A framework for reservoir restoration in The Midwest

by

Harrison P. Dirks

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTERS OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture and Regional Community Planning

College of Landscape Architecture

KANSAS STATE UNIVERSITY
Manhattan, KS

2020

Approved by:

Major Professor
Dr. Timothy D. Keane

Abstract

Reservoirs are built to provide local flood control and recreational activities, but those benefits are often short lived due to the severe ecohydrological problems which come with the process of damming up a watershed. Issues such as sediment deposition, accelerated erosion and loss of natural flood plain will eventually hinder the reservoir from being used for recreation, and significantly decrease its flood storage capacity (Keane, 2019). These are not issues which will correct themselves overtime. In fact, they will begin to rapidly decrease the lifespan of the reservoir, as well as create more problems in the watershed both up and downstream of the dam.

For these reasons, scientists and designers have been developing processes for reservoir assessment and restoration which aim to identify issues, and improve reservoir function. Depending on their field of expertise, reservoir exerts have different approaches for both reservoir assessment and restoration. This report explores an alternative approach to reservoir assessment and restoration which aims to layer new information about reservoir function on top of the pre-existing knowledge of reservoir experts.

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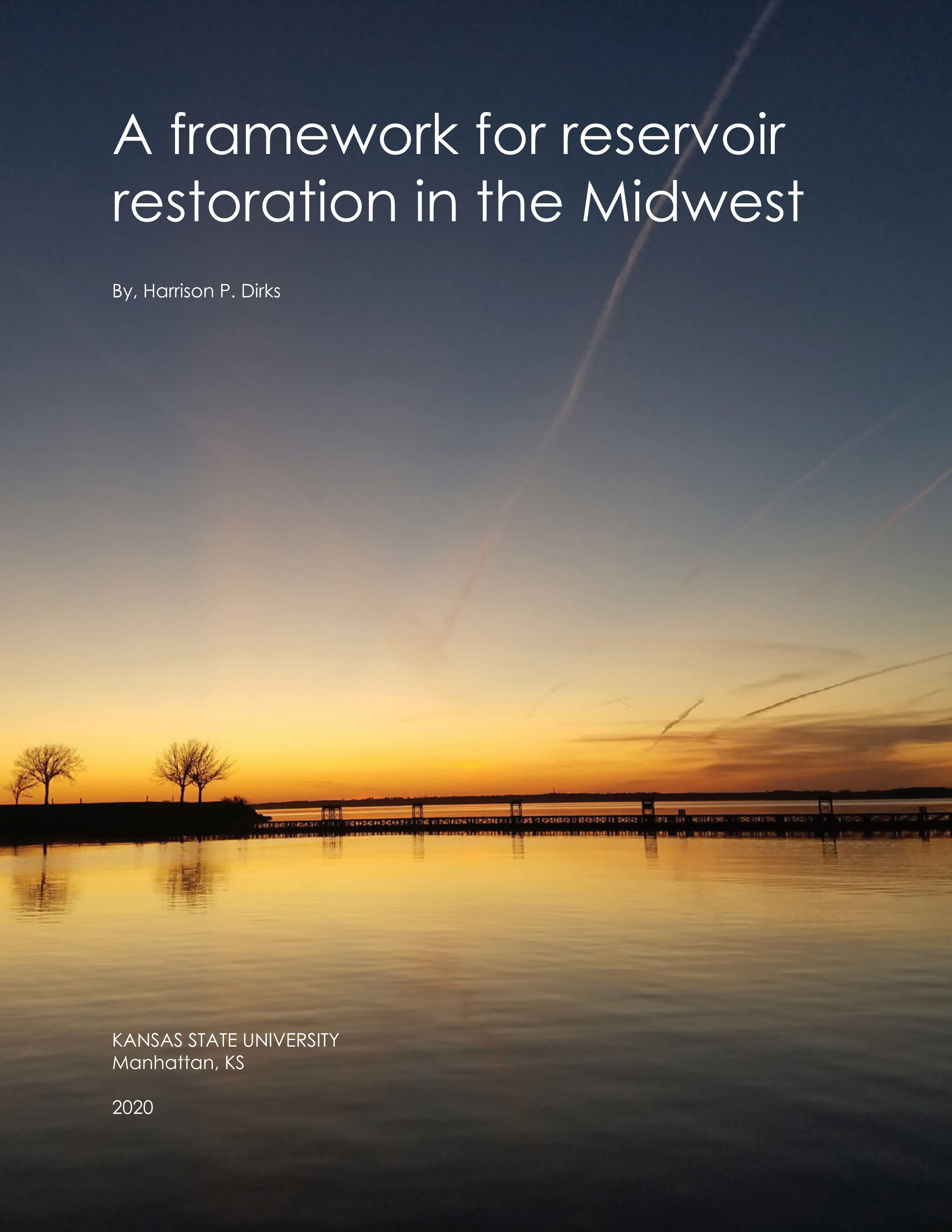

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Acknowledgments

To the Landscape Architecture and regional & Community Planning faculty members that have contributed to my time at Kansas State. I appreciate everything you've done to teach me about the Landscape Architecture profession, the design process, and about becoming a young professional.

To Dr. Tim Keane, your dedication to me and this project didn't go unnoticed. The feedback you gave me throughout the school year, your willingness to help in any way possible, and encouragement motivated me to keep pushing this project through to the end.

To Dr. Keith Gido, your enthusiasm to jump into a masters project for a department you've never worked with before inspired me to study elements of this project I had no experience working with.

To Prof. Kirby Barrett, your commitment to helping me in every phase of this project and your design tutoring gave me the motivation I needed to complete this project.

To my classmates, you guys are the GOAT.

Chapter 1:

Introduction

1 Introduction

Background Information

Reservoir Restoration:

Most reservoirs in the Midwest were constructed in the 1950's and 1960's. Because these reservoirs were initially designed to last only 100-150 years, it's not uncommon to see issues arise with reservoir function. As reservoir problems begin to increase in frequency, more opportunities for reservoir restoration projects appear. Reservoir restoration projects come in a variety of forms, all of which aim to improve or restore specific areas of function. This report looks at three categories of reservoir function, Ecological, Hydrological, and Recreational, all of which are described in Chapter 2, pg 8 - 9. Because of the complicated nature of reservoir restoration, project teams are comprised of a variety of experts including engineers, hydrologists, ecologists, biologists, landscape architects and more. Each expert applies their knowledge throughout the different phases of the project, beginning with reservoir analysis.

Reservoir Analysis:

The first phase of any reservoir restoration project is analysis. In this phase, experts look at a vast range of reservoir features and variables to gauge the reservoir's performance and identify problems. Reservoir analysis procedures differ between disciplines. For example, ecologists might look at variables which deal with vegetation and fish communities, while landscape architects could look at variables such as park visitation and site amenities.

Dilemma

Analysis Procedures

Because experts from different disciplines have differing approaches to reservoir analysis, it is possible that some experts on the project team are not aware of how variables outside of their area of expertise relate to the project. This can make it difficult to draw collective conclusions on where the focus of the restoration efforts should be placed.

Clientele:

While scientists and designers have in depth knowledge about reservoir function. Reservoir or lake owners may not understand the full scope of reservoir analysis or restoration projects. Often times, reservoir problems may stem from a variable that seems to be unrelated to the problem at hand. Without an in-depth understanding of reservoir function, it is can be difficult to understand the correlation between problems and variables. For this reason, it's necessary the clientele of a reservoir restoration project has access to resources which assist in them understanding why the variables selected are being studied, and how they relate to the overall project goal.

Thesis:

It is possible to create a new, goal-oriented framework for reservoir restoration which layers information about reservoir function on top of the existing knowledge of designers and scientists, giving them the capability to understand the full scope of the project and apply their expertise accordingly. A goal-oriented approach to reservoir restoration and a variable/ guideline scoring system will make comparing the final product and the initial project goal easy and measurable. A set of reservoir guidelines will assist all clientele, regardless of their background, in understanding why the project team is focusing on specific areas of reservoir function, and how the variables studied relate to the overall project goal.

Relevance in Landscape Architecture:

It is uncommon for landscape architects to work on reservoirs, but it is certainly not out of the scope of the profession. The American Society of Landscape Architects, (ASLA) defines the profession as follows.

"Landscape architecture encompasses the analysis, planning, design, management, and stewardship of the natural and built environment through science and design. (ASLA, 2019)."

Reservoirs are a perfect example of a built environment which require an extensive amount of planning, design and management. Unfortunately, the profession rarely works with the team of engineers which design, maintain and build these reservoirs. A key role of landscape architects is their ability to draw from other disciplines, and coordinate with experts to ensure the project performs highly in all applicable functions. In the case of reservoirs there are three primary functions which need to be addressed; ecological function, hydrological function, and recreational function. Landscape architects should be involved in the construction and restoration of reservoirs because of its direct relationship to their scope of work, as well as their ability and expertise in coordination of disciplines and project function.

Goals:

This project and report establishes a framework for restoring ecological, hydrological or recreational goals for Midwest reservoirs. Case studies for reservoirs where issues were identified and solved assisted in the development of a set of guidelines defined in this report. However, it was equally as important to research work by professionals outside the landscape architecture discipline as it was to find scientific evidence to support the solutions for specific reservoir issues. Finding work by warm-water hydrologists, local ecologists, fisheries and other professionals provided evidence supporting the information and steps towards solutions established in the set of guidelines.

Further proof of concept will be provided with a projective design conducted on Milford Lake (KS). Using the findings from case studies, information gathered from professionals, and steps from the guidelines created through this research project, the projective design will demonstrate how the restoration framework could be used to help Landscape Architects and reservoir management achieve specific lake goals.

Figure 1: McCall Lake Concept Plan (Dirks, 2017)

Chapter 2: Data

2 Data

Data Collection

The collection of data for this report can be broken into two phases. The first phase focuses on collecting information about general reservoir function. The second phase of data collection examines six case studies which focus on reservoir analysis and restoration. These Case Studies can be found in Appendix B, on pages B4 - B17.

Phase 1: Reservoir Function

Reservoirs are complicated ecosystems. Understanding how these ecosystems function is a critical component in this study. The first phase of data collection focused on reviewing published literature from reservoir experts. The literature reviewed was then separated into three primary levels of reservoir function: Ecological Function, Hydrological Function, and Recreational Function. Additional literature concerning reservoir policy was also researched in this phase of the study.

Ecological Function:

Ecological Function refers to the productivity and health of the ecosystem in the reservoir, and its surroundings. This function can be broken into two categories; the aquatic ecosystem and the riparian ecosystems. While these two ecosystems work together to form the reservoir's full ecosystem, looking at them individually will help in pinpointing where key issues in the reservoir are originating.

Hydrological Function:

Community flood control is often the reason for creating an urban reservoir. As popular as it is, many reservoirs under-perform their potential hydrological function. Hydrological function can be placed into four categories: water quality, sediment deposition, water level fluctuation, and floodwater storage.

Recreational Function:

Recreational function refers to the reservoir's ability to provide recreation and amenities to its site visitors. While it doesn't have a direct impact on the ecological or hydrological function of a reservoir, its success is heavily influenced by the two.

Reservoir Policy:

Policies which dictate water level fluctuation can greatly affect the hydrological function of a reservoir. Fishing and hunting policies can also influence the sport fishing productivity and ecological sustainability of a reservoir.

Phase 2: Reservoir Analysis and Restoration Case Studies

The first step to reservoir restoration is typically analysis. Studying lake features and variables such as vegetation, water level fluctuations and fish species are part of reservoir analysis. The results of the reservoir analysis will shed light on poorly functioning levels of the reservoir ecosystem. These results can then be used to influence design decisions in the reservoir restoration process.

Reservoir Analysis

Two approaches for reservoir analysis were studied in this project, each focusing on a unique set of reservoir variables. Studying reservoir experts' analysis procedures was the starting point in the creation of the new reservoir restoration framework. The procedures gave insight to which variables need be studied, and how they relate to the reservoir's ecosystem.

Reservoir Restoration

Four case studies on reservoir restoration were analyzed to identify relationships between variable analysis and improved lake function. These studies include two smaller reservoirs in Kansas which faced issues regarding fish community balance, a lake in Washington which required recreational improvement, and a fish habitat restoration project on Table Rock Lake (MO). Analyzing how these case studies identifies problems and developed solutions helped inform the design guidelines produced in this report.

Synthesis of Data

Guidelines

Information about reservoir function was collected and distributed into eleven reservoir "guidelines," each of which describe a specific category of reservoir function. Each guideline created in this report is related to one of four general, reservoir goals. Collectively, the guidelines describe how the reservoir needs to function in order to achieve the overall goal. Along with describing how the reservoir needs to function, each guideline also provides a list of variables to be studied in order to assess the reservoir's performance.

Variables

The case studies which focused on reservoir assessment and restoration provided information about which reservoir characteristics and variables were important to study. The process used in this report included Identifying relationships between the variables and reservoir function. These relationships are represented by assigning a unique set of variables to each of the eleven guidelines.

Application of Findings

Projective Design: Milford Lake

After creating the new framework for reservoir restoration, this report examines the effectiveness of the framework by conducting a projective design on Milford Lake (see figure 2, right). The projective design looks at the two design related guidelines of the improved sport fishing goal, sport fish habitat and access to fishing grounds and amenities.

All variables applicable to the two design related guidelines studied in the projective design are analyzed, and design decisions are made accordingly. After the design was created, the variables were assessed again and a comparison was done between the original guideline scores, and the new projective design scores.

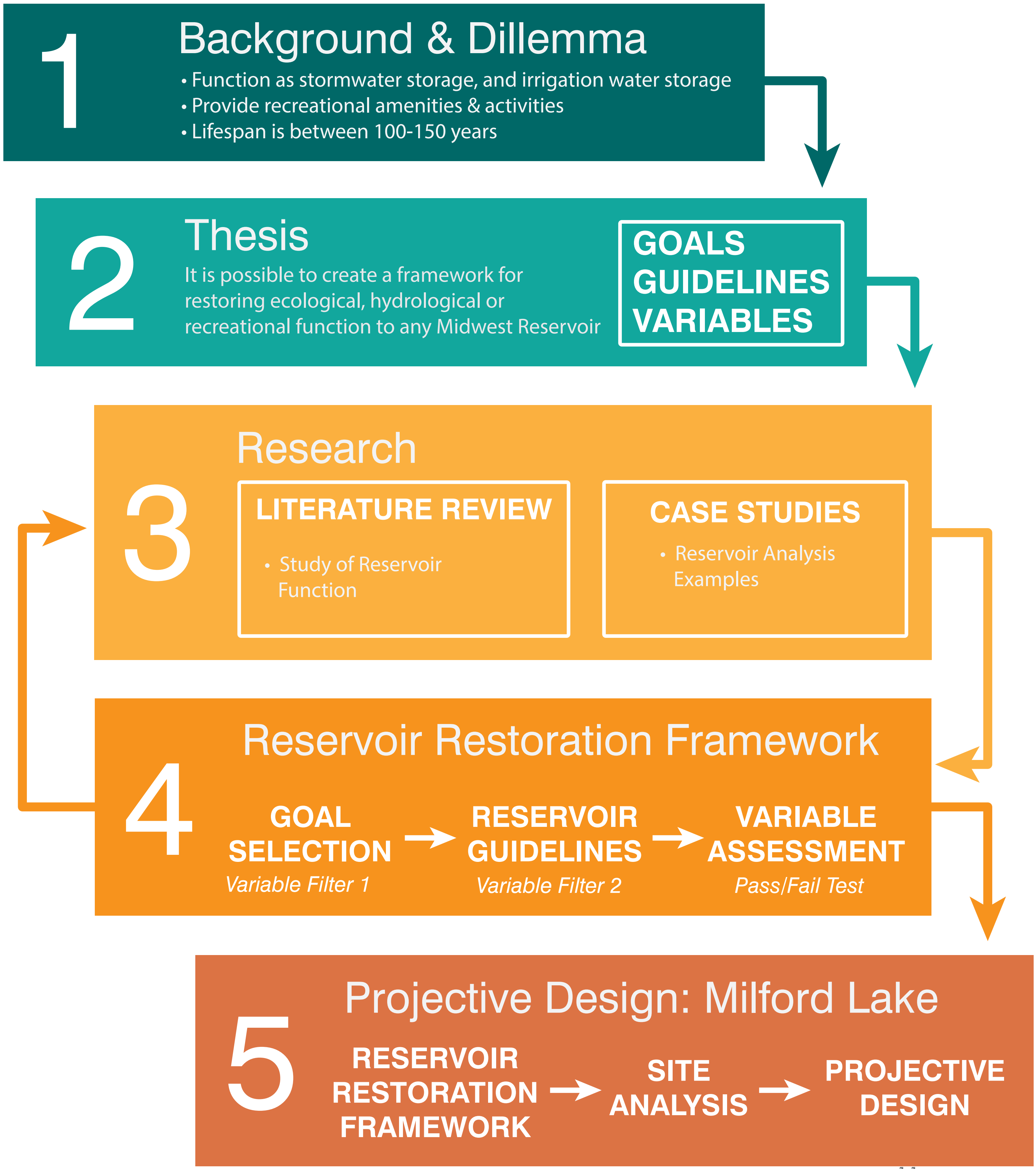


Figure 2: Masters Report Process Diagram (Dirks, 2020)

Chapter 3:

Framework for Reservoir Restoration

3 Framework for Reservoir Restoration

Framework Structure

This framework for reservoir restoration establishes a set of goal-oriented guidelines for reservoir restoration, which can be applied to all reservoirs in the Midwest and still have the capability of assisting reservoir management achieve specific lake goals. Each goal provides a set of guidelines to influence the restoration process, and set the design programming (figure 3, right). Each guideline has a list of variables for study.

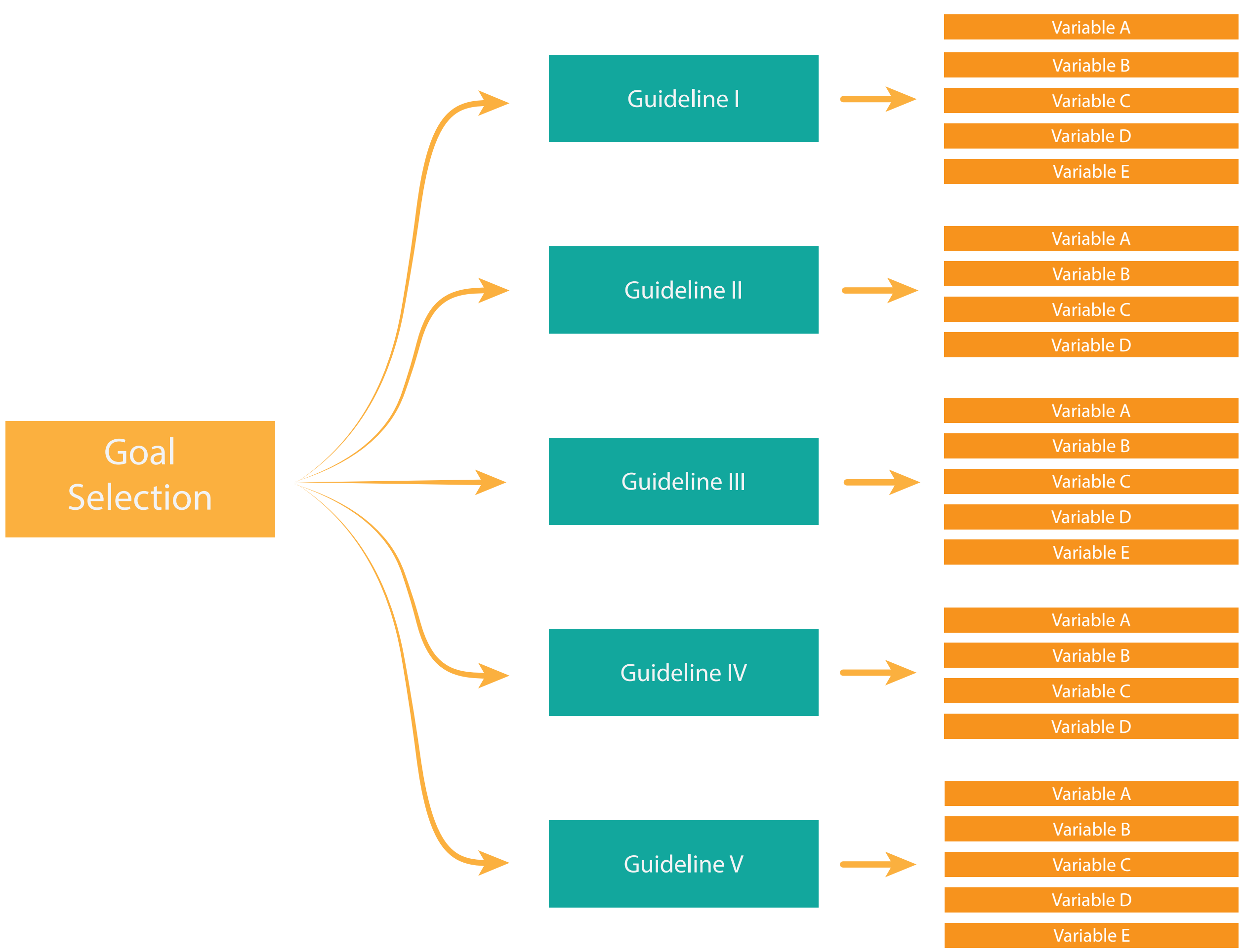


Figure 3: Basic Framework Format Diagram (Dirks, 2020)

Goals

The alternative reservoir restoration framework this report outlines is made up of three parts, the first of which is goal selection. In this report, four reservoir goals (figure 4, below) are used as the starting point for reservoir management during their early phases of reservoir restoration design. The goals in this report were chosen by looking at case studies for reservoir restoration, and identifying the common goals and reasons behind reservoir restoration projects in the Midwest.

Improved Sport Fishing

Extended Reservoir Life Expectancy

Greater Floodwater Storage Capacity

Increased Reservoir Visitation

Figure 4: Framework Goals (Dirks, 2020)

Guidelines

A set of guidelines for reservoir restoration is paired with each goal. Each guideline provides information about the reservoir needs to function in order to reach the selected goal (figure 5, below). The guidelines were developed by researching reservoir function, and examining precedent studies for reservoir restoration. For instance, if improved sport fishing were chosen to be a reservoir goal, guidelines such as Bank Habitat for sportfish, Sport Fishing Amenities and Water Quality and Clarity would inform the reader what the lake needs to improve its sportfishing. Additionally, each guideline will also suggest a range of lake features and variables which need to be analyzed in order to determine if the lake of study meets the requirements of the guideline.

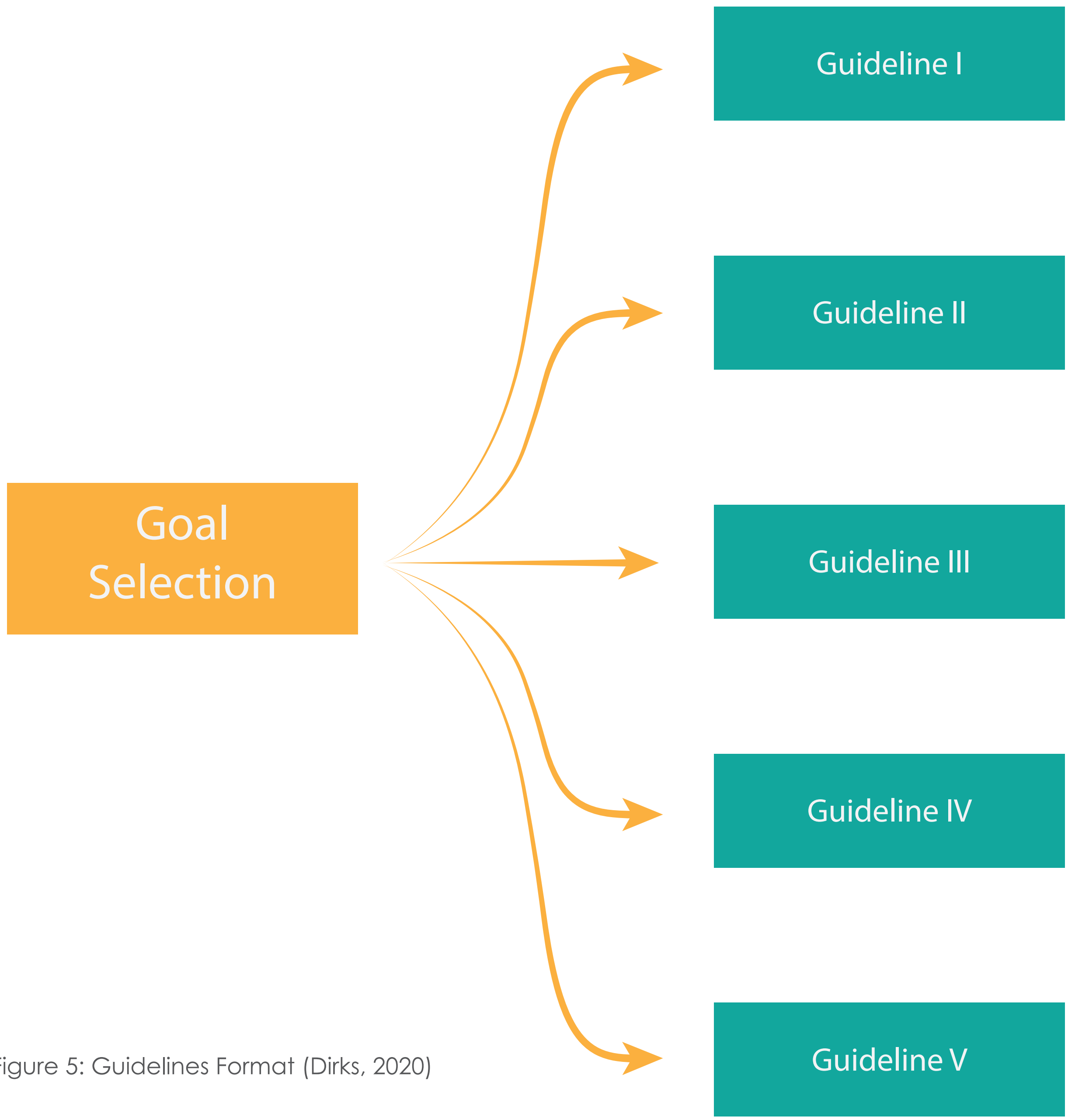


Figure 5: Guidelines Format (Dirks, 2020)

Variables

After selecting a reservoir goal(s), the guidelines provided in the new framework will suggest different variables and/or features to study (figure 6, below). The variables were chosen by researching six reservoir analysis case studies and the variables which were examined in each study. After separating the variables into categories of reservoir function, they were each assigned a point value of either three or zero points depending on how they were classified. Each variable is classified as either an analysis variable or an inventory variable. Analysis variables are variables in which the individual performance in the reservoir can be evaluated and adjusted. Inventory variables are variables which are important to the goal and need to be studied, but their individual performance in relation to the project goal cannot be evaluated or directly adjusted.

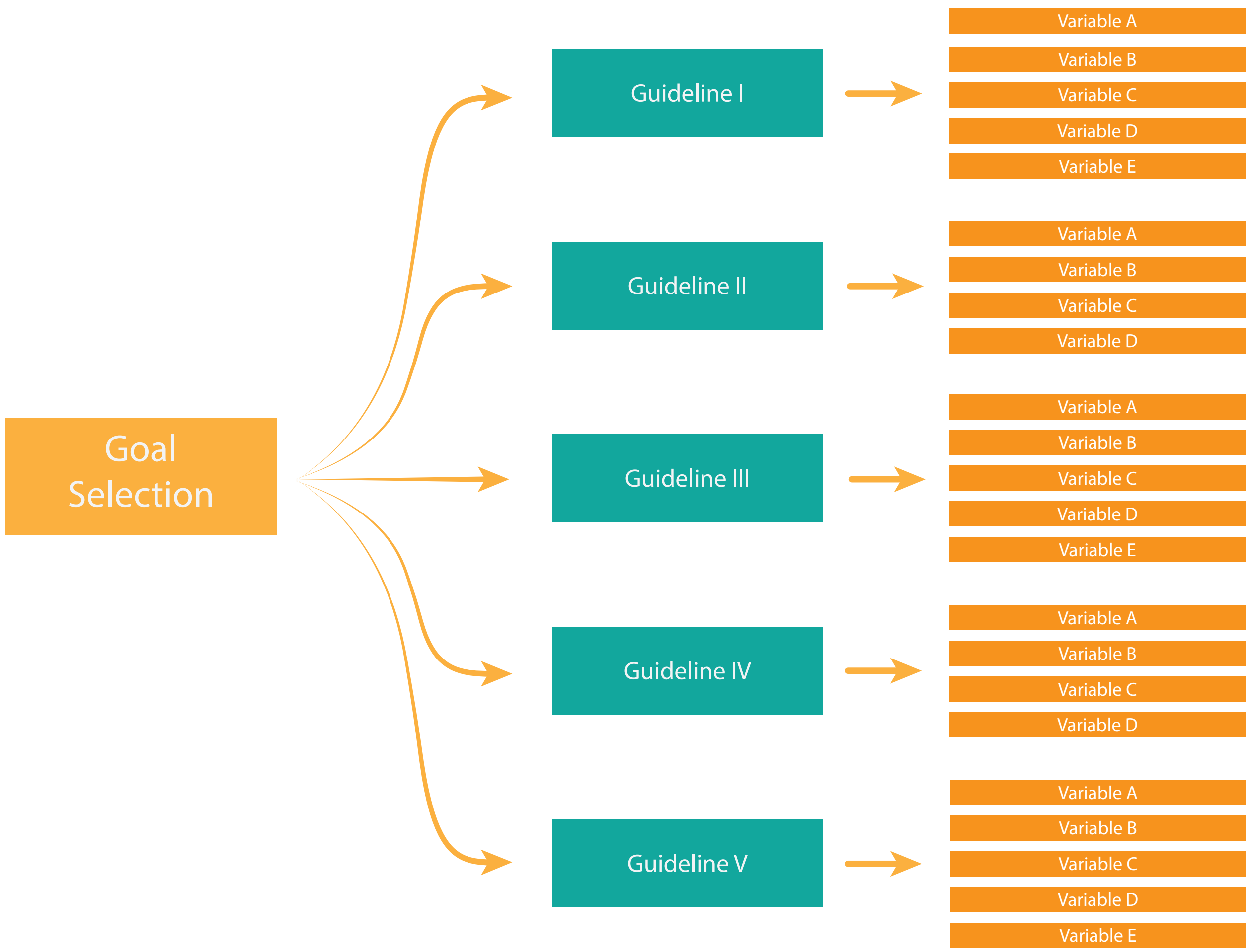


Figure 6: Basic Framework Format Diagram (Dirks, 2020)

Guideline Scoring System

The guidelines will use a point-based scoring system to help the reader determine both the importance of the guideline to achieving the selected goal, as well as quantifying the lake's success in meeting the recommendations of each guideline.

Guideline Scorings:

Each Guideline provides a list of reservoir variables for study. The sum of the variable points will determine the point value of each guideline. For example: Guideline III has four variables, each worth three points. The sum of the point values for all the variables in Guideline III is 12 points, which gives Guideline III a net worth of 12 points. (See Figure 7, next page)

Variable Scoring:

Every variable under any given guideline will be assigned a point value of either three or zero. Variables worth three points are called analysis variables. Analysis variables can earn a score of 1 (poor), 2 (fair), or 3 (good).Variables worth zero points are called inventory variables. Inventory variables are worth zero points for different reasons which are addressed under each variable description. Each variable will have a set of instructions for how to score the results found when analyzing the reservoir. For example: Variable C: Boat Launch Sites (3 points) requires one boat launch site (two-lane boat ramp with a courtesy dock) for every 2,000 acres of navigable water. The reservoir scores 1 point for meeting 33% of the recommended ratio of boat launch sites/navigable water acres. If the reservoir has 16,000 acres of navigable water, eight boat launch sites are required to meet the variable requirements. If the reservoir only has six boat launch sites, it meets 75% of the requirements giving them a score of two out of three points for Variable C. (See Figure 7, next page)

Grading the Guideline Scores:

The guidelines are graded with the letter system below.
A: 100% - 85%
B: 84% - 70%
C: 69% - 50%
F: 49% - 0%

After studying and scoring each variable of a given guideline, the sum of scored points will be compared to the net worth point value of the guideline. For example: Guideline III (12 points) included four variables, each scoring as follows. Variable A (2 points out of 3), Variable B (3 points out of 3), Variable C (3 points out of 3), and Variable D (2 points out of 3). The sum of scored points compared to the net worth point value of the guideline is equal to 10 points out of 12, or 83.33%. This means the guideline receives a passing score of "B" with room for improvement. (See Figure 7, next page)

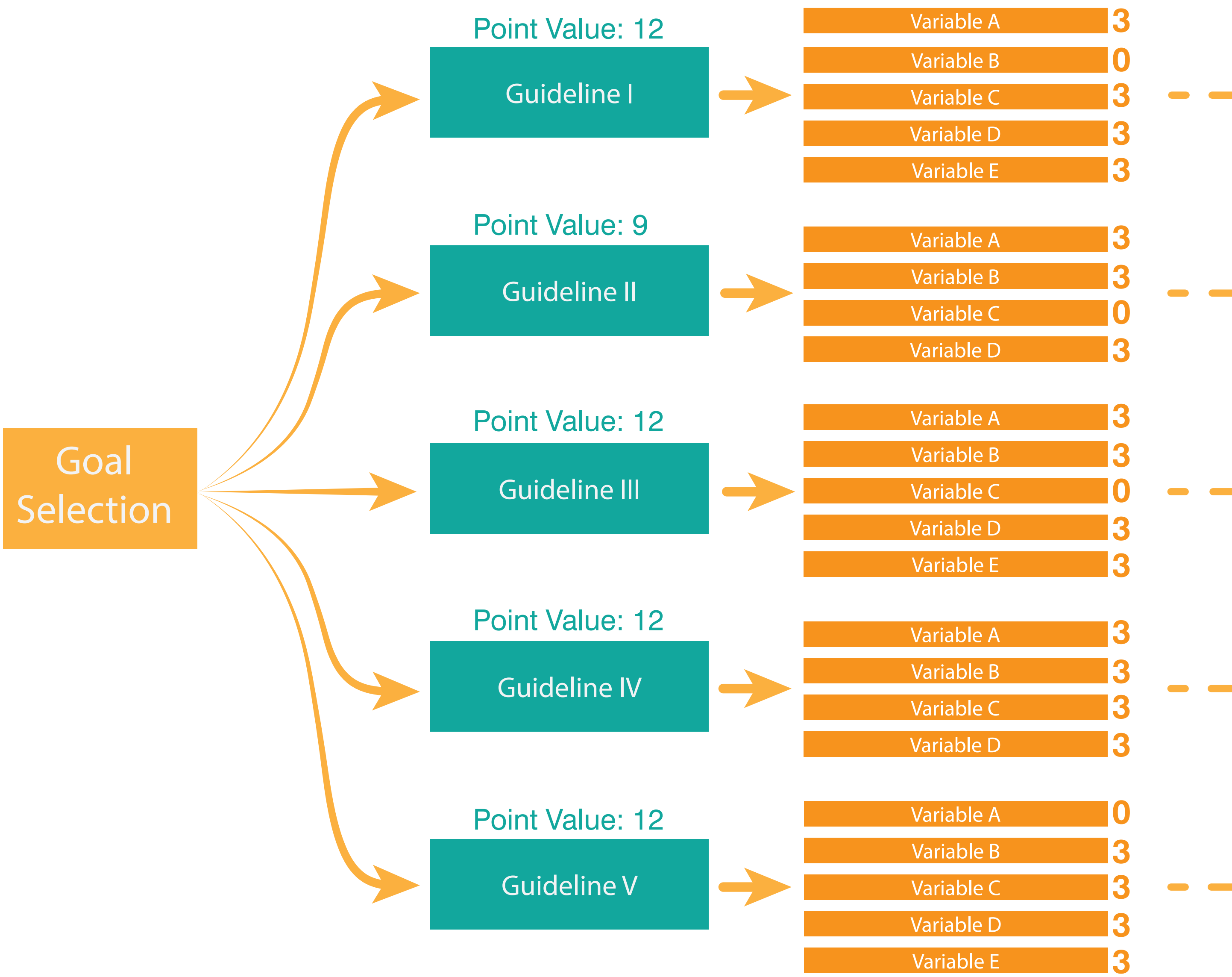
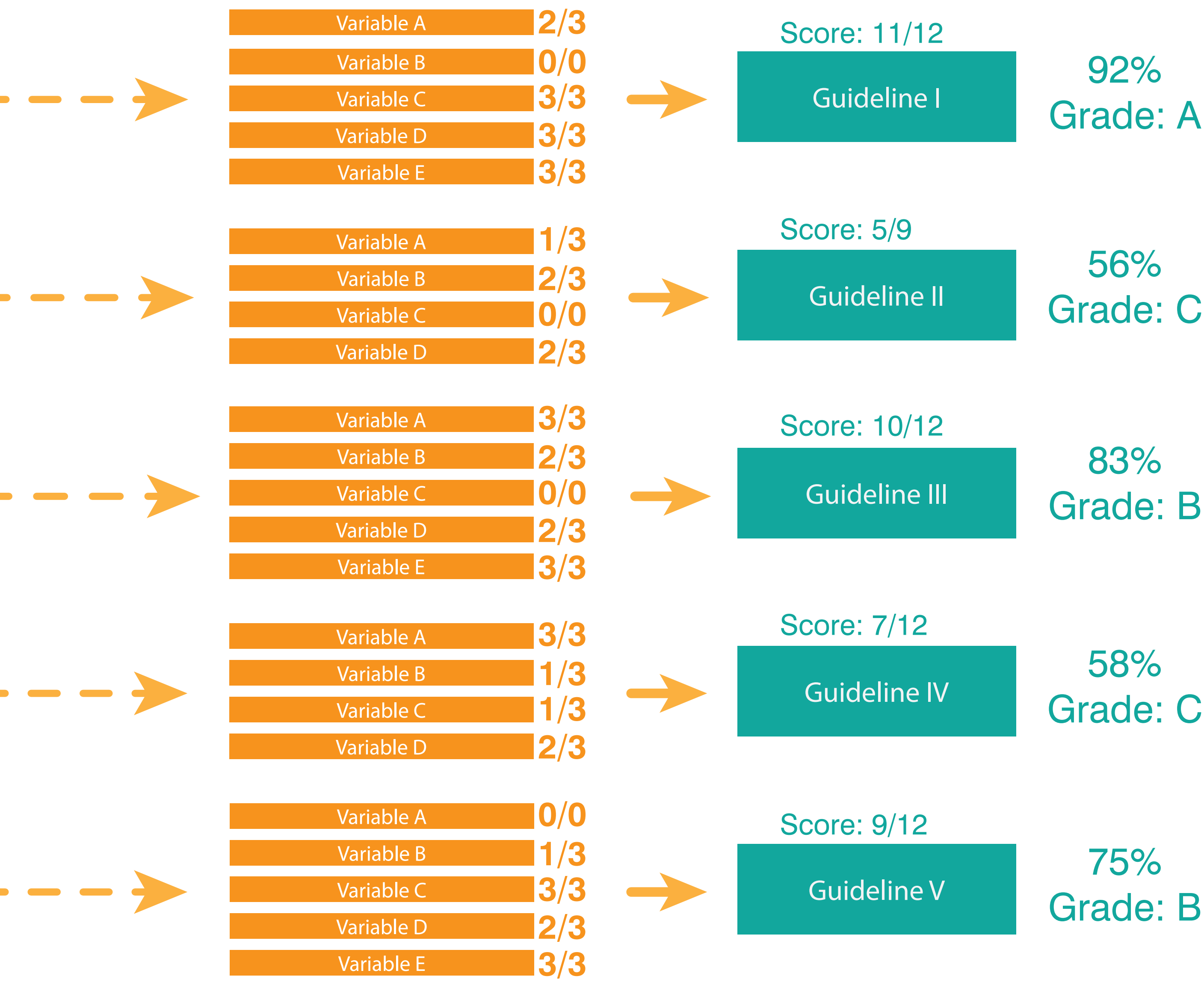


Figure 7: Guideline and Variable Scoring Diagram (Dirks, 2020)


Variable A 2/3
Variable B 0/0
Variable C 3/3
Variable D 3/3
Variable E 3/3
Score: 11/12
Guideline I
92%
Grade: A
Variable A 1/3
Variable B 2/3
Variable C 0/0
Variable D 2/3
Score: 5/9
Guideline II
56%
Grade: C
Variable A 3/3
Variable B 2/3
Variable C 0/0
Variable D 2/3
Variable E 3/3
Score: 10/12
Guideline III
83%
Grade: B
Variable A 3/3
Variable B 1/3
Variable C 1/3
Variable D 2/3
Score: 7/12
Guideline IV
58%
Grade: C
Variable A 0/0
Variable B 1/3
Variable C 3/3
Variable D 2/3
Variable E 3/3
Score: 9/12
Guideline V
75%
Grade: B

Applied Framework

This report applies the new framework to four reservoir goals by assigning a set of guidelines which each describe how the reservoir needs to function in order to achieve the selected goal. Each guideline provides a list of variables which will assist in the reservoir analysis and restoration process. The four goals examined in this report are described on page 29 (right).

