Marion County Lake Shoreline Buffer Zone Health Assessment through Computational and Chemical Analysis

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This study of Marion County Lake was completed as a capstone project with Dr. Aleksey Sheshukov from the department of Biological and Agricultural Engineering as the faculty advisor with support from Dr. Shawn Hutchinson as the lead instructor and director of the Natural Resources and Environmental Science Secondary Major.

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Introduction.

Marion County Park and Lake is located in Marion County, Kansas. The 300-acre county-owned park is home to the 150-acre lake which has become a popular destination for nearby residents and visitors for activities ranging from camping to fishing. The area is primarily surrounded by agricultural and grazing land that drain to the lake, which is the basin of a watershed of over 4000 acres. One of the main issues that Marion County Lake faces is blue-green algae blooms. These events are directly caused by excess nutrients entering the lake from the rest of the watershed through soil erosion and nutrient transport. As a result, the main nutrients of concern are nitrogen and phosphorus. Excessive inputs of nitrogen and phosphorus, in addition to organic matter, can impair water quality and are the main cause of eutrophication in lakes (Schindler, 1974). The blue-green algae blooms are a concern of leadership and residents alike because it impedes recreation lake functions as well as degrades the aesthetics of the park atmosphere.

With the county-owned land having recently transitioned leadership, it was identified by stakeholders that steps need to be taken towards developing a lake management plan to uphold the park's health going forward. The primary goal is to provide the Marion County staff with a document that includes the primary factors contributing to the excess nutrient levels and recommendations to control the incoming nutrients. This report focuses on the shoreline soil health of Marion County lake through computational and chemical soil analysis. Through these analyses, it can be determined whether it is pertinent that Marion County Lake should grow tall grasses, acting as a buffer, along its shoreline as a measure to protect the soil's health.

Background.

An integral part of assessing the shoreline soil health is understanding the complexities of the region surrounding Marion County Lake. Several miles north of Wichita, Marion County has the following characteristics:

Surrounding Watershed.

Marion County Lake is the basin of a 15.9 km^2 watershed that spans north of the lake into land that is comprised of 56.2% grassland or pasture and 27% agricultural land. The remaining percentage is from water and low-density residential areas, according to USGS provided data.

Ecoregion – Flint Hills.

Marion County Lake is located in a unique region of the United States. The lake lies in the Flint Hills which cover much of eastern Kansas and north-central Oklahoma. This geographical location gets its name from residual flint left on the surface due to bedrock erosion. The flint deposits themselves are special to the region, and because of the flint the hills have remained unplowed for all these years. The fact that cultivation has not occurred is exactly why the Flint Hills is the last unplowed tall grass prairie remaining. The ecological traits this gives the hills is heavily studied by scientists and admired by many for its beauty and one-of-a-kind views. Marion County Lake, located in the Flint Hills, has an opportunity to promote the conservation of the last unplowed tallgrass prairie by planting some of these prairie grasses along its shoreline. This buffer zone would then provide an interpretive, educational opportunity for lake visitors about tall grass species found in the Flint Hills. The public could learn about the grasses and region through signs and possibly the implementation of interpretive shoreline trails.

Hardiness Zone 6A.

A hardiness zone is a geographically-defined area in which a specific category of plant life can grow based on certain climatic conditions. These zones are determined by the minimum temperature that these regions experience during the year. The minimum temperature that zone 6A experiences is -22 ºC. For hardiness zone 6A, where Marion County Lake is located, there is a wide range of grasses that could be selected to utilize within the shoreline buffer zone. For the ease of management, the additional benefits of native prairie grasses and the unique ecoregion the lake is in, native grasses are recommended over ornamental varieties. Native grasses will still be visually appealing and will have additional hardiness compared to ornamental grasses. As a result, this would require less maintenance for lake management, with reduced need for irrigation and cutting practices. Shoreline stabilization would be greater for native species, as these grasses' root systems are deeper, thicker, and stronger than some ornamentals.

Frost Zones – Zone 8 and Zone 13.

Marion County Lake falls in first frost zone 8 (October 11^{th} to October 20^{th}) and final frost zone 13 (May 11^{th} to May 20^{th}). Frost zones play a key role in the annual succession of grasses. If first frost is too early, grasses may not be able to seed properly in the fall, restricting the number of grasses that will grow in the spring. If final frost arrives late, the seeds may not have adequate time to germinate, which can lead to reduced grass density and potentially stunted growth of the grasses. Ensuring proper grass selection with these frost zones in mind will help to prevent these frost zone issues and help maintain a healthy grass population.

Heat Zone – 7.

Marion County Lake is located in heat zone 7, meaning that there are 61 to 90 days above 86 ºF every year. With the summer months regularly reaching over 86 ºF, it is important to ensure proper irrigation is carried out during the first two to three growing seasons. The buffer zone, being at the edge of the water, will have minimal problems with soil-water retention. However, issues can arise due to direct sun and excessive heat during the first two to four growing seasons depending on grass species. Irrigation of the grasses will minimize heat stress or wilting of the plants during these summer months, allowing the plants to become well-established without becoming stunted or deformed.

Drought Index – Moderately Moist.

Marion County Lake is currently in a moderately moist region of the United States. Being in this part of the drought index means there will be little to no need for irrigation practices beyond the first 2 to 3 growing seasons. The proximity to the water will play a major role in this as well. Once the root systems are established, the plants will be able to utilize much of the shore water for plant needs. However, Kansas can still be quite arid and dry during the summer months, so it is essential to practice any preventative measures if soil moisture is reduced for an extended period of time.

Shoreline Stabilization.

When managing an aquatic ecosystem, some concerns to take into consideration are shoreline retention and stabilization. Extensive research has gone into comparing plant roots versus other structures such as rocks, synthetic stabilizers added to soil, and plastic or metal structures to retain soil (Stephen W. Broome, & Ernest D. Seneca 2010). Nonetheless, all research results point to strong root systems as the best method for retention (Walters, J.P. 2004). When choosing plants to mitigate shoreline erosion, it is best to consider root depth and density of the viable plant options. (Gyssels, G., Poesen, J., Bochet, E., & Li, Y. 2005). Having the lake in the ideal location to grow some of the native tall grass prairie species is a great advantage for shoreline retention and stabilization. The native tall grasses have very deep and dense root systems since these plants have adapted to survive Kansas's arid, hot summers. Once these root systems are well-established, the plants will reduce erosion rates, increase shoreline stability, and provide more user-friendly lake access.

Wildlife Benefits.

Marion County Lake management has identified geese presence on the lake to be a potential issue that could affect lake quality and recreational usage. Buffer zones can be used as an easy way to manage flocks of geese in an indirect manner. This could lead to improved recreational opportunities as well as a healthier and more user-friendly riparian zone. Since geese population increases have occurred across North America, a variety of different measures to mitigate effects of geese populations have been implemented (Swallow et al. 2010). Tall grass buffers have been utilized with a depth of one to two feet along the shore to decrease the potency of fecal matter entering the water body. This method also keeps geese further from the water as, according to Swallow et al., these birds prefer to roam and nest in shorter grass. In order to reduce the impacts of the geese population on the health of Marion County Lake, it may be useful to add tall grass along the shore. Other tactics have been used to keep geese populations down, such as hunting, geese harassment, and oiling eggs. However, these methods are less humane and may be unfavorable to the local community. Prairie grasses will also provide a nutrient dense source of food in the form of seeds for many aquatic birds and riparian dwelling animals, attracting species that can benefit the lake ecosystem.

Additional Benefits.

A shoreline buffer zone can aid in the management of many other issues associated with aquatic recreation destinations, such as Marion County Lake. The implementation of buffer zones can control human use of the lake in a minimally invasive way. This can lead to a reduction in user conflicts and easier management since some shoreline will be utilized less intensively. Buffer zones also do a good job of litter management along the shoreline. It is not uncommon to see trash getting blown into Kansas lakes as a result of strong winds. With the addition of some buffer zones placed with wind direction in mind, there can be a great decrease in the amount of trash that makes it into the water, making cleanup much easier. Having a grass buffer zone will also increase riparian area health and diversity of the lake. Buffer zones can also add extensive aesthetic benefits along the shoreline with some unique grasses chosen.

Viable Grass Identification.

Below is a list of grass species, native to the Flint Hills, that will be great viable options for the Marion County Lake buffer zone.

Little Bluestem.

Figure 1. Little Bluestem Stalk and Root Character

Scientific name:	Schizachyrium scoparium
Grass Family:	Poaceae
Flowers:	July - September
Height:	2 - 4 feet
Roots:	4.5-5.5 feet, dense, fibrous
Management:	Fire / Cutting

Big Bluestem.

Figure 2. Big Bluestem Stalk and Root Character

Scientific name:	Andropogon gerardii
Grass Family:	Poaceae
Flowers:	July - September
Height:	2 - 7 feet
Roots:	7-8 feet, dense, fibrous
Management:	Fire / Cutting

Switchgrass.

