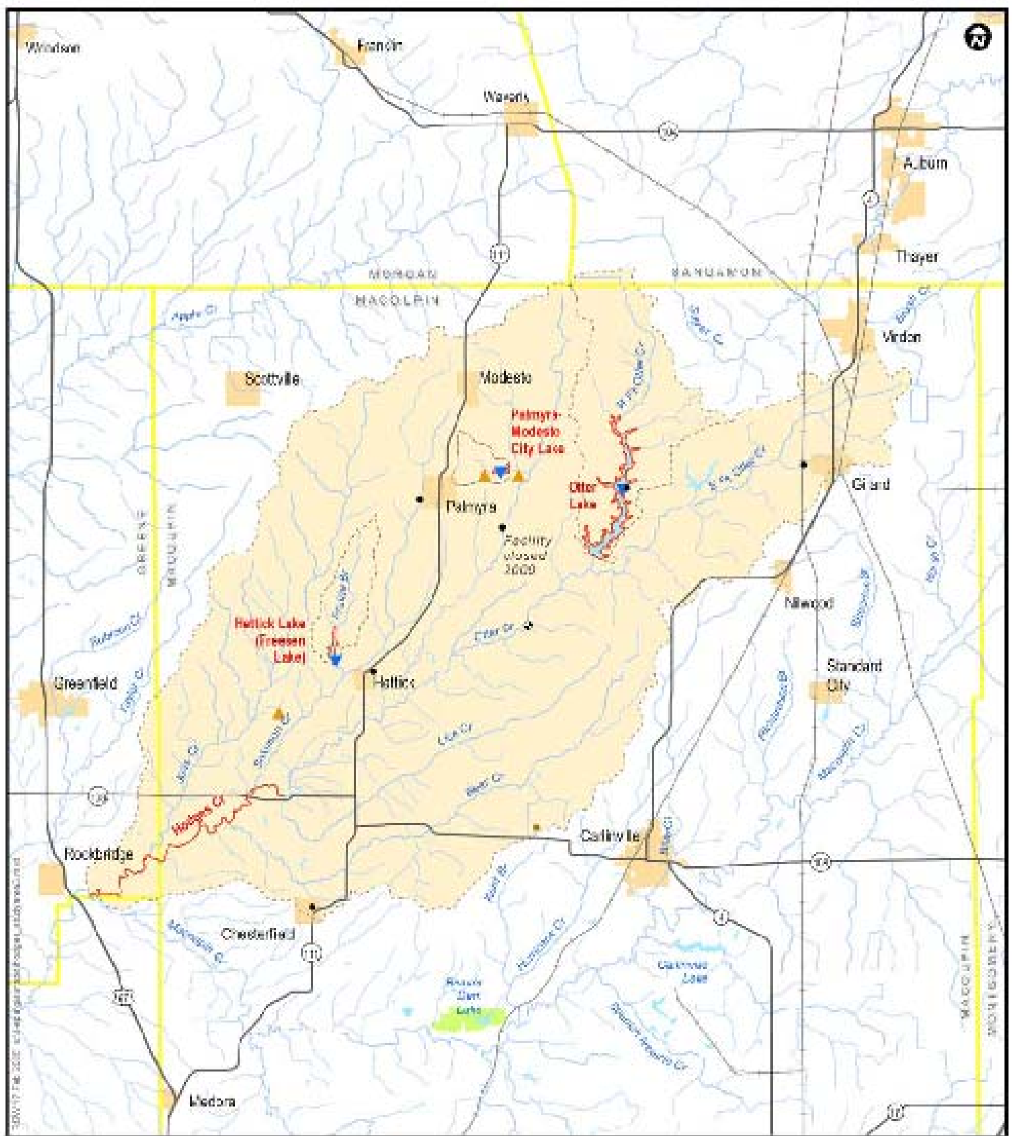
Illinois
Environmental
Protection Agency

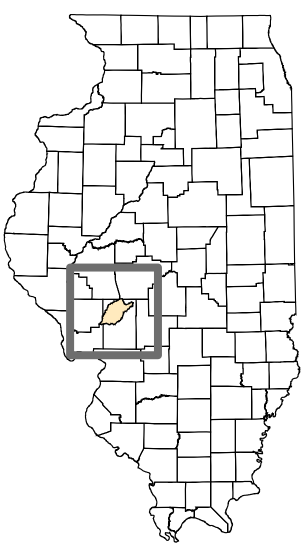
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

November 2006

IEPA/BOW/07-002

HODGES CREEK WATERSHED TMDL REPORT





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

SEP 28 2005

REPLY TO THE ATTENTION OF
WW-16J

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

RECEIVED
OCT 11 2005
Watershed Management Section
BUREAU OF WATER

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Load (TMDL) for the impaired segments in the Hodges Creek watershed (SDZF, RDF, and RDZP) including supporting documentation and follow up information. IEPA's submitted TMDLs address the presence of elevated levels of phosphorous that impairs the General Use and the Public Water Supply Use in Hettick Lake, Otter Lake, and Palmyra-Modesto Lake (Segments SDZF, RDF, and RDZP) in the Hodges Creek watershed. Based on this review, U.S. EPA has determined that Illinois's TMDLs for phosphorous 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 Illinois's 3 TMDLs for the impaired segments in the Hodges Creek watershed (SDZF, RDF, and RDZP). The statutory and regulatory requirements, and U.S. EPA's review of Illinois's compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois's effort in this submitted TMDL, 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,

Jo Lynn Traub
Director, Water Division

Enclosure

cc: Bruce Yurdin, IEPA

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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

DEC 07 2006

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

RECEIVED-BOW
DEC 14 2006
Infrastructure Financial
Assistance Section

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the submittal, "Hodges Creek TMDL," dated August 2006, from the Illinois Environmental Protection Agency (IEPA). Thank you for the submittal. Hodges Creek (IL_DAG-02) in Illinois is listed as impaired due to low dissolved oxygen on the IEPA 2006 303(d) list. The submittal indicates that the cause of the low dissolved oxygen impairment in the water is due to low flow.

U.S. EPA is not taking formal action pursuant to Section 303(d)(2) of the Clean Water Act to approve or disapprove this submittal. It is U.S. EPA's position that total maximum daily loads (TMDLs) are required by the Clean Water Act only for pollutants that are causing or contributing to the impairment of a water quality limited segment (WQLS). Section 303(d)(1) of the Act requires States to identify water quality limited segments, and to establish TMDLs for such waters for "those pollutants" U.S. EPA identifies as suitable for such calculation. The Act in turn defines "pollutants" to include various materials discharged into water. See § 502(6). We interpret the definition of "pollutant" in the Act as excluding low flow, such as those causing the impairment of Hodges Creek, since low flow is not covered by the list of materials in this definition. Therefore, since TMDLs are required only for pollutants, and low flow is not a pollutant, no TMDL for low flow is required for Hodges Creek under the Act or U.S. EPA regulations. The Act requires U.S. EPA to approve or disapprove those TMDLs established under § 303(d)(1)(C) and submitted to the Agency. We interpret this obligation as applying only to those TMDLs required to be established by States and submitted to U.S. EPA. Since U.S. EPA's obligation under the Act is to approve or disapprove only those TMDLs established under § 303(d)(1)(C), we do not believe we are required to take action on this submission.

Although we are not taking official action under section 303(d), we agree that the implementation efforts will help improve water quality, and support the State in its implementation. We look forward to discussing the various options available in addressing this water during the next 303(d) listing cycle.

If you have any questions, please contact Mr. Kevin Pierard, Chief of the Watersheds and Wetlands Branch at 312-886-4448.

Sincerely yours,

Jo Lynn Traub
Director, Water Division

cc: Bruce Yurdin, IEPA
Dean Studer, IEPA

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IMPLEMENTATION PLAN

Final Stage 1 Progress Report

Prepared for Illinois Environmental Protection Agency

April 2005

Hodges Creek Watershed

Hodges Creek (DAG 02), Otter Lake (RDF),
Palmyra-Modesto Lake (RDZP), Hettick Lake (SDZF)

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First Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

August 2004

Hodges Creek Watershed

Hodges Creek (DAG 02), Otter Lake (RDF),
Palmyra-Modesto Lake (RDZP), Hettick Lake (SDZF)

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EXECUTIVE SUMMARY

This is the first in a series of quarterly status reports documenting work completed on the Hodges Creek 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, which is available on the web at: http://www.epa.state.il.us/water/tmdl/303d-list.html. The Clean Water Act requires that a TMDL be completed for each pollutant listed for an impaired waterbody. A TMDL is a report that is submitted by the States to the EPA. In the TMDL report, a determination is made of the greatest amount of a given pollutant that a waterbody can receive without violating water quality standards and designated uses, considering all known and potential sources. The TMDL also takes into account a margin of safety, which reflects scientific uncertainty, as well as the effects of seasonal variation.

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

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

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

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 causes of impairment that are included on the draft 2004 303(d) list.

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

- For **Hodges Creek (Segment DAG 02)**, data are considered sufficient to support the causes listed on the draft 2004 303(d) list, and a dissolved oxygen TMDL is warranted. However, it should be noted that this listing of dissolved oxygen as a cause was based on two measurements taken in 2001. Factors affecting low dissolved oxygen typically include sediment oxygen demand, degradation of CBOD, or nitrification of ammonia. Nutrients, ammonia and BOD may be originating from municipal point sources, failing private sewage disposal systems (septic and surface discharge systems), and runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock). A CAFO that closed in 2000 had a permit for a waste lagoon and manure pit overflow. Legacy amounts of oxygen-demanding substances from this facility may remain in the creek sediments, and this CAFO is another potential source contributing to the low dissolved oxygen. Low flows in late summer months may also contribute to low dissolved oxygen concentrations in this segment.

- For **Otter Lake (RDF),** data are considered sufficient to support the causes listed on the draft 2004 303(d) list, and a manganese TMDL is warranted. The observed manganese concentrations in the lake likely reflect natural background conditions (soils in the watershed are naturally high in manganese) and release from lake bottom sediments under anoxic conditions. For this reason, the general use criteria may be difficult to attain.
- For **Palmyra-Modesto Lake (RDZP),** data are sufficient to support the listings for manganese and dissolved oxygen on the draft 2004 303(d) list, and TMDLs are warranted. The pH data were collected between 1998 and 2000 and the data to support the listing for pH indicate one exceedance of the criteria (recorded in 2000). The observed manganese concentrations in the lake are likely caused by runoff from the watershed (soils in the watershed are naturally high in manganese) and release from lake bottom sediments. Because the manganese concentrations reflect natural background conditions, the general use criteria for manganese may be difficult to attain. The low dissolved oxygen is due to hypolimnetic anoxia in the lake. Potential sources contributing to the low dissolved oxygen include sediment oxygen demand, nutrients, ammonia and BOD from failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock). Exceedance of the pH criteria may be due to excess algal production due to nutrient loadings from the watershed. Potential sources of nutrients include failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock).
- For **Hettick Lake (SDZF),** data are sufficient to support the causes listed on the draft 2004 303(d) list, and total phosphorus and dissolved oxygen TMDLs are warranted. Potential sources of total phosphorus include runoff from lawns and agricultural lands (fertilized cropland and agricultural land with livestock), failing private sewage disposal systems (septic and surface discharge systems) and release from sediments under hypolimnetic anoxic conditions. Potential sources of low dissolved oxygen include sediment oxygen demand and the nutrient sources mentioned above as potentially contributing phosphorus to the lake.

INTRODUCTION

This Stage 1 report describes initial activities related to the development of TMDLs for impaired waterbodies in the Hodges Creek watershed. Stage 1 efforts included watershed characterization activities and data analyses, to confirm the causes and sources of impairments in the watershed. This section provides some background information on the TMDL process, and Illinois assessment and listing procedures. The specific impairments in waterbodies of the Hodges Creek 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 2004), 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) will be strictly voluntary.

Illinois Assessment and Listing Procedures

Water quality assessments in Illinois are based on a combination of chemical (water, sediment and fish tissue), physical (habitat and flow discharge), and biological (macroinvertebrate and fish) data. Illinois EPA conducts its assessment of water bodies using a set of five generic designated use categories: public water supply, aquatic life, primary contact (swimming), secondary contact (recreation), and fish consumption

(IEPA, 2004). 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, 2004).

List of Identified Watershed Impairments

The impaired waterbody segments included in the project watershed are listed in Table 1 below, with the parameters they are listed for, and the use impairments as identified in the draft 2004 303(d) list (IEPA, 2004). TMDLs are currently only being developed for pollutants that have numerical water quality standards. Sources that are listed for pollutants that exceed statistical guidelines are not subject to TMDL development at this time. Table 1 provides information on the targeted waterbodies, including size, causes of impairment, and use support (partial support, full support, nonsupport). Those impairments that are the focus of this report are shown in bold font in Table 1.

The remaining sections of this report include:

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

Table 1. Impaired Waterbodies in the Hodges Creek Watershed

Waterbody Segment	Waterbody Name	Size (miles/acres)	Year Listed	Listed for[1]	Use Support[2]
DAG 02	Hodges Creek	10.7	2002	**Dissolved oxygen**	Aquatic life (P)
RDF	Otter Lake	765	1996	**Manganese**, excess algal growth	Aquatic life (F), Fish consumption (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)
RDZP	Palmyra-Modesto Lake	35	1994	**Manganese, dissolved oxygen, pH**, excess algal growth	Aquatic life (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)
SDZF	Hettick Lake	110	1996	**Total phosphorus, dissolved oxygen**, excess algal growth, unspecified nutrients	Aquatic life (F), Fish consumption (F), Overall use (P), Primary contact (P), Secondary contact (P)

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

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

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WATERSHED CHARACTERIZATION

The purpose of watershed characterization was to obtain information describing the watershed to support the identification of sources contributing to manganese, total phosphorus, low dissolved oxygen, and pH impairments. Watershed characterization activities were focused on gaining an understanding of key features of the watershed, including geology and soils, climate, land cover, hydrology, urbanization and population growth, point source discharges and watershed activities. 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. On December 11, 2003 a meeting was held with Regional and State-level EPA staff and a site visit was conducted later the same day. A second site visit was conducted on June 27-28, 2004 and a meeting was held with the Executive Director (Rhonda Koehne) and the District Conservationist (John Ford) at the Macoupin County Soil and Water Conservation District offices in Carlinville.

The first step in watershed characterization was to delineate the watershed boundaries for three lakes and Hodges Creek in GIS, using topographic and stream network (hydrography) information. Next, 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 and gas wells,
- coal mines,
- dams,
- data collection locations, and
- location of 303(d) listed lakes and streams.

To better describe the watershed and obtain information related to active local watershed groups, data collection efforts, agricultural practices, and septic systems, calls were placed to county-level officials at the Soil and Water Conservation District and the County Health Department. Several calls were also made to Illini Feeders and the University of Illinois Extension to obtain information on Illini Feeders and determine whether it is still operational. Illini Feeders was a concentrated animal feeding operation that was operational in the watershed until May 2000. Other information compiled for this task related to climate, population growth and urbanization. A list of data sources and calls is included in Appendix A.

Hodges Creek Watershed General Characterization

The impaired waterbodies addressed in this report are all located within the Hodges Creek watershed, which is located in West-Central Illinois approximately 45 miles south of Springfield. The majority of Hodges Creek's watershed is in Macoupin County (97%), with small portions extending into Greene, Jersey, Morgan, and Sangamon County. The watershed for Hodges Creek is approximately 148,961 acres (233 square miles) in size. Figure 1 shows a map of the watershed, and includes key features such as waterways, impaired waterbodies, and public water intakes. The map also shows the locations of point source discharges that have a permit to discharge under the National Permit Discharge Elimination System (NPDES). As shown in this figure, the Hodges Creek watershed is roughly bisected by route 111, with route 108 passing through the southern portion of the watershed.

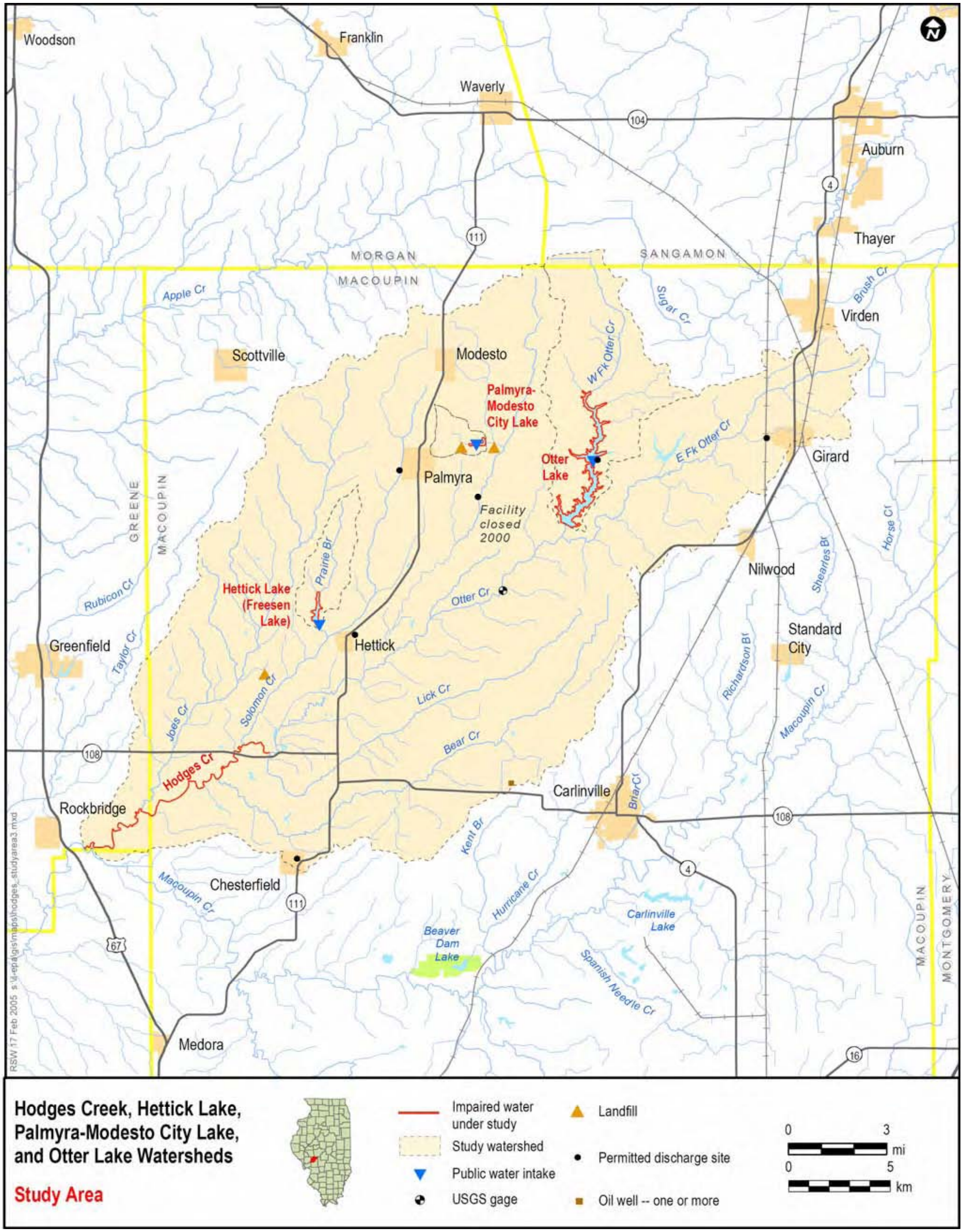

Figure 1. Base Map of Hodges Creek Watershed

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The following sections provide a broad overview of the characteristics of the Hodges Creek watershed. Specific information about the smaller subwatersheds for impaired waterbodies follows the general overview.

Geology and Soils

Information on soils and geology was compiled in order to understand whether the soils are a potential source of manganese. During the Pleistocene era, the Hodges Creek watershed was covered by glacier. After the glacier receded, the land was nearly level, so uplands in the Hodges Creek watershed typically have low relief. The elevation at the most upstream portion of the watershed is approximately 700 feet above mean sea level (AMSL), and the elevation drops to approximately 470 AMSL feet at the confluence with Macoupin Creek.

Figure 2 shows the major soil associations in the Hodges Creek watershed. Each association has a distinctive pattern of soils, relief, and drainage. Typically, an association consists of one or more major soils and some minor soils (USDA, 1990). Deposits of glacial drift average 50 feet thick in Macoupin County, but in some areas, the drift is nearly 200 feet thick over bedrock valleys that trend east to west across the drainage. The loess or silt covering the drift is 50-100 inches thick and is highly erodible (USDA, 1990). There have been ongoing efforts to reduce erosion through various programs, as described below. The most common sediments found in the subsurface of the watershed are diamicton, consisting of a compact mixture of clay, silt, and sand particles. This dense, compact sediment, when exposed in stream banks, can be involved in slumping and minor landslides. Detail on the geology and soils in Macoupin County can be found in the Macoupin County Soil Survey (USDA, 1990) and the *Upper Macoupin Creek Watershed Restoration Action Strategy Report* (Macoupin County SWCD, 2003).

Many of the soils in the Hodges Creek watershed 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, as discussed in later sections of this report.

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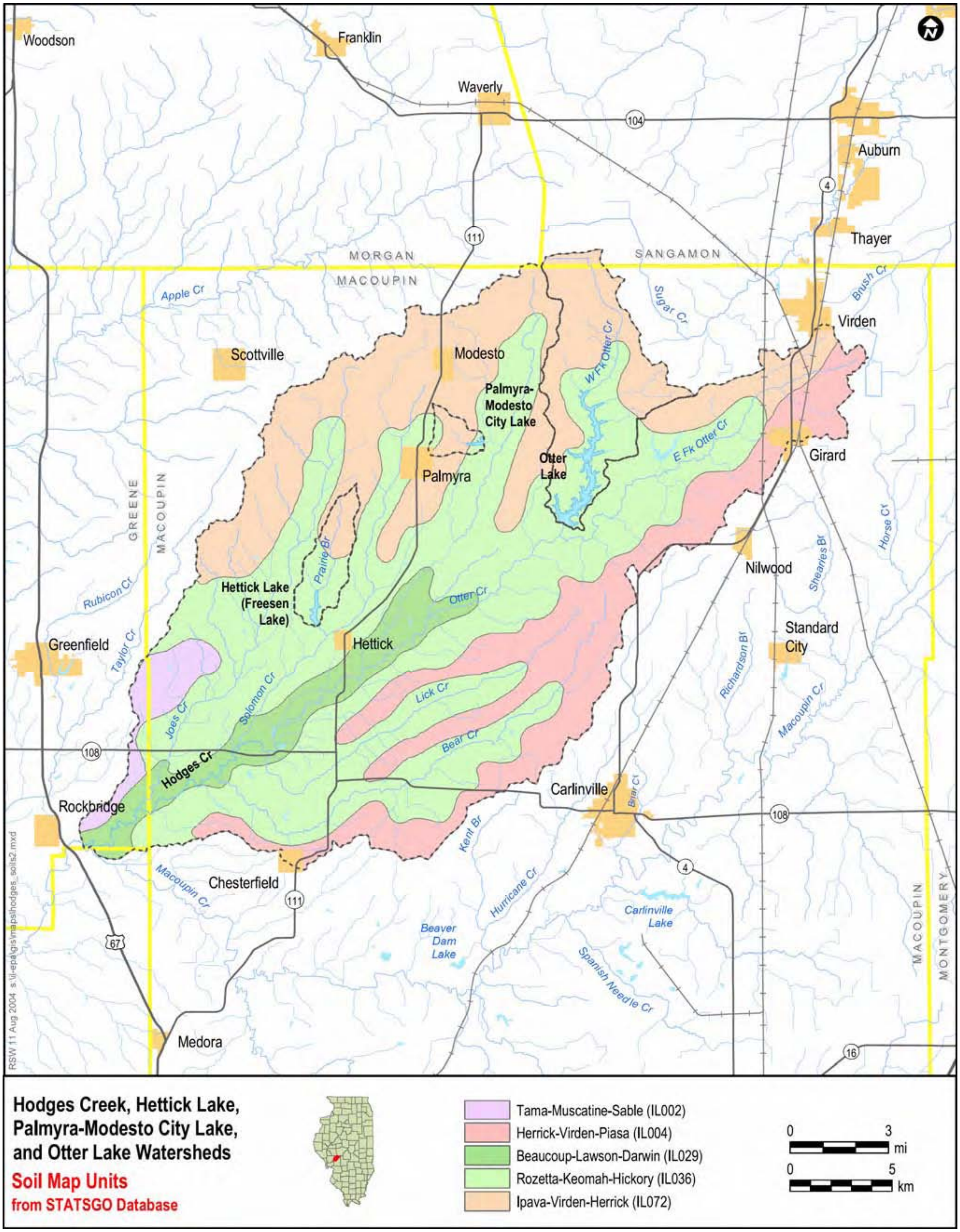

Figure 2. Soils Associations in the Hodges Creek Watershed

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Climate

Climate information was obtained and summarized to support the watershed characterization and gain an understanding of runoff characteristics for this study area. The Hodges Creek watershed has a temperate climate with cold, snowy winters and hot summers. The National Weather Service (NWS) maintains a weather station at Carlinville 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 recorded at Carlinville (Station 111280) is approximately 39 inches. The maximum annual precipitation is 58.14 inches (1927) and the minimum annual precipitation is 21.94 inches (1976). On average there are 114 days with precipitation of at least 0.01 inches and 9 days with precipitation greater than 1 inch. Average snowfall is approximately 20.7 inches per year.

Average maximum and minimum temperatures recorded at Carlinville are 34.9^{o} F and 17.4^{o} F, in January and 87.3^{o} F and 66.6^{o} F in July. These averages are based on measurements collected between 1971 and 2000. The average temperature recorded in January is 26.2^{o} F and the average temperature recorded in July is 77.0^{o} F.

Land Cover

Runoff from the land surface contributes pollutants to nearby receiving waters. In order to understand sources contributing to the waterbody impairments, it was necessary to characterize land cover in the watershed. Land cover in the Hodges Creek watershed in 1999-2000 is shown in Figure 3, and listed in Table 2. The predominant land cover in the watershed is agriculture, shown in yellow on the map. Approximately 72% of the watershed is cropland. The second most common land cover is forest, which covers approximately 16% of the watershed. As shown in Figure 3, much of the forested land is concentrated around the small tributaries and river corridors.

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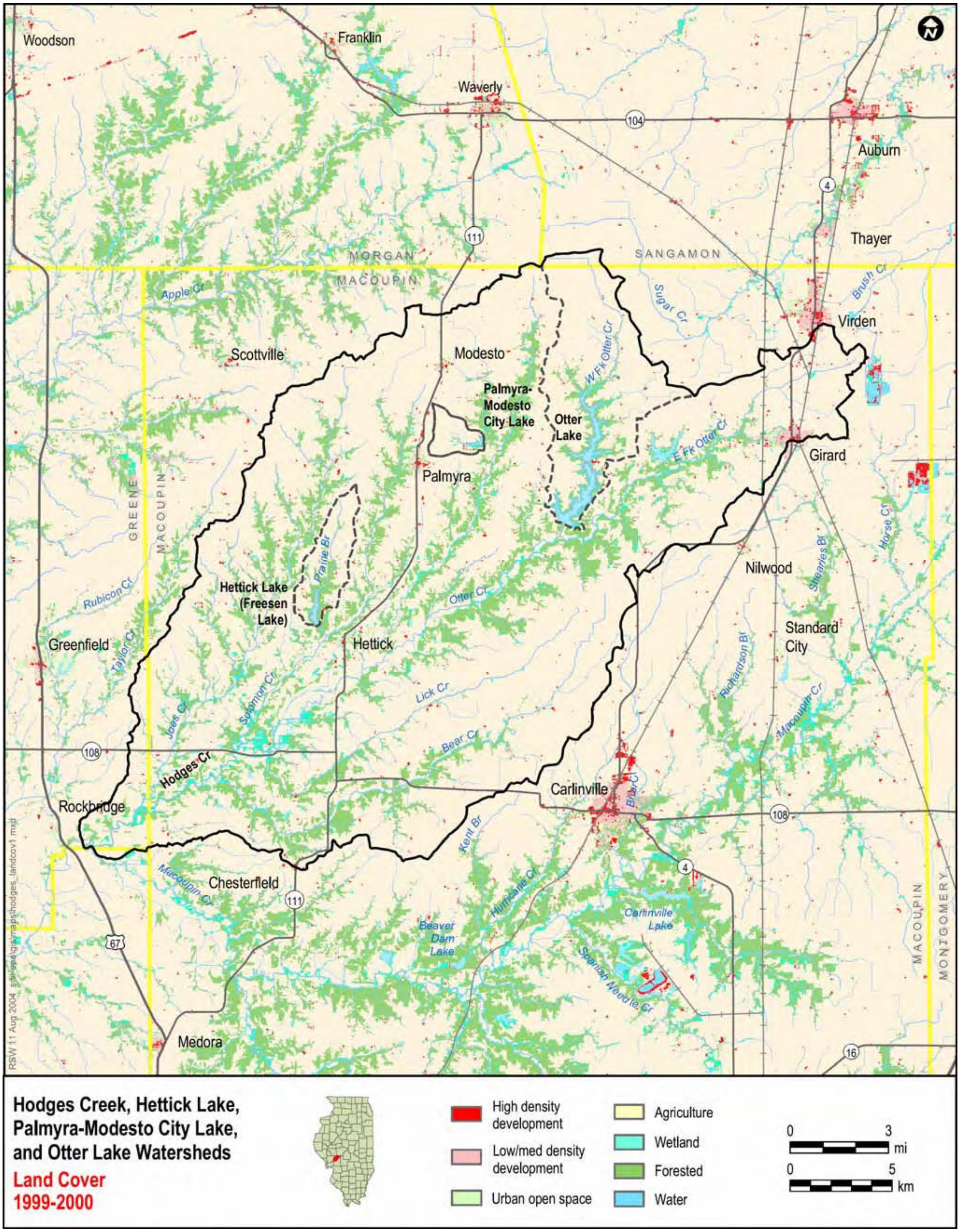

Figure 3. Land Cover in Hodges Creek Watershed 1999-2000

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Table 2. Land Cover in Hodges Creek Watershed

Land Cover Type	Area (acres)	Percent of Watershed Area
Agriculture	107,594	72.2%
Forest	23,345	15.7%
Grassland	10,491	7.0%
Urban	2,474	1.7%
Water	1,051	0.7%
Wetland	3,978	2.7%
Barren Land	27	0.0%
Totals	**148,961**	**100.0%**

Most farms in Macoupin County have a corn-soybean rotation, and some farmers include wheat in their rotations. Based on an analysis of 1999-2000 land cover data, agricultural land is dominated by soybeans (48%) and corn (46%), with lesser amounts of winter wheat, other small grains and hay. A recent report by the Illinois Department of Agriculture (IDA, 2002) reports tillage practices by crop type for Macoupin County, as shown below in Table 3. Most of the corn (91%) and 20% of the soybeans are tilled using conventional methods that leave little or no residue on the surface. Approximately 6% of the corn and 37% of the soybeans are tilled by reduced or mulch-tillage methods, which can reduce soil loss in comparison to conventional methods by 30%. The remaining 4% of corn croplands and 43% of soybean crops are planted without any tillage prior to planting, a process that can reduce soil loss by up to 75%. The majority of the small grains are planted without any tillage, with 38% planted using conventional tillage methods.

Table 3. Tillage Practices in Macoupin County by Crop Type

Percent of Fields, by crop, with indicated tillage system

	Conventional Till[1]	Reduced-Till[2]	Mulch-Till[3]	No-Till[3]
Corn	91	4	2	4
Soybean	20	23	14	43
Small grain	38	0	0	63

[1] Residue level 0 – 15%
[2] Residue level 16-30%
[3] Residue level > 30%

Erosion is a problem in Macoupin County. The *Upper Macoupin Creek Watershed Restoration Action Strategy* reports the results of an erosion/sedimentation inventory that was conducted for the Macoupin Creek watershed, which is similar to the Hodges Creek watershed in terms of geology, soils, and topography. The study found that an estimated 74% of the erosion comes from sheet and rill erosion for all the different land covers in the watershed.

The green areas on Figure 3 show forested lands (approximately 16% of the watershed), which are both upland (generally oak-hickory) and floodplain (mixed composition). Also shown on the map (in red) are areas of low/medium and high density development (approximately 2% of the watershed).

Hydrology

The only flow gage identified in the watershed was a USGS flow gage on Otter Creek near Palmyra (05586800). The drainage area at this gage is reported to be 61.1 mi^2 and this gage was operable from October 1959 through October 1980. It is not currently operable. Water temperature and air temperature measurements were also collected at this location from 1974-1980. A review of the available flow data, found that during the period 1959-1980, Otter Creek flow ranged from 0 to 3670 cfs, with the average and median flow rates calculated as 39 cfs and 4 cfs, respectively. This indicates that this stream is intermittent, and very flashy, with flows increasing significantly during wet weather.

Urbanization and Growth

Urbanization and growth are two factors that can affect the amount and quality of runoff from land surfaces and which also affect the demand on water and sewage treatment facilities. The Hodges Creek watershed encompasses portions of four counties and six communities. The majority of the Hodges Creek watershed lies within Macoupin County (97%), with lesser portions in Greene, Jersey and Montgomery Counties. The six communities are Chesterfield, Girard, Hettick, Modesto, Palmyra, and Virden. Four of these communities have populations under 1000 (2002 population estimate, http://www.city-data.com/city/Illinois3.html). Virden and Girard are the largest of these communities with populations of 3,465 and 2,228, respectively (http://www.city-data.com/city/Illinois2.html).

The State of Illinois Population Trends Report (State of Illinois, 1997) provides projected population trends by county. For Macoupin County, where most of the watershed is located, the population is expected to increase by approximately 9% between 2000 and 2020.

Point Source Discharges

Permit information is available for four entities that are permitted to discharge treated wastewater to Hodges Creek or its tributaries. In addition, there is one water treatment plant permitted to discharge filter backwash. Another facility, Illini Feeders, is a confined animal feeding operation (CAFO) that has an expired permit for a waste lagoon and manure pit overflow and through several calls it was determined that this facility closed in 2000 and is no longer operable. Because of the potential that this facility contributed to the low dissolved oxygen measured in Hodges Creek in 2001, it is included in Table 4, even though it is no longer operable. Table 4 provides a list of permittees and parameters that are permitted to be discharged from these outfalls, and permit expiration dates.

Table 4. NPDES Discharges and Parameters

Facility Name	NPDES ID	Pipe Description	Average Design Flow (MGD)	Permitted to Discharge	Permit expiration date
Girard WWTP	IL0028932	Excess flow (>1.375 MGD) STP outfall	0.55	Fecal coliform, BOD_5, $CBOD_5$, Flow, total ammonia nitrogen, pH, total suspended solids	8/31/04
Otter Lake Water Commission WTP	IL0042552	Filter backwash	0.045	Flow, pH, total suspended solids	7/31/08
Illini Feeders	IL0063436	East waste lagoon overflow Manure pit overflow West waste lagoon overflow	N/A	No permit information available	Permit expired 5/31/2000 Facility is closed
Chesterfield STP	IL0071331	STP outfall	0.026	BOD_5, $CBOD_5$, flow, pH, total suspended solids	11/30/06
Palmyra STP	ILG580177	STP outfall	0.12	BOD_5, $CBOD_5$, flow, pH, total suspended solids	12/31/07
Hettick STP	ILG580219	STP outfall	0.0282	BOD_5, $CBOD_5$, flow, pH, total suspended solids	12/31/07

N/A = Not available

Septic Systems and Surface Discharges

Through a call with the Macoupin County Health Department, it was determined that most towns have sewers, except probably Modesto. There is quite a bit of development going on in the county, with Macoupin County being one of the top counties in Illinois issuing new septic permits. In addition to septic systems, surface discharges are used for waste disposal. Macoupin County has approximately 3,000 surface systems. A surface system discharges waste directly, after minimal treatment, to the ground's surface, a collection tile, a natural drainage way, or body of water. These systems, if not inspected and maintained, are prone to failure, resulting in a discharge of raw sewage These systems have the potential to contribute significant amounts of nutrients, bacteria and BOD to nearby waterbodies (Sierra Club publication, undated). .

Watershed Activities

Local agencies and institutions with an interest in watershed management will be important for successful implementation of this TMDL. The *Upper Macoupin Creek Watershed Restoration Action Strategy* (WRAS) prepared by the Macoupin County Soil and Water Conservation District (Macoupin County SWCD) in 2003 compiled information on agencies and organizations that are active in the region. State agencies currently active in Macoupin County are Illinois Department of Agriculture (IDA), Illinois Department of Natural Resources (IDNR), and the Illinois Environmental Protection Agency (IEPA). The USDA/NRCS in conjunction with the Macoupin County

Soil and Water Conservation District offers landowners programs to cost-share for conservation plans and best management practices. These include programs such as the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP). The Illini Valley Resource Conservation & Development Council (RC&D), which is not yet federally authorized and is currently in the formation process, will provide additional technical support for natural resource related practices in Macoupin County (and other counties). Volunteer programs currently active in the area include:

- RiverWatch (IDNR)
- Acres for Wildlife (IDNR)
- Volunteer Lake Monitoring Program (ILEPA)
- Conservation Practice Program – CPP (IDA)

There are several Federally-funded Section 319 projects in the Hodges Creek watershed. These are described in IEPA (2003) and are summarized below.

- Specific water quality issues, primarily siltation and atrazine of two public water supply lakes were addressed through the construction of thirteen water and sediment control basins in the Otter Lake and/or Palmyra/Modesto Lake watersheds. The Macoupin County SWCD was the local partner for this project.
- The Association of Illinois Soil and Water Conservation District (AISWCD) subcontracted with eleven SWCDs to hire staff to facilitate the enrollment process of the Conservation Reserve Enhancement Program (CREP) by setting appointments with producers to discuss CREP and conduct field visits to determine program eligibility. This project is focused in three of the four counties that the Hodges Creek watershed traverses (Greene, Montgomery and Macoupin).
- Section 319 funding will be used to design and construct a low water sedimentation control structure in the north end of Otter Lake. This structure will provide a controlled sediment basin, controlling sediment and associated pollutants entering from the West Fork of Otter Creek. The local partner is the Otter Lake Water Commission and this project runs from 3/15/03 through 2/28/05.
- In 1998 and 1999, funding was provided to the ADGPTV Water Commission and the Otter Lake Water Commission for two projects to address Otter Lake shoreline erosion. This funding was provided through the Illinois Clean Lakes Program and the Priority Lake and Watershed Implementation Program.
- In 1998, funding was provided to the Palmyra-Modesto Water Commission to control shoreline erosion for Palmyra-Modesto Lake. This funding was provided through the Priority Lake and Watershed Implementation Program.

Hodges Creek (DAG 02) Watershed Characterization

Hodges Creek extends from its point of origin north of Chesterfield to its confluence with Macoupin Creek. The creek is 10.7 miles in length and its watershed is 148,961 acres in size. The creek flows through forest lands and open agricultural areas and flows downstream to the confluence with Macoupin Creek. It receives water from Otter Creek, Solomon Creek, Joe’s Creek, Lick Creek, Bear Creek and several unnamed small creeks. Otter, Hettick and Palmyra-Modesto Lakes are located in the Hodges Creek watershed.

Hodges Creek flows through Macoupin County and the southeast corner of Greene County. There are six communities in this subwatershed: Chesterfield, Girard, Hettick, Modesto, Palmyra, and Virden. As discussed previously, the largest of these communities are Virden and Girard. Land cover information for the Hodges Creek watershed was provided above in Table 2. All of the NPDES-permitted dischargers identified in Table 4 are located within the Hodges Creek watershed. Photos are provided in Appendix B. The Hodges Creek watershed is the same as the entire project watershed previously described and therefore, the general discussion of the project study area also applies to the Hodges Creek watershed.

Otter Lake (RDF) Watershed Characterization

Otter Lake is located west of Girard, Illinois and about 20 miles southwest of Springfield. The lake is 765 acres in size and its watershed is approximately 12,818 acres in size. The lake is an impoundment on Otter Creek. Construction of Otter Lake was completed in 1968. The ADGPTV Water Commission owns and manages Otter Lake and a strip of land around the lake's perimeter. More than 90 percent of the strip is in trees or vegetative cover (Farnsworth et al., 1998). Otter Lake is a public water supply, and it also supports recreational activities such as camping, fishing and boating. The lake also features an underwater search and rescue training area (Farnsworth et al., 1998). The average depth is 19.7 feet, and at its deepest point, the lake is approximately 50 feet deep (Illinois State Water Survey, 1999).

The soils of the Otter Lake watershed are predominantly Ipava-Virden and Hickory-Rozetta-Keomah Associations (see Figure 2). These soils are formed in loess, alluvium, and glacial material. In upland areas of the watershed, slopes range from nearly level to gently sloping. Slopes are very steep in the incised stream valley sides (Illinois State Water Survey, 1999). As described below, many of the soils series contain manganese and iron accumulations and are acidic, thus facilitating the mobilization of the manganese. The Ipava and Virden series are poorly drained, moderately slowly permeable soils on low, broad ridges or flats in uplands. Few fine rounded very dark gray accumulations of iron and manganese oxides are found in the Ipava series at depths of 21 to 60 inches. These soils are also slightly acid to neutral in pH. Manganese and iron accumulations and concretions are also found in the Virden series at depths of 28 to 60 inches, with this series also being slightly acid to neutral in pH (NRCS, 1990). The Hickory series consists of well drained, moderately permeable soils on side slopes of drainageways in the uplands with slopes ranging from 10-60 percent. This series is very strongly acid and has few fine manganese and iron oxide accumulations at depths of 13 to 45 inches. The Rozetta series consists of moderately well drained, moderately permeable soils on ridges and side slopes in uplands. Manganese and iron oxides are noted at depths of 6 to 60 inches in these strongly acid soils. The Keomah series consists of somewhat poorly drained, slowly permeable and moderately permeable soils on broad ridges in the uplands with slopes ranging form 0 to 2 percent. Few fine manganese and iron accumulations are noted at depths between 24 and 50 inches in these slightly to strongly acid soils.

Inflow to the lake is primarily from surface drainage from Otter Creek and smaller tributaries, runoff and direct precipitation. Groundwater inflow to the lake is believed to be limited. The lake has experienced degradation problems from agricultural chemicals including atrazine, siltation, and shoreline erosion. Efforts to stabilize the shoreline and construct sediment control structures for this lake to address sedimentation and atrazine issues were described previously in the "watershed activities" section of this report. Other activities in the Otter Lake watershed, were identified through a review of Farnsworth et al. (1998). This article discusses the implementation of various controls in the Otter Lake watershed, to reduce atrazine loading to the lake. In addition to the projects previously highlighted, this report identified several projects in process as of fall 1998, which were targeted at reducing atrazine loading. Some of these are listed below:

- Twenty-seven farmers filed conservation plans at the local NRCS office, including practices such as nutrient and pest management and some form of conservation tillage. Ten of the 27 plans included the conversion of cropland adjacent to streams to filter strips.
- Other farmers adopted conservation systems, typically mulch till or no-till and lengthened their rotations.

The only point source discharge in this watershed is the Otter Lake Water Commission's water treatment plant, which has a permit to discharge filter backwash to Otter Lake.

Land cover for the Otter Lake subwatershed is provided in Table 5. Approximately 77% of the land is used for agriculture, and approximately 9% is forested. The primary agricultural land use is corn (56%) and soybeans (42%), with lesser amounts of winter wheat, other small grains and hay. Erosion is a problem in the watershed, because of highly erodible soils in hayland, pasture, and woodland uses. The total erosion rate in the watershed is approximately 27,585 tons per year (Illinois State Water Survey, 1999). Photos are provided in Appendix B.

Table 5. Land Cover in Otter Lake Subwatershed

Land Cover	Area (acres)	Percent of Watershed
Agriculture	9,857	76.9%
Forest	1,196	9.3%
Water	653	5.1%
Grassland	632	4.9%
Wetland	362	2.8%
Urban	118	0.9%
Barren	0	0%
Total	**12,818**	**100.0%**

Palmyra-Modesto Lake (RDZP) Watershed Characterization

Palmyra-Modesto Lake is located east of Palmyra and approximately 20 miles southwest of Springfield. The lake is a public water supply. The lake is 35 acres in size and the watershed (shown as a dotted line on Figure 1) is small, covering a total of 1,080 acres, or 1.7 square miles. Land cover for the Palmyra-Modesto Lake listed in Table 6. Approximately 82% of the land is used for agriculture, with the primary crops being soybeans (57%) and corn (39%). There are lesser amounts of winter wheat, other small grains and hay. There are two landfills located in this watershed. One of these is still active, with the other being closed with no monitoring requirements. This closed landfill is identified as Terry Park. Soils in the Palmyra-Modesto watershed are primarily comprised of the Ipava-Virden-Herrick association, with lesser portions of the watershed underlain by the Rozetta-Keomah-Hickory soil association. These soil associations contain manganese accumulations, and are described in more detail in the previous section, which discusses soils in the Otter Lake watershed. Photos are provided in Appendix B.

Table 6. Land Cover in Palmyra-Modesto Lake Subwatershed

Land Cover Type	Area (acres)	Percent of Watershed
Agriculture	888	82.2%
Grassland	87	8.0%
Wetland	32	3.0%
Water	32	2.9%
Forest	26	2.4%
Urban	16	1.4%
Barren	0	0.0%
Total	**1,080**	**100.0%**

Hettick Lake (RDZF) Watershed Characterization

Hettick Lake is also referred to as Freesen Lake. It was formerly a water supply for Hettick, but it is no longer used for this purpose. The lake is approximately 110 acres in size. Its subwatershed is 2,794 acres (4.4 square miles) in size. The land surrounding the lake is largely forested and there is a Boy Scout camp on the lake. Siltation has been an ongoing problem in the lake, and recent measures to reduce loadings of sediment have not been successful (personal communication, Rhonda Koehne).

Land cover for the Hettick Lake subwatershed is listed in Table 7. Approximately 67% of the land is used for agriculture and 20% is forested. The primary crops are soybeans (65%) and corn (28%) with lesser amounts of winter wheat, other small grains and hay. Photos of Hettick Lake are provided in Appendix B.

Table 7. Land Cover in Hettick Lake Subwatershed

Land Cover Type	Area (acres)	Percent of Watershed
Agriculture	1,873	67.0%
Forest	556	19.9%
Grassland	238	8.5%
Water	70	2.5%
Wetland	39	1.4%
Urban	18	0.6%
Total	**2,795**	**100%**

DATABASE DEVELOPMENT AND DATA ANALYSIS

A water quality database was developed and the data were analyzed to confirm the sufficiency of the data to support both the listing decision and the sources of impairment that are included on the draft 2004 303(d) list.

Data Sources and Methods

All readily available existing data to describe water quality in the impaired waterbodies were obtained. All data were either provided by the Illinois EPA in electronic or hard copy format or obtained from the STORET or STORET Modern databases. IEPA data was from the IEPA ambient water quality monitoring program and IEPA NPDES monitoring data. Flow data collected by the United Stated Geological Survey (USGS) were also obtained. All available and relevant data were then compiled in electronic format along with sample location and collection information, in a project database. A list of data sources is included in Appendix A.

The water quality data were analyzed to confirm the 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. Data were first compiled and basic statistics for each parameter were computed. The data were then compared to relevant water quality standards based on beneficial use. Related parameters were also analyzed to understand sources of impairment (e.g., total phosphorus data were reviewed for waterbodies with dissolved oxygen impairments).

A summary of readily available water quality data for the watershed is presented in Table 8 below, including the period of record and data ranges. Sampling station locations are shown in Figure 4.

Table 8. Water quality data summary for the Hodges Creek watershed

Waterbody segment	Parameter	Sampling station	Period of record (#)	Minimum	Maximum	Average
Otter Lake (RDF)	Manganese (ug/l)	RDF-1	8/1996-10/2000 (9 samples)	32	2800	641
		RDF-2	8/1996-1/1997 (4 samples)	49	1400	715
		RDF-3	8/1996-1/1997 (2 samples)	58	130	94
		RDF-4	7/2000-8/2003 (5 samples)	31	320	140
Hodges Creek (DAG 02)	Dissolved oxygen (mg/l)	DAG 03	8/2001-9/2001 (2 samples)	3.6	4.41	4.00
Palmyra-Modesto Lake (RDZP)	Manganese (ug/l)	RDZP-1	5/2000 (1 sample)	73	73	73
		RDZP-2	6/2000-10/2000 (4 samples)	66	720	344
	Dissolved oxygen (mg/l)	RDZP-1	4/1998-10/2000 (155 samples)	0.1	13	4.3
		RDZP-2	4/1998-10/2000 (132 samples)	0.1	12.5	4.5
		RDZP-3	4/1998-10/2000 (58 samples)	0.3	11.4	5.7
	pH	RDZP-1	4/1998-10/2000 (19 samples)	6.8	8.8	7.7
		RDZP-2	4/1998-10/2000 (13 samples)	7.0	9.1	8.0
		RDZP-3	4/1998-10/1999 (9 samples)	7.2	9.0	8.3
Hettick Lake (SDZF)	Phosphorus (mg/l)	SDZF-1	4/1994-10/2000 (25 samples)	0.022	0.60	0.14
		SDZF-2	4/1994-10/2000 (10 samples)	0.025	0.34	0.12
		SDZF-3	4/1994-10/2000 (10 samples)	0.037	0.39	0.15
	Dissolved oxygen (mg/l)	SDZF-1	4/1994-10/2000 (84 samples)	0.1	14.3	5.2
		SDZF-2	4/1994-10/2000 (68 samples)	0.1	15.0	6.5
		SDZF-3	4/1994-10/2000 (31 samples)	4.8	12.8	8.5

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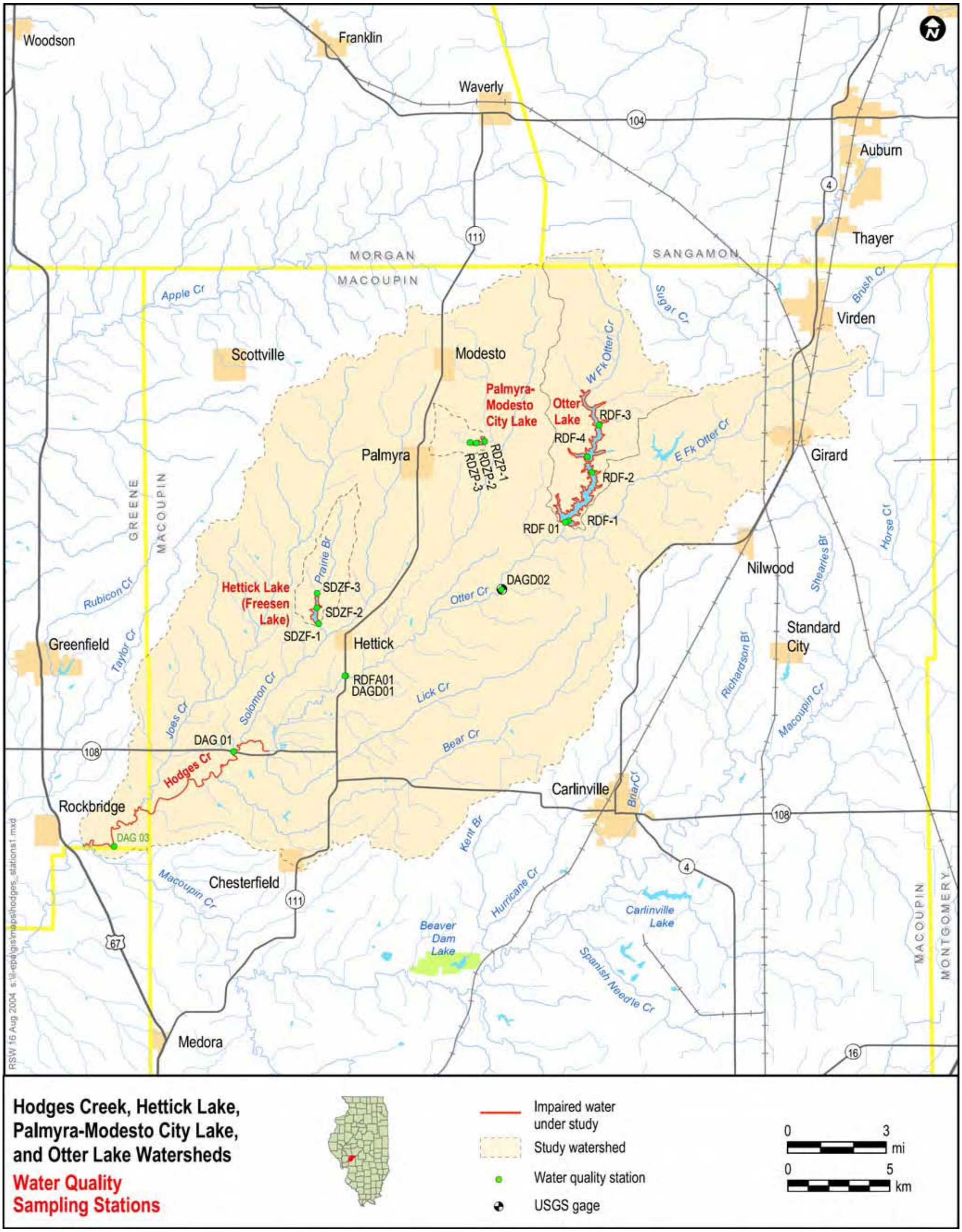

Figure 4. Sampling stations in the Hodges Creek watershed

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CONFIRMATION OF CAUSES AND SOURCES OF IMPAIRMENT

Water quality data were evaluated to confirm the cause of impairment for each waterbody in the Hodges Creek watershed, and in combination with the watershed characterization data, the sufficiency of the data were assessed to support the listing decision and the sources of impairment that are included on the 2004 303(d) list. Table 9 lists the impaired waterbodies, the applicable water quality criteria, and the number of samples exceeding the criteria. These data are discussed by waterbody in the following sections.

Table 9. Water Quality Criteria and Number of Exceedances

Sample location/cause of impairment	Applicable Illinois Nonspecific Use Designation	Water Quality Criteria	Basis of Impairment
Hodges Creek (DAG 02)			
Dissolved oxygen	General Use	5 mg/l Minimum	2 of 2 samples < criterion
Otter Lake (RDF)			
Manganese	Public Water Supply General Use	150 ug/l 1000 ug/L	2 of 8 samples collected in 1999 or later > criterion 3 of 20 samples > criterion
Palmyra-Modesto Lake (RDZP)			
Manganese	Public Water Supply General Use	150 ug/l 1000 ug/L	3 of 5 samples > criterion 0 of 5 samples > criterion
Dissolved Oxygen	General Use	5 mg/l minimum	4 of 30 surface samples < criterion
pH	General Use	6.5 - 9	1 of 41 samples > criterion
Hettick Lake (SDZF)			
Phosphorus	General Use	0.05 mg/l	24 of 29 surface samples > criterion
Dissolved oxygen	General Use	5 mg/l minimum	2 of 30 surface samples < criterion

The following sections also discuss potential sources of impairments. The Illinois EPA (IEPA, 2004) defines potential sources as known or suspected activities, facilities, or conditions that may be contributing to impairment of a designated use. The impairments identified by IEPA in the 305(b) report are listed in Table 10. These potential sources were supplemented with data reflecting point source discharges in the watershed, non-point pollution sources, and data and information collected as part of Stage 1 activities, as summarized in Table 11 and described in the following section.

Table 10. Waterbody Impairment Causes and Sources (from IEPA, 2004)

Waterbody	Cause of impairments	Potential Sources (from 305(b) Report)
Hodges Creek (DAG 02)		
	Dissolved oxygen	Source unknown
Otter Lake (RDF)		
	Manganese	Municipal point sources; Agriculture; Crop-related sources; non-irrigated crop production; Hydrologic/habitat modification; Flow regulation/modification; Habitat modification; Streambank mod./destabilization; Marinas and recreational boating; source unknown
Palmyra-Modesto Lake (RDZP)		
	Manganese	Municipal point sources; Agriculture; Crop-related sources; non-irrigated crop production; Hydrologic/habitat modification; Flow regulation/modification; Recreation and tourism; Forest/grassland/parkland; source unknown
	Dissolved oxygen	
	pH	
Hettick Lake (SDZF)		
	Total Phosphorus	Agriculture; hydrologic/habitat modification; Flow regulation/modification; Forest/grassland/parkland
	Dissolved oxygen	

Table 11. Other Impairment Causes and Sources

Waterbody	Cause of impairments	Other Potential Sources
Hodges Creek (DAG 02)		
	Dissolved oxygen	Sediment oxygen demand Nutrients, ammonia and BOD from municipal point sources, failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock). A CAFO that closed in 2000 is another possible source. Conditions are exacerbated during low flow
Otter Lake (RDF)		
	Manganese	Natural background sources including runoff and soil erosion and release from sediments under hypolimnetic anoxic conditions
Palmyra-Modesto Lake (RDZP)		
	Manganese	Natural background sources including runoff and soil erosion and release from sediments under hypolimnetic anoxic conditions
	Dissolved oxygen	Sediment oxygen demand, Nutrients, ammonia and BOD from failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock)
	pH	Excess algal production resulting from nutrient loading from failing private sewage disposal systems (septic and surface discharge systems), runoff from agricultural land and livestock
Hettick Lake (SDZF)		
	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 under hypolimnetic anoxic conditions
	Dissolved oxygen	Sediment oxygen demand, Nutrients, ammonia and BOD from failing private sewage disposal systems (septic and surface discharge systems), runoff from agricultural land, and livestock

Hodges Creek (DAG 02)

Listed for: Dissolved Oxygen

The IEPA guidelines (IEPA, 2004a) for identifying dissolved oxygen as a cause in streams state that the aquatic life use is not supported if there is at least one exceedance of applicable standard, or a known fish kill resulting from dissolved oxygen depletion. Dissolved oxygen data were collected at one station located at the downstream end of the Hodges Creek (see Figure 4). Two samples were collected at this station, one in July and one in August 2001. Concentrations of 3.6 and 4.4 mg/l were measured, both below the general use criterion of 5 mg/l. These data are very limited, but they represent late summer low flow conditions in the creek, when dissolved oxygen would be expected to be lowest. Low dissolved oxygen concentrations are documented in upstream waterbodies, including Hettick, Palmyra-Modesto, and Otter Lakes. For these reasons, the data are considered sufficient to support the listing of Hodges Creek for dissolved oxygen on the draft 2004 303(d) list.

Data were not available to explore the relationship between dissolved oxygen and ammonia and carbonaceous biochemical oxygen demand (CBOD), and dissolved oxygen and chlorophyll in this waterbody. Typical causes of low dissolved oxygen include sediment oxygen demand, degradation of CBOD, or nitrification of ammonia. These may all contribute to low dissolved oxygen in Hodges Creek. Although the monitoring data are insufficient to identify whether SOD, CBOD and/or ammonia are contributing to low dissolved oxygen, several potential sources of ammonia, nutrients and biochemical oxygen demand were identified through a review of the watershed characterization discussion. These sources include four municipal point sources, failing private sewage disposal systems (septic and surface discharge systems) (BOD, ammonia and nutrients), runoff from lawns and agricultural lands (BOD, ammonia and nutrients) and from pastureland with livestock. A CAFO that closed in 2000 had a permit for a waste lagoon and manure pit overflow. Legacy amounts of oxygen-demanding substances from this facility may remain in the creek sediments, and this CAFO is another potential source contributing to the low dissolved oxygen. Low flows in late summer months may also contribute to low dissolved oxygen concentrations in this segment.

Otter Lake (Segment RDF)

Listed for: Manganese

The IEPA guidelines (IEPA, 2004a) 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 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. Manganese data were collected at four stations in the lake between 1996 and 2003. A total of 20 samples were collected at these stations, at various depths in the water column. For purposes of comparing these data to the public water supply listing guidelines, those data collected after 1999 were identified. Eight manganese samples were collected in 1999 or later. Two of the eight manganese samples (25%) exceeded the public water supply criterion (150 ug/l) and three of the 20 measurements (using data collected between 1996-2003) exceeded the general use criterion. The three samples exceeding the general use criterion were all collected on the same date in August 1996, while an exceedance of the public water supply criteria was noted as recently as July 2003. These data are considered representative of water quality in the lake and sufficient to support the listing of Otter Lake for manganese on the draft 2004 303(d) list. Although the data show that neither the public water supply nor aquatic life use are fully supported due to manganese, the data show no exceedances of the general use manganese criterion after August 1996.

Dissolved oxygen concentrations in the Otter Lake samples indicate that the deeper waters become anoxic in the summer. Under anoxic conditions, manganese may be released from the lake bottom sediments, contributing to elevated levels in the water column. A depth profile of manganese concentrations at Station RDG-1 is shown in Figure 5. The data indicates that in summer months when bottom waters become anoxic, manganese from sediments becomes dissolved in the water column, and manganese concentrations in deeper water increase.

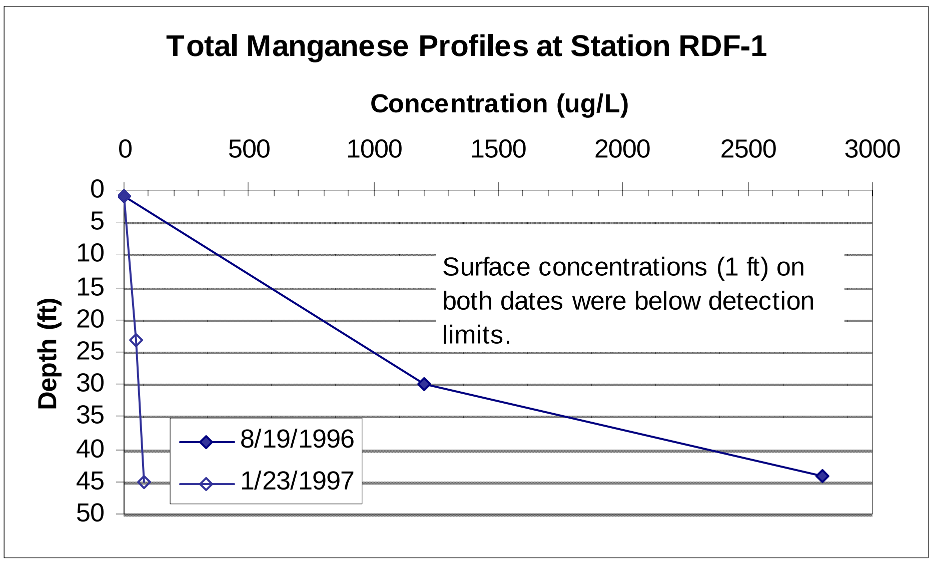

Figure 5. Depth Profile for manganese at Station RDF-1

The oxidation-reduction chemistry of manganese (and the similar metal iron) is well studied in lakes. In the oxidized state, that is in lakes, in the aerobic epilimnion, manganese is in particulate form. During summer stagnation, manganese reduces (before iron does) and becomes dissolved in the water column (Cole, 1994). Limnologists have found that increases in water column profiles of dissolved manganese may be associated with the reduction of manganese as particles settle into the anoxic zones of lakes, or, from reduction and upward transport of dissolved manganese derived from lake bottom sediment (Davison, 1985). Hence, the measurements of manganese in mid-water samples from the lakes exceed the water quality criterion because of thermal stratification and the development of reducing conditions in the hypolimnion.

Oxygen depletions in Otter Lake during summer stagnation are well-documented. The Illinois State Water Survey's (1999) report, *Phase I: Diagnostic-Feasibility Study of Otter Lake* discusses how stratification begins in late April to early May. Oxygen depletion reaches a peak by early June, and data indicate there is no oxygen below depths of 15 feet below the surface during summer stratification. The report cautions that any raw water withdrawal from the anoxic zone will result in increased treatment costs and taste and odor problems because of the presences of products of anaerobic decomposition such as iron, manganese and ammonia. The Phase I Report states that during the period of thermal stratification, nearly 50% of the lake volume south of Emerson Airline Road was devoid of oxygen.

The observed manganese concentrations in the lake likely reflect natural background conditions, as the soils in this watershed are naturally enriched in manganese and are acidic. Manganese is likely mobilized from the soil and transported to the lake through baseflow and runoff. Siltation of the lake and shoreline erosion are documented and may also contribute naturally-occurring manganese to the lake. Because the manganese is naturally occurring in local soils and is ubiquitous throughout the watershed, the public water supply use and possibly the general use criteria may be difficult to attain. Manganese does not present any human health hazards, but may be responsible for offensive tastes and appearances in drinking water, as well as staining laundry and fixtures.

Palmyra-Modesto Lake (RDZP)

Listed for: Dissolved Oxygen, Manganese and pH

Palmyra-Modesto Lake is a public supply. Available data were reviewed and compared to applicable water quality criteria.

Dissolved Oxygen

The IEPA guidelines (IEPA, 2004a) for identifying dissolved oxygen as a cause in lakes state that the aquatic life use is not supported if there is at least one violation of the applicable standard (5.0 mg/l) at one foot depth below the lake surface; or a known fish kill resulting from dissolved oxygen depletion. Between April 1998 and October 2000, a total of 345 samples were collected for dissolved oxygen in Palmyra-Modesto Lake, with 30 samples collected from surface waters. Four of the 30 surface samples (collected at a depth of one foot) had dissolved oxygen concentrations less than 5 mg/l. Figure 6 shows the dissolved oxygen data by depth of sampling compared to the general use criterion. These data are considered representative of water quality in the lake, and sufficient to support the causes listed on the draft 2004 303(d) list.

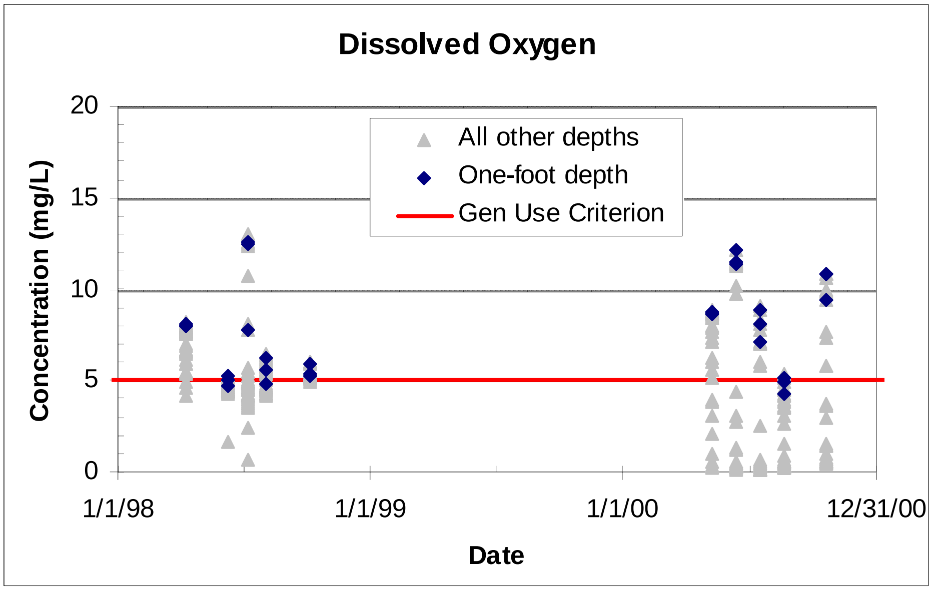

Figure 6. Dissolved oxygen concentrations from Palmyra-Modesto Lake compared to general use criterion

Depth profiles (Figure 7) indicate the bottom waters of the lake become anoxic from May through October. This is due to stagnation of the hypolimnion during when the lake is stratified in the summer. Although the monitoring data are insufficient to identify whether SOD, CBOD and/or ammonia are contributing to low dissolved oxygen, it was noted that ammonia measurements above 3.0 mg/l are associated with very low dissolved oxygen concentrations (< 1.0 mg/l), indicating that ammonia may be one cause of the low dissolved oxygen. Several potential sources of ammonia, nutrients and BOD were identified through a review of the watershed characterization discussion. These sources include: failing private sewage disposal systems (septic and surface discharge systems) (BOD, ammonia and nutrients), runoff from lawns and agricultural lands (BOD, ammonia and nutrients) and runoff from pastureland with livestock.

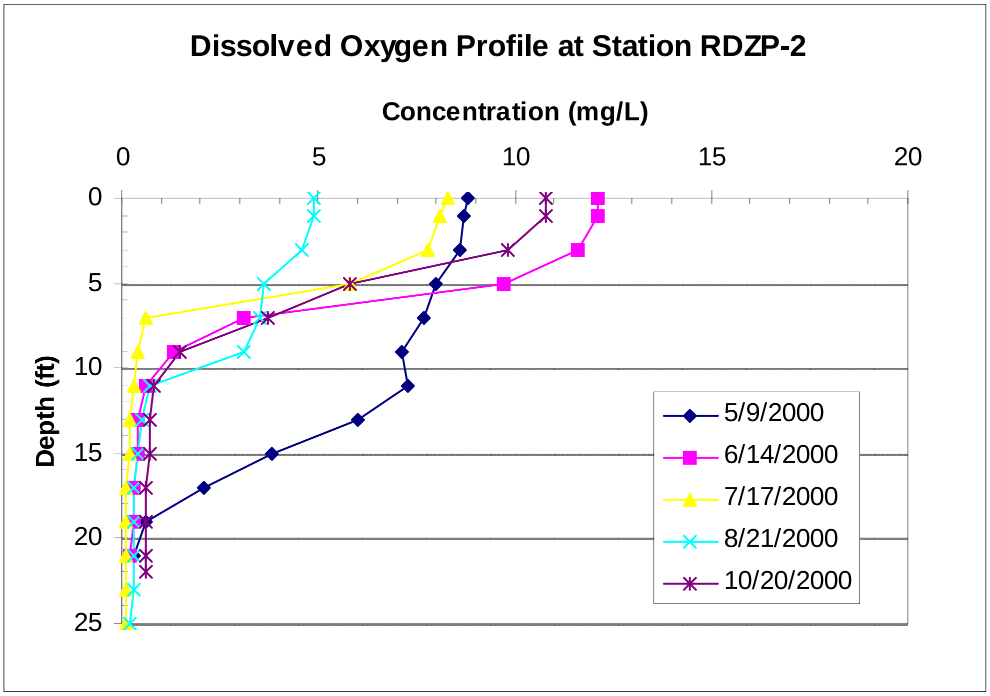

Figure 7. Depth profiles for dissolved oxygen in Modesto-Palmyra Lake

Manganese

The IEPA guidelines (IEPA, 2004a) 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. A total of five samples were collected mid-depth in the water column from May to October, 2000. Three of five samples (60%) exceed the manganese public water supply criterion of 150 ug/l, with exceedances ranging from 140 to 570 ug/l over the criterion. No samples exceed the 1000 ug/L general use criterion. While data are limited, they are consistent with data collected from nearby waterbodies including Otter Lake that support the ubiquitous nature of manganese in this region. For this reason, the data are considered sufficient to support the listing of Palmyra-Modesto Lake for manganese on the draft 2004 303(d) list.

The sources of manganese include natural background sources and release from bottom sediment under anoxic conditions. The soils in the Palmyra-Modesto Lake watershed are naturally enriched in manganese and are also acidic, facilitating the mobilization of the manganese through runoff and groundwater. Shoreline erosion of this lake and erosion in the watershed is another mechanism for transporting the manganese-containing soils to the lake, where the manganese accumulates in the lake bottom sediments. As described above in the discussion of dissolved oxygen, the bottom waters of the Palmyra-Modesto

Lake become anoxic in the summer. Under anoxic conditions, manganese may be released from the sediments, contributing to elevated levels in the water column (see discussion for Otter Lake above). No depth profiles of manganese are available to support this. Because the source of the manganese is naturally occurring and ubiquitous, the public water supply use criterion may be difficult to attain. Manganese does not present any human health hazards, but may be responsible for offensive tastes and appearances in drinking water, as well as staining laundry and fixtures.

pH

The Illinois general use criteria for pH range from a minimum of 6.5 to a maximum of 9.0, except for natural causes. Most Illinois lakes have a pH between 6.5 and 9.0 (Illinois State Water Survey, 1999). Available data for Palmyra-Modesto Lake are shown compared to the general use criteria in Figure 8. Of a total of 41 samples collected in the lake between 1998 and 2000, only one sample exceeded the maximum general use criteria of pH 9. The sample, collected at Station RDZP-2 on October 20, 2000, had a pH of 9.13. No samples fall below the minimum pH criteria of 6.5. Therefore, the listing of this segment for pH based on a single excursion above the criteria

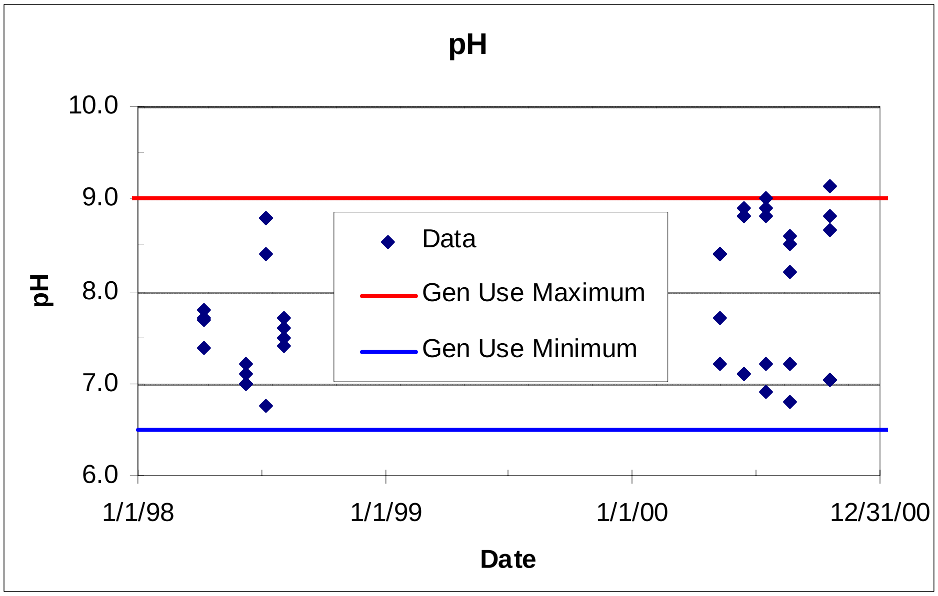

Figure 8. Comparison of pH Data in Palmyra-Modesto Lake to General Use Criterion

The high pH value in October corresponds to the highest chlorophyll-a concentration the sampling record (188 ug/l). This suggests that algal production is raising pH in the lake, which is an expected occurrence due to photosynthetic uptake of carbonic acid. A plot of pH vs. dissolved oxygen (Figure 9) supports this, showing that pH increases as dissolved oxygen concentrations increase in the lake. Potential nutrient sources contributing to algal growth include failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural lands, and runoff from pastureland with livestock.

