Water Quality Improvement Plan
for

East Lake, Osceola

Clarke County, Iowa

Total Maximum Daily Load
for Algae and Turbidity

Iowa Department of Natural Resources
Watershed Improvement Section
2008

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General Report Summary

What is the purpose of this report?

This report has two purposes. First, it is a resource to be used by watershed planners, water quality improvement groups, individual citizens, and local, county and state government staff. This document will serve as a guide to help these groups understand and identify the cause of East Lake's water quality problems caused by excessive algae and lack of clarity. Second, this report satisfies the Federal Clean Water Act requirement to establish a Total Maximum Daily Load (TMDL) for waterbodies on the impaired waters list.

What's wrong with East Lake Water Quality?

East Lake is impaired by excessive growth of algae and the resulting lack of clarity caused by algal growth. Nuisance and potentially noxious blooms of blue green algae also have adverse impacts. These problems combine to limit recreational lake uses.

What is causing the problem?

The nuisance algae growth is caused by excessive nutrients, mostly phosphorus, that are delivered to the lake from nonpoint sources in the watershed. Phosphorus is almost always the limiting nutrient for excessive algal growth. Most of the phosphorus in this watershed comes from recycling of lake bottom sediment by carp and other bottom feeding fish, agricultural activities, and wildlife such as geese.

What can be done to improve East Lake Water Quality?

The recycling of phosphorus from lake bottom sediment by carp turbulence needs to be eliminated. Agricultural activities need to be modified to minimize erosion and the phosphorus content of eroded soil. The number of geese at East Lake needs to be significantly reduced.

Who is responsible for a cleaner East Lake?

There is not a single source of the phosphorus causing the algae and clarity problems in East Lake. IDNR, Clarke County, and other state and federal agency staff are collaborating to understand pollutant sources and searching for solutions to water quality problems in East Lake. However, everyone that lives, works and recreates in the watershed is responsible for correcting the problem. When unregulated sources are the major contributors, water quality improvements happen most quickly if local interests spur voluntary action among those invested through living, working and owning the watershed.

Required Elements of the TMDL

This TMDL has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7 in compliance with the Clean Water Act. These regulations and consequent TMDL development are summarized in Table 1 below.

Table 1. TMDL Elements

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	East Lake (Osceola) is located just east of the City of Osceola city limits in Clarke County. Latitude 41 deg, 01 min, 59.6 sec, Longitude – 93 deg, 44 min, 33.1 sec.
Use designation classes:	Class A1 Recreational Class B (LW) Aquatic Life
Impaired beneficial uses:	Primary Contact Recreation (A1)
Identification of the pollutants and applicable water quality standards:	Class A1 Primary Contact Recreational use has been assessed as not being supported due to aesthetically objectionable conditions caused by algae and turbidity. The TMDL target is a Carlson's Trophic State Index (TSI) of less than 65 for both chlorophyll a and secchi depth. These TSI values are equivalent to a chlorophyll concentration 33 ug/L and a secchi depth of 0.7 meters. The total phosphorus target of 72 ug/l has been related to chlorophyll and secchi depth by BATHTUB lake nutrient modeling.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The cause of the nuisance algal blooms is excessive total phosphorus (TP). The maximum annual allowable TP load from all sources is 134 lbs/year and the maximum daily load is 21.52 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain water quality standards:	The existing mean values for secchi depth, chlorophyll a and TP based on 2000 to 2006 sampling are 0.42 meters, 69 ug/L and 302 ug/l, respectively. A minimum in-lake increase in secchi transparency of 67 percent and minimum in-lake reductions of 109 percent for chlorophyll and 319 percent for TP are required to achieve and maintain water quality goals and protect beneficial uses. The estimated existing annual TP load to East Lake from all sources is 736 lbs/year. Based on watershed and lake modeling, the external watershed load capacity is 88 lbs/yr and the internal recycled load capacity is 43 lbs/yr. Direct deposition to the lake surface is 3 lbs/year for both existing and target conditions. The required total load reduction is 71% for watershed TP sources.

Identification of pollution source categories:	External watershed and internal recycled nonpoint TP loads have been identified as the cause of impairment to East Lake.
Wasteload allocations (WLA) for pollutants from point sources:	There are not any permitted point sources in the watershed so the WLA is zero.
Load allocations for pollutants from nonpoint sources:	The TP load allocation for the external watershed load is 88 lbs/yr, for the internally recycled load is 38.7 lbs/year, and for direct deposition is 3 lbs/year. The total load allocation is 129.7 lbs/yr.
A margin of safety:	The margin of safety for annual maximum loading is an explicit 10 percent of the modeled allowable load for both external and internal loads. Applying the MOS to the allowable TP loads gives a total maximum annual load of 134 lbs/year and a total maximum daily load of 21.52 lbs/day.
Consideration of seasonal variation:	TMDL development is based on an annual phosphorus loading that will result in attainment of TSI targets for the growing season (May through September).
Allowance for reasonably foreseeable increases in pollutant loads:	An allowance for increased phosphorus loading was not included in this TMDL. The Clarke County Conservation Board maintains the entire shoreline around the lake and much of the watershed land use is in agricultural production. Significant changes in the watershed land uses are unlikely.
Implementation plan:	Section 4 of this document is a general implementation plan intended to guide local citizens, government agencies, and water quality improvement groups.

1. Introduction

The Federal Clean Water Act requires states to assess their waterbodies every even numbered year and incorporate these assessments into the 305(b) Water Quality Assessment Report. A list of waters that do not meet the Iowa Water Quality Standards criteria are identified from this report and placed on the 303(d) Impaired Waters List. A pollutant Total Maximum Daily Load (TMDL) must be calculated and a report written for each waterbody on the impaired waters list.

A TMDL is a calculation of the maximum amount of a pollutant a waterbody can receive without exceeding the water quality standards. The total maximum daily load is allocated to permitted point sources (wasteload allocations), nonpoint sources (load allocations), and an allowance for a margin of safety to account for uncertainty in the TMDL calculation.

This TMDL report is for East Lake (Osceola) in Clarke County, Iowa. East Lake is on the 2004 impaired waters list for algae and turbidity problems resulting from excess phosphorus triggering algal blooms. Phosphorus is the nutrient that limits excess algal growth.

There are two primary purposes of this report: 1) to satisfy federal requirements of a Total Maximum Daily Load for impaired waters, and 2) to serve as a resource for guiding water quality projects in the East Lake watershed addressing algae and turbidity problems. Local citizens, water quality groups, and government agencies will find it a useful description of the causes and solutions to East Lake water quality issues.

A TMDL report has some limitations.

- The 305(b) water quality assessment is made with available data that may not sufficiently describe lake water quality. Additional targeted monitoring is often expensive and requires time. Assumptions and simplifications on the nature, extent, and causes of impairment can cause uncertainty in calculated values.
- A TMDL may not deal easily with unregulated nonpoint sources of pollutants. It can be challenging to reduce pollutant loads if nonpoint sources are significant contributors.

A TMDL report can guide projects that target the entire watershed. The water quality in a river or lake is a reflection of the land that drains to it and how that land is managed. Local landowners, tenants, and land managers often have the greatest influence in determining water quality.

2. Description and History of East Lake (Osceola)

East Lake is located in central Clarke County one half mile east of the City of Osceola. It is the central feature of East Lake County Park, a popular recreation area. The 160-acre park was established in the 1920's. The lake and park provide a contrast to nearby residential and agricultural areas. Lake activities include boating and fishing. Facilities include a campground, boat ramp and picnic shelters. East Lake is classified as a Significant Publicly Owned Lake. Other lake information is listed in Table 2. The map in Figure 1 shows the lake and its watershed.

Table 2. East Lake (Osceola) Information

Waterbody Name	East Lake (Osceola)
12 Digit Hydrologic Unit Code (HUC):	071000081301
IDNR Waterbody ID	IA 04-LDM-02190-L
Location	Clarke County, S16 T72N R25W
Latitude	41 deg, 01 min, 59.6 sec
Longitude	-93 deg, 44 min, 33.1 sec
Water Quality Standard Designated Uses	Class A1 Recreational Class B (LW) Aquatic Life
Tributaries	White Breast Creek headwaters
Receiving Waterbody	White Breast Creek
Lake Surface Area	13 acres
Maximum Depth	13.0 feet
Mean Depth	6.9 feet
Volume	92 acre-feet
Length of Shoreline	1.36 miles
Watershed Area (with lake)	310 acres
Watershed/Lake Area Ratio	22
Lake Detention Time (outlet)	0.264 year (96 days) from watershed model

2.1 East Lake

Hydrology.
East Lake and the stream that is its major tributary are part of the headwaters of the Upper White Breast Creek drainage. The lake's outlet discharge eventually flows south to White Breast Creek and then east to Lake Red Rock (Des Moines River). The average annual precipitation is 35 inches/year and the lake retention time is 96 days based on outflow. Detention time was derived from local precipitation data and the GWLF/BasinSims watershed model described in Appendix D.

Morphometry .
East Lake has a mean depth of 6.9 feet and a maximum depth of 13.0 feet. The lake surface area is 13 acres and the storage volume is 92 acre-feet. Temperature and dissolved oxygen profiles indicate that East Lake occasionally stratifies but this tends to be weak and sometimes the lake is completely mixed and oxic.

2.2. The East Lake Watershed

The East Lake watershed consists of 310 acres (including lake surface area) in the uppermost headwater reach of the Upper White Breast Creek drainage. Without the lake the watershed has a drainage area of 297 acres and a watershed to lake ratio of 22:1. The most desirable watershed to lake area ratio is less than 20:1.

The far east side of Osceola is in the watershed but there are not any permitted point sources in the basin. However, there are 12 occupied homes on septic tanks and there are pit toilets in East Lake County Park. The northern edge of the lake's watershed defines part of the divide between the White Breast Creek and Otter Creek HUC 12 sub watersheds. This watershed is one of the headwaters of White Breast Creek.

Land Use.
Table 3 provides land use acreages for the East Lake watershed. The Clarke County Conservation Board owns and maintains the shoreline around the lake.

Table 3. Land use in the East Lake Watershed

Land Uses from Assessment	Area, acres	Percent of total
Corn-Bean, Conventional tillage	9.8	3.2%
Corn-Bean, Mulch tillage	19.8	6.4%
Corn-Bean-OMMM[1], Conventional tillage	44.9	14.5%
Farmstead	11.9	3.9%
Grazed grass land	45.7	14.7%
Ungrazed grass land	68.7	22.2%
Parkland	8.7	2.8%
Residential	27.6	8.9%
Roads and Railroad	22.1	7.1%
Timber	37.6	12.1%
Water	13.0	4.2%
Total	**310**	**100%**

1. Corn-soybean-oats-meadow-meadow-meadow-rotation

Climate, topography, and soils.
The mean annual air temperature is about 50 degrees F (10 degrees C) and the mean annual precipitation is about 35 inches (889 millimeters). The elevation change from the high land in the northwest of the watershed to the lake surface is about 65 feet over a length of 0.75 miles for an average slope of 1.5 percent. The narrower areas to the west and east of the lake have elevation changes of about 40 feet over a distance of 600 feet for an average slope of 6.5 percent.

There are two general soil associations in the East Lake watershed as shown in Figure 15 in Appendix F. The north half of the watershed is the Haig-Grundy-Arispe Association (S1714) and the south half is the Shelby-Lamoni-Grundy Association (S3725). The soil type descriptions are as follows.

- Haig-The Haig series consists of very deep, poorly drained soils formed in Wisconsin age loess. These soils are on broad interfluves on uplands. Slopes range from 0 to 2 percent.
- Grundy-The Grundy series consists of very deep, somewhat poorly drained soils formed in loess. These soils are on divides and interfluves. Slopes range from 0 to 9 percent.
- Arispe-The Arispe series consists of very deep, somewhat poorly drained soils formed in loess. These soils occur on short, convex side slopes and on head slopes. Slope ranges from 2 to 14 percent.
- Shelby-The Shelby series consists of very deep, well-drained soils formed in till. These soils are on convex side slopes, crests, and narrow interfluves on dissected till plains. Slope ranges from 1 to 40 percent.
- Lamoni-The Lamoni series consists of deep, somewhat poorly drained, slowly or very slowly permeable soils formed in a paleosol that developed in glacial till on uplands. Slope ranges from 5 to 18 percent.

