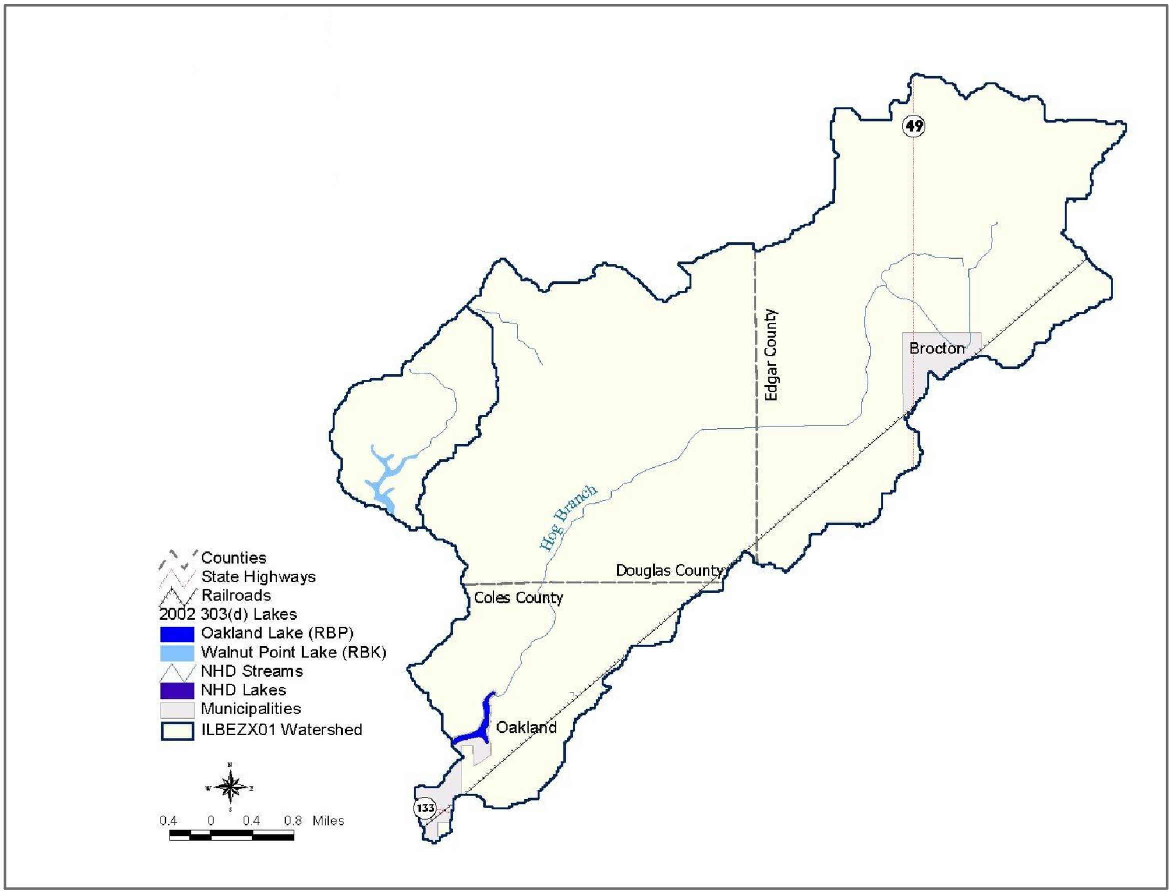
Illinois
Environmental
Protection Agency

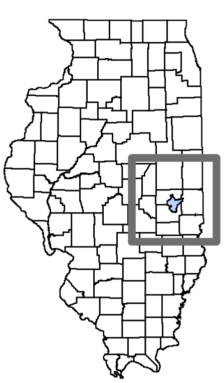
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

June 2008

IEPA/BOW/08-012

LAKE OAKLAND WATERSHED TMDL REPORT





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TMDL Development for Lake Oakland, Illinois

This file contains the following documents:

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

2) Stage One and Stage Three Report: Watershed Characterization and TMDL Development

3) Implementation Plan Report

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

T. Sample

REPLY TO THE ATTENTION OF:
WW-16J

SEP 30 2005

Ms. Marcia Willhite
Bureau of Water
IEPA
1021 North Grand Avenue East
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) from the Illinois Environmental Protection Agency (IEPA) for the Lake Oakland Watershed in Illinois. The TMDL is for Lake Oakland (RBP) for phosphorus and addresses phosphorus, sedimentation/siltation, excessive algal growth, and total suspended solids (TSS) that impair multiple uses.

Based on this review, U.S. EPA has determined that Illinois' TMDL for phosphorus meets 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 the TMDL addressing four impairments for the Lake Oakland Watershed. The statutory and regulatory requirements, and U.S. EPA's review of Illinois' compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois' effort in submitting this 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,

for Jo Lynn Traub
Director, Water Division

Enclosure

cc: Bruce Yurdin, IEPA

TMDL Development for Lake Oakland

FINAL REPORT

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

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

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Stage One Report: Watershed Characterization and Data Analysis for Lake Oakland and Walnut Point Watersheds

Key Findings

As part of the Section 303(d) listing process, the Illinois Environmental Protection Agency has identified Lake Oakland and Walnut Point Lake as being impaired. The purpose of this report is to describe the watersheds in which these waters are located and review the available water quality data to confirm the impairments. This report also identifies several potential options for proceeding with developing total maximum daily loads (TMDLs) for these waters.

A review of the available water quality data confirms most of these impairments. However, insufficient recent data are available for Walnut Point Lake to characterize current conditions. Other key findings described in this report include:

1. There does not appear to be any significant improving or degrading trend over time for the assessed water quality parameters. Nutrient levels in both lakes have remained relatively constant over the period of record, although total phosphorus may have increased in Walnut Point Lake.

2. It is recommended that Walnut Point Lake be de-listed for nitrate nitrogen based on the fact it is not a public and food processing water supply and the available data do not indicate high nitrate concentrations.

3. It is recommended that water quality sampling be performed on the tributaries of both lakes to better estimate loadings to the lakes. Total phosphorus, dissolved phosphorus, total Kjeldahl nitrogen, nitrate+nitrite, chlorophyll-a, total suspended solids, total volatile solids, dissolved oxygen, pH, temperature, and transparency should be sampled.

4. It is recommended that water quality sampling be performed for Walnut Point Lake to gather information on current water quality conditions.

5. Additional information on the potential for shoreline erosion of both lakes is needed.

Illinois water quality standards require that total phosphorus concentrations within lakes not exceed 0.05 mg/L. Historic sampling within Lake Oakland indicates that this standard is routinely exceeded with TP concentrations averaging 0.18 mg/L.

Continuous flow and TP data are not available for the Hog Branch tributary upstream of Lake Oakland. Loads to the lake were therefore estimated based on data from a comparable watershed and these loads were input to the BATHTUB model to determine the load reductions necessary to meet the 0.05 mg/L water quality standard. The BATHTUB analysis indicated that a 80 percent reduction in loads is necessary to meet the 0.05 mg/L standard during each of the modeled years. The specific sources of TP were not a focus of this report. An Implementation Plan will be prepared that fully addresses all potential sources and discusses alternatives for achieving the desired load reductions.

1 Introduction

Lake Oakland and Walnut Point Lake are located within several miles of one another in east-central Illinois (Figure 2-1). The Lake Oakland watershed drains approximately 21 square miles and the Walnut Point Lake watershed drains less than 2 square miles. Together these two watersheds comprise Illinois Environmental Protection Agency (EPA) Watershed ID ILBEZX01.

As part of the Section 303(d) listing process, the Illinois EPA has identified both Lake Oakland (segment RBP) and Walnut Point Lake (segment RBK) as impaired waters (Table 1-1). Both Lake Oakland and Walnut Point Lake are listed for total phosphorus (TP), excessive algal growth, suspended solids, and sedimentation/siltation. Walnut Point Lake is also listed for nitrates, dissolved oxygen, and native aquatic plants (Illinois EPA, 2002). These impairments result in both non- and partial-support of the primary contact (swimming), secondary contact (recreation), and aquatic life designated uses.

Table 1-1. 2002 303(d) List Information for the Lake Oakland and Walnut Point Lake Watersheds.

Segment (size)	Name	Designated Uses and Support Status	Causes of Impairment	Potential Sources of Impairment
RBP (27.6 acres)	Lake Oakland[1]	Non supported–Primary Contact (swimming), Secondary Contact (recreation) Partially supported–Overall Use, Aquatic Life, Drinking Water Supply Fully–Fish Consumption	Total Phosphorus, Excessive Algal Growth, Suspended Solids, Sedimentation/Siltation	Agriculture– crop related sources, non–irrigated crop production, animal holding/management areas Habitat modification– streambank mod/destabilization Source unknown
RBK (41.6 acres)	Walnut Point Lake	Partially supported– Overall Use, Primary Contact (swimming), Secondary Contact (recreation) Fully–Aquatic Life Support Not Assessed– Fish Consumption, Drinking Water Supply	Total Phosphorus, Nitrogen Nitrate, Sedimentation/Siltation, Dissolved Oxygen, Suspended Solids, Aquatic Plants Native, Excess Algal Growth	Agriculture– crop related sources, non–irrigated crop production Contaminated sediments Forest/grassland/ parkland

Source: Illinois EPA, 2002.
[1] In February 2003, the City of Oakland began purchasing water from the Embarras Area Water District Public Water Supply. At that time the use of Lake Oakland as a water source was discontinued.

The Clean Water Act and USEPA regulations require that states develop total maximum daily loads (TMDLs) for waters on the Section 303(d) lists. Illinois EPA is currently developing TMDLs for pollutants that have water quality standards. Of the pollutants impairing Lake Oakland and Walnut Point Lake, phosphorus, nitrate, and dissolved oxygen are the only parameters with numeric water quality standards for lakes. Illinois EPA believes that addressing these impairments should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. For example, reducing loads of phosphorus and nitrate should result in less algal growth and some of the management measures taken to reduce these loads (e.g., reducing shoreline erosion) should also reduce loads of suspended solids.

A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. A TMDL is also required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. The overall goals and objectives in developing the Lake Oakland and Walnut Point Lake TMDLs include:

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

The project is being initiated in three stages. Stage One involves the characterization of the watershed, an assessment of the available water quality data, and identification of potential technical approaches. Stage Two will involve additional data collection, if necessary. Stage Three will involve model development and calibration, TMDL scenarios, and implementation planning. This report documents the results of Stage One.

2 Watershed Characteristics

The physical characteristics of Lake Oakland and Walnut Point Lake and their watersheds are described in the following sections. For the purposes of this characterization, the Lake Oakland and Walnut Point Lake watersheds were delineated using the ArcView interface available with the Soil Water Assessment Tool (SWAT) model. The interface requires digital elevation data (DEM) covering the entire area of the watershed. Thirty-meter DEM data, representing 7.5 minute U.S. Geological Survey (USGS) quadrangle maps, were downloaded from the GEOCommunity <www.geocomm.com> web site. Subbasin delineation was based on the DEM data coupled with a “burn-in” of the National Hydrography Data set (NHD) spatial database of stream reaches. This approach ensures that the subbasin boundaries conform to topographic characteristics while ensuring that catalogued stream segments connect in the proper order and direction. The delineated subbasins, shown in Figure 2-1 and later watershed figures, conform very well to the drainage divides included within the Illinois 12-digit Hydrologic Unit Codes.

2.1 Location and Description of Waterbodies

The Lake Oakland and Walnut Point Lake watersheds (Figure 2-1) are located in east-central Illinois and drain approximately 21 square miles and 1.9 square miles, respectively. Approximately 45 percent of the Lake Oakland watershed lies in eastern Edgar County, 39 percent lies in Douglas County, and 16 percent lies in Coles County. The entire Walnut Point Lake watershed is in Douglas County.

Walnut Point Lake is stream fed and is formed by an earthen dam located on the south side of the lake. The dam was built in 1967 and water filled the basin to spillway level by the fall of 1968. The lake has a maximum depth of 31 feet, an average depth of 11.5 feet and a shoreline length of 6.3 miles (IDNR, 2004). No destratification devices are used in the lake (Rob Hackett, Walnut Point State Park, personal communications, October 13, 2004).

Lake Oakland is also stream fed and is formed by a dam located on the west side of the lake. The dam was originally constructed in 1937 with an original capacity of 94 acre feet. The lake has been periodically dredged over time due to sedimentation problems. The average depth of the lake is 3.9 feet with a maximum depth of 9 feet (during wet years) near the dam. The lake served as the sole source of drinking water to the City of Oakland until February 2003, when the city began purchasing water from the Embarras Area Water District Public Water Supply. At that time the use of Lake Oakland as a water source was discontinued.

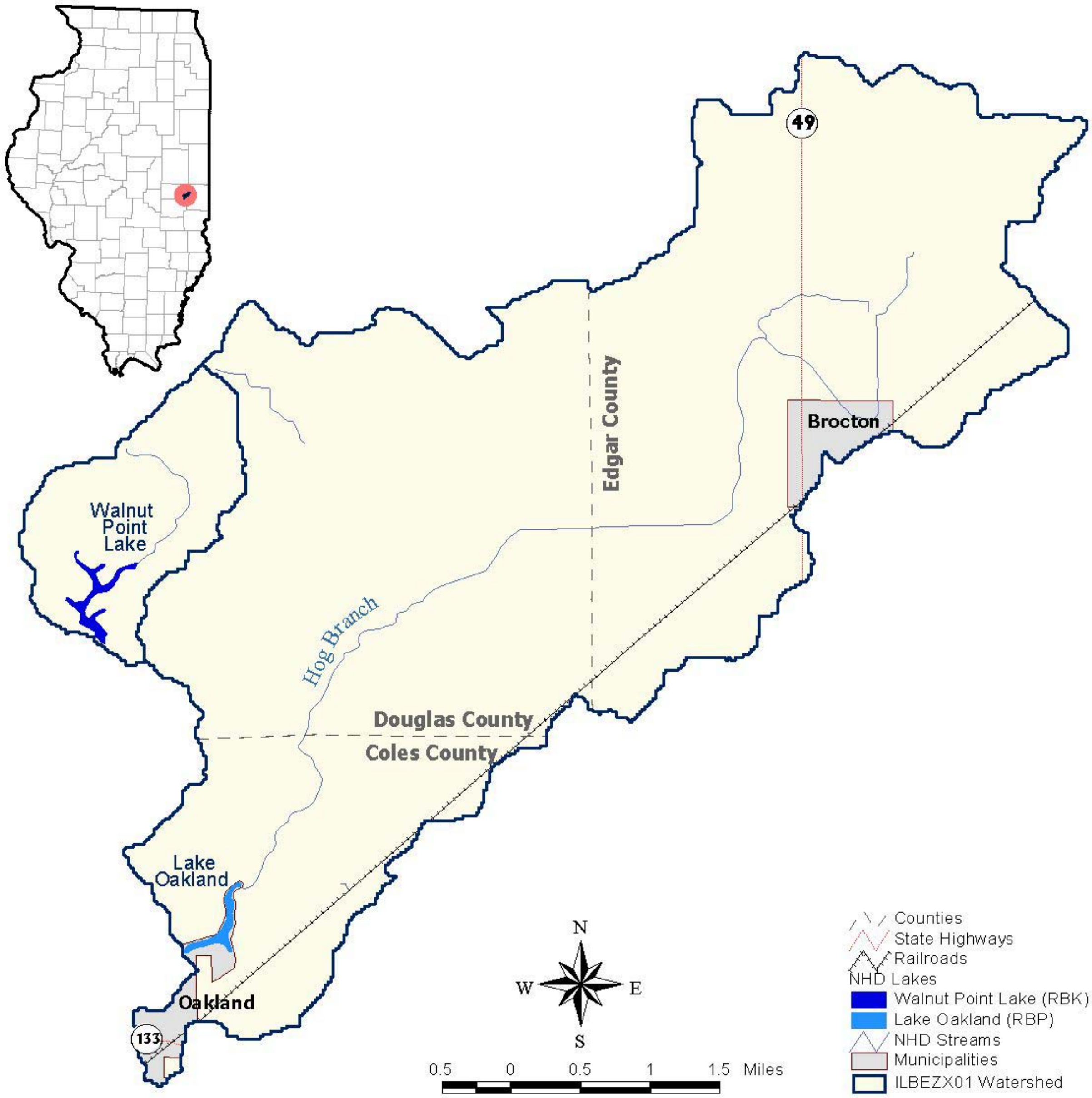

Figure 2-1. Location of the Lake Oakland and Walnut Point Lake watersheds.

2.2 Topography

Elevation in the two watersheds ranges from 730 feet above sea level in the Walnut Point Lake watershed headwaters to 633 feet at the outlet of Lake Oakland. The elevation at the outlet of Walnut Point Lake is 645 feet. The elevations of the two watersheds are shown in Figure 2-2.

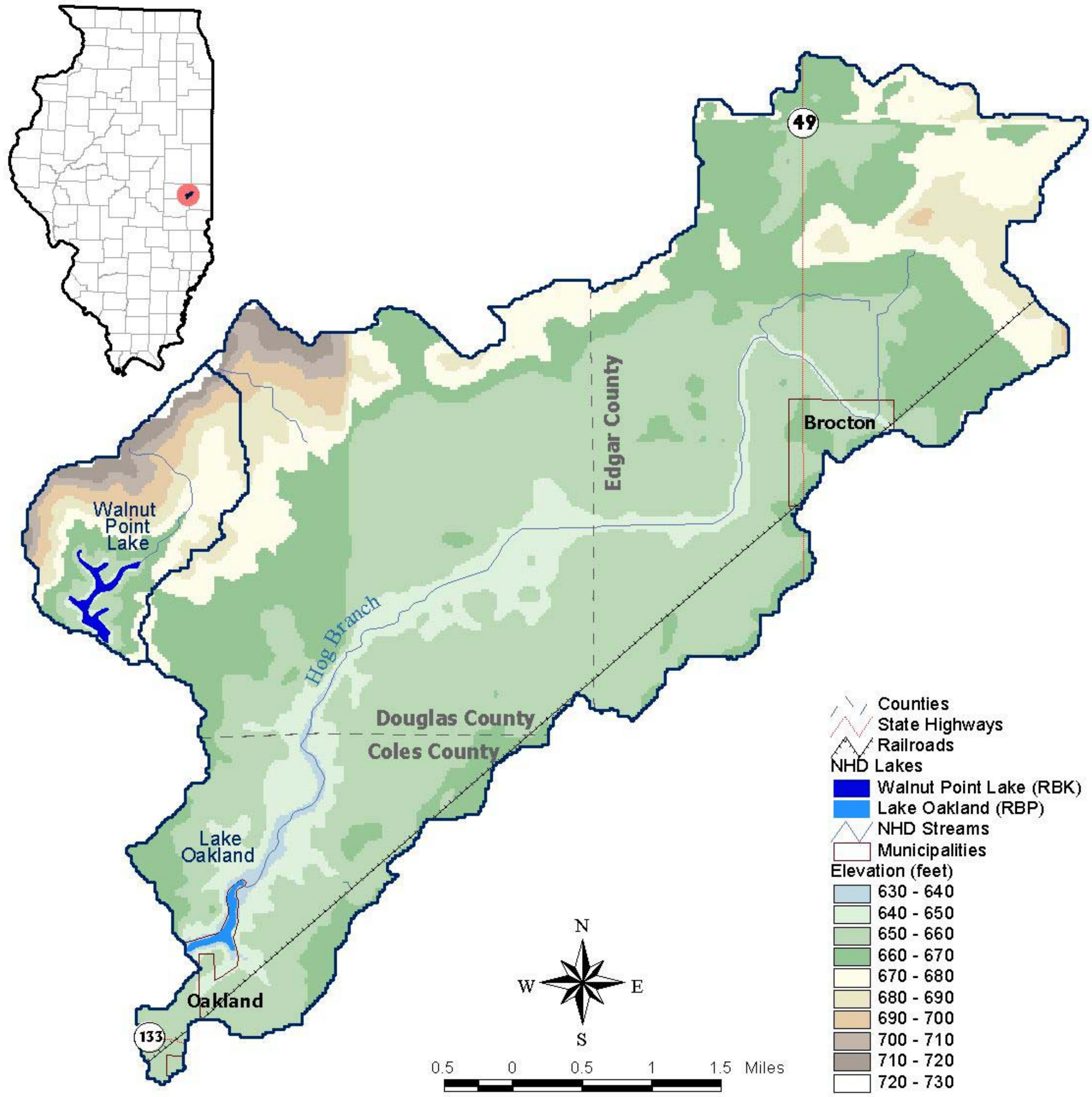

Figure 2-2. Elevation in the Lake Oakland and Walnut Point Lake watersheds.

2.3 Land Use and Land Cover

General land cover data for the Lake Oakland and Walnut Point Lake watersheds were extracted from the Illinois Natural History Survey's GAP Analysis Land cover database (INHS, 2003). This database was derived from satellite imagery taken during 1999 and 2000 and is the most current detailed land cover data known to be available for the two watersheds. Each 98-foot by 98-foot pixel contained within the satellite image is classified according to its reflective characteristics. A complete listing and definition of the Illinois GAP land cover categories is given in Appendix A. The following sections summarize land use and land cover for each of the two watersheds.

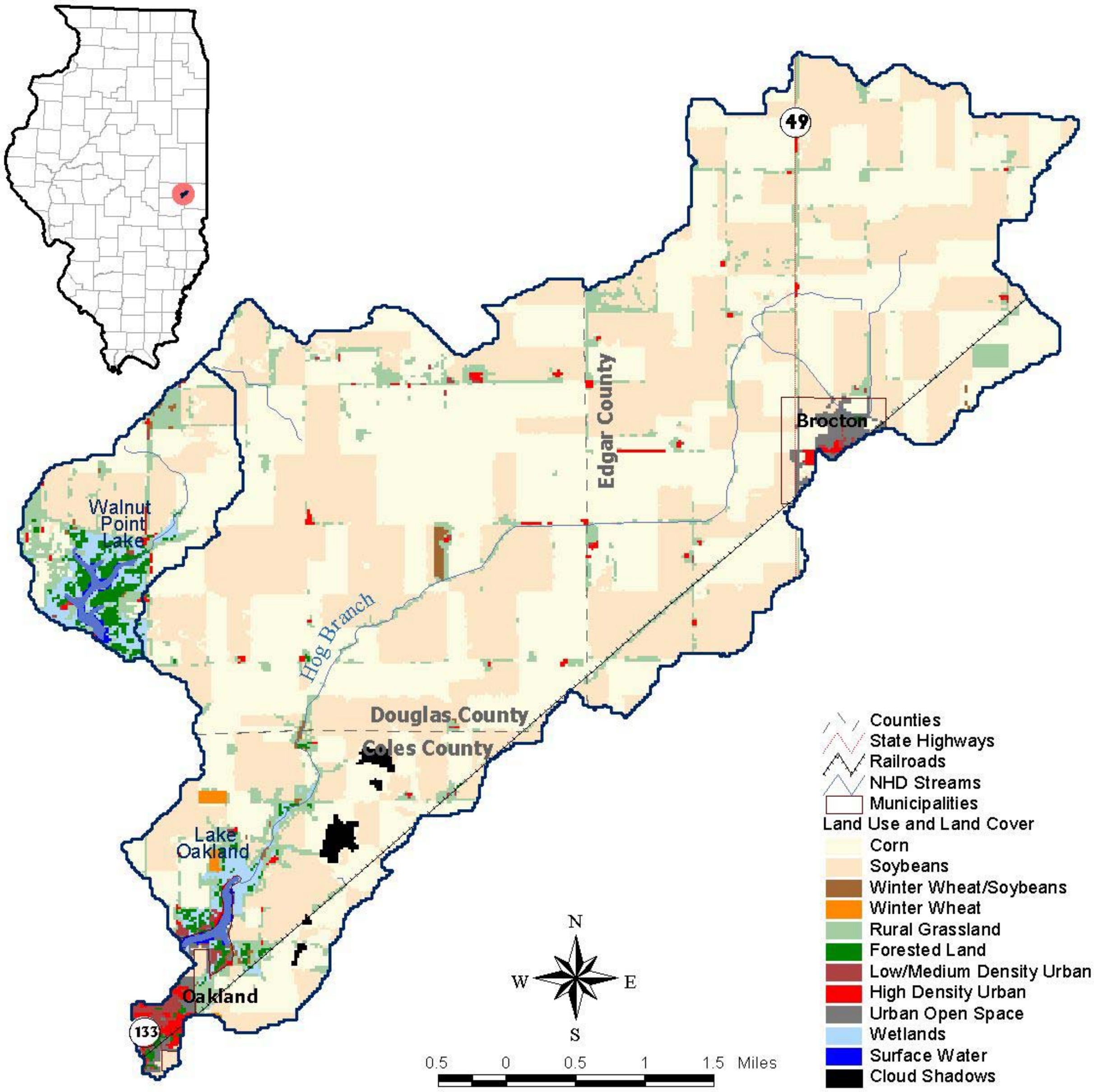

Figure 2-3. GAP land cover in the Lake Oakland and Walnut Point Lake watersheds.

Land use and land cover in the Lake Oakland watershed is summarized in Table 2-1. More than 95 percent of the watershed consists of agricultural land uses, with the primary crops being corn and soybeans. Urban land uses account for 2.1 percent of the land cover while wetlands and forest each represent less than one percent. All other cover types combined represent less that one percent of the watershed area.

Table 2-1. Land Use and Land Cover in the Lake Oakland Subwatershed.

Land Cover Description	Watershed Area		
	Acres	Square Miles	Percent
Agricultural Land: Corn	6,589.10	10.3	48.01
Agricultural Land: Soybeans	5,787.80	9.04	42.17
Agricultural Land: Rural Grassland	747	1.17	5.44
Urban And Built-Up Land: Urban Open Space	123.2	0.19	0.9
Urban And Built-Up Land: High Density	105	0.16	0.76
Other: Cloud Shadows	66.9	0.1	0.49
Urban And Built-Up Land: Low/Medium Density	64.5	0.1	0.47
Wetland: Floodplain Forest: Wet-Mesic	61.4	0.1	0.45
Forested Land: Partial Canopy/Savanna Upland	36	0.06	0.26
Agricultural Land: Winter Wheat/Soybeans	33.1	0.05	0.24
Wetland: Floodplain Forest: Wet	29.1	0.05	0.21
Other: Surface Water	28	0.04	0.2
Forested Land: Upland: Dry-Mesic	21.8	0.03	0.16
Agricultural Land: Winter Wheat	21.3	0.03	0.16
Wetland: Seasonally/Temporarily Flooded	3.6	0.01	0.03
Wetland: Shallow Water	2.9	<0.01	0.02
Wetland: Deep Marsh	2	<0.01	0.02
Forested Land: Upland: Mesic	0.9	<0.01	0.01
Total	13,723.60	21.44	100

Agricultural land uses are also dominant in the Walnut Point Lake watershed, accounting for 76 percent (918 acres) of the total area (Table 2-2). Approximately ten percent (123 acres) of the Walnut Point Lake watershed is classified as wetlands. Forest and surface water represent approximately 9 percent of the subwatershed area. Urban and other land use categories account for 3.4 percent and 1.5 percent of the remaining land uses, respectively.

Table 2-2. Land Use and Land Cover in the Walnut Point Lake Watershed.

Land Cover Description	Watershed Area		
	Acres	Square Miles	Percent
Agricultural Land: Corn	360.3	0.56	29.85
Agricultural Land: Soybeans	349.4	0.55	28.94
Agricultural Land: Rural Grassland	201.3	0.31	16.67
Forested Land: Upland: Dry-Mesic	87.6	0.14	7.26
Wetland: Floodplain Forest: Wet-Mesic	79.8	0.12	6.61
Other: Surface Water	41.1	0.06	3.41
Wetland: Floodplain Forest: Wet	26.9	0.04	2.23
Urban And Built-Up Land: High Density	14.2	0.02	1.18
Forested Land: Upland: Mesic	13.3	0.02	1.11
Wetland: Shallow Water	9.1	0.01	0.76
Agricultural Land: Winter Wheat/Soybeans	7.3	0.01	0.61
Wetland: Seasonally/Temporarily Flooded	6.2	0.01	0.52
Forested Land: Partial Canopy/Savanna Upland	5.3	0.01	0.44
Urban And Built-Up Land: Low/Medium Density	4.4	0.01	0.37
Wetland: Deep Marsh	0.7	<0.01	0.04
Total	1,206.90	1.87	100

2.3.1 Tillage Practices

Tillage system practices are not available specifically for either the Lake Oakland or Walnut Point Lake watersheds. However, countywide tillage system surveys have been undertaken by the Illinois Department of Agriculture (2000; 2002) and are available for Coles, Douglas, and Edgar Counties. It is assumed that the general tillage practice trends evidenced throughout these counties are applicable to the two watersheds. The results of these surveys are presented in Table 2-3. The table shows that the percentage of fields in conventional tillage, averaged across all counties and crop types, is approximately 40 percent for both surveys.

Table 2-3. Percentage of Agricultural Fields Surveyed with Indicated Tillage System in Edgar County, Illinois, in 2000 and 2002.

2000 Transect Survey					
County	Crop Field Type	Tillage Practice			
		Conventional	Reduced-till	Mulch-till	No-till
Edgar County	Corn	70	12	6	12
	Soybean	13	21	19	47
	Small Grain	0	0	0	0
Coles County	Corn	68	19	3	10
	Soybean	8	39	34	19
	Small Grain	43	14	0	43
Douglas County	Corn	94	3	1	3
	Soybean	23	27	2	48
	Small Grain	50	0	0	50
2002 Transect Survey					
County	Crop Field Type	Tillage Practice			
		Conventional	Reduced-till	Mulch-till	No-till
Edgar County	Corn	59	9	2	30
	Soybean	21	24	10	45
	Small Grain	0	100	0	0
Coles County	Corn	73	17	8	3
	Soybean	13	51	20	16
	Small Grain	29	43	14	14
Douglas County	Corn	87	9	1	3
	Soybean	18	37	7	38
	Small Grain	66	17	17	0

Source: Illinois Dept. of Agriculture, 2000; 2002.

2.4 Soils

Soils data and GIS coverages from the Natural Resources Conservation Service (NRCS) were used to characterize soils in the Lake Oakland and Walnut Point Lake watersheds. General soils data and map unit delineations for the country are provided as part of the State Soil Geographic (STATSGO) database. GIS coverages provide locations for the soil map units at a scale of 1:250,000 (USDA, 1995). A map unit is composed of several soil series having similar properties. Figure 2-4 displays the STATSGO soil map units in each watershed. Identification fields in the GIS coverage can be linked to a database that provides information on chemical and physical soil characteristics for each map unit. Of particular interest for this study are the hydrologic soil group, the K-factor of the Universal Soil Loss Equation, and depth to water table. The following sections describe and summarize the specified soil characteristics for the Lake Oakland and Walnut Point Lake watersheds. It should be noted that map units can be highly variable, and the following maps are meant only as a general representation of soil conditions in the watershed.

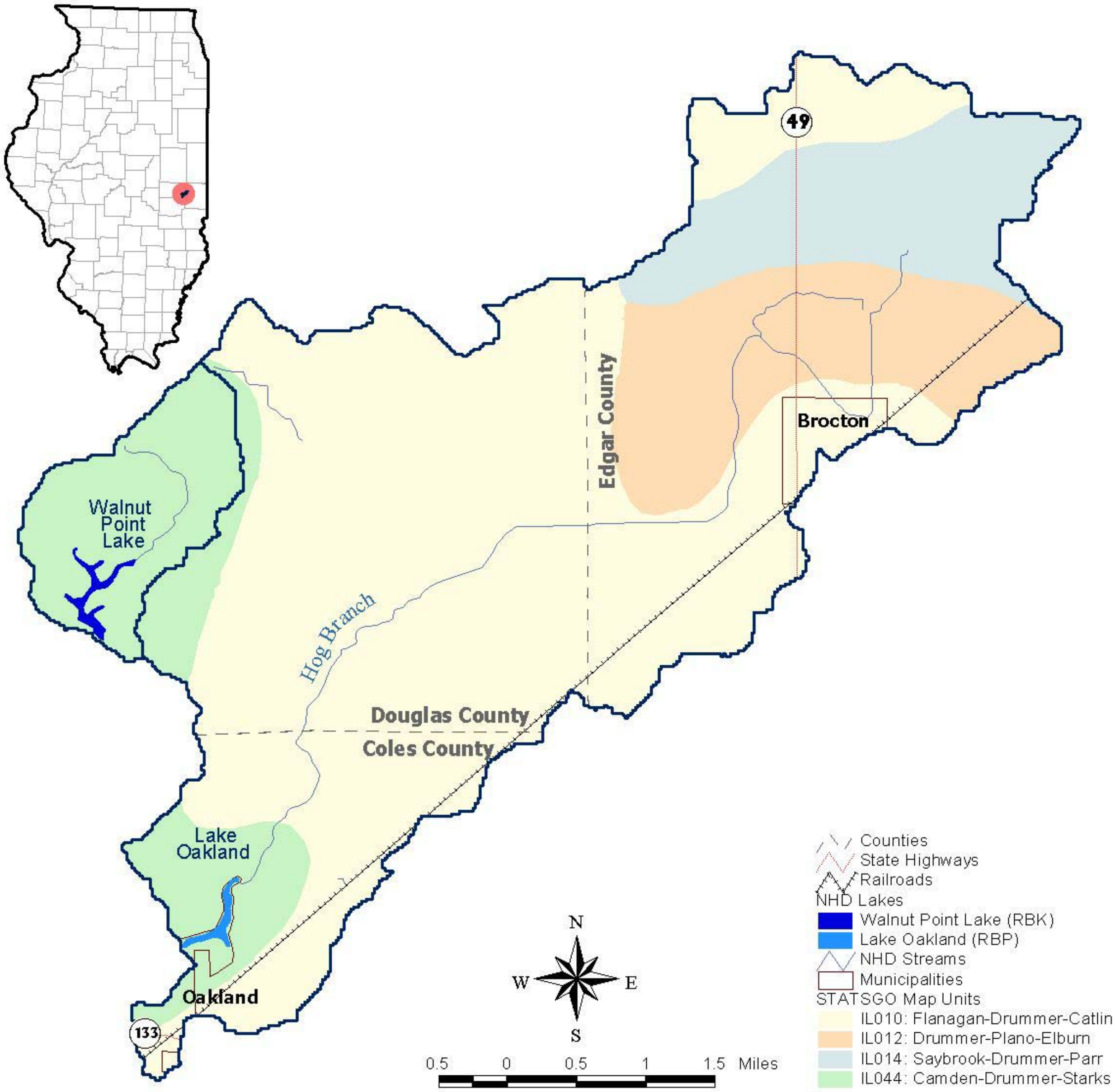

Figure 2-4. Location of STATSGO Map Units in the Lake Oakland and Walnut Point Lake watersheds.

2.4.1 Hydrologic Soil Group

The hydrologic soil group classification is a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, poorly drained clay soils have lower infiltration rates, while well-drained sandy soils have the greatest infiltration rates. NRCS (2001) has defined four hydrologic groups for soils as listed in Table 2-4. In addition, soils with tile drainage in Illinois should be designated as Class B soils (i.e., due to the presence of tile drainage the soil takes on the attribute of a Class B soil ((McKenna, personal communications, December 15, 2004)). Figure 2-5 presents the general distribution of hydrologic soil groups in the two watersheds. The figure shows that soils classified as hydrologic group B compose the entire watershed. This suggests that soils in each watershed are moderately deep, moderately well drained, and have moderate infiltration rates.

Table 2-4. NRCS Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	Soils with high infiltrations rates. Usually deep, well drained sands or gravels. Little runoff.
B	Soils with moderate infiltration rates. Usually moderately deep, moderately well drained soils.
C	Soils with slow infiltration rates. Soils with finer textures and slow water movement.
D	Soils with very slow infiltration rates. Soils with high clay content and poor drainage. High amounts of runoff.

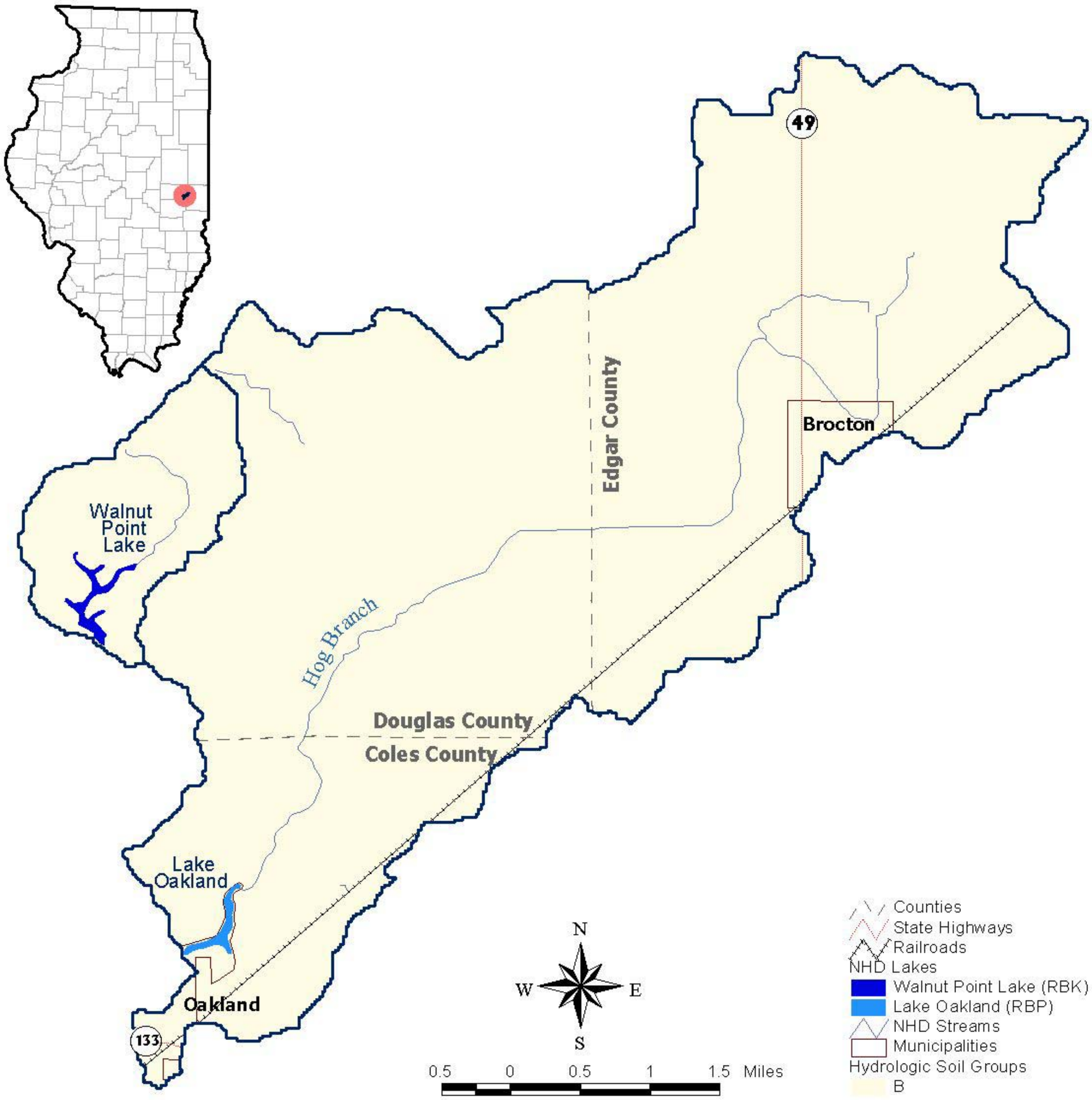

Figure 2-5. Hydrologic soil group distribution in the Lake Oakland and Walnut Point Lake watersheds.

2.4.2 K-Factor

A commonly used soil attribute is the K-factor, a component of the USLE (Wischmeier and Smith, 1978). The K-factor is a dimensionless measure of a soil's natural susceptibility to erosion, and factor values may range from 0 for water surfaces to 1.00 (although in practice, maximum factor values do not generally exceed 0.67). Large K-factor values reflect greater inherent soil erodibility. The distribution of K-factor values in the Lake Oakland and Walnut Point Lake watersheds is shown in Figure 2-6. The figure indicates that soils in the watershed have moderate erosion potential (e.g., K-factors ranging from 0.20 to 0.37). The areas directly adjacent to the two lakes are reported to have the highest K-factors.

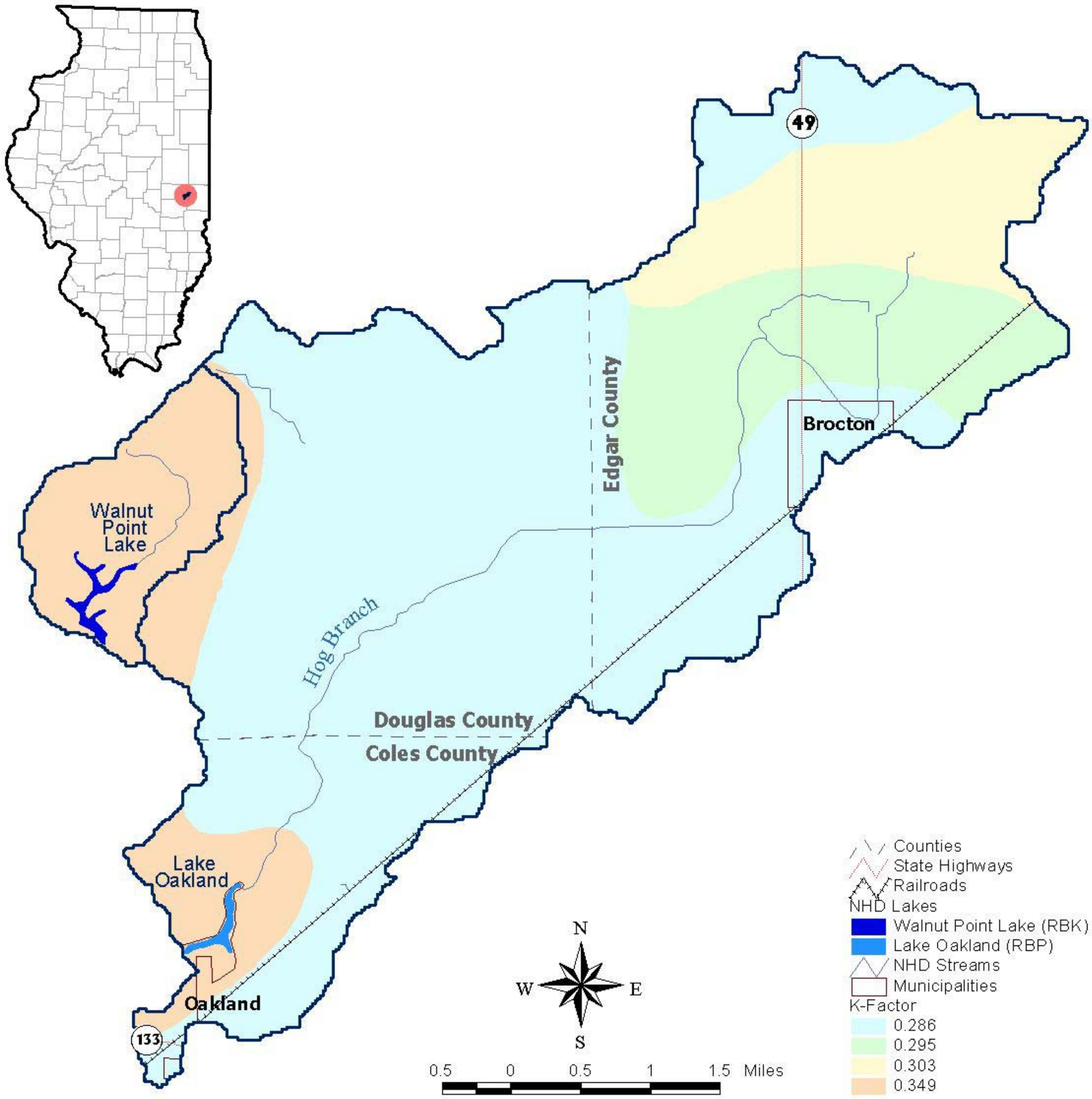

Figure 2-6. USLE K-Factor distribution in the Lake Oakland and Walnut Point Lake watersheds.

2.4.3 Depth to Water Table

Water table depth as described in the STATSGO database is the range in depth to the seasonally high water table level for a specified month. The STATSGO database reports depth to water table as both a minimum and maximum depth. Values were summarized to reflect the weighted sum of the minimum depth to water table for the surface layer of all soil sequences composing a single STATSGO map unit. Figure 2-7 displays the distribution of depth to water table for the basin and shows that depths range from 2.45 feet to 4.28 feet with maximum depths occurring adjacent to Lake Oakland and Walnut Point Lake.

Depths in the central portion of the basin are approximately 2.45 feet with a smaller area near Brocton (2.89 feet). Water table depths in the northern headwaters region are reported as 4.21 feet.

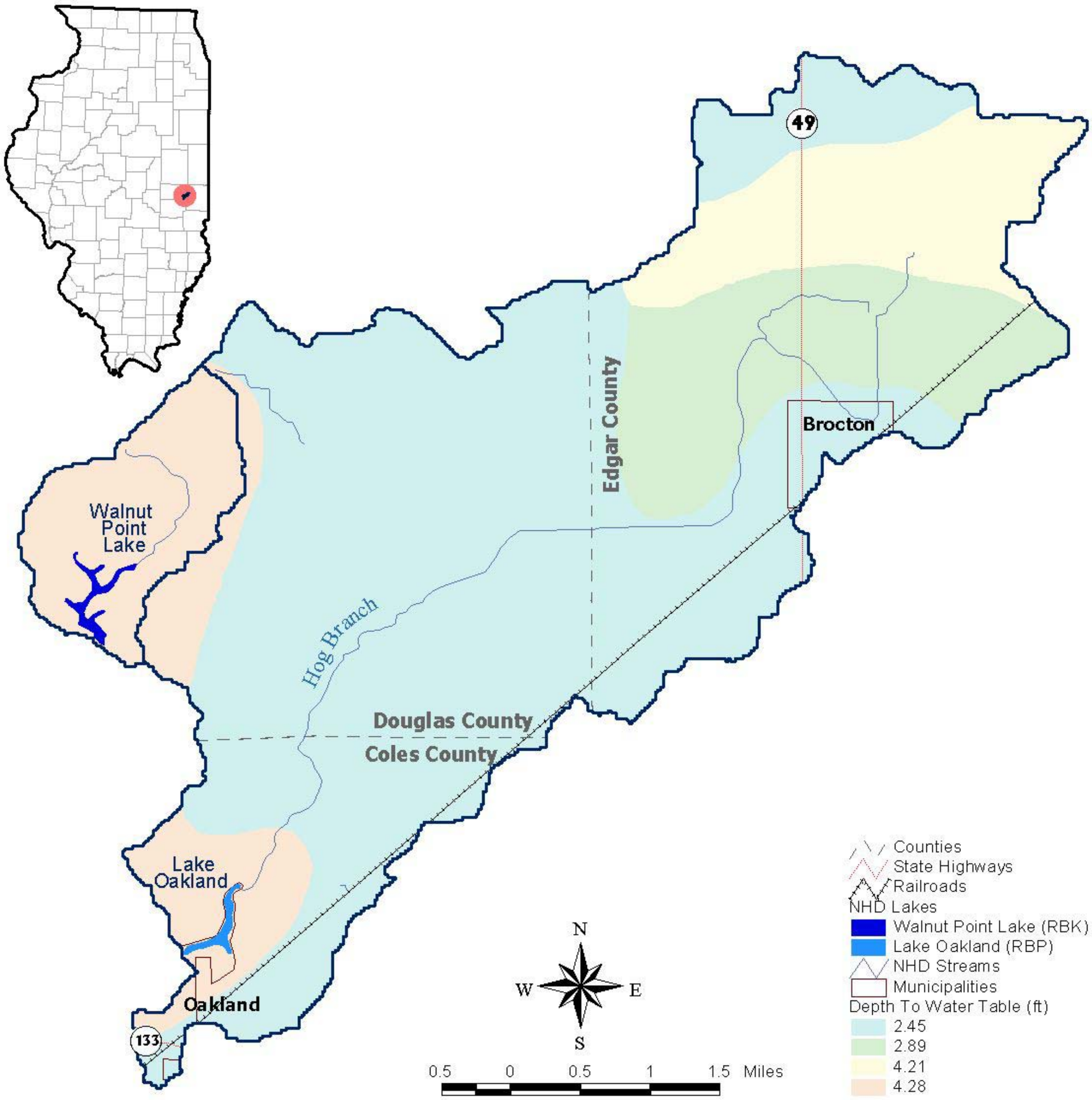

Figure 2-7. Depth to water table in the Lake Oakland and Walnut Point Lake watersheds.

