Water Quality Improvement Plan
for

Lake Iowa

Iowa County, Iowa

Total Maximum Daily Load
for Algae

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Watershed Improvement Section
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General Report Summary

What is the purpose of this report?

This report serves two major purposes. First, this report satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all impaired 303(d) waterbodies. Second, this report should serve as a resource for locally-driven water quality improvements to Lake Iowa in an effort to improve the water quality and successfully restore the lake. Third, it provides a foundation for locally-driven water quality improvements to successfully restore Lake Iowa. Finally, it may be useful for obtaining financial assistance to fund watershed improvement projects.

What's wrong with Lake Iowa?

Lake Iowa is subject to aesthetically objectionable conditions caused by poor water transparency caused by algae blooms. Water quality data suggest very high levels of chlorophyll-a and suspended algae in the water, poor water transparency and very high levels of phosphorus in the water column.

Results from the Iowa State University (ISU) and State Hygienic Laboratory (SHL) lake surveys suggest that the Class A1 (primary contact recreation) uses at Lake Iowa are "partially supported" due to elevated chlorophyll-a (algae) levels, which indicate the presence of algal blooms.

What is causing the problem?

Lake Iowa is subject to aesthetically objectionable conditions due to poor water transparency caused by algae blooms. Water quality data suggest high levels of chlorophyll a and suspended algae in the water, poor water transparency, and high levels of phosphorus in the water column.

What can be done to improve Lake Iowa?

Reducing phosphorus loads entering the lake should be the highest priority for improving water quality. The amount of phosphorus coming off the watershed is large. However, if and when monitoring shows that the external watershed load has been reduced significantly, shifting focus towards in-lake measures may be warranted. It may take many years for the system to process all the phosphorus that has accumulated in the lake sediment over time.

Who is responsible for a cleaner Lake Iowa?

Everyone who lives and works nearby, or wishes to utilize a healthy Lake Iowa, has an important role to play in improving and maintaining the lake. The future of Lake Iowa depends on citizens and landowners adopting land management practices. The best chance for success in improving Lake Iowa lies with private citizens working with government agencies that can provide technical, and in some cases, financial support of improvement efforts. Citizens interested in making a difference in Lake Iowa should contact Iowa County Soil and Water Conservation district or the Iowa DNR Watershed Improvement Section for information on how to get involved.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Waterbody ID: IA 02-IOW-01150-L_0 Location: Iowa County, S19,T79N,R11W, 4 mi. NNW of Millersburg.
Surface water classification and designated uses:	Class A1 – primary contact recreation Class B(LW) – aquatic life Class HH – human health (fish consumptions)
Impaired beneficial uses:	Class A1
Identification of the pollutant and applicable water quality standards:	The Class A1 (primary contact recreation) uses are assessed (monitored) as "partially supported" due to aesthetically objectionable conditions caused by nuisance algae blooms.
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	Excess algae blooms and subsequent chlorophyll-a concentrations are attributed to total phosphorus (TP). The allowable average annual TP load = 436.1 lbs/year; the maximum daily TP load = 4.8 lbs/day.
Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:	The existing annual load of 2,110.7 lbs/year must be reduced by 1,674.6 lbs/year to meet the allowable TP load. This is a reduction of 79 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, and atmospheric deposition.
Wasteload allocations for pollutants from point sources:	With no permitted point sources, the WLA is zero.

Load allocations for pollutants from nonpoint sources:	The allowable annual average TP LA is 392.5 lbs/year, and the allowable maximum daily LA is 4.3 lbs/day.
A margin of safety:	An explicit MOS of 10 percent is incorporated into this TMDL. The annual MOS is 43.6 lbs of P and the daily MOS is 0.5 lbs of P.
Consideration of seasonal variation:	The TMDL is based on annual TP loading. Although daily maximum loads are provided to address legal requirements, the average annual loads are critical to in-lake water quality and lake/watershed management decisions.
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 the associated impairment are 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 a list 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 Iowa, located in Iowa County in east-central Iowa, is to provide a TMDL for algae. 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 watershed management plan, and implement water quality improvement projects. Excessive algal growth impairs primary contact recreation and is addressed by development of a TMDL that limits total phosphorus (TP) loads to the lake.
This 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 includes a description of potential actions to address the impairments. The actions comprise a set of best management practices (BMPs) that could improve water quality in Lake Iowa, with the goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the Section 4 implementation plan.

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 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 Iowa.

2. Description and History of Lake Iowa

Lake Iowa is an 85.2 acre manmade lake surrounded by a 1,300 acre watershed in Iowa County (Figure 2.1). Currently, the lake is about 32 feet deep at the deepest point with an average depth of 11.5 feet (Figure 2.2). Major land uses within the Lake Iowa watershed are summarized in Table 2.1. Note the “Alfalfa/Hay” classification has been aggregated under the “Grassland” landuse in Table 2.1 due to similar growth season and evapotranspiration characteristics. There are no permitted discharges within this watershed. Further discussion of the impacts of these landuses when combined with the natural landscape on Lake Iowa water quality can be found in Section 4 of this report. The watershed to lake ratio is 15.1 to 1.

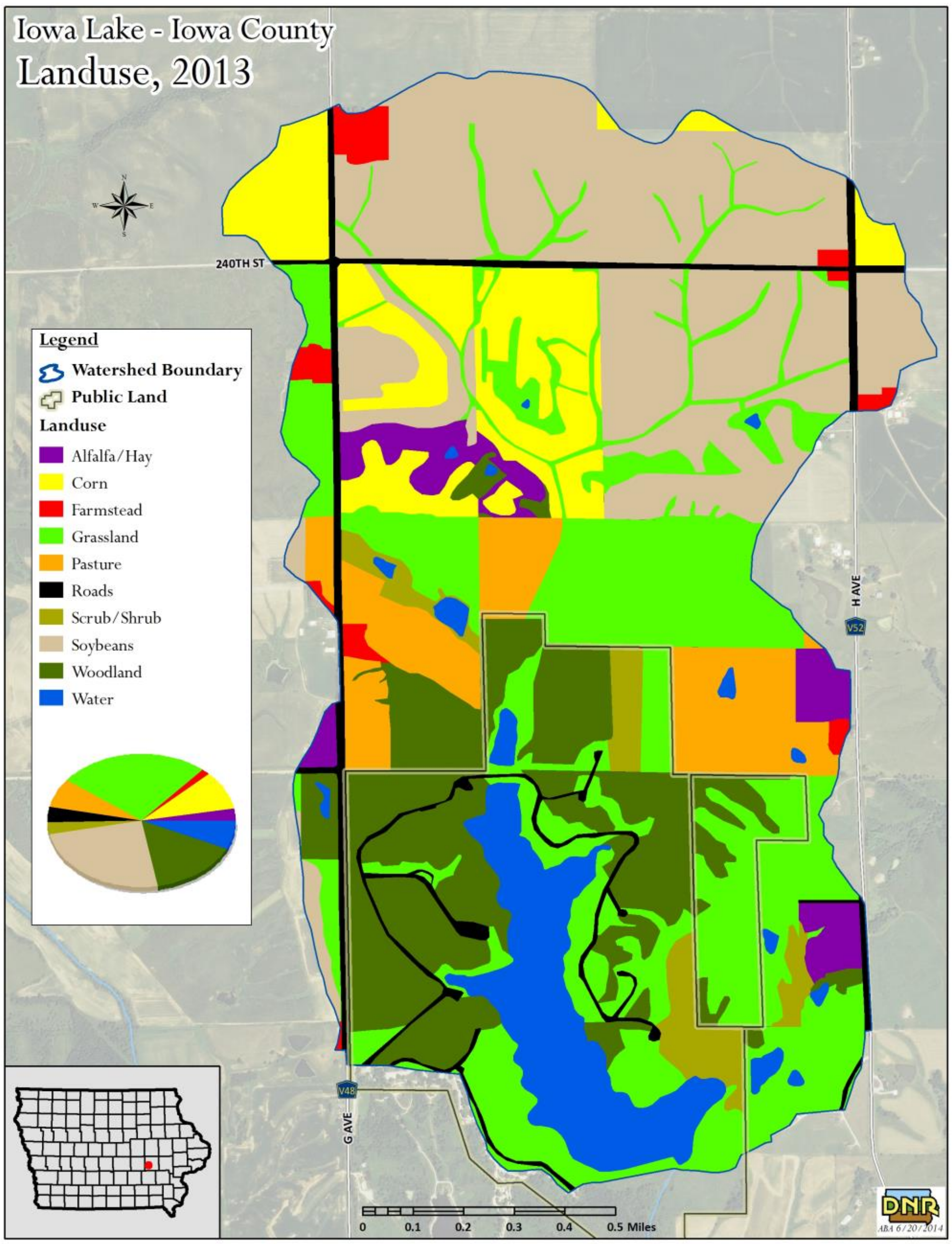

Figure 2.1. Lake Iowa watershed and land use.

Table 2.1. Landuses within the Lake Iowa watershed.

Landuse	Description	Acres	Percent
Cropland	Corn and Soybean	469.1	36.1
Forest	Ungrazed timber includes shrub	251.4	19.3
Pasture	Grazed and ungrazed private	98.9	7.6
Grassland	Public park, ungrazed private, hay/alfalfa	400.4	30.8
Urban	City, town, farmstead, road	68.8	5.3
Water	Open water; excluding Lake Iowa	11.7	0.9
Total		**1300.3**	**100.0**

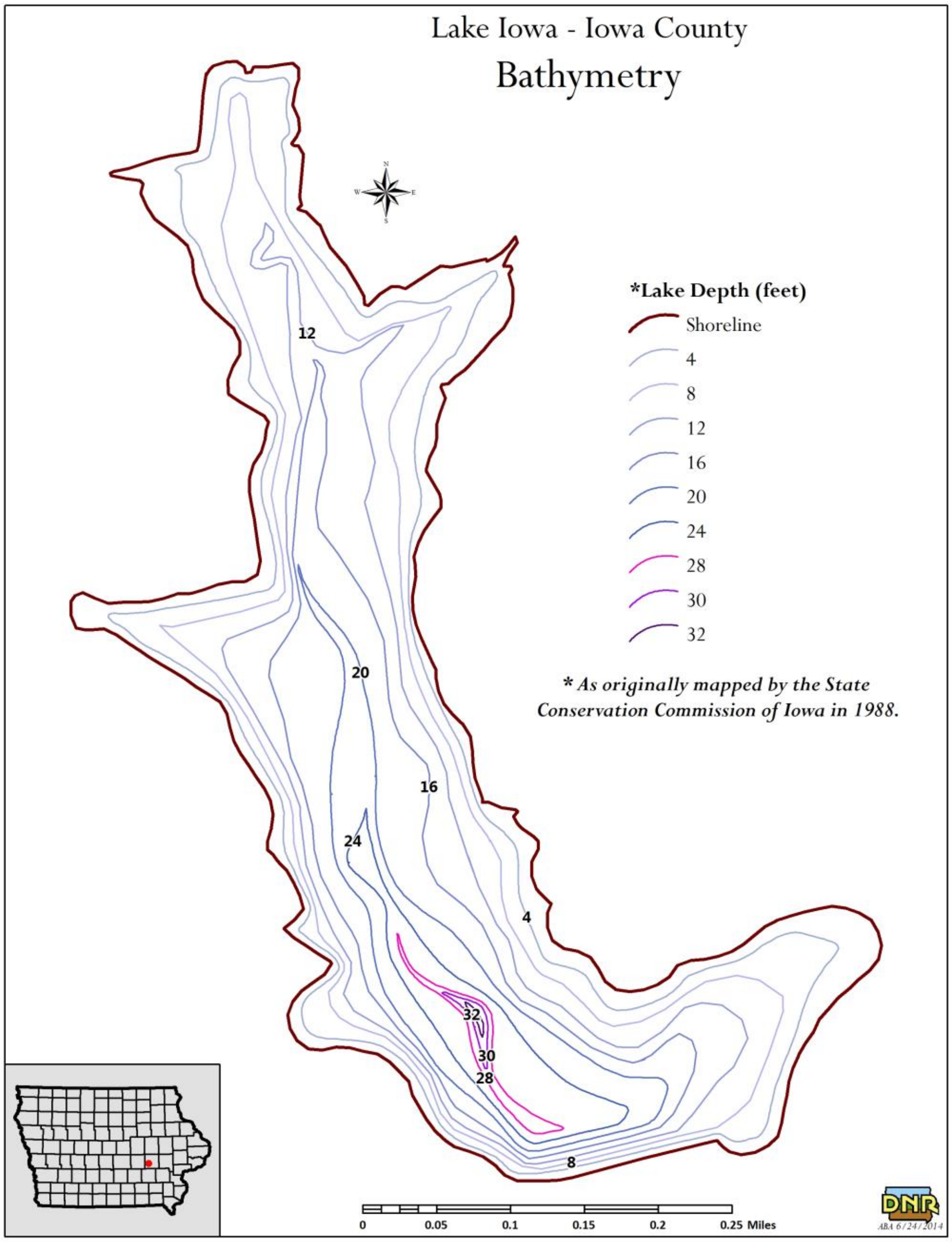

Figure 2.2. Bathymetric map of Lake Iowa.