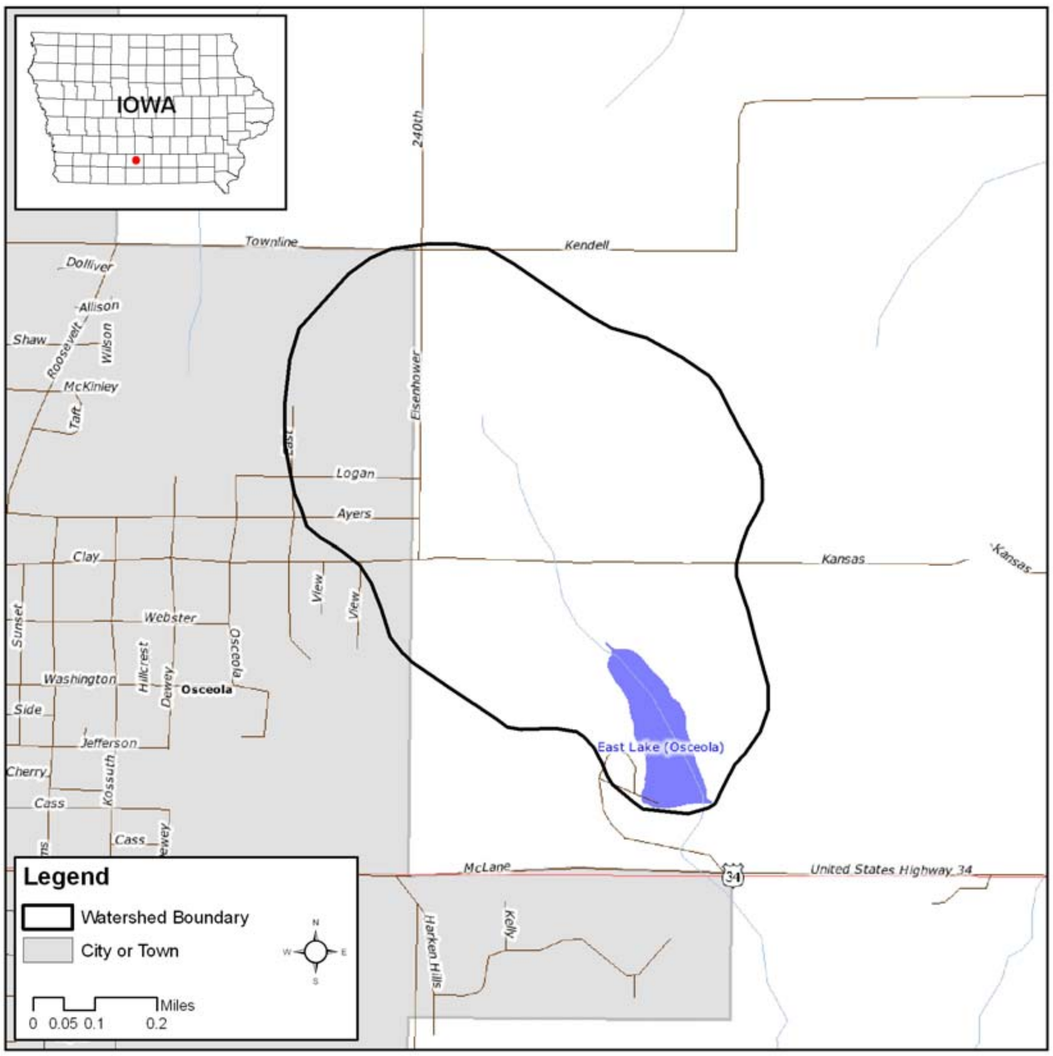

Figure 1. East Lake and its watershed

3. Total Maximum Daily Load (TMDL) for Algae

A Total Maximum Daily Load (TMDL) is required for East Lake by the Federal Clean Water Act since it is on the State of Iowa Impaired Waters List (303d). The impairment is for algae as well as for the turbidity the algae causes. It has been determined that the limiting nutrient for algae growth in this lake is total phosphorus. The following sections will estimate the existing total phosphorus (TP) load to the lake, the maximum allowable load to the lake while meeting water quality standards, and the difference between them, i.e., the needed reductions.

3.1. Problem Identification

Applicable water quality standards.
The Iowa Water Quality Standards (IAC 567-61) list the designated uses for East Lake as Primary Contact Recreational Use (Class A1) and Aquatic Life (Class B(LW)). The East Lake Primary Contact Recreational use has been assessed as not supporting the Class A use due to aesthetically objectionable conditions caused by algae and turbidity, a narrative criteria.

Problem statement.
The following paragraphs are from the 2006 305(b) water quality assessment for East Lake and describe the reason that the recreational use is assessed as not supported.

> *SUMMARY: The Class A (primary contact recreation uses) are assessed (monitored) as "not supported" due to presence of aesthetically objectionable conditions related to poor water transparency related to blooms of algae and high levels of inorganic turbidity. The presence of moderately large populations of nuisance algal species (i.e., bluegreen algae) constitutes an additional water quality concern at this lake. The Class B(LW) aquatic life uses are assessed (evaluated) as "partially supported" due to excessive nutrient loading to the water column, nuisance blooms of algae, and impacts from organic enrichment. Fish consumption remains "not assessed" due to a lack of fish contaminant monitoring at this lake. Sources of data for this assessment include (1) results of the statewide survey of Iowa lakes sponsored by IDNR and conducted by Iowa State University (ISU) from 2000 through 2004, (2) surveys by IDNR Fisheries Bureau, and (3) information on plankton communities collected at Iowa lakes from 2000 through 2005 as part of the ISU lake survey.*
>
> *EXPLANATION: Using the median values from this survey from 2000 through 2004 (approximately 15 samples), Carlson's (1977) trophic state indices at East Lake Osceola for total phosphorus, chlorophyll-a, and secchi depth are 88, 68, and 73 respectively. According to Carlson (1977), the index value for total phosphorus places this lake in the upper range of hyper-eutrophic lakes; the value for chlorophyll-a places is in the upper range between eutrophic and hyper-eutrophic lakes, and the index value for secchi depth is in the lower range of hyper-eutrophic lakes. These index values suggest extremely high levels of*

phosphorus in the water column, moderately high, but somewhat less than expected production of suspended algae, and very poor water transparency.

According to Carlson (1991), the occurrence of a high TSI value for total phosphorus with relatively low values for chlorophyll-a and secchi depth indicate that some factor (e.g., nitrogen limitation, zooplankton grazing, or some other factor) other than phosphorus limits production of algae. The ISU lake data suggest that algal production at East Lake Osceola is limited—although not to levels below impairment thresholds—by a combination of nitrogen availability, zooplankton grazing, and inorganic turbidity. Based on data from the 2000-2004 monitoring period, the relatively low ratio of total nitrogen to total phosphorus (6), suggests that algal production is limited by the availability of nitrogen as opposed to phosphorus.

The presence of extremely large populations of zooplankton at East Lake Osceola that graze on algae, however, may explain the large discrepancy between the TSI value for phosphorus (88) and that for chlorophyll-a (68). In terms of all Iowa lakes sampled, data from the ISU survey show an extremely large population of zooplankton species at this lake that graze on algae. Sampling from 2000 through 2005 showed that Cladoceran taxa (e.g., Daphnia) comprised approximately 65% of the dry mass of the zooplankton community of this lake. The average per summer sample mass of Cladoceran taxa over the 2000-2005 period (348 mg/l) was the sixth highest of the 131 lakes sampled. This large population of zooplankton grazers strongly suggests the potential for this type of non-phosphorus limitation on algal production at East Lake Osceola.

The median level of inorganic suspended solids in the 131 lakes sampled for the ISU lake survey from 2000 through 2004 was 5.2 mg/l; the median level of inorganic suspended solids at East Lake Osceola (7.2 mg/l) is moderately high, thus suggesting the potential of non-algal turbidity to limit production of algae; this median value was the 54th highest of the 131 lakes sampled.

Regardless of the non-phosphorus limitations to algal production suggested by the TSI values, the very poor water transparency at the lake, whether due to the high levels of chlorophyll-a or to the moderately high levels of inorganic suspended solids, continue to suggest a violation of Iowa's narrative water quality standard protecting against aesthetically objectionable conditions.

The moderately high levels of nuisance (=noxious) algal species (i.e., bluegreen algae) at this lake do not suggest an impairment of Class A uses. While data from the ISU survey from 2000 through 2004 suggest that bluegreen algae (Cyanophyta) comprise a large portion (80%) of this lake's summertime phytoplankton community, sampling from 2000 through 2004 showed that the median per summer sample mass of bluegreen algae at East Lake Osceola (20.9 mg/l) was the 42nd highest of the 131 lakes sampled. This level is in the lowest two-thirds of the 131 Iowa lakes sampled. The presence of a moderately large *population of bluegreen algae at this lake does not immediately suggest a violation of Iowa's narrative water quality standard protecting against occurrence of nuisance aquatic life. This assessment, however, is based strictly on a distribution of the lake-specific median bluegreen algae values for the 2000-2004 monitoring period. Median levels less than the 75th percentile of this distribution (~29 mg/l) were arbitrarily considered by IDNR staff to not represent an impairment of the Class A uses of Iowa lakes. No criteria exist, however, upon which to base a more accurate identification of impairments due to bluegreen algae. Thus, while the ability to characterize the levels of bluegreen algae at this lake has improved over that of the previous (2004) assessment due to collection of additional data, the assessment category for assessments based on level of bluegreen algae nonetheless remains, of necessity, "evaluated" (indicating an assessment with relatively lower confidence) as opposed to "monitored" (indicating an assessment with relatively higher confidence).*

The hyper-eutrophic conditions at this lake, along with information from the IDNR Fisheries Bureau, suggest that the Class B(LW) aquatic life uses should be assessed (evaluated) as "partially supported" due to excessive nutrient loading to the water column, nuisance blooms of algae, and impacts from organic enrichment in the lake.

Results of ISU monitoring from 2000 through 2004 suggest generally good chemical water quality at this lake. Results of this monitoring show that only 2 of the 15 samples collected exceeded the Class B(LW) criteria for dissolved oxygen and that only 2 of the 14 samples collected exceeded Iowa's Class A,B(LW) criteria for pH (maximum = 9.3; minimum = 8.7 pH units). Based on IDNR's assessment methodology, these results do not suggest that violation frequencies are significantly greater than 10% for either parameter and thus do not suggest impairment of either the Class A and Class B(LW) uses of East Lake Osceola. The violations of the pH criteria likely reflect the influence of primary productivity at East Lake Osceola and do not reflect the input of pollutants into this lake.

Data sources

The data used to develop the BATHTUB water quality and the GWLF/BasinSims watershed models are described in the following two sub-sections.

<u>Lake Water Quality Data</u>: The primary in-lake data used to assess East Lake water quality and to develop this TMDL are from the Iowa State University Lake Study that began in 2000. Data were collected from 2000 to 2006 three times per season, usually in June, July, and August. The samples were analyzed for variables including total and volatile suspended solids, secchi depth, chlorophyll, phosphorus, and nitrogen. The seven-year average ISU total phosphorus concentration was 302 ug/l. Samples were also examined for phytoplankton and zooplankton composition.

In 2005 and 2006 additional data was collected by the University of Iowa Hygienic Lab (UHL) applying the same protocol used by ISU. However, data was collected six times a season rather than three, starting in April and going through October, and was collected on different dates than the ISU Study data. The mean values for TP, chlorophyll, and secchi depth from the two data sets are compared in Figure 2.

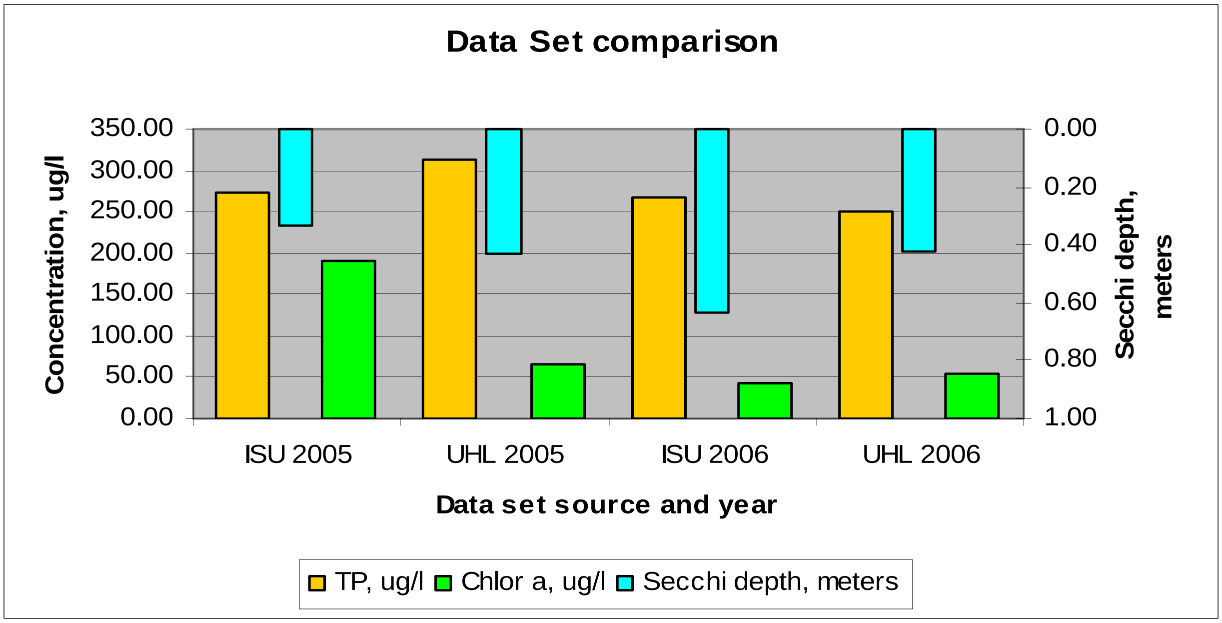

Figure 2. Comparison of the variable means for the ISU and UHL data sets

<u>Watershed loading model data</u>: The GWLF/BasinSims watershed model uses the precipitation and temperature data from the nearby Osceola National Weather Service COOP station (IA6316). Land use data is from a watershed assessment done in 2006 and the factors used for erosion estimates are from IDNR GIS coverages. Soil information is from an IDNR GIS coverage based on SURGO data.

Interpreting East Lake data

The total nitrogen to total phosphorus ratio can often suggest which of these two nutrients limits algae growth. Based on values from ISU sampling from 2000 to 2006, the mean ratio of total nitrogen to total phosphorus is 7.1 and the median ratio is 6.6. This relatively low ratio could lead to the erroneous conclusion that nitrogen is a limiting nutrient for some lake conditions. However, the TN:TP ratio is low because the TP concentration is very high. Phosphorus is so high that algae productivity becomes limited by light before a significant fraction of the phosphorus is used.

Inorganic suspended solids (ISS) represent the fraction of turbidity not caused by algae. It consists mostly of eroded silt. The ISS data from the ISU sampling shows there are episodes of moderate non-algal (inorganic) turbidity. The 2006 305b Water Quality Assessment ranked East Lake 54th highest of 131 Iowa lakes for median inorganic suspended solids. The median ISS concentration for the 131 lakes sampled was 5.2 mg/L. The median ISS for East Lake during the same time period was 7.2 mg/l.

<u>Carlson's Trophic State Index</u>: Carlson's trophic state index (TSI) can be used to relate algae, as measured by chlorophyll, transparency, and total phosphorus to one another. It can also be used as a guide to establish water quality improvement targets. TSI values for the ISU monitoring data are shown in Appendix C, Table C-3. Further explanation of TSI procedures and their use in lake assessments can be found in Appendix E.

