Water Quality Improvement Plan
for

Big Hollow Lake

Des Moines County, Iowa

Total Maximum Daily Load for:
Algae, Turbidity, and pH

Prepared by:
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Water Quality Monitoring and Assessment Section
2025

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Units of measure:

ac	acre	M	meter
cfs	cubic feet per second	mg	milligram
cfu	colony-forming unit	Mg	megagram (= 1 mt)
cm	centimeter	mi	mile
cms	cubic meters per second	mL	milliliter
d	day	mo	month
g	gram	mt	metric ton (= 1 Mg)
ha	hectare	orgs	E. *coli* organisms
hm	hectometer	ppm	parts per million
hr	hour	ppb	parts per billion
in	inch	s	second
kg	kilogram	t	ton (English)
km	kilometer	yd	yard
L	liter	yr	year
lb	pound		

Other abbreviations:

AFO	animal feeding operation
BMP	best management practice
CREP	conservation reserve enhancement program
CRP	conservation reserve program
Chl-a	chlorophyll a
DNR	Iowa Department of Natural Resources
E. coli	Escherichia coli
ET	Evapotranspiration
LA	load allocation
MOS	Margin of Safety
N	nitrogen
ortho-P	ortho-phosphate
P	phosphorus
QAPP	quality assurance project plan
STEPL	spreadsheet tool for estimating pollutant load
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
WLA	waste load allocation
WMP	watershed management plan
WQIP	water quality improvement plan
WQS	water quality standard(s)

General Report Summary

What is the purpose of this report?

This report serves multiple purposes. First, it is a resource for increased understanding of watershed and water quality conditions in and around Big Hollow Lake. Second, it satisfies the Federal Clean Water Act (CWA) requirement to develop a Total Maximum Daily Load (TMDL) for impaired waterbodies. Third, it provides a foundation for locally-driven watershed and water quality improvement efforts. Finally, it may be useful for obtaining financial assistance to implement projects to remove Big Hollow Lake from the Federal 303(d) list of impaired waters.

What is wrong with Big Hollow Lake?

Big Hollow Lake is listed as impaired on the 2024 303(d) list for not supporting its primary contact recreation designated use. The impairment is due to elevated levels of algae, turbidity, and pH, which is caused by overly-abundant nutrients and sediment, including sediment-bound phosphorus in the lake.

What is causing the problem?

The amount of phosphorus transported to the lake from the surrounding watershed is sufficient to cause excessive growth of algae and excessive sediment loads to the lake increase levels of turbidity, both of which reduce water clarity. The excessive levels of algal growth can also lead to widely fluctuating pH values. Phosphorus is carried to the lake in two primary forms: (1) attached to eroded soil that is transported to the lake by rainfall runoff and stream flow, and (2) dissolved phosphorus in runoff and subsurface flow (e.g., shallow groundwater). Phosphorus and sediment within the water column and on the lake bed may become resuspended under certain conditions, which can add to the algae and turbidity issues. There are no permitted point sources for phosphorus in the Big Hollow Lake watershed; therefore, all phosphorus loads to the lake are attributed to nonpoint sources.

Nonpoint sources are discharged in an indirect and diffuse manner and are often difficult to locate and quantify. Nonpoint sources of phosphorus in the Big Hollow Lake watershed include gully and streambank erosion, sheet and rill erosion from various land uses, runoff and subsurface flows from lands that receive fertilizer application, grazed pasture land, poorly functioning septic systems, manure deposited by wildlife, and particles carried by dust and wind (i.e., atmospheric deposition). A portion of the phosphorus carried to the lake eventually settles to the lake bottom and accumulates. Under certain conditions, this accumulated phosphorus can become available for algal uptake and growth through an internal recycling process. Internal loading was found to be a significant source of phosphorus in Big Hollow Lake.

What can be done to improve Big Hollow Lake?

Reducing phosphorus loss from pasture, row crops, and implementing or improving existing structural best management practices (BMPs) such as terraces, grass waterways, and constructed sediment basins in beneficial locations will significantly reduce phosphorus loads to the lake. Increasing the trapping efficiency of the existing sediment basins may be the most cost-effective structural alternative. Stabilization of streambanks and reducing the impact of gully erosion will also limit sediment bound phosphorus to the lake. Finally, removal of curly-leaf pondweed and other invasive plant species may help improve water quality. Curly-leaf pondweed dies back in the summer releasing nutrients that contribute to algal blooms. Additionally, in-lake practices such as dredging or phosphorus stabilization may be necessary in order to address algae, turbidity, and pH concerns.

Who is responsible for a cleaner Big Hollow Lake?

Everyone who lives, works, or recreates in the Big Hollow Lake watershed has a role in water quality improvement. Nonpoint source pollution is unregulated and responsible for the vast majority of sediment and phosphorus entering the lake. Therefore, voluntary management of land, animals, and the lake itself will be required to achieve measurable improvements to water quality. Many of the practices that protect and improve water quality also benefit soil fertility and structure, the overall health of the ecosystem, and the value and productivity of the land. Practices that improve water quality and enhance the long-term viability and profitability of agricultural production should appeal to producers, land owners, and lake users alike. Improving water quality in Big Hollow Lake, while also improving the quality of the surrounding land, will continue to require collaborative participation by various stakeholder groups, with land owners playing an especially important role.

Does a TMDL guarantee water quality improvement?
The Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). The TMDL itself is only a document and without implementation will not improve water quality. Therefore, a basic implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

Reducing pollutants from unregulated nonpoint sources requires voluntary implementation of best management practices. Many solutions have benefits to soil health and sustained productivity as well as water quality. However, quantifying the value of those ecosystem services is difficult, and those benefits are not commonly recognized. Consequently, wide-spread adoption of voluntary conservation practices is often difficult to achieve. A coordinated watershed improvement effort for Big Hollow Lake could address some of these barriers by providing financial assistance, technical resources, and information/outreach to landowners to encourage and facilitate adoption of conservation practices.

What are the primary challenges for water quality implementation?
In most Iowa landscapes, implementation requires changes in land management and/or agricultural operations. Management decisions may include changes in the number of acres that are actively tilled and the diversity and rotation of crops produced. These changes present challenges to producers by requiring new equipment (e.g., no-till planters), narrowing planting, harvesting and fertilization windows, and necessitating more active and complex farm management.

Additionally, potential short-term losses in yields are more easily recognized and quantified than long-term benefits to soil health and sustained productivity. It is not easy to overcome existing incentives and the momentum of current practices. Promoting a longer-term view with an emphasis on long-term soil fertility, production, agroecosystem health, and reduced input costs will be essential for successful, voluntary implementation by willing conservation partners. However, water quality improvement and enhancement of Big Hollow Lake as a recreational resource are certainly attainable goals, and are appropriate and feasible near-term goals for a coordinated watershed improvement effort.

Required Elements of the TMDL

This WQIP 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 below in Table 1-1.

Table 1-1. Technical Elements of the TMDL.

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Big Hollow Lake, Waterbody ID IA 02-ICD-6496, Located in S17, T71N, R3W, 5 miles southwest of Mediapolis.
Surface water classification and designated uses:	A1 - Primary Contact B(LW) - Aquatic Life HH - Human Health (fish consumption)
Impaired beneficial uses:	A1 - Primary Contact (IR 5a) B(LW) - Aquatic Life (IR 5a)
TMDL priority level:	Priority Tier II
Antidegradation Level:	Tier 1
Identification of the pollutants and applicable water quality standards (WQSs):	Poor water transparency due to algae and turbidity. Associated pH issues stemming from algal growth.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQSs:	Impairments were associated with total phosphorus (TP). The allowable average annual TP load = 2,188.1 lbs/year; the allowable maximum daily TP load = 18.7 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 WQSs:	The existing growing season load of 7,414.5 lbs/year must be reduced by 5,226.4 lbs/year to meet the allowable TP load. This is a reduction of approximately 70 percent.
Identification of pollution source categories:	The US Gypsum treatment facility is the only permitted point source requiring pH limits on effluent discharged. This facility is also the only discharger of phosphorus in the watershed. Nonpoint sources of phosphorus include fertilizer and manure from row crops, sheet and rill erosion from row crops and pasture, gully and streambank erosion, wildlife, septic systems, groundwater, atmospheric deposition, and others.
Wasteload allocations (WLAs) for pollutants from point sources:	The US Gypsum treatment facility is receiving an annual TP WLA of 80 lbs/yr, which equates to 2 lbs/day maximum daily load. In addition, 20 lbs/yr is being held as a reserve for the potential of onsite septic systems to convert to a General Permit #4 (GP#4) discharge permit. The single point source discharging pH sensitive effluent is permitted between 6.5 and 9.0 pH, similar to WQS for lake impairment levels
Load allocations (LAs) for pollutants from nonpoint sources:	The allowable annual average TP LA is 1,869.3 lbs/year, and the allowable maximum daily LA is 15.9 lbs/day.

A margin of safety (MOS):	An explicit 10 percent MOS of is incorporated into this TMDL. The MOS annual average TP is 218.8 lbs/yr and the allowable maximum daily MOS is 1.9 lbs/day.
Consideration of seasonal variation:	The TMDL is based on annual TP loading. Although daily maximum loads are provided to address legal uncertainties, the average annual loads are critical to in-lake water quality and lake/watershed management decisions.
Reasonable assurance that load and wasteload allocations will be met:	For the US Gypsum treatment facility, reasonable assurance is provided through the NPDES permit. For nonpoint source, reasonable assurance is provided by: (1) a list of BMPs (see Section 4 of this WQIP) that would provide phosphorus reductions, (2) a group of nonstructural practices that prevent transport of phosphorus, (3) proposed methodology for prioritizing and targeting BMPs on the landscape, (4) best available data for estimating the efficiency/reduction associated with BMPs, (5) development of comprehensive watershed management plan that addresses the pollutant of concern, and (6) local stakeholders already planning for implementation of BMPs.
Allowance for reasonably foreseeable increases in pollutant loads:	Although watershed development may continue in the future, an increase in the pollutant load from land use change is not expected.
Implementation plan:	An implementation plan is outlined in Section 4 of this WQIP. Phosphorus loading and associated impairments must be addressed through a variety of voluntary management strategies and structural practices. Emphasis on watershed best management practices.

1. Introduction

The Federal Clean Water Act requires all states to develop lists of impaired waterbodies that do not meet water quality standards (WQSs) 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 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 WQSs 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 WQIP for Big Hollow Lake, located in Des Moines County in eastern Iowa, is to provide a TMDL for algae, turbidity, and pH, which has decreased water quality in the lake. Another purpose is to provide local stakeholders and watershed managers with a tool to promote awareness and understanding of water quality issues, develop a comprehensive watershed management plan, obtain funding assistance, and implement water quality improvement projects. Over-abundance of phosphorus is largely responsible for excessive algal growth, which impairs the primary contact designated use of Big Hollow Lake. The impairments are addressed by development of a TMDL that limits TP loads to the lake. Phosphorus reductions should be accompanied by reduced algal growth, reduced turbidity, and stabilized pH fluctuations in the water column.

The plan also includes descriptions of potential solutions to the impairments. This group of solutions is presented as a toolbox of BMPs for improving water quality in Big Hollow Lake, with the ultimate goal of meeting WQSs and supporting designated uses. These BMPs are outlined in the implementation plan in Section 4.

The DNR recommends a phased approach to watershed management. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict. Iterative implementation of improvement practices and additional water quality assessment (i.e., monitoring) will help ensure gradual progress towards meeting WQSs, maximize cost efficiency, and prevent unnecessary or ineffective implementation of costly BMPs. Implementation guidance is provided in Section 4 of this report and water quality monitoring guidance is provided in Section 5.

This plan will be of limited value unless additional watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and land owners. Experience has shown that locally-led watershed plans have the highest potential for success. The DNR has designed this plan for stakeholder use and may be able to provide technical support for the improvement of water quality in Big Hollow Lake.

2. Description and History of Big Hollow Lake

Big Hollow Lake is located in Des Moines County approximately five miles southwest of the City of Mediapolis. Construction on Big Hollow Lake dam was completed in 2008. The lake is located within the 798-acre Big Hollow Recreation Area, which is owned and managed by the Des Moines County Conservation Board (CCB). The lake and recreation area provide camping, fishing, hunting, horseback riding, shooting range, and other outdoor recreation activities for the public. Figure 2-1 is a 2019 aerial photograph with the boundaries of the watershed shown.

Table 2-1 lists some of the general characteristics of Big Hollow Lake and its watershed. Estimation of physical characteristics such as surface area, depth, and volume are based on a bathymetric survey conducted by the DNR in August of 2013.

Table 2-1. Big Hollow Lake Watershed and Lake Characteristics.

DNR Waterbody ID Code	IA 02-ICD-6496
12-Digit Hydrologic Unit Code (HUC)	070801041203
12-Digit HUC Name	Big Hollow - Flint Creek
Location	Des Moines County, S17, T71N, R3W; 5 miles southwest of Mediapolis
Latitude	40.944° N (ambient lake monitoring location)
Longitude	91.237° W (ambient lake monitoring location)
Designated Uses	A1 - Primary Recreation B(LW) - Aquatic Life HH - Human Health (fish consumption)
Tributaries	Big Hollow Creek, Unnamed streams
Receiving Waterbody	Big Hollow Creek
Lake Surface Area[1]	169.1 acres
Length of Shoreline	37,305 feet
Shoreline Development Index	3.88
Maximum Depth[1]	56.8 feet
Mean Depth[1]	16.1 feet
Lake Volume[1]	2,701 acre-feet
Watershed Area[1]	4,733 acres (includes lake)
Watershed:Lake Ratio[2]	27:1
Hydraulic Lake Residence Time[3]	232 days

[1]Per August 2013 bathymetric survey.
[2](Watershed Area - Lake Area) / Lake Area.
[3]BATHTUB model prediction for average annual conditions (2015-2023).

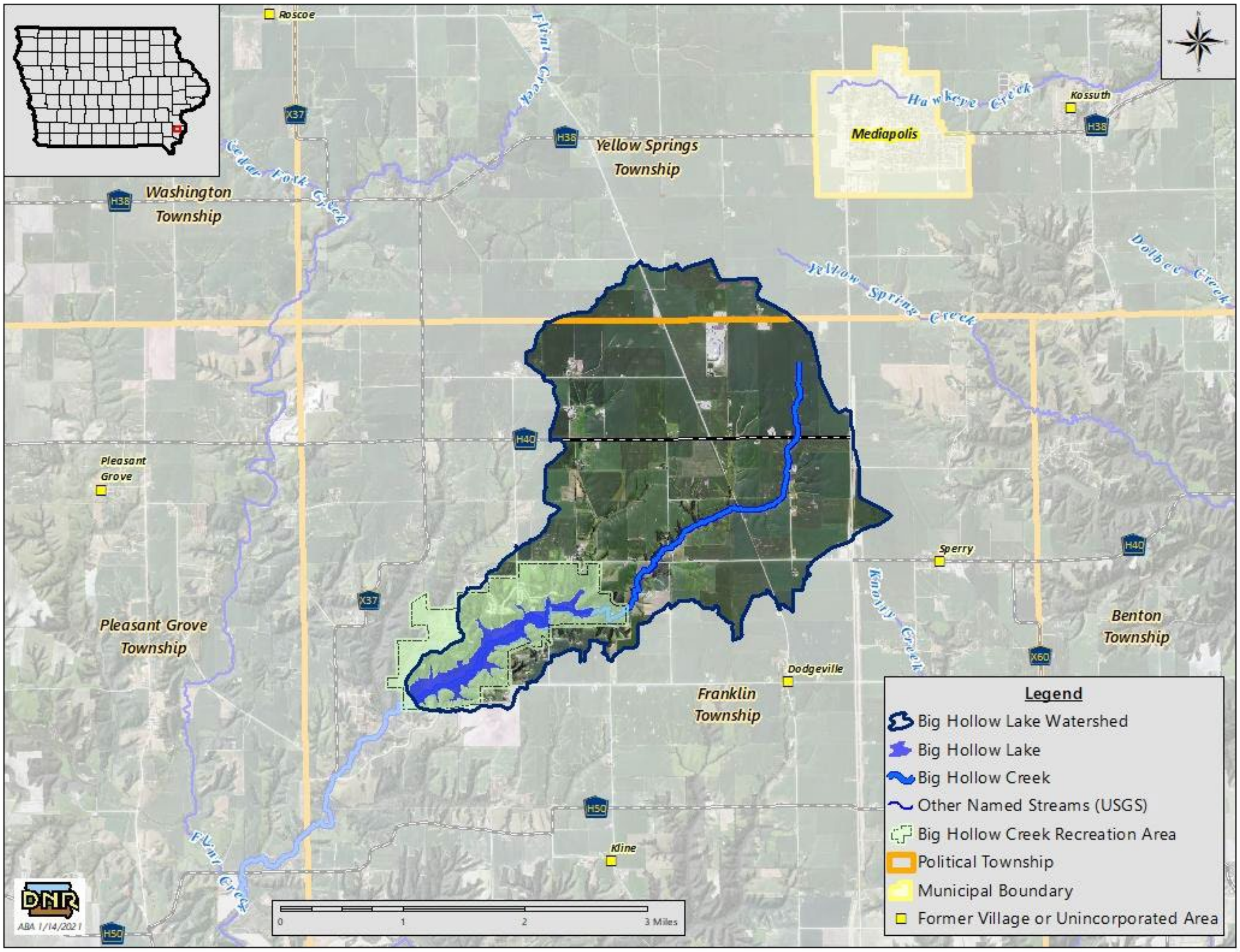

Figure 2-1. Big Hollow Lake Vicinity Map.

2.1 2021 Water Quality Improvement Plan and Related Documents

In 2010, a watershed technical advisory committee (TAC) was formed to discuss water quality improvement efforts at Big Hollow Lake. The TAC was made up of representatives from the Des Moines County Soil and Water Conservation District (SWCD), CCB, Natural Resource Conservation Service (NRCS), DNR, Iowa Department of Agriculture and Land Stewardship (IDALS), and Fyra Engineering. Subsequent activity led to the development of two documents: 1) a WQIP and 2) a Watershed Management Plan (WMP).

Water Quality Improvement Plan

In 2021, a WQIP was completed by the DNR and submitted to EPA for review and approval. This plan addressed the impairments of pH and algae. However, the 2021 WQIP never received approval and significant time had lapsed, necessitating updating and revising the WQIP to include the most current monitoring data and an additional impairment for turbidity. This WQIP supersedes the 2021 WQIP.

Watershed Management Plan

In April 2022, a WMP for the Big Hollow Lake watershed was completed by Fyra Engineering. This WMP was written based on the 2021 WQIP. Although results for both WQIPs are different, the solution to the impairments and improved water quality is the same, which is to reduce nutrients, specifically phosphorus. The purpose of the WMP is to identify sources of water quality problems and develop a management plan for improving the lake's water quality (Fyra, 2022).

The WMP includes: 1) the elements of a 9-Element plan required for 319 funding; 2) an implementation plan including goals and objectives; and 3) encourage watershed community involvement.

Improvements

During the spring of 2024, two new sedimentation basins were constructed within the watershed, west of the campground, in areas where significant gully erosion was observed.

Water Quality History

Water quality data were collected from 2000 through 2023 by Iowa State University (ISU) through the statewide survey of Iowa Lakes. In addition, data were collected by the DNR TMDL lakes program in 2019. Data were available for Big Hollow Lake from 2011 to 2023, which includes the 2024 305(b) assessment period of 2018 to 2022.

2.2 Big Hollow Lake

Hydrology

Daily precipitation data were obtained from the Burlington Station, downloadable from the Iowa Environmental Mesonet (IEM). Daily potential evapotranspiration (PET) data were obtained from the Iowa Ag Climate Network, downloadable from the IEM (IEM, 2024b). The Iowa State Climatologist provides quality control of these data. Daily observations between January 1, 2011 and December 31, 2023 were used in climate assessment and model development. Table 2-2 reports weather station information.

Table 2-2. Weather Station Information for Big Hollow Lake.

Data	Temperature/Precipitation	Potential ET
Network	IACLIMATE	ISU AgClimate/ISU Soil Moisture
Station Name (ID)	Burlington (IA1060)	Crawfordsville (CRFI4)
Latitude	40.83°	41.19°
Longitude	-91.17°	-91.48°

Source: https://mesonet.agron.iastate.edu/climodat

Average annual precipitation near Big Hollow Lake was 38.3 inches from 2011-2023. The annual average precipitation during this time period was less than the 30-year annual average of 40.3 inches. Figure 2-2 illustrates the annual precipitation totals, along with lake evaporation (estimated as 100 percent of annual PET). This chart shows an inverse relationship between precipitation and lake evapotranspiration (ET), mainly due to climatological factors such as cloud cover and temperature. Wet years show a surplus of precipitation, while dry years such as 2012, 2020, and 2022 show a precipitation deficit in comparison to lake ET. The estimated annual lake ET of 44.7 inches is higher than the annual precipitation over the modeled time period. This shows that watershed runoff is needed to maintain a steady state condition for lake water levels over a long modeling period. The dataset for lake ET was not complete for the year 2014 due to missing data during the months of May, June, and July. To account for this the average ET from 2000 - 2023 was used for those three months.

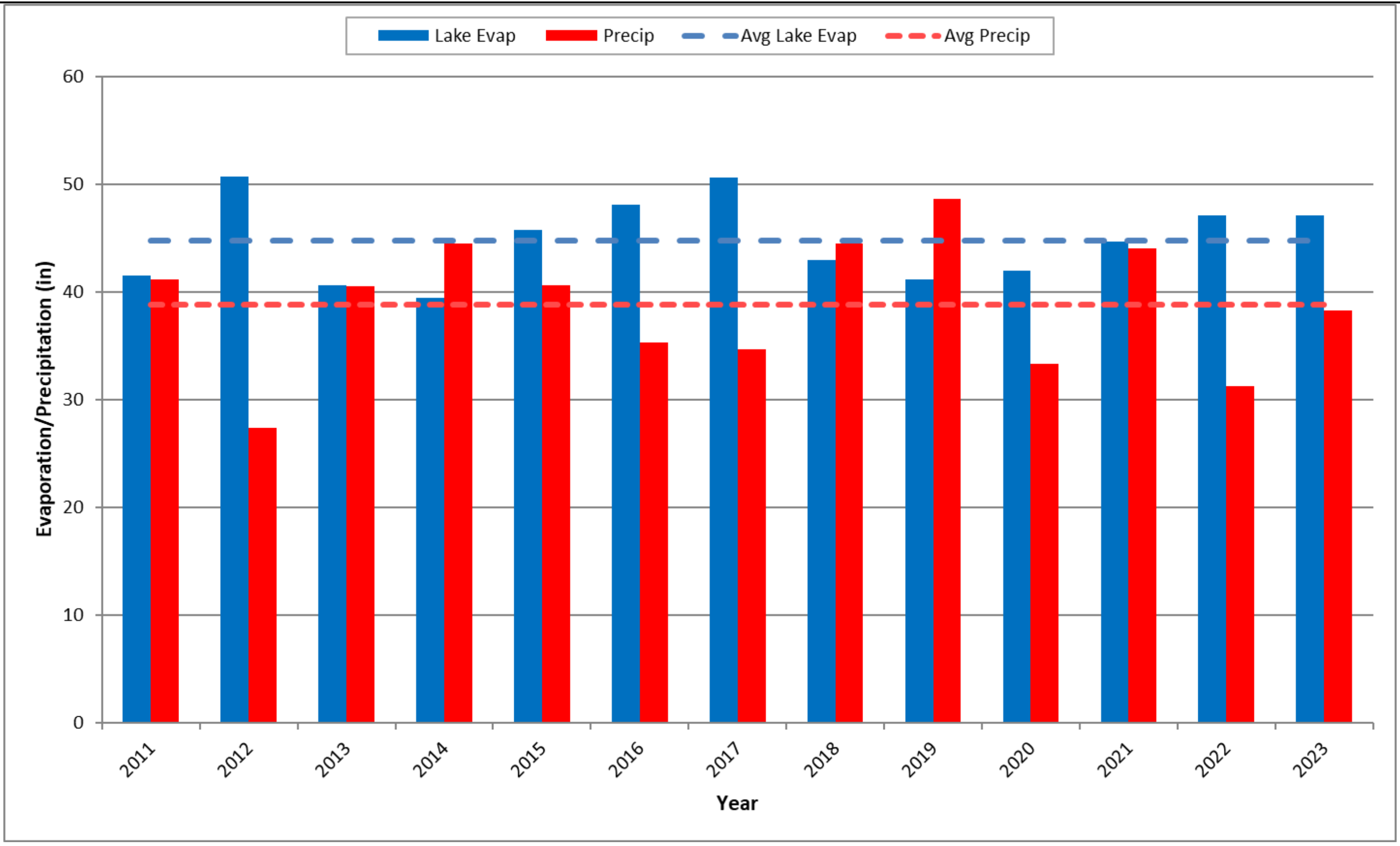

Figure 2-2. Annual Precipitation and Estimated Lake Evaporation.

Precipitation varies greatly by season in Iowa, with approximately 63 percent of annual rainfall taking place in half of the year (April through September). Monthly average precipitation is illustrated in Figure 2-3, along with estimated evapotranspiration (ET) in the watershed based on vegetation cover. Although precipitation is highest during the growing season, so is ET, and a monthly moisture deficit occasionally occurs. Note that watershed ET is typically higher than lake evaporation in the summer months, a result of high temperatures and vegetation transpiring large volumes of moisture from the soil during the peak of the growing season. It is often during this period that harmful algal blooms develop in waterbodies, as water heats up and lake flushing is minimal.

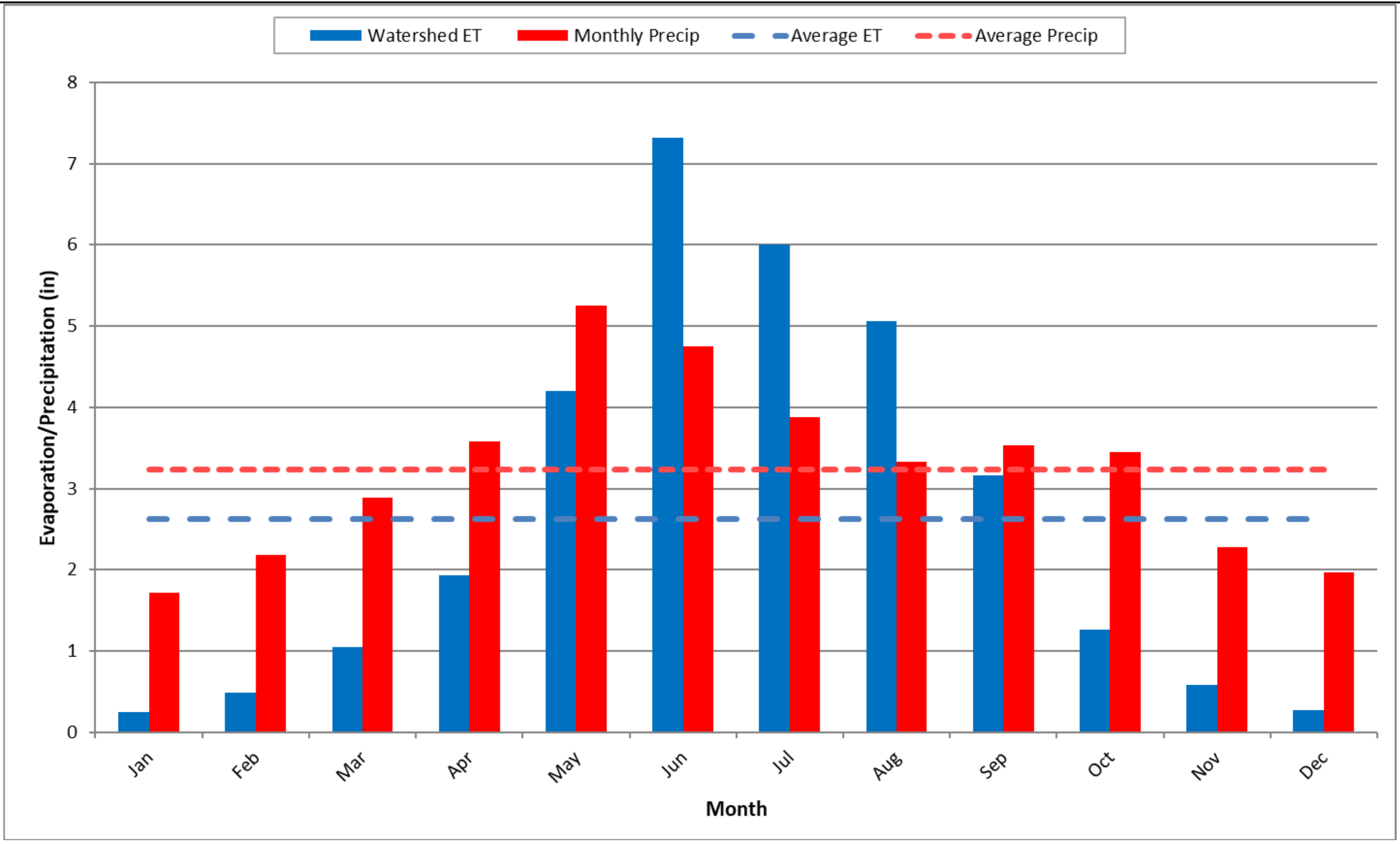

Figure 2-3. Monthly Precipitation and Estimated ET for the Big Hollow Lake Watershed.