2.1. Lake Iowa Watershed

Climate. The mean annual precipitation for the watershed from 2003-2013 (Williamsburg, Iowa Station) was 37.8 inches of precipitation per year (Figure 2.3). The driest month is January, averaging 1.1 inches of precipitation and the wettest month is June with an average of 5.3 inches of precipitation. The lowest mean temperature occurs in January and is 15 degrees Fahrenheit; the highest mean temperature occurs in July and is 87 degrees Fahrenheit.

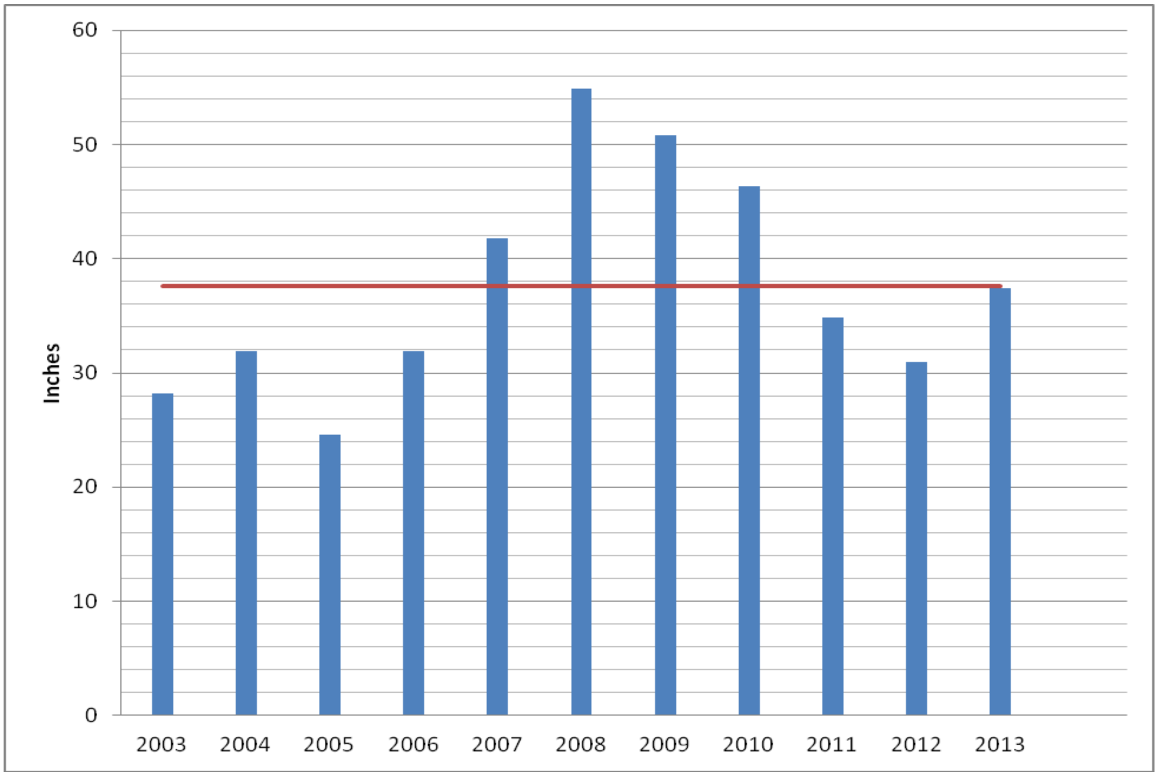

Figure 2.3. Annual precipitation at Williamsburg, Iowa.

Morphometry & Substrate. Lake Iowa is within the Southern Drift Plain landform region. The Southern Drift plain region is dominated by glacial deposits left by ice sheets that extended south into Missouri over 500,000 years ago. The deposits were carved by episodes of stream erosion so that only a horizon line of hill summits marks the once-continuous glacial plain. Numerous rills, creeks, and rivers branch out across the landscape creating steeply rolling hills and valleys. The uplands and upper hill slopes are loess covered.

The majority of soils within the watershed are of the Ladoga-Clinton-Lindley association along with some Otley soils. These soils are moderately sloping to very steep, well drained soils formed in loess. The sandy soils in this association are susceptible to wind erosion and water erosion. The main concerns with management of these soils are controlling water erosion, wind erosion and maintaining fertility.

3. Total Maximum Daily Load (TMDL) for Algae

A Total Maximum Daily Load (TMDL) is required for Lake Iowa by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) describes the pollutant, in this case phosphorus, leading to the algae impairment and the maximum amount of total phosphorus (TP) the lake can assimilate and still support primary contact recreation and aquatic life in Lake Iowa.

3.1. Problem Identification

The Class A1 (primary contact recreation) uses at Lake Iowa are “partially supported” due to elevated chlorophyll-a (algae) levels.

Phosphorus cycle and algal blooms. Most phosphorus enters lakes attached to sediment that washes into the lake with runoff. The erosion and runoff is precipitation driven but can vary largely due to slope, landuse, and other factors. After phosphorus enters the lake a portion of it becomes available for algal uptake and growth. For algae to flourish, three things needed are light, nitrogen and phosphorus. Of these three, phosphorus is usually the limiting factor, meaning the algae run out of phosphorus first. Therefore, when excess phosphorus is introduced into a lake, there is nothing to keep algal growth in check. Thus, by limiting phosphorus, algal growth is also limited.

Under conditions of ample light and nutrients, algae proliferate quickly and are often short lived. As the bloom dies off, the decaying mass can lead to oxygen depletion and/or release of harmful cyanotoxins. Algal blooms are aesthetically objectionable and can make swimming or wading hazardous.

The Water Quality Assessment Database (ADBNet) for Lake Iowa suggests that internal nutrient cycling may be a contributing source of phosphorus leading to aesthetically objectionable algal blooms. However, the ADB assessment did not take into account watershed contributions when interpreting water quality data since watershed water quality data was not available and watershed modeling was not done. Our modeling shows watershed sources dominate Lake Iowa.

303(d) listing for aesthetically objectionable conditions.
The Carlson Trophic State Index (TSI) is used for 303(d) listing to evaluate water quality because it offers a metric to compare lakes and water quality. A trophic state is the level of ecosystem productivity, typically measured in terms of algal biomass. The Carlson Trophic State Index is 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. Therefore, the higher the TSI value for Secchi Depth, phosphorus or chlorophyll-a, the worse the water quality. Table 3.1 reports TSI values to their corresponding eutrophication state and gives additional details of impacts on the lake system, and the resulting impacts to recreation and to aquatic life.

The listing/de-listing of Iowa lakes is tied to the TSI values for Secchi depth and chlorophyll-a. Addition to the 303(d) list occurs when the median summer TSI for either parameter exceeds 65. In order to de-list, the median TSI must not exceed 63 in two consecutive listing cycles.

Table 3.1. Implications of TSI Values on lake attributes.

TSI Value	Attributes	Primary Contact Recreation Implications	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).

Interpreting Lake Iowa Data.
Sources of data used in the development of this TMDL include those used in the 2012 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. These sources are summarized in Table 3.2. Observed water quality data during the lake survey can be found in Appendix C – Water Quality Data. This includes chl-a and phosphorus levels reported in µg/L and Secchi depths in meters. TSI values for all three metrics are summarized as well. Since 2003, TSI (Chl-a) has exceeded the listing threshold of 65 in 61.5 percent of the samples collected between 2003-2013 (Figure 3.1).

Table 3.2. List of data/sources.

Precipitation	• NWS COOP at Williamsburg (2003-2013)
In-Lake Water Quality	• Ambient lake data (2003-2013)
Land Cover/Landuse	• USDA NASS and CLU coverages 2013
Topography	• 10m DEM from Iowa DNR GIS library
Lake Bathymetry	• State Conservation Commission 1988

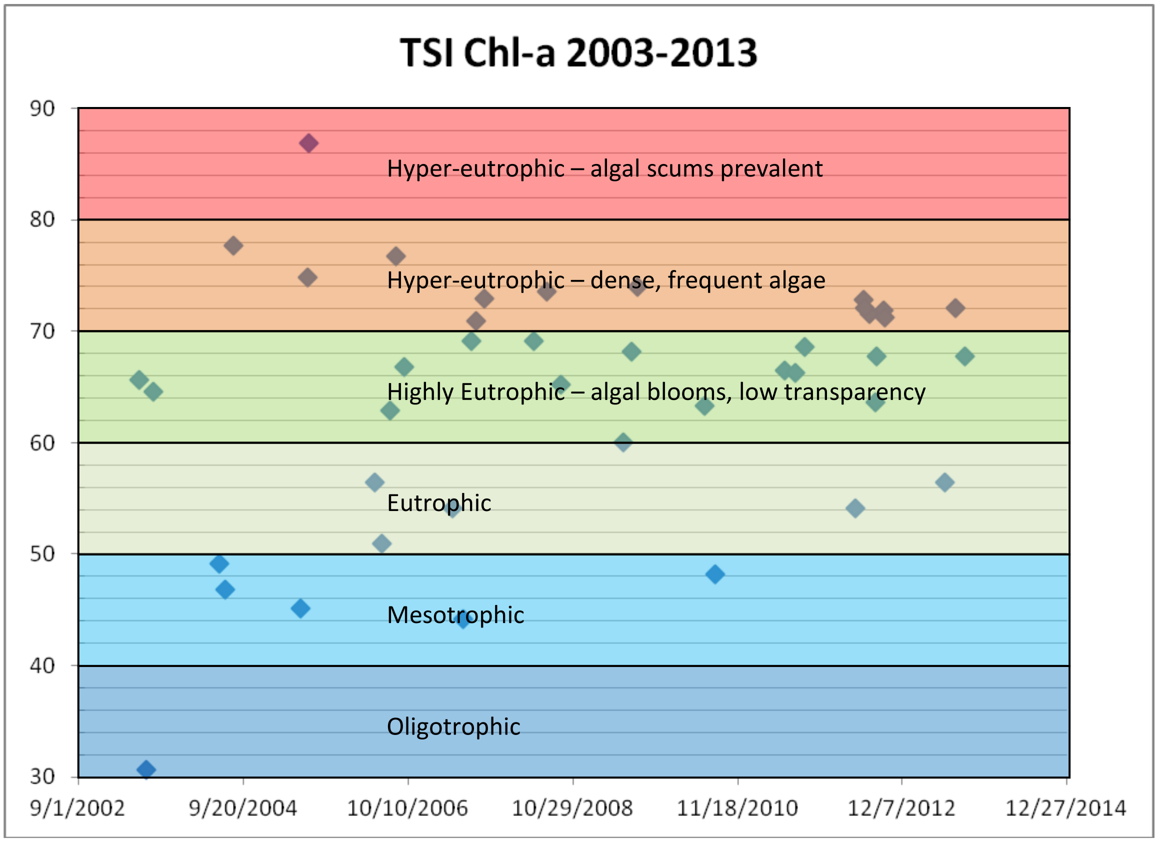

Figure 3.1. Chlorophyll-a TSI values (2003-2013). Values at 65 and above are in violation of the WQS.