Figure 3. Switchgrass Stalk and Root Character

Scientific name:	Panicum virgatum
Grass Family:	Poaceae
Flowers:	August - September
Height:	2-7 feet
Roots:	Dense top 12in, 10ft max depth, dense throughout
Management:	Fire / Cutting

Barnyard Grass.

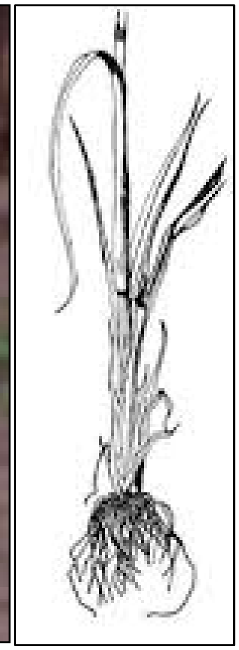

Figure 4. Barnyard Grass Stalk and Root Character

Scientific name:	Echinochloa muricate
Grass Family:	Poaceae
Flowers:	July - September
Height:	1 - 5 feet
Roots:	Shallow, dense, thick stalks
Management:	Fire / Cutting

Indian Grass.

Figure 5. Indian Grass Stalk and Root Character

Scientific name:	Sorghastrum nutans
Grass Family:	Poaceae
Flowers:	July - September
Height:	3 - 7 feet
Roots:	6 feet, dense, fibrous
Management:	Fire / Cutting

Purple Top

Figure 6. Purple Top Stalk and Root Character

Scientific name:	Tridens flavus
Grass Family:	Poaceae
Flowers:	July - September
Height:	2 - 5 feet
Roots:	1 - 3 feet wide
Management:	Fire / Cutting

Soil Profile Importance.

When looking into shoreline retention, soil content is an important factor to consider when understanding the success of plants along the shore as well as nutrients that can enter water bodies due to runoff. In order to effectively retain shoreline plants a great deal of work needs to be dedicated to ensuring proper soil health and structure (Wilson, S. D., & Shay, J. M. 1990). Nutrient runoff from the water shed is another factor to consider when managing for soil quality around the lake, since it is surrounded by agricultural land and some residential areas the amount of runoff could be significant. To address this, later in the report there will be findings from a GIS program that will identify nutrient runoff levels within the watershed.

Below are the ideal soil conditions at Marion County Lake for the previously identified grass species. These levels will be compared to the site levels found later in the report.

Table 1. Ideal level of Ammonium in Soil

Level of Ammonium (NH_4) in Soil	Amount (ppm)
Low	< 2
Average (ideal)	2 - 10
High	> 10

Table 2. Ideal level of Nitrate in Soil

Level of Nitrate (NO_3) in Soil	Amount (ppm)
Low	< 10
Medium (ideal)	10 - 20
High	20 - 30
Excessive	> 30

Table 3. Ideal pH in Soil

pH in Soil	pH Level
Strongly Acidic	< 5.1
Moderately Acidic (ideal)	5.2 - 6.0
Slightly Acidic (ideal)	6.0 - 6.5
Neutral	6.6 - 7.3
Moderately Alkaline	7.4 - 8.4
Strongly Alkaline	> 8.4

Table 4. Ideal Level of Potassium in Soil

Level of Potassium (K) in Soil	Amount (ppm)
Low	< 150
Medium (ideal)	150 - 250
High	250 - 800
Excessive	> 800

Table 5. Ideal Level of Phosphorus in Soil

Level of Phosphorus (P) in Soil	Amount (ppm)
Low	< 10
Medium (ideal)	10 - 20
High	20 - 40
Excessive	> 40

Table 6. Ideal Level of Organic Matter in Soil

Level of Organic Matter in Soil	Amount (%)
Low	< 4
Average (ideal)	4-6
High	> 6

Management Practices.

The identification of the previously mentioned traits of a particular area will guide the decision of what plants to bring in, but it is important to keep in mind care of the plants as well. The management practices followed after planting can be just as important, if not more so, than the decision process (Hill, M., & Pearson, C. 1985). It is necessary to collect proper care information and implement a management plan that will aid in the growth of the plants while also ensuring these grasses do not overtake the shoreline.

Fertilizers.

Fertilizing the soil and grasses will be the first concern to ensure a healthy buffer zone. Later in the document, the current nutrient levels will be discussed and practices to put into place to remedy any deficits or excesses that may be present will be provided. Regardless of current nutrient levels, it will be important to ensure proper nutrient levels through fertilizer applications for at least the first three growing years. After this time period, soils will need to be retested and applications can be adjusted accordingly every 2 to 4 years there-after.

Fire and Cutting Practices.

As the grasses in the buffer zone begin to grow and become well established, it is important to manage growth to ensure proper health and retention. Two main ways of managing growth is through fire, cutting, or a combination of both. For Marion County Lake, a combination approach is recommended. Annual mows and trims of the grasses with a burn off every three years would be the best management practice to promote a healthy riparian buffer zone. Additional cutting and trimming can take place where grass height needs to be limited or shoreline access is priority.

Field Methods.

Soil Sample Extraction.

Nineteen cores of soil were collected from the surrounding buffer zone of the lake (*Figure* 7) in order to properly conduct a soil test. By taking soil cores in the buffer zones, particularly in coves and inlets of the lake, the ecology of the lake and area surrounding it will be further understood. Furthermore, proper recommendations can be made regarding appropriate vegetation that would fit the location due to the nutrient levels and stability of the bank. Using a slide hammer, 58.9 cm^3 soil cores with a 5 cm diameter were extracted, with a length of approximately 6 inches. Locations selected for the samples were areas that could potentially receive high rates of runoff through extreme weather events, with a low to moderate probability of long-term flooding in particularly wet years. Many of the locations had moderate to high slopes and were located within at least a 10-meter radius from the current shoreline. In this experiment, the time of retrieval was recorded for each sample as well as the exact GPS location that would be transferred into ArcGIS. By simply taking pictures on a smart phone with GPS tracker, the soil cores could be specifically located and timed (Appendix 1.1).

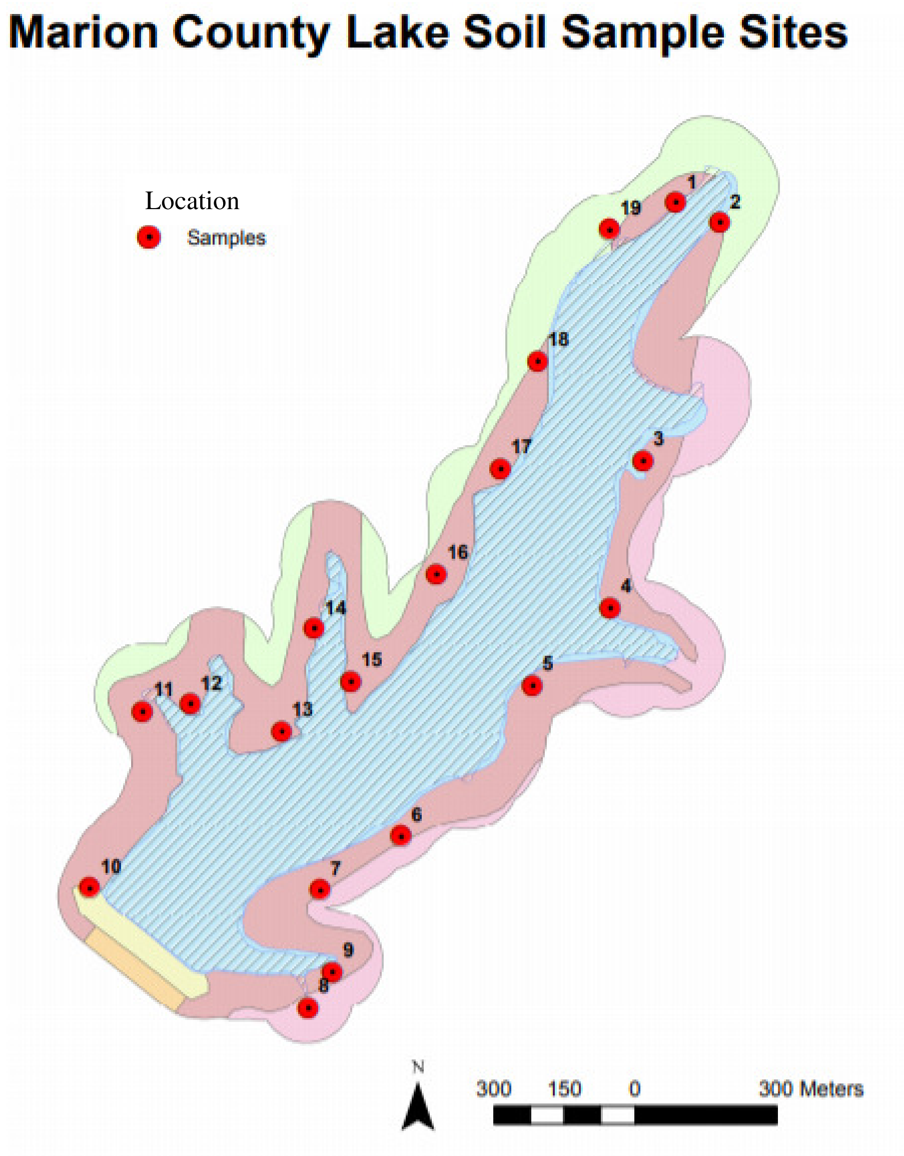

Figure 7. Soil Sample Sites

Soil Sample Analysis.

