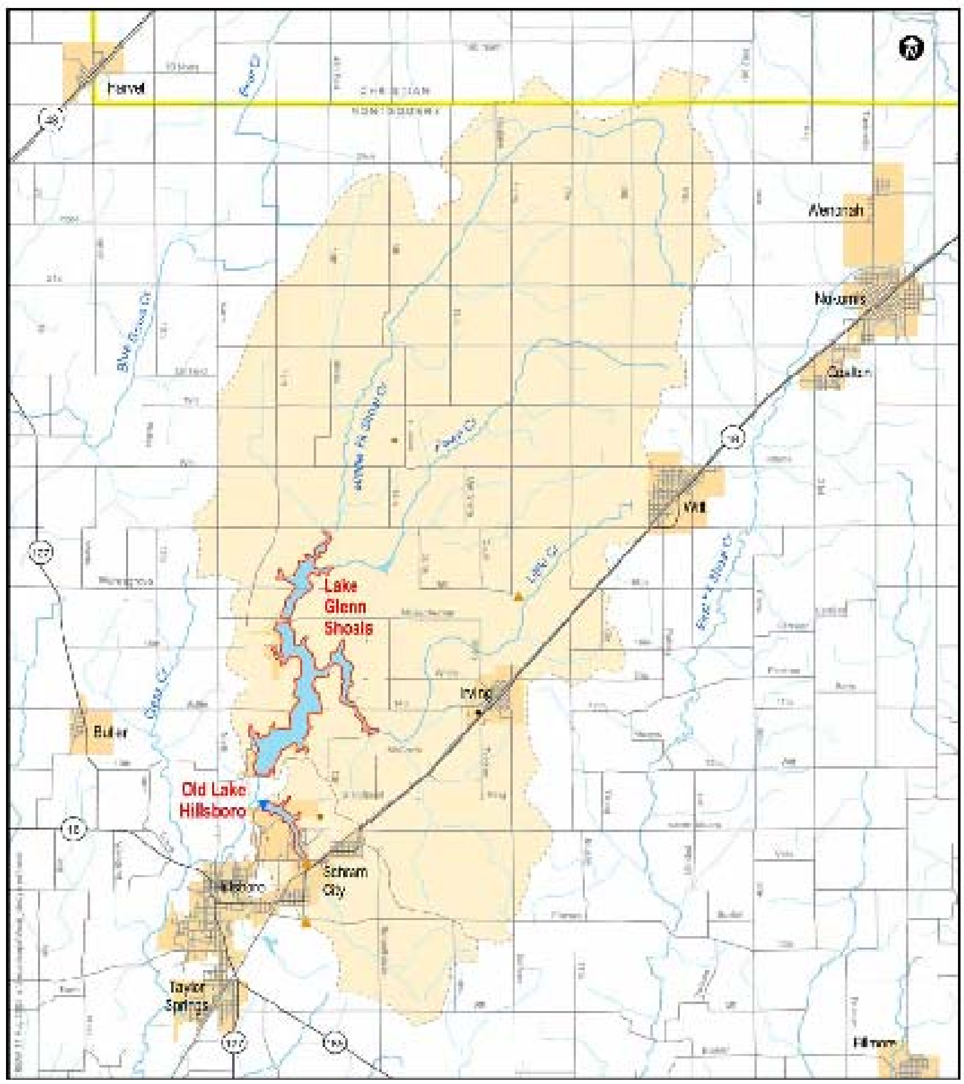
Illinois
Environmental
Protection Agency

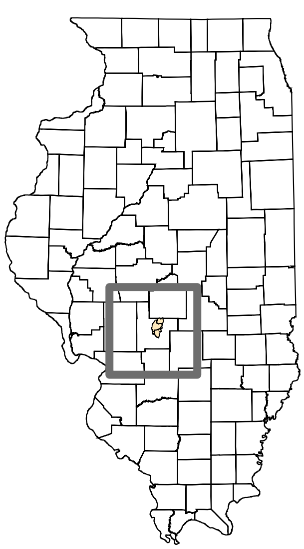
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

November 2006

IEPA/BOW/07-003

GLENN SHOALS-HILLSBORO WATERSHED TMDL REPORT





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

REPLY TO THE ATTENTION OF:
WW-16J

SEP 30 2005

RECEIVED
OCT 17 2005
Watershed Management Section
BUREAU OF WATER

Ms. Marcia Willhite
Bureau of Water
IEPA
1021 North Grand Avenue East
Springfield, IL 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Loads (TMDLs) from the Illinois Environmental Protection Agency (IEPA) for the Glenn Shoals/Old Lake Hillsboro Watersheds in Illinois. The TMDLs are for phosphorus and address phosphorus, manganese, excessive algal growth, and total suspended solids (TSS) that impair multiple uses. Lake Glenn Shoals (ROL) is in partial support of primary and secondary contact. Old Lake Hillsboro (ROT) is in partial support of overall use, primary and secondary contact, and public water supply.

Based on this review, U.S. EPA has determined that Illinois' two TMDLs for phosphorus meet the requirements of Section 303(d) of the Clean Water Act and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves two TMDLs for seven impairments for the Glenn Shoals/Old Lake Hillsboro Watersheds. The statutory and regulatory requirements, and U.S. EPA's review of Illinois' compliance with each requirement, are described in the enclosed decision document.

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

Sincerely yours,

for Jo Lynn Traub
Director, Water Division

Enclosure
cc: Bruce Yurdin, IEPA

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Final Stage 1 Progress Report

Prepared for Illinois Environmental Protection Agency

April 2005

Glenn Shoals/Hillsboro Watershed

Lake Glenn Shoals (ROL), Old Lake Hillsboro (ROT)

Limno-Tech, Inc.

www.limno.com

First Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

August 2004

Glenn Shoals/Hillsboro Watershed

Lake Glenn Shoals (ROL), Old Lake Hillsboro (ROT)

Limno-Tech, Inc.
www.limno.com

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EXECUTIVE SUMMARY

This is the first in a series of quarterly status reports documenting work completed on the Lake Glenn Shoals/Old Lake Hillsboro 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 draft 2004 303(d) list (IEPA, 2004a), 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 waterbody. 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 waterbody 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 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) would be strictly voluntary.

Methods

The effort completed in the first quarter included: 1) two site visits and collection of information to complete a detailed 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 draft 2004 303(d) list of impaired waterbodies.

This evaluation focuses on the following waterbodies and associated sources of impairment:

- Lake Glenn Shoals: phosphorus
- Old Lake Hillsboro: phosphorus, manganese.

Results

The available data support the listing of both Lake Glenn Shoals and Old Lake Hillsboro as impaired by phosphorus. Potential sources include agricultural sources, existing sediments, recreation activities, and failing private sewage disposal systems. The available data also indicate some exceedances of the public water supply criterion for manganese in Old Lake Hillsboro and suggest that the primary source may be background sources due to naturally high concentrations in area soils. In-place lake sediments may also contribute to elevated water column concentrations. It should be noted that the manganese standard for the public water supply use might be difficult to attain. This is due to the fact that the manganese appears to be ubiquitous in the watershed due to naturally occurring manganese in the soils.

INTRODUCTION

This Stage 1 report describes initial activities related to the development of TMDLs for impaired waterbodies in the Lake Glenn Shoals/Old Lake Hillsboro 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 the Lake Glenn Shoals/Old Lake Hillsboro 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 recently issued the draft 2004 303(d) list (IEPA 2004a), which is available on the web at: http://www.epa.state.il.us/water/tmdl/303d-list.html. 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) would 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 five generic designated use categories: public water supply, aquatic life, primary contact (swimming), secondary contact (recreation), and fish consumption (IEPA, 2004b). For each water body, and for each designated use applicable to the water body, Illinois EPA's assessment concludes one of three possible "use-support" levels:

- Fully supporting (the water body attains the designated use);
- Partially supporting (the water body attains the designated use at a reduced level); or
- Not supporting (the water body does not attain the designated use).

All water bodies assessed as having partial or nonsupport attainment for 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.

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, 2004a).

List of Identified Watershed Impairments

The impaired waterbody segments included in the project watershed are listed in Table 1 below, along with the cause of the listing. These impairments were identified in the draft 2004 303(d) list (IEPA, 2004a). Those impairments that are the focus of this report are shown in bold font in Table 1. On the draft 2004 303(d) list, Lake Glenn Shoals was identified as being full support of the following designated uses: overall use, aquatic life, fish consumption, and public water supply. This lake is in partial support of the primary contact (swimming) and secondary contact (recreation) designated uses. Old Lake Hillsboro was listed as being in full support of the aquatic life designated use, and partial support of the following designated uses: overall use, primary contact (swimming), secondary contact (recreation), and public water supply.

Table 1. Impaired waterbodies in the project watershed

Waterbody segment	Waterbody name	Size (acres)	Year Listed	Listed for[1]
ROL	Lake Glenn Shoals	1,350	1994	**Phosphorus**, total suspended solids, excess algal growth
ROT	Old Lake Hillsboro	108.7	1998	**Manganese, phosphorus,** total suspended solids, excess algal growth

[1] Bold font indicates those parameters that are 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.
Source: IEPA, 2004a

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

WATERSHED CHARACTERIZATION

The purpose of watershed characterization was to obtain information describing the watershed to support the identification of sources contributing to manganese and total phosphorus impairments. Watershed characterization activities were focused on gaining an understanding of key features of the watershed, including geology and soils, climate, land cover and uses, and urbanization and growth. Active watershed organizations were also identified. 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. Where available, data were obtained in electronic or Geographic Information System (GIS) format to facilitate mapping and analysis. To develop a better understanding of land management practices in the watershed, calls were placed to local agencies to obtain information on crops, pesticide and fertilizer application practices, tillage practices and best management practices employed. A site visit was conducted on December 11, 2003. A second site visit was conducted on June 29, 2004 and meetings were held with local representatives of the Natural Resource Conservation Service (NRCS) and Soil and Water Conservation District (SWCD), Hillsboro Resource Planning Committee (RPC), and Glenn Shoals Lake Association. The GIS data obtained, calls placed and site visits are described below.

After the watershed boundaries for the impaired waterbodies (Table 1) in the project watershed were delineated in GIS using topographic and stream network (hydrography) information, other relevant information was obtained. 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
- the locations of 303(d) listed waterbodies.

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), Agricultural Extension Office, and Health Department. A list of data sources and calls made is included in Appendix A.

Other information compiled for this task related to climate, population growth and urbanization. These data were obtained from State and Federal sources, including the National Weather Service, U.S. Census Bureau, and the State of Illinois.

Glenn Shoals/Hillsboro Watershed Characterization

The Glenn Shoals/Hillsboro watershed is located in Central Illinois, approximately 40 miles south of Springfield and 60 miles northeast of St. Louis. Lake Glenn Shoals is a 1,350-acre impoundment constructed in the 1970s for flood control, water supply, and recreational uses. It has an average depth of 10 feet, and nearly 27 miles of shoreline (City of Hillsboro, 2004). Lake Hillsboro, often referred to as the "Old Lake," was created in 1918 (City of Hillsboro, 2004) and served as the primary water supply for the area until construction of Lake Glenn Shoals. Currently, both lakes are used as water supply for the City of Hillsboro and several neighboring communities. Lake Hillsboro has a surface area of approximately 110 acres. The combined drainage area for the two lakes covers 53,039 acres (83 square miles), primarily in Montgomery County. A very small portion of the watershed lies in Christian County.

Figure 1 shows a map of the watershed, and includes some key features such as waterways, impaired waterbodies, public water intakes, roads, and other key features. The map also shows the location of a point source discharge that has a permit to discharge under the National Permit Discharge Elimination System (NPDES). The City of Irving is the sole NPDES discharge in the watershed. This facility uses a lagoon for sewage treatment, with periodic discharges (Zahniser Institute, undated)

The following sections provide a broad overview of the characteristics of the Glenn Shoals/Hillsboro watershed.

Geology and Soils

Information on soils and topography was compiled in order to understand whether the soils are a potential source of manganese. The watershed lies in the center of the Springfield Plain, in the Illinois Basin of the Central Lowland Province (Zahniser Institute, undated). During the Pleistocene era, this area was covered by glaciers. This glaciation produced the area's stratigraphy. Loess deposits within the watershed range from 0-50 inches in the south to 50-150 inches in the northern part of the watershed; underlying glacial till is Illinoisan moraine and ground moraine of the Glasford formation. The bedrock layer is 150-300 feet thick and Pennsylvanian in origin (Zahniser Institute, undated). Figure 2 shows the major soil associations in the Glenn Shoals/Hillsboro watershed. These are also listed in Table 2.

The Montgomery County NRCS indicated that they no longer have county soil surveys available; they do not expect a revised one until 2006. The descriptions below were taken from the Macoupin County soil survey (NRCS, 1990). Macoupin County is adjacent to Montgomery County. As discussed below, many of the soils in the Lake Glenn Shoals and Old Lake Hillsboro watersheds contain manganese and iron oxide concretions or accumulations and are also acidic. This could result in manganese and iron moving into solution and being transported in base flow and/or runoff.

The Oconee and Darmstadt soils have nearly level or gently sloping (0 – 5% slopes), slow permeability and are somewhat poorly drained soils that are on low, broad ridges in the uplands and the side slopes of drainageways (NRCS, 1990). In the Macoupin County soil survey (NRCS, 1990), the following descriptions of these two soils were found, which indicate they are naturally occurring source of manganese. Six of the seven upper soil horizons (8 to 60 inches deep) of the Oconee series contain few to common fine rounded accumulations of iron and manganese oxide and are described as being slightly to strongly acid. Six of the upper seven soil horizons (8 – 47 inches) of the Darmstadt series also have few fine rounded accumulations of iron and manganese oxide. The Cowden series is not described as containing accumulations of iron and manganese oxide.

The Virden-Piasa complex is described in NRCS (1990) as being nearly level, poorly drained soils on broad flats in the uplands. These soils are subject to ponding and are generally unsuited to use as sites for dwellings and septic tank absorption fields because of the ponding. Four of the upper seven soil horizons (20-54 inches) of the Herrick series are described as being acidic and containing few to common fine rounded accumulations of manganese and iron oxides. The Piasa series is not described as containing iron or manganese oxides, however, three of the upper six soil horizons of the Virden series (28-60 inches are described as having few fine rounded accumulations and concretions of manganese and iron oxides. The Virden series is described as being neutral to slightly acid.

The Stoy series is not described in the Macoupin County soil survey, however, the Hosmer and Hickory series are. Both the Hosmer and Hickory series consist of moderately to well drained, moderately permeable soils. The Hickory series are on side slopes of drainageways in the uplands, while the Hosmer series are on convex ridgetops and sideslopes in the uplands. Hosmer slopes range from 2 to 5 percent and the Hickory slopes range from 10 to 60 percent. Both of these series are described as being very strongly acid and both contain few fine and medium rounded accumulations of manganese and iron at depths between 13 and 45 inches (Hickory series) and 19 to 60 inches (Hosmer series).

Montgomery County elevation ranges from approximately 510 feet to 767 feet above mean sea level, with a total relief of approximately 257 feet and an average slope of 0.84% (Illinois State Geological Survey, 2004). The upper portions of the Glenn Shoals/Hillsboro watershed are relatively flat, with gently rolling topography closer to the lakes.

Table 2. Major Soil Associations

Soil Map Units (MUID)	Acres	Percentage
Glenn Shoals Watershed		
Herrick-Virden-Piasa (IL004)	30,761	63.2%
Cowden-Oconee-Darmstadt (IL005)	8,511	17.5%
Hosmer-Stoy-Hickory (IL037)	9,400	19.3%
Hillsboro Watershed		
Cowden-Oconee-Darmstadt (IL005)	3,470	77.5%
Hosmer-Stoy-Hickory (IL037)	1,010	22.5%

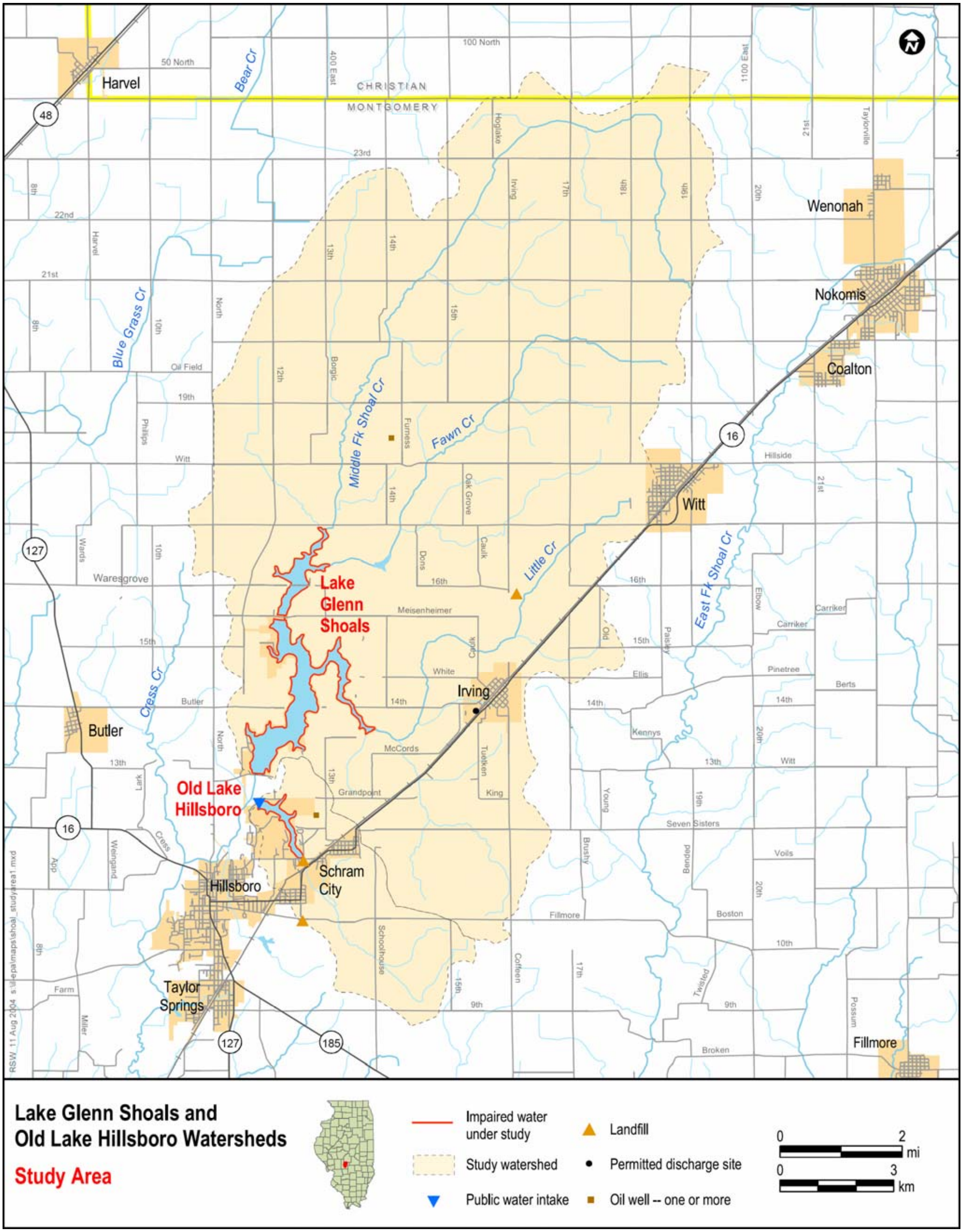

Figure 1. Point source discharge, impaired waterbody segments, and other watershed characteristics

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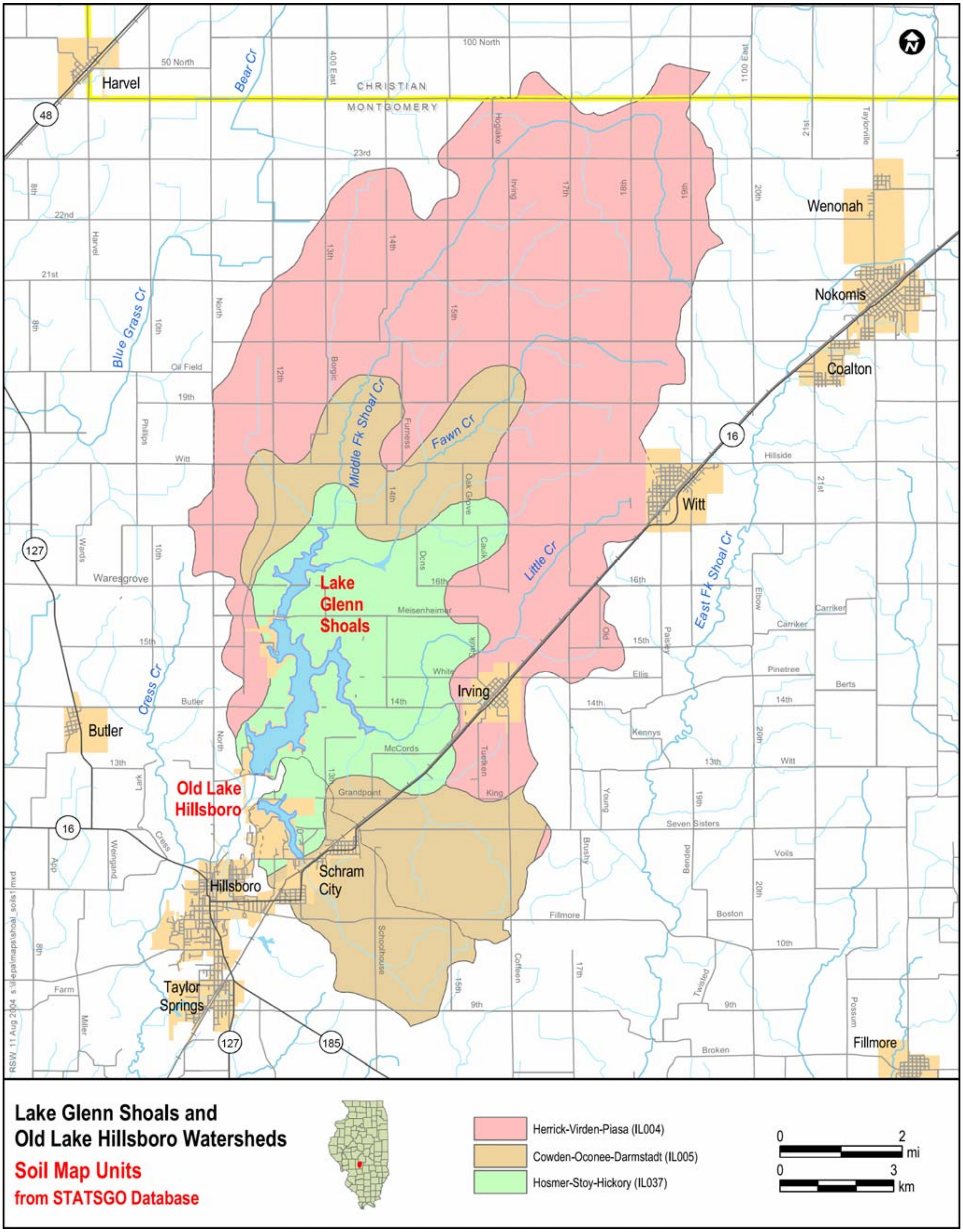

Figure 2. Major soil associations in the Glenn Shoals/Hillsboro Watershed

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Climate

The Glenn Shoals/Hillsboro watershed has a temperate climate, with cold winters and hot summers. The National Weather Service (NWS) maintains a weather station at Hillsboro through the Cooperative Observer Program (COOP). Climate data are archived at the National Climatic Data Center (NCDC) and summaries are available on the web page of the Illinois State Climatologist Office (Illinois Water Survey, 2004). The average long-term precipitation (1971-2000) recorded at Hillsboro (Station 114108) is approximately 40.18 inches. The maximum annual precipitation is 62.39 inches (1982) and the minimum annual precipitation is 25.59 inches (1914). On average, there are 97 days with precipitation of at least 0.01 inches and 10 days with precipitation greater than 1 inch. Average snowfall is approximately 19.4 inches per year.

Average maximum and minimum temperatures recorded at Hillsboro are 37.4 ^{o}F and 21.1 ^{o}F, in January and 90.7 ^{o}F and 68.0 ^{o}F in July (1971-2000 data). The average temperature recorded in January is 29.3 ^{o}F and the average temperature recorded in July is 79.4 ^{o}F.

Land Cover and Use

Runoff from the land surface contributes pollutants to nearby receiving waters. In order to understand sources contributing to the lake impairments, it was necessary to characterize land cover in the watershed. Land cover and land uses in the watershed are shown in Figure 3, and listed in Tables 3 (Glenn Shoals) and 4 (Hillsboro). The predominant land use in the watershed is agriculture, shown in yellow on the map. Approximately 79% of the Glenn Shoals watershed is cropland, while cropland makes up approximately 63% of the Hillsboro watershed. Most farms in the area have a corn-soybean rotation, and a few farmers include wheat in their rotations. Many farmers do not include wheat because they do not believe it is economically feasible (NRCS, personal communication).

A summary of tillage practices in Montgomery County is provided in Table 5. According to estimates prepared by the Illinois Department of Agriculture (2002), approximately 85% of the corn croplands in Montgomery County and 43% of the soybean crops are tilled using conventional tillage methods that leave little or no residue on the surface. Approximately 8% of the corn and 14% of the soybeans are tilled by reduced tillage methods, which can reduce soil loss in comparison to conventional methods by 30%. The remaining 7% of corn croplands and 38% of soybean crops are planted without any tillage prior to planting, a process that can reduce soil loss by up to 75%. Additionally, 5% of the soybean lands are planted using mulch-till methods, in which at least 30% residue of the previous year's crop remains on the land after planting the new crop. Mulch-till and no-till are considered conservation tillage systems that can significantly reduce soil loss. Montgomery County NRCS staff suggested that within the Glenn Shoals/Hillsboro watershed, the percentage of soybeans planted without tillage may be even higher, on the order of 50-75%.

The NRCS and SWCD have been active in this watershed, and programs such as the Water Quality Incentive Program, Environmental Quality Incentives Program, and state cost-share programs have been used to fund a variety of measures to reduce soil loss and protect water quality, including terraces, settling basins, sediment control basins, and buffer strips.

The yellow areas on Figure 3 indicating agricultural land use include livestock operations. There are very few livestock operations within the watershed. There are a couple of small cattle operations and a handful of hog farms. There is one large hog confinement operation in the watershed, which reports that it is operating in accordance with Concentrated Animal Feeding Operations (CAFO) regulations. A few farms also have horses.

Table 3. Land Cover Distribution, Lake Glenn Shoals Watershed

Land Cover Type	Area (Acres)	Percent of Total
Agriculture[1]	38,733	79.7%
Forest	4,757	9.8%
Grassland	2,384	4.9%
Water	1,033	2.1%
Wetland	930	1.9%
Barren	17	0.0%

Source: Illinois Department of Agriculture, 1999-2000 data (http://www.agr.state.il.us/gis/)
[1] Agriculture is primarily comprised of corn (48%) and soybeans (46%), with lesser amount of winter wheat and other small grains.

Table 4. Land Cover Distribution, Old Lake Hillsboro Watershed

Land Cover Type	Area (Acres)	Percent of Total
Agriculture[1]	2,856	64.4%
Forest	602	13.6%
Urban	441	9.9%
Grassland	228	5.1%
Wetland	206	4.6%
Water	100	2.2%
Barren	6	0.1%

Source: Illinois Department of Agriculture, 1999-2000 data (http://www.agr.state.il.us/gis/)
[1] Agriculture is primarily comprised of corn (46%) and soybeans (47%), with lesser amount of winter wheat and other small grains.

Table 5. Percent of Montgomery County fields, by crop, with indicated tillage system

	Tillage system			
	Conventional Till[1]	Reduced-Till[2]	Mulch-Till[3]	No-Till[3]
Corn	79	16	3	2
Soybean	45	30	13	13
Small grain	8	92	0	0

Source: Illinois Department of Agriculture (2002)
[1] Residue level 0 – 15%
[2] Residue level 16-30%
[3] Residue level > 30%

The green areas on Figure 3 show forested lands (approximately 13.6% of the Old Lake Hillsboro watershed and 9.8% of the Lake Glenn Shoals watershed), which are both upland and floodplain. Also shown on the map (in red) are areas of low/medium and high density development. These areas indicate the locations of the towns and residential communities in the watershed. Hillsboro is the major urban area; parts of the City lie in the western portion of the Old Lake Hillsboro watershed. Schram City is also within the Old Lake Hillsboro watershed. The village of Irving is located within the Lake Glenn Shoals watershed, as is a portion of the city of Witt. The developed area on the west side of Lake Glenn Shoals is connected to the City sewer, but the eastern side of the lake and areas in the upper watershed are not sewered. Most of these have surface discharge systems due to the high clay content of the soils and the high slopes, which make septic systems impractical (personal communication, Montgomery County Health Department, 2004). Portions of the Old Lake Hillsboro watershed are also unsewered.

State Route 16 is the major roadway within the watershed, extending from Hillsboro in the southern part of the watershed in a northeast direction Schram City and Irving. Most of the roads in the upper watershed are unpaved rural roads.