Rainfall runoff, direct precipitation, evapotranspiration, shallow groundwater flow, and deep aquifer recharge are all part of the lake's hydrologic system. Estimated residence time is based on annual precipitation and evaporation data, Spreadsheet Tool for Estimating Pollutant Load (STEPL) estimates of average annual inflow, and a water balance calculated within the BATHTUB model. The BATHTUB water balance calculation includes: inflows (from STEPL), direct precipitation, evaporation calculated from measured PET at Crawfordsville, Iowa, and lake morphometry.

During years of below average precipitation the residence time increases. In wet years, the opposite is true as residence time decreases. In lakes with smaller watershed to lake ratios, the residence time may be longer than lakes with larger watershed to lake ratios. The average residence time in Big Hollow Lake is 233 days.

Morphometry

According to the most current bathymetric data (August 2013), the surface area of Big Hollow Lake is 169.1 acres. The estimated water volume of the lake is 2,701 acre-feet (ac-ft), with a mean depth of 16.1 ft and a maximum depth of 56.8 ft in the western section of the lake near the outfall. The reservoir, like most man-made stream impoundments, has an irregular shape, with small dissected arms that lead to upland overland flow paths. Evidence of gully erosion near the lake, and sedimentation in upstream basins, suggest that the watershed of Big Hollow has a large impact on water quality. The significance of sediment (and associated phosphorus) loading from the watershed is further evidenced by a high shoreline development index of 4.91. Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000). High indexes are frequently observed in man-made reservoirs, and it is not surprising that watershed processes are critically important for the chemical, physical, and biological processes that take place in Big Hollow Lake. Lake morphometry and bathymetry data are shown in Figure 2-4.

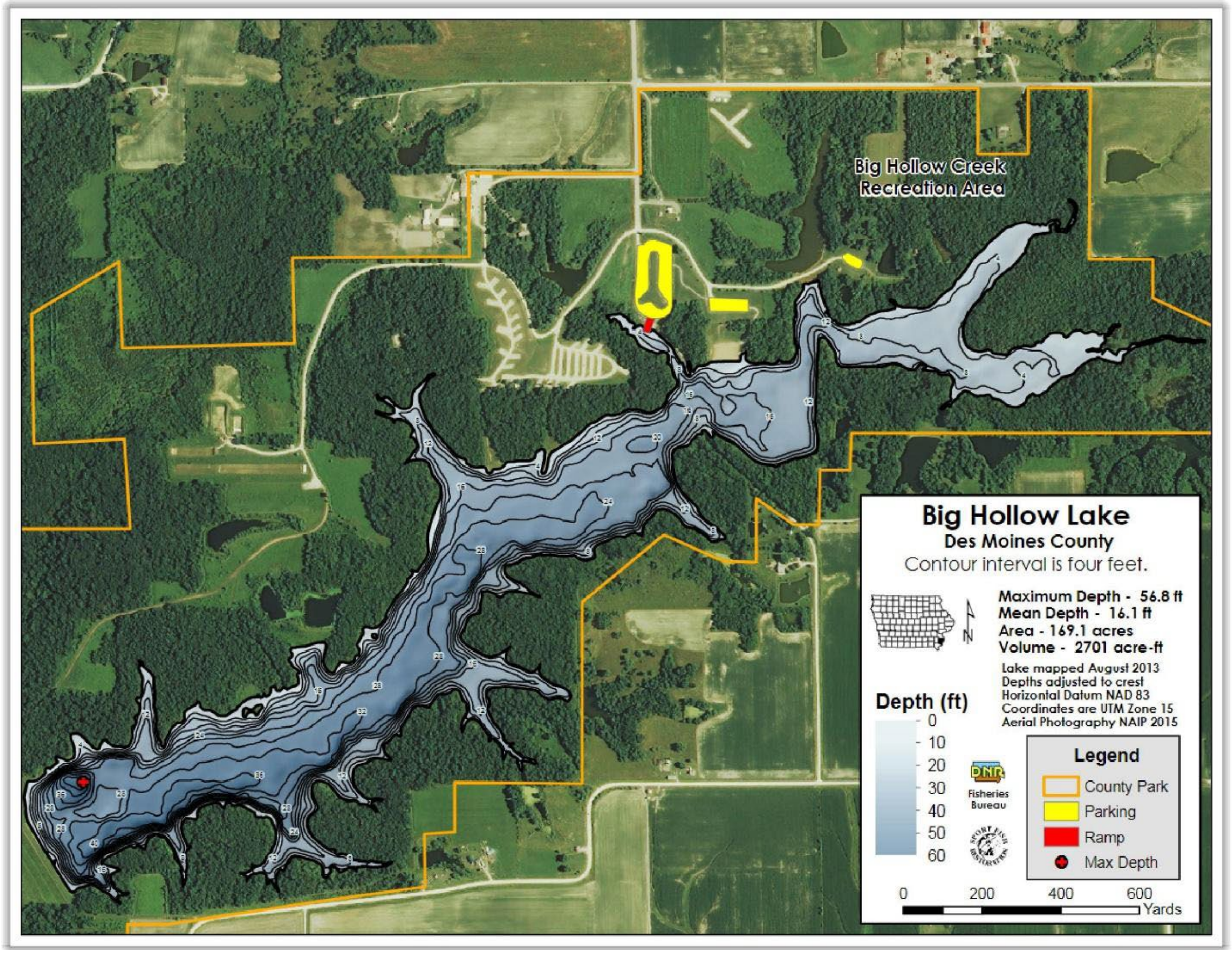

Figure 2-4. 2013 Bathymetric Map of Big Hollow Lake

2.3 The Big Hollow Lake Watershed

The watershed boundary of Big Hollow Lake encompasses 4,733 acres (including the lake) and is illustrated in Figure 2-1. The watershed-to-lake ratio is 27:1. The larger the ratio the more influence the watershed has on the water quality in the lake and more mitigation efforts will be required in the watershed to see water quality improvements. Conversely, a smaller ratio indicates that the watershed may not influence water quality in the lake as much as in situ influences. The ratio of 27:1 means that for every one acre of lake, there are 27 acres of watershed contributing runoff, sediment, and potential pollutants to the lake. This ratio indicates a successful lake restoration program will be based on both watershed and lake-based solutions. Mitigation of watershed influence will be required, and in-lake techniques may have short effective life spans in the absence of watershed improvements and renovations. A prudent watershed management strategy should focus on problem areas that can be most easily addressed and implementing alternatives that provide multiple benefits in addition to water quality, such as increased soil health, erosion reduction, and habitat enhancement. Watershed management and implementation strategies are discussed in more detail in Section 4 - Implementation Planning.

Land Use

Land use information for the area was created from a windshield survey conducted of the area in the summer of 2020, from various aerial photography, and from crop data layer (CDL) sets from 2017-2020 through ArcGIS. The predominant land use is corn and soybean row crops, with row crops making up approximately 70.0 percent of the watershed (Table 2-3 and Figure 2-5). The observed land use, crop rotation, and tillage is also shown for 2020. Extended crop rotations including small grains were considered as row crops as a conservative calculation in subsequent model simulations. Grassland is an aggregate of alfalfa/hay, ungrazed land, and conservation programs.

Table 2-3. Big Hollow Lake Watershed Land Uses.

Land Use	Description	Area (acres)	Percent (%)
Row Crop	Corn and Soybeans	3,314	70.0
Grassland	Un-grazed Grassland, Alfalfa/Hay	190	4.0
Forest	Bottomland, Coniferous, Deciduous	534	11.3
Urban	Farmstead, Roads	333	7.0
Pasture	Grazed grassland	183	3.9
Water/Wetland[1]	Water and Wetland	179	3.8
Total		**4,733**	**100.0**

[1]Includes Big Hollow Lake surface area.

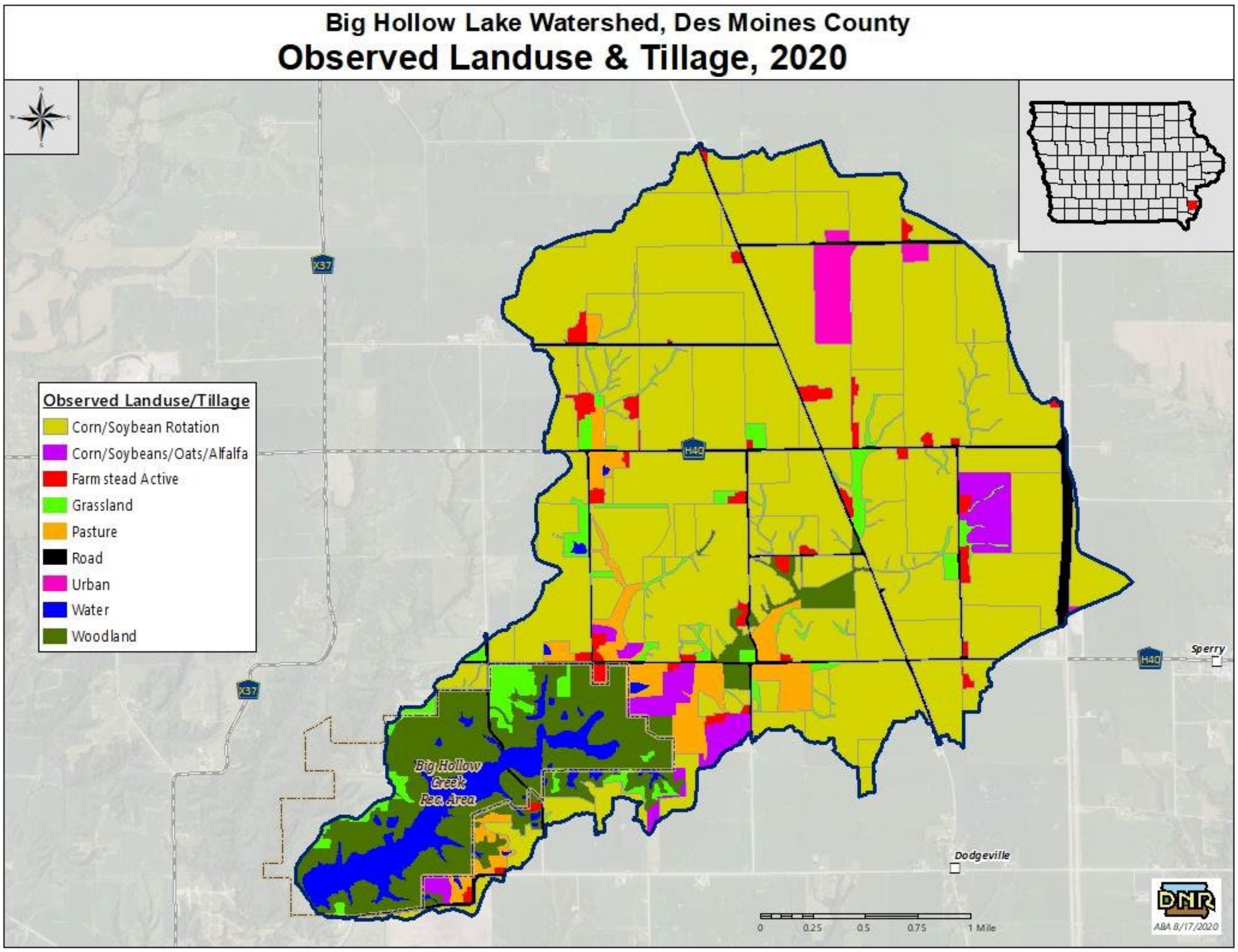

Figure 2-5. Big Hollow Lake Watershed Land Use Map.

Soils, Climate, and Topography

The Big Hollow Lake watershed is on the edge of the Rolling Loess Prairie ecoregion. This landform region is the largest region within the state and extends broadly from the Mississippi River in the east to the west across most of the south-central part of the state. It is a subregion of Pre-Illinoian glacial deposits. In the southeast, there are some flat tabular uplands and the valleys can be relatively steep and forested (Griffith *et al.*, 1994).

The watershed is made up mainly of the Taintor and Mahaska soil series. These associations are characterized by flat to very flat uplands and poorly to somewhat poorly drained soils formed on loess (USDA-NRCS, 1980).

As seen in Table 2-4 the Taintor, Mahaska, and Clinton soils make up a majority of the soils types in the watershed comprising 63.9 percent of the watershed. Table 2-4 shows the soils, map units, area, percent area of the watershed, general description and typical slopes of each soil in the watershed. Figure 2-6 is a map of the soil types in the watershed.

Table 2-4. Predominant Soils of the Big Hollow Lake Watershed.

Soil Name	Map Units	Area (ac)	Area (%)	Description	Hydrologic Soil Group	Typical Slopes (%)
Taintor	279	1333	28.2	Very deep, poorly drained, formed in loess	D	0-2
Mahaska	280	1237	26.1	Very deep, somewhat poorly drained, loess	C/D	0-2
Clinton	80C; 80C2	456	9.5	Very deep, moderately well drained, loess	C	2-9
Lindley	424	322	5.6	Very deep, well drained, upland positioned glacial till	C	14-40
Nira	570	301	6.4	Very deep, moderately well drained, loess	C	2-9
Hedrick	571	269	5.7	Very deep, moderately well drained, loess	C	2-5
Nodaway-Cantril-Klum	730B	158	3.3	Shares characteristics of each soil in complex	B	2-5
Gara-Rinda Complex	893D2	115	2.4	Shares characteristics of each soil in complex	C	9-14
Givin	75	77	1.6	Very deep, somewhat poorly drained, loess	C/D	1-3
Other Minor Soils	---	465	11.2	Minor soils, complexes, quarry, water	N/A	---
Totals		**4733**	**100.0**	**Varies**		**Varies**

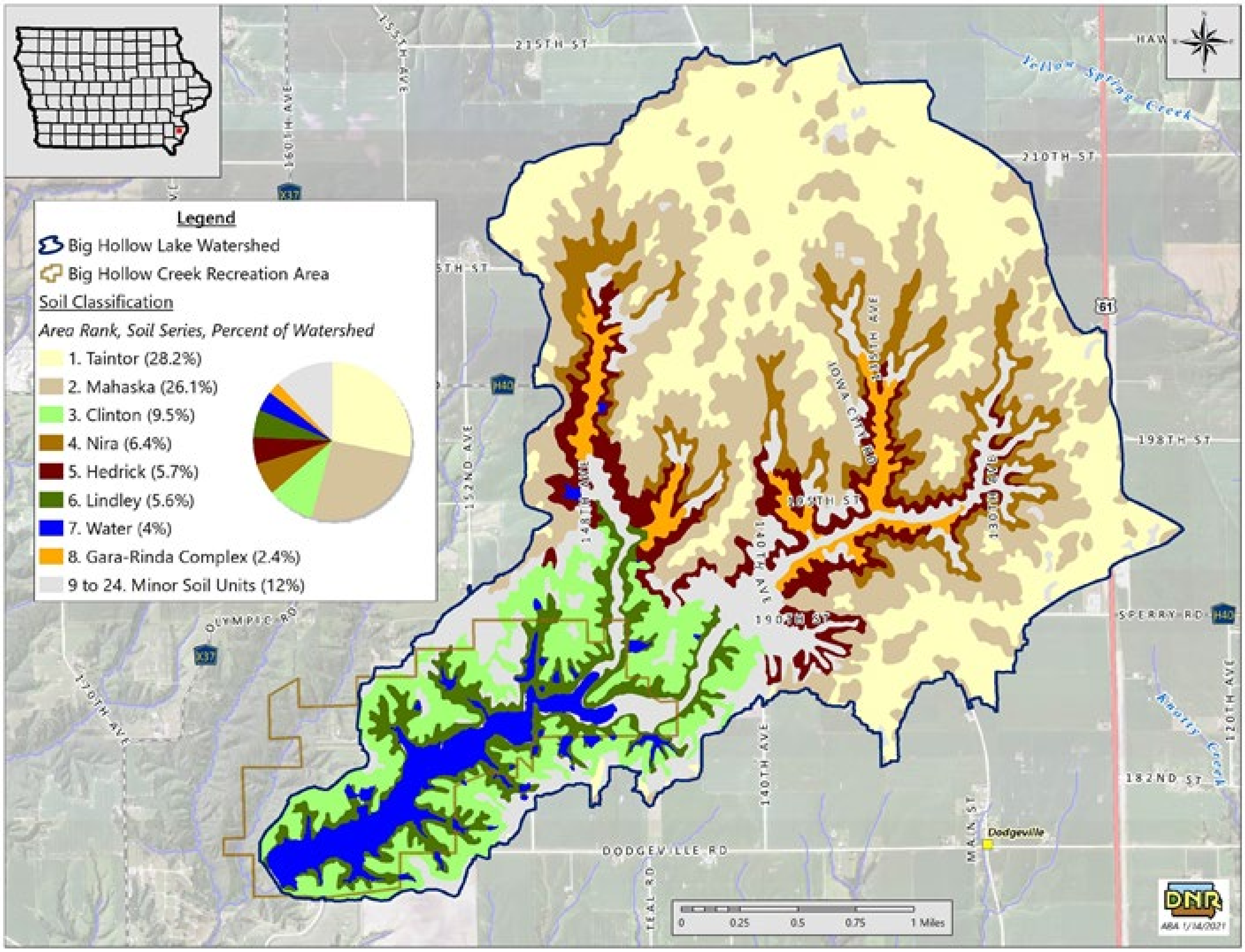

Figure 2-6. Big Hollow Lake Soil Classification Map.

Elevations in the watershed range from a maximum of 964 feet North American Vertical Datum 1988 (NAVD 88) to a minimum of 800 feet NAVD 88. The average slope class of the watershed is Class A with nearly flat (0 - 2 percent slope) regions making up a large percentage of the watershed at 53.3 percent. Table 2-5. Slope Classifications of the Big Hollow Lake Watershed. shows the percentage breakdown of slope classifications throughout the watershed and Figure 2-7 illustrates the distribution of the slopes within the Big Hollow Lake watershed. Note, the extremely flat uplands, the gully formations closer to the lake inlets, and the slopes of an operational gypsum mine located in the watershed.

Table 2-5. Slope Classifications of the Big Hollow Lake Watershed.

Slope Class (%)	Area (%)	Description of Slope Class
Class A (0 - 2)	53.3	Nearly Flat
Class B (2 - 5)	20.8	Gently sloping
Class C (5 - 8)	12.5	Moderately Sloping
Class D (8 - 15)	6.2	Strongly Sloping
Class E (15 - 30)	2.5	Moderately Steep
Class F (30 and up)	4.7	Steep to Very Steep
Total	**100.0**	**---**

The combination of soil classification, slope, topography, and hydrologic soil group (discussed more in Appendix D) indicate that the majority of non-agricultural areas in the Big Hollow Lake watershed would not be tile drained while some of the upland crop areas may be tile drained. The absence of drainage district data could indicate that minimal formal drainage is present in the watershed. However, agricultural management practices related to tile drainage may change in the future, which may lead to changes in watershed loading and its effects on Big Hollow Lake.

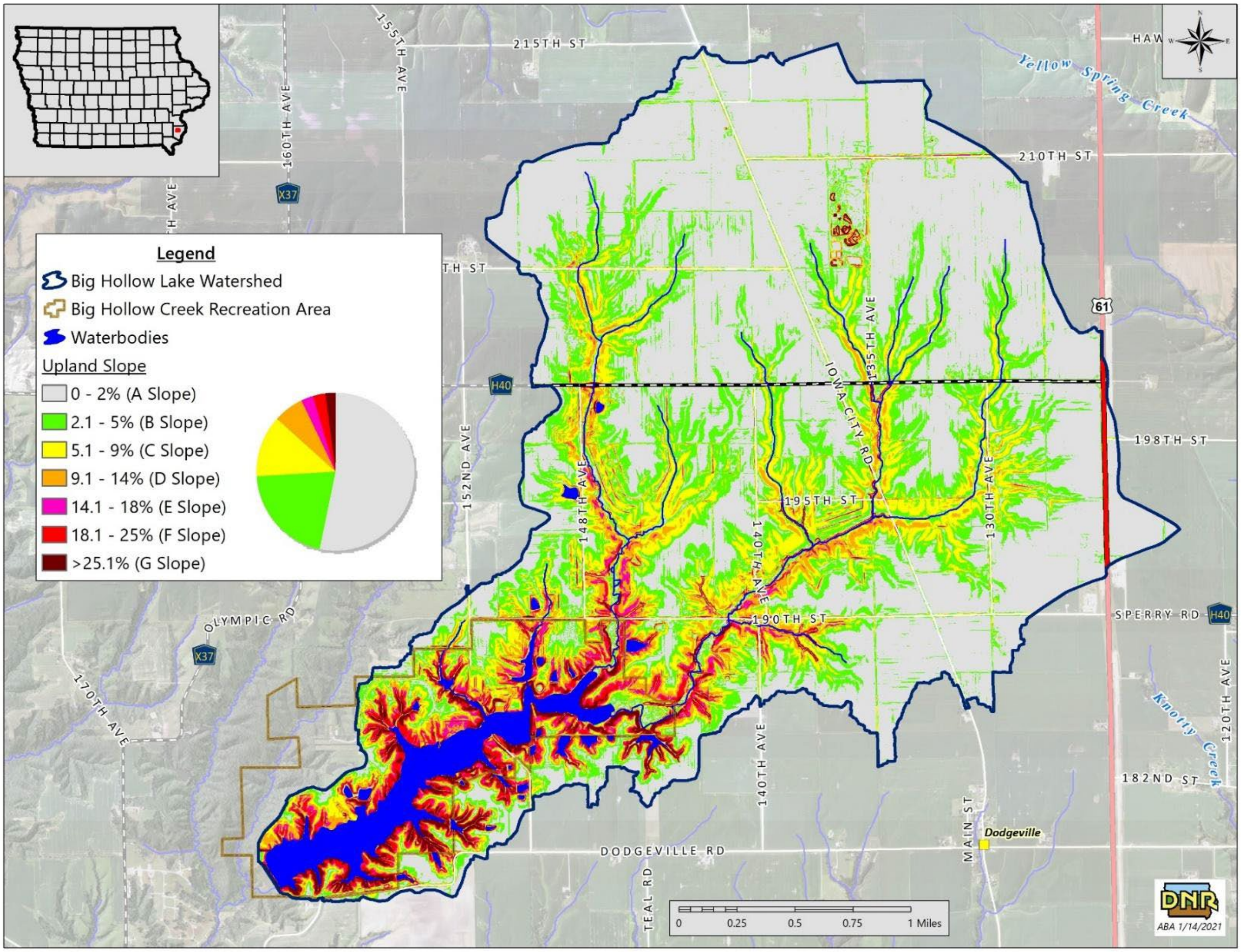

Figure 2-7. Slope Classifications in the Big Hollow Lake Watershed.

3. TMDL for Algae, Turbidity, and pH

A TMDL is required for Big Hollow Lake by the Federal Clean Water Act. This section of the WQIP quantifies the maximum amount of total phosphorus (TP) the lake can assimilate and still fully support primary contact recreation and aquatic life in Big Hollow Lake, which is impaired by algae, turbidity, and fluctuations in pH. This section includes an evaluation of Big Hollow Lake water quality, documents the relationship between algae, turbidity, pH, and TP in Big Hollow Lake, and quantifies the in-lake target and corresponding TMDL. It is assumed the TMDL for algae will also address the pH impairment since both are attributed to excess nutrients, particularly phosphorus.

3.1 Problem Identification

Big Hollow Lake is protected for the following designated uses:

- Primary Contact Recreational Use - Class A1
- Aquatic Life - Class B(LW)
- Human Health - Class HH

The 2024 Section 305(b) Water Quality Assessment Reports state the Class A1 and Class BLW uses of Big Hollow Lake were assessed as "not supported" due to violations of their respective water quality criteria. The 2024 assessment can be accessed at https://programs.iowadnr.gov/adbnet/Segments/6496/Assessment/2024.

Applicable Water Quality Standards

The State of Iowa WQSs are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61 (http://www.legis.iowa.gov/DOCS/ACO/IAC/LINC/Chapter.567.61.pdf). Although the State of Iowa does not have numeric criteria for sediment, nutrients, or algae (chl-a), general (narrative) water quality criteria below do apply:

61.3(2) General water quality criteria. The following criteria are applicable to all surface waters including general use and designated use waters, at all places and at all times for the uses described in 61.3(1)"a".

a. Such waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.
b. Such waters shall be free from floating debris, oil, grease, scum and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.
c. Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.
d. Such waters shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal, or plant life.
e. Such waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life.

The specific WQS for pH impairments for both Class "A" and Class "B" water are listed in subparagraphs 61.3(3)"a"(2) and 61.3(3)"b"(2):

> The pH shall not be less than 6.5 nor greater than 9.0. The maximum change permitted as a result of a waste discharge shall not exceed 0.5 pH units.

In 2010 the State of Iowa enacted an antidegradation policy. This policy was designed to maintain and protect high quality waters and existing water quality in other waters from unnecessary pollution. Protection levels (or tiers) as defined by the Iowa Administrative Code (IAC) 567-61.2 are cited below.

> 567-61.2(2)(a) Tier 1 protection. Existing surface water uses and the level of water quality necessary to protect the existing uses will be maintained and protected.

For 303(d) listing purposes, aesthetically objectionable conditions due to algae can be present in a waterbody when Carlson's Trophic State Indices (TSI) for the median growing season chl-a or Secchi depth exceed 65. In order to delist the algae and turbidity impairments for Big Hollow Lake, the median growing season for chl-a and Secchi depth TSI must not exceed 63 for one listing cycle, per DNR delisting methodology (DNR, 2023). In order to delist the pH impairment for

Big Hollow Lake, pH violations from water quality sampling must not be significantly greater than 10 percent for one listing cycle, per DNR delisting methodology (DNR, 2023).

Problem Statement
The 2024 305(b) report assesses water quality in Big Hollow Lake as follows:

> "The Class A1 use was assessed (monitored) as 'not supported' due to the presence of aesthetically objectionable conditions caused by non-algal turbidity, algal blooms and violations of the Class A1 criterion for pH. The Class BLW use was assessed (monitored) as 'not supported' due to violations of the Class BLW criterion for pH."

High levels of algal production and turbidity fueled by phosphorus loads to the lake cause the impairment. These elevated algae levels can cause pH fluctuations that can also impair the aquatic life designated uses. TP loads must be reduced in order to reduce algae and fully support the lake's designated uses. The TP reductions will reduce chl-a (an algae indicator) and subsequently lower pH in the water column.

