DRAFT

Five Island Lake
Water Quality Management Plan

Prepared for:

City of Emmetsburg, Iowa

2021 Main Street
Emmetsburg, Iowa 50536

In partnership with:

Iowa Department of Natural Resources

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1 INTRODUCTION

Five Island Lake is a prominent recreational feature in Emmetsburg, Iowa. This natural lake was enhanced with a dam embankment in 1915 to increase the volume of permanently impounded water. Residences have been established around the lake and lake access from the campgrounds on the southern shoreline is available to the public. Even with a relatively small watershed and an intensive past dredging effort, water quality is poor and recreation is hindered by frequent, often severe algal blooms. FYRA Engineering has been contracted for the *Five Island Lake Improvement Project* to develop a Water Quality Management Plan (hereinafter referred to as the Plan) to determine a path forward to better water quality.

1.1 Planning Process

FYRA Engineering follows their Seven Steps of Lake Management (Figure 1), which has been developed through our years of experience with water resources projects. Steps 1 through 6 were integrated with development of a Community Based Planning (CBP) process as this Plan was developed. This approach is integral to development of a successful plan that is not only scientifically and technically effective, but also well-received by stakeholders and funding partners.

Figure 1 – FYRA Seven Steps of Lake Management

1. Problem definition
2. Water budget and nutrient mass balance
3. Pollutant load and lake response modeling
4. Management plans
5. Alternatives/cost analysis
6. Management practice design* and implementation
7. Water quality monitoring

Community Based Planning

*Conceptual Design

1.2 History

Research and review of available information identified restoration efforts on Five Island Lake back to 1913 (named Medium Lake at the time) when the lake was first dredged and the spoils were used to reshape the meandering southern shoreline. While sampling data is not readily available for most of the 19th century, restoration efforts were pursued again in 1948-1950. In 1974, a study of several Iowa lakes identified the need to address eutrophication in Five Island Lake with a dredging program and bank stabilization efforts. A large community effort turned this into a locally driven project, voting to purchase their own dredge in 1989 to reduce costs of an anticipated large-scale operation.. A timeline of the relevant studies and actions taken that pertain to water quality (including pollutant load reductions in the watershed) are presented in Figure 2, and a description of each study available for review and their findings is location in Table 1.

Figure 2 – Water Quality Related Studies and Actions Timeline

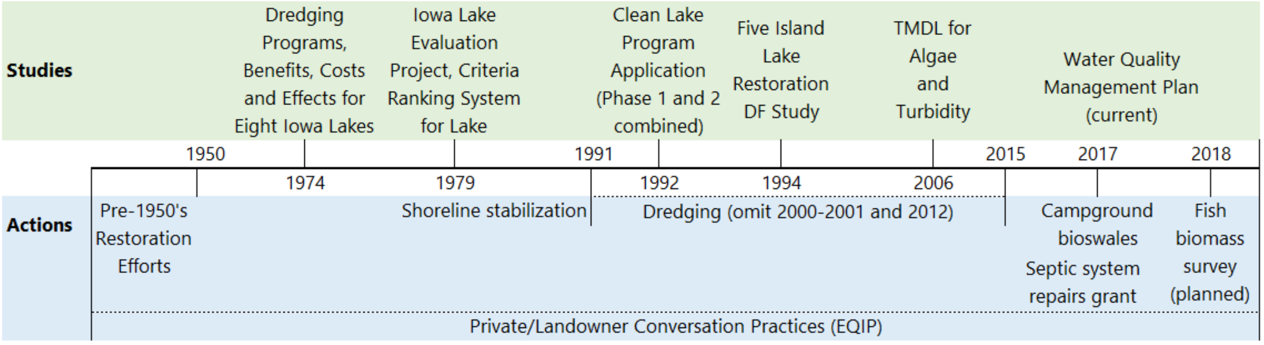


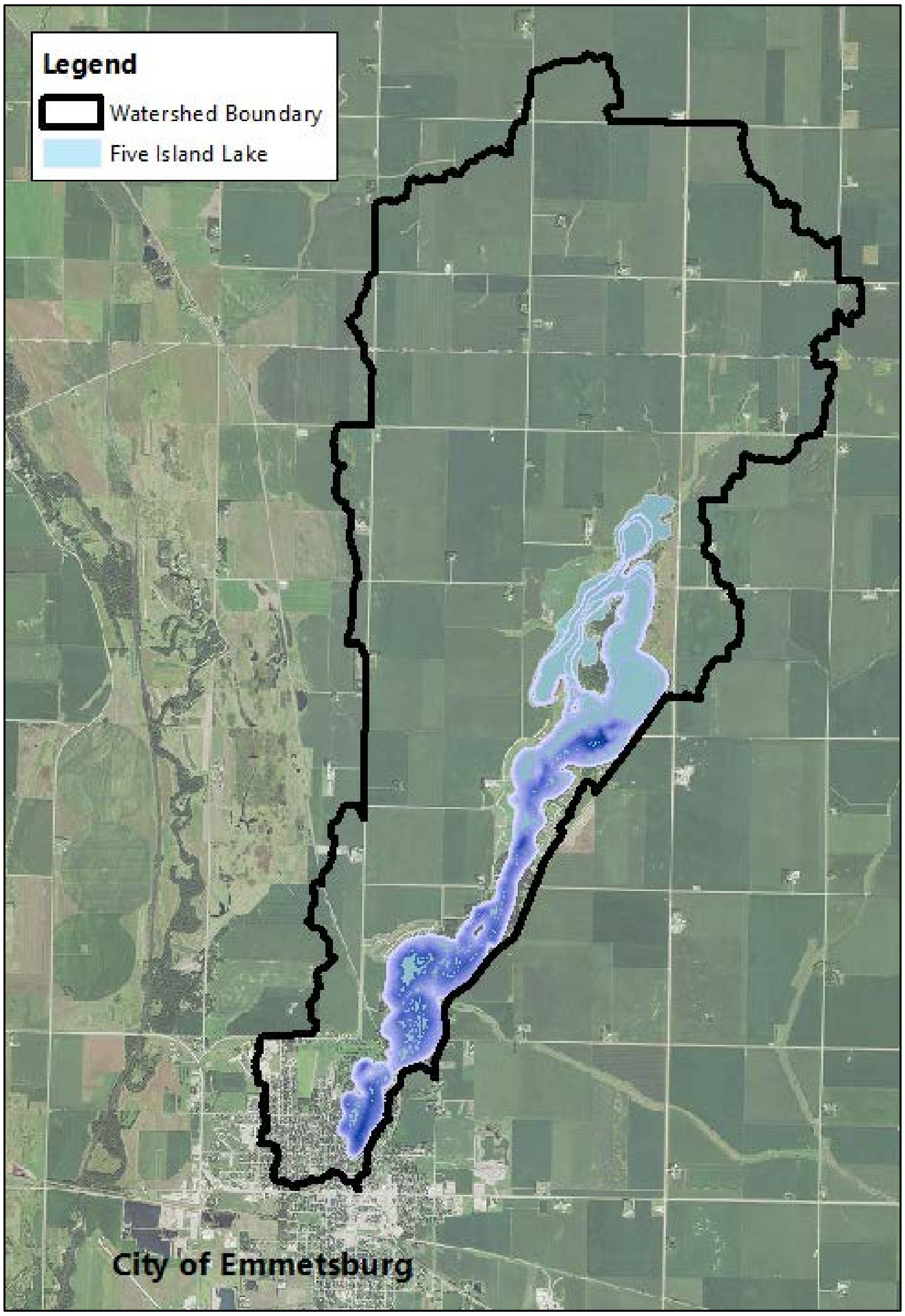
Table 1 – Relevant Past Studies and Reports

Year	Title	Contents
1974	Dredging Programs, Benefits, Costs and Effects for Eight Iowa Lakes	Study of eight lakes to determine impacts of a dredging program. Assessed cost of dredge program against benefits and determine time to recover costs would be 93.8 years.
1979	Iowa Lake Evaluation Project, Criteria Ranking System for Lake Restoration	Ranking of Iowa Lakes. Five Island Lake ranked 20th (of 107) in shallowness. Identified excessive aquatic vegetation, shallowness and non-point pollution identified as main problems at Five Island Lake.
1992	Clean Lake Program - Phase II Application, Five Island Lake	Application for funding to dredge lake. Provides background on previous studies that recommend dredging for water quality improvements and a diagnostic study of the lakes water quality.
1994	Five Island Lake Restoration DF Study	Dredging alternatives analysis
2003	Saving the Glacier's Creation	Background and summary of Five Island Lake restoration projects
2006	TMDL for Algae and Turbidity	Calculation of Total Maximum Daily Load
2012	ISU Paleolimnology Report - Historic Water Quality Conditions in Iowa Natural Lakes	Sedimentation Study - In-filling rates based on coring analysis
2012	DNR Watershed Planning Grant Application	History and background, proposed actions for a watershed coordinator.
2016	Capstone Study	An analysis of drivers of internal loading by Iowa State University (a statewide effort funded by the DNR Lake Restoration Program)

1.3 Background Information

Five Island Lake is a 1,002-acre natural lake that has been enhanced with a man-made embankment and outlet structure to increase water volume and control the surface water outflow. The drainage area delineated during this study is 7,657 acres which yields a relatively low watershed:lake ratio of 8:1. Low ratios are favorable to successful restoration efforts because the watershed generates lower pollutant exports relative to the lake's capacity to receive and process nutrients. Land use primarily consists of agricultural land in the north, west and eastern portions of the watershed, with the urbanized area of Emmetsburg to the south.

Figure 3 – Site Map



Previous studies indicate a history of poor water quality in Five Island Lake, reporting phosphorus concentrations up to 147 µg/L in 1979 (ISU Paleolimnology Report). Additional issues with fish kills and an overabundance of vegetation were reported prior to the installation of an aerator and the commencement of the dredging effort. Currently, the primary concerns include algal blooms, overabundance of rough fish species (e.g., carp and big mouth buffalo) and lack of rooted, aquatic vegetation.

Water quality sampling data, collected 3 times between Memorial Day and Labor Day each year, was summarized from 2002-2016. Key parameters in eutrophic lakes include: phosphorus (the limiting food source for algae in most freshwater lakes), chlorophyll-a (a green pigment in algae which indicates algal abundance), and Secchi disk depths (a physical measurement of water clarity). The Trophic Status Index (TSI) is a classification system designed to rate waterbodies on the amount of biological productivity occurring in the water. Higher TSI values indicate higher productivity, and hence, higher eutrophic conditions. Water quality parameters are reported with their respective TSI values in Table 2.

Table 2 – Five Island Lake Water Quality Summary

Parameter	**2002-2016 Average**	**TSI**
Total Phosphorus (µg/L)	94.4	69
Chlorophyll-a (µg/L)	50.4	67
Secchi Disk Depth (ft)	1.9	69

The average total phosphorus concentration is 94.4 µg/L, and Figure 4 shows that values have ranged from 32 µg/L up to 220 µg/L since 2002. Concentration will also vary throughout the year, and it is important to understand what the levels are during the warm growing season when algal blooms occur. Figure 5 show that the samples were primarily taken during the warmer months, and the average concentration reported above is representative of the growing season.

Figure 4 – Total Phosphorus Concentrations from 2002-2016

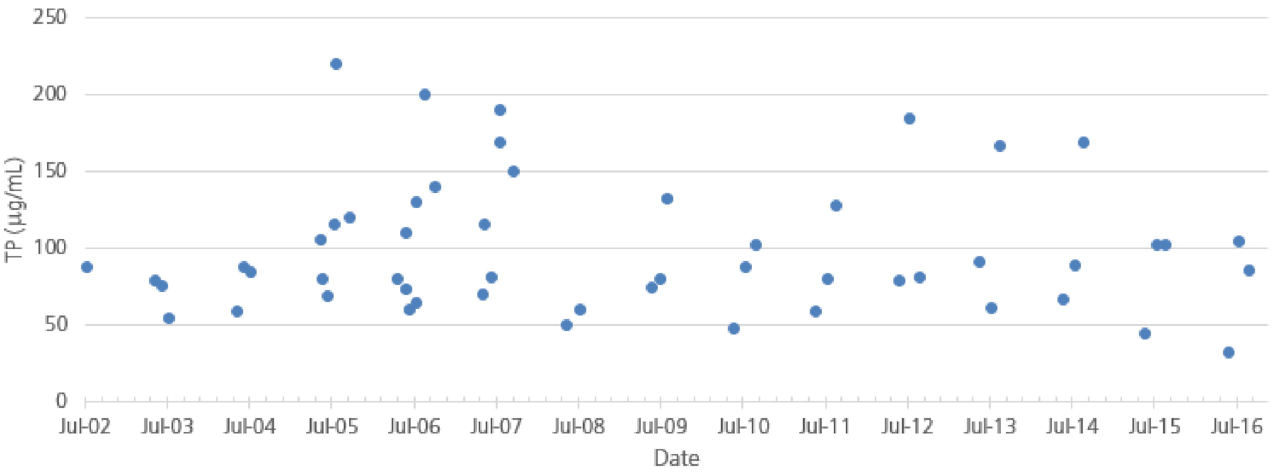
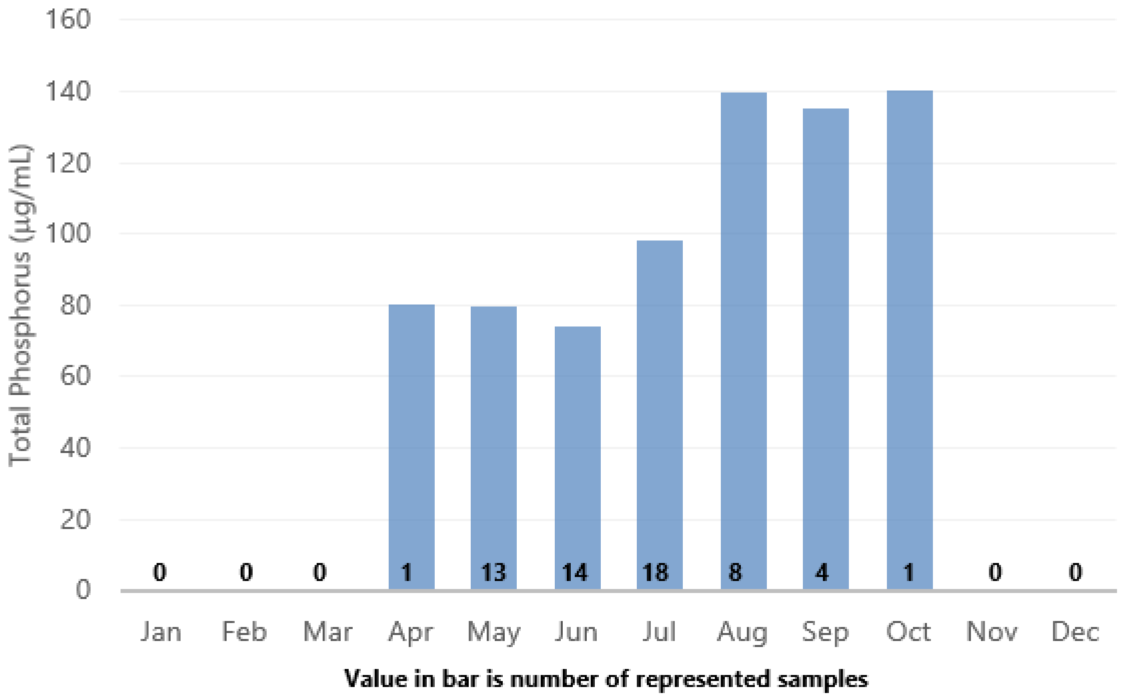


Figure 5 – Monthly Average Phosphorus Concentrations



In order to reduce the potential for algae to grow, phosphorus concentrations should be in the range of 60 to 80 µg/L during the growing season. Different goals were discussed for Five Island Lake during the community based planning process and are reported in Section 2.2.

2 COMMUNITY BASED PLANNING

Public outreach is beneficial to any project to gain insight from stakeholders, receive guidance from local experts, and help establish goals to produce an end product that is socially acceptable to the public. The CBP efforts for included the formation of two committees, conduct coordination meetings with each committee and hold one public meeting. The content of the meetings is generally outlined in Figure 6 to illustrate the process that the committees will take part in.

Figure 6 – Community Based Planning Meeting Outline

CPB Meeting #1

- Introduce the CBP process
- Define role of TAT/WAC
- Develop VISION for the project
- Define the problem
- Discuss (but do not set) goal for project
- Identify immediate tasks for TAT/WAC

Once available data has been collected and organized and the problems and challenges can be conveyed

CPB Meeting #2

- Update TAT/WAC on technical progress
- Discuss lake response to baseline conditions
- Agree on metrics for project success monitoring
- Develop GOALS related to project metrics
- Discuss preliminary alternatives to meet GOALS

Upon model development and methodology has been established to quantitatively predict lake response

CPB Meeting #3

- Update TAT/WAC on technical progress
- Evaluate metrics of alternatives screening
- Discuss lake response to future conditions
- Incorporate public input as desired by TAT/WAC
- Identify potential funding sources
- Discuss next steps: Funding/Grant applications, Plan Revision, etc.

Towards end of project, after alternatives have been screened

2.1 Committees and Roles

The two committees formed were the Watershed Advisory Council (WAC) and Technical Advisory Team (TAT). The WAC consists of interested local citizens that will be informed on lake and watershed processes and concepts. They will help develop goals and provide insight on historical and current lake issues and the local perception of different management strategies. The WAC will spread the knowledge they gain to the community, and help build consensus and public support. They focused their role on identifying nutrient reduction opportunities and developing public educational tools. The members of the WAC are listed in Table 3.

