Reservoir Reserve Consultants
324 Wendt Commons
215 North Randall Avenue
Madison, WI 53715

April 6th, 2021

Ms. Lianna Spencer, Lake Manager
2346 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

RE: 100% Preliminary Design Report for Engineering Services for Watershed Improvements

Dear Ms. Spencer,

Reservoir Reserve Consultants (RRC) is pleased to present the enclosed preliminary design report for the Lake Ripley Management District Flood and Nutrient Control project. The project team at RRC values the opportunity to work with the Lake Ripley Management District and is eager to preserve and enhance Lake Ripley's water quality, wildlife communities, and ecological health.

In developing this preliminary report, our team has compiled in-depth research regarding the purpose and scope of the project, as well as existing conditions and project constraints. In addition, a sustainability impact assessment has been incorporated, which focuses on the triple bottom line: economic, environmental, and social sustainability. Furthermore, a realistic opinion of probable costs and project schedule with critical path items have been strategized to meet project requirements. Three alternative solutions are detailed within the report: Stormwater Management, Best Management Practices, and Inlet Stream Restoration. Each alternative solution details technically feasible designs, as well as a modeling analysis utilizing modern computer software such as WinSLAMM. Through combined efforts, RRC has provided a final recommendation to preserve and enhance Lake Ripley and its surrounding watershed.

The diversity of expertise within RRC has allowed for discipline-specific design services in construction, environmental, geological, hydraulic, and hydrological engineering. With this, our team would like to express its commitment in taking on the Lake Ripley project alongside the Lake Ripley Management District.

In brief, RRC looks forward to continuing working with the Lake Ripley Management District to provide a desirable solution. Please do not hesitate to reach out if you have any additional questions or concerns. You can contact me via email at cjohnson72@wisc.edu or give me a call at 715-307-4394.

Sincerely,

Carson Johnson
cjohnson72@wisc.edu | 715-307-4394
Project Manager/Construction Engineer
Reservoir Reserve Consultants

RRC

Lake Ripley
Management
District

100% Preliminary Design Report

Tuesday, April 6th, 2021

Team 7
CEE 578
Spring 2021

Disclaimer

The concepts, drawings and written materials provided here were prepared by students in the Department of Civil & Environmental Engineering at the University of Wisconsin-Madison as an activity in the course Civ Engr 578 – Senior Capstone Design/GLE 479 – Geological Engineering Design. These do not represent the work products of licensed Professional Engineers. These are not for construction purposes.

Executive Summary

To: Lake Ripley Management District
From: Reservoir Reserve Consultants
Date: April 6th, 2021
RE: Lake Ripley Management District Flood and Nutrient Control – 100% Preliminary Design Report

Project Background

Reservoir Reserve Consultants (RRC) evaluated three designs for the Lake Ripley Management District (LRMD). This project provided designs tailored to inlet restoration, land usage/wetland restoration, and stormwater management. These designs will help to enhance the water quality of Lake Ripley, maintain good health of the native-aquatic species, and verify that the community's recreational needs are prioritized.

The purpose of the Lake Ripley project is to verify that the water quality is restored to acceptable levels corresponding with the Wisconsin DNR requirements, as well as to help preserve the native aquatic and vegetative species. Located near Cambridge, Wisconsin, Lake Ripley covers 420 acres with 2.5 acres of a dredged inlet channel. The total watershed area is 4,700 acres. *Figure 1* depicts Lake Ripley's watershed boundary, along with the sole inlet tributary stream. There are currently 524 acres of wetland in the Lake Ripley watershed, 167 of which were restored by the LRMD. The primary concern of the LRMD is to restore the public use of the lake. In recent years, the levels of Phosphorus concentrations have risen in the lake, with recent Trophic State Index (TSI) values frequently in the 50s. TSI is a water quality index ranging from 1-100, with values less than 50 being desirable for most lakes. Values exceeding 50 imply high Phosphorus, high chlorophyll, and poor water clarity. Phosphorus levels in the lake currently range from 30-200 µg/L, which exceeds the DNR standard of 30 µg/L.

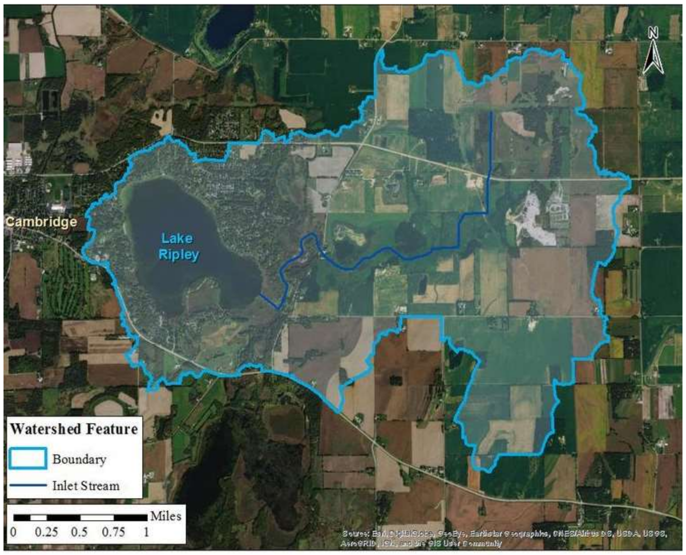


Figure 1. Map of Lake Ripley, featuring the watershed boundary and inlet stream.

RRC is proposing an approach with the triple bottom line as the number one priority. RRC's proposed designs have a systematic approach that help improve the quality of water, with specific engineered processes that are feasible. The first preliminary design is located within the inlet tributary stream itself, consisting of Beaver Dam Analogs (BDAs). The second design is focuses land usage along the inlet, consisting of Best Management Practices (BMPs). The third preliminary design is centered around controlling stormwater runoff, with the construction of a stormwater pond. Since the LRMD only manages the defined watershed area of Lake Ripely, it is imperative that the designs will fall within this specified area.

Project Constraints

For this project to be successfully completed, several criteria need to be met. The proposed designs all need to have the successful function of decreasing phosphorus from entering the lake. Additionally, each design must consider the maintenance required to implement the design on site. With this, according to the LRMD, the final recommendation must be located along the sole inlet tributary stream of Lake Ripley. Finally, the design and construction of the alternatives must fall within the $2,000,000 budget, which was set by the Lake Ripley Management District. Lastly, the solutions must fall within the project constraints, while at the same time considering the triple bottom line. RRC has evaluated possible constraints for the Lake Ripley project within the following categories: economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability. *Table 1* summarizes these project constraints with a short description within each of the aforementioned categories.

Table 1. Summary of project constraints associated with each specified topic.