Data Sources and Monitoring Sites
Sources of data used in the development of this TMDL include those used in the 2024 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. Sources include:

- Ambient Lake Monitoring and / or TMDL monitoring including:
    - Results of available statewide surveys of Iowa lakes sponsored by the DNR and conducted by Iowa State University 2011-2023
- Precipitation data at Burlington, Iowa, the ISU Iowa Environmental Mesonet. (IEM, 2024a)
- PET data at Crawfordsville, Iowa, the ISU Ag Climate Network (IEM, 2024b)
- 3-m Digital Elevation Model (DEM) available from the DNR GIS library
- SSURGO soils data maintained by United States Department of Agriculture -Natural Resource Conservation Service (USDA-NRCS)
- Aerial images (various years) collected and maintained by the DNR
- Lake bathymetric data collected in August 2013
- Crop Data Layers (CDL) from multiple years in the DNR ArcGIS servers

Interpreting Big Hollow Lake Data
The 2024 305(b) assessment was based on results of the ambient monitoring program conducted from 2018 through 2022 by ISU and from supplemental samples collected in 2019 by the DNR TMDL lakes program. Assessment of available in-lake water quality in this TMDL utilized available ISU data from 2015-2023. All in-lake data was collected at the ambient monitoring location, which is shown in Figure 3-1. Development of the in-lake target, the TMDL, and impairment status are based on data collected at this location, per DNR assessment methodology. In-lake water quality data is shown in Appendix C.

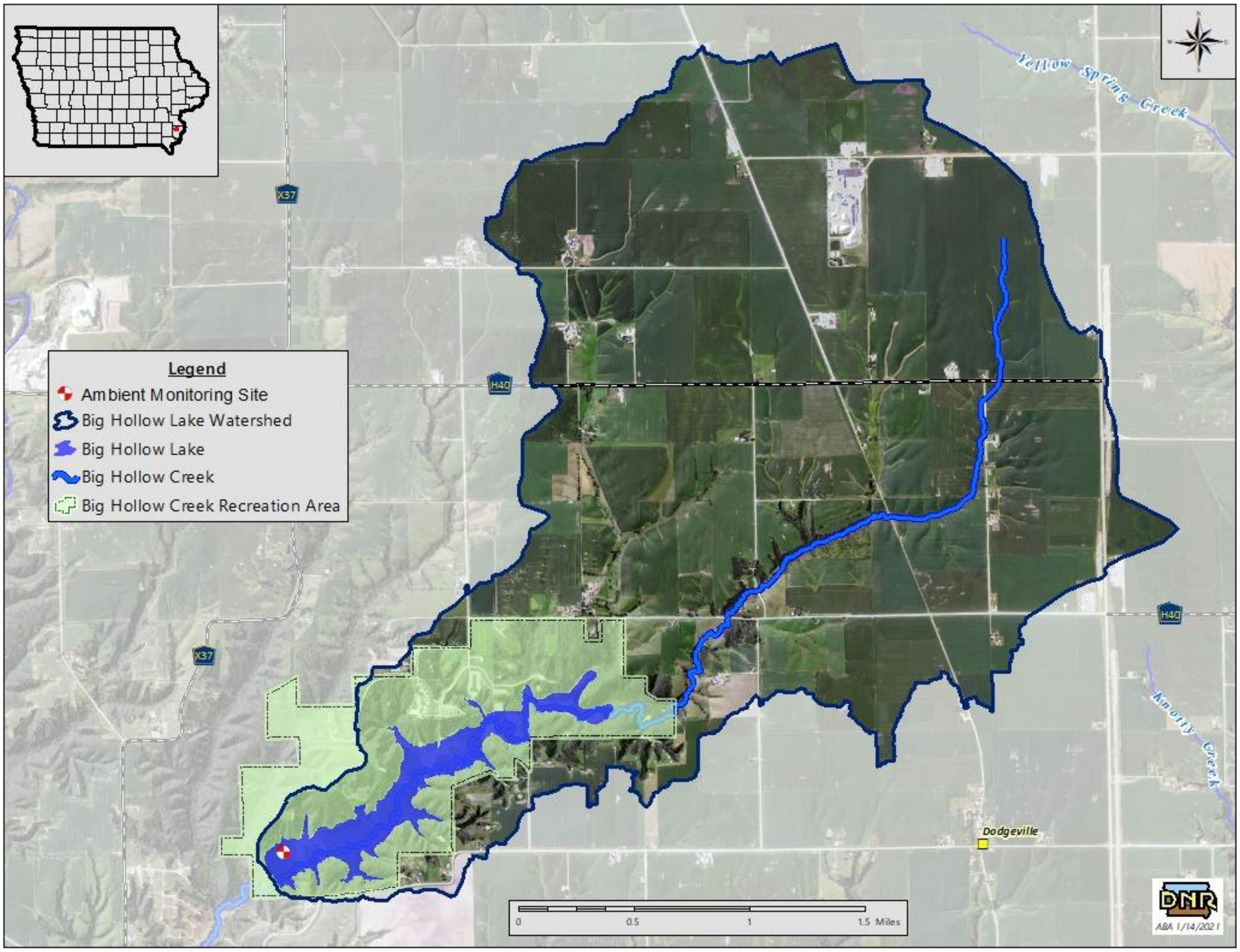

Figure 3-1. Ambient Monitoring Location for Water Quality Assessment.

Carlson's Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chl-a), and transparency (Secchi depth) in Big Hollow Lake. TSI values are not a water quality index but an index of the trophic state of the waterbody. However, the TSI values for Secchi depth and chl-a can be used as a guide to establish water quality improvement targets.

If the TSI values for the three parameters are the same, the relationships between the TP, algae, and transparency are strong. If the TP TSI value is higher than the chl-a TSI, it suggests there are limitations to algal growth besides phosphorus. Figure 3-2 is a plot of the individual TSI values throughout the analysis period (2015-2023). It should be noted that samples were not collected in 2020 due to concerns related to the COVID-19 pandemic. TSI values that exceed the 303(d)-listing threshold of 65 (for chl-a and Secchi depth) are contained within the red box and TSI values from the 2024 305(b) (2018-2022) assessment period are within the blue box. Data points in the area of overlap in both the red box and the blue box indicate TSI values higher than the 303(d)-listing threshold during the 2024 305(b) assessment period. Table 3-1 shows the overall average and median TSI values for Secchi depth, chl-a, and TP for the analysis period.

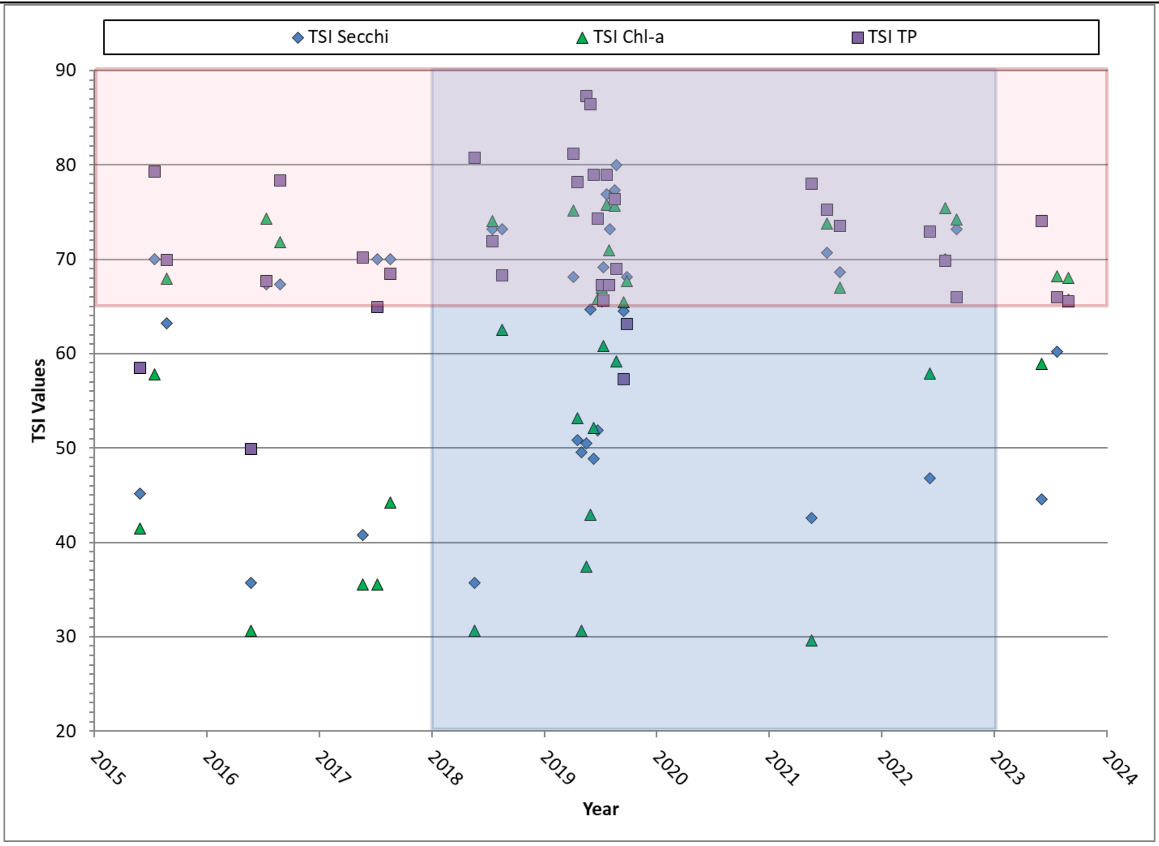

Figure 3-2. TSI Values for Individual Samples in the Analysis Period.

Table 3-1. Average and Median TSI Values for the Analysis Period (2015-2023).

	Secchi Depth	Chlorophyll-a	Total Phosphorus
Average TSI Values	56	66	74
Median TSI Values	66	64	70

Annual average TSI values for the analysis period can be seen in Figure 3-3. The water clarity trend for the analysis period is negative, with increasing TSI values for Secchi depth, chl-a, and TP. From the data it is observed that TP(TSI) values are consistently higher than chl-a(TSI) values, which would suggest that factors besides TP may be limiting (i.e., controlling) algal growth at certain times of the year and under certain conditions. However, there are occurrences of chl-a(TSI) values greater than 70, and a number of instances in which the chl-a TSI is higher than TP TSI. This indicates that algal blooms do occur and suggests that TP is often the limiting factor. In addition, average TSI values for TP and chl-a are higher than for Secchi depth, indicating that algae dominate light attenuation, but some factors such as nitrogen limitation, zooplankton grazing, or toxics limit algal growth (Carlson and Simpson, 1996).

The chl-a(TSI) value in 2017 appears to be abnormally low, skewing the trend line. The low chl-a value could be a result of 1) the phosphorus being tied to sediment and not available for algal production, 2) a higher than normal concentration of zooplankton feeding on the algae consequently, reducing the amount of algae in the lake, or 3) sampling error. Table 3-2 shows the average and median TSI values for Secchi depth, chl-a, and TP for the 2024 305(b) assessment period (2018-2022).

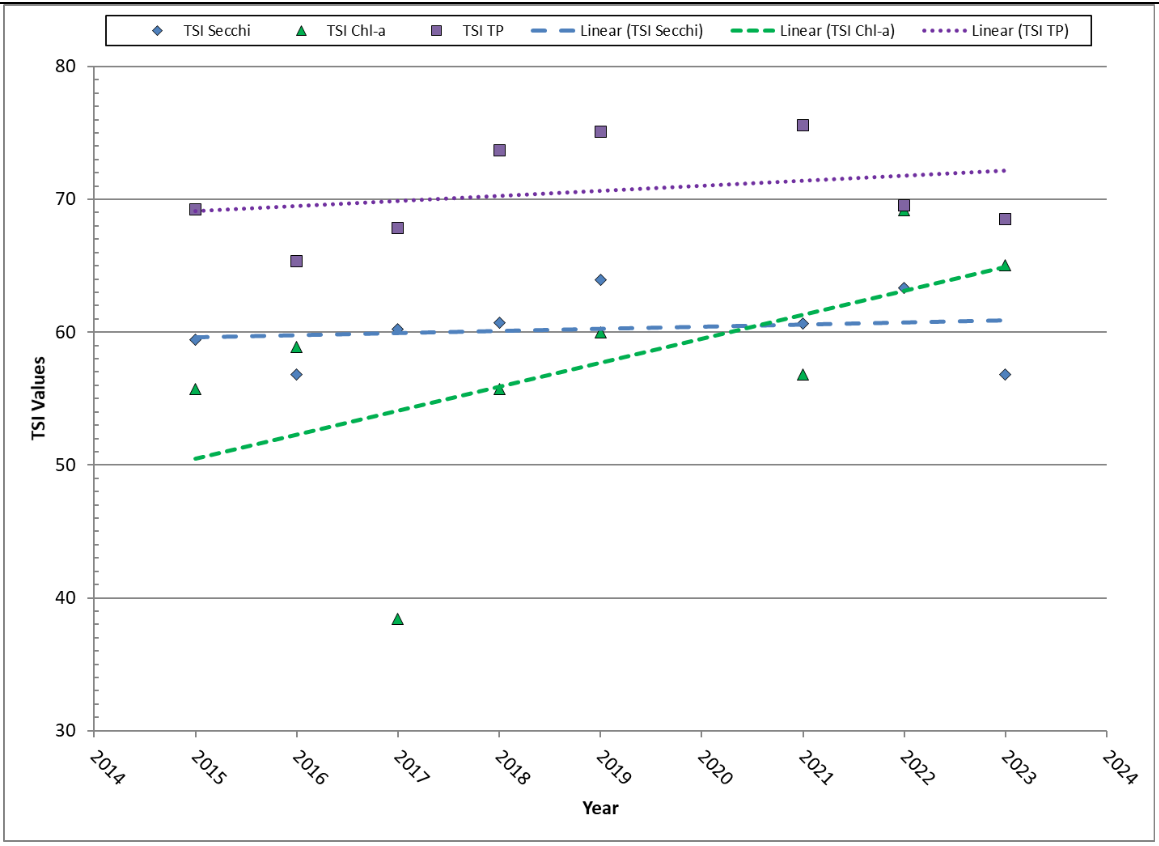

Figure 3-3. Annual Average TSI Values.

Table 3-2. Average and Median TSI Values for the 2024 IR Assessment Period (2018-2022).

	Secchi Depth	Chlorophyll-a	Total Phosphorus
Average TSI Values	57	67	76
Median TSI Values	68	66	73

Table 3-3 describes the implications of TSI scores on attributes of lakes. TSI values for chl-a, Secchi depth, and TP are used to estimate algal biomass. However, chl-a is a better predictor than the other two.

Table 3-3. Implications of TSI Values on Lake Attributes.

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	Warm water fisheries only; percid fishery[1]; 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	Centrarcid fishery[2]
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).

Subsequent analyses show the link between the three indices of in-lake water quality. Figure 3-4 shows the relationship between total phosphorus and Secchi depth TSI values. Figure 3-5 shows the relationship between chl-a and TP. Figure 3-6 shows the relationship between Secchi depth and chl-a. The R^2 values between the various TSI indices are summarized in Table 3-4. There is a positive correlation between chl-a and Secchi depth, and a weak positive correlation between TP and both chl-a and Secchi depth. This suggests that transparency issues can be linked to algae growth and algae blooms. This also indicates that targeting phosphorus reductions to reduce algae growth in the watershed should help to improve chl-a and Secchi depth TSI values.

Table 3-4. Total Phosphorus, Chl-a, Secchi depth, and Total Nitrogen Relationships and R2 Values.

TSI indicator	Total Phosphorus	Chlorophyll-a
Total Phosphorus	---	0.023
Chlorophyll-a	0.023	---
Secchi depth	0.004	0.495

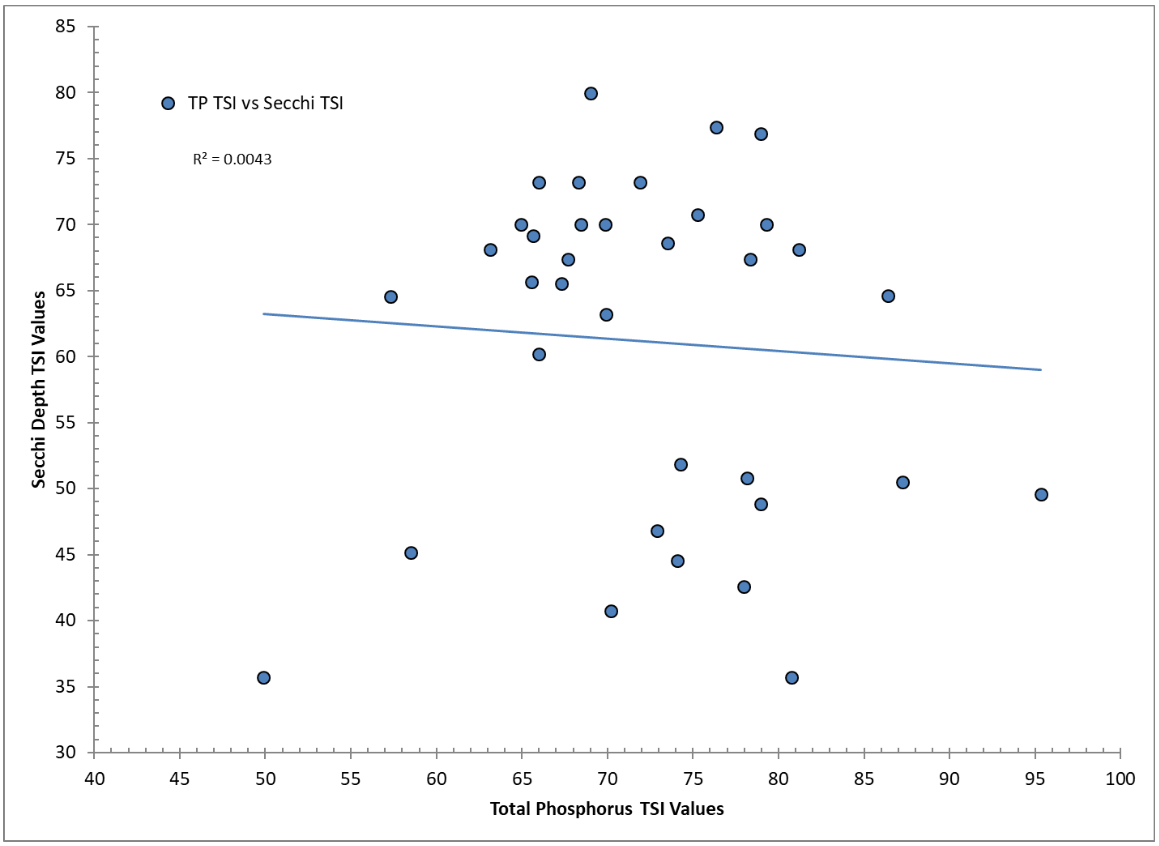

Figure 3-4. Analysis Period TSI Values for Total Phosphorus and Secchi Depth.

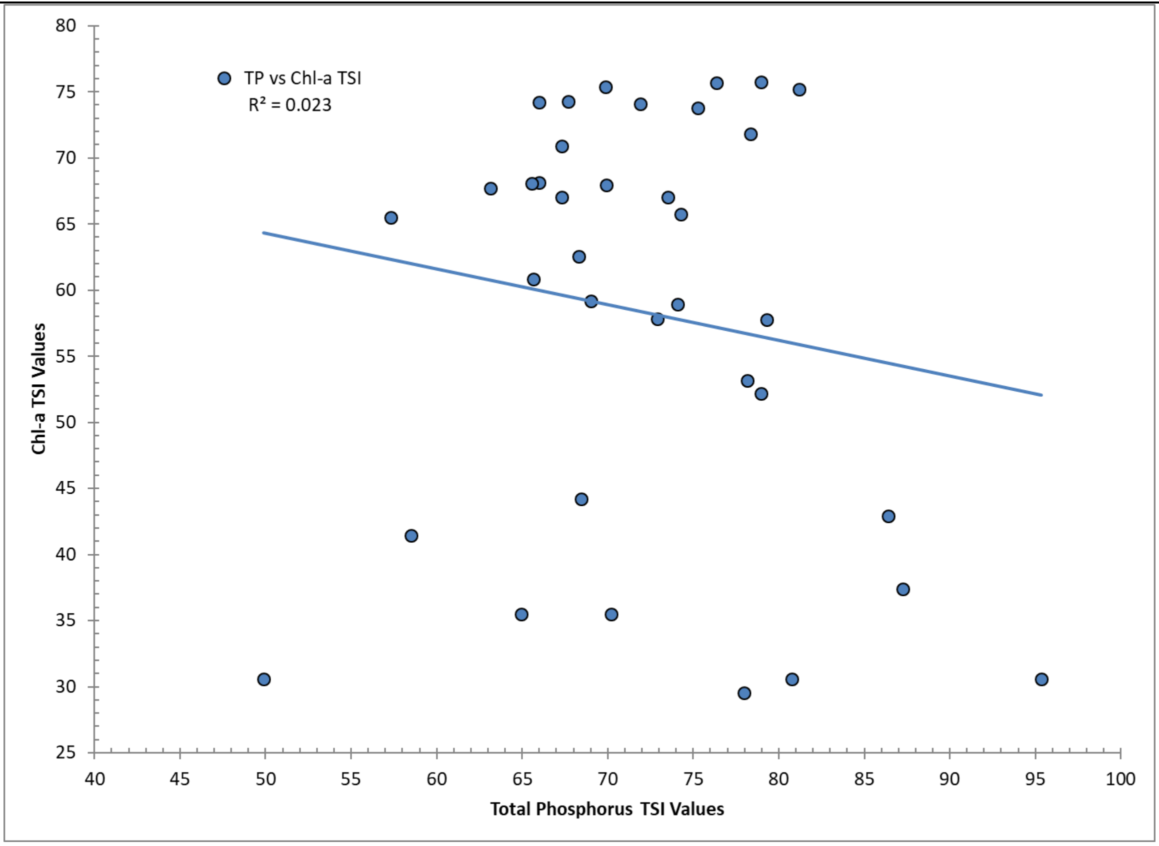

Figure 3-5. Analysis Period TSI Values for Total Phosphorus and Chlorophyll-A.

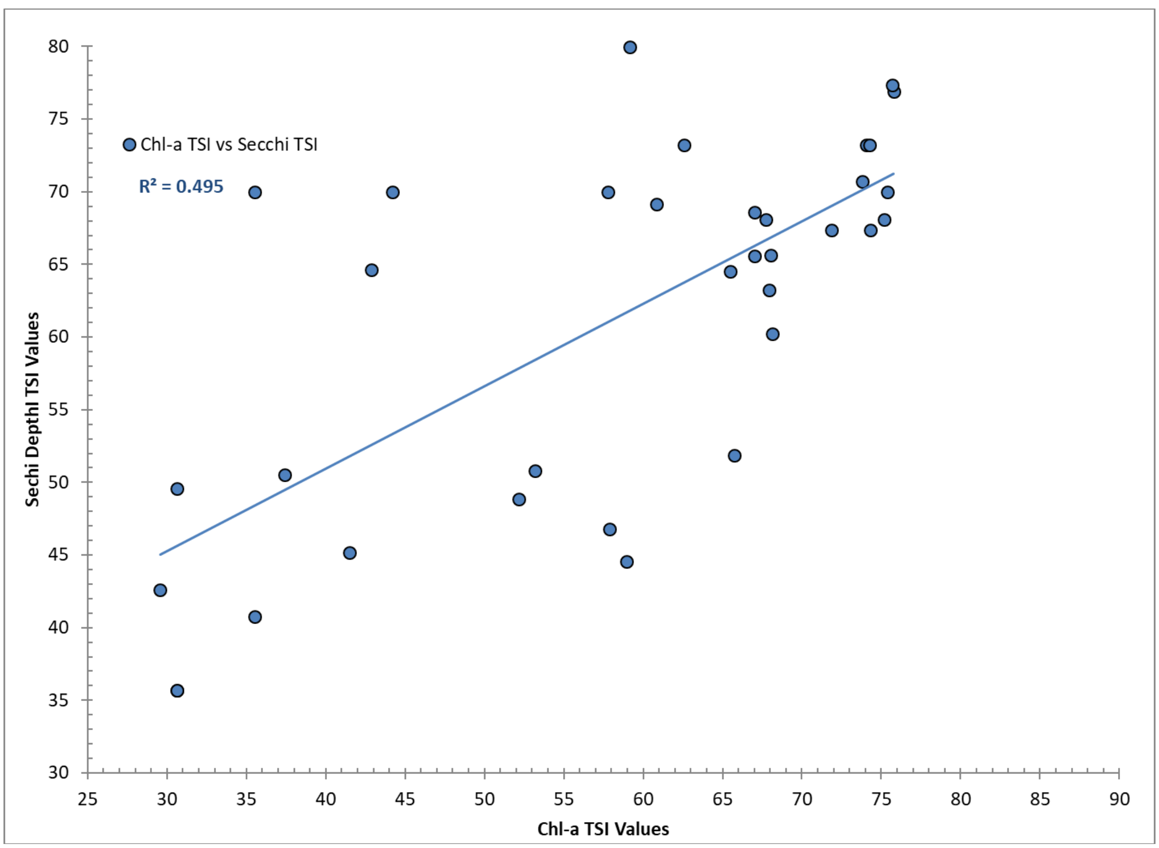

Figure 3-6. Analysis Period TSI Values for Chlorophyll-A and Secchi Depth.

Figure 3-7 and Figure 3-8 illustrates a method for interpreting the meaning of the deviations between Carlson's TSI values for TP, Secchi depth, and chl-a. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chl-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis. This suggests phosphorus may not be the limiting factor in algal growth. The X-axis, or zero line, is related to TN:TP ratios of greater than 33:1 (Carlson, 1996). Because phosphorus is thought to become limiting at ratios greater than 10:1, TP deviations slightly below the X-axis do not necessarily indicate nitrogen limitation.

Points to the left of the Y-axis (Chl TSI < SD TSI) represent conditions in which transparency is reduced by non-algal turbidity, whereas points to the right reflect situations in which transparency is less than chl-a levels would suggest, meaning that large particles, rather than fine clay particles, influence water clarity. Deviations to the right may also be caused by high zooplankton populations that feed on algae, keeping the algal populations lower than expected given other conditions.

It is observed that in Figure 3-7 there are some large deviations between TP(TSI) and Chl-a(TSI). Additional review revealed that the large deviations occurred early in the year (April - June) when temperatures were not warm enough to promote algae growth. Consequently, there are higher levels of phosphorus and lower levels of chl-a during those months, which would account for the large deviations. Those points have been identified with red triangles.

