Water Quality Improvement Plan
for

Avenue of the Saints Lake

Bremer County, Iowa

Total Maximum Daily Load
for Algae, Turbidity, and pH

Prepared by:
Andrew Frana

Iowa Department of Natural Resources
Watershed Improvement Section
2017

Table of Contents

List of Figures 4
List of Tables 5
General Report Summary 6
Technical Elements of the TMDL 9
1. Introduction 11
2. Description and History of Avenue of the Saints Lake 13
Water Quality History 15
2.1. Avenue of the Saints Lake 15
Hydrology 15
Morphometry 17
2.2. The Avenue of the Saints Lake Watershed 18
Land Use 20
Soils, Climate, and Topography 22
3. TMDL for Algae, Turbidity, and pH 25
3.1. Problem Identification 25
Applicable Water Quality Standards 25
Problem Statement 26
Data Sources 26
Interpreting Avenue of the Saints Lake Data 27
3.2. TMDL Target 39
General description of the pollutant 39
Selection of environmental conditions 40
Waterbody pollutant loading capacity (TMDL) 41
Decision criteria for WQS attainment 43
Compliance point for WQS attainment 43
3.3. Pollution Source Assessment 43
Existing load 43
Departure from load capacity 43
Identification of pollutant sources 43
Allowance for increases in pollutant loads 44
3.4. Pollutant Allocation 45
Wasteload allocation 45
Load allocation 45
Margin of safety 46
Reasonable Assurance 46
3.5. TMDL Summary 47
4. Implementation Planning 48
4.1. Previous Watershed Planning and Implementation 48
4.2. Future Planning and Implementation 48
General Approach 48
Timeline 49
Tracking milestones and progress 49
4.3. Best Management Practices 49
Land Management (Prevention Strategies) 50
Structural BMPs (Mitigation Strategies) 50
In-Lake BMPs (Remediation Strategies) 55
Holistic Approach 56
5. Future Monitoring 57

5.1. Routine Monitoring for Water Quality Assessment 57
5.2. Expanded Monitoring for Detailed Analysis 58
6. Public Participation 62
6.1. Public Meeting 62
6.2. Written Comments 62
7. References 63
8. Appendices 65
Appendix A --- Glossary of Terms, Abbreviations, and Acronyms 65
Scientific Notation 74
Appendix B --- General and Designated Uses of Iowa's Waters 75
Appendix C --- Water Quality Data 78
C.1. Individual Sample Results 78
C.2. Annual Mean Data 79
Appendix D --- Watershed Model Development 80
D.1. Modeling Approach 80
D.2. STEPL Model Description 80
D.3. Meteorological Input 81
Precipitation Data 81
D.4. Watershed Characteristics 82
Topography 82
Land Use 82
Soils 84
Slopes 84
Curve Numbers 84
Subsurface Tile Drainage 85
Sediment Delivery Ratio 85
D.5. Animals 85
Agricultural Animals and Manure Application 85
Livestock Grazing 85
Open Feedlots 86
Wildlife 86
Septic Systems 86
D.6. References 86
Appendix E --- Water Quality Model Development 87
E.1. BATHTUB Model Description 87
E.2. Model Parameterization 88
Model Selections 88
Global Variables 89
Segment Data 89
Tributary Data 91
E.3. References 92
Appendix F --- Model Performance and Calibration 93
F.1. STEPL Performance and Calibration 93
F.2. BATHTUB Model Performance 95
F.3. References 96
Appendix G --- Expressing Average Loads as Daily Maximums 97
Appendix H --- 2014 305(b) Water Quality Assessment 99
Appendix I --- DNR Project Files and Locations 102
Appendix J --- Public Comments 103

List of Figures

Figure 2-1. Vicinity Map 14
Figure 2-2. Annual precipitation and estimated lake evaporation 16
Figure 2-3. Monthly precipitation and estimated ET for the watershed 17
Figure 2-4. Bathymetric map of Avenue of the Saints Lake 19
Figure 2-5. Avenue of the Saints Lake watershed land use map 21
Figure 2-6. Slope classifications in the Avenue of the Saints watershed 24
Figure 3-1. Ambient monitoring location for water quality assessment 28
Figure 3-2. Growing season TSI values for individual samples (2002-2014) 29
Figure 3-3. Growing season mean TSI values (2002-2014) 30
Figure 3-4. Annual mean TSI values for total phosphorus and Secchi depth 31
Figure 3-5. Annual mean TSI values for total phosphorus and chlorophyll-a 32
Figure 3-6. Annual mean TSI values for chlorophyll-a and Secchi depth 32
Figure 3-7. Total nitrogen concentration and Secchi depth TSI 33
Figure 3-8. Total nitrogen concentration and chl-a TSI value 33
Figure 3-9. Total nitrogen concentration and TP TSI value 34
Figure 3-10. Phosphorus TSI deviations (2002-2014 grab samples) 35
Figure 3-11. Phosphorus TSI deviations (2002-2014 annual averages) 35
Figure 3-12. TP TSI values plotted against annual and growing season precip 36
Figure 3-13. Chl-a TSI values plotted against annual and growing season precip 36
Figure 3-14. Secchi depth TSI values plotted against annual and growing season precip 37
Figure 3-15. pH values during the assessment period 38
Figure 3-16. pH and Chl-a concentrations from 2002-2014 39
Figure 3-17. Simulated load response of chlorophyll-a and Secchi TSI values to reductions in TP load. 42
Figure 3-18. Relative TP loads by source 45
Figure 4-1. Predicted TP export from each STEPL subwatershed 53
Figure 4-2. Predicted per-acre TP loss for each STEPL subwatershed 54
Figure 5-1. Potential monitoring locations 61
Figure D-1. STEPL subbasin map 83
Figure E-1. Eutrophication control pathways in BATHTUB (Walker, 1999) 87
Figure E-2. Lake segmentation in BATHTUB model. 90
Figure F-1. Sheet and rill erosion in the Avenue of the Saints watershed, 2012 94

List of Tables

Table 2-1. Avenue of the Saints Lake watershed and lake characteristics 13
Table 2-2. Weather station information for Avenue of the Saints Lake 15
Table 2-3. Land use composition of Avenue of the Saints Lake watershed 22
Table 2-4. Predominant soils of the Avenue of the Saints Lake watershed 22
Table 2-5. Slope classifications of the Avenue of the Saints Lake watershed 23
Table 3-1. TSI annual mean values and R^2 values when compared linearly 30
Table 3-2. TSI annual mean values with R^2 values compared to Total Nitrogen 31
Table 3-2. TN:TP ratio summary in Avenue of the Saints Lake 38
Table 3-3. Existing and target water quality (ambient monitoring location) 40
Table 3-4. Average annual TP loads from each source (2002-2014) 45
Table 3-5. Example load allocation scheme to meet target TP load 46
Table 4-1. Potential land management BMPs (prevention strategies) 50
Table 4-2. Potential structural BMPs (mitigation strategies) 51
Table 4-3. Potential in-lake BMPs for water quality improvement 56
Table 5-1. Ambient Lake Monitoring Program water quality parameters 58
Table 5-2. Recommended monitoring plan 59
Table B-1. Designated use classes for Iowa waterbodies 76
Table C-1. ISU and SHL water quality sampling data ([1]ambient location) 78
Table C-2. Precipitation and annual mean TSI values ([1]ambient location) 79
Table D-1. STEPL rainfall inputs (2002-2014 average annual data) 81
Table D-2. STEPL land use inputs 82
Table D-3. C- and P-factors for each land cover and practice (BMP) 84
Table D-4. STEPL curve numbers 85
Table E-1. Model selections for Avenue of the Saints Lake 88
Table E-2. Global variables data for 2002-2014 simulation period 89
Table E-3. Segment morphometry for the Avenue of the Saints Lake 91
Table E-4. Ambient (Segment 1) water quality (2002-2014 annual means) 91
Table E-5. Tributary data for the Avenue of the Saints Lake 91
Table E-6. Flow and transport linkages in STEPL and BATHTUB 92
Table F-1. Sheet and rill erosion in similar watersheds 93
Table F-2. Comparison of TP exports in similar watersheds 95
Table F-3. Observed and simulated water quality with calibration factors 96
Table G-1. LTA to MDL calculations for Avenue of the Saints Lake. 98

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 Avenue of the Saints Lake. Second, it satisfies the Federal Clean Water Act 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 Avenue of the Saints Lake from the federal 303(d) list of impaired waters.

What's wrong with Avenue of the Saints Lake?

Avenue of the Saints Lake is listed as impaired on the 2014 303(d) list for not supporting its aquatic life support designated use. The impairment is due to elevated levels of algae, turbidity, and pH 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 and tile flow). Phosphorus within the water column and on the lake bed may become resuspended under certain conditions, which can add to algae and turbidity issues. There are no permitted point sources of phosphorus in the Avenue of the Saints 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 often are difficult to locate and quantify. Nonpoint sources of phosphorus in the Avenue of the Saints Lake watershed include sheet and rill erosion from various land uses, runoff and subsurface flows (i.e., tile drainage) from lands that receive fertilizer application, poorly functioning septic systems, manure deposited by wildlife, urban stormwater, and particles carried by dust and wind (i.e., atmospheric deposition). A portion of the phosphorus carried to the lake settles to the lake bottom and accumulates. If released or resuspended, 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 Avenue of the Saints Lake.

What can be done to improve Avenue of the Saints Lake?

Reducing phosphorus loss from row crops and implementing or improving existing structural BMPs such as terraces, grass waterways, and constructed sediment basins in beneficial locations will significantly reduce phosphorus loads to the lake. Special attention should be given to row crops on steep slopes, where the adoption of cover crops

or perennial strips may be especially beneficial. 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 Avenue of the Saints Lake?

Everyone who lives, works, or recreates in the Avenue of the Saints 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. Improving water quality in Avenue of the Saints Lake, while also improving the quality of the surrounding land, will require collaborative participation by various stakeholder groups, with land owners playing an especially important role. Additionally, those looking to develop sites within the Avenue of the Saints Lake watershed should recognize the impact of improved water quality on property values.

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 Avenue of the Saints Lake and surrounding lakes 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 Avenue of the Saints Lake as a recreational resource are certainly attainable goals.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Avenue of the Saints Lake, Waterbody ID IA 02-SHL-00105-L_0, located in S7, T91N, R14W, 2 miles E of Shell Rock
Surface water classification and designated uses:	B(LW) – Aquatic life HH – Human health (fish consumption)
Impaired beneficial uses:	B(LW)
TMDL priority level:	Priority Group 1
Identification of the pollutants and applicable water quality standards (WQS):	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 WQS:	Impairments were associated with total phosphorus (TP). The allowable average annual TP load = 959 lbs/year; the maximum daily TP load = 8.2 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain WQS:	The existing annual average load of 6,021 lbs/year must be reduced by 5,062 lbs/year to meet the allowable TP load. This is a reduction of 84.1 percent.
Identification of pollution source categories:	There are no regulated point source discharges of phosphorus in the watershed. Nonpoint sources of phosphorus include fertilizer and manure from row crops, sheet and rill erosion, wildlife, septic systems, groundwater / tile drainage, atmospheric deposition, and others.
Wasteload allocations (WLAs) for pollutants from point sources:	There are no allowable point source discharges.
Load allocations (LAs) for pollutants from nonpoint sources:	The allowable annual average TP LA is 863 lbs/year, and the allowable maximum daily LA is 7.4 lbs/day.
A margin of safety (MOS):	An explicit 10 percent MOS is incorporated into this TMDL.

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:	Reasonable assurances for reductions in nonpoint source pollution are 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, and (4) best available data for estimating the efficiency/reduction associated with 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.

1. Introduction

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

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

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

One purpose of this Water Quality Improvement Plan (WQIP) for Avenue of the Saints Lake, located in Bremer County in northeast Iowa, is to provide TMDLs for algae, turbidity, and pH, which have 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 aquatic life support for the fishery of Avenue of the Saints Lake. The impairments are addressed by development of a TMDL that limits total phosphorus (TP) loads to the lake. Phosphorus reductions should be accompanied by reduced algal growth, reduced turbidity, and stabilized pH 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 best management practices (BMPs) for improving water quality in Avenue of the Saints Lake, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the implementation plan in Section 4.

The Iowa Department of Natural Resources (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 water quality standards, 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 Watershed Improvement Section of DNR has designed this plan for stakeholder use and may be able to provide technical support for the improvement of water quality in Avenue of the Saints Lake.

2. Description and History of Avenue of the Saints Lake

Table 2-1 lists some of the general characteristics of Avenue of the Saints Lake and its watershed. Figure 2-1 shows the vicinity map for the lake and its watershed. Estimation of physical characteristics such as surface area, depth, and volume are based on a bathymetric survey conducted by DNR in 2015.

Table 2-1. Avenue of the Saints Lake watershed and lake characteristics

DNR Waterbody ID	ID Code: IA 02-SHL-00105-L_0
12-Digit Hydrologic Unit Code (HUC)	070802020705
12-Digit HUC Name	Shell Rock River
Location	Bremer County, S7, T91N, R14W
Latitude	42.70° N (ambient lake monitoring location)
Longitude	92.54° W (ambient lake monitoring location)
Designated Uses	B(WW-1) – Aquatic life HH – Human health (fish consumption)
Tributaries	none
Receiving Waterbody	Shell Rock River
Lake Surface Area	[1]42.6 acres
Length of Shoreline	[1]7,880 feet
Shoreline Development Index	1.61
Maximum Depth	[1]16.7 feet
Mean Depth	[1]7.8 feet
Lake Volume	[1]333 acre-feet
Watershed Area	4,225 acres (includes lake)
Watershed:Lake Ratio	99:1
Lake Residence Time	[2]26 days

[1]Per May 2015 bathymetric survey and subsequent calculations
[2]BATHTUB model prediction for average annual conditions (2002-2014)

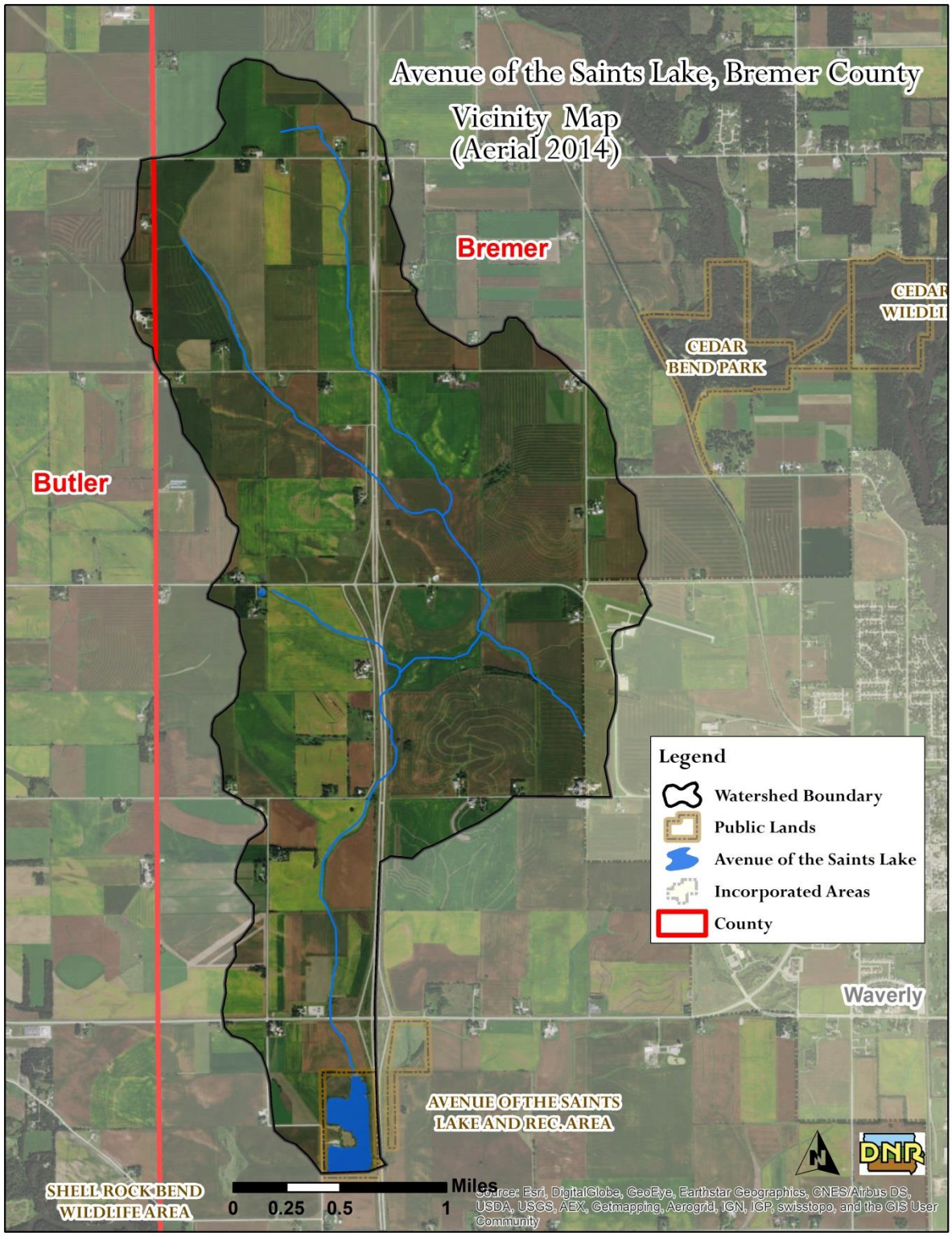

Figure 2-1. Vicinity Map

Water Quality History
Limited water quality history exists for Avenue of the Saints Lake. An Erosion and Sediment Worksheet provided by Natural Resource Conservation Service (NRCS) was used to determine sheet and rill erosion, and sediment delivery to the lake. This is explained further in Appendix D and E.

Avenue of the Saints Lake is part of Iowa's ambient lake monitoring program. In-lake water quality data utilized in the development of this TMDL includes data collected by Iowa State University (ISU) and the University of Iowa State Hygienic Laboratory (SHL) from 2002-2014. These results are listed in Appendix C – Water Quality Data.

2.1. Avenue of the Saints Lake

Hydrology
Avenue of the Saints Lake formed during construction of Highway 218, also known as the Avenue of the Saints. Originally the lake site was used as a borrow pit to supplement materials used during the roadway construction. After completion of the roadway the borrow pit was allowed to fill with water, which led to the creation of the Avenue of the Saints Lake and surrounding wildlife area. The lake discharges from the southeastern corner under the roadway and eventually reaches the Shell Rock River to the south.

The National Weather Service (NWS) Cooperative Program (COOP) station in Allison, Iowa reports daily maximum and minimum temperature and precipitation. The Iowa State Climatologist provides quality control of these data, which are downloadable from the Iowa Environmental Mesonet (IEM, 2016a). Daily observations between January 1, 2002 and December 31, 2014 were used in climate assessment and model development. Daily potential evapotranspiration (PET) data were obtained for 2002-2014 from the Iowa Ag Climate Network, also downloadable from the IEM (IEM, 2016b). Table 2-2 reports weather station information.

Table 2-2. Weather station information for Avenue of the Saints Lake

Data	Temperature/Precipitation	Potential ET
Network	NWS COOP	ISU Ag Climate
Station Name (ID)	Allison, IA (IA0157)	Nashua (A135879)
Latitude	Latitude: 42.75°	42.94°
Longitude	Longitude: -92.78°	-92.57°

Average annual precipitation near Avenue of the Saints Lake was 34.1 inches from 2002-2014. Years 2007 through 2009 were, on average, much wetter than normal, with an annual average rainfall amount of 41.3 inches per year. These wetter than normal years coincide with several of the years of water quality data used to develop the 2014 Water Quality Assessment and 303(d) list and current impairment status of Avenue of the Saints Lake. Conversely, years 2011-2012 were much drier than normal, with an annual average rainfall of 25.6 inches per year. Figure 2-2 illustrates the annual precipitation totals, along with lake evaporation (estimated as 70 percent of annual PET). From 2002 to 2006 precipitation and lake ET closely aligned. Wet years of 2007-2010 and 2013 show a

surplus of precipitation, while 2012 shows a precipitation deficit in comparison to lake ET. Data was not available to complete an ET analysis for 2014; modeling values will be based on 2002-2013 for ET mean values only. Analysis of 2014 precipitation data and historical trends show that ET would not deviate significantly from the long term ET average. Therefore, not including 2014 ET in subsequent models will not significantly affect long term average climatological values.

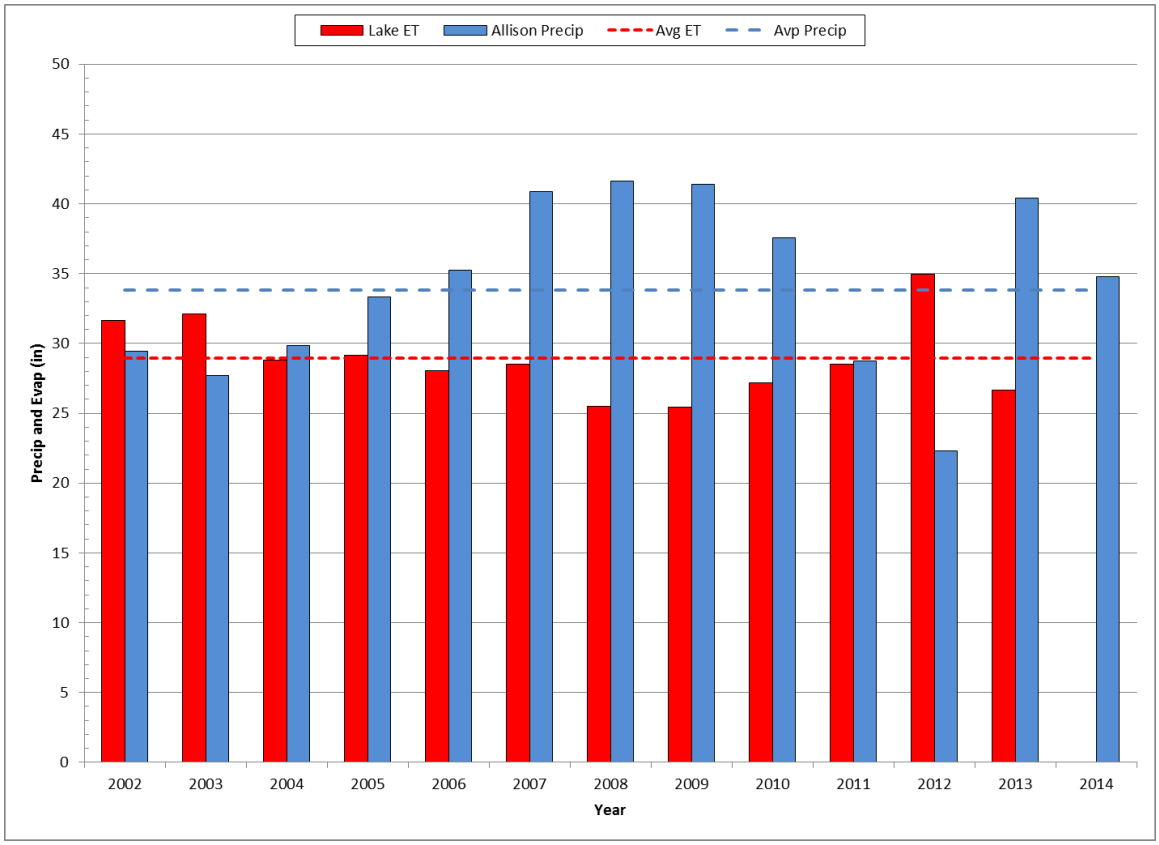

Figure 2-2. Annual precipitation and estimated lake evaporation

Precipitation varies greatly by season in northeast Iowa, with 75 percent of annual rainfall occurring between April and September. Monthly average precipitation (2002-2014) 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 seasonal moisture deficit often occurs between June and September. 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. Additionally, although watershed ET is high, the watershed to lake ratio (99:1) is also high, meaning that rainfall events producing runoff will effect lake water levels much more dramatically than a lake with a lower watershed to lake ratio.