Table 3 – Watershed Advisory Council

Name
Bill Burdick
Roger Faulstick
Gary Koppie
Jim Hobart
Steve Carney
Daniel Reedy
Lisa O'Berg
Mollie Munn
Jeff Stillman

The TAT is comprised of local agencies and leaders with knowledge of technical and financial resources in the area. The TAT understands the efforts taken to date and which items have been more successful than others. The members of the TAT are listed in Table 4.

Table 4 – Technical Advisory Team

Name	Agency
George Antoniou	Iowa DNR
Michelle Balmer	Iowa DNR
Mike Hawkins	Iowa DNR
Jeremy Thilges	NRCS
George Scholten	Iowa DNR
Mark Gulick	Iowa DNR
John Bird	City of Emmetsburg
Bryan Heller	Iowa DNR
Kyle Ament	Iowa DNR
Rick Hopper	Jacobsen-Westergaard

2.2 Outcomes

Meetings that were held for the development of the water quality management plan are summarized in Table 5 (see Appendix for available meeting minutes).

Table 5 – Meeting Summary

Date	Meeting
May 3, 2017 (3:00 p.m.)	TAT (#1)
May 3, 2017 (6:00 p.m.)	WAC (#1)
November 15, 2017 (5:00 p.m.)	WAC/TAT (#2)
March 7, 2018 (4:00 p.m.)	Public Meeting
March 20, 2018 (5:00 p.m.)	WAC/TAT (#3)

Through these meetings the committees identified issues and concerns, and are listed in no particular order related to priority:

- Limited lake level monitoring
- Need locally driven, not model driven project
- Rough fish spawning in shallow areas
- Lack of storm even sampling
- Drainage districts trying to implement a wetland restoration project; encountering land rights issues
- No watershed coordinator
- Storm sewer outlets into the lake
- Sediment and cornstalk wash into southwest portion of lake
- Septic systems around lake – need inspections and potential repairs
- Slight erosion on Fifth Island
- Enforcing boating restrictions
- Aeration system attracting geese in winter
- Need for public outreach and education
- Tile drainage in watershed
- Vegetation in lake is sparse

The main objective identified for this project is to reduce algae and experience better water quality. Approaches to setting goals were discussed and three standards to quantify water quality were provided:

1. Reduce measured algae concentrations to the delisting from impaired waters criteria (chl-a concentration ≤ 27 μg/L = TSI ≤ 63)
2. Increase water clarity to delisting from impaired waters criteria (Secchi depth ≥ 2.6 ft = TSI ≤ 63)
3. Increase water clarity to Iowa DNR Lake Restoration Program standards (Secchi depth ≤ 4.5 ft from April to September)

3 ADDITIONAL INVESTIGATIONS

A healthy fishery is important to the overall health and use of Five Island Lake. Consequently, a detailed analysis of the current condition of the lake's fishery (i.e., the rough fish population) is being conducted this year, with results planned to be available in the Fall of 2018. For the development of this Plan, best available data was used to assume existing rough fish populations and assess possible impacts on water quality. Early in the development of this Plan, concerns were raised about the current condition of the lake's outlet structure. Therefore, an assessment of the outlet structure was performed to identify existing problems/issues and determine the feasibility of potential modifications that could address any identified problems and potentially enhance future water quality conditions and ecological function of the lake. Ultimately, each of these items have a connection to the lake's overall health and water quality and are discussed throughout the plan.

3.1 Rough Fish Assessment

Carp and big mouth buffalo are present, likely in undesirable densities, in Five Island Lake. Both are considered rough fish species, and in large numbers have negative impacts on water quality and ecological function of shallow lakes. Commercial angling data gathered in annual harvests conducted is available, but it is limited in scope and detail. With more detailed information about population and recruitment, approaches to rough fish management can be refined. For the purposes of this Plan, a rough fish biomass density of 250 lbs/ac is assumed, and a post-implementation density of 100 lb/ac was assumed. These assumptions were necessary to simulate the impact rough fish on water quality (discussed in Section 4). Integration of fish renovation (methods and considerations) in combination with other improvement alternatives is discussed in Section 7.

3.1 Outlet Structure Assessment

The outlet structure was assessed during multiple site visits. The current outlet structure is a circular weir approximately five feet in height and around twelve inches thick. The effective length of the weir is approximately 34 feet long and conveys flows to a 5'H x 8'W reinforced concrete box (RCB) culvert that passes under the lake circulation road. The RCB empties into an open channel area that is then blocked by North Huron Road. There are two metal pipe culverts that pass through North Huron Road 36" and 24" in diameter. The weir portion of outlet structure appears to be working as designed and in relatively sound structural condition.

Figure 7 – Outlet Structure Photos

Significant sediment deposition is present in the forebay leading to the weir and can be visually observed to the level of the weir crest, and a small portion of the weir was covered with sediment and vegetation during the site visit. This affects weir discharge capacity and therefore, depending on other potential management strategies, some localized dredging should be considered for the forebay area. The capacity of the downstream culverts under North Huron Road, however, are the limiting features to the magnitude of outflow from the lake.

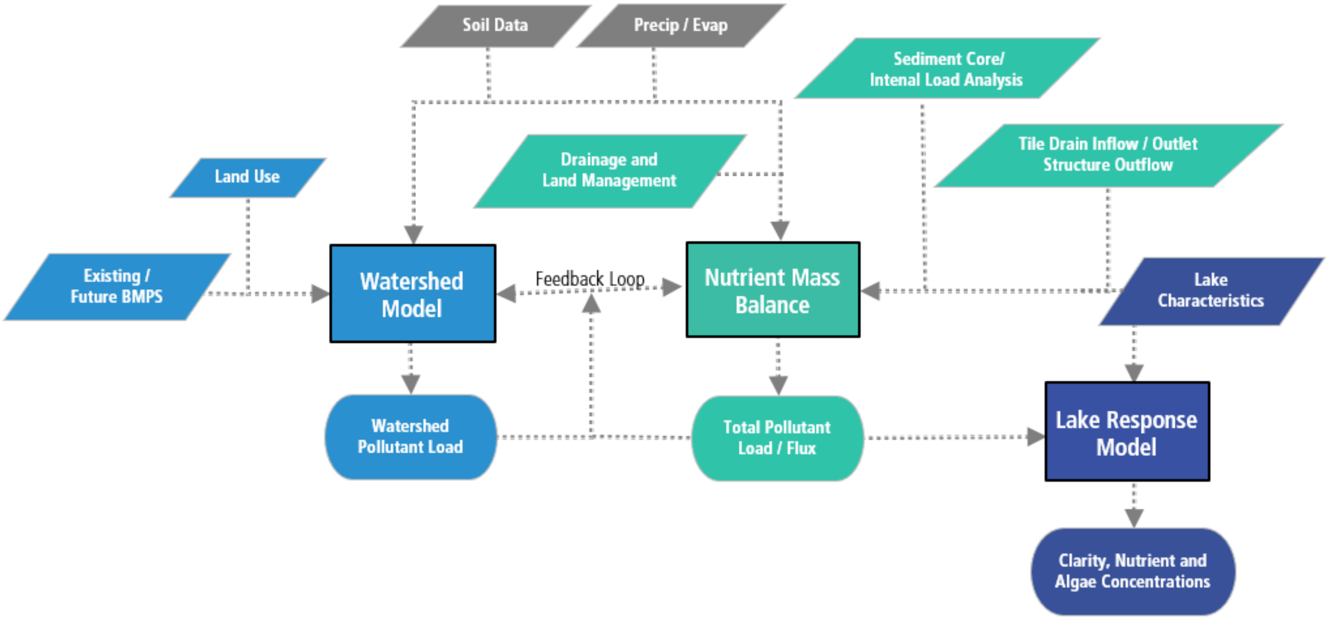
Structural Assessment

The structural condition of the weir itself appears to be in sound condition. Some minor concrete spalling is evident where the weir connects to the RCB headwall, but no exposed steel reinforcement was visible. The spalling should be monitored, but no proposed modifications to the weir structure are deemed necessary at this time. The RCB headwall and endwall are damaged, likely from vehicle collisions, but they do not appear to affect the performance or structural integrity of the outlet structure weir.

4 MODELING APPROACH

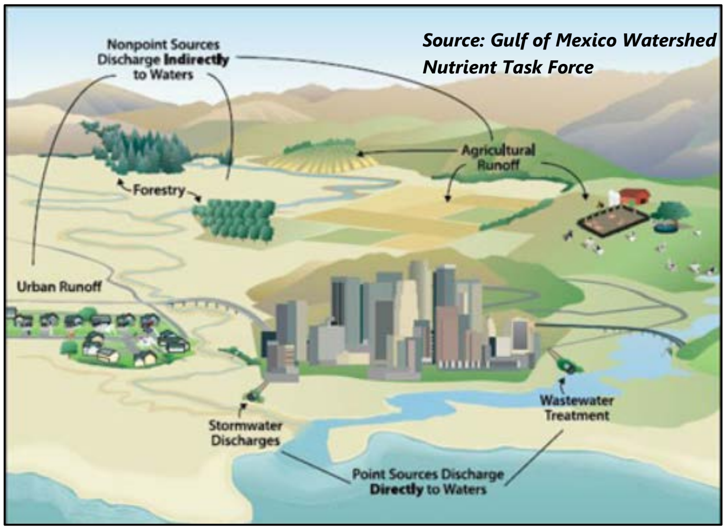
Three different models were developed for Five Island Lake. These models work together to collectively provide a unique set of tools specific to Five Island Lake used for decision making during the planning process. Figure 8 depicts the data inputs and interactions between the model output that was used for this Plan. The models can simulate changes that represent different management practices either in the watershed or in the lake, and will predict the lake's response. This will guide the process in determining how much needs to be done to reach the water quality goals identified.

Figure 8 – Modeling Schematic



4.1 Watershed Loading

Figure 9 – General Watershed Schematic



Source: Gulf of Mexico Watershed Nutrient Task Force

Watershed models are developed to identify pollutant sources and quantify the pollutant loads associated with each source. The Spreadsheet Tool for Estimating Pollutant Loads (STEPL) model used for this project incorporates data from the watershed and performs hydrologic computations to quantify annual flows and associated pollutant loads. Existing conditions can be analyzed to identify high contributing areas and/or sources (i.e., priority areas/sources). Implementation of conservation measures to address these priority areas/sources has a large potential impact on water quality. One of the greatest benefits of a watershed model is the ability to simulate load reductions from best management practices (BMPs). The model can be used to determine the amount of BMPs required to reach load reduction goals in the watershed.

The data utilized in the model includes the following standard data that is readily available to the public through cataloged databases:

- Soil information
- Precipitation
- Land use
- Septic systems
- Cattle head count

Additional investigation and data collection was performed to refine inputs and gather more specific information that would impact the location and quantity of pollutant loading. This includes:

- Registered CAFOs and NRCS info on grazing operations
- Manure/fertilization management (from NRCS)
- Existing conservation practices (no till, buffers, WSF from NRCS)
- Tile drain info from NRCS

The Five Island Lake watershed was divided into 5 subwatersheds, as depicted in Figure 10. The land use and existing management practices have a very large impact on pollutant loads. A detailed land use assessment had been performed by Iowa DNR and coordination with the NRCS provided background of general practices and EQIP funds used in the watershed. This information is summarized in Tables 6 and 7.

Figure 10 – Five Island Lake Subwatershed Map

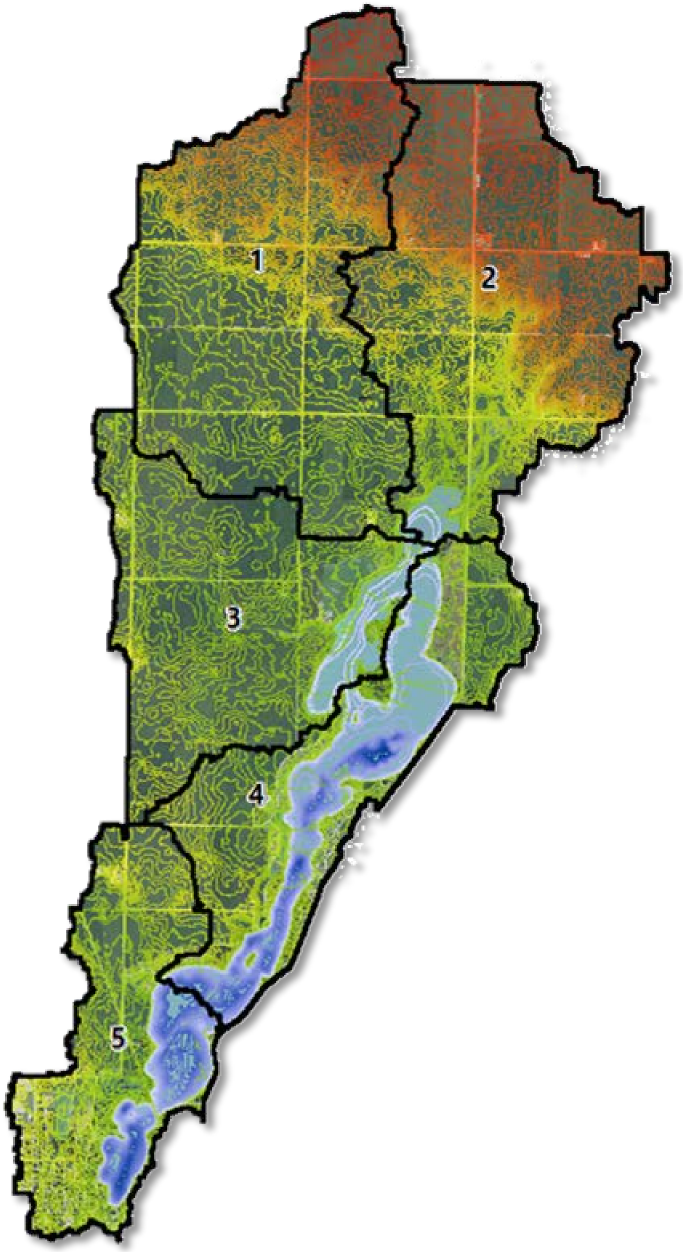


Table 6 – Watershed Information

Land Use	Area (ac)	% Watershed
Urban	784	10%
Cropland	6,332	83%
Pasture	347	5%
Forested	193	3%
Total	7,657	100%

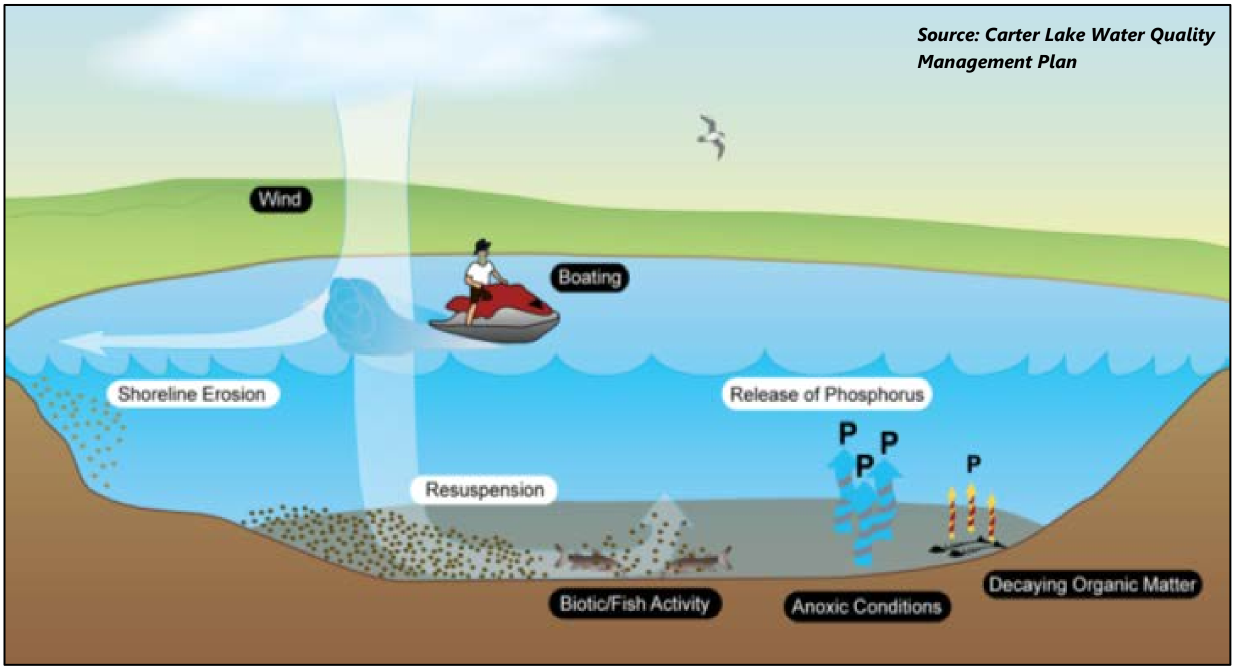
Table 7 – Existing Conservation Practices

Existing Conservation Practices	Area Treated (acres)	% Watershed
Terraces	92	1%
CRP	198	2%
No Till	126	1%
Conservation Till	4,383	49%
Bioswale	0.5	0.1%

4.2 Sediment Cores and Internal Loading

Internal loading is a nutrient pathway that emanates from within the lake itself. Several factors can contribute to internal loading. Shoreline erosion and mechanical disturbances of the lakebed caused by wind, boating or bottom feeding fish can resuspend and mix fine sediment particles and associated nutrients like phosphorus, into the water column. The decay of vegetation also releases nutrients into the water column. If this occurs while algae are present, an algal bloom can occur. The release of sediment-bound phosphorus during anoxic (lack of oxygen) conditions in the sediment layer is another common, often large, contributor to internal phosphorus loading.

