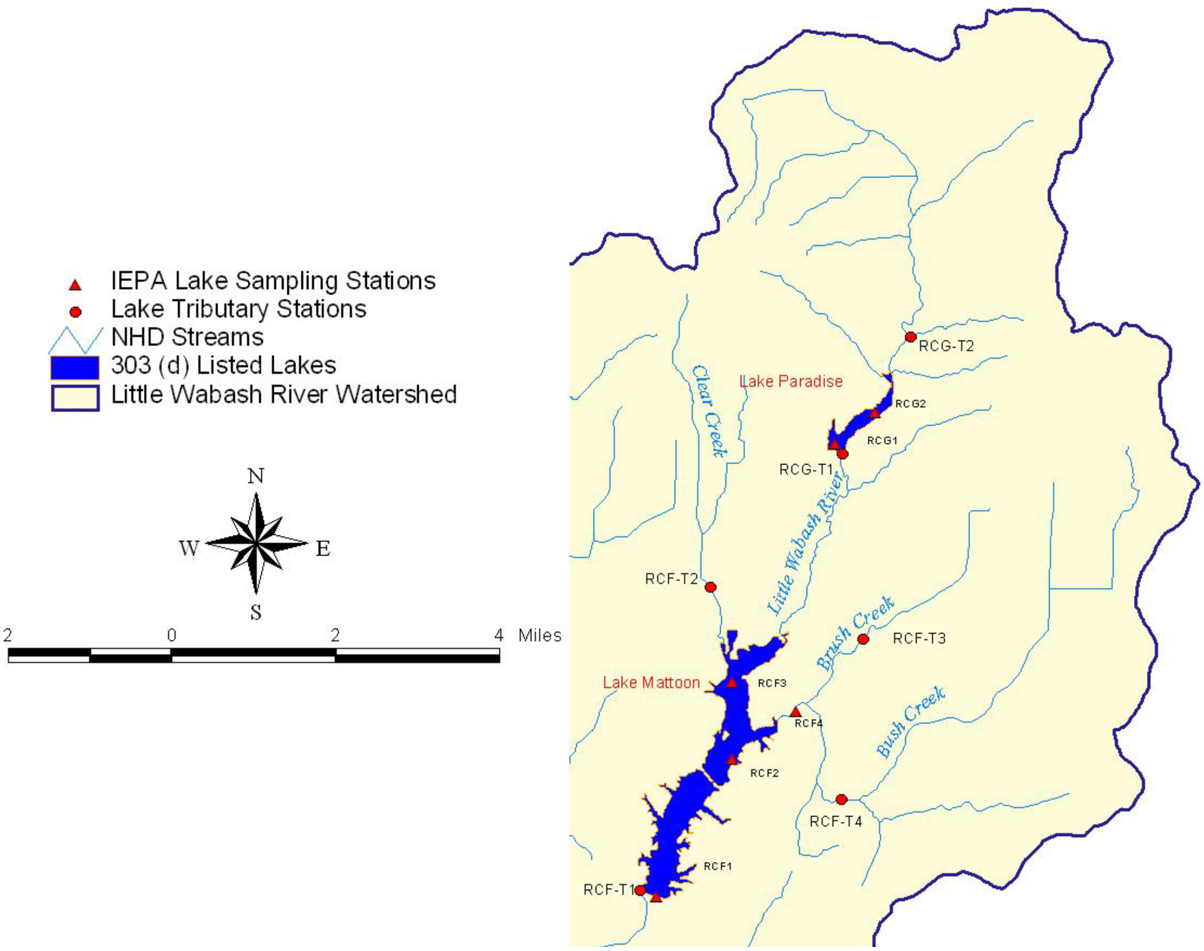

Figure 4. Lake Paradise and Lake Mattoon Tributary and Lake Monitoring Stations

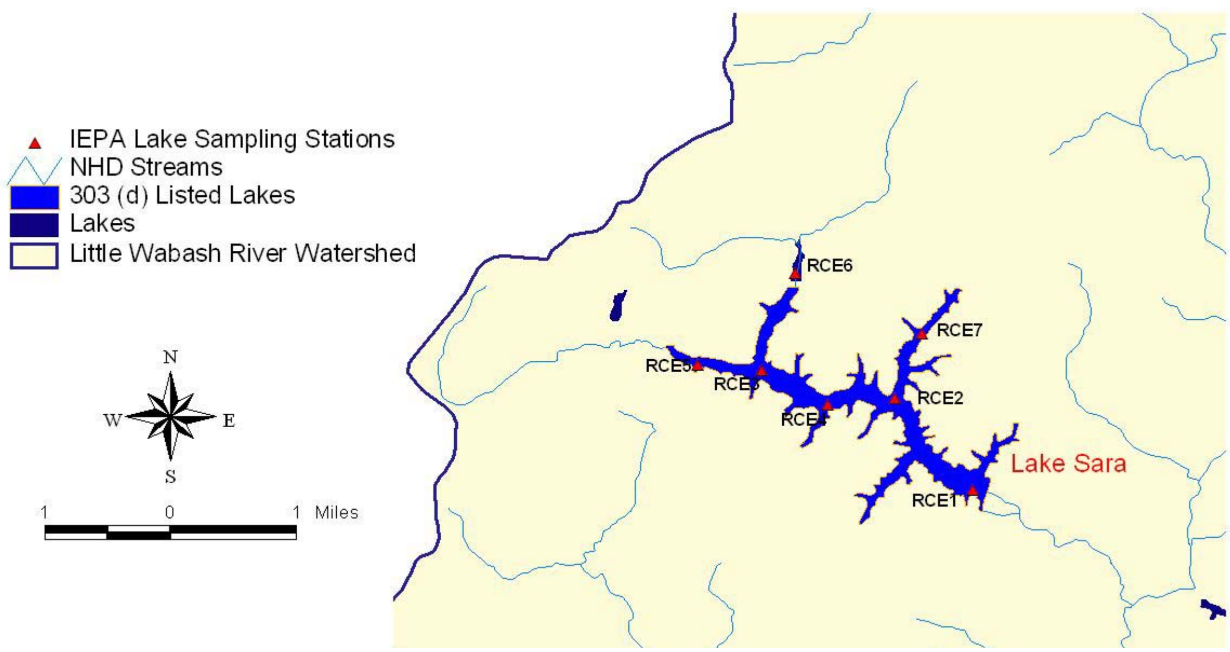

Figure 5. Lake Sara Monitoring Stations

Table 9. Regression on Flow (Q in cfs) for Estimating Nutrient Loads to Lake Paradise and Lake Mattoon

Lake	Station	Phosphate (kg/d)	Total Phosphorus (kg/d)	Nitrate plus Nitrite (kg/d)	Ammonia (kg/d)	TKN (kg/d)
Lake Paradise	RCG-T2	ND	$0.0554Q^{1.6928}$	$24.343Q^{1.0774}$	$0.0297Q^{1.9806}$	$1.1669Q^{1.4011}$
Lake Mattoon	RCG-T1	ND	$0.7948Q^{0.6743}$	$3.2934Q^{1.3083}$	$0.0041Q^{2.3887}$	$6.6820Q^{0.7943}$
	RCF-T2	ND	$0.2416Q^{1.8768}$	$19.359Q^{1.1936}$	$0.7377Q^{1.4440}$	$2.7396Q^{1.4831}$
	RCF-T3	ND	$0.2149Q^{1.5180}$	$6.2057Q^{1.3453}$	$0.1579Q^{2.3910}$	$2.4932Q^{1.2480}$
	RCF-T4	ND	$0.0815Q^{1.6146}$	$6.9372Q^{0.9245}$	$0.0235Q^{2.3206}$	$1.5499Q^{1.3455}$

ND: No water quality samples were available to develop a regression equation for this parameter.

The regression equations require an estimate of daily average flow at each station. Flow rates to Lake Paradise, Lake Mattoon, and Lake Sara were estimated by area weighting flows observed at USGS gage 03378635 on the Little Wabash River near Effingham, Illinois. Watershed loads and total flow volumes to the Little Wabash River watershed lakes are summarized for the annual and summer season periods in Table 10 and Table 11.

Table 10. Annual Watershed Loading to the Little Wabash River Watershed Lakes.

Lake	Year	Stream Flow (MG)	TN Load (ton)	TP Load (ton)
Lake Paradise	1991	2,356	146	2.9
	1992	3,039	213	8.7
	1993	8,924	645	25.5
	1994	3,693	264	10.2
	1995	4,157	304	13.3
	1996	5,632	431	22.1
	1997	3,402	240	9.1
	1998	4,341	298	9.7
	2001	3,959	276	9.9
	2004	4,818	331	10.9
Lake Mattoon	1991	7,097	316	8.7
	1992	9,156	552	26.3
	1993	26,887	1,697	74.8
	1994	11,127	690	29.8
	1995	12,529	818	39.5
	1996	16,968	1,219	66.3
	1997	10,249	615	27.2
	1998	13,080	740	28.3
	2001	11,930	703	29.2
	2004	14,515	822	32.0
Lake Sara	1991	1,594	99	1.9
	1992	2,056	144	5.9
	1993	6,037	436	17.3
	1994	2,498	179	6.9
	1995	2,812	206	9.0
	1996	3,810	292	15.0
	1997	2,301	162	6.2
	1998	2,937	202	6.5
	2001	2,679	187	6.7
	2002	4,320	334	17.7

Table 11. Summer Season Watershed Loading to the Little Wabash River Watershed Lakes.

Lake	Summer	Stream Flow (MG)	TN Load (ton)	TP Load (ton)
Lake Paradise	1991	254	14	0.2
	1992	274	16	0.2
	1993	2485	181	7.9
	1994	654	41	0.9
	1995	2545	191	8.8
	1996	2663	207	11.0
	1997	368	21	0.3
	1998	2009	136	4.2
	2001	950	68	2.8
	2004	992	69	2.5
Lake Mattoon	1991	766	28	0.7
	1992	827	31	0.8
	1993	7,488	485	23.4
	1994	1,971	91	2.7
	1995	7,667	525	25.9
	1996	8,024	595	32.8
	1997	1,109	41	1.0
	1998	6,054	333	12.4
	2001	2,863	180	8.2
	2004	2,989	175	7.6
Lake Sara	1991	172	10	0.1
	1992	186	11	0.2
	1993	1,681	122	5.3
	1994	442	28	0.6
	1995	1,721	129	5.9
	1996	1,802	140	7.4
	1997	249	14	0.2
	1998	1,359	92	2.9
	2001	643	46	1.9
	2002	2,174	185	13.1

The BATHTUB model requires input of the fraction of inorganic nutrient load. Inorganic fractions for nitrogen were estimated from the ratio of ammonia plus nitrite plus nitrate to total nitrogen and the inorganic phosphorus fraction was estimated from the ratio of dissolved phosphorus to total phosphorus.

BATHTUB was set up to simulate nutrient responses in Lake Paradise and Lake Mattoon for the years 1991 through 2004 and from 1991 to 2002 in Lake Sara to correspond with available water quality data. Second order, available nutrient models were used to simulate both nitrogen and phosphorus. Lake Paradise nutrient calibration factors were set to 1 for nitrogen and 0.79 for phosphorus. Lake Mattoon nutrient calibration factors were set to 2.15 for nitrogen and 0.57 for phosphorus. Lake Sara nutrient calibration factors were set to 1.8 for nitrogen and 0.2 for phosphorus. Calibration factors for Lake Paradise and Lake Mattoon were adjusted within the default range so that the average ratio of simulated to observed nutrient concentrations was close to 1. A calibration factor of 1 indicates that no adjustment to the model is needed. The phosphorus calibration factor for Lake Sara had to be set out of range to simulate the concentrations observed in 2001 (see Section 5.2.3).

Internal phosphorus loading is accounted for in BATHTUB by application of a net phosphorus sedimentation rate (settling minus resuspension). The Nürnberg method (1984) was therefore chosen to approximate the internal load. This method uses mean depth, flushing rate, average inflow, and average outflow concentrations to estimate internal load. The accuracy of the method is dependent on the available tributary data, which are relatively limited, but the results are nevertheless provided here to provide some perspective on the potential significance of internal loading. For all three lakes the internal load was estimated to be a negligible fraction of the total load.

5.0 TMDL

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 Little Wabash River watershed is presented in this section of the report, organized according to pollutants and modeling analysis.

5.1 Loading Capacity for Atrazine, Fecal Coliform, and Manganese in the Little Wabash River

A TMDL must identify the loading capacity of a waterbody for the applicable pollutant. U.S. EPA regulations define loading capacity as the greatest amount of a pollutant that a waterbody can receive without violating water quality standards. The loading capacity is often referred to as the "allowable" load. The following sections provide the TMDL results for Segments C 21 and C 19 of the Little Wabash River, which were based on application of the load duration method. Appendix A presents the entire load duration analysis performed for the Little Wabash River at stations C 21 and C 19.

5.1.1 Loading Capacity of Stream Segment C 21

Existing and allowable loads were calculated for the Little Wabash River at station C 21 located downstream of Lake Sara near the city of Effingham. This location drains 261 square miles and land use/land cover is primarily agricultural (73%). Numerous livestock operations are located within the watershed. A total of 58 fecal coliform samples and 114 manganese samples were available for the load duration analysis (Appendix B).

Both the geometric mean (200 cfu/100 mL) and the not-to-exceed (400 cfu/100 mL) components of Illinois's water quality standard were evaluated as part of this study. The results of the load duration analysis based on the not-to-exceed 400 cfu/100 mL standard are presented in Appendix A for information purposes. The TMDL is based on meeting the geometric mean component of the standard because it is more restrictive and ensures both standards will be met. The Illinois fecal coliform standard is designated for the months of May to October and so only fecal coliform data collected during these months were used for load duration analysis.

A load duration analysis completed using only the data after December 31, 1999 (Appendix A) results in similar load reductions within all flow regimes, with slightly higher reductions identified than the analysis conducted using all of the available data. Based on this finding, and to take advantage of as many data as possible, the TMDL was developed using all of the data between January 1, 1991 and August 30, 2005.

Table 12 presents the TMDL summary for this assessment location. The current observed loads for each flow regime are based on the highest observed flow in each regime. Results of the load duration analysis indicate that significant load reductions of both fecal coliform and manganese are needed for most flow conditions.

Potential sources of fecal coliform in this segment include livestock, private sewage systems, and discharges from the following permitted National Pollutant Discharge Elimination System (NPDES) facilities:

- Effingham STP (permit number IL0028622)
- Neoga STP (permit number IL0030091)
- IL DOT-157 Effingham County (permit number IL0006028)

Loads from these permittees are further discussed in Section 5.1.3. Wildlife, including waterfowl and terrestrial animals, might also be significant sources of fecal coliform.

Livestock and animal feeding operations are prevalent throughout Effingham County (personal communication, Effingham County Soil and Water Conservation District) and are potential contributors of fecal coliform to Segment C 21. Private surface sewage systems are also common in the area and if not treated properly can release untreated sewage to local waterways. It has been estimated that statewide between 20 and 60 percent of surface discharging systems are failing or have failed (IEPA, 2004) suggesting that such systems may be a significant source of pollutants).

It should also be noted that there are two upstream water quality monitoring stations CSB08 and CSB07 at East Branch Green Creek. Three fecal coliform samples are available from each of these sites and the fecal coliform concentrations observed at these sites are much higher that those observed at station C 21. Die off of fecal coliform, and adsorption to sediments could have resulted in a decrease in fecal coliform numbers downstream of East Branch Green Creek. A fecal coliform TMDL will not be developed for East Branch Green Creek at this time until the waterbody can be further assessed.

The high manganese levels are primarily attributed to natural background conditions. Many of the soils in Little Wabash contain naturally-occurring manganese concentrations or accumulations and most soils in the watershed are acidic (pH of 6.6). Low pH accelerates the manganese movement into solution and its transportation through baseflow and or/runoff. Release of manganese from river bottom sediments is also a potential source of manganese. Additionally, a historic source of manganese in the watershed might have been oil operations in the Little Wabash River watershed. In the past, the process of extracting the oil included pumping out brine water, which is typically high in manganese, and dumping it on the surface or storing it in lagoons that drained to surface waters.

Therefore, the observed manganese levels are likely due to a combination of the natural geochemical environment and historic oil operation practices. This issue will be further explored during the development of the implementation plan. None of the permitted point sources discharging to stream segment C 21 are required to monitor or control for manganese as none of them would be expected to have high concentrations of this parameter.

Table 12. Fecal Coliform and Manganese TMDL Summary for Stream Segment C 21

Station C 21 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Fecal Coliform (Million/day)	Current Load	957,432,512	42,277,782	1,155,018	678,342	50,204
	TMDL= LA+WLA+MOS	**3,172,735**	**266,197**	**77,817**	**38,189**	**31,377**
	LA	2,921,478	192,097	3,716	6,829	17
	WLA: Effingham STP Outfall Pipe 001	68,137	68,137	68,137	28,391	28,391
	WLA: Effingham STP Outfall Pipe 002	56,781	0	0	0	0
	WLA: Neoga STP Outfall Pipe 001 (and 002)	5,542	5,542	5,542	2,801	2,801
	WLA: Neoga STP Outfall Pipe A01	120,376	0	0	0	0
	WLA: IL DOT-I57 Outfall Pipe 001	421	421	421	168	168
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (Implicit)	Implicit	Implicit	Implicit	Implicit	Implicit
	TMDL Reduction (%)	>99%	99%	93%	94%	38%
Manganese (kg/day)	Current Load	11,337,431,078	167,932,945	46,582,808	17,199,456	88,080
	TMDL= LA+WLA+MOS	**344,526,736**	**37,799,595**	**10,275,619**	**1,651,442**	**3,673**
	LA	310,074,063	34,019,635	9,248,057	1,486,297	3,305
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	34,452,674	3,779,959	1,027,562	165,144	367
	TMDL Reduction (%)	97%	80%	80%	91%	96%

Notes: n/a = Not Applicable because there are no NPDES permittees discharging to this segment. An entry of "n/a" for the WLA counts as zero in the calculation of the TMDL.

5.1.2 Loading Capacity of Stream Segment C 19

Existing and allowable loads of atrazine, fecal coliform, and manganese were calculated for the Little Wabash River at station C 19 located near the confluence of Little Wabash River and Panther Creek near the city of Louisville. This location drains 805 square miles and land use/land cover is primarily agricultural (70%). A total of 89 atrazine samples, 55 fecal coliform samples, and 114 manganese samples were available for the load duration analysis (Appendix B).

Table 13 presents the TMDL summary for this assessment location. Results of the load duration analysis indicate that fecal coliform observations exceed the loading limit during all but the low flow condition. Manganese loadings are above the threshold loadings throughout the entire flow.

The Little Wabash River at station C-19 is designated as a public water supply and IEPA therefore had to determine whether the TMDL should be based on either the aquatic life atrazine criterion (9 µg/L) or the Public Water Supply (3 µg/L) criterion. IEPA decided to use the aquatic life use standard after calculating quarterly averages and running annual averages of atrazine in the untreated water at station C-19. These untreated-water results were interpreted similar to how treated-water Maximum Contamination Limits (MCLs) are interpreted. Although there were individual atrazine concentrations in untreated water that exceeded 3.0 µg/L, and there was at least one quarterly average over 3.0 µg/L, the running annual average did not exceed 3.0 µg/L for untreated water; therefore, untreated-water results did not justify listing atrazine as a cause of Public Water Supply use impairment. Out of 81 atrazine samples from 2001 to 2005 five of those samples exceeded the chronic aquatic life criteria of 9 µg/L and none of the samples exceeded the acute criteria of 82 µg/L. The TMDL was therefore based on meeting the 9 µg/L criterion and the results indicate that maximum loads must be reduced by 54 percent during moist flow conditions (Table 13). It is important to note that although the TMDL is based on meeting the 9 µg/L Aquatic Life criterion, the rolling 3.0 µg/L Public Water Supply criterion still applies and is expected to be met.

There were numerous observed fecal coliform loadings that exceeded the standard during all but low flow conditions. Potential sources of fecal coliform include livestock, animal feeding operations, private surface sewage disposal systems, and the five NPDES permitted dischargers that are allowed to discharge fecal coliform to the Little Wabash River or its tributaries:

- Clay City WWTP (permit number IL0020974)
- IL DOT-FAI 70 Rest Area (permit number IL 0025429)
- Effingham STP (permit number IL0028622)
- Neoga STP (permit number IL0030091)
- IL DOT-157 Effingham County (permit number IL0006028)

Loads from these permittees are further discussed in Section 5.1.3. Wildlife, including waterfowl and terrestrial animals, might also be significant sources of fecal coliform.

The observed manganese levels are likely due to a combination of the natural geochemical environment and historic oil operation practices. None of the permitted point sources discharging to stream segment C 19 are required to monitor or control for manganese as none of them would be expected to have high concentrations of this parameter.

Table 13. Atrazine, Fecal Coliform, and Manganese TMDL Summary for Stream Segment C 19

Station C 19 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Atrazine (kg/day)	Current Load	62,333,269	18,513,263	1,947,607	142,570	16,004
	TMDL= LA+WLA+MOS	**82,527,168**	**9,461,071**	**2,448,591**	**478,132**	**98,528**
	LA	74,274,451	8,514,964	2,203,732	430,319	88,676
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	8,252,717	946,107	244,859	47,813	9,853
	TMDL Reduction (%)	0%	54%	0%	0%	0%
Fecal Coliform (Million/day)	Current Load	1,226,714,173	431,297,909	764,921	5,511,631	18,067
	TMDL= LA+WLA+MOS	**14,784,931**	**1,034,437**	**251,240**	**90,267**	**50,006**
	LA	14,651,322	962,711	179,514	60,438	20,177
	WLA: Clay City WWTP Outfall Pipe 001	2,271	2,271	2,271	908	908
	WLA: Clay City WWTP Outfall Pipe 002	5,103	0	0	0	0
	WLA: IL DOT-FAI 70 Outfall Pipe 001	1,317	1,317	1,317	530	530
	WLA: Effingham STP Outfall Pipe 001	68,137	68,137	68,137	28,391	28,391
	WLA: Effingham STP Outfall Pipe 002	56,781	0	0	0	0
	WLA: Neoga STP Outfall Pipe 001 (and 002)	5,542	5,542	5,542	2,801	2,801
	WLA: Neoga STP Outfall Pipe A01	120,376	0	0	0	0
	WLA: IL DOT-I57 Outfall Pipe 001	421	421	421	168	168
	TMDL Reduction (%)	99%	>99%	67%	98%	0%
Manganese (kg/day)	Current Load	15,312,862,173	1,950,813,590	250,685,646	71,155,770	9,273,081
	TMDL= LA+WLA+MOS	**1,375,452,793**	**157,684,512**	**40,809,848**	**7,968,870**	**1,642,140**
	LA	1,237,907,514	141,916,060	36,728,863	7,171,983	1,477,926
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	137,545,279	15,768,451	4,080,985	796,887	164,214
	TMDL Reduction (%)	92%	93%	85%	90%	84%

Notes: n/a = Not Applicable because there are no NPDES permittees discharging to this segment. An entry of “n/a” for the WLA counts as zero in the calculation of the TMDL.

5.1.3 Waste Load Allocations

There are five facilities regulated by the National Pollutant Discharge Elimination System that are allowed to discharge fecal coliform in the Little Wabash River. Information on these and other dischargers in the watershed are shown in Table 14; the WLAs for fecal coliform are shown in Table 15.

Table 14. Wastewater treatment plants discharging to impaired streams within the Little Wabash River watershed.

Facility Name	Permit Number	Receiving Stream	Design Average Flow (MGD)	Design Maximum Flow (MGD)	Daily Fecal Coliform Limit (count/100 mL)	Daily CBOD Limit (mg/L)	Daily Ammonia Limit (mg/L)
IL DOT-157 Effingham County	IL0060208	East Branch of Green Creek	0.0111	0.0278	400	25	none
Effingham STP	IL0028622	Unnamed trib of Salt Creek	3.75	9	Disinfection Exemption	20	1.5
Teutopolis STP	ILG582024	Second Salt Creek	0.372	1.5	Disinfection Exemption	25	none
Clay City WWTP	IL0020974	Unnamed ditch trib to Little Wabash River	0.12	0.3	Disinfection Exemption	25	none
Mason STP	ILG580276	Trib to Little Wabash River	0.0525	0.131	Disinfection Exemption	25	none
Edgewood STP	ILG580070	Little Wabash	0.0615	0.123	Disinfection Exemption	25	none
IL DOT-FAI 70	IL0025429	Unnamed trib of Salt Creek	0.035	0.087	400	20	none
Neoga STP	IL0030091	Unnamed trib to Copperas Creek (tributary to Little Wabash River)	0.37	0.732	Disinfection Exemption	25	none

Notes: The Harper Oil Company used to hold a permit (IL0077607) to discharge into an unnamed trib to Salt Creek; however, this facility ceased operations in April 2007; N/A = Not Available

Sewage from treatment plants treating domestic and/or municipal waste contain fecal coliform–it is indigenous to sanitary sewage. In Illinois, a number of these treatment plants, including those identified in Table 14, have applied for and received disinfection exemptions which allow a facility to discharge wastewater water without disinfection. All of these treatment facilities are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water or where the water flows into a fecal-impaired segment. WLAs for facilities with disinfection exemptions were therefore based on the design flows for each facility multiplied by 200 cfu/100 mL. The resulting WLAs apply at the end of their respective disinfection exemptions. Facilities with year-round disinfection exemptions may be required to provide IEPA with updated information to demonstrate compliance with these requirements and facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions.

The WLAs for IL DOT-FAI70 Outfall 001 and IL DOT-157 Outfall 001 were determined by multiplying the facilities maximum design flows by their permit limit (400/100 mL) during high to mid range flows and by multiplying the average design flows by the permit limit during low flows and moist conditions. The WLAs for Outfall 001 of each of the remaining facilities (those with disinfection exemptions) were determined by multiplying the average design flows by the geometric mean water quality permit limit (200/100 mL) during all flow ranges. The facilities with disinfection exemptions are required to meet the geometric mean standard at the nearest point downstream where recreational use occurs in the receiving water (not at the pipe outfall).

WLAs for Clay City Outfall 002, Effingham STP Outfall 002, and Neoga STP Outfall Pipe A01 were set based on average reported flow information and the permit limit of 400/100 mL. The WLAs for these outfalls only apply to the high flow conditions as discharges from these stormwater-related outfalls should be limited to these high flow periods. Recent monitoring data for these outfalls are documented in Appendix C and indicate that the permit limit of 400/100 mL is usually met for each of these facilities.

No manganese or atrazine WLAs were developed as none of the NPDES facilities are considered significant sources of either of these pollutants.

There are no stormwater communities regulated by the in the Little Wabash Watershed so no WLAs were assigned for MS4s.

Table 15. Fecal Coliform Limits and WLA for NPDES Facilities in Little Wabash watershed

WLA Summary		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
NPDES Permit	**Parameter**	**0-10**	**Oct-40**	**40-60**	**60-90**	**90-100**
Clay City WWTP Outfall Pipe 001	Flow (MGD)	0.30	0.30	0.30	0.12	0.12
	Value used to calculate WLA	200				
	Fecal Coliform WLA (Million/day)	2,271	2,271	2,271	908	908
Clay City WWTP Outfall Pipe 002	Flow (MGD)	0.337	0	0	0	0
	Value used to calculate WLA	400	N/A	N/A	N/A	N/A
	Fecal Coliform WLA (Million/day)	5,103	0	0	0	0
IL DOT-FAI 70 Outfall Pipe 001	Flow (MGD)	0.087	0.087	0.087	0.035	0.035
	Value used to calculate WLA	400				
	Fecal Coliform WLA (Million/day)	1,317	1,317	1,317	530	530
Effingham STP Outfall Pipe 001	Flow (MGD)	9.00	9.00	9.00	3.75	3.75
	Value used to calculate WLA	200				
	Fecal Coliform WLA (Million/day)	68,137	68,137	68,137	28,391	28,391
Effingham STP Outfall Pipe 002	Flow (MGD)	2.7	0	0	0	0
	Value used to calculate WLA	400	N/A	N/A	N/A	N/A
	Fecal Coliform WLA (Million/day)	56,781	0	0	0	0
Neoga STP Outfall Pipe 001 (and 002)	Flow (MGD)	0.732	0.732	0.732	0.370	0.370
	Value used to calculate WLA	200				
	Fecal Coliform WLA (Million/day)	5,542	5,542	5,542	2,801	2,801
Neoga STP Outfall Pipe A01	Flow (MGD)	7.95	0	0	0	0
	Value used to calculate WLA	400	N/A	N/A	N/A	N/A
	Fecal Coliform WLA (Million/day)	120,376	0	0	0	0
IL DOT-I57 Outfall Pipe 001	Flow (MGD)	0.0278	0.0278	0.0278	0.0111	0.0111
	Value used to calculate WLA	400				
	Fecal Coliform WLA (Million/day)	421	421	421	168	168

*Flows for CSO and stormwater outfalls were based on the average of reported flows during the recreational season where available and on the average flows when recreational season flows were not available.
Notes: MGD = million gallons per day; N/A = Not Applicable

5.1.4 Load Allocation

The load allocations are based on subtracting the allocations for WLAs and the MOS from allowable loads and are presented in Table 12 and Table 13. The control of fecal coliform, atrazine, and manganese loadings from nonpoint sources such as wildlife and agriculture will be explored during the development of the implementation plan.

5.1.5 Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for uncertainties in the relationship between pollutants loads and receiving water quality. U.S. EPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS). A 10 percent explicit MOS has been applied as part of this TMDL for manganese and atrazine. A moderate MOS was specified because the use of the load duration curves is expected to provide accurate information on the loading capacity of the stream, but this estimate of the loading capacity may be subject to potential error associated with the method used to estimate flows within the watershed. An implicit MOS is also associated with the fact that the estimated level of load reductions that are necessary are based on the maximum observed loads for each flow condition. The MOS for fecal coliform is an implicit one because the load duration analysis does not address die-off of pathogens.

5.1.6 Critical Conditions and Seasonality

TMDLs should also take into account critical conditions and seasonal variations. Critical conditions refer to the periods when greatest reductions of pollutants are needed. The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. From the load duration approach it has been determined that critical conditions for fecal coliform and manganese occur during high flows (load reduction percentages are highest during these periods) and a separate loading capacity has been specified for these periods. Critical conditions for atrazine are associated with moist flow conditions that tend to occur during and after periods when atrazine is typically applied.

The Clean Water Act also requires that TMDLs be established with consideration of seasonal variations. Seasonal variations for fecal coliform TMDL are addressed by only assessing conditions during the season when the water quality standard applies (May through October). The load duration approach also accounts for seasonality by evaluating allowable loads on a daily basis over the entire range of observed flows and presenting daily allowable loads that vary by flow.

5.2 Loading Capacity for Lakes in the Little Wabash River Watershed

As described in Section 4.3, the BATHTUB model was used to assess total phosphorus concentrations in the impaired lakes in the Little Wabash River watershed. After the models were calibrated, the following general approach was used to determine the magnitude of the load reduction necessary to achieve the 0.05 mg/L target:

1) The load reductions were based on achieving an average annual total phosphorus concentration of 0.05 mg/L for the critical modeled year (i.e., the year with the highest simulated TP) so long as that year had observed data and was well calibrated.
2) For situations where the simulated critical year was not well calculated or didn't have observed data, the reductions were based on either the next most critical year (if that was well calibrated) or on achieving a long-term average concentration (i.e., for all modeled years) of 0.05 mg/L or less.

The following sections summarize the resulting TMDLs for Lake Paradise, Lake Mattoon, and Lake Sara.

5.2.1 Lake Paradise Loading Capacity

Figure 6 shows the observed and modeled total phosphorus concentrations in Lake Paradise and indicates that no observed data were available for the critical modeled year (1996). In addition, the simulated total phosphorus in the next most critical year (1995) was over-estimated by 41 percent. A TMDL reduction of 88 percent is therefore recommended to achieve the water quality standard as a long-term average over the entire simulated period. Table 16 shows the average total phosphorus concentrations if an 88 percent reduction is implemented. Table 17 presents the existing load, loading capacity, margin of safety and load allocation for Lake Paradise. Existing loads were estimated through the model calibration process, which is more fully explained in Appendix E.

Lake Paradise is also listed as being impaired due to pH, which is considered to be a side-effect of the phosphorus impairment. Excessive phosphorus loadings are believed to be exerting negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al., 1994). Excessive algal production is believed responsible for the pH impairment because photosynthetic uptake of carbonic acid during periods of algal blooms can raise pH. 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 pH meeting the water quality standard.

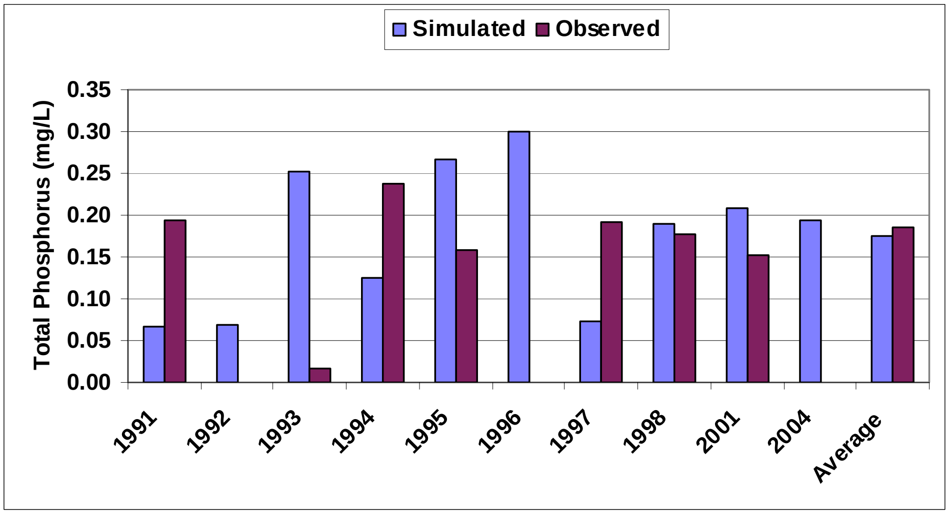

Figure 6. Comparison of Simulated and Observed Total Phosphorus Concentrations in Lake Paradise.

Table 16. Average Total Phosphorus Concentration in Lake Paradise with 88 Percent Reduction in Loading

Average Existing Lake Paradise TP (mg/L)	Lake Paradise TP (mg/L) with 88% Reduction of TP Load
0.18	0.05

Table 17. TMDL Summary for Lake Paradise.

Lake	Category	Phosphorus (kg/day)	Phosphorus (lbs/day)
Lake Paradise	Existing Load	22.9	50.5
	Loading Capacity	2.7	6.0
	Wasteload Allocation	0.0	0.0
	Margin of Safety	0.3	0.7
	Load Allocation	2.4	5.3

5.2.2 Lake Mattoon Loading Capacity

Figure 7 shows the observed and modeled total phosphorus concentrations in Lake Mattoon and indicates that no observed data were available for the critical modeled year (1996). In addition, the simulated total phosphorus in the next most critical year (1995) was over-estimated by 38 percent. A TMDL reduction of 84 percent is therefore recommended to achieve the water quality standard as a long-term average over the entire simulated period. Table 18 shows the average total phosphorus concentrations if an 85 percent reduction is implemented. Table 19 shows the existing load, loading capacity, margin of safety and load allocation for Lake Mattoon.

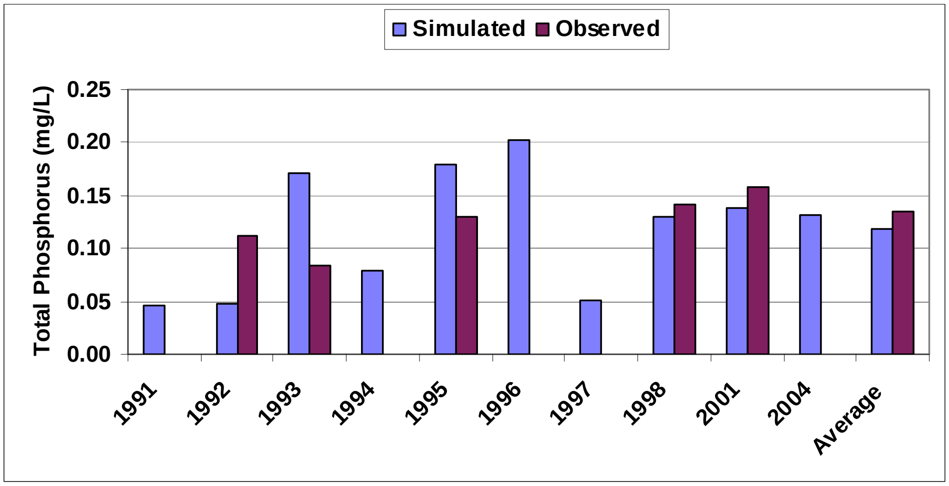

Figure 7. Comparison of Simulated and Observed Total Phosphorus Concentrations in Lake Mattoon

Table 18. Average Total Phosphorus Concentration in Lake Mattoon with 85 Percent Reduction in Loading

Average Existing Lake Mattoon TP (mg/L)	Lake Mattoon TP (mg/L) with 85% Reduction of TP Load
0.14	0.05

Table 19. TMDL Summary for Lake Mattoon.

Lake	Category	Phosphorus (kg/day)	Phosphorus (lbs/day)
Lake Mattoon	Existing Load	68.6	151.2
	Loading Capacity	10.29	22.69
	Wasteload Allocation	0	0
	Margin of Safety	1.03	2.27
	Load Allocation	9.26	20.42

5.2.3 Lake Sara Loading Capacity

Based on the yearly averages of observed water quality data shown in Figure 8, the TP target of 0.05 mg/L is met during all years except 2001 (which is not well calibrated). Simulated concentrations exceed the target in four years, two of which have no monitoring data for comparison. To meet the target for the critical year of 2001, the model was re-calibrated for only that year and then those results were used to establish the TMDL. An 81 percent reduction of phosphorus loads is required and Table 20 shows the average total phosphorus concentrations if an 81 percent reduction is implemented. Table 21 shows the existing load, loading capacity, margin of safety and load allocation for Lake Sara.

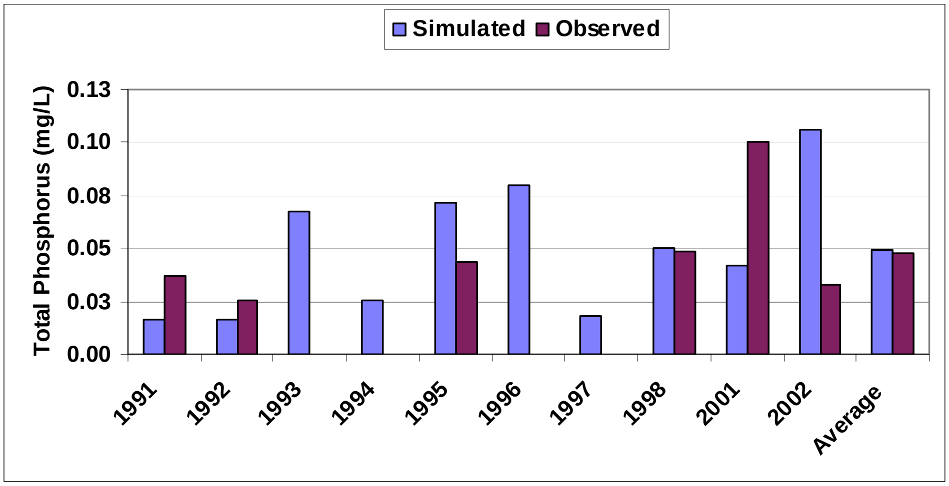

Figure 8. Comparison of Simulated and Observed Total Phosphorus Concentrations in Lake Sara.