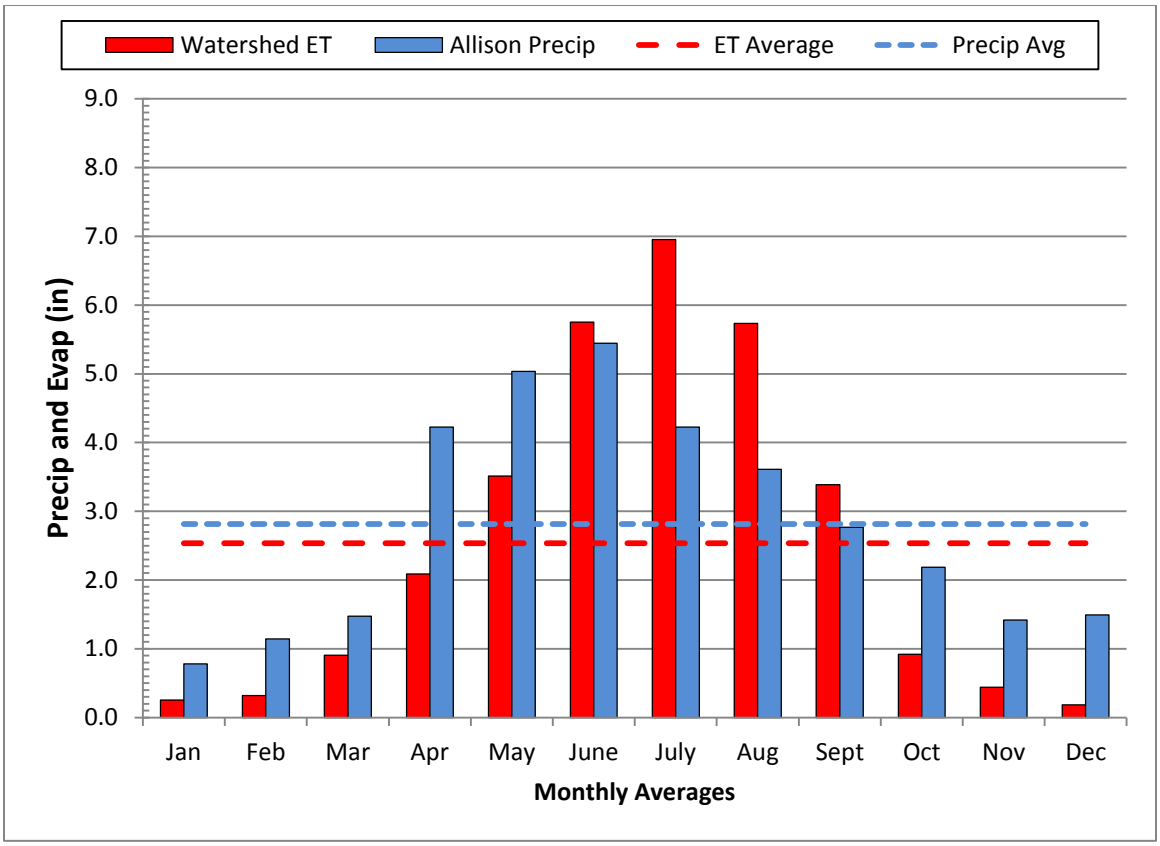

Figure 2-3. Monthly precipitation and estimated ET for the watershed

Rainfall runoff, direct precipitation, evapotranspiration, tile drainage, 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 Nashua, Iowa and obtained from the Iowa State University Ag Climate Network on the Iowa Environmental Mesonet (IEM, 2016b), and lake morphometry.

During years of below average precipitation, residence time increases. In wet years, the opposite is true as residence time decreases. Although a low residence time (26 days) may point to limited internal loading, analyses of watershed loading and lake water quality show that internal loading is a significant contributor to total phosphorus in Avenue of the Saints Lake.

Morphometry

According to the most current bathymetric data (2015), the surface area of Avenue of the Saints is 42.6 acres. Estimated water volume of the main lake is 333.0 acre-feet (ac-ft), with a mean depth of 7.8 ft and a maximum depth of 16.7 ft in the southern section of the lake. The lake has an irregular shape, with two distinct sections, one south and one north

of a small neck connecting the two main bodies. Evidence of sedimentation, particularly at the upstream (north) end of the lake where flow enters, suggests that the watershed of Avenue of the Saints Lake has a large impact on water quality. The significance of sediment (and associated phosphorus) loading from the watershed is further evidenced by the shoreline development index of 1.63, which is moderately high. 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 Avenue of the Saints Lake. Lake morphometry and bathymetry data are shown in Figure 2-4.

2.2. The Avenue of the Saints Lake Watershed

The watershed boundary of Avenue of the Saints Lake encompasses 4,225 acres (including the lake) and is illustrated in Figure 2-1. The watershed-to-lake ratio of 99:1 is much larger than 20:1, which has been identified as an optimal value for highly successful lake restoration in Iowa. Full support of all designated uses in Avenue of the Saints Lake will be challenging and will require a comprehensive approach. Significant mitigation of watershed influence will be required in addition to in-lake improvement strategies. However, in-lake techniques may have short effective life spans in the absence of extensive watershed improvements and renovations. A prudent watershed management strategy should focus on water quality improvement, 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.

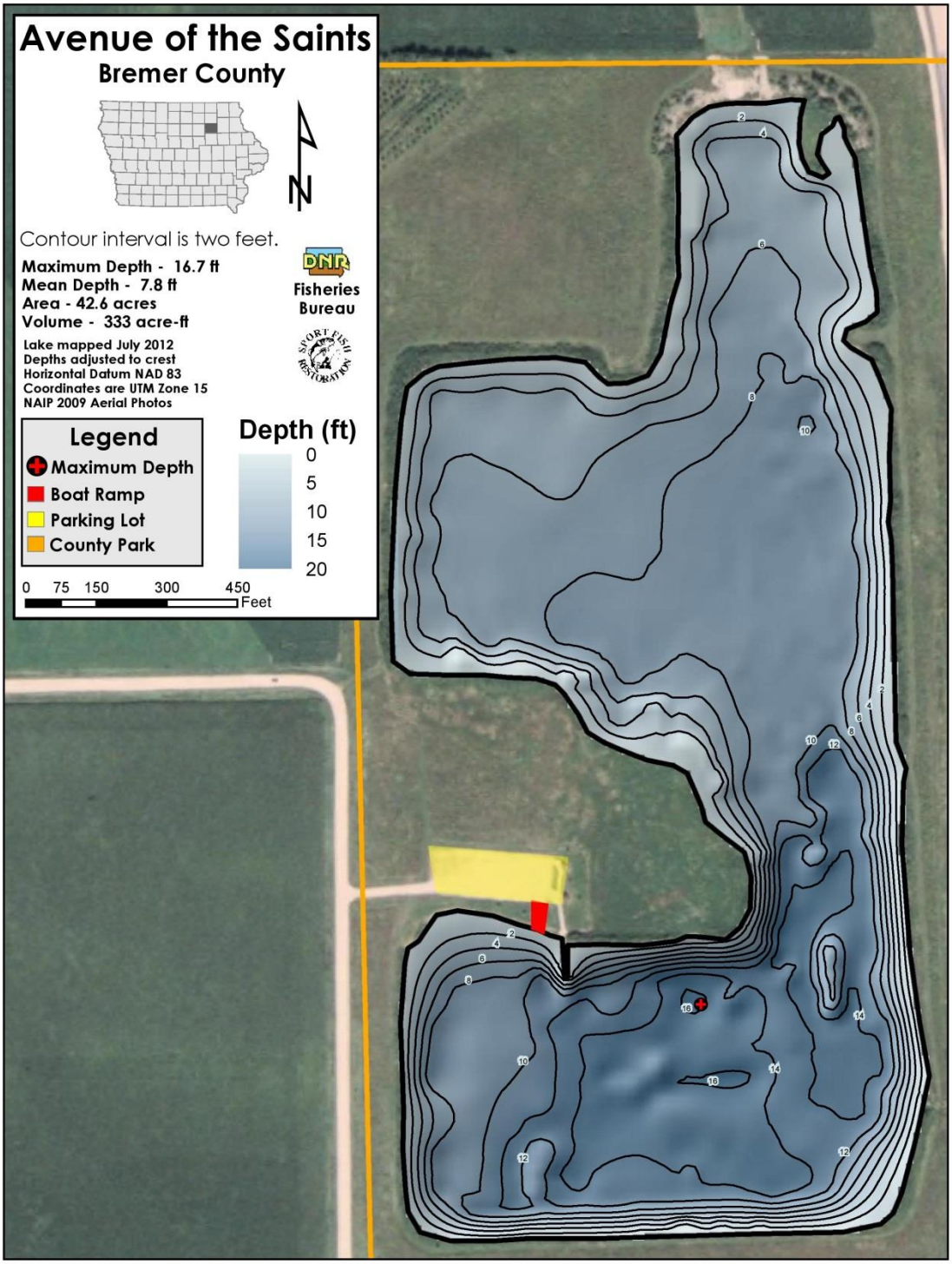

Figure 2-4. Bathymetric map of Avenue of the Saints Lake

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using tablet assessed surveys over multiple years of land cover and operations (tillage, management, rotation). Land use information was compiled in 2006 for a RUSLE assessment of the Avenue of the Saints watershed. Current land use and management practices were confirmed and / or revised after a supplementary windshield survey by Iowa DNR staff in 2016.

Due to agricultural management operations in the watershed, areas with multiple land covers consisting of soybean and corn ground have been aggregated together under a "Row Crop" land cover. Extended crop rotations where two years of row crops is followed by four years of meadow or other grasses have been modeled as perennial grassland. Assessment period land use is shown in Figure 2-5 and itemized in Table 2-3.

Analysis of historical aerial photography data reveals several trends. Crop diversification has decreased substantially in recent times to mainly consist of corn / soybean rotations. The implementation of contour strips, terraces, and grassed waterways in the watershed is higher than other watersheds due to the rolling topography in the area. This effect of the increased level best management practices in the watershed is reflected in the STEPL model and documented in Appendix D.

Prior to the construction of the Avenue of the Saints Roadway near Waverly in 2002, the watershed delineation would have been slightly different than it is today. This is due to changes in local topography and drainage infrastructure required for the roadway. The ratio of agricultural to non-agricultural ground would have been similar to current conditions, which is confirmed by historical land use coverages of the watershed pre-roadway.

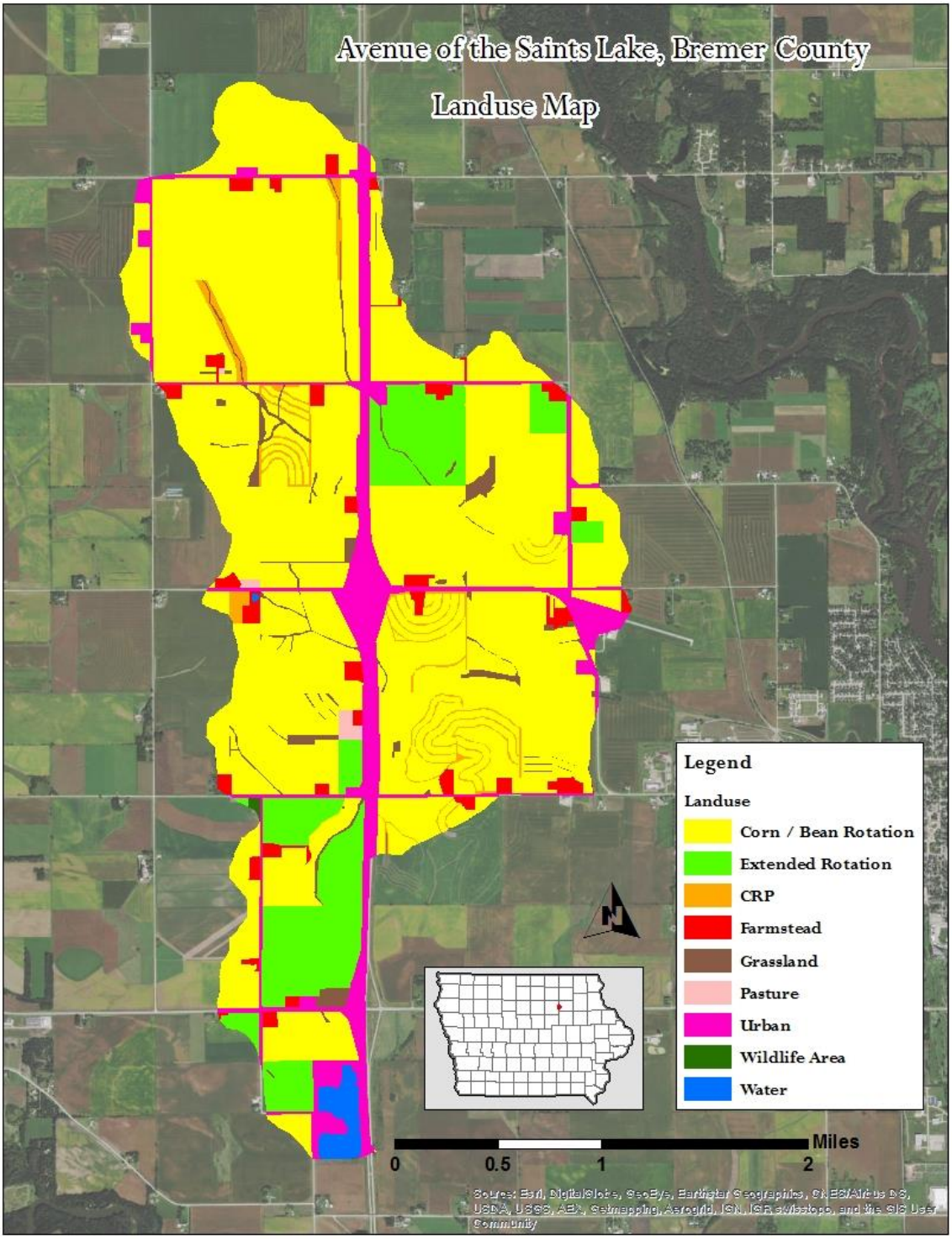

Figure 2-5. Avenue of the Saints Lake watershed land use map

Table 2-3. Land use composition of Avenue of the Saints Lake watershed

Land Use	Area (acres)	Percent (%)
Corn / Soybean Rotation	2,984.6	70.6
Corn / Soybean / Meadow Rotation	459.7	10.9
[1]Developed	424.9	10.0
CRP	89.1	2.1
Grassland	87.9	2.1
Pasture	12.2	0.3
Farmstead Active	121.9	2.9
[2]Water	42.6	1.0
Wildlife Area	2.1	0.1
Total area =	**4,225**	**100.0**

[1]Includes roadways, paved lots, commercial and industrial areas
[2]Includes Avenue of the Saints Lake surface area

Soils, Climate, and Topography

The Avenue of the Saints Lake watershed is located in the central region of the Iowan Surface landform. Four soils series dominate the Avenue of the Saints Lake watershed, as shown in Table 2-4. Of these, the Ostrander / Clyde / Floyd soil association comprise 52.8 percent of the watershed. These soils are characterized by gently rolling, long slopes of dissected till plains (USDA-NRCS, 1979). This association is well drained to poorly-drained as the landscape transitions from upland to low lying areas. Table 2-4 show descriptions and percentages of all major soils in the watershed. Many of the lower position landscape formations have been drained for use in agriculture. All other minor classes are listed as "Other."

Table 2-4. Predominant soils of the Avenue of the Saints Lake watershed

Soil Name	Area (ac)	Area (%)	Description of Surface Soil Layer	Typical Slopes (%)
Ostrander	982.1	23.2	Very deep, well drained soils of loamy sediment	0-18
Floyd	679.3	16.1	Very deep, somewhat poorly drained loamy sediment	0-5
Clyde	630.7	14.9	Very deep, poorly and very poorly drained loamy glacial outwash	0-4
Fort	341.6	8.1	Very deep, well drained eolian and alluvium formed soils	0-18
Udorthents	239.9	5.7	Moderately well drained fill material for construction	0-40
Dickinson	222.0	5.3	Very deep, well drained glacial or alluvial deposits	0-25
Sparta	190.8	4.5	Very deep, excessively drained soils formed in sandy outwash	0-15
Waukee	163.8	3.9	Very deep, well drained soils formed in loamy alluvium	0-14
Kenyon	155.8	3.7	Very deep, moderately well drained soils formed in silt sediment	2-35
Minor Soils	576.4	13.6	Varies	0-5
Water	42.6	1.0	---	
Total	4225	100.0	Varies	Varies

The topography consists of long slopes and low relief topographic features formed over underlying glacial till. Typical features of the region include exposed large boulders from

glacial periods and *pahas*, elongated hill formations oriented in a distinct northwest to southeast direction. Slopes are therefore mostly gently sloping (2-5 percent), to moderately sloping (5-9 percent), but there are areas of strongly sloping (9-14 percent) to moderately steep slopes (14 and up) where the topography transitions to developed areas. Flat to gently sloping (0 – 5 percent slope) regions make up 82.6 percent of the watershed. The majority of slopes above 14 percent are part of roadway drainage ditch networks along the Avenue of the Saints roadway. Table 2-5 shows the percentage breakdown of slope classifications throughout the watershed, and Figure 2-7 illustrates the distribution of the slopes within the Avenue of the Saints Lake watershed.

Table 2-5. Slope classifications of the Avenue of the Saints Lake watershed

Slope Class (%)	Area (%)	Description of Slope Class
0 – 2 (Class A)	37.0	Flat to very gently sloping
2 – 5 (Class B)	45.6	Gently sloping
5 – 9 (Class C)	12.7	Moderately Sloping
9 – 14 (Class D)	2.7	Strongly sloping
14 and up (Class E, F)	2.0	Moderately steep, steep
Total	100.0	---

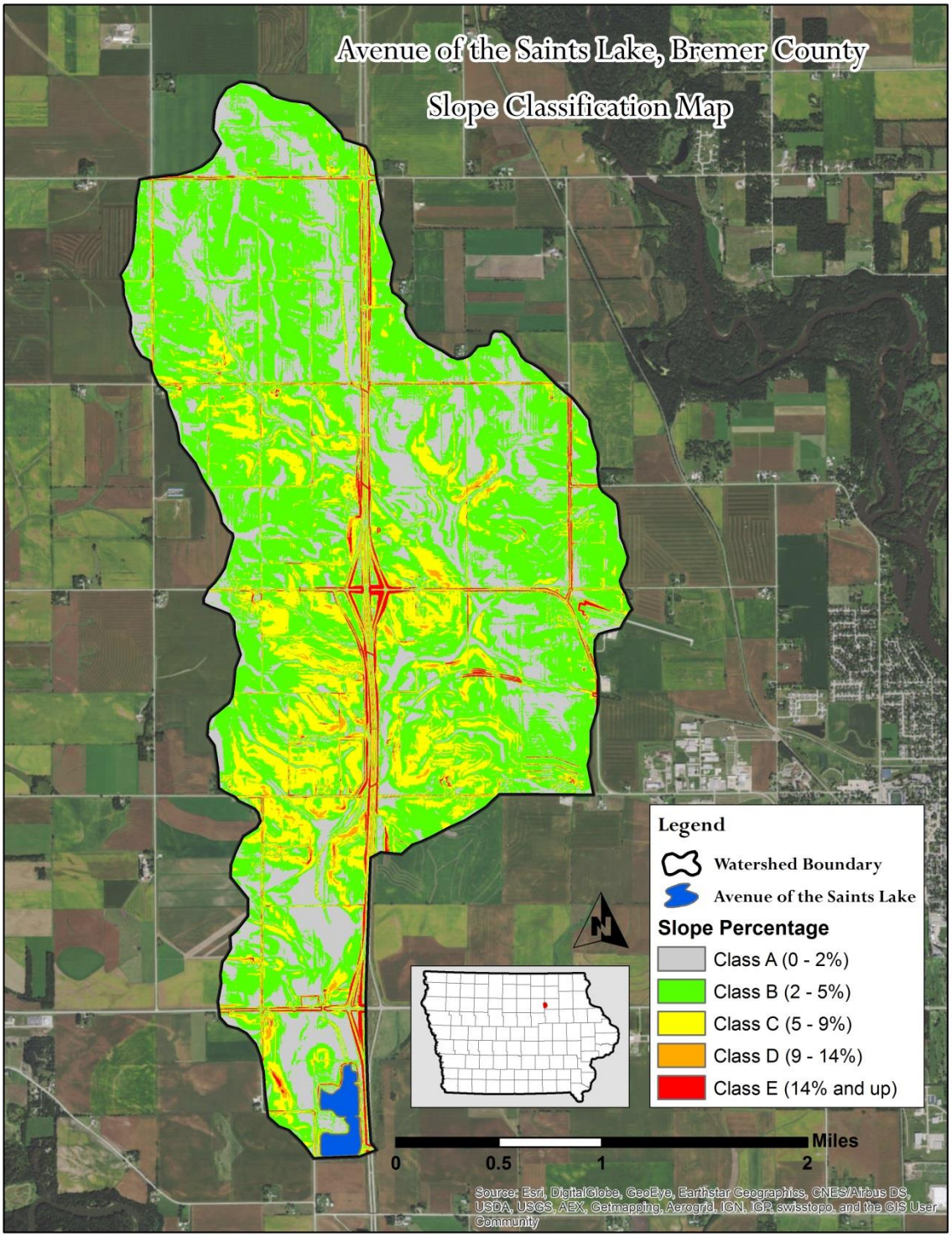

Figure 2-6. Slope classifications in the Avenue of the Saints watershed

3. TMDL for Algae, Turbidity, and pH

A Total Maximum Daily Load (TMDL) is required for Avenue of the Saints Lake by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) quantifies the maximum amount of total phosphorus (TP) the lake can assimilate and still fully support aquatic life in Avenue of the Saints Lake, which is impaired by algae, non-algal turbidity, and pH fluctuations. This section includes an evaluation of Avenue of the Saints Lake water quality, documents the relationship between algae, turbidity, pH, and TP, and quantifies the in-lake target and corresponding TMDL.