The samples were then taken to Dr. Sheshukov's lab where the samples were cut to have a depth of 3 cm, avoiding areas of the soil sample containing large concentrations of rock or organic material. These reduced soil cores were then weighed and the volume of each was calculated. After a 24-hour period of drying in an oven at 105 ºC, the samples were reduced from field capacity to wilting point, and the bulk density could be calculated for all of the soil samples. The bulk density values for each sample can be found in Appendix 1.1. To calculate the bulk density, the following equation was used:

$$\text{Bulk density} = \text{field capacity mass (g)} - \text{wilting point mass (g)} / \text{volume of sample (cm}^3\text{)}$$

The remaining soil was sent to the K-State Research and Extension Soil Testing Lab for nutrient and composition analysis. To prepare the soil for testing, each sample was dried to remove any moisture and was ground to create a homogenous mixture. The following tests in *Table 7* were performed on each soil sample. These tests were purchased through the NRCS, providing a more solid perspective and understanding of the characteristics of soil. With this information, more accurate recommendations could be made regarding management and potential native grass types to install around the perimeter of the lake. Having a clear understanding of nutrient levels of soils surrounding the lake can give a better picture of the conditions of both the watershed and potential pollution issues. Additionally, this could alert to some possible runoff and sediment issues that could be disrupting the ecology of the lake. The results from the Soil Testing Lab are located in Appendix 1.2.

Table 7. Types of Tests and Methods Used for Soil Analysis

Test	Procedure
pH	1:1 (Soil:Water)
Phosphorus	Mehlich-3
Potassium	Ammonium Acetate Extraction
NO_3-N and NH_4-N	1 N KCl Extraction
Texture (Particle Size)	Hydrometer
Organic Matter	Loss on Ignition

Limitations.

There are some limitations to take into consideration with the soil sample collection method used. These methods can easily be improved for future usage in the Marion County Lake management plan. It might be beneficial to take multiple samples throughout the year to monitor the soil changes that can occur from varying degrees of precipitation. When the soil samples were collected, the soil samples were quite wet as a result of a previous rain storm. Some nutrients, such as nitrates, are more mobile in soils than other nutrients, i.e. phosphorus, so a recent rainstorm may have caused certain variables to not be properly represented in the collected data set. By attaining a larger spread of data during the year, abnormal readings can be smoothed out and minimized. Nonetheless, the wet ground made it more manageable to extract samples with a slide hammer. Samples were mostly taken in short grass areas that could potentially be converted into a tall grass buffer zone. Areas near man-made objects or areas with significant amounts of trees were avoided. As a result, these soil samples may not be representative of all types of topography surrounding the shore of the lake.

Since soil samples were collected immediately after a rainstorm, these samples remained quite wet for multiple days. When some samples were removed from the metal holding container after a few days of air drying, there was some difficulty taking the soil samples out of the container. This result of significant pushing caused the specific soil samples to compact, impacting the final overall bulk density calculation. Compaction of the soil would cause the bulk density to be larger than expected. The best recommendation would be to collect soil samples under dry conditions or to allow the samples to air dry for a longer period of time.

Another consideration to examine when acquiring soil samples is the presence of large rocks and roots. When a portion of the soil sample was collected for bulk density measurements, care was taken to avoid layers that contained large chunks of rock. However, some samples contained rocks throughout the entire volume, making it difficult to accurately obtain a constant volume of soil for bulk density acquirement. As a result, some samples that were dried for bulk density determination contained some small rocks. This likely impacted the overall bulk density of some samples, making the bulk density larger than expected. In addition, some samples contained some roots, causing the expected bulk density to not be completely representative of the soil sample.

Results.

Bulk Density.

Through bulk density calculations, conditions of the buffer zone soil can be further understood. High bulk density is indicative of compacted soils, which can lead to inhibition of root growth as well as low infiltration rates. Infiltration is the process of water passing through the soil surface into the soil horizons. This process is imperative to prevent high erosion rates and allow for proper movement of water to plant roots. In systems where erosion and runoff are a problem, having a moderate to low bulk density is necessary to mitigate as much sediment as possible from entering waterways. The primary soil constituent in the nineteen samples was silt (Appendix 2.8). As a result, the appropriate bulk density levels that will allow proper plant growth are equivalent to or less than 1.40 g/cm^3. From the samples collected, all bulk densities were appropriately low with the exception of sample #9, which may cause some inhibition of plant growth. With an average bulk density of 1.1 g/cm^3, the porosity of the soil should encourage infiltration of rain and runoff, helping promote plant root growth. These soils have been relatively undisturbed, preventing compaction and overworking of the soil. With the implementation of native grasses in the future, compaction of soils can be avoided, maintaining the current, healthy bulk density. Incorporation of this organic matter will be highly recommended. Additionally, planting tall growing grasses will also prohibit heavy traffic in many of the areas, further improving or maintaining the bulk density.

pH.

Traditionally, pH is an indication of nutrient availability and potential uptake of nutrients by plants. pH is not a reflection of how much of those nutrients are present within the soil, but rather, how easily accessible the nutrients will be to the plants. According to the soil analysis, the samples were generally slightly alkaline ranging from 6.8 to 8.1 with an average of 7.7. While there is not a stark contrast in pH measurements, generally the highest accounts of alkalinity were present closer to the dam while the lowest rates were the most distant from the dam (Appendix 2.2). Optimal plant growth occurs between 5.5 and 7, where all essential nutrients have appropriate bioavailability. Nitrogen is not as heavily affected by varying pH levels as other nutrients. However, phosphorus and potassium both favor alkaline conditions, making these nutrients more easily accessible to the plant. Iron deficiencies are common in soils with high alkalinity, and the plants could potentially experience side effects such as iron chlorosis, slowing plant growth and potentially reducing amount of groundcover assist with lowering erosion rates. Additionally, manganese, boron, copper, and zinc may also be relatively unavailable at high pH levels. Although these nutrient deficiencies are less common than iron deficiencies, it is important to be able to identify these deficits and be able to monitor how these factors affect plant growth. Finding methods of reducing the pH could be greatly beneficial to the health of the plants, but proper selection of species would be a more effective method of adapting to the soil conditions. Selecting plants that are better suited to alkaline conditions and require lower rates of iron to complete metabolic processes will be crucial to fostering a functional ecological system.

The pH of the nineteen samples is almost ubiquitously higher than the recommended optimal plant growth pH range of 5.5 to 7. As a result, the lakeshore soil resides primarily within moderately alkaline conditions. While ag-lime and other methods can more easily be applied to help raise the pH, acidifying soil can pose a more challenging issue, and proper actions will need to be determined to create proper living conditions to facilitate healthy and productive plant growth. While sulfur applications could be applied in minute amounts, the capacity for erosion to occur is great enough to where fertilizer applications should try to be minimized as much as possible. If fertilizer or soil amendments are a necessary input into the system, utilizing acidic organic matter such as coffee grounds or an acidifying form of nitrogen will be the most effective method of lowering the pH to increase nutrient availability.

Nitrogen.

The two most common forms of nitrogen available in soils is nitrate (NO_3) and ammonium (NH_4). Both forms may be taken up by plants, however nitrate, an anion, is taken up much more prevalently throughout the growing season through nitrification. Soil organisms will convert the ammonium into nitrate over time when the soil conditions allow for a moist environment. While both forms of nitrogen may be present, most ammonium will transition into nitrate before being adsorbed. Nitrate is one of the most mobile soil nutrients, and depending on moisture and atmospheric conditions, nitrate can concentrate in different soil horizons or completely leach away. Rapid movement of nitrates could potentially create a lack of availability for plant roots, causing the nutrient to be too close to the surface or too deep in the soil. Nitrate can be hard to estimate, and may differ drastically throughout the growing season, making estimations and performing soil tests at the proper time a difficult feat. Additionally, nitrate can be converted through denitrification into nitrous oxide, releasing an incredibly potent greenhouse gas.

Ammonium differs from nitrate in that it is highly immobile within soils and prefers to stay in relatively the same soil horizons. For this reason, ammonium will have much lower rates of leaching and will not pose as much of a threat in terms of runoff. Additionally, ammonium could acidify and add to the efforts to lower the pH of the soil. In the buffer zones of Marion County Lake, having higher rates of ammonium would be beneficial to the ecology of the system as it will diminish the amount of nitrogen entering the lake and be more effectively used by the plants.