Lake Sara is also listed as being impaired due to manganese, which is considered to be a side-effect of the phosphorus impairment. Excessive phosphorus loadings are believed to be exerting negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al., 1994). Excessive algal production is believed responsible for the manganese impairment because it is leading to anoxic (no dissolved oxygen) conditions in the bottom of the lake. Dissolved oxygen levels below 13 feet deep in Lake Sara approach zero during summer months at all three stations (RCE-1, RCE-2 and RCE-2) (IEPA, 2006b). These anoxic conditions, in turn, can lead to the release of manganese from the bottom sediments of the lake which have been documented as being elevated (Mitzelfelt, 1996). 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 manganese concentrations falling below the water quality standard of 150 µg/L.

Table 20. Average Total Phosphorus Concentration in Lake Sara with 81 Percent Reduction in Loading

Average Existing Lake Sara TP in 2001 (mg/L)	Lake Sara TP in 2001 (mg/L) with 81 % Reduction of TP Load
0.10	0.05

Table 21. TMDL Summary for Lake Sara.

Lake	Category	Phosphorus (kg/day)	Phosphorus (lbs/day)
Lake Sara	Existing Load	11.1	24.5
	Loading Capacity	2.1	4.6
	Wasteload Allocation	0.0	0.0
	Margin of Safety	0.1	0.2
	Load Allocation	2.0	4.4

5.2.4 Waste Load Allocations

There are no permitted dischargers of total phosphorus to Lake Paradise, Lake Mattoon, or Lake Sara so wasteload allocations for total phosphorus are zero.

5.2.5 Load Allocation

The allocation of loads for the Little Wabash River Watershed Lake TMDLs are summarized in Table 17, 19, and 21. The existing loads were determined from a load duration analysis based on the tributary monitoring data available for each lake. The existing loads are the average summer loads to each lake for the period 1991 to 2004 (in years where observed data were available). The loading capacity was calculated based on the percent reduction from existing loads determined to be necessary from the modeling analysis. Five percent of the loading capacity is reserved for a margin of safety (as required by the Clean Water Act; see Section 5.2.6 for more information on the margin of safety).

5.2.6 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 Lake Sara TMDL by reserving a portion of the loading capacity. A relatively low margin of safety was applied because observed data indicate that the lake already meets the water quality standard during most years. A ten percent explicit margin of safety has been incorporated into the Lake Paradise and Lake Mattoon TMDLs by reserving a portion of the loading capacity. A higher margin of safety was applied because the TMDL was based on achieving the total phosphorus target as a long-term annual average.

5.2.7 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. The Stage 1 report shows sampling data with high phosphorus concentrations in all three lakes during the months of May through September where available. The TMDL is therefore expressed in terms of the summer average load. If the loading capacity identified for the summer months is achieved the beneficial use of the lakes are expected to be supported year-round.

6.0 ASSESSMENT OF DISSOLVED OXYGEN ISSUES IN THE LITTLE WABASH RIVER WATERSHED

Five streams in the Little Wabash River watershed are listed as impaired due to low dissolved oxygen concentrations: Little Wabash River (C-19), First Salt Creek (CPC-TU-C1), Second Salt Creek (CPD-04, CPD-03, and CPD-01), Salt Creek (CP-EF-C2), and East Branch Green Creek (CSB-08 and CSB-07). No TMDLs are being developed for these streams at this time due to the considerations described below.

6.1 Dissolved Oxygen Analysis for Little Wabash River (C-19)

Little Wabash River segment C-19 is listed as impaired due to low dissolved oxygen. The original listing was made based on 2 of 30 (7%) dissolved oxygen measurements being below the aquatic life water quality criterion of 5 mg/L. The impairment was confirmed based on the Stage 2 sampling which resulted in additional observations below 5 mg/L from continuous monitoring of dissolved oxygen (refer to Stage 1 and Stage 2 reports for details). The QUAL2K model was setup and calibrated to the August 2006 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Based upon the results of the Stage 1 study, the Stage 2 sampling, and the QUAL2K modeling the low dissolved oxygen conditions in the Little Wabash River appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools[1]. For example, the following was noted during the Stage 2 sampling:

> *"There is uncertainty associated with discharge values generated from flow data for some locations. Results that are very near zero accurately represent the fact that little to no downstream discharge was present, but should be used with caution in terms of defining a specific magnitude of flow. Field observations of "no apparent flow" were common."*

To further investigate this issue three separate analyses were conducted to evaluate the potential for meeting the dissolved oxygen water quality standard in Little Wabash River segment C-19:

- 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

[1] Excessive algal activity due to enriched nutrient concentrations is not considered a likely factor in any of the dissolved oxygen impaired streams in the Little Wabash River watershed because the continuous dissolved oxygen measurements did not show supersaturated conditions or large differences between the maximum and minimum dissolved oxygen values.

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 water quality standards 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 1.52 per day to 2.5 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.

6.2 Dissolved Oxygen Analysis for First Salt Creek (CPC-TU-C1)

First Salt Creek segment CPC-TU-C1 is listed as impaired due to low dissolved oxygen. The original listing was made based on four dissolved oxygen measurements that were all below 5 mg/L, with the most recent excursion occurring in 2001. Dissolved oxygen concentrations less than the criterion were observed at all three monitoring stations, both upstream and downstream of the Teutopolis STP. The impairment was confirmed based on the Stage 2 sampling which resulted in 96 of 96 dissolved oxygen measurements less than 5 mg/L and average hourly dissolved oxygen less than 6 mg/L for 16 of 22 hours (refer to Stage 1 and Stage 2 reports for details). The QUAL2K model was setup and calibrated to the August 2006 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Similar to Little Wabash River segment C-19, the results of the Stage 1 study, the Stage 2 sampling, and the QUAL2K modeling indicate that the low dissolved oxygen conditions in First Salt Creek appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools. To further investigate this issue three separate analyses were conducted to evaluate the potential for meeting the dissolved oxygen water quality standard:

- 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 suggest that complete removal of CBOD and total ammonia loads from both point and nonpoint sources would be sufficient to achieve a minimum dissolved oxygen concentration of 5 mg/L. However, even the complete removal of nonpoint and point source loads is not enough to achieve the 6 mg/L component of the standard. The modeling analysis also suggests that the water quality standards cannot be met even with the complete elimination of sediment oxygen demand. Although the water quality standards could be met if the average re-aeration rate is increased from 17 per day to 95 per day, this may not be technically feasible and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDL will be developed at this time.

6.3 Dissolved Oxygen Analysis for Second Salt Creek (CPD-04, CPD-03, and CPD-01)

Second Salt Creek segments CPD-04, CPD-03, and CPD-01 are listed as impaired due to low dissolved oxygen. The original listings were made based on dissolved oxygen measurements that were collected in 1991 and indicated values of less than 5 mg/L in each segment. The impairments were confirmed based on the Stage 2 sampling which resulted in additional single samples of less than 5 mg/L in segments CPD-04 and CPD-03 and 100 of 100 continuous dissolved oxygen measurements less than 5 mg/L in segment CPD-01 (average hourly dissolved oxygen in segment CPD-01 was also less than 6 mg/L for 24 of 24 hours) (refer to Stage 1 and Stage 2 reports for details). The QUAL2K model was setup and calibrated to the August 2006 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Similar to the other streams in the Little Wabash River watershed, the results of the Stage 1 study, the Stage 2 sampling, and the QUAL2K modeling indicate that the low dissolved oxygen conditions in Second Salt Creek appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools. CBOD and total ammonia loads would need to be reduced by 90 percent to achieve both components of the dissolved oxygen water quality standard. It is doubtful whether that level of nonpoint source load reduction is reasonable or feasible, given that much of this load could be associated with natural background sources. There are no point sources discharging to this stream segment.

The modeling analysis also suggests that the water quality standards cannot be met even with the complete removal of sediment oxygen demand. Although the water quality standards could be met if the average re-aeration rate is increased from 3.7 per day to 20 per day, this may not be technically feasible 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 will be outlined in the Implementation Plan.

6.4 Dissolved Oxygen Analysis for Salt Creek (CP-EF-C2)

Salt Creek segment CP-EF-C2 is listed as impaired due to low dissolved oxygen. The original listing was made based on a single sample of 2.4 mg/L collected in 1999 as part of a facility-related stream survey. The impairment was confirmed based on the Stage 2 sampling which resulted in additional single samples of less than 5 mg/L and 63 of 85 continuous dissolved oxygen measurements less than 5 mg/L (average hourly dissolved oxygen was also less than 6 mg/L for 6 of 24 hours) (refer to Stage 1 and Stage 2 reports for details). The QUAL2K model was setup and calibrated to the August 2006 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Similar to the other streams in the Little Wabash River watershed, the results of the Stage 1 study, the Stage 2 sampling, and the QUAL2K modeling indicate that the low dissolved oxygen conditions in Salt Creek appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools. CBOD and total ammonia loads would need to be reduced by more than 95 percent to achieve both components of the dissolved oxygen water quality standard. It is doubtful whether that level of nonpoint source load reduction is reasonable or feasible, given that much of this load could be associated with natural background sources during these low flow periods when the dissolved oxygen problem is most prevalent.

The modeling analysis also suggests that the water quality standards cannot be met even with the complete removal of sediment oxygen demand. Although the water quality standards could be met if the average re-aeration rate is increased from 4 per day to 30 per day, this may not be technically feasible and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDL will be developed at this time.

6.5 Dissolved Oxygen Analysis for East Branch Green Creek (CSB-08 and CSB-07)

East Branch Green Creek segments CSB-08 and CSB-07 are listed as impaired due to low dissolved oxygen. The original listing for segment CSB-08 was made based on one of two dissolved oxygen measurements from 1991 that was 0.6 mg/L. The original listing for segment CSB-07 was made based on one of two dissolved oxygen measurements from 1991 that was 3.1 mg/L. The impairments were confirmed based on the Stage 2 sampling which resulted in additional single samples of less than 5 mg/L in both segments and 48 of 102 continuous dissolved oxygen measurements less than 5 mg/L in segment CSB-07 (average hourly dissolved oxygen was also less than 6 mg/L for 17 of 24 hours) (refer to Stage 1 and Stage 2 reports for details). The QUAL2K model was setup and calibrated to the August 2006 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Similar to the other streams in the Little Wabash River watershed, the low dissolved oxygen conditions in Salt Creek appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools. CBOD and total ammonia loads would need to be reduced by approximately 60 percent to achieve a minimum dissolved oxygen concentration of 5 mg/L; however, not even the complete removal of all point and nonpoint sources is sufficient to achieve the 6 mg/L component of the water quality standards.

The modeling analysis also suggests that the water quality standards cannot be met even with the complete removal of sediment oxygen demand. Although the water quality standards could be met if the average re-aeration rate is increased from 33 per day to 105 per day, this may not be technically feasible and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDL will be developed at this time.

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Appendix A : Load Duration Analysis

Appendix B : Atrazine, Fecal Coliform, and Manganese Data for Load Duration Analysis

Table B-1. Available Fecal Coliform Data for Segment C 21

Date	Fecal Coliform at station C 21 (cfu/100ml)
1/23/1991	40
3/7/1991	130
4/11/1991	100
5/16/1991	800
6/3/1991	7000
8/8/1991	1500
11/12/1991	710
12/18/1991	1540
1/8/1992	280
3/11/1992	215
4/23/1992	216
5/21/1992	300
7/7/1992	290
8/13/1992	235
9/2/1992	2800
10/5/1992	3300
12/9/1992	85
2/1/1993	20
4/19/1993	300
5/19/1993	20000
6/14/1993	4600
7/26/1993	190
9/27/1993	20000
11/8/1993	50
12/6/1993	200
1/24/1994	420
2/23/1994	2600
4/12/1994	5800
5/11/1994	450
6/22/1994	470
7/25/1994	4000
9/7/1994	310
10/26/1994	320
12/5/1994	100
1/25/1995	10
2/27/1995	30
3/29/1995	200
5/24/1995	290
6/21/1995	20000
7/31/1995	100
9/25/1995	30
11/13/1995	340
1/29/1996	180
4/8/1996	30

Date	Fecal Coliform at station C 21 (cfu/100ml)
5/20/1996	200
6/17/1996	20
7/29/1996	200
9/23/1996	20
10/28/1996	52
12/16/1996	1200
1/27/1997	210
2/24/1997	78
4/7/1997	490
5/12/1997	12
6/16/1997	540
8/18/1997	530
9/22/1997	40
10/29/1997	19
12/15/1997	2
1/12/1998	220
2/23/1998	50
4/6/1998	240
5/18/1998	72
6/15/1998	840
7/27/1998	3770
9/28/1998	47
10/26/1998	2
12/21/1998	62
2/22/2000	106
4/10/2000	350
5/15/2000	890
6/7/2000	250
8/2/2000	674
8/30/2000	280
10/30/2000	60
12/18/2000	420
1/29/2001	24
2/28/2001	60
3/28/2001	12
5/21/2001	1340
6/25/2001	340
8/13/2001	48
9/24/2001	62
10/29/2001	470
11/28/2001	490
1/30/2002	118
2/25/2002	60
3/25/2002	4400
5/6/2002	11800

Date	Fecal Coliform at station C 21 (cfu/100ml)
7/30/2002	92
9/3/2002	6
10/9/2002	10
12/16/2002	28
4/22/2003	510
11/3/2003	160
12/8/2003	110
1/26/2004	32
3/8/2004	80
4/19/2004	26
5/24/2004	140
6/21/2004	780
8/2/2004	370
9/13/2004	230
10/26/2004	410
12/15/2004	94
5/18/2005	102
6/15/2005	410
8/30/2005	88
9/13/2005	40
10/25/2005	58
5/16/2006	54000
7/13/2006	190
9/27/2006	33
10/18/2006	2000

Table B-2. Available Fecal Coliform Data for Segment C19

Date	Fecal Coliform at Station C 19 (cfu/100ml)
1/31/1991	150
2/26/1991	30
4/11/1991	150
5/21/1991	640
6/20/1991	700
8/13/1991	410
9/17/1991	70
11/5/1991	300
12/10/1991	240
2/20/1992	6000
3/26/1992	100
6/4/1992	100
9/22/1992	13000
11/10/1992	1000
12/17/1992	2200

Date	Fecal Coliform at Station C 19 (cfu/100ml)
2/23/1993	1100
3/30/1993	110
5/6/1993	3000
9/23/1993	20000
11/4/1993	80
12/2/1993	3300
1/27/1994	5600
3/8/1994	45
4/20/1994	220
5/17/1994	250
6/21/1994	310
7/21/1994	170
8/30/1994	268
10/6/1994	22
11/29/1994	2900
1/12/1995	170
2/23/1995	44
3/28/1995	110
5/31/1995	1340
6/29/1995	6100
7/27/1995	1740
9/21/1995	70
11/9/1995	22
12/7/1995	42
1/23/1996	570
2/27/1996	25
4/4/1996	300
5/14/1996	590
6/11/1996	5300
7/23/1996	110
9/19/1996	36
11/7/1996	118
12/10/1996	550
2/4/1997	1950
3/4/1997	1350
4/15/1997	86
5/22/1997	20
6/12/1997	400
7/22/1997	47600
9/9/1997	40
10/21/1997	12
12/2/1997	4
1/27/1998	56
3/19/1998	1400
4/21/1998	380

Date	Fecal Coliform at Station C 19 (cfu/100ml)
6/2/1998	110
7/14/1998	220
8/4/1998	5760
9/22/1998	135
11/10/1998	170
7/15/1999	32
1/13/2000	8
2/15/2000	460
3/28/2000	80
4/25/2000	980
5/31/2000	700
8/8/2000	4300
8/29/2000	328
10/17/2000	1060
12/5/2000	24
1/23/2001	9
2/27/2001	800
4/10/2001	76
5/15/2001	33
6/12/2001	88
8/7/2001	480
9/11/2001	32
10/22/2001	116
11/27/2001	300
1/29/2002	54
2/20/2002	2100
4/9/2002	675
5/14/2002	1350
7/31/2002	9500
9/17/2002	8
10/22/2002	48
12/11/2002	4
5/13/2003	468
6/17/2003	400
8/5/2003	660
9/2/2003	5600
10/20/2003	800
11/12/2003	31
1/22/2004	185
2/24/2004	24
4/22/2004	52
5/20/2004	108
6/24/2004	380
8/10/2004	110
9/8/2004	185

Date	Fecal Coliform at Station C 19 (cfu/100ml)
10/26/2004	220
11/30/2004	2100
5/11/2005	25
6/21/2005	17
5/18/2006	3400
7/13/2006	360
8/22/2006	120
10/18/2006	30000

Table B-3. Available Manganese data for Segment C 21

Date	Manganese Data at Station 21 (µg/L)
1/23/1991	125
3/7/1991	142
4/11/1991	154
5/16/1991	280
6/3/1991	350
8/8/1991	169
9/25/1991	131
11/12/1991	320
12/18/1991	230
1/8/1992	240
3/11/1992	250
4/23/1992	130
5/21/1992	490
7/7/1992	770
8/13/1992	270
9/2/1992	220
10/5/1992	480
12/9/1992	290
2/1/1993	150
3/3/1993	270
4/19/1993	180
5/19/1993	160
6/14/1993	230
7/26/1993	170
9/27/1993	270
11/8/1993	180
12/6/1993	120
1/24/1994	320
2/23/1994	690
4/12/1994	400
5/11/1994	110
6/22/1994	740
7/25/1994	460
9/7/1994	420

Date	Manganese Data at Station 21 (µg/L)
10/26/1994	930
12/5/1994	190
1/25/1995	140
2/27/1995	290
3/29/1995	190
5/24/1995	150
6/21/1995	280
7/31/1995	360
9/25/1995	160
11/13/1995	110
12/11/1995	170
1/29/1996	120
2/21/1996	230
4/8/1996	160
5/20/1996	120
6/17/1996	150
7/29/1996	240
9/23/1996	240
10/28/1996	320
12/16/1996	260
1/27/1997	98
2/24/1997	130
4/7/1997	100
5/12/1997	320
6/16/1997	120
8/18/1997	680
9/22/1997	220
10/29/1997	400
12/15/1997	730
1/12/1998	120
2/23/1998	150
4/6/1998	140
5/18/1998	140
6/15/1998	160
7/27/1998	510
9/28/1998	250
10/26/1998	240
12/21/1998	300
1/25/1999	190
2/22/1999	180
4/19/1999	30
5/24/1999	180
6/28/1999	150
7/13/1999	180
9/27/1999	26

Date	Manganese Data at Station 21 (µg/L)
10/18/1999	130
11/22/1999	1900
1/11/2000	140
2/22/2000	150
4/10/2000	270
5/15/2000	610
6/7/2000	400
8/2/2000	190
8/30/2000	250
12/18/2000	140
1/29/2001	160
2/28/2001	110
3/28/2001	220
5/21/2001	130
6/25/2001	270
8/13/2001	280
9/24/2001	320
10/29/2001	130
11/28/2001	150
1/30/2002	220
2/25/2002	99
3/25/2002	870
5/6/2002	1400
6/10/2002	130
7/30/2002	300
9/3/2002	180
10/9/2002	170
12/16/2002	540
1/13/2003	1200
3/17/2003	310
4/22/2003	400
5/27/2003	510
6/30/2003	620
8/11/2003	690
9/22/2003	320
11/3/2003	800
12/8/2003	300
1/26/2004	270
3/8/2004	120
4/19/2004	190
5/24/2004	140
6/21/2004	190
8/2/2004	280
9/13/2004	500
10/26/2004	190

Date	Manganese Data at Station 21 (µg/L)
12/15/2004	180
1/12/2005	170
3/9/2005	150
4/13/2005	170
5/18/2005	440
6/15/2005	130
8/30/2005	320
9/13/2005	110
10/25/2005	200
11/28/2005	180
1/25/2006	100
2/1/2006	170
2/23/2006	150
4/24/2006	170
5/16/2006	280
6/6/2006	210
7/13/2006	730
9/27/2006	240
10/18/2006	95
11/13/2006	1500

Table B-4. Available Atrazine Data for Segment C 19

Date	Atrazine at station C 19 (µg/ml)
4/11/1991	3.60
5/21/1991	17.00
11/5/1991	0.14
3/26/1992	1.40
5/12/1992	1.50
3/30/1993	0.15
6/3/1993	4.20
6/21/1994	15.00
10/6/1994	0.11
4/4/1996	0.72
5/14/1996	5.90
6/11/1996	13.00
4/15/1997	1.60
5/22/1997	2.20
6/12/1997	4.30
4/13/1999	3.20
6/15/1999	11.00
7/15/1999	0.98
4/10/2001	0.26
5/15/2001	0.80
6/12/2001	3.30
8/7/2001	0.70

Date	Atrazine at station C 19 (µg/ml)
9/11/2001	0.48
10/22/2001	0.46
5/14/2002	0.71
5/14/2002	0.55
6/18/2002	9.50
6/18/2002	8.00
7/31/2002	1.30
7/31/2002	1.20
9/17/2002	0.15
9/17/2002	0.13
10/22/2002	1.40
10/22/2002	0.91
1/29/2003	0.25
1/29/2003	0.16
3/18/2003	0.11
4/22/2003	20.00
4/22/2003	18.00
5/13/2003	5.50
5/13/2003	5.40
6/17/2003	8.00
6/17/2003	7.00
8/5/2003	0.78
8/5/2003	0.55
9/2/2003	0.41
9/2/2003	0.19
10/20/2003	0.45
10/20/2003	0.36
11/12/2003	0.25
11/12/2003	0.25
1/22/2004	0.19
2/24/2004	0.18
4/12/2004	0.60
4/19/2004	0.17
4/22/2004	0.32
4/26/2004	3.50
5/3/2004	4.38
5/10/2004	10.52
5/17/2004	2.36
5/20/2004	4.60
5/24/2004	0.14
6/1/2004	2.22
6/7/2004	1.42
6/14/2004	1.11
6/21/2004	1.10
6/24/2004	0.90
6/28/2004	1.02
7/6/2004	0.82

Date	Atrazine at station C 19 (µg/ml)
7/12/2004	1.41
7/19/2004	1.08
7/26/2004	0.82
8/9/2004	1.17
8/10/2004	0.41
8/23/2004	0.99
9/7/2004	0.45
9/8/2004	0.29
9/20/2004	0.79
10/4/2004	0.53
10/18/2004	0.29
10/26/2004	0.15
11/8/2004	1.12
11/22/2004	0.93
12/6/2004	0.60
12/20/2004	0.27
4/20/2005	1.90
6/21/2005	2.50
8/23/2005	0.19
9/27/2005	0.11
12/6/2005	0.96
3/1/2006	0.13
4/20/2006	0.17
5/18/2006	10
6/6/2006	4
7/13/2006	1.1
8/22/2006	0.26
10/18/2006	0.1
11/29/2006	0.16

Table B-5. Available Manganese Data for Segment C 19

Date	Manganese Data at Station C 19 (µg/L)
1/31/1991	356
2/26/1991	232
4/11/1991	167
5/21/1991	410
6/20/1991	420
8/13/1991	574
9/17/1991	960
11/5/1991	165
12/10/1991	190
1/23/1992	160
2/20/1992	216
3/26/1992	160
5/12/1992	220
6/4/1992	580
8/11/1992	620

Date	Manganese Data at Station C 19 (µg/L)
9/22/1992	680
11/10/1992	130
12/17/1992	280
1/26/1993	100
2/23/1993	210
3/30/1993	180
5/6/1993	250
6/3/1993	250
7/22/1993	470
9/23/1993	380
11/4/1993	180
12/2/1993	260
1/27/1994	230
3/8/1994	230
4/20/1994	290
5/17/1994	180
6/21/1994	330
7/21/1994	520
8/30/1994	1100
10/6/1994	520
11/29/1994	480
1/12/1995	230
2/23/1995	140
3/28/1995	280
5/31/1995	290
6/29/1995	350
7/27/1995	250
9/21/1995	430
11/9/1995	920
12/7/1995	350
1/23/1996	210
2/27/1996	380
4/4/1996	160
5/14/1996	430
6/11/1996	240
7/23/1996	300
9/19/1996	410
11/7/1996	470
12/10/1996	130
2/4/1997	430
3/4/1997	220
4/15/1997	190
5/22/1997	650
6/12/1997	130
7/22/1997	390
9/9/1997	400
10/21/1997	440

Date	Manganese Data at Station C 19 (µg/L)
12/2/1997	450
1/27/1998	220
3/19/1998	180
4/21/1998	200
6/2/1998	210
7/14/1998	200
8/4/1998	280
9/22/1998	460
11/10/1998	210
12/8/1998	380
1/20/1999	160
3/9/1999	200
4/13/1999	200
5/18/1999	180
6/15/1999	710
7/15/1999	290
8/31/1999	860
10/13/1999	260
11/16/1999	920
1/13/2000	180
2/15/2000	200
3/28/2000	270
4/25/2000	220
5/31/2000	220
10/17/2000	260
12/5/2000	250
1/23/2001	140
2/27/2001	310
5/15/2001	430
6/12/2001	200
9/11/2001	640
10/22/2001	240
11/27/2001	240
1/29/2002	210
2/20/2002	510
4/9/2002	250
5/14/2002	290
6/18/2002	170
7/31/2002	960
9/17/2002	600
10/22/2002	380
12/11/2002	460
1/29/2003	400
3/18/2003	300
4/22/2003	200
5/13/2003	170
6/17/2003	160

Date	Manganese Data at Station C 19 (µg/L)
8/5/2003	72
9/2/2003	580
10/20/2003	210
11/12/2003	130
1/22/2004	160

Appendix C : Fecal Coliform Data for NPDES Facilities

Table C-1. Fecal Coliform Counts from IL DOT- I57 Effingham County

Date	Fecal Count (cfu/100 mL)	Flows (MGL)	Rec Season
3/31/2003	470	0.012	No
4/30/2003	580	0.013	No
5/31/2003	300	0.012	Yes
8/31/2003	10250	0.016	Yes
9/30/2003	9600	0.012	Yes
11/30/2003	4900	0.011	No
3/31/2004	40	0.012	No
4/30/2004	105	0.006	No
7/31/2004	155	0.007	Yes
9/30/2004	90	0.01	Yes
10/31/2004	115	0.01	Yes
11/30/2004	65	0.01	No
12/31/2004	10	0.009	No
1/31/2005	20	0.006	No
2/28/2005	25	0.008	No
4/30/2005	10	0.008	No
5/31/2005	10	0.013	Yes
6/30/2005	45	0.014	Yes
7/31/2005	27	0.015	Yes
8/31/2005	78	0.012	Yes
11/30/2005	218	0.0014	No
12/31/2005	23	0.002	No
1/31/2006	62	0.023	No
2/28/2006	100	0.00018	No
3/31/2005	40	0.013	No
4/30/2006	55	0.0432	No
5/31/2006	105	0.022	Yes
6/30/2006	220	0.00144	Yes
7/31/2006	25	0.003	Yes
8/31/2006	14	0.043	Yes
9/30/2006	28	0.029	Yes
11/30/2006	197	0.0058	No
12/31/2006	130	0.0014	No

Table C-2. Fecal Coliform Counts from IL DOT FAI-70 Rest Area

Date	Fecal Count (cfu/100 mL)	Flows (MGL)	Rec Season
5/31/2003	90		Yes
6/30/2003	65	0.015	Yes
7/31/2003	847	0.014	Yes
9/30/2003	1920	0.006	Yes
3/31/2004	20	0.005	No
7/31/2004	120	0.01	Yes
8/31/2004	163	0.012	Yes
11/30/2004	110	0.009	No
1/31/2005	140	0.3	No
6/30/2005	190	0.015	Yes
12/31/2004	20	0.011	No
2/28/2005	50	0.009	No
10/31/2005	280	0.00036	Yes
3/31/2005	55	0.011	No
10/31/2006	23	0.006	Yes
11/30/2006	57	0.0014	No
12/31/2006	83	0.0014	No

Table C-3. Fecal Coliform Counts from Clay City WWTP

Date	Overflow count (cfu/100mL)	Overflow Flow(MGL)	Rec Season
1/31/2003	180	0.142	No
2/28/2003	240	0.205	No
3/31/2003	300	0.259	No
4/30/2003	140	0.211	No
5/31/2003	180	0.337	Yes
11/30/2003	240	0.489	No
6/30/2004	260	0.245	No
1/31/2004	200	0.528	No
11/30/2004	360		No
12/31/2004	340		No
2/28/2005	320		No
3/31/2006	400	120	No

Table C-4. Fecal Coliform Counts from Effingham STP

Date	Overflow count (cfu/100mL)	Treated CSP outfall Overflow Flow(MGL)	Rec Season
5/31/2003	330	2.229	Yes
9/30/2003	25	2.584	Yes
11/30/2003	20	1.852	No
1/31/2004	237	4.675	No
3/31/2004	20	2.806	No
5/31/2004	5	5.147	Yes
8/31/2004		0.849	Yes
1/31/2005		22.402	No
3/31/2006		1.786	No

Table C-5. Fecal Coliform Counts from Neoga STP

Date	Overflow count (cfu/100mL)	Overflow Flow(MGL)	Rec Season
3/31/2006	0	18.437	No
4/30/2006	0	4.102	No
5/31/2006	0	1.31	No

Appendix D : QUAL2K Modeling

D.0 Dissolved Oxygen Model (QUAL2K)

The QUAL2K water quality model was selected for the development of Little Wabash River watershed dissolved oxygen TMDLs. 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. Five QUAL2K models were set up for each impaired stream to address low dissolved oxygen conditions. The impaired streams are East Brach Green Creek, Second Salt Creek, First Salt Creek, Salt Creek, and Little Wabash River.

D.1 Model Setup

This section of the appendix describes the process that was used to setup the QUAL2K model for the Little Wabash River watershed.

D.1.1 Stream Segmentation

Each impaired stream was segmented into a series of subsegments in the QUAL2K model. The subsegment is referred to as an element in the QUAL2K model and the element can be defined as a computational cell. Flow and mass balance calculations are performed within this cell at each time step that the user specifies. The QUAL2K model for East Branch Green Creek consists of 22 elements with the length of each element ranging from 0.4 km to 1 km. The total modeled length of the creek is 15.05 km. The QUAL2K model for Second Salt Creek consists of 15 elements with the length of each element ranging from 0.5 km to 1 km. The total modeled length of the creek is 11.4 km. The QUAL2K model for First Salt Creek consists of 24 elements with each element length set at 0.1 km. The total modeled length of the creek is 2.4 km. The QUAL2K model for Salt Creek consists of 34 elements with the length of each element ranging from 0.5 km to 1 km. The QUAL2K model for Little Wabash River consists of 91 elements with the length of each element set at 1 km. The total modeled length of the river is 91 km. The element length for each QUAL2K model was determined in relation to hydrogeometry of the streams, tributaries locations, point and nonpoint source locations, and flow and water quality sampling points.

D.1.2 Geometry, Elevation and Weather data

Measurement data, such as flow (cfs), river width (ft) and average water depth (ft) are available at several locations throughout the impaired segments. The Manning Formula was selected for the QUAL2K model to simulate flow, water depth, and water velocity. The selected Manning's n value was in the range of 0.05 to 0.055. The cross sectional stream geometry was configured as either rectangular or trapezoidal in each QUAL2K model. The bottom stream widths were estimated from the river widths measured in the field and adjusted during the model calibration process. Elevation data for each stream segment was estimated using digital elevation map (DEM). The slopes of the streams were estimated from DEM and stream lengths, and adjusted during the model calibration process. 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. The weather data from Effingham County Memorial Airport was selected to use for all of the QUAL2K models based on the availability of the type of the data and the proximity to all the impaired streams. Tables Table D-1 and Table D-2 show the hourly weather data for August 24, 2006 and September 6, 2006 used in the QUAL2K models. These dates were selected for calibration because they exhibited the lowest overall dissolved oxygen concentrations for the most recently collected data and a full suite of water chemistry data were available.

Table D-1. The hourly weather data on August 24, 2006 from Effingham County Memorial Airport

Day	Time	SkyConditions	Dry Bulb Temperture(degC)	Dew Point Temperture(degC)	Wind Speed(mph)
08/24/06	45	CLR	17	16	0
08/24/06	145	CLR	17	16	0
08/24/06	245	CLR	16	15	0
08/24/06	345	CLR	16	15	0
08/24/06	445	SCT001	16	14	0
08/24/06	545	CLR	16	14	0
08/24/06	645	CLR	18	17	0
08/24/06	745	CLR	22	18	0
08/24/06	845	CLR	24	18	3
08/24/06	945	CLR	26	17	5
08/24/06	1045	CLR	27	17	6
08/24/06	1145	CLR	28	17	8
08/24/06	1245	CLR	29	17	8
08/24/06	1345	CLR	29	17	8
08/24/06	1445	CLR	29	17	8
08/24/06	1545	CLR	29	18	6
08/24/06	1645	CLR	29	18	6
08/24/06	1745	CLR	26	19	5
08/24/06	1845	CLR	23	18	5
08/24/06	1945	CLR	21	18	5
08/24/06	2045	CLR	20	17	5
08/24/06	2145	CLR	20	17	3
08/24/06	2245	CLR	20	17	0
08/24/06	2345	CLR	19	17	0

Table D-2. The hourly weather data on September 7, 2006 from Effingham County Memorial Airport

Day	Time	SkyConditions	Dry Bulb Temperture(degC)	Dew Point Temperture(degC)	Wind Speed(mph)
09/07/06	45	SCT090	16	14	0
09/07/06	145	CLR	15	14	0
09/07/06	245	CLR	15	14	0
09/07/06	345	CLR	14	13	0
09/07/06	445	VV005	13	12	0
09/07/06	545	CLR	13	12	0
09/07/06	645	CLR	16	14	0
09/07/06	745	CLR	19	16	0
09/07/06	845	CLR	22	16	0
09/07/06	945	CLR	24	16	3
09/07/06	1045	CLR	26	14	9
09/07/06	1145	CLR	27	15	5
09/07/06	1245	CLR	27	14	5
09/07/06	1345	CLR	28	14	8
09/07/06	1445	CLR	28	13	7
09/07/06	1545	CLR	28	13	3
09/07/06	1645	CLR	27	14	0
09/07/06	1745	CLR	23	18	0
09/07/06	1845	CLR	20	16	0
09/07/06	1945	CLR	19	16	0
09/07/06	2045	CLR	17	15	0
09/07/06	2145	CLR	17	14	0
09/07/06	2245	CLR	16	14	0
09/07/06	2345	CLR	16	14	0

D.1.3 Boundary conditions for headwater flows

The QUAL2K model requires model boundary conditions. It uses the headwater data group to define upstream boundary conditions of model domain. The point source data group defines the condition of point source discharges from facilities or small tributaries that enter simulated stream segments.

Headwater flow conditions for all of the QUAL2K models developed for the Little Wabash River watershed TMDLs were derived by the area weighted estimation method. This method entails that the closest available flow measurement to the headwater staring point is multiplied by the ratio of the area above the starting point to the area contributing to the flow measurement point. The simulated flows from First Salt Creek and Second Branch Creek were added to comprise the head water flow for Salt Creek head water. Headwater flow for Little Wabash River was estimated by the area weighted method from USGS 03379500 data collected at the mouth of the river.

D.2 Calibration

This section of the appendix describes the process that was used to calibrate the QUAL2K model for the Little Wabash River watershed and presents the calibration results.

D.2.1 Critical Conditions

Critical conditions for dissolved oxygen were determined to be the summer low flow condition. This is due to high water temperature that increases oxygen consumption reaction rates. Limno-Tech conducted two low-flow surveys in 2006 (Stage 2 Report). In order to determine critical dates for each impaired segment, dissolved oxygen data collected on August 24, 2006 and September 7, 2006 were used as the basis for the modeling. The mean of the dissolved oxygen data within each impaired segment was calculated separately. The mean values of dissolved oxygen between the two dates were compared and the lower one was selected as an indication of the critical date for the stream. Table D-3 shows the calculated means for dissolved oxygen in each of the impaired streams. The highlighted dissolved oxygen value indicates the lower mean dissolved oxygen, thus, the critical date for the stream. The QUAL2K model was run for each impaired stream using the data collected during the determined critical date.

Table D-3. The mean values of the collected dissolved oxygen (mg/L) at each streams

Name	8/24/2006	9/7/2006
East Branch Green Creek	6.82	5.54
Second Salt Creek	0.98	1.70
First Salt Creek	3.27	3.70
Salt Creek	4.65	5.98
Little Wabash River	6.41	6.27

D.3 Flow and Water Depth Simulation

Flows and the water depths were simulated by the QUAL2K models for all impaired streams. Each model simulated the critical date's flow and depth condition. The flows considered in the models are boundary headwater inflows, tributary inflows, point and nonpoint source inflows and the abstraction of flow by a mechanism such as groundwater outflow from segments. The primary uncertainty of flow input is related to the estimation of nonpoint source inflows and groundwater outflows. Sensitivity analysis was conducted by adjusting these flows to generate model results similar to the available flows and depths data. For the impaired segment in Little Wabash River, there were no observed flow data to compare except for USGS 03379500 located at the mouth of Little Wabash River. Flows at each water quality sampling point within the river's impaired segment were estimated using the area weighted estimation method described previously. Figure D-1 through Figure D-5 show the comparisons of flows and depths between the modeled results and the observed data.