Figure 11 – Sources of Internal Loading Diagram



The amount of sediment-bound phosphorus that is available for release was measured for Five Island Lake. Sediment core samples were collected in March 2015 through holes augured into the ice, and a laboratory analysis was performed to determine the phosphorus content. The sampling results indicate there an average of 13 grams of total phosphorus in the top 5 cm of sediment across the bottom of the lake, and that at least 1.5 grams are biologically available for algal growth. This equates to 12,948 lbs of sediment-attached phosphorus readily available for release and uptake. The sediment chemistry analysis indicates that the internal load is a potentially large contributor of phosphorus, and the data was incorporated into a predictive mass balance model, which simulates actual release of sediment-phosphorus to the water column.

4.3 Water and Nutrient Mass Balance

A dynamic water balance model was developed to simulate/predict the lake volume (and corresponding water level) on a daily time-step (Figure 12). Inflows include surface runoff, subsurface (tile) inflows, and direct precipitation. Water outflows include water lost to the atmosphere via evaporation from the lake surface, golf course irrigation use, and water leaving the lake via the overflow spillway (Figure 13).

Figure 12 – Water Budget Model Interface

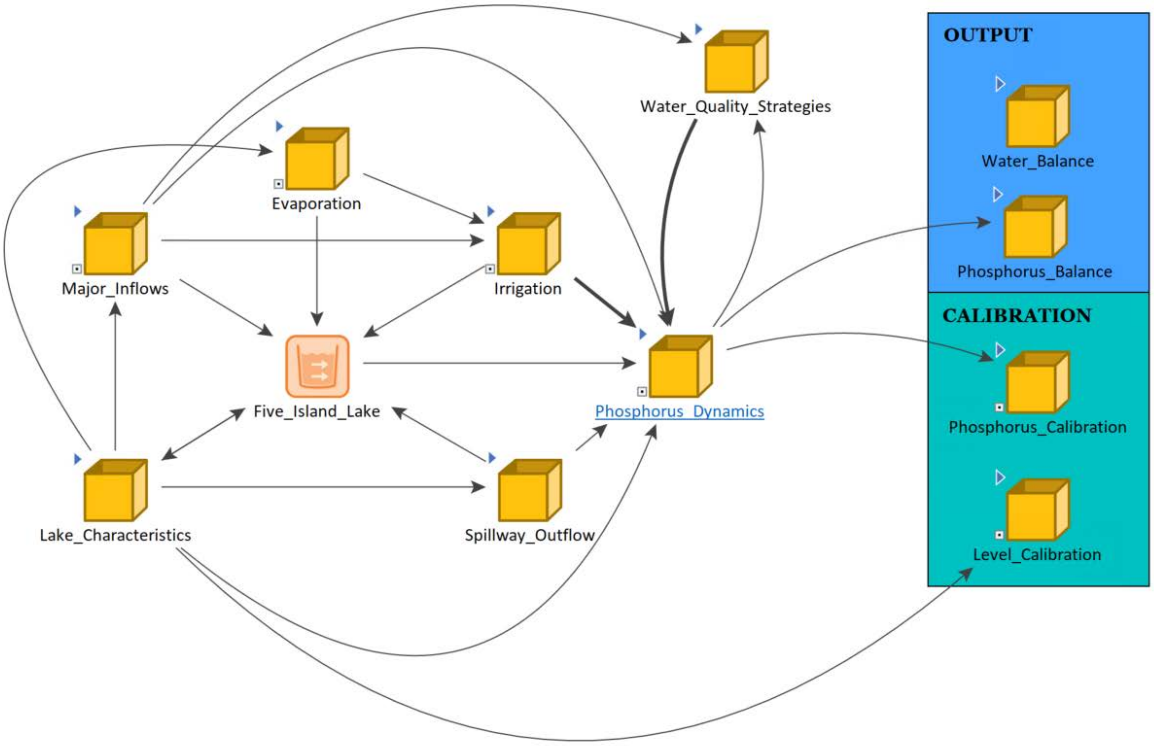
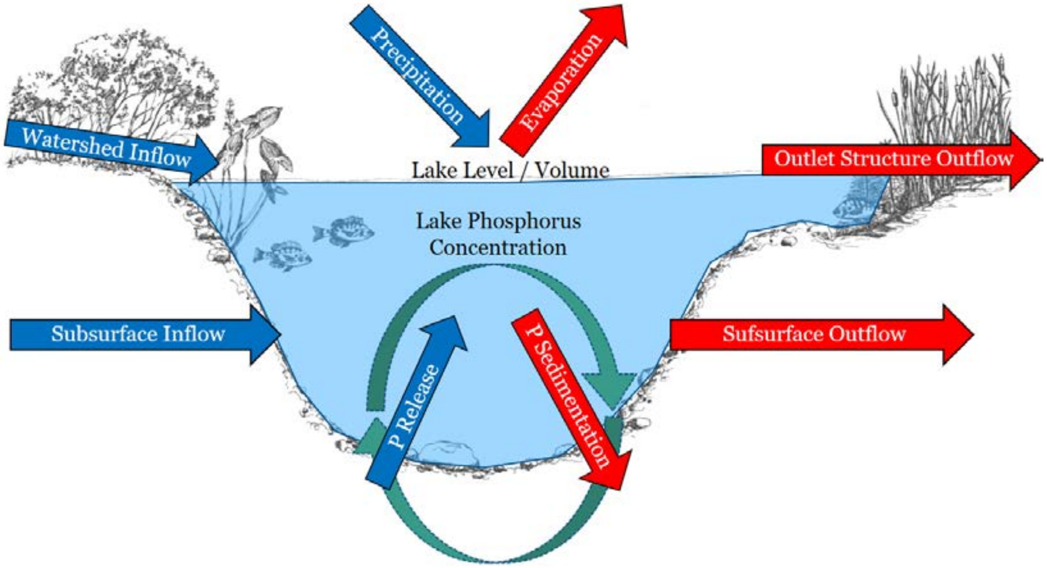


Figure 13 – Mass Balance Schematic



There is very little historical water level information for calibration of the water balance model and validation of model performance. Two historical high-water marks (from flooding events in 2007 and 2014) were obtained from discussions with local citizens and City staff, and frequent observations water elevations have been recorded by City staff since June of 2017. Fortunately, available data reveals that the water balance model represents actual conditions very well, with a Nash-Sutcliffe Efficiency (NSE) value of 0.84, which suggests an accurate accounting of model inflows and outflows (Figure 14 and Figure 15).

Figure 14 – Modeled and Observed 2002-2017 Lake Water Levels

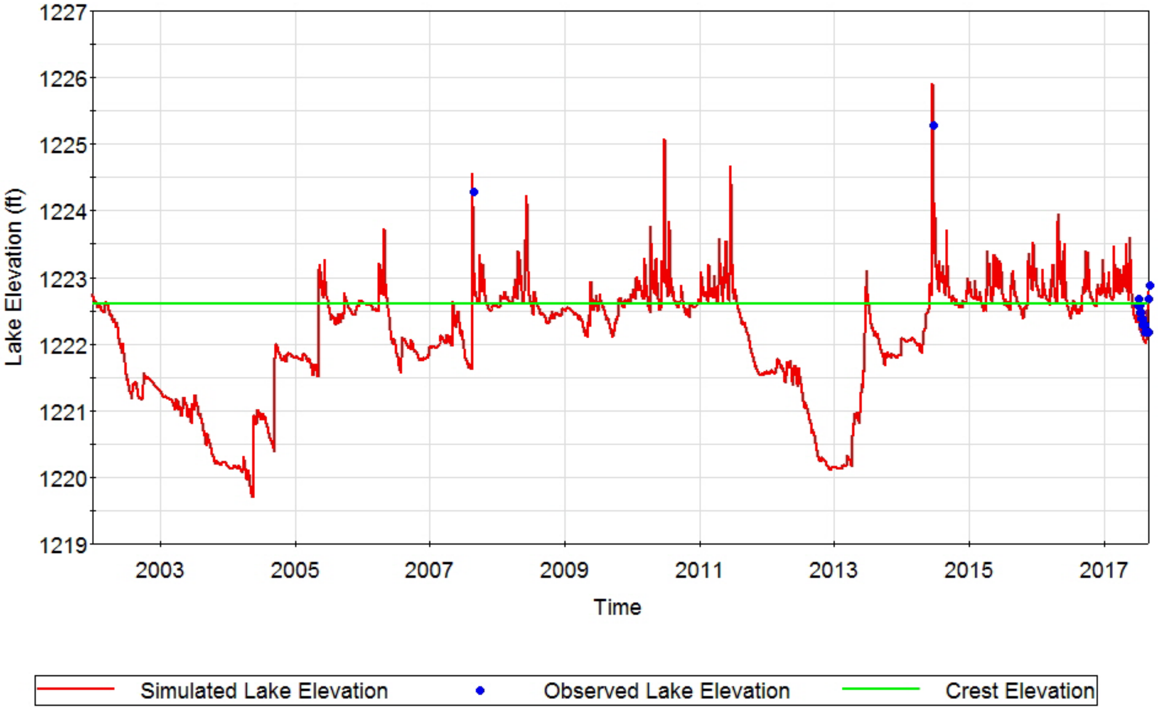
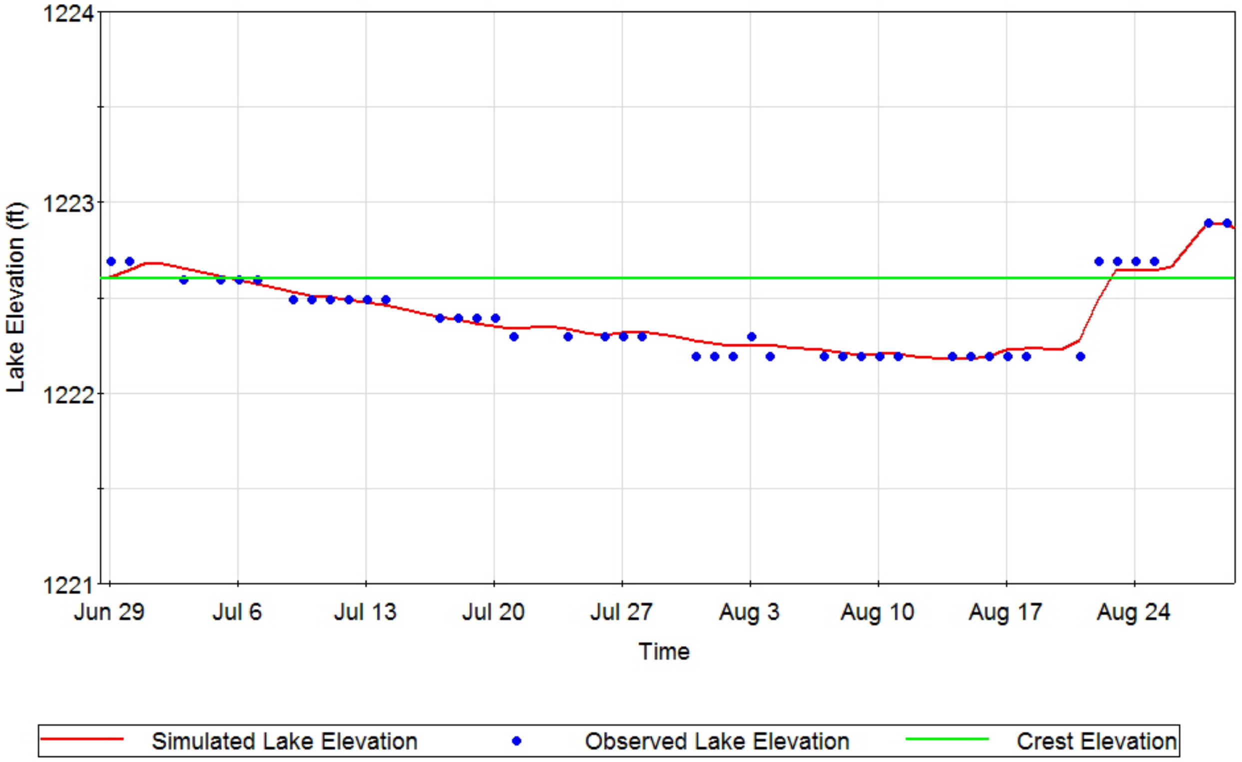
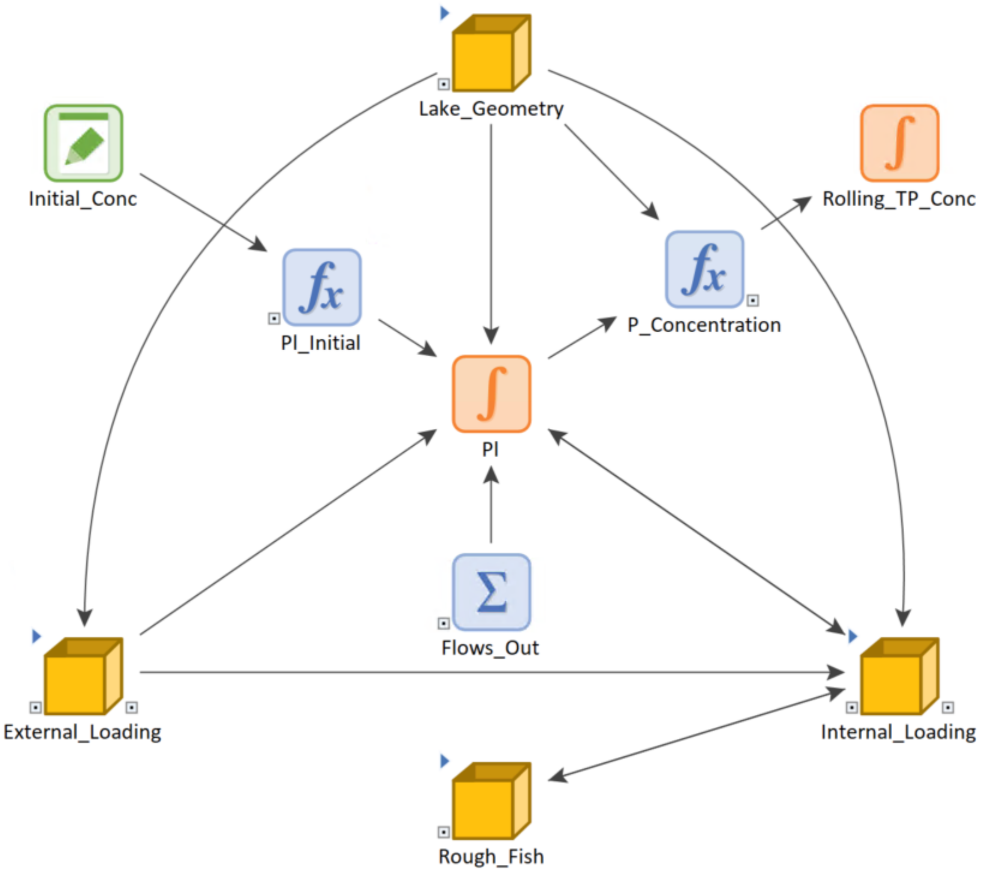


Figure 15 – Modeled and Observed 2017 Lake Water Levels



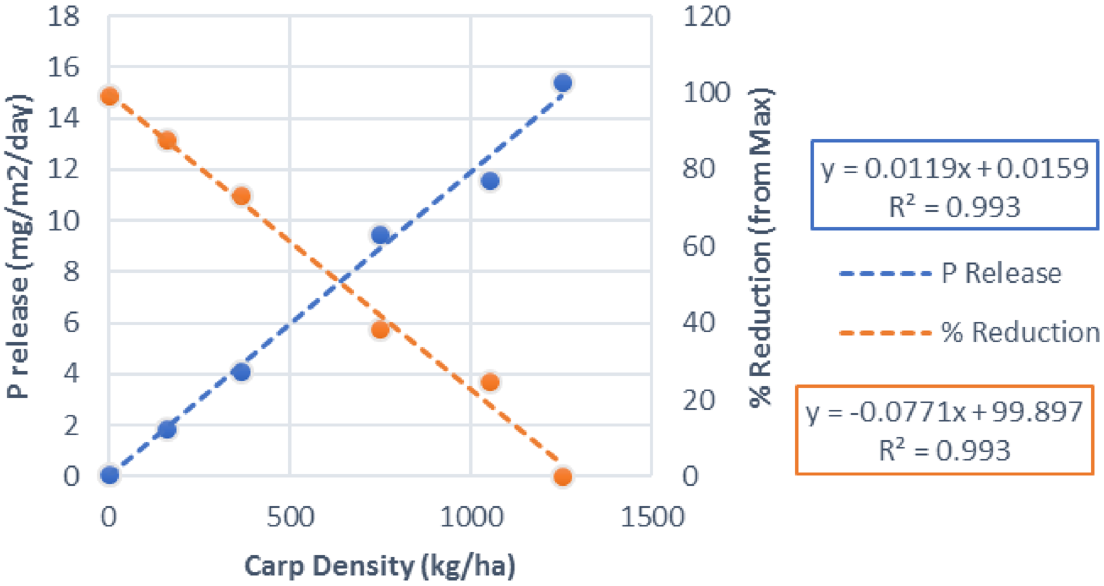
Upon calibration of the water balance model, the associated sources and pathways for phosphorus were added to create the nutrient mass balance model (Figure 16). Phosphorus concentrations were added to the existing flow pathways, with surface runoff and subsurface flow concentrations estimated from relevant tile drain research studies conducted in the region (Crumpton et al., 2012; Ghana et al., 2015). The concentrations were iteratively adjusted during calibration process to maximize agreement with observed in-lake concentrations. The resulting mean surface runoff concentration is 0.76 mg/L, and the mean subsurface flow TP concentration is 0.19 mg/L.