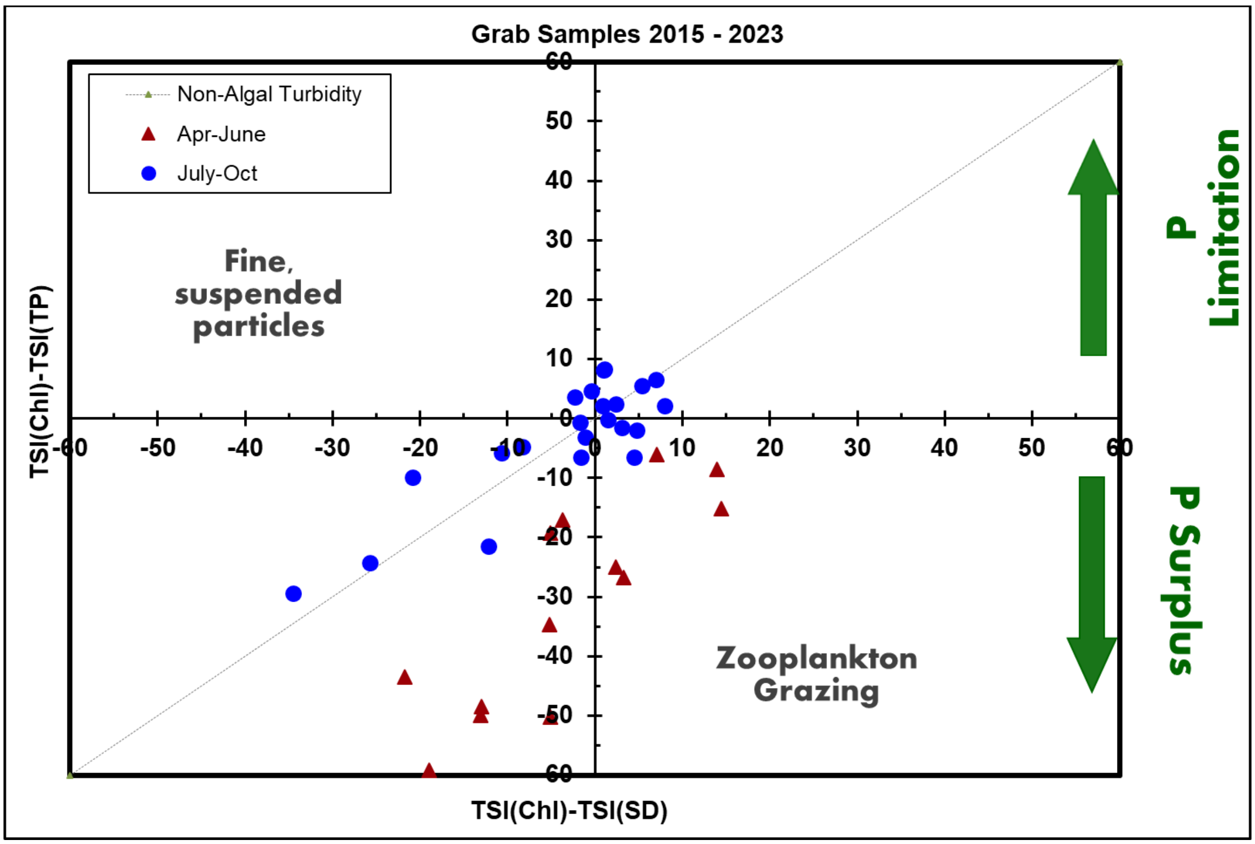

Figure 3-7. Phosphorus TSI Deviations Grab Samples for Analysis Period.

For the blue data points, where the water temperature typically exceeds 23.89 °C (75 °F), chlorophyll-a and TP TSI deviations are divided between positive and negative deviations with 59 percent of samples (13 of 22 samples) below the x-axis while 41 percent of samples (9 of 22 samples) are above the x-axis as shown in Figure 3-7. A majority of the deviations are located in the bottom left hand quadrant (9 of 22 samples, 41%) and the upper right-hand quadrant (7 of 22 samples, 32%). Samples located in the bottom left hand quadrant would indicate smaller particles dominate and something other than phosphorus limits the growth of algae. Samples in the upper right-hand quadrant would indicate large particles dominate and that phosphorus limits the growth of algae.

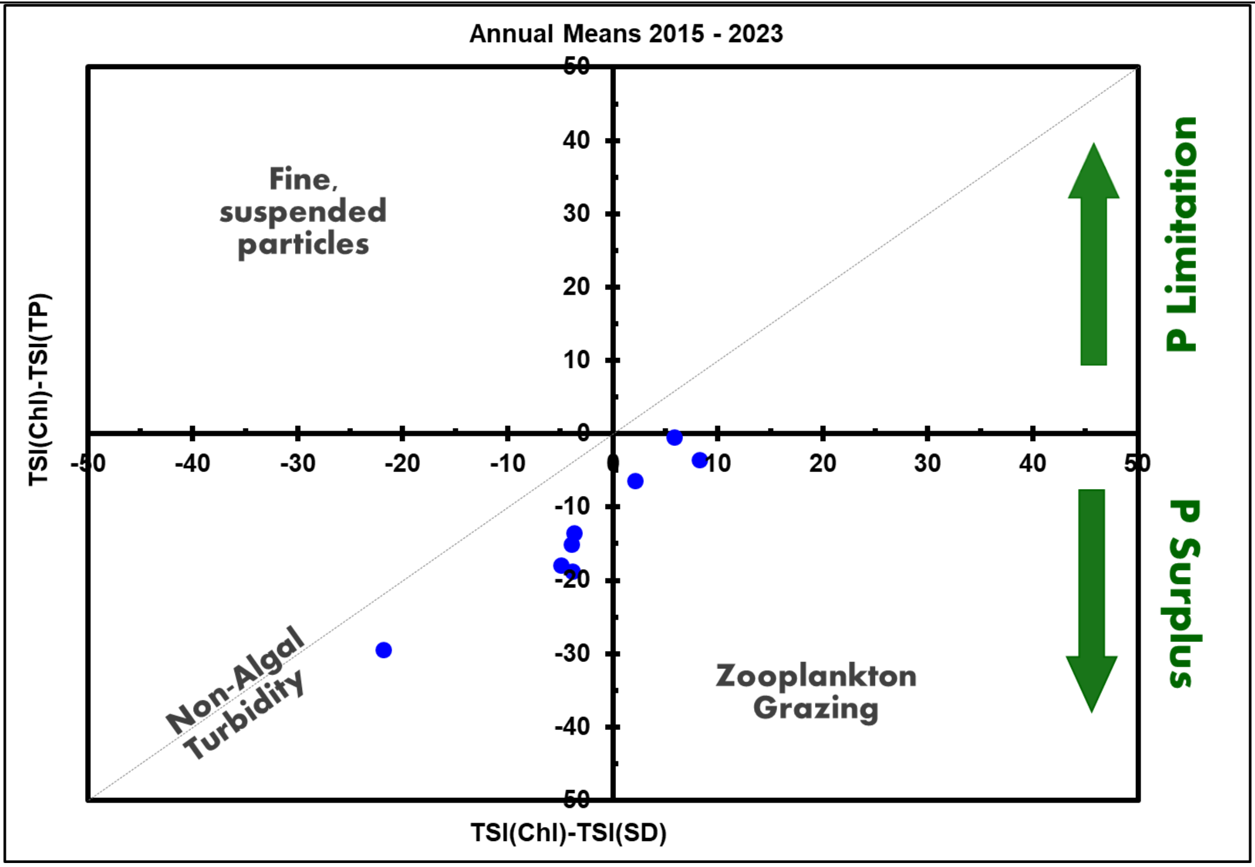

Figure 3-8. Phosphorus TSI Deviations Annual Averages for Analysis Period.

Chl-a TSI shows no correlation to annual and growing season precipitation. Secchi depth TSI shows a mild positive correlation to annual and growing season precipitation and TP TSI a moderate positive correlation to annual and growing season precipitation as shown (Figure 3-9, Figure 3-10, and Figure 3-11).

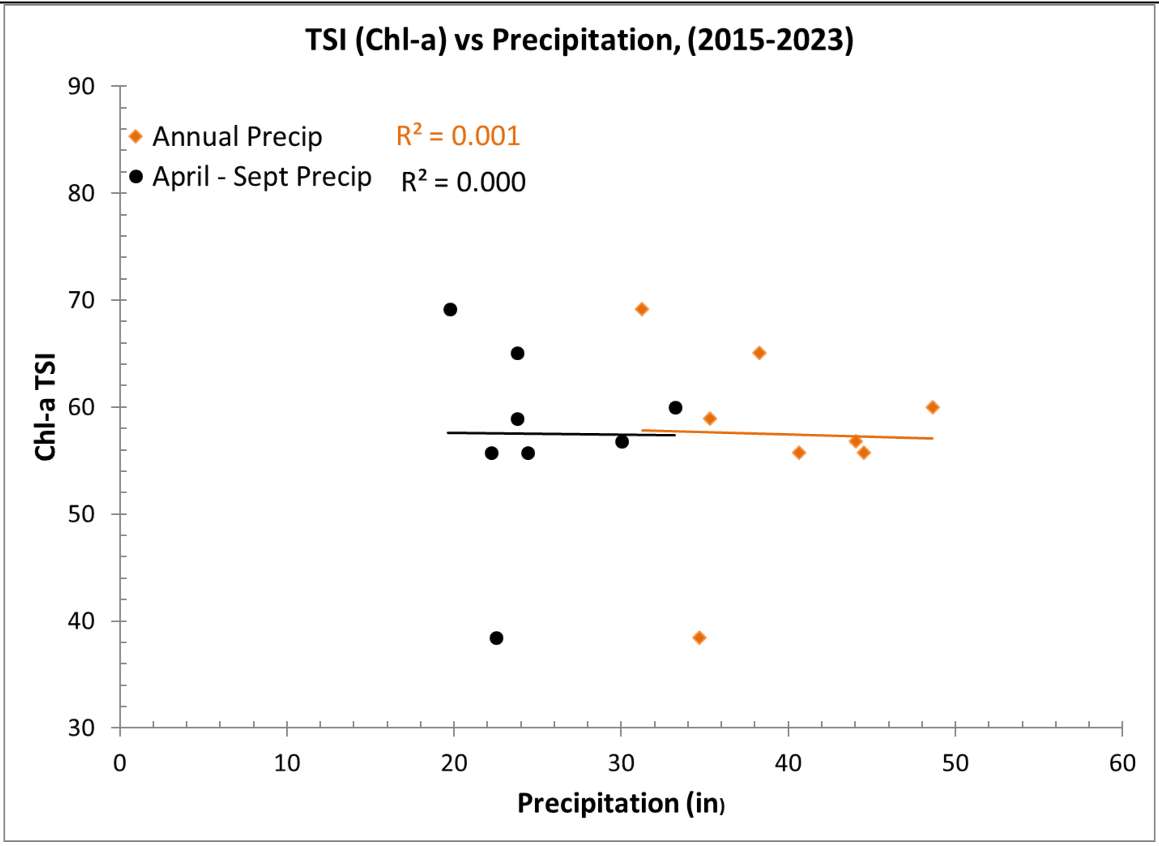

Figure 3-9. Chl-a TSI Values vs Annual and Growing Season Precipitation.

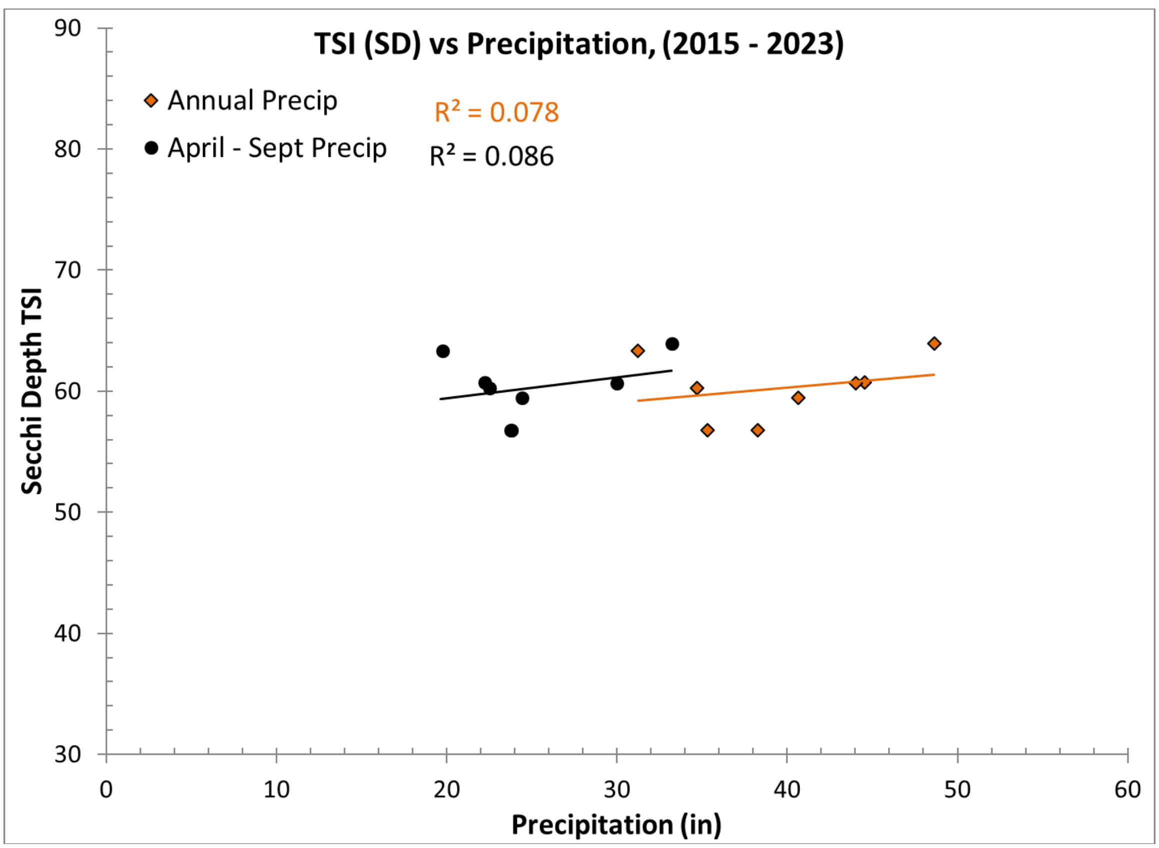

Figure 3-10. Secchi Depth TSI Values vs Annual and Growing Season Precipitation.

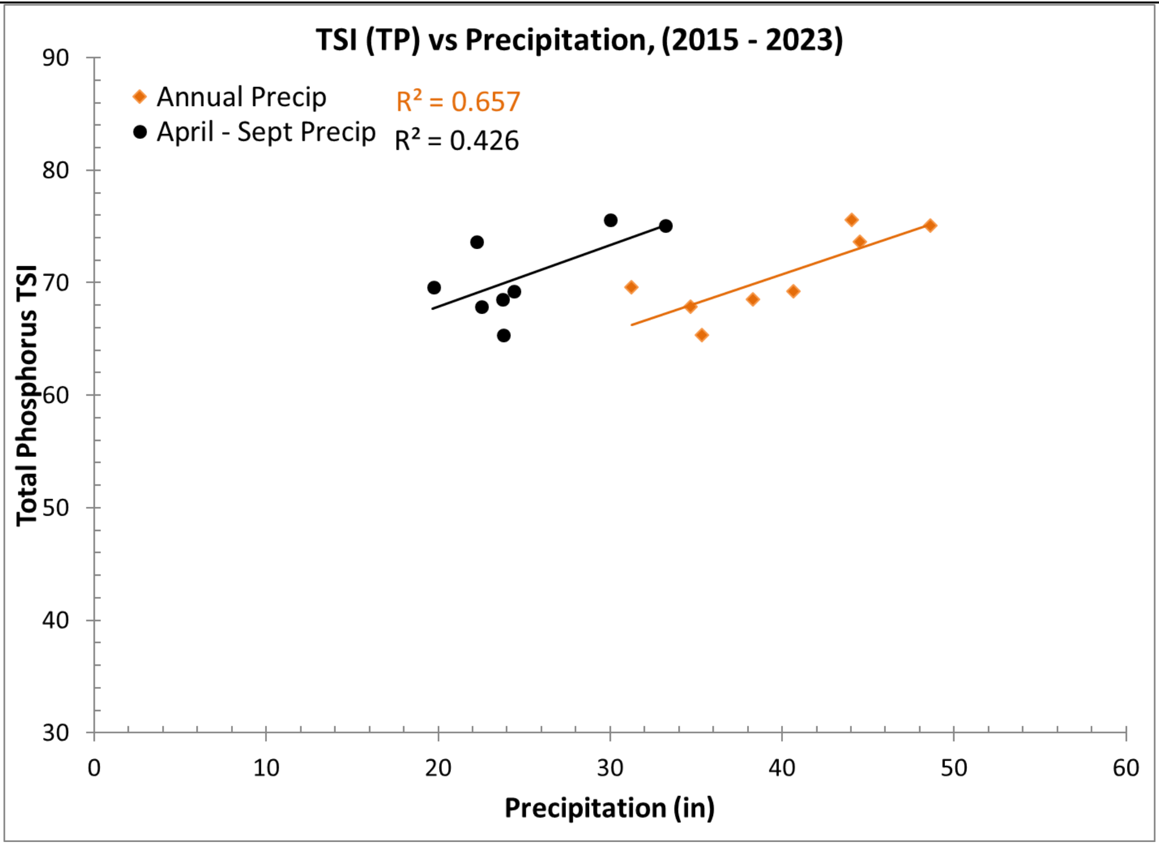

Figure 3-11. Total Phosphorus TSI Values vs Annual and Growing Season Precipitation.

In a lake environment, 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 Big Hollow Lake, using average grab sample concentrations from 2015-2023, is 26. 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.

Table 3-5 lists the number of samples for each nutrient limiting condition for all samples, when TSI(chl-a) is greater than 65, and when TSI(SD) is greater than 65. Analysis of the TN:TP ratio in Big Hollow Lake samples reveals that the lake is P-limited 66 percent of the time and co-limited 31 percent of the time. In addition, when the chl-a TSI or the Secchi depth TSI exceeds 65, the lake is either P-limited or co-limited 100 percent of the time. This analysis reveals that water quality improvement of algal blooms and turbidity via TP reduction is most feasible. 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.

Table 3-5. TN:TP Ratio Summary in Big Hollow Lake.

Samples Collected	# of Samples	N-Limited (<10)	Co-Limited (10-17)	P-Limited (>17)
All Samples, 2015-2023	22	0 (0%)	5 (23%)	17 (77%)
Samples with Chl-a TSI > 65	16	0 (0%)	4 (25%)	12 (75%)
Samples with Secchi TSI > 65	19	0 (0%)	5 (26%)	14 (74%)
Both Chl-a and Secchi > 65	13	0 (0%)	5 (31%)	9 (69%)

The pH values for the assessment period are shown in Figure 3-12. The red boxes represent values outside the acceptable pH range. Water quality samples below 6.5 and above 9.0 comprising significantly greater than 10 percent of the total samples within an assessment period trigger an impairment.

The main cause of pH fluctuations in Big Hollow Lake is primary production by photosynthetic biomass. Figure 3-13 reveals a positive correlation (R^2=0.1758) between chl-a TSI and pH over the assessment period of 2015-2023, but these samples do not capture the diurnal nature of this phenomenon. Continuous data or data collected at peak production times (i.e., late in the day on sunny afternoons) would likely strengthen this relationship. Reducing algal production will decrease pH spikes in Big Hollow Lake, and the first step towards reduced algal blooms requires phosphorus load reductions. The line of best fit for comparing chl-a and pH also shows that when the value for chl-a TSI is less than 63 the value for pH is less than 9.0, meaning both are meeting the WQS.

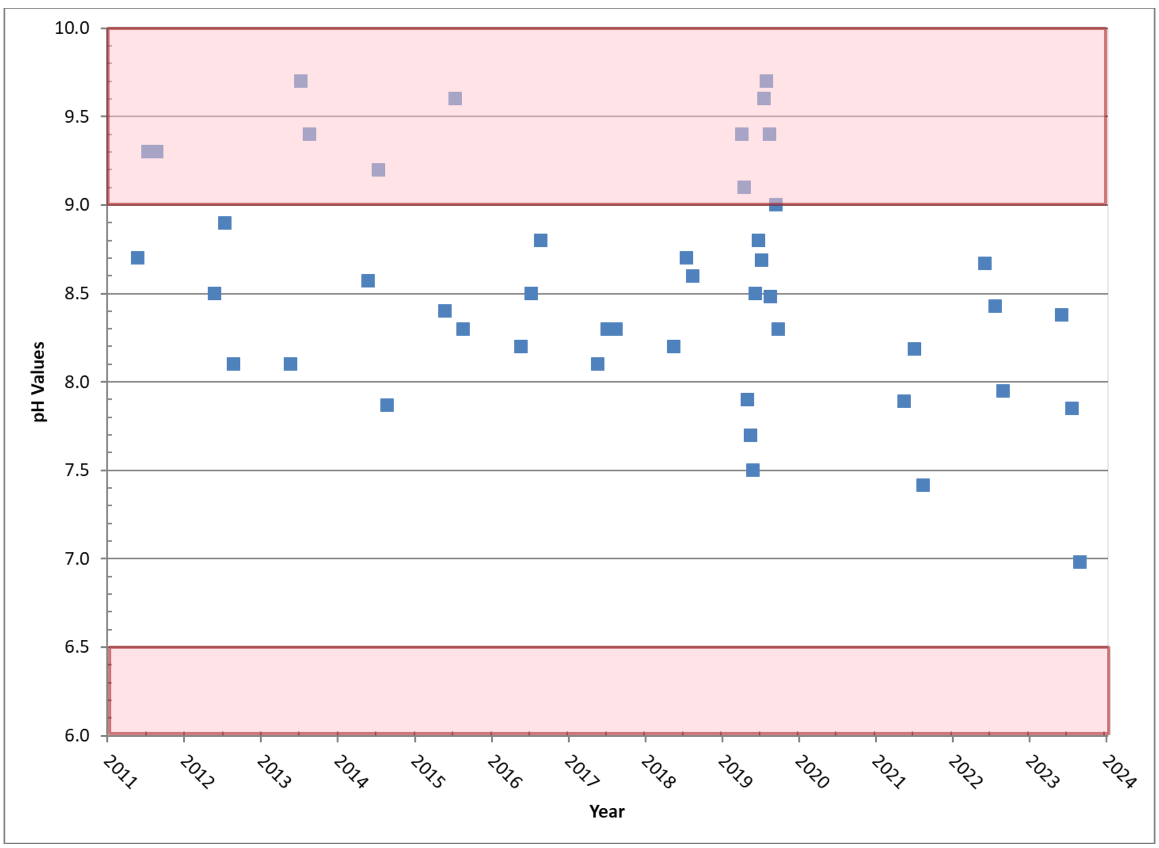

Figure 3-12. pH Values During the 2015 - 2023 Analysis Period

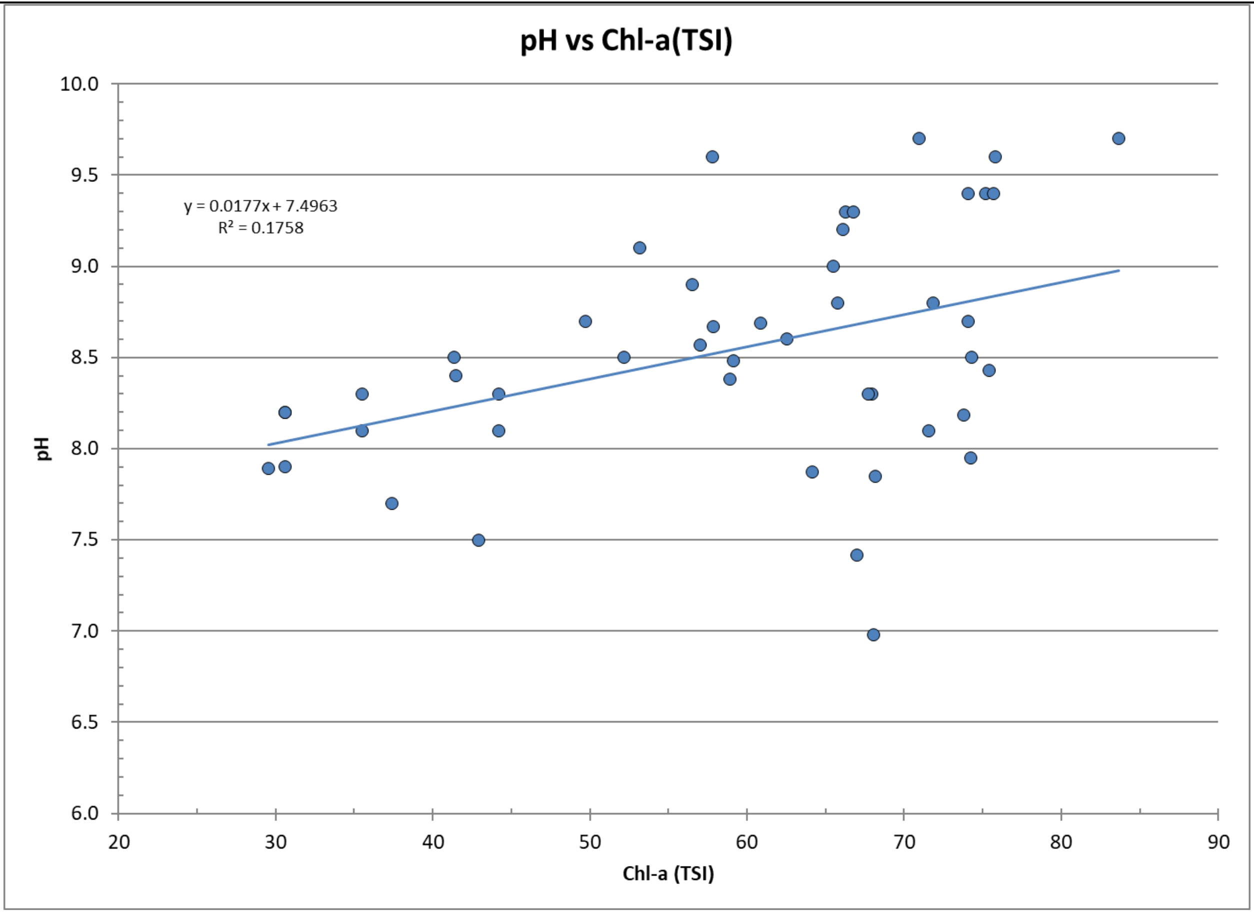

Figure 3-13. pH and Chl-a TSI Values During the Analysis Period.

3.2 TMDL Target

General Description of the Pollutant

The 2024 305(b) assessment attributes poor water quality in Big Hollow Lake to excess algae, turbidity, and pH fluctuations that are outside allowable levels. It will be important to continue to assess TSI values for chl-a and Secchi depth as phosphorus reduction practices are implemented. If phosphorus reductions are not accompanied by reductions in algal blooms, then reductions of 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 and pH fluctuations. 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, often referred to as blue-green algae, can emit cyanotoxins to the water, which can harm humans, pets, and wildlife if ingested.

Table 3-6 reports the Secchi depth, chl-a, and TP at the ambient monitoring location for both existing and simulated target conditions. In-lake water quality was simulated using the BATHTUB model, which is described in more detail in Appendix E. The chl-a TSI target of 63 complies with the narrative “free from aesthetically objectionable conditions” criterion. The Secchi depth TSI target of 63 or less complies with the turbidity impairment. Meeting both of these targets will result in delisting Big Hollow Lake if attained during one 303(d) listing cycle. Note that TP values in Table 3-6 are not TMDL targets. Rather, they represent in-lake water quality resulting from TP load reductions required to obtain the chl-a and Secchi depth TSI targets in Big Hollow Lake.

Table 3-6. Existing and Target Water Quality (Ambient Monitoring Location).

Parameter	2015-2023[1]	2018-2022[2]	TMDL Target Conditions
Secchi Depth (meter)	1.4	1.2	1.8
TSI (Secchi Depth)	56	57	51.7
Chlorophyll-a (µg/L)	37.3	42.0	27.2
TSI (Chlorophyll-a)	66	67	63
TP (µg/L)	130.1	148.3	81.1
TSI (TP)	74	76	67.5
pH average	8.5	8.5	6.5 - 9.0
pH violations / total %	7/35 (20 %)	6/23 (26 %)	*

[1]Modeled period.
[2]2024 Assessment/Listing Cycle Values.
* Less than significantly greater than 10% of pH values outside of the accepted pH range.

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 can contribute to algal growth and turbidity regardless of when phosphorus first enters the lake. Additionally, the combined watershed and in-lake modeling approach using EPA's STEPL and BATHTUB lends itself to analysis of annual average conditions. Therefore, both existing and allowable TP loads to Big Hollow Lake are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Waterbody Pollutant Loading Capacity (TMDL)
This TMDL establishes a chlorophyll-a TSI target of 63 and a Secchi depth TSI target of 63 using analyses of existing water quality data, Carlson's trophic state index methodology, and a pH target consistent with WQSs. The allowable TP loading capacity was developed by performing water quality simulations using the BATHTUB model. BATHTUB is a steady-state water quality model that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). The BATHTUB model was calibrated to available water quality data collected by ISU and SHL from 2015 through 2023.