Improved Sport Fishing (pg 30-63)

This goal aims to improve sportfishing opportunities in a reservoir for three of the most common sport fish in the Midwest: bass, crappie and bluegill. Five guidelines describe how the reservoir needs to function in order to improve the reservoir's sport fishing opportunities.

Slowing Reservoir Sedimentation (pg 64-73)

The goal of slowing reservoir sedimentation focuses on both finding the main sources of sedimentation in the reservoir, and stabilizing the banks of the reservoir and it's watershed. Two guidelines describe how both the reservoir and it's watershed need to function in order to slow reservoir sedimentation.

Greater Floodwater Storage Capacity (pg 74-83)

While the volume of floodwater storage capacity in a reservoir is restricted by the height and design of the dam, this goal looks into alternative ways to increase the time it takes for a reservoir to fill up with water. Two guidelines describe how upstream conditions, floodplains, and lake level management plans can all be used to provide greater floodwater storage.

Increased Reservoir Visitation (pg 84-99)

This goal focuses on increasing the visitation in a reservoir by surveying the local community to identify preferred reservoir activities, and providing site amenities. Two guidelines describe the process for increasing visitation, and provide instructions on how to select appropriate reservoir amenities.

Improved Sport Fishing

For Bass, Crappie and Bluegill fish species.

Guidelines:

Guideline I: Fish Habitat
Guideline II: Water Level Fluctuation
Guideline III: Access to Fishing Grounds and Fishing Amenities
Guideline IV: Sport Fish Community Health
Guideline V: Reservoir Fishing Policies and Enforcement

See figure 8 (right)

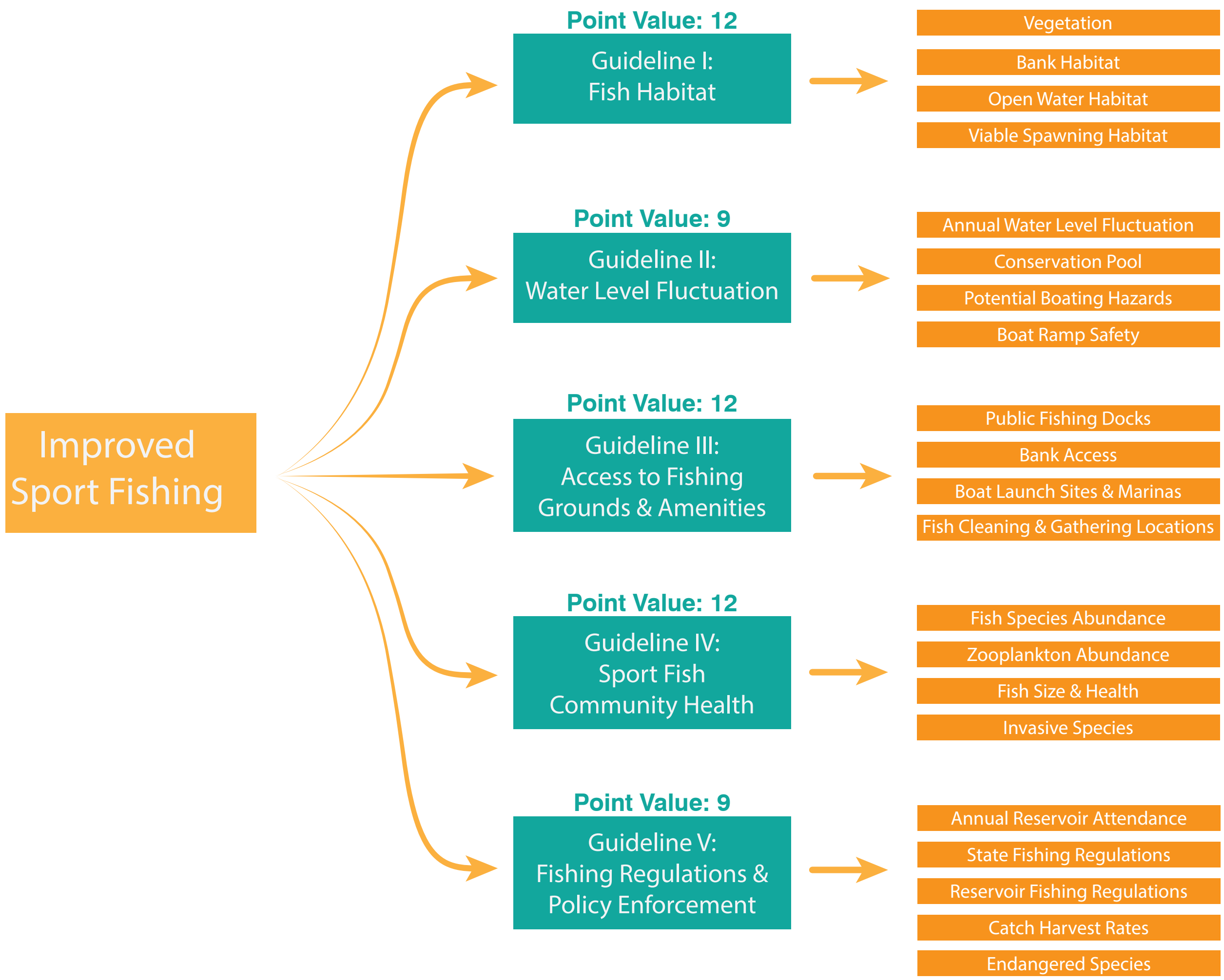


Figure 8: Improved Sport Fishing Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline I: Fish Habitat (12 Points)

Bank Habitat:

When constructing new reservoirs or restoring existing ones, providing habitat for the future fish population is critical for the ecological success of the reservoir. Most of the necessary sport fish habitat lies close to the bank, and near vegetation (Pander 2009). Vegetation provides numerous benefits for sport fish such as high oxygen levels, protection from predator species, ambush points for feeding, and a rich habitat for smaller prey fish (Wright, 1954).

Open Water Habitat:

Sport Fish such as bass, crappie and bluegill tend to retreat to deeper water as the water temperatures drop in the winter. These fish also seek deep-water habitat such as rock clusters, or submerged trees. Providing deep-water cover in a reservoir provides sportfish protection from predators, thus giving them a better chance of survival for the winter. If reservoir management chooses to provide anglers with the location of these structures, it could help anglers be more successful. Both artificial and natural structures can be used to create fish habitat (Pander 2009). Natural habitat structures such as hardwood trees, cedar trees, pine trees, stump fields, rock structures and combinations of rock and stumps have proved to be successful (MDC, 2014). Using on-site trees which are scheduled for removal, dead, or a nuisance is a green and cost-efficient way to create deep-water sportfish habitat (MDC, 2014).

Spawning Habitat:

In the spring, bass and crappie search for shallow water areas with a gravel bottom material to create their nesting beds. Once water temperatures reach roughly 70 degrees Fahrenheit, the fish will begin spawning. This can be a very exciting time to fish, as angers can often see the fish near the bank. The more spawning habitat a reservoir has, the higher the fish population will be in the coming years. A lake with a higher percentage of viable spawning habitat makes it difficult for predator species to find the spawning beds and feed on the eggs, which could potentially ruin a successful spawn year (Sprenkle, 2015).

Variables for Study

- Vegetation (3 pts)
- Bank Habitat Quality (3 pts)
- Open Water Habitat Quality (3 pts)
- Viable Spawning Habitat (3 pts)

Illustrated in figure 9 (below)

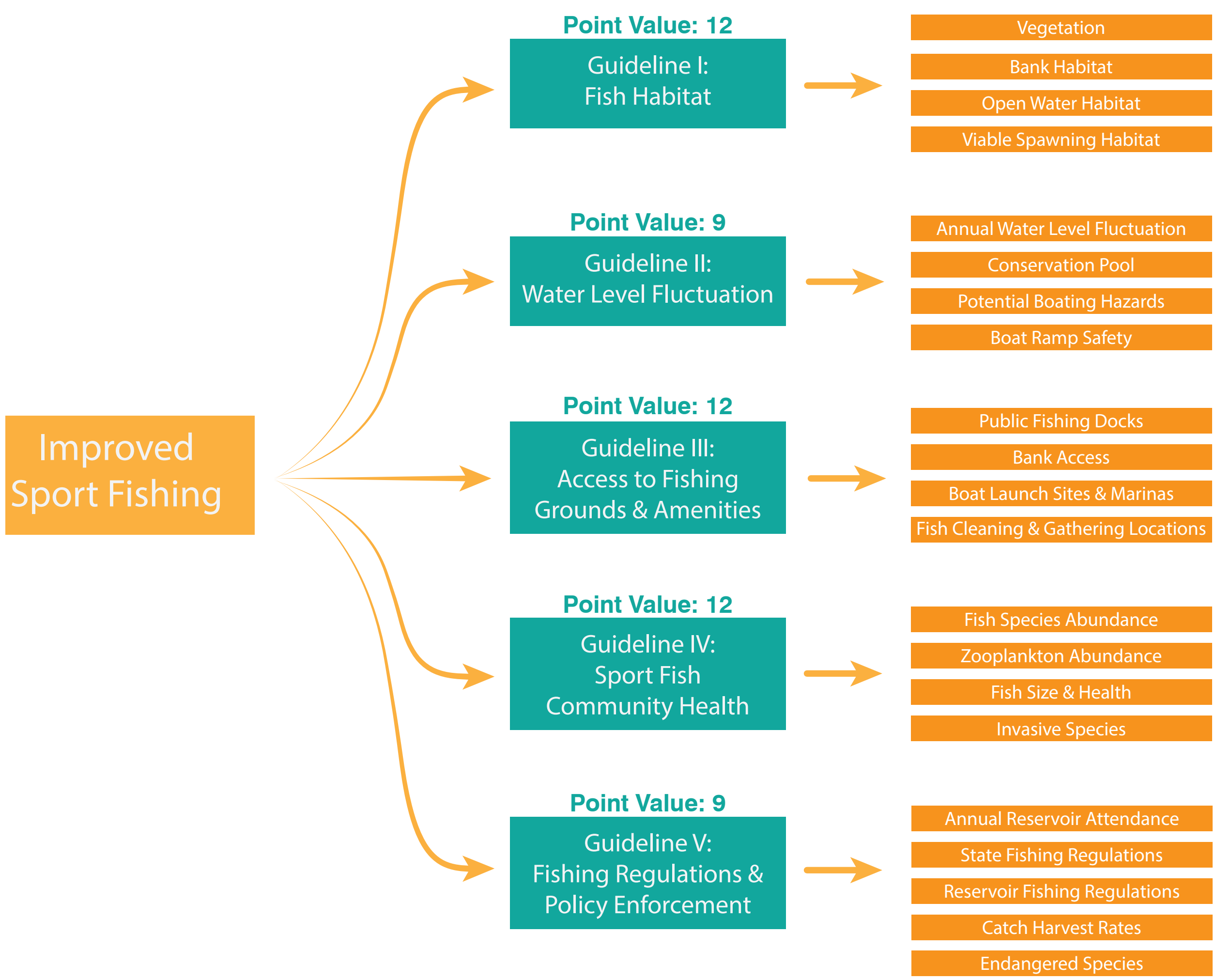


Figure 9: Improved Sport Fishing Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline I Variables

Vegetation (3 pts)

Importance:

Vegetation is a crucial component of bank habitat and spawning habitat for sport fish species. It provides oxygen and shelter from predators. More information about vegetation classification and function can be found in Appendix A: Literature Review, on pages A4 and A5, and Appendix B: Case Studies on pages B4 and B5. (Blabolil 2017, 2) (Lovell, 2005) (Wright 1954) (Zhu 2012)

Point Scoring:

(Good) 3 points: All three categories of aquatic vegetation are found throughout the lake and provide good habitat for sport fish.

(Fair) 2 points: All three categories of aquatic vegetation are found at some places in the lake. The vegetation provides some habitat for sport fish.

(Poor) 1 point: Not all three categories of aquatic vegetation are present in the lake. The vegetation provides little habitat for sport fish.

Viable Spawning Habitat (3 pts)

Importance:

While spawning only occurs for a few weeks out of the year (depending on the species) fish have specific habitat requirements such as substrate material, vegetative cover, and depth. More information about viable spawning habitat can be found in Appendix A: Literature Review, on pages A6 and A8, and Appendix B: Case Studies on pages B14, B15, and B17. (Blabolil 2017, 2) (MDC, 2014) (Sprenkle, 2015)

Point Scoring:

(Good) 3 points: Throughout the reservoir, areas which are shallower than 1 meter, have a gravel bottom material and have plenty of vegetative cover can be found.

(Fair) 2 points: There are some areas of the reservoir where gravel bottom material can be found in depths less than 1 meter, but vegetation is scarce.

(Poor) 1 point: Very few shallow areas with a gravel bottom can be found in the reservoir, and vegetation is scarce.

Goal: Improved Sport Fishing

Guideline I Variables

Bank Habitat Quality (3 pts)

Importance:

Bank habitat is where sport fish species spend the most time throughout the year. Bank habitat for bass, crappie, and other similar sport fish requires vegetation and structure for the fish to relate too (Pander, 2009.) More information about bank habitat can be found in Appendix A: Literature Review, on pages A6 and A8, and Appendix B: Case Studies on pages B16 and B17. (Blabolil 2017, 2) (MDC, 2014) (Pander 2009).

Point Scoring:

Bank habitat can be analyzed with a sonar device which shows submerged objects in section view. Figures 10 - 12 (below and on the next page) represent good bank habitat, fair bank habitat, and poor bank habitat. The figure which best aligns with the sonar scans of the reservoir's bank habitat will determine the points scored for bank habitat quality.

(Good) 3 point: Sonar scans are most similar to figure 10 (below) in both structure and density of cover.

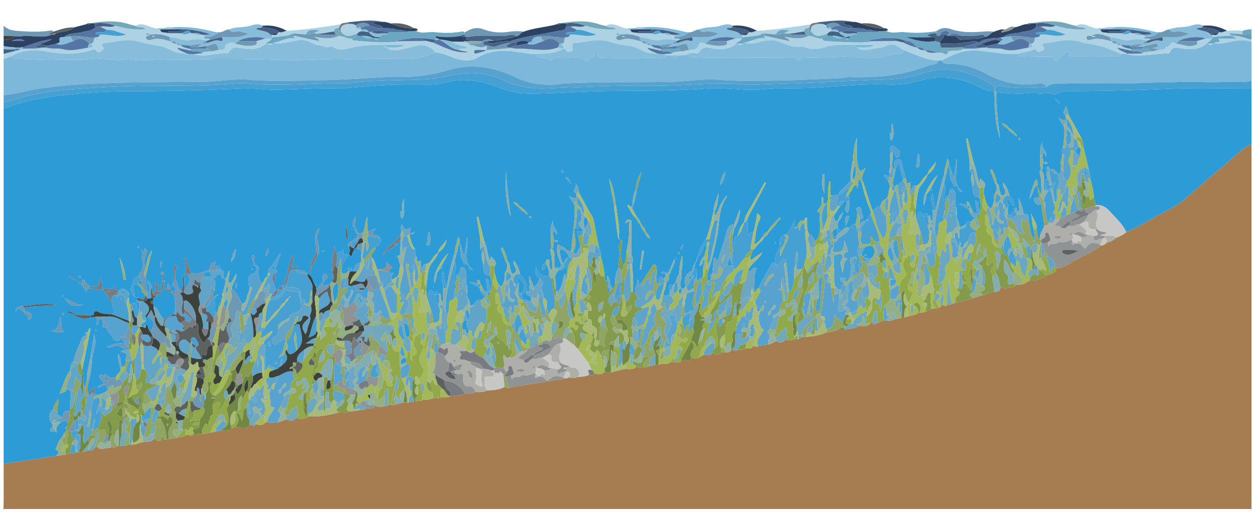


Figure 10: Good Bank Habitat Diagram (Dirks, 2020)

(Fair) 2 points: Sonar scans are most similar to figure 11 (below) in both structure and density of cover.

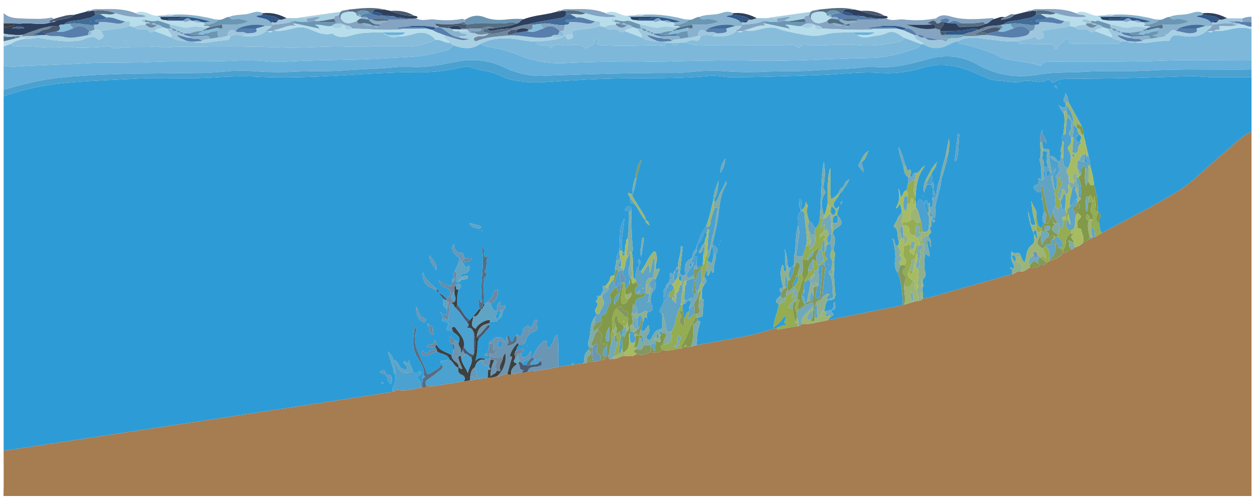


Figure 11: Fair Bank Habitat Diagram (Dirks, 2020)

(Poor) 1 point: Sonar scans are most similar to figure 12 (below) in both structure and density of cover.

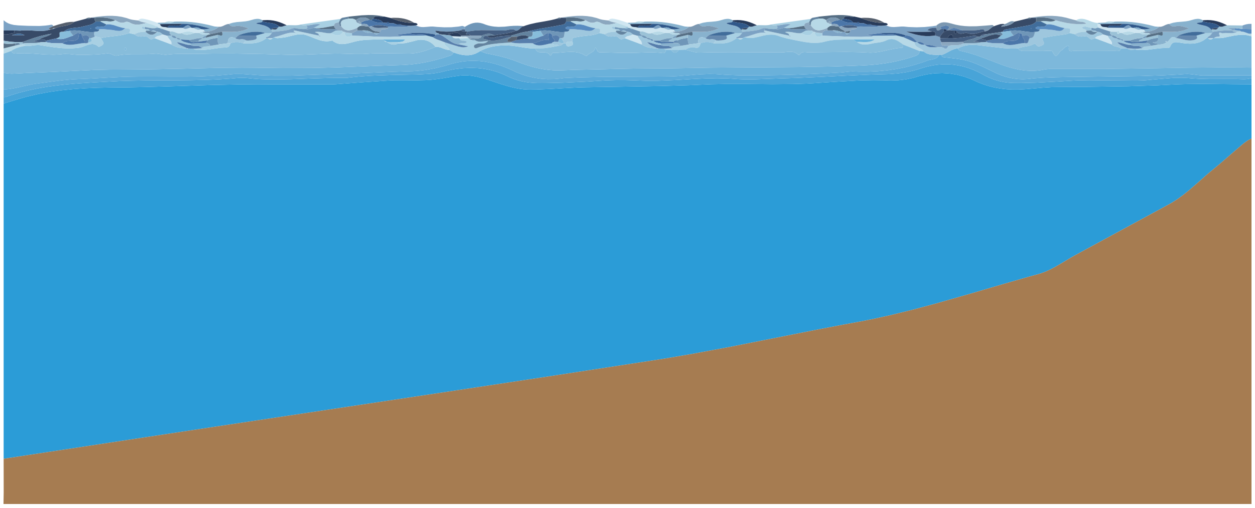


Figure 12: Poor Bank Habitat Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline I Variables

Open Water Habitat Quality (3 pts)

Importance:

Open water habitat represents areas that sport fish search for during the colder months of the year. They use this habitat as protection from predators. More information about open water habitat can be found in Appendix A: Literature Review, on page A8 and Appendix B: Case Studies on pages B16 and B17. (Blabolil 2017, 2) (MDC, 2014) (Pander 2009).

Point Scoring:

Open Water Habitat can be analyzed with a sonar device. Figures 13 - 15 (below and on the next page) represent three examples of open water habitat. The figure which best aligns with the sonar scans of the reservoir's open water habitat will determine the points scored for open water habitat quality.

(Good) 3 point: Sonar scans are most similar to figure 13 (below) in both structure and density of cover.

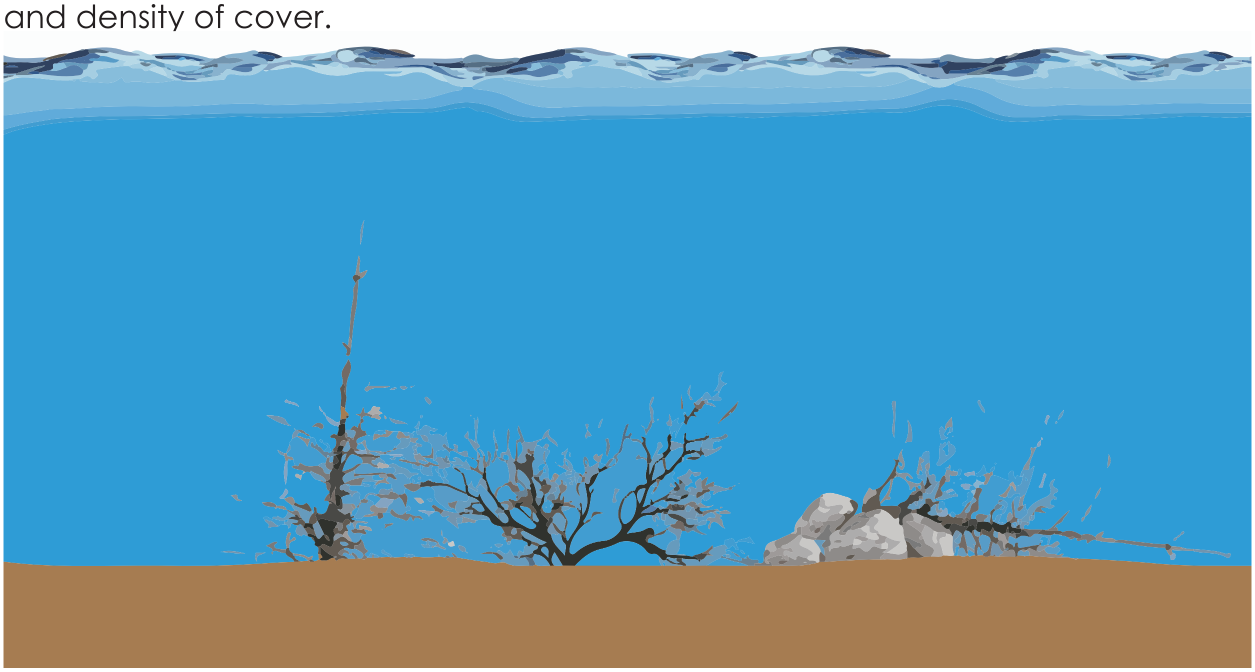


Figure 13: Good Open Water Habitat Diagram (Dirks, 2020)

(Fair) 2 points: Sonar scans are most similar to figure 14 (below) in both structure and density of cover.

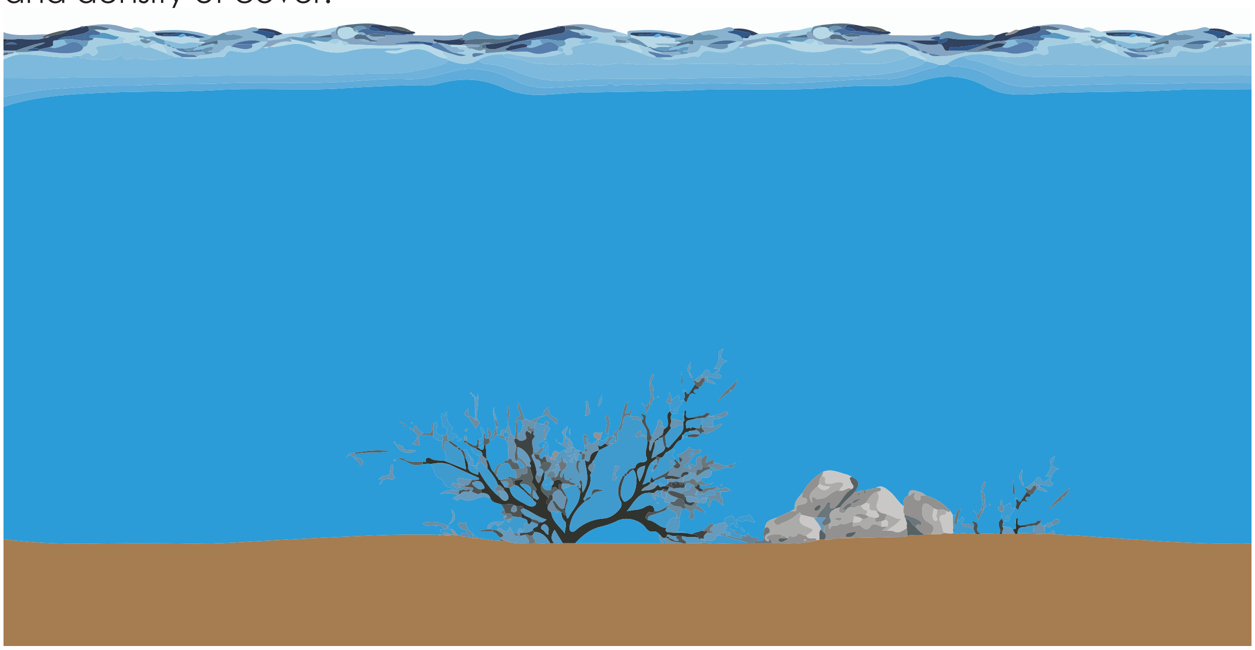


Figure 14: Fair Open Water Habitat Diagram (Dirks, 2020)

(Poor) 1 point: Sonar scans are most similar to figure 15 (below) in both structure and density of cover.

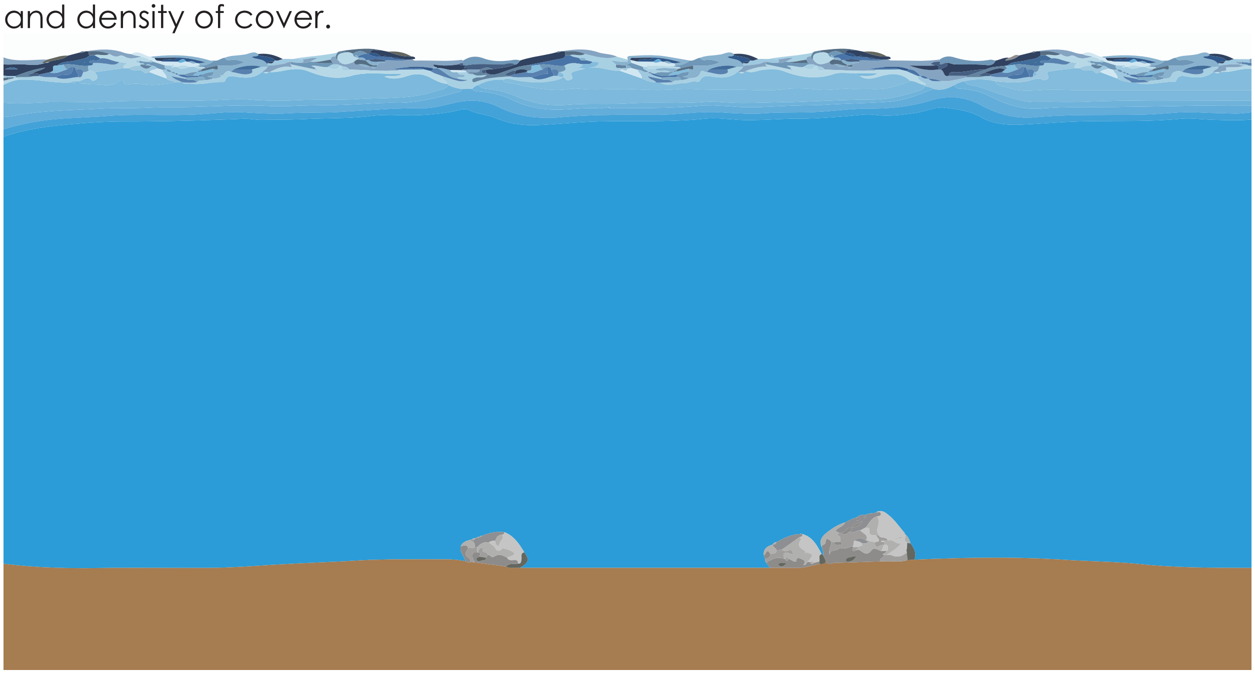


Figure 15: Poor Open Water Habitat Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline II: Water Level Fluctuation (9 Points)

Effects on Fish Spawning

Studies on reservoirs with frequently changing water levels have revealed correlations between changes in the water level, and the success rates of fish spawns. Reservoirs with high water levels in the spring tend to have high numbers of sport fish larvae, especially crappie (Maceina, 1998). This is due to the increase in viable spawning habitat which becomes available with the rising water level. With more shallow water areas to spawn, sport fish have an easier time finding space for their beds, and predators have a more difficult time locating and feeding on the fish larvae (Maceina, 1998). Rising water levels also serve as an indicator for some sport fish such as white bass to begin to move shallow and build their spawning beds (Schultz, 2002). While these studies agree that higher water levels tend to result in a successful sportfish spawn, consistent water levels year-round have proven to increase the survival of sportfish species such as crappie and bluegill. This means that while higher water levels in the spring promote a successful fish spawn, it should not come at the cost of large water level fluctuations throughout the rest of the year. While the rapid rising of water levels in the spring tend to be unpredictable, and the release of water is often out of control of lake management, the effects that the water level fluctuation have on the annual fish spawn should be monitored. Studying the change in water levels could help reservoir management predict the annual fish yields in the years to come (Schultz, 2002).

