Studying Potential Effects of Changing Climate and Changing Land Cover on Marion County Lake

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I. Introduction

Marion County Lake was completed in 1937 by the Civilian Conservation Corps, a public work relief program established by President Franklin Roosevelt. The primary purpose of the lake, then and now, is for recreation. Recreation at Marion County Lake includes fishing, swimming, and watersports. In 2002, Marion County Lake was listed on the registrar of the National Register of Historic Places (NRHP). The NHRP is part of a national program to support both public and private efforts to identify, evaluate, and protect the United States' historic and archaeological resources (National Park Service, n.d.).

Marion County Lake is about 1.5 miles southeast of Marion, KS. Its primary outflow is the Cottonwood River and exists in a watershed basin spanning 6.28 square miles. The lake itself has a surface area of about 300 acres and is surrounded by residential neighborhoods. There are both permanent and non-permanent residents living in the established homes surrounding half of the lake. The other half of the lake is surrounded by campground sites, both primitive and in the form of mobile homes. The lake has both fishing docks and loading/unloading docks for boats. The lake also has a designated swim beach. Fish populations are stocked by KS Fish & Wildlife.

The officials at Marion County Lake seek to establish a management strategy for Marion County Lake and its surrounding watershed. The primary use of the lake is recreation based. With that in mind, this work will establish the foundation of a lake management plan that seeks to preserve the lake for recreation. To be discussed are the principles of lake management plans, the potential effects climate change will have on Marion County Lake and what management strategies need to be employed, and the effects that changes in land cover will have on the lake - all in terms of the recreation potential of the lake. Results of climate trend analysis, climate model analysis, and runoff model analysis are to be discussed.

II. Literature Review

What is a lake management plan?

A lake management plan is a fluid, dynamic document that outlines goals and action items for the purpose of creating, protecting, and/or maintaining desired conditions in a lake and its according watershed. For Marion County Lake, the lake management plan should be used by lake officials and the surrounding community to preserve the condition of the lake for its primary purpose. Every lake management plan is unique to the lake and surrounding watershed.
The possible components of a lake management plan are as follows: ecological concepts, identification of lake problems, lake water quality analysis, management of the watershed, lake restoration and management techniques, implementation of the lake management plan, and lake protection and maintenance (Thornton, 1990). Within this work, only three components of the

lake management plan will be discussed: managing the watershed, restoration and management techniques, and the implementation of a lake management plan.

Managing the Watershed

There exists an everlasting connection between lakes and their corresponding watershed. In order to effectively manage a lake, the surrounding watershed must also be managed appropriately. Since recreation is the primary use of the lake, water quality is of utmost concern. Lake water quality is "critically linked" to the quality of the water draining into the lake from the surrounding watershed via both point and nonpoint sources (Thornton, 1990). The lake is simply one piece of a larger system - the watershed. Many typical problems associated with lakes truly stem from issues arising in the surrounding land. In most cases, the largest cause of decreased water quality is a result of point source pollution. For most lakes, one of the most essential forms of treatment for the lake in the management plan is wastewater treatment and controlling point-source inputs. One suggested method of natural wastewater treatment is the utilization of surrounding wetlands that act as a biological filter of the water flowing into lake.

Assessing current and potential sources of pollution is one of the first steps in any management plan. If a point source is not the cause for decreased water quality, nonpoint sources and cultural sources are most likely the culprit. To mitigate these sources of pollution, best management practices should be observed throughout the watershed. Best management practices refer to practices developed for agriculture, silviculture, urban, and construction activities. Landowners must first implement best management practices on their own land before developing watershed scale management practices. With so many homes in close proximity to the lake, it will be important to establish what is allowed in terms of fertilizer use on yards or what can and cannot go into the lake. Implementation and regulation of best management practices are the surest way to improve and protect lake quality (Thornton, 1990).

Restoration and Management Techniques

The biggest factor affecting lake restoration is the quantity and quality of input into the lake. Before conducting any restoration, it must be determined if the lake is sustainable. This requires water inflow and outflow analysis to determine if natural methods are sufficient for maintaining water levels in the lake. One important distinction to make is the difference between restoration and management. Restoration refers to the attempt to return a lake or body of water back to its original condition whereas management seeks to improve the lake (Thornton, 1990). Determining what technique is necessary for a given lake is highly important in creating a long-lasting lake management plan.

At this point in establishing the lake management plan, it is useful to assess what problems are seen in the lake consistently. There are six highly common problems found in most lakes: nuisance algae, excessive shallowness, excessive macrophytes and their attached algal mats, drinking water taste, odor, color, and organics, poor fishing, and acidic conditions (Thornton, 1990). The *Lake and Reservoir Restoration Guidance Manual* put out by the EPA provides detailed reports on the problems itself, the mode of action, the effectiveness of treatment, the impacts, and the costs associated with the six problems listed. A common problem suffered by lakes across Kansas is consistent outbreaks of blue-green algae. There are restoration techniques which focus on controlling intake of phosphorus or curtailing phosphorus release and cycling within the lake since spikes in phosphorus concentrations is one of the leading causes of blue-green algae outbreaks (Thornton, 1990).

Implementation of a Lake Management Plan

After going through the process of developing a lake management plan, it is important to actually adhere to that plan. This requires the support of not just lake officials, but also residents of the lake, and visitors of the lake. There are many barriers to implementing a management plan including: money, manpower, planning, scheduling, and permission. Permits and regulations require money and coordination before any restoration or many management techniques can be applied. Additionally, if the lake exists in a watershed which has multiple owners, a coordinated effort must be undertaken to implement and follow through with a plan (Thornton, 1990).

Funding for lake restoration and management can be acquired from federal, state, and local agencies. Implementation requires time due to circumstances such as: inclement weather, unanticipated obstacles, and other factors can delay management plan implementation. One of the key factors in implementing a successful lake management plan is maintaining public support through public education. Restrictions typically need to be put in place while restoration and management equipment are installed which requires public approval. Public meetings and providing material for local community members are two ways suggested by the report to reach the maximum amount of people.

The greatest deficiency in lake management is a lack of available information on treatment longevity and effectiveness. Post-restoration monitoring is key for observing changes in the lake. It is nearly as important to implement a monitoring plan as it is the initial management plan. Monitoring is also one of the most cost-effective ways to ensure the value of the input cost for the management plan. Monitoring quality is essential in order to reliably assess the conclusions obtained from management and restoration practices. There are many long-term monitoring strategies outlined in the *Lake and Reservoir Restoration Guidance Manual* including monitoring of: ambient water quality, total phosphorus, water temperature, pH, chlorophyll a, lake water level, fish surveys, macrophytes, phytoplankton, macroinvertebrates, and watershed maps (Thornton, 1990).

Summary

Lake management plans require extensive research, planning, and support. These documents can be long, detailed, and hard to read. To see positive results from the implementation of a lake management plan, public support and flexibility is crucial. Land and homeowners must have a stake in the management and restoration of a lake. As a starting point for the future lake management plan, this report will look at the effects of climate change, especially as it relates to rainfall and temperature, and the effects of changing land use and land cover on the water quality and volume of Marion County Lake.

What are the effects of a changing climate on lakes?

It is widely accepted in the scientific community that climate change will increase the recurrence of extreme weather events, especially drought and heavy rainfall (Jentsche, 2008). Weather events will become more extreme meaning that it should be expected to see fewer rain events, releasing more water, thus leading to more flooding and droughts. It would be irresponsible to ignore the potential impacts of climate change when developing a lake management plan. This section will focus on climate change's potential impacts on water quality and water volume. In terms of water quality, climate change could amplify eutrophication and algae growth, as well as prevent dilution of pollutants existing in the water today. Changes in rainfall patterns will strongly affect water volume, while changes in temperature will affect water evaporation rates.

The legality of the Organic Act, which in 1916 brought the National Parks Service into existence (Biber, 2008) is the basis for the rational argument and thinking of how park managers and government officials should apply techniques and models to protect their parks and historic places from the long and short-term effects of a changing climate. This act, as well as projections and outcasts into the future are necessary to continue to protect and keep the National Parks as close to the same as they were when the first people laid eyes on them. Not only will this help our team find context as we look at how climate change is affecting the National Parks, but also give us different variables to try when calculating projections into the future.

Impact of Climate Change

This study focuses on the geomorphology of animals in the Western United States and the possible impacts of theses habits due to climate change. Highlighting specific animals known to cause higher levels of geomorphological impacts (beavers, grizzly bears, and pikas), the author emphasizes the spatial patterns, intensities, and changes of these animals' habits due to climate change. As climate change impacts have the potential to change these animals' habitats, burrowing and foraging habits, and other geomorphic processes, this has direct implications for the future of several important animal species in the Western United States.

In relation to our specific project, this study illustrates the connection between key animal species and ecosystem health in many of the national parks in the Western U.S. Granted we do not have Grizzly Bears in Kansas, but native wildlife is just as important. Changes in their habits due to climate change can provide valuable information to climate scientists and wildlife biologists regarding environmental health. Utilizing the Surficial Geology map in Glacier National Park (GNP), the author generates valuable mapping information on the geomorphic habits and the impacts climate change may have on those habits. Conclusions made by the author emphasize the importance of effective, proactive mapping of key habitats and wildlife to help protect species that are currently threatened by impacts of climate change. This information and its spatial mapping methods will be a useful reference for our own project regarding determination of "at risk" parks due to climate change.