One method used to assess lakes is a TSI multivariate comparison (Carlson 1992). If both of the deviations, TSI(CHL) - TSI(TP) and TSI(CHL) - TSI(SD), are simultaneously plotted on a single graph, it is possible to interpret what these deviations tell us about the eutrophic status of the lake based on which quadrant(s) that data resides in most of the time (Figure 3.2).

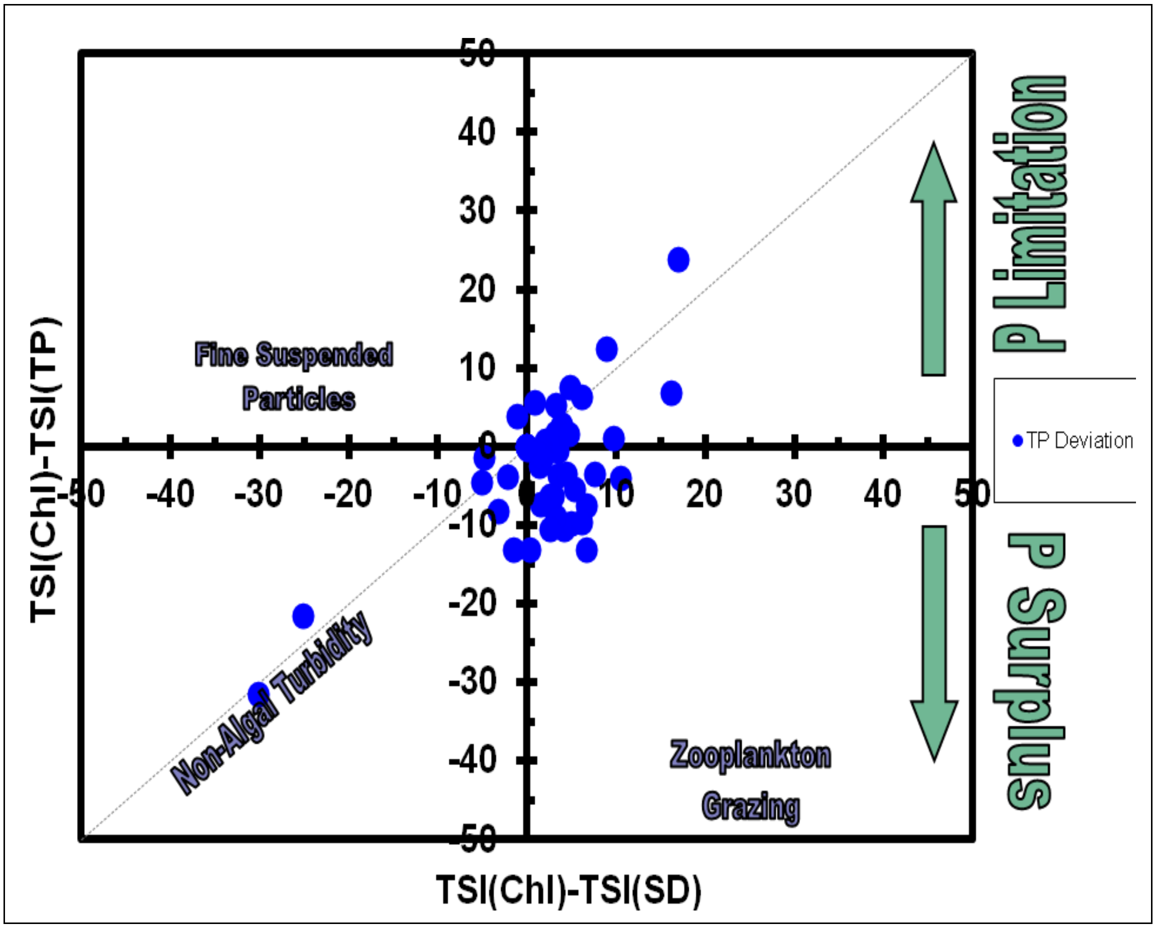

Figure 3.2. TSI multivariate comparison for 2003-2013 of individual samples.

If TSI (CHL) - TSI (TP) is plotted on the vertical axis, then points below the X-axis would be associated with situations where phosphorus may not be limiting chlorophyll. Points above the zero axis, would suggest an increasing possibility of phosphorus limitation. Points lying to the right of the Y-axis indicate situations where the transparency is greater than expected from the chlorophyll index. These deviations may occur if large particulates, such as blue-green algae (Cyanobacteria), dominate, and transparency is less affected by the particulates. Deviations to the right may also occur if zooplankton grazing removes smaller particles and leaves only large forms. Points to the left of the Y-axis would be related to situations where transparency is dominated by non-algal factors such as color or turbidity or where very small particles predominate.

Points lying on the diagonal to the left of the origin indicate situations where phosphorus and transparency are correlated, but chlorophyll is not. Points on or near this line would be found in turbid situations where phosphorus is bound to clay particles and therefore turbidity and phosphorus are related, but chlorophyll is not.

In the case of Lake Iowa, this analysis did not give a clear picture of what is the limiting factor in algal bloom development. Further analysis is needed to determine the limiting factor.

Within lakes, the main two nutrients necessary for algal bloom development are nitrogen and phosphorus. When one nutrient is in short supply relative to the other, this nutrient supply will be exhausted first during growth. Once this nutrient is no longer available, growth is limited. Generally, in Iowa lakes, phosphorus is the limiting nutrient. Ratios of nitrogen to phosphorus can provide clues as to which nutrient is limiting growth in a given waterbody.

The overall TN:TP ratio in water quality samples from Lake Iowa, using average growing season mean concentrations from 2003-2013, is 25. 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). Ratios that fall between 10 to 17 are often considered "co-limiting," meaning either nitrogen or phosphorus is the limiting nutrient or light is limited due to high non-algal turbidity. Further analysis of the TN:TP ratio in Lake Iowa samples reveal that 65.9 percent of the time the ratio exceeds 17 and 24.4 percent of the time the ratio falls between 10 and 17 as shown in Table 3.3, Table 3.4 breaks down each nutrient limiting condition by mean TSI score. Only 9.8 percent of the time is Lake Iowa nitrogen limited (as indicated by TN:TP ratios less than 10).

Table 3.3. TN:TP ratio summary for Lake Iowa

Samples Collected	# of Samples	N-limited (< 10)	Co-Limited (10-17)	P-limited (>17)
All samples 2003-2013	41	4 (9.8%)	10 (24.4%)	27 (65.9%)

Table 3.4. TN:TP ratio and TSI summary for Lake Iowa

Samples Collected	# of Samples	Mean Secchi TSI	Mean Chl-a TSI	Mean TP TSI
All samples 2003-2013	41	62.0	64.2	67.5
N-limited (<10)	4	65.9	68.9	77.6
Co-Limited (10-17)	10	66.6	69.4	72.2
P-limited (>17)	27	60.4	62.3	65.0

This analysis shows that phosphorus is the limiting nutrient nearly two-thirds of the time in Lake Iowa. Further investigation shows phosphorus concentrations are increasing over time while nitrogen levels are remaining stable, as shown in Figure 3.3. This nutrient balance leads to lower TN:TP ratios over time, as shown in Figure 3.4. However, when considering how to best address the issue of seasonal algal blooms decreasing phosphorus may be the most effective method to increase water quality in Lake Iowa, suggesting that water quailty improvement via TP reduction is most feasible.

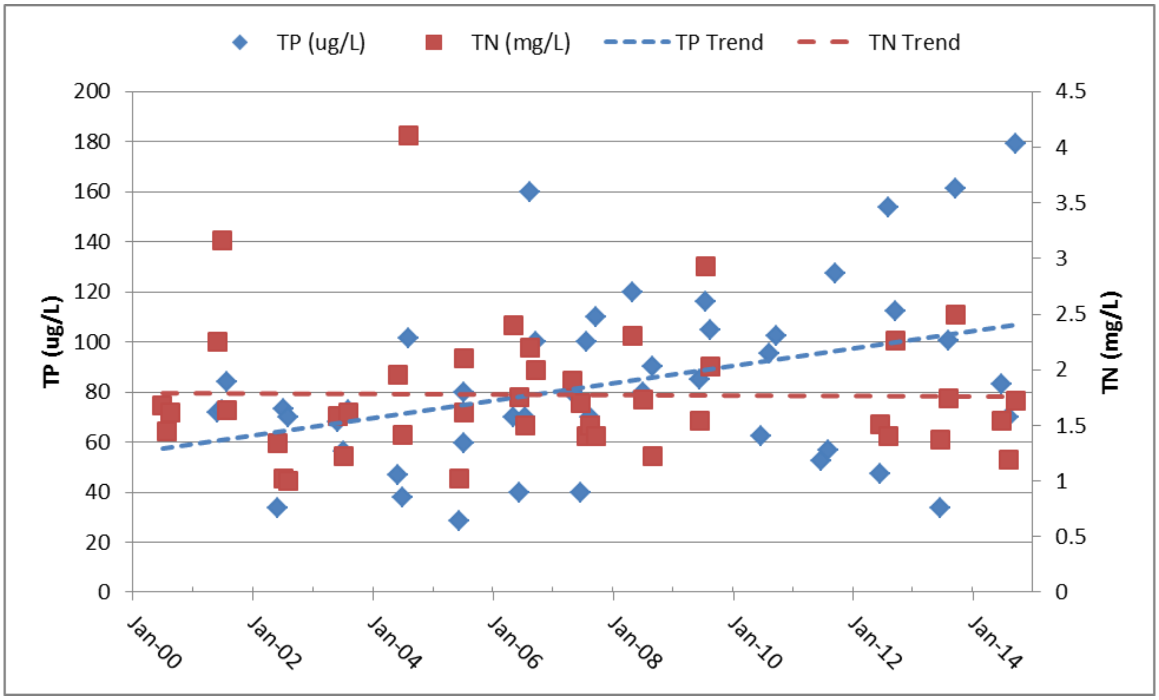

Figure 3.3. Nitrogen and phosphorus concentrations in Lake Iowa (2000-2014)

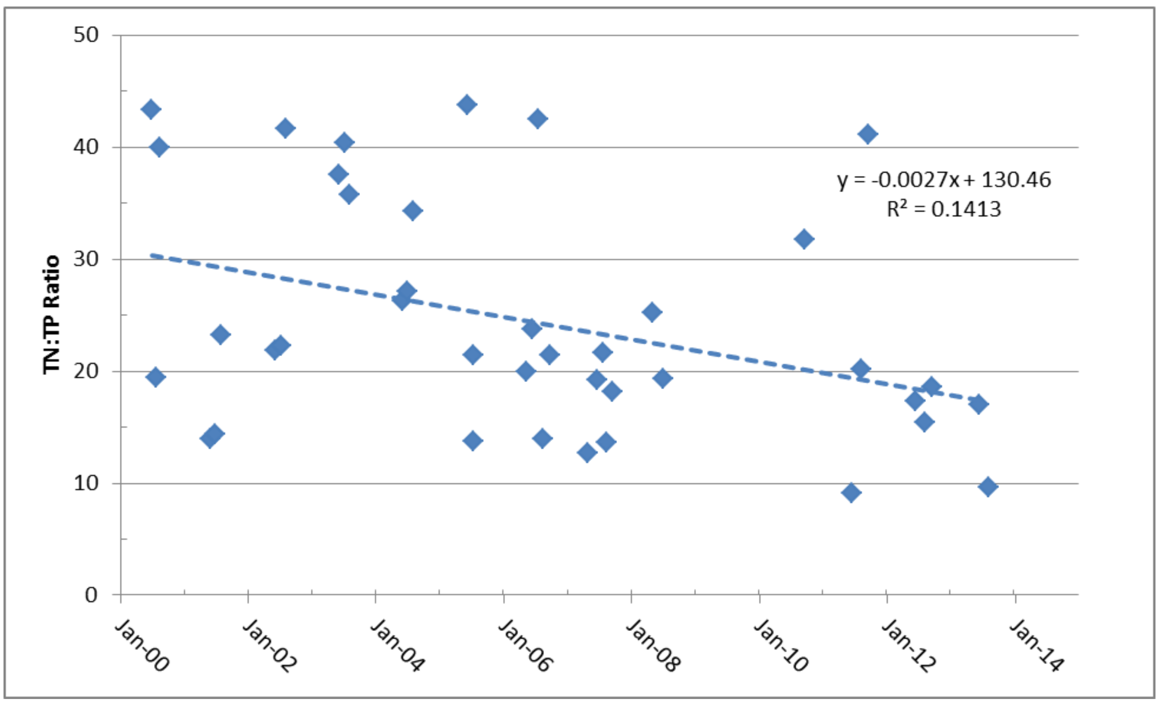

Figure 3.4. TN:TP ratios in Lake Iowa (2000-2014)

3.2. TMDL Target

General description of the pollutants. The 2014 305(b) assessment attributes poor water quality in Iowa Lake to excess algae, and the data interpretation in Section 3.1 indicates phosphorus load reduction will best address the impairment. It will be important to continue to assess TSI values for chlorophyll-a as phosphorus reduction practices are implemented. If phosphorus reductions are not accompanied by reductions in algal blooms then reductions in nitrogen may prove necessary to reduce algae to an acceptable level. However, phosphorus should be reduced first, as it is the primary limiting nutrient in algal growth. Additionally, reductions in nitrogen that result in nitrogen limitation favor growth of harmful cyanobacteria, which have the ability to fix nitrogen from the atmosphere. These bacteria can emit cyanotoxins to the water which can harm humans, pets, and wildlife if ingested.