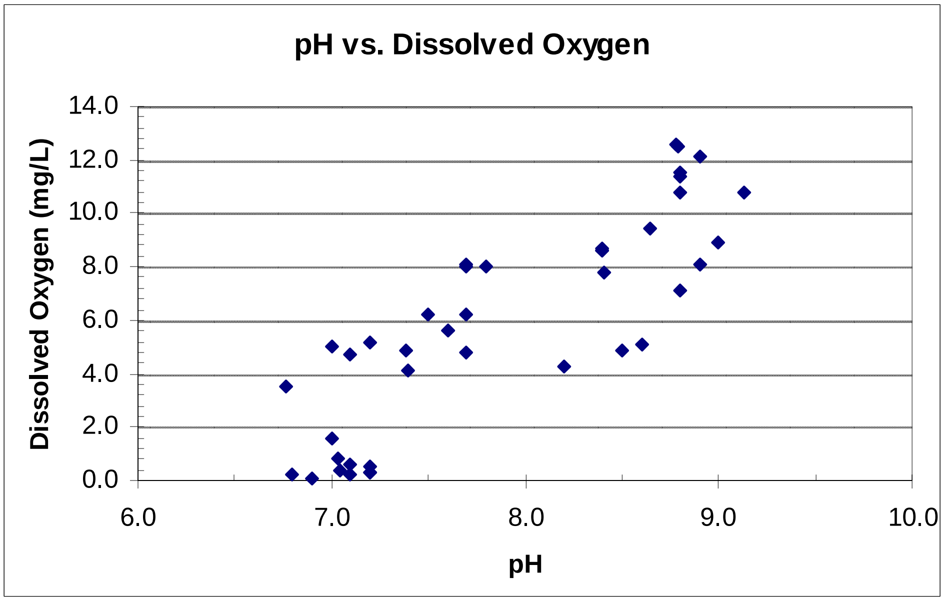

Figure 9. pH vs. dissolved oxygen in Palmyra-Modesto Lake

Hettick Lake (SDZF)

Listed for: Total Phosphorus and Dissolved Oxygen
Available data for total phosphorus and dissolved oxygen were analyzed and compared to general use criteria. Samples were collected at three stations in the lake between 1994 and 2000, from April through October.

Total Phosphorus

The IEPA guidelines (IEPA, 2004a) 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.

A total of 45 samples were collected at three stations and at various depths, with 29 samples collected at the surface. Of these 29 surface samples, 24 samples exceed the general use criterion of 0.05 mg/l (see Figure 10). These surface samples were collected at three stations, with exceedances of the criteria at all three locations. The percent of total phosphorus samples that exceeded the criteria at these stations ranged from 78% to 90% at the three stations. These exceedances occurred throughout the sampling record, with 14 of 15 surface samples exceeding the criterion in 1994, and 10 of 14 surface samples exceeding the criterion in 2002. The available data are considered representative of water quality in the lake, and sufficient to support the listing of Hettick Lake for total phosphorus on the draft 2004 303(d) list.

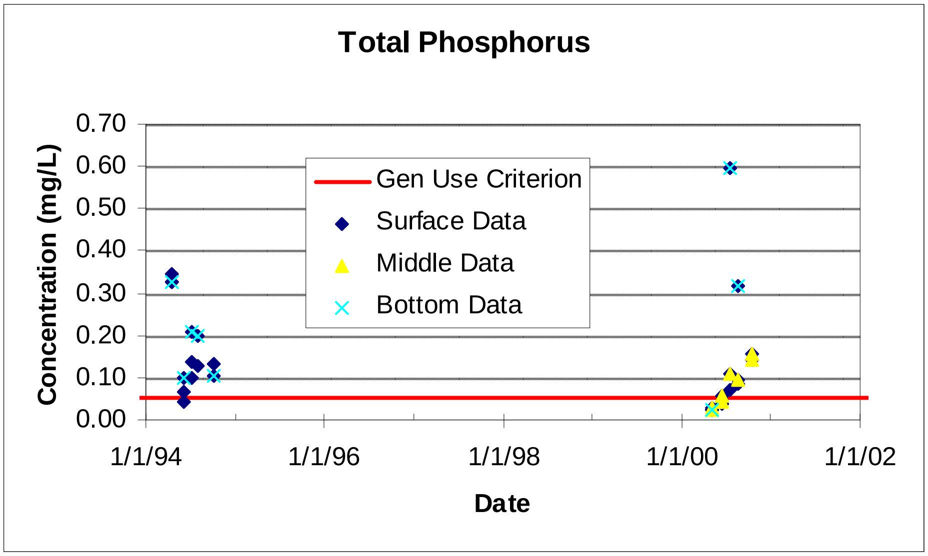

Figure 10. Comparison of Total Phosphorus Data for Hettick Lake to General Use Criterion

An analysis of dissolved and particulate phosphorus data indicates that approximately 50% of total phosphorus is in dissolved form. A fraction of the observed dissolved phosphorus may originate from lake bottom sediments. An examination of data collected at Station SDZF-1 in 2002 (Figure 11) indicates a significant increase in phosphorus with depth in the summer, suggesting that phosphorus release from sediments may be occurring under anoxic conditions. Dissolved oxygen data (discussed below) indicate that the bottom waters of the lake do indeed become anoxic under summer stagnation conditions.

Another source of phosphorus in Hettick Lake, in addition to release from the lake bottom sediments, is runoff and erosion from agricultural land. Common fertilizers include phosphorus (diammonium phosphate), as well as anhydrous ammonia and potash. Runoff from fertilized lawns, pasture land with livestock and failing private sewage disposal systems (septic and surface discharge systems) may also contribute phosphorus to the lake. Through a review of the data, it was noted that total phosphorus generally increases with total suspended solids, indicating that some of the phosphorus is being transported to the lake during wet weather conditions.

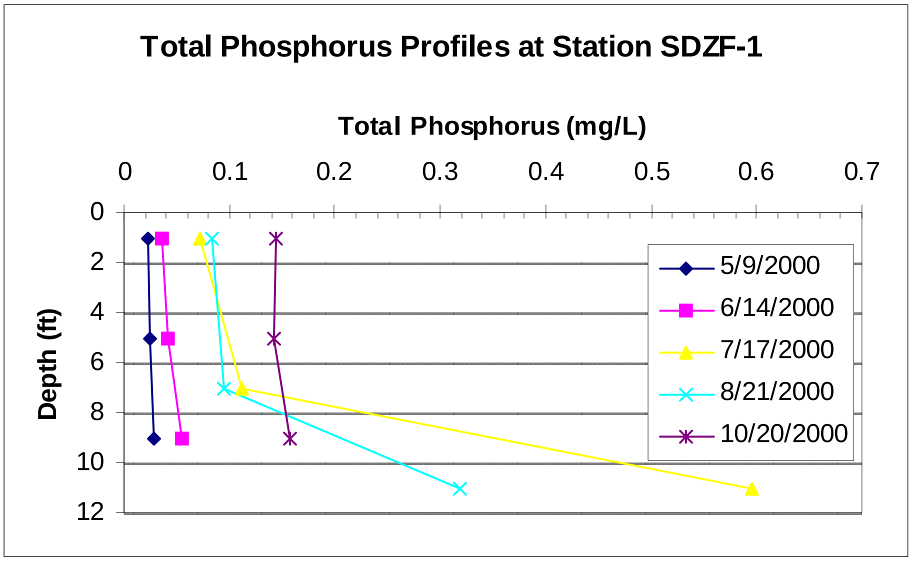

Figure 11. Total Phosphorus Profiles at Station SDZF-1

Dissolved Oxygen

The IEPA guidelines (IEPA, 2004a) for identifying dissolved oxygen as a cause in lakes state that the aquatic life use is not supported if there is at least one violation of the applicable standard (5.0 mg/l) at one foot depth below the lake surface; or a known fish kill resulting from dissolved oxygen depletion. A total of 183 samples were collected for dissolved oxygen in Hettick Lake. The samples were collected in 1994 and 2000 from April through October. Of these, 30 samples were collected at a depth of one foot. Two of these surface samples, both collected in 2000, were lower than the dissolved oxygen criterion of 5 mg/l. Figure 12 shows the dissolved oxygen data compared to the general use criterion. These data are representative of water quality in the lake and considered sufficient to support the causes listed on the draft 2004 303(d) list.

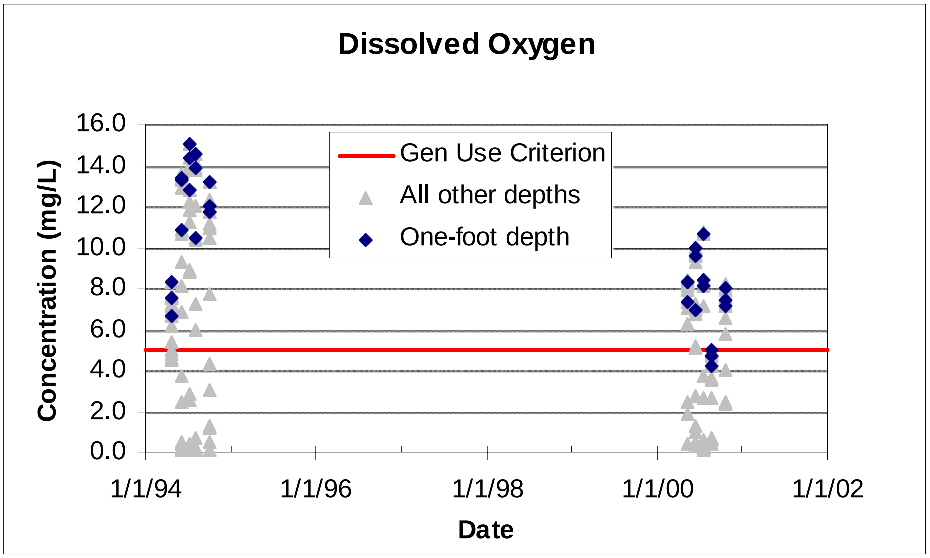

Figure 12. Dissolved oxygen data in Hettick Lake compared to general use criterion

Depth profiles of dissolved oxygen indicate that this shallow lake becomes anoxic in summer months below depths of approximately 7 feet (Figure 13). In addition, the data show that as chlorophyll-a concentrations increase, dissolved oxygen concentrations increase. In eutrophic lakes, low dissolved oxygen concentrations may result from algae respiration and die-off. The sources contributing to the elevated total phosphorus in the lake (see previous discussion) are likely contributing to algal growth and low dissolved oxygen. These sources include lake bottom sediments (sediment release of phosphorus under anoxic conditions), failing private sewage disposal systems (septic and surface discharge systems), watershed runoff from lawns and agricultural cropland and runoff from pastureland with livestock.

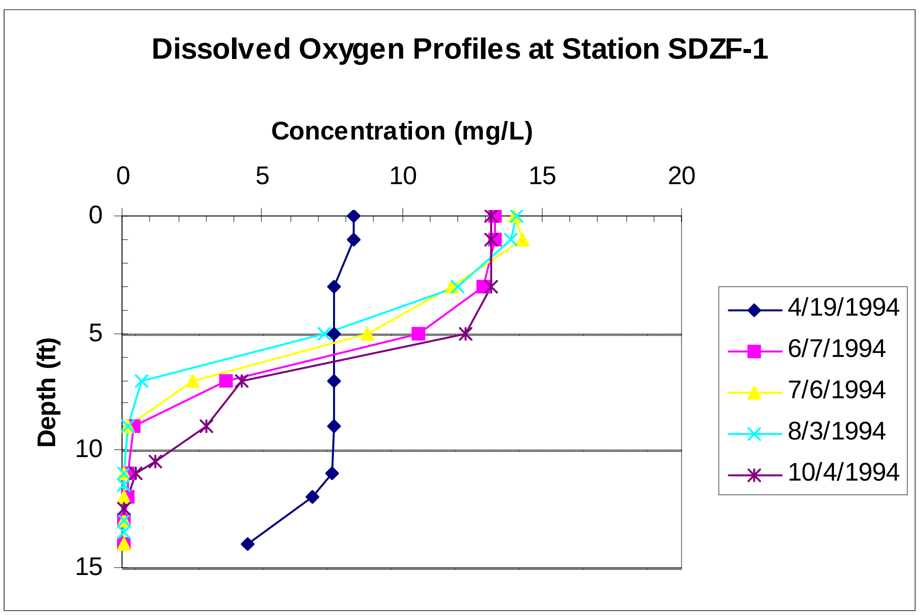

Figure 13. Depth Profiles of Dissolved Oxygen in Hettick Lake

CONCLUSIONS

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

- For **Hodges Creek (Segment DAG 02)**, data are considered sufficient to support the causes listed on the draft 2004 303(d) list, and a dissolved oxygen TMDL is warranted. However, it should be noted that this listing was based on two measurements taken in 2001. Causes of low dissolved oxygen typically include sediment oxygen demand, degradation of CBOD, or nitrification of ammonia. Nutrients, ammonia and BOD may be originating from municipal point sources, failing private sewage disposal systems (septic and surface discharge systems), and runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock). A CAFO that closed in 2000 had a permit for a waste lagoon and manure pit overflow. Legacy amounts of oxygen-demanding substances from this facility may remain in the creek sediments, and this CAFO is another potential source contributing to the low dissolved oxygen. Low flows in late summer months may also contribute to low dissolved oxygen concentrations in this segment.
- For **Otter Lake (RDF),** data are considered sufficient to support the causes listed on the draft 2004 303(d) list, and a manganese TMDL is warranted. The observed manganese concentrations in the lake likely reflect natural background conditions (soils in the watershed are naturally high in manganese) and release from lake bottom sediments under anoxic conditions. For this reason, the general use criteria may be difficult to attain.
- For **Palmyra-Modesto Lake (RDZP),** data are sufficient to support the listings for manganese and dissolved oxygen on the draft 2004 303(d) list, and TMDLs are warranted. The pH data were collected between 1998 and 2000 and the data to support the listing for pH indicate one exceedance of the criteria (recorded in 2000). The observed manganese concentrations in the lake are likely caused by runoff from the watershed (soils in the watershed are naturally high in manganese) and release from lake bottom sediments. Because the manganese concentrations reflect natural background conditions, the general use criteria for manganese may be difficult to attain. The low dissolved oxygen is due to hypolimnetic anoxia in the lake. Potential sources contributing to the low dissolved oxygen include sediment oxygen demand, nutrients, ammonia and BOD from failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock). Exceedance of the pH criteria may be due to excess algal production due to nutrient loadings from the watershed. Potential sources of nutrients include failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock).
- For **Hettick Lake (SDZF),** data are sufficient to support the causes listed on the draft 2004 303(d) list, and total phosphorus and dissolved oxygen TMDLs are warranted. Potential sources of total phosphorus include runoff from lawns and

agricultural lands (fertilized cropland and agricultural land with livestock), failing private sewage disposal systems (septic and surface discharge systems) and release from sediments under hypolimnetic anoxic conditions. Potential sources of low dissolved oxygen include sediment oxygen demand and the nutrient sources mentioned above as potentially contributing phosphorus to the lake.

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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http://www.epa.gov/SAFEWATER/ccl/cclregdetermine.html

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	
Nature preserves	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Oil wells	United States Geological Survey	http://energy.cr.usgs.gov/oilgas/noga/
Railroads	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Roads	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/

Data description	Agency	Website
Roads – state highways	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Roads – U.S. highways	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Roads- detailed road network	U.S. Census Bureau	http://www.census.gov/geo/www/tiger/tigerua/ua_tgr2k.html
Survey-level soils	United States Department of Agriculture Natural Resources Conservation Service	http://www.il.nrcs.usda.gov/technical/soils/ssurgo.html
State-level soils	United States Department of Agriculture Natural Resources Conservation Service	http://www.il.nrcs.usda.gov/technical/soils/statsgo_inf.html - statsgo8
State boundary	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State conservation areas	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State forests	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State fish and wildlife areas	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
State parks	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Topographic map quadrangle index	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
Topographic map quadrangles	Illinois Natural Resources Geospatial Data Clearinghouse	http://www.isgs.uiuc.edu/nsdihome/
USGS stream gages	Illinois State Water Survey	
Watersheds	Illinois Environmental Protection Agency	http://maps.epa.state.il.us/website/wqinfo/
Water supply – Public water supply intakes	Illinois State Water Survey	
DMR data and information on NPDES permitted facilities	IEPA Springfield Regional Office	Provided by e-mail from Tim Kelly
Flow, water temperature, air temperature data for Otter Creek near Palmyra (05586800)	USGS	http://waterdata.usgs.gov/nwis/qw
Hardcopy lake data for Otter Lake, Palmyra-Modesto Lake, Hettick Lake	IEPA	Provided by mail
Water quality data for Otter Lake, Palmyra-Modesto Lake, Hettick Lake	STORET	http://www.epa.gov/storet/dbtop.html
Stream water quality data for Hodges Creek	STORET Modern	http://www.epa.gov/storet/dbtop.html

Table A-2. Local and State Contacts

Contact	Agency/ Organization	Contact Means	Phone #	Subject
Rhonda Koehne	Executive Director. Macoupin County SWCD	In person	217-854-2628	Soils, farming practices, watershed characterization, SWCD programs
John Ford	District Conservationist, Macoupin County SWCD	In person	217-854-2628	Soils, farming practices, watershed characterization, SWCD programs
John Ford	District Conservationist, Macoupin County SWCD	Telephone	217-854-2628	Erosion, fertilization
Craig Bussmann	Macoupin County Health Department	Telephone	217-854-3223	Surface wastewater discharges
Mary Sue ??	U of I Extension	Telephone	217-854-9604	Illini Feeders
John Nolan	FSA	Telephone	217-854-2626 ext 2	Illini Feeders
Don Hunt	One of former partners of Illini Feeders	Telephone	217-436-2406	Illini Feeders
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		618-566-9493	Discussed CRP maps
Steve Sobaski	Illinois Department of National Resources		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.Meneghetti@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.state.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. PHOTOGRAPHS

PHOTOGRAPHS FROM FIELD VISIT
June 27-28, 2004

Hodges Creek from iron bridge on Chism Road

Hettick (Freesen) Lake from beach at Boy Scout Camp

Palmyra-Modesto Lake from road between golf course lake and Terry Park lake (tower is water treatment plant)

Looking down road toward Palmyra-Modesto Lake that runs between the lake and Terry Park showing open terrain

Otter Lake from road that divides the lake, looking south

Otter Lake from road that divides the lake, looking north

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Second Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

October 2004

Hodges Creek Watershed

Hodges Creek (DAG 02), Otter Lake (RDF),
Palmyra-Modesto Lake (RDZP), Hettick Lake (SDZF)

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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 Hodges Creek 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 Hodges Creek 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 Hodges Creek, the relevant site-specific characteristics include a watershed with predominantly agricultural land use, which also contains several municipal point sources and a CAFO suspected of being a continuing source, and a creek impaired by low dissolved oxygen. For Otter Lake, the relevant site-specific characteristics include a watershed that is predominantly agricultural with soils naturally enriched in manganese, and a lake impaired by manganese. For Palmyra-Modesto Lake, the relevant site-specific characteristics include a watershed with predominantly agricultural land uses and soils naturally enriched in manganese, and a lake impaired by manganese, low dissolved oxygen and pH. For Hettick Lake, the relevant site-specific characteristics include a watershed with predominantly agricultural land uses and a lake impaired by phosphorus and low dissolved oxygen.

- **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 and time and data available to support TMDL development. Water quality data currently exist for Hodges Creek, Otter Lake, Palmyra-Modesto Lake and Hettick Lake. 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 water quality model QUAL2E to address dissolved oxygen problems in Hodges Creek Segment DAG 02. Watershed loads for this segment will be defined using an empirical approach. Application of this approach will require conduct of additional field sampling to synoptically measure sources and receiving water concentrations of oxygen demanding substances and dissolved oxygen.

The recommended approach for Otter, Hettick and Palmyra-Modesto Lakes consists of using the GWLF and BATHTUB models to address total phosphorus, dissolved oxygen, pH and manganese problems. Specifically, GWLF will be applied to calculate phosphorus loads to Otter, Hettick and Palmyra-Modesto Lakes over a time scale consistent with the nutrient residence time of each of the lakes. BATHTUB will then be used for all three lakes to predict the relationship between phosphorus load and resulting in-lake phosphorus, pH (Palmyra-Modesto Lake only) and dissolved oxygen concentrations, as well as the resulting potential for manganese release from sediments in Palmyra-Modesto and Otter Lakes. The relationship between phosphorus and dissolved oxygen, and phosphorus and pH, 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. Application of these models will require no additional data collection.

Two alternative approaches are also provided for Otter, Hettick and Palmyra-Modesto Lakes. 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 approach is also provided for Otter, Hettick and Palmyra-Modesto Lakes in the event that more detailed implementation plans are desired. The model frameworks included in the second alternative approach 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 Hodges Creek 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 of the four waterbodies in the Hodges Creek watershed affect the recommendation of specific methodologies.
- **Selection of specific methodologies and future data requirements:** This section provides specific recommendation of methodologies for the four listed waterbodies in the Hodges Creek 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

Hodges Creek 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	DO, nutrients, metals, organics, bacteria	Potentially applicable to all sites, if sufficient data exist

Spreadsheet Approaches

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

EUTROMOD

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

BATHTUB

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

BATHTUB contains a number of regression equations that have been calibrated using a wide range of lake and reservoir data sets. It can treat the lake or reservoir as a continuously stirred, mixed reactor, or it can predict longitudinal gradients in trophic state variables in a reservoir or narrow lake. These trophic state variables include in-lake total and ortho-phosphorus, organic nitrogen, hypolimnetic dissolved oxygen, metalimnetic dissolved oxygen, 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 four listed waterbodies in the Hodges Creek watershed. This chapter presents the general guidelines used in model selection process, and then applies these guidelines to make specific recommendations. In summary, two alternative approaches are recommended for Hodges Creek and three alternative approaches are recommended for each of the listed reservoirs in the Hodges Creek watershed. The selection of the final approach will be 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 the development of differing levels of TMDL implementation plans. For each approach, the degree of implementation that can be supported to produce a credible TMDL will be provided. Specific recommendations are provided which correspond to the level of detail provided in other Illinois TMDL implementation plans conducted to date.

Model Selection for the Hodges Creek 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 Hodges Creek watershed was provided in the first quarterly status report (LTI, 2004). In summary, there are four impaired waterbodies that are located within the Hodges Creek watershed; one is a creek and three are reservoirs. The Hodges Creek watershed is located in West-Central Illinois approximately 45 miles south of Springfield. The majority of Hodges Creek's watershed is in Macoupin County (97%), with small portions extending into Greene, Jersey, Morgan, and Sangamon County. The watershed for Hodges Creek is approximately 148,961 acres (233 square miles) in size.

The Hodges Creek watershed is predominantly agricultural (72%), with corn and soybeans being the most commonly grown crop. Forest is the next most common land cover (16%). Six small communities are located in the watershed and are: Chesterfield, Girard, Hettick, Modesto, Palmyra, and Virden. Permit information is available for four entities that are permitted to discharge treated wastewater to Hodges Creek or its tributaries. In addition, there is one water treatment plant permitted to discharge filter backwash. Another facility, Illini Feeders, is a confined animal feeding operation (CAFO) that is no longer in operation. This facility has the potential for releases from an old waste lagoon. Most towns are served by sewer, but within Macoupin County, there are approximately 3,000 surface discharge systems. Potential sources contributing to low dissolved oxygen include: municipal point sources, failing private sewage disposal systems (septic and surface discharge systems), and runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock). The closed CAFO is another potential source of oxygen-demanding material. Low flows in late summer months may also contribute to low dissolved oxygen concentrations in this segment.

Otter Lake is located west of Girard, Illinois and about 20 miles southwest of Springfield. The lake is 765 acres in size and its watershed is approximately 12,818 acres in size. The lake is an impoundment on Otter Creek. Construction of Otter Lake was completed in 1968. The ADGPTV Water Commission owns and manages Otter Lake and a strip of land around the lake's perimeter. More than 90 percent of the strip is in trees or vegetative cover (Farnsworth et al., 1998). Otter Lake is a public water supply, and it also supports recreational activities such as camping, fishing and boating. The average depth is 19.7 feet, and at its deepest point, the lake is approximately 50 feet deep (Illinois State Water Survey, 1999). Many of the soils series in this watershed contain manganese accumulations and are acidic, thus facilitating the mobilization of the manganese. Some work has been done previously to address shoreline erosion on Otter Lake, and another project to construct a low water sedimentation control structure in the north end of Otter Lake will be completed in February 2005. The observed manganese concentrations in the lake likely reflect natural background conditions (soils in the watershed are naturally high in manganese) and release from lake bottom sediments under anoxic conditions.

Palmyra-Modesto Lake is located east of Palmyra and approximately 20 miles southwest of Springfield. The lake is a public water supply. The lake is 35 acres in size and the watershed is small, covering a total of 1,080 acres, or 1.7 square miles. The predominant land use is agriculture and the soil associations in the watershed contain manganese accumulations. The observed manganese concentrations in the lake are likely caused by runoff from the watershed (soils in the watershed are naturally high in manganese) and release from lake bottom sediments. The low dissolved oxygen is due to hypolimnetic anoxia in the lake. Potential sources include failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock). Exceedance of the pH criteria may be due to excess algal production due to nutrient loadings from the watershed. Potential sources of nutrients include failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock).

Hettick Lake is also referred to as Freesen Lake. It was formerly a water supply for Hettick, but it is no longer used for this purpose. The lake is approximately 110 acres in size. Its subwatershed is 2,794 acres (4.4 square miles) in size. The land surrounding the lake is largely forested and there is a Boy Scout camp on the lake. Siltation has been an ongoing problem in the lake, and recent measures to reduce loadings of sediment have not been successful. Approximately 67% of the watershed is used for agriculture and 20% is forested. Potential sources of total phosphorus include runoff from lawns and agricultural lands (fertilized cropland and agricultural land with livestock), failing private sewage disposal systems (septic and surface discharge systems) and release from sediments under hypolimnetic anoxic conditions. Potential sources of low dissolved oxygen include sediment oxygen demand and the nutrient sources mentioned above as potentially contributing phosphorus to the lake.

Data Available

Table 3 provides 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 not sufficient to support development of a rigorous watershed or water quality model. Specific items lacking in this data set include tributary loading data for all pollutants of concern, data describing the distribution of manganese and phosphorus throughout the watershed and chlorophyll a data to better define the processes controlling dissolved oxygen (and manganese release from the sediments) within Otter Lake (RDF).

Table 3. Water Quality Data Summary for the Hodges Creek Watershed

Waterbody segment	Parameter	Sampling station	Period of record (#)	Minimum	Maximum	Average
Otter Lake (RDF)	Manganese (ug/l)	RDF-1	8/1996-10/2000 (9 samples)	32	2800	641
		RDF-2	8/1996-1/1997 (4 samples)	49	1400	715
		RDF-3	8/1996-1/1997 (2 samples)	58	130	94
		RDF-4	7/2000-8/2003 (5 samples)	0.19	320	140
Hodges Creek (DAG 02)	Dissolved oxygen (mg/l)	DAG 03	8/2001-9/2001 (2 samples)	3.6	4.41	4.00
Palmyra-Modesto Lake (RDZP)	Manganese (ug/l)	RDZP-1	5/2000 (1 sample)	73	73	73
		RDZP-2	6/2000-10/2000 (4 samples)	66	720	344
	Dissolved oxygen (mg/l)	RDZP-1	4/1998-10/2000 (155 samples)	0.1	13	4.3
		RDZP-2	4/1998-10/2000 (132 samples)	0.1	12.5	4.5
		RDZP-3	4/1998-10/2000 (58 samples)	0.3	11.4	5.7
	pH	RDZP-1	4/1998-10/2000 (19 samples)	6.8	8.8	7.7
		RDZP-2	4/1998-10/2000 (13 samples)	7.0	9.1	8.0
		RDZP-3	4/1998-10/1999 (9 samples)	7.2	9.0	8.3
Hettick Lake (SDZF)	Phosphorus (mg/l)	SDZF-1	4/1994-10/2000 (25 samples)	0.022	0.60	0.14
		SDZF-2	4/1994-10/2000 (10 samples)	0.025	0.34	0.12
		SDZF-3	4/1994-10/2000 (10 samples)	0.037	0.39	0.15
	Dissolved oxygen (mg/l)	SDZF-1	4/1994-10/2000 (84 samples)	0.1	14.3	5.2
		SDZF-2	4/1994-10/2000 (68 samples)	0.1	15.0	6.5
		SDZF-3	4/1994-10/2000 (31 samples)	4.8	12.8	8.5

Recommended Approaches

This section provides recommendations for specific modeling approaches to be applied for the Hodges Creek watershed TMDLs. Table 4 provides recommendations for Hodges Creek (Segment DAG 02), while three alternative sets of approaches are provided in Tables 5, 6 and 7 for each reservoir, with each approach having unique data needs and resulting degree of detail.

Table 4. Recommended Modeling Approaches for Hodges Creek (DAG 02)

Modeling Approach	Pollutants considered	Watershed Model	Water Quality Model	Additional data needs	Level of TMDL implementation supported
Recommended					
	Dissolved oxygen	Empirical approach	QUAL2E	Low flow stream surveys	Identify primary sources to be controlled; and approximate level of control needed

Table 5. Recommended Modeling Approaches for Otter Lake (RDF)

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

Table 6. Recommended Modeling Approaches for Palmyra-Modesto Lake (RDZP)

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

Table 7. Recommended Modeling Approaches for Hettick Lake (SDZF)

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

The recommended approach consists of using the water quality model QUAL2E to address dissolved oxygen problems in Segment DAG 02 of Hodges Creek. Watershed loads for this segment will be defined using an empirical approach. QUAL2E was selected for dissolved oxygen modeling because it is the most commonly used water quality model for addressing low flow conditions. Because problems are restricted to low flow conditions, watershed loads beyond the CAFO are not expected to be significant contributors to the impairment. For this reason, an empirical approach was selected for determining watershed loads.

The recommended approach for the three lakes consists of using the GWLF and BATHTUB models to address total phosphorus, dissolved oxygen, pH and manganese problems. Specifically, GWLF will be applied to calculate phosphorus loads to each of the three lakes for each land-use category. BATHTUB will then be used for all three lakes to predict the relationship between phosphorus load and resulting in-lake phosphorus, dissolved oxygen concentrations and pH (Palmyra-Modesto Lake only), as well as the resulting potential for manganese release from sediments in Palmyra-Modesto and Otter Lakes. The relationship between phosphorus and dissolved oxygen, and phosphorus and pH, 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 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.

The first alternative approach for the three reservoirs 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 all pollutants, coupled with application of the reservoir model CE-QUAL-W2 to describe in-lake water quality response. CE-QUAL-W2 would be applied to define hydrodynamics and eutrophication processes. This alternative approach would be capable of defining with some detail the specific action strategies necessary to attain water quality standards.

Assumptions Underlying the Recommended Methodologies

The recommended approach is based upon the following assumptions:

- Nutrient enrichment is the primary cause of dissolved oxygen and pH problems in the lakes, such that dissolved oxygen problems can be addressed via attainment of the total phosphorus standard.
- The only controllable source of manganese to the lakes is that which enters from lake sediments during periods of low dissolved oxygen; this source can be (partially) controlled by reducing phosphorus loads and increasing hypolimnetic dissolved oxygen concentrations.
- A credible TMDL implementation plan can be developed based upon relatively simple models.

LTI believes that these assumptions are appropriate. Average phosphorus concentrations, which contribute to dissolved oxygen and manganese problems, currently exceed the water quality standard by a factor of 1.4 (Otter Lake) to four (Palmyra-Modesto Lake). This indicates that phosphorus loads will need to be reduced by 25 to 75% to attain water quality standards. The dominant land use in the watershed 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

Application of the recommended approaches for Hodges Creek will require conduct of additional field sampling to support TMDL development. The existing data, while sufficient to document impairment, are not sufficient to define the cause-effect relationships. Two low- to medium-flow surveys are recommended to synoptically measure sources and receiving water concentrations of oxygen demanding substances in Hodges Creek.

Both the recommended modeling approach and the first alternative approach for the three reservoirs 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 for the three reservoirs, 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
2) define important reaction processes in each of the reservoirs

To satisfy objective one, wet weather event sampling of phosphorus and manganese (Palmyra-Modesto and Otter Lakes only) at multiple tributary and mainstem locations in the watershed will be needed. To satisfy objective two, routine monitoring of loads to the lake will be needed. Continuous flows would need to be measured at the mouth of each of the major tributaries to the lakes (West Fork Otter Creek, Prairie Branch and the unnamed tributary to Palmyra-Modesto Lake). In addition, water quality sampling and analyses would be required for several wet and dry weather events for: total suspended solids, manganese (Palmyra-Modesto and Otter Lakes only), total phosphorus, ortho-phosphorus, dissolved oxygen, CBOD, ammonia, organic nitrogen, nitrate-nitrogen and chlorophyll a. To satisfy the third objective, routine in-lake monitoring will be needed. In each of the reservoirs, bi-monthly sampling would need to be conducted for water temperature, in addition to total suspended solids, manganese (Palmyra-Modesto and Otter Lakes only), total phosphorus, ortho-phosphorus, dissolved oxygen, CBOD, ammonia, organic nitrogen, nitrate-nitrogen, and chlorophyll a.

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Third Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

October 2004

Hodges Creek Watershed

Hodges Creek (DAG 02), Otter Lake (RDF),
Palmyra-Modesto Lake (RDZP), Hettick Lake (SDZF)

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EXECUTIVE SUMMARY

This is the third in a series of quarterly status reports documenting work completed on the Hodges Creek 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 consists of using the water quality model QUAL2E to address dissolved oxygen problems in Hodges Creek Segment DAG 02. Watershed loads for this segment will be defined using an empirical approach. The recommended approach for Otter, Hettick and Palmyra-Modesto Lakes consists of using the GWLF and BATHTUB models to address total phosphorus, dissolved oxygen, pH and manganese problems.

Application of the recommended approaches for Hodges Creek will require conduct of additional field sampling to synoptically measure sources and receiving water concentrations of oxygen demanding substances and dissolved oxygen. A data collection plan is provided for two low- to medium-flow surveys of the Hodges Creek watershed.

Application of the recommended models to Otter, Hettick and Palmyra-Modesto Lakes will require no additional data collection.

INTRODUCTION/PURPOSE

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

The remaining sections of this report include:

- **Description of additional data collection, if any, to support modeling:** This section describes the amount (temporal and spatial) of data, 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 Hodges Creek watershed (LTI, 2004), modeling approaches were recommended. The recommended approach consists of using the water quality model QUAL2E to address dissolved oxygen problems in Hodges Creek Segment DAG 02. Watershed loads for this segment will be defined using an empirical approach. Application of this approach will require conduct of additional field sampling to synoptically measure sources and receiving water concentrations of oxygen demanding substances and dissolved oxygen.

The recommended approach for Otter, Hettick and Palmyra-Modesto Lakes consists of using the GWLF and BATHTUB models to address total phosphorus, dissolved oxygen, pH and manganese problems. Specifically, GWLF will be applied to calculate phosphorus loads to Otter, Hettick and Palmyra-Modesto Lakes over a time scale consistent with the nutrient residence time of each of the lakes. BATHTUB will then be used for all three lakes to predict the relationship between phosphorus load and resulting in-lake phosphorus, pH (Palmyra-Modesto Lake only) and dissolved oxygen concentrations, as well as the resulting potential for manganese release from sediments in Palmyra-Modesto and Otter Lakes. The relationship between phosphorus and dissolved oxygen, and phosphorus and pH, 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. Application of these models will require no additional data collection.

Data Collection Plan

The data collection plan outlined in general terms below, will support development of the recommended approaches for TMDL development. Two low-to medium-flow surveys are recommended to synoptically measure sources and receiving water concentrations of oxygen demanding substances in the Hodges Creek watershed. No additional data collection is recommended for the three lakes.

Sample collection

Seven essential monitoring stations and six discretionary stations are shown in Figure 1. At a minimum the seven essential stations should be sampled during low- to medium-flow conditions to support model development and application. The essential stations are located along Hodges Creek and throughout the watershed to characterize tributary contributions and instream water quality downstream of treatment plant discharges and a CAFO that is a suspected source.

Essential monitoring

Two low- to medium-flow surveys are recommended to provide data to support model development and application. At each of the seven essential stations shown in Figure 1, it is recommended that the following measurements be collected on the same day:

- dissolved oxygen,
- water temperature,
- biochemical oxygen demand (BOD),
- ammonia, and
- channel morphometry.

In addition, it is recommended that depth and velocity be measured at four locations: Hodges Creek near the mouth (station DAG 03), Hodges Creek at the Rte. 108 bridge (station DAG 01), Otter Creek near the headwaters and one of the tributary stations. Depth and velocity should be measured at the same time as the water quality sampling, to support flow calculation.

Finally, at a station determined to be representative based on a field survey, it is recommended that sediment oxygen demand (SOD) be measured, in addition to either continuous dissolved oxygen measurements or dissolved oxygen measurements collected in the morning and afternoon. The purpose of these dissolved oxygen measurements is to assess the effect of algae on instream dissolved oxygen concentrations.

Discretionary monitoring

Six discretionary monitoring stations are shown in Figure 1. These stations are located on the larger tributaries in the Hodges Creek watershed. Dissolved oxygen, water temperature, BOD, ammonia, flow, and channel morphometry measurement at these stations would improve the modeling and contributions of watershed sources to low dissolved oxygen. However, data collection at these stations is not required to support development of a credible model and, as such, these stations would only be sampled at the discretion of the agency.

Potential parties that may be responsible for additional data collection

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

NEXT STEPS

In the upcoming month, the IEPA will confer with the Scientific Advisory Committee to discuss the work presented in the three quarterly status reports. A public meeting will also be scheduled and held 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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Limno-Tech, Inc., 2004. Second Quarterly Status Report Hodges Creek Watershed. October 2004.

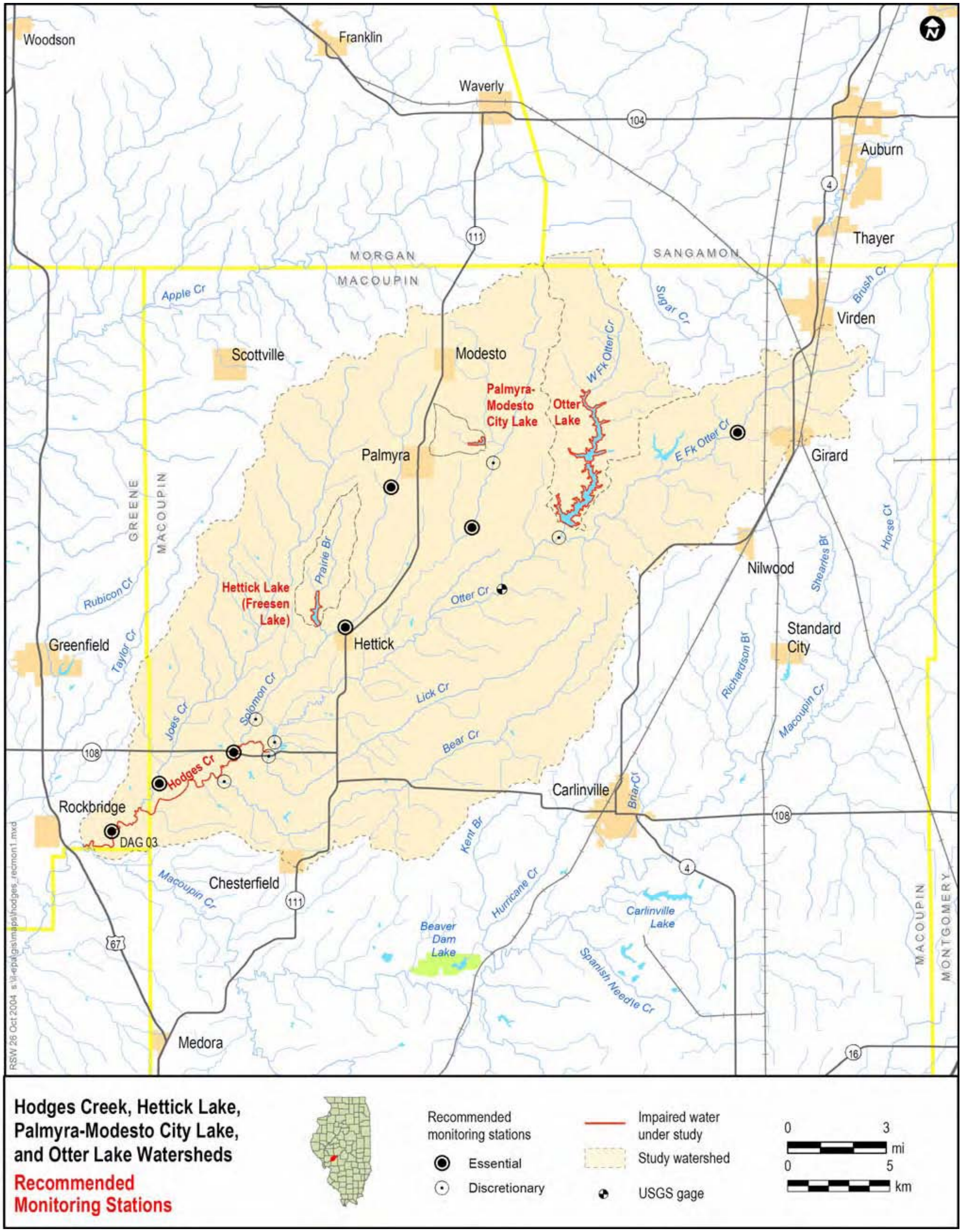

Figure 1. Recommended Stage 2 Sampling Locations

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Fourth Quarterly Progress Report

Prepared for Illinois Environmental Protection Agency

April 2005

Hodges Creek Watershed

Hodges Creek (DAG 02), Otter Lake (RDF),
Palmyra-Modesto Lake (RDZP), Hettick Lake (SDZF)

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PUBLIC PARTICIPATION

Stage 1 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 February 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 Tuesday, March 22, 2005 in Girard, Illinois at the former Otter Lake Pump Building. In addition to the meeting's sponsors, nine 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 22, 2005. At the meeting, there were several general questions, including questions about schedule and process, and concerns that the TMDL will bring new regulations for farmers. In response, the voluntary nature of the program with respect to nonpoint sources was emphasized. A participant asked about the approach that will be used for the pH TMDL for Palmyra-Modesto Lake. A resident who fishes in Otter Lake noted that the upstream end of the lake is silting in. The ongoing and planned sedimentation controls were discussed. A question was asked about whether the TMDL will include recommendations for measures to improve the watershed, and IEPA responded that the TMDL report will provide this type of information. Some participants expressed interest in getting involved in future watershed improvement efforts. Dennis Ross, General Manager of the Otter Lake Water Commission said the Commission spends about $60K per year addressing sedimentation problems and would be interested in working with other stakeholders on reducing sediment loads through watershed management/restoration activities.

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

REFERENCES

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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FINAL

March 2006

Macoupin Creek Watershed

Hodges Creek Watershed

North Fork Kaskaskia River Watershed

Skillet Fork Watershed

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INTRODUCTION

Limno-Tech, Inc. (LTI) completed surface water sampling in the summer and fall of 2005 to support Total Maximum Daily Load (TMDL) development for impaired water bodies in four State of Illinois watersheds. This report describes the field investigations and results of the sampling program completed in 2005. This report is divided into sections describing:

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

FIELD INVESTIGATION OVERVIEW

TMDL streams and their tributaries were sampled during the summer and fall of 2005 to collect data needed to support water quality modeling and TMDL development. The sampled waterbodies are all located within the following watersheds:

- Macoupin Creek (Figure 1),
- Hodges Creek (Figure 2),
- North Fork Kaskaskia River (Figure 3), and
- Skillet Fork (Figure 4).

Sampling was initially planned for six watersheds, as described in the IEPA-approved Quality Assurance Project Plan (LTI, 2005); however, weather conditions did not permit completion of sampling in two of the project watersheds (Mauvaise Terre and East Fork Kaskaskia River). Sampling in these two watersheds will be completed in 2006 and documented separately.

Data were collected during two low-flow periods in accordance with an Illinois EPA-approved QAPP (Appendix 1; LTI, 2005). In each of the sampled watersheds, the 303(d)-listed stream segment(s) had water present, although tributaries to these segments were not always flowing. Samples were collected from the tributaries if water was present.

Table 1 presents a summary of the sampling completed by watershed, field observations, and any changes in station location.

The sampling and analysis activities included:

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

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

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

Table 1. Sampling summary

Site ID	IEPA Station ID	Station Description	Location Change From QAPP Listing	DO, NH_3, BOD_5, Water Temp, channel morphometry		Flow (depth & velocity)		SOD & diurnal DO	Fe		Mn		Round 1 Notes	Round 2 Notes
				Round 1	Round 2	Round 1	Round 2	Round 1	Round 1	Round 2	Round 1	Round 2		
Macoupin Creek Watershed													**8/22-25/2005**	**10/11/2005**
MAC-1	DA 03	Macoupin Ck at US 67		✔	✔	✔	✔				✔	✔	Water flowing; Sampled u.s. side of bridge	Same as Round 1
MAC-2		Coop Branch at Victory Rd											Upstream - dry; Downstream - pooled water covered with duckweed; Not sampled	Same as Round 1
MAC-3	DA 04	Macoupin Ck at Shipman Rd		✔	✔	✔	✔				✔	✔	Water present; Sampled u.s. side of bridge	Same as Round 1
MAC-4		Dry Fork at Lake Catatoga Rd											Dry; Not sampled	Same as Round 1
MAC-5		Honey Ck at Brushy Mount Rd		✔	✔						✔	✔	Water present, no apparent flow; Sampled u.s. side of bridge	Same as Round 1
MAC-6	DAZN	Briar Ck at Crumystone Rd		✔	✔						✔	✔	Water flowing; 3 8' circular c.s. culverts; discharge from W. culvert; Sampled ~20' d.s. of W. culvert; flow measurements ~80 d.s. of culverts and beyond sand bar	Water present; flow from all 3 culverts; Sampled ~80 d.s. of culverts and beyond sand bar
MAC-7	DA 05	Macoupin Ck at Illinois Rte 4		✔	✔	✔	✔	✔			✔	✔	Water present; Sampled u.s. side of bridge	Water present; Sampled d.s. side of bridge
MAC-8		Shaw Point Branch at Sumpter Rd			✔							✔	Dry with pools of water 100'-200' upstream and downstream; Not sampled	Upstream - water under bridge and ~50 u.s., then dry channel for ~75', then water present beyond; Downstream - water present for ~15' d.s., then ~10' of dry bed, then water present beyond; Sampled u.s. side of bridge
MAC-9	DA 11	Macoupin Ck at Coops Mound Rd		✔	✔	✔	✔				✔	✔	Water present; Sampled d.s. side of bridge	No flow, low water levels, duckweed covered
MAC-10		Horse Ck (East) at Sulphur Springs Road		✔	✔						✔	✔	Dry under bridge with water upstream and downstream; Sampled 50' d.s. of bridge & ~10' below u.s. edge of water	Same as Round 1
---			Additional observation: Macoupin Ck at Sulphur Springs Rd										Upstream - dry; Downstream - water present	
---			Additional observation: Macoupin Ck at Boston Chapel Rd										Water present upstream and downstream, duckweed covered	
MAC-11		Horse Ck (West) at Boston Chapel Road		✔							✔		Upstream - dry; Downstream and under bridge - pooled with duckweed cover; sampled d.s. side of bridge	Dry with small pool under bridge; Not sampled
---			Additional observation: Macoupin Ck at Macoupin Rd./Co. Rd. 2725N Rd										Dry under bridge with pooled water upstream and downstream	
---			Additional observation: Macoupin Ck at East 1st Rd./Co. Rd. 100E										Dry under bridge with puddled water upstream and downstream	
---			Pasture Rd./Co. Rd. 2850N										Water present	
MAC-12		Macoupin Ck at East 2nd Rd/County Rd. 200E		✔	✔		✔				✔	✔	Dry under bridge with moist sediments and small puddle, water present `10' upstream and ~25' downstream; Sampled d.s. side of bridge	Pools u.s. and d.s. with slow trickle of water between under bridge; Sampled
---			Additional observation: Macoupin Ck at I-55										Upstream and under bridge - very little water with trickle flow under bridge; Downstream - duckweed covered pool	
---			Additional observation: Mine Ave./Co. Rd. 3050N (E. of I-55)										Upstream - very little water; Downstream - dry	

Table 1. Sampling Summary Continued

Site ID	IEPA Station ID	Station Description	Location Change From QAPP Listing	DO, NH_3, BOD_5, Water Temp, channel morphometry		Flow (depth & velocity)		SOD & diurnal DO	Fe		Mn		Round 1 Notes	Round 2 Notes
				Round 1	Round 2	Round 1	Round 2	Round 1	Round 1	Round 2	Round 1	Round 2		
Hodges Creek Watershed													**8/22-25/2005**	**10/11/2005**
HOD-1	DAG 03	Hodges Ck at Co. Hwy. 24/Co. Rd. 1050N/Chesterfield Rd.		✓	✓	✓	✓	✓					Water present, ~40' wide, narrows to ~10' under bridge with flow observed; Sampled channel (10' width) and measured flows (20' width) under d.s. side of bridge	Pooled water, very low flow
HOD-2		Joes Ck. At Joes Ck Rd.											Dry with small puddle at upstream side of bridge	Same as Round 1
---			Additional observation: Joes Cr at Illinois Rte 108										Upstream - water present; Downstream - dry	
HOD-3		Hodges Ck at Illinois Route 108	Otter Cr. incorrectly referenced in QAPP	✓	✓	✓	✓						Shallow, narrow 1-4' wide stream widening to a ~50' pool ~50' downstream of bridge; Sampled 2' wide channel under d.s. side of bridge	Water pooled u.s. and d.s. and connected by small trickle of water
HOD-4		Solomon Ck at Boyscout Rd (d/s of Hettick STP)											Dry with small puddle downstream	Same as Round 1
HOD-5		Solomon Ck East off of Goshen Rd., no bridge (d.s. of Palmyra STP)											Dry, 2.5-3' c.s. culvert, no bridge	Same as Round 1
HOD-6		Nassa Ck near end of Wildcat Ln, no bridge											Dry with pool ~60' upstream (pool size: 12'x12'x2-6" deep), no bridge	Dry, small puddles, no flow
HOD-7		East Fork Otter Ck at Henry Rd (W of Girard)		✓	✓	✓	✓						Water present, narrows to <1' under bridge, no apparent flow; Sampled d.s. side of bridge	Similar to Round 1
North Fork Kaskaskia River Watershed													**8/26/05-9/2/05**	**10/13/2005**
NFK-1		N.F. Kaskaskia R. at Boulder Rd/Co. Rd 300E/2700E		✓	✓	✓	✓		✓	✓	✓	✓	Water present; Sampled u.s. side of bridge	Water present; Sampled d.s. side of bridge
NFK-2		Louse Run at Co. Rd. 2150/Co. Rd. 475E/Co. Rd. 450E		✓	✓				✓	✓	✓	✓	Water present, flow observed; Sampled u.s. side of bridge	Same as Round 1
NFK-3		N.F. Kaskaskia R. at Co. Rd 100N		✓	✓			✓	✓	✓	✓	✓	Water present, duckweed covered u.s.; Sampled d.s. side of bridge	Same as Round 1; deer carcass observed in water
NFK-4		Unnamed tributary 600' S of Bond Ave., no bridge. D/S of Patoka STP											Dry, ~5' wide shallow channel, no bridge; Not sampled	Same as Round 1
NFK-5	OKA 01	N.F. Kaskaskia R at US 51		✓	✓	✓	✓		✓	✓	✓	✓	Water present; Sampled u.s. side of bridge	Water present; Sampled u.s. side of bridge; flow measurements d.s. side of bridge
NFK-6		N.F. Kaskaskia R at Griffin Rd.		✓	✓	✓	✓		✓	✓	✓	✓	Water present; Sampled u.s. side of bridge	Same as Round 1
NFK-7		N.F. Kaskaskia R at Hadley Rd.		✓	✓				✓	✓	✓	✓	Upstream - water present; Downstream - only small puddles present for ~50' d.s. of bridge, then water; Sampled u.s. side of bridge	Sampled from u.s. side of bridge; water present u.s., under bridge & ~6' d.s., then dry for ~15' d.s., then a 20' long puddle, then dry for ~5', then water present

Table 1. Sampling Summary Continued

Site ID	IEPA Station ID	Station Description	Location Change From QAPP Listing	DO, NH_3, BOD_5, Water Temp, channel morphometry		Flow (depth & velocity)		SOD & diurnal DO	Fe		Mn		Round 1 Notes	Round 2 Notes
				Round 1	Round 2	Round 1	Round 2	Round 1	Round 1	Round 2	Round 1	Round 2		
Skillet Fork Watershed													**8/26/05-9/1/05**	**10/12/2005**
SKIL-1		Skillet Fork at Neal Road/Faye Road		✓	✓								Upstream - water pooled from under bridge to ~50' u.s.; Downstream - dry for ~75', then a pool; Sampled	Similar to Round 1
SKIL-2		Dums Cr. at Williams Road		✓	✓								Water present, not continuous u.s., no flow; Sampled	Similar to Round 1
SKIL-3		Sutton Cr. At Co. Rd. 050E/Scotch Pine Rd.		✓	✓								Water present; Sampled	Same as Round 1
SKIL-4	CA 09	Skillet Fork at Wilcoxen Rd.		✓	✓	✓	✓	✓					Water present; Sampled	Same as Round 1
SKIL-5		Dums Cr. At Bee Branch Rd.		✓	✓								Upstream and under bridge - dry for ~50' u.s., then pooled; Downstream - dry for ~20', then pooled; Sampled	Similar to Round 1
SKIL-6		Skillet Fork at Allen Rd/Kirby Rd		✓	✓								Water present; skinned animal carcass observed in water on 8/26/05; Sampled	Same as Round 1
SKIL-7	CAW 04	Dums Cr at end of Landmark Rd (no bridge)		✓	✓	✓	✓	✓					Water present, duckweed covered; Sampled	Same as Round 1
SKIL-8	CA 08	Skillet Fork at River Rd.	Difficult access at end of Blank Rd., no bridge, moved d.s. to nearest bridge	✓	✓								Water present; Sampled	Same as Round 1
SKIL-9		Brush Cr. at Co. Rd 2200N		✓	✓						✓		Water present; Sampled	no visible flow, pooled water u.s. and d.s.; 50 gal. drum and trash in water; Sampled u.s. side of culvert
SKIL-10		Fulton Cr at Landmark Rd.		✓	✓								Water on u.s. side of bridge; pool of water on d.s. side, then dry d.s.; concreted wash over culvert; Sampled u.s. side of culvert	no visible flow, pooled water u.s. and d.s.; Sampled u.s. side of culvert
SKIL-11		Nickolson Cr at Dago Hill Rd.		✓	✓								Water present, flow observed; Sampled	Small pond under bridge, no flow
SKIL-12		Skillet Fork beyond end of Seed House Rd.		✓	✓								Water present, flowing, no bridge; Sampled	Same as Round 1
SKIL-13		Bob Branch Co. Rd 1900N											Water present on 8/26/05 after heavy thunderstorms, Dry on 9/1/05; 2 4' culverts; Not sampled u.s. side	Dry with very small pools u.s.; water level ~1' below culverts; Not sampled
SKIL-14		Brush Cr at Co. Hwy 16/Co. Rd. 1825 N		✓	✓								Water present; Sampled	
SKIL-15	CA 06	Skillet Fork at State Route 161		✓	✓	✓	✓	✓			✓		Water present; Sampled u.s. side of bridge	Same as Round 1
SKIL-16	CAR 01	Brush Creek at Co. Hwy. 27/Co. Rd. 1500N		✓	✓	✓	✓	✓			✓		Water present; Sampled d.s. side of bridge	Same as Round 1
SKIL-17		Skillet Fork at Co. Hwy. 13/Co. Rd 250E		✓	✓						✓		Water present; Sampled d.s. side of bridge	Same as Round 1
SKIL-18		Horse Creek beyond end of Moonbeam Ln		✓	✓						✓		Water present, small 6" wide trickle of water flowing between pools u.s. and d.s., no bridge; Sampled	Pools u.s. and d.s., no flow between; Sampled pool, no morphometry measurements recorded
---			Additional observation: Horse Cr at Harmony Rd./Co. Rd. 1900E										Water present	
SKIL-19		Horse Cr at Malecki R./Co. Rd. 2050N		✓	✓						✓		Water present; no observable flow; Sampled u.s. side of bridge	Same as Round 1
SKIL-20		Skillet Fork at Co. Rd. 900N		✓	✓			✓ SOD only					Water present; flow observed; Sampled u.s. side of bridge	Same as Round 1
SKIL-21	CAN 01	Horse Cr at Co. Rd. 200E		✓	✓	✓	✓	✓			✓		Water present; Sampled d.s. side of bridge	Same as Round 1
SKIL-22		Puncheon Cr at Co. Rd. 000E/2400E		✓	✓								Water present; slight flow observed; Sampled u.s. side of bridge	Same as Round 1
SKIL-23	CA 05	Skillet Fork at Illinois Route 15		✓	✓			✓ DO only			✓		Water present; Sampled u.s. side of bridge	Same as Round 1
SKIL-24		Skillet Fork at Co. Rd. 100N at corner with 1500 E	No access at Co. Rd. 1225E, no bridge, moved d.s. to nearest bridge	✓	✓						✓		Water present; Sampled d.s. side of bridge	Same as Round 1
SKIL-25	CA 02	Skillet Fork at Co. Rd. 800E		✓	✓						✓		Water present; Sampled d.s. side of bridge	Same as Round 1; deer carcass observed in water
SKIL-26		Limekiln Cr at Co. Rd. 2000N		✓	✓								Water present; Sampled u.s. side of bridge	Same as Round 1
SKIL-27	CA 03	Skillet Fork at Co. Hwy 1/Co. Rd. 1125E/1150E		✓	✓	✓	✓	✓			✓		Water present; Sampled d.s. side of bridge	Same as Round 1
SKIL-28		Sevenmile Cr. At Co. Rd. 750E (N. of Co. Rd. 1800N)	No access, private land, no bridge at original location, moved u.s. to nearest bridge	✓	✓								Water present; Sampled u.s. side of bridge	Same as Round 1

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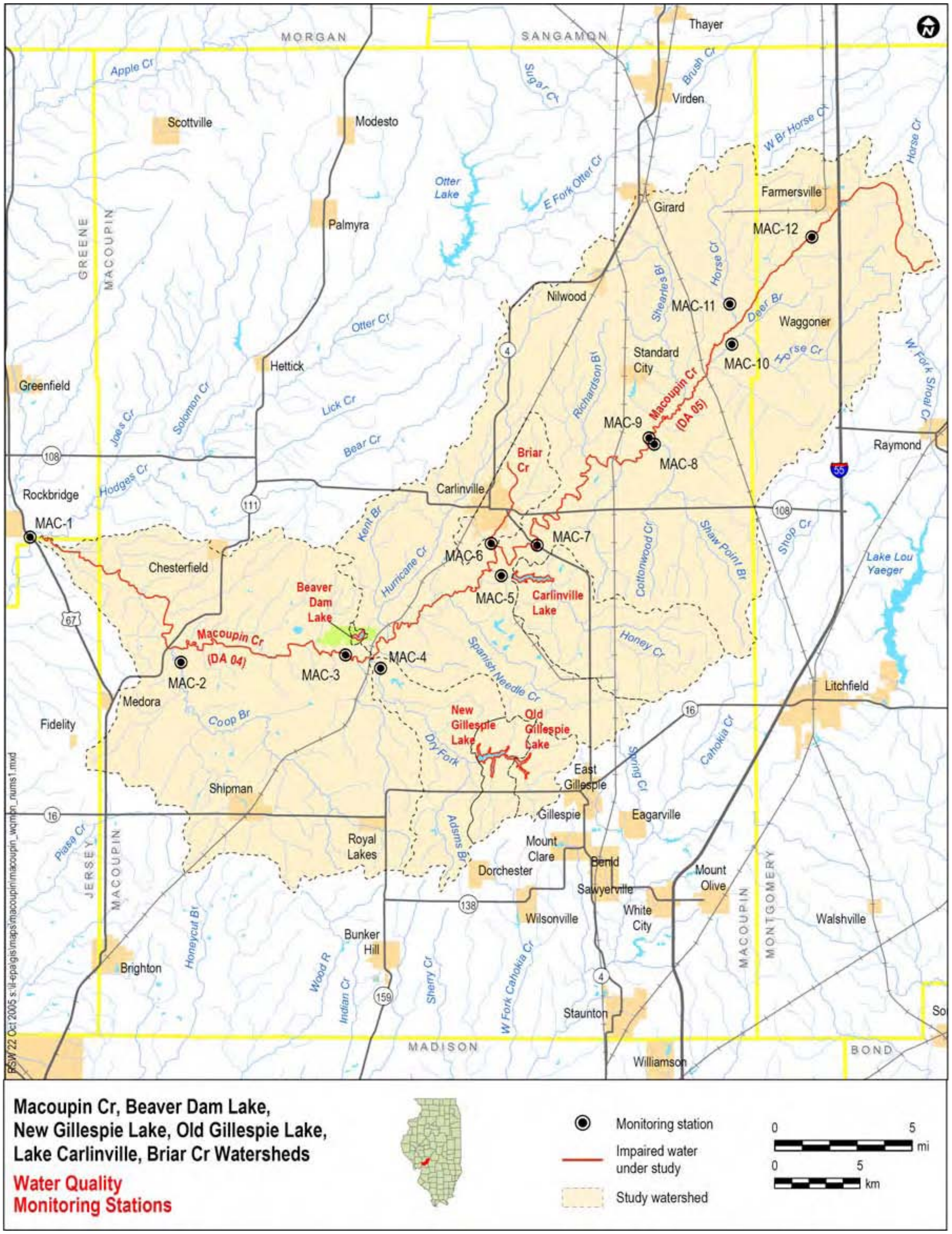

Figure 1. Macoupin Creek Watershed Sampling Locations

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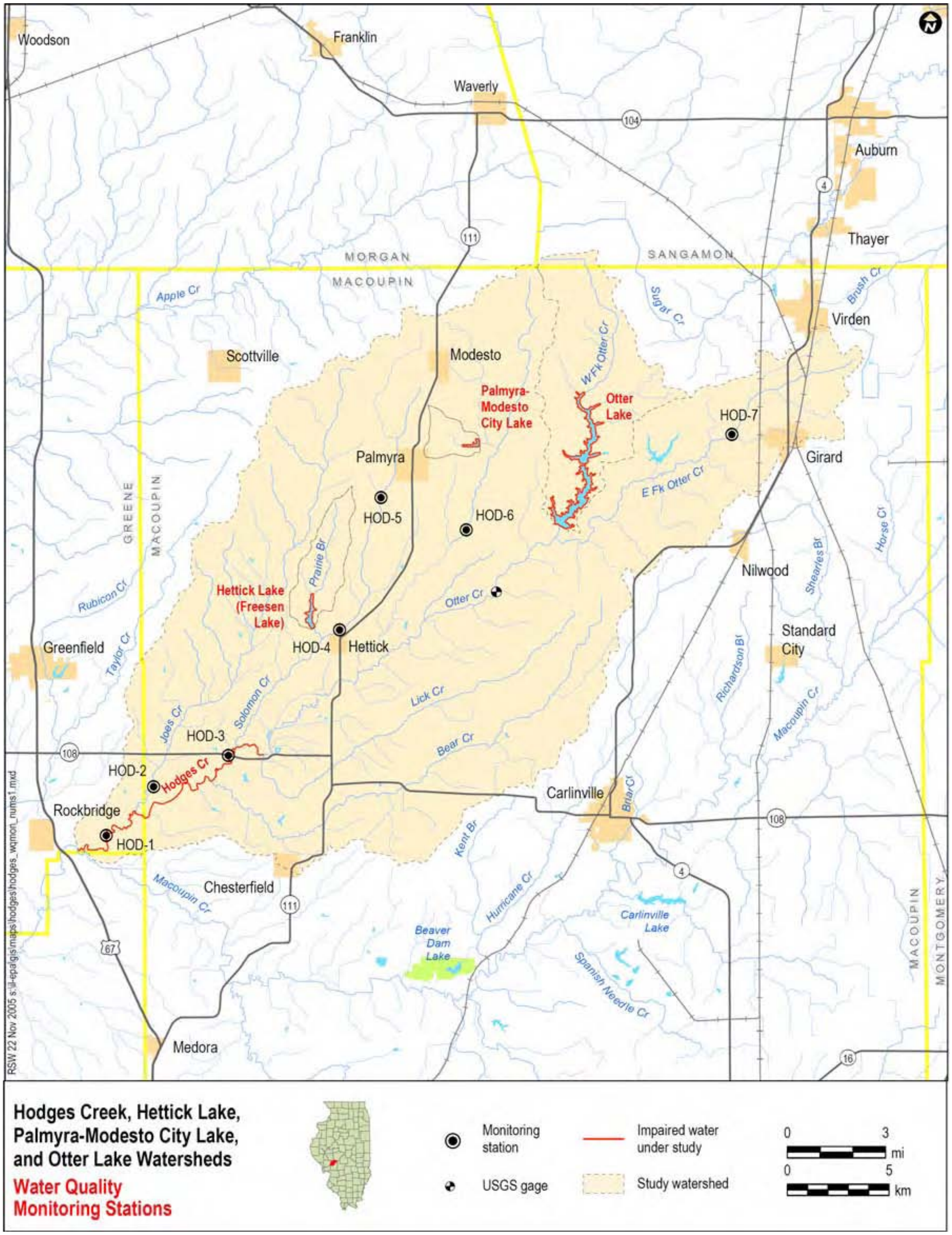

Figure 2. Hodges Creek Watershed Sampling Locations

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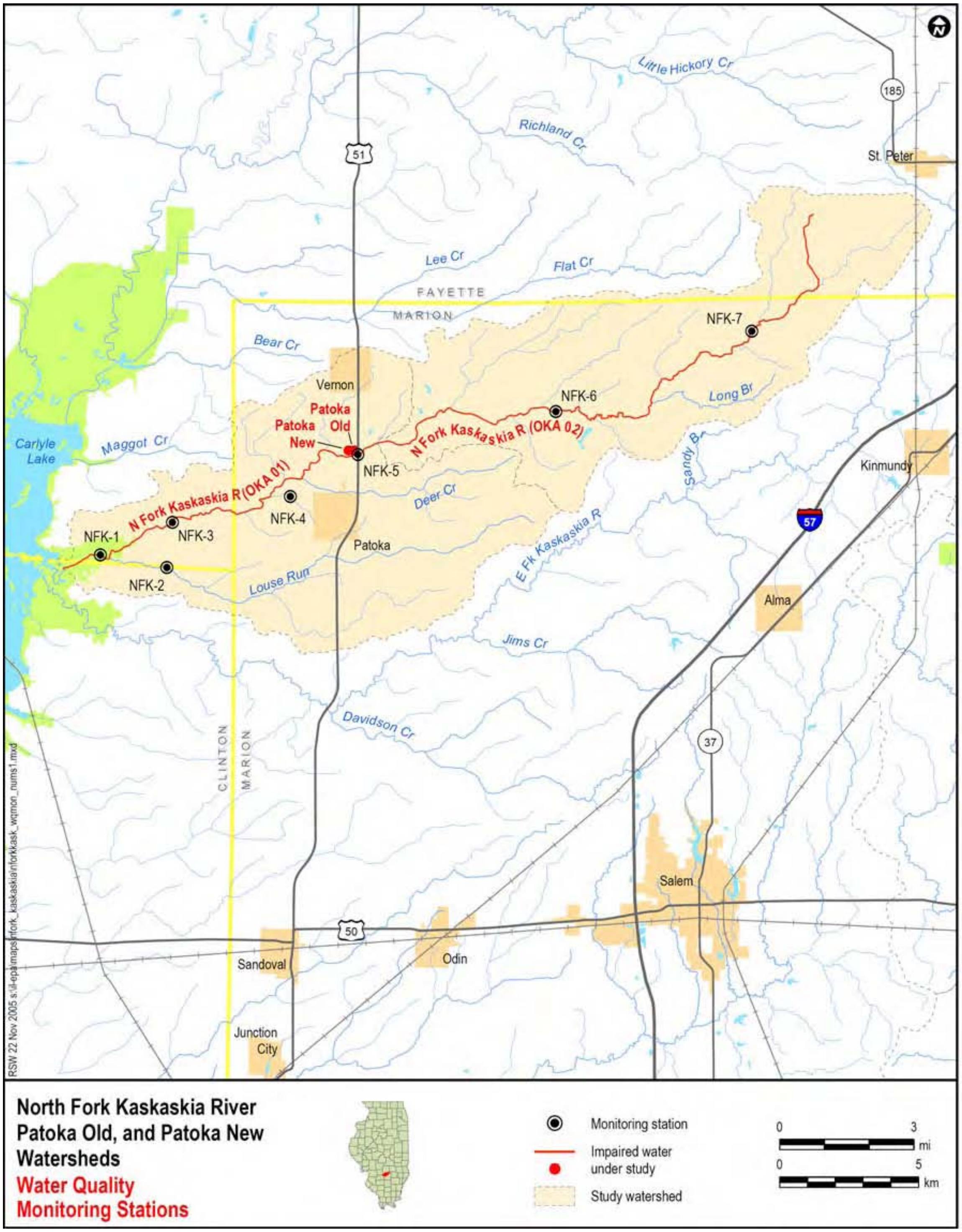

Figure 3. North Fork Kaskaskia River Watershed Sampling Locations

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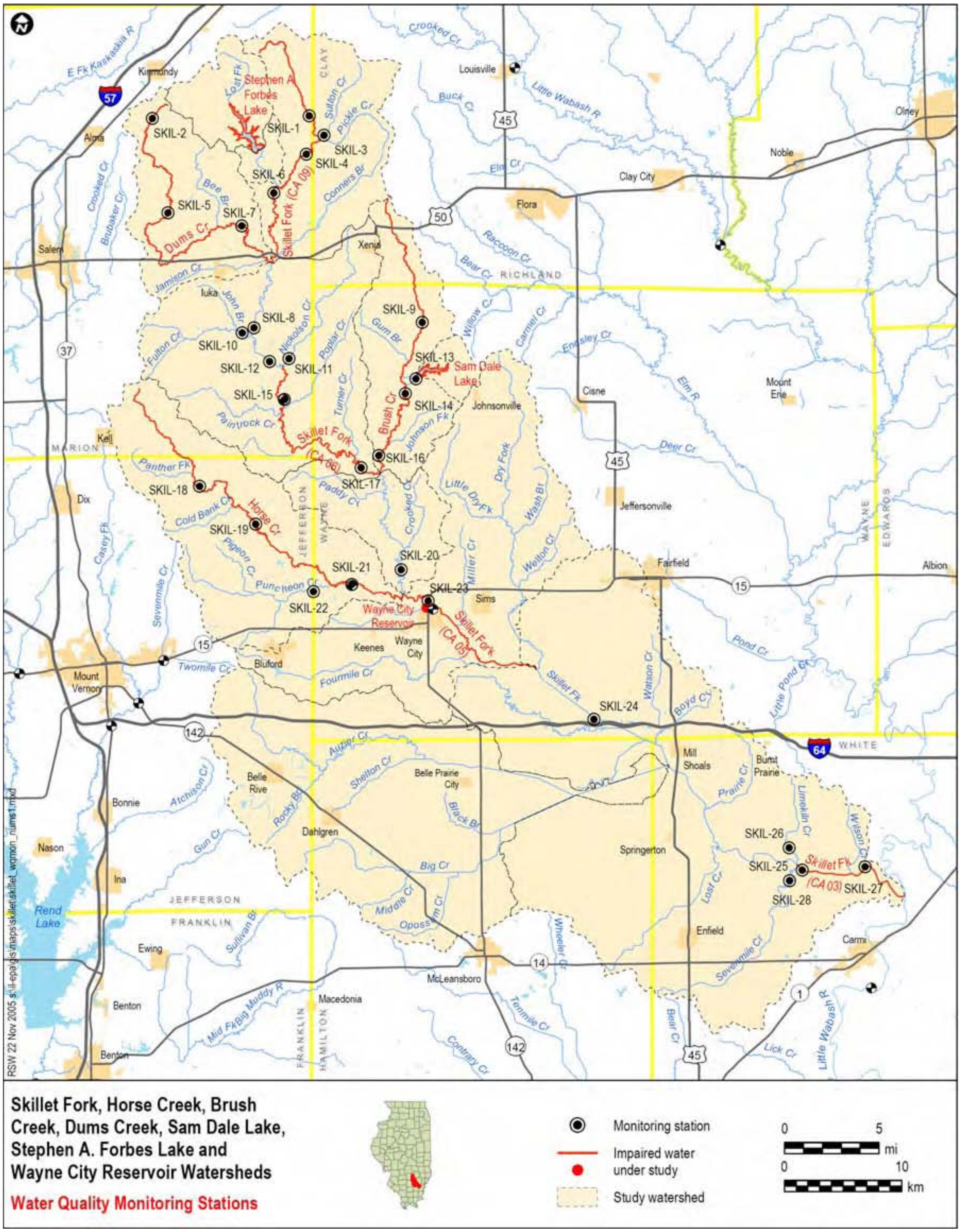

Figure 4. Skillet Fork Watershed Sampling Locations

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WATER SAMPLE COLLECTION AND FIELD MEASUREMENTS

Sampling activities were conducted in accordance with the QAPP during low flow conditions on two separate occasions (Round 1 and Round 2) for each watershed, as noted in Table 1. Surface water samples and field measurements were collected by LTI at 45 stream locations (out of a possible 54 planned locations) in four watersheds; nine locations were not sampled because there was insufficient water present. For some streams, alternating reaches of water-filled and "dry" channels were observed. In these locations, it appears that the stream went underground for a short stretch, resurfacing further downstream. A small number of locations were sampled from standing pools of water such as these, which had no observable surface hydraulic connection to upstream or downstream sampling locations. Water level conditions observed in the field are noted in Table 1.