3.1. Problem Identification

Avenue of the Saints Lake is a Significant Publicly Owned Lake, and is protected for the following designated uses:

- Aquatic life – Class B(LW)
- Fish consumption – Class HH

The 2014 Section 305(b) Water Quality Assessment Report states that aquatic life support in Avenue of the Saints Lake is assessed (monitored) as "partially supported" due to poor water quality caused by algae and inorganic turbidity. Decision criteria for addressing historical pH violations have also been included in this TMDL. Although the 2014 assessment does explicitly not list pH violations as a source of impairment, the 2016 draft assessment is expected to add pH violations to the existing algal and inorganic turbidity impairments based on the most recent available water quality data. For this reason, pH values have been added to the TMDL target. The 2014 assessment is included in its entirety in Appendix H, and can be accessed at https://programs.iowadnr.gov/adbnet/Assessments/Legacy/16073

Applicable Water Quality Standards
The State of Iowa Water Quality Standards (WQS) are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61 (http://www.legis.iowa.gov/DOCS/ACO/IAC/LINC/Chapter.567.61.pdf) [Note: This link must be copied and pasted into a web browser]. Although the State of Iowa does not have numeric criteria for sediment, nutrients, or algae (chlorophyll-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 water quality standard for pH impairments is listed below in subrule (2):

61.3(3) Specific water quality criteria.

b. *Class "B" waters. All waters which are designated as Class B(CW1), B(CW2), B(WW-1), B(WW-2), B(WW-3) or B(LW) are to be protected for wildlife, fish, aquatic, and semiaquatic life. The following criteria shall apply to all Class "B" waters designated in subrule 61.3(5).*
    1) *Dissolved oxygen. Dissolved oxygen shall not be less than the values shown in Table 2 of this subrule.*
    2) *pH. 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.*

For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when Carlson's Trophic State Index (TSI) for the median growing season chlorophyll-a and / or median Secchi depth exceed 65 (DNR, 2008). In order to de-list the algae and turbidity impairments for Avenue of the Saints Lake, the median growing season chlorophyll-a and Secchi depth TSI must not exceed 63 in two consecutive listing cycles, per DNR de-listing methodology. In order to delist the pH impairment for Avenue of the Saints Lake, pH violations from water quality sampling must not be significantly greater than 10 percent for two consecutive listing cycles, per DNR delisting methodology.

Problem Statement

Avenue of the Saints Lake is impaired because aquatic life uses in the lake are not fully supported due to violations of WQS. 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 use. 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

Sources of data used in the development of this TMDL include those used in the 2014 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 Program and / or TMDL monitoring including:
    - results of statewide surveys of Iowa lakes sponsored by DNR and conducted by Iowa State University (ISU) from 2002-2014
    - Water quality data collected by the State Hygienic Laboratory (SHL) at the University of Iowa from 2008-2012
- Precipitation Allison, Iowa, from the NWS COOP program (IEM, 2016a)
- PET data at Nashua, Iowa, the ISU Ag Climate Network (IEM, 2016b)
- 3-m Digital Elevation Model (DEM) available from 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 DNR
- Lake bathymetric data collected in 2015

Interpreting Avenue of the Saints Lake Data
The 2014 305(b) assessment was based on results of the ambient monitoring program conducted from 2008 through 2012 by ISU and SHL, and information from the DNR Fisheries Bureau. Assessment of in-lake water quality in this TMDL utilized SHL and ISU data from 2002-2014. All 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 reported in Appendix C.

Figure 3-1. Ambient monitoring location for water quality assessment

Carlson's TSI was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Avenue of the Saints Lake. Figure 3-2 illustrates each of the individual TSI values throughout the analysis period. TSI values that exceed the 303(d) listing threshold of 65 (for chlorophyll-a) are in the red-shaded box on the top half of Figure 3-2. Data incorporated into the 2014 305(b) report is in the blue-shaded box (2008-2012) in Figure 3-2.

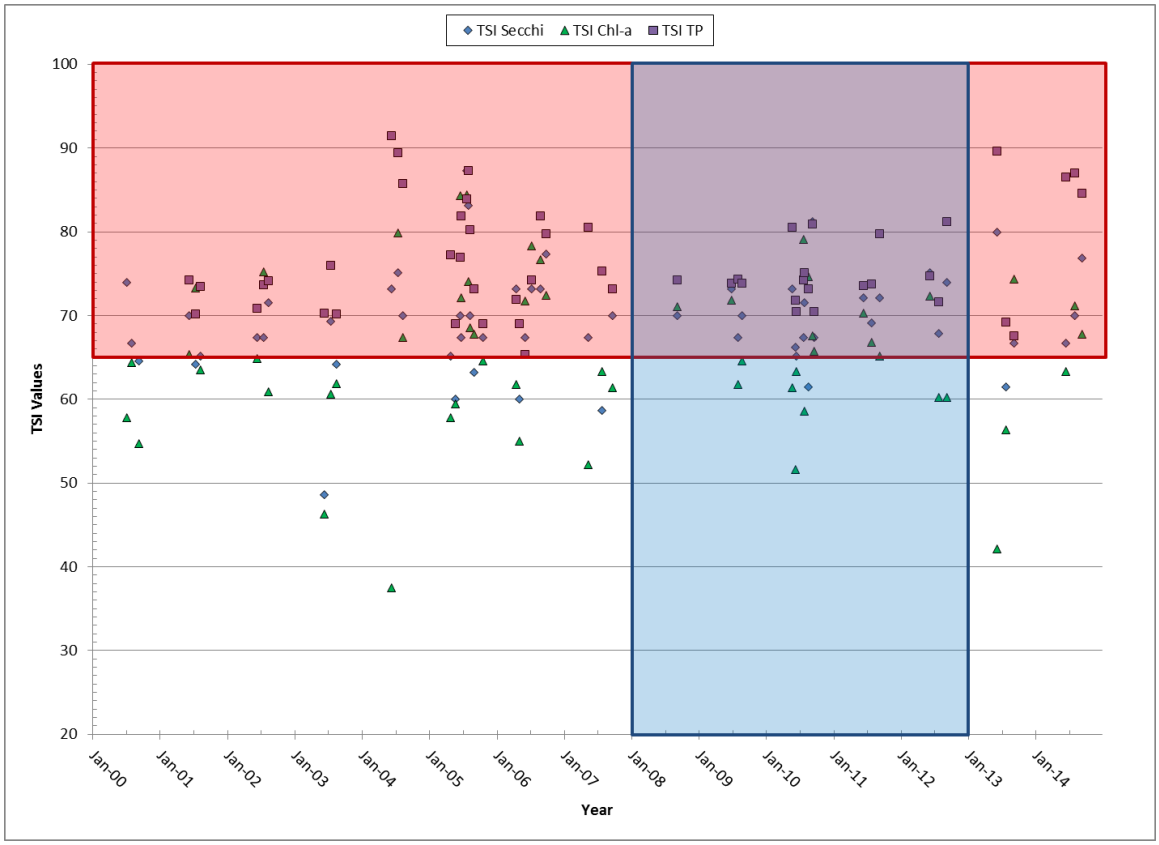

Figure 3-2. Growing season TSI values for individual samples (2002-2014)

Averaging the growing season TSI values for each year (2002-2014) results in overall TSI values of 68 for Secchi depth, 68 for chlorophyll-a, and 78 for phosphorus. The water clarity trend is negative, with increasing TSI values for TP, and Secchi depth, and not improving for chl-a (Figure 3-3). Averaging growing season TSI values from data used in the 2014 Water Quality Assessment (2008-2012) results in TSI values of 70 for Secchi depth, 68 for chlorophyll-a, and 75 for TP.

Subsequent analyses show the link between the three indices of in-lake water quality. Figure 3-4 shows the relationship between TP and Secchi depth TSI values. Figure 3-5 shows the relationship between chlorophyll-a and total phosphorus. Figure 3-6 shows the relationship between Secchi depth and total phosphorus. The R^2 values between the various TSI indices are summarized in Table 3-1 below. There is a relatively strong, positive correlation (R^2=0.42) between Secchi depth TSI and chl-a TSI, with weaker correlations between TP TSI and Secchi depth TSI (0.22) or chl-a TSI (0.08). However,

this may be due to exceedingly high levels of TP in the water column. At such high concentrations of TP, the relationships start to break down because of the limits of productivity and turbidity. This justifies phosphorus reductions, but also indicates that very large reductions will be required to improve chlorophyll-a and Secchi depth TSI values in Avenue of the Saints Lake.

Analysis of total nitrogen compared to Secchi, chl-a, and total phosphorus TSI values in Table 3-2 show that total nitrogen is most closely related to total phosphorus and least related to chl-a. R^2 values for these relationships are 0.419 and 0.060, respectively. This shows that while phosphorus levels remain high, reductions in total nitrogen may not produce satisfactory reductions in chl-a values and related algal issues. This also shows that phosphorus reductions should be prioritized over total nitrogen reductions when planning and implementing best management practices.

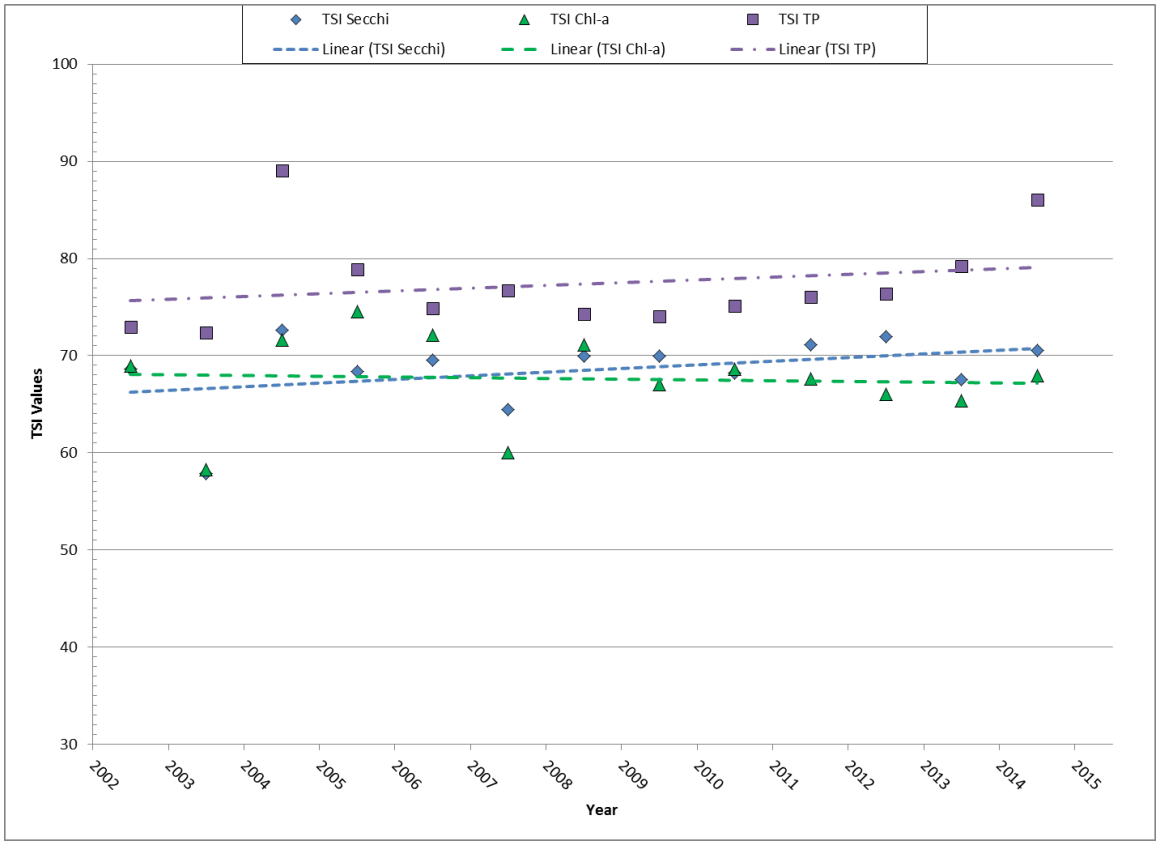

Figure 3-3. Growing season mean TSI values (2002-2014)

Table 3-1. TSI annual mean values and R^2 values when compared linearly

TSI indicator	Total Phosphorus	Chlorophyll-a
Secchi depth	0.215	0.420
Chlorophyll-a	0.076	---

Table 3-2. TSI annual mean values with R^2 values compared to Total Nitrogen

TSI indicator	Total Nitrogen
Secchi depth	0.202
Chlorophyll-a	0.060
Total Phosphorus	0.419