Topics	Constraints
Economic	The total budget for all activities associated with this project is $2,000,000. This project qualifies for state grants that are awarded through the DNR, however, RRC aims to stay within the budget.
Environmental	The current phosphorus levels that enter Lake Ripley are 39 µg/L, which exceeds the DNR standard of 30 µg/L. The higher the concentration of Phosphorus, the greater the likelihood of the lake experiencing eutrophication, which results in toxic blue-green algal blooms.
Social	Lake Ripley is utilized not only by the community of Cambridge, but also a large, diverse tourist community, specifically for recreational use such as boating and fishing. Mitigating the effects of eutrophication is, therefore, critical to keeping the lake functional for human use.
Political	Lake Ripley is surrounded by private farmland, and RRC does not have the authority to tell the farmers what to do. RRC is only able to suggest BMPs and will not be in direct contact with the local farmers, per LRMD's request.
Ethical	Lake Ripley is currently above DNR standards of acceptable Phosphorus levels (30 µg/L). This calls for implementation of a systematic design that would lower the Phosphorus to an acceptable level.
Health and Safety	The proposed sites within the watershed are located near residential areas. RRC has kept human health and safety implications in mind as the design is constructed during the construction phase of the project. Additionally, RRC will ensure a safe work environment followed by the standards set by the Occupational Safety and Health Administration.
Manufacturability	The proposed sites for each of the three designs are accessible for construction development, and site development/initial grading will proceed following the site logistics plan. Minimal site disturbance will be enforced to preserve the natural features that already exist within the watershed.
Sustainability	RRC has designed a solution that enhances the environmental, social, and economic sustainability. RRC has minimized the environmental alterations and keep the communities natural appeal to stay as original as possible. Additionally, all the designs will require the use of native vegetative species that are recommended by the LRMD.

Design Alternatives

Inlet Restoration: Beaver Dam Analogs

The first alternative design for the Lake Ripley project focuses on inlet restoration, specifically with the implementation of Beaver Dam Analogs (BDAs). BDAs are man-made structures placed into streams to mimic a natural beaver dam. These structures are meant to restore streams by slowing the water velocity and allowing suspended particles to settle during large storm events with increased runoff. They also divert flows which forces the stream to cut into the banks, allowing for natural remeandering of the stream. The dams also capture sediment, such as sediment Phosphorus, flowing in the inlet stream, and this reduction of sediment can improve the trophic state index (TSI) of the water body the inlet is entering. BDAs are constructed by putting several wooden fence posts across the width of the stream and using branches and brush to fill the spaces between posts. RRC has recommended the construction of (13) BDAs along the inlet tributary stream, with a general cross-sectional design shown in *Figure 2*. The quantity and locations of the BDAs were determined based off prior case studies, which places the structures in the most straight-line areas of the stream to force remeandering. Due to the diversion and slowing of the stream flow, there is a chance of minor flooding occurring around the BDAs. The wetlands surrounding the locations specified have been evaluated and deemed sufficient at controlling this excess water.

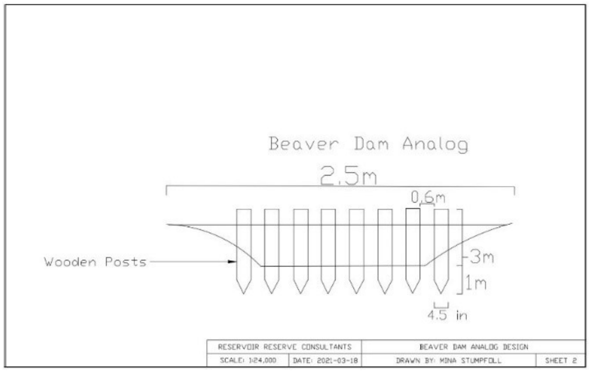


Figure 2. AutoCAD design of the proposed Beaver Dam Analog structure.

Land Usage/Wetland Restoration: Best Management Practices

The second alternative design is the introduction of best management practices (BMPs), which will target the wetland restoration along the inlet tributary stream. RRC is proposing implementation of three main BMPs: rain gardens, biofilters, and vegetative buffers. Rain gardens are gardens that include shrubs, grasses, and flowers in a small depression. The purpose of a raingarden is to temporarily hold run-off rainwater and to prevent this water from entering a larger body of water. RRC has proposed the design of (6) raingardens, with a foot of ponding depth, and six-inch depressions on both sides of the ponding area. The total area of each raingarden will be 10,890 square feet, or one-fourth of an acre. Next, biofilters are beneficial in pollution control, and capture and biologically degrade pollutants such as phosphorus, nitrogen, and heavy metals. RRC has designed (6) biofilters, with (4) located along Lake Ripley Road, and (2) off County 18. Each biofilter will be 91 square feet, with a grade of 6 inches. The final BMP being proposed are vegetative buffers. Vegetative buffers are strips of vegetation that can store sedimentation, prevent soil erosion, and collect stormwater run-off. RRC has designed (6) - one-acre strips along the inlet that flows into Lake Ripley. Locations and quantities of each BMP were generated based off modeling results in Appendix C. With this, raingardens were placed in high stormwater run-off areas, biofilters in close proximity to roads crossing the inlet, and vegetative buffers in straight-line areas.

Stormwater Management: Stormwater Retention Pond

The final alternative design is the construction of a stormwater retention pond. A stormwater retention pond contains a permanent pool of water with designed dimensions, inlets, outlets, and storage capacity, constructed to collect, detain, treat, and release stormwater runoff. The pond will reduce peak flows during storm events and improve water overall water quality through the reduction of total suspended solids (TSS) and Phosphorus. Additionally, the pond will slow the flow of water down, acting as a median before the stormwater enters nearby water sources, such as Lake Ripley. A conceptual cross-sectional drawing of the proposed stormwater retention pond is shown in *Figure 3.* The pond is to contain a sediment forebay constructed at the inlet, which helps isolate sediment deposition, facilitate maintenance, and increase overall pond effectiveness. The pond inlet consists of a sloped rip rap swale off the stream, leading to a 30” sloped inlet pipe. In addition to the permanent pool normal water level (NWL), the pond contains calculated NWLs and outflow orifices for the 24-hour - 2-year, 10-year, 50-year, and 100-year storm event.

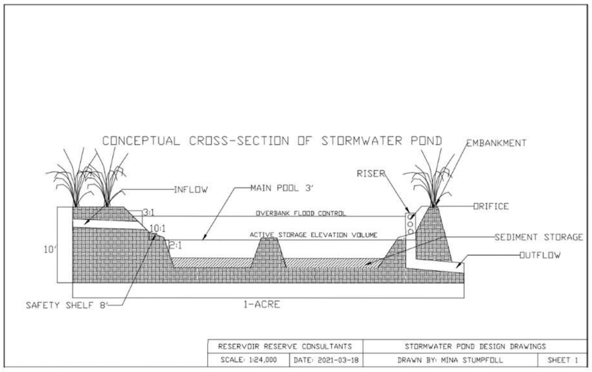
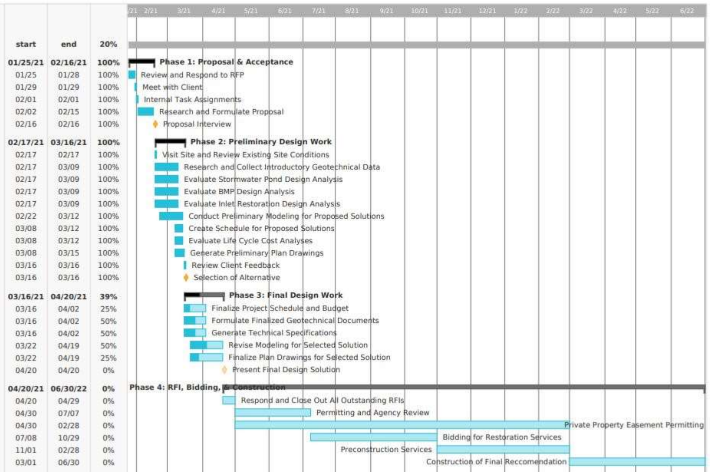


Figure 3. AutoCAD cross-sectional design of the proposed Stormwater Pond.