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

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

Table 2. Round 1 Laboratory and Field Measurement Results

Sample ID	Colletion Date/Time	Ammonia (mg/L)	BOD_5 (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)		Temp (degC)	DO (mg/L)	pH (s.u.)
Hodges Creek Watershed									
HOD-1	8/24/05 8:25	<0.01	<2				23.00	5.00	
HOD-3	8/24/05 9:55	0.14	<2				22.40	8.60	
HOD-7	8/24/05 10:45	0.07	<2				19.40	4.35	
Macoupin Creek Watershed									
MAC-1	8/23/05 8:15	<0.01	2.7		0.57	J	25.80	4.28	
MAC-1 Dup	8/23/05 8:15	<0.01	3.2						
MAC-3	8/23/05 10:05	<0.01	2.9		0.52	J	25.30	4.65	
MAC-5	8/23/05 11:40	0.02	<2		0.06	J	27.00	13.10	
MAC-6	8/23/05 12:10	<0.01	<2		0.03	J	19.00	8.65	
MAC-7	8/23/05 12:50	0.01	4.8		0.5	J	24.50	4.15	
MAC-9	8/23/05 14:25	0.31	<2		0.65	J	25.00	3.90	
MAC-10	8/23/05 15:30	0.16	5.5		0.95	J	22.00	6.60	
MAC-11	8/23/05 15:50	0.22	4.9		1.9	J	21.80	1.50	
MAC-12	8/23/05 16:25	0.06	2.8		0.19	J	22.00	9.40	
North Fork Kaskaskia River Watershed									
NFK-1	8/31/05 12:05	0.08	3.2	0.88	0.47		26.00	3.50	7.90
NFK-1 Dup	8/31/05 12:05	0.09	3.2	0.89					
NFK-2	8/31/0511:40	0.24	<2	1.5	0.47		23.10	2.30	7.50
NFK-3	8/31/05 11:10	0.07	3.2	1.7	1.7		23.10	0.50	7.50
NFK-5	8/31/05 9:40	0.51	<2	0.93	1.2		22.10	1.85	7.60
NFK-6	8/31/05 8:40	0.3	<2	1.6	1.1		21.50	1.65	7.60
NFK-7	8/31/05 7:55	0.2	<2	0.85	1.4		21.50	1.40	7.60
Skillet Fork Watershed									
SKIL-1	9/1/05 14:55	0.66	<2				24.00	4.10	
SKIL-2	9/1/05 15:40	0.04	<2				28.00	10.20	
SKIL-3	9/1/05 14:10	0.72	<2				25.00	2.20	
SKIL-4	9/1/05 13:30	0.03	6.7				21.00	0.40	
SKIL-5	9/1/05 12:00	0.41	<2				22.80	5.00	
SKIL-6	9/1/05 11:25	0.02	<2				23.90	2.50	
SKIL-6 Dup	9/1/05 11:25	<0.01	<2						
SKIL-7	9/1/05 10:40	0.13	<2				22.00	3.00	
SKIL-8	9/1/05 9:50	0.27	<2				22.90	3.10	7.28
SKIL-9	9/1/05 9:35	0.25	<2		2.3		21.20	1.56	
SKIL-10	9/1/05 7:45	1.2	<2				19.90	2.36	
SKIL-11	9/1/05 9:00	0.06	<2				20.70	4.74	
SKIL-12	9/1/05 8:20	0.51	<2				22.20	1.78	
SKIL-14	9/1/05 10:00	0.15	<2				21.80	3.25	
SKIL-15	9/1/05 7:50	0.16	<2		0.69		22.50	3.50	7.22
SKIL-16	9/1/05 7:55	0.16	<2		1.2		21.55	2.10	6.67
SKIL-17	9/1/05 8:50	0.12	<2		0.6		22.96	3.51	6.78

Sample ID	Colletion Date/Time	Ammonia (mg/L)	BOD_5 (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Temp (degC)	DO (mg/L)	pH (s.u.)
SKIL-18	9/1/05 11:55	0.14	<2		0.98	23.50	6.74	
SKIL-19	9/1/05 12:20	0.08	<2		0.58	22.40	3.75	
SKIL-19 Dup	9/1/05 12:20	0.09	<2		0.61			
SKIL-20	9/1/05 13:30	0.09	<2			24.60	5.03	
SKIL-21	9/1/05 9:20	0.16	<2		1.2	21.96	3.20	6.92
SKIL-22	9/1/05 12:55	0.03	<2			22.60	3.60	
SKIL-23	9/1/05 10:35	0.15	<2		0.6	24.36	3.15	7.12
SKIL-24	9/1/05 11:20	0.2	<2		0.75	25.26	6.06	7.32
SKIL-25	9/1/05 12:40	<0.01	<2		0.3	24.89	5.54	7.23
SKIL-26	9/1/05 12:15	0.12	<2			22.35	4.20	6.89
SKIL-27	9/1/05 13:30	<0.01	<2		0.26	25.94	8.12	7.61
SKIL-27 Dup	9/1/05 13:30	<0.01	<2		0.26			
SKIL-28	9/1/05 13:00	0.07	<2			22.47	4.19	6.85
Rinse Blank	9/1/05 16:00	<0.01	<2		<0.02			
Rinse Blank 2	9/1/05 16:30	0.04	<2		<0.02			

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

Table 3. Round 2 Laboratory and Field Measurement Results

Sample ID	Collection Date/TIme	Ammonia (mg/L)	BOD_5 (mg/L)	Dissolved Fe (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Temp (degC)	DO (mg/L)	pH (s.u.)
Hodges Creek Watershed									
HOD-1	10/11/05 8:55	<0.01	2.7				14.85	5.77	
HOD-3 DUP1	10/11/05 9:50	0.23	<2				14.60	5.67	
HOD-3 DUP2	10/11/05 9:50	0.23	<2						
HOD-7	10/11/05 11:45	0.02	<2				14.17	6.96	
Rinse Blank H	10/11/05 7:00	0.06	<2						
Macoupin Creek Watershed									
MAC-1	10/11/05 9:20	<0.01	<2			0.35 J	14.69	8.39	
MAC-3	10/11/05 10:15	<0.01	<2			0.34 J	13.56	7.92	
MAC-5	10/11/05 12:20	0.01	3.5			1.1 J	15.67	8.73	
MAC-6	10/11/05 12:50	0.05	<2			<0.02 J	18.42	8.57	
MAC-7 DUP1	10/11/05 14:00	0.02	2.6			0.21 J	14.42	5.59	
MAC-7 DUP2	10/11/05 14:00	0.03	<2						
MAC-8	10/11/05 14:45	0.02	<2			0.2 J	14.02	4.27	
MAC-9	10/11/05 13:45	0.2	6			1.6 J	13.85	0.67	
MAC-10	10/11/05 13:10	0.36	<2			0.39 J	14.25	4.05	
MAC-12	10/11/05 12:30	1.8	16			0.47 J	13.18	2.57	
Rinse Blank MAC	10/11/05 7:00	0.05	<2						
North Fork Kaskaskia River Watershed									
NFK-1	10/13/05 8:35	0.13	<2	0.06	1.9	0.31	16.41	3.88	6.57
NFK-2	10/13/05 12:00	0.41	5.1	0.34	2.3	1.3	14.40	1.74	7.24
NFK-3	10/13/05 10:10	0.44	3.8	0.34	3.6	1.8	14.41	0.57	6.90
NFK-5 DUP1	10/13/05 10:55	0.25	3.7	0.6	2.6	0.89	13.92	2.26	6.89
NFK-5 DUP2	10/13/05 10:55	0.22	4.5	0.55	2.8				
NFK-6	10/13/05 12:45	0.43	4.3	1.4	3.8	1.9	13.67	0.49	6.64
NFK-7	10/13/05 13:25	0.33	4.5	0.48	2.8	1.6	15.85	1.25	7.19
Rinse Blank	10/13/05 8:00	0.09	<2	0.06	0.11				
Skillet Fork Watershed									
SKIL-1	10/12/05 13:20	0.03	<2				14.67	3.40	
SKIL-2	10/12/05 12:45	0.15	3				16.34	9.01	
SKIL-3	10/12/05 13:40	0.47	<2				14.03	2.22	
SKIL-4	10/12/05 14:00	0.02	17				13.54	1.02	
SKIL-5	10/12/05 11:40	1.5	<2				14.37	2.65	
SKIL-6 DUP1	10/12/05 14:35	0.16	3.7				14.94	2.74	
SKIL-6 DUP2	10/12/05 14:35	0.02	3						
SKIL-7	10/12/05 11:10	0.18	<2				13.73	1.73	
SKIL-8	10/12/05 10:30	0.24	4.8				13.72	2.65	
SKIL-9	10/12/05 9:30	0.16	<2				14.18	3.64	7.78
SKIL-10	10/12/05 8:20	1.2	<2				13.64	4.07	7.95
SKIL-11	10/12/05 9:05	0.06	<2				13.87	5.29	7.89
SKIL-12	10/12/05 8:45	0.19	<2				14.55	2.93	7.78
SKIL-14	10/12/05 9:50	0.08	<2				14.19	6.17	7.82
SKIL-15	10/12/05 8:15	0.14	<2				14.42	3.69	7.41

Sample ID	Collection Date/TIme	Ammonia (mg/L)	BOD_5 (mg/L)	Dissolved Fe (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Temp (degC)	DO (mg/L)	pH (s.u.)
SKIL-16	10/12/05 8:20	0.18	<2				13.85	3.43	7.09
SKIL-17	10/12/05 9:10	0.08	<2				14.62	5.94	7.32
SKIL-18	10/12/05 10:50	0.09	<2				15.26	4.82	7.80
SKIL-19 DUP1	10/12/05 11:05	0.32	<2				14.19	2.42	7.57
SKIL-19 DUP2	10/12/05 11:05	0.36	<2						
SKIL-20	10/12/05 11:40	0.12	<2				16.54	7.36	7.66
SKIL-21	10/12/05 9:40	0.08	<2				14.47	3.48	7.24
SKIL-22	10/12/05 12:05	0.12	<2				15.15	7.37	7.59
SKIL-23	10/12/05 10:35	0.03	8.1				16.71	4.22	7.00
SKIL-24	10/12/05 11:30	0.05	4.8				17.07	8.76	7.23
SKIL-25	10/12/05 12:55	0.05	<2				18.80	6.85	7.60
SKIL-26	10/12/05 12:35	0.07	2.5				16.00	6.60	7.60
SKIL-27 DUP1	10/12/05 15:00	<0.01	4.1				19.71	7.21	7.91
SKIL-27 DUP2	10/12/05 15:00	0.03	4						
SKIL-28	10/12/05 13:35	0.09	5.8				15.39	3.35	7.25
RB-1	10/12/05 7:00	0.07	<2						
RB-2	10/12/05 7:00	0.04	<2						
RB-3	10/12/05 7:00	0.07	<2						

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

Table 4. Stream Morphometry Results

	Round 1			Round 2		
Site ID	**Time**	**River Width (ft)**	**Avg. Water Depth (ft)**	**Time**	**River Width (ft)**	**Avg. Water Depth (ft)**
Macoupin Watershed						
	8/23/2005			**10/11/2005**		
MAC-1	8:15	48	1.09	9:00	48	1.11
MAC-2	9:40	dry	dry	9:45	dry	dry
MAC-3	10:05	60	3.34	10:15	60	3.30
MAC-4	11:15	dry	dry	11:55	dry	dry
MAC-5	11:40	14	0.28	12:15	14	0.33
MAC-6	12:10	14	0.55	12:50	10	0.72
MAC-7	10:05	58	1.83	14:00	55	1.03
MAC-8	14:10	dry	dry	14:45	15	0.27
MAC-9	14:25	41	1.42	13:45	31	0.84
MAC-10	15:30	10.5	0.39	13:05	6	0.40
MAC-11	15:50	22	1.42	12:50	dry	dry
MAC-12	16:25	18	0.28	12:45	5	0.20
Hodges Watershed						
	8/24/2005			**10/11/2005**		
HOD-1	10:45	20	0.78	8:55	20	0.76
HOD-2	na	dry	dry	9:30	dry	dry
HOD-3	9:55	2	0.20	9:55	2	0.15
HOD-4	na	dry	dry	10:10	dry	dry
HOD-5	na	dry	dry	10:30	dry	dry
HOD-6	na	dry	dry	11:15	dry	dry
HOD-7	8:25	15	0.48	11:45	13	0.86
N. Fork Kaskaskia Watershed						
	8/31/2005			**10/13/2005**		
NFK-1	12:05	104	4.87	8:35	105	4.89
NFK-2	11:40	20.5	1.43	12:00	19	1.21
NFK-3	11:10	31	1.06	10:10	28	1.22
NFK-4	10:40	dry	dry	10:45	dry	dry
NFK-5	12:05	42	1.77	10:55	38	1.39
NFK-6	8:40	17.5	0.75	12:45	18.5	0.73
NFK-7	7:55	14	0.57	13:25	16	0.61
Skillet Fork Watershed						
	9/1/2005			**10/12/2005**		
SKIL-1	14:55	16	0.68	13:20	16	0.79
SKIL-2	15:40	6	0.33	12:45	4	0.15
SKIL-3	14:10	22	1.14	13:40	23	1.07
SKIL-4	13:30	24	1.30	14:00	25	1.19
SKIL-5	12:00	13.5	0.41	11:40	13	0.37
SKIL-6	11:25	67	2.30	14:35	65	2.29
SKIL-7	10:30	30	0.71	11:10	29	0.68
SKIL-8	9:50	18	1.05	10:30	14	0.71
SKIL-9	9:35	20	1.10	9:30	14.5	1.32

	Round 1			Round 2		
Site ID	**Time**	**River Width (ft)**	**Avg. Water Depth (ft)**	**Time**	**River Width (ft)**	**Avg. Water Depth (ft)**
SKIL-10	7:45	6	0.81	8:20	7.5	0.40
SKIL-11	9:00	31	1.51	9:05	28	1.65
SKIL-12	8:20	13.5	0.24	8:45	10.5	0.13
SKIL-13	9:55	dry	dry	9:40	dry	dry
SKIL-14	10:00	33	1.73	9:50	24	1.76
SKIL-15	10:30	70	4.75	8:15	60	5.03
SKIL-16	7:55	40	1.36	8:20	38	1.45
SKIL-17	8:50	59	2.56	9:10	59	2.32
SKIL-18	11:55	0.5	0.04	10:50	dry	dry
SKIL-19	12:20	46	1.97	11:05	39	1.54
SKIL-20	13:30	52	0.81	11:40	10	0.25
SKIL-21	9:20	57	1.71	9:40	55	1.91
SKIL-22	12:55	23	1.44	12:05	23	1.36
SKIL-23	10:35	82	5.92	10:35	81	5.81
SKIL-24	11:20	60	2.32	11:30	60	1.70
SKIL-25	12:40	90	3.49	12:55	88	3.29
SKIL-26	12:15	23	0.71	12:30	19	0.46
SKIL-27	13:30	92	5.01	15:00	90	5.20

DISCHARGE MEASUREMENTS

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

- Site location,
- Date and time,
- Measurement monitoring point,
- Distance between measurement points,
- Depth at each measurement point,
- Velocities at each measurement point,
- Angle of flow at each measurement point,
- Angle of bridge with respect to river channel (where measurements were conducted from bridges), and
- Any significant observations of monitoring procedures or river conditions

The discharge measurement results are presented in Table 5.

Table 5. Discharge Results

Macoupin Creek Watershed												
Site ID:	MAC-1		MAC-3		MAC-7		MAC-9		MAC-12			
Date	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**		
8/23/05	8:15	1.67	10:05	0*	12:50	0.28	14:25	0.09				
10/11/05	9:00	0.76	10:15	0*	12:50	1.27	13:45	0*	12:45	0*		
Hodges Creek Watershed							**North Fork Kaskaskia Watershed**					
Site ID:	HOD-1		HOD-3		HOD-7		NFK-1		NFK-5		NFK-6	
Date	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**
8/24/05	10:35	0.067	9:55	0.008	8:25	0*	12:05	1.62	12:05	1.33	8:40	0.2
10/11/05	8:55	0*	9:55	0.0006	11:45	0.13	8:35	0*	10:55	0*	12:45	0*
Skillet Fork Watershed												
Site ID:	SKIL-4		SKIL-7		SKIL-15		SKIL-16		SKIL-21		SKIL-27	
Date	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**	**Time**	**Q (cfs)**
9/1/05	13:30	0*	10:30	0*	10:30	0.74	7:55	0*	9:20	0.08	13:30	35.07
10/12/05	14:00	0*	11:10	0*	8:15	0*	8:20	1.05	9:40	0.82	15:00	3.81

Notes: Q = discharge
*No observable and/or measured downstream current

SEDIMENT OXYGEN DEMAND AND CONTINUOUS DO MONITORING

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

In-Situ Mini-Troll multi-parameter data-logging sondes were used for continuous DO measurements. The sondes were deployed for at least 24 hours at each of the selected locations. Calibration of the sondes for DO using the Winkler titration method was conducted before deployment and again after deployment to check the system for drift in DO values over time. Calibration and drift-check results were recorded in the field notes and are presented in Table 7. DO and temperature data were recorded at 15 minute intervals during sonde deployment, after which the sonde was removed and data were downloaded to a laptop computer. The continuous DO and temperature data are presented in Figures 5 through 14 and are also presented in Appendix 2.

Table 6. Sediment Oxygen Demand Results

Date	Site ID	<=SOD, g/m2/day @ 20c
8/25/2005	HOD1	1.24
8/25/2005	MAC7	0.78
8/31/2005	NFK3	0.38
8/28/2005	SKIL4	0.95
8/28/2005	SKIL7	0.63
8/28/2005	SKIL15	0.31
8/29/2005	SKIL16	0.56
8/29/2005	SKIL21	0.025
8/30/2005	SKIL20	0.32
8/29/2005	SKIL27	0.99

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

		Pre-Deployment Calibration	Post-Deployment Drift Check						
Station	Sonde ID	Winkler DO (mg/L)	Water Sample DO (mg/L)	Winkler DO (mg/L)	DO Drift (mg/L)	DO Drift (%)	Hours Deployed	Average Drift/hr (mg/L)	Average Drift/hr (%)
HOD-1	40813	5.3	6.42	6.75	-0.33	-5.0%	26	-0.0127	-0.19%
MAC-7	SS0002	5.425	5.16	6.65	-1.49	-25.2%	27.02	-0.0552	-0.93%
SKIL-4	40813	0.45	0.48	0.6	-0.12	-22.2%	24.75	-0.0048	-0.90%
SKIL-7	40067	4.4	3.23	3.05	0.18	5.7%	42.05	0.00428	0.14%
SKIL-15	SS0002	4.8	3.5	4.2	-0.7	-18.2%	26.58	-0.0263	-0.68%
SKIL-23	40813	3.4	3.74	3.45	0.29	8.1%	23.77	0.0122	0.34%
SKIL-16	40067	3.55	2.41	2.75	-0.34	-13.2%	27.08	-0.0126	-0.49%
SKIL-21	SS0002	5.3	3.72	3.6	0.12	3.3%	26.58	0.00451	0.12%
SKIL-27	40813	4.05	10.37	10.2	0.17	1.7%	44.75	0.0038	0.04%
NFK-3	SS0002	4.15	1.29	0.95	0.34	30.4%	40.58	0.00838	0.75%

Notes: Sonde deployed was Hydrolab MiniSonde 4a

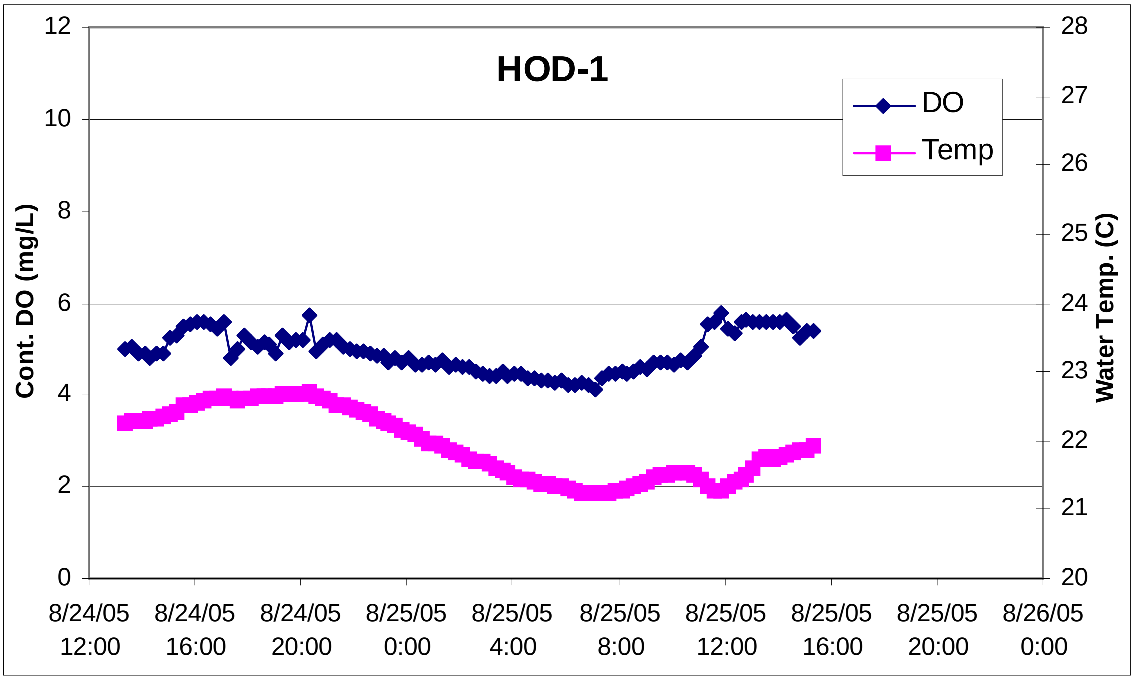

Figure 5. Continuous DO and Temperature at Hodges Creek Station HOD-1

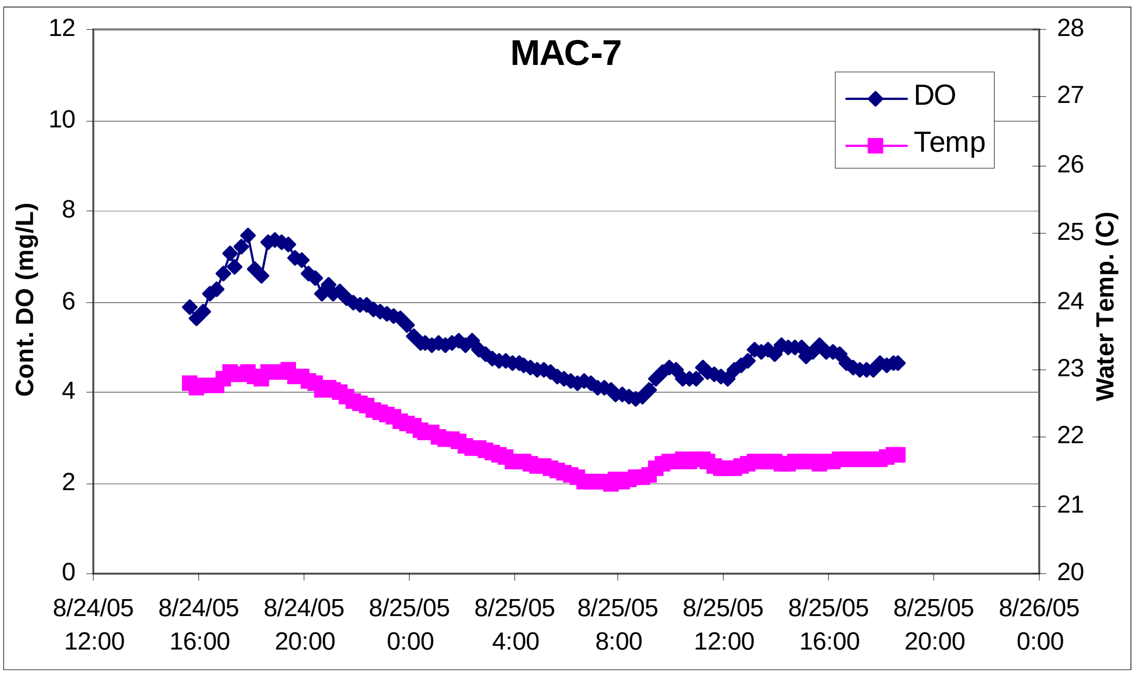

Figure 6. Continuous DO and Temperature at Macoupin Creek Station MAC-7

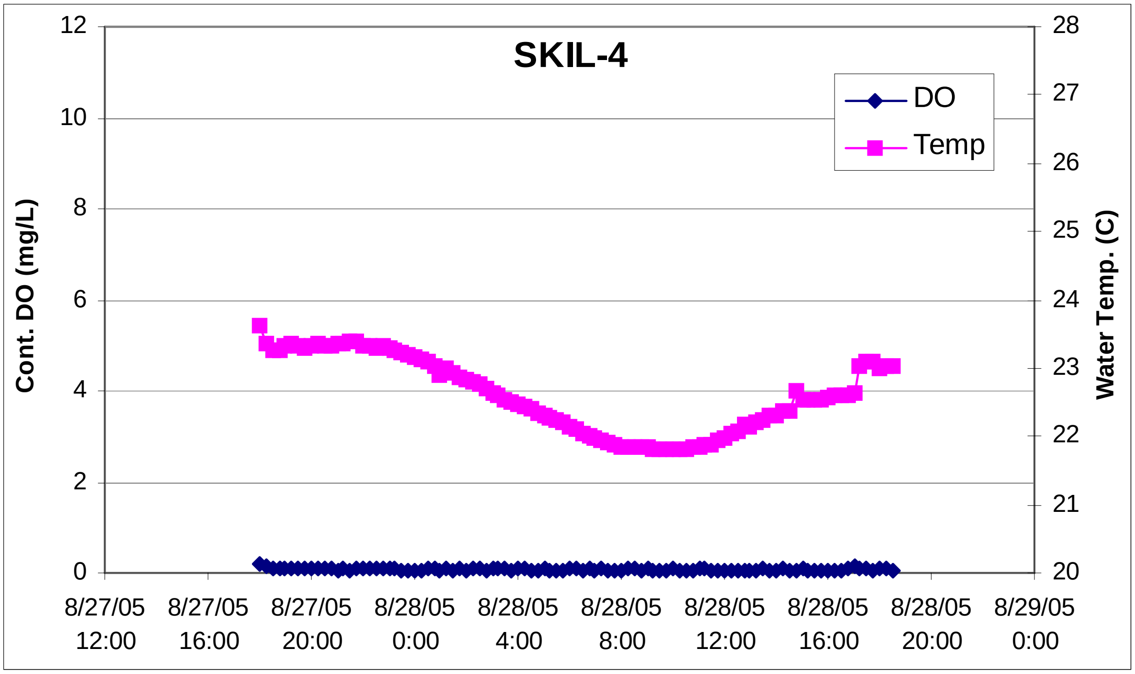

Figure 7. Continuous DO and Temperature at Skillet Fork Station SKIL-4

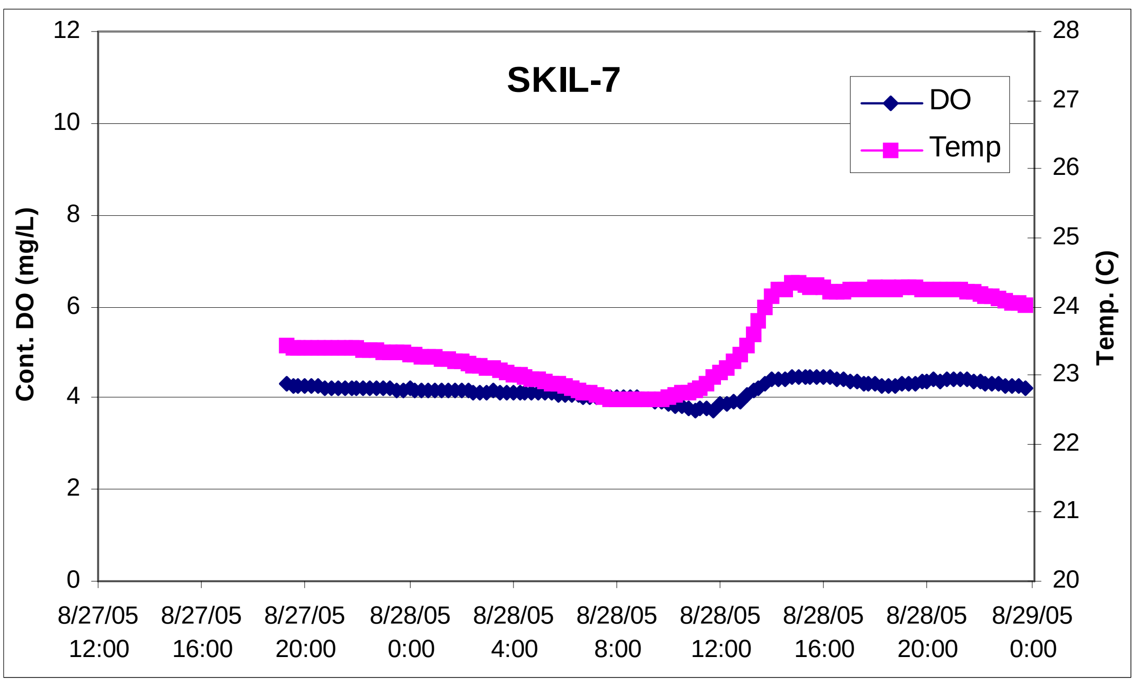

Figure 8. Continuous DO and Temperature at Dums Creek Station SKIL-7

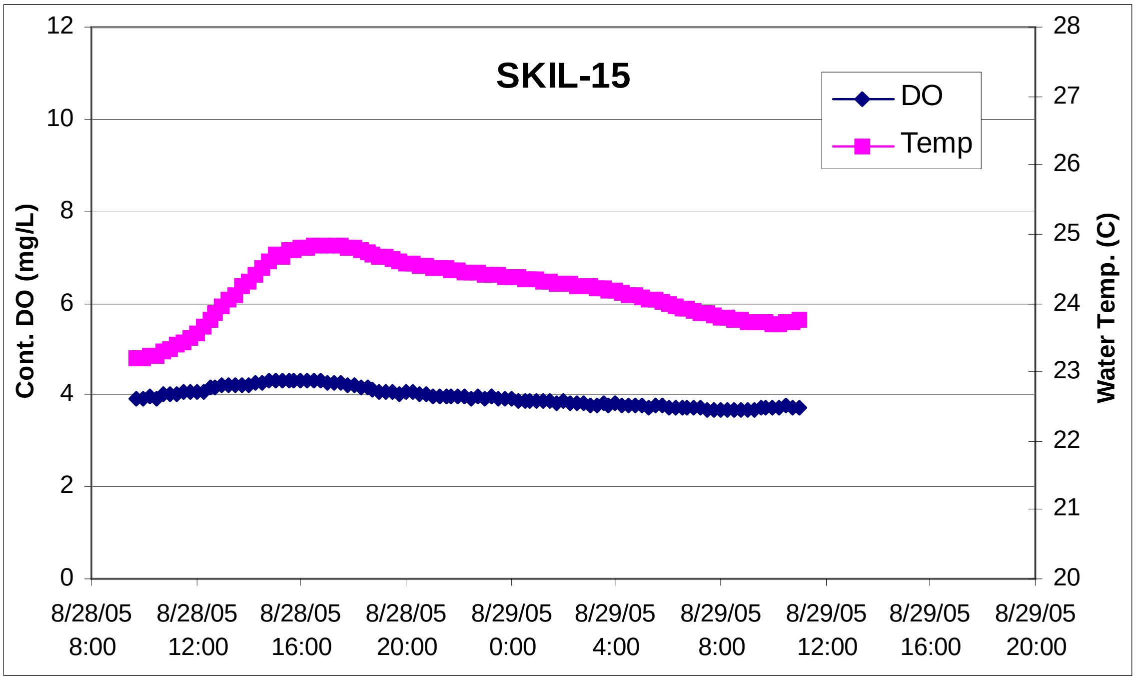

Figure 9. Continuous DO and Temperature at Skillet Fork Station SKIL-15

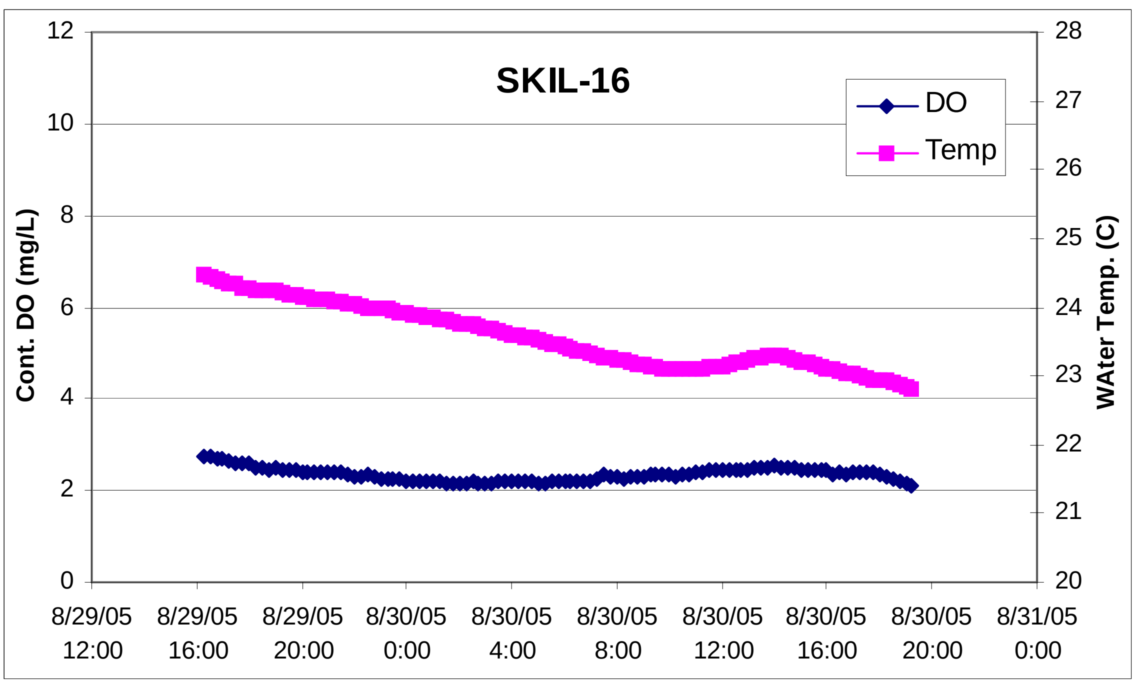

Figure 10. Continuous DO and Temperature at Brush Creek Station SKIL-16

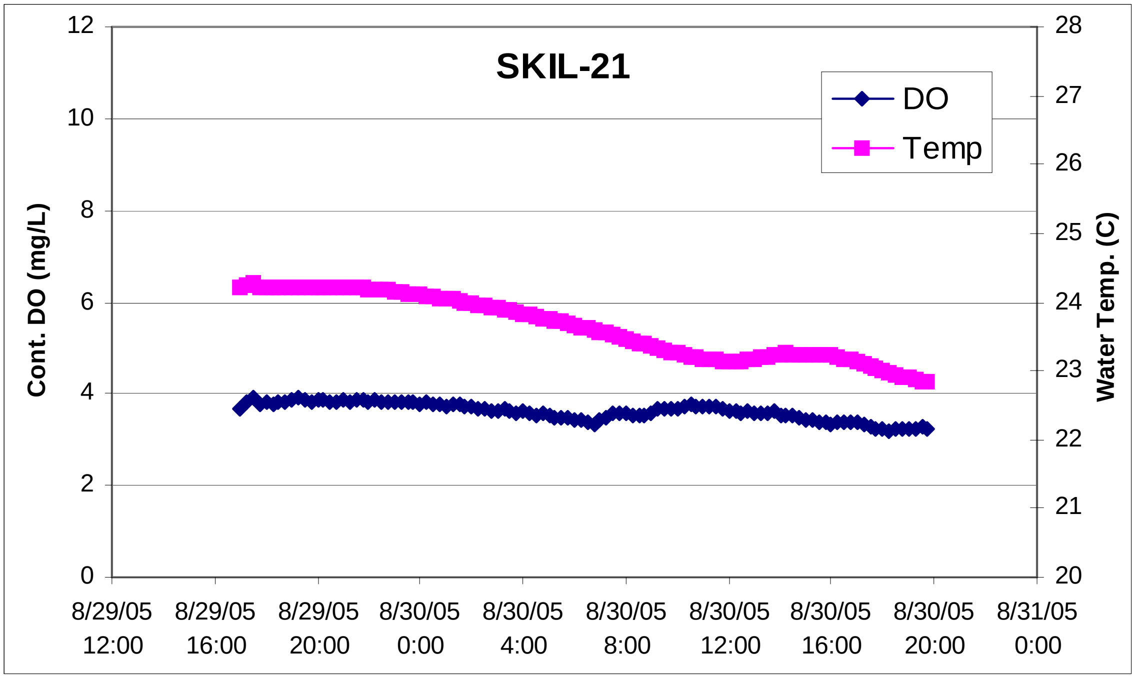

Figure 11. Continuous DO and Temperature at Horse Creek Station SKIL-21

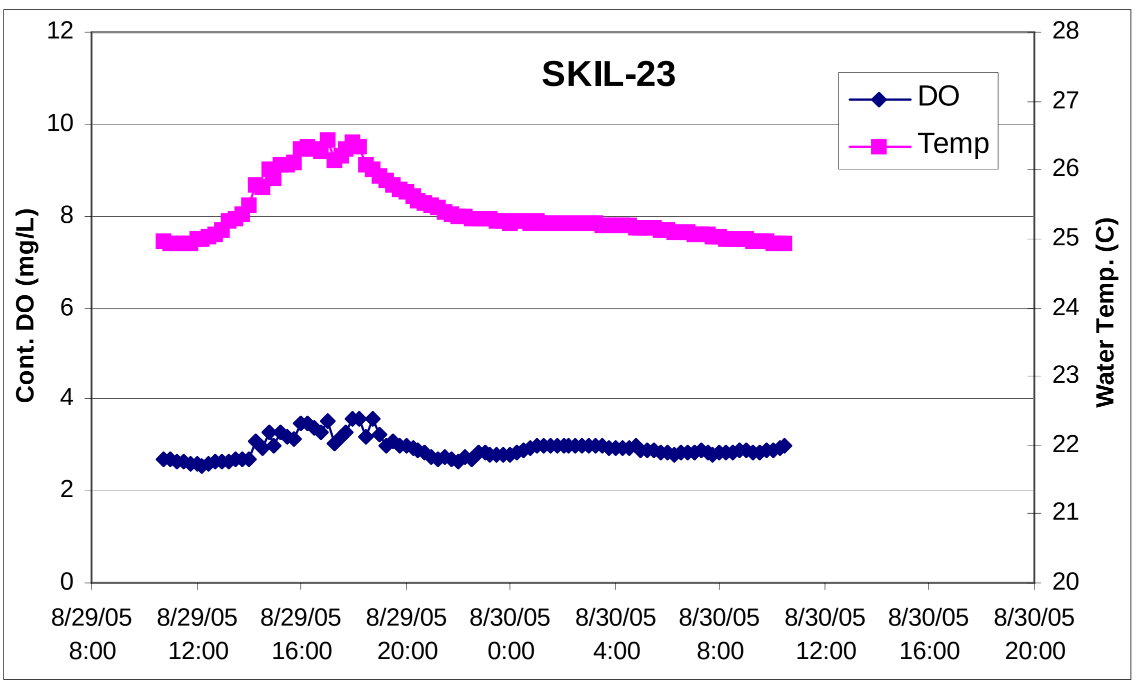

Figure 12. Continuous DO and Temperature at Skillet Fork Station SKIL-23

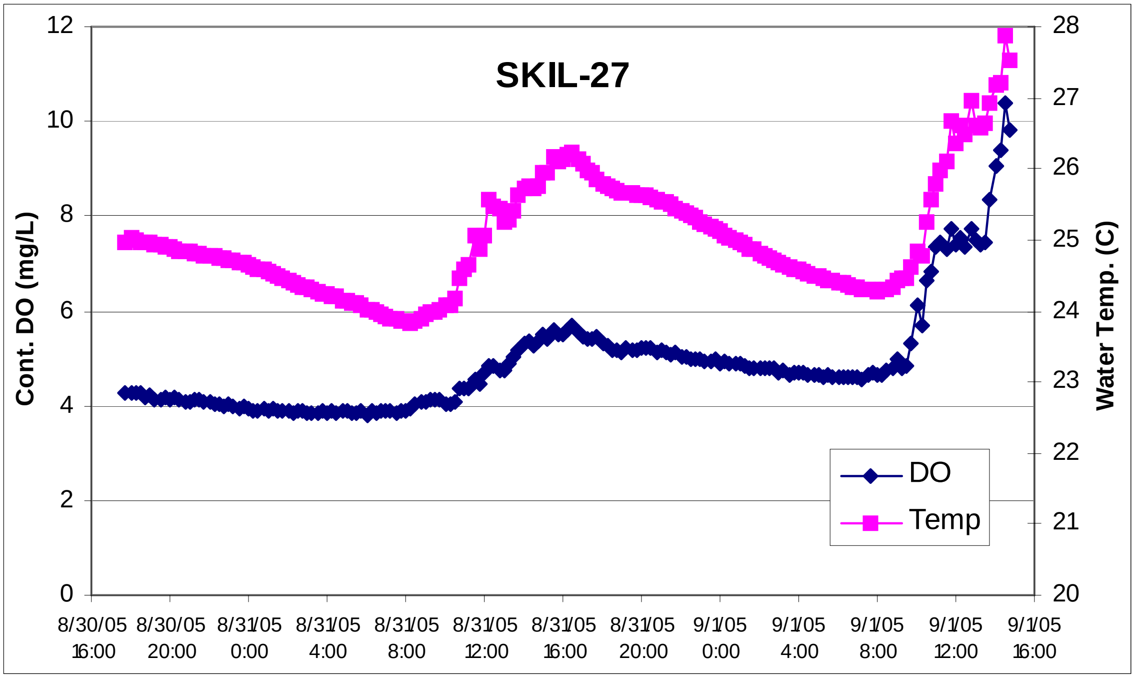

Figure 13. Continuous DO and Temperature at Skillet Fork Station SKIL-27

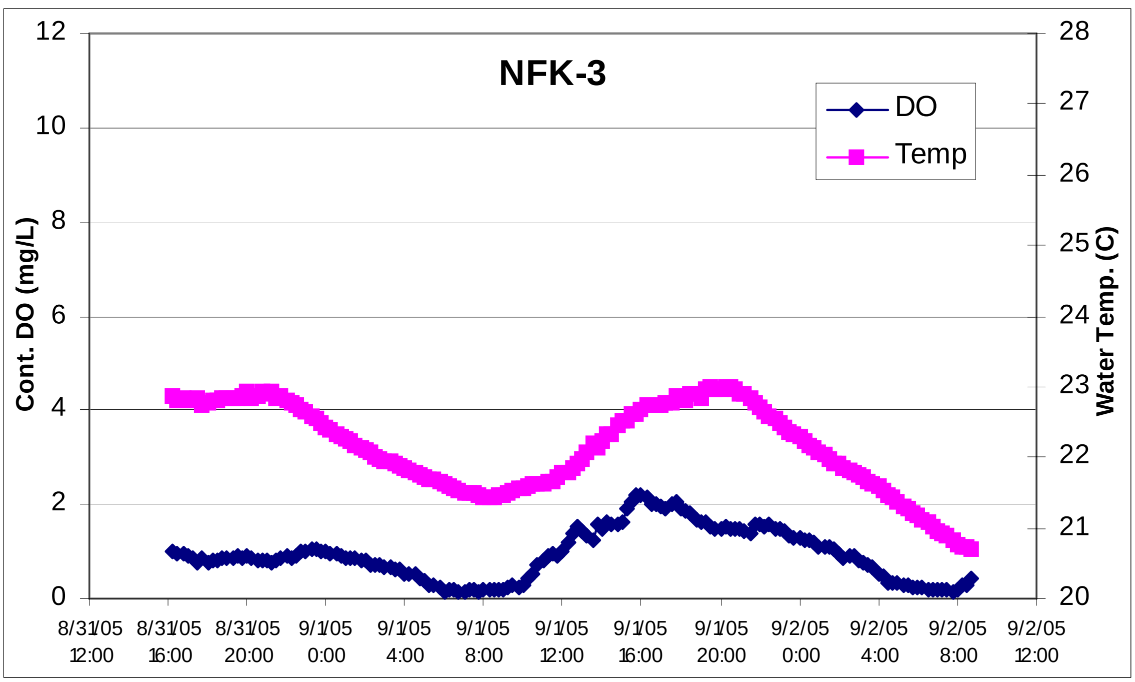

Figure 14. Continuous DO and Temperature at North Fork Kaskaskia River Station NFK-3

QUALITY ASSURANCE REVIEW

A review was conducted to assess the quality and usability of data generated from implementation of the work activities and to assess adherence to protocols specified in the QAPP. Field and laboratory methods were reviewed and found to be in accordance with the QAPP; however, certain changes to sampling and analysis activities were implemented that deviated from the sampling plan presented in the QAPP and are documented in the remainder of this section. Field measurement data and laboratory analytical data were verified and validated in accordance with the QAPP.

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

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

Changes from Sampling Plan (QAPP)

Certain changes were made to the sampling plan or sampling protocols specified in the QAPP as noted in the following list.

- ➢ A number of Round 1 BOD_5 samples were frozen at the lab upon receipt. The result is that the BOD_5 analysis was initiated six days after sample collection. Based on discussions with the lab, which has commonly followed this practice and which has conducted studies to assess the impact of this practice, the effect of freezing the samples has a minimal effect on the results.
- A number of sampling locations were changed from those presented in the QAPP because of difficult access conditions noted during field reconnaissance. The location changes made are documented in Table 1.
- Samples were not collected at stations that were dry. Locations not sampled due to dry conditions are identified in Table 1.
- The QAPP describes one round of pH measurements in the North Fork Kaskaskia River and Skillet Fork watersheds. A second round of pH field measurements was added to the sampling plan to provide additional data for assessment of this parameter at the sampled locations. The Round 1 pH measurements in the North Fork Kaskaskia River watershed were performed by the laboratory using samples submitted for BOD_5 analysis, rather than in the field. pH measurements are presented in Table 3.
- The QAPP describes one round of total iron sampling in the North Fork Kaskaskia River watershed. To better compare iron measurements to the Illinois Water Quality Criteria for iron, which are based on the dissolved fraction, both total and dissolved iron samples were added to Round 2 sampling and analysis

activities. The total iron samples were collected to enable correlation between the solid and dissolved fractions. Iron results are presented in Table 3.

- Manganese measurements were not originally outlined in the QAPP for the Macoupin Creek and North Fork Kaskaskia River watersheds. After discussions with the IL-EPA project manager, the lab was contacted on 10/24/05 and authorized to complete manganese analyses from samples already at the lab. Manganese was analyzed for the North Fork Kaskaskia River using the samples submitted for iron analysis, which were properly preserved with nitric acid. Samples submitted for BOD_5 analysis, which contained no chemical preservative, were used for the Macoupin Creek watershed manganese analyses after discussions with the laboratory regarding the effects of analyzing manganese from improperly preserved samples. The manganese results are presented in Tables 2 and 3.

Data Verification and Validation

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

Discharge data. There is uncertainty associated with discharge values generated from flow data for many locations. Results that are negative and very near zero accurately represent the fact that little to no downstream discharge was present, but should be used with caution in terms of defining a specific magnitude of flow. Drought conditions in southern Illinois during summer and fall 2005 created very low water levels and stream velocities. Field observations of "no apparent flow" were common. Uncertainties in the data may be associated with the following:

- Recorded water velocities were very low or negative, often below the sensitivity of the velocity meter (±0.05 feet per second),
- Stream flow was often insufficient to overcome measurement system inertia and accurately orient the velocity sensor in the direction of flow, resulting in inaccurate recordings of flow angle when using a bridgeboard,
- Stream flow was often insufficient to overcome water currents induced by the presence of sampling personnel when measuring velocities while wading in the stream, and
- At the SKIL-15 sampling location, hydraulic conditions were observed that may have been associated with the presence of underwater springs.

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

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

- ***BOD_5 holding times*** - BOD_5 samples arrived at the lab in time for analysis, however, due to arrival on a holiday weekend, the laboratory froze the samples, and analyzed them 6 days after the samples were collected. The holding time for these frozen samples exceeded the method specified holding time of 48 hours from sample collection to analysis. The samples affected are presented below.

- All Round 1 samples collected on 9/1/05 from the Skillet Fork watershed (SKIL-1, SKIL-2, SKIL-3, SKIL-4, SKIL-5, SKIL-6 DUP1, SKIL-6 DUP2, SKIL-7, SKIL-8, SKIL-9, SKIL-10, SKIL-11, SKIL-12, SKIL-14, SKIL-15, SKIL-16, SKIL-17, SKIL-18, SKIL-19 DUP1, SKIL-19 DUP2, SKIL-20, SKIL-21, SKIL-22, SKIL-23, SKIL-24, SKIL-25, SKIL-26, SKIL-27 DUP1, SKIL-27 DUP2, SKIL-28, Rinse Blank, Rinse Blank 2)

The laboratory indicated that they have commonly frozen BOD_5 samples and have previously conducted analyses on split samples to determine the impact of freezing on results. The potential error introduced is between 10 and 30 percent and no significant bias was observed. Because this is consistent with the precision measurement objective as stated in the QAPP and as such these results were not flagged. Furthermore, a review of the BOD_5 results between Round 1 and Round 2, found that the BOD_5 results are similar for the majority of Skillet Fork locations. If appropriate, the BOD_5 inputs to the model may be adjusted within the estimated range of uncertainty, to calibrate the water quality model.

- ***Manganese sample preservation*** – As discussed previously, manganese analyses were added to the project scope after field sampling had been completed. The laboratory was contacted and asked to analyze manganese from the Macoupin watershed water samples remaining from previous BOD_5 analyses. Because these samples were collected for BOD_5 analyses, they did not meet the field preservation specifications for metals (using nitric acid). As a result, these manganese results (detected and non-detected) were qualified as estimated (J flag). It should be noted that the samples were analyzed for manganese within method specified holding times (6 months) for properly preserved samples and the laboratory sample preparation procedures of acid digestion brought back into solution any manganese that was precipitated or adsorbed to the container. However, it is possible that other processes such as volatilization or microbial breakdown may have been present to affect analytical results. The analytical method does not discuss procedures for unpreserved samples. The samples affected are presented below.

  - All Round 1 samples collected on 8/23/05 from the Macoupin Creek watershed (MAC-1, MAC-3, MAC-5, MAC-6, MAC-7, MAC-9, MAC-10, MAC-11, MAC-12)
  - All Round 2 samples collected on 10/11/05 from the Macoupin Creek watershed (MAC-1, MAC-3, MAC-5, MAC-6, MAC-7, MAC-8, MAC-9, MAC-10, MAC-12)

  The effect of the change in sample preservation is expected to be minimal and these data are considered sufficient to support model and TMDL development.

Field QC data. Field quality control (QC) samples were collected to assess bias associated with field and laboratory methods. The field QC samples included 11 field duplicate sample pairs and eight rinse blank samples. The results of these analyses are presented below.

- ***Ammonia contamination in rinse blanks*** - Ammonia was detected in 7 out of 8 rinse blanks analyzed from the Round 1 and Round 2 sampling events. Although no qualifications were made to the sample results based on the presence of rinse blank contamination, the possibility must be acknowledged that sample results with levels near or below those detected in blanks may be attributable to contamination introduced during field sampling and rinsing procedures and not representative of stream quality. Sample containers were all rinsed using station stream water prior to sample collection, rather than the deionized water used for preparation of the rinse blanks; however, caution is indicated. Positive ammonia results for rinse blanks ranged 0.04-0.09 mg/L while positive sample results ranged 0.01-1.8 mg/L.

  Because the sample bottles were all rinsed with stream water prior to sample collection, the ammonia detected in the rinse blanks is not expected to affect the results and the data are suitable for use in model and TMDL development. Additionally, the magnitude of ammonia concentrations observed in the rinse blanks is small, relative to the management concern (i.e., ammonia concentration < 1.0 mg/l isn't considered a problem).

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

Table 8. Field Duplicate Pair Sample Results

Sample ID	Ammonia (mg/L)	BOD_5 (mg/L)	Dissolved Iron (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)
Round 1 Results					
MAC-1 DUP1	<0.01	2.7			0.57 J
MAC-1 DUP2	<0.01	3.2			
RPD (%)		**4.2 b**			
NFK-1 DUP1	0.08	3.2		0.88	0.47
NFK-1 DUP2	0.09	3.2		0.89	
RPD (%)	**2.9 b**	**0.0 b**		**0.3 a**	
SKIL-6 DUP1	0.02	<2 J			
SKIL-6 DUP2	<0.01	<2 J			
RPD (%)	**16.7 b**				
SKIL-19 DUP1	0.08	<2 J			0.58
SKIL-19 DUP2	0.09	<2 J			0.61
RPD (%)	**2.9 b**				**1.3 a**
SKIL-27 DUP1	<0.01	<2 J			0.26
SKIL-27 DUP2	<0.01	<2 J			0.26
RPD (%)					**0.0 a**
Round 2 Results					
HOD-3 DUP1	0.23 J	<2			
HOD-3 DUP2	0.23 J	<2			
RPD (%)	**0.0 b**				
MAC-7 DUP1	0.02 J	2.6			0.21 J
MAC-7 DUP2	0.03 J	<2			
RPD (%)	**10.0 b**	**6.5 b**			
NFK-5 DUP1	0.25	3.7	0.6	2.6	0.89
NFK-5 DUP2	0.22	4.5	0.55	2.8	
RPD (%)	**3.2 b**	**4.9 b**	**2.2 a**	**1.9 a**	
SKIL-6 DUP1	0.16	3.7			
SKIL-6 DUP2	0.02	3			
RPD (%)	**38.9 b**	**5.2 b**			
SKIL-19 DUP1	0.32	<2			
SKIL-19 DUP2	0.36	<2			
RPD (%)	**2.9 b**				
SKIL-27 DUP1	0.01 U	4.1			
SKIL-27DUP2	0.03	4			
RPD (%)	**25.0 b**	**0.6 b**			

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

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

c One or both results should be considered estimated and have been flagged with a J in the data tables due to the disparity observed between the field duplicate results.

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

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

The QA check shows apparent deficiencies with minimum measurement criteria for iron results and with completeness criteria for DO, temperature, ammonia and BOD_5. In the case of iron, the method detection limit (0.02 mg/L) did meet its criterion and this value is essentially rounded up to one significant digit from the minimum measurement criterion for iron (0.017 mg/L). The completeness criteria reflect the number of samples and measurements that were originally planned; however, as noted previously, the drought conditions prevalent during the investigations precluded sampling at tributary locations that were dry or had insufficient water. Adjusting the completeness criterion to reflect actual field conditions by eliminating locations that were not possible to sample results in the criterion being met at 100%. The completeness value for pH monitoring exceeds 100% because measurements were obtained during the second round of sampling and at a number of additional locations not present in the original sampling plan.

Table 9. Measurement Objectives and Criteria Check

					MS/MSD *				**LCS ***			
Parameter	**Minimum Measurement Criteria**	**Minimum Measurement Objectives**	**Method*; MDL[1]**	**QA check**	**Accuracy (% recovery)**	**QA check**	**Precision (RPD)**	**QA check**	**Accuracy (% recovery)**	**QA check**	**Completeness Criteria**	**QA check**
Dissolved Oxygen	NA	0.1 mg/l [s]	Field; NA	S	NA	NA	NA	NA	NA	NA	90%	S[3] (83%)
Water Temperature	NA	0.1 degree C [s]	Field; NA	S	NA	NA	NA	NA	NA	NA	90%	S[3] (83%)
pH	NA	0.1 pH unit[s]	Field; NA	S	NA	NA	NA	NA	NA	NA	90%	S (162%)
Ammonia	15.0 mg/l[G]	3.0 mg/l	EPA 350.1/ 350.3; 0.01/0.03 mg/l	S (0.01 mg/l)	80-120%	S	20%	S	80-120%	S	90%	S[3] (88%)
BOD_5	No Standard	No Standard	EPA 405.1/ SM5210 B; 2 mg/l	S (2 mg/l)	NA	NA	20%	S	NA	NA	90%	S[3] (88%)
Iron, Total & Dissolved	0.017 mg/l[G, 2]	0.005 mg/l	EPA 200.8; 0.02 mg/l	S (0.02 mg/l)	70-130%	S (80-120%)	20%	S	80-120%	S	90%	S (97%)
Manganese, Total	1 mg/l[G]	0.2 mg/l	EPA 200.8 0.02 mg/l	S (0.02 mg/l)	70-130%	S (80-120%)	20%	S	80-120%	S	90%	S (98%)

Notes

1 Method Detection Limit (MDL) from SM and EPA.
2 Calculated acute standard based on a minimum water hardness of 100 mg/L as CaCO3
* Limits are subject to change based upon capabilities of contract labs
G State of Illinois General Use Water Quality Standard
s Required sensitivity
EPA U.S. EPA Methods for Chemical Analysis of Water and Wastes, March 1983
NA Not Applicable
SM Standard Methods of the Examination of Water and Wastewater, 20th Edition
S QA check is satisfactory, criteria met
S[3] QA check is satisfactory for adjusted criteria

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Appendix 1. Quality Assurance Project Plan

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Quality Assurance Project Plan

for TMDL Sampling Activities
at the following State of Illinois Watersheds:

Macoupin Creek
Hodges Creek
Mauvaise Terre Creek
East Fork Kaskaskia River
North Fork Kaskaskia River
Skillet Fork

Prepared for Illinois Protection Agency

Revised: July, 2005

Project Contact: David Dilks (734) 332-1200, ddilks@limno.com

Limno-Tech, Inc.
Environmental Engineering
Ann Arbor, Michigan

APPROVAL SHEET

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1 Project Management (Group A)

The purpose of the Quality Assurance Project Plan (QAPP) is to document the necessary procedures required to assure that the project is executed in a manner consistent with applicable United States Environmental Protection Agency (U.S. EPA) guidance documents and with generally accepted and approved quality assurance objectives. In this QAPP, U.S. EPA QAPP Guidance Group A requirements are discussed in this section (Section 1), Group B requirements are discussed in Section 2, Group C requirements are discussed in Section 3 and Group D requirements are discussed in Section 4.

This QAPP was prepared to support surface water sampling activities related to the development of Total Maximum Daily Loads (TMDLs) for impaired water bodies in the following six State of Illinois watersheds:

- Macoupin Creek,
- Hodges Creek,
- Mauvaise Terre Creek,
- East Fork Kaskaskia River,
- North Fork Kaskaskia River and
- Skillet Fork.

This QAPP provides guidance and specifications to assure that:

- proper preventive maintenance, equipment calibration, and approved analytical protocols will be implemented so that all field measurements and sampling analytical results will be valid;
- sampling is conducted using sample tracking systems and chain-of-custody procedures which properly identify samples being collected and ensure the control of those samples from field collection through analysis and data reduction;
- records are produced and retained to document the quality of samples collected and analyzed, the validity of applied procedures, and the completeness of the investigation in relation to the approved scope of the project;
- generated data is validated; and
- calculations, evaluations, and decisions completed or deduced during the execution of the study are accurate, appropriate, and consistent with the objectives of the investigation.

The requirements of this QAPP are applicable to the activities of all participants in the investigation. This QAPP will address all anticipated activities necessary to execute the investigation.

1.1. Distribution List (A3)

Each organization listed on the approval sheet will receive a copy of this quality assurance project plan. Individuals taking part in the project may request additional copies of the Quality Assurance Project Plan (QAPP) from the LTI project manager listed in the following section of this QAPP.

1.2. Project Organization (A4)

Limno-Tech, Inc. (LTI) of Ann Arbor, Michigan, and its subcontractors, Baetis

Environmental Services, Inc. (Baetis) of Chicago, Illinois, Brighton Analytical Laboratories (BAL) of Brighton, Michigan, Animal Disease Laboratory – Illinois Department of Agriculture of Centralia, Illinois and ARDL, Inc. of Mt. Vernon, Illinois will conduct activities on behalf of the Illinois Environmental Protection Agency in support of TMDL development for impaired water bodies. LTI will maintain the technical responsibility for implementing the water quality sampling activities for the following watersheds: Macoupin Creek, Hodges Creek, Mauvaise Terre Creek, North Fork Kaskaskia River and Skillet Fork. Baetis will maintain the technical responsibility for implementing the water quality sampling activities for East Fork Kaskaskia River watershed. Brighton Analytical Laboratories (BAL) of Brighton, Michigan will provide analytical laboratory services for LTI. The Animal Disease Laboratory of Centralia, Illinois and ARDL, Inc. of Mount Vernon, Illinois will provide analytical laboratory services for Baetis.

LTI will coordinate activities with its subcontractors. The staff of LTI, Baetis and the laboratories will report to their respective team leaders and project managers for technical and administrative direction. Each staff member has responsibility for performance of assigned quality control duties in the course of accomplishing identified tasks. The quality control duties include:

- completing the assigned task in a quality manner in accordance with the schedule and with established procedures.
- ascertaining that the work performed is technically correct and meets all aspects of the QAPP.

The roles and responsibilities of LTI and Baetis personnel that will work on this project are presented below and in Table 1:

Table 1 Project Organization/Responsibilities

Role	Personnel	General Responsibilities
Project Administrator, Quality Assurance Officer	David Dilks/LTI	General and QA oversight; Review/approval of all work products
Project Manager	Penelope Moskus/LTI David Pott/Baetis	Project management; Direct all field, data evaluation, and reporting activities
Project Engineer/Scientist	Robert Betz, Chris Cieciek, Cathy Whiting/LTI David Pott/Baetis	Supervise all field sampling, quality assurance, data evaluation, and reporting activities
Assistant Project Engineer/Scientist	Chris Behnke, Nick Bogater, Brian Lord, Cullen O'Brien, Ed Verhamme/LTI Chloe Pott/Baetis	Field and technical support

Responsibilities and duties of the analytical laboratories include the following:

- Perform analytical procedures;
- Supply sampling containers and shipping cartons;
- Maintain laboratory custody of samples;
- Strictly adhere to all protocols in the QAPP;
- Notify LTI project manager in advance of any deviations to QA protocols.

Project Administrator. The project administrator is responsible for the overall administration and staffing of the project. As part of the QA/QC responsibilities, the project administrator will:

- Provide for overall direction of project objectives and activities;
- Provide for QA/QC management of all aspects of the project within the stated scope of responsibility;
- Approve reports and other materials for release to members of the project team and other external organizations.

Project Manager. The project manager is responsible for maintaining a clear definition of and adherence to the scope, schedule, and budget of the project. As a part of this responsibility, the project manager will:

- Serve as the communication link with the project team members and client(s);
- Direct all work performed by the organization and its subcontractors;
- Perform final review of field data reductions, report submittals, and presentations;
- Assure corrective actions are taken for deficiencies noted during project activities;
- Maintain budgetary and schedule surveillance of the work.

Project Engineer/Scientist. The project engineer/scientist is responsible for the implementation of field activities, initial data acquisition, health and safety aspects of field activities, and for the proper selection and execution of procedures that have been accepted for use in the investigation. As part of the QA/QC responsibilities, the project engineer/scientist will:

- Supervise assistant project engineers/scientists, technicians, or subcontractors executing data gathering tasks;
- Supervise the collection of samples so that sampling remains representative of actual field conditions;
- Supervise the regular maintenance of equipment to prevent unnecessary equipment failures and project delays caused thereby;
- Review the effectiveness of procedures and suggest changes that will enhance or more efficiently accomplish the objectives of the investigation;
- Prepare and review field data reductions, reports, submittals, and presentations to assure that data and conclusions accurately reflect observed conditions in the field;
- Assist in the maintenance of budgetary and scheduling surveillance.

Assistant Project Engineer/Scientist. The assistant project engineer/scientist is responsible for the assisting in the implementation of field activities, initial data acquisition, health and safety aspects of field activities, and for the proper selection and execution of procedures that have been accepted for use in the investigation. As part of the QA/QC responsibilities, the assistant project engineer/scientist will:

- Perform data gathering and compilation tasks;

- Assist in supervising technicians and subcontractors;
- Assist in reviewing the effectiveness of procedures and suggest changes that will enhance or more efficiently accomplish the objectives of the investigation;
- Assist in the collection of samples so that sampling remains representative of actual field conditions;
- Perform regular maintenance and calibration of equipment to prevent unnecessary equipment failures and project delays caused thereby;
- Assist in the preparation and review of field data reductions, reports, submittals, and presentations to assure that data and conclusions accurately reflect observed conditions in the field.

1.3. Problem Definition/Background (A5)

The project activities associated with this QAPP will include surface water sampling activities to provide data that will be used to support development of TMDLs for impaired water bodies in the following six State of Illinois watersheds:

- Macoupin Creek,
- Hodges Creek,
- Mauvaise Terre Creek,
- East Fork Kaskaskia River,
- North Fork Kaskaskia River and
- Skillet Fork.

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 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 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 compiled, reviewed and evaluated the sufficiency of available data to support TMDL development for the listed watersheds. For each listed watershed, the data review included:

- confirmation of the impairments identified on the 303(d) list,
- further identification of potential sources causing these impairments,
- identification, description and recommendations for methodologies, procedures and/or models to be used in the development of TMDLs, and
- recommendations for additional data needed to support the modeling, where necessary, along with general data collection plans

The additional data collection work approved by Illinois EPA for the above-bulleted watersheds is presented and described in the following subsection of this QAPP. The data will be used for model development and calibration in support of TMDL development. Stream measurements of flow, dissolved oxygen, BOD, ammonia, water temperature, SOD and diurnal dissolved oxygen will be used to support QUAL2E dissolved oxygen modeling in streams. Coliform bacteria measurements will be used support development of a load-duration curve, and pH and iron measurements will support an empirical approach combined with spreadsheet calculations. Finally, manganese measurements in the Skillet Fork watershed will be collected to help determine its source (e.g., mining or natural background).

1.4. Project/Task Description (A6) and Schedule

Monitoring will be conducted within six watersheds in southern Illinois. Table 2 summarizes the scope of work for each watershed. The sampling sites and coordinates for each watershed are presented in Table 3 and depicted on Figures 1-6. All sampling activities will be conducted in accordance with standard operating procedures (SOPs) presented in Appendix A.

Stream Surveys. Stream sampling surveys will be conducted during low to medium flow conditions, as specified in Table 2. Coliform sampling will also be conducted during wet weather conditions. Survey deployment decisions will be based on real-time streamflows at USGS gages in or near the watershed. Low to medium flow surveys will be targeted for dry conditions and periods when the real-time streamflow of the nearest gage is in the vicinity of the 20^{th} percentile flow value, based on the period of record data.. If necessary, low to medium flow surveys may be conducted at slightly higher flows, when the real-time streamflows are in the vicinity of or less than the 50^{th} percentile flow value. Tributary monitoring will be conducted if the tributaries are flowing. The USGS gages and daily mean flow statistics are presented in Table 4.

Surface Water Quality Sampling. Water quality grab samples and water quality measurements will be collected at mid-stream or at the location where maximum flow is observed, where safely practicable. Grab samples will be collected from bridges, where possible, preferably using weighted bottle, dip or direct samplers attached to a pole or a line. Sampling equipment will be decontaminated between locations using a river water rinse followed by a triple deionized water rinse and generally following the SOP for Equipment Cleaning presented in Appendix A. Water quality samples will be stored in an iced cooler prior to and during overnight express shipment to the analytical laboratory following strict chain-of-custody procedures as specified in the Sample Handling, Packing and Shipping SOP presented in Appendix A. As an exception, E. coliform samples will be delivered directly to the laboratory by sampling personnel or picked up in the field by a laboratory courier in order to meet holding times. The samples will be analyzed for BOD_5, ammonia, nitrate-nitrite, coliform bacteria, total manganese and/or total iron, as specified for the different watershed surveys in Table 2.

Surface Water Measurements. Field water quality measurements (i.e., water temperature, pH, dissolved oxygen (DO)) will be recorded using instruments (e.g., YSI, Hydrolab meters) that are calibrated daily in accordance with manufacturer recommendations. Channel morphometry/stream depth, and water velocity measurements will be conducted in accordance with the SOP for Surface Water Flow Measurements in Appendix A. Locations will be selected for channel morphometry/stream depth and water velocity measurements based on two factors: 1) is it a good site for flow calculation; and 2) are the sites spaced out throughout the watershed. Sediment oxygen demand (SOD) and continuous DO measurements will be conducted in accordance with the SOPs for Sediment Oxygen Demand Measurements and Field Water Quality Measurements, respectively, presented in Appendix A. Locations for SOD measurements will be selected in the field, and will be representative of conditions in the river.

Schedule. An example schedule for implementation of data collection activities is presented in Table 5. Field activities will commence within two weeks after Illinois EPA communicates approval of the QAPP and approval to proceed, subject to the sampling requirements (i.e., discharge level and precipitation conditions) being met for each watershed. It is anticipated that all dry weather low or medium flow events will be conducted before the fall wet weather season. Available USGS surface water discharge gages in or near the watersheds will be monitored to determine the occurrence of appropriate flow levels for field deployment. The schedule will be updated as necessary and will be used by the Project Manager to review overall progress of the project.