GIS and Climate Change

A group of scientists wanted to see how climate change affected Yellowstone Ecosystems. They completed this by mapping multiple projections in GIS dealing with species distribution under climate changes. Interestingly enough, they mapped this out using GIS to see if there was a way to actively change current or future management techniques. The group spent time in Idaho, Wyoming, and Montana. The main modeling method used was VisTrails. The results of this model showed that with less spring snowpack and an increasing summer season soil moisture, a deficit in the mountain forest species would occur in addition to an increase in the habitat area for sagebrush and juniper ecosystems.

Water Quality

Cultural eutrophication, the process of speeding up natural eutrophication rates due to human activity, is prevalent in lakes across the country. Both large sources of phosphorus input, such as fertilizer runoff from crop fields, and small sources, such as "small communities and individual homes on septic lines", can perpetuate and accelerate eutrophication in lakes (Schindler, 1974). Schindler studied the effects of phosphorus on eutrophication, the effects of phosphorus removal, and the possibility of recovering existing culturally eutrophic lakes in a lake, divided in two, in Canada.

Experiments were conducted varying phosphate, nitrate, and carbon concentrations using ammonia and sucrose to control nitrate and carbon elements. It was found that when two nearly-identical lakes were both treated with equal levels of nitrate and carbon input, only the lake with phosphates added became eutrophic. After confirming that phosphorus was the primary cause of eutrophication, a study was conducted to determine the recovery of a eutrophic lake after phosphorus control measures, as a part of a nutrient management plan, were undertaken. Schindler set out to disprove that phosphate, "returned from anoxic sediments in eutrophic lakes" would perpetuate eutrophic conditions despite the implementation of phosphorus control measures. It was shown over the course of one year, little to no phosphorus was returned from sediments. These results are encouraging and suggest that the implementation and monitoring of a phosphorus control management plan can mitigate the potential for a lake to become eutrophic.

The Kansas Department of Health and Environment (KDHE) has maintained records of reported outbreaks of blue-green algae since 2010. There has been a consistent rise in the number of outbreaks throughout the state, as well as the duration of time the outbreak lasts (Kansas Department of Health and Environment, n.d.). There is bias in these results since KDHE only tracks outbreaks that are officially reported to them. Blue-green algae poses a high risk of health hazard to drinking and recreational waters. The toxins of blue-green algae include hepatotoxic peptides, a cytotoxic alkaloid, neurotoxic alkaloids, and saxitoxin derivatives, as well as allergens and lipopolysaccharides. There have been recorded deaths of dialysis patients caused by liver injury as a result of blue-green algal toxins contaminating drinking water supply. Recreational exposures to water containing toxic blue–green algae have caused illnesses ranging from acute pneumonia and hepatoenteritis to mild skin irritation and gastroenteritis (Falconer, 1999).

Another study, conducted at a tributary of Lake Simcoe in Canada over a 99-year time period focused on the impacts of climate change on hydrology and water quality. This study used the integration of two climate models: HBV and INCA-P, as well as "statistically downscaled data from the Global Circulation Model CGCM3 for two IPCC scenarios" (Crossman, 2013). The implications of climate change can alter precipitation patterns, thus changing the timing and scale of runoff and soil moisture, change lake levels, alter groundwater availability and storage, and affect water quality of both surface and groundwater resources. Water scarcity is a concern with increasing population rates, which in turn causes a greater concern for water quality. Using climate models to simulate the effects of climate change on nitrogen, total phosphorus, sediments, and dissolved oxygen, one study found that "changing flow [of rivers], temperature, soil moisture, and rainfall" caused a wide range of responses dependent upon location and land use (Crossman, 2013).

Adaptation strategies or management techniques can attempt to prevent these effects, however, "future proofing" needs to be done with models to determine their effectiveness long term. INCA is a widely used "dynamic, process-based model, producing daily estimates of stream discharge, and water quality, analyzing inputs form both diffuse and point sources" (Crossman, 2013). The model simulates flow pathways and pollutant fluxes in both terrestrial and aquatic environments. Model management scenarios are used to determine the effectiveness of mitigation techniques. The article gives the example of controlling total phosphorus by limiting sewage loads from treatment works, controlling total phosphorus loading from fertilizer and manure, and implementing buffer strips and bank erosion controls (Crossman, 2013). Adaptation strategies were measured on short and long term scales to check the accuracy of model predictions. From the models, it was determined that the management of total phosphorus will be most challenging during periods and high rainfall and flow events. This shows that the most attention should be paid to these time periods when developing mitigation strategies.

Water Volume

Climate variability is affecting evaporation of water in lakes, especially as it relates to the overall water and energy budget of the system. A 10-year study was conducted analyzing seasonal, intraseasonal, and interannual variations in lake evaporation in Wisconsin. The data were analyzed over 2 week periods to provide bi-weekly energy budget estimates. Changes in water levels are indicators of changes in the water balance which can result from changes in: precipitation over the lake and watershed, land surface evapotranspiration and snowmelt, and/or direct evaporation from the surface of the lake (Lenters, 2005). Evaporation studies are difficult to conduct, but there are a variety of documented methods to measure evaporation including: mass transfer, water balance, eddy correlation, and energy budget methods. 10-year energy budget studies have been conducted consistently in the literature, however, they are very costly and time-consuming.

The lake that was studied (Sparkling Lake) is a part of the North Temperate Lakes LTER Program; it is a 64-ha seepage lake in northern Wisconsin. The lake is clear, relatively deep (max depth of 20 m, mean depth of 10 m), and oligotrophic (Lenters, 2005). An equation for the evaporation rate and overall energy budget was derived as a part of the methodology. Evaporation rates are affected by more than just temperature; color, clarity, depth, and area also play a role. In this study, measurements were taken for radiation, lake temperature, air temperature, relative humidity, and wind speed. An energy budget method was used to study evaporation rates over the 10-year period.

The evaporation rate was shown to have high variability day to day. The mean evaporation rate for the entire study period was 3.1 mm/day with a standard deviation of 0.8 mm/day. The conclusions can likely be applied to most mid-latitude lakes of comparable size and depth with little variation. Lake evaporation was found to be highly variable based on a wide range of timescales - especially seasonal; however, the results are consistent with other similar studies (Lenters, 2005). Relative humidity played a large role in intraseasonal evaporation rate variability; this is due to a significant difference in timing between water and air temperatures which is a function of lake depth and regional climatic variability. Another key finding of the study is that the effectiveness of the common mass transfer formula for calculating evaporation rates is highly dependent on the timescale considered and the local wind field (Lenters, 2005).

What are the effects of land cover on lake water quality?

Land Cover Effects on Water Quality

Effect of watershed land use on water quality. The water quality is related to the hydrologic and limnological properties of ground and surface water, and significant efforts have been made to monitor water sources to understand the effects of land use changes in agricultural areas, with significant socioeconomic activities. In this article they looked at the following, total nitrogen, total phosphorus, hardness, nitrate, ammonium, fecal coliforms.The water quality was monitored in the morning, for twelve months at the spring of each tributary, from October 2013 to September 2014. The measurement of water quality followed the Standard Methods for Examination of Water & Wastewater (American Public Health Administration, 1999), from Brazilian Protocol. According to Simedo, Water quality differs at each subbasin and is linked to land uses or the conservation status of river basins. The evaluated parameters of total nitrogen, total phosphorus, hardness, nitrate, ammonium, fecal coliforms and temperature indicated that upstream soil use is altering the water quality of the Córrego da Olaria Basin.

Soil types and textures play roles in water retention of the watershed. Using web soil survey online we are able to map the watershed and evaluate the soils in the surrounding areas. According to Wrublack, "Mosaicked images were used from Google Earth, Digital Elevation Model and soil types of maps" (2018). Several technologies have been used in studies of environmental planning and management, especially in river watersheds. By integrating data from different sources, the use of these tools has allowed generation of information that can be used in decision making, supporting management actions, especially in land management.

Agricultural Land Use

The growth in ethanol production in the United States has sparked interest in potential land-use change and the associated environmental impacts that may occur to accommodate the increasing demand for grain feedstocks. In this study, water quality and sustainability indicators are used to evaluate the impacts of land-use change to increase corn and grain sorghum acreage for biofuel production in the Perry Lake watershed in northeast Kansas. The water quality indicators in this study, "Impacts of biofuel-based land-use change on water quality and sustainability in a Kansas watershed," include: sediment loads per converted land acreage and the relative increase of total nitrogen and total phosphorus and sediment loads compared to the baseline conditions. The study does 60 situations, and it shows that increased corn and sorghum production leads to an increase in sediment and nutrient loads. This study uses the Soil and Water Assessment Tool (SWAT). The study also talks about CRP production and winter wheat production which is also very relevant to the Marion County region.

Many conservation programs have been established to motivate producers to adopt best management practices (BMP) to minimize pasture runoff and nutrient loads, but a process is needed to assess BMP effectiveness to help target implementation efforts. The study "Pasture BMP effectiveness using an HRU-based subarea approach in SWAT", looks at dividing up a pasture into different regions and then comparing the stocking rate and looking at the sediment and nutrient runoff from the different pastures.