If the TSI values for the three variables are the same, the relationships between TP and algae and transparency are strong. If the TP TSI values are higher than the chlorophyll values, there are limitations to algae growth besides phosphorus. Figure 3 shows a comparison of the TSI values for chlorophyll, secchi depth and total phosphorus for East Lake. The TP TSI values are consistently higher than those for chlorophyll and transparency are. This indicates that algal growth limitation results from suspended solids light attenuation and that zooplankton predation may reduce algae chlorophyll.

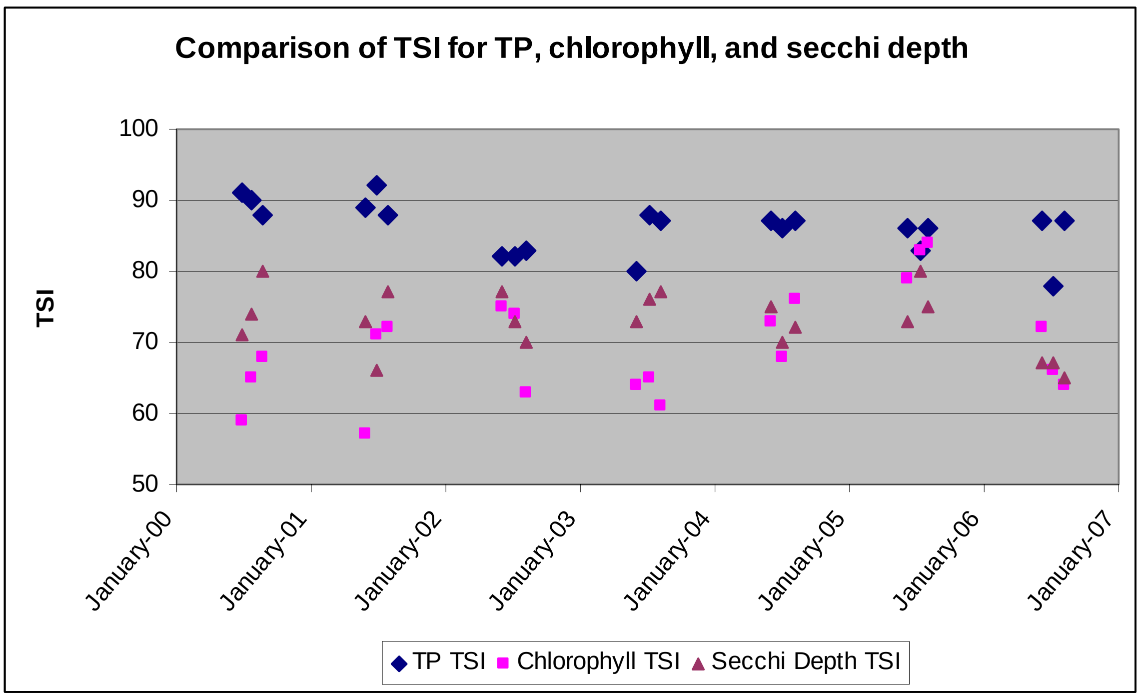

Figure 3. TSI values for ISU Study data, 2000 to 2006

Charts that compare the three TSI variables and interpret the differences are given in Figure 4. The left hand chart plots the differences between TP, chlorophyll, and secchi depth in one of four quadrants. If the three TSI values are identical they plot in the center, or zero-zero. The East Lake system plots in the lower left quadrant. The right hand chart interprets what the East Lake plotted point location suggests. The East Lake point location indicates surplus phosphorous. Not all-available TP is being expressed as algae. It also indicates suspended solids in the lake are limiting light penetration and that non-algal turbidity is a factor.

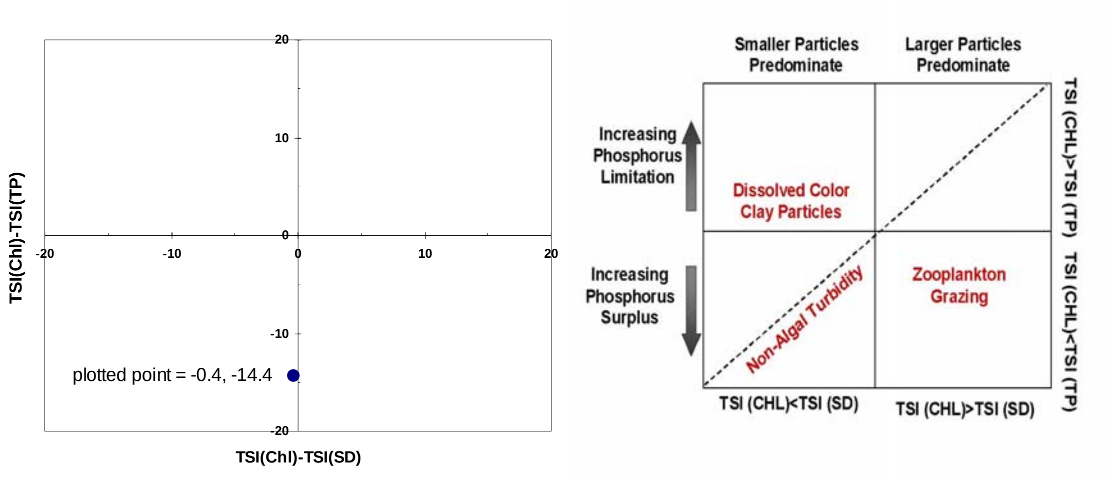

Figure 4. East Lake Mean TSI Multivariate Comparison Plot

Blue-green Algae: Phytoplankton (algae) composition can be an indicator of the extent of the algae problem. A significant blue-green phytoplankton fraction aggravates nuisance conditions and is a concern because it can grow rapidly in warm weather algal blooms. Blue-green algae cause taste and odor problems, form dense mats on the water surface, and can produce toxins such as microcystin. Microcystin and related compounds can be very harmful to plants and animals, including humans. The toxin concentrations in a bloom can quickly exceed safe levels, so most algal blooms should be treated as potentially hazardous.

Data from the 2000 to 2006 ISU Lake Study sampling shows that, on average, blue-green algae are 80% of the total summertime phytoplankton community in East Lake. The median for blue green concentration makes East Lake the 42nd highest of 131 Iowa lakes for blue green algae.

3.2. TMDL Target

Based on the Iowa 305b assessment protocol that determines if a lake is impaired by algae and turbidity, the targets for this TMDL are a mean TSI value of less than 65 for both chlorophyll and secchi depth. These values are equivalent to a chlorophyll concentration of 33 ug/L and a secchi depth of 0.7 meters. Using the BATHTUB model, estimates were developed for East Lake, yielding a total phosphorus target concentration of 72 ug/l. The existing and target values for concentration and TSI are shown in Table 4.

Table 4. East Lake Existing vs. Target TSI Values

Parameter	2000-2006 Mean TSI Value	Existing 2000-2006 Mean Value	Target TSI Value	Target Value	Water quality improvement needed
Chlorophyll a	72	69 ug/L	<65	<33 ug/L	Decrease 109%
secchi Depth	72	0.42 m	<65	>0.7 m	Increase 67%
Total Phosphorus	NA[1]	302 ug/L	NA	<72 ug/L	Decrease 319%

1. Not applicable

General description of the pollutant
The TP load is directly related to the summer algae blooms. Although it is not the only factor in algal productivity (light attenuation and clouds also affect algal growth), excess TP is the primary reason for blooms of algae and the resulting turbidity.

Inorganic suspended solids (i.e. non-algal turbidity) also contribute to lake turbidity. Most TP is attached to soil particles, therefore a reduction in phosphorous entering a water body results in a reduction of sediment and the turbidity it causes. In other words, inorganic turbidity is reduced together with algal turbidity. Future monitoring will determine if the targeted phosphorus reductions and corresponding reduction in suspended solids loading results in achievement of the TSI targets for chlorophyll and secchi depth.

Selection of environmental conditions
The critical condition for which the chlorophyll and secchi depth TSI targets apply is the growing season, April through September. It is during this period that nuisance algal blooms are prevalent. The existing and target TP concentrations for the lake are expressed as annual averages as are the TP load estimates calculated for the existing and maximum allowable loads.

Potential pollution sources
There are no permitted point sources in the watershed. External watershed loads and internal loads recycled from bottom sediment are the nonpoint sources that adversely affect water quality in East Lake. The potential nonpoint sources are agricultural activities, inadequate septic tank systems, wildlife, residential runoff, atmospheric deposition, and internal recycling loads.

Natural background conditions
The only natural background condition is atmospheric direct deposition to the lake surface. The phosphorus load attributed to direct deposition is included separately in the BATHTUB lake model. Based on a review of available literature and the default values used in the BATHTUB model, estimated direct deposition is an annual average areal load of 3 $mg/m^2/yr$ giving a total annual load of 3 pounds. Groundwater is not a natural background condition since it originates as precipitation infiltration and land use has a strong influence on the pollutant load it carries. All groundwater contributions were included in the total stream flow load in the GWLF/BasinSims watershed model.

Water body pollutant loading capacity
The chlorophyll and secchi depth targets were related through the BATHTUB lake nutrient model to total phosphorus. The load capacity is the annual average TP load East Lake can receive and still meet the chlorophyll and secchi depth targets. Based on meeting the annual average TP concentration of 72 ug/l estimated by the BATHTUB model, the annual average loading capacity is 134 lbs/year.

Criteria for water quality standards attainment
Iowa does not have numeric water quality criteria for algae or turbidity. The primary cause of the East Lake algae and turbidity impairments are algal blooms caused by excessive nutrient input to the lake. Secondary causes of turbidity are inorganic suspended solids in watershed runoff and from resuspension of lake sediment.

The criteria for assessing lake algae and turbidity impairment are based on TSI scores for chlorophyll and secchi depth. The 305b assessment impairment thresholds for nuisance conditions are TSI values of 65 for both chlorophyll and secchi depth, giving a target chlorophyll concentration of 33 ug/l and a target secchi depth of 0.7 meters. The average annual TP concentration goal for these targets has been estimated using the BATHTUB model and is 72 ug/l. Appendix E – Carlson's Trophic State Index contains a more detailed explanation of the TSI and its use in water quality assessments.

Inorganic suspended solids (non-algal turbidity) also contribute to lake turbidity. Since load reductions from phosphorus sources will require reductions in sediment and suspended solids loads, the targeted pollutant is phosphorus. Monitoring will determine if the targeted phosphorus reductions and corresponding reduction in suspended solids results in achievement of the chlorophyll and secchi depth targets.

3.3. Pollutant Source Assessment

There are three quantified phosphorus sources for East Lake in this TMDL. The first of these sources is the phosphorus from the watershed areas draining into the lake. The second is the phosphorus recycled from lake sediments. The third is natural background atmospheric direct deposition. Estimates of watershed phosphorus loads are calculated in the GWLF/BasinSims model. An estimate of the internal recycle phosphorus load is calculated in the BATHTUB model, as is the direct deposition load.

Identification of pollutant sources
The TMDL approach is to separate pollutant sources into those that are regulated by discharge permits from those that are not. Point sources are those that are permitted and nonpoint sources are those that are not

<u>Point Sources</u>: There are not any permitted point sources in the East Lake watershed.

<u>Nonpoint Sources</u>: Phosphorus is delivered to the lake from external watershed and internal recycled nonpoint sources. The internal recycled phosphorus load is estimated to be more than half of the load to the lake. The external load and internal loads are 308 and 425 lbs/year, respectively. Figure 5 shows the relative external and internal loads.

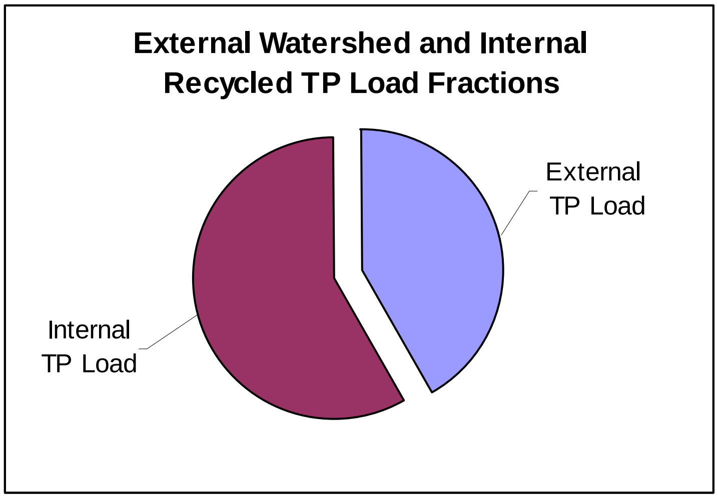

Figure 5. External and internal load fractions

Table 5 and Figure 6 show the total phosphorus loads for the external watershed sources estimated by the GWLF/BasinSims watershed model. Much of the external nonpoint source phosphorus delivered to the lake is from row-crop landuses. Besides row-crop and other agriculturally related uses such as grasslands, geese are a significant external source of phosphorus.