Parkland and other recreational uses are in proximity to the lakes. The watershed includes two boat launch areas on Lake Glenn Shoals, a small beach area on Lake Hillsboro, a city campground, a Girl Scout camp, and numerous campsites available for lease. Members of the local community have indicated that there are as many as 240 campsites around the lake that are accessible only by boat and lack any sort of sanitation facilities. Hillsboro Country Club also drains to Old Lake Hillsboro.

Urbanization and Growth

Hillsboro is the major urban area in the watershed; parts of the City lie in the western portion of the Old Lake Hillsboro watershed. Schram City is also within the Old Lake Hillsboro watershed. The village of Irving is located within the Lake Glenn Shoals watershed, as is a portion of the city of Witt.

The current population of Montgomery County is 30,652 (U.S. Census Bureau, 2000). Illinois Population Trends (State of Illinois, 1997) predict a decrease in population of approximately 1.3% between 2000 and 2010.

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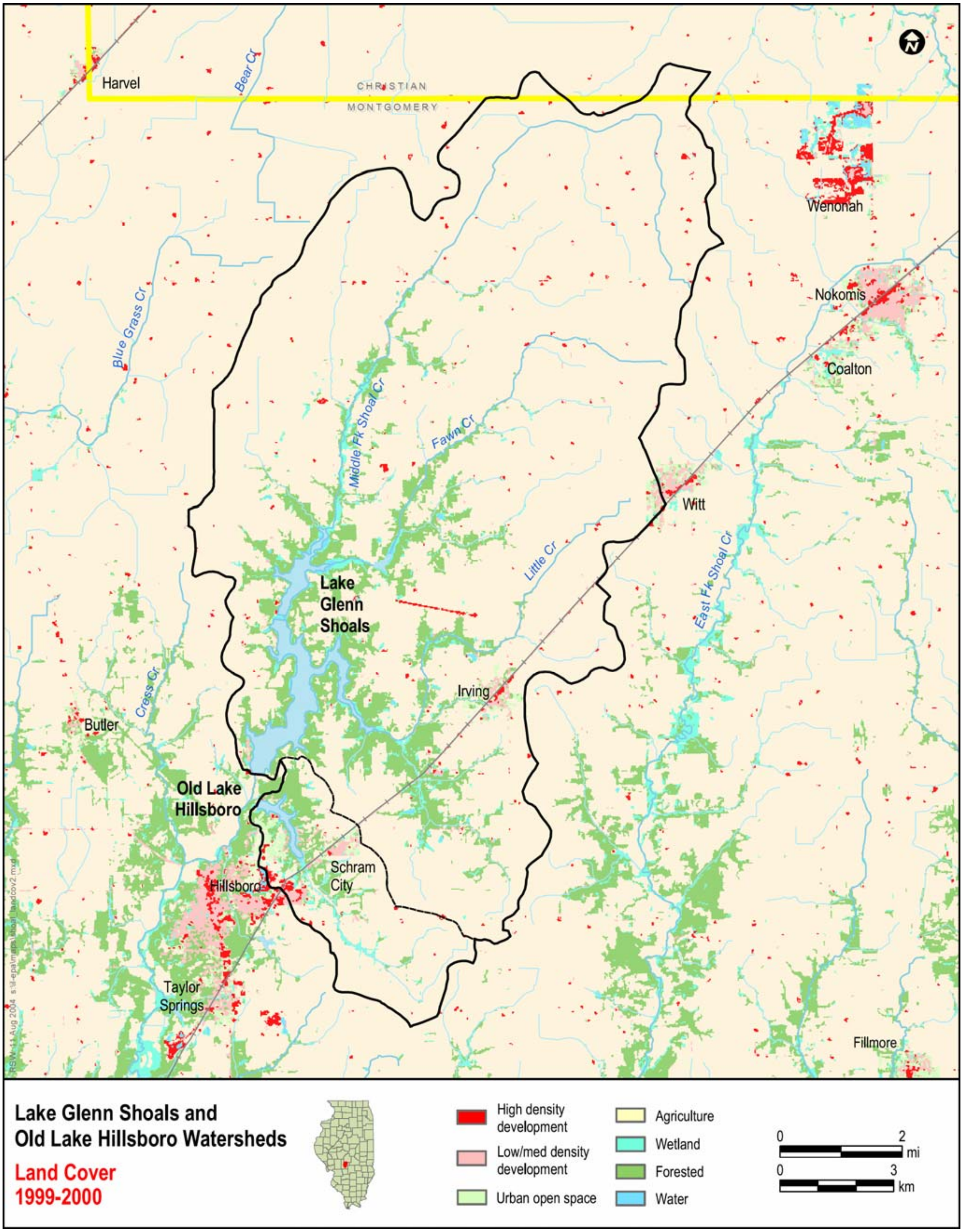

Figure 3. Current land cover in the project watershed

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Watershed Organizations

Local watershed organizations with an interest in watershed management will be important for successful implementation of this TMDL. There are two watershed organizations within the Glenn Shoals/Hillsboro watershed, the Hillsboro Resource Planning Committee and the Glenn Shoals Lake Association. The Resource Planning Committee was organized in 1994, focusing on water quality issues in both Glenn Shoals and Hillsboro Lakes. They act in an advisory role to the City, with no funding and strictly voluntary participation. The committee has been actively involved in reviewing the results of the ongoing Clean Lakes Study.

The Lake Association has about 40-45 members. Membership is on a voluntary basis, made up of either residents or others who have an interest in the lake, for example, people who lease a site for camping. This group is specific to Lake Glenn Shoals; there is no corresponding Old Lake Hillsboro group. The association's goal is to have controlled, sensible development, to preserve as much of the lake as possible, for as long as possible. Members have participated in conservation programs conducted in conjunction with the NRCS, for example, cypress and willow plantings for erosion control.

DATABASE DEVELOPMENT AND 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 draft 2004 303(d) list.

Data Sources and Methods

All readily available existing data to describe water quality in the impaired lakes were obtained. Sources contacted for data include the Illinois Environmental Protection Agency (State and Regional offices) and the United States Geologic Survey (USGS). All available and relevant data were then compiled in electronic format along with sample location and collection information, in a project database. No USGS data were identified for this watershed. A list of data sources is included in Appendix A.

Summaries of readily available water quality data are presented for Lake Glenn Shoals in Table 6, and for Old Lake Hillsboro, in Table 7. Sampling station locations are shown in Figure 4. Data were also available for several tributary sampling locations. The tributary sampling data were not included in the tables, since they do not pertain directly to the impairment assessment; however, they provide useful information on pollutant loadings within the watershed.

Table 6. Water quality data summary for Lake Glenn Shoals

Sample location and parameter	Criterion (mg/l)	Period of record and number of data points	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)
Lake Glenn Shoals, near the dam (ROL-1)					
Total Phosphorus	0.05 mg/l	1990-2002 64 samples	0.156	1.013	0.037
Lake Glenn Shoals, at Little Creek (ROL-2)					
Total Phosphorus	0.05 mg/l	1990-2002 30 samples	0.177	0.407	0.051
Lake Glenn Shoals, at confluence of Middle Fork Shoal Creek arm and Fawn Creek arm (ROL-3)					
Total Phosphorus	0.05 mg/l	1990-2002 32 samples	0.305	0.651	0.084

Data are also available for parameters that may be related to total phosphorus, including dissolved phosphorus, chlorophyll *a*, and total suspended solids.

Table 7. Water quality data summary for Old Lake Hillsboro

Sample location and parameter	Criterion (mg/l)	Period of record and number of data points	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)
Old Lake Hillsboro, "Site 1", near the dam (ROT-1)					
Total Phosphorus	0.05 mg/l	1994-2002 51 samples	0.534	3.99	0.141
Total Manganese	0.150 mg/l	May 2001 – Oct 2001 5 samples	0.170	0.220	0.100
Old Lake Hillsboro, mid-lake (ROT-2)					
Total Phosphorus	0.05 mg/l	1994-2002 23 samples	0.272	0.40	0.115
Old Lake Hillsboro Headwaters (ROT-3)					
Total Phosphorus	0.05 mg/l	1994-2002 22 samples	0.318	0.60	0.203

The water quality data were analyzed to confirm the cause 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 draft 2004 303(d) list. Analysis methods included computing summary statistics, evaluating trends and correlations, and using graphical analysis to discern relationships in the data.

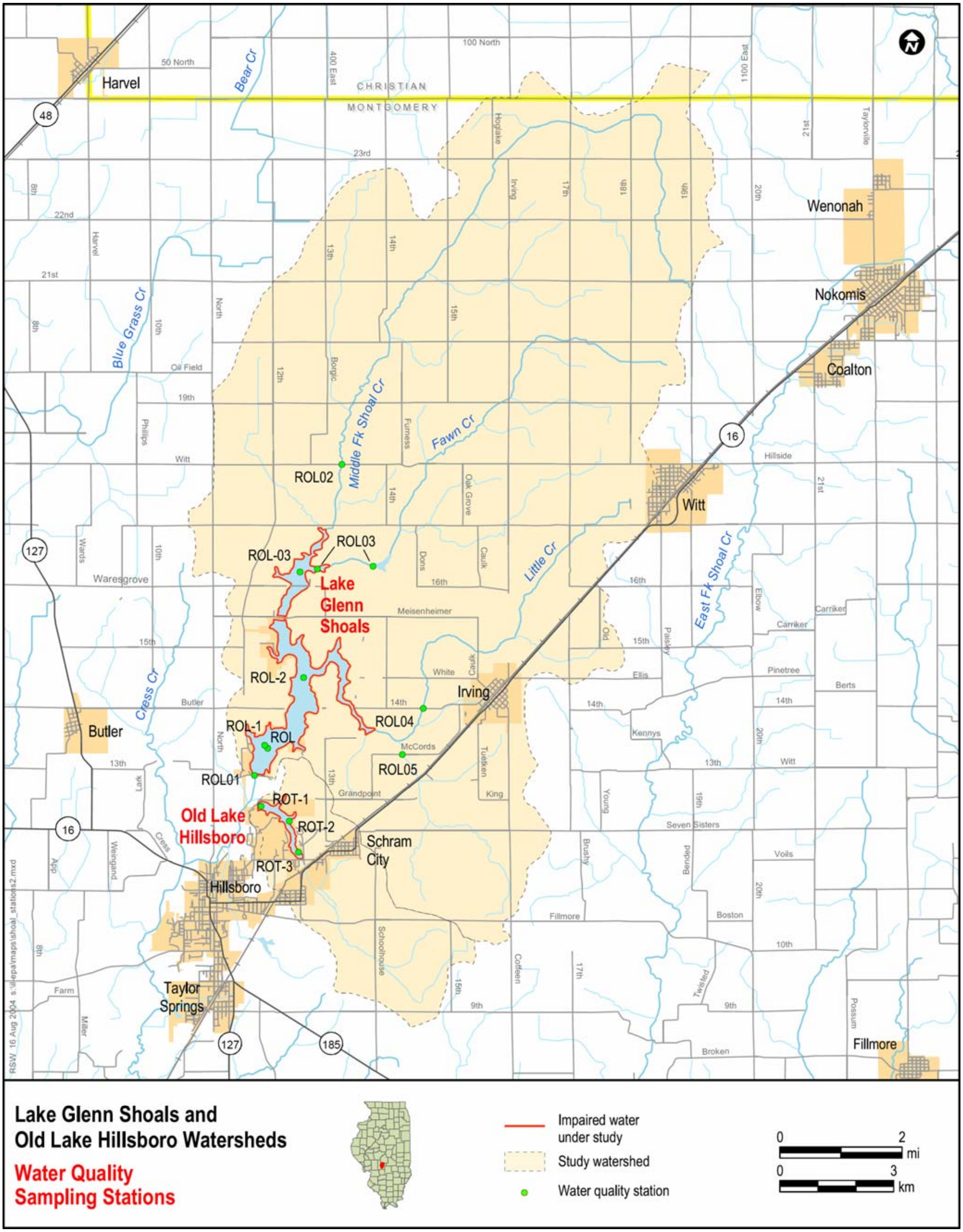

Figure 4. Sampling stations in the project watershed

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CONFIRMATION OF CAUSES AND SOURCES OF IMPAIRMENT

Water quality data were evaluated, in combination with the watershed characterization data, to:

1. assess the sufficiency of the data to support the listing decision; and
2. identify suspected or known sources of impairment.

Lake Glenn Shoals (ROL)

Lake Glenn Shoals is listed on the 303(d) list as impaired for phosphorus. The IEPA guidelines (IEPA, 2004a) for identifying total phosphorus as a cause in lakes (for lakes ≥ 20 acres) state that the aquatic life use and the secondary contact use are not supported if the surface phosphorus concentration exceeds the applicable standard (0.05 mg/l) in at least one sample during the monitoring year. The available data confirm that the lake routinely exceeds the state standard for phosphorus and that the aquatic life and secondary contact uses are not fully supported. At sampling locations in the middle and upper portions of the lake, 100% of the surface sample results exceed the water quality criterion of 0.05 mg/l. Data collected near the dam (station ROL-1) show 95% of the surface samples exceeding the criterion. Average concentrations exceed the criterion by two to five times the criterion. These data support the listing of the lake as impaired by phosphorus.

Linear regression was used to evaluate the relationship between total and dissolved phosphorus. This evaluation determined that 54% of the total phosphorus is in the dissolved form (R^2 = 0.81; Figure 5).

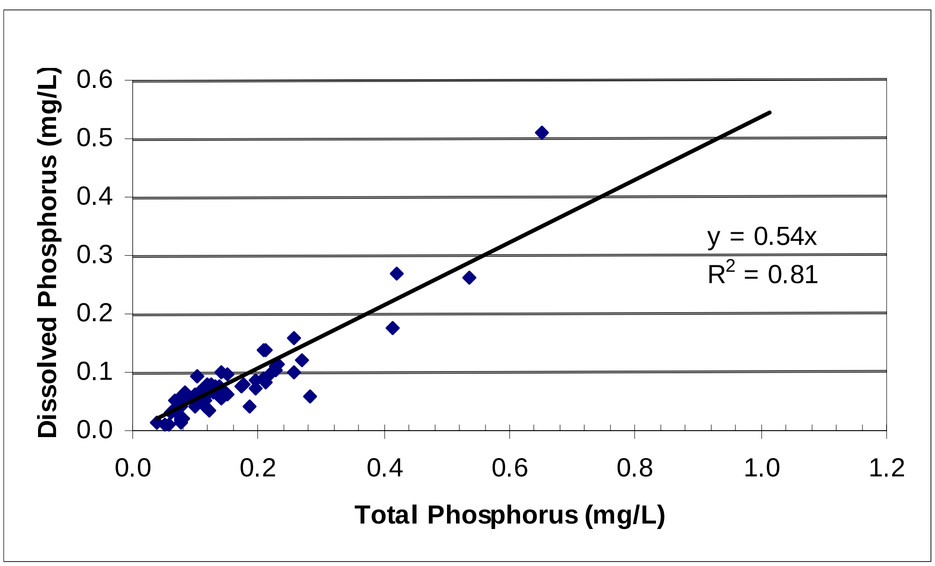

Figure 5. Dissolved and Total Phosphorus Concentrations in Lake Glenn Shoals

Total phosphorus concentrations appear consistently higher in the upper part of the lake (station ROL-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.

Samples were collected near the dam at several water depths in 2001. These data suggest that phosphorus may be released from the sediment during summer conditions (Figure 6). Concentrations near the bottom of the lake were much higher than surface and mid-depth samples collected on August 24, 2001. A similar pattern was not observed in samples collected in June and October. July samples suggest that stratification of the lake may have been occurring, with bottom phosphorus concentrations becoming higher than surface levels (temperature data are not available to confirm this observation).

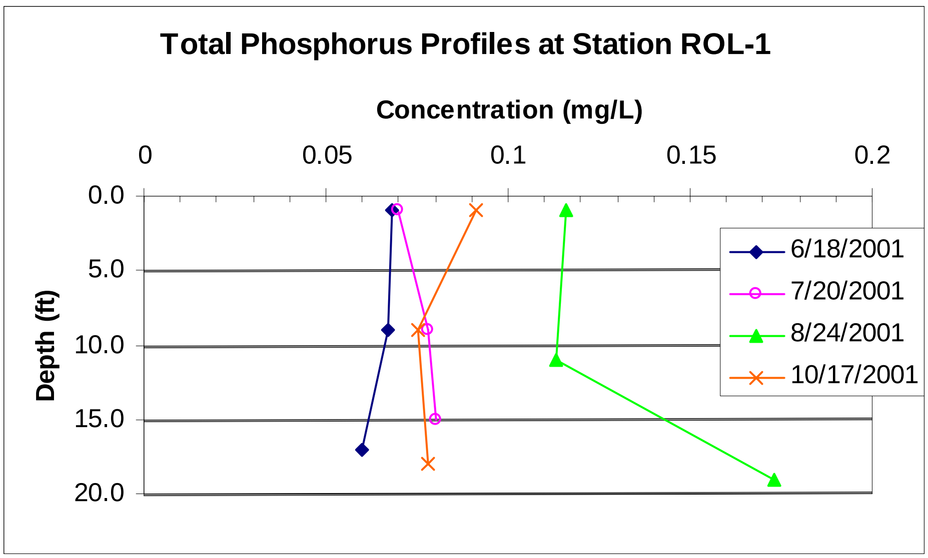

Figure 6. Total Phosphorus Concentrations at Varying Depths in Lake Glenn Shoals

Old Lake Hillsboro (ROT)

Old Lake Hillsboro is listed on the 303(d) list as impaired for phosphorus and manganese. The available data confirm that the lake routinely exceeds the state standard for phosphorus and that the aquatic life and secondary contact uses are not fully supported. All 118 surface samples exceeded the water quality criterion of 0.05 mg/l, as did all of the samples at other depths. The average surface concentrations exceed the criterion by four to five times the criterion. These data confirm that the lake is impaired for phosphorus.

Linear regression was used to evaluate the relationship between total and dissolved phosphorus. This evaluation showed a strong correlation and determined that 80% of the total phosphorus is in the dissolved form ($R^2 = 0.92$; Figure 7).

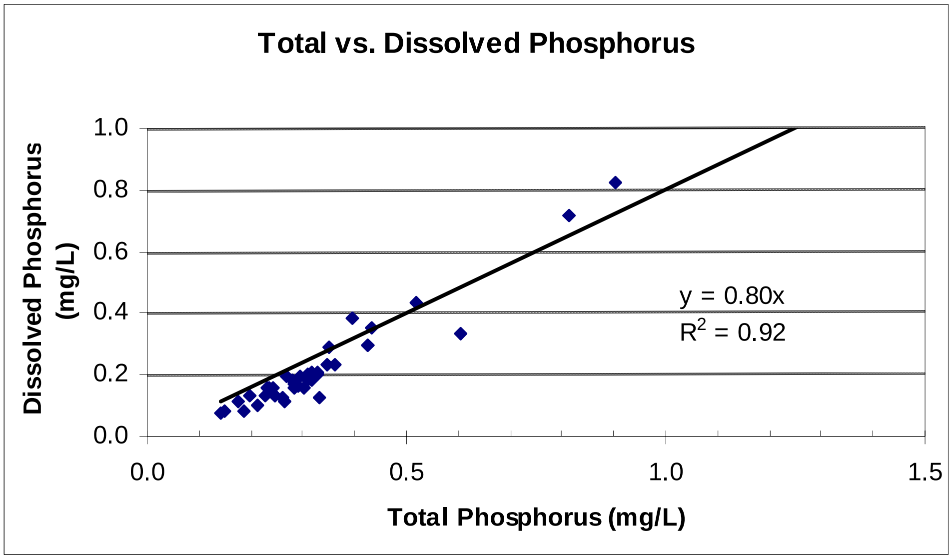

Figure 7. Dissolved and Total Phosphorus Concentrations in Old Lake Hillsboro

Samples were collected near the dam at several water depths in 2001. These data suggest that phosphorus may be released from the sediment during summer conditions (Figure 8). Concentrations near the bottom of the lake were much higher than surface and mid-depth samples collected in May, June, July, and especially August of 2001. A similar pattern was not observed in samples collected in October, perhaps due to mixing of the lake (temperature data are not available to confirm this observation).

The available data, while somewhat limited, suggest inverse relationships between total phosphorus and chlorophyll *a*, and total suspended solids and chlorophyll *a*. Lower biomass, as determined by chlorophyll *a*, at high suspended solids and phosphorus concentrations suggest that light availability may be limiting productivity in the lake.

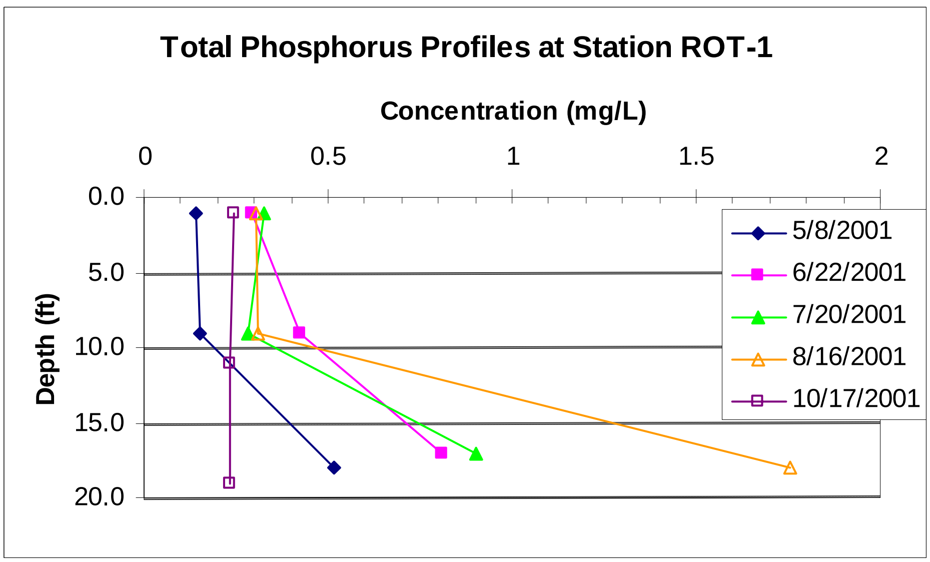

Figure 8. Total Phosphorus Concentrations at Varying Depths in Old Lake Hillsboro

Substantially fewer data points are available for assessing impairment due to manganese (five samples). Three of the five available samples for Old Lake Hillsboro exceed the applicable public water supply criterion of 0.15 mg/l (150 ug/l). None of the samples exceed the higher general use criterion. Manganese concentrations for samples exceeding the criterion ranged from 180 ug/l to 220 ug/l, exceeding the criterion by only 20-35%.

IEPA guidelines (IEPA, 2004a) for identifying manganese as a cause in lakes state that the public water supply use is not supported if, in untreated water, greater than 10% of the observations exceed the applicable standard, for water samples collected in 1999 or later, and for which results are readily available. With more than half of the samples exceeding the criterion, it was determined that the listing of Old Lake Hillsboro for manganese is supported. All manganese samples were collected in 2001.

The data were evaluated to identify potential relationships between manganese concentrations and levels of total suspended solids and iron. The available data suggest a possible inverse relationship between manganese and total suspended solids, but are too limited to draw any firm conclusions. The limited available data show no apparent relationship between manganese and iron concentrations.

Potential Sources

The Illinois EPA (IEPA, 2004a) defines potential sources as known or suspected activities, facilities or conditions that may be contributing to impairment of a designated use. Through a review of available information, including telephone calls to local agency staff, site visits, and evaluation of the available water quality data, the following potential sources of phosphorus for Lake Glenn Shoals and Old Lake Hillsboro were identified:

- Agriculture/crops
- Existing in-lake sediment sources
- Recreation and tourism activities (campsites and golf courses)
- Failing private sewage disposal systems (surface discharge systems)

The Illinois EPA (IEPA, 2004a) identified agriculture, crops, and recreation and tourism as potential sources of impairment. This evaluation suggests that existing sediments and failing private sewage disposal systems may also contribute to the impairment. 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.

It appears that the primary source of manganese is natural sources. Montgomery County NRCS staff confirmed that there is manganese in the soils within the Glenn Shoals/Hillsboro watershed (personal communication, 2004). In addition, soils in neighboring Macoupin County are known to have naturally high levels of manganese, with the Macoupin County Soil Survey (USDA, 1990) describing “nodules’ of manganese in many soils. Soils in southern Illinois have also been described as acidic, which could result in manganese bound to the soil moving into solution and being transported to the lakes in base flow and/or runoff (personal communication, State Water

Quality Specialist, July 2004). Sediments in the lake may also be a source, contributing manganese to the water column when dissolved oxygen is low.

The observed levels of manganese are likely due to the natural geochemical environment and most likely reflect natural background conditions. For this reason, the general use standard may be difficult to attain. The existing water quality standard is designed not to protect against human health hazards, but to prevent offensive tastes and appearances in drinking water, as well as staining laundry and fixtures.

In addition to the natural sources, there are two potential sources to be investigated. Within the Old Lake Hillsboro watershed, there is a smelter, Eagle Zinc, that is no longer functioning, but it is not known whether it could be contributing manganese. There is also a glass plant that is no longer operational. The Agency for Toxic Substances and Disease Registry (ATSDR) indicates that manganese dioxide is commonly used in production of porcelain and glass-bonding materials and amethyst glass (ATSDR, 2000). The Illinois EPA (IEPA, 2004a) lists "unknown sources" as a suggested source of impairment.

CONCLUSIONS

The available data support the listing of both Lake Glenn Shoals and Old Lake Hillsboro as impaired by phosphorus. Potential sources include agricultural sources, existing sediments, recreation activities, and failing private sewage disposal systems. The available data also indicate some exceedances of the public water supply criterion for manganese in Old Lake Hillsboro and suggest that the primary source may be background sources due to naturally high concentrations in area soils.

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
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	
NPDES discharge data	Illinois 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	http://www.isgs.uiuc.edu/nsdihome/

Data description	Agency	Website
	Geospatial Data Clearinghouse	
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	
Water quality data	Illinois Environmental Protection Agency	
Watersheds	Illinois Environmental Protection Agency	http://maps.epa.state.il.us/website/wqinfo/
Water supply – Public water supply intakes	Illinois State Water Survey	

Table A-2. Local and state contacts

Contact	Agency/ Organization	Contact Means	Phone #	Subject
David Booher	Hillsboro City Clerk, Chair of Resource Planning Committee	meeting	217-532-5566	Glen Shoals/Hillsboro are Resource Planning Committee activities, water quality concerns, etc.
CJ Liddell	District Conservationist, NRCS	meeting	217-532-3610 x 111	Agricultural practices in watershed, "windshield tour" of watershed
Kris Reynolds	SWCD Resource Conservationist	meeting		Agricultural practices
Richard Small	President, Glenn Shoals Lake Association	meeting		Lake Association's interests & objectives, current water quality issues
C.J. Liddell	Montgomery County NRCS	telephone	(217) 532-3610 ext 3	Crops, livestock, fertilization practices, potential sources of manganese
Jodi Schoen	Montgomery County Health Department	Telephone	(217) 532-2001	Private wastewater discharges
Rich Nickels	Illinois Department of Agriculture	Telephone	217-782-6297	Requested Cropland Transect Survey
Sue Ebetsch	Illinois State Data Center	Telephone	217-782-1381	Requested Population projection report
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
Sharie Heller	SW Illinois GIS resource Center	Telephone	618-566-9493	Discussed CRP maps
Steve Sobaski	Illinois Department of National Resources	e-mail	ssobaski@dnrmail .state.il.us	Formal request for conservation related GIS files
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.Meneghe tti@epa.state.il.us	Lake data and SWAPs
Dave Muir	IEPA Marion Regional office	Personal visit	618-993-7200	Assessment data used in 303(d) and 305(b) reports
Tim Kelly	IEPA Springfield Regional office	Telephone and e-mail	217/-786-6892 Tim.Kelly@epa.st ate.il.us	NPDES DMR data
Jeff Mitzelfelt	IEPA	e-mail	jeff.mitzelfelt@epa .state.il.us	Websites for GIS information

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APPENDIX B. PHOTOS

Old Lake Hillsboro, near inlet, looking north from Smith Rd, Schram City area.

Old Lake Hillsboro inlet area, looking south from Smith Rd, Schram City

Old Lake Hillsboro, near outlet (note public water supply intake)

Looking up Old Lake Hillsboro, sweeping right from previous picture (near outlet)

Looking up Old Lake Hillsboro, sweeping right from previous picture

Little Creek (tributary to Lake Glenn Shoals) at 14th Ave – looking downstream

Lake Glenn Shoals, looking east from North access

Lake Glenn Shoals, looking south from north access area

Lake Glenn Shoals at Meisenheimer Rd.

Looking south down Lake Glenn Shoals from Meisenheimer Road bridge

Looking north up Lake Glenn Shoals from Meisenheimer Road bridge

New subdivision on west side of Lake Glenn Shoals

New construction in subdivision (note lack of soil erosion controls)

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Second Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

October 2004

Glenn Shoals/Hillsboro Watershed

Lake Glenn Shoals (ROL), Old Lake Hillsboro (ROT)

Limno-Tech, Inc.

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Table of Contents

List of Tables

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EXECUTIVE SUMMARY

This is the second in a series of quarterly status reports documenting work completed on the Lake Glenn Shoals/Old Lake Hillsboro 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 draft 2004 303(d) list (IEPA, 2004), 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
- 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 Lake Glenn Shoals/Old Lake Hillsboro 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 Lake Glenn Shoals, the relevant site-specific characteristics include a watershed with predominantly agricultural land use, and a lake impaired by total phosphorus. For Old Lake Hillsboro, the relevant site-specific characteristics include a watershed with predominantly agricultural land use that is also 10% urban. Old Lake Hillsboro is a reservoir impaired by total phosphorus and manganese.