Project Cost and Schedule

RRC has proposed a project schedule consisting of four separate phases: Proposal & Acceptance, Preliminary Design Work, Final Design Work, and RFI, Bidding, & Construction. *Figure 4* depicts a Gantt chart detailing project tasks and milestones, along with durations and progress for the Lake Ripley project. While the final design is to be determined, the construction of selected alternative has been estimated to complete at the end of June 2022. In addition to the project schedule, RRC has formulated an opinion of probable cost utilizing a present worth life cycle cost analysis. The analysis is over a 20-year life span, and considers present worth capital, operations and maintenance (O&M), and replacement costs. *Table 2* below summarizes the opinion of probable cost for the analysis of each alternative. BDAs exhibited the lowest total present worth cost, followed by the stormwater pond and BMPs, respectively. In comparing the pond to BMPs, it is worth noting the BMPs have a significantly higher present worth O&M cost. The stormwater pond exhibits the highest present worth capital cost.



start	end	20%	
01/25/21	**02/16/21**	**100%**	**Phase 1: Proposal & Acceptance**
01/25	01/28	100%	Review and Respond to RFP
01/29	01/29	100%	Meet with Client
02/01	02/01	100%	Internal Task Assignments
02/02	02/15	100%	Research and Formulate Proposal
02/16	02/16	100%	Proposal Interview
02/17/21	**03/16/21**	**100%**	**Phase 2: Preliminary Design Work**
02/17	02/17	100%	Visit Site and Review Existing Site Conditions
02/17	03/09	100%	Research and Collect Introductory Geotechnical Data
02/17	03/09	100%	Evaluate Stormwater Pond Design Analysis
02/17	03/09	100%	Evaluate BMP Design Analysis
02/17	03/09	100%	Evaluate Inlet Restoration Design Analysis
02/22	03/12	100%	Conduct Preliminary Modeling for Proposed Solutions
03/08	03/12	100%	Create Schedule for Proposed Solutions
03/08	03/12	100%	Evaluate Life Cycle Cost Analyses
03/08	03/15	100%	Generate Preliminary Plan Drawings
03/16	03/16	100%	Review Client Feedback
03/16	03/16	100%	Selection of Alternative
03/16/21	**04/20/21**	**39%**	**Phase 3: Final Design Work**
03/16	04/02	25%	Finalize Project Schedule and Budget
03/16	04/02	50%	Formulate Finalized Geotechnical Documents
03/16	04/02	50%	Generate Technical Specifications
03/22	04/19	50%	Revise Modeling for Selected Solution
03/22	04/19	25%	Finalize Plan Drawings for Selected Solution
04/20	04/20	0%	Present Final Design Solution
04/20/21	**06/30/22**	**0%**	**Phase 4: RFI, Bidding, & Construction**
04/20	04/29	0%	Respond and Close Out All Outstanding RFIs
04/30	07/07	0%	Permitting and Agency Review
04/30	02/28	0%	Private Property Easement Permitting
07/08	10/29	0%	Bidding for Restoration Services
11/01	02/28	0%	Preconstruction Services
03/01	06/30	0%	Construction of Final Reccomendation

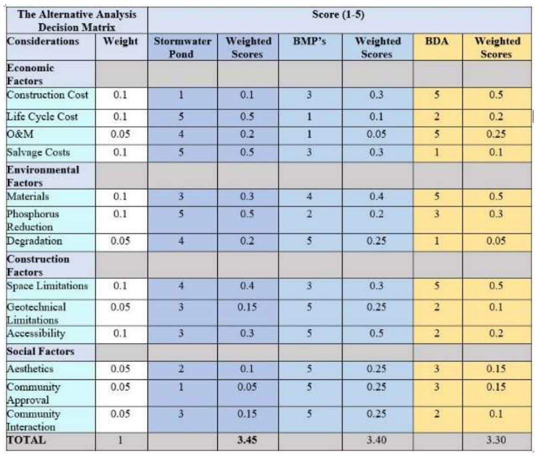
Figure 4. Gantt chart of proposed schedule for the Lake Ripley project.

Table 2. Summary of the present worth life cycle cost analysis for each alternative.

Alternatives	Beaver Dam Analogs	Best Management Practices	Stormwater Pond
PW Capital Costs	$9,600	$277,000	$500,000
PW O&M Costs	$16,400	$1,060,000	$95,000
PW Replacement Costs	$10,000	N/A	$14,000
Total PW Cost	$40,000	$1,337,000	$609,000

Design Considerations

To further evaluate each of the three alternatives, a decision matrix was created. The decision matrix is broken down into four main categories: economic factors, environmental factors, construction factors, and social factors. The summary table of the decision matrix is shown in *Figure 5*. The environmental factors that were considered include the materials being used for each design, the effectiveness of Phosphorus reduction, and the overall degradation of each design. For construction, each alternative was analyzed based on site excavation and how elaborate construction labor would be for earthwork. For hydraulic, each was analyzed based on how well the designs could capture and store stormwater run-off. For geological engineering, the subsurface profiles were analyzed to see how much of the wetland would be disturbed. Finally, for environmental engineering, the designs were analyzed to test efficiency at removing Phosphorus and sediment.



The Alternative Analysis Decision Matrix		Score (1-5)					
Considerations	**Weight**	**Stormwater Pond**	**Weighted Scores**	**BMP's**	**Weighted Scores**	**BDA**	**Weighted Scores**
Economic Factors							
Construction Cost	0.1	1	0.1	3	0.3	5	0.5
Life Cycle Cost	0.1	5	0.5	1	0.1	2	0.2
O&M	0.05	4	0.2	1	0.05	5	0.25
Salvage Costs	0.1	5	0.5	3	0.3	1	0.1
Environmental Factors							
Materials	0.1	3	0.3	4	0.4	5	0.5
Phosphorus Reduction	0.1	5	0.5	2	0.2	3	0.3
Degradation	0.05	4	0.2	5	0.25	1	0.05
Construction Factors							
Space Limitations	0.1	4	0.4	3	0.3	5	0.5
Geotechnical Limitations	0.05	3	0.15	5	0.25	2	0.1
Accessibility	0.1	3	0.3	5	0.5	2	0.2
Social Factors							
Aesthetics	0.05	2	0.1	5	0.25	3	0.15
Community Approval	0.05	1	0.05	5	0.25	3	0.15
Community Interaction	0.05	3	0.15	5	0.25	2	0.1
TOTAL	1		**3.45**		3.40		3.30

Figure 5. Decision matrix utilized in comparing each design alternative.