2.5 Population

The populations of the Lake Oakland and Walnut Point Lake watersheds are not directly available but may be estimated from the 2000 U.S. Census data. The 2000 U.S. Census data were downloaded for all towns, cities, and counties whose boundaries lie wholly or partially in the watershed (U.S. Census, 2000).

Urban and nonurban populations were estimated for the watershed area and were summed to estimate the total watershed population (Table 2-5). Using this methodology approximately 700 people are estimated to reside in the Lake Oakland watershed and less than 30 people are estimated to reside in the Walnut Point Lake watershed.

Table 2-5. ILBEZX01 Watershed Population Summarized by Waterbody Segment and County

Waterbody	County	Watershed Population	Nonurban Population	Urban Population
Lake Oakland	Edgar County	414	75	339
	Coles County	299	107	192
	Total	**713**	**182**	**531**
Walnut Point Lake	Douglas County	29	29	0
	Total	**29**	**29**	**0**

Source: U.S. 2000 Census and GIS analysis.

The 1990 U.S. Census data were compiled to estimate population change for the ten-year period between 1990 and 2000 for both watersheds. Population in the Lake Oakland watershed is estimated to have increased from 706 people in 1990 to 713 people in 2000. The population of the Walnut Point Lake watershed is estimated to have increased by one person.

3 Climate and Hydrology

This section provides information on the climate and hydrology of the two watersheds.

3.1 Climate

No meteorological stations are located in the ILBEZX01 watershed; data from the Tuscola station (station ID 118684) were therefore used to assess climate. The Tuscola station is located approximately 13.75 miles to the northwest of Walnut Point Lake and approximately 15.5 miles northwest of Oakland Lake. Average annual precipitation at this station is 40.66 inches and, on average, there are 124 days with at least 0.01 inches of precipitation. The annual average snowfall is 23.1inches. The monthly variation in precipitation and temperatures is presented in Figure 3-1 and illustrates that June and July are typically the months with the most rainfall and that January and December typically receive the greatest amount of snowfall.

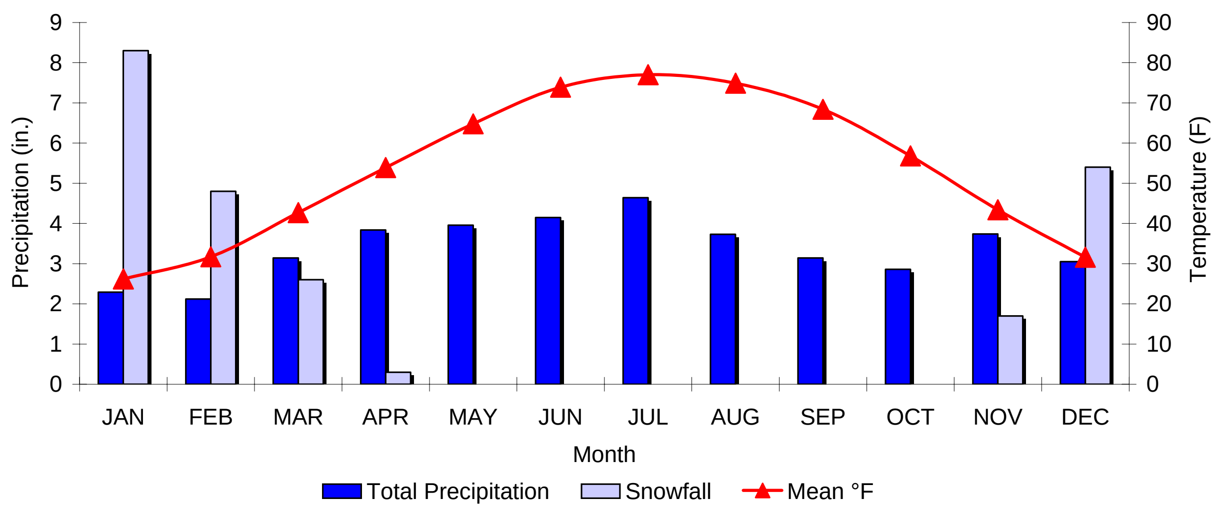

Figure 3-1. Climate Summary for Tuscola Station (118684). Data cover the period 1971 to 2000.

3.2 Hydrology

This section of the report presents information on the stream types and flow data available in the two watersheds.

3.2.1 Stream Types

The National Hydrography Database (NHD) maintained by USEPA and USGS identifies only a few waterbodies in the two watersheds (Figure 3-2). The largest waterbody (other than the two lakes) is Hog Branch, portions of which are classified as a canal/ditch. Several intermittent and perennial streams are also located in the two watersheds (Table 3-1 and Figure 3-2).

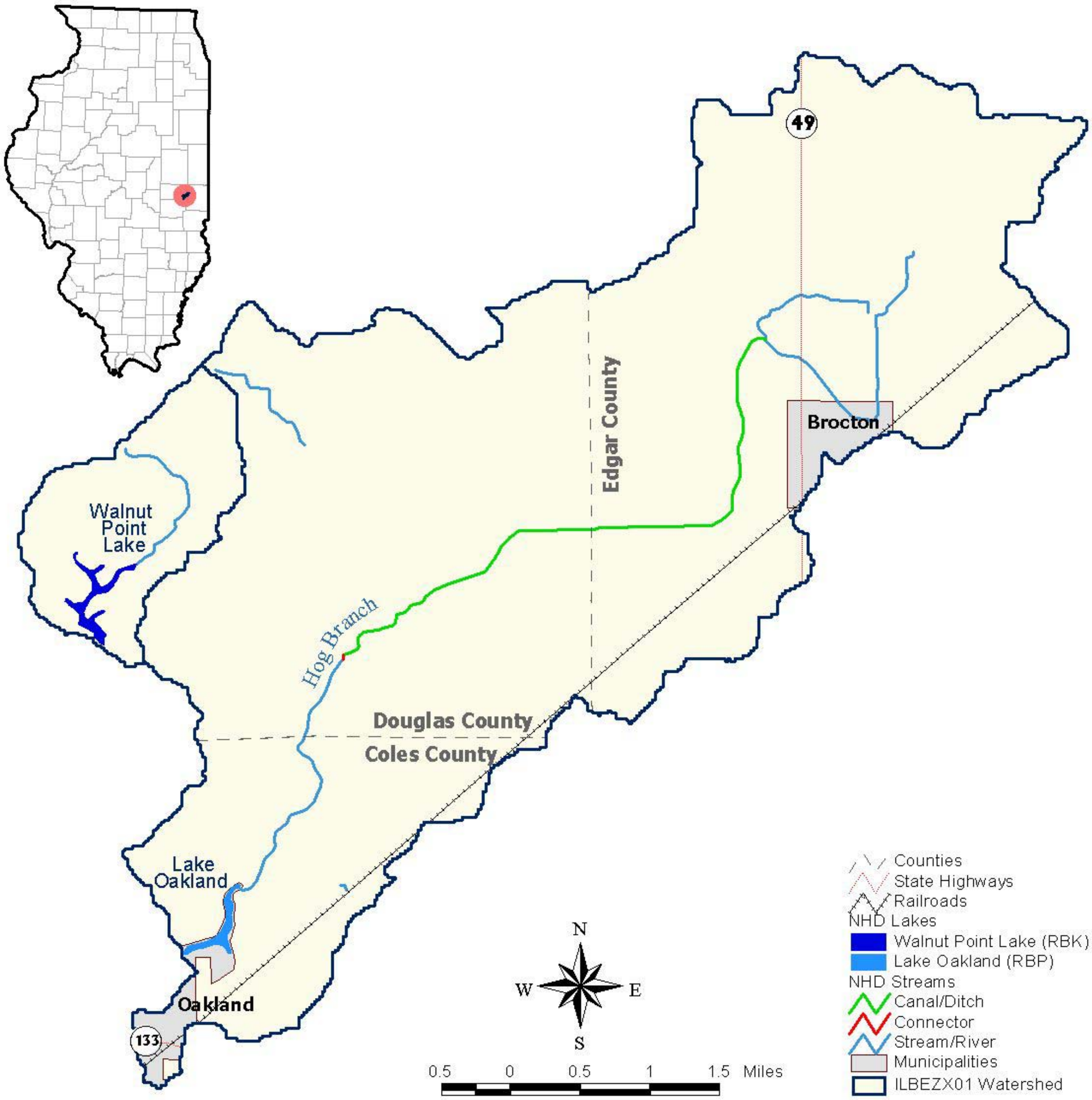

Figure 3-2. Stream types in the Lake Oakland and Walnut Point Lake Watersheds.

Table 3-1. Summary of Stream Types in the combined Lake Oakland and Walnut Point Lake Watershed.

Stream Type	Stream Length (ft)	Percent
Canal/Ditch	24,307	38.98
Intermittent Stream	18,193	29.17
Perennial Stream	11,311	18.14
Artificial Path	8,381	13.44
Connector	173	0.28
Total	62,364	100

3.2.2 Tile Drainage

Both the Lake Oakland and Walnut Point Lake watersheds are underlain by drain tile designed to remove standing water from the soil surface. Subsurface drainage is designed to remove excess water from the soil profile. The water table level is controlled through a series of drainage pipes (tile or tubing) that are installed below the soil surface, usually just below the root zone. In Illinois, subsurface drainage pipes are typically installed at a depth of 3 to 4 feet and at a spacing of 80 to 120 feet. The subsurface drainage network generally outlets to an open ditch or stream.

Researchers at the University of Illinois and elsewhere have studied the impact of tile drainage on hydrology and water quality. Some impacts are relatively well understood while others are not. Zucker and Brown (1998) provided the following summary of the impacts (statements compare agricultural land with subsurface drainage to that without subsurface drainage):

- The percentage of rain that falls on a site with subsurface drainage and leaves the site through the subsurface drainage system can range up to 63 percent.
- The reduction in the total runoff that leaves the site as overland flow ranges from 29 to 65 percent.
- The reduction in the peak runoff rate ranges from 15 to 30 percent.
- Total discharge (total of runoff and subsurface drainage) is similar to flows on land without subsurface drainage, if flows are considered over a sufficient period of time before, during, and after the rainfall/runoff event.
- The reduction in sediment loss by water erosion from a site ranges between 16 to 65 percent. This reduction relates to the reduction in total runoff and peak runoff rate.
- The reduction in loss of phosphorus ranges up to 45 percent, and is related to the reductions in total runoff, peak runoff rate, and soil loss. However, in high phosphorus content soils, dissolved phosphorus levels in tile flow can be high.
- In terms of total nutrient loss, by reducing runoff volume and peak runoff rate, the reduction in soil-bound nutrients is 30 to 50 percent.
- In terms of total nitrogen losses (sum of all N species), there is a reduction. However, nitrate-N, a soluble nitrogen ion, has great potential to move wherever water moves. Numerous studies throughout the Midwest and southeast U.S., and Canada document that the presence of a subsurface drainage system enhances the movement of nitrate-N to surface waters. Proper management of drainage waters along with selected in-field BMPs helps reduce this potential loss.

3.2.3 Flow Data

There are no USGS stream flow monitoring stations within either watershed. No other sources of continuous stream flow data have been identified.

4 Inventory and Assessment of Water Quality Data

This section of the document presents the 2002 303(d) list information for the Lake Oakland and Walnut Point Lake watersheds followed by a description of the parameters of concern, the applicable water quality standards, and a review of water quality data for each waterbody.

4.1 Illinois 303(d) List Status

Both Lake Oakland and Walnut Point Lake are listed for total phosphorus (TP), excessive algal growth, suspended solids, and sedimentation/siltation. Walnut Point Lake is also listed for nitrates, dissolved oxygen, and aquatic plants (native) (Illinois EPA, 2002). These impairments result in both non- and partial-support of primary contact (swimming), secondary contact (recreation), and aquatic life designated uses.

4.2 Previous Studies

Several previous studies of Lake Oakland, Walnut Point Lake, and their respective watersheds have been conducted. A committee made up of the City of Oakland, local landowners, the Coles County Soil and Water Conservation District, the Edgar County Soil and Water Conservation District, and the Natural Resources Conservation Service released the Lake Oakland Watershed Management Plan in March 1997 (Lake Oakland Watershed Committee, 1997). The purpose of the plan was to improve water quality and quantity; reduce soil erosion; improve drainage in the watershed; improve wildlife and woodland habitat; create incentives for new programs; and promote a healthy and adequate water supply for the City of Oakland. Among the conclusions and recommendations of the Lake Oakland Watershed Management Plan are:

- Sheet and rill erosion is the largest source of erosion in the watershed.
- 29,000 tons of soil per year is lost in the watershed and 7,000 tons of soil per year enters the lake (based on a preliminary erosion inventory completed by the Natural Resources Conservation Service)
- Landowners are concerned that raising the lake water level could obstruct tile drainage from fields
- The report estimated that approximately $340,000 in conservation measures was needed to significantly reduce the rate and amount of soil erosion into Oakland Lake. The identified measures included: waterways, filter strips, terraces, nutrient and pesticide management, and ditch work.

The Illinois Department of Conservation also estimated erosion in the Walnut Point Lake watershed in 1985 (Shafer, 1985). Sediment yield to Walnut Point Lake was estimated at 3,584 tons annually which resulted in a lake volume loss of 2.5 acre feet per year. The sources of erosion were reported to be sheet and rill erosion (84%) megarill erosion (12%), and gully, streambank, and roadside erosion (4%).

4.3 Parameters of Concern

The following sections provide a summary of the parameters identified on Illinois 2002 303(d) list for Lake Oakland and Walnut Point Lake. The purpose of these sections of the report is to provide an overview of the parameters, units, sampling methods, and potential sources. The relevance of the parameter to the various beneficial uses is also briefly discussed.

4.3.1 Nutrients/Organic Enrichment/Low DO/Excessive Algal Growth

The term *nutrients* usually refers to the various forms of nitrogen and phosphorus found in a waterbody. Both nitrogen and phosphorus are necessary for aquatic life, and both elements are needed at some level in a waterbody to sustain life. The natural amount of nutrients in a waterbody varies depending on the type of system. A pristine mountain spring might have little to almost no nutrients, whereas a lowland, mature stream flowing through wetland areas might have naturally high nutrient concentrations. Various forms of nitrogen and phosphorus can exist at one time in a waterbody, although not all forms can be used by aquatic life. Common phosphorus sampling parameters are total phosphorus (TP), dissolved phosphorus, and orthophosphate. Common nitrogen sampling parameters are total nitrogen (TN), nitrite (NO_2), nitrate (NO_3), total Kjeldahl nitrogen (TKN), and ammonia (NH_3). Concentrations are measured in the lab and are typically reported in milligrams per liter.

Nutrients generally do not pose a direct threat to the beneficial uses of a waterbody, although high nitrate concentrations can pose a risk to drinking water supplies. However, excess nutrients can cause an undesirable abundance of plant and algae growth. This process is called eutrophication or organic enrichment. Organic enrichment can have many effects on a stream or lake. One possible effect of eutrophication is low dissolved oxygen concentrations. Aquatic organisms need oxygen to live and they can experience lowered reproduction rates and mortality with lowered dissolved oxygen concentrations. Dissolved oxygen concentrations are measured in the field and are typically reported in milligrams per liter. Ammonia, which is toxic to fish at high concentrations, can be released from decaying organic matter when eutrophication occurs. Recreational uses can be impaired because of eutrophication. Nuisance plant and algae growth can interfere with swimming, boating, and fishing. Nutrients generally do not pose a threat to agricultural uses.

Nitrogen and phosphorus exist in rocks and soils and are naturally weathered and transported into waterbodies. Organic matter is also a natural source of nutrients. Systems rich with organic matter (e.g., wetlands and bogs) can have naturally high nutrient concentrations. Phosphorus and nitrogen are potentially released into the environment through different anthropogenic sources including septic systems, wastewater treatment plants, fertilizer application, and animal feeding operations.

4.3.2 Suspended Solids and Sedimentation/Siltation

Excess total suspended solids (TSS) in a stream or lake can pose a threat to aquatic organisms. Turbid waters created by excess TSS concentrations reduce light penetration, which can adversely affect aquatic organisms. TSS can also interfere with fish feeding patterns because of the turbidity. Prolonged periods of very high TSS concentrations can be fatal to aquatic organisms (Newcombe and Jensen, 1996). As TSS settles to the bottom of a stream, critical habitats such as spawning sites and macroinvertebrate habitats can be covered in sediment. This is referred to as *siltation*. Excess sediment in a stream bottom can reduce dissolved oxygen concentrations in stream bottom substrates, and it can reduce the quality and quantity of habitats for aquatic organisms. TSS can also pose a threat to recreational uses because of murky conditions.

Erosion and overland flow contribute some natural TSS to most streams and lakes. In watersheds with highly erodible soils and steep slopes, natural TSS concentrations can be very high. Excess TSS in overland flow can occur when poor land use and land cover practices are in place. This potentially includes grazing, row crops, construction activities, road runoff, and mining. Grazing and other practices that can degrade stream channels are other possible sources of TSS. Shoreline erosion in lakes can contribute significant TSS loads due to wave action.

4.4 Applicable Water Quality Standards

A description of the designated use support for waters within Illinois and a narrative of Illinois EPA's water quality standards are presented in this section. Additionally, numeric water quality criteria for the parameters of interest in this TMDL are provided.

4.4.1 Use Support Guidelines

To assess the designated use support for Illinois waterbodies the Illinois EPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB). The General Use Standards apply to both Lake Oakland and Walnut Point Lake.

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

4.4.2 Numeric Standards

Numeric water quality standards for the State of Illinois for general use and public and food processing and water supply are presented in Table 4-1. These standards form the basis for determining whether the lakes are currently impaired and will also be used in the development of any necessary TMDLs.

Table 4-1. Illinois Numeric Water Quality Standards

Parameter	Units	General Use
Nutrients/Organic Enrichment/Low DO/Excessive Algal Growth		
Total Phosphorus[1]	mg/L	0.05
Nitrates	mg/L	None
Dissolved Oxygen	mg/L	5.0 minimum
Chlorophyll-a	µg/L	None
Sedimentation/Siltation		
Sedimentation/Siltation		None
Total Suspended Solids		
Total Suspended Solids		None

[1]The total phosphorus standard applies to all depths but is typically assessed using only the sample taken at one foot.

4.5 Water Quality Data Assessment

Water quality data for Lake Oakland and Walnut Point Lake were downloaded from the STORET and USGS NWIS databases and were also provided by Illinois EPA. The locations of the monitoring stations within the watershed are shown in Figure 4-1. Data are only available for the two lakes and a closer view of the lake monitoring stations is shown in Figure 4-2. An analysis of the available water quality data important to the TMDL development process is presented in this section.

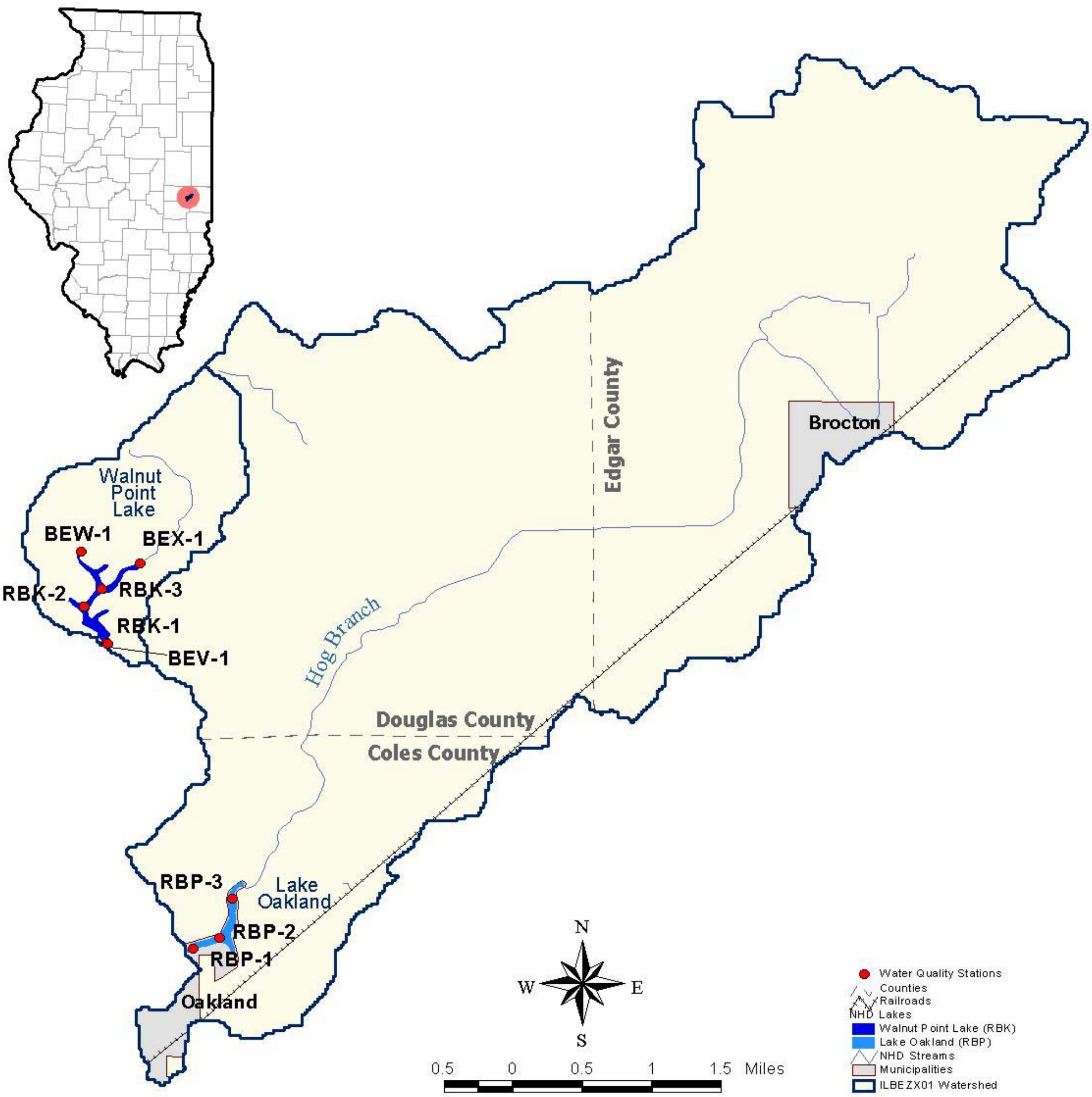

Figure 4-1. Monitoring stations in the Lake Oakland and Walnut Point Lake watersheds.

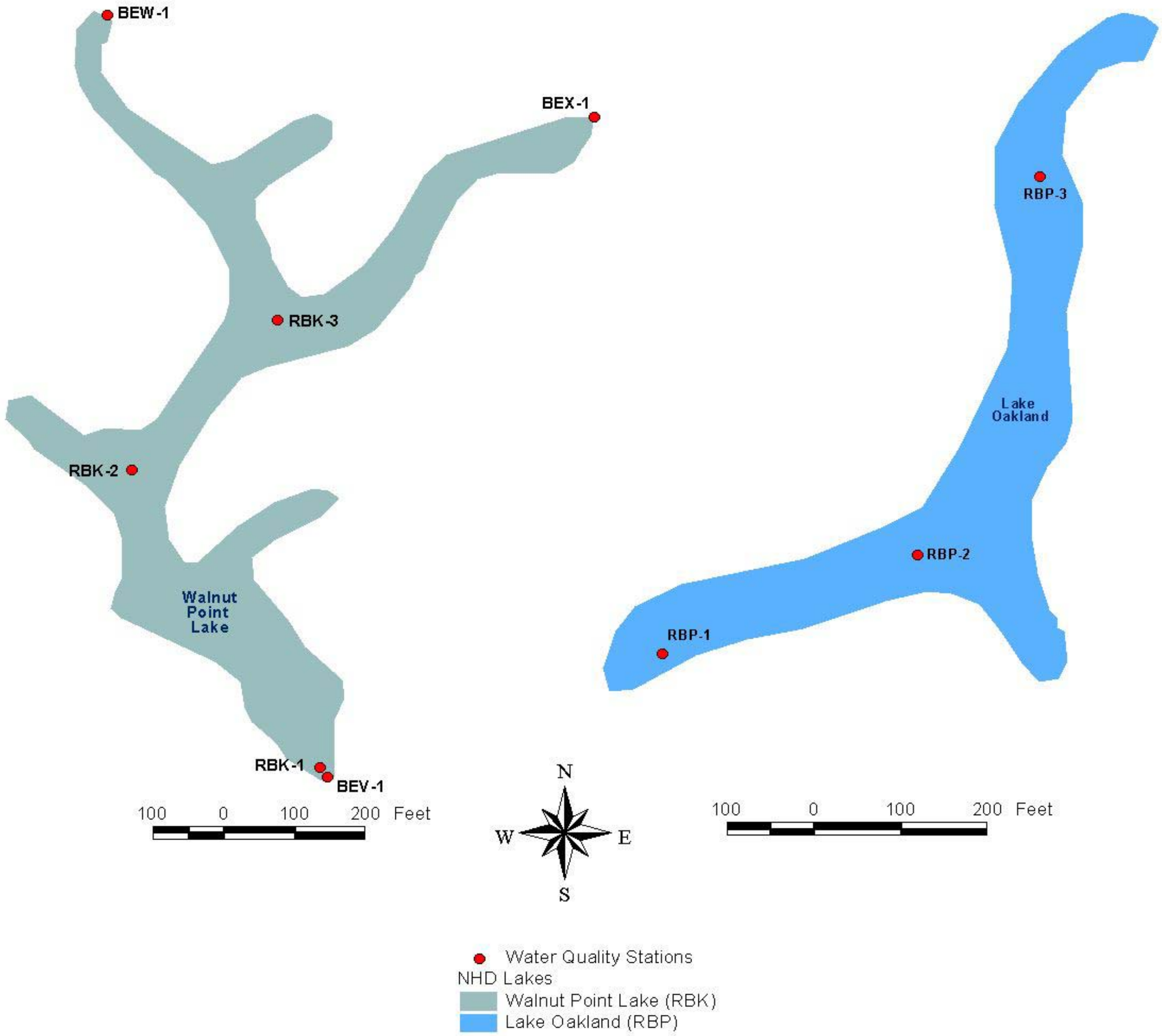

Figure 4-2. Monitoring stations in Lake Oakland and Walnut Point Lake.

4.5.1 Lake Oakland (Segment RBP)

Lake Oakland is a shallow 27.6 acre lake listed as being impaired due to total phosphorus, excessive algal growth, suspended solids, and sedimentation/siltation. The available water quality data are summarized below.

4.5.1.1 Total Phosphorus

Table 4-2 summarizes the available total phosphorus and other nutrient data for Lake Oakland. The available dissolved and total phosphorus data are also shown graphically in Figure 4-3. Data are available for the period 1981 to 2001 and no increasing or decreasing trend in TP concentrations is apparent, although the oldest data exhibit the lowest concentrations. Almost all of the samples exceed the 0.05 mg/L TP water quality standard, including all samples taken during the past six years (Table 4-3).

Table 4-2. Summary of total phosphorus and other nutrient-related parameters for Lake Oakland.

Parameter	Samples (Count)	Start	End	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	CV*
Total Phosphorus	80	6/3/1981	10/15/2001	0.01	0.18	0.49	0.66
Dissolved Phosphorus	46	6/3/1981	10/15/2001	0.00	0.06	0.37	1.56

*CV = standard deviation/average

Table 4-3. Violations of the TP standard in Lake Oakland.

Parameter	Samples (Count)	Violations (Count)	Percent Violating	Samples (Count), 1998 to Present	Violations (Count), 1998 to present	Percent Violating, 1998 to Present
Total Phosphorus (All Depths)	80	77	96%	39	39	100%
Total Phosphorus (1-Foot Depth)	71	68	96%	31	31	100%

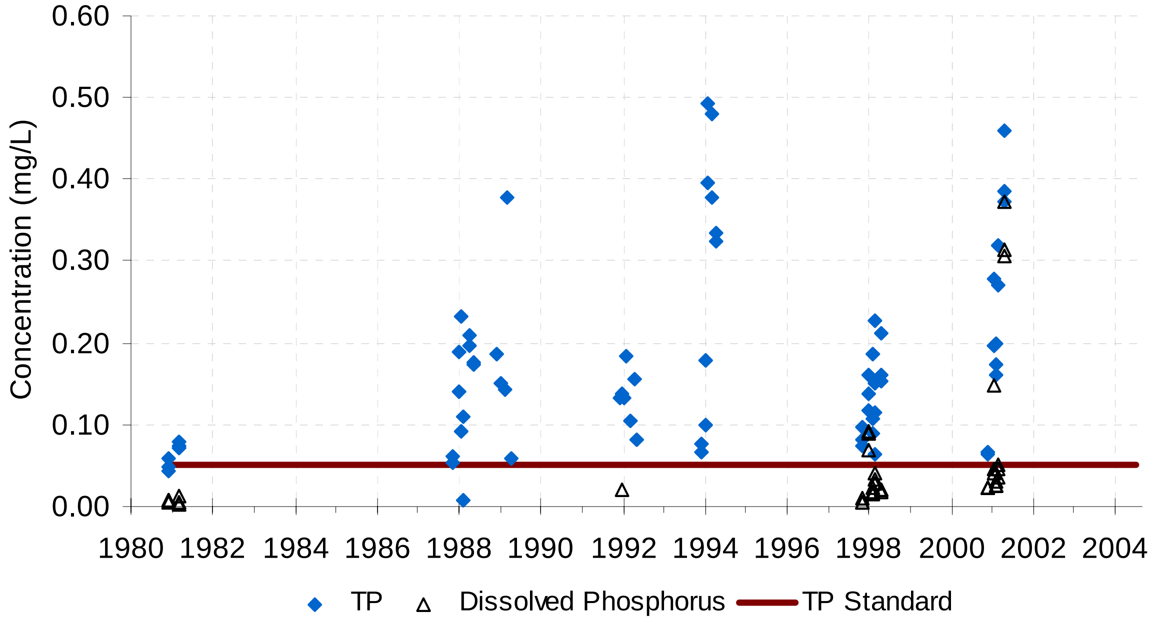

Figure 4-3. All total and dissolved phosphorus data for Lake Oakland.

Monthly median and mean TP concentrations for the period of record are presented in Figure 4-4 and Figure 4-5. Data are not available for the winter. The figure shows that the water quality standard of 0.05 mg/L is exceeded in all months. Additionally, median and mean monthly TP concentrations display seasonal variability, increasing from May to July, declining in August, and increasing again in September and October. Figure 4-5 indicates that the limited TP samples at depths greater than one foot increase consistently from May to October.

The dissolved phosphorus data exhibit a similar pattern (Figure 4-6 and Figure 4-7), although fewer data are available.

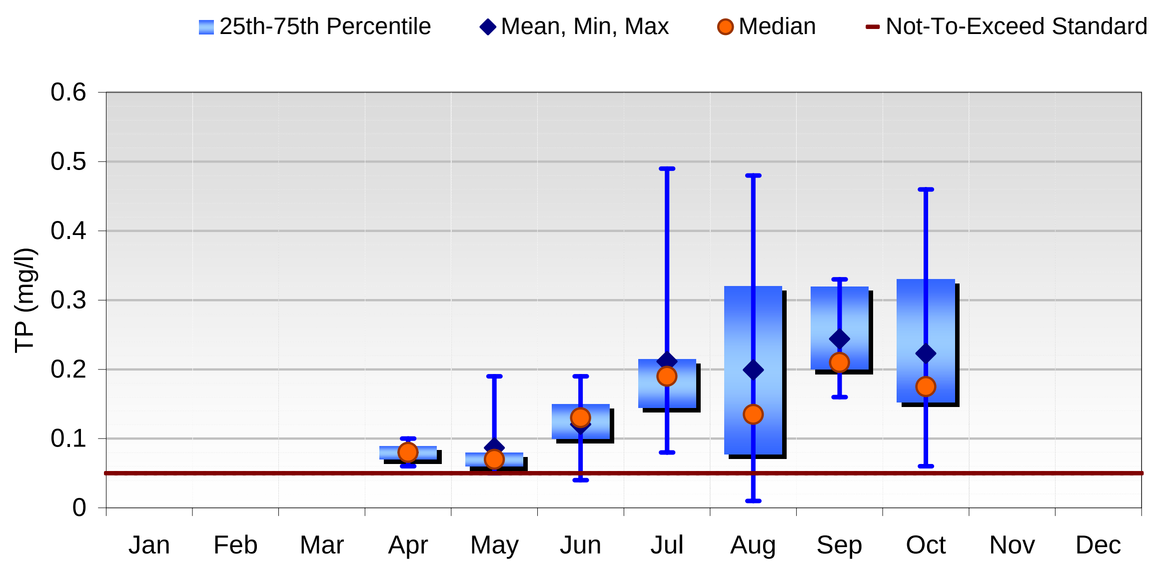

Figure 4-4. Seasonal variation of total phosphorus in Lake Oakland (all data at 1-foot depth).

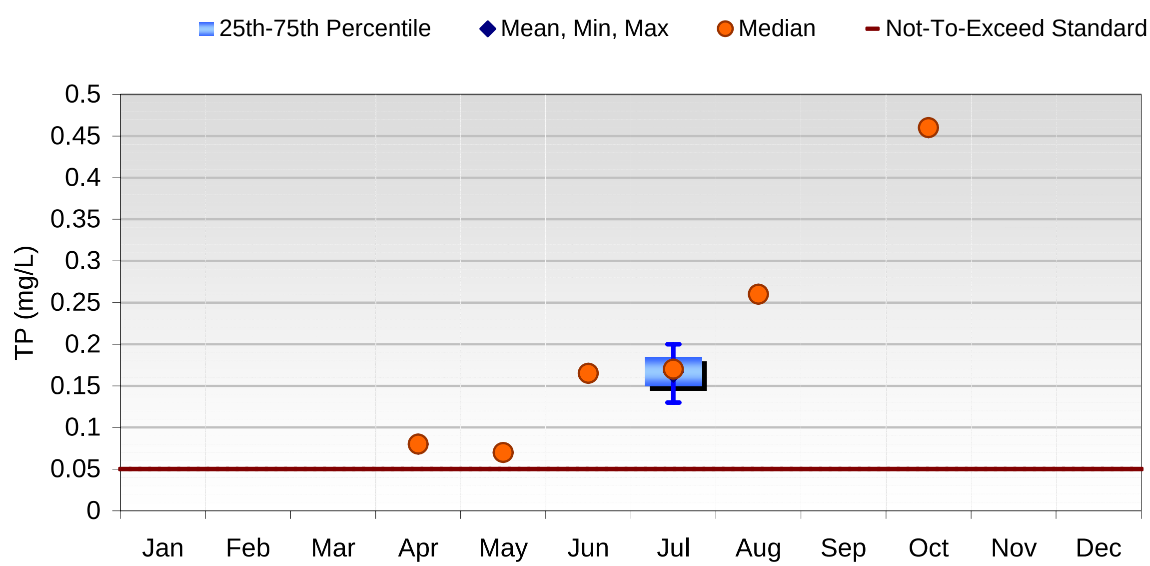

Figure 4-5. Seasonal variation of total phosphorus in Lake Oakland (all data at greater than 1-foot depth).

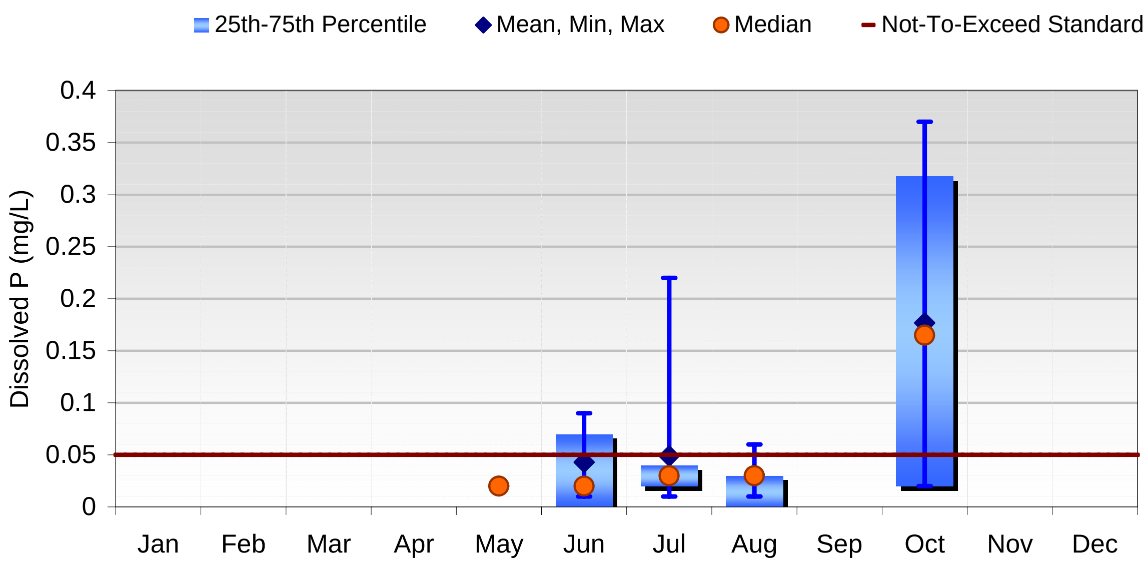

Figure 4-6. Seasonal variation of dissolved phosphorus in Lake Oakland (all data at 1-foot depth).

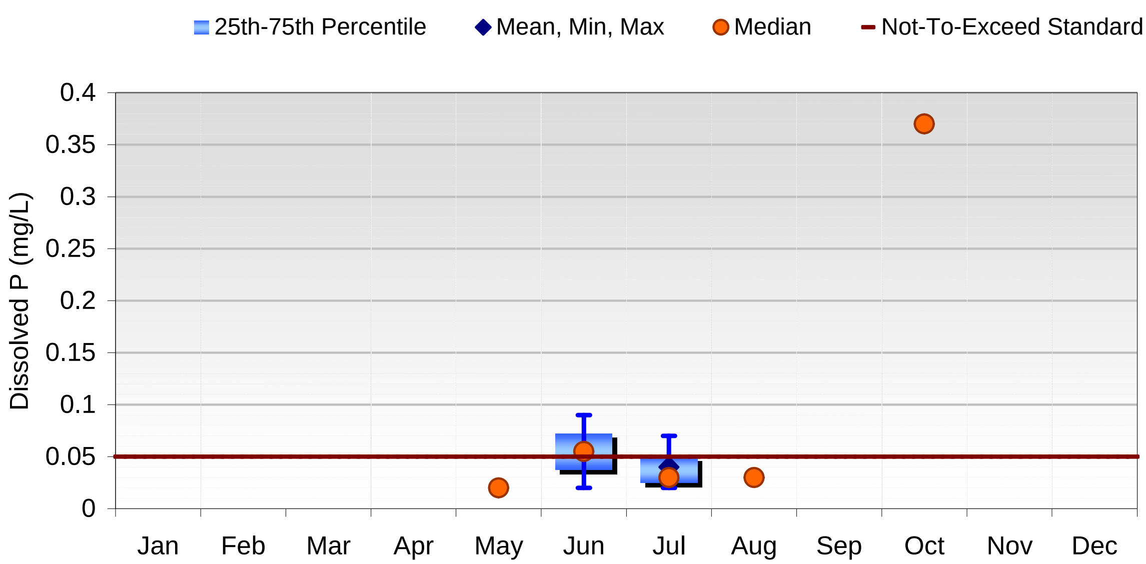

Figure 4-7. Seasonal variation of dissolved phosphorus in Lake Oakland (all data at greater than 1-foot depth).

Dissolved phosphorus as a proportion of total phosphorus can be an important value because it can often be used to help determine the source of the phosphorus loading. Samples that are relatively high in dissolved phosphorus can indicate anthropogenic sources such as wastewater treatment plants, failing septic systems, or fertilizer drained through agricultural tiles. Samples that are relatively low in dissolved phosphorus (and thus high in particulate phosphorus) are more likely to indicate sources associated with soil erosion.

Comparisons of dissolved and total phosphorus concentrations are shown in Figure 4-8 and Figure 4-9. The data indicate that dissolved phosphorus is a relatively small fraction of total phosphorus for all months except October (Figure 4-8). This could be due algal uptake. However, there appears to be a great deal of variability in the relationship (Figure 4-9).

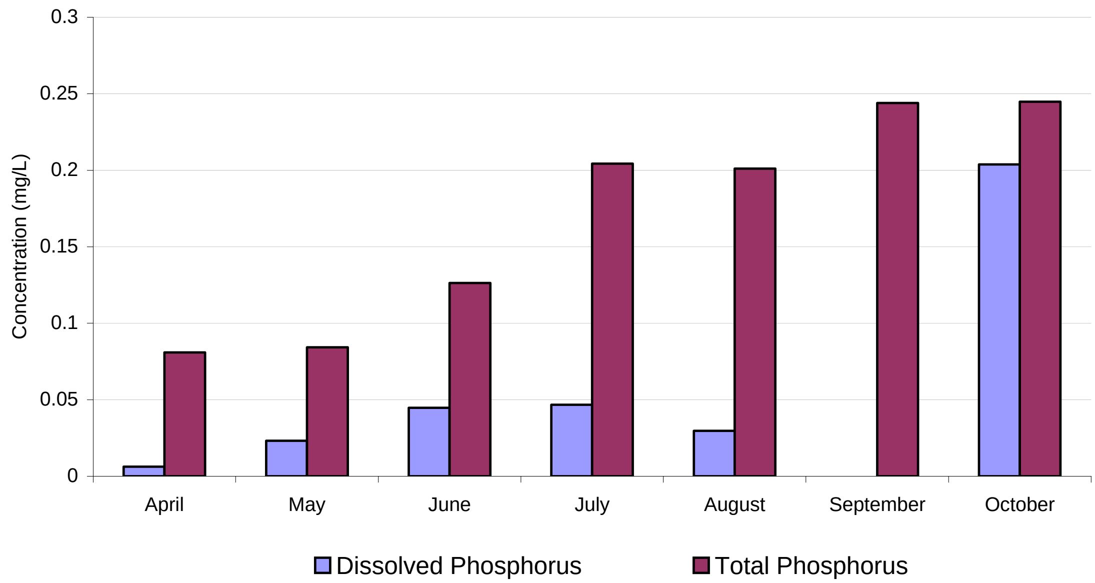

Figure 4-8. Comparison of seasonal dissolved and total phosphorus data for Lake Oakland (all data).

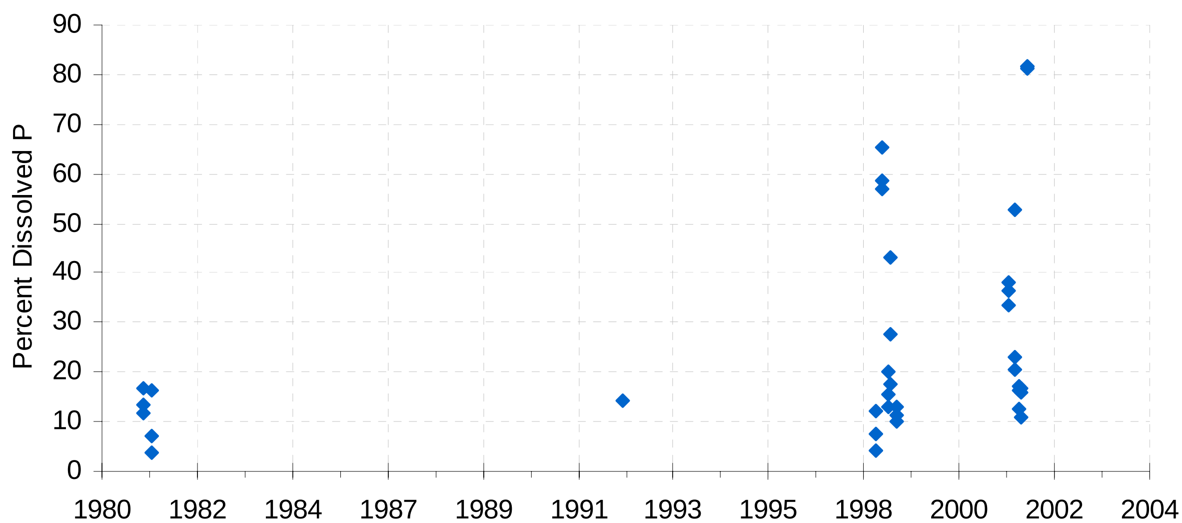

Figure 4-9. Proportion of dissolved phosphorus for Lake Oakland.

4.5.1.2 Total Nitrogen (TN)-to-Total Phosphorus (TP) Ratio

Eutrophication in freshwater systems is typically controlled by either nitrogen or phosphorus. The limiting nutrient is defined as the nutrient that limits plant growth when it is not available in sufficient quantities. Controlling the limiting nutrient can often slow the rate of eutrophication and improve conditions in the waterbody. An initial identification of the limiting nutrient can be made by comparing the levels of nutrients in the waterbody with the plant stoichiometry. The ratio of nitrogen to phosphorus in biomass is approximately 7.2:1. Therefore, a nitrogen:phosphorus ration in water that is less than 7.2 suggests that nitrogen is limiting. In contrast, a ratio greater than 7.2 suggests that phosphorus is the limiting nutrient (Chapra, 1997).