Water Levels and Boating

Fluctuating water levels pose many safety risks to boaters, and property in and around the lake. Falling water levels expose hazards which were of no risk at normal lake levels such as standing timber, old building foundations and high points in the lake. Lower lake levels can also affect safety of boat ramps, as vehicles may not have the traction or incline to safely launch boats. Floating marinas are usually safe, but if water levels drop drastically, boats and marina infrastructure could be damaged. With abnormally high-water levels, we see similar risks. Hazards which were previously visible at normal pool level are hidden beneath the surface, and boaters unfamiliar with the area could strike one of these hazards. Boat ramps with high water levels are usually safe, unless traction strips are covered up, or the angle of incline is too steep or shallow for a safe boat launch. (MDC, 2014)

Variables for Study

- Annual Water Level Fluctuations (3 pts)
- Conservation Pool (0 pts)
- Potential Low and High-water Boating Hazards (3 pts)
- Boat Ramp Safety (3 pts)

Illustrated in figure 16 (below)

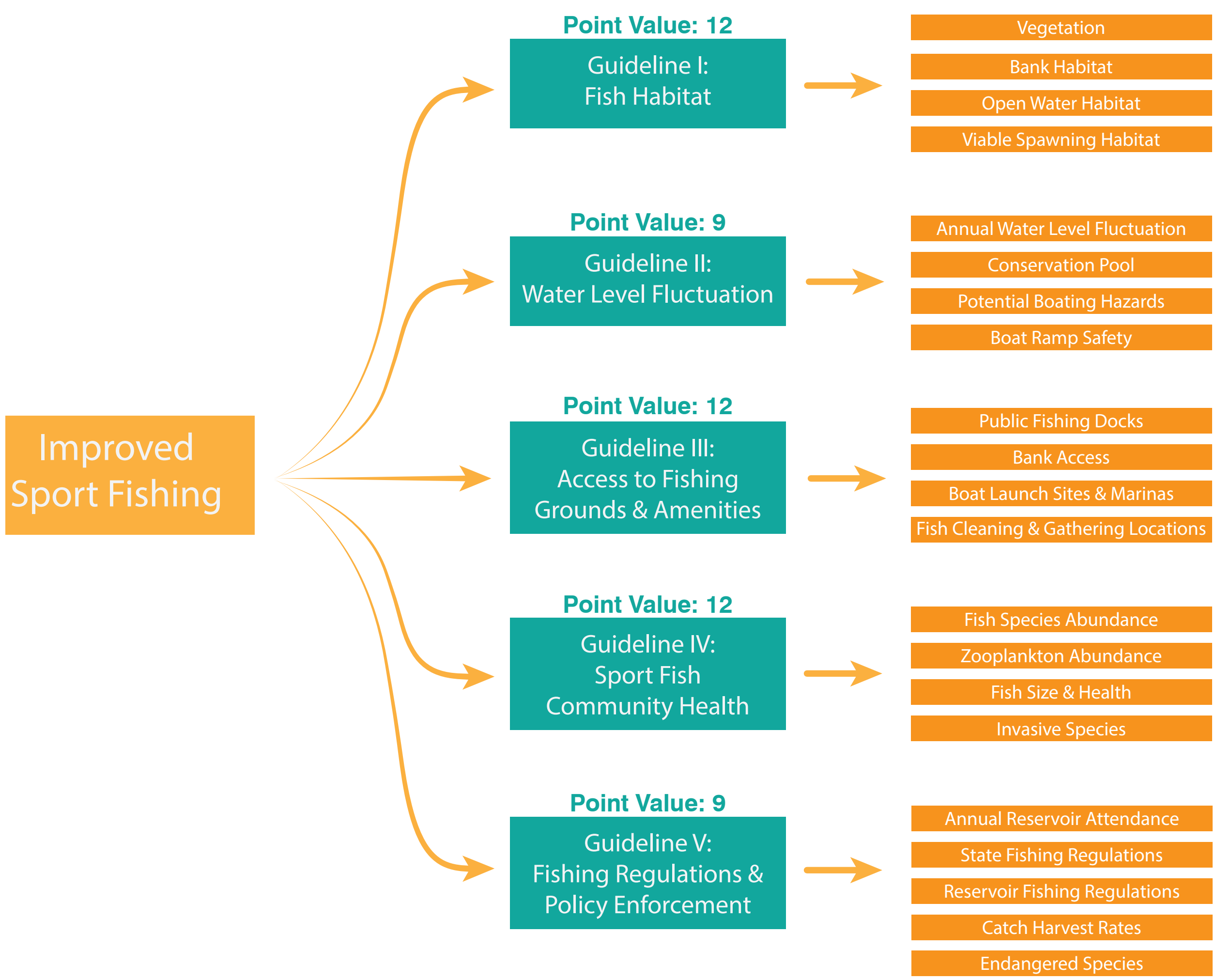


Figure 16: Improved Sport Fishing Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline II Variables

Annual Water Level Fluctuations (3 pts)

Importance:

Understanding the trends in annual water level fluctuations can help lake management predict fish spawning rates and identify potential boating hazards. Identifying the seasonal high and low water levels provides excellent insight for future stormwater management planning. It can also help influence potential policy changes to maximize water usage both in the reservoir, and downstream. Data from each season for a minimum of the past 5 years should be analyzed, and any seasonal patterns should be identified. More information about water level fluctuations can be found in Appendix A: Literature Review, on page A14. (Maceina 1990, 104) (Schultz 2002)

Point Scoring:

(Good) 3 points: Lake water levels fluctuate within a similar range each year. In the spring, the water is higher which creates more access to fish spawning grounds. In the winter, the lake levels are lower in order to compensate for the heavy rains in the spring.

(Fair) 2 points: Lake water level fluctuations are similar in some years, but the annual high and low water levels are inconsistent from year to year.

(Poor) 1 point: Lake water level fluctuations are not consistent. Spring water levels fluctuate drastically.

Conservation Pool (0 pts)

Importance:

According to Texas Water, Conservation pool level refers to the range of elevation between the dead pool (elevation at which water cannot be drained by gravity through the dam) and the maximum normal operating level (Texas Water). Identifying this range will determine the elevation placement for design amenities, help identify potential boating hazards. The conservation pool level is also helpful when bank habitat and spawning habitat restoration measures are being taken, as it can give a range of depth which the reservoir normally operates under (Texas water, 2020).

Point Scoring:

This inventory variable does not contribute to the overall guideline score because it's performance cannot be evaluated.

Potential Low and High-Water Boating Hazards (3 pts)

Importance:

Changing water levels can present dangers to boaters. During low and high-water levels, some hazards such as standing timber and natural lake high points are hidden just below the surface of the lake. These hazards could catch boaters off guard and cause accidents on the water. More information about boating hazards can be found in Appendix B: Case Studies on page B17. (MDC, 2014)

Point Scoring:

(Good) 3 points: All boating hazards which could become hidden during low or high-water events are marked on maps, or with buoys. There are no hazards in areas of high-speed boater traffic.

(Fair) 2 points: Most boating hazards are marked on maps or with buoys. There are no hazards in areas of high-speed boater traffic.

(Poor) 1 point: Very few boating hazards are marked on a map or with buoys. Some hazards exist in areas of high-speed boater traffic.

Goal: Improved Sport Fishing

Guideline II Variables

Boat Ramp Safety (3 pts)

Importance:

In order to prevent accidents or difficulty at a boat launch site, it's important that the ramps are designed properly. Each boat ramp should be 15' wide and have a slope of 12% - 15%. Drainage grooves should run perpendicular to the slope of the ramp to move water off the surface and provide traction during slippery conditions. The ramp should also extend far enough above and below the water's surface so that it's still safe to use during high or low water conditions. Courtesy docks (docks which allow boaters to secure their boat and walk back to land) aren't necessary, but they make launching and loading boats much easier and faster (Mathew, 2012). Boat launch sites should have at least two ramps at each site (Sunflower H2O Coalition, 2013) More information about boat ramp design can be found in Appendix A: Literature Review, on page A19. (Mathew, 2012, Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: All boat launch sites meet the dimension guidelines, and have courtesy docks to allow for easy access in and out of the boat.

(Fair) 2 points: Most boat launch sites meet the dimensions guidelines. Some of the launch sites have courtesy docks.

(Poor) 1 point: Very few if any boat launch sites meet the dimension guidelines. There are no courtesy docks at any of the boat launches.

Goal: Improved Sport Fishing

Guideline III: Access to Fishing Grounds and Fishing Amenities (12 pts)

A lake which excels in sport fishing needs to have access to a wide variety of fishable water, as well as have the amenities and infrastructure to support high numbers of anglers.

Bank Fishing Access

Access to fishable water is typically not an issue with boaters, but bank anglers can often struggle to find areas which have a potential of holding fish. Dense vegetation, vertical separation from the water, or physical barriers are all potential deterrents for bank anglers. These obstacles make it difficult and often dangerous to attempt fishing at a decent fishing spot. This problem can easily be solved by using solutions such as public fishing docks, or trails which lead to a stable bank (Sunflower H2O Coalition, 2013).

Fishing Amenities

Reservoirs with convenient fishing amenities attract anglers. Standard requirements of serious anglers include amenities such as two-lane boat launches with courtesy docks, proximity boat trailer parking, and fish cleaning stations (Sunflower H2O Coalition, 2013). Boat launch sites with protection from the wind by use of floating levees, rock levees, or a location protected by natural barriers such as the back of a cove are preferred. Marinas selling fuel and bait shops with live bait are also a sought-after commodity by anglers. More serious anglers and fishing tournaments will likely visit a reservoir if it has the amenities and infrastructure to support them. They look for many of the same amenities as typical anglers, but at a larger scale. Two-lane boat launch sites will work but launch sites with 3-4 lanes are preferred. These sites should be in a wind protected area where 10-20 boats could wait safely in the water until its their turn to leave the launch location. A gathering space on land near the launch where the anglers could weigh their catch is also preferred by tournament anglers (Sunflower H2O Coalition, 2013).

Variables for Study

- Public Fishing Docks (3 pts)
- Bank Access (3 pts)
- Boat Launch Sites and Marinas (3 pts)
- Fish Cleaning/ Gathering Locations (3 pts)

Illustrated in figure 17 (below)

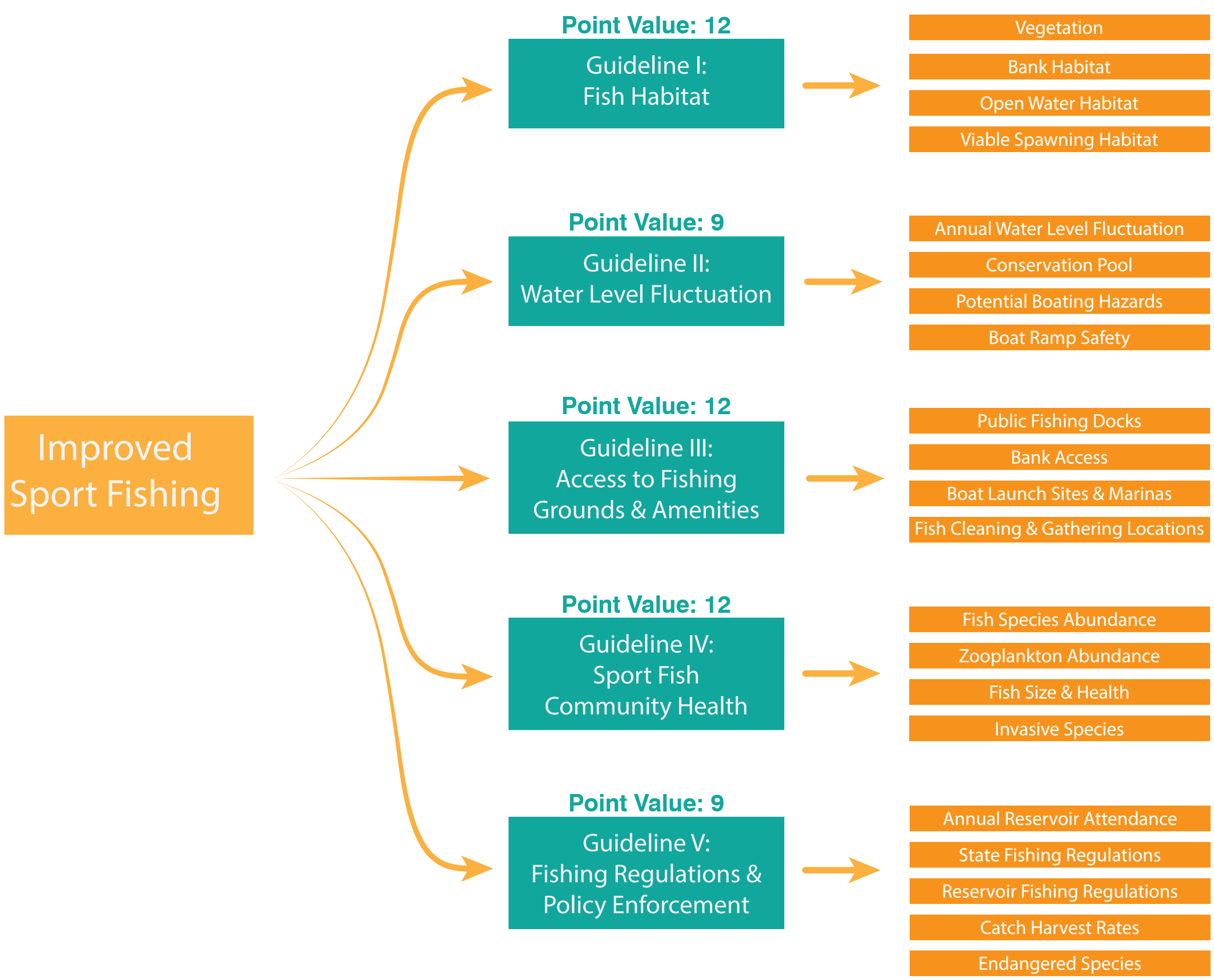


Figure 17: Improved Sport Fishing Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline III Variables

Public Fishing Docks (3 pts)

Importance:

Public Fishing docks give bank anglers access to fish deeper waters, and also provide structure for smaller sport fish and bait fish to take shelter. Public docks can also provide ADA access, or easier access for anglers who have limited mobility and struggle to navigate the rough terrain of a shoreline. (Derbyshire, 2006).

Point Scoring:

(Good) 3 points: Bank anglers have access to multiple public fishing docks around the lake.

(Fair) 2 points: There is one public dock on the reservoir which allows fishing.

(Poor) 1 point: There are no docks open to fishing on the reservoir.

Bank Fishing Access (3 pts)

Importance:

While serious anglers often fish from boats, bank fishing is very popular with causal fishermen, or people who are just getting into the sport. Reservoirs with plenty of easy bank access is often attractive to casual anglers (Sunflower H2O Coalition, 2013).

Point Scoring:

(Good) 3 points: The reservoir has plenty of accessible bank fishing spots, with roads and trails which allow for anglers to easily move from spot to spot with their equipment.

(Fair) 2 points: There is some bank accessible to shore-anglers, but much of the reservoir is blocked by terrain with very few trails.

(Poor) 1 point: Little to no accessible bank fishing spots exist in the reservoir. There are no trails, and access to most of the reservoir is very restricted.

Goal: Improved Sport Fishing

Guideline III Variables

Boat Launch Sites and Marinas (3 pts)

Importance:

Reservoirs need good, public boat launch sites in order to attract anglers and fishing tournaments. Boat launch sites should each consist of at least 2 boat ramp lanes and a courtesy dock for boaters to temporarily hold their boat while they park their boat trailer. Boat lanes without courtesy docks may deter some anglers from using the launch site, as it would require them to "beach" their boat on shore while they park their boat trailer or load in other passengers. Anglers also look for reservoirs with marinas which provide gas or live bait. More information about boat ramp design can be found in Appendix A: Literature Review, on page A19, and Appendix B: Case Studies on page B12. (Mathew, 2012, Sunflower H2O Coalition, 2013)

Point Scoring:

Based on the Sunflower H2O Coalition's reservoir analysis, reservoirs require one, public boat launch site (two-lane boat ramp with a courtesy dock) for every 2,000 acres of navigable water. The reservoir scores 1 point for meeting 33% of the recommended ratio of boat launch sites/navigable water acres.

(Good) 3 points: The reservoir meets between 66% and 100% of the required one, public boat launch site for every 2,000 acres of navigable water ratio. Marinas which provide fuel and live bait can be found at different locations in the reservoir.

(Fair) 2 points: The reservoir meets between 33% and 65% of the required one boat launch site for every 2,000 acres of navigable water ratio. The reservoir has a marina which provides fuel and live bait.

(Poor) 1 point: The reservoir meets 32% or less of the required one, public boat launch site for every 2,000 acres of navigable water ratio. No marinas are found on the reservoir.

Fish Cleaning/ Gathering Locations (3 pts)

Importance:

Fish cleaning stations and open space for gatherings are both amenities that have the potential to improve reservoir sport fishing and visitation. Tournament groups often look for places to gather to weigh fish and declare a winner. A shaded location near the boat launch is typically preferred. Fish cleaning stations are an amenity that guides look for, as well as anglers who want to keep their day's catch (Sunflower H2O Coalition, 2013).

Point Scoring:

(Good) 3 points: Shaded gathering areas near boat launch sites can be found around the reservoir, as can the occasional fish cleaning station.

(Fair) 2 points: The reservoir has a gathering space near a boat launch site, and fish cleaning stations an be found nearby.

(Poor) 1 point: It's difficult to find gathering spaces close to boat launch sites, and there are no fish cleaning stations.

Goal: Improved Sport Fishing

Guideline IV: Sport Fish Community and Health (12 pts)

Food-Chain Balance:

A healthy and well-balanced fish community is an essential part of any sport fishing lake. Fish communities should have a strong balance of predator species vs prey species to keep the food-chain in balance. Without a balanced food-chain, sport fishing can be hindered due to issues such as stunted and over-populated mid-tier predators such as crappie and bluegill. Prey species such as shad and minnows should be abundant and found in multiple schools around the reservoir. Mid-tier predator species such as crappie and bluegill should be schooling in habitats which support them around the reservoir, and apex predators such as bass, wiper or pike should have the smallest quantities and found near food sources and structure (Sprenkle, 2015).

Non-native Fish Species:

Reservoirs will often contain fish species non-native to the region such as carp, trout, sturgeon and pike. If these species are introduced to fulfill a unique sport fishing desire from the community, their numbers should be monitored to ensure the food-chain doesn't become unbalanced. Species such as grass carp, which are often used to control excess amounts of vegetation, can often destroy sport fish habitats with their feeding habits, and should be closely monitored as they can rapidly grow in both size and numbers. Invasive species which were not introduced intentionally have the ability to overtake the natural species in the reservoir and should be removed either policy (do not release) or if necessary, by lake management (Sprenkle, 2015).

Fish Health:

The reservoir should also be free of any fish illness or disease, as infected species won't be able to be kept by anglers. If a common disease is found in any species in the reservoir, a deeper analysis may be required to find the source of the problem (Sprenkle, 2015).

Variables for Study

- Fish Species Abundance (3 pts)
- Zooplankton Abundance (3 pts)
- Fish Size/Health (3 pts)
- Invasive Species (3 pts)

Illustrated in figure 18 (below)

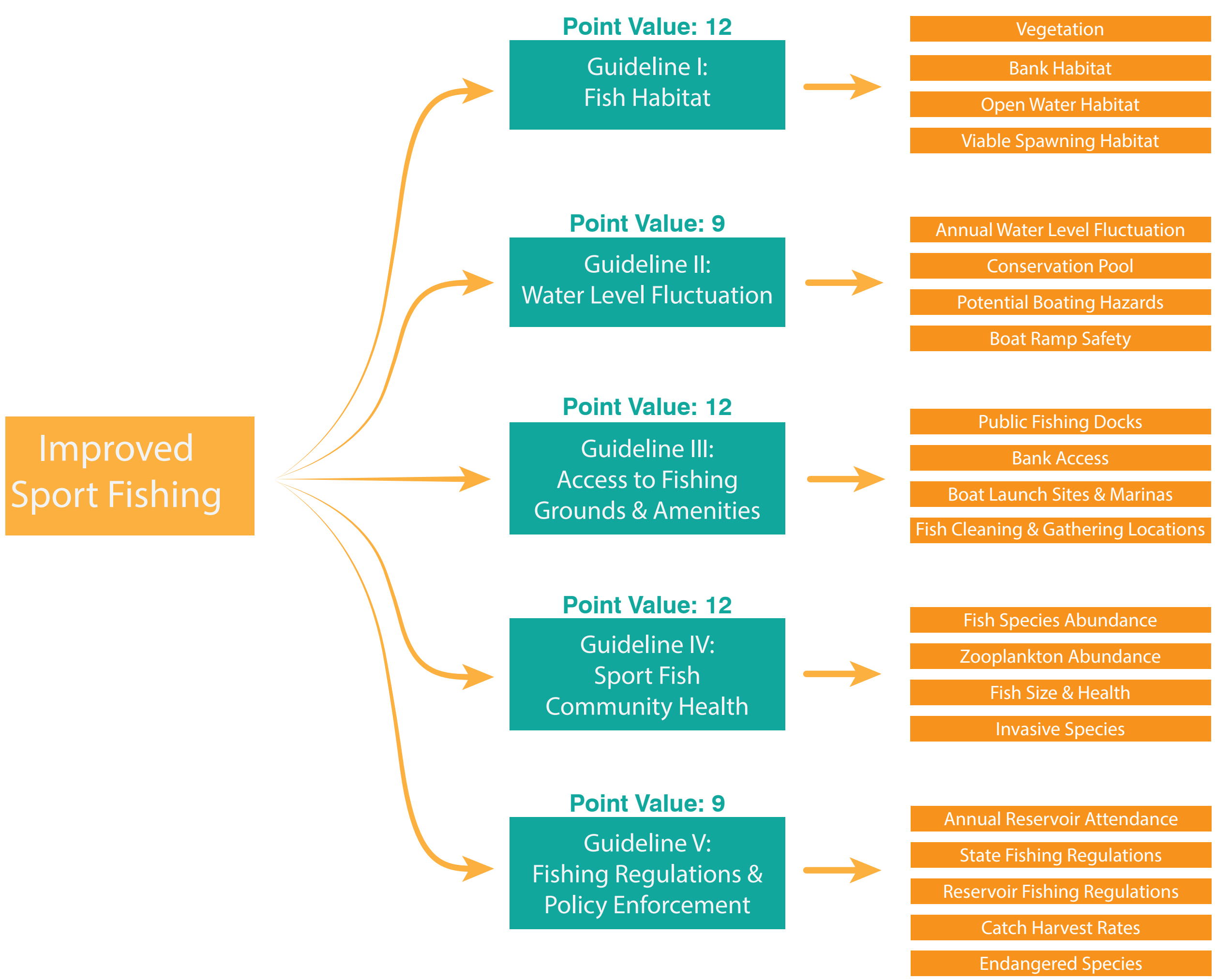


Figure 18: Improved Sport Fishing Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline IV Variables

Fish Species Abundance (3 pts)

Importance:

Fish species abundance is a good indicator of where fish tend to migrate to at different times of the year. This can be useful for future restoration efforts. Species abundance is also useful when setting creel limits for anglers. When the population of a particular sport fish is known by lake management, they can make informed decisions about how many fish each angler can keep in order for the lake to still host a healthy population of fish More information about Fish species abundance can be found in Appendix A: Literature Review, on pages A6 and A7. (Sprenkle, 2013) (Sprenkle, 2015) (Sprenkle, 2016)

Point Scoring:

(Good) 3 points: Fish species abundance has been documented for all sport fish. Lake management use the species abundance to set updated creel limits.

(Fair) 2 points: Fish species abundance has been documented for some of the sport fish in the reservoir, but that information is not used to update creel limits.

(Poor) 1 point: Fish species abundance has not been documented.

Zooplankton Abundance (3 pts)

Importance:

The use of zooplankton as indicators for water quality is an effective measuring tool which can be used in both urban ponds and rural reservoirs. Zooplankton relocate carbon, energy, and other nutrients from bacteria and organic matter into organisms, which can transfer it on to the rest of the trophic levels. If these transfers are not happening, it's common to see an increase in phytoplankton blooms, which results in a loss of energy from the aquatic system. More information about zooplankton can be found in Appendix A: Literature Review, on page A11. (Jurczak 2018).

Point Scoring:

(Good) 3 points: Zooplankton are abundant in the reservoir. There are no phytoplankton blooms and water quality is good.

(Fair) 2 points: Zooplakton are fairly abundant, but the reservoir has had occasional issues of phytoplankton blooms and poor water quality.

(Poor) 1 point: Zooplankton are not abundant in the reservoir, and there are frequent phytoplankton blooms resulting in poor water quality.

Goal: Improved Sport Fishing

Guideline IV Variables

Fish Size/Health (3 pts)

Importance:

Data on the size of specimen caught can be a very useful insight to the overall health of a fish community, as it reveals imbalances in the fish ecosystem's structure. For example, small, stunted crappie could be indicative of a lack of predator species, resulting in an overpopulation of crappie. More information about fish size and health can be found in Appendix A: Literature Review, on A6 and A7. (Sprenkle, 2013) (Sprenkle, 2015) (Sprenkle, 2016)

Point Scoring:

(Good) 3 points: All sport fish/ bait fish are of normal size, and healthy.

(Fair) 2 points: Some fish species are stunted/ unhealthy, but the ecosystem is generally healthy.

(Poor) 1 point: The lake has an abundance of stunted/ unhealthy fish.

Invasive Species (3 pts)

Importance:

Some invasive species can quickly take over an ecosystem by destroying native habitats and decimating native fish populations. While invasive species may not be a major concern when looking at a reservoir, they could be flushed out of the reservoir and begin to multiply downstream where non-native species become an issue. Lake officials should annually monitor and track the abundance of invasive species in a reservoir to ensure that they don't pose a threat to the reservoir or it's watershed. More information about invasive species can be found in Appendix A: Literature Review, on page A6. (Onsoy 2011)

Point Scoring:

(Good) 3 points: The reservoir has very few invasive species, and they pose no immediate threat to the reservoir or it's ecosystem.

(Fair) 2 points: Some invasive species are found in the reservoir. While their population isn't out of control, they are threatening the native ecosystem.

(Poor) 1 point: The reservoir has an abundance of invasive species which pose a threat to the reservoir and it's watershed.

Goal: Improved Sport Fishing

Guideline V: Reservoir Fishing Policy & Enforcement (6 pts)

Sport Fishing & Hunting Regulations:

Implementing fishing regulations is a necessary step for reservoir management. The regulations should balance the ecological productivity of fish communities with the current and future demand for fishery resources to ensure long term success. There are five decision factors that should influence fishing regulations:

1. Society: Strong social ties are critical at all scales of management in fisheries. The more a fisherman conforms to community rules, the more benefits he or she will likely reap (Lynch 2015).

2. Politics: Often times, fisheries are tasked with producing time-sensitive results from government agencies which can have little to no biological meaning. An example of this would be adopting climate change-inspired policies. Fisheries Management are more likely to implement a policy change if it promotes desirable catch regulations, and not when they align with scientific recommendations (Lynch 2015).

3. Economics: Fisherman will attempt to maximize their profit (catch and harvest rates) (Lynch 2015).

4. Science: Policy decision making should be flexible and adaptive to account for new information and changing ecological conditions (Lynch 2015). "Managing inland fisheries is a complex task, with or without the added potential effects of climate change. Addressing climate-related risks proactively, whether the impacts are mild or severe, will be beneficial to fisheries because these actions may buffer against other ecological changes" (Lynch 2015, 18).

5. Endangered Species: Policies aiming to protect endangered species within a reservoir's watershed are of major concern in the Midwest. Bottom feeders such as the pallid sturgeon which migrate through rivers are often put at risk due to the lack of policy, or the lack of policy enforcement (Garrison, 2019).

Variables for Study

- Annual Reservoir Attendance (0 pts)
- State Fishing Regulations (0 pts)
- Lake Specific Fishing Regulations (0 pts)
- Catch/Harvest Rates (3 pts)
- Endangered Species (3 pts)

Illustrated in figure 19 (below)

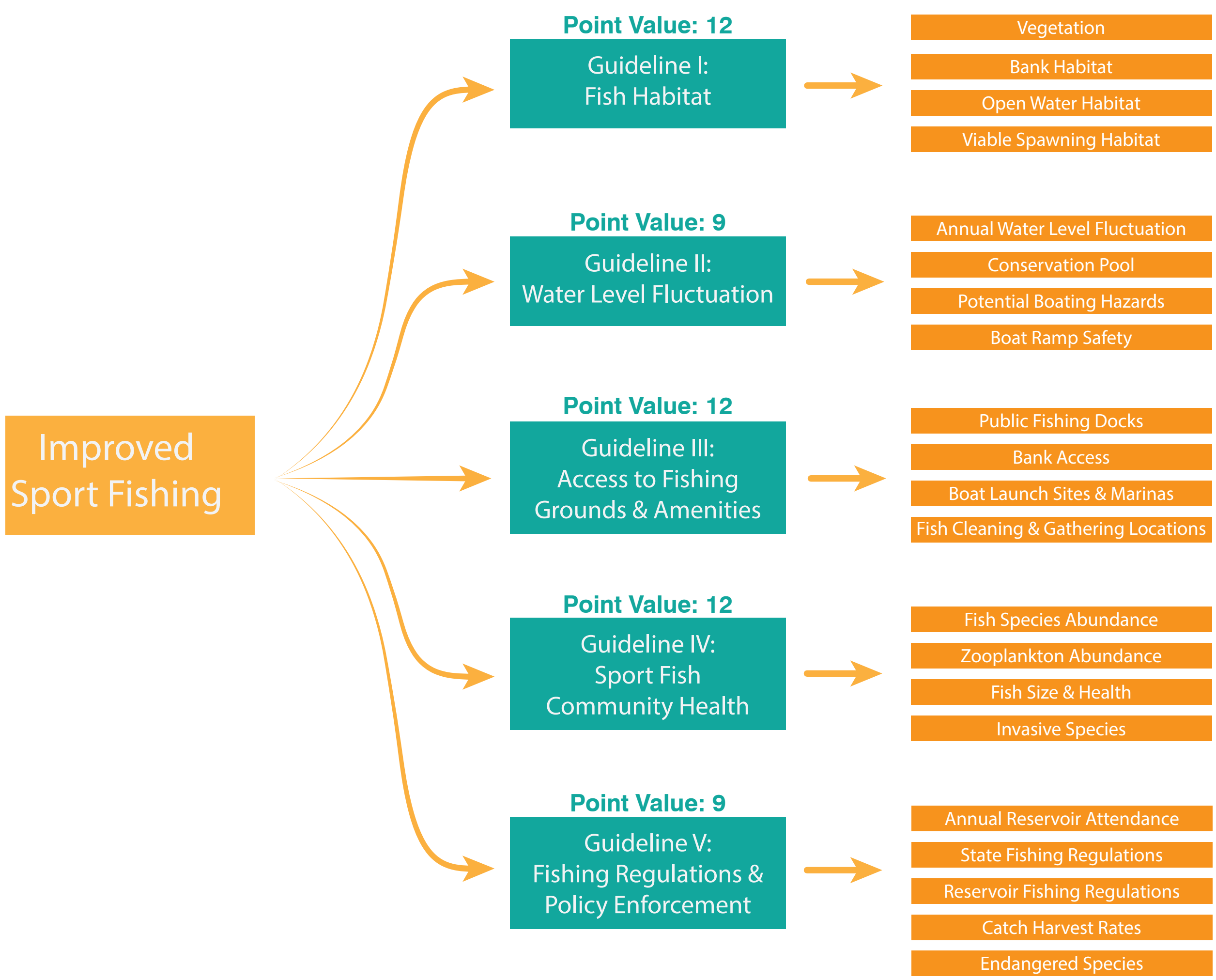


Figure 19: Improved Sport Fishing Diagram (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline V Variables

Annual Reservoir Attendance (0 pts)

Importance:

Site visitation can be broken down into two categories: Day use, and Camp use. Both these categories include all activities which take place at the reservoir. Information about site visitation can help designers and planners make decisions about quantities of amenities such as parking spaces, camping spots, boat ramps, etc... More information about reservoir attendance can be found in Appendix B: Case Studies on page B8. (Sunflower H2O Coalition, 2013).

Point Scoring:

In this report, annual reservoir attendance is an inventory variable worth zero points because it is meant to serve as a gauge for how many visitors the reservoir needs to provide amenities for. Design decisions regarding the quantity of amenities should be made based on the annual reservoir attendance.

State Fishing Regulations (0 pts)

Importance:

State's have general fishing regulations which are used to ensure that anglers don't over-fish reservoirs. Some lakes can have their own specific policies and creel limits, and it's important to understand the purpose and reasoning of state regulations before creating any lake-specific regulations or limits (Lynch, 2015).

Point Scoring:

State fishing regulations are classified as an inventory variable worth zero points because their individual performance cannot be evaluated.

Catch/Harvest Rates (3 pts)

Importance:

Taking a survey of a reservoir's catch/harvest rates can provide lake management with helpful information about how much success anglers have at the reservoir. Lake management can then use this information to adjust lake specific regulations accordingly (Lynch, 2015).

Point Scoring:

(Good) 3 points: Catch/Harvest rates are good, and anglers are frequently meeting their limits.

(Fair) 2 points: Occasionally anglers can reach their creel limits, but it doesn't happen often.

(Poor) 1 point: Anglers very rarely reach the lake's creel limit, indicating that the limit could be too high for the reservoir.

Lake Specific Fishing Regulations (0 pts)

Importance:

Some lakes have specific fishing regulations which differ from the state regulations due to certain conditions at the reservoir. These lake specific regulations could include a unique creel limit to protect a species of fish which had a low spawn rate in previous years, or specific instructions about what to do with invasive fish species caught. It's important that each reservoir monitors their sport fish populations annually to determine if any lake specific regulations are necessary. More information about reservoir policy can be found in Appendix A: Literature Review, on pages A20 and A21. (Garrison, 2019) (Lynch, 2015)

Point Scoring:

Lake specific fishing regulations are classified as an inventory variable worth zero points because their individual performance cannot be evaluated.

Goal: Improved Sport Fishing

Guideline V Variables

Endangered Species (3 pts)

Importance:

Some reservoirs in the Midwest are home to endangered or protected fish species such as the Lake Sturgeon. It's crucial that these reservoirs preserve habitat for protected fish species, and ensure visitors are made aware of their presence in the lake. This can most effectively be communicated through signage. Policies which protect these species should be implemented at the reservoir. More information about endangered species can be found in Appendix A: Literature Review, on page A20. (Garrison, 2019).

Point Scoring:

(Good) 3 points: Lake management is aware of all endangered species in the reservoir. Habitat for the species' is protected, and signs around the reservoir inform visitors of the presence of the species.

(Fair) 2 points: Lake management is aware of all endangered species in the reservoir. Very little information about the species is made aware to site visitors, but there is some habitat for the protected species.

(Poor) 1 point: Lake management does not track endangered species, and has no way to know if they have enough habitat. There are no signs to indicate the presence of a protected fish species.

Slowing Reservoir Sedimentation

Guidelines:

Guideline I: Targeting the Sediment Source
Guideline II: Bank Erosion

See figure 20 (right)

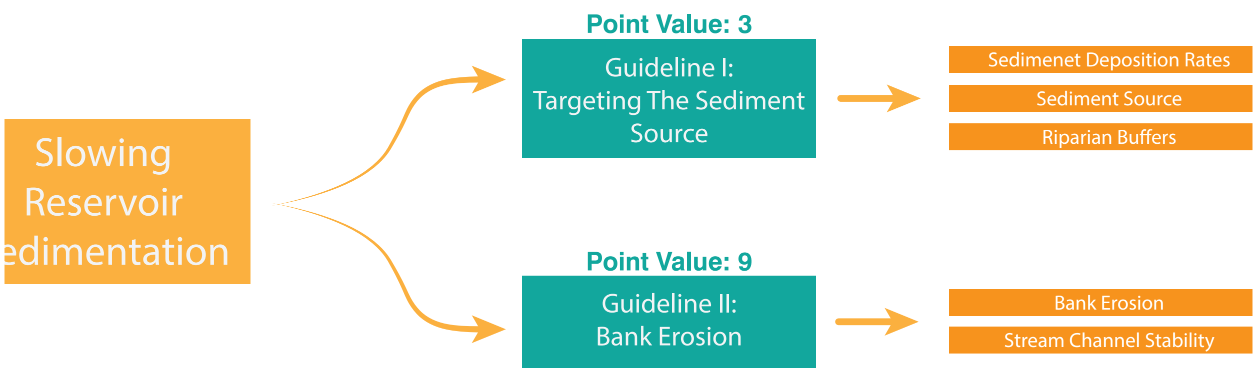


Figure 20: Slowing Reservoir Sedimentation Diagram (Dirks, 2020)

Goal: Slowing Reservoir Sedimentation

Guideline I: Targeting The Sediment Source (3 pts)

Sedimentation in Reservoirs:

Accelerated sedimentation in reservoirs is an issue that all reservoirs face, and it eventually causes the reservoir to lose functionality, and is the reason for the average 100 year lifespan. Over long periods of time, this sediment will fill the reservoir to a point where it can no longer hold the floodwater it was designed to hold, and drastic steps for removing the sediment such as sluicing or density current venting need to be used to extend the reservoir's life expectancy (Kansas water Office, 2008). Steps can be taken to reduce the rate at which sediment is deposited into the reservoir. The most successful strategy slowing down sediment without damaging the watershed ecosystem is to target sediment at the source (Keane, 2019).