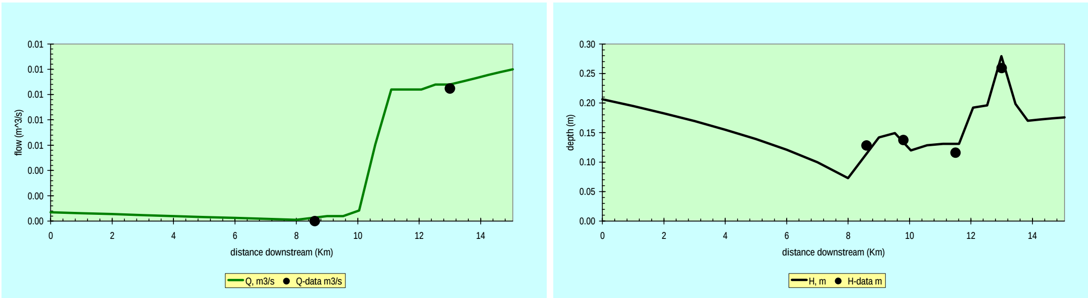

Figure D-1. Comparisons of observed and simulated flow (left) and depth (right) in East Branch Green Creek

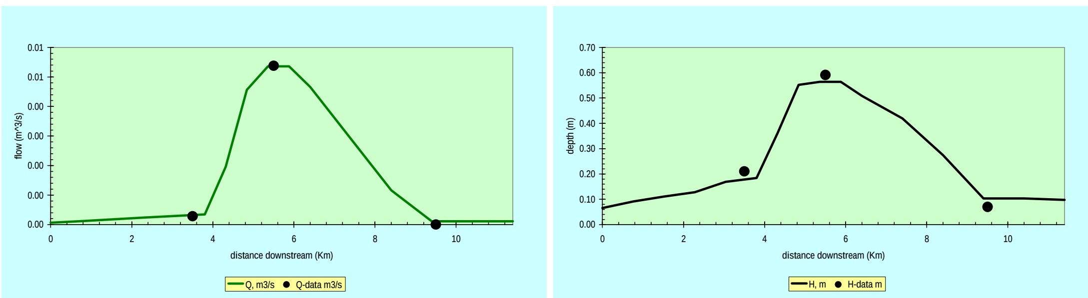

Figure D-2. Comparisons of observed and simulated flow (left) and depth (right) in Second Salt Creek

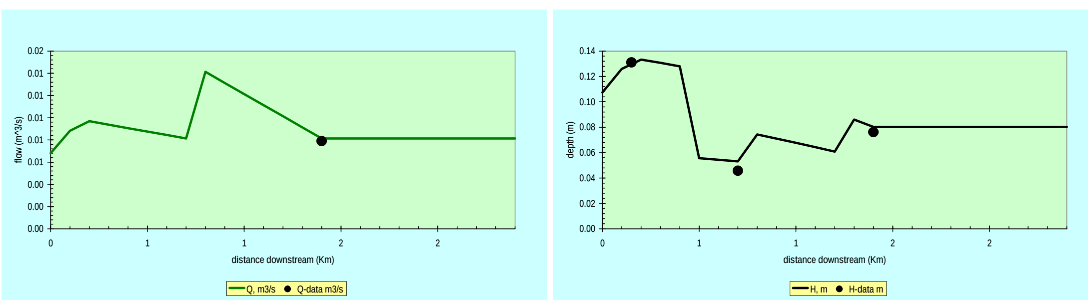

Figure D-3. Comparisons of observed and simulated flow (left) and depth (right) in First Salt Creek

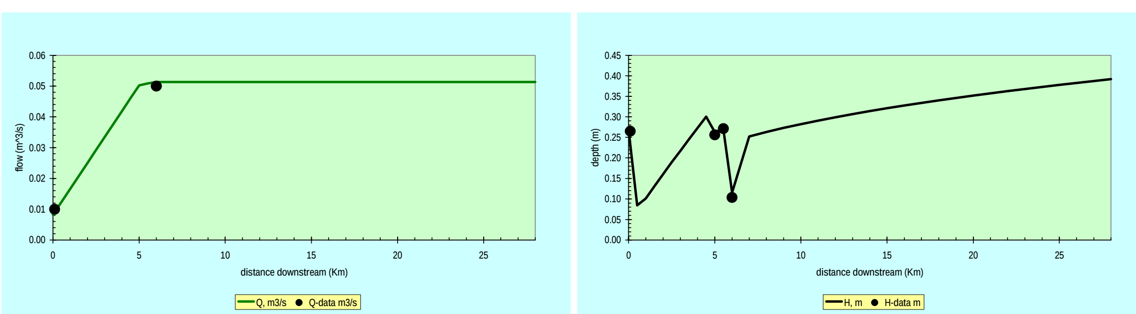

Figure D-4. Comparisons of observed and simulated flow (left) and depth (right) in Salt Creek

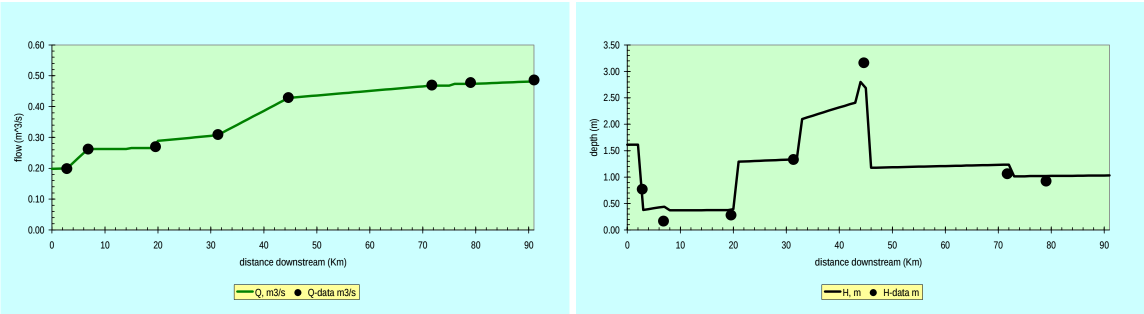

Figure D-5. Comparisons of observed and simulated flow (left) and depth (right) in Little Wabash River

D.4 Point Source Loads

There are seven identified point sources discharging into the impaired segments. The table below shows the summary of the point source data that were incorporated in the models.

Table D-4. Point Source Data Summary

Stream Name/Segment ID	Facility Name & NPDES	Discharging point(km)**	Flow(m^3/s)	Dissolved Oxygen(mg/L)	BOD5 (mg/L)	NH3 + NH4(μg/L)
East Branch Green Creek/CSB08	IL DOT-157 Effingham County (IL0060208)	12.5	0.009	***	9	2000*
First Salt Creek/CPC-TU-C1	Teutopolis STP (ILG582024)	0.7	0.007	***	4	2000*
Salt Creek/CP-EF-C2	Effingham STP (IL0028622)	5.75	0.083	6.8	3	30
Salt Creek/CP-EF-C2	IL DOT-FAI 70 REST AREA (IL0025429)	5.75	0.0007	6.8	4	2000*
Little Wabash River/C19	Clay City WWTP (IL0020974)	75	0.0053	7.1	4	2000*
Little Wabash River/C19	Mason STP (ILG580276)	30	0.0006	***	32	2000*
Little Wabash River/C19	Edgewood STP (ILG580070)	30	0.0004	***	11	2000*
Little Wabash River/C19	Neoga STP (IL0030091)	30	0.008	3.2	3	2000*

*Estimated from “Technical Guidance Manual for Developing TMDLs” (U.S. EPA, 1997).
** The stream starting point is 0 km.
*** No reported values available from facility. Estimated during the calibration process.

D.5 Water Quality Calibration

Each QUAL2K model was calibrated against the observed water quality parameters, such as BOD5, ammonium, dissolved oxygen, and temperature for the critical dates. BOD typically consists of two parts; carbonaceous oxygen demand (CBOD) and nitrogenous oxygen demand. Nitrogenous oxygen demand usually occurs slower than CBOD oxygen demand so the observed BOD5 is regarded as similar to the “fast reacting CBOD” QUAL2K modeling parameter. Thus, the fast reacting CBOD results were compared with the available BOD5 data. Both “fast reacting and slowly reacting” CBOD were added as CBOD nonpoint loads during the model calibration process. Slowly reacting CBOD increases due to detritus dissolution and is lost through hydrolysis and oxidation. Fast reacting CBOD is gained through the dissolution of detritus and the hydrolysis of slowly-reacting CBOD and is lost through oxidation and denitrification.

QUAL2K models were set up so that only CBOD hydrolysis and oxidation, nitrification of ammonium, and denitrification of nitrate could be considered. The observed water quality boundary concentrations were used to input as inflow loadings to the impaired segments. Sensitivity analysis was conducted to determine the input loadings of the parameters from non-point source by adjusting the loads during the calibration period. The reaction rates for hydrolysis, oxidation, nitrification, and denitrification were selected within the range of the literature values (Brown and Barnwell, 1986). Figure D-6 through Figure D-15 show the results of the model calibrations for temperature, dissolved oxygen, BOD5, and ammonium.

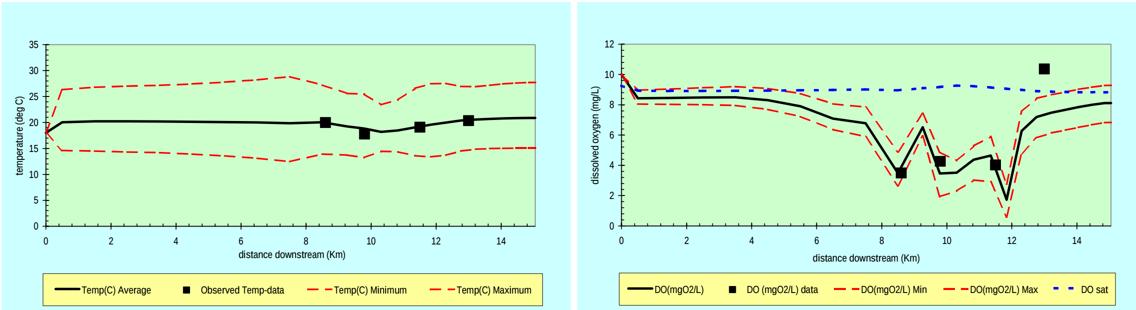

Figure D-6. Temperature (left) and dissolved oxygen (right) calibration in East Branch Green Creek

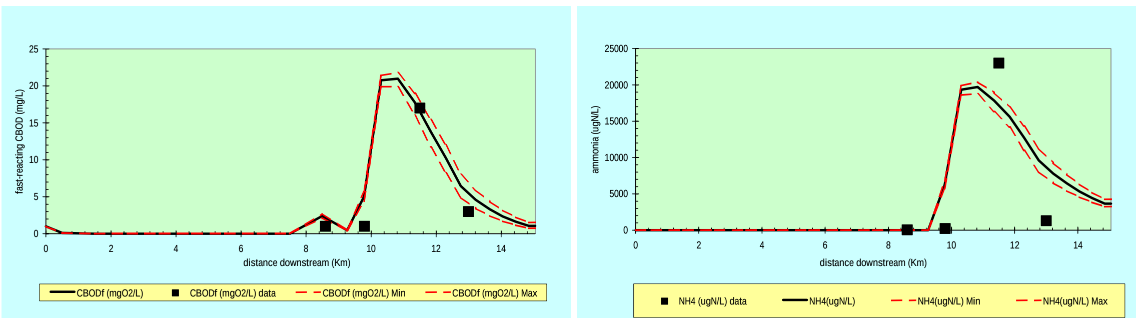

Figure D-7. CBOD (left) and ammonium (right) calibration in East Branch Green Creek

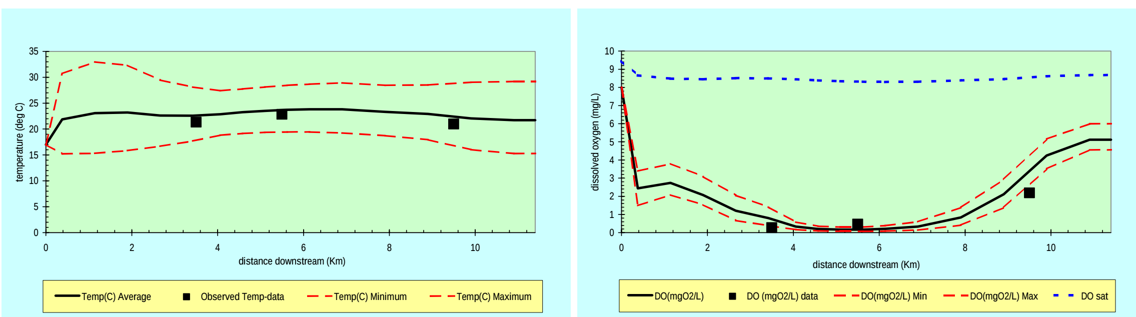

Figure D-8. Temperature (left) and dissolved oxygen (right) calibration in Second Salt Creek

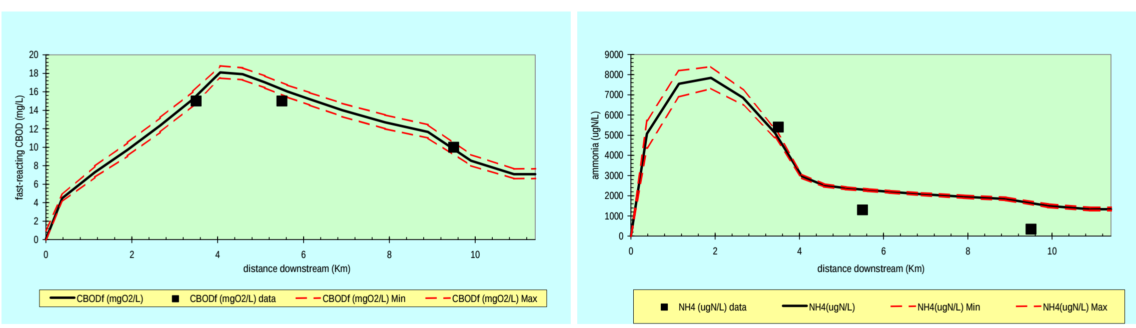

Figure D-9. CBOD (left) and ammonium (right) calibration in Second Salt Creek

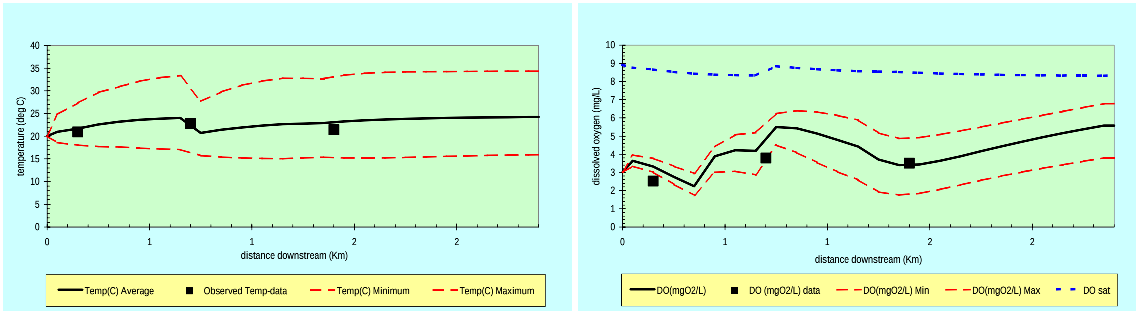

Figure D-10. Temperature (left) and dissolved oxygen (right) calibration in First Salt Creek

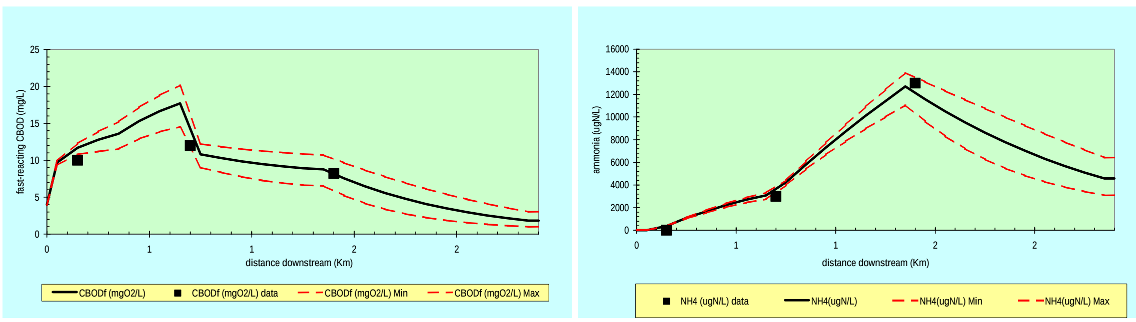

Figure D-11. CBOD (left) and ammonium (right) calibration in First Salt Creek

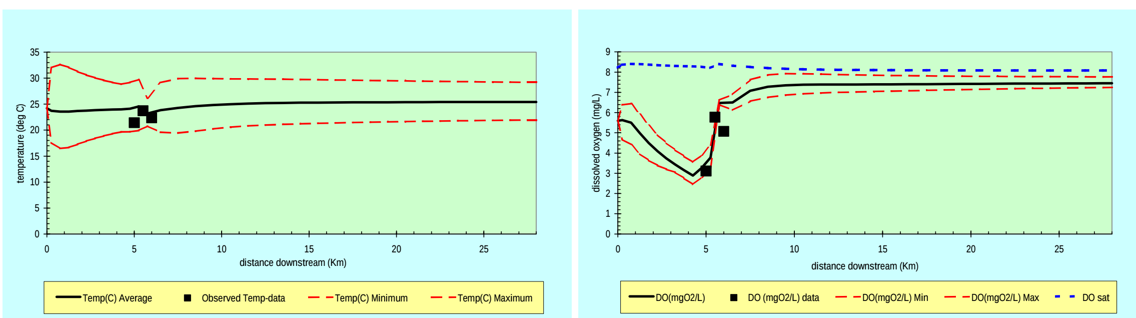

Figure D-12. Temperature (left) and dissolved oxygen (right) calibration in Salt Creek

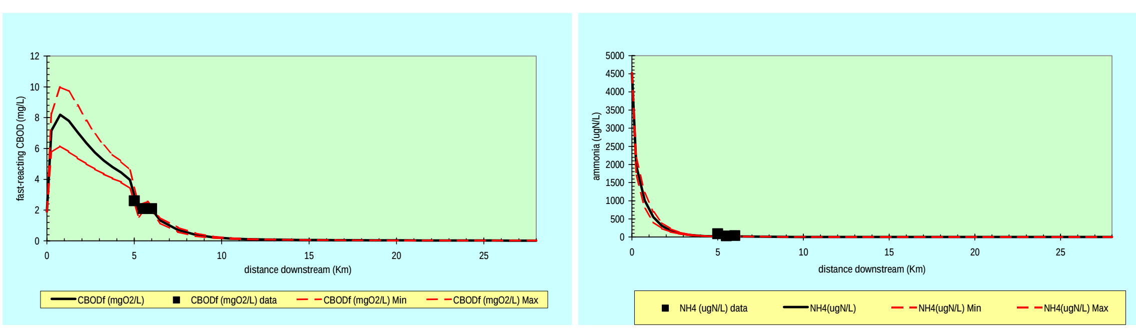

Figure D-13. CBOD (left) and ammonium (right) calibration in Salt Creek

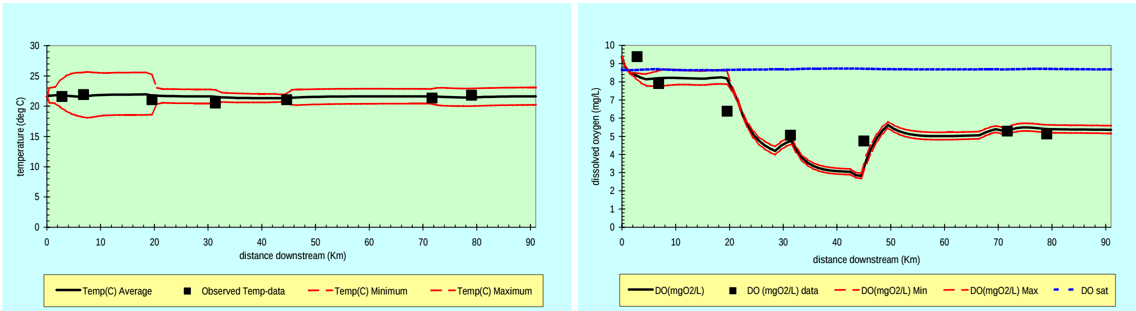

Figure D-14. Temperature (left) and dissolved oxygen (right) calibration in Little Wabash River

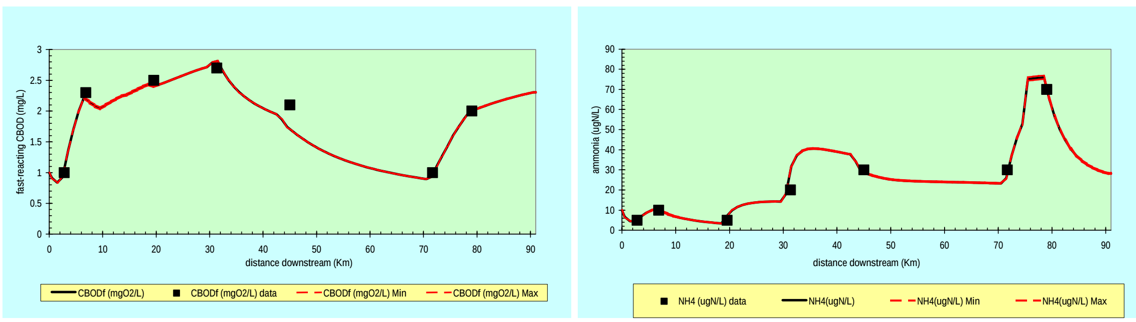

Figure D-15. CBOD (left) and ammonium (right) calibration in Little Wabash River

References

Chapra, S.C., Pelletier, G.J. and Tao, H. 2005. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.04: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

U.S. EPA. 1997. Technical Guidance Manual For Developing Total Maximum Daily Loads; Book2 Streams and Rivers, Oart1: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication, U.S. EPA, Office of Water, 1997

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 E : BATHTUB Model

E.0 Estimating Existing Loads and Flows to the Little Wabash River Watershed Lakes

The BATHTUB model can be used to simulate either an annual or summer season averaging period. Calculation of the nutrient turnover ratio for the limiting nutrient, in this case phosphorus, determines which averaging period is appropriate. The calculation requires analysis of inlake water quality data as well as flow and loading estimates for each period. Simulated loads to Lake Paradise, Lake Mattoon, and Lake Sara include watershed loading as well as atmospheric deposition.

E.1 Lake Paradise Watershed Loading

During Phase 1 of the Clean Lakes Study for this lake, water quality data were collected on the Little Wabash River upstream of Lake Paradise. Tetra Tech used these data to develop load duration curves to estimate nutrient loading to the lake. These regression equations are based on water quality samples collected from March through May 2001 at one water quality station (RCG-T2) in the watershed (Figure E-1). Table E-1 summarizes the regression equations for each nutrient species monitored at this station.

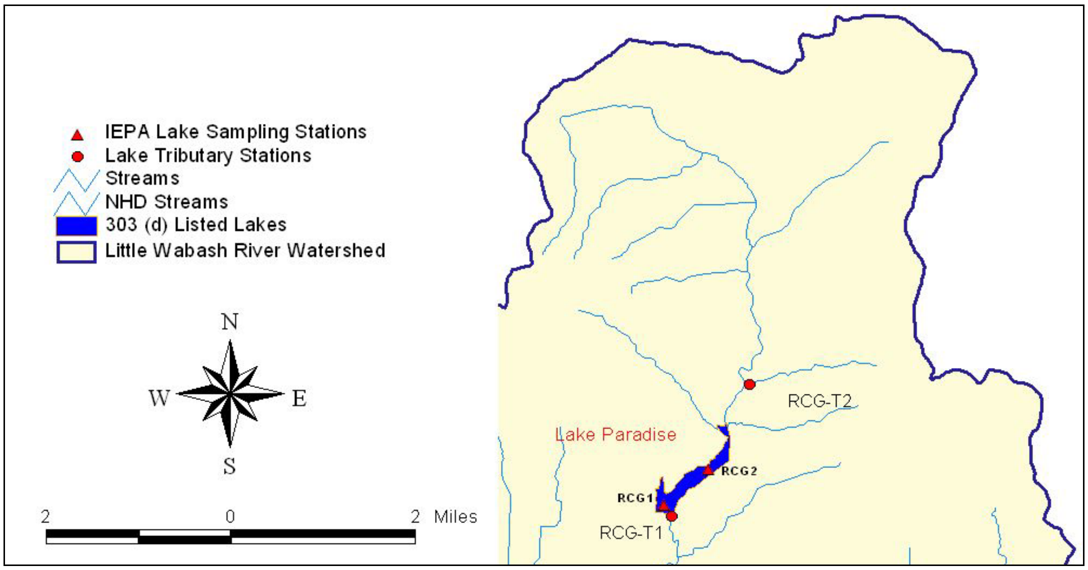

Figure E-1. Lake Paradise Tributary Monitoring Stations

Table E-1. Regression on Flow (Q cfs) for Estimating Nutrient Loads to Lake Paradise

Station	Phosphate (kg/d)	Total Phosphorus (kg/d)	Nitrate plus Nitrite (kg/d)	Ammonia (kg/d)	TKN (kg/d)
RCG-T2	ND	$0.0554Q^{1.6928}$	$24.343Q^{1.0774}$	$0.0297Q^{1.9806}$	$1.1669Q^{1.4011}$

ND: No water quality samples were available to develop a regression equation for this parameter.

The regression equations require an estimate of daily average flow at the station. Flows measured at USGS Gage 03378635 on the Little Wabash River near Effingham, Illinois were scaled down based on the ratio of drainage area at the monitoring station. The drainage area of this gage is approximately 240 square miles. Table E-2 summarizes the drainage area to the water quality monitoring station as well as the total drainage area of the tributary and the shoreline drainage.

Table E-2. Drainage Areas of Water Quality Stations and Tributaries to Lake Paradise

Tributary	Water Quality Station	Drainage Area at Station (mi^2)	Drainage Area at Lake (mi^2)
Little Wabash River	RCG-T2	14.30	14.39
Tributary 1	-	-	1.54
Tributary 2	-	-	0.87
Shoreline Drainage	-	-	1.66

Note: The shoreline drainage area represents all drainages not associated with one of the major tributaries listed in this table. There are currently no stations that monitor water quality from these areas.

Loads passing the water quality station were estimated based on the daily flow and regression equation for each nutrient species. No permitted discharges of nutrients are known to exist upstream of this monitoring station, so total loads to the lake were scaled up by drainage area to account for the downstream area below this station as well as the unnamed tributaries and shoreline drainage. Watershed loads and total flow volumes to Lake Paradise are summarized for the annual and summer season periods in Table E-3 and Table E-4, respectively. The annual season includes all annual data, the summer season includes the months of May through September.

Table E-3. Annual Watershed Loading to Lake Paradise

Year	Stream Flow (MG)	TN Load (ton)	TP Load (ton)
1991	2,356	146	2.9
1992	3,039	213	8.7
1993	8,924	645	25.5
1994	3,693	264	10.2
1995	4,157	304	13.3
1996	5,632	431	22.1
1997	3,402	240	9.1
1998	4,341	298	9.7
2001	3,959	276	9.9
2004	4,818	331	10.9

Table E-4. Summer Season Watershed Loading to Lake Paradise

Summer	Stream Flow (MG)	TN Load (ton)	TP Load (ton)
1991	254	14	0.2
1992	274	16	0.2
1993	2485	181	7.9
1994	654	41	0.9
1995	2545	191	8.8
1996	2663	207	11.0
1997	368	21	0.3
1998	2009	136	4.2
2001	950	68	2.8
2004	992	69	2.5

The BATHTUB model requires input of the fraction of inorganic nutrient load. Inorganic fractions for nitrogen were estimated from the ratio of ammonia plus nitrite plus nitrate to total nitrogen. Inorganic fractions for phosphorus were estimated from the ratio of dissolved phosphorus to total phosphorus.

E.1.1 Lake Paradise Atmospheric Deposition

The BATHTUB model includes rates of direct deposition to the lake surface for total nitrogen and total phosphorus. The EPA Clean Air Status and Trends Network (CASTNET) database reports annual average total nitrogen deposition rates at three sites surrounding Lake Paradise. Site VIN140 is located in Knox County, IL; site ALH157 is located in Madison County, IL; and site BVL130 is located in Champaign County, IL (Figure E-2). Table E-5 lists the reported total nitrogen deposition rate at each site from 1991 through 2004. The average of the rates reported for these three stations was used to estimate the deposition rate to Lake Paradise.

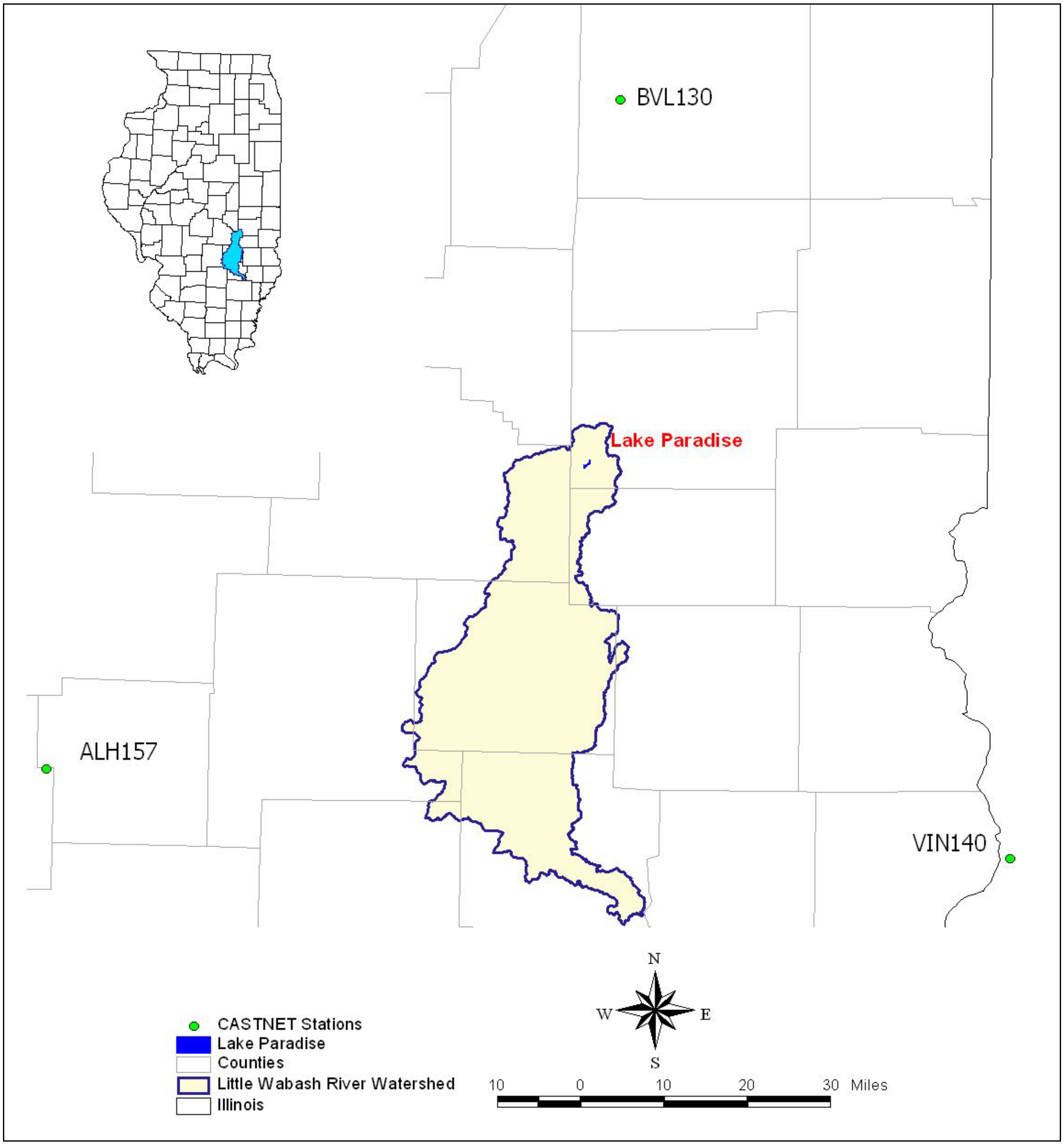

Figure E-2. Location of CASTNET Sites Relative to Lake Paradise

Table E-5. Total Nitrogen Deposition Rates at Three CASTNET Monitoring Stations

Year	TN Deposition at VIN140 (lb/ac/yr)	TN Deposition at ALH157 (lb/ac/yr)	TN Deposition at BVL130 (lb/ac/yr)	Average TN Deposition (lb/ac/yr)
1991	ND	8.2	7.2	7.7
1992	7.8	8.2	7.9	8
1993	10	12	8.8	10.3
1994	9.1	7.4	8.2	8.2
1995	8.4	8.7	8.3	8.5
1996	10.7	ND	ND	10.7
1997	8.4	7.1	7.8	7.8
1998	10.6	10	11	10.6
2001	7.4	5.5	6.4	6.4
2004	9	7	6.8	7.6
Average	9.1	8.2	8	8.6

Direct atmospheric deposition of phosphorus to a lake surface is generally considered insignificant compared to watershed loading rates. In studying phosphorus inputs to Lake Michigan, USGS determined that atmospheric deposition rates in agricultural areas were approximately 0.18 lb/ac/yr (Robertson, 1996). This rate was used for all simulation years.

E.1.2 Lake Paradise Internal Loading

Nutrients can be released from the lake bottom sediments in the summer months during lake stratification and the empirical data within the BATHTUB model implicitly take these loads into account; however, the BATHTUB model does not provide an estimate of internal loads. The Nürnberg method (1984) was therefore chosen to approximate the internal load. This method uses mean depth, flushing rate, average inflow, and average outflow concentrations to estimate internal load. The accuracy of the method is dependent on the available tributary data, which are relatively limited, but the results are nevertheless provided here to provide some perspective on the potential significance of internal loading. For Lake Paradise the internal load is estimated as 14.8 lb/yr, a negligible fraction of the total load.

E.1.3 Summary of Lake Paradise Inlake Water Quality Data

Water quality data for Lake Paradise were obtained from IEPA as a result of the Stage 1 TMDL development activities and Phase I of the Clean Lakes Study. Average nutrient, chlorophyll *a*, and Secchi depth measurements are summarized for the annual and summer season periods in Table E-6 and Table E-7, respectively.

Table E-6. Annual Average Water Quality Parameters for Lake Paradise

Year	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Secchi Depth (in)
1991	0.190	ND	ND	12.9
1992	ND	ND	ND	12.1
1993	0.018	1.86	83.9	12.9
1994	0.238	ND	ND	9.6
1995	0.177	4.65	123.4	11.3
1996	ND	ND	ND	8.2
1997	0.190	ND	85.8	11.0
1998	0.171	4.62	70.5	12.3
2001	0.131	6.17	93.3	12.2
2004	ND	ND	47.0	16.6

Table E-7. Summer Average Water Quality Parameters for Lake Paradise

Year	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Secchi Depth (in)
1991	0.194	ND	ND	13.3
1992	ND	ND	ND	12.1
1993	0.018	1.86	83.9	12.4
1994	0.238	ND	ND	9.3
1995	0.159	5.80	135	11.6
1996	ND	ND	ND	8.3
1997	0.191	ND	83.8	11.2
1998	0.177	4.21	70.8	12.3
2001	0.153	5.46	90.6	10.7
2004	ND	ND	47	16.9

The BATHTUB model may be run for either an annual or summer season period. Determination of the appropriate period is based on evaluation of the turnover ratio. A ratio greater than two indicates that external watershed loading displaces the mass of phosphorus in the lake at least two times during the averaging period. The application of this approach was found by the BATHTUB developers in their study of hundreds of lakes to lead to more accurate simulations of the phosphorus balance. The annual and summer season turnover ratios were calculated using the average inlake total phosphorus concentrations and external nutrient loads for both periods. Because the summer season turnover ratio was greater than two (5.9), the summer season averaging period was chosen to simulate lake response.

E.1.4 Lake Paradise BATHTUB Modeling Results

The USACOE BATHTUB model (Walker, 1987) was set up to simulate nutrient responses in Lake Paradise for the years 1991 through 2004 to correspond with available water quality data. Second order, available nutrient models were used to simulate both nitrogen and phosphorus. Nutrient calibration factors were set to 1 for nitrogen and 0.79 for phosphorus. Calibration factors were adjusted within the default range so that the average ratio of simulated to observed nutrient concentrations was close to 1. A calibration factor of 1 indicates that no adjustment to the model is needed.

Table E-8 compares the simulated and observed nutrient concentrations in Lake Paradise. Results are also shown in Figure E-3 and Figure E-4. Because the observed concentrations of nitrogen and phosphorus from 1993 were significantly lower than all other sampled years, and only two samples for each parameter were collected in 1993, the model calibration and averaged results shown in the figure omit the observed nutrient data from 1993.

Table E-8. Simulated and Observed Nutrient Concentrations in Lake Paradise

Year	Simulated TN (mg/L)	Observed TN (mg/L)	Simulated TP (mg/L)	Observed TP (mg/L)
1991	2.49	ND	0.07	0.19
1992	2.59	ND	0.07	ND
1993	6.00	1.86[1]	0.25	0.02[1]
1994	3.99	ND	0.12	0.24
1995	6.13	5.80	0.27	0.16
1996	6.39	ND	0.30	ND
1997	2.95	ND	0.07	0.19
1998	5.41	4.21	0.19	0.18
2001	4.76	5.46	0.21	0.15
2004	4.71	ND	0.19	ND

[1] The nutrient data observed in 1993 are based on two observations and are significantly lower than all other observed summer averages.

Whether or not concentrations are over-predicted or underpredicted depends on the flow rate condition for each summer. Because a very small data set was used to estimate the load regression equations, and flows during this period were relatively low, the regression equations are not able to accurately predict loading patterns when flows are much higher or lower than those used to develop the equations. If more data are collected, the equations can be updated and more accurate loads input to the BATHTUB model.

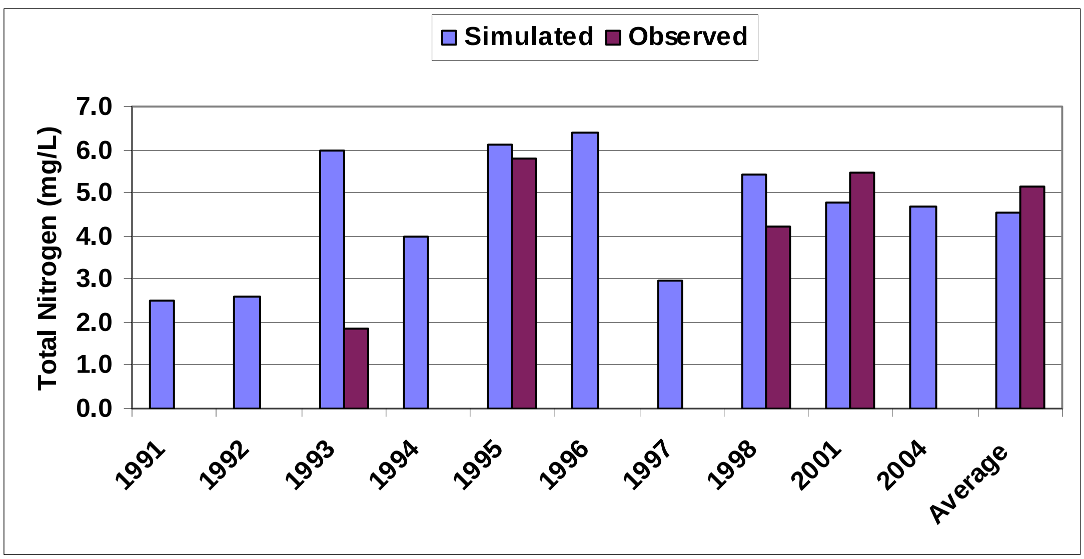

Figure E-3. Comparison of Simulated and Observed Total Nitrogen Concentrations in Lake Paradise

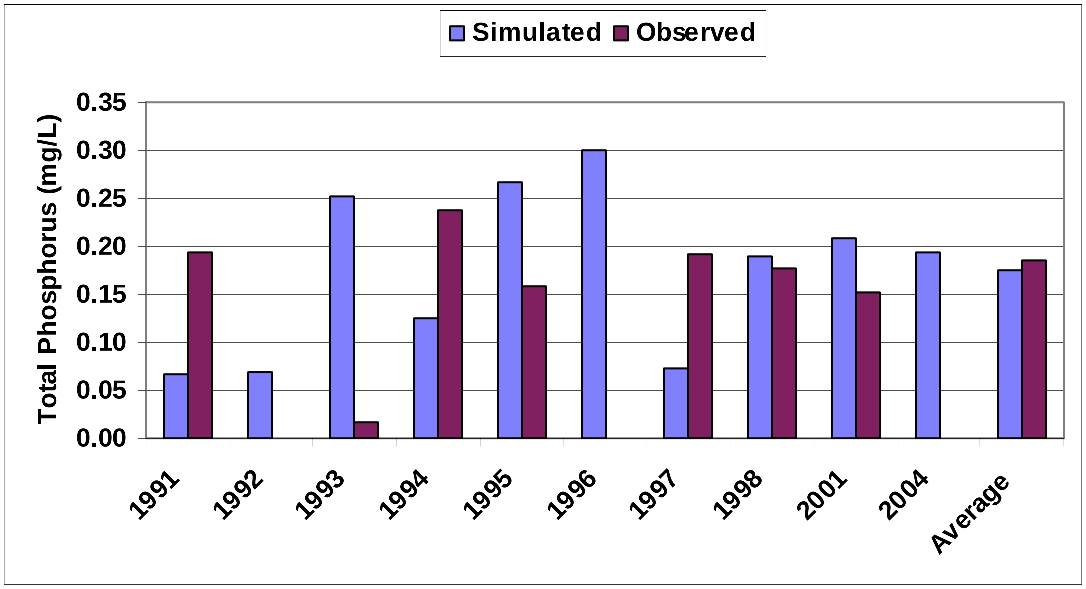

Figure E-4. Comparison of Simulated and Observed Total Phosphorus Concentrations in Lake Paradise

E.2 Lake Mattoon Watershed Loading

During Phase 1 of the Clean Lakes Study for this lake, water quality data were collected on four tributaries upstream of Lake Mattoon. Tetra Tech used these data to develop load duration curves to estimate nutrient loading to the lake. These regression equations are based on water quality samples collected in April and May 2001 at four water quality stations in the watershed (Figure E-5). Table E-9 summarizes the regression equations for each nutrient species monitored.