Table 2 Scope of Work

Watershed	Waterbody name (ID)	Work Description
Macoupin Creek	Macoupin Creek (DA04, DA05), Briar Creek (DAZN)	1 low-to-medium-flow survey to measure: • DO, temperature, BOD, ammonia, channel morphometry at 12 sites (5 mainstem, 7 tribs) • Depth and velocity at 4 mainstem sites (to be determined in the field) • SOD and continuous DO monitoring at 1 site representative of river (to be determined in field) 1 low-to-medium flow survey to measure: • DO, temperature, BOD, ammonia, channel morphometry at 12 sites (5 mainstem, 7 tribs) • Depth and velocity at 4 mainstem sites (to be determined in the field)
Hodges Creek	Hodges Creek (DAG02)	1 low-to-medium-flow survey to measure: • DO, temperature, BOD, ammonia, channel morphometry at 7 sites (1 mainstem, 6 tribs) • Depth and velocity at 4 sites (Hodges Ck @ Cnty Hwy 24, Otter Ck @ Rte 108 bridge, Otter Cr @ Henry Rd, 1 tributary to be determined in the field) • SOD and continuous DO monitoring at 1 site representative of river (to be determined in field) 1 low-to-medium-flow survey to measure: • DO, temperature, BOD, ammonia, channel morphometry at 7 sites (1 mainstem, 6 tribs) • Depth and velocity at 4 sites (Hodges Ck @ Cnty Hwy 24, Otter Ck @ Rte 108 bridge, Otter Cr @ Henry Rd, 1 tributary to be determined in the field)
Mauvaise Terre Creek	North Fork Mauvaise Terre Creek (DDC)	1 low-to-medium-flow survey to measure: • DO, water temperature, BOD, ammonia, channel morphometry at 4 sites (3 mainstem, 1 trib) • Depth and velocity at 2 sites (NF Mauvaise Terre Ck @ IL Rte 123, NF Mauvaise Terre Ck @ Lisbon Rd) • SOD and continuous DO monitoring at 1 site representative of river (to be determined in field)
East Fork Kaskaskia River	East Fork Kaskaskia River (OK01)	1 low-to-medium flow survey to measure: • BOD, nitrate-nitrite, ammonia at 15 locations (3 IEPA legacy stations, 2 other mainstem stations, 10 tributary stations) • SOD at one location representative of river (to be determined in the field) • DO and water temperature at 35 locations (4 IEPA legacy stations, 7 other mainstem stations, 3 NPDES stations, and 21 tributary stations) • Discharge, stream morphology, depth and velocity at 12 locations (3 IEPA legacy stations, 1 other mainstem station, 3 NPDES stations, 5 tributary stations) • Coliform bacteria at 17 stations (3 IEPA legacy stations, 1 other mainstem station, 3 NPDES stations, 10 tributary stations) 1 wet weather survey to measure: • Coliform bacteria at 17 stations (3 IEPA legacy stations, 1 other mainstem station, 3 NPDES stations, 10 tributary stations)

Watershed	Waterbody name (ID)	Work Description
North Fork Kaskaskia River	North Fork Kaskaskia (OKA01, OKA02)	1 low-to-medium-flow survey to measure: • DO, temperature, BOD, ammonia, channel morphometry at 7 sites (5 mainstem, mouth Louse Run, unnamed trib with discharge from Patoka STP) • Depth and velocity at 3 mainstem sites (to be determined in the field) 1 low-to-medium flow survey to measure: • pH and total Fe at 7 locations (5 mainstem, mouth Louse Run, unnamed trib with discharge from Patoka STP) • SOD and continuous DO monitoring at 1 site representative of river (to be determined in field) • DO, temperature, BOD, ammonia, channel morphometry at 7 sites (5 mainstem, mouth Louse Run, unnamed trib with discharge from Patoka STP) • Depth and velocity at 3 mainstem sites (to be determined in the field)
Skillet Fork	Skillet Fork (CA03, CA05, CA06, CA09), Horse Creek (CAN01), Brush Creek (CAR01), Dums Creek (CAW01)	1 low-to-medium flow survey to measure: • Mn at 10 locations (2 each per segments CA03, CA05, CA06, CAN01, CAR01) • pH at 6 locations (2 each per segments CA03, CA05, CA06) • SOD and continuous DO at 7 sites representative of each stream segment (to be determined in field) • DO, temperature, BOD, ammonia, channel morphometry at 28 sites (12 mainstem, 16 tribs) • Depth and velocity at 6 sites representative of each stream segment (excluding segment CA05 with USGS gage) 1 low-to-medium-flow survey to measure: • DO, temperature, BOD, ammonia, channel morphometry at 28 sites (12 mainstem, 16 tribs) • Depth and velocity at 6 sites representative of each stream segment (excluding segment CA05 with USGS gage)

Table 3 Sampling Locations

Stream	Access	TMDL Station ID	Longitude	Latitude
Macoupin Creek Watershed				
Macoupin Cr	U.S. 67	DA 03	-90.19483079590	39.26235488860
Coop Branch	Victory Rd		-90.09148094130	39.19683004470
Macoupin Cr	Shipman Rd	DA 04	-89.97935149050	39.20104990470
Dry Fork	Lake Catatoga Rd		-89.95550388800	39.19418235490
Honey Cr	Brushy Mound Rd		-89.87360501930	39.24342942380
Briar Cr	Crumystone Rd	DAZN	-89.88056449760	39.26046630510
Macoupin Cr	Illinois Route 4	DA 05	-89.84931859880	39.25961219940
Shaw Point Branch	Sumpter Rd		-89.76970998510	39.31317888700
Macoupin Cr	Coops Mound Rd	DA 11	-89.77338896040	39.31660949520
Horse Cr	Sulphur Springs Rd		-89.71699036180	39.36629309710
Horse Cr	Boston Chapel Rd		-89.71851666130	39.38752831690
Macoupin Cr	2nd Rd		-89.66246194810	39.42305698530
Hodges Creek Watershed				
Hodges Cr	County Highway 24	DAG 03	-90.16966141040	39.26941869650
Joes Cr	Joes Cr Rd		-90.14273781100	39.29107306560
Otter Cr	Illinois Route 108		-90.10025314080	39.30522380070
Solomon Cr	Boyscout Rd		-90.03690323180	39.36116261880
Solomon Cr	not at a bridge		-90.01120398330	39.42342966540
unnamed tributary	near end of Wildcat Rd		-89.96479296510	39.40580948260
East Fork Otter Cr	Henry Rd		-89.81287422150	39.44858595910
Mauvaise Terre Creek Watershed				
N Fork Mauvaise Terre Cr	Lisbon Rd	DDC 11	-90.20582047410	39.74953834210
N Fork Mauvaise Terre Cr	Mobil Rd	DDC 12	-90.18233912890	39.74710985640
unnamed tributary	I-72		-90.15349792340	39.73605259570
N Fork Mauvaise Terre Cr	Illinois Route 123		-90.04261497410	39.77177676000

Stream	Access	TMDL Station ID	Longitude	Latitude
East Fork Kaskaskia River Watershed				
East Fork Kaskaskia River	Gerrish Road	B OK 99	-89.12058888889	38.70354444444
East Fork Kaskaskia River	US 51	B OK 01	-89.10000000000	38.69102222222
Davidson Creek	Ferrydale Road	B OKB 11	-89.09776944444	38.68897222222
Davidson Creek	Seven Hills Road	B OKB 12	-89.04945833333	38.67211388889
Davidson Creek	Hoots Chapel Road	B OKB 13	-89.01400000000	38.66851111111
Barden Creek	Seven Hills Road	B OKBA 11	-89.04880833333	38.68203055556
East Fork Kaskaskia River	County Rd 1600	B OK 11	-89.07460833333	38.70666666667
East Fork Kaskaskia River	Marshall Creek Road	B OK 12	-89.03108888889	38.72515833333
East Fork Kaskaskia River	McNicol Road	B OK 02	-89.01072500000	38.73550000000
Jims Creek	Marshall Creek Road	B OKC 11	-89.03095555556	38.71138333333
Jims Creek	Jims Creek Road	B OKC 12	-89.00461388889	38.70933055556
Jims Creek	Oak Grove Road	B OKC 13	-88.97185555556	38.72206944444
Wills Creek	Alma Hatchery Road	B OKCA 11	-88.98985555556	38.70728611111
Warren Branch	Bilek Road	B OKG 11	-88.94855277778	38.75850555556
Warren Branch	Hicks Road	B OKG 12	-88.93192777778	38.73668055556
unnamed tributary 1	Hester Lane	B OKGZ 11	-88.91284722222	38.72951388889
unnamed tributary 2	Malone Road	B OKGZ 21	-88.92349166667	38.72885833333
East Fork Kaskaskia River	Kinoka Road	B OK 13	-88.94912500000	38.76224444444
unnamed tributary 3	County Road 1425	B OKZ 11	-88.87928611111	38.77494722222
unnamed tributary 4	West Case Street	B OKZ 21	-88.85903888889	38.77711388889
East Fork Kaskaskia River	St Peter Road	B OK 03	-88.84549166667	38.80626111111
East Fork Kaskaskia River	Gentry Road	B OK 14	-88.85922777778	38.80478611111
Lone Grove Branch	Gentry Road	B OKE 11	-88.86239166667	38.81023611111
Lone Grove Branch	County Road 700	B OKE 12	-88.84495555556	38.83899722222
Lone Grove Branch	County Road 800	B OKE 13	-88.83516944444	38.85336111111
unnamed tributary 5	County Road 2200	B OKEZ 11	-88.84451111111	38.85566388889
East Fork Kaskaskia River	Blomberg Road	B OK 15	-88.82674722222	38.80373888889
unnamed tributary 6	Vandeveer Street	B OKFZ 11	-88.82664722222	38.78469166667
Schneider Springs Branch	Illinois Route 37	B OKF 11	-88.81688055556	38.79656667000
East Fork Kaskaskia River	Sullivan Road	B OK 16	-88.80781666667	38.81533333000

Stream	Access	TMDL Station ID	Longitude	Latitude
unnamed tributary 7	local Farina street	B OKZ 31	-88.78804722222	38.82535555556
unnamed tributary 8	local Farina street	B OKZ 41	-88.78504722222	38.82707777778
unnamed tributary 7	Echof Street	B OKZ 32	-88.78126944444	38.83217500000
unnamed tributary 7	Illinois Road 185	B OKZ 33	-88.77479166667	38.83786111000
East Fork Kaskaskia River	Echof Street	B OK 17	-88.79771388889	38.82601111111
North Fork Kaskaskia River Watershed				
North Fork Kaskaskia River	County Road 300	OKA 01	-89.19385616200	38.74162579850
Louse Run	County Road 2150		-89.16621508190	38.73750964400
North Fork Kaskaskia River	County Road 100		-89.16377644200	38.75219332070
unnamed tributary	not at a bridge		-89.11480254660	38.76036325090
North Fork Kaskaskia River	U.S. 51		-89.08657432240	38.77396168120
North Fork Kaskaskia River	not at a bridge		-88.98827934220	38.78507402690
North Fork Kaskaskia River	Hadley Rd		-88.92251900000	38.81332160000
Deer Cr	Boat Dock Rd		-89.10775406760	38.76519444490

Stream	Access	TMDL Station ID	Longitude	Latitude
Skillet Fork Watershed				
Skillet Fork	County Highway 1	CA 03	-88.16415217920	38.15479579740
Limekiln Cr	not at a bridge		-88.22938678370	38.16103442950
Sevenmile Cr	not at a bridge		-88.23160843460	38.15357838750
Skillet Fork	County Road 475	CA 02	-88.28406719800	38.16359967360
Skillet Fork	~1 mi south of County Road 500N		-88.49457745840	38.31343869660
Skillet Fork	near Illinois Route 15	CA 05	-88.58337492580	38.35831917750
Puncheon Cr	near County Rd 100E		-88.68415188910	38.37476836780
Horse Cr	County Road 200E	CAN 01	-88.66257719530	38.37677587620
Skillet Fork	County Road 900N		-88.61409624450	38.38777369600
Horse Cr	Malecki Rd		-88.75649378860	38.42393172170
Horse Cr	Moonbeam Ln		-88.81111003440	38.45344064110
Skillet Fork	County Highway 13		-88.65238195360	38.46648093630
Brush Cr	County Highway 27	CAR 01	-88.63489866570	38.47584424840
Skillet Fork	Strt 161 Extension	CA 06	-88.72705842260	38.51960397070
Brush Cr	County Highway 16		-88.60850107560	38.52338314200
Bob Branch	County Road 1900N		-88.59792835420	38.53449893060
Skillet Fork	at end of Seed House Rd		-88.74108667380	38.54880816290
Nickolson Cr	Dago Hill Rd		-88.72201515260	38.55124806790
Fulton Cr	Landmark Rd		-88.76797079850	38.57135034760
Brush Cr	County Road 2200N		-88.59131791570	38.57809407280
Skillet Fork	near end of Blank Rd	CA 08	-88.74828647270	38.59112024710
Dums Cr	Landmark Rd	CAW 04	-88.76750287030	38.65369981820
Skillet Fork	near end of Burkett Rd		-88.73375590070	38.65647408140
Dums Cr	Bee Branch Rd		-88.83988279890	38.66420459560
Skillet Fork	at end of County Road 80E	CA 09	-88.69735030890	38.71610228030
Sutton Cr	County Road 150		-88.68603981220	38.72281392080
Dums Cr	Williams Rd		-88.85472799280	38.73694029780
Skillet Fork	near Krustinger Rd		-88.70500602780	38.74410228390

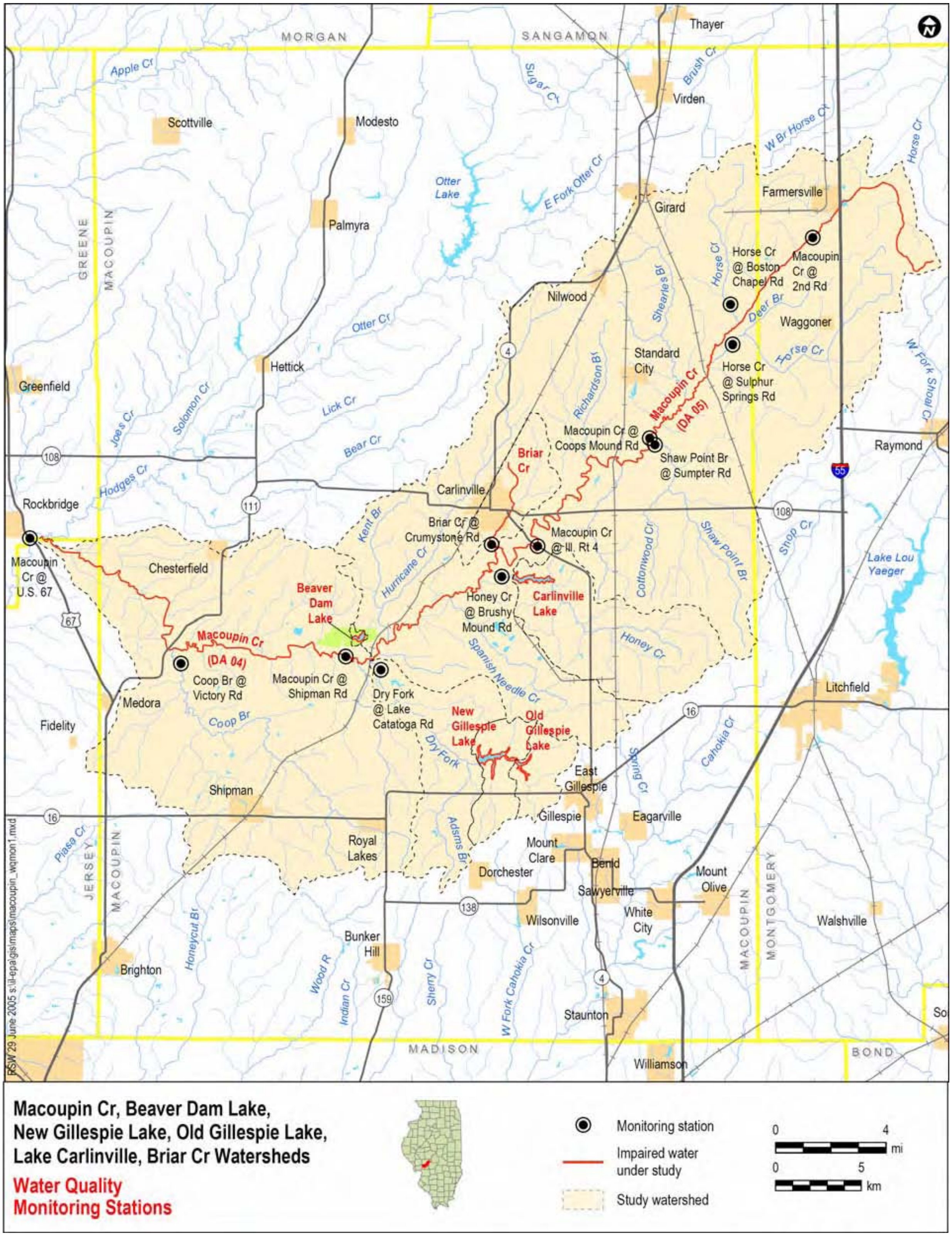

Figure 1. Macoupin Creek Watershed Sampling Locations

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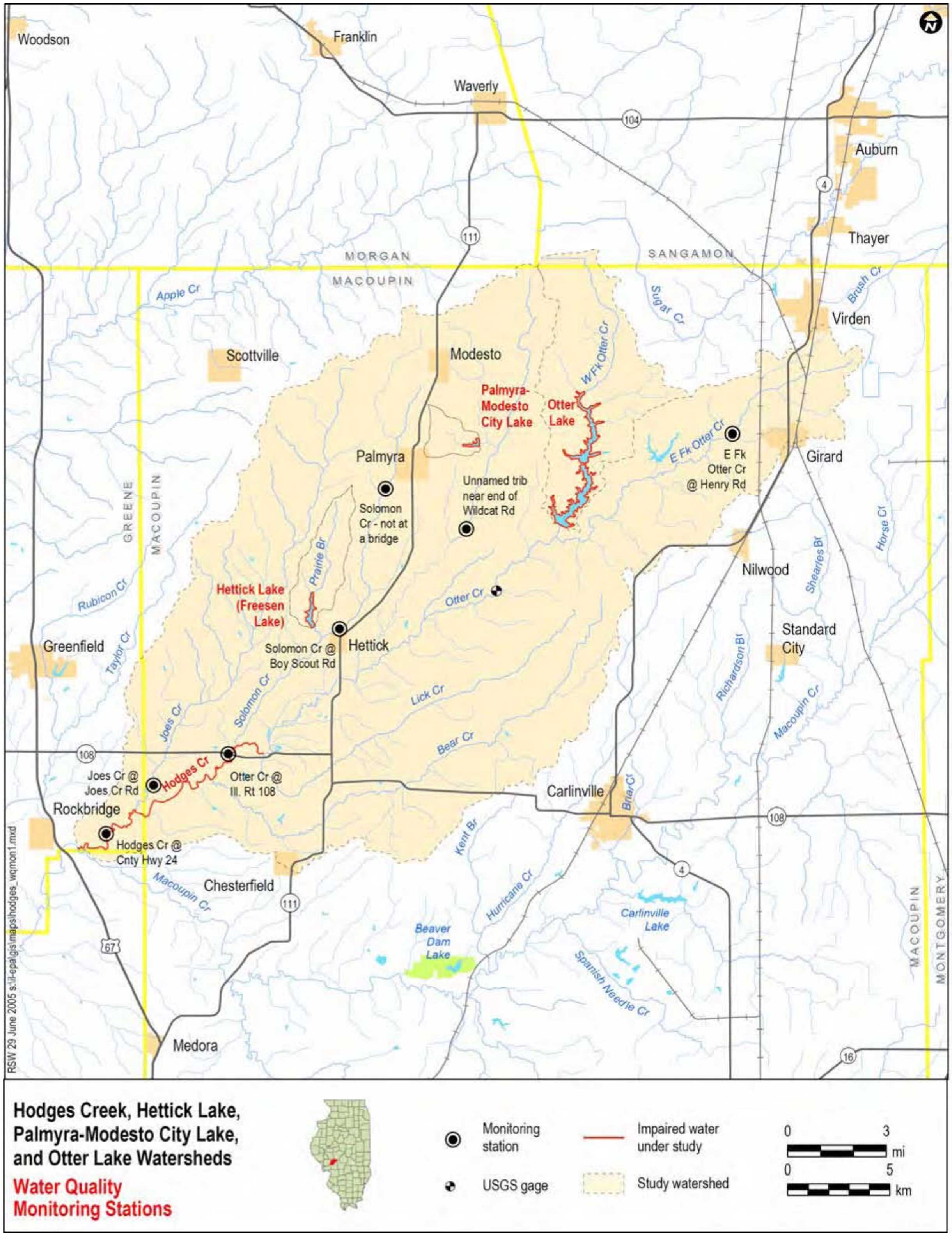

Figure 2. Hodges Creek Watershed Sampling Locations

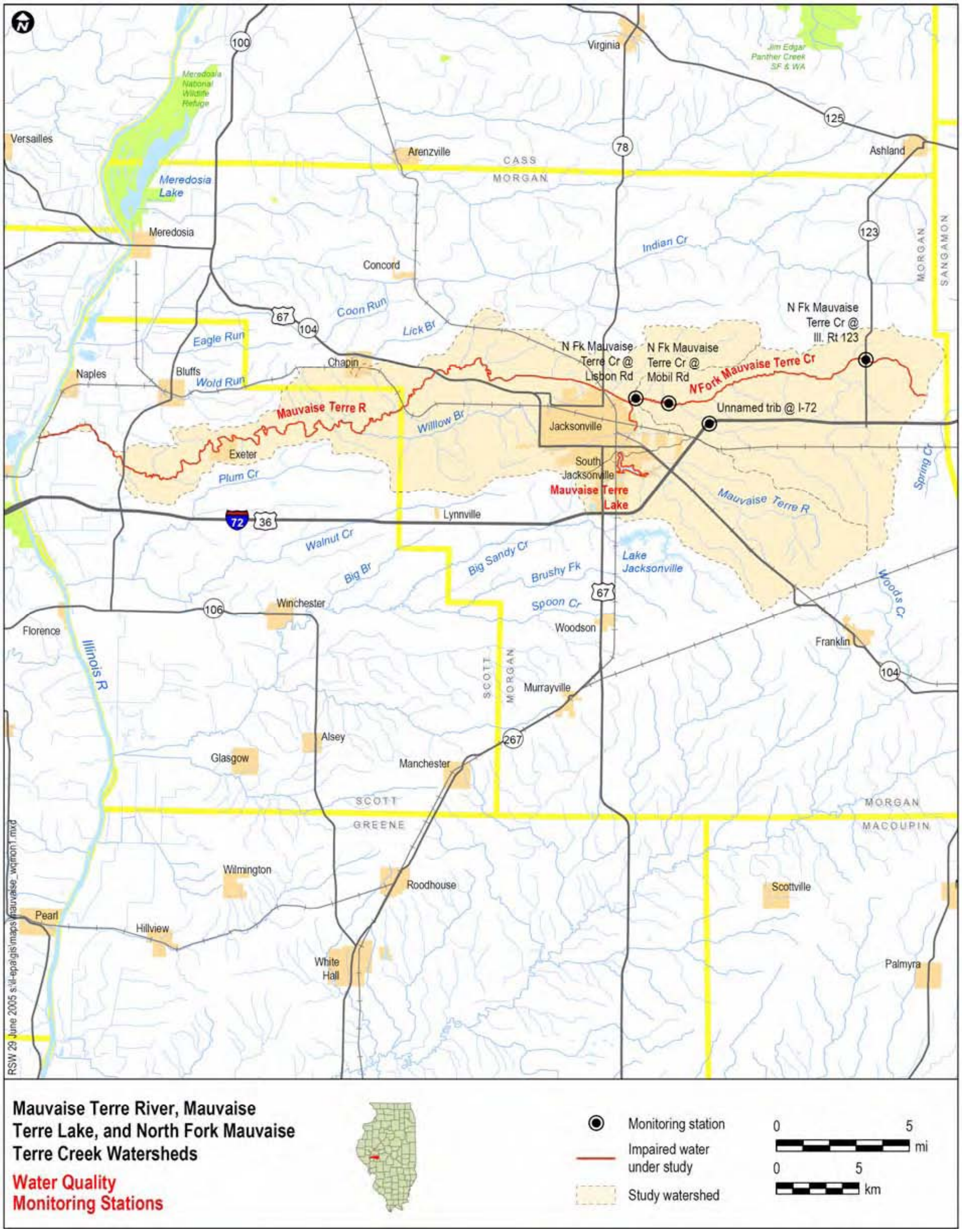

Figure 3. Mauvaise Terre Creek Watershed Sampling Locations

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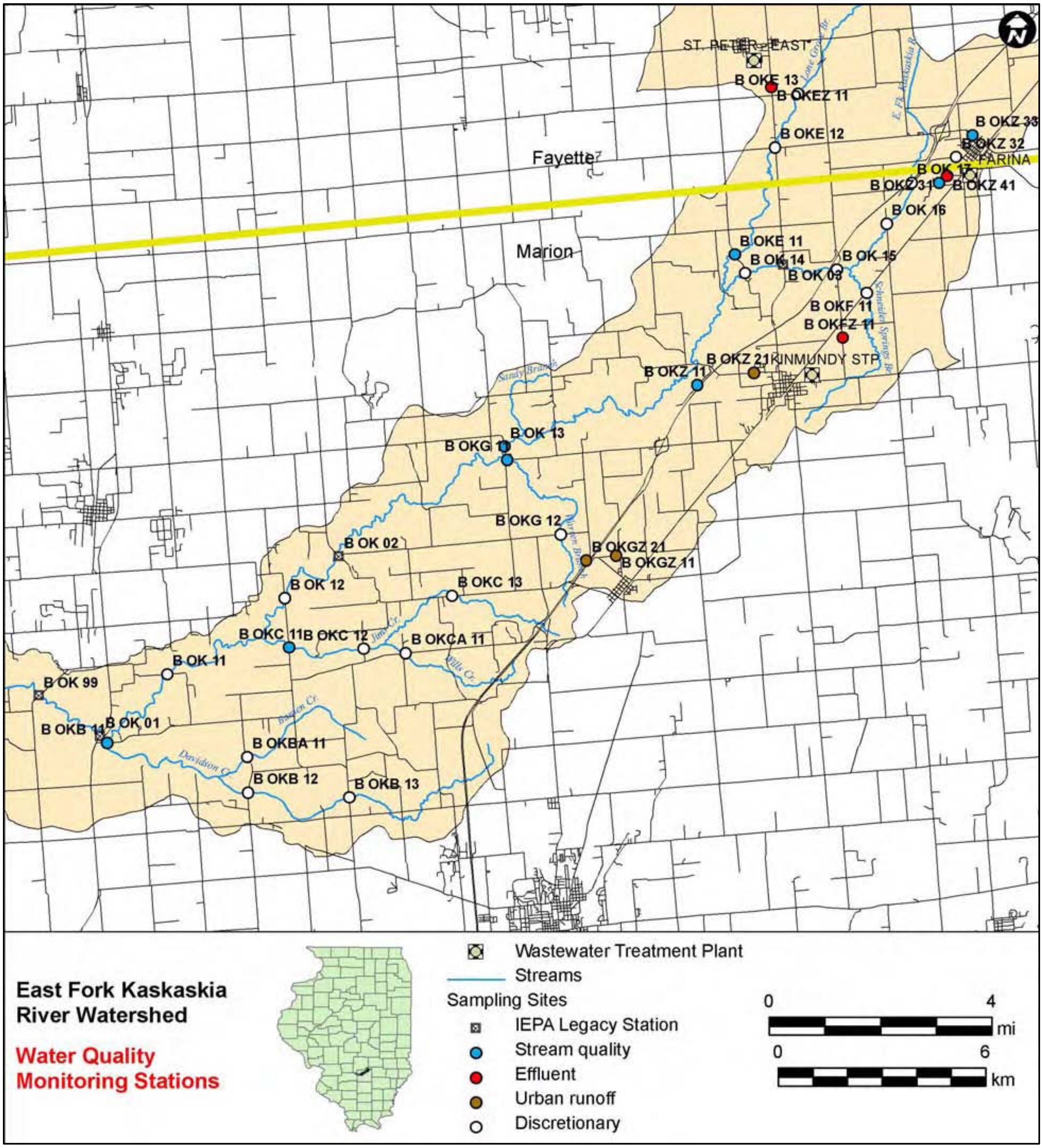

Figure 4. E. Fork Kaskaskia River Watershed Sampling Locations

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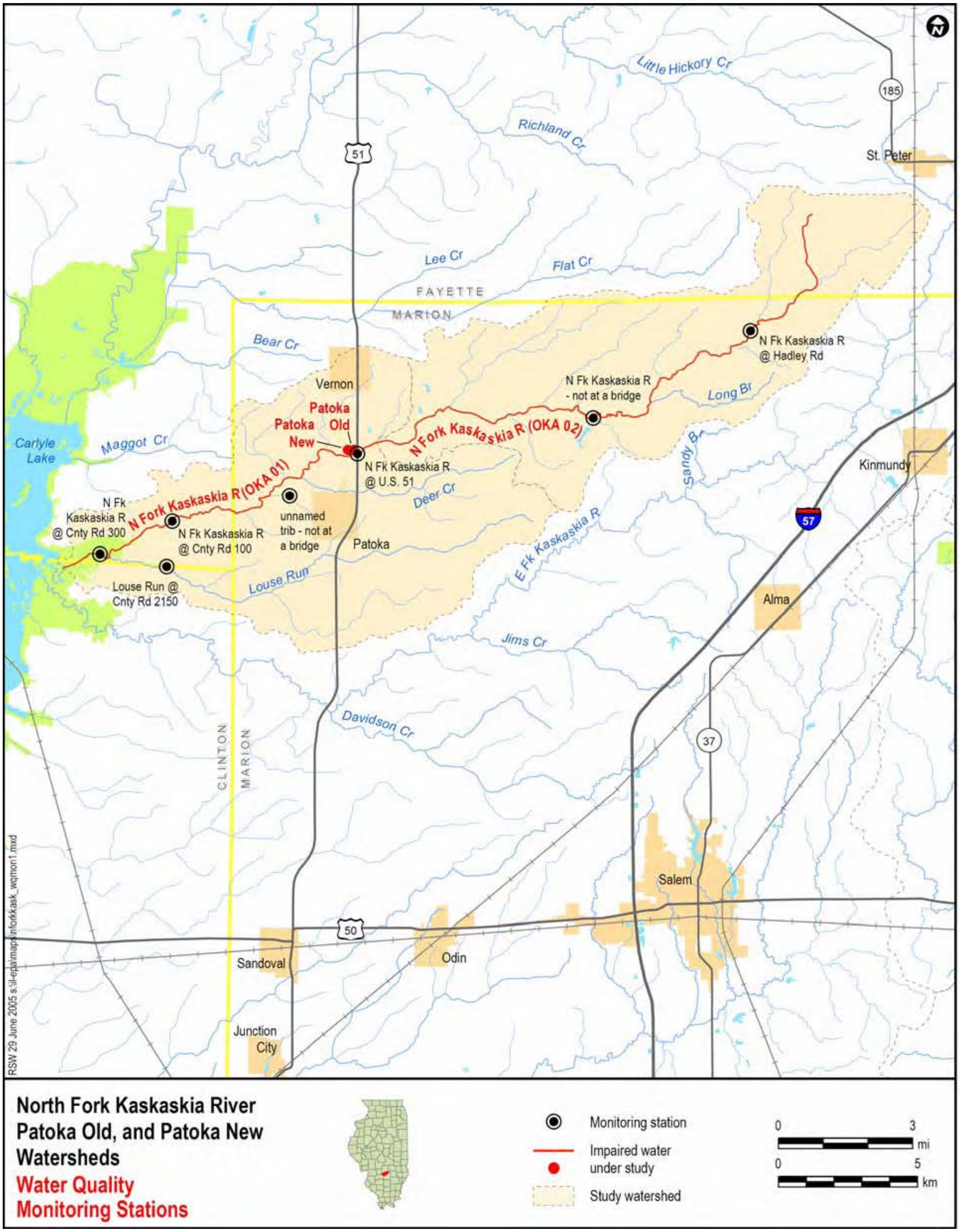

Figure 5. N. Fork Kaskaskia River Watershed Sampling Locations

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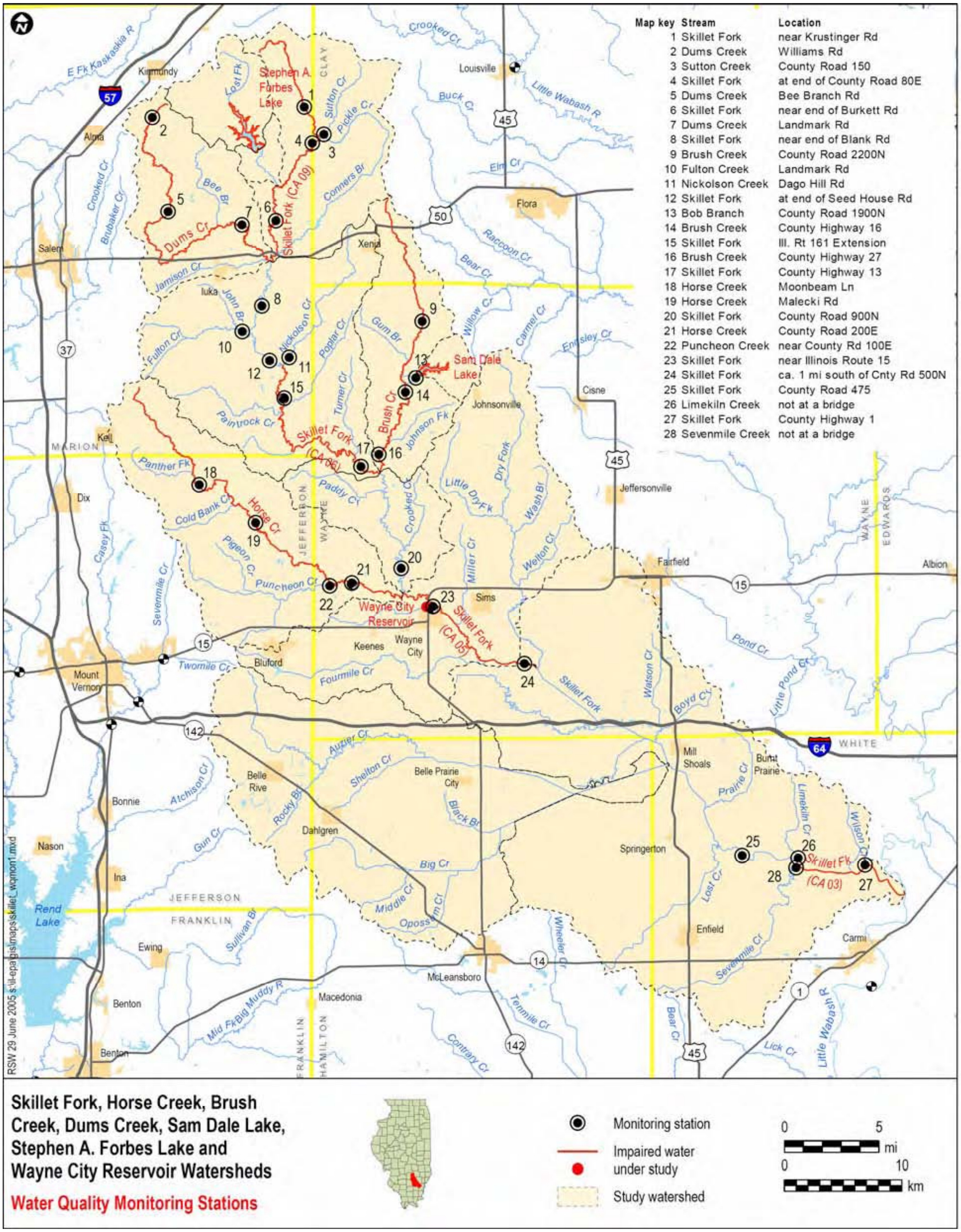

Figure 6. Skillet Fork Watershed Sampling Locations

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Table 4 USGS Gage Streamflow Statistics

Watershed	Nearest USGS Gage	USGS Gage Number	20th Percentile Flow (cfs)	50th Percentile Flow (cfs)	80th Percentile Flow (cfs)
Mauvaise Terre	Spring Cr at Springfield, IL	05577500	1.2	21	80
Hodges	(See Macoupin Cr Gage)				
Macoupin	Macoupin Cr near Kane, IL	05587000	16	100	465
NF Kaskaskia	(See E Fork Kaskaskia River gage)				
EF Kaskaskia	E Fork Kaskaskia River near Sandoval, IL	05592900	0.5	8.5	54
Skillet Fork	Skillet Fork at Wayne City, IL	03380500	3.9	36	312

Percentile values calculated from USGS website daily mean streamflow values for the period of record
The USGS real-time streamflow values for these gages can be accessed at the following URL:
http://waterdata.usgs.gov/il/nwis/uv?multiple_site_no=05587000%0D%0A05586800%0D%0A05586000%0D%0A05577500%0D%0A05594450%0D%0A05592900%0D%0A03380500%0D%0A&search_site_no_match_type=exact&index_pmcode_00065=3&index_pmcode_00060=4&index_pmcode_00045=5&index_pmcode_00055=&index_pmcode_72019=&sort_key=site_no&group_key=NONE&sitefile_output_format=html_table&column_name=agency_cd&column_name=site_no&column_name=station_nm&column_name=lat_va&column_name=long_va&column_name=state_cd&column_name=county_cd&column_name=alt_va&column_name=huc_cd&period=7&begin_date=&end_date=&format=gif&date_format=YYYY-MM-DD&rdb_compression=file&list_of_search_criteria=multiple_site_no%2Crealtime_parameter_selection

Table 5 Schedule

Event	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Approval to proceed from IL-EPA	X							
Macoupin Creek								
Survey 1 - low/medium flow								
Survey 2 - low/medium flow								
Hodges Creek								
Survey 1 - low/medium flow								
Survey 2 - low/medium flow								
Mauvaise Terre Creek								
Survey 1 - low/medium flow								
East Fork Kaskaskia River								
Survey 1 – low/medium flow								
Wet Weather Bacteria Survey		As weather permits						
North Fork Kaskaskia River								
Survey 1 - low/medium flow								
Survey 2 - low/medium flow								
Skillet Fork								
Survey 1 - low/medium flow								
Survey 2 - low/medium flow								

1.5. Quality Objectives and Criteria (A7)

The monitoring information collected will meet the quality objectives and criteria outlined in this section and presented in Table 6. Data quality will be measured for the monitored parameters in terms of minimum measurement criteria, minimum measurement objectives, required detection limits, accuracy, precision and completeness.

Minimum measurement criteria will be established at the lowest analyte concentration required for planned uses of the measurement data. Minimum measurement criteria are State of Illinois water quality standards for general use waters, where applicable. Where no minimum measurement criteria can be identified, the water samples will be analyzed to the lowest concentration readily achievable by the contract laboratory.

The minimum measurement objectives will be set at approximately one-fifth of the minimum measurement criteria shown to ensure that analytes will be measured with reasonable accuracy at the minimum measurement criteria concentrations, and measured to reasonable levels below the minimum measurement criteria. The minimum measurement objective for any analyte will be achieved when the analytical procedure selected for sample analysis can be shown to have a method detection limit (MDL) at or below the minimum measurement objective. Analyte MDLs will be determined from the USEPA analytical methods used (as found in the Code of Federal Regulations (CFR), Volume 40, Part 136, Appendix B). The MDL is defined as the minimum constituent concentration that can be distinguished from a sample with no analyte at a 95 percent confidence level. Since the MDL procedure is based upon precision obtained for a standard greater than the MDL, it also is a measure of method sensitivity at concentrations near the MDL.

For analytes without minimum measurement criteria, the minimum measurement objectives will be understood to be the MDL level that is readily achievable using analytical methods generally employed at the contract laboratory. For field parameters where MDLs are not applicable such as pH, temperature, and dissolved oxygen, the minimum measurement objectives are the sensitivity of the measurement method.

Table 6 Measurement Objectives and Criteria

Parameter	Minimum Measurement Criteria	Minimum Measurement Objectives	Method*; MDL[1]	MS/MSD * Accuracy (% recovery)	MS/MSD * Precision (RPD)	LCS * Accuracy (% recovery)	Completeness
Dissolved Oxygen	NA	0.1 mg/l [s]	Field; NA	NA	NA	NA	90%
Water Temperature	NA	0.1 degree C [s]	Field; NA	NA	NA	NA	90%
pH	NA	0.1 pH unit[s]	Field; NA	NA	NA	NA	90%
Ammonia	15.0 mg/l[G]	3.0 mg/l	EPA 350.1/ 350.3; 0.01/0.03 mg/l	80-120%	20%	80-120%	90%
Nitrate-Nitrite	No Standard	0.05 mg/l	EPA 353.1	80-120%	6%	80-120%	90%
BOD_5	No Standard		EPA 405.1/ SM5210 B; 2 mg/l	N/A	20%	N/A	90%
Iron, Total	0.017 mg/l[G, 2]	0.005 mg/l	EPA 200.8; 0.02 mg/l	70-130%	20%	80-120%	90%
Manganese, Total	1 mg/l[G]	0.2 mg/l	EPA 200.8 0.02 mg/l	70-130%	20%	80-120%	90%
Eschericia coli	No standard	20 counts/100ml	SM 9223 B; 1 count/100ml	NA	NA	Positive	90%

NA = Not Applicable
SM - Standard Methods of the Examination of Water and Wastewater, 20th Edition
s = Required sensitivity
EPA - EPA Methods for Chemical Analysis of Water and Wastes, March 1983
* = Limits are subject to change based upon capabilities of contract labs
1 = Method Detection Limit (MDL) from SM and EPA.
2 = Calculated acute standard based on a minimum water hardness of 100 mg/L as $CaCO_3$
G = State of Illinois General Use Water Quality Standard

1.6. Special Training/Certification (A8)

A variety of professional staff (engineers, scientists and others) will be involved in this monitoring program. Project staff will be assigned duties based on their qualifications to accomplish the task. The Project Manager will determine the appropriateness of an individual to undertake a task.

Training sessions will be carried out for all field staff on proper sampling, sample handling and shipping, and general field procedures prior to conducting the first sampling event. Specific emphasis will be placed on QA/QC issues as well as on health and safety. Field staff will receive a safety briefing conducted by the Field Manager with emphasis on field hazards and materials handling. Training will also include the operation, maintenance and calibration of field equipment, including multi-parameter probes, velocity meters, and all other on-site equipment used throughout the field program. SOPs for program elements will be distributed to appropriate staff and available at all times.

The laboratory Technical Director will be responsible for training and certifications of laboratory personnel. All laboratory personnel will receive appropriate training and have proven proficiency in their designated analytical procedures. Laboratory personnel will be provided copies of the appropriate laboratory procedures, which will be available at all times.

1.7. Documents and Records (A9)

The Project Manager will ensure that the project team has the most current approved version of the QAPP. The project manager is responsible for initiating project files and for overseeing maintenance of the files during the course of the project. All project files will be properly identified by client, project name, project code and file description for all appropriate correspondence, memoranda, calculations, technical work products, and other project-related data. In addition, a quality assurance file will be maintained containing all QA/QC related information. A back up of all computer files containing important project information will also be maintained.

Documents generated by field activities may include staff notes, field logs, equipment logs, field on-site measurement data sheets, field audit reports and chain of custody forms. Documents generated by laboratory activities may include QA/QC documentation, laboratory bench sheets, laboratory results, and laboratory audit reports. These documents will be maintained in the project files.

At the conclusion of the project, all relevant information from the project files and computer disks will be archived. Documents will be retained for a minimum period of three years following archiving.

2 Data Generation and Acquisition (Group B)

The U.S. EPA QAPP Guidance Group B Data Generation and Acquisition elements (B1-B10) are addressed below.

2.1. Sampling Process Design (B1)

The sampling process design is presented in Sections 1.3 and 1.4 of this QAPP, including sampling rationale, locations, media, frequencies, and schedules.

2.2. Sampling Methods (B2)

Standard operating procedures (SOPs) will be employed to provide consistency and reproducibility to the sampling methods used by field personnel. The following sections present or reference the detailed methods for performing sampling activities including related support procedures for equipment cleaning, field measurements, and calibration and maintenance of field instruments. Sample custody procedures are presented in the Sample Handling and Custody Section of this QAPP.

2.2.1. Surface Water Sample Collection

Surface water grab samples will be collected as specified in the Section 1.4 and according to the procedures presented in Appendix A.

2.2.2. Stream Morphometric and Discharge Monitoring

Stream discharge monitoring will be conducted as specified in Section 1.4 and according to the procedures presented in Appendix A.

2.2.3. Field Water Quality Measurements and Monitoring

Instantaneous water quality measurements (e.g. temperature, pH and DO) will be collected using field instruments according to the procedures presented in Appendix A. In-situ monitoring instruments and equipment will be installed in a manner using methods that incorporate the unique requirements of specific locations. The main concern will be the security of the instruments, equipment and generated data. Maintenance, cleaning and/or data download activities for in-situ instruments will be performed at a frequency necessary to assure that representative data are generated and recorded for transfer to the project files.

2.2.4. Cleaning of Equipment and Materials

All reusable equipment and materials used during the field activities will be cleaned prior to use at the site and at specified intervals during the field activities. Cleaning will be performed according to the procedures specified in Section 1.4 and as presented in Appendix A to avoid the introduction of any chemical constituents or cross-contamination to the soils or groundwater. Equipment and materials that may be used during the investigation include water and/or sediment sample collection devices.

Equipment cleaning will be performed using water from a source approved by the project manager. If needed, a designated cleaning or decontamination area will be used or constructed so that all water generated during cleaning operations will be contained for proper disposal.

2.3. Sample Handling and Custody (B3)

Sample handling will be performed so as to collect, store, submit to the laboratory and analyze representative samples using methods as specified in Section 1.4 and according to the procedures presented in Appendix A. Sample containers, volumes, preservatives and holding times are summarized in Table 7. Laboratory sample custody will be performed in accordance with the laboratory's Quality Assurance Manual

2.4. Analytical Methods (B4)

The following section details aspects of the analytical requirements, ensuring that appropriate analytical methods are employed. Table 6 summarizes the analytical methods to be used by the contract laboratory. Table 7 displays the required container type, sample volume, preservation, and holding time for each parameter according to the previously referenced methods. The laboratory will provide sample containers from a commercial supplier. All sample containers will be new and pre-cleaned by the supplier. In addition, the contract laboratory will provide sample labels for each bottle and add the required preservative for each parameter, where feasible.

The analytical data results and intra-laboratory QA/QC results will be submitted by the contract laboratory to the Field Manager or other designated contact person within a specified time frame from the completion of each sampling event.

Table 7 Guidelines for Sample Container Preparation and Preservation

Parameter	Container	Recommended Sample Volume	Preservation	Holding Time
Coliform Bacteria	Pre-Sterilized Polyethylene or Glass	200 ml	Add $Na_2S_2O_7$ [1] Refrigerate to 4°C	6 hours[2]
NH_3 and nitrate-nitrite	Polyethylene or Glass	1000 ml	Add H_2SO_4, pH<2 Refrigerate to 4°C	28 days
BOD_5	Polyethylene or Glass	1000 ml	Refrigerate to 4°C	48 hours
Iron	Polyethylene or Glass	500 ml	Add HNO_3, pH<2 Refrigerate to 4°C	180 days
Manganese	Polyethylene or Glass	500 ml	Add HNO_3, pH<2 Refrigerate to 4°C	180 days

1. Sodium Thiosulfate ($Na_2S_2O_7$) prevents continuation of bacteriocidal action.
2. The maximum allowable holding time for bacteria samples is 30 hours with a regulatory goal of 6 hours when practical.

2.5. Quality Control (B5)

All field operations personnel are responsible for ensuring that proper procedures are followed for sample collection and handling, sample preservation, and sample custody of the delivered samples to the designated laboratory. If noncompliance issues arise, an investigation and corrective action report prepared by the responsible supervising field personnel will be submitted to the Project Manager. The accuracy and precision of all data measurements must be quantifiable. Analytical procedures used for data analysis must be performed according to approved standard methods. Data measurements should be recorded in a controlled environment in which a quality control program can be maintained.

Field quality will also be assessed through the collection of field duplicate samples and equipment rinse blank samples. Field duplicates will be collected at a frequency of one for every group of 10 samples. Rinse blank samples will be collected at a frequency of one for each day of sampling or one for every group of 20 samples.

The contract laboratory is responsible for implementing its QA/QC Manual, which is an internal quality assurance plan for laboratory procedures. The contract lab is responsible for the accuracy and reliability of analytical methods and final data reports. If noncompliance issues arise, an investigation and corrective action report will be prepared and submitted from the Laboratory Manager to the Project Manager. The contract lab is responsible for providing data qualifiers and/or case narratives to inform the Project Manager of any analytical exceptions that fall outside of routine method protocols. Analytical quality control will be performed in accordance with the laboratory QA/QC Manual, the specified analytical methods, and as discussed under the Quality Objectives and Criteria Section of this QAPP.

2.6. Instrument/Equipment Testing, Inspection, and Maintenance (B6)

All field and laboratory instruments/equipment shall be routinely maintained according to manufacturer instructions and accepted procedures associated with the selected analytical methods, SOPs and the laboratory's QA/QC Manual, as applicable. Field instruments and equipment shall be tested and inspected prior to sampling events. An adequate supply of spare parts shall be maintained as necessary for equipment maintenance.

2.7. Instrument/Equipment Calibration and Frequency (B7)

Calibration procedures for field and laboratory instruments/equipment will follow manufacturer instructions and accepted procedures associated with the selected analytical methods, SOPs and the laboratory's QA/QC Manual, as applicable. In order to maintain field precision and accuracy, the instruments will be calibrated to known standards.

2.8. Inspection/Acceptance of Supplies and Consumables (B8)

All supplies and consumables for field and laboratory activities will be inspected by the field operations teams and laboratory managers, respectively, to guarantee their usability. Supplies or consumables found to be deficient for the needs of the project will not be used.

2.9. Non-direct Measurements (B9)

Non-direct measurements will not be used in implementation of the monitoring program.

2.10. Data Management (B10)

Data generated through field and laboratory activities will be used for developing models and reports. Reporting formats will vary depending on the purpose for which the data has been assembled, but will include such items as field books, field calibration and measurement records, electronic data downloaded from field instruments, laboratory analytical results and QC reports. The Project Manager or designee has the responsibility of maintaining all documents and data generated during field programs and received from the laboratory. The Laboratory Technical Director has the same responsibility for laboratory data and information.

Field and laboratory documents will be kept in the project files. All electronic files will be backed up on a regular basis. At the conclusion of the project all relevant information, project files and electronic data will be turned over to the Project Manager. Paper and electronic files will be retained for a minimum period of three years following archiving.

3 Assessment and Oversight (Group C)

The U.S. EPA QAPP Guidance Group C Assessment and Oversight elements are addressed in this section.

3.1. Assessment and Response Actions (C1)

The sampling team will be evaluated to determine if sampling protocol is followed. Quality control and noncompliance issues related to field activities will require an investigation and corrective action conducted under the supervision of the Project Manager.

Laboratories contracted for data analysis shall maintain internal quality assurance programs described in their quality assurance plans. When the possibility of quality control problems or noncompliance issues arise that may affect the usability of data, an investigation and corrective action will be conducted by the Laboratory Technical Director and communicated to the Project Manager.

3.2. Reports to Management (C2)

Periodic summary reports will be prepared by the Project Engineer in charge of Quality Assurance, if necessary, to inform the Project Manager of the project status. The reports will include:

- Periodic assessment of measurement data accuracy, precision, and completeness;
- Results of performance audits and/or systems audits;
- Significant Quality Assurance/Quality Control problems and recommended corrective action;
- Status of corrective action implementation to any problems previously identified.

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4 Data Validation and Usability (Group D)

The U.S. EPA QAPP Guidance Group D Data Validation and Usability elements are addressed in this section. The purpose of these elements is to determine if the data meet the project's Data Quality Objectives (validation) and to evaluate the data against the method, procedural and/or contractual requirements (verification). Data validation, verification, and usability assessment will be conducted as outlined in this QAPP.

The data generated from the sampling program will be subjected to a multi-tiered review process described below. This process includes:

- A review of the data at the bench and field levels;
- A secondary review of field records by the Field Manager and analytical results within the laboratory by the lab QA/QC Manager to verify the data against method and SOP requirements;
- A review of the verified data by the Project Manager or designee for reasonableness and to identify obvious data anomalies;
- A validation by an objective third party, if necessary; and
- An assessment of the data by project team members for its usability to meet the project goals.

4.1. Data Review, Verification and Validation (D1)

All environmental measurement data collected by project staff will be subjected to quality control checks before being utilized in the interpretive reporting. A data generation system that incorporates reviews at several steps in the process is designed to protect the integrity of the data and reduce the number of data that do not meet the Data Quality Objectives (DQOs) or the project goals. This section describes the requirements of each review step that will be used in this project.

4.1.1. Data Verification Requirements

Data verification will occur at the field and laboratory level. This section describes the requirements of the data verification.

Field Activities Data Verification. The Field Manager will be responsible for ensuring that the samples are collected and handled according to the specified procedures. Sample collection verification will include confirming that the samples were collected with the proper equipment at the appropriate locations with the appropriate frequency. Sample handling verification will include confirming that the samples were stored in the appropriate containers with the correct preservative, that the samples were stored at the proper temperature during transport from the field to the laboratory, and that all of the appropriate information is logged on the chain-of-custody records.

Lab Activities Data Verification. The laboratory QA/QC Manager will be responsible for verification of laboratory-generated data, although the laboratory SOPs for each method may require some components of the verification to also be conducted at the bench level. Laboratory verification will include assessing that the procedures used to generate the data are consistent with the method requirements as specified in the laboratory's SOPs and that the QA/QC requirements for each method are met. Examples of method requirements include verifying the calibration and data reduction procedures. However, these requirements vary by analyte and are presented in more detail in the laboratory QA/QC Manual.

4.1.2. Data Review Requirements

The Field Manager will perform data reviews that consist of screening the field data sheets and laboratory data sheets according to established criteria listed in this section. If the established screening criteria are not met, an additional review of available laboratory data (e.g., quality control checks, relevant laboratory bench sheets) may be conducted. Investigation of the issue will be documented and the data will be discarded or flagged appropriately, identifying the limitations of the data.

Field Data Sheet Reviews. The following criteria may be used to screen the physical parameter measurements recorded by the field crews:

- temperature readings – check for reasonableness of values
- pH readings – check for reasonableness of values
- dissolved oxygen readings –compare concentrations to percent saturation

Laboratory Data Sheet Reviews. The following criteria will be used to screen the analytical measurements performed by the contract laboratory:

- equipment blanks –values should be less than detection limits
- method blanks –values should be less than detection limits
- field blanks – are values less than detection limits
- review of all analytical results – check for reasonableness of values

4.1.3. Data Validation Requirements

Data validation is typically performed by someone independent of the project activity and not associated with the organization responsible for producing the dataset. However, the data validator needs to be familiar with both the data validation requirements and the project objectives. A scientist/engineer not directly involved in the project administration, project management, field or laboratory operations will conduct the data validation. There are four requirements in the data validation process as follows:

- Inspect the data verification and review records to ensure that no oversights were made during that process.
- Evaluate the data against the project DQOs. If data do not meet one or more of the DQOs, the data validation process will include an investigation into causes and an assessment of the impact of the noncompliant data on project objectives.
- Evaluate the data in the context of the project's overall objectives.
- Communicate the data validation results to the rest of the project team.

4.2. Verification and Validation Methods (D2)

All environmental measurement data and samples collected by project staff will be subjected to quality control prior to being entered into the project database. This is a multi-step process where the laboratory QA/QC Manager will have primary responsibility for verifying the data and a third party, preferably one who is not involved in data collection or analysis, conducts the data validation. These steps are described in more detail in the following sections.

4.2.1. Data Verification

This section describes the procedures that will be utilized in this project for verifying the data against method, procedural and/or contractual requirements.

Field Activities Data Verification. Individual crew leaders will verify the completion of their field data sheets and chain-of-custody forms. In addition, crew leaders will also verify the proper calibration and operation of their multi-parameter instruments. At the completion of each monitored event, the Field Manager will review all field data sheets, calibration sheets, and chain-of-custody forms for accuracy and completeness. The Field Manager will also verify that monitoring QA objectives for all accuracy, precision, completeness, and adherence to the required collection techniques are being met.

Laboratory Analytical Results Verification. Individual analysts will verify the completion of the appropriate analytical test and required bench sheets. The laboratory Technical Director or designee will review calculations and inspect laboratory bench sheets and log books daily to verify their accuracy, completeness, and adherence to the specified analytical method protocols. Calibration and QC data will be examined daily by the individual analyst. The laboratory Technical Director or designee will verify that all instrument systems are operating within control limits and that QA objectives for accuracy, precision, completeness, and adherence to the required detection limits are being met.

A summary of reportable QA/QC results and any non-conformance issues will be included in the laboratory deliverable to the Field or Project Manager.

4.2.2. Data Validation

This section describes the process that will be used to validate the data generated for this project. The first requirement is to inspect the data verification results and review records to ensure that no oversights were made during that process. A complete set of field and laboratory information will be provided to the data validator for this task.

The primary objective of the data validation in this project is to evaluate the data conformance with the project DQOs. These DQOs include criteria for accuracy, precision, completeness, and compliance with required detection limits. The components described under the Data Management Section of this QAPP will provide the necessary information to make this evaluation. The following must be reviewed as part of the measurement data and analytical data validation activities:

- field measurement data,
- field sample collection information,
- sample custody records,
- laboratory analytical results,
- data review information and/or laboratory case narrative,
- quality control data.

The data validator will conduct a systematic review of the data for compliance with the established quality control criteria based on duplicate, replicate, spiked, control, and blank data results provided by the laboratory. In addition, quality assurance evaluations of data accuracy, precision, and completeness will be performed on the field measurement data and the laboratory analytical results for each monitored event. The data validation qualifiers listed in Table 8 will be used when validating the data:

Table 8 Data Validation Qualifiers

Qualifier	Definition
U	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
J	The associated value is an estimated quantity.
R	The data are unusable (note: analyte may or may not be present)
UJ	The material was analyzed for, but was not detected. The associated value is an estimated level.
B	Chemical was detected in the field blank at a concentration equal to or greater than the ML, or greater than one-fifth the level in the associated sample, whichever is greater.
D	Out of control field duplicate based on RPD control limit

If quality control checks or objectives were not met, an investigation of the non-conformance may be initiated by the data validator with the project team personnel, such as the Field Manager, the laboratory QA/QC Manager, and the Project Manager. The non-conformance will be documented and the affected data set will be flagged appropriately, identifying any limitations.

Another objective of the data validation is to evaluate the data within the context of the project goals. These goals include providing datasets that can be used to develop model inputs, to calibrate and validate the models, and to ensure consistency among different sources of data. Suitable datasets for the modeling portion of this project will be based on the data quality assessment described above as well as an assessment of the spatial and temporal extent of the sample collection. Comparability with other sources of data will be evaluated by comparing and, if necessary, plotting the data with previously collected data to identify outliers or anomalous values.

The data validation results will be communicated to the project team in the form of a summary table that lists the validation tasks and the associated results and conclusions. If the validated dataset includes non-compliant data, this data will be addressed in a memo that accompanies the summary table. Data qualifiers assigned to the data during validation will be maintained in the project database to ensure communication of validation results with current and future data users.

4.3. Reconciliation with User Requirements (D3)

Once all field measurements and analytical data have been reviewed, quality control measures assessed, and any problems addressed, the measurement and analytical data will be assessed by the Project Manager or designee.

The assessment of the information generated from the monitoring program will be initiated by entering all analytical data and field measurement data into the project database. Other data (such as precipitation, flow data, velocity data, stage data, field notes, and information on any sampling anomalies) may be appended. All of these data will be evaluated and any relationships or correlations will be noted. The compilation of all information surrounding a sampling and/or monitoring event will be available to facilitate reconciliation with user requirements.

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5 References

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United States Environmental Protection Agency (EPA), 1998. *EPA Guidance for Quality Assurance Project Plans*, EPA QA/G-5. Washington , DC.

United States Environmental Protection Agency (EPA), 2002. *Guidance on Environmental Verification and Data Validation*. EPA QA/G-8. Washington, DC.

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Appendix A

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I. Introduction

This standard operating procedure (SOP) is applicable to the collection of representative liquid samples, both aqueous and non-aqueous, from streams, rivers, lakes, ponds, lagoons, and surface impoundments. It includes samples collected from depth, as well as samples collected from the surface. These typically applicable procedures have been adapted from the U.S. EPA Environmental Response Team Surface Water Sampling SOP No. 2013, dated 11/17/94 and may be varied or changed as required, dependent upon site conditions or equipment and procedural limitations. The actual procedures used should be documented in the field notes, especially if changes are made.

There are two primary interferences or potential problems with representative surface water sampling. These include cross contamination of samples and improper sample collection. Following proper decontamination procedures and minimizing disturbance of the sample site will eliminate these problems as follows:

- Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Refer to the Equipment Cleaning SOP.
- Improper sample collection can involve using contaminated equipment, disturbance of the stream or impoundment substrate, and sampling in an obviously disturbed area.

In order to collect a representative sample, the hydrology and morphometry of a stream or impoundment should be determined prior to sampling. This will aid in determining the presence of phases or layers in lagoons or impoundments, flow patterns in streams, and appropriate sampling locations and depths. In addition, water quality indicator data may be collected, if necessary, in impoundments to determine if stratification is present. Measurements such as dissolved oxygen, pH, temperature, and redox potential can indicate if strata exist which would affect analytical results. Measurements should be collected at sufficiently sized intervals (e.g., 1 meter) from the substrate to the surface using the appropriate instrument (e.g., Hydrolab).

II. Materials

The following materials shall be available, as required, during surface water sampling. Back-up field instruments/equipment should be available, if required.

- Personal protective equipment (as necessary);
- Cleaning equipment (as required in the Standard Operating Procedure for Equipment Cleaning);
- Appropriate sampling apparatus and accessories (e.g., Kemmerer, weighted bottle, or Dip sampler, sample containers, sampling line, weights, messengers);
- Appropriate sample bottles, preservatives (if required) and sample bottle labels;
- Ziploc®-type bags;
- Insulated coolers, ice, and appropriate packing material;
- Chain of Custody records and custody seals;
- Field data sheets, field log book, waterproof pen, camera and film;

- Decontamination equipment;
- Maps/plot plan, survey stakes/flags/buoys and anchors;

III. Preparations

- Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.
- Obtain the necessary sampling and monitoring equipment to suit the task. Consider sample volume, depth, deployment circumstances (shore, wading, boat, currents), type of sample, sampler composition materials, and analyses to be conducted.
- Decontaminate or pre-clean equipment and ensure that it is in working order.
- Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
- Perform a general site survey.
- Use stakes, flagging, or buoys to identify and mark all sampling locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. If also collecting sediment samples, this procedure may disturb the bottom and cause interferences with collection of representative water samples.

IV. General Sample Collection Procedures

1. Record pertinent data on the field log (see attached Surface Water Sampling Field Log, or equivalent).

2. Label all sample containers with the date, time, site location, sampling personnel, and other requested information.

3. Don appropriate personal protective equipment (as necessary).

4. For coliform bacteria samples, use a sterile sample bottle and store the bottle cap in a sterile plastic bag to prevent contamination during sampling.

5. Clean all sampling equipment prior to sample collection according to the procedures in the Standard Operating Procedure for Equipment Cleaning.

6. At designated surface water sampling locations, thoroughly rinse the sampler in the water body prior to collecting the first sample.

7. For samples requiring field filtering, use a pump and in-line disposable filter, if possible to collect the sample directly into the sample container.

8. If field preservation is required, place appropriate preservative into the sample container prior to sample collection. Note the preservative and preservative column on the sample container and sampling log.

9. If any quality control samples are specified, they will be collected in the following manner:

- Duplicate samples should be collected at the same time or immediately following one another in accordance with the above procedures. If blind duplicate samples are specified, one of the duplicate samples should be labeled so that it does not identify the other sample of the duplicate pair to the laboratory on the chain-of-custody (COC). For example, one sample of the duplicate pair would be labeled following the normal protocol, while the second would be labeled with a sample ID of "DUPLICATE" and a blank line placed in the location, date and time boxes of the sample label. It is important that the duplicate pair samples are identified separately in the field notes with information including location, sample ID (as entered on the sample container label and COC), sample date and time so that analytical results can be paired after received from the laboratory.
- Rinse (or equipment) blanks should be collected from a final distilled/deionized water rinse of the specified sampling equipment after that piece of equipment has been cleaned in accordance with appropriate specified cleaning procedures.
- Field blanks, such as samples of water or reagents used to clean sampling equipment, should be collected directly into the sample bottle from the appropriate source container.

10. Record sample collection information on the field log and store the samples in an iced cooler as described in the Standard Operating Procedure for the Shipping and Handling of Samples.

11. Handle, pack, and ship samples according to the procedures in Standard Operating Procedure for the Shipping and Handling of Samples.

V. Equipment-Specific Sample Collection Procedures

Kemmerer Bottle. A Kemmerer bottle may be used in most situations where site access is from a boat or structure such as a bridge or pier, and where samples at depth are required. Sampling procedures are as follows:

1. Use a properly cleaned Kemmerer bottle. Set the sampling device so that the sampling end pieces (upper and lower stoppers) are pulled away from the sampling tube (body), allowing the substance to be sampled to pass through this tube.

2. Lower the pre-set sampling device to the pre-determined depth. Avoid bottom disturbance.

3. When the Kemmerer bottle is at the required depth, send down the messenger, closing the sampling device.

4. Retrieve the sampler and discharge from the bottom drain the first 10-20 mL to clear any potential contamination of the valve.

5. Transfer the sample to the appropriate sample container, as necessary, and cap securely.

Weighted Bottle Sampler. A weighted bottle sampler may be used in situations similar to those outlined for the Kemmerer bottle, but for near surface samples. Sampling procedures are as follows:

1. Use a thoroughly cleaned weighted bottle sampler with clean and/or disposable sample containers. For coliform bacteria samples, use a sterile sample bottle with the special sample bottle holder and store the bottle cap in a sterile plastic bag to prevent contamination.

3. Upon arrival at each field site, thoroughly rinse the sampler in the stream prior to collecting the first sample.

4. At the designated sampling location, carefully lower the weighted bottle sampler, allowing the sampler to fully submerse and fill with water. Coliform samples will be collected just below the surface of the stream at the center of flow.

5. Retrieve the sampler, transfer the sample to the appropriate sample container, as necessary, and cap securely.

Dip Sampler

A dip sampler is useful in situations where a sample is to be recovered from locations (e.g., outfall pipe, sump manhole, along a pond or lagoon bank) where direct access is limited. The long handle (or line if sampling from a bridge or other structure directly above the water body) on such a device allows access from a safe location. Sampling procedures are as follows:

1. Assemble the device in accordance with the manufacturer's instructions.

2. Thoroughly clean the sampler prior to use and use only clean sample containers.

3. Upon arrival at each field site, thoroughly rinse the sampler in the stream prior to collecting the first sample.

4. Extend the device to the sample location and fill the sample container by dipping and/or submersion.

5. Retrieve the sampler, transfer the sample to the appropriate sample container, as necessary, and cap securely.

Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be used to collect water samples from the surface directly into the sample bottle. This method may not be appropriate for sampling lagoons or other impoundments where contact with contaminants is a concern. When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation. The procedures are as follows:

1. Using adequate protective clothing, access the sampling station by appropriate means.

2. For shallow stream stations, collect the sample under the water surface while pointing the sample container upstream. The container must be upstream of the collector. Avoid disturbing the substrate.

3. For lakes and other impoundments, collect the sample under the water surface avoiding surface debris and boat wakes.

VI. Disposal Methods

If required, all water generated during equipment cleaning procedures will be collected and contained on site for determination of proper treatment or disposal. In addition, personal protective equipment (e.g., gloves, disposable clothing) and other disposable equipment resulting from cleaning and sampling procedures will be placed in plastic bags and appropriately contained for proper disposal.

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SURFACE WATER SAMPLING FIELD LOG

Project Name: Project Code: Page __ of __

Date	Time	Sample ID	Sample Location	Equipment Used	Samplers	Comments

Notes:

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I. Introduction

This standard operating procedure (SOP) is applicable to the collection of representative data (stream dimensions and water velocity) for use in determining discharge in streams and open channels. These typically applicable procedures have been adapted from the USGS *Techniques in Water Resources Investigations*, Book 3, Chapter A8: Discharge Measurements at Gaging Stations (http://water.usgs.gov/pubs/twri/twri3a8/pdf/TWRI_3-A8.pdf) and the *Open Channel Profiling Handbook*, January 1989 (Rev. May 1, 1990), Marsh-McBirney, Inc. The procedures herein may be varied or changed as required, dependent upon site conditions or equipment and procedural limitations. The actual procedures used should be employed in consultation of the more detailed procedures found in the USGS discharge measurement guidance document and the actual procedures used should be documented in the field notes, especially any changes made.

II. Materials

The following materials shall be available, as required, during collection of surface water flow data. Back-up field instruments/equipment should be available, if required.

- Personal protective equipment (as necessary);
- Boat and/or waders;
- Cleaning equipment (see the Standard Operating Procedure for Equipment Cleaning);
- Flowmeter/velocimeter and appropriate accessories (e.g., Marsh-McBirney Flo-Mate 2000, Pigmy-Gurly velocimeter, profiling/wading rod, boat/bridge board with suspension cable and weight, operation manuals);
- Protractor and compass;
- Measuring tape and/or measuring wheel;
- Field data sheets, field log book, waterproof pen, camera and film;
- Maps/plot plan, survey stakes/flags/buoys and anchors;

III. Preparations

- Determine the extent of the sampling effort, the methods to be employed, and the types and amounts of equipment and supplies needed.
- Obtain the necessary sampling and monitoring equipment to suit the task. Consider stream morphometry (width, depths, channels) and deployment circumstances (bridges, shoreline, wading, boats, obstructions, currents).
- Decontaminate or pre-clean equipment and ensure that it is in working order.
- Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
- Perform a general site survey.
- Use stakes, flagging, or buoys to identify and mark all sampling locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

IV. Flow Measurement Procedures

The methods of determining cross-sectional area and velocity must be selected prior to the field event. Data required for use in calculation of stream flow includes measurements of cross-sectional area (water depth and transect segment width), water velocity, flow angle, and transect angle. The mid-section method of computing cross-sectional area for discharge measurements is recommended by USGS and there are a number of different methods for measuring velocity. The two methods of velocity measurement that follow are frequently used for normal stream conditions:

- Six tenths Depth Method (0.6 depth below the water surface) uses observed velocity at this depth as the mean velocity in the vertical. This method gives extremely reliable results whenever the water depth is between 0.3 and 2.5 feet. It is also quicker to measure so is good for times of rapidly changing water level (stage).
- Two Point Method (0.2 and 0.8 depth below the water surface) averages velocities observed at these relative depths at each location and this average is used as the same mean velocity in the vertical. This method gives more consistent and accurate results than any of the other methods except the vertical-velocity curve method. The two point method is generally not used at depths less than 2.5 feet because the current meter settings would be too close to the water surface and stream bed for dependable results.

Flow measurement data collection using wading techniques are preferred by USGS, if conditions permit. Wading measurements offer the advantage over measurements from bridges (or other techniques such as cableways, not discussed herein) in that it is usually possible to select the best of several available cross-sections for the measurement.

When a stream cannot be waded, bridges may be used to obtain flow measurements (though cableway measurements are usually better, if available). No set rule can be given for choosing between the upstream or downstream side of the bridge to collect flow data. The advantages of using the upstream side of the bridge are:

- Hydraulic characteristics at the upstream side of bridge openings usually are more favorable.
- Approaching drift can be seen and be more easily avoided.
- The streambed at the upstream side of the bridge is not likely to scour as badly as at the downstream side.

The advantages of using the downstream side of the bridge are:

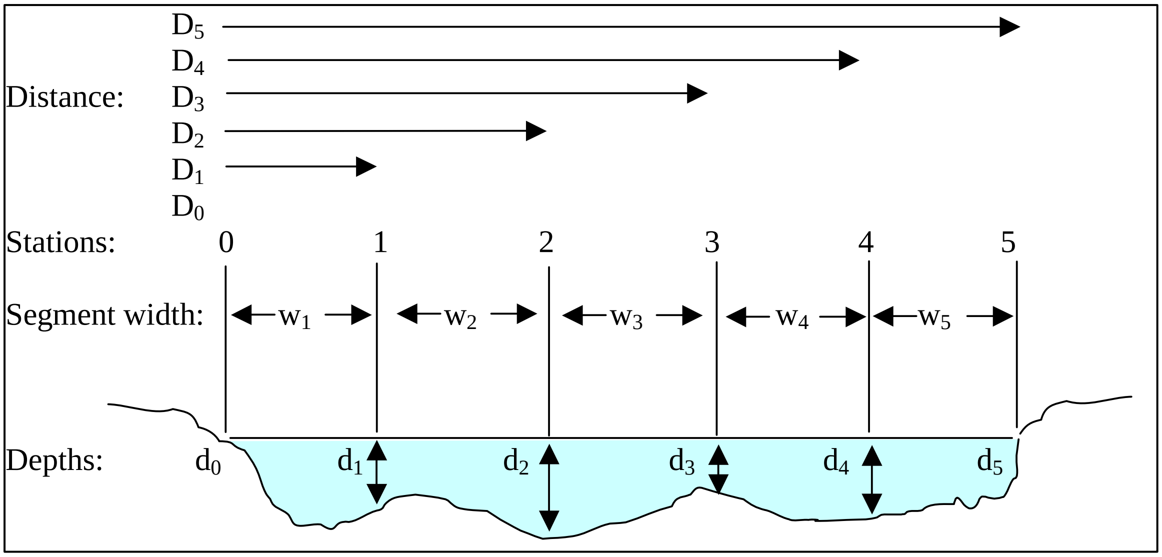
- Vertical angles are more easily measured because the sounding line will move away from the bridge.
- The flow lines of the stream may be straightened out by passing through a bridge opening with piers (see points under step 2 below).