Overland Flow Erosion:

Traditional farming methods such as tilling disturb the soils and loosen sediment, making the land highly susceptible to sediment runoff during storm events (USEPA, 2002). While these farming practices will likely continue, there are additional practices which can conserve nutrients in the ground and protect against soil erosion. Cover cropping and field terracing are both methods which have proven to reduce erosion and runoff rates (Brady and Well, 2008).

Riparian Buffers:

Reducing sediment input from overland flow is possible with the implementation of riparian buffers. Riparian buffers possess three characteristics which reduce sediment runoff. The first characteristic is the fine, tight root systems present in most riparian species. These roots are able to grab sediment particles and hold them from being swept into the channel. The second characteristic is the density of the vegetation, which slows down the flow velocity of the overland flow. A slower velocity flow makes it easier for the root systems of the vegetation to trap and slow down sediment particles. The third characteristic is the fibrous root system's capability to open soils and allow for more infiltration (Robinson et al., 1996).

Variables for Study

- Sedimentation Deposition Rates (0 pts)
- Sediment Sources (0 pts)
- Riparian Buffers (3 pts)

Illustrated in figure 21 (below)

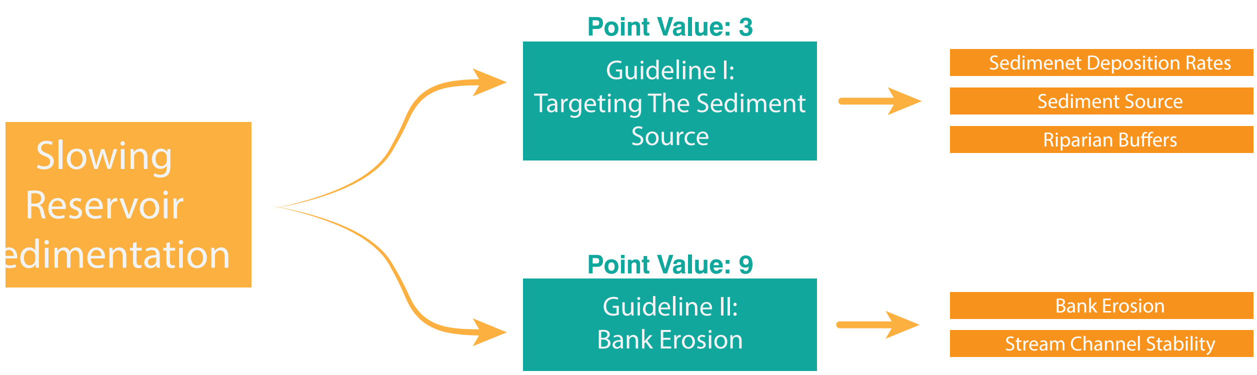


Figure 21: Slowing Reservoir Sedimentation Diagram (Dirks, 2020)

Goal: Slowing Reservoir Sedimentation

Guideline I Variables

Sediment Deposition Rates (0 pts)

Importance:

While all reservoirs fill with sediment from natural stream processes, accelerated sediment deposition rates can lead to an early loss of reservoir function. In order to determine if accelerated sediment deposition is an issue, it is necessary to evaluate the rates at which sediment is accumulating in the reservoir. More information about reservoir sedimentation can be found in Appendix A: Literature Review, on pages A12 and A13. (Julien, 2010) (Kansas Water Office, 2008)

Point Scoring:

Sediment Deposition Rates are classified as an inventory variable worth zero points because they are meant to be used as a gauge to determine how severe the sedimentation issue is inside the reservoir.

Sediment Source (0 pts)

Importance:

Identifying the sediment source assists lake management in determining how to approach new policies or designs upstream of the reservoir to reduce sedimentation. Often times the sediment source in reservoirs is agricultural fields or stream bank erosion. Policies which aim to reduce the sediment supply can often be more effective than any sediment-retardant structures placed in the watershed, and also increase the health of the watershed. More information about reservoir sedimentation can be found in Appendix A: Literature Review, on pages A12 and A13. (Brady and Well, 2008) (Julien, 2010) (Keane, 2019) (Simon et al, 1999)

Point Scoring:

Sediment Source is classified as an inventory variable worth zero points because it's individual performance cannot be measured.

Riparian Buffers (3 pts)

Importance:

Riparian buffers can slow and trap sediment being transferred from agricultural fields and other sediment sources, as well as provide numerous environmental benefits for the watershed's ecosystem. More information about riparian buffers can be found in Appendix A: Literature Review, on pages A9, A12, and A13. (Gleason, 1998) (Robinson et al., 1996)

Point Scoring:

(Good) 3 points: Riparian buffers exist between all agricultural fields and the stream channel in the watershed upstream of the reservoir.

(Fair) 2 points: Some riparian buffers exist near the reservoir, but there are some fields which drain directly into the watershed with no riparian buffer.

(Poor) 1 point: There are very few riparian buffers in the watershed. Most agricultural fields drain directly into the watershed with no riparian buffer.

Goal: Slowing Reservoir Sedimentation

Guideline II: Bank Erosion (6 pts)

Streambank Erosion:

Sediment from streambank erosion is often the leading source of sedimentation in reservoirs. Depending on variables such as flow conditions, bank protection and soil structure, bank erosion can be responsible for up to 80% of the sedimentation rates in reservoirs (Simon et al, 1999). All stream banks degrade overtime, but accelerated erosion occurs when streams or disturbed and channelized (Keane, 2019). Some control measures can be used in the reservoir, but the most effective way to extend the life expectancy of a reservoir is to control sediment production upstream in the watershed. Soil conservation practices, increasing vegetation along banks and off-channel reservoirs are all common tactics used to slow down sediment deposition in reservoirs (Julien, 2010).

Stream Stabilization:

Many stream channels in the Midwest have been channelized or straightened to provide more room for farming or development (Admiraal, 2007). Channelized streams lack the natural meander that streams use to slow down water velocity. This lack of meander means that the streams are highly susceptible to erosion and bank degradation during storm and flood events. It's important to first analyze and classify the stream before attempting any restoration efforts, as doing so can provide information on the stream channel type, flood levels, and sediment transport rates. Methods for stream analysis such as Dave Rosgen's Watershed Assessment of River Stability and Sediment Supply (WARSSS) is widely used as it describes methods for stabilization which treat the root of the problem opposed to patching the cause of a problem (Rosgen, 2007).

Variables for Study

- Bank Erosion (3 pts)
- Stream Channel Stability (3 pts)

Illustrated in figure 22 (below)

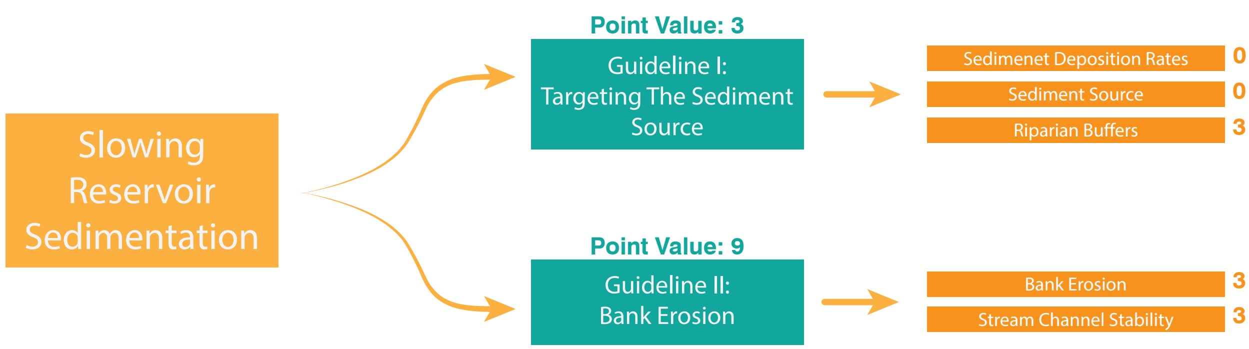


Figure 22: Slowing Reservoir Sedimentation Diagram (Dirks, 2020)

Goal: Slowing Reservoir Sedimentation

Guideline II Variables

Bank Erosion (3 pts)

Importance:

Bank erosion is often the leading cause of accelerated reservoir sedimentation. The stream banks upstream of the reservoir should be analyzed for areas of rapid erosion. More information about bank erosion can be found in Appendix A: Literature Review, on page A13. (Keane, 2019) (Simon et al, 1999)

Point Scoring:

The assessment of bank erosion upstream of the reservoir should be conducted by a river morphology expert who can identify areas of unstable bank erosion, and determine if bank restoration efforts are necessary.

(Good) 3 points: Bank erosion upstream of the reservoir is under control. The banks are eroding at a regular rate.

(Fair) 2 points: Bank erosion is slightly accelerated, and sediment from the stream banks make up a significant portion of the sedimentation in the reservoir.

(Poor) 1 point: Stream banks are eroding rapidly and are the leading source of reservoir sediment.

Stream Channel Stability (3 pts)

Importance:

Stream channels change forms overtime, but can remain stable if undisturbed. Stable stream channels pose a lower risk of bank erosion, therefore watersheds with stable stream channels will contribute smaller amounts of sediment to the reservoir. More information about stream channel stability can be found in Appendix A: Literature Review, on page A13. (Admiraal, 2007) (Keane, 2019) (Rosgen, 2007) (Simon et al, 1999)

Point Scoring:

(Good) 3 points: Stream channels are stable, and accelerated erosion isn't an issue.

(Fair) 2 points: The majority of stream channels in the watershed are stable, but some areas still pose a risk of accelerated sedimentation due to bank erosion.

(Poor) 1 point: Stream channels are unstable and pose a risk of accelerated sedimentation for the downstream reservoir.

Greater Floodwater Storage Capacity

Guidelines:

Guideline I: Upstream Floodplain Access
Guideline II: Reservoir Flood Control

See figure 23 (right)

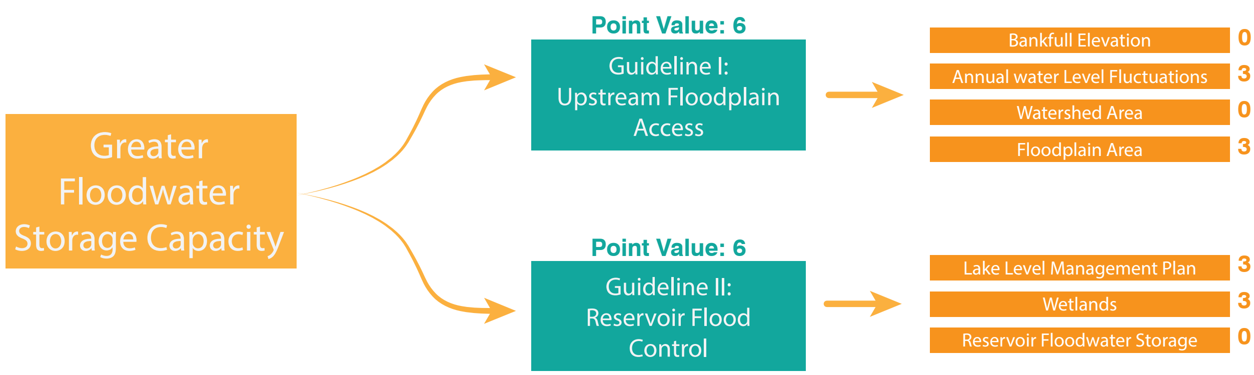


Figure 23: Greater Floodwater Storage Capacity Diagram (Dirks, 2020)

Goal: Greater Floodwater Storage Capacity

Guideline I: Upstream Floodplain Access (6 pts)

Watershed Floodplain Function:

Rivers and streams flood naturally throughout the year, and an undisturbed stream is equipped with characteristics and features to prevent the flood from damaging the landscape. The most important flood control feature of a natural stream is its floodplain (American Rivers, 2019). Reservoirs downstream of a watershed with no floodplain will fill up with water much faster than a reservoir downstream of a watershed with access to floodplains.

Natural Floodplain Design:

Floodplains are formed naturally, and even incised stream channels will begin to morph the surrounding landscape to create floodplains over time. This process is known as stream succession and is described in detail by Dave Rosgen. Streams are always trying to achieve equilibrium and stability, and if left alone they will do just that (Rosgen, 2007). Human intervention in the form of levees, dams, and channelization disrupts the natural stream restoration process (American Rivers, 2019). Even if these man-made solutions may provide temporary relief from flood events, they will eventually lead to a major flood event which could have been prevented by natural stream floodplains (Keane, 2019).

Floodplain Storage:

The floodplains of a watershed should be able to withstand the same magnitude of storm event that the reservoir is designed to handle. In most cases, reservoirs are designed to withstand watershed runoff from a 100 year storm event (Mogollon, 2016), so the watershed should have enough floodplain to store the same amount. This will increase the reservoir's storage capacity, as the watershed upstream will hold and slow down the flow of water into the reservoir (American Rivers, 2019).

Variables for Study

- Bankfull Elevation (0 pts)
- Annual Water Level Fluctuations (3 pts)
- Watershed Area (0 pts)
- Floodplain Area (3 pts)

Illustrated in figure 24 (below)

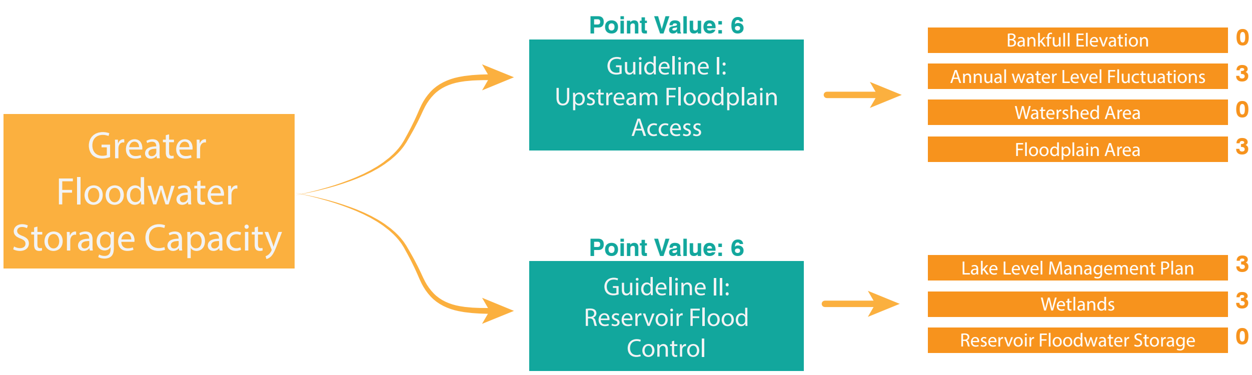


Figure 24: Greater Floodwater Storage Capacity Diagram (Dirks, 2020)

Goal: Greater Floodwater Storage Capacity

Guideline I Variables

Bankfull Elevation (0 pts)

Importance:

Bankfull elevation is the elevation at which a stream channel is the most morphologically productive (Keane, 2019). Streams will change their bankfull elevation when disturbed, and will try to establish a new floodplain at a different bankfull elevation (Keane, 2019). While bankful elevation is not a variable which can be evaluated in this report, knowing the elevation will assist in future design decisions.

Point Scoring:

Bankful Elevation is an inventory variable worth zero points because it's individual performance cannot be measured.

Annual Water Level Fluctuations (3 pts)

Importance:

Understanding the trends in annual water level fluctuations can help lake management plan for annual flood events, and adjust water levels accordingly. It can also influence potential policy changes to maximize water usage both in the reservoir, and downstream. Data from each season for a minimum of the past 5 years should be analyzed, and any seasonal patterns should be identified. More information about water level fluctuation can be found in Appendix A: Literature Review, on pages A14 and A20. (City of MHK) (Keane, 2019) (Maceina 1990, 104) (Schultz 2002)

Point Scoring:

(Good) 3 points: Lake water levels fluctuate within a similar range each year. In the spring, the water is higher due to flood events. In the winter, the lake levels are lower in order to compensate for the heavy rains in the spring.

(Fair) 2 points: Lake water level fluctuations are similar in some years, but the annual high and low water levels are inconsistent from year to year.

(Poor) 1 point: Lake water level fluctuations are not consistent. Spring water levels fluctuate drastically.

Watershed Area (0 pts)

Importance:

Identifying the area of a reservoirs watershed can help predict how much water the reservoir will take on during a flood event.

Point Scoring:

Watershed Area is an inventory variable worth zero points because it is not possible to measure the performance of watershed area.

Watershed Floodplain Area (3 pts)

Importance:

River and streams use floodplains to naturally slow down water from flood events, and allow flood water to infiltrate the ground in riparian and wetland zones. With more floodplain area, a reservoir will not receive as much water during a flood event, as some of it will be stored upstream in floodplain areas. More information about watershed floodplains can be found in Appendix A: Literature Review, on page A16. (Day 2007) (Mogollon 2016)

Point Scoring:

(Good) 3 points: The watershed above the reservoir has enough floodplain to hold excess water from a 100 year flood event.

(Fair) 2 points: The watershed above the reservoir has some floodplain, but not enough to hold flood water from a 100 year flood event.

(Poor) 1 point: There is very little to no floodplain in the watershed above the reservoir.

Goal: Greater Floodwater Storage Capacity

Guideline II: Reservoir Flood Control (6 pts)

Wetland Flood Control Potential:

Wetlands have the potential to improve a reservoir's flood control capabilities. In Nature, wetlands are found in flood plains near river and lake systems, as they are equipped to naturally absorb and filter flood water, and quickly recover from severe flood events (Day 2007). Restoring wetland areas can help diminish flood waters, and release water at a slower and safer rate. While dams and levees certainly help mitigate reservoir outflow, these control structures do fail occasionally, which can have devastating effects downstream (Mogollon 2016). Wetlands with dense vegetation cover and landscape structure slow the duration of water outflow significantly in both urban and rural areas, regardless of steep or shallow topography (Musamba 2012).

Lake Level Management Plans:

Most reservoirs in the Midwest are operated by a set LLMP (Lake Level Management Plan) which sets regulations on seasonal water levels for the reservoir. Updating the LLMP to account for reservoir sedimentation can decrease the sedimentation rates and allow for greater flood storage. Keeping a lower pool in the summer may prevent deltas from forming on shore and eroding more sediment into the reservoir (Kansas Water Office, 2008).

Variables for Study

- Lake Level Management Plan (3 pts)
- Wetlands (3 pts)
- Reservoir Floodwater storage Capacity (0 pts)

Illustrated in figure 25 (below)

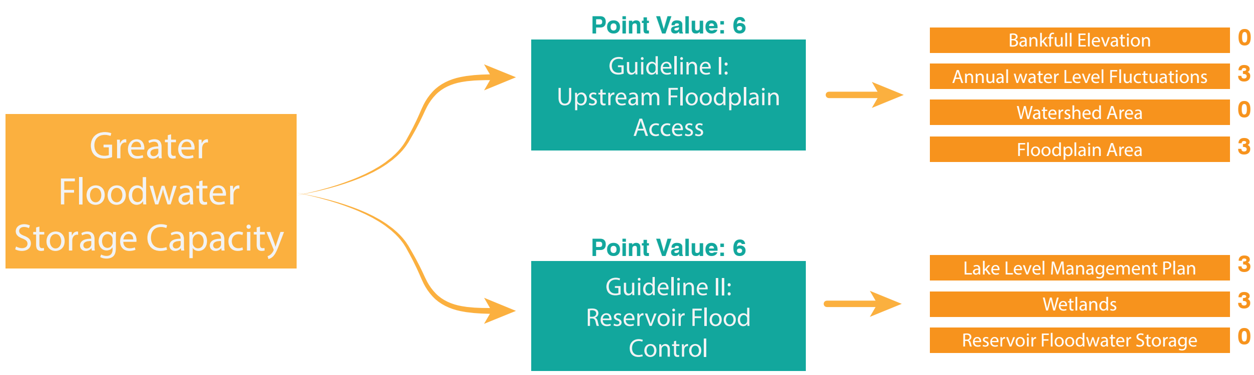


Figure 25: Greater Floodwater Storage Capacity Diagram (Dirks, 2020)

Goal: Greater Floodwater Storage Capacity

Guideline II Variables

Lake Level Management Plan (3 pts)

Importance:

Lake level management plans assist reservoir management when planning for flood events. LLMP's should be updated frequently to account for changing variables such as climate and upstream and down stream conditions (Kansas water Office, 2008).

Point Scoring:

(Good) 3 points: The reservoir's LLMP has been updated to account for changing variables related to flood events.

(Fair) 2 points: The reservoir has an LLMP, but it hasn't been updated recently.

(Poor) 1 point: There is no LLMP in place on the reservoir.

Wetlands (3 pts)

Importance:

Wetlands have the potential to greatly increase the floodwater storage capacity of a reservoir. Naturally found near streams and lowland areas, wetlands absorb and filter water. The dense vegetation in these wetlands also slows down the transport of sediment into the reservoir. More information about wetlands can be found in Appendix A: Literature Review, on pages A16 and A17. (Day 2007) (Mogollon 2016) (Schwartz 2016)

Point Scoring:

(Good) 3 points: The reservoir has wetlands in the backs of creeks and low-lying areas designated for flood control.

(Fair) 2 points: There are some wetlands on the reservoir.

(Poor) 1 point: There are no designated wetlands on the reservoir.

Reservoir Floodwater Storage Capacity (0 pts)

Importance:

Reservoirs are designed with a predetermined floodwater storage capacity based on the geology of the reservoir, and the height and strength of the dam. The storage capacity of the reservoir cannot be significantly changed without dredging sediment from the reservoir, raising the dam, or clearing out large geological features around the reservoir. It is necessary to know the reservoir storage capacity when looking at ways to increase floodwater storage for the entire reservoir and its watershed. For example, a lower reservoir storage capacity means the reservoir should have lower conservation pool elevations, and greater floodplain area upstream to allow for greater floodwater storage during flood events. More information about floodwater storage can be found in Appendix A: Literature Review, on pages A16 and A17. (Day 2007) (Mogollon 2016) (Schwartz 2016) (Sprenkle 2012) (Wang, 2011)

Point Scoring:

Reservoir floodwater storage capacity is an inventory variable worth zero points because it is meant to serve as a gauge which helps the project team determine how much excess floodwater storage needs to be provided outside of the existing reservoir storage capacity.

Increased Reservoir Visitation

Guidelines:

Guideline I: Recreation Potential Analysis
Guideline II: Designing for User Groups

See figure 26 (right)

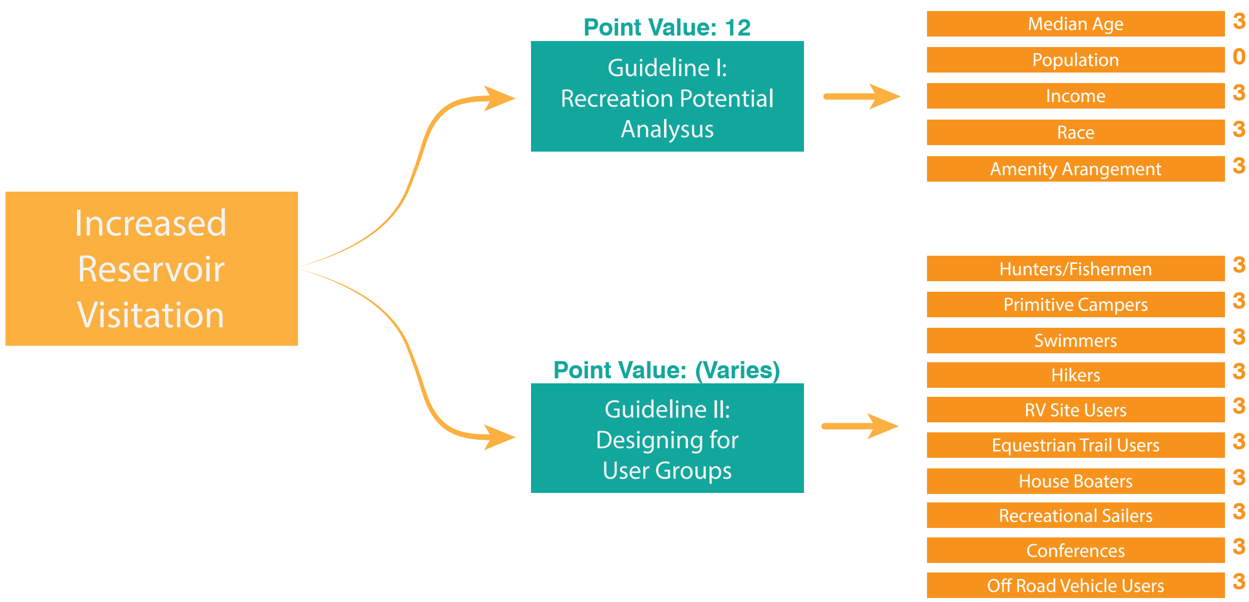


Figure 26: Increased Reservoir Visitation Diagram (Dirks, 2020)

Goal: Increased Reservoir Visitation

Guideline I: Recreation Potential Analysis (12 Points)

Designing for Recreation:

The recreational activities which are going to take place on a reservoir site need to be established prior to any remediation or construction efforts are made. Site amenities which attract different kinds of site users can benefit a reservoir's visitation (Copeland, 2011). Adding basic recreational amenities such as shared hard surface trails, playground equipment, open space, free ride area, shared use soft surface trails, hiking trails, waterfront and equestrian trails could attract more day visitors to the site. Attracting camp visitors (multi-day visitors) can be accomplished by adding amenities such as restroom facilities, campgrounds with easy access, and plenty of parking for both standard vehicles and RV's (Sunflower H2O Coalition, 2013).

Recreation Variety:

Terrain and access to recreational space is often overlooked in reservoir site design. A majority of people enjoy easy access, and developed recreational activities, but some people desire a more secluded area for activities such as hunting grounds, hiking trails, and tough-to-find fishing spots. An ideal reservoir would be able to accommodate people looking for both kinds of activities. A strategy suggested by the Sunflower Coalition is to allow private development around parts of the lake which are near the highway and reserve the land farther from the main roads for the secluded and rough terrain activities (Sunflower H2O Coalition, 2013).

Demographics

Demographics can be very helpful when trying do determine what sort of amenities reservoirs should acquire in order to attract more site visitors. Different age groups tend to have differences in preferred activities, so it's crucial to understand which crowd the reservoir is catering to before making any recreation programming decisions.

Variables for Study

- Median Age (3)
- Population (0)
- Income (3)
- Race (3)
- Amenity Arrangement (3)

Illustrated in figure 27 (below)

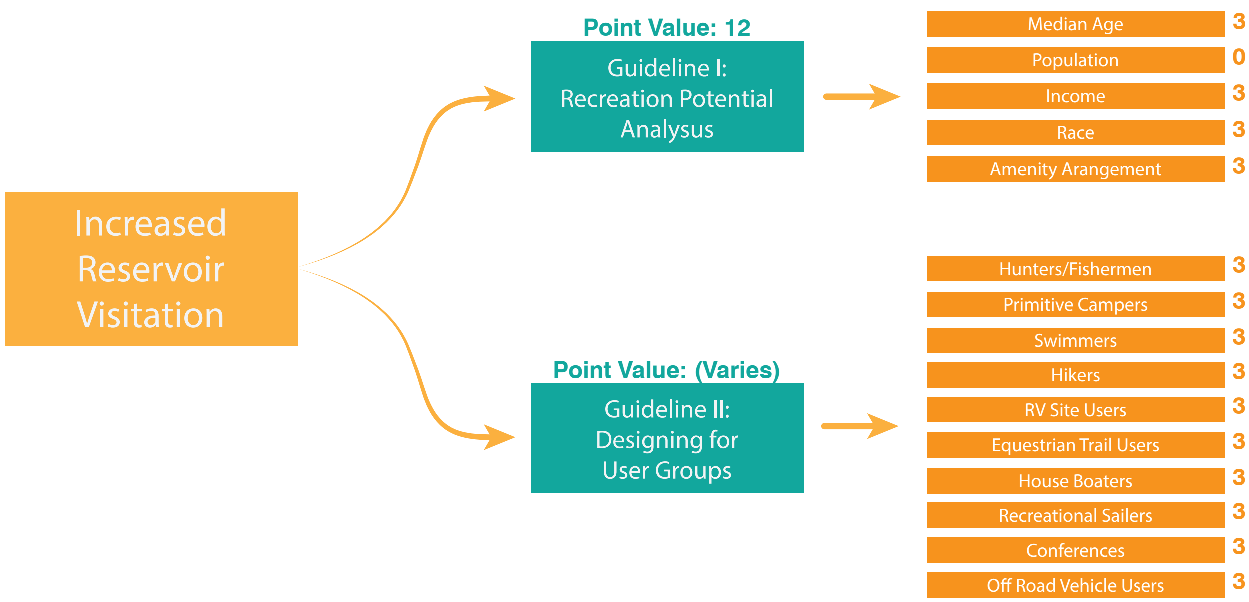


Figure 27: Increased Reservoir Visitation Diagram (Dirks, 2020)

Goal: Increased Reservoir Visitation

Guideline I Variables

Median Age (3 pts)

Importance:

Median age functions as an excellent indicator to what kinds of activities a community could participate in at any given reservoir. Older populations, for example, tend to participate in higher valued activities such as boating, sailing and resort amenities. More information about the importance of demographics can be found in Appendix B: Case Studies, on pages B8 and B10. (Sunflower H2O Coalition, 2013).

Point Scoring:

(Good) 3 points: Median age has been identified, and the reservoir has amenities which cater towards the designated demographic.

(Fair) 2 points: Median age has been identified, but reservoir amenities do not align with the designated demographic.

(Poor) 1 point: Median age has not been identified.

Population (0 pts)

Importance:

Knowing the population of the local community around the reservoir can help designers decide how many site amenities the reservoir site needs. For example, a larger population could indicate that more campgrounds are needed on the site. More information about the importance of demographics can be found in Appendix B: Case Studies, on pages B8 - B10. (Sunflower H2O Coalition, 2013).

Point Scoring:

Population is an inventory variable worth zero points because it’s performance cannot be measured. The population variable is meant to serve as a gauge for how many amenities the reservoir should have.

Goal: Increased Reservoir Visitation

Guideline I Variables

Income (3 pts)

Importance:

Understanding the average incomes of local communities will help predict how many high-value activity participants should be anticipated to visit a site. Traditionally, lower income groups tend to partake in lake recreation less frequently. However, providing infrastructure such as public fishing docks or areas can increase visitation numbers for this group. Site visitors with higher income tend to prefer activities such as fishing tournaments and enjoy marinas for boat rental or storage. More information about the importance of demographics can be found in Appendix B: Case Studies, on pages B8 and B10. (Sunflower H2O Coalition, 2013).

Point Scoring:

(Good) 3 points: Community income has been assessed. The reservoir has amenities which cater to all income groups in the community.

(Fair) 2 points: Community income has been assessed. The reservoir has some amenities for most of the communities' income groups.

(Poor) 1 point: Community income hasn't been assessed. The reservoir has few amenities that gear towards all income groups in the community.

Race (3 pts)

Importance:

Understanding racial recreational trends can help influence recreational amenity design. For example, studies show that Hispanic visitors tend to participate in activities in large groups or families. More information about the importance of demographics can be found in Appendix B: Case Studies, on pages B8 and B10. (Sunflower H2O Coalition, 2013).

Point Scoring:

(Good) 3 points: The demographics of the community have been studied, and amenities which cater towards the visiting habits of all races are present on site.

(Fair) 2 points: The demographics of the community have been studied, but the amenities on site don't align directly with the visiting habits of all races in the community.

(Poor) 1 point: Demographics of the community have not been studied, and there is no way to tell if the amenities on site cater towards all races in the community.

Goal: Increased Reservoir Visitation

Guideline II: Designing for User Groups (Point Value Varies)

Variable Selection and Point Values

Reservoir user groups should inform the design of recreational amenities, and those user groups are different for every reservoir. This guideline doesn't give specific instructions for improving user group amenities, as each reservoir will have different requirements. Instead, common reservoir user groups are listed as independent variables, and each variable has general guidelines for improving visitation for that user group. The point value for this guideline is undefined, as it will vary between reservoirs depending on the number of variables chosen for study. Variables (User Groups) should be chosen based on the most sought-after reservoir activities. The sum of the point values for all selected variables will equal the overall point value of this Guideline. For example, if the chosen variables are , Swimmers (3 pts), Hikers (3 pts), Recreational Sailors (3 pts) and Primitive Campers (3 pts), the overall point value of the guideline would equal 12 points.

Attracting User Groups

Attracting a multitude of user groups to reservoirs can be very simple, if the necessary amenities for the desired activity can be easily accessed. While site users are often interested in a variety of different activities, it's best to design recreation amenities by looking at each activity alone. Instead of adding a variety of common reservoir amenities to a site in hopes of improving visitation, design solutions should focus on improving amenities for the most sought-after reservoir recreation activities in the community (Sunflower H2O Coalition, 2013).

Variables for Study

- Hunters/Fishermen (3)
- Primitive Campers (3)
- Swimmers (3)
- Hikers (3)
- RV Site Users (3)
- Equestrian Trail Users (3)
- House Boaters (3)
- Recreational Sailors (3)
- Conferences (3)
- Off Road Vehicle Users (3)

Illustrated in figure 28 (below)

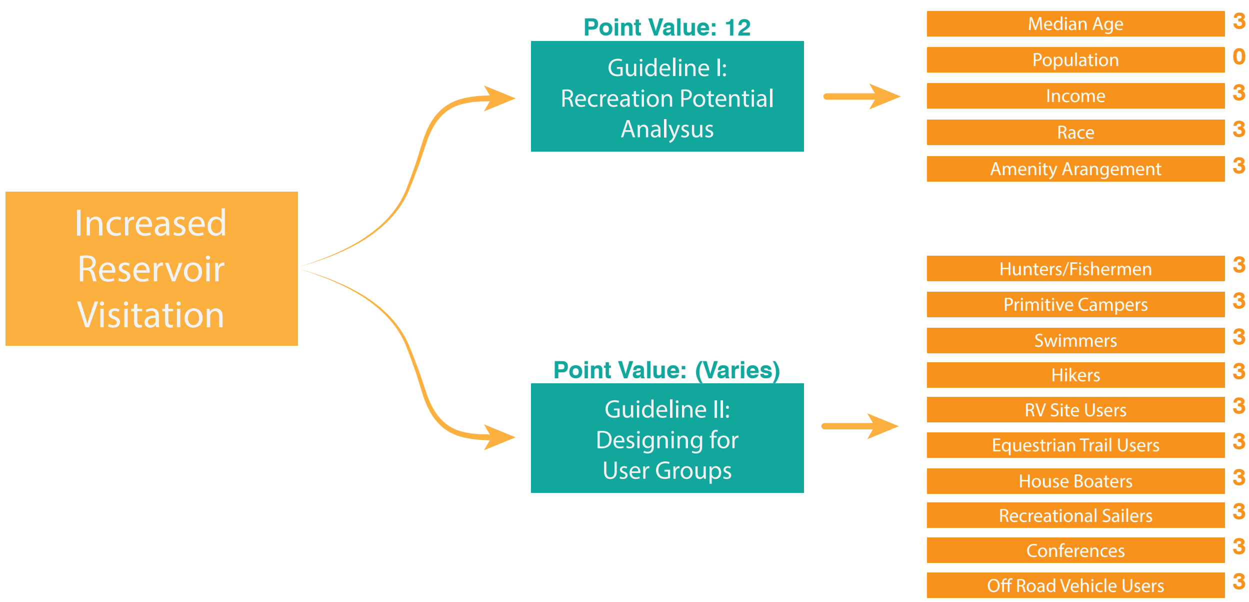


Figure 28: Increased Reservoir Visitation Diagram (Dirks, 2020)

Goal: Increased Reservoir Visitation

Guideline II Variables

Hunters and Fishermen (3 pts)

There are many practices which could attract both hunters and fisherman. A seasonal pool or fish stocking program could assist the fish spawn process. It could also provide space to plant mill or winter crops which attract wildlife for hunters. Additionally, fisherman need a boat ramp with 2-3 lanes. If tournaments are expected to take place, an area with two, ADA compliant boat ramps, a fish weighing area, restrooms, courtesy docks and parking are necessary. Ideally, this area is in a cove where fishermen are protected from wind and can wait until their number is called. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: The lake has plenty of amenities for both hunters and fishermen, as well as monitoring programs which track fish quantity and catch rates.