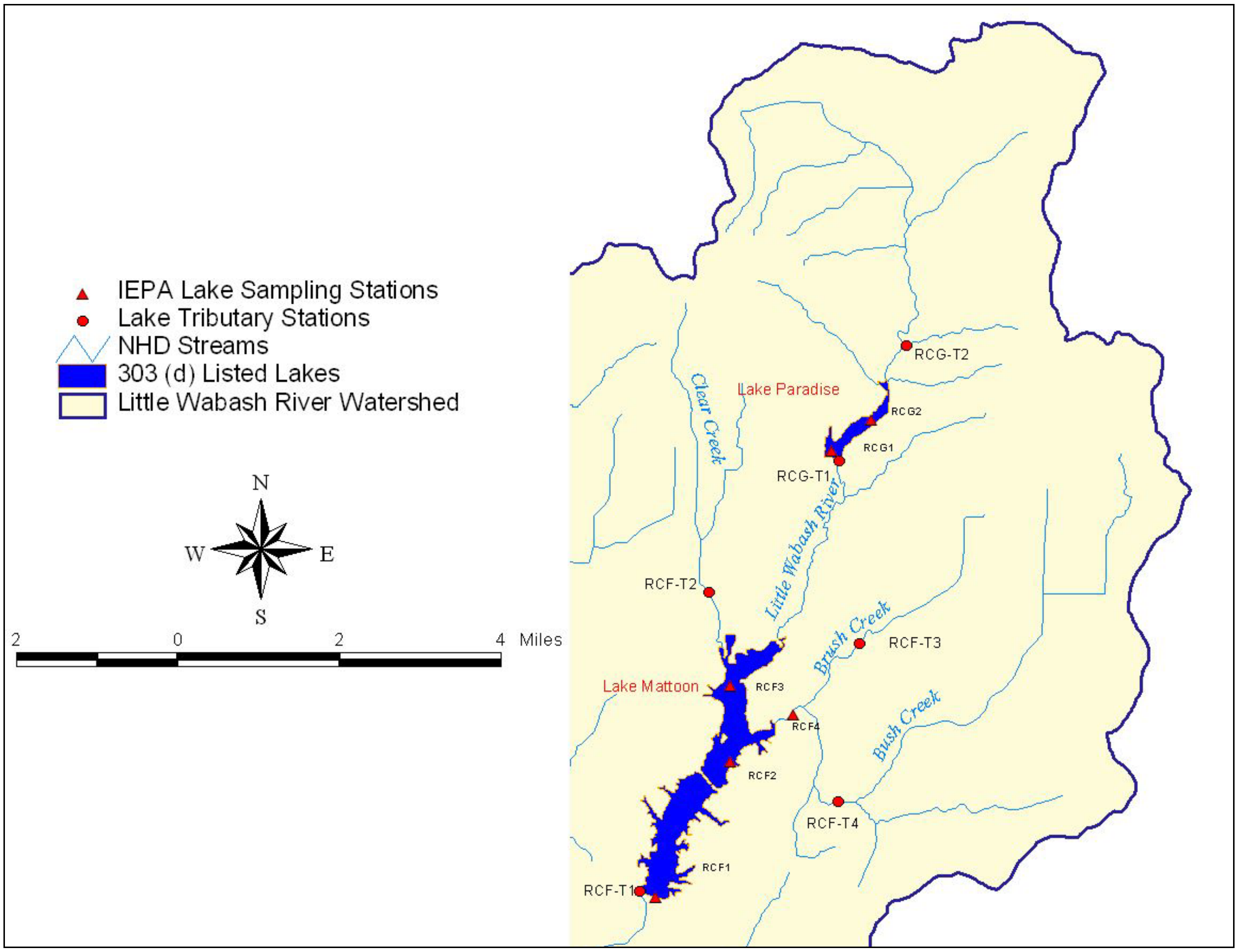

Figure E-5. Lake Mattoon Tributary Monitoring Stations

Table E-9. Regression on Flow (Q cfs) for Estimating Nutrient Loads to Lake Mattoon

Station	Phosphate (kg/d)	Total Phosphorus (kg/d)	Nitrate plus Nitrite (kg/d)	Ammonia (kg/d)	TKN (kg/d)
RCG-T1	ND	$0.7948Q^{0.6743}$	$3.2934Q^{1.3083}$	$0.0041Q^{2.3887}$	$6.6820Q^{0.7943}$
RCF-T2	ND	$0.2416Q^{1.8768}$	$19.359Q^{1.1936}$	$0.7377Q^{1.4440}$	$2.7396Q^{1.4831}$
RCF-T3	ND	$0.2149Q^{1.5180}$	$6.2057Q^{1.3453}$	$0.1579Q^{2.3910}$	$2.4932Q^{1.2480}$
RCF-T4	ND	$0.0815Q^{1.6146}$	$6.9372Q^{0.9245}$	$0.0235Q^{2.3206}$	$1.5499Q^{1.3455}$

ND: No water quality samples were available to develop a regression equation for this parameter.

The regression equations require an estimate of daily average flow at each station. Flows measured at USGS Gage 03378635 on the Little Wabash River near Effingham, Illinois were scaled down based on the ratio of drainage area at each monitoring station. The drainage area of this gage is approximately 240 square miles. Table E-10 summarizes the drainage area to each water quality monitoring station as well as the total drainage area of each tributary and the shoreline drainage.

Table E-10. Drainage Areas of Water Quality Stations and Tributaries to Lake Mattoon

Tributary	Water Quality Station	Drainage Area at Station (mi^2)	Drainage Area at Lake (mi^2)
Little Wabash River	RCG-T1	18.46	23.08
Clear Creek	RCF-T2	4.32	6.07
Brush Creek	RCF-T3	2.62	3.58
Bush Creek	RCF-T4	14.50	14.76
Shoreline Drainage	-	-	8.13

Note: The shoreline drainage area represents all drainages not associated with one of the major tributaries listed in this table. There are currently no stations that monitor water quality from these areas.

Loads passing each water quality station were estimated based on the daily flow and regression equation for each nutrient species. No permitted discharges of nutrients are known to exist upstream of these monitoring stations, so total loads to the lake were scaled up by drainage area to account for the downstream area below each station. To estimate the load from the unmonitored drainage around the lake, an average of the areal loading rates was calculated for Clear, Brush, and Bush Creeks and multiplied by the area of shoreline drainage. Areal rates from the Little Wabash River were excluded from the average because of trapping effects in upstream Lake Paradise which decrease the nutrient loads from this tributary.

Watershed loads and total flow volumes to Lake Mattoon are summarized for the annual and summer season periods in Table E-11 and Table E-12, respectively.

Table E-11. Annual Watershed Loading to Lake Mattoon

Year	Stream Flow (MG)	TN Load (ton)	TP Load (ton)
1991	7,097	316	8.7
1992	9,156	552	26.3
1993	26,887	1,697	74.8
1994	11,127	690	29.8
1995	12,529	818	39.5
1996	16,968	1,219	66.3
1997	10,249	615	27.2
1998	13,080	740	28.3
2001	11,930	703	29.2
2004	14,515	822	32.0

Table E-12. Summer Season Watershed Loading to Lake Mattoon

Summer	Stream Flow (MG)	TN Load (ton)	TP Load (ton)
1991	766	28	0.7
1992	827	31	0.8
1993	7,488	485	23.4
1994	1,971	91	2.7
1995	7,667	525	25.9
1996	8,024	595	32.8
1997	1,109	41	1.0
1998	6,054	333	12.4
2001	2,863	180	8.2
2004	2,989	175	7.6

The BATHTUB model requires input of the fraction of inorganic nutrient load. Inorganic fractions for nitrogen were estimated from the ratio of ammonia plus nitrite plus nitrate to total nitrogen. Inorganic fractions for phosphorus were estimated from the ratio of dissolved phosphorus to total phosphorus.

E.2.1 Lake Mattoon Atmospheric Deposition

The BATHTUB model includes rates of direct deposition to the lake surface for total nitrogen and total phosphorus. The EPA Clean Air Status and Trends Network (CASTNET) database reports annual average total nitrogen deposition rates at three sites surrounding Lake Mattoon. Site VIN140 is located in Knox County, IL; site ALH157 is located in Madison County, IL; and site BVL130 is located in Champaign County, IL (Figure E-6). Table E-13 lists the reported total nitrogen deposition rate at each site from 1991 through 2004. The average of the rates reported for these three stations was used to estimate the deposition rate to Lake Mattoon.

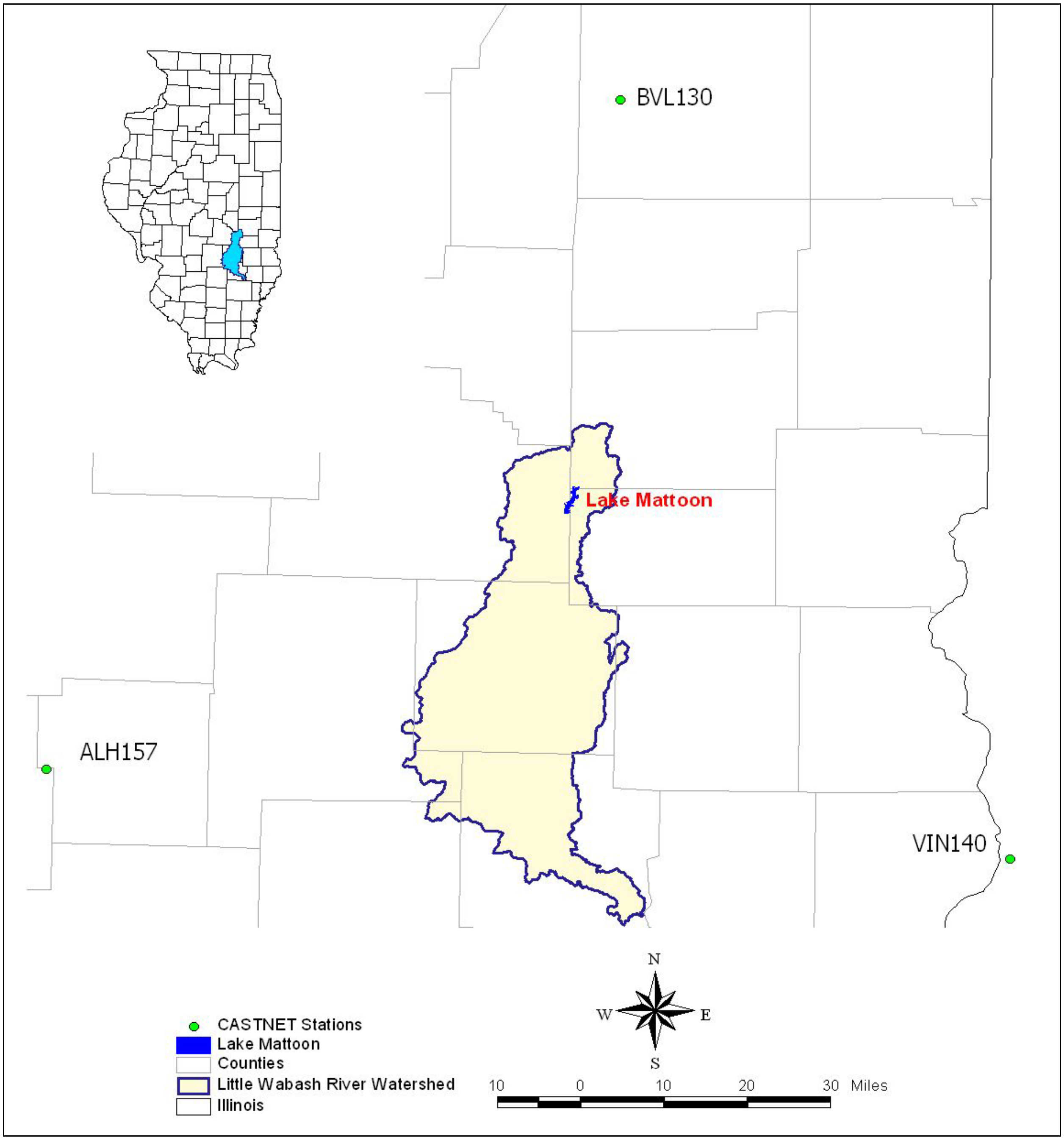

Figure E-6. Location of CASTNET Sites Relative to Lake Mattoon

Table E-13. Total Nitrogen Deposition Rates at Three CASTNET Monitoring Stations

Year	TN Deposition at VIN140 (lb/ac/yr)	TN Deposition at ALH157 (lb/ac/yr)	TN Deposition at BVL130 (lb/ac/yr)	Average TN Deposition (lb/ac/yr)
1991	ND	8.2	7.2	7.7
1992	7.8	8.2	7.9	8
1993	10	12	8.8	10.3
1994	9.1	7.4	8.2	8.2
1995	8.4	8.7	8.3	8.5
1996	10.7	ND	ND	10.7
1997	8.4	7.1	7.8	7.8
1998	10.6	10	11	10.6
2001	7.4	5.5	6.4	6.4
2004	9	7	6.8	7.6
Average	9.1	8.2	8	8.6

Direct atmospheric deposition of phosphorus to a lake surface is generally considered insignificant compared to watershed loading rates. In studying phosphorus inputs to Lake Michigan, USGS determined that atmospheric deposition rates in agricultural areas were approximately 0.18 lb/ac/yr (Robertson, 1996). This rate was used for all simulation years.

E.2.2 Lake Mattoon Internal Loading

Nutrients can be released from the lake bottom sediments in the summer months during lake stratification and the empirical data within the BATHTUB model implicitly take these loads into account; however, the BATHTUB model does not provide an estimate of internal loads. The Nürnberg method (1984) was therefore chosen to approximate the internal load. This method uses mean depth, flushing rate, average inflow, and average outflow concentrations to estimate internal load. The accuracy of the method is dependent on the available tributary data, which are relatively limited, but the results are nevertheless provided here to provide some perspective on the potential significance of internal loading. For Lake Mattoon the internal load is estimated to be insignificant (less than 1 lb/yr).

E.2.3 Summary of Lake Mattoon Inlake Water Quality Data

Water quality data for Lake Mattoon were obtained from the IEPA as a result of Phase 1 of the Clean Lakes Study for Lake Paradise and Lake Mattoon. Annual and summer average nutrient, chlorophyll *a*, and Secchi depth measurements are summarized in Table E-14 and Table E-15.

Table E-14. Annual Average Water Quality Parameters for Lake Mattoon

Year	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Secchi Depth (in)
1991	ND	ND	ND	15.1
1992	0.112	ND	ND	14.5
1993	0.084	0.61	144.9	16.2
1994	ND	ND	ND	16.0
1995	0.130	2.09	89.3	16.0
1996	ND	ND	ND	13.3
1997	ND	ND	ND	15.8
1998	0.129	2.25	83.0	15.4
2001	0.139	2.80	98.3	16.2
2004	ND	ND	ND	ND

Table E-15. Summer Average Water Quality Parameters for Lake Mattoon

Year	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Secchi Depth (in)
1991	ND	ND	ND	15.4
1992	0.112	ND	ND	14.5
1993	0.084	0.61	144.9	16.4
1994	ND	ND	ND	15.9
1995	0.130	2.61	96.5	16.1
1996	ND	ND	ND	14.0
1997	ND	ND	ND	16.2
1998	0.141	1.92	81.1	14.8
2001	0.157	2.06	103.4	15.6
2004	ND	ND	ND	ND

The annual and summer season turnover ratios for Lake Mattoon were calculated using the average inlake total phosphorus concentrations and external nutrient loads for both periods. Because the summer season turnover ratio was greater than two (2.5), the summer season averaging period was chosen to simulate lake response.

E.2.4 Lake Mattoon BATHTUB Modeling Results

The USACOE BATHTUB model (Walker, 1987) was set up to simulate nutrient responses in Lake Mattoon for the years 1991 through 2001to correspond with available water quality data. Second order, available nutrient models were used to simulate both nitrogen and phosphorus. Nutrient calibration factors were set to 2.15 for nitrogen and 0.57 for phosphorus. Calibration factors were adjusted within the default range so that the average ratio of simulated to observed nutrient concentrations was close to 1. A calibration factor of 1 indicates that no adjustment to the model is needed.

Table E-16 compares the simulated and observed nutrient concentrations in Lake Mattoon. Results are also shown in Figure E-7 and Figure E-8.

Table E-16. Simulated and Observed Nutrient Concentrations in Lake Mattoon

Year	Simulated TN (mg/L)	Observed TN (mg/L)	Simulated TP (mg/L)	Observed TP (mg/L)
1991	0.82	ND	0.046	ND
1992	0.86	ND	0.048	0.112
1993	2.42	0.61	0.172	0.084
1994	1.39	ND	0.080	ND
1995	2.51	2.61	0.180	0.130
1996	2.63	ND	0.202	ND
1997	0.97	ND	0.052	ND
1998	2.13	1.92	0.130	0.141
2001	1.88	2.06	0.139	0.157
2004	1.85	ND	0.132	ND

Whether or not concentrations are over-predicted or underpredicted depends on the flow rate condition for each summer. Because a very small data set was used to estimate the load regression equations, and flows during this period were relatively low, the regression equations are not able to accurately predict loading patterns when flows are much higher or lower than those used to develop the equations. If more data are collected, the equations can be updated and more accurate loads input to the BATHTUB model.

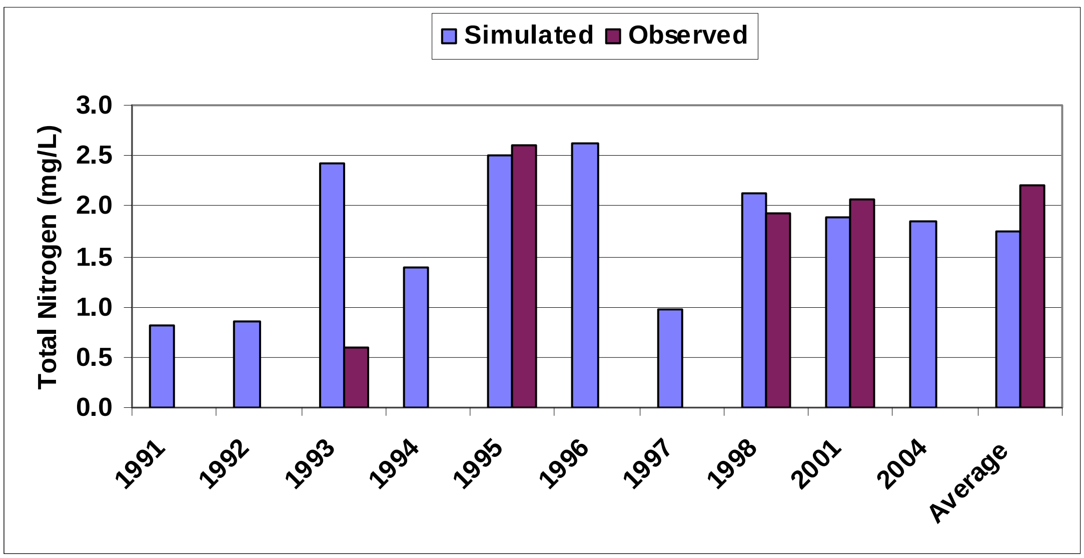

Figure E-7. Comparison of Simulated and Observed Total Nitrogen Concentrations in Lake Mattoon

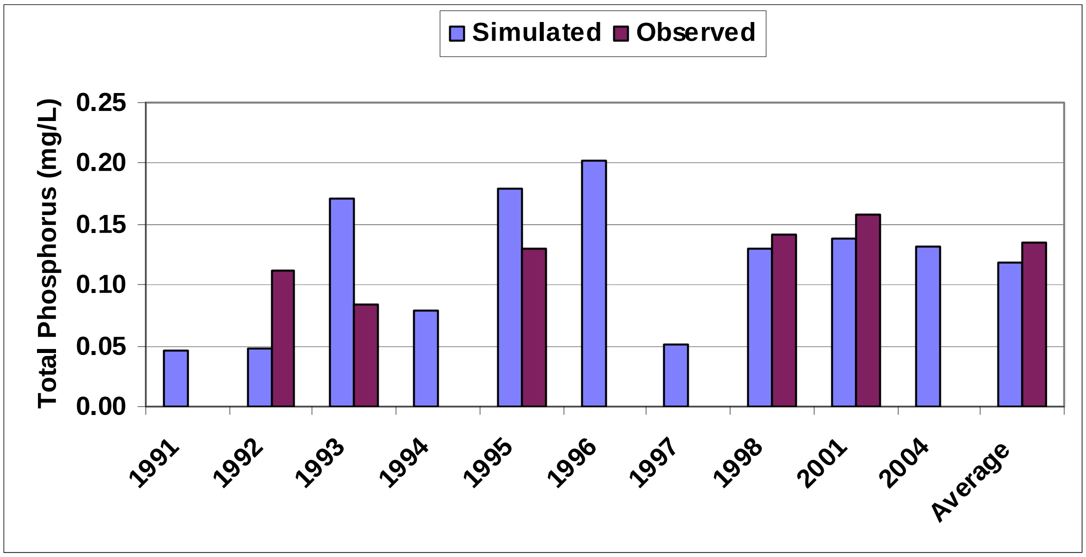

Figure E-8. Comparison of Simulated and Observed Total Phosphorus Concentrations in Lake Mattoon

E.3 Lake Sara Watershed Loading

Tributary monitoring data have not been collected upstream of Lake Sara. Loads and flows estimated to Lake Paradise were scaled down based on the ratio of the drainage areas to each lake. The Lake Paradise watershed is approximately 18 mi^2 and the drainage area to Lake Sara is approximately 12 mi^2. Watershed loads and total flow volumes to Lake Sara are summarized for the annual and summer season periods in Table E-17 and Table E-18, respectively.

Table E-17. Annual Watershed Loading to Lake Sara

Year	Stream flow (MG)	TN load (ton)	TP load (ton)
1991	1,594	99	1.9
1992	2,056	144	5.9
1993	6,037	436	17.3
1994	2,498	179	6.9
1995	2,812	206	9.0
1996	3,810	292	15.0
1997	2,301	162	6.2
1998	2,937	202	6.5
2001	2,679	187	6.7
2002	4,320	334	17.7

Table E-18. Summer Season Watershed Loading to Lake Sara

Summer	Stream flow (MG)	TN load (ton)	TP load (ton)
1991	172	10	0.1
1992	186	11	0.2
1993	1,681	122	5.3
1994	442	28	0.6
1995	1,721	129	5.9
1996	1,802	140	7.4
1997	249	14	0.2
1998	1,359	92	2.9
2001	643	46	1.9
2002	2,174	185	13.1

The BATHTUB model requires input of the fraction of inorganic nutrient load. Inorganic fractions for nitrogen were estimated from the ratio of ammonia plus nitrite plus nitrate to total nitrogen observed in the Lake Paradise watershed. Inorganic fractions for phosphorus were estimated from the ratio of dissolved phosphorus to total phosphorus.

E.3.1 Lake Sara Atmospheric Deposition

The BATHTUB model includes rates of direct deposition to the lake surface for total nitrogen and total phosphorus. The EPA Clean Air Status and Trends Network (CASTNET) database reports annual average total nitrogen deposition rates at three sites surrounding Lake Sara. Site VIN140 is located in Knox County, IL; site ALH157 is located in Madison County, IL; and site BVL130 is located in Champaign County, IL (Figure E-9). Table E-19 lists the reported total nitrogen deposition rate at each site from 1991 through 2004. The average of the rates reported for these three stations was used to estimate the deposition rate to Lake Sara.

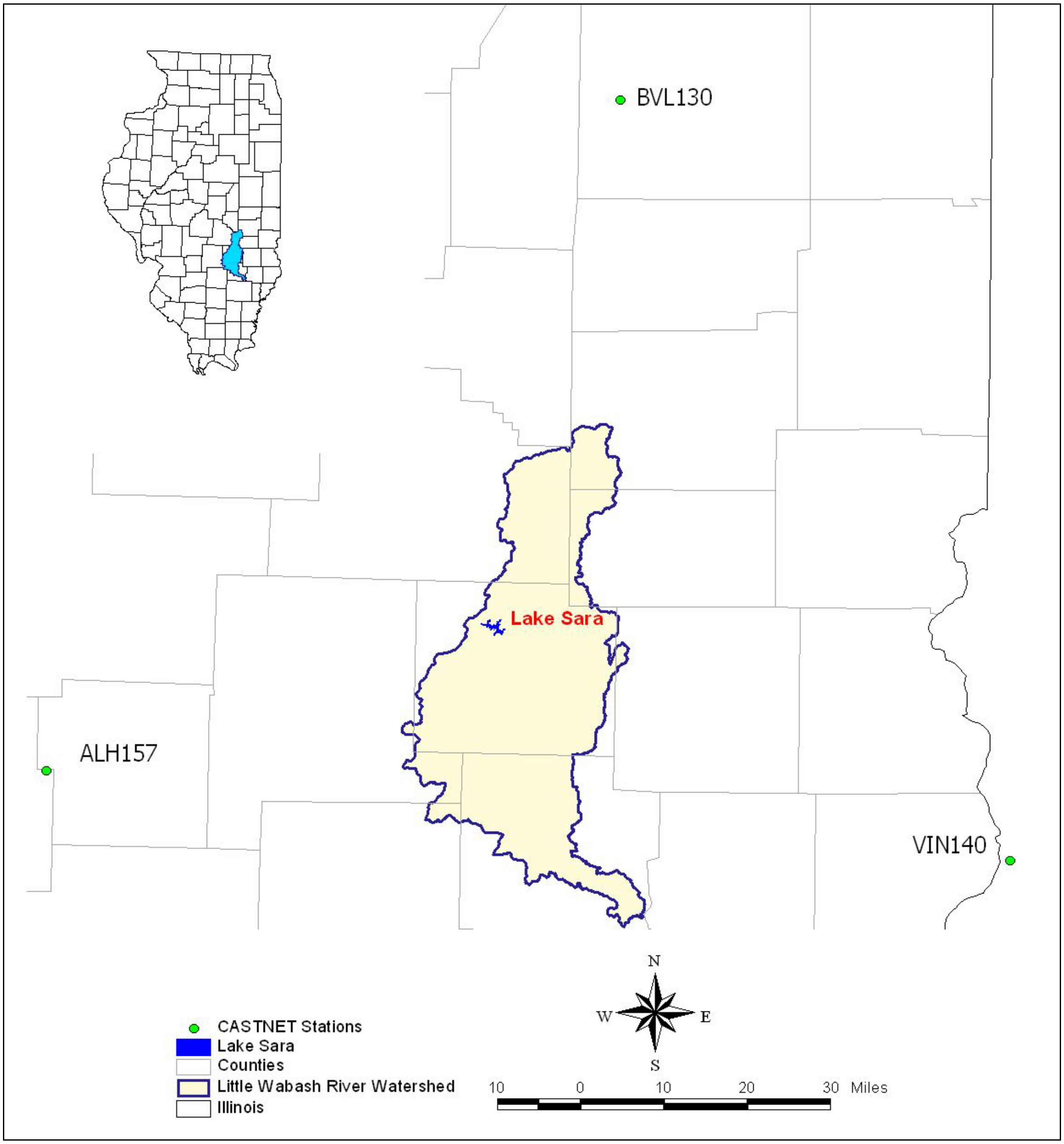

Figure E-9. Location of CASTNET Sites Relative to Lake Sara

Table E-19. Total Nitrogen Deposition Rates at Three CASTNET Monitoring Stations

Year	TN Deposition at VIN140 (lb/ac/yr)	TN Deposition at ALH157 (lb/ac/yr)	TN Deposition at BVL130 (lb/ac/yr)	Average TN Deposition (lb/ac/yr)
1991	ND	8.2	7.2	7.7
1992	7.8	8.2	7.9	8
1993	10	12	8.8	10.3
1994	9.1	7.4	8.2	8.2
1995	8.4	8.7	8.3	8.5
1996	10.7	ND	ND	10.7
1997	8.4	7.1	7.8	7.8
1998	10.6	10	11	10.6
2001	7.4	5.5	6.4	6.4
2004	9	7	6.8	7.6
Average	9.1	8.2	8	8.6

Direct atmospheric deposition of phosphorus to a lake surface is generally considered insignificant compared to watershed loading rates. In studying phosphorus inputs to Lake Michigan, USGS determined that atmospheric deposition rates in agricultural areas were approximately 0.18 lb/ac/yr (Robertson, 1996). This rate was used for all simulation years.

E.3.2 Lake Sara Internal Loading

Nutrients can be released from the lake bottom sediments in the summer months during lake stratification and the empirical data within the BATHTUB model implicitly take these loads into account; however, the BATHTUB model does not provide an estimate of internal loads. The Nürnberg method (1984) was therefore chosen to approximate the internal load. This method uses mean depth, flushing rate, average inflow, and average outflow concentrations to estimate internal load. The accuracy of the method is dependent on the available tributary data, which are relatively limited, but the results are nevertheless provided here to provide some perspective on the potential significance of internal loading. For Lake Sara the internal load is estimated to be insignificant (less than 1 lb/yr).

E.3.3 Summary of Lake Sara Inlake Water Quality Data

Water quality data for Lake Sara were obtained from IEPA as a result of Stage 1 activities. Average nutrient, chlorophyll *a*, and Secchi depth measurements are summarized for the annual and summer season periods in Table E-20 and Table E-21, respectively.

Table E-20. Annual Average Water Quality Parameters for Lake Sara

Year	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Secchi Depth (in)
1991	0.037	ND	ND	35.4
1992	0.033	0.67	14.2	43.0
1993	ND	ND	ND	40.2
1994	ND	ND	ND	36.1
1995	0.034	0.60	27.6	36.1
1996	ND	ND	ND	30.4
1997	ND	ND	ND	35.3
1998	0.047	0.79	18.7	40.3
2001	0.068	0.94	28.6	36.7
2002	0.036	1.11	21.7	37.2

Table E-21. Summer Average Water Quality Parameters for Lake Sara

Year	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Secchi Depth (in)
1991	0.037	ND	ND	35.1
1992	0.026	0.58	13.5	43.8
1993	ND	ND	ND	40.4
1994	ND	ND	ND	35.0
1995	0.044	0.70	30.2	34.6
1996	ND	ND	ND	29.7
1997	ND	ND	ND	36.3
1998	0.049	0.74	26.2	39.8
2001	0.100	0.96	33.0	43.6
2002	0.033	1.02	23.3	42.2

The annual and summer season turnover ratios were calculated using the average inlake total phosphorus concentrations and external nutrient loads for both periods. Even though the summer season turnover ratio was less than two (1.8), it was chosen over the annual averaging period because the summer season simulation more accurately predicts nutrient concentrations in the lake and all of the observed data are from the summer months.

E.3.4 Lake Sara BATHTUB Modeling Results

The USACOE BATHTUB model (Walker, 1987) was set up to simulate nutrient responses in Lake Sara for the years 1991 through 2002 to correspond with available water quality data. The second order, available phosphorus model was used to simulate phosphorus; the second order fixed rate function was used to simulate nitrogen. Nutrient calibration factors were set to 1.8 for nitrogen and 0.2 for phosphorus. Calibration factors were adjusted so that the average ratio of simulated to observed nutrient concentrations was close to 1. A calibration factor of 1 indicates that no adjustment to the model is needed. The phosphorus calibration factor for Lake Sara had to be set out of range to simulate the concentrations observed in 2001.

Table E-22 compares the simulated and observed nutrient concentrations in Lake Sara. Results are also shown in Figure E-10 and Figure E-11. Whether or not concentrations are over-predicted or underpredicted depends on the flow rate condition for each summer. Load regression equations and areal loading rates to Lake Sara are based on values estimated for Lake Paradise. Because a very small data set was used to estimate the load regression equations, and flows observed during the monitoring were relatively low, the regression equations likely do not accurately predict loading patterns when flows are much higher or lower than those used to develop the equations. Ideally, data would be collected on the tributaries upstream of Lake Sara across a wide range of flows to more accurately predict loads to the lake.

Table E-22. Simulated and Observed Nutrient Concentrations in Lake Sara

Year	Simulated TN (mg/L)	Observed TN (mg/L)	Simulated TP (mg/L)	Observed TP (mg/L)
1991	0.34	ND	0.016	0.037
1992	0.36	0.58	0.017	0.026
1993	1.08	ND	0.067	ND
1994	0.54	ND	0.026	ND
1995	1.10	0.70	0.071	0.044
1996	1.15	ND	0.080	ND
1997	0.40	ND	0.018	ND
1998	0.94	0.74	0.050	0.049
2001	0.67	0.96	0.042	0.100
2002	1.31	1.02	0.106	0.033

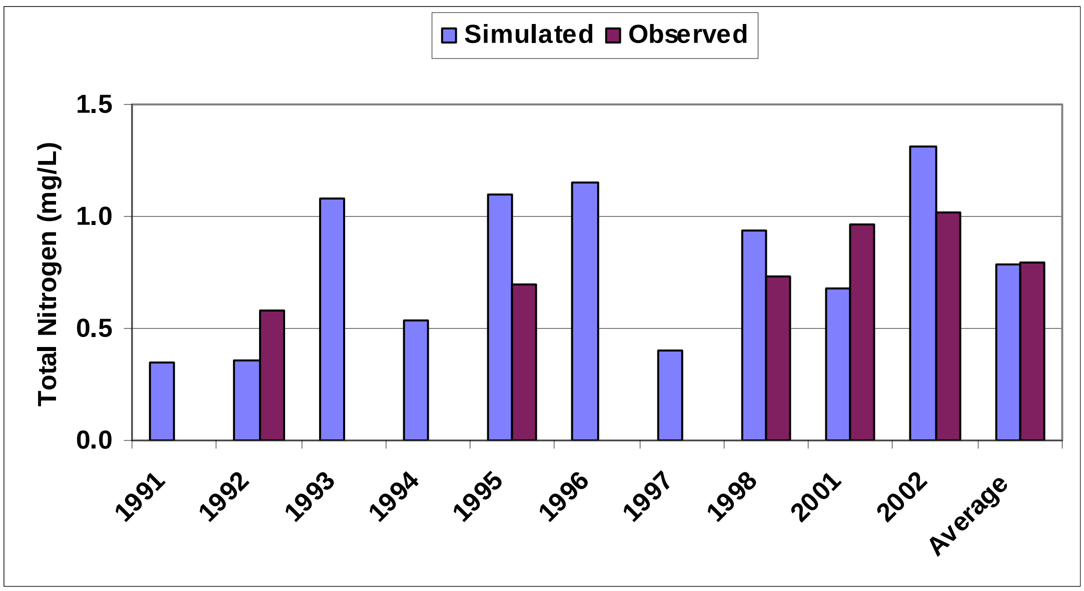

Figure E-10. Comparison of Simulated and Observed Total Nitrogen Concentrations in Lake Sara

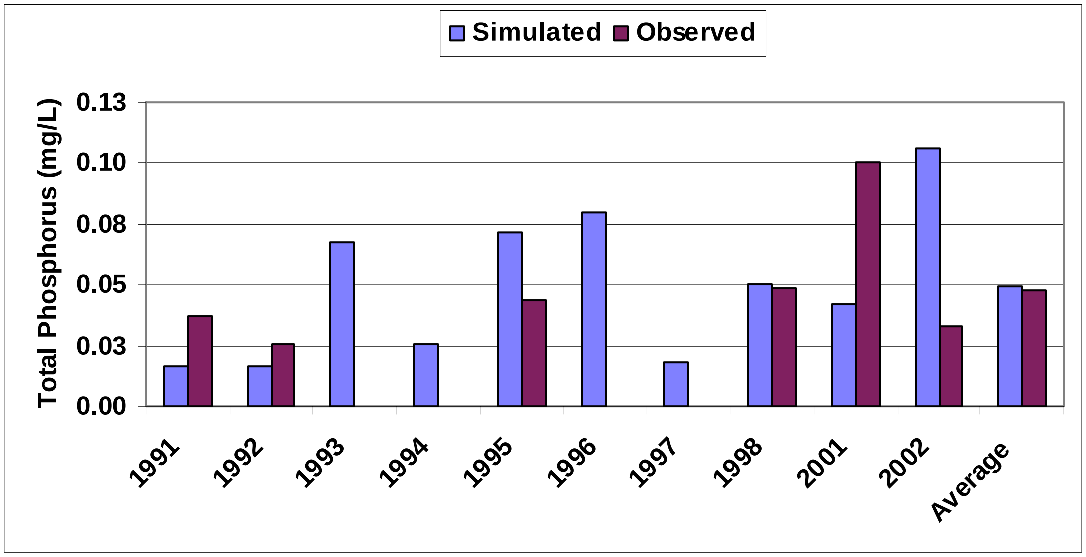

Figure E-11. Comparison of Simulated and Observed Total Phosphorus Concentrations in Lake Sara

Figure E-12. Histograms for Simulated and Observed Phosphorus Concentrations in Lake Sara

Appendix F : Responsiveness Summary

Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from July 26, 2007 through August 17, 2006 postmarked, including those from the August 7, 2007 public meeting discussed below.

What is a TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Little Wabash River watershed Stage 3 TMDL report details the necessary reduction in pollutant loads to the impaired water bodies to ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations thereunder.

Background

The watershed targeted for TMDL development is the Little Wabash River watershed, which originates in Coles County and flows through Cumberland, Shelby, Effingham, and Clay Counties. The watershed encompasses an area of approximately 515,185 acres (805 square miles). Land use in the watershed is predominately agriculture. Three lakes and several stream segments in the Little Wabash River watershed are listed as being impaired according to the *Illinois Integrated Water Quality Report and Section 303(d) List-2006*. . The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards.

Impaired waterbodies and the causes for which TMDLs are addressed in this report are as follows--Little Wabash River segment C-19: dissolved oxygen, manganese, atrazine; Little Wabash River segment C-21: manganese, total fecal coliform; Lake Paradise: total phosphorus and pH; Lake Mattoon: Total phosphorus; Lake Sara: total phosphorus and manganese; First Salt Creek segment CPC-TU-C1, Second Salt Creek segments CPD-01, CPD-03, and CPD-04, Salt Creek segment CP-EF-C2, East Branch Green Creek segments CSB-07 and CSB-08 are all listed as impaired for dissolved oxygen.