Table 5. Total Phosphorus loading by land use

Source Land Use	Area, acres	Existing Total-P Load (lb/year)	Existing Total P Unit Load (lb/acre/year)
CB[1]–conv. till	9.8	10.4	1.06
CB-mulch till	19.8	54.0	2.72
CB-OMMM[2] conv.	44.9	39.2	0.87
Farmstead	11.9	2.4	0.20
Grazed grass	45.7	31.5	0.69
Ungrazed grass	68.7	28.2	0.41
Parkland	8.7	2.0	0.23
Residential	27.6	9.5	0.34
Road and railroads	22.1	7.3	0.33
Timber	37.6	19.2	0.51
Surface Water	13.0	0.9	0.07
Groundwater	NA	21.4	NA
Geese	NA	65.0	NA
Septic systems	NA	17.4	NA
TOTAL	**309.7**	**308.6**	**1.00**

1. Corn soybean rotation; conventional tillage
2. Corn-soybean-oats-meadow-meadow-meadow-rotation; conventional tillage

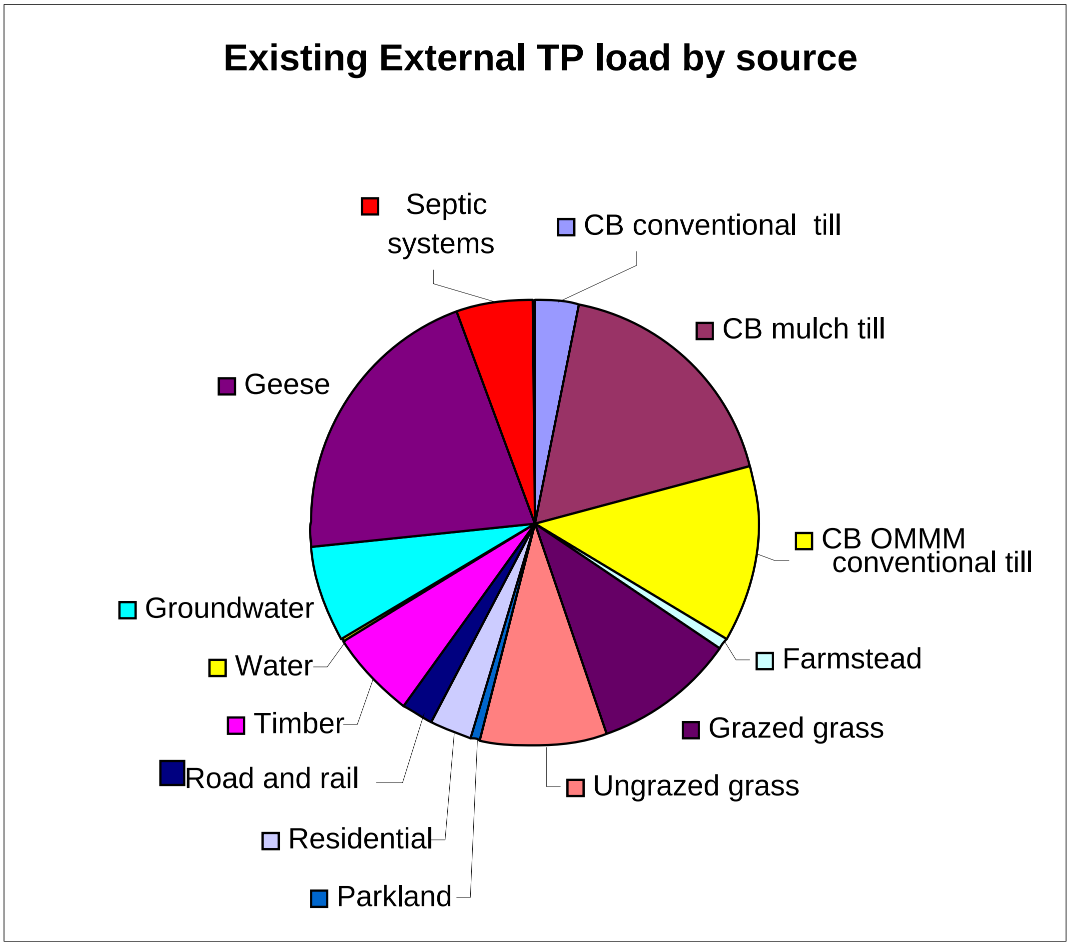

Figure 6. External watershed TP loads to East Lake by source

Existing load
The annual total phosphorus load to East Lake consists of external watershed loads, internally recycled loads, and direct deposition. The existing watershed load based on the GWLF/BasinSims model is 308 lbs/year. The internal load is 425 lbs/year as estimated using the BATHTUB model. The direct deposition load is 3 lbs/year. The total average annual load is 736 lbs/year. The watershed and lake modeling are described in Appendix D, Analysis and Modeling.

Departure from load capacity
The targeted total phosphorus load capacity for East Lake is 134 lbs/year, 88 lbs/year externally from the watershed, 43 lbs/year from internal recycle, and 3 lbs/year from direct deposition. The existing total load is estimated to be 736 lbs/year. The estimate for the external watershed load is 308 lbs/year, for the internal load is 425 lbs/year, and for the direct deposition load is 3 lbs/year. The difference between external and internal target and existing loads are 220 and 382 lbs/year, respectively. Direct deposition loads are considered constant. The target and existing external, internal, and total TP loads are shown in Figure 7.

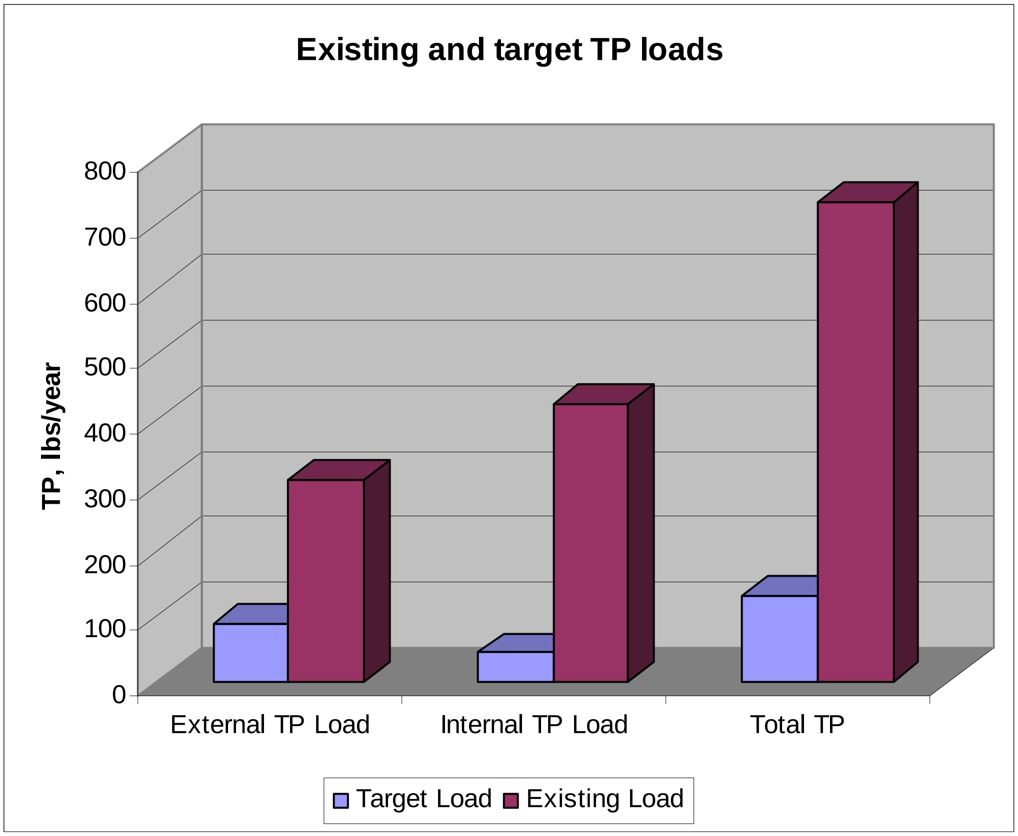

Figure 7. Existing and target external and internal TP loads (does not include direct deposition load of 3 lbs/year)

Linkage of Sources to Target
The phosphorus load to East Lake originates entirely from external watershed and internally recycled nonpoint sources as well as a small amount directly deposited on the lake surface (0.005 of the total load). The watershed sources have been linked to the impairment using the GWLF/BasinSims model to estimate monthly and annual phosphorus delivery. The internal and directly deposited loads have been linked to the nuisance algae condition using the BATHTUB lake nutrient model.

Allowance for pollutant load increase
An allowance for increased phosphorus loading was not included in this TMDL. The Clarke County Conservation Board maintains the entire shoreline around the lake. Much of watershed landuse is in agricultural production with row-crop predominating. A significant change in watershed land use is unlikely.

3.4. Pollutant Allocation

Wasteload allocation
There are not any permitted point sources in the East Lake watershed. Therefore, the sum of the wasteload allocations is zero.

Load allocations
The total phosphorus load to East Lake has two components, the loads from the watershed and the loads from turbulent internal recycling of phosphorus from lake sediments. The loads from the watershed were estimated using the GWLF/BasinSims model as described in Appendix D and in the TMDL Support Documentation. The internal loads were estimated using BATHTUB in-lake nutrient modeling.

External Watershed Loads: The watershed load allocation was developed using the seven year summarized output (2000 to 2006) from GWLF/BasinSims. The existing external TP load is 308 lbs/year while the load allocation is 88 lbs/year. A ten percent margin of safety has been applied to the estimated allowable loads generated by GWLF/BasinSims in the allocation spreadsheet. Table 6 shows the total load allocation as well as a potential allocation distribution by watershed source. The overall load reduction required is 71.4%.

Table 6. Potential load allocations by land use

Source	Area, acres	Existing Total-P Load (lbs/yr)	Allocated Total-P Load (lbs/yr)	Percent reduction needed
CB[1]–conv. till	9.8	10.4	4.4	*57.4%*
CB-mulch till	19.8	54.0	15.4	*71.4%*
CB-OMMM[2] conv.	44.9	39.2	13.2	*66.3%*
Farmstead	11.9	2.4	1.2	*50.0%*
Grazed grass	45.7	31.5	6.3	*80.0%*
Ungrazed grass	68.7	28.2	15.4	*45.3%*
Parkland	8.7	2.0	1.2	*40.0%*
Residential	27.6	9.5	4.4	*53.5%*
Road and railroads	22.1	7.3	1.5	*80.0%*
Timber	37.6	19.2	3.8	*80.0%*
Surface Water	13.0	0.9	0.9	*0.0%*
Groundwater	0.0	21.4	15.4	*27.8%*
Geese	0.0	65.0	3.2	*95.0%*
Septic systems	0.0	17.4	0.9	*95.0%*
TOTAL	**310**	**308**	**88**	**71.4%**

1. Corn soybean rotation; conventional tillage
2. Corn-soybean-oats-meadow-meadow-meadow-rotation; conventional tillage

GWLF/BasinSims output has been charted in Figure 8 to show the distribution of the external watershed TP load over the year displayed as monthly existing and allocated TP loads plotted with the average monthly stream flow. (The stream flow volume is the sum of the groundwater and runoff in centimeters multiplied by the watershed area of 297 acres.) The average monthly allocation, 3.33 kg/month (7.33 lbs/month) is plotted as a horizontal line on the chart to provide a reference for the existing and allocated loads. The allocation is distributed unevenly through the year because geese load reduction must occur in the winter months when most of the population is on the lake and loads from the watershed are higher during wet months.

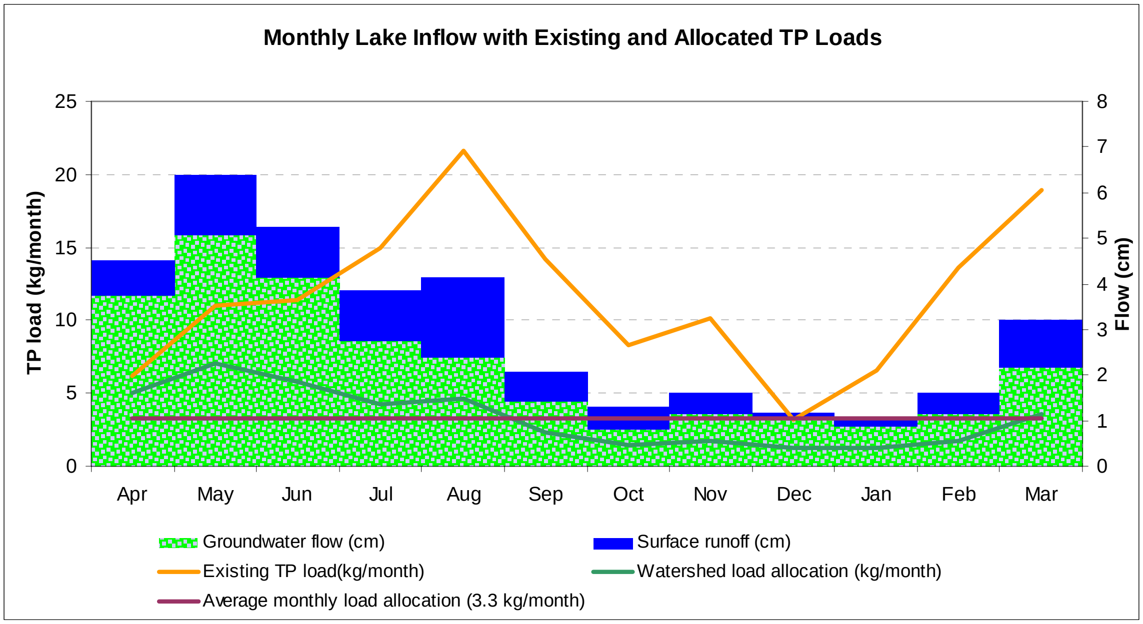

Figure 8. Estimated existing and allocated TP loads for average monthly stream flow (runoff + groundwater)

Internal Recycled Load Allocation: The existing internal TP load is estimated to be 425 lbs/year. Based on BATHTUB lake nutrient modeling, this load must be reduced 90 percent. Therefore, the internal allowable TP load is 43 lbs/year. The internal load allocation is the allowable TP load less a 10 percent MOS. The internal load allocation is 38.7 lbs/year.

Total Load Allocation (LA): The total load allocation for East Lake is the sum of the external and internal load allocations and the direct deposition load. This is 129.7 lbs/year as shown in Table 7.

Table 7. Maximum Annual Average Load Allocations

Source	**Annual Average TP Allocation**
External watershed LA	88 lbs/year (MOS applied)
Internal recycle LA	38.7 lbs/year (MOS applied)
Direct deposition to lake surface	3 lbs/year
Total LA	**129.7 lbs/year**

Federal regulations require that all TMDL reports include a daily maximum load. Table 8 shows the daily allowable TP load less a 10 percent MOS for an external load allocation of 19.3 lbs/day and an internal load allocation of 0.11 lbs/day. Section 3.5, Total Maximum Daily Load Summary, details the development of the daily load allocations.

Table 8. Maximum Daily Load Allocations

Source	Maximum Daily TP Allocation
External Watershed LA	19.3 lbs/day (MOS applied)
Internal Recycle LA	0.11 lbs/day (MOS applied)
Total LA	**19.41 lbs/day**

Margin of safety
The procedures used to provide the margin of safety (MOS) for the maximum annual average load and maximum daily load are different.