"Five scenarios applied to both a synthetic pasture and a whole watershed were simulated to assess various combinations of widely used pasture BMPs: (1) baseline conditions with an open stream access, (2) an off-stream watering site installed in individual subareas in the pasture, and (3) stream or riparian zone fencing with an off-stream watering site. Results indicated that pollutant loads increase with increasing stocking rates whereas off-stream watering site and/or stream fencing reduce time cattle spend in the stream and nutrient loads. These two BMPs lowered organic P and N loads by more than 59% and nitrate loads by 19%, but TSS and sediment-attached P loads remained practically unchanged."

The study, "Effects of Agriculture on Ground-Water Quality in Five Regions of the United States" by Hamilton, & Helsel speaks on fertilizer application, for example manure is a very common fertilizer application in this area. "Concentrations of nitrate in ground water in these areas have increased because of applications of commercial fertilizers and manure. Nitrate concentrations exceed the maximum contaminant level (MCL) for drinking water of 10 milligrams per liter as nitrogen established by the U.S." "Concentrations of other inorganic constituents related to agriculture, such as potassium and chloride from potash fertilizers, and calcium and magnesium from liming, also are significantly elevated in ground water beneath the agricultural areas."

This study looked at five agricultural regions in the US, Delmarva Peninsula, and parts of Long Island, Connecticut, Kansas, and Nebraska. With continuous applications of beef manure there can be surpluses of nutrients in the soil. For example, when you apply beef manure you can build up the phosphorus pools to a point where you are no longer aloud to apply that manure.

Cattle and Bison grazing has historically been practiced in the Kansas Flint Hills. In the study, "Bison and Cattle Grazing Impacts on Grassland Stream Morphology in the Flint Hills of Kansas" watershed alterations from grazing practices was discussed (Spencer & Anibas, 2018). In this study, the authors determine whether grazing management is a significant driver of grassland stream morphology within the Flint Hills Ecoregion (Kansas, United States). However, longer time periods containing more diverse hydrologic conditions may be necessary to generate larger geomorphic changes between surveys. Although modest changes to stream morphology in response to grazing over short time periods were detected, overall, stream morphology does not vary among grazing treatments in the study area.

Burning Native Grasses

Fire transforms fuels (i.e. biomass, necromass, soil organic matter) into materials with different chemical and physical properties. One of these materials is ash, which is the particulate residue remaining or deposited on the ground that consists of mineral materials and charred organic components. The Marion Co. lake is in the grass flint hills where seasonal burning has been used to control the native range. This article speaks on this and several other topics. Stated in the abstract, "Ash is a highly mobile material that, after its deposition, may be incorporated into the soil profile, redistributed or removed from a burned site within days or weeks by wind and water erosion to surface depressions, foot slopes, streams, lakes, reservoirs and, potentially, into marine deposits." In Kansas lakes are often fighting a surplus of nutrients in their lakes that are causing fish kills and algal blooms. The specific effect of ash on stream or reservoir water quality is difficult to quantify, given that the contribution of ash is rarely distinguished from that of mineral sediment delivered to streams (Smith et al., 2011). However, an increase in nutrients in streams and lakes due to ash after wildland fires has been documented.

Fire is known for its potential to profoundly affect nitrogen (N) dynamics in both terrestrial and aquatic ecosystems. However, few studies have investigated fire effects on several important watershed N pools simultaneously or have directly compared effects of spring prescribed burns and wildfires that occurred in the same geographic area. The study, "Effects of spring prescribed burning and wildfires on watershed nitrogen dynamics of central Idaho headwater areas" by Stephan, Kirsten discusses nitrogen pool alteration when the watershed is burned. Fire effects were found in the terrestrial and aquatic ecosystems after wildfire but were limited to the terrestrial ecosystem after prescribed burns. Soil ammonium (NH_4^+) and nitrate (NO_3^-) concentrations were increased several-fold ($P < 0.05$) in burned relative to corresponding unburned plots in prescribed burn and wildfire sites.

Summary

Land cover and land management play big roles in the water quality of the watershed. Sediment loads, nutrient levels, and runoff amounts are just a few of the key effects of land use and management on water quality of a watershed. Developing or altering the land cover around the lake can have positive or negative effects on the lake. For example, if the area in the watershed were to be developed that would cause more runoff that would get into the lake. Having a firm grasp on these concepts are key parts in the Lake Management Plan and must be evaluated seasonally.

What field techniques should be used in the development of a lake management plan?

Because hydrologic conditions are extremely complex and they can be costly and time consuming, a good groundwater model is required. Once made, it is often not feasible to improve all aspects of the model. Therefore, it is of extreme interest that attributes of the watershed that are the most important predictors are identified. The problem is to determine the parameters that are most important for the prediction model. Data can be collected on hydraulic tests for estimating transmissivity, storativity values, features of the flow system such as the geometry, and internal variability of a hydrogeologic unit associated with a hydraulic conductivity parameter.

Prediction Scaled Sensitivities (PSS) and Value of Improved Information (VOII)

The PSS and VOII methods are used as a basis for judging the importance of model parameters to model predictions. The PSS depends on two important conditions: 1) the model must be a true system, 2) the model must be linear. The other method, VOII, computes prediction uncertainty using calibrated models and existing information about parameters. Although a refined model is under construction, this preliminary model of the flow system is sufficiently complicated to demonstrate the strengths and weaknesses of the methods considered (Tiedeman, Hill, D' Agnese, & Faunt, 2003).

Stokes and Darcy Coupled Equations

The Stokes and Darcy coupled equations appear in porous media modeling. We first need to introduce a new formulation for the Stokes/Darcy coupled equations, subject respectively to the Beavers–Joseph–Saffman interface condition and an alternative matching interface condition. Secondly, we prove the well-posed of these weak problems by using the classical saddle point theory. Thirdly, some spectral approximations to the weak problems are proposed and analyzed, and some error estimates are provided. It is found that the new formulations significantly simplify the error analysis and numerical implementation. Finally, some two-dimensional spectral and spectral element numerical examples are provided to demonstrate the efficiency of our methods (Wang, & Xu, 2014).

Telemetric system for hydrology and water quality monitoring

Monitoring systems are comprised of a datalogger (Campbell CR10X-2M), gas pressure sensor for stream depth/discharge, rainfall (tipping bucket gauge), electrical conductivity and temperature. Each site is also equipped with an automated 24 bottle water sampler (ISCO) that is activated by the datalogger to collect flow weighted stream samples during storm events (Meyer, & Huey, 2006).

The system selection was determined by site access, cost, and software/hardware capabilities. The use of satellites is costlier than a radio system. The radio system's cost was less than the satellites and was greater than the telephonic system. A telephonic system was limited to phone line access, which would not work in the mountain site. The costlier system was the satellite system, which had more cost up front than both other systems but was the most cost effective for remote area access. The researchers, like our team, had to decide based on multiple factors.

Accessibility, cost, data retrieval, and location. It is my hope that future researchers will consider these factors

HOBO Water Level Logger

During our site survey, it was mentioned about installing a HOBO Water Level Loggers. The only article I could find about this piece of equipment was from the Journal of Environmental Health. The HOBO Water Level Logger is a pressure-based water level recording device that combine research-grade accuracy, durability, with a price tag that is roughly half the cost of most comparable solutions. Most level loggers rely on desiccant packs and vent tubes, which can be cumbersome. The newer HOBO simplifies deployment and eliminates many maintenance issues that have been associated with other loggers. The cost for a deluxe kit is roughly $1,137.00. This is not a typical annotated bibliography but thought some information on a viable data collection device was warranted.

Geographic Information Science

Geographic information science (GIS) can be used in public health programs to better understand humans and their interactions with their environment. Geographic information systems (GIS) can be used in public health programs to better understand humans and their interactions with their environment (Miller, 2005). At present, there are four methods for the delineation of these areas: 1) the calculated-fixed-radius (CFR) method, 2) the analytical method, 3) hydrogeologic mapping, and 4) the numerical flow/transport model.

The use GIS to compare the basic CFR methods with other methods, such as CFR versus analytical method, CFR versus hydrogeologic mapping, and CFR versus numerical flow/transport modeling. With the GIS overlay comparisons in the study, however, showed the CFR method having land capture areas that were most like those delineated by the more advanced hydrogeologic method and least like those delineated by the less advanced analytical method. The analytical method had the least similar GIS overlay.

The usefulness of GIS in applying the CFR model around public supply wells as initial protective measures, especially for smaller water systems with limited funds or for larger systems as an interim protection measure. These measures can be successfully adopted by local and state public health agencies in various land use planning processes.

Advancing process- based watershed hydrological research

A best practice is to develop a dialogue between geophysicists and hydrologists interested in synergistically advancing process-based watershed research. The paper discusses recent advances in geophysical instrumentation and provide a vision for the use of electrical and magnetic geophysical instrumentation in watershed scale hydrology. The focus of the paper is to identify instrumentation that could significantly advance this vision for geophysics and hydrology during the next 3–5 years (Robinson, Binley, Crook, Day- Lewis, Ferré, Grauch, Slater, 2008).