The Illinois EPA contracted with Limno-Tech, Inc., to prepare the Stage 1 and Stage 2 reports, and with Tetra Tech, Inc. for preparing the Stage 3 report for the Little Wabash River watershed.

Public Meetings

Public meetings were held in the City of Effingham on August 1, 2006 and August 7, 2007. The Illinois EPA provided public notice for both meetings by placing display ads in the Effingham Daily News and Mattoon Journal Gazette. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 177 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the University of Illinois-Effingham County Extension Office, the Effingham County Soil and Water Conservation District office, as well as the Agency's website at http://www.epa.state.il.us/public-notices .

The Stage 3 public meeting started at 6:00 p.m. on Tuesday, August 7, 2007. It was attended by approximately 12 people and concluded at 7:30 p.m. with the meeting record remaining open until midnight, August 17, 2007.

Questions and Comments

1. Can you identify the sources of the fecal coliform?

   Response: Potential sources of fecal coliform include wildlife, livestock, failing private sewage disposal systems, and municipal point sources that have been granted disinfection exemptions.

2. Can you identify fecal coliform estimates among animal species?

   Response: Laboratory DNA analysis is available to distinguish the species that contributed to the bacteria in the water. Illinois EPA labs currently do not use this analysis.

3. If you increase vegetative growth it may increase dissolved oxygen and decrease sedimentation, but will also attract more wildlife, which may increase the fecal coliform.

   Response: : Increasing vegetative growth along the banks of waterways may attract more wildlife and ultimately may increase the fecal contribution from wildlife. However, the incremental increase is expected to be relatively small and insignificant when compared to the cumulative effects from all sources.

4. Does fecal coliform travel very far downstream?

   Response: Fecal coliform can travel very far downstream. Die-off of fecal coliform is dependent on a number of variables, such as exposure to the sun (ultraviolet light) and sedimentation.

5. Is fecal coliform dormant in the winter months?

   Response: Fecal coliform does not go dormant in the winter months. However, the primary contact water quality standard only applies to the recreation season, defined as May through October.

6. Will farm chemicals be addressed in the implementation plan?

   Response: Yes. In the Stage 3 draft report, an atrazine TMDL is developed for Little Wabash River segment C-19. The Implementation Plan will recommend best management practices for reducing the amount of atrazine that enters this segment.

7. What kinds of aquatic life are most affected by atrazine?

   Response: Since atrazine is an herbicide, aquatic plant species are more sensitive to exposure to atrazine than fish or animals. The

chronic water quality standard for protecting aquatic life use is based on a level necessary to protect algae and duckweed species.

8. Is manganese a human health problem?

   Response: The manganese TMDL developed for Little Wabash River segments C-19 and C-21, as well as Lake Sara, is based on the public water supply standard of 150 µg/L. Manganese is not a human health concern at this level. When manganese is over 150 µg/L, there is the potential that it can produce staining in laundry.

9. What is the greatest source of phosphorus in the watershed?

   Response: The draft report lists potential sources of phosphorus as agriculture runoff from crop production, point sources, stream bank erosion, livestock, and failing private sewage disposal systems as potential sources of total phosphorus. Since a watershed model was not used for TMDL analysis, these sources cannot be individually quantified.

10. Does decaying leaf matter contribute to phosphorus?

    Response: Yes, decaying leaf matter does contribute a phosphorus load to waterbodies. However, the magnitude of this source in an impaired watershed is typically much less than anthropogenic sources such as the application of commercial fertilizers or livestock manure, the discharge from wastewater treatment plants, or loads from failing onsite wastewater treatment systems. Terrestrial leaf litter is typically depleted in nitrogen and phosphorus relative to carbon due to nutrient retention in the tree followed by bacterial uptake on the ground.

Little Wabash River I Watershed TMDL Implementation Plan

FINAL REPORT

April 14, 2008

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

Submitted by:
Tetra Tech

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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KEY FINDINGS

The TMDLs developed for the impaired waterbodies in the Little Wabash River I watershed were approved by USEPA in September 2007. The results indicate that significant reductions of fecal coliform and manganese are needed to attain water quality standards in the river. The lower segment also requires a reduction in atrazine loading. Each of the three listed lakes in the watershed (Paradise, Mattoon, and Sara) are impaired for phosphorus. In addition, Lake Paradise is impaired for pH, and Lake Sara is impaired for manganese. Dissolved oxygen impairments occur in streams throughout the drainage basin, but no TMDLs were calculated for this parameter. The potential sources of pollutant loading in the watershed were difficult to quantify but are expected to include animal operations, crop production, onsite wastewater treatment systems, sewage treatment plants, and natural sources.

Manure from animal operations contributes nutrients, pathogens, and biodegradable organic material. In addition, animals with access to stream channels deposit fecal material 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) livestock fencing, 3) vegetative controls such as grassed waterways, filter strips, and constructed wetlands, 4) manure composting, and 5) restoration of riparian buffers.

Crop production in the watershed results in loadings of nutrients, sediment, manganese, and pesticides. 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, phosphorus, and manganese loads. The most cost-effective management strategy that addresses all pollutants of concern is conservation tillage. Other effective practices include cover crops, 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 most of the facilities are not required to monitor for the TMDL pollutants. The recommendations of the TMDL, as well as any future effluent monitoring data, could result in permit modifications for one or more of the point sources in the watershed. For example, facilities with year-round disinfection exemptions may be required to provide IEPA with updated information to demonstrate compliance with these requirements and facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions.

The number 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.

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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 Little Wabash River I 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 Little Wabash River I Watershed.

Waterbody Name	Waterbody Segment	Segment and Lake Size (Segment Length in Miles, Lake Area in Acres)	Cause of Impairment[a]	Impaired Designated Use
Little Wabash River	C-19	57.17	**Dissolved Oxygen**	Aquatic Life
			Manganese	Public Water Supplies
			Total Fecal Coliform	Primary Contact Recreation
			Atrazine	Aquatic Life
			pH	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Little Wabash River	C-21	31.12	**Manganese**	Public Water Supplies
			Total Fecal Coliform	Primary Contact Recreation
First Salt Creek	CPC-TU-C1	1.45	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
Second Salt Creek	CPD-04	2.92	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Second Salt Creek	CPD-03	1.39	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Second Salt Creek	CPD-01	2.67	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Salt Creek	CP-EF-C2	2.34	**Dissolved Oxygen**	Aquatic Life

Waterbody Name	Waterbody Segment	Segment and Lake Size (Segment Length in Miles, Lake Area in Acres)	Cause of Impairment[a]	Impaired Designated Use
			Total Nitrogen	Aquatic Life
			Total Phosphorus	Aquatic Life
East Branch Green Creek	CSB-08	5.64	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
East Branch Green Creek	CSB-07	3.23	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Lake Paradise	RCG	176	**Total Phosphorus**	Aesthetic Quality & Aquatic Life
			pH	Aquatic Life
			Total Nitrogen	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
Lake Mattoon	RCF	1,010[b]	**Total Phosphorus**	Aesthetic Quality
			Total Suspended Solids	Aesthetic Quality
Lake Sara	RCE	765	**Total Phosphorus**	Aesthetic Quality
			Manganese	Public Water Supplies
			Total Suspended Solids	Aesthetic Quality

[a] Causes of impairment highlighted in bold have numeric water quality standards.

[b] The surface area for Lake Mattoon has been reported as a variety of values over the years, ranging from 750 acres (Mattoon Public Water Supply) to 1,027 (Bogner, 2003) with IEPA traditionally reporting the surface area as 765 acres. However, IEPA re-calculated the surface area as 1,010 acres for this study using the most recent aerial photo and the Illinois Transmercator geographic information system projection and this value was used for the modeling and TMDL development.

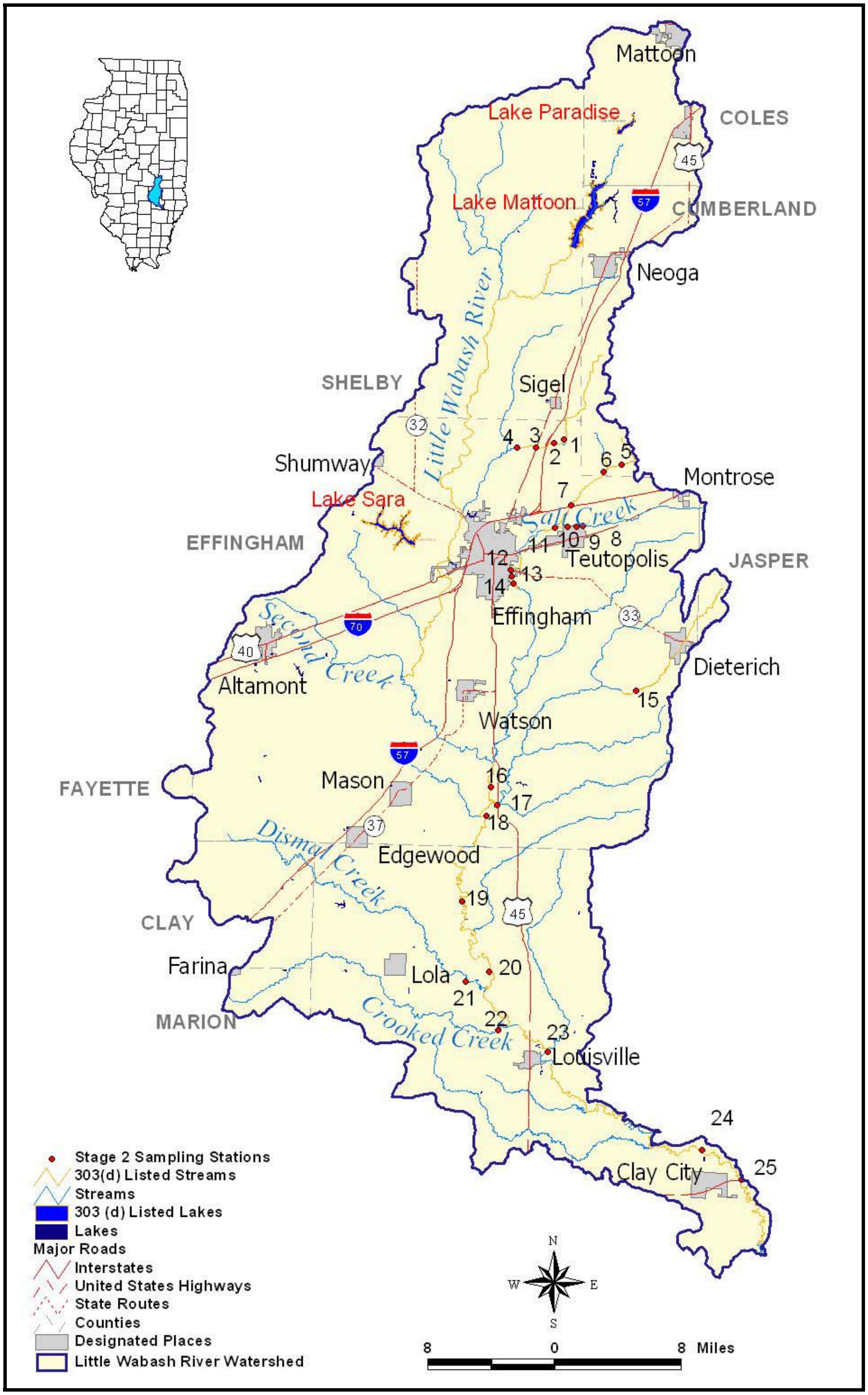

Figure 1-1. 303(d) Listed Reaches in the Little Wabash River I Watershed.

IEPA is currently developing TMDLs for pollutants that have numeric water quality standards. Of the pollutants impairing waterbodies in the Little Wabash River I watershed, total phosphorus, dissolved oxygen, manganese, atrazine, and fecal coliform 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 September 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 segments with little water quality data. The first part of Stage Three was completed and approved by USEPA in September 2007 and involved modeling and TMDL analyses for the Little Wabash River I watershed impairments. 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 Little Wabash River I watershed were developed using load duration equations, QUAL2K, or BATHTUB models depending on the pollutant causing the impairment as well as the hydraulic function of the listed reach. 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 3 TMDL report for the watershed which is available online at:

http://www.epa.state.il.us/water/tmdl/report-status.html#litwab

2.0 DESCRIPTION OF WATERBODY AND WATERSHED CHARACTERISTICS

The purpose of this section of the report is to provide a brief background of the Little Wabash River I 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 IL038 (Bluford-Ava-Hickory) and IL006 (Cisne-Hoyleton-Darmstadt) (Figure 2-1). Soil erodibility factors reported for these soils in the STATSGO database range from 0.32 to 0.43, indicating moderate soil erodibility. Soils identified by STATSGO as highly erodible generally have slopes greater than 5 percent and represent only 13 percent of the total watershed area (Figure 2-2). Based on an intersection of soils data with 2001 land use data (see below), most of the highly erodible soils are currently forest, cultivated land, or pasture.

Land use/land cover in the watershed is largely crop production (69 percent) based on satellite imagery collected around 2001 (INHS, 2003) (Figure 2-3). Additional land use/land cover includes pasture/hay (7 percent), forest (19 percent), urban areas (3 percent), and wetlands (1 percent).

This watershed is located within the Upper Little Wabash River Ecosystem Partnership (Figure 2-4). This partnership includes the headwaters of the Little Wabash River as well as the Skillet Fork and Fox River watersheds. In 2007, the partnership developed a strategic watershed plan with the following goals: improve stream quality; improve water quality; increase the area of wetlands, forest, high quality pasture, and grasslands; protect groundwater; improve livestock operations; address point sources; and increase species richness (ULWREP, 2007). Much of the area draining to the listed segments in this watershed has been prioritized for addressing all of these goals comprehensively. A copy of the plan can be found at the website listed below.

http://www.littlewabash.com/index.htm

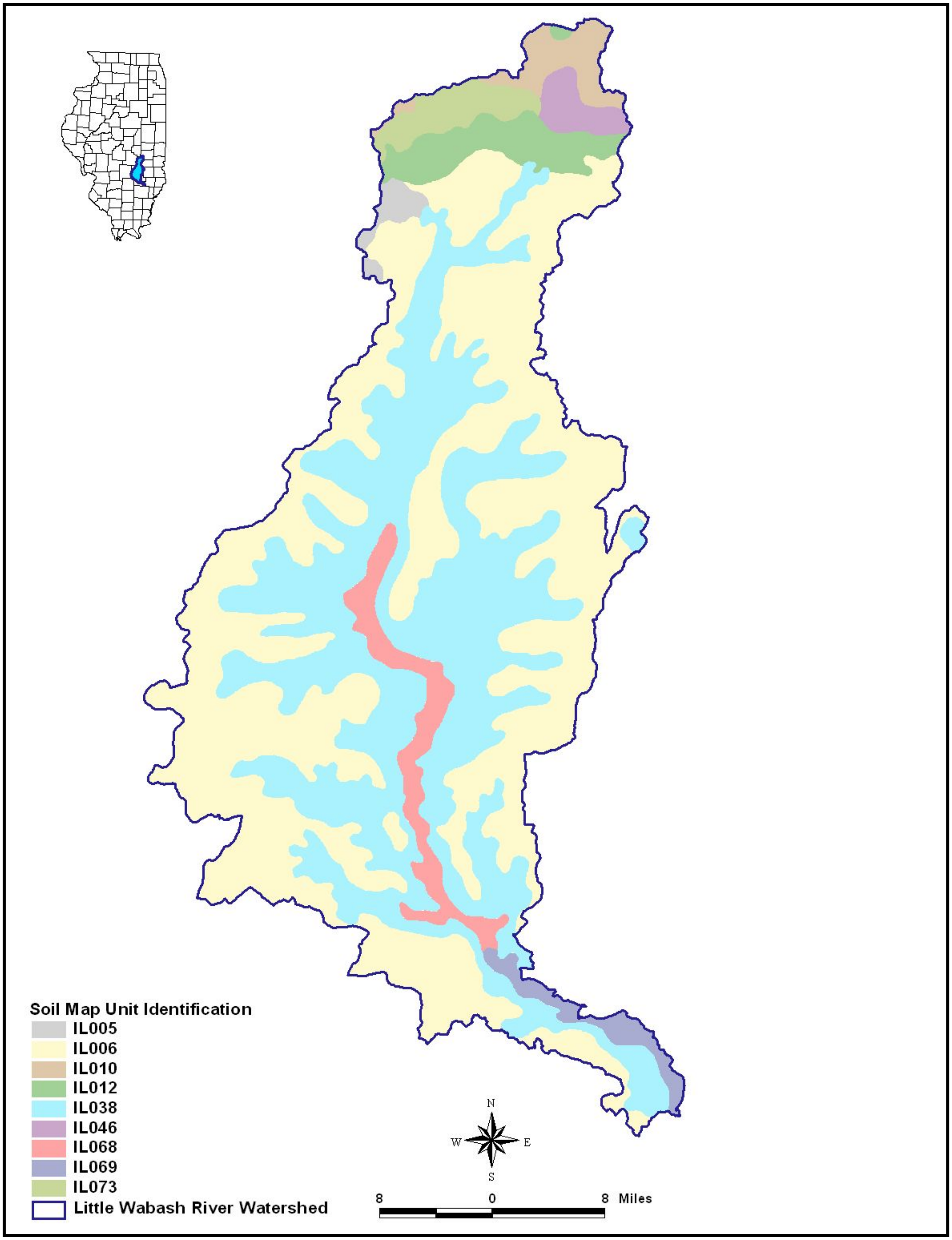

Figure 2-1. Soil Types in the Little Wabash River I Watershed.

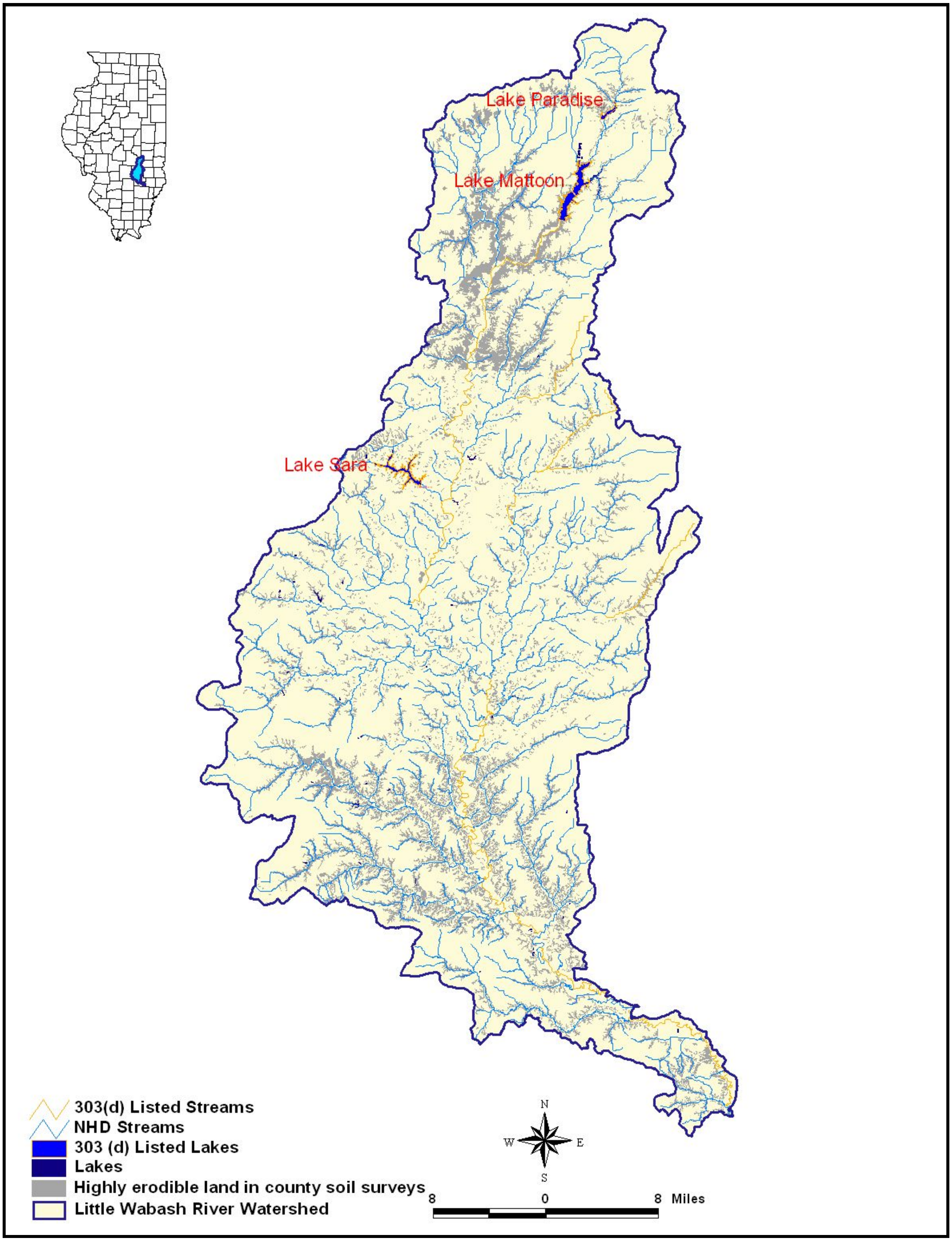

Figure 2-2. Highly Erodible Soils in the Little Wabash River I Watershed.

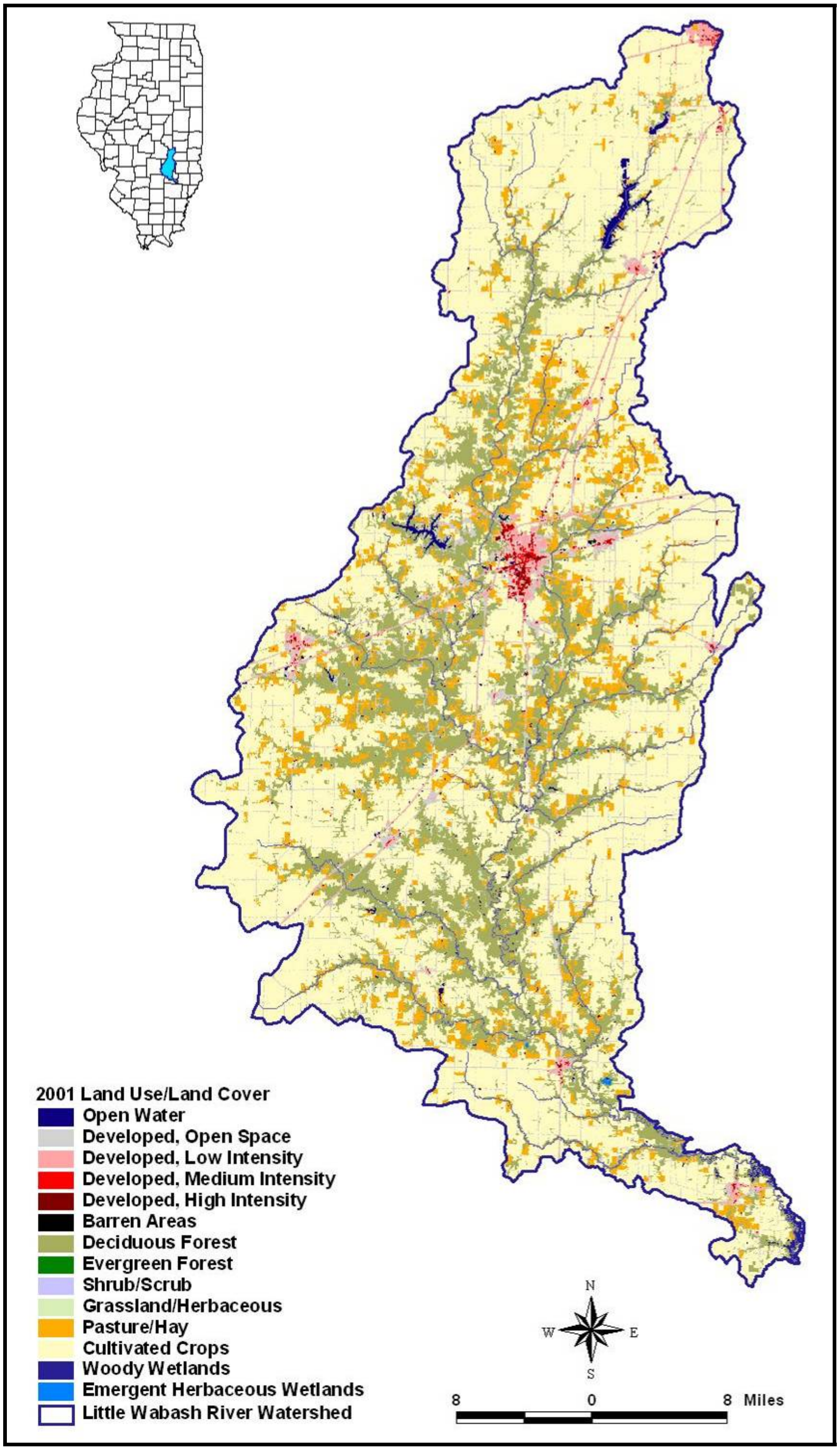

Figure 2-3. Land Use/Land Cover in the Little Wabash River I Watershed (Year 2001 GAP Data).

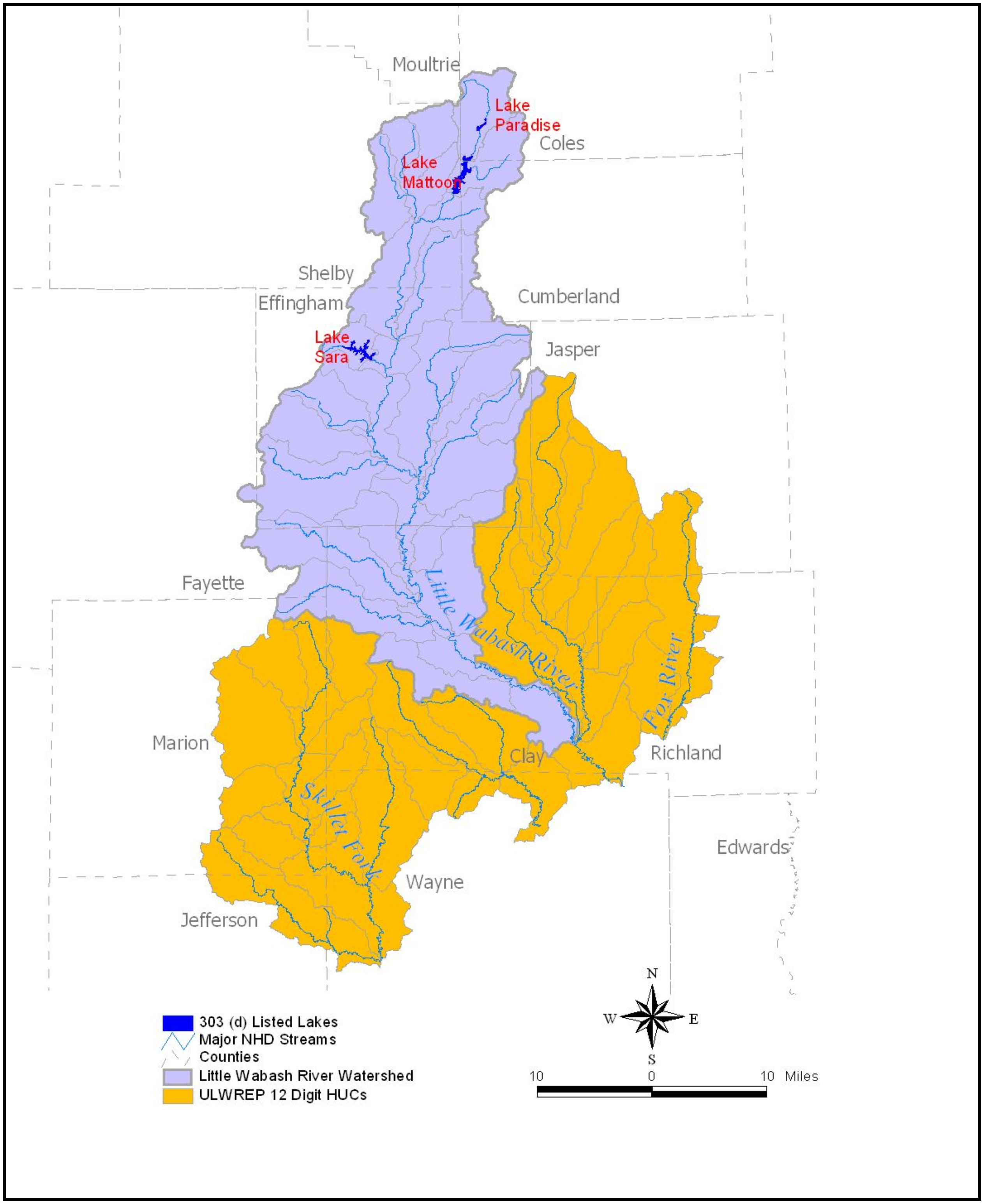

Figure 2-4. Extent of the Upper Little Wabash River Ecosystem Partnership (ULWREP).

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3.0 WATER QUALITY DATA, IMPAIRMENTS, AND TMDL ALLOCATIONS

Waters in the Little Wabash River I watershed are currently listed for several impairments. Those that carry numeric water quality standards (total phosphorus, dissolved oxygen, manganese, atrazine, and fecal coliform) 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, Stage Two Data 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, IEPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB). The following are the use support designations applicable in the Little Wabash River I 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.

The following sections present the numeric water quality standards for the various causes of impairment in the Little Wabash River I watershed. The purpose of the numeric standards is to ensure the designated uses are supported.

3.1 Total Phosphorus

3.1.1 Water Quality Standards

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

3.1.2 Impairments in the Little Wabash River I Watershed

Three lakes in the Little Wabash River I watershed are impaired by total phosphorus. Table 3-1 summarizes the total phosphorus data collected at one foot depth for each lake, and Figure 3-1 shows their location in the watershed.

The watershed area to lake surface area ratios for the three impaired lakes in the Little Wabash River I watershed are shown in Table 3-2. IEPA considers any lake with a ratio greater than 100:1 to be one where it will be difficult to attain adequate water quality (Illinois Environmental Protection Act, Subtitle C, Chapter II, Part 368).

Table 3-1. Summary of Total Phosphorus Data Collected in the Listed Lakes of the Little Wabash River I Watershed.

Waterbody Name (Segment)	Station	Period of Record (#)	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
Lake Paradise (RCG)	RCG-1	5/91 – 5/01 (52 samples)	0.01	0.28	0.14
	RCG-2	8/93 – 5/01 (16 samples)	0.01	0.32	0.14
	RCG-3	5/91 – 5/01 (25 samples)	0.08	0.39	0.23
Lake Mattoon (RCF)	RCF-1	5/92 – 10/01 (43 samples)	0.03	0.65	0.16
	RCF-2	5/92 – 10/01 (22 samples)	0.03	0.18	0.10
	RCF-3	6/95 – 10/01 (17 samples)	0.12	0.33	0.21
	RCF-4	5/92 – 6/92 (2 samples)	0.17	0.18	0.18
Lake Sara (RCE)	RCE-1	5/91 – 8/02 (63 samples)	0.02	1.25	0.21
	RCE-2	4/92 – 8/02 (24 samples)	0.02	0.08	0.04
	RCE-3	5/91 – 8/02 (29 samples)	0.02	0.09	0.05

Table 3-2. Watershed Area:Lake Surface Area Ratios for the impaired lakes in the Little Wabash River I watershed.

Lake	Watershed Area (acres)	Lake Surface Area (acres)	Watershed Area:Lake Surface Area Ratio
Lake Paradise (RCG)	11,494	168	68.4
Lake Mattoon (RCF)	35,140	1010 [a]	34.8
Lake Sara (RCE)	7,777	765	10.2

[a] The surface area for Lake Mattoon has been reported as a variety of values over the years, ranging from 750 acres (Mattoon Public Water Supply) to 1,027 (Bogner, 2003) with IEPA traditionally reporting the surface area as 765 acres. However, IEPA re-calculated the surface area as 1,010 acres for this study using the most recent aerial photo and the Illinois Transmercator geographic information system projection and this value was used for the modeling and TMDL development.

3.1.3 TMDL Allocations

The phosphorus TMDLs for the impaired lakes require reductions in phosphorus loading of 81 to 88 percent. The allocations are summarized in Table 3-3.

Table 3-3. Phosphorus TMDL Allocations for Impaired Lakes.

Lake (Segment)	Category	Phosphorus (lb/yr)	Phosphorus (lbs/day)
Lake Paradise (RCG)	Existing Load	18,433	50.5
	Loading Capacity	2,190	6.0
	Wasteload Allocation	0	0
	Margin of Safety	256	0.7
	Load Allocation	1,935	5.3
	TMDL Reduction	88%	88%
Lake Mattoon (RCF)	Existing Load	55,188	151.2
	Loading Capacity	8,282	22.69
	Wasteload Allocation	0	0
	Margin of Safety	829	2.27
	Load Allocation	7,453	20.42
	TMDL Reduction	85%	85%
Lake Sara (RCE)	Existing Load	8,943	24.5
	Loading Capacity	1,679	4.6
	Wasteload Allocation	0	0
	Margin of Safety	73	0.2
	Load Allocation	1,606	4.4
	TMDL Reduction	81%	81%

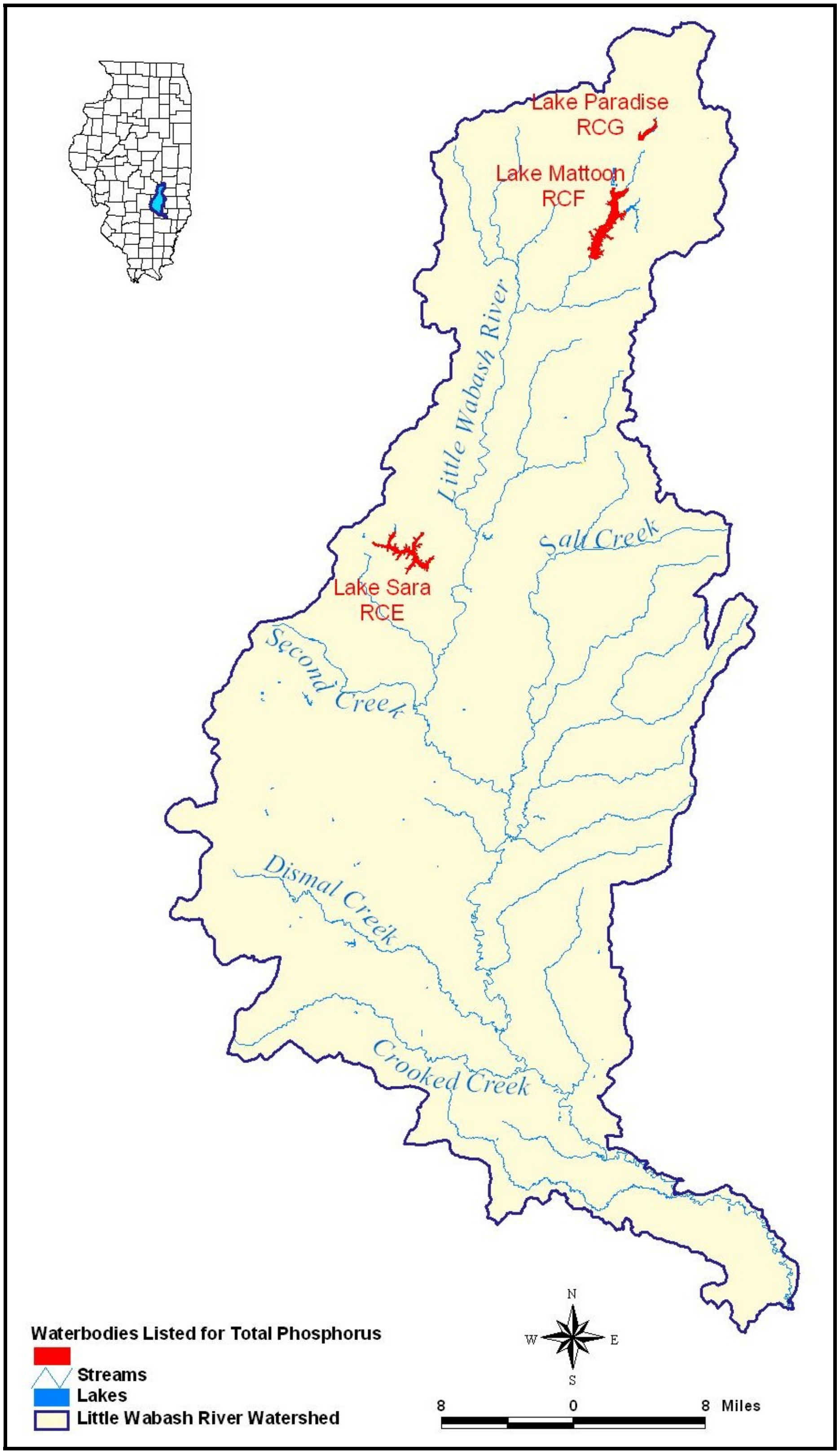

Figure 3-1. Waterbodies Listed for Phosphorus Impairment in the Little Wabash River I Watershed.

3.2 Dissolved Oxygen

3.2.1 Water Quality Standards

The numeric water quality standard for dissolved oxygen requires that concentrations in streams remain above 5 mg/L at all times and above 6 mg/L for at least 16 hours per day.

3.2.2 Impairments in the Little Wabash River I Watershed

Eight waterbodies in the Little Wabash River I watershed are listed for dissolved oxygen. The Stage One data are summarized in Table 3-4 and, as shown in Figure 3-2, the impaired segments are located throughout the watershed. Additional data were collected in Stage Two and are presented in the Stage Two report.

Table 3-4. Summary of Dissolved Oxygen Data Collected in the Listed Streams of the Little Wabash River I Watershed.

Waterbody Name (Segment ID)	Station	Period of Record (#)	Minimum (µg/L)	Maximum (µg/L)	Average (µg/L)
Little Wabash C 19	C 19	1/91 – 1/04 (111 samples)	2.1	20.0	7.7
First Salt Creek CPC-TU-C1	CPC-TU-A1	9/99 (1 sample)	3.1	3.1	3.1
	CPC-TU-C1	9/99 – 9/01 (2 samples	2.8	3.1	3.0
	CPC-TU-C2	9/99 (1 sample)	2.8	2.8	2.8
Second Salt Creek CPD 04	CPD 06	4/91 – 10/91 (3 samples)	0.5	3.9	2.0
	CPD 05	10/91 (1 sample)	2.6	2.6	2.6
	CPD 04	4/91 – 10/91 (2 samples)	1.9	5.1	3.5
Second Salt Creek CPD 03	CPD 03	4/91 – 10/91 (2 samples)	0.6	5.8	3.2
Second Salt Creek CPD 01	CPD 02	4/91 – 10/92 (2 samples)	3.5	6.0	4.8
Salt Creek CP-EF-C2	CP-EF-C2	9/99 (1 sample)	2.4	2.4	2.4
E. Br. Green Creek CSB 08	CSB 08	4/91 – 10/91 2 samples	0.6	7.5	4.1
E. Br. Green Creek CSB 07	CSB 07	4/91 – 10/91 2 samples	3.1	6.6	4.9

3.2.3 TMDL Allocations

No loading allocations were defined for the dissolved oxygen impairments in the Little Wabash River I 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 combine pollutant load reduction, stream protection measures, and increased canopy cover. In some cases, stream restoration to improve reaeration may be needed.