The TN:TP ratios in Lake Oakland are presented in Figure 4-10. TN:TP ratios are somewhat variable over the period of record but are generally much higher than 10. This suggests that phosphorus is the limiting nutrient in Lake Oakland. The high variability might be due to multiple algal species (some that are nitrogen limited and some that are phosphorus limited) outcompeting one another during different periods of the year.

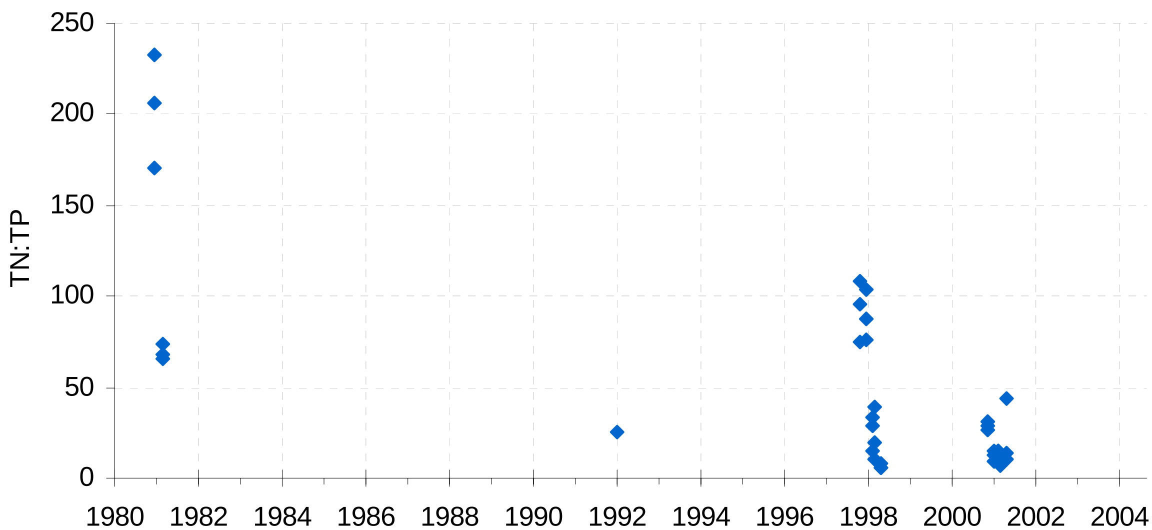

Figure 4-10. TN:TP ratios over the period of record in Lake Oakland.

4.5.1.3 Excessive Algal Growth

The dominant pigment in algal cells is chlorophyll-a, which is easy to measure and is a valuable surrogate measure for algal biomass. Chlorophyll-a is desirable as an indicator because algae are either the direct (e.g. nuisance algal blooms) or indirect (e.g. high/low dissolved oxygen, pH, and high turbidity) cause of most problems related to excessive nutrient enrichment. The Illinois water quality standard for general use states that “waters of the state shall be free from algal growth of other than natural origin” (Section 302.203).

Table 4-4 presents a summary of the chlorophyll-a data collected in Lake Oakland. Figure 4-11 displays the data graphically and indicates that recent values are greater than data from the early 1980s. Monthly median and mean chlorophyll-a concentrations are presented in Figure 4-12, which shows that chlorophyll-a concentrations are highest in August. The relationship between TP and chlorophyll-a is displayed in Figure 4-13 and the relationship between TSS and chlorophyll-a is displayed in Figure 4-14. The figures indicate that there is a weak positive relationship between both TP and chlorophyll-a and TSS and chlorophyll-a.

Table 4-4. Summary of chlorophyll-a data for Lake Oakland.

Parameter	Samples (Count)	Start	End	Minimum (µg/L)	Average (µg/L)	Maximum (µg/L)	CV*
Chlorophyll-a	34	6/3/1981	10/15/2001	2.32	62.31	248.31	0.88

*CV = standard deviation/average

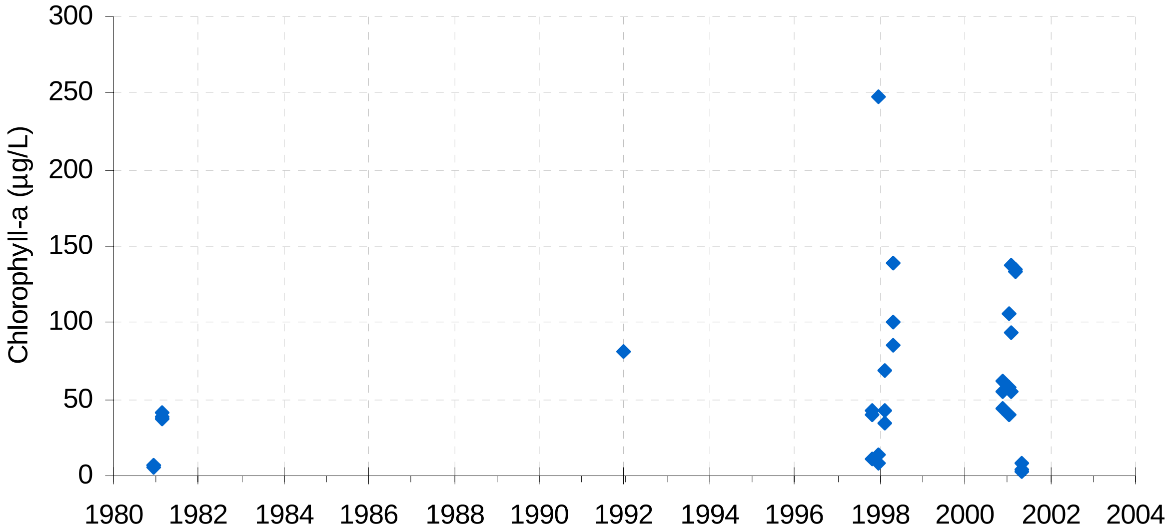

Figure 4-11. All chlorophyll-a data for Lake Oakland.

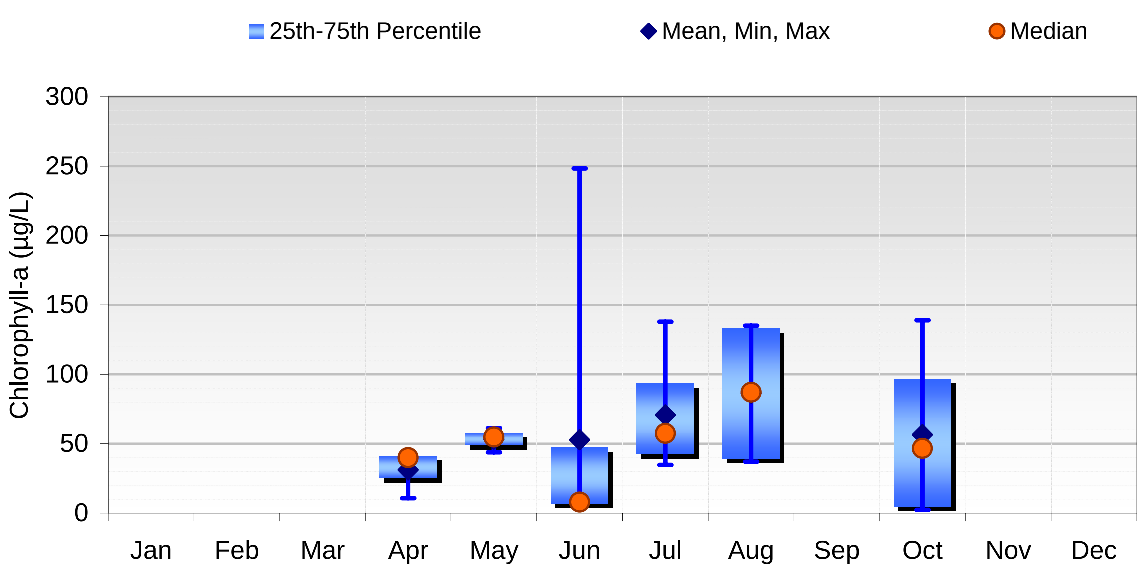

Figure 4-12. Seasonal variation of chlorophyll-a for Lake Oakland (all data).

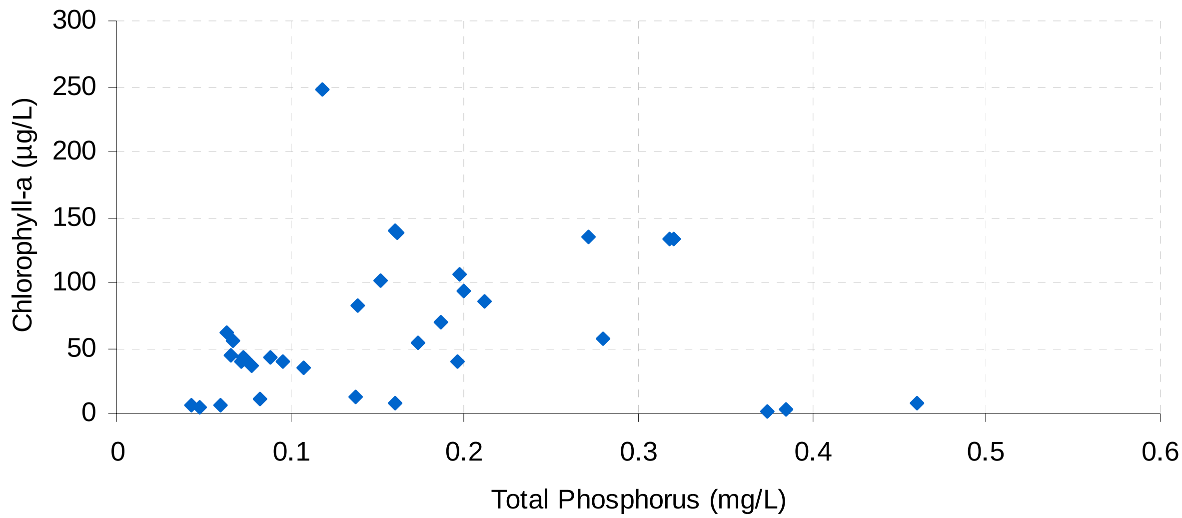

Figure 4-13. Correlation between TP and chlorophyll-a for Lake Oakland.

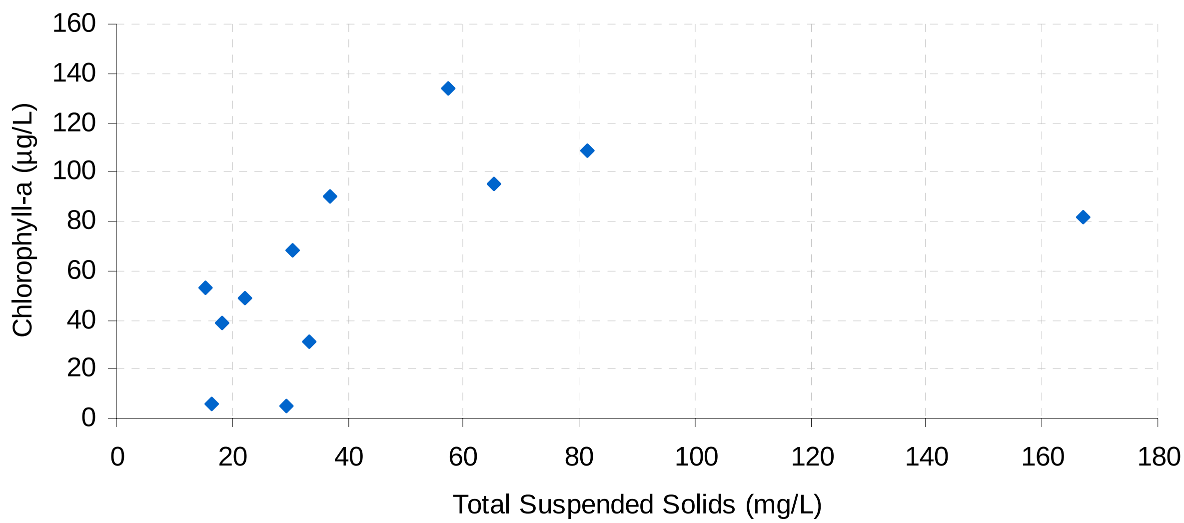

Figure 4-14. Correlation between TSS and chlorophyll-a for Lake Oakland.

Carlson developed a frequently used biomass-related trophic status index in 1977. His trophic status index (TSI) uses Secchi depth (SD), chlorophyll-a (Chl) and TP, each producing an independent measure of trophic state. Index values range from approximately 0 (ultraoligotrophic) to 100 (hypereutrophic). The index is scaled so that TSI = 0 represents secchi depth transparency of 64 meters. Each halving of transparency represents an increase of 10 TSI units. For example, a TSI of 50 represents a transparency of 2 meters. A TSI is calculated from each of secchi depth, chlorophyll *a* concentration, and TP concentration (Carlson, 1977; Carlson and Simpson, 1996). Each variable is used to estimate algal biomass independently, and the values should not be averaged (Carlson, 1983). Chlorophyll-a is a better predictor of trophic state than either of the other two variables.

The long-term average chlorophyll-a concentration for Lake Oakland (62 µg/L) results in a Carlson TSI of 71. This value is indicative of hyper-eutrophic conditions. TSI values above 60 suggest the presence of blue-green algae during the summer, algal scum, and a considerable macrophyte problem.

4.5.1.4 Suspended Solids

The total suspended solids (TSS) data for Lake Oakland are summarized in Table 4-5 and are shown in Figure 4-15. Data are available for the period 1981 to 2001 and no long-term increasing or decreasing trends are apparent. Monthly median and mean TSS concentrations are presented in Figure 4-16 and indicate that concentrations typically increase during the summer and peak in September. There is also a high degree of variability in observed TSS concentrations.

Table 4-5. Summary of suspended solids data for Lake Oakland.

Parameter	Samples (Count)	Start	End	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	CV*
Suspended Solids	80	6/3/1981	10/15/2001	4.00	40.44	178.00	0.85

*CV = standard deviation/average

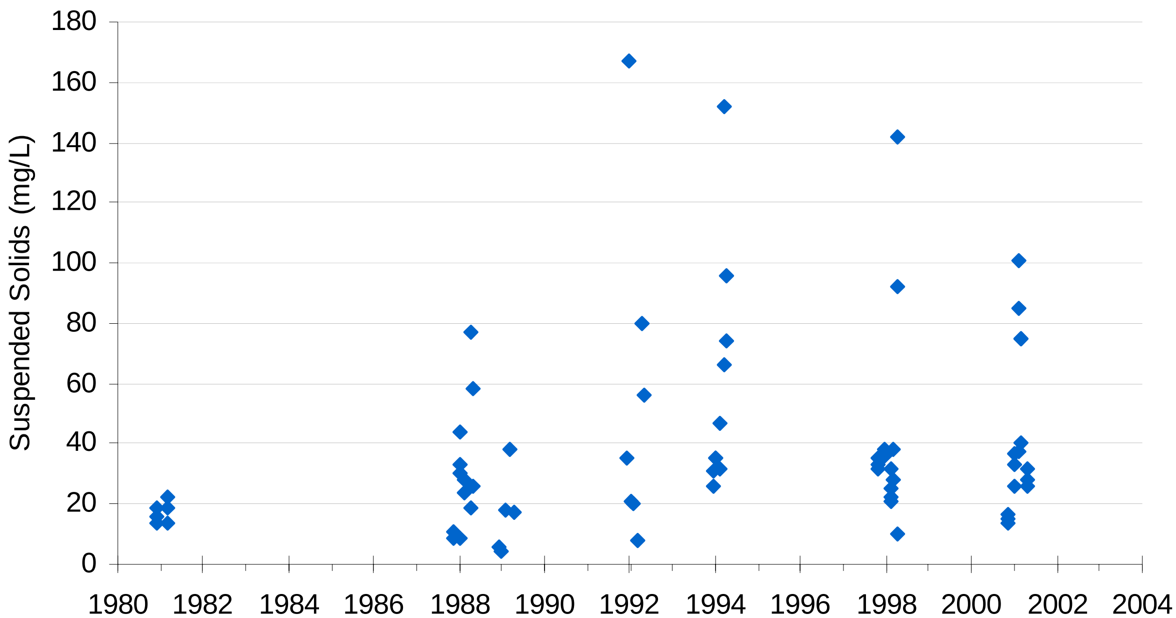

Figure 4-15. All suspended solids data for Lake Oakland.

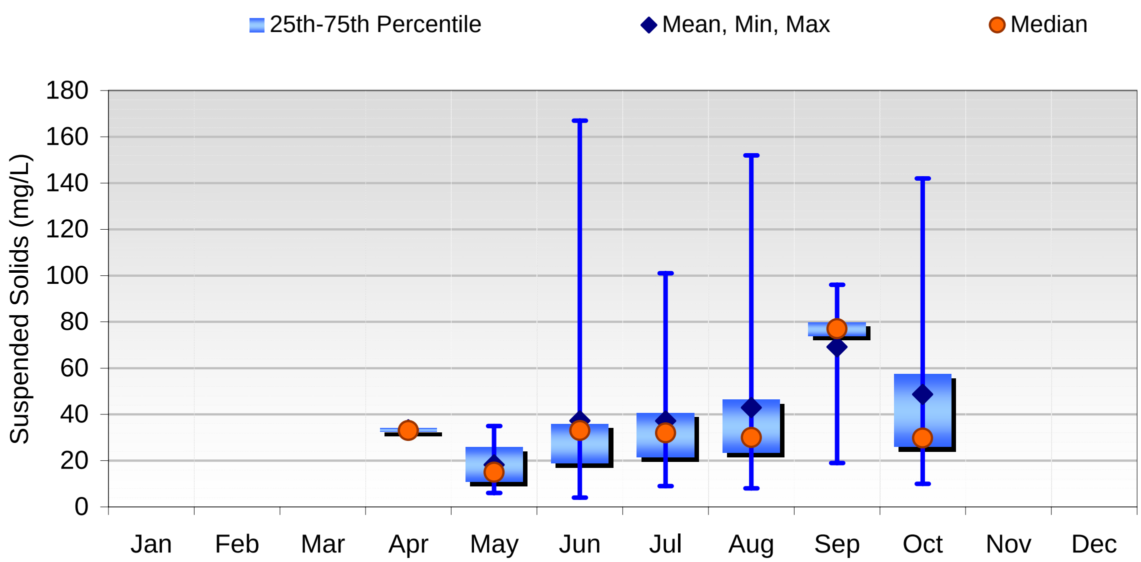

Figure 4-16. Seasonal variation in suspended solids data for Lake Oakland (all data).

4.5.2 Walnut Point Lake (Segment RBK)

Walnut Point Lake is a 41.6 acre lake listed as impaired due total phosphorus, nitrate, sedimentation/siltation, suspended solids, dissolved oxygen, native aquatic plants, and excess algal growth. The fishery is good with high catch rates of bass and bluegill (Mike Mounce, Illinois Department of Natural Resources, personal communications, October 26, 2004). The available water quality data are summarized below.

4.5.2.1 Total Phosphorus

Table 4-6 summarizes the available dissolved phosphorus and total phosphorus data for Walnut Point Lake. The available TP data are also shown graphically in Figure 4-17 and indicate a slight increasing trend. Data are only available for the period 1979 to 1995 and more than 75 percent of the samples exceed the 0.05 mg/L TP water quality standard (Table 4-7). Seasonal concentrations of dissolved and total phosphorus do not exhibit any apparent pattern (Figure 4-18 to Figure 4-21), although samples taken at deeper depths have considerably higher TP and dissolved phosphorus concentrations.

Table 4-6. Summary of total phosphorus and other nutrient-related parameters for Walnut Point Lake.

Parameter	Samples (Count)	Start	End	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	CV
Dissolved Phosphorus	56	6/18/1979	10/4/1995	0.00	0.23	2.45	2.26
Total Phosphorus	57	6/18/1979	10/4/1995	0.02	0.28	2.88	2.02

*CV = standard deviation/average

Table 4-7. Violations of the TP standard in Walnut Point Lake.

	Samples (Count)	Violations (Count)	Percent Violating	Samples (Count), 1998 to Present	Violations (Count), 1998 to present	Percent Violating, 1998 to Present
Total Phosphorus (All Depths)	57	44	77%	0	NA	NA
Total Phosphorus (1-Foot Depth)	40	30	75%	0	NA	NA

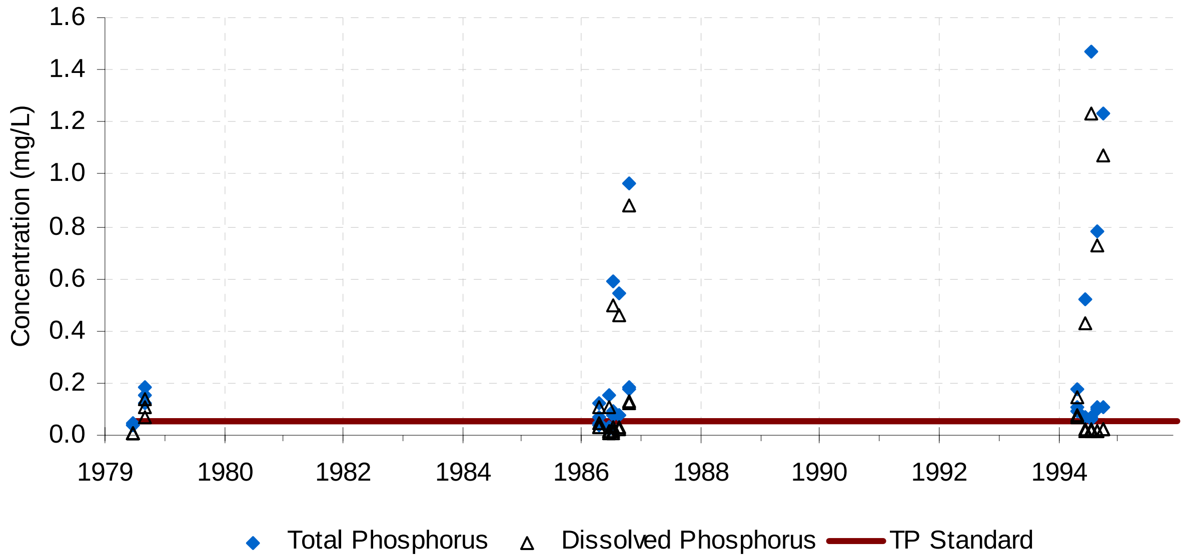

Figure 4-17. All total phosphorus and dissolved phosphorus data for Walnut Point Lake.

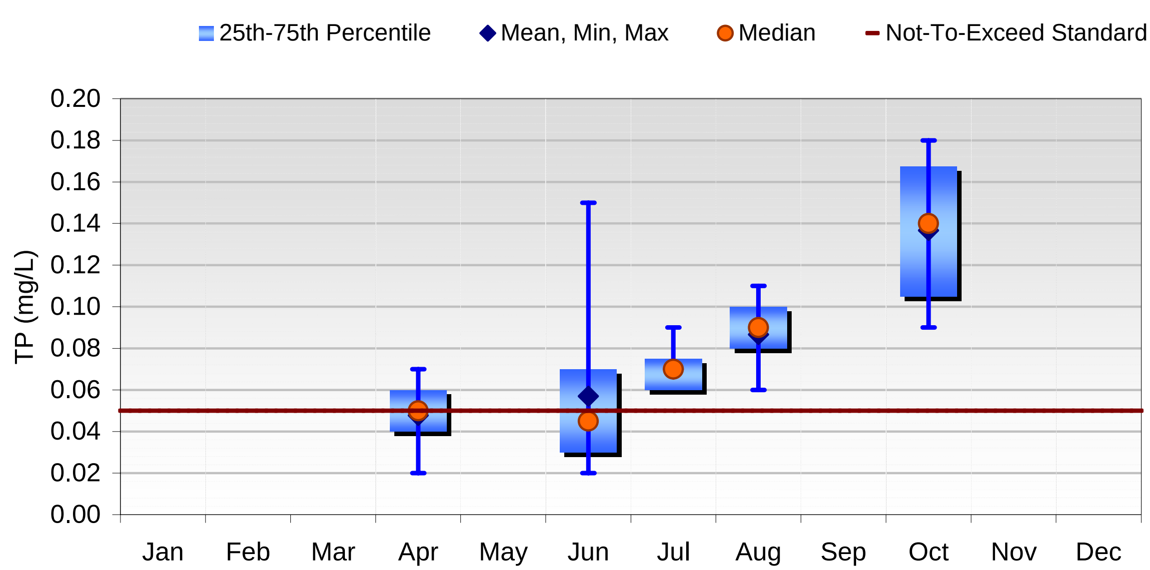

Figure 4-18. Seasonal variation of TP in Walnut Point Lake (all data at 1-foot depth).

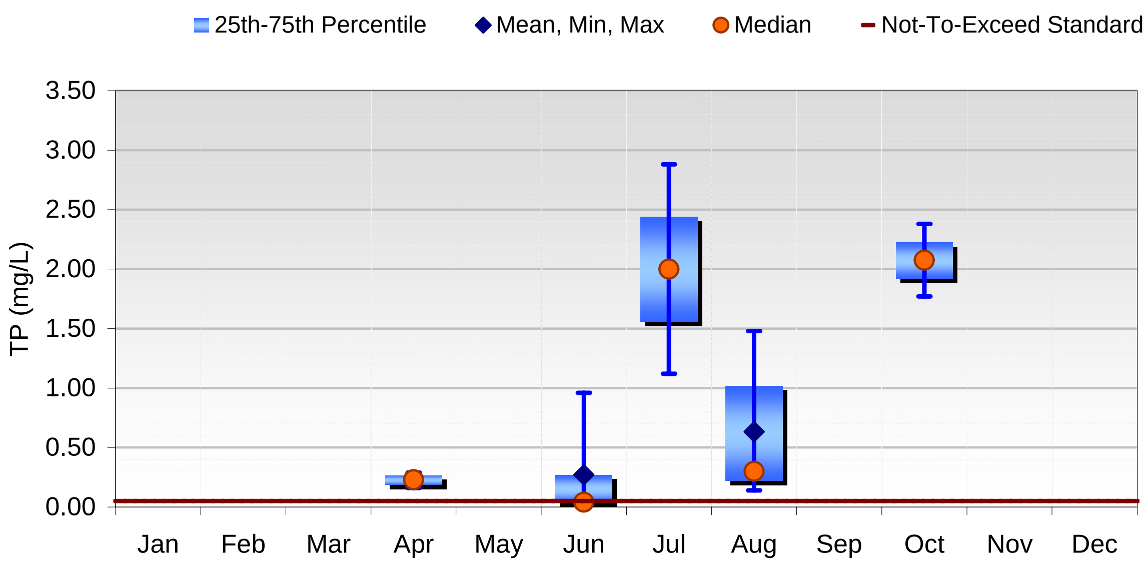

Figure 4-19. Seasonal variation of TP in Walnut Point Lake (all data at greater than 1-foot depth).

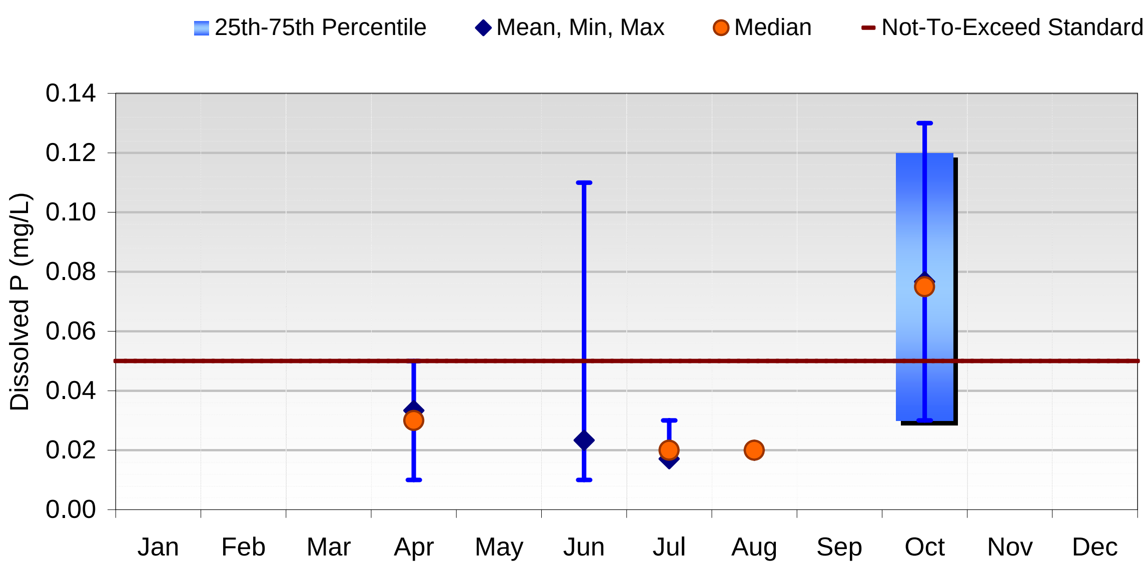

Figure 4-20. Seasonal variation of dissolved phosphorus in Walnut Point Lake (all data at 1-foot depth).

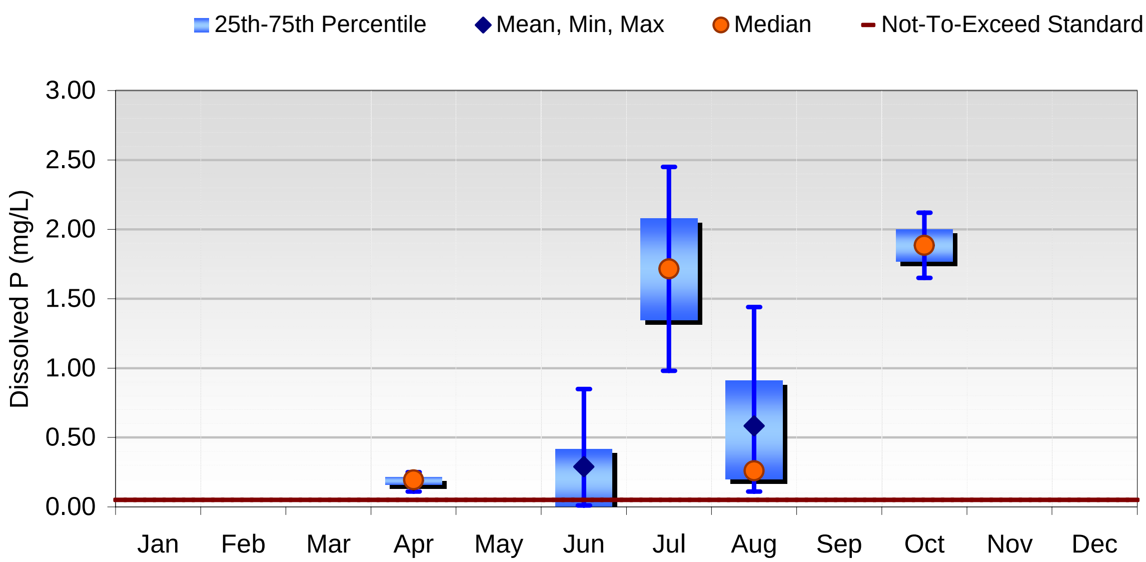

Figure 4-21. Seasonal variation of dissolved phosphorus in Walnut Point Lake (all data at greater than 1-foot depth).

Figure 4-22 and Figure 4-23 display the relationship between dissolved and total phosphorus in Walnut Point Lake. The data indicate that dissolved phosphorus is a much higher proportion of total phosphorus compared to Lake Oakland.

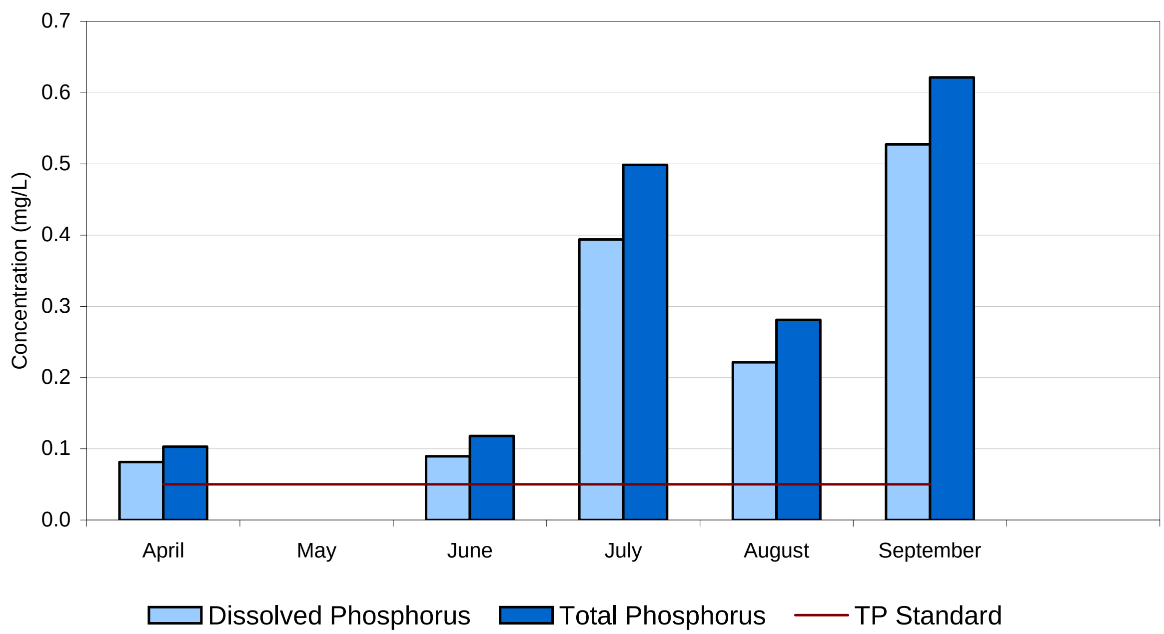

Figure 4-22. Comparison of seasonal dissolved and total phosphorus data for Walnut Point Lake (all data).

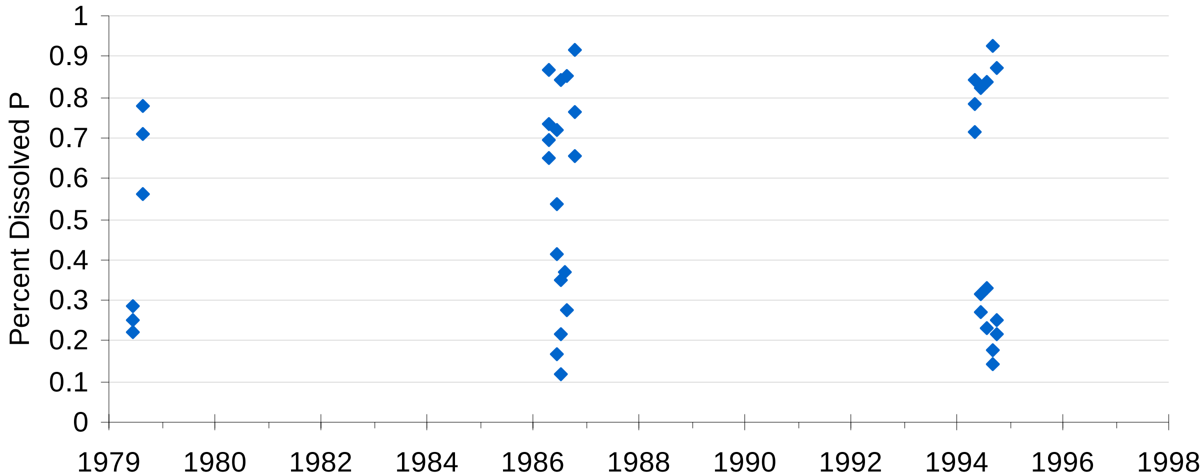

Figure 4-23. Proportion of dissolved phosphorus in Walnut Point Lake.

4.5.2.2 Total Nitrogen (TN)-to-Total Phosphorus (TP) Ratio

The TN:TP ratios in Walnut Point Lake are presented in Figure 4-24. TN:TP ratios are fairly consistent over the period of record and are generally higher than 10. The average of all ratios is 24, which suggests that phosphorus is the limiting nutrient in Walnut Point Lake.

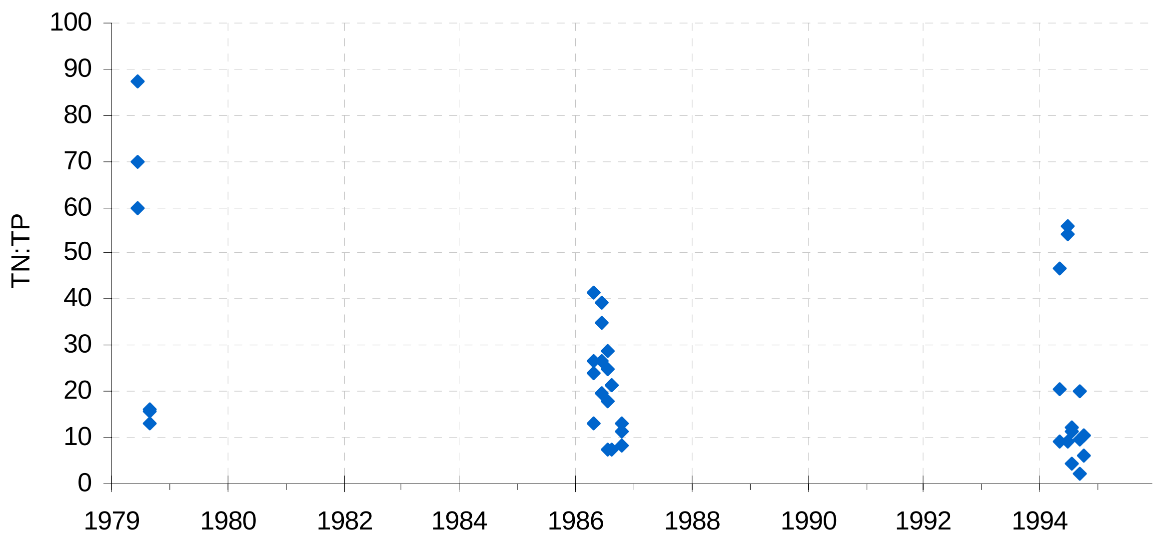

Figure 4-24. TN:TP ratios over the period of record for Walnut Point Lake.

4.5.2.3 Nitrate Nitrogen

Walnut Point Lake is listed as being impaired due to nitrate nitrogen. The nitrate water quality standard for public and food processing water supplies is 10 mg/L. Table 4-8 summarizes the available nitrate+nitrite data and indicates that no values have exceeded the 10 mg/L standard[1]. The nitrate+nitrite data are also presented in Figure 4-25 and do not indicate any clear increasing or decreasing trends. It is recommended that Walnut Point Lake be de-listed for nitrate nitrogen based on the fact it is not a public and food processing water supply and the available data do not indicate high nitrate concentrations.

Table 4-8. Summary of nitrogen parameters for Walnut Point Lake.

Parameter	Samples (Count)	Start	End	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	CV
Nitrate + Nitrite	53	6/18/1979	10/4/1995	0.01	0.65	8.00	2.11

*CV = standard deviation/average

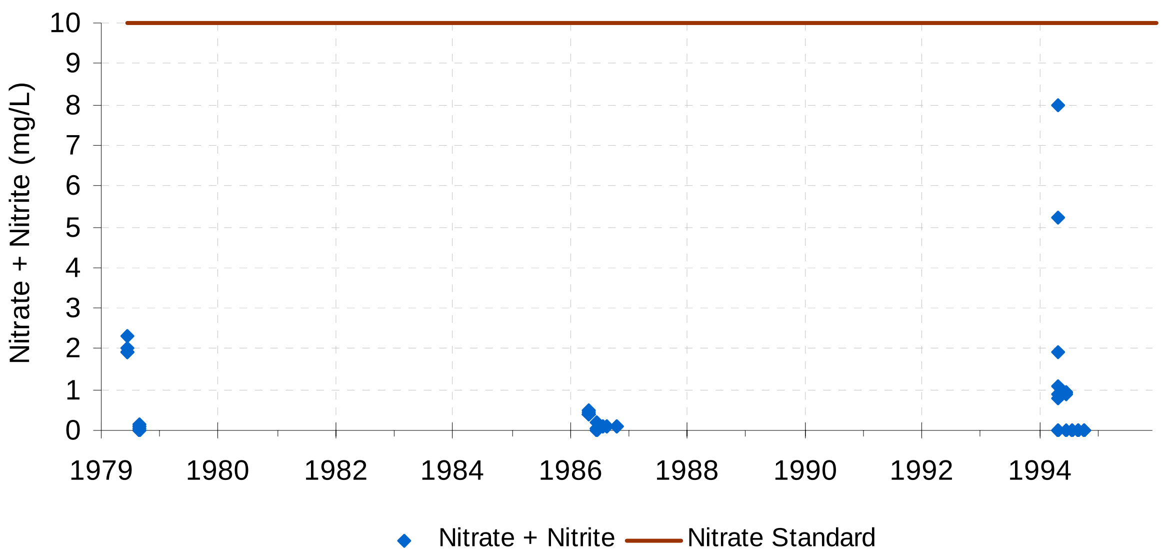

Figure 4-25. All nitrate+nitrite data for Walnut Point Lake.

4.5.2.4 Excessive Algal Growth

The chlorophyll-a data for Walnut Point Lake are summarized in Table 4-9 and presented graphically in Figure 4-26. The 1995 values appear to be slightly higher than the samples taken in 1979 and 1987. No recent (post 1998) data are available. Monthly median and mean chlorophyll-a concentrations are presented in Figure 4-27, which shows that chlorophyll-a concentrations increase from June to October. The relationship between chlorophyll-a and TP is graphically displayed in Figure 4-28. The figure shows that there is a weak positive relationship between TP and chlorophyll-a. The relationship between TSS and chlorophyll-a is graphically displayed in Figure 4-29 and indicates a relatively strong correlation between the two variables.

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[1] Only nitrate+nitrite data are reported for Walnut Point Lake. These data are used to compare to the nitrate standard based on the assumption that nitrite is quickly converted to nitrate through the process of nitrification.

Table 4-9. Summary of the chlorophyll-a data for Walnut Point Lake.

Parameter	Samples (Count)	Start	End	Minimum (µg/L)	Average (µg/L)	Maximum (µg/L)	CV*
Chlorophyll-a	36	6/18/1979	10/4/1995	1.60	64.03	301.92	0.96

*CV = standard deviation/average

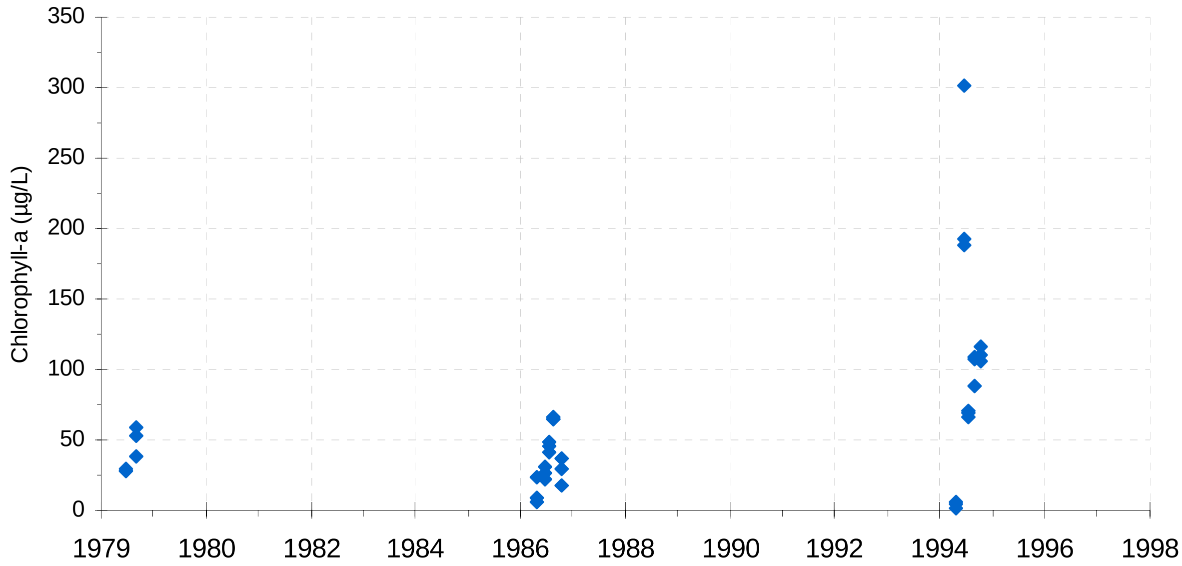

Figure 4-26. All chlorophyll-a data for Walnut Point Lake.

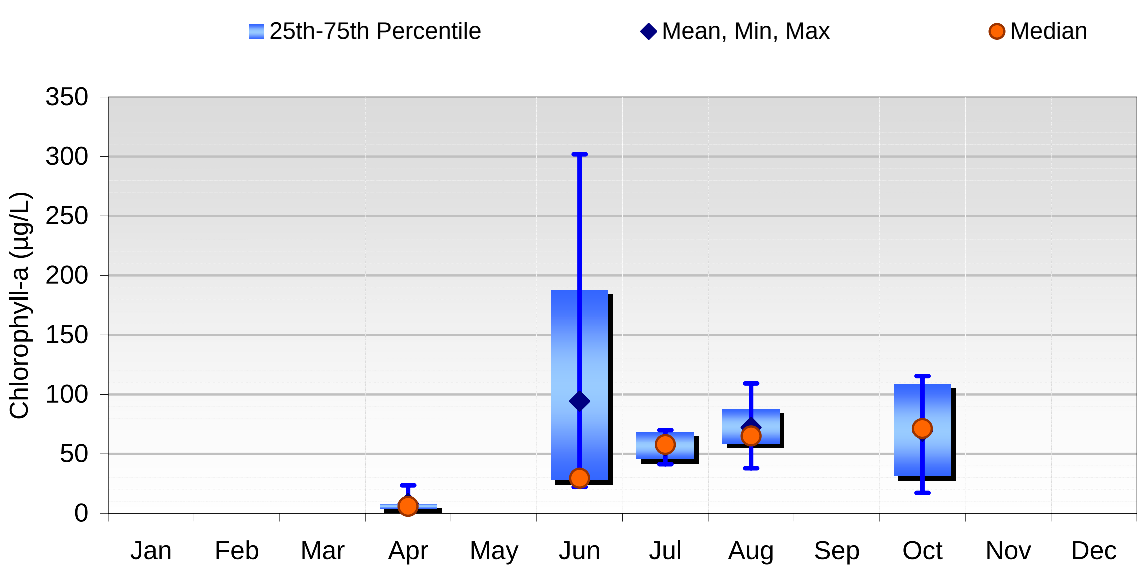

Figure 4-27. Seasonal variation in chlorophyll-a data for Walnut Point Lake (all data).

