Water Quality Improvement Plan
for

Lake Keomah

Mahaska County, Iowa

Total Maximum Daily Load
for Algae and pH

Prepared by:
Charles D. Ikenberry, P.E.

Iowa Department of Natural Resources
Watershed Improvement Section
2012

Table of Contents

List of Figures

List of Tables

General Report Summary

What is the purpose of this report?

This report serves multiple purposes. First, it is a resource for guiding locally-driven water quality improvements in Lake Keomah. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for impaired waterbodies. As an impaired waterbody, it is eligible for financial assistance to improve water quality. This document is meant to help guide watershed improvement efforts to remove Lake Keomah from the federal 303(d) list of impaired waters.

What's wrong with Lake Keomah?

Lake Keomah is listed as impaired on the 2010 303(d) list for not supporting its primary contact recreation designated use. The impairment is due to elevated pH levels and aesthetically objectionable conditions caused by excessive algae growth. Aquatic life support is also impaired due to elevated pH. These impairments indicate an imbalanced ecosystem in Lake Keomah caused by overly abundant nutrients.

(Note: In addition to algae and pH, E. coli levels, which may indicate the presence of potentially harmful bacteria and viruses (also called pathogens), have occasionally impaired recreation in Lake Keomah. The bacteria impairment is marginal, and phosphorus reduction measures (discussed in Section 4 of this report), in combination with control of the waterfowl population at the swimming beach, will likely result in removal of this impairment. Water quality improvement activities will be implemented as part of a long-term watershed management plan developed by local stakeholders. Therefore, an E. coli TMDL will not be developed at this time. If the bacteria impairment persists after implementation of a watershed management plan, a bacteria TMDL will be developed at a later date.)

What is causing the problem?

Pollutants that affect water quality, such as sediment, nutrients, and bacteria, can originate from point or nonpoint sources, or a combination of both. Point sources are easily identified sources that enter a stream or lake at a distinct location, such as a wastewater treatment outfall. Nonpoint sources are discharged in a more indirect and diffuse manner, and often are more difficult to locate and quantify. Nonpoint sources are usually carried with rainfall or snowmelt flowing over the land surface and into a nearby lake or stream. The area of land that drains to a lake or stream is called a watershed. Watershed runoff often carries nonpoint source pollutants that degrade water quality.

There are several small animal feeding operations near the Lake Keomah watershed. However, none of them are within the watershed boundary, although manure produced may be applied within the watershed. No regulated municipal or industrial point sources are located in the watershed. Therefore, all sediment, nutrients, and *E. coli* bacteria in the lake are attributed to nonpoint sources including wildlife, particles carried by dust and wind (i.e., atmospheric deposition), livestock, cropland, pets, and humans that live, work, and play in and around the lake.

What can be done to improve Lake Keomah?

To improve the water quality and overall health of Lake Keomah, the amount of nutrients entering the lake must be reduced. Phosphorus is of particular concern because it is the limiting nutrient for excess algae and aquatic plant growth. A combination of land, animal, and in-lake management practices must be implemented to obtain required reductions. Reducing nutrient loss from row crops through strategic timing and methods of manure and fertilizer application, increasing use of conservation tillage methods, and implementing or improving existing structural BMPs such as terraces, grass waterways, and constructed wetlands in beneficial locations will significantly reduce nutrient loads to the lake. Targeted in-lake dredging and retrofitting or maintenance of the sediment basins upstream of the lake will improve and protect water quality in the lake. Preventing waterfowl from gathering at the beach and ensuring septic systems throughout the watershed are functioning properly will also benefit water clarity and reduce the amount of nutrients (and bacteria) that enter the lake.

Who is responsible for a cleaner Lake Keomah?

Everyone who lives, works, or plays in the Lake Keomah watershed has a role in water quality improvement. Because there are no permitted or regulated point sources of pollutants in the watershed, voluntary management of land, animals, and the lake itself will be required to reduce nonpoint source pollutants and achieve positive results in water quality. Much of the land draining to the lake is in agricultural production, and financial assistance is available from government agencies to individual landowners willing to adopt best management practices (BMPs) such as grassed waterways, wetlands, and vegetated buffer strips. Moreover, many of the practices that protect and improve water quality are beneficial to soil quality and the overall health of the agroecosystem. Practices that improve water quality and enhance the long-term viability and profitability of production should appeal to producers, land owners, and lake users. Improving water quality in Lake Keomah will require a collaborative effort of citizens and agencies with a genuine interest in protecting the lake now and in the future.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Lake Keomah, Waterbody ID IA 03-SSK-00120-L_0, located in S13, T75N, R15W, 6 miles east of Oskaloosa in Mahaska County
Surface water classification and designated uses:	A1 – Primary contact recreation B(LW) – Aquatic life (lakes/wetlands) C – Drinking water HH – Human health (fish consumption)
Impaired beneficial uses:	A1 B(LW)
TMDL priority level:	High
Identification of the pollutants and applicable water quality standards (WQS):	Class A1 (primary contact recreation) is not supported due to: (1) “aesthetically objectionable conditions” caused by algae, and (2) violations of Iowa’s pH criterion. Additionally, Class B(LW), aquatic life, is not supported due to violations of Iowa’s pH criterion.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS:	Excess algae and subsequent chlorophyll-a concentrations and high pH levels are attributed to total phosphorus (TP). The allowable average growing season TP load = 1,161 lbs/year (3 lbs/day); the maximum daily TP load = 13 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain WQS:	The existing growing season load of 4,567 lbs/year must be reduced by 3,406 lbs/year to meet the allowable TP load. This is a reduction of 74.6 percent.

Identification of pollution source categories:	There are no permitted or regulated point source discharges of phosphorus in the watershed. Nonpoint sources of phosphorus include fertilizer and manure from row crops, sheet and rill erosion, waterfowl, other wildlife, septic systems, atmospheric deposition, and others.
Wasteload allocations (WLAs) for pollutants from point sources:	There are no permitted or regulated point source discharges in the watershed. Therefore, there is no numeric WLA in this TMDL.
Load allocations (LAs) for pollutants from nonpoint sources:	The allowable annual average TP LA is 1,161 lbs/year, and the allowable maximum daily LA is 13 lbs/day.
A margin of safety (MOS):	An implicit MOS is incorporated into this TMDL. The implicit MOS is applied by using the whole-lake area-weighted average chlorophyll-a TSI as the WQ target. This requires larger reductions than setting the target only in the main segment (Segment 3), which includes the IDNR ambient monitoring location.
Consideration of seasonal variation:	The TMDL is based on annual TP loading. Although daily maximum loads are provided to address legal uncertainties, the average annual loads are critical to in-lake water quality and lake/watershed management decisions.
Reasonable assurance that load and wasteload allocations will be met:	Only nonpoint sources of pollution are contributing to the impairment of Lake Keomah. Therefore, documentation of reasonable assurance is not required. See Section 3.4 for more detailed discussion of reasonable assurance and attainment of nonpoint source reductions.
Allowance for reasonably foreseeable increases in pollutant loads:	Because there are no urbanizing areas in the watershed and significant land use change is unlikely, there is no allowance for reasonably foreseeable increases in pollutant loads.

Implementation plan:	An implementation plan is outlined in Section 4 of this Water Quality Improvement Plan. Phosphorus loading and associated impairments must be addressed through a variety of voluntary nutrient and soil management strategies and structural BMPs

1. Introduction

The Federal Clean Water Act requires all states to develop lists of impaired waterbodies that do not meet water quality standards (WQS) and support designated uses. This list of impaired waterbodies is referred to as the state's 303(d) list. In addition to developing the 303(d) list, a Total Maximum Daily Load (TMDL) must be developed for each impaired waterbody included on the list. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can tolerate without exceeding WQS and impairing the waterbody's designated uses. The TMDL calculation is represented by the following general equation:

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

Where:
TMDL = total maximum daily load
LC = loading capacity
Σ WLA = sum of wasteload allocations (point sources)
Σ LA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

One purpose of this Water Quality Improvement Plan (WQIP) for Lake Keomah, located in Mahaska County in southern Iowa, is to provide a TMDL for algae and pH, which have decreased water quality in the lake. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, develop a comprehensive watershed management plan, and implement water quality improvement projects. Algae, which impairs primary contact recreation, and pH, which impairs both primary contact recreation and aquatic life support, are addressed collectively by development of a TMDL that limits total phosphorus (TP) loads to the lake.

The TMDL includes an assessment of the existing phosphorus load to the lake and a determination of how much phosphorus the lake can tolerate and still support its designated uses. The allowable amount of phosphorus that the lake can receive is the loading capacity, or the TMDL target load.

The plan also includes a description of potential solutions to the algae and pH impairments. This group of solutions is more precisely defined as a system of best management practices (BMPs) that will improve water quality in Lake Keomah, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the implementation plan in Section 4.

The Iowa Department of Natural Resources (IDNR) recommends a phased approach to watershed management. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict. Iterative implementation of improvement practices and additional water quality assessment (i.e., monitoring) will help ensure gradual progress towards water quality standards, maximize cost efficiency, and prevent unnecessary or ineffective implementation of costly BMPs. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Section 5.

This plan will be of little value unless additional watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies. Experience has shown that locally-led watershed plans have the highest potential for success. The Watershed Improvement Section of IDNR has designed this plan for stakeholder use and is committed to providing ongoing technical support for the improvement of water quality in Lake Keomah.

2. Description and History of Lake Keomah

Lake Keomah is a man-made impoundment located six miles east of Oskaloosa in Mahaska County, Iowa (Figure 2-1). The Iowa Department of Natural Resources (IDNR) maintains and operates Lake Keomah State Park, which encompasses 366 acres surrounding the 78-acre lake. Park amenities include picnic shelters, walking trails, and campsites. The Center for Agricultural and Rural Development (CARD) at Iowa State University estimates that between 2002 and 2005, Lake Keomah averaged nearly 50,000 visitors per year (CARD, 2008). Lake visitors spend money at local businesses, thereby supporting the local economy of nearby communities. CARD estimated that spending related to recreational use of Lake Keomah exceeds $3.2 million per year, which is significant to the local economy.

Table 2-1 lists some of the general characteristics of Lake Keomah and its watershed, as it exists today. Estimation of physical characteristics such as surface area, depth, and volume are based on a bathymetric survey conducted by IDNR in 2006.

Table 2-1. Lake Keomah watershed and lake characteristics.

IDNR Waterbody ID	IA 03-SSK-00120-L_0
STORET ID	22620002
12-Digit Hydrologic Unit Code (HUC)	070801051204
12-Digit HUC Name	Snyder Creek – South Skunk River
Location	Mahaska County, S13, T75N, R15W
Latitude	41° 17’ N
Longitude	92° 32' W
Designated Uses	A1 – Primary contact recreation B(LW) – Aquatic life (lakes and wetlands) C – Drinking water HH – Human health (fish consumption)
Tributaries	Unnamed tributaries
Receiving Waterbody	Unnamed tributary to South Skunk River
Lake Surface Area	78 acres (per 2006 bathymetric study)
Maximum Depth	18.9 feet
Mean Depth	9.3 feet
Lake Volume	725 acre-feet
Length of Shoreline	2.94 miles (15,504 feet)
Watershed Area	1,873 acres (excludes lake)
Watershed:Lake Ratio	24:1
Lake Residence Time	93 days (2001-2010 annual average)

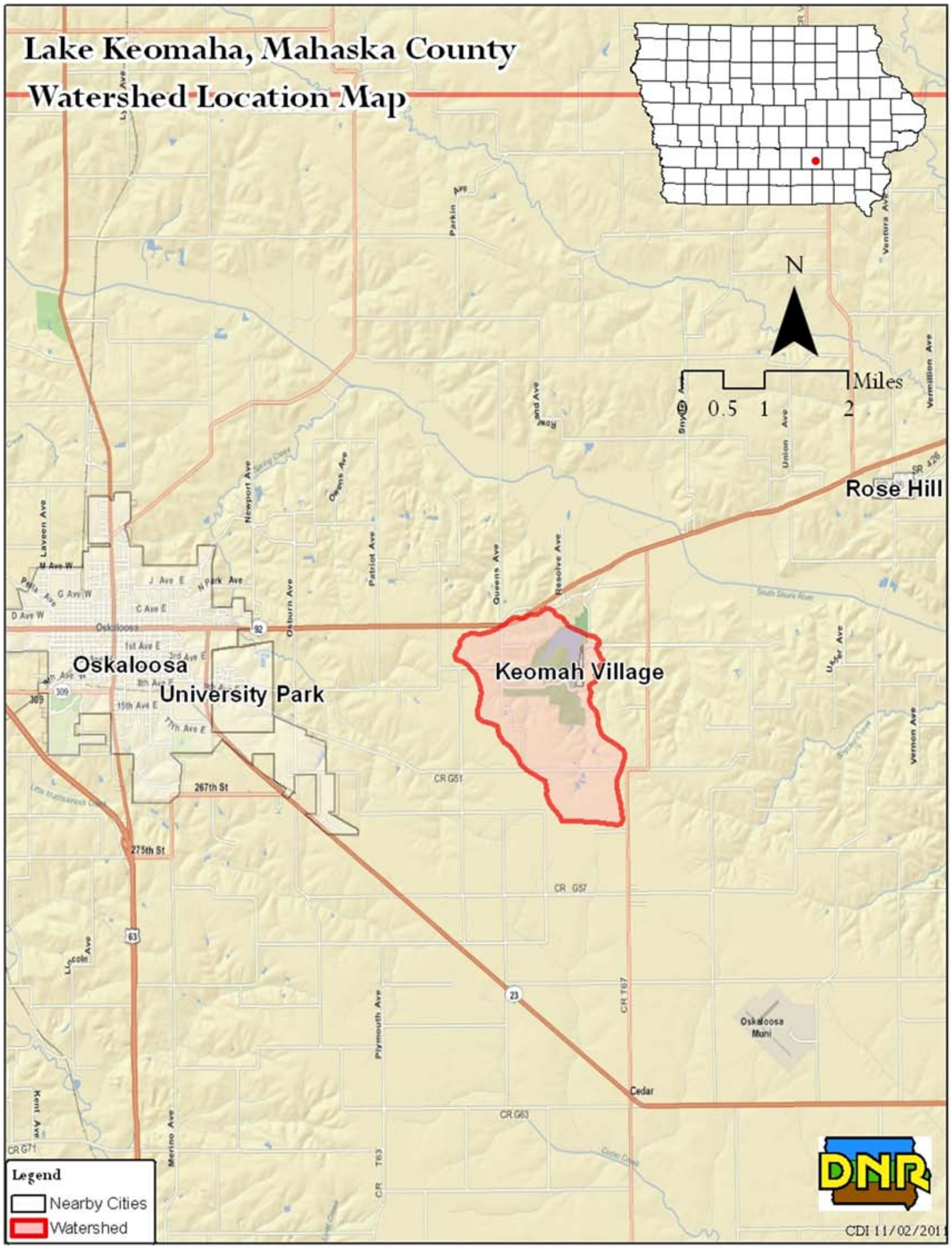

Figure 2-1. Watershed location map.

2.1. Lake Keomah

Hydrology
There are 14 National Weather Service (NWS) stations within 25 miles of the Lake Keomah watershed with daily precipitation data available through the Iowa Environmental Mesonet (IEM). The nearest station is located at Oskaloosa and is 4.8 miles northwest of watershed boundary. Data is also available for these stations through the National Climatic Data Center (NCDC). The Thiessen polygon method was employed to develop an area-weighted precipitation data set for the watershed using the closest weather stations. However, application of the Thiessen polygon method resulted in a polygon that included only the Oskaloosa station. Therefore, rainfall data from the NCDC and NWS COOP station at Oskaloosa was used for modeling purposes. The data is nearly identical, with slight discrepancies resulting from differing quality assurance/quality control (QA/QC) procedures. A composite dataset was developed for the Lake Keomah TMDL that utilizes all available NCDC data. There are several dates for which NCDC data is missing. NWS COOP data was utilized to fill in data gaps in the NCDC record.

Weather station information is provided in Table 2-2. Figure 2-2 shows the annual precipitation at Oskaloosa from 1995-2010. A map of nearby precipitation gages and the resulting Thiessen polygons is provided in Figure 2-3.

Table 2-2. Weather station information for Webster City, Iowa.

Station Description	Station Data
Location	Oskaloosa
NCDC ID	136327
IEM ID	IA6327
Latitude	41.32
Longitude	-92.65
Average Annual Precipitation: 1995-2010 2001-2006 2007-2010	 39.3 inches 33.2 inches 50.1 inches

(IEM, 2011a and NCDC, 2011)

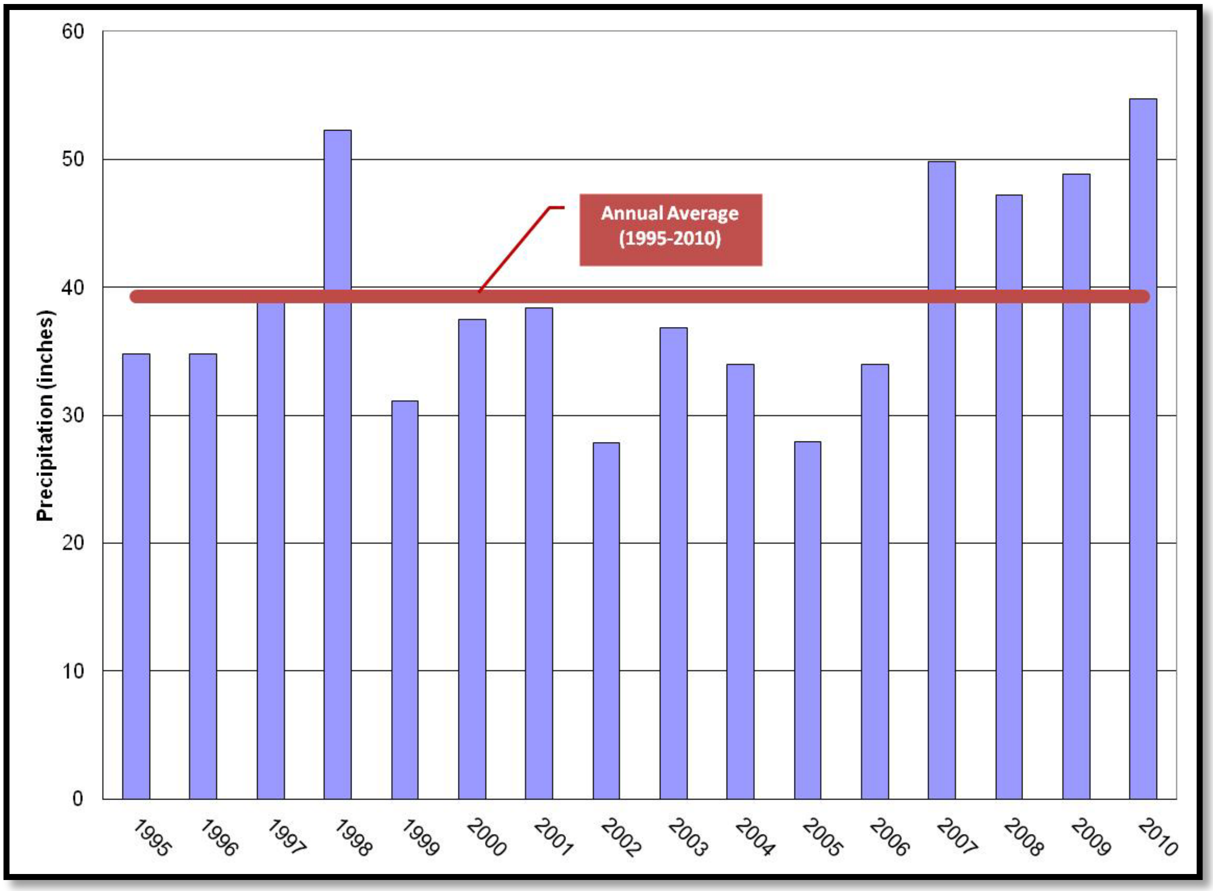

Figure 2-2. Annual precipitation at Oskaloosa, Iowa

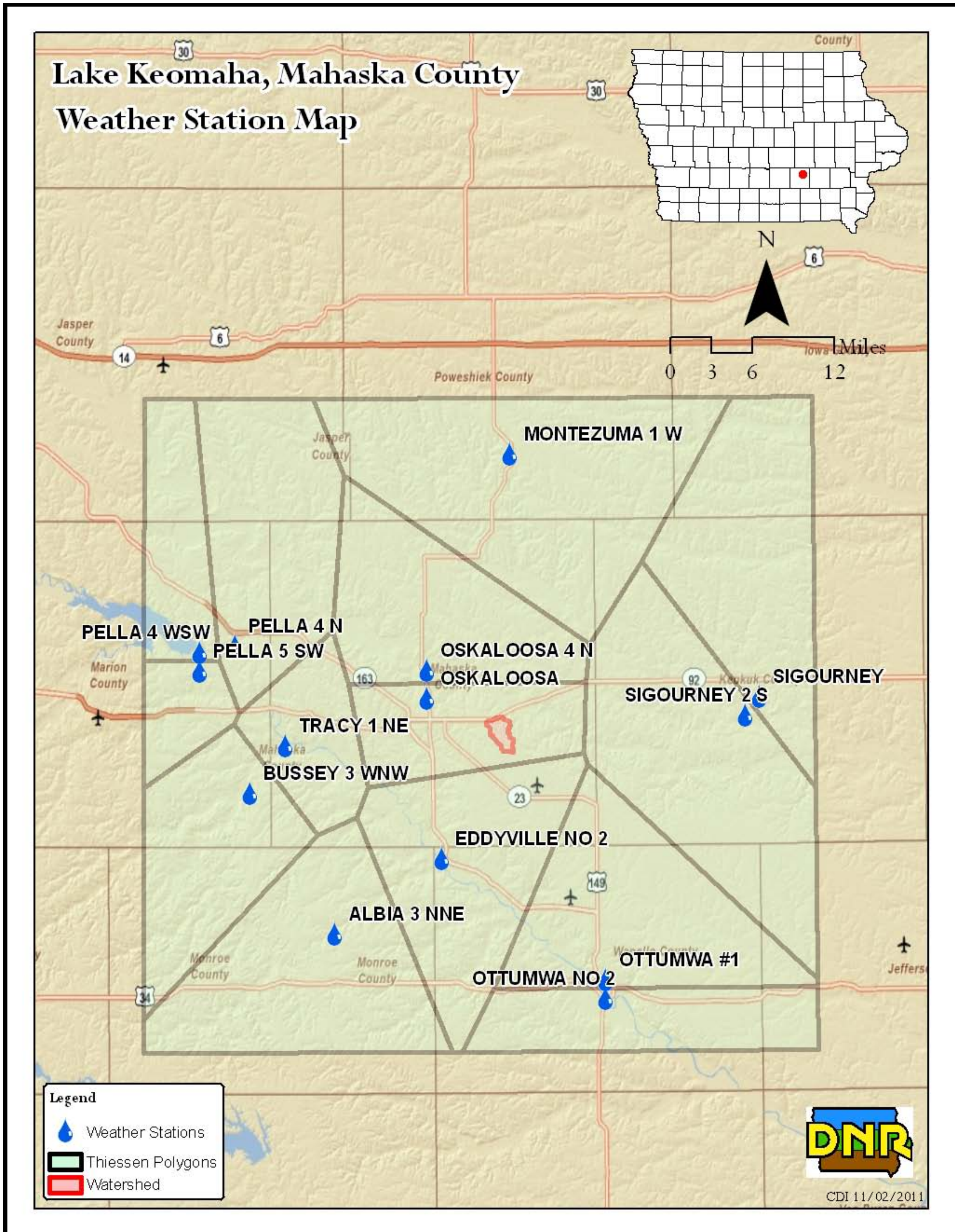

Figure 2-3. Map of nearby precipitation gages and Thiessen polygons.

Lake Keomah is a man-made reservoir that lies within the South Skunk River HUC-8 and Snyder Creek HUC-12. The reservoir was constructed in 1935 by the Civilian

Conservation Corp. A 1,100-ft long, 42-ft high earthen embankment and concrete spillway, illustrated in Figure 2-4, controls outflow from the northeast corner of the lake.

Figure 2-4. Embankment and spillway at NE corner of Lake Keomah.

The spillway is 60-ft wide at the crest elevation, but narrows to a 20-ft wide, 360-ft long chute that drops over 30 feet in elevation. The spillway transitions into a St. Anthony Falls (SAF) stilling basin to dissipate energy before water discharges to an unnamed tributary to the South Skunk River.

Rainfall runoff, direct precipitation, evapotranspiration, and shallow groundwater flow are all part of the lake's hydrologic system. The hydraulic residence time varies seasonally and is weather dependant. During years of below average precipitation from 2001-2006, the average residence time of the lake was 122 days. During above average precipitation years from 2007-2010, residence time was estimated to be 67 days. Over the entire 10 year period, the average residence time was 93 days. Estimated residence time is based on annual precipitation statistics, Spreadsheet Tool for Estimating Pollutant Load (STEPL) estimates of average annual inflow, and a water balance calculated within the BATHTUB model. The BATHTUB water balance calculation includes inflows (from STEPL), direct precipitation, evapotranspiration estimates at Chariton, Iowa obtained from the Iowa State University Ag Climate Network on the Iowa Environmental Mesonet (IEM, 2011b), and lake morphometry.

Morphometry & Substrate

The historical surface area of Lake Keomah was 84 acres, according to a 1994 lake assessment survey (IDNR, 1994). More recent aerial photography and a bathymetric survey, as shown in Figure 2-5, indicate a surface area of 78 acres. The shoreline development index of the lake is 2.91 (Bachman et al., 1994). Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000).

For modeling purposes, the lake was divided into three segments. The east branch of the lake (Segment 1) drains 949 acres directly south of the lake, and the west branch (Segment 2) drains 768 acres southwest of the lake. Both branches feed into a deeper, open water area adjacent to the earthen embankment (Segment 3). This open water area is considered the "main" segment of the lake, and includes the location where ambient water quality data is collected. There are no channelized streams discharging directly to the open water area, but 156 acres drain to Segment 3 via overland flow, small ditches, and shallow groundwater. Table 2-3 reports the area, mean depth, and maximum depth of each segment, and Figure 2-6 illustrates the segments on a map. Further discussion of lake segmentation is provided in the Appendix E.

Table 2-3. Lake segment morphometry information.

Segment	Surface Area (ac)	Average Depth (ft)	Maximum Depth (ft)
(1) East Branch	25.1	6.8	16.0
(2) West Branch	14.7	5.5	14.0
(3) Main Segment	38.3	12.4	18.9
Whole-Lake	**78.1**	**9.3**	**18.9**

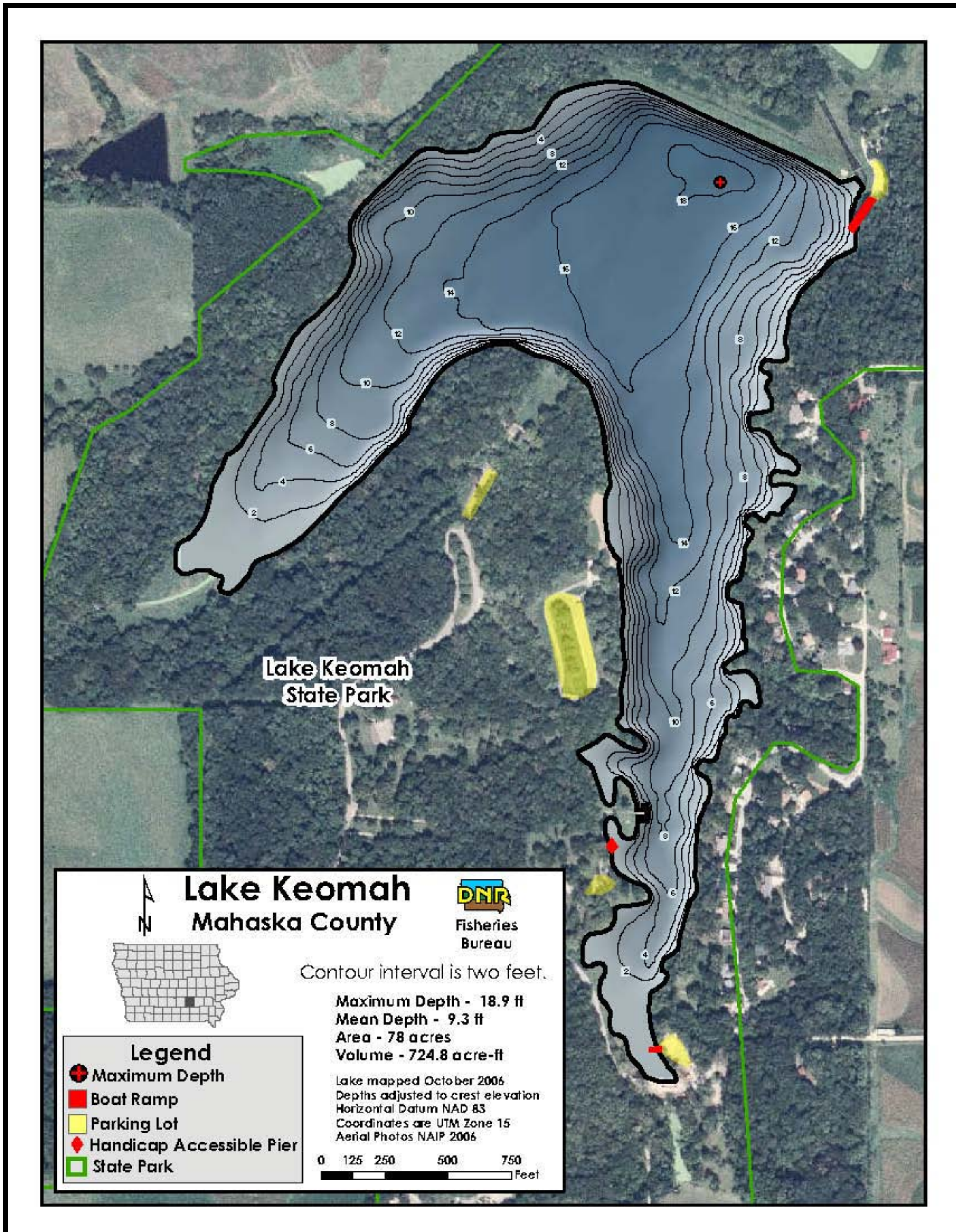

Figure 2-5. Bathymetric map of Lake Keomah.