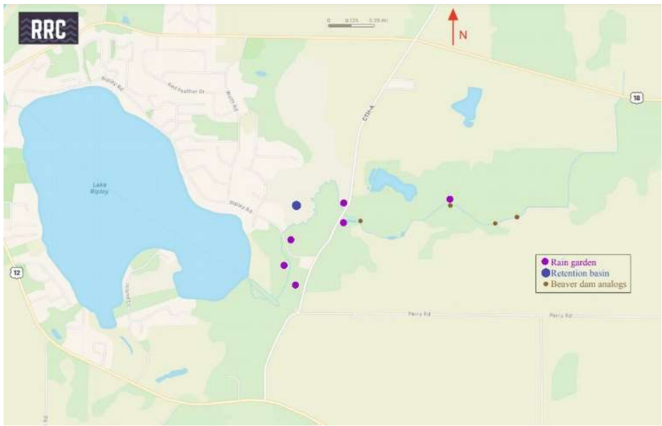


Figure 6. Map of all proposed locations for the modified final recommendation.

Final Recommendation

In conclusion, the final recommendation includes the Stormwater Pond alternative design in-full, as well as a reduced implementation of BMPs and BDAs. *Figure 6* depicts a map of all proposed locations for the modified final recommendation. The stormwater pond reduces the most Phosphorus out of all three designs, at a rate of 15.96%. The quantities of each of the BMP's and BDA's were modified and derived from the modeling in WinSLAMM. For the BMP's, each raingarden removed up to 0.27% of Phosphorus, with the proposed six BMP's removing 1.69%. When the BDA's were modeled individually, each removed up to 3.61%, with the average being 0.02%, of Phosphorus. This reduction of BMPs will consist of (6) – 1/4-acre rain gardens. The vegetative buffers and biofilters were removed due to negligible Phosphorus removal concentrations. The number of the raingardens and the locations of each in the modified final recommendation optimize reduction in nutrient loading because they are each placed in locations where excess run-off accumulates. In addition, instead of (13) BDAs, the final recommendation includes (4), which is based off the modeling as well as location. The Phosphorus reduced from the BDA's was quantified to 5.53%. This reduction of BDAs came about following a site assessment that was inspected by RRC as well as modeling each individual BDA to achieve a maximum reduction in Phosphorus. The four BDA's contribute to a maximum reduction of nutrient loading, which is quantified to be 21.53%. The final recommendation reduction value exceeds the project goal of a total annual Phosphorus loading reduction of at least 19%.

Table of Contents

List of Figures and Tables

Introduction (Purpose and Scope)

Introduction

Reservoir Reserve Consultants evaluated three designs for the Lake Ripley Management District (LRMD). The water quality of the lake is to be addressed with improvements on the inlet stream that flows into Lake Ripley, and the project overall considers stormwater, stream bank and instream improvements. The designs are also tailored to stormwater management, best management practices (BMPs), and inlet stream restoration. The three designs help to enhance the water quality of Lake Ripley, maintain good health of the native-aquatic species, while prioritizing the community's recreational needs. From the discussion with the LRMD on February 22nd, initial design parameters have been altered concerning acceptable locations of the three alternatives. The entirety of the 4.25-mile inlet stream is to be considered in addressing a solution for the excess nutrient loading in addition to the LRMD property.

Project Background

The purpose of the Lake Ripley project is to improve the water quality to meet the needs of the community and to enhance the habitat of the native aquatic and vegetative species. Located near Cambridge, Wisconsin, Lake Ripley covers 420 acres with 2.5 acres of a dredged inlet channel. The total watershed area is 4,700 acres. The Lake Ripley Management District, LRMD, has helped protect and effectively manage the lake since 1990. The primary concerns of the LRMD include the public use of the lake. The major threats to the lake are from polluted runoff from agricultural lands. In recent years, the levels of Phosphorus concentrations have risen in the lake at a concentration of 39.7 µg/L, which exceeds the acceptable level of Phosphorus which is set at 30 µg/L from the Wisconsin Department of Natural Resources (WIDNR). Phosphorus is a watershed-wide issue, but a significant amount enters the lake via the inlet stream. Other issues also arise from different land-use practices from shoreland development as well as draining and filling of wetlands. Since most of the farmers in the surrounding area perform different farming management practices, it is challenging to pinpoint one solution to solve the water quality problem. For these reasons, RRC is implementing an approach with the triple bottom line as the number one priority. This will introduce the opportunity of improving the current conditions of Lake Ripley, while at the same time, keeping the community's needs and concerns as the number one priority.

The proposed designs have a systematic approach that is tailored to improving the quality of water, with specific engineered processes that are feasible. The first preliminary design is located within the watershed boundaries that surrounds Lake Ripley. The second design is located along the inlet stream perimeter, as well as the watershed. The third preliminary design is in the inlet stream itself. The accessibility along the district property is why RRC is focusing on inlet stream improvements. The inlet stream name is not defined; however, it is a part of the Lower Koshkonong Creek Watershed, which is managed by the LRMD. Since the LRMD only manages the defined watershed area of Lake Ripley, it is imperative that the designs will fall within this specified area.

Project Needs

For this project to be successfully completed, several criteria need to be met. The two most important goals of the project are to improve the water quality of Lake Ripley and to protect and restore native fish and wildlife habitat found in and around the lake. The proposed designs all need to have the successful function of decreasing Phosphorus from entering the lake. This goal will be achieved by reducing the delivery of pollutants into the lake that originate from surrounding agricultural land. Each design must also consider the maintenance required to implement the proposed design on site, and the design must fall within the land parameters specified by the LRMD. Additionally, the design and construction of the project must fall within the 2-million-dollar budget, which was set by the LRMD. Lastly, the solutions must fall within the constraints, and meet the objectives of a triple bottom line approach.

Existing Conditions

Agriculture

Lake Ripley is located on the western side of a highly agricultural watershed, with crop land making up half of all land use. Agricultural runoff is estimated to contribute 76% of Phosphorus loading to the lake, going from the field and into drainage ditches that connect to the inlet stream. The 76% of Phosphorus, therefore, flows directly into the stream, and the stream carries the nutrient loads into Lake Ripley. Nutrient management plans, planting cover crops, modifying tillage, and installing various BMPs could help further reduce effects of agricultural runoff. There are currently farms in the watershed that take these conservation measures, but further implementation in the watershed could benefit the lake.

Residential Development

The Lake Ripley Management District reports high density development around the lakeshore. This urbanized area is estimated to contribute 17% of total Phosphorus loading to the lake. The watershed is currently estimated to be 11% impervious, according to Jefferson County's Land and Water Conservation Department. A watershed with 10-12% impervious surfaces begins to exhibit a decline in water quality and native wildlife populations, which is noted by LRMD. Shoreline development has contributed significantly to habitat alteration and, consequently, threatened native species.

Wetlands

There are currently 524 acres of wetland in the Lake Ripley watershed, 167 of which were restored by the LRMD to protect the inlet stream and lake. The 1.7 miles of farm drainage ditches were closed and redirected through the wetlands. This allowed nature to play its role in Phosphorus and sediment load reduction as well as store runoff from storm events. The current wetlands provide habitat to frogs, turtles, and birds that would have not had that habitat available before the LRMD's intervention. There are currently 60 acres available for restoration. Most of the Phosphorus within the watershed works its way directly into the creek or indirectly into the wetland which is drained by the creek. The creek, therefore, provides opportunity to reduce Phosphorus runoff that enters the lake.