MOS for Maximum Annual Average Load: The explicit numeric margin of safety for this TMDL has two components, one for external watershed TP loads and one for internal recycle TP loads.

The external load MOS is a 10 percent decrease in the allocation for the maximum average annual load. This decrease is accounted for in the allocation spreadsheet calculations (*ELO Allocations 3.xls*). The hydrology and total phosphorus loads used in the allocation spreadsheet are from GWLF/BasinSims modeling output.

The internal load MOS is a 10 percent reduction of the allowable recycle TP load, i.e., for the estimated internal load of 43 lbs/year, the internal MOS is 4.3 lbs/year. The internal load allocation after the MOS is applied is 38.7 lbs/year (43-[43*0.1] = 38.7 lbs/year).

MOS for Maximum Daily Load: The margin of safety for the maximum daily load is an explicit 10% reduction in the external and internal allocated loads. There is also an implicit MOS in the external watershed load allocation. The daily maximum allocation is based on a 2-year return storm but the design day is a 10-year return storm. This results in a higher fractional TP reduction of 82.5 percent for the external watershed load.

3.5. Total Maximum Daily Load Summary

Nutrient impaired lakes, such as East Lake, do not function hydrologically, ecologically or chemically in daily time steps. Average annual targets as previously described are more appropriate for analysis and modeling purposes. In addition, natural systems undergo extreme daily fluctuations and assessments using annual averages are better suited for bringing the system into compliance with water quality standards. Therefore, the TMDL is calculated based on average annual maximum load as well as maximum daily load. The daily load is included to meet regulatory requirements.

Average Annual Maximum Load
The TMDL based on a maximum average annual TP load is:

TMDL = WLA (zero lbs/year) + LA (129.7 lbs/year) + MOS (4.3 lbs/year) = 134 lbs/year

The procedures and information used to calculate these loads have been described previously.

Total Maximum Daily Load
Federal regulations require that a maximum daily load be calculated for this report. As represented here, the total phosphorus load for East Lake has two major components:

- the external watershed load than consists mostly of TP from precipitation driven erosion, and
- the internal recycle load from the turbulent resuspension of sediment.

The external watershed load varies considerably over the year, driven by rainfall. This also includes the small (0.01 lbs) load from direct deposition to the lake's surface. The internal recycle load is assumed more consistent over time. The total daily load is the sum of these two components for the design day load. The design day is the 10-year return 24-hour duration storm.

External Watershed Daily LA, MOS, and TMDL: The 2-year return 24-hour duration storm is generally accepted as the condition that defines the maximum daily erosion load for TMDL purposes. During precipitation events, nearly all of the delivered TP is attached to sediment. The 2-year return 24-hour duration event in the East Lake region is 3.14-inches. Figure 9 shows daily precipitation from 1997 through 2006. Two days in this 10-year period had rainfall about the same as the 2-year storm, 3.21 and 3.09 inches. Altogether, five events were equal to or greater than the 2-year 24-hour storm.

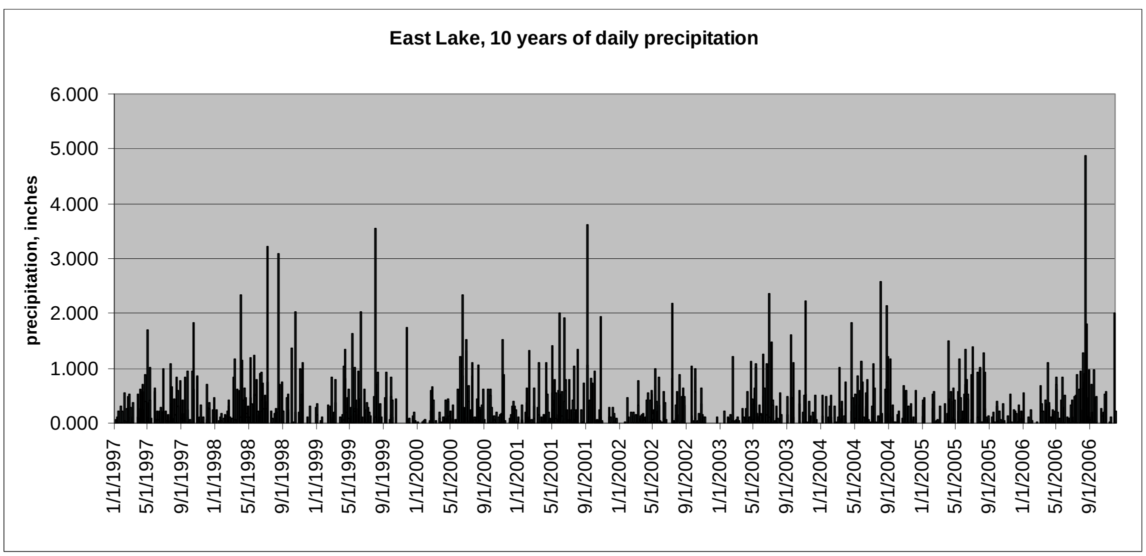

Figure 9. Daily precipitation from 1997 to 2007

The maximum daily rainfall during this 10-year period occurred on August 14, 2006 and was 4.87 inches. This is similar to the regional 10-year return 24-hour duration storm of 4.67 inches. The GWLF/BasinSims generated daily TP load for the August 14, 2006 event was 122 lbs, for the month of August was 213 lbs, and for the entire 2006 water year was 303 lbs. Table 9 shows the two 2-year return events, the single 10 year return event, the daily, monthly, and annual modeled loads for each, the average for the two 2-year storms, and the daily loads with a 71 percent load reduction. This is the modeled existing load reduction needed to achieve the load allocations.

The reduced watershed load for the averaged 2-year storms is 21.4 lbs/day. This load applies to the 10-year return storm and reduces the existing TP load by 82.5 percent. The load allocation, using a 10 percent MOS of 2.1 lbs, is 19.3 lbs/day. The maximum daily load from external watershed sources is 21.4 lbs/day.

Table 9. Events and modeled loads used for development of maximum daily loads

Event date	24 hour rainfall, inches	Modeled daily load, lbs/day	Modeled load for month and year, lbs/time	Daily load with 71% reduction, lbs/day
7/7/1998 2 yr event	3.21	81.3	923 / 389	23.6
8/14/1998 2 yr event	3.09	65.8	75 / 389	19.1
Average for 2 yr storms	3.15	73.6	84 / 389	21.4
8/14/2006 10 yr event	4.87	121.8	213 / 303	35.3

Calculation of the TMDL based on a maximum daily TP load estimated using the 24-hour 10-year return storm.

External TMDL = WLA (zero lbs/day) + LA (19.3 lbs/day) + MOS (2.1 lb/day) = 21.4 lbs/day

Internal Recycle LA, MOS, and TMDL: It is assumed that the internal recycle load caused primarily by turbulence is constant throughout the year. Therefore, the internal maximum daily load is the average annual internal TP load divided by 365. In the BATHTUB lake nutrient modeling the estimated existing internal load is 425 lbs/year and the daily load is 1.2 lbs/day. The allocation for internal load is 10 percent of the existing load, less a 10 percent MOS, or 0.11 lbs/day using an MOS of 0.01 lbs/day. The internal maximum daily load is 0.12 lbs/day.

Internal TMDL = WLA (zero lbs/day) + LA (0.11 lbs/day) + MOS (0.01 lbs/day) =0.12 lbs/day

Total Maximum Daily Load: The equation for the total maximum daily load shows the total phosphorus load capacity.

TMDL = WLA (zero lbs/day) + LA (19.3 lbs/day external + 0.11 lbs/day internal) + MOS (2.1 +0.01) = 21.52 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 recognizes that guidance is important to attaining the TMDL goals. Local watershed managers and citizens should use this report as a general guideline for decision making and planning. The best management practices (BMPs) discussed below act as a set of tools to direct watershed activities towards achievement of water quality goals. Ultimately, it is up to land managers, citizens, and local conservation professionals to determine how best to apply them.

4.1. Implementation Approach and Timeline

The best way to reduce algae blooms in East Lake is to lower the lake phosphorus concentration by systematically reducing watershed and internally recycled TP loads starting with the most significant sources. As shown previously in Figures 5 and 7 (Section 3.3), the largest TP source is turbulent recycling of sediment in the lake itself. Most of this turbulence is caused by carp and other rough fish and their removal from the lake should be a high priority.

The existing external watershed loads and potential load allocations for the different land uses are shown in Figure 10. The suggested allocations in this figure reduce the total watershed TP load to the TMDL load targets.

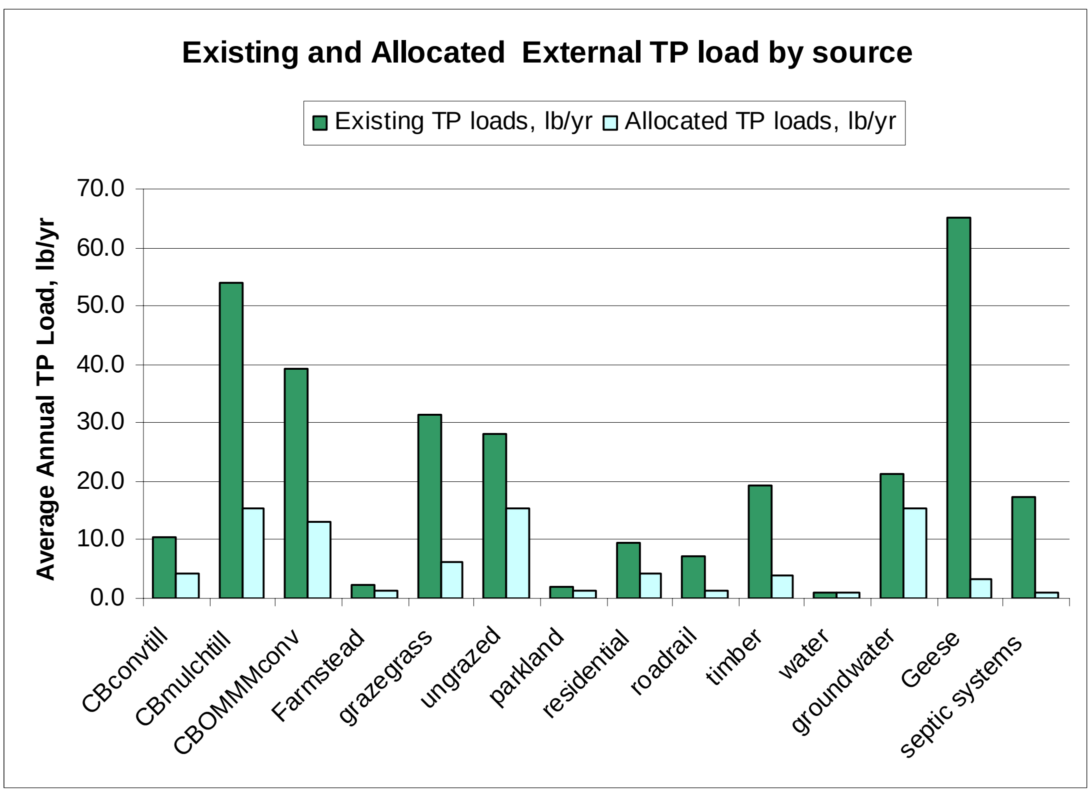

Figure 10. Existing and reduced loads needed to achieve allocation goals

As can be seen from the figure, combined agricultural activities are the biggest phosphorus source and cover 65 percent of the watershed area. The most intensive agricultural activities make up 43 percent of watershed land uses and ungrazed grasslands make up 22 percent. Table 6 in Section 3.4 shows the reduced TP loads seen in Figure 10 as a percent reduction of the existing load. The suggested land use reductions should be managed to give the most practical and effective reductions that achieve the allocated load. As an example, unit reductions (lbs/acre) for ungrazed grassland cannot be expected to be as great as those that can be achieved for row-cropped land uses where management of erosion and fertilizer application can have a significant impact.

In monitoring, data analysis, and modeling there is always some uncertainty as to how representative sampling and models are of actual conditions and system dynamics. While some natural variability and data gaps are inevitable, it is felt that the procedures used in this report are a reasonable explanation of the pollutant sources and water quality situation. In the TMDL report, uncertainty is dealt with through the application of a margin of safety.

As the stakeholders move to implementation of phosphorus reductions, adaptive management of remediation activities and best practices can be a sensible and efficient way to ensure that these measures are having the desired impact. Adaptive management reduces both watershed and recycled loads by incrementally applying best management practices and monitoring the resulting water quality to see if progress is being made towards achieving goals. External watershed load reduction requires land management changes and control of geese populations that take time to implement. For these reasons, the following watershed improvement timetable is recommended:

- Reduce watershed loading from 308 lbs/year to 160 lbs/year by 2012, mostly by decreasing the numbers of geese and implementing best management practices on agricultural activities.
- Reduce internal loading from 425 lbs/year to 100 lbs/year by 2010 largely by removing carp from the lake.
- Reduce watershed loading from 160 lbs/year to 88 lbs/year using best management practices (BMP) by 2015.
- Reduce internal recycle loads from 100 lbs/year to 40 lbs/year by 2012.

Phosphorus delivery from the East Lake watershed can be reduced by utilizing BMPs that may include the following.

- Nutrients applied to production agricultural ground should be managed to achieve the optimum soil test category. Over the long term, maintaining this soil test category is the most profitable for producers.
- Manure and commercial fertilizer should be incorporated while controlling soil erosion. Incorporation physically separates phosphorus from surface runoff.
- Adoption of no till and strip tillage reduced tillage systems should be encouraged.
- A fall-seeded cover crop incentive program should be initiated that targets low residue producing crops (e.g. soybeans) or low residue crops after harvest (e.g.

corn silage fields). This practice increases residue cover on the soil surface and improves water infiltration.
- Landscape diversity should be encouraged to reduce runoff volume and velocity by strategically locating filter strips and grass waterways.
- Terraces, ponds, and other erosion and water control structures should be appropriately located in the watershed to control erosion and reduce delivery of sediment and phosphorus to the lake.
- The number of open vertical intakes connected to tile lines in cropland and road ditches should be reduced or converted to filtered systems. Vertical intakes provide a short fast trip to East Lake for soil particles and attached phosphorus.