The BATHTUB model is driven by weather, lake morphometry (i.e., size and shape), watershed hydrology, and sediment and nutrient loads predicted by the STEPL model. STEPL utilizes simple equations to predict sediment and nutrient loads from various land use and animal sources, and includes a tool that estimates potential sediment and nutrient reductions resulting from implementation of BMPs. STEPL input included local soil, land use, and climate data. A detailed discussion of the parameterization and calibration of the STEPL and BATHTUB models is provided in Appendices D through F.

The annual TP loading capacity was obtained by adjusting the TP loads (tributary concentrations) in the calibrated BATHTUB model until chl-a and Secchi depth TSIs no greater than 63 were attained for the lake segment in which ambient monitoring data is collected. Due to the complexity of controlling internal lake loading and external watershed loading, many solutions exist to meet the water quality standard criteria. Figure 3-14 is a load response curve from the BATHTUB model showing one possible solution upon which this TMDL was based. It represents a 50 percent reduction in internal P loading and 77.3 percent reduction in watershed P loading. Modeling reductions in external and internal TP loading shows the annual loading capacity of Big Hollow Lake is 2,188.1 lbs/yr.

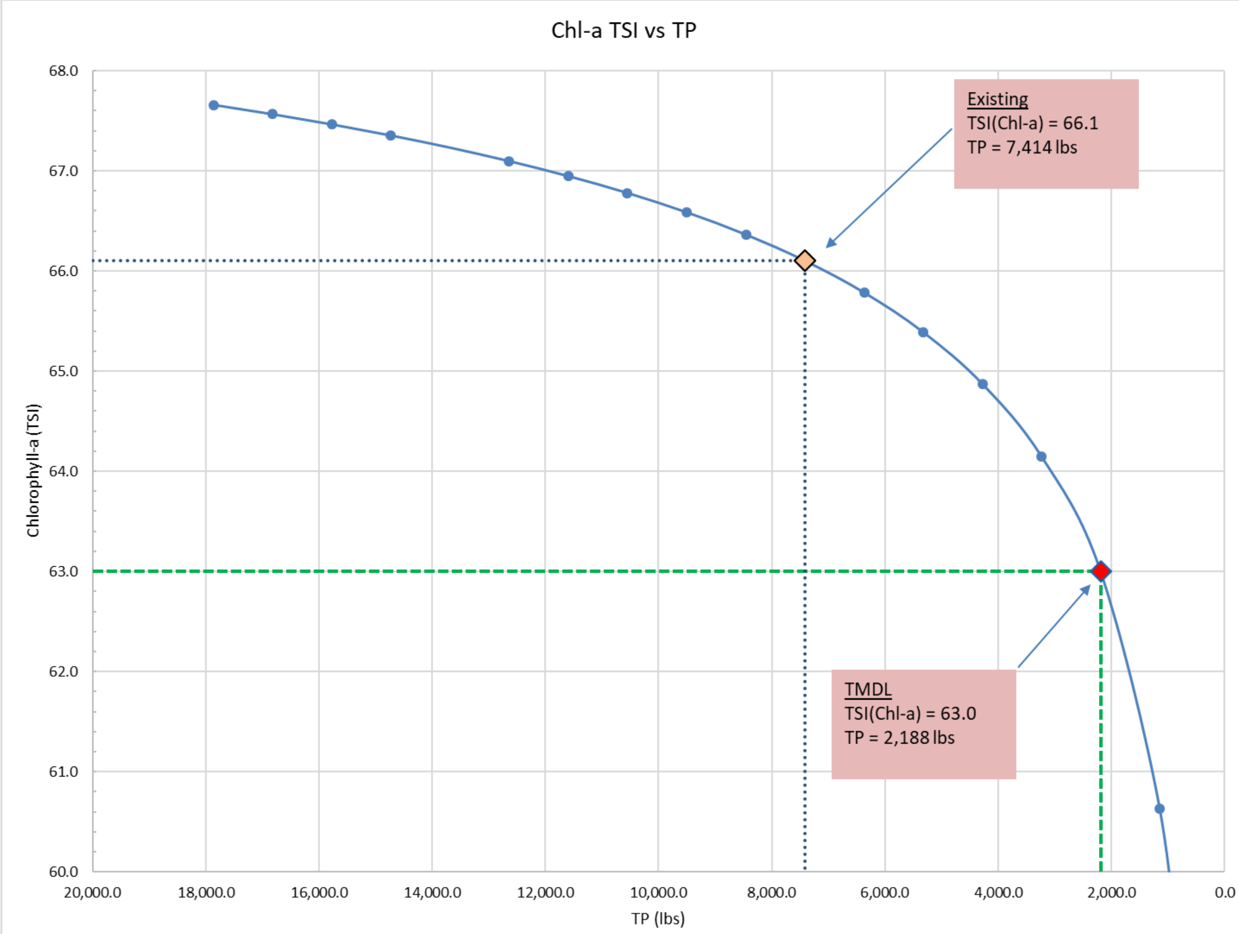

Figure 3-14. Simulated Load Response Between Chl-a TSI and TP Load.

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 be expressed in terms of 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…"

As recommended by EPA, the loading capacity of Big Hollow Lake for TP is expressed as a daily maximum load, in addition to the annual loading capacity of 2,188.1 lbs/year. The annual average load is applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load satisfies EPA's recommendation for expressing the loading capacity as a daily load.

The maximum daily load was estimated from the growing season average load using a statistical approach that is outlined in more detail in Appendix G. This approach uses a log-normal distribution to calculate the daily maximum from the long-term (e.g., annual) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), and was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*. Using the approach, the annual loading capacity of 2,188.1 lbs/yr is equivalent to an average daily load of 6.0 pounds per day (lbs/day) and a maximum daily load of 18.7 lbs/day.

Decision Criteria for WQS Attainment

The narrative criteria in the WQSs require that Big Hollow Lake support primary contact for recreation. The metrics for WQS attainment for delisting the impairments are a chl-a TSI and Secchi depth TSI of 63 or less for one 303(d) listing cycle, and pH values not to exceed significantly greater than 10 percent of values outside the acceptable range of 6.5 - 9.0 as defined by DNR IR methodology.

Compliance Point for WQS Attainment
The TSI target for listing and delisting of Big Hollow Lake is measured at the ambient monitoring location shown in Figure 3-1. For modeling purposes, the lake was divided into multiple segments (Figure E-2). To maintain consistency with other Clean Water Act programs implemented by the DNR, such as the 305(b) assessment and 303(d) listing process, the TMDL target is based on water quality of Segment 1, which best represents the ambient monitoring location in Big Hollow Lake.

3.3 Pollution Source Assessment

Existing Load
Average annual simulations of hydrology and pollutant loading were developed using the STEPL model (Version 4.3). STEPL was developed by Tetra Tech, for the US EPA Office of Wetlands, Oceans, and Watersheds (OWOW), 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 to simulate annual average conditions between 2015-2023, the annual TP load to Big Hollow Lake was estimated to be 7,414.5 lbs/yr. The simulation period (for existing conditions) includes the assessment period for (the 2024 IR) as well as prior and subsequent years where monitoring data were available.

Departure from Load Capacity
The TP loading capacity for Big Hollow Lake is 2,188.1 lbs/yr and 18.7 lbs/day (maximum daily load). To meet the target loads, an overall reduction of 5,226.4 lbs (70.5 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 Big Hollow Lake is primarily from nonpoint sources of pollution, but does include one (1) point source operating under a National Pollution Discharge Elimination System (NPDES) permit. Table 3-7 reports estimated annual average TP loads to the lake from all known sources, based on the STEPL simulation of average annual conditions from 2015-2023. The predominant sources of phosphorus to Big Hollow Lake include erosion from row crops and internal recycling. Row crops comprise 70 percent of the watershed and approximately 60 percent of the phosphorus loads to the lake (Table 3-7).

Internal recycling of phosphorus in the lake, sometimes referred to as internal loading, comprised 19.6 percent of the average TP load from 2015 - 2023. The BATHTUB model allows users to quantify an internal loading input to the model. In lakes with substantial internal loading issues, inclusion of additional internal load inputs is sometimes necessary. Internal recycling of phosphorus may be important in extremely dry conditions, typically late in the growing season, when the water level falls below the spillway crest, creating a stagnant pool in the reservoir. Reduction of internal loads is still thought to be a valid water quality improvement alternative, but watershed loads also need to be addressed to ensure long term water quality in the lake.

Phosphorus discharged from the United States Gypsum facility is estimated at approximately one percent of the total load. In addition, the effluent from this facility is required to maintain a pH between 6.5 and 9.0, which is the same range as the WQS for Big Hollow Lake and therefore should not influence pH to unacceptable levels in the lake.

Table 3-7. Average Annual TP Loads from each Source.

Source	Descriptions and Assumptions	TP Load (lbs/yr)	Percent (%)
Pastureland	Seasonally grazed grassland	103.8	1.4%
Row Crops	Sheet and rill erosion from corn and soybeans dominated agriculture	4,448.6	60.0%
Internal Recycling	Phosphorus below thermocline	1,453.7	19.6%
Point Sources[1]	US Gypsum treatment facility and future reserve capacity for GP#4.	100.0	1.3%
Grassland	Ungrazed Grassland, Alfalfa/Hay	33.6	0.5%
Forest	Forested park grounds surrounding lake	96.1	1.3%
Urban	Urban areas, roads, and farmsteads	678.1	9.1%
Groundwater	Agricultural tile discharge, natural groundwater flow	202.3	2.7%
Gully	Gully formation and incision	169.9	2.3%
All Others	Wildlife, atmospheric deposition, septics, streambank	128.4	1.7%
Total		**7,414.5**	**99.9%[2]**

[1]Includes 80 lbs (1%) for US Gypsum treatment facility and 20 lbs (0.3%) reserve capacity for future GP#4 discharging facilities.
[2]Does not equal 100 due to rounding.

Allowance for Increases in Pollutant Loads
Some allowance for increased phosphorus loading included as part of this TMDL has been incorporated into this TMDL. 20 lbs/yr has been set aside in reserve to allow for the conversion of existing onsite septic systems to a General Permit #4 (GP#4) discharging facility or facility growth. This allowance has been included as part of the point source load as shown in Table 3-7.

A majority of the watershed is in agricultural row crop production and is likely to remain in these land uses in the future. Any future residential or urban development may contribute similar sediment loads and therefore will not increase phosphorus to the lake system. There are currently no incorporated unsewered communities in the watershed; therefore, it is unlikely that a future WLA would be needed for a new point source discharge. Any future development of animal feeding operations (AFO) qualifying as large concentrated animal feeding operations (CAFO) or meeting the requirements for NPDES permits as small or medium sized CAFOs will have zero discharge permits.

3.4 Pollutant Allocation

Wasteload Allocation
The US Gypsum wastewater treatment facility is located approximately 3.5 miles north of the lake outlet and is the only permitted point source discharger in the watershed. The treatment facility is a three-cell controlled-discharge lagoon that is permitted to discharge twice per year, once in the spring and once in the fall/early winter. Existing phosphorus loads from the facility were estimated using daily discharge records and an assumed effluent concentration of 2.0 mg/L TP. This concentration is based on the findings of a Minnesota Pollution Control Association (MPCA) study. The study found that TP in lagoon effluent ranges from 1 to 3 mg/L, with the mean and median TP concentrations both equal to 2.0 mg/L (MPCA, 2000).

The estimated load contributed by the US Gypsum facility is approximately one percent of the overall TP load to Big Hollow Lake. However, because no observed phosphorus data are available for this facility, there is uncertainty associated with this allocation. The WLA is based on the best estimate of the existing effluent concentration of 2.0 mg/L and actual discharge (flow) records. Using daily monitoring records, it was determined that the 90th percentile of flows from this facility between 2015 - 2023 is 4.77 MG/year, which translates to an annual TP load of 80 lbs/yr. This is reasonable and most likely a conservative assumption since the facility discharges sanitary waste as well as storm water, which would have the effect of diluting the effluent. Assuming that this load is discharged over the course of 40 days the maximum daily load would be 2 lbs/day. 40 days is based on the 10th percentile of number of days the facility discharged from 2015 - 2023. In addition, this facility is required to maintain a pH between 6.5 and 9.0 in the effluent.

There are two small animal feeding operations within the watershed neither of which are permitted to discharge. However, manure generated at these facilities is applied to row crop and pastureland in the watershed, which is reflected in the LA calculations. In addition, there are several onsite septic systems in the watershed but they are not designed or permitted discharge. A portion of the existing septic systems are assumed to be failing or directly discharging to tile drains and are included as nonpoint sources. Therefore, there is no wasteload allocation (WLA) for these facilities and onsite systems. However, 20 lbs/yr has been held in reserve to allow for the conversion of several onsite septic systems to a GP#4 discharge permit.

Load Allocation
Nonpoint sources of phosphorus to Big Hollow Lake include erosion from land in pasture and row crop production, land applied manure, erosion from grasslands, erosion from timber/wooded areas, transport from developed areas (roads, residences, etc.), wildlife defecation, atmospheric deposition (from dust and rain), and groundwater contributions. Septic systems in this watershed, which are not regulated or permitted under the Clean Water Act, but can fail or drain illegally to ditches, are assumed to have contributed phosphorus to the lake during the assessment period.

Changes in agricultural land management, implementation of structural BMPs, repair or replacement of failing septic systems, and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Big Hollow Lake. Based on the inventory of sources, management and structural practices targeting surface runoff contributions of phosphorus offer the largest potential reductions in TP loads.

Table 3-8 shows an example load allocation scenario for the Big Hollow Lake watershed that meets the overall TMDL phosphorus target. The LA is 1,869.3 lbs/year, with a maximum daily LA of 15.9 lbs/day. The daily maximum LA was obtained by subtracting the daily WLA and daily MOS from the statistically derived TMDL (as described in Section 3.2 and Appendix G). The specific reductions shown in Table 3-8 are not required, but provide one of many possible combinations of reductions that would achieve water quality goals.

Table 3-8. Example Load Allocation Scheme to Meet Target TP Load.

TP Source	Existing Load (lbs/year)	LA (lbs/year)	NPS Reduction (%)
Pastureland	103.8	14.5	86
Row Crops	4,448.6	622.8	86
Internal Recycling	1,453.7	726.9	50
Point Source	100.0	100.0	0
Grassland[1]	33.6	4.7	86
Forest	96.1	13.5	86
Urban	678.1	94.9	86
Groundwater	202.3	202.3	0
Gully	169.9	85.0	50
All Others[2,3]	116.9	86.0	33
Total	**7,414.5**	**1,950.6**	**--**

[1]Non grazed grassland and Alfalfa/Hay.
[2]Atmospheric contributions, direct lake contributions by waterfowl, septics, streambank.
[3]Represents a 50 percent reduction from septic systems and streambank erosion.

Margin of Safety

To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. These uncertainties may include seasonal changes in nutrient concentrations of influent to Big Hollow Lake, changes in internal recycling that may be seasonal in nature, and maintenance and efficiency of existing BMPs. Implicit and explicit considerations were used in establishing the MOS for this TMDL. Ultimately, an explicit MOS of 10 percent (218.8 lbs/yr, 1.9 lbs/day) was utilized.

The 10 percent explicit MOS is deemed appropriate for the following reasons:

1) The STEPL model overpredicts a TP load that is approximately 0.29 percent higher than the SPARROW calibration site.
2) The model shows good agreement between predicted and observed loadings, after calibration, indicating that the model reasonably reflects the conditions in the lake.
3) Using an explicit 10 percent MOS provides an additional level of conservatism in the final TMDL calculations.

Reasonable Assurance

Under current EPA guidance, TMDLs that allocate loads to both point sources (WLAs) and nonpoint sources (LAs) must demonstrate reasonable assurance that implementation and pollutant reductions will occur. For point sources, reasonable assurance is provided through NPDES permits. Permits include operation requirements and compliance schedules that are developed based on water quality protection.

Reasonable assurance for reduction of nonpoint sources is provided by the list of potential BMPs that would deliver phosphorus reductions, a group of nonstructural practices that prevent transport of phosphorus, a proposed methodology for prioritizing and targeting BMPs on the landscape, and monitoring for best available data for estimating the reductions associated with implemented BMPs. As discussed previously, a WMP has been written and portions of that plan have already been implemented. In addition, the WMP contains a schedule and plan for implementation of BMPs in the watershed. Continued monitoring of the Iowa DNR as part of the Ambient Lake Monitoring Program will track the progress and success of implemented projects.

3.5 TMDL Summary

The following general equation represents the TMDL calculation and its components:

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

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

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

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

TMDL = LC = Σ WLA (100 lbs-TP/year) + Σ LA (1,869.3 lbs-TP/year) + MOS (218.8 lbs-TP/year) = **2,188.1 lbs-TP/year**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0.9 lbs-TP/day) + Σ LA (15.9 lbs-TP/day) + MOS (1.9 lbs-TP/day) = **18.7 lbs-TP/day**

The maximum daily load is presented on a 365 days/year basis to satisfy EPA requirements. However, the point source discharger (US Gypsum, Permit # 2900103) in the watershed is a CDL. Consequently, as it does not discharge daily for NPDES purposes, the US Gypsum facility will be given a WLA of 80 lbs/yr or a maximum daily load of 2 lbs/day.

4. Implementation Planning

An implementation plan is not a requirement of the CWA. However, the DNR recognizes that technical guidance and support are critical to achieving the goals outlined in this WQIP. Therefore, this implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. The BMPs discussed are potential tools that will help achieve water quality goals if appropriately utilized. It is possible that only a portion of BMPs included in this plan will be feasible for implementation in the Big Hollow Lake watershed. Additionally, there may be potential BMPs not discussed in this implementation plan that should be considered. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

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

4.1 Watershed Planning and Implementation

Since the development of Big Hollow Lake in 2008, agricultural producers have updated management practices, installed grassed waterways, and implemented conservation tillage practices. The CCB manages the park and recreation area around the lake and has made continued efforts to implement BMPs wherever possible. These practices help prevent and mitigate soil loss from the landscape, which can in turn decrease nutrient and pollutant loading to the lake system. In addition, sedimentation basins were added to aid in the improvement of the water quality of Big Hollow Lake by settling out sediment laden runoff.

4.2 Existing Watershed Planning and Implementation

As discussed in Section 2, a WMP for the Big Hollow Lake watershed was developed by Fyra Engineering. The WMP includes: 1) the elements of a 9-Element plan required for 319 funding; 2) an implement plan including goals and objectives; and 3) encourage watershed community involvement. For convenience, a copy of the implementation schedule contained within the WMP is presented in this document as Table 4-1. At the time of this writing, two sedimentation basins have been constructed on the west side of the lake. Full effects of these ponds on water quality may not be known until water quality data is collected and analyzed as part of a future assessment cycle.

Table 4-1. Implementation Schedule from WMP[1]

	20-Year Plan		Phase 1	Phase 2		Phase 3		Phase 4	
# Years	20		1	4		5		10	
Practice	Goal	Cost	Cost	Phase Goal	Phase Cost	Phase Goal	Phase Cost	Phase Goal	Phase Cost
Watershed Coordinator	N/A	$2,084,466	$70,000	N/A	$309,143	N/A	$461,285	N/A	$1,244,038
WQ Monitoring	N/A	$160,000	$8,000	N/A	$32,000	N/A	$40,000	N/A	$80,000
OU	N/A	$7,000	$2,500	N/A	$1,500	N/A	$1,500	N/A	$1,500
Grassed WW	334	$35,430	$0	84	$8,857	84	$8,857	167	$17,715
Wetlands	316	$126,416	$0	79	$31,604	79	$31,604	158	$63,208
Sediment Ponds	490	$281,917	$0	123	$70,479	123	$70,479	245	$140,958
Terraces	205	$269,384	$0	51	$67,346	51	$67,346	103	$134,692
WASCOBs	130	$237,633	$0	33	$59,408	33	$59,408	65	$118,817
No-Till	580	$2,799	$0	145	$2,900	145	$2,900	290	$5,799
Cover Crops	828	$41,425	$0	207	$20,712	207	$20,712	414	$41,425
Extended Rotation	298	$8,948	$0	75	$6,711	75	$6,711	149	$13,422
Perennial Conversion	166	$31,814	$0	41	$23,861	41	$23,861	83	$47,722
Riparian Buffers	8	$5,178	$0	2	$1,346	2	$1,346	4	$2,693
Streambank stabilization (ft)	270	$56,700	$0	68	$14,175	68	$14,175	135	$28,350
Gully Stabilization (ft)	1708	$179,314	$0	427	$44,828	427	$44,828	854	$89,657
Access Control (Fencing, ft)	5000	$15,000	$0	1,250	$3,750	1,250	$3,750	2,500	$7,500
Park Pond Rehab # ponds)	6	$300,000	$0	0	$0	0	$0	6	$300,000
Lake Forebays (# forebays)	2	$500,000	$0	0	$0	0	$0	2	$500,000
Total		**$4,343,424**	**$80,500**		**$698,620**		**$858,762**		**$2,837,496**

[1]Adapted from the WMP. For full details see Table 7.1 in the WMP.

4.3 Future Planning and Implementation

General Approach

Watershed management and BMP implementation to reduce algae in the lake should utilize a phased approach to improving water quality. The existing loads, loading targets, a general listing of BMPs needed to improve water quality, and a monitoring plan to assess progress are established in this WQIP. Completion of the WQIP should be followed by the development of a watershed management plan by a local planning group. The watershed plan should include more comprehensive and detailed actions to better guide the implementation of specific BMPs. Tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of water quality trends, assessment of WQS attainment, and adjustment of proposed BMP types, location, and implementation schedule to account for changing conditions in the watershed.

Timeline

Planning and implementation of future improvement efforts may take several years, depending on stakeholder interest, availability of funds, landowner participation, and time needed for design and construction of any structural BMPs.

Realization and documentation of significant water quality benefits may take 5-10 years or longer, depending on weather patterns, amount of water quality data collected, and the successful selection, location, design, construction, and maintenance of BMPs. Monitoring should continue throughout implementation of BMPs and beyond to document water quality improvement.

Tracking milestones and progress

This WQIP, including the proposed monitoring plan outlined in Section 5, would address several of the elements required for a nine-element plan approved by EPA for the use of 319 funds. It may also prove useful in attempting to obtain other state and federal funding sources, as available. Establishment of specific short, intermediate, and long-term water quality goals and milestones would also be needed for additional funding from available sources. A path to full attainment of WQSs and designated uses must be included for most funding sources, but efforts should first focus on documenting water quality improvement resulting from BMPs and elimination of any phosphorus "hot spots" that may exist.

4.4 Best Management Practices

No stand-alone BMP will be able to sufficiently reduce phosphorus loads to Big Hollow Lake. Rather, a comprehensive package of BMPs will be required to reduce sediment and phosphorus loads to the lake. The majority of phosphorus enters the lake via nutrient loss from cropland, non-grazed grassland and forested land through sheet / rill, and gully erosion. These sources have distinct phosphorus transport pathways and processes; therefore, each requires a different set of BMPs and strategies.

Other sources, although relatively small on an annualized basis, can have important localized and seasonal effects on water quality. It is important that all sources are considered to reduce phosphorus loads in the most comprehensive manner possible. Experience has shown that watershed projects that involve widespread "ownership" of potential solutions have the best chance of success. At the same time, resources to address the various sources of phosphorus should be allocated in a manner that is reflective of the importance to the impairment: algal blooms and turbidity issues caused primarily by excess phosphorus loads to the lake and in the lake. Potential BMPs are grouped into three types: land management (prevention), structural (mitigation), and in-lake alternatives (remediation).

Land Management (Prevention Strategies)

Many agricultural BMPs are designed to reduce erosion and nutrient loss from the landscape. These BMPs provide the highest level of soil conservation and soil health benefits because they prevent erosion and nutrient loss from occurring. Land management alternatives implemented in row crop areas should include conservation practices such as no-till and strip-till farming, diversified crop rotation methods, utilization of in-field buffers, and cover crops. Incorporation of fertilizer into the soil by knife injection equipment reduces phosphorus levels, as well as nitrogen and bacteria levels, in runoff from application areas. Strategic timing of fertilizer application and avoiding over-application may have even greater benefits to water quality. Application of fertilizer on frozen ground should be avoided, as should application when heavy rainfall is forecasted. Land retirement programs such as the conservation reserve program (CRP), and conservation reserve enhancement program (CREP) constructed wetlands may be considered where appropriate. Table 4-4 summarizes land management BMPs and associated phosphorus reduction estimates.

Table 4-2. Potential Land Management BMPs (Prevention Strategies).

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

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

Structural BMPs (Mitigation Strategies)

Although they do not address the underlying generation of sediment or nutrients, structural BMPs such as sediment control basins, terraces, grass waterways, saturated buffers, riparian buffers, and wetlands can play a valuable role in reduction of sediment and nutrient transport to Big Hollow Lake. These BMPs attempt to mitigate the impacts of soil erosion and nutrient loss by intercepting them before they reach a stream or lake. Structural BMPs should be targeted to “priority areas” to increase their cost effectiveness and maximize pollutant reductions. Landowner willingness and the physical features of potential sites must also be considered when targeting structural practices. These practices may offer additional benefits not directly related to water quality improvement. These secondary benefits are important to emphasize to increase landowner and public interest and adoption. Potential structural BMPs are listed in Table 4-3. Potential Structural BMPs (Mitigation Strategies)., which includes secondary benefits and potential TP reductions.

Table 4-3. Potential Structural BMPs (Mitigation Strategies).

BMP or Activity	Secondary Benefits	Potential TP Reduction[1]
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50%
Grass Waterways	Prevent in-field gullies, prevent washouts, some ecological services	50%
Sediment Control Structures[2]	Some ecological services, gully prevention and mitigation	Varies
Wetlands[3]	Ecological services, potential flood mitigation, aesthetic value	15%
Riparian Buffers	Ecological services, aesthetic value, alternative agriculture	45%
Saturated Buffers	Nitrate removal	Varies[4]

[1]Adopted from Dinnes (2004). Actual reduction percentages may vary widely across sites and runoff events.

[2]Not discussed in Dinnes (2004). Phosphorus removal in sediment basins varies widely and is dependent upon the size of the structure relative to the drainage area, the length:width ratio, and drawdown time of a specified rainfall/runoff event.

[3]Note: TP reductions in wetlands vary greatly depending on site-specific conditions, such as those listed for sediment control structures. Generally, removal of phosphorus is lower in wetlands than in sediment control structures. Wetland can sometimes be sources, rather than sinks, of phosphorus

[4]Limited research in total phosphorus reduction values

Landowner buy-in, ease of construction, and difficulty implementing preventative land management measures all contribute to the popularity of sediment control structures as a sediment and phosphorus mitigation strategy. This is a proven practice, if properly located, designed, constructed, and maintained. However, if not properly designed and constructed, sediment control basins may trap substantially less sediment and phosphorus than widely-used rules-of-thumb that are often assumed when quantifying reductions in the context of a watershed management plan.

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

The STEPL model was used in TMDL development to predict phosphorus loads to Big Hollow Lake. Figure 4-1 shows the annual phosphorus export from each subbasin in the Big Hollow Lake watershed. Phosphorus export rates range from 316 to 1,570 lbs/year. Figure 4-2 shows the annual phosphorus export rate per acre of subbasin. Export rates range from 0.86 to 1.56 lbs/acre-year. The darker shaded basins indicate the heaviest phosphorus export rates and the lighter shaded basins indicate the lowest export rates relative to the subbasins in this study.

More detailed information should be collected in order to target specific BMPs to specific areas (e.g., singular fields or waterways) within a subbasin. This level of detailed targeting is best accomplished by local officials working collaboratively with local stakeholders and land owners.