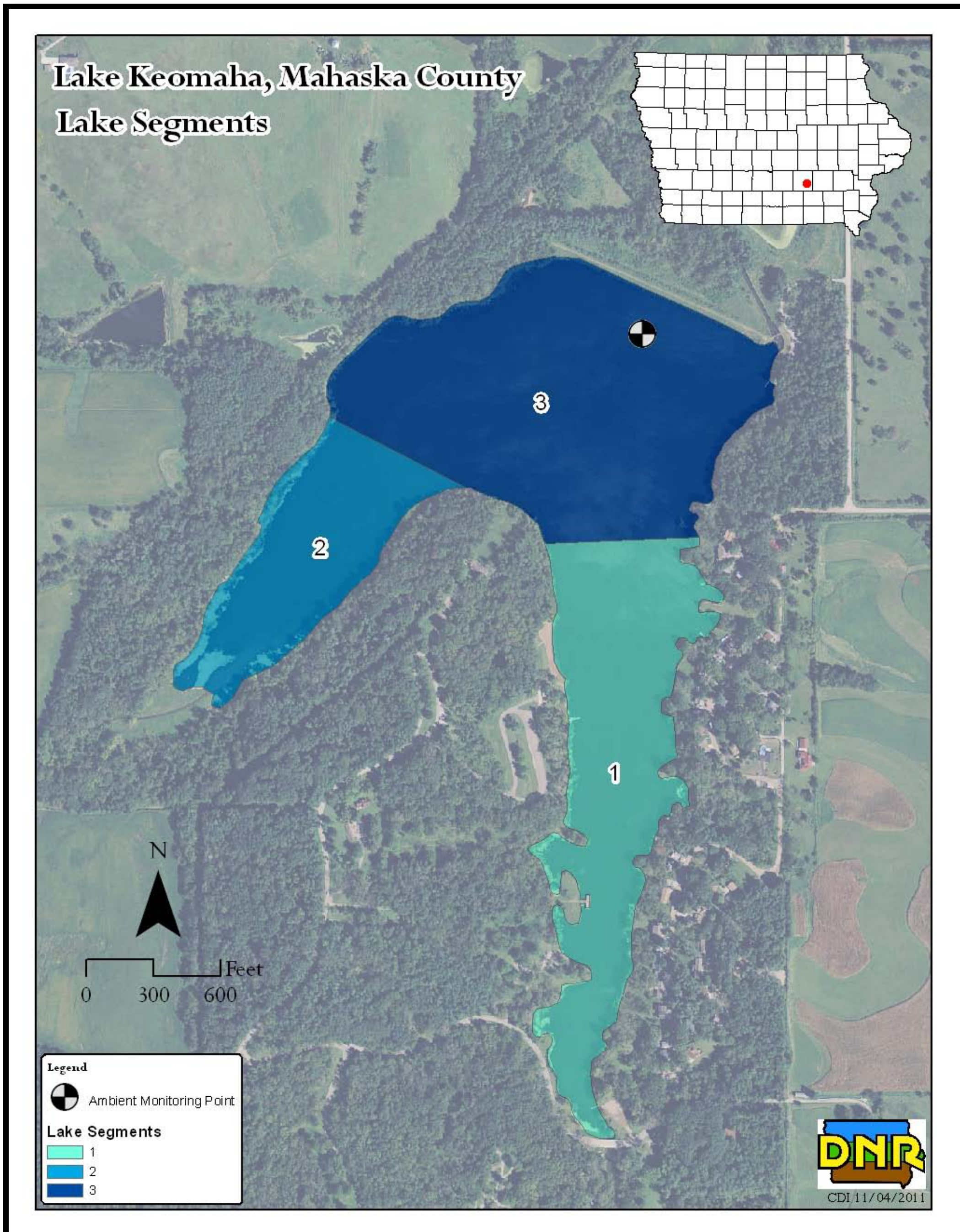

Figure 2-6. Lake segmentation map.

2.2. The Lake Keomah Watershed

The drainage area to Lake Keomah is a 1,873-acre watershed, not including the surface area of lake. The watershed is illustrated in Figure 2-7. The watershed to lake ratio of 24 to 1 is moderately high and indicates that watershed characteristics influence water quality in Lake Keomah. The potential for successful lake restoration efforts is generally considered favorable in cases where the watershed to lake ratio is less than 20:1. Lakes with larger ratios usually require more costly measures to obtain significant water quality improvement. While there are many opportunities to improve the watershed and water quality of Lake Keomah, implementation activities should be carefully planned so that limited resources and funds are used efficiently to obtain reasonable goals.

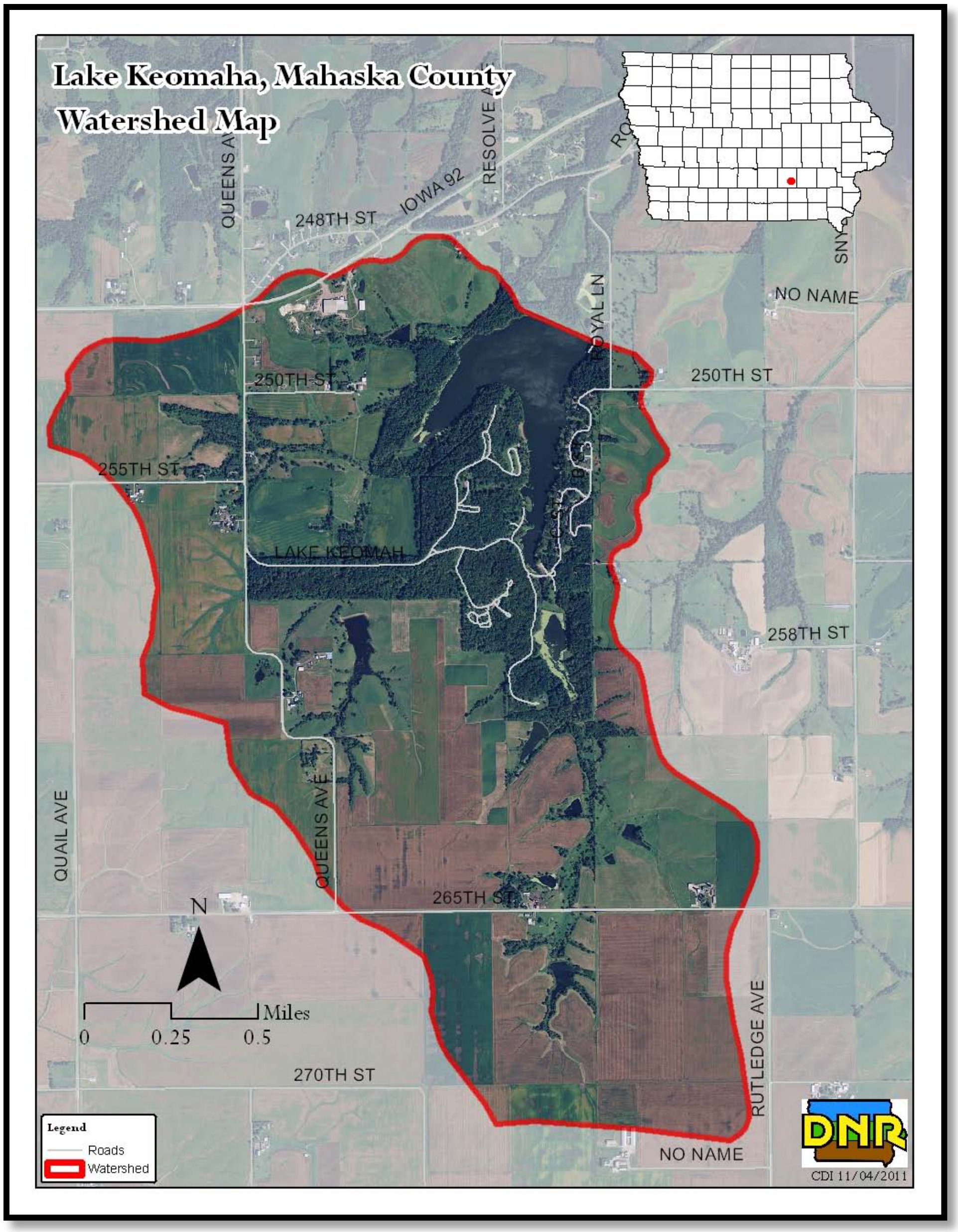

Figure 2-7. Watershed map.

Land Use

Land use information developed by IDNR in 2002 was compared to 2010 land use as defined by the United States Department of Agriculture-National Agricultural Statistics Service (USDA-NASS). Aerial photography and professional judgment were used to modify both sources of data slightly. Differences in land use composition of the watershed between the 2002 and 2010 data sources were minimal, so the 2002 data was utilized for watershed assessment and modeling purposes, after changing 49 acres of grassland to row crops, per updated information. A land use map is provided in Figure 2-8.

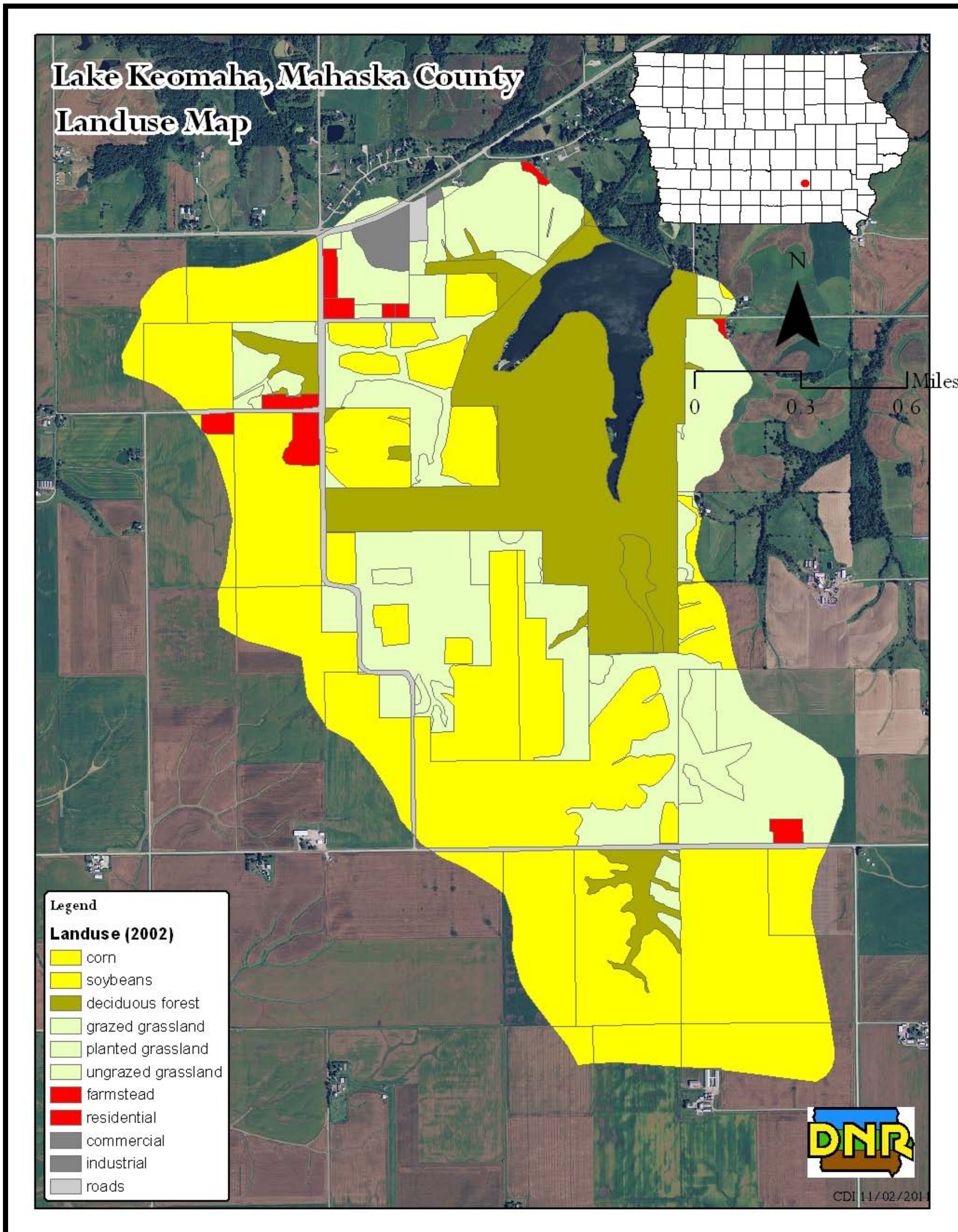

Figure 2-8. Lake Keomah watershed land cover (2002).

Land cover information reveals that row crop agriculture is the most prevalent feature of the Lake Keomah watershed, followed by grass/hay. Other land uses include forest/timber, roads (including right-of-way), wetland/ponds, residential, and small isolated areas of commercial and/or industrial use. Table 2-4 reports land uses by acre and percent of watershed. The pie chart in Figure 2-9 illustrates the land use composition of the watershed.

Table 2-4. Land use composition of Lake Keomah watershed.

2002 Land Use	Area (Acres)	% of Watershed
Row Crop	875.2	46.7
Grass/Hay	553.8	29.6
Forest/Timber	317.2	16.9
Roads/ROW	53.3	2.8
Water/wetland	45.2	2.4
Residential	14.4	0.8
Commercial/Industrial	14.3	0.8
Totals =	**1873.4**	**100.0**

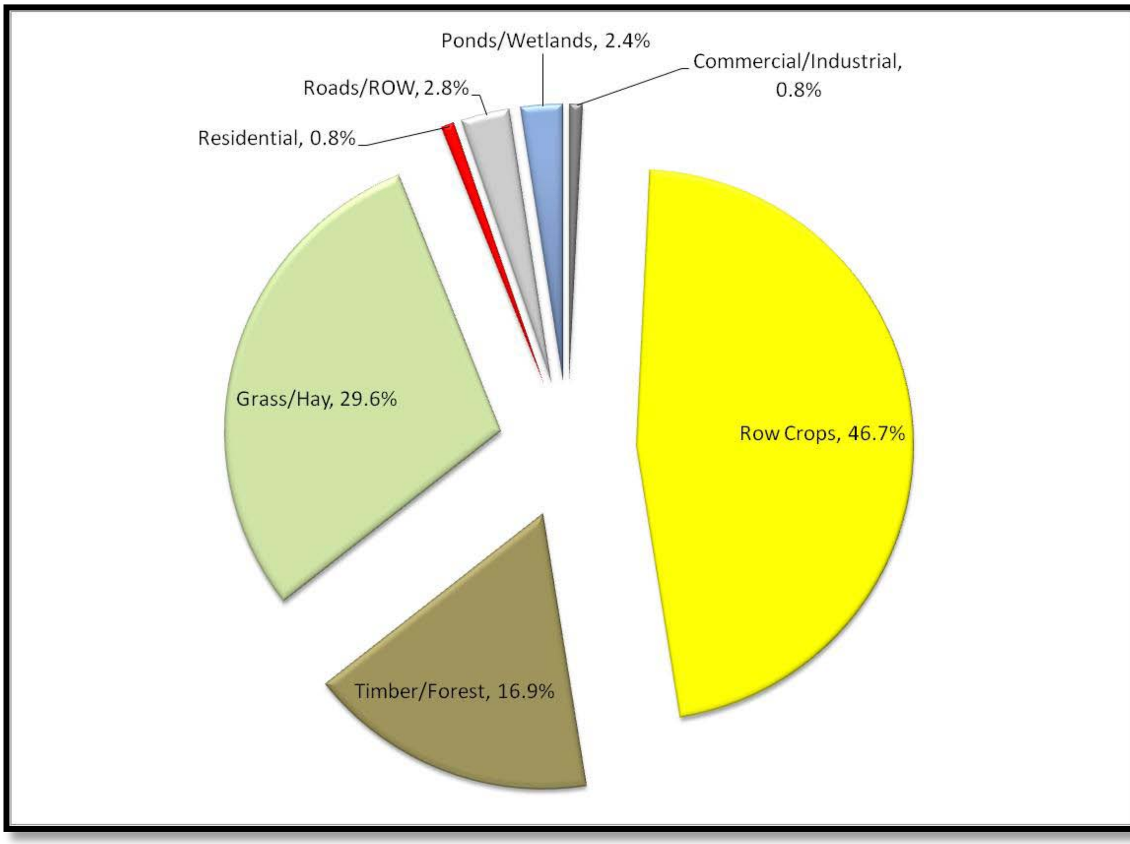

Figure 2-9. Land use composition of Lake Keomah watershed.

Soils, Climate, and Topography

Seven soil series dominate the Lake Keomah watershed, which are listed in Table 2-5. Of these, Ladoga and Clinton soils comprise the largest portion of the watershed (17.9 percent and 16.6 percent, respectively). Generally, soils in the relatively flat upland areas of the watershed are silty clay loams, such as Mahaska, Taintor, and Nira. In areas where uplands transition to steeper convex slopes, silt loams such as Ladoga and Clinton soils are common. The steepest side slopes along drainage channels and streams are comprised of Hedrick silt loam and Lindley loam soils.

Table 2-5. Predominant soils in the Lake Keomah watershed.

Soil Name	Watershed Area (%)	Description of Surface Soil Layer	Typical Slopes (%)
Ladoga	17.9	Silt loam, moderately well-drained	5-9
Clinton	16.6	Silt loam, moderately well-drained	9-14
Mahaska	12.3	Silty clay loam, somewhat poorly-drained	0-2, 2-5
Lindley	10.2	Loam, well-drained	14-18
Taintor	8.2	Silty clay loam, poorly-drained	0-2
Hedrick	8.0	Silt loam, moderately well-drained	9-14
Nira	7.7	Silty clay loam, moderately well-drained	5-9
All others	19.1	varies	varies

Source: USDA-NRCS, 1977

3. TMDL for Algae and pH

A Total Maximum Daily Load (TMDL) is required for Lake Keomah by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) quantifies the maximum amount of total phosphorus (TP) the lake can assimilate and still support primary contact recreation and aquatic life in Lake Keomah. It is assumed that the TMDL for algae also addresses the pH impairment, because both are attributed to excess nutrients, particularly phosphorus.

3.1. Problem Identification

Lake Keomah is a Significant Publicly Owned Lake, and is protected for the following designated uses:

- Primary contact recreation – Class A1
- Aquatic life – Class B(LW)
- Fish consumption – Class HH
- Drinking water – Class C

The 2010 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Lake Keomah is assessed (evaluated) as "partially supported" due to elevated pH levels and "aesthetically objectionable conditions" attributed to excess algal growth. Additionally, aquatic life uses are assessed (monitored) as "partially supported" due to elevated pH.

The 2010 assessment is included in its entirety in Appendix H. This section details the development of the TMDL for algae and pH. The 305(b) report can be accessed at http://programs.iowadnr.gov/adbnet/assessment.aspx?aid=11499.

Applicable Water Quality Standards
The State of Iowa Water Quality Standards (WQS) are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61. Although the State of Iowa does not have numeric criteria for sediment, nutrients, or algae (chlorophyll-a), narrative water quality criteria do apply. Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters. These narrative criteria require that waters be free from "aesthetically objectionable conditions." The WQS can be accessed on the web at http://www.legis.iowa.gov/DOCS/ACO/IAC/LINC/Chapter.567.61.pdf

For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when Carlson's Trophic State Index (TSI) for the median growing season chlorophyll-a or Secchi depth exceeds 65 (IDNR, 2008). In order to de-list a lake impaired by algae from the 303(d) list, the median growing season chlorophyll-a TSI must not exceed 63 in two consecutive listing cycles, per IDNR de-listing methodology. To avoid exceeding a TSI value of 63, the median growing season chlorophyll-a concentration must not exceed 27 micrograms per liter (ug/L).

With respect to pH, the same numeric criteria apply to primary contact recreation (Class A1) and aquatic life (Class B(LW)). Per Section 61.3(3) of the WQS, pH shall not be less than 6.5 or greater than 9.0 for full support of either designated use. Water quality data and subsequent analysis suggest that addressing the eutrophication in Lake Keomah causing the algae impairment will also address the pH impairment. It is excess nutrients, particularly phosphorus, that leads to eutrophic conditions associated with both impairments.

Problem Statement
Lake Keomah is impaired because primary contact recreation and aquatic life are not fully supported due to violations of WQS. High levels of *E. coli* bacteria, elevated pH, and excess algal growth all impair water quality in the lake. Excess phosphorus contributes to impairments related to high pH and algal growth.

Data Sources
Sources of data used in the development of this TMDL include those used in the 2010 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. Sources include:

- Results of statewide surveys of Iowa lakes sponsored by IDNR and conducted by Iowa State University (ISU) from 2001-2010
- Water quality data collected by the State Hygienic Laboratory (SHL) at the University of Iowa from 2005-2009 as part of the Ambient Lake Monitoring Program and/or TMDL monitoring
- Precipitation data from the National Climatic Data Center (NCDC)
- National Weather Service (NWS) precipitation data (IEM, 2011a) and evaporation data (IEM, 2011b) accessed through the Iowa Environmental Mesonet
- 3-m LiDAR elevation data maintained by IDNR
- SSURGO soils data maintained by United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS)
- Statewide 2002 land cover data

Interpreting Lake Keomah Data
The 2010 305(b) assessment was based on both ISU and SHL ambient monitoring data from 2004-2008. Assessment of in-lake water quality in this TMDL utilized SHL and ISU data from 2001-2010, with the exclusion of several outliers. In-lake water quality data is reported in Appendix C, along with the outlier analysis.

Carlson's Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Lake Keomah. If the TSI values for the three parameters are the same, the relationships between the three are strong. If the TP TSI values are higher than chlorophyll TSI, it suggests there are limitations to algal growth besides phosphorus. Figure 3-1 illustrates each of the individual TSI values throughout the analysis period.

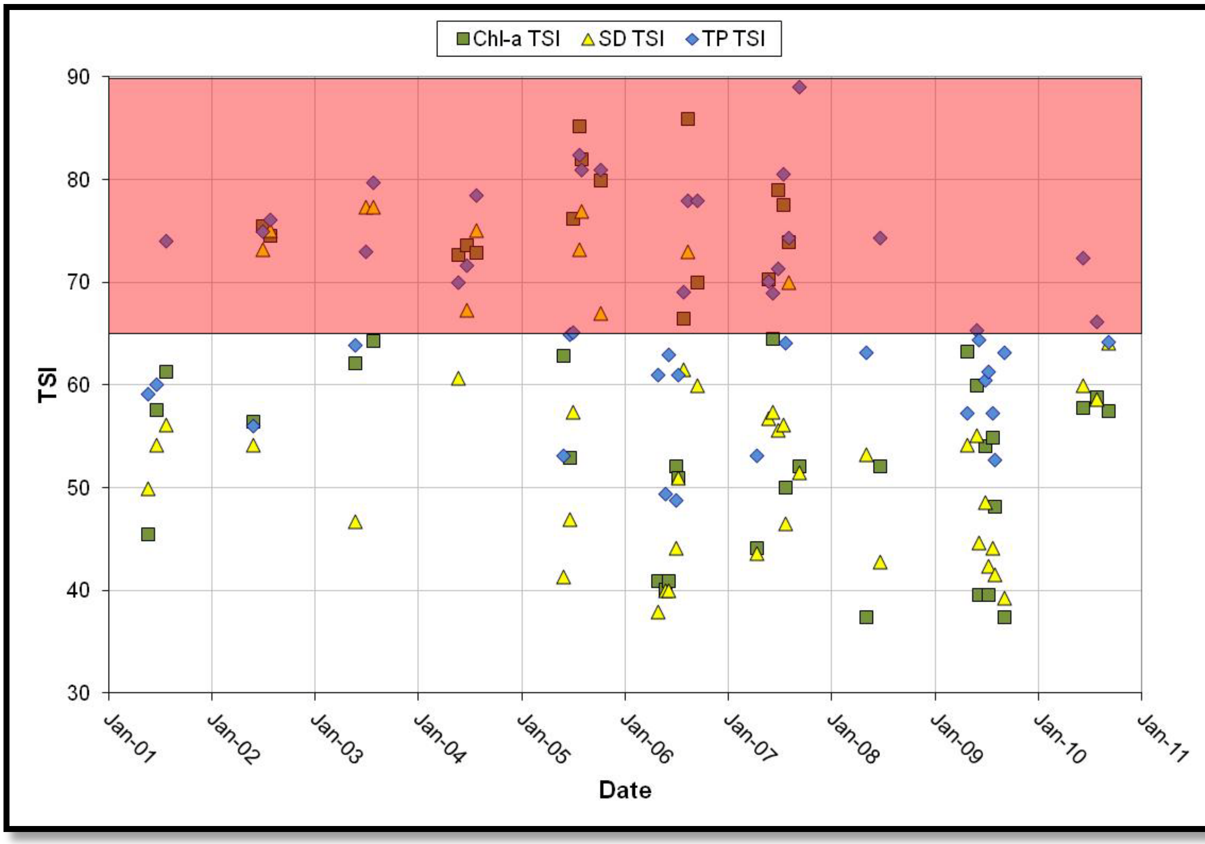

Figure 3-1. Lake Keomah mean TSI values (2001-2010).

Averaging the mean growing season TSI values for each year (2001-2010) results in overall TSI values of 53 for Secchi depth, 66 for chlorophyll-a, 70 for phosphorus, and 65 for nitrogen. This suggests that factors besides TP may be limiting (i.e., controlling) algal growth at certain times of the year and under certain conditions. However, there are many occurrences of chlorophyll-a TSI values above 70, and several instances in which the TSI is higher for chlorophyll-a than TP. This indicates that severe algal blooms do occur, and suggests that TP is often the limiting factor. TSI scores for both TP and chlorophyll-a are significantly higher than for Secchi depth, indicating that non-algal turbidity is not a concern and that light is seldom limiting. Table 3-1 describes the implications of TSI values on attributes of lakes. Figure 3-2 shows these classifications on the plot of Lake Keomah TSI values.

The general trend is that chlorophyll-a TSI values are significantly higher than those for Secchi depth, and TSI values for TP are slightly higher than those for chlorophyll-a. Additionally, TSIs were relatively low in 2008-2010, compared to previous years, with no chlorophyll-a TSI values exceeding the impairment threshold of 65. Table 3-2 reports mean and median TSI values calculated using the ambient lake monitoring data.

Table 3-1. Implications of TSI values on lake attributes.

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	Warm water fisheries only; [1]percid fishery; bass may be dominant
60-70	blue green algae dominate; algal scums and macrophyte problems occur	weeds, algal scums, and low transparency discourage swimming and boating	[2]Centrarcid fishery
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	algal scums; few macrophytes	algal scums, and low transparency discourage swimming and boating	rough fish dominate; summer fish kills possible

[1]Fish commonly found in percid fisheries include walleye and some species of perch
[2]Fish commonly found in centrarcid fisheries include crappie, bluegill, and bass
Note: Modified from Carlson and Simpson (1996).

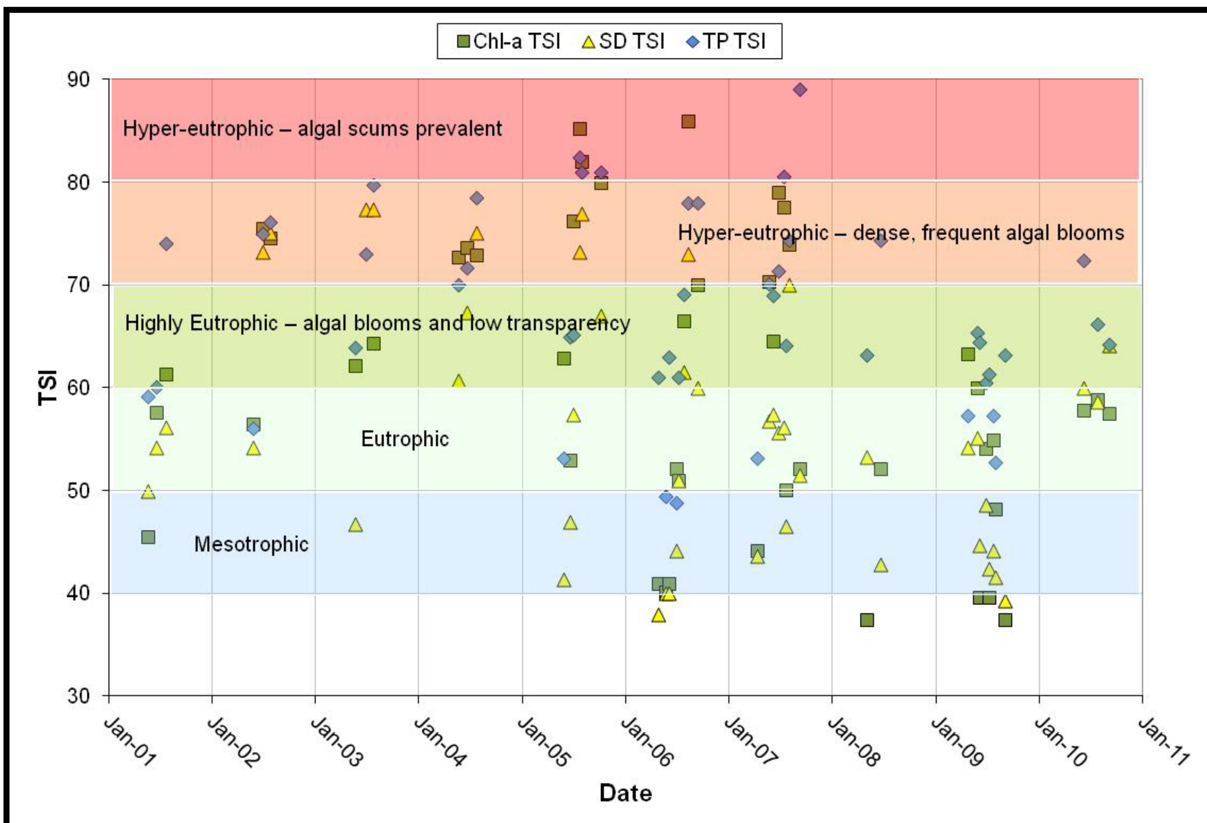

Figure 3-2. Lake Keomah TSI values with productivity ranges shown.

Table 3-2. Growing season TSI values in open water area (Segment 3).

		TSI (SD)	TSI (Chl)	TSI (TP)	TSI (TN)
2001-2010	Mean	53	66	70	65
	Median	55	67	69	65
2001-2006	Mean	56	68	72	64
	Median	60	70	71	62
2007-2010	Mean	50	61	68	66
	Median	51	59	67	69

Figure 3-3 illustrates a method for interpreting the deviations between Carlson's TSI values for TP, Secchi depth, and chlorophyll-a. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chlorophyll-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis. This suggests factors other than phosphorus may limit algal growth. The X-axis, or zero line, is related to TN:TP ratios of greater than 33:1 (Carlson, 1992). Because phosphorus is thought to be a limiting nutrient at ratios greater than 10:1, deviations slightly below the X-axis do not necessarily indicate nitrogen limitation.

The majority of the TSI deviations lie in the lower-right quadrant of Figures 3-3, but the central tendency is near zero on the Y-axis. Because the central tendency of TP deviations is near the Y-axis, the importance of phosphorus in algal growth and transparency must be considered. TN deviations are shown Figure 3-4, but caution should be used when assessing these data. TN deviations may not be a reliable indicator of nitrogen limitation; however, the presence of both positive and negative deviations of both TN and TP suggest there are times when neither N nor P limit algal growth (Carlson and Simpson, 1996).

Points to the left of the Y-axis (Chl TSI < SD TSI) represent conditions in which transparency is reduced by non-algal turbidity. Points to the right reflect situations in which transparency is greater than chlorophyll-a levels would suggest, meaning that large particles, rather than fine clay particles, influence water clarity. Deviations to the right may also be caused by high zooplankton populations that feed on algae, keeping the algal populations lower than expected given other conditions. This phenomenon does appear to occur in Lake Keomah, based on the deviation between the chlorophyll-a and Secchi depth TSI values. This may explain why chlorophyll-a TSI is lower than TP TSI – zooplankton graze on algae, keeping levels lower than TP levels would suggest.

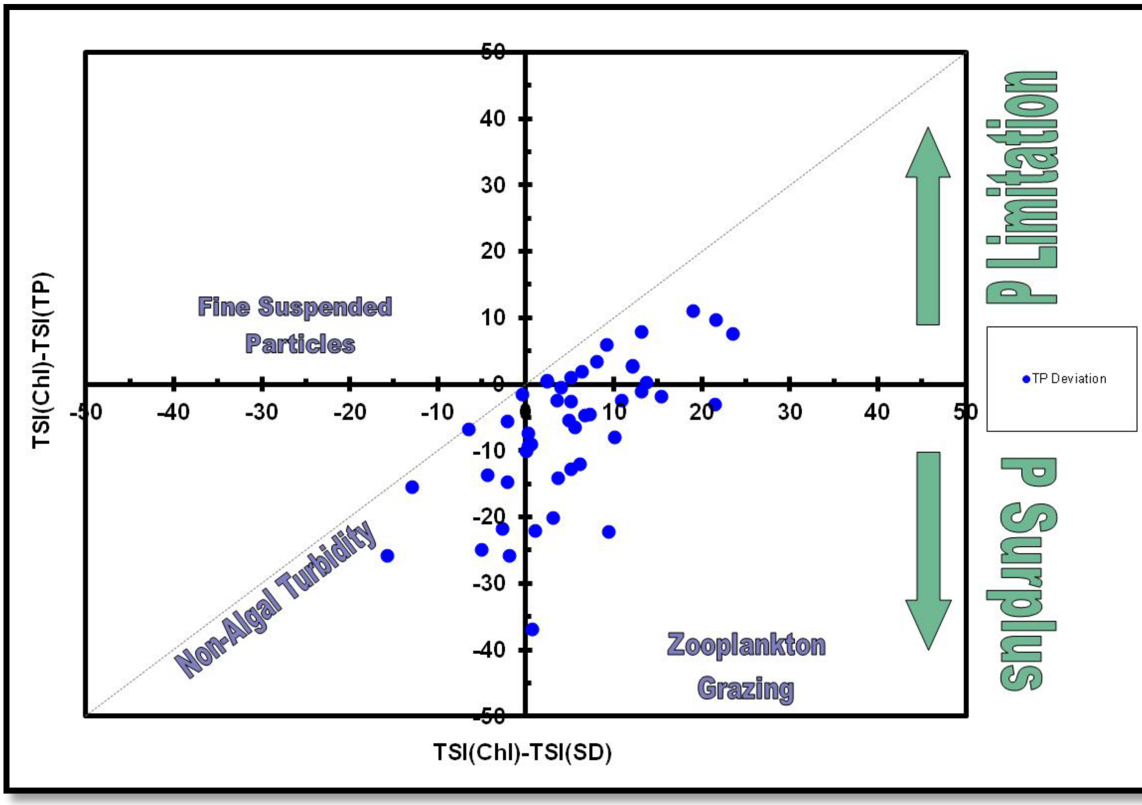

Figure 3-3. Phosphorus TSI deviations (2001-2010).