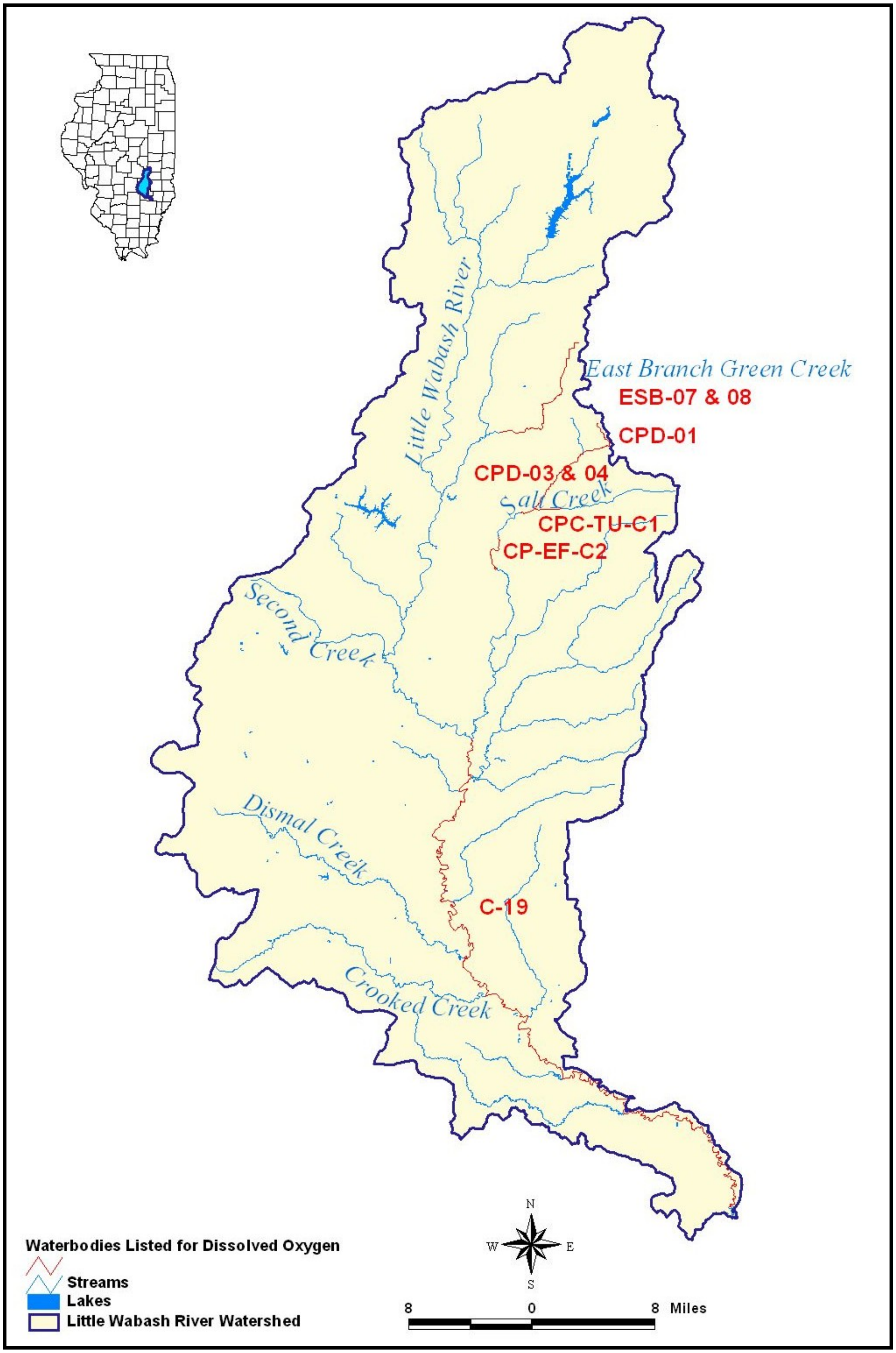

Figure 3-2. Waterbodies Listed for Dissolved Oxygen Impairment in the Little Wabash River I Watershed.

3.3 pH

3.3.1 Water Quality Standards

The numeric water quality standard for pH in both lakes and streams states that pH should not be less than 6.5 or greater than 9.0 standard units.

3.3.2 Impairments in the Little Wabash River I Watershed

Lake Paradise is the only waterbody in the Little Wabash River I watershed listed for pH. Table 3-5 summarizes the pH data collected in the lake and Figure 3-3 shows its location.

Table 3-5. Summary of pH Data Collected in the Listed Reaches of the Little Wabash River I Watershed.

Waterbody Name (Segment ID)	Station	Number of Samples	Minimum	Maximum	Average
Lake Paradise (RCG)	RCG-1	8/93 – 10/04 (37 samples)	7.2	9.19	8.09
	RCG-2	8/93 – 10/04 (17 samples)	7.5	9.25	8.45
	RCG-3	4/95 – 10/04 (15 samples)	7.6	8.9	8.39

3.3.3 TMDL Allocations

The pH impairment for Lake Paradise is considered a side-effect of the phosphorus impairment (see Stage Three TMDL Report). Excessive phosphorus loads are believed to be exerting negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al., 1994). Excessive algal production is believed responsible for the pH impairment because photosynthetic uptake of carbonic acid during periods of algal blooms can raise pH. 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 pH meeting the water quality standard.

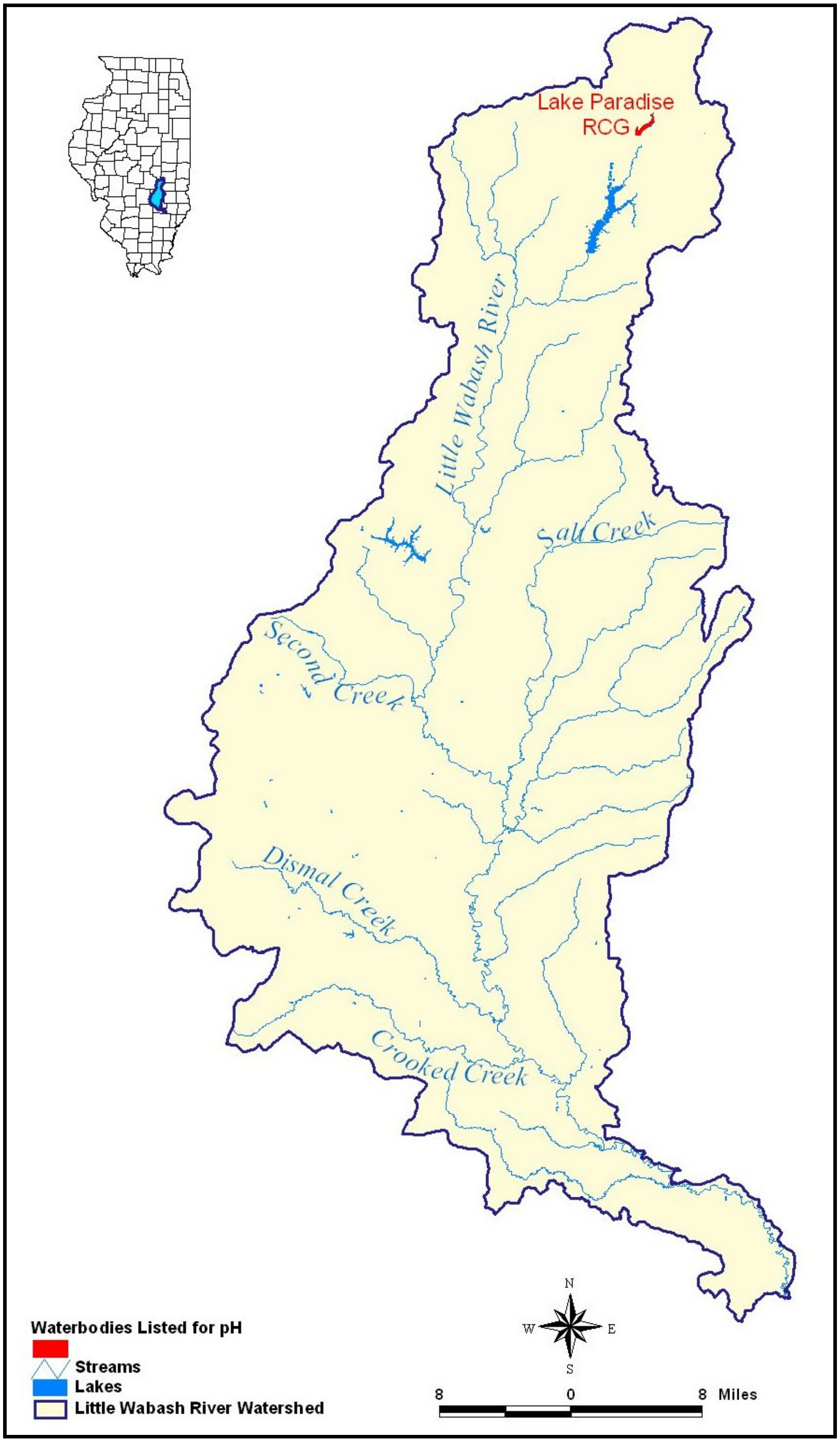

Figure 3-3. Waterbodies Listed for pH Impairment in the Little Wabash River I Watershed.

3.4 Manganese

3.4.1 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.

3.4.2 Impairments in the Little Wabash River I Watershed

Three waterbodies designated for public water supply are impaired for manganese. Table 3-6 summarizes the Stage One manganese data and Figure 3-4 shows the location of the waterbodies. Additional data were collected in Stage Two and are presented in the Stage Two report.

Table 3-6. Summary of Manganese (Mn) Data Collected in the Listed Lakes of the Little Wabash River I Watershed.

Waterbody Name (Segment ID)	Period of Record (#)	Minimum (µg/L)	Maximum (µg/L)	Average (µg/L)
Little Wabash River (C 19)	1/91 – 6/04 (86 samples)	100	1,100	339
Little Wabash River (C 21)	1/91 – 1/04 (117 samples)	26	1900	306
Lake Sara (RCE)	4/01 – 10/04 (14 samples)	51	3,200	1,104

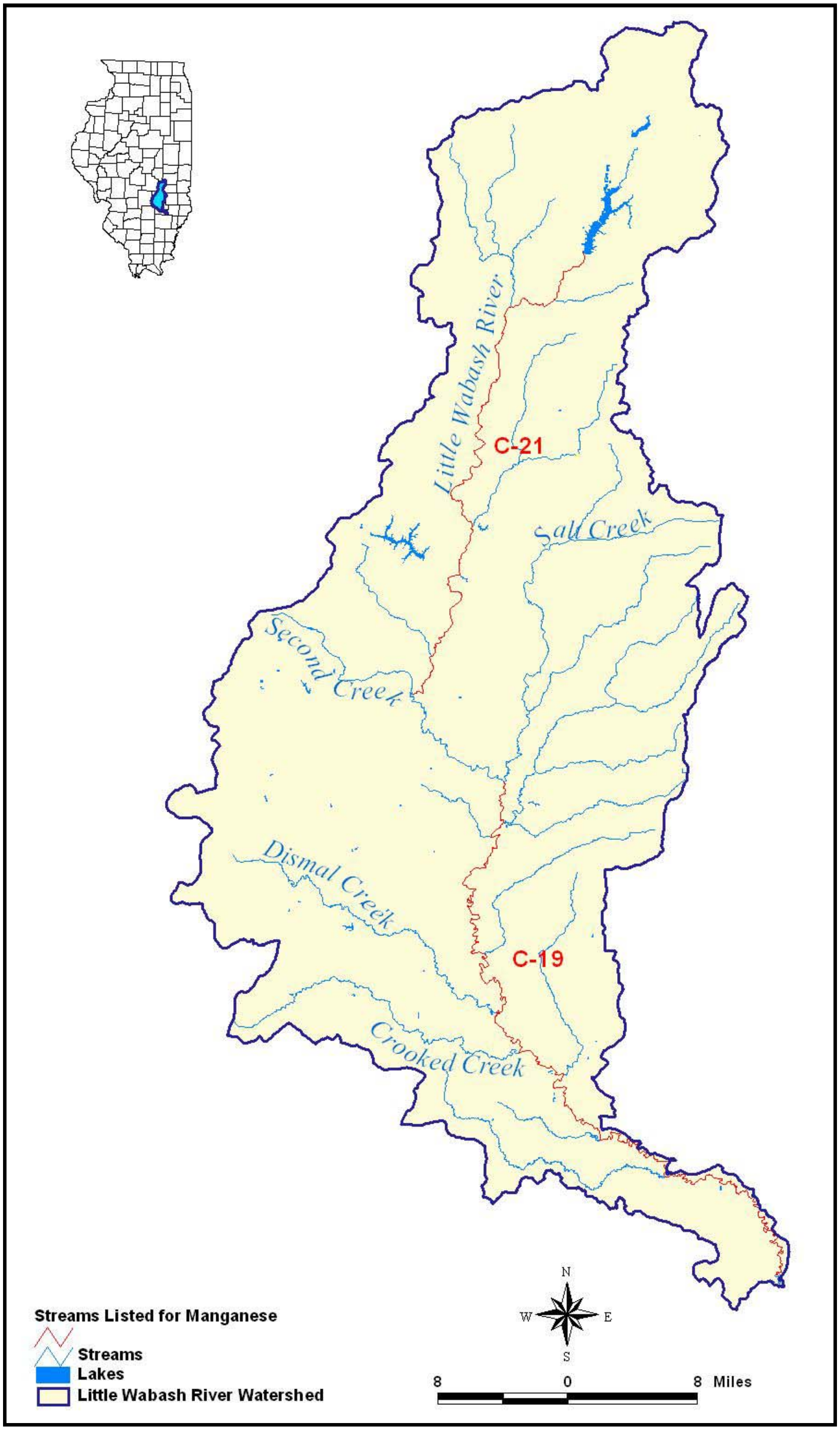

Figure 3-4. Waterbodies Listed for Manganese Impairment in the Little Wabash River I Watershed.

3.4.3 TMDL Allocations

TMDLs were developed differently for the flowing reaches in the watershed and the lake. For the river segments, the load duration approach was used, and allocations for manganese were calculated for five flow regimes. The allocations for each reach and flow percentile are summarized in Table 3-7. 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.

Table 3-7. Manganese TMDL Allocations for Waterbodies in the Little Wabash River I Watershed.

Manganese TMDLs (lb/d)		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Segment	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Little Wabash River (C 19)	Current Load	33,759	4,301	553	157	20
	TMDL= LA+WLA+MOS	3,031	348	90	18	4
	LA	2,729	313	82	15	3
	WLA	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	304	35	9	2	0.4
	TMDL Reduction	92%	93%	85%	90%	84%
Little Wabash River (C 21)	Current Load	24,994	370	103	38	0
	TMDL= LA+WLA+MOS	760.6	83	23	3.7	0.008
	LA	683.4	75.0	20.3	3.3	0.007
	WLA	n/a	n/a	n/a	n/a	n/a
	MOS (Implicit)	75.0	8.4	2.2	0.44	0.0009
	TMDL Reduction	97%	80%	80%	91%	96%

Lake Sara is also listed as being impaired due to manganese, which is considered to be a side-effect of the phosphorus impairment. Excessive phosphorus loadings are believed to be exerting negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al., 1994). Excessive algal production is believed responsible for the manganese impairment because it is leading to anoxic (no dissolved oxygen) conditions in the bottom of the lake. Dissolved oxygen levels below 13 feet deep in Lake Sara approach zero during summer months at all three stations (RCE-1, RCE-2 and RCE-2) (IEPA, 2006). These anoxic conditions, in turn, can lead to the release of manganese from the bottom sediments of the lake which have been documented as being elevated (Mitzelfelt, 1996). 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 manganese concentrations falling below the water quality standard of 150 µg/L.

3.5 Atrazine

3.5.1 Water Quality Standards

The acute water quality standard for atrazine in waters designated general use is 82 µg/L. The chronic standard in waters designated general use is 9 µg/L (evaluated as the average of at least three samples collected in the spring, summer, and fall). However, IEPA is currently requiring TMDLs be developed for all general use waters with any individual measurements greater than 9 µg/L as a proactive measure. For waters designated as public water supply, the running annual average must not exceed 3 µg/L and the instantaneous concentrations should not exceed 9 µg/L.

3.5.2 Impairments in the Little Wabash River I Watershed

Segment C 19 of the Little Wabash River is the only waterbody listed as impaired for atrazine, and this segment is a designated public water supply. Table 3-8 summarizes the atrazine data collected in this segment. Five of 12 years exceeded the running annual average standard of 3 µg/L, and 9 of 98 measurements exceeded the chronic standard of 9 µg/L. Figure 3-5 shows the location of the segment listed for atrazine in the watershed.

Table 3-8. Summary of Atrazine Data Collected in the Listed Reaches of the Little Wabash River I Watershed.

Waterbody Name (Segment ID)	Sampling Station	Period of Record (#)	Minimum (µg/L)	Maximum (µg/L)	Average (µg/L)
Little Wabash River (C 19)	C 19	1/91 – 10/05 (88 samples)	<0.05	20	2.2

3.5.3 TMDL Allocations

The atrazine TMDL for segment C 19 of the Little Wabash River I watershed was developed using a load duration approach which calculates a reduction for each hydrologic flow regime. These are summarized in Table 3-9, and reductions are only required in "moist" conditions.

Table 3-9. Atrazine Reductions By Flow Regime for Waterbodies in the Little Wabash River I Watershed.

Atrazine TMDLs (lb/d)		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Segment	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Little Wabash River (C 19)	Current Load	137	41	4.3	0.3	0.04
	TMDL= LA+WLA+MOS	182	21	5.4	1.1	0.22
	LA	164	19	4.9	0.9	0.20
	WLA	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	18	2.1	0.5	0.1	0.02
	TMDL Reduction	0%	54%	0%	0%	0%

3.6 Fecal Coliform

Fecal coliform is a commonly used indicator to test for the presence of fecal matter and pathogenic organisms. Because so many disease-causing organisms exist in the environment, it is less expensive to test for an indicator organism, such as fecal coliform bacteria, than it is to test for each individual pathogen. For this reason, most water quality regulations and water quality standards are written in terms of fecal coliform counts.

Unlike other water quality parameters which report concentration as mass per volume (e.g., mg/L or ppm), fecal coliform is usually reported as the number of bacterial colonies, or colony forming units, observed in 100 milliliters of sample. The abbreviated units for this measurement are cfu/100 mL; in some cases the cfu is omitted.

In general, TMDLs are reported as a load per day of pollutant (e.g., lb/d), rather than as a concentration (e.g., mg/L). This allows for comparison of the contribution from each source, which depends not only on the pollutant concentration, but also on the volume. TMDLs for fecal coliform must also be reported as a daily load (or in this case a count), rather than concentration. The daily loads are often on the order of billions and trillions of counts per day. For the TMDL tables, the fecal coliform counts are presented as millions per day (multiply the value by 1,000,000 to get the final value).

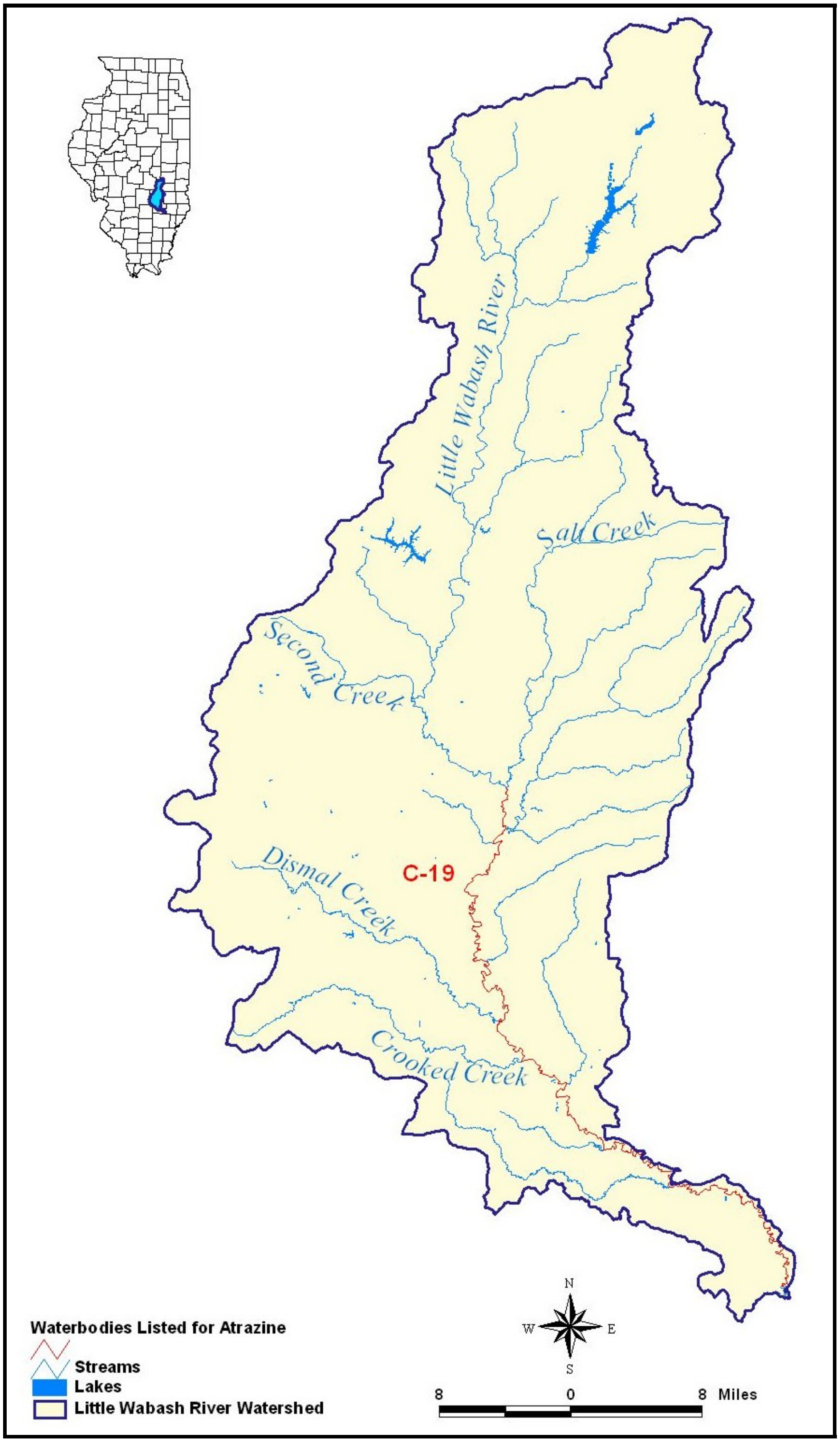

Figure 3-5. Waterbodies Listed for Atrazine Impairment in the Little Wabash River I Watershed.

3.6.1 Water Quality Standards

The fecal coliform water quality standards vary by season and designated use. For Primary Contact Use waterbodies during the months May through October, no more than 10 percent of samples collected within a 30-day period should exceed 400 cfu/100 mL, and the geometric mean of at least five samples collected within a 30-day period should not exceed 200 cfu/100 mL. From November through April, no numeric standard applies for general use waters.

3.6.2 Impairments in the Little Wabash River I Watershed

Two segments in the Little Wabash River I watershed are listed for fecal coliform. Table 3-10 summarizes the fecal coliform data collected in the impaired waterbodies and Figure 3-6 shows the location of the segments.

Table 3-10. Summary of Fecal Coliform Data Collected in the Listed Reaches of the Little Wabash River I Watershed.

Waterbody Name (Segment ID)	Sampling Station	Period of Record (#)	Minimum (cfu/100 mL)	Maximum (cfu/100 mL)	Average (cfu/100 mL)
Little Wabash River (C 19)	C 19	1/91 – 6/05 (109 samples)	4	47,600	1,600
Little Wabash River (C 21)	C 21	1/91 – 8/05 (107 samples)	2	20,000	1,261

3.6.3 TMDL Allocations

The fecal coliform TMDLs for impairments in the Little Wabash River I watershed are based on a load duration approach which identifies separate reductions for five flow regimes. The reductions for the two listed segments are summarized in Table 3-11.

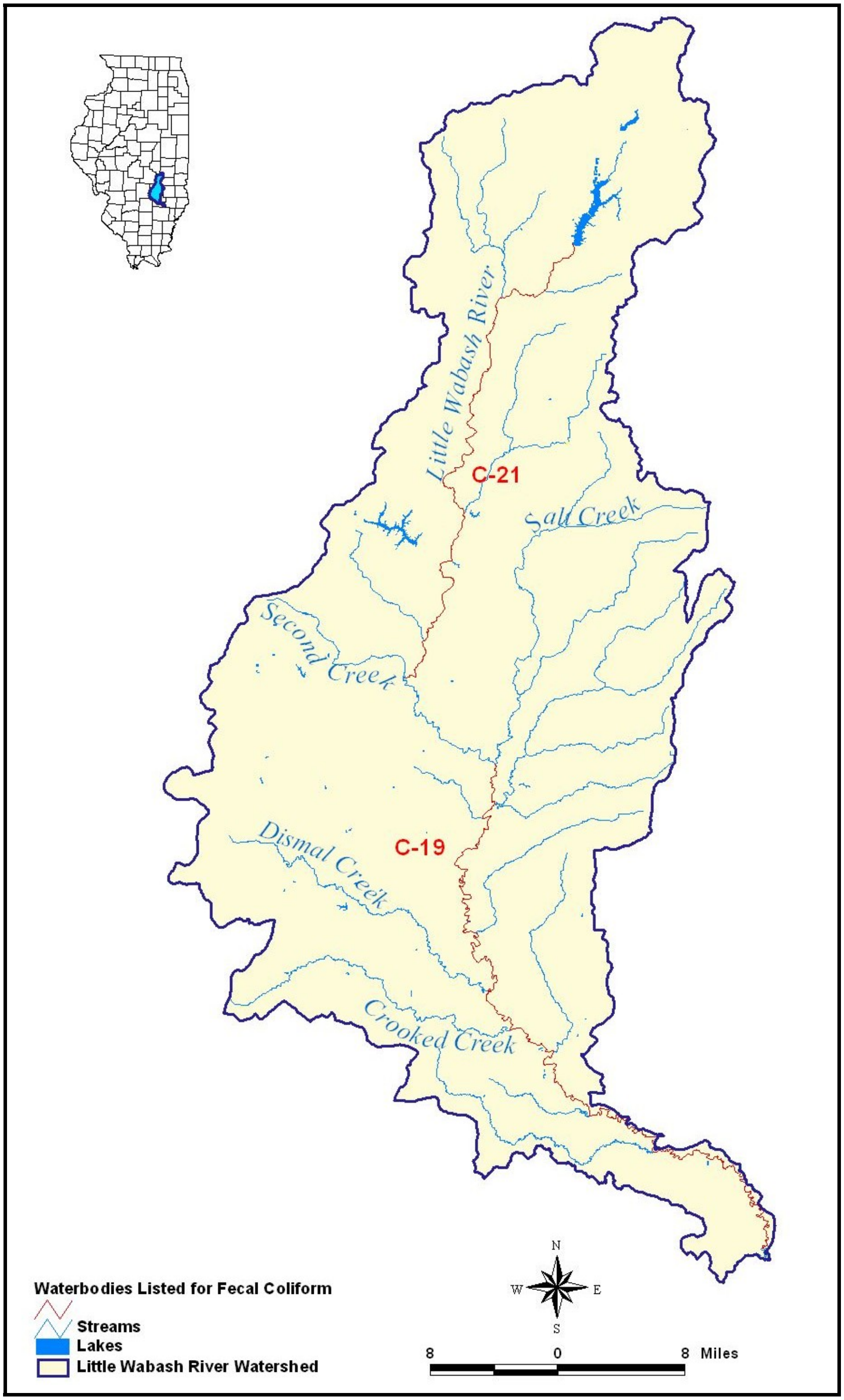

Figure 3-6. Waterbodies Listed for Fecal Coliform Impairment in the Little Wabash River I Watershed.

Table 3-11. Fecal Coliform Reductions by Flow Regime for Waterbodies in the Little Wabash River I Watershed.

Fecal Coliform TMDLs (million cfu/d)		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Segment	TMDL Component	0-10	10-40	40-60	60-90	90-100
Little Wabash River (C 19)	Current Load	1,226,714,173	431,297,909	764,921	5,511,631	18,067
	TMDL= LA+WLA+MOS	14,784,931	1,034,437	251,240	90,267	50,006
	LA	14,651,322	962,711	179,514	60,438	20,177
	WLA: Clay City WWTP Outfall Pipe 001	2,271	2,271	2,271	908	908
	WLA: Clay City WWTP Outfall Pipe 002	5,103	0	0	0	0
	WLA: IL DOT-FAI 70 Outfall Pipe 001	1,317	1,317	1,317	530	530
	WLA: Effingham STP Outfall Pipe 001	68,137	68,137	68,137	28,391	28,391
	WLA: Effingham STP Outfall Pipe 002	56,781	0	0	0	0
	WLA: Neoga STP Outfall Pipe 001 (and 002)	5,542	5,542	5,542	2,801	2,801
	WLA: Neoga STP Outfall Pipe A01	120,376	0	0	0	0
	WLA: IL DOT-I57 Outfall Pipe 001	421	421	421	168	168
	MOS (Implicit)	Implicit	Implicit	Implicit	Implicit	Implicit
	TMDL Reduction	99%	>99%	67%	98%	0%
Little Wabash River (C 21)	Current Load	957,432,512	42,277,782	1,155,018	678,342	50,204
	TMDL= LA+WLA+MOS	3,172,735	266,197	77,817	38,189	31,377
	LA	2,921,478	192,097	3,716	6,829	17
	WLA: Effingham STP Outfall Pipe 001	68,137	68,137	68,137	28,391	28,391
	WLA: Effingham STP Outfall Pipe 002	56,781	0	0	0	0
	WLA: Neoga STP Outfall Pipe 001 (and 002)	5,542	5,542	5,542	2,801	2,801
	WLA: Neoga STP Outfall Pipe A01	120,376	0	0	0	0
	WLA: IL DOT-I57 Outfall Pipe 001	421	421	421	168	168
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (Implicit)	Implicit	Implicit	Implicit	Implicit	Implicit
	TMDL Reduction	>99%	99%	93%	94%	38%

4.0 POLLUTANT SOURCES IN THE LITTLE WABASH RIVER I WATERSHED

The Little Wabash River I watershed contains waterbodies listed for impairments due to total phosphorus, dissolved oxygen, manganese, atrazine, and fecal coliform. Both point and nonpoint sources contribute to the impairments. This section describes each major source category as well as the potential impacts and contributions to pollutant loading in this watershed.

Wherever possible, the pollutant loads from each significant source have been estimated to help prioritize implementation activities. However, the data with which to estimate these source loads varies significantly from source to source and pollutant to pollutant and thus there is a significant amount of uncertainty in the estimates. Furthermore, some of the available data is conducive to estimating the potential *delivered loads* (i.e., the load that reaches a waterbody) whereas other data is more conducive to estimating *potential source loads* (i.e., loads prior to being delivered to a waterbody). These two types of loads are not directly comparable because a significant proportion of the potential source loads might never impact water quality. For example, the loads estimated from sewage treatment plants are delivered loads (i.e., we know they impact water quality). Alternatively, the loads estimated for livestock are potential source loads (e.g., a cow in pasture might deposit a load of fecal coliform that dies off before it ever reaches the nearest stream). Furthermore, potential source loads cannot be directly compared to the TMDL loading capacities, which are delivered loads. It was outside the scope of this Implementation Plan to convert all the potential source loads to delivered loads. These factors should be taken into account by the local stakeholders as they decide how to implement this Plan.

4.1 Point Source Dischargers

There are eight facilities regulated by the National Pollutant Discharge Elimination System that are allowed to discharge municipal wastewater, which may contribute fecal coliform, phosphorus, and degradable organic material to waterbodies located in the Little Wabash River I watershed. Information on these dischargers is shown in Table 4-1.

Table 4-1. Wastewater Treatment Plants Discharging to Impaired Streams within the Little Wabash River I Watershed.

Facility Name	Permit Number	Receiving Stream	Design Average Flow (MGD)	Design Maximum Flow (MGD)	Daily Fecal Coliform Limit (count/100 mL)	Daily CBOD Limit (mg/L)	Daily Ammonia Limit (mg/L)
IL DOT-157 Effingham County	IL0060208	East Branch of Green Creek	0.0111	0.0278	400	25	none
Effingham STP	IL0028622	Unnamed trib of Salt Creek	3.75	9	Disinfection Exemption	20	1.5
Teutopolis STP	ILG582024	Second Salt Creek	0.372	1.5	Disinfection Exemption	25	none
Clay City WWTP	IL0020974	Unnamed ditch trib to Little Wabash River	0.12	0.3	Disinfection Exemption	25	none
Mason STP	ILG580276	Trib to Little Wabash River	0.0525	0.131	Disinfection Exemption	25	none
Edgewood STP	ILG580070	Little Wabash	0.0615	0.123	Disinfection Exemption	25	none
IL DOT-FAI 70	IL0025429	Unnamed trib of Salt Creek	0.035	0.087	400	20	none
Neoga STP	IL0030091	Unnamed trib to Copperas Creek (tributary to Little Wabash River)	0.37	0.732	Disinfection Exemption	25	none

Notes: The Harper Oil Company used to hold a permit (IL0077607) to discharge into an unnamed tributary to Salt Creek; however, this facility ceased operations in April 2007.

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. However, only sewage treatment plants would be expected to discharge significant quantities of phosphorus and none of these facilities are located upstream of the lakes impaired for phosphorus.

4.1.2 Dissolved Oxygen

Impacts on dissolved oxygen concentrations resulting from point source dischargers may be due to nutrient induced eutrophication, oxidation of ammonia and other compounds, or degradation of biodegradable organic material. Based on the findings of the QUAL2K TMDL modeling, reducing or even eliminating loads from point source dischargers will not result in impaired segments meeting the dissolved oxygen targets.

Each of the NPDES permitted dischargers in the watershed have permit limitations for the amount of biodegradable organic material in their effluent. Permitted loads from these facilities are presented in Table 4-2 as average daily loads of BOD_5 (the amount of oxygen consumed in a five-day period). The permit limits for these facilities are reflective of secondary treatment levels and are not likely to be altered.

Table 4-2. Average Daily BOD_5 Loads from Facilities Carrying Permit Limitations.

Facility Name	Permit Number	Receiving Stream	BOD_5 (lb/d)
IL DOT-157 Effingham County	IL0060208	East Branch of Green Creek	2.3
Effingham STP	IL0028622	Unnamed trib of Salt Creek	625.8
Teutopolis STP	ILG582024	Second Salt Creek	77.6
Clay City WWTP	IL0020974	Unnamed ditch trib to Little Wabash River	25.0
Mason STP	ILG580276	Trib to Little Wabash River	11.0
Edgewood STP	ILG580070	Little Wabash	12.8
IL DOT-FAI 70	IL0025429	Unnamed trib of Salt Creek	5.8
Neoga STP	IL0030091	Unnamed trib to Copperas Creek (tributary to Little Wabash River)	77.2

4.1.3 Fecal Coliform

Sewage from treatment plants treating domestic and/or municipal waste contains fecal coliform bacteria, which is indigenous to sanitary sewage. In Illinois, a number of these treatment plants have applied for and received disinfection exemptions, which allow a facility to discharge wastewater without disinfection. All of these treatment facilities are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water or where the water flows into a fecal-impaired segment. However, the facilities are not required to monitor fecal coliform so it is difficult to determine whether this requirement is being met. Facilities with year-round disinfection exemptions that are discharging to fecal coliform impaired streams may be required to provide the Agency with updated information to demonstrate compliance with these requirements.

Loads from the sewage treatment plants are difficult to quantify given the lack of monitoring data. Because it is possible that meeting the fecal coliform water quality standards will require that these facilities disinfect their primary effluent, this implementation plan addresses plant upgrades to include a disinfection process step in Section 5.1. In addition, controlling combined sewer overflows is addressed in Section 5.2.

4.2 Onsite Wastewater Treatment Systems

Onsite wastewater treatment 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 the failure rate of systems in the watershed.

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. This Implementation Plan recommends that systems older than 20 years and those located close to the impaired waterbodies be inspected to determine whether they might be contributing to the impairments.

4.2.1 Phosphorus

Three lakes in the Little Wabash River I watershed are impaired for phosphorus: Lake Sara, Lake Paradise, and Lake Mattoon. To approximate the phosphorus loading rate from onsite wastewater systems in this drainage area, a rough calculation based on the population served by onsite wastewater treatment systems and net loading rates reported in the Generalized Watershed Loading Function (GWLF) User's manual were assumed.

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.

Data presented in the Stage 1 report for this watershed indicate that 7,747 people are served by onsite wastewater treatment systems in the Little Wabash River I watershed. Assuming an average household size of 2.5 people per household, there are an estimated 3,100 onsite wastewater treatment systems in the watershed.

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; however, the failure rate in this watershed is unknown. Phosphorus loading rates under five 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 4-3 shows the phosphorus load if 0, 7, 15, 30, and 60 percent of systems in the watershed are failing. The loads represent the potential loading from this source but do not account for the locations of the systems relative to the impaired waterbodies (e.g., the loading from some systems might never reach an impaired waterbody). Estimating the amount of phosphorus from this source that actually reaches the impaired waterbodies in the watershed was outside the scope of this Implementation Plan.

Table 4-3. Failure Rate Scenarios and Resulting Phosphorus Loads in the Little Wabash River I Watershed.

Failure Rate[a] (%)	Average Annual Phosphorus Load (lb/yr)
0	0
7[b]	1,030
15	2,210
30	4,430
60	8,850

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

4.2.2 Dissolved Oxygen

Septic systems contribute nutrient loads to the environment that may result in eutrophication of streams and lakes. The systems also discharge substances that consume oxygen during decomposition, referred to as biological oxygen demand or BOD. Once these substances reach the streams and lakes in the watershed, their decay will consume oxygen and decrease dissolved oxygen concentrations.

Quantifying the impacts of septic systems on oxygen concentrations is difficult because so many factors influence oxygen concentrations: decay rates of BOD, algal growth and respiration rates, reaeration rates, and so on. Since the algae and plant life in this watershed are likely limited by phosphorus for their growth, and phosphorus loading was discussed in the previous section, this section will discuss the BOD loading rates for normal and failing onsite systems. According to data presented in the Stage 1 report 7,747 people are served by onsite wastewater treatment systems. To approximate the BOD loading rate from onsite wastewater systems, a rough calculation based on the population served by onsite systems and typical loading rates reported in the literature were assumed.

Measurements of biological oxygen demand are typically reported as a five-day biological oxygen demand or BOD_5. This value represents the amount of oxygen consumed over a five-day period. Typical BOD_5 concentrations from septic tank effluent range from 140 to 200 mg/L. Reductions of approximately 90 percent occur in the drainfield of a properly functioning system (Siegrist et al., 2000). A malfunctioning system, however, does not provide adequate soil-zone treatment, and concentrations similar to tank effluent are typical. Translating these concentrations to daily loads from the population served is achieved by assuming a wastewater generation rate. Rates reported in the literature are typically 100 gpd (gallons per person per day). In addition, assumptions regarding the rate of failure are needed. As with total phosphorus, BOD_5 loading rates under five scenarios were calculated to show the range of loading from this source. Table 4-4 shows the range of BOD_5 load if 0, 7, 15, 30, and 60 percent of systems in the watershed are failing. Estimating the amount of BOD_5 from this source that actually reaches the impaired waterbodies in the watershed was outside the scope of this Implementation Plan.