To accomplish flow data collection using the methods selected, a transect of measurement stations across a stream is set up and marked before collecting section depth, width, and velocity data using the following steps:

1. Follow appropriate safety procedures and use personal protective equipment as necessary.
2. Select the transect site location following as many of the following considerations as possible:

- The channel should have as much straight run as possible – at least such that the length upstream from the profile should be twice the downstream length.
- The channel should be free of flow disturbances. Look for protruding pipe joints, sudden changes in diameter, contributing sidestreams, outgoing sidestreams, or obstructions.
- The flow should be free of swirls, eddies, vortices, backward flow, or dead zones.
- Avoid areas immediately downstream from sharp bends or obstructions.
- Avoid converging or diverging flow (approach to a flume) and vertical drops.
- Avoid areas immediately downstream from a sluice gate or where the channel empties into a body of stationary water.

3. Determine the width of the stream starting and ending at the stream's edges. Use a measuring wheel on a bridge or string a measuring tape between stakes if wading or in a boat.
4. Record the angle of the transect with respect to the stream channel and direction of flow. The transect should most preferably be at right angles to the direction of flow to avoid having to correct for the angle of the transect when calculating discharge.
5. Mark/record the partial section locations (measurement recording stations) of the measurement transect. These should be spaced so that no partial section contains more than 10 percent of the total flow. The ideal measurement would have less than 5 percent of the flow in any one partial section. Equal width partial sections across the transect are not recommended. Make the width of the partial sections less as depths and velocities become greater.
6. Assemble the appropriate equipment for the velocity and depth measurements.
7. Prepare the measurement note sheets to include the following information:
   - Name of stream and exact location of transect site.
   - Date, party, type of meter suspension, type of meter.
   - Measurement data (depth, width, position location, velocity, flow angle, time measurements were started and ended).
   - Bank of stream that was the starting point. Identify the stream bank by either LEW or REW (left edge of water or right edge of water, respectively) when facing downstream.
   - Gage height measurement and corresponding times.
   - Other pertinent information regarding site conditions and accuracy of the measurement.
8. Begin recording depth, width (transect distance) and velocity measurements at each station of the transect, successively, according to the remaining steps below and in reference to the figure that follows.



w = width of segment
D = distance from stream's edge
d = depth of water

9. Record distance (D1, D2, D3 …) from steam's edge at initial station (measurement point 0) to each successive station (1, 2, 3, …).

10. Record the water depth (d0, d1, d2, d3, …) at each measurement point, including the edge of the water at each end of the transect.

11. Measure velocity (0.2 depth & 0.8 depth – or – 0.6 depth below water surface) at each station and record the reading and associated meter depth position (0.2, 0.6, 0.8). Follow manufacturer instructions for operation of the meter.

    Note: If wading, stand in a position that least affects the velocity of the water passing the meter sensor (sufficiently downstream or to the side of the sensor – approximately an arm's length). Avoid standing in the water if feet and legs would occupy a considerable percentage of the cross section of a narrow stream (use a plank or other support). Keep the wading rod in a vertical position and the velocity sensor parallel to the direction of flow.

12. Measure and record the angle of flow with respect to the transect and direction of flow, especially if the flow is not at right angles to the transect.

V. Discharge Calculation

The USGS-preferred midpoint method of determining discharge uses the products of the partial areas of the stream cross-section (segment) and their respective average velocities (Q = A * V). It is assumed that the velocity measurement at each station represents the mean velocity in a partial rectangular area. The area extends laterally from half the distance from the preceding station to half the distance to the next and vertically from the water surface to the sounded depth. The cross-section is defined by depths at the station locations (d_1, d_2, …, d_n). There are two cases in the calculation, as follows:

For segments in the middle of the transect:

$Q_{middle\text{-}segment} = (D_{n+1} – D_{n-1})/2 * d_n * V_n$

For segments at the end of the transect:

$Q_{first\text{-}end\text{-}segment} = (D_{n+1} – D_n)/2 * d_n * V_n$
$Q_{last\text{-}end\text{-}segment} = (D_n – D_{n-1})/2 * d_n * V_n$

- Q = A * V (discharge = area * velocity; where)
- A = w * d (area = width * depth; where)
- w = $D_{n-1} – D_{n+1}$ or $D_{n+1} – D_n$ or $D_n – D_{n-1}$
(segment width = distance between alternate or adjacent stations; and)

Sum the segment discharges to get the total discharge for the river at a particular location

VI. Other considerations for less than ideal site conditions:

Non-perpendicularity:

Ideally, the cross-section is perpendicular to the stream channel, which has a straight run of sufficient length, and the stream flow is perpendicular to the cross-section. However, this is not always possible in the real world.

Angle of flow measurements should be collected and incorporated into the discharge calculation when flow is not perpendicular to the stream cross-section (insufficient straight run length of channel, presence of swirls, eddies, etc.).

Calculation of discharge should consider only the velocity component vector that is parallel to the stream channel (perpendicular to the ideal cross-section). This can be obtained by multiplying the velocity reading by the cosine of the flow angle (V * cos(a)). If the cross-section measurements are taken from a bridge that is not perpendicular to the stream channel, then correction for the angle of the bridge is also necessary.

Backwater and reverse flow:

Backwater areas or areas to shallow to measure are usually assigned a velocity of zero. Velocity values in areas of flow reversal (from eddies, or lake seiche effects near river mouths) must be assigned the opposite sign (if downstream velocities are positive, upstream velocities are negative).

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Flow Monitoring Datasheet

Site: ______________________________

Crew: ____________________ Date: ____________________

Staff Gage Reading (ft): ______________ Begin Time: ____________________

Tape Down (ft): ______________ End Time: ____________________

Equipment Used:

Transect Starting Point is on (circle one): left bank facing downstream right bank facing downstream

Bridge measurements are from (circle one): upstream side downstream side

Distance Starting Point to Nearest Edge of Water (ft): ______________

Distance Ending Point to Nearest Edge of Water (ft): ______________

Depth at Left Edge of Water (facing downstream): ______________

Depth at Right Edge of Water (facing downstream): ______________

Observations:

Transect Point No.	Transect Tape Reading (ft)	Water Depth (ft)	0.8D Velocity (ft/s) (if Depth >2.5 ft)	0.2D Velocity (ft/s) (if Depth >2.5 ft)	0.6D Velocity (ft/s) (if Depth <2.5 ft)	Angle coeff.	Notes

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I. Introduction

The equipment cleaning procedures described in this document include pre-field, in-field, and post-field cleaning of sampling equipment. The sampling equipment may consist of surface water sampling devices; water testing instruments; or other activity-specific sampling equipment. All non-disposable sampling equipment will be cleaned after completion of each sampling event. If appropriate, cleaning procedures will be monitored through the analysis of rinse blank samples as described in the project QAPP. Equipment cleaning areas will be located within or adjacent to a specific work area as necessary.

II. Materials

The following materials will be available during equipment cleaning, as needed:

- Personal protection equipment (as necessary);
- Distilled/deionized water;
- Non-phosphate detergent (Alconox, Liquinox, or equivalent);
- Tap water;
- Appropriate cleaning solvent (e.g., methanol, nitric acid);
- High-pressure hot water/steam cleaning unit;
- Wash basins;
- Brushes;
- Polyethylene sheeting;
- Aluminum foil;
- Plastic overpack drum, garbage can, or stainless steel tubes (for bladder or other pumps);
- Large heavy-duty garbage bags;
- Spray bottles (to hold tap water, distilled/deionized water, methanol, or nitric acid); and
- Disposable and/or heavy duty reusable (PVC, latex or nitrile) gloves.

III. Storage of Equipment

All cleaned sampling equipment will be stored in a clean environment and, if appropriate, the equipment will be covered/sealed with aluminum foil.

IV. Safety Procedures During Equipment Cleaning

1. Personnel will wear the following personal protection equipment as necessary, when cleaning sampling equipment (e.g., Kemmerer sampler, split-spoon sampler, trowels) and larger equipment (e.g., drill rig, augers):

   - Safety glasses, goggles, or a splash shield; and
   - PVC, latex, or nitrile outer gloves,

- Coated Tyvek® disposable coveralls or rainsuit, optional for small equipment cleaning; and
- Chemical resistant over boots, optional for small equipment cleaning.

2. All solvent rinsing if required, will be conducted in an adequately ventilated area.

3. All solvents transported into the field will be stored and packaged in appropriate containers with care taken to avoid exposure to extreme heat.

4. Handling of solvents will be consistent with the manufacturer's Material Safety Data Sheets (MSDS).

V. Field Cleaning Procedures

Cleaning Station

If a designated field equipment cleaning station location is required, it will be established to conduct all cleaning at each work area of the Site. The field equipment cleaning station will be located away from the immediate work area to minimize adverse impacts from work activities on the cleaning procedures, but close enough so the sampling teams can minimize equipment handling and transport.

Cleaning of Smaller Sampling Equipment

Cleaning of smaller sampling equipment (e.g., Kemmerer samplers, sample composite vessels, split-spoon samplers, bailers, trowels) will be conducted according to the following sequential procedure:

- Non-phosphate detergent (Alconox, Liquinox, or equivalent) and tap water wash;
- Tap water rinse;
- Solvent rinse, if required (e.g., methanol for organic constituent analysis, nitric acid for inorganic constituent analysis); and
- Triple distilled/deionized water rinse.

The first step, non-phosphate detergent and tap water scrub, is intended to remove all visible particulate matter and residual oil and grease. This may be preceded by a steam cleaning to facilitate soils removal. The tap water rinse is necessary to remove all soapy residues. The need for a specific solvent used for the solvent rinse, if required in the QAPP, will depend upon what the sample will be analyzed for. The final rinse of distilled/deionized water will be repeated three times. The equipment will then be allowed to air dry.

Collection and Disposal of used Solvents, Residuals and Rinse Solutions

All solvents, residuals, and rinse waters generated during the cleaning of equipment on-site will be collected, containerized, and stored on-site until arrangements can be made for proper disposal.

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I. Introduction

This standard operating procedure (SOP) is applicable to the collection of representative sediment oxygen demand (SOD) data from streams, rivers, lakes, ponds, lagoons, and surface impoundments. These typically applicable procedures have been adapted from the Ohio EPA Sediment Sampling Guide and Methodologies (OEPA, 2001), and may be varied or changed as required, dependent upon site conditions or equipment and procedural limitations. The actual procedures used should be documented in the field notes, especially if changes are made.

In order to collect representative SOD data, the hydrology and morphometry of a stream or impoundment should be determined prior to sampling. This will aid in determining appropriate sampling locations (see Section II).

SOD is measured using a dark chamber (resembling a large, inverted bowl) that isolates a known area of sediment and a known volume of water. A pump and tubing are used to form a closed system loop to circulate the volume of water over the area of sediment and ensure complete mixing. A dissolved oxygen (DO) probe in the chamber provides a continuous display of the DO concentration inside the chamber, which is recorded every five minutes for two hours or until the DO drops by 2 mg/L.

By using a dark chamber, photosynthesis does not affect the DO of the water in the chamber, and respiration and SOD are the only influences in the DO chamber. The effects of respiration are quantified by filling a blank SOD chamber or dark bottle with a known volume of water from the same location as the measurement chamber and measuring the DO at the beginning and end of the SOD test. The change in DO in the blank chamber or dark bottle provides an estimate of the amount of DO consumed by algal respiration in the water column.

The rate of change of DO in the chamber is determined by plotting the DO recorded in the chamber every five minutes. A regression analysis is then performed on the dataset. The rate of change of DO in the chamber is equal to the slope of the regression. The respiration rate measured in the dark bottle is subtracted from this rate. The corrected value is then divided by the area of the underlying sediment, resulting in an SOD value expressed as grams of oxygen consumed per square meter per day (g/m2/day) at the ambient temperature. To provide for standardization, temperatures are usually corrected to 20 degrees Celsius using a temperature correction factor.

II. Site Selection

SOD should be evaluated when any of the following conditions exist:

- Reaches having extensive low velocity pools (less than 0.25 fps).
- Reaches having diurnal DO swings greater than 100%.
- Reaches having extensive sludge deposits.

Sites should be selected based on a field evaluation that includes:

- Stream velocity; less than 0.25 fps (Velz, 1970), i.e., pools.
- Discharger location.

- Accessibility.
- Presence and extent of sludge deposits. Sludge deposits present the greatest impact of sediment types on instream DO. Sites for SOD measurement should include sludge deposits, if present, or locations with hydraulic characteristics conducive to sludge deposition.

III. Materials

The following materials shall be available, as required, during SOD surveys. Back-up field instruments/equipment should be available, if required.

- Personal protective equipment (as necessary).
- Cleaning equipment (as required in the Standard Operating Procedure for Equipment Cleaning).
- SOD chambers (benthic respirometer) and accessories (mixing pump with tubing and fittings, battery with connecting cables, rheostat for adjusting pump velocity).
- DO Meters – YSI Model 56 DO meter for each chamber, YSI Model 57 DO meter for algal production outside chamber, chart recorder.
- Primary productivity bottles, rope.
- Turbidimeter and accessories.
- Pyranograph and photometer with submersible sensor.
- Sediment sampling equipment (scoop, ponar dredge, etc.).
- Field data sheets, field log book, waterproof pen, camera and film.
- Miscellaneous supplies: Maps/plot plan, extra rope, bungee cords, survey stakes/flags/buoys, anchors and safety equipment.

IV. Preparations

- Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.
- Decontaminate or pre-clean equipment and ensure that it is in working order.
- Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
- Perform a general site survey.
- Use stakes, flagging, or buoys to identify and mark all sampling locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. If also collecting sediment samples, this procedure may disturb the bottom and cause interferences with collection of representative water samples.

V. SOD Instrument Setup and Measurement Procedures

Benthic Respirometer – Instrument Setup

1. Measure and record on SOD data sheet: water velocity at 0.2 feet above sediments, SOD chamber number.

2. Calibrate DO meter. Record DO concentration near water surface.

3. Place chamber in sediments. If sediments are disturbed, wait several minutes before proceeding.

4. Purge all air from the mixing pump and tubing by running the pump for a sufficient time period with tubing ends under water.

5. Attach the mixing pump inlet and outlet tubing to the SOD chamber fittings. Turn on pump to begin mixing water and verify that no air is trapped within chamber.

6. Insert the DO probe in the chamber. Verify that no air bubbles are introduced inside the chamber via the probe.

7. If possible, regulate water velocity within chamber to approximate stream velocity near the sediments outside the chamber. If a rheostat is used in-line with the pump, the rheostat settings will need to be calibrated to velocity using the pump and tubing, a bucket and a flowmeter.

8. Install a similar respirometer next to the first one, but seal the bottom with a plastic lid, excluding all sediment (for quality control "blank" measurements). This chamber will measure the respiration oxygen demand of the water column, to be subtracted from the DO change measured by the first SOD chamber. If only one chamber is available, use the DO change measured in the dark productivity bottles to make this correction.

9. Start the DO meter.

10. Record the starting time, date, site data, meter number and, if using a non-auto-recording DO meter, manually record the DO and temperature readings on the SOD field data sheet. Write the values at 5 minute intervals initially, and alter the interval depending on the rate of oxygen uptake.

11. Retrieve chamber after DO concentration has decreased by 2 mg/l or after two hours.

VI. Calculations

The following equation is used to determine the SOD:

SOD = 1.44 * (V/A)*(b1-b2) where:

SOD	=	sediment oxygen demand, in g/m2/day
1.44	=	conversion factor, converts results to g/m2/day
V	=	volume of chamber, in liters
A	=	area of chamber, in square meters (A=p*r2)
b1	=	rate of change of DO inside the SOD chamber, in mg/L/minute
b2	=	rate of change of DO inside the "blank" SOD chamber or dark productivity bottles, in mg/L/minute

To facilitate the comparison of results among different sites, the SOD should be converted to 20^{o}C by using the following equation:

SOD20 = SODT/(1.065T-20) where:

SODT	=	SOD at original temperature, in g/m2/day

SOD20	=	SOD at 20°C, in g/m2/day
T	=	Ambient temperature, in °C

VII Disposal Methods

If required, all water generated during equipment cleaning procedures will be collected and contained for determination of proper treatment or disposal. In addition, personal protective equipment (e.g., gloves, disposable clothing) and other disposable equipment resulting from cleaning and sampling procedures will be placed in plastic bags and appropriately contained for proper disposal.

VIII. References

Ohio EPA. 2001. Sediment Sampling Guide and Methodologies, 2nd Edition. Division of Surface Water, Columbus, Ohio. Nov. 2001

Velz, Clarence. 1970. Applied Stream Sanitation. Wiley Interscience. New York, NY.

I. Introduction

Water quality parameters, such as water temperature, dissolved oxygen and pH are routinely measured during surface water investigations. Instantaneous measurements may be recorded using individual probes or multi-sensor sondes, as available and appropriate for each situation. These probes should be calibrated daily using manufacturer procedures. Collection of continuous data is most commonly performed using a data sonde with internal batteries and memory capacity that can be deployed for extended periods to record data over a range of conditions. The primary limiting factor for extended deployment duration is usually degradation of data quality because of biofouling of the sensor surfaces. The rate of biofouling is related to productivity of the water where monitoring is being conducted. In general, a sonde should be downloaded, checked for reading stability (drift), and recalibrated at a frequency of no more than seven to ten days. An initial check within this time period may allow for modification of subsequent visits, depending on the magnitude of drift observed. The calibration and maintenance log for the above referenced meters is included as an attachment to this Standard Operating Procedure.

II. Materials

The following materials, as required, shall be available for installation of and field visits to the continuous monitoring station(s):

- Personal protective equipment (as necessary);
- Perforated PVC housing(s) for extended deployment installations;
- Fence post(s) and pounder for extended deployment installations;
- Attachment hardware for extended deployment installations;
- Data probes or sonde;
- Manufacturer's operating manuals for each instrument;
- Calibration solutions appropriate for each instrument;
- Tools and equipment necessary for field maintenance of instruments;
- Laptop computer for setup and downloading sondes (as necessary);
- Clean container;
- pH calibration buffer solution within and bracketing expected range of measurements;
- Cleaning equipment (as required in the Standard Operating Procedure for Equipment Cleaning);
- Distilled/deionized water; and
- Appropriate forms and field notebook.

III. Procedures for Instantaneous Field Water Quality Measurements

1. Calibrate and operate all meters in accordance with manufacturer’s operating manuals.
2. For in-situ surface water measurements place probe(s) at the designated location in the water body, allow instrument readings to stabilize, and record the readings for each parameter:
3. If measuring ex-situ samples, collect a water sample from the designated location in the designated container, insert probes into container and record readings (especially temperature

and pH readings) as soon as possible after collecting the sample to minimize inaccuracies from the changing temperature of the sample as it equilibrates to ambient temperature.

4. Rinse probes off in distilled/deionized water, if required.
5. Log results and observations in field notebook.

IV. Procedures for Extended Sonde Deployment and Continuous Measurements

Installation. Installation of the data sonde is accomplished using a perforated PVC housing attached to a fence post or other structure, if present and appropriate. The goal of the installation is to place the sensors in a location that is representative of the water column (e.g. mid-channel, mid-depth, middle of flow volume). It is important to consider water level fluctuations, obstructions, and debris that may be present during wet or dry weather conditions and plan the installation accordingly to maximize the collection of accurate data. After an appropriate location is identified, install the perforated PVC housing in the stream channel.

Data Sonde Set-up and Calibration. The dissolved oxygen and pH sensors are calibrated according to manufacturer specifications prior to installation. Temperature is usually a factory-calibrated parameter. A logging file is created in the sonde for the storage of data according to manufacturer specifications. Start date and time is specified to ensure that data logging occurs when the sonde is deployed. Specify the sampling interval/data recording frequency. After calibration and logging file set-up, remove calibration chamber and attach the weighted strainer. Place the sonde into the protective housing. Secure the cap to the housing. Record deployment time in field notes.

Field Maintenance. The data sonde should be maintained at a minimum frequency of every seven to ten days. The current readings should be checked to evaluate drift, the logging file should be downloaded, the sonde should be cleaned and recalibrated, and the sonde should be redeployed. Each of these activities is described below.

The readings being reported by the sensors are checked for drift by comparing to known values. Dissolved oxygen is compared to a winkler titration and pH readings are compared to calibration solutions. The procedure is as follows:

1. Collect a water sample using a 5-gallon bucket, taking care to minimize turbulence. Keep sample out of direct sunlight.

2. Remove sonde from housing, connect to laptop, and place sensors in sample bucket. NOTE: take care to minimize disturbance to sensors;

3. Record current dissolved oxygen reading;

4. Conduct a Winkler titration to determine dissolved oxygen concentration of sample. Perform this step with an aliquot of the water collected in step 1 and as near as possible to the same time the sonde DO reading is recorded. Treat both sample aliquots identically otherwise, collect;

5. Calculate relative percent difference (RPD) between Winkler and sonde dissolved oxygen readings using the formula noted below. The acceptance criterion for this comparison is an RPD of 20% or less.

$$RPD = \left| \frac{(Abs(Winkler\ D.O. - Sonde\ D.O.))}{(Winkler\ D.O. + Sonde\ D.O\ /\ 2)} \right| * 100$$

6. Record result in the field notebook;
7. Repeat process for the pH sensors;
8. Download logging file to laptop;
9. Gently clean the sensors to remove biofilms according to manufacturer specifications;
10. Recalibrate sensors;
11. Set up logging file;
12. Redeploy sonde, record date and time in field notes.

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FIELD INSTRUMENT CALIBRATION AND MAINTENANCE LOG
Temperature, pH and Dissolved Oxygen Meters

Instrument	Temperature	pH	D.O.
Manufacturer			
Model			
Identification No.			

Date	Time	Initials	Temp °C	pH 4	pH 7	pH 10	D.O.	Battery Check	Comments

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I. Handling

1. Fill in sample label (see attachment). Use indelible waterproof marking pen and include:
    - Sample Identification code (if possible, should reflect site name, sample location and sample interval)
    - Sample type (e.g., soil, sediment, water, vapor);
    - Project code;
    - Analysis required;
    - Date sampled;
    - Time sampled;
    - Name or initials of person who collected the sample;
    - Mode of collection (composite or grab); and
    - Preservation added, if applicable.
2. Check the caps on the sample containers so that they are tightly sealed.
3. Cover the label and sample container cap with clear packing tape to secure the label and cap onto the container, if necessary.
4. Place a signed custody seal label (see attachment) over the cap such that the cap cannot be removed without breaking the custody seal, if required.

II. Packing

1. If using a laboratory-supplied transpack, follow the laboratory's instructions for packing. Generally, repack the transpack in the same way in which the empty containers were received. If using a standard cooler, follow the instructions below.
2. Using packaging tape, secure the outside and inside the drain plug at the bottom of the cooler that is used for sample transport.
3. Place 1 to 2 inches of vermiculite or other cushioning material at the bottom of the cooler.
4. Place the sealed container upright in the cooler.
5. Place additional cushioning material around the sides of each sample container.
6. Place frozen gel cold packs on top of sample containers. If ice is used, repackage ice in small Ziploc® - type plastic bags and place loosely in the cooler. Do not pack cold packs or ice so tightly that it may prevent the addition of sufficient cushioning material.
7. Fill the remaining space in the cooler with vermiculite or other cushioning material.

8. Place the chain-of-custody forms (see attachment) in a large Ziploc® type bag and tape the forms to the inside of the cooler lid.

9. Close the cooler lid and fasten with packaging tape.

10. Wrap strapping or packaging tape around both ends of the cooler at least twice.

11. Mark the cooler on the outside with the following information: return address, "Fragile" labels (see attachment) on the top and on one side, and arrows indicating "This Side Up" (see attachment) on two adjacent sides.

12. Place custody seal evidence tape (see attachment) over front right and back left of the cooler lid and cover with clear plastic tape.

III. Shipping

1. Environmental samples will be shipped according to 40 CFR 761.65 (i)(3) and in accordance with current and applicable D.O.T. standards.

2. All samples will be delivered by an express carrier, allowing for sufficient time for analysis to be performed within the applicable holding time periods.

3. The following chain-of-custody procedures will apply to sample shipping:

   - Relinquish the sample containers to the laboratory via express carrier. The signed and dated forms should be taped inside the top of the cooler. The express carrier will not be required to sign the chain-of-custody forms.
   - When the samples are received by the laboratory, the laboratory personnel shall complete the chain-of-custody forms by signing and dating to acknowledge receipt of samples. The internal temperature of the shipping container is measured and recorded. The sample identification numbers on the containers are then checked to ensure that they are consistent with the chain of custody forms

Sample Shipping Label

	Limno-Tech, Inc. **734-332-1200**
Client/Source:	☐ **Grab** ☐ **Composite**
Site Name:	**Date:**
Sample #	**Time:**
Analysis:	**Preservatives:**
	Collected by:

Sample Custody Seal Label

Limno-Tech, Inc. **501 Avis Drive** **Ann Arbor, MI 48108**	Sealed by: ____________________ Date: _________Time: ___________

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Sample Chain of Custody Form

Limno-Tech, Inc.
Excellence in Environmental Engineering Since 1975

CHAIN OF CUSTODY RECORD

Check Originating Office

☐ Corporate Office
501 Avis Drive
Ann Arbor, MI 48108
(734) 332-1200 (phone)
(734)332-1212 (fax)

☐ Kalamazoo Field Office
2980 Business One Drive
Kalamazoo, MI 49001
(616) 226-0190 (phone)
(616) 226-0192 (fax)

Proj. No.	Project Name
Samplers: *(Signature)*	

Sta. No.	Date	Time	COMP	GRAB	Station Location	Number of Containers							Remarks

Relinquished by: *(Signature)*	Date	Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date	Time	Relinquished by: *(Signature)*
Relinquished by: *(Signature)*	Date	Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date	Time	Relinquished by: *(Signature)*
Relinquished by: *(Signature)*	Date	Time	Received for Laboratory by: *(Signature)*	Date	Time	Remarks:	

Distribution: Original Accompanies Shipment; Copy to Coordinator Field Files

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Appendix 2. Continuous Data

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Continuous Dissolved Oxygen (DO) Data - Hodges, Macoupin, North Fork Kaskaskia and Skillet Fork Watersheds

HOD-1			MAC-7			NFK-3			SKIL-4		
Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]	Date / Time	Temp [°C]	DO [mg/l]
8/24/2005 13:20	22.26	5.01	8/24/2005 15:40	22.79	5.9	8/31/2005 16:15	22.87	1	8/27/2005 18:00	23.61	0.19
8/24/2005 13:35	22.27	5.03	8/24/2005 15:55	22.72	5.65	8/31/2005 16:30	22.82	0.96	8/27/2005 18:15	23.36	0.14
8/24/2005 13:50	22.28	4.88	8/24/2005 16:10	22.76	5.77	8/31/2005 16:45	22.83	0.94	8/27/2005 18:30	23.26	0.12
8/24/2005 14:05	22.29	4.91	8/24/2005 16:25	22.77	6.17	8/31/2005 17:00	22.79	0.91	8/27/2005 18:45	23.26	0.11
8/24/2005 14:20	22.31	4.78	8/24/2005 16:40	22.78	6.25	8/31/2005 17:15	22.8	0.88	8/27/2005 19:00	23.33	0.09
8/24/2005 14:35	22.33	4.9	8/24/2005 16:55	22.87	6.6	8/31/2005 17:30	22.85	0.77	8/27/2005 19:15	23.35	0.09
8/24/2005 14:50	22.35	4.89	8/24/2005 17:10	22.97	7.07	8/31/2005 17:45	22.75	0.86	8/27/2005 19:30	23.32	0.11
8/24/2005 15:05	22.39	5.25	8/24/2005 17:25	22.94	6.75	8/31/2005 18:00	22.77	0.77	8/27/2005 19:45	23.29	0.1
8/24/2005 15:20	22.42	5.3	8/24/2005 17:40	22.94	7.22	8/31/2005 18:15	22.79	0.79	8/27/2005 20:00	23.34	0.08
8/24/2005 15:35	22.51	5.48	8/24/2005 17:55	22.97	7.44	8/31/2005 18:30	22.82	0.8	8/27/2005 20:15	23.36	0.08
8/24/2005 15:50	22.5	5.55	8/24/2005 18:10	22.89	6.72	8/31/2005 18:45	22.85	0.84	8/27/2005 20:30	23.31	0.09
8/24/2005 16:05	22.56	5.59	8/24/2005 18:25	22.88	6.59	8/31/2005 19:00	22.84	0.88	8/27/2005 20:45	23.34	0.08
8/24/2005 16:20	22.58	5.59	8/24/2005 18:40	22.97	7.29	8/31/2005 19:15	22.83	0.87	8/27/2005 21:00	23.37	0.07
8/24/2005 16:35	22.62	5.52	8/24/2005 18:55	22.97	7.35	8/31/2005 19:30	22.84	0.93	8/27/2005 21:15	23.36	0.09
8/24/2005 16:50	22.62	5.44	8/24/2005 19:10	22.97	7.33	8/31/2005 19:45	22.88	0.88	8/27/2005 21:30	23.4	0.07
8/24/2005 17:05	22.63	5.58	8/24/2005 19:25	22.98	7.27	8/31/2005 20:00	22.92	0.89	8/27/2005 21:45	23.39	0.09
8/24/2005 17:20	22.6	4.82	8/24/2005 19:40	22.91	6.94	8/31/2005 20:15	22.85	0.88	8/27/2005 22:00	23.33	0.09
8/24/2005 17:35	22.58	5.01	8/24/2005 19:55	22.89	6.89	8/31/2005 20:30	22.87	0.8	8/27/2005 22:15	23.34	0.09
8/24/2005 17:50	22.6	5.29	8/24/2005 20:10	22.83	6.62	8/31/2005 20:45	22.92	0.82	8/27/2005 22:30	23.3	0.08
8/24/2005 18:05	22.61	5.12	8/24/2005 20:25	22.8	6.5	8/31/2005 21:00	22.9	0.81	8/27/2005 22:45	23.31	0.09
8/24/2005 18:20	22.65	5.04	8/24/2005 20:40	22.71	6.16	8/31/2005 21:15	22.92	0.76	8/27/2005 23:00	23.28	0.09
8/24/2005 18:35	22.66	5.13	8/24/2005 20:55	22.73	6.37	8/31/2005 21:30	22.85	0.82	8/27/2005 23:15	23.25	0.09
8/24/2005 18:50	22.65	5.07	8/24/2005 21:10	22.7	6.19	8/31/2005 21:45	22.86	0.85	8/27/2005 23:30	23.23	0.06
8/24/2005 19:05	22.65	4.9	8/24/2005 21:25	22.67	6.2	8/31/2005 22:00	22.82	0.9	8/27/2005 23:45	23.2	0.06
8/24/2005 19:20	22.68	5.3	8/24/2005 21:40	22.61	6.06	8/31/2005 22:15	22.76	0.85	8/28/2005 0:00	23.16	0.07
8/24/2005 19:35	22.67	5.13	8/24/2005 21:55	22.54	5.96	8/31/2005 22:30	22.73	0.92	8/28/2005 0:15	23.12	0.06
8/24/2005 19:50	22.69	5.19	8/24/2005 22:10	22.51	5.94	8/31/2005 22:45	22.69	0.99	8/28/2005 0:30	23.09	0.08
8/24/2005 20:05	22.69	5.18	8/24/2005 22:25	22.47	5.93	8/31/2005 23:00	22.64	1.02	8/28/2005 0:45	23.04	0.09
8/24/2005 20:20	22.7	5.75	8/24/2005 22:40	22.41	5.81	8/31/2005 23:15	22.58	1.06	8/28/2005 1:00	22.9	0.06
8/24/2005 20:35	22.65	4.97	8/24/2005 22:55	22.37	5.78	8/31/2005 23:30	22.54	1.03	8/28/2005 1:15	22.98	0.09
8/24/2005 20:50	22.61	5.1	8/24/2005 23:10	22.33	5.75	8/31/2005 23:45	22.49	1.02	8/28/2005 1:30	22.92	0.07
8/24/2005 21:05	22.57	5.19	8/24/2005 23:25	22.29	5.7	9/1/2005 0:00	22.43	1	8/28/2005 1:45	22.88	0.09
8/24/2005 21:20	22.53	5.18	8/24/2005 23:40	22.24	5.62	9/1/2005 0:15	22.38	0.96	8/28/2005 2:00	22.83	0.06
8/24/2005 21:35	22.5	5.06	8/24/2005 23:55	22.2	5.47	9/1/2005 0:30	22.34	0.94	8/28/2005 2:15	22.8	0.08
8/24/2005 21:50	22.48	4.99	8/25/2005 0:10	22.16	5.23	9/1/2005 0:45	22.3	0.93	8/28/2005 2:30	22.76	0.08
8/24/2005 22:05	22.44	4.97	8/25/2005 0:25	22.11	5.1	9/1/2005 1:00	22.25	0.87	8/28/2005 2:45	22.69	0.06
8/24/2005 22:20	22.41	4.94	8/25/2005 0:40	22.08	5.1	9/1/2005 1:15	22.22	0.84	8/28/2005 3:00	22.64	0.08
8/24/2005 22:35	22.37	4.91	8/25/2005 0:55	22.06	5.05	9/1/2005 1:30	22.18	0.85	8/28/2005 3:15	22.6	0.09
8/24/2005 22:50	22.33	4.85	8/25/2005 1:10	22.01	5.09	9/1/2005 1:45	22.15	0.8	8/28/2005 3:30	22.54	0.09
8/24/2005 23:05	22.29	4.86	8/25/2005 1:25	21.99	5.06	9/1/2005 2:00	22.11	0.82	8/28/2005 3:45	22.5	0.07
8/24/2005 23:20	22.25	4.69	8/25/2005 1:40	21.96	5.09	9/1/2005 2:15	22.06	0.74	8/28/2005 4:00	22.46	0.08
8/24/2005 23:35	22.21	4.8	8/25/2005 1:55	21.94	5.16	9/1/2005 2:30	22.02	0.74	8/28/2005 4:15	22.43	0.09
8/24/2005 23:50	22.17	4.72	8/25/2005 2:10	21.88	5.05	9/1/2005 2:45	21.99	0.74	8/28/2005 4:30	22.39	0.06
8/25/2005 0:05	22.12	4.81	8/25/2005 2:25	21.85	5.12	9/1/2005 3:00	21.96	0.66	8/28/2005 4:45	22.35	0.07
8/25/2005 0:20	22.08	4.67	8/25/2005 2:40	21.86	4.96	9/1/2005 3:15	21.93	0.68	8/28/2005 5:00	22.3	0.09
8/25/2005 0:35	22.03	4.65	8/25/2005 2:55	21.82	4.83	9/1/2005 3:30	21.9	0.63	8/28/2005 5:15	22.27	0.06
8/25/2005 0:50	21.96	4.71	8/25/2005 3:10	21.78	4.74	9/1/2005 3:45	21.87	0.63	8/28/2005 5:30	22.24	0.07
8/25/2005 1:05	21.97	4.67	8/25/2005 3:25	21.74	4.69	9/1/2005 4:00	21.84	0.54	8/28/2005 5:45	22.19	0.06
8/25/2005 1:20	21.92	4.74	8/25/2005 3:40	21.7	4.67	9/1/2005 4:15	21.82	0.51	8/28/2005 6:00	22.15	0.08
8/25/2005 1:35	21.87	4.62	8/25/2005 3:55	21.66	4.64	9/1/2005 4:30	21.79	0.51	8/28/2005 6:15	22.1	0.08
8/25/2005 1:50	21.83	4.65	8/25/2005 4:10	21.66	4.62	9/1/2005 4:45	21.76	0.45	8/28/2005 6:30	22.05	0.07
8/25/2005 2:05	21.79	4.59	8/25/2005 4:25	21.63	4.59	9/1/2005 5:00	21.73	0.39	8/28/2005 6:45	22.01	0.08
8/25/2005 2:20	21.74	4.59	8/25/2005 4:40	21.6	4.56	9/1/2005 5:15	21.69	0.3	8/28/2005 7:00	21.97	0.06
8/25/2005 2:35	21.7	4.5	8/25/2005 4:55	21.59	4.49	9/1/2005 5:30	21.68	0.27	8/28/2005 7:15	21.94	0.09
8/25/2005 2:50	21.69	4.45	8/25/2005 5:10	21.57	4.49	9/1/2005 5:45	21.65	0.22	8/28/2005 7:30	21.9	0.06
8/25/2005 3:05	21.65	4.43	8/25/2005 5:25	21.54	4.42	9/1/2005 6:00	21.61	0.15	8/28/2005 7:45	21.88	0.07
8/25/2005 3:20	21.61	4.41	8/25/2005 5:40	21.52	4.34	9/1/2005 6:15	21.58	0.19	8/28/2005 8:00	21.86	0.07
8/25/2005 3:35	21.56	4.49	8/25/2005 5:55	21.49	4.29	9/1/2005 6:30	21.56	0.17	8/28/2005 8:15	21.85	0.08
8/25/2005 3:50	21.53	4.41	8/25/2005 6:10	21.46	4.24	9/1/2005 6:45	21.53	0.13	8/28/2005 8:30	21.84	0.08
8/25/2005 4:05	21.48	4.46	8/25/2005 6:25	21.42	4.2	9/1/2005 7:00	21.51	0.16	8/28/2005 8:45	21.84	0.06
8/25/2005 4:20	21.45	4.45	8/25/2005 6:40	21.36	4.23	9/1/2005 7:15	21.49	0.17	8/28/2005 9:00	21.83	0.08
8/25/2005 4:35	21.43	4.38	8/25/2005 6:55	21.35	4.21	9/1/2005 7:30	21.49	0.18	8/28/2005 9:15	21.82	0.07
8/25/2005 4:50	21.4	4.36	8/25/2005 7:10	21.35	4.12	9/1/2005 7:45	21.47	0.14	8/28/2005 9:30	21.82	0.06
8/25/2005 5:05	21.38	4.33	8/25/2005 7:25	21.34	4.12	9/1/2005 8:00	21.45	0.19	8/28/2005 9:45	21.82	0.06
8/25/2005 5:20	21.36	4.33	8/25/2005 7:40	21.33	4.06	9/1/2005 8:15	21.45	0.18	8/28/2005 10:00	21.82	0.08
8/25/2005 5:35	21.35	4.26	8/25/2005 7:55	21.37	3.97	9/1/2005 8:30	21.44	0.18	8/28/2005 10:15	21.81	0.07
8/25/2005 5:50	21.33	4.31	8/25/2005 8:10	21.36	3.93	9/1/2005 8:45	21.46	0.2	8/28/2005 10:30	21.82	0.07
8/25/2005 6:05	21.32	4.19	8/25/2005 8:25	21.39	3.9	9/1/2005 9:00	21.47	0.17	8/28/2005 10:45	21.83	0.05
8/25/2005 6:20	21.27	4.23	8/25/2005 8:40	21.4	3.85	9/1/2005 9:15	21.5	0.23	8/28/2005 11:00	21.84	0.08
8/25/2005 6:35	21.24	4.24	8/25/2005 8:55	21.41	3.9	9/1/2005 9:30	21.54	0.28	8/28/2005 11:15	21.87	0.08
8/25/2005 6:50	21.24	4.21	8/25/2005 9:10	21.46	4.05	9/1/2005 9:45	21.56	0.26	8/28/2005 11:30	21.89	0.06
8/25/2005 7:05	21.23	4.1	8/25/2005 9:25	21.56	4.31	9/1/2005 10:00	21.55	0.3	8/28/2005 11:45	21.93	0.07
8/25/2005 7:20	21.24	4.37	8/25/2005 9:40	21.6	4.44	9/1/2005 10:15	21.59	0.43	8/28/2005 12:00	21.98	0.05
8/25/2005 7:35	21.25	4.44	8/25/2005 9:55	21.64	4.54	9/1/2005 10:30	21.61	0.54	8/28/2005 12:15	22.03	0.07
8/25/2005 7:50	21.26	4.45	8/25/2005 10:10	21.65	4.47	9/1/2005 10:45	21.63	0.71	8/28/2005 12:30	22.06	0.07
8/25/2005 8:05	21.27	4.52	8/25/2005 10:25	21.68	4.32	9/1/2005 11:00	21.63	0.82	8/28/2005 12:45	22.17	0.07
8/25/2005 8:20	21.29	4.48	8/25/2005 10:40	21.66	4.3	9/1/2005 11:15	21.66	0.91	8/28/2005 13:00	22.15	0.07
8/25/2005 8:35	21.33	4.49	8/25/2005 10:55	21.68	4.31	9/1/2005 11:30	21.67	0.94	8/28/2005 13:15	22.19	0.05
8/25/2005 8:50	21.38	4.59	8/25/2005 11:10	21.68	4.52	9/1/2005 11:45	21.72	0.93	8/28/2005 13:30	22.24	0.08
8/25/2005 9:05	21.42	4.56	8/25/2005 11:25	21.63	4.43	9/1/2005 12:00	21.78	1	8/28/2005 13:45	22.29	0.06
8/25/2005 9:20	21.46	4.72	8/25/2005 11:40	21.59	4.4	9/1/2005 12:15	21.8	1.21	8/28/2005 14:00	22.32	0.07
8/25/2005 9:35	21.49	4.7	8/25/2005 11:55	21.56	4.35	9/1/2005 12:30	21.86	1.4	8/28/2005 14:15	22.36	0.08
8/25/2005 9:50	21.51	4.69	8/25/2005 12:10	21.56	4.29	9/1/2005 12:45	21.9	1.51	8/28/2005 14:30	22.37	0.07
8/25/2005 10:05	21.52	4.64	8/25/2005 12:25	21.55	4.48	9/1/2005 13:00	21.99	1.43	8/28/2005 14:45	22.68	0.07
8/25/2005 10:20	21.53	4.74	8/25/2005 12:40	21.57	4.6	9/1/2005 13:15	22.06	1.34	8/28/2005 15:00	22.55	0.08
8/25/2005 10:35	21.53	4.7	8/25/2005 12:55	21.61	4.7	9/1/2005 13:30	22.19	1.26	8/28/2005 15:15	22.55	0.07
8/25/2005 10:50	21.51	4.86	8/25/2005 13:10	21.65	4.96	9/1/2005 13:45	22.12	1.6	8/28/2005 15:30	22.53	0.05
8/25/2005 11:05	21.45	5.04	8/25/2005 13:25	21.64	4.9	9/1/2005 14:00	22.22	1.49	8/28/2005 15:45	22.55	0.05
8/25/2005 11:20	21.34	5.52	8/25/2005 13:40	21.63	4.96	9/1/2005 14:15	22.34	1.62	8/28/2005 16:00	22.56	0.07
8/25/2005 11:35	21.26	5.59	8/25/2005 13:55	21.64	4.84	9/1/2005 14:30	22.33	1.59	8/28/2005 16:15	22.59	0.05
8/25/2005 11:50	21.27	5.8	8/25/2005 14:10	21.62	5.05	9/1/2005 14:45	22.44	1.56	8/28/2005 16:30	22.61	0.07
8/25/2005 12:05	21.35	5.43	8/25/2005 14:25	21.61	4.97	9/1/2005 15:00	22.51	1.63	8/28/2005 16:45	22.6	0.11
8/25/2005 12:20	21.39	5.34	8/25/2005 14:40	21.65	5.01	9/1/2005 15:15	22.53	1.93	8/28/2005 17:00	22.62	0.17
8/25/2005 12:35	21.44	5.58	8/25/2005 14:55	21.63	4.97	9/1/2005 15:30	22.61	2.04	8/28/2005 17:15	23.04	0.12
8/25/2005 12:50	21.5	5.62	8/25/2005 15:10	21.63	4.79	9/1/2005 15:45	22.62	2.22	8/28/2005 17:30	23.08	0.09
8/25/2005 13:05	21.6	5.59	8/25/2005 15:25	21.63	4.9	9/1/2005 16:00	22.68	2.22	8/28/2005 17:45	23.11	0.07
8/25/2005 13:20	21.72	5.57	8/25/2005 15:40	21.61	5.03	9/1/2005 16:15	22.73	2.16	8/28/2005 18:00	22.98	0.08
8/25/2005 13:35	21.75	5.6	8/25/2005 15:55	21.63	4.89	9/1/2005 16:30	22.75	2.01	8/28/2005 18:15	23.04	0.08
8/25/2005 13:50	21.73	5.57	8/25/2005 16:10	21.63	4.87	9/1/2005 16:45	22.75	2	8/28/2005 18:30	23.04	0.07
8/25/2005 14:05	21.77	5.58	8/25/2005 16:25	21.68	4.83	9/1/2005 17:00	22.74	1.98			
8/25/2005 14:20	21.8	5.63	8/25/2005 16:40	21.68	4.64	9/1/2005 17:15	22.76	1.91			
8/25/2005 14:35	21.82	5.47	8/25/2005 16:55	21.68	4.54	9/1/2005 17:30	22.78	2.03			
8/25/2005 14:50	21.85	5.24	8/25/2005 17:10	21.68	4.49	9/1/2005 17:45	22.86	2.07			
8/25/2005 15:05	21.86	5.4	8/25/2005 17:25	21.69	4.47	9/1/2005 18:00	22.83	1.92			
8/25/2005 15:20	21.93	5.39	8/25/2005 17:40	21.69	4.5	9/1/2005 18:15	22.8	1.88			
			8/25/2005 17:55	21.68	4.62	9/1/2005 18:30	22.9	1.82			
			8/25/2005 18:10	21.7	4.61	9/1/2005 18:45	22.9	1.65			
			8/25/2005 18:25	21.73	4.66	9/1/2005 19:00	22.83	1.64			
			8/25/2005 18:40	21.75	4.64	9/1/2005 19:15	22.97	1.61			
						9/1/2005 19:30	23	1.52			
						9/1/2005 19:45	22.98	1.47			
						9/1/2005 20:00	22.96	1.48			
						9/1/2005 20:15	23	1.55			
						9/1/2005 20:30	23	1.5			
						9/1/2005 20:45	22.96	1.5			
						9/1/2005 21:00	22.89	1.46			
						9/1/2005 21:15	22.89	1.43			
						9/1/2005 21:30	22.83	1.41			
						9/1/2005 21:45	22.77	1.59			
						9/1/2005 22:00	22.71	1.59			
						9/1/2005 22:15	22.66	1.52			
						9/1/2005 22:30	22.59	1.56			
						9/1/2005 22:45	22.55	1.5			
						9/1/2005 23:00	22.48	1.46			
						9/1/2005 23:15	22.43	1.42			
						9/1/2005 23:30	22.37	1.36			
						9/1/2005 23:45	22.32	1.27			
						9/2/2005 0:00	22.28	1.27			
						9/2/2005 0:15	22.23	1.25			
						9/2/2005 0:30	22.17	1.23			
						9/2/2005 0:45	22.12	1.19			
						9/2/2005 1:00	22.08	1.11			
						9/2/2005 1:15	22.03	1.12			
						9/2/2005 1:30	21.98	1.09			
						9/2/2005 1:45	21.92	1.05			
						9/2/2005 2:00	21.9	0.96			
						9/2/2005 2:15	21.86	0.86			
						9/2/2005 2:30	21.81	0.92			
						9/2/2005 2:45	21.77	0.91			
						9/2/2005 3:00	21.74	0.81			
						9/2/2005 3:15	21.71	0.77			
						9/2/2005 3:30	21.67	0.7			
						9/2/2005 3:45	21.62	0.66			
						9/2/2005 4:00	21.58	0.52			
						9/2/2005 4:15	21.53	0.47			
						9/2/2005 4:30	21.48	0.35			
						9/2/2005 4:45	21.43	0.35			
						9/2/2005 5:00	21.38	0.35			
						9/2/2005 5:15	21.32	0.29			
						9/2/2005 5:30	21.27	0.31			
						9/2/2005 5:45	21.22	0.26			
						9/2/2005 6:00	21.17	0.25			
						9/2/2005 6:15	21.11	0.25			
						9/2/2005 6:30	21.07	0.17			
						9/2/2005 6:45	21.01	0.18			
						9/2/2005 7:00	20.96	0.2			
						9/2/2005 7:15	20.92	0.19			
						9/2/2005 7:30	20.89	0.2			
						9/2/2005 7:45	20.84	0.16			
						9/2/2005 8:00	20.78	0.19			
						9/2/2005 8:15	20.74	0.28			
						9/2/2005 8:30	20.72	0.3			
						9/2/2005 8:45	20.69	0.43			

Continuous Dissolved Oxygen (DO) Data - Hodges, Macoupin, North Fork Kaskaskia and Skillet Fork Watersheds

SKIL-7

Date / Time	Temp [°C]	DO [mg/l]
8/27/2005 19:15	23.42	4.33
8/27/2005 19:30	23.41	4.28
8/27/2005 19:45	23.41	4.28
8/27/2005 20:00	23.41	4.26
8/27/2005 20:15	23.41	4.25
8/27/2005 20:30	23.41	4.25
8/27/2005 20:45	23.41	4.23
8/27/2005 21:00	23.41	4.23
8/27/2005 21:15	23.4	4.22
8/27/2005 21:30	23.4	4.22
8/27/2005 21:45	23.39	4.21
8/27/2005 22:00	23.38	4.21
8/27/2005 22:15	23.37	4.2
8/27/2005 22:30	23.36	4.2
8/27/2005 22:45	23.36	4.19
8/27/2005 23:00	23.34	4.19
8/27/2005 23:15	23.33	4.2
8/27/2005 23:30	23.32	4.17
8/27/2005 23:45	23.32	4.18
8/28/2005 0:00	23.31	4.19
8/28/2005 0:15	23.29	4.17
8/28/2005 0:30	23.28	4.16
8/28/2005 0:45	23.27	4.17
8/28/2005 1:00	23.25	4.15
8/28/2005 1:15	23.24	4.16
8/28/2005 1:30	23.22	4.14
8/28/2005 1:45	23.2	4.15
8/28/2005 2:00	23.19	4.15
8/28/2005 2:15	23.17	4.15
8/28/2005 2:30	23.15	4.13
8/28/2005 2:45	23.13	4.12
8/28/2005 3:00	23.1	4.12
8/28/2005 3:15	23.09	4.14
8/28/2005 3:30	23.07	4.13
8/28/2005 3:45	23.04	4.11
8/28/2005 4:00	23.02	4.11
8/28/2005 4:15	23.01	4.1
8/28/2005 4:30	22.97	4.09
8/28/2005 4:45	22.95	4.12
8/28/2005 5:00	22.93	4.11
8/28/2005 5:15	22.9	4.1
8/28/2005 5:30	22.87	4.1
8/28/2005 5:45	22.86	4.07
8/28/2005 6:00	22.83	4.05
8/28/2005 6:15	22.8	4.07
8/28/2005 6:30	22.77	4.08
8/28/2005 6:45	22.75	4.04
8/28/2005 7:00	22.73	4.04
8/28/2005 7:15	22.7	4.03
8/28/2005 7:30	22.68	4.03
8/28/2005 7:45	22.66	4.03
8/28/2005 8:00	22.65	4.03
8/28/2005 8:15	22.64	4.03
8/28/2005 8:30	22.63	4.02
8/28/2005 8:45	22.63	4.01
8/28/2005 9:00	22.63	3.99
8/28/2005 9:15	22.63	3.96
8/28/2005 9:30	22.64	3.93
8/28/2005 9:45	22.66	3.91
8/28/2005 10:00	22.69	3.88
8/28/2005 10:15	22.71	3.83
8/28/2005 10:30	22.74	3.81
8/28/2005 10:45	22.75	3.79
8/28/2005 11:00	22.78	3.74
8/28/2005 11:15	22.8	3.77
8/28/2005 11:30	22.86	3.76
8/28/2005 11:45	22.98	3.74
8/28/2005 12:00	23.04	3.86
8/28/2005 12:15	23.09	3.89
8/28/2005 12:30	23.21	3.94
8/28/2005 12:45	23.31	3.91
8/28/2005 13:00	23.44	4.05
8/28/2005 13:15	23.58	4.14
8/28/2005 13:30	23.78	4.21
8/28/2005 13:45	23.97	4.33
8/28/2005 14:00	24.15	4.43
8/28/2005 14:15	24.26	4.43
8/28/2005 14:30	24.26	4.42
8/28/2005 14:45	24.33	4.45
8/28/2005 15:00	24.33	4.44
8/28/2005 15:15	24.3	4.46
8/28/2005 15:30	24.29	4.46
8/28/2005 15:45	24.32	4.44
8/28/2005 16:00	24.27	4.44
8/28/2005 16:15	24.21	4.46
8/28/2005 16:30	24.2	4.4
8/28/2005 16:45	24.22	4.42
8/28/2005 17:00	24.23	4.37
8/28/2005 17:15	24.23	4.36
8/28/2005 17:30	24.25	4.33
8/28/2005 17:45	24.25	4.32
8/28/2005 18:00	24.28	4.32
8/28/2005 18:15	24.26	4.28
8/28/2005 18:30	24.27	4.27
8/28/2005 18:45	24.26	4.28
8/28/2005 19:00	24.27	4.31
8/28/2005 19:15	24.27	4.3
8/28/2005 19:30	24.27	4.33
8/28/2005 19:45	24.26	4.35
8/28/2005 20:00	24.25	4.35
8/28/2005 20:15	24.25	4.39
8/28/2005 20:30	24.24	4.38
8/28/2005 20:45	24.24	4.41
8/28/2005 21:00	24.24	4.4
8/28/2005 21:15	24.23	4.42
8/28/2005 21:30	24.22	4.39
8/28/2005 21:45	24.2	4.35
8/28/2005 22:00	24.18	4.36
8/28/2005 22:15	24.16	4.33
8/28/2005 22:30	24.14	4.32
8/28/2005 22:45	24.13	4.29
8/28/2005 23:00	24.09	4.27
8/28/2005 23:15	24.06	4.26
8/28/2005 23:30	24.04	4.24
8/28/2005 23:45	24.02	4.2

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Date / Time	Temp [°C]	DO [mg/l]
8/28/2005 9:45	23.2	3.93
8/28/2005 10:00	23.21	3.92
8/28/2005 10:15	23.23	3.97
8/28/2005 10:30	23.24	3.93
8/28/2005 10:45	23.3	4
8/28/2005 11:00	23.32	4
8/28/2005 11:15	23.38	4.01
8/28/2005 11:30	23.44	4.06
8/28/2005 11:45	23.5	4.07
8/28/2005 12:00	23.55	4.07
8/28/2005 12:15	23.66	4.08
8/28/2005 12:30	23.75	4.15
8/28/2005 12:45	23.85	4.15
8/28/2005 13:00	23.96	4.19
8/28/2005 13:15	24.04	4.22
8/28/2005 13:30	24.11	4.19
8/28/2005 13:45	24.25	4.22
8/28/2005 14:00	24.31	4.2
8/28/2005 14:15	24.41	4.24
8/28/2005 14:30	24.51	4.26
8/28/2005 14:45	24.59	4.29
8/28/2005 15:00	24.7	4.3
8/28/2005 15:15	24.68	4.31
8/28/2005 15:30	24.76	4.3
8/28/2005 15:45	24.78	4.31
8/28/2005 16:00	24.81	4.31
8/28/2005 16:15	24.81	4.3
8/28/2005 16:30	24.83	4.32
8/28/2005 16:45	24.84	4.3
8/28/2005 17:00	24.84	4.28
8/28/2005 17:15	24.83	4.27
8/28/2005 17:30	24.82	4.24
8/28/2005 17:45	24.8	4.19
8/28/2005 18:00	24.79	4.19
8/28/2005 18:15	24.76	4.15
8/28/2005 18:30	24.74	4.16
8/28/2005 18:45	24.71	4.11
8/28/2005 19:00	24.67	4.08
8/28/2005 19:15	24.66	4.05
8/28/2005 19:30	24.63	4.06
8/28/2005 19:45	24.6	4.02
8/28/2005 20:00	24.57	4.05
8/28/2005 20:15	24.56	4.05
8/28/2005 20:30	24.55	4
8/28/2005 20:45	24.53	4
8/28/2005 21:00	24.52	3.99
8/28/2005 21:15	24.49	3.97
8/28/2005 21:30	24.49	3.98
8/28/2005 21:45	24.47	3.97
8/28/2005 22:00	24.46	3.95
8/28/2005 22:15	24.44	3.95
8/28/2005 22:30	24.44	3.94
8/28/2005 22:45	24.43	3.95
8/28/2005 23:00	24.41	3.94
8/28/2005 23:15	24.4	3.96
8/28/2005 23:30	24.4	3.93
8/28/2005 23:45	24.37	3.9
8/29/2005 0:00	24.37	3.92
8/29/2005 0:15	24.36	3.88
8/29/2005 0:30	24.35	3.88
8/29/2005 0:45	24.34	3.88
8/29/2005 1:00	24.33	3.86
8/29/2005 1:15	24.31	3.87
8/29/2005 1:30	24.3	3.85
8/29/2005 1:45	24.29	3.82
8/29/2005 2:00	24.28	3.85
8/29/2005 2:15	24.27	3.84
8/29/2005 2:30	24.26	3.82
8/29/2005 2:45	24.23	3.81
8/29/2005 3:00	24.23	3.79
8/29/2005 3:15	24.21	3.79
8/29/2005 3:30	24.2	3.8
8/29/2005 3:45	24.19	3.77
8/29/2005 4:00	24.17	3.81
8/29/2005 4:15	24.15	3.76
8/29/2005 4:30	24.12	3.77
8/29/2005 4:45	24.11	3.77
8/29/2005 5:00	24.08	3.75
8/29/2005 5:15	24.06	3.74
8/29/2005 5:30	24.04	3.76
8/29/2005 5:45	24.01	3.76
8/29/2005 6:00	23.98	3.74
8/29/2005 6:15	23.95	3.74
8/29/2005 6:30	23.92	3.74
8/29/2005 6:45	23.92	3.73
8/29/2005 7:00	23.88	3.72
8/29/2005 7:15	23.86	3.7
8/29/2005 7:30	23.84	3.69
8/29/2005 7:45	23.82	3.69
8/29/2005 8:00	23.8	3.68
8/29/2005 8:15	23.78	3.68
8/29/2005 8:30	23.75	3.67
8/29/2005 8:45	23.75	3.67
8/29/2005 9:00	23.73	3.67
8/29/2005 9:15	23.72	3.69
8/29/2005 9:30	23.71	3.7
8/29/2005 9:45	23.71	3.72
8/29/2005 10:00	23.7	3.71
8/29/2005 10:15	23.7	3.7
8/29/2005 10:30	23.71	3.75
8/29/2005 10:45	23.71	3.7
8/29/2005 11:00	23.74	3.71

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Date / Time	Temp [°C]	DO [mg/l]
8/29/2005 16:15	24.48	2.72
8/29/2005 16:30	24.44	2.73
8/29/2005 16:45	24.4	2.7
8/29/2005 17:00	24.37	2.68
8/29/2005 17:15	24.34	2.63
8/29/2005 17:30	24.33	2.62
8/29/2005 17:45	24.29	2.59
8/29/2005 18:00	24.27	2.61
8/29/2005 18:15	24.26	2.51
8/29/2005 18:30	24.25	2.5
8/29/2005 18:45	24.24	2.47
8/29/2005 19:00	24.23	2.48
8/29/2005 19:15	24.21	2.46
8/29/2005 19:30	24.19	2.45
8/29/2005 19:45	24.18	2.43
8/29/2005 20:00	24.16	2.42
8/29/2005 20:15	24.15	2.42
8/29/2005 20:30	24.13	2.4
8/29/2005 20:45	24.12	2.39
8/29/2005 21:00	24.1	2.41
8/29/2005 21:15	24.08	2.42
8/29/2005 21:30	24.07	2.38
8/29/2005 21:45	24.06	2.35
8/29/2005 22:00	24.05	2.31
8/29/2005 22:15	24.03	2.31
8/29/2005 22:30	24	2.34
8/29/2005 22:45	24	2.3
8/29/2005 23:00	23.99	2.27
8/29/2005 23:15	23.97	2.25
8/29/2005 23:30	23.95	2.24
8/29/2005 23:45	23.93	2.24
8/30/2005 0:00	23.91	2.22
8/30/2005 0:15	23.9	2.21
8/30/2005 0:30	23.88	2.21
8/30/2005 0:45	23.86	2.2
8/30/2005 1:00	23.84	2.21
8/30/2005 1:15	23.83	2.18
8/30/2005 1:30	23.81	2.15
8/30/2005 1:45	23.79	2.15
8/30/2005 2:00	23.77	2.16
8/30/2005 2:15	23.75	2.16
8/30/2005 2:30	23.74	2.18
8/30/2005 2:45	23.71	2.17
8/30/2005 3:00	23.7	2.15
8/30/2005 3:15	23.68	2.16
8/30/2005 3:30	23.65	2.19
8/30/2005 3:45	23.63	2.2
8/30/2005 4:00	23.6	2.19
8/30/2005 4:15	23.58	2.19
8/30/2005 4:30	23.56	2.19
8/30/2005 4:45	23.55	2.18
8/30/2005 5:00	23.53	2.17
8/30/2005 5:15	23.5	2.17
8/30/2005 5:30	23.47	2.18
8/30/2005 5:45	23.45	2.18
8/30/2005 6:00	23.42	2.2
8/30/2005 6:15	23.4	2.18
8/30/2005 6:30	23.37	2.18
8/30/2005 6:45	23.36	2.19
8/30/2005 7:00	23.33	2.22
8/30/2005 7:15	23.3	2.26
8/30/2005 7:30	23.28	2.33
8/30/2005 7:45	23.26	2.29
8/30/2005 8:00	23.24	2.28
8/30/2005 8:15	23.22	2.27
8/30/2005 8:30	23.2	2.29
8/30/2005 8:45	23.18	2.3
8/30/2005 9:00	23.17	2.32
8/30/2005 9:15	23.14	2.36
8/30/2005 9:30	23.12	2.36
8/30/2005 9:45	23.1	2.34
8/30/2005 10:00	23.1	2.36
8/30/2005 10:15	23.1	2.32
8/30/2005 10:30	23.09	2.33
8/30/2005 10:45	23.1	2.34
8/30/2005 11:00	23.09	2.38
8/30/2005 11:15	23.1	2.42
8/30/2005 11:30	23.12	2.44
8/30/2005 11:45	23.13	2.45
8/30/2005 12:00	23.14	2.45
8/30/2005 12:15	23.16	2.46
8/30/2005 12:30	23.19	2.47
8/30/2005 12:45	23.19	2.45
8/30/2005 13:00	23.22	2.47
8/30/2005 13:15	23.25	2.49
8/30/2005 13:30	23.27	2.51
8/30/2005 13:45	23.29	2.52
8/30/2005 14:00	23.29	2.53
8/30/2005 14:15	23.29	2.52
8/30/2005 14:30	23.26	2.5
8/30/2005 14:45	23.23	2.49
8/30/2005 15:00	23.21	2.47
8/30/2005 15:15	23.2	2.45
8/30/2005 15:30	23.16	2.45
8/30/2005 15:45	23.14	2.43
8/30/2005 16:00	23.1	2.44
8/30/2005 16:15	23.09	2.37
8/30/2005 16:30	23.06	2.4
8/30/2005 16:45	23.05	2.36
8/30/2005 17:00	23.03	2.4
8/30/2005 17:15	23.02	2.4
8/30/2005 17:30	22.97	2.41
8/30/2005 17:45	22.95	2.4
8/30/2005 18:00	22.94	2.34
8/30/2005 18:15	22.93	2.29
8/30/2005 18:30	22.9	2.24
8/30/2005 18:45	22.86	2.19
8/30/2005 19:00	22.84	2.15
8/30/2005 19:15	22.81	2.11

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Date / Time	Temp [°C]	DO [mg/l]
8/29/2005 17:00	24.22	3.66
8/29/2005 17:15	24.23	3.82
8/29/2005 17:30	24.29	3.91
8/29/2005 17:45	24.21	3.76
8/29/2005 18:00	24.2	3.8
8/29/2005 18:15	24.2	3.79
8/29/2005 18:30	24.2	3.84
8/29/2005 18:45	24.2	3.83
8/29/2005 19:00	24.22	3.87
8/29/2005 19:15	24.22	3.9
8/29/2005 19:30	24.22	3.88
8/29/2005 19:45	24.21	3.8
8/29/2005 20:00	24.22	3.88
8/29/2005 20:15	24.22	3.89
8/29/2005 20:30	24.22	3.83
8/29/2005 20:45	24.21	3.84
8/29/2005 21:00	24.21	3.85
8/29/2005 21:15	24.21	3.81
8/29/2005 21:30	24.21	3.86
8/29/2005 21:45	24.2	3.85
8/29/2005 22:00	24.19	3.83
8/29/2005 22:15	24.18	3.85
8/29/2005 22:30	24.18	3.83
8/29/2005 22:45	24.17	3.84
8/29/2005 23:00	24.15	3.8
8/29/2005 23:15	24.14	3.82
8/29/2005 23:30	24.13	3.8
8/29/2005 23:45	24.11	3.82
8/30/2005 0:00	24.1	3.78
8/30/2005 0:15	24.09	3.8
8/30/2005 0:30	24.07	3.78
8/30/2005 0:45	24.05	3.77
8/30/2005 1:00	24.04	3.73
8/30/2005 1:15	24.04	3.79
8/30/2005 1:30	24.02	3.76
8/30/2005 1:45	23.99	3.74
8/30/2005 2:00	23.98	3.71
8/30/2005 2:15	23.96	3.67
8/30/2005 2:30	23.95	3.68
8/30/2005 2:45	23.93	3.64
8/30/2005 3:00	23.91	3.62
8/30/2005 3:15	23.9	3.65
8/30/2005 3:30	23.87	3.63
8/30/2005 3:45	23.85	3.59
8/30/2005 4:00	23.82	3.62
8/30/2005 4:15	23.81	3.59
8/30/2005 4:30	23.79	3.55
8/30/2005 4:45	23.77	3.57
8/30/2005 5:00	23.75	3.55
8/30/2005 5:15	23.73	3.46
8/30/2005 5:30	23.72	3.5
8/30/2005 5:45	23.69	3.47
8/30/2005 6:00	23.67	3.44
8/30/2005 6:15	23.64	3.43
8/30/2005 6:30	23.62	3.37
8/30/2005 6:45	23.6	3.33
8/30/2005 7:00	23.57	3.44
8/30/2005 7:15	23.55	3.47
8/30/2005 7:30	23.53	3.56
8/30/2005 7:45	23.49	3.58
8/30/2005 8:00	23.46	3.57
8/30/2005 8:15	23.43	3.55
8/30/2005 8:30	23.4	3.53
8/30/2005 8:45	23.38	3.54
8/30/2005 9:00	23.36	3.59
8/30/2005 9:15	23.32	3.67
8/30/2005 9:30	23.3	3.67
8/30/2005 9:45	23.27	3.68
8/30/2005 10:00	23.25	3.69
8/30/2005 10:15	23.23	3.74
8/30/2005 10:30	23.21	3.75
8/30/2005 10:45	23.19	3.74
8/30/2005 11:00	23.18	3.73
8/30/2005 11:15	23.16	3.74
8/30/2005 11:30	23.16	3.71
8/30/2005 11:45	23.15	3.69
8/30/2005 12:00	23.15	3.63
8/30/2005 12:15	23.15	3.64
8/30/2005 12:30	23.15	3.59
8/30/2005 12:45	23.16	3.63
8/30/2005 13:00	23.17	3.6
8/30/2005 13:15	23.19	3.59
8/30/2005 13:30	23.2	3.58
8/30/2005 13:45	23.22	3.61
8/30/2005 14:00	23.23	3.54
8/30/2005 14:15	23.25	3.53
8/30/2005 14:30	23.24	3.52
8/30/2005 14:45	23.23	3.48
8/30/2005 15:00	23.23	3.44
8/30/2005 15:15	23.23	3.41
8/30/2005 15:30	23.24	3.4
8/30/2005 15:45	23.23	3.37
8/30/2005 16:00	23.22	3.35
8/30/2005 16:15	23.21	3.39
8/30/2005 16:30	23.17	3.36
8/30/2005 16:45	23.16	3.4
8/30/2005 17:00	23.14	3.37
8/30/2005 17:15	23.11	3.32
8/30/2005 17:30	23.08	3.29
8/30/2005 17:45	23.05	3.21
8/30/2005 18:00	23.02	3.22
8/30/2005 18:15	22.98	3.2
8/30/2005 18:30	22.95	3.24
8/30/2005 18:45	22.92	3.21
8/30/2005 19:00	22.9	3.25
8/30/2005 19:15	22.88	3.24
8/30/2005 19:30	22.85	3.26
8/30/2005 19:45	22.83	3.23

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Date / Time	Temp [°C]	DO [mg/l]
8/29/2005 10:45	24.95	2.69
8/29/2005 11:00	24.94	2.69
8/29/2005 11:15	24.92	2.63
8/29/2005 11:30	24.93	2.63
8/29/2005 11:45	24.94	2.59
8/29/2005 12:00	24.98	2.6
8/29/2005 12:15	24.99	2.57
8/29/2005 12:30	25.03	2.6
8/29/2005 12:45	25.07	2.63
8/29/2005 13:00	25.14	2.64
8/29/2005 13:15	25.26	2.64
8/29/2005 13:30	25.29	2.7
8/29/2005 13:45	25.34	2.69
8/29/2005 14:00	25.47	2.71
8/29/2005 14:15	25.77	3.08
8/29/2005 14:30	25.76	2.96
8/29/2005 14:45	26	3.28
8/29/2005 15:00	25.89	2.97
8/29/2005 15:15	26.07	3.26
8/29/2005 15:30	26.06	3.18
8/29/2005 15:45	26.09	3.13
8/29/2005 16:00	26.29	3.46
8/29/2005 16:15	26.34	3.46
8/29/2005 16:30	26.29	3.39
8/29/2005 16:45	26.28	3.28
8/29/2005 17:00	26.42	3.51
8/29/2005 17:15	26.15	3.05
8/29/2005 17:30	26.2	3.17
8/29/2005 17:45	26.31	3.28
8/29/2005 18:00	26.39	3.57
8/29/2005 18:15	26.33	3.6
8/29/2005 18:30	26.07	3.17
8/29/2005 18:45	26.01	3.58
8/29/2005 19:00	25.9	3.22
8/29/2005 19:15	25.83	3.01
8/29/2005 19:30	25.79	3.09
8/29/2005 19:45	25.72	3
8/29/2005 20:00	25.68	2.98
8/29/2005 20:15	25.62	2.92
8/29/2005 20:30	25.56	2.89
8/29/2005 20:45	25.51	2.84
8/29/2005 21:00	25.49	2.75
8/29/2005 21:15	25.44	2.71
8/29/2005 21:30	25.4	2.73
8/29/2005 21:45	25.36	2.7
8/29/2005 22:00	25.33	2.65
8/29/2005 22:15	25.31	2.73
8/29/2005 22:30	25.3	2.7
8/29/2005 22:45	25.3	2.83
8/29/2005 23:00	25.3	2.83
8/29/2005 23:15	25.28	2.81
8/29/2005 23:30	25.27	2.79
8/29/2005 23:45	25.26	2.8
8/30/2005 0:00	25.24	2.8
8/30/2005 0:15	25.25	2.84
8/30/2005 0:30	25.25	2.9
8/30/2005 0:45	25.24	2.93
8/30/2005 1:00	25.25	2.99
8/30/2005 1:15	25.24	2.97
8/30/2005 1:30	25.24	2.98
8/30/2005 1:45	25.24	2.99
8/30/2005 2:00	25.23	3
8/30/2005 2:15	25.23	3.01
8/30/2005 2:30	25.23	2.98
8/30/2005 2:45	25.22	2.97
8/30/2005 3:00	25.22	2.98
8/30/2005 3:15	25.21	2.98
8/30/2005 3:30	25.2	2.98
8/30/2005 3:45	25.19	2.92
8/30/2005 4:00	25.19	2.93
8/30/2005 4:15	25.19	2.94
8/30/2005 4:30	25.18	2.92
8/30/2005 4:45	25.17	2.97
8/30/2005 5:00	25.16	2.9
8/30/2005 5:15	25.16	2.91
8/30/2005 5:30	25.15	2.89
8/30/2005 5:45	25.13	2.84
8/30/2005 6:00	25.12	2.82
8/30/2005 6:15	25.11	2.81
8/30/2005 6:30	25.11	2.82
8/30/2005 6:45	25.08	2.85
8/30/2005 7:00	25.07	2.85
8/30/2005 7:15	25.06	2.87
8/30/2005 7:30	25.06	2.82
8/30/2005 7:45	25.04	2.8
8/30/2005 8:00	25.02	2.84
8/30/2005 8:15	25	2.83
8/30/2005 8:30	25.01	2.84
8/30/2005 8:45	24.98	2.87
8/30/2005 9:00	24.98	2.88
8/30/2005 9:15	24.96	2.86
8/30/2005 9:30	24.95	2.85
8/30/2005 9:45	24.95	2.91
8/30/2005 10:00	24.93	2.87
8/30/2005 10:15	24.93	2.96
8/30/2005 10:30	24.92	2.99

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Date / Time	Temp [°C]	DO [mg/l]
8/30/2005 17:45	24.97	4.27
8/30/2005 18:00	25.02	4.25
8/30/2005 18:15	25.01	4.29
8/30/2005 18:30	24.98	4.28
8/30/2005 18:45	24.95	4.18
8/30/2005 19:00	24.95	4.23
8/30/2005 19:15	24.92	4.14
8/30/2005 19:30	24.92	4.14
8/30/2005 19:45	24.9	4.17
8/30/2005 20:00	24.89	4.12
8/30/2005 20:15	24.86	4.17
8/30/2005 20:30	24.85	4.11
8/30/2005 20:45	24.85	4.1
8/30/2005 21:00	24.84	4.08
8/30/2005 21:15	24.81	4.13
8/30/2005 21:30	24.81	4.12
8/30/2005 21:45	24.79	4.06
8/30/2005 22:00	24.78	4.07
8/30/2005 22:15	24.76	4.02
8/30/2005 22:30	24.74	4.01
8/30/2005 22:45	24.73	3.99
8/30/2005 23:00	24.7	4.01
8/30/2005 23:15	24.7	4
8/30/2005 23:30	24.68	3.93
8/30/2005 23:45	24.67	3.97
8/31/2005 0:00	24.65	3.93
8/31/2005 0:15	24.62	3.9
8/31/2005 0:30	24.59	3.91
8/31/2005 0:45	24.57	3.94
8/31/2005 1:00	24.55	3.91
8/31/2005 1:15	24.52	3.92
8/31/2005 1:30	24.49	3.88
8/31/2005 1:45	24.46	3.9
8/31/2005 2:00	24.43	3.89
8/31/2005 2:15	24.39	3.83
8/31/2005 2:30	24.36	3.88
8/31/2005 2:45	24.33	3.87
8/31/2005 3:00	24.32	3.82
8/31/2005 3:15	24.29	3.86
8/31/2005 3:30	24.27	3.84
8/31/2005 3:45	24.25	3.89
8/31/2005 4:00	24.23	3.84
8/31/2005 4:15	24.21	3.88
8/31/2005 4:30	24.19	3.86
8/31/2005 4:45	24.15	3.88
8/31/2005 5:00	24.13	3.87
8/31/2005 5:15	24.11	3.84
8/31/2005 5:30	24.1	3.86
8/31/2005 5:45	24.07	3.89
8/31/2005 6:00	24.03	3.81
8/31/2005 6:15	24.03	3.88
8/31/2005 6:30	23.99	3.83
8/31/2005 6:45	23.96	3.88
8/31/2005 7:00	23.93	3.88
8/31/2005 7:15	23.9	3.89
8/31/2005 7:30	23.88	3.84
8/31/2005 7:45	23.86	3.87
8/31/2005 8:00	23.86	3.91
8/31/2005 8:15	23.84	3.94
8/31/2005 8:30	23.86	4.01
8/31/2005 8:45	23.88	4.06
8/31/2005 9:00	23.94	4.08
8/31/2005 9:15	23.97	4.12
8/31/2005 9:30	23.99	4.11
8/31/2005 9:45	24.03	4.13
8/31/2005 10:00	24.08	4.05
8/31/2005 10:15	24.08	4.02
8/31/2005 10:30	24.16	4.09
8/31/2005 10:45	24.45	4.34
8/31/2005 11:00	24.58	4.35
8/31/2005 11:15	24.65	4.37
8/31/2005 11:30	25.07	4.55
8/31/2005 11:45	24.87	4.45
8/31/2005 12:00	25.07	4.69
8/31/2005 12:15	25.56	4.82
8/31/2005 12:30	25.47	4.84
8/31/2005 12:45	25.44	4.76
8/31/2005 13:00	25.25	4.76
8/31/2005 13:15	25.28	4.88
8/31/2005 13:30	25.41	5.04
8/31/2005 13:45	25.63	5.19
8/31/2005 14:00	25.73	5.29
8/31/2005 14:15	25.77	5.36
8/31/2005 14:30	25.71	5.26
8/31/2005 14:45	25.74	5.34
8/31/2005 15:00	25.95	5.52
8/31/2005 15:15	25.95	5.42
8/31/2005 15:30	26.16	5.6
8/31/2005 15:45	26.11	5.52
8/31/2005 16:00	26.13	5.5
8/31/2005 16:15	26.2	5.62
8/31/2005 16:30	26.24	5.69
8/31/2005 16:45	26.13	5.53
8/31/2005 17:00	26.06	5.46
8/31/2005 17:15	25.99	5.4
8/31/2005 17:30	25.96	5.43
8/31/2005 17:45	25.86	5.45
8/31/2005 18:00	25.8	5.33
8/31/2005 18:15	25.74	5.28
8/31/2005 18:30	25.71	5.19
8/31/2005 18:45	25.68	5.17
8/31/2005 19:00	25.67	5.11
8/31/2005 19:15	25.66	5.21
8/31/2005 19:30	25.67	5.16
8/31/2005 19:45	25.64	5.16
8/31/2005 20:00	25.63	5.24
8/31/2005 20:15	25.62	5.22
8/31/2005 20:30	25.6	5.2
8/31/2005 20:45	25.58	5.13
8/31/2005 21:00	25.54	5.17
8/31/2005 21:15	25.52	5.14
8/31/2005 21:30	25.49	5.09
8/31/2005 21:45	25.44	5.11
8/31/2005 22:00	25.4	5.05
8/31/2005 22:15	25.36	5.05
8/31/2005 22:30	25.35	4.99
8/31/2005 22:45	25.3	4.99
8/31/2005 23:00	25.26	4.98
8/31/2005 23:15	25.22	4.92
8/31/2005 23:30	25.17	4.92
8/31/2005 23:45	25.14	4.96
9/1/2005 0:00	25.11	4.89
9/1/2005 0:15	25.07	4.91
9/1/2005 0:30	25.03	4.89
9/1/2005 0:45	24.99	4.9
9/1/2005 1:00	24.96	4.88
9/1/2005 1:15	24.93	4.82
9/1/2005 1:30	24.88	4.78
9/1/2005 1:45	24.86	4.8
9/1/2005 2:00	24.82	4.78
9/1/2005 2:15	24.78	4.8
9/1/2005 2:30	24.74	4.79
9/1/2005 2:45	24.72	4.77
9/1/2005 3:00	24.69	4.71
9/1/2005 3:15	24.66	4.72
9/1/2005 3:30	24.62	4.66
9/1/2005 3:45	24.6	4.71
9/1/2005 4:00	24.58	4.71
9/1/2005 4:15	24.55	4.69
9/1/2005 4:30	24.53	4.67
9/1/2005 4:45	24.5	4.67
9/1/2005 5:00	24.49	4.66
9/1/2005 5:15	24.46	4.62
9/1/2005 5:30	24.44	4.66
9/1/2005 5:45	24.42	4.61
9/1/2005 6:00	24.41	4.62
9/1/2005 6:15	24.38	4.62
9/1/2005 6:30	24.37	4.6
9/1/2005 6:45	24.34	4.61
9/1/2005 7:00	24.32	4.59
9/1/2005 7:15	24.31	4.56
9/1/2005 7:30	24.3	4.63
9/1/2005 7:45	24.29	4.69
9/1/2005 8:00	24.28	4.63
9/1/2005 8:15	24.29	4.64
9/1/2005 8:30	24.3	4.74
9/1/2005 8:45	24.34	4.81
9/1/2005 9:00	24.43	4.99
9/1/2005 9:15	24.45	4.81
9/1/2005 9:30	24.47	4.85
9/1/2005 9:45	24.63	5.32
9/1/2005 10:00	24.84	6.11
9/1/2005 10:15	24.77	5.67
9/1/2005 10:30	25.26	6.66
9/1/2005 10:45	25.56	6.82
9/1/2005 11:00	25.78	7.36
9/1/2005 11:15	25.97	7.47
9/1/2005 11:30	26.11	7.3
9/1/2005 11:45	26.67	7.75
9/1/2005 12:00	26.36	7.38
9/1/2005 12:15	26.6	7.52
9/1/2005 12:30	26.49	7.36
9/1/2005 12:45	26.97	7.72
9/1/2005 13:00	26.61	7.48
9/1/2005 13:15	26.58	7.4
9/1/2005 13:30	26.65	7.46
9/1/2005 13:45	26.93	8.34
9/1/2005 14:00	27.18	9.08
9/1/2005 14:15	27.22	9.37
9/1/2005 14:30	27.86	10.37
9/1/2005 14:45	27.51	9.84

FINAL APPROVED TMDL

Otter Lake (RDF)
Palmyra-Modesto Lake (RDZP)
Hettick Lake (SDZF)

Hodges Creek Watershed

Prepared for Illinois Environmental Protection Agency

September 2005

Otter Lake (RDF): Manganese

Palmyra-Modesto Lake (RDZP): Manganese, Dissolved Oxygen, pH

Hettick Lake (SDZF): Total Phosphorus, Dissolved Oxygen

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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 (EPA) recently issued the 2004 303(d) list, 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).