Figure 16 – Nutrient Mass Balance Model Interface



The sediment-phosphorus data described in Section 3.2 was used to inform a subroutine within the mass balance model that predicts the internal release rate of sediment-attached phosphorus from the bottom of the lake (Jensen et al., 2006). The mass balance model simulates phosphorus settling and sediment release based on the hydraulic loading rate, mean depth, sediment-phosphorus concentration, temperature, and water column concentration. The internal loading algorithm was modified using the work of Lamarra (1975) and others to quantify the potential impacts of rough fish on the internal phosphorus release rate (Figure 17). A rough fish biomass concentration of 250 lbs/ac was assumed for baseline conditions, with a temperature sensitive factor added to introduce seasonality. This assumed rough fish biomass concentration may need refinement upon receipt of the ISU fish population survey.

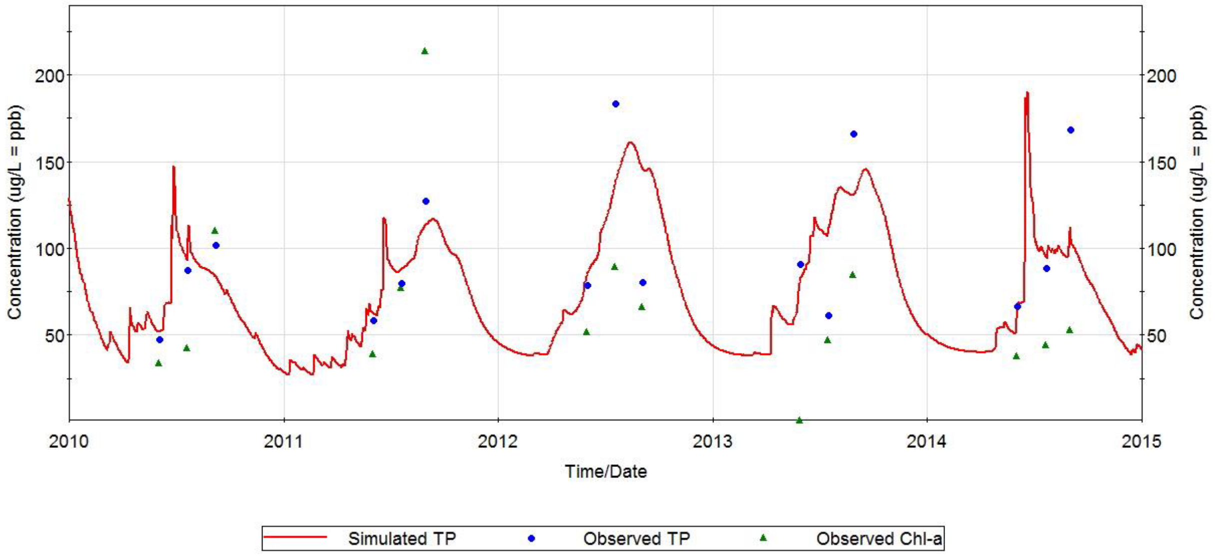
Figure 17 – Carp Biomass and Phosphorus Release



Adapted from Lamarra, 1975

Short-term fluctuation of phosphorus in a eutrophic lake is a dynamic and complex phenomenon, and simulating this behavior is inherently difficult. However, understanding short-term trends and behavior is important for better assessing the true condition of the lake and for evaluating potential benefits of water quality improvement strategies. With those goals in mind, the calibrated mass balance model provides satisfactory simulations of daily phosphorus concentrations (NSE = 0.44). The overall range and timing of phosphorus concentrations are well-represented (Figure 18) and the mass balance model will provide meaningful insights for prioritization and assessment of management alternatives.

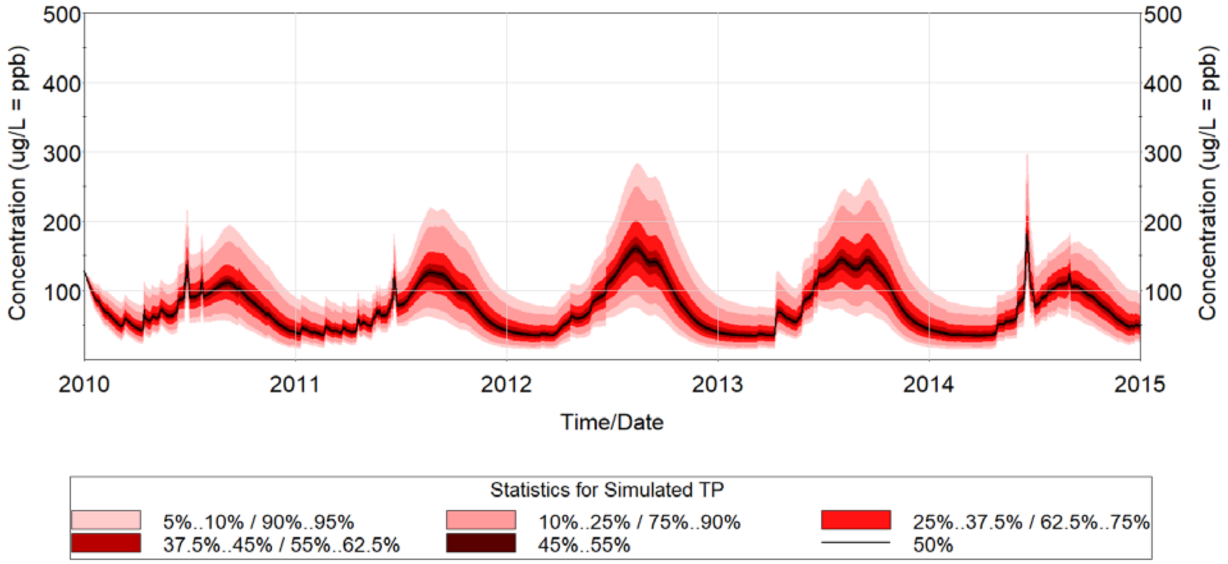
Figure 18 – Simulated and Observed 2010-2015 Phosphorus Concentrations



The primary use of the water and nutrient mass balance model is to predict baseline conditions and the impacts of management strategies. As simplified representations of complex systems, models are not capable of replicating natural processes perfectly. Fortunately, the water and nutrient mass balance model for Five Island Lake features the ability to quantify and predict parameter uncertainty and illustrate the potential impacts of uncertainty to help guide the decision-making process. The practical benefits of this feature include the ability to better assess model reliability, predict the probability of water quality conditions (for both existing and post-implementation conditions), and quantify likelihood of obtaining desired water quality goals at specified levels of implementation.

Parameter uncertainty is defined by evaluating relevant, available data sets that may be from other systems or studies. For example, uncertainty in subsurface flow phosphorus concentrations are represented by using a mean TP concentration of 0.19 mg/L obtained from research literature, and applying a normal probability distribution to the data, with a standard deviation of 0.17 mg/L (also obtained from literature data). Probability distribution statistics were also defined for other potentially significant sources of variation in the input parameter set. The GoldSim software uses this information along with Monte Carlo statistical methods to run a large number of simulations, with each simulation based on a random sampling of all the probability distributions that define model inputs. This produces a series of confidence bands for all related model parameters, which quantifies both the magnitude of the simulated variable and the probability that parameter values are met or exceeded. This approach, called stochastic modeling, is best illustrated by the example shown in Figure 19, which shows the quantified uncertainty in phosphorus concentrations previously reported in Figure 18.

Figure 19 – Uncertainty Analysis of Simulated Phosphorus Concentrations



4.4 Lake Response

BATHTUB is a steady-state lake response model that simulates eutrophication-related water quality conditions. Pollutant load outputs from STEPL and GoldSim were incorporated into BATHTUB along with lake characteristics. BATHTUB computes the lake's response to predict total phosphorus, chlorophyll-a, transparency i.e., Secchi depth, and associated TSI values using empirical relationships.

The BATHTUB model of Five Island Lake utilizes the Canfield-Bachman equation to simulate total phosphorus, predicts chlorophyll-a based on phosphorus using a relationship established by Jones and Bachman, and simulates Secchi depth using an algorithm that considers both chlorophyll-a and non-algal turbidity. The model was segmented as illustrated in Figure 20, but was calibrated only to the segment in which ambient water quality data is collected by the DNR (green segment in Figure 20). The model required very little calibration for any simulated parameter and predicted phosphorus, chlorophyll-a, and Secchi depth very well (Table 8). The calibrated BATHTUB model was used to predict lake's water quality response (algae and transparency) to simulated phosphorus reductions, which helps identify the extent of reductions needed to meet project water quality goals. This was performed for Five Island Lake and is reported in Section 5.3.

Figure 20 – Map of BATHTUB Model Segments

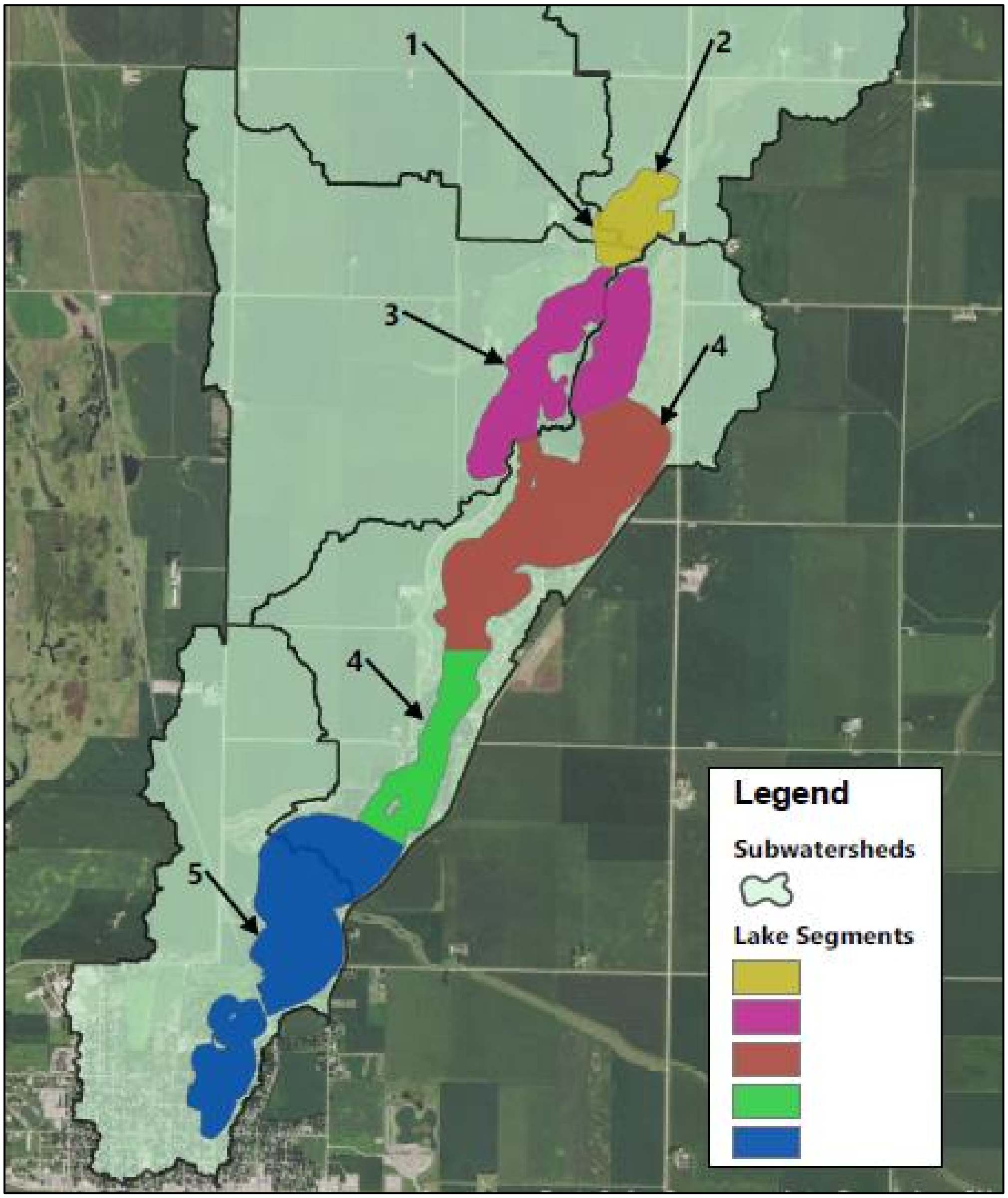


Table 8 – Comparison of Observed Water Quality and BATHTUB Predictions (2010-2014 Averages)

Parameter	Units	Observed	Simulated
TP	ppb	99.5	99.4
Secchi Depth	m	0.5	0.5
Chlorophyll-a	ppb	66.3	66.5

5 POLLUTANT LOADS AND LAKE RESPONSE

5.1 Pollutant Source Load Allocation

The watershed model results indicate an annual total external load of 6,617 lbs. The subwatershed table and figure below report how the phosphorus load is distributed throughout the watershed.

Table 9 – Total Annual Phosphorus Load by Subwatershed

Subwatershed	TP Load (lbs)	%
1	2,031	31%
2	1,869	28%
3	1,020	15%
4	651	10%
5	1,045	16%
Total	6,617	100%

Figure 21 – Total Annual Phosphorus Load by Subwatershed

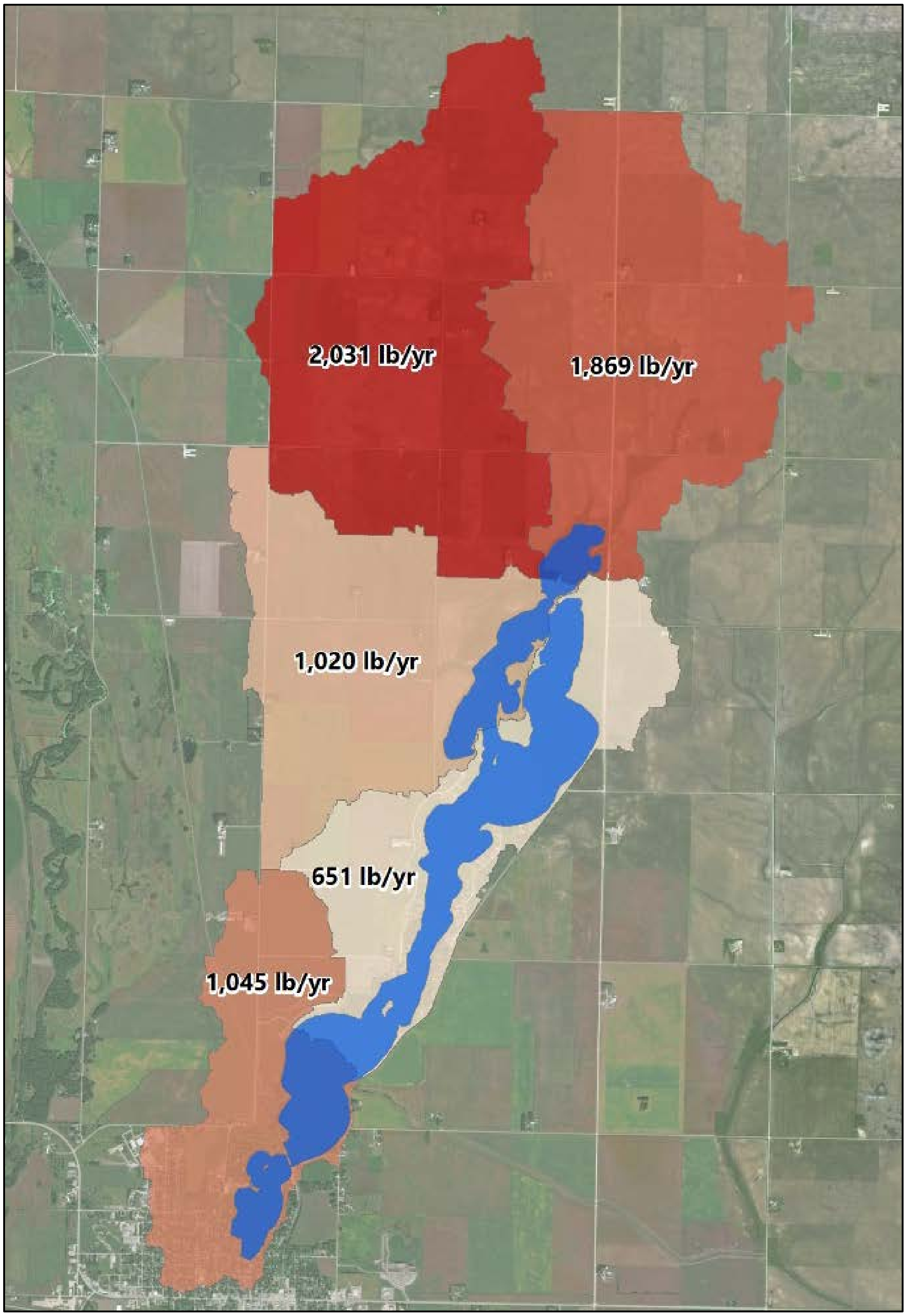


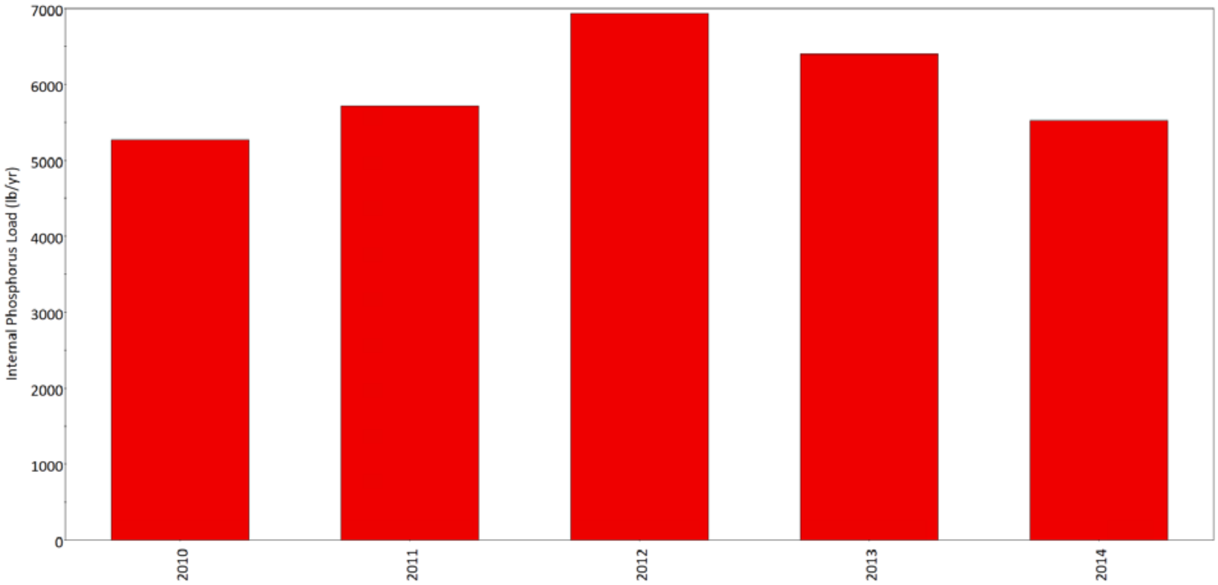
Table 10 summarizes the load by source, as well as reporting the break down between surface and subsurface (primarily tile drain) flow. The phosphorus loads from surface and subsurface flow are nearly equal. The majority of the watershed is cropland, so it is not surprising that it generates the majority the watershed load (78%).