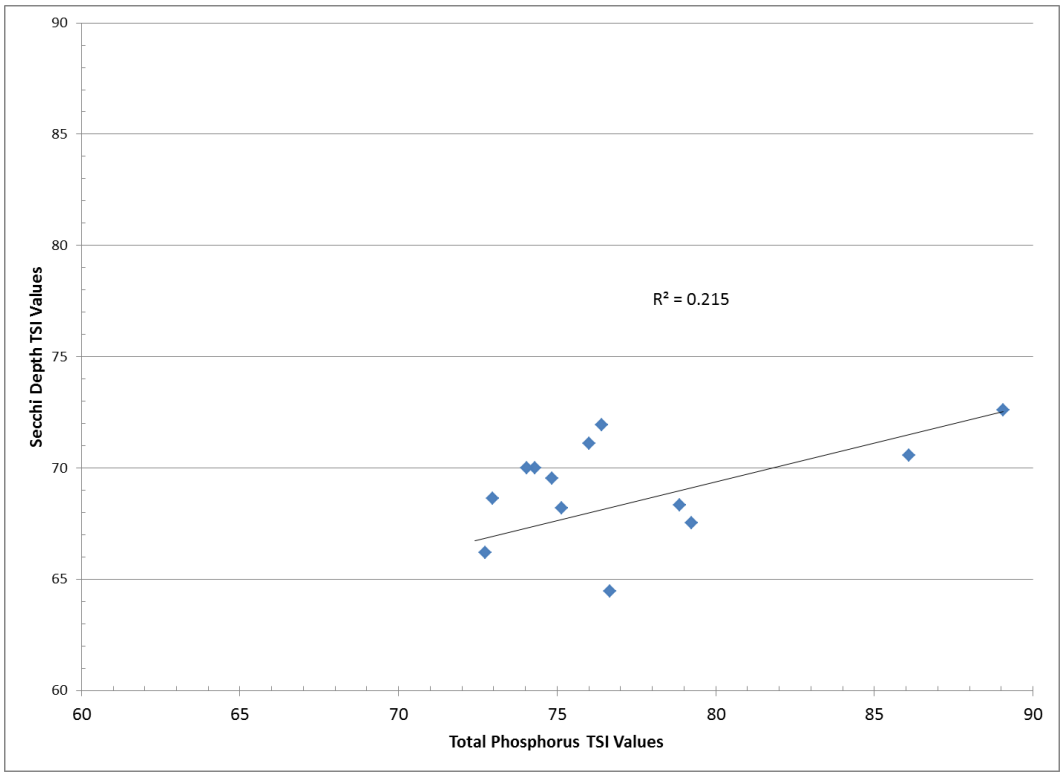

Figure 3-4. Annual mean TSI values for total phosphorus and Secchi depth

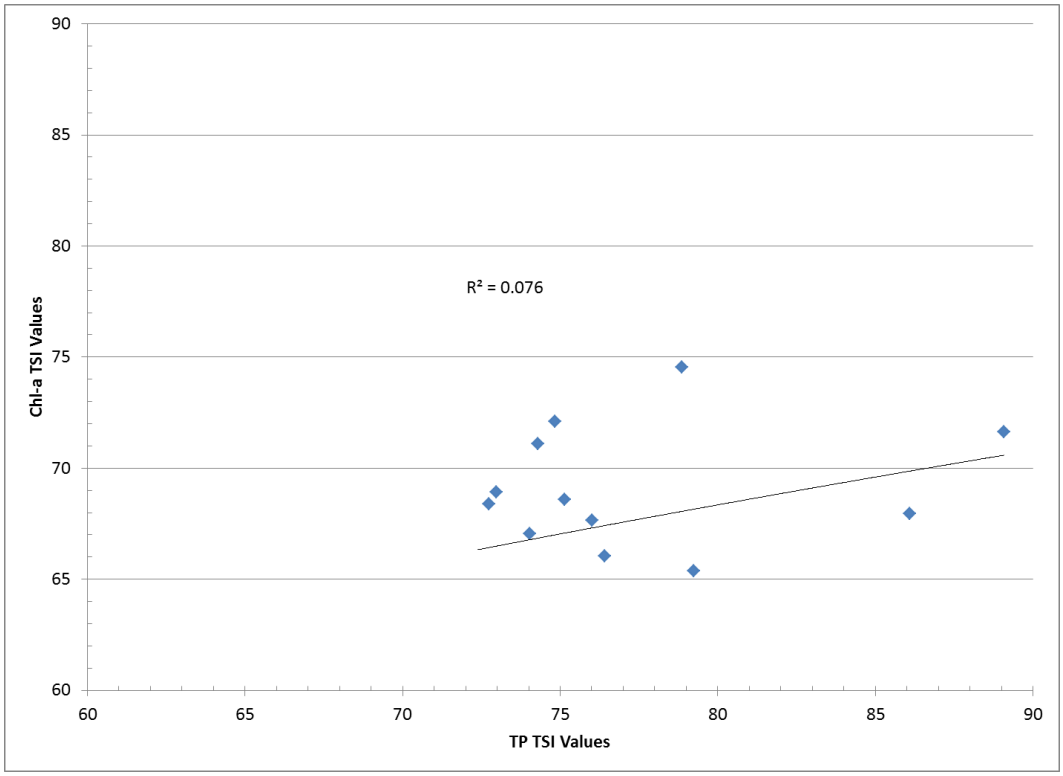

Figure 3-5. Annual mean TSI values for total phosphorus and chlorophyll-a

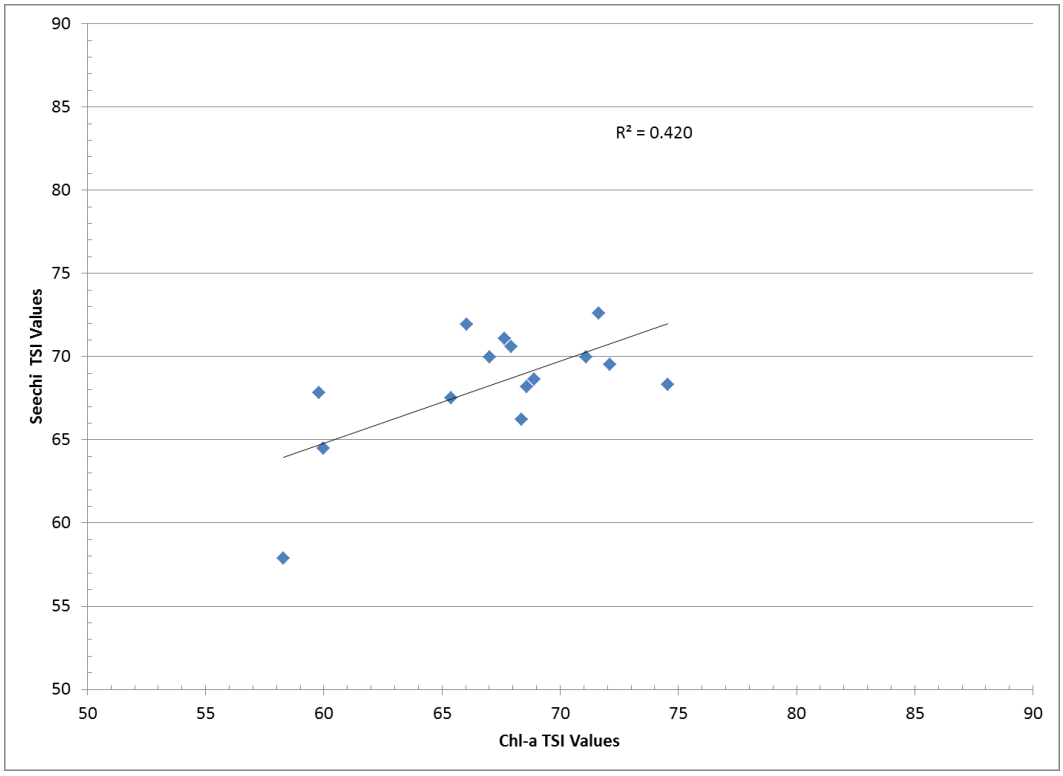

Figure 3-6. Annual mean TSI values for chlorophyll-a and Secchi depth

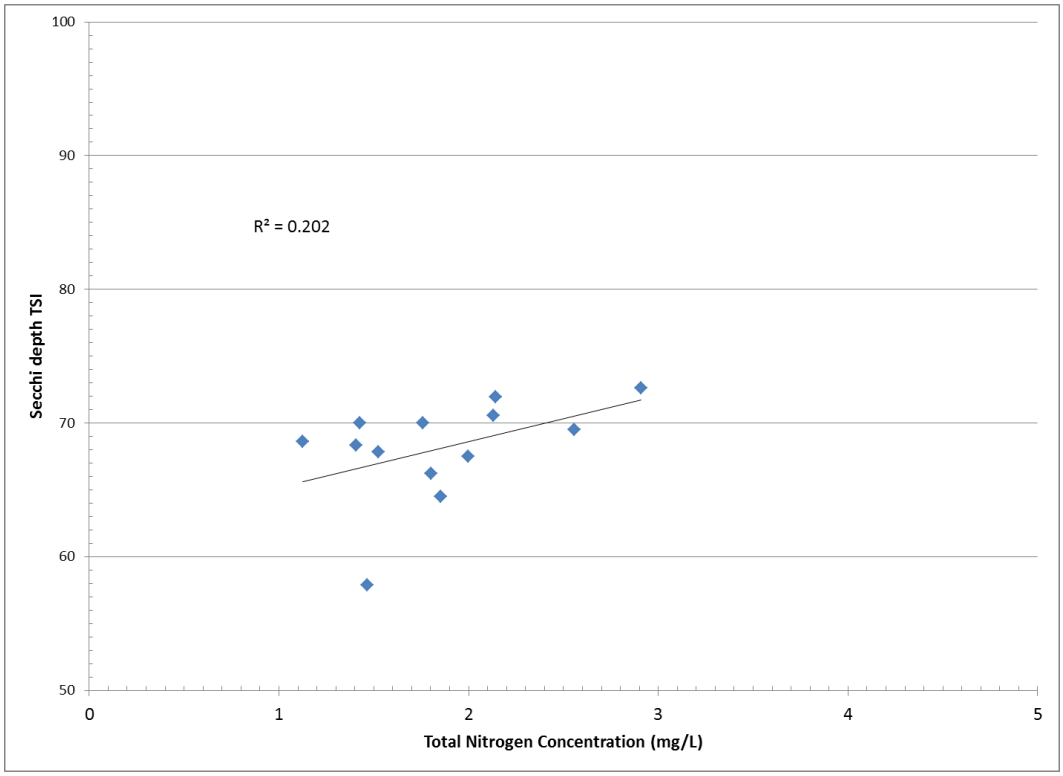

Figure 3-7. Total nitrogen concentration and Secchi depth TSI

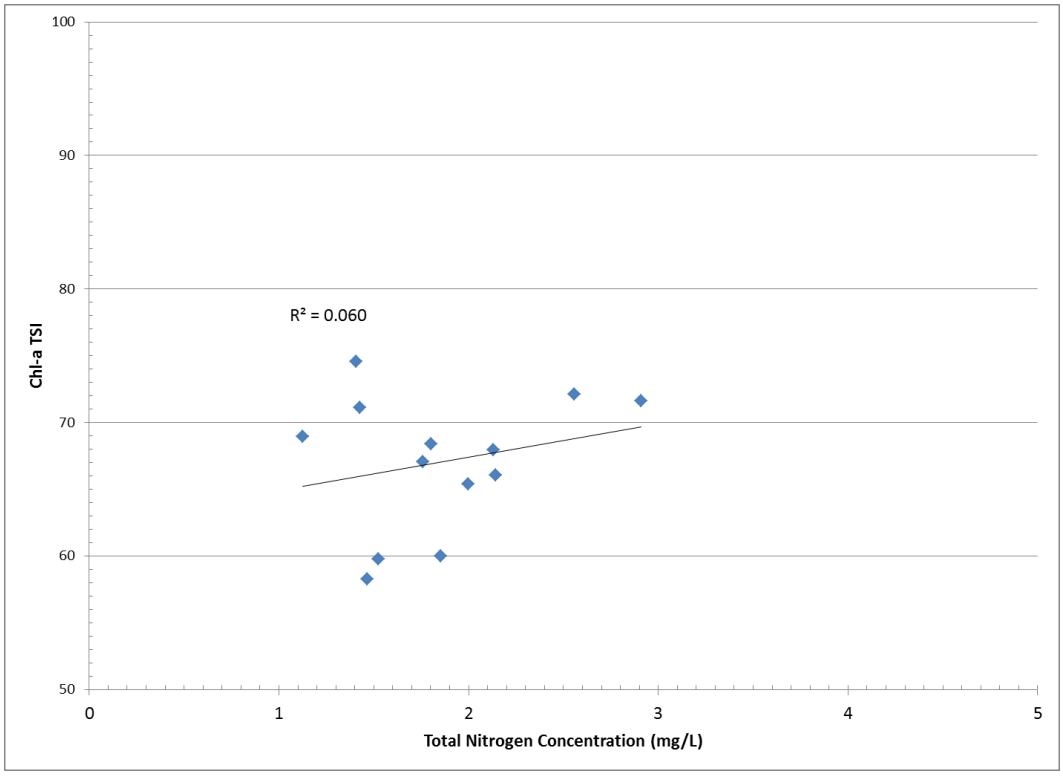

Figure 3-8. Total nitrogen concentration and chl-a TSI value

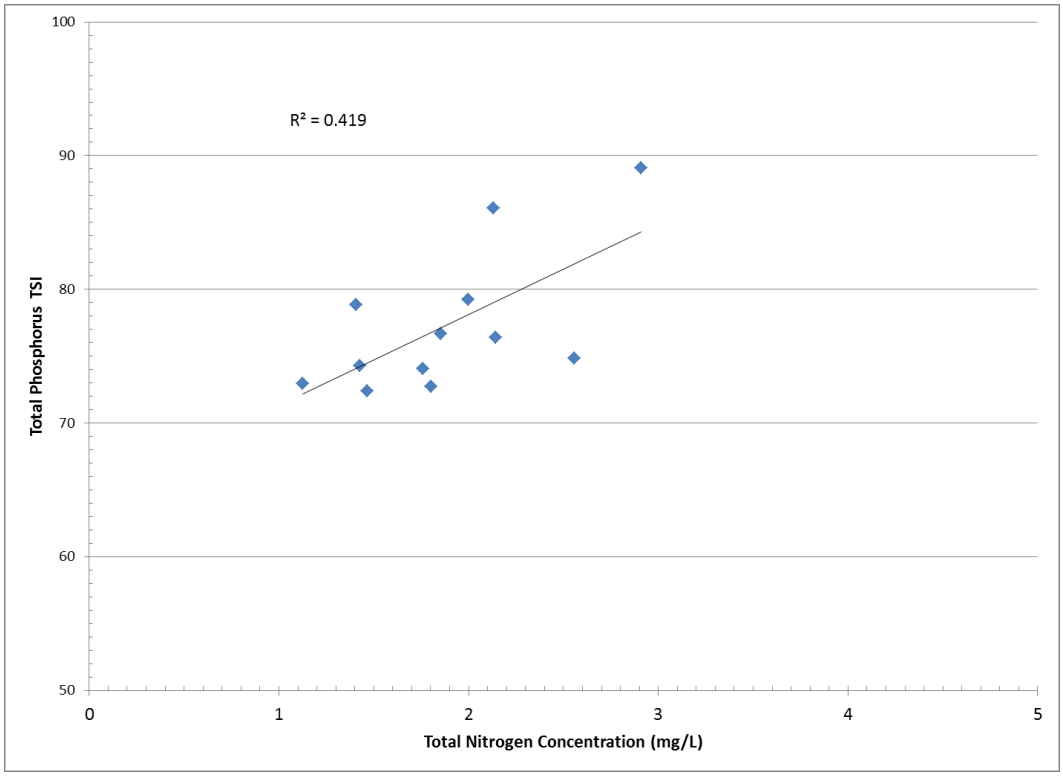

Figure 3-9. Total nitrogen concentration and TP TSI value

Figures 3-10 and 3-11 can be utilized to interpret differences (deviations) between Carlson's TSI values for TP, Secchi depth, and chlorophyll-a. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the TSI values for the three parameters are the same, the relationships between the three are strong. If the TP TSI values are higher than chlorophyll TSI, it suggests there are limitations to algal growth besides phosphorus. If the deviation between the chlorophyll-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis.

A significant majority (45 of 54 samples) of Chlorophyll-a and TP TSI deviations lie below the x-axis in Figure 3-7, which indicates high levels of phosphorus in the lake relative to algal productivity. In addition, the lack of samples in upper left quadrant, indicating low levels of finely suspended particles and the low number of samples in upper right quadrant (8 of 54 samples) show that excess phosphorus causing algal blooms may be causing turbidity issues as well.

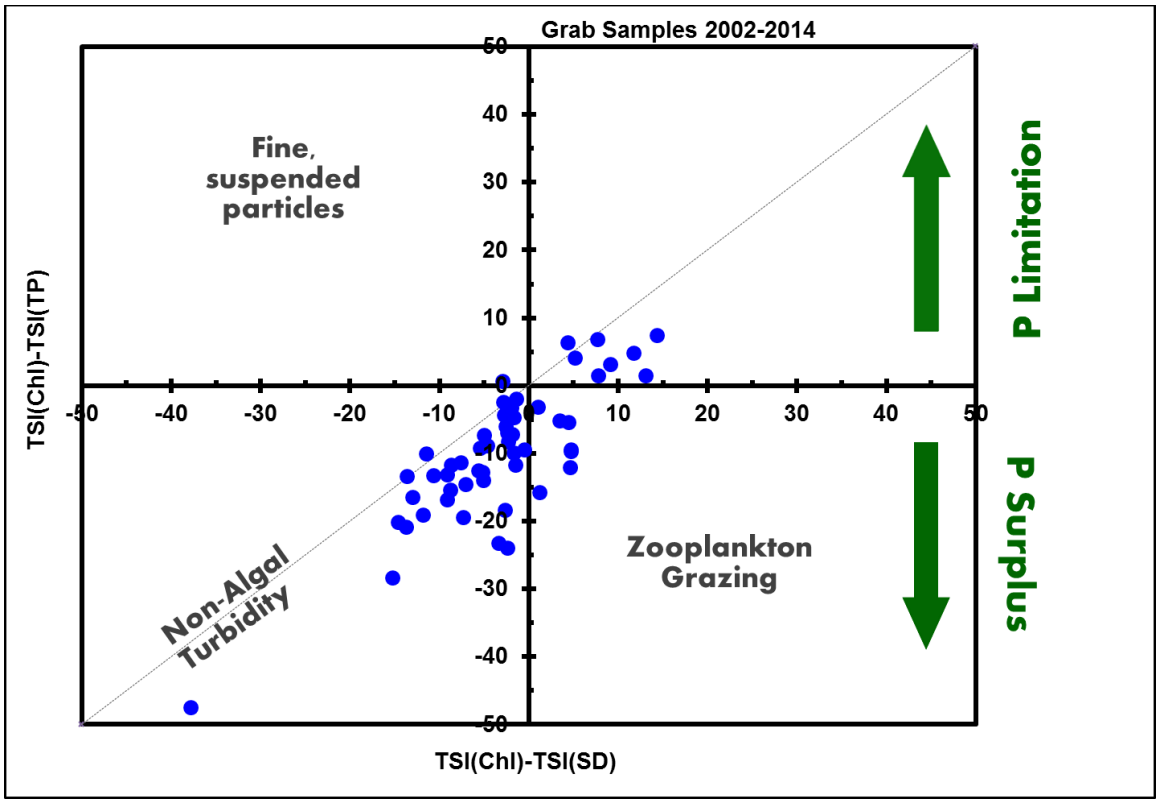

Figure 3-10. Phosphorus TSI deviations (2002-2014 grab samples)

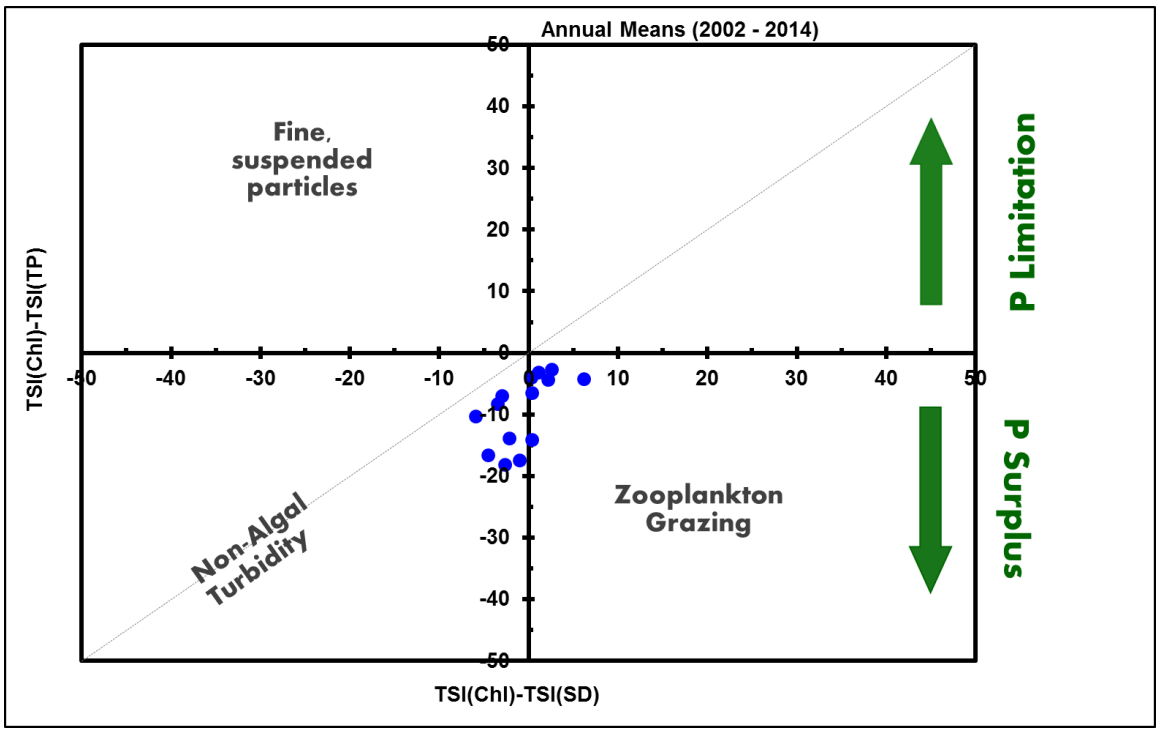

Figure 3-11. Phosphorus TSI deviations (2002-2014 annual averages)

Neither Secchi depth, chlorophyll-a, nor TP annual average TSI values show any correlation to annual or growing season precipitation (Figures 3-12, 3-13, 3-14). This analysis reveals that high Secchi depth, chlorophyll-a, and TP levels are observed in both wet and dry years, and that both conditions must be considered when developing the TMDL.

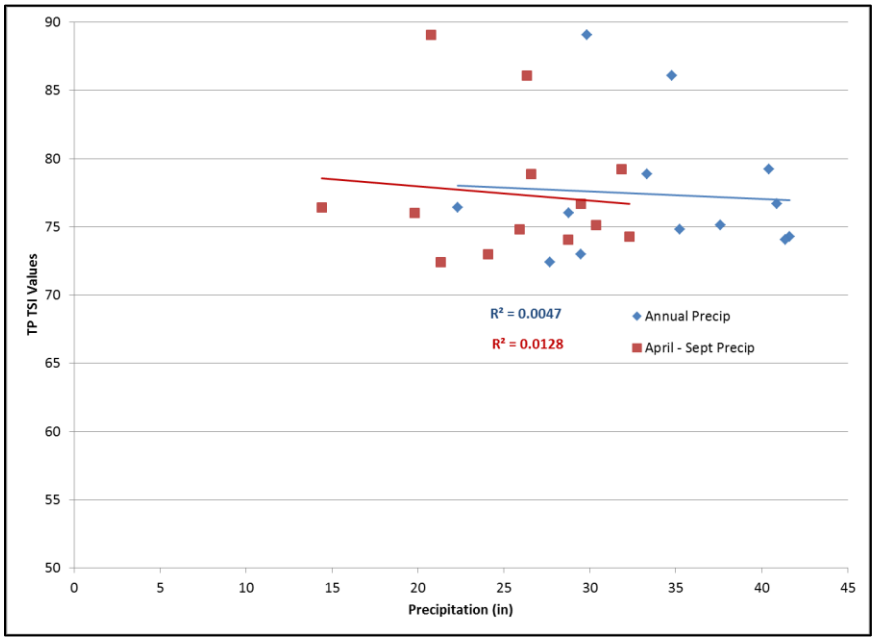

Figure 3-12. TP TSI values plotted against annual and growing season precip

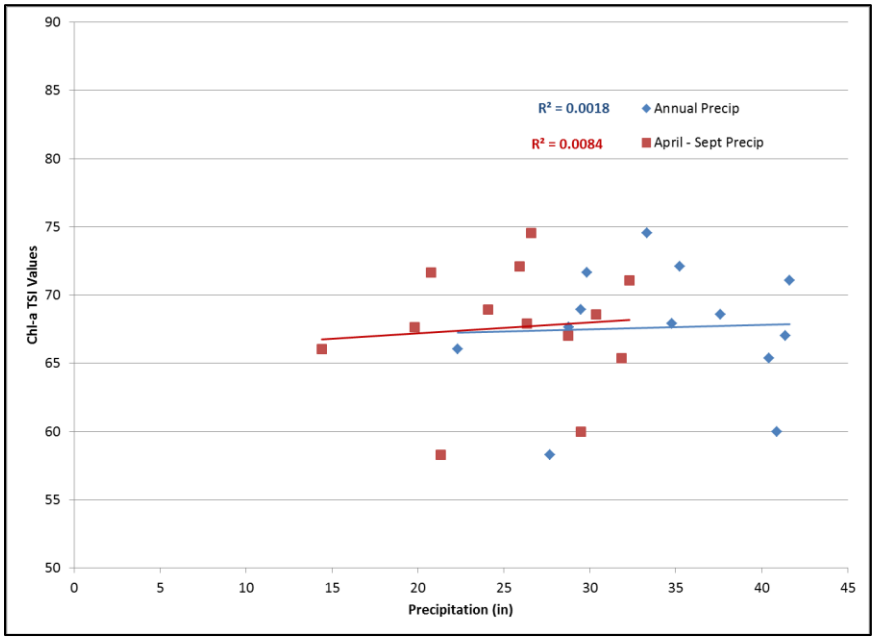

Figure 3-13. Chl-a TSI values plotted against annual and growing season precip

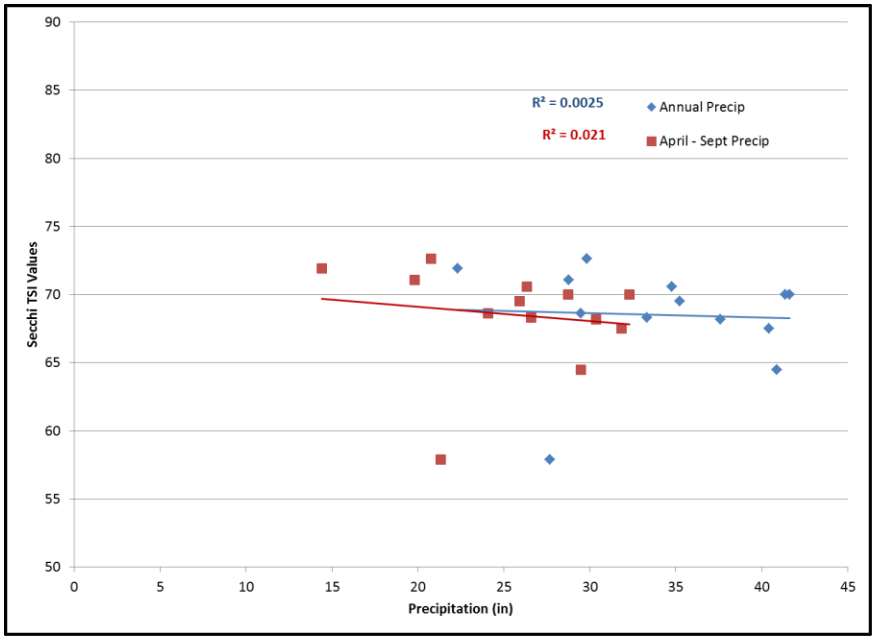

Figure 3-14. Secchi depth TSI values plotted against annual and growing season precip

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

The overall TN:TP ratio in water quality samples from Avenue of the Saints Lake, using average growing season mean concentrations from 2002-2014, is 12.8. 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.

Analysis of the TN:TP ratio in Avenue of the Saints samples reveals that the lake is P-limited 12.5 percent of the time and co-limited 47.5 percent of the time. Table 3-2 lists the mean TSI score for each nutrient limiting condition. The high total phosphorus TSI for N-limiting conditions seems to indicate an oversupply of phosphorus, rather than a limiting quantity of nitrogen. The applicability of the N-limiting concept is questionable at such high eutrophic states, where often light, temperature, or biological constraints on algal growth limit even higher states of productivity. Although a recent study recommends dual control of both N and P to limit eutrophication (Paerl et al., 2016), other studies indicate that phosphorus-only control is more effective and pushing lakes

towards N-limiting conditions (by N reductions) can actually increase the prevalence of nitrogen fixing cyanobacteria (Schindler et al., 2016).

Table 3-2. TN:TP ratio summary in Avenue of the Saints Lake

Samples Collected	# of Samples	N-limited (< 10)	Co-Limited (10-17)	P-limited (>17)
All samples 2002-2014	40	16 (40.0%)	19 (47.5%)	5 (12.5%)
Samples with Chl-a TSI > 65	19	11 (57.9%)	5 (26.3%)	3 (15.8%)
Samples with Secchi TSI > 65	33	14 (42.4%)	16 (48.5%)	3 (9.1%)

When the chl-a TSI exceeds 65, the lake is either P-limited or co-limited 42.1 percent of the time. When the Secchi depth TSI exceeds 65, the lake is either P-limited or co-limited 57.6 percent of the time. Further, the BATHTUB model that predicts chl-a levels is independent of nitrogen concentrations. These lines of evidence suggest that water quality improvement of algal blooms and turbidity via TP reduction is most feasible. Thus, the Avenue of the Saints Lake TMDL targets phosphorus reductions. If phosphorus reductions are not accompanied by reductions in algal blooms, then future reductions in nitrogen may prove necessary to reduce algae to an acceptable level.

The pH values for the assessment period are shown in Figure 3-15. 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.