Table 4-4. Failure Rate Scenarios and Resulting BOD_5 Loads in the Little Wabash River I Watershed.

Failure Rate (%)	Load From Normal Systems (lb/d)	Load From Failing Systems (lb/d)	Total Load (lb/d)
0	68 to 97	0	68 to 97
7[a]	63 to 90	48 to 68	111 to 158
15	58 to 82	102 to 145	160 to 228
30	48 to 68	204 to 291	251 to 359
60	27 to 39	407 to 582	434 to 621

[a] This is the average annual failure rate across the nation.

4.2.3 Fecal Coliform

Even properly functioning onsite wastewater systems contribute fecal coliform loading to the surrounding environment. Typically, by the time effluent reaches the groundwater zone, concentrations have been reduced by 99.99 percent by natural processes (Siegrist et al., 2000). However, if systems are placed on unsuitable soils, not maintained properly, or are connected to subsurface drainage systems such as tile drains, loading rates to receiving waterbodies may be relatively high.

Fecal coliform impairments occur throughout the Little Wabash River I Watershed. Approximately 7,747 people are served by onsite wastewater treatment systems according to data presented in the Stage 1 report. To approximate the fecal coliform loading rate from onsite wastewater systems, a rough calculation based on the population served by onsite systems and typical loading rates reported in the literature were assumed.

In a properly functioning septic system, wastewater effluent leaves the septic tank and percolates through the system drainfield. Failing systems that short circuit the soil adsorption field, result in ponding on the ground surface, or backup into homes will have concentrations typical of raw (untreated) sewage. Direct discharge systems that intentionally bypass the drainfield by connecting the septic tank directly to a waterbody or other transport line (such as an agricultural tile drain) will also have concentrations similar to raw sewage.

A properly functioning onsite wastewater treatment system typically achieves fecal coliform concentrations of 100 to 10,000 cfu/100 mL (Siegrist et al., 2000), or an average reduction in loading of 99.99 percent. A malfunctioning system, however, does not provide adequate soil-zone treatment, and concentrations of 1E06 to 1E08 cfu/100 mL are typical (Siegrist et al., 2000). Translating these concentrations to daily loads from the population served is achieved by assuming a wastewater generation rate and a failure rate.

Fecal coliform loading rates under five scenarios were calculated to show the range of loading from this source. Table 4-5 shows the range of fecal coliform load if 0, 7, 15, 30, and 60 percent of systems in the watershed are failing. Estimating the amount of fecal coliform from this source that actually reaches the impaired waterbodies in the watershed was outside the scope of this Implementation Plan.

Table 4-5. Failure Rate Scenarios and Resulting Fecal Coliform Loads in the Little Wabash River I Watershed.

Failure Rate (%)	Load from Normal Systems (million cfu/d)	Load from Failing Systems (million cfu/d)	Total Load (million cfu/d)
0	2,199 to 219,918	0	2,199 to 219,918
7[a]	2,045 to 204,524	2,052,568 to 205,256,765	2,054,613 to 205,461,289
15	1,869 to 186,930	4,398,359 to 439,835,925	4,400,229 to 440,022,855
30	1,539 to 153,943	8,796,719 to 879,671,850	8,798,258 to 879,825,793
60	880 to 87,967	17,593,437 to 1,759,343,700	17,594,317 to 1,759,431,667

[a] This is the average annual failure rate across the nation.

4.3 Crop Production

The majority of land in the Little Wabash River I watershed (69 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 can be 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 Little Wabash River I watershed: 356,256 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. (Comparable data for this part of Illinois are not available.) Based on this data, the phosphorus loads from crop production areas may range from 178,130 to 534,380 lb/yr. These loads represent loads that actually reach a waterbody, and thus are not directly comparable to some of the source loads presented elsewhere in this report.

4.3.2 Dissolved Oxygen

Crop production activities likely have indirect impacts on dissolved oxygen concentrations. Issues related to eutrophication will be mitigated by controlling phosphorus loads. Runoff concentrations and sediment bound levels of biodegradable organic material should be negligible. This excludes fields that spread manure for fertilizer, which are discussed in Section 4.4.2.

4.3.3 Manganese

Impairments due to manganese occur throughout the Little Wabash River I watershed but there are limited data with which to estimate the loads from each source. Manganese is found naturally in the environment in groundwater and soils. Any activity that increases rates of erosion, such as construction or tilling, can contribute increased loads of manganese. This is especially true for the many highly erodible soils in the watershed (Figure 2-2).

4.3.4 Atrazine

Atrazine is a commonly used herbicide for controlling broadleaf and grassy weeds. The lower segment of the Little Wabash River (C-19) is listed as impaired due to atrazine, and the primary source is crop production. Because many herbicides containing atrazine are available for use, it is not possible to quantify the load to this segment without farm-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 and swine may exist. In addition, page 21 of the Ecosystem Restoration Plan includes a table and figure of livestock survey data for the portion of the watershed within the ULWREP. 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.

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. Livestock operations either consist of confined or pasture-based systems. If a confined operation has greater than 1,000 animal units or is determined to threaten water quality, the operation requires a federal Concentrated Animal Feeding Operation (CAFO) permit. CAFOs are required to develop a nutrient management plan (NMP) as part of the CAFO permitting process (USEPA, 2003) which consists of manure management and disposal strategies that minimize the release of excess nutrients into surface and ground water. The CAFO NMPs are based on NRCS standards and technical expertise.

There are currently less than 20 permitted CAFOs in Illinois at this time and Illinois EPA is in the process of determining which facilities will continue to be permitted and those which can be terminated based upon the revised regulations and recent court orders. Many of the facilities previously permitted are no longer in operation and may not need an NPDES permit. Due to the uncertainties associated with these facilities, the TMDL did not identify NPDES permitted CAFO facilities.

The Stage 1 report for the Little Wabash River I watershed summarized the 2002 Census of Agriculture data for the nine counties that comprise the drainage area. These data were area weighted to estimate the number of animals in the watershed (Table 4-6).

Table 4-6. Estimated Number of Livestock and Poultry in the Little Wabash River I Watershed.

Animal	Number of Head
Poultry	836
Beef cattle	7,435
Dairy cattle	4,727
Other cattle: heifers, bulls, calves, etc.	20,134
Hogs and pigs	96,812

Large animals produce more fecal matter per animal compared to smaller animals, so the concept of animal unit is used to normalize the loading from various operations. Table 4-7 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 number of animal units in the watershed. In this watershed, the majority of animal units are either beef, other cattle, or hogs and pigs.

Table 4-7. Animal Unit Data for the Little Wabash River I Watershed.

Animal	Number of Animals in One Animal Unit	Number of Animal Units in Watershed	Percent of Animal Units in Watershed
Poultry	50	17	0.02
Beef cattle	1	7,345	10
Dairy cattle	0.71	6,658	9
Other cattle: heifers, bulls, calves, etc.	1	20,134	28
Hogs and pigs	2.5	38,725	53

4.4.1 Phosphorus

Animal operations contribute phosphorus loads to waterbodies when precipitation or runoff comes into contact with fecal material. This may occur on pasture lands where animals deposit manure directly on the land surface, at manure storage facilities, or following land application for final disposal.

Beef and other cattle are likely contained on pasture land in the watershed. Approximately 33,665 ac are classified by the 2001 GAP land use coverage as rural grassland, which is the only category of land use that might include pasture. Phosphorus export rates for pasture range from 0.12 to 4.4 lb-P/ac/yr (Lin, 2004) yielding potential loads of 4,040 to 148,130 lb-P/yr from pastured animals in this watershed.

Hogs and swine are typically confined in housing units or feedlots. Assuming a feedlot density ranging from 50 to 200 animals per acre (Barker, 1996) and feedlot export rates of 19 to 709 lb-P/ac/yr (Lin, 2004) yields a phosphorus load from these animals ranging from 9,200 to 1,372,800 lb-P/ac/yr.

These loads represent the potential phosphorus load from animals in the watershed and do not account for nutrient assimilation, soil adsorption, manure management practices currently in place, or final disposal outside of the watershed. Estimating the amount of phosphorus from this source that actually reaches the impaired waterbodies in the watershed was outside the scope of this Implementation Plan.

4.4.2 Dissolved Oxygen

Dissolved oxygen impairments due to animal operations may result from 1) degradation of organic material in the streams and lakes or 2) eutrophication due to excessive nutrients, which leads to eventual algal decay as well as nighttime respiration. As total phosphorus is discussed separately in this report, the dissolved oxygen impairments caused by animal operations will be discussed relative to the loading of organic material. It should be noted that animals with access to streambanks will exacerbate dissolved oxygen problems by increasing bank erosion and decreasing canopy cover. This impact is difficult to quantify, but can be controlled by animal management BMPs as discussed in Section 5.0.

Loading rates of organic material are often expressed as the biological oxygen demand over a five-day period (BOD_5). USEPA (1999a) has summarized the BOD_5 loading rates from various animal species as pounds per day per animal unit. This data along with the number of animal units in the watershed and the potential BOD_5 load is summarized in Table 4-8. The potential load does not account for natural degradation, manure management practices currently in place, or final disposal outside of the watershed. Relative to the permitted loads from point sources in the watershed (838 lb/d), animal operations have the potential to exert a significant biological oxygen demand. However, estimating the amount of BOD_5 from this source that actually reaches the impaired waterbodies in the watershed was outside the scope of this Implementation Plan. Figure 4-2 shows the relative contribution from each category to the potential load.

Table 4-8. Animal Unit Data and BOD_5 Loading Rates for the Little Wabash River I Watershed.

Animal	Number of Animals in One Animal Unit	Number of Animal Units in Watershed	BOD_5 Load (lb/au/d)	BOD_5 Load (lb/d)
Poultry	50	17	3.3	56
Beef cattle	1	7,345	1.6	11,752
Dairy cattle	0.71	6,658	1.6	10,653
Other cattle: heifers, bulls, calves, etc.	1	20,134	1.6	32,215
Hogs and pigs	2.5	38,725	3.1	120,047
BOD_5 Load from Agricultural Animals in the Little Wabash I River Watershed				**174,722**

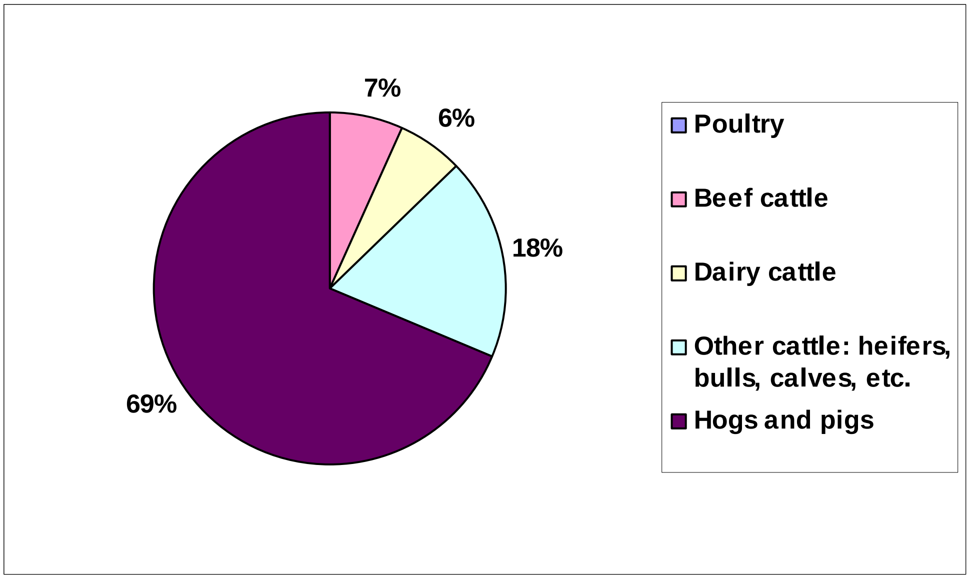

Figure 4-2. Percent Contribution to the BOD_5 Load from Agricultural Animals.

4.4.3 Fecal Coliform

Fecal coliform impairments occur in both reaches of the Little Wabash River I watershed and each county in the watershed contains animal operations that may contribute to this load. Animal operations located further away from a waterbody will have less impact on water quality as natural factors cause die-off of bacteria in the environment.

Insufficient information on fecal coliform loading rates by animal were available with which to estimate fecal coliform loads from this source.

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, physical, and chemical transformations. Release of phosphorus may increase rates of algal and plant growth (eutrophication), which leads to issues with pH, 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.

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. In addition, IDNR (2004) assisted the Upper Little Wabash River Ecosystem Partnership (ULWREP) in the identification of channelized reaches within the watershed.

Lake Paradise had a Phase I and Clean Lakes Study completed; Phase II is ongoing. A Phase I study is currently being completed for Lake Mattoon as well. Once completed, these studies will likely indicate whether or not shoreline erosion is impacting water quality.

An aerial assessment of the Little Wabash River from the confluence with Hog Run Creek at the Clay County line to Lake Mattoon in Shelby County (97 miles) was prepared by the Illinois Department of Agriculture (Kinney, 2005). Copies of this report are available at the county soil and water conservation districts, the Illinois Department of Agriculture, and the Illinois EPA. The following observations were made during the assessment:

- Streambanks along the middle reaches of the Little Wabash River are more prone to failure due to geotechnical failures. Failures in the upper and lower reaches are due to flow conditions.
- Failure types correlate strongly to soil types and valley slope.
- There is an increasing trend in flow volume recorded at two USGS gages on the river.
- More study of the system is needed to make recommendations for restoration alternatives.

For those stream channels and lake shores that have not yet been inventoried, 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 and River Bottom Sediments

Three lakes in the Little Wabash River I watershed are listed for pollutants that may be released from bottom sediments under anoxic conditions. Lakes Paradise, Sara, and Mattoon are listed for phosphorus. Lake Sara is also listed for manganese.

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, the water is able to contain less oxygen, and biological and chemical reactions occur more quickly.

Each of the lakes in the Little Wabash River I watershed is monitored at three stations for dissolved oxygen. The following graphs show the measurements collected at all three stations relative to depth. Figure 4-3 shows the measurements collected in Lake Paradise and indicates that anoxic conditions (zero dissolved oxygen) has never been measured at the bottom depths. Based on this dataset, the release of phosphorus from bottom sediments is most likely not a significant fraction of the total load. Dissolved oxygen concentrations in Lake Mattoon are generally lower than in Lake Paradise, and anoxic conditions are prevalent (Figure 4-4). Release of phosphorus from bottom sediments is more likely in this lake, although quantitative estimates cannot be made without additional data. Monitoring data collected in Lake Sara (Figure 4-5) also indicate anoxic conditions at the sediment-water interface, which may stimulate releases of phosphorus and manganese from bottom sediments.

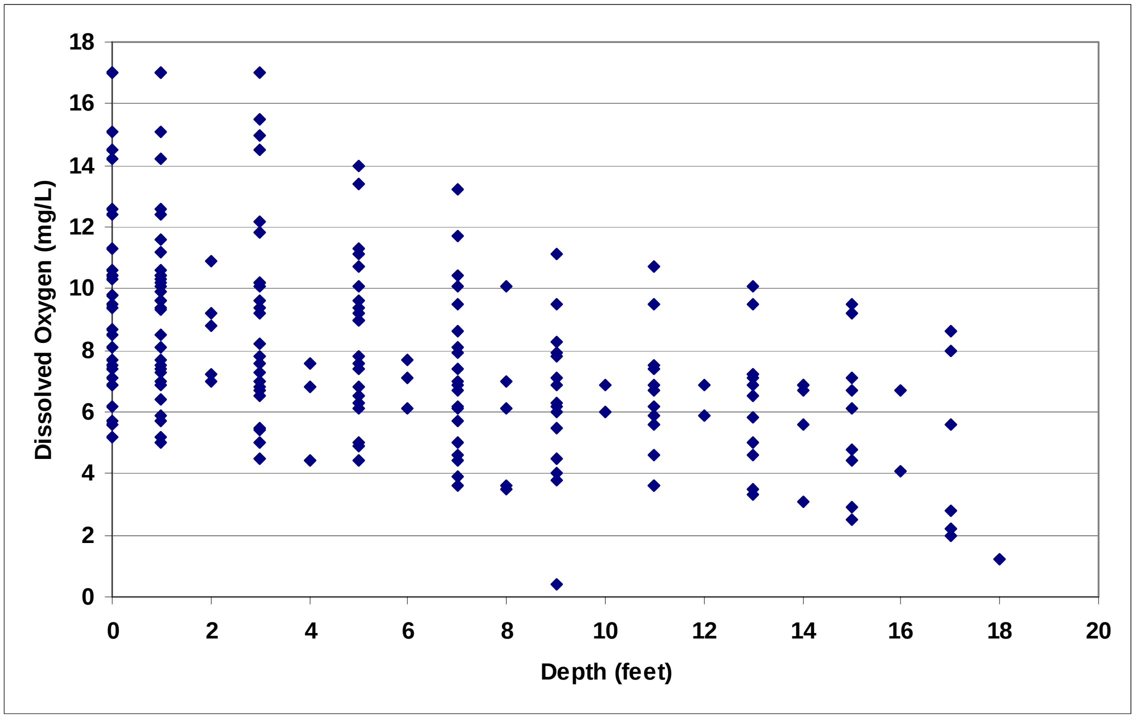

Figure 4-3. Dissolved Oxygen Profile for Lake Paradise.

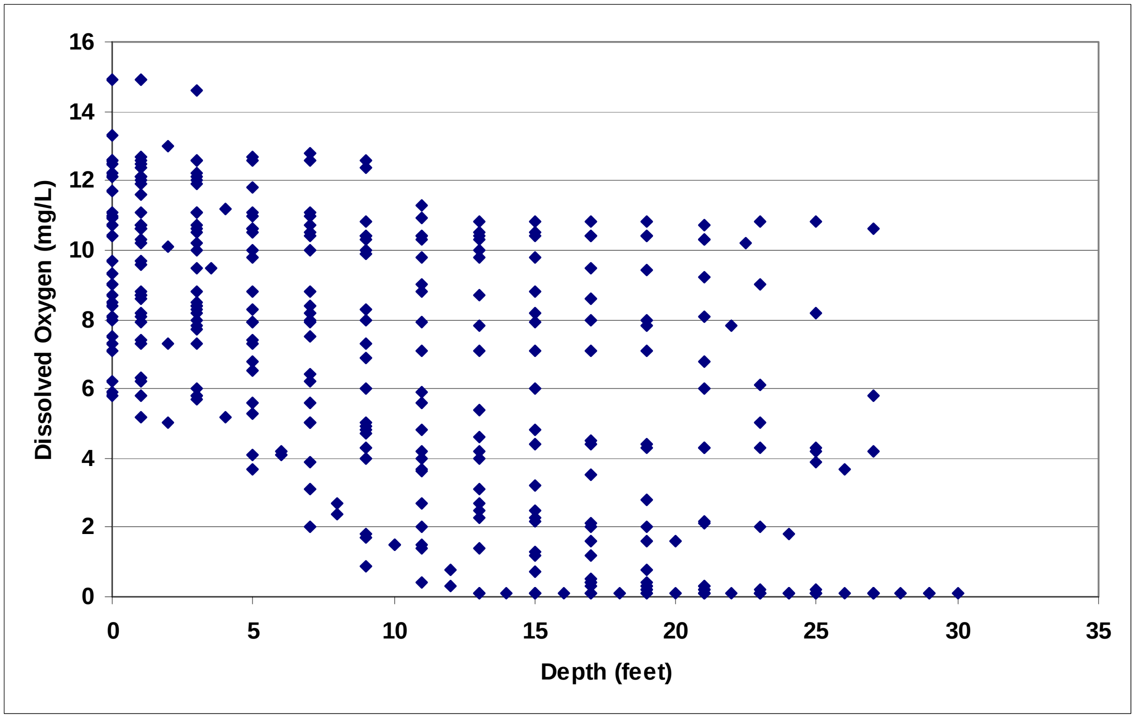

Figure 4-4. Dissolved Oxygen Profile for Lake Mattoon.

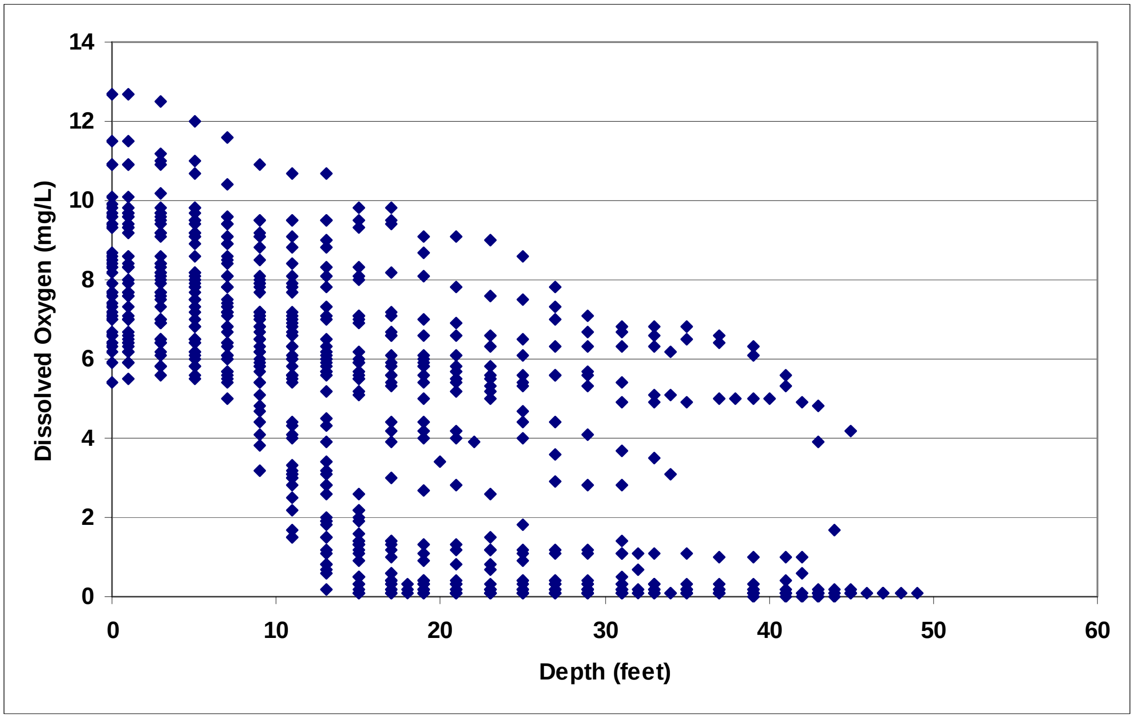

Figure 4-5. Dissolved Oxygen Profile for Lake Sara.

In addition to these three lakes, both of the impaired segments of the Little Wabash River are impaired by manganese and Segment C 19 is impaired for dissolved oxygen. It is possible that anoxic conditions in Segment C 19 may stimulate the release of manganese from the bottom sediments. Profile data for this segment are not available.

4.6.1 Phosphorus

Three lakes in the Little Wabash River I 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. Each of these lakes has a relatively long residence time (based on TMDL lake modeling), and lakes Mattoon and Sara have average depths of 11 and 17 ft, respectively. This, combined with the dissolved oxygen observations near zero in these two lakes, indicates that bottom releases of phosphorus may occur. In Lake Paradise, dissolved oxygen concentrations have not been observed near zero for an extended period of time, and the average depth is approximately 7 ft. Release of phosphorus from bottom sediments in Lake Paradise is not likely a significant source of loading.

More intensive water quality studies of these lakes and their tributaries will be required to estimate the significance of internal loading. This information may be available upon completion of the Phase I can II lake studies. 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

Lake Sara is also impaired by manganese. The low dissolved oxygen concentrations observed at the bottom of this lake combined with a long residence time and average depth of approximately 17 ft indicate that manganese releases from bottom sediments may be a potential source of loading. Collection of additional manganese data in the lake and its tributaries will allow for a quantitative estimate from this source. If internal loading is deemed a significant source, then inlake management measures may be necessary.

4.7 Historic and Active Oil Mining Operations

The ULWREP (2007) discusses the impacts of historic and active oil mining operations on soil and water quality. Byproducts from the operation include a brine solution that is usually stored in a lagoon, discharged to a surface water, or land applied. The salt content reduces vegetative growth and increased rates of erosion are prevalent at these sites. In addition, the brine solution contains high concentrations of manganese which may eventually reach surface waterbodies. The ULWREP report shows a map of the oil operations in the watershed. This implementation plan will not focus on BMPs to address this source as many of the operations are no longer active.

4.8 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 pollutant loading in watersheds that have high densities of urban populations or rural communities with relatively undisturbed land use patterns. In the Little Wabash River I watershed, where the majority of land is used for agricultural production, these sources are likely not significant relative to the loading from other sources.

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5.0 BEST MANAGEMENT PRACTICES

Controlling pollutant loading to the impaired reaches of the Little Wabash River I 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 point source dischargers, 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, carbon trading, 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 is the latest year for which gross income estimates for corn and soybean production were available when the 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 reported 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. Given that both market demand and production costs have risen considerably in the past few years, it is recognized that these estimates may no longer reflect conditions in 2008.

5.1 Disinfection of Primary Effluent from Sewage Treatment Plants

The majority of the sewage treatment plants in the Little Wabash River I watershed operate under a disinfection exemption. Reducing the fecal coliform concentrations from a primary outfall of an exempt facility to 200 cfu/100 mL will require a permit change and disinfection of the effluent prior to discharge. Common disinfection techniques include chlorination, ozonation, and UV disinfection. In most cases, chlorination is the most cost-effective alternative, although residuals and oxidized compounds are toxic to aquatic life; subsequent dechlorination may be necessary prior to discharge which will increase costs similar to the other two options (USEPA, 1999b). The options most frequently employed are discussed below.

Chlorination

Chlorine compounds used for disinfection are usually either chlorine gas or hypochlorite solutions although other liquid and solid forms are available. Oxidation of cellular material destroys pathogenic organisms. The remaining chlorine residuals provide additional disinfection, but may also react with organic material to form harmful byproducts. To reduce the impacts on aquatic life from chlorine residuals and byproducts, a dechlorination step is often included in the treatment process (USEPA, 1999b).

The advantages of chlorine disinfection are

- Generally more cost-effective relative to UV disinfection or ozonation if dechlorination is not required
- Residuals continue to provide disinfection after discharge
- Effective against a wide array of pathogens
- Capable of oxidizing some organic and inorganic compounds
- Provides some odor control
- Allows for flexible dosing

There are several disadvantages as well:

- Chlorine residuals are toxic to aquatic life and may require dechlorination, which may increase costs by 30 to 50 percent
- Highly corrosive and toxic with expensive shipping and handling costs
- Meeting Uniform Fire Code requirements can increase costs by 25 percent
- Oxidation of some organic compounds can produce toxic byproducts
- Effluent has increased concentrations of dissolved solids and chloride

More information about disinfection with chlorine is available online at
http://www.consolidatedtreatment.com/manuals/Fact_sheet_chlorine_disinfection.pdf

Ozonation

Ozone is generated onsite by passing a high voltage current through air or pure oxygen (USEPA, 1999c). The resulting gas (O_3) provides disinfection by destroying the cell wall, damaging DNA, and breaking carbon bonds. The advantages of ozonation include

- Ozone is more effective than chlorine and has no harmful residuals
- Ozone is generated onsite so there are no hazardous transport issues
- Short contact time of 10 to 30 minutes
- Elevates the DO of the effluent

Disadvantages are

- More complex technology than UV light or chlorine disinfection
- Highly reactive and corrosive
- Not economical for wastewater with high concentrations of BOD, TSS, COD, or TOC
- Initial capital, maintenance, and operating costs are typically higher than for UV light or chlorine disinfection

More information about ozonation is available online at
http://www.epa.gov/owmitnet/mtb/ozon.pdf

Ultraviolet Disinfection

UV radiation is generated by passing an electrical current through a lamp containing mercury vapor. The radiation attacks the genetic material of the organisms, destroying reproductive capabilities (NSFC, 1998).

The advantages of UV disinfection are

- Highly effective
- Destruction of pathogens occurs by physical process, so no chemicals must be transported or stored
- No harmful residuals
- Easy to operate
- Short contact time (20 to 30 min)
- Requires less space than chlorination or ozonation

Disadvantages of UV disinfection are

- Organisms can sometimes regenerate
- Turbidity and TSS can interfere with disinfection at high concentrations
- Not as cost effective compared to chlorination alone, but when fire code regulations and dechlorination are considered, costs are comparable.

More information about disinfection with UV radiation is available online at http://www.nsfc.wvu.edu/nsfc/pdf/eti/UV_Dis_tech.pdf

5.1.1 Effectiveness

Because the sewage treatment plants that operate under a disinfection exemption are not required to monitor fecal coliform concentrations in the primary effluent, it is difficult to estimate the existing load from this source. The use of disinfection techniques to reduce fecal coliform concentrations to 200 cfu/100 mL should result in a substantial reduction in loading from this source.

5.1.2 Costs

Upgrading the existing sewage treatment plants to include disinfection prior to discharge can be achieved with either chlorination, ozonation, or UV radiation processes. The costs associated with these three techniques include upfront capital costs to construct additional process units, operating and maintenance costs for chemicals, electricity, labor, etc., as well as chemical storage and fire code requirements associated with the chlorination option. The USEPA compares costs of chlorination, ozonation, and UV disinfection in a series of fact sheets available online. This information is summarized below as well as in Table 5-1. Prices in the fact sheets were listed in either 1995 or 1998 dollars and have not been updated more recently. Prices have been converted to year 2004 dollars, assuming a 3 percent per year inflation rate, for comparison with the other BMPs discussed in this plan that must be described in year 2004 dollars.

Chlorine dosage usually ranges from 5 mg/L to 20 mg/L depending on the wastewater characteristics and desired level of disinfection. The cost of adding a chlorination/dechlorination system meeting fire code requirements and treating 1 MGD of wastewater with a chlorine dosage of 10 mg/L was approximately $1,260,000 in 1995 with annual operation and maintenance costs of $59,200 (USEPA, 1999b). If a

3 percent per year inflation rate is assumed, these costs in 2004 dollars are $1,640,000 and $77,200, respectively.

Costs for ozonation were given by USEPA (1999c) in 1998 dollars. The capital costs in 1998 for treating 1 MGD of secondary wastewater with BOD and TSS concentrations each less than 30 mg/L was $300,000. The operating and maintenance costs were listed at $18,500 plus the costs of electricity. In 2004 dollars, these costs are $358,200 and $22,000, respectively.

Ultraviolet radiation costs were listed in 1995 dollars by USEPA (1995) relative to the cost per bulb. Based on vendor information available online, approximately 40 bulbs would be required to treat 1 MGD of secondary wastewater. Based on the information presented, the capital costs in 2004 for a 1 MGD facility would be approximately $750,000 and the annual operating and maintenance costs would range from $4,500 to $5,100.

Table 5-1 compares the costs for these three disinfection technologies. Annualized costs are calculated assuming a 20-year system life for each technology before major repairs or replacement would be required.

Table 5-1. Comparison of Disinfection Costs (2004) per 1 MGD of Sewage Treatment Plant Effluent.

Technology	Capital Costs	Annual Operating and Maintenance Costs	Annualized Costs
Chlorination (10 mg/L dosage), dechlorination, fire code regulations	$1,640,000	$77,200	$159,200
Ozonation	$358,200	$22,000	$39,900, plus cost of electricity
UV Disinfection	$750,000	$4,500 to $5,100	$42,000 to $42,600

5.2 Control of Combined Sewer Overflows (CSOs)

Combined sewer systems transport both wastewater and stormwater/snowmelt to the treatment plant. During extremely wet weather, if the capacity of the system is exceeded, the plants are designed to overflow to surface waterbodies such as streams or lakes. There are four CSOs in Effingham:

- Treated Outfall 002 which discharges to Salt Creek
- Outfall 003 which discharges to an unnamed tributary of Salt Creek at 3rd and Wabash
- Outfall 006 which discharges to an unnamed tributary of the Little Wabash River at the Rolling Hills Lift Station
- Outfall 007 which discharges to an unnamed tributary of Salt Creek at the East Temple Lift Station

Outfall 002 has permit limits for fecal coliform, pH, and chlorine residual whereas the others do not. However, the permit requires that "all combined sewer overflows and treatment plant bypasses shall be given sufficient treatment to prevent pollution and the violation of applicable water quality standards."

In 1994, EPA issued a list of nine minimum control measures that will reduce the frequency and volume of overflows without requiring significant engineering or construction to implement. The nine controls are listed below (USEPA, 1994):

- Proper operating and maintenance procedures should be followed for the sewer system, treatment plant, and CSO outfalls. Periodic inspections are necessary to identify problem areas.

- Maximize use of the collection system for storage:
    - Remove obstructions and repair valves and flow devices
    - Adjust storage levels in the sewer system
    - Restrict the rate of stormwater flows:
        - Disconnect impervious surfaces
        - Use localized detention
    - Upgrade or adjust the rate of lift stations
    - Remove obstructions in the conveyance system
- Review and modification of pretreatment requirements to ensure that CSO impacts are minimized:
    - Minimize impacts of discharges from industrial and commercial facilities
    - May need to require more onsite storage of process wastewater or stormwater runoff
- Maximize flow to the POTW for treatment:
    - Assess the capacity of the pumping stations, major interceptors, and individual process units
    - Identify locations of additional available capacity
    - Identify unused units or storage facilities onsite that may be used to store excess flows
- Elimination of CSOs during dry weather:
    - Initiate an inspection program to identify dry weather overflows
    - Adjust or repair flow regulators
    - Fix gates stuck in the open position
    - Remove blockages that prevent the wastewater from entering the interceptor
    - Cleanout interceptors
    - Repair sewer lines that are infiltrated by groundwater
- Control of solid and floatable materials in CSOs:
    - Use of baffles, screens, and racks to reduce solids
    - Street sweeping
- Pollution prevention programs to reduce contaminants in CSOs:
    - Education, street sweeping, solid waste and recycling collection programs
- Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts:
    - Notifying the public of the locations, health concerns, impacts on the environment
- Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls:
    - Record the flow and duration of each CSO event as well as the total daily rainfall
    - Quality monitoring for permit requirements or modeling exercises

The USEPA Guidance for Nine Minimum Controls for Combined Sewer Overflows is available online at http://www.epa.gov/npdes/pubs/owm0030.pdf

The Water Environment Research Foundation suggests a decentralized approach to minimizing the frequency and volumes of CSO events (WERF, 2005). This approach utilizes individual site BMPs that encourage evapotranspiration and infiltration to reduce the volume of runoff, rather than storing large volumes of stormwater from larger land areas in the conventional, centralized controls. Practices that reduce CSOs include

- routing gutter downspouts to pervious surfaces
- collecting rainwater in barrels and cisterns
- using vegetative controls such as vegetated roofs, filter strips, grass swales, pocket wetlands, or rain gardens
- porous pavement
- infiltration ditches
- soil amendments that improve vegetative growth and/or increase water retention
- and tree box filters

Excessive stormwater volumes contributing to CSOs typically occur in urban areas with large amounts of impervious surface, overly compacted soil, and little pervious or open space. Because decentralized controls treat a smaller volume of stormwater runoff, they require a smaller footprint and are easier to incorporate into a pre-existing landscape compared to the larger, more conventional practices such as stormwater detention ponds. However, retrofitting a previously developed area with BMPs does present challenges which must be considered during design: potential damage to roadway and building foundations, issues with standing water and mosquito breeding, and perceptions of private property owners. All of these may be overcome with proper planning and education.

If the nine minimum controls, including decentralized BMPs, do not reduce the frequency and impacts of CSOs from the two sewage treatment plants (STPs), then long-term measures may be required. These are listed below and described in more detail in the Combined Sewer Overflows Guidance for Long-term Control Plan (USEPA, 1995):

- Characterization, monitoring, and modeling activities as the basis for selection and design of effective CSO controls
- A public participation process that actively involves the affected public in the decision making to select long-term CSO controls
- Consideration of sensitive areas as the highest priority for controlling overflows
- Evaluation of alternatives that will enable the permittee, in consultation with the NPDES permitting authority, water quality standards (WQS) authority, and the public, to select CSO controls that will meet Clean Water Act (CWA) requirements
- Cost/performance considerations to demonstrate the relationships among a comprehensive set of reasonable control alternatives
- Operational plan revisions to include agreed-upon long-term CSO controls

- Maximization of treatment at the existing publicly owned treatment works (POTW) treatment plant for wet weather flows
- An implementation schedule for CSO controls
- A post-construction compliance monitoring program adequate to verify compliance with water quality-based CWA requirements and ascertain the effectiveness of CSO controls

The USEPA Guidance for Long-term Controls for Combined Sewer Overflows is available online at http://www.epa.gov/npdes/pubs/owm0272.pdf

5.2.1 Effectiveness

The effectiveness of CSO controls on reducing the fecal coliform load depends on the existing flows and frequencies of CSOs and the fecal coliform concentrations present in the releases. Most sewage treatment plants in Illinois, even those that discharge primary effluent under a disinfection exemption, are required to disinfect releases that occur as a result of CSOs. It may be possible with the controls described in this section to reduce fecal coliform loading from this source substantially.

5.2.2 Costs

Relative to the cost of upgrading the sewage treatment plants to include a disinfection process, instituting the nine minimum controls for CSOs should be a minimal cost to each facility. Plant operators and inspection personnel are likely already on hand to perform most of these functions. If the nine minimum controls are not effective in reducing the fecal coliform loading from the CSOs, the more costly long-term measures may be needed. These may include additional monitoring, modeling, and plant upgrades to provide adequate storage during wet weather events.

5.3 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.

At this time, there is not a formal inspection and maintenance program in the watershed. The county health departments do issue permits for new onsite systems and major repairs and investigate complaints as they arise.

5.3.1 Effectiveness

The reductions in pollutant loading resulting from improved operation and maintenance of all systems in the watershed depend 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 may be reduced by 3 to 24 lb/d
- BOD_5 loads may be reduced by 43 to 524 lb/d
- Fecal coliform loads in the watershed may be reduced by 99.99 percent

5.3.2 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 back ups.

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 7,750 households in the watershed. 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 5-2).

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 5-2. 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

5.4 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.

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 south-eastern 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 5-3 and Table 5-4 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:	*No application*

Table 5-3. 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 5-4. 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). 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, although upfront equipment costs may be high.

5.4.1 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.

5.4.2 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 5-5 summarizes the assumptions used to develop the annualized cost for this BMP.

Table 5-5. 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**

5.5 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.

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 Little Wabash River I 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 are applicable to the watershed and the results of the 2006 surveys are presented in Table 5-6. Mulch till and no-till are considered conservation tillage practices: reduced till practices do not necessarily maintain 30 percent ground cover. The last column in the table sums the percentages that would classify as conservation tillage for the requirements of this implementation plan.

In 2006, the use of conservation tillage practices on corn fields typically occurred on less than 21 percent of the fields surveyed. The exception is Clay County, where 39 percent of corn fields employ conservation tillage practices. It is more common for soybean fields to use conservation practices with participation ranging from 36 to 81 percent in each county. Practices on small grain fields vary widely from county to county and range from 0 to 89 percent.

Table 5-6. Percentage of Agricultural Fields Surveyed with Indicated Tillage System in 2006.