Otter Lake, Palmyra-Modesto Lake, and Hettick Lake are listed on the 2004 Illinois Section 303(d) List of Impaired Waters (IEPA, 2004) 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 three 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 three impaired waterbody segments addressed in this TMDL are listed below, with the parameters they are listed for, and the use impairments as identified in the 2004 303(d) list (IEPA, 2004). TMDLs are currently only being developed for pollutants that have numerical water quality standards. Those impairments that are the focus of this report are shown in bold font.

Otter Lake	
Waterbody Segment	RDF
Size (Miles/Acres)	765
Listed For	**Manganese**, excess algal growth
Use Support[1]	Aquatic life (F), Fish consumption (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)
Palmyra-Modesto Lake	
Waterbody Segment	RDZP
Size (Miles/Acres)	35
Listed For	**Manganese, dissolved oxygen, pH**, excess algal growth
Use Support[1]	Aquatic life (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)
Hettick Lake	
Waterbody Segment	SDZF
Size (Miles/Acres)	110
Listed For	**Total phosphorus, dissolved oxygen**, excess algal growth, unspecified nutrients
Use Support[1]	Aquatic life (F), Fish consumption (F), Overall use (P), Primary contact (P), Secondary contact (P)

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

A fourth waterbody in the Hodges Creek watershed will be addressed in a separate TMDL report. As part of the Section 303(d) listing process, the Illinois EPA identified Hodges Creek (DAG 02) as an impaired waterbody. The potential cause of impairment is dissolved oxygen (IEPA, 2004). During the data review stage of this TMDL study (see Stage 1 Report), a determination was made that additional data are required before a TMDL can be conducted for this waterbody. These data will be collected in the summer of 2005.

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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.

Otter Lake

1. **Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking:** Otter Lake, HUC 713001202. The pollutant of concern addressed in this TMDL is manganese. Pollutant sources are natural background sources including runoff and soil erosion, and release from sediments under hypolimnetic anoxic conditions. Otter Lake 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 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 the 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 dissolved oxygen 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 average allowable phosphorus load that will eliminate the excess release of manganese from lake sediments is 3.86 kg/day between March and August, with the total load not to exceed 710 kg over this period. This corresponds to a 66 percent reduction of existing loads.
4. **Load Allocations (LA):** The load allocation given to non-point source loads from watershed sources is 3.13 kg/day between March and August.
5. **Wasteload Allocations (WLA):** The Otter Lake Water Commission is the sole NPDES permitted point source discharge in the watershed. The WLA was set at estimated existing loading conditions of 0.34 kg/day.
6. **Margin of Safety:** The TMDL contains an explicit margin of safety corresponding to 10% of the loading capacity, or 0.39 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. Model results

indicate that the phosphorus residence time in Otter Lake is three to seven 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:** 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 (Otter Lake Water Commission) 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:** A monitoring plan will be prepared as part of the implementation plan.

10. **Transmittal Letter:** A letter was included with the transmittal of this TMDL 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. (listed in tables in the Stage 1 Report). Two public meetings were conducted in Girard, Illinois and one additional public meeting is planned to present the implementation plan.

Palmyra-Modesto Lake

1. **Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking:** Palmyra-Modesto Lake, HUC 713001202. The pollutants of concern addressed in this TMDL are manganese, dissolved oxygen, and pH. Pollutant sources of manganese are natural background sources, including runoff and soil erosion, and release from sediments under hypolimnetic anoxic conditions. Pollutant sources contributing to pH and dissolved oxygen impairments are excess algal production (and respiration) resulting from nutrient loading from failing private sewage

disposal systems, runoff from agricultural land, and livestock. Palmyra-Modesto Lake 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 **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.

   The general use water quality standard for **dissolved oxygen** in Illinois waters is an average of 6 mg/l and a minimum of 5 mg/l. The Illinois general use criteria for **pH** ranges from a minimum of 6.5 to a maximum of 9.0, except for natural causes. Violation of the dissolved oxygen and pH standards are presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding or pH altering materials to the lake. For this reason, attainment of the total phosphorus standard is expected to result in attainment of the dissolved oxygen and pH standards. The TMDL targets for dissolved oxygen and pH are 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 comply with the water quality targets is 0.24 kg/day for the period March through August, with the total load for this period not to exceed 43 kg. This corresponds to a 38 percent reduction of existing loads.

4. **Load Allocations (LA):** The load allocation given to non-point source loads from watershed sources is 0.212 kg P/day for the period March - August.

5. **Wasteload Allocations (WLA):** No point sources of manganese or related parameters exist in the Palmyra-Modesto Lake watershed, so wasteload allocations are not required.

6. **Margin of Safety:** The TMDL contains an explicit margin of safety corresponding to 10% of the loading capacity, or 0.024 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. Model results indicate that the phosphorus residence time in Palmyra-Modesto Lake is one to four 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 Palmyra-Modesto Lake 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 these watershed activities is provided in the Stage 1 Report.
9. **Monitoring Plan to Track TMDL Effectiveness:** A monitoring plan will be prepared as part of the implementation plan.
10. **Transmittal Letter:** A letter was included with the transmittal of this TMDL 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. (listed in tables in the Stage 1 Report). Two public meetings were conducted in Girard, Illinois and one additional public meeting is planned to present the implementation plan.

Hettick Lake

1. **Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking:** Hettick Lake, HUC 713001202. The pollutants of concern addressed in this TMDL are total phosphorus and dissolved oxygen. Pollutant sources of phosphorus include runoff from lawns and agricultural lands (fertilized cropland and agricultural land with livestock), failing private sewage disposal systems (septic and surface discharge systems), and release from sediments under hypolimnetic anoxic conditions. Pollutant sources contributing to dissolved oxygen impairment are excess algal production (and respiration) resulting from nutrient loading from failing private sewage disposal systems, runoff from

agricultural land, and livestock. Hettick Lake 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 applicable **phosphorus** standard for Hettick Lake is 0.05 mg/l. The general use water quality standard for **dissolved oxygen** in Illinois waters is an average of 6 mg/l and a minimum of 5 mg/l. For the Hettick Lake phosphorus TMDL, the target is set at the water quality criterion for total phosphorus of 0.050 mg-P/l. Violation of the dissolved oxygen standard is presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding materials (e.g., animal droppings, sewage overflows, fallen leaves, and grass clippings) to the lake. For this reason, attainment of the total phosphorus standard is expected to result in attainment of the dissolved oxygen standard. The TMDL target for dissolved oxygen 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 and the dissolved oxygen target is 0.75 kg/day over the period March through August, with the total load over this period not to exceed 138 kg. This corresponds to an 82 percent reduction of existing loads.

4. **Load Allocations (LA):** The load allocation given to non-point source loads from watershed sources is 0.673 kg/day for the period March - August.

5. **Wasteload Allocations (WLA):** No point sources of phosphorus exist in the Hettick Lake 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 0.075 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. Model results indicate that the phosphorus residence time in Hettick Lake is one 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.

8. **Reasonable Assurances:** There are no permitted point sources in the Old Hettick Lake 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:** A monitoring plan will be prepared as part of the implementation plan.
10. **Transmittal Letter:** A letter was included with the transmittal of this TMDL 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. (listed in tables in the Stage 1 Report). Two public meetings were conducted in Girard, Illinois and one additional public meeting is planned to present the implementation plan.

3 WATERSHED CHARACTERIZATION

The Stage 1 Report presents and discusses information describing the watersheds of the impaired waterbodies to support the identification of sources contributing to manganese, total phosphorus, low dissolved oxygen, and pH impairments as applicable. 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 impaired waterbodies addressed in this report are located within the Hodges Creek watershed, which is located in West-Central Illinois approximately 45 miles south of Springfield. The majority of Hodges Creek's watershed is in Macoupin County (97%), with small portions extending into Greene, Jersey, Morgan, and Sangamon Counties. The watershed for Hodges Creek is approximately 148,961 acres (233 square miles) in size. Figure 1 shows a map of the watershed, and includes key features such as waterways, impaired waterbodies, and public water intakes. The map also shows the locations of point source discharges that have a permit to discharge under the National Permit Discharge Elimination System (NPDES). As shown in this figure, the Hodges Creek watershed is roughly bisected by route 111, with route 108 passing through the southern portion of the watershed.

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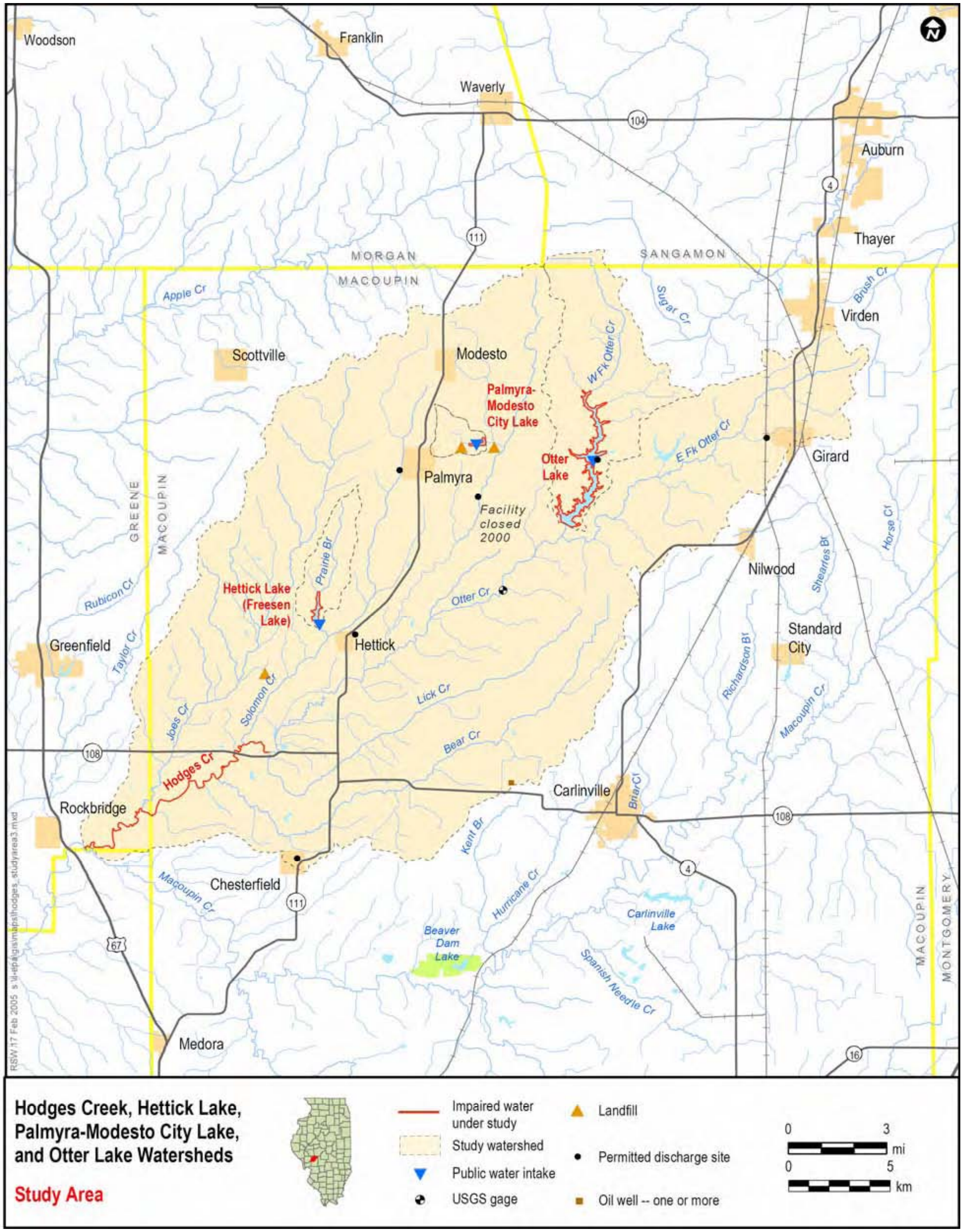

Figure 3.1. Base Map of Hodges Creek Watershed

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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 Otter Lake, Palmyra-Modesto Lake, and Hettick Lake.

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, total phosphorus, dissolved oxygen, and pH 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 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 1,000 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.

4.2.2 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.

4.2.3 Dissolved Oxygen

The IEPA guidelines (IEPA, 2004b) for identifying dissolved oxygen as a cause in lakes state that the aquatic life use is not supported if there is at least one violation of the applicable standard (5.0 mg/l minimum; 6.0 mg/l average) at one foot depth below the lake surface; or a known fish kill resulting from dissolved oxygen depletion.

4.2.4 pH

The Illinois general use criteria for pH range from a minimum of 6.5 to a maximum of 9.0, except for natural causes.

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. This section presents the TMDL targets used for each of the lakes.

As discussed below, a surrogate parameter (total phosphorus concentration) is selected as the TMDL target for dissolved oxygen, manganese and pH. The linkage between the TMDL target (total phosphorus) and the other impairments is explained as follows. First, phosphorus loadings to lakes can stimulate excess algal growth. Excess algal growth can affect pH through the uptake of carbonic acid. 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.

4.3.1 Otter Lake

For the Otter Lake manganese TMDL, the target is maintenance of hypolimnetic dissolved oxygen concentrations above zero. The only controllable 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, 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.

4.3.2 Palmyra-Modesto Lake

For the manganese TMDL, the target is maintenance of hypolimnetic dissolved oxygen concentrations above zero. The only controllable 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, 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.

Violations of the dissolved oxygen and pH standards are also presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding or pH altering materials to the lake. For this reason, attainment of the total phosphorus standard is expected to result in attainment of the dissolved oxygen and pH standards. The TMDL targets for dissolved oxygen and pH are therefore set as a total phosphorus concentration of 0.050 mg-P/l.

4.3.3 Hettick Lake

For the Hettick Lake phosphorus TMDL, the target is set at the water quality criterion for total phosphorus of 0.050 mg-P/l. Violation of the dissolved oxygen standard is presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding materials to the lake. For this reason, attainment of the total phosphorus standard is expected to result in attainment of the dissolved oxygen standard. The TMDL target for dissolved oxygen is therefore set as a total phosphorus concentration of 0.050 mg-P/l.

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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 Palmyra-Modesto, Otter and Hettick Lake watersheds is provided in the Stage 1 Report. Of the models discussed, the BATHTUB model was selected for application to all three lakes.

The BATHTUB model was selected for all three 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 concentrations for all three lakes, as well as the resulting potential for manganese release from sediments in Palmyra-Modesto and Otter Lakes. 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 Palmyra-Modesto and Otter Lakes is that which enters from lake sediments during periods when there is 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 all three lakes exceed the TMDL targets by several fold. 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 all three 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 (Walker, 1986). 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 Otter Lake, Table 5-2 for Palmyra-Modesto Lake, and Table 5-3 for Hettick Lake, with the rationale for these options discussed below. No conservative substance was being simulated for any of the lakes, so this option was not needed. The second order available phosphorus option was selected for phosphorus in all three lakes, as it is the default option for BATHTUB. Nitrogen was not simulated in any of the lakes, because phosphorus is the nutrient of concern.

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

Table 5-1. BATHTUB Model Options for Otter Lake

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 Palmyra-Modesto

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 5-3. BATHTUB Model Options for Hettick Lake

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 the 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. The nutrient residence time for Otter Lake was calculated as three to seven months; the nutrient residence time for Palmyra-Modesto Lake was one to four months, and the nutrient residence time for Hettick Lake was calculated as one to two months. Therefore, the averaging period used for this analysis was set to the seasonal period March - August.

Precipitation inputs were taken from the observed long term March - August precipitation data. This resulted in precipitation inputs of 20 inches for all three 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 the three lakes were designed to provide one segment for each of the primary lake sampling stations. Otter Lake was divided into four segments, as shown in Figure 5.1, while Palmyra-Modesto and Hettick Lakes were each divided into three segments (Figures 5.2 and 5.3). The areas of segments and watersheds for each segment were determined by Geographic Information System (GIS).

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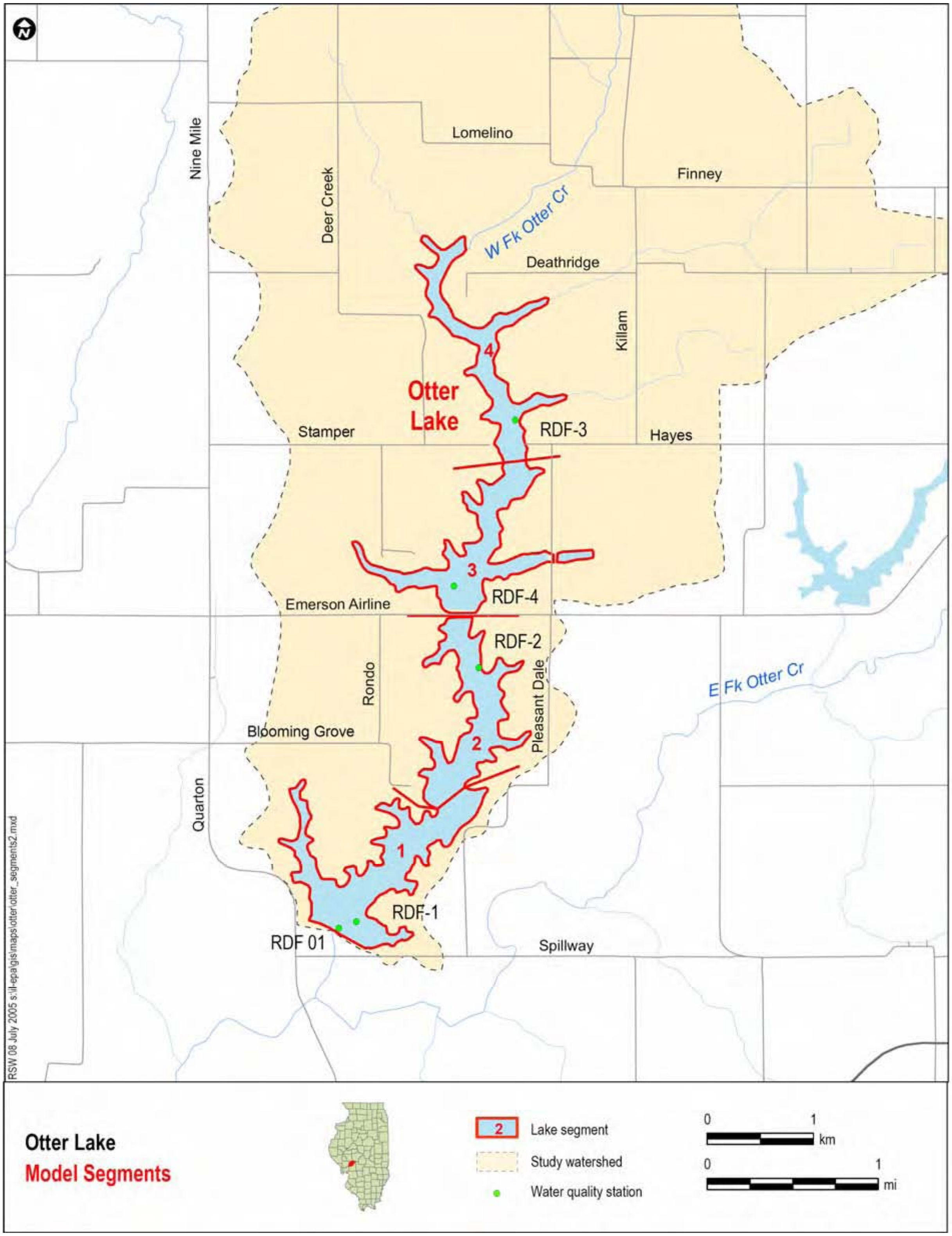

Figure 5.1 Otter Lake Segmentation Used in BATHTUB

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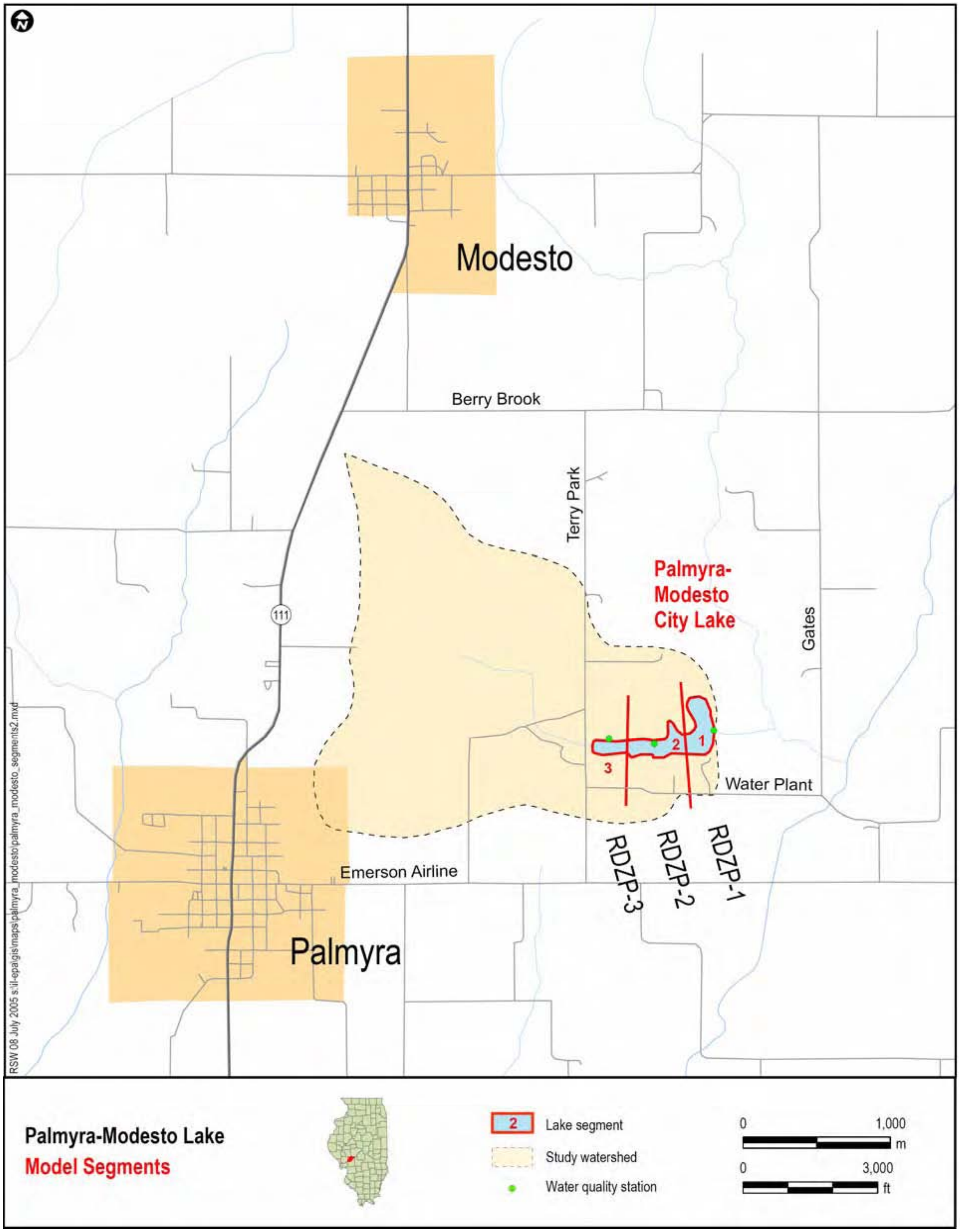

Figure 5.2 Palmyra-Modesto Lake Segmentation Used in BATHTUB

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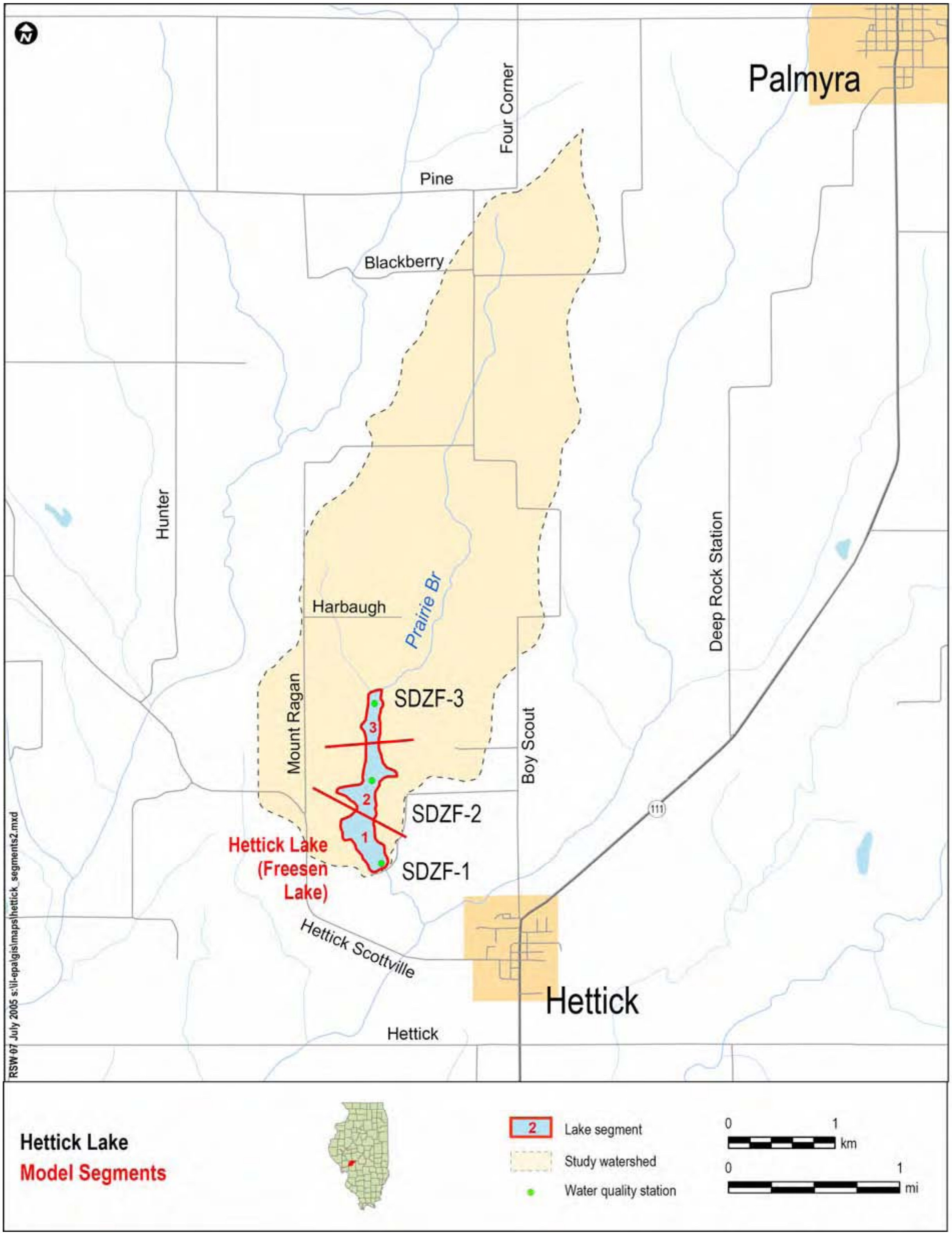

Figure 5.3 Hettick Lake Segmentation Used in BATHTUB

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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 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 the average of the observed flows at three similar USGS gaging stations: Kaskaskia Ditch (05590000), 7-Mile Creek (05595800), and Indian Creek (05588000). These were selected because they were the most similar in terms of watershed size and land use. Flows into each lake segment were calculated through the use of drainage area ratios as follows:

Flow into segment = Average flow at USGS gages x Segment-specific drainage area ratio

$$\text{Drainage area ratio} = \frac{\text{Drainage area of watershed contributing to model segment}}{\text{Average drainage area of watersheds contributing to USGS gages}}$$

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 Otter Lake, Palmyra-Modesto Lake, and Hettick Lake are provided below.

5.4.1 Otter Lake

The BATHTUB model was initially applied with the model inputs as specified above. Observed data for the year 1997 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 total phosphorus concentrations. The default calibration coefficients in BATHTUB provided an acceptable fit to the observed data in segments 3 and 4, and no additional calibration activities were required. Model results in segments 1 and 2 initially under-predicted the observed phosphorus data. Phosphorus loss rates in BATHTUB rates reflect a typical "net settling rate" (i.e. settling – 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 5 $mg/m^2/day$ in segments 1 and 2. The resulting predicted lake average total phosphorus concentration was 74 ug/l, compared to an observed average of 80 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 Palmyra-Modesto Lake

The BATHTUB model was initially applied with the model inputs as specified above. The average of observed data from 1992, 1996, 1998, and 2000 were used to develop model inputs, as no single year provided a robust data set. The average August observed lake data were used for calibration purposes, 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 20 $mg/m^2/day$ was added to model segments 1, 2 and 3 to provide the best comparison between model predictions and observed data. The resulting predicted lake average total phosphorus concentration was 125 ug/l, compared to an observed average of 120 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.

5.4.3 Hettick Lake

The BATHTUB model was initially applied with the model inputs as specified above. Observed data for the year 2000 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 phosphorus concentrations. The default calibration coefficients in BATHTUB provided an acceptable fit to the observed data in all segments, and no additional calibration activities were required. The predicted lake average total phosphorus concentration was 129 ug/l, compared to an observed average of 153 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 Hettick, Otter, and Palmyra-Modesto Lakes. 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 water quality objectives. The maximum tributary concentration that results in compliance with water quality targets 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 Otter Lake

Initial BATHTUB load reduction simulations indicated that Otter Lake 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. This results in a total average allowable load of 3.86 kg/day between March and August, with the total load not to exceed 710 kg over this period. This allowable load corresponds to an approximately 66% reduction from existing loads (estimated as 2,098 kg for the March-August season). Loads are expressed on a seasonal basis because model results indicate that the average phosphorus residence time in the three lakes is on the order of a few 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.

6.1.2 Palmyra-Modesto Lake

Initial BATHTUB load reduction simulations indicated that Palmyra-Modesto Lake 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 average allowable load was 0.24 kg/day between March and August, with the total load not to exceed 43 kg over this period. This allowable load corresponds to an approximately 38% reduction from existing loads (estimated as 70 kg over the March – August period).

6.1.3 Hettick Lake

The tributary phosphorus concentration that led to compliance with water quality targets was 73 ug/l. This concentration, combined with average March - August flows, results in a total allowable average load of 0.75 kg/d over the March – August period, with the total load not to exceed 138 kg. This allowable load corresponds to an approximately 82% reduction from existing loads (estimated as 755 kg for the March-August period).

6.2 ALLOCATION

6.2.1 Otter Lake

The Otter Lake Water Commission is the sole NPDES permitted point source discharge in the watershed. Current phosphorus loads from this plant were estimated based on an assumption that the plant is discharging at its permitted flow rate (0.045 MGD) and the phosphorus concentration in the discharge is 2 mg/l. The phosphorus concentration is based on the average phosphate concentrate measured in the finished water prior to filtration (personal communication with Otter Lake WTP operations supervisor). Current phosphorus loads from this plant are estimated to be at 0.34 kg/day. The wasteload allocation for the Otter Lake Water Commission NPDES permit is set at its current loading rate of 0.34 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 3.86 kg/day, a WLA of 0.34 kg/day, and an explicit margin of safety of 10% (discussed below), this results in a load allocation for Otter Lake of 3.13 kg/day.

6.2.2 Palmyra-Modesto Lake

No point sources of phosphorus exist in the Palmyra-Modesto Lake 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 in Section 6.4), this corresponds to a load allocation of 0.212 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.

6.2.3 Hettick Lake

No point sources of phosphorus exist in the Hettick Lake 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 in Section 6.4), this corresponds to load allocation of 0.673 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 the three lakes is on the order of a few 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 reasonable 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 loads allocated to the margin of safety are 0.39 kg/day for Otter Lake, 0.024 kg/day for Palmyra-Modesto Lake, and 0.075 kg/day for Hettick Lake.

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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). As quarterly progress reports were produced during the first stage of the TMDL process, the Agency posted them to their website for public review. A public meeting was conducted in Girard, Illinois on March 22, 2005 to present the results of Stage 1 work. A second meeting was conducted in the same location on August 3, 2005, to present TMDL results. A third meeting will be held at a later date to discuss the implementation planning.

7.1 SUMMARY OF MARCH 22, 2005 PUBLIC MEETING

In February 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 Tuesday, March 22, 2005 in Girard, Illinois at the former Otter Lake Pump Building. In addition to the meeting's sponsors, nine 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 22, 2005. At the meeting, there were several general questions, including questions about schedule and process, and concerns that the TMDL will bring new regulations for farmers. In response, the voluntary nature of the program with respect to nonpoint sources was emphasized. A participant asked about the approach that will be used for the pH TMDL for Palmyra-Modesto Lake. A resident who fishes in Otter Lake noted that the upstream end of the lake is silting in. The ongoing and planned sedimentation controls were discussed. A question was asked about whether the TMDL will include recommendations for measures to improve the watershed, and IEPA responded that the TMDL report will provide this type of information. Some participants expressed interest in getting involved in future watershed improvement efforts. Dennis Ross, General Manager of the Otter Lake Water Commission said the Commission spends about $60K per year addressing sedimentation problems and would be interested in working with other stakeholders on reducing sediment loads through watershed management/restoration activities.

7.2 SUMMARY OF AUGUST 3, 2005 PUBLIC MEETING

In July 2005, a public meeting was announced for presentation of the development of the draft Total Maximum Daily Loads for Otter, Palmyra-Modesto and Hettick Lakes, which are located within the Hodges Creek watershed. 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, August 3, 2005 in Girard, Illinois at the former Otter Lake pump building. In addition to the meeting's sponsors, 3 individuals attended the meeting. Attendees registered and listened to a presentation on the draft TMDLs developed by Limno-Tech, Inc. for Otter Lake (manganese), Palmyra-Modesto Lake (manganese, dissolved oxygen and pH) and Hettick Lake (total phosphorus and dissolved oxygen). This was followed by a general question and answer session. There were several questions focused on whether anoxia could really be eliminated to control manganese. The majority of the discussion was focused on the implementation phase of this project. Potential projects discussed included cost-share ponds, a sediment dam for which the Otter Lake water commission currently has 319 funding, streambank erosion controls and controls for new construction.

The Agency entertained questions and concerns from the public through August 19, 2005. A responsiveness summary is included in Attachment 2. This responsiveness summary addresses substantive questions and comments received during the public comment period.

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 each lake 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. Model files

Hettick 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	3.7	0.1415	27.9	3.7	7.7	1.0	0.0
2	Segment 2	1	3.6	0.1259	24.5	5.4	9.7	1.8	7.6
3	Segment 3	2	3.1	0.0195	46.7	26.2	48.9	6.7	9.9

Morphometry

Seg	Name	Area km^2	Zmean m	Zmix m	Length km	Volume hm^3	Width km	L/W -
1	Segment 1	0.1	4.0	2.3	0.5	0.5	0.3	2.0
2	Segment 2	0.1	3.1	2.1	0.7	0.5	0.2	3.2
3	Segment 3	0.1	0.9	0.8	0.5	0.1	0.1	3.9
Totals		0.3	3.0			1.0		

Hettick Lake

Segment & Tributary Network

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

Hettick Lake
Description:
Single reservoir (110 acres)
3 segments

Global Variables	Mean	CV
Averaging Period (yrs)	0.5	0.0
Precipitation (m)	0.508	0.0
Evaporation (m)	0.508	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	1	DECAY RATES
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	0.134	3.95	0.52	2.35	0.12	2.35	0	1	0	0	0	0	0	0	0
2	Segment 2	1	1	0.146	3.09	0.68	2.13	0.12	2.13	0	1.58	0	0	0	0	0	0	0
3	Segment 3	2	1	0.067	0.91	0.51	0.76	0.12	0.69	0	9	0	0	0	0	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)	
Seq	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	165	0.6	0	0	59	0	0.15	0	0	0	0	0	0	0	0	0
2	0	0	125	0	0	0	69	0	0.41	0	0	0	0	0	0	0	0	0
3	0	0	189	0	0	0	57	0	0.25	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)	
Seq	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	1	9.45	3.1294	0	0	0	400	0	0	0	0	0	0	0
2	Segment 2 Direct Drainage	2	1	1.37	0.4547	0	0	0	400	0	0	0	0	0	0	0
3	Segment 1 Direct Drainage	1	1	0.48	0.1573	0	0	0	400	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	6.7	0.81	1.78	0.05	0.09	0.04	0	0
2	Segment 2 Direct Drainage	0.72	0.13	0.33	0.03	0.05	0.12	0	0
3	Segment 1 Direct Drainage	0.16	0.02	0.15	0	0.02	0.12	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	0.331	0	0	0	388	0	0	0	0	0	0	0
2	Grassland	0.331	0	0	0	388	0	0	0	0	0	0	0
3	Forest	0.331	0	0	0	388	0	0	0	0	0	0	0
4	Urban	0.331	0	0	0	388	0	0	0	0	0	0	0
5	Wetland	0.331	0	0	0	388	0	0	0	0	0	0	0
6	Other	0.331	0	0	0	388	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

Hettick Lake

Variable = TOTAL P MG/M3 **R^2 = -1.93**
Global Calibration Factor = 1.00 CV = 0.45

			Calibration Factor		Predicted		Observed		Log (Obs/Pred)		
Seg	**Group**	**Name**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**SE**	**t**
1	1	Segment 1	1.00	0.00	99.3	0.00	165.0	0.60	0.51	0.60	0.85
2	1	Segment 2	1.00	0.00	130.2	0.00	125.0	0.00	-0.04	0.00	0.00
3	1	Segment 3	1.00	0.00	183.2	0.00	189.0	0.00	0.03	0.00	0.00
4	1	Area-Wtd Mean			128.5	0.00	152.8	0.25	0.17	0.25	0.69

Hettick 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**

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	152.8	0.25	128.5	0.00	1.19	0.69	0.64	

Segment: **1 Segment 1**

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	165.0	0.60	99.3	0.00	1.66	0.85	1.89	

Segment: **2 Segment 2**

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	125.0	0.00	130.2	0.00	0.96		-0.15	

Segment: **3 Segment 3**

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	189.0	0.00	183.2	0.00	1.03		0.12	

Hettick 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	99.3	130.2	183.2	128.5
TURBIDITY 1/M	1.0	1.6	9.0	2.8
ZMIX * TURBIDITY	2.3	3.4	6.8	3.6
CARLSON TSI-P	70.5	74.4	79.3	73.8

OBSERVED CONCENTRATIONS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	165.0	125.0	189.0	152.8
CHL-A MG/M3	59.0	69.0	57.0	62.8
SECCHI M	0.2	0.4	0.3	0.3
ANTILOG PC-1	8365.5	3802.1	5029.4	5801.3
ANTILOG PC-2	4.8	11.7	7.0	8.2
TURBIDITY 1/M	1.0	1.6	9.0	2.8
ZMIX * TURBIDITY	2.3	3.4	6.8	3.6
ZMIX / SECCHI	15.7	5.2	3.0	8.8
CHL-A * SECCHI	8.9	28.3	14.3	18.1
CHL-A / TOTAL P	0.4	0.6	0.3	0.4
FREQ(CHL-a>10) %	99.5	99.7	99.4	99.6
FREQ(CHL-a>20) %	92.4	95.4	91.6	93.5
FREQ(CHL-a>30) %	78.3	84.9	76.6	80.7
FREQ(CHL-a>40) %	62.4	71.5	60.3	65.9
FREQ(CHL-a>50) %	48.3	58.3	46.1	52.1
FREQ(CHL-a>60) %	36.8	46.6	34.7	40.5
CARLSON TSI-P	77.8	73.8	79.7	76.5
CARLSON TSI-CHLA	70.6	72.1	70.3	71.2
CARLSON TSI-SEC	87.3	72.8	80.0	79.8

OBSERVED/PREDICTED RATIOS:

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	1.7	1.0	1.0	1.2
TURBIDITY 1/M	1.0	1.0	1.0	1.0
ZMIX * TURBIDITY	1.0	1.0	1.0	1.0
CARLSON TSI-P	1.1	1.0	1.0	1.0

OBSERVED STANDARD ERRORS

Variable Segment-->	1	2	3	Mean
TOTAL P MG/M3	99.0			38.2

PREDICTED STANDARD ERRORS

Variable Segment-->	1	2	3	Mean

Hettick 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	128.5		86.4%	152.8	0.25	90.1%
CHL-A MG/M3				62.8		99.3%
SECCHI M				0.3		3.7%
ANTILOG PC-1				5801.3		99.2%
ANTILOG PC-2				8.2		67.4%
TURBIDITY 1/M	2.8		95.8%	2.8		95.8%
ZMIX * TURBIDITY	3.6		57.4%	3.6		57.4%
ZMIX / SECCHI				8.8		85.5%
CHL-A * SECCHI				18.1		79.0%
CHL-A / TOTAL P				0.4		89.1%
FREQ(CHL-a>10) %				99.6		99.3%
FREQ(CHL-a>20) %				93.5		99.3%
FREQ(CHL-a>30) %				80.7		99.3%
FREQ(CHL-a>40) %				65.9		99.3%
FREQ(CHL-a>50) %				52.1		99.3%
FREQ(CHL-a>60) %				40.5		99.3%
CARLSON TSI-P	73.8		86.4%	76.5		90.1%
CARLSON TSI-CHLA				71.2		99.3%
CARLSON TSI-SEC				79.8		96.3%

Segment: 1 Segment 1

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	99.3		79.1%	165.0	0.60	91.5%
CHL-A MG/M3				59.0		99.2%
SECCHI M				0.2		0.5%
ANTILOG PC-1				8365.5		99.6%
ANTILOG PC-2				4.8		29.3%
TURBIDITY 1/M	1.0		71.3%	1.0		71.3%
ZMIX * TURBIDITY	2.3		35.3%	2.3		35.3%
ZMIX / SECCHI				15.7		97.9%
CHL-A * SECCHI				8.9		42.1%
CHL-A / TOTAL P				0.4		82.8%
FREQ(CHL-a>10) %				99.5		99.2%
FREQ(CHL-a>20) %				92.4		99.2%
FREQ(CHL-a>30) %				78.3		99.2%
FREQ(CHL-a>40) %				62.4		99.2%
FREQ(CHL-a>50) %				48.3		99.2%
FREQ(CHL-a>60) %				36.8		99.2%
CARLSON TSI-P	70.5		79.1%	77.8		91.5%
CARLSON TSI-CHLA				70.6		99.2%
CARLSON TSI-SEC				87.3		99.5%

Segment: 2 Segment 2

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	130.2		86.7%	125.0		85.7%
CHL-A MG/M3				69.0		99.5%
SECCHI M				0.4		10.1%
ANTILOG PC-1				3802.1		98.2%
ANTILOG PC-2				11.7		87.4%
TURBIDITY 1/M	1.6		86.1%	1.6		86.1%
ZMIX * TURBIDITY	3.4		53.4%	3.4		53.4%
ZMIX / SECCHI				5.2		55.8%
CHL-A * SECCHI				28.3		92.5%
CHL-A / TOTAL P				0.6		94.8%
FREQ(CHL-a>10) %				99.7		99.5%
FREQ(CHL-a>20) %				95.4		99.5%
FREQ(CHL-a>30) %				84.9		99.5%
FREQ(CHL-a>40) %				71.5		99.5%
FREQ(CHL-a>50) %				58.3		99.5%
FREQ(CHL-a>60) %				46.6		99.5%
CARLSON TSI-P	74.4		86.7%	73.8		85.7%
CARLSON TSI-CHLA				72.1		99.5%
CARLSON TSI-SEC				72.8		89.9%

Segment: 3 Segment 3

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	183.2		93.2%	189.0		93.6%
CHL-A MG/M3				57.0		99.0%
SECCHI M				0.3		2.7%
ANTILOG PC-1				5029.4		98.9%
ANTILOG PC-2				7.0		56.6%
TURBIDITY 1/M	9.0		99.9%	9.0		99.9%
ZMIX * TURBIDITY	6.8		84.1%	6.8		84.1%
ZMIX / SECCHI				3.0		21.9%
CHL-A * SECCHI				14.3		68.2%
CHL-A / TOTAL P				0.3		75.1%
FREQ(CHL-a>10) %				99.4		99.0%
FREQ(CHL-a>20) %				91.6		99.0%
FREQ(CHL-a>30) %				76.6		99.0%
FREQ(CHL-a>40) %				60.3		99.0%
FREQ(CHL-a>50) %				46.1		99.0%
FREQ(CHL-a>60) %				34.7		99.0%
CARLSON TSI-P	79.3		93.2%	79.7		93.6%
CARLSON TSI-CHLA				70.3		99.0%
CARLSON TSI-SEC				80.0		97.3%

Hettick Lake

Water Balance Terms (hm3/yr) **Averaging Period = 0.50 Years**

Seg	Name	Inflows External	Precip	Advect	Storage Increase	Outflows------> Advect	Disch.	Downstr Exchange	Evap
1	Segment 1	0	0	4	0	4	0	0	0
2	Segment 2	0	0	3	0	4	0	8	0
3	Segment 3	3	0	0	0	3	0	10	0
Net		4	0	0	0	4	0	0	0

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

Seg	Name	Inflows--> External	Atmos	Advect	Storage Increase	Outflows-----> Advect	Disch.	Net Exchange	Net Retention
1	Segment 1	63	4	467	0	372	0	-235	397
2	Segment 2	182	4	573	0	467	0	-289	582
3	Segment 3	1252	2	0	0	573	0	525	156
Net		1497	10	0	0	372	0	0	1135

Hettick 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	1	Segment 1 Direct Drainage	0.2	4.1%	62.9	8.2%	400
PRECIPITATION			0.1	3.5%	4.0	0.5%	30
TRIBUTARY INFLOW			0.2	4.1%	62.9	8.2%	400
ADVECTIVE INFLOW			3.6	92.4%	466.7	60.7%	130
NET DIFFUSIVE INFLOW			0.0	0.0%	235.5	30.6%	
***TOTAL INFLOW			3.9	100.0%	769.1	100.0%	198
ADVECTIVE OUTFLOW			3.7	96.5%	371.6	48.3%	99
***TOTAL OUTFLOW			3.7	96.5%	371.6	48.3%	99
***EVAPORATION			0.1	3.5%	0.0	0.0%	
***RETENTION			0.0	0.0%	397.5	51.7%	

Hyd. Residence Time = 0.1415 yrs
Overflow Rate = 27.9 m/yr
Mean Depth = 4.0 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	1	Segment 2 Direct Drainage	0.5	12.2%	181.9	17.3%	400
PRECIPITATION			0.1	4.0%	4.4	0.4%	30
TRIBUTARY INFLOW			0.5	12.2%	181.9	17.3%	400
ADVECTIVE INFLOW			3.1	83.8%	573.3	54.7%	183
NET DIFFUSIVE INFLOW			0.0	0.0%	289.2	27.6%	
***TOTAL INFLOW			3.7	100.0%	1048.8	100.0%	281
ADVECTIVE OUTFLOW			3.6	96.0%	466.7	44.5%	130
***TOTAL OUTFLOW			3.6	96.0%	466.7	44.5%	130
***EVAPORATION			0.1	4.0%	0.0	0.0%	
***RETENTION			0.0	0.0%	582.1	55.5%	

Hyd. Residence Time = 0.1259 yrs
Overflow Rate = 24.5 m/yr
Mean Depth = 3.1 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	1	Inlet Tributary	3.1	97.9%	1251.8	99.8%	400
PRECIPITATION			0.1	2.1%	2.0	0.2%	30
TRIBUTARY INFLOW			3.1	97.9%	1251.8	99.8%	400
***TOTAL INFLOW			3.2	100.0%	1253.8	100.0%	392
ADVECTIVE OUTFLOW			3.1	97.9%	573.3	45.7%	183
NET DIFFUSIVE OUTFLOW			0.0	0.0%	524.7	41.8%	
***TOTAL OUTFLOW			3.1	97.9%	1098.0	87.6%	351
***EVAPORATION			0.1	2.1%	0.0	0.0%	
***RETENTION			0.0	0.0%	155.8	12.4%	

Hyd. Residence Time = 0.0195 yrs
Overflow Rate = 46.7 m/yr
Mean Depth = 0.9 m

Hettick Lake

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 0.50 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	3	Inlet Tributary	9.4	3.1	0.00E+00	0.00	0.33
2	1	2	Segment 2 Direct Drainage	1.4	0.5	0.00E+00	0.00	0.33
3	1	1	Segment 1 Direct Drainage	0.5	0.2	0.00E+00	0.00	0.33
PRECIPITATION				0.3	0.4	0.00E+00	0.00	1.02
TRIBUTARY INFLOW				11.3	3.7	0.00E+00	0.00	0.33
***TOTAL INFLOW				11.6	4.1	0.00E+00	0.00	0.35
ADVECTIVE OUTFLOW				11.6	3.7	0.00E+00	0.00	0.32
***TOTAL OUTFLOW				11.6	3.7	0.00E+00	0.00	0.32
***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	1	3	Inlet Tributary	1251.8	83.1%	0.00E+00		0.00	400.0	132.5
2	1	2	Segment 2 Direct Drainage	181.9	12.1%	0.00E+00		0.00	400.0	132.8
3	1	1	Segment 1 Direct Drainage	62.9	4.2%	0.00E+00		0.00	400.0	131.1
PRECIPITATION				10.4	0.7%	0.00E+00		0.00	29.5	30.0
TRIBUTARY INFLOW				1496.6	99.3%	0.00E+00		0.00	400.0	132.4
***TOTAL INFLOW				1507.0	100.0%	0.00E+00		0.00	368.1	129.4
ADVECTIVE OUTFLOW				371.6	24.7%	0.00E+00		0.00	99.3	31.9
***TOTAL OUTFLOW				371.6	24.7%	0.00E+00		0.00	99.3	31.9
***RETENTION				1135.3	75.3%	0.00E+00		0.00		

Overflow Rate (m/yr)	10.8	Nutrient Resid. Time (yrs)	0.0888
Hydraulic Resid. Time (yrs)	0.2783	Turnover Ratio	5.6
Reservoir Conc (mg/m3)	129	Retention Coef.	0.753

Otter Lake

Water Balance Terms (hm3/yr) **Averaging Period = 0.50 Years**

Seg	Name	External	Inflows Precip	Advect	Storage Increase	Outflows------> Advect	Disch.	Downstr Exchange	Evap
1	Segment 1	1	1	16	0	17	0	0	1
2	Segment 2	1	1	15	0	16	0	15	1
3	Segment 3	2	1	13	0	15	0	35	1
4	Segment 4	13	1	0	0	13	0	13	1
Net		17	3	0	0	17	0	0	3

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

Seg	Name	Inflows--> External	Atmos	Advect	Storage Increase	Outflows-----> Advect	Disch.	Net Exchange	Net Retention
1	Segment 1	190	29	1033	0	956	0	-147	442
2	Segment 2	134	20	1031	0	1033	0	7	144
3	Segment 3	321	22	1526	0	1031	0	-522	1360
4	Segment 4	3518	17	0	0	1526	0	662	1347
Net		4162	88	0	0	956	0	0	3294

Otter 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**
4	1	Segment 1 Direct Drainage	1.4	7.5%	189.9	6.0%	140
PRECIPITATION			1.0	5.4%	28.8	0.9%	30
INTERNAL LOAD			0.0	0.0%	1753.2	55.6%	
TRIBUTARY INFLOW			1.4	7.5%	189.9	6.0%	140
ADVECTIVE INFLOW			15.8	87.1%	1033.5	32.8%	65
NET DIFFUSIVE INFLOW			0.0	0.0%	146.7	4.7%	
***TOTAL INFLOW			18.1	100.0%	3152.1	100.0%	174
ADVECTIVE OUTFLOW			17.2	94.6%	956.4	30.3%	56
***TOTAL OUTFLOW			17.2	94.6%	956.4	30.3%	56
***EVAPORATION			1.0	5.4%	0.0	0.0%	
***RETENTION			0.0	0.0%	2195.7	69.7%	

Hyd. Residence Time =	0.7913	yrs
Overflow Rate =	17.9	m/yr
Mean Depth =	14.1	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**
3	1	Segment 2 Direct Drainage	1.0	5.8%	134.0	5.6%	140
PRECIPITATION			0.7	4.1%	20.0	0.8%	30
INTERNAL LOAD			0.0	0.0%	1219.9	50.7%	
TRIBUTARY INFLOW			1.0	5.8%	134.0	5.6%	140
ADVECTIVE INFLOW			14.9	90.1%	1030.7	42.9%	69
***TOTAL INFLOW			16.5	100.0%	2404.7	100.0%	146
ADVECTIVE OUTFLOW			15.8	95.9%	1033.5	43.0%	65
NET DIFFUSIVE OUTFLOW			0.0	0.0%	6.8	0.3%	
***TOTAL OUTFLOW			15.8	95.9%	1040.3	43.3%	66
***EVAPORATION			0.7	4.1%	0.0	0.0%	
***RETENTION			0.0	0.0%	1364.3	56.7%	

Hyd. Residence Time =	0.3878	yrs
Overflow Rate =	23.7	m/yr
Mean Depth =	9.2	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**
2	1	Segment 3 Direct Drainage	2.3	14.7%	320.7	13.4%	140
PRECIPITATION			0.7	4.7%	21.7	0.9%	30
TRIBUTARY INFLOW			2.3	14.7%	320.7	13.4%	140
ADVECTIVE INFLOW			12.6	80.6%	1526.0	63.8%	121
NET DIFFUSIVE INFLOW			0.0	0.0%	521.9	21.8%	
***TOTAL INFLOW			15.6	100.0%	2390.3	100.0%	153
ADVECTIVE OUTFLOW			14.9	95.3%	1030.7	43.1%	69
***TOTAL OUTFLOW			14.9	95.3%	1030.7	43.1%	69
***EVAPORATION			0.7	4.7%	0.0	0.0%	
***RETENTION			0.0	0.0%	1359.5	56.9%	

Hyd. Residence Time =	0.3650	yrs
Overflow Rate =	20.6	m/yr
Mean Depth =	7.5	m

Component:		**TOTAL P**		**Segment:**	**4**	**Segment 4**	
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
1	1	Inlet Tributary	12.6	95.6%	3517.8	99.5%	280
PRECIPITATION			0.6	4.4%	17.2	0.5%	30
TRIBUTARY INFLOW			12.6	95.6%	3517.8	99.5%	280
***TOTAL INFLOW			13.1	100.0%	3534.9	100.0%	269
ADVECTIVE OUTFLOW			12.6	95.6%	1526.0	43.2%	121
NET DIFFUSIVE OUTFLOW			0.0	0.0%	661.8	18.7%	
***TOTAL OUTFLOW			12.6	95.6%	2187.8	61.9%	174
***EVAPORATION			0.6	4.4%	0.0	0.0%	
***RETENTION			0.0	0.0%	1347.1	38.1%	

Hyd. Residence Time =	0.1396	yrs
Overflow Rate =	21.9	m/yr
Mean Depth =	3.1	m

Otter Lake

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 0.50 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	4	Inlet Tributary	38.0	12.6	0.00E+00	0.00	0.33
2	1	3	Segment 3 Direct Drainage	6.9	2.3	0.00E+00	0.00	0.33
3	1	2	Segment 2 Direct Drainage	2.9	1.0	0.00E+00	0.00	0.33
4	1	1	Segment 1 Direct Drainage	4.1	1.4	0.00E+00	0.00	0.33
PRECIPITATION				2.9	3.0	0.00E+00	0.00	1.02
TRIBUTARY INFLOW				51.9	17.2	0.00E+00	0.00	0.33
***TOTAL INFLOW				54.8	20.1	0.00E+00	0.00	0.37
ADVECTIVE OUTFLOW				54.8	17.2	0.00E+00	0.00	0.31
***TOTAL OUTFLOW				54.8	17.2	0.00E+00	0.00	0.31
***EVAPORATION					3.0	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	4	Inlet Tributary	3517.8	48.7%	0.00E+00		0.00	280.0	92.7
2	1	3	Segment 3 Direct Drainage	320.7	4.4%	0.00E+00		0.00	140.0	46.3
3	1	2	Segment 2 Direct Drainage	134.0	1.9%	0.00E+00		0.00	140.0	46.4
4	1	1	Segment 1 Direct Drainage	189.9	2.6%	0.00E+00		0.00	140.0	46.3
PRECIPITATION				87.7	1.2%	0.00E+00		0.00	29.5	30.0
INTERNAL LOAD				2973.1	41.2%	0.00E+00		0.00		
TRIBUTARY INFLOW				4162.3	57.6%	0.00E+00		0.00	242.5	80.2
***TOTAL INFLOW				7223.1	100.0%	0.00E+00		0.00	358.7	131.8
ADVECTIVE OUTFLOW				956.4	13.2%	0.00E+00		0.00	55.7	17.5
***TOTAL OUTFLOW				956.4	13.2%	0.00E+00		0.00	55.7	17.5
***RETENTION				6266.7	86.8%	0.00E+00		0.00		

Overflow Rate (m/yr)	5.9	Nutrient Resid. Time (yrs)	0.2762
Hydraulic Resid. Time (yrs)	1.5665	Turnover Ratio	1.8
Reservoir Conc (mg/m3)	74	Retention Coef.	0.868

Otter Lake

Variable = TOTAL P MG/M3 **R^2 = 0.09**

Global Calibration Factor = 1.00 **CV = 0.45**

			Calibration Factor		Predicted		Observed		Log (Obs/Pred)		
Seg	**Group**	**Name**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**SE**	**t**
1	1	Segment 1	1.00	0.00	55.7	0.00	101.0	0.00	0.59	0.00	0.00
2	1	Segment 2	1.00	0.00	65.4	0.00	33.0	0.00	-0.68	0.00	0.00
3	1	Segment 3	1.00	0.00	69.4	0.00	72.0	0.00	0.04	0.00	0.00
4	1	Segment 4	1.00	0.00	121.5	0.00	111.0	0.00	-0.09	0.00	0.00
5	1	Area-Wtd Mean			74.2	0.00	80.3	0.00	0.08	0.00	0.00

Otter 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

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	80.3	0.00	74.2	0.00	1.08		0.29	

Segment: 1 Segment 1

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	101.0	0.00	55.7	0.00	1.81		2.21	

Segment: 2 Segment 2

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	33.0	0.00	65.4	0.00	0.50		-2.54	

Segment: 3 Segment 3

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	72.0	0.00	69.4	0.00	1.04		0.14	

Segment: 4 Segment 4

Variable		Observed Mean	CV	Predicted Mean	CV	Obs/Pred Ratio	T-Statistics ----> T1	T2	T3
TOTAL P	MG/M3	111.0	0.00	121.5	0.00	0.91		-0.33	

Otter Lake

Segment	Name
1	Segment 1
2	Segment 2
3	Segment 3
4	Segment 4
Mean	Area-Wtd Mean

PREDICTED CONCENTRATIONS:

Variable Segment-->	1	2	3	4	Mean
TOTAL P MG/M3	55.7	65.4	69.4	121.5	74.2
TURBIDITY 1/M	0.8	0.8	0.5	0.5	0.7
ZMIX * TURBIDITY	5.7	5.3	3.0	1.5	4.1
CARLSON TSI-P	62.1	64.4	65.3	73.4	65.6

OBSERVED CONCENTRATIONS:

Variable Segment-->	1	2	3	4	Mean
TOTAL P MG/M3	101.0	33.0	72.0	111.0	80.3
CHL-A MG/M3	17.0	19.0	31.0	57.0	28.8
SECCHI M	1.1	1.0	0.5	0.4	0.8
ANTILOG PC-1	397.7	465.4	1425.8	2969.6	1171.3
ANTILOG PC-2	9.9	10.2	8.2	10.9	9.8
TURBIDITY 1/M	0.8	0.8	0.5	0.5	0.7
ZMIX * TURBIDITY	5.7	5.3	3.0	1.5	4.1
ZMIX / SECCHI	6.9	6.2	11.3	7.0	7.8
CHL-A * SECCHI	18.9	19.9	16.1	25.1	19.7
CHL-A / TOTAL P	0.2	0.6	0.4	0.5	0.4
FREQ(CHL-a>10) %	70.7	76.6	93.5	99.4	83.3
FREQ(CHL-a>20) %	28.4	34.7	65.4	91.6	51.4
FREQ(CHL-a>30) %	11.0	14.8	39.8	76.6	31.8
FREQ(CHL-a>40) %	4.5	6.5	23.5	60.3	20.6
FREQ(CHL-a>50) %	2.0	3.1	14.0	46.1	13.8
FREQ(CHL-a>60) %	1.0	1.5	8.5	34.7	9.6
CARLSON TSI-P	70.7	54.6	65.8	72.1	66.1
CARLSON TSI-CHLA	58.4	59.5	64.3	70.3	62.4
CARLSON TSI-SEC	58.5	59.3	69.4	71.8	64.0

OBSERVED/PREDICTED RATIOS:

Variable Segment-->	1	2	3	4	Mean
TOTAL P MG/M3	1.8	0.5	1.0	0.9	1.1
TURBIDITY 1/M	1.0	1.0	1.0	1.0	1.0
ZMIX * TURBIDITY	1.0	1.0	1.0	1.0	1.0
CARLSON TSI-P	1.1	0.8	1.0	1.0	1.0

OBSERVED STANDARD ERRORS

Variable Segment-->	1	2	3	4	Mean

PREDICTED STANDARD ERRORS

Variable Segment-->	1	2	3	4	Mean

Otter Lake

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment:	**5**	**Area-Wtd Mean**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	74.2		68.7%	80.3		71.7%
CHL-A MG/M3				28.8		92.7%
SECCHI M				0.8		35.8%
ANTILOG PC-1				1171.3		88.4%
ANTILOG PC-2				9.8		78.7%
TURBIDITY 1/M	0.7		53.2%	0.7		53.2%
ZMIX * TURBIDITY	4.1		63.4%	4.1		63.4%
ZMIX / SECCHI				7.8		80.3%
CHL-A * SECCHI				19.7		82.3%
CHL-A / TOTAL P				0.4		86.4%
FREQ(CHL-a>10) %				83.3		92.7%
FREQ(CHL-a>20) %				51.4		92.7%
FREQ(CHL-a>30) %				31.8		92.7%
FREQ(CHL-a>40) %				20.6		92.7%
FREQ(CHL-a>50) %				13.8		92.7%
FREQ(CHL-a>60) %				9.6		92.7%
CARLSON TSI-P	65.6		68.7%	66.1		71.7%
CARLSON TSI-CHLA				62.4		92.7%
CARLSON TSI-SEC				64.0		64.2%

Segment:	**1**	**Segment 1**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	55.7		56.7%	101.0		79.6%
CHL-A MG/M3				17.0		78.0%
SECCHI M				1.1		51.4%
ANTILOG PC-1				397.7		64.4%
ANTILOG PC-2				9.9		79.6%
TURBIDITY 1/M	0.8		59.4%	0.8		59.4%
ZMIX * TURBIDITY	5.7		77.9%	5.7		77.9%
ZMIX / SECCHI				6.9		73.5%
CHL-A * SECCHI				18.9		80.8%
CHL-A / TOTAL P				0.2		40.5%
FREQ(CHL-a>10) %				70.7		78.0%
FREQ(CHL-a>20) %				28.4		78.0%
FREQ(CHL-a>30) %				11.0		78.0%
FREQ(CHL-a>40) %				4.5		78.0%
FREQ(CHL-a>50) %				2.0		78.0%
FREQ(CHL-a>60) %				1.0		78.0%
CARLSON TSI-P	62.1		56.7%	70.7		79.6%
CARLSON TSI-CHLA				58.4		78.0%
CARLSON TSI-SEC				58.5		48.6%

Segment:	2	Segment 2				
	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	65.4		63.5%	33.0		33.9%
CHL-A MG/M3				19.0		82.0%
SECCHI M				1.0		48.5%
ANTILOG PC-1				465.4		68.8%
ANTILOG PC-2				10.2		81.2%
TURBIDITY 1/M	0.8		62.7%	0.8		62.7%
ZMIX * TURBIDITY	5.3		74.7%	5.3		74.7%
ZMIX / SECCHI				6.2		67.4%
CHL-A * SECCHI				19.9		82.8%
CHL-A / TOTAL P				0.6		95.5%
FREQ(CHL-a>10) %				76.6		82.0%
FREQ(CHL-a>20) %				34.7		82.0%
FREQ(CHL-a>30) %				14.8		82.0%
FREQ(CHL-a>40) %				6.5		82.0%
FREQ(CHL-a>50) %				3.1		82.0%
FREQ(CHL-a>60) %				1.5		82.0%
CARLSON TSI-P	64.4		63.5%	54.6		33.9%
CARLSON TSI-CHLA				59.5		82.0%
CARLSON TSI-SEC				59.3		51.5%