- **Management objectives:** These objectives consist of the specific questions to be addressed by the model. For this application, the management objective is to define 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 both Lake Glenn Shoals and Old Lake Hillsboro. 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.

The recommended approach consists of using the GWLF and BATHTUB models to address total phosphorus and manganese problems in Lake Glenn Shoals and Old Lake Hillsboro. Specifically, GWLF will be applied to calculate phosphorus loads to both of the lakes, over a time scale consistent with their nutrient residence times. BATHTUB will then be used to predict the relationship between phosphorus load and resulting in-lake phosphorus and dissolved oxygen concentrations. This relationship will be used to define the dominant sources of phosphorus to the lake, and the extent to which they must be controlled to attain water quality standards. It is assumed that the only controllable source of manganese to the lake 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.

Two alternative approaches are also provided. The first alternative approach would not include any watershed modeling for phosphorus, but would focus only on determining the pollutant loading capacity of the lake. This approach would be used to determine existing loading sources, prioritize restoration alternatives and support development of a voluntary implementation plan that includes both accountability and the potential for adaptive management. A second alternative is also provided in the event that more detailed implementation plans are desired. The frameworks included with the second alternative 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 impaired water bodies in the Lake Glenn Shoals/Old Lake Hillsboro 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 Glenn Shoals/Hillsboro watershed affect the recommendation of specific methodologies.
- **Selection of specific methodologies and future data requirements:** This section provides specific recommendation of methodologies for the Glenn Shoals/Hillsboro 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 Glenn Shoals/Hillsboro 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 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. 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	X	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, and 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 Glenn Shoals/Hillsboro watershed. This chapter presents the general guidelines used in model selection process, and then applies these guidelines to make specific recommendations. In summary, three alternative approaches are recommended for the Glenn Shoals/Hillsboro watershed, with final selection dependent upon the level of implementation to be immediately conducted for the TMDLs.

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 effort 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 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 Glenn Shoals/Hillsboro Watershed

Tables 1 and 2 summarized the characteristics of the various watershed and water quality methodologies with potential applicability to TMDL development. This section reviews the relevant site-specific characteristics of the systems, summarizes the data available, and provides recommended approaches. Data needs, assumptions, and level of TMDL implementation support are provided for each of the recommended approaches.

Site Characteristics

Watershed characterization for the Lake Glenn Shoals/Old Lake Hillsboro watershed was provided in the first quarterly status report (LTI, 2004). In summary, the Glenn Shoals/Hillsboro watershed is located in Central Illinois, approximately 40 miles south of Springfield and 60 miles northeast of St. Louis. Lake Glenn Shoals is a 1,350-acre impoundment constructed in the 1970s for flood control, water supply, and recreational uses. It has an average depth of 10 feet, and nearly 27 miles of shoreline (City of Hillsboro, 2004). Lake Hillsboro, often referred to as the “Old Lake,” was created in 1918 (City of Hillsboro, 2004) and served as the primary water supply for the area until construction of Lake Glenn Shoals. Currently, both lakes are used as water supply for the City of Hillsboro and several neighboring communities. Lake Hillsboro has a surface area of approximately 110 acres. The combined drainage area for the two lakes covers 53,039 acres (83 square miles), primarily in Montgomery County. A very small portion of the watershed lies in Christian County.

The listing of Lake Glenn Shoals on the Illinois 303(d) list for impairment for due to total phosphorus and the listing of Old Lake Hillsboro for manganese and total phosphorus have been confirmed based on a review of the data.

Potential sources contributing to the listing of Lake Glenn Shoals and Old Lake Hillsboro for total phosphorus include: Agriculture/crops, existing in-lake sediment sources, recreation and tourism activities (campsites and golf courses), and failing private sewage disposal systems (surface discharge systems). The primary potential source of manganese in the Old Lake Hillsboro watershed is natural sources, with the soils being described as containing manganese nodules or concretions. Soils in southern Illinois have also been described as acidic, which could result in manganese bound to the soil moving into solution and being transported to the lakes in base flow and/or runoff (personal communication, State Water Quality Specialist, July 2004). In-place sediments may also contribute manganese to the water column under anoxic conditions. In addition to the natural sources, there are two potential sources to be investigated. Within the Old Lake Hillsboro watershed, there is a smelter, Eagle Zinc, that is no longer functioning, but it is not known whether it could be contributing manganese. There is also a glass plant that is no longer operational.

Data Available

Tables 3 and 4 provide a summary of available water quality data from the first quarterly status report (LTI, 2004). This amount of data is sufficient to confirm the presence of water quality impairment, but are not sufficient to support development of a rigorous watershed or water quality model. The primary items lacking in this data set are tributary flows and tributary concentrations of manganese.

Table 3. Water Quality Data Summary for Lake Glenn Shoals

Sample location and parameter	Criterion (mg/l)	Period of record and number of data points	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)
Lake Glenn Shoals, near the dam (ROL-1)					
Total Phosphorus	0.05 mg/l	1990-2002 64 samples	0.156	1.013	0.037
Lake Glenn Shoals, at Little Creek (ROL-2)					
Total Phosphorus	0.05 mg/l	1990-2002 30 samples	0.177	0.407	0.051
Lake Glenn Shoals, at confluence of Middle Fork Shoal Creek arm and Fawn Creek arm (ROL-3)					
Total Phosphorus	0.05 mg/l	1990-2002 32 samples	0.305	0.651	0.084

Table 4. Water Quality Data Summary for Old Lake Hillsboro

Sample location and parameter	Criterion (mg/l)	Period of record and number of data points	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)
Old Lake Hillsboro, "Site 1", near the dam (ROT-1)					
Total Phosphorus	0.05 mg/l	1994-2002 51 samples	0.534	3.99	0.141
Total Manganese	0.150 mg/l	May 2001 – Oct 2001 5 samples	0.170	0.220	0.100
Old Lake Hillsboro, mid-lake (ROT-2)					
Total Phosphorus	0.05 mg/l	1994-2002 23 samples	0.272	0.40	0.115
Old Lake Hillsboro Headwaters (ROT-3)					
Total Phosphorus	0.05 mg/l	1994-2002 22 samples	0.318	0.60	0.203

Recommended Approaches

This section provides recommendations for specific modeling approaches to be applied for the Lake Glenn Shoals watershed and Old Lake Hillsboro watershed TMDLs. Three alternative sets of approaches are provided in Tables 5 and 6, with each approach having unique data needs and resulting degree of detail.

Table 5. Recommended Modeling Approaches for Lake Glenn Shoals

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Total Phosphorus	GWLF	BATHTUB	None	Identify primary sources to be controlled; and approximate level of control needed
Alternative 1					
	Total Phosphorus	None	BATHTUB	None	Identify approximate level of control needed
Alternative 2					
	Total Phosphorus	SWAT	CE-QUAL-W2	Tributary flows and concentrations	Define detailed control strategies

Table 6. Recommended Modeling Approaches for Old Lake Hillsboro

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Total Phosphorus, Manganese	GWLF	BATHTUB	None	Identify primary sources to be controlled; and approximate level of control needed
Alternative 1					
	Total Phosphorus, Manganese	None	BATHTUB	None	Identify approximate level of control needed
Alternative 2					
	Total Phosphorus, Manganese	SWAT	CE-QUAL-W2	Tributary flows and concentrations	Define detailed control strategies

The recommended approach consists of using the GWLF and BATHTUB models to address total phosphorus in both Lake Glenn Shoals and Old Lake Hillsboro, as well as manganese problems in Old Lake Hillsboro. Specifically, GWLF will be applied to calculate phosphorus loads to each of the lakes for each land-use category. The BATHTUB model will then be used to predict the relationship between phosphorus load and resulting in-lake phosphorus and dissolved oxygen concentrations. This relationship will be used to define the dominant sources of phosphorus to the lake, and the extent to which they must be controlled to attain water quality standards. 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 the available 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. If data are available to describe loads from two abandoned facilities (Eagle Zinc smelter and glass plant) in the Old Lake Hillsboro watershed, GWLF also has the capability to simulate loads from these potential sources.

The first alternative approach would not include any watershed modeling for phosphorus, but would focus only on determining the pollutant loading capacity of the lake. Determination of existing loading sources and prioritization of restoration alternatives would be conducted by local experts as part of the implementation process. Based upon their recommendations, a voluntary implementation plan would be developed that includes both accountability and the potential for adaptive management.

The second alternative approach would consist of applying the SWAT watershed model to define watershed loads for manganese and total phosphorus, coupled with application of the reservoir models CE-QUAL-W2 and WASP to describe in-lake water quality response. CE-QUAL-W2 would be applied to define hydrodynamics and eutrophication processes.

Assumptions Underlying the Recommended Methodologies

The recommended approach is based upon the following assumptions:

- The only controllable sources of manganese to the lake are those which enter from lake sediments during periods of low dissolved oxygen. The manganese in the lake sediments 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. Phosphorus concentrations in Old Lake Hillsboro, which are believed to contribute to manganese problems, currently (2002) exceed the water quality standard by a factor of 7. Phosphorus concentrations in Lake Glenn Shoals currently (2002) exceed the water quality standard by a factor of approximately 7. This indicates that phosphorus loads will need to be reduced by more than 85% to attain water quality standards. The dominant land use in both watersheds is agriculture. This level of load reduction is likely not attainable in the near future, if at all. Implementation plans for agricultural sources will require voluntary controls, applied on an incremental basis. The recommended approach, which requires no additional data collection, will expedite these implementation efforts.

DATA NEEDS FOR THE METHODOLOGIES TO BE USED

The recommended modeling approach and the first alternative approach 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 the lake response.

Should the second alternative approach be selected, 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,
2. define the extent to which these loads are being delivered to the lakes, and
3. define important reaction processes in Lake Glenn Shoals and Old Lake Hillsboro.

To satisfy objective one, wet weather event sampling of manganese (for Old Lake Hillsboro only) at multiple tributary locations in the watershed will be needed. To satisfy objective two, routine monitoring of loads to the lake will be needed. For Lake Glenn Shoals, this would involve collection of continuous flows where either Middle Fork Shoal Creek, Fawn Creek or Little Creek enter the lake in addition to water quality analyses for several wet and dry weather events for: total suspended solids, total phosphorus, and ortho-phosphorus. For Old Lake Hillsboro, routine monitoring of loads to the lake would involve collection of continuous flows where the primary unnamed tributary enters the lake. In addition, water quality analyses for several wet and dry weather events would be needed for manganese and total suspended solids. To satisfy the third objective, routine in-lake monitoring will be needed. In Lake Glenn Shoals and

Old Lake Hillsboro, bi-monthly sampling would need to be conducted for water temperature, in addition to total suspended solids, manganese (Old Lake Hillsboro only), total phosphorus, ortho-phosphorus, dissolved oxygen, and chlorophyll a.

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Third Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

October 2004

Glenn Shoals/Hillsboro Watershed

Lake Glenn Shoals (ROL), Old Lake Hillsboro (ROT)

Limno-Tech, Inc.
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EXECUTIVE SUMMARY

This is the third in a series of quarterly status reports documenting work completed on the Glenn Shoals/Hillsboro 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 draft 2004 303(d) list (IEPA, 2004), 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.

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 approach for the Glenn Shoals/Hillsboro watershed consists of using the GWLF and BATHTUB models to address total phosphorus and manganese problems in Lake Glenn Shoals and Old Lake Hillsboro. As noted in the second quarterly status report, application of these models will require no additional data collection.

Because no additional data collection is required to support development of the recommended models, a data collection plan is not needed.

INTRODUCTION/PURPOSE

This Stage 1 report describes intermediate activities related to the development of TMDLs for impaired water bodies in the Glenn Shoals/Hillsboro watershed. Previous 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 address:

- **Description of additional data collection, if any, to support modeling:** This section describes the amount (temporal and spatial) of data, if any, 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

In the second quarterly progress report for the Glenn Shoals/Hillsboro watershed (LTI, 2004), modeling approaches were recommended. The recommended approach for the Glenn Shoals/Hillsboro watershed consists of using the GWLF and BATHTUB models to address total phosphorus and manganese problems in Lake Glenn Shoals and Old Lake Hillsboro. Specifically, GWLF will be applied to calculate phosphorus loads to both of the lakes, over a time scale consistent with their nutrient residence times. BATHTUB will then be used to predict the relationship between phosphorus load and resulting in-lake phosphorus and dissolved oxygen concentrations. This relationship will be used to define the dominant sources of phosphorus to the lake, and the extent to which they must be controlled to attain water quality standards. It is assumed that the only controllable source of manganese to the lake 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. As noted in the second quarterly status report, the recommended modeling approach described above can be applied without collection of any additional data.

Data Collection Plan

Because no additional data collection is needed to support development and application of the recommended models, a data collection plan is not included as part of this third quarterly status report.

NEXT STEPS

In the upcoming month, the IEPA will confer with the Scientific Advisory Committee to discuss the work presented in the first three quarterly status reports. A public meeting will also be scheduled in the watershed to present the conclusions and recommendations of Stage 1 to local stakeholders and to obtain feedback on the work completed to date.

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Illinois Environmental Protection Agency, 2004. Final Draft Illinois Water Quality Report 2004 Illinois Environmental Protection Agency Bureau of Water. IEPA/BOW/04-006. May 2004

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Fourth Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

April 2005

Glenn Shoals/Hillsboro Watershed

Lake Glenn Shoals (ROL), Old Lake Hillsboro (ROT)

Limno-Tech, Inc.

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PUBLIC PARTICIPATION

Stage 1 of the Glenn Shoals/Hillsboro TMDL activities 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 Summer 2004 to initiate Stage 1. As quarterly progress reports were produced, the Agency posted them to their website.

In January 2005, a public meeting was announced for presentation of the Stage 1 findings. This announcement was mailed to everyone on the previous TMDL mailing list and published in local newspapers. The public meeting was held at 6:30 pm on Wednesday, March 2, 2005 at the University of Illinois Extension Office in Hillsboro, Illinois. In addition to the meeting's sponsors, fifteen (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 1 findings by Limno-Tech, Inc. (LTI). This was followed by a general question and answer session.

The Agency entertained questions and concerns from the public through April 2, 2005. At the meeting, discussion included several questions and comments with regard to private sewage disposal systems, TMDL implementation, and possible funding for water quality improvements in the watershed.

This is the fourth in a series of quarterly status reports documenting work completed on the Glenn Shoals/Hillsboro 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.

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FINAL APPROVED TMDL

Glenn Shoals/Hillsboro Watershed

Lake Glenn Shoals (ROL), Old Lake Hillsboro (ROT)

Prepared for Illinois Environmental Protection Agency

September 2005

Lake Glenn Shoals (ROL): Phosphorus

Old Lake Hillsboro (ROT): Phosphorus, Manganese

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EXECUTIVE SUMMARY

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 Illinois Environmental Protection Agency's (IEPA) 2004 303(d) list is available on the web at: http://www.epa.state.il.us/water/tmdl/303d-list.html. 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 (U.S. EPA, 1991).

Lake Glenn Shoals and Old Lake Hillsboro are listed on the 2004 Illinois Section 303(d) List of Impaired Waters (IEPA, 2004a) as water bodies that are not meeting their designated uses. As such, these lakes have been targeted as high priority waters for TMDL development. This document presents the TMDLs designed to allow these two lakes to fully support their designated uses. The report covers each step of the TMDL process and is organized as follows:

- Problem Identification
- Required TMDL Elements
- Watershed Characterization
- Description of Applicable Standards and Numeric Targets
- Development of Water Quality Model
- TMDL Development
- Public Participation and Involvement
- Adaptive Implementation Process

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1 PROBLEM IDENTIFICATION

The two impaired lakes addressed in this TMDL are listed below, with the parameters (causes) they are listed for, and the impairment status of each designated use, as identified in the 2004 303(d) list (IEPA, 2004a). TMDLs are currently only being developed for pollutants that have numerical water quality standards. Those causes that are the focus of this report are shown in bold font.

Lake Glenn Shoals	
Waterbody Segment	ROL
Size (Acres)	1,350
Listed For	**Phosphorus**, total suspended solids, excess algal growth
Use Support[1]	Overall use (F), Aquatic life (F), Fish consumption (F), Public water supply (F), Primary contact (P), Secondary contact (P)
Old Lake Hillsboro	
Waterbody Segment	ROT
Size (Acres)	108.7
Listed For	**Manganese, phosphorus,** total suspended solids, excess algal growth
Use Support[1]	Aquatic life (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)

[1]F=full support, P=partial support, N=nonsupport

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2 REQUIRED TMDL ELEMENTS

USEPA Region 5 guidance for TMDL development requires TMDLs to contain specific components. Each of those components is summarized here, by waterbody.

Lake Glenn Shoals

1. **Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking:** Lake Glenn Shoals, HUC 0714020302. The pollutant of concern addressed in this TMDL is phosphorus. Potential sources include agricultural sources, release from existing sediments under anoxic conditions, recreation activities, and failing private sewage disposal systems. Lake Glenn Shoals is ranked high priority on the 2004 Illinois EPA 303(d) list.
2. **Description of Applicable Water Quality Standards and Numeric Water Quality Target:** The water quality standard for phosphorus to protect aquatic life and secondary contact uses in Illinois lakes is 0.05 mg/l. For this TMDL, the numeric water quality target was set at the water quality criterion for total phosphorus of 0.05 mg-P/l.
3. **Loading Capacity – Linking Water Quality and Pollutant Sources:** The water quality model BATHTUB was applied to determine that the maximum phosphorus load that will maintain compliance with the phosphorus standard is an average load of 20.44 kg/day between April and August, with the total load not to exceed 3,127 kg over this period. This allowable load corresponds to an approximately 85% reduction from existing loads.
4. **Load Allocations (LA):** The load allocation given to non-point source loads from watershed sources is 17.3 kg/day for the period April - August.
5. **Wasteload Allocations (WLA):** The City of Irving is the sole NPDES permitted point source discharge in the watershed. Because the phosphorus load from this source is a small contributor to the overall existing phosphorus load, the WLA was set at estimated existing loading conditions of 1.1 kg/day.
6. **Margin of Safety:** The TMDL contains an explicit margin of safety corresponding to 10% of the loading capacity, or 2.04 kg/day. This value was set to reflect the uncertainty in the BATHTUB model predictions.
7. **Seasonal Variation:** The TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate seasonal to annual loads. The seasonal loading analysis that was used is appropriate due to the long response time between phosphorus loading and biotic response. The April-August duration for the seasonal loading was determined based on a calculation of phosphorus residence time in Lake Glenn Shoals of two weeks to a month.

Loads entering the lake in the fall through early spring period do not directly affect summer phosphorus concentrations, and therefore were excluded from the TMDL analysis.

8. **Reasonable Assurances:** In terms of reasonable assurances for point sources, Illinois EPA has the NPDES permitting program for treatment plants, stormwater permitting and CAFO permitting. The permit for the only point source discharger in the watershed (Irving WWTP) will be modified if necessary to ensure it is consistent with the applicable wasteload allocation.

   In terms of reasonable assurances for nonpoint sources, Illinois EPA is committed to:
   - Convene local experts familiar with nonpoint sources of pollution in the watershed
   - Ensure that they define priority sources and identify restoration alternatives
   - Develop a voluntary implementation plan that includes accountability.

   Local agencies and institutions with an interest in watershed management will be important for successful implementation of this TMDL. Detail on watershed activities is provided in the Stage 1 Report.

9. **Monitoring Plan to Track TMDL Effectiveness:** The implementation plan will include a monitoring plan to track effectiveness.

10. **Transmittal Letter:** A transmittal letter was prepared and accompanied the TMDL submitted to US EPA Region V.

11. **Public Participation:** Numerous opportunities were provided for local watershed institutions and the general public to be involved. The Agency and its consultant met with local municipalities and agencies in summer 2004 to gather and share information and initiate the TMDL process. A number of phone calls were made to identify and acquire data and information (See Appendix A in the Stage 1 Report - First Quarterly Progress Report). Two public meetings were conducted in Hillsboro, Illinois and one additional meeting will be held to present the implementation plan.

Old Lake Hillsboro

1. **Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking:** Old Lake Hillsboro, HUC 0714020302. The pollutants of concern addressed in this TMDL are phosphorus and manganese. Potential sources of phosphorus include agricultural sources, release from existing sediments under anoxic conditions, recreation

activities, and failing private sewage disposal systems. Sources of manganese are background sources due to naturally high concentrations in area soils, and release from existing sediments under anoxic conditions. Old Lake Hillsboro is ranked high priority on the 2004 Illinois EPA 303(d) list.

2. **Description of Applicable Water Quality Standards and Numeric Water Quality Target:** The water quality standard for **phosphorus** to protect aquatic life and secondary contact uses in Illinois lakes is 0.05 mg-P/l. For the Old Lake Hillsboro phosphorus TMDL, the numeric water quality target was set at the water quality criterion for total phosphorus of 0.05 mg-P/l.

   The water quality standard for **manganese** in Illinois waters designated as public water supply is 150 ug/l, and the general use standard is 1,000 ug/l. The primary source of manganese to the lake is the release of manganese from lake sediments during periods when there is no dissolved oxygen in lake bottom waters. The lack of dissolved oxygen in lake bottom waters is presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding materials to the lake. For this reason, release from lake sediments is considered a controllable source and attainment of the total phosphorus standard is expected to result in oxygen concentrations that will reduce sediment manganese flux to natural background levels. The TMDL target for manganese is therefore set as a total phosphorus concentration of 0.050 mg-P/l.

3. **Loading Capacity – Linking Water Quality and Pollutant Sources:** The water quality model BATHTUB was applied to determine that the maximum phosphorus load that will maintain compliance with the phosphorus standard is an average of 0.88 kg/day between April and August, with the total load not to exceed 134 kg over this period. This allowable load corresponds to an approximately 83% reduction from existing loads.

4. **Load Allocations (LA):** The load allocation given to non-point source loads from watershed sources is 0.79 kg/day between April and August.

5. **Wasteload Allocations (WLA):** No point sources of phosphorus exist in the Old Lake Hillsboro watershed, and the wasteload allocation for this TMDL is zero.

6. **Margin of Safety:** The TMDL contains an explicit margin of safety corresponding to 10% of the loading capacity, or 0.088 kg/day. This value was set to reflect the uncertainty in the BATHTUB model predictions.

7. **Seasonal Variation:** The TMDL was conducted with an explicit consideration of seasonal variation. The BATHTUB model used for this TMDL is designed to evaluate seasonal to annual loads. The seasonal loading analysis that was used is appropriate due to the long response time

between phosphorus loading and biotic response. The April-August duration for the seasonal loading was determined based on a calculation of phosphorus residence time in Old Lake Hillsboro that ranged between two weeks and two months. Loads entering the lake in the fall through early spring period do not directly affect summer phosphorus concentrations, and therefore were excluded from the TMDL analysis.

8. **Reasonable Assurances:** There are no permitted point sources in the Old Lake Hillsboro watershed, so reasonable assurances for point sources are not discussed. In terms of reasonable assurances for nonpoint sources, Illinois EPA is committed to:

   - Convene local experts familiar with nonpoint sources of pollution in the watershed
   - Ensure that they define priority sources and identify restoration alternatives
   - Develop a voluntary implementation plan that includes accountability.

   Local agencies and institutions with an interest in watershed management will be important for successful implementation of this TMDL. Detail on watershed activities is provided in the Stage 1 Report.

9. **Monitoring Plan to Track TMDL Effectiveness:** The implementation plan will include a monitoring plan to track effectiveness.

10. **Transmittal Letter:** A transmittal letter was prepared and accompanied the TMDL submitted to US EPA Region V.

11. **Public Participation:** Numerous opportunities were provided for local watershed institutions and the general public to be involved. The Agency and its consultant met with local municipalities and agencies in summer 2004 to gather and share information and initiate the TMDL process. A number of phone calls were made to identify and acquire data and information (See Stage 1 Report, Appendix A of the First Quarterly Progress Report). Two public meetings were conducted in Hillsboro, Illinois and one additional meeting will be held to present the implementation plan.

3 WATERSHED CHARACTERIZATION

The Stage 1 Report previously describes the Lake Glenn Shoals and Old Lake Hillsboro watersheds, to support the identification of sources contributing to manganese and total phosphorus impairments as applicable. The Stage 1 report was divided into four sections, called Quarterly Progress Reports; and the watershed characterization is discussed in the First Quarterly Progress Report. Watershed characterization activities were focused on gaining an understanding of key features of the watersheds, including geology and soils, climate, land cover, hydrology, urbanization and population growth, point source discharges and watershed activities.

The Glenn Shoals/Hillsboro watershed is located in Central Illinois, approximately 40 miles south of Springfield and 60 miles northeast of St. Louis. Lake Glenn Shoals is a 1,350-acre impoundment constructed in the 1970s for flood control, water supply, and recreational uses. It has an average depth of 10 feet, and nearly 27 miles of shoreline (City of Hillsboro, 2004). Lake Hillsboro, often referred to as the "Old Lake," was created in 1918 (City of Hillsboro, 2004) and served as the primary water supply for the area until construction of Lake Glenn Shoals. Currently, both lakes are used as water supply for the City of Hillsboro and several neighboring communities. Lake Hillsboro has a surface area of approximately 110 acres. The combined drainage area for the two lakes covers 53,039 acres (83 square miles), primarily in Montgomery County. A very small portion of the watershed lies in Christian County.

Figure 3.1 shows a map of the watershed, and includes waterways, impaired waterbodies, public water intakes, roads, and other key features. The map also shows the location of a point source discharge that has a permit to discharge under the National Permit Discharge Elimination System (NPDES). The City of Irving is the sole NPDES discharge in the watershed.

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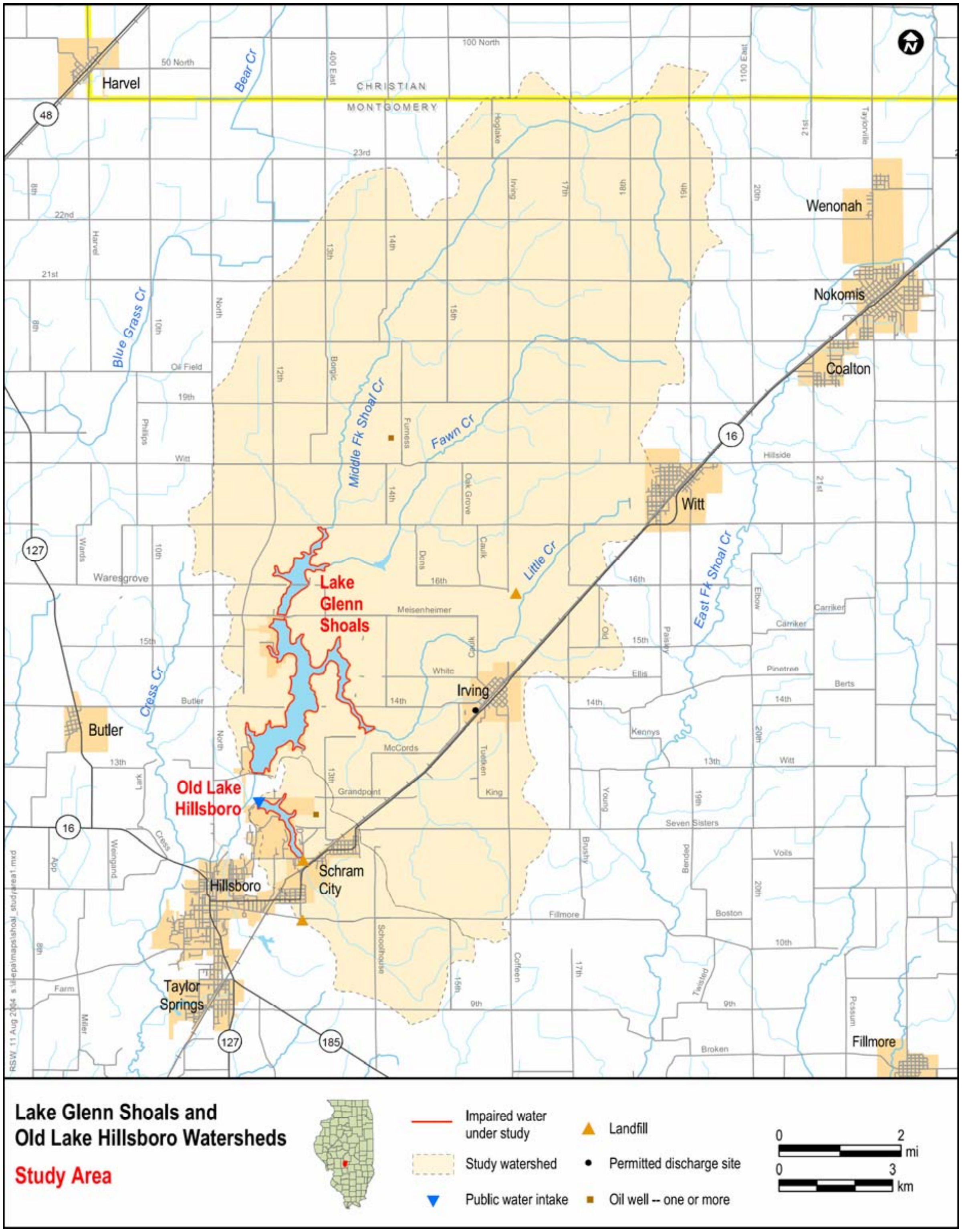

Figure 3.1 Base Map of Lake Glenn Shoals and Old Lake Hillsboro Watersheds

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4 DESCRIPTION OF APPLICABLE STANDARDS AND NUMERIC TARGETS

A water quality standard includes the designated uses of the waterbody, water quality criteria to protect designated uses, and an antidegradation policy to maintain and protect existing uses and high quality waters. This section discusses the applicable designated uses, use support, and criteria for Lake Glenn Shoals and Old Lake Hillsboro.