From this section on, the primary focus of this document will be quantifying and reducing phosphorus loads to remediate the water clarity issues.

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 may contribute to blooms during extremely dry conditions. At this time, internal recycling of phosphorus is not a significant driver of overall water quality in Lake Iowa. 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 Iowa are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Decision criteria for water quality standards attainment. The narrative criteria in the water quality standards require that Lake Iowa be free from "aesthetically objectionable conditions." For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when the median summer chlorophyll-a or Secchi depth TSI 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 summer chlorophyll-a concentration must not exceed 27 micrograms per liter (ug/L). Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters. The WQS can be accessed on the web at: https://www.legis.iowa.gov/docs/ACO/chapter/567.61.pdf (link may require copy and paste into browser).

Compliance point for WQS attainment
The TSI target for listing and delisting of Lake Iowa is measured at the ambient monitoring location. For modeling purposes, the lake was divided into two segments (see Figure D-1 of Appendix D). To maintain consistency with DNR ambient monitoring programs which aid in the development of 305(d) and 303(d) lists, the TMDL target is based on water quality of Segment 2, which best represents the ambient monitoring location in Lake Iowa.

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 Iowa from 2003-2013, including watershed and atmospheric loading was estimated to be 2,110 lbs/yr.

Departure from load capacity. The target TP load, also referred to as the loading capacity, for Lake Iowa is 436.1 lbs of total phosphorus annually. To meet the target loads, an overall reduction of 79 percent of the TP load is required. 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 Iowa is entirely from nonpoint sources of pollution. The main sources include: sheet, rill, and ephemeral gully erosion from cropland; organic material deposition from forested areas; and surface runoff from all land uses. 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 and resulting water quality based on the modeling simulation of 2003-2013 conditions.

There are three small animal feeding operations (AFO) within the Iowa Lake watershed: two beef operations totaling 700 animal units (AU) and one swine operation totaling 200 AU. None of these AFOs qualify as concentrated animal feeding operations (CAFO) due to size limitations and lack of discharge; therefore they do not receive WLAs. However, manure applications on row crops may occur. The STEPL model accounts for land applied manure applications by calculating a separate phosphorus concentration for surface runoff during months of manure application.

Other sources of phosphorus load include groundwater intrusion into Lake Iowa, accidental discharge from septic tanks, and atmospheric deposition. Groundwater phosphorus load is dependent upon the percent of total phosphorus that is soluble and can be readily infiltrated into the soil. STEPL utilizes regional standard values for infiltration and groundwater concentration of phosphorus. The load is then determined by volume of groundwater flow to Lake Iowa.

Rural residents of the Lake Iowa watershed may contribute to total phosphorus loads via aging septic tank systems. When given the inputs on the number of septic systems and the average users per system, STEPL calculates the potential phosphorus loading via septic systems by using a standard rate of failure for the systems and a standard phosphorus concentration of effluent.

Atmospheric deposition for Lake Iowa includes precipitation and windblown deposits across the lake surface over the course of the year. Regional values were used in place of default BATHTUB values in order to provide a more accurate portrayal of Lake Iowa atmospheric loading.

The STEPL model developed for the TMDL accesses landuse inputs of phosphorus and allows for quantification of inputs. Figure 3.5 quantifies the percentage of the phosphorus load per land use. This will allow for better targeting when considering phosphorus reduction strategies. The majority of phosphorus appears to come from row crops. Therefore, reduction strategies should primarily be focused there. That is not to say that other land uses should be ignored when developing a long term management plan. Section 4 of this document will further discuss strategies.

Table 3.5. Phosphorus contributions per source.

Source	Description	TP Load (lb/year)	Percent (%)
Cropland	Corn and Soybean	1028.6	48.8
Forest	Ungrazed timber includes shrub	530.3	25.1
Pasture	Grazed and ungrazed private	51.3	2.4
Grassland	Public parkland, ungrazed private, savanna	219.4	10.4
Urban	City, town, farmstead, road	72.5	3.4
Groundwater	Groundwater into lakes and streams	95.5	4.5
Streambank Erosion	Gully formation and stream bank loss	58.3	2.7
Septic	Discharge from septic tanks	31.7	1.5
Atmospheric	Deposition from wind, rain, etc.	23.1	1.1
TOTAL		**2,110.7**	**100**

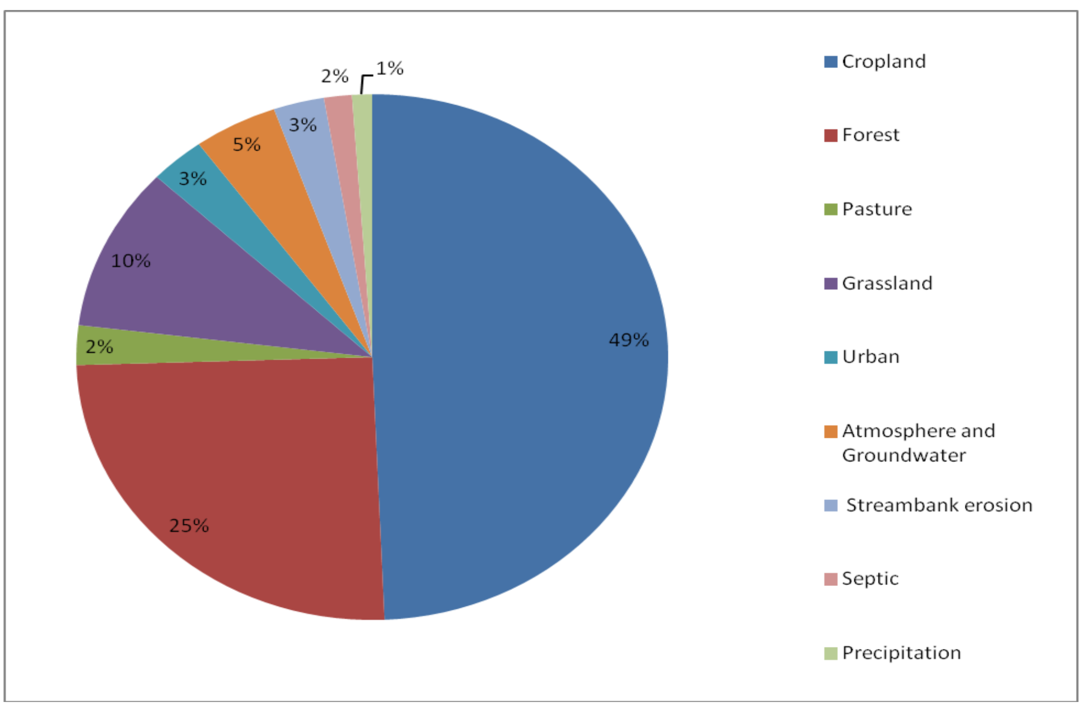

Figure 3.5. Percentage of the phosphorus load per land use.

Allowance for increases in pollutant loads. There is no allowance for increased phosphorus loading included as part of this TMDL. There are no incorporated unsewered communities in the watershed. 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 Iowa watershed. Therefore, the wasteload allocation (WLA) is zero.

Load allocation. Nonpoint sources to Lake Iowa include loads from urban and agricultural land uses, streambank erosion, grassland and forest, and natural/background sources in the watershed, including groundwater and atmospheric deposition (from dust and rain). Changes in agricultural land management, implementation of structural best management practices (BMPs), gully repair/stabilization, and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Lake Iowa.

The load allocation for this lake is:

Annual: LA 392.5lbs-TP/year

Daily: LA 4.3 lbs-TP/day

Margin of safety. To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An explicit MOS of ten percent was utilized in the development of this TMDL. MOS for this lake is:

Annual: MOS 43.6 lbs-TP/year

Daily: MOS 0.5 lbs TP-day

3.5. TMDL Summary

The following equation represents the total maximum daily load (TMDL) and its components for Lake Iowa:

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

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 Iowa watershed, the general equation above can be expressed for the Lake Iowa algae TMDL.

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

Annual = LC = Σ WLA (0 lbs-TP/year) + Σ LA (392.5 lbs-TP/year)
+ MOS (43.6 lbs-TP/year) = **436.1 lbs-TP/year**

Expressed as the allowable maximum daily load as required by EPA:

TMDL= LC = Σ WLA (0 lbs-TP/day) + Σ LA (4.3 lbs-TP/day)
+ MOS (0.5 lbs TP-day) = **4.8 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 general 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 represents a package of potential tools that will help achieve water quality goals if appropriately utilized. It is likely that only a portion of BMPs included in this plan will be feasible for implementation in the Lake Iowa watershed. Additionally, there may be potential BMPs not discussed that should be considered. This implementation plan should be used as a guide or foundation for a detailed and comprehensive management/restoration plan development by local stakeholders.

Collaboration and action by residents, landowners, lake patrons, and local agencies will be essential to improve water quality in Lake Iowa and support its designated uses. Locally-driven efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality in Lake Iowa 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 additional BMPs and land management changes in the watershed.

The primary focus of this implementation plan will be reducing phosphorus loads to remediate the water clarity issues. Successful phosphorus controls will reduce algal blooms in the lake, improving clarity and reducing the Chl-a and Secchi depth TSIs.

4.1 General Approach & Reasonable Timeline

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 of watershed BMPs required to meet water quality standards (WQS). A reasonable timeline for long term watershed projects aimed at improving water quality is usually measured in years or decades.

4.2. Land Management Best Management Practices

Best management practices are dictated by landscape (including both natural conditions and landuse). Both the installation and effectiveness of any practice is entirely dependent on proper installation in the right location and landuse. The Lake Iowa watershed sits on The Southern Iowa Drift Plain. This is the largest of Iowa’s landforms. It is composed almost entirely of glacial drift.

The resulting slopes of this landscape are fairly steep (Figure 4.1) and have high erosion rates. The soil parent material is dominantly loess, which is a looser material and susceptible to erosion (Figure 4.2). Additionally there are alluvial soils along the stream beds. Therefore, it will be important in the planning process to first assess slope and soil since there is variability within this watershed.