Segment:	3	Segment 3				
	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	69.4		66.0%	72.0		67.5%
CHL-A MG/M3				31.0		94.0%
SECCHI M				0.5		16.8%
ANTILOG PC-1				1425.8		91.1%
ANTILOG PC-2				8.2		68.1%
TURBIDITY 1/M	0.5		41.1%	0.5		41.1%
ZMIX * TURBIDITY	3.0		46.6%	3.0		46.6%
ZMIX / SECCHI				11.3		93.2%
CHL-A * SECCHI				16.1		74.1%
CHL-A / TOTAL P				0.4		89.2%
FREQ(CHL-a>10) %				93.5		94.0%
FREQ(CHL-a>20) %				65.4		94.0%
FREQ(CHL-a>30) %				39.8		94.0%
FREQ(CHL-a>40) %				23.5		94.0%
FREQ(CHL-a>50) %				14.0		94.0%
FREQ(CHL-a>60) %				8.5		94.0%
CARLSON TSI-P	65.3		66.0%	65.8		67.5%
CARLSON TSI-CHLA				64.3		94.0%
CARLSON TSI-SEC				69.4		83.2%

Segment: **4** **Segment 4**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	121.5		84.9%	111.0		82.5%
CHL-A MG/M3				57.0		99.0%
SECCHI M				0.4		11.9%
ANTILOG PC-1				2969.6		97.2%
ANTILOG PC-2				10.9		84.2%
TURBIDITY 1/M	0.5		41.1%	0.5		41.1%
ZMIX * TURBIDITY	1.5		17.6%	1.5		17.6%
ZMIX / SECCHI				7.0		74.1%
CHL-A * SECCHI				25.1		89.8%
CHL-A / TOTAL P				0.5		93.5%
FREQ(CHL-a>10) %				99.4		99.0%
FREQ(CHL-a>20) %				91.6		99.0%
FREQ(CHL-a>30) %				76.6		99.0%
FREQ(CHL-a>40) %				60.3		99.0%
FREQ(CHL-a>50) %				46.1		99.0%
FREQ(CHL-a>60) %				34.7		99.0%
CARLSON TSI-P	73.4		84.9%	72.1		82.5%
CARLSON TSI-CHLA				70.3		99.0%
CARLSON TSI-SEC				71.8		88.1%

Otter 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	17.2	0.7913	17.9	2.2	7.2	1.9	0.0
2	Segment 2	1	15.8	0.3878	23.7	4.3	10.6	3.6	15.2
3	Segment 3	2	14.9	0.3650	20.6	4.1	17.5	3.1	34.8
4	Segment 4	3	12.6	0.1396	21.9	14.6	45.1	14.9	12.7

Morphometry

Seg	Name	Area km^2	Zmean m	Zmix m	Length km	Volume hm^3	Width km	L/W -
1	Segment 1	1.0	14.1	7.6	1.7	13.6	0.6	3.2
2	Segment 2	0.7	9.2	6.5	1.7	6.1	0.4	4.2
3	Segment 3	0.7	7.5	5.9	1.5	5.4	0.5	3.1
4	Segment 4	0.6	3.1	3.1	2.0	1.8	0.3	7.3
Totals		2.9	9.2			26.9		

Otter Lake

Segment & Tributary Network

--------Segment:	1	Segment 1		
Outflow Segment:	0	Out of Reservoir		
Tributary:	4	Segment 1 Direct Drainage	Type:	Monitored Inflow
--------Segment:	2	Segment 2		
Outflow Segment:	1	Segment 1		
Tributary:	3	Segment 2 Direct Drainage	Type:	Monitored Inflow
--------Segment:	3	Segment 3		
Outflow Segment:	2	Segment 2		
Tributary:	2	Segment 3 Direct Drainage	Type:	Monitored Inflow
--------Segment:	4	Segment 4		
Outflow Segment:	3	Segment 3		
Tributary:	1	Inlet Tributary	Type:	Monitored Inflow

Otter Lake
Description:
Single reservoir (765 acres)
4 segments

Global Variables	Mean	CV
Averaging Period (yrs)	0.5	0.0
Precipitation (m)	0.508	0.0
Evaporation (m)	0.508	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	1	DECAY RATES
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	0.96	14.15	1.74	7.63	0.12	5.16	0	0.75	0	0	0	5	0	0	0
2	Segment 2	1	1	0.668	9.18	1.68	6.51	0.12	5.03	0	0.81	0	0	0	5	0	0	0
3	Segment 3	2	1	0.722	7.51	1.5	5.9	0.12	2.79	0	0.5	0	0	0	0	0	0	0
4	Segment 4	3	1	0.573	3.06	2.04	3.06	0.12	1.81	0	0.5	0	0	0	0	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	101	0	0	0	17	0	1.11	0	0	0	0	0	0	0	0	0
2	0	0	33	0	0	0	19	0	1.05	0	0	0	0	0	0	0	0	0
3	0	0	72	0	0	0	31	0	0.52	0	0	0	0	0	0	0	0	0
4	0	0	111	0	0	0	57	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
4	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	4	1	37.96	12.5634	0	0	0	280	0	0	0	0	0	0	0
2	Segment 3 Direct Drainage	3	1	6.92	2.2907	0	0	0	140	0	0	0	0	0	0	0
3	Segment 2 Direct Drainage	2	1	2.89	0.9569	0	0	0	140	0	0	0	0	0	0	0
4	Segment 1 Direct Drainage	1	1	4.1	1.3562	0	0	0	140	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	32.44	1.8	2.51	0.23	0.53	0.45	0	0
2	Segment 3 Direct Drainage	4.26	0.35	1.26	0.09	0.28	0.67	0	0
3	Segment 2 Direct Drainage	1.16	0.21	0.51	0.13	0.29	0.6	0	0
4	Segment 1 Direct Drainage	2.05	0.18	0.55	0.02	0.37	0.93	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	0.331	0	0	0	140	0	0	0	0	0	0	0
2	Grassland	0.331	0	0	0	140	0	0	0	0	0	0	0
3	Forest	0.331	0	0	0	140	0	0	0	0	0	0	0
4	Urban	0.331	0	0	0	140	0	0	0	0	0	0	0
5	Wetland	0.331	0	0	0	140	0	0	0	0	0	0	0
6	Other	0.331	0	0	0	140	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)	0.007	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

Palmyra-Modesto Lake

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 4 Area-Wtd Mean

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	125.0		85.7%	120.3		84.7%
CHL-A MG/M3				62.6		99.3%
SECCHI M				0.3		3.4%
ANTILOG PC-1				6019.3		99.3%
ANTILOG PC-2				7.9		65.4%
TURBIDITY 1/M	1.2		76.8%	1.2		76.8%
ZMIX * TURBIDITY	5.2		73.9%	5.2		73.9%
ZMIX / SECCHI				26.2		99.8%
CHL-A * SECCHI				17.4		77.5%
CHL-A / TOTAL P				0.6		96.3%
FREQ(CHL-a>10) %				99.6		99.3%
FREQ(CHL-a>20) %				93.5		99.3%
FREQ(CHL-a>30) %				80.6		99.3%
FREQ(CHL-a>40) %				65.7		99.3%
FREQ(CHL-a>50) %				51.9		99.3%
FREQ(CHL-a>60) %				40.4		99.3%
CARLSON TSI-P	73.7		85.7%	72.3		84.7%
CARLSON TSI-CHLA				71.2		99.3%
CARLSON TSI-SEC				80.4		96.6%

Segment: 1 Segment 1

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	112.5		82.9%	166.0		91.6%
CHL-A MG/M3				59.0		99.2%
SECCHI M				0.2		0.5%
ANTILOG PC-1				8365.5		99.6%
ANTILOG PC-2				4.8		29.3%
TURBIDITY 1/M	1.0		71.3%	1.0		71.3%
ZMIX * TURBIDITY	6.4		81.9%	6.4		81.9%
ZMIX / SECCHI				42.6		100.0%
CHL-A * SECCHI				8.9		42.1%
CHL-A / TOTAL P				0.4		82.5%
FREQ(CHL-a>10) %				99.5		99.2%
FREQ(CHL-a>20) %				92.4		99.2%
FREQ(CHL-a>30) %				78.3		99.2%
FREQ(CHL-a>40) %				62.4		99.2%
FREQ(CHL-a>50) %				48.3		99.2%
FREQ(CHL-a>60) %				36.8		99.2%
CARLSON TSI-P	72.3		82.9%	77.9		91.6%
CARLSON TSI-CHLA				70.6		99.2%
CARLSON TSI-SEC				87.3		99.5%

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

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	127.7		86.2%	75.0		69.1%
CHL-A MG/M3				69.0		99.5%
SECCHI M				0.4		10.1%
ANTILOG PC-1				3802.1		98.2%
ANTILOG PC-2				11.7		87.4%
TURBIDITY 1/M	0.3		15.6%	0.3		15.6%
ZMIX * TURBIDITY	1.4		15.3%	1.4		15.3%
ZMIX / SECCHI				13.9		96.7%
CHL-A * SECCHI				28.3		92.5%
CHL-A / TOTAL P				0.9		99.2%
FREQ(CHL-a>10) %				99.7		99.5%
FREQ(CHL-a>20) %				95.4		99.5%
FREQ(CHL-a>30) %				84.9		99.5%
FREQ(CHL-a>40) %				71.5		99.5%
FREQ(CHL-a>50) %				58.3		99.5%
FREQ(CHL-a>60) %				46.6		99.5%
CARLSON TSI-P	74.1		86.2%	66.4		69.1%
CARLSON TSI-CHLA				72.1		99.5%
CARLSON TSI-SEC				72.8		89.9%

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

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	152.5		90.1%	106.0		81.1%
CHL-A MG/M3				57.0		99.0%
SECCHI M				0.3		2.7%
ANTILOG PC-1				5029.4		98.9%
ANTILOG PC-2				7.0		56.6%
TURBIDITY 1/M	3.9		98.2%	3.9		98.2%
ZMIX * TURBIDITY	11.1		94.8%	11.1		94.8%
ZMIX / SECCHI				11.5		93.5%
CHL-A * SECCHI				14.3		68.2%
CHL-A / TOTAL P				0.5		94.4%
FREQ(CHL-a>10) %				99.4		99.0%
FREQ(CHL-a>20) %				91.6		99.0%
FREQ(CHL-a>30) %				76.6		99.0%
FREQ(CHL-a>40) %				60.3		99.0%
FREQ(CHL-a>50) %				46.1		99.0%
FREQ(CHL-a>60) %				34.7		99.0%
CARLSON TSI-P	76.6		90.1%	71.4		81.1%
CARLSON TSI-CHLA				70.3		99.0%
CARLSON TSI-SEC				80.0		97.3%

Palmyra-Modesto Lake

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 0.50 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	3.7	1.0	0.00E+00	0.00	0.27
2	2	2	Segment 2 Direct Drainage	0.5	0.1	0.00E+00	0.00	0.27
3	2	1	Segment 1 Direct Drainage	0.3	0.1	0.00E+00	0.00	0.27
PRECIPITATION				0.1	0.1	0.00E+00	0.00	1.02
NONPOINT INFLOW				4.4	1.2	0.00E+00	0.00	0.27
***TOTAL INFLOW				4.5	1.3	0.00E+00	0.00	0.30
ADVECTIVE OUTFLOW				4.5	1.2	0.00E+00	0.00	0.27
***TOTAL OUTFLOW				4.5	1.2	0.00E+00	0.00	0.27
***EVAPORATION					0.1	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	2	3	Inlet Tributary	115.9	10.5%	0.00E+00		0.00	116.0	31.7
2	2	2	Segment 2 Direct Drainage	14.9	1.4%	0.00E+00		0.00	116.0	31.7
3	2	1	Segment 1 Direct Drainage	7.9	0.7%	0.00E+00		0.00	116.0	31.7
PRECIPITATION				3.9	0.4%	0.00E+00		0.00	29.5	30.0
INTERNAL LOAD				957.0	87.0%	0.00E+00		0.00		
NONPOINT INFLOW				138.7	12.6%	0.00E+00		0.00	116.0	31.7
***TOTAL INFLOW				1099.6	100.0%	0.00E+00		0.00	827.3	244.3
ADVECTIVE OUTFLOW				134.6	12.2%	0.00E+00		0.00	112.5	29.9
***TOTAL OUTFLOW				134.6	12.2%	0.00E+00		0.00	112.5	29.9
***RETENTION				965.1	87.8%	0.00E+00		0.00		

Overflow Rate (m/yr)	9.1	Nutrient Resid. Time (yrs)	0.1073
Hydraulic Resid. Time (yrs)	0.7891	Turnover Ratio	4.7
Reservoir Conc (mg/m3)	125	Retention Coef.	0.878

Palmyra-Modesto 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	1.2	0.4277	20.6	1.0	1.2	0.1	0.0
2	Segment 2	1	1.1	0.3297	21.7	1.2	0.4	0.2	0.3
3	Segment 3	2	1.0	0.0605	47.6	4.0	1.2	0.5	0.8

Morphometry

Seg	Name	Area km^2	Zmean m	Zmix m	Length km	Volume hm^3	Width km	L/W -
1	Segment 1	0.1	8.8	6.4	0.2	0.5	0.3	0.8
2	Segment 2	0.1	7.2	5.7	0.4	0.4	0.1	3.1
3	Segment 3	0.0	2.9	2.9	0.2	0.1	0.1	2.7
Totals		0.1	7.2			0.9		

Palmyra-Modesto Lake

Segment & Tributary Network

--------Segment:	1	Segment 1		
Outflow Segment:	0	Out of Reservoir		
Tributary:	3	Segment 1 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

Palmyra-Modesto Lake
Description:
Single reservoir (35 acres)
3 segments

Global Variables	Mean	CV
Averaging Period (yrs)	0.5	0.0
Precipitation (m)	0.508	0.0
Evaporation (m)	0.508	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	0.058	8.82	0.21	6.39	0	5.53	0	1	0	0	0	20	0	0	0
2	Segment 2	1	1	0.052	7.15	0.4	5.7	0	1.81	0	0.25	0	0	0	20	0	0	0
3	Segment 3	2	1	0.021	2.88	0.24	2.88	0	1.4	0	3.86	0	0	0	20	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	166	0	0	0	59	0	0.15	0	0	0	0	0	0	0	0	0
2	0	0	75	0	0	0	69	0	0.41	0	0	0	0	0	0	0	0	0
3	0	0	106	0	0	0	57	0	0.25	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	3.65	0.9986	0	0	0	0	0	0	0	0	0	0	0
2	Segment 2 Direct Drainage	2	2	0.47	0.1284	0	0	0	0	0	0	0	0	0	0	0
3	Segment 1 Direct Drainage	1	2	0.25	0.0687	0	0	0	0	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	3.19	0.3	0.03	0.05	0.05	0.03	0	0
2	Segment 2 Direct Drainage	0.26	0.05	0.05	0.02	0.05	0.04	0	0
3	Segment 1 Direct Drainage	0.13	0.01	0.03	0	0.03	0.05	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	0.2737	0	0	0	116	0	0	0	0	0	0	0
2	Grassland	0.2737	0	0	0	116	0	0	0	0	0	0	0
3	Forest	0.2737	0	0	0	116	0	0	0	0	0	0	0
4	Urban	0.2737	0	0	0	116	0	0	0	0	0	0	0
5	Wetland	0.2737	0	0	0	116	0	0	0	0	0	0	0
6	Other	0.2737	0	0	0	116	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)	0.002	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

Attachment 2. Responsiveness Summary

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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 19, 2005, postmarked, including those from the August 3, 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 Otter, Palmyra-Modesto and Hettick 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 watershed targeted for TMDL development is Hodges Creek, which is located in West-Central Illinois approximately 45 miles south of Springfield. The majority of Hodges Creek's Watershed is in Macoupin County, with small portions extending into Greene, Jersey, Morgan, and Sangamon Counties. The watershed for Hodges Creek is approximately 148,961 acres (233 square miles) in size. TMDLs developed for impaired water bodies in the Hodges Creek Watershed include Otter Lake (RDF), Palmyra-Modesto Lake (RDZP), and Hettick Lake (SDZF). A fourth waterbody in the Hodges Creek Watershed will be addressed in a separate TMDL report. As part of the Section 303(d) listing process, the Illinois EPA identified Hodges Creek segment DAG 02 as an impaired waterbody. During the data review stage of this TMDL study, a determination was made that additional data are required.

In the 2004 303(d) List, Otter Lake (RDF) was listed as impaired for the following parameters: manganese and excess algal growth. Palmyra-Modesto Lake (RDZP) was listed as impaired for the following parameters: manganese, dissolved oxygen, pH, and excess algal growth. Hettick Lake (SDZF) was listed as impaired for the following parameters: total phosphorus, dissolved oxygen, excess algal growth and unspecified nutrients. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were developed for manganese for Otter Lake (RDF), for manganese, DO and pH for Palmyra-Modesto Lake (RDZP), and for total phosphorus and DO for Hettick Lake (SDZF). The Illinois EPA contracted with Limno-Tech, Inc. to prepare a TMDL report for the Hodges Creek Watershed.

Public Meetings

Public meetings were held in the City of Girard on March 22, 2005, and August 3, 2005. The Illinois EPA provided public notice for the March 22, 2005, meeting by placing display ads in the *Girard Gazette* and *Palmyra Northwestern News* on February 9, 2005, in the *Carlinville*

Enquirer-Democrat on February 10, 2005, and the *Springfield State Journal-Register* on February 11, 2005. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 34 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the Otter Lake Water Commission offices and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl.

The final public meeting started at approximately 6:30 p.m. on Wednesday, August 3,2005. It was attended by approximately seven people and concluded at 8:30 p.m. with the meeting record remaining open until midnight, August 19, 2005. The Illinois EPA received no written substantive questions and comments during the public comment period.

Questions and Comments

1. Is there anything that can really be done about manganese?

Response: Improving the dissolved oxygen and nutrient concentrations in the lake on a seasonal basis will also improve the ability of the manganese in the lake to remain bound to the lake sediment. Under anoxic conditions in the lower depths of the lake (hypolimnion), which now occurs due to water temperature induced stratification of the lake, concentrations of DO, P and Mn are all adversely affected as the sediment releases P and MN to the water column.

2. I think there would be a tremendous demand for cost-share ponds in the watershed. Ponds would help reduce loading to the lake, enhance property values and serve as an educational tool to landowners. I estimate that a 50/50 cost share would probably be enough of an incentive.

Response: That is an interesting idea and is something that can be looked at further as we develop the Implementation Plan.

FINAL TMDL

Hodges Creek (DAG 02)

Hodges Creek Watershed

Prepared for Illinois Environmental Protection Agency

September 2006

Hodges Creek (IL_DAG-02): Dissolved oxygen

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INTRODUCTION

Section 303(d) of the 1972 Clean Water Act requires States to define impaired waters and identify them on a list, which is referred to as the 303(d) list. The State of Illinois recently issued the 2006 303(d) list, 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).

Hodges Creek (Segment IL_DAG-02) is listed on the 2006 Illinois Section 303(d) List of Impaired Waters (IEPA, 2006) as a waterbody that is not meeting its designated uses. As such, it has been targeted as a high priority waterbody for TMDL development. This document presents the TMDL designed to allow this waterbody to fully support its 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 listing of Hodges Creek on the 303(d) list (IEPA, 2006) is summarized below, with the parameter (cause) that it is listed for, and the impairment status of each designated use.

Hodges Creek	
Assessment Unit ID	IL_DAG-02
Length (miles)	10.7
Listed For	**Dissolved oxygen**
Use Support[1]	Aquatic life (N), Fish consumption (X), Primary contact (X), Secondary contact (X), Aesthetic quality (X)

[1]F = Fully supporting, N=not supporting, X= not assessed

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2 REQUIRED TMDL ELEMENTS

USEPA Region 5 guidance for TMDL development requires TMDLs to contain eleven specific components. Each of these components is summarized below.

Hodges Creek (IL_DAG-02)

1. **Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking:**

   Hodges Creek, HUC 07130012. The impairment of concern addressed in this TMDL is dissolved oxygen. Potential sources contributing to the listing of this segment of Hodges Creek include: creek bottom sediments, permitted point sources, failing private sewage disposal systems and runoff from lawns and agricultural lands.

   Hodges Creek is reported on the 2006 303(d) list as being in category 5, meaning available data and/or information indicate that at least one designated use is not being supported or is threatened, and a TMDL is needed (IEPA, 2006).

2. **Description of Applicable Water Quality Standards and Numeric Water Quality Target:**

   The IEPA guidelines (IEPA, 2006) for identifying **dissolved oxygen** as a cause of impairment in streams state that dissolved oxygen is a potential cause of impairment of the aquatic life use if greater than 10% of the samples are less than 5 mg/l. The TMDL target for dissolved oxygen is 5 mg/l. For QUAL2E model runs, a modeling target of 6.0 mg/l was used to consider diurnal variation and ensure that the 5.0 mg/l water quality standard is met.

3. **Loading Capacity – Linking Water Quality and Pollutant Sources:**

   Based on a review of all available data, dissolved oxygen violations of the water quality standard were observed to occur only during low flow conditions. The QUAL2E water quality model was calibrated to observed data for Hodges Creek and used to define the reduction in pollutant load required to attain water quality standards. Examination of model results indicated that sediment oxygen demand (SOD) was the dominant source of the oxygen deficit. QUAL2E water quality model simulations for low flow conditions showed that, even with external BOD and ammonia loads set to zero, compliance with the dissolved oxygen standards was not attained without a reduction in SOD. Although SOD is the overwhelming oxygen sink, the true cause of low DO is a lack of base flow (which greatly exacerbates the effect of SOD). Because TMDLs cannot be written to control flow, the focus of this TMDL was instead on SOD, as its effect on dissolved oxygen is dominant under low flow conditions. Ammonia and BOD5 are also addressed in this TMDL.

QUAL2E simulations show that SOD must be reduced by 35% during low flow conditions to meet the TMDL target for dissolved oxygen, assuming that other sources are maintained at existing loads. To achieve this, a 35% reduction of particulate organic carbon loading to the stream is required.

The load capacity is calculated as follows:

CBOD5 Load Capacity (lbs/day)	Ammonia Load Capacity (lbs/day)		
	March	Apr. – Oct.	Nov. – Feb.
83	13	7	18

4. Load Allocations (LA):

Load allocations designed to achieve compliance with the dissolved oxygen TMDL are as follows:

CBOD5 LA (lbs/day)	Ammonia LA (lbs/day)
0.325	0.046

5. Wasteload Allocations (WLA):

Most of the point sources that discharge to this segment, including the Chesterfield, Palmyra and Hettick sewage treatment plants (STPs), are small facilities that were determined not to contribute to low dissolved oxygen. The Palmyra STP is a lagoon system located on Solomon Creek, a tributary to Hodges Creek, a substantial distance from the mainstem. This STP was observed not to be discharging during the 2005 field surveys, and the tributary to which it discharges was dry. The Hettick STP is a lagoon system located on a tributary to Hodges Creek. According to IEPA records, this facility has periodic discharges between March and May, November and December. This facility was not discharging during the 2005 field surveys and the receiving stream was dry. The Chesterfield STP is a small lagoon system that discharges to Bear Creek, a tributary to Hodges Creek. According to IEPA records, this facility discharges intermittently between December and February and has flows that are so low that the effluent discharged to a drainage ditch rarely reaches the receiving water. The Girard STP is by far the largest point source, discharging to Otter Creek, approximately 23 miles upstream of the listed Hodges Creek segment. Because of its location far from the impaired segment, this discharge has a negligible effect on dissolved oxygen levels in Hodges Creek. Because of their negligible contributions, the WLAs for the four dischargers were calculated from their current permit limits for flow, CBOD5 and ammonia; no reductions are necessary. WLAs for Hodges Creek segment IL_DAG-02 are as follows:

Season	CBOD5 WLA (lbs/day)	Ammonia WLA (lbs/day)
March	82	13
Apr - Oct	82	7
Nov - Feb	82	18

In addition to the WLAs presented above, the Girard STP also has an excess flow discharge that is very infrequent. The WLA for excess flow discharges was based on a presumed flow, and current water quality permit limits. Under high flow conditions, an additional WLA of 29 lbs/day CBOD5 is allocated to the Girard excess flow bypass.

6. Margin of Safety:

The dissolved oxygen TMDL contains an explicit margin of safety of 10% of the load allocation, corresponding to the values shown below. A 10% margin of safety is considered to be adequate to address the uncertainty in the TMDL, based upon the data available.

CBOD5 MOS (lbs/day)	Ammonia MOS (lbs/day)
0.036	0.005

7. Seasonal Variation:

The dissolved oxygen TMDL was conducted with an explicit consideration of seasonal variation. The TMDL was evaluated for a range of flow conditions that are expected to be observed throughout the year. Dissolved oxygen problem are only predicted to occur during low flow periods. Furthermore, this TMDL requires a 35% reduction in watershed loadings of particulate organic carbon, which are expected to be delivered to the stream during wet weather conditions. Finally, this TMDL considers seasonal ammonia permit limits for the sewage treatment plants, where applicable.

8. Reasonable Assurances:

In terms of reasonable assurances for point sources, Illinois EPA administers the NPDES permitting program for treatment plants, stormwater permitting and CAFO permitting. The permits for the point source dischargers in the watershed will be modified if necessary as part of the permit review process (typically every 5 years), to ensure that they are 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.

The involvement of 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 Watershed Characterization Report.

9. Monitoring Plan to Track TMDL Effectiveness:

A monitoring plan will be prepared as part of the implementation plan.

10. Transmittal Letter:

A letter was included with the transmittal of this TMDL 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 (Stage 1 Report). As quarterly progress reports were produced, the Agency posted them to their website. A public meeting was held on March 22, 2005 in Girard, Illinois to present the results of this work.

The draft TMDL was posted on the Agency's website for public comment. A second public meeting was subsequently held in Girard, Illinois on August 2, 2006 to present the TMDL. In addition to the meeting's sponsors, two individuals attended the meeting.

3 WATERSHED CHARACTERIZATION

A description of the Hodges Creek watershed to support the identification of sources contributing to the listed impairments is provided in the Stage 1 Report. The Stage 1 Report is divided into sections, called Quarterly Progress Reports. 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 watershed, including geology and soils, climate, land cover, hydrology, urbanization and population growth, point source discharges and watershed activities.

The Hodges Creek watershed is located in West-Central Illinois approximately 45 miles south of Springfield. The majority of Hodges Creek's watershed is in Macoupin County (97%), with small portions extending into Greene, Jersey, Morgan, and Sangamon County. The watershed for Hodges Creek is approximately 148,961 acres (233 square miles) in size.

The Hodges Creek watershed is predominantly agricultural (72%) and forested (16%). Six small communities are located in the watershed and are: Chesterfield, Girard, Hettick, Modesto, Palmyra, and Virden. Permit information is available for four entities that are permitted to discharge treated wastewater to Hodges Creek or its tributaries. In addition, there is one water treatment plant permitted to discharge filter backwash. Another facility, Illini Feeders, is a confined animal feeding operation (CAFO) that is no longer in operation. This facility has the potential for releases from an old waste lagoon. Most towns are served by sewer, but within Macoupin County, there are approximately 3,000 surface discharge systems. Figure 1 shows a map of the Hodges Creek watershed, and includes key features such as waterways, impaired waterbodies, and public water intakes. The map also shows the locations of point source discharges that have a permit to discharge under the National Pollutant Discharge Elimination System (NPDES). The Stage 1 Report provides detailed characterizations of the impaired waterways and their watersheds.

In 2001, IEPA conducted a survey of Hodges Creek during low flow conditions. During this period, low dissolved oxygen concentrations were measured in Hodges Creek near the mouth. In August and October 2005, additional low-flow sampling was conducted at two locations in the listed Hodges Creek segment (near the mouth and at an upstream location). In total six dissolved oxygen measurements were recorded in Hodges Creek segment IL_DAG-02 between 2001 and 2005. A review of these data showed that two of the six measurements (both in 2001) were below the minimum dissolved oxygen standard of 5.0 mg/l. All four measurements taken in 2005 were above 5.0 mg/l standard; however, 58% of the continuous dissolved oxygen measurements collected at the downstream end of the segment in August 2005 showed violations of the 5.0 mg/l water quality standard. All dissolved oxygen measurements, and violations of the water quality standard were recorded during low flow conditions. The data are summarized in the Stage 2 data report.

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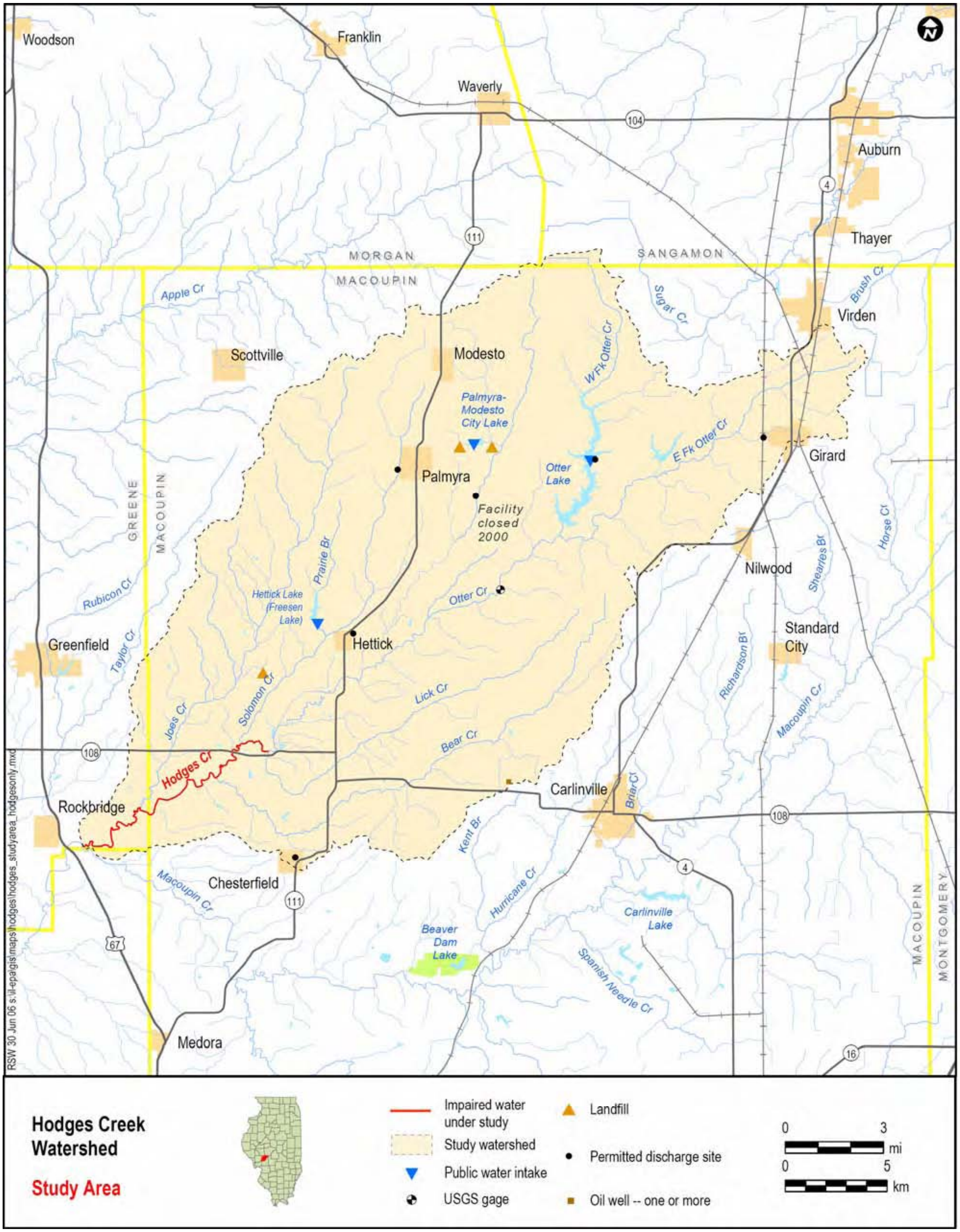

Figure 1. Base Map of the Hodges Creek Watershed

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4 DESCRIPTION OF APPLICABLE STANDARDS AND NUMERIC TARGETS

The ultimate goal of TMDL development is to achieve attainment with water quality standards. A water quality standard consists of 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. Water quality criteria are sometimes in a form that are not directly amenable for use in TMDL development and may need to be translated into a target value for TMDLs. This section discusses the applicable designated uses, use support, criteria and TMDL targets for Hodges Creek.

4.1 DESIGNATED USES AND USE SUPPORT

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

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

Water bodies assessed as "Not Supporting" 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 (IEPA, 2006).

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

4.2 WATER QUALITY CRITERIA

Illinois has established water quality criteria and guidelines for allowable concentrations of dissolved oxygen under its CWA Section 305(b) program, as summarized below.

4.2.1 Dissolved oxygen

The water quality standard for dissolved oxygen in Illinois waters designated for aquatic life is 5.0 mg/l. The aquatic life guideline for streams indicates impairment if more than 10% of the observations measured in the last five years are below 5 mg/l. The available data confirm that the listing of Hodges Creek (IL_DAG-02) for dissolved oxygen 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.

4.3.1 Dissolved oxygen

The water quality standard for dissolved oxygen in Illinois waters designated for aquatic life is that dissolved oxygen shall not be less than 6.0 mg/l during at least 16 hours of any 24 hour period, nor less than 5.0 mg/l at any time. For Hodges Creek (IL_DAG-02) the target was based upon the water quality criterion for minimum dissolved oxygen of 5 mg/l. The QUAL2E model used to calculate the TMDL predicts a daily average dissolved oxygen concentration and does not directly predict daily minimum values. QUAL2E results can be translated into a form comparable to a daily minimum, by subtracting the observed difference between daily average and daily minimum dissolved oxygen from the model output. For QUAL2E model runs, a modeling target of 6.0 mg/l was used to consider diurnal variation and ensure that the 5.0 mg/l water quality standard is met.

5 DEVELOPMENT OF WATER QUALITY MODEL

Water quality models are used to define the relationship between pollutant loading and the resulting water quality. The dissolved oxygen TMDL is based on the QUAL2E model. The development of this approach is described in the following sections, including information on:

- Model selection
- Modeling approach
- Model inputs
- Model calibration

5.1 QUAL2E MODEL

The QUAL2E water quality model was used to define the relationship between external oxygen-demanding loads and the resulting concentrations of dissolved oxygen in Hodges Creek. QUAL2E is a one-dimensional stream water quality model applicable to dendritic, well-mixed streams. It assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the main direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows.

5.1.1 Model Selection

A detailed discussion of the model selection process for Hodges Creek is provided in the Stage 1 Report.

Of the models discussed, the QUAL2E model (Brown and Barnwell, 1987) was selected to address dissolved oxygen impairments in Hodges Creek. QUAL2E is the most commonly used water quality model for addressing low flow conditions. Because observed problems are restricted to low flow conditions, watershed loads are not expected to be significant contributors to impairment during these periods. For this reason, an empirical approach was selected for determining watershed loads.

5.1.2 Modeling Approach

The approach selected for the dissolved oxygen TMDL is based upon discussions with IEPA and their Scientific Advisory Committee. The approach consists of using data collected during two field surveys (August 2005 and October 2005) to define current loads to the river, and using the QUAL2E model to define the extent to which loads must be reduced to meet water quality standards. This is the recommended approach presented in the detailed discussion of the model selection process provided in the Second Quarterly Progress Report in the Stage 1 Report. The dominant land use in the watershed is agriculture. Implementation plans for nonpoint sources will consist of voluntary controls, applied on an incremental basis. The approach taken for these TMDLs will expedite these implementation efforts.

Determination of existing loading sources and prioritization of restoration alternatives may be conducted by local experts as part of the implementation process (see Section 8).

Based upon their recommendations, a voluntary implementation plan could be developed that includes both accountability and the potential for adaptive management.

5.1.3 Model Inputs

This section provides an overview of the model inputs required for QUAL2E application, and how they were derived. The following categories of inputs are required for QUAL2E:

- Model options (title data)
- Model segmentation
- Hydraulic characteristics
- Initial conditions
- Incremental inflow conditions
- Point source loads

5.1.3.1 Model options

This portion of the input file defines the specific water quality parameters to be simulated. QUAL2E was set up to simulate five-day biochemical oxygen demand, the nitrogen series, and dissolved oxygen.

5.1.3.2 Model Segmentation

The QUAL2E model divides the river being simulated into discrete segments (called "reaches") that have constant channel geometry and hydraulic characteristics. Reaches are further divided into "computational elements", which define the interval at which results are provided. The Hodges Creek QUAL2E model consists of four reaches, which are comprised of a varying number of computational elements. Computational elements have a fixed length of 0.2 miles. Each reach was defined to begin and end at a confluence point. Model segmentation is presented below in Table 1.

Table 1. QUAL2E Segmentation

Reach	River miles	Number of computational elements	Other features
1	10.6 – 9.6	5	Otter/Lick Creeks
2	9.6 – 7.6	10	Solomon Creek
3	7.6 – 3.8	19	Bear Creek
4	3.8 – 0.0	19	Joes Creek

5.1.3.3 Hydraulic Characteristics

A functional representation was used to describe the hydraulic characteristics of the system. For each reach, velocity and depth were specified, based on measurements taken during the two field surveys (primarily the first survey, as flow conditions during the second survey were found to be stagnant in parts of the creek).

5.1.3.4 Initial Conditions

Initial model conditions were based on field observations taken during the two surveys. Specifically, site-specific information on creek flow, velocity, morphometry, and concentrations of BOD and ammonia were used to specify initial conditions.

5.1.3.5 Incremental Inflow Conditions

Incremental inflows are additional flows into the system that are not represented by point source inflows or headwaters. Incremental inflows were not included in the model. Flows during the two surveys were extremely low, and incremental inflows were determined to be insignificant.

5.1.3.6 Point Source Loads

There are no point source dischargers considered directly in the modeling. Three of the four sewage treatment plants discharge to tributaries that were not flowing at the time of the field surveys. The fourth sewage treatment plant (Girard STP) is located over 23 miles upstream of the 303(d)-listed segment. Water quality sampling at the upstream boundary of the Hodges Creek segment was the basis for characterizing upstream loads.

5.1.4 QUAL2E Calibration

QUAL2E model calibration consisted of:

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

The QUAL2E dissolved oxygen calibration for Hodges Creek is discussed below.

The QUAL2E model was initially applied with the model inputs as specified above. Observed data for the first of two dry weather surveys were used for calibration purposes. The surveys were conducted on August 22-25, 2005 and October 11, 2005. Because the creek was flowing during the first survey, this survey was more suitable for calibration. The creek was stagnant during the second survey.

QUAL2E was calibrated to match the observed dissolved oxygen concentration measured at station HOD-1 in Reach 4 (see QUAL2E segmentation in Table 1 above). The dissolved oxygen mass balance component analysis showed that the most important source of dissolved oxygen was reaeration and the most important sink was sediment oxygen demand. Because SOD was constrained by site-specific measurements, as were CBOD and ammonia, the data were matched using the reaeration rate as the sole calibration parameter.

Calibration consisted of graphical comparisons between model results and data, and statistical error calculations. The resulting dissolved oxygen predictions compared well to the measured concentrations, as shown in Figure 2. The difference between the modeled dissolved oxygen concentration (solid line in Figure 2) and the average daily measured dissolved oxygen concentration (triangle in Figure 2) at the downstream location was 0.14 mg/l. This comparison represents an acceptable model calibration. A complete listing of all the observed data used for calibration, as well as a comparison between model predictions and observed data, is provided in the Stage 2 Report and Attachment 1.

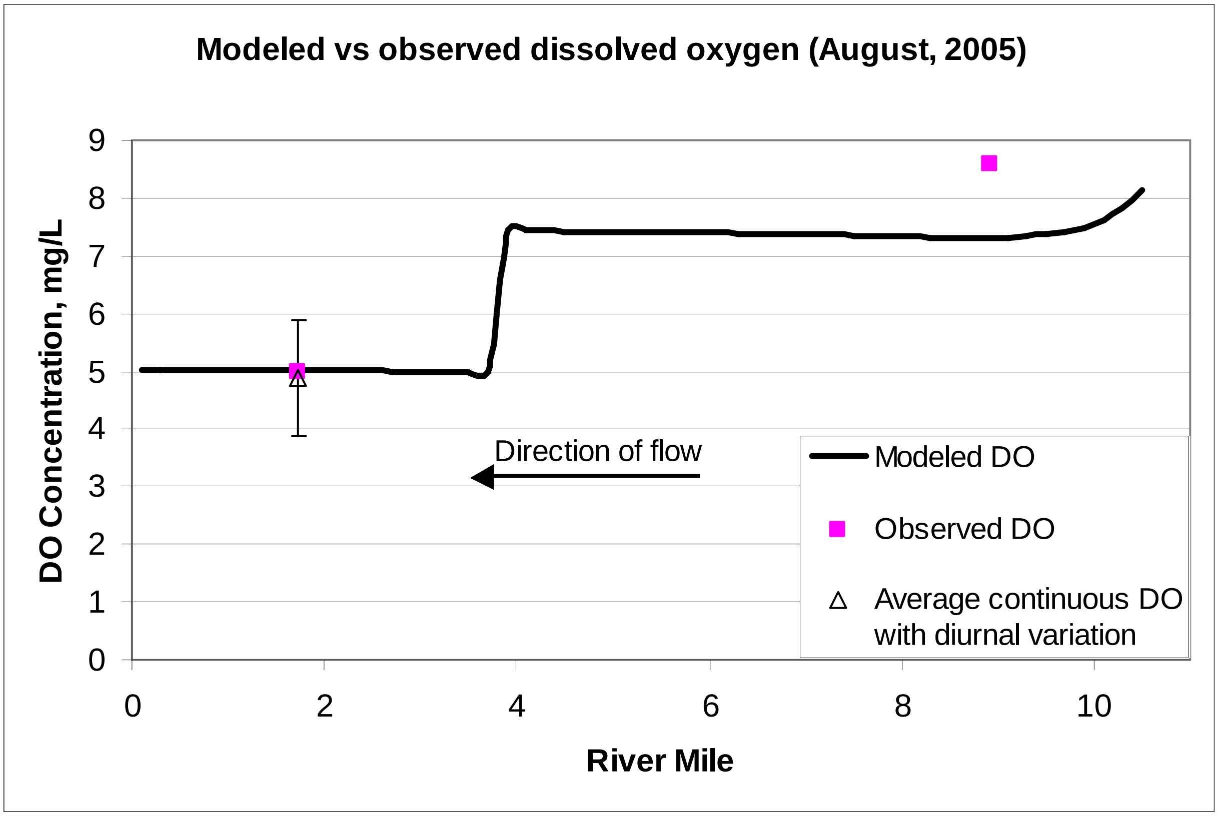

Figure 2. Model Calibration Results for August 2005 Survey Data

A component analysis was subsequently conducted using the calibrated model to determine the magnitude of the various sources contributing to the dissolved oxygen deficit. Sediment oxygen demand was confirmed as the dominant oxygen sink, decreasing dissolved oxygen at a rate up to 6.21 mg/l/day. CBOD and ammonia had a much lesser effect, consuming dissolved oxygen at maximum rates of 0.25 and 0.24 mg/l/day, respectively.

6 TMDL DEVELOPMENT

This section presents the development of the total maximum daily load for dissolved oxygen in Hodges Creek. Included in this section is a description of how the total loading capacity was calculated, and a discussion on 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 DISSOLVED OXYGEN TMDL

A dissolved oxygen TMDL was developed for Hodges Creek (IL_DAG-02). The specific steps followed in developing this TMDL are described below.

6.1.1 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 traditional first step in determining the loading capacity is to reduce external sources of oxygen-demanding substances (BOD and ammonia) to determine the extent of reductions required to result in the river attaining the modeling target of 6.0 mg/l[1]. The component analysis of QUAL2E results provided in Section 5.2.1 demonstrated that sediment oxygen demand has more than twelve times the effect on the dissolved than the combined effect of BOD and ammonia. QUAL2E simulations subsequently showed that, even with external loads BOD and ammonia loads set to zero, compliance with the dissolved oxygen standard was not attained. Because sediment oxygen demand (SOD) was the dominant source of the oxygen deficit during critical conditions, DO standards could only be attained via reduction of SOD[2]. A less traditional approach was therefore taken to determine the loading capacity, with the focus being on reduction in SOD instead of external BOD or ammonia loads. The QUAL2E model was run repeatedly, uniformly reducing sediment oxygen demand (SOD) until model results demonstrated attainment of TMDL targets along the length of the river. The maximum SOD that results in compliance with water quality standards was used as the basis for determining the creek's loading capacity.

Model simulations determined that it was necessary to reduce sediment oxygen demand by 35 percent to meet the TMDL target for dissolved oxygen. It is difficult to accurately predict the necessary reductions in organic solids necessary to achieve specific SOD reductions; however, in a TMDL assessment relating SOD reductions for a watershed in Michigan, it was estimated that SOD rates would respond proportionally to reductions in total suspended solids (TSS) loads (Suppnick, 1992). This response appears reasonable if the appropriate solids are targeted for reduction. As such, a 35% reduction of particulate

[1] This modeling target considers observed diurnal variation and ensures that the 5.0 mg/l water quality standard is met.
[2] Although SOD is the dominant source of the oxygen deficit, the true cause of low dissolved oxygen is a lack of base flow (which greatly exacerbates the effect of SOD). Because TMDLs cannot be written to control flow, the focus of this TMDL was instead on SOD, as its effect on dissolved oxygen is dominant under low flow conditions.

organic carbon loading to the stream (which occurs primarily during higher flow periods), is required.

Model results were used to calculate the TMDL load allocation (Table 2), which is a component of the loading capacity. The load capacity was calculated as the sum of the load allocation, the wasteload allocation for point sources and the margin of safety, which are described in the next section.

6.1.2 Allocation

A TMDL consists of point source/waste load allocations (WLAs), nonpoint sources/load allocations (LAs), and a margin of safety (MOS). This definition is illustrated by the following equation:

$$TMDL = WLA + LA \pm MOS$$

The following section presents the allocations for Hodges Creek.

6.1.2.1 Hodges Creek (IL_DAG-02)

Point source dischargers to Hodges Creek segment IL_DAG-02 were determined not to contribute significantly to low dissolved oxygen. There are a total of four NPDES permitted sewage treatment plants (STPs) that discharge within the Hodges Creek watershed. These are described below:

- Palmyra STP – provides lagoon treatment, secondary treatment and sand filters.
- Hettick STP – provides lagoon treatment.
- Chesterfield STP – provides 2-celled lagoon treatment, final treatment through a rock filter.
- Girard STP – provides tertiary treatment.

According to IEPA records, the Palmyra and Girard STPs discharge continuously, although during the unusually dry conditions monitored in August and October of 2005, the Palmyra STP was observed not to be discharging. IEPA records report that both the Chesterfield and Hettick STPs discharge intermittently, 3 and 4 times a year, respectively.

Based on a review of available discharge monitoring data available in the USEPA PCS database, it was found that the Chesterfield STP and Palmyra STP had no permit violations for CBOD5 for the period of the posted data (January 2002 – December 2003 and March 2003 – February 2006, respectively). For the period October 2004 – January 2006, the Girard STP had no violations of their ammonia or CBOD5 permit limits. Furthermore there were no discharges from the excess flow bypass for this period. The Hettick STP reported two violations of their CBOD5 permit limit for the period January 2003 – April 2006. These violations were observed in February 2006 and October 2004, periods when Hodges Creek was not monitored.

The Palmyra STP and Hettick STP discharge to Solomon Creek, which was dry at the time of the field surveys. The Chesterfield STP discharges to a drainage ditch that drains to Bear Creek. Effluent flow from the Chesterfield STP typically does not reach the receiving stream. The fourth facility, the Girard STP, is a larger facility that discharges to Otter Creek over 23 miles upstream of the listed Hodges Creek segment. Due to the distance of the Girard STP from the listed segment of Hodges Creek and the fact that the tributaries the others discharge to were dry during the presence of water quality standards violations during the two 2005 field surveys, these facilities were determined not to cause or contribute to the dissolved oxygen impairment.

Because of their negligible contribution, the WLAs for these dischargers were computed using design average flows (Palmyra 0.12 MGD, Hettick 0.0282 MGD, Chesterfield 0.026 MGD and Girard 0.55 MGD) and existing permit limits for CBOD5 and ammonia. The available permit information from EPA's PCS database indicates that the Hettick STP, Palmyra STP and Chesterfield STP have CBOD5 limits, but do not have ammonia limits. The Girard STP has both CBOD5 and ammonia limitations (including seasonally varying limits for ammonia). CBOD5 and ammonia wasteload allocations are listed below by facility and presented for the watershed in Tables 2 and 3. For facilities without ammonia limits, the ammonia WLA was not calculated.

Palmyra STP	25 lbs CBOD5/day
Chesterfield STP	5.4 lbs CBOD5/day
Hettick STP	5.9 lbs CBOD5/day
Girard STP	45.9 lbs CBOD5/day

The load allocation was calculated for nonpoint sources under low flow conditions because this is the period when low dissolved oxygen problems have been observed. The load allocation, representing low flow periods, was based on the inflow to segment IL_DAG-02 and measured concentrations because these are considered background conditions and do not significantly contribute to low dissolved oxygen. The load allocations presented in Tables 2 and 3 were reduced by 10%, which was designed to serve as a margin of safety (discussed below). The load allocation 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 oxygen demand.

Table 2. CBOD5 Allocation for Segment IL_DAG-02*

Loading Capacity (lbs/day)	Point Source Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)	Margin of Safety (lbs/day)
83	82	0.325	0.036

*Numbers may not sum exactly due to rounding

Table 3. Ammonia Allocation for Segment IL_DAG-02*

Season	Loading Capacity (lbs/day)	Point Source Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)	Margin of Safety (lbs/day)
March	13	13	0.05	0.005
Apr. – Oct.	7	7	0.05	0.005
Nov. – Feb.	18	18	0.05	0.005

*Numbers may not sum exactly due to rounding

In addition to the WLAs described above, the Girard STP also has a permit for an excess flow bypass that may occur under wet weather conditions. Excess flow, beyond 1.375 MGD is stored in a stormwater lagoon and returned to the plant for treatment, then discharged through the primary STP outfall. During extreme precipitation, excess flow is discharged from the lagoon to Hurricane Creek until the precipitation subsides; bypasses are very infrequent. There were no reported bypasses found in EPA's PCS database (October 2004 – January 2006). For purposes of allocating a load to this bypass, a flow of 0.1375 was presumed (10% of the maximum design flow for the Girard STP); the WLA for this bypass was based on this flow. The permit limit for BOD5 (30 mg/l) was translated to CBOD5 (25 mg/l) (Hall and Foxen, 1983) and used to calculate the CBOD5 WLA. The excess flow bypass does not have ammonia nitrogen limits. During high flow conditions, the wasteload allocation for the excess flow bypass is 29 lbs/day for CBOD5.

6.1.3 Critical Conditions

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 by conducting the modeling at low flow summer conditions; all of the dissolved oxygen problems were observed at low flow. To effectively consider critical conditions, this TMDL is based upon the flows and temperatures measured during the August 2005 low flow survey. This was the warmest period during which flow, water temperature, dissolved oxygen, ammonia and CBOD5 were measured. It was also a period of very low instream flow.

6.1.4 Seasonality

The TMDL was conducted with an explicit consideration of seasonal variation. The TMDL was evaluated for a range of flow conditions that are expected to be observed throughout the year. Dissolved oxygen problem are only predicted to occur during low flow periods. Furthermore, this TMDL requires a 35% reduction in watershed particulate organic carbon loadings, which are expected to be delivered to the stream during wet weather conditions. Finally, this TMDL considers seasonal ammonia permit limits for the sewage treatment plants, where applicable.

6.1.5 Margin of Safety

Total maximum daily loads are required to contain a Margin of Safety (MOS) to account for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The MOS can be either implicit (e.g., incorporated into the TMDL analysis through conservative assumptions), or explicit (e.g., expressed in the TMDL as a portion of the loading), or expressed as a combination of both. The Hodges Creek dissolved oxygen TMDL contains an explicit margin of safety equal to 10% of the load allocation. The 10% margin of safety is considered an appropriate value based upon the generally good agreement between the QUAL2E water quality model predicted values and the observed values. In particular, model predictions of minimum dissolved oxygen match extremely well with both the continuous dissolved oxygen measurements and the grab sampling that was conducted at the location of minimum dissolved oxygen. 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 CBOD5 and ammonia loads allocated to the margin of safety were presented in Tables 2 and 3.

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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). 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 February 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 Tuesday, March 22, 2005 in Girard, Illinois at the former Otter Lake Pump Building. In addition to the meeting's sponsors, nine 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.

In July 2006, a public meeting was announced for presentation of the Stage 3 TMDL findings. This announcement was mailed to everyone on the previous TMDL mailing list and published in local newspapers. The public meeting was held at 6:00 pm on Wednesday August 2, 2006 in Girard, Illinois at the former Otter Lake Pump Building. In addition to the meeting’s sponsors, two individuals attended the meeting.

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8 ADAPTIVE IMPLEMENTATION PROCESS

The 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. QUAL2E) to define the load-response relationship and define the maximum allowable pollutant load that the waterbodies 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. 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 correspond to TMDL development and have been completed, as described in Section 5 of this document. Steps 4 and 5 correspond to implementation.

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Attachment 1

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                                        * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                                Version 3.22  --  May 1996
     $$$ (PROBLEM TITLES) $$$

   CARD TYPE                          QUAL-2E PROGRAM TITLES
   TITLE01               Hodges Creek TMDL
   TITLE02               Final Calibration Run Plus Nitrogen
   TITLE03   NO          CONSERVATIVE MINERAL   I
   TITLE04   NO          CONSERVATIVE MINERAL  II
   TITLE05   NO          CONSERVATIVE MINERAL III
   TITLE06   NO          TEMPERATURE
   TITLE07  YES          5-DAY BIOCHEMICAL OXYGEN DEMAND
   TITLE08   NO          ALGAE AS CHL-A IN UG/L
   TITLE09   NO          PHOSPHORUS CYCLE AS P IN MG/L
   TITLE10                 (ORGANIC-P; DISSOLVED-P)
   TITLE11  YES          NITROGEN CYCLE AS N IN MG/L
   TITLE12                 (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
   TITLE13  YES          DISSOLVED OXYGEN IN MG/L
   TITLE14   NO          FECAL COLIFORM IN NO./100 ML
   TITLE15   NO          ARBITRARY NON-CONSERVATIVE
   ENDTITLE
     $$$ DATA TYPE 1 (CONTROL DATA) $$$

   CARD TYPE                                   CARD TYPE
   LIST DATA INPUT                0.00000                                         0.00000
   NOWRITE OPTIONAL SUMMARY       0.00000                                         0.00000
   NO FLOW AUGMENTATION           0.00000                                         0.00000
   STEADY STATE                   0.00000                                         0.00000
   NO TRAPEZOIDAL CHANNELS        0.00000                                         0.00000
   NO PRINT LCD/SOLAR DATA        0.00000                                         0.00000
   NO PLOT DO AND BOD             0.00000                                         0.00000
   FIXED DNSTM CONC (YES=1)=      0.00000      5D-ULT BOD CONV K COEF   =         0.23000
   INPUT METRIC             =     0.00000      OUTPUT METRIC            =         0.00000
   NUMBER OF REACHES        =     4.00000      NUMBER OF JUNCTIONS      =         0.00000
   NUM OF HEADWATERS        =     1.00000      NUMBER OF POINT LOADS    =         3.00000
   TIME STEP (HOURS)        =     1.00000      LNTH. COMP. ELEMENT (MI)=          0.20000
   MAXIMUM ROUTE TIME (HRS)=     60.00000      TIME INC. FOR RPT2 (HRS)=          1.00000
   LATITUDE OF BASIN (DEG) =     39.27000      LONGITUDE OF BASIN (DEG)=         90.17000
   STANDARD MERIDIAN (DEG) =      0.00000      DAY OF YEAR START TIME   =       217.00000
   EVAP. COEF.,(AE)         =     0.00068      EVAP. COEF.,(BE)         =         0.00027
   ELEV. OF BASIN (ELEV)    =   400.00000      DUST ATTENUATION COEF.   =         0.06000
   ENDATA1                        0.00000                                         0.00000
     $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

   CARD TYPE                                         CARD TYPE
   O UPTAKE BY NH3 OXID(MG O/MG N)=    3.4300        O UPTAKE BY NO2 OXID(MG O/MG N)=      1.1400
   O PROD  BY ALGAE (MG O/MG A)   =    1.8000        O UPTAKE BY ALGAE (MG O/MG A)   =     1.9000
   N CONTENT OF ALGAE (MG N/MG A) =    0.0900        P CONTENT OF ALGAE (MG P/MG A)  =     0.0140
   ALG MAX SPEC GROWTH RATE(1/DAY)=    2.0000        ALGAE RESPIRATION RATE (1/DAY)  =     0.1050
   N HALF SATURATION CONST (MG/L) =    0.0300        P HALF SATURATION CONST  (MG/L)=      0.0050
   LIN ALG SHADE CO (1/FT-UGCHA/L=)    0.0030        NLIN SHADE(1/FT-(UGCHA/L)**2/3)=      0.0000
   LIGHT FUNCTION OPTION (LFNOPT) =    2.0000        LIGHT SAT'N COEF (BTU/FT2-MIN)  =     0.6600
   DAILY AVERAGING OPTION (LAVOPT)=    3.0000        LIGHT AVERAGING FACTOR  (INT)   =     0.9000
   NUMBER OF DAYLIGHT HOURS (DLH) =   14.2000        TOTAL DAILY SOLR RAD (BTU/FT-2)= 1500.0000
   ALGY GROWTH CALC OPTION(LGROPT)=    2.0000        ALGAL PREF FOR NH3-N (PREFN)    =     0.1000
   ALG/TEMP SOLR RAD FACTOR(TFACT)=    0.4500        NITRIFICATION INHIBITION COEF   =     0.6000
   ENDATA1A                            0.0000                                              0.0000
     $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

   CARD TYPE      RATE CODE      THETA VALUE

   THETA( 1)       BOD DECA         1.047      DFLT
   THETA( 2)       BOD SETT         1.024      DFLT
   THETA( 3)       OXY TRAN         1.024      DFLT
   THETA( 4)       SOD RATE         1.060      USER
   THETA( 5)       ORGN DEC         1.047      DFLT
   THETA( 6)       ORGN SET         1.024      DFLT
   THETA( 7)       NH3 DECA         1.083      DFLT
   THETA( 8)       NH3 SRCE         1.074      DFLT
   THETA( 9)       NO2 DECA         1.047      DFLT
   THETA(10)       PORG DEC         1.047      DFLT
   THETA(11)       PORG SET         1.024      DFLT
   THETA(12)       DISP SRC         1.074      DFLT
   THETA(13)       ALG GROW         1.047      DFLT
   THETA(14)       ALG RESP         1.047      DFLT
   THETA(15)       ALG SETT         1.024      DFLT
   THETA(16)       COLI DEC         1.047      DFLT
   THETA(17)       ANC DECA         1.000      DFLT
   THETA(18)       ANC SETT         1.024      DFLT
   THETA(19)       ANC SRCE         1.000      DFLT
   ENDATA1B
     $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$
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        CARD TYPE           REACH ORDER AND IDENT            R. MI/KM              R. MI/KM
        STREAM REACH     1.0  RCH= To Solomon Cr.     FROM      10.6      TO        9.6
        STREAM REACH     2.0  RCH= To Bear Cr.        FROM       9.6      TO        7.6
        STREAM REACH     3.0  RCH= To Joes Cr.        FROM       7.6      TO        3.8
        STREAM REACH     4.0  RCH= To Macoupin Cr.    FROM       3.8      TO        0.0
        ENDATA2          0.0                                     0.0                0.0
          $$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

        CARD TYPE                     REACH  AVAIL HDWS TARGET     ORDER OF AVAIL SOURCES
        ENDATA3                         0.         0.        0.0   0.   0.   0.   0.   0.   0.
          $$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

        CARD TYPE        REACH ELEMENTS/REACH             COMPUTATIONAL FLAGS
        FLAG FIELD        1.         5.         1.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
        FLAG FIELD        2.        10.         6.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.
        FLAG FIELD        3.        19.         6.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.0.
        FLAG FIELD        4.        19.         6.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.5.0.
        ENDATA4           0.         0.         0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
          $$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

        CARD TYPE        REACH  COEF-DSPN  COEFQV    EXPOQV    COEFQH    EXPOQH    CMANN
        HYDRAULICS        1.    100.00     0.056     0.000     0.200     0.000     0.020
        HYDRAULICS        2.    100.00     0.056     0.000     0.200     0.000     0.020
        HYDRAULICS        3.    100.00     0.056     0.000     0.200     0.000     0.020
        HYDRAULICS        4.    100.00     0.014     0.000     0.780     0.000     0.020
        ENDATA5           0.      0.00     0.000     0.000     0.000     0.000     0.000
          $$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

        CARD TYPE                             DUST      CLOUD   DRY BULB  WET BULB    ATM                SOLAR RA
D
                        REACH   ELEVATION     COEF      COVER     TEMP      TEMP    PRESSURE     WIND    ATTENUATI
ON
        TEMP/LCD          1.      400.00      0.06       0.10     80.00     60.00     29.59      2.00       1.00
        TEMP/LCD          2.      400.00      0.06       0.10     80.00     60.00     29.59      2.00       1.00
        TEMP/LCD          3.      400.00      0.06       0.10     80.00     60.00     29.59      2.00       1.00
        TEMP/LCD          4.      400.00      0.06       0.10     80.00     60.00     29.59      2.00       1.00
        ENDATA5A          0.        0.00      0.00       0.00      0.00      0.00      0.00      0.00       0.00
          $$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

        CARD TYPE        REACH      K1        K3        SOD        K2OPT      K2     COEQK2    OR   EXPQK2
                                                        RATE                         TSIV COEF OR    SLOPE
                                                                                     FOR OPT 8     FOR OPT 8
        REACT COEF        1.       0.23      0.00      0.012        1.       2.10     0.000        0.00000
        REACT COEF        2.       0.23      0.00      0.012        1.       2.10     0.000        0.00000
        REACT COEF        3.       0.23      0.00      0.012        1.       2.10     0.000        0.00000
        REACT COEF        4.       0.23      0.00      0.115        1.       2.10     0.000        0.00000
        ENDATA6           0.       0.00      0.00      0.000        0.       0.00     0.000        0.00000
           $$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

        CARD TYPE           REACH    CKNH2    SETNH2     CKNH3     SNH3     CKNO2     CKPORG   SETPORG     SPO4
        N AND P COEF         1.       0.10      0.00      0.50     0.00      3.00      0.10      0.00      0.00
        N AND P COEF         2.       0.10      0.00      0.50     0.00      3.00      0.10      0.00      0.00
        N AND P COEF         3.       0.10      0.00      0.50     0.00      3.00      0.10      0.00      0.00
        N AND P COEF         4.       0.10      0.00      0.50     0.00      3.00      0.10      0.00      0.00
        ENDATA6A             0.       0.00      0.00      0.00     0.00      0.00      0.00      0.00      0.00
          $$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

        CARD TYPE           REACH    ALPHAO    ALGSET    EXCOEF     CK5      CKANC     SETANC    SRCANC
                                                                  CKCOLI
        ALG/OTHER COEF       1.      15.00      2.00      0.10     0.00      0.00      0.00      0.00
        ALG/OTHER COEF       2.      15.00      2.00      0.10     0.00      0.00      0.00      0.00
        ALG/OTHER COEF       3.      15.00      2.00      0.10     0.00      0.00      0.00      0.00
        ALG/OTHER COEF       4.      15.00      2.00      0.10     0.00      0.00      0.00      0.00
        ENDATA6B             0.       0.00      0.00      0.00     0.00      0.00      0.00      0.00
          $$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

        CARD TYPE           REACH    TEMP      D.O.      BOD       CM-1      CM-2      CM-3      ANC       COLI
        INITIAL COND-1       1.      72.30     8.60      1.00      0.00      0.00      0.00      0.00      0.00
        INITIAL COND-1       2.      72.30     8.60      1.00      0.00      0.00      0.00      0.00      0.00
        INITIAL COND-1       3.      72.30     8.60      1.00      0.00      0.00      0.00      0.00      0.00
        INITIAL COND-1       4.      73.40     5.00      1.00      0.00      0.00      0.00      0.00      0.00
        ENDATA7              0.       0.00     0.00      0.00      0.00      0.00      0.00      0.00      0.00
          $$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

        CARD TYPE           REACH    CHL-A     ORG-N     NH3-N     NO2-N     NO3-N     ORG-P     DIS-P
        INITIAL COND-2       1.       0.00      0.00      0.01      0.00      0.00      0.00      0.00
        INITIAL COND-2       2.       0.00      0.00      0.01      0.00      0.00      0.00      0.00
        INITIAL COND-2       3.       0.00      0.00      0.01      0.00      0.00      0.00      0.00
        INITIAL COND-2       4.       0.00      0.00      0.01      0.00      0.00      0.00      0.00
        ENDATA7A             0.       0.00      0.00      0.00      0.00      0.00      0.00      0.00
          $$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$
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         CARD TYPE           REACH     FLOW      TEMP      D.O.      BOD      CM-1      CM-2      CM-3      ANC
       COLI
         INCR INFLOW-1         1.     0.000     70.00      0.00      0.00      0.00      0.00      0.00      0.00
       0.00
         INCR INFLOW-1         2.     0.000     70.00      0.00      0.00      0.00      0.00      0.00      0.00
       0.00
         INCR INFLOW-1         3.     0.000     70.00      0.00      0.00      0.00      0.00      0.00      0.00
       0.00
         INCR INFLOW-1         4.     0.000     70.00      0.00      0.00      0.00      0.00      0.00      0.00
       0.00
         ENDATA8               0.     0.000      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       0.00
           $$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

         CARD TYPE           REACH     CHL-A     ORG-N     NH3-N     NO2-N     NO3-N     ORG-P     DIS-P
         INCR INFLOW-2         1.       0.00      0.00      0.00      0.00      0.00      0.00      0.00
         INCR INFLOW-2         2.       0.00      0.00      0.00      0.00      0.00      0.00      0.00
         INCR INFLOW-2         3.       0.00      0.00      0.00      0.00      0.00      0.00      0.00
         INCR INFLOW-2         4.       0.00      0.00      0.00      0.00      0.00      0.00      0.00
         ENDATA8A              0.       0.00      0.00      0.00      0.00      0.00      0.00      0.00
           $$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

         CARD TYPE              JUNCTION ORDER AND IDENT          UPSTRM   JUNCTION    TRIB
         ENDATA9                0.                                  0.        0.        0.
           $$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

         CARD TYPE     HDWTR     NAME                   FLOW      TEMP      D.O.       BOD      CM-1      CM-2      CM-
     3
                       ORDER
         HEADWTR-1      1.   Otter/Lick Crks            0.07     72.30      8.60      1.00      0.00      0.00      0.0
     0
         ENDATA10       0.                              0.00      0.00      0.00      0.00      0.00      0.00      0.0
     0
           $$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS,
                              COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

         CARD TYPE     HDWTR     ANC      COLI      CHL-A     ORG-N     NH3-N     NO2-N     NO3-N     ORG-P     DIS-P
                       ORDER
         HEADWTR-2      1.       0.00 0.00E+00     0.00      0.00      0.14      0.00      0.00      0.00      0.00
         ENDATA10A      0.       0.00 0.00E+00     0.00      0.00      0.00      0.00      0.00      0.00      0.00
           $$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

                       POINT
         CARD TYPE     LOAD     NAME                 EFF      FLOW      TEMP      D.O.      BOD      CM-1      CM-2      C
    M-3
                       ORDER
         POINTLD-1      1.    Solomon Cr.           0.00      0.00     77.00      8.00      1.00      0.00      0.00      0
    .00
         POINTLD-1      2.    Bear Creek            0.00      0.00     77.00      8.00      1.00      0.00      0.00      0
    .00
         POINTLD-1      3.    Joes Creek            0.00      0.00     77.00      8.00      1.00      0.00      0.00      0
    .00
         ENDATA11       0.                          0.00      0.00      0.00      0.00      0.00      0.00      0.00      0
    .00
           $$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS,
                              COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

                       POINT
         CARD TYPE     LOAD      ANC      COLI      CHL-A     ORG-N     NH3-N     NO2-N     NO3-N     ORG-P     DIS-P
                       ORDER
         POINTLD-2      1.       0.00 0.00E+00     0.00      0.00      0.00      0.00      0.00      0.00      0.00
         POINTLD-2      2.       0.00 0.00E+00     0.00      0.00      0.00      0.00      0.00      0.00      0.00
         POINTLD-2      3.       0.00 0.00E+00     0.00      0.00      0.00      0.00      0.00      0.00      0.00
         ENDATA11A      0.       0.00 0.00E+00     0.00      0.00      0.00      0.00      0.00      0.00      0.00
           $$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

                                DAM    RCH    ELE    ADAM      BDAM      FDAM      HDAM

         ENDATA12                 0.     0.     0.    0.00      0.00      0.00      0.00
           $$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

              CARD TYPE                TEMP       D.O.      BOD       CM-1      CM-2      CM-3         ANC       COLI

         ENDATA13                      DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED
           $$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

              CARD TYPE                CHL-A      ORG-N     NH3-N     NO2-N     NH3-N     ORG-P     DIS-P

         ENDATA13A                     DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED
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STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
NITRIFICATION INHIBITION	1	34
NITRIFICATION INHIBITION	2	33
NITRIFICATION INHIBITION	3	0
NITRIFICATION INHIBITION	4	0

STREAM QUALITY SIMULATION OUTPUT PAGE NUMBER 1
QUAL-2E STREAM QUALITY ROUTING MODEL Version 3.22 -- May 1996

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
1	1	1	10.60	10.40	0.07	0.00	0.00	0.056	0.218	0.200	5.982	1.26	6.74	1.20	0.11
2	1	2	10.40	10.20	0.07	0.00	0.00	0.056	0.218	0.200	5.982	1.26	6.74	1.20	0.11
3	1	3	10.20	10.00	0.07	0.00	0.00	0.056	0.218	0.200	5.982	1.26	6.74	1.20	0.11
4	1	4	10.00	9.80	0.07	0.00	0.00	0.056	0.218	0.200	5.982	1.26	6.74	1.20	0.11
5	1	5	9.80	9.60	0.07	0.00	0.00	0.056	0.218	0.200	5.982	1.26	6.74	1.20	0.11
6	2	1	9.60	9.40	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
7	2	2	9.40	9.20	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
8	2	3	9.20	9.00	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
9	2	4	9.00	8.80	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
10	2	5	8.80	8.60	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
11	2	6	8.60	8.40	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
12	2	7	8.40	8.20	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
13	2	8	8.20	8.00	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
14	2	9	8.00	7.80	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
15	2	10	7.80	7.60	0.07	0.00	0.00	0.056	0.218	0.200	5.983	1.26	6.74	1.20	0.11
16	3	1	7.60	7.40	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
17	3	2	7.40	7.20	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
18	3	3	7.20	7.00	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
19	3	4	7.00	6.80	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
20	3	5	6.80	6.60	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
21	3	6	6.60	6.40	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
22	3	7	6.40	6.20	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
23	3	8	6.20	6.00	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
24	3	9	6.00	5.80	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
25	3	10	5.80	5.60	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74		

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
														1.20	0.11
26	3	11	5.60	5.40	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
27	3	12	5.40	5.20	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
28	3	13	5.20	5.00	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
29	3	14	5.00	4.80	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
30	3	15	4.80	4.60	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
31	3	16	4.60	4.40	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
32	3	17	4.40	4.20	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
33	3	18	4.20	4.00	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
34	3	19	4.00	3.80	0.07	0.00	0.00	0.056	0.218	0.200	5.984	1.26	6.74	1.20	0.11
35	4	1	3.80	3.60	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
36	4	2	3.60	3.40	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
37	4	3	3.40	3.20	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
38	4	4	3.20	3.00	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
39	4	5	3.00	2.80	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
40	4	6	2.80	2.60	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09

STREAM QUALITY SIMULATION OUTPUT PAGE NUMBER 2

QUAL-2E STREAM QUALITY ROUTING MODEL Version 3.22 -- May 1996

******* STEADY STATE SIMULATION *******

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
41	4	7	2.60	2.40	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
42	4	8	2.40	2.20	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
43	4	9	2.20	2.00	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
44	4	10	2.00	1.80	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
45	4	11	1.80	1.60	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
46	4	12	1.60	1.40	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
47	4	13	1.40	1.20	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
48	4	14	1.20	1.00	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
49	4	15	1.00	0.80	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
50	4	16	0.80	0.60	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
51	4	17	0.60	0.40	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
52	4	18	0.40	0.20	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09
53	4	19	0.20	0.00	0.07	0.00	0.00	0.014	0.855	0.780	6.010	4.95	7.99	4.69	0.09