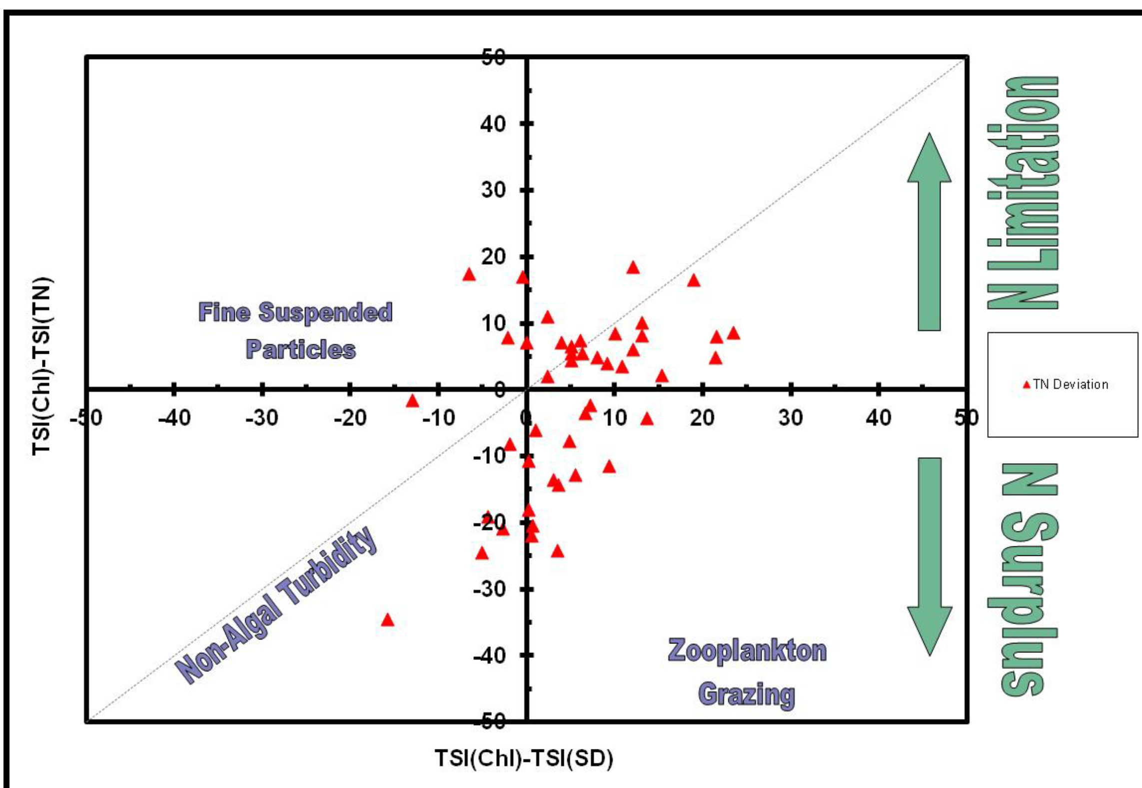

Figure 3-4. Nitrogen TSI deviations (2001-2010).

The overall TN:TP ratio in Lake Keomah, using average growing season mean concentrations from 2001-2010, is 17.1. According to a study on blue-green algae dominance in lakes, ratios greater than 17 suggest a lake is phosphorus, rather than nitrogen, limited (MPCA, 2005). Carlson states that phosphorus may be a limiting factor at TN:TP ratios greater than 10 (Carlson and Simpson, 1996). As Figure 3-5 shows, TN:TP ratios suggest that Lake Keomah is either strongly or weakly limited by phosphorus approximately 55 percent of the time. It appears as though nitrogen limitation does play a role in algal growth and speciation under certain conditions, and this should be acknowledged when developing restoration plans for Lake Keomah. However, nitrogen limitation, as indicated by TN:TP ratios less than 10, occurs less than 20 percent of the time. The distribution of TN:TP ratios under various conditions, as illustrated in Figure 3-6, suggests phosphorus is more limiting than nitrogen under most circumstances and especially when light limitation is not an issue, which is normally the case in Lake Keomah. However, during severe algal blooms, TN:TP ratios may indicate that the lake often becomes co-limited, or even nitrogen limited.

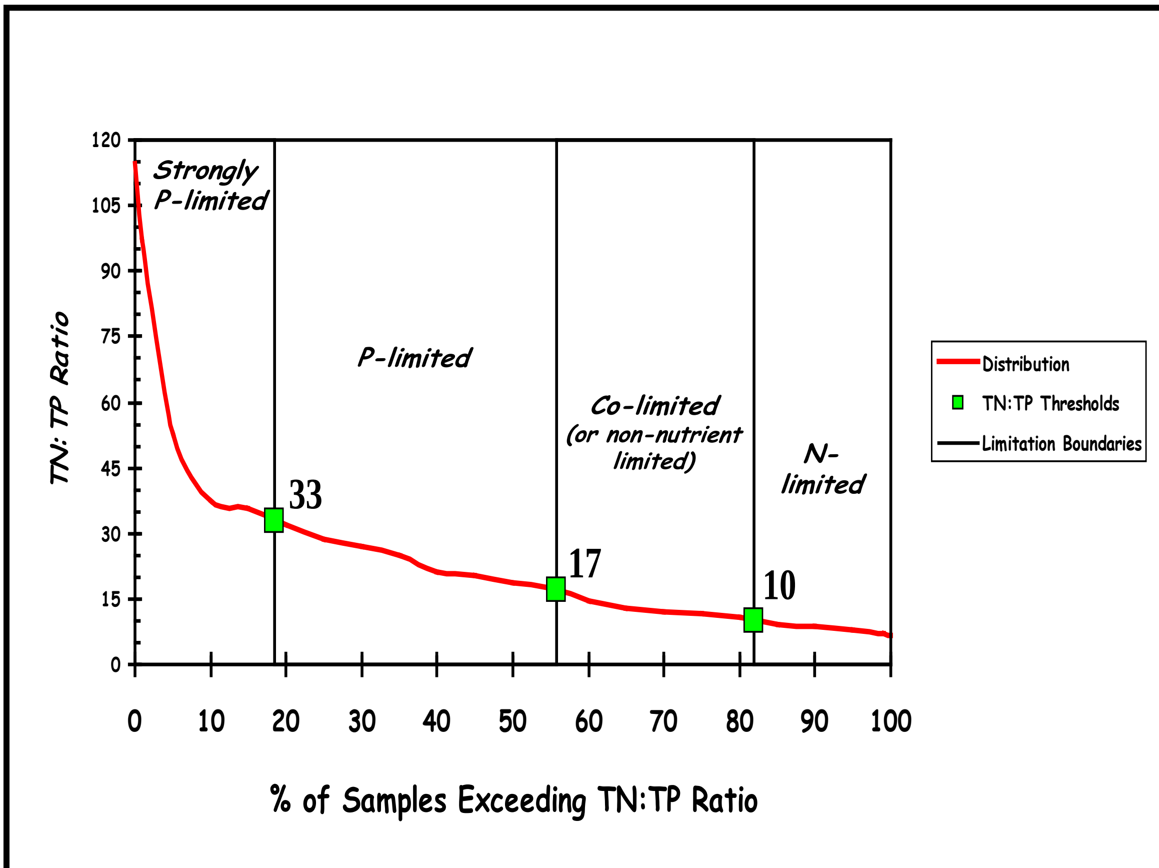

Figure 3-5. Distribution of TN:TP values in Lake Keomah (2001-2010).

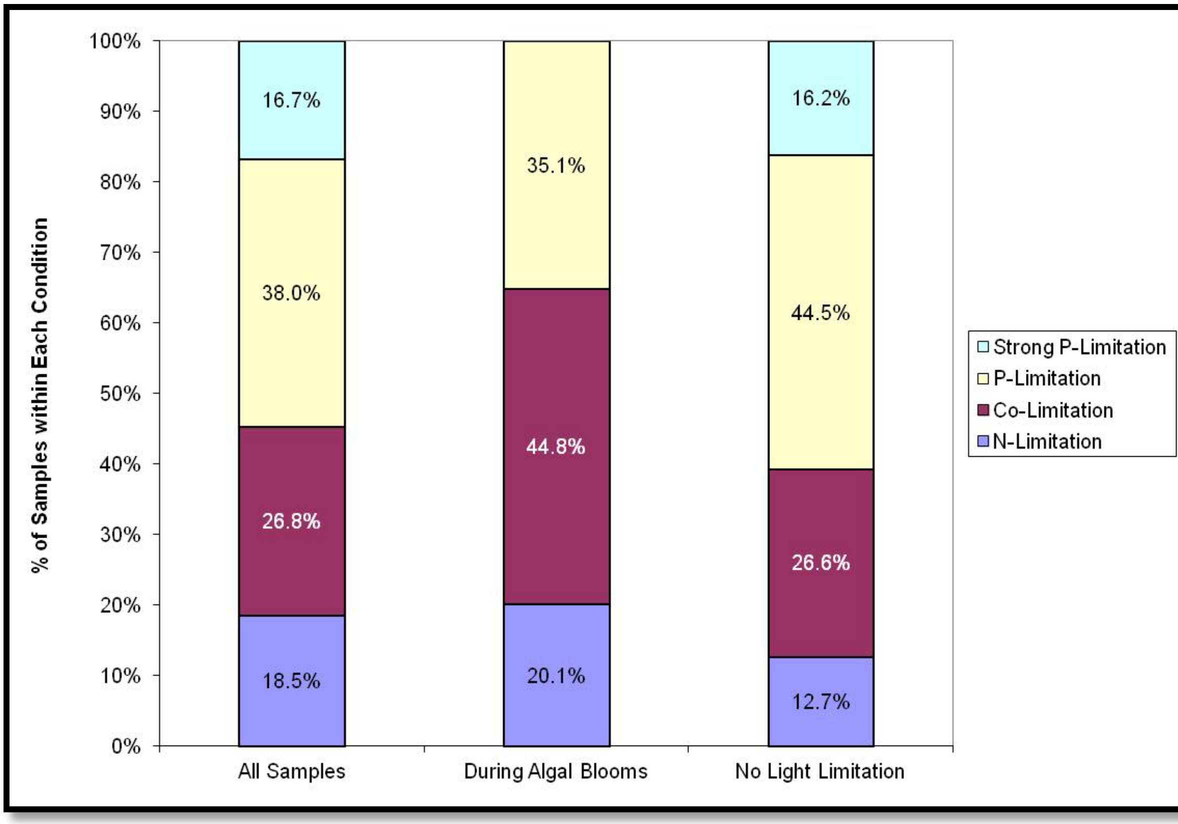

Figure 3-6. Summarization of TN:TP values under various conditions.

Examination of the presence or lack of correlation between nutrients and indicators of water quality such as chlorophyll-a and Secchi depth provide further insight regarding probable causes of eutrophication. It is important to recognize that correlation is not equivalent to causation, but this does not render correlation useless. It can be a valuable tool when used with other analyses to evaluate the relationship between water quality and nutrients. Figures 3-7 and 3-8 illustrate correlation, as expressed by linear regression, of chlorophyll-a (i.e., algae) to nitrogen and phosphorus, respectively. Analysis of Figure 3-7 reveals a weak positive correlation ($R^2 = 0.10$) between chlorophyll-a and TN. Figure 3-8 reveals a stronger, positive relationship ($R^2 = 0.48$) between chlorophyll-a and TP.

Although phosphorus may not be the sole limiting factor for algal growth at all times and under all conditions, it plays a larger role in limitation than nitrogen. The fact that the TN:TP ratio is often greater than 17, per Figures 3-5 and 3-6, support this conclusion. Additionally, Figure 3-8 may imply that lowering TP will lower algal levels, as measured by chlorophyll-a. However, lakes are complex and dynamic systems, and these relationships vary spatially and temporally. It is likely that nitrogen limitation does play a role in algal growth and speciation under certain conditions, and this should be acknowledged when developing lake restoration plans, even though phosphorus more directly and consistently influences eutrophication in Lake Keomah. Many phosphorus reduction activities will also reduce nitrogen loads to the lake. If the phosphorus targets set forth in this TMDL are attained and excess algae persist, lake managers should consider implementation of additional nitrogen reduction measures.

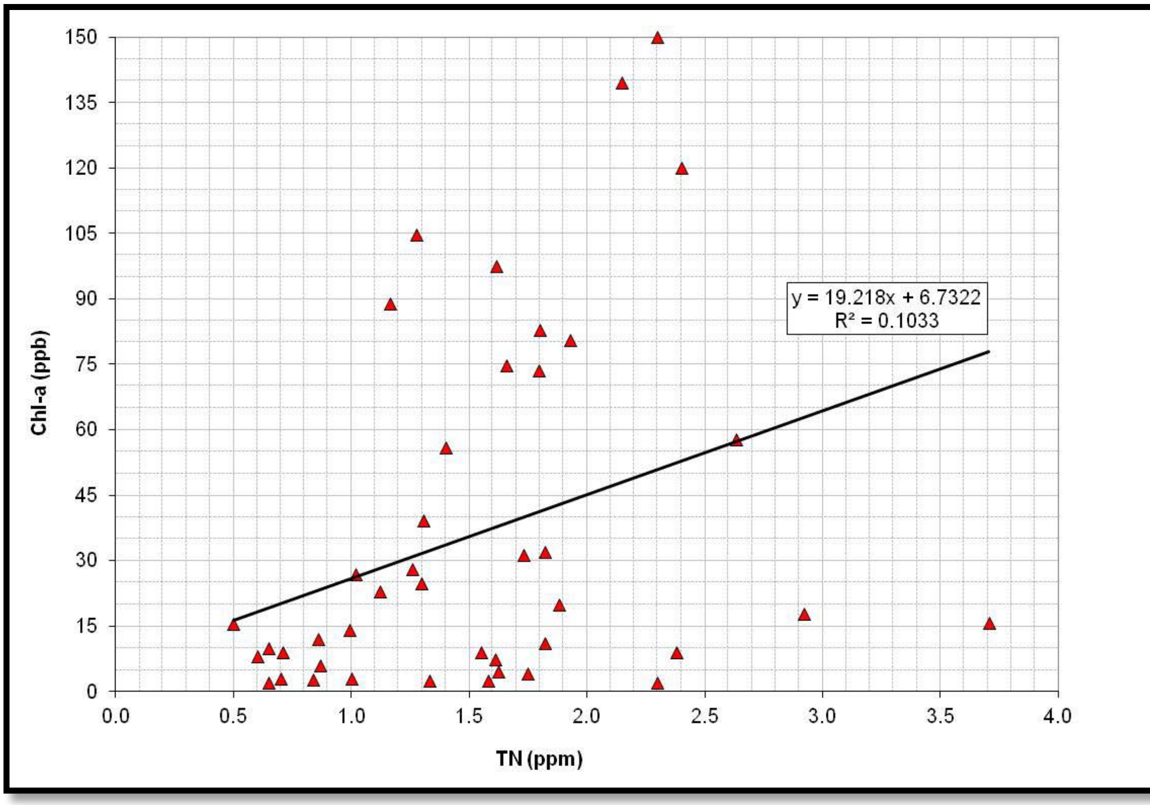

Figure 3-7. Chlorophyll-a vs. TN (2001-2010).

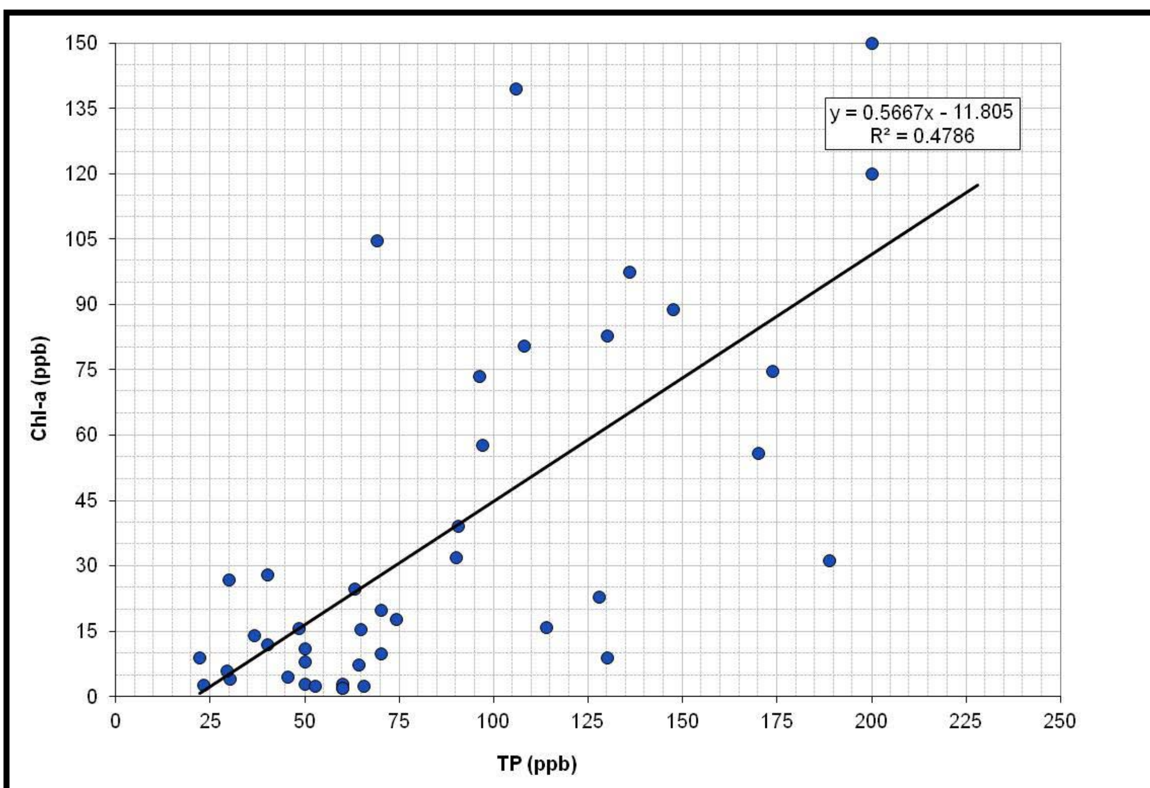

Figure 3-8. Chlorophyll-a vs. TP (2001-2010).

High pH levels also impair primary contact recreation in Lake Keomah, as well as aquatic life. Figure 3-9 shows that pH exceeded the maximum criterion of 9.0 regularly between 2001 and 2007. Elevated pH is often related to and a direct result of algal blooms, which affect the lake's carbon cycle and hence, pH.

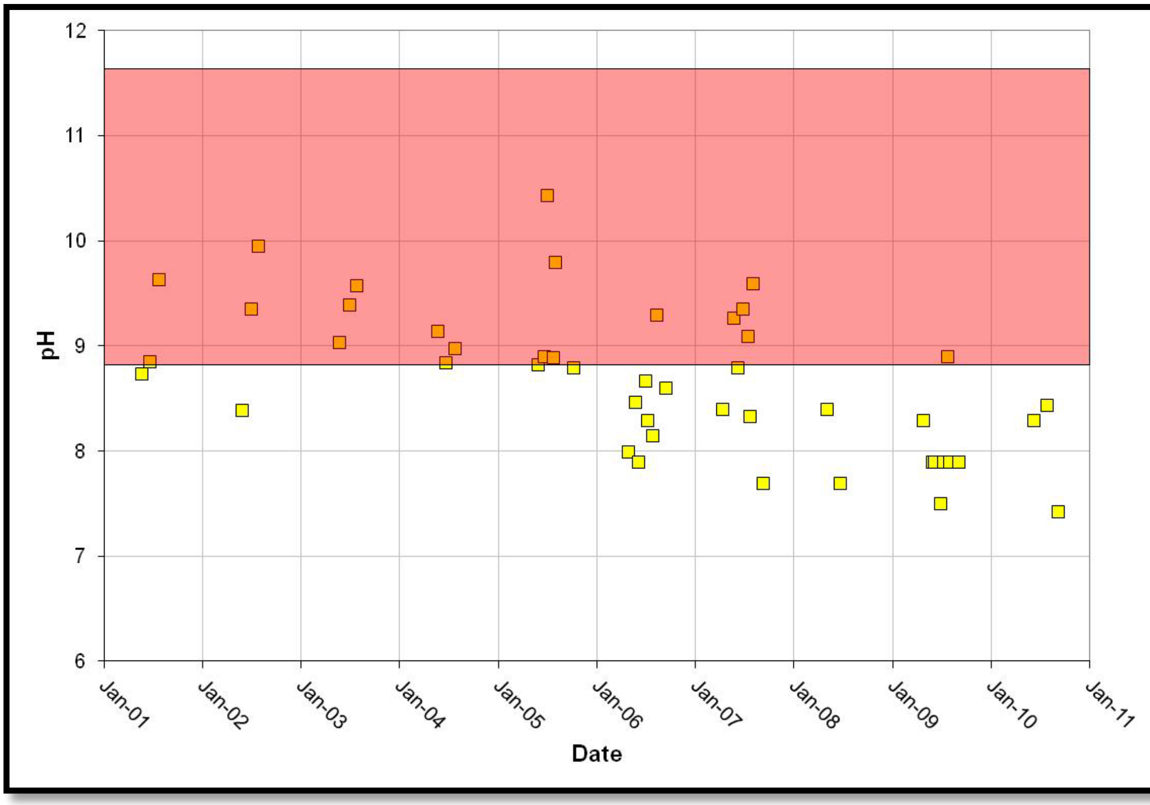

Figure 3-9. Measured pH levels in Lake Keomah (2001-2010).

As shown in Figure 3-10, there is a relatively strong positive relationship (R^2 = 0.44) between pH levels and chlorophyll-a (natural log). The confidence interval indicates that pH levels in Lake Keomah do not exceed the maximum criterion of 9.0 when chlorophyll-a concentrations do not exceed 32.1 ug/L (with 95 percent confidence). This concentration is equivalent to the natural log value of 3.5, as shown on Figure 3-10. Therefore, if algal growth in Lake Keomah is sufficiently reduced, pH levels will decrease and remain below the maximum criterion expressed in the state's WQS.

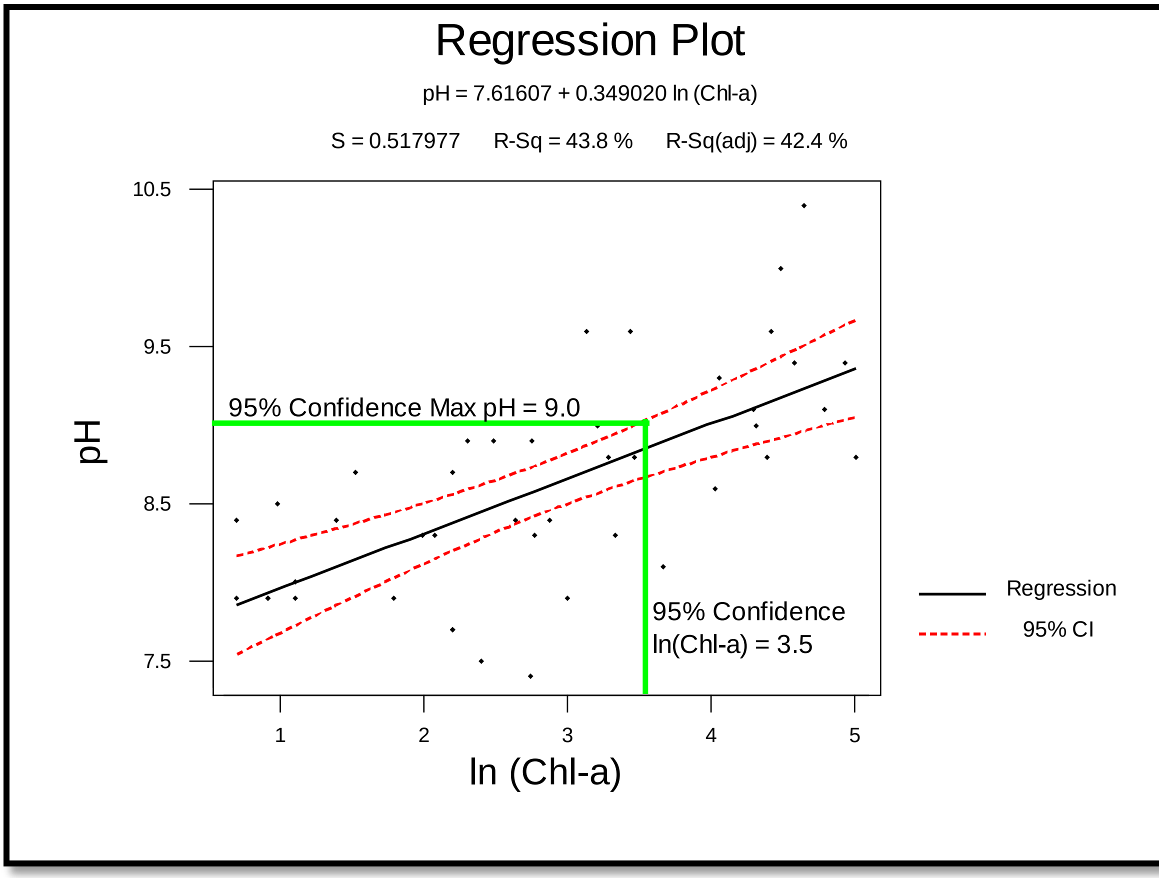

Figure 3-10. pH vs. chlorophyll-a (2001-2010).

3.2. TMDL Target

General description of the pollutant

The 2010 305(b) assessment and the data interpretation described in Section 3.1 do not allow a conclusive determination of nutrient limitation in Lake Keomah. Therefore, professional judgment is required to develop water quality targets within the TMDL. Observed data and subsequent analysis revealed that algae are causing poor water quality, including elevated pH levels, in Lake Keomah. Carlson's TSI methodology, TN:TP ratios, and correlations suggest that at times algal growth may be limited solely by phosphorus. At other times, both phosphorus and nitrogen are limiting. In many cases, something other than nutrients appears to limit algal growth. There are few occasions where nitrogen is the limiting nutrient.

While some studies suggest that control of both nitrogen and phosphorus may be needed to limit eutrophication in some lakes (Conley et al., 2009), phosphorus control is still thought to be critical in mitigating eutrophication (Carpenter, 2008). If phosphorus reductions are attained and algal blooms continue to impair designated uses, a dual-nutrient approach should be implemented in the Lake Keomah watershed. Nitrogen reduction in lieu of phosphorus controls may tilt the TN:TP ratio higher, which could lead to conditions that increase risk of potentially dangerous blue-green algae called cyanobacteria (Smith, 1983).

For these reasons, the TMDL for algae and pH is based on in-lake targets for each, which will be achieved by reducing phosphorus loads to the lake. Phosphorus reductions will be accompanied by nitrogen reductions, since they share many common sources and transport mechanisms. If phosphorus targets are met and the algae and/or pH impairments persist, additional reduction of nitrogen should be considered.

One TMDL targeting phosphorus will address both pH and algae impairments. The TP target is expected to result in a chlorophyll-a TSI value not exceeding 63, per IDNR's delisting criteria. This TSI value corresponds to a chlorophyll-a concentration of 27 ug/L, which is below the chlorophyll-a concentration needed to comply with the pH target of 9.0, per the regression and 95 percent confidence interval illustrated in Figure 3-10.

Table 3-3 reports the simulated whole-lake average chlorophyll-a TSI, TP concentration, and Secchi depth for both existing and target conditions. In-lake water quality was simulated using a calibrated BATHTUB model, which is described in more detail in Appendix E. The TSI target complies with the narrative "free from aesthetically objectionable conditions," and also satisfies the maximum pH criterion of "not greater than 9.0." A growing-season mean chlorophyll-a TSI of 63 will result in delisting Lake Keomah if attained in two consecutive 303(d) listing cycles. In order to incorporate an implicit margin of safety (MOS), this TMDL targets a "whole-lake area-weighted average" chlorophyll-a TSI of 63, rather than focusing compliance strictly at the ambient monitoring location in the main, open water segment of the lake. This provides an implicit margin of safety (MOS) because ambient data used for assessment and de-listing purposes will be collected only in the main, open water area of the lake (Segment 3 in Table 2-3). Note that the total phosphorus and Secchi depths in Table 3-3 are not TMDL targets, rather, they represent in-lake water quality associated with existing and TMDL conditions.

Table 3-3. Simulated existing and target water quality (whole lake average).

Parameter	2001-2010 Mean	[1]TMDL Target
Chlorophyll-a TSI	69	63
Total Phosphorus	123 ug/L	54 ug/L
Secchi Depth	1.1 m	1.8 m

[1]Target is chlorophyll-a TSI of 63 or less. Resulting TP and SD values are not targets.

Selection of environmental conditions
The critical period for the occurrence of algal blooms resulting from high phosphorus levels in the lake is the growing season (April through September). However, long-term phosphorus loads lead to buildup of phosphorus in the reservoir and contributes to blooms regardless of when phosphorus first enters the lake. Additionally, the combined watershed and in-lake modeling approach using EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL) and BATHTUB lends itself to analysis of annual average conditions. Therefore, both existing and allowable TP loads to Lake Keomah are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Waterbody pollutant loading capacity (TMDL)
This TMDL for algae establishes an in-lake target for chlorophyll-a and an associated target TP load using analysis of existing water quality data and Carlson's trophic state index methodology. IDNR anticipates that the resulting TMDL will also address the pH impairment, as documented in Section 3.1. Attainment of the water quality target will require implementation of a comprehensive watershed management and lake restoration plan that builds on previous implementation efforts.

The allowable in-lake chlorophyll-a target was translated to the TP loading capacity by performing water quality simulations using the BATHTUB model. BATHTUB is a steady-state water quality model that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). The BATHTUB model was calibrated to water quality data collected by ISU and SHL from 2001 through 2010, and is driven by weather, lake morphometry (i.e., size and shape), watershed hydrology, and sediment and nutrient loads predicted by the STEPL model. STEPL utilizes simple equations to predict sediment and nutrient loads from various land use and animal sources, and includes a tool that estimates potential sediment and nutrient reductions resulting from implementation of Best Management Practices (BMPs). STEPL input included local soil, land cover, and climate data, as well as detailed information regarding agricultural practices and other land management activities. A detailed discussion of the parameterization and calibration of the STEPL and BATHTUB models is provided in Appendices D through F.

The annual TP loading capacity was obtained by adjusting the watershed and internal TP loads in the calibrated BATHTUB model until the target chlorophyll-a TSI of no greater than 63 was attained for the whole-lake area-weighted average. The allowable TP load to the lake (i.e., the loading capacity) varies, depending on the respective reductions in watershed and internal phosphorus loads. Table 3-4 reports the internal and external loads, reductions, and overall loading capacity under 11 scenarios (0 to 100 percent reduction of internal loading). Figure 3-11 illustrates the loading capacity curve across all possible combinations of internal and watershed load reductions. The Lake Keomah TMDL target assumes a 70 percent reduction to the internal load, which results in a loading capacity target of 1,161 pounds per year (lbs/yr) and a required watershed reduction of 76 percent. However, watershed planners and stakeholders should have the flexibility to allocate internal vs. watershed reductions, provided the resulting phosphorus load results in attainment of in-lake water quality goals.

Table 3-4. Potential phosphorus loading capacity scenarios.