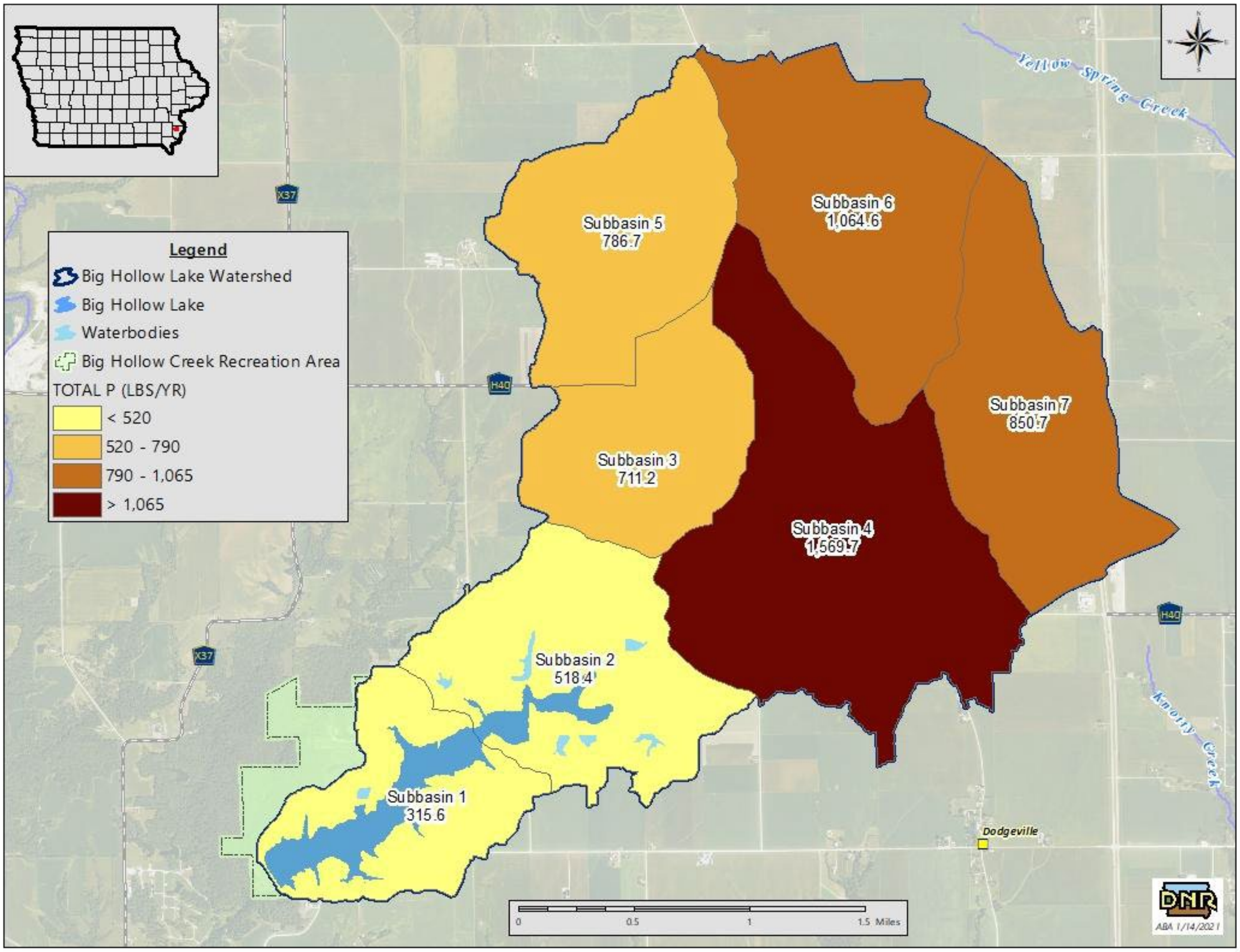

Figure 4-1. Pounds of Total Phosphorus export to Big Hollow Lake by Subbasin.

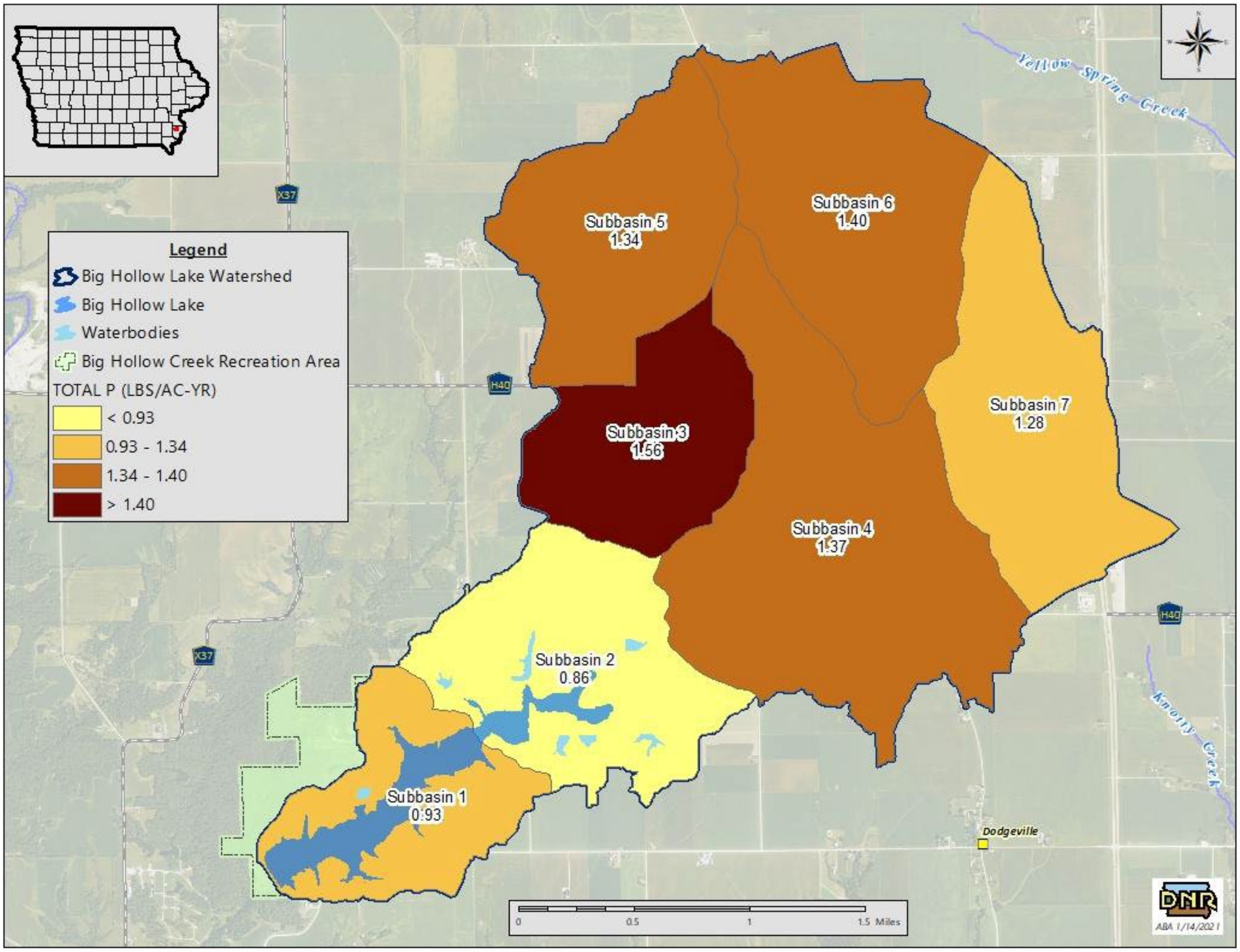

Figure 4-2. Pounds per Acre of Total Phosphorus export to Big Hollow Lake by Subbasin.

In-Lake BMPs (Remediation Strategies)

Phosphorus recycled between the bottom sediment and water column of the lake has the potential to be a contributor of bioavailable phosphorus to lakes. The average annual contribution of TP to the system from internal loading appears to be relatively small in Big Hollow Lake. The reservoir has a s watershed-to-lake ratio (27:1) and a rather deep mean depth (16.1 ft) and max depth (56.8 ft) compared to other lakes of similar size, so external inputs typically dwarf internal recycling. However, internal loading may influence in-lake water under certain conditions despite its relatively insignificant average annual phosphorus contribution. Internal loads may exacerbate algal blooms in late summer periods, especially if lake outflow ceases and water temperatures exceed normal levels. It is important to understand that external phosphorus loads from wet weather supply the build-up of phosphorus in the bottom sediments. Estimates of external loads from the Big Hollow Lake watershed are of large enough magnitude to fully account for observed in-lake phosphorus and subsequent algae levels. Even in lakes with high suspected internal loads, uncertainty regarding the magnitude of internal loads is one of the biggest challenges to TMDL development and lake restoration. Because of these factors, reductions from watershed sources of TP should be given implementation priority. If and when monitoring shows that the external watershed load has been adequately reduced, then additional in-lake measures may be warranted.

Brief descriptions of potential in-lake restoration methods are included in Table 4-4. Potential in-lake BMPs for Water Quality Improvement.. Phosphorus reduction impacts of each alternative will vary and depend on a number of site-specific factors. It is difficult to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict phosphorus reductions associated with individual improvement strategies. In-lake measures should be a part of a comprehensive watershed management plan that includes watershed practices in order to enhance, prolong, and protect the effectiveness of in-lake investments.

Table 4-4. Potential in-lake BMPs for Water Quality Improvement.

In-Lake BMPs	Comments
Fisheries management	Low to moderate reductions in internal phosphorus load may be attained via continued fisheries management. The reduction of in-lake phosphorus as a result of this practice is variable, but the overall health of the aquatic ecosystem may be improved, which typically improves overall water quality as well. Resident grass carp may be a problem and could be controlled through this method.
Targeted dredging and sediment basin improvement	Strategic dredging would also increase the sediment capacity, thereby reducing sediment and phosphorus loads to the main body where ambient conditions are monitored.
Shoreline stabilization	Helps establish and sustain vegetation, which provides local erosion protection and competes with algae for nutrients. Impacts of individual projects may be small, but cumulative effects of widespread stabilization projects can help improve water quality.
Phosphorus stabilization	Adding compounds, such as alum, to the water column can help stabilize phosphorus that may be resuspended from the lake bottom. This additive precipitates a layer of floc that removes phosphorus as it settles to the lake bottom, and can combine with phosphorus as it is released from sediment

Holistic Approach

An example of a holistic implementation plan would involve prevention, mitigation, and remediation practices across the Big Hollow Lake watershed. These may include any of the practices from Table 4-2, Table 4-3, and Table 4-4 at any scale. Extending grass waterways in conjunction with renovation of existing terraces and contour buffers in corn and soybean ground will help mitigate soil loss from row crop ground. Addressing gully erosion and streambank sloughing near the park areas may mitigate further sediment deposition and phosphorus transport to the lake. Further adoption of agricultural prevention measures like those listed in Table 4-2. Potential Land Management BMPs (Prevention Strategies). will retain topsoil in the soil profile of the fields and prevent erosion. Potential in-lake strategies such phosphorus stabilization treatments in Big Hollow Lake are included as well.

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 BMP implementation, to document attainment of TMDLs, and progress towards meeting WQSs.

Future monitoring in the Big Hollow Lake watershed can be agency-led, volunteer-based, or a combination of both. For those interested in participating in a volunteer based water quality monitoring program, more information can be found at the program website: http://www.iowadnr.gov/Environmental-Protection/Water-Quality/Water-Monitoring/Volunteer-Water-Monitoring.

Volunteer-based monitoring efforts should include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here: https://www.legis.iowa.gov/docs/iac/chapter/01-18-2017.567.61.pdf.

Failure to prepare an approved QAPP will prevent data collected from being used to evaluate the waterbody in the 305(b) Integrated Report - the biennial assessment of water quality in the state, and the 303(d) list - the list that identifies impaired waterbodies.

5.1 Routine Monitoring for Water Quality Assessment

Data collection in Big Hollow Lake to assess water quality trends and compliance with WQSs will include monitoring conducted as part of the DNR Ambient Lake Monitoring Program. The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured.

The Ambient Lake Monitoring Program sampling parameters are reported in Table 5-1. At least three sampling events are scheduled every summer. Samples are collected from as early as May 1 to as late as October 31. While the ambient lake monitoring program can be used to identify trends overall and in-lake water quality, it does not necessarily lend itself to calculation of watershed loads, identification of individual pollutant sources, or the evaluation of BMP implementation.

Table 5-1. Ambient Lake Monitoring Program Water Quality Parameters.

Chemical	Physical	Biological
Total Phosphorus (TP)	Secchi Depth	Chlorophyll a
Orthophosphate	Temperature	Phycocyanin[1]
Total Kjeldahl Nitrogen (TKN)	Dissolved Oxygen (DO)	Microcystin[1]
Ammonia	Turbidity	
Un-ionized Ammonia	Total Suspended Solids (TSS)	
Nitrate + Nitrite Nitrogen	Total Fixed Suspended Solids	
Alkalinity	Total Volatile Suspended Solids	
pH	Specific Conductivity	
Total Dissolved Solids	Thermocline Depth	
TP Below Thermocline[1]	Lake Depth	

[1]Not typically included with the ambient monitoring samples. However, data on these parameters can be provided by additional sampling collected by the DNR.

5.2 Expanded Monitoring for Detailed Analysis

Given current resources and funding, future water quality data collection in the Big Hollow Lake watershed to assess water quality trends and compliance with WQSs may be limited. However, there may be enough interest by local stakeholders to seek out funding to implement BMPs and allow for future monitoring of those practices to ensure phosphorus and other pollutant reductions to Big Hollow Lake.

Data available from the DNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS violations and 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.

If the goal of monitoring is to evaluate spatial and temporal trends and differences in water quality resulting from implementation of BMPs, a more intensive monitoring program will be needed. Table 5-2 outlines potential locations, type of monitoring, parameters collected, and the purpose of each type of data collected as part of an expanded monitoring effort. It is unlikely that available funding will allow collection of all data included in Table 5-2, but the information should be used to help stakeholders identify and prioritize data needs.

Table 5-2. Recommended Monitoring Plan.

Parameter(s)	Intervals	Duration	Location(s)[1]
Routine grab sampling for flow, sediment, P, and N	Every 1-2 weeks	April through October	Ambient location in Big Hollow Lake, plus secondary locations
Flow and & stage data for stage-discharge curve development	15-60 minute	April through October	Big Hollow Lake outlet
Continuous pH, DO, and temperature	15-60 minute	April through October	Ambient location in Big Hollow Lake
Runoff event flow, sediment, P, N, TSS, ortho-P, temperature, DO, pH, chloride, & *E. coli* [2]	15-60-minute intervals during runoff	2 events between April and October	Select tributaries, tile and/or culvert discharge locations in areas of focused BMP implementation to evaluate efficacy
Event or continuous tile drain flow, sediment, P, N, TSS, ortho-P, temperature, DO, pH, chloride, & *E. coli*[2]	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	Select tributaries, tile and/or culvert discharge locations in areas of focused BMP implementation to evaluate efficacy
Shoreline mapping, bathymetry studies	Before and after dredging or construction, every 5 years	Design lifespan of waterbody	Near future dredging operations, or near lake inlets, upstream sediment basins
Grab samples for sulfide[3]	Annually	Spring and fall	Near the sediment-water interface.

[1]Tributary, tile drain, and gully site selection to be based on suspected pollutant source location, BMP placement, landowner permission, and access/installation feasibility.
[2]Adapted from WMP.
[3]See Appendix C, Big Hollow Lake Sediment Analysis, of the WMP.

It may be useful to divide the recommended monitoring plan into several tiers based on ease of deployment and cost effectiveness. This will help stakeholders and management personnel best direct their resources. This monitoring plan may be reevaluated at any time to change the management strategy. Data collection should commence before new BMPs are implemented or existing ones are renovated in the watershed to establish baseline conditions. Selection of tributary sites should consider location of BMPs, location of historical data (for comparative purposes), landowner permission (if applicable), and logistical concerns such as site access and feasibility of equipment installation (if necessary). These data could form the foundation for assessment of water quality trends; however, more detailed information will be necessary to make any statements about water quality trends with certainty. Therefore, routine grab sampling should be viewed only as a starting point for assessing trends in water quality. Possible monitoring scenarios above the current monitoring condition are described below.

In 2020, the DNR prepared a draft tributary monitoring plan for the Big Hollow Lake watershed, which was included in the WMP. The monitoring plan included a schedule and five monitoring locations within the watershed. These monitoring locations are located on the east and west tributary branches, as shown in Figure 5-1, to assess the influence of row crop agriculture, livestock management activities, household septic systems, and effectiveness of BMPs. Frequency of samples and parameters sampled for are outlined in Table 5-2. Initial samples were taken during the 2022 and 2023 monitoring season and can serve as a baseline to determine the effectiveness of future watershed improvements.

In addition, as part of the WMP, sediment core samples were taken from the lake bottom in late 2021 and analyzed. The analysis was conducted to determine the fraction of iron in the sediment and the potential impacts from sulfate loading in the lake.

Some of the concern for sulfate on lake and lakebed chemistry comes from a fishkill that occurred in 2014. At the time of the fishkill, low DO and white solids were observed in Big Hollow Creek below the dam. It was hypothesized that gypsum clays may have been the source of the white solids observed in the creek. Additionally, there were concerns regarding the toxicity of sulfur in the lake and the potential for sulfur to reduce to sulfide, which would bind with iron making iron unavailable to bind with phosphorus.

Results of the analysis indicated 1) there are trace concentrations of sulfide in sediment samples but are not at levels that significantly compromise the availability of free iron to participate in sequestration of phosphorus and 2) that sulfate levels are below those presenting concerns for toxicity. Additionally, eutrophic conditions may exhaust the supply of free iron, reducing the capacity for phosphorus retention and allowing sulfide concentration to climb. Therefore, it is recommended that sulfide monitoring near the sediment-water interface be done annually in the spring and fall. The report also suggests that the white solids observed in the creek during the 2014 fishkill may be from natural sources and not gypsum clays.

Basic Monitoring
Targeted grab sampling of the Big Hollow Lake ambient monitoring point should be continued on a bi-weekly basis. Grab samples on a seasonal basis at the inlet would be done to support data provided by the main lake.

Targeted Monitoring
Grab samples should continue on a routine and runoff event-based schedule. Flow data may be recorded with manual flow readings based on developed rating curves. Locations and sampling approaches would include the ambient monitoring station and upstream inlets.

Advanced Monitoring
Automated data recorded by ISCO devices would provide information on continuous flow, and continuous pH, DO, and temperature. Routine grab sampling for flow, sediment, P, and N will help provide a check on the automated sampling. In addition to routine sampling, runoff event sampling for event flow, sediment, N, and P will help show the effects of high recurrence interval events. Locations and sampling approaches would include the ambient monitoring station, inlets and outlets of newly constructed sedimentation basins, and outlets from upstream tributaries- such as roadway culverts. 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, saturated buffers, terraces and grass waterways, riparian buffers, and wetlands.

Monitoring of chemicals associated with gypsum production in the watershed may provide useful feedback of the overall impact of the facility on the health of the lake. Information on calcium and sulfate levels (the two components of gypsum) in the lake could be compared to academic sources or other waterbodies with similar industrial activity in the watershed.

To further gather information on erosion in the watershed, a “rapid assessment of stream conditions along length” (RASCAL) procedure can be done on gullies and channels on an annual basis to show erosion mitigation over several years. These RASCAL assessments would be compared to past assessments to show if gully and streambank erosion problems are worsening or lessening. Previous assessments will provide a benchmark of current conditions and will allow stakeholders to identify potential problem areas for implementation of BMPs. Gully and streambank erosion labeled as moderate, severe, or very severe in the most recent RASCAL assessment are marked in Figure 5-1.

Core samples from several points throughout Big Hollow Lake would also help provide insight on the significance of gypsum sediment on the lake bed. Although gypsum may have a slight mitigation impact on phosphorus in the water column by helping phosphorus settle out of the water column, gypsum byproducts may create an aesthetically objectionable layer of sediment on the bottom of the lake as well as negatively affecting the benthic macroinvertebrate community.

The proposed 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 Water Quality Improvement Section may provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Big Hollow Lake watershed. A look at how these proposed monitoring plans may be deployed in the Big Hollow Lake watershed is shown in Figure 5-1. It should be noted that as part of the WMP, samples were collected in 2022 and 2023 at five sites throughout the watershed, which are identified Figure 5-1. These sites should be included in any future monitoring plans.

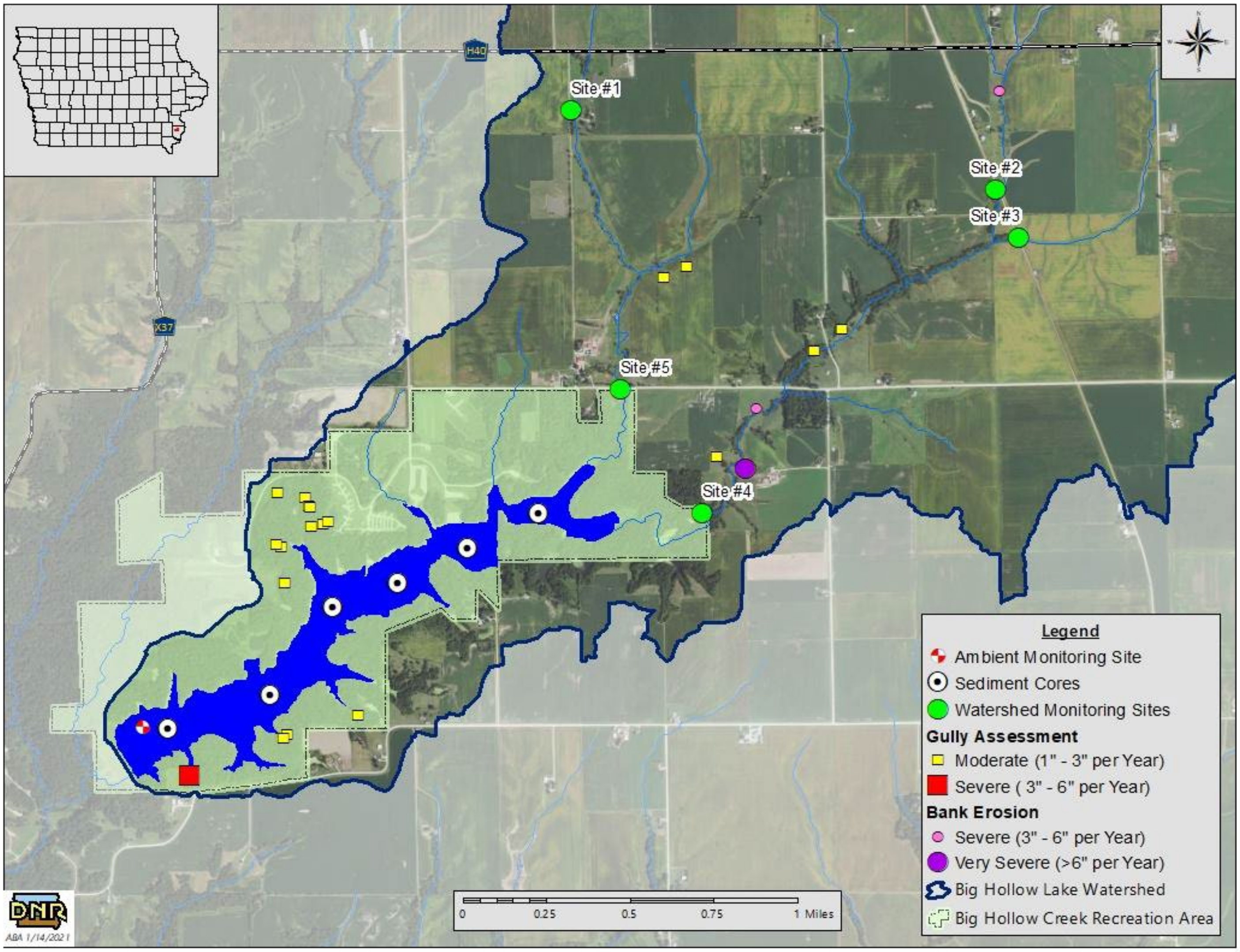

Figure 5-1. Potential Monitoring Locations.

6. Public Participation

Public involvement is important in the 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 Big Hollow Lake.

6.1 Public Meeting

Public Presentations

A virtual on-line presentation was posted on the DNR's YouTube channel for public viewing on May 1, 2025. A link was provided to the presentation on the DNR's website at https://www.iowadnr.gov/environmental-protection/water-quality/watershed-improvement/watershed-planning/water-quality-improvement-plans. The presentation will be available for viewing through the public comment period.

6.2 Written Comments

A press release was issued on May 1, 2025 to begin a 30-day public comment period, which will end on June 2, 2025. All comments received by the DNR during the 30-day public comment period will be included in Appendix I.

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Appendix A. Glossary of Terms, Abbreviations, and Acronyms

A.1. Terms

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 their uses are placed on the 303(d) list.

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

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

AU: Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000-pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.4 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 1,000 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 the most probable number (MPN), the two terms are often used interchangeably.

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

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

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

Designated use(s): Uses specified in water quality standards for each water body or segment. Typical designated uses described in the clean water act include protection and propagation of fish, shellfish, and wildlife; recreation; and public water supply. See Appendix B for a description of all general and designated uses.

DNR: 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): Waters that are protected for livestock and wildlife watering, aquatic life, noncontact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. General use waters must meet the narrative water quality criteria. See Appendix B for a description of all general and designated uses.

Geometric Mean (GM): A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's WQSs 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 that 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 (IR): 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. Sources include but are not limited to municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river. 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 in section A.2. Scientific Notation.

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: 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 (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 structured scientific assessment of the factors affecting the attainment of uses specified in Section 101(a)(2) of the Clean Water Act. The factors to be considered in such an analysis include the physical, chemical, biological, and economic use removal criteria described in the EPA's water quality standards (WQS) regulation at 40 CFR 131.10(g)(1)-(6). See Appendix B for a description of all general and designated uses.

USDA: United States Department of Agriculture

USGS: United States Geological 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 567 IAC Chapter 61, they include designated uses, antidegradation, and 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.

A.2. 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 WQSs (567 IAC Chapter 61) include the narrative and numerical criteria by which waterbodies are judged when determining the health and quality of our aquatic ecosystems. These criteria vary depending on the type of waterbody (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the waterbody that is being dealt with. This appendix is intended to provide information about how Iowa's waterbodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, surface waters in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because the water quality criteria that are applied to the waterbody will differ depending on what classification the waterbody is given.

General Use Segments

A general use segment waterbody is one that does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins that are consistently dry almost all year during normal flows would be classified as general use segments. For the full definition of a general use waterbody, consult 567 subrule 61.3(1).

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 567 subrule 61.3(2).

Designated Use Segments

Designated use segments are waterbodies that maintain flow throughout the year, or at least hold pools of water that are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as recreation, drinking water sources, or aquatic life. There are 11 different designated uses (Table B-1) that may apply, and a waterbody may have more than one designated use. For definitions of the uses and more detailed descriptions, consult 567 subrule 61.3(1).

Table B-1. Designated Uses for Iowa Waterbodies.

Class	Designated Use	Brief Comments
A1	Primary contact recreation	Prolonged/direct contact with the water. Supports swimming, water skiing, etc.
A2	Secondary contact recreation	Accidental/incidental contact with the water. Supports shoreline activities, fishing, and commercial and recreational boating.
A3	Children's contact recreation	Uses by children are common. Primarily occurs in urban or residential areas. Supports use by children.
B(CW1)	Cold water aquatic life - Type 1	Supports coldwater fish (e.g. trout) populations
B(CW2)	Cold water aquatic life - Type 2	Typically, unable to support consistent trout populations but can support other organisms.
B(WW-1)	Warm water aquatic life - Type 1	Supports game and nongame fish populations.
B(WW-2)	Warm water aquatic life - Type 2	Smaller streams that are able to support nongame fish, but cannot maintain game fish populations.
B(WW-3)	Warm water aquatic life - Type 3	Intermittent streams with perennial pools that can support organisms that can survive in relatively harsh aquatic conditions.
B(LW)	Warm water aquatic life - Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions.
C	Drinking water supply	Raw water source of potable water supply.
HH	Human health	Waters where fish are routinely harvested for human consumption.