STREAM QUALITY SIMULATION OUTPUT PAGE NUMBER 3

QUAL-2E STREAM QUALITY ROUTING MODEL Version 3.22 -- May 1996

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
1	1	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	3	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	4	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	5	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	4	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	6	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	7	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	8	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	9	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	1	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	2	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	3	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	4	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	5	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	6	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	7	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	8	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	9	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	10	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	12	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	13	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	14	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	15	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	16	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	17	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	18	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	19	8.59	1	2.22	0.26	0.00	0.01	0.11	0.00	0.60	0.00	3.31	0.00	0.00	0.00	0.00	0		

```
    .00   0.00   0.00


    4   1   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4   2   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4   3   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4   4   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4   5   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4   6   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00

           STREAM QUALITY SIMULATION                                                                                    OUTPUT PA
  GE NUMBER      4
           QUAL-2E STREAM QUALITY ROUTING MODEL                                                                 Version 3.22  --
   May 1996
                                                            ***** STEADY STATE SIMULATION *****

                                                            ** REACTION COEFFICIENT SUMMARY **

  RCH ELE       DO  K2  OXYGN     BOD     BOD     SOD    ORGN    ORGN     NH3     NH3     NO2    ORGP    ORGP    DISP    COLI
  ANC     ANC      ANC
  NUM NUM     SAT OPT  REAIR   DECAY    SETT    RATE   DECAY    SETT   DECAY    SRCE   DECAY   DECAY    SETT    SRCE   DECAY  DE
  CAY    SETT    SRCE
              MG/L        1/DAY   1/DAY   1/DAY   G/F2D   1/DAY   1/DAY   1/DAY MG/F2D   1/DAY   1/DAY   1/DAY MG/F2D   1/DAY  1/
  DAY  1/DAY MG/F2D

    4   7   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4   8   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4   9   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  10   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  11   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  12   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  13   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  14   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  15   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  16   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  17   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  18   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00
    4  19   8.49   1    2.25    0.26    0.00    0.14    0.11    0.00    0.60    0.00    3.27    0.00    0.00    0.00    0.00    0
   .00   0.00   0.00



           STREAM QUALITY SIMULATION                                                                                    OUTPUT PA
  GE NUMBER      5
           QUAL-2E STREAM QUALITY ROUTING MODEL                                                                 Version 3.22  --
   May 1996
                                                            ***** STEADY STATE SIMULATION *****

                                                               ** WATER QUALITY VARIABLES **

  RCH ELE                 CM-1    CM-2    CM-3
          ANC
  NUM NUM         TEMP                                    DO     BOD    ORGN    NH3N    NO2N    NO3N   SUM-N    ORGP   DIS-P   SUM-P    C
  OLI             CHLA
                  DEG-F                                 MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L #/1
  00ML            UG/L

    1   1         72.30    0.00    0.00    0.00    8.13    0.95    0.00    0.12    0.01    0.01    0.14    0.00    0.00    0.00.00E
  +00   0.00      0.00
    1   2         72.30    0.00    0.00    0.00    7.83    0.90    0.00    0.11    0.01    0.02    0.14    0.00    0.00    0.00.00E
  +00   0.00      0.00
    1   3         72.30    0.00    0.00    0.00    7.62    0.85    0.00    0.10    0.02    0.03    0.14    0.00    0.00    0.00.00E
  +00   0.00      0.00
    1   4         72.30    0.00    0.00    0.00    7.49    0.80    0.00    0.09    0.02    0.04    0.14    0.00    0.00    0.00.00E
```

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    +00   0.00   0.00
     1    5      72.30   0.00   0.00   0.00   7.41   0.76   0.00   0.08   0.01   0.05   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00


     2    1      72.30   0.00   0.00   0.00   7.36   0.72   0.00   0.07   0.01   0.06   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    2      72.30   0.00   0.00   0.00   7.33   0.68   0.00   0.06   0.01   0.07   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    3      72.30   0.00   0.00   0.00   7.32   0.65   0.00   0.05   0.01   0.08   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    4      72.30   0.00   0.00   0.00   7.31   0.61   0.00   0.05   0.01   0.08   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    5      72.30   0.00   0.00   0.00   7.31   0.58   0.00   0.04   0.01   0.09   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    6      72.30   0.00   0.00   0.00   7.32   0.55   0.00   0.04   0.01   0.10   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    7      72.30   0.00   0.00   0.00   7.32   0.52   0.00   0.03   0.01   0.10   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    8      72.30   0.00   0.00   0.00   7.33   0.49   0.00   0.03   0.01   0.11   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    9      72.30   0.00   0.00   0.00   7.34   0.47   0.00   0.03   0.01   0.11   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     2    10     72.30   0.00   0.00   0.00   7.35   0.44   0.00   0.02   0.00   0.11   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00


     3    1      72.30   0.00   0.00   0.00   7.35   0.42   0.00   0.02   0.00   0.12   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    2      72.30   0.00   0.00   0.00   7.36   0.40   0.00   0.02   0.00   0.12   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    3      72.30   0.00   0.00   0.00   7.37   0.37   0.00   0.02   0.00   0.12   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    4      72.30   0.00   0.00   0.00   7.37   0.36   0.00   0.01   0.00   0.12   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    5      72.30   0.00   0.00   0.00   7.38   0.34   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    6      72.30   0.00   0.00   0.00   7.39   0.32   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    7      72.30   0.00   0.00   0.00   7.39   0.30   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    8      72.30   0.00   0.00   0.00   7.40   0.29   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    9      72.30   0.00   0.00   0.00   7.40   0.27   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    10     72.30   0.00   0.00   0.00   7.40   0.26   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    11     72.30   0.00   0.00   0.00   7.41   0.24   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    12     72.30   0.00   0.00   0.00   7.41   0.23   0.00   0.01   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    13     72.30   0.00   0.00   0.00   7.42   0.22   0.00   0.00   0.00   0.13   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    14     72.30   0.00   0.00   0.00   7.42   0.21   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    15     72.30   0.00   0.00   0.00   7.42   0.19   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    16     72.30   0.00   0.00   0.00   7.42   0.18   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    17     72.30   0.00   0.00   0.00   7.43   0.17   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    18     72.30   0.00   0.00   0.00   7.43   0.17   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     3    19     72.30   0.00   0.00   0.00   7.43   0.16   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00


     4    1      73.40   0.00   0.00   0.00   4.97   0.14   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     4    2      73.40   0.00   0.00   0.00   4.99   0.11   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     4    3      73.40   0.00   0.00   0.00   4.99   0.09   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     4    4      73.40   0.00   0.00   0.00   5.00   0.07   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     4    5      73.40   0.00   0.00   0.00   5.00   0.06   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00
     4    6      73.40   0.00   0.00   0.00   5.00   0.05   0.00   0.00   0.00   0.14   0.14   0.00   0.00   0.00.00E
    +00   0.00   0.00

                STREAM QUALITY SIMULATION                                                                  OUTPUT PA
GE NUMBER     6
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          QUAL-2E STREAM QUALITY ROUTING MODEL                                                  Version 3.22  --
 May 1996
                                                        ***** STEADY STATE SIMULATION *****

                                                           ** WATER QUALITY VARIABLES **

RCH ELE                 CM-1    CM-2    CM-3
       ANC
NUM NUM          TEMP                                DO     BOD    ORGN    NH3N    NO2N    NO3N   SUM-N    ORGP   DIS-P   SUM-P     C
OLI              CHLA
                 DEG-F                             MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L    MG/L #/1
00ML             UG/L

  4   7          73.40   0.00    0.00    0.00      5.01    0.04    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4   8          73.40   0.00    0.00    0.00      5.01    0.03    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4   9          73.40   0.00    0.00    0.00      5.01    0.03    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  10          73.40   0.00    0.00    0.00      5.01    0.02    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  11          73.40   0.00    0.00    0.00      5.01    0.02    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  12          73.40   0.00    0.00    0.00      5.01    0.01    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  13          73.40   0.00    0.00    0.00      5.01    0.01    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  14          73.40   0.00    0.00    0.00      5.01    0.01    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  15          73.40   0.00    0.00    0.00      5.01    0.01    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  16          73.40   0.00    0.00    0.00      5.01    0.01    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  17          73.40   0.00    0.00    0.00      5.01    0.01    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  18          73.40   0.00    0.00    0.00      5.01    0.00    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00
  4  19          73.40   0.00    0.00    0.00      5.01    0.00    0.00    0.00    0.00    0.14    0.14    0.00    0.00     0.00.00E
+00   0.00       0.00



          STREAM QUALITY SIMULATION                                                                               OUTPUT PA
GE NUMBER      7
          QUAL-2E STREAM QUALITY ROUTING MODEL                                                  Version 3.22  --
 May 1996
                                                        ***** STEADY STATE SIMULATION *****

                                                            ** DISSOLVED OXYGEN DATA **

                                                                      COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG
/L-DAY)
ELE RCH ELE              DO               DO      DAM      NIT
ORD NUM NUM    TEMP      SAT      DO      DEF    INPUT    INHIB      F-FNCTN   OXYGN                          NET
               DEG-F     MG/L     MG/L    MG/L    MG/L     FACT        INPUT   REAIR    C-BOD      SOD        P-R     NH3-N
  NO2-N

  1   1   1    72.30     8.59     8.13    0.45    0.00     0.99        39.40    1.00    -0.24    -2.33      0.00     -0.25
  -0.04
  2   1   2    72.30     8.59     7.83    0.76    0.00     0.99         0.00    1.69    -0.23    -2.33      0.00     -0.23
  -0.05
  3   1   3    72.30     8.59     7.62    0.96    0.00     0.99         0.00    2.14    -0.22    -2.33      0.00     -0.20
  -0.06
  4   1   4    72.30     8.59     7.49    1.09    0.00     0.99         0.00    2.43    -0.21    -2.33      0.00     -0.18
  -0.06
  5   1   5    72.30     8.59     7.41    1.18    0.00     0.99         0.00    2.61    -0.20    -2.33      0.00     -0.16
  -0.06


  6   2   1    72.30     8.59     7.36    1.23    0.00     0.99         0.01    2.72    -0.19    -2.33      0.00     -0.14
  -0.05
  7   2   2    72.30     8.59     7.33    1.25    0.00     0.99         0.00    2.79    -0.18    -2.33      0.00     -0.12
  -0.05
  8   2   3    72.30     8.59     7.32    1.27    0.00     0.99         0.00    2.82    -0.17    -2.33      0.00     -0.11
  -0.04
  9   2   4    72.30     8.59     7.31    1.27    0.00     0.99         0.00    2.83    -0.16    -2.33      0.00     -0.10
  -0.04
 10   2   5    72.30     8.59     7.31    1.27    0.00     0.99         0.00    2.83    -0.15    -2.33      0.00     -0.08
  -0.03
 11   2   6    72.30     8.59     7.32    1.27    0.00     0.99         0.00    2.82    -0.14    -2.33      0.00     -0.07
  -0.03
 12   2   7    72.30     8.59     7.32    1.26    0.00     0.99         0.00    2.81    -0.13    -2.33      0.00     -0.07
```

-0.03

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
13	2	8	72.30	8.59	7.33	1.26	0.00	0.99	0.00	2.79	-0.13	-2.33	0.00	-0.06	-0.02
14	2	9	72.30	8.59	7.34	1.25	0.00	0.99	0.00	2.77	-0.12	-2.33	0.00	-0.05	-0.02
15	2	10	72.30	8.59	7.35	1.24	0.00	0.99	0.00	2.76	-0.11	-2.33	0.00	-0.05	-0.02
16	3	1	72.30	8.59	7.35	1.23	0.00	0.99	0.01	2.74	-0.11	-2.33	0.00	-0.04	-0.02
17	3	2	72.30	8.59	7.36	1.23	0.00	0.99	0.00	2.72	-0.10	-2.33	0.00	-0.04	-0.01
18	3	3	72.30	8.59	7.37	1.22	0.00	0.99	0.00	2.71	-0.10	-2.33	0.00	-0.03	-0.01
19	3	4	72.30	8.59	7.37	1.21	0.00	0.99	0.00	2.69	-0.09	-2.33	0.00	-0.03	-0.01
20	3	5	72.30	8.59	7.38	1.21	0.00	0.99	0.00	2.68	-0.09	-2.33	0.00	-0.02	-0.01
21	3	6	72.30	8.59	7.39	1.20	0.00	0.99	0.00	2.67	-0.08	-2.33	0.00	-0.02	-0.01
22	3	7	72.30	8.59	7.39	1.20	0.00	0.99	0.00	2.66	-0.08	-2.33	0.00	-0.02	-0.01
23	3	8	72.30	8.59	7.40	1.19	0.00	0.99	0.00	2.65	-0.07	-2.33	0.00	-0.02	-0.01
24	3	9	72.30	8.59	7.40	1.19	0.00	0.99	0.00	2.64	-0.07	-2.33	0.00	-0.02	-0.01
25	3	10	72.30	8.59	7.40	1.18	0.00	0.99	0.00	2.63	-0.07	-2.33	0.00	-0.01	-0.01
26	3	11	72.30	8.59	7.41	1.18	0.00	0.99	0.00	2.62	-0.06	-2.33	0.00	-0.01	0.00
27	3	12	72.30	8.59	7.41	1.17	0.00	0.99	0.00	2.61	-0.06	-2.33	0.00	-0.01	0.00
28	3	13	72.30	8.59	7.42	1.17	0.00	0.99	0.00	2.60	-0.06	-2.33	0.00	-0.01	0.00
29	3	14	72.30	8.59	7.42	1.17	0.00	0.99	0.00	2.59	-0.05	-2.33	0.00	-0.01	0.00
30	3	15	72.30	8.59	7.42	1.16	0.00	0.99	0.00	2.59	-0.05	-2.33	0.00	-0.01	0.00
31	3	16	72.30	8.59	7.42	1.16	0.00	0.99	0.00	2.58	-0.05	-2.33	0.00	-0.01	0.00
32	3	17	72.30	8.59	7.43	1.16	0.00	0.99	0.00	2.58	-0.04	-2.33	0.00	-0.01	0.00
33	3	18	72.30	8.59	7.43	1.16	0.00	0.99	0.00	2.57	-0.04	-2.33	0.00	-0.01	0.00
34	3	19	72.30	8.59	7.43	1.16	0.00	0.99	0.00	2.57	-0.04	-2.33	0.00	0.00	0.00
35	4	1	73.40	8.49	4.97	3.52	0.00	0.95	0.00	7.93	-0.04	-6.21	0.00	0.00	0.00
36	4	2	73.40	8.49	4.99	3.50	0.00	0.95	0.00	7.89	-0.03	-6.21	0.00	0.00	0.00
37	4	3	73.40	8.49	4.99	3.49	0.00	0.95	0.00	7.88	-0.02	-6.21	0.00	0.00	0.00
38	4	4	73.40	8.49	5.00	3.49	0.00	0.95	0.00	7.87	-0.02	-6.21	0.00	0.00	0.00
39	4	5	73.40	8.49	5.00	3.49	0.00	0.95	0.00	7.86	-0.02	-6.21	0.00	0.00	0.00
40	4	6	73.40	8.49	5.00	3.48	0.00	0.95	0.00	7.85	-0.01	-6.21	0.00	0.00	0.00

STREAM QUALITY SIMULATION OUTPUT PAGE NUMBER 8

QUAL-2E STREAM QUALITY ROUTING MODEL Version 3.22 -- May 1996

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
41	4	7	73.40	8.49	5.01	3.48	0.00	0.95	0.00	7.85	-0.01	-6.21	0.00	0.00	0.00
42	4	8	73.40	8.49	5.01	3.48	0.00	0.95	0.00	7.85	-0.01	-6.21	0.00	0.00	0.00
43	4	9	73.40	8.49	5.01	3.48	0.00	0.95	0.00	7.84	-0.01	-6.21	0.00	0.00	

																0.00
566	44	4	10	73.40	8.49	5.01	3.48	0.00	0.95	0.00	7.84	-0.01	-6.21	0.00	0.00	0.00
567	45	4	11	73.40	8.49	5.01	3.48	0.00	0.95	0.00	7.84	0.00	-6.21	0.00	0.00	0.00
568	46	4	12	73.40	8.49	5.01	3.48	0.00	0.95	0.00	7.84	0.00	-6.21	0.00	0.00	0.00
569	47	4	13	73.40	8.49	5.01	3.47	0.00	0.95	0.00	7.84	0.00	-6.21	0.00	0.00	0.00
570	48	4	14	73.40	8.49	5.01	3.47	0.00	0.95	0.00	7.83	0.00	-6.21	0.00	0.00	0.00
571	49	4	15	73.40	8.49	5.01	3.47	0.00	0.95	0.00	7.83	0.00	-6.21	0.00	0.00	0.00
572	50	4	16	73.40	8.49	5.01	3.47	0.00	0.95	0.00	7.83	0.00	-6.21	0.00	0.00	0.00
573	51	4	17	73.40	8.49	5.01	3.47	0.00	0.95	0.00	7.83	0.00	-6.21	0.00	0.00	0.00
574	52	4	18	73.40	8.49	5.01	3.47	0.00	0.95	0.00	7.83	0.00	-6.21	0.00	0.00	0.00
575	53	4	19	73.40	8.49	5.01	3.47	0.00	0.95	0.00	7.83	0.00	-6.21	0.00	0.00	0.00

Attachment 2

Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from July 19, 2006 through August 16, 2006 postmarked, including those from the August 2, 2006 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 and designated uses. The Hodges Creek Stage 3 TMDL report details the necessary reduction in pollutant loads to the impaired water bodies to ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations promulgated thereunder.

Background

The watershed targeted for TMDL development is Hodges Creek, which originates in Macoupin County. The watershed encompasses an area of approximately 233 square miles. Land use in the watershed is predominately agriculture. Hodges Creek segment DAG-02 is 10.7 miles in length and is on the *Illinois Integrated Water Quality Report and Section 303(d) List-2006* as being impaired for low dissolved oxygen. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. The Illinois EPA contracted with Limno-Tech, Inc., to prepare a TMDL report for the Hodges Creek watershed.

Public Meetings

Public meetings were held in the village of Girard on March 22, 2005, and August 2, 2006. The Illinois EPA provided public notice for both meetings by placing display ads in the Carlinville Enquirer-Democrat, the Springfield State Journal-Register, the Girard Gazette, and the Palmyra Northwestern News. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 74 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the Otter Lake Water Commission office and also on the Agency's web page at http://www.epa.state.il.us/public-notices .

The Stage 3 public meeting started at 6:00 p.m. on Wednesday, August 2, 2006, and was attended by 2 people. The meeting concluded at 6:30 p.m. with the meeting record remaining open until midnight, August 16, 2006.

Questions and Comments

1. The discussion of loading capacity (Element 3 under Section 2) explains the link between the target reduction in particulate organic carbon loading and needed reduction in sediment oxygen demand (SOD) to improve dissolved oxygen (DO) conditions. The report calculates loads and allocations for ammonia without explaining a connection to SOD and DO conditions. The report should clarify what the TMDL targets are.

   Response: This matter will be clarified in the final report.

2. This report and the implementation plan should specifically address the contributions of septic systems, including surface-discharging systems, on particulate organic carbon and ammonia loads to Hodges Creek. Approaches to lower these loads will differ from approaches to dealing with loads from agricultural runoff.

   Response: Text will be added to the final version of this report to clarify the intent of IEPA to address this issue in the implementation plan. Since little data are currently available t clearly identify loads from these sources, investigations and monitoring under the implementation plan will be needed.

3. The report states in some places (Page 6 and Section 5.1.2) that an implementation plan *may* be prepared by local stakeholders, and in other places (Section 8) implies that IEPA will prepare an implementation plan. Please clarify what the next steps are and who will be taking them.

   Response: IEPA will prepare a TMDL implementation plan that will give general recommendations for addressing reductions of the pollutants of concern. It will be up to local stakeholders to then take those recommendations and prepare a more site-specific plan that will detail which practices will be adopted, where those practices will be applied, how much it will cost, and under what time frame the actions will be taken.

4. I appreciate that IEPA is following steps recommended by the Science Advisory Committee to accelerate TMDL implementation in nonpoint source-dominated watersheds. However, it seems that the plan outlined here is to leave all analyses of the significance of nonpoint sources to local experts to be convened at an unspecified time on a voluntary basis. A much more effective approach would be for IEPA, who has just devoted considerable resources to collecting data and performing analyses on this and other similar watersheds, to at least include a few sample load reduction plans showing different ways load reductions could be achieved in the watershed as a starting point for the stakeholder process.

   Response: IEPA will work with our consultant to include load reduction information, such as BMP types, anticipated benefits and costs, and financial assistance program, in the TMDL implementation plan.

TMDL Implementation Plan

Hodges Creek Watershed

Prepared for Illinois Environmental Protection Agency

November 2006

Otter Lake (RDF): Manganese

Palmyra-Modesto Lake (RDZP): Manganese, Dissolved Oxygen, pH

Hettick Lake (SDZF): Total Phosphorus, Dissolved Oxygen

Hodges Creek (DAG 02): Dissolved Oxygen

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SUMMARY

Total Maximum Daily Loads (TMDLs) were developed and approved by the U.S. EPA in September 2005 for Otter Lake, Palmyra-Modesto Lake, and Hettick Lake within the Hodges Creek watershed in West-Central Illinois, to address a number of water quality impairments in the lakes. Specifically, TMDLs were developed for manganese in Otter Lake; for manganese, dissolved oxygen, and pH in Palmyra-Modesto Lake; and for total phosphorus and dissolved oxygen in Hettick Lake. 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. A separate TMDL report was developed and submitted to U.S. EPA in September 2006 for Hodges Creek to address low dissolved oxygen. This TMDL determined that while sediment oxygen demand is the overwhelming oxygen sink, the true cause of low DO is a lack of base flow (which greatly exacerbates the effect of SOD). 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, identifies priority areas for controls and provides monitoring recommendations.

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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).

Otter Lake, Palmyra-Modesto Lake, Hettick Lake, and Hodges Creek are listed on the 2004 Illinois Section 303(d) List of Impaired Waters (IEPA, 2004) as water bodies that are not meeting their designated uses. As such, these waterbodies were targeted as high priority waters for TMDL development. TMDLs for the lakes have been developed and approved by the U.S. EPA (LTI, 2005). The TMDL for Hodges Creek has also been submitted to U.S. EPA Region V. Although this TMDL is considered completed by IEPA, it will not be approved by U.S. EPA Region V because the low dissolved oxygen levels were determined to be due to low flow, and not pollutants; TMDLs cannot be written to control flow. 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 Otter Lake, Palmyra-Modesto Lake, Hettick Lake and Hodges Creek 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, describing priority areas for controls, describing reasonable assurances that the measures will be implemented, and outlining future monitoring and adaptive management.

WATERSHED DESCRIPTION

The impaired waterbodies addressed in this report are located within the Hodges Creek watershed, which is located in West-Central Illinois approximately 45 miles south of Springfield. The majority of Hodges Creek's watershed is in Macoupin County (97%), with small portions extending into Greene, Jersey, Morgan, and Sangamon Counties. The watershed for Hodges Creek is approximately 148,961 acres (233 square miles) in size. Figure 1 shows a map of the watershed, and includes key features such as waterways, impaired waterbodies, and public water intakes. The map also shows the locations of point source discharges that have a permit to discharge under the National Pollutant Discharge Elimination System (NPDES). As shown in this figure, the Hodges Creek watershed is roughly bisected by route 111, with route 108 passing through the southern portion of the watershed.

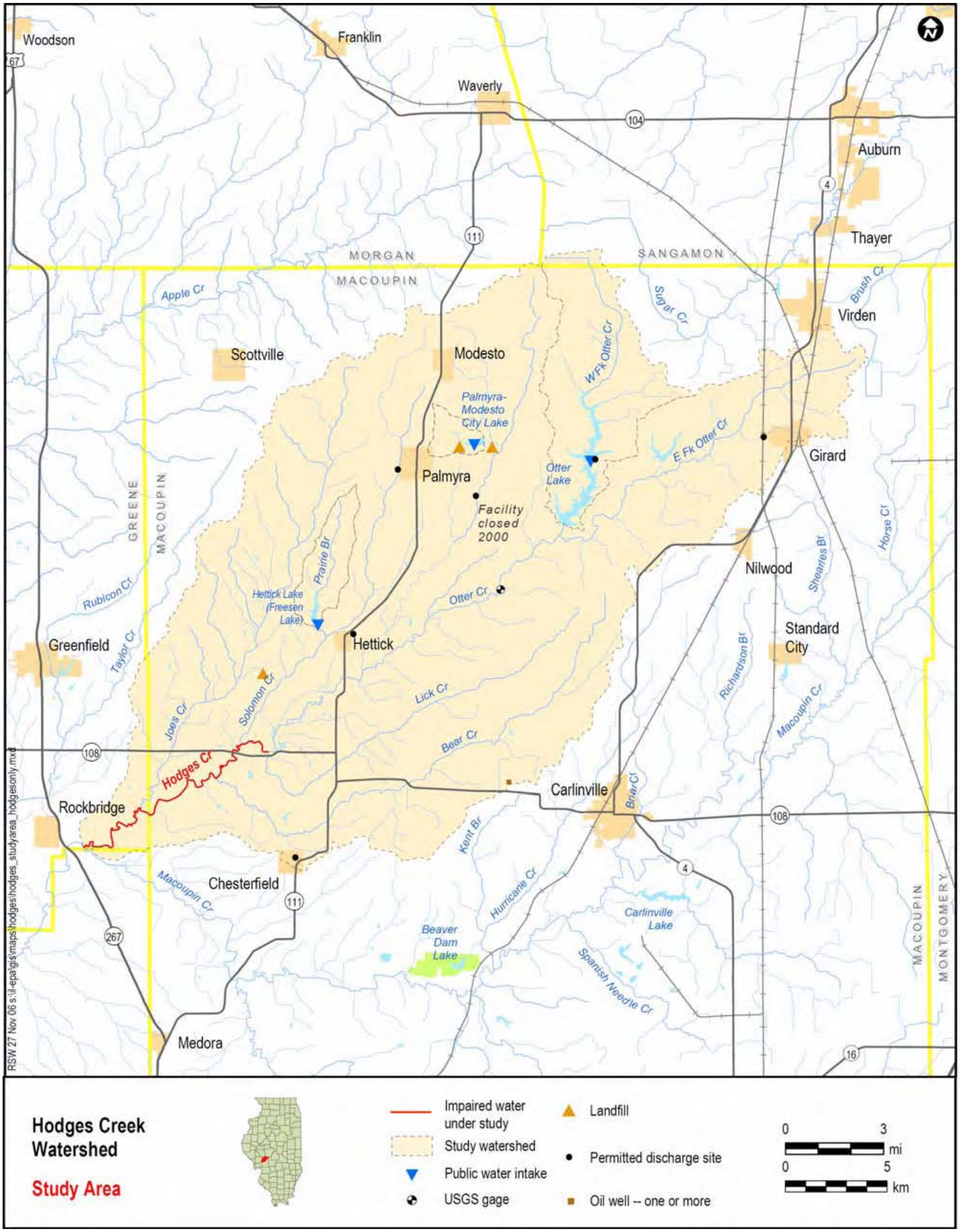

Figure 1. Base Map of Hodges Creek Watershed

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Otter Lake (RDF) Watershed

Otter Lake is located west of Girard, Illinois and about 20 miles southwest of Springfield. The lake is 765 acres in size and its watershed is approximately 12,818 acres in size. The lake is an impoundment on Otter Creek. Construction of Otter Lake was completed in 1968. The ADGPTV Water Commission owns and manages Otter Lake and a strip of land around the lake's perimeter. More than 90 percent of the strip is in trees or vegetative cover (Farnsworth et al., 1998). Otter Lake is a public water supply, and it also supports recreational activities such as camping, fishing and boating. The lake also features an underwater search and rescue training area (Farnsworth et al., 1998). The average depth is 19.7 feet, and at its deepest point, the lake is approximately 50 feet deep (Lin et al, 1999).

Approximately 77% of the land in the Otter Lake subwatershed is used for agriculture, and approximately 9% is forested. The primary agricultural land use is corn (56%) and soybeans (42%), with lesser amounts of winter wheat, other small grains and hay (LTI, 2004). Erosion is a problem in the watershed. Approximately 15% of the acreage in the Otter Lake watershed consists of highly erodible soils (Lin, et al, 1999). The total erosion rate in the watershed is approximately 27,585 tons per year (Lin et al, 1999).

Palmyra-Modesto Lake (RDZP) Watershed

Palmyra-Modesto Lake is located east of Palmyra and approximately 20 miles southwest of Springfield. The lake is a public water supply. The lake is 35 acres in size and the watershed is small, covering a total of 1,080 acres, or 1.7 square miles. Approximately 82% of the land is used for agriculture, with the primary crops being soybeans (57%) and corn (39%). There are lesser amounts of winter wheat, other small grains and hay (LTI, 2004).

Hettick Lake (RDZF) Watershed

Hettick Lake is also referred to as Freesen Lake. It was formerly a water supply for Hettick, but it is no longer used for this purpose. The lake is approximately 110 acres in size. Its subwatershed is 2,794 acres (4.4 square miles) in size. The land surrounding the lake is largely forested and there is a Boy Scout camp on the lake. Siltation has been an ongoing problem in the lake, and recent measures to reduce loadings of sediment have not been successful (LTI, 2004). Approximately 67% of the land in the Hettick Lake subwatershed is used for agriculture and 20% is forested. The primary crops are soybeans (65%) and corn (28%) with lesser amounts of winter wheat, other small grains and hay (LTI, 2004).

Hodges Creek (DAG 02) Watershed

The impaired segment of Hodges Creek is 10.7 miles long and its watershed is 148,961 acres (233 square miles) in size. The upstream end of this segment begins near the Route 108 road crossing and the downstream end is marked by the confluence of Hodges Creek with Macoupin Creek. Approximately 72% of the land in the Hodges Creek watershed is used for agriculture and 16% is forested. Although forested areas are generally found near streams, recent land cover information shows very little forest near the banks of the segment DAG 02. A recently completed aerial assessment of Otter and Hodges Creek (IDOA, 2005) found numerous erosion sites in Otter Creek as well as within Hodges Creek Segment DAG 02.

TMDL SUMMARY

The four impaired waterbody segments 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). TMDLs have currently only been developed for pollutants that have numerical water quality standards. Those impairments that are the focus of this report are shown in bold font.

Potential sources contributing to the listing of these waterbodies on the 303(d) list are summarized in Table 2.

TMDLs require targets, or 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.

Otter Lake

The water quality standard for manganese in Illinois waters designated as public water supplies is 150 ug/l. The only controllable source of manganese to Otter Lake is the release of manganese from lake sediments during periods when there is no dissolved oxygen in lake bottom waters. For the Otter Lake manganese TMDL, the water quality goal is therefore maintenance of hypolimnetic dissolved oxygen concentrations above zero. The lack of dissolved oxygen in lake bottom waters is presumed to be due to sediment oxygen demand resulting from the effects of nutrient enrichment, as no known significant sources of oxygen demanding materials to the lake were identified during the watershed characterization (LTI, 2004). For this reason, attainment of the total phosphorus standard is expected to result in oxygen concentrations that will reduce sediment manganese flux to natural background levels. The TMDL target for manganese is therefore set as a total phosphorus concentration of 0.050 mg-P/l, consistent with state standards for phosphorus.

Palmyra-Modesto Lake

A surrogate parameter (total phosphorus concentration) was selected as the TMDL target for the dissolved oxygen, manganese and pH TMDLs. The linkage between the TMDL target (total phosphorus) and the other impairments is explained as follows. First, phosphorus loadings to lakes can stimulate excess algal growth. Excess algal growth can affect pH through the uptake of carbonic acid. 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. The TMDL targets for manganese, dissolved oxygen, and pH were therefore set as a total phosphorus concentration of 0.050 mg-P/l.

Hettick Lake

For the Hettick Lake phosphorus TMDL, the target is set at the water quality criterion for total phosphorus of 0.050 mg-P/l. Violation of the dissolved oxygen standard is presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding materials to the lake. For this reason, attainment of the total phosphorus standard is expected to result in attainment of the dissolved oxygen standard. The TMDL target for dissolved oxygen is therefore set as a total phosphorus concentration of 0.050 mg-P/l.

Hodges Creek

For the Hodges Creek dissolved oxygen TMDL, the target was based upon the water quality criterion for minimum dissolved oxygen of 5 mg/l. The QUAL2E model used to calculate the TMDL predicts a daily average dissolved oxygen concentration and does not directly predict daily minimum values. QUAL2E results can be translated into a form comparable to a daily minimum, by subtracting the observed difference between daily average and daily minimum dissolved oxygen from the model output. For QUAL2E model runs, a modeling target of 6.0 mg/l was used to consider diurnal variation and ensure that the 5.0 mg/l water quality standard is met.

Table 1. Summary of Impairments

Otter Lake	
Waterbody Segment	RDF
Size (Miles/Acres)	765
Listed For	**Manganese**, excess algal growth
Use Support[1]	Aquatic life (F), Fish consumption (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)
Palmyra-Modesto Lake	
Waterbody Segment	RDZP
Size (Miles/Acres)	35
Listed For	**Manganese, dissolved oxygen, pH**, excess algal growth
Use Support[1]	Aquatic life (F), Overall use (P), Primary contact (P), Secondary contact (P), Public water supply (P)
Hettick Lake	
Waterbody Segment	SDZF
Size (Miles/Acres)	110
Listed For	**Total phosphorus, dissolved oxygen**, excess algal growth, unspecified nutrients
Use Support[1]	Aquatic life (F), Fish consumption (F), Overall use (P), Primary contact (P), Secondary contact (P)
Hodges Creek	
Assessment Unit ID	IL_DAG-02
Length (miles)	10.7
Listed For	**Dissolved oxygen**
Use Support[1]	Aquatic life (N), Fish consumption (X), Primary contact (X), Secondary contact (X), Aesthetic quality (X)

[1]F=full support, P=partial support, N=nonsupport; X= not assessed

Table 2. Waterbody Impairment Causes and Sources

Waterbody	Cause of impairments	Potential Sources
Otter Lake (RDF)		
	Manganese	Natural background sources including runoff and soil erosion and release from sediments when dissolved oxygen is absent
Palmyra-Modesto Lake (RDZP)		
	Manganese	Natural background sources including runoff and soil erosion and release from sediments when dissolved oxygen is absent
	Dissolved Oxygen	Sediment oxygen demand, Nutrients, ammonia and BOD from failing private sewage disposal systems (septic and surface discharge systems), runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock)
	pH	Excess algal production resulting from nutrient loading from failing private sewage disposal systems (septic and surface discharge systems), runoff from agricultural land and livestock
Hettick Lake (SDZF)		
	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
	Dissolved Oxygen	Sediment oxygen demand, nutrients, ammonia and BOD from failing private sewage disposal systems (septic and surface discharge systems), runoff from agricultural land, and livestock
Hodges Creek (DAG 02)		
	Dissolved oxygen	Sediment oxygen demand Conditions are exacerbated during low flow Nutrients, ammonia and BOD from municipal point sources, failing private sewage disposal systems, runoff from lawns and agricultural land (fertilized cropland and agricultural land with livestock).[1]

[1]Modeling showed that these are not a cause of low DO in Hodges Creek.

The TMDL determined the total allowable load for each lake and to Hodges Creek, as well as the level of reduction needed to achieve the TMDL targets. Table 3 summarizes the existing phosphorus loads to the lakes, the total loading capacity, the waste load allocations for point sources, the load allocations given to non-point sources, the explicit margin of safety incorporated in the TMDLs, and the amount of reduction of exiting load that would be needed to attain the water quality objective.

Table 3. TMDL Summary for Otter, Palmyra-Modesto, and Hettick Lakes

Lake	Existing Phosphorus Load (kg/day[1])	Allowable Load (kg/day[1])	Waste Load Allocation (kg/day[1])	Load Allocation (kg/day[1])	Margin of Safety (kg/day[1])	Percent Reduction Needed
Otter	11.4	3.86	0.34[2]	3.13	0.39	66%
Palmyra-Modesto	0.38	0.24	--	0.212	0.024	38%
Hettick	4.1	0.75	--	0.673	0.075	82%

[1] Loads apply to the period March – August
[2] Estimated existing load (LTI, 2005)

The TMDL for Hodges Creek determined that sediment oxygen demand is the dominant source of the oxygen deficit; however, the true cause of low dissolved oxgyen is a lack of base flow (which greatly exacerbates the effect of sediment oxygen demand). Because TMDLs cannot be written to control flow, the focus of the TMDL was instead on SOD, as its effect on dissolved oxygen is dominant under low flow conditions.

In order to meet the target for dissolved oxygen, SOD must be reduced by 35% during low flow conditions to meet the TMDL target for dissolved oxygen, assuming that other sources are maintained at existing loads. To achieve this, a 35% reduction of particulate organic carbon loading to the stream is needed. In addition, allocations given to BOD and ammonia are based on natural background loads and current point source permit limits. The TMDL allocations for BOD and ammonia are summarized in Tables 4 and 5.

Table 4. TMDL Summary for Hodges Creek CBOD5

Allowable Load (kg/day)	Waste load Allocation (kg/day)	Load Allocation (kg/day)	Margin of Safety (kg/day)
37.4	37.2	0.2	0.02

*Numbers may not sum exactly due to rounding

In addition to the WLAs described above, the Girard STP also has a permit for an excess flow bypass that may occur under wet weather conditions. During high flow conditions, the wasteload allocation for the excess flow bypass is 13.5 kg/day for CBOD5, based on current point source permit limits.

Table 5. TMDL Summary for Hodges Creek Ammonia

Season	Allowable Load (kg/day)	Waste load Allocation (kg/day)	Load Allocation (kg/day)	Margin of Safety (kg/day)
March	6	6	0.02	0.002
Apr. – Oct.	3.2	3.2	0.02	0.002
Nov. – Feb.	8.2	8.2	0.02	0.002

*Numbers may not sum exactly due to rounding

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, QUAL2E) 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, 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 reports (LTI, 2005; LTI, 2006). 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 TMDLs, discussions with local personnel, information obtained at the public meetings, a Clean Lakes Study for Otter Lake, an aerial assessment survey of Otter and Hodges Creeks, and experience in other watersheds, a number of alternatives have been identified for the implementation phase of these TMDLs.

It is noted that a number of projects have already been undertaken in the Otter Lake and Palmyra-Modesto Lake watersheds, including the following Federally funded activities (LTI, 2005):

- Specific water quality issues, primarily siltation and atrazine of two public water supply lakes were addressed through the construction of thirteen water and sediment control basins in the Otter Lake and/or Palmyra/Modesto Lake watersheds. The Macoupin County SWCD was the local partner for this project.
- The Association of Illinois Soil and Water Conservation District (AISWCD) subcontracted with eleven SWCDs to hire staff to facilitate the enrollment process of the Conservation Reserve Enhancement Program (CREP) by setting appointments with producers to discuss CREP and conduct field visits to determine program eligibility. This project is focused in three of the four counties that the Hodges Creek watershed traverses (Greene, Montgomery and Macoupin).
- Section 319 funding has been obtained for the design and construction of a low water sedimentation control structure in the north end of Otter Lake. This structure will provide a controlled sediment basin, trapping sediment and associated pollutants, including phosphorus, entering from the West Fork of Otter Creek. Construction of this structure was initiated in 2006.
- In 1998 and 1999, funding was provided to the ADGPTV Water Commission and the Otter Lake Water Commission for two projects to address Otter Lake shoreline erosion. This funding was provided through the Illinois Clean Lakes Program and the Priority Lake and Watershed Implementation Program.
- In 1998, funding was provided to the Palmyra-Modesto Water Commission to control shoreline erosion for Palmyra-Modesto Lake. This funding was provided through the Priority Lake and Watershed Implementation Program.

As of 1998, 27 farmers in the Otter Lake watershed had conservation plans filed with the local NRCS office (Farnsworth et al, 1998). These plans included practices such as nutrient and pesticide management and some form of conservation tillage. Ten of the 27 plans included the conversion of cropland adjacent to streams to filter strips. Other farmers adopted conservation systems, typically mulch till or no-till and lengthened their rotations (Farnsworth et al, 1998).

For the three impaired lakes, implementation alternatives are focused on those sources suspected of contributing phosphorus loads to the lakes (agricultural sources, release from existing lake bottom sediments under anoxic conditions, streambank and shoreline erosion, and failing private sewage disposal systems), since the TMDL targets are total phosphorus levels in the lake. These alternatives include:

- Sediment Control Basins
- Conservation Buffers
- Grassed Waterways
- Nutrient Management
- Animal Waste Management
- Conservation Tillage
- Streambank and Shoreline Enhancement and Protection
- Erosion Control Measures for New Development
- Private Sewage Disposal System Inspection and Maintenance Program
- Aeration/Destratification
- Dredging
- Phosphorus Inactivation

For the Hodges Creek TMDL, implementation alternatives are focused on improving aeration, improving flow rate and decreasing water temperature. The alternatives include:

- Conservation Buffers
- Streambank Enhancement and Protection

Each of these alternatives is described briefly below, including information about their costs and effectiveness. 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). Some of the measures described below are most applicable to a single pollutant, while others will have broader applicability. In general, any controls that reduce erosion and phosphorus will also reduce particulate organic carbon (POC) loads. Decreases in POC loading will reduce sediment oxygen demand and therefore improve instream dissolved oxygen concentrations. Controls that improve aeration, decrease temperature and increase infiltration will improve dissolved oxygen levels. Table 6 summarizes the implementation alternatives and the improvements expected from each.

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, 2006a). 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, 2006a).

Table 6. Applicability of Implementation Alternatives

Alternative	Decrease phosphorus loads	Improve aeration	Decrease temperature	Increase infiltration
Sediment Control Structures	◆*			◆
Conservation Buffers	◆*	◆	◆	◆
Grassed Waterways	◆*			
Nutrient Management Plans	◆*			
Animal Waste Management	◆*			
Conservation Tillage	◆*			◆
Shoreline Enhancement and Protection	◆*	◆	◆	
Erosion Control Measures for New Development	◆*			
Private Sewage Disposal System Inspection and Maintenance Program	◆			
Aeration/Destratification	◆			
Dredging	◆			
Phosphorus Inactivation	◆			

* While not directly tied to primary sources of particulate organic carbon, BMPs designed to reduce erosion are expected to provide secondary benefits in reducing POC loads to Hodges Creek.

Sediment Control Basins

Sediment control basins trap sediments (and nutrients bound to that sediment) before they reach surface waters (EPA, 2003). Such basins could be installed throughout the watershed, in areas selected to minimize disruption to existing croplands. This could be particularly useful in the upper part of the Otter Lake watershed, given that the upper portion of Otter Lake is heavily silted in. In addition to controlling sediment, these basins would reduce phosphorus loads to the lakes and increase groundwater recharge. As noted previously, Section 319 funding has been obtained in the past for sediment control basins in both the Otter Lake and Palmyra/Modesto Lake watersheds. Costs for these basins can vary widely depending on location and size; estimates prepared for another Illinois watershed range from $1,200 to more than $200,000 per basin (Zahniser Institute, undated). This same study estimated a trapping efficiency for sediment of 75%.

Section 319 funding has been obtained for the design and construction of a low water sedimentation control structure in the north end of Otter Lake. This structure will provide a controlled sediment basin, trapping sediment and associated pollutants entering from the West Fork of Otter Creek. Construction of this structure was initiated in 2006. Discussions at the August 2005 TMDL public meeting suggested that local interest in cost-share ponds would be high in these watersheds. Ponds would not only reduce loadings to the lakes, but also enhance property values and serve as an educational tool to landowners. Section 319 funding could be a potential source of cost-share funds.

Storm water detention wetlands could be considered for phosphorus control, but only in a few areas; there are very few areas with hydric soils in the Hodges Creek watershed and in the watersheds draining to the three lakes. These wetlands would trap sediments and nutrients and increase groundwater recharge; a study prepared for another Illinois watershed provides an estimated phosphorus removal rate of 45% (Zahniser Institute, undated). Wetlands generally have low to moderate effectiveness at reducing particulate phosphorus, and low to negative effectiveness at reducing dissolved phosphorus (NRCS, 2006a).

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, 2006a).

Conservation buffers can help stabilize a stream and reduce its water temperature (NRCS undated). Riparian buffers can work to improve instream dissolved oxygen by: promoting increased infiltration and baseflow and lowering stream temperature.

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.

Grassed Waterways

Grassed waterways were also recommended as part of the 1999 Clean Lakes Study for Otter Lake (Lin, et al, 1999). 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).

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, 2006a). 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 improved nutrient management on corn fields led to a savings of about $3.60/acre (EPA, 2003).

Animal Waste Management

The Otter Lake Clean Lakes Study (Lin, et al, 1999) indicated that at that time there were eight farms in the Otter Lake watershed that produced a substantial number of livestock. Wastes were disposed of by injection into the soil and spreading on the land (Lin et al, 1999). The number of producers has likely gone down since the Clean Lakes Study was prepared (NRCS, 2006b), but no more recent information on number of producers or waste disposal methods was readily available. While land application is the preferred disposal option, it can contribute nutrients (as well as pathogens) to the lake. Waste handling and storage; disposal methods; and application timing and rates should all be considered. Manure should be tested for nutrient content, and soil sampling and nutrient management planning should be incorporated. Specific activities might include construction of waste storage facilities to hold waste until they can be properly applied. Feedlot waste control has been estimated to cost approximately $9,500 per year for every 50 animals, while manure storage averages $3,600 per storage facility (Lin et al, 1999). Additional information regarding practices, effectiveness, and costs, is available from the U.S. EPA (2003) (http://www.epa.gov/owow/nps/agmm/chap4d.pdf).

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. Another benefit is reduced surface runoff and increased infiltration (NRCS, 1999). In areas that are not tiled, increased infiltration improves baseflow, and higher dry weather velocities will improve aeration and dissolved oxygen concentrations. The Natural Resources Conservation Service (NRCS) has replaced the term conservation tillage with the term crop residue management, 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. Currently, most landowners in the watershed use conventional tillage (NRCS, 2004). The most recent Illinois Soil Transect Survey (IDOA, 2004) suggests that 92% of land under soybean production in Macoupin County is farmed using reduced till, mulch till, or no-till, while 72% of cornfields and 100% of lands producing small grain are farmed with conventional methods. Expanding conservation tillage measures should 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, 2006a). 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/ 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).

Aeration/Destratification

As noted in the TMDL report (LTI, 2005), the existing lake bottom 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 lake 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 similar in size to Otter Lake (754 acres, vs. 765 acres for Otter Lake), but much larger than Palmyra-Modesto and Hettick Lakes (35 and 110 acres, respectively) 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 a smaller Illinois lake at $65,000 (CMT, 2004).

Otter Lake already has a destratification/aeration system (Lin, et al, 1999). The 1999 Clean Lakes Study recommended upgrading or replacing the existing system to improve water quality in Otter Lake; the old system was replaced as a result. Four Solar Bee in-lake mixing devices have also been installed to address algae growth.

Streambank and Shoreline Enhancement and Protection

Streambank and shoreline erosion have been problems in the project watershed. Sediment derived from erosion not only increases solids in the lakes and decreases lake volume, but also can increase nutrient loads to the lakes. Shoreline enhancement efforts, such as planting deep-rooted vegetation or installing rip-rap in the unprotected shoreline areas, will provide protection against erosion and the associated increased pollutant loads. Similar to shoreline erosion controls, streambank erosion controls will decrease sediment, phosphorus and POC loads to the lakes and streams. Stabilized streambanks will therefore result in decreased sedimentation in the stream, decreased sediment oxygen demand, and improved flow and aeration.

The Illinois EPA, in cooperation with the U.S. Department of Agriculture and the U.S. Geological Survey, has conducted aerial stream assessments for several TMDL watersheds. Parts of the aerial stream assessment for Otter Creek were viewed prior to the August 2005 public meeting. Discussion at the August 2005 TMDL public meeting suggested that the Otter Lake Water Commission could use these aerial flyover DVDs, either alone or in conjunction with boat surveys, to identify areas of severe streambank erosion and help to prioritize sites for restoration. The results of the survey are available and are presented in an aerial assessment report (IDOA, 2005). The report identifies 23 erosion sites upstream of Otter Lake. An additional 141 erosion sites were identified in Hodges Creek, with many more identified upstream of the listed Hodges Creek segment. The results of this study are discussed in more detail in the "Identifying Priority Areas for Controls" section of this report. In addition to the sites recommended in the IDOA report, other sites for streambank stabilization likely exist in the project watersheds.

The cost for the recommended Rock Riffle Grade Controls and Stone Toe Protection to control streambank erosion in Otter Creek upstream of the lake is estimated at $380,625 (IDOA, 2005). The cost for the recommended Rock Riffle Grade Controls and Stone Toe Protection for a reach corresponding closely to the listed Hodges Creek segment was $3,954,000. The cost to implement recommended controls along the entire length of surveyed streams (Otter and Hodges) was estimated at $8,299,125.

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 observation of bank conditions, as well as an assessment of stream hydraulics and geomorphology to support identification and design of effective stabilization measures.

Erosion Control Measures for New Development

There is a considerable amount of development occurring in this region, (LTI, 2004). Discussion at the August 2005 public meeting indicated that the Otter Lake watershed in particular is undergoing substantial development, and that recent residential development near and around the lake is causing significant erosion into the lake. Erosion control measures for new developments are therefore recommended as part of TMDL implementation. A permit is required for construction activities disturbing more than one acre, under the NPDES Phase II storm water regulations (information on IEPA's construction general permit is available at http://www.epa.state.il.us/water/permits/storm-water/construction.html). Additional erosion control measures can be implemented at the local level to reduce loads delivered to the lakes. Such measures could include new or revised local ordinances, as well as increased local planning and enforcement of ordinances. Development of ordinances would be relatively inexpensive; the primary cost of this alternative would be the additional resource staff time that might be needed to review and approve plans and enforce the ordinances.

Private Sewage Disposal System Inspection and Maintenance Program

Most towns within the watershed have sewers, except Modesto (LTI, 2004). Areas outside the towns, however, are unsewered. The homes around Palmyra-Modesto, Hettick and Otter Lakes are not on public sewer; however there are a few homes around Otter Lake that are served by private sewers. In rural Illinois, many unsewered areas use individual surface discharging sewage disposal systems (generally either sand filters with chlorination, or aerobic systems). These systems, if not inspected and properly maintained, are prone to failure, resulting in a discharge of raw sewage. 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.

There is quite a bit of development occurring in the county, with Macoupin County being one of the top counties in Illinois issuing permits for individual disposal systems (LTI, 2004). Macoupin County has approximately 3,000 surface systems. A proactive program to maintain functioning systems and address nonfunctioning systems could be developed to minimize the potential for releases from private sewage disposal systems and reduce phosphorus loads from these systems. The U.S. EPA has developed guidance for managing private sewage disposal systems (EPA, 2005). This guidance includes procedures for assessing existing conditions, assessing public health and environmental risks, selecting a management approach, and implementing a management program (including funding information).

This alternative would require the commitment of staff time for County Health Department personnel; cost depends on whether the additional inspection activities could be accomplished by existing Health Department staff or would require additional personnel.

Dredging

In-place lake sediments have been identified as significant sources of phosphorus and manganese. In addition, sedimentation reduces the water volume of the lake, 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. Some dredging has been completed in the vicinity of the Otter Lake boat ramps (OLWC, 2006). Costs for dredging have been estimated at $6 to $20 per cubic yard of sediment removed for hydraulic dredging (IEPA, 1998).

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 costs of $765,000 to $995,000 for Otter Lake, $35,000 to $ 46,000 for Palmyra-Modesto Lake, and $110,000 to $143,000 for Hettick Lake.

Summary of Alternatives

Table 7 summarizes the alternatives identified for the Otter Lake, Palmyra-Modesto Lake, Hettick Lake and Hodges Creek 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 7. Summary of Implementation Alternatives

Alternative	Estimated Cost*	Notes
Sediment Control Basins	$1,200 to $229,000 per basin, depending on size	May be able to provide cost-share with 319 funds
Conservation Buffers	$200 - $360/acre	
Grassed Waterways	$1,800/acre	
Nutrient Management Plans	$6 to $20/acre	May lead to cost savings
Animal Waste Management	$9,500/50 animals for feedlot waste control $3,600 per manure storage facility	
Conservation Tillage	$12 to $83/acre	
Shoreline Enhancement & Protection	$5,100 each for tree cutting and tree planting $47,700 for rip-rapping severely eroded areas $5/linear foot for plantings $67-$73/ton for rip-rap	
Streambank Stabilization	$25 per foot for stone toe protection $30 per ton for rock riffle grade control Other streambank stabilization projects at priority sites. Cost varies depending on nature and size of site	Recommended by Illinois Department of Agriculture Additional study required to identify priority sites
Erosion Control for New Development	Variable	Low cost to develop ordinances; additional staff costs are likely
Private Sewage Disposal System Inspection & Maintenance	Variable	Cost would be low if existing staff could accomplish
Aeration/Destratification	$65,000 - $72,000	Aeration/Destratification
Dredging	$6 - $20/cubic yard removed	Only in concert with watershed reductions
Phosphorus Inactivation	Otter Lake: $765,000 - $994,500 Palmyra-Modesto Lake: $35,000 - $45,500 Hettick Lake: $110,000 - $143,000	Only in concert with watershed reductions; best for smaller lakes

*Costs expressed in 2006 dollars

IDENTIFYING PRIORITY AREAS FOR CONTROLS

Priority areas for locating controls were identified through a review of available information. Information reviewed included: tributary water quality data (no tributary data were identified); an aerial assessment report; and GIS-based information. Based on this review, it is recommended that streambank stabilization be initiated in the Otter Lake watershed to reduce bank erosion, and that this work occur concurrently with watershed controls in priority areas. Streambank stabilization is also recommended for the portions of Otter Creek downstream of Otter Lake, and for Hodges Creek. This work too, should be conducted in concert with watershed control efforts. Although an aerial erosion survey was not conducted for the Hettick Lake or Palmyra-Modesto Lake watersheds, it is highly recommended that tributaries to Hettick Lake and Palmyra-Modesto Lake be investigated to assess whether streambank erosion is occurring and whether bank stabilization is an appropriate control option. Additional data collection is also recommended, to help focus control efforts.

Tributary Monitoring

Available water quality data obtained as part of the Stage 1 Watershed Characterization work were reviewed and no recent tributary monitoring data were identified. Additional data collection is therefore recommended to help understand where loads are being generated in the watershed and focus control efforts. Specific data collection recommendations are provided in the Monitoring and Adaptive Management section later in this Implementation Plan.

Aerial Assessment Report

A 2005 aerial assessment report (IDOA, 2005) examined streambank conditions in Otter Creek and Hodges Creek. Otter Creek originates upstream of Otter Lake and continues downstream of the lake outlet to its confluence with Lick Creek. At that point, Otter Creek becomes Hodges Creek, proceeding downstream to the confluence of Otter and Macoupin Creeks. In general, streambank erosion in Otter and Hodges Creeks is severe and a significant effort is needed to stabilize the banks. The results of the IDOA report are detailed below and are directly relevant to the Otter Lake watershed and the Hodges Creek Watershed.

The reach of interest for Otter Lake begins just upstream of Otter Lake and ends just north of the Macoupin-Sangamon County line. The IDOA study found that the channel of Otter Creek upstream of Otter Lake is incised at all three locations investigated. The location closest to the lake (near Finney Road) is influenced by backwater and is depositional. The other two locations are further upstream (approx. ½ mile downstream of 9 Mile Road, and approximately ½ mile upstream of 9 Mile Road), and were found to be still degrading, but partially armored by the heavy cobble eroded from the exposed glacial till. A total of 23 erosions sites were identified in the investigated reach. The IDOA (2005) report recommends installation of Rock Riffle Grade controls upstream of the lake to a point about ½ mile above cross section 10 (approximately 1 mile upstream of the 9 Mile Road crossing of Otter Creek). These controls will prevent further downgrading of the stream channel, help dissipate energy and provide better aquatic habitat. Lateral bank treatment is also recommended using Stone Toe Protection at the 23 erosion sites. This will help stabilize the banks and prevent further undercutting and failure. The total cost for these controls is estimated as $380,625.

The portion of Otter Creek between the Otter Lake outlet and Hodges Creek, was analyzed as three segments. Within these segments, a total of 174 locations with erosion and geotechnical failures were identified. The total cost for lateral bank protection and Rock Riffle Grade control in this approximately 14.5 mile long reach equals $3,964,500. These three reaches are described in more detail below.

The first segment begins immediately downstream of Otter Lake and extends downstream for approximately four miles. In this segment, Otter Creek was characterized as having a very unstable channel, with 30 erosion sites, 20 geotechnical failures and 11 log jams. The channel is both degrading and widening and the recommended treatment is to install Rock Riffle Grade control structures to increase pool depths, dissipate energy, halt downcutting and improve aquatic habitat. Stone Toe protection is also recommended to control lateral bank erosion. These controls will reduce the sediment load delivered downstream, and help improve conditions in the 303(d)-listed segment of Hodges Creek. The estimated costs for controls in this four-mile long segment total $1,005,000.

The second segment is about 4.5 miles long and extends downstream approximately one-half mile below Hettick Road. This reach was characterized as being very unstable; Rock Riffle Grade control structures and lateral bank treatment are required to achieve stability in the near future. At a cross section investigated below Circle Tree Road, channel degradation was identified as being severe. Within the creek segment, a total of 35 erosion sites, ten additional sites with severe erosion and 19 geotechnical failures were identified. The estimated cost to treat this segment total $1,309,500.

The third segment between the Otter Lake outlet and Hodges Creek is approximately 6 miles long and ends about a mile above the Illinois Route 108 bridge. This segment is immediately upstream of Hodges Creek. This segment has been extensively channelized and has 44 erosion sites and 16 geotechnical failures. Both Rock Riffle Grade control structures and lateral bank protection with Stone Toe Protection are recommended. The total cost for these controls equals $1,650,000.

The portion of Hodges Creek that is on the 303(d) list for low dissolved oxygen roughly corresponds with the most downstream segment assessed in the aerial assessment report. In this 10-mile section of the creek, a total of 141 erosion sites were identified as well as several locations with geotechnical failures. The report recommendation is to install Rock Riffle Grade control structures to halt any current downcutting masked by low flow conditions redepositing bedload, and to prevent additional degradation on Macoupin Creek from migrating up Hodges Creek. The total cost to implement lateral bank protection in 141 locations and Rock Riffle Grade controls at 106 locations in this 10-mile reach of Hodges Creek is estimated at $3,954,000.

If streambank erosion is identified in other tributaries, then controls similar to those recommended for Otter and Hodges Creeks may also be appropriate in other watersheds.

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 2), highly erodible soils (Figure 3), and finally, priority areas for BMPs (Figure 4). 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 used to investigate the presence of hydric soils in the Hodges Creek watershed, to assess the viability of wetlands restoration or creation as an implementation option. The analysis identified areas that have hydric soils, and which are not already developed, forested or covered by water. In each of the watersheds, it is concluded that there are only small areas with a potential for wetland restoration or creation.

- Within the Hodges Creek watershed, only 3,153 acres were identified (2% of the watershed).
- Within the Otter Lake watershed, only 160 acres were identified (1% of the watershed).
- Within the Palmyra-Modesto Lake watershed, less than 2 acres were identified (<1% of the watershed).
- Within the Hettick Lake watershed, only 6 acres were identified (<1% of the watershed).

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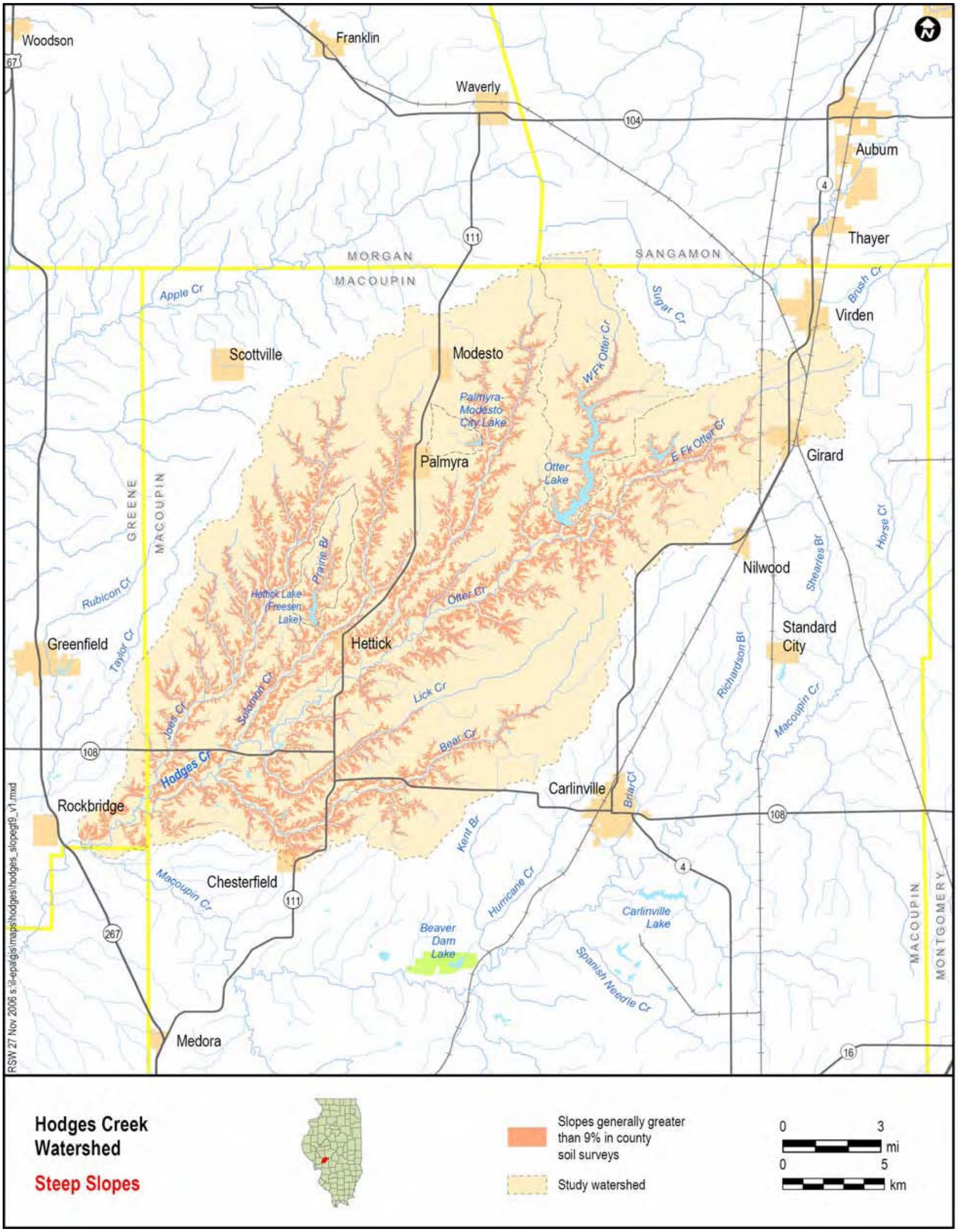

Figure 2. Areas with Steep Slopes

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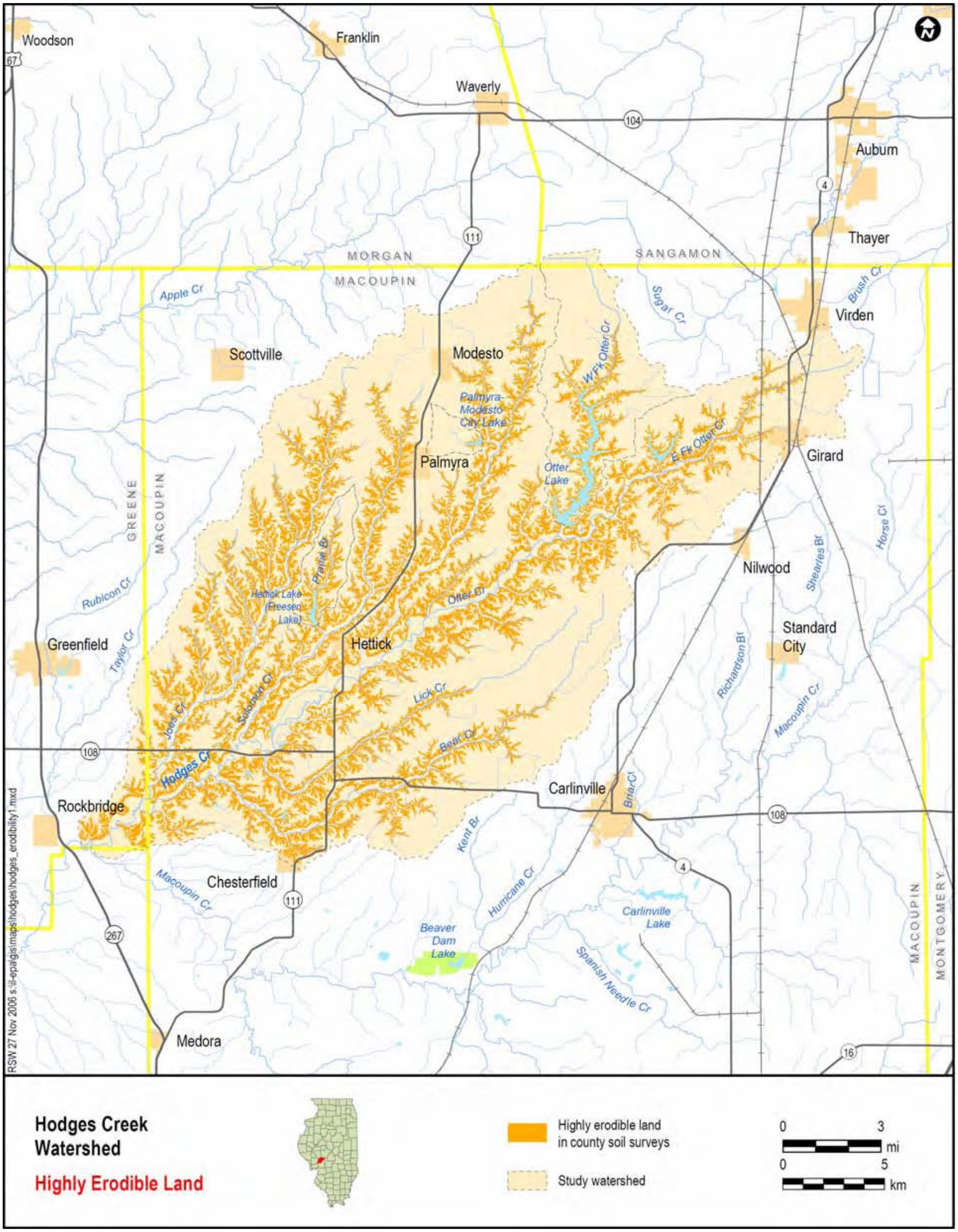

Figure 3. Areas with Highly Erodible Soils

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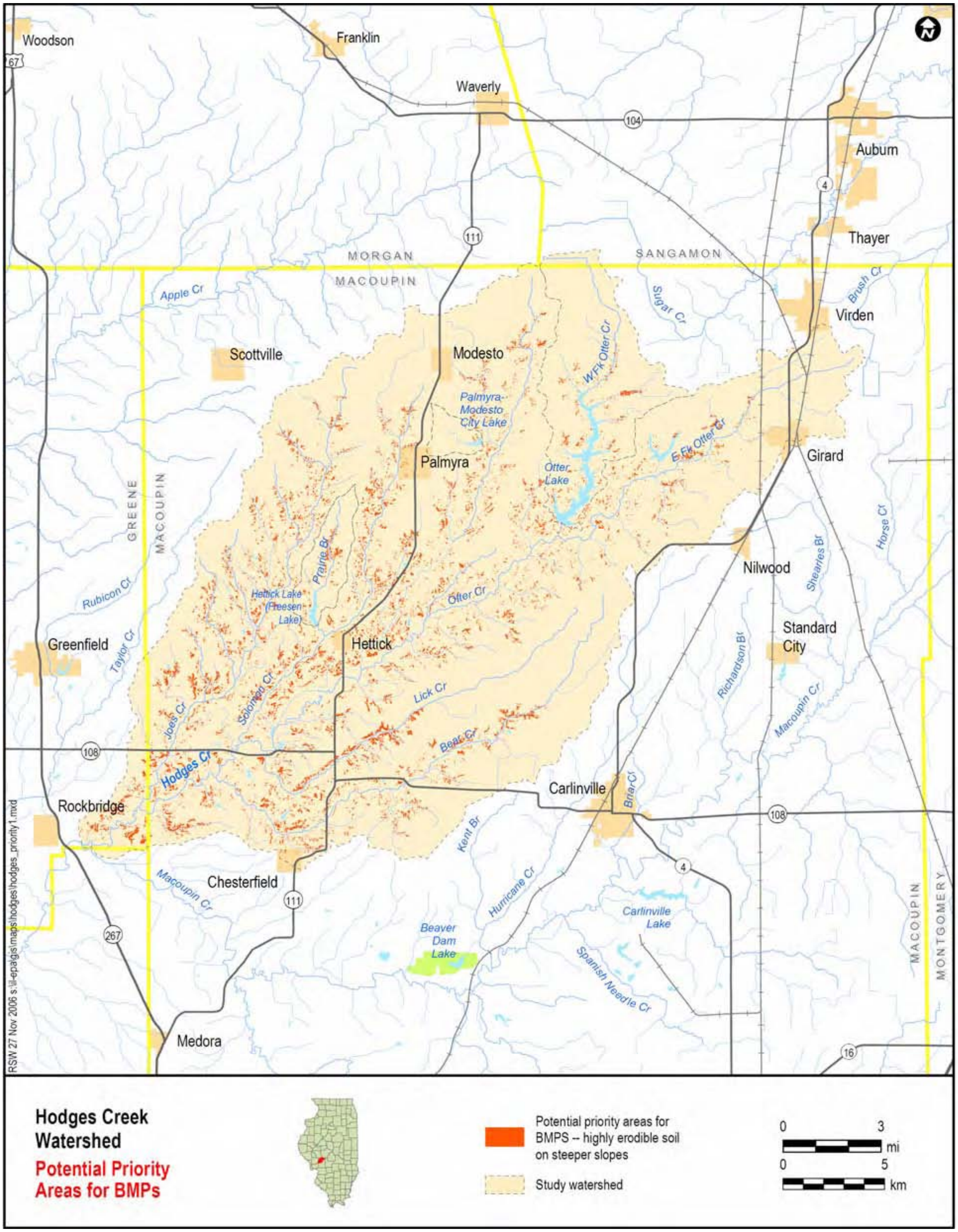

Figure 4. Potential Priority Areas for BMPs

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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. In terms of reasonable assurance for point sources, Illinois EPA administers the NPDES permitting program for treatment plants, stormwater permitting and CAFO permitting. Reasonable assurance for point sources means that NPDES permits will be consistent with any applicable wasteload allocation contained in the TMDL. The permits for the point source dischargers in the watershed (Otter Lake Water Commission, Palmyra STP, Hettick STP, Chesterfield STP, and Girard STP) will be modified if necessary to ensure they are consistent with the applicable wasteload allocation. The current permits for these facilities expire July 31, 2008; December 31 2007; December 31, 2007; November 30, 2006; and September 30, 2009 respectively.

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 non-point 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* (http://www.agr.state.il.us/Environment/conserv/index.html). 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. This program may have limited applicability in Macoupin County, since the predominant soil type is not hydric; many areas may not be eligible for WRP funding (NRCS, 2006b).
- *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; and a Volunteer Lake Monitoring Program that encompasses over 170 lakes each year. Otter Lake is also considered a core lake by IEPA, and is monitored approximately every three years. 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.

In particular, monitoring for phosphorus and suspended solids is recommended in major tributaries upstream of each of the three lakes, to better understand where loads are being generated in the watershed. This monitoring should be conducted during both wet and dry weather. For Hodges Creek, monitoring for suspended solids is recommended, along with temperature and dissolved oxygen measurements. The monitoring is described in more detail below.

Preliminary recommended locations in the Otter Lake watershed include:

- West Fork Otter Creek, at Finney Road or a nearby location that is upstream of any backwater effects from the lake.
- West Fork Otter Creek, at the 9 Mile Road crossing to assess spatial differences in phosphorus loads.
- Other tributary watersheds in which controls are planned. The purpose of this is to assess the effectiveness of controls.
- Tributaries observed to have heavy sediment effects

Preliminary recommended locations in the Palmyra-Modesto Lake watershed include:

- Tributary monitoring at the mouth of each tributary to the lake (upstream of backwater effects).

Preliminary recommended locations in the Hettick Lake watershed include:

- Prairie Branch near the lake, to assess phosphorus loads.
- Prairie Branch at the Boyscout Road crossing, to assess spatial differences in concentrations and loads.

Monitoring for suspended solids is recommended in the Hodges Creek watershed during wet weather, to assess the relative contribution of the tributaries to sediment load in the creek. Preliminary recommended locations in the Hodges Creek watershed include:

- Hodges Creek at the IL Route 108 crossing.
- Hodges Creek at Co. Highway 24.
- Lick Creek at the confluence with Hodges Creek.
- Solomon Creek at the confluence with Hodges Creek.
- Joes Creek at the confluence with Hodges Creek.

Periodic low flow dissolved oxygen monitoring in Hodges Creek at the IL Route 108 crossing and at Co. Highway 24 is also recommended to provide feedback on the effect that improvement projects have on instream dissolved oxygen.

The monitoring activities described above will provide additional information to identify or confirm potential sources of the pollutants of concern and assist in targeting implementation efforts.

Continued monitoring efforts will provide the basis for assessing 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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