Internal Load (lbs/yr)	Internal Reduction (%)	Watershed Load (lbs/yr)	Watershed Reduction (%)	[1]Loading Capacity (lbs/yr)	Total Reduction (%)
811	0	523	86	1,355	70.3
730	10	260	85	1,311	71.3
649	20	598	84	1,267	72.3
567	30	672	82	1,261	72.4
486	40	691	81.5	1,198	73.8
405	50	747	80	1,173	74.3
324	60	822	78	1,167	74.4
243	70	897	76	1,161	74.6
162	80	971	74	1,154	74.7
81	90	1,046	72	1,148	74.9
0	100	1,121	70	1,142	75.0

[1] Loading capacity = watershed load + internal load + atmospheric deposition (20.9 lbs).
[2] TMDL equation assumes 70% internal and 76% watershed reductions (74.6% overall reduction).

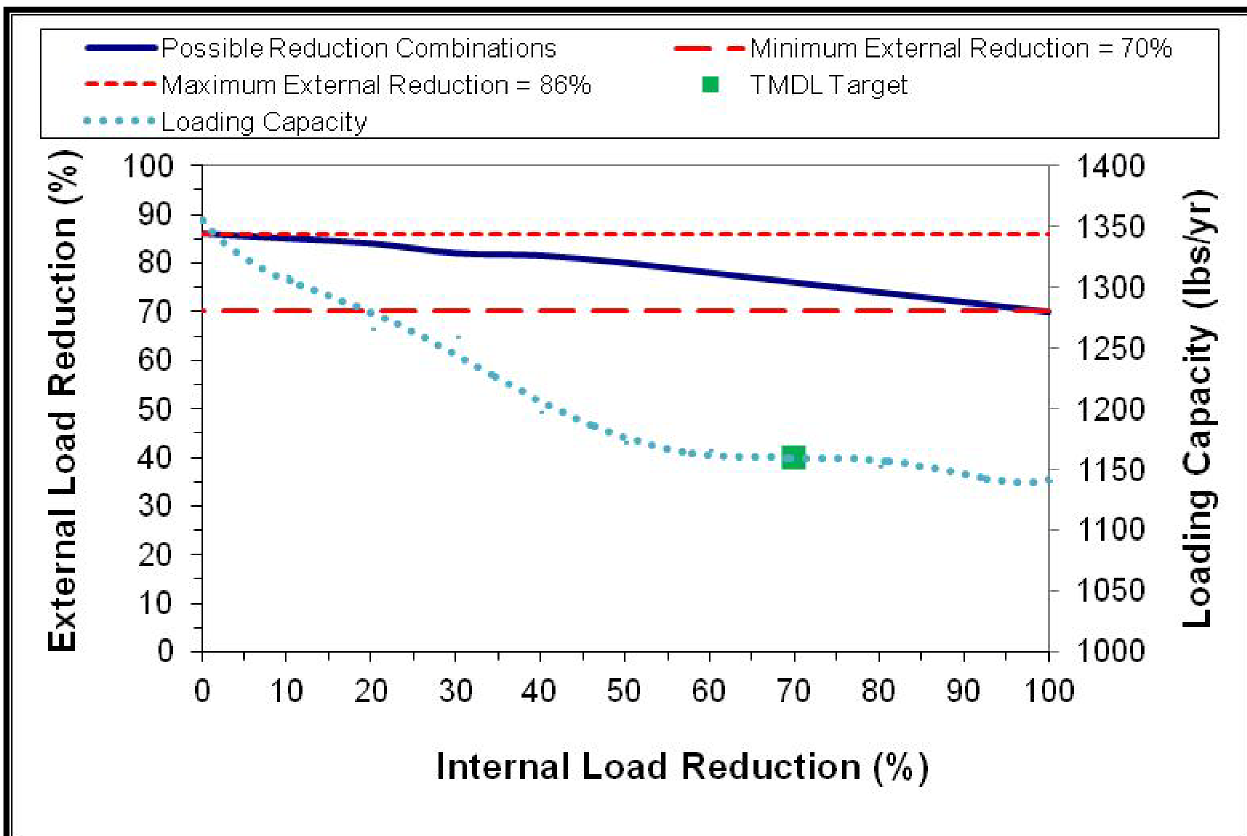

Figure 3-11. Phosphorus loading capacity curve for Lake Keomah.

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No.*

05-5015, (April 25, 2006) and Implications for NPDES Permits. In the context of the memorandum, EPA

> *"…recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards…"*

As recommended by EPA, the loading capacity of Lake Keomah for TP is expressed as a daily maximum load, in addition to the annual loading capacity of 1,161 lbs/year. The annual average load is applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load expression satisfies legal uncertainty.

The maximum daily load was estimated from the growing season average load using a statistical approach that is outlined in more detail in Appendix G. This approach uses a log-normal distribution to calculate the daily maximum from the long-term (e.g., seasonal) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), and was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*. Using the approach, the allowable loading capacity of 1,161 lbs/yr is equivalent to an average daily load of 3 pounds per day (lbs/day) and a maximum daily load of 13 lbs/day.

Decision criteria for water quality standards attainment
The narrative criteria in the water quality standards require that Lake Keomah be free from "aesthetically objectionable conditions." There are no numeric criteria associated with water clarity, therefore attainment of the standard is based on maintaining relatively good water clarity compared to other Iowa lakes. The primary metric for water quality standards attainment set forth in this TMDL is obtaining/maintaining a chlorophyll-a TSI of no greater than 63, which corresponds to a chlorophyll-a concentration of 27 ug/L. IDNR will de-list the impairment if the chlorophyll-a TSI is 63 or less in two consecutive 303(d) listing cycles. As discussed in Sections 3.1 and 3.2, attainment of the TSI criterion should result in compliance with the numeric pH standard.

3.3. Pollution Source Assessment

Existing load
Average annual simulations of hydrology and pollutant loading were developed using the STEPL model (Version 4.1). STEPL was developed by Tetra Tech, for the US EPA Office of Water, and has been utilized extensively in the United States for TMDL development and watershed planning. Model description and parameterization are described in detail in Appendix D.

Using STEPL and BATHTUB, the average annual TP load to Lake Keomah from 2001-2010, including watershed, internal, and atmospheric loading was estimated to be 4,567 lbs/yr. This is equivalent to an average daily load of 3 lbs/day and a daily maximum of 13 lbs/day (using the same statistical approach described for the loading capacity). This simulation period includes a dry period with consecutive years of below normal precipitation (2001-2006), and a wet period with consecutive years of above normal precipitation (2007-2010). These two periods were analyzed separately during model calibration, described in Appendix F. However, the 10-year period, which includes both conditions, was determined to be most appropriate for development of the numeric TMDL.

Departure from load capacity
The TP loading capacity for Lake Keomah is 1,161 lbs/yr and 13 lbs/day (maximum daily load). To meet the target loads, an overall reduction of 74.6 percent of the TP load is required. This will require BMPs in addition to those already implemented during previous watershed improvement efforts. The implementation plan included in Section 4 describes potential BMPs, potential TP reductions, and considerations for targeted selection and location of BMPs.

Identification of pollutant sources
The existing TP load to Lake Keomah is entirely from nonpoint sources of pollution. There are no point sources operating under a National Pollution Discharge Elimination System (NPDES) permit or regulated by other Clean Water Act programs. Table 3-5 reports estimated annual average TP loads to the lake from all known sources, based on the STEPL simulation of 2001-2010 conditions. Figure 3-12 illustrates the relative contributions of each source to the overall phosphorus load.

The predominant source of phosphorus to Lake Keomah is runoff and erosion from land in row crop production, which accounts for 57.9 percent of the total load to the lake. Row crops comprise nearly half (46.7 percent) of the land in the watershed, so it is not surprising that cropland is the largest contributor of phosphorus to Lake Keomah.

Internal recycling of phosphorus in the lake is the second largest source of phosphorus. Internal loading contributed an estimated 17.8 percent of the load from 2001-2010 on an average annual basis. However, internal recycling may be more critical to in-lake water quality than this contribution suggests. In dry years, the internal load may drive algal blooms in the absence of significant phosphorus loads from the watershed. BATHTUB simulations indicate that between 2001 and 2006, in which annual precipitation was below normal, the internal load accounted for 22.2 percent of the total load.

Phosphorus recycled from the bottom of a lake is more available for algal uptake and growth than phosphorus attached to soil particles washed in from watershed sources. It is likely that short-term internal loads under certain conditions may contribute enough biologically available phosphorus to cause algal blooms, even though the net annual internal load may be relatively small. Estimation of internal phosphorus loads in lakes is challenging, and there is often uncertainty associated with internal load estimates.

Table 3-5. Average annual TP loads from each source (2001-2010).

Source	Descriptions and Assumptions	TP Load (lb/yr)	Percent (%)
Row Crops	Corn and soybeans	2,643	57.86
Streambank/gully	Stream bank and ephemeral gullies	421	9.23
Grass/Hay	Alfalfa and ungrazed grassland	277	6.07
Developed	Includes farmsteads, roads/ROW, and quarry	199	4.37
Septic systems	Private on-site wastewater treatment systems	141	3.08
Timber	Wooded areas	54	1.18
Internal Recycling	Phosphorus recycled from lake bottom	811	17.75
Atmospheric Deposition	Wet and dry deposition from the atmosphere	21	0.46
Total		4,567	100.00

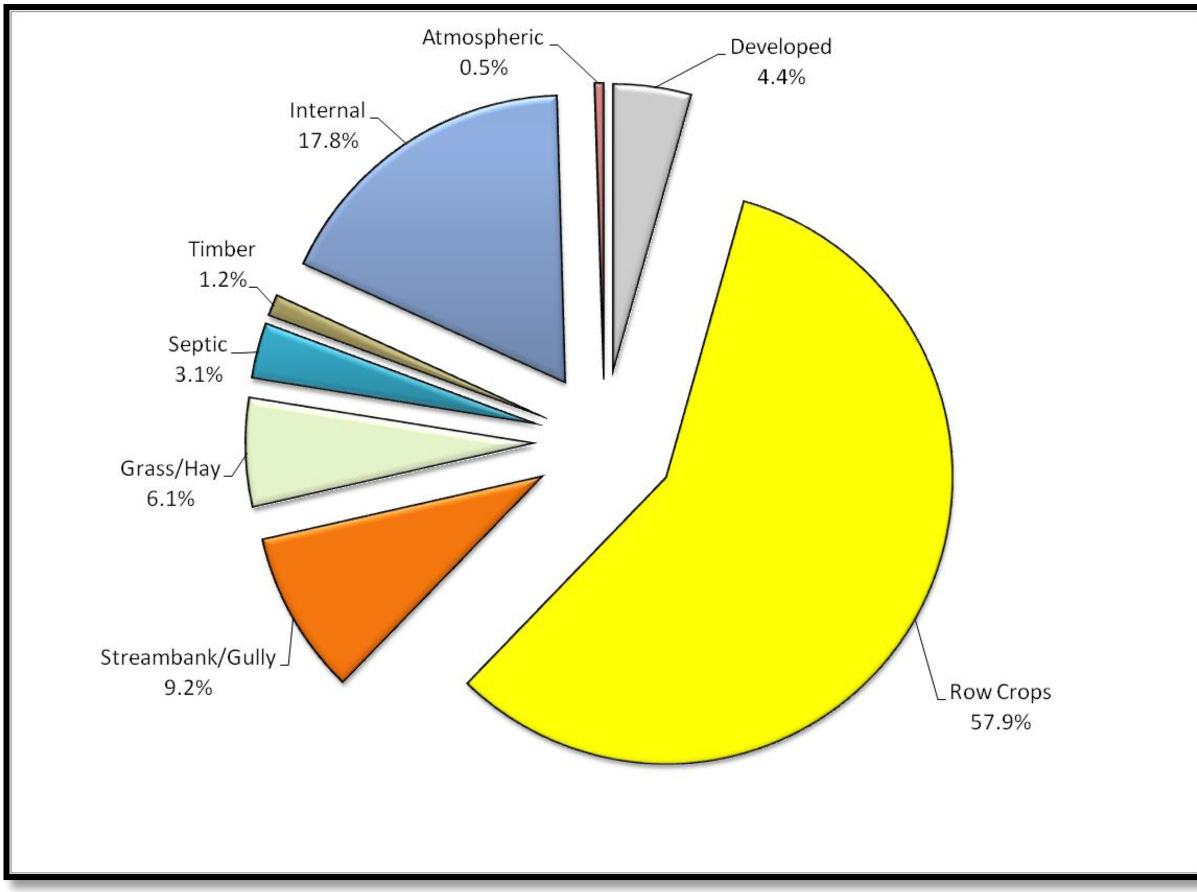

Figure 3-12. Relative TP loads by source.

Reduction of internal loading in Lake Keomah will be a critical component of a successful management/restoration plan; however, adequate control and reduction of watershed sources must first be implemented. Failure to address watershed sources will shorten the life of the in-lake BMPs, and is an inefficient use of limited resources.

Other phosphorus sources include erosion from stream banks and ephemeral gullies and leakage from failing or improperly designed septic systems. Runoff and groundwater originating in developed areas (i.e., Keomah Village), hay and grassland, and wooded areas also contribute some phosphorus to the lake. Natural and background sources such as wildlife and atmospheric deposition, are relatively small potential sources. However, even small sources of phosphorus have collective impacts on water quality or cause localized problems (e.g., near tributaries or outfalls) and should be considered when developing a watershed management and lake restoration plan.

Allowance for increases in pollutant loads
There is no allowance for increased phosphorus loading included as part of this TMDL. A majority of the watershed is in agricultural row crop production, and is likely to remain in cropland in the future. Lake Keomah State Park, which is adjacent to the lake, is unlikely to undergo significant land use changes. There are no incorporated unsewered communities in the watershed (Keomah Village is sewered and has a sewage lagoon located downstream from the lake). Therefore, it is unlikely that a future WLA would be needed for a new point source discharge.

3.4. Pollutant Allocation

Wasteload allocation
There are no permitted point source dischargers of phosphorus in the Lake Keomah watershed. Keomah Village is a sewered community, but the lagoon is located downstream of the lake. Private on-site septic systems are common in the watershed, but they are not designed or permitted to discharge. A portion of existing septic systems are assumed to be failing or directly discharging to tile drains and are included as nonpoint sources. Therefore, there is no wasteload allocation (WLA) included in the TMDL.

Load allocation
Nonpoint sources to Lake Keomah include loads from agricultural land uses, internal recycling in the lake, and natural/background sources in the watershed, including wildlife and atmospheric deposition (from dust and rain). Septic systems, which are not regulated or permitted under the Clean Water Act, but occasionally fail or drain directly to tiles, also contribute phosphorus to the lake. It is seldom feasible or economical to achieve large load reductions from natural/background sources. However, changes in agricultural land management, implementation of structural best management practices (BMPs), repair or replacement of failing septic systems, and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Lake Keomah.

Table 3-6 shows an example load allocation for the Lake Keomah watershed that meets the overall TMDL phosphorus target. The LA is 1,161 lbs/year, with a maximum daily LA of 13 lbs/day. Individual reductions shown in Table 3-6 are not required, but provide examples of how the overall reduction may be accomplished.

Table 3-6. Example load allocation scheme to meet target TP load.

TP Source	Existing Load (lb/year)	LA (lb/year)	Load Reduction (%)
Row Crops	2,643	581	78.0
Streambank/gully	421	93	78.0
Grass/Hay	277	144	48.0
Developed	199	44	78.0
Septic systems	141	7	95.0
Timber	54	28	48.0
Internal Recycling	811	243	70.0
Atmospheric Deposition	21	21	0.0
Total	**4,567**	**1,161**	**74.6**

Margin of safety
To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An implicit MOS was utilized in the development of this TMDL. The implicit MOS is justified by targeting a "whole-lake area-weighted average" chlorophyll-a TSI value of 63 or less, which is equivalent to the IDNR de-listing criterion. However, this is a conservative approach because IDNR assessment methodology is based entirely on water quality data collected in the deepest part of the lake near the earthen dam. This ambient monitoring station is in Segment 3 (of the BATHTUB model), which has consistently lower TSI values than the area-weighted average values. Therefore, targeting the weighted-average TSI requires larger reductions than those necessary to meet IDNR's delisting criteria.

Reasonable Assurance
Under current EPA guidance, when a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurance that nonpoint source control measures will achieve expected load reductions. Because there are no permitted or regulated point sources contributing phosphorus to Lake Keomah, reasonable assurance is not required in this TMDL.

3.5. TMDL Summary

The following general equation represents the total maximum daily load (TMDL) calculation and its components:

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

Where:
TMDL = total maximum daily load
LC = loading capacity
Σ WLA = sum of wasteload allocations (point sources)
Σ LA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

Once the loading capacity, wasteload allocations, load allocations, and margin of safety have all been determined for the Lake Keomah watershed, the general equation above can be expressed for the Lake Keomah algae TMDL.

Expressed as the allowable annual average, which is helpful for water quality assessment and watershed management:

TMDL = LC = Σ WLA (0 lbs-TP/year) + Σ LA (1,161 lbs-TP/year)
+ MOS (0, implicit) = **1,161 lbs-TP/year**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (13 lbs-TP/day)
+ MOS (0, implicit) = **13 lbs-TP/day**

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources (IDNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). Therefore, this implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) discussed are potential tools that will help achieve water quality goals if appropriately utilized. It is possible that only a portion of BMPs included in this plan will be feasible for implementation in the Lake Keomah watershed. Additionally, there may be potential BMPs not discussed in this implementation plan that should be considered. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

Collaboration and action by residents, landowners, lake users, and local agencies will be essential to improve water quality in Lake Keomah and support its designated uses. Locally-led efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality results in economic and recreational benefits for people that live, work, and play in the watershed. Therefore, each group has a stake in promoting awareness and educating others about water quality, working together to adopt a comprehensive watershed improvement plan, and applying BMPs and land management changes in the watershed.

4.1. Previous Watershed Planning and Implementation

Public agencies, residents, and landowners in the Lake Keomah watershed have previously implemented a watershed management plan to improve and protect water quality. The Mahaska County Soil and Water Conservation District (SWCD) worked with local stakeholders to develop and implement a watershed project, which was completed in 1996. Implementation activities included:

- Construction of sediment basins and terraces
- Adoption of conservation tillage practices
- Livestock manure management (via waste containment structures)
- Promotion of contour farming practices
- Urban lawn care program in Keomah Village to promote reduced fertilizer losses
- Integrated crop management to reduced herbicide and pesticide use
- Exclusion of livestock from directly assessing tributaries to the lake

These activities have reduced the amount of pollutants transported to Lake Keomah the past 15 years. However, some of these practices require retrofitting or maintenance in order to provide continued water quality benefits. And despite the improvement in watershed management, water quality problems in the lake persist. Further management of Lake Keomah and its watershed will be required to support all designated uses of the lake.

4.2. General Approach & Timeline

General Approach

Watershed management and BMP implementation to reduce algae in the lake should utilize a phased approach to improving water quality. The preliminary phase(s) should consist of planning and implementation required to meet water quality standards (WQS) in the deep, open water area of the lake. This portion of the lake is represented by Segment 3 in the BATHTUB model utilized in TMDL development. The ambient lake monitoring location and water quality assessment are based on this segment, specifically at the location shown within Segment 3 in Figure 4-1.

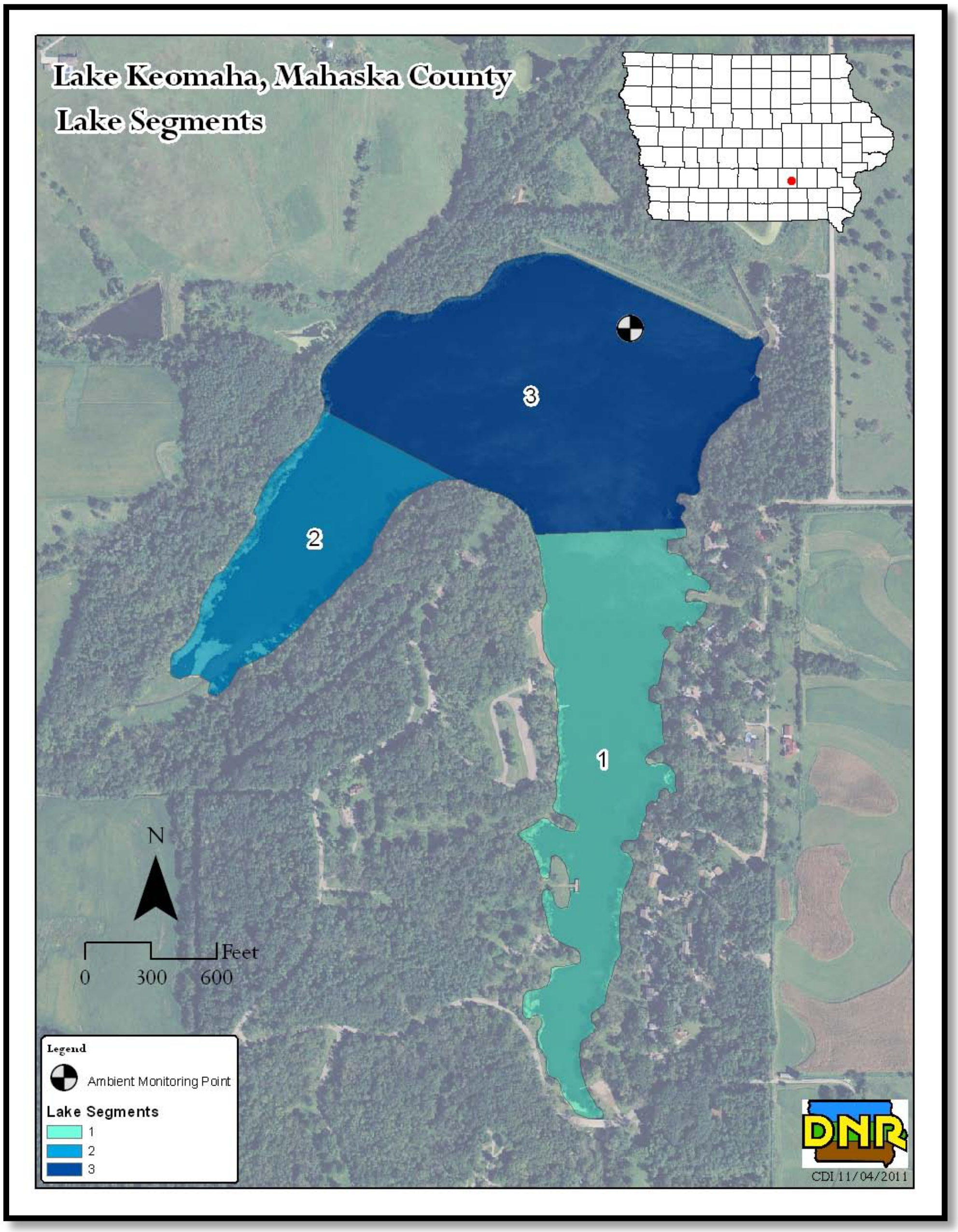

Figure 4-1. Lake segmentation for phased approach.

In IDNR's view, the TMDL and associated in-lake water quality goals developed in Section 3 should consider only Segment 3 and the associated ambient monitoring location. However, EPA review of the modeling approach required that the water quality targets (for chlorophyll-a TSI and pH) be set for the area-weighted average of the entire lake (i.e., Segments 1 through 3 in Figure 4-1). IDNR views this requirement as overly restrictive, since compliance will be assessed only at the ambient monitoring location in Segment 3. Therefore, successful implementation of preliminary phase(s) should result in de-listing Lake Keomah from the state's impaired waters list, and will indicate full support of designated uses.

Subsequent phases of planning and implementation may be necessary if additional phosphorus, or possibly nitrogen reductions, prove necessary to attain water quality standards (WQS). Future phases could also be pursued by local stakeholders if the desire and resources exist to improve in-lake water quality to a level beyond compliance with WQS. For example, a secondary target might consider the area-weighted average of Segments 1 through 3, which would require total phosphorus (TP) reductions consistent with the TMDL described in Section 3. If even higher water quality is desired, stakeholders could implement a third phase to obtain compliance in each individual segment of the lake, which would require even greater TP reductions than those set forth in the TMDL (i.e., Section 3).

Implementation of subsequent phases would require more ambitious BMP implementation to attain water quality goals, as well as additional monitoring efforts to document compliance. This implementation plan for Lake Keomah is based solely on attaining a chlorophyll-a TSI of no greater than 63 and pH levels that do not exceed 9.0 in the main, open water area of Lake Keomah.

Preliminary Water Quality Goals

Internal and external load reduction scenarios and an example load allocation scheme to meet the TMDL target as required by EPA were developed and reported in Section 3 of this report. Those calculations were repeated, but adjusted to attain WQS compliance at the ambient monitoring location during preliminary phase(s) of implementation. The allowable load scenarios are reported in Table 4-1. Assuming that an internal load reduction of 70 percent is attained through implementation of in-lake water quality improvement activities, a watershed load reduction of 48 percent is required. This scenario is highlighted in Table 4-1.

The allowable load curve in Figure 4-2 illustrates the full range of internal and external load reductions that will satisfy the preliminary water quality goal. Local stakeholders, working with technical advisors, should determine how to identify and obtain internal and external TP reductions. An example load allocation that quantifies source-specific reductions to meet the preliminary target is provided in Table 4-2. Local stakeholders should determine how to address each potential phosphorus source.

Table 4-1. Allowable phosphorus load scenarios for preliminary WQ goal.

Internal Load (lbs/yr)	Internal Reduction (%)	Watershed Load (lbs/yr)	Watershed Reduction (%)	[1]Allowable TP (lbs/yr)	Total Reduction (%)
811	0	784	79	1,616	64.6
730	10	934	75	1,684	63.1
649	20	1,121	70	1,790	60.8
567	30	1,270	66	1,858	59.3
486	40	1,457	61	1,964	57.0
405	50	1,644	56	2,070	54.7
324	60	1,793	52	2,138	53.2
[2]243	[2]70	[2]1,942	[2]48	[2]2,207	[2]51.7
162	80	2,129	43	2,312	49.4
81	90	2,391	36	2,493	45.4
0	100	2,577	31	2,598	43.1

[1] Preliminary allowable TP load = watershed load + internal load + atmospheric deposition (20.9 lbs).
[2] Preliminary goal assumes 70% internal and 48% watershed reductions (51.7% overall reduction).

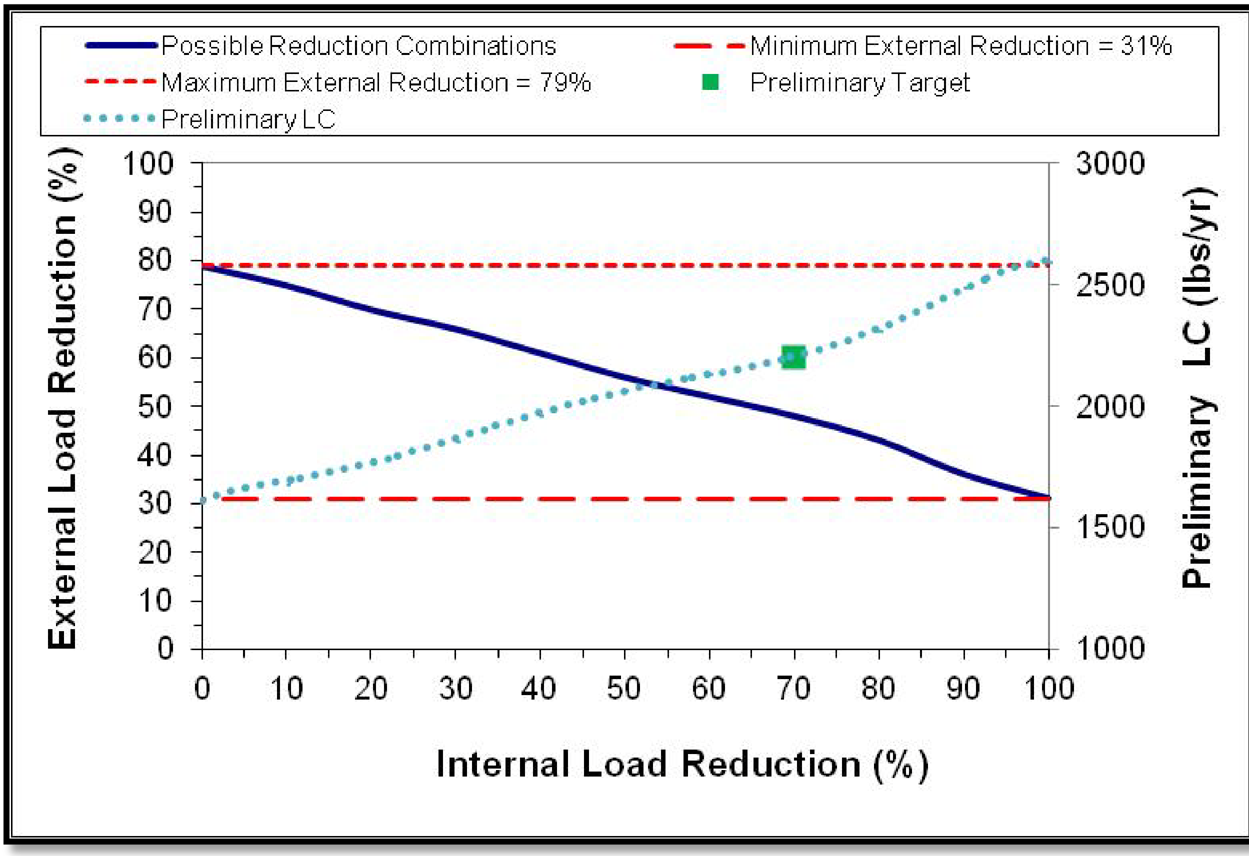

Figure 4-2. TP Reductions and LC for preliminary phase(s) of implementation.

Table 4-2. Example load allocation scheme to meet preliminary TP goal.

TP Source	Existing Load (lb/year)	Share of Existing Load (%)	Preliminary LA (lb/year)	Load Reduction (%)
Row Crops	2,643	57.9	1,321	50
Streambank/gully	421	9.2	253	40
Grass/Hay	277	6.1	194	30
Developed	199	4.4	120	40
Septic systems	141	3.1	14	90
Timber	54	1.2	41	25
Internal Recycling	811	17.8	243	70
Atmospheric Deposition	21	0.5	21	0
Total	**4,567**		**2,207**	**51.7**

Timeline

Planning and implementation of preliminary phase(s) may take several years, depending on stakeholder interest, availability of funds, landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of significant water quality benefits may take 5-10 years or longer, depending on weather patterns, amount of water quality data collected, and the successful location, design, construction, and maintenance of BMPs. A monitoring plan, based on the one outlined in Section 5 of this WQIP, should be implemented as soon as possible and before implementation begins to establish baseline conditions. Monitoring efforts should continue throughout implementation of BMPs and beyond. Watershed planners should establish short-term and intermediate goals and milestones, verify achievement of goals with monitoring, and use monitoring data to guide future implementation towards WQS attainment.

4.3. Best Management Practices

No stand-alone BMP will be able to sufficiently reduce nutrient loads to Lake Keomah. Rather, a comprehensive package of BMPs will be required to reduce algal blooms and pH levels, which impair designated uses in Lake Keomah. The majority of phosphorus and sediment that enter the lake is from agricultural land uses, specifically land in row crop production. Although relatively small on an annual average basis (17.8 percent of the total load), internal recycling is the second largest source of phosphorus and can be a primary driver of algal blooms, particularly in dry years. Additionally, internally recycled phosphorus is more biologically available (for algal growth) than runoff-derived phosphorus, which is largely attached to sediment. Erosion and sediment transported from ephemeral gullies and unstable ditches/channels is the third largest source, comprising over nine percent of the average annual load to Lake Keomah.

Because non-agricultural drainage area is very small, non-agricultural sources contribute small amounts of phosphorus to the lake. However, small sources can have important localized and seasonal affects on water quality. It is also important that all sources are addressed to reduce nutrient loads in the most comprehensive manner possible.

Additionally, experience has shown that watershed projects that involve widespread "ownership" of potential solutions have the best chance of success.

Potential BMPs are grouped into three types: land management, structural, and in-lake alternatives. Tables 4-3 through 4-5 identify potential BMPs in each of these groups. These lists are not all-inclusive, and further investigation may reveal some alternatives are more feasible and applicable to site-specific conditions than others. Development of a detailed watershed management plan will be helpful in selecting, locating, and implementing an effective and comprehensive package of BMPs, and will maximize opportunities for future technical and funding assistance.