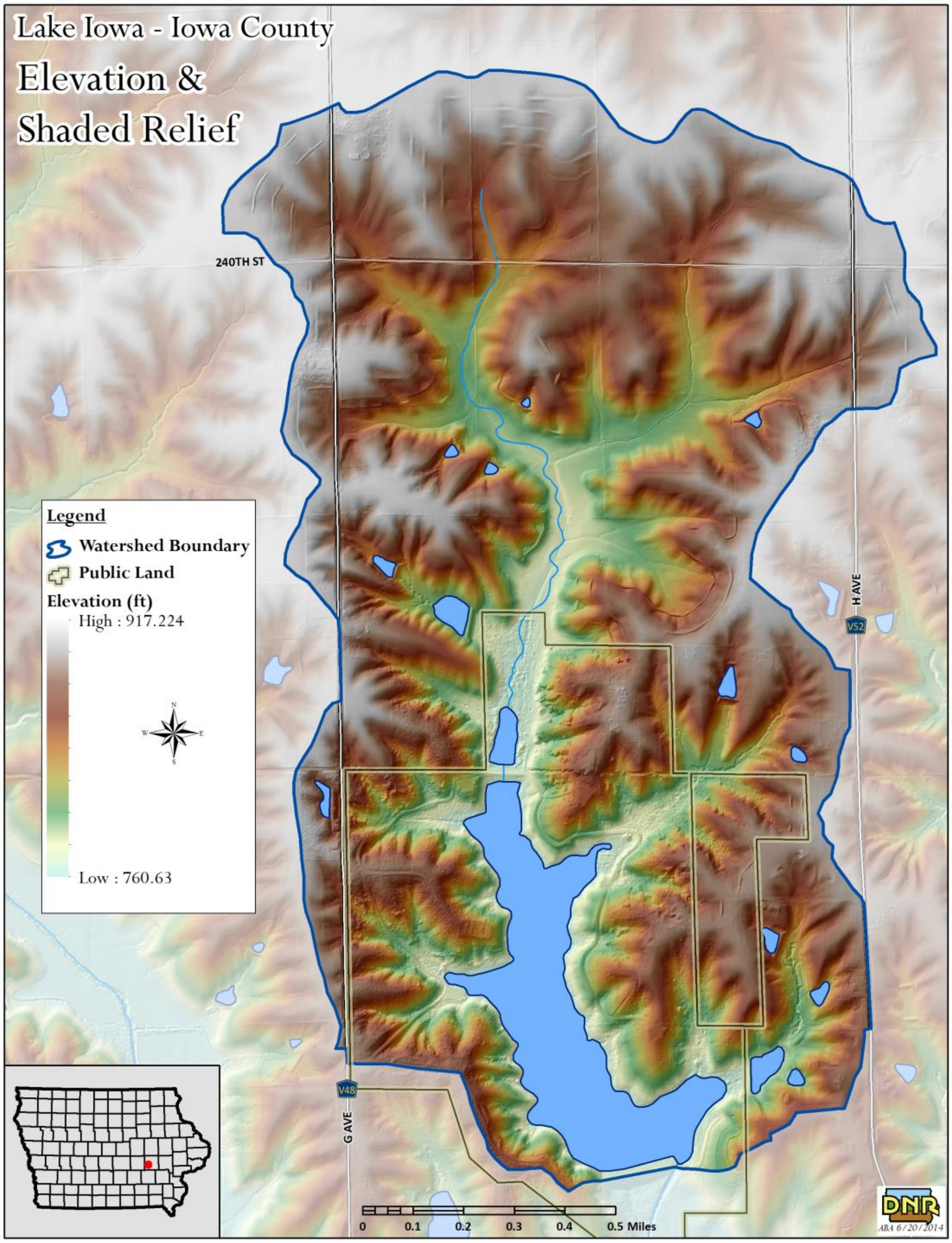

Figure 4.1. Slopes within the Lake Iowa Watershed are fairly steep particularly in gullies and streams

Highly erodible land (HEL) is classified by the Natural Resource Conservation Service (NRCS) as land, which if used to produce an agricultural commodity, would have an excessive annual rate of erosion as determined by the Universal Soil Loss Equation (USLE). Figure 4.2 depicts the HEL lands within the Lake Iowa watershed.

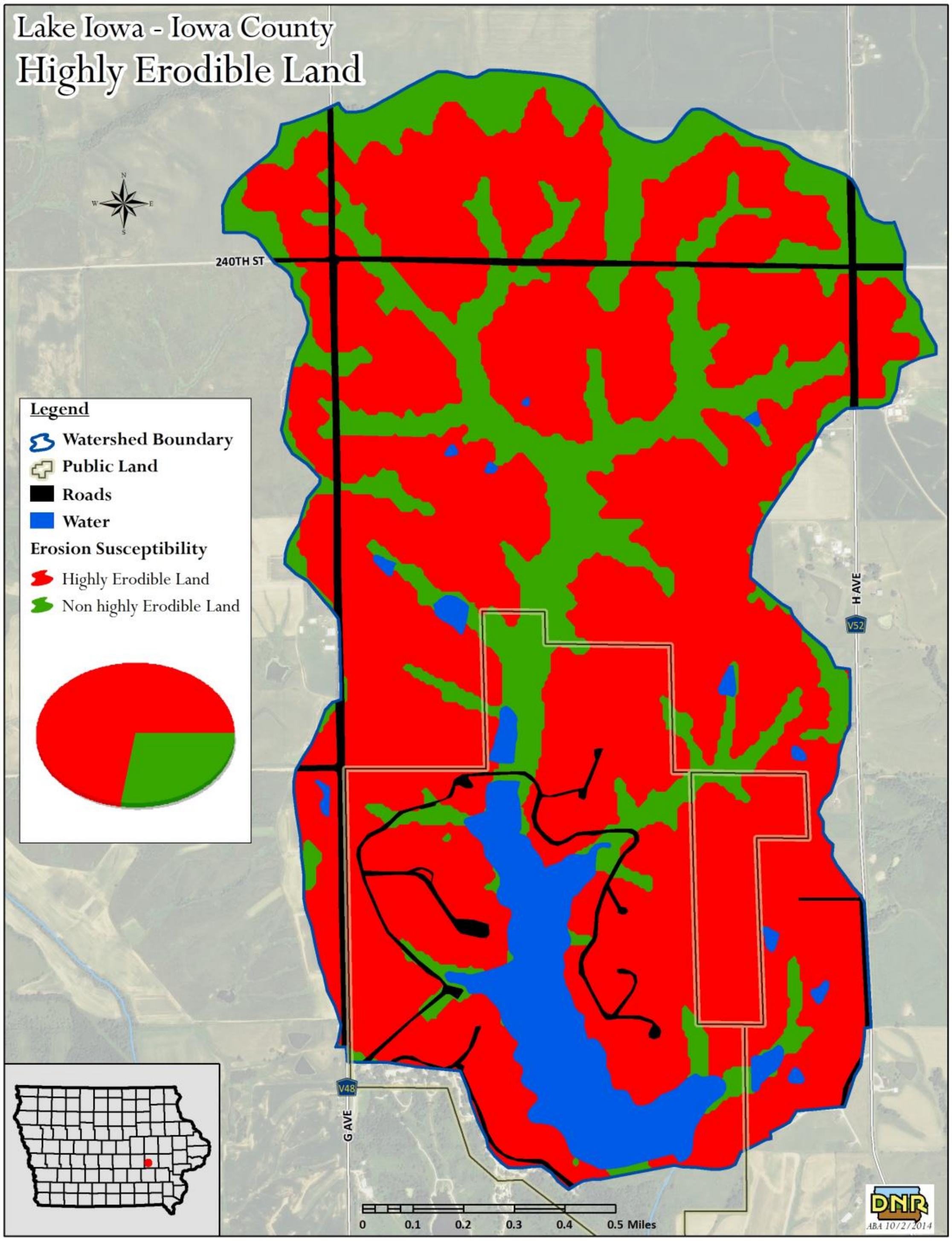

Figure 4.2. HEL land within the Lake Iowa watershed.

Figure 4.3 overlays where row crops are planted within the watershed. Areas of HEL that are row cropped represent areas that should be considered high priority for watershed BMPs.

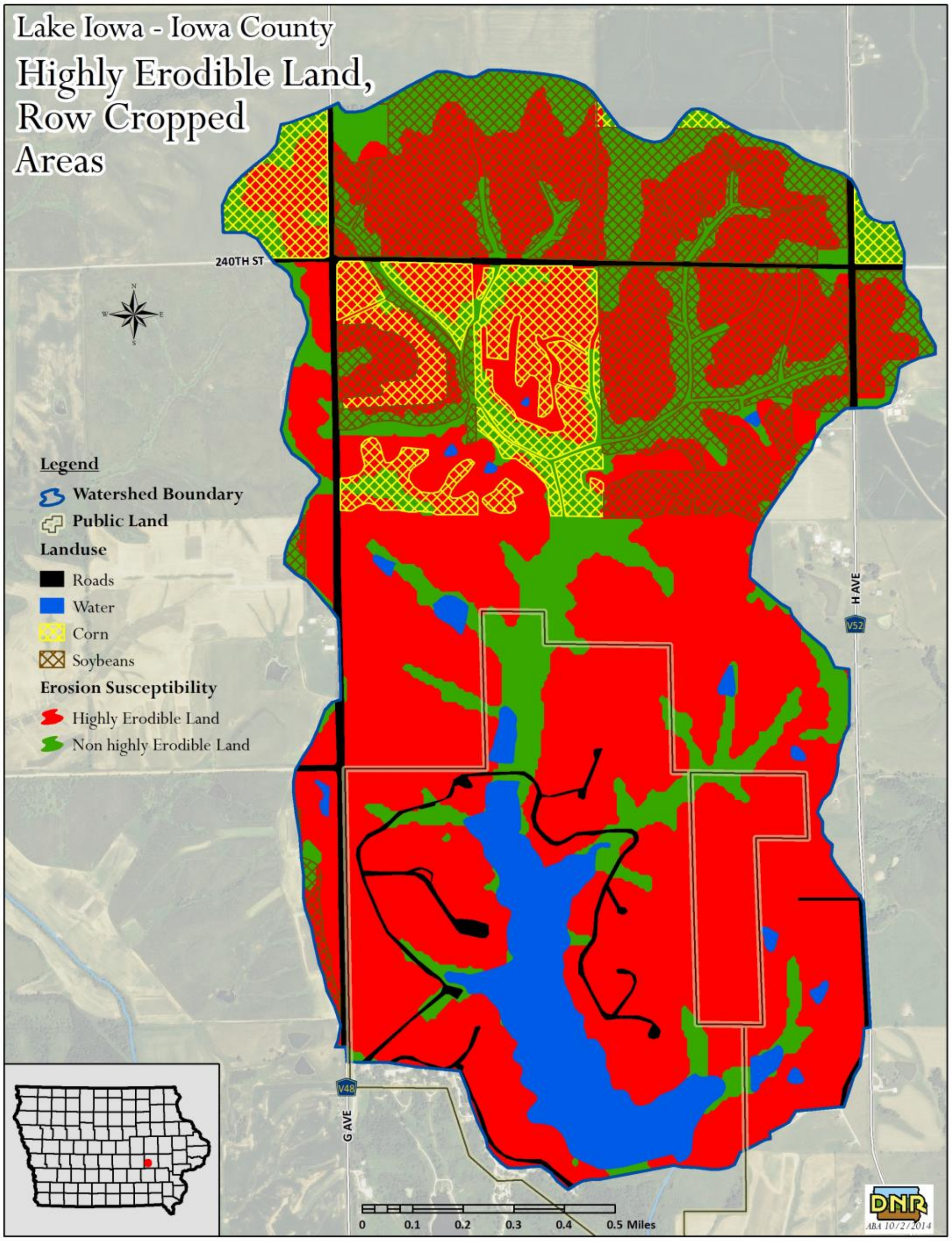

Figure 4.3. Row cropped land within the watershed. Row cropped HEL should be considered high priority for BMPs.

Table 4.1 lists commonly used BMPs in watershed management. These are generally used on agricultural land but should be explored as options for grasslands as well. Table 4.2 specifically addresses agricultural BMPs that might be options for the cropland in the northern portion of the watershed.

Table 4.1. Potential structural BMPs.

BMP or Activity	Secondary Benefits	[1] Potential TP Reduction
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50%
[2]Sediment Control Structures	Some ecological services, gully prevention	Variable
[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] Reductions reported by Section 2: Nonpoint Source Nutrient Reduction Science Assessment (2012), Iowa Nutrient Reduction Strategy.
[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

Table 4.2. Potential land management BMPs.

BMP or Activity	[1] Potential TP Reduction
Conservation Tillage: Moderate vs. Intensive Tillage No-Till vs. Intensive Tillage No-Till vs. Moderate Tillage	 50% 70% 45%
Cover Crops	50%
Diversified Cropping Systems	50%
In-Field Vegetative Buffers	50%
Phosphorus Nutrient Application Techniques Knife/Injection Incorporation vs. Surface Broadcast	 35%
Phosphorus Nutrient Application Timing and Rates: Spring vs. Fall Application Soil-Test P Rate vs. Over-Application Rates Application: 1-month prior to runoff event vs. 1-day	 30% 40% 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.