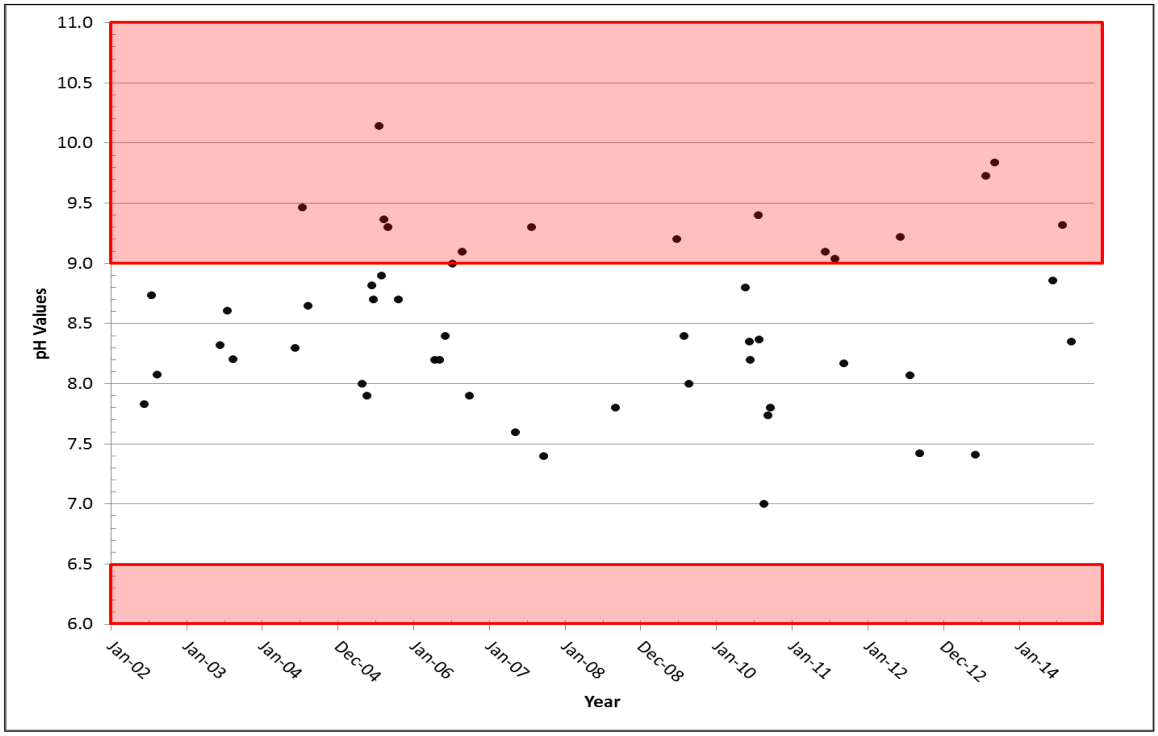

Figure 3-15. pH values during the assessment period

The main cause of pH fluctuations in Avenue of the Saints Lake is primary production by photosynthetic biomass. Figure 3-16 reveals moderate, positive correlation (R^2=0.239) between chl-a and pH over the assessment period of 2002-2014, 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 Avenue of the Saints Lake, and the first step towards reduced algal blooms requires phosphorus load reductions.

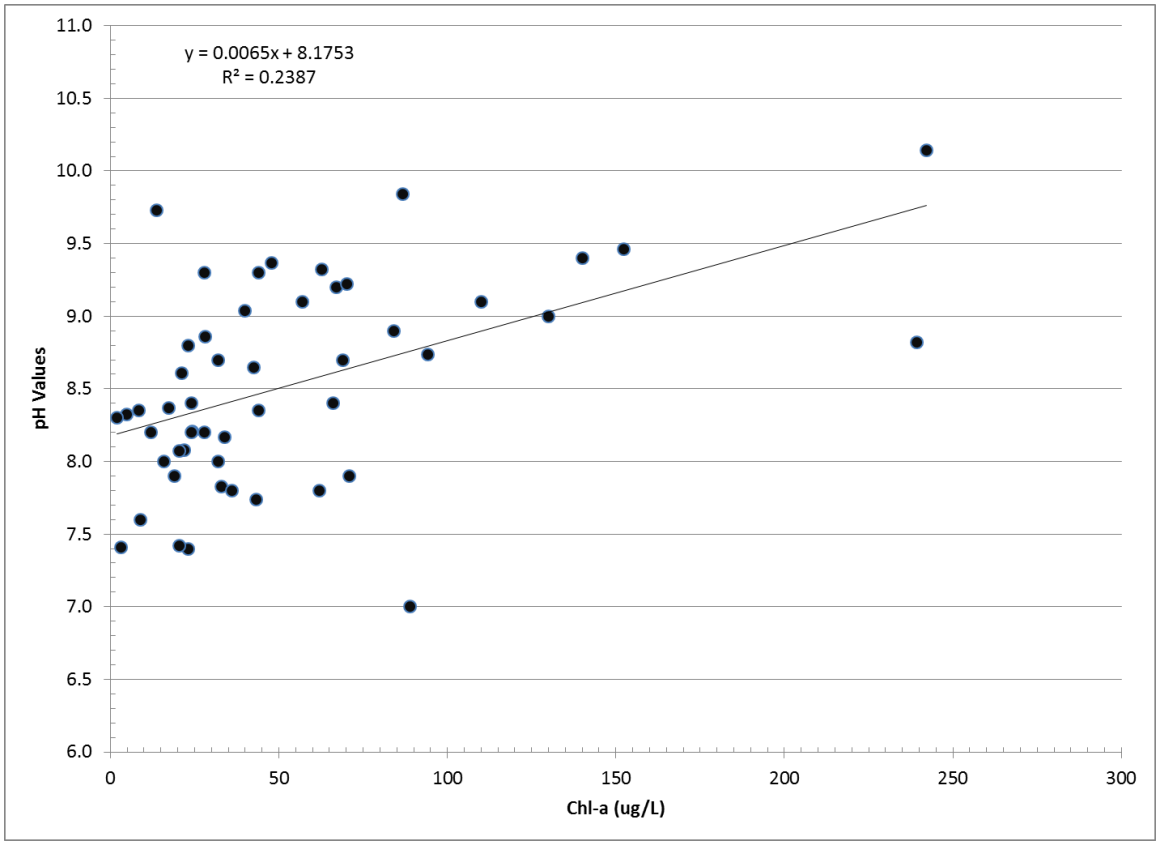

Figure 3-16. pH and Chl-a concentrations from 2002-2014

3.2. TMDL Target

General description of the pollutant

The 2014 305(b) assessment attributes poor water quality in Avenue of the Saints Lake to excess algae, turbidity, and pH fluctuations that exceed allowable levels (i.e., 9.0). The data interpretation described in Section 3.1 indicates phosphorus load reduction will best address the impairment. It will be important to continue to assess TSI values for chlorophyll-a and Secchi depth as phosphorus reduction practices are implemented. If phosphorus reductions are not accompanied by reductions in algal blooms and turbidity levels, 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 associated pH fluctuations. Additionally, reductions in nitrogen that

result in nitrogen limitation may 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 3-3 reports the simulated chlorophyll-a, TP, Secchi depth, and observed pH value at the ambient monitoring location for both existing and target conditions. In-lake water quality was simulated using the BATHTUB model, which is described in more detail in Appendix E. The chlorophyll-a TSI target of 63 complies with the narrative "free from aesthetically objectionable conditions" criterion. The Secchi depth target of 63 complies with turbidity impairment.

The pH target was calculated using the linear regression equation in Figure 3-16 to determine what value of pH corresponds with the TMDL target chl-a TSI value of 63. Then observed pH values at or below this chl-a value were compared to the pH water quality standard to determine if they met the Iowa DNR's assessment methodology of less than significantly greater than 10 percent of pH values outside 6.5 to 9.0. Of the pH values corresponding to observed chl-a values below the water quality target, only 1 out of 22 samples were outside the acceptable pH range. This satisfies the assessment methodology, which would show pH values are at acceptable values when the chl-a target is met.

Meeting these targets for two consecutive assessment periods will result in delisting Avenue of the Saints if attained in two consecutive 303(d) listing cycles. The TP values in Table 3-3 represent predicted in-lake water quality resulting from the required TP load reductions.

Table 3-3. Existing and target water quality (ambient monitoring location)

Parameter	[1]2008-2012 Mean	[2]2002-2014 Mean	[2]TMDL Target
Secchi Depth	0.5 m	0.6 m	0.8 m
TSI (Secchi Depth)	70	68	63
Chlorophyll-a	46.4 μg/L	47.7 μg/L	27.1 μg/L
TSI (Chlorophyll-a)	68	69	63
TP	138.5 μg/L	171.8 μg/L	50.1 μg/L
TSI (TP)	75	78	61
[3]pH avg	8.3	8.5	6.5 – 9.0
pH violations / total (%)	5/18 (28 %)	17/57 (29 %)	*

[1]303(d) assessment period
[2]Modeling period for existing conditions and TMDL target
[3]pH values not explicitly calculated by BATHTUB
*Less than significantly greater than 10% of pH values outside of accepted pH range

Selection of environmental conditions

The critical period for poor water clarity 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. Therefore, both existing and allowable TP loads to Avenue of the

Saints 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, a Secchi depth TSI target of 63 using analysis of existing water quality data and Carlson's trophic state index methodology, and a pH target consistent with WQS. 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 water quality data collected by ISU and SHL from 2002 through 2014. 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 Best Management Practices (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 (internal load and inflow concentrations) in the calibrated BATHTUB model until the target chlorophyll-a and Secchi depth TSIs no greater than 63 were attained for the lake segment in which ambient monitoring data is collected. The load response curve from the BATHTUB model output is illustrated in Figure 3-17. The annual loading capacity of Avenue of the Saints Lake is set at 437 kg/yr (959 lbs/yr).

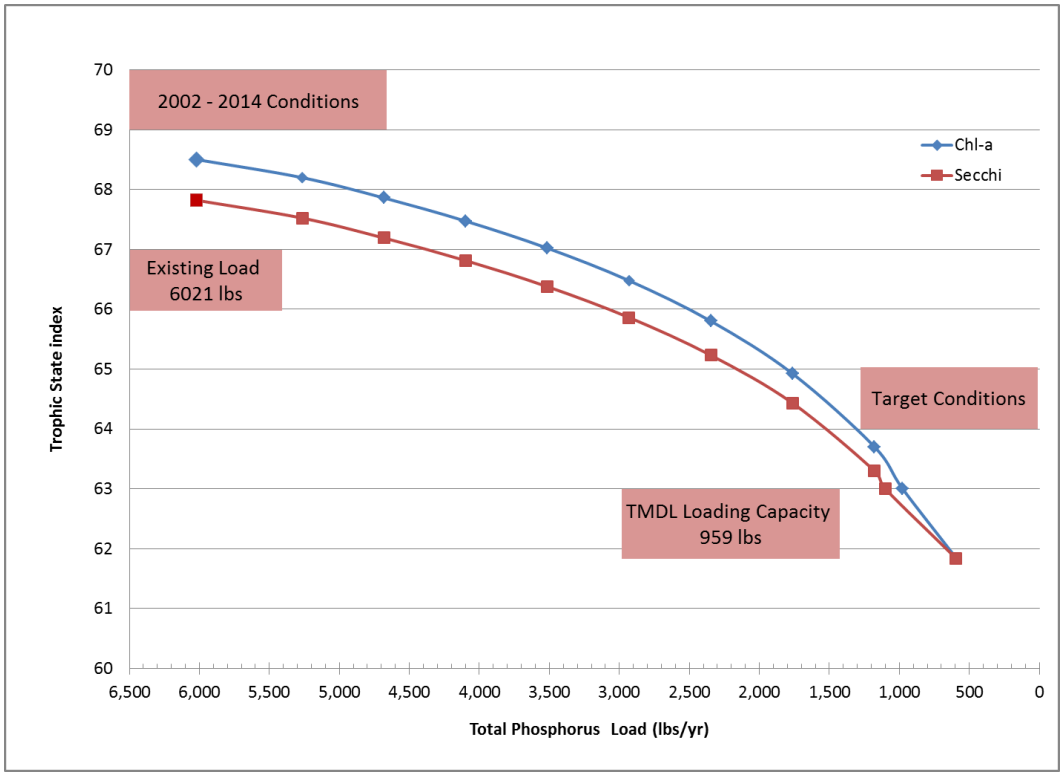

Figure 3-17. Simulated load response of chlorophyll-a and Secchi TSI values to reductions in TP load.

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 include a daily time increment. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards…"*

As recommended by EPA, the loading capacity of Avenue of the Saints Lake for TP is expressed as a daily maximum load, in addition to the annual loading capacity of 959 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., seasonal) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs*

(EPA, 2007), that 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 959 lbs/yr is equivalent to an average daily load of 2.6 pounds per day (lbs/day) and a maximum daily load of 8.2 lbs/day.

Decision criteria for WQS attainment
The narrative criteria in the water quality standards require that Avenue of the Saints Lake support aquatic life for game and non-game fish. The metrics for WQS attainment for de-listing the impairments are a chlorophyll-a TSI and Secchi depth TSI of 63 or less in two consecutive 303(d) listing cycles, 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 Iowa DNR methodology.

Compliance point for WQS attainment
The TSI target for listing and delisting of Avenue of the Saints Lake is measured at the ambient monitoring location shown in Figure 3-1. For modeling purposes, the lake was divided into multiple segments (see Figure E-2 of Appendix E). To maintain consistency with other Clean Water Act programs implemented by the Iowa 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 Avenue of the Saints Lake.

3.3. Pollution Source Assessment

Existing load
Average annual simulations of hydrology and pollutant loading were developed using the STEPL model (Version 4.1). STEPL was developed by Tetra Tech, for the US EPA Office of 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 2002 and 2014, the annual TP load to Avenue of the Saints Lake was estimated to be 6,021 lbs/yr. The simulation period (for existing conditions) includes assessment period (for the 2014 Integrated Report) as well as prior and subsequent years where monitoring data was available.

Departure from load capacity
The TP loading capacity for Avenue of the Saints is 959 lbs/yr and 8.2 lbs/day (maximum daily load). To meet the target loads, an overall reduction of 86 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 Avenue of the Saints Lake is entirely from nonpoint sources of pollution. Table 3-4 reports estimated annual average TP loads to the lake from all known

sources, based on the STEPL simulation of average annual conditions from 2002-2014. The predominant sources of phosphorus to Avenue of the Saints Lake include erosion from land in row crop production and internal recycling. Row crops in various rotations comprise over 80 percent of the land area of the watershed (Table 2-3), and 30.5 percent of the phosphorus load to the lake (Figure 3-18 and Table 3-4). Other contributing sources of phosphorus include groundwater / tile discharge (6.7 percent), developed areas such as roads, residential, and other urban areas (11.4 percent); erosion and runoff from grazed and non-grazed grassland (0.4 percent); and septic systems in the watershed (0.4 percent).

Internal recycling of phosphorus in the lake was included in the nutrient analysis of Avenue of the Saints Lake contributing 50.4 percent of the total phosphorus in the system. 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. Although there is evidence of an elevated flushing rate in the model, the characteristics of the outlet structure, lake morphology, downstream topography, and evaporation rate contribute to the significance of internal loading in Avenue of the Saints Lake. 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 lake 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.

Allowance for increases in pollutant loads

There is no allowance for increased phosphorus loading included as part of this TMDL. A majority of the watershed is in agricultural row crop production, and is likely to remain in cropland in the future. Any future residential or urban development may contribute similar sediment loading rates and therefore will not increase phosphorus to the lake system. Avenue of the Saints Recreation Area, which circumscribes the lake, is unlikely to undergo significant land use changes. 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.

Table 3-4. Average annual TP loads from each source (2002-2014)

Source	Descriptions and Assumptions	TP Load (lb/yr)	Percent (%)
Row Crops	Sheet and rill erosion from corn and soybeans dominated agriculture	1781.5	29.6
Internal Recycling	Phosphorus in lake sediment	3120.3	51.8
Urban	Urban areas, roads, and farmsteads	668.6	11.1
Groundwater	Agricultural tile discharge, natural groundwater flow	394.0	6.5
Septic Systems	Private wastewater systems, infiltration/inflow from deficient systems	23.7	0.4
Grassland	Grazed and non-grazed grassland, CRP	21.3	0.4
All others	Wildlife, atmospheric deposition	11.4	0.2
Total		**6020.8**	**100**

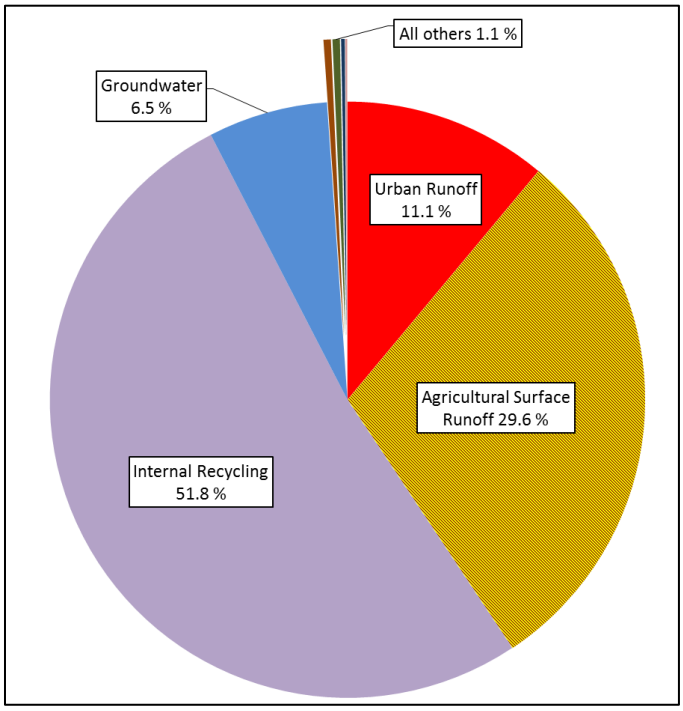

Figure 3-18. Relative TP loads by source

3.4. Pollutant Allocation

Wasteload allocation
There are no permitted point source dischargers of phosphorus in the Avenue of the Saints Lake watershed.

Load allocation
Nonpoint sources of phosphorus to Avenue of the Saints Lake include erosion from land in row crop production, erosion from grasslands, erosion from timber / wooded areas,

transport from developed areas (roads, residences, etc.), wildlife defecation, and atmospheric deposition (from dust and rain), and significant 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, also contributed phosphorus to the lake during the assessment period. In addition to watershed nonpoint sources, internal lake recycling has an impact on water quality when sediment becomes resuspended due to natural lake actions. Changes in agricultural land management, implementation of structural best management practices (BMPs), repair or replacement of failing septic systems, and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Avenue of the Saints Lake. Based on the inventory of sources, management and structural practices targeting surface runoff and internal recycling contributions of phosphorus offer the largest potential reductions in TP loads.

Table 3-5 shows an example load allocation scenario for the Avenue of the Saints Lake watershed that meets the overall TMDL phosphorus target. The LA is 863 lbs/year, with a maximum daily LA of 9.5 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 3-5 are not required, but provide one of many possible combinations of reductions that would achieve water quality goals.

Table 3-5. Example load allocation scheme to meet target TP load

TP Source	Existing Load (lb/year)	LA (lb/year)	NPS Reduction (%)
Row Crops	1781.5	146	92
Internal Recycling	3120.3	283	91
Urban	668.6	25	96
Groundwater / Tile Discharge	394.0	394	0
Septic Systems	23.7	2	92
Grassland	21.3	2	91
[1]All others	11.4	11.4	0
Total	**6020.8**	**863**	**86%**

[1]Atmospheric contributions, direct lake contributions by waterfowl

Margin of safety
To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An explicit MOS of 10 percent (96 lbs/year, 1.1 lbs/day) was utilized in the development of this TMDL. These uncertainties may include seasonal changes in nutrient concentrations of influent to Avenue of the Saints Lake, changes in internal recycling that may be seasonal in nature, and / or maintenance and efficiency of existing BMPs.

Reasonable Assurance
Under current EPA guidance, when a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurance that nonpoint

source control measures will achieve expected load reductions. There are no permitted or regulated point source discharges contributing phosphorus to Avenue of the Saints Lake and the WLA is zero, therefore reasonable assurance of point source reductions is not applicable. Reasonable assurance for reduction of nonpoint sources is provided by the list of potential best management practices 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.

3.5. TMDL Summary

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

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

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

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

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

TMDL = LC = Σ WLA (0 lbs-TP/year) + Σ LA (863 lbs-TP/year)
+ MOS (96 lbs-TP/year) = **959 lbs-TP/year**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (7.4 lbs-TP/day)
+ MOS (0.8 lbs-TP/day) = **8.2 lbs-TP/day**

4. Implementation Planning

This implementation plan is not a requirement of the Federal Clean Water Act. However, 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). Therefore, this implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) discussed are potential tools that will help achieve water quality goals if appropriately utilized. It is possible that only a portion of BMPs included in this plan will be feasible for implementation in the Avenue of the Saints 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 Avenue of the Saints 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. Previous Watershed Planning and Implementation

Since the development of the Avenue of the Saints Lake in the 2000's coincident with the construction of the Avenue of the Saints roadway, agricultural producers have adopted terraces, grassed waterways, riparian corridors and more recently and conservation tillage practices. These practices help prevent and mitigate soil loss from the landscape, which can in turn decrease nutrient and pollutant loading to the lake system. Extensive use of these practices can be found throughout the watershed.

4.2. Future Planning and Implementation

General Approach
Future watershed management and BMP implementation efforts in the Avenue of the Saints Lake watershed should utilize a phased approach. Given the watershed-to-lake ratio and the morphology of this lake system, attainment of existing water quality standards may take considerable time to see improvement in the watershed. Efforts should be targeted to maximize benefits and minimize costs. Emphasis should be placed on non-structural water quality practices that increase infiltration (thereby reducing runoff and erosion), keep the soil covered with vegetation, and maximize water uptake by perennial non-agricultural plant species. Upon successful implementation of watershed alternatives, substantial water quality improvement may be greatly facilitated by in-lake practices such as dredging and fish renovation.

Projects with multiple benefits (e.g., wildlife habitat, soil conservation, and water quality) may do more to protect and preserve the use of Avenue of the Saints Lake for future generations than those focused solely on water quality. Additional funding avenues include, but are not limited to state and federal funding opportunities, which may help facilitate multiple-objective projects.

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. Sustained improvement may be a more appropriate short term goal than impairment delisting.

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, or 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 to secure additional funding from available sources. A path to full attainment of water quality standards 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.

4.3. Best Management Practices

No stand-alone BMP will be able to sufficiently reduce phosphorus loads to Avenue of the Saints Lake. Rather, a comprehensive package of BMPs will be required to reduce sediment and phosphorus transport to the lake. The majority of phosphorus enters the lake via nutrient loss from agricultural fields through sheet / rill erosion and internal recycling in the lake. 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, turbidity issues, and pH fluctuations caused primarily by external and internal phosphorus loads. 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.

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 Avenue of the Saints 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 4-2, which includes secondary benefits and potential TP reductions.

Table 4-1. Potential land management BMPs (prevention strategies)

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

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

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. There are at least three general criteria that should be considered when designing sediment control basins. First, the area of the basin should be appropriately sized relative to the size of the drainage area. Effective sediment control basins require a minimum size of at least one percent of the total drainage area to the basin. Second, drawdown times (i.e., the time it takes for runoff from a storm event to drain from the basin) should be no less than 24 hours, and preferably 40 hours. Shorter drawdown periods do not adequately settle fine sediments, which carry a large portion of attached phosphorus that can influence algal blooms, turbidity, and pH fluctuations. Third, sediment basins should be shaped such that the length to width ratio is maximized to prevent short-circuiting across the shortest flow-path through the basin. A minimum length to width ratio of 3:1 is commonly cited in the literature.

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, steep slopes; proximity to waterbodies; tillage practices, and method, timing, and amount of manure and commercial fertilizer application.