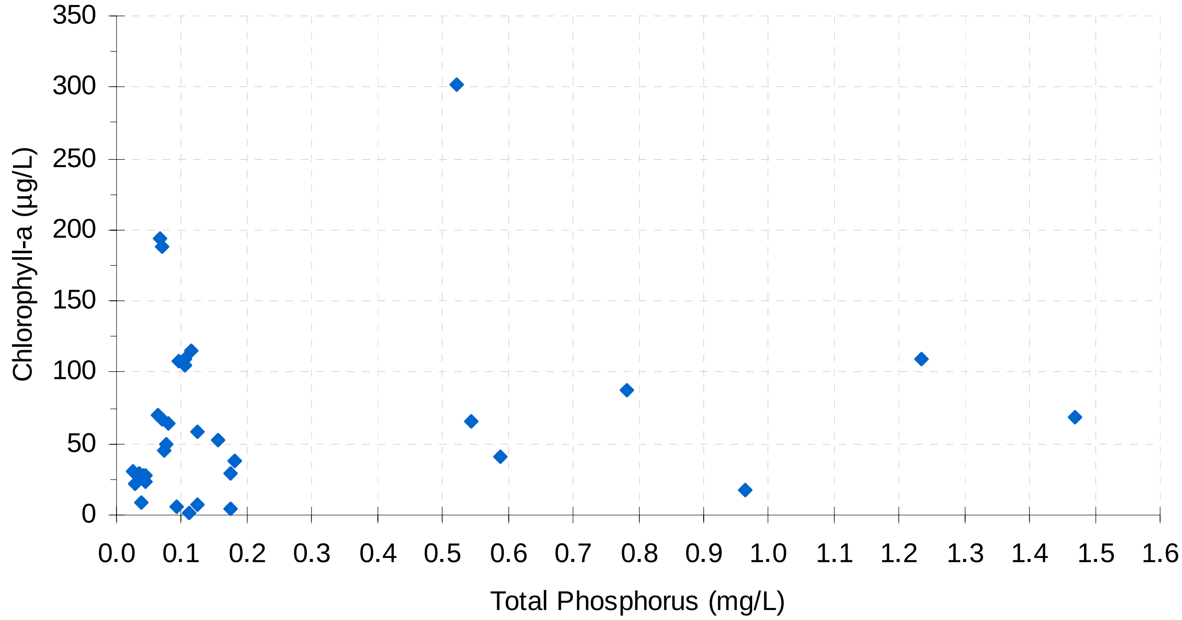

Figure 4-28. Correlation between TP and chlorophyll-a for Walnut Point Lake.

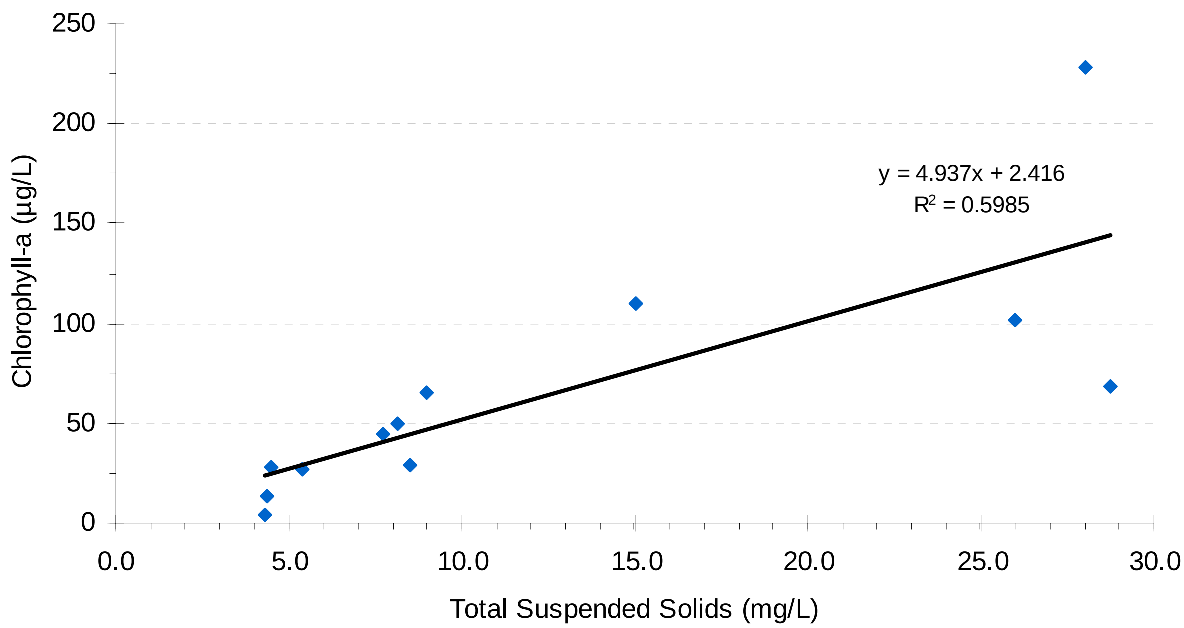

Figure 4-29. Correlation between TSS and chlorophyll-a for Walnut Point Lake.

The long-term average chlorophyll-a concentration for Walnut Point Lake (64 µg/L) results in a Carlson TSI of 71. This value is indicative of hyper-eutrophic conditions.

4.5.2.5 Suspended Solids

The total suspended solids (TSS) data for Walnut Point Lake are summarized in Table 4-10 and shown in Figure 4-30. Data are available for the period 1979 to 1995 and the more recent data appear to be slightly greater than the older data. Monthly median and mean TSS concentrations are presented in Figure 4-31 and indicate that concentrations are typically greatest in July and August, although no data are available for several months of the year.

Table 4-10. Summary of the suspended solids data for Walnut Point Lake.

Parameter	Samples (Count)	Start	End	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	CV*
Suspended Solids	57	6/18/1979	10/4/1995	1.00	11.46	80.00	1.10

*CV = standard deviation/average

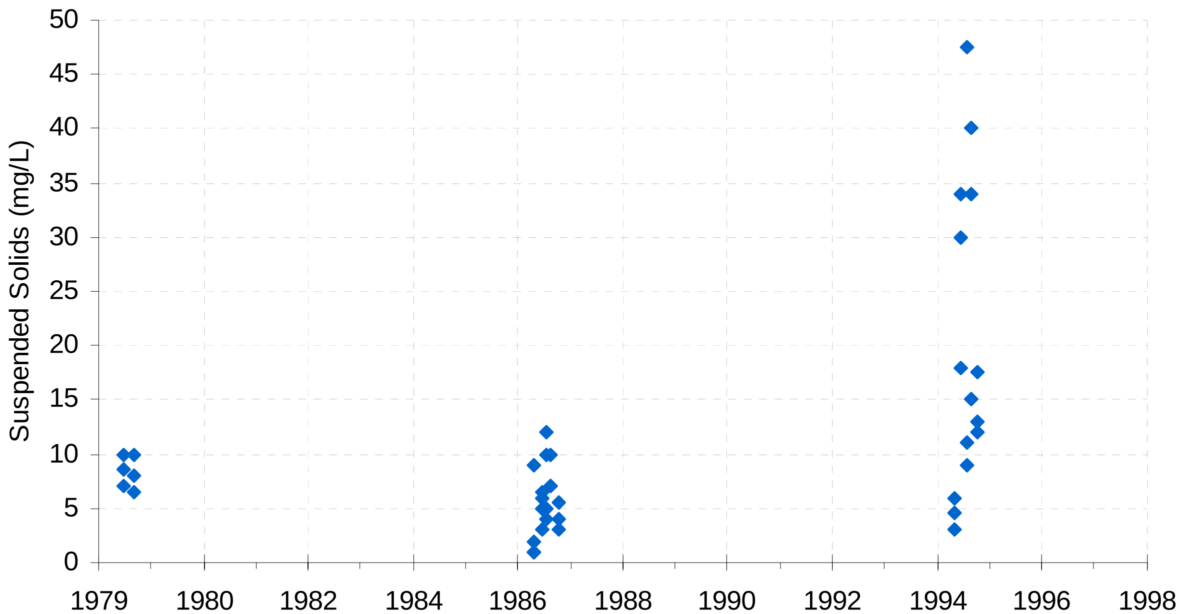

Figure 4-30. All suspended solids data for Walnut Point Lake.

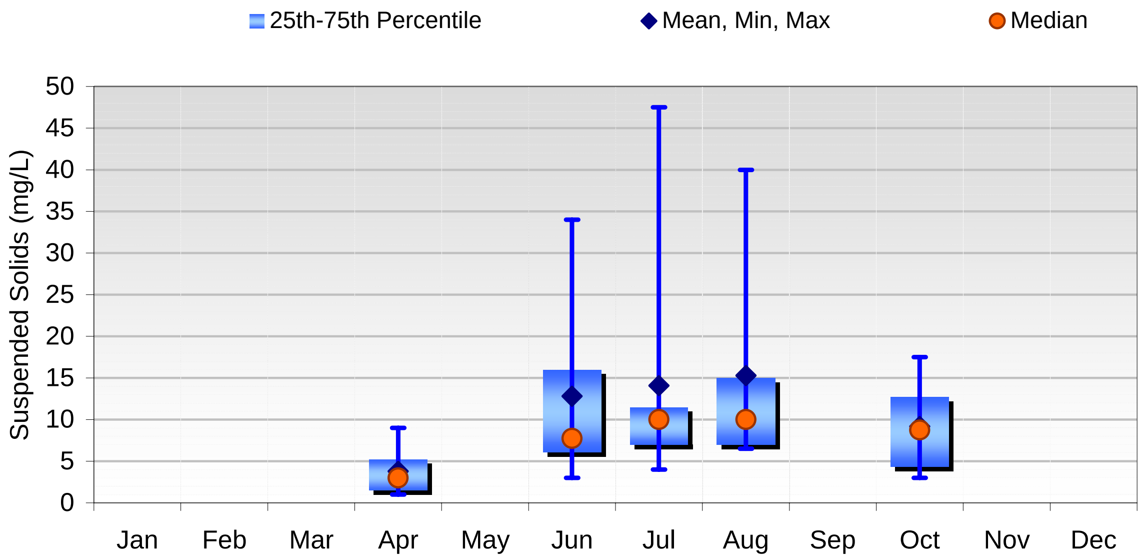

Figure 4-31. Seasonal variation in suspended solids data for Walnut Point Lake (all data).

4.5.2.6 Dissolved Oxygen

Walnut Point Lake is listed as being impaired due to dissolved oxygen. Table 4-11 summarizes the available dissolved oxygen for Walnut Point Lake. These data are shown graphically in Figure 4-32. Data are available for the period 1979 to 1995 and no increasing or decreasing trend in DO concentrations is apparent throughout the record. Dissolved oxygen concentrations decrease with increasing depth (Table 4-3). In addition, the percent of samples violating the 5.0 mg/L minimum numeric water quality standard increases with increasing depth.

Table 4-11. Summary of dissolved oxygen data in Walnut Point Lake.

Sample Depth (ft)	Start	End	Samples (Count)	Violations (Count)	Percent Violating	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	CV*
0	6/18/1979	10/4/1995	28	3	10.7	3.2	10.5	14.2	0.3
1	6/18/1979	10/13/1987	16	2	12.5	3.3	10.2	13.6	0.3
2	6/15/1995	10/4/1995	9	0	0.0	8.5	13.3	16.6	0.2
3	6/18/1979	10/13/1987	18	2	11.1	3.8	10.0	13.8	0.3
4	4/25/1995	10/4/1995	14	1	7.1	3.5	9.4	14.3	0.4
5	6/18/1979	10/13/1987	17	5	29.4	2.4	8.8	14.3	0.4
6	4/25/1995	10/4/1995	14	7	50.0	0.3	5.2	12.0	0.8
7	6/18/1979	10/13/1987	17	7	41.2	0.1	6.3	12.3	0.7
8	4/25/1995	10/4/1995	10	6	60.0	0.3	3.5	11.3	1.1
9	6/18/1979	10/13/1987	16	10	62.5	0.0	4.0	11.2	1.1
10	4/25/1995	10/4/1995	9	6	66.7	0.2	2.6	9.3	1.3
11	6/18/1979	10/13/1987	10	6	60.0	0.5	3.8	10.5	1.0
12	4/25/1995	10/4/1995	7	5	71.4	0.2	1.7	7.3	1.6
13	6/18/1979	10/13/1987	8	5	62.5	0.6	3.8	9.0	0.9
14	4/25/1995	10/4/1995	5	5	100.0	0.1	1.6	5.0	1.2
15	6/18/1979	10/13/1987	8	6	75.0	0.7	3.8	7.5	0.7
16	4/25/1995	6/15/1995	3	3	100.0	0.1	0.6	1.5	1.0
17	6/18/1979	10/13/1987	7	5	71.4	0.8	3.8	6.9	0.7
18	10/13/1987	4/25/1995	2	2	100.0	0.5	2.1	3.7	1.1
19	6/18/1979	10/13/1987	8	6	75.0	0.8	2.9	6.2	0.8
20	4/25/1995	4/25/1995	2	2	100.0	0.4	0.5	0.5	0.2
21	6/18/1979	10/13/1987	7	6	85.7	0.4	2.5	5.7	0.8
22	4/20/1987	4/25/1995	4	4	100.0	0.3	1.1	3.4	1.2
23	6/18/1979	4/20/1987	2	2	100.0	2.3	2.7	3.1	0.2
24	4/25/1995	4/25/1995	2	2	100.0	0.2	0.2	0.2	0.0
25	6/18/1979	8/18/1987	3	3	100.0	1.1	1.7	2.1	0.3
26	4/25/1995	4/25/1995	1	1	100.0	0.1	0.1	0.1	NA
27	6/18/1979	10/13/1987	4	4	100.0	0.3	1.3	2.0	0.6
28	4/20/1987	4/20/1987	1	1	100.0	1.4	1.4	1.4	NA
29	4/20/1987	4/20/1987	1	1	100.0	1.1	1.1	1.1	NA

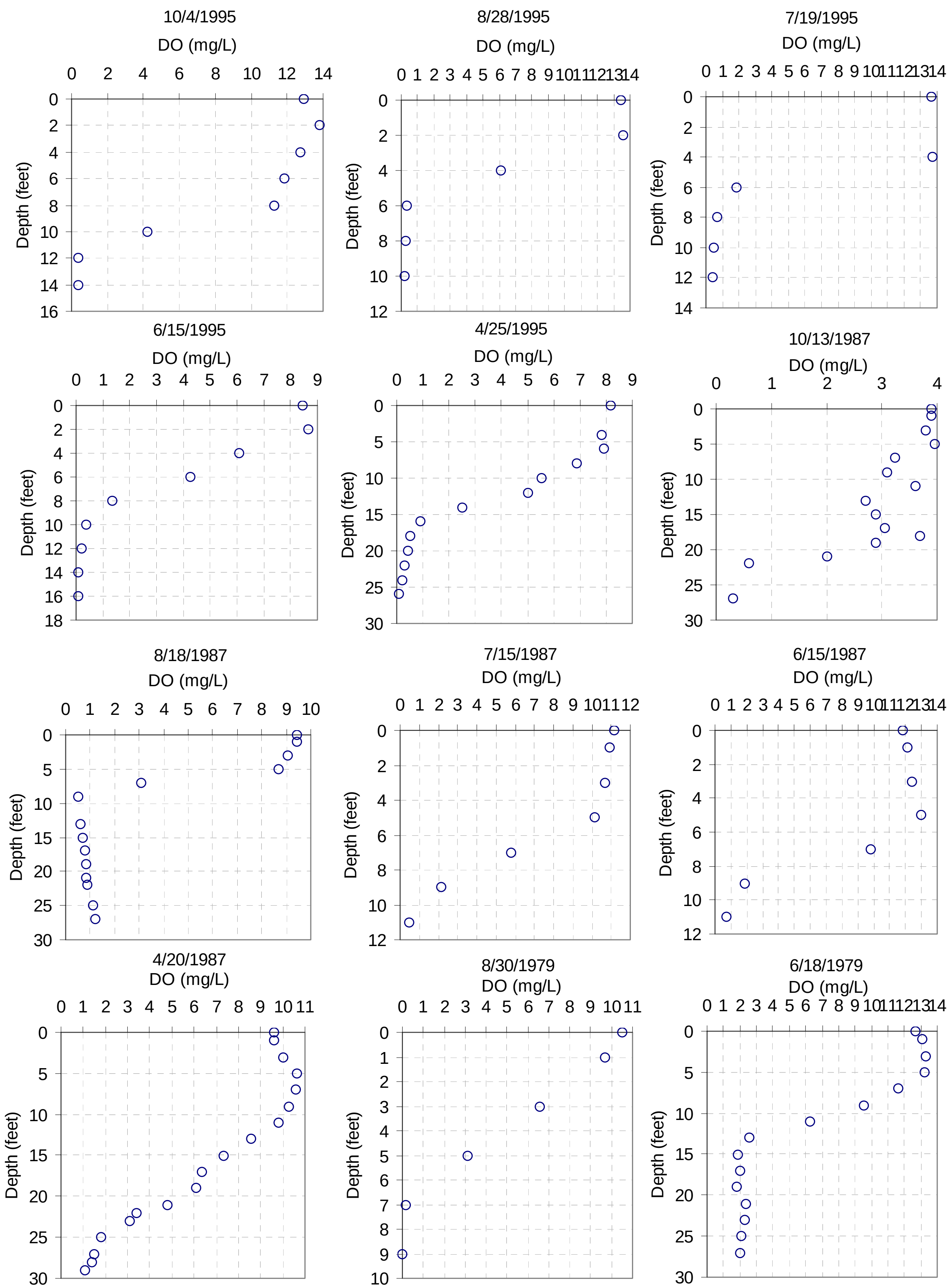

Figure 4-32. Dissolved oxygen concentrations in Walnut Point Lake, 1979 to 1995.

4.5.2.7 Aquatic Plants Native

Walnut Point Lake is listed as being impaired due to native aquatic plants; however, no data on plant types or densities are currently available.

4.5.3 Potential Pollutant Sources

4.5.3.1 Point Sources

A query of the National Pollutant Discharge Elimination System (NPDES) data provided by Illinois EPA revealed no point source dischargers in either the Lake Oakland or Walnut Point Lake watersheds.

4.5.3.2 Nonpoint Sources

Potential nonpoint sources of sediments and nutrients to Lake Oakland and Walnut Point Lake include sheet and rill erosion, lake shoreline erosion, stream channel erosion, fertilizer use, livestock operations, storm water runoff, atmospheric deposition, internal lake recycling, and natural sources. The campground at Walnut Point Lake is a potential source of nutrients because it has a pumpout area which is believed to discharge to a leach field and then the lake (Mike Mounts, Illinois Department of Natural Resources, personal communications, October 26, 2004). Septic systems are not considered a significant source of nutrients to Lake Oakland because the houses around the lake were connected to the city's sewer system approximately fifteen years ago (Dan Stretch, Coles County Health Department, personal communications, October 26, 2004). The relative magnitude the various nonpoint sources has not yet been estimated and will be the focus of Stage 2 and 3 activities.

5 Identification of Data Gaps and Sampling Plan

Several data gaps have been identified in the Lake Oakland and Walnut Point Lake watersheds that will have implications for TMDL development. First, no continuous flow data exist in either watershed. The lack of flow data limits the extent to which loads from tributaries can be estimated. Tributary flows at the mouth of Hog Branch for Lake Oakland and at the mouth of the tributary to Walnut Point Lake will need to be estimated based on observed data at a nearby flow gage. For example, if a tributary drains 10 percent of the area drained by a gage, the tributary flows can estimated to be 10 percent of the flows observed at the gage. A major assumption of this approach is therefore that streamflow in the tributaries is linearly related to the flows measured at the flow gage.

Sufficient water quality are available to develop the necessary TMDLs for Lake Oakland. However, additional water quality sampling is recommended for Walnut Point Lake since no recent data are available. Water quality sampling in Walnut Point Lake should be conducted at the historical Illinois EPA monitoring stations (Figure 4-2). The lake should be sampled two times a month from April through October. This schedule will capture the expected seasonal variation in water quality parameters related to nutrient loading, eutrophication and oxygen-demanding processes. Water samples should be analyzed to determine concentrations of TP, soluble reactive phosphorus, chlorophyll a, nitrate/nitrite nitrogen, total Kjeldahl nitrogen, and zooplankton (Table 8-1). In the field, measurements should be made throughout the lake water column using a Hydrolab to obtain vertical profiles of pH, temperature and dissolved oxygen. Hydrolab profiles should be collected at additional lake stations if reconnaissance shows vertical profiles to vary according to lake location. Secchi depth should also be measured at each lake sampling station. Nutrient samples should be collected at three depths at each station if stratification is observed. Single mid-depth samples should be collected at each station when the lakes are not stratified. Chlorophyll-a should be measured in a composite sample of water collected within the photic zone, from the water surface to twice the Secchi depth.

Surficial (i.e., top 10 cm) sediment samples should also be collected using a dredge at the deepest sampling stations, and should be analyzed for total phosphorus and total organic carbon. These data may be important for estimating the release of phosphorus from the sediment if dissolved oxygen concentrations are depleted near the lake bottom.

Tributary water quality data is also lacking and should be collected at the mouth of the tributary to Walnut Point Lake if access can be obtained. The extent of the tributary sampling is summarized in Table 8-1 and Table 8-2.

Another source of potential sediment and nutrient loadings to Walnut Point Lake is from shoreline erosion. Information should be collected regarding the current potential extent of such erosion, such as length and height of eroding banks. Persons with historical knowledge of the lake should also be contacted to determine the extent to which shoreline erosion has been a significant factor in the past.

Lastly, detailed bathymetric data do not appear to be available for either lake and should be collected during one of the sampling events.

A summary of the sampling plan is provided in Table 8-2. Sampling should be conducted by qualified personnel and might include representatives from Illinois EPA, local government agencies, or private consulting companies. A cost estimate can be made once Illinois EPA has decided on the extent of the sampling effort and the responsible party.

Table 8-1. Identification of parameters to be analyzed in Walnut Point Lake.

Parameter	Water column profiles	Lake samples	Tributary	Lake Sediment
Temperature	x			
pH	x			
Dissolved Oxygen	x			
Secchi disk depth	x			
Total Phosphorus		x	x	x
Soluble Reactive P		x	x	
Nitrate/nitrite N		x		
Total Kjeldahl N		x		
Chlorophyll a		x		
TOC				x

Table 8-2. Summary of sampling for Walnut Point Lake.

	April	May	June	July	Aug	Sept	Oct
Water Column							
Number of sampling events	2	2	2	2	2	2	2
Number of stations in each lake	3	3	3	3	3	3	3
Number of depths	3	3	3	3	3	3	3
Major Tributaries							
Number of sampling events	2	2	2	1	1	1	1

6 Technical Approach

Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Of the pollutants impairing Lake Oakland and Walnut Point Lake, phosphorus, nitrate, and dissolved oxygen are the only parameters with numeric water quality standards for lakes. Illinois EPA believes that addressing these impairments should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. Technical approaches for developing phosphorus, nitrate, and dissolved oxygen TMDLs for Lake Oakland and Walnut Point Lake are presented in this section. Both simple and more advanced technical approaches are presented.

6.1 Simple Approach

A simple approach to TMDL development would be to use a mass balance analysis to assess the extent to which TP and nitrate loadings need to be reduced in the lake. Necessary reductions would essentially be calculated based on a comparison of existing concentrations to the standard. For example, if the existing TP concentration is twice the standard, loads would need to be reduced by 50 percent (plus perhaps a margin of safety). Existing loads from the tributaries would be estimated using the available flow and water quality data and other sources (e.g., shoreline erosion) would need to be estimated separately.

The advantages of the simple approach are that it would be easy to apply and therefore could be done quickly. The disadvantages include the fact that loadings and water quality response are not always linearly related (as is assumed with the approach) and limited information would be available on certain other potential sources of the pollutants (e.g., TP from the lake bottom sediments). Dissolved oxygen concentrations would also not be simulated using the simple approach.

6.2 Detailed Approach

Under a more detailed approach both a watershed and a lake model would be developed and applied for the TMDLs. The Soil Water Assessment Tool (SWAT) model would be used to estimate watershed loadings and conditions in the two watersheds, and the LAKE2K model would be used to evaluate conditions in the two lakes. A lake model is needed to estimate the extent to which lake bottom sediments contribute phosphorus loads and to assess the potential water quality response of reduced loadings. A watershed model is needed for several reasons:

1) Help estimate existing inflows to the lakes (due to the lack of flow data).
2) Help estimate existing sediment and nutrient loads to the lakes by complementing the available water quality data.
3) Provide additional perspective on the relative magnitude of the various sediment and nutrient sources.
4) Assess the potential benefit of various best management practices.

The SWAT model, version 2000A, is proposed for developing the nutrient and dissolved oxygen TMDLs for the Lake Oakland and Walnut Point Lake watersheds. The SWAT model was designed specifically to address loadings from rural, agriculture-dominated watersheds. It is able to predict the impact of land management practices, such as vegetative changes, conservation practices, and groundwater withdrawals, on water quality and sediment. SWAT can analyze large watersheds and river basins (greater than 100 square miles) by subdividing the area into subwatersheds. SWAT simulates hydrology, pesticide and nutrient cycling, erosion and sediment transport.

SWAT is proposed because it:

- models the constituents of concern (TP, nitrate and nitrite, dissolved oxygen, and sediments)
- is designed for primarily agricultural watersheds
- provides daily output to link to a lake model
- provides the ability to directly evaluate management practices (such as altering fertilizer application rates, tillage practices, and erosion control structures)
- has been used elsewhere in Illinois for TMDL development
- can incorporate multiple point sources, such as flow from waste water treatment facilities
- has a greater level of acceptance with the agricultural community because it was developed by the U.S. Department of Agriculture, Agricultural Research Service.

Calibrating the hydrologic component of SWAT presents a challenge since there are no flow gauges located within the basin. However, daily mean stream flow and water quality information is available for watersheds with similar physical characteristics (e.g. land use, soils, topography, agricultural practices). Consequently, a SWAT model can be built for a watershed with similar characteristics, and the calibrated hydrologic and water quality parameters can be used for Lake Oakland and Walnut Point Lake.

The issue of tile drainage will be addressed in the SWAT model by using the model's tile drainage module and making other parameter adjustments to reflect known hydrologic and water quality impacts.

An additional potential source of nutrients and sediment to the two lakes is shoreline erosion. Existing models have limited capability of estimating shoreline erosion and therefore a non-modeling approach will be taken for this project. This non-modeling approach will require obtaining representative data on the extent of shoreline erosion in each lake by taking quantitative measurements and also discussing the issue with knowledgeable individuals.

Establishing the relationship between the in-lake water quality targets and source loading is a critical component in the development of a TMDL. It allows for the evaluation of management options that will achieve the desired outcome in terms of water quality. The link can be established through a range of techniques, from simple mass balance analyses to sophisticated computer modeling. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses with flow and loading conditions. The LAKE2K model is recommended for establishing this linkage for Lake Oakland and Walnut Point Lake.

LAKE2K is a model that is designed to compute seasonal trends of water quality in stratified lakes (Chapra and Martin, 2004). A beta version of the model has recently been released and is supported by the U.S. EPA Office of Research and Development. LAKE2K is implemented within the Microsoft Windows environment and uses Microsoft Excel as the graphical user interface. The model requires information on lake elevation, area, volume, inflows, meteorology, and initial water quality conditions. Daily water quality output is provided for three vertical layers (epilminion, metalimnion, and hypolimnion), including daily predictions of TP, dissolved oxygen, and three phytoplankton groups. LAKE2K also includes a sediment diagenesis model for nutrient release during low dissolved oxygen conditions

LAKE2K is recommended for the Lake Oakland and Walnut Point Lake projects because it is sufficiently detailed to provide the output necessary to compare to numeric water quality standards, and yet is not so complex as to require an extensive amount of data to set up and run. It falls between the less complex BATHTUB model and the more rigorous and data-intensive CE-QUAL-W2 or Environmental Fluid Dynamics Code (EFDC) models. A comparison of the BATHTUB and LAKE2K models is provided in Table 6-1

Table 6-1. Comparison of the BATHTUB and LAKE2K models.

	BATHTUB	LAKE-2K
Model Basis	Empirical	Physically -based (complicated water quality kinetics, no hydrodynamics)
Time Step	Steady State	Dynamic
Vertical Segmentation	Depth Averaged	Vertically segmented into 3 layers (each constituent simulated for each layer, epi, meta, hypo)
Longitudinal Segmentation	Spatially segmented network	Cannot represent spatially segmented network (may not be appropriate if data show spatial variablity in the lake)
Chlorophyll-a Simulation	Can only provide seasonal average predictions; unable to evaluate maximums. Cannot simulate more than one species	Able to simulate 3 types of phytoplankton.
DO Simulation	Meta and Hypolimnetic Depletion Rate	Predicts for each vertical layer
Sediment Diagenisis	No	Yes
Predictive Capability/Scenario Testing	Short-term responses and effects related to structural modifications or responses to variables other than nutrients cannot be evaluated	Represents whole-lake as one box. Model may not be predictive of local impacts due to loadings or in-lake management measures are to be evaluated

Stage Three Report: TMDL Development for Lake Oakland

(Stage Three TMDL Development for Walnut Point Lake is Available in a Separate Report)

7 Source Assessment

This section of the report briefly identifies potential sources of TP. An implementation plan will be prepared that will address these sources in more detail.

7.1 Point Sources

There are no point sources upstream of Lake Oakland.

7.2 Nonpoint Sources

Potential nonpoint sources of TP to Lake Oakland include sheet and rill erosion, lake shoreline erosion, stream channel erosion, fertilizers applied to both crops and lawns, livestock operations, storm water runoff, atmospheric deposition, and natural sources. Septic systems are not considered a significant source of nutrients to Lake Oakland because the houses around the lake were connected to the city's sewer system approximately fifteen years ago (Dan Stretch, Coles County Health Department, personal communications, October 26, 2004). Internal recycling of phosphorus is also not considered a significant source because the lake is so shallow and the observed data do not suggest low oxygen conditions. One of the purposes of the Implementation Plan will be to assess the relative significance of each of the various nonpoint sources of TP and the extent to which they can be controlled.

8 Technical Analysis

Establishing the link between pollutant loads and resulting water quality is one of the most important steps in developing a TMDL. This link can be established through a variety of techniques ranging from simple mass balance analyses to sophisticated computer modeling. The objective of this section of the report is to describe the approach that was used to link the TP loads with the resulting concentrations in Lake Oakland.

8.1 Modeling Approach and Model Selection

BATHTUB was selected for modeling water quality in Lake Oakland. BATHTUB performs steady-state water and phosphorus balance calculations in a spatially segmented hydraulic network, which accounts for pollutant transport and sedimentation. In addition, the BATHUB model automatically incorporates internal phosphorus loadings into its calculations. Eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker, 1987). BATHTUB was determined to be appropriate because it addresses the parameter of concern (phosphorus) and has been used previously for reservoir TMDLs in Illinois and elsewhere. USEPA also recommends the use of BATHTUB for phosphorus TMDLs (USEPA, 1999).

8.2 Model Setup

The BATHTUB model requires the following data to configure and calibrate: tributary flows and concentrations, reservoir bathymetry, in-lake water quality concentrations, and global parameters such as evaporation rates and annual average precipitation. Lake bathymetry data were available from IEPA's sampling data and maps of the lake:

Table 8-3. Bathymetry Data for Lake Oakland

Parameter	Lake Oakland
Surface Area (ha)	11.15
Maximum Depth (m)	2.7
Mean Depth (m)	1.8

Tributary flows and corresponding phosphorus concentrations are not available for Hog Branch upstream of Lake Oakland. Daily stream flow and phosphorus loading into the lake were therefore estimated from a USGS monitoring station where both flow and phosphorus data are available. Suitable surrogate monitoring stations are limited; however, the West Okaw River station (USGS 05591700) was deemed acceptable. The station drains an area of 112 square miles devoted mostly to corn and soy production. Additionally, there are no NPDES permitted dischargers above the monitoring station. Furthermore, the station has water quality data available from 1980 through 1997.

Stream flow for the drainage above Lake Oakland was estimated from observed West Okaw River daily stream flows. Stream flows were calculated as proportional flow at Lake Oakland based upon the ratio of drainage area of the lakes to the West Okaw River drainage area. The ratio of the Lake Oakland drainage area to the West Okaw River drainage area is 21 mi^2 to 112 mi^2 or 0.188. Thus, the West Okaw River daily stream flows were multiplied by 0.188 to estimate daily tributary inflow for Lake Oakland.

A daily stream flow and total phosphorus time series of tributary flows entering Lake Oakland was calculated using the following procedure:

1. Computed percentile-rank flow for daily stream flow at West Okaw River USGS gage 5591700.
2. Divided percentile flows into 5-percent increments (e.g. all flows up to the 5^{th} percentile, all flows from 5.1 to the 10^{th} percentile, etc.)
3. Matched date of observed TP observation with date and mean daily flow from West Okaw River data.
4. Selected all observed West Okaw River TP data within each percentile flow range and calculated a median TP for each range.
5. Assigned calculated median TP concentrations for each flow percentile range to corresponding flow observations observed at West Okaw River.
6. Calculated new flow estimates for Hog Branch through use of unit area weighting method and flow data observed at West Okaw River.

The estimated watershed loading and total annual flow volumes to Lake Oakland are reported in Table 8-4.

Table 8-4. Watershed Loading To Lake Oakland

Year	Average Stream flow (cubic feet per second)	TP (1000 kg)	TP (lbs)
1992	23	4.2	9,260
1993	36	6.2	13,670
1994	19	3.1	6,830
1995	17	2.9	6,390
1996	25	5.7	12,570
1997	13	1.8	3,970
1998	32	6.5	14,330
1999	20	3.4	7,500
2000	13	1.3	2,870
2001	23	3.6	7,940
2002	35	8	17,640
2003	11	1.9	4,190

Atmospheric deposition of total phosphorus for the BATHTUB model was assumed at 0.1 kg/ha/yr and is relatively insignificant compared to the watershed loading.

The BATHTUB model requires input of the fraction of inorganic nutrient load. Inorganic fractions for Lake Oakland were assumed to be 0.3 for phosphorus based on the long-term average of observed data at the most upstream water quality sampling station (RBP-3).

The BATHTUB model was set up to simulate nutrient responses in Lake Oakland for the years 1992 through 2003 to correspond with the available water quality data. Several of the nutrient response routines available within BATHTUB were tested. These included the Canfield and Bachman, Vollenweider, Simple First Order, and Second Order Decay routines. Second order nutrient response models were used to simulate both nitrogen and phosphorus. Nutrient calibration factors were set to 3 for nitrogen and 1 for phosphorus. Calibration factors were adjusted within the default range so that the average ratio of simulated to observed nutrient concentrations was close to 1. A calibration factor of 1 signifies that no adjustment to the model was needed.

Table 8-5 and Figure 8-1 compare the simulated and observed TP concentrations in Lake Oakland. A relatively good match between predicted and observed concentrations was obtained for almost all years given the limitations regarding the loading data.

Table 8-5. Simulated and Observed Nutrient Concentrations in lake Oakland

Year	Simulated TP (mg/L)	Observed TP (mg/L)	Relative Error
1992	0.134	0.133	0.75%
1993	0.252		N/A
1994	0.117		N/A
1995	0.074		N/A
1996	0.221		N/A
1997	0.088		N/A
1998	0.205	0.131	56.49%
1999	0.181		N/A
2000	0.041		N/A
2001	0.146	0.240	-39.17%
2002	0.343		N/A
2003	0.075	0.133	-43.61%
1992 to 2003 Average	0.15641667	0.15925	-6.38%

Notes: Relative error equals (Simulated TP – Observed TP)/(Observed TP); N/A = Not Applicable

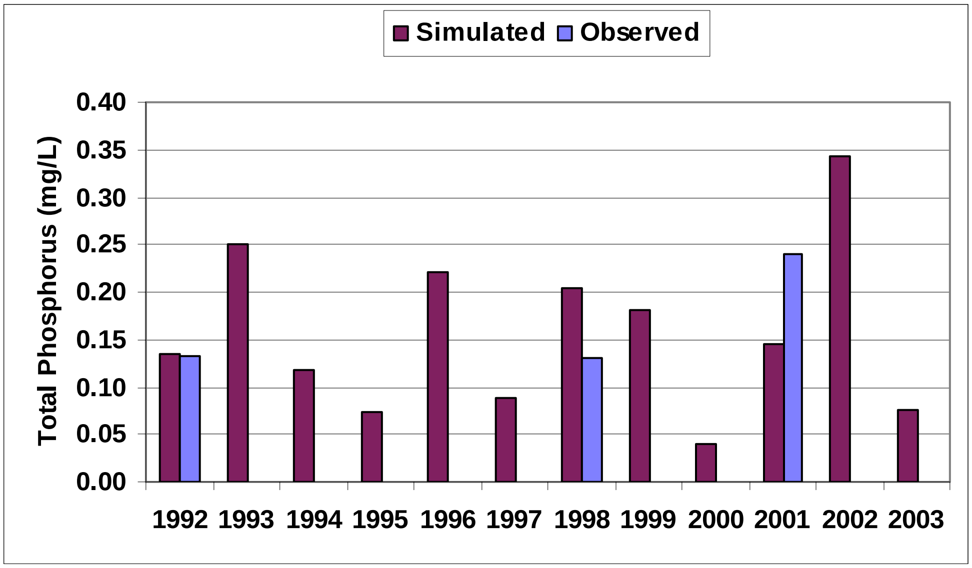

Figure 8-1. Comparison of Simulated and Observed Total Phosphorus Concentrations in Lake Oakland.

9 TMDL

This section of the report presents the various components of the TMDL, as required by the Clean Water Act.

9.1 Loading Capacity

The calibrated BATHTUB model was used to identify the load reductions necessary to achieve a target concentration of 0.05 mg/L total phosphorus. In order to meet the target during all modeled years, a 91 percent reduction of phosphorus load is required. However, no observed TP data are available for the critical modeled year (2002) and the predicted TP concentrations for this year are considerably higher than in any of the observed years. The TMDL is therefore based on the load reduction (80 percent) that is needed to meet the TP target during all years with observed data (i.e., 1992, 1998, and 2001). Table 9-1 shows the predicted annual average total phosphorus concentrations with an 80 percent reduction in loads. The table indicates that during most years an 80 percent reduction in loads will result in lake water quality being significantly less than the water quality standard, thus providing an added margin of safety (see Section 9.4).

Table 9-1. Average Total Phosphorus Concentration in the Lake Oakland with 80 Percent Reduction in Loading.

Year	Lake Oakland TP (mg/L)	Lake Oakland Comparison to WQS
1992	0.030	-40%
1993	0.065	31%
1994	0.026	-47%
1995	0.015	-69%
1996	0.055	10%
1997	0.020	-60%
1998	0.048	-3%
1999	0.046	-7%
2000	0.008	-83%
2001	0.034	-32%
2002	0.100	100%
2003	0.016	-68%
1992 to 2003 Average	0.039	23%

9.2 Allocations

The allocation of loads for the Lake Oakland TMDL is summarized in Table 9-2. The existing load is the average estimated load to Lake Oakland for the period 1992 to 2003. The loading capacity represents the 80 percent reduction from existing loads determined to be necessary from the modeling analysis. The wasteload allocation is zero because there are no point sources in the Lake Oakland watershed. Five percent of the loading capacity is reserved for a margin of safety (as required by the Clean Water Act; see Section 9.4).

Table 9-2. TMDL Summary for Lake Oakland.

Category	Phosphorus (kg/yr)
Existing Load	4,050
Loading Capacity	810
Wasteload Allocation	0
Margin of Safety	41
Load Allocation	769

9.3 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7(c)(1) require that a TMDL be established that addresses seasonal variations normally found in natural systems. For Lake Oakland, the impact of seasonal and other short-term variability in loading is damped out by the fact that it is the long-term average TP concentrations that drives the biotic response. The TMDL can therefore be adequately expressed in terms of an annual average load.

9.4 Margin of Safety

Section 303(d) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7 require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991). A 5 percent explicit margin of safety has been incorporated into the Lake Oakland TMDL by reserving a portion of the loading capacity. An additional implicit margin of safety is associated with the loading capacity resulting in lake water quality being significantly less than the water quality standard in all but the most critical years (see Table 9-1).

10 Implementation

A project Implementation Plan will be prepared that will more fully address likely TP sources and potential implementation activities that can achieve the desired reductions in phosphorus loading. The Implementation Plan will include a range of alternatives along with their expected costs and benefits. IEPA will work with local agencies and stakeholder groups to identify best management practices that will result in meeting water quality goals. A separate public meeting will be held to specifically discuss the Implementation Plan once it is completed.

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Appendix A: Illinois GAP Land Cover Description

Table A-1. Values and class names in the Illinois Gap Analysis Project Land Cover 1999-2000 Arc/Info GRID coverage.

GRID VALUE	LAND COVER CATEGORY
	AGRICULTURAL LAND
11	Corn
12	Soybeans
13	Winter Wheat
14	Other Small Grains and Hay
15	Winter Wheat/Soybeans
16	Other Agriculture
17	Rural Grassland
	FORESTED LAND
22	Dry Upland
23	Dry-Mesic Upland
24	Mesic Upland
25	Partial Canopy/Savannah Upland
26	Coniferous
	URBAN LAND
31	High Density
32	Low/Medium Density (excluding TM Scene 2331)
33	Medium Density (TM Scene 2331)
34	Low Density (TM Scene 2331)
35	Urban Open Space
	WETLAND
41	Shallow Marsh/Wet Meadow
42	Deep Marsh
43	Seasonally/Temporarily Flooded
45	Mesic Floodplain Forest
46	Wet-Mesic Floodplain Forest
47	Wet Floodplain Forest
48	Swamp
49	Shallow Water
	OTHER
51	Surface Water
52	Barren and Exposed Land
53	Clouds
53	Cloud Shadows

Appendix B: Water Quality Data for Lake Oakland and Walnut Point Lakes

Table B-1. Results of nutrient, dissolved oxygen, and suspended solids sampling in Lake Oakland and Walnut Point Lakes.