The research focuses on measurements of geological structures, then uses the identification of flow paths using electrical and magnetic methods. The paper identifies instruments, provides examples of their use, and describes how synergy between measurement and modelling could be achieved.

An interesting concept is the use of airborne systems that can cover large areas and are appropriate for watershed studies. Airborne geophysics has been around for some time, only in the last few years have systems designed exclusively for hydrological applications begun to emerge. The systems used airborne electromagnetic (EM) and transient electromagnetic (TEM), could change how we interpret hydrogeological processes.

The paper states that the authors realize that that the integration of geophysical measurement methods, and data, into watershed process characterization and modelling can only be achieved through dialogue. This is why I think the Natural Resources and Environmental Science major is an excellent idea. We can network with other disciples to reach a common goal.

Sustainability index for water resources planning and management

This paper presents a water resources sustainability index that makes it possible to evaluate and compare different water management policies with respect to their sustainability. The sustainability index identifies policies that preserve or improve the desired water management characteristics of the basin in the future. This index is based on a previous sustainability index with improvements in its structure, scale, and content to make it more flexible and adjustable to the requirements of each water user, type of use, and basin (Sandoval-Solis, McKinney, & Loucks, 2011).

The methods used are to evaluate water management policies and enable the comparison of alternative policies. The variables can be simple averages, such as system storage, water supply, evaporation, average deficits, and outflow of water from a system. Time, volumetric reliability, and resilience were the probability-based performance criteria that were used.

The research took place in the Rio Grande transboundary basin. This location provided a tailor-made sustainability indexes are defined for water users in Mexico, the United States, the environment. Sustainability indexes by sub-basins are calculated to identify areas of potential improvement and regions at risk. The results identify policies that improve the desired water management of the basin in the future. This makes it easier to evaluate, compare, and identify adaptive policies that improve water management when trade-offs among performance criteria occur. Along with GIS, field techniques, and a proper index for water resources planning and management is required for our project. I would be excited to see this used at The Marion County Lake.

Summary

Field techniques for a lake management plans are vast. Data acquired with proper field techniques can be used as a blueprint to help identifies the "what" and "how" for a successful lake management plan. A good lake management plan is thus organic and, by design, meant to aid the community in meeting existing lake management challenges while at the same time serving as the framework for ongoing management needs.

III. Research Objective

The research presented seeks to develop the foundation for a lake management plan for Marion County Lake. The plan will focus on managing the lake for recreation purposes including fishing and water sports. The volume of water in the lake and the quality of the lake water will be of highest importance in regards to managing the lake for recreation purposes. Changes in both climate and land cover are the focus of this report. These are the most imminent threats to Marion County Lake, at present. Additionally, negative impacts from both climate change and land cover change can have a ripple effect across other aspects of lake management.

A 36-year review of daily temperatures and precipitation depths taken from a NOAA site at Marion Lake will be studied to assess climate trends at Marion County Lake. Additionally, a climate model using PRISM data will be generated to show a 36-year review of trends of climate change across the United States and specifically in Marion County. These data pools will be analyzed to offer management strategies for maintaining lake water volumes and lake water quality. The effects of land cover change will also be assessed in this body of work. Runoff calculations will be performed to determine how changes in land cover will affect the amount of runoff into Marion County Lake, and, subsequently, the lake water volume and water quality.

IV. Methods

Climate Data Trend Analysis

Weather data was collected from the National Centers for Environmental Information at NOAA between the years 1981 to 2017, including the last climate normal. From this data, information on temperature and rain events were calculated using Excel, including: annual minimum temperature (ºF), annual maximum temperature (ºF), date of first frost per year, date of last frost per year, number of rain events per year, number of rain events per month, depth of precipitation per year, depth of precipitation per month, and average depth of precipitation per rain event. Trend lines were generated after graphing the relevant data in Excel to observe general climate patterns over the 36-year period.

Climate Model Analysis

Climate data was collected from PRISM Climate Group between the years 1981 and 2017. This data included 30 year normal temperature(ºF), 30 year normal precipitation, 2017 mean temperature (ºF), and 2017 precipitation. From this data, a model and map were created. The first step in the model (Figure 1) was to input the temperature and precipitation data. Raster Calculators were used to find the greatest temperature between the 30 year normal and 2017 mean temperature. Another Raster Calculator was used to evaluate the smallest amount of precipitation between the 30 year normal and the input year, 2017. A final Raster Calculator was used to show the sum of the previous Raster Calculator. The summation of the raster calculator creates three classes: Output Temperature, Output Precipitation, and a Final Output of the sum of the Output Temperature and Output Precipitation. Each of these are depicted in the model (Figure 1). From the results of the model, a map was created showing the climate change in the United States and in Marion County divided into 3 categories: no impact, moderate impact or high impact.

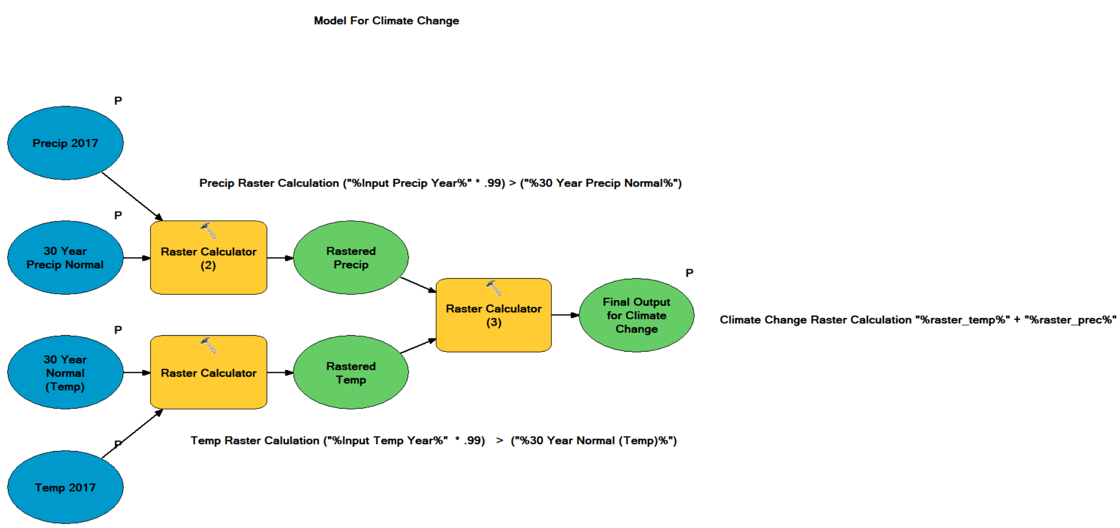


Figure 1. Model developed in ModelBuilder in ArcGIS Desktop to determine impacts of climate change based on precipitation amounts and temperatures throughout the United States

Runoff Modeling

The runoff models were made using the "curve number" or CN method found in the *Urban Hydrology for Small Watershed* document by the USDA (1986). The major factors that determine the curve number or CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Starting with the equation on the left, you take the CN number provided by the TR-55 and calculate S. The second step is to plug that into the Q formula, where P is the rainfall amount you wish to use. Lastly you find Q and multiply that by the area, for example Q x A (Acres), to obtain acre inches of water runoff.

$$S = \frac{1000}{CN} - 10$$

Figure 2. First step in CN curve method

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Figure 3. Second step in CN curve method.

V. Results

Climate Data Trend Analysis

Temperature

The annual maximum temperature varied across 12 ºF over the 36-year period, and there was an observed increasing trend in maximum temperatures (Figure 4). The annual minimum temperature varied across 30 ºF over the 36-year period, and there was, again, an observed increasing trend (Figure 5). Over the 36-year period the date of the first frost always fell between September 30 and November 19, with the highest frequency dates occurring from October 20-October 26 (Figure 6). The date of the last frost always occurred between March 11 and May 4, with the highest frequency dates occurring between April 3 and April 8 (Figure 7).

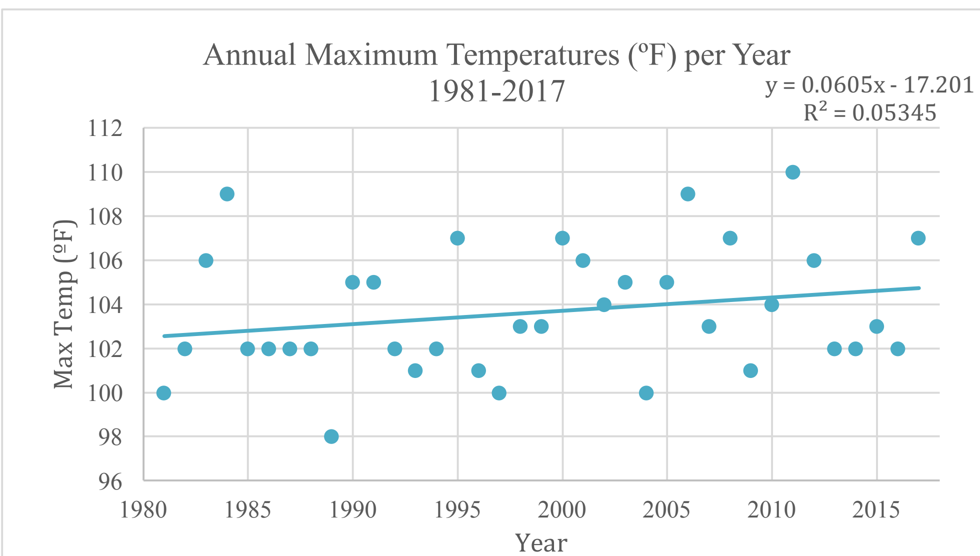


Figure 4. Graph of plotted annual maximum temperature (ºF) from 1981-2017. There is an increasing trend in maximum temperatures from year to year.