Table 4-2. Potential structural BMPs (mitigation strategies)

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

[1]Adopted from Dinnes (2004) with professional judgment. 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

The Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was used in TMDL development to predict phosphorus loads to Avenue of the Saints Lake. Figure 4-1 shows the annual phosphorus export from each subbasin in the Avenue of the Saints Lake watershed STEPL model. Red-shaded basins indicate the heaviest phosphorus export and green shaded bars indicate the lowest export rates relative to the sub basins in this study. The figures reveal that more phosphorus is annually exported from Subbasins 2, 3 and 5 (718.3 lbs, 718.6 lbs, 655.9 lbs, respectively). Subbasin 1 has the lowest TP export at 361.9 lbs. Figure 4-2 shows TP losses for each subbasin after adjusting for drainage area. On a per-area basis, all sub basins have very similar export rates between 0.65 and 0.72 pounds per acre per year (lbs/ac/yr).

Subbasin-level information indicates that best management practices reducing phosphorus export should concentrate on upstream sub basins with higher levels of total phosphorus transport.

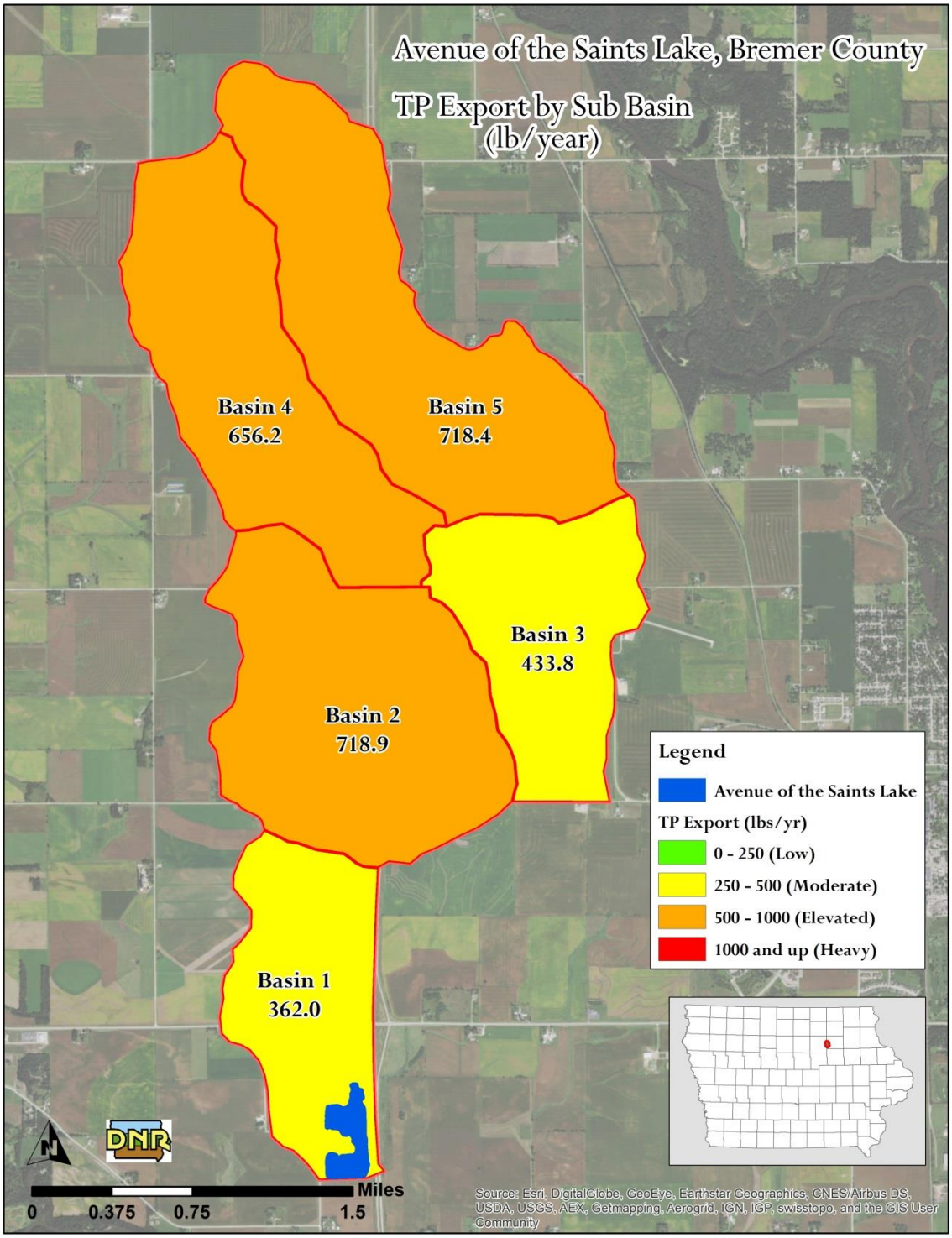

Figure 4-1. Predicted TP export from each STEPL subwatershed

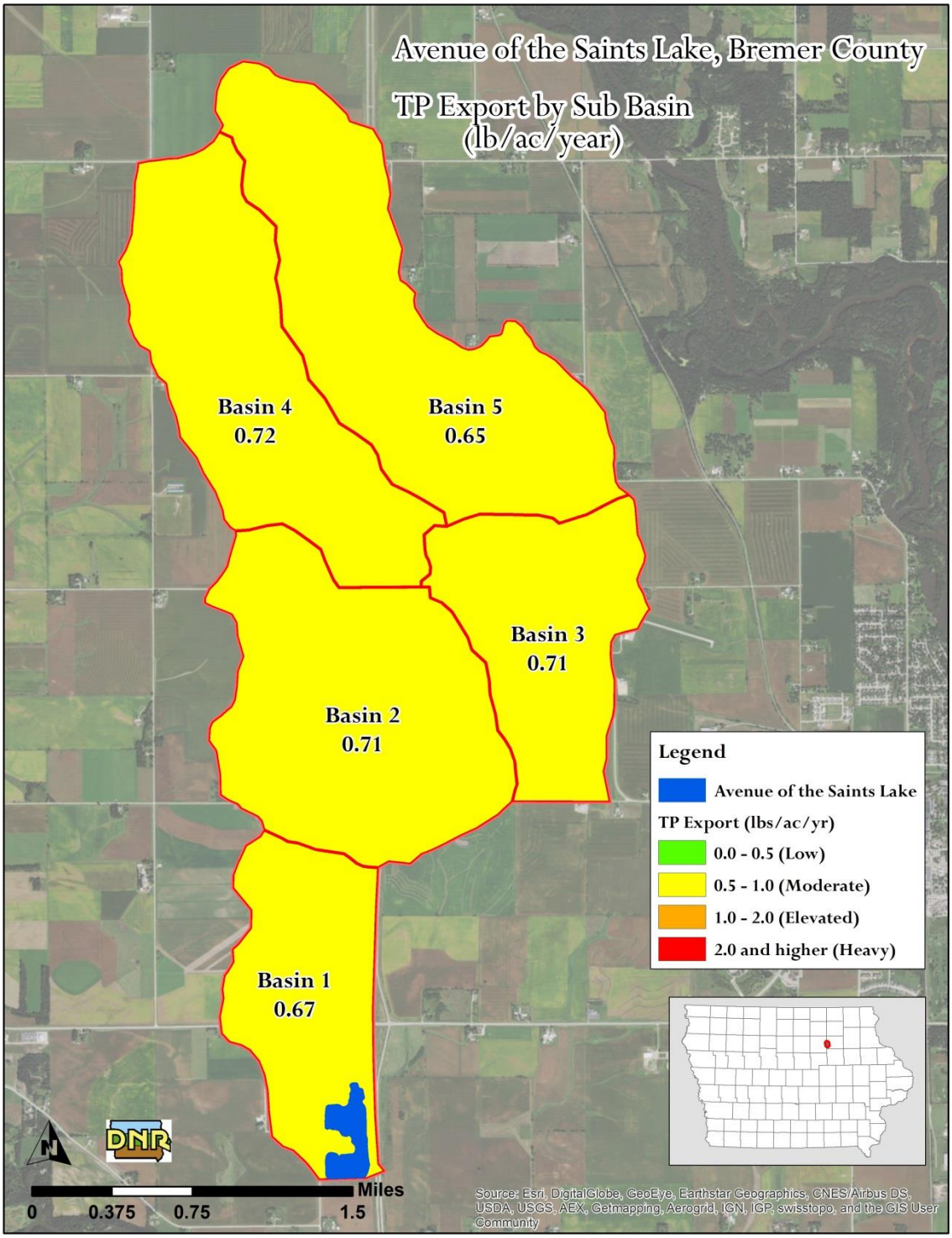

Figure 4-2. Predicted per-acre TP loss for each STEPL subwatershed

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

In-Lake BMPs (Remediation Strategies)
Internal loading may influence in-lake water quality under certain conditions despite its watershed-to-lake ratio and flushing rate (26 days). The average annual contribution of TP to the system from internal loading is estimated as half the amount of total phosphorus entering the water column. Internal loads may aggravate algal blooms, leading to pH fluctuations and turbidity issues in late summer periods, especially if lake outflow ceases and water temperatures exceed normal levels. External phosphorus loads from the watershed supply continue the build-up of phosphorus in the bottom sediments. 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. Once existing watershed practices have been renovated and new practices have been implemented, a final phase of in-lake BMP implementation can begin.

Brief descriptions of potential in-lake restoration methods are included in Table 4-3. Phosphorus reduction impacts of each alternative will vary and depend on a number of site-specific factors. It is virtually impossible to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict 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 4-3. 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 fisheries improvement. The reduction of in-lake phosphorus as a result of this practice is uncertain, but the overall health of the aquatic ecosystem may be improved, which typically improves overall water quality as well. Resident rough fish may be problem and could be controlled through this method.
Targeted dredging and sediment basin improvement	Targeted dredging in shallow inlet areas of the north pool would recreate pockets of deep-water habitat for predatory fish that would help control rough fish populations. Strategic dredging would also increase the sediment capacity of both pools, thereby reducing sediment and phosphorus loads to the larger, southern pool 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 Avenue of the Saints Lake watershed. These may include any of the practices from Table 4-3 at any scale. Existing grassed 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. Further adoption of agricultural prevention measures like those listed in Table 4-1 will retain topsoil in the soil profile of the fields and prevent erosion. Potential in-lake strategies such as dredging and phosphorus stabilization treatments in Avenue of the Saints Lake would be included in such an approach 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 best management practice (BMP) implementation and to document attainment of total maximum daily loads (TMDLs) and progress towards water quality standards (WQS).

Volunteer-based and / or locally-led 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/567.61.pdf

Failure to prepare an approved QAPP will prevent data collected from being used to evaluate waterbody in the 305(b) Integrated Report – the biannual assessment of water quality in the state, and the 303(d) list – the list that identifies impaired waterbodies. In addition to raising concerns about the accuracy of the data collected, sampling efforts lacking a QAPP cannot be utilized to delist the waterbody from the impaired waters list.

5.1. Routine Monitoring for Water Quality Assessment

Data collection in Avenue of the Saints Lake to assess water quality trends and compliance with water quality standards (WQS) will include monitoring conducted as part of the DNR Ambient Lake Monitoring Program. This is the same source of data used to develop the TMDL. The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 134 of Iowa's lakes are sampled as part of this program, including Avenue of the Saints Lake. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured.

Sampling parameters are reported in Table 5-1. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day. While the ambient monitoring program can be used to identify trends in long-term, in-lake water quality, it does not lend itself to evaluation of short-term water quality trends, 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) • Soluble Reactive Phosphorus (SRP) • Total Nitrogen (TN) • Total Kjeldahl Nitrogen (TKN) • Ammonia • Nitrate + Nitrite Nitrogen • Alkalinity • pH • Total Organic Carbon • Total Dissolved Solids • Dissolved Organic Carbon	• Secchi Depth • Temperature • Dissolved Oxygen (DO) • Turbidity • Total Suspended Solids (TSS) • Total Volatile Suspended Solids • Specific Conductivity • Thermocline Depth • Lake Depth	• Chlorophyll a • Phytoplankton (mass and composition) • Zooplankton (mass and composition)

5.2. Expanded Monitoring for Detailed Analysis

Data available from the Iowa 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. Locations for expanded monitoring in the Avenue of the Saints Lake watershed have been chosen to take into account sub basin boundaries and can be used in assigning nutrient concentrations to each sub basin if deployed in such a manner.

Table 5-2. Recommended monitoring plan

Parameter(s)	Intervals	Duration	[1]Location(s)
Routine grab sampling for flow, sediment, P, and N	Every 1-2 weeks	April through October	Ambient location plus secondary locations
Continuous flow	15-60 minute	April through October	Lake inlet & outlet
Continuous pH, DO, and temperature	15-60 minute	April through October	Ambient in-lake location
Runoff event flow, sediment, P, and N	15-60 minute intervals during runoff	5 events between April and October	Select tile and/or culvert discharge locations in areas of focused BMP implementation to evaluate efficacy
Event or continuous tile drain flow, N, and P sampling	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	Select 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 dredging operations, or near lake inlets

[1]Tributary, tile drain, and gully site selection to be based on suspected pollutant source location, BMP placement, landowner permission, and access/installation feasibility.

It may be useful to divide the recommended monitoring plan into several different plans 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 BMPs are renovated or implemented in the watershed to establish baseline conditions. Selection of tributary sites should consider location of BMPs, location of historical data (for comparative purposes), landowner permission (if applicable), and logistical concerns such as site access and feasibility of equipment installation (if necessary). This 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.

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, a secondary ambient location in the northern segment of Avenue of the Saints, 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 grassed waterways, riparian buffers, and wetlands.

Targeted Monitoring
If automated sampling devices cannot be procured, then grab samples should continue on a routine and runoff event based schedule. Flow data may be recorded by area-velocity measurements, or manual flow readings based on developed rating curves. Locations and sampling approaches would include the ambient monitoring station upstream inlets, and the main tile drainage ditch to the southeast.

Basic Monitoring
Targeted grab sampling of the Avenue of the Saints 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.

Current Monitoring
With no locally-led effort, only three grab samples would be collected at the ambient location of Avenue of the Saints Lake between Memorial Day and Labor Day of each year.

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 Iowa DNR Watershed Improvement Section may provide technical support to locally led efforts if resources are requested and available. A look at how these proposed monitoring plans may be deployed in the Avenue of the Saints Lake watershed is shown in Figure 5-1.

This expanded monitoring information would improve statistical analysis for evaluating changes and / or trends in water quality over time. Additionally, more detailed data could be used to develop / improve watershed and water quality models for simulation of implementation scenarios and prediction of water quality response. 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.

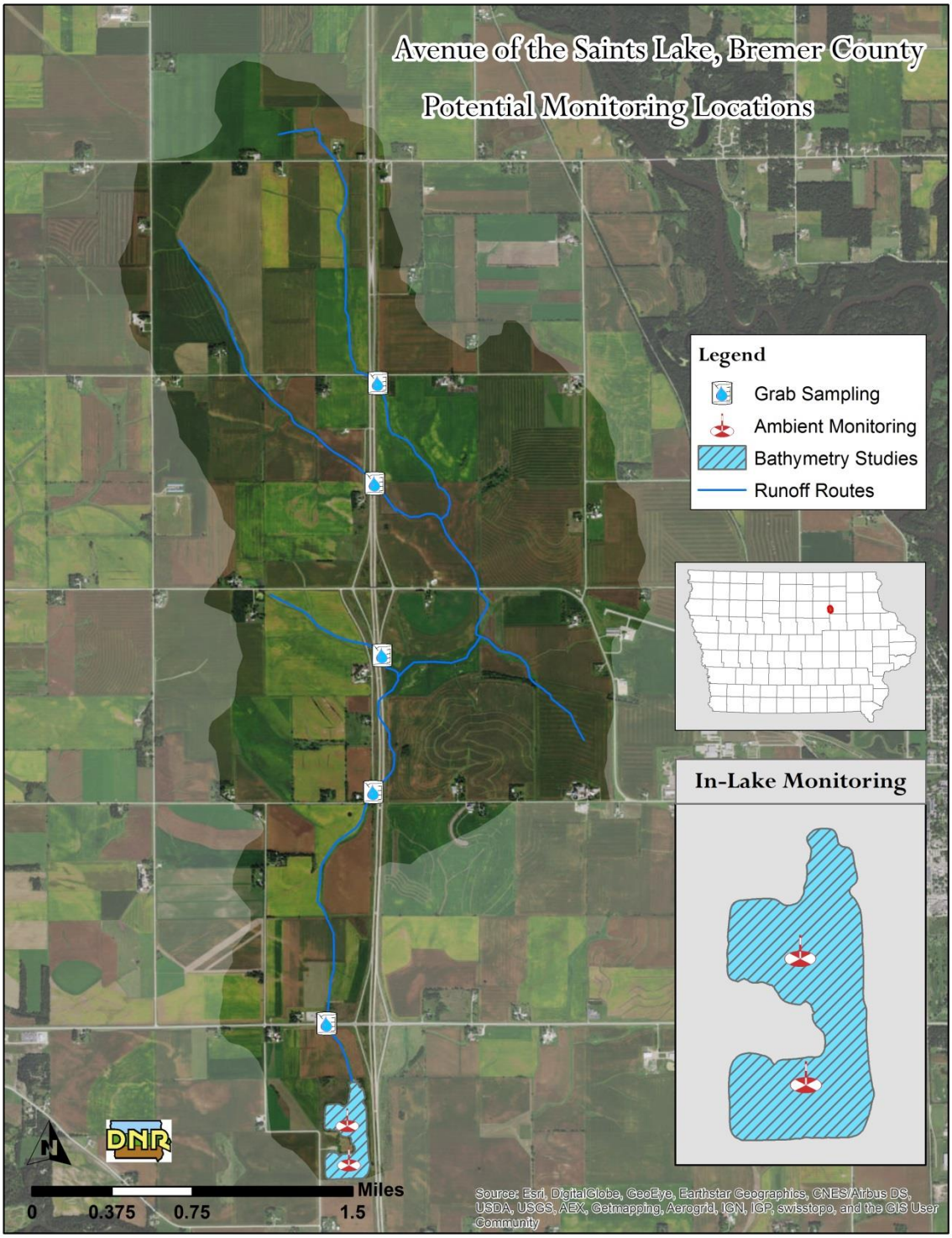

Figure 5-1. Potential monitoring locations

6. Public Participation

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

6.1. Public Meeting

Preliminary Meetings

September 16, 2016
Site investigation to ground truth the various land uses, topography, and flow paths of the Avenue of the Saints Lake and surrounding watershed.

Public Presentations

August 9, 2017
A public meeting to present the results of the TMDL study, obtain stakeholder input, and discuss next steps for community-based watershed planning will be held in the Waverly Room at the Waverly Public Library from 6:00 to 7:30 pm on Wednesday, August 9, 2017.

6.2. Written Comments

The public comment period will begin July 28, and lasts for thirty days. All public comments and the corresponding official response from DNR will be included in Appendix I.

7. References

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22(2):361-369.

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

Center for Agricultural and Rural Development (CARD). 2009. Iowa State University. Iowa Lakes Valuation Project. Information specific to Avenue of the Saints available at http://www.card.iastate.edu/lakes/lake_usage.aspx?id=72. Accessed in December, 2016.

Dinnes, D.L. 2004. Assessments of practices to reduce nitrogen and phosphorus nonpoint source pollution of Iowa's surface waters. Iowa Department of Natural Resources; USDA-ARS National Soil Tilth Laboratory, Ames, Iowa.

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

Iowa Environmental Mesonet (IEM). 2016a. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/request/coop/fe.phtml
Accessed in August 2016.

Iowa Environmental Mesonet (IEM). 2016b. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/agclimate/hist/dailyRequest.php.
Accessed in August 2016.

Paerl, Hans W.; et al. (2016). It takes two to tango: When and where dual nutrient (N & P) reductions are needed to protect lakes and downstream systems. *Environmental Science and Technology*, 20(20), 10805-10813.

Prior, Jean Cutler. *Landforms of Iowa*. Iowa City: U of Iowa for the Dept. of Natural Resources, 1991. Print.

Schindler, D. W., et al. (2008). Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment. *Proceedings of the National Academy of Sciences*, 105(32), 11254-11258.

Schindler, D. W., et al. (2016). Reducing Phosphorus to Curb Lake Eutrophication is a Success. *Environmental Science and Technology*, 50(17), 8923-8929.

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

U.S. Department of Agriculture – National Agricultural Statistical Summary (USDA-NASS). 2016. http://nassgeodata.gmu.edu/CropScape/. Accessed August 2016.

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

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

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

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

8. Appendices

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

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

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

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

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

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

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

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

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

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

DNR: Iowa Department of Natural Resources.

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

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

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

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

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

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

Geometric Mean (GM): A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's water quality standards and assessment procedures, the geometric mean criterion for *E. coli* is measured using at least five samples collected over a 30-day period.

GIS: Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

Groundwater: Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

Gully erosion: Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land, which has the potential for long-term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

IDALS: Iowa Department of Agriculture and Land Stewardship

Integrated report: Refers to a comprehensive document that combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the wasteload and load allocations.)

LiDAR: Light Detection and Ranging. Remote sensing technology that uses laser scanning to collect height or elevation data for the earth's surface.

Load: The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.

Macrophyte: An aquatic plant that is large enough to be seen with the naked eye and grows either in or near water. It can be floating, completely submerged (underwater), or partially submerged.

MOS: Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the water quality of a waterbody to pollutant loads.

MPN: Most Probable Number. Used as a unit of bacteria concentration when a more rapid method of analysis (such as Colisure or Colilert) is utilized. Though not necessarily equivalent to colony forming units (CFU), the two terms are often used interchangeably.

MS4: Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.

Nonpoint source pollution: Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.

NPDES: National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.

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

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

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

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

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

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

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

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

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

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

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

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

Scientific notation: See explanation on page 107.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

USDA: United States Department of Agriculture

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

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

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

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

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

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

Scientific Notation

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

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

Here are some examples of scientific notation.