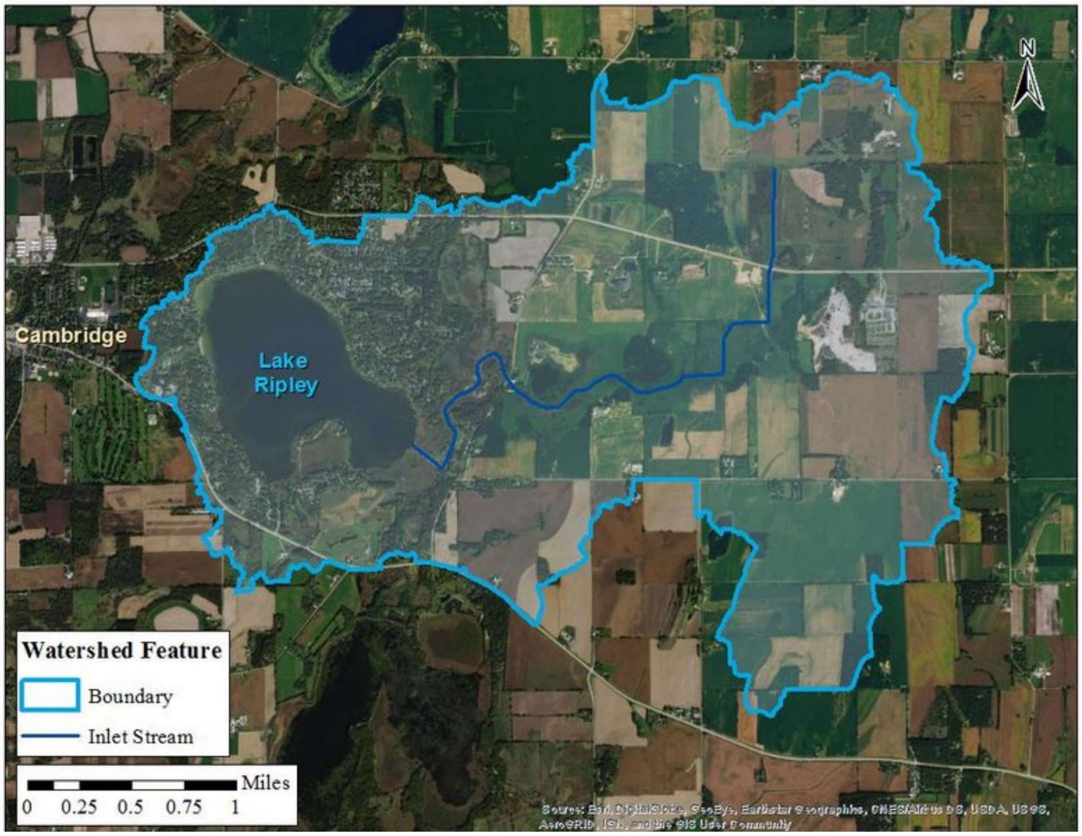


Figure 1. Map of Lake Ripley showing the watershed boundary and the Lake Ripley Management District boundary.

Project Constraints

Economic: The total budget for all activities associated with this project is $2,000,000. This project qualifies for state grants that are awarded through the DNR (Department of Natural Resources), however, RRC's goal is to stay within the original budget so no outside funding would be required.

Environmental: The current Phosphorus levels that enter Lake Ripley are 39.7 µg/L, according to most recent LRMD monitoring data, and exceed the DNR standard, 30 µg/L. The current concentrations of Phosphorus in Lake Ripley are of concern due to the detrimental effects it has on the water quality and aquatic life. The higher the concentration of Phosphorus, the greater the likelihood of the lake experiencing eutrophication, which results in toxic blue-green algal blooms. This impacts the non-invasive ecosystem that currently exists in Lake Ripley.

Social: Lake Ripley is utilized by the community of Cambridge, but also a large, diverse tourist community, specifically for recreational use such as boating and fishing. Mitigating the effects of eutrophication is, therefore, critical to keeping the lake functional for human use.

Political: Lake Ripley is surrounded by private farmland, and RRC does not have the authority to tell the farmers how to manage their land. RRC is only able to suggest BMP's and will not be in direct contact with the local farmers, per LRMD's request.

Ethical: Lake Ripley is above the DNR standards of acceptable Phosphorus levels (30 µg/L). This calls for a strong emphasis on the LRMD to implement a systematic design that would lower the Phosphorus levels to below or right at the standard. Violation of these ethical standards may lead to disciplinary action by the State of Wisconsin.

Health and Safety: The proposed sites within the watershed are located near residential areas, and RRC kept the human health and safety implications in mind as we designed the solution during the construction phase of the project. Additionally, RRC ensured a safe work environment followed by the standards set by the Occupational Safety and Health Administration. The public and workers health is of utmost importance to RRC.

Manufacturability: RRC is aware of the constraints due to site location and the natural environment. The proposed sites for each of the three designs require soil excavation and earthwork to meet the design criteria needed for the construction of the stormwater pond, raingardens, biofilters, and beaver dam analogs. Minimal site disturbance will be enforced to preserve the natural features that already exist within the watershed.

Sustainability: RRC designed a solution that will enhance the environmental, social, and economic sustainability. The goal was to minimize the environmental alterations and keep the communities natural appeal to stay as original as possible. Additionally, all the designs required the use of native vegetative species that are recommended by the LRMD.

Regulatory Codes

While designing and evaluating solution alternatives, RRC will be abiding to all necessary professional codes at the federal, state, and local level. This includes section 404 of the Clean Water Act, stating that the Environmental Protection Agency does not permit discharge of dredged or fill material into waters of the United States. Section 10 of the Rivers and Harbors Act regulates the construction within navigable or historically navigable waters of the US, requiring permits through the US Army Corps of Engineers. RRC will adhere to the Town of Oakland Ordinances as well. Lastly, the Wisconsin Department of Natural Resources regulates stormwater construction technical standards, erosion and sediment control standards, and surface water standards. The following codes will be applicable to the Lake Ripley project:

- NR 102 – Water Quality Standards for Wisconsin Surface Waters – Establishes, in conjunction with chs. NR 103 to 105, water quality standards for the surface waters of Wisconsin.

- NR 103 – Water Quality Standards for Wetlands – Establishes water quality standards for wetlands, including storm and flood water retention, shoreline protection against erosion, sediment and pollutant attenuation, and hydrologic cycle maintenance.

- NR 104 – Uses and Design Standards – Surface water classifications for Wisconsin districts, as well as effluent limitations.

- NR 105 – Establishes methods for developing the water quality criteria. The chapter also establishes how bioaccumulation factors will be determined. The chapter is applicable to surface waters for public and private supplies.

- NR 151 – Runoff Management – Establishes performance standards for urban areas and farms, as well as prohibitions for farms regarding soil loss, nutrient runoff, and tilling limitations. Water quality standards required in chs. NR 281 must be met.

- NR 216 – Strom Water Discharge Permits – Establishes criteria for defining stormwater discharges needing permits and implement appropriate performance standards of ch. NR 151.

- NR 281 – Water and Sewage – Grants regulatory powers to protect, maintain, and improve water quality around the state by water quality regulations, septage disposal, financial assistance, and enforcement.