Table 10 – Total Annual Watershed Phosphorus Load by Source

Source	Surface (lbs)	Subsurface (lbs)	Total (lbs)	%
Urban	783	108	891	14%
Cropland	2,023	3,144	5,167	78%
Pastureland	77	47	125	2%
Forest	14	4	18	0%
Feedlots	346	0	346	5%
Septic	71	0	71	1%
Total	3,313	3,303	6,617	100%

Internal loading of phosphorus from the bottom of the lake is a significant contributor to water quality problems in Five Island Lake. This phenomenon is driven by several factors, including sediment chemistry, temperature/seasonality, mechanical disturbance due wind or boat-induced mixing, rough fish (e.g., carp and big mouth buffalo) and sometimes lack of dissolved oxygen at the sediment/water interface. Because these factors are always changing, growing season internal loads vary with time, and even vary from year to year. The water and nutrient mass balance model simulates internal loading, and allows quantification of internal loads in a dynamic fashion (Figure 22).

Figure 22 – Growing Season Internal Loads



The allocation of the annual phosphorus loads impacting water quality is presented in Table 11. The annual summary does not illustrate seasonality of loads, but seasonality is accounted for in the nutrient mass balance modeling described below.

Table 11 – Total Annual Phosphorus Load Breakdown

Origin		TP Load (lbs)	%
Watershed	Surface	3,314	53%
	Subsurface	3,303	
Internal (Growing Season)		5,969	47%
Total		12,586	100%

5.2 Dynamic Simulations

The water and nutrient mass balance model can predict resulting water levels and in-lake phosphorus concentrations on a daily time-step, more accurately representing the timing of the loads delivered to the lake and short-term fluctuation in water quality.

The mass balance and nutrient budget model was also used in conjunction with the STEPL watershed model to determine the total watershed load and proportions delivered to the lake via surface and subsurface flow. The model determined that while approximately 80% of the water from the watershed is delivered to the lake from subsurface flow, it accounts for only 50% of the watershed phosphorus load, with the other half emanating from surface runoff.

Figure 23 – Modeled Subsurface Flow (SSF) and Surface Runoff Volumes

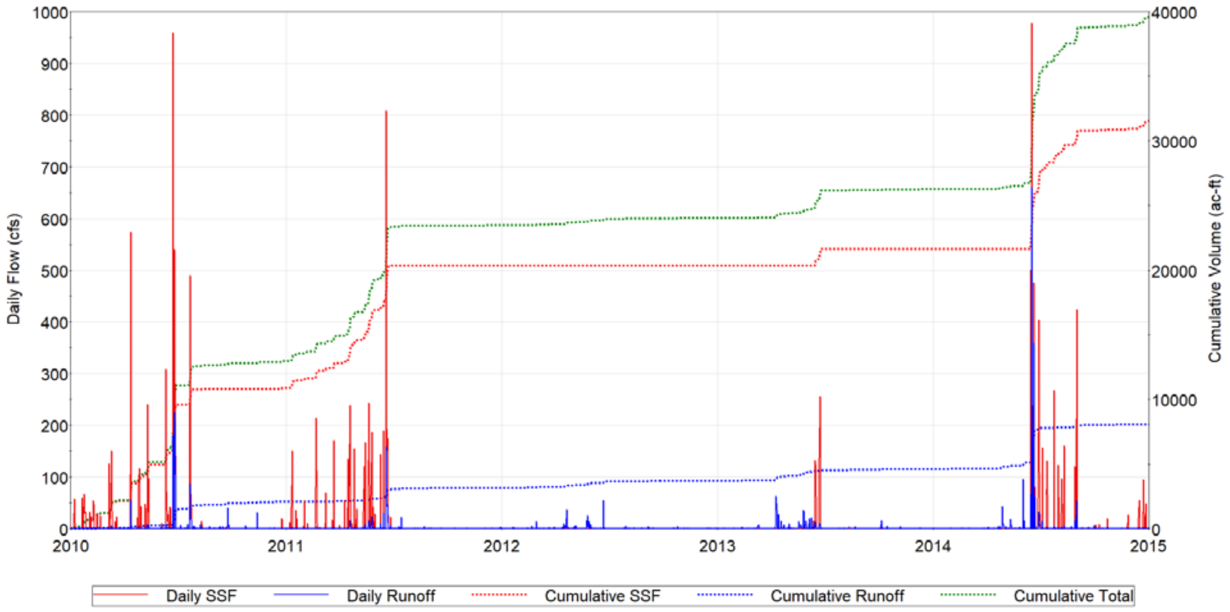
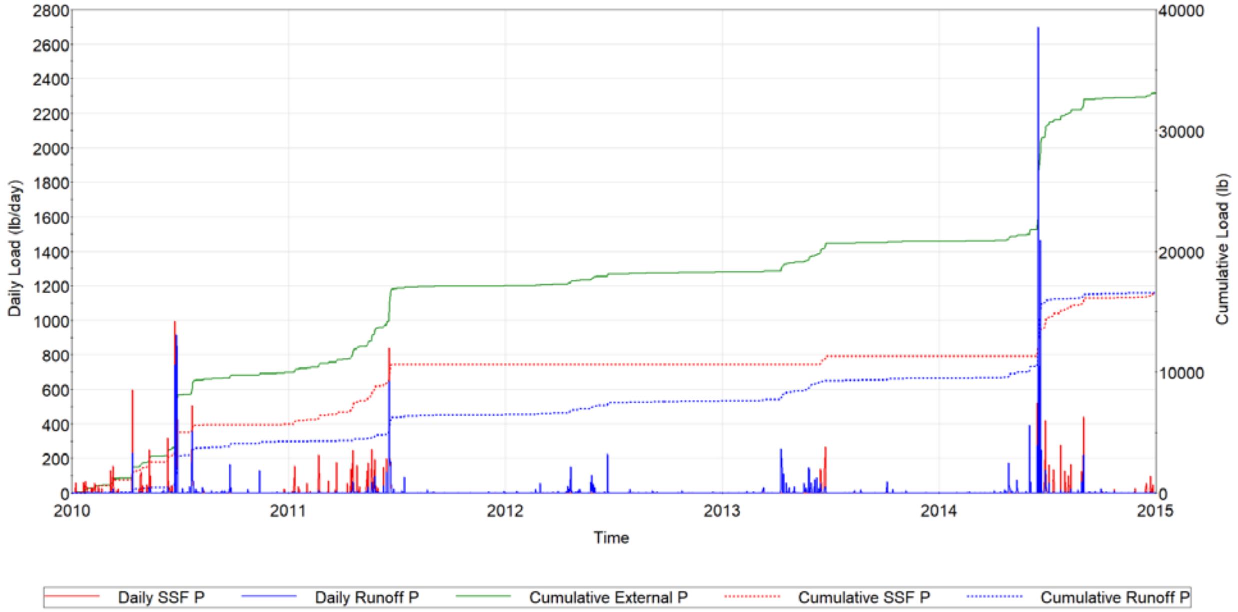
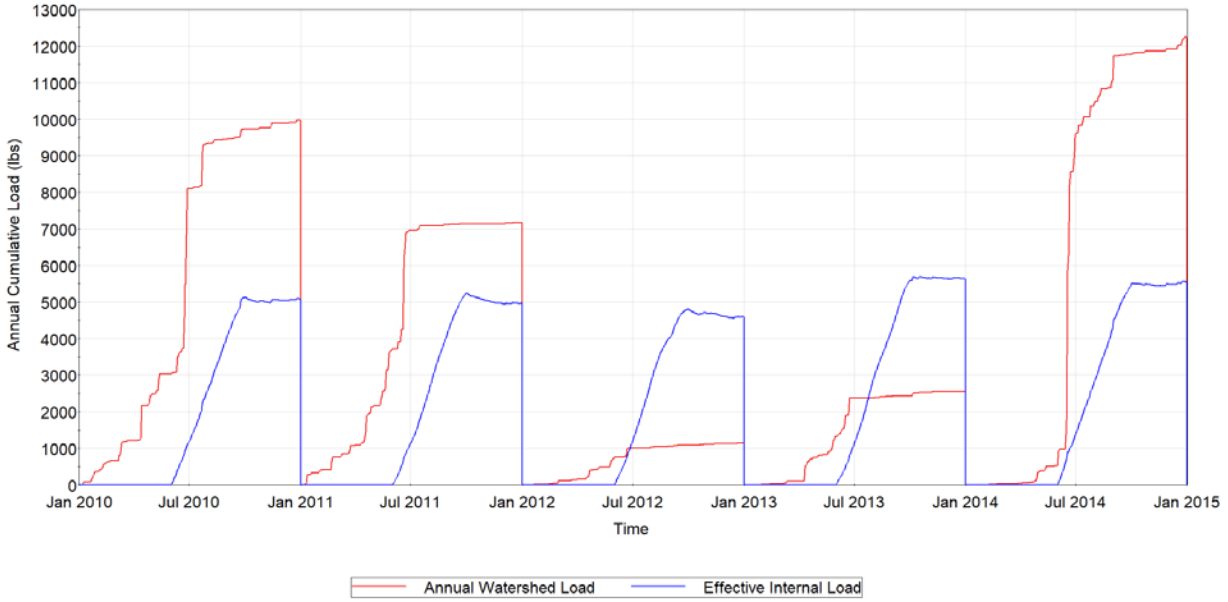


Figure 24 – Modeled Subsurface Flow (SSF) and Surface Runoff Phosphorus Loads



The timing and magnitude of the watershed and internal loads are depicted in the figure below. The majority of watershed loads occur in late spring during wet conditions. Conversely, internal loads spike during mid-lake summer. This figure also depicts how the magnitudes and relative importance of each both sources vary year to year. This variation is largely driven by different rainfall quantity, frequency, and intensity.

Figure 25 – Cumulative Annual Watershed and Internal Phosphorus Loads



Because the major phosphorus pathways and important variables are explicitly accounted for in the mass balance model, the model can be modified to represent potential water quality improvement strategies and predict the expected lake response. The water and mass balance model for Five Island

Lake was used to develop, assess, and prioritize potential water quality improvements, as described in Section 6.

5.3 Load Reduction Goals

The Five Island Lake BATHTUB model was used to simulate the improvements in water clarity and algae levels to phosphorus load reductions. The load reduction required to reach each of the three goals discussed under Section 2.2 were interpreted from the BATHTUB output reported in Table 12.

1. Reduce measured algae concentrations to delisting from impaired waters criteria (chlorophyll-a TSI ≤ 63 = concentration ≤ 27 µg/L) = **67% Load Reduction**
2. Increase water clarity to delisting from impaired waters criteria (Secchi depth TSI ≤ 63 = Secchi depth ≥ 2.6 ft) = **40% Load Reduction**
3. Increase water clarity to Iowa DNR Lake Restoration Program standards (Secchi depth ≥ 4.5 ft form April to September) = **70% Load Reduction**

Table 12 – Lake Response to Annual Load Reductions

% P Load Reduction	TP		Secchi		Chl-a	
	µg/L	TSI	ft	TSI	µg/L	TSI
0%	101.7	71	2.0	69	69.1	72
20%	89.5	69	2.3	66	57.3	70
30%	82.9	68	2.3	65	51.2	69
40%	75.8	67	2.6	63	44.9	68
50%	68.2	65	3.3	61	38.4	66
60%	59.8	63	3.6	58	31.7	64
70%	50.4	61	4.5	55	24.7	62
80%	39.6	58	6.2	52	17.4	60
90%	26.4	51	9.8	44	9.6	53

Table 13 – Annual Load Reductions Goals

Origin	Annual Load (lbs)	%
External	6,617	53%
Internal	5,969	47%
Total	12,586	100%
Reduction Goal	5,034-8,810	40-70%

6 MANAGEMENT ALTERNATIVES

Model results and an understanding of the sources and the nature of the pollutants in this landscape were used to identify and assess a suite of water quality improvement strategies. The general placement for the practices are broken down in the following categories:

- Watershed-Based
- Near-Lake
- In-Lake

A general description of each practice is provided, along with an assessment of water quality benefits (i.e., phosphorus reduction) and costs.

6.1. Watershed-Based Management Practices

- Cropland Practice Improvements
- Livestock Management
- Urban Practices
- Septic Repairs
- Construction Ordinances

6.1.1 Cropland Practice Improvements

Description – Incorporation of additional conservation practices in lands supporting row crop production will improve soil health and water quality. Many nonstructural management practices reduce soil erosion and increase infiltration, which reduces sediment and phosphorus transported to the lake. Structural conservation practices provide the next level of protection that intercept and trap/ treat pollutant loads during transport. In the poorly-drained landscape surrounding Five Island Lake, subsurface tile drainage has been used extensively to improve row crop production. This feature alters water and nutrient transport, and must be considered when selecting and locating conservation practices.

Ability to Assist in Achieving Goals – Because cropland the majority of the drainage area to the lake, and hence the largest source of phosphorus exported, implementation of agricultural conservation practices provides significant opportunities to reduce phosphorus losses to the lake. Non-structural management practices that are most applicable to the Five Island Lake watershed include (but are not limited to):

- Conservation tillage and no-till farming
- Cover crops
- Extended crop rotations (to include small grains and/or hay)
- Fertilizer and manure management

- Increased perennial vegetation using the Conservation Reserve Program (CRP) or Wetland Reserve Program (WRP)

Structural conservation practices can be implemented by private landowners on fields and waterways on their property. The watershed for Five Island Lake is dominated by gentle sloped terrain with many low-lying depressions and a subsurface tile drainage. Consequently, commonly-used structures such as terraces and farm ponds are not suitable in much of the watershed. Practices that focus on filtration and nutrient uptake are more appropriate for this watershed include:

- Grassed waterways
- Riparian buffer strips (traditional and saturated buffers)
- Restoration of pothole wetlands
- Iron-enhanced sand filters

Qualitative Description of Cost – The cost of implementing non-structural conservation practices varies widely depending by practice type and position in the landscape. There are a wide range of Federal programs available largely through USDA-NRCS that provide cost-share for conservation practices, but the implementation is voluntary through landowner participation. Applications to the NRCS Environmental Quality Incentives Program (EQIP) that are located within the drainage area to Five Island Lake will be given priority points when applications are evaluated. The iron-enhanced sand filter is not an approved practice for cost sharing and is not a traditional practice commonly applied in the watershed. Implementation of this alternative would require additional education and design assistance, which could be a task for a watershed coordinator. A watershed coordinator would also assist USDA-NRCS employees with landowner/operator outreach and education. a This focused attention on the drainage area to Five Island Lake should increase the rate of adoption and implementation of voluntary conservation practices.

6.1.2 Livestock Management Practices

Description – While all registered concentrated animal feeding operations (CAFOs) are required to have proper storage facilities, smaller animal feeding operations and grazing operations are unregulated. Smaller operations should develop a Comprehensive Nutrient Management Plan (CNMP) with the NRCS to ensure efficient manure management and prevention of nutrient losses to waterways. Common practices include Waste Storage Facilities (WSF), grazing management (i.e., rotational grazing), and exclusion of livestock from streams (via alternate water sources and fencing).

Ability to Assist in Achieving Goals – Permitted feeding operations in the watershed were mapped, all of which should have the proper runoff controls in place. Based on investigation of aerial photographs, there does not appear to be many unregulated AFOs in the watershed; however, outreach and education may still be helpful to minimize or eliminate any instance where flow is discharged from a feeding operation without treatment. This effort would be significantly aided by the availability of a watershed coordinator.

Qualitative Description of Cost – Similar to the land management practices, the cost varies widely depending on what practice measures are made. Implementation is voluntary by individual landowners in the watershed, but is encouraged and assisted (technically and financially) by USDA-NRCS. A designated watershed coordinator would help identify opportunities and coordinate these practices.

6.1.3 Urban Land Practices

Description – There are a different set of practices that are suitable for urban area, but similar to cropland practices, there are non-structural and structural opportunities. Non-structural practices or ordinances can be implemented to reduce the amount of nutrients introduced into the runoff. Structural practices provide the next level of protection that trap and/or treat pollutant loads that are generated from urban land uses and transported with overland runoff.