(Fair) 2 points: There are some amenities for both hunters and fishermen, but no programs to monitor/predict hunting fishing conditions.

(Poor) 1 point: There are very few amenities for hunters and fishermen.

Primitive Campers (3 pts)

Attracting primitive campers is very inexpensive, and easy to do. Providing flat ground for camps spots, and a restroom with water for every 10-20 camp sites are the only requirements to fill camp sites. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: Plenty of flat, shaded camp areas are located around the reservoir. Restrooms are available for every 10-20 camp sites.

(Fair) 2 points: Most camp areas are relatively flat and shaded, restrooms are available, but can be far away from some camp sites.

(Poor) 1 point: Camp sites are on rough terrain surfaces, and very few restroom facilities are in close proximity to the campgrounds.

Swimmers (3 pts)

Swim beaches often require constant maintenance, and a steady supply of capital for cleaning and refilling annually. Maintenance costs can be lowered by selecting a site with a gradual incline and a low rate of sedimentation. Outside of maintenance, the swim area also requires parking, restrooms and water. The restrooms and water can be shared with a camp site. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: A swim beach is maintained for cleanliness regularly, and parking/restrooms are found close by.

(Fair) 2 points: A swim beach is found on the site, but it is seldom maintained. Parking/restrooms can be found in the area.

(Poor) 1 point: There is no designated swim beach on site. Areas where site users can go to swim are far from parking/restroom facilities.

Hikers (3 pts)

While hikers and distance runners don't require much capital or maintenance, they do need a large space. Often local running, hiking, or biking groups will offer to maintain and/or build their own trails if they are given the space and a permit to do so. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: hiking/biking trails are found around on site and maintained by local groups.

(Fair) 2 points: There are some trails fro hiking/biking, but they are rarely maintained.

(Poor) 1 point: There are no designated hiking/biking trails on site.

Goal: Increased Reservoir Visitation

Guideline II Variables

RV Site Users (3 pts)

RV sites typically need about double the space that primitive campers use, as well as larger roads, turning areas and parking spaces. Dump site facilities are necessary as well. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: The site offers spaces for RV camping and has the necessary infrastructure to support the large vehicles. Dump site facilities are in close proximity.

(Fair) 2 points: The site offers spaces for RV camping, but it can be difficult to navigate large vehicles to the camp site due to the lack of adequate infrastructure.

(Poor) 1 point: There are no adequate RV campground on site.

Equestrian Trail Users (3 pts)

Equestrian trails are generally considered to have a low impact on the site, but they are heavily used and could have an impact on the landscape. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: Equestrian trails can be found on site, and they are well maintained.

(Fair) 2 points: Some equestrian trails can be found on site, but they are not maintained.

(Poor) 1 point: There are no equestrian trails on site.

House Boaters (3 pts)

House boaters require a protective cove with a marina or a slip, which could be funded by a partnership with a private group. Additional anchoring sites around the lake should also be considered. House boaters are typically attracted to lakes with good water quality and clarity. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: House boaters have access to protected coves and marinas to anchor in. The lake has good water quality and clarity.

(Fair) 2 points: There are some protected coves, and one marina/slip which can be used by house boaters. Water quality and clarity are fair.

(Poor) 1 point: It's difficult to find protected coves or marinas for house boaters to anchor in. The water quality and clarity are poor.

Recreational Sailors (3 pts)

Sailors have little impact on other recreation groups outside of the potential for crowding. They do require a marina and slip. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: The reservoir has a marina/slip large enough to accommodate for a reasonable number of recreational sailors given the size of the reservoir.

(Fair) 2 points: The reservoir has a marina/slip, but it can only accommodate a low number of vessels.

(Poor) 1 point: There is no marina/slip to accommodate for recreational sailors.

Goal: Increased Reservoir Visitation

Guideline II Variables

Conferences (3 pts)

Conference facility users typically have a higher regional purchasing coefficient. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: Conference rooms are available to attract large groups of visitors to the site.

(Fair) 2 points: Occasionally the reservoir has a conference room available to attract visitors to the site.

(Poor) 1 point: There are no conference rooms available on the site.

Off Road Recreational Vehicles (3 pts)

Off road vehicles require trails and a large space to operate. They do create loud noise and can be destructive to the landscape. Placement of off-road vehicle trails should be looked at carefully in the site design. More information about providing site amenities can be found in Appendix B: Case Studies, on pages B10 - B12. (Sunflower H2O Coalition, 2013)

Point Scoring:

(Good) 3 points: Off road vehicle trails are located away from camp sites and other amenities in which the sound of off road vehicles could disturb other site guests. The trails are maintained.

(Fair) 2 points: Off road vehicle trails can be found on site, but they are in close proximity to other site amenities.

(Poor) 1 point: There are no off road vehicle trails on site.

Chapter 4:

Projective Design: Milford Lake

4 Projective Design: Milford Lake

Applied Framework

In order to demonstrate how the framework for reservoir restoration can be used by landscape architects, this report includes a projective design for improving sport fishing at Milford Lake (figure 29, right). This design focuses on two of the sport fishing guidelines: Guideline I: Fish Habitat, and Guideline III: Access to fishing grounds and amenities. Out of the five guidelines for improved sportfishing described in this report, Guidelines I and II were chosen for the projective design because they are both design related. As a landscape architecture student, I chose to work on the two design related guidelines which best relate to my degree and future career.

Figure 29: Milford Lake Map (Dirks, 2020)

Focus Area - Rush Creek

The projective design focuses its area of study on Rush Creek (figure 30, below). The variables were studied in Rush Creek, and the design solutions were developed to meet the requirements found in the two guidelines chosen for this projective design. While a full Milford Lake design is not part of this study, the design solutions developed in Rush Creek could be replicated throughout the reservoir after a full reservoir analysis is conducted on Milford Lake.

Rush Creek Information:

As shown in figure 31, (right) Rush Creek is located on the East side of the reservoir, and has nearly 170 acres of navigable water (Google Earth, 2020). On the south side of the creek, Milford State Park provides an abundance of camping spots, a full service marina, and boat ramps which can be used by anybody with a Kansas Parks pass (KDWPT, 2018).

Rush Creek Map (Not to scale)

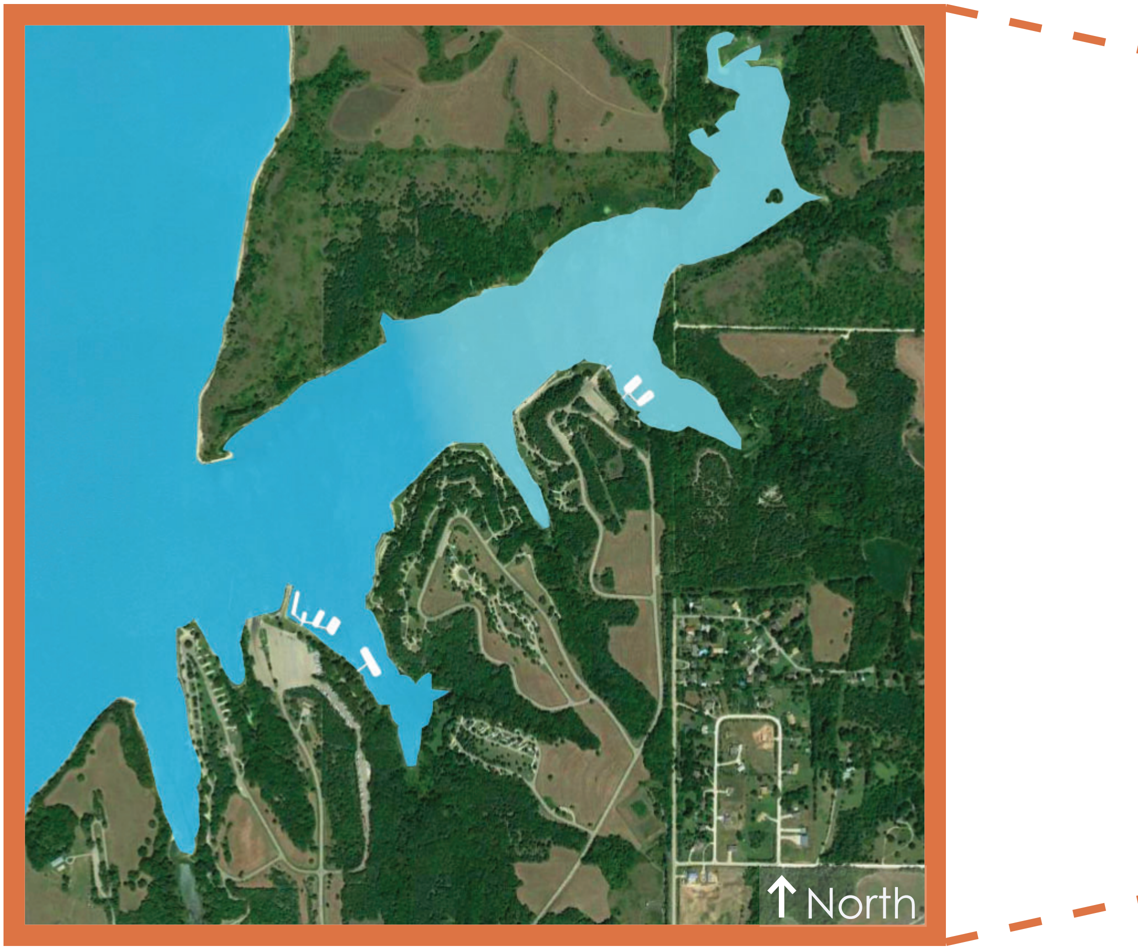


Figure 30: Rush Creek Map (Dirks, 2020)

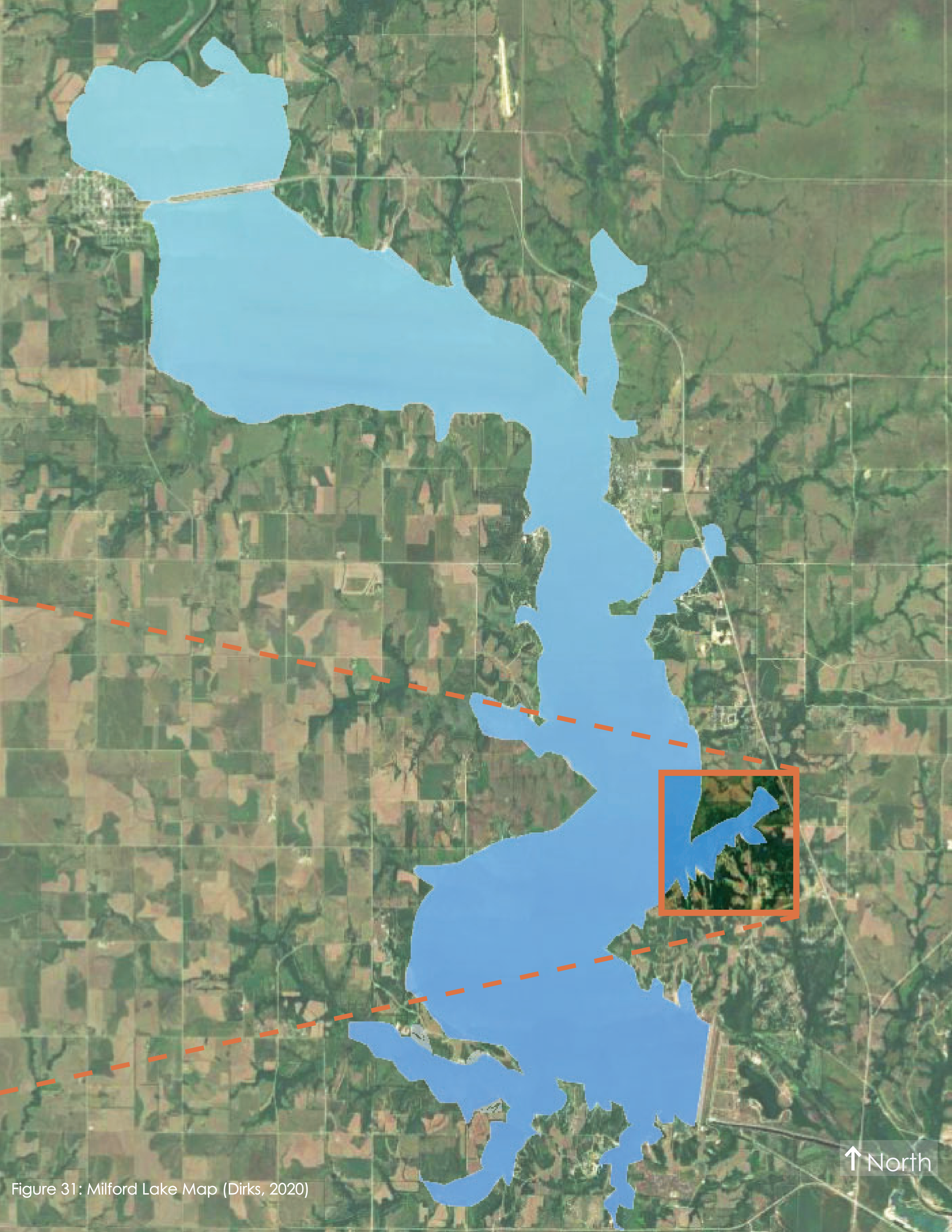


Figure 31: Milford Lake Map (Dirks, 2020)

Rush Creek, Milford Lake Analysis

Guideline I: Fish Habitat Analysis

Figure 32: Fish Habitat Analysis Score (Dirks, 2020)

Legend:

- Rip Rap
- Vegetated Spawning Habitat
- Fish Habitat Structure

Vegetation: Poor

While there is an abundance of riparian and woody vegetation on land surrounding Rush Creek, very little aquatic vegetation can be found (see figure 33, right). The banks are almost exclusively rip rap, and emergent vegetation can only be found occasionally in the very back of the secondary creeks. Submerged vegetation is very scarce, and only found in the shallow northeast corner. Floating vegetation is nowhere to be found, outside of the occasional algae blooms (Google Earth, 2020).

Bank Habitat: Poor

Due to the lack of vegetation in Rush Creek, good bank habitat is very scarce (see figure 33, right). The best bank habitat can be found in the shallow waters of the Northeast portion of the creek. Bank cover in the form of wood or brush are rarely seen. (Beck, 2020) (Google Earth, 2020).

Open Water Habitat: Fair

Open water habitat can be found occasionally in the form of artificial structure, rock piles, sunken trees and brush (Beck, 2020) (US Army Corps of Engineers, 2010). The reservoir could benefit from additional structures along the seasonal migration routes of sport fish such as bass and crappie (see figure 33, right).

Viable Spawning Habitat: Fair

Some good spawning habitat can be found in the shallow waters of Rush Creek, especially in the northeast portion of the creek (see figure 33, right). The bottom substrate ranges from silt to gravel (Beck, 2020) (Google Earth, 2020). More emergent vegetation and submerged vegetation along the banks could create more spawning habitat.

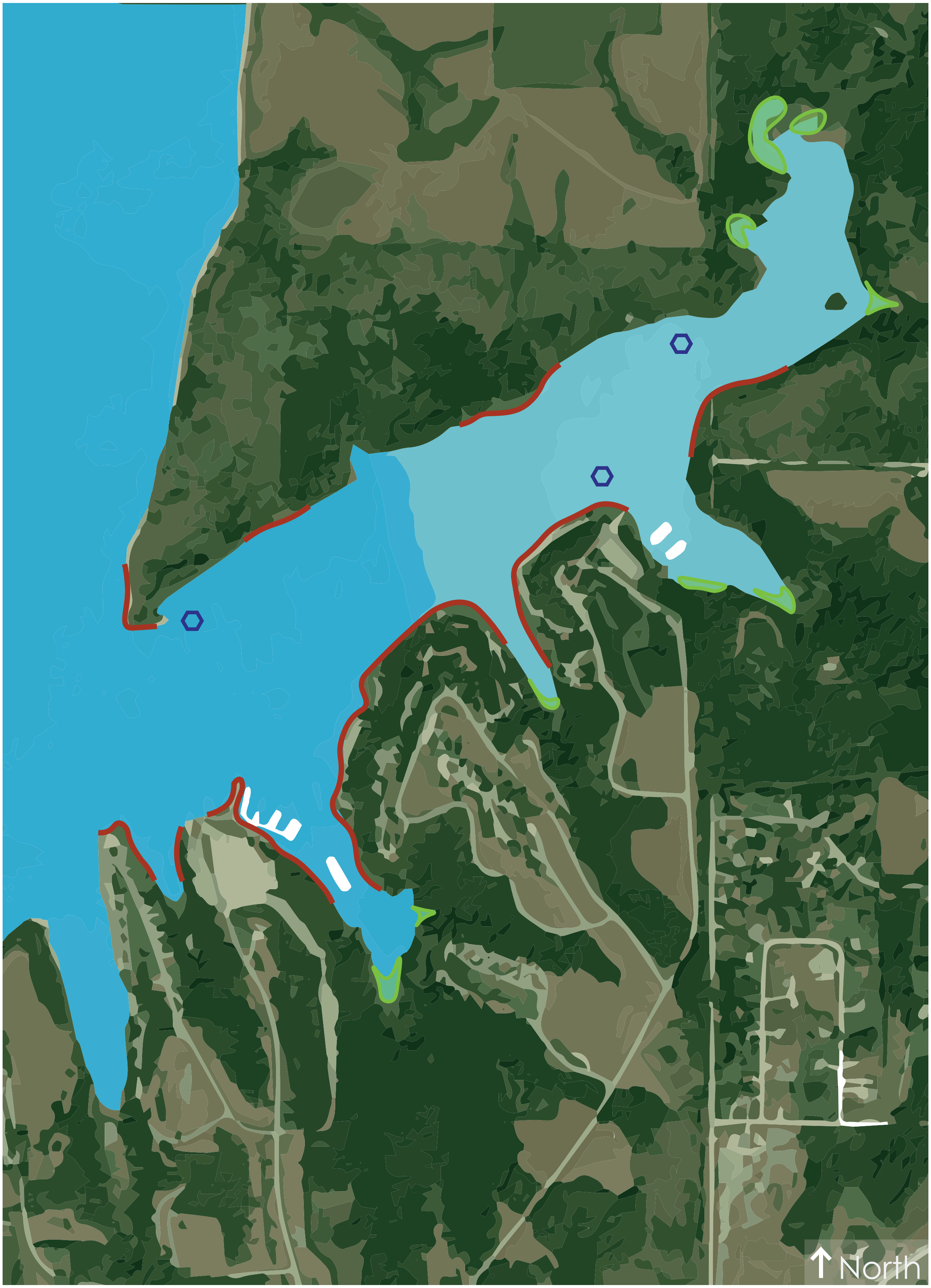


Figure 33: Fish Habitat Analysis Map of Rush Creek (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline I: Sport Fish Habitat: (6 out of 12 points)

Vegetation: Poor (1 out of 3 points)

Vegetation is a crucial component of bank habitat and spawning habitat for sport fish species. It provides oxygen and shelter from predators. More information about vegetation classification and function can be found in Appendix A: Literature Review, on pages A4 and A5, and Appendix B: Case Studies on pages B4 and B5. (Blabolil 2017, 2) (Lovell, 2005) (Wright 1954) (Zhu 2012)

(Poor) 1 Point: Not all three categories of aquatic vegetation are present in the lake. The vegetation provides little habitat for sport fish.

Bank Habitat: Poor (1 out of 3 points)

Bank habitat is where sport fish species spend the most time throughout the year. Bank habitat for bass, crappie, and other similar sport fish requires vegetation and structure for the fish to relate too (Pander, 2009.) More information about bank habitat can be found in Appendix A: Literature Review, on pages A6 and A8, and Appendix B: Case Studies on pages B16 and B17. (Blabolil 2017, 2) (MDC, 2014) (Pander 2009).

(Poor) 1 Point: Sonar scans of the bank habitat Structure and Density in Rush Creek are represented in figure 34 (below).

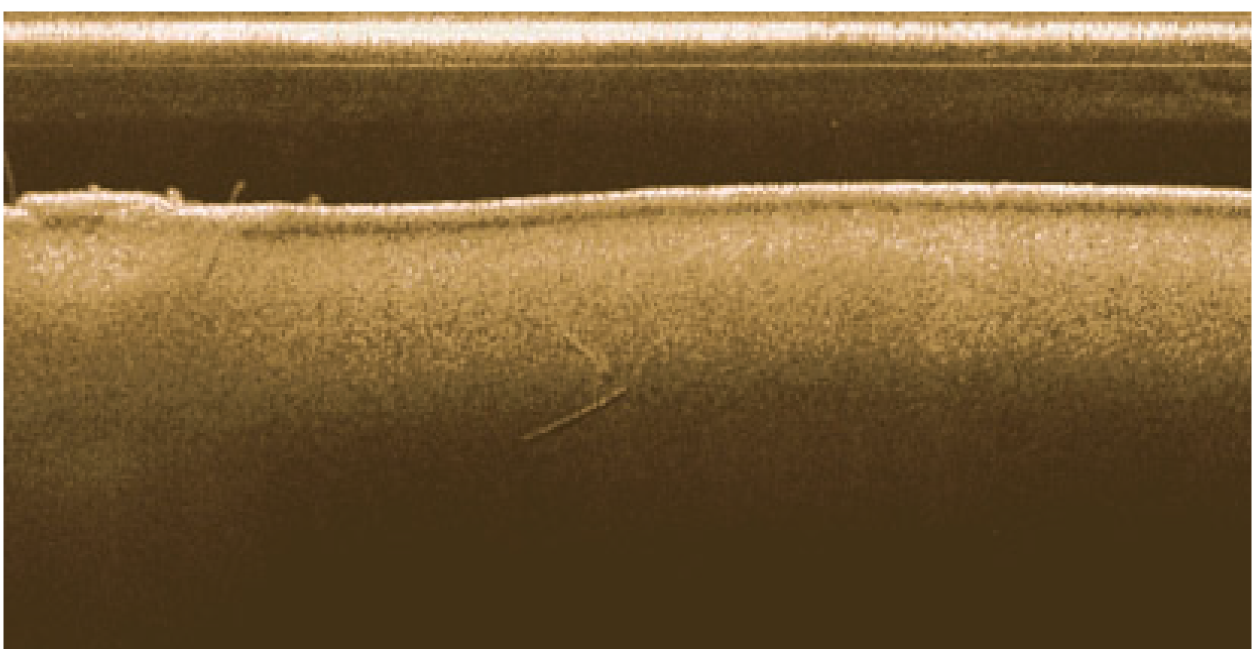


Figure 34: Sonar Scan of Rush Creek Bank Habitat Provided by Jordan Beck (Beck, 2020)

Viable Spawning Habitat: Fair (2 out of 3 points)

While spawning only occurs for a few weeks out of the year (depending on the species) fish have specific habitat requirements such as substrate material, vegetative cover, and depth. More information about viable spawning habitat can be found in Appendix A: Literature Review, on pages A6 and A8, and Appendix B: Case Studies on pages B14, B15, and B17. (Blabolil 2017, 2) (MDC, 2014) (Sprenkle, 2015)

(Fair) 2 points: There are some areas of the reservoir where gravel bottom material can be found in depths less than 1 meter, but vegetation is scarce.

Open Water Habitat: Fair (2 out of 3 points)

Open water habitat represents areas that sport fish search for during the colder months of the year. They use this habitat as protection from predators. More information about open water habitat can be found in Appendix A: Literature Review, on page A8 and Appendix B: Case Studies on pages B16 and B17. (Blabolil 2017, 2) (MDC, 2014) (Pander 2009).

(Fair) 2 Points: Sonar scans of the open water habitat Structure and Density in Rush Creek are represented in figure 35 (below).

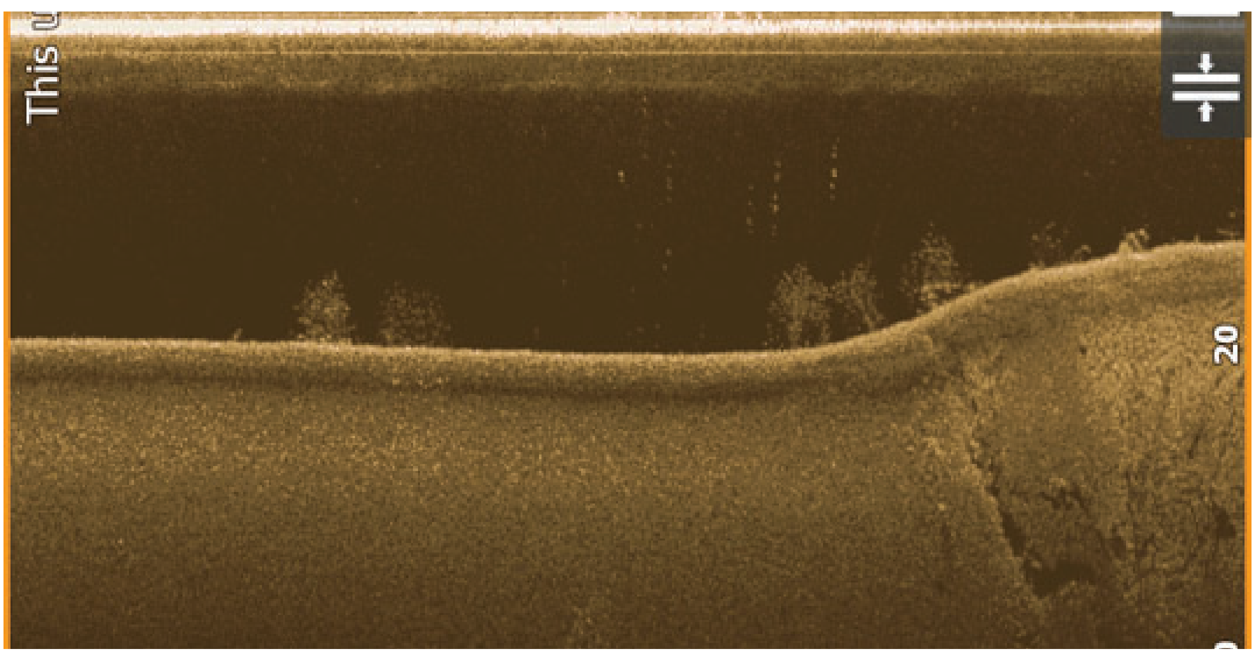


Figure 35: Sonar Scan of Rush Creek Open Water Habitat Provided by Jordan Beck (Beck, 2020)

Rush Creek, Milford Lake Analysis

Guideline III: Access to Fishing Grounds and Fishing Amenities Analysis

Figure 36: Access to Fishing Grounds and Amenities Analysis Score (Dirks, 2020)

Legend:

- No Bank Access
- Public Boat Ramp & Marina
- Private Boat Ramp & Marina
- Fish Cleaning and Gathering Location

Public Fishing Docks: Poor

There are two docks located in Rush Creek, but only one is public, and fishing is prohibited on both (see figure 37, right). Fishing docks in Rush Creek would provide better fishing amenities for site users, and give bank anglers better access to deeper water (KDWPT, 2018) (Google Earth, 2020).

Bank Access: Poor

While the majority of the South shoreline in Rush Creek can be fished from shore, the rip rap is very steep in some places making it difficult to access. There is no bank access on the North side, and the far East portion of the creek has no bank access either (see figure 37, right). Trails which provide access to more of the bank in rush creek could give bank anglers more options and locations to fish. (Google Earth, 2020).

Boat Launch Sites and Marinas: Good

The Miflord State Park boat ramp and marina provide excellent sport fishing amenities. The three lane boat ramp and courtesy docks are protected from wind by a floating levee (see figure 37, right). The marina offers live bait and boat slips for boaters. (KDWPT, 2018, Google Earth, 2020).

Fish Cleaning/ Gathering Locations: Good

A fish cleaning location is located on shore next to the marina (see figure 37, right). Shaded structures provide a gathering space for tournaments to gather and weigh their fish. (KDWPT, 2018) (Google Earth, 2020).

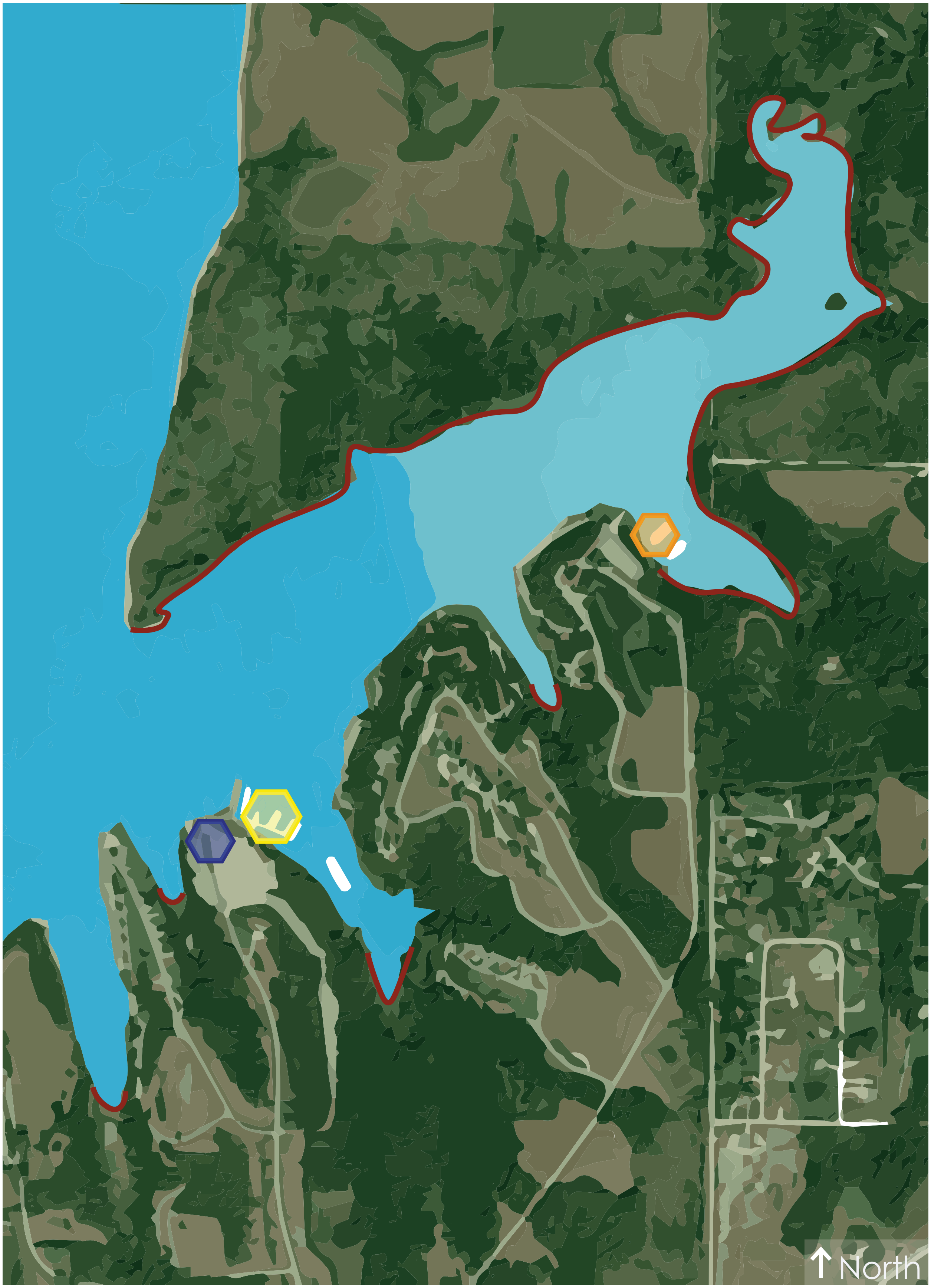


Figure 37: Access to Fishing Grounds and Amenities Analysis Map of Rush Creek (Dirks, 2020)

Goal: Improved Sport Fishing

Guideline III: Access to Fishing Grounds and Fishing Amenities (9 out of 12 points)

Public Fishing Docks: Poor (1 out of 3 points)

Public Fishing docks give bank anglers access to fish deeper waters, and also provide structure for smaller sport fish and bait fish to take shelter. Public docks can also provide ADA access, or easier access for anglers who have limited mobility and struggle to navigate the rough terrain of a shoreline. (Derbyshire, 2006).

(Poor) 1 point: There are no docks open to fishing on the reservoir.

Bank Access: Fair (2 out of 3 points)

While serious anglers often fish from boats, bank fishing is very popular with causal fishermen, or people who are just getting into the sport. Reservoirs with plenty of easy bank access is often attractive to casual anglers (Sunflower H2O Coalition, 2013).

(Fair) 2 points: There is some bank accessible to shore-anglers, but much of the reservoir is blocked by terrain with very few trails.

Boat Launch Sites and Marinas: Good (3 out of 3 points)

Reservoirs need good, public boat launch sites in order to attract anglers and fishing tournaments. Boat launch sites should each consist of at least 2 boat ramp lanes and a courtesy dock for boaters to temporarily hold their boat while they park their boat trailer. Boat lanes without courtesy docks may deter some anglers from using the launch site, as it would require them to "beach" their boat on shore while they park their boat trailer or load in other passengers. Anglers also look for reservoirs with marinas which provide gas or live bait. More information about boat ramp design can be found in Appendix A: Literature Review, on page A19, and Appendix B: Case Studies on page B12. (Mathew, 2012, Sunflower H2O Coalition, 2013)

Based on the Sunflower H2O Coalition's reservoir analysis, reservoirs require one, public boat launch site (two-lane boat ramp with a courtesy dock) for every 2,000 acres of navigable water. The reservoir scores 1 point for meeting 33% of the recommended ratio of boat launch sites/navigable water acres.

(Good) 3 points: The reservoir meets between 66% and 100% of the required one, public boat launch site for every 2,000 acres of navigable water ratio. Marinas which provide fuel and live bait can be found at different locations in the reservoir.

Fish Cleaning/ Gathering Locations: Good (3 out of 3 points)

Fish cleaning stations and open space for gatherings are both amenities that have the potential to improve reservoir sport fishing and visitation. Tournament groups often look for places to gather to weigh fish and declare a winner.
A shaded location near the boat launch is typically preferred. Fish cleaning stations are an amenity that guides look for, as well as anglers who want to keep their day's catch (Sunflower H2O Coalition, 2013).

(Good) 3 points: Shaded gathering areas near boat launch sites can be found around the reservoir, as can the occasional fish cleaning station.

Design Proposal

Guideline I: Fish Habitat

The design proposal improves all variables identified in the guideline. Vegetation is improved by replacing much of the rip rap with emergent vegetation to stabilize the bank. Submerged vegetation enhances bank habitat and provides shelter and ambush points for sport fish species. The added vegetation also improves spawning habitat. Multiple open water habitat structures are added to the reservoir. A mix of hardwood and cedar trees scheduled for removal are combined with rocks found on site create a variety of habitat for sport fish during the colder months of the year (see figure 38, right).

Guideline III: Access to Fishing Grounds and Fishing Amenities

Two public docks and six rock jetties give bank anglers better access to deeper fishing spots on both sides of Rush Creek. 2.36 miles of new trails give bank anglers more access to the shores of Rush Creek. The marina and boat ramp are kept as they are to continue providing boating amenities for Rush Creek.