4.3. In Lake Best Management Practices

Uncertainty regarding the magnitude of internal loads is one of the biggest challenges to lake restoration. Because of this uncertainty, and the importance of long-term external loads, reductions from watershed sources of TP should be given implementation priority.

If and when monitoring shows that the external watershed load has been reduced significantly, increasing focus on in-lake measures may be warranted.

Usually, as the watershed sources are remediated, focus should shift to in-lake approaches that could be used. Phosphorus recycled between the bottom sediment and water column of the lake may be, at times, an important contributor of bioavailable phosphorus in lakes. In the case of Lake Iowa, the external loads contribute enough phosphorus to produce the observed water quality (i.e., algal levels). An explicit internal load was not calculated for the lake. It is likely that internal recycling occurs for short periods of time under certain conditions, but is relatively small on an annual basis Uncertainty regarding the magnitude of internal loads is one of the biggest challenges to lake restoration. Because of this uncertainty, and the importance of long-term external loads, reductions from watershed sources of TP should be given implementation priority. If and when monitoring shows that the external watershed load has been reduced significantly, shifting focus towards in-lake measures may be warranted.

While not considered a significant source in this TMDL, shorelines in man-made reservoirs are subject to erosion from water level fluctuations and wave action. Assessing shorelines in spring and fall for eroding areas and stabilization with bio-engineering or hard armoring techniques may improve habitat and water clarity near the shoreline.

Table 4.3. Potential in-lake BMPs for water quality improvement.

In-Lake BMPs	Comments	[1]Relative TP Reduction
Targeted dredging	Targeted dredging in shallow inlet areas, particularly the northern tributary. Strategic dredging may increase the sediment capacity of the inlet areas, thereby reducing sediment loads to the larger, open water area of the lake	Med
Large-scale dredging	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 financial viability of large-scale dredging in Lake Iowa.	Med-High
Shoreline stabilization (public areas)	Helps establish and sustain vegetation, which provides local erosion protection and competes with algae for nutrients. The entire shoreline of Lake Iowa 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. In the case of Lake Iowa all of these are low priority as the external load alone accounted for the concentrations seen within ambient monitoring.

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 water quality improvements made in the watershed and document the status of the waterbody in terms of achieving Total Maximum Daily Loads (TMDLs) and Water Quality Standards (WQS).

Future monitoring in the Lake Iowa watershed can be agency-led, volunteer-based, or a combination of 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.iowadnr.gov/Environment/WaterQuality/WaterMonitoring/IOWATER.aspx

It is important that volunteer-based monitoring efforts 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. Monitoring Plan to Track TMDL Effectiveness

Future data collection in Lake Iowa to assess water quality trends and compliance with water quality standards (WQS) is expected to include monitoring conducted as part of the Iowa DNR 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 Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 137 of Iowa's lakes are being sampled as part of this program, including Lake Iowa. 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 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 DNR. Only through the interest and action of local stakeholders will funding and resources needed to acquire this important information become available. Figure 5.1 depicts where the ambient lake monitoring site and additional samples will be gathered. As data from the lake is gathered and analyzed, additional tributary sites may be added if these would be helpful in monitoring the effectiveness of BMPs and the water quality entering the upper portion of the lake. Section 5.3 will further describe tributary monitoring.

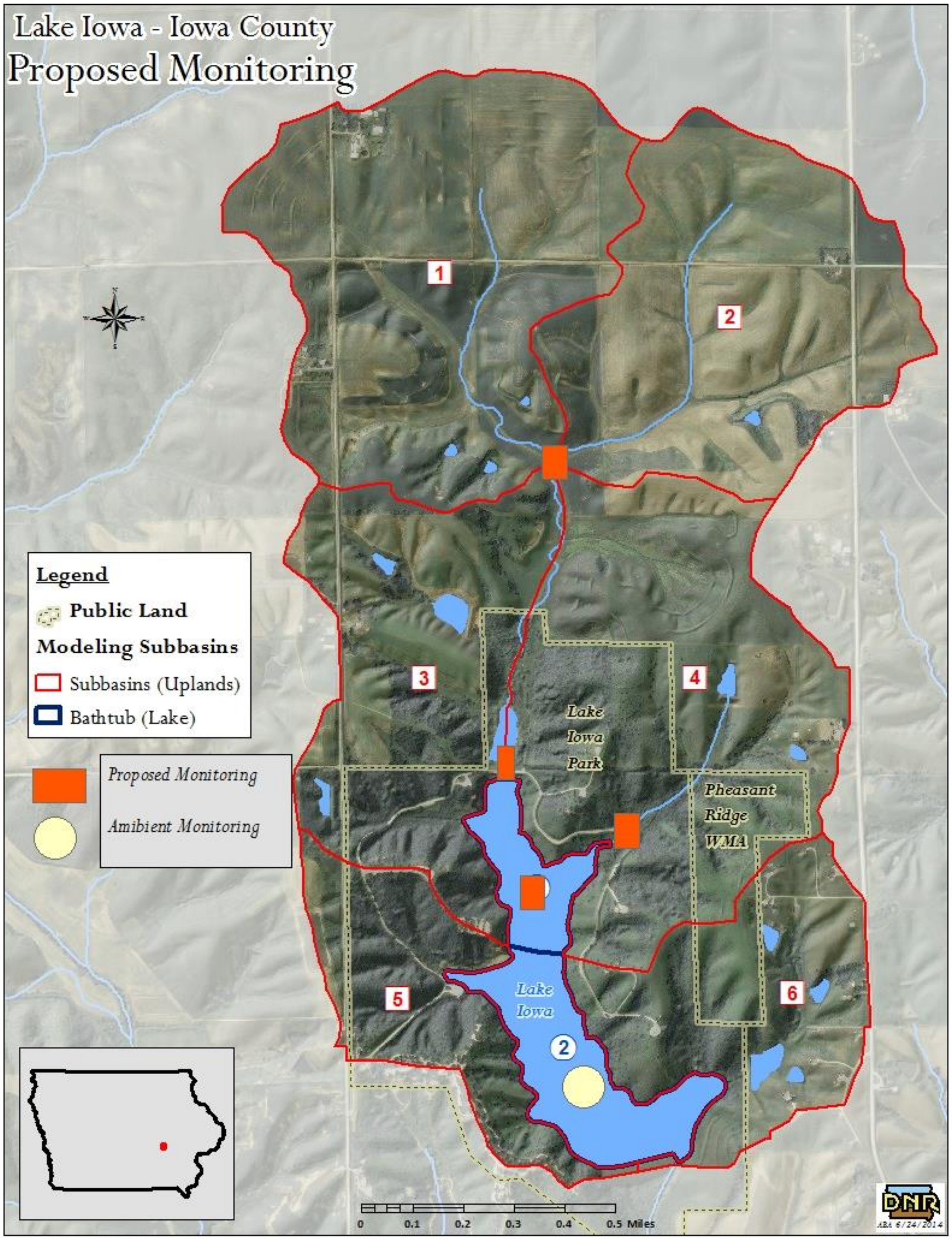

Figure 5.1. Sample locations for Lake Iowa monitoring.

5.3. Enhanced Plan for Future Watershed Projects

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 expanded plan can be used to help identify and prioritize monitoring data needs.

Table 5.2. Expanded monitoring plan.

Parameter(s)	Intervals	Duration	[1]Location(s)
Routine grab sampling for flow, sediment, and P	Every 1-2 weeks	April through October	Ambient and Tributaries
Continuous pH, DO, turbidity, chl-a and temperature	15-60 minute	April through October	Ambient and additional in-lake site
Runoff event flow, sediment and P	Continuous flow, composite WQ	3 events between April and October	Tributaires

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

Routine weekly or bi-weekly grab sampling with concurrent in-lake and tributary data (ambient location, additional in-lake sites and tributaries in Figure 5.1) would help identify long-term trends in water quality and nutrient loading. Particularly, grab samples both upstream and downstream of BMPs to assess efficiency of each structure would be helpful in assessing the implementation strategy and for making adjustments.

Ideally, data collection should commence before additional BMPs are implemented in the watershed to establish baseline conditions. This data could form the foundation for assessment of general water quality trends; however, more detailed information will be necessary to evaluate loading processes, storm events, and reduce uncertainty. Therefore, routine grab sampling should be viewed only as a starting point for assessing trends in water quality.

Continuous flow data in the tributaries 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 Iowa. 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.

If funding is available, lake managers should consider deploying a data logger at the ambient monitoring location and possibly in tributaries to measure pH, temperature, and dissolved oxygen (DO) on a continuous basis during wet periods when these tributaries will run continuously. 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.

The proposed expanded monitoring information would assist utilization of watershed and water quality models to simulate various scenarios and water quality response to BMP 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 DNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Lake Iowa 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 Iowa. During the development of this TMDL, efforts were made to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in Lake Iowa.

6.1. Public Meetings

Prior to TMDL development, park officials were contacted to give input on lake history and conditions. A teleconference was held and attended by park and county personnel and the local NRCS on July 2, 2014.

A public meeting was held on February 26, 2015. Staff from the DNR's Watershed Improvement Section was on hand to deliver the presentation and answer questions.

6.2. Written Comments

A public comment period was held from February 12, 2015 to March 16, 2015. No comments were received during the public comment period.

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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 measurement based upon the product of multiplying the number of animals of each category by a special equivalency factor. For example, a mature dairy cow is 1.4 AU, whereas a swine weighing more than 55 pounds is 0.4 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	An animal feeding operation (AFO) in which animals are

feeding operation: 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 A statistic that is a type of mean or average (different from

(GM): 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 water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies 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 water body.

General Use Segments

A general use segment water body is one which 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 which 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 water body, 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 water bodies which maintain flow throughout the year, or at least hold pools of water which 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 a total of thirteen different designated use classes (Table B.1) which may apply, and a water body 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 water bodies.

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

Appendix C --- Water Quality Data

The following is a summary of the sampling data from the Iowa State University (ISU), Iowa Lakes Information System, and University of Iowa State Hygienic Laboratory (UHL) monitoring efforts.

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

Source	Date Time	Chl-a (ug/L)	TP (ug/l)	Secchi (m)	TSI Chl-a	TSI Secchi	TSI TP
ISU	6/2/2003	35.5	68	0.78	66	63.6	65.0
ISU	7/7/2003	1	56	0.95	31	60.7	62.2
ISU	8/5/2003	32.1	73	0.52	65	69.4	66.0
ISU	6/1/2004	6.6	47	2.85	49	44.9	59.7
ISU	6/29/2004	5.2	38	3.55	47	41.7	56.6
ISU	8/3/2004	121.6	102	0.9	78	61.5	70.8
ISU	6/7/2005	4.4	29	4.45	45	38.5	52.7
ISU	7/11/2005	91	80	0.5	75	70.0	67.3
UHL	7/12/2005	311.7	60	0.5	87	70.0	63.2
ISU	5/10/2006	14	70	1.6	56	53.2	65.4
UHL	6/14/2006	8	40	2.3	51	48.0	57.3
UHL	7/20/2006	27	70	0.9	63	61.5	65.4
UHL	8/17/2006	110	160	0.4	77	73.2	77.3
UHL	9/21/2006	40	100	0.8	67	63.2	70.6
UHL	5/1/2007	11	80	2.4	54	47.4	67.3
UHL	6/19/2007	4	40	2.7	44	45.7	57.3
UHL	7/24/2007	51	100	0.6	69	67.4	70.6
UHL	8/14/2007	61	70	0.5	71	70.0	65.4
UHL	9/19/2007	75	110	0.8	73	63.2	71.9
UHL	5/1/2008	51	120	1.1	69	58.6	73.2
UHL	7/2/2008	80	80	0.6	74	67.4	67.3
UHL	9/3/2008	34	90	0.6	65	67.4	69.0
UHL	6/16/2009	20	84.9	0.8	60	63.2	68.2
ISU	7/21/2009	46	115.9	0.4	68	73.2	72.7
ISU	8/18/2009	83	104.8	0.5	74	70.0	71.2
ISU	6/21/2010	28	62.3	0.8	63	63.2	63.7
ISULL	8/9/2010	6	95	0.4	48	73.2	69.8
ISULL	6/20/2011	39	52.5	0.8	67	63.2	61.3
ISULL	8/8/2011	38	56.9	0.6	66	67.4	62.4
ISU	9/19/2011	48	127.2	0.8	69	63.2	74.0
ISU	5/8/2012	11	50	1.8	54	51.5	60.6
ISU	6/12/2012	74	150	0.7	73	65.1	76.4
ISU	6/18/2012	69	47.5	0.8	72	63.2	59.8