Ability to Assist in Achieving Goals – Since urban area is a small portion of the land use in the watershed, it is not a major contributor of phosphorus to the lake. However, the phosphorus loading rate (pounds per acre) is high, so efforts to reduce the amount of nutrients generated from urban land have some water quality benefit. Further, cooperation and adoption by urban landowners often increases participation by rural residents and farmers. Non-structural management practices that are most applicable to urban areas in the Five Island Lake watershed include (but are not limited to):

- Use of no-phosphorus fertilizer
- Pet waste management
- Soil quality restoration

Structural conservation practices can be implemented by private landowners to treat runoff from individual properties. Similar to the bioswale implemented in the campgrounds, larger properties that have to the space and ability to treat concentrated flow are encouraged. The local golf course may have these opportunities and a watershed coordinator could also help identify and orchestrate urban practices. Structural practices that focus on filtration and nutrient uptake that would be highly suitable for this watershed include:

- Rain Gardens
- Bioswales

Qualitative Description of Cost – Costs will vary dependent upon the particular practice. Stormwater ordinances may cost little to implement, with only minor costs required for public outreach and education. Iowa's Resource Enhancement and Protection (REAP) will provide cost-share for some urban practices. A watershed coordinator would help identify opportunities, coordinate activities, and educate the public on the benefits of urban practices.

6.1.4 Septic System Repairs

Description – Faulty onsite wastewater treatment systems (septic tank and leaching systems) can develop leaks or untreated discharges that contribute pollutants to surface and groundwater. Not only nutrients, but also bacteria that can lead to health concerns. Failing septic systems should be identified and repaired.

Ability to Assist in Achieving Goals – There is limited information on the number of septic systems that are failing, but any system should have routine inspections to ensure proper function. Since the current level of function/failure is unknown, it is difficult to estimate the pollutant load from septic, as well and the load reductions that would be achieved. The relatively small number of systems would not generate a large flux of phosphorus compared to other sources, but would provide overall lake/health benefits. Any site located directly on the lake with an older system is likely to have the biggest impact on the lake from any leaks; these systems should be inspected and repaired as needed.

Qualitative Description of Cost – Dependent upon the problem, repairs to or complete replacement of septic systems can be high for individual property owners. A specific grant opportunity through the Palo Alto Gaming Development Corporation Grant (Casino Grant) that should undoubted be taken advantage of by landowners in the watershed.

6.1.5 Construction Ordinances

Description – Controlling sediment and erosion on construction sites is important to prevent transport of the sediment and associated pollutants to local waterbodies. Common methods for sediment control includes silt fence, erosion control blankets, detention ponds, rock entrances at access points, and haybales or coir rolls as checks along drainage paths within a construction site.

Ability to Assist in Achieving Goals – Any construction directly along the lakefront should have very strict controls to prevent immediate delivery of sediment to the lake. Any development or construction activity should abide by a set of established rules to help protect Five Island Lake. It is understood that the Emmetsburg currently has a policy, but practices throughout the watershed outside city limits could be improved. Potential methods to implement and enforce runoff from construction sites should be investigated in more detail, which may be another potential activity for a watershed coordinator.

Qualitative Description of Cost – Costs associated with this alternative include implementation and enforcement by the responsible entity and relatively minor increased costs to the party responsible for the construction activity.

6.2 Near-Lake Management Practices

Near-lake alternatives, which are capable of treating large drainage areas, provide good opportunities for significant load reductions at improved economies of scale. These features are sometimes installed on private land with potential cost-share dollars, but the City could implement several alternatives upon acquiring the necessary land rights. Examples of some near-lake strategies include:

- Constructed/CREP wetlands
- Detention basins or
- Sediment forebays

6.2.1 Constructed/CREP Wetlands

Description – Wetlands can provide uptake of dissolved phosphorus via the growth of aquatic vegetation and adsorption to wetland soils. Secondary benefits include aquatic habitat and a more diverse ecosystem around the lake. Wetlands initially have relatively high phosphorus removal rates;

however, over time phosphorus-binding decreases as the wetland soils "fill up" with phosphorus. Additionally, phosphorus taken up by plants is released when the plants die and decay. Research suggests the phosphorus removal efficiency in unmanaged wetlands begins to decrease after 5-10 years. During periods of vegetation die-off, nutrients can be released, making the wetland a temporary source of phosphorus to the lake. Ideally, this die-off would occur only after the recreation season has ended, therefore impacts to algal growth and recreational uses should be minimal. With proper management, which may require occasional harvest and removal of wetland vegetation, nutrient uptake can be enhanced and sustained over time.

Ability to Assist in Achieving Goals – Constructing large wetlands at major inlets to the lake could provide substantial phosphorus load reduction. A wetland design that provided treatment of tile drain outlets would have the greatest potential water quality benefits.

Qualitative Description of Cost – Costs associated with constructing wetlands are primarily earthwork and water level control structures. If this is pursued by the City and land rights need to be acquired, that would also be a factor in the cost. If implemented through the Iowa Conservation Reserve Enhancement Program (CREP) and IDALs or the local conservation district, financial incentives are provided to private landowners. Constructed wetlands are also eligible for EQIP funding through USDA-NRCS. If the City pursued a constructed wetland, grant opportunities through REAP, IDALs and/or the Casino Grant should be investigated.

6.2.2 Detention Basins or Sediment Forebays

Description – Detention basins are earth embankment structures installed on tributaries to impound water and help improve water quality by trapping sediment and sediment-attached phosphorus. A sediment forebay is a similar alternative to the detention basin that traps/treats the watershed load, however if there are space/land rights limitations in the uplands, a sediment forebay can be implemented in the lake at a concentrated location of stormwater discharge.

Ability to Assist in Achieving Goals – The design of a detention structure includes impounding a tributary and artificially raising the water level. This is not conducive to intercepting tiling drain outlets that discharge immediately at the lake., however any tile drains that are outlet into overland drainage paths throughout the watershed would be treated. The feasibility of a detention basin at each near-lake outlet should be investigated to ensure the space and topography allowed for a proper design, and care would have to be taken to place detention basins at locations where elevated water levels do not inundate tile drainage outlets and prevent proper drainage from the fields they are draining

Qualitative Description of Cost – The primary cost of detention basins is for earthwork, outlet control structures, and land rights. Sediment forebays are generally constructed with rock, which can be expensive and often limits the size (and trapping efficiency) of the structure. EQIP funds will provide cost-share for private land owners that install detention basin/farm ponds. If the City pursued a constructed wetland, grant opportunities through REAP, IDALs and/or the Casino Grant should be investigated.

6.3 In-Lake Management Practices

- Rough Fish Management
- Wetland Creation
- Shallow Vegetation/Lake Level Management
- Phosphorus Inactivation
- Boating Restrictions
- Dredging

6.3.1 Rough Fish Management

Description – Fish that have bottom feeding habits that disturb lakebed sediments and create turbid conditions are often referred to as ‘rough fish’. The most commons species encountered in the Midwest are common carp and bigmouth buffalo. Controlling the rough fish species reduces the amount of sediment resuspension and release of phosphorus that contributes to internal loading. Reduction of the rough fish population would also facilitate establishment of desirable, shallow aquatic vegetation.

Ability to Assist in Achieving Goals – If the biomass density at Five Island Lake could be reduced down to 50-100 lbs/acres, significant water quality benefits would be achieved though reduced lakebed resuspension/internal loading, and improvements to the aquatic habitat and fishery would be experienced. There are several approaches to managing the rough fish described below that together could bring down the population. These include fish removal, reducing access to spawning habitat (via hard barriers or lake level drawdown), fish passage barriers, and public education.

Fish Removal

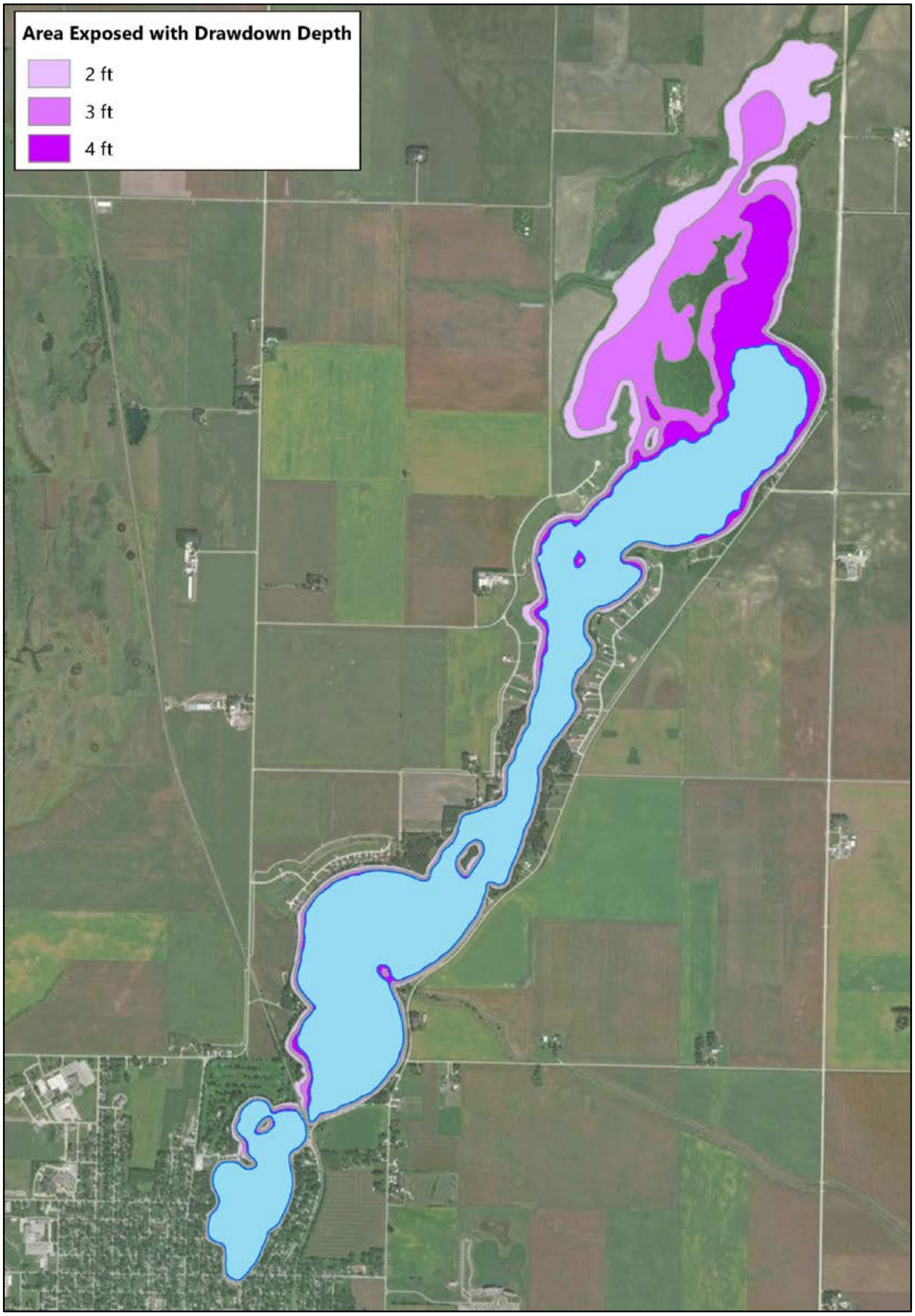
Commercial harvests of rough fish at Five Island Lake are reported to DNR, but available data has limited utility for estimating the population and understanding recruitment trends. The results of the study by Iowa State will be available in the fall and will be used to evaluate the feasibility of options to meet rough fish population goals.

If commercial harvesting cannot meet goals, chemical applications such as Rotenone or physical removal of the fish may be necessary. Both options would be made easier and more affordable by concentrating fish within smaller areas of the lake. This would be facilitated by the implementation of a fish passage barrier in the northern portion of the lake and/or a lake level management (i.e., drawdown) system.

Reduce Spawning Habitat

Rough fish typically spawn in shallow waters, and removing access of undesirable species to shallow areas of Five Island Lake will help reduce recruitment. A permanent or temporary fish barrier can be placed in the lake to prevent access to the shallow waters on the north end from the remainder of the lake. Installing this barrier would be facilitated by a lower lake level during construction. Additionally, lowering the lake level may limit rough fish access to some spawning areas without the need for additional barriers. For those reasons, the incorporation of a lake level drawdown system may benefit rough fish removal. Figure 26 depicts the areas that would be exposed with varying levels of drawdown.

Figure 26 – Drawdown Map



Fish Passage Barrier

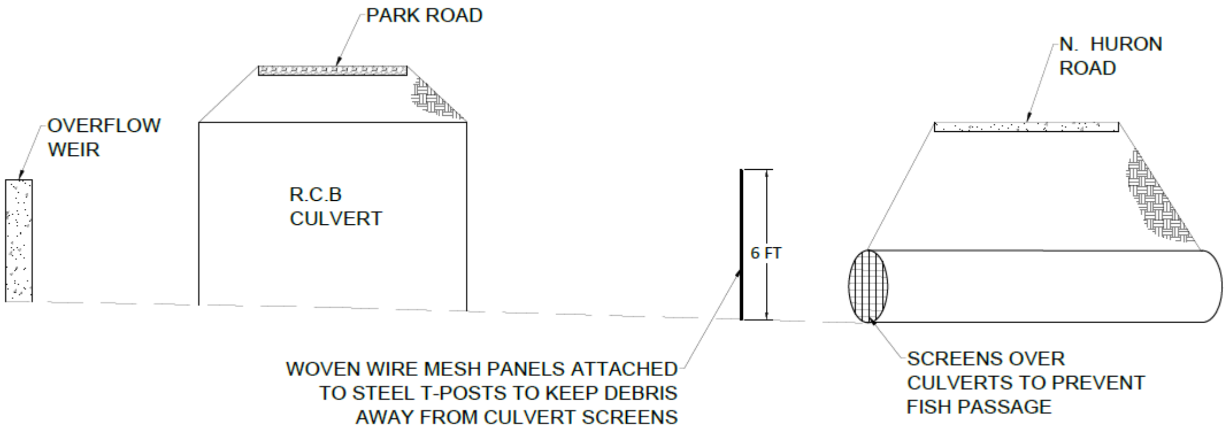
Rough fish can enter the lake by swimming upstream and jumping over the weir when there is enough flow in the outlet channel to provide depth for the fish in the approach to the weir. Screens serve as an effective fish barrier and it appears that there is a simple solution to preventing fish from passing into the lake through this route.

A screen can be fabricated to cover the upstream (not downstream) opening of the two culverts under North Huron Road. This screen should have a maximum opening of 2" x 2" to prevent fish in the downstream channel passing through. A depiction of this screen has been imposed onto a photo of the culvert inlets in Figure 27.

Figure 27 – Fish Passage Barrier Screen

Screens require maintenance. Debris will eventually block the screen and reduce hydraulic capacity of the culverts. For this reason, a second screen should be placed between the RCB outlet and the North Huron Road culverts to create a larger screened area (which is less likely to be clogged to the point that it reduces hydraulic capacity) and is easier to remove debris and maintain. This screen can have larger openings such as present in a 4" x 4" woven wire mesh panel. This screen can be attached to fence posts that will span the open channel area. Collectively, this inexpensive system should prevent fish passage into the lake and require only minor maintenance.

Figure 28 – Fish Barrier Screen Series Concept



Rough Fish Public Education

Because there are no upstream impoundments in the watershed, rough fish are likely entering the system through one of two avenues; they are passing through the downstream channel and jumping over the outlet weir or they are being brought in by fishermen through live bait or in fishing wells in boats and get released into the lake.

Fish passage through the outlet structure is identified within this Plan and a renewed effort with the public on education related to keeping invasive and undesired species of fish, aquatic vegetation and other organisms such as mussels, etc. should accompany the implementable portions of the Plan. Iowa DNR has a wealth of available information and education tools to assist the community in getting the word out.

Qualitative Description of Cost – The rough fish management approach will depend upon the results of the results of the Iowa State study, which will dictate the costs. The fish passage barrier screen costs are estimated at only $4,000, and the major costs associated with this alternative will be function of the fish removal method selected.

6.3.2 Wetland Creation

Description – Establishing a large designated area of wetlands in the lake, often created by separating a portion of the lake with hard structures or buoys, can improve water quality in multiple ways. The wetlands capture sediment, uptake nutrients and compete with algae for their food source. Rooted aquatic vegetation on the bottom of the lake thrives in shallow wetlands, and this can reduce resuspension of lakebed material that contributes to the internal load.

Ability to Assist in Achieving Goals – The geometry of Five Island Lake is conducive to implementing a large, in-lake wetland feature. The north portion of the lake is shallow, with power boating already restricted in portions of this area. The north end of the lake also has three major inflow location that drains a large portion of the watershed. An in-lake wetland in north portion of the lake would help trap and treat sediment and phosphorus from the watershed, and the rooted vegetation would help reduce resuspension of the shallow lakebed. The establishment of wetland vegetation would be assisted through lake level drawdowns, discussed in more detail below in 6.3.3. A hard barrier at the south end of this area would also assist in establishing the wetland. It would protect the area from resuspension and disturbance to help establish aquatic vegetation, limit movement of rough fish into this shallow, ideal spawning habitat, and act as a speed control barrier that help enforce no-wake boating in the wetland area.

Figure 29 – Hard Barrier Structure

The potential hard barrier location identified in Figure 29 was selected to minimize the length (and associated costs) of the structure. The configuration on the east side of the island consists of two parallel structures with a slight overlap. The gap between the structures would be temporarily blocked with a highly durable fabric curtain until the rough fish have been successfully reduced to desired levels. Once the curtain is removed, this configuration will allow boating access to the northern portion of the lake, but the structure will act as a speed control mechanism requiring boats to maneuver between the two structures. It is recommended that only trolling motors be allowed in the area north of the barrier even after access is resumed.