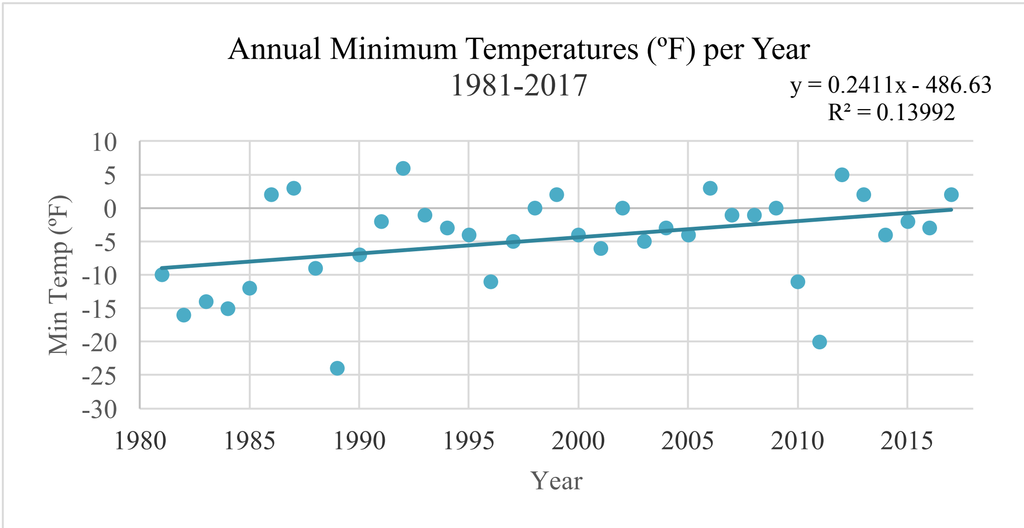


Figure 5. Graph of plotted annual minimum temperature (ºF) from 1981-2017. There is an increasing trend in minimum temperatures from year to year.

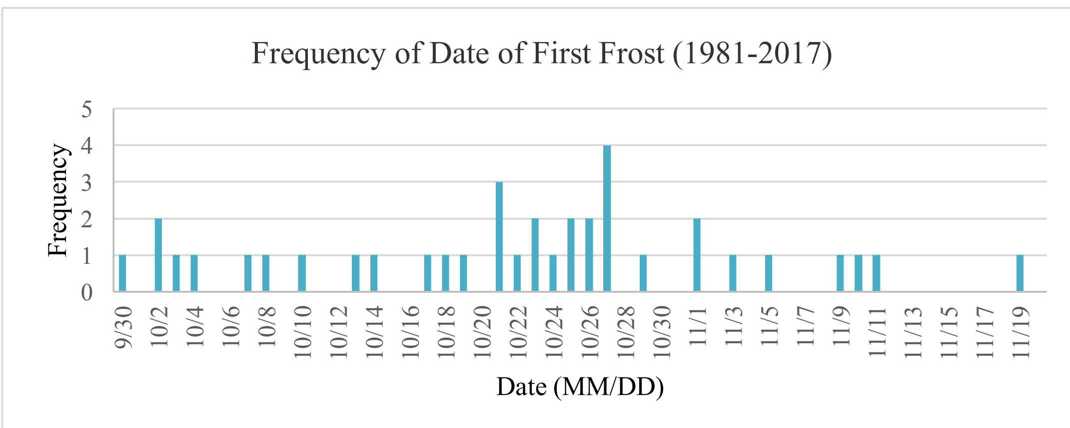


Figure 6. Frequency bar graph of the date of the first frost every year from 1981-2017.

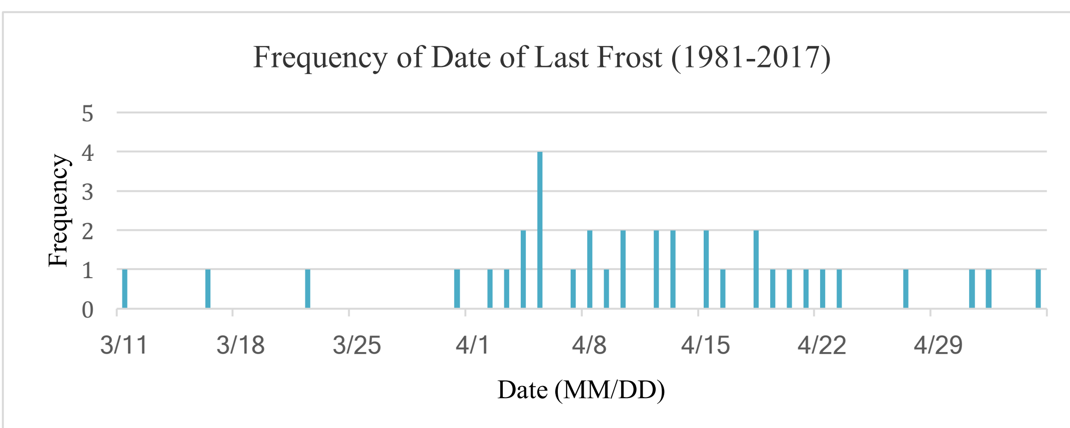


Figure 7. Frequency bar graph of the date of the last frost every year from 1981-2017.

Precipitation

The total number of rain events per year ranged from 112 rain events in 1993 to 50 rain events in 2017. The overall observed trend shows a decrease in the total number of rain events per year over the 36-year period (Figure 8). The total precipitation per year ranged from >47 inches in 1993 to just over 22 inches in 1994. While the total precipitation has fluctuated from year to year, the average depth of precipitation has not changed significantly over the 36-year period (Figure 9). Subsequently, the average depth of precipitation per rain event was calculated for every year in the 36-year period. There is an overall increase in the depth of precipitation generated by each rain event (Figure 10). Within each year the majority of rain falls during the April, May, and August. The driest months are consistently December, January, and February.

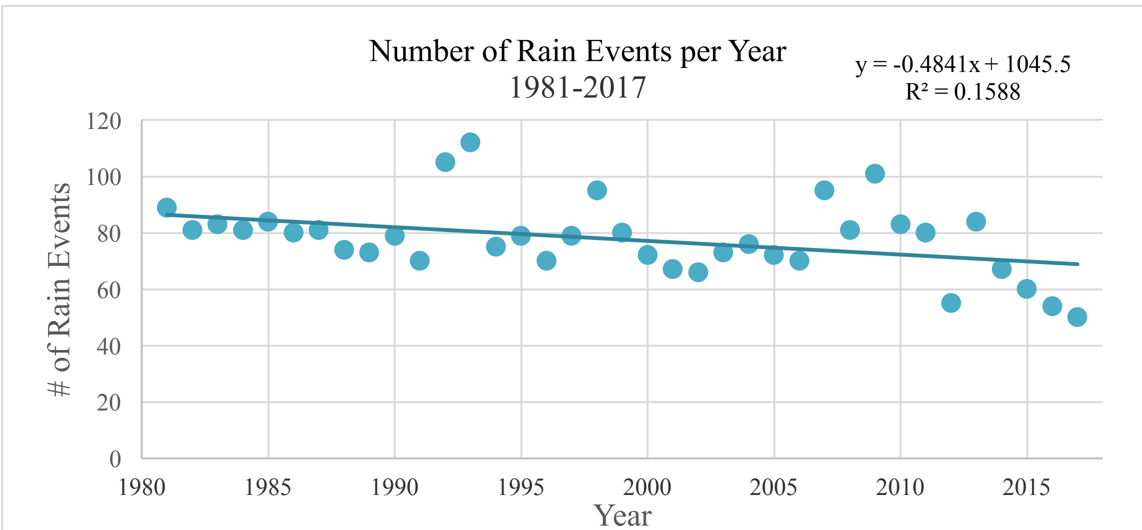


Figure 8. Scatter plot of the total number of rain events per year. There is an overall decreasing trend in the number of rain events that occur every year.