- NR 528 – Management of Accumulated Sediment from Strom Water Management Structures – Provides process for the management of accumulated sediment removed from storm water management structures to protect public health, safety, and the environment.

Design Alternative Solutions

Reservoir Reserve Consultants conducted research on potential solutions to the nutrient loading that occurs in Lake Ripley. After the research was performed, we focused on three viable solutions that we thought would be best. We decided to focus on stormwater management, best management practices, and inlet stream restoration. Each of these three solutions are described in detail below.

Stormwater Management

The first alternative solution is the construction of a stormwater retention pond. A stormwater retention pond contains a permanent pool of water with designed dimensions, inlets, outlets, and storage capacity, which is constructed to collect, detain, treat, and release stormwater runoff. Specifically pertaining to the Lake Ripley project, the pond will reduce peak flows during storm events and improve overall water quality through the reduction of total suspended solids (TSS) and Phosphorus. Additionally, the pond will slow the flow of water, acting as a median before the stormwater enters nearby water sources. Once the excess stormwater is collected, it is released at decreased flow rates, which helps prevent flooding and soil erosion. The proposed location for the pond, shown in Figure 2 below, is along Lake Ripley's sole inlet tributary stream, west of County Road A.

Figure 2. Map of the inlet stream to Lake Ripley showing where the stormwater pond will be located.

The proposed stormwater retention pond will contain a permanent pool surface area of 1 acre, with a maximum pool depth of 3 feet. The permanent pool surface area was calculated utilizing Equation 5 in Appendix D, which follows specifications laid out by the Wisconsin Department of Natural Resources Conservative Practice Standard for a wet pond. The sizing of the required maximum pool depth coincides with these specifications (minimum 3 ft). This depth also aligns with a typical 1-acre pond depth to optimize functionality and maintenance, according to Zachary Haas (Senior Aquatic Biologist at Wisconsin Lake and Pond Rescue, LLC). The pond is to contain a sediment forebay constructed at the inlet, which helps isolate sediment deposition, facilitate maintenance, and increase overall pond effectiveness. A safety shelf of 8 feet and a slope of 10:1 (horizontal: vertical) is to be established directly above the normal water level (NWL). Side slopes below the safety shelf will be 2:1, and interior side slopes above the safety shelf will be 3:1. All proposed slopes are required by the Wisconsin Department of Natural Resources Conservation Practice Standard and are utilized to maintain soil stability. In addition to the permanent pool NWL, the pond's capacity will also contain NWLs for the 24-hour - 2-year, 25-year, 50-year and 100-year storm event. These levels detail the active storage elevation and volume within the pond during large storm events. A minimum of 1 foot of embankment is required above the 100-year storage elevation level.

Focusing specifically on the inlet and outlet structures, the pond will be hydraulically connected to the stream via piping. Figure 3 below depicts the cross section of the inlet swale as well as the front view of the outflow pipe orifice. A rip rap swale with a slope of 2%, which will have 1 foot of elevation drop over 50 feet, is to branch off the stream, which will take in excess runoff during storm events and connect to the pond's inlet pipe. The start of the rip rap swale will begin at 837 feet of elevation and run to 836 feet of elevation at the orifice of the inlet pipe. The outlet structure exhibits a concrete riser system containing various orifices to control outflow during storm events with an increasing pond volume elevation. The outlet pipe will be 50 feet long and run at a 2% slope, allowing water to flow back into the stream at controlled levels. The outlet pipe will begin at 834 feet of elevation and run to 833 feet of elevation, entering back into the bottom of the stream. Figure 3 details the proposed AutoCAD drawing for the pond with the inlet and outlet piping and design. The pipe sizing for the inlet and outlet was calculated utilizing Equation 6 in Appendix D. The 24-hour – 2-year, 25-year, and 50-year storm events will each require 4-inch circular orifices with 10-inch spacing between each orifice. The 100-year volume elevation denotes the top of the riser, which contains a 30-inch orifice with metal grating. The heavy influx of runoff from a 24-hour – 100-year storm event will initiate the emergency spillway, which redirects the excess runoff into the wetlands that are northwest of the pond, and away from the stream.

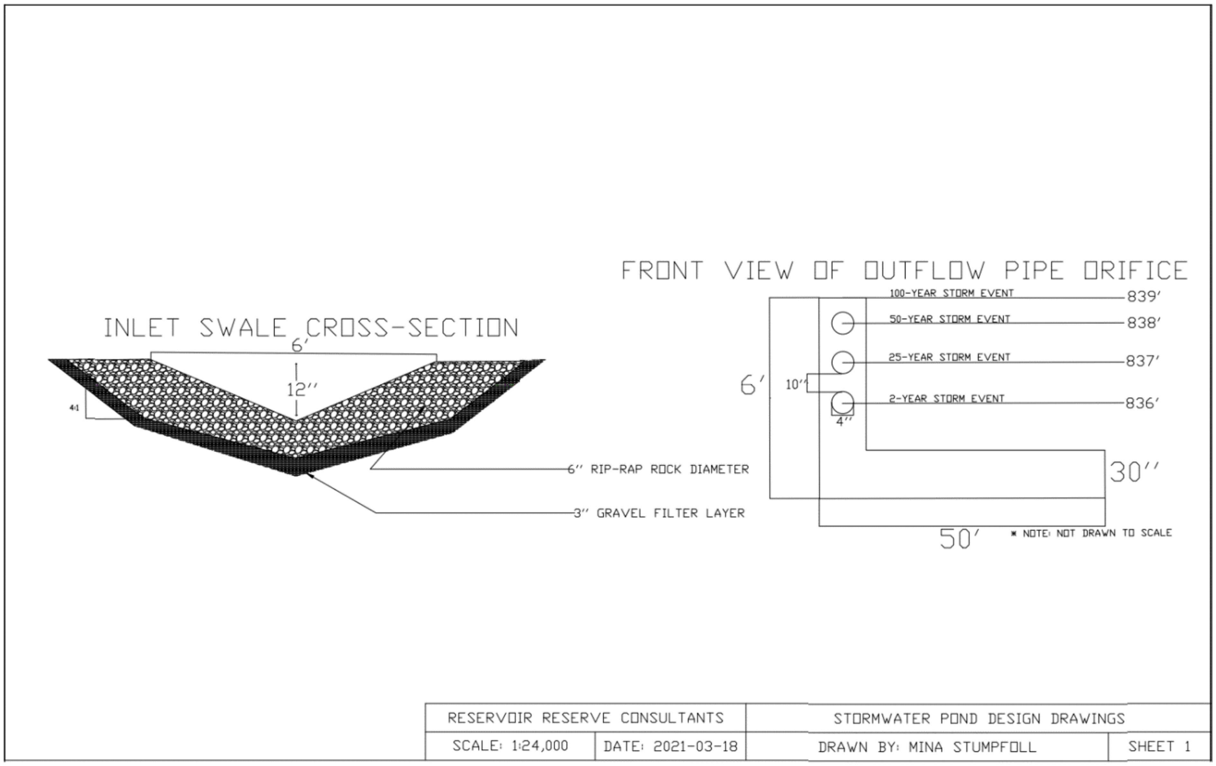


Figure 3. Cross-sections of the inlet swale and outlet piping system.