Qualitative Description of Cost – The largest expense for establishing wetlands would be to construct a hard barrier structure in wet conditions. Costs would vary depending on barrier location, size, materials, and methods of construction. For this study, a rock riprap structure was assumed to rise 2 ft above the water level with 5 ft top width and 3:1 slopes. The total length of the structure would be approximately 2,000 ft.

6.3.3 Shallow Vegetation/Lake Level Management

Description – Similar to wetlands discussed above, increasing aquatic vegetation in a lake provides numerous benefits to a waterbody. The management of shallow vegetation in the lake would be enhanced by the ability to vary the water level in the lake during a growing season approximately 2-4 ft to help establish vegetation in the shallow areas primarily around the perimeter of the lake. This is most commonly achieved by making modifications to the outlet control structures to allow for water level control.

Ability to Assist in Achieving Goals – At Five Island Lake, the ability to temporarily lower lake levels would not only help establish shallow vegetation around the perimeter of the lake, but it would also greatly assist in establishing aquatic vegetation behind the lake segmentation structure and facilitate the harvesting and removal of rough fish from the lake.

Figure 30 - Outlet Structure Modifications

Potential modifications to the outlet structure were assessed. Based on existing geometry, it should be possible to lower lake levels up to four feet. The incorporation of a slide gate or a stop log structure are both potential modification alternatives to consider. The capacity of the modification may determine the most reasonable alternative. A ten-foot wide weir would take approximately 15 days to lower the lake the first two feet with no additional inflow. A gate this wide would be more expensive and more difficult to incorporate into the existing weir and for that reason, incorporating a stop-log system would be proposed.

This system would likely require removing the central portion of the weir and incorporating channels into the sides of the removed portion of the weir so that stainless steel panels could be dropped into the channels to control the desired lake depth. A general concept is shown in the image above.

Qualitative Description of Cost – These modifications are relatively simple, with the primary cost associated with the installation of the stop-log system.

6.3.5 Whole-Lake Phosphorus Inactivation

Description – Phosphorus inactivation across the entire lake involves use of a chemical agent to bind with phosphorus in the water column and the lake bed sediments. The most common compound that is used for this treatment is aluminum sulfate (alum). Alum is applied just below the water surface of a waterbody with a barge. As it sinks, it will bind to phosphorus, form a floc, and strip it from the water column as the floc settles to the lake bottom creates a thin, unnoticeable layer. To control internal loading, dose of alum should allow for available binding sites in the floc after stripping phosphorus from the water column and settling to the bottom. The floc will provide reductions in the internal load by binding with any phosphorus released from sediments during anoxic conditions.

Ability to Assist in Achieving Goals – Whole lake treatments provide immediate stripping of water column phosphorus (and other constituents) and can be very effective in reducing lake phosphorus concentrations and increasing clarity to meet water quality goals. The longevity of water quality improvement is a function of proper dosing rate, timing of application, and other factors that increase phosphorus levels to pre-treatment levels (watershed load, organic matter decay, etc).

Qualitative Description of Cost – The cost of whole lake phosphorus inactivation is dependent upon type and amount of the chemical agent used. Typically, it is most efficient and effective to apply an amount that can strip the quantity of phosphorus in the water column while also addressing the potential release of phosphorus from the sediment layer. The required dose it typically based on the amount of potentially available phosphorus in the sediment or estimated phosphorus release rates over some designated time frame. For planning purposes, dosing costs in this study assumed that alum would be dosed in a quantity sufficient to capture potentially available phosphorus, which is equivalent to a 4-year release rate (estimated from sediment core analysis and mass balance modeling). The proposed dosing rate (and cost) should be refined based on more detailed investigation/study before implementation of this alternative.

6.3.6 Wake Zone Management

Description – High speed boating activities in lake can cause shoreline erosion and disturbance of lakebed sediments in shallow areas (less than 8-12 ft, depending on motor size). Implementing no-wake boating rules in shallow areas and near the shoreline help protect the shoreline and prevent resuspension, which contributes to poor water clarity and internal phosphorus loading.

Ability to Assist in Achieving Goals – Five Island Lake's dredging project had greatly reduced the area of lakebed that is susceptible to resuspension. Additionally, much of the lake's shoreline has been armored and limited bank erosion was observed during site visits. The lake would benefit most from no-wake zones in the shallow, northern portion of the lake. Buoys or hard barriers can be used to implement this alternative. Enforcement is often difficult unless hard barriers are installed. The hard barrier structure that would be used to create the potential in-lake wetland would be an effective barrier for no-wake zones. Any water quality benefits achieved from establishing no-wake boating behind the hard barrier structure is reflected through the in-lake wetland alternative.

Qualitative Description of Cost – The cost is highly dependent upon the method of implementing and enforcing no-wake zones. Buoys would be inexpensive but much less effective. A hard barrier would have much greater costs, but there are multiple benefits associated with the structure that were considered in the cost-benefit analysis below. Often, obtaining widespread buy-in and support for wake zone management is more limiting to implementation than cost.

6.3.7 Dredging

Description – Removal of lakebed material by dredging is often performed to increase lake depths and volume. Increasing lake depths in shallow areas can help reduce the amount of wave-induced resuspension. Increases in volume can help dilute pollutants and change the lake's response to loading, however this requires very large removal volumes to achieve noticeable water quality improvement.

Ability to Assist in Achieving Goals – Historical dredging in Five Island Lake has increased volume and reduced the area of lakebed susceptible to resuspension. Additional large-scale dredging in the main basin of the lake north of the railroad bridge and south of the 2nd island would build upon historical efforts. This alternative was assessed and the costs and benefits are described below. Another approach to consider is localized dredging to target shallow areas in the high-use boating areas on the south end of the lake, and pair this with wake-zone management on the north end of the lake that is highly susceptible to resuspension.

Qualitative Description of Cost – The unit cost of dredging is dependent on method (mechanical vs. hydraulic) and directly related to the volume of material dredged and the proximity of the location to spoil the material. Mechanical dredging may not be an option due to lake size and the requirement to lower (and dewater) the lake entirely for a long period of time. Since the City owns their own dredge, this reduces the costs and is likely less than the standard hydraulic dredging rates that often range from \$6-\$20 per cubic yard. A reduced rate of \$4 per cubic yard was assumed for the purposes of the cost-benefit analysis.

7 ALTERNATIVES ASSESSMENT

7.1 Cost-Benefit Analysis

The best management practices that achieved the load reduction goals were quantified using the models developed for Five Island Lake and assessed for cost effectiveness. The models were used to determine the pollutant load reductions associated with each alternative when applied in/near Five Island Lake or the watershed. Cost per pound of removal were developed for each alternative to prioritize the selection of the most effective practices to be implemented for the Plan. Phosphorus removal rates and unit costs/cost estimates applied to this analysis are presented in the following tables.

Table 14 – Management Practices Phosphorus Removal Efficiencies

Location	BMP	External	Internal
Watershed	Conservation Tillage	33%	0%
	No Till	60%	0%
	Cover Crop	40%	0%
	Extended Crop Rotation	40%	0%
	CRP/WRP	75%	0%
	Grassed Waterways	60%	0%
	Iron Enhanced Sand Filter	77%	0%
	Riparian Buffer Strips	50%	0%
	Pothole Wetland Restoration	60%	0%
	No Phosphorus Fertilizer	100%	0%
	Bioswale	65%	0%
	Rain Garden	81%	0%
	Septic System Repairs	100%	0%
Near-Lake	CREP Wetlands	40%	0%
	Detention Basins	70%	0%
	Sediment Forebay	30%	0%
In-Lake*	Wetland	30%	30%
	Rough Fish Management	0%	33%
	Whole Lake Alum	0%	85%
	Dredging	0%	---

**Load reductions were simulated in the water and mass balance model.*

The impacts of dredging additional areas of the lake north of the railroad bridge and south of Fourth Island (near the outlet structure) were assessed by increasing lake depth and volume. Model simulation suggests that overall water quality benefits of this alternative were minimal; however, there may be localized benefits to water clarity if boat and wind-induced mixing causes turbidity in this area.

Table 15 – Management Practices Cost Estimates

Location	BMP	Unit Cost	Unit
Watershed	Conservation Tillage*	$30	acre
	No Till*	$100	acre
	Cover Crop*	$225	acre
	Extended Crop Rotation*	$150	acre
	CRP/WRP	$800	acre
	Grassed Waterways	$3,000	acre
	Iron Enhanced Sand Filter	$6	ft^2
	Riparian Buffer Strips	$700	acre
	Pothole Wetland Restoration	$500	acre
	No Phosphorus Fertilizer	$0	---
	Bioswale	$4	ft
	Rain Garden	$200	lot
	Septic System Repairs	$6,000	ea
Near-Lake	Constructed/CREP Wetlands**	$18,000	acre
	Detention Basins**	$140,000	ea
	Sediment Forebay	$92,000	ea
In-Lake	Wetland***	$940,000	lump sum
	Rough Fish Management****	$75,000	lump sum
	Shallow Vegetation/Lake Level Management	$87,000	lump sum
	Whole Lake Alum	$2.47	gal
	Dredging	$4	cy

**Based on 5 yrs of cost-sharing*

***Includes land rights purchase*

****Cost for the hard barrier has been assigned to the wetland, although it also aids the rough fish management and wake zone management alternatives*

***** Cost estimate based on previous rough fish removal program at Lost Island Lake and fish passage barrier screens.*

Each alternative was assessed separately to compare phosphorus reduction effectiveness of individual practices. The table below shows the resulting cost per pound of phosphorus reduction in order of the most effective practice per location.

Table 16 – Cost-Benefit Analysis Results

Location	BMP	Cost/Lb
Watershed	No Phosphorus Fertilizer	$0
	Improved Tillage Practices	$210
	Grassed Waterways	$240
	Riparian Buffer Strips	$340
	Pothole Wetland Restoration	$340
	Extended Crop Rotation	$460
	Iron Enhanced Sand Filter	$480
	Cover Crop	$720
	Bio-swales	$970
	Septic System Repairs	$1,180
	CRP/WRP	$1,330
	Rain Gardens	$2,220
Near-Lake	Constructed/CREP Wetlands	$540
	Detention Basins	$670
	Sediment Forebay	$5,460
In-Lake	Rough Fish Management	$40
	Wetland	$370
	Whole Lake Alum	$540
	Dredging*	---
	Shallow Vegetation/Lake Level Management**	---

**Only costs reported above, benefits are realized from volume increases and not load reductions*

***Only costs reported above, benefits are realized through the wetland and rough fish management alternatives that are supported by this practice*

7.2 Example Scenarios

There are numerous combinations of watershed, near-lake and in-lake practices that can attain the load reduction goals. An example scenario has been developed using a variety of high performing practices from the cost-benefit analysis to reach the minimum and maximum goals identified in Section 5.3.

Watershed load reductions estimated from STEPL for the watershed and near-lake practices were also incorporated into the mass balance model. Alternatives to reduce internal loading, as well as the watershed load reduction to the lake, are simulated by the mass balance model. Ultimately, the mass balance model will predict daily lake phosphorus concentrations in response to each combination of alternatives to demonstrate the lake's response and show that the water quality goals are being met.

7.2.1 Secchi Depth Goal (for delisting from impaired waters list)

A 40% total load reduction is required to reach the Secchi depth goal of 2.6 ft, which is equivalent to a Secchi depth TSI value of 63 and would remove Five Island Lake from the 303(d) impaired waters list. An example scenario that achieves the 5,034 lb/yr reduction includes the management strategies listed below. Load reductions and in-lake response is reported in Table 17 and Figure 31, respectively.

Watershed –

- Improved Tillage: a combination upgrading to conservation or no-tillage practices on approximately 1,000 acres (15%) of cropland
- Extended Crop Rotation: approximately 1,000 acres (15%) of new cropland entered into rotation
- Grassed Waterways: 15 acres of new 40′ wide waterways to treat approximately 1,000 acres (15%) of cropland runoff
- Iron Enhanced Sand Filters: 10,000 square ft of filter to treat approximately 200 acres (3%) of cropland drainage
- Riparian Buffer Strips: 2 acres of 60′ buffer to treat approximately 25 acres (1%) of cropland drainage
- Pothole Wetland Restoration: 107 acres of wetlands installed to treat approximately 320 acres (8%) of cropland drainage
- No Phosphorus Fertilizer: Replace fertilizers with phosphorus with no/low phosphorus fertilizer on approximately 190 acres (30%) of urban drainage area
- Septic System Repairs: Inspect all and repair/replace any faulty septic systems

Near-Lake –

- Constructed/CREP Wetlands: 21 acres of wetlands at one near-lake location (subwatershed 2 inflow point) that treat approximately 2,040 acres (27%) of the total drainage area

In-Lake –

- Wetlands: Establish in-lake wetlands in 290 acres of the lake behind a hard barrier structure. No-wake restrictions and reductions to rough fish spawning and recruitment will also be promoted with this structure. Approximately 5,900 (77%) of the total drainage area enters the lake behind the structure.
- Rough Fish Management: Reduce fish population from an estimated 250 lbs/ac to a maximum of 100 lbs/ac. Prevent fish from entering the lake via fish passage barriers installed on downstream road culverts and prevent fish from accessing shallow spawning habitat with hard barrier structure.
- Shallow Vegetation/Lake Level Management: Enable the ability to drawdown the lake to establish shallow wetlands along the perimeter of the lake and behind the lake segmentation structure by modifying the outlet structure.

- Wake Zone Management: Implement no-wake boating behind the hard barrier

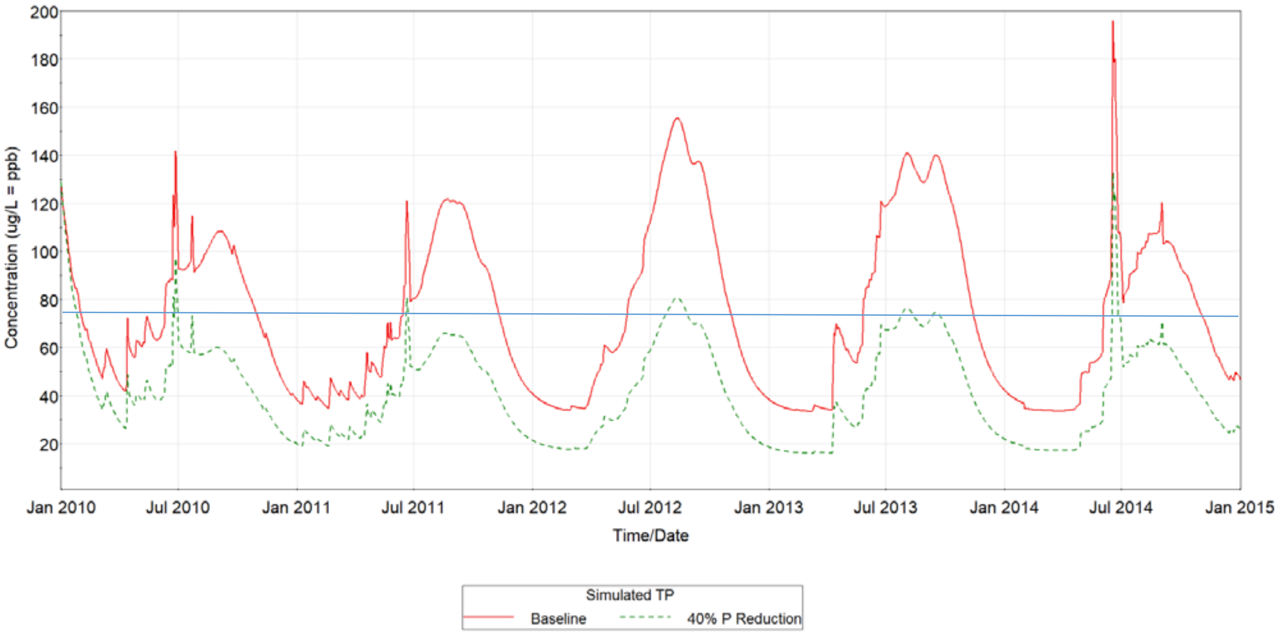
Table 17 – 40% Load Reduction Example Scenario

Location	BMP	External		Internal		Total	
		(lbs/yr)	%	(lbs/yr)	%	(lbs/yr)	%
Watershed	Improved Tillage	333	5%	0	---	326	3%
	Extended Crop Rotation	309	5%	0	---	309	2%
	Grassed Waterways	157	2%	0	---	157	1%
	Iron Enhanced Sand Filter	101	2%	0	---	101	1%
	Buffer Strips	5	0%	0	---	5	0%
	Pothole Wetlands	60	1%	0	---	60	0%
	No-Low P Fertilizer	144	2%	0	---	144	1%
	Septic Repairs	71	1%	0	---	71	0.6%
Near-Lake	CREP Wetlands	606	9%	0	---	606	5%
In-Lake	Wetland	446	7%	2,841	48%	3,287	26%
	Rough Fish Management	0	0%				
TOTAL		2,233	34%	2,841	48%	**5,074**	**40%**