4.1 Designated Uses and Use Support

Illinois EPA conducts its assessment of water bodies using a set of five generic designated use categories: public water supply, aquatic life, primary contact (swimming), secondary contact (recreation), and fish consumption (IEPA, 2004b). 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. For each water body, and for each designated use applicable to the water body, Illinois EPA's assessment concludes one of three possible "use-support" levels:

- Fully supporting (the water body attains the designated use);
- Partially supporting (the water body attains the designated use at a reduced level); or
- Not supporting (the water body does not attain the designated use).

All water bodies assessed as partial or nonsupport attainment for 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.

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, 2004a).

4.2 Water Quality Criteria

Illinois has established water quality criteria and guidelines for allowable concentrations of manganese and total phosphorus under its CWA Section 305(b) program, as summarized below. A comparison of available water quality data to these criteria is provided in the Stage 1 Report.

4.2.1 Total Phosphorus

The IEPA guidelines (IEPA, 2004b) for identifying total phosphorus as a cause in lakes (for lakes $\geq$ 20 acres) state that the aquatic life use and the secondary contact use are not supported if the surface phosphorus concentration exceeds the applicable standard (0.05 mg/l) in at least one sample during the monitoring year. The available data support the listing of phosphorus as a cause of impairment in Lake Glenn Shoals and Old Lake Hillsboro.

4.2.2 Manganese

The water quality standard for manganese in Illinois waters designated as public water supply is 150 ug/l, and the general use standard is 1000 ug/l. The IEPA guidelines (IEPA, 2004b) for identifying manganese as a cause in lakes state that the aquatic life use is not supported if there is at least one exceedance of the applicable standard. The guidelines also state that the public water supply use is not supported if, in untreated water, greater than 10% of the observations exceed the applicable standard, for water samples collected in 1999 or later, and for which results are readily available. The available data confirm that the listing of Old Lake Hillsboro for manganese is appropriate based on IEPA’s guidelines.

4.3 Development of TMDL Targets

The TMDL target is a numeric endpoint specified to represent the level of acceptable water quality that is to be achieved by implementing the TMDL. Where possible, the water quality criterion for the pollutant of concern is used as the numeric endpoint. When appropriate numeric standards do not exist, surrogate parameters must be selected to represent the designated use. As discussed below, a surrogate parameter (total phosphorus concentration) is selected as the TMDL target for manganese. The linkage between the TMDL target (phosphorus) and manganese is explained as follows. Phosphorus loadings to lakes can stimulate excess algal growth, and when the algae die and decompose, they then settle to the lake bottom where they contribute to low dissolved oxygen levels and anoxic conditions at depth. Under anoxic conditions, manganese is released from the lake sediments.

For the Lake Glenn Shoals and Old Lake Hillsboro phosphorus TMDLs, the target is set at the water quality criterion for total phosphorus of 0.05 mg-P/l. For the Old Lake Hillsboro manganese TMDL, the target is maintenance of hypolimnetic dissolved oxygen concentrations above zero. The primary source of manganese to the lake is the release of manganese from lake sediments during periods when there is no dissolved oxygen in lake bottom waters. The lack of dissolved oxygen in lake bottom waters is presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding materials to the lake. For this reason, release from lake sediments is considered a controllable source, and attainment of the total phosphorus standard is expected to result in oxygen concentrations that will reduce sediment manganese flux to natural background levels. The TMDL target is for manganese is therefore also set as a total phosphorus concentration of 0.050 mg-P/l.

5 DEVELOPMENT OF WATER QUALITY MODEL

The BATHTUB water quality model was used to define the relationship between external phosphorus loads and the resulting concentrations of total phosphorus and manganese in the lakes. The following sections:

- summarize the model selection process,
- provide an overview of the BATHTUB model,
- present the model inputs used in BATHTUB, and
- describe the model application and comparison of model output to data.

5.1 Model Selection

A detailed discussion of the model selection process for the Lake Glenn Shoals and Old Lake Hillsboro watersheds is provided in the Second Quarterly Progress Report in the Stage 1 Report. Of the models discussed, the BATHTUB model (Walker, 1986) was selected for application to both lakes.

The BATHTUB model was selected for both lakes to estimate the loading capacity of the lakes. The model was used to predict the relationship between phosphorus load and resulting in-lake phosphorus for both lakes, as well as the resulting potential for manganese release from sediments in Old Lake Hillsboro. 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. BATHTUB has been used previously for several reservoir TMDLs in Illinois, and has been cited as an effective tool for lake and reservoir water quality assessment and management, particularly where data are limited (Ernst et al., 1994).

The BATHTUB model does not directly model manganese concentrations, but it is still appropriate for TMDL application. The only controllable source of manganese to Old Lake Hillsboro is that which enters from lake sediments during periods of no dissolved oxygen in lake bottom waters. This source of manganese can be controlled by reducing phosphorus loads to the lake, which will reduce algal growth and increase hypolimnetic dissolved oxygen concentrations.

5.1.1 Selected Modeling Approach

This approach to be taken for this TMDL is based upon discussions with IEPA and the Scientific Advisory Committee. The approach consists of using existing empirical data to define current loads to the lakes, and using the BATHTUB model to define the extent to which these loads must be reduced to meet water quality standards. This approach corresponds to Alternative 1 in the detailed discussion of the model selection process provided in the Stage 1 Report. This approach was taken because phosphorus concentrations in both lakes exceed the water quality standard by a factor of 7. This indicates that phosphorus loads will need to be reduced to a small fraction of existing loads in order to attain water quality standards. The dominant land use in both watersheds is agriculture. This level of load reduction is likely not attainable in the near future, if at all. Implementation plans for agricultural sources will require voluntary controls, applied on an incremental basis. The approach taken for these TMDLs, which requires no additional data collection and can be conducted immediately, will expedite these implementation efforts.

Determination of existing loading sources and prioritization of restoration alternatives will be conducted by local experts as part of the implementation process (see Section 8). Based upon their recommendations, a voluntary implementation plan will be developed that includes both accountability and the potential for adaptive management.

5.2 Model Overview

BATHTUB is a software program for predicting the lake/reservoir response to nutrient loading. 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 empirical 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). Both tabular and graphical displays are available from the program.

5.3 BATHTUB Model Inputs

This section gives an overview of the model inputs required for BATHTUB application, and how they were derived. The following categories of inputs are required for BATHTUB:

- Model Options
- Global Variables
- Reservoir Segmentation
- Tributary Loads

5.3.1 Model Options

BATHTUB provides a multitude of model options to estimate nutrient concentrations in a reservoir. Model options were entered as shown in Table 5-1 for Lake Glenn Shoals and Table 5-2 for Old Lake Hillsboro, with the rationale for these options discussed below. No conservative substance was being simulated for either lake, so this option was not needed. The second order available phosphorus option was selected for phosphorus in both lakes, as it is the default option for BATHTUB. Nitrogen was not simulated in either lake, because phosphorus is the nutrient of concern.

Chlorophyll a and transparency were not simulated for either lake. The Fischer numeric dispersion model was selected for both lakes, which is the default approach in BATHTUB for defining mixing between lake segments. Phosphorus calibrations were based on lake concentrations for both lakes. No nitrogen calibration was required. The use of availability factors was not required for either lake, and estimated concentrations were used to generate mass balance tables for both lakes.

Table 5-1. BATHTUB Model Options for Lake Glenn Shoals

MODEL	MODEL OPTION
Conservative substance	Not computed
Total phosphorus	2nd order, available phosphorus
Total nitrogen	Not computed
Chlorophyll-a	Not computed
Transparency	Not computed
Longitudinal dispersion	Fischer-numeric
Phosphorus calibration	Concentrations
Nitrogen calibration	None
Error analysis	Not computed
Availability factors	Ignored
Mass-balance tables	Use estimated concentrations

Table 5-2. BATHTUB Model Options for Old Lake Hillsboro

MODEL	MODEL OPTION
Conservative substance	Not computed
Total phosphorus	2nd order, available phosphorus
Total nitrogen	Not computed
Chlorophyll-a	Not computed
Transparency	Not computed
Longitudinal dispersion	Fischer-numeric
Phosphorus calibration	Concentrations
Nitrogen calibration	None
Error analysis	Not computed
Availability factors	Ignored
Mass-balance tables	Use estimated concentrations

5.3.2 Global Variables

The global variables required by BATHTUB consist of:

- The averaging period for the analysis
- Precipitation, evaporation, and change in lake levels
- Atmospheric phosphorus loads

BATHTUB is a steady state model, whose predictions represent concentrations averaged over a period of time. A key decision in the application of BATHTUB is the selection of length of time over which inputs and outputs should be modeled. The length of the appropriate averaging period for BATHTUB application depends upon what is called the nutrient residence time, i.e. the average length of time that phosphorus spends in the water column before settling or flushing out of the lake. Guidance for the BATHTUB model recommends that the averaging period used for the analysis be at least twice as large as nutrient residence time for the lake of interest. For lakes with a nutrient residence time on the order of 1 to 3 months, a seasonal (e.g. spring-summer) averaging period is recommended. Nutrient residence times in both lakes under current conditions are approximately two weeks to two months. The nutrient residence time will increase as nutrient loads are reduced to allowable levels for meeting the TMDL target. Therefore, the averaging period used in the model needs to account for both scenarios. For these lakes, a seasonal period of April-August was used as the averaging period.

Precipitation inputs were taken from the observed long term annual average precipitation data and scaled for the April-August simulation period. This resulted in precipitation values of 16.7 inches for both lakes. Evaporation was set equal to precipitation and there was no assumed increase in storage during the modeling period for either lake, to represent steady state conditions. The values selected for precipitation and change in lake levels have little influence on model predictions. Atmospheric phosphorus loads were specified using default values provided by BATHTUB.

5.3.3 Reservoir Segmentation

BATHTUB provides the capability to divide the reservoir under study into a number of individual segments, allowing prediction of the change in phosphorus concentrations over the length of each reservoir. The segmentation schemes selected for Lake Glenn Shoals and Old Lake Hillsboro were designed to provide one segment for each of the primary lake sampling stations. Lake Glenn Shoals and Old Lake Hillsboro were each divided into three segments as shown in Figures 5.1 and 5.2. The areas of segments and watersheds for each segment were determined by Geographic Information System (GIS).

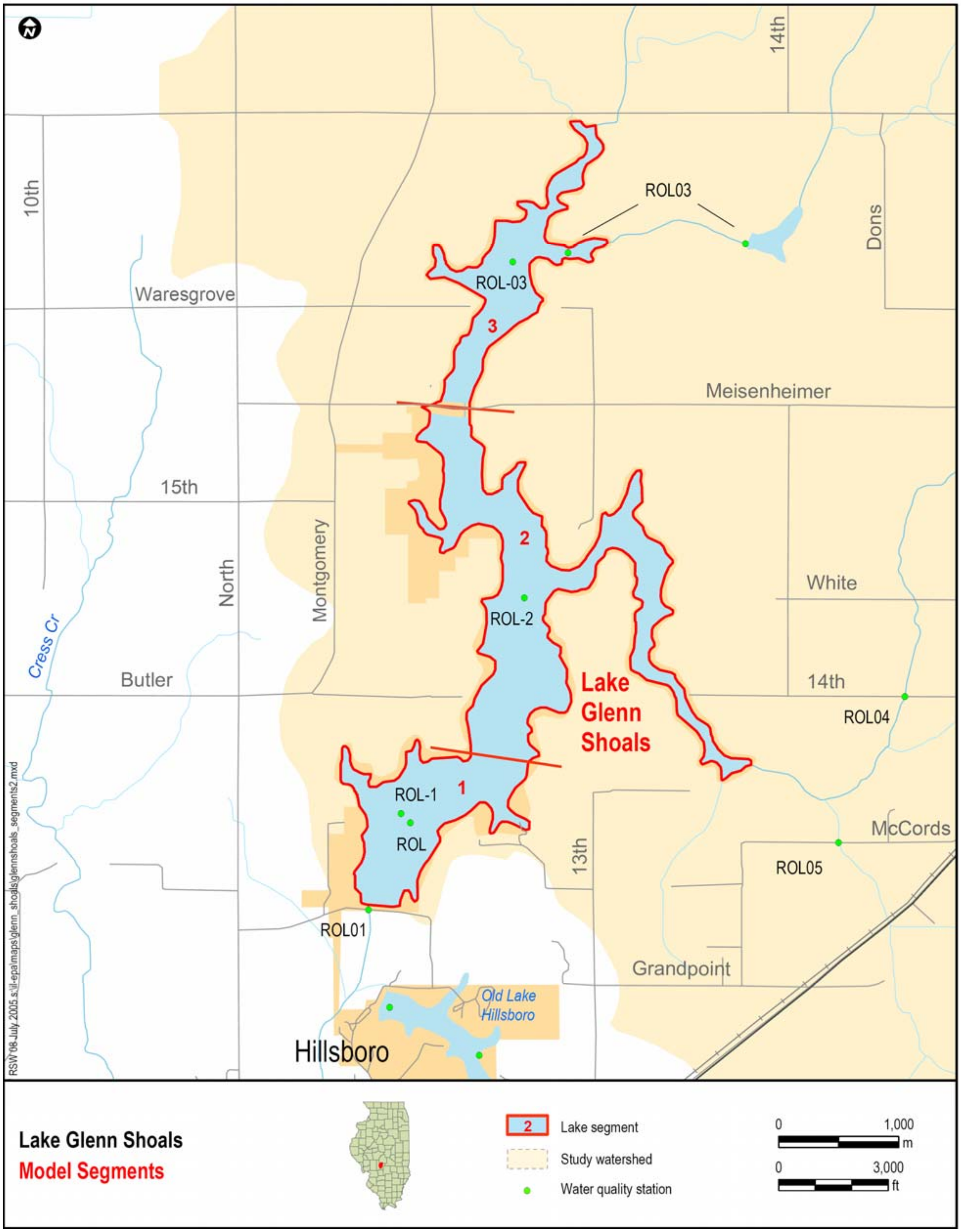

Figure 5.1 Lake Glenn Shoals Segmentation Used in BATHTUB

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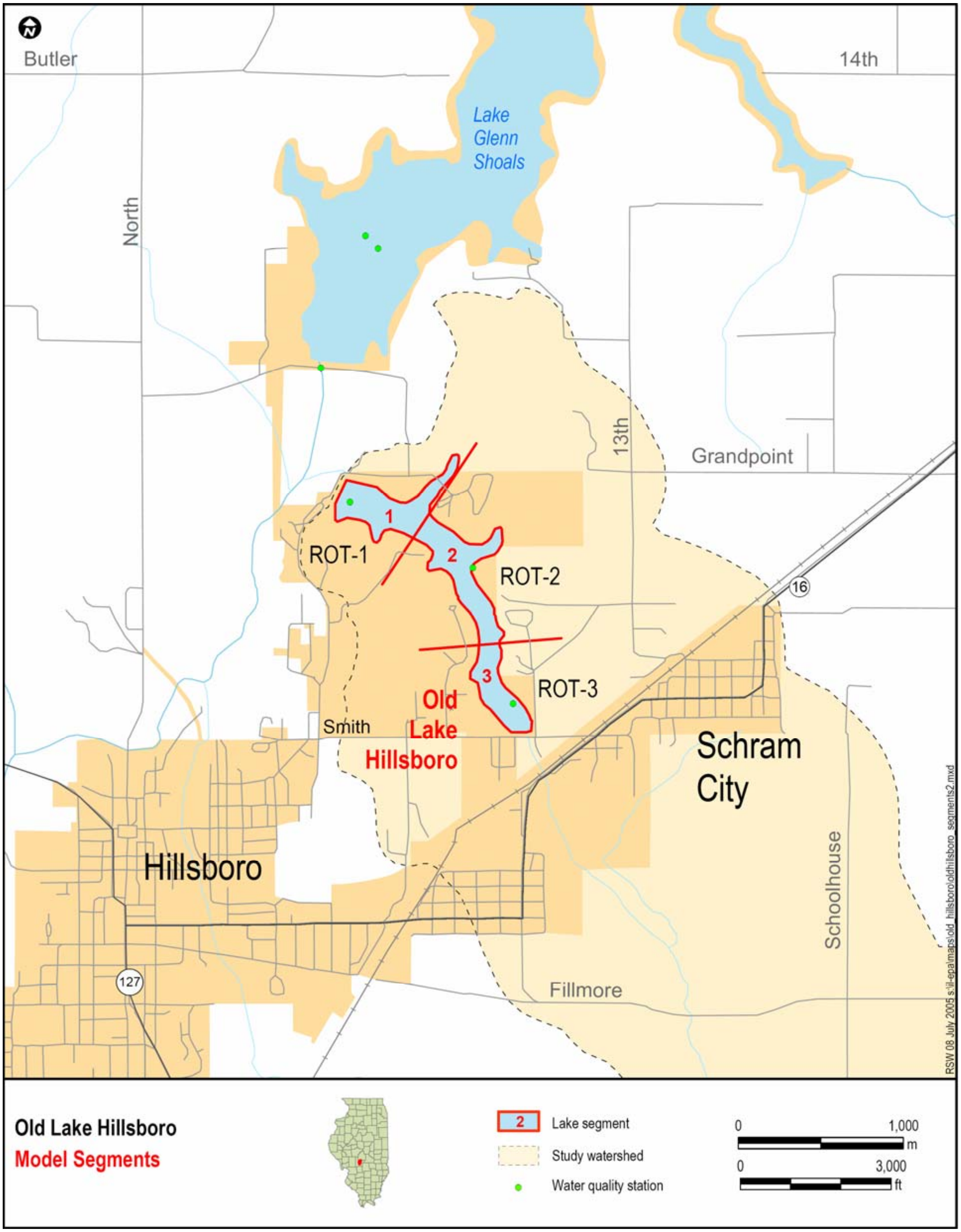

Figure 5.2 Old Lake Hillsboro Segmentation Used in BATHTUB

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BATHTUB requires that a range of inputs be specified for each segment. These include segment surface area, length, total water depth, and depth of thermocline and mixed layer. Segment-specific values for segment depths (total, thermocline and mixed layer) were calculated from the lake monitoring data, while segment lengths and surface areas were calculated via GIS. A complete listing of all segment-specific inputs is provided in Attachment 1.

5.3.4 Tributary Loads

BATHTUB requires tributary flow and nutrient concentrations for each reservoir segment. Flows to each segment were estimated using observed flows at the USGS gaging station at East Fork Shoal Creek (05593900), adjusted through the use of drainage area ratios as follows:

Flow into segment = Flow at USGS gage * Segment-specific drainage area ratio

$$\text{Drainage area ratio} = \frac{\text{Drainage area of watershed contributing to model segment}}{\text{Drainage area of watershed contributing to USGS gage}}$$

Segment-specific drainage area ratios were calculated via GIS information.

Total phosphorus concentrations for each major lake tributary were based upon springtime measurements taken near the headwaters of each lake. Concentrations for small tributaries were set equal to the assumed concentration for the major tributary. A complete listing of all segment-specific flows and tributary concentrations is provided in Attachment 1.

5.4 BATHTUB Calibration

BATHTUB model calibration consists of:

1. Applying the model with all inputs specified as above
2. Comparing model results to observed phosphorus data
3. Adjusting model coefficients to provide the best comparison between model predictions and observed phosphorus data.

Separate discussions of the BATHTUB model calibration for Lake Glenn Shoals and Old Lake Hillsboro are provided below.

5.4.1 Lake Glenn Shoals

The BATHTUB model was initially applied with the model inputs as specified above. Observed data for the year 2001 were used for calibration purposes, as this year provided the most robust data set. The August observed lake data were used for calibration, as these data best reflect the steady state conditions assumed for the BATHTUB model.

BATHTUB was first calibrated to match the observed reservoir-average phosphorus concentrations. The default calibration coefficients in BATHTUB provided an acceptable fit to the observed data in segments 1 (most downstream segment) and 2 (middle of the lake), and no additional calibration activities were required. Model results in segment 3 (northern-most portion of the lake) initially under-predicted the observed phosphorus data. Phosphorus loss rates in BATHTUB reflect a typical "net settling rate" (i.e. settling minus sediment release) observed in a range of reservoirs. Under-prediction of observed phosphorus concentrations can occur in cases of elevated phosphorus release from lake sediments. The mismatch between model and data was corrected via the addition of an internal phosphorus load of 100 mg/m^2/day in the near-dam segment. The resulting predicted lake average total phosphorus concentration was 187 ug/l, compared to an observed average of 186 ug/l. A complete listing of all the observed data used for calibration purposes, as well as a comparison between model predictions and observed data, is provided in Attachment 1.

5.4.2 Old Lake Hillsboro

The BATHTUB model was initially applied with the model inputs as specified above. Observed data for the year 2001 were used for calibration purposes, as this year provided the most robust data set. The August observed lake data were used for calibration, as these data best reflect the steady state conditions assumed for the BATHTUB model.

BATHTUB was calibrated to match the observed reservoir-average total phosphorus concentrations. An internal sediment phosphorus load of 60 mg/m^2/day was used in all three model segments to provide the best comparison between model predictions and observed data. The resulting predicted lake average total phosphorus concentration was 296 ug/l, compared to an observed average of 297 ug/l.

A complete listing of all the observed data used for calibration purposes, as well as a comparison between model predictions and observed data, is provided in Attachment 1.

6 TMDL DEVELOPMENT

This section presents the development of the total maximum daily load for both Lake Glenn Shoals and Old Lake Hillsboro. It begins with a description of how the total loading capacity was calculated for each lake, and then describes how the loading capacity is allocated among point sources, non-point sources, and the margin of safety. A discussion of critical conditions and seasonality considerations is also provided.

6.1 Calculation of Loading Capacity

The loading capacity is defined as the maximum pollutant load that a waterbody can receive and still maintain compliance with water quality standards. The loading capacity of each lake was determined by running the BATHTUB model repeatedly, reducing the tributary nutrient concentrations for each simulation until model results demonstrated attainment of the water quality objective. The maximum tributary concentration that results in compliance with water quality standards was used as the basis for determining each lake's loading capacity. The tributary concentration was then converted into a loading rate through multiplication with the tributary flow.

6.1.1 Lake Glenn Shoals

Initial BATHTUB load reduction simulations indicated that Lake Glenn Shoals phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional sediment phosphorus source for all future scenarios where tributary phosphorus loads averaged 100 ug/l or less. The resulting total allowable load was an average of 20.44 kg/day over the April to August period, with the total load over this period not to exceed 3,127 kg. This allowable load corresponds to an approximately 85% reduction from existing loads (estimated as 20,715 over the April to August period).

6.1.2 Old Lake Hillsboro

Initial BATHTUB load reduction simulations indicated that Old Lake Hillsboro phosphorus concentrations would exceed the water quality standard regardless of the level of tributary load reduction, due to the elevated internal phosphorus loads from lake sediments. This internal phosphorus flux is expected to decrease in the future in response to external phosphorus load reductions, reverting back to more typical conditions. This reduction in future sediment phosphorus release was represented in the model by eliminating the additional sediment phosphorus source for all future scenarios where tributary phosphorus loads averaged 100 ug/l or less. The resulting total allowable load was an average of 0.88 kg/day over the April to August period, with the total load over this period not to exceed 134 kg. This allowable load corresponds to an approximately 83% reduction from existing loads (estimated as 789 kg over the April to August period.

6.2 Allocation

6.2.1 Lake Glenn Shoals

The City of Irving is the sole NPDES permitted point source discharge in the Lake Glenn Shoals watershed. Current phosphorus loads from this plant are estimated to be at 1.1 kg/day, based on the permitted flow rate (0.075 MGD) and an assumed lagoon effluent phosphorus concentration of 4 mg/l. This load can be considered an insignificant component of the overall load to the lake, such that reduction of this load will not appreciably benefit the TMDL. The wasteload allocation for the City of Irving NPDES permit is set at its current loading rate of 1.1 kg/day. The remainder of the loading capacity is given to the load allocation for nonpoint sources and the margin of safety. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load. Given a loading capacity of 20.44 kg/day, and an explicit margin of safety of 10% (discussed below in Section 6.4), this results in a load allocation for Lake Glenn Shoals of 17.3 kg/day.

6.2.2 Old Lake Hillsboro

No point sources of phosphorus exist in the Old Lake Hillsboro watershed. The wasteload allocation for this TMDL is set at zero. The remainder of the loading capacity is allocated to non-point sources and the margin of safety. Given a 10% margin of safety (discussed below), this corresponds to load allocation of 0.79 kg/day. The loading capacity is not divided into individual source categories for purposes of this TMDL, as it is the intent of the implementation plan to provide detail on the contributions of specific sources to the overall phosphorus load.

6.3 Critical condition

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events can transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. This TMDL is based upon a seasonal period that takes into account both spring loads and summer water quality in order to effectively consider these critical conditions.

6.4 Seasonality

These TMDLs were conducted with an explicit consideration of seasonal variation. The BATHTUB model used for these TMDLs is designed to evaluate loads over a seasonal to annual averaging period. Model results indicate that the average phosphorus residence time in Lake Glen Shoals and Old Lake Hillsboro is on the order of two weeks to two months. Loads entering the lake in the fall through early spring period do not directly affect summer phosphorus concentrations, and therefore were excluded from the TMDL analysis.

6.5 Margin of Safety

The TMDL contains an explicit margin of safety of 10%. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the BATHTUB water quality model predicted values and the observed values. Since the model reasonably reflects the conditions in the watershed, a 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. This margin of safety can be reviewed in the future as new data are developed. The resulting explicit load allocated to the margin of safety is 2.04 kg/day for Lake Glenn Shoals and 0.088 kg/day for Old Lake Hillsboro.

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7 PUBLIC PARTICIPATION AND INVOLVEMENT

The TMDL process included numerous opportunities for local watershed institutions and the general public to be involved. The Agency and its consultant met with local municipalities and agencies in Summer 2004 to notify stakeholders about the upcoming TMDLs, and initiate the TMDL process. A number of phone calls were made to identify and acquire data and information. (see Stage 1 Report, Appendix A to the First Quarterly Progress Report). As quarterly progress reports were produced during the first stage of the TMDL process, the Agency posted them to their website for public review. In addition, a public meeting was conducted in Hillsboro, Illinois on March 2, 2005, to present the findings of the Stage 1 TMDL work. A second public meeting was conducted on August 9 to present the draft TMDL. A third public meeting will be held at a later date to present the implementation plan.

7.1 Summary of March 2, 2005 Public Meeting

In January 2005, a public meeting was announced for presentation of the Stage 1 findings. This announcement was mailed to everyone on the previous TMDL mailing list and published in local newspapers. The public meeting was held at 6:30 pm on Wednesday, March 2, 2005 at the University of Illinois Extension Office in Hillsboro, Illinois. In addition to the meeting's sponsors, fifteen (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 1 findings by Limno-Tech, Inc. (LTI). This was followed by a general question and answer session.

At the meeting, discussion included several questions and comments with regard to private sewage disposal systems, TMDL implementation, and possible funding for water quality improvements in the watershed. The Agency entertained questions and concerns from the public through April 2, 2005.

7.2 Summary of August 9, 2005 Public Meeting

In July 2005, a public meeting was announced for presentation of the draft TMDL. This announcement was mailed to everyone on the previous TMDL mailing list and published in local newspapers. The public meeting was held at 6:30 pm on Tuesday, August 9, 2005 at the University of Illinois Extension Office in Hillsboro, Illinois. In addition to the meeting's sponsors, ten (10) individuals attended the meeting. Attendees registered and listened to a 20-minute presentation on the draft phosphorus TMDLs for Lake Glenn Shoals and Old Lake Hillsboro and the draft manganese TMDL for Old Lake Hillsboro by Limno-Tech, Inc. (LTI). This was followed by a general question and answer session.

Much of the discussion focused on the phosphorus impairment and eutrophication, including trends in agricultural practices and what might happen if no action is taken. In addition, several ideas related to implementation, such as prospects for reducing siltation and alternative strategies for agricultural funding at the Federal level, were raised. Potential sources of implementation funding were also discussed. The Agency entertained questions and concerns from the public through midnight on August 24, 2005. A responsiveness summary is included in Attachment 2, which addresses substantive questions and comments received during the public comment period.

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8 ADAPTIVE IMPLEMENTATION PROCESS

This approach to be taken for TMDL implementation is based upon discussions with Illinois EPA and its Scientific Advisory Committee. The approach consists of the following steps:

1. Use existing data to define overall existing pollutant loads, as opposed to developing a watershed model that might define individual loading sources.
2. Apply relatively simple models (e.g. BATHTUB) to define the load-response relationship and define the maximum allowable pollutant load that the lakes can assimilate and still attain water quality standards
3. Compare the maximum allowable load to the existing load to define the extent to which existing loads must be reduced in order to meet water quality standards
4. Convene local experts to prioritize pollutant sources and identify restoration alternatives.
5. Based upon the results of step 4, develop a voluntary implementation plan that includes both accountability and the potential for adaptive management. Adaptive management will be conducted through the implementation of a long-term monitoring plan designed to assess the effectiveness of pollution controls as they are implemented, as well as progress towards attaining water quality standards.