In addition to the constructed pond, various maintenance equipment and products will be required to ensure legal and functional operation. To start, a surface aerating fountain with a float switch will be a beneficial addition to the pond due to its ability to promote biological activity. Not only do surface aerating fountains provide aesthetics to the waterbody, but they also mitigate the damage caused by excessive nutrient loading. By reducing stagnation and inducing circulation, the aerating fountain helps add dissolved oxygen throughout the pond. Reduced likelihood of excessive algae growth, removal of foul odors, enhanced fish habitat, decreased mosquito activity, and reduced accumulation of bottom sediment are just a few benefits of an aerating fountain. The float switch is included to ensure the fountain switches off during storm events with increasing water levels. Regarding the reduction of Phosphorus levels, applied Polymer Floc Logs will be placed in the pond yearly. These floating logs are located at the inlet of the pond and assist in capturing fine particles and reducing turbidity. Additional operations and maintenance requirements include herbicide and algicidal chemical treatments, as well as nuisance vegetation management. While it can be drastically prevented with proper care and maintenance, dredging will be recommended every 10 years for the Lake Ripley stormwater retention pond. All operations and maintenance costs are included in Table 6 and further detailed in Appendix B, within the LCCA calculations. All additional product data for the surface aerating fountain, geosynthetic liner, and floc logs are referenced in Appendix E.

Best Management Practices

The second alternative solution is the introduction of best management practices (BMP's), and RRC decided to implement rain gardens, biofilters, and vegetative buffers. Rain gardens are gardens that include shrubs, grasses, and flowers in a small depression. The purpose of a raingarden is to temporarily hold run-off rainwater and to prevent this water from entering a larger body of water. According to the Wisconsin Department of Natural Resources, rain gardens can effectively remove 90% of nutrients from entering larger bodies of water and remove 80% of sediment from entering the water. Based on the research of BMP's, the design is composed of six raingardens, with a foot of ponding depth, and six-inch depressions on both sides of the ponding area. The total area of each raingarden will be 10,890 square feet, or one-fourth of an acre. Based on the Lake Ripley Management District's list of native plant species, we will design each of the six rain gardens to include Prairie Smoke, Wild Strawberry, Meadow Anemone, TurtleHead, Southern Blue Flag Iris, Jacobs Ladder, Ohio Spiderwort, Common Oak Sedge, and Hardstem Bulrush as the proposed plants within the raingarden. Figure 4 shows the location of each of the raingardens. The locations of each of the raingardens were determined because they currently filter run-off heading to the stream, and the gardens would enhance this process. Additionally, the raingardens were placed along each side of the inlet to capture run-off from both sides. The total number of raingardens was determined from modeling the raingardens with simulated high stormwater run-off events and choosing the locations that would be most affected by this stormwater run-off. The modeling results of the raingardens are summarized in Figure 12 of Appendix A. The raingarden will be prepared by site excavation and soil will be cut and filled to level the area where the raingarden will be designed. Next, mulch and fertilizer will be added as the base of the raingarden. Finally, the native plant seeds will be added to this base layer of soil, and each site design will be maintained to ensure proper growth of the vegetation.

Figure 4. Map showing the inlet stream to Lake Ripley and where rain gardens will be implemented along the stream.

Along with raingardens, we are also proposing the use of biofilters. Biofilters are beneficial pollution controls that can capture and biologically degrade pollutants such as Phosphorus, Nitrogen, and Heavy Metals. The biofilters are also optimized to maintain a high volume of stormwater run-off while removing considerable amounts of pollutants. Six biofilters will be designed in total, with four located along Lake Ripley Road, and two off County 18 as shown in Figure 5 and Figure 6. Each biofilter will be 91 square feet, with a grade of six inches. The total number of biofilters were chosen based on the two surrounding roads around the inlet. There are four biofilters located along Lake Ripley Road and there are two biofilters on each side of the road. The two biofilters along County 18 are placed on both sides of the road, and the number of biofilters is quantified from the proximity of the roads to the inlet stream. Biofilters must operate from run-off water that is collected from a curb, so the locations were based on the roads and the proximity they had with the inlet stream. A summary of the effects of biofilters from the modeling simulation is summarized in Figure 12 of Appendix A. A maple tree will be planted in each biofilter concrete container. Additionally, a treated stormwater underdrain system will be installed underneath the mulch and media, and energy dissipator stones will be added to the top layer of the mulch. The stones will help with the flow of stormwater that enters the biofiltration system. The biofilter system first functions with stormwater entering through a curb-inlet. The stormwater then flows through the mulch and media, and into the underdrain system. Through the underdrain system, the treated water can then be released. All the pollutants are stored within the media, and the system efficiently reduces the spread of nutrients.

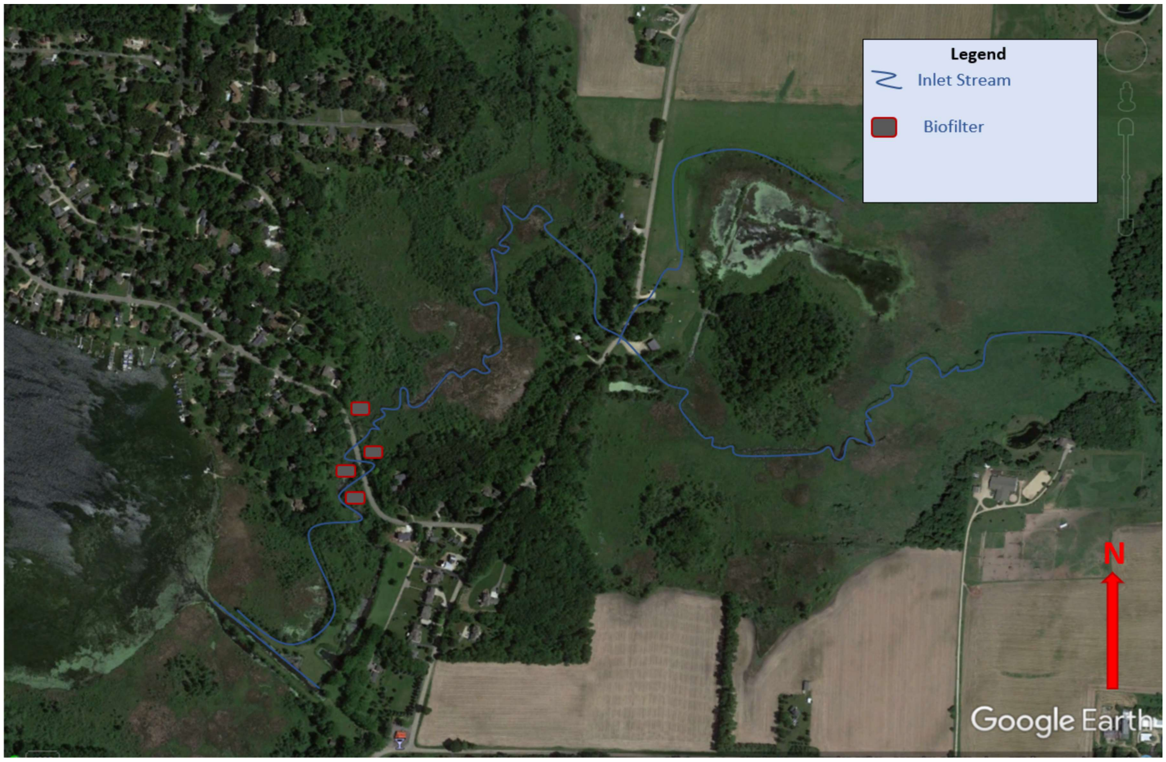


Figure 5. Map showing the west most side of the inlet stream to Lake Ripley and where the biofilters will be implemented along the stream.