Internal loading can be controlled largely through the management of carp and other rough fish. The mechanisms of resuspension and recycle are rough bottom feeding fish and wind-driven waves and currents in shallower parts of the lake. Historically, carp have been a problem at East Lake and most internally recycled loads are due to a large carp population and aggravated by wind and wave action. Internal loads can be decreased by:

- Significantly reducing the numbers of bottom feeding fish,
- Minimizing the factors that contribute to turbulence in shallow areas, and
- Encouraging the growth of rooted aquatic plants in shallow areas to stabilize bottom sediments.

5. Future Watershed and Water Quality Monitoring

Watershed and in-lake water quality monitoring are important elements in any plan to improve East Lake. It plays key roles in both the analysis and modeling of pollutant sources and water quality. Monitoring is necessary to track the effectiveness of improvement measures taken in the watershed and in the lake itself.

5.1. Monitoring to Track TMDL Effectiveness

Monitoring similar to that done for the ISU Lake Study and the 2005 and 2006 UHL sampling will continue at East Lake. This monitoring, three to six samples in the growing season, will provide enough information to assess the waterbody for 305b reporting purposes and to detect trends over time if evaluated using the right statistical tools. However, it will not be adequate for mechanistic understanding and problem diagnosis.

Monitoring that will support analysis and modeling would need to include the following:

- Continuous measurement of flow through the lake discharge structure to accurately determine lake detention time, help calibrate the watershed model, and provide important data on how TP and chlorophyll respond to hydrologic conditions,
- Biweekly sampling of important water quality variables that supports a mechanistic representation of the lake system, and
- Continuous measurement of flows from the lake's primary tributary and water quality sampling during rainfall events.

5.2. Monitoring to Support Watershed Improvement Projects

Modeled watershed scenarios can estimate potential TP reduction as source characteristics or land uses are modified. For example, areas that are now row crop could be represented as grasslands in a watershed model to show how loads to East Lake might be reduced. Improved lake sampling and flow measurement may permit the modeling and evaluation of seasonal changes in algal productivity and the impact of precipitation. Phosphorus from septic tanks and geese can be reduced in a model to show how algal blooms respond to specific tributary flow conditions.

Ideally, modeling should be started prior to the design of monitoring systems so that the information needed for an analytical or modeling procedure is available. In lieu of that, the first modeling effort should take the existing data and show where additional sampling is needed. Well designed follow-up monitoring can fill the information gap, providing improved representation and understanding of the lake system.

5.3. Monitoring to Support Further Understanding of the Lake System

Watershed hydrology and East Lake response to it are best understood by a combination of continuous monitoring of inflow and outflow rates, dissolved oxygen, chlorophyll, , and phosphorus concentrations, temperature, and turbidity. The variability in lake systems from year to year is considerable and averaging available data over a few or many years will likely conceal important responses to changing hydrology and other factors.

For example, the trophic condition of East Lake seems to be very different for dry and wet years. In 2005 and 2006, sampling was done at a higher frequency than had been done before; nine samples were taken during the growing season. The data shows extremely elevated chlorophyll concentrations in 2005, as high as 232 ug/l. In 2006, the highest chlorophyll concentration was 65 ug/l.

The GWLF/BasinSims watershed model was used to generate estimated flow to the lake for both of these years and the resulting hydrographs for the 2005 and 2006 growing seasons (April through November) were dramatically different. The modeled total annual flow for 2006, a wet year, was about three times higher than for 2005, a dry year. Figures 11 and 12 show the TP, chlorophyll and secchi depth data plotted with the modeled hydrographs. Both charts are plotted at the same scale for comparison.

The highest average daily flow in 2005 was 7,000 m^3/day and for 2006 was 65,100 m^3/day, an order of magnitude difference. Oddly enough, the average TP concentrations for the two years were not very different, the 2005 mean TP was 291 ug/l and the 2006 mean TP was 259 ug/l. Also interesting are the modeled watershed TP loads to the lake for these two years. The 2005 load was 245 lbs/year and the 2006 load was 304 lbs/year. The wet year has the higher TP load but lower chlorophyll concentrations. The dry year has a lower TP load but much higher chlorophyll concentrations.

One can speculate on what the reasons are for these results:

- The flushing rates for the two years are so different that watershed-loading rates are less important than might be expected.
- The internal recycle has a greater impact on chlorophyll and attendant algae blooms in dry years.
- The year 2005 was a big one for East Lake geese.

With only two years of frequent interval sampling data, many questions posed by these two charts remain unanswered. Additional monitoring, data analysis, and modeling is needed to understand the significance of these observations.

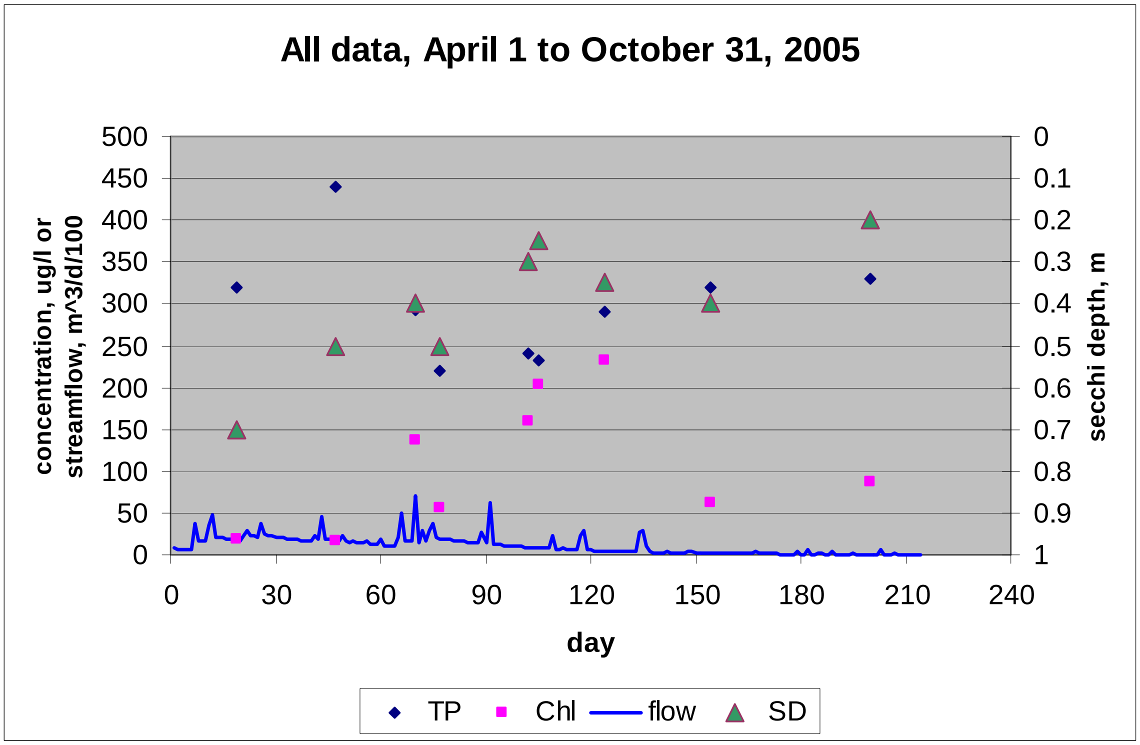

Figure 11. Modeled flow and observed data for the 2005 growing season

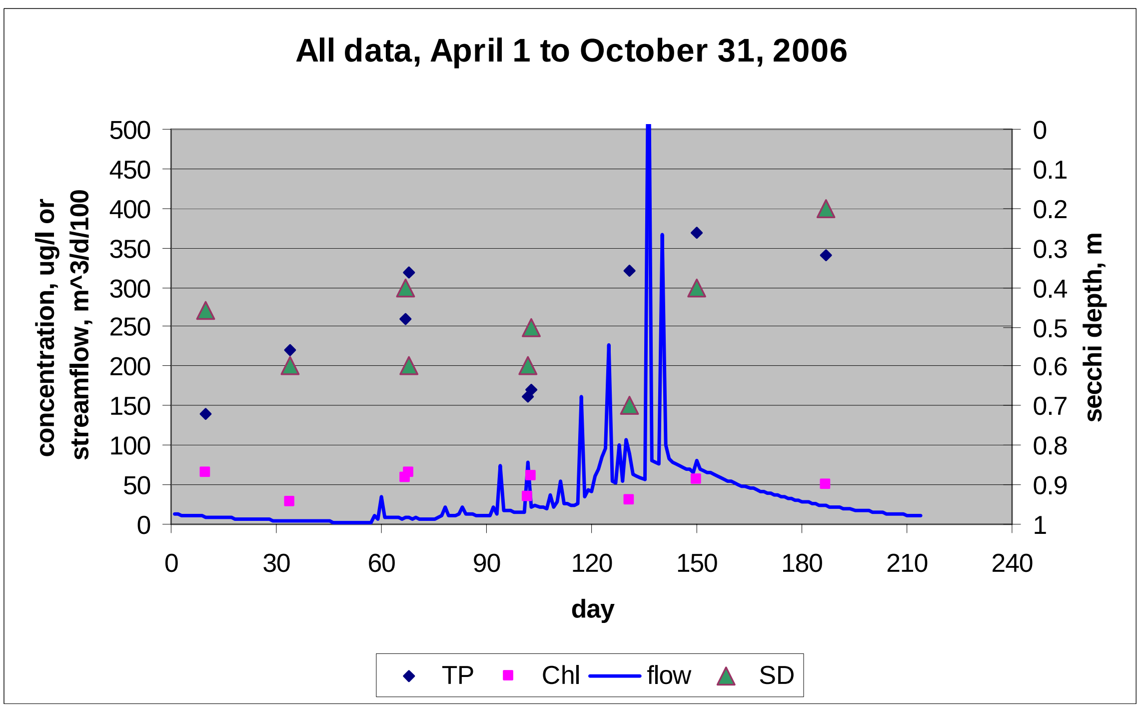

Figure 12. Modeled flow and observed data for the 2006 growing season

6. Public Participation

Public involvement is important in the TMDL process. The landowners, tenants, and citizens who directly manage the land and live in the watershed determine the water quality in East Lake. Efforts were made during the development of this TMDL report to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in East Lake.

6.1. Public Meetings

A preliminary meeting with the Clarke County Conservation Board Executive Director, Anita Foland, was held on September 19, 2007 at East Lake Park. IDNR staff toured the park and the watershed and obtained important information for the development of this report. The Clarke County Conservation Board owns and operates the park and lake.

The draft TMDL was available for public comment from January 17 through February 18, 2008. A public meeting was held on January 29, 2008 in Osceola to present and discuss the Draft TMDL for East Lake Osceola. The meeting was attended by members of the Clarke County Conservation Board, the Director of the Clarke County Conservation Board, and the Natural Resources Conservation Service.

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8. Appendices

Appendix A --- Glossary of Terms and Acronyms

303(d) list:	Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface water bodies (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 assessment of the state's water bodies ability to support their general and designated uses. Those found to be not 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. States receive EPA grants to provide technical & financial assistance, education, and monitoring for local nonpoint source water quality improvement projects.
AFO:	Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed to become concentrated.
Base flow:	The fraction of stream flow from ground water.
BMP:	Best Management Practice. A general term for any structural or upland soil or water conservation practice. Examples are terraces, grass waterways, sediment retention ponds, and reduced tillage systems.
CAFO:	Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof.
Cyanobacteria (blue-green algae):	Phytoplankton that are not true algae but can photosynthesize. Some species produce toxins that can be harmful to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecologic activities that a specific water body is intended to support. See Appendix B for a description of general and designated uses.
DNR (or IDNR):	Iowa Department of Natural Resources.
Ecoregion:	A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.
EPA (or USEPA):	United States Environmental Protection Agency.
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 water bodies must meet to satisfy public needs and expectations. See Appendix B for a description of general and designated uses.

GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
Gully erosion:	Soil loss occurring in upland channels and ravines that are too wide and deep to fill with traditional tillage methods.
HEL:	Highly Erodible Land. Land defined by NRCS as having the potential for long term annual soil losses that exceed the tolerance for an agricultural field eightfold.
LA:	Load Allocation. The fraction of a waterbody pollutant load that comes from *nonpoint sources* in a watershed.
Load:	The total amount (mass) of a particular pollutant in a waterbody.
MOS:	Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.
Nonpoint source pollutants:	Contaminants that originate from diffuse sources not covered by NPDES permits.
NPDES:	National Pollution Discharge Elimination System. A federal system of regulatory discharge controls that sets pollutant limits in permits for point source discharges to waters of the United States.
NRCS:	Natural Resources Conservation Service (United States Department of Agriculture). Federal agency that provides technical assistance for the conservation and enhancement of natural resources.
Periphyton:	Algae that are attached to stream substrates (rocks, sediment, wood, and other living organisms).
Phytoplankton:	Collective term for all suspended photosynthetic organisms that are the base of the aquatic food chain. Includes algae and cyano-bacteria.
Point source pollution:	Point sources are regulated by an NPDES permit. Point source discharges are usually from a location of flow concentration such as an outfall pipe.
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).
Riparian:	The area near water associated with streambanks and lakeshores and the physical, chemical, and biological characteristics that cause them to be different from dry upland sites.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Secchi disk:	A device used to measure transparency in water bodies. The greater the secchi depth, the greater the water transparency.