Legend:

- Trail
- Public Boat Ramp & Marina
- Private Boat Ramp & Marina
- Fish Cleaning and Gathering Location
- Vegetated Bank Habitat
- Open Water Habitat
- Public Fishing Dock
- Rock Jetty

Rush Creek Detailed Plan

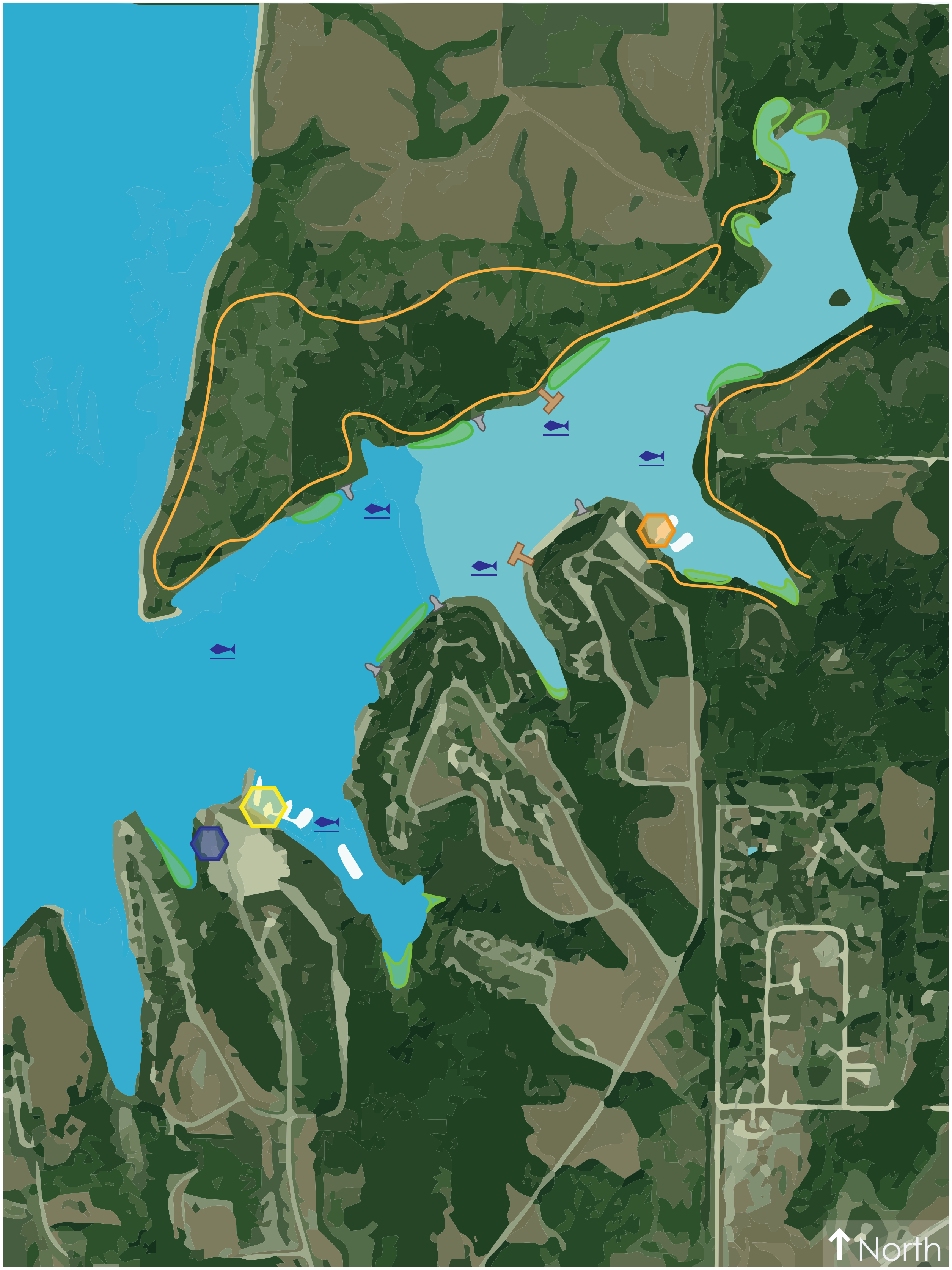


Figure 38: Projective Design Master Plan Map of Rush Creek (Dirks, 2020)

Detailed Plan

Figure 39: Detailed Plan Rendering of Rush Creek (Dirks, 2020)

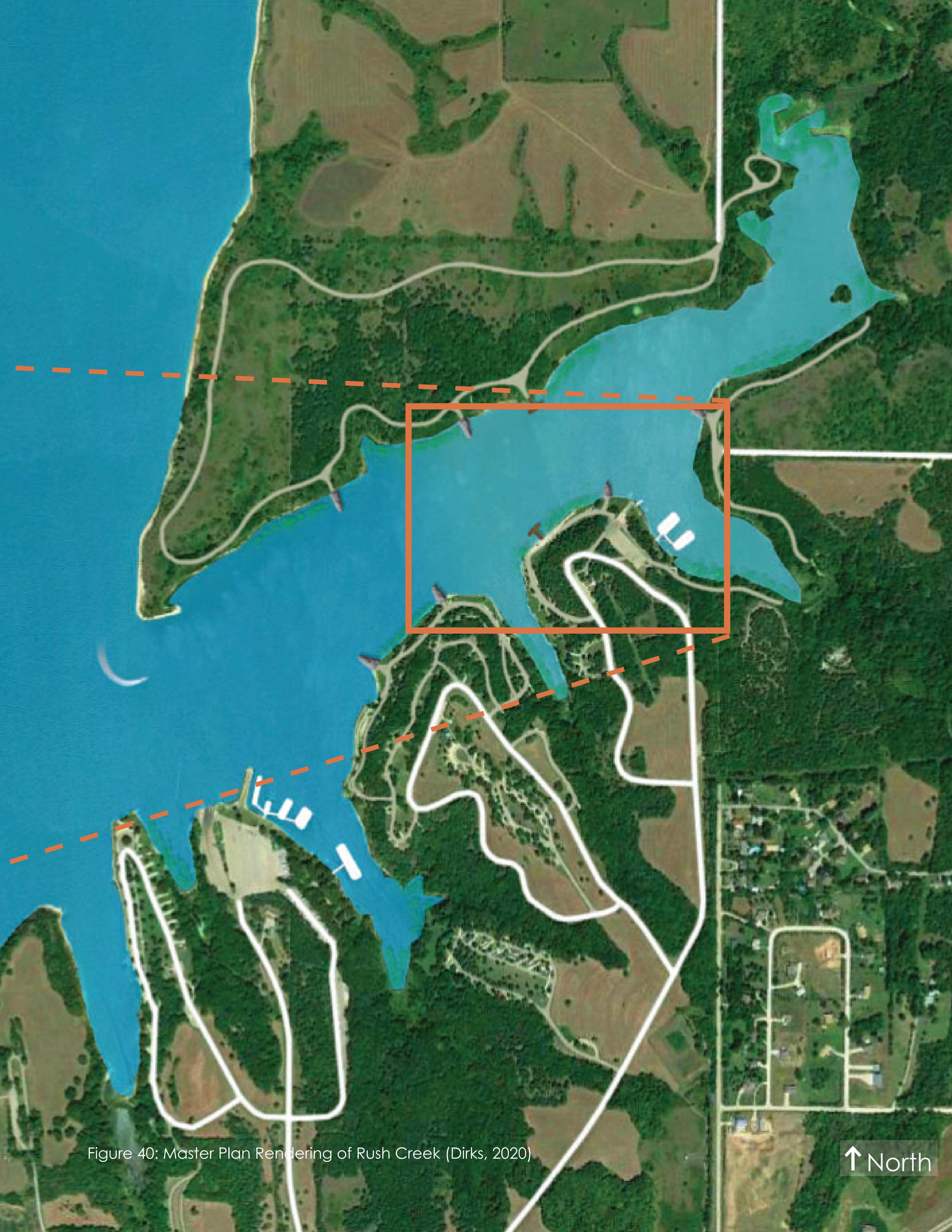


Figure 40: Master Plan Rendering of Rush Creek (Dirks, 2020)


Rock Jetty
Bank Vegetation
Public Fishing Dock
Open Water Habitat

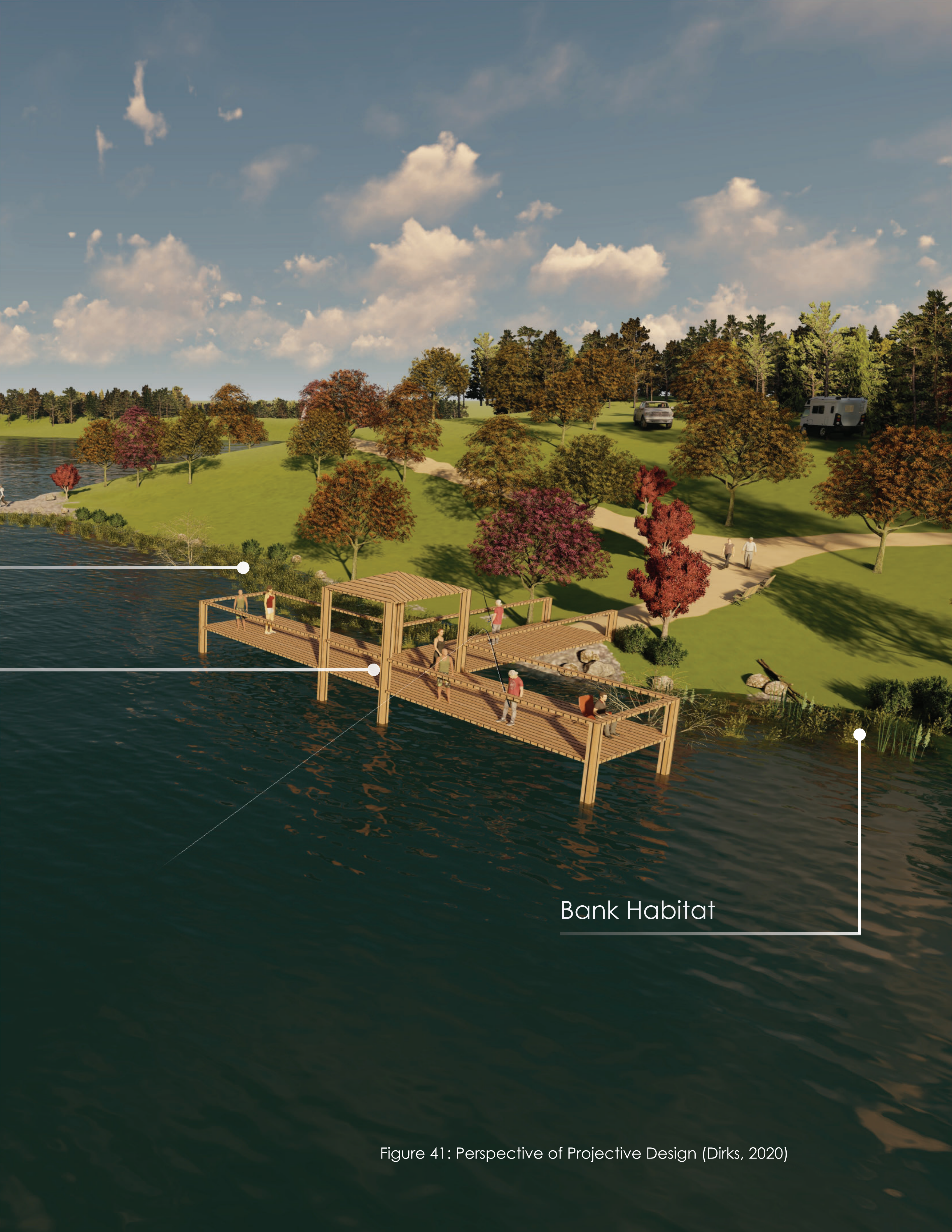


Figure 41: Perspective of Projective Design (Dirks, 2020)

Guideline Score Improvement

Guideline I: Fish Habitat

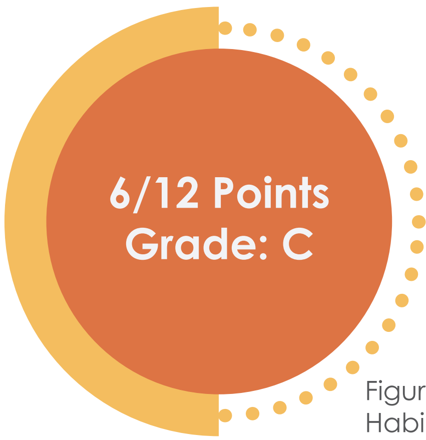


Figure 42: Sport Fish Habitat Analysis Score (Dirks, 2020)

Figure 43: Sport Fish Habitat Final Score (Dirks, 2020)

Vegetation: Fair

(Fair) 2 points: All three categories of aquatic vegetation are found at some places in the lake. The vegetation provides some habitat for sport fish.

Bank Habitat: Good

(Good) 3 point: Sonar scans are most similar to figure 44 (right).

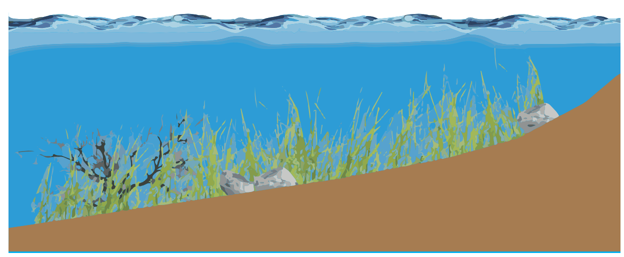


Figure 44: Good Bank Habitat Diagram (Dirks, 2020)

Open Water Habitat: Good

(Good) 3 point: Sonar scans are most similar to figure 45 (right).

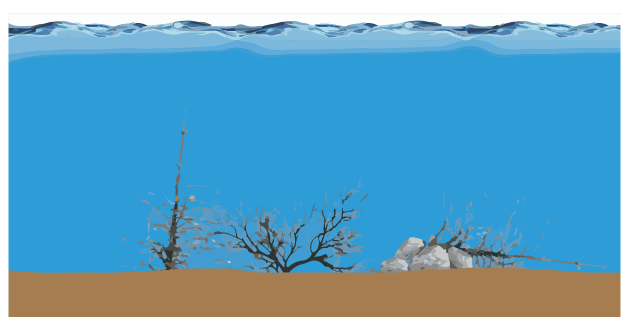


Figure 45: Good Open Water Habitat Diagram (Dirks, 2020)

Viable Spawning Habitat: Good

(Good) 3 points: Throughout the reservoir, areas which are shallower than 1 meter, have a gravel bottom material and have plenty of vegetative cover can be found.

Guideline III: Access to Fishing Grounds and Fishing Amenities

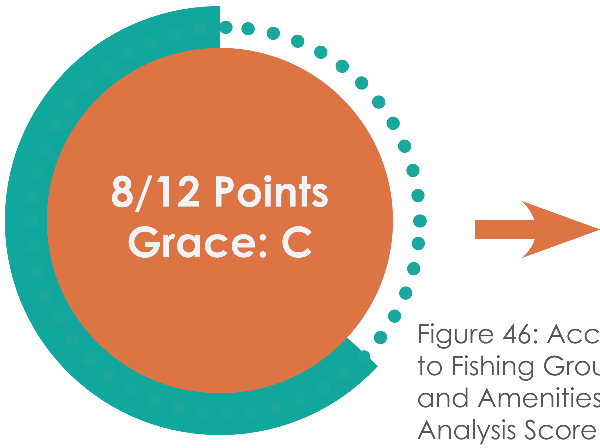


Figure 46: Access to Fishing Grounds and Amenities Analysis Score (Dirks, 2020)

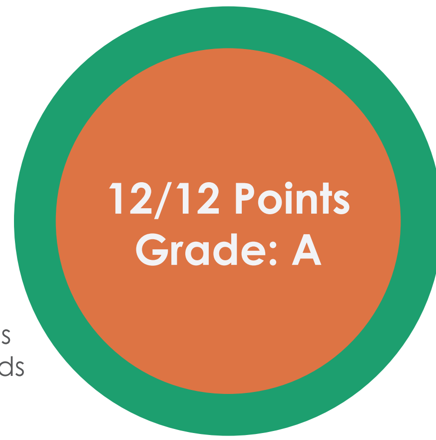


Figure 47: Access to Fishing Grounds and Amenities Final Score (Dirks, 2020)

Public Fishing Docks: Good

(Good) 3 points: Bank anglers have access to multiple public fishing docks around the lake.

Bank Access: Good

(Good) 3 points: The reservoir has plenty of accessible bank fishing spots, with roads and trails which allow for anglers to easily move from spot to spot with their equipment.

Boat Launch Sites and Marinas: Good

(Good) 3 points: The reservoir meets between 66% and 100% of the required one, public boat launch site for every 2,000 acres of navigable water ratio. Marinas which provide fuel and live bait can be found at different locations in the reservoir.

Fish Cleaning/ Gathering Locations: Good

(Good) 3 points: Shaded gathering areas near boat launch sites can be found around the reservoir, as can the occasional fish cleaning station.

Chapter 5:

Conclusion

5 Conclusion

Evaluating The Effectiveness of The New Framework

The goal of this report was to create a goal-oriented framework for reservoir restoration which builds on the existing knowledge of reservoir experts, and makes it easy for experts and clientele to gain a general understanding of the scope of their reservoir project. There were two sets of findings in this report: the new framework, and the projective design. The new framework was comprised of four reservoir goals. Each goal used a set of guidelines and variables to describe exactly how the reservoir needs to function in order to achieve the project goal. The goals and their respective guidelines and variables successfully demonstrated how an alternative approach to reservoir restoration could assist project team's and clientele in understanding the scope of their project.

The projective design built on the findings described above by demonstrating how the alternative framework could be implemented in a reservoir analysis and restoration project. The projective design focused on Rush Creek in Milford Lake (KS). Improved Sport Fishing was the goal identified for the project, and the two design related guidelines along with their variables were analyzed. After the conclusion of the projective design, the initial scores of Rush Creek were compared to the projected scores of the new design. Guideline I's score improved from six out of twelve points to eleven out of twelve points, and guideline III's score improved from eight out of twelve points to twelve out of twelve points.

Personal Achievements

I knew it would be difficult to tie in my passion for fishing into a master's report, but my professors and peers helped me develop an academically beneficial report. The project went through many changes of general project goals, processes, and even topics of research before finally settling at a framework for reservoir restoration. One of my personal goals for this report was to ensure that my project could have the potential to be useful outside of this class, and that it wasn't just a "final school project." While further research is required to get this report to that point, I believe that the methods and format I used could be replicated and expanded across a wide range of professions.

Further Research

While this report does an effective job of describing an alternative approach to reservoir restoration, it could be improved. The framework doesn't go into great detail about each variable, rather it gives a shallow but very broad range of information relevant to the topic of reservoir assessment and restoration. The following areas could use further development to improve the findings made in this report.

Variable Scoring:

Scoring the individual variables for each guideline was a process that changed throughout the entire length of this project. The goal of scoring individual variables was to create a system which a team of experts could use to assign a grade for the reservoir on each variable, and transfer that score to the appropriate guideline. This would allow the team to assess how well the reservoir was performing in each guideline. I encountered issues when trying to assign a point value to each variable. My first approach involved a system where each variable had a point value between 1 and 10 to represent its importance in the guideline. The feedback I received for this system was that experts would likely disagree with many of the values I assigned, and I would need concrete information to prove why I have some variables ranking more important than others. For this reason, I created a new system where all variables are worth 3 points, except for the variables which could not be evaluated for individual performance. While this system is likely to be more accepted from experts in the field, further research is required to create a system which portrays the individual importance of each variable.

Projective Design:

The projective design did an effective job of demonstrating how the new framework could be implemented on a reservoir project. It could be improved by gathering input from lake management officials regarding which goal they would like to pursue, where on the reservoir they wanted to see improvement, and which guidelines they wanted to focus on. Unfortunately, I wasn't able to get in contact with Milford lake management during the course of this project, so those decisions were made by me. While this certainly would improve the demonstration of how the framework could be used on a specific lake, the projective design was able to demonstrate the framework's process for applying guidelines to a reservoir restoration and analysis project.

References

Admiraal, David. 2007. Streambank Stabilization Using Traditional and Bioengineering Methods: A literature Review. University of Nebraska Lincoln, The Nebraska Department of Roads: 1-5

American Rivers. 2019. “Why We Need to Restore Floodplains.” American Rivers, 2019, www.americanrivers.org/threats-solutions/restoring-damaged-rivers/benefits-of-restoring-floodplains/.

Annis, Gust, Douglas Pearsall, Katherine Kahl, Erika Washburn, Christopher May, James Cole, David Ewert, Edward Game, and Patrick Doran. 2017. Designing coastal conservation to deliver ecosystem and human well-being benefits. PLoS One 12 (2): e0172458.

Aqua Sierra. 2016. “Causes of Low Dissolved Oxygen and Impact to Fish.” Aqua Sierra, Inc., 22 Nov. 2016, www.aqua-sierra.com/causes-of-low-dissolved-oxygen-and-impact-to-fish/.

Baumgartner, M., G. Baumgartner, and L. Gomes. 2018. Spatial and temporal variations in fish assemblage: Testing the zonation concept in small reservoirs. Brazilian Journal of Biology 78 (3): 487-500.

Beard, Elizabeth. 2011. Nurturing nature: Three waterfront parks provide environmental stimulus. Parks & Recreation 46 (6): 48.

Blabolil, Petr, Milan Říha, Daniel Ricard, Jiří Peterka, Marie Prchalová, Mojmír Vašek, Martin Čech, et al. 2017. A simple fish-based approach to assess the ecological quality of freshwater reservoirs in central europe. Knowledge and Management of Aquatic Ecosystems 2017- (418).

Brady, N.C. and Weil, R.R. The Nature and Properties of Soils. Upper Saddle River, NJ: Prentice Hall. (2008)

Chang, T., and Shirlena Huang. 2011. Reclaiming the city: Waterfront development in singapore. Urban Studies 48 (10): 2085.

Copeland, Gregory A. 2011. Camp design : Master planning basics. Akron, OH: Akron, OH : Domokur Architects.

Day, John W., Jr., Donald F. Boesch, Ellis J. Clairain, G. P. Kemp, Shirley B. Laska, William J. Mitsch, Kenneth Orth, et al. 2007. Restoration of the mississippi delta: Lessons from hurricanes katrina and rita. Science 315 (5819): 1679.

Derbyshire, Kurt. “Queensland Government Department of Primary Industries and Fisheries.” Queensland Government Department of Primary Industries and Fisheries, 2006.

EPA. (2018, June 7). National Highlight - Comparing Natural Lakes and Manmade Reservoirs. Retrieved November 4, 2019, from https://www.epa.gov/national-aquatic-resource-surveys/national-highlight-comparing-natural-lakes-and-manmade-reservoirs.

Hamer, Andrew J., and Kirsten M. Parris. 2011. Local and landscape determinants of amphibian communities in urban ponds. Ecological Applications 21 (2): 378-90.

Julien, Pierre Y.. (2010). Erosion and Sedimentation (2nd Edition). Cambridge University Press. Retrieved from https://app.knovel.com/hotlink/toc/id:kpESE0000E/erosion-sedimentation/erosion-sedimentation

Jurczak, Tomasz, Adrianna Wojtal-Frankiewicz, Piotr Frankiewicz, Zbigniew Kaczkowski, Zuzanna Oleksińska, Agnieszka Bednarek, and Maciej Zalewski. 2018. Comprehensive approach to restoring urban recreational reservoirs. part 2 – use of zooplankton as indicators for the ecological quality assessment. Science of the Total Environment; Science of the Total Environment.

Kansas Department of Health. (n.d.). Bureau of Water, Watershed Planning Section, Lake Methodology. Retrieved from http://www.kdheks.gov/tmdl/eutro.htm.

Kansas Department of Wildlife, Parks and Tourism (KDWPT), 2018. Milford State Park.

Keane, T. (2019, September). Reservoir Life Expectancy & Sediment Deposition [Lecture notes]. Manhattan, KS.

Le Fur, J., A. Guilavogui, and A. Teitelbaum. 2011. Contribution of local fishermen to improving knowledge of the marine ecosystem and resources in the republic of guinea, west africa. Canadian Journal of Fisheries and Aquatic Sciences 68 (8): 1454-69.

Lovell, S. T., & Sullivan, W. C. (20015). Environmental benefits of conservation buffers in the United States: Evidence, promise, and open questions. University of Illinois.

Lynch, A. J., E. Varela-Acevedo, and W. W. Taylor. 2015. The need for decision-support tools for a changing climate: Application to inland fisheries management. (report). 22 (1): 14.

Maceina, Michael J., and Marc R. Stimpert. 1998. Relations between reservoir hydrology and crappie recruitment in alabama. North American Journal of Fisheries Management 18 (1): 104-13.

Matthew. "Proper Dimensions for a Boat Launch Ramp." M.B. Marsh Marine Design, 14 Nov. 2012, marine.marsh-design.com/content/proper-dimensions-boat-launch-ramp.

Miranda, L. E. 1999. A typology of fisheries in large reservoirs of the united states. North American Journal of Fisheries Management 19 (2): 536-50.

Missouri Department of Conservation (MDC), Missouri Cooperative Fish and Wildlife Research Unit, Table Rock Lake water Quality Inc. 2014. A Comprehensive Approach to Reservoir Habitat Management in Table Rock Lake.

Mogollón, Beatriz, Emmanuel A. Frimpong, Andrew B. Hoegh, and Paul L. Angermeier. 2016. An empirical assessment of which inland floods can be managed. Journal of Environmental Management 167 : 38-48.

Musamba, E., E. Boon, Y. Ngaga, R. Giliba, and T. Dumulinyi. 2012. The recreational value of wetlands: Activities, socio-economic activities and consumers' surplus around lake victoria in musoma municipality, tanzania. Journal of Human Ecology 37 (2): 85-92.

Onsoy, Bahadir, Halit Filiz, Ali Tarkan, Gokcen Bilge, and Ahmet Tarkan. 2011. Occurrence of non-native fishes in a small man-made lake (lake ula, mugla): Past, present, future perspectives. Turkish Journal of Fisheries and Aquatic Sciences 11 (2): 209-15.

Pander, J., and J. Geist. 2010. Seasonal and spatial bank habitat use by fish in highly altered rivers – a comparison of four different restoration measures. Ecology of Freshwater Fish 19 (1): 127-38.

Robinson, C. A., Ghaffarzadeh, M. and Cruse, R. M.: 1996, 'Vegetative filter strip effects on sediment concentration in cropland runoff', J. Soil Water Cons. 50(3), 227–230.

Rosgen, Dave. 2007. "WARSSS – Watershed Assessment of River Stability and Sediment Supply. Hydrological Science and Technology 23 (4)

Sammons, S., and P. Bettoli. 1999. Spatial and temporal variation in electrofishing catch rates of three species of black bass (micropterus spp.) from normandy reservoir, tennessee. North American Journal of Fisheries Management 19 (2): 454-61.

Schultz, Randall D., Christopher S. Guy, and Douglas A. Robinson. 2002. Comparative influences of gizzard shad catch rates and reservoir hydrology on recruitment of white bass in kansas reservoirs. North American Journal of Fisheries Management 22 (2): 671-6.

Schwartz, Stuart S., and Brennan Smith. 2016. Restoring hydrologic function in urban landscapes with suburban subsoiling. Journal of Hydrology; Journal of Hydrology 543 : 770-81.

Simon, A., Curini, A., Darby, S., and Langendoen, E., (1999) "Streambank Mechanics and the role of bank and near-bank processes in incised channels," in Incised River Channels: Processes, Forms, Engineering and Management, Eds. Stephen Darby and Andrew Simon, John Wiley and Sons Ltd. Chichester. 442 p.

Sprenkle, Ely. 2012. "Tuttle creek fisheries newsletter summer 2012." Manhattan Newsletter (July 2012): 1-3.

Sprenkle, Ely. 2013. "Tuttle Creek Fisheries Newsletter Spring 2013." Manhattan Newsletter (April 2013): 1-3.

Sprenkle, Ely. 2014. "Tuttle Creek Fisheries Newsletter Summer 2014." Manhattan Newsletter (August 2014): 1-3.

Sprenkle, Ely. 2015. "Tuttle Creek Fisheries Newsletter Summer 2015." Manhattan Newsletter (August 2015): 1-4.

Sprenkle, Ely. 2018. "Tuttle Creek Fisheries Newsletter Spring 2018." Manhattan Newsletter (May 2018): 1-7.

Texas Water. 2020. "Glossary of Terms." Water Data For Texas, waterdatafortexas.org/reservoirs/glossary.

References

US Army Corps of Engineers, 2010. Milford lake Fish Structure Map.
USEPA: 2002, Water Quality Conditions in the United States: A Profile from the 2000 National Water Quality Inventory, Publication EPA 841-F-02-003, Office of Water (4503F), Washington, DC.

(A) Walter, Ed, Grayson, Burgess, Chung, Kim, Loocke, Mulligan, Rose, Ellis. June, 2018. "ULI Case Studies." Bridgeland. https://casestudies-uli-org.er.lib.k-state.edu/wp-content/uploads/2018/06/Bridgeland-scr.pdf

(B) Walter, Ed, Grayson, Burgess, Chung, Kim, Loocke, Mulligan, Rose, Ellis. June, 2018. "ULI Case Studies." Buffalo Bayou Park. https://casestudies-uli-org.er.lib.k-state.edu/wp-content/uploads/2018/04/BuffaloBayouFinalv3.pdf

Wang, Guoqiang, and Zongxue Xu. 2011. Assessment on the function of reservoirs for flood control during typhoon seasons based on a distributed hydrological model. Hydrological Processes 25 (16): 2506-17.

Wright, John C. 1954. The hydrobiology of atwood lake, A Flood Control reservoir. Ecology 35 (3): 305-16.

Zhu, Jiaying. 2012. Criteria for aquatic planting design in ecological redevelopment of urban riverfronts, ed. Kansas State University,degree granting institutionManhattan, Kan. : Kansas State University.

Zhu, Jie, and Qianghua Duan. 2011. Urban waterfront landscape cultural design studies.

Appendix A: Literature Review

Reservoirs in the Midwest:

In the Midwest, it is uncommon to find natural lakes, which is why reservoirs, or “constructed lakes” are so prevalent. With most of these reservoirs being constructed in the 1950’s and 1960’s, their flood storage life expectancy are beginning to run out do to accelerated sediment deposition. Without these reservoirs, stormwater storage would drop significantly in the Midwest and lake recreation would become sparse. This emphasizes the importance of developing a solution to issues which limit the lifespan and functionality of reservoirs.

Reservoir Ecology

Vegetation

The health of fish communities largely depends on the abundance and form of vegetation and organic matter present in the reservoir. Reservoirs with large amounts of vegetation are typically rich in oxygen and nutrients, which often results in high counts of zooplankton. Too much vegetation, and too little zooplankton can often result in an imbalanced food chain, as the microorganisms which convert organic matter into organisms and baitfish are unable to filter through the vegetation quick enough. This imbalance in the food chain is often catastrophic for reservoirs and can often lead to algae blooms and dense vegetation which can diminish the lake's ecological functionality, as well as it's aesthetic. These issues can be identified by finding an abundance of small, stunted fish species (Wright 1954).

Vegetation Type:

Emergent Vegetation: Emergent vegetation refers to the vegetation that grows in shallow water, above the waters surface (USF, 2009). This vegetation is crucial to both stabilizing the shoreline and providing habitat for aquatic and amphibious species. The roots of the emergent vegetation provide structure which stabilizes the bank and reduces sediment runoff. The vegetation also provides oxygen for fish species which take shelter in shallow reeds and plants, while also lowering water temperatures to preserve oxygen (Blabolil 2017, 2).

Submerged Vegetation: Submerged vegetation grows from underwater and provides cover and oxygen for fish species (USF, 2009). Predator species such as bass and crappie tend to stay in locations with submerged vegetation, as it gives them oxygen and conceals them from prey species (Blabolil 2017, 2).

Floating Vegetation: Floating vegetation grows on the surface of the water and provides shelter and oxygen for fish species. Smaller predator fish such as bluegill, and baitfish such as minnows tend to hide from birds under floating vegetation as it hides them from view, while also providing them with oxygen (Aqua Sierra, 2016).

Riparian Vegetation: Riparian buffers are very underutilized in landscape restoration efforts. They can be used to help reduce the impacts of agricultural lands runoff and sedimentation. They also increase biodiversity and provide habitat for wildlife. The conservation buffers can come at a cost to landowners, as they take space for crops. Therefore, it's important to also issue policies which encourage restoration strategies such as conservation buffers. Another benefit for landowners is the flood storage potential of these areas. Further research is necessary on these buffer zones so that qualitative data on the effectiveness of conservation buffers can be used as proof of concept (Lovell, 2005).

Invasive Vegetation Species:

One of the most common mistakes in waterfront design is the introduction of foreign species. While they might provide a unique aesthetic for the area, foreign and invasive species often take over riparian plant communities. Not only do invasive species throw plant ecosystems out of balance, but they destroy aquatic habitats for the amphibians and fish species. With careful design and plant selection, aquatic plants should accomplish three primary goals. The first goal is to adjust the flow of water by being placed in wetlands and shallow banks where they can absorb water. The second goal is to reinforce slopes and soils with roots to prevent bank erosion. The third is to improve water purification and absorb pollutants on site (Zhu 2012).

Plant Health:

The health of aquatic ecosystems in reservoirs heavily influences ecological and recreational function. It's important to understand how a healthy aquatic ecosystem functions so that similar results can be achieved in reservoirs. One of the most important things to study when looking at aquatic ecosystems is the fish community. Many reservoir issues such as water turbidity, lack of aquatic vegetation, or water quality problems can be further explained by observing and measuring the health of fish communities. "Fish communities are among the best indicators of ecological quality in freshwaters because fish occupy most trophic levels, including top predators, in aquatic food webs and therefor often integrate inputs and the effects of pressures across the ecosystem" (Blabolil 2017, 2).

Reservoir Ecology

Fish Communities

The health of aquatic ecosystems in reservoirs heavily influences ecological and recreational function. It's important to understand how a healthy aquatic ecosystem functions so that similar results can be achieved in reservoirs. One of the most important things to study when looking at aquatic ecosystems is the fish community. Many reservoir issues such as water turbidity, lack of aquatic vegetation, or water quality problems can be further explained by observing and measuring the health of fish communities. "Fish communities are among the best indicators of ecological quality in freshwaters because fish occupy most trophic levels, including top predators, in aquatic food webs and therefor often integrate inputs and the effects of pressures across the ecosystem" (Blabolil 2017, 2).

Invasive Fish Species:

When reservoirs are constructed, native fish species from the region will move from the streams and channels in the reservoir's watershed into the reservoir. Some non-native sportfish species may also be introduced into the reservoirs to meet the demand for select species such as trout or pike. These fish are often introduced in areas across the country, including reservoirs which are located far from naturally occurring trout or pike fisheries. Before lakes are stocked with non-native species, the fish community must be evaluated, so that officials can be sure that the new species won't interfere with the balance of the aquatic ecosystem. While invasive species may not be a major concern when looking at a reservoir, they could be flushed out of the reservoir and begin to multiply downstream where non-native species become an issue. Lake Ula, a small reservoir located in southwest Turkey, was the site of an invasive species study in 2009, where scientist recorded the fish species present in the lake, as they were concerned about how the invasive fish affected the native fish community both in the reservoir and downstream. When the lake was stocked in 2009, common carp, and chub were the only species present. In 2008, surveyors found gibel carp, common carp, mosquitofish, goldfish, chub and gizani. Two of these species could have come from upstream, but the common carp, mosquitofish, and goldfish had to be introduced by humans (Onsoy 2011).

Evaluating Fish Communities:

Ely Sprenkle a biologist in Manhattan, KS, publishes annual reports on the integrity and productivity of local reservoirs and their respective fish communities in the Manhattan area. Evaluating these reports provides us with in-depth studies over multiple lake conditions and research techniques over a 6-year period. Studies on lakes in Manhattan KS, which range from 300,000 acre reservoirs to 50 acre lakes, use fish community health as the primary evaluation tool (Sprenkle 2015). Multiple variables, such as species abundance, fish diversity, and fish size are used when evaluating fish communities. Species abundance can be used to identify which areas of a reservoir fish are migrating too, although these numbers can change depending on the time of year (Sprenkle 2016). A high fish diversity is indicative of a healthy and balanced fish community (Sprenkle 2013). Data on the size of specimen caught can be a very useful insight to the overall health of a fish community, as it reveals imbalances in the fish ecosystems structure (Sprenkle 2015).

Collecting Fish Community Data:

The most common technique for evaluating fish communities is electrofishing. Electrofishing is conducted using an electrofishing boat (Sprenkle 2014). This boat has a generator which releases an electric current into the water, stunning fish in the nearby area (Sprenkle 2014). Once stunned, the fish are collected, counted, weighed, measured, and then released (Sprenkle 2014). While proving to be one of the most efficient data collection techniques, electrofishing only works in specific conditions. The catch rates can drastically differ depending on the time of year, and the electric current is only effective in shallow water under ten feet (Sammons 2011). This means that typically, electrofishing is only conducted near the shore, as it is largely ineffective in open water (Sammons 2011).