ISU	7/9/2012	65	180	0.5	72	70.0	79.0
ISU	8/6/2012	29	153.7	0.8	64	63.2	76.8
ISU	8/9/2012	44	170	0.7	68	65.1	78.2
ISU	9/13/2012	67	140	0.6	72	67.4	75.4
ISU	9/20/2012	63	112.2	0.5	71	70.0	72.2
ISU	6/18/2013	14	33.5	1.6	56	53.2	54.8
ISU	8/5/2013	69	100.6	0.6	72	67.4	70.6
ISU	9/18/2013	44	161.2	0.9	68	61.5	77.4
	average	**49.6**	**89.8**	**1.1**	**69**	**58.7**	**69**

[1]Ambient monitoring location = STORET ID 22480001

Appendix D --- Watershed Modeling Methodology

Watershed and in-lake modeling were used in conjunction with observed water quality data to develop the Total Maximum Daily Load (TMDL) for phosphorus as the primary cause for the algae impairment to Lake Iowa in Iowa County, Iowa. 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 6.14, 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 Iowa and its watershed. This section of the Water Quality Improvement Plan (WQIP) discusses the overall modeling approach, as well as the development of the STEPL watershed model and BATHTUB lake model.

D.1. 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 developed 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 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/or local soil and precipitation data. Precipitation inputs include average annual rainfall amount and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation.

Land use characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, presence/population of agricultural animals, wildlife populations, population served by septic systems, and characteristics of 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 Iowa watershed was delineated into subbasins based on 10m DEM and pre-existing BMPs. The watershed was divided into six subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with assessing current BMPs and targeting potential future BMP locations. Hydrology and pollutant loadings are summarized for each subbasin and also aggregated as watershed totals.

D.2. 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. For the purpose of Lake Iowa, data from the Williamsburg, Iowa station for the 2003-2013 sampling period was input. This resulted in an annual average rainfall of 37.6 inches to be used in the STEPL model and also within BATHTUB.

D.3. Watershed Characteristics

Delineation.
The Lake Iowa watershed boundary was delineated based on 10-m DEM and the number of subbasins was determined using drainage as guides. Figure D.1 illustrates the watershed and subbasin boundaries.

Soils and Slopes and Curve Numbers.
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 NRCS soil coverages

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.
USLE land slope (LS) factors were area-weighted by land use within each STEPL subwatershed.

The STEPL model includes default curve numbers (CN) selected automatically based on HSG and land use inputs. The STEPL default CN was left in place for other land uses.

Sediment Delivery Ratio.
The total 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 subbasins were not treated as a single watershed allowing STEPL to assign different SDR for each subbasin. Therefore subbasins farther away from the lake have lower SDR than those adjacent to the lake.

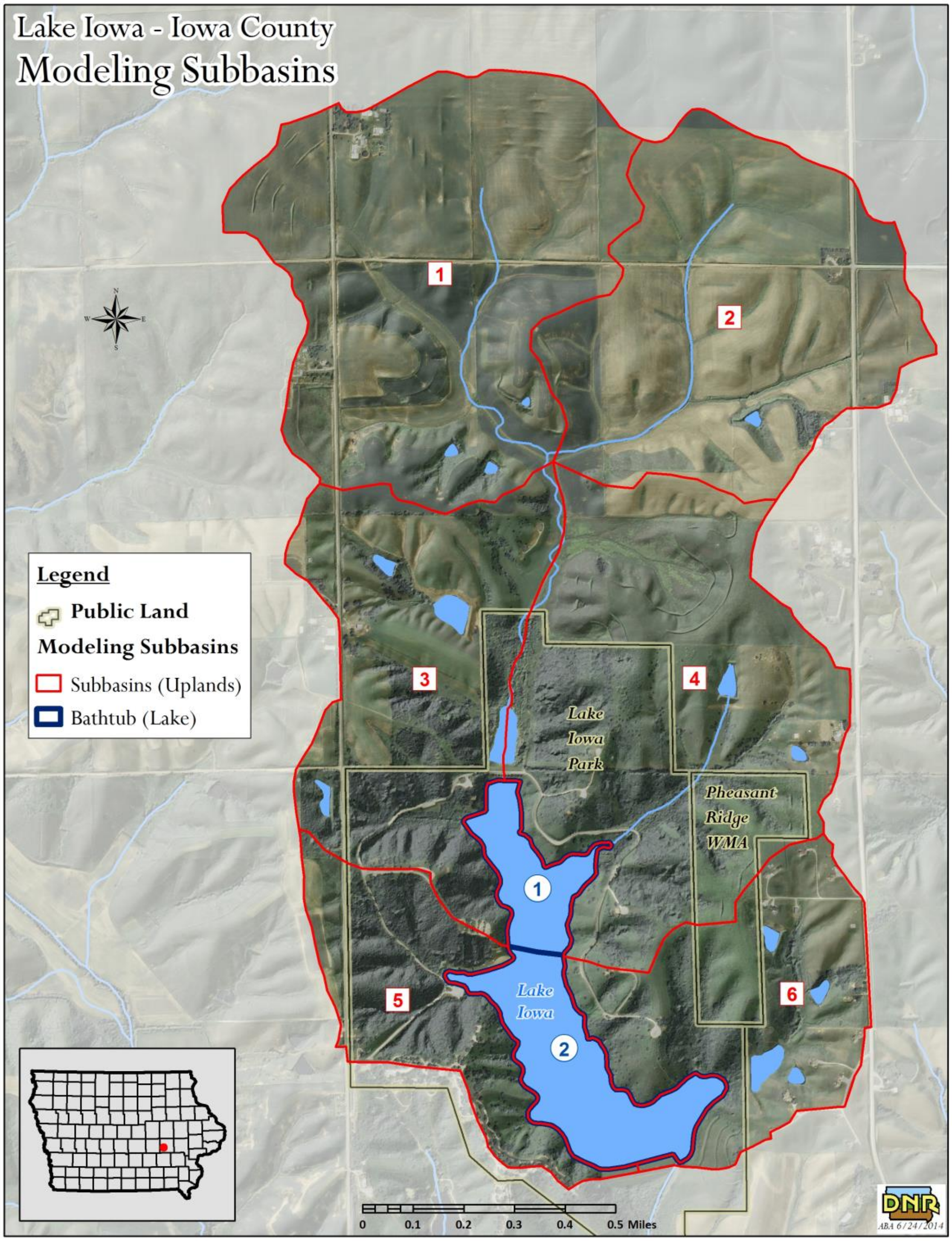

Figure D.1. Subbasins used in model development.

D.4. 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.

There are approximately a total of 700 head of cattle and 200 sheep in the watershed (Iowa County staff communication).

Wildlife.
STEPL assumes that wildlife add to the manure deposited on the land surface. If animal densities are significant, nutrient concentration in runoff is increased. For Lake Iowa, an estimate of 20 geese and 15 deer per square mile (Lake Iowa Park staff communication) were used. Both of these numbers represent over estimates. Even with overestimates of geese and deer populations, wildlife contributions are relatively insignificant (in terms of nutrient loading to the lake) and do not increase STEPL nutrient runoff parameters.

D.5. Other Potential Sources and Total Loads

Gully Erosion and Streambank Erosion
There is no current RASCAL assessment for the Lake Iowa watershed so no gully or stream bank erosion data were readily available. A method of estimating stream bank erosion based on adjacent landuse was employed (Zaimes 2004). Since assessment data was not available, literature values and best professional judgment were used to determine values for percent of stream bank severely eroding, soil P concentration and lateral erosion rates.

$$L \times \%E \times H \times R \times BD \times P$$

Where:
L = length of eroding stream bank
%E = percent of stream length with severe erosion
H = average height of eroding stream bank
R = lateral recession rate (i.e., erosion rate)
BD = bulk density of soil
P = phosphorus concentration of soil

Stream geometry was estimated using GIS and LiDAR coverage. A recession rate of 13.7 mm/yr was based on Zaimes value used for continuous pasture. This may be high but was used as a conservative measure. The bulk density of soil was taken from county soil survey. Soil phosphorus concentration was assumed to be 520 mg/kg (Zaimes, 2004). The phosphorus load resulting from streambank erosion is 58 lbs/yr. A breakdown of streambank erosion by sub watershed is provided in Table D.1.

Table D.1. Phosphorus Contributions via Streambank Erosion

Subwatershed	Total Phosphorus (lbs/yr)	Percent of total (%)
W1	25	43.1
W2	25	43.1
W3	8	13.8
Total	58	100

Runoff and Groundwater
STEPL default concentrations were used to calculate nutrient input from runoff and groundwater. In respect to the user-defined grasslands (prairie or ungrazed) the nutrient concentrations used to calculate forest were used as this was the best estimate.

Table D.1 provides the acres of landuse per watershed used to develop the STEPL model. The outputs of the model provided both a load to enter into BATHTUB and also provided a breakdown of the TP input from landuses (Figure D.2). This output suggests slightly less than half the TP load comes from the row cropped regions. The row cropped lands in the HEL depicted in Section 4 should be of highest priority.

Table D.2. Subbasin landuse inputs for STEPL (acres).

Watershed	Urban	Cropland	Pastureland	Forest	Grassland
W1	21.8	233.9	0	2.9	53.5
W2	11.8	205.6	0	0	30.9
W3	13.2	9.1	55.8	82.8	34.4
W4	6.2	15.7	43.1	82.1	146.4
W5	11	4.8	0	50.2	33.4
W6	4.8	0	0	33.4	101.8
TOTAL	**68.8**	**469.1**	**98.9**	**251.4**	**400.4**

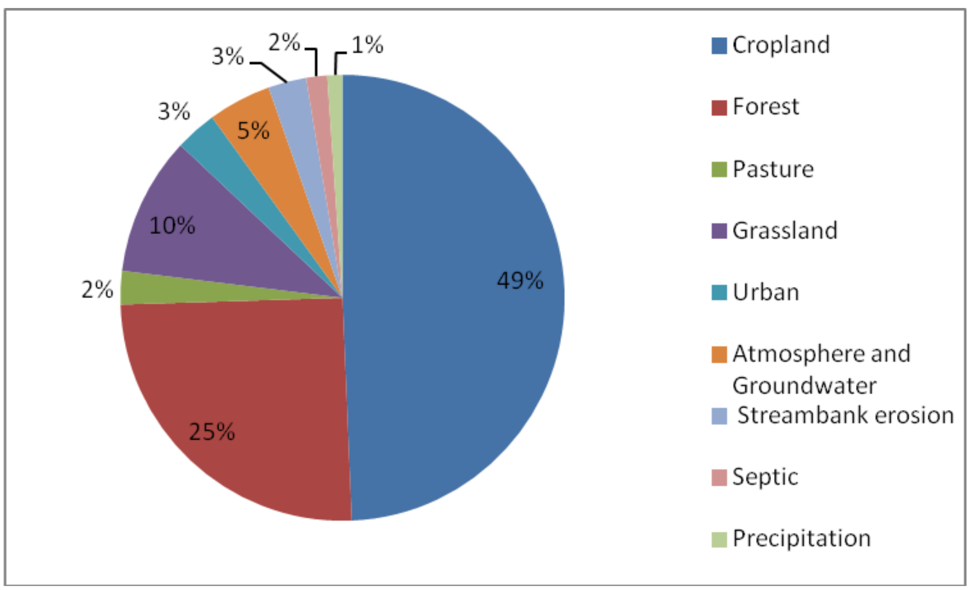

Figure D.2. Percent of phosphorus load per landuse

The model was developed based on the average conditions observed from 2003 to 2013. No special consideration was given to wet or dry periods since relationships between precipitation and TSI values or chlorophyll-a concentrations could not be established.