According to the soil test results, derived nitrate concentrations are primarily low across the lakeshore. There were four samples that contained ideal, moderate levels (Appendix 2.4). These samples were spread throughout the perimeter of the lake and were not localized to one specific area. The soil tests were taken immediately after a rain storm event, likely contributing to the lower readings of nitrates in the soil. These low nitrate levels could be indicative of the high mobility leading to higher accessibility to leaching. Nitrate levels could be escalated within the lake after the rainstorm. Normal concentrations of ammonium are typically between 2 to 10 ppm and nearly all samples were within this range. Ammonium concentrations appear to be at a relatively healthy and stable amount for the soil surrounding the lake (Appendix 2.7). While the average concentration of nitrate is higher than that of ammonium, nitrate mobility may prove to create a lower level of accessibility to plants and exhibit more leaching as well as runoff.

Phosphorus.

Phosphorus is an essential plant macronutrient that is necessary for plants to produce lush growth; however, it is also known as one of the largest contributors to freshwater eutrophication. Excess phosphorus entering waterways can create algal blooms, cause human health issues, and reduce recreational capacity of a body of water. As phosphorus can enter water systems through both surface level runoff and subsurface leaching, it is necessary to have a clear understanding of phosphorus conditions in an area and the potential risks involved. This allows for proper management and protection of the aquatic health of the lake system. Excess phosphorus is primarily caused by agricultural lands, as well as residential areas.

In the case of Marion County Lake, the highest levels of phosphorus were found in the northern-most part of the lake, in contrast for the rest of the surrounding perimeter with low rates of phosphorus (Appendix 2.5). While the majority of the surrounding perimeter is residential areas, agricultural runoff from both grazing cattle and crops flow in from this region of the lake. The soil test results exhibit a high likelihood that incoming phosphorus deposits are primarily flowing into the lake via the northern-most region of the lake, resulting in the eutrophication. Soil sample #13, located on the lower half of the northern bank, also showed higher levels of phosphorus than the remainder of the perimeter, and could be contributed to the residential areas adjacently north of the sample, or the agricultural land located to the northwest. Low phosphorus rates found in the remainder of the lake may be attributed to natural deposits of the phosphorus being depleted over time from runoff accumulating in the water. Conversely, the area may have had naturally low phosphorus deposits, and the area was simply never able to accumulate deposits. The sample areas that show low rates of phosphorus could potentially need fertilization in order to get established and maintain prolific growth. That being said, phosphorus fertilization in these conditions is risky and establishing methods such as band fertilization or targeting certain plots will have less of an impact than allowing broadband fertilization.

Potassium.

Nearly all samples tested contained high amounts of potassium (Appendix 2.6). Ranging between 226 and 530 ppm, the potassium levels of the lake are considerably high. While these higher potassium concentrations in the samples are not a serious cause for concern, it is important to take these numbers into account when fertilizing and in the future. While excessive rates of potassium can result in a decrease in forage quality and even a magnesium deficiency within the plants, the current rates have not exceeded a detrimental level as of now. Potassium concentration exceeding 800 ppm in soil should be monitored in case of a potential deficiency or toxicity issue within the plants. Because of the uniform nature of the potassium rates, it does not appear that the high rates are due to runoff or sediment. When selecting proper fertilizers to establish the plants, fertilizer with low or preferably no potassium additions should be applied to the area. If grasses are potentially going to be planted on the lower northwest bank of the lake where the potassium levels are lower, further soil samples should be taken to understand the overall conditions of that particular area prior to any fertilizer applications. The two lower rates of potassium could be indicative of the overall area or an outlier in the buffer zone.

Organic Matter.

A high percentage of organic matter can come with both positive and negative implications. On one hand, organic matter incorporation into soil allows for an influx of mesopores, medium-sized pores within the soil that will allow for infiltration of water that is still accessible to plant roots. Macropores, inter-aggregate cavities, are too large and do not hold water, ultimately causing precipitation and runoff to leach down to the water table. Mesopores create an environment where water and nutrients are more easily accessible to be taken up by plants. This infiltration is essential to helping reduce and mitigate runoff in the future, as infiltration and runoff have an inverse relationship (Huffman, et al. 2013). Additionally, organic matter provides the soil with microbial activity, and stable plant nutrients. Soil that is rich in organic matter will create a fertile ecological system through the ability to grow healthy plants. Decomposing organic matter within soils sequesters carbon and creates a carbon sink, rather than source. Conversely, in unstable environments, soil organic matter that is not properly protected from the soil surface and is on sloped areas can lead to erosion, contributing to cultural eutrophication within waterways. Protecting soil surfaces through mulching, crop residue, or a permeable protection can also help prevent surface sealing. While the potential harm that is caused by organic matter entering waterways is not in the same light as most applied chemical fertilizers due to the stability of the compounds and lower rates of nutrients, the accumulation of sediment can potentially pose a problem. In the case of Marion County Lake, the minutely excess rates of organic matter do not pose a serious threat to the ecology of the lake. Organic matter located in higher levels surrounding the buffer zone of the lake will potentially provide an improved infiltration rates and help establish the prairie grasses at a better rate (Appendix 2.3). This reduces the need to use chemical fertilization that has the opportunity to enter waterways. While the percentage of organic matter are high for the samples, they are not cripplingly so, and will most likely not create a direct hindrance on the performance of the lake.

Soil Texture and Unit Class.

Soil samples collected surrounding Marion County Lake were easily divisible into four primary soil texture classes: silty clay loam, silt loam, loam, and clay loam (Appendix 1.2). These soil classes were mapped out beforehand using geographical data from USDA's Soil Survey, which supports that there are main four classes of soil: Clime-Sogn Complex, Labette Sogn Silty Clay Loam, Sogn Silty Clay Loam, and Verdigris Silt Loam (Appendix 2.1). While high rates of sand will allow for high infiltration rates do to macropores, the primary component of most of these soils is silt. Silt will allow for a moderate amount of infiltration to occur, but on slopes this amount may be diminished. According to the USDA's Web Soil Survey, the entirety of the buffer zone is zoned as hydrologic group "D" (Appendix 2.8). This group is characterized as having the highest runoff potential, due to aspects such as compaction, slope, and soil texture. Unlike soil nutrients, soil texture is not as easily repaired, and while soil amendments can be incorporated to alter the soil texture and thus infiltration, it is not typically feasible. For this reason, incorporating tallgrass prairie grasses into the buffer zone of the lake would reduce the amount of runoff entering the lake. Planting species to create a native prairie is a much more beneficial and possible method of reducing runoff and erosion while not greatly disturbing the soil profile. While ideally the soil texture does not encourage infiltration, the high rates of organic matter and the introduction of grasses both work to help capture runoff and reduce sediment gathering in the lake. When possible, selecting grasses that have a higher tolerance for poorly-drained soils would help increase the rate of survival and establishment of plants.

Modeling Methods.

To see where the sources of the nutrients of concern are, Purdue's Long-Term Hydrologic Impact Analysis (L-THIA) was used to estimate the runoff and nonpoint source pollution associated with the land use and soil type of the area of interest. L-THIA allows the user to input varying scenarios to simulate development or changing landscape. Seen in Appendix 3, the L-THIA model was based on 2 scenarios, the current land use (taken from the United States Geological Survey Database) and scenario 1, which is calculated based on if 15% of the current land dedicated to grassland/pasture, forests, and agricultural land was evenly split and converted into low- and high-density residential areas. Overall, a majority of the excess nutrients in Marion County Lake are from the agricultural land to the north of the basin. As seen throughout all the L-THIA results, in the coming years as development of the area increases, there will be higher amounts of nutrient transport that will cause the algae events.

Plant Recommendations.

When deciding what plants to have along the shoreline of a water body, it is always important to research particular growing conditions of that particular geographic region. Although this seems like something that would be common sense it is overlooked a surprising amount (Walters, J.P. 2004). Geography plays a major role in the success of a plant since varieties have such extreme variances of nutrient, sunlight, and water needs (Changnon, S. A., Kunkel, K. E., & Winstanley, D. 2002). These important factors were taken into consideration when creating a list of recommended plants to use. Due to the erosion potential of the shoreline, species were chosen that provide great stability to the soil and sustain the health of the general root system.

As a result, there are a variety of different grasses that could be planted along the shoreline of Marion County Lake. Both big bluestem and little bluestem have a dense and deep root system that would add great retention and stabilization qualities to the shoreline. Big bluestem has a unique "turkey foot"-shaped seed panicle and little bluestem grass is considered to be ornamental, providing a nice aesthetic quality to the lake environment. Switchgrass is another viable grass as its root system can reach great depths, making for a great shoreline plant that offers stability. The open panicle of switchgrass gives a unique ornamental quality. Barnyard grass would be a great species to have because its shallow, dense root system would increase shoreline stability and help protect early establishment of deeper root systems against erosion. There are also many large seeds that will be produced by barnyard grass, providing a notable food source for wildlife. Indian grass would offer stability as well to the soil with its deep, dense roots, but its gold seeds and tiny yellow flowers in late summer would provide beautiful scenery for the lake. The seeds from Indian grass are also great food sources for many animals and the grass provides shelter opportunities for riparian animals as well. Purple top would add a great late season splash of color to the shoreline with its deep purple panicles. This would add a nice aesthetic value to the Marion County Lake shoreline buffer zone. The seeds are also enjoyed by many animals as well. The wide root system will help bind other grass roots together and increase stability.

Conclusions.