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

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 (SHL) monitoring efforts.

C.1. Individual Sample Results

Table C-1. ISU and DNR TMDL Water Quality Sampling Data (Ambient Location1).

Source	Date[2]	TP (mg/l)[4]	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	pH	Secchi TSI	Chl-a TSI	TP TSI
ISU	5/25/2011		2.60	6.93	34.43	8.65	46.2	49.6	55.1
ISU	7/13/2011		1.00	38.40	50.65	8.29	60.0	66.4	60.7
ISU	8/23/2011		0.33	39.54	42.41	9.33	76.0	66.7	58.1
ISU	5/23/2012		3.65	2.83	26.50	8.48	41.3	40.8	51.4
ISU	7/11/2012		0.98	14.48	57.30	8.94	60.3	56.8	62.5
ISU	8/23/2012		0.38	65.41	57.60	8.10	73.9	71.6	62.6
ISU	5/22/2013		2.27	3.79	153.70	8.11	48.2	43.7	76.7
ISU	7/10/2013		0.91	223.36	105.35	9.68	61.4	83.7	71.3
ISU	8/21/2013		0.34	84.24	96.32	9.42	75.5	74.1	70.0
ISU	5/28/2014		2.80	14.76	97.85	8.57	45.2	57.0	70.2
ISU	7/16/2014		0.80	37.28	66.65	9.20	63.2	66.1	64.7
ISU	8/24/2014		1.18	30.64	33.85	7.87	57.6	64.2	54.9
ISU	5/28/2015		2.80	3.03	43.45	8.42	45.2	41.5	58.5
ISU	7/15/2015		0.45	15.60	184.20	9.64	71.5	57.6	79.3
ISU	8/23/2015		0.80	44.73	95.75	8.30	63.2	67.9	69.9
ISU	5/25/2016		5.40	1.02	23.95	8.18	35.7	30.8	49.9
ISU	7/13/2016		0.67	86.56	82.30	8.45	65.8	74.4	67.7
ISU	8/26/2016		0.67	67.72	172.30	8.76	65.8	72.0	78.4
ISU	5/24/2017		3.75	1.65	97.90	8.11	41.0	35.5	70.2
ISU	7/10/2017		0.50	1.65	67.90	8.30	70.0	35.5	64.9
ISU	8/20/2017		0.50	4.00	86.60	8.30	70.0	44.2	68.4
ISU	5/21/2018		5.43	1.00	203.70	8.20	35.6	30.6	80.8
ISU	7/9/2018		0.40	84.00	110.30	8.70	73.2	74.1	71.9
ISU	8/19/2018		0.40	26.00	85.90	8.60	73.2	62.6	68.3
TMDL	4/10/2019	0.36	0.57	94.00	210.00	9.40	68.1	75.2	81.2
TMDL	4/22/2019	0.41	1.89	10.00	170.00	9.10	50.8	53.2	78.2
TMDL	5/6/2019	0.56	2.06	1.00	560.00	7.90	49.6	30.6	95.3
TMDL	5/22/2019	0.46	1.93	2.00	320.00	7.70	50.5	37.4	87.3
ISU	6/3/2019		0.73	3.50	301.15	7.50	64.6	42.9	86.4
TMDL	6/13/2019	0.40	2.17	9.00	180.00	8.50	48.8	52.2	79.0
TMDL	6/27/2019	0.46	1.76	36.00	130.00	8.80	51.9	65.8	74.3
TMDL	7/9/2019	0.43	0.68	41.00	80.00		65.6	67.0	67.3
ISU	7/15/2019		0.53	21.83	71.40	8.69	69.1	60.8	65.7
TMDL	7/25/2019	0.44	0.31	100.00	180.00	9.60	76.9	75.8	79.0
TMDL	8/4/2019	0.13		61.00	80.00			70.9	67.3

Source	Date[2]	TP (mg/l)[4]	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	pH	Secchi TSI	Chl-a TSI	TP TSI
TMDL	8/5/2019		0.4		0.00	9.70	73.2		
TMDL	8/22/2019	0.49	0.3	99.00	150.00	9.40	77.3	75.7	76.4
ISU	8/26/2019		0.3	18.38	90.00	8.48	80.0	59.2	69.0
TMDL	9/20/2019	0.49	0.7	35.00	40.00	9.00	64.5	65.5	57.3
TMDL	10/1/2019	0.55	0.6	44.00	60.00	8.30	68.1	67.7	63.1
ISU	5/24/2021		3.4	0.90	168.00	7.89	42.6	29.6	78.0
ISU	7/12/2021		0.5	81.78	139.00	8.19	70.7	73.8	75.3
ISU	8/22/2021		0.6	40.90	123.00	7.42	68.6	67.0	73.5
ISU	6/13/2022		2.5	16.10	118.00	8.67	46.8	57.9	72.9
ISU	8/1/2022		0.5	96.20	95.50	8.43	70.0	75.4	69.8
ISU	9/6/2022		0.4	85.50	73.00	7.95	73.2	74.2	66.0
ISU	6/12/2023		2.9	17.96	128.00	8.38	44.5	58.9	74.1
ISU	8/1/2023		1.0	46.00	73.00	7.85	60.2	68.2	66.0
ISU	9/7/2023		0.7	45.50	71.00	6.98	65.7	68.1	65.6
Average	**--**	**0.43**	**1.38**	**39.7**	**116.08**	**8.54**	**55.4**	**66.7**	**72.7**

[1]Ambient monitoring location = STORET ID 22290002
[2]Data between 2018 - 2022 were used for the 2024 Water Quality Assessment Period.
[3]Data between 2011 - 2014 were used in calibration and Data between 2015 - 2023 were used in analysis.
[4]TP sampled below thermocline.
[5]Samples were not collected in 2020 due to concerns related to the COVID-19 pandemic.

C.2. Annual Mean Data

Table C-2. Precipitation and Annual Mean TSI Values (Ambient Location1).

Date	Annual Precipitation (in)	Apr-Sep Precipitation (in)	Secchi TSI	Chl-a TSI	TP TSI	pH
2011	41.1	24.7	61.2	60.9		9.10
2012	27.4	16.1	58.1	56.5	58.8	8.50
2013	40.5	25.0	62.3	67.3	72.6	9.07
2014	44.4	30.9	55.3	62.4	63.3	8.55
2015	40.6	24.4	59.5	55.7	69.2	8.77
2016	35.3	23.8	56.8	58.9	65.3	8.50
2017	34.7	22.5	60.2	38.4	67.9	8.23
2018	44.5	22.2	60.7	55.7	73.7	8.50
2019	48.6	33.2	63.9	60.0	75.1	8.72
2020[2]	33.4	19.7				
2021	44.1	30.0	60.6	56.8	75.6	7.83
2022	31.2	19.8	63.3	69.2	69.6	8.35
2023	38.3	23.8	56.8	65.0	68.5	7.74
Average	**38.8**	**24.3**	**59.9**	**59.1**	**68.4**	**8.49**

[1]Ambient monitoring location = STORET 22290002.
[2]Samples not collected due to concerns related to COVID-19.

Appendix D. Watershed Model Development

Watershed and in-lake modeling were used in conjunction with analysis of observed water quality data to develop the TMDL for the algae, turbidity, and pH impairments to Big Hollow Lake in Des Moines County, Iowa. This TMDL targets an allowable phosphorus load that will satisfy the primary contact recreation and aquatic life impairments (see Section 3 of this document for details). Reduction of phosphorus is expected to reduce algal blooms and non-algal turbidity, which decrease water clarity and impair the ability of the public to enjoy the recreational benefits of the lake. In addition, reduction of phosphorus will also limit algal growth, which will in turn stabilize water column pH within an acceptable range.

The STEPL, version 4.4, was utilized to simulate watershed hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.20, 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 Big Hollow Lake and its watershed. This section of the WQIP discusses the modeling approach and development of the STEPL watershed and BATHTUB lake models.

D.1. Modeling Approach

Data from a 13-year period of record, 2011-2023, were analyzed and used to develop watershed and lake models for the simulation and prediction of phosphorus loads and in-lake response. This simulation period is supplemental to the water quality assessment period (2018-2022) upon which the 2024 IR and 303(d) list were generated.

D.2. STEPL Model Description

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

The watershed was divided into seven subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with targeting potential BMP locations. The basins were created to coincide with the natural drainage network and physical features as shown in Figure D-1. Hydrology and pollutant loadings are summarized for the subbasin and also aggregated as watershed totals.

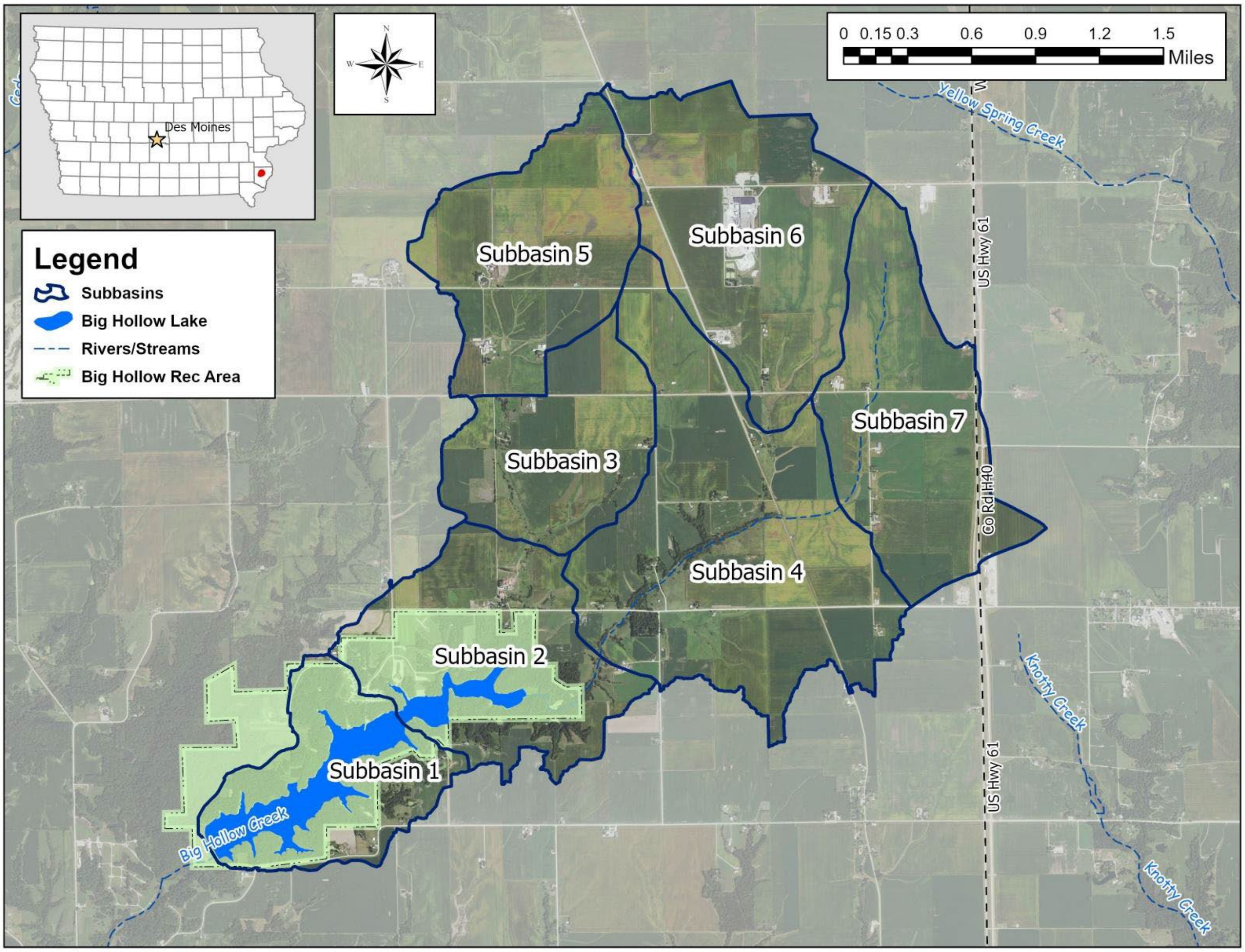

Figure D-1. STEPL Subbasin Map

D.3. Meteorological Input

Precipitation Data

The STEPL model includes a pre-defined set of weather stations from which the user may obtain precipitation-related model inputs. Unfortunately, none of the NWS COOP stations within a reasonable distance of Big Hollow Lake are included in the STEPL model. Therefore, rainfall data from the Iowa Environmental Mesonet network were used for modeling purposes. Weather station information and rainfall data were reported in Section 2.1 (see Table 2-2 and Figure 2-2 and Figure 2-3). Annual rainfall was calculated for two time periods 2000 - 2014 and 2015 - 2023. Rainfall data from 2000 - 2014 was used in the STEPL calibration model. Average annual precipitation for this time period was 41.4 inches/year. Annual average precipitation from 2015 - 2023 used in the STEPL simulation model was 39.0 inches/year, which was slightly lower than the 30-year average (1994-2023) of 40.3 inches.

The STEPL precipitation correlation and rain day correction factors were calculated outside of STEPL and entered directly in the STEPL "Input" worksheet to override the default rainfall data. Precipitation data from the modeling period were utilized in parameterization. Precipitation inputs for the calibration model are shown in Table D-1 and precipitation inputs for the simulation model are reported in Table D-2.

Table D-1. STEPL Rainfall Inputs Calibration Model (2000-2014 Average Annual Data).

Rain Correction Factors			
0.899	0.474[2]		
Annual Rainfall[3]	**Rain Days[4]**	**Avg. Rain/Event[5]**	**Input Notes/Descriptions**
41.4	113	0.695	[1]The percent of rainfall that exceeds 5 mm per event [2]The percent of rain events that generate runoff [3]Annual average precipitation for modeling period (in) [4]Average days of precipitation per year (days) [5]Average precipitation per event (in)

Table D-2. STEPL Rainfall Inputs Simulation Model (2015-2023 Average Annual Data).

Rain Correction Factors			
0.909[1]	0.479[2]		
Annual Rainfall[3]	**Rain Days[4]**	**Avg. Rain/Event[5]**	**Input Notes/Descriptions**
39.0	103	0.721	[1]The percent of rainfall that exceeds 5 mm per event [2]The percent of rain events that generate runoff [3]Annual average precipitation for modeling period (in) [4]Average days of precipitation per year (days) [5]Average precipitation per event (in)

D.4. Watershed Characteristics

Topography

The Big Hollow Lake watershed was delineated into seven subbasins. The subbasin boundaries were chosen to coincide with natural and artificial boundaries as shown in Figure D-1. These will aid in identifying areas to implement best management practice strategies in water quality improvement programs in the future.

Land Use

A Geographic Information System (GIS) coverage of land use was developed using 2017-2020 aerial photography and the 2017-2020 Cropland Data Layers (CDL), which were obtained from the United States Department of Agriculture - National Agricultural Statistics Service (USDA-NASS, 2017). The CDL land cover data is summarized by Common Land Units (CLUs). According to the USDA - Farm Service Agency, CLUs are the smallest units of land that have a permanent, contiguous boundary, common land cover, common owner, and common producer (USDA-FSA, 2016). Because land cover pixels are much smaller than CLU field boundaries, many CLUs have one primary land cover, but small isolated pixels with several minor land cover types. In those cases, the dominant land cover within each CLU boundary was determined using a zonal statistic command within Spatial Analyst. This step served as a land cover “filter” to simplify the data and eliminate small isolated pixels of various land uses within a single field boundary. In addition, 2017 aerial photography was used to further refine the GIS land use coverage. STEPL land cover classifications are reported in Table D-3, with land use distribution previously illustrated in the map (Figure 2-4) and Table 2-3 in Section 2.

Table D-3. STEPL Land Use Inputs.

Watershed	Urban[1]	Cropland	Pastureland	Forest	User Defined[2]	Total[3]
W1	13.3	42.6	22.8	236.5	22.7	337.9
W2	29.2	220.1	62.0	237.0	56.7	605.1
W3	18.7	389.1	22.0	1.6	24.4	455.9
W4	73.2	907.3	62.1	58.8	40.7	1142.2
W5	31.1	523.1	13.8	0.0	17.3	585.3
W6	110.4	640.1	0.0	0.0	10.3	760.8
W7	57.2	591.7	0.0	0.0	18.1	667.1
Total [3]	**333.2**	**3,314.0**	**182.7**	**534.0**	**190.2**	**4,554.1**

[1]Urban includes all developed areas, including roads and farmsteads.
[2]Includes hay / alfalfa, non-pasture grassland and conservation reserve programs.
[3]Totals exclude open water in STEPL land use inputs.

Land use type was assigned a specific USLE C-factor based on regional estimates developed by the DNR and the Iowa Department of Agriculture (IDALS) personnel during in-field land use assessments. USLE-P factors were determined in the same manner for cropland. These factors were area-weighted and entered into the “Input” worksheet in the STEPL model. The STEPL default value for the USLE P-factor was used for all other land uses. A summary of the C and P-factor values are provided in Table D-4.

Soils
Soils are discussed in detail in Section 2.2. The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Watershed soils are split between HSG type C and type D. with some C/D soils interspersed. HSG type C/D soils were assigned an HSG type D since it is more conservative than an HSG type C soil. USLE K-factors are specific to each soil type, and were determined based on K values from USGS Web Soil Survey data for the Big Hollow Lake watershed. K factors were area-weighted and entered into the “Input” worksheet in the STEPL model (See Table D-4).

Table D-4. C, P, and K Factors for each Land Use.

Land Use Description	C-Factor	P-Factor	K-Factor
Row Crop	0.099 - 0.133	0.932 - 1.0	0.243 - 0.295
Forest	0.002	1.0	0.274 - 0.294
Pasture	0.002	1.0	0.268- 0.309
User Defined	0.001 - 0.005	1.0	0.269 - 0.316

Slopes
Slopes are described in more detail in Section 2.2. USLE land slope (LS) factors were obtained from the subroutine Ls-factor, field based, in Quantum GIS (QGIS). Resulting LS-factors entered into the “Input” worksheet in the STEPL model vary between 0.23 in row crop areas to 2.48 in forest ground near the park area. Slopes are heavily influenced by the highly dissected loess hill landform. Slopes for each land use in each basin are listed below in Table D-5.

Table D-5. STEPL LS Factors.

Watershed	Cropland	Pastureland	Forest	User Defined[1]
W1	0.493	1.276	2.074	0.558
W2	0.785	2.357	2.481	0.851
W3	0.574	1.414	1.223	1.181
W4	0.459	1.716	1.540	1.502
W5	0.282	1.455	---	1.107
W6	0.230	---	---	1.691
W7	0.296	---	---	0.831

[1]Includes hay / alfalfa, non-pasture grassland, and conservation reserve programs.

Curve Numbers
The STEPL model includes curve numbers (CNs) selected based on HSG and land use. CNs were selected within a range of values to calibrate the STEPL model. CNs were entered in the "Input" worksheet of STEPL, and are reported in Table D-6. For additional discussion on the selection of CNs see Appendix F.

Table D-6. STEPL Curve Numbers.

Subbasin	HSG	Urban[1]	Cropland	Forest	Pastureland	User Defined[2]
W1	C	89	79	73	77	71
W2	C	89	79	73	77	71
W3	D	91	80	77	85	78
W4	C	89	79	73	77	71
W5	D	91	80	77	85	78
W6	D	91	80	77	85	78
W7	D	91	80	77	85	78

[1]Urban includes all developed areas, including transportation and farmstead areas.
[2]User defined Includes hay / alfalfa, non-pasture grassland, and conservation reserve programs.

Sediment Delivery Ratio
The sediment load to Big Hollow Lake will be dependent upon watershed morphology, water velocity, residence time, and other factors. The sediment load to the lake is smaller than total sheet and rill erosion because some of the eroded material is deposited in depressions, ditches, or streams before it reaches the watershed outlet (i.e., the lake). The sediment delivery ratio (SDR) is the portion of sheet and rill erosion that is transported to the watershed outlet. STEPL calculates the SDR for each subbasin using a simple empirical formula based on drainage area (i.e., subbasin area). The resulting SDR values range from 0.259 in subbasin 4 to 0.328 in subbasin 1.

D.5. Animals
Agricultural Animals and Manure Application
The STEPL model utilizes livestock population data and the duration (in months) that manure is applied to account for nutrient loading from livestock manure application. The number of livestock animals within the watershed were determined using available data from two sources: 1) the DNR and 2) from the PLET Input Data Server located on the EPA's website (EPA, 2024).

Based on available data from the DNR, there are two small cattle animal feeding operations (<500 animal units) within the watershed. In addition, based on manure management plans (MMP) on file with the DNR, there are two larger swine AFOs, with an estimated head count of 9,880 swine, outside the watershed that apply manure within the watershed.

Livestock confinements are not permitted to discharge manure, therefore the WLA for the facilities within the watershed is zero. However, a portion of the liquid manure generated is land applied to cropland and pastureland within the watershed. The number of cattle and swine for these facilities were calculated by finding a ratio of land applied manure within a subbasin to the total of land applied manure and then relating this to the total number of animals for each facility as shown in Table D-7.

It is assumed that manure will be applied to cropland and pastureland twice a year. Twice a year was selected because it provided favorable results when comparing STEPL model TP loadings to TP loadings from the SPARROW calibration site.

Table D-7. Agricultural Animals and Manure Application.

Watershed	Beef Cattle	Dairy Cattle	Swine (Hog)	Sheep	Horse	Turkey	Duck	# of months manure applied[1]
W1	0	0	126	2	1	1	<1	2
W2	0	0	235	2	1	1	<1	2
W3	77	0	161	2	1	1	<1	2
W4	25	1	37	6	2	2	<1	2
W5	223	1	0	3	1	1	<1	2
W6	225	1	0	4	2	1	<1	2
W7	0	1	0	3	1	1	<1	2
Totals	**550**	**4**	**559**	**22**	**9**	**8**	**1**	**--**

[1]Manure is applied twice per year to cropland and pastureland.

Livestock Grazing
Pastureland makes up approximately four percent of the entire land use within the watershed, which includes several small grazing areas in the Big Hollow Lake watershed. Erosion from pasture (and other grassland that may be in poor condition) carries sediment-bound phosphorus, which is accounted for by using a sediment nutrient enrichment ratio. The STEPL default enrichment ratio is 2.0. STEPL simulates nutrient loss in pasture and grassland runoff by assuming a phosphorus concentration of 0.3 mg/L in the runoff. Similarly, a phosphorus concentration of 0.063 was used to simulate phosphorus loads from shallow groundwater in grazed areas.

Open Feedlots
There are no open feedlots in the Big Hollow Lake watershed in the DNR Animal Feeding Operations Database. Feedlot operators are not required to report open feedlot information to the DNR for feedlots with less than 1000 animal units (AUs).

Wildlife
Due to insufficient data, population densities were assumed to be as follows: 200 geese and a density of 10 animals per square mile of cropland and pastureland for all other wildlife.

Septic Systems
A GIS coverage of rural residences with private onsite wastewater treatment systems (e.g., septic systems) was developed using aerial images. This procedure resulted in the identification of 33 septic systems in this sparsely populated watershed. It is estimated that 20 percent of these systems are not functioning adequately (i.e., are ponding or leaching). This is a fairly common occurrence in some rural parts of the state. This information is included in the "Inputs" worksheet of the STEPL model for Big Hollow Lake.

D.6. References

U.S. Department of Agriculture - Farm Service Agency (USDA-FSA). 2016. http://www.fsa.usda.gov/Internet/FSA_File/clu_2007_infosheetpdf.pdf.

U.S. Environmental Protection Agency. 2024. https://ordspub.epa.gov/ords/grts/f?p=109:333.

Appendix E. Water Quality Model Development

Two models were used to develop the TMDL for Big Hollow Lake. Watershed hydrology and pollutant loading was simulated using the STEPL, version 4.4. STEPL model development was described in detail in Appendix D.

In-lake water quality simulations were performed using BATHTUB 6.20, an empirical lake and reservoir eutrophication model. The BATHTUB model developed for Big Hollow Lake does not simulate dynamic conditions associated with storm events or individual growing seasons. Rather, the model predicts average water quality in the modeling period of 2015-2023, which includes the time period for the 2024 Integrated Report (2018-2022). This appendix discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Big Hollow Lake and its watershed.

E.1. BATHTUB Model Description

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

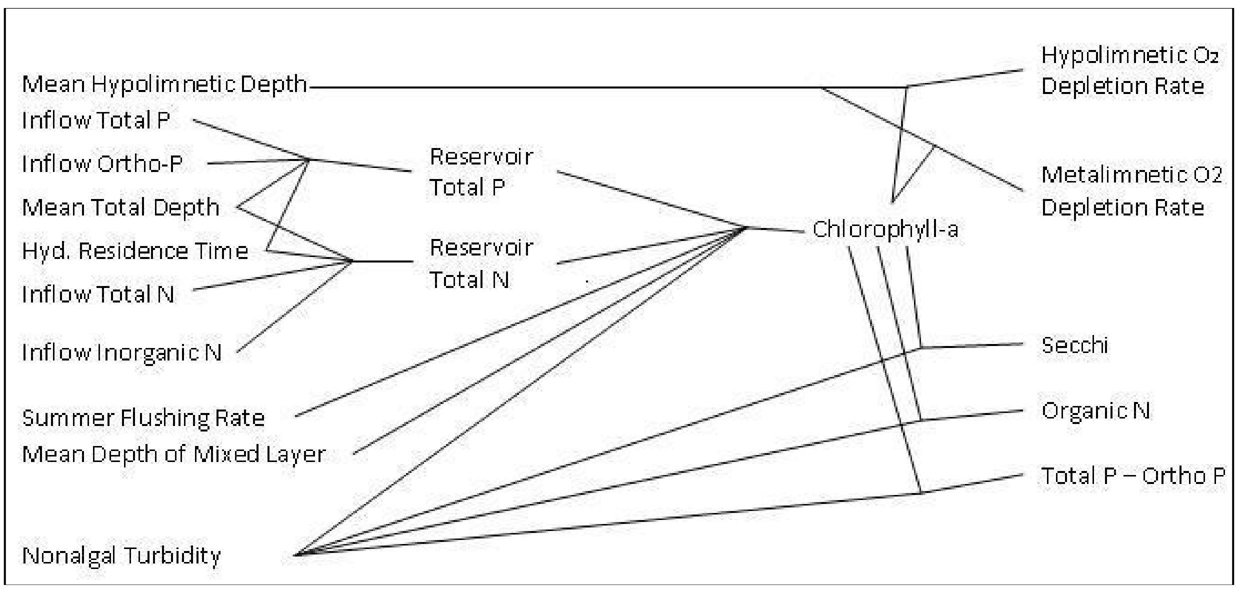

Figure E-1. Eutrophication control pathways in BATHTUB (Walker, 1999)

E.2. Model Parameterization

BATHTUB includes several data input menus and modules to describe lake characteristics, simulation equations, and external (i.e., watershed) inputs. Data menus utilized to develop the BATHTUB model for Big Hollow Lake 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 used in the simulation of in-lake nitrogen, phosphorus, chl-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 or 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 Big Hollow Lake BATHTUB model and report input parameters for each menu.

Model Selections

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

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

Table E-1. Model selections for Big Hollow Lake.

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

* Asterisks indicate BATHTUB defaults

Global Variables
Global input data for Big Hollow Lake 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 Big Hollow Lake.

Table E-2. Global Variables Data for Simulation Period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 years
Precipitation[1]	39.0 in	0.990 m
Evaporation[1]	45.5 in	1.15 m
Increase in Storage[2]	0	0
Atmospheric Loads: [3]		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Precip and evaporation data are from 2015 - 2023 in order to provide accurate long-term data.
[2]Change in lake volume from beginning to end of simulation period.
[3]From Anderson and Downing, 2006.