**Simulated all practices simultaneously and load reduction unable to be separated out between practices*

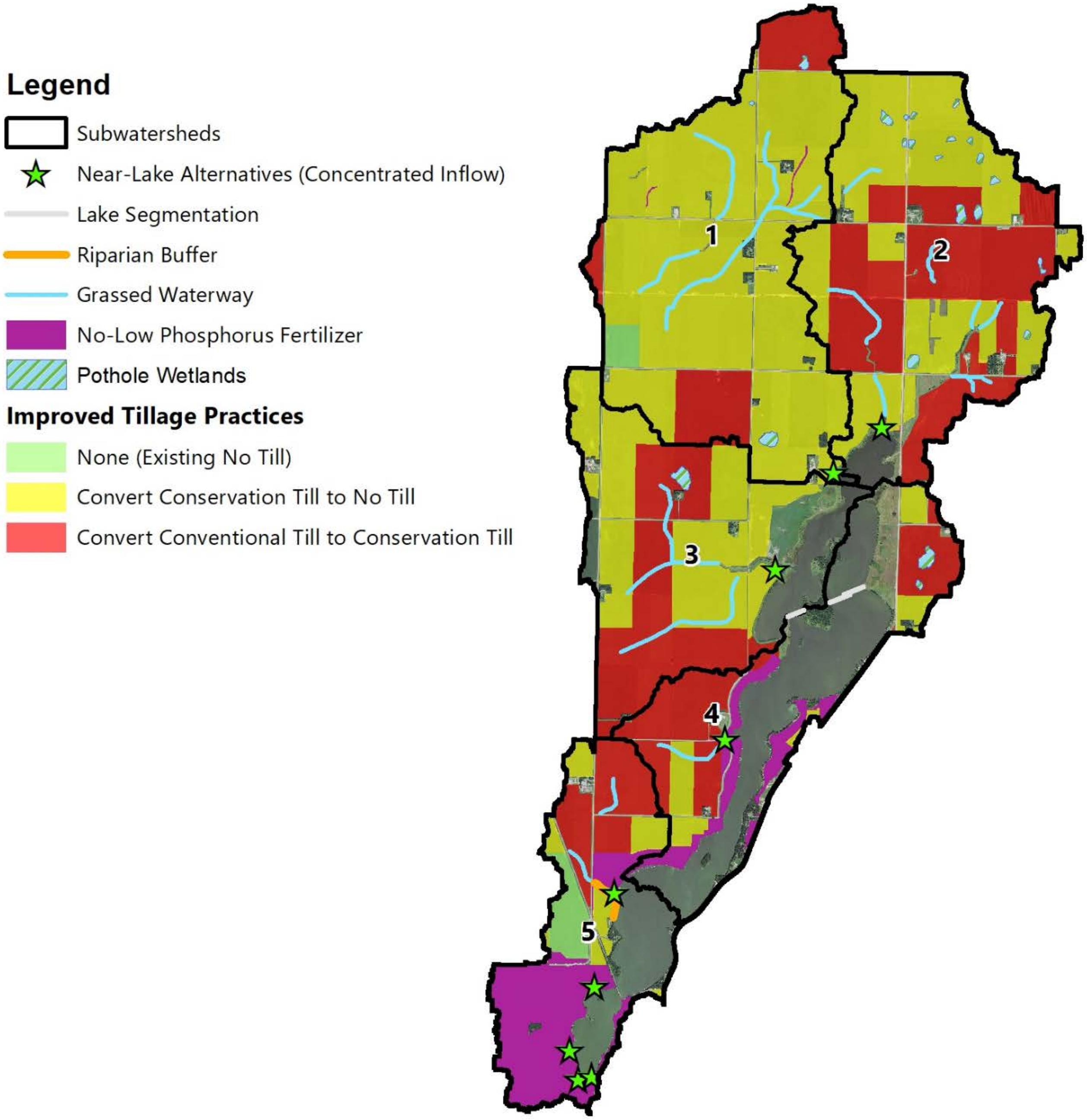
As shown in Table 12, the estimated phosphorus concentration that corresponds to 2.6 ft of clarity is 75.8 μg/L. This target concentration is identified by the blue line in Figure 31.

Figure 31 – 40% Load Reduction Lake Response



This scenario achieved a 34% reduction in the external load and a 48% load reduction of the internal load, for a total load reduction of 40%. Exact locations for watershed practices were not established during this analysis, as there are numerous combinations of practices that can be implemented to reach the 34% external load reduction. Potential locations for placement of several practices were identified through an assessment of watershed and lake characteristics. This could serve as a guide to help landowner identify potential practices that are feasible on their property, or the help identify potential locations for any practices the City is interested in pursuing.

Figure 32 – Potential Locations for Management Practices



7.2.2 Iowa DNR Secchi Depth Goal

A 70% total load reduction is required to reach the Secchi depth goal of 4.5 ft, which is equivalent to a Secchi depth TSI value of 55 and would reach the Iowa DNR clarity goal for a minimum of 50% of the growing season. To increase the load reduction from 40% to 70% and achieve the 8,810 lb/yr reduction, a more aggressive approach needs to be taken watershed and near-lake implementation to reduce the external load and whole lake alum treatments were added to further reduce the internal load. An example scenario is provided below, and the load reductions and lake response are reported in Table 18 and Figure 33.

Watershed –

- Improved Tillage: a combination upgrading to conservation or no-tillage practices on approximately 1,600 acres (25%) of cropland
- Extended Crop Rotation: approximately 1,600 acres (25%) of new cropland entered into rotation
- Grassed Waterways: 26 acres of new 40′ wide waterways to treat approximately 1,600 acres (25%) of cropland drainage
- Iron Enhanced Sand Filters: 15,900 square ft of filter to treat approximately 320 acres (5%) of cropland drainage
- Riparian Buffer Strips: 2 acres of 60′ buffer to treat approximately 25 acres (1%) of cropland drainage
- Pothole Wetlands: 176 acres of wetlands installed to treat approximately 525 acres (8%) of cropland drainage
- No Phosphorus Fertilizer: Replace fertilizers with phosphorus with no/low phosphorus fertilizer on approximately 190 acres (30%) of urban drainage area
- Septic System Repairs: Inspect all and repair/replace any faulty septic systems

Near-Lake –

- Constructed/CREP Wetlands: 44 acres of wetlands between two locations (subwatershed 1 and 2 inflow points) that treat approximately 4,400 acres (57%) of the total drainage area
- Detention Basin: 1 basin (subwatershed 4 inflow point) that treat approximately 250 acres (3%) of the total drainage area

In-Lake –

- Wetland: Establish in-lake wetlands in 290 acres of the lake behind a hard barrier structure (no-wake restrictions and access shallow spawning habitat restrictions will also be promoted with this structure). Approximately 5,900 (77%) of the total drainage area enters the lake behind the structure.
- Rough Fish Management: Reduce fish population from 250 lbs/ac to 100 lbs/ac from harvesting. Prevent fish from entering the lake via fish passage barriers installed on downstream road culverts and prevent fish from accessing shallow spawning habitat with hard barrier structure.

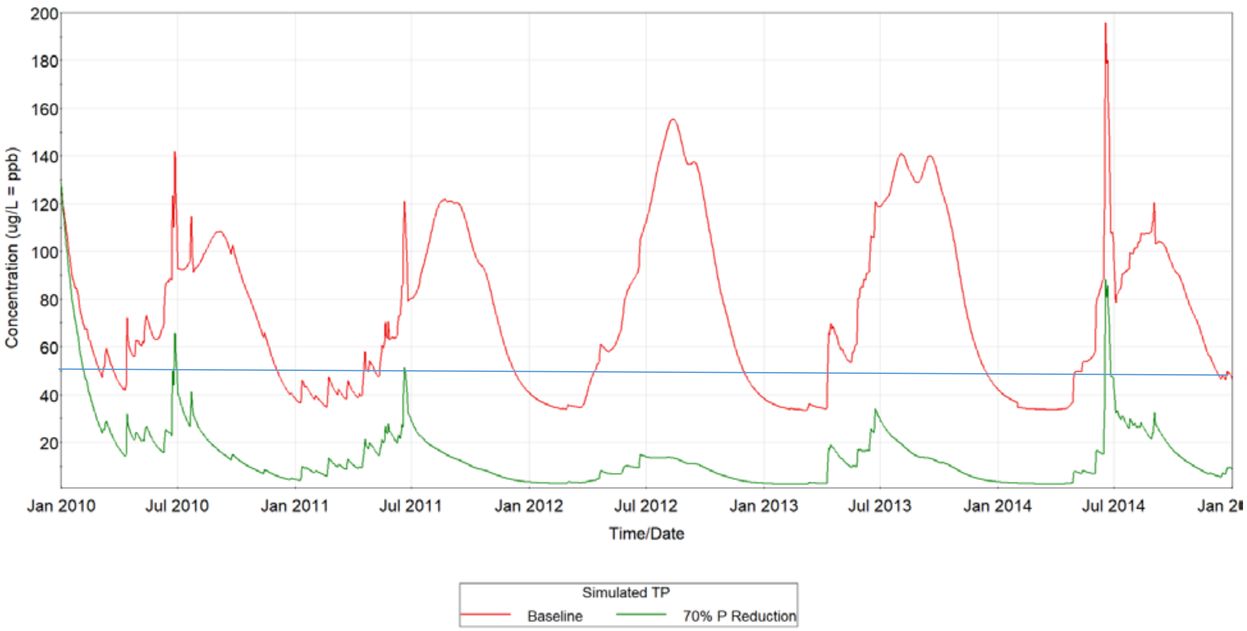
- Shallow Vegetation/Lake Level Management: Enable the ability to drawdown the lake to establish shallow wetlands along the perimeter of the lake and behind the lake segmentation structure by modifying the outlet structure.
- Wake Zone Management: Implement no-wake boating behind the hard barrier
- Whole Lake Alum: Implement a whole lake alum treatment to strip the water column phosphorus and inactivate lakebed sediment release of phosphorus.

Table 18 – 70% Load Reduction Example Scenario

Location	**BMP**	**External**		**Internal**		**Total**	
		(lbs/yr)	**%**	**(lbs/yr)**	**%**	**(lbs/yr)**	**%**
Watershed	Improved Tillage	570	9%	0	---	570	5%
	Extended Crop Rotation	515	8%	0	---	515	4%
	Grassed Waterways	276	4%	0	---	276	2%
	Iron Enhanced Sand Filter	168	3%	0	---	168	1%
	Buffer Strips	5	0%	0	---	5	0%
	Pothole Wetlands	98	1%	0	---	98	1%
	No-Low P Fertilizer	144	2%	0	---	144	1%
	Septic Repairs	71	1%	0	---	71	0.6%
Near-Lake	CREP Wetlands	1,083	16%	0	---	1,083	9%
	Detention	38	1%	0	---	38	0.3%
In-Lake	Wetland	327	5%	5,505	92%	5,677	45%
	Rough Fish Management	0	0%				
	Whole Lake Alum	0	0%				
TOTAL		3,297	50%	5,505	92%	**8,802**	**70%**

As shown in Table 12, the equivalent phosphorus concentration to 2.6 ft of clarity is 50.4 μg/L and is marked with the blue line in Figure 33.

Figure 33 – 70% Load Reduction Lake Response



8 RECCOMENDATIONS

8.1 City Action Items

The following action items are recommended to be implemented in an adaptive management approach, which is outlined in Figure 34 below. The immediate action items that are recommended include:

Watershed Coordinator

- Assist in watershed and near-lake implementation
- Community education/outreach
- Funding assistance
- Monitoring lake response

Rough Fish Management

- Harvesting/removal of rough fish that can cause lakebed resuspension
- Fish barrier screens to prevent entrance to lake

Outlet Structure Modifications

- Modify concrete structure to incorporate stop-logs
- Allows for shallow vegetation/lake level management

Shallow Vegetation/Lake Level Management

- Lower lake level to establish in-lake wetland vegetation (April drawdown and gradually raise as vegetation is established to full pool by end of May).
- Use for assistance in rough fish management as needed

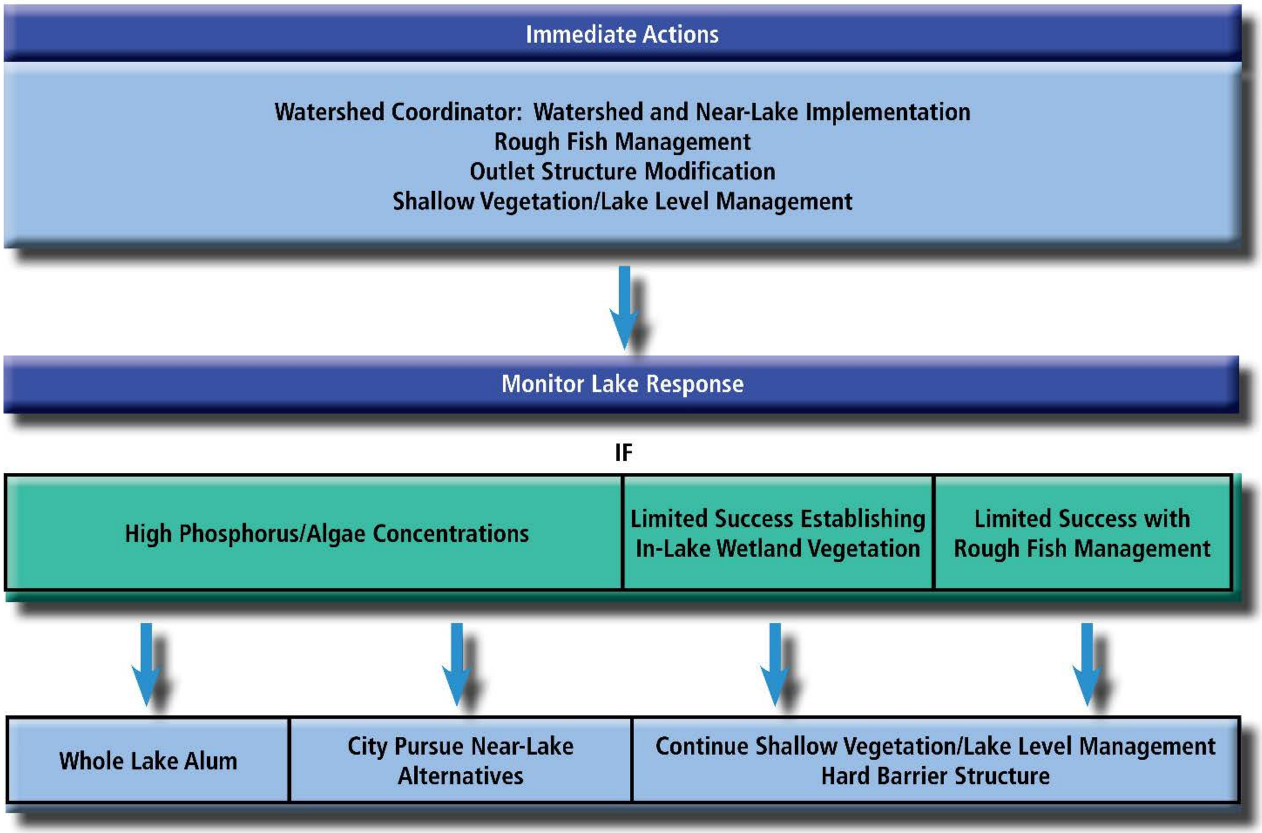


Figure 34 – Adaptive Management Approach

The lake should be allowed time to adjust and respond to the practices implemented. Monitoring data should be collected and after a minimum of one year, the lake's response should be assessed. Dependent upon how the lake has responded to the practices, the appropriate following actions items as guided by the adaptive management plane should be investigated and implemented.

Hard Barrier Structure

- In-Lake wetlands
- Assists with rough fish management
- Protects from wind/wave actions
- Configuration enforces boating restrictions while still allowing access (upon removal of temporary section once rough fish management is complete)

Whole Lake Alum Treatments

- Strip phosphorus from water column
- Phosphorus inactivation of lakebed sediments

- Apply as needed until watershed/near-lake implementation has reach completion

Near-Lake Alternatives

- City to pursue near-lake alternatives if watershed load reduction progress is not occurring

Continued Shallow Vegetation/Lake Level Management

- Continue to manipulate water level as needed

8.2 Cost Estimates

The costs estimates that will be associated with the City's action were developed and are presented in Tables 19 and 20.

Table 19 – Immediate Action Item Cost Estimates

Description	Quantity	Unit	Unit Cost	Total
Watershed Coordinator	5	years	$60,000	$300,000
Rough Fish Management	1	lump sum	$75,000	$75,000
Outlet Structure Modification	1	lump sum	$87,000	$87,000
Shallow Vegetation/Lake Level Management	N/A			
			TOTAL	**$462,000**

Table 20 – Potential Future Action Item Cost Estimates

Description	Cost Range	Notes
Whole Lake Alum	$660,000 - $1.8 million	Dependent on future lake phosphorus concentrations
Near-Lake Pursuits	$46,000 - $1 million	Varies with selected practice and quantity
Shallow Vegetation/Lake Level Management	N/A	Only labor for operating outlet structure stop-logs
Hard Barrier Structure	$940,000	Changes in location or material would alter cost

8.3 Timeline

Develop after feedback and in coordination with stakeholders

9 FUNDING

Preliminary research was performed to help identify available funding sources to supplement any dollars put towards improving Five Island Lake. Multiple programs to support conservation practices in the watershed already exist and should be taken advantage of to the fullest extent possible by individual landowners. Additional larger-scale programs or grant opportunities have been identified for consideration for future management scenario implementation and are summarized in Figure 35.

Figure 35 – Funding Opportunities

FEDERAL	**$$$**	- **USDA/FSA/NRCS (High Priority Watershed)** - EQIP - CRP/WRP and Farmable Wetlands Program - REAP (urban) - **USFWS - Sportfish Restoration Program** - **EPA - Section 319 Program**
STATE	**$$**	- **Iowa Conservation Enhancment Program (CREP)** - **IDALS - Urban Conservation Project** - **IDNR - Lake Restoration Program** - **State Revolving Fund**
LOCAL	**$$**	- **Palo Alto Gaming Development Corporation Grant** - **Drainage Districts** - **City of Emmetsburg**

10 REFERENCES

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