This approach is designed to accelerate the pace at which TMDLs are being developed for sites dominated by nonpoint sources, which will allow implementation activities (and water quality improvement) to begin sooner. The approach also places decisions on the types of nonpoint source controls to be implemented at the local level, which will allow those with the best local knowledge to prioritize sources and identify restoration alternatives. Finally, the adaptive management approach to be followed recognizes that models used for decision-making are approximations, and that there is never enough data to completely remove uncertainty. The adaptive process allows decision-makers to proceed with initial decisions based on modeling, and then to update these decisions as experience and knowledge improve.

Steps 1-3 have been completed, as described in Section 5 of this document. Upon receipt of public comments and approval of the TMDL, Illinois EPA will conduct steps 4 and 5.

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ATTACHMENT 1

Glenn Shoals Lake

Variable = TOTAL P MG/M3 **R^2 = 0.12**
Global Calibration Factor = 1.00 CV = 0.45

Seg	Group	Name	Calibration Factor Mean	Calibration Factor CV	Predicted Mean	Predicted CV	Observed Mean	Observed CV	Log (Obs/Pred) Mean	Log (Obs/Pred) SE	Log (Obs/Pred) t
1	1	Segment 1	1.00	0.00	233.3	0.00	202.0	0.85	-0.14	0.85	-0.17
2	1	Segment 2	1.00	0.00	168.7	0.00	126.0	0.00	-0.29	0.00	0.00
3	1	Segment 3	1.00	0.00	186.6	0.00	299.0	0.00	0.47	0.00	0.00
4	1	Area-Wtd Mean			186.8	0.00	186.1	0.19	0.00	0.19	-0.02

Variable = CHL-A MG/M3 **R^2 = 0.93**
Global Calibration Factor = 1.00 CV = 0.26

Seg	Group	Name	Calibration Factor Mean	Calibration Factor CV	Predicted Mean	Predicted CV	Observed Mean	Observed CV	Log (Obs/Pred) Mean	Log (Obs/Pred) SE	Log (Obs/Pred) t
1	1	Segment 1	1.00	0.00	79.4	0.00	89.0	0.00	0.11	0.00	0.00
2	1	Segment 2	1.00	0.00	37.2	0.00	39.0	0.00	0.05	0.00	0.00
3	1	Segment 3	1.00	0.00	37.3	0.00	32.0	0.00	-0.15	0.00	0.00
4	1	Area-Wtd Mean			46.1	0.00	47.7	0.00	0.03	0.00	0.00

Glenn Shoals Lake

T Statistics Compare Observed and Predicted Means Using the Following Error Terms:
1 = Observed Water Quality Error Only
2 = Error Typical of Model Development Dataset
3 = Observed & Predicted Error

Segment:	**Area-Wtd Mean**							
	Observed		**Predicted**		**Obs/Pred**	**T-Statistics ---->**		
Variable	**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P MG/M3	186.1	0.19	186.8	0.00	1.00	-0.02	-0.02	
CHL-A MG/M3	47.7	0.00	46.1	0.00	1.04		0.10	
SECCHI M	0.4	0.00	0.4	0.00	1.00		0.01	
ANTILOG PC-1	3561.8	0.00	3335.2	0.00	1.07		0.19	
ANTILOG PC-2	8.4	0.00	8.4	0.00	1.00		0.00	

Segment:	**1**	**Segment 1**						
	Observed		**Predicted**		**Obs/Pred**	**T-Statistics ---->**		
Variable	**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P MG/M3	202.0	0.85	233.3	0.00	0.87	-0.17	-0.53	
CHL-A MG/M3	89.0	0.00	79.4	0.00	1.12		0.33	
SECCHI M	0.2	0.00	0.2	0.00	0.99		-0.03	
ANTILOG PC-1	9913.9	0.00	8820.1	0.00	1.12		0.33	
ANTILOG PC-2	7.6	0.00	7.1	0.00	1.07		0.23	

Segment:	**2**	**Segment 2**						
	Observed		**Predicted**		**Obs/Pred**	**T-Statistics ---->**		
Variable	**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P MG/M3	126.0	0.00	168.7	0.00	0.75		-1.08	
CHL-A MG/M3	39.0	0.00	37.2	0.00	1.05		0.14	
SECCHI M	0.4	0.00	0.4	0.00	1.00		-0.01	
ANTILOG PC-1	2163.3	0.00	2063.8	0.00	1.05		0.13	
ANTILOG PC-2	8.1	0.00	7.9	0.00	1.03		0.10	

Segment:	**3**	**Segment 3**						
	Observed		**Predicted**		**Obs/Pred**	**T-Statistics ---->**		
Variable	**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P MG/M3	299.0	0.00	186.6	0.00	1.60		1.75	
CHL-A MG/M3	32.0	0.00	37.3	0.00	0.86		-0.44	
SECCHI M	0.6	0.00	0.6	0.00	1.02		0.06	
ANTILOG PC-1	1266.3	0.00	1487.3	0.00	0.85		-0.46	
ANTILOG PC-2	9.5	0.00	10.4	0.00	0.91		-0.29	

Glenn Shoals Lake

Segment	Name
1	Segment 1
2	Segment 2
3	Segment 3
Mean	Area-Wtd Mean

PREDICTED CONCENTRATIONS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	233.3	168.7	186.6	186.8
CHL-A MG/M3	79.4	37.2	37.3	46.1
SECCHI M	0.2	0.4	0.6	0.4
ORGANIC N MG/M3	2329.6	1169.8	1119.0	1400.3
TP-ORTHO-P MG/M3	251.4	114.0	97.4	138.6
HOD-V MG/M3-DAY	2395.7			2395.7
MOD-V MG/M3-DAY	827.6			827.6
ANTILOG PC-1	8820.1	2063.8	1487.3	3335.2
ANTILOG PC-2	7.1	7.9	10.4	8.4
TURBIDITY 1/M	4.8	2.2	1.5	2.6
ZMIX * TURBIDITY	8.1	9.4	8.2	8.8
ZMIX / SECCHI	8.8	10.2	9.2	9.7
CHL-A * SECCHI	15.2	15.7	22.4	17.3
CHL-A / TOTAL P	0.3	0.2	0.2	0.2
FREQ(CHL-a>10) %	99.9	96.5	96.5	97.2
FREQ(CHL-a>20) %	97.2	75.5	75.7	80.1
FREQ(CHL-a>30) %	89.6	51.5	51.7	59.5
FREQ(CHL-a>40) %	78.7	33.4	33.6	43.0
FREQ(CHL-a>50) %	66.8	21.5	21.7	31.1
FREQ(CHL-a>60) %	55.6	14.0	14.1	22.7
CARLSON TSI-P	82.8	78.1	79.6	79.4
CARLSON TSI-CHLA	73.5	66.1	66.1	67.6
CARLSON TSI-SEC	83.8	72.5	67.4	73.5

OBSERVED CONCENTRATIONS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	202.0	126.0	299.0	186.1
CHL-A MG/M3	89.0	39.0	32.0	47.7
SECCHI M	0.2	0.4	0.6	0.4
ANTILOG PC-1	9913.9	2163.3	1266.3	3561.8
ANTILOG PC-2	7.6	8.1	9.5	8.4
TURBIDITY 1/M	4.8	2.2	1.5	2.6
ZMIX * TURBIDITY	8.1	9.4	8.2	8.8
ZMIX / SECCHI	8.9	10.2	9.1	9.7
CHL-A * SECCHI	16.9	16.4	19.5	17.3
CHL-A / TOTAL P	0.4	0.3	0.1	0.3
FREQ(CHL-a>10) %	99.9	97.0	94.1	96.9
FREQ(CHL-a>20) %	98.2	77.9	67.3	79.4
FREQ(CHL-a>30) %	92.6	54.5	41.8	59.3
FREQ(CHL-a>40) %	83.6	36.3	25.1	43.4
FREQ(CHL-a>50) %	73.2	23.9	15.2	32.0
FREQ(CHL-a>60) %	62.8	15.7	9.3	24.0
CARLSON TSI-P	80.7	73.9	86.4	78.5
CARLSON TSI-CHLA	74.6	66.5	64.6	67.7
CARLSON TSI-SEC	83.9	72.5	67.1	73.5

OBSERVED/PREDICTED RATIOS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	0.9	0.7	1.6	1.0
CHL-A MG/M3	1.1	1.0	0.9	1.0
SECCHI M	1.0	1.0	1.0	1.0
ANTILOG PC-1	1.1	1.0	0.9	1.1
ANTILOG PC-2	1.1	1.0	0.9	1.0
TURBIDITY 1/M	1.0	1.0	1.0	1.0
ZMIX * TURBIDITY	1.0	1.0	1.0	1.0
ZMIX / SECCHI	1.0	1.0	1.0	1.0
CHL-A * SECCHI	1.1	1.0	0.9	1.0
CHL-A / TOTAL P	1.3	1.4	0.5	1.2
FREQ(CHL-a>10) %	1.0	1.0	1.0	1.0
FREQ(CHL-a>20) %	1.0	1.0	0.9	1.0
FREQ(CHL-a>30) %	1.0	1.1	0.8	1.0
FREQ(CHL-a>40) %	1.1	1.1	0.7	1.0
FREQ(CHL-a>50) %	1.1	1.1	0.7	1.0
FREQ(CHL-a>60) %	1.1	1.1	0.7	1.1
CARLSON TSI-P	1.0	0.9	1.1	1.0
CARLSON TSI-CHLA	1.0	1.0	1.0	1.0
CARLSON TSI-SEC	1.0	1.0	1.0	1.0

OBSERVED STANDARD ERRORS

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	171.7			36.0

PREDICTED STANDARD ERRORS

Variable Segment-->	1	2	3	Mean

Glenn Shoals Lake

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 4 Area-Wtd Mean

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	186.8		93.5%	186.1	0.19	93.4%
CHL-A MG/M3	46.1		98.1%	47.7		98.3%
SECCHI M	0.4		10.6%	0.4		10.7%
ORGANIC N MG/M3	1400.3		98.3%			
TP-ORTHO-P MG/M3	138.6		94.6%			
HOD-V MG/M3-DAY	2395.7		100.0%			
MOD-V MG/M3-DAY	827.6		100.0%			
ANTILOG PC-1	3335.2		97.7%	3561.8		97.9%
ANTILOG PC-2	8.4		69.3%	8.4		69.4%
TURBIDITY 1/M	2.6		94.9%	2.6		94.9%
ZMIX * TURBIDITY	8.8		90.8%	8.8		90.8%
ZMIX / SECCHI	9.7		88.7%	9.7		88.7%
CHL-A * SECCHI	17.3		77.2%	17.3		77.2%
CHL-A / TOTAL P	0.2		62.6%	0.3		72.3%
FREQ(CHL-a>10) %	97.2		98.1%	96.9		98.3%
FREQ(CHL-a>20) %	80.1		98.1%	79.4		98.3%
FREQ(CHL-a>30) %	59.5		98.1%	59.3		98.3%
FREQ(CHL-a>40) %	43.0		98.1%	43.4		98.3%
FREQ(CHL-a>50) %	31.1		98.1%	32.0		98.3%
FREQ(CHL-a>60) %	22.7		98.1%	24.0		98.3%
CARLSON TSI-P	79.4		93.5%	78.5		93.4%
CARLSON TSI-CHLA	67.6		98.1%	67.7		98.3%
CARLSON TSI-SEC	73.5		89.4%	73.5		89.3%

Segment: 1 Segment 1

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	233.3		96.1%	202.0	0.85	94.5%
CHL-A MG/M3	79.4		99.7%	89.0		99.8%
SECCHI M	0.2		1.1%	0.2		1.1%
ORGANIC N MG/M3	2329.6		99.9%			
TP-ORTHO-P MG/M3	251.4		98.7%			
HOD-V MG/M3-DAY	2395.7		100.0%			
MOD-V MG/M3-DAY	827.6		100.0%			
ANTILOG PC-1	8820.1		99.7%	9913.9		99.8%
ANTILOG PC-2	7.1		57.8%	7.6		62.9%
TURBIDITY 1/M	4.8		99.1%	4.8		99.1%
ZMIX * TURBIDITY	8.1		89.0%	8.1		89.0%
ZMIX / SECCHI	8.8		85.4%	8.9		85.8%
CHL-A * SECCHI	15.2		71.4%	16.9		76.2%
CHL-A / TOTAL P	0.3		80.7%	0.4		89.9%
FREQ(CHL-a>10) %	99.9		99.7%	99.9		99.8%
FREQ(CHL-a>20) %	97.2		99.7%	98.2		99.8%
FREQ(CHL-a>30) %	89.6		99.7%	92.6		99.8%
FREQ(CHL-a>40) %	78.7		99.7%	83.6		99.8%
FREQ(CHL-a>50) %	66.8		99.7%	73.2		99.8%
FREQ(CHL-a>60) %	55.6		99.7%	62.8		99.8%
CARLSON TSI-P	82.8		96.1%	80.7		94.5%
CARLSON TSI-CHLA	73.5		99.7%	74.6		99.8%
CARLSON TSI-SEC	83.8		98.9%	83.9		98.9%

Segment: **2** **Segment 2**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	168.7		91.9%	126.0		85.9%
CHL-A MG/M3	37.2		96.3%	39.0		96.8%
SECCHI M	0.4		10.7%	0.4		10.7%
ORGANIC N MG/M3	1169.8		96.2%			
TP-ORTHO-P MG/M3	114.0		92.0%			
ANTILOG PC-1	2063.8		94.8%	2163.3		95.2%
ANTILOG PC-2	7.9		65.2%	8.1		67.3%
TURBIDITY 1/M	2.2		92.7%	2.2		92.7%
ZMIX * TURBIDITY	9.4		92.0%	9.4		92.0%
ZMIX / SECCHI	10.2		90.4%	10.2		90.5%
CHL-A * SECCHI	15.7		72.7%	16.4		74.8%
CHL-A / TOTAL P	0.2		57.3%	0.3		76.4%
FREQ(CHL-a>10) %	96.5		96.3%	97.0		96.8%
FREQ(CHL-a>20) %	75.5		96.3%	77.9		96.8%
FREQ(CHL-a>30) %	51.5		96.3%	54.5		96.8%
FREQ(CHL-a>40) %	33.4		96.3%	36.3		96.8%
FREQ(CHL-a>50) %	21.5		96.3%	23.9		96.8%
FREQ(CHL-a>60) %	14.0		96.3%	15.7		96.8%
CARLSON TSI-P	78.1		91.9%	73.9		85.9%
CARLSON TSI-CHLA	66.1		96.3%	66.5		96.8%
CARLSON TSI-SEC	72.5		89.3%	72.5		89.3%

Segment: **3** **Segment 3**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	186.6		93.5%	299.0		97.9%
CHL-A MG/M3	37.3		96.3%	32.0		94.4%
SECCHI M	0.6		22.0%	0.6		22.6%
ORGANIC N MG/M3	1119.0		95.4%			
TP-ORTHO-P MG/M3	97.4		89.2%			
ANTILOG PC-1	1487.3		91.6%	1266.3		89.5%
ANTILOG PC-2	10.4		82.1%	9.5		77.3%
TURBIDITY 1/M	1.5		84.4%	1.5		84.4%
ZMIX * TURBIDITY	8.2		89.2%	8.2		89.2%
ZMIX / SECCHI	9.2		87.2%	9.1		86.6%
CHL-A * SECCHI	22.4		86.7%	19.5		82.0%
CHL-A / TOTAL P	0.2		51.2%	0.1		17.1%
FREQ(CHL-a>10) %	96.5		96.3%	94.1		94.4%
FREQ(CHL-a>20) %	75.7		96.3%	67.3		94.4%
FREQ(CHL-a>30) %	51.7		96.3%	41.8		94.4%
FREQ(CHL-a>40) %	33.6		96.3%	25.1		94.4%
FREQ(CHL-a>50) %	21.7		96.3%	15.2		94.4%
FREQ(CHL-a>60) %	14.1		96.3%	9.3		94.4%
CARLSON TSI-P	79.6		93.5%	86.4		97.9%
CARLSON TSI-CHLA	66.1		96.3%	64.6		94.4%
CARLSON TSI-SEC	67.4		78.0%	67.1		77.4%

Glenn Shoals Lake

Water Balance Terms (hm3/yr)			Averaging Period =		0.42	Years			
			Inflows		Storage	Outflows------>		Downstr	
Seg	**Name**	**External**	**Precip**	**Advect**	**Increase**	**Advect**	**Disch.**	**Exchange**	**Evap**
1	Segment 1	88	1	0	0	88	0	180	1
2	Segment 2	16	2	88	0	104	0	499	2
3	Segment 3	1	1	104	0	105	0	0	1
Net		105	4	0	0	105	0	0	4

Mass Balance Terms (kg/yr) Based Upon			Predicted	Reservoir & Outflow Concentrations			Component:	TOTAL P	
		Inflows-->			Storage	Outflows----->		Net	Net
Seg	**Name**	**External**	**Atmos**	**Advect**	**Increase**	**Advect**	**Disch.**	**Exchange**	**Retention**
1	Segment 1	40978	25	0	0	20578	0	11603	8822
2	Segment 2	7953	65	20578	0	17523	0	-20547	31621
3	Segment 3	487	31	17523	0	19561	0	8945	-10465
Net		49418	121	0	0	19561	0	0	29978

Glenn Shoals Lake

Segment Mass Balance Based Upon Predicted Concentrations

Component:		**TOTAL P**		**Segment:**	**1**	**Segment 1**	
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
1	1	Middle Fork Shoal Cr.	72.9	81.8%	31111.2	75.9%	427
2	1	Fawn Creek	9.5	10.7%	6852.1	16.7%	719
3	2	Segment 1 Direct Drainage	5.8	6.5%	3014.4	7.4%	517
PRECIPITATION			0.9	1.0%	25.5	0.1%	30
TRIBUTARY INFLOW			82.4	92.5%	37963.3	92.6%	461
NONPOINT INFLOW			5.8	6.5%	3014.4	7.4%	517
***TOTAL INFLOW			89.1	100.0%	41003.2	100.0%	460
ADVECTIVE OUTFLOW			88.2	99.0%	20578.1	50.2%	233
NET DIFFUSIVE OUTFLOW			0.0	0.0%	11602.7	28.3%	
***TOTAL OUTFLOW			88.2	99.0%	32180.8	78.5%	365
***EVAPORATION			0.9	1.0%	0.0	0.0%	
***RETENTION			0.0	0.0%	8822.4	21.5%	

Hyd. Residence Time =	0.0164	yrs
Overflow Rate =	103.9	m/yr
Mean Depth =	1.7	m

Component:		**TOTAL P**		**Segment:**	**2**	**Segment 2**	
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
4	1	Little Creek	5.1	4.8%	2474.5	5.0%	490
5	2	Segment 2 Direct Drainage	10.6	10.0%	5478.6	11.1%	517
PRECIPITATION			2.2	2.1%	64.9	0.1%	30
TRIBUTARY INFLOW			5.1	4.8%	2474.5	5.0%	490
NONPOINT INFLOW			10.6	10.0%	5478.6	11.1%	517
ADVECTIVE INFLOW			88.2	83.2%	20578.1	41.9%	233
NET DIFFUSIVE INFLOW			0.0	0.0%	20547.3	41.8%	
***TOTAL INFLOW			106.1	100.0%	49143.4	100.0%	463
ADVECTIVE OUTFLOW			103.9	97.9%	17522.6	35.7%	169
***TOTAL OUTFLOW			103.9	97.9%	17522.6	35.7%	169
***EVAPORATION			2.2	2.1%	0.0	0.0%	
***RETENTION			0.0	0.0%	31620.8	64.3%	

Hyd. Residence Time =	0.0952	yrs
Overflow Rate =	48.0	m/yr
Mean Depth =	4.6	m

Component:		TOTAL P		Segment:	3	Segment 3	
			Flow	Flow	Load	Load	Conc
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
6	2	Segment 3 Direct Drainage	0.9	0.9%	487.2	0.9%	517
PRECIPITATION			1.0	1.0%	30.9	0.1%	30
INTERNAL LOAD			0.0	0.0%	37657.3	67.6%	
NONPOINT INFLOW			0.9	0.9%	487.2	0.9%	517
ADVECTIVE INFLOW			103.9	98.1%	17522.6	31.5%	169
***TOTAL INFLOW			105.9	100.0%	55698.0	100.0%	526
ADVECTIVE OUTFLOW			104.8	99.0%	19560.8	35.1%	187
NET DIFFUSIVE OUTFLOW			0.0	0.0%	8944.6	16.1%	
***TOTAL OUTFLOW			104.8	99.0%	28505.4	51.2%	272
***EVAPORATION			1.0	1.0%	0.0	0.0%	
***RETENTION			0.0	0.0%	27192.6	48.8%	

Hyd. Residence Time = 0.0663 yrs
Overflow Rate = 101.7 m/yr
Mean Depth = 6.7 m

Glenn Shoals Lake

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 0.42 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Middle Fork Shoal Cr.	72.9	72.9	0.00E+00	0.00	1.00
2	1	1	Fawn Creek	36.7	9.5	0.00E+00	0.00	0.26
3	2	1	Segment 1 Direct Drainage	23.5	5.8	0.00E+00	0.00	0.25
4	1	2	Little Creek	19.5	5.1	0.00E+00	0.00	0.26
5	2	2	Segment 2 Direct Drainage	40.8	10.6	0.00E+00	0.00	0.26
6	2	3	Segment 3 Direct Drainage	3.6	0.9	0.00E+00	0.00	0.26
PRECIPITATION				4.0	4.1	0.00E+00	0.00	1.02
TRIBUTARY INFLOW				129.1	87.4	0.00E+00	0.00	0.68
NONPOINT INFLOW				67.9	17.4	0.00E+00	0.00	0.26
***TOTAL INFLOW				201.0	108.9	0.00E+00	0.00	0.54
ADVECTIVE OUTFLOW				201.0	104.8	0.00E+00	0.00	0.52
***TOTAL OUTFLOW				201.0	104.8	0.00E+00	0.00	0.52
***EVAPORATION					4.1	0.00E+00	0.00	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**

Component: **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Middle Fork Shoal Cr.	31111.2	35.7%	0.00E+00		0.00	427.0	427.0
2	1	1	Fawn Creek	6852.1	7.9%	0.00E+00		0.00	719.0	186.6
3	2	1	Segment 1 Direct Drainage	3014.4	3.5%	0.00E+00		0.00	517.0	128.5
4	1	2	Little Creek	2474.5	2.8%	0.00E+00		0.00	490.0	127.1
5	2	2	Segment 2 Direct Drainage	5478.6	6.3%	0.00E+00		0.00	517.0	134.2
6	2	3	Segment 3 Direct Drainage	487.2	0.6%	0.00E+00		0.00	517.0	134.6
PRECIPITATION				121.3	0.1%	0.00E+00		0.00	29.5	30.0
INTERNAL LOAD				37657.3	43.2%	0.00E+00		0.00		
TRIBUTARY INFLOW				40437.8	46.4%	0.00E+00		0.00	462.5	313.3
NONPOINT INFLOW				8980.2	10.3%	0.00E+00		0.00	517.0	132.2
***TOTAL INFLOW				87196.6	100.0%	0.00E+00		0.00	800.6	433.8
ADVECTIVE OUTFLOW				19560.8	22.4%	0.00E+00		0.00	186.6	97.3
***TOTAL OUTFLOW				19560.8	22.4%	0.00E+00		0.00	186.6	97.3
***RETENTION				67635.8	77.6%	0.00E+00		0.00		

Overflow Rate (m/yr)	25.9	Nutrient Resid. Time (yrs)	0.0392
Hydraulic Resid. Time (yrs)	0.1744	Turnover Ratio	10.6
Reservoir Conc (mg/m3)	187	Retention Coef.	0.776

Glenn Shoals Lake

Hydraulic & Dispersion Parameters

Seg	Name	Outflow Seg	Net Inflow hm^3/yr	Resid Time years	Overflow Rate m/yr	Velocity km/yr	Dispersion--------> Estimated km^2/yr	Numeric km^2/yr	Exchange hm^3/yr
1	Segment 1	2	88.2	0.0164	103.9	160.8	1072.7	211.4	179.7
2	Segment 2	3	103.9	0.0952	48.0	30.6	471.6	44.5	498.9
3	Segment 3	0	104.8	0.0663	101.7	24.1	201.7	19.3	0.0

Morphometry

Seg	Name	Area km^2	Zmean m	Zmix m	Length km	Volume hm^3	Width km	L/W -
1	Segment 1	0.8	1.7	1.7	2.6	1.4	0.3	8.1
2	Segment 2	2.2	4.6	4.3	2.9	9.9	0.7	3.9
3	Segment 3	1.0	6.7	5.6	1.6	6.9	0.6	2.5
Totals		4.0	4.5			18.3		

Glenn Shoals Lake

Segment & Tributary Network

--------Segment:	1	Segment 1		
Outflow Segment:	2	Segment 2		
Tributary:	1	Middle Fork Shoal Cr.	Type:	Monitored Inflow
Tributary:	2	Fawn Creek	Type:	Monitored Inflow
Tributary:	3	Segment 1 Direct Drainage	Type:	Non Point Inflow
--------Segment:	2	Segment 2		
Outflow Segment:	3	Segment 3		
Tributary:	4	Little Creek	Type:	Monitored Inflow
Tributary:	5	Segment 2 Direct Drainage	Type:	Non Point Inflow
--------Segment:	3	Segment 3		
Outflow Segment:	0	Out of Reservoir		
Tributary:	6	Segment 3 Direct Drainage	Type:	Non Point Inflow

Glenn Shoals Lake
Description:

Single reservoir
5 segments

Global Variables	Mean	CV
Averaging Period (yrs)	0.4167	0.0
Precipitation (m)	0.4234	0.0
Evaporation (m)	0.4234	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.00
Total N	0	0.00
Ortho P	0	0.00
Inorganic N	0	0.00

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	2	P, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	2	CONCENTRATIONS
Nitrogen Calibration	1	DECAY RATES
Error Analysis	0	NOT COMPUTED
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

													Internal Loads (mg/m2-day)					
		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Segment 1	2	1	0.849	1.7	2.63	1.69	0.12	0.68	0	4.82	0	0	0	0	0	0	0
2	Segment 2	3	1	2.164	4.57	2.91	4.29	0.12	3.05	0	2.19	0	0	0	0	0	0	0
3	Segment 3	0	1	1.031	6.74	1.6	5.55	0	3.73	0	1.48	0	0	0	100	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	202	0.85	0	0	89	0	0.19	0	0	0	0	0	0	0	0	0
2	0	0	126	0	0	0	39	0	0.42	0	0	0	0	0	0	0	0	0
3	0	0	299	0	0	0	32	0	0.61	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

Trib	Trib Name	Segment	Type	Dr Area km^2	Flow (hm^3/yr) Mean	CV	Conserv. Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Ortho P (ppb) Mean	CV	Inorganic N (ppb) Mean	CV
1	Middle Fork Shoal Cr.	1	1	72.86	72.86	0	0	0	427	0	50	0	20	0	40	0
2	Fawn Creek	1	1	36.73	9.53	0	0	0	719	0	0	0	0	0	0	0
3	Segment 1 Direct Drainage	1	2	23.46	6.09	0	0	0	429	0	0	0	0	0	0	0
4	Little Creek	2	1	19.47	5.05	0	0	0	490	0	0	0	0	0	0	0
5	Segment 2 Direct Drainage	2	2	40.83	10.6	0	0	0	517	0	50	0	20	0	40	0
6	Segment 3 Direct Drainage	3	2	3.62	0.9399	0	0	0	517	0	50	0	20	0	40	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->							
Trib	Trib Name	1	2	3	4	5	6	7	8
1	Middle Fork Shoal Cr.	67.67	2.47	1.67	0.45	0.58	0.02	0	0
2	Fawn Creek	30.54	2.11	3.29	0.23	0.4	0.16	0	0
3	Segment 1 Direct Drainage	15.38	1.44	3.56	0.17	0.95	0.96	0	0
4	Little Creek	16.03	0.92	1.44	0.82	0.22	0.03	0	0
5	Segment 2 Direct Drainage	25.5	2.42	8.23	1.18	1.42	2.07	0	0
6	Segment 3 Direct Drainage	1.04	0.25	1.04	0.16	0.2	0.94	0	0

Non-Point Source Export Coefficients

Categ	Land Use Name	Runoff (m/yr) Mean	CV	Conserv. Subs. Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Ortho P (ppb) Mean	CV	Inorganic N (ppb) Mean	CV
1	Row Crop	0.2596	0	0	0	517	0	0	0	0	0	0	0
2	Grassland	0.2596	0	0	0	517	0	0	0	0	0	0	0
3	Forest	0.2596	0	0	0	517	0	0	0	0	0	0	0
4	Urban	0.2596	0	0	0	517	0	0	0	0	0	0	0
5	Wetland	0.2596	0	0	0	517	0	0	0	0	0	0	0
6	Other	0.2596	0	0	0	517	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.005	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	1.000	0
Avail. Factor - Ortho P	0.000	0
Avail. Factor - Total N	0.000	0
Avail. Factor - Inorganic N	0.000	0