Structural BMPs

Although they do not address the underlying generation of sediment or nutrients, structural BMPs such as sediment control basins, terraces, grass waterways, and wetlands can play a valuable role in reduction of sediment and nutrient transport to Lake Keomah. Structural BMPs should be targeted to increase their cost effectiveness and maximize pollutant reductions. Landowner willingness and the physical features of potential sites must also be considered when targeting structural practices. These practices may offer additional benefits not directly related to water quality improvement. These "secondary" benefits are important to emphasize to increase landowner and public interest and adoption. Potential structural BMPs are listed in Table 4-3, which includes secondary benefits and potential TP reductions.

Repair and replacement of faulty septic systems would eliminate phosphorus from this source, if all failing systems were addressed. The example load allocation in Table 4-2 identifies a reduction of 90 percent because it is likely that there will always be some small portion of poorly functioning septic systems.

Table 4-3. Potential structural BMPs.

BMP or Activity	Secondary Benefits	[1] Potential TP Reduction
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50%
[2]Grass Waterways	Prevent in-field gullies, prevent washouts, some ecological services	Not reported
[2]Sediment Control Structures	Some ecological services, gully prevention	Not reported
[3]Wetlands	Ecological services, potential flood mitigation, aesthetic value	20%

[1]Adopted from USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.
[2]No reductions reported by USDA-ARS for grass waterways or sediment structures
[3]Note: TP reductions in wetlands vary greatly depending on site-specific conditions. Increasing surface area, implementing multiple wetlands in series, and managing vegetation can increase potential TP reductions.

Land Management

Many agricultural BMPs are designed to reduce erosion and nutrient loss from the landscape. Because a large portion of TP is attached to sediment, BMPs that reduce erosion and sediment transport will also reduce TP loads. Land management alternatives implemented in row crop areas should include conservation practices such as cross-slope farming, no-till and strip-till farming, diversified crop rotation methods, utilization of in-field and riparian buffers, and planting winter cover crops. Potential land management activities and potential phosphorus reductions are reported in Table 4-4.

Incorporation of applied manure and fertilizer into the soil by knife injection equipment reduces phosphorus levels, as well as nitrogen and bacteria levels, in runoff from application areas. Strategic timing of manure and fertilizer application and avoiding over-application may have even greater benefits to water quality. Application of manure on frozen ground should be avoided, as should application prior to forecasted heavy rainfall.

Table 4-4. Potential land management BMPs.

BMP or Activity	[1] Potential TP Reduction
Conservation Tillage:	
Moderate vs. Intensive Tillage	50%
No-Till vs. Intensive Tillage	70%
No-Till vs. Moderate Tillage	45%
Cover Crops	50%
Diversified Cropping Systems	50%
In-Field Vegetative Buffers	50%
Pasture/Grassland Management:	
Livestock Exclusion from Streams	75%
Rotational Grazing vs. Constant Intensive Grazing	25%
Seasonal Grazing vs. Constant Intensive Grazing	50%
Phosphorus Nutrient Application Techniques	
[2]Deep Tillage Incorporation vs. Surface Broadcast	-15%
[2]Shallow Tillage Incorporation vs. Surface Broadcast	-10%
Knife/Injection Incorporation vs. Surface Broadcast	35%
Phosphorus Nutrient Application Timing and Rates:	
Spring vs. Fall Application	30%
Soil-Test P Rate vs. Over-Application Rates	40%
Application: 1-month prior to runoff event vs. 1-day	30%
Riparian Buffers	45%

[1]Adopted from USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.
[2]Note: Tillage incorporation can increase TP in runoff.

To obtain reductions in TP load necessary to meet water quality targets, land management strategies and structural BMPs should be implemented to obtain the largest and most cost-effective water quality benefit. Targeting efforts should consider areas with the highest potential phosphorus loads to the lake. Factors affecting phosphorus contribution include: steep slopes; proximity to waterbodies and surface intakes; and method, timing, and amount of manure and commercial fertilizer application.

Figure 4-3 illustrates three subbasins in the Lake Keomah watershed. The Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was used in TMDL development to estimate nutrient loads from each subbasin. Subwatershed TP and TN loads are illustrated in Figure 4-4, whereas average annual unit loads (lbs/ac/yr) are shown in Figure 4-5. Although the pollutant of concern in the algae TMDL is phosphorus, nitrogen loads should also be reduced. Not surprisingly, subbasins with the highest TP contributions also contribute the most TN. Subwatersheds W1 and W2 are the highest contributors of nutrients to Lake Keomah, on an aggregate and per acre basis, and therefore warrant special attention in the implementation of BMPs.

To reduce TP transport to the lake in the most cost-efficient manner, structural BMPs should be located near the outlets of these subwatersheds. TP loads per unit area are more uniform across subwatersheds than total loads, but slightly higher in Subbasin 1 (W1). Higher per area loads suggest these areas should be given priority for structural and land management alternatives.

Because much of the phosphorus transported from the watershed to the lake is attached to sediment, targeting BMP implementation should also consider areas prone to erosion. Figure 4-6 shows highly erodible land (HEL) shaded in red. HEL is susceptible to higher rates of erosion than land not designated as HEL. In the Lake Keomah watershed, most of the HEL is located in areas of steep slopes that transition from the flatter, upland areas into low-lying, wooded valleys. Most of the phosphorus loading from the watershed comes from HEL in row crop production. Implementation of both structural and land management BMPs should focus on HEL vs. flatter, less erosion-prone areas. The existing sediment load to the lake predicted using STEPL is 1,569 tons/year. Approximately 2.4 pounds of total phosphorus per ton of sediment is delivered to the lake; however, this number includes dissolved phosphorus as well as attached forms. The assumed concentration of total phosphorus in the soil is 800 parts per million (ppm). This is equivalent to 1.6 lbs-P/ton-sediment.

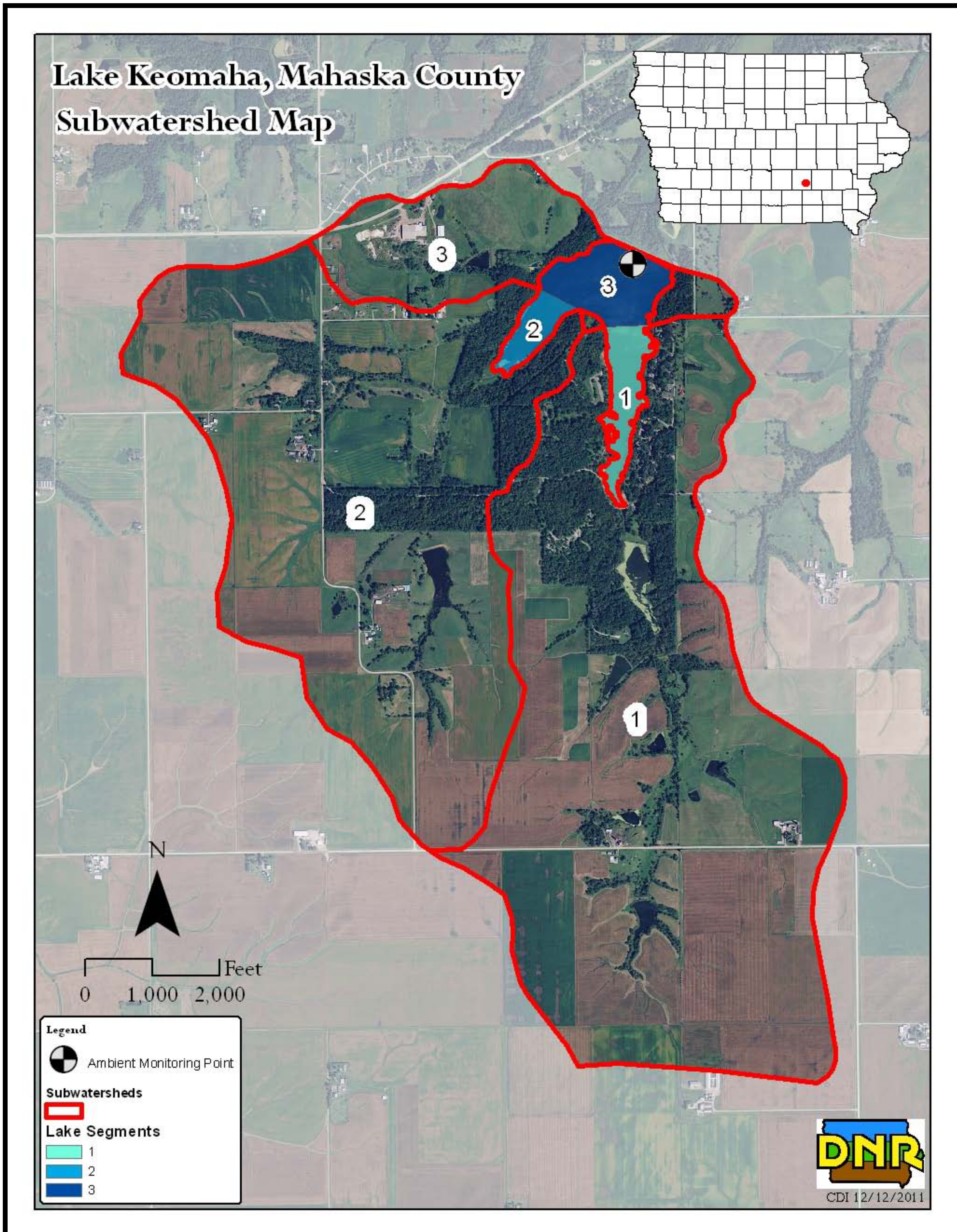

Figure 4-3. Subwatersheds modeled using STEPL.

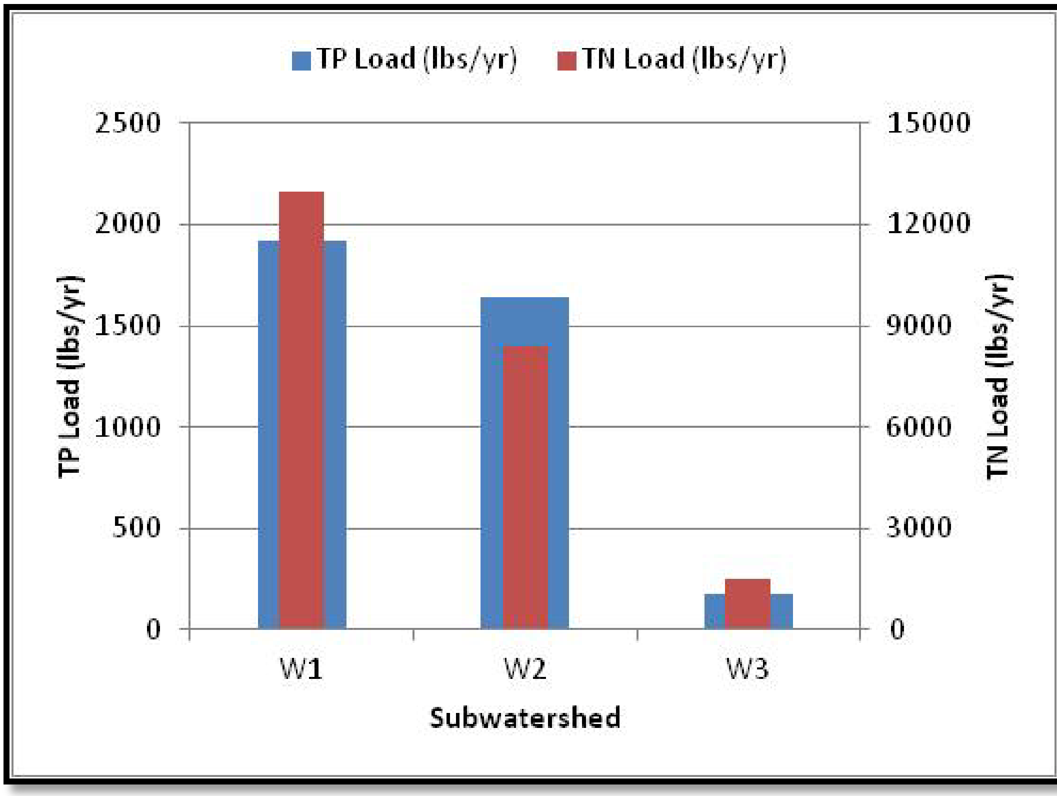

Figure 4-4. Predicted average annual loads by subbasin (2001-2010).

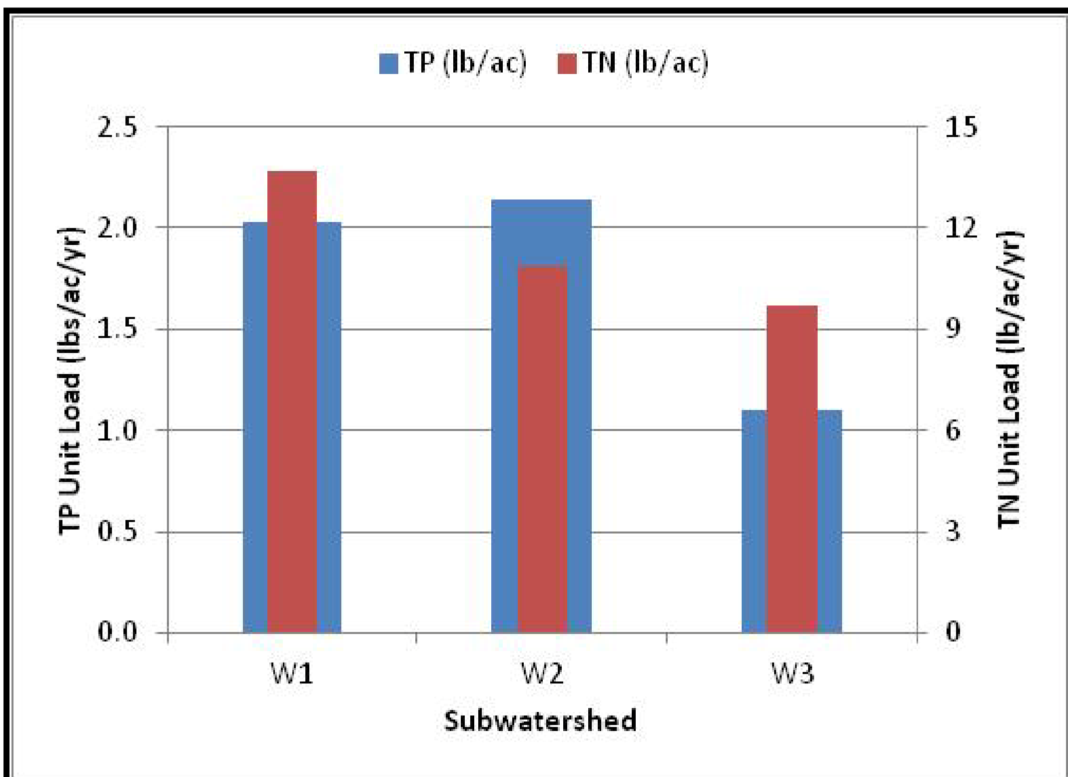

Figure 4-5. Predicted unit-area loads by subbasin (2001-2010).

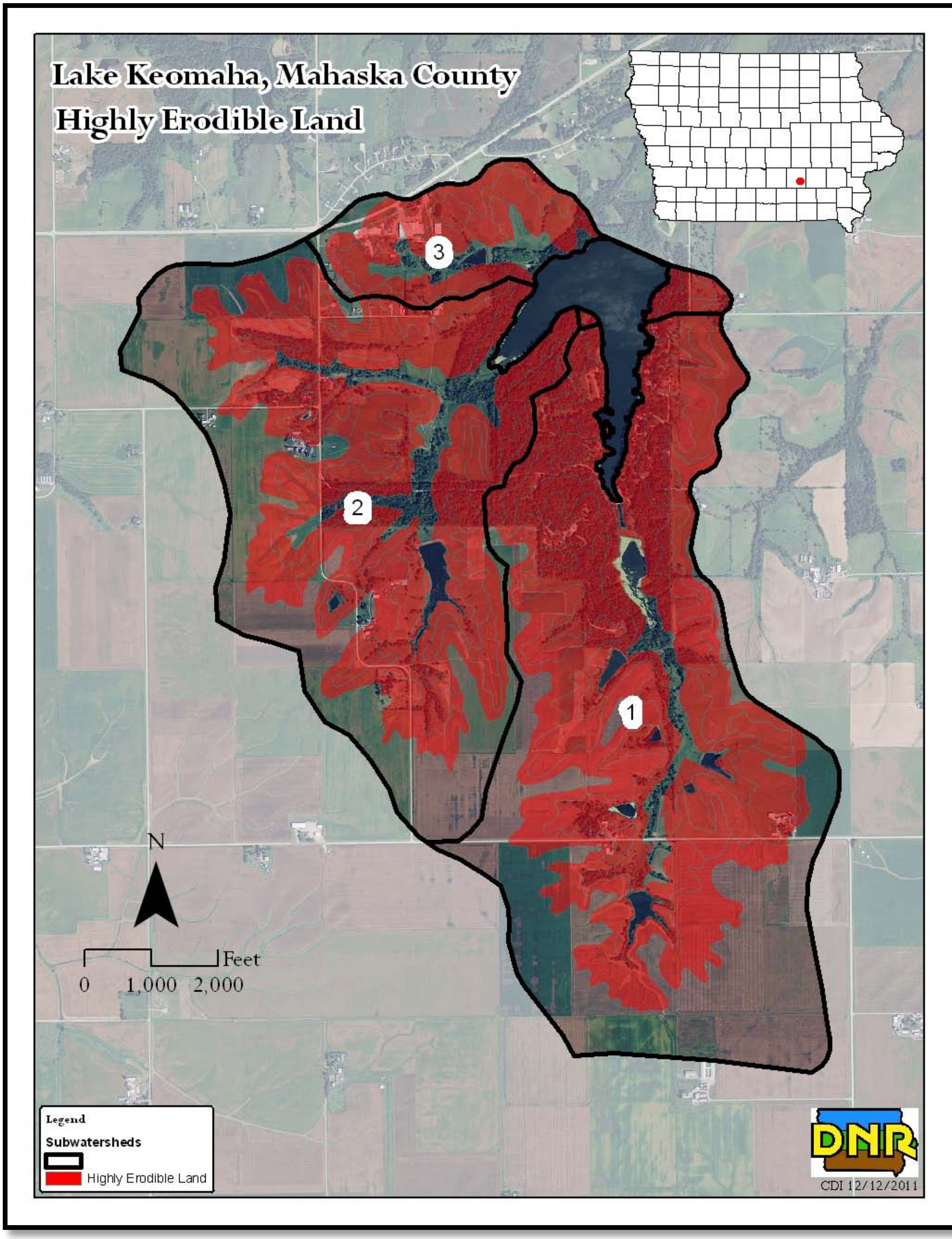

Figure 4-6. Map of highly erodible land (HEL) in the Lake Keomah watershed.

In-Lake BMPs

Phosphorus recycled between the bottom sediment and water column of the lake is, at times, an important contributor of bioavailable phosphorus to Lake Keomah. The average annual contribution of TP to the system from internal loading is estimated to be 17.8 percent of the total load. However, the influence of internal loading on in-lake water quality may be greater than the average annual contribution would suggest. While smaller than watershed loads on an annualized basis, internal loads can be the primary driver of eutrophication in dry years with little surface runoff to the lake. Additionally, internal loads may exacerbate algal blooms in late summer periods, which are typically dry with low external loads. Phosphorus exported from the watershed to the lake bottom sediments may become available through internal loading, which is most likely to happen during prolonged hot, dry periods in late summer. Uncertainty regarding the magnitude of internal loads is one of the biggest challenges to lake restoration. Because of this uncertainty, reductions from watershed sources of TP should be given implementation priority. If and when monitoring shows that the external watershed load has been reduced/controlled, then additional in-lake measures may be warranted.

A brief description of potential in-lake restoration methods are included in Table 4-5, along with relative TP reductions. Actual reduction percentages of each alternative will vary and depend on a number of site-specific factors. It is virtually impossible to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict TP reductions associated with individual improvement strategies. In-lake measures should be a part of a comprehensive watershed management plan that includes watershed practices in order to enhance, prolong, and protect the effectiveness of in-lake investments.

Increasing Mean Depth

One potential in-lake alternative is dredging a significant enough volume of sediment from the lake to increase the average lake depth. This option is often one of the most cost-prohibitive methods of improving water quality. However, in some cases a cost-benefit analysis may reveal it is worthy of consideration, as long as adequate watershed improvement alternatives are implemented first. Increasing the mean depth has several benefits, including increased areas of deep water habitat for desirable fish species, removal of nutrient-laden sediment that can provide a phosphorus source for algae, and increased assimilative capacity created by a deeper lake with more water volume.

Increasing the mean depth of Lake Keomah would lessen the reductions of internal and external TP loading required to meet water quality goals. This effect was not considered in the development of the TMDL in Section 3 or the Phase 1 implementation guidance provided previously in this section. If dredging is a desired alternative and adequate funding is available, technical analysis for watershed management and lake restoration planning should evaluate the impact of increased mean depth on in-lake water quality. However, emphasis and implementation must first be focused on the root cause of the water quality problems in the lake, which is phosphorus that has been introduced to the lake from its watershed over the years.

Table 4-5. Potential in-lake BMPs for water quality improvement.

In-Lake BMPs	Comments	[1]Relative TP Reduction
Fisheries management	Low to moderate reductions in internal TP load may be possible. The existing carp population is thought to be low. Full-scale restoration may not be possible without significant water level drawdown. Although this alternative may provide some benefit, the cost-benefit ratio may be unfavorable due to the depth of the lake and low-density carp population.	Low
Targeted dredging, sediment forebays, and flow re-direction in the shallow inlet area	Targeted dredging in shallow inlet areas would create pockets of deep-water habitat for predatory fish that would help control rough fish populations. Strategic dredging would also increase the sediment capacity of the inlet areas, thereby reducing sediment loads to the larger, open water area of the lake. Sediment and nutrient capture in the inlet could be enhanced by constructing submerged berms and/or jetties to create additional sediment forebays and increasing the low-flow residence time of the inlet. Additional sediment forebays could be located and constructed in a manner that would facilitate future sediment removal.	Med
In-Lake Dredging	Dredging is seldom cost-effective on a large scale and as a stand-alone measure; disposal of dredged material is often a challenge; dredging should be focused on areas of known sediment deposition or to create deep-water habitat as part of fisheries management. A cost benefit analysis may be necessary to examine the feasibility of large-scale dredging in Lake Keomah.	Med-High
Shoreline stabilization (public areas)	Helps establish and sustain vegetation, which provides local erosion protection and competes with algae for nutrients. Impacts of individual projects may be small, but cumulative effects of widespread stabilization projects can be significant. The entire shoreline of Lake Keomah is publicly owned, making this alternative possible in all areas of the lake.	Low

[1]Reductions (High/Med/Low) are relative to each other and based on numerous research studies and previous IDNR projects.

5. Future Monitoring

Water quality monitoring is critical for assessing the current status of water resources as well as historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of best management practice (BMP) implementation and to document attainment of total maximum daily loads (TMDLs) and water quality standards (WQS).

Future monitoring in the Lake Keomah watershed can be agency-led, volunteer-based, or both. The Iowa Department of Natural Resources (IDNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program, called IOWATER, that provides training to interested volunteers. More information can be found at the program web site: http://www.iowater.net/Default.htm

Volunteer-based monitoring efforts should include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here:
http://search.legis.state.ia.us/NXT/gateway.dll/ar/iac/5670___environmental%20protection%20commission%20__5b567__5d/0610___chapter%2061%20water%20quality%20standards/_c_5670_0610.xml?f=templates$fn=default.htm.

Failure to prepare an approved QAPP will prevent data collected from being used to assess a waterbody's status on the state's 303(d) list – the list that identifies impaired waterbodies.

5.1. Routine Monitoring for Water Quality Assessment

Data collection in Lake Keomah to assess water quality trends and compliance with water quality standards (WQS) will include monitoring conducted as part of the IDNR Beach Monitoring Program and the IDNR Ambient Lake Monitoring Program. Unless there is local interest in collecting additional water quality data, future sampling efforts will be limited to these basic monitoring programs.

The Beach Monitoring Program consists of routine *E. coli* monitoring at state park beaches and locally managed beaches throughout Iowa. The beaches are sampled at least two times per week from Memorial Day to Labor Day. The reported *E. coli* concentration for a particular sampling event is typically a composite sample average of nine sampling points collected at three approximate depths (ankle, knee, and chest) at three locations (e.g., left, middle, right) along the beach.

The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 132 of Iowa's lakes are being sampled as part of this program, including Lake Keomah. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured. Sampling parameters are reported in Table 5-1. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day.

Table 5-1. Ambient Lake Monitoring Program water quality parameters.

Chemical	Physical	Biological
• Total Phosphorus (TP) • Soluble Reactive Phosphorus (SRP) • Total Nitrogen (TN) • Total Kjeldahl Nitrogen (TKN) • Ammonia • Un-ionized Ammonia • Nitrate + Nitrite Nitrogen • Alkalinity • pH • Silica • Total Organic Carbon • Total Dissolved Solids • Dissolved Organic Carbon	• Secchi Depth • Temperature • Dissolved Oxygen (DO) • Turbidity • Total Suspended Solids (TSS) • Total Fixed Suspended Solids • Total Volatile Suspended Solids • Specific Conductivity • Lake Depth • Thermocline Depth	• Chlorophyll a • Phytoplankton (mass and composition) • Zooplankton (mass and composition)

5.2. Expanded Monitoring for Detailed Assessment and Planning

Data available from the IDNR Beach Monitoring Program and the IDNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS attainment. More detailed monitoring data is required to reduce the level of uncertainty associated with water quality trend analysis, better understand the impacts of implemented watershed projects (i.e., BMPs), and guide future water quality modeling and BMP implementation efforts.

Existing resources will not allow more detailed monitoring data to be collected by IDNR. Only through the interest and action of local stakeholders will funding and resources needed to acquire this important information become available. Proposed locations for detailed monitoring are illustrated in Figure 5-1.

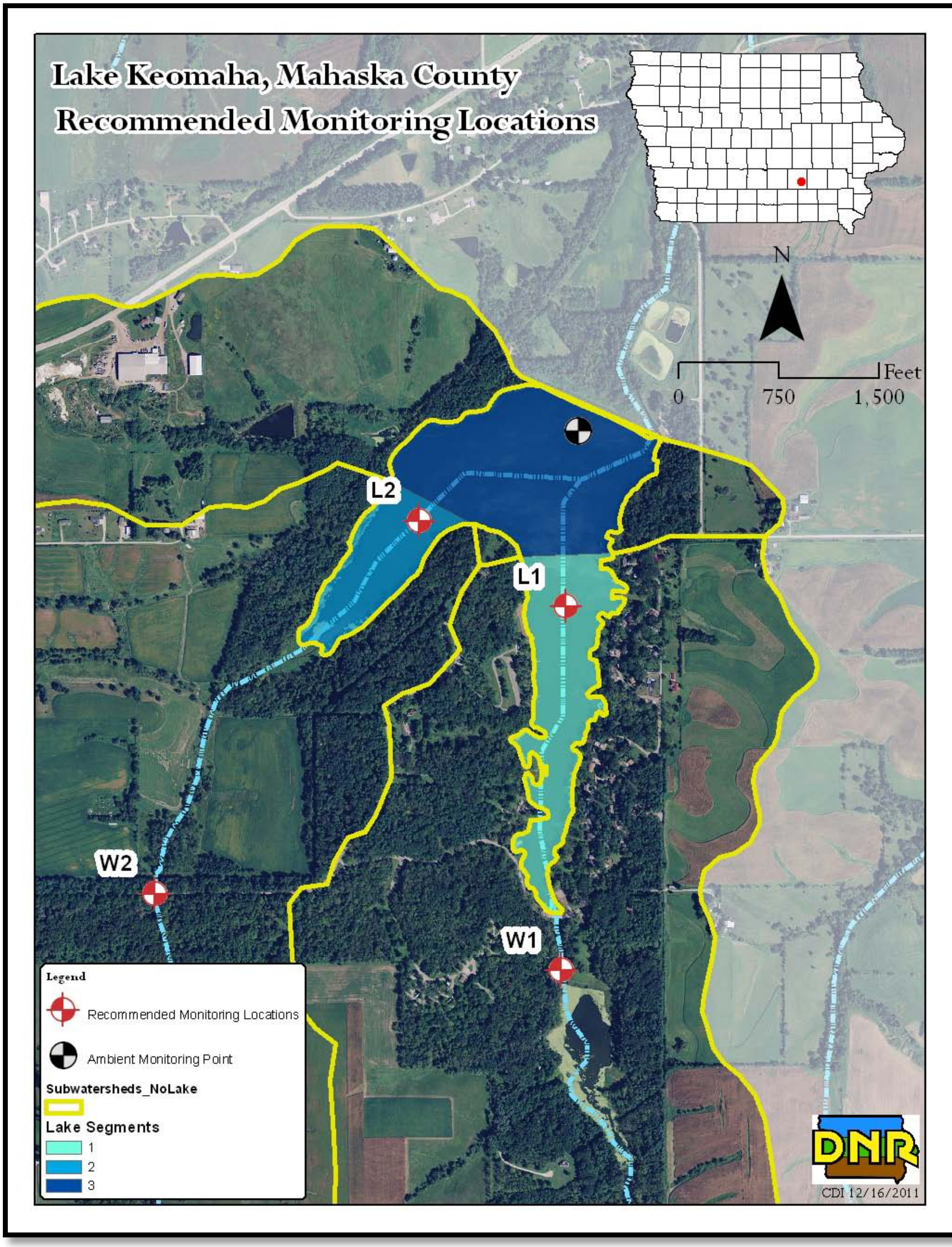

Figure 5-1. Recommended monitoring locations.

Table 5-2 outlines the detailed monitoring plan by listing the components in order, starting with the highest priority recommendations. While it is unlikely that available funding will allow collection of all recommended data, this plan can be used to identify and prioritize data needs.

Table 5-2. Expanded monitoring plan.

Parameter(s)	Intervals	Duration	[1]Location(s)
Routine grab sampling for flow, sediment, P, and N	Every 1-2 weeks	April through October	Ambient, L1 and L2, W1 and W2
Continuous flow	15-60 minute	April through October	Outfall, W1 and W2
Continuous pH, DO, and temperature	15-60 minute	April through October	Ambient, L1 and L2
Runoff event flow, sediment, P, and N	Continuous flow, composite WQ	5 events between April and October	W1 and W2
Event or continuous tile drain flow, N, and P sampling	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	W1and W2

[1]Final location of tributary sites should be based BMP placement, landowner permission, and access/installation feasibility.

Routine weekly or bi-weekly grab sampling with concurrent in-lake and tributary data (Ambient location, L1, L2, W1, and W2 in Figure 5-1) will document long-term trends in water quality and nutrient loading. Data collection should commence before additional BMPs are implemented in the watershed to establish baseline conditions. Selection of tributary sites should consider location of BMPs, location of historical data (for comparative purposes), landowner permission, and logistical concerns such as site access and feasibility of equipment installation. This data would form the foundation for assessment of general water quality trends; however, more detailed information is required to evaluate loading processes, storm events, and reduce uncertainty. Therefore, routine grab sampling should be viewed as a starting point for data collection. Unless resources allow a significant number of grab samples to be collected across a range of hydrologic conditions, collecting grab samples in the tributaries (W1 and W2) may not be economically justifiable because statistical analysis requires a large sample size.

Continuous flow data in the tributaries (L1 and L2) and at the outlet (i.e., spillway) of the lake would improve the predictive ability and accuracy of modeling tools, such as those used to develop the TMDL for Lake Keomah. Reliable long-term flow data is also important because hydrology drives many important processes related to water quality, and a good hydrologic data set will be necessary to evaluate the success of BMPs such as reduced-tillage, sediment control structures, terraces and grass waterways, riparian buffers, and wetlands.