From the soil analysis, it was noticed that phosphorus levels are above normal on the northern end of the lake. It is not known what the cause of these high concentrations originated from; however, the stream leading to the mouth of the lake could be collecting runoff from agricultural land upstream. Additionally, when acquiring soil samples around this area of the lake, a high concentration of waterfowl was present. This high phosphorus concentration could also be a result of manure deposits from the geese inhabiting the lake. Although nitrate levels will considerably low when the measurements were taken, there was potentially leaching that took place as a rainstorm occurred before samples were collected. Nonetheless, to minimize erosion along the shoreline and reduce the amount of nutrients entering the lake that contribute to algal blooms, it is recommended that some of the following species are planted along the shore: big bluestem, little bluestem, switchgrass, barnyard grass, Indian grass, and purple top grass.

This would retain nutrients, reducing the concentration of nutrients that enter the lake. If restricted to sections along the lake, placing grasses along the northern end of the lake would be ideal to catch nutrients and any pollutants that flow into the lake. Nitrogen and phosphorus are both limiting factors toward blue-green algal blooms that have been a major issue for Marion County Lake. L-THIA modeling showed that this nutrient contribution would only continue to grow as the watershed continues to develop towards more residential-based land cover, providing more evidence to grow these natural catchment systems. The tall grasses would also limit the amount of space available for geese populations, indirectly deterring these waterfowl from nesting in the area. The remaining factors analyzed from the soil analysis did not appear to show results of notable concern. In addition to these suggestions for buffer zone modification, a lake management plan will need to support educational programs on water conservation, cost-sharing, and regulation of fertilizer usage upstream to maintain a healthy watershed surrounding the Marion County Lake for the future (Pierzynski, G. M., Sims, J. T., & Vance, G. F. 2005).

Acknowledgements.

We really appreciate the funding and support provided by Matt Meyerhoff and Lisa Suderman from the Natural Resources Conservation Service for the Marion County Lake Area. We would like to thank our NRES Advisor, Dr. Aleksey Sheshukov, for guiding us through the capstone project and teaching us vital information about modeling with ArcGIS. We would also like to thank Dr. Shawn Hutchinson for leading the NRES Capstone class.

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Appendices.

Appendix 1. Sample Specifications

Appendix 1.1 – Soil Sample Time and Bulk Density

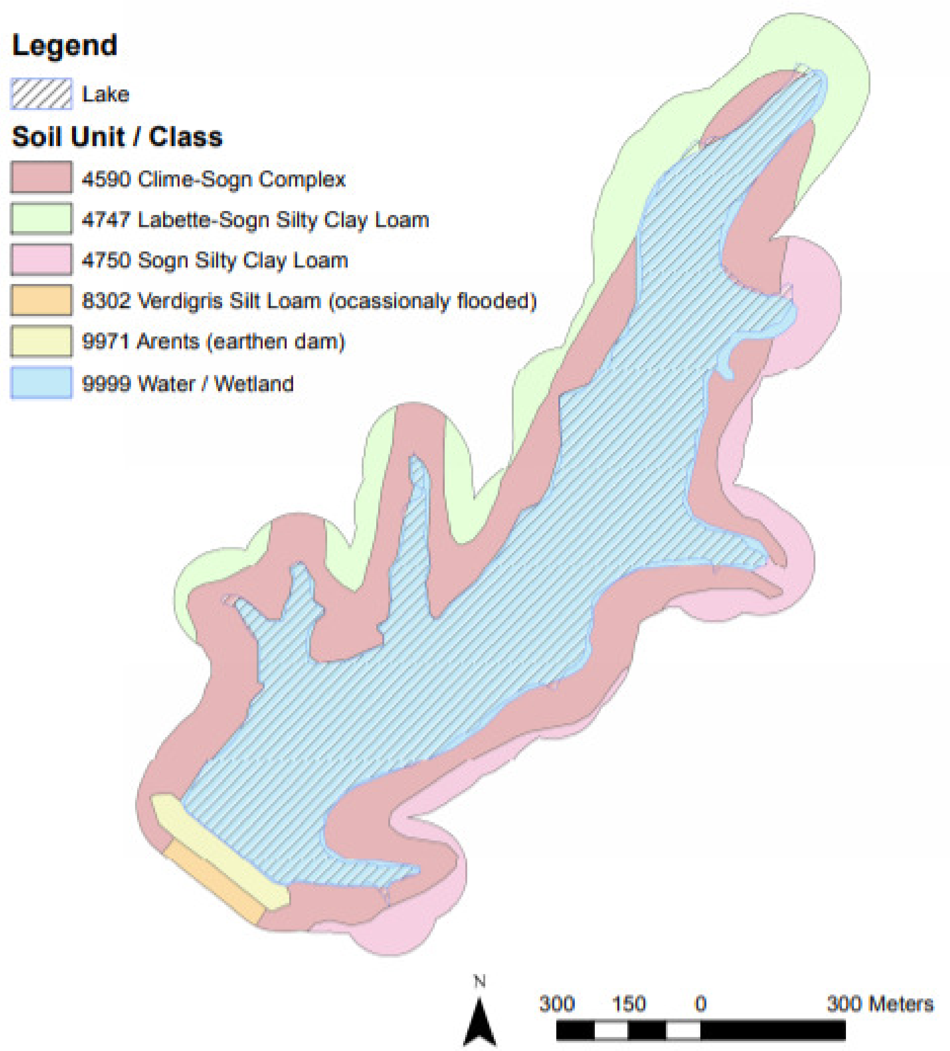
Sample	Time Taken	Bulk Density (g/cm^3)
1	9:31 AM	0.977
2	9:39 AM	1.011
3	9:48 AM	1.014
4	9:52 AM	0.908
5	9:58 AM	1.036
6	10:03 AM	1.215
7	10:06 AM	0.938
8	10:11 AM	1.013
9	10:17 AM	1.484
10	10:26 AM	1.134
11	10:31 AM	1.295
12	10:35 AM	1.137
13	10:39 AM	1.051
14	10:45 AM	1.173
15	10:48 AM	1.041
16	10:52 AM	1.246
17	10:55 AM	1.073
18	10:59 AM	0.999
19	11:03 AM	1.162

Appendix 1.2 – Soil Sample Analysis

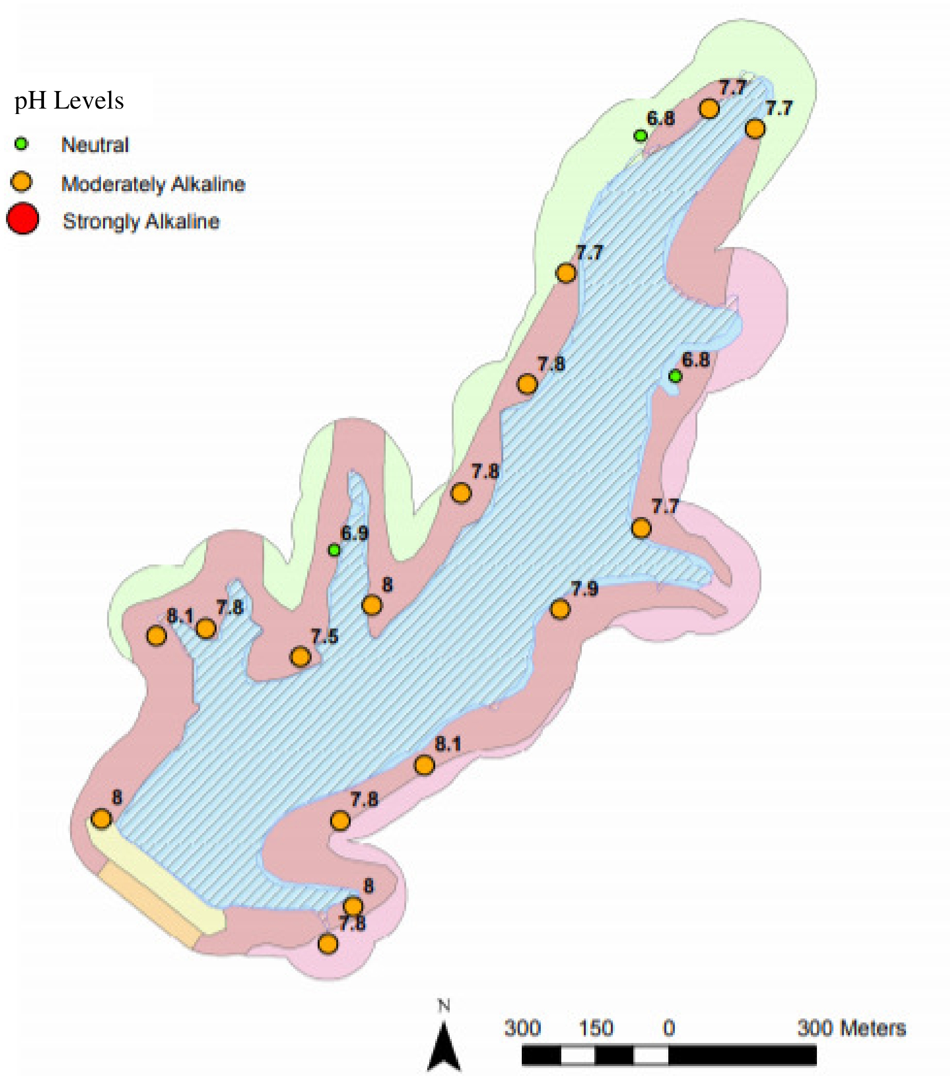
Sample	pH	OM LOI %	NO_3-N (ppm)	P-M (ppm)	K (ppm)	NH_4-N (ppm)	Soil Classification
1	7.7	6	3.9	17	402	4.3	Silty clay loam
2	7.7	6.3	3.7	32	306	4.7	Silty clay loam
3	6.8	7.6	4.1	4	362	19.8	Silty clay loam
4	7.7	9.2	10.1	4	323	8.1	Silty clay loam
5	7.9	8.6	4	4	273	3.4	Silt loam
6	8.1	7.2	5.2	3	337	3.4	Silt loam
7	7.8	10	4.4	4	257	4.3	Silt loam
8	7.8	8.2	11.7	4	305	6.2	Silty clay loam
9	8	5.6	2.4	3	253	6.2	Silt loam
10	8	8.2	6.4	4	248	4.4	Loam
11	8.1	7.1	3.3	2	226	4.6	Silty clay loam
12	7.8	6.2	3.3	4	405	6.6	Silty clay loam
13	7.5	7.3	2.6	18	518	4.9	Silty clay loam
14	6.9	8.5	6.8	3	406	4.3	Silty clay loam
15	8	6.1	3.6	4	292	3.5	Silt loam
16	7.8	6.1	12.5	4	444	4.5	Silty clay loam
17	7.8	7.3	14.8	6	526	3.9	Clay loam
18	7.7	8.5	9.8	4	448	5.2	Silty clay loam
19	6.8	7.8	18.3	21	530	6.1	Silt loam