Old Hillsboro Lake

Variable = TOTAL P MG/M3 **R^2 = -0.04**

Global Calibration Factor = 1.00 CV = 0.45

Seg	Group	Name	Calibration Factor Mean	CV	Predicted Mean	CV	Observed Mean	CV	Log (Obs/Pred) Mean	SE	t
1	1	Segment 1	1.00	0.00	232.2	0.00	275.0	0.00	0.17	0.00	0.00
2	1	Segment 2	1.00	0.00	310.4	0.00	284.0	0.00	-0.09	0.00	0.00
3	1	Segment 3	1.00	0.00	372.5	0.00	354.0	0.00	-0.05	0.00	0.00
4	1	Area-Wtd Mean			296.3	0.00	297.1	0.00	0.00	0.00	0.00

Old Hillsboro Lake

Overall Water & Nutrient Balances

Overall Water Balance | **Averaging Period = 0.42 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	2	3	Inlet Tributary	14.8	3.8	0.00E+00	0.00	0.26
2	2	2	Segment 2 Direct Drainage	1.8	0.5	0.00E+00	0.00	0.26
3	2	1	Segment 3 Direct Drainage	1.5	0.4	0.00E+00	0.00	0.26
PRECIPITATION				0.4	0.4	0.00E+00	0.00	1.02
NONPOINT INFLOW				18.1	4.7	0.00E+00	0.00	0.26
***TOTAL INFLOW				18.5	5.1	0.00E+00	0.00	0.28
ADVECTIVE OUTFLOW				18.5	4.7	0.00E+00	0.00	0.25
***TOTAL OUTFLOW				18.5	4.7	0.00E+00	0.00	0.25
***EVAPORATION					0.4	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	2	3	Inlet Tributary	1533.7	14.6%	0.00E+00		0.00	400.0	103.8
2	2	2	Segment 2 Direct Drainage	190.0	1.8%	0.00E+00		0.00	400.0	105.0
3	2	1	Segment 3 Direct Drainage	158.9	1.5%	0.00E+00		0.00	400.0	102.5
PRECIPITATION				11.8	0.1%	0.00E+00		0.00	29.5	30.0
INTERNAL LOAD				8634.5	82.0%	0.00E+00		0.00		
NONPOINT INFLOW				1882.6	17.9%	0.00E+00		0.00	400.0	103.8
***TOTAL INFLOW				10528.9	100.0%	0.00E+00		0.00	2061.7	568.4
ADVECTIVE OUTFLOW				1092.7	10.4%	0.00E+00		0.00	232.2	59.0
***TOTAL OUTFLOW				1092.7	10.4%	0.00E+00		0.00	232.2	59.0
***RETENTION				9436.3	89.6%	0.00E+00		0.00		

Overflow Rate (m/yr)	11.9	Nutrient Resid. Time (yrs)	0.0440
Hydraulic Resid. Time (yrs)	0.3319	Turnover Ratio	9.5
Reservoir Conc (mg/m3)	296	Retention Coef.	0.896

Old Hillsboro Lake

T Statistics Compare Observed and Predicted Means Using the Following Error Terms:
1 = Observed Water Quality Error Only
2 = Error Typical of Model Development Dataset
3 = Observed & Predicted Error

Segment:		Area-Wtd Mean							
		Observed		Predicted		Obs/Pred	T-Statistics ---->		
Variable		**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P	MG/M3	297.1	0.00	296.3	0.00	1.00		0.01	

Segment:		1 Segment 1							
		Observed		Predicted		Obs/Pred	T-Statistics ---->		
Variable		**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P	MG/M3	275.0	0.00	232.2	0.00	1.18		0.63	

Segment:		2 Segment 2							
		Observed		Predicted		Obs/Pred	T-Statistics ---->		
Variable		**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P	MG/M3	284.0	0.00	310.4	0.00	0.92		-0.33	

Segment:		3 Segment 3							
		Observed		Predicted		Obs/Pred	T-Statistics ---->		
Variable		**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P	MG/M3	354.0	0.00	372.5	0.00	0.95		-0.19	

Old Hillsboro Lake

Segment	Name
1	Segment 1
2	Segment 2
3	Segment 3
Mean	Area-Wtd Mean

PREDICTED CONCENTRATIONS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	232.2	310.4	372.5	296.3
TURBIDITY 1/M	5.0	1.0	5.0	3.4
ZMIX * TURBIDITY	6.0	3.4	6.0	4.9
CARLSON TSI-P	82.7	86.9	89.5	86.0

OBSERVED CONCENTRATIONS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	275.0	284.0	354.0	297.1
CHL-A MG/M3	84.0	79.0	82.0	81.5
SECCHI M	0.5	0.5	0.4	0.5
ANTILOG PC-1	3545.0	3464.2	4193.6	3664.1
ANTILOG PC-2	16.6	15.5	13.9	15.5
TURBIDITY 1/M	5.0	1.0	5.0	3.4
ZMIX * TURBIDITY	6.0	3.4	6.0	4.9
ZMIX / SECCHI	2.2	6.6	2.7	4.1
CHL-A * SECCHI	45.4	41.1	36.1	41.5
CHL-A / TOTAL P	0.3	0.3	0.2	0.3
FREQ(CHL-a>10) %	99.9	99.9	99.9	99.9
FREQ(CHL-a>20) %	97.7	97.2	97.5	97.5
FREQ(CHL-a>30) %	91.2	89.5	90.5	90.3
FREQ(CHL-a>40) %	81.2	78.5	80.2	79.9
FREQ(CHL-a>50) %	70.1	66.6	68.7	68.4
FREQ(CHL-a>60) %	59.2	55.3	57.7	57.3
CARLSON TSI-P	85.1	85.6	88.8	86.2
CARLSON TSI-CHLA	74.1	73.5	73.8	73.8
CARLSON TSI-SEC	68.9	69.4	71.8	69.8

OBSERVED/PREDICTED RATIOS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	1.2	0.9	1.0	1.0
TURBIDITY 1/M	1.0	1.0	1.0	1.0
ZMIX * TURBIDITY	1.0	1.0	1.0	1.0
CARLSON TSI-P	1.0	1.0	1.0	1.0

OBSERVED STANDARD ERRORS

Variable Segment-->	1	2	3	Mean

PREDICTED STANDARD ERRORS

Variable Segment-->	1	2	3	Mean

Old Hillsboro Lake

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: **4** **Area-Wtd Mean**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	296.3		97.9%	297.1		97.9%
CHL-A MG/M3				81.5		99.7%
SECCHI M				0.5		16.1%
ANTILOG PC-1				3664.1		98.1%
ANTILOG PC-2				15.5		95.3%
TURBIDITY 1/M	3.4		97.5%	3.4		97.5%
ZMIX * TURBIDITY	4.9		71.9%	4.9		71.9%
ZMIX / SECCHI				4.1		39.6%
CHL-A * SECCHI				41.5		97.6%
CHL-A / TOTAL P				0.3		70.7%
FREQ(CHL-a>10) %				99.9		99.7%
FREQ(CHL-a>20) %				97.5		99.7%
FREQ(CHL-a>30) %				90.3		99.7%
FREQ(CHL-a>40) %				79.9		99.7%
FREQ(CHL-a>50) %				68.4		99.7%
FREQ(CHL-a>60) %				57.3		99.7%
CARLSON TSI-P	86.0		97.9%	86.2		97.9%
CARLSON TSI-CHLA				73.8		99.7%
CARLSON TSI-SEC				69.8		83.9%

Segment: **1** **Segment 1**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	232.2		96.0%	275.0		97.4%
CHL-A MG/M3				84.0		99.8%
SECCHI M				0.5		18.1%
ANTILOG PC-1				3545.0		97.9%
ANTILOG PC-2				16.6		96.4%
TURBIDITY 1/M	5.0		99.2%	5.0		99.2%
ZMIX * TURBIDITY	6.0		79.4%	6.0		79.4%
ZMIX / SECCHI				2.2		9.2%
CHL-A * SECCHI				45.4		98.2%
CHL-A / TOTAL P				0.3		75.7%
FREQ(CHL-a>10) %				99.9		99.8%
FREQ(CHL-a>20) %				97.7		99.8%
FREQ(CHL-a>30) %				91.2		99.8%
FREQ(CHL-a>40) %				81.2		99.8%
FREQ(CHL-a>50) %				70.1		99.8%
FREQ(CHL-a>60) %				59.2		99.8%
CARLSON TSI-P	82.7		96.0%	85.1		97.4%
CARLSON TSI-CHLA				74.1		99.8%
CARLSON TSI-SEC				68.9		81.9%

Segment: **2** **Segment 2**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	310.4		98.1%	284.0		97.6%
CHL-A MG/M3				79.0		99.7%
SECCHI M				0.5		16.8%
ANTILOG PC-1				3464.2		97.8%
ANTILOG PC-2				15.5		95.2%
TURBIDITY 1/M	1.0		71.3%	1.0		71.3%
ZMIX * TURBIDITY	3.4		54.5%	3.4		54.5%
ZMIX / SECCHI				6.6		71.3%
CHL-A * SECCHI				41.1		97.5%
CHL-A / TOTAL P				0.3		70.9%
FREQ(CHL-a>10) %				99.9		99.7%
FREQ(CHL-a>20) %				97.2		99.7%
FREQ(CHL-a>30) %				89.5		99.7%
FREQ(CHL-a>40) %				78.5		99.7%
FREQ(CHL-a>50) %				66.6		99.7%
FREQ(CHL-a>60) %				55.3		99.7%
CARLSON TSI-P	86.9		98.1%	85.6		97.6%
CARLSON TSI-CHLA				73.5		99.7%
CARLSON TSI-SEC				69.4		83.2%

Segment: **3** **Segment 3**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	372.5		98.9%	354.0		98.7%
CHL-A MG/M3				82.0		99.8%
SECCHI M				0.4		11.9%
ANTILOG PC-1				4193.6		98.5%
ANTILOG PC-2				13.9		92.9%
TURBIDITY 1/M	5.0		99.2%	5.0		99.2%
ZMIX * TURBIDITY	6.0		79.4%	6.0		79.4%
ZMIX / SECCHI				2.7		16.5%
CHL-A * SECCHI				36.1		96.3%
CHL-A / TOTAL P				0.2		60.4%
FREQ(CHL-a>10) %				99.9		99.8%
FREQ(CHL-a>20) %				97.5		99.8%
FREQ(CHL-a>30) %				90.5		99.8%
FREQ(CHL-a>40) %				80.2		99.8%
FREQ(CHL-a>50) %				68.7		99.8%
FREQ(CHL-a>60) %				57.7		99.8%
CARLSON TSI-P	89.5		98.9%	88.8		98.7%
CARLSON TSI-CHLA				73.8		99.8%
CARLSON TSI-SEC				71.8		88.1%

Old Hillsboro Lake

Water Balance Terms (hm3/yr) **Averaging Period = 0.42 Years**

		Inflows			Storage	Outflows------>		Downstr	
Seg	**Name**	**External**	**Precip**	**Advect**	**Increase**	**Advect**	**Disch.**	**Exchange**	**Evap**
1	Segment 1	0	0	4	0	5	0	0	0
2	Segment 2	0	0	4	0	4	0	4	0
3	Segment 3	4	0	0	0	4	0	13	0
Net		5	0	0	0	5	0	0	0

Mass Balance Terms (kg/yr) Based Upon Predicted Reservoir & Outflow Concentrations **Component: TOTAL P**

		Inflows-->			Storage	Outflows----->		Net	Net
Seg	**Name**	**External**	**Atmos**	**Advect**	**Increase**	**Advect**	**Disch.**	**Exchange**	**Retention**
1	Segment 1	159	4	1338	0	1093	0	-332	740
2	Segment 2	190	5	1428	0	1338	0	-488	774
3	Segment 3	1534	3	0	0	1428	0	820	-712
Net		1883	12	0	0	1093	0	0	802

Old Hillsboro Lake

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Segment 1**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
3	2	Segment 3 Direct Drainage	0.4	8.2%	158.9	3.2%	400
PRECIPITATION			0.1	3.0%	4.3	0.1%	30
INTERNAL LOAD			0.0	0.0%	3155.8	63.3%	
NONPOINT INFLOW			0.4	8.2%	158.9	3.2%	400
ADVECTIVE INFLOW			4.3	88.8%	1337.5	26.8%	310
NET DIFFUSIVE INFLOW			0.0	0.0%	331.9	6.7%	
***TOTAL INFLOW			4.9	100.0%	4988.4	100.0%	1028
ADVECTIVE OUTFLOW			4.7	97.0%	1092.7	21.9%	232
***TOTAL OUTFLOW			4.7	97.0%	1092.7	21.9%	232
***EVAPORATION			0.1	3.0%	0.0	0.0%	
***RETENTION			0.0	0.0%	3895.8	78.1%	

Hyd. Residence Time = 0.1909 yrs
Overflow Rate = 32.7 m/yr
Mean Depth = 6.2 m

Component: TOTAL P **Segment: 2 Segment 2**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
2	2	Segment 2 Direct Drainage	0.5	10.6%	190.0	3.4%	400
PRECIPITATION			0.2	3.6%	4.7	0.1%	30
INTERNAL LOAD			0.0	0.0%	3462.6	62.1%	
NONPOINT INFLOW			0.5	10.6%	190.0	3.4%	400
ADVECTIVE INFLOW			3.8	85.8%	1428.3	25.6%	373
NET DIFFUSIVE INFLOW			0.0	0.0%	488.2	8.8%	
***TOTAL INFLOW			4.5	100.0%	5573.9	100.0%	1247
ADVECTIVE OUTFLOW			4.3	96.4%	1337.5	24.0%	310
***TOTAL OUTFLOW			4.3	96.4%	1337.5	24.0%	310
***EVAPORATION			0.2	3.6%	0.0	0.0%	
***RETENTION			0.0	0.0%	4236.3	76.0%	

Hyd. Residence Time = 0.1269 yrs
Overflow Rate = 27.3 m/yr
Mean Depth = 3.5 m

Component: TOTAL P **Segment: 3 Segment 3**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	2	Inlet Tributary	3.8	97.6%	1533.7	43.2%	400
PRECIPITATION			0.1	2.4%	2.8	0.1%	30
INTERNAL LOAD			0.0	0.0%	2016.2	56.8%	
NONPOINT INFLOW			3.8	97.6%	1533.7	43.2%	400
***TOTAL INFLOW			3.9	100.0%	3552.7	100.0%	904
ADVECTIVE OUTFLOW			3.8	97.6%	1428.3	40.2%	373
NET DIFFUSIVE OUTFLOW			0.0	0.0%	820.2	23.1%	
***TOTAL OUTFLOW			3.8	97.6%	2248.5	63.3%	586
***EVAPORATION			0.1	2.4%	0.0	0.0%	
***RETENTION			0.0	0.0%	1304.2	36.7%	

Hyd. Residence Time = 0.0305 yrs
Overflow Rate = 41.7 m/yr
Mean Depth = 1.3 m

Old Hillsboro Lake

Hydraulic & Dispersion Parameters

Seg	Name	Outflow Seg	Net Inflow hm^3/yr	Resid Time years	Overflow Rate m/yr	Velocity km/yr	Dispersion--------> Estimated km^2/yr	Numeric km^2/yr	Exchange hm^3/yr
1	Segment 1	0	4.7	0.1909	32.7	2.8	4.4	0.7	0.0
2	Segment 2	1	4.3	0.1269	27.3	6.6	8.3	2.8	4.2
3	Segment 3	2	3.8	0.0305	41.7	18.4	40.6	5.1	13.2

Morphometry

Seg	Name	Area km^2	Zmean m	Zmix m	Length km	Volume hm^3	Width km	L/W -
1	Segment 1	0.1	6.2	1.2	0.5	0.9	0.3	2.0
2	Segment 2	0.2	3.5	3.4	0.8	0.5	0.2	4.5
3	Segment 3	0.1	1.3	1.2	0.6	0.1	0.2	3.4
Totals		0.4	4.0			1.6		

Old Hillsboro Lake

Segment & Tributary Network

--------Segment:	1	Segment 1		
Outflow Segment:	0	Out of Reservoir		
Tributary:	3	Segment 3 Direct Drainage	Type:	Non Point Inflow
--------Segment:	2	Segment 2		
Outflow Segment:	1	Segment 1		
Tributary:	2	Segment 2 Direct Drainage	Type:	Non Point Inflow
--------Segment:	3	Segment 3		
Outflow Segment:	2	Segment 2		
Tributary:	1	Inlet Tributary	Type:	Non Point Inflow

Old Hillsboro Lake
Description:
Single reservoir
3 segments

Global Variables	Mean	CV
Averaging Period (yrs)	0.4167	0.0
Precipitation (m)	0.4234	0.0
Evaporation (m)	0.4234	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.00
Total N	0	0.00
Ortho P	0	0.00
Inorganic N	0	0.00

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	2	CONCENTRATIONS
Nitrogen Calibration	1	DECAY RATES
Error Analysis	0	NOT COMPUTED
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Segment 1	0	1	0.144	6.24	0.53	1.19	0	3.67	0	5	0	0	0	60	0	0	0
2	Segment 2	1	1	0.158	3.46	0.84	3.44	0.12	2.33	0	1	0	0	0	60	0	0	0
3	Segment 3	2	1	0.092	1.27	0.56	1.19	0.12	1.1	0	5	0	0	0	60	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	275	0	0	0	84	0	0.54	0	0	0	0	0	0	0	0	0
2	0	0	284	0	0	0	79	0	0.52	0	0	0	0	0	0	0	0	0
3	0	0	354	0	0	0	82	0	0.44	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

Trib	Trib Name	Segment	Type	Dr Area km^2	Flow (hm^3/yr) Mean	CV	Conserv. Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Ortho P (ppb) Mean	CV	Inorganic N (ppb) Mean	CV
1	Inlet Tributary	3	2	14.77	3.4326	0	0	0	317	0	0	0	0	0	0	0
2	Segment 2 Direct Drainage	2	2	1.81	0.4211	0	0	0	279	0	0	0	0	0	0	0
3	Segment 3 Direct Drainage	1	2	1.55	0.3592	0	0	0	488	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->							
Trib	**Trib Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Inlet Tributary	10.95	0.48	1.21	1.38	0.64	0.11	0	0
2	Segment 2 Direct Drainage	0.45	0.17	0.66	0.28	0.12	0.15	0	0
3	Segment 3 Direct Drainage	0.32	0.29	0.56	0.15	0.07	0.14	0	0

Non-Point Source Export Coefficients

Categ	Land Use Name	Runoff (m/yr) Mean	CV	Conserv. Subs. Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Ortho P (ppb) Mean	CV	Inorganic N (ppb) Mean	CV
1	Row Crop	0.2596	0	0	0	400	0	0	0	0	0	0	0
2	Grassland	0.2596	0	0	0	400	0	0	0	0	0	0	0
3	Forest	0.2596	0	0	0	400	0	0	0	0	0	0	0
4	Urban	0.2596	0	0	0	400	0	0	0	0	0	0	0
5	Wetland	0.2596	0	0	0	400	0	0	0	0	0	0	0
6	Other	0.2596	0	0	0	400	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.013	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	1.000	0
Avail. Factor - Ortho P	0.000	0
Avail. Factor - Total N	0.000	0
Avail. Factor - Inorganic N	0.000	0

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ATTACHMENT 2

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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from July 25, 2005 through August 24, 2005 postmarked, including those from the August 9, 2005 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 Glenn Shoals/Hillsboro Old Lakes TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the impaired water bodies and 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 Glenn Shoals/Hillsboro watershed is located in Central Illinois, approximately 40 miles south of Springfield and 60 miles northeast of St. Louis. Lake Glenn Shoals is a 1,350 acre impoundment constructed in the 1970s for flood control, water supply, and recreational uses. Lake Hillsboro, often referred to as the “Old Lake,” served as the primary water supply for the area until construction of Lake Glenn Shoals. Old Lake Hillsboro has a surface area of approximately 110 acres. Currently, both lakes are used as water supply for the City of Hillsboro and several neighboring communities. Lake Glenn Shoals is listed as impaired for phosphorus, total suspended solids, and excess algal growth. Old Lake Hillsboro is listed as impaired for manganese, phosphorus, total suspended solids, and excess algal growth. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, the Glenn Shoals/Hillsboro Watershed TMDL was developed for phosphorus and manganese. The Illinois EPA contracted with Limno-Tech, Inc. (LTI) to prepare a TMDL report for the Glenn Shoals/Hillsboro Watershed.

Public Meetings

Public meetings were held in the city of Hillsboro on March 2, 2005 and August 9, 2005. The Illinois EPA provided public notice for the meetings by placing display ads in the “Hillsboro Journal” and the “Litchfield News Herald” on January 28, 2005 and July 25, 2005. The notices gave the date, time, location, and purpose of the meetings. The notices also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Illinois EPA also sent the public notice for the August 9 meeting, by first class mail, to approximately 50 individuals and organizations. The draft TMDL Report was available for review at the offices of the University of Illinois Extension - Montgomery County and also on the Agency’s web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 6:30 p.m. on Tuesday, August 9, 2005. It was attended by approximately fifteen people and concluded at 8:30 p.m. with the meeting record remaining open until midnight, August 24, 2005.

Questions and Comments

1. Is phosphorus impairment common for this type of lake or is it unusual?

Response: Phosphorus impairment is common to many Illinois streams and lakes, particularly in areas where agriculture is the predominant land use. The phosphorus standard of 0.05 mg/L only applies to lakes, not to streams. We have completed and are currently developing several TMDLs for phosphorus in Illinois lakes.

2. Why is manganese a problem for Old Lake Hillsboro but not Glenn Shoals?

Response: Water samples collected by the Illinois EPA exceeded the Public Water Supply (PWS) water quality standard of 150 ug/l in Lake Hillsboro and they did not exceed the standard in Lake Glenn Shoals. The higher concentration of manganese in Old Hillsboro Lake may be related to the relative age of the lakes in question—Old Lake Hillsboro is approximately 87 years old while Lake Glenn Shoals is only 30 years old. Land use and conservation practices in the two watersheds can also be expected to contribute to this difference.

3. When did grant funding become available? I thought at the first meeting it was stated that grant funds are not available?

Response: Grant funding is available through the Illinois Environmental Protection Agency Section 319 Non-point Source Pollution Program. Funding for certain conservation practices may also be available from Natural Resources Conservation Service/Soil and Water Conservation District (NRCS/SWCD). In the next phase of this TMDL, we will begin exploring what practices may be possible and practical for these watersheds, and how those practices may be funded.

4. Is there money available through Conservation 2000?

Response: Conservation 2000 money is split up between the Illinois Department of Natural Resources, Illinois Department of Agriculture, and Illinois EPA. Funds may be available for farmland conservation practices through IDOA or for in-lake practices through IDNR. These funding sources will be explored in the upcoming implementation phase.

5. Would the city or the county serve as a main contact for a grant?

Response: Since there is a 60-40 cost share associated with the Section 319 Grants, applications are usually completed by communities, municipalities, watershed groups, etc. In the case of these lakes, the City of Hillsboro would be a logical entity to serve as main contact for a grant to do restoration work on the lakes.

6. Can historical data be used to determine a trend in the phosphorus levels? Agriculture has changed practices over the years.

Response: There are data available on cropping practices and land use in the county that could be used in a trend analysis. However, that was not in the scope of work for this TMDL report. This report used the most recent 10 years of water quality and flow data to determine the loading capacity of the lake and load reductions necessary to meet the target concentration. The information we provided in this report on cropping practices (e.g., how many no-till acres are in the watershed) is based on recent data and was not intended to serve as a means of analyzing trends in these practices and their affect on water quality.

7. Glenn Shoals Lake has a siltation problem. Would a sedimentation basin or dredging help?

Response: Siltation was not addressed by this TMDL. We believe that these are both options that could be explored in the implementation process as ways to reduce phosphorus and manganese loading and internal cycling.

8. Is an 85% reduction feasible?

Response: The Clean Water Act requires the Agency to determine the total maximum daily load and the reduction necessary to meet water quality standards. We recognize this is a large reduction. This is our best estimate using the data available. While this may be a difficult target to achieve, it is important to have a goal to work towards as we begin the implementation process.

9.: I've heard that when a siltation problem is corrected, other problems result, such as increased algae growth? Is this correct?

Response: If turbidity is decreased, there could be a potential for increased penetration of sunlight and increased algal growth. Any plans the community may have for building a sediment retention basin, dredging or conducting any other sediment or erosion control practices should also include an investigation of this possibility. Practices that jointly control sediment and reduce phosphorus input should be considered.

10. What would happen to the lake if we didn't do anything?

Response: Eutrophication of the lakes would likely continue. This would cause increased occurrences of high algae levels, decreased dissolved oxygen, changes to the abundance and types of aquatic life present in the lakes and the potential for fish kills. Doing nothing will also decrease the lifespan of the lake, increase the frequency of taste and odor problems in the drinking water and increase treatment costs to combat these problems.

11. When is the next meeting?

Response: The tentative schedule for the meeting on the implementation plan is mid to late November.

TMDL Implementation Plan

Glenn Shoals/Hillsboro Watershed

Lake Glenn Shoals (ROL), Old Lake Hillsboro (ROT)

Prepared for Illinois Environmental Protection Agency

November 2006

Lake Glenn Shoals (ROL): Phosphorus

Old Lake Hillsboro (ROT): Phosphorus, Manganese

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SUMMARY

Total Maximum Daily Loads (TMDLs) were developed and submitted to the U.S. EPA in August 2005 for Lake Glenn Shoals and Old Lake Hillsboro in Montgomery County, Illinois, to address water quality impairments due to total phosphorus and manganese. These TMDLs, which determined that significant reductions in existing pollutant loadings were needed to meet water quality objectives, have been approved by the U.S. EPA. The next step in the TMDL process is to develop a voluntary implementation plan that includes both accountability and the potential for adaptive management. This document identifies a number of alternative actions to be considered by local stakeholders for TMDL implementation; these are summarized in the table below.

Summary of Implementation Alternatives

Alternative	Estimated Cost[1]	Notes
Nutrient Management Plans	$6 to $20/acre	• May lead to cost savings
Conservation Tillage	$12 to $83/acre	
Conservation Buffers	$200 - $360/acre	
Sediment Control Basins	$1,200 to $229,000 per basin, depending on size	
In-lake Control Structures	$554,000 - $683,000	
Shoreline Enhancement & Protection	$5/linear foot for plantings $67-$73/ton for rip-rap	
Streambank Stabilization	$25/foot for lateral bank protection at 51 erosion sites $30/ton for rock riffle grade control Other streambank stabilization projects at priority sites, cost varies depending on nature of site.	Recommended by Illinois Department of Agriculture Additional study required to identify priority sites
Grassed Waterways	$1,800/acre	
Aeration/Destratification	$65,000 - $72,000	
Private Sewage Disposal System Inspection & Maintenance	Variable	• Cost would be low if existing staff could accomplish
Dredging	$6 - $20/cubic yard removed $2.2 million or more per cove in Lake Glenn Shoals	• Only in concert with watershed reductions • Not recommended unless other efforts are unsuccessful
Phosphorus Inactivation	$1,350,000 to $1,755,000 for Lake Glenn Shoals $110,000 to $143,000 for Old Lake Hillsboro	• Only in concert with watershed reductions • Could be prohibitively expensive, especially for Lake Glenn Shoals

[1] Costs expressed in 2006 dollars

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INTRODUCTION

Section 303(d) of the 1972 Clean Water Act requires States to define waters that are not meeting designated uses under technology-based controls and identify them on a list of impaired waters, which is referred to as the 303(d) list. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop Total Maximum Daily Loads (TMDLs) for these impaired water bodies. 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 conditions in the water body. 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 (U.S. EPA, 1991).

Lake Glenn Shoals and Old Lake Hillsboro are listed on the 2004 Illinois Section 303(d) List of Impaired Waters (IEPA, 2004a) as water bodies that are not meeting their designated uses. As such, these lakes were targeted as high priority waters for TMDL development. TMDLs for these lakes have been developed (LTI, 2005a) and approved by the U.S. EPA. The next step in the TMDL process is to develop a voluntary implementation plan that includes both accountability and the potential for adaptive management. Adaptive management recognizes that proceeding with some initial improvement efforts is better than waiting to find a “perfect” solution. In an adaptive management approach, the TMDL and the watershed to which it applies are revisited over time to assess progress and make adjustments that continue to move toward achieving the TMDL’s goals. Adaptive management may be conducted through the implementation of a long-term monitoring plan designed to assess the effectiveness of pollution controls as they are implemented, as well as progress towards attaining water quality standards.

This document presents the implementation plan for the Lake Glenn Shoals/Old Lake Hillsboro watershed TMDLs. It is divided into sections describing the watershed, summarizing the allowable loads and needed reductions identified in the TMDL, describing the implementation strategy, discussing alternatives to reduce the existing loadings of the pollutants of concern, discussing priority areas for targeting efforts, describing reasonable assurances that the measures will be implemented, and outlining future monitoring and adaptive management.