Lake managers should consider deploying a data logger at the ambient monitoring location and possibly at L1 and L2 to measure pH, temperature, and dissolved oxygen (DO) on a continuous basis. This information will help answer questions about the causes and effects of algal blooms and will provide spatial resolution for evaluation of water quality in different areas of the lake. Routine grab sampling, described previously, should be coordinated with deployment of data loggers.

Because water quality appears to be predominately driven by lands in row crop production, data collection efforts should attempt to answer questions about the relative importance of surface runoff, baseflow (i.e., dry weather flow), and tile drainage. Collection of flow, sediment, and nutrient data in tributaries (W1 and W2) during multiple periods of dry and wet weather will facilitate assessment of these distinct pollutant pathways. Final selection of tributary sites must be based on the need to quantify specific pollutant sources, the location of proposed BMPs, land owner permission, and feasibility of equipment installation.

This expanded monitoring information would improve watershed and water quality models used to simulate scenarios and water quality response to implementation. Monitoring parameters and locations should be continually evaluated. Adjustment of parameters and/or locations should be based on BMP placement, newly discovered or suspected pollution sources, and other dynamic factors. The IDNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Lake Keomah watershed.

6. Public Participation

Public involvement is important in the Total Maximum Daily Load (TMDL) process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Lake Keomah.

6.1. Stakeholder/Agency Meeting

November 8, 2011
A stakeholder meeting to discuss the goals and development of the TMDL was held as part of the local Soil and Water Conservation District (SWCD) commissioner's meeting in Mahaska County before completion of a draft TMDL. This meeting provided local agency staff with an opportunity to ask questions about the TMDL, as well as offer information and insight to the development process. Stakeholders were informed of the process, goals, and requirements of the TMDL. Possible "next steps" for implementation were also discussed. Key agency staff and representatives included:

- Mahaska County SWCD Board Members and District Conservationist
- Iowa Dept. of Agriculture and Land Stewardship (IDALS) State Secretary
- Natural Resources Conservation Service (NRCS) Soil Conservationist and Conservation Technicians
- Iowa Farm Bill Biologist
- Local Watershed Coordinators
- IDALS Southeast Iowa Regional Basin Coordinator
- IDNR TMDL Program Manager

6.2. Public Meeting

March 15, 2012
A public meeting to present the results of the TMDL study and discuss next steps for community-based watershed planning was held from 6:00 to 7:30 pm at the Oskaloosa Public Library. The meeting was attended by approximately 10 private citizens/landowners, as well as staff/representative from the following agencies:

- Iowa DNR Watershed Improvement Program
- Iowa DNR Lakes Restoration Program
- State of Iowa Legislature
- Mahaska County Soil and Water Conservation District (SWCD)
- City of Oskaloosa

6.3. Written Comments

All comments received during the public comment period (March 1 through March 30, 2012) will be included in Appendix I of this document, along with an official response from IDNR.

7. References

Bachman, R., T. Hoyman, L. Hatch, B. Hutchins. 1994. A Classification of Iowa's Lakes for Restoration. Iowa Cooperative Fisheries Unit and Department of Animal Ecology. Iowa State University, Ames, Iowa, pp 235-237.

Carlson, R.E. 1992. Expanding the trophic state concept to identify non-nutrient limited lakes and reservoirs. pp. 59-71 [In] Proceedings of a National Conference on Enhancing the States' Lake Management Programs. Monitoring and Lake Impact Assessment. Chicago.

Carlson, R, and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Carpenter, S. 2008. Phosphorus control is critical to mitigating eutrophication. Proceedings of the National Academy of Sciences of the United States of America. Vol. 105, No. 32 pp 11039-11040. Available online at http://www.pnas.org/content/105/32/11039

Center for Agricultural and Rural Development (CARD). 2008. Iowa State University. Iowa Lakes Valuation Project. Information specific to Lake Keomah available at http://www.card.iastate.edu/lakes/lake_economic.aspx?id=59. Accessed in October, 2011

Conley, D., H. Paerl, R. Howarth, D. Boesch, S. Seitzinger, K. Havens, C. Lancelot, and G. Likens. 2009. Controlling eutrophication: nitrogen and phosphorus. Science 323: 1014-1015.

Dodds, W. 2000. Freshwater Ecology: Concepts and Environmental Applications. Draft textbook. Division of Biology, Kansas State University, Manhattan, Kansas.

Iowa Environmental Mesonet (IEM). 2011a. Iowa State University Department of Agronomy. National Weather Service Cooperative Observer Program (NWS COOP). Download available at http://mesonet.agron.iastate.edu/COOP/. Accessed in September 2011.

Iowa Environmental Mesonet (IEM). 2011b. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/agclimate/hist/dailyRequest.php. Accessed in September 2011.

Minnesota Pollution Control Agency (MPCA). 2005. Lake Water Quality Assessment Report: Developing Nutrient Criteria. Third Edition.

National Climatic Data Center (NCDC). 2011. National Climatic Data Center, National Weather Service. Available at http://www.ncdc.noaa.gov/oa/climate/stationlocator.html. Accessed September 2011.

Smith, V. 1983. Low nitrogen to phosphorus ratios favors dominance by blue-green algae in lake phytoplankton. Science 221: 669-671.

U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS). 2004. Assessments of Practices to Reduce Nitrogen and Phosphorus Nonpoint Source Pollution of Iowa's Surface Waters. Prepared for the Iowa Department of Natural Resources in Cooperation with the USDA-ARS National Soil Tilth Laboratory. Ames, Iowa.

U.S. Department of Agriculture, Natural Resource Conservation Service (USDA-NRCS). 1977. Soil Survey of Mahaska County, Iowa.

U.S. Environmental Protection Agency (EPA). 1991. Technical Support Document for Water Quality-based Toxics Control. EPA/505/2-90-001. EPA Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA). 2006. Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits. Memorandum from Benjamin Grumbles, Assistant Administrator, EPA Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA). 2007. Options for Expressing Daily Loads in TMDLs (Draft). EPA Office of Wetlands, Oceans & Watersheds, Washington, DC.

Walker, W., 1996 (Updated 1999). Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. US Army Corps of Engineers Waterways Experiment Station. Instruction Report W-96-2.

8. Appendices

Appendix A --- Glossary of Terms, Abbreviations, and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies' ability to support their general and designated uses. Those bodies of water which are found to be not supporting or only partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.

AU: Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000 pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.2 AU.

Benthic: Associated with or located at the bottom (in this context, "bottom" refers to the bottom of streams, lakes, or wetlands). Usually refers to algae or other aquatic organisms that reside at the bottom of a wetland, lake, or stream (see periphyton).

Benthic macroinvertebrates: Animals larger than 0.5 mm that do not have backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Base flow:	Sustained flow of a stream in the absence of direct runoff. It can include natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.
Biological impairment:	A stream segment is classified as biologically impaired if one or more of the following occurs, the FIBI and or BMIBI scores fall below biological reference conditions, a fish kill has occurred on the segment, or the segment has seen a > 50% reduction in mussel species.
Biological reference condition:	Biological reference sites represent the least disturbed (i.e. most natural) streams in the ecoregion. The biological data from these sites are used to derive least impacted BMIBI and FIBI scores for each ecoregion. These scores are used to develop Biological Impairment Criteria (BIC) scores for each ecoregion. The BIC is used to determine the impairment status for other stream segments within an ecoregion.
BMIBI:	Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.
BMP:	Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.
CAFO:	Concentrated Animal Feeding Operation. A federal term defined as any animal feeding operation (AFO) with more than 1000 animal units confined on site, or an AFO of any size that discharges pollutants (e.g. manure, wastewater) into any ditch, stream, or other water conveyance system, whether man-made or natural.
CBOD5:	5-day Carbonaceous Biochemical Oxygen Demand. Measures the amount of oxygen used by microorganisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.
CFU:	A Colony Forming Unit is a cell or cluster of cells capable of multiplying to form a colony of cells. Used as a unit of bacteria concentration when a traditional membrane filter method of analysis is used. Though not necessarily equivalent to most probably number (MPN), the two terms are often used interchangeably.

Confinement feeding operation: An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate. To be considered “credible,” data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).

Cyanobacteria (blue-green algae): Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.

Designated use(s): Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.

DNR (or IDNR): Iowa Department of Natural Resources.

Ecoregion: Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.

EPA (or USEPA): United States Environmental Protection Agency.

Ephemeral gully erosion: Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.

FIBI: Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.

FSA: Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.

General use(s): Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.

Geometric Mean (GM):	A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's water quality standards and assessment procedures, the geometric mean criterion for *E. coli* is measured using at least five samples collected over a 30-day period.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
Groundwater:	Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.
Gully erosion:	Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.
HEL:	Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land, which has the potential for long-term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.
IDALS:	Iowa Department of Agriculture and Land Stewardship
Integrated report:	Refers to a comprehensive document that combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.
LA:	Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the wasteload and load allocations.)
LiDAR:	Light Detection and Ranging. Remote sensing technology that uses laser scanning to collect height or elevation data for the earth's surface.

Load:	The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.
Macrophyte:	An aquatic plant that is large enough to be seen with the naked eye and grows either in or near water. It can be floating, completely submerged (underwater), or partially submerged.
MOS:	Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the water quality of a waterbody to pollutant loads.
MPN:	Most Probable Number. Used as a unit of bacteria concentration when a more rapid method of analysis (such as Colisure or Colilert) is utilized. Though not necessarily equivalent to colony forming units (CFU), the two terms are often used interchangeably.
MS4:	Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.
Nonpoint source pollution:	Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.
NPDES:	National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency that provides technical assistance for the conservation and enhancement of natural resources.

Open feedlot: An unroofed or partially roofed animal feeding operation (AFO) in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation.

Periphyton: Algae that are attached to substrates (rocks, sediment, wood, and other living organisms). Are often located at the bottom of a wetland, lake, or stream.

Phytoplankton: Collective term for all photosynthetic organisms suspended in the water column. Includes many types of algae and cyanobacteria.

Point source pollution: Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources are generally regulated by a federal NPDES permit.

Pollutant: As defined in Clean Water Act section 502(6), a pollutant means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Pollution: The man-made or man-induced alteration of the chemical, physical, biological, and/or radiological integrity of water.

PPB: Parts per Billion. A measure of concentration that is the same as micrograms per liter (µg/L).

PPM: Parts per Million. A measure of concentration that is the same as milligrams per liter (mg/L).

RASCAL: Rapid Assessment of Stream Conditions Along Length. RASCAL is a global positioning system (GPS) based assessment procedure designed to provide continuous stream and riparian condition data at a watershed scale.

Riparian: Refers to areas near the banks of natural courses of water. Features of riparian areas include specific physical, chemical, and biological characteristics that differ from upland (dry) sites. Usually refers to the area near a bank of a stream or river.

RUSLE: Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.

Scientific notation: See explanation on page 107.

Secchi disk: A device used to measure transparency in waterbodies. The greater the Secchi depth (typically measured in meters), the more transparent the water.

Sediment delivery ratio: A value, expressed as a percent, which is used to describe the fraction of gross soil erosion that is delivered to the waterbody of concern.

Seston: All particulate matter (organic and inorganic) suspended in the water column.

SHL: State Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring, ambient monitoring, biological reference monitoring, and impaired water assessments.

Sheet & rill erosion: Sheet and rill erosion is the detachment and removal of soil from the land surface by raindrop impact, and/or overland runoff. It occurs on slopes with overland flow and where runoff is not concentrated.

Single-Sample Maximum (SSM): A water quality standard criterion used to quantify *E. coli* levels. The single-sample maximum is the maximum allowable concentration measured at a specific point in time in a waterbody.

SI: Stressor Identification. A process by which the specific cause(s) of a biological impairment to a waterbody can be determined from cause-and-effect relationships.

Storm flow (or stormwater): The discharge (flow) from surface runoff generated by a precipitation event. *Stormwater* generally refers to runoff that is routed through some artificial channel or structure, often in urban areas.

STP: Sewage Treatment Plant. General term for a facility that treats municipal sewage prior to discharge to a waterbody according to the conditions of an NPDES permit.

SWCD: Soil and Water Conservation District. Agency that provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.

TDS: Total Dissolved Solids: The quantitative measure of matter (organic and inorganic material) dissolved, rather than suspended, in the water column. TDS is analyzed in a laboratory and quantifies the material passing through a filter and dried at 180 degrees Celsius.

TMDL: Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses. A TMDL is mathematically defined as the sum of all individual wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS).

Trophic state: The level of ecosystem productivity, typically measured in terms of algal biomass.

TSI (or Carlson's TSI): Trophic State Index. A standardized scoring system developed by Carlson (1977) that places trophic state on an exponential scale of Secchi depth, chlorophyll, and total phosphorus. TSI ranges between 0 and 100, with 10 scale units representing a doubling of algal biomass.

TSS: Total Suspended Solids. The quantitative measure of matter (organic and inorganic material) suspended, rather than dissolved, in the water column. TSS is analyzed in a laboratory and quantifies the material retained by a filter and dried at 103 to 105 degrees Celsius.

Turbidity: A term used to indicate water transparency (or lack thereof). Turbidity is the degree to which light is scattered or absorbed by a fluid. In practical terms, highly turbid waters have a high degree of cloudiness or murkiness caused by suspended particles.

UAA: Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)

USDA: United States Department of Agriculture

USGS: United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.

Watershed: The land area that drains water (usually surface water) to a particular waterbody or outlet.

WLA: Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities).

WQS: Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.

WWTF: Wastewater Treatment Facility. General term for a facility that treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility's NPDES permit. Used interchangeably with wastewater treatment plant (WWTP).

Zooplankton: Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation

Scientific notation is the way that scientists easily handle very large numbers or very small numbers. For example, instead of writing 45,000,000,000 we write 4.5E+10. So, how does this work?

We can think of 4.5E+10 as the product of two numbers: 4.5 (the digit term) and E+10 (the exponential term).

Here are some examples of scientific notation.

10,000 = 1E+4	24,327 = 2.4327E+4
1,000 = 1E+3	7,354 = 7.354E+3
100 = 1E+2	482 = 4.82E+2
1/100 = 0.01 = 1E-2	0.053 = 5.3E-2
1/1,000 = 0.001 = 1E-3	0.0078 = 7.8E-3
1/10,000 = 0.0001 = 1E-4	0.00044 = 4.4E-4

As you can see, the exponent is the number of places the decimal point must be shifted to give the number in long form. A **positive** exponent shows that the decimal point is shifted that number of places to the right. A **negative** exponent shows that the decimal point is shifted that number of places to the left.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which waterbodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of waterbody (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the waterbody that is being dealt with. This appendix is intended to provide information about how Iowa's waterbodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the waterbody.

General Use Segments

A general use segment waterbody is one that does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins that consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use waterbody, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are waterbodies that maintain flow throughout the year, or at least hold pools of water that are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are thirteen different designated use classes (Table B-1) that may apply, and a waterbody may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B-1. Designated use classes for Iowa waterbodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Designated use classes are determined based on a Use Attainability Analysis, or UAA. This is a procedure in which the waterbody is thoroughly scrutinized, using existing knowledge, historical documents, and visual evidence of existing uses, in order to determine what its designated use(s) should be. This can be a challenging endeavor, and as such, conservative judgment is applied to ensure that any potential uses of a waterbody are allowed for. Changes to a waterbody's designated uses may only occur based on a new UAA, which depending on resources and personnel, can be quite time consuming.

It is relevant to note that on March 22, 2006, a revised edition of Iowa's water quality standards became effective which significantly changed the use designations of the state's surface waters. Essentially, the changes that were made consisted of implementing a "top down" approach to use designations, meaning that all waterbodies should receive the highest degree of protection applicable until a UAA could be performed to ensure that a particular waterbody did not warrant elevated protection. For more information about Iowa's water quality standards and UAAs, contact the Iowa DNR's Water Quality Bureau.

Appendix C --- Water Quality Data

The following include a portion of the sampling data from the Iowa State University (ISU) Iowa Lakes Information System and the Iowa Department of Natural Resources and University Hygienic Laboratory (IDNR/SHL) Ambient Lake Monitoring Program.

C.1. Outlier Analysis

Outliers were determined with a box plot analysis using the MINITAB™ statistical software. This approach assumes that observed values greater than 1.5 times the middle 50 percent (i.e., the interquartile range) of the data are outliers. Outliers are circled in red on the box plots of chlorophyll-a (Figure C-1), total phosphorus (Figure C-2), and total nitrogen (Figure C-3). Outliers were eliminated from the data set before calculation of water quality statistics and analysis of correlations involved with interpreting data or evaluating model performance.

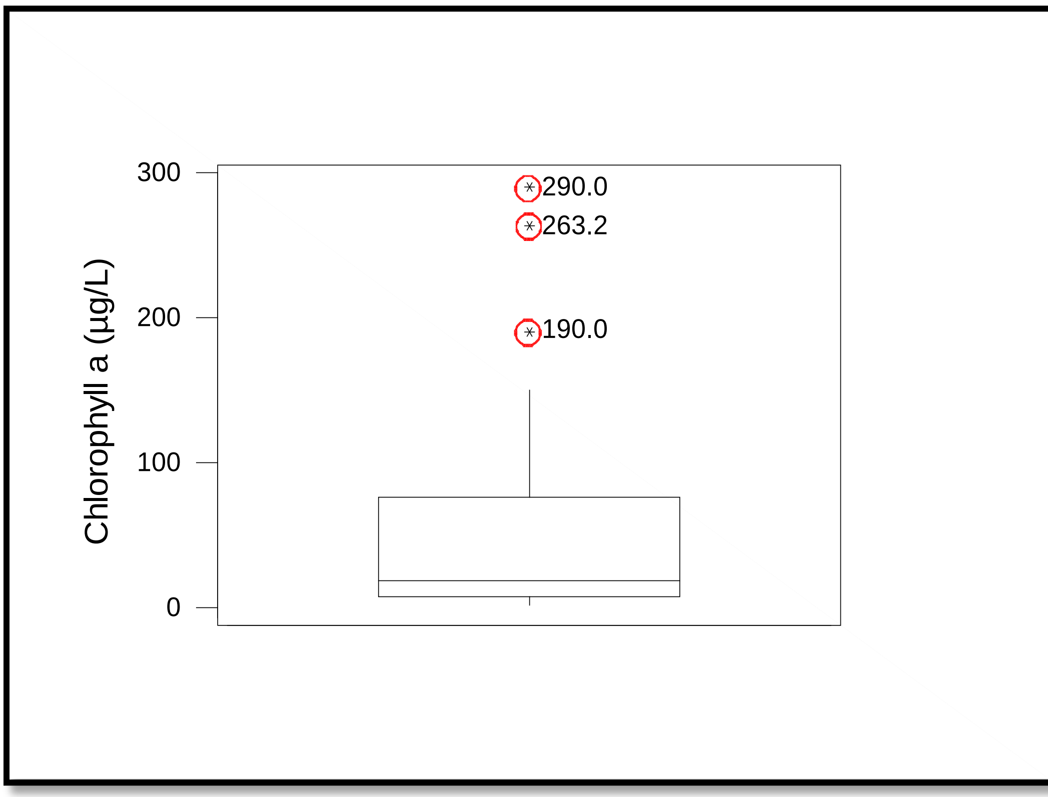

Figure C-1. Box plot and outliers for chlorophyll-a data.

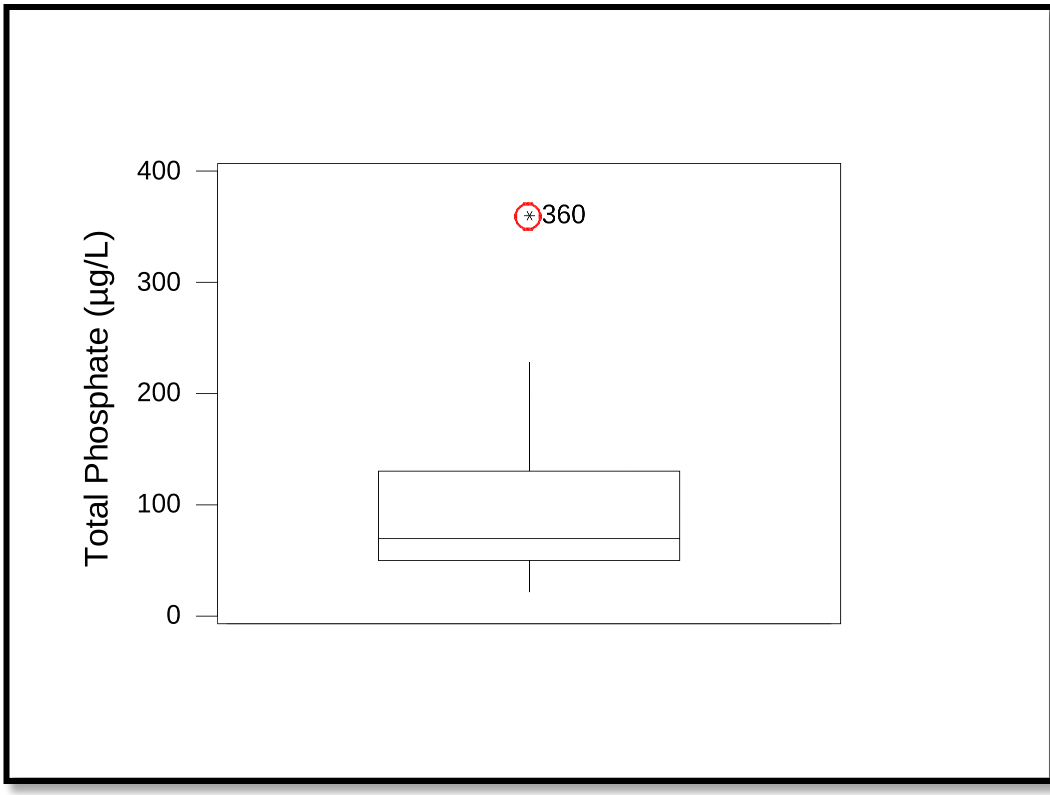

Figure C-2. Box plot and outliers for TP data.

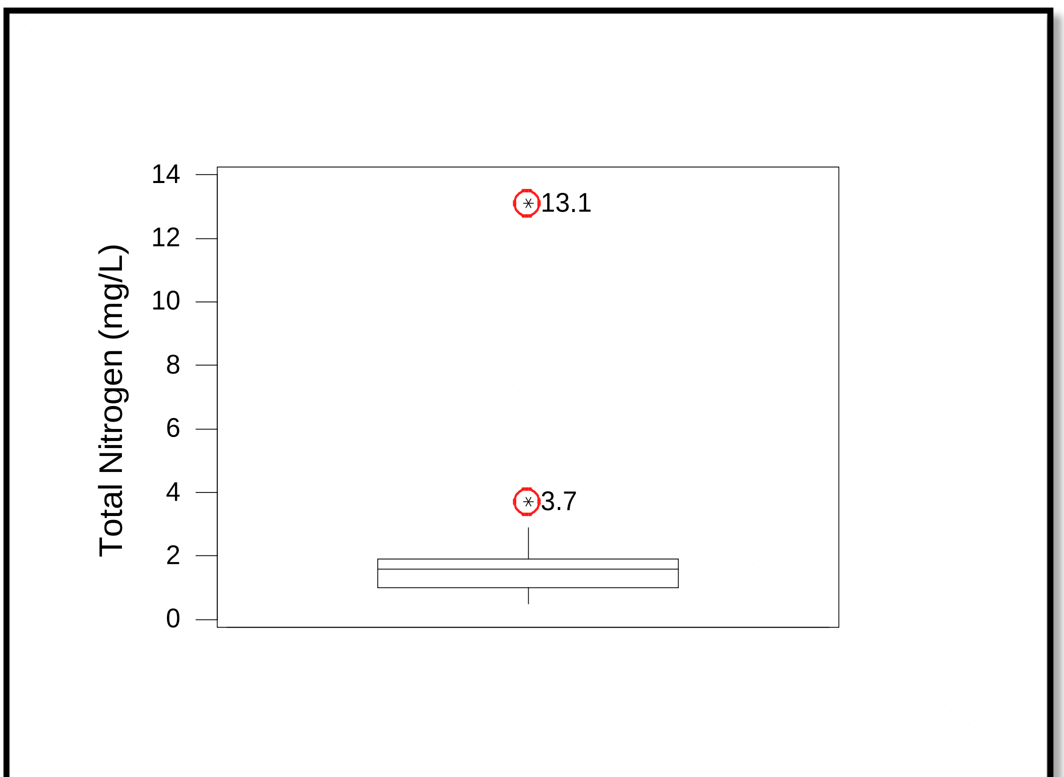

Figure C-3. Box plot and outliers for TN data.

C.2. Individual Sample Results

Table C-1. ISU and SHL water quality sampling data ([1]ambient location).

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	Ortho-P (ug/L)	TN (mg/L)	TKN (mg/L)	NH_3/NH_4 (ug/L)	NO_2/NO_3 (mg/L)
[2]5/29/2001	2.0	4.6	45.4	[4]No data	1.6	[4]No data	[4]No data	0.94
[2]6/26/2001	1.5	15.7	48.4	[4]No data	3.7	[4]No data	[4]No data	1.41
[2]7/30/2001	1.3	22.9	127.7	[4]No data	1.1	[4]No data	[4]No data	0.35
[2]6/4/2002	1.5	14.0	36.6	0.5	1.0	[4]No data	[4]No data	0.22
[2]7/9/2002	0.4	97.6	135.8	0.5	1.6	[4]No data	[4]No data	0.16
[2]8/5/2002	0.3	88.9	147.5	2.9	1.2	[4]No data	[4]No data	0.05
[2]6/2/2003	2.5	24.9	63.2	1.7	1.3	[4]No data	[4]No data	0.13
[2]7/7/2003	0.3	[4]No data	118.4	1.1	1.5	[4]No data	[4]No data	0.16
[2]8/5/2003	0.3	31.2	188.8	0.5	1.7	[4]No data	[4]No data	0.16
[2]6/1/2004	0.9	73.6	96.2	8.1	1.8	[4]No data	43.5	0.50
[2]6/28/2004	0.6	80.5	108.1	1.3	1.9	[4]No data	8.0	0.17
[2]8/3/2004	0.3	74.8	173.6	2.8	1.7	[4]No data	8.0	0.17
[2]6/6/2005	3.7	26.8	30.0	1.4	1.0	[4]No data	80.7	0.28
[3]6/30/2005	2.4	10.0	70.0	10.0	0.7	0.7	25.0	0.03
[2]7/11/2005	1.2	104.8	68.9	[4]No data	1.3	[4]No data	8.0	0.05
[2]8/1/2005	0.4	[5]Outlier	228.1	17.3	1.8	[4]No data	8.0	0.12
[3]8/11/2005	0.3	[5]Outlier	200.0	10.0	2.9	2.8	25.0	0.07
[3]10/18/2005	0.6	150.0	200.0	50.0	2.3	2.3	180.0	0.03
[3]5/10/2006	4.5	3.0	50.0	10.0	1.0	0.9	25.0	0.10
[2]6/5/2006	4.0	2.7	23.1	[4]No data	0.8	[4]No data	72.4	0.13
[3]6/13/2006	4.0	3.0	60.0	20.0	0.7	0.7	25.0	0.03
[2]7/10/2006	3.0	9.0	22.1	[4]No data	0.7	[4]No data	24.4	0.05
[3]7/19/2006	1.9	8.0	50.0	10.0	0.6	0.6	25.0	0.03
[2]8/7/2006	0.9	39.1	90.5	3.2	1.3	[4]No data	8.0	0.05
[3]8/23/2006	0.4	[5]Outlier	170.0	10.0	2.8	2.8	25.0	0.03
[3]9/25/2006	1.0	56.0	170.0	60.0	1.4	1.4	200.0	0.03
[3]4/23/2007	3.1	4.0	30.0	10.0	1.8	0.8	25.0	0.95
[2]6/4/2007	1.3	57.7	97.0	2.5	2.6	[4]No data	129.8	1.08
[3]6/19/2007	1.2	32.0	90.0	20.0	1.8	1.7	260.0	0.12
[2]7/9/2007	1.4	139.6	105.8	2.5	2.1	[4]No data	41.0	0.29
[3]7/26/2007	1.3	120.0	200.0	10.0	2.4	2.4	320.0	0.03
[2]8/1/2007	2.5	7.3	64.2	2.5	1.6	[4]No data	289.4	0.29
[3]8/14/2007	0.5	83.0	130.0	30.0	1.8	1.8	25.0	0.03
[3]9/19/2007	1.8	9.0	[5]Outlier	240.0	2.4	2.3	1200.0	0.08
[3]5/13/2008	1.6	2.0	60.0	20.0	2.3	0.9	90.0	1.40
[3]7/1/2008	3.3	9.0	130.0	70.0	1.6	1.5	850.0	0.05
[3]5/7/2009	1.5	28	40	10	1.3	0.7	25	0.56
[3]6/8/2009	1.4	20	70	10	1.9	1.4	130	0.48
[2]6/16/2009	2.9	2.5	65.6	15.5	1.6	0.8	200.0	0.78
[3]7/9/2009	2.2	11	50	20	1.8	1.1	250	0.72
[2]7/22/2009	3.4	2.5	52.6	4.5	1.3	1.0	140.0	0.33

Table C-1. (continued)

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	Ortho-P (ug/L)	TN (mg/L)	TKN (mg/L)	NH_3/NH_4 (ug/L)	NO_2/NO_3 (mg/L)
[3]8/5/2009	3.0	12	40	10	0.9	0.8	25	0.06
[2]8/13/2009	3.6	6.0	29.2	4.5	0.9	0.8	50.0	0.07
[3]9/16/2009	4.2	2	60	30	0.7	0.6	70	0.05
[2]6/21/2010	1.0	16.0	113.9	44.6	[5]Outlier	11.6	163.2	1.45
[2]8/9/2010	1.1	17.8	74.1	4.0	2.9	2.7	68.0	0.25
[2]9/20/2010	0.8	15.6	64.7	4.0	0.5	0.3	192.2	0.25

[1] Ambient monitoring location = STORET ID 22620002
[2] ISU data
[3] SHL data
[4] No data collected/reported
[5] Determined to be an outlier (see previous outlier analysis)

Table C-2. Biomass sampling ([1]ambient location).

Date	Cyanobacteria Wet Mass (mg/L)	Phytoplankton Wet Mass (mg/L)	Zooplankton Dry Mass (mg/L)
[2]5/29/2001	0.0	0.1	619.4
[2]6/26/2001	20.0	19.8	452.5
[2]7/30/2001	5.0	5.5	24.4
[2]6/4/2002	153.0	154.7	129.7
[2]7/9/2002	483.0	487.0	9.4
[2]8/5/2002	263.0	263.2	47.2
[2]6/2/2003	18.0	18.2	543.1
[2]7/7/2003	197.0	197.1	49.8
[2]8/5/2003	228.0	228.2	12.6
[2]6/1/2004	59.0	59.9	188.4
[2]6/28/2004	177.0	178.1	370.9
[2]8/3/2004	590.0	589.9	21.4
[2]6/6/2005	72.0	1640.9	411.5
[3]6/30/2005	7.0	11.7	466.6
[2]7/11/2005	78.0	82.2	121.4
[2]8/1/2005	35.0	40.2	13.9
[3]8/11/2005	51.0	55.0	16.2
[3]10/18/2005	3.0	42.4	37.1
[3]5/10/2006	0.0	0.7	237.9
[2]6/5/2006	7.0	6.7	88.9
[3]6/13/2006	[4]No data	[4]No data	[4]No data
[2]7/10/2006	8.0	12.5	1286.4
[3]7/19/2006	0.0	13.7	41.3
[2]8/7/2006	7.0	8.7	22.7
[3]8/23/2006	[4]No data	[4]No data	[4]No data
[3]9/25/2006	4.0	20.7	142.8
[3]4/23/2007	0.0	0.7	176.7
[2]6/4/2007	50.0	50.3	246.8

Table C-2. (continued)

Date	Cyanobacteria Wet Mass (mg/L)	Phytoplankton Wet Mass (mg/L)	Zooplankton Dry Mass (mg/L)
[3]6/19/2007	12.0	11.9	1519.7
[2]7/9/2007	20.0	20.3	171.4
[3]7/26/2007	0.0	1661.0	162.5
[2]8/1/2007	157.0	157.5	85.9
[3]8/14/2007	154.0	155.2	249.1
[3]9/19/2007	0.0	0.7	928.1
[3]5/13/2008	2.0	4.4	523.4
[3]7/1/2008	0.0	0.5	1074.0
[3]5/7/2009	0.000	7.428	322.3870
[3]6/8/2009	26.726	27.075	1542.7929
[2]6/16/2009	18.2	23.1	91.0
[3]7/9/2009	0.404	2.767	390.7720
[2]7/22/2009	64.5	68.7	209.0
[3]8/5/2009	20.109	32.497	270.9487
[2]8/13/2009	0.6	107.5	150.0
[3]9/16/2009	0.947	1.325	371.1482
[2]6/21/2010	24.5	26.7	243.9
[2]8/9/2010	29.1	35.0	37.1
[2]9/20/2010	27.4	32.3	101.8

[1] Ambient monitoring location = STORET ID 22620002
[2] ISU data
[3] SHL data
[4] No data collected/reported

C.3. Annual Mean Results

Table C-3. Precipitation and annual mean water quality ([1]ambient location).