Sediment delivery ratio:	The fraction of total eroded soil that is actually delivered to the stream or lake.
Seston:	All suspended particulate matter (organic and inorganic) in the water column.
Sheet & rill erosion	Water eroded soil loss that occurs diffusely over large flatter landscapes before the runoff concentrates.
Storm flow (or stormwater):	The fraction of stream flow that is direct surface runoff from precipitation.
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.
TMDL:	Total Maximum Daily Load. The maximum allowable amount of a pollutant that can be in a waterbody and still comply with the Iowa Water Quality Standards and support designated uses.
TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland. Index values for TP, chlorophyll, and transparency are calculated for this purpose.
TSS:	Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column. It is defined by the lab filtration procedures used to measure it.
Turbidity:	A measure of the scattering and absorption of light in water caused by suspended particles.
UHL:	University Hygienic Laboratory (University of Iowa). Collects field samples and does lab analysis of water for assessment of water quality.
USGS:	United States Geologic Survey. Federal agency responsible for flow gauging stations on Iowa streams.
Watershed:	The land surface that drains to a particular body of water or outlet.
WLA:	Waste Load Allocation. The allowable pollutant load that a point source NPDES permitted point source may discharge without exceeding water quality standards.
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.
WWTP:	Waste Water Treatment Plant. A facility that treats municipal and industrial wastewater so that the effluent discharged complies with NPDES permit limits.
Zooplankton:	Collective term for small suspended animals that are secondary producers in the aquatic food chain and are a primary food source for larger aquatic organisms.

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 used to assess water bodies for support of their aquatic life, recreational, and drinking water uses. There are different criteria for different waterbodies depending on their designated uses. All waterbodies must support the general use criteria.

General Use Segments

A general use water body does not have perennial flow or permanent pools of water in most years, i.e. ephemeral or intermittent waterways. General use water bodies are defined in IAC 567-61.3(1) and 61.3(2). General use waters are protected for livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses.

Designated Use Segments

Designated use water bodies maintain year-round flow or pools of water sufficient to support a viable aquatic community. In addition to being protected for general use, perennial waters are protected for three specific uses, primary contact recreation (Class A), aquatic life (Class B), and drinking water supply (Class C). Within these categories there are thirteen designated use classes as shown in Table B1. Water bodies can have more than one designated use. The designated uses are found in IAC 567-61.3(1).

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 --- East Lake Water Quality Data

The following two tables contain the monitoring data from the Iowa State University Lakes Study and the IDNR/UHL sampling. The means and coefficients of variation from these tables were used as the observed inputs for the BATHTUB water quality modeling.

Table C-1. ISU Lake Study monitoring data, 2000 to 2006

Sample Date	Total Phos. ug/l	Chlor-a, ug/l	secchi Depth, m	Total Nitrogen, mg/l	Inorganic Suspended Solids, mg/l	Volatile Suspended Solids, mg/l	Total Suspended Solids, mg/l
6/30/2000	406	18	0.48	5.02	4	7	11
7/26/2000	383	32	0.37	1.13	6	3	9
8/23/2000	337	46	0.25	2.43	5	3	8
5/31/2001	370	15	0.40	2.44	15	6	21
6/28/2001	436	61	0.65	2.67	14	18	32
8/1/2001	328	67	0.30	2.10	2	11	12
6/6/2002	219	93	0.30	1.39	14	23	37
7/11/2002	221	79	0.40	1.45	2	16	18
8/8/2002	234	26	0.50	1.79	6	6	12
6/5/2003	189	29	0.40	2.03	7	12	19
7/10/2003	332	32	0.32	2.32	12	23	35
8/7/2003	321	23	0.30	1.56	15	14	29
6/4/2004	323	73	0.35	1.76	15	9	24
7/1/2004	301	46	0.50	1.83	8	17	25
8/6/2004	316	100	0.45	1.88	4	12	16
6/9/2005	293	138	0.40	0.41	13	10	24
7/14/2005	232	203	0.25	2.88	3	22	25
8/2/2005	290	232	0.35	1.99	7	10	17
6/7/2006	318	65	0.60	1.97	8	9	17
7/11/2006	162	36	0.60	1.74	6	9	15
8/9/2006	320	30	0.70	2.64	1	8	9
Mean	**302**	**69**	**0.42**	**2.07**	**8**	**12**	**20**
Median	**318.0**	**46.2**	**0.4**	**2.0**	**7.2**	**10.2**	**17.9**
Std. Dev.	**70.71**	**58.42**	**0.13**	**0.88**	**4.93**	**5.91**	**8.50**
Coef. Of Var.	**0.23**	**0.85**	**0.31**	**0.43**	**0.62**	**0.50**	**0.43**

Table C-2. UHL/IDNR lake monitoring data, 2005 and 2006

Sample Date	Total Phos., ug/l	Chlor.-a, ug/l	Secchi Depth, m	Total Nitrogen, mg/l	Inorganic Suspended Solids, mg/l	Volatile Suspended Solids, mg/l	Total Suspended Solids, mg/l
4/19/2005	320	18	0.70	3.01	3	5	8
5/17/2005	440	17	0.50	3.04	1	2	2
6/16/2005	220	56	0.50	1.71	7	10	17
7/11/2005	240	160	0.30	8.00	9	22	31
9/1/2005	320	63	0.40	2.31	3	12	15
10/17/2005	330	87	0.20	3.91	2	50	52
4/10/2006	140	65	0.46	2.74	7	13	20
5/4/2006	220	28	0.60	6.15	6	7	13
6/7/2006	260	59	0.40	2.35	11	16	27
7/12/2006	170	61	0.50	2.15	14	14	28
8/28/2006	370	57	0.40	2.45	3	12	15
10/4/2006	340	50	0.20	3.11	4	29	32
Mean	281	60	0.43	3.41	5.8	16.0	21.7
Median	290.0000	58.0	0.430	2.9	5.0	12.5	18.5
Std. Dev.	87.3299	37.57	0.15	1.84	3.95	12.93	13.30
Coef. Of Var.	0.3110	0.63	0.35	0.54	0.68	0.81	0.61

Table C-3. East Lake Osceola TSI Values based on ISU Lake Study data

Sample Date	TSI (TP)	TSI (CHL)	TSI (SD)
6/30/00	91	59	71
7/26/00	90	65	74
8/23/00	88	68	80
5/31/01	89	57	73
6/28/01	92	71	66
8/1/01	88	72	77
6/6/02	82	75	77
7/11/02	82	74	73
8/8/02	83	63	70
6/5/03	80	64	73
7/10/03	88	65	76
8/7/03	87	61	77
6/4/04	87	73	75
7/1/04	86	68	70
8/6/04	87	76	72
6/9/05	86	79	73
7/14/05	83	83	80
8/2/05	86	84	75
6/7/06	87	72	67
7/11/06	78	66	67
8/9/06	87	64	65

Appendix D --- Analysis and Modeling

A set of models and spreadsheets evaluated available data and performed watershed and in-lake water quality modeling for East Lake. The watershed-loading model used was GWLF/BasinSims. The in-lake water quality model used was BATHTUB, a model developed by the U.S. Army Corps of Engineers to evaluate eutrophication dynamics in reservoirs and lakes. Generally, EPA accepts these two models for TMDL development and both can be freely downloaded from internet web sites. Adequate East Lake water quality, weather, and watershed data is available to use with these models and get reasonable results.

The GWLF/BasinSims watershed model uses the precipitation and temperature data from the nearby Osceola National Weather Service COOP station (IA6316). Land use data is from a watershed assessment done in 2006 by a retired NRCS employee working for IDNR. The factors used for erosion estimates are from IDNR GIS coverages. Soil information is from an IDNR GIS coverage based on SURGO data.

Besides the two models, several spreadsheets were developed for the following purposes:

- Analyze in-lake data,
- Create weather, transport, and nutrient files for GWLF/BasinSims,
- Transform GWLF/BasinSims output for use in BATHTUB,
- Evaluate and interpret BATHTUB and GWLF/BasinSims output.

The lake data from the ISU Lake Study and more recently from UHL, has been analyzed in a spreadsheet set up to calculate means, medians, standard deviations, and coefficients of variance. These values are used as BATHTUB model input.

The mean of all the ISU Lake Study data was used as the observed data input to the BATHTUB model. Mean GWLF/BasinSims output for the years matching the ISU data, 2000 to 2006, was used as the BATHTUB model tributary input.

Mean GWLF/BasinSims output is based on the weather information for the years of existing lake data, from 2000 to 2006. Both models can then be run for the individual years allowing for the changes in annual precipitation and nutrient loading to be evaluated against the in lake water quality impacts. The BATHTUB model output spreadsheet compares the predicted and observed water quality variables.

Modeling Procedures

The procedures used to evaluate TP loads to East Lake consist of:

- Estimates of the delivered loads from external watershed non-point sources using GWLF/BasinSims modeling,
- Estimates of the annual TP load to East Lake using measured in-lake phosphorus concentrations, estimated hydraulic detention time, and mean depth as inputs for the BATHTUB modeling,

- Estimates of the allowable TP loads at the target concentration (TP=72 ug/l) for the lake, using BATHTUB modeling.

The following flow chart outlines these procedures.

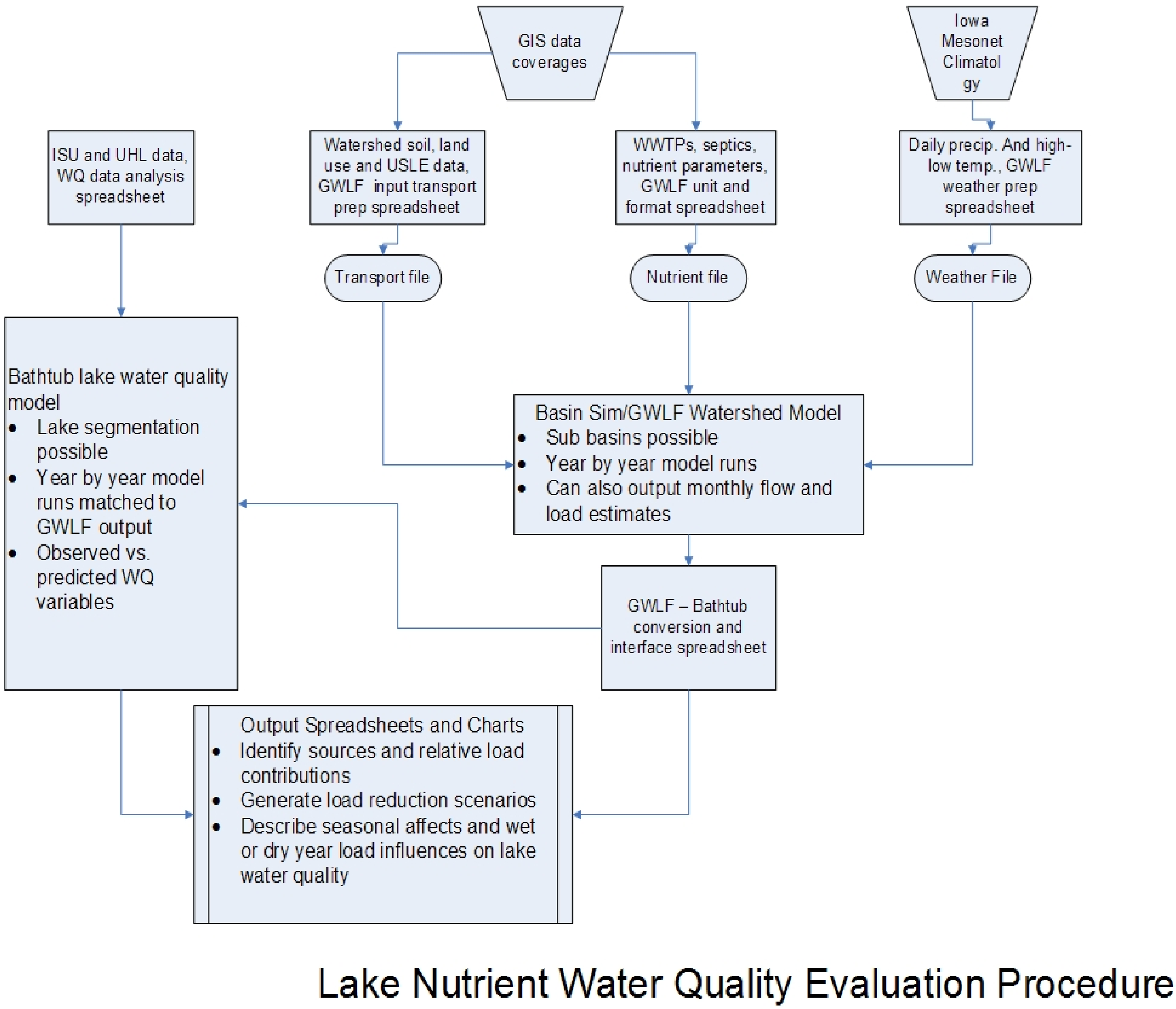

Figure 13. East Lake modeling flowchart

GWLF/BasinSims Watershed load estimates
The watershed load estimates are based on GWLF/BasinSims watershed modeling using temperature and precipitation data from a weather station in the City of Osceola, adjacent to East Lake Park. The period used as weather input to the model was April 1, 1997 to March 30, 2007. The sediment delivery ratio for East Lake is 33% based on the watershed size and ecoregion

These loads include the watershed non-point and point source loads, phosphorus recycled by resuspension of sediment, and phosphorus from direct rainfall and dry deposition. A small lake with numbers of geese and some rough fish such as carp, East Lake has a significant wildlife and recycled TP component.

BATHTUB model load response
The predicted values from the BATHTUB model for total phosphorus, chlorophyll and secchi depth are compared to the observed values from the in-lake monitoring data in the BATHTUB model output spreadsheet called *ELO existoutput.xls*. The model has been calibrated to account for the high TP concentrations seen throughout the year. The internal load has been adjusted to the watershed model loads and is estimated to be 10 mg/m^2/day. Multiplying the areal loads by the lake area in square meters and converting the resulting values from milligrams to pounds gives the annual internal load of 425 lbs/year.

Analysis and Model Documentation

The detailed data analysis and modeling specifics for the East Lake TMDL are contained in the spreadsheet files listed below in Table D-1. These spreadsheets are located in the folder *TMDL support documentation*.