WATERSHED DESCRIPTION

The Glenn Shoals/Hillsboro watershed is located in Central Illinois, approximately 40 miles south of Springfield and 60 miles northeast of St. Louis. Lake Glenn Shoals is a 1,350-acre impoundment constructed in the 1970s for flood control, water supply, and recreational uses. It has an average depth of 10 feet, and nearly 27 miles of shoreline (City of Hillsboro, 2004). Lake Hillsboro, often referred to as the "Old Lake," was created in 1918 (City of Hillsboro, 2004) and served as the primary water supply for the area until construction of Lake Glenn Shoals. Currently, both lakes are used as water supply for the City of Hillsboro and several neighboring communities. Lake Hillsboro has a surface area of approximately 110 acres. The combined drainage area for the two lakes covers 53,039 acres (83 square miles), primarily in Montgomery County. A very small portion of the watershed lies in Christian County.

Figure 1 shows a map of the watershed, and includes waterways, impaired waterbodies, public water intakes, roads, and other key features. The map also shows the location of a point source discharge that has a permit to discharge under the National Pollutant Discharge Elimination System (NPDES). The City of Irving is the sole NPDES discharge in the watershed.

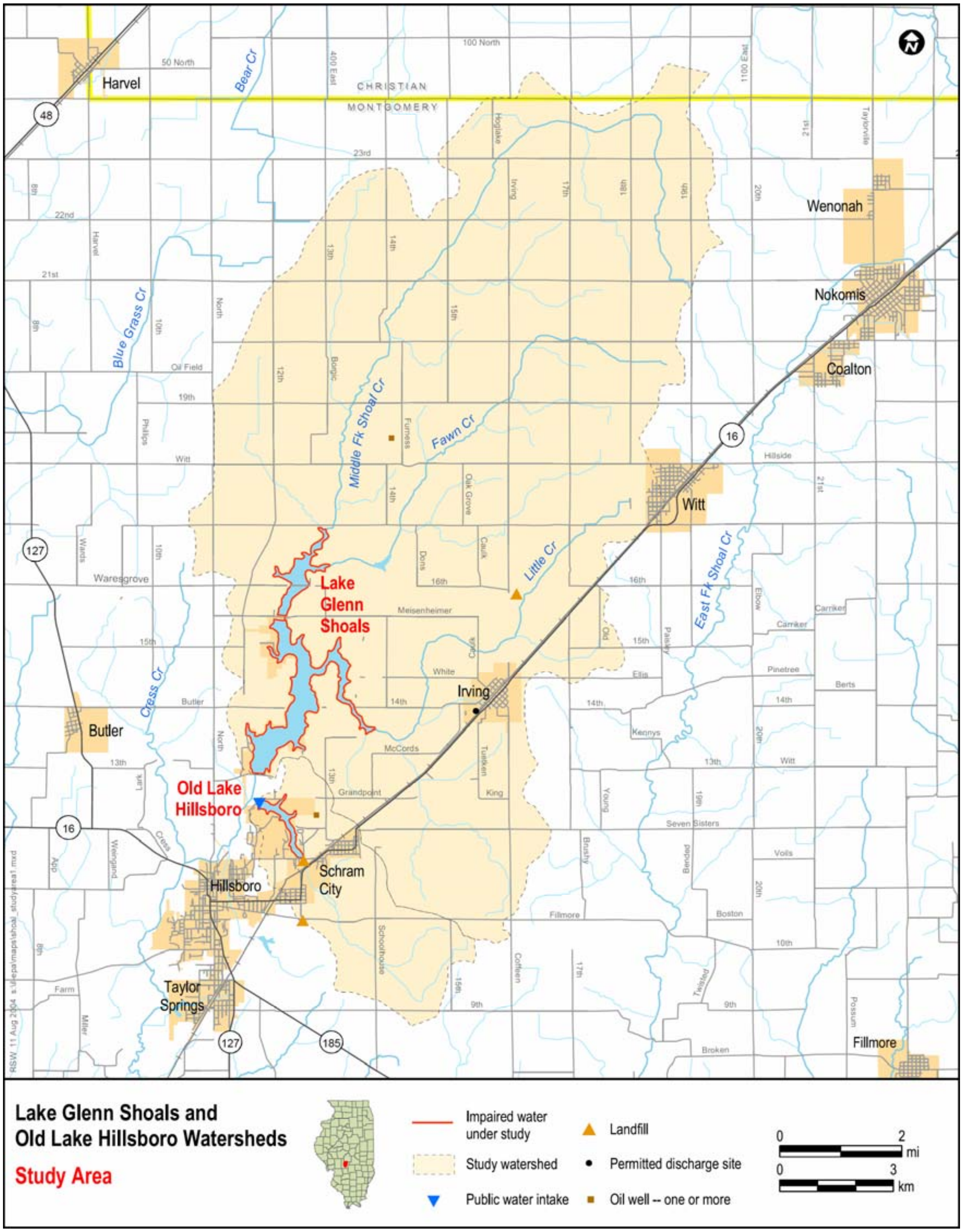

Figure 1. Map of Lake Glenn Shoals and Old Lake Hillsboro Watersheds

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TMDL SUMMARY

The two impaired lakes addressed in this TMDL are listed in Table 1, with the parameters they are listed for, and the use impairments as identified in the 2004 303(d) list (IEPA, 2004). Lake Glenn Shoals is listed on the 2004 303(d) list as impaired, with total phosphorus as a cause, while Old Lake Hillsboro is listed as impaired, with total phosphorus and manganese as causes (IEPA, 2004). Potential sources contributing to the listing of these lakes on the 303(d) list are summarized in Table 2. For phosphorus, these include agricultural sources, release from existing lake bottom sediments under anoxic conditions, recreation activities (golf course and camp sites), and failing private sewage disposal systems. Sources of manganese are background sources due to naturally high concentrations in area soils, and release from existing sediments under anoxic conditions.

Table 1. Summary of Impairments

Lake Glenn Shoals	
Waterbody Segment	ROL
Size (Acres)	1,350
Listed For	**Phosphorus**, total suspended solids, excess algal growth
Use Support[1]	Overall use (F), Aquatic life (F), Fish consumption (F), Public water supply (F), Primary contact (P), Secondary contact (P)
Old Lake Hillsboro	
Waterbody Segment	ROT
Size (Acres)	108.7
Listed For	**Manganese, phosphorus,** total suspended solids, excess algal growth
Use Support[1]	Aquatic life (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)

[1]F=full support, P=partial support, N=nonsupport

Table 2. Waterbody Impairment Causes and Sources

Waterbody	Cause of impairments	Potential Sources
Lake Glenn Shoals (ROL)		
	TOTAL PHOSPHORUS	Runoff from lawns and agricultural lands (fertilized cropland and agricultural land with livestock), failing private sewage disposal systems (septic and surface discharge systems), release from sediments when dissolved oxygen is absent, recreational activities (golf courses and campsites)
Old Lake Hillsboro (ROT))		
	MANGANESE	Natural background sources including runoff and soil erosion and release from sediments when dissolved oxygen is absent
	TOTAL PHOSPHORUS	Runoff from lawns and agricultural lands (fertilized cropland and agricultural land with livestock), failing private sewage disposal systems (septic and surface discharge systems), release from sediments when dissolved oxygen is absent, recreational activities (golf courses and campsites)

TMDLs require targets, numeric endpoints specified to represent the level of acceptable water quality to be achieved by implementing the TMDL. Where possible, the water quality criterion for the pollutant of concern is used as the numeric endpoint. When appropriate numeric standards do not exist or are not practical for TMDL implementation, surrogate parameters must be selected to represent the designated use. TMDL targets were developed to represent each pollutant addressed in these TMDLs.

The water quality standard for phosphorus to protect aquatic life and secondary contact uses in Illinois lakes is 0.05 mg/l; this value was used as the numeric water quality target for both lakes. For manganese, the water quality standard for Illinois waters designated as public water supply is 150 ug/l. The primary source of manganese to the Old Lake Hillsboro is the release of manganese from lake sediments during periods when there is no dissolved oxygen in lake bottom waters. The lack of dissolved oxygen in lake bottom waters is presumed to be due primarily to sediment oxygen demand resulting from the effects of nutrient enrichment, as there are no significant point source discharges to the lake, nor were other significant sources of oxygen demanding materials identified in the watershed characterization (LTI, 2005b). For this reason, release from lake sediments is considered a controllable source and attainment of the total phosphorus standard is expected to result in oxygen concentrations that will reduce sediment manganese flux to natural background levels. The manganese TMDL target was therefore set as a total phosphorus concentration of 0.050 mg-P/l.

The TMDL determined the total allowable load for each lake, as well as the level of reduction needed to achieve the TMDL targets. Table 3 summarizes the existing phosphorus loads to each lake, the total loading capacity (LC) for the lakes, the load allocations (LA) given to non-point source loads, the wasteload allocation (WLA) for point sources, the explicit margin of safety incorporated in the TMDL, and the amount of reduction of existing loads that would be needed to attain the water quality objective.

Table 3. Summary of Glenn Shoals/Hillsboro TMDLs

Lake	Existing Phosphorus Load (kg*)	Allowable Phosphorus Load (kg*)	Waste Load Allocation (kg*)	Load Allocation (kg*)	Margin of Safety (kg*)	Percent Reduction Needed
Glenn Shoals	49,418	7,460	414	6,300	746	85%
Hillsboro	1,883	320	--	288	32	83%

* Total load for the critical period from April through August

IMPLEMENTATION APPROACH

The approach to be taken for TMDL development and implementation is based upon discussions with Illinois EPA and its Scientific Advisory Committee. The approach consists of the following steps, with the first three steps corresponding to TMDL development and the latter two steps corresponding to implementation:

1. Use existing data to define overall existing pollutant loads, as opposed to developing a watershed model that might define individual loading sources.
2. Apply relatively simple models (e.g. BATHTUB) to define the load-response relationship and define the maximum allowable pollutant load that the lakes can assimilate and still attain water quality standards.
3. Compare the maximum allowable load to the existing load to define the extent to which existing loads must be reduced in order to meet water quality standards.
4. Develop a voluntary implementation plan that includes both accountability and the potential for adaptive management.
5. Carry out adaptive management through the implementation of a long-term monitoring plan designed to assess the effectiveness of pollution controls as they are implemented, as well as progress towards attaining water quality standards.

This approach is designed to accelerate the pace at which TMDLs are being developed for sites dominated by nonpoint sources, which will allow implementation activities (and water quality improvement) to begin sooner. The approach also places decisions on the types of nonpoint source controls to be implemented at the local level, which will allow those with the best local knowledge to prioritize sources and identify restoration alternatives. The Association of Illinois Soil and Water Conservation Districts (SWCDs), using Section 319 grant funding, have made available a Watershed Liaison to provide educational, informational, and technical assistance to local agencies and communities. The liaison can assist in establishing local watershed planning groups, as well as acting as an overall facilitator for coordination between local, state, and Federal agencies.

The adaptive management approach to be followed recognizes that models used for decision-making are approximations, and that there is never enough data to completely remove uncertainty. The adaptive process allows decision-makers to proceed with initial decisions based on modeling, and then to update these decisions as experience and knowledge improve.

Steps One through Three described above have been completed, as described in the TMDL report (LTI, 2005a). This plan represents Step Four of the process. Step Five is briefly described in the last section of this document, and will be conducted as implementation proceeds.

IMPLEMENTATION ALTERNATIVES

Based on the objectives for the TMDL, information obtained at the public meetings, ideas presented in the Clean Lakes Study for Lake Glenn Shoals, and experience in other watersheds, a number of alternatives have been identified for the implementation phase of these TMDLs. These alternatives are focused on those sources suspected of contributing phosphorus loads to the lake (agricultural sources, release from existing lake bottom sediments under anoxic conditions, recreation activities such as campsites and a golf course, and failing private sewage disposal systems.) The alternatives include:

- Nutrient Management Plans
- Conservation Tillage
- Conservation Buffers
- Sediment Control Structures
- In-lake Control Structures
- Shoreline Enhancement and Protection
- Streambank Stabilization
- Grassed Waterways
- Aeration/Destratification
- Private Sewage Disposal System Inspection and Maintenance Program
- Dredging
- Phosphorus Inactivation

Each of these alternatives is described briefly below, including information about their costs and effectiveness in reducing phosphorus inputs. Costs have been updated from their original sources, based on literature citations, to 2006 costs using the Engineering News Record Construction Cost Index, as provided by the Natural Resource Conservation Service (NRCS) (http://www.economics.nrcs.usda.gov/cost/priceindexes/index.html).

It should be noted that there is usually a wide range in the effectiveness of the various practices; this is largely due to variations in climate, soils, crops, topography, design, construction, and maintenance of the practices (NRCS, 2006). Establishing the effectiveness of alternatives for phosphorus reduction is complicated by the different forms in which phosphorus can be transported. Some practices are effective at reducing particulate phosphorus, but may exacerbate the transport of dissolved phosphorus, the more bioavailable form (NRCS, 2006).

NUTRIENT MANAGEMENT

Nutrient management plans are designed to minimize nutrient losses from agricultural lands, and therefore minimize the amount of phosphorus transported to the lakes. Because agriculture is the most common land use in the watershed, controls focused on reducing phosphorus loads from these areas are expected to help reduce phosphorus loads delivered to the lakes. The focus of a nutrient management plan is to increase the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and ground waters (EPA, 2003). The majority of phosphorus lost from agricultural land is transported via surface runoff (vs. leaching through the soil, as occurs for nitrogen), mostly in particulate form attached to eroded soil particles. A nutrient management plan identifies the amount, source, time of application, and placement of each nutrient needed to produce each crop grown on each field each year, to optimize efficient use of all sources of nutrients (including soil reserves, commercial fertilizer, legume crops, and organic sources) and minimize the potential for losses that lead to degradation of soil and water quality (UIUC, 2005).

Steps in developing a nutrient management plan include (UIUC, 2005):

- Assess the natural nutrient sources (soil reserves and legume contributions).
- Identify fields or areas within fields that require special nutrient management precautions.
- Assess nutrient needs for each field by crop.
- Determine quantity of nutrients that will be available from organic sources, such as manure or industrial or municipal wastes.
- Allocate nutrients available from organic sources.
- Calculate the amount of commercial fertilizer needed for each field.
- Determine the ideal time and method of application.
- Select nutrient sources that will be most effective and convenient for the operation.

A U.S. Department of Agriculture study reported that average annual phosphorus application rates were reduced by 36 lb/acre when nutrient management practices were adopted (EPA, 2003). Nutrient management is generally effective, but for phosphorus, most fertilizer is applied to the surface of the soil and is subject to transport (NRCS, 2006). In an extensively cropped watershed, the loss of even a small fraction of the fertilizer-applied phosphorus can have a significant impact on water quality.

Costs of developing nutrient management plans have been estimated at $6 to $20/acre (EPA, 2003). These costs are often offset by the savings associated with using less fertilizer. For example, a study in Iowa showed that improved nutrient management on cornfields led to a savings of about $3.60/acre (EPA, 2003).

It is believed that some soil testing is currently being done in the watershed, but it may need to be done more often, and testing should be performed in such a way as to differentiate the sources of the phosphorus (for example, whether the top three inches have high levels), as this will affect the mechanism of transport to the lakes, and the alternatives selected (NRCS, 2005). The Clean Lakes Study for Lake Glenn Shoals (Zahniser Institute, undated) suggested developing a program to pay for soil testing of phosphorus, which might encourage improved nutrient management.

CONSERVATION TILLAGE

The objective of conservation tillage is to provide profitable crop production while minimizing soil erosion (UIUC, 2005). This reduction in erosion also reduces the amount of phosphorus lost from the land and delivered to the lake. The Natural Resources Conservation Service (NRCS) has replaced the term conservation tillage with the term crop residue management, or the year-round management of residue to maintain the level of cover needed for adequate control of erosion. This often requires more than 30% residue cover after planting (UIUC, 2005). Conservation tillage/crop residue management systems are recognized as cost-effective means of significantly reducing soil erosion and maintaining productivity. At the present time, many producers within the Glenn Shoals/Hillsboro watershed are practicing crop residue management (NRCS, 2004). The most recent Illinois Soil Transect Survey (IDOA, 2004) suggests that 94% of land under soybean production and all of the land in small grain production in Montgomery County is farmed using reduced till, mulch till, or no-till, while 76% of corn fields are farmed with conventional methods. Additional conservation tillage measures might want to be considered as part of this implementation plan, particularly for cornfields.

Conservation tillage practices have been reported to reduce total phosphorus loads by 45% (EPA, 2003). In general, conservation tillage and no-till practices are moderate to highly effective at reducing particulate phosphorus, but exhibit low or even negative effectiveness in reducing dissolved phosphorus (NRCS, 2006). A wide range of costs has been reported for conservation tillage practices, ranging from $12/acre to $83/acre in capital costs (EPA, 2003). For no-till, costs per acre provided in the Illinois Agronomy Handbook for machinery and labor range from $36 to $66 per acre, depending on the farm size and planting methods used (UIUC, 2005). In general, the total cost per acre for machinery and labor decreases as the amount of tillage decreases and farm size increases (UIUC, 2005).

CONSERVATION BUFFERS

Conservation buffers are areas or strips of land maintained in permanent vegetation to help control pollutants (NRCS, 1999), generally by slowing the rate of runoff, while filtering sediment and nutrients. Additional benefits may include the creation of wildlife habitat, improved aesthetics, and potential economic benefits from marketing specialty forest crops (Trees Forever, 2005). This category of controls includes buffer strips, field borders, filter strips, vegetative barriers, riparian buffers, etc. (NRCS, 1999).

Filter strips and similar vegetative control methods can be very effective in reducing nutrient transport. The relative gross effectiveness of filter strips in reducing total phosphorus has been reported as 75% (EPA, 2003). Reduction of particulate phosphorus is moderate to high, while effectiveness for dissolved phosphorus is low to negative (NRCS, 2006).

Costs of conservation buffers vary from about $200/acre for filter strips of introduced grasses or direct seeding of riparian buffers, to approximately $360/acre for filter strips of native grasses or planting bare root riparian buffers, to more than $1,030/acre for riparian buffers using bare root stock shrubs (NRCS, 2005).

The Conservation Practices Cost-Share Program (CPP), part of the Illinois Conservation 2000 Program, provides cost sharing for conservation practices including field borders and filter strips (http://www.agr.state.il.us/Environment/conserv/index.html). The Department of Agriculture distributes funding for the cost-share program to Illinois' soil and water conservation districts (SWCDs), which prioritize and select projects. The Illinois Buffer Partnership offers cost sharing for installation of streamside buffer plantings at selected sites. An additional program that may be of interest is the Visual Investments to Enhance Watersheds (VIEW), which involves a landscape design consultant in the assessment and design of targeted BMPs within a watershed. Sponsored by Trees Forever (www.treesforever.org), VIEW guides a committee of local stakeholders through a watershed landscape planning process (Trees Forever, 2005). Additional funding for conservation buffers may be available through other sources such as the Conservation Reserve Program.

SEDIMENT CONTROL BASINS

Sediment control basins trap sediments (and nutrients bound to that sediment) before they reach surface waters (EPA, 2003). The Clean Lakes Study (Zahniser Institute, undated) indicated that the NRCS has identified 26 potential locations for sediment control basins of varying size. These potential sites are scattered throughout the Glenn Shoals watershed, and are generally located in deeply incised draws, where the effects on croplands would be minimized (Zahniser Institute, undated). In addition to controlling sediment, these basins would reduce phosphorus loads to the lakes. The study provides costs ranging from $1,200 to $229,000 per basin, with a total cost for all 26 basins of $546,000. It was estimated that if all 26 basins were constructed and attained a trapping efficiency of 75%, sediment loads to Lake Glenn Shoals would be reduced by 17,250 tons per year (Zahniser Institute, undated). The associated reduction in phosphorus delivered to the lake would be significant.

Storm water detention wetlands might also warrant consideration, as recommended in the Clean Lakes Study (Zahniser Institute, undated). Implementation of storm water wetlands at various locations in the watershed may be feasible where hydric soils exist, but where wetlands, forest or development does not currently exist. This is discussed in more detail in the section “Identifying Priority Areas for Control.” These wetlands would trap sediments and nutrients; the study provides an estimated phosphorus removal rate of 45% (Zahniser Institute, undated). Wetlands have low to moderate effectiveness at reducing particulate phosphorus, and low to negative effectiveness at reducing dissolved phosphorus (NRCS, 2006).

IN-LAKE CONTROL STRUCTURES

The Clean Lakes Study (Zahniser Institute, undated) also recommended in-lake control structures at Meisenheimer Road and Irving Cove. These are weirs that are placed in the lake itself and serve to slow the flow of water while the sediment settles out. The primary objective of these structures would be to reduce sediment, but they would also serve to reduce phosphorus loads to Lake Glenn Shoals. The Clean Lakes Study indicates that such a structure at Meisenheimer Road would divide the lake into two sections and eventually create a wetland in the upper part of the lake.

Expected phosphorus removal rates for these structures range from 10% to 50% (Zahniser Institute, undated). The Clean Lakes Study reported that during the study period, the Irving Cove watershed contributed 32% of the phosphorus load to Lake Glenn Shoals. Thus, controls at this location could provide significant reductions in loads. Estimated costs for these structures are approximately $683,000 for Meisenheimer Road and $554,000 for Irving Cove.

SHORELINE ENHANCEMENT AND PROTECTION

Shoreline erosion has been a problem in this watershed. Sediment derived from shoreline erosion not only increases solids in the lakes and decreases lake volume, but also can increase nutrient loads to the lakes. Significant effort has been invested in shoreline protection in the past, with the City of Hillsboro spending approximately $20,000-$30,000 per year on rip-rap (City of Hillsboro, 2004). The Glenn Shoals Lake Association has also done plantings of cypress and willow for erosion control (GSLA, 2004). Additional shoreline enhancement efforts, such as planting deep-rooted vegetation or installing rip-rap in the remaining unprotected shoreline areas, will provide further protection against erosion and the associated increased pollutant loads. Estimates for rip-rapping are approximately $67-$73/ton (NRCS, 2005), while estimates for plantings at another Illinois lake suggest a cost of approximately $5/linear foot (CMT, 2004).

STREAMBANK STABILIZATION

Erosion of the banks and beds of tributary streams is a potentially significant source of sediment to Lake Glenn Shoals and Old Lake Hillsboro. This sediment load not only leads to sedimentation in the lake, but also contributes to phosphorus loading. Streambank stabilization (including grade stabilization to reduce erosive velocities and shear stresses) is a key measure in reducing loads.

A recent aerial assessment report of Middle Fork Shoal Creek identified streambank erosion as prevalent upstream of Lake Glenn Shoals (IDOA, 2005). This study recommends rock riffle grade control and lateral bank protection to stabilize the banks of Middle Fork Shoal Creek. Using costs presented in the report, the estimated cost to stabilize Middle Fork Shoal Creek 5.1 miles upstream of Lake Glenn Shoals is $449,400.

In addition to the sites recommended in the IDOA report, other sites for streambank stabilization likely exist in the Lake Glenn Shoals and Old Lake Hillsboro watersheds. Because of the potential cost of stabilizing streambanks throughout the watershed, additional study is recommended to prioritize sites for streambank stabilization. Such study should include direct observations of bank conditions, as well as an assessment of stream hydraulics and geomorphology to support identification and design of effective stabilization measures.

GRASSED WATERWAYS

Grassed waterways are another alternative to consider for these watersheds. A grassed waterway is a natural or constructed channel that is planted with suitable vegetation to reduce erosion (NRCS, 2000). Grassed waterways are used to convey runoff without causing erosion or flooding, to reduce gully erosion, and to improve water quality. They may be used in combination with filter strips, and are effective at reducing soil loss, with typical reductions between 60 and 80 percent (Lin et al, 1999). Grassed waterways cost approximately $1,800/acre, not including costs for tile or seeding (MCSWCD, 2006).

AERATION/DESTRATIFICATION

As noted in the TMDL report (LTI, 2005a), the existing sediments are a significant source of both phosphorus and manganese. When dissolved oxygen is absent in the hypolimnion (deep layer) of the lakes, phosphorus and manganese are released from the sediments. Control of this internal load requires either removal of phosphorus (and manganese) from the lake bottom (such as through dredging), or preventing oxygen-deficient conditions from occurring. Aeration of portions of the lakes might be considered as an alternative to increase mixing and improve oxygen levels. Destratifiers have also been installed in other Illinois lakes to prevent thermal stratification, and thus increase oxygen concentrations in the deeper lake waters. Studies have indicated that such systems can significantly improve water quality (Raman et. al, 1998). A destratification system installed in Lake Evergreen in McLean County, a lake significantly larger than Old Lake Hillsboro (754 acres, vs. 110 acres for Old Lake Hillsboro) but smaller than Lake Glenn Shoals (1,350 acres), was effective in improving dissolved oxygen levels throughout the lake, up to the depth of its operation (Raman et al, 1998). The destratifier used on Lake Evergreen cost approximately $72,000 (Raman et al, 1998). The cost of a destratifier or an aeration system has been estimated for another Illinois lake similar in size to Old Lake Hillsboro at $65,000 (CMT, 2004).

PRIVATE SEWAGE DISPOSAL SYSTEM INSPECTION AND MAINTENANCE PROGRAM

Most of the watershed, with the exception of the City of Hillsboro, is unsewered. Due to the topography and geology of the area, unsewered areas primarily use individual surface discharging sewage disposal systems (generally either sand filters with chlorination, or aerobic systems) (MCHD, 2004). It has been estimated that statewide, between 20 and 60 percent of surface discharging systems are failing or have failed (IEPA, 2004b), suggesting that such systems may be a significant source of pollutants. The Montgomery County Health Department maintains detailed records of individual disposal systems. At the present time, these systems are not routinely inspected; inspections occur only when complaints are received (MCHD, 2004). A more proactive program to maintain functioning systems and address nonfunctioning systems could be developed to minimize the potential for releases from private sewage disposal systems. This alternative would require the commitment of staff time for Health Department personnel; cost depends on whether the additional inspection activities could be accomplished by existing MCHD staff or would require additional personnel.

DREDGING

In-place sediments have been identified as significant sources of phosphorus (and manganese, for Old Lake Hillsboro). In addition, sedimentation has reduced the water volume of the lake by an estimated fifteen percent (Zahniser Institute, undated), with a corresponding reduction in the lake’s assimilative capacity. Dredging of the existing sediments is one alternative to address this source. It is, however, an expensive alternative, and would be only a temporary solution; if sediment and phosphorus loads are not reduced in the watershed, it is likely that sedimentation and nutrient flux from the sediments will continue to be a problem in the future. The Clean Lakes Study provided cost estimates for dredging several areas of Lake Glenn Shoals, ranging from $2.2 million to $5.4 million (Zahniser Institute, undated).

PHOSPHORUS INACTIVATION

Phosphorus inactivation involves application of aluminum salts or calcium compounds to the lake to reduce phosphorus in the water column and slow its release from sediments (McComas, 1993). This can be an effective means of mitigating excess phosphorus in lakes and reservoirs (NALMS, 2004). Addition of aluminum sulfate (alum) is most common, but compounds such as calcium carbonate and calcium hydroxide (lime) can also be used (McComas, 1993). When alum is added to lake water, a series of chemical hydrolysis steps leads to the formation of a solid precipitate that has a high capacity to absorb phosphates. This flocculent material settles to the lake bottom, removing the phosphorus from the water column and providing a barrier that retards release of phosphorus from the sediments (NALMS, 2004). Aluminum concentrations in lake water are usually at acceptable levels for drinking water shortly after alum application (NALMS, 2004).

This alternative is best used in combination with a reduction in phosphorus inputs from watershed sources. If the external phosphorus load is being addressed, and most of the phosphorus comes from in-place sediments, a single dose treatment will likely be sufficient (Sweetwater, 2006). If watershed sources are not controlled, repeated treatments will be needed. Often, it is possible to do repeat dosing over several years, giving a partial dose every three to five years (Sweetwater, 2006). Studies have indicated that the effectiveness of alum at controlling internal phosphorus loading in stratified lakes averaged 80% over several years of observation (Welch and Cooke, 1999). Costs for phosphorus inactivation are approximately $1,000 to $1,300 per acre (Sweetwater, 2006). This translates to a cost of $110,000 to $143,000 for Old Lake Hillsboro, and $1,350,000 to $1,755,000 for Lake Glenn Shoals. These costs could be prohibitively expensive for Lake Glenn Shoals, particularly if watershed sources are not addressed. This alternative is therefore primarily recommended for consideration for Old Lake Hillsboro, and only in concert with watershed load reductions.

SUMMARY OF ALTERNATIVES

Table 4 summarizes the alternatives identified for the Glenn Shoals/Hillsboro TMDLs. These alternatives should be evaluated by the local stakeholders to identify those most likely to provide the necessary load reductions, based on site-specific conditions in the watersheds.