Waterbody	Station ID	Date	Parameter	Sample Depth (ft)	Value	Units
RBK	RBK-1	6/18/1979	Dissolved Oxygen	0	12.2	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	1	12.6	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	3	12.9	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	7	12.3	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	9	11.2	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	11	7.9	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	13	4.6	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	15	3.4	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	17	3	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	19	2.6	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	21	2.4	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	23	2.3	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	25	2.1	mg/L
RBK	RBK-1	6/18/1979	Dissolved Oxygen	27	2	mg/L
RBK	RBK-1	8/30/1979	Dissolved Oxygen	0	9.3	mg/L
RBK	RBK-1	8/30/1979	Dissolved Oxygen	1	8.7	mg/L
RBK	RBK-1	8/30/1979	Dissolved Oxygen	3	8.3	mg/L
RBK	RBK-1	8/30/1979	Dissolved Oxygen	5	2.4	mg/L
RBK	RBK-1	8/30/1979	Dissolved Oxygen	7	0.2	mg/L
RBK	RBK-1	8/30/1979	Dissolved Oxygen	9	0	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	0	9.6	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	3	9.9	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	5	10.1	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	7	9.7	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	9	9.4	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	11	9.1	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	13	8.2	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	15	7.5	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	17	6.9	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	19	6.2	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	21	5.7	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	23	3.1	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	25	1.8	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	27	1.5	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	28	1.4	mg/L
RBK	RBK-1	4/20/1987	Dissolved Oxygen	29	1.1	mg/L
RBK	RBK-1	6/15/1987	Dissolved Oxygen	0	12.1	mg/L
RBK	RBK-1	6/15/1987	Dissolved Oxygen	1	12.3	mg/L
RBK	RBK-1	6/15/1987	Dissolved Oxygen	3	12.2	mg/L
RBK	RBK-1	6/15/1987	Dissolved Oxygen	5	10.9	mg/L
RBK	RBK-1	6/15/1987	Dissolved Oxygen	9	1.7	mg/L
RBK	RBK-1	6/15/1987	Dissolved Oxygen	11	0.7	mg/L
RBK	RBK-1	7/15/1987	Dissolved Oxygen	0	10.6	mg/L

RBK	RBK-1	7/15/1987	Dissolved Oxygen	1	10.4	mg/L
RBK	RBK-1	7/15/1987	Dissolved Oxygen	3	10	mg/L
RBK	RBK-1	7/15/1987	Dissolved Oxygen	5	9.8	mg/L
RBK	RBK-1	7/15/1987	Dissolved Oxygen	7	5.6	mg/L
RBK	RBK-1	7/15/1987	Dissolved Oxygen	9	2.2	mg/L
RBK	RBK-1	7/15/1987	Dissolved Oxygen	11	0.5	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	0	9.4	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	1	9.5	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	3	8.7	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	5	8.2	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	7	2	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	9	0.5	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	13	0.6	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	15	0.7	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	17	0.8	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	19	0.9	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	21	1	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	25	1.1	mg/L
RBK	RBK-1	8/18/1987	Dissolved Oxygen	27	1.2	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	0	3.2	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	1	3.3	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	7	3.1	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	9	3	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	11	2.9	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	13	2.7	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	15	2.5	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	17	2	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	19	1.8	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	21	0.4	mg/L
RBK	RBK-1	10/13/1987	Dissolved Oxygen	27	0.3	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	0	7.9	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	4	7.7	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	6	7.6	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	8	5.8	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	10	2.3	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	12	1.2	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	14	0.9	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	16	0.6	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	20	0.5	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	22	0.3	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	24	0.2	mg/L
RBK	RBK-1	4/25/1995	Dissolved Oxygen	26	0.1	mg/L
RBK	RBK-1	6/15/1995	Dissolved Oxygen	0	8.5	mg/L
RBK	RBK-1	6/15/1995	Dissolved Oxygen	2	8.8	mg/L
RBK	RBK-1	6/15/1995	Dissolved Oxygen	4	5.3	mg/L
RBK	RBK-1	6/15/1995	Dissolved Oxygen	6	2.9	mg/L
RBK	RBK-1	6/15/1995	Dissolved Oxygen	8	1	mg/L
RBK	RBK-1	6/15/1995	Dissolved Oxygen	10	0.3	mg/L
RBK	RBK-1	6/15/1995	Dissolved Oxygen	12	0.2	mg/L

RBK	RBK-1	6/15/1995	Dissolved Oxygen	14	0.1	mg/L
RBK	RBK-1	7/19/1995	Dissolved Oxygen	0	13.5	mg/L
RBK	RBK-1	7/19/1995	Dissolved Oxygen	2	14.9	mg/L
RBK	RBK-1	7/19/1995	Dissolved Oxygen	4	12.9	mg/L
RBK	RBK-1	7/19/1995	Dissolved Oxygen	6	1	mg/L
RBK	RBK-1	7/19/1995	Dissolved Oxygen	10	0.4	mg/L
RBK	RBK-1	8/28/1995	Dissolved Oxygen	0	12.3	mg/L
RBK	RBK-1	8/28/1995	Dissolved Oxygen	4	3.5	mg/L
RBK	RBK-1	8/28/1995	Dissolved Oxygen	6	0.3	mg/L
RBK	RBK-1	10/4/1995	Dissolved Oxygen	0	14	mg/L
RBK	RBK-1	10/4/1995	Dissolved Oxygen	2	14.7	mg/L
RBK	RBK-1	10/4/1995	Dissolved Oxygen	4	13.1	mg/L
RBK	RBK-1	10/4/1995	Dissolved Oxygen	6	11.9	mg/L
RBK	RBK-1	10/4/1995	Dissolved Oxygen	10	0.5	mg/L
RBK	RBK-1	10/4/1995	Dissolved Oxygen	12	0.3	mg/L
RBK	RBK-1	6/18/1979	Suspended Solids	1	9	mg/L
RBK	RBK-1	6/18/1979	Suspended Solids	27	11	mg/L
RBK	RBK-1	8/30/1979	Suspended Solids	1	6	mg/L
RBK	RBK-1	8/30/1979	Suspended Solids	27	7	mg/L
RBK	RBK-1	4/20/1987	Suspended Solids	1	8	mg/L
RBK	RBK-1	4/20/1987	Suspended Solids	28	10	mg/L
RBK	RBK-1	6/15/1987	Suspended Solids	1	7	mg/L
RBK	RBK-1	6/15/1987	Suspended Solids	29	6	mg/L
RBK	RBK-1	7/15/1987	Suspended Solids	29	12	mg/L
RBK	RBK-1	8/18/1987	Suspended Solids	1	8	mg/L
RBK	RBK-1	8/18/1987	Suspended Solids	26	12	mg/L
RBK	RBK-1	10/13/1987	Suspended Solids	1	2	mg/L
RBK	RBK-1	10/13/1987	Suspended Solids	28	9	mg/L
RBK	RBK-1	4/25/1995	Suspended Solids	1	2	mg/L
RBK	RBK-1	4/25/1995	Suspended Solids	1	4	mg/L
RBK	RBK-1	4/25/1995	Suspended Solids	30	3	mg/L
RBK	RBK-1	6/15/1995	Suspended Solids	1	28	mg/L
RBK	RBK-1	6/15/1995	Suspended Solids	26	32	mg/L
RBK	RBK-1	7/19/1995	Suspended Solids	1	15	mg/L
RBK	RBK-1	7/19/1995	Suspended Solids	25	80	mg/L
RBK	RBK-1	8/28/1995	Suspended Solids	1	10	mg/L
RBK	RBK-1	8/28/1995	Suspended Solids	25	20	mg/L
RBK	RBK-1	10/4/1995	Suspended Solids	1	15	mg/L
RBK	RBK-1	10/4/1995	Suspended Solids	26	20	mg/L
RBK	RBK-1	6/18/1979	Ammonia	1	0.01	mg/L
RBK	RBK-1	6/18/1979	Ammonia	27	0.63	mg/L
RBK	RBK-1	8/30/1979	Ammonia	1	0.12	mg/L
RBK	RBK-1	8/30/1979	Ammonia	27	3.3	mg/L
RBK	RBK-1	4/20/1987	Ammonia	1	0.1	mg/L
RBK	RBK-1	4/20/1987	Ammonia	28	0.64	mg/L
RBK	RBK-1	6/15/1987	Ammonia	1	0.1	mg/L
RBK	RBK-1	7/15/1987	Ammonia	1	0.1	mg/L
RBK	RBK-1	7/15/1987	Ammonia	29	6	mg/L
RBK	RBK-1	8/18/1987	Ammonia	1	0.1	mg/L

RBK	RBK-1	8/18/1987	Ammonia	26	5.2	mg/L
RBK	RBK-1	10/13/1987	Ammonia	1	0.76	mg/L
RBK	RBK-1	10/13/1987	Ammonia	28	11	mg/L
RBK	RBK-1	4/25/1995	Ammonia	1	0.03	mg/L
RBK	RBK-1	4/25/1995	Ammonia	1	0.09	mg/L
RBK	RBK-1	4/25/1995	Ammonia	1	0.27	mg/L
RBK	RBK-1	4/25/1995	Ammonia	30	1.9	mg/L
RBK	RBK-1	6/15/1995	Ammonia	1	0.02	mg/L
RBK	RBK-1	6/15/1995	Ammonia	26	4.4	mg/L
RBK	RBK-1	7/19/1995	Ammonia	1	0.01	mg/L
RBK	RBK-1	7/19/1995	Ammonia	25	17	mg/L
RBK	RBK-1	8/28/1995	Ammonia	1	0.01	mg/L
RBK	RBK-1	8/28/1995	Ammonia	25	9.1	mg/L
RBK	RBK-1	10/4/1995	Ammonia	1	0.07	mg/L
RBK	RBK-1	10/4/1995	Ammonia	26	17	mg/L
RBK	RBK-1	6/18/1979	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-1	6/18/1979	Un-inonized Ammonia	27	0	mg/L
RBK	RBK-1	8/30/1979	Un-inonized Ammonia	1	0.02	mg/L
RBK	RBK-1	8/30/1979	Un-inonized Ammonia	27	0	mg/L
RBK	RBK-1	4/20/1987	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-1	4/20/1987	Un-inonized Ammonia	28	0	mg/L
RBK	RBK-1	6/15/1987	Un-inonized Ammonia	1	0.01	mg/L
RBK	RBK-1	6/15/1987	Un-inonized Ammonia	29	0	mg/L
RBK	RBK-1	7/15/1987	Un-inonized Ammonia	1	0.02	mg/L
RBK	RBK-1	7/15/1987	Un-inonized Ammonia	29	0	mg/L
RBK	RBK-1	8/18/1987	Un-inonized Ammonia	1	0.03	mg/L
RBK	RBK-1	10/13/1987	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-1	10/13/1987	Un-inonized Ammonia	28	0	mg/L
RBK	RBK-1	4/25/1995	Un-inonized Ammonia	30	0.01	mg/L
RBK	RBK-1	10/4/1995	Un-inonized Ammonia	26	0.02	mg/L
RBK	RBK-1	6/18/1979	TKN	1	0.6	mg/L
RBK	RBK-1	6/18/1979	TKN	27	1.2	mg/L
RBK	RBK-1	8/30/1979	TKN	1	1.6	mg/L
RBK	RBK-1	8/30/1979	TKN	27	4	mg/L
RBK	RBK-1	4/20/1987	TKN	1	0.8	mg/L
RBK	RBK-1	4/20/1987	TKN	28	1.6	mg/L
RBK	RBK-1	6/15/1987	TKN	1	1.4	mg/L
RBK	RBK-1	6/15/1987	TKN	29	0.9	mg/L
RBK	RBK-1	7/15/1987	TKN	1	1.5	mg/L
RBK	RBK-1	7/15/1987	TKN	29	7	mg/L
RBK	RBK-1	8/18/1987	TKN	1	1.5	mg/L
RBK	RBK-1	8/18/1987	TKN	26	6.6	mg/L
RBK	RBK-1	10/13/1987	TKN	1	2	mg/L
RBK	RBK-1	10/13/1987	TKN	28	14	mg/L
RBK	RBK-1	4/25/1995	TKN	1	0.1	mg/L
RBK	RBK-1	4/25/1995	TKN	1	0.21	mg/L
RBK	RBK-1	4/25/1995	TKN	1	0.71	mg/L
RBK	RBK-1	4/25/1995	TKN	30	2.1	mg/L
RBK	RBK-1	6/15/1995	TKN	1	2.3	mg/L

RBK	RBK-1	6/15/1995	TKN	26	6.2	mg/L
RBK	RBK-1	7/19/1995	TKN	1	0.82	mg/L
RBK	RBK-1	7/19/1995	TKN	25	11.4	mg/L
RBK	RBK-1	8/28/1995	TKN	1	1.8	mg/L
RBK	RBK-1	8/28/1995	TKN	25	1.6	mg/L
RBK	RBK-1	10/4/1995	TKN	1	0.98	mg/L
RBK	RBK-1	10/4/1995	TKN	26	13.8	mg/L
RBK	RBK-1	6/18/1979	Nitrate + Nitrite	1	1.9	mg/L
RBK	RBK-1	8/30/1979	Nitrate + Nitrite	1	0.08	mg/L
RBK	RBK-1	8/30/1979	Nitrate + Nitrite	27	0.01	mg/L
RBK	RBK-1	4/20/1987	Nitrate + Nitrite	1	0.46	mg/L
RBK	RBK-1	4/20/1987	Nitrate + Nitrite	28	0.37	mg/L
RBK	RBK-1	6/15/1987	Nitrate + Nitrite	1	0.04	mg/L
RBK	RBK-1	6/15/1987	Nitrate + Nitrite	29	0.03	mg/L
RBK	RBK-1	7/15/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-1	8/18/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-1	10/13/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-1	4/25/1995	Nitrate + Nitrite	1	0.77	mg/L
RBK	RBK-1	4/25/1995	Nitrate + Nitrite	1	5.2	mg/L
RBK	RBK-1	4/25/1995	Nitrate + Nitrite	1	8	mg/L
RBK	RBK-1	4/25/1995	Nitrate + Nitrite	30	0.01	mg/L
RBK	RBK-1	6/15/1995	Nitrate + Nitrite	1	0.9	mg/L
RBK	RBK-1	6/15/1995	Nitrate + Nitrite	26	0.01	mg/L
RBK	RBK-1	7/19/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-1	8/28/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-1	8/28/1995	Nitrate + Nitrite	25	0.02	mg/L
RBK	RBK-1	10/4/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-1	6/18/1979	Total Phosphorus	1	0.04	mg/L
RBK	RBK-1	8/30/1979	Total Phosphorus	1	0.06	mg/L
RBK	RBK-1	8/30/1979	Total Phosphorus	27	0.3	mg/L
RBK	RBK-1	4/20/1987	Total Phosphorus	1	0.04	mg/L
RBK	RBK-1	4/20/1987	Total Phosphorus	28	0.2	mg/L
RBK	RBK-1	6/15/1987	Total Phosphorus	1	0.02	mg/L
RBK	RBK-1	6/15/1987	Total Phosphorus	29	0.04	mg/L
RBK	RBK-1	7/15/1987	Total Phosphorus	1	0.06	mg/L
RBK	RBK-1	7/15/1987	Total Phosphorus	29	1.12	mg/L
RBK	RBK-1	8/18/1987	Total Phosphorus	1	0.07	mg/L
RBK	RBK-1	8/18/1987	Total Phosphorus	26	1.02	mg/L
RBK	RBK-1	10/13/1987	Total Phosphorus	1	0.16	mg/L
RBK	RBK-1	10/13/1987	Total Phosphorus	28	1.77	mg/L
RBK	RBK-1	4/25/1995	Total Phosphorus	1	0.02	mg/L
RBK	RBK-1	4/25/1995	Total Phosphorus	1	0.03	mg/L
RBK	RBK-1	4/25/1995	Total Phosphorus	1	0.06	mg/L
RBK	RBK-1	4/25/1995	Total Phosphorus	30	0.26	mg/L
RBK	RBK-1	6/15/1995	Total Phosphorus	1	0.08	mg/L
RBK	RBK-1	6/15/1995	Total Phosphorus	26	0.96	mg/L
RBK	RBK-1	7/19/1995	Total Phosphorus	1	0.06	mg/L
RBK	RBK-1	7/19/1995	Total Phosphorus	25	2.88	mg/L
RBK	RBK-1	8/28/1995	Total Phosphorus	1	0.09	mg/L

RBK	RBK-1	8/28/1995	Total Phosphorus	25	1.48	mg/L
RBK	RBK-1	10/4/1995	Total Phosphorus	1	0.09	mg/L
RBK	RBK-1	10/4/1995	Total Phosphorus	26	2.38	mg/L
RBK	RBK-1	6/18/1979	Dissolved Phosphorus	27	0.01	mg/L
RBK	RBK-1	8/30/1979	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-1	8/30/1979	Dissolved Phosphorus	27	0.26	mg/L
RBK	RBK-1	4/20/1987	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-1	4/20/1987	Dissolved Phosphorus	28	0.18	mg/L
RBK	RBK-1	6/15/1987	Dissolved Phosphorus	1	0	mg/L
RBK	RBK-1	6/15/1987	Dissolved Phosphorus	29	0.01	mg/L
RBK	RBK-1	7/15/1987	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-1	7/15/1987	Dissolved Phosphorus	29	0.98	mg/L
RBK	RBK-1	8/18/1987	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-1	8/18/1987	Dissolved Phosphorus	26	0.91	mg/L
RBK	RBK-1	10/13/1987	Dissolved Phosphorus	1	0.12	mg/L
RBK	RBK-1	10/13/1987	Dissolved Phosphorus	28	1.65	mg/L
RBK	RBK-1	4/25/1995	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-1	4/25/1995	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-1	4/25/1995	Dissolved Phosphorus	1	0.04	mg/L
RBK	RBK-1	4/25/1995	Dissolved Phosphorus	30	0.21	mg/L
RBK	RBK-1	6/15/1995	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-1	6/15/1995	Dissolved Phosphorus	26	0.85	mg/L
RBK	RBK-1	7/19/1995	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-1	7/19/1995	Dissolved Phosphorus	25	2.45	mg/L
RBK	RBK-1	8/28/1995	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-1	8/28/1995	Dissolved Phosphorus	25	1.44	mg/L
RBK	RBK-1	10/4/1995	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-1	10/4/1995	Dissolved Phosphorus	26	2.12	mg/L
RBK	RBK-1	6/18/1979	Fecal Coliform	1	2	#/100 mL
RBK	RBK-1	8/30/1979	Fecal Coliform	1	18	#/100 mL
RBK	RBK-1	6/18/1979	Chlorophyll-a	4	28	µg/L
RBK	RBK-1	8/30/1979	Chlorophyll-a	6	38	µg/L
RBK	RBK-1	4/20/1987	Chlorophyll-a	30	6.61	µg/L
RBK	RBK-1	6/15/1987	Chlorophyll-a	8	22.3	µg/L
RBK	RBK-1	7/15/1987	Chlorophyll-a	5	41.37	µg/L
RBK	RBK-1	8/18/1987	Chlorophyll-a	4	66.16	µg/L
RBK	RBK-1	10/13/1987	Chlorophyll-a	13	17.24	µg/L
RBK	RBK-1	4/25/1995	Chlorophyll-a	30	5.34	µg/L
RBK	RBK-1	6/15/1995	Chlorophyll-a	2	301.92	µg/L
RBK	RBK-1	7/19/1995	Chlorophyll-a	3	68.89	µg/L
RBK	RBK-1	8/28/1995	Chlorophyll-a	3	88.11	µg/L
RBK	RBK-1	10/4/1995	Chlorophyll-a	4	110.01	µg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	0	12.6	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	1	13.1	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	3	13.3	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	5	13.2	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	7	12	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	9	10.6	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	11	7.8	mg/L

RBK	RBK-2	6/18/1979	Dissolved Oxygen	13	1.9	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	15	1.3	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	17	1.1	mg/L
RBK	RBK-2	6/18/1979	Dissolved Oxygen	19	1	mg/L
RBK	RBK-2	8/30/1979	Dissolved Oxygen	0	10.8	mg/L
RBK	RBK-2	8/30/1979	Dissolved Oxygen	1	8.5	mg/L
RBK	RBK-2	8/30/1979	Dissolved Oxygen	3	5	mg/L
RBK	RBK-2	8/30/1979	Dissolved Oxygen	5	3.6	mg/L
RBK	RBK-2	8/30/1979	Dissolved Oxygen	7	0.1	mg/L
RBK	RBK-2	8/30/1979	Dissolved Oxygen	9	0	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	0	9.5	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	1	9.6	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	3	10.1	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	5	11	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	7	10.6	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	9	10.3	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	13	8.5	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	15	7.5	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	17	6.9	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	19	6	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	21	3.9	mg/L
RBK	RBK-2	4/20/1987	Dissolved Oxygen	22	3.4	mg/L
RBK	RBK-2	6/15/1987	Dissolved Oxygen	0	11.6	mg/L
RBK	RBK-2	6/15/1987	Dissolved Oxygen	1	11.7	mg/L
RBK	RBK-2	6/15/1987	Dissolved Oxygen	3	12.3	mg/L
RBK	RBK-2	6/15/1987	Dissolved Oxygen	5	13.8	mg/L
RBK	RBK-2	6/15/1987	Dissolved Oxygen	7	8.6	mg/L
RBK	RBK-2	6/15/1987	Dissolved Oxygen	9	2	mg/L
RBK	RBK-2	6/15/1987	Dissolved Oxygen	11	0.7	mg/L
RBK	RBK-2	7/15/1987	Dissolved Oxygen	0	11.1	mg/L
RBK	RBK-2	7/15/1987	Dissolved Oxygen	3	11	mg/L
RBK	RBK-2	7/15/1987	Dissolved Oxygen	5	10.6	mg/L
RBK	RBK-2	7/15/1987	Dissolved Oxygen	7	3.4	mg/L
RBK	RBK-2	7/15/1987	Dissolved Oxygen	9	1.5	mg/L
RBK	RBK-2	7/15/1987	Dissolved Oxygen	11	0.5	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	0	9.5	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	1	9.4	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	3	9.3	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	5	8.8	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	7	2.2	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	9	0.5	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	13	0.6	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	19	0.8	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	21	0.7	mg/L
RBK	RBK-2	8/18/1987	Dissolved Oxygen	22	0.9	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	0	3.9	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	3	3.8	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	5	3.5	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	7	3.4	mg/L

RBK	RBK-2	10/13/1987	Dissolved Oxygen	9	3.2	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	11	3.1	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	15	3.3	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	19	4	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	21	3.6	mg/L
RBK	RBK-2	10/13/1987	Dissolved Oxygen	22	0.6	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	0	8.3	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	4	8	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	6	7.9	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	8	7.2	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	10	6.8	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	12	6.5	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	14	1.7	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	16	0.6	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	18	0.5	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	20	0.4	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	22	0.3	mg/L
RBK	RBK-2	4/25/1995	Dissolved Oxygen	24	0.2	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	0	8.4	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	2	8.5	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	4	6.4	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	6	4.8	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	8	1.4	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	10	0.5	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	12	0.2	mg/L
RBK	RBK-2	6/15/1995	Dissolved Oxygen	16	0.1	mg/L
RBK	RBK-2	7/19/1995	Dissolved Oxygen	0	13.4	mg/L
RBK	RBK-2	7/19/1995	Dissolved Oxygen	2	15.9	mg/L
RBK	RBK-2	7/19/1995	Dissolved Oxygen	4	13.9	mg/L
RBK	RBK-2	7/19/1995	Dissolved Oxygen	6	1.1	mg/L
RBK	RBK-2	7/19/1995	Dissolved Oxygen	8	0.9	mg/L
RBK	RBK-2	7/19/1995	Dissolved Oxygen	10	0.5	mg/L
RBK	RBK-2	8/28/1995	Dissolved Oxygen	0	14.2	mg/L
RBK	RBK-2	8/28/1995	Dissolved Oxygen	2	13.5	mg/L
RBK	RBK-2	8/28/1995	Dissolved Oxygen	4	5.8	mg/L
RBK	RBK-2	8/28/1995	Dissolved Oxygen	6	0.4	mg/L
RBK	RBK-2	8/28/1995	Dissolved Oxygen	8	0.3	mg/L
RBK	RBK-2	8/28/1995	Dissolved Oxygen	10	0.2	mg/L
RBK	RBK-2	10/4/1995	Dissolved Oxygen	0	12.6	mg/L
RBK	RBK-2	10/4/1995	Dissolved Oxygen	2	12.9	mg/L
RBK	RBK-2	10/4/1995	Dissolved Oxygen	4	13	mg/L
RBK	RBK-2	10/4/1995	Dissolved Oxygen	6	12	mg/L
RBK	RBK-2	10/4/1995	Dissolved Oxygen	10	9.3	mg/L
RBK	RBK-2	10/4/1995	Dissolved Oxygen	12	0.5	mg/L
RBK	RBK-2	10/4/1995	Dissolved Oxygen	14	0.4	mg/L
RBK	RBK-2	6/18/1979	Suspended Solids	1	10	mg/L
RBK	RBK-2	6/18/1979	Suspended Solids	20	7	mg/L
RBK	RBK-2	8/30/1979	Suspended Solids	1	10	mg/L
RBK	RBK-2	8/30/1979	Suspended Solids	20	6	mg/L

RBK	RBK-2	4/20/1987	Suspended Solids	1	1	mg/L
RBK	RBK-2	6/15/1987	Suspended Solids	1	5	mg/L
RBK	RBK-2	7/15/1987	Suspended Solids	1	4	mg/L
RBK	RBK-2	8/11/1987	Suspended Solids	1	7	mg/L
RBK	RBK-2	10/13/1987	Suspended Solids	1	3	mg/L
RBK	RBK-2	4/25/1995	Suspended Solids	1	1	mg/L
RBK	RBK-2	4/25/1995	Suspended Solids	22	8	mg/L
RBK	RBK-2	6/15/1995	Suspended Solids	1	34	mg/L
RBK	RBK-2	7/19/1995	Suspended Solids	1	11	mg/L
RBK	RBK-2	8/28/1995	Suspended Solids	1	40	mg/L
RBK	RBK-2	10/4/1995	Suspended Solids	1	13	mg/L
RBK	RBK-2	6/18/1979	Ammonia	1	0.02	mg/L
RBK	RBK-2	6/18/1979	Ammonia	20	0.44	mg/L
RBK	RBK-2	8/30/1979	Ammonia	1	0.07	mg/L
RBK	RBK-2	8/30/1979	Ammonia	20	1.8	mg/L
RBK	RBK-2	4/20/1987	Ammonia	1	0.1	mg/L
RBK	RBK-2	6/15/1987	Ammonia	1	0.1	mg/L
RBK	RBK-2	7/15/1987	Ammonia	1	0.1	mg/L
RBK	RBK-2	8/11/1987	Ammonia	1	0.1	mg/L
RBK	RBK-2	10/13/1987	Ammonia	1	0.76	mg/L
RBK	RBK-2	4/25/1995	Ammonia	1	0.28	mg/L
RBK	RBK-2	4/25/1995	Ammonia	22	1.7	mg/L
RBK	RBK-2	6/15/1995	Ammonia	1	0.06	mg/L
RBK	RBK-2	7/19/1995	Ammonia	1	0.01	mg/L
RBK	RBK-2	8/28/1995	Ammonia	1	0.03	mg/L
RBK	RBK-2	10/4/1995	Ammonia	1	0.09	mg/L
RBK	RBK-2	6/18/1979	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-2	6/18/1979	Un-inonized Ammonia	20	0	mg/L
RBK	RBK-2	8/30/1979	Un-inonized Ammonia	1	0.01	mg/L
RBK	RBK-2	8/30/1979	Un-inonized Ammonia	20	0	mg/L
RBK	RBK-2	4/20/1987	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-2	6/15/1987	Un-inonized Ammonia	1	0.02	mg/L
RBK	RBK-2	7/15/1987	Un-inonized Ammonia	1	0.02	mg/L
RBK	RBK-2	10/13/1987	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-2	4/25/1995	Un-inonized Ammonia	22	0.01	mg/L
RBK	RBK-2	6/18/1979	TKN	1	0.8	mg/L
RBK	RBK-2	6/18/1979	TKN	20	1.1	mg/L
RBK	RBK-2	8/30/1979	TKN	1	1.7	mg/L
RBK	RBK-2	8/30/1979	TKN	20	2.3	mg/L
RBK	RBK-2	4/20/1987	TKN	1	0.8	mg/L
RBK	RBK-2	6/15/1987	TKN	1	0.9	mg/L
RBK	RBK-2	7/15/1987	TKN	1	1.8	mg/L
RBK	RBK-2	8/11/1987	TKN	1	1.6	mg/L
RBK	RBK-2	10/13/1987	TKN	1	2.2	mg/L
RBK	RBK-2	4/25/1995	TKN	1	0.59	mg/L
RBK	RBK-2	4/25/1995	TKN	22	1.8	mg/L
RBK	RBK-2	6/15/1995	TKN	1	3	mg/L
RBK	RBK-2	7/19/1995	TKN	1	0.78	mg/L
RBK	RBK-2	8/28/1995	TKN	1	1.9	mg/L

RBK	RBK-2	10/4/1995	TKN	1	1.1	mg/L
RBK	RBK-2	6/18/1979	Nitrate + Nitrite	1	1.9	mg/L
RBK	RBK-2	6/18/1979	Nitrate + Nitrite	20	2.3	mg/L
RBK	RBK-2	8/30/1979	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-2	8/30/1979	Nitrate + Nitrite	20	0.01	mg/L
RBK	RBK-2	4/20/1987	Nitrate + Nitrite	1	0.4	mg/L
RBK	RBK-2	6/15/1987	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-2	7/15/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-2	8/11/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-2	10/13/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-2	4/25/1995	Nitrate + Nitrite	1	0.87	mg/L
RBK	RBK-2	4/25/1995	Nitrate + Nitrite	22	0.01	mg/L
RBK	RBK-2	6/15/1995	Nitrate + Nitrite	1	0.92	mg/L
RBK	RBK-2	7/19/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-2	8/28/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-2	10/4/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-2	6/18/1979	Total Phosphorus	1	0.03	mg/L
RBK	RBK-2	6/18/1979	Total Phosphorus	20	0.04	mg/L
RBK	RBK-2	8/30/1979	Total Phosphorus	1	0.09	mg/L
RBK	RBK-2	8/30/1979	Total Phosphorus	20	0.22	mg/L
RBK	RBK-2	4/20/1987	Total Phosphorus	1	0.05	mg/L
RBK	RBK-2	6/15/1987	Total Phosphorus	1	0.03	mg/L
RBK	RBK-2	7/15/1987	Total Phosphorus	1	0.08	mg/L
RBK	RBK-2	8/11/1987	Total Phosphorus	1	0.08	mg/L
RBK	RBK-2	10/13/1987	Total Phosphorus	1	0.17	mg/L
RBK	RBK-2	4/25/1995	Total Phosphorus	1	0.06	mg/L
RBK	RBK-2	4/25/1995	Total Phosphorus	22	0.29	mg/L
RBK	RBK-2	6/15/1995	Total Phosphorus	1	0.07	mg/L
RBK	RBK-2	7/19/1995	Total Phosphorus	1	0.07	mg/L
RBK	RBK-2	8/28/1995	Total Phosphorus	1	0.1	mg/L
RBK	RBK-2	10/4/1995	Total Phosphorus	1	0.1	mg/L
RBK	RBK-2	6/18/1979	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-2	8/30/1979	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-2	8/30/1979	Dissolved Phosphorus	20	0.2	mg/L
RBK	RBK-2	4/20/1987	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-2	6/15/1987	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-2	7/15/1987	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-2	8/11/1987	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-2	10/13/1987	Dissolved Phosphorus	1	0.13	mg/L
RBK	RBK-2	4/25/1995	Dissolved Phosphorus	1	0.05	mg/L
RBK	RBK-2	4/25/1995	Dissolved Phosphorus	22	0.25	mg/L
RBK	RBK-2	6/15/1995	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-2	7/19/1995	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-2	8/28/1995	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-2	10/4/1995	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-2	6/18/1979	Fecal Coliform	1	2	#/100 mL
RBK	RBK-2	8/30/1979	Fecal Coliform	1	4	#/100 mL
RBK	RBK-2	6/18/1979	Chlorophyll-a	4	29.5	µg/L
RBK	RBK-2	8/30/1979	Chlorophyll-a	5	53	µg/L

RBK	RBK-2	4/20/1987	Chlorophyll-a	22	23.58	µg/L
RBK	RBK-2	6/15/1987	Chlorophyll-a	8	26.99	µg/L
RBK	RBK-2	7/15/1987	Chlorophyll-a	5	49	µg/L
RBK	RBK-2	8/18/1987	Chlorophyll-a	4	65.09	µg/L
RBK	RBK-2	10/13/1987	Chlorophyll-a	11	29.36	µg/L
RBK	RBK-2	4/25/1995	Chlorophyll-a	22	4.01	µg/L
RBK	RBK-2	6/15/1995	Chlorophyll-a	2	187.97	µg/L
RBK	RBK-2	7/19/1995	Chlorophyll-a	3	66.75	µg/L
RBK	RBK-2	8/28/1995	Chlorophyll-a	3	107.69	µg/L
RBK	RBK-2	10/4/1995	Chlorophyll-a	5	105.28	µg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	0	13.3	mg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	1	13.6	mg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	3	13.8	mg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	7	10.5	mg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	9	6.9	mg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	11	3.2	mg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	13	1.2	mg/L
RBK	RBK-3	6/18/1979	Dissolved Oxygen	15	1	mg/L
RBK	RBK-3	8/30/1979	Dissolved Oxygen	0	11.4	mg/L
RBK	RBK-3	8/30/1979	Dissolved Oxygen	1	11.9	mg/L
RBK	RBK-3	8/30/1979	Dissolved Oxygen	3	6.4	mg/L
RBK	RBK-3	8/30/1979	Dissolved Oxygen	5	3.4	mg/L
RBK	RBK-3	8/30/1979	Dissolved Oxygen	7	0.2	mg/L
RBK	RBK-3	8/30/1979	Dissolved Oxygen	9	0	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	0	9.7	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	3	10	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	5	10.8	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	7	11.4	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	9	11.1	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	11	10.5	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	13	9	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	15	7	mg/L
RBK	RBK-3	4/20/1987	Dissolved Oxygen	17	5.2	mg/L
RBK	RBK-3	6/15/1987	Dissolved Oxygen	0	11.8	mg/L
RBK	RBK-3	6/15/1987	Dissolved Oxygen	1	12.4	mg/L
RBK	RBK-3	6/15/1987	Dissolved Oxygen	3	12.8	mg/L
RBK	RBK-3	6/15/1987	Dissolved Oxygen	5	14.3	mg/L
RBK	RBK-3	6/15/1987	Dissolved Oxygen	7	11	mg/L
RBK	RBK-3	6/15/1987	Dissolved Oxygen	9	1.9	mg/L
RBK	RBK-3	6/15/1987	Dissolved Oxygen	11	0.7	mg/L
RBK	RBK-3	7/15/1987	Dissolved Oxygen	0	11.8	mg/L
RBK	RBK-3	7/15/1987	Dissolved Oxygen	1	11.5	mg/L
RBK	RBK-3	7/15/1987	Dissolved Oxygen	3	11.1	mg/L
RBK	RBK-3	7/15/1987	Dissolved Oxygen	5	10.1	mg/L
RBK	RBK-3	7/15/1987	Dissolved Oxygen	7	8.3	mg/L
RBK	RBK-3	7/15/1987	Dissolved Oxygen	9	2.7	mg/L
RBK	RBK-3	7/15/1987	Dissolved Oxygen	11	0.5	mg/L
RBK	RBK-3	8/18/1987	Dissolved Oxygen	0	9.4	mg/L
RBK	RBK-3	8/18/1987	Dissolved Oxygen	3	9.2	mg/L

RBK	RBK-3	8/18/1987	Dissolved Oxygen	5	9.1	mg/L
RBK	RBK-3	8/18/1987	Dissolved Oxygen	7	5	mg/L
RBK	RBK-3	8/18/1987	Dissolved Oxygen	9	0.5	mg/L
RBK	RBK-3	8/18/1987	Dissolved Oxygen	13	0.6	mg/L
RBK	RBK-3	10/13/1987	Dissolved Oxygen	0	4.6	mg/L
RBK	RBK-3	10/13/1987	Dissolved Oxygen	1	4.5	mg/L
RBK	RBK-3	10/13/1987	Dissolved Oxygen	5	4.4	mg/L
RBK	RBK-3	10/13/1987	Dissolved Oxygen	11	4.8	mg/L
RBK	RBK-3	10/13/1987	Dissolved Oxygen	17	4.1	mg/L
RBK	RBK-3	10/13/1987	Dissolved Oxygen	18	3.7	mg/L
RBK	RBK-3	4/25/1995	Dissolved Oxygen	0	8.3	mg/L
RBK	RBK-3	4/25/1995	Dissolved Oxygen	6	8.2	mg/L
RBK	RBK-3	4/25/1995	Dissolved Oxygen	8	7.6	mg/L
RBK	RBK-3	4/25/1995	Dissolved Oxygen	10	7.5	mg/L
RBK	RBK-3	4/25/1995	Dissolved Oxygen	12	7.3	mg/L
RBK	RBK-3	4/25/1995	Dissolved Oxygen	14	5	mg/L
RBK	RBK-3	4/25/1995	Dissolved Oxygen	16	1.5	mg/L
RBK	RBK-3	6/15/1995	Dissolved Oxygen	0	8.5	mg/L
RBK	RBK-3	6/15/1995	Dissolved Oxygen	4	6.5	mg/L
RBK	RBK-3	6/15/1995	Dissolved Oxygen	6	5.1	mg/L
RBK	RBK-3	6/15/1995	Dissolved Oxygen	8	1.7	mg/L
RBK	RBK-3	6/15/1995	Dissolved Oxygen	10	0.3	mg/L
RBK	RBK-3	6/15/1995	Dissolved Oxygen	12	0.2	mg/L
RBK	RBK-3	6/15/1995	Dissolved Oxygen	16	0.1	mg/L
RBK	RBK-3	7/19/1995	Dissolved Oxygen	0	14	mg/L
RBK	RBK-3	7/19/1995	Dissolved Oxygen	2	16.6	mg/L
RBK	RBK-3	7/19/1995	Dissolved Oxygen	4	14.3	mg/L
RBK	RBK-3	7/19/1995	Dissolved Oxygen	6	3.4	mg/L
RBK	RBK-3	7/19/1995	Dissolved Oxygen	8	0.5	mg/L
RBK	RBK-3	7/19/1995	Dissolved Oxygen	12	0.4	mg/L
RBK	RBK-3	8/28/1995	Dissolved Oxygen	0	13.9	mg/L
RBK	RBK-3	8/28/1995	Dissolved Oxygen	2	13.7	mg/L
RBK	RBK-3	8/28/1995	Dissolved Oxygen	4	9.1	mg/L
RBK	RBK-3	8/28/1995	Dissolved Oxygen	6	0.4	mg/L
RBK	RBK-3	8/28/1995	Dissolved Oxygen	8	0.3	mg/L
RBK	RBK-3	10/4/1995	Dissolved Oxygen	0	12.2	mg/L
RBK	RBK-3	10/4/1995	Dissolved Oxygen	4	12.1	mg/L
RBK	RBK-3	10/4/1995	Dissolved Oxygen	6	11.6	mg/L
RBK	RBK-3	10/4/1995	Dissolved Oxygen	8	11.3	mg/L
RBK	RBK-3	10/4/1995	Dissolved Oxygen	10	2.9	mg/L
RBK	RBK-3	10/4/1995	Dissolved Oxygen	12	0.4	mg/L
RBK	RBK-3	6/18/1979	Suspended Solids	1	8	mg/L
RBK	RBK-3	6/18/1979	Suspended Solids	13	6	mg/L
RBK	RBK-3	8/30/1979	Suspended Solids	1	9	mg/L
RBK	RBK-3	8/30/1979	Suspended Solids	16	11	mg/L
RBK	RBK-3	4/20/1987	Suspended Solids	1	1	mg/L
RBK	RBK-3	6/15/1987	Suspended Solids	1	6	mg/L
RBK	RBK-3	7/15/1987	Suspended Solids	1	5	mg/L
RBK	RBK-3	8/18/1987	Suspended Solids	1	7	mg/L

RBK	RBK-3	10/13/1987	Suspended Solids	1	4	mg/L
RBK	RBK-3	4/25/1995	Suspended Solids	1	1	mg/L
RBK	RBK-3	4/25/1995	Suspended Solids	14	11	mg/L
RBK	RBK-3	6/15/1995	Suspended Solids	1	18	mg/L
RBK	RBK-3	7/19/1995	Suspended Solids	1	9	mg/L
RBK	RBK-3	8/28/1995	Suspended Solids	1	34	mg/L
RBK	RBK-3	10/4/1995	Suspended Solids	1	12	mg/L
RBK	RBK-3	6/18/1979	Ammonia	1	0.02	mg/L
RBK	RBK-3	6/18/1979	Ammonia	13	0.05	mg/L
RBK	RBK-3	8/30/1979	Ammonia	1	0.06	mg/L
RBK	RBK-3	8/30/1979	Ammonia	16	1.1	mg/L
RBK	RBK-3	4/20/1987	Ammonia	1	0.1	mg/L
RBK	RBK-3	6/15/1987	Ammonia	1	0.1	mg/L
RBK	RBK-3	7/15/1987	Ammonia	1	0.1	mg/L
RBK	RBK-3	8/18/1987	Ammonia	1	0.1	mg/L
RBK	RBK-3	10/13/1987	Ammonia	1	0.67	mg/L
RBK	RBK-3	4/25/1995	Ammonia	1	0.28	mg/L
RBK	RBK-3	4/25/1995	Ammonia	14	0.72	mg/L
RBK	RBK-3	6/15/1995	Ammonia	1	0.03	mg/L
RBK	RBK-3	7/19/1995	Ammonia	1	0.01	mg/L
RBK	RBK-3	8/28/1995	Ammonia	1	0.01	mg/L
RBK	RBK-3	10/4/1995	Ammonia	1	0.07	mg/L
RBK	RBK-3	6/18/1979	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-3	6/18/1979	Un-inonized Ammonia	13	0	mg/L
RBK	RBK-3	8/30/1979	Un-inonized Ammonia	1	0.01	mg/L
RBK	RBK-3	8/30/1979	Un-inonized Ammonia	16	0.01	mg/L
RBK	RBK-3	4/20/1987	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-3	6/15/1987	Un-inonized Ammonia	1	0.02	mg/L
RBK	RBK-3	7/15/1987	Un-inonized Ammonia	1	0.01	mg/L
RBK	RBK-3	8/18/1987	Un-inonized Ammonia	1	0.02	mg/L
RBK	RBK-3	10/13/1987	Un-inonized Ammonia	1	0	mg/L
RBK	RBK-3	4/25/1995	Un-inonized Ammonia	14	0.01	mg/L
RBK	RBK-3	6/18/1979	TKN	1	0.7	mg/L
RBK	RBK-3	6/18/1979	TKN	13	0.8	mg/L
RBK	RBK-3	8/30/1979	TKN	1	2	mg/L
RBK	RBK-3	8/30/1979	TKN	16	1.8	mg/L
RBK	RBK-3	4/20/1987	TKN	1	1.2	mg/L
RBK	RBK-3	6/15/1987	TKN	1	0.9	mg/L
RBK	RBK-3	7/15/1987	TKN	1	2	mg/L
RBK	RBK-3	8/18/1987	TKN	1	1.6	mg/L
RBK	RBK-3	10/13/1987	TKN	1	2	mg/L
RBK	RBK-3	4/25/1995	TKN	1	0.65	mg/L
RBK	RBK-3	4/25/1995	TKN	14	0.9	mg/L
RBK	RBK-3	6/15/1995	TKN	1	2.7	mg/L
RBK	RBK-3	7/19/1995	TKN	1	0.78	mg/L
RBK	RBK-3	8/28/1995	TKN	1	0.98	mg/L
RBK	RBK-3	10/4/1995	TKN	1	1.2	mg/L
RBK	RBK-3	6/18/1979	Nitrate + Nitrite	1	1.9	mg/L
RBK	RBK-3	6/18/1979	Nitrate + Nitrite	13	2	mg/L

RBK	RBK-3	8/30/1979	Nitrate + Nitrite	1	0.17	mg/L
RBK	RBK-3	8/30/1979	Nitrate + Nitrite	16	0.06	mg/L
RBK	RBK-3	4/20/1987	Nitrate + Nitrite	1	0.41	mg/L
RBK	RBK-3	6/15/1987	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-3	7/15/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-3	8/18/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-3	10/13/1987	Nitrate + Nitrite	1	0.1	mg/L
RBK	RBK-3	4/25/1995	Nitrate + Nitrite	1	1.09	mg/L
RBK	RBK-3	4/25/1995	Nitrate + Nitrite	14	1.94	mg/L
RBK	RBK-3	6/15/1995	Nitrate + Nitrite	1	0.93	mg/L
RBK	RBK-3	7/19/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-3	8/28/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-3	10/4/1995	Nitrate + Nitrite	1	0.01	mg/L
RBK	RBK-3	6/18/1979	Total Phosphorus	1	0.05	mg/L
RBK	RBK-3	6/18/1979	Total Phosphorus	13	0.04	mg/L
RBK	RBK-3	8/30/1979	Total Phosphorus	1	0.11	mg/L
RBK	RBK-3	8/30/1979	Total Phosphorus	16	0.14	mg/L
RBK	RBK-3	4/20/1987	Total Phosphorus	1	0.04	mg/L
RBK	RBK-3	6/15/1987	Total Phosphorus	1	0.03	mg/L
RBK	RBK-3	7/15/1987	Total Phosphorus	1	0.07	mg/L
RBK	RBK-3	8/18/1987	Total Phosphorus	1	0.08	mg/L
RBK	RBK-3	10/13/1987	Total Phosphorus	1	0.18	mg/L
RBK	RBK-3	4/25/1995	Total Phosphorus	1	0.06	mg/L
RBK	RBK-3	4/25/1995	Total Phosphorus	14	0.16	mg/L
RBK	RBK-3	6/15/1995	Total Phosphorus	1	0.07	mg/L
RBK	RBK-3	7/19/1995	Total Phosphorus	1	0.06	mg/L
RBK	RBK-3	8/28/1995	Total Phosphorus	1	0.1	mg/L
RBK	RBK-3	10/4/1995	Total Phosphorus	1	0.12	mg/L
RBK	RBK-3	6/18/1979	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-3	8/30/1979	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-3	8/30/1979	Dissolved Phosphorus	16	0.11	mg/L
RBK	RBK-3	4/20/1987	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-3	6/15/1987	Dissolved Phosphorus	1	0.01	mg/L
RBK	RBK-3	7/15/1987	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-3	8/18/1987	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-3	10/13/1987	Dissolved Phosphorus	1	0.12	mg/L
RBK	RBK-3	4/25/1995	Dissolved Phosphorus	1	0.05	mg/L
RBK	RBK-3	4/25/1995	Dissolved Phosphorus	14	0.11	mg/L
RBK	RBK-3	6/15/1995	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-3	7/19/1995	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-3	8/28/1995	Dissolved Phosphorus	1	0.02	mg/L
RBK	RBK-3	10/4/1995	Dissolved Phosphorus	1	0.03	mg/L
RBK	RBK-3	6/18/1979	Fecal Coliform	1	4	#/100 mL
RBK	RBK-3	8/30/1979	Fecal Coliform	1	4	#/100 mL
RBK	RBK-3	6/18/1979	Chlorophyll-a	4	28.1	µg/L
RBK	RBK-3	8/30/1979	Chlorophyll-a	5	59	µg/L
RBK	RBK-3	4/20/1987	Chlorophyll-a	17	8.71	µg/L
RBK	RBK-3	6/15/1987	Chlorophyll-a	8	31.15	µg/L
RBK	RBK-3	7/15/1987	Chlorophyll-a	5	44.97	µg/L

RBK	RBK-3	8/18/1987	Chlorophyll-a	4	64.03	µg/L
RBK	RBK-3	10/13/1987	Chlorophyll-a	10	37.38	µg/L
RBK	RBK-3	4/25/1995	Chlorophyll-a	14	1.6	µg/L
RBK	RBK-3	6/15/1995	Chlorophyll-a	3	193.31	µg/L
RBK	RBK-3	7/19/1995	Chlorophyll-a	3	69.95	µg/L
RBK	RBK-3	8/28/1995	Chlorophyll-a	3	109.3	µg/L
RBK	RBK-3	10/4/1995	Chlorophyll-a	5	115.46	µg/L
RBP	RBP-1	6/3/1981	Dissolved Oxygen	0	9	mg/L
RBP	RBP-1	6/3/1981	Dissolved Oxygen	3	6.6	mg/L
RBP	RBP-1	6/3/1981	Dissolved Oxygen	5	3.4	mg/L
RBP	RBP-1	6/3/1981	Dissolved Oxygen	7	1.7	mg/L
RBP	RBP-1	8/24/1981	Dissolved Oxygen	0	16.8	mg/L
RBP	RBP-1	8/24/1981	Dissolved Oxygen	1	16.6	mg/L
RBP	RBP-1	8/24/1981	Dissolved Oxygen	3	9	mg/L
RBP	RBP-1	8/24/1981	Dissolved Oxygen	5	5	mg/L
RBP	RBP-1	8/24/1981	Dissolved Oxygen	7	1	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	0	12.4	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	1	11.4	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	2	11.2	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	3	11.1	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	5	10.8	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	6	10.7	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	7	10.4	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	8	10.3	mg/L
RBP	RBP-1	6/22/1992	Dissolved Oxygen	9	10.2	mg/L
RBP	RBP-1	4/21/1998	Dissolved Oxygen	0	12.6	mg/L
RBP	RBP-1	4/21/1998	Dissolved Oxygen	1	12.3	mg/L
RBP	RBP-1	4/21/1998	Dissolved Oxygen	3	12	mg/L
RBP	RBP-1	4/21/1998	Dissolved Oxygen	5	9	mg/L
RBP	RBP-1	6/11/1998	Dissolved Oxygen	0	7.2	mg/L
RBP	RBP-1	6/11/1998	Dissolved Oxygen	1	6.7	mg/L
RBP	RBP-1	6/11/1998	Dissolved Oxygen	2	6.1	mg/L
RBP	RBP-1	7/29/1998	Dissolved Oxygen	0	10.6	mg/L
RBP	RBP-1	7/29/1998	Dissolved Oxygen	3	9.3	mg/L
RBP	RBP-1	7/29/1998	Dissolved Oxygen	4	5.7	mg/L
RBP	RBP-1	7/29/1998	Dissolved Oxygen	5	3.3	mg/L
RBP	RBP-1	7/29/1998	Dissolved Oxygen	6	2.4	mg/L
RBP	RBP-1	8/17/1998	Dissolved Oxygen	0	6.3	mg/L
RBP	RBP-1	8/17/1998	Dissolved Oxygen	3	5.6	mg/L
RBP	RBP-1	10/7/1998	Dissolved Oxygen	0	6.8	mg/L
RBP	RBP-1	10/7/1998	Dissolved Oxygen	1	6	mg/L
RBP	RBP-1	10/7/1998	Dissolved Oxygen	3	6.1	mg/L
RBP	RBP-1	6/3/1981	Suspended Solids	1	16	mg/L
RBP	RBP-1	8/24/1981	Suspended Solids	1	14	mg/L
RBP	RBP-1	5/9/1988	Suspended Solids	1	9	mg/L
RBP	RBP-1	6/30/1988	Suspended Solids	1	33	mg/L
RBP	RBP-1	7/11/1988	Suspended Solids	1	9	mg/L
RBP	RBP-1	8/8/1988	Suspended Solids	1	28	mg/L
RBP	RBP-1	9/27/1988	Suspended Solids	1	19	mg/L