Table D-1. List of Analysis and Model Documentation Spreadsheets

Spreadsheet file name	Description of contents
20 yr daily T and rain ELO2.xls	Temperature and precipitation data from the Osceola weather station.
ISU Study Data ELO.xls	Original water quality data from the ISU Lake Study.
Data Evaluation 7ELO.xls	Analysis and evaluation of all ISU Lake Study and UHL water quality data, 2000 to 2006.
Weather2006 to 2007.xls	Weather data from the Osceola weather station for 2006 and 2007
ELO GWLF monthly output.xls	GWLF/BasinSims output by month, source, and an averaged summary of all years output.
ELO GWLF daily output.xls	GWLF/BasinSims daily output.
ELO existoutput.xls	BATHTUB output for existing lake water quality conditions.
ELO TMDLoutput.xls	BATHTUB output for TMDL lake water quality conditions
ELO Allocations 3.xls	Watershed nonpoint source allocations made using the GWLF/BasinSims output summary

Appendix E --- Carlson's Trophic State Index

Carlson's Trophic State Index is a numeric indicator of the continuum of the biomass of suspended algae in lakes and thus reflects a lake's nutrient condition and water transparency. The level of plant biomass is estimated by calculating the TSI value for chlorophyll-a. TSI values for total phosphorus and secchi depth serve as surrogate measures of the TSI value for chlorophyll.

The TSI equations for total phosphorus, chlorophyll and secchi depth are:

$$TSI\ (TP) = 14.42 \ln(TP) + 4.15$$
$$TSI\ (CHL) = 9.81 \ln(CHL) + 30.6$$
$$TSI\ (SD) = 60 - 14.41 \ln(SD)$$

where

TP = in-lake total phosphorus concentration, ug/L
CHL = in-lake chlorophyll-a concentration, ug/L
SD = lake secchi depth, meters

The three index variables are related by linear regression models and *should* produce the same index value for a given combination of variable values. Therefore, any of the three variables can theoretically be used to classify a waterbody.

Table E-1. Changes in temperate lake attributes according to trophic state (modified from U.S. EPA 2000, Carlson and Simpson 1995, and Oglesby et al. 1987).

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	warm water fisheries only; 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	Centrarchid 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

Table E-2. Summary of ranges of TSI values and measurements for chlorophyll-a and secchi depth used to define Section 305(b) use support categories for the 2004 reporting cycle.

Level of Support	TSI value	Chlorophyll-a (ug/l)	Secchi Depth (m)
fully supported	<=55	*<=12*	*>1.4*
fully supported / threatened	55 → 65	*12 → 33*	*1.4 → 0.7*
partially supported (evaluated: in need of further investigation)	65 → 70	*33 → 55*	*0.7 → 0.5*
partially supported (monitored: candidates for Section 303(d) listing)	65-70	*33 → 55*	*0.7→ 0. 5*
not supported (monitored or evaluated: candidates for Section 303(d) listing)	>70	*>55*	*<0.5*

Table E-3. Descriptions of TSI ranges for secchi depth, phosphorus, and chlorophyll-a for Iowa lakes.

TSI value	Secchi description	Secchi depth (m)	Phosphorus & Chlorophyll-a description	Phosphorus levels (ug/l)	Chlorophyll-a levels (ug/l)
> 75	extremely poor	< 0.35	extremely high	> 136	> 92
70-75	very poor	0.5 – 0.35	very high	96 - 136	55 – 92
65-70	poor	0.71 – 0.5	high	68 – 96	33 – 55
60-65	moderately poor	1.0 – 0.71	moderately high	48 – 68	20 – 33
55-60	relatively good	1.41 – 1.0	relatively low	34 – 48	12 – 20
50-55	very good	2.0 – 1.41	low	24 – 34	7 – 12
< 50	exceptional	> 2.0	extremely low	< 24	< 7

The relationship between TSI variables can be used to identify potential causal relationships. For example, TSI values for chlorophyll that are consistently well below those for total phosphorus suggest that something other than phosphorus limits algal growth.

Appendix F --- Maps

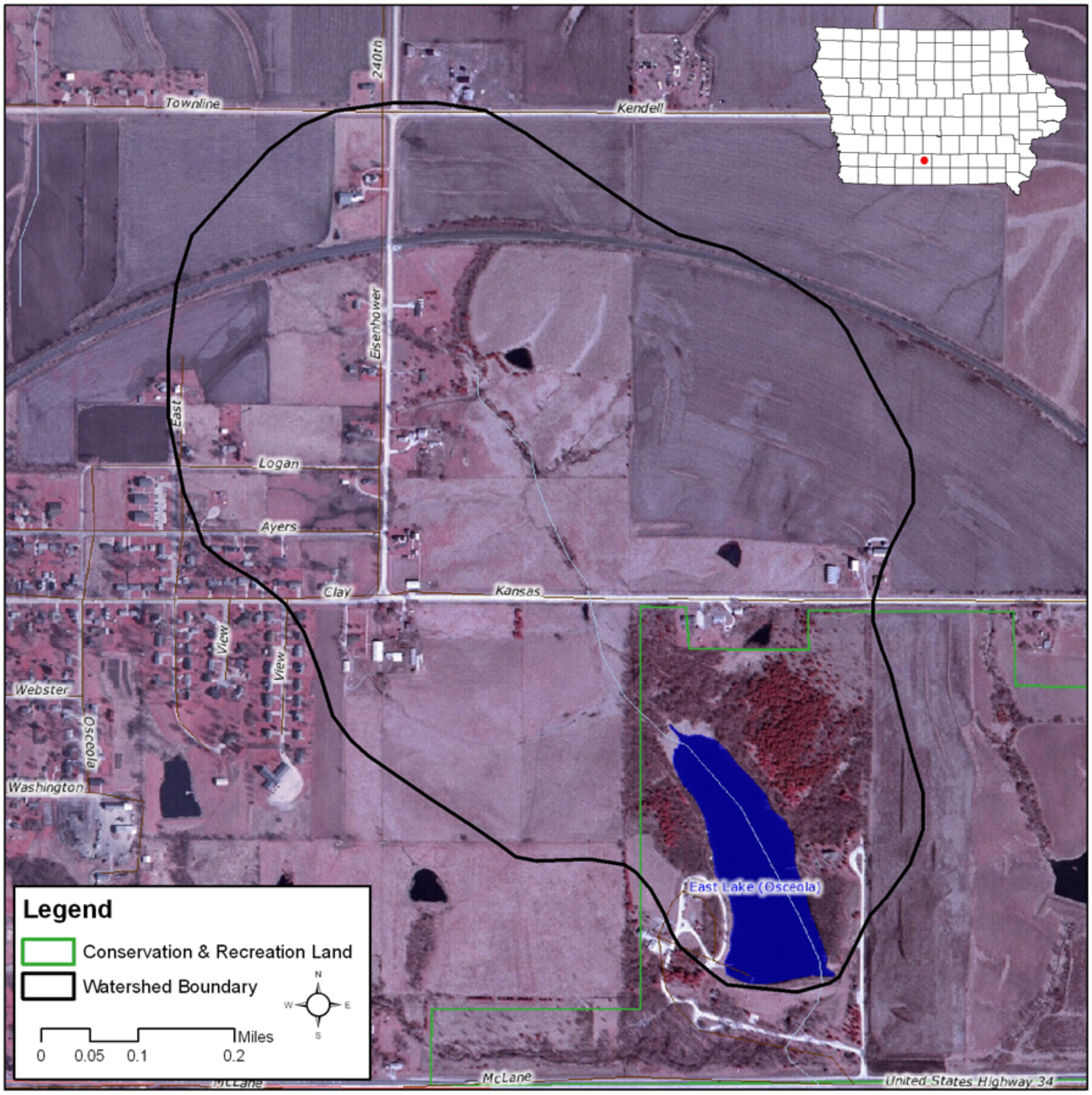

Figure 14. East Lake and its watershed, 2002 photography

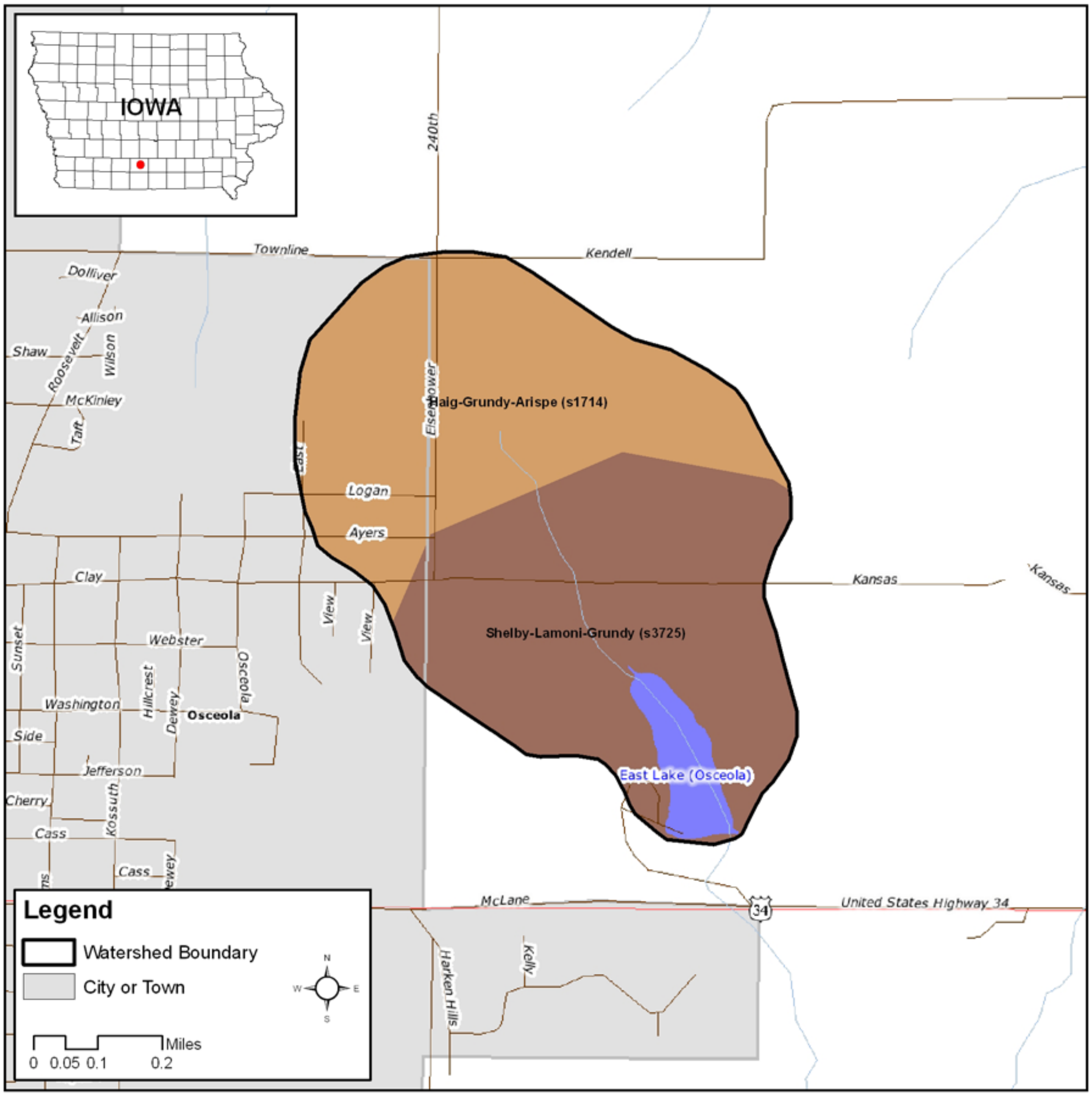

Figure 15. East Lake soil map

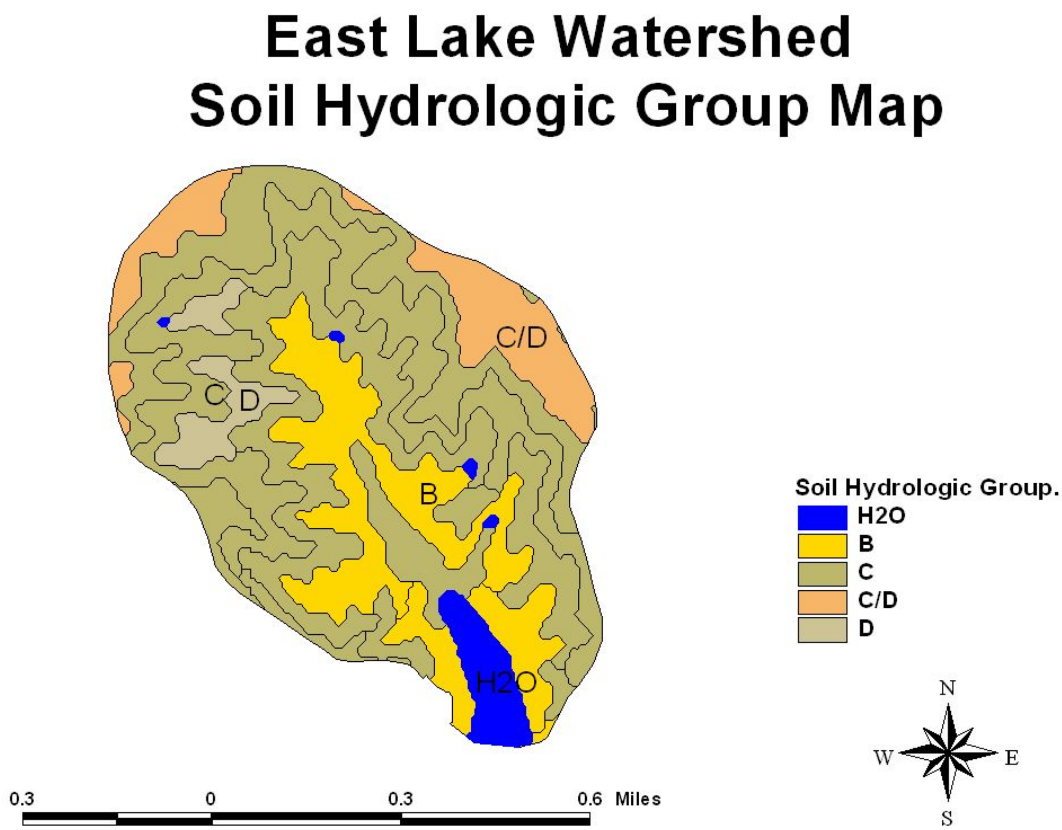

Figure 16. East Lake Soil Hydrologic Groups

Appendix G --- Public Comments

No public comments were received on the Draft TMDL.