Appendix II. ArcGIS Maps

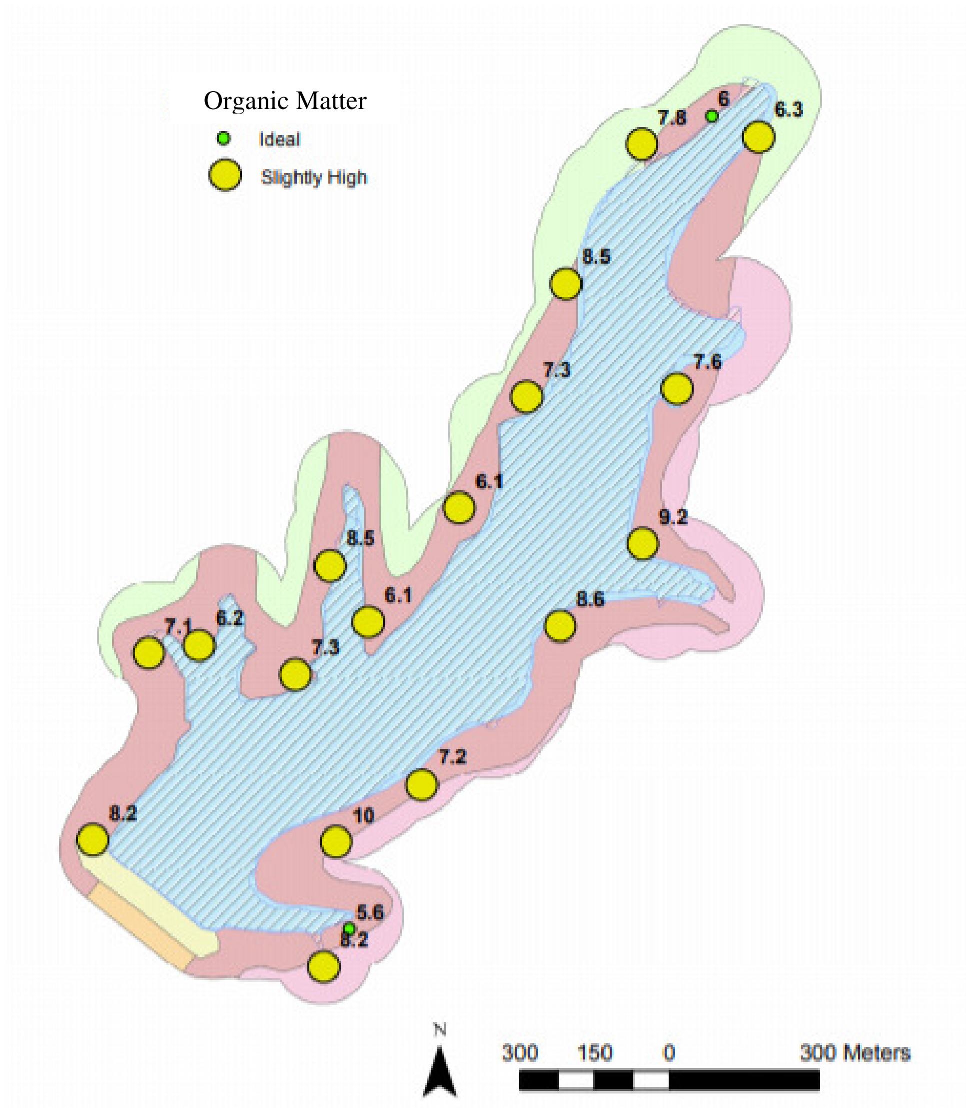
Appendix 2.1 – Marion County Lake Soil Map Units



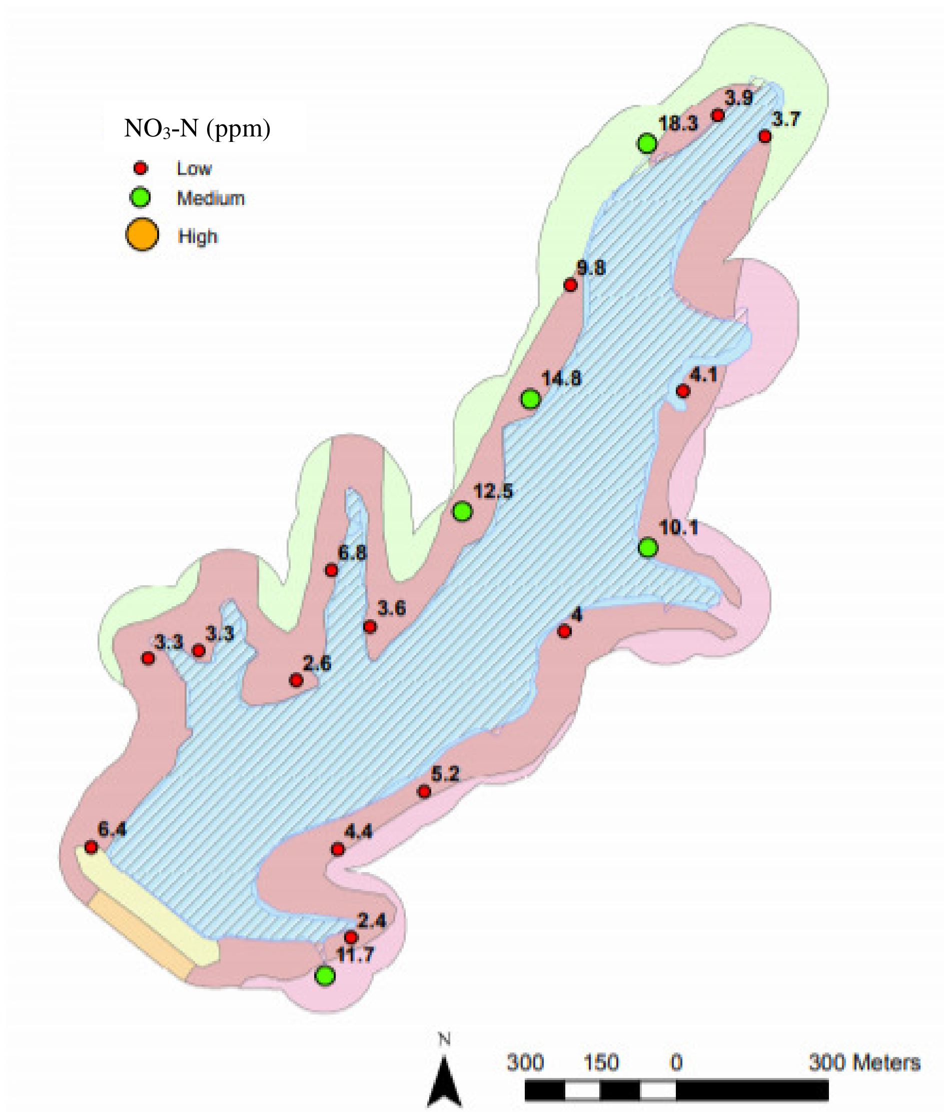
Appendix 2.2 – Marion County Lake Soil pH