RBP	RBP-1	10/25/1988	Suspended Solids	1	26	mg/L
RBP	RBP-1	5/30/1989	Suspended Solids	1	6	mg/L
RBP	RBP-1	6/26/1989	Suspended Solids	1	4	mg/L
RBP	RBP-1	7/31/1989	Suspended Solids	1	18	mg/L
RBP	RBP-1	8/29/1989	Suspended Solids	1	38	mg/L
RBP	RBP-1	10/3/1989	Suspended Solids	1	17	mg/L
RBP	RBP-1	5/26/1992	Suspended Solids	1	35	mg/L
RBP	RBP-1	6/22/1992	Suspended Solids	1	156	mg/L
RBP	RBP-1	6/22/1992	Suspended Solids	7	178	mg/L
RBP	RBP-1	6/29/1992	Suspended Solids	1	21	mg/L
RBP	RBP-1	7/28/1992	Suspended Solids	1	20	mg/L
RBP	RBP-1	8/25/1992	Suspended Solids	1	8	mg/L
RBP	RBP-1	9/30/1992	Suspended Solids	1	80	mg/L
RBP	RBP-1	10/28/1992	Suspended Solids	1	56	mg/L
RBP	RBP-1	5/31/1994	Suspended Solids	1	26	mg/L
RBP	RBP-1	6/29/1994	Suspended Solids	1	35	mg/L
RBP	RBP-1	7/26/1994	Suspended Solids	1	32	mg/L
RBP	RBP-1	8/31/1994	Suspended Solids	1	66	mg/L
RBP	RBP-1	9/28/1994	Suspended Solids	1	74	mg/L
RBP	RBP-1	4/21/1998	Suspended Solids	1	37	mg/L
RBP	RBP-1	4/21/1998	Suspended Solids	3	29	mg/L
RBP	RBP-1	6/11/1998	Suspended Solids	1	39	mg/L
RBP	RBP-1	6/11/1998	Suspended Solids	2	37	mg/L
RBP	RBP-1	7/29/1998	Suspended Solids	1	12	mg/L
RBP	RBP-1	7/29/1998	Suspended Solids	4	30	mg/L
RBP	RBP-1	8/4/1998	Suspended Solids	1	32	mg/L
RBP	RBP-1	8/17/1998	Suspended Solids	1	28	mg/L
RBP	RBP-1	10/7/1998	Suspended Solids	1	92	mg/L
RBP	RBP-1	5/7/2001	Suspended Solids	1	16	mg/L
RBP	RBP-1	5/7/2001	Suspended Solids	2	17	mg/L
RBP	RBP-1	7/2/2001	Suspended Solids	1	24	mg/L
RBP	RBP-1	7/2/2001	Suspended Solids	2	28	mg/L
RBP	RBP-1	7/26/2001	Suspended Solids	1	35	mg/L
RBP	RBP-1	7/26/2001	Suspended Solids	2	40	mg/L
RBP	RBP-1	8/21/2001	Suspended Solids	1	42	mg/L
RBP	RBP-1	8/21/2001	Suspended Solids	2	38	mg/L
RBP	RBP-1	10/15/2001	Suspended Solids	1	30	mg/L
RBP	RBP-1	10/15/2001	Suspended Solids	3	33	mg/L
RBP	RBP-1	6/3/1981	Ammonia	1	0.12	mg/L
RBP	RBP-1	8/24/1981	Ammonia	1	1.7	mg/L
RBP	RBP-1	5/9/1988	Ammonia	1	0.1	mg/L
RBP	RBP-1	6/30/1988	Ammonia	1	0.47	mg/L
RBP	RBP-1	7/11/1988	Ammonia	1	0.1	mg/L
RBP	RBP-1	8/8/1988	Ammonia	1	0.1	mg/L
RBP	RBP-1	9/27/1988	Ammonia	1	0.1	mg/L
RBP	RBP-1	10/25/1988	Ammonia	1	0.1	mg/L
RBP	RBP-1	5/30/1989	Ammonia	1	0.24	mg/L
RBP	RBP-1	6/26/1989	Ammonia	1	0.25	mg/L
RBP	RBP-1	7/31/1989	Ammonia	1	0.38	mg/L

RBP	RBP-1	8/29/1989	Ammonia	1	0.1	mg/L
RBP	RBP-1	10/3/1989	Ammonia	1	0.3	mg/L
RBP	RBP-1	5/26/1992	Ammonia	1	0.04	mg/L
RBP	RBP-1	6/22/1992	Ammonia	1	0.28	mg/L
RBP	RBP-1	6/22/1992	Ammonia	7	0.19	mg/L
RBP	RBP-1	6/29/1992	Ammonia	1	0.05	mg/L
RBP	RBP-1	7/28/1992	Ammonia	1	0.13	mg/L
RBP	RBP-1	8/25/1992	Ammonia	1	0.63	mg/L
RBP	RBP-1	9/30/1992	Ammonia	1	0.45	mg/L
RBP	RBP-1	10/28/1992	Ammonia	1	0.24	mg/L
RBP	RBP-1	5/31/1994	Ammonia	1	0.01	mg/L
RBP	RBP-1	6/29/1994	Ammonia	1	0.03	mg/L
RBP	RBP-1	7/26/1994	Ammonia	1	0.04	mg/L
RBP	RBP-1	8/31/1994	Ammonia	1	0.21	mg/L
RBP	RBP-1	9/28/1994	Ammonia	1	0.01	mg/L
RBP	RBP-1	4/21/1998	Ammonia	1	0.39	mg/L
RBP	RBP-1	4/21/1998	Ammonia	3	0.42	mg/L
RBP	RBP-1	6/11/1998	Ammonia	1	0.29	mg/L
RBP	RBP-1	6/11/1998	Ammonia	2	0.21	mg/L
RBP	RBP-1	7/29/1998	Ammonia	1	0.22	mg/L
RBP	RBP-1	7/29/1998	Ammonia	4	0.46	mg/L
RBP	RBP-1	8/4/1998	Ammonia	1	0.38	mg/L
RBP	RBP-1	8/17/1998	Ammonia	1	0.55	mg/L
RBP	RBP-1	10/7/1998	Ammonia	1	0.01	mg/L
RBP	RBP-1	5/7/2001	Ammonia	1	0.44	mg/L
RBP	RBP-1	5/7/2001	Ammonia	2	0.42	mg/L
RBP	RBP-1	7/2/2001	Ammonia	1	0.11	mg/L
RBP	RBP-1	7/2/2001	Ammonia	2	0.07	mg/L
RBP	RBP-1	7/26/2001	Ammonia	1	0.29	mg/L
RBP	RBP-1	7/26/2001	Ammonia	2	0.3	mg/L
RBP	RBP-1	8/21/2001	Ammonia	1	0.01	mg/L
RBP	RBP-1	8/21/2001	Ammonia	2	0.01	mg/L
RBP	RBP-1	10/15/2001	Ammonia	1	0.01	mg/L
RBP	RBP-1	10/15/2001	Ammonia	3	0.01	mg/L
RBP	RBP-1	6/3/1981	Un-inonized Ammonia	1	0.01	mg/L
RBP	RBP-1	8/24/1981	Un-inonized Ammonia	1	0.07	mg/L
RBP	RBP-1	4/21/1998	Un-inonized Ammonia	1	0.01	mg/L
RBP	RBP-1	4/21/1998	Un-inonized Ammonia	3	0.01	mg/L
RBP	RBP-1	6/11/1998	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-1	6/11/1998	Un-inonized Ammonia	2	0	mg/L
RBP	RBP-1	7/29/1998	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-1	7/29/1998	Un-inonized Ammonia	4	0.01	mg/L
RBP	RBP-1	8/17/1998	Un-inonized Ammonia	1	0.04	mg/L
RBP	RBP-1	10/7/1998	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-1	6/3/1981	TKN	1	0.7	mg/L
RBP	RBP-1	8/24/1981	TKN	1	1.2	mg/L
RBP	RBP-1	6/22/1992	TKN	1	1.3	mg/L
RBP	RBP-1	6/22/1992	TKN	7	1.5	mg/L
RBP	RBP-1	4/21/1998	TKN	1	0.78	mg/L

RBP	RBP-1	4/21/1998	TKN	3	0.92	mg/L
RBP	RBP-1	6/11/1998	TKN	1	0.7	mg/L
RBP	RBP-1	7/29/1998	TKN	1	0.67	mg/L
RBP	RBP-1	7/29/1998	TKN	4	1.2	mg/L
RBP	RBP-1	8/17/1998	TKN	1	1.6	mg/L
RBP	RBP-1	10/7/1998	TKN	1	1.1	mg/L
RBP	RBP-1	5/7/2001	TKN	1	1.73	mg/L
RBP	RBP-1	5/7/2001	TKN	2	1.43	mg/L
RBP	RBP-1	7/2/2001	TKN	1	1.61	mg/L
RBP	RBP-1	7/2/2001	TKN	2	1.55	mg/L
RBP	RBP-1	7/26/2001	TKN	1	2.57	mg/L
RBP	RBP-1	7/26/2001	TKN	2	1.38	mg/L
RBP	RBP-1	8/21/2001	TKN	1	1.71	mg/L
RBP	RBP-1	8/21/2001	TKN	2	3.16	mg/L
RBP	RBP-1	10/15/2001	TKN	1	1.69	mg/L
RBP	RBP-1	10/15/2001	TKN	3	2.13	mg/L
RBP	RBP-1	6/3/1981	Nitrate + Nitrite	1	9.3	mg/L
RBP	RBP-1	8/24/1981	Nitrate + Nitrite	1	4.1	mg/L
RBP	RBP-1	5/9/1988	Nitrate + Nitrite	1	4.2	mg/L
RBP	RBP-1	6/30/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-1	7/11/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-1	8/8/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-1	9/27/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-1	10/25/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-1	5/30/1989	Nitrate + Nitrite	1	8.8	mg/L
RBP	RBP-1	6/26/1989	Nitrate + Nitrite	1	6.1	mg/L
RBP	RBP-1	7/31/1989	Nitrate + Nitrite	1	0.7	mg/L
RBP	RBP-1	8/29/1989	Nitrate + Nitrite	1	1.9	mg/L
RBP	RBP-1	10/3/1989	Nitrate + Nitrite	1	1.2	mg/L
RBP	RBP-1	5/26/1992	Nitrate + Nitrite	1	10	mg/L
RBP	RBP-1	6/22/1992	Nitrate + Nitrite	1	2	mg/L
RBP	RBP-1	6/22/1992	Nitrate + Nitrite	7	2.1	mg/L
RBP	RBP-1	6/29/1992	Nitrate + Nitrite	1	0.96	mg/L
RBP	RBP-1	7/28/1992	Nitrate + Nitrite	1	4.8	mg/L
RBP	RBP-1	8/25/1992	Nitrate + Nitrite	1	0.12	mg/L
RBP	RBP-1	9/30/1992	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-1	10/28/1992	Nitrate + Nitrite	1	1.16	mg/L
RBP	RBP-1	5/31/1994	Nitrate + Nitrite	1	3.3	mg/L
RBP	RBP-1	6/29/1994	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-1	7/26/1994	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-1	8/31/1994	Nitrate + Nitrite	1	0.02	mg/L
RBP	RBP-1	9/28/1994	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-1	4/21/1998	Nitrate + Nitrite	1	7.07	mg/L
RBP	RBP-1	4/21/1998	Nitrate + Nitrite	3	7.08	mg/L
RBP	RBP-1	6/11/1998	Nitrate + Nitrite	1	11.52	mg/L
RBP	RBP-1	6/11/1998	Nitrate + Nitrite	2	11.61	mg/L
RBP	RBP-1	7/29/1998	Nitrate + Nitrite	1	2.2	mg/L
RBP	RBP-1	7/29/1998	Nitrate + Nitrite	4	2.11	mg/L
RBP	RBP-1	8/4/1998	Nitrate + Nitrite	1	1.5	mg/L

RBP	RBP-1	8/17/1998	Nitrate + Nitrite	1	0.98	mg/L
RBP	RBP-1	10/7/1998	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-1	5/7/2001	Nitrate + Nitrite	1	0.34	mg/L
RBP	RBP-1	5/7/2001	Nitrate + Nitrite	2	0.31	mg/L
RBP	RBP-1	7/2/2001	Nitrate + Nitrite	1	0.99	mg/L
RBP	RBP-1	7/2/2001	Nitrate + Nitrite	2	1	mg/L
RBP	RBP-1	7/26/2001	Nitrate + Nitrite	1	0.42	mg/L
RBP	RBP-1	7/26/2001	Nitrate + Nitrite	2	0.52	mg/L
RBP	RBP-1	8/21/2001	Nitrate + Nitrite	1	0.05	mg/L
RBP	RBP-1	8/21/2001	Nitrate + Nitrite	2	0.04	mg/L
RBP	RBP-1	10/15/2001	Nitrate + Nitrite	1	2.6	mg/L
RBP	RBP-1	10/15/2001	Nitrate + Nitrite	3	2.6	mg/L
RBP	RBP-1	6/3/1981	Total Phosphorus	1	0.04	mg/L
RBP	RBP-1	8/24/1981	Total Phosphorus	1	0.07	mg/L
RBP	RBP-1	5/9/1988	Total Phosphorus	1	0.06	mg/L
RBP	RBP-1	6/30/1988	Total Phosphorus	1	0.14	mg/L
RBP	RBP-1	7/11/1988	Total Phosphorus	1	0.09	mg/L
RBP	RBP-1	8/8/1988	Total Phosphorus	1	0.01	mg/L
RBP	RBP-1	9/27/1988	Total Phosphorus	1	0.21	mg/L
RBP	RBP-1	10/25/1988	Total Phosphorus	1	0.18	mg/L
RBP	RBP-1	5/30/1989	Total Phosphorus	1	0.19	mg/L
RBP	RBP-1	6/26/1989	Total Phosphorus	1	0.15	mg/L
RBP	RBP-1	7/31/1989	Total Phosphorus	1	0.14	mg/L
RBP	RBP-1	8/29/1989	Total Phosphorus	1	0.38	mg/L
RBP	RBP-1	10/3/1989	Total Phosphorus	1	0.06	mg/L
RBP	RBP-1	5/26/1992	Total Phosphorus	1	0.13	mg/L
RBP	RBP-1	6/22/1992	Total Phosphorus	1	0.11	mg/L
RBP	RBP-1	6/22/1992	Total Phosphorus	7	0.16	mg/L
RBP	RBP-1	6/29/1992	Total Phosphorus	1	0.13	mg/L
RBP	RBP-1	7/28/1992	Total Phosphorus	1	0.18	mg/L
RBP	RBP-1	8/25/1992	Total Phosphorus	1	0.11	mg/L
RBP	RBP-1	9/30/1992	Total Phosphorus	1	0.16	mg/L
RBP	RBP-1	10/28/1992	Total Phosphorus	1	0.08	mg/L
RBP	RBP-1	5/31/1994	Total Phosphorus	1	0.07	mg/L
RBP	RBP-1	6/29/1994	Total Phosphorus	1	0.18	mg/L
RBP	RBP-1	7/26/1994	Total Phosphorus	1	0.4	mg/L
RBP	RBP-1	8/31/1994	Total Phosphorus	1	0.38	mg/L
RBP	RBP-1	9/28/1994	Total Phosphorus	1	0.33	mg/L
RBP	RBP-1	4/21/1998	Total Phosphorus	1	0.06	mg/L
RBP	RBP-1	4/21/1998	Total Phosphorus	3	0.08	mg/L
RBP	RBP-1	6/11/1998	Total Phosphorus	1	0.16	mg/L
RBP	RBP-1	6/11/1998	Total Phosphorus	2	0.17	mg/L
RBP	RBP-1	7/29/1998	Total Phosphorus	1	0.08	mg/L
RBP	RBP-1	7/29/1998	Total Phosphorus	4	0.13	mg/L
RBP	RBP-1	8/4/1998	Total Phosphorus	1	0.15	mg/L
RBP	RBP-1	8/17/1998	Total Phosphorus	1	0.07	mg/L
RBP	RBP-1	10/7/1998	Total Phosphorus	1	0.21	mg/L
RBP	RBP-1	5/7/2001	Total Phosphorus	1	0.07	mg/L
RBP	RBP-1	5/7/2001	Total Phosphorus	2	0.07	mg/L

RBP	RBP-1	7/2/2001	Total Phosphorus	1	0.36	mg/L
RBP	RBP-1	7/2/2001	Total Phosphorus	2	0.2	mg/L
RBP	RBP-1	7/26/2001	Total Phosphorus	1	0.15	mg/L
RBP	RBP-1	7/26/2001	Total Phosphorus	2	0.17	mg/L
RBP	RBP-1	8/21/2001	Total Phosphorus	1	0.29	mg/L
RBP	RBP-1	8/21/2001	Total Phosphorus	2	0.26	mg/L
RBP	RBP-1	10/15/2001	Total Phosphorus	1	0.46	mg/L
RBP	RBP-1	10/15/2001	Total Phosphorus	3	0.46	mg/L
RBP	RBP-1	6/3/1981	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-1	8/24/1981	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-1	6/22/1992	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-1	6/22/1992	Dissolved Phosphorus	7	0.02	mg/L
RBP	RBP-1	4/21/1998	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-1	4/21/1998	Dissolved Phosphorus	3	0	mg/L
RBP	RBP-1	6/11/1998	Dissolved Phosphorus	1	0.09	mg/L
RBP	RBP-1	6/11/1998	Dissolved Phosphorus	2	0.09	mg/L
RBP	RBP-1	7/29/1998	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-1	7/29/1998	Dissolved Phosphorus	4	0.02	mg/L
RBP	RBP-1	8/17/1998	Dissolved Phosphorus	1	0.03	mg/L
RBP	RBP-1	10/7/1998	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-1	5/7/2001	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-1	5/7/2001	Dissolved Phosphorus	2	0.02	mg/L
RBP	RBP-1	7/2/2001	Dissolved Phosphorus	1	0.22	mg/L
RBP	RBP-1	7/2/2001	Dissolved Phosphorus	2	0.07	mg/L
RBP	RBP-1	7/26/2001	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-1	7/26/2001	Dissolved Phosphorus	2	0.03	mg/L
RBP	RBP-1	8/21/2001	Dissolved Phosphorus	1	0.06	mg/L
RBP	RBP-1	8/21/2001	Dissolved Phosphorus	2	0.03	mg/L
RBP	RBP-1	10/15/2001	Dissolved Phosphorus	1	0.37	mg/L
RBP	RBP-1	10/15/2001	Dissolved Phosphorus	3	0.37	mg/L
RBP	RBP-1	6/3/1981	Chlorophyll-a	3	6.7	µg/L
RBP	RBP-1	8/24/1981	Chlorophyll-a	3	38.92	µg/L
RBP	RBP-1	6/22/1992	Chlorophyll-a	2	81.88	µg/L
RBP	RBP-1	4/21/1998	Chlorophyll-a	2	42.72	µg/L
RBP	RBP-1	6/11/1998	Chlorophyll-a	2	8.01	µg/L
RBP	RBP-1	7/29/1998	Chlorophyll-a	3	34.7	µg/L
RBP	RBP-1	10/7/1998	Chlorophyll-a	2	85.4	µg/L
RBP	RBP-1	5/7/2001	Chlorophyll-a	2	54.8	µg/L
RBP	RBP-1	7/2/2001	Chlorophyll-a	3	57.5	µg/L
RBP	RBP-1	7/26/2001	Chlorophyll-a	2	138	µg/L
RBP	RBP-1	8/21/2001	Chlorophyll-a	2	135	µg/L
RBP	RBP-1	10/15/2001	Chlorophyll-a	2	7.96	µg/L
RBP	RBP-2	6/3/1981	Dissolved Oxygen	0	9.1	mg/L
RBP	RBP-2	6/3/1981	Dissolved Oxygen	3	9	mg/L
RBP	RBP-2	8/24/1981	Dissolved Oxygen	0	17.1	mg/L
RBP	RBP-2	8/24/1981	Dissolved Oxygen	1	17	mg/L
RBP	RBP-2	8/24/1981	Dissolved Oxygen	3	13.6	mg/L
RBP	RBP-2	4/21/1998	Dissolved Oxygen	0	12.6	mg/L
RBP	RBP-2	4/21/1998	Dissolved Oxygen	1	11	mg/L

RBP	RBP-2	4/21/1998	Dissolved Oxygen	3	9.3	mg/L
RBP	RBP-2	6/11/1998	Dissolved Oxygen	0	7.5	mg/L
RBP	RBP-2	6/11/1998	Dissolved Oxygen	1	7.2	mg/L
RBP	RBP-2	6/11/1998	Dissolved Oxygen	2	6.8	mg/L
RBP	RBP-2	8/17/1998	Dissolved Oxygen	0	8.8	mg/L
RBP	RBP-2	10/7/1998	Dissolved Oxygen	0	8.3	mg/L
RBP	RBP-2	6/3/1981	Suspended Solids	1	14	mg/L
RBP	RBP-2	8/24/1981	Suspended Solids	1	19	mg/L
RBP	RBP-2	4/21/1998	Suspended Solids	1	32	mg/L
RBP	RBP-2	6/11/1998	Suspended Solids	1	36	mg/L
RBP	RBP-2	7/29/1998	Suspended Solids	1	22	mg/L
RBP	RBP-2	8/17/1998	Suspended Solids	1	38	mg/L
RBP	RBP-2	10/7/1998	Suspended Solids	1	142	mg/L
RBP	RBP-2	5/7/2001	Suspended Solids	1	15	mg/L
RBP	RBP-2	7/2/2001	Suspended Solids	1	33	mg/L
RBP	RBP-2	7/26/2001	Suspended Solids	1	85	mg/L
RBP	RBP-2	8/21/2001	Suspended Solids	1	75	mg/L
RBP	RBP-2	10/15/2001	Suspended Solids	1	28	mg/L
RBP	RBP-2	6/3/1981	Ammonia	1	0.14	mg/L
RBP	RBP-2	8/24/1981	Ammonia	1	0.01	mg/L
RBP	RBP-2	4/21/1998	Ammonia	1	0.57	mg/L
RBP	RBP-2	6/11/1998	Ammonia	1	0.16	mg/L
RBP	RBP-2	7/29/1998	Ammonia	1	0.25	mg/L
RBP	RBP-2	8/17/1998	Ammonia	1	0.56	mg/L
RBP	RBP-2	10/7/1998	Ammonia	1	0.11	mg/L
RBP	RBP-2	5/7/2001	Ammonia	1	0.49	mg/L
RBP	RBP-2	7/2/2001	Ammonia	1	0.04	mg/L
RBP	RBP-2	7/26/2001	Ammonia	1	0.08	mg/L
RBP	RBP-2	8/21/2001	Ammonia	1	0.01	mg/L
RBP	RBP-2	10/15/2001	Ammonia	1	0.01	mg/L
RBP	RBP-2	6/3/1981	Un-inonized Ammonia	1	0.01	mg/L
RBP	RBP-2	8/24/1981	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-2	4/21/1998	Un-inonized Ammonia	1	0.02	mg/L
RBP	RBP-2	6/11/1998	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-2	10/7/1998	Un-inonized Ammonia	1	0.01	mg/L
RBP	RBP-2	6/3/1981	TKN	1	0.6	mg/L
RBP	RBP-2	8/24/1981	TKN	1	1.1	mg/L
RBP	RBP-2	4/21/1998	TKN	1	0.43	mg/L
RBP	RBP-2	6/11/1998	TKN	1	0.6	mg/L
RBP	RBP-2	7/29/1998	TKN	1	0.81	mg/L
RBP	RBP-2	8/17/1998	TKN	1	1.5	mg/L
RBP	RBP-2	10/7/1998	TKN	1	1	mg/L
RBP	RBP-2	5/7/2001	TKN	1	1.6	mg/L
RBP	RBP-2	7/2/2001	TKN	1	1.95	mg/L
RBP	RBP-2	7/26/2001	TKN	1	1.95	mg/L
RBP	RBP-2	8/21/2001	TKN	1	2.26	mg/L
RBP	RBP-2	10/15/2001	TKN	1	1.52	mg/L
RBP	RBP-2	6/3/1981	Nitrate + Nitrite	1	9.3	mg/L
RBP	RBP-2	8/24/1981	Nitrate + Nitrite	1	4	mg/L

RBP	RBP-2	4/21/1998	Nitrate + Nitrite	1	6.77	mg/L
RBP	RBP-2	6/11/1998	Nitrate + Nitrite	1	11.54	mg/L
RBP	RBP-2	7/29/1998	Nitrate + Nitrite	1	2.14	mg/L
RBP	RBP-2	8/17/1998	Nitrate + Nitrite	1	0.91	mg/L
RBP	RBP-2	10/7/1998	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-2	5/7/2001	Nitrate + Nitrite	1	0.44	mg/L
RBP	RBP-2	7/2/2001	Nitrate + Nitrite	1	0.94	mg/L
RBP	RBP-2	7/26/2001	Nitrate + Nitrite	1	0.75	mg/L
RBP	RBP-2	8/21/2001	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-2	10/15/2001	Nitrate + Nitrite	1	3.6	mg/L
RBP	RBP-2	6/3/1981	Total Phosphorus	1	0.05	mg/L
RBP	RBP-2	8/24/1981	Total Phosphorus	1	0.08	mg/L
RBP	RBP-2	4/21/1998	Total Phosphorus	1	0.1	mg/L
RBP	RBP-2	6/11/1998	Total Phosphorus	1	0.14	mg/L
RBP	RBP-2	7/29/1998	Total Phosphorus	1	0.09	mg/L
RBP	RBP-2	8/17/1998	Total Phosphorus	1	0.23	mg/L
RBP	RBP-2	10/7/1998	Total Phosphorus	1	0.16	mg/L
RBP	RBP-2	5/7/2001	Total Phosphorus	1	0.07	mg/L
RBP	RBP-2	7/2/2001	Total Phosphorus	1	0.2	mg/L
RBP	RBP-2	7/26/2001	Total Phosphorus	1	0.2	mg/L
RBP	RBP-2	8/21/2001	Total Phosphorus	1	0.32	mg/L
RBP	RBP-2	10/15/2001	Total Phosphorus	1	0.39	mg/L
RBP	RBP-2	6/3/1981	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-2	8/24/1981	Dissolved Phosphorus	1	0	mg/L
RBP	RBP-2	4/21/1998	Dissolved Phosphorus	1	0	mg/L
RBP	RBP-2	6/11/1998	Dissolved Phosphorus	1	0.09	mg/L
RBP	RBP-2	7/29/1998	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-2	8/17/1998	Dissolved Phosphorus	1	0.04	mg/L
RBP	RBP-2	10/7/1998	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-2	5/7/2001	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-2	7/2/2001	Dissolved Phosphorus	1	0.05	mg/L
RBP	RBP-2	7/26/2001	Dissolved Phosphorus	1	0.03	mg/L
RBP	RBP-2	8/21/2001	Dissolved Phosphorus	1	0.05	mg/L
RBP	RBP-2	10/15/2001	Dissolved Phosphorus	1	0.32	mg/L
RBP	RBP-2	6/3/1981	Chlorophyll-a	3	4.86	µg/L
RBP	RBP-2	8/24/1981	Chlorophyll-a	3	37.03	µg/L
RBP	RBP-2	4/21/1998	Chlorophyll-a	2	40.05	µg/L
RBP	RBP-2	6/11/1998	Chlorophyll-a	2	13.35	µg/L
RBP	RBP-2	7/29/1998	Chlorophyll-a	3	42.7	µg/L
RBP	RBP-2	10/7/1998	Chlorophyll-a	2	139	µg/L
RBP	RBP-2	5/7/2001	Chlorophyll-a	2	43.9	µg/L
RBP	RBP-2	7/2/2001	Chlorophyll-a	2	40.4	µg/L
RBP	RBP-2	7/26/2001	Chlorophyll-a	2	93.7	µg/L
RBP	RBP-2	8/21/2001	Chlorophyll-a	2	133	µg/L
RBP	RBP-2	10/15/2001	Chlorophyll-a	2	3.76	µg/L
RBP	RBP-3	6/3/1981	Dissolved Oxygen	0	9.2	mg/L
RBP	RBP-3	6/3/1981	Dissolved Oxygen	3	7	mg/L
RBP	RBP-3	8/24/1981	Dissolved Oxygen	0	15.8	mg/L
RBP	RBP-3	8/24/1981	Dissolved Oxygen	1	15.2	mg/L

RBP	RBP-3	8/24/1981	Dissolved Oxygen	3	12.2	mg/L
RBP	RBP-3	4/21/1998	Dissolved Oxygen	0	9.3	mg/L
RBP	RBP-3	4/21/1998	Dissolved Oxygen	1	8.6	mg/L
RBP	RBP-3	6/11/1998	Dissolved Oxygen	0	7	mg/L
RBP	RBP-3	6/11/1998	Dissolved Oxygen	1	6.8	mg/L
RBP	RBP-3	7/29/1998	Dissolved Oxygen	0	10.8	mg/L
RBP	RBP-3	7/29/1998	Dissolved Oxygen	0	11.7	mg/L
RBP	RBP-3	7/29/1998	Dissolved Oxygen	1	11.3	mg/L
RBP	RBP-3	7/29/1998	Dissolved Oxygen	2	11	mg/L
RBP	RBP-3	7/29/1998	Dissolved Oxygen	3	8.8	mg/L
RBP	RBP-3	7/29/1998	Dissolved Oxygen	4	8.4	mg/L
RBP	RBP-3	8/17/1998	Dissolved Oxygen	0	9.7	mg/L
RBP	RBP-3	8/17/1998	Dissolved Oxygen	1	9.3	mg/L
RBP	RBP-3	10/7/1998	Dissolved Oxygen	0	6.7	mg/L
RBP	RBP-3	10/7/1998	Dissolved Oxygen	1	6.2	mg/L
RBP	RBP-3	6/3/1981	Suspended Solids	1	19	mg/L
RBP	RBP-3	8/24/1981	Suspended Solids	1	22	mg/L
RBP	RBP-3	5/9/1988	Suspended Solids	1	11	mg/L
RBP	RBP-3	6/30/1988	Suspended Solids	1	30	mg/L
RBP	RBP-3	7/11/1988	Suspended Solids	1	44	mg/L
RBP	RBP-3	8/8/1988	Suspended Solids	1	24	mg/L
RBP	RBP-3	9/27/1988	Suspended Solids	1	77	mg/L
RBP	RBP-3	10/25/1988	Suspended Solids	1	58	mg/L
RBP	RBP-3	5/31/1994	Suspended Solids	1	31	mg/L
RBP	RBP-3	6/29/1994	Suspended Solids	1	35	mg/L
RBP	RBP-3	7/26/1994	Suspended Solids	1	47	mg/L
RBP	RBP-3	8/31/1994	Suspended Solids	1	152	mg/L
RBP	RBP-3	9/28/1994	Suspended Solids	1	96	mg/L
RBP	RBP-3	4/21/1998	Suspended Solids	1	35	mg/L
RBP	RBP-3	6/11/1998	Suspended Solids	1	36	mg/L
RBP	RBP-3	7/29/1998	Suspended Solids	1	25	mg/L
RBP	RBP-3	8/17/1998	Suspended Solids	1	28	mg/L
RBP	RBP-3	10/7/1998	Suspended Solids	1	10	mg/L
RBP	RBP-3	5/7/2001	Suspended Solids	1	14	mg/L
RBP	RBP-3	7/2/2001	Suspended Solids	1	37	mg/L
RBP	RBP-3	7/26/2001	Suspended Solids	1	101	mg/L
RBP	RBP-3	8/21/2001	Suspended Solids	1	75	mg/L
RBP	RBP-3	10/15/2001	Suspended Solids	1	26	mg/L
RBP	RBP-3	6/3/1981	Ammonia	1	0.06	mg/L
RBP	RBP-3	8/24/1981	Ammonia	1	0.17	mg/L
RBP	RBP-3	5/9/1988	Ammonia	1	0.1	mg/L
RBP	RBP-3	6/30/1988	Ammonia	1	0.74	mg/L
RBP	RBP-3	7/11/1988	Ammonia	1	0.1	mg/L
RBP	RBP-3	8/8/1988	Ammonia	1	0.1	mg/L
RBP	RBP-3	9/27/1988	Ammonia	1	0.1	mg/L
RBP	RBP-3	10/25/1988	Ammonia	1	0.13	mg/L
RBP	RBP-3	5/31/1994	Ammonia	1	0.01	mg/L
RBP	RBP-3	6/29/1994	Ammonia	1	0.1	mg/L
RBP	RBP-3	7/26/1994	Ammonia	1	0.01	mg/L

RBP	RBP-3	8/31/1994	Ammonia	1	0.02	mg/L
RBP	RBP-3	9/28/1994	Ammonia	1	0.03	mg/L
RBP	RBP-3	4/21/1998	Ammonia	1	0.41	mg/L
RBP	RBP-3	6/11/1998	Ammonia	1	0.16	mg/L
RBP	RBP-3	7/29/1998	Ammonia	1	0.29	mg/L
RBP	RBP-3	8/17/1998	Ammonia	1	0.55	mg/L
RBP	RBP-3	10/7/1998	Ammonia	1	0.42	mg/L
RBP	RBP-3	5/7/2001	Ammonia	1	0.48	mg/L
RBP	RBP-3	7/2/2001	Ammonia	1	0.01	mg/L
RBP	RBP-3	7/26/2001	Ammonia	1	0.19	mg/L
RBP	RBP-3	8/21/2001	Ammonia	1	0.01	mg/L
RBP	RBP-3	10/15/2001	Ammonia	1	0.01	mg/L
RBP	RBP-3	6/3/1981	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-3	8/24/1981	Un-inonized Ammonia	1	0.01	mg/L
RBP	RBP-3	4/21/1998	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-3	6/11/1998	Un-inonized Ammonia	1	0	mg/L
RBP	RBP-3	7/29/1998	Un-inonized Ammonia	1	0.01	mg/L
RBP	RBP-3	8/17/1998	Un-inonized Ammonia	1	0.11	mg/L
RBP	RBP-3	10/7/1998	Un-inonized Ammonia	1	0.01	mg/L
RBP	RBP-3	6/3/1981	TKN	1	0.9	mg/L
RBP	RBP-3	8/24/1981	TKN	1	1	mg/L
RBP	RBP-3	4/21/1998	TKN	1	0.59	mg/L
RBP	RBP-3	6/11/1998	TKN	1	0.8	mg/L
RBP	RBP-3	7/29/1998	TKN	1	0.71	mg/L
RBP	RBP-3	8/17/1998	TKN	1	1.4	mg/L
RBP	RBP-3	10/7/1998	TKN	1	1.2	mg/L
RBP	RBP-3	5/7/2001	TKN	1	1.33	mg/L
RBP	RBP-3	7/2/2001	TKN	1	1.7	mg/L
RBP	RBP-3	7/26/2001	TKN	1	1.75	mg/L
RBP	RBP-3	8/21/2001	TKN	1	2.76	mg/L
RBP	RBP-3	10/15/2001	TKN	1	13.2	mg/L
RBP	RBP-3	6/3/1981	Nitrate + Nitrite	1	9.3	mg/L
RBP	RBP-3	8/24/1981	Nitrate + Nitrite	1	4	mg/L
RBP	RBP-3	5/9/1988	Nitrate + Nitrite	1	4.6	mg/L
RBP	RBP-3	6/30/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-3	7/11/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-3	8/8/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-3	9/27/1988	Nitrate + Nitrite	1	0.1	mg/L
RBP	RBP-3	10/25/1988	Nitrate + Nitrite	1	0.13	mg/L
RBP	RBP-3	5/31/1994	Nitrate + Nitrite	1	3.6	mg/L
RBP	RBP-3	6/29/1994	Nitrate + Nitrite	1	0.05	mg/L
RBP	RBP-3	7/26/1994	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-3	8/31/1994	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-3	9/28/1994	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-3	4/21/1998	Nitrate + Nitrite	1	7.23	mg/L
RBP	RBP-3	6/11/1998	Nitrate + Nitrite	1	11.5	mg/L
RBP	RBP-3	7/29/1998	Nitrate + Nitrite	1	2.14	mg/L
RBP	RBP-3	8/17/1998	Nitrate + Nitrite	1	0.91	mg/L
RBP	RBP-3	10/7/1998	Nitrate + Nitrite	1	0.01	mg/L

RBP	RBP-3	5/7/2001	Nitrate + Nitrite	1	0.33	mg/L
RBP	RBP-3	7/2/2001	Nitrate + Nitrite	1	0.82	mg/L
RBP	RBP-3	7/26/2001	Nitrate + Nitrite	1	0.8	mg/L
RBP	RBP-3	8/21/2001	Nitrate + Nitrite	1	0.01	mg/L
RBP	RBP-3	10/15/2001	Nitrate + Nitrite	1	3.1	mg/L
RBP	RBP-3	6/3/1981	Total Phosphorus	1	0.06	mg/L
RBP	RBP-3	8/24/1981	Total Phosphorus	1	0.07	mg/L
RBP	RBP-3	5/9/1988	Total Phosphorus	1	0.05	mg/L
RBP	RBP-3	6/30/1988	Total Phosphorus	1	0.19	mg/L
RBP	RBP-3	7/11/1988	Total Phosphorus	1	0.23	mg/L
RBP	RBP-3	8/8/1988	Total Phosphorus	1	0.11	mg/L
RBP	RBP-3	9/27/1988	Total Phosphorus	1	0.2	mg/L
RBP	RBP-3	10/25/1988	Total Phosphorus	1	0.17	mg/L
RBP	RBP-3	5/31/1994	Total Phosphorus	1	0.08	mg/L
RBP	RBP-3	6/29/1994	Total Phosphorus	1	0.1	mg/L
RBP	RBP-3	7/26/1994	Total Phosphorus	1	0.49	mg/L
RBP	RBP-3	8/31/1994	Total Phosphorus	1	0.48	mg/L
RBP	RBP-3	9/28/1994	Total Phosphorus	1	0.32	mg/L
RBP	RBP-3	4/21/1998	Total Phosphorus	1	0.08	mg/L
RBP	RBP-3	6/11/1998	Total Phosphorus	1	0.12	mg/L
RBP	RBP-3	7/29/1998	Total Phosphorus	1	0.19	mg/L
RBP	RBP-3	8/17/1998	Total Phosphorus	1	0.12	mg/L
RBP	RBP-3	10/7/1998	Total Phosphorus	1	0.15	mg/L
RBP	RBP-3	5/7/2001	Total Phosphorus	1	0.06	mg/L
RBP	RBP-3	7/2/2001	Total Phosphorus	1	0.2	mg/L
RBP	RBP-3	7/26/2001	Total Phosphorus	1	0.17	mg/L
RBP	RBP-3	8/21/2001	Total Phosphorus	1	0.32	mg/L
RBP	RBP-3	10/15/2001	Total Phosphorus	1	0.37	mg/L
RBP	RBP-3	6/3/1981	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-3	8/24/1981	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-3	4/21/1998	Dissolved Phosphorus	1	0.01	mg/L
RBP	RBP-3	6/11/1998	Dissolved Phosphorus	1	0.07	mg/L
RBP	RBP-3	7/29/1998	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-3	8/17/1998	Dissolved Phosphorus	1	0.03	mg/L
RBP	RBP-3	10/7/1998	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-3	5/7/2001	Dissolved Phosphorus	1	0.02	mg/L
RBP	RBP-3	7/2/2001	Dissolved Phosphorus	1	0.04	mg/L
RBP	RBP-3	7/26/2001	Dissolved Phosphorus	1	0.03	mg/L
RBP	RBP-3	8/21/2001	Dissolved Phosphorus	1	0.04	mg/L
RBP	RBP-3	10/15/2001	Dissolved Phosphorus	1	0.31	mg/L
RBP	RBP-3	6/3/1981	Chlorophyll-a	3	7.1	µg/L
RBP	RBP-3	8/24/1981	Chlorophyll-a	3	41.3	µg/L
RBP	RBP-3	4/21/1998	Chlorophyll-a	2	10.68	µg/L
RBP	RBP-3	6/11/1998	Chlorophyll-a	1	248.31	µg/L
RBP	RBP-3	7/29/1998	Chlorophyll-a	1	69.4	µg/L
RBP	RBP-3	10/7/1998	Chlorophyll-a	1	101	µg/L
RBP	RBP-3	5/7/2001	Chlorophyll-a	2	61.3	µg/L
RBP	RBP-3	7/2/2001	Chlorophyll-a	2	106	µg/L
RBP	RBP-3	7/26/2001	Chlorophyll-a	2	54.7	µg/L

RBP	RBP-3	8/21/2001	Chlorophyll-a		1	133	µg/L
RBP	RBP-3	10/15/2001	Chlorophyll-a		2	2.32	µg/L

Lake Oakland TMDL Implementation Plan

FINAL REPORT

March 6, 2008

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

Submitted by:
Tetra Tech

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As part of the Section 303(d) listing process, the Illinois Environmental Protection Agency identified both Lake Oakland and Walnut Point Lake as impaired. A comprehensive review of the available water quality data confirmed the Lake Oakland total phosphorus (TP) impairment, whereas additional data were determined to be needed for Walnut Point Lake. Those data were collected, the impairment was confirmed, and a phosphorus TMDL for Walnut Point Lake was approved by EPA in October 2007. The Walnut Point Lake TMDL results are available in a separate report. Illinois water quality standards require that total phosphorus concentrations within lakes not exceed 0.05 mg/L. Historic sampling within Lake Oakland indicates that this standard is routinely exceeded with TP concentrations averaging 0.18 mg/L.

Continuous flow and TP data are not available for the Hog Branch tributary upstream of Lake Oakland. Loads to the lake were therefore estimated based on data from a comparable watershed and these loads were input to the BATHTUB model to determine the load reductions necessary to meet the 0.05 mg/L water quality standard. The BATHTUB analysis indicated that an 80 percent reduction in loads is necessary to meet the 0.05 mg/L standard during each of the modeled years and the U.S. Environmental Protection Agency approved a Total Maximum Daily Load (TMDL) report in September 2005 that included this recommendation. This report addresses all potential sources of TP to Lake Oakland and discusses alternatives for achieving the desired load reductions.

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1.0 INTRODUCTION

The Clean Water Act and USEPA regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters identified as impaired on the Section 303(d) lists. Lake Oakland, located in east-central Illinois, appeared on the Illinois 2004 Section 303(d) list of impaired waters as described in Table 1-1.

Table 1-1. 2004 303(d) List Information for Lake Oakland.

Segment (size)	Name	Designated Uses and Support Status	Causes of Impairment	Potential Sources of Impairment
RBP (27.6 acres)	Lake Oakland[1]	Non supported–Primary Contact (swimming), Secondary Contact (recreation) Partially supported–Overall Use, Aquatic Life, Drinking Water Supply Fully–Fish Consumption	Total Phosphorus, Excessive Algal Growth, Suspended Solids, Sedimentation/Siltation	Agriculture– crop related sources, non–irrigated crop production, animal holding/management areas Habitat modification– streambank mod/destabilization Source unknown

Source: Illinois EPA, 2004.
[1] In February 2003, the City of Oakland began purchasing water from the Embarras Area Water District Public Water Supply. At that time the use of Lake Oakland as a water source was discontinued.

IEPA is currently developing TMDLs for pollutants that have numeric water quality standards. Of the pollutants impairing Lake Oakland, total phosphorus is the only parameter with a numeric water quality standard. IEPA believes that addressing the phosphorus impairment for Lake Oakland should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. For example, reducing loads of phosphorus should result in less algal growth and some of the management measures taken to reduce phosphorus loads (e.g., reducing agricultural erosion) should also reduce loads of suspended solids.

This project is being initiated in three stages. Stage One was completed in the Spring of 2005 and involved the characterization of the watershed, an assessment of the available water quality data, and identification of potential technical approaches. Stage Two involved additional data collection for waters where a TMDL could not yet be developed; Stage Two was not conducted for Lake Oakland because sufficient data were already available. Stage Three involved model development and calibration, TMDL scenarios, and implementation planning and the TMDL report was approved by USEPA in September 2005. This report presents the implementation plan portion of Stage Three.

The TMDL for Lake Oakland was based on application of the U.S. Army Corps of Engineers BATHTUB model. The total phosphorus loads required to simulate the observed concentrations with the BATHTUB model are listed in Table 1-2.

Table 1-2. Watershed Loading To Lake Oakland.

Year	Average Stream flow (cubic feet per second)	TP (1000 kg/yr)	TP (lbs/yr)
1992	23	4.2	9,260
1993	36	6.2	13,670
1994	19	3.1	6,830
1995	17	2.9	6,390
1996	25	5.7	12,570
1997	13	1.8	3,970
1998	32	6.5	14,330
1999	20	3.4	7,500
2000	13	1.3	2,870
2001	23	3.6	7,940
2002	35	8	17,640
2003	11	1.9	4,190
1992 to 2003 Average	22	4.1	8,930

The BATHTUB model was used to identify the load reductions necessary to achieve a target concentration of 0.05 mg/L total phosphorus. A 91 percent load reduction is needed to meet the target during all modeled years. However, no observed TP data are available for the critical modeled year (2002) and the predicted TP concentrations for this year are considerably higher than in any of the observed years. The TMDL is therefore based on the load reduction (80 percent) that is needed to meet the TP target during all years with observed data (i.e., 1992, 1998, and 2001). Table 1-3 shows the predicted annual average total phosphorus concentrations with an 80 percent reduction in loads. The table indicates that during most years an 80 percent reduction in loads will result in lake water quality being significantly less than the water quality standard, thus providing an added margin of safety.

Table 1-3. Average Total Phosphorus Concentration in Lake Oakland with 80 Percent Reduction in Loading.

Year	Lake Oakland TP (mg/L)	Lake Oakland Comparison to WQS
1992	0.030	-40%
1993	0.065	31%
1994	0.026	-47%
1995	0.015	-69%
1996	0.055	10%
1997	0.020	-60%
1998	0.048	-3%
1999	0.046	-7%
2000	0.008	-83%
2001	0.034	-32%
2002	0.100	100%
2003	0.016	-68%
1992 to 2003 Average	0.039	23%

The allocation of loads for the Lake Oakland TMDL is summarized in Table 1-4. The existing load is the average estimated load to the lake for the period 1992 to 2003. The loading capacity represents the 80 percent reduction from existing loads determined to be necessary from the modeling analysis. The wasteload allocation is zero because there are no permitted point sources in the Lake Oakland watershed. Five percent of the loading capacity is reserved for a margin of safety.

Table 1-4. TMDL Summary for Lake Oakland.

Category	Phosphorus (kg/yr)	Phosphorus (lbs/yr)	Phosphorus (lbs/day)
Existing Load	4,050	8,929	24.5
Loading Capacity	810	1,786	4.8
Wasteload Allocation	0	0	0
Margin of Safety	41	90	0.2
Load Allocation	769	1,695	4.6

The TMDL report for Lake Oakland, which has been approved by USEPA, suggests an 80 percent reduction in phosphorus loading to meet the water quality standard in the lake. This report presents an Implementation Plan that identifies feasible and cost-effective management measures capable of reducing phosphorus loads to the required levels. The purpose of the Implementation Plan is to provide information to local stakeholders regarding the selection of the most cost-effective best management practices (BMPs).