Reservoir Ecology

Sport Fish Habitat

Bank Habitat:

When creating bank habitats for man-made reservoirs, it is proven most successful to restore natural habitats (Pander 2009). Observing natural rivers and lakes is an excellent strategy to use when determining which bank habitats would best fit a new reservoir. J Pander built examples of four, healthy fish habitats in the Gunz River in Germany: HA, HB, HC, and HD. The first, Habitat HA is made up of a combination of rip rap & boulder bank enforcements, riparian woody species and an underlying layer of aquatic shrubs and vegetation. During evaluation, 347 fish specimens were caught in Habitat HA. The second, Habitat HB is comprised of a rip rap and boulder bank reinforcement, as well as an array of overhanging aquatic vegetation. This habitat differs from Habitat HA, as Habitat HA has a layer of riparian wood species, whereas Habitat HB has no such layer. During evaluation, 206 fish specimens were caught in Habitat HB. The third, Habitat HC is made up of smaller rip rap, with an embankment of grassland vegetation. During evaluation, 355 fish specimens were caught in Habitat HC. The fourth, Habitat HD is similar to HC, but has an addition of artificial/dead wood piles anchored together with steel wires; these wood piles are large enough to serve as refuge & habitat for smaller fish species. During the fish collection, 2,939 fish specimens were caught in habitat HD, almost ten times the amount caught in the other three habitats (Pander 2009).

Open Water Habitat:

Sport Fish such as bass, crappie and bluegill tend to retreat to deeper water as the water temperatures drop in the winter. These fish also s¬eek deep water refuge by seeking deep-water habitat such as rock clusters, or submerged trees. Providing deep-water cover in a reservoir will sportfish protection from predators, thus giving them a better chance of survival for the winter. Both artificial and natural habitats can be used (Pander 2009). Natural habitat structures such as hardwood trees, cedar trees, pine trees, stump fields, rock structures and combinations of rock and stumps have proved to be successful (MDC, 2014). Using on-site trees which are scheduled for removal, dead, or a nuisance is a green and cost-efficient way to create deep-water sportfish habitat (MDC, 2014).

Spawning Habitat:

In the spring, bass and crappie search for shallow water areas with a gravel bottom to create their nesting beds. Once water temperatures reach roughly 60 degrees Fahrenheit, the fish will begin spawning. This can be a very exciting time to fish, as angers can often see the fish near the bank. The more spawning habitat a reservoir has, the higher the fish population will be in the coming years (Sprenkle, 2015).

Wetlands

While sediment retention in wetlands is usually a positive contributor to better water quality, it becomes an issue when the sediment is being supplied by an agricultural field. This issue is very apparent in areas of high erosion, as the contaminated sediment can quickly fill in wetland areas, destroying riparian habitats and degrading water quality. In this study, Gleason found that wetland basins surrounded by agricultural fields accumulate nearly twice the rate of sediment than those wetlands surrounded by grasslands. Another negative effect of wetland sedimentation is the impact on primary production. Sedimentation decreases the water depth, and the suspended sediment in the water column reduces the light which the microphytes and algae depend on. The vegetation loss associated with sedimentation means less habitat & food for invertebrates. Other issues associated with wetland sedimentation include effects on wildlife, water quality, and hydrology (Gleason, 1998)

Reservoir Hydrology

Water Quality

Protecting water quality in reservoirs is important to both the ecological and hydrological function of reservoirs, as well as the overall health of the community. The quality of water directly influences the ability of a reservoir to develop and sustain a stable fish community, provide sustainable drinking water, and indirectly influences recreational activities such as fishing, and swimming.

Water Chemistry:

Water chemistry can greatly change the productivity of a reservoir ecosystem. There are two primary nutrients which should be measured: Phosphorus and Nitrogen. Too much of these nutrients in a reservoir could cause Eutrophication, a process where high nutrient levels cause issues such as algae blooms and poses potential health hazards to people (USF, 2009).

Chlorophyll Levels:

Chlorophyll is produced by vegetation, and too much chlorophyll could cause health problems. The state of Kansas has set target levels of Chlorophyll for two forms of water contact: Primary and Secondary. Recreation activities with primary contact such as swimming have a chlorophyll target level of 12ug/L. Secondary contact recreation activities such as fishing have a higher target level of 20 ug/L (Kansas Department of Health).

Phosphorus Levels:

In order to reduce chlorophyll levels, it is necessary to reduce phosphorus levels. Phosphorus is the most common nutrient which causes eutrophication (Kansas Department of Health). Excess phosphorus is also one of the leading causes of low dissolved oxygen levels (Aqua Sierra, 2016).

Nitrogen Levels:

If phosphorus is not the primary contributor to high reservoir chlorophyll levels, nitrogen reduction is necessary. Nitrogen is often introduced to reservoirs by fertilizer runoff from agricultural fields which drain into the reservoir and its watershed (Kansas Department of Health).

Dissolved Oxygen:

Fish breathe dissolved oxygen (DO) and will move to different areas of reservoirs in search of adequate DO levels. Dissolved oxygen depletion can be deadly to fish communities. Excessive algae growth is one of the leading causes of dissolved oxygen depletion and results from plants consuming dissolved oxygen at night. Dense algae blooms can quickly deplete the DO in a reservoir causing harm to fish communities and potentially even fish kills (Aqua Sierra, 2016).

Potential Trophic State Index:

The potential trophic state index is a concept which is used to measure the potential amount of nutrients in a reservoir held in the various forms of aquatic vegetation. Measuring this parameter is critical for reservoirs in which management is considering the use of herbicides or the introduction of herbivores such as the Grass Carp. Once the vegetation control measures take effect, the nutrients will saturate the reservoir, and could cause high-nutrients related issues such as algae blooms. (USF, 2009).

Water Column and Strata Zones:

When analyzing water quality and fish assemblage, it's important to understand that most reservoirs contain three distinguished levels of strata, Littoral, Pelagic, and Bathypelagic (Baumgartner 2018). These levels are used to define vertical layers of water in a reservoir with Littoral being at the top, Pelagic being in the middle, and Bathypelagic being on the bottom. The Littoral strata is often similar to rivers and is frequently inhabited with many fish species due to the high levels of oxygen and plant matter. Littoral strata often exhibit high structural complexity and high amounts of organic matter. The Pelagic levels are generally vacant of plant matter, but larger, predator fish may school in the Pelagic strata, and many fish will retreat to this level in search of colder water temperatures in the summer. The Bathypelagic strata is rarely filled with any fish or organic matter, as the low levels of oxygen create limits for fish surviving for long in the conditions (Baumgartner 2018).

Zooplankton:

A common method for measuring water quality in a reservoir is to use zooplankton as a biological quality element. Zooplankton play crucial roles in the Littoral strata levels, as well as at the top of the trophic pyramid in reservoirs. They are able to relocate carbon, energy, and other nutrients from bacteria and organic matter into organisms, which can transfer it on to the rest of the trophic levels. If these transfers are not happening, due to poor water quality, it's common to see an increase in phytoplankton blooms, which results in a loss of energy from the aquatic system. The use of zooplankton as indicators for water quality is an effective measuring tool, one which can be used in both urban ponds and rural reservoirs (Jurczak 2018).

Reservoir Hydrology

Sedimentation

Sediment Deposition:

After construction, the reservoirs typically have a lifespan of 100 years before they are filled with sediment and are no longer able to hold excess stormwater (Keane, 2019). In natural stream systems, sediment doesn't degrade streams, it builds them by creating features which influence the channel path. However, when a natural stream flows into a reservoir the velocity decreases, causing the sediment to settle over the reservoir bed (Julien, 2010). Over time this sediment builds up to the point where it fills the reservoir, rendering it useless for flood storage capacity and hazardous for some recreational activities such as boating.

Accelerated sedimentation in reservoirs is an issue that all reservoirs face, and it eventually causes the reservoir to lose functionality, particularly in storm water storage capacity. The cause of this rapid sedimentation has to do with the delta where the water and sediment from a natural stream first enters the reservoir. When the stream enters the reservoir, the velocity of the stream flow decreases, and sediment begins to settle across the reservoir bed. Some control measures can be used in the reservoir, but the most effective way to extend the life expectancy of a reservoir is to control sediment production upstream in the watershed. Soil conservation practices, increasing vegetation along banks and off-channel reservoirs are all common tactics used to slow down sediment deposition in reservoirs (Julien, 2010).

Overland Flow Erosion:

Traditional farming methods such as tilling disturb the soils and loosen sediment, making the land highly susceptible to sediment runoff during storm events (USEPA, 2002). While these farming practices will likely continue, there are additional practices which can conserve nutrients in the ground and protect against soil erosion. Cover cropping and field terracing are both methods which have proven to reduce erosion and runoff rates (Brady and Well, 2008).

The process of overland flow erosion can be described in three steps: Detachment, Transport, and Deposition. Detachment is when sediment is disengaged from the ground by raindrops or fast flowing water. Sediment Transport is the process of the sediment being moved by water over the land and into a stream channel. The final stage, Deposition, is the accumulation of sediment in streams and eventually reservoirs (Brady and Well, 2008).

Riparian Buffers:

Reducing sediment input from overland flow is possible with the implementation of riparian buffers. Riparian buffers possess three characteristics which reduce sediment runoff. The first characteristic is the fine, tight root systems present in most riparian species. These roots are able to grab sediment particles and hold them from being swept into the channel. The second characteristic is the density of the vegetation, which slows down the flow velocity of the overland flow. A slower velocity flow makes it easier for the root systems of the vegetation to trap and slow down sediment particles. The third characteristic is the fibrous root system's capability to open soils and allow for more infiltration (Robinson et al., 1996).

Streambank Erosion:

Sediment from streambank erosion is often the leading source of sedimentation in reservoirs. Depending on variables such as flow conditions, bank protection and soil structure, bank erosion can be responsible for up to 80% of the sedimentation rates in reservoirs (Simon et al, 1999).

Reservoir Sedimentation Control Measures

Strategies for reducing reservoir sedimentation have proven to extend the life of reservoirs, but they often come with negative consequences downstream. After choosing a strategy, research should be conducted on the ramifications the selected strategy could cause in the reservoir and its watershed.

Sluicing: This technique focuses on the movement of sediment from the inflow areas directly to the dam before the sediment can settle. Sluicing is most successful when used during the flood season. By lowering the operating level of the reservoir, the flow velocity and sediment transport capacity are accelerated, giving the sediment less time to settle in the reservoir. This technique is requires high rates of excess runoff, and results can vary depending on the reservoir morphology, and sediment size (Kansas Water Office, 2008).

Density Current Venting: Density current venting uses the natural, hydrological processes of a reservoir to direct higher densities of sediment currents through gates in the dam. Unlike Sluicing, this technique doesn't require any lowering of the water level on an annual basis. Because high-density currents are being flushed from the reservoir without allowing deposition, this technique can have negative impacts downstream of the dam. Downstream impacts of Density Current Venting include degraded stream habitat, and a wide dispersion of sediment which makes it difficult to track and remove from the watershed (Kansas Water Office, 2008).

Reservoir Hydrology

Water Level Fluctuation

Relationship Between Water Levels and Fisheries:

Understanding how changing water levels affect fisheries in reservoirs is important to maintain a healthy fish community. "Fishery biologists have suspected that reservoir hydrology influences crappie reproductive success and contributes to the cyclic nature of these fisheries (Maceina 1998). By conducting a side by side comparison of water fluctuation and crappie spawn success on the Chickamauga Reservoir in Tennessee, correlations can be found. The crappie larvae were most abundant during high water conditions. The crappie spawn is often more successful in high water conditions, because more spawning ground is available. With a larger spawning ground area, it's more difficult for predator species to find and consume crappie eggs. "Understanding relations between hydrology and crappie recruitment would assist fisheries managers in predicting crappie year-class abundance, and when possible, manipulation of reservoir hydrology could increase production of young crappies" (Maceina 1990, 104).

Data from other reservoirs back up this concept, as high water levels and low discharge in Rathburn Lake, Iowa, are positively related to crappie larvae abundance. More studies on a multitude of reservoirs in Alabama suggest that maintaining consistent water levels improves fish spawn rates for multiple species. Correlations can be found with high numbers of 1-year old crappie after a year of where minimal water level changes occurred. This suggests that more crappie fry were able to survive due to consistent water levels (Maceina 1998).

White bass are popular sport fish in Kansas, ranking in as the 2nd most harvested fish species in the state, with the most popular species being white crappie. Being a popular game fish, it's important that Kansas reservoirs are maintained in a state where white bass can thrive. By combining information gathered on white bass in the 1990's, correlations between fish population and water levels become apparent. White bass tend to spawn in headwaters and river tributaries, and their spawn is generally triggered by the increased inflow of water in the spring. Although it's easier to identify correlations between white bass pawns and gizzard shad levels, there is a clear relationship between rising water levels influencing the white bass spawn period (Schultz 2002). Understanding the effects that rising water in the spring has on the fish community should influence the rate of outflow during the spring. Kansas Reservoir officials and engineers should allow for an annual rise in water level in the spring to promote a healthy white bass spawn (Schultz 2002).

Reservoir Hydrology

Floodwater Storage Capacity

Flooding is a global issue which affects more 178 million people world-wide, and costs more than $40 Billion US dollars in 2010 (Mogollon 2016). Managing floods is difficult. "If it were easy or straightforward, it would not be an issue" (Mogollon 2016). Flood control reservoirs can be found all over the country, in both rural and urban areas. The ever-growing, impermeable fabric of cities combined with the desire for waterfront development generate a growing need for more flood control infrastructure. Integrating Reservoirs and floodplains into flood control infrastructure systems is not only a proven method for minimalizing flood risk, but also for providing a variety of recreational and ecological amenities for the local communities.

Flood control reservoirs have a significant impact on reducing flood risk in areas downstream. Typically, flood control reservoirs are created in river valleys where annual floods occur. The reservoir is designed to hold a predetermined volume of water, conservation pool level (Sprenkle 2012), and also be able to contain the runoff from a storm event of at least a 100-year occurrence (Mogollon 2016). A flood control device such as a dam or a levee is used to control how much water is let out downstream of the reservoir (Mogollon 2016).
In recent years, cities around the world have turned to reservoirs to solve storm water problems. "In order to control flood and keep stable water supply, reservoirs have become the most effective water storage facilities for regulating water release" (Wang 2011, 2506). The Tone River in Japan is an excellent example of how reservoirs can become part of a city's stormwater infrastructure. From June through October, heavy rains and typhoons pummel the Tone River Region. By converting the larger lakes reservoirs in the area into flood control reservoirs, the cities along the Tone River are able to control the water output at a safe rate (Wang, 2011).

Reservoir Wetlands – Flood Control Potential:

Wetlands have the potential to improve a reservoir's flood control capabilities. In Nature, wetlands are found in flood plains near river and lake systems, as they are equipped to naturally absorb and filter flood water, and quickly recover from sever flood events (Day 2007). With man-made Reservoir's flood plains are rarely looked into, because of the false sense of security provided from reservoir dams being rated to hold a 100-year storm event (Mogollon 2016). A study conducted on 31 reservoirs in the southern US show that implementing wetland areas can help diminish flood waters, and release water at a slower and safer rate. While dams and levees certainly help mitigate reservoir outflow, these control structures do fail occasionally, which can have devastating effects downstream (Mogollon 2016). Wetlands with dense vegetation cover and landscape structure slow the duration of water outflow significantly in both urban and rural areas, regardless of steep or shallow topography (Musamba 2012).

Restoring Wetlands for Flood Control:

With wetlands being proven to improve the flood control capability of reservoirs, it is important that regions such as the Mississippi Delta Plains, which have frequent tropical storm and flood events, have healthy and thriving floodplains. In coastal Louisiana, wetlands are being destroyed at rates as high as 100 square kilometers per year (Day 2007). With the Mississippi river nearly completely leveed in the area, surface overflow is nearly impossible, rendering the wetlands useless. Cities in the region have been becoming more aware that the need to reconnect the river and reservoirs to the deltaic flood plain is critical for the protection of developments. The quickest, and most effective technique to restore wetlands is dredging sediment from near bodies of water and pumping it across vast expanses of wetlands. The tactic is expensive, but it restores wetlands very quickly (Day 2007). Suburban Sub-Soiling is a hydrological function restoration tactic very similar to sediment dredging, which urbanized areas can use as a “controlled application” alternative (Schwartz 2016).

Reservoir Recreation

Recreational Function

"Water in a city gives the city a sense of vitality and vigor, and profoundly demonstrates the connotation and extension of human history and culture" (Zhu 2011, 6564). Throughout history, people and civilizations are drawn to water for both a survival, and for recreation. Often the development of cities is based around its relative location to a water supply. Today, water is viewed as a recreational amenity. In cities, waterfronts act as gathering spaces for people to escape the noise and congestion of city life. In suburbs and rural areas, reservoirs provide a much-needed retreat and escape. Designing waterfront landscapes is a crucial construct of today's society and culture (Zhu 2011). Many waterfronts in cities today are developed, but underutilized. It's important to understand that recreational function can be added into reservoirs after initial design. Bringing people to the water by restoring wildlife and providing outdoor connections for urban populations can be achieved at any reservoir, at any point in time if adequate research is performed.

Recreation Program Design

The recreational activities which are going to take place on a reservoir site need to be established prior to any remediation or construction efforts are made. Boating, for example, requires reservoirs to have boat ramps with nearby parking. The boat ramps should also be positioned on the reservoir in locations which are protected from wind. They should have southern exposure, to prevent ice from developing on the ramps during colder months of the year before lakes freeze over. Other amenities such as swim beaches should be protected from the main lake by rock jetties, or by being placed back in lake coves. Circulation around the lake is another crucial element, as it will be used by joggers, bikers, and bank fisherman. Seasonal activities can be difficult to design for, as they may only be relevant during certain times of the year. Ice-skating, for example, only occurs in the winter, but requires easy access to water across a shallow slope. Other seasonal activities such as sailing may require temporary infrastructure such as anchoring docks in the which can be removed before lakes freeze (Copeland 2011).

Fishing

Whether intended to be a fishing reservoir or not, people will try and fish in almost any size of reservoir. One way to design a reservoir for fishing is to create fish habitats near the shore. If boats are to be allowed on reservoirs, off shore structure should be implemented. When creating a reservoir, it's important to consider structures which will be covered by water and decide if they will be a benefit or safety issue for the reservoir. Reservoirs are commonly created over existing creeks, which often are surrounded by trees. Once flooded, trees make a perfect fish habitat for crappie, bluegill, pike, bass, and countless other game fish. Other structures like buildings, or vertical timber could pose a risk to boaters. Fluctuating water levels could bring these structures, which are usually a safe distance under water, much closer to the surface endangering boaters (MDC, 2014).

Boat Launch Sites

Boat Ramp Design:

In order to prevent accidents or difficulty at a boat launch site, it's important that the ramps are designed properly. An ideal boat ramp is 15' wide and has a slope of 12% - 15%. The ramp should extend far enough into the reservoir that when the lake is in low water conditions, the ramp extends to roughly 4' below the surface of the water. The ramp should extend at least 1.5' above the surface of the water when the lake is in high water conditions. There should always be at least 6' of paved surface which continues above the ramp in order to provide traction and space for larger boats or vehicles with front wheel drive (Mathew, 2012).

Boat Ramp Safety Precautions:

When boat ramps don't extend far enough into the water, trailers can get stuck in the gravel or mud at the base of the ramp. Prop wash can also erode the substrate at the end of a boat ramp, requiring frequent maintenance. All concrete ramps need drainage grooves which run perpendicular to the ramp. These grooves will move water off the ramp, as well as provide traction for vehicles during slick conditions. (Mathew, 2012).

Side Docks:

While side docks aren't necessary, they make it much easier and quicker for boaters to use ramps. Side docks should either float or move up and down with the water level. A minimum distance of 4' is necessary or the dock will be too unstable to use. Anchor cleats should be placed every 8' to secure boats when the boater needs to leave to pull the trailer into or out of the launch space. (Mathew, 2012).

Reservoir Policy

Lake Management and Policy

Often, it's not physical change that will most improve a reservoir's function, but policy changes. Specific lake policies can affect the ecological health of a reservoir, it's hydrology, and the recreational practices which take place on the reservoir.

Water Level Fluctuation:

Reservoir water levels vary depending on a range of factors. This report will focus on four main drivers which are common for reservoirs in the Midwest: Navigation, Flood Control, Endangered Species, and Sport Fishing & Hunting.

1. Navigation:
   Boat navigation on major rivers such as the Missouri requires a minimum amount of water to allow for safe navigation between ports and destination. These navigational needs often influence the output of major reservoirs (Keane, 2019).

2. Flood Control:
   Many reservoirs in the Midwest were built by the corps of engineers to provide flood control for communities surrounding and downstream of the reservoir. These flood control reservoirs are built to hold water from large storm events, and slowly release it depending on the water levels of the river downstream. In Manhattan KS, the Floodplain Management Plan was created by the city of Manhattan and U.S. Army Corps of Engineers to monitor Tuttle Creek Reservoir's flood storage capabilities and identify areas of concern (City of MHK).

3. Endangered Species:
   Policies aiming to protected endangered species within a reservoirs watershed are of major concern in the Midwest. Migratory bird species which use sandbars to nest along the Missouri River, as well as bottom feeders such as the pallid sturgeon which need migrate along the river are often put at risk due to the lack of policy, or the lack of policy enforcement (Garrison, 2019).

4. Sport Fishing & Hunting Regulations:
   Implementing fishing regulations is a necessary step for reservoir management. The regulations should balance the ecological productivity of fish communities with the current and future demand for fishery resources to ensure long term success. There are four decision factors that should influence fishing regulations:

   Society: Strong social ties are critical at all scales of management in fisheries. The more a fisherman conforms to community rules, the more benefits he or she will likely reap (Lynch 2015).

   Politics: Often times, fisheries are tasked with producing time-sensitive results from government agencies which can have little to no biological meaning. An example of this would be adopting climate change-inspired policies. Fisheries Management are more likely to implement a policy change if it promotes desirable catch regulations, and not when they align with scientific recommendations (Lynch 2015).

   Economics: Fisherman will attempt to maximize their profit (catch and harvest rates) (Lynch 2015).

   Science: Policy decision making should be flexible and adaptive to account for new information and changing ecological conditions (Lynch 2015). "Managing inland fisheries is a complex task, with or without the added potential effects of climate change. Addressing climate-related risks proactively, whether the impacts are mild or sever, will be beneficial to fisheries because these actions may buffer against other ecological changes" (Lynch 2015, 18).

Appendix B: Case Studies

Case Study - Medard Reservoir Analysis

Background Information

This analysis was conducted in collaboration with the University of South Florida's Center for Community Design and Research, and the Hillsborough County Stormwater Management Section. The study on Medard Reservoir was part of a rapid assessment of physical and ecological data over a five-year period of up to 150 lakes in Hillsborough County. The report is broken up into three sections: Morphological Assessment, Vegetative Assessment, and Water Quality Sampling.

Reservoir Morphology Assessment

A bathymetric map was created using a sonar device with GPS location. This device was attached to a boat, which made passes over the entire lake in order to map the bottom depth and boat position. The information gathered was used to derive data for estimate reservoir area, mean & max depths, water volume and a bottom contour map. The map will also assist reservoir management by identifying deep fishing holes, areas of reservoir vegetation and flood storage data (USF, 2009).

Reservoir Vegetation Assessment

The vegetation aspect of reservoir ecology was divided into three categories: Emergent, Submerged, and floating. It was determined that these three categories are sufficient for an ecology analysis for reservoirs. I believe the study could have benefited from studying riparian vegetation in areas which flow into the reservoir.

Data Collection

Emergent vegetation data was collected by studying the most recent aerial photography of the banks. Site data is gathered in GIS where it's easy to identify shoreline vegetation zones. Data for submerged vegetation was collected by studying the sonar scans of the lake conducted during the bathymetric map creation process in section 1. Floating vegetation was documented using a boat to survey the lake (USF, 2009).

Vegetation Sampling

The vegetation sampling analysis process for Medard Lake documented vegetation type, exotic vegetation, predominant plant species, and submerged vegetation biomass. The data collected on Medard Lake was compared to other regional lakes in order to approximate the diversity of aquatic vegetation and invasive species present. This project began in 2006, but information on plant species in the watershed was gathered through 2008 (USF, 2009).

Water Chemistry Assessment

This analysis section collected data on phosphorus, nitrogen and chlorophyll levels and compared them to the Florida DEP's classifications for impaired water quality. The data collected was from samples taken in 2005, so there is no current data for how the reservoir's water quality was during the time of the study in 2009. This makes it difficult to find connections between variables, because the data taken for different lake functions is separated by up to 4 years in some cases (USF, 2009).

POTENTIAL TROPHIC STATE INDEX (pTSI):

"This parameter is determined by calculating the amount of nutrients (phosphorus and nitrogen) that could be released by existing submerged vegetation if this vegetation were treated with an herbicide or managed by the addition of Triploid Grass Carp." -pg 16 (USF, 2009).

DISSOLVED OXYGEN:

A multi-probe which measures water temperature, ph level, dissolved oxygen, percent dissolved oxygen and turbidity was used to measure the productivity of the system. Based on their findings, it was determined that the reservoir exhibited properties of a eutrophic system; high DO on the surface, and a decreasing DO with depth. "The DO and pH levels indicate a productive system with algal photosynthesis producing high levels of oxygen and high pH (acid condition). The later indicates removal of carbon from the water which shifts the system to a less alkaline system." -pg 16 (USF, 2009).

Figure XX: Lake Medard Bathymetric Map (USF, 2009)

Case Study - Sunflower H2O Recreation Demand

Background Information

The Sunflower H2O Coalition is a study which evaluated existing and future bodies of water (both surface and ground water supplies) within the H20 Coalition region. Specifically, the study poses the question, "what would be the recreation demand opportunity for a large reservoir in this area?" The study focuses on three proposed lakes, Turkey Creek, East Branch Little Sandy Creek, and Elm Creek (Sunflower H2O Coalition, 2013).

Comprehensive Outdoor Recreation Plan (SCORP)

The State of Kansas Comprehensive Outdoor Recreation Plan (SCORP) was used to take an inventory of outdoor recreational activities available in the area, as well as to list challenges, goals and priorities to focus on for the next five years. They were able to conclude that Elm Creek Reservoir site could expand on three different goals defined in SCORP (Sunflower H2O Coalition, 2013).

- Expand efforts to develop and conduct outdoor recreation skills clinics and education programs, in particularly urban areas.
- Continue and expand urban nature centers, nature trails and wildlife and wildflower viewing opportunities for urban residents.
- Develop and publish youth-oriented information and education materials related to outdoor recreation pursuits.

Database for Outdoor Recreation Opportunities:

Along with using SCORP to identify recreation goals for the site, the Database for Outdoor Recreation Opportunities, created by KDWPT, assisted the Sunflower H2O Coalition in taking an inventory for existing recreation supply in the area. A 50-mile radius was used for this supplemental recreation opportunities inventory, but an 80-mile radius was used for other portions of the study (Sunflower H2O Coalition, 2013).

Risk and Uncertainty

Lake Levels:

The control of lake levels is often influenced by outside sources such as regional drought/ flood conditions and irrigation. Evidence shows that there is a connection between lake levels and visitation. One theory to explain this is that the aesthetic value of the lake is lost when the water is too high or too low. A physical variable affected by changing lake levels is boat ramp safety. When a lake has dropped 15' from conservation pool, it is no longer safe to launch a boat from a ramp, and lake management may shut down the ramps, preventing boaters from using the lake (Sunflower H2O Coalition, 2013).

Nutrients and Total Dissolved Solids:

Blue-green algae blooms also affect visitation. While some may avoid lakes with excessive blooms because of the lower aesthetic value, often lakes with excessive algae blooms are forced to shut down the lake due to safety/health reasons (Sunflower H2O Coalition, 2013).

Location & Access:

Terrain and access to recreational space is often overlooked in reservoir site design. A majority of people enjoy easy access, and developed recreational activities, but some people desire a more secluded, or rough terrain for activities such as hunting grounds, hiking trails, and tough-to-find fishing spots. An ideal reservoir would be able to accommodate people looking for both kinds of activities. A strategy suggested by the Sunflower Coalition is to allow private development around parts of the lake which are near the highway and reserve the land farther from the main roads for the secluded and rough terrain activities (Sunflower H2O Coalition, 2013).

Demographic Variables

Studying the demographics of an area can give insight to what sort of recreational activities the local community desire.

Median Age:

"Median age also gives insight to the types of activities that will be in higher demand" (U.S. Army Corps of Engineers, 2013). Two different considerations measured in this study for median age include visitation numbers, and type of recreation activity used. Older populations, for example, tend to participate in higher valued activities such as boating, sailing and resort amenities.

Income:

Understanding the average incomes of local communities will help predict how many high-value activity participants should be anticipated to visit a site.

Race:

Understanding racial recreational trends can help influence recreational amenity design. For example, studies show that Hispanic visitors tend to participate in activities in large groups or families.

Education:

Education was not measured for this study, but opportunities for education at reservoirs should not be overlooked. Programs which encourage youth to become involved in outdoor recreational activities could be used, especially to align with the Kansas SCORP (Sunflower H2O Coalition, 2013).

Site Visitation

Site visitation was broken down into two main groups for this study: Day use, and Camp. Both these categories include all activities which were likely to take place at Elm Creek Reservoir. The study suggests that more recreational amenities such as shared hard surface trails, playground equipment, open space, free ride area, shared use soft surface trails, hiking trails, waterfront and equestrian trails could also be implemented to improve the site's recreational function.

Project Variables:

Demographic Variables:

Population:	2010 county population
Income:	2010 per capita income
Total cost:	Travel cost of recreation user.
Population Under 18:	Percentage of population under eighteen or percent of total population minus population over eighteen population (2010 population)
Minority:	Percentage of minority population per county
Substitute index:	Sum of the lake level over distance indexes which apply to all substitute lakes.

Project Variables:

Surface Acres:	Reservoir surface acres covered at normal level
Boat Lanes:	Boat launching lanes
Beaches:	Public swimming beaches and swimming areas
Marinas:	Description being a 150 slip marina. A 300 slip marina would count as 2
Docks:	Public courtesy docks, could include heated fishing docks
Parking:	Actual parking spaces, at boat launching facilities
Picnic:	Public picnic tables
Camps:	Primitive camping site, adjustment of 1.5 for a improved camped site
TDS:	Total dissolved solids
Species:	Number of sought after sport fish species
CV:	Coefficient of variation in lake level variations
Percent Full:	A variable that captures the extreme variability of lake levels

User Groups by Demographics

A key takeaway from this study is that user groups and activities can be selected based on the demographic information of a region.

Younger Age Groups:

The younger age groups tend to gravitate towards activities such as swimming or hiking. Infrastructure such as swim beaches and hiking trails could assist a marketing campaign targeting younger groups.

Median Age Groups:

Identifying median age groups will often promote the most successful marketing strategies for promoting reservoir visitation.

Lower Income Groups:

Traditionally, lower income groups tend to partake in lake recreation less frequently. However, providing infrastructure such as public fishing docks or areas can increase visitation numbers for this group.

Higher Income Groups:

Site visitors with higher income tend to prefer activities such as fishing tournaments, and enjoy marinas for boat rental or storage.

Site User Groups

The study identified a set of "User Groups" for the Elm Creek Reservoir based on the regional demographics. The users are categorized by activity to assist management in determining the type and quantity of amenities to be added (Sunflower H2O Coalition, 2013).

Site User Groups:

- Hunter/Fisherman
- Primitive campers
- Swimmers
- Hikers
- Equestrian Trail users
- Recreation Vehicle (RV) site users
- House boaters
- Sailors
- Conferences
- Off road recreational vehicle riding
- Boaters
- Bird and Wildlife watchers

User Groups Amenity Requirements

Hunters/Fishermen:

There are many practices which could attract both hunters and fisherman. A seasonal pool or fish stocking program could assist the fish spawn process. It could also provide space to plant mill or winter crops which attract wildlife for hunters. Additionally, fisherman need a boat ramp with 2-3 lanes. If tournaments are expected to take place, an area with two, ADA compliant boat ramps, a fish weighing area, restrooms, courtesy docks and parking are necessary. Ideally, this area is in a cove where fishermen are protected from wind and can wait until their number is called (Sunflower H2O Coalition, 2013).

Primitive Camper:

Attracting primitive campers is very inexpensive, and easy to do. Providing flat ground for camps spots, and a restroom with water for every 10-20 camp sites are the only requirements to fill camp sites (Sunflower H2O Coalition, 2013).

Swimmers:

Swim beaches often require constant maintenance, and a steady supply of capital for cleaning and refilling annually. Maintenance costs can be lowered by selecting a site with a gradual incline and a low rate of sedimentation. Outside of maintenance, the swim area also requires parking, restrooms and water. The restrooms and water can be shared with a camp site (Sunflower H2O Coalition, 2013).

Hikers:

While hikers and distance runners don't require much capital or maintenance, they do need a large space. Often local running, hiking, or biking groups will offer to maintain and/or build their own trails if they are given the space and a permit to do so (Sunflower H2O Coalition, 2013).

Equestrian trail user:

Equestrian trails are generally considered to have a low impact on the site, but they are heavily used and could have an impact on the landscape (Sunflower H2O Coalition, 2013).

Recreational vehicle (RV) site user:

RV sites typically need about double the space that primitive campers use, as well as larger roads, turning areas and parking spaces. Dump site facilities are necessary as well (Sunflower H2O Coalition, 2013).

House boater:

House boaters require a protective cove with a marina or a slip, which could be funded by a partnership with a private group. Additional anchoring sites around the lake should also be considered. House boaters are typically attracted to lakes with good water quality and clarity (Sunflower H2O Coalition, 2013).

Recreational Sailor:

Sailors have little impact on other recreation groups outside of the potential for crowding. They do require a marina and slip (Sunflower H2O Coalition, 2013).

Conferences:

Conference facility users typically have a higher regional purchasing coefficient (Sunflower H2O Coalition, 2013).

Off road recreation vehicles:

Off road vehicles require trails and a large space to operate. They do create loud noise and can be destructive to the landscape. Placement of off-road vehicle trails should be looked at carefully in the site design (Sunflower H2O Coalition, 2013).

Problem-Sollution Case Studies

Washington State Fishing Lake (KS)

Washington State Fishing Lake, a reservoir under the observation of Ely Sprenkle, had excessively high numbers of small, stunted crappie in 2012 (Sprenkle 2013). With so many stunted fish of the same species, the mature crappie population plummeted, as there was too much competition for the same food source (Sprenkle 2013). With plenty of natural predators in the area, it was determined that the issue was not actually an imbalance in the fish community, but the lack of visibility due to consistent muddy conditions in the reservoir prevented the predators from being able to find the smaller fish (Sprenkle 2013). Placing a new pipe in a silt pond upstream of Washington SFL allowed silt and debris to settle quicker, clearing up conditions (Sprenkle 2013). As a result, the crappie population was restored to normal conditions, and the mature crappie population began to grow (Sprenkle 2014).

Centralia Lake (KS)

Centralia fishing lake, another reservoir in the Manhattan, KS region, recorded astonishing numbers of large crappie and saugeye in 2017. The numbers didn't get to be as high as they were by luck, but rather by site analysis and multiple restoration efforts. High numbers of carp had increased lake turbidity, which caused debris to stain the reservoir, limiting the vision of predator species. With limited vision, the predator fish were unable to feed on smaller species, resulting in high numbers of small, stunted crappie.

The problem was addressed by planting water willow in shallow areas where carp feed. The water willow effectively contained the debris stirred up by the carp and cleared up the water in the rest of the reservoir. Clearer water made it easier for natural predator fish like saugeye to hunt small crappie. Within 2 years, the fish ecosystem was once again well balanced, with plenty of healthy crappie and saugeye in the reservoir. For comparison, Centralia lake had the highest numbers of 8-inch, 10-inch and greater than 12-inch crappie caught than any other lake in the region. The saugeye population was a new lake record, with nearly 50% of fish being over the 18-inch minimum length limit (Sprenkle 2018).

Lake Washington (WA)

Juanita Beach Park in Kirkland Washington is a project that focused on improving water quality in Lake Washington to allow for swimming and fishing. Taken on by J.A. Brennan Associates, the project implemented site improvements which eliminated parking lot runoff, minimized Canadian geese presence, and restored wetlands to trap sediment before entering the water. While ridding the park of Canadian geese may seem like a step in the wrong direction, the design team noted that very few people used the grass areas adjacent to the water, because they were littered with goose droppings. By building concrete seawalls near the water, the view of the grass is blocked from the lake, deterring most geese from moving up onto land. This is an example where human recreation needs outweigh ecological needs. While the lake is still a common stopping ground for Canadian geese, it's now also a gathering space for people to fish, swim, and play (Beard 2011).