Crop Field Type	Tillage Practice				Conservation Tillage
	Conventional	Reduced-till	Mulch till	No till	
Clay County					
Corn	54	7	8	31	**39**
Soybean	15	5	6	75	**81**
Small Grain	9	1	18	71	**89**
Coles County					
Corn	72	16	8	4	**12**
Soybean	13	40	16	31	**47**
Small Grain	0	50	17	33	**50**
Cumberland County					
Corn	87	3	1	9	**10**
Soybean	22	17	6	55	**61**
Small Grain	11	22	39	28	**67**
Effingham County					
Corn	77	10	4	10	**14**
Soybean	33	18	12	37	**49**
Small Grain	82	0	2	16	**18**
Fayette County					
Corn	80	6	7	7	**14**
Soybean	21	14	18	47	**65**
Small Grain	0	13	40	47	**87**
Jasper County					
Corn	76	3	2	19	**21**
Soybean	24	4	4	68	**72**
Small Grain	0	10	3	86	**89**
Marion County					
Corn	71	10	0	19	**19**
Soybean	16	18	4	62	**66**
Small Grain	59	20	1	19	**20**
Moultrie County					
Corn	72	20	7	0	**7**
Soybean	8	26	43	24	**67**
Small Grain	0	75	0	25	**25**
Shelby County					
Corn	74	24	1	0	**1**
Soybean	18	47	11	25	**36**
Small Grain	70	30	0	0	**0**

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.

5.5.1 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

5.5.2 Costs

Conservation tillage practices generally require fewer trips to the field, saving on labor, fuel, and equipment repair costs, although 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 the cost for conservation tillage at $0/ac.

Hydrologic inputs are often the limiting factor for crop yields and farm profits. Conservation practices reduce evaporative losses by covering the soil surface. USDA (1999) reports a 30 percent reduction in evaporative losses when 30 percent ground cover is maintained. Harman et al. (2003) and the Southwest Farm Press (2001) report substantial yield increases during dry years on farms managed with conservation or no-till systems compared to conventional till systems.

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 5-7 summarizes the available information for determining average annual cost for this BMP.

Table 5-7. 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**

5.6 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

5.6.1 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).

5.6.2 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 5-8 summarizes the costs and savings associated with ryegrass and hairy vetch.

Table 5-8. 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		

5.7 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. Filter strips have been found to effectively remove pollutants from agricultural runoff.

5.7.1 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
- 55 to 87 percent reduction in fecal coliform
- 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

5.7.2 Costs

Filter strips cost approximately $0.30 per sq ft to construct, and the system life is typically assumed 20 years (Weiss et al., 2007). Assuming that the required filter strip area is 2 percent of the area drained (OSUE, 1994) means that 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/acre. Table 5-9 summarizes the costs assumptions used to estimate the annualized cost to treat one acre of agricultural drainage with a filter strip.

Table 5-9. 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) assumes 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 5-10 summarizes the capital, maintenance, and annualized costs for filter strips per head of animal.

Table 5-10. 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

5.8 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

5.8.1 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
- 5 percent reduction in fecal coliform
- 68 percent reduction of total suspended solids (and potentially manganese)

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

5.8.2 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 costs spread out over the life of the waterway are 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 5-11 summarizes the annual costs assumptions for grassed waterways.

Table 5-11. 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 5-12 summarizes the capital, maintenance, and annualized costs of this practice per head of cattle as summarized by NRCS (2003).

Table 5-12. 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

5.9 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

5.9.1 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)
- 34 to 74 percent reduction of fecal coliform for 30 ft wide buffers (Wenger, 1999)
- 87 percent reduction of fecal coliform for 200 ft wide buffers (Wenger, 1999)
- 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

5.9.2 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 5-13).

Table 5-13. 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 costs of restoration are approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). Fecal coliform reductions have been reported for buffers at least 30 ft wide (Wenger, 1999). Large reductions are reported for 200 ft wide buffers. 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 5-14. A system life of 30 years is assumed.

Table 5-14. 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

5.10 Constructed Wetlands

Constructed wetlands used to treat animal wastes are typically surface flowing systems comprised of cattails, bulrush, and reed plants. Wetlands may also be used to remove nutrients and pesticides from cropland runoff. 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

5.10.1 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)
- 92 percent reduction in fecal coliform (USEPA, 2002a)
- 53 to 81 percent reduction in total suspended solids (and potentially manganese) (USEPA, 2002a)
- 50 percent reduction in atrazine in wetlands with a retention time of 35 days (Moore, 1999)

5.10.2 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.

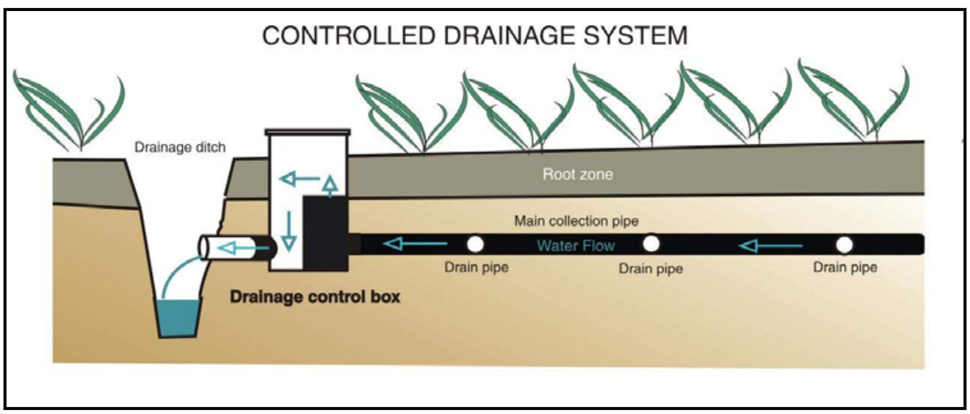
Capital and maintenance costs reported in the literature for dairy and swine operations are summarized per head in Table 5-15. No example studies including costs were available for beef cattle operations, which should generate less liquid waste than the other two operations. It would therefore be expected that constructing a wetland for beef cattle operation would cost less than for a dairy or swine operation.

Table 5-15. 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

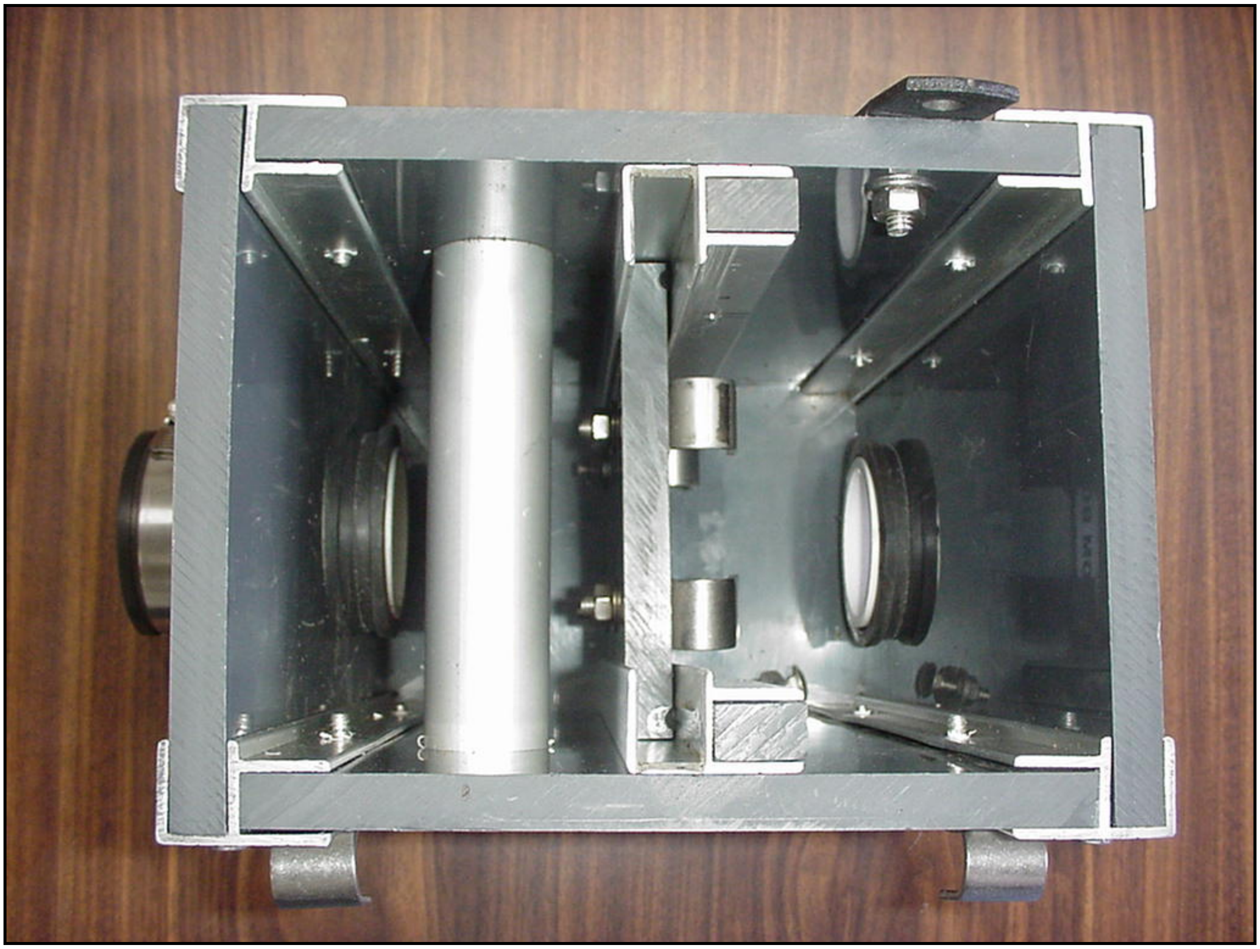
5.11 Controlled Drainage

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.

5.11.1 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, a 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 tile drain 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.

5.11.2 Costs

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 5-16.

Table 5-16. 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[a]	$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**

[a]Based on costs available for Champaign County, Illinois.

5.12 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

5.12.1 Effectiveness

Though little change in total phosphorus or organic content have 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)

5.12.2 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 5-17 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 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 5-17. 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

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

Table 5-17. Costs Calculations for Manure Handling, Storage, and Treatment Per Head (continued).

Item	Application	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
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
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

Table 5-17. Costs Calculations for Manure Handling, Storage, and Treatment Per Head (continued).

<table>
<tr><th>Item</th><th>Application</th><th>Capital Costs per Head</th><th>Annual Operation and Maintenance Costs per Head</th><th>Total Annualized Costs per Head</th></tr>
<tr><td colspan="5">Final Disposal</td></tr>
<tr><td>Pumping and land application of liquid/slurry</td><td>Operations handling manure primarily as liquid or slurry.</td><td colspan="2">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.</td><td>$19.50 - dairy cattle
$0.25 - layer
$2.75 - swine</td></tr>
<tr><td>Pumping and land application of contaminated runoff</td><td>Operations with outside feedlots and manure handled primarily as solid</td><td colspan="2">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.</td><td>$4 - dairy cattle
$3.75 - beef cattle
$4.50 - swine</td></tr>
<tr><td>Land application of solid manure</td><td>Operations handling manure primarily as solid</td><td colspan="2">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.</td><td>$11 - dairy cattle
$0.25 - layer
$1.50 - swine
$10.25 - fattened cattle</td></tr>
</table>

5.13 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

5.13.1 Effectiveness

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

- 99 percent reduction of fecal coliform concentrations as a result of the heat produced during the composting process (Larney et al., 2003).
- 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).

5.13.2 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 Costs Associated with Development and Implementation of Comprehensive Nutrient Management Plans (NRCS, 2003). Once published, these estimates should provide a good comparison with the costs summarized for the Midwest region in Table 5-17. For now, costs are presented in Table 5-18 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 include 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 5-18 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 one-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.

The University of Alberta summarized the per ton costs of windrow composting with a front end loader 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 5-18 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 5-17, as no phosphorus losses occur during the composting process.

Table 5-18. 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, 2001a 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

5.14 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).

5.14.1 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
- Reductions in the phosphorus content of dairy manure may be achieved by reducing over-supplementation practices, which are common in the dairy industry
- Beef cattle typically do not require supplementation. Eliminating supplementation reduces the phosphorus content of manure by 40 to 50 percent (Klopfenstein and Erickson, 2002)

5.14.2 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.

5.15 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 their county NRCS office 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

5.15.1 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 barriers:

- 15 to 49 percent reductions in total phosphorus loading
- 29 to 46 percent reductions in fecal coliform 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.

5.15.2 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 5-19 lists the capital, maintenance, and annualized costs for a well, pump, and storage system assuming a system life of 20 years.

Table 5-19. 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**

5.16 Cattle Exclusion from Streams

Cattle manure is a substantial source of nutrient and fecal coliform 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), biological oxygen demand (BOD), and fecal coliform bacteria 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 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

5.16.1 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 and fecal coliform loading as a result of cattle exclusion practices:

- 15 to 49 percent reductions in total phosphorus loading
- 29 to 46 percent reductions in fecal coliform loading

5.16.2 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). Fencing materials vary by installation cost, useful life, and annual maintenance cost as presented in Table 5-20.

Table 5-20. Installation and Maintenance Costs of Fencing Material per Foot.

Material	Construction Costs (per ft)	Annual Maintenance Costs (per ft)	Total Annualized Costs (per ft)
Woven Wire	$1.46	$0.25	$0.32
Barbed Wire	$1.19	$0.20	$0.26
High tensile (non-electric) 8-strand	$1.09	$0.14	$0.18
High tensile (electric) 5-strand	$0.68	$0.09	$0.12

NRCS reports that the average operation needs approximately 35 ft of additional fencing per head to protect grazing lands and streams. Table 5-21 presents the capital, maintenance, and annualized costs per head of cattle for four fencing materials based on the NRCS assumptions.

Table 5-21. Installation and Maintenance Costs of Fencing Material per Head.

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

5.17 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 fecal coliform, 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

5.17.1 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 (USEPA, 2003; Government of Alberta, 2007):

- 49 to 60 percent reduction in total phosphorus loading
- 40 percent reduction in fecal coliform loading as a result of grazing land protection measures
- 90 percent reduction in fecal coliform loading with rotational grazing

5.17.2 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.

5.18 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. Though aerators are operating in Lake Paradise, bottom water dissolved oxygen concentrations remain low. Lake Mattoon and Lake Sara do not currently operate aeration systems.

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.

5.18.1 Effectiveness

If lake sediments are a significant source of phosphorus or manganese in the Little Wabash River I 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.

5.18.2 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 20 years.

Table 5-22 summarizes the cost analyses for the three inlake management measures. The final column lists the annualized cost per lake surface area treated.

Table 5-22. Cost Comparison of Inlake Controls.

Control	Construction or Application Cost	Annual Maintenance Cost	Annualized Costs $/ac/yr
Lake Paradise (166 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$460 to $610
Alum Treatment	$48,000 to $119,000	$0	$36 to $90
Artificial Circulation	$73,000	$32,000	$210
Lake Mattoon (1,010 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$76 to $100
Alum Treatment	$293,000 to $730,000	$0	$36 to $90
Artificial Circulation	$444,000	$192,000	$210
Lake Sara (765 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$100 to $130
Alum Treatment	$222,000 to $551,000	$0	$36 to $90
Artificial Circulation	$336,000	$145,000	$210

5.19 Atrazine BMPs

Atrazine application to reduce weed growth within crop fields is a common agricultural practice. Atrazine can be applied before or after planting and primarily reaches the soil through dissolved rainwater. Atrazine applied prior to plant growth is absorbed through the roots of plants while postemergence applications are primarily absorbed through the leaves. Most atrazine moves off-site in solution rather than attached to soil (Purdue University, 2004).

Tillage practices and drainage tiles can affect the movement of atrazine from the field to the stream. Reducing soil tillage will leave more crop residue on the land which will slow the movement of water across a field after rain, reducing runoff, and increasing the adsorption of atrazine into the soil at the treatment site. It is important to use tillage practices that minimize runoff and increase water infiltration to reduce the loading of atrazine directly to nearby streams (Purdue University, 2004).

In some cases clay soils with a restrictive layer will have increased atrazine runoff in no till systems. These soils tend to be wetter in spring when herbicide applications are made. On these soils incorporation of soil-applied atrazine is recommended to help atrazine move into the soil profile and reduce loads to the streams through direct runoff (Purdue University, 2004).

Purdue University water quality researchers have studied the effects of drainage tiles on atrazine movement. Their data showed that very little atrazine movement occurs in tile flow. Drainage tiles reduce atrazine loadings to the stream by encouraging water and atrazine infiltration into the soils where it is adsorbed by organic matter, clay, and absorbed plant roots (Purdue University, 2004).

Another factor that affects the movement of atrazine directly to the stream is the distance from the field to the surface waters. The greater the distance between an atrazine-treated field and a stream, the less likely it is that atrazine will affect stream water quality. Timing of precipitation can also affect the loading of atrazine to the stream. Applications of atrazine should be delayed if soils are saturated and more rain is predicted. An increased separation time between heavy rainfall and atrazine application improves the potential to keep it in the field (Purdue University, 2004).

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 have found that 90 percent of atrazine losses occur in the dissolved form during runoff events (Kansas State University, 2007; University of Nebraska, 1996).

Several practices should be considered when fields are close to surface water to reduce atrazine losses from those fields to surface waters. The following options are all viable for Illinois fields as detailed in the atrazine use and weed management strategies document written by Purdue University in 2004.

Delay application of herbicides when soil is saturated and/or rainfall is predicted.

Manage soil to maximize water infiltration through steps like installing tiles to expedite the drainage of water from the soil surface.

Allow soils to dry before tilling or other operations to reduce compaction.

Target applications away from tile standpipes. Consider planting grass filter strips around standpipes to keep weeds in check and minimize the entrance of soil into the tile system.

Use filter strips and grass waterways to slow water movement. Manage filter strips to maintain optimal growth. Eliminate weeds and tall brush that can shade the grass, resulting in bare spots, and prevent water from channeling across narrow areas of grass. Channels conducive to atrazine pooling can develop when a berm is allowed to form along the edge of a buffer strip. Atrazine can injure cool-season grasses such as fescue and bluegrass keeping waterways and filter strips from functioning properly. Warm-season species such as switchgrass are more tolerant of atrazine, but are more difficult to establish and maintain. Turn off the sprayer when crossing grass waterways, and avoid spray drift into waterways, streams, and impounded water.

Using herbicides that do not contain atrazine is possibly the best method for reducing atrazine loading to the stream. Herbicide-resistant corn varieties allow the use of broad-spectrum herbicides directly to corn, with little risk of crop injury. These types of weed management programs allow you to use alternative herbicides in lieu of atrazine; and in many ways this is the perfect option. However, the potential for development of resistant weeds raises concerns among agricultural scientists and the crop protection industry.

In addition to practices that can be used to reduce the loading of atrazine directly to the stream there are other alternative weed management tactics and alternative herbicides that use less atrazine. Research has shown that light tillage following application increases the infiltration of atrazine into the soil, reducing off-site movement. This method could result in loads higher than those from herbicide runoff since erosion losses are greater on highly erodible soils that are tilled.

Applying atrazine postemergence can reduce atrazine rates by 30 to 75 percent and in some cases is more effective at weed control than preemergence application. The downside to making a postemergence application of atrazine, alone or tank-mixed with other products, is a narrower window of opportunity to make the application: the label requires atrazine to be applied on corn

12 inches high (or shorter) and two hours before rain. Target fields with the greatest runoff potential for postemergence application to reduce the risk of a missed application.

Although atrazine can be used alone, it is more commonly used in combination with other herbicides; and applying atrazine postemergence allows you to reduce the total amount applied (because it reaches the foliage immediately). Consider other farm operations that must occur during the same time to determine if you can make a timely postemergence application. Atrazine applied preemergence to unprotected soil is vulnerable to escaping the field in runoff if rain occurs shortly thereafter.

If you tank-mix atrazine with postemergence broadleaf herbicides, consult the labels of each product for appropriate spray additives.

Herbicides that include atrazine label the setback requirements. The label specifically states how, when, and where applications are to be made to prevent atrazine from leaving the application site and reaching surface water. Key points on the label include the following.

For streams and rivers:

1. Do not mix or load within 50 feet of any stream or river.

2. Do not apply within 66 feet of points where surface water enters an intermittent or perennial stream or river.

3. Do not apply within 66 feet of a tile inlet unless atrazine is incorporated and/or greater than 30 percent residue is present. Consider establishing a 66-foot filter strip around the inlet

A four- year study in Missouri found that early preplant herbicide applications resulted in lower weed control and crop yield than did applications made at or near planting. Applying herbicide as close to planting as possible and using supplemental postemergence weed management strategies will provide the most consistent weed control and yields corn (Purdue University, 2004).

5.19.1 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. This option could be used by farmers currently engaged in tillage operations.
- Applying a low-rate atrazine premix, tank-mixed with another broadleaf herbicide, can reduce the amount of atrazine applied by 30 to 50 percent without sacrificing overall weed control.
- 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.
- Riparian areas and filter strips that allow for water infiltration may reduce loads by 25 to 35 percent.
- Applying atrazine postemergence can reduce atrazine rates by 30 to 75 percent.
- Using proper mixing, application, and disposal practices will prevent additional environmental impacts.

5.19.2 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.

5.20 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 5.7 and 5.9 and the agricultural BMPs that reduce the quantity and volume of runoff (Sections 5.5, 5.6, 5.8 5.10, and 5.11) or prevent cattle access (Section 5.16) 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.

5.20.1 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 streambank protection and runoff control are therefore underestimated in this report.

5.20.2 Costs

Costs associated with the BMPs that offer secondary benefits to streambank and lake erosion are discussed separately for each BMP in Sections 5.5, 5.6, 5.7, 5.8, 5.9,5.10, 5.11, and 5.16.

5.21 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 cost 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.

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6.0 PRIORITIZATION OF IMPLEMENTATION

The listed reaches in the Little Wabash River I watershed require varying degrees of reductions to meet water quality standards. This section briefly summarizes the required reductions for each segment and discusses the most cost-effective BMPs for the most likely significant sources.

6.1.1 Lake Paradise

Lake Paradise is impaired for phosphorus and requires an 88 percent reduction in loading to attain water quality standards. The lake is also impaired by pH, but 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 pH meeting the water quality standard.

The majority of the phosphorus loading likely originates from crop production and animal operations. The most cost effective BMPs for controlling phosphorus loads from crop production are conservation tillage, cover crops, and nutrient management planning. The most cost effective BMPs for controlling phosphorus loads from animal operations are animal feeding strategies, cattle exclusion from streams with alternative watering systems, and grazing land management.

Treatment level BMPs such as filter strips, 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.

The Lake Paradise watershed is part of the Upper Little Wabash River Ecosystem Partnership. The subwatershed draining to the lake was ranked among the top 10 (of 53) for having inadequately buffered streams and was prioritized for improving stream quality. The BMPs suggested above should improve conditions in this watershed and help the partnership reach some of its goals.

6.1.2 Lake Mattoon

Lake Mattoon is impaired for phosphorus and requires an 85 percent reduction in loading to attain water quality standards. The majority of the loading likely originates from crop production and animal operations and the same BMPs discussed above for Lake Paradise are therefore recommended.

The Lake Mattoon watershed is part of the Upper Little Wabash River Ecosystem Partnership. The subwatershed draining to the lake was ranked among the top 10 (of 53) for having inadequately buffered streams and was prioritized for increasing the area of wetlands and high quality pasture and improving stream quality. The BMPs suggested above should improve conditions in this watershed and help the partnership reach some of its goals.

6.1.3 Lake Sara

Lake Sara is impaired for phosphorus and requires an 81 percent reduction in loading to attain water quality standards. The lake is also impaired by manganese, but IEPA believes that attaining the total phosphorus target of 0.05 mg/L will eliminate anoxic conditions at the sediment-water interface and reduce the resuspension of manganese from lake bottom sediments.

The majority of the phosphorus loading likely originates from crop production and animal operations, and the same BMPs discussed above for Lake Paradise are therefore recommended. With the exception of nutrient management planning, these crop production BMPs also offer significant reductions in manganese loading by reducing rates of erosion. The Stage 1 report also lists runoff from a nearby golf course as a potential source of phosphorus to Lake Sara. Modification of fertilizer application rates, methods, and timing may reduce loading from this source.

The Lake Sara watershed is part of the Upper Little Wabash River Ecosystem Partnership. The subwatershed draining to the lake was ranked among the top 10 (of 53) subwatersheds prioritized for increasing wildlife grasslands and improving stream quality. The BMPs suggested above should improve conditions in this watershed and help the partnership reach some of its goals.

6.1.4 Little Wabash River I Segment (C 21)

Segment C 21 of the Little Wabash River is listed for fecal coliform and manganese. The required reductions for each flow regime are summarized in Table 6-1.

Table 6-1. TMDL Reductions for Impairments in Little Wabash River I Segment (C 21).

Parameter	High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Manganese	97%	80%	80%	91%	96%
Fecal Coliform	>99%	99%	93%	94%	38%

The majority of the fecal coliform load likely originates from animal operations, failing onsite wastewater systems, sewage treatment plants, and natural sources such as wildlife. Obtaining the required reductions will require proper management of manure combined with composting practices, grazing land management, or cattle exclusion from streams with alternative water sources. In addition, sewage treatment plants may need to be upgraded to include a disinfection step prior to discharge and should take all reasonable measures to reduce the volume and frequency of combined sewer overflows. Identifying and repairing or replacing failing onsite wastewater systems is also important.

The manganese impairments are likely due to erosion from crop production and streambank erosion. Soils in this area have naturally high manganese contents. This segment is not impaired by dissolved oxygen, so manganese releases from anoxic riverbed sediments are not likely a significant source of loading. Therefore, reducing manganese concentrations will likely depend on erosion control strategies. These include conservation tillage and use of cover crops for crop production areas.

Segment C 21 of the Little Wabash River is located in the Upper Little Wabash River Ecosystem Partnership. The subwatersheds draining to this segment have been prioritized for improving livestock operations, addressing point sources, increasing the amount of wetland area, increasing high quality pasture, and increasing woodlands. The BMPs suggested above should improve conditions in this watershed and help the partnership reach some of its goals.

6.1.5 Little Wabash River I Segment (C 19)

Segment C 19 of the Little Wabash River is impaired for manganese, atrazine, and fecal coliform. TMDL reductions for these impairments are summarized in Table 6-2. Dissolved oxygen impairments also exist in this segment, though TMDLs were not developed.

Table 6-2. TMDL Reductions for Impairments in Little Wabash River I Segment (C 19).

Parameter	High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Manganese	92%	93%	85%	90%	84%
Atrazine	0%	54%	0%	0%	0%
Fecal Coliform	99%	>99%	67%	98%	0%

The manganese impairments likely originate from crop production activities and streambank erosion. Reducing manganese concentrations will likely depend on source reduction strategies used on crop production areas. The required reductions will likely require more than one BMP per farm. It is suggested that conservation tillage or cover crops be combined with strategically located treatment level

BMPs such as filter strips, grassed waterways, riparian buffers, and constructed wetlands to meet these targets.

Atrazine impairments are due solely to crop production activities in the watershed. Following recommended best management practices for using atrazine on corn acres will probably result in attainment of the water quality standard.

The majority of the fecal coliform load likely originates from animal operations, failing onsite wastewater systems, sewage treatment plants, and natural sources. Obtaining the required reductions will require proper management of manure combined with composting practices, grazing land management, or cattle exclusion from streams with alternative water sources. The Agency will re-evaluate all major dischargers and those within close proximity to fecal-impaired waters to determine if a continued disinfection exemption is warranted. Sewage treatment plants that cannot continue to justify a disinfection exemption may need to be upgraded to include a disinfection step prior to discharge. Combined Sewer Overflow (CSO) discharges should take all reasonable measures to reduce the volume and frequency of combined sewer overflows. Identifying and repairing or replacing failing onsite wastewater systems is also important.

The dissolved oxygen impairments in segment C 19, and many of the tributaries in the watershed, were found to be caused by low flow conditions. Though TMDLs were not developed for these impairments, some of the BMPs discussed in this plan will improve DO conditions in the streams. For example, riparian buffer restoration and stream restoration will allow vegetation to grow along the channels. The resulting canopy cover shades the water, reduces temperatures, and increases dissolved oxygen concentrations. Livestock fencing and proper manure management strategies will reduce direct inputs of oxygen demanding substances. Repairing failing onsite wastewater treatment systems will also decrease loading to nearby surface waters.

Segment C 19 of the Little Wabash River is located in the Upper Little Wabash River Ecosystem Partnership. The subwatersheds draining to this segment have been prioritized for addressing point sources, protecting and improving species richness, increasing the amount of wetland area, and increasing the area of woodlands. The BMPs suggested above should improve conditions in this watershed and help the partnership reach some of its goals.

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7.0 MEASURING AND DOCUMENTING PROGRESS

Water quality monitoring is a critical component throughout the entire TMDL process, from the original decision to list a waterbody to post-TMDL implementation monitoring to determine the effectiveness of the controls. Monitoring is used to address a variety of goals, and different types of monitoring are often required to address different goals. Separate agencies might also conduct monitoring for different purposes. In general, however, monitoring efforts can be categorized as supporting one the following three primary objectives:

1) Obtain additional data to address information gaps and uncertainty in the current analysis (data gaps monitoring and assessment).
2) Ensure that identified management actions are undertaken (implementation monitoring)
3) Ensure that management actions are having the desired effect (effectiveness monitoring)

7.1 Data Gaps Monitoring

Due to resource constraints and other reasons, TMDLs are often written despite information gaps. Monitoring to fill data gaps can therefore sometimes be a high priority because these data can be needed to move forward with specific restoration strategies. For example, the significance of internal loading of phosphorus and manganese in the impaired lakes in the watershed is not known with any certainty due to a lack of data. Additional sampling of the lakes to monitor pollutant loads from the lake bottoms could therefore help to determine whether in-lake controls are needed (Section 5.18). Additional data are also needed to better determine the impact of sewage treatment plants on downstream fecal coliform counts.

7.2 Implementation Monitoring

The purpose of implementation monitoring is to document whether or not management practices are applied as designed. Objectives of an implementation monitoring program include:

- Measuring, documenting, and reporting the watershed-wide extent of BMP implementation and other restoration measures.
- Evaluating the general effectiveness of BMPs as applied operationally in the field.
- Determining the need and direction of BMP education and outreach programs.

Implementation monitoring for structural BMPs consists of detailed visual monitoring of BMPs, with emphasis placed on determining if they were implemented or installed in accordance with approved design criteria. BMPs that have not been installed correctly (or not installed at all) should be targeted for improvement.

The ULWREP (2007) is beginning to inventory BMPs in the watershed. Tracking the implementation of BMPs while continuing to monitor water quality parameters in the watershed will assist the stakeholders and public agencies in determining the effectiveness of the watershed plans. 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.

7.3 Effectiveness Monitoring

The ultimate purpose of developing a TMDL and implementing controls is to restore waterbodies to their full support of designated uses. The primary purpose of effectiveness monitoring is therefore to measure progress towards this goal. Effectiveness monitoring will almost always include sampling of water quality within the impaired waterbody, but might also include biological or habitat monitoring if those are necessary to determine the effectiveness of restoration activities. Benefits of post-TMDL implementation monitoring include measuring progress toward meeting water quality standards and also targeting of resources to critical areas requiring additional controls.

Effectiveness monitoring in the Little Wabash I River watershed should be based on the existing network of sampling stations (see Stage Two report). Success indicators will be reductions in the frequency, magnitude, and duration of violations of the water quality standards over a given time period (e.g., over the next decade). Although monitoring of the impaired waterbody will eventually need to be conducted by IEPA, typically several years after the TMDL is completed, a much more thorough assessment will be possible if additional data are collected during the intervening years by concerned stakeholders, including permittees.

Monitoring should also be performed to determine which BMPs are actually effective in improving water quality and to assess their level of performance. Although this can require a long-term commitment to high-quality discrete and continuous monitoring, the alternative is not knowing if implemented BMPs are actually working as intended to improve water quality. Without information on BMP effectiveness, time and money may be wasted with little or no benefit to the waterbody. Obtaining information on the effectiveness of BMPs is therefore a critical part of adaptive management in that lessons learned about the most cost-effective BMPs can be used to inform later stages of implementation.

7.4 Monitoring and Adaptive Management

As the TMDL is being implemented and water quality is being monitored, adaptations to the implementation plan will be necessary to address unforeseen circumstances or conditions. The adaptive management approach is not linear, but rather circular, and should allow stakeholders to integrate results back into this Implementation Plan. Stakeholders should create decision points at which information is reviewed and decisions are made on whether to make changes in the Plan or stay the course.

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 BMPs for nonpoint sources 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). New CRP Enrollments are allowed for practices that fall under the continuous signup. A new general signup period has not been announced. At the time of writing, a new Farm Bill is being developed, and the future extent of these federal programs is unknown.

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 Little Wabash River I 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 Little Wabash River I 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 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 being 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/nonpoint.html

8.5 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 0.2 to 0.6 metric tons (one metric ton = 1.1 US ton) of carbon per acre per year (mt/ac/yr) depending on location, 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.

Current exchange rates for carbon credits 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 Little Wabash River I 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 Little Wabash River I Watershed.

<table>
<tr><th>Assistance Program</th><th>Program Description</th><th>Contact Information</th></tr>
<tr><td>NSMP</td><td>Provides grant funding for educational programs and implementation of nonpoint source pollution controls.</td><td>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</td></tr>
<tr><td>ULWREP</td><td>Provides funding for implementation of BMPs and land improvement projects to farmers and landowners within the partnership.</td><td>IDNR Region 4 Office
4521 Alton Commerce Parkway
Alton, IL 62002
Phone: 618-462-1181
Fax: 618-462-2424</td></tr>
<tr><td>NRCS EQIP</td><td>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.</td><td rowspan="6">Contact local USDA Service Center (Table 8-3)</td></tr>
<tr><td>FSA CRP</td><td>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.</td></tr>
<tr><td>Conservation 2000 CPP</td><td>Provides up to 60 percent cost share for several agricultural BMPs: cover crops, filter strips, grassed waterways.</td></tr>
<tr><td>Conservation 2000 Streambank Stabilization Restoration Program</td><td>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.</td></tr>
<tr><td>SARE</td><td>Funds educational programs for farmers concerning sustainable agricultural practices.</td></tr>
<tr><td>ICCI</td><td>Allows farmers to earn carbon trading credits for use of conservation tillage, grass, and tree plantings.</td></tr>
</table>

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, 400 ac. max. CPP: $10/ac, 200 ac. max. ULWREP: contact agency for individual resource allocations
Conservation Tillage	EQIP: $15/ac for three years, 400 ac. max. CPP: $20/ac for three years, 40 ac. max. ICCI: earns 0.2 to 0.6 mt/ac/yr of carbon trading credit depending on location ULWREP: contact agency for individual resource allocations
Cover Crops	CPP: $20/ac ULWREP: contact agency for individual resource allocations
Filter Strips	EQIP: $100/ac for three years, 50 ac. max. CPP: up to 60 percent of installation 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: up to 60 percent of installation 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 USDA Service Centers

Organization Name	Address	Contact Numbers
Clay County USDA Service Center	155 Route 45 North Louisville, IL 62858	Phone: 618/665-3327 Fax: 618/665-3385
Coles County USDA Service Center	6021 Development Drive, Suite 2, Charleston, IL 61920	Phone: 217/345-3901 Fax: 217/345-9669
Cumberland County USDA Service Center	201 East Main, Toledo, IL 62468	Phone: 217/849-2201 Fax: 217/849-2003
Effingham County USDA Service Center	2301 Hoffman Drive Effingham, IL 62401	Phone: 217/347-7107 Fax: 217/342-9855
Fayette County USDA Service Center	301 South Third St., Vandalia, IL 62471	Phone: 618/283-1095 Fax: 618/283-4962
Jasper County USDA Service Center	1403 Clayton Avenue Newton, IL 62448	Phone: 618/783-2319 Fax: 618/783-2374
Marion County USDA Service Center	1550 E. Main Street, Salem, IL 62881	Phone: 618/548-2230 Fax: 618/548-2341
Moultrie County USDA Service Center	1412A S. Hamilton, Sullivan, IL 61951	Phone: 217/728-7921 Fax: 217/728-4031
Shelby County USDA Service Center	111 N. Cedar St., Suite 3, Shelbyville, IL 62565	Phone: 217/774-5564 Fax: 217/774-2171

9.0 IMPLEMENTATION TIME LINE

This implementation plan for the Little Wabash River I watershed defines a phased approach for achieving the water quality standards (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. In addition, point source dischargers operating under a disinfection exemption are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water or where the water flows into a fecal-impaired segment. Facilities with year-round disinfection exemptions may be required to provide the Agency with updated information to demonstrate compliance with these requirements. Facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions. This section outlines a 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, the Illinois Environmental Protection Agency, and the local Soil and Water Conservation Districts. During this phase, the sewage treatment plants may be asked to submit fecal coliform data to IEPA to determine if a disinfection exemption is still appropriate. In addition, all facilities with CSOs should begin to institute the nine minimum controls.

Phase II of the implementation schedule will involve voluntary participation of farmers using 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. Plant upgrades to include a disinfection process should also begin during Phase II if necessary. 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 the nine minimum controls are not mitigating the fecal coliform load from CSOs, the more expensive, long-term measures should be implemented. If required, this phase may last five to ten years.

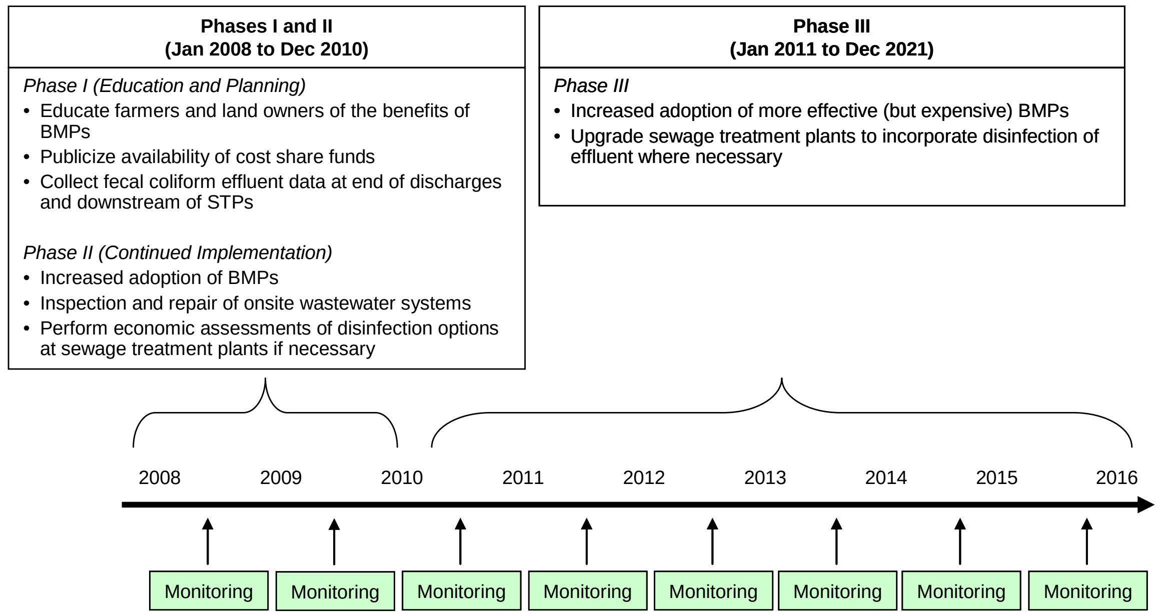

Figure 9-1. Timeline for the Little Wabash River I TMDL Implementation Plan.

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