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2.0 DESCRIPTION OF WATERBODY AND WATERSHED CHARACTERISTICS

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

Lake Oakland is stream fed and is formed by a dam located on the west side of the lake. The dam was originally constructed in 1937 with an original capacity of 94 acre-feet. The lake has been periodically dredged over time due to sedimentation problems. The average depth of the lake is 3.9 feet with a maximum depth of 9 feet (during wet years) near the dam. The lake served as the sole source of drinking water to the City of Oakland until February 2003, when the city began purchasing water from the Embarras Area Water District Public Water Supply. At that time the use of Lake Oakland as a water source was discontinued.

Lake Oakland drains approximately 13,700 acres of land whereas the surface area of the lake is only 28 acres; the watershed area to lake surface area ratio is therefore very large (490:1). IEPA considers any lake with a ratio greater than 100:1 to be one where it will be difficult to attain adequate water quality (Illinois Environmental Protection Act, Subtitle C, Chapter II, Part 368).

Soils in the watershed have erodibility factors ranging from 0.20 to 0.37, indicating moderate soil erodibility. Figure 2-1 shows the distribution of erodible soils in the Lake Oakland watershed and indicates that the majority of the most erodible soils are located directly adjacent to the lake.

More than 95 percent of the watershed consists of agricultural land uses, with the primary crops being corn and soybeans (Figure 2-2). Urban land uses account for 2.1 percent of the land cover while wetlands and forest each represent less than one percent. All other cover types combined represent less that one percent of the watershed area.

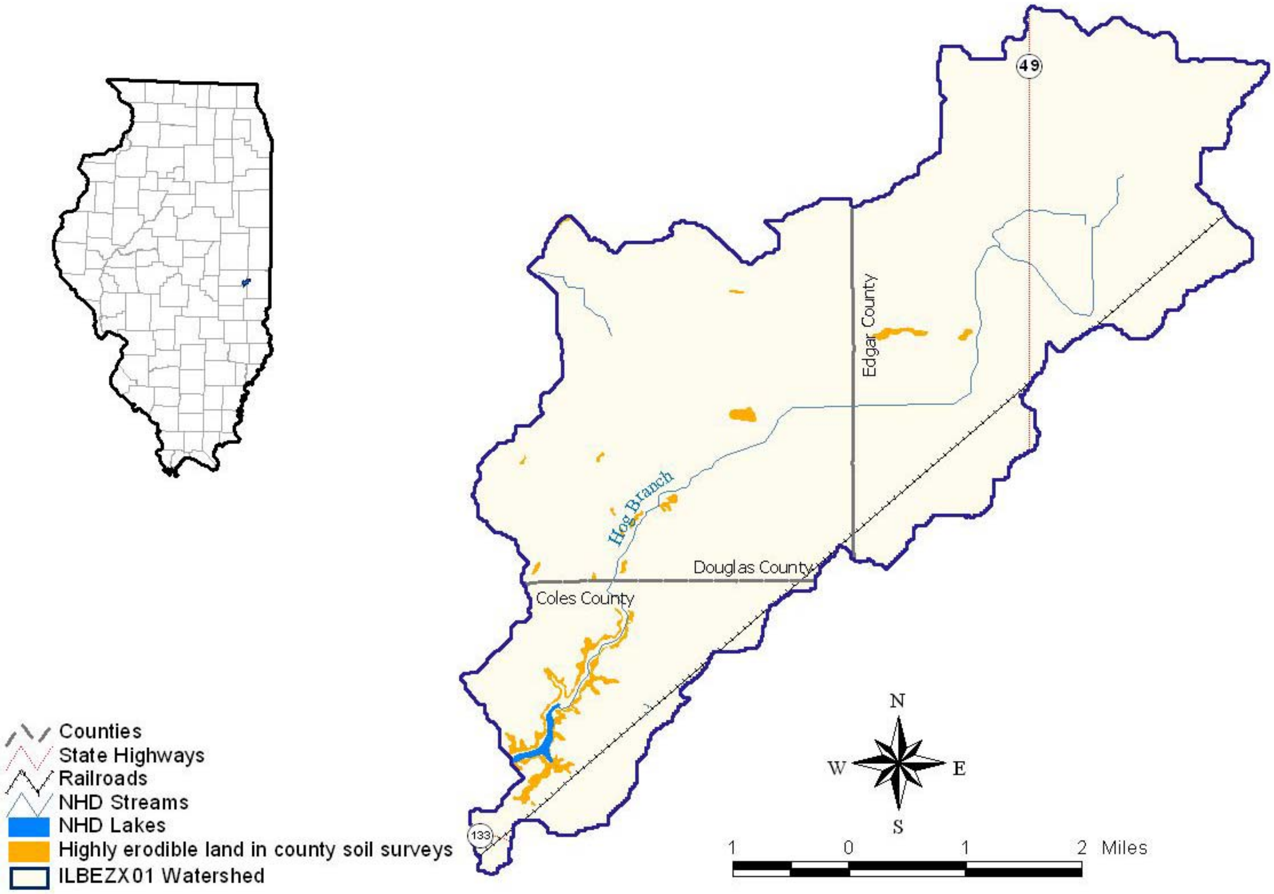

Figure 2-1. Highly Erodible Soils in the Lake Oakland Watershed.

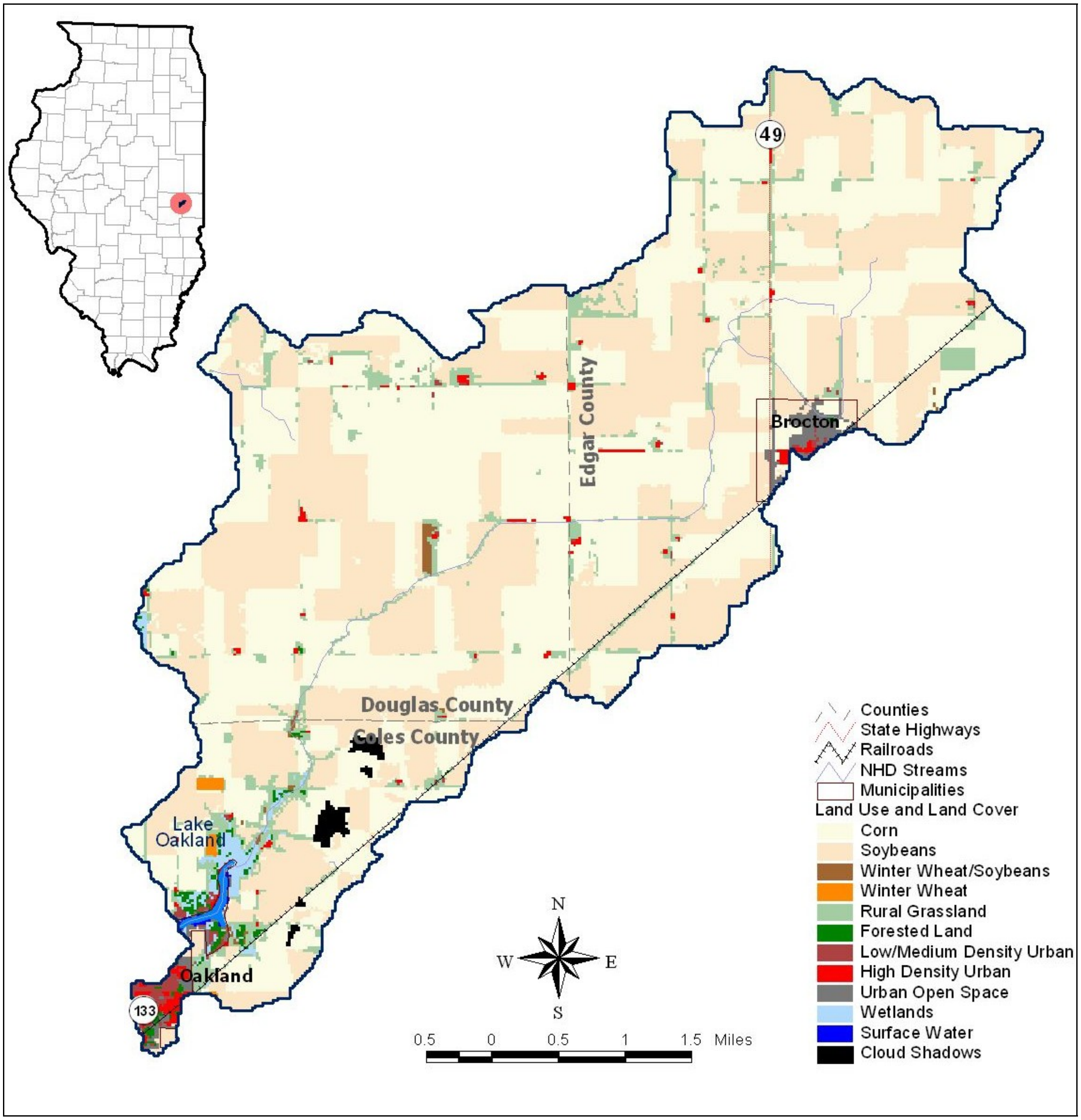

Figure 2-2. Land Use/Land Cover in the Lake Oakland Watershed.

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3.0 WATER QUALITY STANDARDS AND ASSESSMENT OF WATER QUALITY DATA

This section presents the applicable water quality standards and a summary of the historic water quality data for Lake Oakland. A more detailed discussion of the available water quality data is located in the Stage One Watershed Characterization Report.

3.1 Applicable Water Quality Standards

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

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

Numeric water quality standards have been adopted to correspond to these designated uses. The water quality standards require that total phosphorus concentrations remain at or below 0.05 mg/L.

3.2 Water Quality Assessment

Water quality data collected in Lake Oakland from 1981 to 2000 show that almost all the data collected at the surface (one foot depth) as well as at deeper depths violate the standard of 0.05 mg/L. TN:TP ratios are somewhat variable over the period of record but are generally much higher than 10. This suggests that phosphorus is the limiting nutrient in the lake (Chapra, 1997). The high variability might be due to multiple algal species (some that are nitrogen limited and some that are phosphorus limited) outcompeting one another during different periods of the year.

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4.0 POLLUTION SOURCES AND MANAGEMENT ACTIVITIES

As discussed in Section 2.0, more than 95 percent of the land is used for agricultural purposes in the Lake Oakland watershed. Other land uses include wetlands, forest, urban areas, and rural grasslands. This section of the report describes typical pollutant loading rates from each source category in the watershed along with appropriate best management practices (BMPs) to achieve a reduction in phosphorus loading. The TMDL allocation for Lake Oakland indicates that a reduction in phosphorus load of 80 percent is required to meet the Illinois water quality standard. This is a significant reduction and will thus require a combination of multiple BMPs.

4.1 WWTP/NPDES Permittees

There are no permitted direct discharges of phosphorus in the Lake Oakland watershed and so this report will not focus on the control of this source category.

4.2 Agricultural Land Uses

Because the majority of land in the Lake Oakland watershed (95 percent) is used for agricultural production, and no permitted discharges of phosphorus exist in the watershed, agriculture is likely the primary source of phosphorus loading to Lake Oakland. This section of the implementation plan describes the mechanisms of phosphorus loading from farmland and the corresponding management practices that have been employed in other watersheds to reduce loading. This report does not contain an exhaustive list of agricultural BMPs. Only cost-effective practices with demonstrated phosphorus removal capabilities are included. Currently, no confined animal operations are known to exist in the watershed, so that source is not considered in this plan.

4.2.1 Source Description and Approximate Loading

Accumulation of phosphorus on farmland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta, irrigation water, and application of waste products from municipal and industrial wastewater treatment facilities. Phosphorus is transported from agricultural land in both dissolved and particulate form. Losses occur through soil erosion, infiltration to groundwater and subsurface flow systems, and surface runoff. Crop harvesting also results in a phosphorus loss which should be accounted for when performing a field scale phosphorus balance. The USDA (2003) reports that crops utilize 30 percent of the phosphorus applied, and that, on average, 30 lb/ac/yr of phosphorus is lost via adsorption to soil particles or transport in runoff.

> *Adsorption refers to the processes that bind phosphorus to soil particles.*

4.2.1.1 Fertilizer Inputs

The majority of nutrient loading from farmland occurs from fertilization with commercial and manure fertilizers (USEPA, 2003). In heavily fertilized areas, soil phosphorus content has increased significantly over natural levels.

> *The majority of nutrient loading from farmland occurs from fertilization with commercial and manure fertilizers.*

Soil phosphorus tests are used to measure the phosphorus available for crop growth. Test results reported in parts per million (ppm) can be converted to lb/ac by multiplying by 2 (USDA, 2003). Based on a survey of state soil testing laboratories in 1997, 64 percent of soils in Illinois had high soil phosphorus test concentrations (> 50 ppm). By 2000, the percentage of soils testing high decreased to 58 percent (USDA, 2003). Guidelines in the Illinois Agronomy Handbook (IAH) recommend maintaining soil test phosphorus content in east-central Illinois at 22.5 ppm (45 lb/ac). Soils that test at or above 32.5 ppm (65 lb/ac) should not be fertilized until subsequent crop uptake decreases the test to 22.5 ppm (45 lb/ac) (IAH, 2002). Soil phosphorus tests should be conducted once every three or four years to monitor accumulation or depletion of phosphorus (USDA, 2003).

Phosphorus levels as high as 100 ppm have been observed in the Lake Oakland watershed. The minimum phosphorus level observed is 15 ppm, although this is not believed to be representative of the watershed (Coombes, 2007). Figure 4-1 shows the range of values observed in the Lake Oakland watershed along with the target maintenance level and level at which no additional phosphorus should be applied according to the IAH. The variability in measurements across the watershed illustrates the need for soil testing prior to fertilizer application.

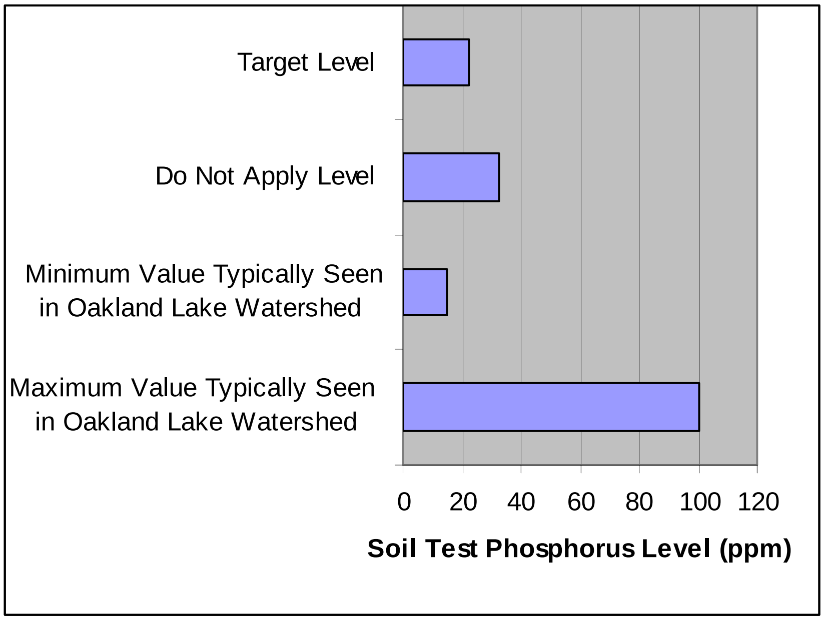


Figure 4-1. Soil Test Phosphorus Levels Measured in the Lake Oakland Watershed.

4.2.1.2 Tile Drain Systems

Tile drainage systems are used to lower the water table below the root zone to maximize crop yields on fields that otherwise would not be suitable for crop production. The systems allow for greater rates of infiltration by draining the soil profile more quickly. Runoff is reduced since more water is infiltrated to the groundwater zone, and as a result, rates of erosion and particulate pollutant transport are reduced. However, the concentrations of dissolved pollutants in the tile water tend to be higher relative to typical surface runoff. Because nitrate is a public health hazard at concentrations greater than 10 mg/L, most of the work concerning water quality impacts and appropriate BMPs for tile drain systems has focused on this parameter. Concerns with eutrophication and the role of phosphorus have prompted more recent studies for controlling this nutrient as well.

Tile drainage systems are used extensively in Illinois to lower the water table and increase the area of land available for agricultural production. Flows discharged from tile drainage systems located under high phosphorus content soils have significantly higher phosphorus concentrations than those under low to medium content soils. The majority of phosphorus transported through tile systems is in the dissolved form. However, particulate phosphorus is also transported as water passes through the soil profile and dislodges particles. Concentrations of both dissolved and particulate phosphorus increase significantly in tile systems following large rain events (Gentry et al., 2007).

The USDA (2003) reports that dissolved phosphorus concentrations in tile drainage increased dramatically above a soil test phosphorus breakpoint. One study showed a linear increase in tile drain phosphorus concentrations when the soil test concentration exceeded 60 ppm by the Olsen test or 100 ppm by the Bray-1 test (USDA, 2003; HWRCI, 2005). The maximum concentration occurred on soils testing at 110 ppm (Olsen test) with a tile drain dissolved phosphorus concentration of 2.75 mg/L. Researchers in Iowa found the breakpoint for increased tile drain phosphorus concentrations to be 80 ppm[1] (Mallarino, 2004).

Research conducted in other watersheds in east-central Illinois estimated that tile drains contribute 45 to 90 percent of the annual total phosphorus load from agricultural fields, depending on climate conditions (Gentry et al., 2007). It is recommended that sampling of tile drains be performed in the Lake Oakland watershed when the tile lines are running to determine the typical total and dissolved phosphorus concentrations.

Tile drains may contribute 45 to 90 percent of the total phosphorus load from agricultural fields in east-central Illinois.

4.2.1.3 Phosphorus Loading Rates

Phosphorus loading rates from agricultural lands vary widely based on climate, topography, soil characteristics, and farm management practices. IEPA (2004) estimated an average loading rate from row crop agriculture in the Altamont Reservoir watershed in Effingham County to be 1.7 lb/ac/yr based on GWLF modeling results. Loading rates from row crop agriculture to the Charleston Side Channel Reservoir are estimated to range from 2.1 to 3.5 lb/ac/yr based on SWAT modeling of the Upper Embarras River Watershed (IEPA, 2003). Neither of these models is capable of directly simulating tile drainage systems, though model parameters may be altered during calibration to approximate conditions.

Gentry et al. (2007) studied three heavily tiled watersheds in east-central Illinois with extensive row crop production. The average annual total phosphorus transport to streams from agricultural fields was estimated to be 0.41 to 0.67 lb/ac/yr based on instream measurements, with loads in high precipitation years ranging from 0.9 to 1.9 lb/ac/yr. Loads were estimated based on measurements taken near the mouth of each monitored stream; no discussion of instream phosphorus kinetics (plant uptake, soil adsorption, etc.) was included. Loads from one tile system were measured directly over a 2-year period. The tile system transported 0.1 to 1.2 lb/ac/yr of total phosphorus. Both dissolved reactive phosphorus and particulate bound phosphorus are transported through tile systems (Gentry et al., 2007).

To summarize Section 4.2.1:

- Agricultural lands are a primary source of phosphorus loading in the Lake Oakland watershed.
- A large fraction of the phosphorus load is directly or indirectly related to the application of fertilizer.
- Tile drain systems in the Lake Oakland watershed may transport a significant fraction of the total phosphorus load.
- Based on data collected in other heavily tiled, east-central Illinois watersheds, the phosphorus loading rate during a normal to dry year is approximately 0.5 lb/ac/yr, and during extremely wet years is approximately 1.5 lb/ac/yr. The BATHTUB modeling indicates that current average loading rates are approximately 0.64 lb/ac/yr (daily load times 365 days per year) and that an average load of 0.13 lb/ac/yr would be required to meet the water quality standard in the lake.

[1] The type of test (e.g., Olsen or Bray P-1) was not specified.

4.2.2 Appropriate BMPs

Phosphorus is typically exported from agricultural fields by overland flow or subsurface pathways. The contribution to each pathway depends on field topography, soil compaction, surface roughness, and use of artificial subsurface drainage systems. While tile drain systems are used extensively throughout east-central Illinois, the exact location and extent of these systems in the Lake Oakland watershed is not known.

Several structural and non-structural BMPs have been developed and studied for use in agricultural areas and some have already been employed in the Lake Oakland watershed (Table 4-1 and Figure 4-2). The following sections describe these BMPs in terms of removal mechanisms, effectiveness, and cost. Though the BMPs are presented individually, they typically must be used in combinations to mitigate hydrologic and water quality impacts. Some BMPs will be effective on all farms, regardless of drainage patterns. Others are only applicable to artificially drained fields. It will be up to the individual operator to determine the BMPs best suited for his or her operation.

Table 4-1. Summary of existing BMPs in the Lake Oakland watershed.

Practice	Area
Grass Waterways, noneasement	9.1 Acres
Filter Strips	13.71 Acres
Terraces	4,752 feet
Buffer Strips	10.4 Acres
Grasses	16.8 Acres
No-Till	286 Acres

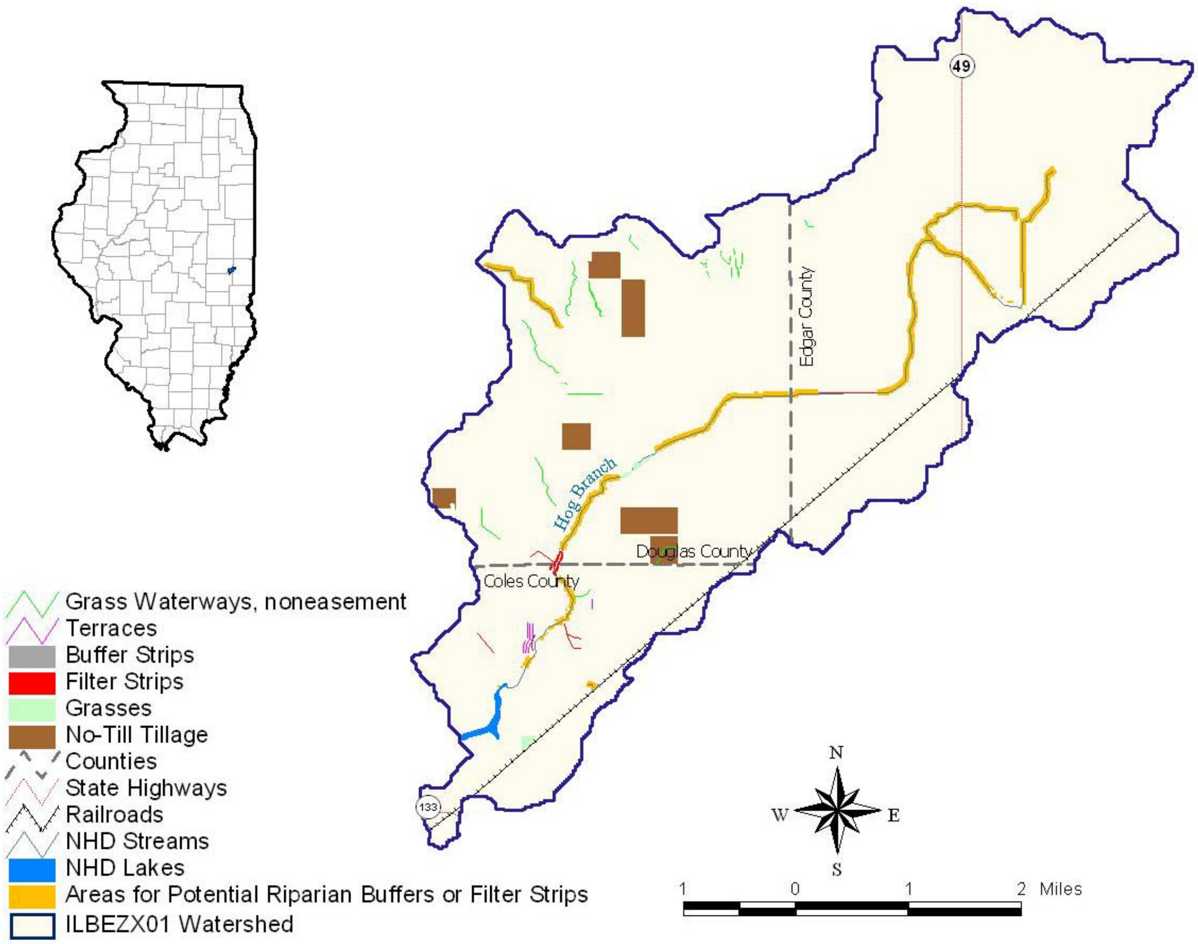


Figure 4-2. Existing BMPs in the Lake Oakland Watershed and areas potentially suitable for riparian buffers or filter strips.

4.2.2.1 Nutrient Management Plans

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

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

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

The IAH lists guidelines for fertilizer application rates based on the inherent properties of the soil (typical regional soil phosphorus concentrations, root penetration, pH, etc.), the starting soil test phosphorus concentration for the field, and the crop type and expected yield (IAH, 2002). If the starting soil test phosphorus concentration is less than 22.5 ppm, the IAH suggests building up the phosphorus levels over a four year period to achieve a soil test phosphorus concentration of 22.5 ppm (45 lb/ac). At starting concentrations greater than 32.5 ppm (65 lb/ac), the IAH recommends that no phosphorus be applied until subsequent crop uptake reduces the starting value to 22.5 ppm (45 lb/ac). Table 4-2 and Table 4-3 summarize the buildup, maintenance, and total application rates for various starting soil test concentrations for sample corn and soybean yields, respectively. For a complete listing of buildup and maintenance rates for the three availability zones and varying yields of corn, soybeans, oats, wheat, and grasses, see Chapter 11 of the IAH.

Starting Soil Test Phosphorus	***Fertilization Guidelines***
Less than 22.5 ppm:	*Buildup plus maintenance*
Between 22.5 and 32.5 ppm:	*Maintenance only*
Greater than 32.5 ppm:	*None*

Table 4-2. Suggested Buildup and Maintenance Application Rates of P_2O_5 for Corn Production in the Medium Inherent Phosphorus Availability Zone (IAH, 2002).

Starting Soil Test P ppm (lb/ac)	Buildup P_2O_5 (lb/ac)[1]	Maintenance P_2O_5 (lb/ac)[2]	Total P_2O_5 (lb/ac)
10 (20)	56	71	127
15 (30)	34	71	105
20 (40)	11	71	82
22.5 (45)	0	71	71
25 (50)	0	71	71
30 (60)	0	71	71
32.2 (65) or higher	0	0	0

[1] Rates based on buildup for four years to achieve target soil test phosphorus of 22.5 ppm (45 lb/ac).
[2] Maintenance rates assume a corn yield of 165 bushels per acre. The IAH lists maintenance rates discretely for yields of 90 to 200 bushels per acre.

Table 4-3. Suggested Buildup and Maintenance Application Rates of P_2O_5 for Soybean Production in the Medium Inherent Phosphorus Availability Zone (IAH, 2002).

Starting Soil Test P ppm (lb/ac)	Buildup P_2O_5 (lb/ac)[1]	Maintenance P_2O_5 (lb/ac)[2]	Total P_2O_5 (lb/ac)
10 (20)	56	51	107
15 (30)	34	51	85
20 (40)	11	51	62
22.5 (45)	0	51	51
25 (50)	0	51	51
30 (60)	0	51	51
32.2 (65) or higher	0	0	0

[1] Rates based on buildup for four years to achieve target soil test phosphorus of 22.5 ppm (45 lb/ac).
[2] Maintenance rates assume a soybean yield of 60 bushels per acre. The IAH lists maintenance rates discretely for yields of 30 to 100 bushels per acre.

Nutrient management plans also address methods of application. Fertilizer may be applied directly to the surface, placed in bands below and to the side of seeds, or incorporated in the top several inches of the soil profile through drilled holes, injection, or tillage. Surface applications that are not followed by incorporation may result in accumulation of phosphorus at the soil surface and increased dissolved phosphorus concentrations in surface runoff (Mallarino, 2004). Incorporation of fertilizer to a minimum depth of two inches prior to planting has shown a decrease in dissolved phosphorus runoff concentrations of 60 to 70 percent and reductions in total phosphorus runoff concentrations of 20 percent (HWRCI, 2005). Subsurface application, such as deep placement, has similar impacts on dissolved phosphorus in runoff with reductions in total phosphorus of 20 to 50 percent (HWRCI, 2005).

Methods of phosphorus application have shown no impact on crop yield (Mallarino, 2004). The Champaign County Soil and Water Conservation District (CCSWCD) reports that deep placement of phosphorus in bands next to the seed zone requires only one-third to one-half the amount of phosphorus fertilizer to achieve the same yields and that on average, fertilizer application rates were decreased by 13 lb/ac (Stikkers, 2007). Thus, deep placement will not only reduce the amount of phosphorus available for transport, but will also result in lower fertilizer costs. Figure 4-3 shows the deep placement attachment used by the CCSWCD.

Phosphorus application rates may be reduced by one-third to one-half with deep placement.

(Photo Courtesy of CCSWCD)

Figure 4-3. Deep Placement Phosphorus Attachment Unit for Strip-till Toolbar.

For corn-soybean rotations, it is recommended that phosphorus fertilizer be applied once every two years, following harvest of the corn crop if application consists of broadcast followed by incorporation (UME, 1996). Band placement should occur prior to or during corn planting, depending on the type of field equipment available. In this watershed, most fertilizer is applied after bean harvest and before corn planting (Sample, 2007). Fertilizer should be applied when the chance of a large precipitation event is low. Researchers in Iowa found that runoff concentrations of phosphorus were 60 percent lower when the following precipitation event occurred 10 days after fertilizer application, as opposed to 24 hours after application. Application to frozen ground or snow cover should be strongly discouraged. Researchers studying loads from agricultural fields in east-central Illinois found that fertilizer application to frozen ground or snow followed by a rain event could transport 40 percent of the total annual phosphorus load (Gentry et al., 2007).

Check the weather forecast before applying fertilizer. Apply fertilizer only when the chance of heavy rain is low.

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

The effectiveness of nutrient management plans (application rates, methods, and timing) in reducing phosphorus loading from agricultural land will be site specific. Average reductions of total phosphorus load in Pennsylvania are reported at 35 percent (USEPA, 2003). Total phosphorus load reductions with subsurface application at agronomic rates are reported at 20 to 50 percent (HWRCI, 2005).

4.2.2.2 Tillage Practices

Conservation tillage practices and residue management are commonly used to control erosion and surface transport of pollutants from fields used for crop production. The IAH (2002) defines conservation tillage as any tillage practice that results in at least 30 percent coverage of the soil surface by crop residuals after planting. Tillage practices leaving 20 to 30 percent residual cover after planting reduce erosion by approximately 50 percent compared to bare soil. Practices that result in 70 percent residual cover reduce erosion by approximately 90 percent (IAH, 2002). The residuals not only provide erosion control, but also provide a nutrient source to growing plants, and continued use of conservation tillage results in a more productive soil with higher organic and nutrient content. Increasing the organic content of soil has the added benefit of reducing the amount of carbon in the atmosphere by storing it in the soil. Researchers estimate that croplands and pasturelands could be managed to trap 5 to 17 percent of the greenhouse gases produced in the United States (Lewandrowski et al., 2004).

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

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

The NRCS provides additional information on these conservation tillage practices:

no-till and strip till:	http://efotg.nrcs.usda.gov/references/public/IL/329a.pdf
ridge till:	http://efotg.nrcs.usda.gov/references/public/IL/329b.pdf
mulch till:	http://efotg.nrcs.usda.gov/references/public/IL/329c.pdf

Tillage system practices are not available specifically for the Lake Oakland watershed. However, countywide tillage system surveys have been undertaken by the Illinois Department of Agriculture (2006) and are available for Coles, Douglas, and Edgar Counties. It is assumed that the general tillage practice trends evidenced throughout these counties are applicable to the watershed. The results of these surveys are presented in Table 4-4. The table shows that the percentage of fields in conventional tillage, averaged across all counties and crop types, is approximately 36 percent.

Table 4-4. Percentage of Agricultural Fields Surveyed with Indicated Tillage System in Edgar, Coles, and Douglas Counties, Illinois, in 2006.

2006 Transect Survey					
County	Crop Field Type	Tillage Practice			
		Conventional	Reduced-till	Mulch-till	No-till
Edgar County	Corn	48	21	4	27
	Soybean	7	21	10	63
	Small Grain	0	67	33	0
Coles County	Corn	72	16	8	4
	Soybean	13	40	16	31
	Small Grain	0	50	17	33
Douglas County	Corn	83	8	0	8
	Soybean	18	36	2	43
	Small Grain	80	0	20	0

Source: Illinois Department of Agriculture, 2006.

Corn residues are more durable and capable of sustaining the required 30 percent cover required for conservation tillage. Soybeans generate less residue, the residue degrades more quickly, and supplemental measures or special care may be necessary to meet the 30 percent cover requirement (UME, 1996). Figure 4-4 shows a comparison of ground cover under conventional and conservation tillage practices.

Figure 4-4. Comparison of conventional (left) and conservation (right) tillage practices.

No-till systems typically concentrate phosphorus in the upper two inches of the soil profile due to surface application of fertilizer and decomposition of plant material (IAH, 2002; UME, 1996). This pool of phosphorus readily mixes with precipitation and can lead to increased concentrations of dissolved phosphorus in surface runoff. Chisel plowing may be required once every several years to reduce stratification of phosphorus in the soil profile.

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

4.2.2.3 Cover Crop

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

Cover crops alone may reduce soil and runoff losses by 50 percent, and when used with no-till systems may reduce soil loss by more than 90 percent (IAH, 2002). On naturally drained fields where surface runoff is the primary transport mechanism of phosphorus, reduction in phosphorus loading would be substantial as well. In Oklahoma, use of cover crops resulted in 70 to 85 percent reductions in total phosphorus loading (HRWCI, 2005) (cropping rotation was not described). Cover crops have the added benefit of reducing the need for pesticides and fertilizers (OSUE, 1999), and are also used in conservation tillage systems following low residue crops such as soybeans (USDA, 1999). Use of cover crops is illustrated in Figure 4-5.

(Photo Courtesy of CCSWCD)

Figure 4-5. Use of Cover Crops.

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

4.2.2.4 Vegetative Controls

Other phosphorus control measures for agricultural land use include vegetated filter strips, grassed waterways, and riparian buffers. The USDA (2003) does not advocate using these practices solely to control phosphorus loading, but rather as supplemental management measures following operational strategies. USEPA (2003) lists the percent effectiveness of vegetative controls on phosphorus removal at 75 percent.

Vegetated Filter Strips

Filter strips are used in agricultural and urban areas to intercept and treat runoff before it leaves the site. If topography allows, filter strips may also be used to treat effluent from tile drain outlets. Filter strips will require maintenance, including grading and seeding, to ensure distributed flow across the filter and protection from erosion. Periodic removal of vegetation will encourage plant growth and uptake and remove nutrients stored in the plant material. Filter strips are most effective on sites with mild slopes of generally less than 5 percent, and to prevent concentrated flow, the upstream edge of a filter strip should follow one elevation contour (NCDENR, 2005). A grass filter strip is shown in Figure 4-6.

(Photo Courtesy of CCSWCD)

Figure 4-6. Grass Filter Strip Protecting Stream from Adjacent Agriculture.

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

Filter strips also serve to reduce the quantity and velocity of runoff. Filter strip sizing is dependent on site specific features such as climate and topography, but at a minimum, the area of a filter strip should be no less than 2 percent of the drainage area for agricultural land (OSUE, 1994). The minimum filter strip width suggested by NRCS (2002) is 30 ft. The strips are assumed to function properly with annual maintenance for 30 years before requiring replacement of soil and vegetation. Filter strips have been found to effectively remove pollutants from agricultural runoff. Reductions in phosphorus loading of 65 percent are reported (USEPA, 2003; Kalita, 2000). Figure 4-2 shows areas in the watershed that potentially could benefit from the installation of filter strips based on satellite imagery suggesting that streams are draining through row crops.

Grassed Waterways

Grassed waterways are stormwater conveyances lined with grass that prevent erosion of the transport channel. In addition, the grassed channel reduces runoff velocities, allows for some infiltration, and filters out some particulate pollutants. Phosphorus reductions for grassed waterways are reported at 30 percent (Winer, 2000). A grassed waterway providing surface drainage for a corn field is shown in Figure 4-7.

(Photo Courtesy of CCSWCD)

Figure 4-7. Grassed Waterway.

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

Creation of Riparian Buffers

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

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

Even more important than the filtering capacity of the buffers is the protection they provide to streambanks. The rooting systems of the vegetation serve as reinforcements in streambank soils, which helps to hold streambank material in place and minimize erosion. Due to the increase in stormwater runoff volume and peak rates of runoff associated with agriculture and development, stream channels are subject to greater erosional forces during stormflow events. Thus, preserving natural vegetation along stream channels minimizes the potential for water quality and habitat degradation due to streambank erosion and enhances the pollutant removal of sheet flow runoff from developed areas that passes through the buffer.

Converting land adjacent to streams for the creation of riparian buffers will provide stream bank stabilization, stream shading, and nutrient uptake and trapping from adjacent treated areas**.** A GIS analysis of land use within 25 feet of the streams in the Lake Oakland watershed indicates that 82 percent of the land is currently farmed; 6.5% percent is developed and the remaining areas are either forest or wetland.

Riparian buffers should consist of native species and may include grasses, grass-like plants, forbs, shrubs, and trees. Minimum buffer widths of 25 feet are required for water quality benefits. Higher removal rates are provided with greater buffer widths. NCSU (2002) reports phosphorus removal rates of approximately 25 to 30 percent for 30 ft wide buffers and 70 to 80 percent for 60 to 90 ft wide buffers. Riparian corridors typically treat a maximum of 300 ft of adjacent land before runoff forms small channels that short circuit treatment. In addition to the treated area, the land converted from agricultural land to buffer will generate 90 percent less phosphorus based on data presented in Haith et al. (1992). Buffer widths based on slope measurements and recommended plant species should conform to NRCS Field Office Technical Guidelines. A riparian buffer protecting the stream corridor from adjacent agricultural areas is shown in Figure 4-8. Figure 4-2 highlights areas in the watershed that have potential to house riparian buffers.

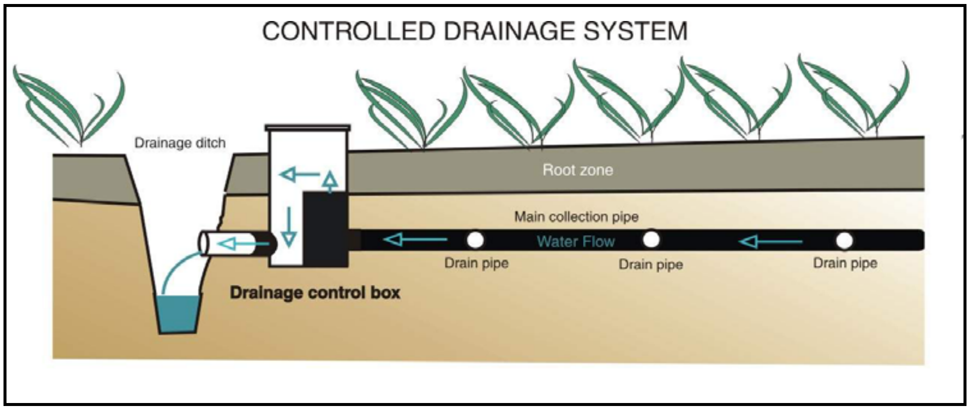
(Photo Courtesy of CCSWCD)

Figure 4-8. Riparian Buffer Between Stream Channel and Agricultural Areas.

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

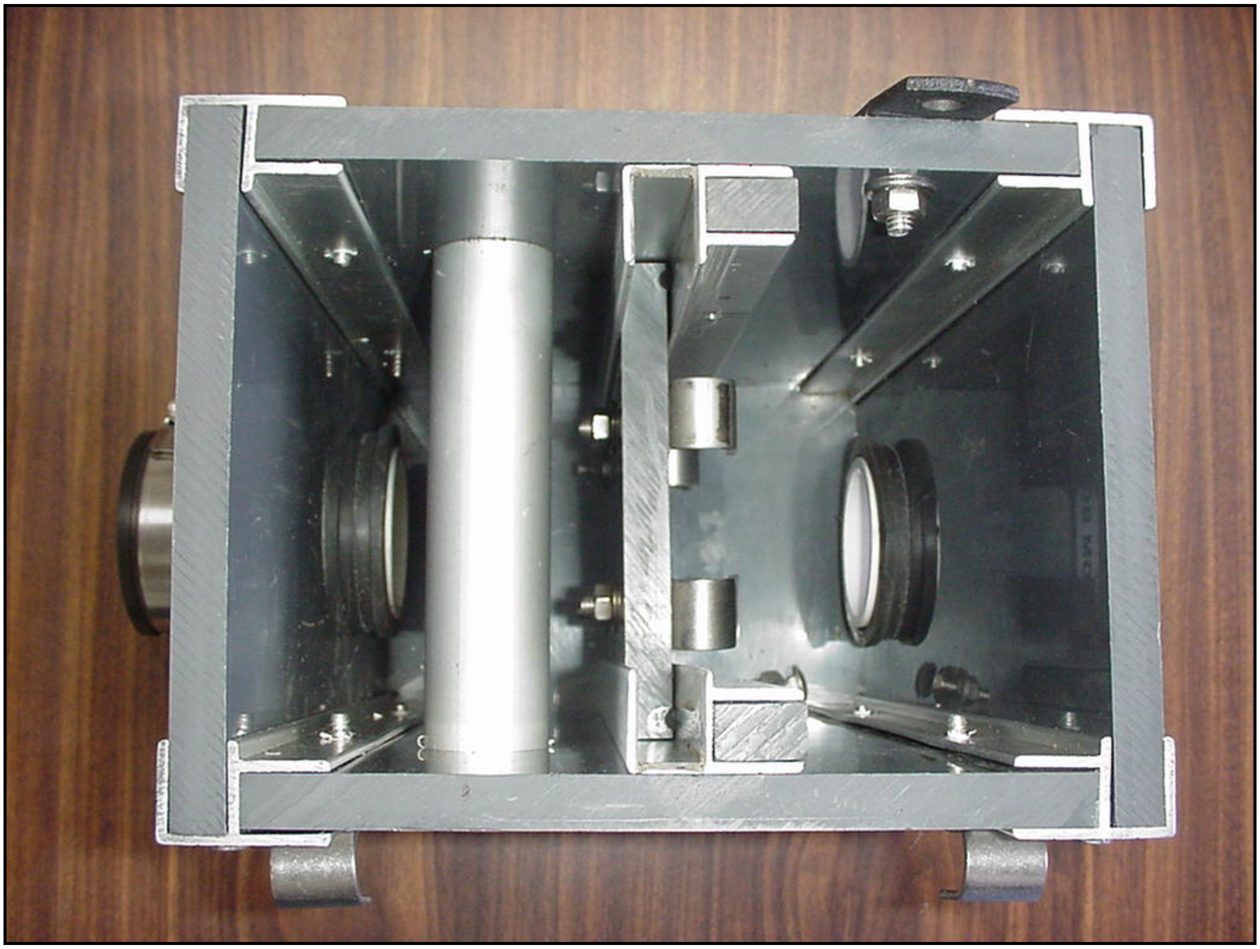
4.2.2.5 Drainage Control Structures for Tile Drain Outlets

A conventional tile drain system collects infiltrated water below the root zone and transports the water quickly to a down-gradient surface outlet. Placement of a water-level control structure at the outlet (Figure 4-9 and Figure 4-10) allows for storage of the collected water to a predefined elevation. The stored water becomes a source of moisture for plants during dry conditions and undergoes biological, chemical, and physical processes that result in lower nutrient concentrations in the final effluent. Use of control structures on conventional tile drain systems in the coastal plains has resulted in reductions of total phosphorus loading of 35 percent (Gilliam et al., 1997). Researchers at the University of Illinois also report reductions in phosphorus loading with tile drainage control structures. Concentrations of phosphate were reduced by 82 percent, although total phosphorus reductions were not quantified in this study (Cooke, 2005). Going from a surface draining system to a tile drain system with outlet control reduces phosphorus loading by 65 percent (Gilliam et al., 1997).



(Illustration Courtesy of the Agricultural Research Service Information Division)

Figure 4-9. Controlled Drainage Structure for a Tile Drain System.



(Photo Courtesy of CCSWCD)

Figure 4-10. Interior View of a Drainage Control Structure with Adjustable Baffle Height.

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

The main points discussed in Section 4.2.2 are summarized in the following list. In addition, Table 4-5 gives a brief description of each BMP as well as the reported reductions in phosphorus loading.

Section 4.2.2.1:

- Phosphorus fertilizer should be applied at rates suggested in the Illinois Agronomy Handbook depending on crop type, expected yield, and Bray P-1 soil test phosphorus level.
- Deep placement of phosphorus adjacent to the seed bed may reduce fertilizer application rates by one-third to one-half. Total phosphorus loading may be reduced by 20 to 50 percent.
- Fertilizer should be applied when the chance of precipitation is low (predicted by local weather forecasting). Fertilizer should never be applied to frozen ground or snow.

Section 4.2.2.2:

- Conservation tillage practices reduce erosion and add nutrients and organic material to the soil profile.
- No-till systems tend to concentrate phosphorus in the upper two inches of the soil and may result in increased concentrations of dissolved phosphorus in runoff.
- Strip till practices may reduce phosphorus loading from agricultural fields by 68 percent and no-till may reduce loads by 76 percent.

Section 4.2.2.3:

- Cover crops reduce erosion during winter months and contribute nitrogen to the following cash crop.
- Reductions in phosphorus loading range from 70 to 85 percent.

Section 4.2.2.4:

- Filter strips intercept and treat agricultural water before it leaves the field. Reductions in phosphorus are approximately 65 percent.
- Grassed waterways are vegetated channels designed to convey stormwater. Phosphorus load reductions are approximately 30 percent.
- Riparian buffers effectively remove phosphorus from a small area of adjacent land, and are essential for maintaining streambank stability, appropriate water temperatures, and adequate habitat. Phosphorus reductions from the area converted from agriculture to buffer are approximately 90 percent; the buffer should remove approximately 80 percent of the phosphorus from the adjacent 300 ft of agricultural area.

Section 4.2.2.5:

- Use of drain-control structures on tile drain outlets reserves water for crop use during dry periods.
- Reductions in dissolved phosphorus of 82 percent and total phosphorus of 35 percent have been documented.

Table 4-5. Phosphorus Removal BMPs for Agricultural Land Uses.