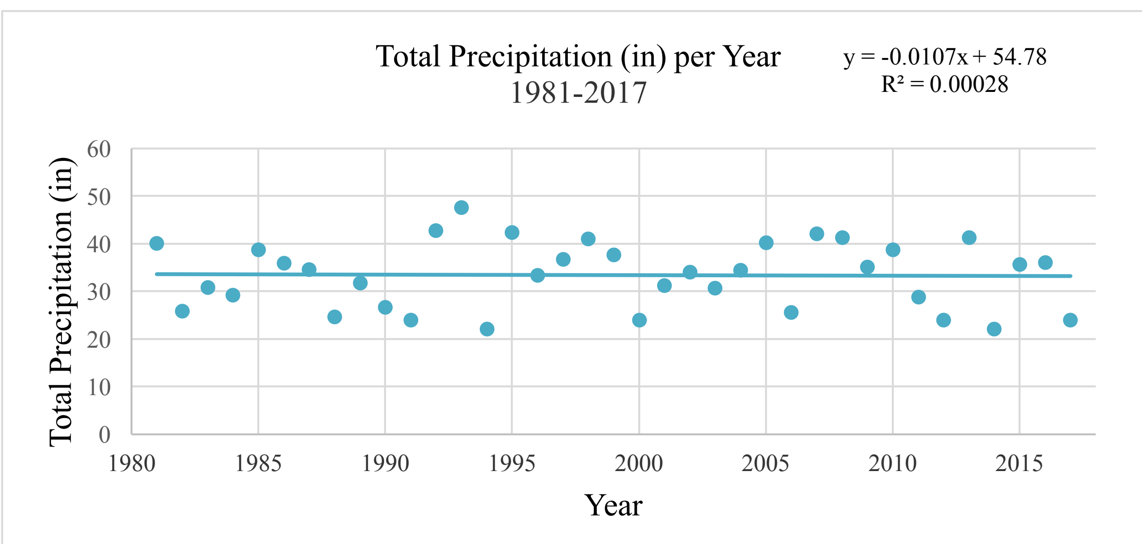


Figure 9. Scatter plot of the total depth of precipitation (in) per year. Based on the data for 1981-2017, the total depth of precipitation received per year is remaining fairly constant.

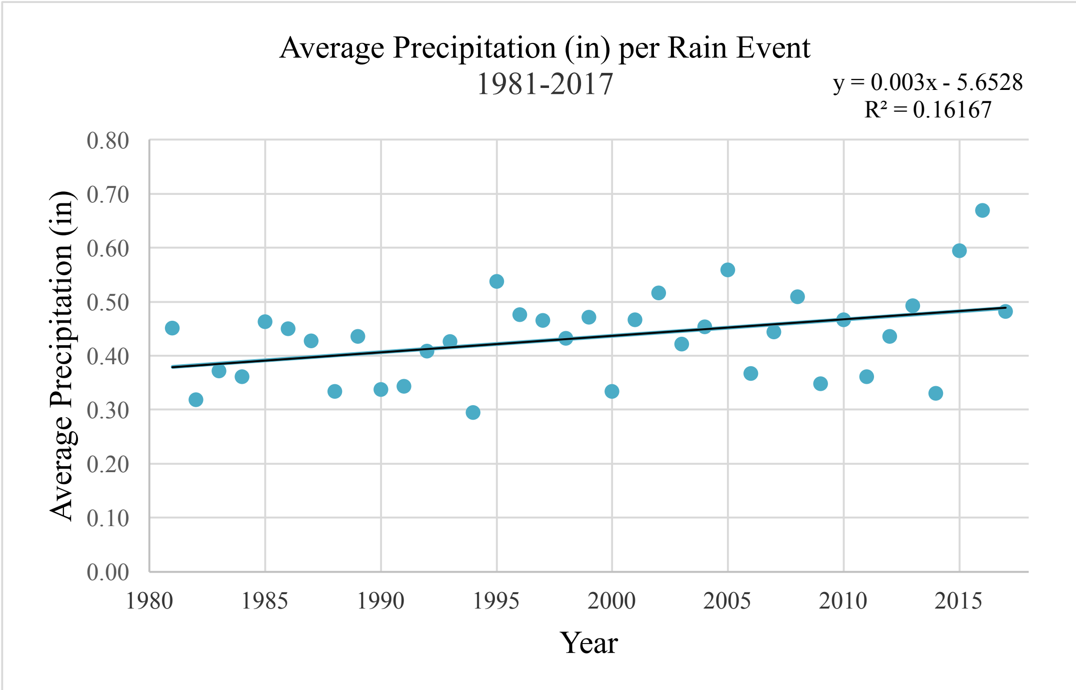


Figure 10. Scatter plot showing the calculated average precipitation (in) per rain event every year. This was calculated by dividing the total precipitation for one year and dividing it by the corresponding number of rain events in that same year. There is an overall increasing trend, showing that there is a greater depth of rain received per rain event in more recent years.

Climate Model Analysis

After running the climate model in ArcGIS desktop, the results were depicted in a map (Supplementary). The first map showed the degree of climate change throughout the United States. There are three degrees of climate change shown; no climate change, moderate climate change, and high climate change. The majority of the United States has experienced moderate climate change. With this data, we clipped the map to show Marion County, with the same degrees of climate change. The results of the model show that Marion County Lake Watershed is experiencing moderate climate change.

Runoff Modeling

Based on the calculations performed using the CN curve method, it is obvious that land cover type alters the amount of runoff that makes it into the lake. As there is an increase in impervious land cover, an increase in runoff also occurs. Calculations were performed on pasture, current, and fully developed land. Calculations assuming pasture land yielded the least amount of runoff, while an assumed completely developed landscape produced the most runoff.

Table 1 shows how changes in land type effect the total runoff. Highest amounts of runoff come from fully developed land cover; intermediate amounts of runoff come from the current land cover; lowest amounts of runoff come from all pasture land. Currently about 25% of the watershed is pasture land. The land cover of the entire watershed is shown in Map 2 of the Supplementary. Based on the calculations, if the watershed is converted from its current state into entirely developed, almost twice as much runoff is observed. That is due to the soil type present in the watershed, which is mostly clay soils. A second set of calculations was produced using projected 24 hour rain event with the effect of climate change to gauge recharge rates of the lake from large scale rain evens.

Land Cover Type	**"S"**	**"Q"**	**Runoff amount (acre feet)**
All Pasture	2.14	0.67	223
Current	1.65	0.84	281
All Developed	0.77	1.3	437

Table 1. Showing runoff amounts for all pasture, current, and all developed land cover assuming rainfall of P = 2 inches.

24hr rain events with projected climate change	**"P"**	**"Q"**	**Runoff amount (acre feet)**
1yr event	3.79	2.34	784
5yr	5.5	3.92	1312
10yr	6.5	4.87	1630
25yr	8.27	6.57	2201
50yr	9.6	7.87	2635
100yr	11.2	9.43	3160
200yr	12.9	11.11	3721
500yr	15.3	13.48	4515
1000yr	17.2	15.36	5146

Table 2. Showing 24-hour rain events and associated runoff amounts, assuming current land cover.

VI. Discussion

Climate Data Trend Analysis

As early as 1981, major television networks around the world were reporting on the potential negative side effects of climate change, including: temperatures rising, shorter winter seasons, fewer rain events, and more regular flooding events. The analysis of the NOAA data from Marion County (1981-2017) appear to support these predicted trends.

Marion County Lake's primary use revolves around recreation activities including: fishing, swimming, and water sports. Water quality is of high concern whenever humans have direct contact with a water source. The combination of warming temperatures and fewer rain events can perpetuate harmful algae growth. In 2011, 2012, 2016, and 2017, Kansas Department of Health and Environment (KDHE) reported blue-green algae blooms at Marion County Lake causing extended closures (Kansas Department of Health and Environment, n.d.). The year 2011 saw a high temperature of 110 ºF, a total of 80 rain events, and only 28 inches of precipitation recorded over the course of the year. 2012 saw a high temperature of 106 ºF, a total of 55 rain events, and only 23 inches of precipitation recorded. In 2016, the high temperature was 102 ºF, there were a total of 54 rain events and 36 inches of precipitation recorded over the course of the year. In 2017, the high temperature was 107 ºF, there were a total of 50 rain events and only 24 inches of precipitation recorded over the course of the year. Based on the available data, there is no significant correlation between outbreaks of blue-green and temperature or rainfall at Marion County Lake. However, the blue-green algae data is limited in the sense that KDHE only records what has been reported to them, and these records only go back 8 years. Warmer climates and fewer rain events have been reported to perpetuate algae blooms, so monitoring blue-green algae outbreaks along with yearly temperature and precipitation data will be vital for the health of Marion County Lake (Jentsche, 2008).

Fewer rain events can prevent dilution of pollutants in the lake, while extended droughts can perpetuate the growth of toxic algae. Boating activities make up a large portion of Marion County Lake's recreation. Boats can add metals and other chemicals into the water column of a lake; motors can also discharge gasoline and oil into the lake (RMBEL, 2013). Marion County Lake maintains no-wake zones which should help prevent some of the pollution problems described above. However, the other danger of boats in lakes is the high probability of stirring up sediments at the bottom of the lake which can often re-suspend nutrients, such as phosphorus, in waters reaching the surface (RMBEL, 2013). As phosphorus reaches the surface, algae blooms can expand rapidly due to their access to a new food source. Changes to rainfall patterns greatly influence the effects boat pollution has on lake water quality, and boat pollution is just one example of the pollutants present in a given lake. Extended droughts will prevent dilution of pollutants which could pose greater risk to patrons of the lake.