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

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

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

Introduction

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

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

General Use Segments

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

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

Designated Use Segments

Designated use segments are waterbodies that maintain flow throughout the year, or at least hold pools of water that are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are thirteen different designated use classes (Table B-1) that may apply, and a waterbody

may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B-1. Designated use classes for Iowa waterbodies

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

Designated use classes are determined based on a Use Attainability Analysis, or UAA. This is a procedure in which the waterbody is thoroughly scrutinized, using existing

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

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

Appendix C --- Water Quality Data

The following 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 SHL water quality sampling data ([1]ambient location)

Source	DATE	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	pH
ISU	11-Jun-02	0.60	32.8	102.5	1.1	7.8
ISU	16-Jul-02	0.60	94.3	124.8	1.2	8.7
ISU	12-Aug-02	0.45	21.9	128.6	1.1	8.1
ISU	10-Jun-03	2.20	4.9	98.4	1.7	8.3
ISU	16-Jul-03	0.52	21.2	145.9	1.4	8.6
ISU	12-Aug-03	0.75	24.3	97.7	1.3	8.2
ISU	08-Jun-04	0.40	2.0	427.7	4.8	8.3
ISU	13-Jul-04	0.35	152.2	371.2	2.5	9.5
ISU	10-Aug-04	0.50	42.5	288.9	1.4	8.6
UHL	25-Apr-05	0.70	16.0	160.0	1.8	8.0
UHL	19-May-05	1.00	19.0	90.0	1.4	7.9
ISU	14-Jun-05	0.50	239.2	156.1	1.3	8.8
UHL	20-Jun-05	0.60	69.0	220.0	2.0	8.7
ISU	19-Jul-05	0.15	242.1	252.9	1.8	10.1
UHL	28-Jul-05	0.20	84.0	320.0	1.6	8.9
ISU	08-Aug-05	0.50	47.8	197.0	0.9	9.4
UHL	30-Aug-05	0.80	44.0	120.0	1.0	9.3
UHL	17-Oct-05	0.60	32.0	90.0	0.9	8.7
UHL	13-Apr-06	0.40	24.0	110.0	1.5	8.2
UHL	04-May-06	1.00	12.0	90.0	4.4	8.2
UHL	01-Jun-06	0.60	66.0	70.0	2.0	8.4
UHL	05-Jul-06	0.40	130.0	130.0	2.2	9.0
UHL	24-Aug-06	0.40	110.0	220.0	2.5	9.1
UHL	26-Sep-06	0.30	71.0	190.0	2.7	7.9
UHL	08-May-07	0.60	9.0	200.0	2.9	7.6
UHL	25-Jul-07	1.10	28.0	140.0	1.0	9.3
UHL	18-Sep-07	0.50	23.0	120.0	1.7	7.4
UHL	02-Sep-08	0.50	62.0	130.0	1.4	7.8
ISU	24-Jun-09	0.40	67.0	126.1	2.1	9.2
ISU	29-Jul-09	0.60	24.0	130.7	1.7	8.4
ISU	19-Aug-09	0.50	32.0	126.5	1.4	8.0
UHL	20-May-10	0.40	23.0	200.0	*	8.8
ISULL	07-Jun-10	0.65	8.5	109.3	*	8.4
UHL	10-Jun-10	0.70	28.0	100.0	*	8.2
UHL	21-Jul-10	0.60	140.0	130.0	*	9.4
ISULL	26-Jul-10	0.45	17.3	137.6	*	8.4

Source	DATE	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	pH
UHL	17-Aug-10	0.90	89.0	120.0	*	7.0
ISULL	07-Sep-10	0.23	43.2	206.0	*	7.7
UHL	16-Sep-10	0.60	36.0	100.0	*	7.8
ISU	08-Jun-11	0.43	57.1	124.1	*	9.1
ISU	25-Jul-11	0.53	40.0	125.2	*	9.0
ISU	06-Sep-11	0.43	33.9	189.9	*	8.2
ISU	04-Jun-12	0.35	70.3	134.1	3.1	9.2
ISU	23-Jul-12	0.58	20.5	107.8	1.2	8.1
ISU	05-Sep-12	0.38	20.6	210.0	2.2	7.4
ISU	03-Jun-13	0.25	3.3	377.5	2.8	7.4
ISU	22-Jul-13	0.90	13.8	91.2	1.1	9.7
ISU	02-Sep-13	0.63	86.8	81.4	2.1	9.8
ISU	09-Jun-14	0.63	28.2	304.7	1.5	8.9
ISU	28-Jul-14	0.50	62.6	313.8	2.7	9.3
ISU	07-Sep-14	0.31	44.1	266.3	2.2	8.4

[1] Ambient monitoring location = STORET ID 29090001
* Missing data

C.2. Annual Mean Data

Table C-2. Precipitation and annual mean TSI values ([1]ambient location)

Date	Annual Precipitation (in)	Apr-Sep Precipitation (in)	Secchi TSI	Chl-a TSI	TP TSI	pH
2002	29.47	24.09	68.61	68.92	72.97	8.21
2003	27.68	21.33	57.88	58.28	72.40	8.38
2004	29.84	20.75	72.62	71.64	89.07	8.80
2005	33.34	26.59	68.33	74.54	78.86	8.87
2006	35.23	25.92	69.52	72.11	74.84	8.47
2007	40.89	29.49	64.47	59.99	76.67	8.10
2008	41.61	32.30	69.99	71.09	74.29	7.80
2009	41.37	28.72	69.99	67.03	74.04	8.53
2010	37.58	30.36	68.20	68.60	75.14	8.21
2011	28.77	19.79	71.09	67.65	76.00	8.77
2012	22.32	14.42	71.94	66.05	76.41	8.24
2013	40.43	31.85	67.52	65.37	79.25	8.99
2014	34.76	26.34	70.58	67.93	86.09	8.84

[1] Ambient monitoring location = STORET 29090001

Appendix D --- Watershed Model Development

Watershed and in-lake modeling were used in conjunction with analysis of observed water quality data to develop the Total Maximum Daily Load (TMDL) for the algae, turbidity, and pH impairments to Avenue of the Saints Lake in Bremer County, Iowa. This TMDL targets an allowable phosphorus load that will satisfy the aquatic life support designated use (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 lake to sustain game and non-game fish. Reduction of bioavailable phosphorus will also limit algal growth which will in turn stabilize water column pH. The Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1, was utilized to simulate watershed hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.1, an empirical lake and reservoir eutrophication model. The integrated watershed and in-lake modeling approach connects long-term annual average watershed hydrology and pollutant loads to in-lake water quality in Avenue of the Saints Lake. This section of the Water Quality Improvement Plan (WQIP) discusses the modeling approach and development of the STEPL watershed and BATHTUB lake models.

D.1. Modeling Approach

Data from a 13-year period of record, 2002-2014, 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 (2008-2012) upon which the 2014 Integrated Report and 303(d) list were generated. As such, it best reflects the long term conditions of the impairment.

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, nitrogen, and phosphorus. Required input data is minimal if the use of county-wide soils and coarse precipitation information is acceptable to the user. If available, the user can modify soil and precipitation inputs with higher resolution and local soil and precipitation data. Precipitation inputs include average annual rainfall and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation. Characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, population of agricultural 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 5 subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with targeting potential BMP locations. These basins were created to coincide with the topography and distribution of drainage districts throughout the Avenue of the Saints Lake watershed. Hydrology and pollutant loadings are summarized for each subbasin and also aggregated as watershed totals.

D.3. Meteorological Input

Precipitation Data
The STEPL model includes a pre-defined set of weather stations from which the user may obtain precipitation-related model inputs. Unfortunately, none of the NWS COOP stations within a reasonable distance of Avenue of the Saints Lake are included in the STEPL model. Therefore, rainfall data from the NWS COOP station at Allison, Iowa, was used for modeling purposes. Weather station information and rainfall data were reported in Section 2.1 (see Table 2.2 and Figures 2.2 and 2.3.)

Average annual precipitation from 2008-2012 was 31.2 inches/year, slightly below the 13-year (2002-2014) annual average of 34.3 inches. Annual rainfall used in the STEPL model coincided with the long term 13-year period in order to simulate longer-term precipitation patterns.

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 of 2002-2014 were utilized in parameterization. The rain day correction factor of 0.410 was calculated by dividing the number of days that it rained at least 5 mm by the number of days with at least 1 mm of rainfall. This ratio is intended to estimate the number of days that could potentially generate surface runoff. Precipitation inputs are reported in Table D-1, as entered in the "Input" worksheet of the 2008-2012 Avenue of the Saints Lake STEPL model.

Table D-1. STEPL rainfall inputs (2002-2014 average annual data)

Rain correction factors			
[1]0.874	[2]0.410		
[3]Annual Rainfall	**[4]Rain Days**	**[5]Avg. Rain/Event**	**Input Notes/Descriptions**
34.1	110	0.648	[1]The percent of rainfall that exceeds 5 mm per event
			[2]The percent of rain events that generate runoff
			[3]Annual average precipitation from 2002-2014 (in)
			[4]Average days of precipitation per year (days)
			[5]Average precipitation per event (in)

D.4. Watershed Characteristics

Topography
The Avenue of the Saints Lake watershed was delineated into 5 subbasins using ArcGIS (version 10.1) and a 3-meter resolution digital elevation model (DEM) developed by the Iowa Department of Natural Resources (DNR). Figure D-1 illustrates the watershed and subbasin boundaries. The subbasins boundaries were chosen to coincide with internal ridges and boundaries both natural and artificial. These will aide in prioritizing areas to for future BMP implementation for water quality improvement.

Land Use
A previous watershed assessment was used to generate land use characteristics. Included in this assessment are RUSLE characteristics used to generate sheet and rill erosion in Figure F-1. STEPL land cover classifications are reported in Table D-2, with land use distribution previously illustrated in the map (Figure 2-5) and table (Table 2-3) in Section 2.

Table D-2. STEPL land use inputs

Watershed	[1]Urban	Cropland	Pastureland	Forest	[2]User Defined	[3]Total
W1	115.5	414.0	0.0	0.0	11.3	540.8
W2	142.7	804.6	11.6	0.0	59.6	1018.5
W3	83.5	504.7	0.0	0.0	23.8	612.0
W4	88.0	765.9	0.6	0.0	57.6	912.1
W5	117.1	954.8	0.0	0.0	26.5	1098.4
[3]Total	546.8	3444.0	12.2	0.0	178.8	**[3]4181.8**

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

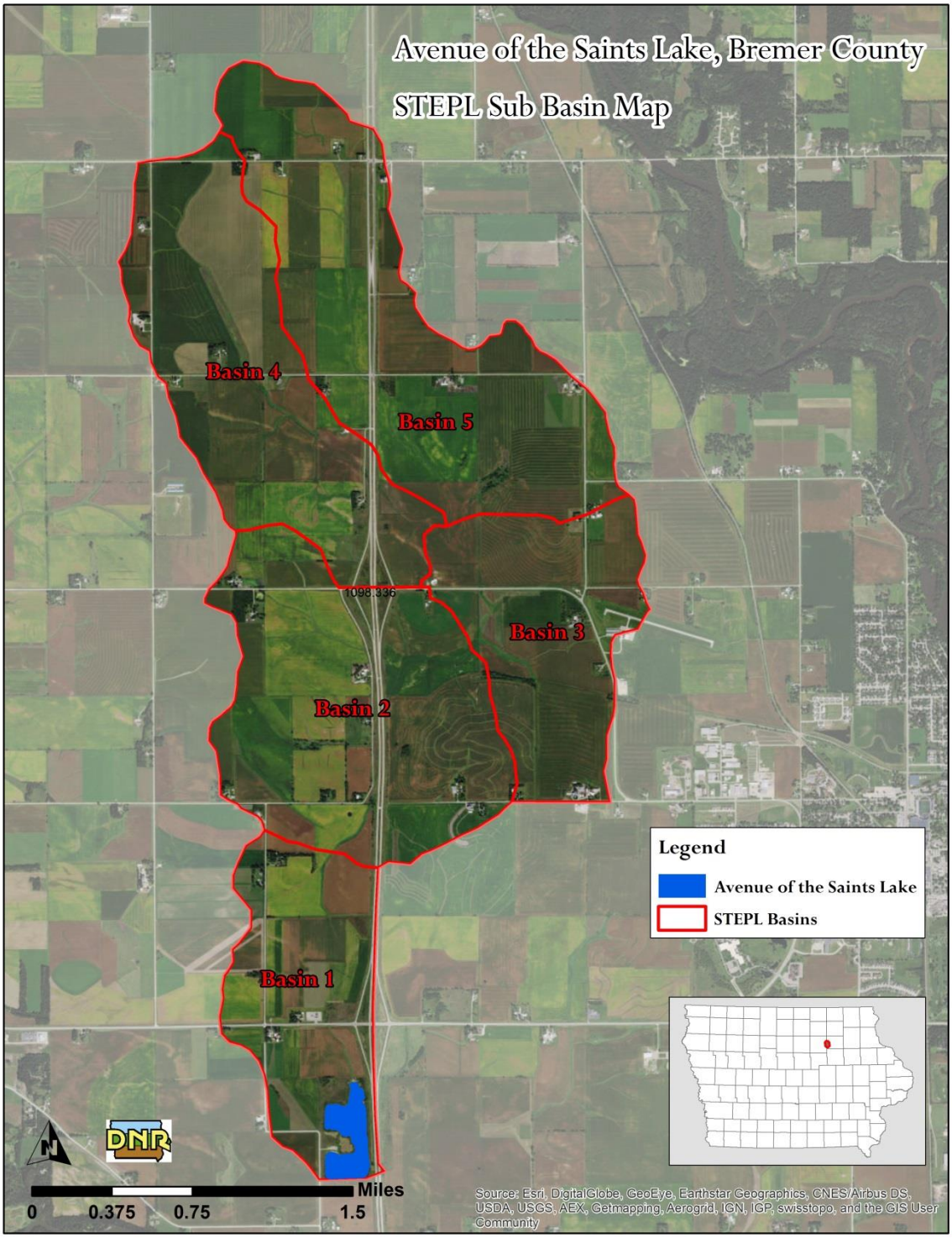

Figure D-1. STEPL subbasin map

Each land cover type was assigned a specific USLE C-factor and P-factor (Table D-3), based on regional estimates developed by DNR and Soil and Water Conservation district personnel for watershed assessments performed in the same ecoregion. C- and P-factors were assigned to each CLU using best available data. P-factors for row crop fields ranged from 0.67 to 0.9, with values of 1 representing no existing erosion practices. C-factors vary widely, from 0.0 for paved roads to 0.14 for row crops with extensive tillage and little plant residue. All USLE parameters were area-weighted and summarized for each subwatershed before input to the STEPL model.

Table D-3. C- and P-factors for each land cover and practice (BMP)

Land Cover Description	C-Factor	Practice	P-Factor
Corn-Soybeans; Conventional-Till	0.260	Terraces	0.6
Corn-Soybeans; Mulch-Till	0.125	Contour Farming	0.7
Corn-Soybeans; No-Till Beans, Mulch-Till Corn	0.080	Contour Buffers	0.7
Corn-Soybeans; No-Till Beans and Corn	0.050	Field Buffers	0.8
Grassland and Pasture	0.001	Ponds/Basins	0.4
Farmstead	0.020		
Timber	0.013		
Road	0.000		

Soils

Soils are discussed in detail in Section 2.2. The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Watershed soils are predominantly HSG type B soils, with some C and D soils interspersed. HSG values were area-weighted for each subbasin and used to modify curve numbers (CNs) in STEPL. Area-weighted calculations concluded HSG B is appropriate for all five sub basins. USLE K-factors are also specific to each soil type, and were area-weighted in the same fashion as C- and P-factors and entered into the “Input” worksheet in the STEPL model.

Slopes

Slopes are described in more detail in Section 2.2. USLE land slope (LS) factors were obtained from the SSURGO data and were assigned at the field-scale, then area-weighted to develop land-use specific LS factors for each STEPL subwatershed. Resulting LS-factors in entered into the “Input” worksheet in the STEPL model vary between 0.34 and 0.69.

Curve Numbers

The STEPL model includes default curve numbers (CNs) selected automatically based on HSG and land use. CNs in the Avenue of the Saints Lake STEPL model were manually adjusted by area-weighting HSG values so that differences in soil types are better reflected in CN values. In Iowa watershed modeling professionals across multiple agencies have found that standard NRCS curve numbers result in overestimation of surface runoff and flow (IDNR and ISU, unpublished data). Therefore, the HSG Type B CNs were modified to better reflect the distribution of HSG types throughout the basins. Urban land use curve numbers were developed within STEPL based on percent landuse

of the urban subcategories. Adjusted CNs were entered in the "Input" worksheet of STEPL, and are reported in Table D-4.

Table D-4. STEPL curve numbers

Subwatershed	[1]Urban	Cropland	[2]Pastureland	[3]User Defined
W1	89	77	69	65
W2	89	80	69	65
W3	89	80	69	65
W4	89	79	69	65
W5	89	81	69	65

[1]Urban includes all developed areas, including transportation and farmstead areas
[2]Pastureland includes pasture and alfalfa ground in crop rotations
[3]User defined areas include non-pasture grassland

Subsurface Tile Drainage
STEPL has the ability to simulate groundwater flow in each subbasin. In areas where row crops are prevalent, and soil types prevent adequate drainage, producers may install sub surface drainage to influence the flow of groundwater. This groundwater flow in row crop landuse can be assumed to be tile flow. Data was not available to adjust nutrient concentrations from default values.

Sediment Delivery Ratio
The sediment load to each lake in the Avenue of the Saints Lake watershed 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 0.30 (Basin 1) to 0.26 (Basin 5).

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. There are no estimated animals in the Avenue of the Saints Lake watershed, but several small animal feeding operations exist outside the watershed delineation. Inspection of manure management plans (MMP) showed that neither facility directly contributed to manure application within the Avenue of the Saints Lake watershed.

Livestock Grazing
There are no significant cattle grazing operations in the Avenue of the Saints Lake watershed.

Open Feedlots
There are no open feedlots in the Avenue of the Saints Lake watershed in the Iowa DNR Animal Feeding Operations Database. Feedlot operators are not required to report open feedlot information to Iowa DNR for feedlots with less than 1000 animal units (AUs). No active open feedlot operations were observed during the September 2016 windshield survey.

Wildlife
The estimated county-wide average deer density is approximately 5 deer per square mile, but an average of 10 deer per square mile was entered in the "Animals" worksheet of the STEPL model for Avenue of the Saints Lake watershed to account for increased density of deer around the lake. Population densities of 5 raccoons, 5 beavers, and 5 other per square mile were used to account for other wildlife (e.g., furbearers, upland birds, etc.) for which data is lacking.

Phosphorus contributions from waterfowl in and near the lake by Canada geese were also simulated by STEPL. An estimate of goose population and subsequent phosphorus contributions at Avenue of the Saints Lake were provided by DNR staff. On an annual average basis, there are less than 50 geese residing at the lake; however, populations vary throughout the year due to migratory patterns and nesting seasons.

Septic Systems
A GIS coverage of rural residences with private onsite wastewater treatment systems (e.g., septic systems) was developed using aerial images and anecdotal data from various state, county, and local agencies. This procedure resulted in the identification of 39 septic systems in this sparsely populated watershed. Based on age of systems, it is estimated that 5 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 Avenue of the Saints Lake.

D.6. References

U.S. Department of Agriculture – Farm Service Agency (USDA-FSA). 2013. http://www.fsa.usda.gov/Internet/FSA_File/clu_2007_infosheetpdf.pdf. Accessed August 2013.

U.S. Department of Agriculture – National Agricultural Statistical Summary (USDA-NASS). 2013. http://nassgeodata.gmu.edu/CropScape/. Accessed August 2013.

Appendix E --- Water Quality Model Development

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

In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. The BATHTUB model developed for Avenue of the Saints 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 2002-2014, which includes the 2014 Integrated Report (2008-2012). This appendix discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of long-term average hydrology and water quality in Avenue of the Saints 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.

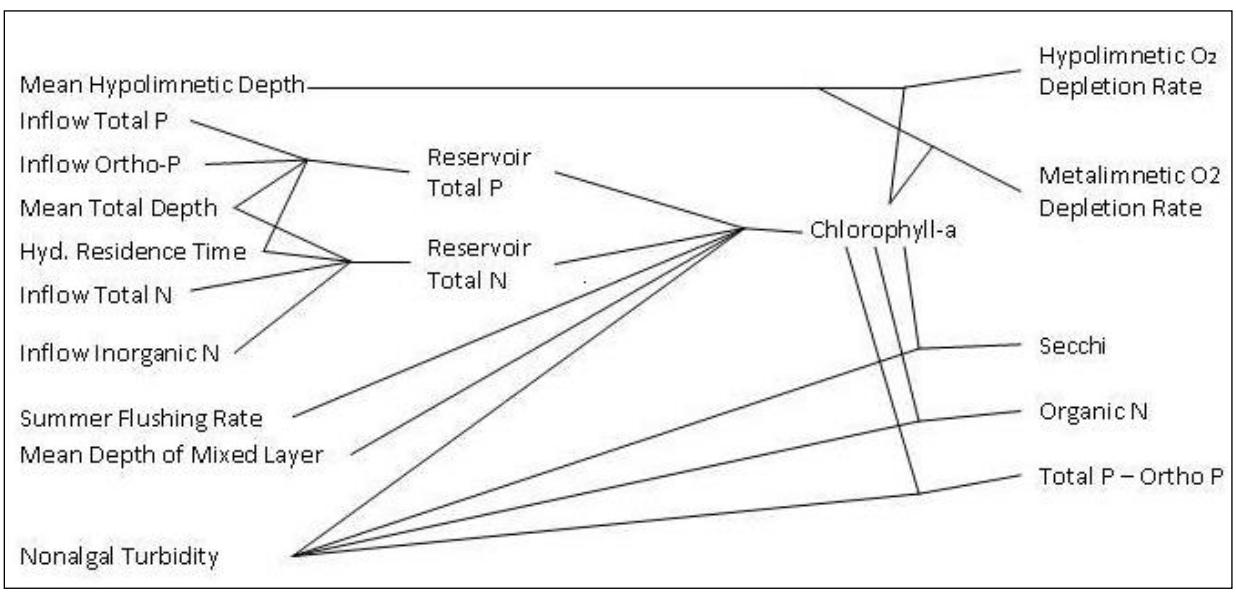

Figure E-1. Eutrophication control pathways in BATHTUB (Walker, 1999)

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 Avenue of the Saints 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, chlorophyll-a, transparency, and other parameters. The global variables menu describes parameters consistent throughout the lake such as precipitation, evaporation, and atmospheric deposition. The segment data menu is used to describe lake morphometry, observed water quality, calibration factors, and internal loads in each segment of the lake 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 Avenue of the Saints 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, chlorophyll-a, and transparency, Models 1 and 2 are the most general formulations, based upon model testing results (Walker, 1999). Alternative models are provided in BATHTUB to allow 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 Avenue of the Saints Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Avenue of the Saints 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. The default models were left to predict in-lake phosphorus and chl-a levels because it provided the best agreement with observed data, and because Avenue of the Saints Lake is a manmade reservoir and representative of aquatic systems for which these specific models were developed. Model performance is discussed in more detail in Appendix F.