Date	Precipitation (in)	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	TN (mg/L)
2001	38.4	1.6	14	74	2.15
2002	27.9	0.8	67	107	1.26
2003	36.8	1.0	28	123	1.51
2004	34.0	0.6	76	126	1.79
2005	27.9	1.4	73	133	1.65
2006	34.0	2.5	17	79	1.17
2007	49.8	1.6	57	102	2.07
2008	47.2	2.5	6	95	1.93
2009	48.9	2.8	11	51	1.28
2010	54.7	1.0	16	84	1.71

[1] Ambient monitoring location = STORET ID 22620002

C.4. Lake Profile Data (2009)

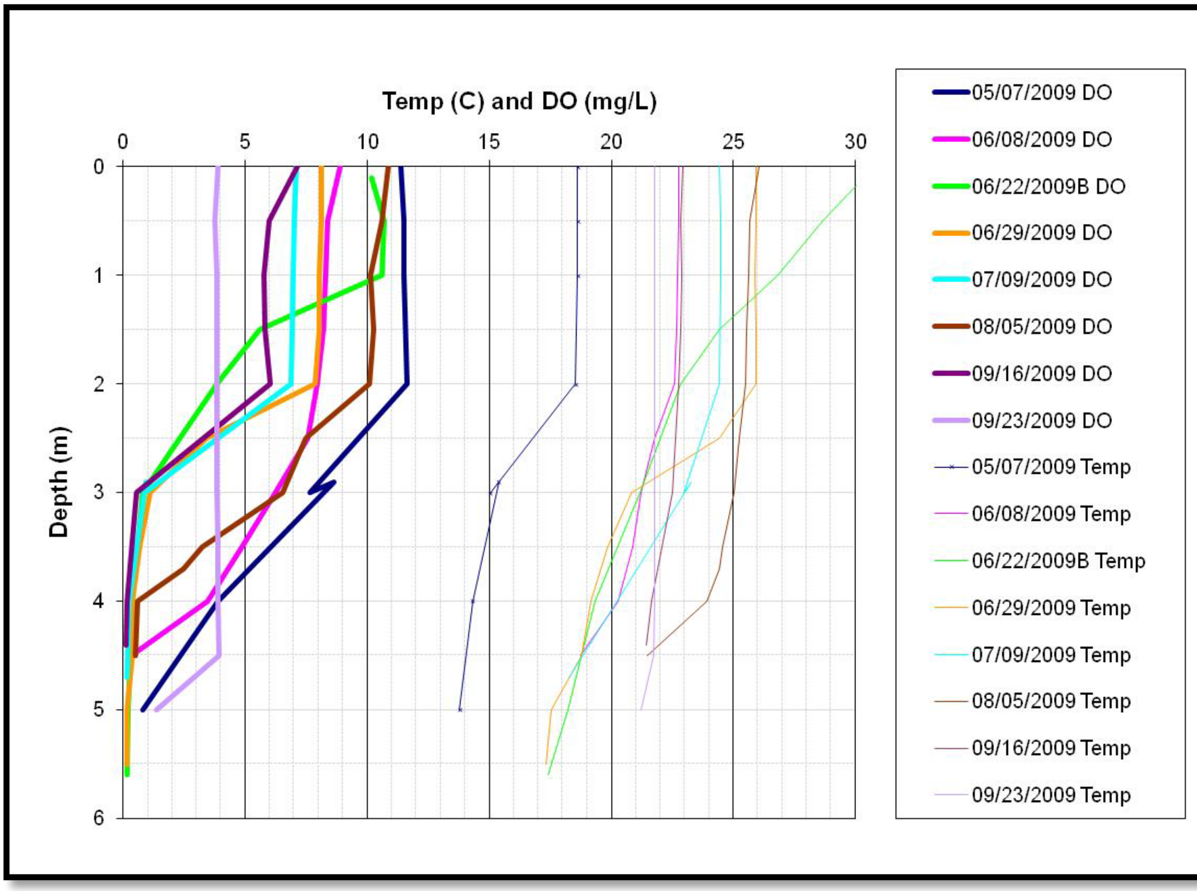

Figure C-4. Temperature and dissolved oxygen profiles (2009).

Appendix D --- Watershed Model Development

Watershed and in-lake modeling were used in conjunction with observed water quality data to develop the Total Maximum Daily Load (TMDL) for the algae and pH impairments to Lake Keomah in Mahaska County, Iowa. A single TMDL targeting phosphorus reductions will satisfy both the algae and pH impairments (see Section 3 of this document for details). The Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1, was utilized to simulate watershed hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.1, an empirical lake and reservoir eutrophication model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Lake Keomah and its watershed. This section of the Water Quality Improvement Plan (WQIP) discusses the modeling approach and development of the STEPL watershed and BATHTUB lake models.

D.1. Modeling Approach

Data from a 10-year period of record, 2001-2010, was utilized for model development. Watershed and lake models were utilized to simulate and predict eutrophication response in Lake Keomah. Data was separated into two distinct periods. The first six years (2001-2006) were dry years, each having below normal precipitation. The next four years (2007-2010) were wet years, each with above average precipitation. STEPL and BATHTUB models were set up and calibrated for each of the two periods in order to evaluate water quality response in both dry and wet conditions. Models were also developed for the entire period (2001-2010) to evaluate long-term average conditions. The integrated STEPL and BATHTUB models for the full 10-year period (2001-2010) were utilized for TMDL development (Section 3) and implementation planning (Section 4).

D.2. STEPL Model Description

STEPL is a watershed-scale hydrology and water quality model developed for the U.S. Environmental Protection Agency (EPA) by Tetra Tech, Incorporated. STEPL is a long-term average annual model used to assess the impacts of land use and best management practices on hydrology and pollutant loads. STEPL is capable of simulating a variety of pollutants, including sediment, nutrients (nitrogen and phosphorus), and 5-day biochemical oxygen demand (BOD5). Required input data is minimal if the use of county-wide soils and coarse precipitation information is acceptable to the user. If available, the user can modify soil and precipitation inputs with higher resolution and local soil and precipitation data. Precipitation inputs include average annual rainfall and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation. Characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, population of agricultural animals, wildlife populations, population served by septic systems, and urban land uses. STEPL also quantifies the impacts of manure application and best management practices

(BMPs). Almost all STEPL inputs can be customized if site-specific data is available and more detail is desired.

The Lake Keomah watershed was delineated into subbasins using ArcGIS (version 9.3) and a 3-meter resolution digital elevation model (DEM). The watershed was divided into three subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with targeting potential BMP locations. Hydrology and pollutant loadings are summarized for each subbasin and also aggregated as watershed totals.

D.3. Meteorological Input

Precipitation Data
The STEPL model includes a pre-defined set of weather stations from which the user must choose to obtain precipitation-related model inputs. Unfortunately, none of the NWS COOP stations within a reasonable distance of Lake Keomah are included in the STEPL model. Therefore, rainfall data from the NCDC and NWS COOP station at Oskaloosa were used for modeling purposes, even though it is not included in the STEPL model. The NCDC and NWS data are nearly identical, with slight discrepancies resulting from differing quality assurance/quality control (QA/QC) procedures. A “composite” dataset was developed for the Lake Keomah TMDL that utilizes all available NCDC data. There are several dates for which NCDC data is missing. NWS COOP data was utilized to fill in data gaps in the NCDC record. Weather station information and rainfall data were reported in Section 2.1 (see Table 2.2 and Figure 2.2)

Average annual precipitation in recent years (2007-2010) was 50.1 inches per year (in/yr), well above the 10-year (2001-2010) annual average of 40.0 inches. In fact, 2008 had the lowest amount of annual precipitation in this 5-year period, 47.2 inches, which is over 7 inches above normal. The preceding years (2001-2006) were consistently dry, with an annual average of only 33.2 in/yr and no years with rainfall exceeding 38.4 in/yr.

The STEPL precipitation correlation and rain day correction factors were calculated outside of STEPL and entered directly in the STEPL “Input” worksheet to override the available Des Moines or Waterloo airport data. Precipitation inputs are reported in Table D-1, which is copied from the “Input” worksheet of the 2001-2006 Lake Keomah STEPL model. The inputs for precipitation parameters for 2007-2010 are shown in Table D-2, and 2001-2010 inputs are in Table D-3.

Table D-1. STEPL rainfall inputs (2001-2006 average annual data).

Rain correction factors			
[1]0.883	[2]0.437		
[3]Annual Rainfall	[4]Rain Days	[5]Avg. Rain/Event	Input Notes/Descriptions
33.2	105.0	0.639	[1]The percent of rainfall that exceeds 5 mm per event
33.2	105.0	0.639	[2]The percent of rain events that generate runoff
33.2	105.0	0.639	[3]Annual average precipitation from 2001-2006 (in)
33.2	105.0	0.639	[4]Average days of precipitation per year (days)
33.2	105.0	0.639	[5]Average precipitation per event (in)

Table D-2. STEPL rainfall inputs (2007-2010 average annual data).

Rain correction factors			
[1]0.936	[2]0.542		
[3]Annual Rainfall	[4]Rain Days	[5]Avg. Rain/Event	Input Notes/Descriptions
50.1	110.5	0.783	[1]The percent of rainfall that exceeds 5 mm per event
50.1	110.5	0.783	[2]The percent of rain events that generate runoff
50.1	110.5	0.783	[3]Annual average precipitation from 2007-2010 (in)
50.1	110.5	0.783	[4]Average days of precipitation per year (days)
50.1	110.5	0.783	[5]Average precipitation per event (in)

Table D-3. STEPL rainfall inputs (2001-2010 average annual data).

Rain correction factors			
[1]0.904	[2]0.479		
[3]Annual Rainfall	[4]Rain Days	[5]Avg. Rain/Event	Input Notes/Descriptions
40.0	107.2	0.704	[1]The percent of rainfall that exceeds 5 mm per event
40.0	107.2	0.704	[2]The percent of rain events that generate runoff
40.0	107.2	0.704	[3]Annual average precipitation from 2001-2010 (in)
40.0	107.2	0.704	[4]Average days of precipitation per year (days)
40.0	107.2	0.704	[5]Average precipitation per event (in)

D.4. Watershed Characteristics

Topography

The Lake Keomah watershed boundary was delineated in the ArcSWAT 2.3.4 Interface for SWAT2005 using digital elevation model (DEM) developed by the Iowa Department of Natural Resources (IDNR). Figure D-1 illustrates the watershed and subbasin boundaries. Subbasin 1 includes 949 acres on the east half of the watershed, and drains to the east branch (Segment 1) of Lake Keomah through a well-established linear network of small streams and channels. Subbasin 2 drains 768 acres to the west branch (Segment 2), and includes a number of similar sized streams and channels that branch out to the south and west. Subbasin 3 includes the area immediately adjacent to the lake on both the east and west side of the main open water area (Segment 3).

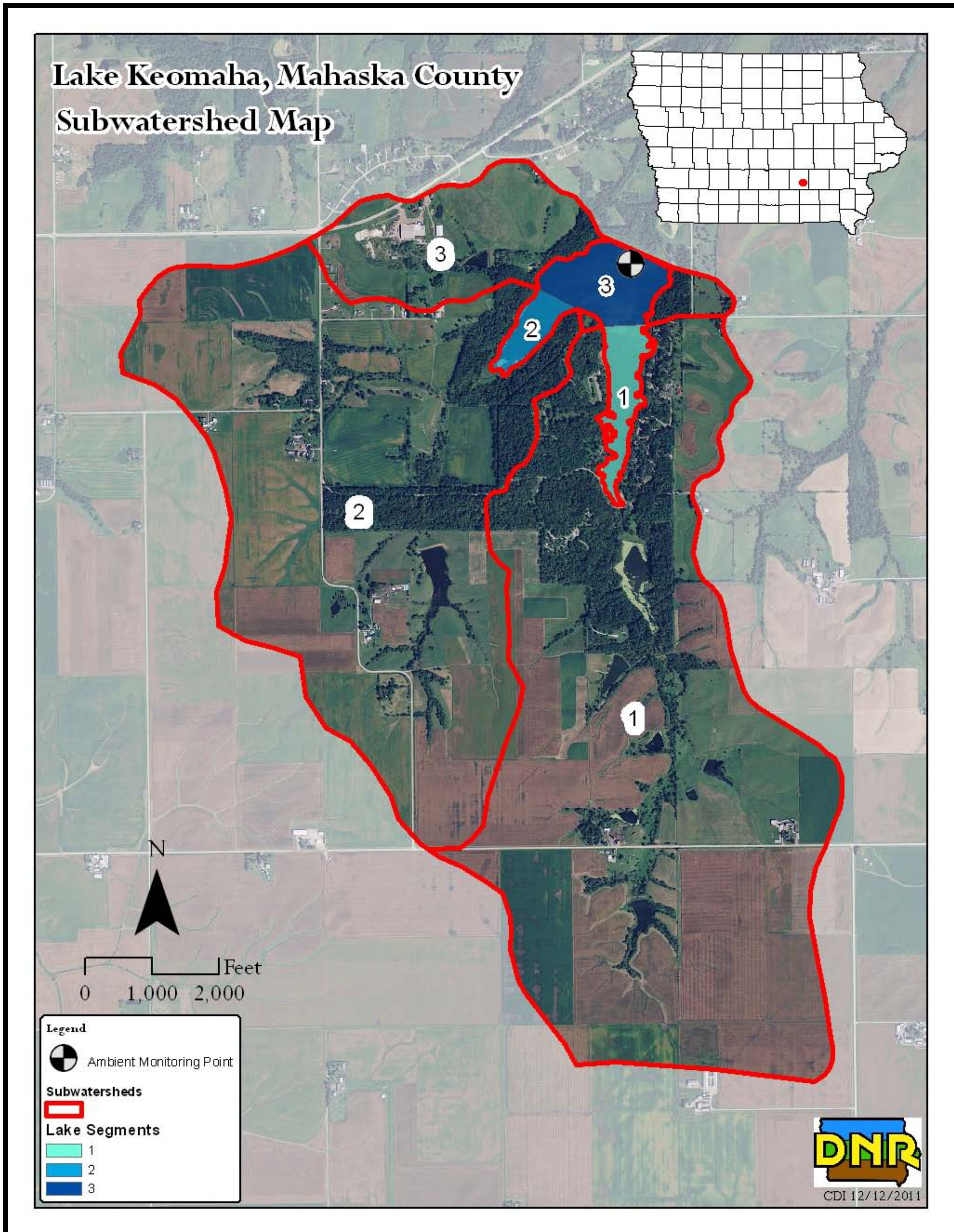

Figure D-1. Watershed and subbasin delineation map.

Land Use

A Geographic Information System (GIS) coverage of land use was developed based on statewide 2002 land cover data, as described in detail in Section 2.2. Individual land uses of similar type were aggregated into a more general classification for watershed modeling in STEPL. The STEPL land cover classifications are reported in Table D-4, which was copied from the STEPL "Input" worksheet. The STEPL land use distribution is illustrated in pie-chart form in Figure D-2.

Table D-4. STEPL land use inputs.

1. Input watershed land use area (ac) and precipitation (in)						
Watershed	**Urban**	**Cropland**	**[1]Pastureland**	**Forest**	**[2]User Defined**	**Feedlots**
W1	27.09	482.99	240.69	170.91	27.54	0.00
W2	31.25	388.83	213.47	120.04	14.45	0.00
W3	23.63	3.39	99.69	26.22	3.22	0.00

[1]Pastureland includes both grazed and ungrazed grassland and hay
[2]User-defined includes wetlands and ponds

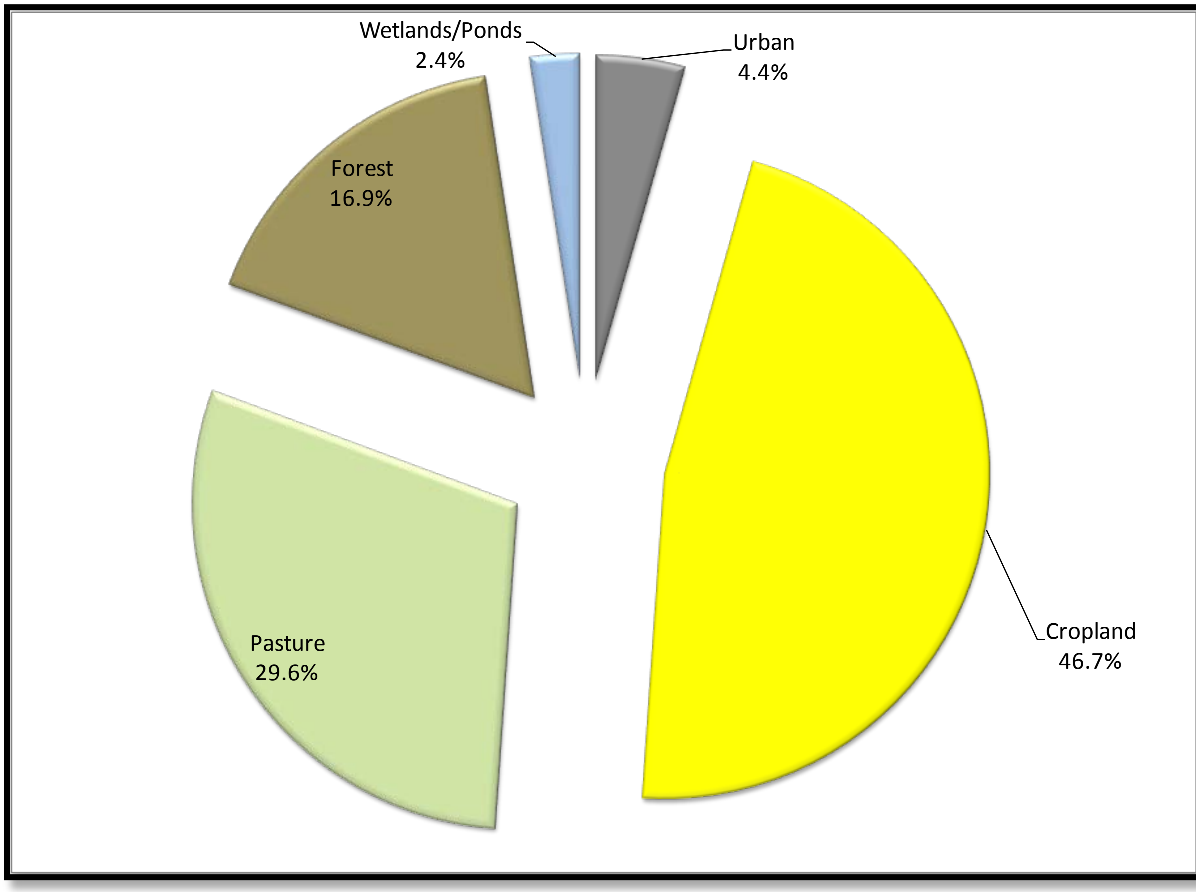

Figure D-2. Relative land cover composition in STEPL watershed model.

Land cover parameters critical for STEPL simulation include the Universal Soil Loss Equation (USLE) C-factor and P-factor for each land cover classification. C-factor and P-factors developed for a previous watershed assessment conducted by IDNR and the Mahaska County SWCD were obtained for each land use in the STEPL model. P-factors ranged from 0.050 for forested areas to 0.518 for row crops. C-factors vary widely, from

0.010 for pasture/grass/hay to 0.390 for row crops. C- and P-factors for each landuse are entered into the "Input" worksheet in the STEPL model.

Soils

Soils are discussed in detail in Section 2.2. The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Watershed soils are predominantly HSG type B soils. USLE inputs were obtained from a previous RUSLE assessment completed for the Lake Keomah watershed. USLE K-factors vary spatially and by land use. K-factors for each landuse and subwatershed are entered into the "Input" worksheet in the STEPL model.

Slopes

Slopes are described in more detail in Section 2.2. USLE land slope (LS) factors were obtained from a previous RUSLE assessment, and were area-weighted by land use within each STEPL subwatershed. LS-factors vary between 1.581 and 2.691, and are entered into the "Input" worksheet in the STEPL model.

Curve Numbers

The STEPL model includes default curve numbers (CNs) selected automatically based on HSG and land use inputs. The user-defined CN was changed to 99 to reflect water surfaces of wetland and ponds. The STEPL default CN was left in place for other land uses.

Sediment Delivery Ratio

The sediment load to the lake is smaller than total sheet and rill erosion because some of the eroded material is deposited in depressions, ditches, or streams before it reaches the watershed outlet (i.e., the lake). The sediment delivery ratio (SDR) is the portion of sheet and rill erosion that is transported to the watershed outlet. STEPL calculates SDR using a simple empirical formula based on drainage area (i.e., watershed size). The resulting SDR values are 26.9 percent for Subbasin 1, 28.0 percent in Subbasin 2, and 50.1 percent for Subbasin 3. The high ratio in Subbasin 3 is due to its steep slopes and small area.

D.5. Animals

Agricultural Animals and Manure Application

The STEPL model utilizes livestock population data and the amount of time (in months) that manure is applied to account for nutrient loading from livestock manure sources. Over 6,300 hogs and 250 dairy cattle are raised in or near the watershed, resulting in application of the manure produced at these facilities. There are no significant beef, dairy, or poultry operations. The number of hogs in each subwatershed is entered into the "Input" worksheet of the STEPL model. Manure application is assumed to occur in 2 months of the year and is limited to Subbasin 1, per DNR animal feeding operations records. STEPL utilizes these inputs to estimate nutrient concentrations in runoff, as reported in the "Animal" worksheet of the STEPL model.

Livestock Grazing
There are no significant livestock grazing operations in the Lake Keomah watershed.

Open Feedlots
There are no open feedlots in the Lake Keomah watershed in the IDNR Animal Feeding Operations Database. Feedlot operators are not required to report open feedlot information to IDNR for feedlots with less than 500 animal units (AUs). No active open feedlot operations were observed during the October 2011 windshield survey.

Wildlife
The estimated deer population in the Lake Keomah watershed is based on the Mahaska County total deer population obtained from the IDNR deer biologist. The county-wide average deer density is between 5.4 and 8.1 deer per square mile. This equates to 16 to 24 deer living in the Lake Keomah watershed. A conservative estimate of 100 deer in the watershed was entered into the "Animals" worksheet of the STEPL model to account for increased density of deer around the lake and for other wildlife (e.g., raccoons and other furbearers, upland birds, etc.) for which data is lacking.

Pollutant contributions from waterfowl included nutrients and bacteria contained in feces deposited in and near the lake by Canada geese. Estimates of goose populations at Lake Keomah were provided by IDNR waterfowl biologists (Guy Zenner, IDNR, August 29, 2011, personal communication). Estimates consider the changes in the goose population throughout the year due to migratory patterns, nesting season, and number of resident geese. Calculations also consider the amount of time geese spend on land versus in the lake. On an annual average basis, there are 1,353 geese residing at the lake. This estimated population was entered on a "per square mile" basis in the "Animals" worksheet of the STEPL model.

STEPL assumes that wildlife add to the manure deposited on the land surface. If animal densities are significant, nutrient concentration in runoff is increased. Even with overestimates of geese and deer populations, wild life contributions are relatively insignificant (in terms of nutrient loading to the lake) and do not increase STEPL nutrient runoff parameters.

D.6. Septic Systems

A GIS coverage of rural residences with private onsite wastewater treatment systems (e.g., septic systems) was developed using aerial images and anecdotal data from various state, county, and local agencies. This procedure resulted in the identification of 32 septic systems in this sparsely populated watershed. It is estimated that 15 percent of these systems are not functioning adequately (i.e., are ponding or leaching), and another 15 percent drain directly to agricultural tile drains and subsequently, to streams. This is a fairly common occurrence in some rural parts of the state. This information is included in the "Inputs" worksheet of the STEPL model for Lake Keomah.

Appendix E --- Water Quality Model Development

Two models were used to develop the Total Maximum Daily Load (TMDL) for Lake Keomah. Watershed hydrology and pollutant loading was simulated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1. STEPL model development was described in detail in Appendix D.

In-lake water quality simulations were performed using BATHTUB 6.1, an empirical lake and reservoir eutrophication model. This appendix discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Lake Keomah and its watershed.

E.1. BATHTUB Model Description

BATHTUB is a steady-state water quality model developed by the U.S. Army Corps of Engineers that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). Eutrophication-related parameters are expressed in terms of total phosphorus (TP), total nitrogen (TN), chlorophyll a (chl-a), and transparency. The model can distinguish between organic and inorganic forms of phosphorus and nitrogen, and simulates hypolimnetic oxygen depletion rates. Water quality predictions are based on empirical models that have been calibrated and tested for lake and reservoir applications (Walker, 1985). Control pathways for nutrient levels and water quality response are illustrated in Figure E-1.

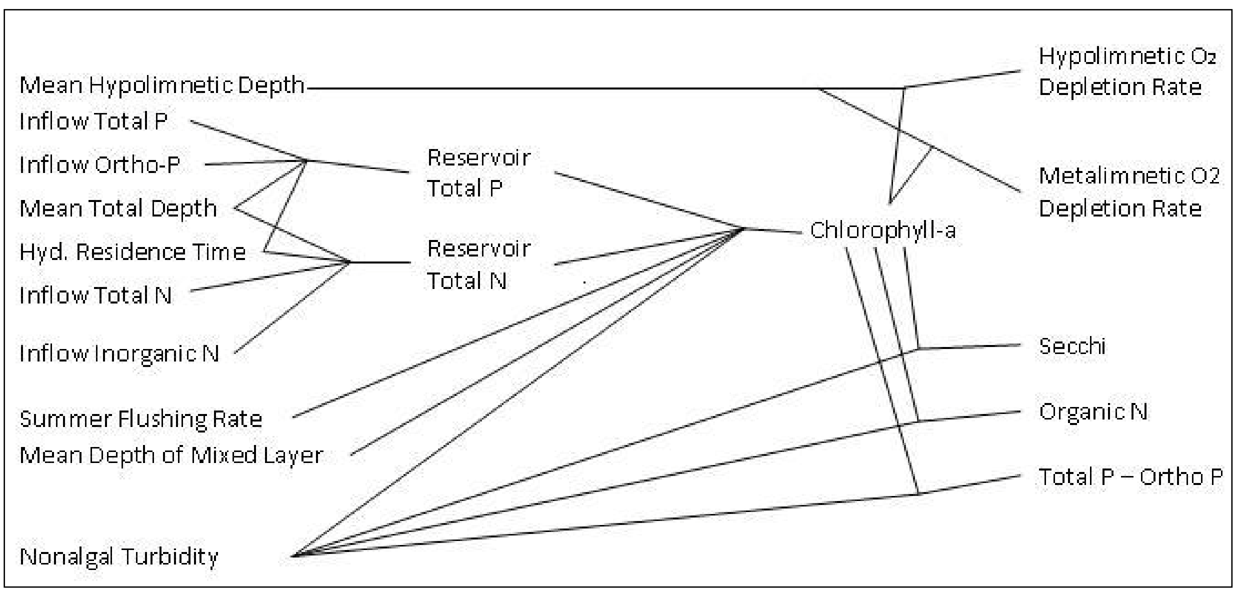

Figure E-1. Eutrophication control pathways in BATHTUB (Walker, 1999).

E.2. Model Parameterization

BATHTUB includes several data input menus/modules to describe lake characteristics, simulation equations, and external (i.e., watershed) inputs. Data menus utilized to develop the BATHTUB model for Lake Keomah include: model selections, global variables, segment data, and tributary data. The model selections menu allows the user to specify which modeling equations (i.e., empirical relationships) are to be used in the simulation of in-lake nitrogen, phosphorus, chlorophyll-a, transparency, and other parameters. The global variables menu describes parameters consistent throughout the lake such as precipitation, evaporation, and atmospheric deposition. The segment data menu is used to describe lake morphometry, observed water quality, calibration factors, and internal loads in each segment of the lake/reservoir. The tributary data menu specifies nutrient loads to each segment using mean flow and concentration in the averaging period. The following sub-sections describe the development of the Lake Keomah BATHTUB model and report input parameters for each menu.

Model Selections

BATHTUB includes several models/empirical relationships for simulating in-lake nutrients and eutrophication response. For TP, TN, chlorophyll-a, and transparency, Models 1 and 2 are the most general formulations, based upon model testing results (Walker, 1999). Alternative models are provided in BATHTUB to allow the user to evaluate other common eutrophication models, evaluate sensitivity of each model, and allow water quality simulation in light of data constraints.

Table E-1 reports the models selected for each parameter used to simulate eutrophication response in Lake Keomah. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Lake Keomah model. Final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data. Model performance is discussed in more detail in Appendix F.

Table E-1. Model selections for Lake Keomah.

Parameter	Model No.	Model Description
Total Phosphorus	01	2nd order*
Total Nitrogen	01	2nd order
Chlorophyll-a	02	P, Light, T *
Transparency	01	vs. Chl-a & Turbidity *
Longitudinal Dispersion	01	Fischer-Numeric *
Phosphorus Calibration	01	Decay rates *
Nitrogen Calibration	01	Decay rates *
Availability Factors	00	Ignore *

* Asterisks indicate BATHTUB defaults

Global Variables

Global input data for Lake Keomah are reported in Tables E-2 (2001-2006), E-3 (2007-2010), and E-4 (2001-2010). Global variables are independent of watershed hydrology or lake morphometry, but affect the water balance and nutrient cycling of the lake. The first global input is the averaging period. Both seasonal and annual averaging periods are appropriate, depending on site-specific conditions. An annual averaging period was utilized to quantify existing loads and in-lake water quality, and to develop TMDL targets for Lake Keomah.

Table E-2. Global variables data for 2001-2006 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	33.2 in	0.843 m
Evaporation	52.6 in	1.336 m
[1]Increase in Storage	0	0
[2]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Change in lake volume from beginning to end of simulation period.
[2]From Anderson and Downing, 2006.

Table E-3. Global variables data for 2007-2010 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	50.1 in	1.273 m
Evaporation	43.5 in	1.105 m
[1]Increase in Storage	0	0
[2]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Change in lake volume from beginning to end of simulation period.
[2]From Anderson and Downing, 2006.

Table E-4. Global variables data for 2001-2010 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	40.0 in	1.016 m
Evaporation	49.0 in	1.237 m
[1]Increase in Storage	0	0
[2]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Change in lake volume from beginning to end of simulation period.
[2]From Anderson and Downing, 2006.

Precipitation was obtained for the 10-year period of 2001-2010 from the Oskaloosa NWS COOP and NCDC weather stations (IEM, 2011a; NCDC, 2011). The NCDC data was utilized as the main data set, with NWS COOP data used to fill in missing data. Potential evapotranspiration data for the same period was obtained from the Chariton weather station via the ISU Ag Climate database (IEM, 2011b). Net change in reservoir storage was assumed to be zero. These data were summarized and converted to BATHTUB units (meters) and entered in the global data menu. Atmospheric deposition rates were obtained from a regional study (Anderson and Downing, 2006). Nutrient deposition rates are assumed constant from year to year.

Segment Data

Lake morphometry, observed water quality, calibration factors, and internal loads are all included in the segment data menu of the BATHTUB model. Separate inputs can be made for each segment of the lake or reservoir system that the user wishes to simulate. In lakes with simple morphometry and one primary tributary, simulation of the entire lake as one segment is often acceptable. Assessment and calibration of model performance for Lake Keomah utilizes a three-segment model. Segment 1 is the east branch of the lake, Segment 2 the west branch, and Segment 3 the main, open water area, which includes the ambient water quality monitoring location (Figure E-2). Flow from Segments 1 and 2 enter Segment 3, which includes the lake outfall structure. Segment morphometry data is reported in Table E-5.