Lake volumes are of primary concern when considering activities such as water skiing, fishing, or any other boating activities for safety reasons. The overall decreasing trend of the number of rain events per year shown in Figure 8 shows that Marion County Lake can not necessarily depend on precipitation as a major source of input in the water balance of the lake. Rain events are becoming more significant, as shown in Figure 10, and there isn't much change to the total precipitation observed from year to year, which means that the lake will most likely be able to maintain healthy levels. However, as rain events become more spaced out and extended droughts and rising temperatures become more common, Marion County Lake will need to monitor the lake closely between major rain events when lake levels get low.

Climate Model Analysis

Marion County Lake Watershed is experiencing moderate impacts of climate change. This means that the lake is experiencing reduced rainfall and/or higher temperatures. The results of the model analysis show that the Marion County Lake watershed borders an area experiencing high impacts of climate change. Marion County Lake should monitor rainfall and temperature data to detect significant changes in rainfall and temperature norms.

Runoff Modeling

Alterations to the land cover of the Marion County Lake watershed will have direct impacts to the quality and quantity of runoff. The composition of the watershed currently is largely pasture ground and herbaceous cover. These cover types reduce runoff compared to other types present in this watershed. Runoff from pasture and herbaceous land covers is cleaner than runoff from crop ground. When a watershed is made up of mostly row crop, sediment and nutrient loads are higher due to increased soil alterations used in common farming practices. Since the watershed is mostly pasture ground, things like stocking rate can greatly affect runoff quality and quantity. Light to moderate stocking rates will yield less runoff compared to heavy stocking rates, this is due to the amount of litter left on the soil surface that can absorb rainfall.

VII. Conclusions / Recommendations

Marion County Lake is currently experiencing moderate impacts of climate change, but NOAA data for the area does show some warning signs for climate change to get worse in the coming years. The majority of the deviation from normal precipitation and temperature trends have occurred within the last 5-10 years. Temperature and precipitation data should be regularly monitored to ensure swift action can be taken when discrepancies with norms become apparent. As precipitation events are expected become more intense and more frequent, we would strongly recommend regularly monitoring and testing the infrastructure of the dam and the inflow system into Marion County Lake. It will be important to confirm the loads of rain that both the dam and the inflow system can hold. If extended droughts become more frequent, it would be worth looking into new outflow systems as well.

As we look into the future we can see that further development of the watershed will result in an increase in the total runoff that makes it into the lake. Coupling that with the changes in climate we can expect more scenarios where large amounts of rain will come to the watershed is shorter amounts of time. It will be crucial that this watershed and lake can handle large amounts of rainfall in short amounts of time. We would not recommend developing any more of the land in order to manage runoff levels and maintain better quality runoff.

References

Biber, Eric, and Elisabeth Long Esposito (2008) "Climate change: National Park Service Organic Act." *Natural Resources & Environment Summer 2017*: 62. Global Reference on the Environment, Energy, and Natural Resources.

Bodí, Merche B., et al. "Wildland Fire Ash: Production, Composition and Eco-Hydro-Geomorphic Effects." Earth-Science Reviews. Elsevier B.V, vol. 130, Mar. 2014, pp. 103–127. EBSCOhost, doi:http://dx.doi.org.er.lib.k-state.edu/10.1016/j.earscirev.2013.12.007

Butler, David R (2012) The impact of climate change on patterns of zoo geomorphological influence: *Examples from the Rocky Mountains of the Western U.S.A. Geomorphology*. Vol. 157-158, pp. 183-191

Crossman, J., Futter, M. N., Oni, S. K., Whitehead, P. G., Jin, L., Butterfield, D., Baulch, H. M., Dillion, P.J., (2013) Impacts of climate change on hydrology and water quality: Future proofing management strategies in the Lake Simcoe watershed, Canada. *Journal of Great Lakes Research*. 39. 19-32.

Falconer, I. (1999). An Overview of problems caused by toxic blue-green algae (cyanobacteria) in drinking and recreational water. *Environmental Toxicology*, *14* (1), 5-12.

Hamilton, P. A., and D. R. Helsel. "Effects of Agriculture on Ground-Water Quality in Five Regions of the United States." Ground Water, vol. 33, no. 2, Mar. 1995, pp. 217–226. EBSCOhost, search.ebscohost.com/login.aspx?direct=true&db=agr&AN=IND20510969&site=ehost-live.

Jentsche, A., & Beierkuhnlein, C. (2008). Research frontiers in climate change: Effects of extreme meteorological events on ecosystems. *Geoscience, 340*, 621-628. doi:10.1016/j.crte.2008.07.002

Kansas Department of Health and Environment. (n.d.). Historical HABs. Retrieved October 30, 2018, from http://www.kdheks.gov/algae-illness/historical_habs.htm

Lenters, J. D., Kratz, T. K., Bowser, C. J. (2005). Effects of climate variability on lake evaporation: Results from a long-term energy budget study of Sparkling Lake, northern Wisconsin (USA). *Journal of Hydrology*, *308*, 168-195.

Meyer, M., & Huey, G. (2006). Telemetric system for hydrology and water quality monitoring in watersheds of northern New Mexico, USA. *Environmental Monitoring and Assessment; an International Journal Devoted to Progress in the use of Monitoring Data in Assessing Environmental Risks to Man and the Environment*, 116(1), 9-19. doi:10.1007/s10661-006-7242-0

Miller, C. (2005). *The use of a GIS to compare the land areas captured by very basic and complex wellhead protection area models*. Journal of Environmental Health, 68(4), 6, 28.

National Park Service. (n.d.). National Register of Historic Places. Retrieved November 4, 2018, from https://www.nps.gov/subjects/nationalregister/index.htm

Onset computer corporation announces improved accuracy of HOBO water level loggers. (products & services) (HOBO water level loggers). (2008). *Journal of Environmental Health*, 71(4), 76.

Piekielek, N.B., et al (2015) "Using custom scientific workflow software and GIS to inform protected area climate adaptation planning in the Greater Yellowstone Ecosystem." *Ecological Informatics*, vol. 30, p. 40.

RMBEL. (2013, May 2). Boat Motors and Water Quality. Retrieved December 5, 2018, from https://www.rmbel.info/boat-motors-and-water-quality/

Robinson, D. A., Binley, A., Crook, N., Day- Lewis, F. D., Ferré, T. P. A., Grauch, V. J. S., . . . Slater, L. (2008). Advancing process- based watershed hydrological research using near-surface geophysics: A vision for, and review of, electrical and magnetic geophysical methods. *Hydrological Processes, 22*(18), 3604-3635. doi:10.1002/hyp.6963

Sandoval-Solis, S., McKinney, D. C., & Loucks, D. P. (2011). Sustainability index for water resources planning and management.. *Journal of Water Resources Planning and Management, 137*(5), 381. doi:10.1061/(ASCE)WR.1943-5452.0000134

Sheshukov, Aleksey Y., et al. “Pasture BMP Effectiveness Using an HRU-Based Subarea Approach in SWAT.” Journal of Environmental Management, vol. 166, Jan. 2016, pp. 276–284. EBSCOhost, doi:http://dx.doi.org.er.lib.k-state.edu/10.1016/j.jenvman.2015.10.023.

Simedo, et al. “Effect of Watershed Land Use on Water Quality: a Case Study in Córrego Da Olaria Basin, São Paulo State, Brazil.” Química Nova, SBQ.

Stephan, Kirsten, et al. “Effects of Spring Prescribed Burning and Wildfires on Watershed Nitrogen Dynamics of Central Idaho Headwater Areas.” Forest Ecology & Management, vol. 263, Jan. 2012, pp. 240–252. EBSCOhost, doi:10.1016/j.foreco.2011.09.013.

Spencer, D. and Anibas, K. (2018). Shibboleth Authentication Request.[online]Onlinelibrary-wiley-com.er.lib.k-state.edu. Available at: https://onlinelibrary-wiley-com.er.lib.k-state.edu/doi/full/10.1111/1752-1688.12364 [Accessed 1 Oct. 2018].

Tiedeman, C. R., Hill, M. C., D' Agnese, F. A., & Faunt, C. C. (2003). *Methods for using groundwater model predictions to guide hydrogeologic data collection, with application to the Death Valley regional groundwater flow system.* Water Resources Research, 39(1), n/a. doi:10.1029/2001WR001255

Thornton, K. (1990). *Lake and Reservoir Restoration Guidance Manual* (2nd ed.) (United States, EPA, North American Lake Management Society) (L. Moore, Ed.). Retrieved September 23, 2018.

Thornton, K. (1990). Lake and Reservoir Restoration and Management Techniques in *Lake and Reservoir Restoration Guidance Manual* (2nd ed., pp. 117-159) (United States, EPA, North American Lake Management Society) (L. Moore, Ed.). Retrieved September 23, 2018.

Thornton, K. (1990). Implementing a Management Plan in *Lake and Reservoir Restoration Guidance Manual* (2nd ed., pp. 191-201) (United States, EPA, North American Lake Management Society) (L. Moore, Ed.). Retrieved September 23, 2018.