Table E-1. Model selections for Avenue of the Saints Lake

Parameter	Model No.	Model Description
Total Phosphorus	*01	2nd order, Avail. P
Total Nitrogen	*00	Not Computed
Chlorophyll-a	*02	P, Light, T
Transparency	*01	vs. chlorophyll-a & turbidity
Longitudinal Dispersion	*01	Fischer-numeric
Phosphorus Calibration	*01	decay rates
Nitrogen Calibration	*01	decay rates
Availability Factors	*00	ignore

* Asterisks indicate BATHTUB defaults

Global Variables

Global input data for Avenue of the Saints 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 Avenue of the Saints Lake.

Table E-2. Global variables data for 2002-2014 simulation period

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 years
[1]Precipitation	34.1 in	0.87 m
[1]Evaporation	28.9 in	0.73 m
[2]Increase in Storage	0	0
[3]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Precip and evaporation data are from 2002-2014 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 13-year assessment period of 2002-2014 from the National Weather Service Cooperative weather station at Allison, Iowa (IEM, 2016a). Potential evapotranspiration data for the same period was obtained from the Waterloo, Iowa weather station via the ISU Ag Climate database (IEM, 2016b). Net change in reservoir storage was assumed to be zero. This 13 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 impairment at Avenue of the Saints Lake. It was shown in Section 3.1 (Figures 3-9 to 3-11) that precipitation is not highly correlated with total phosphorus and the impairment seen at Avenue of the Saints Lake. For these reasons, it was assumed the extended assessment period climate conditions may be a more suitable basis for global variable data. 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 Avenue of the Saints Lake BATHTUB model includes two lake segments to facilitate simulation of diffusion, dispersion, and sedimentation that occur as water

traverses between the two main bodies of the lake. This relationship is shown in Table E-5. Segment 1 contains the deep water area in which water quality data is regularly collected through DNR's Ambient Monitoring Program. Because the ambient monitoring location is used for listing and delisting purposes, the TMDL target applies only to this segment of the lake system. Figure E-2 shows the location and naming convention of each lake in the BATHTUB model. Table E-4 shows the model variables for the monitored and assessed segment.

Figure E-2. Lake segmentation in BATHTUB model.

Segment morphometry was calculated for each segment in the model. Bathymetric survey data and ESRI GIS software was used to estimate segment surface area, mean depth, and segment length. Temperature and dissolved oxygen (DO) profiles were used to estimate the mixed layer and hypolimnetic depth at the ambient monitoring location in Avenue of the Saints Lake. Segment physical parameters input into BATHTUB for the lake system area shown in Table E-3.

Table E-3. Segment morphometry for the Avenue of the Saints Lake

Segment	Outflow Segment	Segment Group	Surface Area (km^2)	Mean Depth (m)	Length (km)
Segment 1	Out of Reservoir	1	0.085	3.20	0.341
Segment 2	Segment 1	1	0.087	1.92	0.411

Mean water quality parameters observed for the modeling period (2002-2014) are reported in Table E-4. These data were compared to output in Segment 1 of the BATHTUB lake model to evaluate model performance and calibrate the BATHUB and STEPL models for each scenario. Data for model calibration was available only for Segment 1 in Avenue of the Saints Lake. The TMDL and future water quality assessment and listing will be based solely on water quality data from Segment 1.

Table E-4. Ambient (Segment 1) water quality (2002-2014 annual means)

Parameter	Measured Data	[1]BATHTUB Input
Total Phosphorus	171.8 µg/L	171.8 ppb
Total Nitrogen	1.89 mg/L	1890 ppb
Chlorophyll-a	47.7 µg/L	47.7 ppb
Secchi Depth	0.58 m	0.58 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 Avenue of the Saints 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 Avenue of the Saints Lake.

Table E-5. Tributary data for the Avenue of the Saints Lake

Tributary name	BATHTUB Segment	Total Watershed Area (km^2)	Avg Period Flow Rate (hm^3/yr)	STEPL Total P concentration (ppb)
Basin 1	Segment 2	2.19	0.806	203.7
Basin 2	Segment 2	4.13	1.518	214.8
Basin 3	Segment 2	2.48	0.903	217.8
Basin 4	Segment 2	3.69	1.359	219.0
Basin 5	Segment 2	4.45	1.611	202.2

Tributary data were obtained from the STEPL model, converted to units consistent with BATHTUB, and entered in the tributary data menu. Table E-6 lists the STEPL subbasins that drain to the tributary and also illustrates the connectivity of BATHTUB segments.

Table E-6. Flow and transport linkages in STEPL and BATHTUB

STEPL Subbasin	BATHTUB Tributary	BATHTUB Segment
W1	Tributary 1	Segment 2
W2	Tributary 2	
W3	Tributary 3	Segment 1
W4	Tributary 4	
W5	Tributary 5	

E.3. References

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

Iowa Environmental Mesonet (IEM). 2016a. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/request/coop/fe.phtml
Accessed in August 2016.

Iowa Environmental Mesonet (IEM). 2016b. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/agclimate/hist/dailyRequest.php.
Accessed in August 2016.

Appendix F --- Model Performance and Calibration

The Avenue of the Saints 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 University of Iowa State Hygienic Laboratory (SHL) between 2002 and 2014. 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 Avenue of the Saints 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 or upstream lakes in the Avenue of the Saints 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.

Table F-1. Sheet and rill erosion in similar watersheds

Watershed	County	Area (acres)	Proximity (miles)	Erosion (tons/ac/yr)
South Fork Iowa River	Hardin, Hamilton	193,000	40	0.4 – 0.6
Brushy Creek Lake	Webster	56,930	77	0.8
Briggs Woods Lake	Hamilton	7,210	66	1.6
Eldred Sherwood Lake	Hancock	6,270	54	1.6
Silver Lake	Dickinson	17,019	150	1.6
[1]Avenue of the Saints Lake	**Hancock**	**4,182**	**--**	**1.1**

[1]Annual sheet/rill erosion estimated for this TMDL using STEPL (2002-2014) does not include water areas.

The Avenue of the Saints Lake STEPL model predicts sheet and rill erosion rates that are consistent with those predicted by DNR for other watersheds in the area. The 2002-2014 simulated annual average sheet and rill erosion rate was 1.1 tons/acre, compared with average estimated rates between 0.4 to 1.6 tons/acre/year estimated in other watersheds. Note that erosion rates in Table F-1 reflect sheet and rill erosion, not sediment delivered to the lake. Figure F-1 shows the sheet and rill erosion in the Avenue of the Saints Lake watershed.

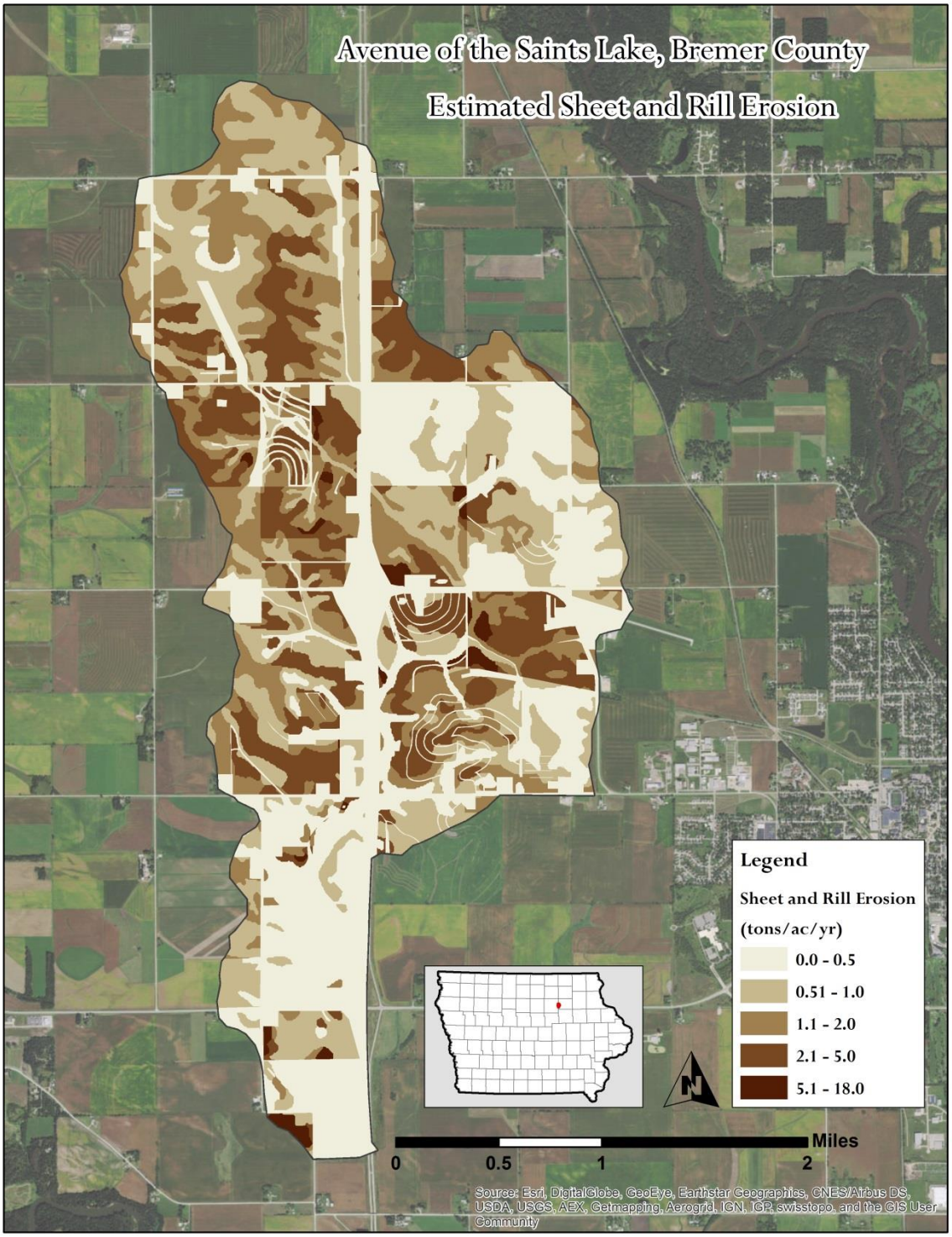

Figure F-1. Sheet and rill erosion in the Avenue of the Saints watershed, 2012

Table F-2 compares the annual average TP export simulated by the Avenue of the Saints Lake STEPL model with past study results in other watersheds in the Midwest. Average annual TP export in the Avenue of the Saints Lake watershed is 0.7 pounds per acre per year. Because the STEPL model predicted sediment and phosphorus loads similar in magnitude to estimates developed for other local and regional watersheds, IDNR has determined the STEPL model to be adequate for estimation of phosphorus loads to Avenue of the Saints Lake for development of TMDLs and implementation planning.

Table F-2. Comparison of TP exports in similar watersheds

Watershed Location	Source	TP Export (lb/ac)
South Fork Iowa River	Tomer et al., 2008	0.4 – 0.6
Lake Geode, Henry Co.	IDNR (Previous TMDL)	1.4
Silver Lake, Dickinson Co.	IDNR (Previous TMDL)	0.7
Briggs Woods Lake, Hamilton Co.	IDNR (Previous TMDL)	1.4
Eldred Sherwood Lake, Hancock Co.	IDNR (Previous TMDL)	1.1
Avenue of the Saints Lake, Hancock Co.	**STEPL Model (Current TMDL)**	**0.7**

F.2. BATHTUB Model Performance

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

Calibration
Table F-3 reports observed and predicted annual average TP, chlorophyll-a, and Secchi depths in the open water area (Segment 1), along with the calibration coefficients for each parameter of interest. More comprehensive observed data is reported in Appendix C. Predicted water quality is based on BATHTUB simulations, and the calibration coefficients were iteratively adjusted in order to obtain the best possible agreement between observed and predicted water quality, while minimizing changes in the default coefficients. The calibration period was 2002-2014.

Calibration coefficients listed alongside the simulated values in Table F-3 were entered in the “Segments” menu of the BATHTUB model, and apply to only the ambient monitoring segment (Segment 1) of Avenue of the Saints Lake. Other lake segments were uncalibrated due to lack of historical water quality data. Calibration coefficients for Avenue of the Saints Lake are within the recommended range according to the BATHTUB user guidance (Walker, 1999).

Initial testing showed phosphorus levels from watershed loading predicted by STEPL were inadequate for meeting observed water quality data in Avenue of the Saints Lake. Internal loading concentrations were increased for each lake segment until simulated phosphorus levels at the ambient monitored segment reached observed phosphorus levels. This resulted in an internal load comprising 50 percent of the total load to Avenue of the Saints Lake. Internal areal loading rates of 20 and 25 $mg/m^2/day$ were estimated for

Segment 1 and Segment 2, respectively. Different rates for each segment were based on mean depth and proximity to overland flow. The shallower nature and role as receiving body of overland flow in Segment 2 justified the higher internal loading rate compared to Segment 1. Once simulated phosphorus levels were calibrated to observed phosphorus levels, other water quality measurements were calibrated by increasing or decreasing model coefficients within the BATHTUB model.

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

Parameter	[1]Observed	[2]Predicted	Calibration Coefficient
Modeling period and TMDL conditions (2002-2014)			
Total Phosphorus (ug/L)	171.8	171.3	1.00
Chlorophyll-a (ug/L)	47.7	47.7	1.645
Secchi depth (m)	0.6	0.6	1.00

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

F.3. References

U.S. Geological Survey (USGS), 2001. Water Quality Assessment of the Eastern Iowa Basins – Nitrogen, Phosphorus, Suspended Sediment, and Organic Carbon in Surface

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

Appendix G --- Expressing Average Loads as Daily Maximums

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

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

Per the EPA requirements, the loading capacity of Avenue of the Saints 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 959 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:

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

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

The allowable annual average of 959 lbs/year is equivalent to a long-term average (LTA) daily of 2.6 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 8.2 lbs/day. The TMDL calculation is summarized in Table G-2. An explicit MOS of 10 percent (0.8 lbs) was applied, resulting in a daily LA of 7.4 lbs/day to the daily equation daily TMDL equations. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (7.4 lbs-TP/day)
+ MOS (0.8 lbs-TP/day) = **8.2 lbs-TP/day**

Table G-1. LTA to MDL calculations for Avenue of the Saints Lake.

Parameter	TMDL	Σ WLA	Σ LA	MOS
LTA (lbs/day)	2.6	0.0	2.35	0.25
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)	**8.2**	**0.0**	**7.4**	**0.8**
Seasonal (lbs/day)	**959**	**0.0**	**863**	**96**

Appendix H --- 2014 305(b) Water Quality Assessment

Segment Summary

Waterbody ID Code: IA 02-SHL-00105-L_0
Location: Bremer Co., approximately 2 miles E of Shell Rock in S7, T91N, R14W
Waterbody Type: Lake
Segment Size: 30 Acres

Segment Classes:
Class B(LW)
Class HH

Assessment Comments

Assessment is based on: (1) results of the statewide survey of Iowa lakes conducted from 2009 through 2012 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted in 2008 by University Hygienic Laboratory (UHL),(3) information from the IDNR Fisheries Bureau, and (4) IDNR RAFT fish tissue monitoring.

Assessment Summary and Beneficial Use Support

Overall Use Support - Partial
Aquatic Life Support - Partial
Fish Consumption - Fully

Assessment Type: Monitored
Integrated Report Category: 5a
Trend: Stable
Trophic Level: Hypereutrophic

Basis for Assessment and Comments

SUMMARY: This lake is not designated for Class A1 primary contact recreation uses. The Class B(LW) (aquatic life) uses are assessed (monitored) as “fully supporting.” Information from the IDNR Fisheries Bureau suggests poor water transparency due to algae and inorganic turbidity (suspended solids) have led to a poor fishery that suggests an impairment of the aquatic life uses. Fish consumption are assessed as "fully supporting." Sources of data for this assessment include (1) results of the statewide survey of Iowa lakes conducted from 2009 through 2012 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted from in 2008 by University Hygienic Laboratory (UHL),(3) information from the IDNR Fisheries Bureau, and (4) IDNR RAFT fish tissue monitoring.

EXPLANATION: For the 2014 reporting cycle, the Class B(LW) uses for Avenue of the Saints Lake are assessed (monitored) as “fully supported” based on results from the ISU statewide survey of lakes and the UHL ambient lake monitoring program. The water chemistry data from the ISU and UHL lake surveys show no violations of the Class B(LW) criteria for ammonia in 13 samples and 1 violation to the dissolved oxygen criteria in 13 samples. The pH data show 3 violations of the Class B(LW) criterion in 13 samples (21%). These violations are not significantly greater than 10% of the samples and therefore do not suggest impairment of the Class B(LW) uses. Avenue of the Saints

Lake was assessed as "partially supporting" its Class B (LW) use in the 2010 reporting cycles due to significant violations to the pH criteria (6 violations in 22 samples). Based on IDNR's assessment methodology 2 consecutive assessment/listing cycles without significantly greater than 10% of the samples violating the criterion are necessary to propose delisting based on pH violations. Because there have been two consecutive assessment/listing cycles without significantly greater than 10% of the samples violating the criteria, the Class B(LW) uses will be listed as "fully supported" based on results of the ISU and UHL lake monitoring programs.

Using the median values from these surveys from 2008 through 2012 (approximately 13 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 72, 65, and 74 respectively for Avenue of the Saints Lake. According to Carlson (1977) the Secchi depth and total phosphorus values place Avenue of the Saints Lake in the hypereutrophic category while the chlorophyll a value places Avenue of the Saints Lake between the eutrophic and hypereutrophic categories. These values suggest moderately high levels of chlorophyll a and suspended algae in the water, very poor water transparency, and very high levels of phosphorus in the water column.

The levels of inorganic suspended solids at this lake were high and suggest water quality problems exist related to non-algal turbidity. The median level of inorganic suspended solids in Avenue of the Saints Lake (10.9 mg/L) was ranked 117th among the 134 lake monitored.

Data from the 2008-2012 ISU and UHL surveys suggest a large population of cyanobacteria exists at Avenue of the Saints Lake, which contributes to water quality problems at this lake. These data show that cyanobacteria comprised 98% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (91.1 mg/L) was ranked 130th of the 134 lakes sampled. This median is in the worst 25% of the 134 lakes sampled. The presence of a large population of cyanobacteria at this lake suggests a potential violation of Iowa's narrative water quality standard protecting against the occurrence of nuisance aquatic life. This assessment is based strictly on the distribution of the lake-specific median cyanobacteria values for the 2008-20012 period. Median levels greater than the 75th percentile of this distribution were arbitrarily considered to represent potential impairment. No other criteria exist, however, upon which to base a more accurate identification of impairments due to cyanobacteria. The assessment category for assessments based on level of cyanobacteria will be considered "evaluated" (indicating an assessment with relatively lower confidence) as opposed to "monitored" (indicating an assessment with relatively higher confidence) to account for this lower level of confidence.

Fish consumption uses were assessed (monitored) as "fully supported" based on results of U.S. EPA/IDNR fish contaminant (RAFT) monitoring at Avenue of the Saints Lake in 2013. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of support of fish consumption uses in Iowa's rivers and lakes. The fish contaminant data generated from the 2013 RAFT sampling conducted at Avenue of the Saints Lake show that levels of mercury are sufficiently high for concern

and thus justify follow-up monitoring. Results from the 2013 sampling show that the level of mercury in the sample of largemouth bass fillets (0.786 ppm) exceeds the 1 meal/week trigger level (0.30 ppm) as defined in Iowa's revised (2007) fish consumption advisory protocol. According to IDNR's assessment methodology, the single occurrence of contaminant above an advisory trigger level neither warrants issuance of an advisory nor indicates impairment of the fish consumption uses: two consecutive samplings that show contaminant levels are above the trigger level in fillet samples are needed to justify issuance of an advisory. Thus, follow-up monitoring is needed at Avenue of the Saints Lake is needed. Levels of primary contaminants in the composite sample of fillets were as follows: total PCBs: <0.6 ppm; and technical chlordane: <0.2 ppm. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of the degree to which Iowa's lakes and rivers support their fish consumption uses. The fish contaminant data generated from the 2013 RAFT sampling conducted at this Avenue of the Saints Lake show the need for follow-up monitoring.

Monitoring and Methods

Assessment Key Dates

9/2/2008	Fixed Monitoring Start Date
9/5/2012	Fixed Monitoring End Date

Methods

- Surveys of fish and game biologists/other professionals
- Non-fixed-station monitoring (conventional during key seasons and flows)
- Primary producer surveys (phytoplankton/periphyton/macrophyton)

Appendix I --- DNR Project Files and Locations

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

Directory\folder path	File name	Description
\\iowa.gov.state.ia.us\...\Data\Raw\	Various files	All raw data received from others
\\iowa.gov.state.ia.us\...\Data\Reduced\	Water_Quality_Data_AotS.xls	Summary of in-lake WQ data
\\iowa.gov.state.ia.us\...\Data\Reduced\Climate	Climate_Precip_ET_AotS.xls	Summary of precipitation and PET data
\\iowa.gov.state.ia.us\...\Documents\Draft_TMDL	Draft TMDL reports	Includes review comments
\\iowa.gov.state.ia.us\...\Documents\Final_TMDL	Final report	Report fir submittal to EPA
\\iowa.gov.state.ia.us\...\Documents\References	Various .pdf and .doc files	References cited in the WQIP and/or utilized to develop model input parameters
\\iowa.gov.state.ia.us\...\GIS\GIS_Data	Various shapefiles (.shp) and raster files (.grd)	Used to develop models and maps
\\iowa.gov.state.ia.us\...\GIS\Projects	ArcGIS project files	Used to develop models and maps
\\iowa.gov.state.ia.us\...\Maps, Figures, Images\Maps	Various .pdf and .jpg files	Maps/figures used in the WQIP document
\\iowa.gov.state.ia.us\...\Modeling	Allocations_Final.xls	Used to develop phosphorus source inventory and potential load allocation scenario
	TMDL_Equation_Calcs_AotS.xls	Used to develop the TMDL equation (LA, WLA, and MOS)
		Load response curve calcs
\\iowa.gov.state.ia.us\...\Modeling\STEPL	Stepl_AotS_2002-2014_.xls	Used to simulated/predict existing watershed loads
	Various .xls files	Used to develop/calculate STEPL model inputs
\\iowa.gov.state.ia.us\...\Modeling\BATHTUB\InputFiles	STEPL_Conversion_AotS.xls	Calculated/converted STEPL outputs to BATHTUB inputs for existing conditions
	BATHTUB _2002-2014.xls	
	Various .btb files	BATHTUB input files for various scenarios

Appendix J --- Public Comments

Public Comment:

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