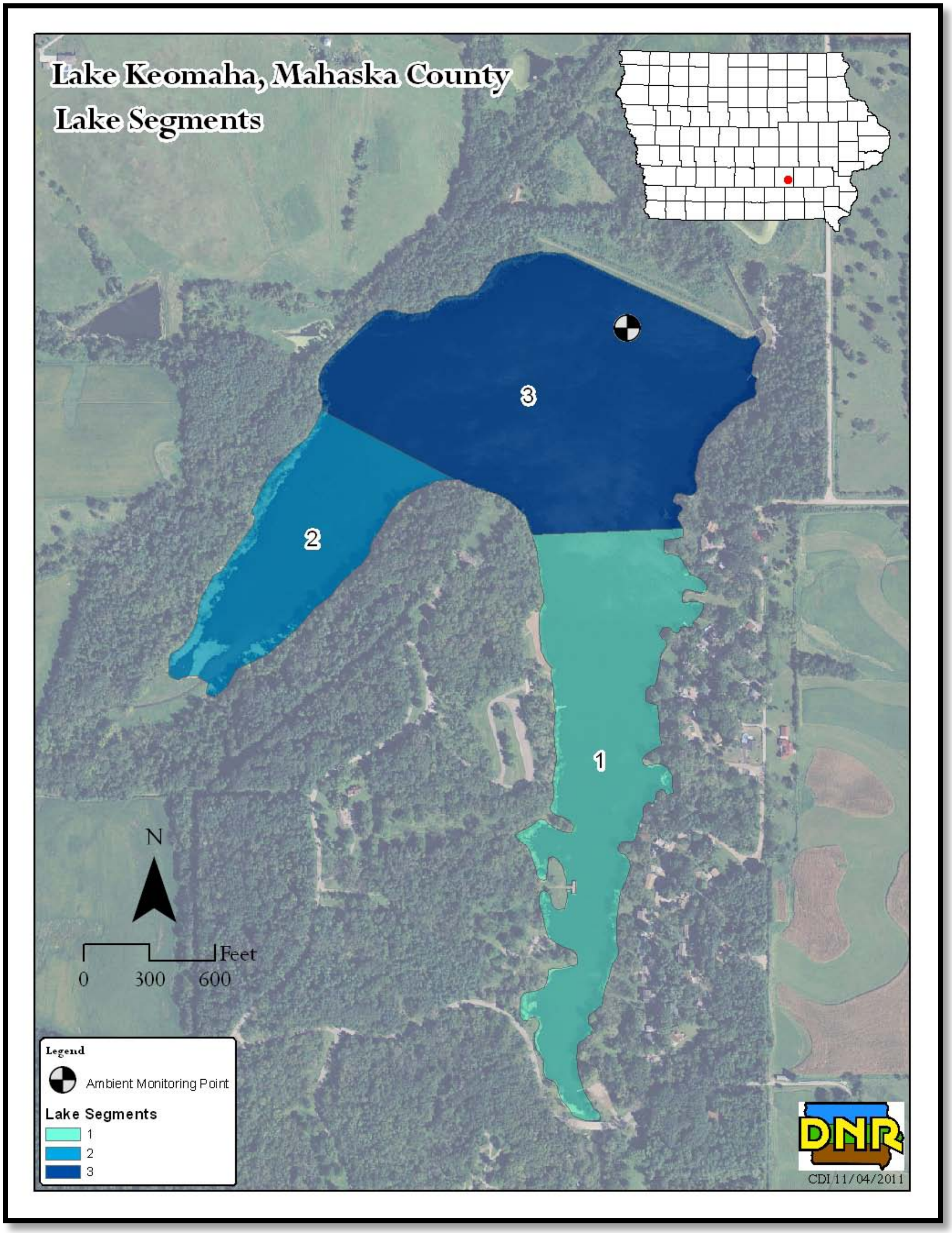

Figure E-2. Segmentation Lake Keomah BATHTUB model.

Table E-5. Segment morphometry for each segment of the lake model.

Parameter	Measured or Monitored Data	BATHTUB Input
Segment 1		
Lake Surface Area	25.1 ac	0.10 km^2
Mean Depth	6.8 ft	2.07 m
[1]Segment Length	838 m	0.84 km
Mixed Layer Depth	6.8 ft	2.1 m
Hypolimnetic Depth	0.0 ft	0.0 m
Segment 2		
Lake Surface Area	14.7 ac	0.06 km^2
Mean Depth	5.5 ft	1.68 m
[1]Reservoir Length	422 m	0.42 km
Mixed Layer Depth	5.5 ft	1.7 m
Hypolimnetic Depth	0.0 ft	0.0 m
Segment 3		
Lake Surface Area	38.3 ac	0.15 km^2
Mean Depth	12.4 ft	3.78 m
[1]Reservoir Length	463 m	0.46 km
Mixed Layer Depth	11.5 ft	3.5 m
Hypolimnetic Depth	4.9 ft	1.5 m

[1] Estimated using GIS

The BATHTUB model developed for Lake Keomah does not simulate dynamic conditions associated with storm events or even between individual growing seasons. Rather, the model predicts water quality in dry periods (2001-2006), wet periods (2007-2010), and average annual conditions (2001-2010).

Observed water quality data for the lake is included in Appendix C – Water Quality Data. Mean water quality parameters observed for the three simulation scenarios (dry, wet, and average conditions) are reported in Tables E-6 (2001-2006), E-7 (2007-2010), and E-8 (2001-2010). These data were compared to output in Segment 3 of the BATHTUB lake model to evaluate model performance and calibrate the BATHUB and STEPL models for each scenario. Lack of data prevented validation of the models. Calibration of the STEPL and BATHTUB models was performed in tandem, and is described in further detail in Appendix F.

Table E-6. Ambient (Segment 3) water quality (2001-2006 annual means).

Parameter	Measured or Monitored Data	[1]BATHTUB Input
Total Phosphorus	107 ug/L	107 ppb
Total Nitrogen	1.59 mg/L	1,589 ppb
Chlorophyll-a	46 ug/L	46 ppb
Secchi Depth	1.32 m	1.32 m
Ammonia	42 ug/L	[2]N/A
Nitrate/Nitrite	0.3 mg/L	[2]N/A
Organic Nitrogen	1.28 mg/L	1,277 ppb
Ortho P	9 ug/L	[2]N/A
TP – Ortho P	98 ug/L	98 ppb

[1] Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)
[2] Used to calculate organic form of nutrient, not an input parameter

Table E-7. Ambient (Segment 3) water quality (2007-2010 annual means).

Parameter	Measured or Monitored Data	[1]BATHTUB Input
Total Phosphorus	83 ug/L	83 ppb
Total Nitrogen	1.75 mg/L	1,746 ppb
Chlorophyll-a	22 ug/L	22 ppb
Secchi Depth	1.95 m	1.95 m
Ammonia	252 ug/L	[2]N/A
Nitrate/Nitrite	0.5 mg/L	[2]N/A
Organic Nitrogen	0.96 mg/L	964 ppb
Ortho P	29 ug/L	[2]N/A
TP – Ortho P	54 ug/L	54 ppb

[1] Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)
[2] Used to calculate organic form of nutrient, not an input parameter

Table E-8. Ambient (Segment 3) water quality (2001-2010 annual means).

Parameter	Measured or Monitored Data	[1]BATHTUB Input
Total Phosphorus	98 ug/L	98ppb
Total Nitrogen	1.65 mg/L	1,652 ppb
Chlorophyll-a	37 ug/L	37 ppb
Secchi Depth	1.57 m	1.57 m
Ammonia	162 ug/L	[2]N/A
Nitrate/Nitrite	0.4 mg/L	[2]N/A
Organic Nitrogen	1.12 mg/L	1,120 ppb
Ortho P	18 ug/L	[2]N/A
TP – Ortho P	80 ug/L	80 ppb

[1] Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)
[2] Used to calculate organic form of nutrient, not an input parameter

Tributary Data

The empirical eutrophication relationships in the BATHTUB model are influenced by the global and segment parameters previously described, but are heavily driven by flow and nutrient loads from the contributing drainage area (watershed). Flow and nutrient loads can be input to the BATHTUB model in a number of ways. Flow and nutrient loads used in the development of the Lake Keomah BATHTUB models utilize watershed hydrology and nutrient loads predicted using the STEPL model described in Appendix D. Output from STEPL includes annual average flow and nutrient loads. STEPL output requires conversion into forms compatible with BATHTUB. This includes unit conversion and converting STEPL nutrient loads and flow into mean concentrations and flow for BATHTUB input.

Because of the segmented nature of Lake Keomah, three subbasins were included in the STEPL model to provide tributary inputs for Segment 1 (Tributary 1), Segment 2 (Tributary 2), and Segment 3 (Tributary 3). Tributary data are reported for dry years in Table E-9 (2001-2006), wet years in Table E-10 (2007-2010), and 10-year average conditions in Table E-11 (2001-2010).

Table E-9. BATHTUB tributary data (2001-2006 annual averages).

Parameter	STEPL Output	[1]BATHTUB Input
Tributary 1 – East Tributary		
Flow	1,160 ac-ft	[2]1.43 hm^3/yr
Total P	1,681 lb	533 ppb
Ortho P	[3]NA	[3]NA
Total N	10,515 lb	3,333 ppb
Inorganic N	[3]NA	[3]NA
Tributary 2 – West Tributary		
Flow	924 ac-ft	[2]1.14 hm^3/yr
Total P	1,541 lb	489 ppb
Ortho P	[3]NA	[3]NA
Total N	7,199 lb	2,282 ppb
Inorganic N	[3]NA	[3]NA
Tributary 3 – Adjacent to Lake		
Flow	174 ac-ft	[2]0.21 hm^3/yr
Total P	149 lb	47 ppb
Ortho P	[3]NA	[3]NA
Total N	1,232 lb	391 ppb
Inorganic N	[3]NA	[3]NA

[1]STEPL output converted to units required by BATHTUB
[2]hm^3/yr = cubic hectometers per year
[3]Ortho P and Inorganic N not applicable, bioavailability ignored in BATHTUB

Table E-10. BATHTUB tributary data (2007-2010 annual averages).

Parameter	STEPL Output	[1]BATHTUB Input
Tributary 1 – East Tributary		
Flow	1,973 ac-ft	[2]2.43 hm^3/yr
Total P	2,311 lb	431 ppb
Ortho P	[3]NA	[3]NA
Total N	16,992 lb	3,167 ppb
Inorganic N	[3]NA	[3]NA
Tributary 2 – West Tributary		
Flow	1,574 ac-ft	[2]1.94 hm^3/yr
Total P	1,806 lb	337 ppb
Ortho P	[3]NA	[3]NA
Total N	10,255 lb	1,911 ppb
Inorganic N	[3]NA	[3]NA
Tributary 3 – Adjacent to Lake		
Flow	296 ac-ft	[2]0.37 hm^3/yr
Total P	210 lb	39 ppb
Ortho P	[3]NA	[3]NA
Total N	1,978 lb	369 ppb
Inorganic N	[3]NA	[3]NA

[1]STEPL output converted to units required by BATHTUB
[2]hm^3/yr = cubic hectometers per year
[3]Ortho P and Inorganic N not applicable, bioavailability ignored in BATHTUB

Table E-11. BATHTUB tributary data (2001-2010 annual averages).

Parameter	STEPL Output	[1]BATHTUB Input
Tributary 1 – East Tributary		
Flow	1,473 ac-ft	[2]1.82 hm^3/yr
Total P	1,921 lb	480 ppb
Ortho P	[3]NA	[3]NA
Total N	12,988 lb	3,242 ppb
Inorganic N	[3]NA	[3]NA
Tributary 2 – West Tributary		
Flow	1174 ac-ft	[2]1.45 hm^3/yr
Total P	1,642 lb	410 ppb
Ortho P	[3]NA	[3]NA
Total N	8,371 lb	2,090 ppb
Inorganic N	[3]NA	[3]NA
Tributary 3 – Adjacent to Lake		
Flow	221 ac-ft	[2]0.27 hm^3/yr
Total P	172 lb	43 ppb
Ortho P	[3]NA	[3]NA
Total N	1,518 lb	379 ppb
Inorganic N	[3]NA	[3]NA

[1]STEPL output converted to units required by BATHTUB
[2]hm^3/yr = cubic hectometers per year
[3]Ortho P and Inorganic N not applicable, bioavailability ignored in BATHTUB

E.3. References

Anderson, K., and J. Downing. 2006. Dry and wet atmospheric deposition of nitrogen, phosphorus, and silicon in an agricultural region. Water, Air, and Soil Pollution, 176:351-374.

Walker, W. 1985. Empirical methods for predicting eutrophication in impoundments; Report 4, Phase III: Applications manual, "Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Walker, W. 1996 (Updated 1999). Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. US Army Corps of Engineers Waterways Experiment Station. Instruction Report W-96-2.

Appendix F --- Model Performance and Calibration

The Lake Keomah watershed and water quality models were calibrated by comparing simulated and observed local and regional data. The primary source of calibration data is the ambient lake monitoring data collected by Iowa State University (ISU) and the University of Iowa State Hygienic Laboratory (SHL) between 2001 and 2010. Literature values and results from regional studies regarding sediment and phosphorus exports in similar watersheds were also utilized to evaluate model performance. Calibration was an iterative process that involved running both the watershed model (STEPL) and in-lake model (BATHTUB), and refining model parameters to (1) produce simulated values that were within reasonable ranges according to similar studies, and (2) provide good agreement with observed water quality in Lake Keomah.

F.1. STEPL Performance and Calibration

The STEPL model is a long-term average annual simulation model, and is incapable of simulating storm events or short-term fluctuations in hydrology and nutrient loads. There is little to no long-term monitoring data for tributaries in the Lake Keomah watershed, therefore model calibration relied heavily upon sediment and phosphorus exports reported in similar watersheds in the region. Table F-1 reports estimated sheet and rill erosion rates found in several Iowa watersheds that lie within the Southern Iowa Drift Plain ecoregion, which is characterized by irregular plains with open, low hills and moderate loess soils overlaying loamy and clay glacial till. Regional watershed erosion estimates in Table F-1 include a previous RUSLE assessment conducted in the Lake Keomah watershed.

Table F-1. Sheet and rill erosion in Southern Iowa Drift Plain watersheds.

Watershed	County	Area (acres)	Proximity (miles)	Erosion (tons/ac/yr)
[1]Lake Keomah	**Mahaska**	**1,951**	**--**	**3.4**
Diamond Lake	Poweshiek	2,767	25	2.9
Fox River	Appanoose	119,067	45	3.1
Lake Hawthorne	Mahaska	3,289	15	5.3
Badger Creek Lake	Madison	11.397	80	3.9-4.5
Lake Miami	Monroe	3,595	30	2.2
Miller Creek	Monroe	19,930	15	2.3
[2]Lake Keomah	**Mahaska**	**[3]1,873**	**--**	**[4]3.7**

[1]Previous erosion study conducted in the Lake Keomah watershed by IDNR.
[2]Annual erosion estimated for this WQIP using STEPL (2001-2010).
[3]Area per updated delineation (excludes area of lake)
[4]Erosion estimate ignores existing BMPs, consistent with other watersheds in table.

The Lake Keomah STEPL model predicts sheet and rill erosion rates that are similar to rates predicted by IDNR for other watersheds in the ecoregion. The 2001-2010 simulated annual average rate was 3.7 tons/acre, near the average estimated rate observed in other watersheds (2.3 to 5.3 tons/acre), and slightly higher than the rate estimate in the previous RUSLE estimate for the Lake Keomah watershed.

Table F-2 compares the annual average TP export simulated by the Lake Keomah STEPL model with study results in other watersheds in the Southern Iowa Drift Plain ecoregion. TP export in the Lake Keomah watershed is near the middle of the range of rates observed or simulated in the literature. Because the STEPL model predicted sediment and phosphorus loads similar in magnitude to estimates developed for other local and regional watersheds, IDNR has determined the STEPL model to be adequate for estimation of phosphorus loads to Lake Keomah for development of TMDLs and implementation planning.

Table F-2. Comparison of TP exports in tile-drained watersheds.

Watershed/Location	Source	TP Export (lb/ac)
[1]Old Mans Creek near Iowa City, IA	USGS, 2001	4.0
[1]Skunk River at August, IA	USGS, 2001	2.4
[2]Lake Geode, Henry Co.	IDNR (Previous TMDL)	1.4
[2]Badger Creek Lake	IDNR (Previous TMDL)	2.2
Lake Keomah	**Current STEPL model**	**[2]2.0**

[1] Average annual TP export, 1996-1998, (USGS, 2001)
[2] Annual average TP export per previous IDNR TMDL modeling studies

F.2. BATHTUB Model Performance

Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Lake Keomah from 2001 to 2010. Simulation of TP concentration was critical for TMDL development, as was chlorophyll-a and transparency predictions. Nitrogen constituents are less important because Lake Keomah is not nitrogen limited. Therefore, nitrogen simulations were not calibrated.

Calibration
Table F-3 reports observed and predicted annual average TP, chlorophyll-a, and Secchi depths in the open water area (Segment 3) of Lake Keomah, along with calibration coefficients for each parameter. The observed data was obtained as part of the ambient lake monitoring program, and is based on data reported in Appendix C. Predicted water quality is based on BATHTUB simulations, and the calibration coefficients were iteratively adjusted in order to obtain the best possible agreement between observed and predicted water quality. Calibration was not possible in Segments 1 or 2 of the lake model due to lack of observed data. The calibration coefficients listed alongside the simulated values in Table F-3 were entered for each segment (e.g., Segments 1-3) of the BATHTUB models, and are within the recommended range according to the BATHTUB user guidance (Walker, 1996).

Table F-3 reports annual average data for the dry period (2001-2006), wet period (2007-2010), and the entire simulation period (2001-2010). It was necessary to use distinct chlorophyll-a calibration coefficients for varying climatic conditions (i.e., dry, wet, and average conditions). This is because the processes that govern algal growth are weather dependant. Calibration parameters for TP and Secchi depth are consistent across wet, dry, and average conditions. Lack of additional years of in-lake water quality data prevented validation of the BATHTUB models for Lake Keomah. However, the good performance of the model across both wet and dry periods, and the chlorophyll-a calibration coefficient of 1.01 for average conditions, indicate that it is appropriate to use the average conditions BATHTUB model for TMDL development and watershed/lake planning purposes.

Anecdotal evidence suggests that internal loads are at times significant in Lake Keomah, and this was considered during calibration. Very little internal loading takes place in wet years because watershed loads drive TP concentration, and hence, algal growth. However, in dry years, algae readily utilize resuspended and recycled phosphorus. Once the overall TP calibration factor for wet, dry, and average conditions was obtained, internal loads were adjusted to reflect in-lake phosphorus levels across all three conditions. Internal loads were input in the main, open water area of the lake (Segment 3), and are reported in Table F-4.

Table F-3. Observed and simulated water quality with calibration factors.

Parameter	[1]Observed	[2]Predicted	Calibration Factor
Dry weather conditions (2001-2006)			
Total Phosphorus (ug/L)	107	108	1.6
Chlorophyll-a (ug/L)	46	45	1.23
Secchi depth (m)	1.3	1.2	1.4
Wet weather conditions (2007-2010)			
Total Phosphorus (ug/L)	83	84	1.6
Chlorophyll-a (ug/L)	22	23	0.73
Secchi depth (m)	2.0	2.1	1.4
Average weather conditions (2001-2010)			
Total Phosphorus (ug/L)	98	99	1.6
Chlorophyll-a (ug/L)	36	35	1.01
Secchi depth (m)	1.6	1.5	1.4

[1]Average concentration observed at ambient monitoring location
[2]Average annual concentration predicted in Segment 3 of BATHTUB lake model

Table F-4. Internal TP loads

Years	Conditions	Internal TP ($mg/m^2/d$)	Internal TP (lb/yr)
2007-2010	Wet	2.00	249
2001-2006	Dry	7.75	967
2001-2010	Average	6.50	811

F.3. References

U.S. Geological Survey (USGS), 2001. Water Quality Assessment of the Eastern Iowa Basins – Nitrogen, Phosphorus, Suspended Sediment, and Organic Carbon in Surface Waters, 1996-98. Water Resources Investigations Report 01-4175. Iowa City, Iowa.

Walker, W. 1996 (Updated 1999). Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. US Army Corps of Engineers Waterways Experiment Station. Instruction Report W-96-2.

Appendix G --- Expressing Average Loads as Daily Maximums

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits.* In the context of the memorandum, EPA

> *"…recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increments. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards…"*

Per the EPA recommendations, the loading capacity of Lake Keomah for TP is expressed as both a maximum annual average and a daily maximum load. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, whereas the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum. The allowable annual average was derived using the BATHTUB model described in Appendix E, and is 1,161 lbs/year.

The maximum daily load was estimated from the allowable growing season average using a statistical approach. The methodology for this approach is taken directly from the follow-up guidance document titled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), which was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control.*

The *Options for Expressing Daily Loads in TMDLs* document presents a similar case study in which a statistical approach is considered the best option for identifying a maximum daily load (MDL) that corresponds to the allowable average load. The method calculates the daily maximum based on a long-term average and considers variation. This method is represented by the equation:

$$MDL = LTA \times e^{[z\sigma - .05\sigma^2]}$$

Where:
MDL = maximum daily limit
LTA = long term average
z = z statistic of the probability of occurrence
$\sigma^2 = \ln(CV^2 + 1)$
CV = coefficient of variation

The allowable annual average of 1,161 lbs/year is equivalent to a long-term average (LTA) daily of 3 lbs/day. The LTA is the allowable annual load divided by the 365-day averaging period. The average annual allowable load must be converted to a MDL. The 365-day averaging period equates to a recurrence interval of 99.7 percent and corresponding z statistic of 2.778, as reported in Table G-1. The coefficient of variation

(CV) is the ratio of the standard deviation to the mean. However, there is insufficient data to calculate a CV as it relates to TP loads to the lake, because the models are based on annual averages over several years. In cases where data necessary for calculating a CV is lacking, EPA recommends using a CV of 0.6 (EPA, 1991). The resulting σ^2 value is 0.31. This yields a TMDL of 13 lbs/day. The TMDL calculation is summarized in Table G-2.

Because there are no permitted/regulated point source discharges in the watershed, the WLA is zero. An implicit MOS is applied by targeting a chlorophyll-a TSI value of 63, the IDNR delisting criterion, for the whole lake average, rather than for the ambient monitoring location in Segment 3. This is a conservative assumption because water quality in Segment 3 is better than in upstream Segments 1 and 2 as a result of settling and decay of nutrients as water moves through the system. If the whole-lake average chlorophlyll-a TSI is 63, the corresponding TSI at the ambient location where data is collected will be lower. This implicit MOS is numerically larger than the typical explicit 10 percent of the TMDL, which increases assurance that the TMDL will result in compliance with water quality standards. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (13 lbs-TP/day)
+ MOS (0, implicit) = **13 lbs-TP/day**

Table G-1. Multipliers used to convert a LTA to an MDL.

Averaging Period (days)	Recurrence Interval	Z-score	Coefficient of Variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8%	1.849	1.41	1.89	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.05	7.89	8.66
180	99.4%	2.541	1.62	2.47	3.51	4.66	5.87	7.06	8.20	9.29	10.3
210	99.5%	2.594	1.64	2.52	3.61	4.84	6.13	7.42	8.67	9.86	11.0
365	99.7%	2.778	1.70	2.71	4.00	5.51	7.15	8.83	10.5	12.1	13.7

Table G-2. Summary of LTA to MDL calculation for the TMDL.

Parameter	Value	Description
LTA	3 lbs/day	Growing season MOS (9,366 lbs/ 182 days)
Z Statistic	2.778	Based on 180-day averaging period
CV	0.6	Used CV from annual GWLF TP loads
σ^2	0.31	ln (CV^2 + 1)
MDL	**13 lbs/day**	**TMDL expressed as daily load**

Appendix H --- 2010 305(b) Water Quality Assessment

Segment Summary

Waterbody ID Code: IA 03-SSK-00120-L_0
Location: Mahaska County, S13,T75N,R15W, 4.5 mi E of Oskaloosa.
Waterbody Type: Lake
Segment Size: 84 Acres
This is a Significant Publically Owned Lake

Segment Classes:
Class A1
Class B(LW)
Class C
Class HH

Assessment Comments

Assessment is based on: (1) the results of the IDNR-UHL beach monitoring program in summers of 2006, 2007, and 2008, (2) results of the statewide survey of Iowa lakes conducted from 2004 through 2007 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted from 2005 through 2008 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) results of U.S. EPA/IDNR fish contaminant (RAFT) monitoring in 2000.

Assessment Summary and Beneficial Use Support

Overall Use Support - Not supporting
Aquatic Life Support - Partial
Fish Consumption - Fully
Primary Contact Recreation - Not supporting
Drinking Water - Not assessed

Assessment Type: Monitored
Integrated Report Category: 5a
Water is impaired or a declining water quality trend is evident, and a TMDL is needed.
Trend: Stable
Trophic Level: Eutrophic

Basis for Assessment and Comments

SUMMARY: The Class A1 (primary contact recreation) uses are assessed (monitored) as "not supported" due to levels of indicator bacteria that exceed Iowa's water quality standard, violations of the state criterion for pH, and aesthetically objectionable conditions caused by algae blooms. The Class B(LW) uses are assessed (monitored) as "partially supported" due to violations of the state's pH criterion. The Class C (drinking water) uses are "not assessed" due to a lack of information on which to base an assessment. Fish consumption uses remain assessed (evaluated) as "fully supported." Sources of data for this assessment include (1) the results of the IDNR-UHL beach monitoring program in summers of 2006, 2007, and 2008, (2) results of the statewide survey of Iowa lakes conducted from 2004 through 2007 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted from 2005 through 2008 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) results of U.S. EPA/IDNR fish contaminant (RAFT) monitoring in 2000.

Note: A TMDL for siltation at Lake Keomah was prepared by IDNR and approved by EPA in 2002; thus, this lake was placed into IR Category 4a for the 2004 assessment/listing cycle. Not all of the section 303(d) impairments identified for the current (2010) assessment/listing cycle (indicator bacteria, algal growth, and pH), however, are addressed in the TMDL. Thus, this waterbody remains in Category 5a (impaired; TMDL required) for the 2010 assessment/listing cycle.

EXPLANATION: Results of IDNR beach monitoring from 2006 through 2008 suggest that the Class A1 uses are "not supported." Levels of indicator bacteria at Lake Keomah beach were monitored once per week during the primary contact recreation seasons (May through September) of 2006 (28 samples), 2007 (17 samples), and 2008 (22 samples) as part of the IDNR beach monitoring program. According to IDNR's assessment methodology, all thirty-day geometric means for the three-year assessment period must be less than the state's geometric mean criterion of 126 E. coli orgs/100 ml for results of beach monitoring to indicate "full support" of the Class A1 (primary contact recreation) uses. If a 5-sample, 30-day geometric mean exceeds the state criterion of 126 orgs/100 ml during the three-year assessment period, the Class A1 uses should be assessed as "not supported". This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

At Lake Keomah beach, the geometric means of 6 thirty-day periods during the summer recreation season of 2006 exceeded the Iowa water quality standard of 126 E. coli orgs/100 ml. No geometric means violated this criterion in 2007 or 2008. The percentage of samples exceeding Iowa's single-sample maximum criterion (235 E. coli orgs/100 ml) was 18% in 2006, 24% in 2007 and 5% in 2008. According to IDNR's assessment methodology and U.S. EPA guidelines, the exceedences of the geometric mean criterion suggest impairment (nonsupport) of the Class A1 (primary contact recreation) uses.

Results from the ISU and UHL lake surveys suggest that the Class A1 uses at Lake Keomah are assessed (monitored) as "partially supported" due to aesthetically objectionable conditions caused by algae blooms and violations of Iowa's pH criterion. Using the median values from these surveys from 2004 through 2008 (approximately 27 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 56, 67, and 70 respectively for Lake Keomah. According to Carlson (1977) the Secchi depth, and chlorophyll a values place Lake Keomah in between the eutrophic and hypereutrophic categories, while the total phosphorus value places Lake Keomah in the hypereutrophic category. These values suggest high levels of chlorophyll a and suspended algae in the water, relatively good water transparency, and very high levels of phosphorus in the water column.
The level of inorganic suspended solids was relatively low at this lake and does not suggest impairment due to high non-algal turbidity. The median inorganic suspended

solids concentration at Lake Keomah was 2.0 mg/L, which was the 28th lowest of the 132 monitored lakes. Although this lake was indentified as impaired by non-algal turbidity for the 2006 listing cycle, identification of this impairment was an error: data for ISS have never suggested that water transparency problems at this lake were due to ISS. Thus, the turbidity impairment was de-listed for the 2008 assessment/listing cycle.

Data from the 2004-2008 ISU and UHL surveys suggest a moderate population of cyanobacteria exists at Lake Keomah. These data show that cyanobacteria comprised 39% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (8.0 mg/L) was also the 41st lowest of the 132 lakes sampled.

The Class B(LW) (aquatic life) uses are assessed (monitored) as “partially supported” due to a high frequency of violations of Iowa’s criterion for pH. Based on data from the ISU and UHL lake surveys from 2004 through 2008, there was one violation of the Class B(LW) criterion for ammonia in 27 samples (4%) and two violations of the Class B(LW) criterion for dissolved oxygen in 27 samples (7%). Based on IDNR’s assessment methodology, these violations are not significantly greater than 10% of the samples and therefore do not constitute an impairment of the aquatic life uses of Lake Keomah. Data from the ISU and UHL surveys, however, show 8 violations of the Class A1,B(LW) criterion for pH in 27 samples (30%). Based on IDNR’s assessment methodology these results are significantly greater than 10% of the samples and therefore constitute an impairment (partial support/monitored) of the Class B(LW) uses of Lake Keomah.

Drinking water (Class C) uses were not assessed due to the lack of water quality information upon which to base an assessment. The only parameter collected as part of the ISU and UHL lake surveys relevant to support of Class C (drinking water) uses is nitrate. While the results of these surveys from 2004-08 show that nitrate levels at Lake Keomah (maximum value = 1.4 mg/l; median = 0.1 mg/l) are very low relative to the drinking water MCL (10 mg/l), these data are not sufficient for developing a valid assessment of support of the Class C uses.

Fish consumption uses are assessed (evaluated) as “fully supported” based on results of U.S. EPA/IDNR fish contaminant (RAFT) monitoring at Lake Keomah in 2000. Because these data are now considered too old (greater than five years) to accurately characterize current water quality conditions, the assessment category is considered “evaluated” (indicating an assessment with relatively lower confidence) as opposed to "monitored" (indicating an assessment with relatively higher confidence). The composite samples of fillets from channel catfish and largemouth bass had low levels of contaminants. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of the degree to which Iowa’s lakes and rivers support their fish consumption uses. The fish contaminant data generated from the 2000 RAFT sampling conducted at Lake Keomah show that the levels of contaminants do not exceed any of the advisory trigger levels, thus suggesting no justification for issuance of a consumption advisory for this waterbody.

Monitoring and Methods

Assessment Key Dates

8/9/2000 Fish Tissue Monitoring

6/1/2004 Fixed Monitoring Start Date

7/1/2008 Fixed Monitoring End Date

Methods

- Surveys of fish and game biologists/other professionals
- Non-fixed-station monitoring (conventional during key seasons and flows)
- Primary producer surveys (phytoplankton/periphyton/macrophyton)
- Fish tissue analysis
- Water column surveys (e.g. fecal coliform)

Causes and Sources of Impairment

Causes	Use Support	Cause Magnitude	Sources	Source Magnitude
Pathogens	Primary Contact Recreation	Moderate	Source Unknown	High
Algal Grwth/Chlorophyll a	Primary Contact Recreation	Moderate	Internal nutrient cycling (primarily lakes)	Moderate
pH	Primary Contact Recreation	Slight	Internal nutrient cycling (primarily lakes)	Moderate
pH	Aquatic Life Support	Slight	Internal nutrient cycling (primarily lakes)	Moderate

Appendix I --- Public Comments

The Iowa Department of Natural Resources (IDNR) received no public comments during the public comment period for the Lake Keomah TMDL.