Appendix 2.3 – Marion County Lake Soil Organic Matter %

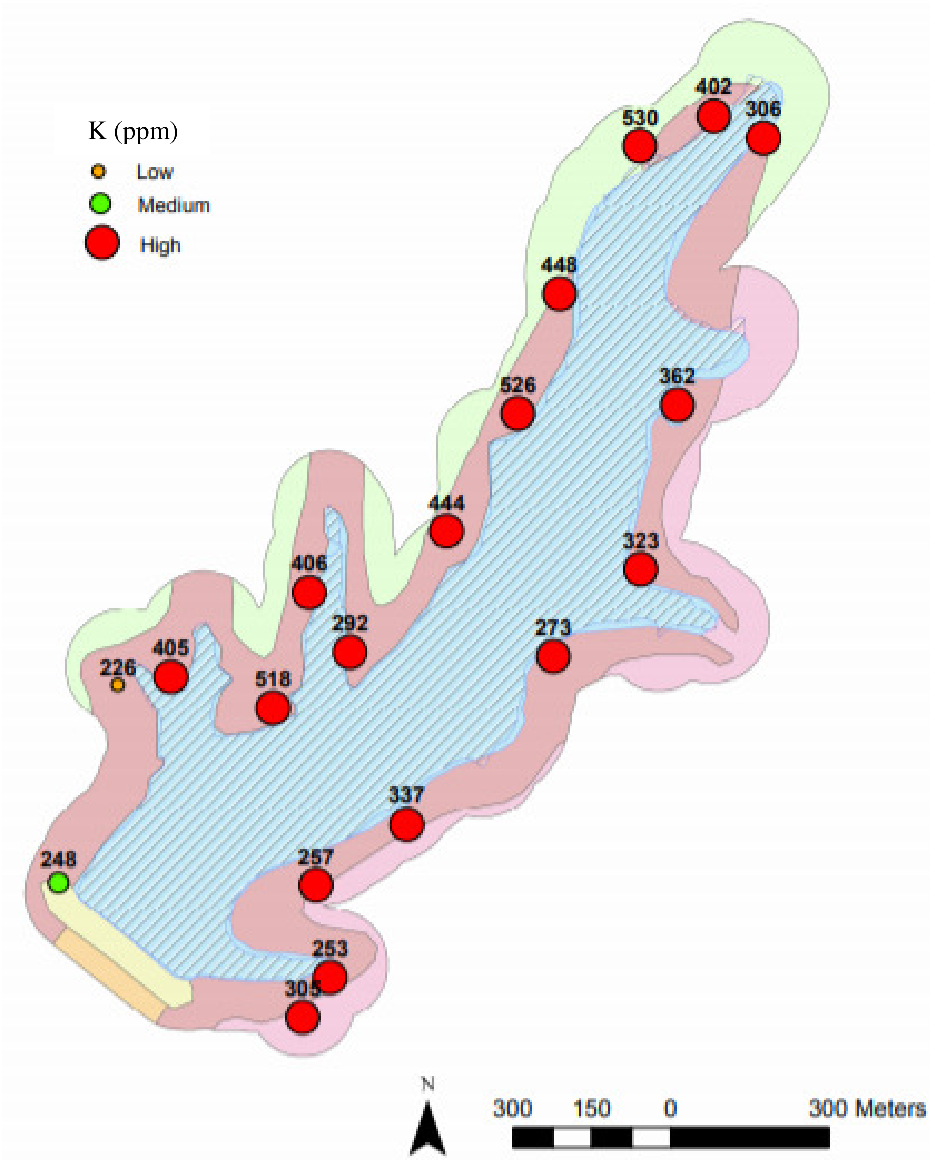


Appendix 2.4 – Marion County Lake Soil Nitrate Levels

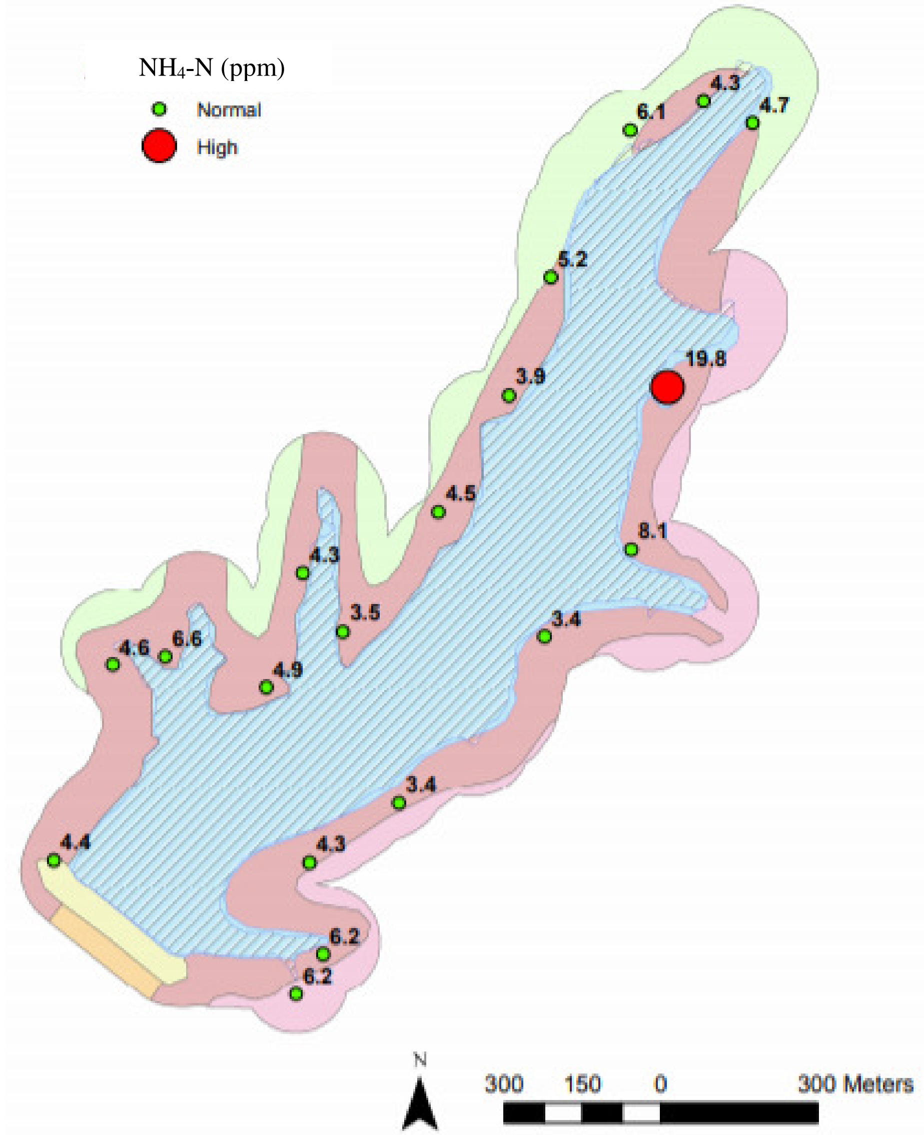


Appendix 2.5 – Marion County Lake Soil Phosphorus Levels

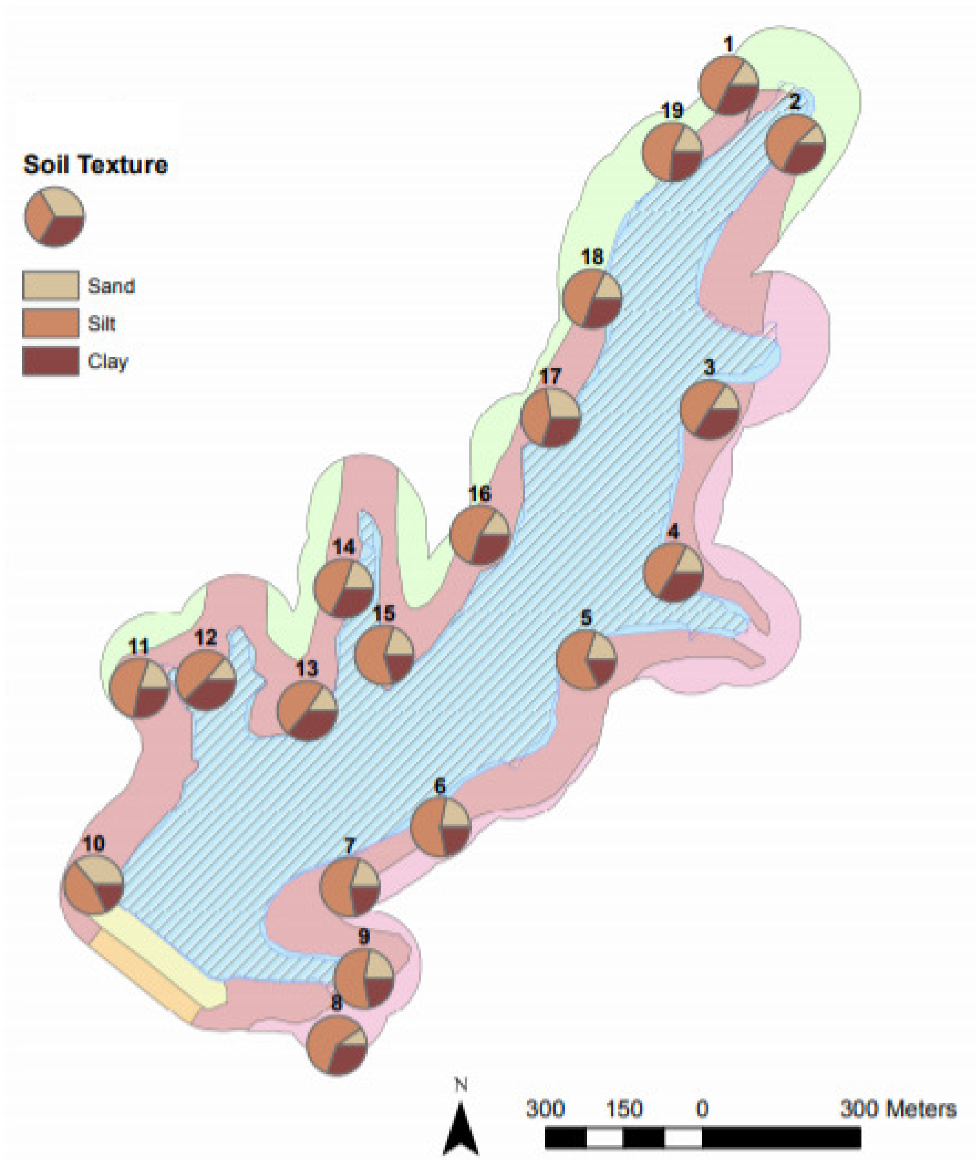
Appendix 2.6 – Marion County Lake Soil Potassium Levels