Table 4. Summary of Implementation Alternatives

Alternative	Estimated Cost	Notes
Nutrient Management Plans	$6 to $20/acre	• May lead to cost savings
Conservation Tillage	$12 to $83/acre	
Conservation Buffers	$200 - $360/acre	
Sediment Control Basins	$1,200 to $229,000 per basin, depending on size	
In-lake Control Structures	$554,000 - $683,000	
Shoreline Enhancement & Protection	$5/linear foot for plantings $67-$73/ton for rip-rap	
Streambank Stabilization	$25/foot for lateral bank protection at 51 erosion sites $30/ton for rock riffle grade control Other streambank stabilization projects at priority sites, cost varies depending on nature of site.	Recommended by Illinois Department of Agriculture Additional study required to identify priority sites
Grassed Waterways	$1,800/acre	
Aeration/Destratification	$65,000 - $72,000	
Private Sewage Disposal System Inspection & Maintenance	Variable	• Cost would be low if existing staff could accomplish
Dredging	$6 - $20/cubic yard removed $2.2 million or more per cove in Lake Glenn Shoals	• Only in concert with watershed reductions • Not recommended unless other efforts are unsuccessful
Phosphorus Inactivation	$1,350,000 to $1,755,000 for Lake Glenn Shoals $110,000 to $143,000 for Old Lake Hillsboro	• Only in concert with watershed reductions • Could be prohibitively expensive, especially for Lake Glenn Shoals

IDENTIFYING PRIORITY AREAS FOR CONTROLS

Priority areas for locating watershed controls were identified through a review of available information, including: tributary water quality data; an aerial assessment report; and GIS-based information. The findings of this review are summarized below.

TRIBUTARY MONITORING

Tributary data were available for both lakes. Within the Lake Glenn Shoals watershed, measurements collected in 2001 and 2002 show the highest phosphorus concentrations were consistently measured in Little Creek (station ROL04) and a tributary to Little Creek (station ROL05). Although not consistently as high over the 2001-2002 period, measurements collected from Middle Fork Shoal Creek (station ROL02) and Fawn Creek

(ROL03) show an increasing trend over time. Most recent data at these two locations (2002) show phosphorus concentrations surpassing the levels of those measured in Little Creek and the tributary to Little Creek in 2002. The locations of the Glenn Shoals tributary monitoring stations are shown in Figure 2. It is recommended that these locations be sampled again during wet and dry weather to characterize current conditions and identify priority watersheds for implementing controls.

The largest tributary to Old Lake Hillsboro flows from the southeast towards the lake. This is the only tributary that has been monitored. Although not shown in Figure 2, the monitoring location is described as being at the south side of the Route 16 bridge, just upstream of the lake. Phosphorus concentrations measured at this location in 2001 and 2002 all exceed the lake phosphorus standard of 0.05 mg/l. Monitoring at this same location is recommended to characterize current conditions and compare current concentrations to previous measurements. If total phosphorus concentrations have not significantly decreased, then it is recommended that controls be targeted within this watershed.

AERIAL ASSESSMENT REPORT

A 2005 report (IDOA, 2005) examined streambank conditions in Middle Fork Shoal Creek. The two reaches of interest for this implementation plan begin at the upper end of Lake Glenn Shoals and extend upstream for a total of 5.1 miles. Two cross sections measured 2.5 to 5.1 miles upstream of the lake indicate degrading and/or widening of the channel, however, Lake Glenn Shoals backwater is preventing degradation at the other two cross sections, which are located downstream and closer to the lake.

Lateral bank protection is recommended for 28 erosion sites for the reach beginning at the upper end of Lake Glenn Shoals proceeding upstream for 2.5 miles. The cost for implementing these controls in this reach is estimated as $140,000. There is no need for grade control in this reach. For the more upstream reach of Middle Fork Shoal Creek (2.5 miles upstream of the lake to 5.1 miles upstream of the lake), lateral bank protection is recommended at 23 erosion sites and rock riffle grade control is also recommended at 54 locations. The total cost for this second reach is $309,400.

For the entire 5.1-mile reach of Middle Fork Shoal Creek, lateral bank protection and rock riffle grade control is estimated to cost $449,400.

GIS ANALYSIS

GIS soils, land use and topography data were analyzed to identify areas that are expected to generate the highest sediment and associated phosphorus loads. Within the GIS, maps were generated to show areas with steep slopes (Figure 3), highly erodible soils (Figure 4), and finally, priority areas for BMPs (Figure 5). The priority areas are defined as agricultural areas that have both steep slopes and highly erodible soils. Priority areas are logical locations for targeting phosphorus control projects, to maximize the benefit of the controls. Other locations that should be investigated for control projects are those that have either erodible soils or steep slopes, because both of these characteristics make soil more prone to erosion.

GIS analysis was also used to investigate the presence of hydric soils in the Glenn Shoals and Old Lake Hillsboro watershed to determine where wetland restoration or creation would be a viable option. To support this analysis, areas having hydric soils, which are not already developed, forested, or covered by water or wetlands were identified. A significant proportion (19%) of the Lake Glenn Shoals & Old Lake Hillsboro watershed was identified as being potentially suitable for wetland restoration or creation. These areas are shown in Figure 6.

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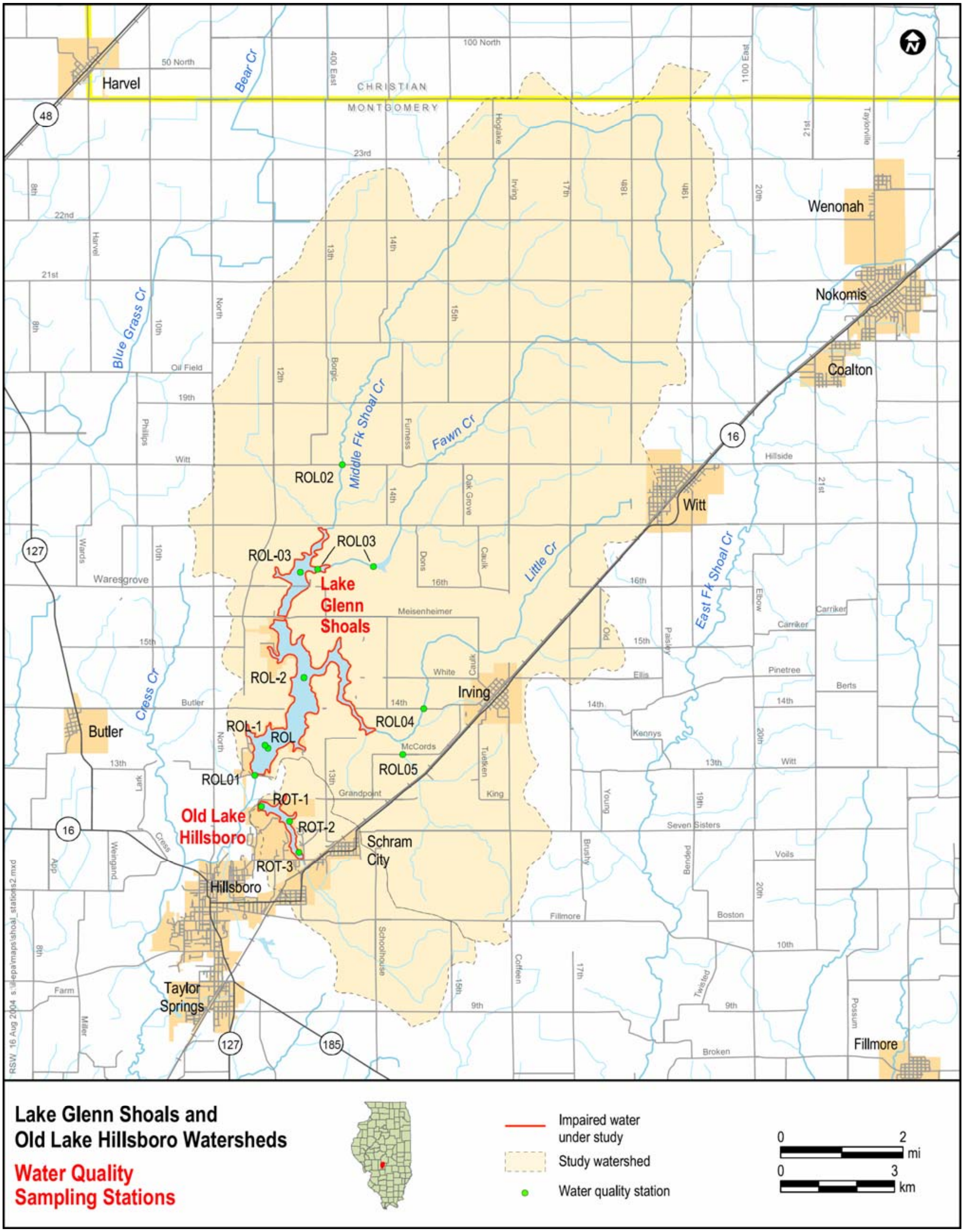

Figure 2. Water Quality Sampling Stations

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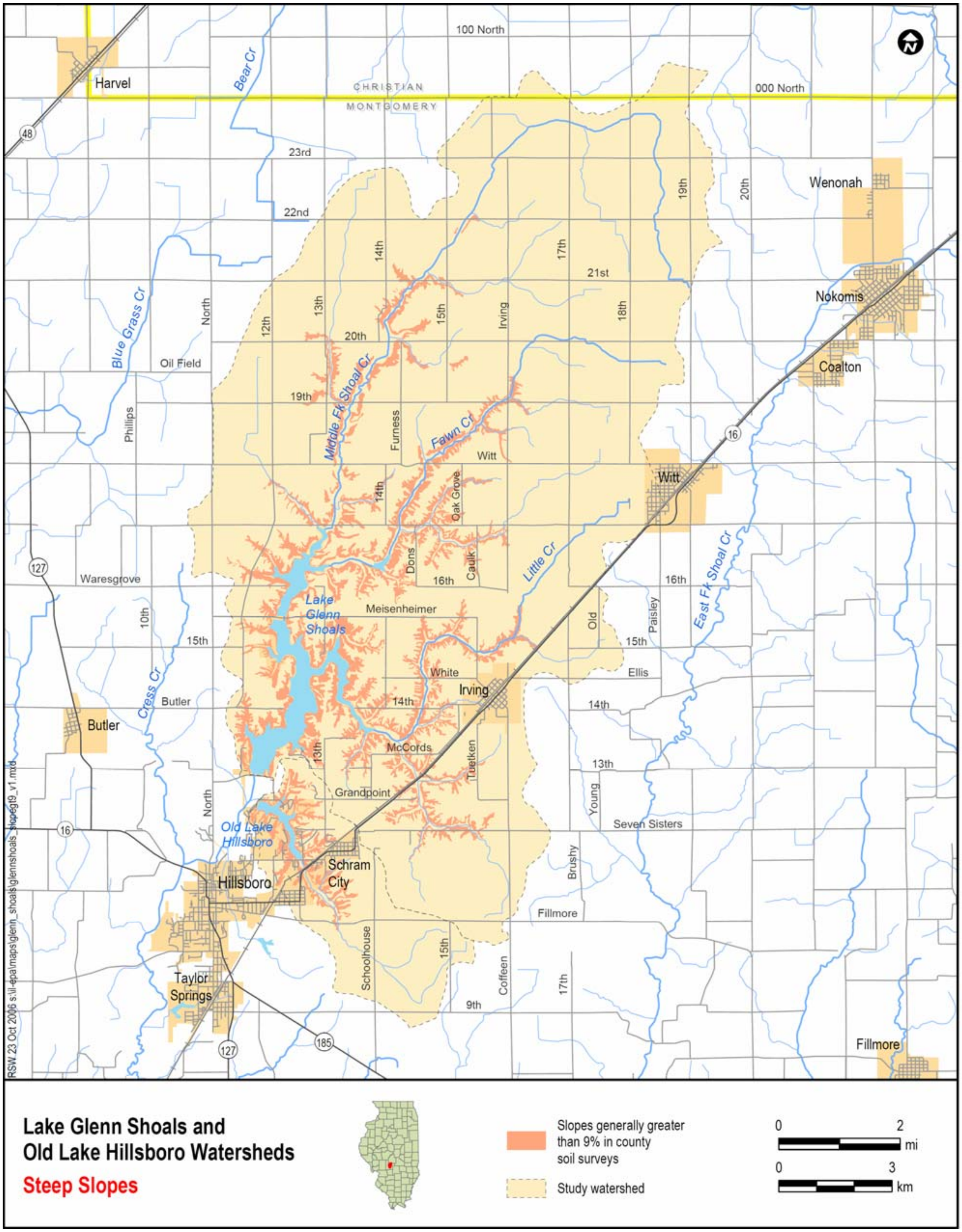

Figure 3. Areas with Steep Slopes

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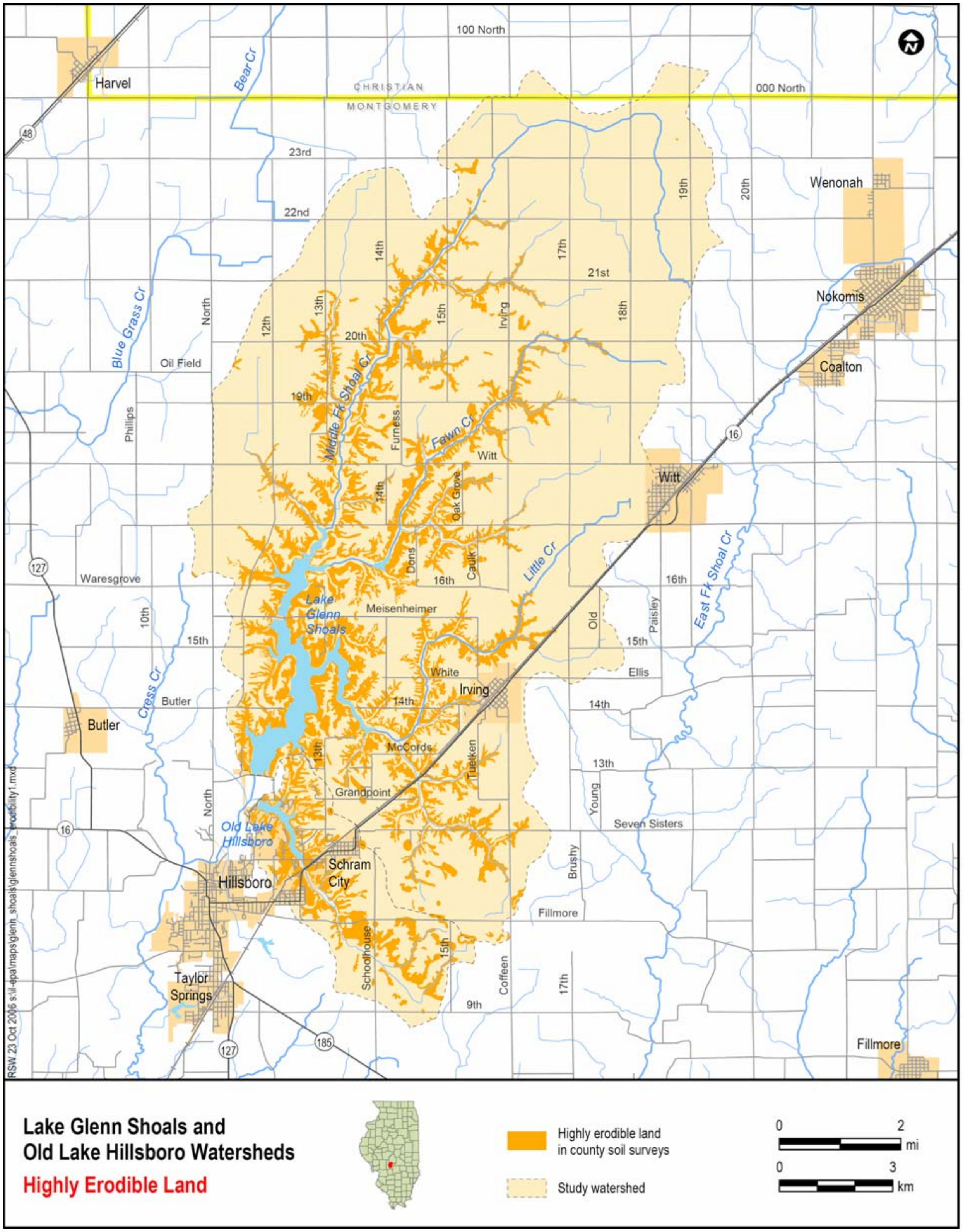

Figure 4. Areas with Highly Erodible Soils

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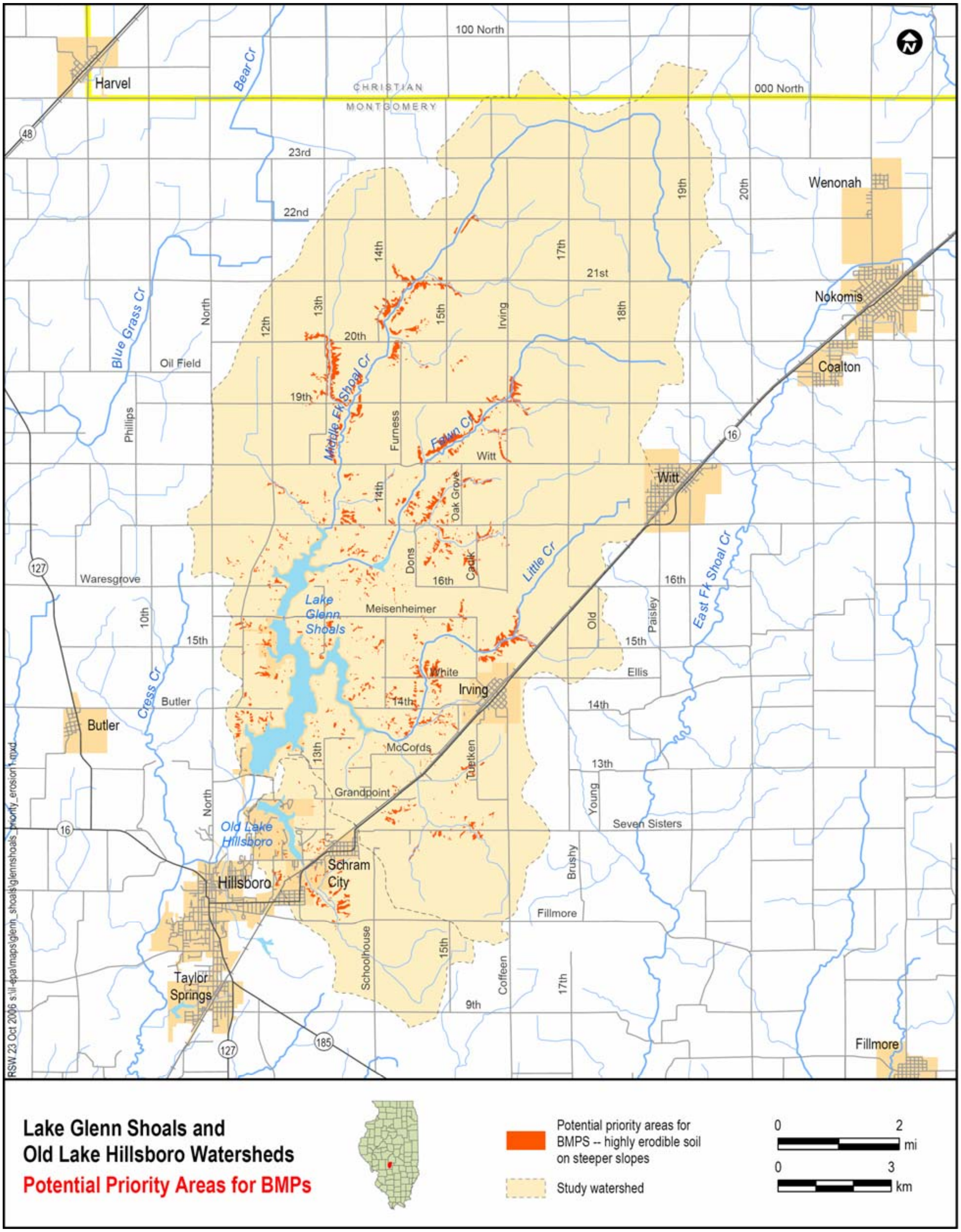

Figure 5. Potential Priority Areas for Best Management Practices

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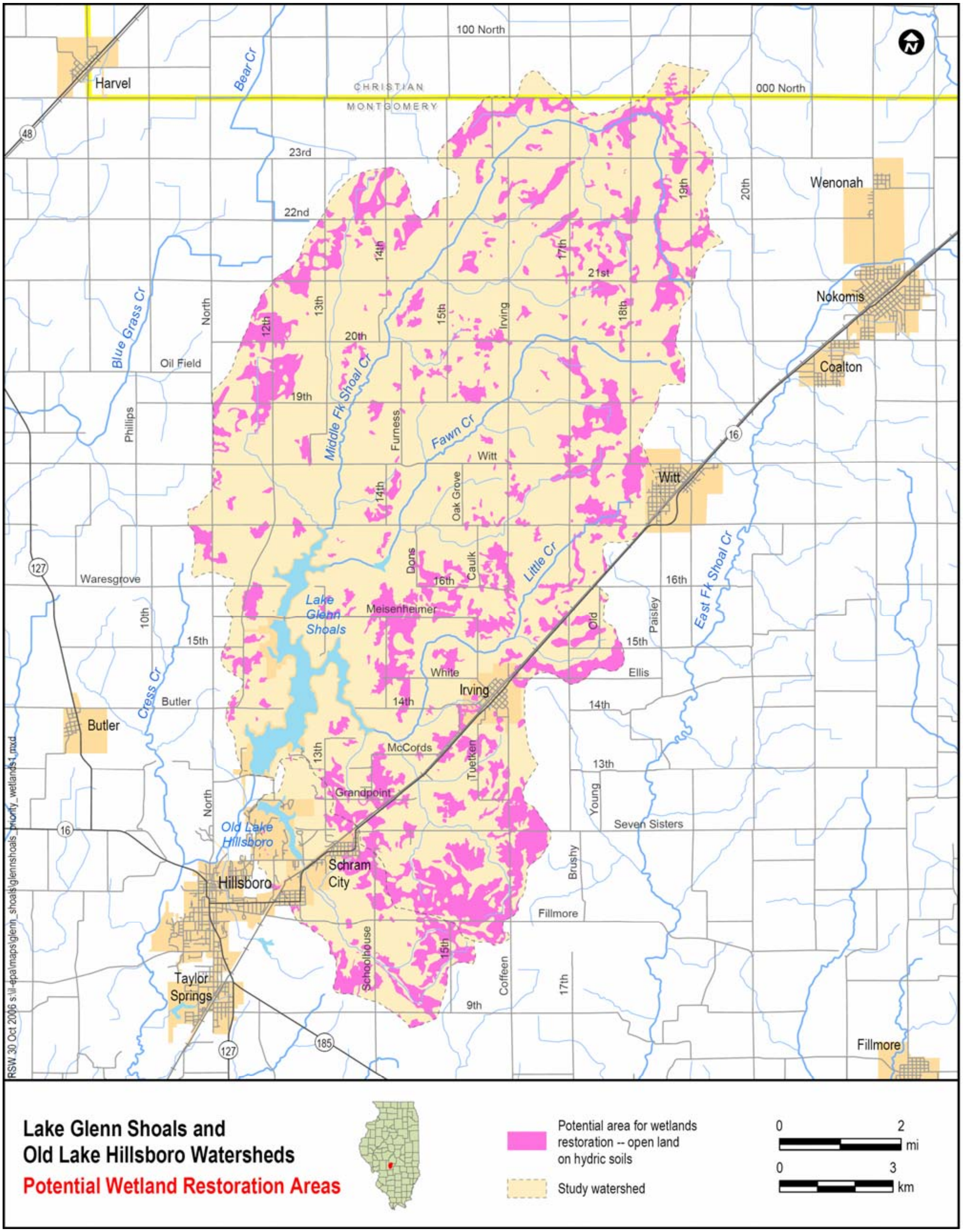

Figure 6. **Potential Wetland Restoration Areas**

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REASONABLE ASSURANCE

The U.S. EPA requires states to provide reasonable assurance that the load reductions identified in the TMDL will be met. Reasonable assurance for point sources means that NPDES permits will be consistent with any applicable wasteload allocation contained in the TMDL. In terms of reasonable assurance for point sources, Illinois EPA administers the NPDES permitting program for treatment plants, stormwater permitting and CAFO permitting. The permit for the only point source discharger in the watershed (Irving WWTP) will be modified if necessary to ensure it is consistent with the applicable wasteload allocation. The current permit for this facility expires December 31, 2007.

For nonpoint sources, reasonable assurance means that nonpoint source controls are specific to the pollutant of concern, implemented according to an expeditious schedule and supported by reliable delivery mechanisms and adequate funding (U.S. EPA, 1999).

One of the most important aspects of implementing nonpoint source controls is obtaining adequate funding to implement voluntary or incentive-based programs. Funding is available from a variety of sources, including the following:

- *Illinois Nutrient Management Planning Program*, cosponsored by the Illinois Department of Agriculture (IDOA) and IEPA (http://www.agr.state.il.us/Environment/LandWater/tmdl.html). This program targets funding to Soil and Water Conservation Districts (SWCDs) for use in impaired waters. The nutrient management plan practice cost share is only available to landowners/operators with land in TMDL watersheds. The dollar amount allocated to each eligible SWCD is based on their portion of the total number of cropland acres in eligible watersheds.
- *Clean Water Act Section 319 grants* to address nonpoint source pollution (http://www.epa.state.il.us/water/financial-assistance/non-point.html). Section 319 of the Clean Water Act provides Federal funding for states for the implementation of approved nonpoint source (NPS) management programs. Funding under these grants has been used in Illinois to finance projects that demonstrate cost-effective solutions to NPS problems. Projects must address water quality issues relating directly to NPS pollution. Funds can be used for the implementation of watershed management plans, including the development of information/education programs, and for the installation of best management practices.
- *Conservation 2000* (http://www.epa.state.il.us/water/conservation-2000/), which funds nine programs across three state natural resource agencies (IEPA, IDOA, and the Department of Natural Resources). Conservation 2000 is a six-year, $100 million initiative designed to take a broad-based, long-term ecosystem approach to conserving, restoring, and managing Illinois' natural lands, soils, and water resources while providing additional high-quality opportunities for outdoor recreation. This program includes the Priority Lake and Watershed Implementation Program and the Clean Lakes Program.

- *Conservation Practices Cost-Share Program*. Another component of Conservation 2000, the Conservation Practices Program (CPP) focuses on conservation practices, such as terraces, filter strips and grass waterways, that are aimed at reducing soil loss on Illinois cropland to tolerable levels. IDOA distributes funding for the cost-share program to Illinois' SWCDs, which prioritize and select projects. Construction costs are divided between the state and landowners.
- *Conservation Reserve Program* administered by the Farm Service Agency (http://www.nrcs.usda.gov/programs/crp/). The Conservation Reserve Program (CRP) provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. CRP is administered by the Farm Service Agency, with NRCS providing technical land eligibility determinations, conservation planning and practice implementation.
- *Wetlands Reserve Program* (http://www.nrcs.usda.gov/programs/wrp/). NRCS's Wetlands Reserve Program (WRP) is a voluntary program offering landowners the opportunity to protect, restore, and enhance wetlands on their property. The NRCS provides technical and financial support to help landowners with their wetland restoration efforts. This program offers landowners an opportunity to establish long-term conservation and wildlife practices and protection. Within the Lake Glenn Shoals/Old Lake Hillsboro watershed, nineteen percent of the soils are hydric and are not currently developed, covered by water or forested. These are potential wetland restoration areas and are shown in Figure 6.
- *Environmental Quality Incentive Program* sponsored by NRCS (general information at http://www.nrcs.usda.gov/PROGRAMS/EQIP/; Illinois information and materials at http://www.il.nrcs.usda.gov/programs/eqip/). The Environmental Quality Incentives Program (EQIP) provides a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical assistance to eligible participants to install or implement structural and management practices on eligible agricultural land. EQIP may cost-share up to 75 percent of the costs of certain conservation practices. Incentive payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the incentive.
- *Wildlife Habitat Incentives Program* (WHIP) (http://www.il.nrcs.usda.gov/programs/whip/index.html). WHIP is a NRCS program for developing and improving wildlife habitat, primarily on private lands. It provides both technical assistance and cost-share payments to help establish and improve fish and wildlife habitat.

In terms of reasonable assurances for nonpoint sources, Illinois EPA is committed to:

- Convene local experts familiar with nonpoint sources of pollution in the watershed

- Ensure that they define priority sources and identify restoration alternatives
- Develop a voluntary implementation plan that includes accountability
- Use the results of future monitoring to conduct adaptive management.

MONITORING AND ADAPTIVE MANAGEMENT

Future monitoring is needed to assess the effectiveness of the various restoration alternatives and conduct adaptive management. The Illinois EPA conducts a variety of lake and stream monitoring programs (IEPA, 2002). Ongoing stream monitoring programs include: a statewide 213-station Ambient Water Quality Monitoring Network; an Intensive Basin Survey Program that covers all major watersheds on a five-year rotation basis; and a Facility-Related Stream Survey Program that conducts approximately 20-30 stream surveys each year. The ongoing Illinois EPA Lake Monitoring Program includes: an Ambient Lake Monitoring Program that samples approximately 50 lakes annually; an Illinois Clean Lakes Program that typically monitors three to five projects each year; and a Volunteer Lake Monitoring Program that encompasses over 170 lakes each year. Lake Glenn Shoals is considered a core lake and is monitored approximately every three years. Old Lake Hillsboro is not a core lake; however; because it is a public water supply, it does receive precedence for monitoring. Beyond this IEPA monitoring, local agencies and watershed organizations are encouraged to conduct additional monitoring to assess sources of pollutants and evaluate changes in water quality in the lakes.

These ongoing efforts will provide the basis for assessment of the effectiveness of the TMDLs, as well as future adaptive management decisions. As various alternatives are implemented, the monitoring will determine their effectiveness and identify which alternatives should be expanded, and which require adjustments to meet the TMDL goals.

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