Precipitation was summarized for the 9- year assessment period of 2015-2023 from the Iowa Mesonet network collected and discussed in Chapter 2. Potential evapotranspiration data for the same period was obtained from the Crawfordsville, Iowa weather station via the ISU Ag Climate database (IEM, 2024b). Net change in reservoir storage was assumed to be zero. This 9-year period was chosen in order to reflect the climate during the assessment period when water quality data was collected and analyzed to show the algal impairments at Big Hollow Lake. It was shown in Section 3.1 (Figures 3-9 to 3-11) that precipitation is somewhat correlated with total phosphorus and not highly correlated with the impairment seen at Big Hollow Lake. These data were summarized and converted to BATHTUB units and entered in the global data menu. Atmospheric deposition rates were obtained from a regional study (Anderson and Downing, 2006). Nutrient deposition rates are assumed constant from year to year.

Segment Data

Lake morphometry, observed water quality, calibration factors, and internal loads are all included in the segment data menu of the BATHTUB model. Separate inputs can be made for each segment of the lake or reservoir system that the user wishes to simulate. In lakes with simple morphometry and one primary tributary, simulation of the entire lake as one segment is often acceptable. If evaluation of individual segments of the lake (or inflowing tributaries) is desirable, the lake can be split into multiple segments. Each segment may have a distinct tributary.

The Big Hollow Lake BATHTUB model includes nine segments to facilitate simulation of diffusion, dispersion, and sedimentation that occur as water traverses between the upstream segments and downstream segments of Big Hollow Lake. For the BATHTUB model, Subbasin 1 was further divided into three subbasins to model the main body of the lake separately from the arms or upper reaches of the lake. The subbasins are designated as Subbasin 1A, 1B, and 1C, with Subbasin 1A being the outlet of the reservoir as shown in Figure E-2. The relationship between watershed basins and the BATHTUB segment is shown in Table E-5. The ambient monitoring location is used for listing and delisting purposes; therefore, the TMDL target applies at the ambient monitoring location in that segment.

Segment data input to the BATHTUB model includes morphometry and internal loading. Segment morphometry was calculated in the model. Bathymetric survey data and ESRI GIS software were used to estimate segment surface area, mean depth, and segment length. Internal loading was calculated from TP concentrations from samples collected below the thermocline, at the ambient monitoring location, during the 2019 monitoring season. Segment physical parameters and internal loading input into BATHTUB for the lake system area shown in Table E-3.

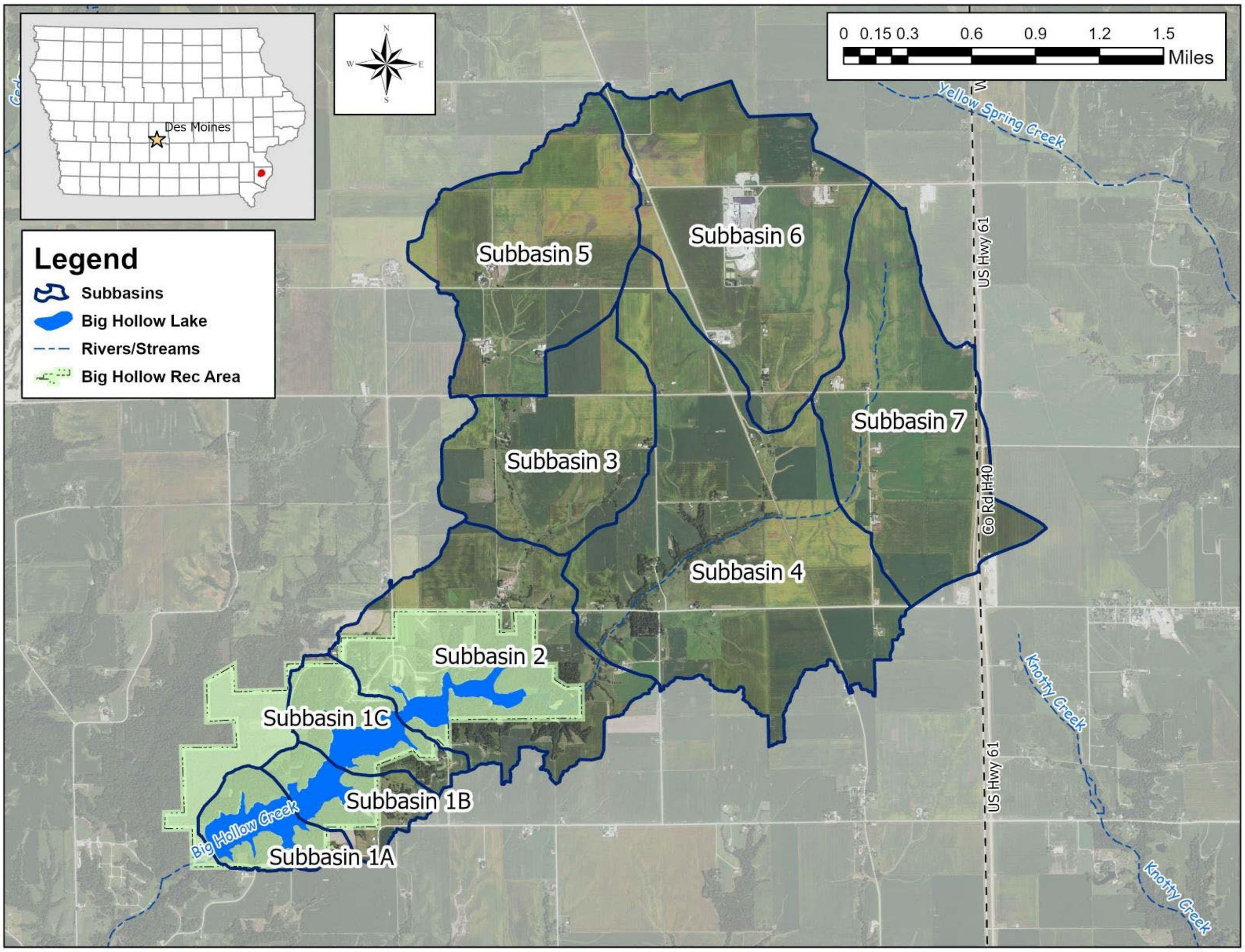

Figure E-2. Big Hollow Lake, Subbasins for BATHTUB Modeling.

Table E-3. Segment Input Data for the Big Hollow Lake.

Segment	Outflow Segment	Segment Group	Surface Area (km^2)	Mean Depth (m)	Length (km)	MLD[2]	IL[3] (mg/m^2-day)
01 Segname 1A[1]	Out of Reservoir	1	0.205	6.60	0.688	2.63	3.925
01 Segname 1B[1]	01 Segname 1A	1	0.126	5.71	0.463	2.21	3.389
01 Segname 1C[1]	02 Segname 1B	1	0.166	5.03	0.611	1.96	2.986
01 Segname 2	03 Segname 1C	1	0.179	2.39	1.177	1.52	0.0436

[1]Subdivided from Subbasin 1.
[2]Mixed Layer Depth.
[3]Internal Loading.

Mean water quality parameters observed for the modeling period (2015-2023) are reported in Table E-4. These data were compared to output in segment "01 Segname 1A" of the BATHTUB lake model to evaluate model performance and calibrate the BATHUB and STEPL models for each scenario. The TMDL and future water quality assessment and listing will be based solely on water quality data from the ambient monitoring location in segment "01 Segname 1A".

Table E-4. Ambient Water Quality (2015-2023 Annual Means).

Parameter	Measured Data	[1]BATHTUB Input
Total Phosphorus	130.1 µg/L	130.1 ppb
Total Nitrogen	2.61 mg/L	2,614.7 ppb
Chlorophyll-a	37.3 µg/L	37.3 ppb
Secchi Depth	1.36 m	1.36 m

[1]Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)

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 Big Hollow Lake BATHTUB model 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. Table E-5 summarizes the physical parameters and monitored inputs for Big Hollow Lake.

Table E-5. Tributary Data for the Big Hollow Lake.

Tributary Name	BATHTUB Receiving Segment	Total Watershed Area (km)	Avg Period Flow Rate (hm3/yr)	STEPL TP Concentration (ppb)
Trib 1[1]	--	1.367	0.386	371.4
Trib 1A[2]	Segname 1A	0.375	0.106	371.4
Trib 1B[2]	Segname 1B	0.457	0.129	371.4
Trib 1C[2]	Segname 1C	0.535	0.151	371.4
Trib 2	Segname 2	2.449	0.721	326.2
Trib 3	Segname 2	1.845	0.506	638.2
Trib 4	Segname 2	4.622	1.452	490.3
Trib 5	Segname 2	2.369	0.652	547.5
Trib 6	Segname 2	3.079	0.876	551.0
Trib 7	Segname 2	2.700	0.748	516.0
US Gypsum	Segname 2	--	0.0181	2,009.1
GP#4[3]	Segname 2	--	0.0006	14,590.9

[1]This is proved as reference information only and was not used in the BATHTUB model.
[2]Subdivided from Subbasin 1. Flow and TP loads entered as a ratio of the subdivided subbasin area to the area of Trib 1, multiplied by the flow rate or TP of Trib 1.
[3]Future reserve capacity for transition of onsite septic systems to a GP#4 facility.

E.3. References

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Appendix F. Model Performance and Calibration

The Big Hollow Lake watershed and water quality models were calibrated by comparing simulated and observed local and regional data. The primary source of calibration data is the ambient lake monitoring data collected by Iowa State University (ISU) and the DNR between 2011 and 2023. Literature values and results from regional studies regarding sediment and phosphorus exports in similar watersheds were also utilized to evaluate model performance. Calibration was an iterative process that involved running both the watershed model (STEPL) and in-lake model (BATHTUB), and refining model parameters to (1) produce simulated values that were within reasonable ranges according to similar studies, and (2) provide good agreement with observed water quality in Big Hollow Lake.

F.1. STEPL Performance and Calibration

The STEPL model is a long-term average annual simulation model, and is incapable of simulating storm events or short-term fluctuations in hydrology and nutrient loads. There is no long-term monitoring data for tributaries in the Big Hollow Lake watershed, therefore model calibration relied heavily upon sediment and phosphorus exports reported in similar watersheds in the region. Table F-1 reports estimated sheet and rill erosion rates found in several Iowa watersheds that are similar composition or proximate in location. Values for all watersheds are before any potential BMP reductions.

Table F-1. Sheet and Rill Erosion in Similar Watersheds.

Watershed	County	Area (acres)	Proximity (miles)	Erosion[1] (tons/ac/yr)
Arbor Lake	Poweshiek	1,069	95	0.8
Hannen Lake	Benton	628	78	3.1
Hawthorn Lake	Mahaska	3,069	74	4.2
Iowa Lake	Iowa	1,288	69	1.8
Lake Keomah	Mahaska	1,873	72	3.7
Kent Park Lake	Johnson	673	59	0.7
Lake of the Hills	Scott	1,683	48	2.2
Big Hollow Lake	**Des Moines**	**4,554**	**--**	**1.4**

[1]Gross annual sheet/rill erosion before any potential BMP reductions.

The Big Hollow Lake STEPL model predicts sheet and rill erosion rates that are slightly lower, but still consistent with those predicted by the DNR for other watersheds in the area. The 2015-2023 simulated annual average sheet and rill erosion rate was 1.4 tons/acre-year, compared with average estimated rates between 0.7 to 4.2 tons/acre-year estimated in other similar watersheds within the Rolling Loess Prairie ecoregion. Note that erosion rates in Table F-1 reflect sheet and rill erosion, not sediment delivered to the lake.

Table F-2 compares the annual average TP export simulated by the Big Hollow Lake STEPL model with past study results in other watersheds in Iowa with an emphasis on watersheds in close proximity and within the Rolling Loess Prairie ecoregion. TP exports in the Big Hollow Lake watershed are 1.7 pounds per acre per year, compared with average estimated rates between 0.9 to 3.0 pounds per acre per year in other watersheds. Because the STEPL model predicted sediment and phosphorus loads similar in magnitude to estimates developed for other local and regional watersheds. The DNR has determined the STEPL model to be adequate for estimation of phosphorus loads to Big Hollow Lake for development of TMDLs and implementation planning.

Table F-2. Comparison of TP Exports in Similar Watersheds.

Watershed	County	Source	TP Export (lb.ac)
Arbor Lake	Poweshiek	Iowa DNR (Previous TMDL)	2.0
Hannen Lake	Benton	Iowa DNR (Previous TMDL)	1.0
Hawthorn Lake	Mahaska	Iowa DNR (Previous TMDL)	1.6
Iowa Lake	Iowa	Iowa DNR (Previous TMDL)	1.0
Lake Keomah	Mahaska	Iowa DNR (Previous TMDL)	2.4
Kent Park Lake	Johnson	Iowa DNR (Previous TMDL)	0.9
Lake of the Hills	Scott	Iowa DNR (Previous TMDL)	3.0
Big Hollow Lake	**Des Moines**	**STEPL Model (Current TMDL)**	**1.7**

Sparrow Calibration
In addition to comparing erosion rates and TP loads from other watersheds, the STEPL model was calibrated to three parameters 1) flow rate 2) TP; and 3) groundwater (GW) flow. Flow rate and TP values from STEPL were compared to values from the SPARROW model and the GW flow was compared to the base flow index (BFI). The STEPL calibration model, used data from 2000 - 2014 since this was the same time frame used to develop the SPARROW models.

SPARROW, was developed by the USGS and stands for SPAtially Referenced Regression On Watershed attributes. It is a model developed to describe long-term mean annual streamflow, total nitrogen, total phosphorus, and suspended solids in streams of the midwestern part of the United States. (Robertson and Sadd, 2019). The SPARROW calibration site coincides with the USGS gaging station, Skunk River at Augusta, IA (Station ID 05474000) as shown in Figure F-1. This site was selected as the STEPL calibration site since it was the closest site that met the following criteria: 1) It is a SPARROW calibration site used for both flow and TP; 2) It is not immediately downstream of a reservoir; and 3) based on a USGS study (SIR 2012-5232) Big Hollow Lake and the SPARROW calibration site are in the same local region (local region 1). “A local region is an area in which the streamflows measured at all the streamgages are highly correlated” (Linhart, et al. 2012).

The BFI was also developed by the USGS for the conterminous United States. “The base-flow index (BFI) grid for the conterminous United States was developed to estimate (1) BFI values for ungaged streams, and (2) ground-water recharge throughout the conterminous United States.” (Wolock, DM. 2003). BFI is the portion of a stream’s discharge that comes from the groundwater and is represented in the form of a ratio. The BFI for Big Hollow Lake is 0.31.

The STEPL model was calibrated by iteratively adjusting the curve numbers (CN) and the soil infiltration fraction for precipitation values within the STEPL model. The iterative process of determining the CNs and infiltration fraction value was accomplished using the SOLVER add-in module within Microsoft EXCEL. CNs were adjusted within a range of values using literature data listed in the runoff curve number tables found in the TR-55 manual (Cronshey, R. 1986). The infiltration fraction values were adjusted within a range of values using literature data listed in the HEC-RAS 2D User’s Manual (Brunner, 2024). The SOLVER calculates the value of a cell formula within Microsoft EXCEL, while setting constraints in other cells. A target flow rate value of 4,460 ac-ft/year was set in the SOLVER and values were iteratively changed within a specified set of constraints until the target flow rate value was achieved. A summary of the CNs, soil infiltration fraction value, flow rate, BFI, and TP loading targets and constraints are presented in Table F-3.

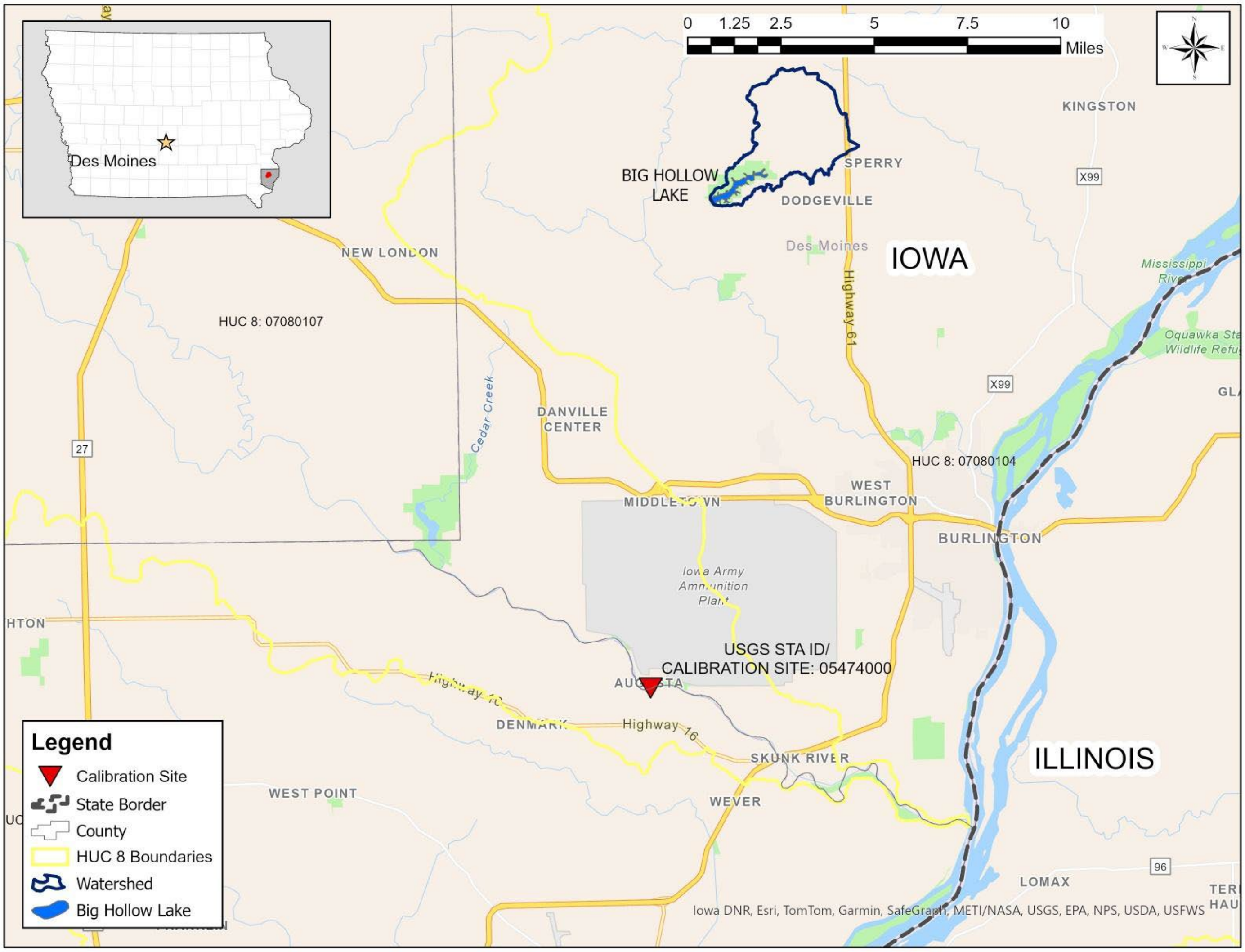

Figure F-1. SPARROW Calibration Site Location Map.

Table F-3. STEPL Calibration Value Summary.

STEPL Land Use Categories	Curve Number Values				Soil Infiltration Fraction for Precipitation			
	HSG C		HSG D		HSG C		HSG D	
	Range	Final	Range	Final	Range	Final	Range	Final
Cropland	77 - 88	79	80 - 91	80	0.05 - 0.15	0.139	0.025 - 0.075	0.073
Forest	70 - 73	73	77 - 79	77	0.05 - 0.15	0.139	0.025 - 0.075	0.072
Pastureland	74 - 86	77	80 - 89	85	0.05 - 0.15	0.139	0.025 - 0.075	0.072
Urban	89	89	91	91	0.05 - 0.12	0.111	0.025 - 0.06	0.058
User Defined	71	71	78	78	0.05 - 0.15	0.139	0.025 - 0.075	0.073

Parameter	Model		Percent Difference
	SPARROW/BFI (Target)	STEPL	
Flow Rate (ac-ft/yr)	4,460	4,460	0.00%
TP (lbs/yr)	5,907	5,924	0.29%
Percent GW Flow	0.31	0.309	0.32%

F.2. BATHTUB Model Performance

Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Big Hollow Lake. Simulation of TP concentration and Secchi depth / chl-a (algae) were critical for TMDL development, and were the focus of calibration efforts.

Calibration

Table F-4 reports the initial modeling results for the observed and predicted annual average TP, chl-a, and Secchi depths, observed to predicted ratios, and T-test values in the open water area of Big Hollow Lake (Segment 1A). More comprehensive observed data is reported in Appendix C.

Table F-4. Initial BATHTUB Modeling Results with Internal Loading.

Parameter	Observed[1]	Predicted[2]	Obs/Pred Ratio	T-Test		
Modeling period and TMDL conditions (2015-2023)				T1	T2	T3
Total Phosphorus (µg/L)	130.1	82.5	1.58	0.75	1.70	0.60
Chlorophyll-a (µg/L)	37.3	46.6	0.80	-0.24	-0.64	-0.22
Secchi depth (m)	1.40	1.10	1.22	0.19	0.71	0.18

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

Statistical comparisons, such as the T-test, can be used to determine if model calibration is needed or if there is any significant difference between the observed vs the predicted values. The T-test procedure evaluates the means of two data sets to determine if they are significantly different and to check the reasonableness of a model. (Walker, 1999; EPA-R7, 2022). Three t values are produced by the BATHTUB model, T(1), T(2), and T(3). It should be noted that T(1) values are provided only when the coefficient of variation (CV) values are provided as part of the input data for the observed parameters of interest.

T(2) and T(3) values are used to test the applicability of the model. If their absolute values exceed 2 there is less than a five percent chance that nutrient sedimentation dynamics in the reservoir are typical of those in the model development data set (Walker, 1999). As shown in Table F-4, the absolute T(2) and T(3) values for all parameters of interest are less than two, which would indicate that there is a 95 percent chance that the nutrient sedimentation dynamics in the reservoir are typical of those in the model development data set.

T(1) values can be used to determine if calibration of the model is appropriate. If the absolute value of T(1) is greater than two, there is less than a five percent chance that the observed and predicted means are equal. In this case, it may be desirable to calibrate the model. However, in our model, the absolute value of T(1) for phosphorus is 0.55, which would indicate that there is a 95 percent chance that the observed mean value is not significantly different from the predicted mean value and that calibration of the model is not needed (Walker, 1999).

Even though T(1) was less than two for all three parameters it was decided to do further calibration since predicted TP load in the model was underpredicted. Table F-5 reports the final modeling results, after calibration and reduction of phosphorus loads from the tributaries, for the observed and predicted annual average TP, chl-a, Secchi depths, along with the calibration coefficients for each parameter of interest. Predicted water quality is based on BATHTUB simulations, and the calibration coefficients were iteratively adjusted in order to obtain the best possible agreement between observed and predicted water quality, while minimizing changes in the default coefficients.

Calibration coefficients listed alongside the simulated values in Table F-5 were entered in the “Model Coefficients” menu of the BATHTUB model, and apply only to the ambient monitoring segment (Segment 1A) of Big Hollow Lake. Other lake segments were uncalibrated due to lack of historical water quality data. Calibration coefficients for Big Hollow Lake are within the recommended range according to the BATHTUB user guidance (Walker, 1999).

Table F-5. BATHTUB Calibration Modeling Results.

Parameter	Observed[1]	Predicted[2]	Calibration Coefficient
Modeling period and TMDL conditions (2015-2023)			
Total Phosphorus (µg/L)	130.1	130.1	1.578
Chlorophyll-a (µg/L)	37.3	37.3	0.591
Secchi depth (m)	1.36	1.36	1.0

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

F.3. References

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Appendix G. Expressing Average Loads as Daily Maximums

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

> "…recommends that all TMDLs and associated load allocations and wasteload allocations be expressed in terms of 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 requirements, the loading capacity of Big Hollow Lake 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 2,188.1 lbs/year.

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

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

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

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

The allowable annual average of 2,188.1 lbs/year is equivalent to a long-term average (LTA) daily of 6.0 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 2.326, as reported in Table G-1. The coefficient of variation (CV) is the ratio of the standard deviation to the mean. However, there is insufficient data to calculate a CV as it relates to TP loads to the lake, because the models are based on annual averages over several years. In cases where data necessary for calculating a CV is lacking, EPA recommends using a CV of 0.6 (EPA, 1991). The resulting σ^2 value is 0.31. This yields a TMDL of 18.7 lbs/day. The TMDL calculation is summarized in Table G-2. An explicit MOS of 10 percent (0.6 lbs) was applied, resulting in a daily LA of 1.9 lbs/day to the daily TMDL equations. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (0.9 lbs-TP/day) + Σ LA (15.9 lbs-TP/day) + MOS (1.9 lbs-TP/day) = **18.7 lbs-TP/day**

The maximum daily load is presented on a 365 days/year basis to satisfy EPA requirements. However, the point source discharger (US Gypsum, Permit # 2900103) in the watershed is a CDL. Consequently, it does not discharge daily so for NPDES purposes, the US Gypsum facility will be given a WLA of 80 lbs/yr and a maximum daily load of 2 lbs/day.

Table G-1. Multipliers Used to Convert a LTA to an MDL.

Parameter	TMDL	Σ WLA	Σ LA	MOS
LTA (lbs/day)	6.0	0.3	5.4	0.6
Z Statistic	2.326	2.326	2.326	2.326
CV	0.6	0.6	0.6	0.6
σ^2	0.31	0.31	0.31	0.31
MDL (lbs/day)	**18.7**	**0.9**	**15.9**	**1.9**

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

Parameter	Value	Description
LTA	6.0 lbs/day	Annual TMDL (2,188.1 lbs) divided by 365 days
Z Statistic	2.326	Based on 180-day averaging period
CV	0.6	Used CV from annual GWLF TP loads
σ^2	0.31	$\ln(CV^2 + 1)$
MDL	**18.7 lbs/day**	**TMDL expressed as daily load**

Appendix H. DNR Project Files and Locations

This appendix is primarily for future reference for DNR staff that may wish to access the original spreadsheets, models, maps, figures, and other files utilized in the development of the TMDL.

Table H-1. Project Files and Locations.

Directory\folder path	File name	Description
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\Data\Raw	Various files	All raw data received from others
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\Data\Reduced	WQ_dataset_BHL.xlsx	Summary of in-lake WQ data
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\Data\Reduced\ Weather	CrawfordsvilleET.xlsx	Summary of precipitation and PET data
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\Documents_ Presentations\Draft TMDL	Draft TMDL reports	Includes review comments
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\Documents_ Presentations\Final TMDL	Final report	Report for submittal to EPA
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\Documents_ Presentations\References	Various .pdf and .doc files	References cited in the WQIP and/or utilized to develop model input parameters
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\GIS\GIS_Data	Various shapefiles (.shp) and raster files (.grd)	Used to develop models and maps
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\GIS\Projects	ArcGIS project files	Used to develop models and maps
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\GIS\Maps	Various .pdf and .jpg files	Maps/figures used in the WQIP document
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_29_Revised\Modeling	TMDL_Equation_Calcs_ BHL.xlsx	Calculate the TMDL
		Used to develop the TMDL equation (LA, WLA, and MOS)
		Load response curve calcs
\\iowa.gov.state.ia.us...\ Big_Hollow_L_29_Revised\Modeling\STEPL	STEPL_BHL.xlsm	Used to simulated/predict existing watershed loads
	Various .xls files	Used to develop/calculate STEPL model inputs
\\iowa.gov.state.ia.us\...\ Big_Hollow_L_09_Revised\Modeling\ BATHTUB	BHL_Calibration.xlsx; BHL_TMDL.xlsx;	Calculated/converted STEPL outputs to BATHTUB inputs for existing conditions
	Various .btb files	BATHTUB input files for various scenarios

Appendix I. Public Comments

Public Comment:

All public comments received during the public comment period will be placed in this section, along with the DNR responses.