Appendix 2.7 – Marion County Lake Soil Ammonium Levels



Appendix 2.8 – Marion County Lake Soil Texture

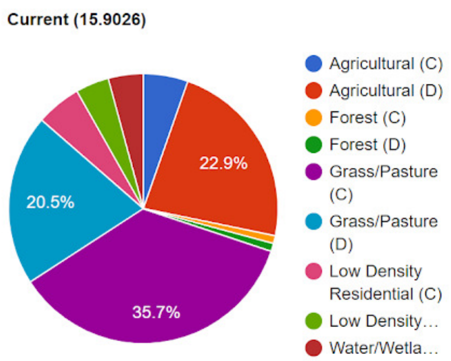


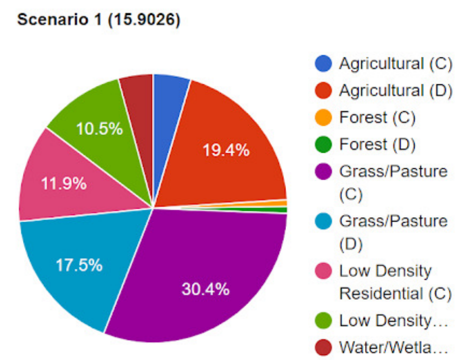
Appendix III. L-THIA Results

Appendix 3.1 – L-THIA for Allen County, KS

Land Use	Hydrologic Soil Group	Current	km^2 Scenario 1
Agricultural	C	.8543	.7262
Agricultural	D	3.6340	3.0884
Forest	C	.1511	.1284
Forest	D	.1529	.1300
Grass/Pasture	C	5.6800	4.8280
Grass/Pasture	D	3.2650	2.7753
Low Density Residential	C	.8593	1.8900
Low Density Residential	D	.6375	1.6678
Water/Wetlands	C	.6685	.6685
	D	.0366	.0366

Appendix 3.2 – Land Use in km²

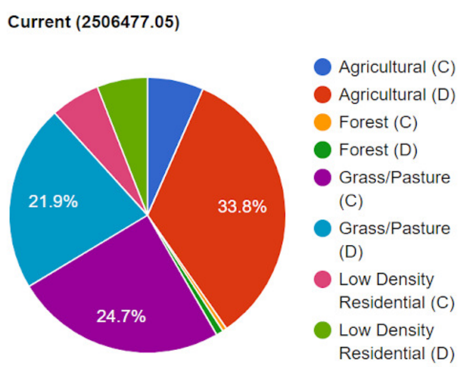


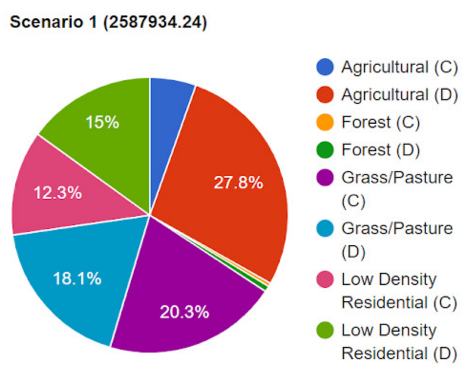


Appendix 3.3 – Average Annual Runoff Volume (m^3)

Land Use	Current	Scenario 1
Agricultural	164697.07	140001.19
Agricultural	846424.01	719343.95
Forest	12703.58	10795.10
Forest	20699.90	17599.66
Grass/Pasture	618926.88	526087.84
Grass/Pasture	549832.53	467366.07
Low Density Residential	144707.83	318279.78
Low Density Residential	148485.22	388460.64
Water/Wetlands	0	0

Appendix 3.4 – Average Annual Runoff Volume (m^3)

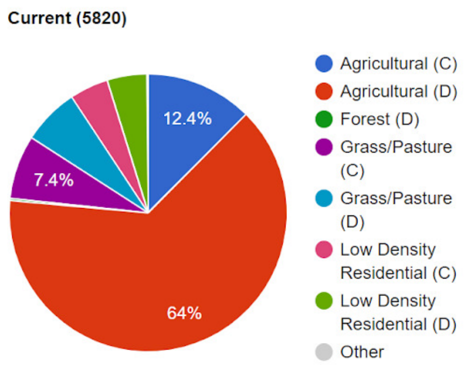


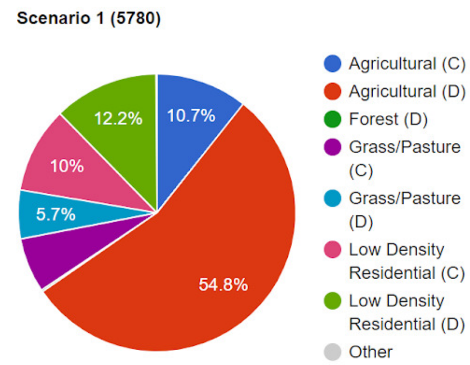


Appendix 3.5 – Nonpoint Source Pollutant Results – Nitrogen (kgs)

Land Use	Current	Scenario 1
Agricultural	724	616
Agricultural	3724	3165
Forest	8	7
Forest	14	12
Grass/Pasture	433	368
Grass/Pasture	384	327
Low Density Residential	263	579
Low Density Residential	270	706
Water/Wetlands	0	0
	616	0
Total	5820	5780

Appendix 3.6 – Average Annual Nitrogen Losses (kgs)

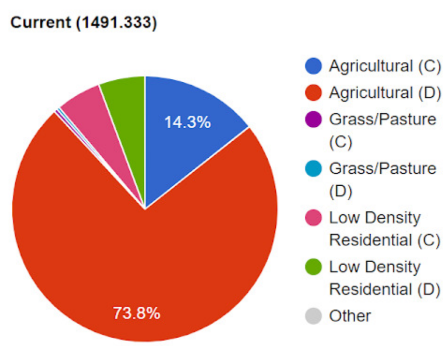


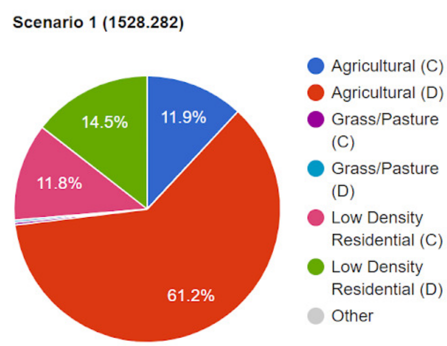


Appendix 3.7 – Nonpoint Source Pollutant Results – Phosphorus (kgs)

Land Use	Current	Scenario 1
Agricultural	214	182
Agricultural	1100	935
Forest	0.127	0.107
Forest	0.206	0.175
Grass/Pasture	6	5
Grass/Pasture	5	4
Low Density Residential	82	181
Low Density Residential	84	221
Water/Wetlands	0	0
	182	0
Total	1491.333	1528.282

Appendix 3.8 – Average Annual Phosphorus Losses (kgs)





Appendix 3.9 – Nonpoint Source Pollutant Results – Suspended Solids (kgs)

Land Use	Current	Scenario 1
Agricultural	17622	14980
Agricultural	90567	76969
Forest	12	10
Forest	20	17
Grass/Pasture	618	526
Grass/Pasture	549	467
Low Density Residential	5933	13049
Low Density Residential	6087	15926
Water/Wetlands	0	0
	14980	0
Total	121408	121944

Appendix 3.10 – Average Annual Suspended Solids Losses (kgs)