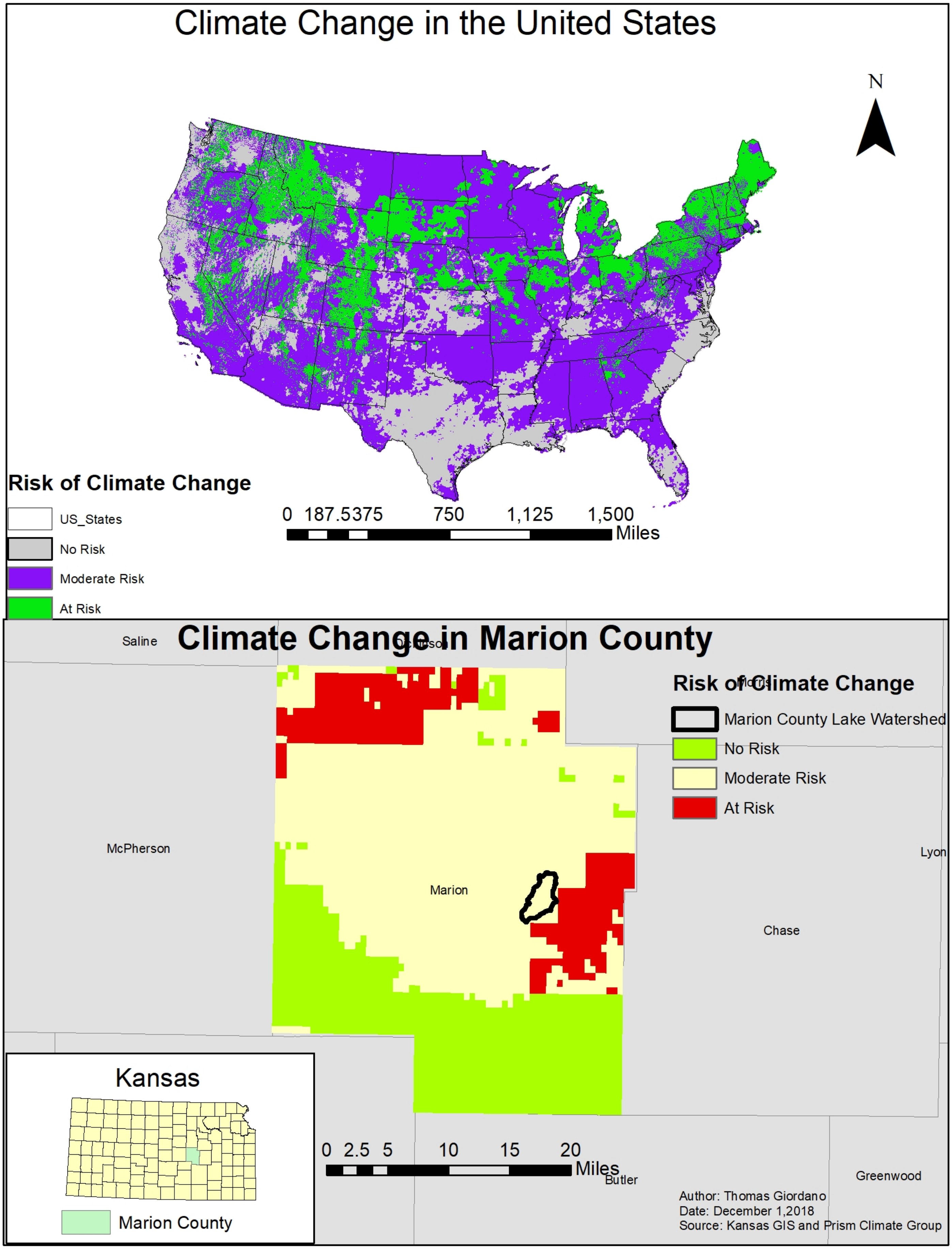
Urban hydrology for small watersheds. (1986). Washington, D.C.: U.S. Dept. of Agriculture, Soil Conservation Service, Engineering Division.

Wang, W., & Xu, C. (2014). *Spectral methods based on new formulations for coupled Stokes and Darcy equations*. Journal of Computational Physics, 257, 126-142. doi:10.1016/j.jcp.2013.09.036

Wrublack, S., Mercante, E., Boas, M., Prudente, V. and Silva, J. (2018). VARIATION OF WATER QUALITY ALONG A RIVER IN AGRICULTURAL WATERSHED WITH SUPPORT OF GEOGRAPHIC INFORMATION SYSTEMS AND MULTIVARIATE ANALYSIS.

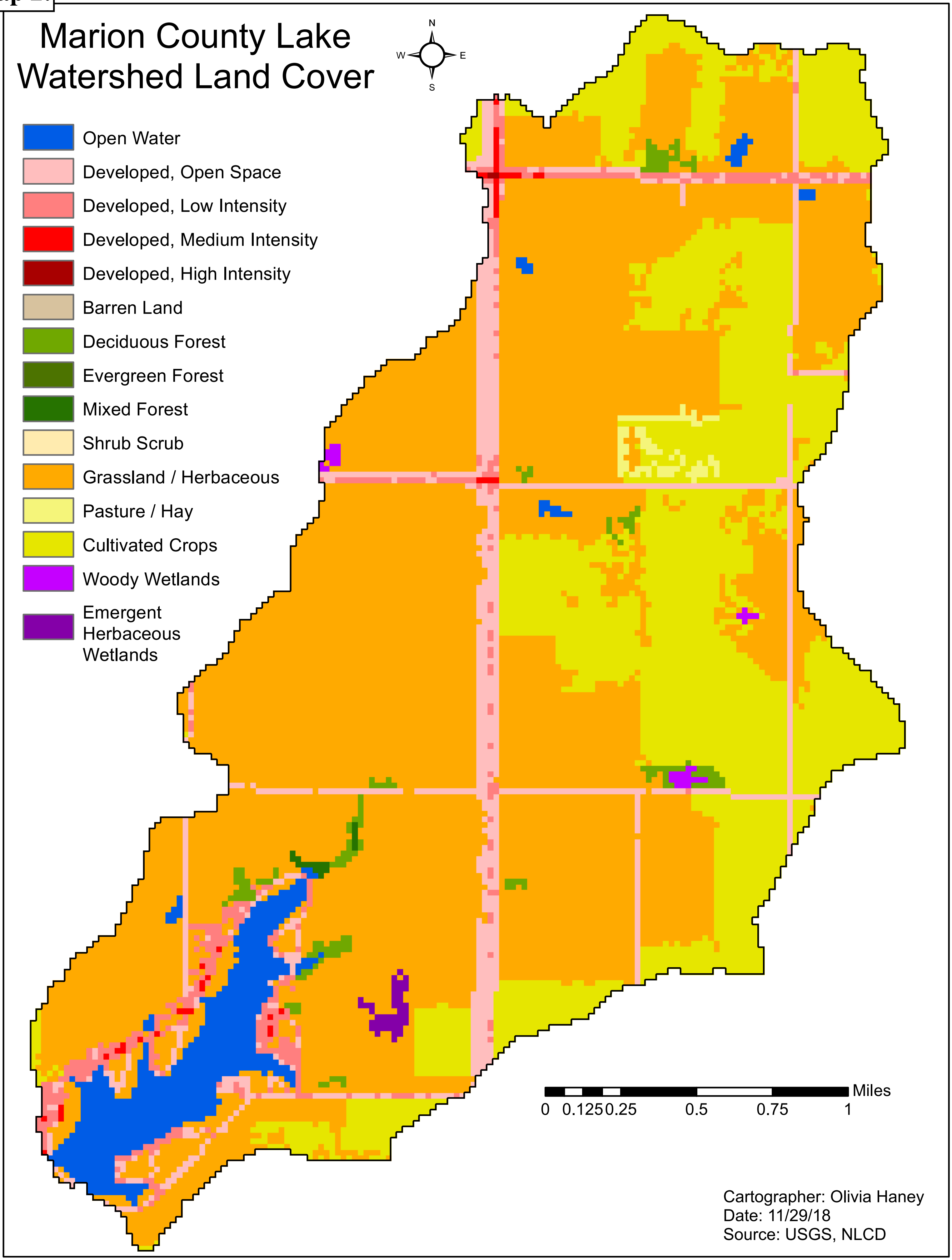
Yasarer, Lindsey M. W., et al. “Impacts of Biofuel-Based Land-Use Change on Water Quality and Sustainability in a Kansas Watershed.” Agricultural Water Management, vol. 175, Sept. 2016, pp. 4–14. EBSCOhost, doi:https://dx-doi-org.er.lib.k-state.edu/10.1016/j.agwat.2016.05.002.

Map 1.



Climate Change in the United States
N
Risk of Climate Change
US_States
No Risk
Moderate Risk
At Risk
0 187.5375 750 1,125 1,500
Miles
Climate Change in Marion County
Saline
McPherson
Marion
Chase
Lyon
Risk of Climate Change
Marion County Lake Watershed
No Risk
Moderate Risk
At Risk
Kansas
Marion County
0 2.5 5 10 15 20
Miles
Butler
Greenwood
Author: Thomas Giordano
Date: December 1,2018
Source: Kansas GIS and Prism Climate Group

Map 2.



Marion County Lake Watershed Land Cover
N
W
E
S
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub Scrub
Grassland / Herbaceous
Pasture / Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Miles
0 0.125 0.25 0.5 0.75 1
Cartographer: Olivia Haney
Date: 11/29/18
Source: USGS, NLCD