BMP	Description and Removal Mechanism	Estimated Phosphorus Reduction
Nutrient Management Plan	Site specific guidance on appropriate fertilization rates, methods of application, and timing. Appropriate application rates for optimized crop yield reduce loading from excessive nutrient application.	Depends on current application rates and methods compared to site specific guidance. Total phosphorus reductions of **20 to 50 percent** are reported (USEPA, 2003; HRWCI, 2005).
Conservation Tillage	Tillage practices that maintain a minimum of 30 percent ground cover with crop residuals. Reduces erosion rates and phosphorus losses. Increases soil quality by providing organic material and nutrient supplementation.	Strip till and no-till can reduce total phosphorus loads by **68 and 76 percent**, respectively (Czapar, 2006).
Cover Crop	Use of ground cover plants on fallow fields. Reduces erosion, provides organic materials and nutrients to soil matrix, reduces nutrient losses, suppresses weeds, and controls insects.	Total phosphorus reductions of **70 to 85 percent** are reported (HRWCI, 2005).
Filter Strips	Placement of vegetated strips in the path of field drainage to treat sediment and nutrients.	Total phosphorus reductions of **65 percent** are reported (USEPA, 2003; Kalita, 2000).
Grassed Waterway	A stormwater conveyance planted with grass to reduce erosion of the transport channel. Provides filtering of particulate pollutants and reduces runoff volume and velocity.	Total phosphorus reductions of **30 percent** are reported (Winer, 2000).
Restoration of Riparian Buffers	Conversion of land adjacent to stream channels to vegetated buffer zones. Removes phosphorus by sedimentation and plant uptake. Provides stream bank stability, stream shading, and aesthetic enhancement.	Riparian buffers may achieve an **80 percent** reduction in total phosphorus from treated areas, assuming a 90 ft buffer width (NCSU, 2002). Lands converted from agricultural use are estimated to have a **90 percent** reduction in total phosphorus loading (Haith et al, 1992).
Controlled Drainage, Retrofit	Use of outlet control structure to store tile drain water for crop use during dry periods.	Reductions in total phosphorus loading of **35 percent** are reported (Gilliam et al., 1997).
Controlled Drainage, New Tile System	Converting from a surface drained system to a tile drained system with outlet control structures.	Reductions in total phosphorus loading of **65 percent** are reported (Gilliam et al., 1997).

4.2.3 Estimated Cost of Implementation

The net costs associated with the agricultural BMPs described in Section 4.2.2 depend on the cost of construction (for structural BMPs), maintenance costs (seeding, grading, etc.), and operating costs (electricity, fuel, labor, etc). In addition, some practices require that land be taken out of farm production and converted to treatment areas, which results in a loss of income from the cash crop. On the other hand, taking land out of production does save money on future seed, fertilizer, labor, etc., and this must be accounted for as well. This section describes how the various costs apply to each BMP, and presents an estimate of the annualized cost spread out over the service life of the BMP. Incentive plans, carbon trading, and cost share programs are discussed separately in Section 7.0.

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

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

4.2.3.1 Nutrient Management Plans

A good nutrient management plan should address the rates, methods, and timing of fertilizer application. To determine the appropriate fertilizer rates, consultants in Illinois typically charge $6 to $18 per acre, which includes soil testing, manure analysis, scaled maps, and site specific recommendations for fertilizer management (USEPA, 2003**).**

Placing the fertilizer below and to the side of the seed bed (referred to as banding) reduces the required application by one third to one half to achieve the same crop yields**.** The Heartland Regional Water Coordination Initiative lists the cost for deep placement of phosphorus fertilizer at $3.50/ac per application (HRWCI, 2005).

Table 4-6 summarizes the assumptions used to develop the annualized cost for this BMP.

Table 4-6. Costs Calculations for Nutrient Management Plans.

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

4.2.3.2 Tillage Practices

Conservation tillage practices generally require fewer trips to the field, saving on labor, fuel, and equipment repair costs, though increased weed production may result in higher pesticide costs relative to conventional till (USDA, 1999). In general, conservation tillage results in increased profits relative to conventional tillage (Olson and Senjem, 2002; Buman et al., 2004; Czapar, 2006). The HRWCI (2005) lists the cost for conservation tillage at $0/ac.

Hydrologic inputs are often the limiting factor for crop yields and farm profits. Conservation practices reduce evaporative losses by covering the soil surface. USDA (1999) reports a 30 percent reduction in evaporative losses when 30 percent ground cover is maintained. Harman et al. (2003) and the Southwest Farm Press (2001) report substantial yield increases during dry years on farms managed with conservation or no-till systems compared to conventional till systems.

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

Table 4-7 summarizes the available information for determining average annual cost for this BMP.

Table 4-7. Costs Calculations for Conservation Tillage.

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

4.2.3.3 Cover Crop

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

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

Accounting for the seed cost, herbicide cost, and fertilizer offset results in an average net cost of approximately $19.25/ac assuming that cover crop planting recommendations for a typical 2 year corn/soybean rotation are followed (Mannering et al., 1998). These costs do not account for yield increases which may offset the costs completely. Table 4-8 summarizes the costs and savings associated with ryegrass and hairy vetch.

Table 4-8. Costs Calculations for Cover Crops.

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

4.2.3.4 Vegetative Controls

The BMPs discussed above are farm management strategies that are applied over large areas; costs are estimated for each acre of agricultural land operating with the BMP. The vegetated controls are structural BMPs that collect runoff from agricultural fields and treat it in small zone using infiltration, sedimentation, and plant uptake to remove phosphorus. To compare costs with the farm management BMPs, the cost analyses for these structural BMPs are listed as the cost to treat one acre of agricultural drainage.

Filter Strips

Filter strips can either be seeded with grass or sodded for immediate function. The seeded filter strips cost approximately $0.30 per sq ft to construct, and sodded filter strips cost approximately $0.70 per sq ft to construct. Assuming that the required filter strip area is 2 percent of the area drained (Section 4.2.2.4) means that 870 square feet of filter strip are required for each acre of agricultural land treated. The construction cost to treat one acre of land is therefore $261/ac for a seeded filter strip and $609/ac for a sodded strip. At an assumed system life of 20 years (Weiss et al., 2007), the annualized construction costs are $13/ac/yr for seeded and $30.50/ac/yr for sodded strips. Annual maintenance of filter strips is estimated at $0.01 per sq ft (USEPA, 2002b) for an additional cost of $8.70/ac/yr of agricultural land treated. In addition, the area converted from agricultural production to filter strip will result in a net annual income loss of $3.50. Table 4-9 summarizes the costs assumptions used to estimate the annualized cost to treat one acre of agricultural drainage using either a seeded or sodded filter strip.

Table 4-9. Costs Calculations for Seeded and Sodded Filter Strips.

Item	Costs of Seeded Filter Strip Required to Treat One Acre of Agricultural Land	Costs of Sodded Filter Strip Required to Treat One Acre of Agricultural Land
Costs per Square Foot		
Construction Costs	$0.30	$0.70
Annual Maintenance Costs	$0.01	$0.01
Costs to Treat One Acre of Agricultural Land (assuming 870 sq ft of filter strip)		
Construction Costs	$261	$609
System Life (years)	20	20
Annualized Construction Costs	$13	$30.50
Annual Maintenance Costs	$8.70	$8.70
Annual Income Loss	$3.50	$3.50
Average Annual Costs	**$25/ac treated**	**$43/ac treated**

Grassed Waterways

Grassed waterways costs approximately $0.50 per sq ft to construct (USEPA, 2002b). These stormwater conveyances are best constructed where existing bare ditches transport stormwater, so no income loss from land conversion is expected with this practice. It is assumed that the average area required for a grassed waterway is approximately 0.1 to 0.3 percent of the drainage area, or between 44 and 131 sq ft per acre. The range is based on examples in the Illinois Drainage Guide, information from the NRCS Engineering Field Handbook, and a range of waterway lengths (100 to 300 feet). Waterways are assumed to remove phosphorus effectively for 20 years before soil, vegetation, and drainage material need to be replaced (Weiss et al., 2007). The construction costs spread out over the life of the waterway is thus $2.25/yr for each acre of agriculture draining to a grassed waterway. Annual maintenance of grassed waterways is estimated at $0.02 per sq ft (Rouge River, 2001) for an additional cost of $1.75/ac/yr of agricultural land treated. Table 4-10 summarizes the annual costs assumptions for grassed waterways.

Table 4-10. Costs Calculations for Grassed Waterways.

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

Riparian Buffers

Restoration of riparian areas costs approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). Maintenance of a riparian buffer should be minimal, but may include items such as period inspection of the buffer, minor grading to prevent short circuiting, and replanting/reseeding dead vegetation following premature death or heavy storms. Assuming a buffer width of 90 ft on either side of the stream channel and an adjacent treated width of 300 ft of agricultural land, one acre of buffer will treat approximately 3.3 acres of adjacent agricultural land. The cost per treated area is thus $30/ac to construct and $142.50/ac to maintain over the life of the buffer. Assuming a system life of 30 years results in an annualized cost of $59.25/yr for each acre of agriculture land treated (Table 4-11).

Table 4-11. Costs Calculations for Riparian Buffers.

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

4.2.3.5 Drainage Control Structures for Tile Drain Outlets

Cooke (2005) estimates that the cost of retrofitting tile drain systems with outlet control structures ranges from $20 to $40 per acre. Construction of new tile drain systems with outlet control is approximately $75/ac. The yield increases associated with installation of tile drain systems are expected to offset the cost of installation (Cooke, 2005). It is assumed that outlet control structures have a system life of 30 years. Cost assumptions for retrofitting and installation of new tile drain systems with outlet control devices are summarized in Table 4-12.

Table 4-12. Costs Calculations for Outlet Control Devices on Tile Drain Systems.

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

Estimated net costs per acre of land managed or treated are summarized in Table 4-13 for each of the agricultural BMPs discussed in this plan. Costs were adjusted to reflect year 2004 prices for the Oakland, Illinois area and represent total annualized costs to maintain and construct. The total costs were derived without accounting for the difference in value between costs incurred in the first year of the project versus costs incurred over the lifetime of the project (this process is typically termed "discounting"). If discounting had been used, the comparison would change between projects with relatively high upfront costs and projects with relatively high annual costs. When selecting the BMPs, farmers should consider how the timing of costs affects their operation as well as the total relative differences.

Table 4-13. Estimated 2004 Costs of Agricultural BMPs for Lake Oakland Watershed

BMP	Annualize Cost per Acre Treated per Year
Nutrient Management Plan	$0.75/ac to $3.75/ac
Conservation Tillage	$1.25/ac to $2.25/ac
Cover Crops	$19.25/ac
Filter Strips, Seeded	$25/ac
Filter Strips, Sodded	$43/ac
Grassed Waterways	$2/ac to $6/ac
Restoration of Riparian Buffers	$59.25/ac
Controlled Drainage, Retrofit	$0.75/ac to $1.50/ac
Controlled Drainage, New	$2.50/ac

4.2.4 BMP Effectiveness and Estimated Load Reductions

Several BMPs are available for use in the Lake Oakland watershed to reduce phosphorus loading from agricultural areas. Selecting a BMP will depend on estimated removal efficiencies, construction and maintenance costs, and individual preferences. Table 4-14 summarizes the annualized costs (construction, maintenance, and operation) for each BMP to treat one acre of agricultural runoff. The removal efficiencies reported in the literature are included as well.

Table 4-14. Cost and Removal Efficiencies for Agricultural BMPs.

BMP	Total Phosphorus Percent Reduction	Annualize Cost per Acre Treated per Year
Nutrient Management Plan	20 to 50	$0.75/ac to $3.75/ac
Conservation Tillage	68 to 76	$1.25/ac to $2.25/ac
Cover Crops	70 to 85	$19.25/ac
Filter Strips, Seeded	65	$25/ac
Filter Strips, Sodded	65	$43/ac
Grassed Waterways	30	$2/ac to $6/ac
Restoration of Riparian Buffers	90, 80[1]	$59.25/ac
Controlled Drainage, Retrofit	35	$0.75 to $1.50/ac
Controlled Drainage, New	65	$2.50/ac

[1]Land converted to a buffer from agricultural production will have a 90 percent lower phosphorus loading rate (Haith et al., 1992). Loads from adjacent treated areas will have an 80 percent reduction in phosphorus loading (NCSU, 2002).

4.3 Livestock

4.3.1 Source Description and Approximate Loading

Cattle manure can be a substantial source of nutrient loading to streams, particularly where direct access is not restricted and/or where cattle feeding structures are located adjacent to riparian areas. Direct deposition of feces into streams may be a primary mechanism of nutrient loading during baseflow periods. During storm events, overbank and overland flow may entrain manure accumulated in riparian areas resulting in pulsed loads of nutrients into streams. In addition, cattle with unrestrained stream access typically cause severe streambank erosion. The impacts of cattle on stream ecosystems are shown in Figure 4-11 and Figure 4-12.

Figure 4-11. Typical Stream Bank Erosion in Pastures with Cattle Access to Stream.

Figure 4-12. Cattle-induced Streambank Mass Wasting and Deposition of Manure into Stream.

The NRCS provides additional information on fencing at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 382

4.3.2 Appropriate BMPs

Allowing limited or no animal access to streams will provide the greatest water quality protection. On properties where cattle need to cross streams to have access to pasture, stream crossings should be built so that cattle can travel across streams without degrading streambanks and contaminating streams with manure. Figure 4-13 shows an example of a reinforced cattle access point to minimize time spent in the stream and mass wasting of streambanks.

(Photo courtesy of USDA NRCS.)

Figure 4-13. Restricted Cattle Access Point with Reinforced Banks.

The NRCS provides additional information on use exclusion and controlled access at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 472

4.3.3 Estimated Cost of Implementation

The costs of excluding cattle from streams depends more on the length of channel that needs to be protected than the number of animals on site. Fencing may also be used in a grazing land protection operation to control cattle access to individual plots. Costs were published by the Iowa State University Cooperative Extension Service in 1999 on the World Wide Web. The system life of the wire fences was reported as 20 years; the high tensile fence materials have a reported system life of 25 years. NRCS reports that the average operation needs approximately 35 ft of additional fencing per head to protect grazing lands and streams. Table 4-15 presents the capital, maintenance, and annualized costs for four fencing materials based on the NRCS assumptions.

Table 4-15. Installation and Maintenance Costs of Fencing Material.

Material	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Woven Wire	$43.50	$3.50	$5.75
Barbed Wire	$33.50	$2.75	$4.50
High Tensile (non-electric) 8-strand	$30.75	$1.75	$3.00
High Tensile (electric) 5-strand	$23.00	$1.50	$2.50

4.3.4 Effectiveness and Estimated Load Reductions

Fencing cattle from streams and riparian areas using vegetative or fencing materials will reduce streambank trampling and direct deposition of fecal material in the streams. As a result, phosphorus loads will decrease. The USEPA (2003) reports reductions in phosphorus loading of 15 to 49 percent as a result of cattle exclusion practices. Because the existing loads from livestock in the Lake Oakland watershed could not be quantified, the estimated load reductions are not known.

4.4 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems are not typically a significant source of phosphorus loading if they are operating as designed. However, if the failure rates of systems in this watershed are high, then the loading from this source may be significant. At this time, no database of onsite wastewater treatment systems is available for the Lake Oakland watershed, so it is difficult to estimate the extent to which systems might be failing.

4.4.1 Source Description and Approximate Loading

Phosphorus loading rates from properly functioning onsite wastewater systems are typically insignificant. However, if systems are placed on unsuitable soils, not maintained properly, or are connected to subsurface drainage systems, loading rates to receiving waterbodies may be relatively high.

In a properly functioning septic system, wastewater effluent leaves the septic tank and percolates through the system drainfield. Phosphorus is removed from the wastewater by adsorption to soil particles. Plant uptake by vegetation growing over the drainfield is assumed negligible since all of the phosphorus is removed in the soil treatment zone. Failing systems that either short circuit the soil adsorption field or cause effluent to pool at the ground surface are assumed to retain phosphorus through plant uptake only (average annual uptake rate of 0.2 g/capita/day). Direct discharge systems intentionally bypass the drainfield by connecting the septic tank effluent directly to a waterbody or other transport line (such as an agricultural tile drain) so that no soil zone treatment or plant uptake occurs.

To approximate the phosphorus loading rate from onsite wastewater systems, a rough calculation based on the population density of the counties, the area of the watershed, and net loading rates reported in the Generalized Watershed Loading Function (GWLF) User's manual were assumed. Year 2000 US Census data for Edgar, Douglas, and Coles Counties indicate that the population in the watershed is approximately 713 people. Because no centralized treatment plants exist in Edgar County, it is assumed that the population residing in Brocton (339) also uses individual onsite systems for wastewater treatment. The Oakland Sewage Treatment Plant is assumed to treat wastewater from the urban population of Oakland (192). The total number of people assumed to be served by onsite systems is therefore 521 (713 minus 192).

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

In a properly functioning septic system, wastewater effluent leaves the septic tank and percolates through the system drainfield. Phosphorus is removed from the wastewater by adsorption to soil particles. Plant uptake by vegetation growing over the drainfield is assumed negligible since all of the phosphorus is removed in the soil treatment zone. Failing systems that either short circuit the soil adsorption field or cause effluent to pool at the ground surface are assumed to retain phosphorus through plant uptake only (average annual uptake rate of 0.2 g/capita/day). Direct discharge systems intentionally bypass the drainfield by connecting the septic tank effluent directly to a waterbody or other transport line (such as an agricultural tile drain) so that no soil zone treatment or plant uptake occurs.

The USEPA Onsite Wastewater Treatment Systems Manual (2002b) estimates that septic systems fail (do not perform as designed) at an average rate of 7 percent across the nation. Phosphorus loading rates under four scenarios were calculated to show the range of loading from this source. System failures were distributed evenly over the three failure types: short circuiting, ponding, and directly discharging. Table 4-16 shows the phosphorus load if 7, 15, 30, and 60 percent of systems in the watershed are failing.

Table 4-16. Failure Rate Scenarios and Resulting Phosphorus Loads to Lake Oakland.

Failure Rate[1] (%)	Average Annual Phosphorus Load (lb/yr)
7[2]	69
15	149
30	298
60	595

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

4.4.2 Appropriate BMPs

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

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

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

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

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

The county health departments are the agencies which administer septic tank regulations. The health departments are responsible for the issuance of septic installation permits and the inspection of newly constructed and/or renovated/repaired septic systems located in the counties. The counties require septic development to maintain a permit or registration as well as an inspection after it is put in. All three counties in this watershed inspect septic system compliance when a complaint is filed.

The Illinois EPA has proposed a new Clean Water Act general permit for private sewage disposal systems that discharge wastewater to the ground surface, storm sewers, streets, curbs, gutters, swales, ditches, streams, rivers, lakes or ponds. The proposed permit applies only to private surface discharging sewage disposal systems; conventional septic systems that discharge to a below-ground septic field are not required to be covered by this permit. The permit would limit how much fecal bacteria and other pollution the surface-discharging systems can emit. The permit would put in place a continuing system of maintenance and monitoring to reduce the chances that systems will fail and to catch them early if they do. The permit establishes one set of conditions rather than trying to re-write the parameters for every case.

4.4.3 Estimated Cost of Implementation

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

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

The cost of developing and maintaining a watershed-wide database of the onsite wastewater treatment systems in the Lake Oakland watershed depends on the number of systems that need to be inspected. Based on Census data collected in 2000, there are approximately 212 households in the watershed (521 people divided by 2.45 people in each home). After the initial inspection of each system and creation of the database, only systems with no subsequent maintenance records would need to be inspected. An inspection program in South Carolina found that inspections cost approximately $160 per system (Hajjar, 2000).

Education of home and business owners that use onsite wastewater treatment systems should occur periodically. Public meetings; mass mailings; and radio, newspaper, and TV announcements can all be used to remind and inform owners of their responsibility to maintain their systems (Table 4-17).

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

Table 4-17. Costs Associated with Maintaining and Replacing an Onsite Wastewater Treatment System.

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

4.4.4 Effectiveness and Estimated Load Reductions

It is difficult to estimate the phosphorus loading rate from septic systems in the Lake Oakland watershed because local estimates of failure rates are not available. Depending on the level of failure, septic systems in the watershed could contribute between 69 lb-P/yr and 595 lb-P/yr. The total annual cost for an initial inspection and periodic maintenance (pumping every three to five years) is approximately $100 to $120 per system per year.

4.5 Lake Bottom Sediments

Internal cycling of phosphorus from bottom sediments in Lake Oakland is not considered a significant source of phosphorus loading because there are limited periods of anoxic conditions which lead to release of phosphorus from the lake bottom. The lake is shallow and thermal stratification is unlikely to occur.

4.6 Precipitation and Atmospheric Deposition

Phosphorus loading from atmospheric deposition is not considered a significant fraction of the loading to Lake Oakland.

4.7 Shoreline Erosion

No information is currently available to assess the impacts of shoreline erosion to the water quality of Lake Oakland.

4.8 Stream Channel Erosion

The land use imagery shows that riparian buffers such as wetlands and forested land are present between the lake and adjacent farmlands. However, their extent in reducing phosphorus load to the lake are unknown. Stream channel erosion is a potential source of sediment and nutrient loading to streams and lakes. Inspection of the streambanks is needed to quantify the loading from this source.

4.8.1 Source Description and Approximate Loading

Without field inspections of the streambanks in the watershed, it is not possible to quantify the amount of phosphorus loading from this source. The most cost-effective way to assess streambank erosion is to visually inspect representative reaches of each channel and rank the channel stability using a bank erosion index. Banks ranked moderately to severely eroding should be targeted for stabilization efforts. A more time and resource intensive method is to determine the rate of erosion by inserting bank pins and measuring the rate of recession. Once soil loss estimates are obtained, phosphorus loading can be calculated from soil phosphorus contents.

4.8.2 Appropriate BMPs

Streambanks in the Lake Oakland watershed should be inspected for signs of erosion. Banks showing moderate to high erosion rates (indicated by poorly vegetated reaches, exposed tree roots, steep banks, etc.) can be stabilized by engineering controls, vegetative stabilization, and restoration of riparian areas. Peak flows and velocities from runoff areas can be mitigated by infiltration in grassed waterways and passage of runoff through filter strips.

4.8.3 Estimated Cost of Implementation

Because the extent of streambank erosion in the watershed is not known, specialized BMPs, such as engineering controls, are not suggested. Rather, the agricultural BMPs discussed in Section 4.2 that also address streambank stability are recommended (Table 4-18).

Table 4-18. Agricultural Phosphorus BMPs with Secondary Benefits for Streambank Stability.

BMP	Description	Annualized Cost Estimates
Filter Strips	Placement of vegetated strips in the path of field drainage to remove sediment and nutrients and reduce runoff velocities.	Seeded filter strips cost $25/ac treated Sodded strips cost $43/ac treated
Grassed Waterways	A runoff conveyance that removes phosphorus by sedimentation and plant uptake. Reduces peak flow velocities and subsequent erosion.	$2/ac to $6/ac
Restoration of Riparian Buffers	Conversion of land adjacent to stream channels to vegetated buffer zones. Removes phosphorus by sedimentation and plant uptake. Provides stream bank stability, stream shading, and aesthetic enhancement.	$59.25/ac treated

4.8.4 Effectiveness and Estimated Load Reductions

Because the phosphorus loading from streambank erosion has not been quantified, it is not possible to estimate the additional phosphorus removed by these BMPs (over that assumed for agricultural load reductions). The benefits of filter strips, grassed waterways, and riparian buffers are therefore underestimated in this report.

5.0 PRIORITIZATION OF IMPLEMENTATION

The phosphorus TMDL for Lake Oakland requires a 80 percent reduction in annual loading. Section 4.0 provides loading estimates by source category and describes management options in terms of cost and load reduction capability. This section condenses the information presented in Section 4.0 so that the management strategies can be prioritized based on cost effectiveness.

5.1 Current Phosphorus Loading to Lake Oakland

Phosphorus loads to Lake Oakland vary yearly due to the frequency and intensity of rainfall events and the timing of fertilizer application. Crop production likely represents the greatest source of phosphorus loading to this lake. Phosphorus loads from 12,377 acres of tiled, row crop agriculture likely range from 6,188 to 18,565 lb/yr based on phosphorus loading data presented by Gentry et al. (2007). The variability in these loads depends on the amount and timing of rainfall events and timing of fertilizer application. The BATHTUB modeling performed by USACE indicates that average loads for the period 1992 to 2003 to Lake Oakland were 8,930 lb/yr (Table 1-2).

The treatment of domestic wastewater is the second potential source of phosphorus loading. Depending on the rates of failure in this watershed, onsite systems may contribute 69 to 595 lb/yr of phosphorus to the lake.

Loads from livestock could not be estimated and other sources of phosphorus loading, such as internal generation and atmospheric deposition, are considered negligible.

Table 5-1 summarizes the potential loading from each source (without considering BMPs) along with reported reductions and the total cost to implement the measures over all applicable areas. The information in the table is not to suggest that each BMP will be implemented watershed wide, nor does it account for BMPs already in place. The purpose is to compare the potential load reduction from each BMP as well as the cost associated with achieving that reduction.

Note that the source area, and therefore the loading rate, for riparian buffers is much less than for the other agricultural controls because riparian buffers are only applicable along stream channels and only treat the adjacent 300 ft of land on either side of the buffer, not the entire watershed. In addition to the treated area adjacent to the buffer, the land converted to a buffer also recognizes a reduction in phosphorus loading. To achieve a reduction of 80 percent, we are assuming a buffer width on both sides of the stream channel of 90 ft. The estimated stream length in the watershed where riparian buffers could be constructed is 8.86 miles. Thus, the area that could be converted to a buffer is approximately 191 acres and the area treated by this amount of buffer is 758 acres. Given phosphorus loading rates from tiled agricultural land ranging from 0.5 lb/ac/yr to 1.5 lb/ac/yr, the loading from the source area (758ac) is approximately 379 to 1137 lb/yr. The other agricultural BMPs are applicable to all 12,377 ac of farmland in the watershed and are not restricted by the presence of a stream channel.

Table 5-1. Comparison of Phosphorus BMPs for Agricultural Production, and Onsite Wastewater Treatment Systems

<table>
<tr><th>BMP</th><th>Reported Phosphorus Removal Rate (%)</th><th>Estimated Loading from Source (lb/yr)</th><th>Potential Reduction in Phosphorus Loading (lb/yr)</th><th>Annualized Costs for Full Management</th></tr>
<tr><td colspan="5">Agricultural BMPs for 12,377 Acres of Farmland in the Watershed</td></tr>
<tr><td>Nutrient Management Plan with Deep Phosphorus Placement</td><td>20 to 50</td><td>6,188 to 18,565</td><td>1,237 to 9,280</td><td>$9,280 to $46,413</td></tr>
<tr><td>Conservation Tillage</td><td>68 to 76</td><td>6,188 to 18,565</td><td>4,200 to 14,000</td><td>$15,470 to $27,848</td></tr>
<tr><td>Cover Crops</td><td>70 to 85</td><td>6,188 to 18,565</td><td>4,300 to 15,780</td><td>$238,257</td></tr>
<tr><td>Seeded Filter Strips</td><td>65</td><td>6,188 to 18,565</td><td>4,000 to 12,000</td><td>$309,425</td></tr>
<tr><td>Sodded Filter Strips</td><td>65</td><td>6,188 to 18,565</td><td>4,000 to 12,000</td><td>$532,211</td></tr>
<tr><td>Grassed Waterways</td><td>30</td><td>6,188 to 18,565</td><td>1,856 to 5,570</td><td>$24,754 to $74,262</td></tr>
<tr><td>Restoration of Riparian Buffers</td><td>80 for treated area and 90 for converted area</td><td>379 to 1137</td><td>303 to 1,000</td><td>$733,337</td></tr>
<tr><td>Retrofit Controlled Drainage</td><td>35</td><td>6,188 to 18,565</td><td>2,165 to 6,500</td><td>$9,280 to $18,565</td></tr>
<tr><td colspan="5">Onsite Wastewater Treatment BMPs Assuming 212 Systems in the Watershed</td></tr>
<tr><td>Pumping/ Maintenance</td><td rowspan="4">100 percent reduction if all systems are maintained properly and functioning as designed with replacement likely occurring once every 30 years</td><td rowspan="4">69 to 595</td><td rowspan="4">69 to 595</td><td>$14,840to $18,000 to pump each system once every three to five years</td></tr>
<tr><td>Inspection</td><td>Up to $6,784 if each system has to be inspected once every five years.</td></tr>
<tr><td>Replacement</td><td>$14,200 to $70,600 assuming each system is replaced once every 30 years</td></tr>
<tr><td>Education</td><td>$212</td></tr>
</table>

Extending agricultural BMPs to additional areas in the watershed will likely result in significant reductions in phosphorus loading above those already achieved with current management measures. Nutrient management plans with deep phosphorus placement, conservation tillage, grassed waterways, and retrofitting tile drain systems with outlet control devices are all relatively inexpensive BMPs with potential phosphorus reductions ranging from 1,200 to 14,000 lb/yr. These load reductions are comparable to the more expensive BMPs at less than one-fourth of the cost.

Given the insignificant loading from atmospheric deposition and lake bottom sediments control of these sources is not cost-effective. Therefore, for the Lake Oakland watershed, load reductions should be focused primarily on agricultural BMPs and secondarily on treatment of failing septic systems. .

5.1.1 Implementation Strategy for Agricultural BMPs

Focusing on the low cost-high reduction options first will likely result in greater participation in the community. The use of grassed waterways along drainage pathways is applicable watershed-wide and is capable of reducing phosphorus loads by approximately 30 percent. Another relatively low cost option is retrofitting the tile drain systems in the watershed with outlet control devices that store water for crop use during dry periods and have been shown to reduce phosphorus loading by 35 percent.

Nutrient management planning, conservation tillage practices, grassed waterways, and controlled drainage structures are all relatively low cost BMPs, with approximate net costs ranging from $1 to $6/ac/yr. Once these practices have been adopted on as many fields as possible through voluntary participation of growers in the watershed, future water quality sampling will determine whether or not the higher cost BMPs may be necessary. Use of cover crops, filter strips, and restoration of riparian buffers would be supplemental strategies with the expected costs of these practices ranging from $19 to $60 per acre treated.

Conservation tillage practices, particularly on corn fields, should also be encouraged. Many soybean fields (36 percent) in Coles County use some form of conservation tillage, but only 11 percent of corn fields meet the 30 percent residual cover. Extending conservation tillage to the remaining 64 percent of soybean fields and 89 percent of corn fields may reduce phosphorus loading by 68 to 76 percent, assuming that half of the fields are planted in soybean or corn during any given year.

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6.0 MEASURING AND DOCUMENTING PROGRESS

Volunteer Lake Monitoring Program (VLMP) has not been active in Lake Oakland since 1999. The VLMP consists of the following monitoring levels

- Tier 1 – In this tier, volunteers perform Secchi disk transparency monitoring and field observations only. Monitoring is conducted twice per month from May through October typically at three in-lake sites.
- Tier 2 – In addition to the tasks of Tier 1, Tier 2 volunteers collect water samples for nutrient and suspended solid analysis at the representative lake site: Site 1. Water quality samples are taken only once per month in May-August and October in conjunction with one Secchi transparency monitoring trip.
- Tier 3 – This is the most intensive tier. In addition to the tasks of Tier 1, Tier 3 volunteers collect water samples at up to three sites on their lake (depending on lake size and shape). Their samples are analyzed for nutrients and suspended solids. They also collect and filter their own chlorophyll samples. This component may also include DO/Temp. profiles as equipment is available. As in Tier 2, water quality samples are taken only once per month in May-August and October in conjunction with one Secchi transparency monitoring trip.

Data collected in either Tier 1 or Tier 2 is considered educational. It is used to make general water quality assessments. Data collected in Tier 3 is used in the Integrated Report and is subject to the impaired waters listing. It would also be useful to determine why concentrations in the lake are higher during dry summers compared to wet summers. The following tests and measurements would be helpful in this effort.

- Measuring dissolved and total phosphorus concentrations in tile drain effluent.
- Inspection of onsite wastewater treatment systems in the watershed to determine rates of failure and approximate contribution to the lake.

Monitoring total phosphorus and other water quality parameters in Lake Oakland will determine how effective these management practices are. If the concentrations are still observed above the water quality standard, encouragement of the use of BMPs across the watershed through education and incentives will be a priority. It may also be necessary to begin funding efforts for structural BMPs such as filter strips and riparian buffer restoration.

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7.0 REASONABLE ASSURANCE

USEPA requires that a TMDL provide reasonable assurance that the required load reductions will be achieved and water quality will be restored. For this watershed, use of agricultural BMPs is the primary management strategies to reach these goals. Participation of farmers and landowners is essential to improving water quality, but resistance to change and upfront cost may deter participation. Educational efforts and cost share programs will likely increase participation to levels needed to protect water quality.

7.1 Environmental Quality Incentives Program (EQIP)

Several cost share programs are available to farmers who voluntarily implement resource conservation practices in the Lake Oakland watershed. The most comprehensive is the NRCS Environmental Quality Incentives Program (EQIP) which offers cost sharing and incentives to farmers statewide who utilize approved conservation practices to reduce pollutant loading from agricultural lands.

- The program will pay $10 for one year for each acre of farmland that is managed under a nutrient management plan (up to 400 acres per farmer).
- Use of vegetated filter strips will earn the farmer $100/ac/yr for three years (up to 50 acres per farmer).
- The program will also pay 60 percent of the cost to construct grassed waterways, riparian buffers, and windbreaks.
- Use of residue management will earn the farmer $15/ac for three years (up to 400 acres per farmer).
- Installation of drainage control structures on tile outlets will earn the farmer $5/ac/yr for three years for the effected drainage area as well as 60 percent of the cost of each structure.

In order to participate in the EQIP cost share program, all BMPs must be constructed according to the specifications listed for each conservation practice.

The specifications and program information can be found online at
http://www.il.nrcs.usda.gov/programs/eqip/cspractices.html.

7.2 Conservation 2000

In 1995 the Illinois General Assembly passed the Conservation 2000 bill providing $100 million in funding over a 6-year period for the promotion of conservation efforts. In 1999, legislation was passed to extend the program through 2009. Conservation 2000 currently funds several programs applicable to the Lake Oakland watershed through the Illinois Department of Agriculture.

General information concerning the Conservation 2000 Program can be found online at
http://www.agr.state.il.us/Environment/conserv/

7.2.1 Streambank Stabilization Restoration Program

Conservation 2000 also funds a streambank stabilization and restoration program aimed at restoring highly eroding streambanks. Research efforts are also funding to assess the effectiveness of vegetative and bioengineering techniques.

More information about this program is available online at:
http://dnr.state.il.us/orep/c2000/grants/proginfo.asp?id=20

7.2.2 Sustainable Agriculture Grant Program (SARE)

The Sustainable Agricultural Grant Program funds research, education, and outreach efforts for sustainable agricultural practices. Private landowners, organizations, educational, and governmental institutions are all eligible for participation in this program.

More information concerning the Sustainable Agricultural Grant Program can be found online at:
http://www.sare.org/grants/

7.3 Conservation Reserve Program (CRP)

The Farm Service Agency of the USDA supports the Conservation Reserve Program (CRP) which rents land converted from crop production to grass or forestland for the purposes of reducing erosion and protecting sensitive waters. This program is available to farmers who establish vegetated filter strips or grassed waterways. The program typically provides 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years.

More information about this program is available online at:
http://www.nrcs.usda.gov/programs/crp/

7.4 Nonpoint Source Management Program (NSMP)

Illinois EPA receives federal funds through Section 319(h) of the Clean Water Act to help implement Illinois' Nonpoint Source (NPS) Pollution Management Program. The purpose of the Program is to work cooperatively with local units of government and other organizations toward the mutual goal of protecting the quality of water in Illinois by controlling NPS pollution. The program emphasizes funding for implementing cost-effective corrective and preventative best management practices (BMPs) on a watershed scale; funding is also available for BMPs on a non-watershed scale and the development of information/education NPS pollution control programs.

The Maximum Federal funding available is 60 percent, with the remaining 40 percent coming from local match. The program period is two years unless otherwise approved. This is a reimbursement program.

Section 319(h) funds are awarded for the purpose of implementing approved NPS management projects. The funding will be directed toward activities that result in the implementation of appropriate BMPs for the control of NPS pollution or to enhance the public's awareness of NPS pollution. Applications are accepted June 1 through August 1.

More information about this program is available online at:
http://www.epa.state.il.us/water/financial-assistance/non-point.html

7.5 Agricultural Loan Program

The Agricultural Loan Program offered through the Illinois State Treasury office provides low-interest loans to assist farmers who implement soil and water conservation practices. These loans will provide assistance for the construction, equipment, and maintenance costs that are not covered by cost share programs.

More information about this program is available online at:
http://www.state.il.us/TREAS/ProgramsServices.aspx

7.6 Illinois Conservation and Climate Initiative (ICCI)

The Illinois Conservation and Climate Initiative (ICCI) is a joint project of the State of Illinois and the Delta Pollution Prevention and Energy Efficiency (P2/E2) Center that allows farmers and landowners to earn carbon credits when they use conservation practices. These credits are then sold to companies or agencies that are committed to reducing their greenhouse gas emissions. Conservation tillage earns 0.5 metric tons (1.1 US ton) of carbon per acre per yr (mt/ac/yr), grass plantings (applicable to filter strips and grassed waterways) earn 0.75 mt/ac/yr, and trees planted at a density of at least 250 stems per acre earn somewhere between 3.5 to 5.4 mt/ac/yr, depending on the species planted and age of the stand.

Current exchange rates are available online at http://chicagoclimatex.com. Administrative fees of $0.14/mt plus 8 percent are subtracted from the sale price.

Program enrollment occurs through the P2/E2 Center which can be found online at http://p2e2center.org/. The requirements of the program are verified by a third party before credits can be earned.

More information about carbon trading can be found online at:
http://illinoisclimate.org/

Table 7-1 and Table 7-2 summarize the cost share programs available for phosphorus reduction BMPs in the Lake Oakland watershed. Table 7-3 lists the contact information for each county's USDA Service Center, which include the local soil and water conservation district (SWCD), Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA).

Table 7-1. Summary of Assistance Programs Available for Farmers in the Lake Oakland Watershed.

Assistance Program	Program Description
NRCS EQIP	Offers cost sharing and rental incentives to farmers statewide who utilize approved conservation practices to reduce pollutant loading from agricultural lands. Applies to nutrient management plans, filter strips, grassed waterways, riparian buffers, and conservation tillage.
Conservation 2000 CPP	Provides up to 60 percent cost share for several agricultural phosphorus BMPs: cover crops, filter strips, grassed waterways.
Conservation 2000 Streambank Stabilization Restoration Program	Provides 75 percent cost share for establishment of riparian corridors along severely eroding stream banks. Also provides technical assistance and educational information for interested parties.
SARE	Funds educational programs for farmers concerning sustainable agricultural practices.
FSA CRP	Offsets income losses due to land conversion by rental agreements. Targets highly erodible land or land near sensitive waters. Provides up to 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years for converted land.
NSMP	Provides grant funding for educational programs and implementation of nonpoint source pollution controls.
Agricultural Loan Program	Provides low-interest loans for the construction and implementation of agricultural BMPs. Loans apply to equipment purchase as well.
ICCI	Allows farmers to earn carbon trading credits for use of conservation tillage, grass, and tree plantings.

Table 7-2. Assistance Programs Available for Agricultural Phosphorus BMPs.

BMP	Cost Share Programs and Incentives
Education and Outreach	Conservation 2000 Streambank Stabilization Restoration Program SARE NSMP SWCD
Nutrient Management Plan	EQIP: $10/ac for one year, 400 ac. max. SWCD: up to $30/ac for one year
Conservation Tillage	EQIP: $15/ac for three years, 400 ac. max. ICCI: earns 0.5 mt/ac/yr of carbon trading credit
Cover Crops	CPP: cost share of 60 percent
Filter Strips	EQIP: $100/ac for three years, 50 ac. max. CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Grassed Waterways	EQIP: 60 percent of construction of costs CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Land Retirement of Highly Erodible Land or Land Near Sensitive Waters	CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted
Restoration of Riparian Buffers	EQIP: 60 percent of construction of costs CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years CPP: up to 75 percent of construction costs SWCD: $250 contract incentive ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted

Note: Cumulative cost shares from multiple programs will not exceed 100 percent of the cost of construction.

Table 7-3. Contact Information for Local Soil and Water Conservation Districts.

Organization Name	Address	Contact Numbers
Cole County USDA Service Center	Charleston Service Center 6021 Development Dr	Phone: (217) 345-3901 Fax: (217) 345-9669
Douglas County USDA Service Center	900 S. Washington Tuscola, IL 61953	Phone: 217/253-2022 Fax: 217/253-4359
Edgar County USDA Service Center	11757 IL Hwy 1 Paris, IL 61944	Phone: 217/465-5325 Fax: 217/466-1130

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8.0 IMPLEMENTATION TIME LINE

This implementation plan for Lake Oakland defines a phased approach for achieving the phosphorus standard in the lake (Figure 8-1). Ideally, implementing phosphorus control measures in the watershed will be based on voluntary participation which will depend on 1) the effectiveness of the educational programs for farmers and owners of onsite wastewater systems, and 2) the level of participation in the programs. This section outlines a schedule for implementing the control measures and determining whether or not they are sufficient to meet the water quality standard.

Phase I of this implementation plan should build on existing efforts and continue to focus on education of farm owners concerning the benefits of agricultural BMPs on crop yield, soil quality, and water quality as well as cost share programs available in the watershed. In addition, all owners of onsite wastewater treatment systems should be informed of their responsibilities to maintain and repair their systems. It is expected that initial education through public meetings, mass mailings, TV and radio announcements, and newspaper articles could be achieved in less than 6 months. As described in Section 7.0, assistance with educational programs is available through the following agencies: the Illinois Department of Agriculture Conservation 2000 Streambank Stabilization Restoration Program, the Illinois Department of Agriculture Sustainable Agriculture Grant Program (SARE), and the Illinois Environmental Protection Agency Nonpoint Source Management Program (NSMP).

Phase II of the implementation schedule will involve voluntary participation of farmers in BMPs such as nutrient management planning, conservation tillage, grassed waterways, and tile drain outlet control. The local Natural Resources Conservation Service office will be able to provide technical assistance and cost share information for these BMPs. In addition, initial inspections of all onsite wastewater treatment systems and necessary repairs may begin. Continued monitoring of water quality in the lake could occur at the three Illinois EPA monitoring stations. This phase of the plan will likely take one to three years.

If phosphorus concentrations measured during Phase II monitoring remain above the water quality standard, Phase III of the implementation plan will be necessary. The load reduction achieved during Phase II should be estimated by 1) summarizing the areas where BMPs are in use, 2) calculating the reductions in loading from BMPs as outlined in this report, and 3) determining the impacts on total phosphorus concentrations measured before and after Phase II implementation. If BMPs are resulting in decreased phosphorus concentrations, and additional areas could be incorporating these practices, further efforts to include more stakeholders in the voluntary program will be needed. If the Phase II BMPs are not having the desired impacts on phosphorus concentrations, or additional areas of incorporation are not available, supplemental agricultural BMPs will be needed: cover crops, filter strips, restoration of riparian areas, etc. Strategic placement of these more expensive BMPs near stream channels and the lake shore will provide maximized benefits. If required, this phase may last five to ten years.

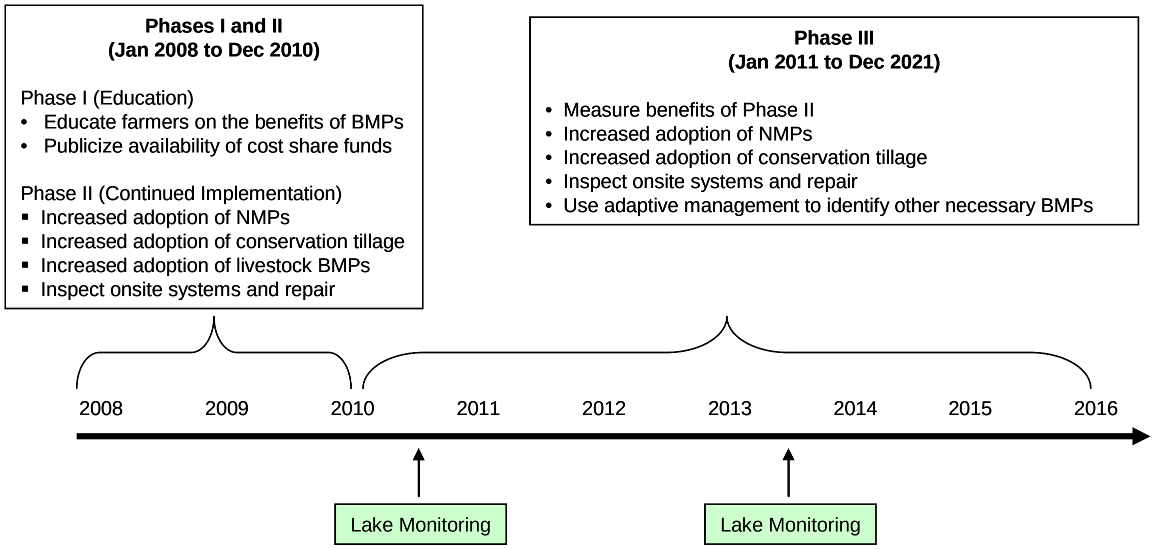

Figure 8-1. Timeline for the Lake Oakland Phosphorus TMDL Implementation Plan.

9.0 CONCLUSIONS

Total phosphorus concentrations collected in Lake Oakland frequently exceed the Illinois water quality standard of 0.05 mg/L. IEPA has included the lake on the Illinois 303(d) list of impaired waters, and the phosphorus TMDL was approved in September 2005. The total phosphorus TMDL indicates that a reduction in loading of 80 percent is required to maintain the total phosphorus standard. This implementation plan has identified the major sources of phosphorus loading to the lake and suggests a phased approach to achieve the water quality standard.

The major source of phosphorus to the lake is agricultural runoff. Failing septic systems are a secondary concern. Four cost-effective agricultural BMPs have been identified to reduce phosphorus loading to the lake: nutrient management planning with deep phosphorus placement, conservation tillage, grassed waterways, and use of outlet control structures on tile drain systems. These BMPs can each be implemented at a cost ranging from $1 to $6/ac/yr (not considering cost share programs) and may be sufficient to meet the water quality standard in the lake if they are used widely across the watershed.

Phase I of this implementation plan will provide education and incentives to farmers in the watershed to encourage the use of these BMPs. Phase II will occur during and following Phase I and will involve voluntary participation of farmers in the watershed**.** Continued water quality monitoring will determine whether or not the voluntary BMPs are capable of reaching the water quality goals in the watershed.

Whether or not Phase III will be required depends on the results of future water quality sampling. If the water quality standard is not being met after implementation of the voluntary BMPs on as many acres as possible, then the more expensive BMPs (ranging from $19 to $60 per acre treated, not accounting for cost share programs) will need to be considered. These include cover crops, filter strips, and restoration of riparian buffers. Due to the expense of these BMPs, it will be necessary to strategize their placement to maximize the benefits to water quality.

In addition to the agricultural sources, septic systems likely contribute 69 to 595 lb-P/yr to Lake Oakland. Though controlling phosphorus loads from agricultural areas will likely achieve the required phosphorus reduction, failing wastewater treatment systems are a public health hazard and potential source of other pollutants. Ensuring proper onsite treatment will require a comprehensive inspection, maintenance, and education program. Reduction in phosphorus loading to Lake Oakland will be a secondary benefit of the program.

As agricultural BMPs are implemented and failing septic systems are corrected, water quality in Lake Oakland should improve accordingly. Measuring the effectiveness of these BMPs will require continued sampling of water quality in Lake Oakland over the next several years. Measurements should continue for a minimum of two monitoring cycles to document progress and direct future management strategies.

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