Case Study - Table Rock Lake Fish Habitat Restoration

Background Information

A fish habitat improvement project for Table Rock Lake, started by the Missouri Department of Conservation, used focus groups comprised of anglers and guides who frequently fish the lake to determine where to place improved fish habitat structures. The goal of the project was to raise awareness about the decline in native fish species and restore healthy fish communities across the nation by using Table Rock Lake as a precedent for habitat restoration (MDC, 2014).

Fish Habitat

Materials:

All materials used for habitat construction were natural and posed no threat to water quality, the dam infrastructure, or aquatic life. The trees used for habitat creation were gathered from the reservoir site and shoreline. This cut down on costs bringing trees in from an off-site location. All the trees taken from the site were already scheduled for removal. Typically, the trees would have been mulched or burned, so recycling them for habitat creation was a very productive use for the materials (MDC, 2014).

Hardwood Trees:

Hardwood trees were used mostly at a depth of 10-30 feet, which allowed fish to use them at different times of the year. Large hardwood trees were placed deeper and stand taller in the water column. These deeper trees provide habitat for fish which that use wider ranges of depth throughout the year, and great habitat for sport fish such as bass and crappie which retreat to lower depths in the colder months (MDC, 2014).

Cedar Trees:

Cedar trees are very commonly used by biologists for fish habitat restoration, and the Ozark highlands is home to an abundance of Cedars. Cedar trees can provide very complex habitat for a wide range of fish species and are used at various depths (MDC, 2014).

Stumps:

Stump fields were created using the root balls of hardwood trees. Because stumps could pose as boating hazards during low water, they were installed at a minimum depth of 10 ft or deeper. Buoys were used to mark the location of stumps for fisherman and boaters (MDC, 2014).

Rocks:

Rocks had the same depth requirement as stumps (10 ft or deeper) and provided shallow water structure near the bank for sport fish such as bass to relate to during the warmer months. Since most of the substrate along the banks of the lake was loose cobble, rock piles were a perfect solution to provide habitat and stabilize the bank material for better spawning habitat (MDC, 2014).

Habitat Installation

Vehicles:

The majority of the habitats installed were done so with pontoon style boats with hydraulic platforms which could safely drop habitat structures into the lake. Excavators were used to collect trees and large rocks from the reservoir site, and then place them on the boats for installation (MDC, 2014).

Anchors:

Most of the habitat installed was comprised of wood, which naturally floats. This issue was solved by using concrete anchors in the form of concrete cinder blocks with anchor handles (MDC, 2014).

Appendix C:
Reservoir Sonar Scans

This appendix contains sonar scans of Rush Creek in Milford Reservoir which were used when analyzing the reservoir's open water fish habitat and bank fish habitat. All scans of Rush Creek were provided courtesy of Jordan Beck. In addition, this appendix contains sonar scans of other reservoirs which were provided by Zach Vielhauer, Josh Flynn and Will Andrie. These scans were used in combination with the scans take by Jordan Beck to create diagrams of open water habitat and bank habitat.

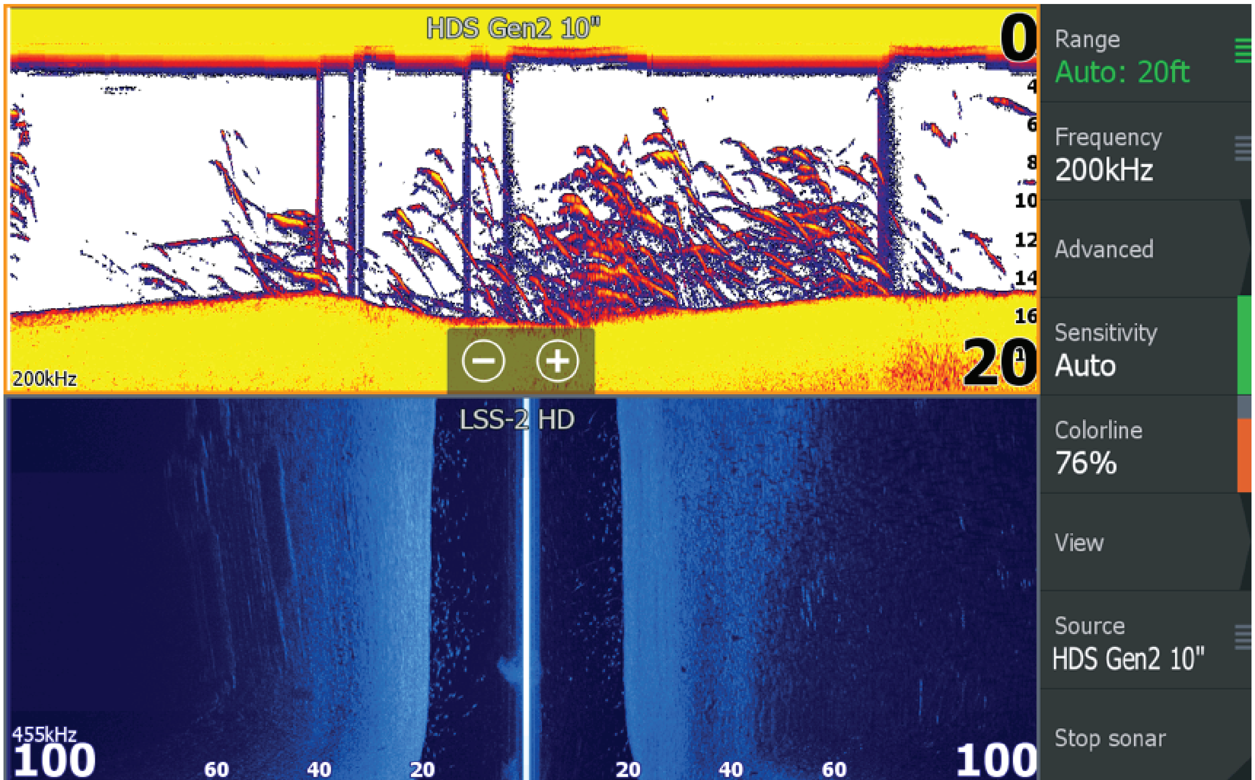


Figure 48: Rush Creek sonar scan, courtesy of Jordan Beck (2020)

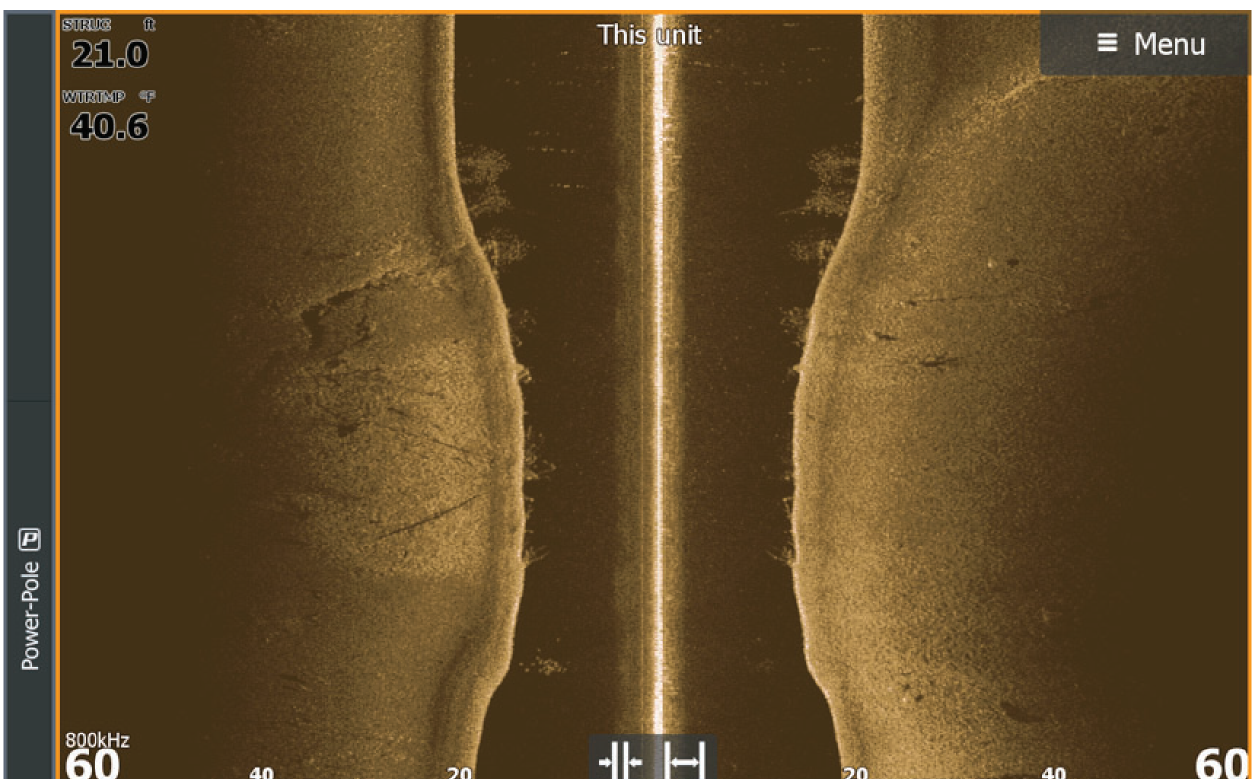


Figure 49: Rush Creek sonar scan, courtesy of Jordan Beck (2020)

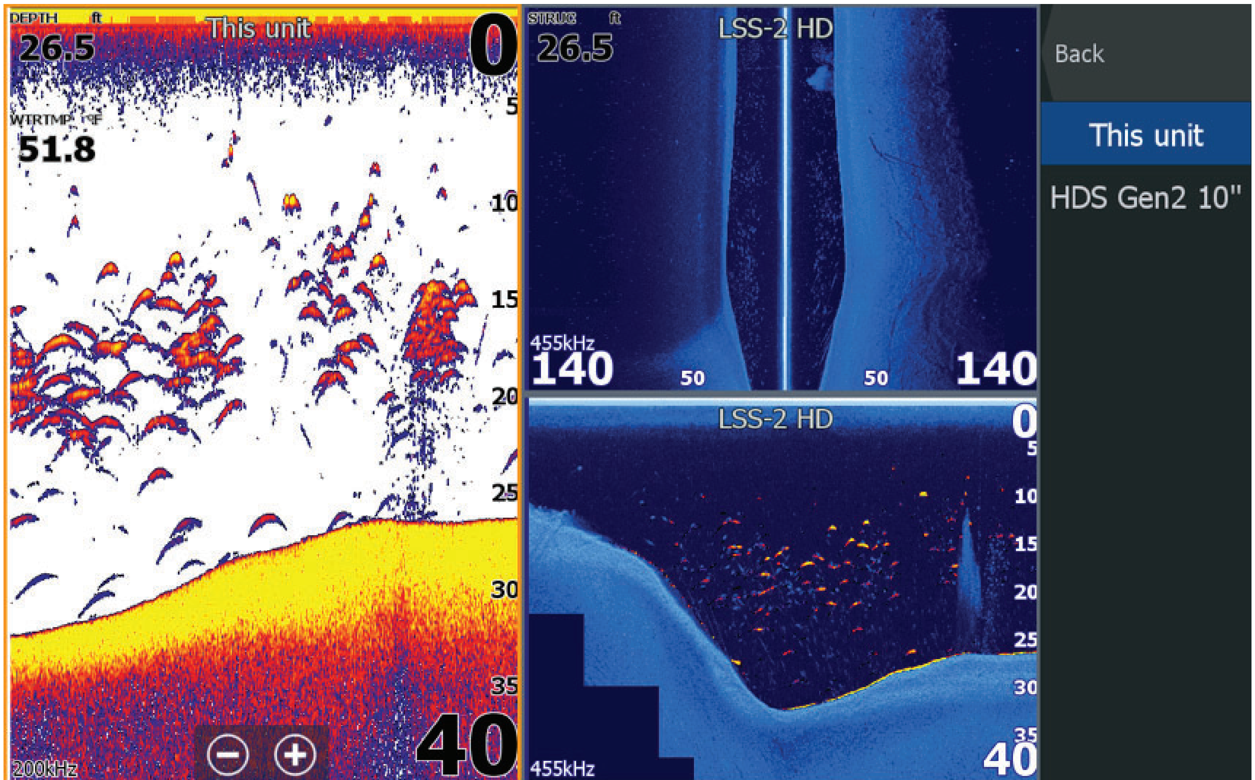


Figure 50: Rush Creek sonar scan, courtesy of Jordan Beck (2020)

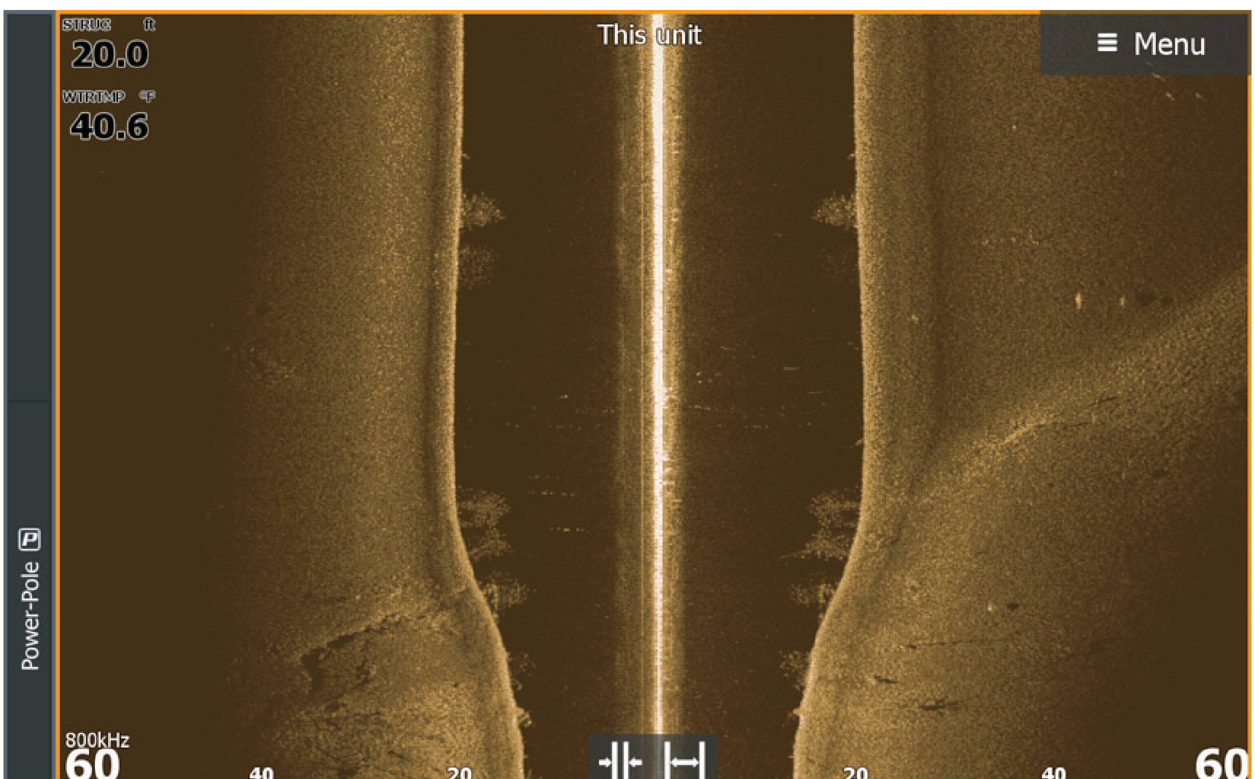


Figure 51: Rush Creek sonar scan, courtesy of Jordan Beck (2020)

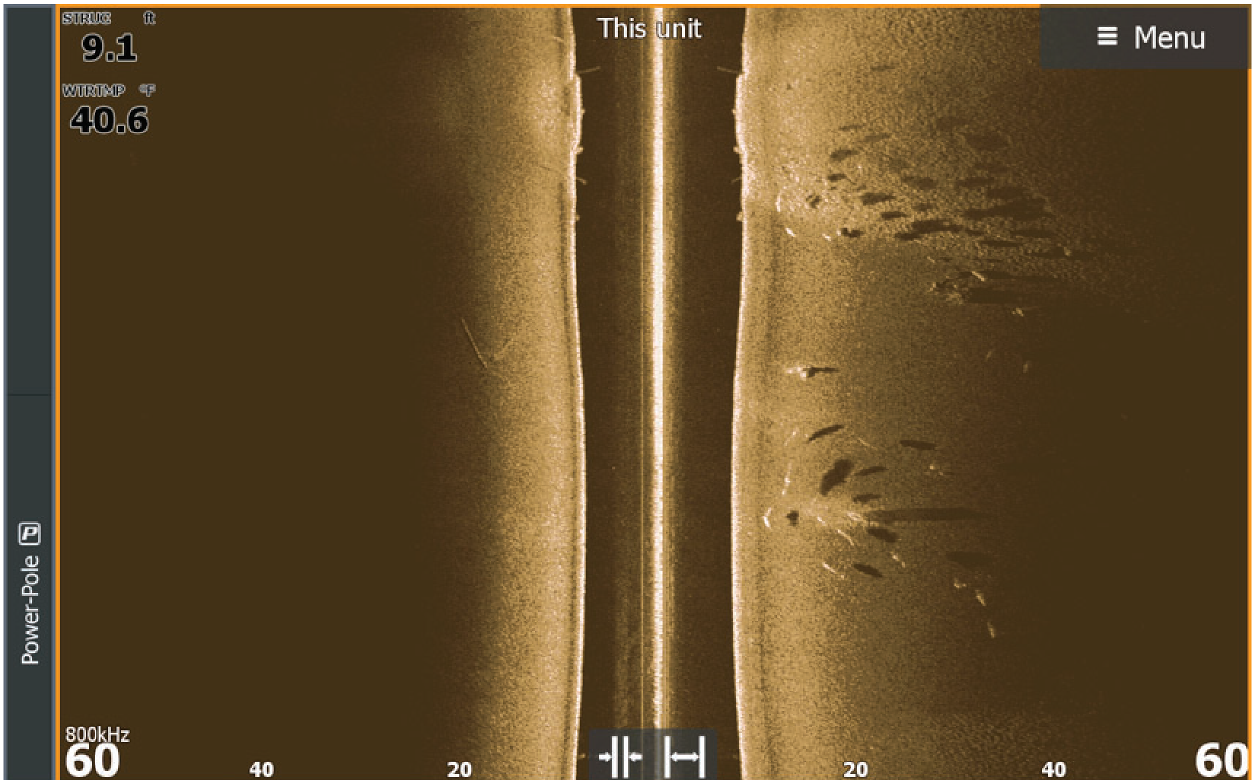


Figure 52: Rush Creek sonar scan, courtesy of Jordan Beck (2020)

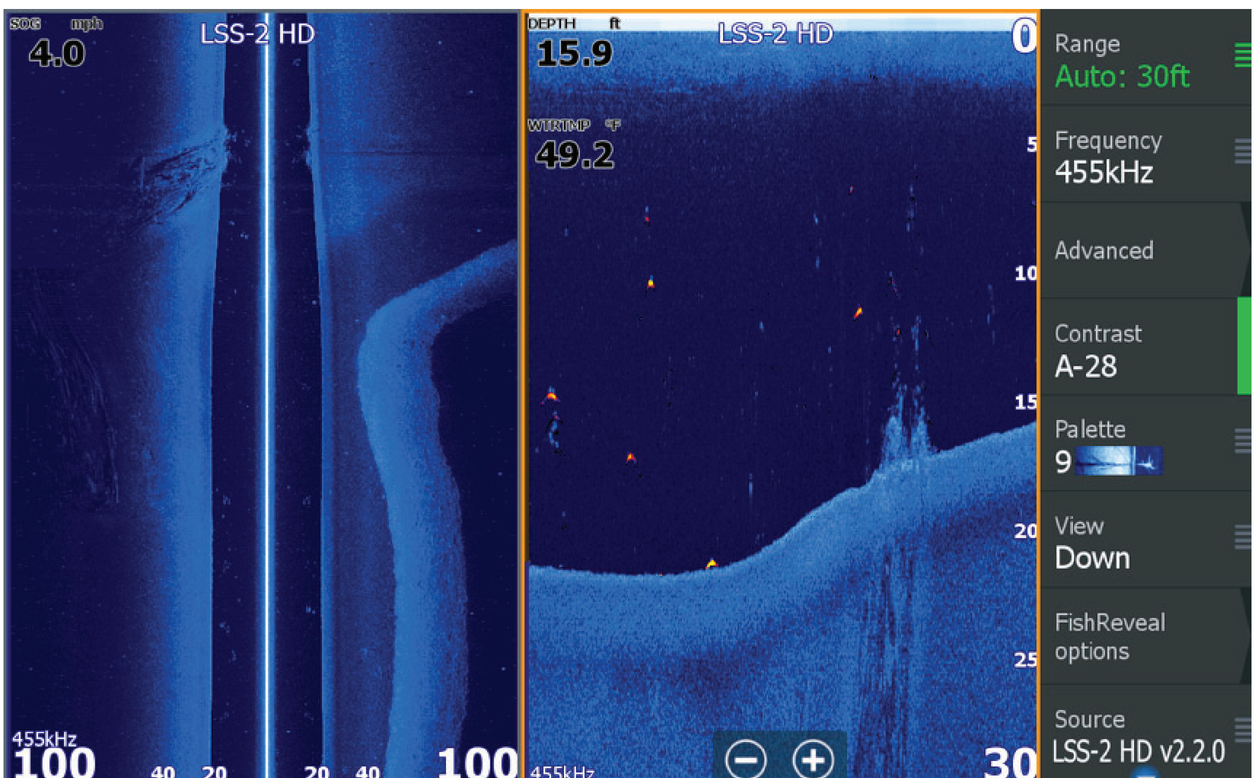


Figure 53: Rush Creek sonar scan, courtesy of Jordan Beck (2020)

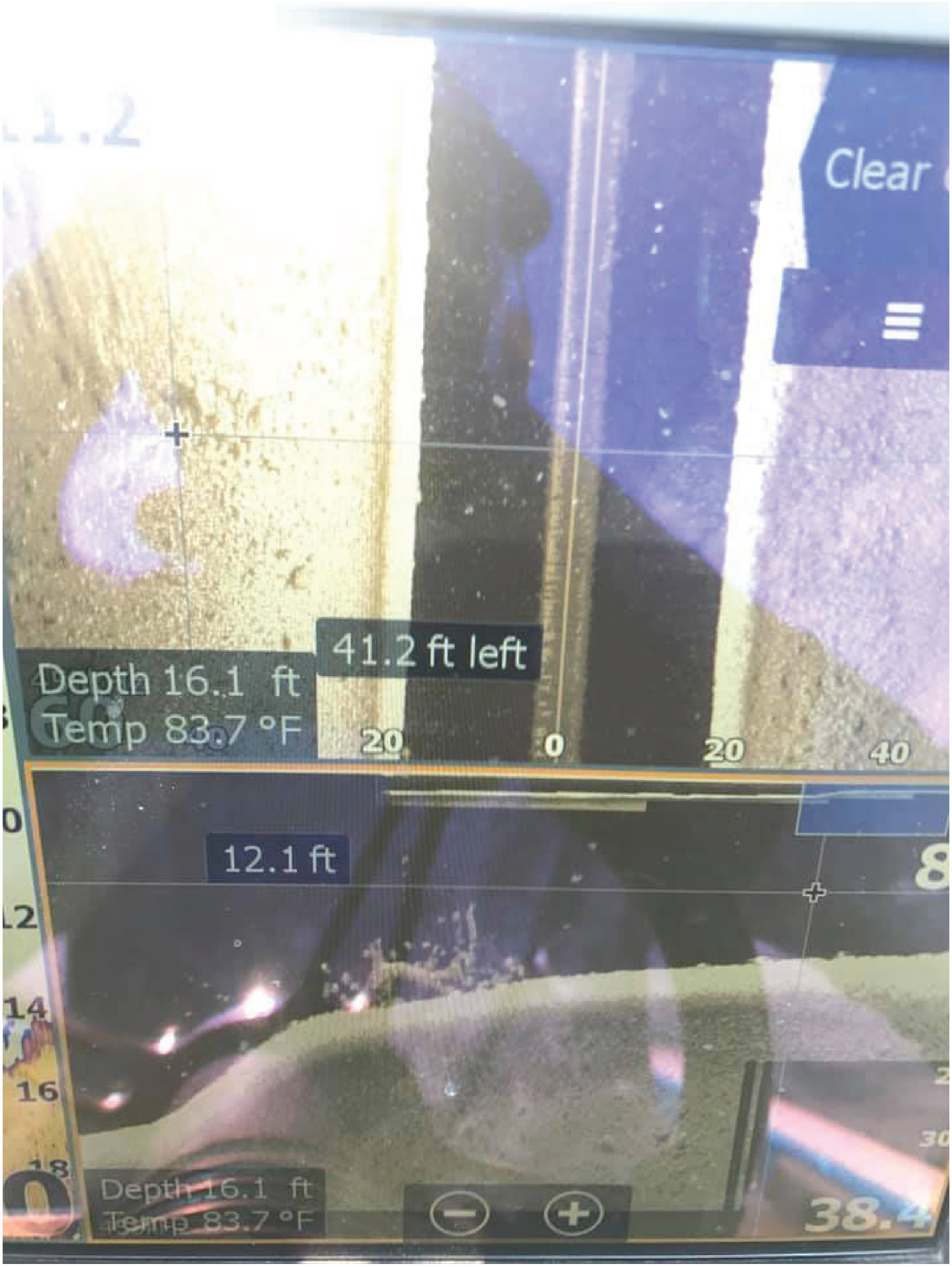


Figure 54: Reservoir sonar scan, courtesy of Will Andrie (2020)

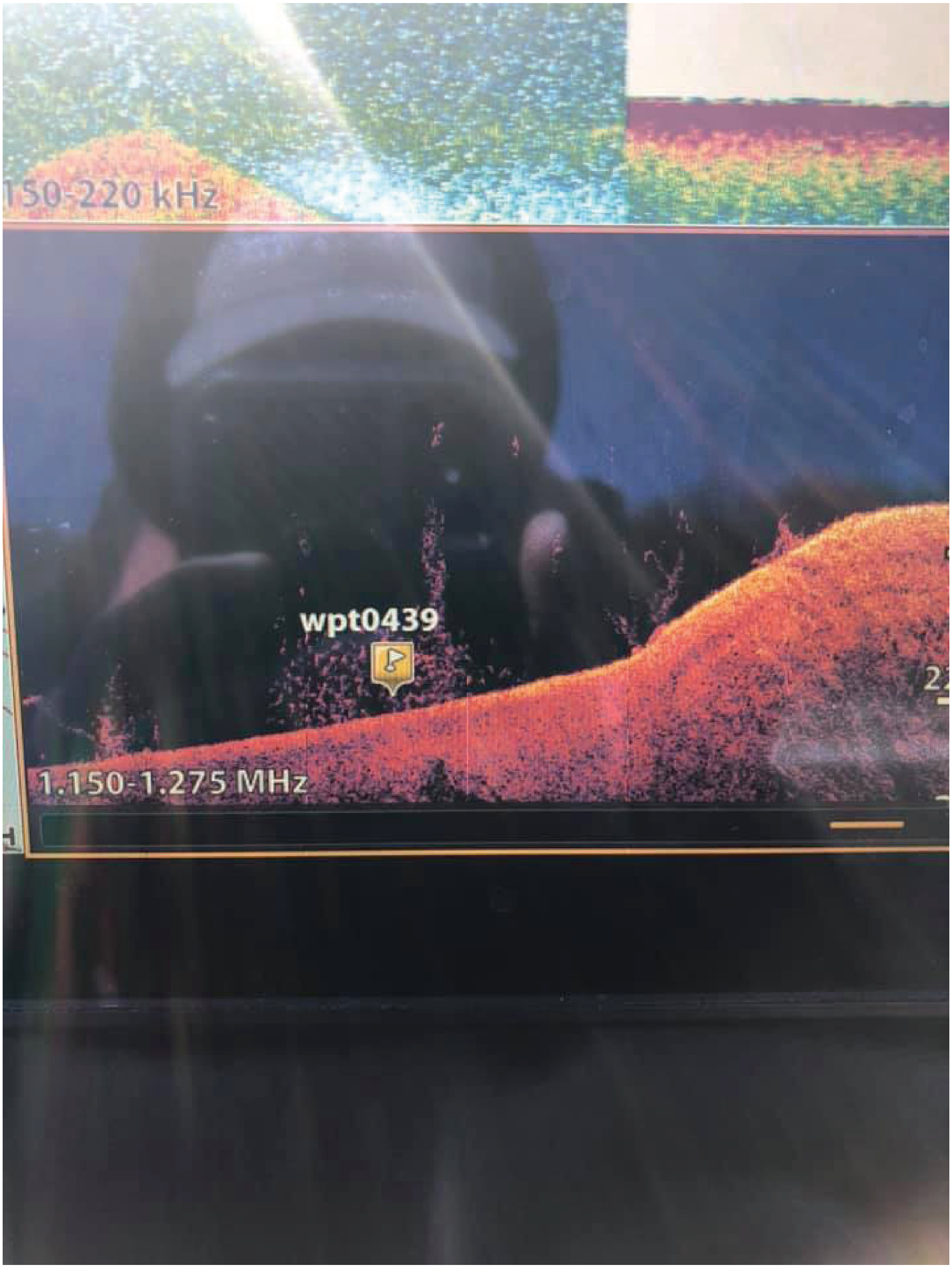


Figure 55: Reservoir sonar scan, courtesy of Zach Vielhauer (2020)

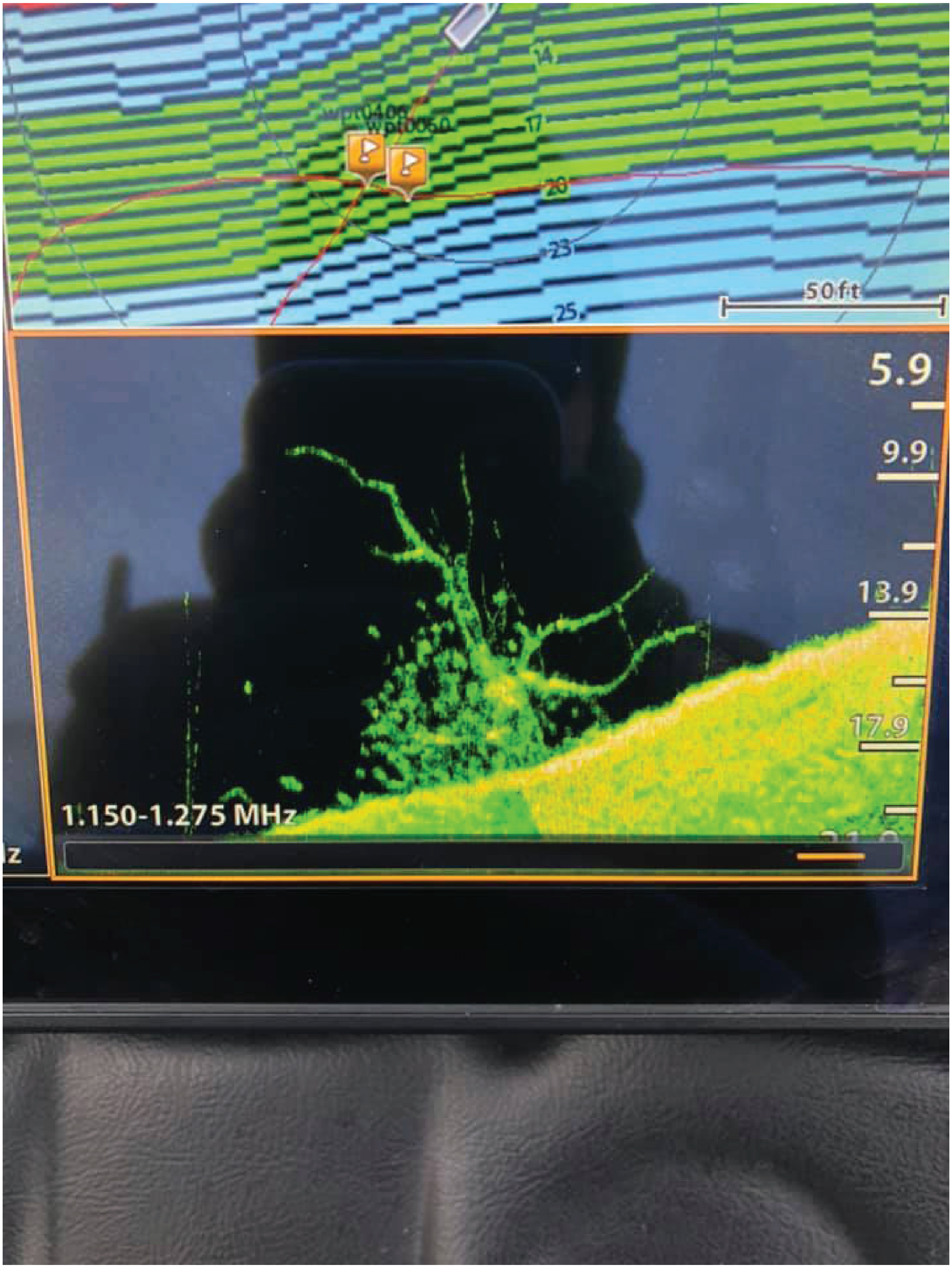


Figure 56: Reservoir sonar scan, courtesy of Zach Vielhauer (2020)

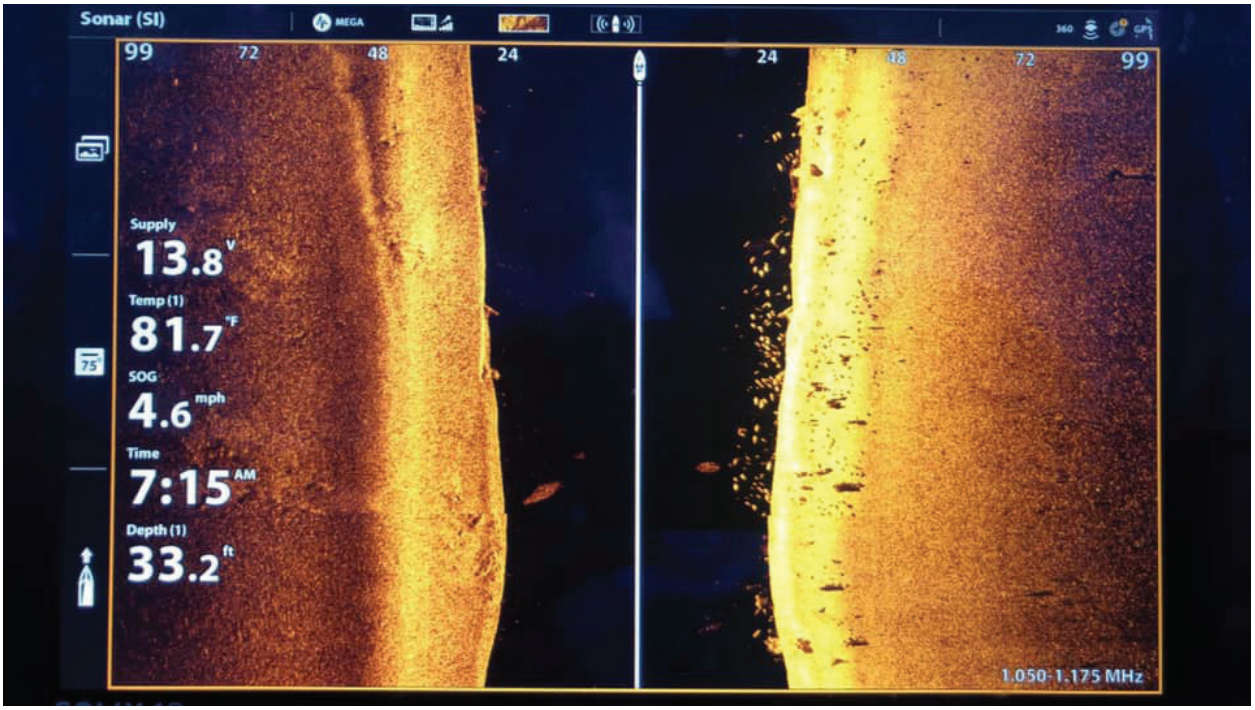


Figure 57: Reservoir sonar scan, courtesy of Josh Flynn (2020)