Appendix E --- In-Lake Water Quality Model

A combination of modeling software packages were used to develop the Total Maximum Daily Load (TMDL) for Lake Iowa. 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 of this Water Quality Improvement Plan (WQIP).

In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. This appendix of the WQIP 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 Iowa 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, if applicable/desired. Water quality predictions are based on empirical models that have been calibrated and tested for lake and reservoir applications (Walker, 1985).

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 Iowa 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 Iowa BATHTUB model and report input parameters for each menu.

Model Selections.

BATHTUB includes several models 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. Table E.1 reports the models selected for each parameter used to simulate eutrophication response in Lake Iowa. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Lake Iowa model. Final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data.

Table E.1. Model selections for Lake Iowa.

Parameter	Model No.	Model Description
Total Phosphorus	01	2nd Order, Avail P
Total Nitrogen	00	Not computed
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 Iowa are reported in Table E.2. 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 Iowa.

Table E.2. Global variables data for 2003-2013 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	37.6 in	0.960m
Evaporation	40.8 in	1.04 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.

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 Iowa utilizes a two-segment model (Figure E.1). Because the ambient monitoring location is used for listing and delisting purposes, the TMDL target applies to segment 2 of Lake Iowa. The TMDL and future water quality assessment and listing will be based solely on data from this segment.

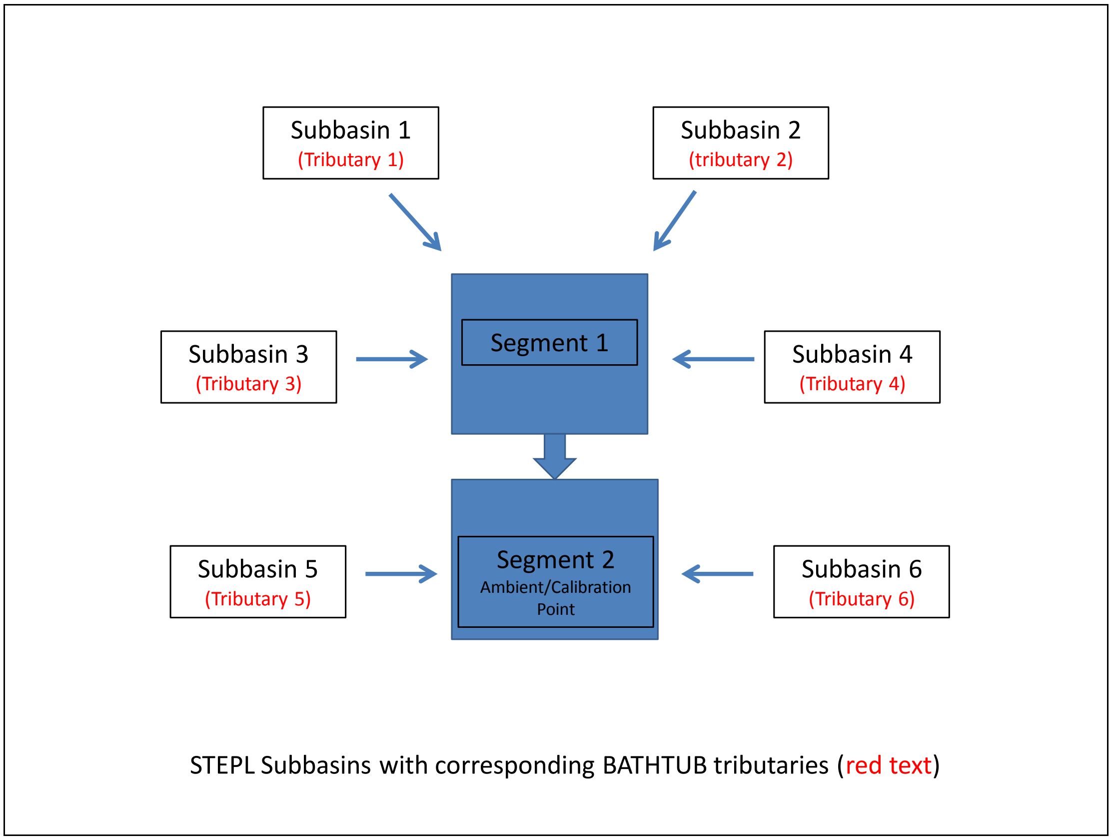

Figure E.1. Segmentation based on Bathymetry

The BATHTUB model developed for Lake Iowa does not simulate dynamic conditions associated with storm events or even between individual growing seasons. Rather, the model predicts the water quality period of 2003-2013. Observed water quality data during the lake survey is included in Appendix C – Water Quality Data. Table E.3 lists BATHTUB segment inputs for segments 1 and 2. Observable water quality data is only available for segment 2 through the monitoring program. Therefore water quality inputs are not listed for segment 1 and 2.

Table E.3. Segment inputs for BATHTUB

Segment 1 Parameter	BATHTUB Input	Calibration Factor
Surface Area (km2)	0.11	N/A
Mean Depth (m)	2.7	N/A
Length (km)	0.53	N/A
Non-Algal Turbidity (1/m)	0.08	1*
Total Phosphorus (ug/l)	0	1*
Chlorophyll-a (ug/l)	0	1*
Secchi Depth (m)	0	1*
Internal Load P (mg/mg2-day)	0	N/A

Segment 2 Parameter	BATHTUB Input	Calibration Factor
Surface Area (km2)	0.24	N/A
Mean Depth (m)	4.3	N/A
Length (km)	0.73	N/A
Non-Algal Turbidity (1/m)	0.08	1*
Total Phosphorus (ug/l)	89.8	1*
Chlorophyll-a (ug/l)	49.6	1*
Secchi Depth (m)	1.1	1*
Internal Load P (mg/mg2-day)	0.0	N/A

* Indicates Default

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 Iowa 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 units conversion and converting STEPL nutrient loads and flows to nutrient concentrations.

Because of the segmented nature of Lake Iowa and the implementation of BMPs, six subbasins were included in the STEPL model to provide tributary inputs for BATHTUB. Tributary data are reported in table E.4.

Table E.4. Tributary inputs for BATHTUB.

Tributary Subbasin	Area (ac)	TP (ug/l)	Flow (hm3)
W1	312.1	447.67	0.598
W2	248.3	455.7	0.480
W3	195.3	445.78	0.320
W4	293.5	339.85	0.487
W5	99.4	515.4	0.163
W6	140	293.1	0.233

E.3. Model Performance and Calibration

The Lake Iowa water quality model was 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 2003 and 2013. 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, and (2) provide good agreement with observed water quality in Lake Iowa.

BATHTUB Calibration.
Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Lake Iowa from 2003 to 2013 in segment 2 of the BATHTUB model. Simulation of TP concentration was critical for TMDL development, as was chlorophyll-a. As discussed in Section 3.1, Lake Iowa is not nitrogen limited during critical periods in which violations occur. Therefore, nitrogen simulations were not preformed.

BATHTUB Target Assessment.
After calibration the bathtub model was used to determine the water quality target. This was done by incrementally reducing loads of TP in tributaries until the desired Chl-a TSI of 63 was achieved for the segment 2 average. This was expressed as an annual load and then expressed as an average daily maximum via a statistical approach described in Appendix F.

The model assumes a uniform reduction in loads of all sources. In reality there would be many combinations of practices and pathways to achieve this goal and would most likely not be accomplished by trying to cut 79 percent of the load across all sources equally. In fact, that is most likely not possible. The best approach would be to target the highest contributing sources as discussed in Section 3 of this report and systematically treat watershed based sources and then follow up with treating in-lake sources. Figures E.2 provides the load response curves for Chl-a annual TP loads.

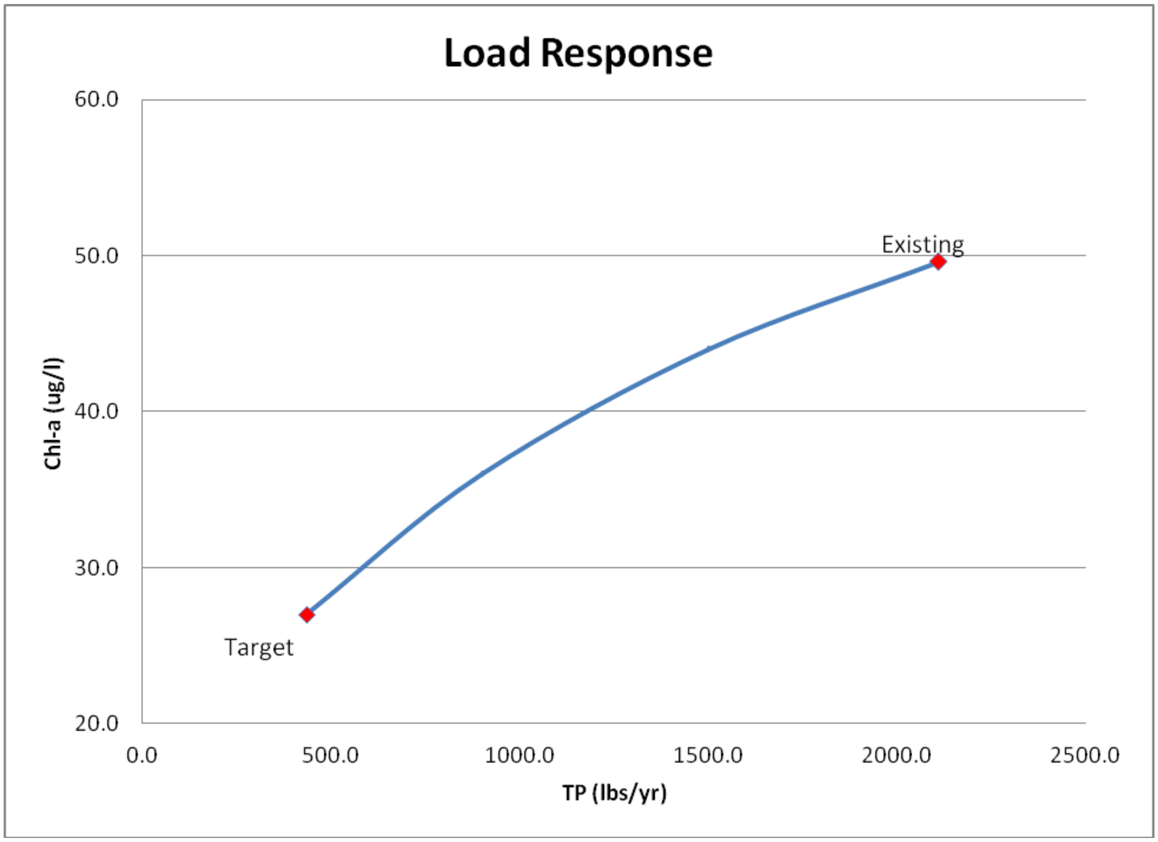

Figure E.2. The load response relationship between Chl-a and total P as predicted by BATHTUB.

Appendix F --- Establishing 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 Iowa 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 435.4 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 an option for identifying a maximum daily load (MDL) that corresponds to the allowable annul average load. The method calculates the daily maximum based on a long-term average and considers variation. This method is represented by the equation:

$$MDL = LTA \times e^{[z\sigma - 0.5\sigma^2]}$$

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 436.1 lbs/year is equivalent to a long-term average (LTA) daily of 1.2 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 F.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 4.8 lbs/day. This is without the applied MOS of 10 percent. The TMDL calculation is summarized in Table F.2.

Because there are no permitted/regulated point source discharges in the watershed, the WLA is zero. An explicit MOS of 10 percent is applied. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (4.3 lbs-TP/day)
+ MOS (0.5, explicit 10 percent) = **4.8 lbs-TP/day**

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

Parameter	Value	Description
LTA	1.2 lbs/day	Long-term average
Z Statistic	2.778	Based on 365-day averaging period
CV	0.6	Used CV from annual TP loads
σ^2	0.31	ln (CV^2 + 1)
MDL	**4.8 lbs/day**	**TMDL expressed as daily load**

Appendix G --- Public Comments

No comments were received during the public comment period.