Figure 6. Map showing the east most side of the inlet stream to Lake Ripley and where biofilters will be implemented along the stream.

The final BMP that will be designed are vegetative buffers. Vegetative buffers are strips of vegetation that can store sedimentation and prevent soil erosion while simultaneously collecting stormwater run-off. We plan to design six one-acre strips along the inlet stream that flows into Lake Ripley. The vegetation that will be used include River Oats, Hardstem Bulrush, and Indian Grass. Figure 7 and Figure 8 below outlines where each of the six vegetative buffers will be installed. The vegetative buffers were designed to be along the inlet stream because they would help capture excess stormwater run-off that spills out of the channel. Furthermore, the vegetative buffers are in locations that do not interfere with lake association property since the land along the inlet stream is owned by the LRMD or is public through the Town of Oakland Conservancy. The total number of vegetative buffers was determined from the shape of the inlet stream itself and choosing locations along the stream that were straight. The straight paths along the inlet stream have faster velocities and therefore a faster flow rate, which would allow the buffers to collect more run-off water from high rainstorm events. The vegetative buffers require minimal site excavation to level the proposed site areas. The mulch and plants will be added after site excavation, and after the plants fully develop, they will absorb the run-off that enters the buffer. Vegetative buffers are highly effective at intercepting pollutants and mitigating the movement of sediments, nutrients, and other suspended solids that are sourced from agricultural farmland.

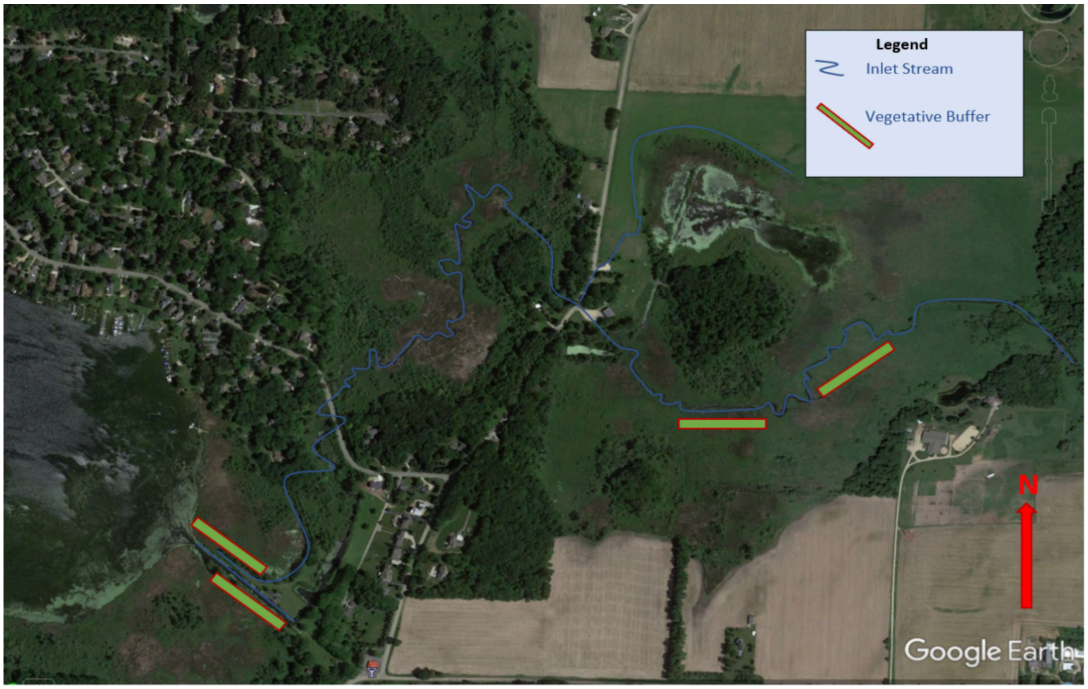


Figure 7. Map showing the west most side of the inlet stream to Lake Ripley and where the vegetative buffers will be implemented along the stream.

Figure 8. Map showing the east most side of the inlet stream to Lake Ripley and where the vegetative buffers will be implemented along the stream.

Inlet Stream Restoration

Our final alternative solution is to restore the inlet stream to Lake Ripley, specifically by using Beaver Dam Analogs (BDAs). BDAs are man-made structures added to streams to mimic a natural beaver dam. BDAs improve the water quality of streams by reducing suspended sediments in the water column, moderating stream temperatures, improving nutrient cycling, and removing and storing contaminants. These structures are meant to improve streams by slowing the water velocity and allowing suspended particles to settle. They can also divert flows to make the stream cut into banks, adding meandering to the stream. Rather than dredging a stream, BDAs can provide natural meandering, and they are a cheaper option. The dams create pools in the stream and as the pools become deeper, the impoundments force flow laterally, causing overbank flow onto flood plains, and the creation of side channels. The side channels and distributaries can increase the soil saturation in the area to promote wetland expansion. While the LRMD has restored wetlands on the property they own, the expansion of wetlands increases the amount of nutrients that can be filtered.

The BDAs can capture sediment moving in the inlet stream, and this reduction of sediment can improve the trophic state index (TSI) of the body of water that the stream enters. The rates and volume of sedimentation are best predicted by the size of the pools the BDA creates in the stream. Based on the location of the Lake Ripley inlet stream, RRC is proposing several smaller BDAs in the stream to avoid the pools in the stream being too large, which could lead to flooding. Implementing several small BDAs will allow for sediment deposition without the BDAs causing too much backwater, as this would be the effect of larger BDAs. The removal processes within the pools from the BDAs include deposition, microbial decomposition, plant uptake, and chemical transformation augmented by filtering. The effect of Beaver Dam Removal on Total Phosphorus Concentrations in Taylor Creek and wetland study showed that the removal of beaver dams within the Lake Tahoe inlet stream, Taylor Creek, caused an increase in Phosphorus concentrations of 100 μg/L. According to Charnna Gilmore, the Executive Director of the Scott River Watershed Council, BDAs work best when constructed in sequence so that the structures work in concert with each other, which is like natural beaver dams. BDAs only have a life span of one to five years and can be rebuilt in the same areas where they were initially installed. Due to the low cost, rebuilding is not of a concern because it still falls within budget.

BDAs are implemented by installing several wooden fence posts across the width of the stream and using branches and brush to fill the spaces between the posts. The posts are driven into the stream to ensure that they do not come loose from the force of the water. The wooden posts are installed in the creek bed for the stream water to pass through each of the posts. The brush and branches used for the BDAs are recommended to come from the surrounding area to make the structure as natural as possible. We are proposing the implementation of 13 BDAs into the Lake Ripley inlet stream, as shown in Figure 9 and Figure 10. As mentioned, BDAs are intended to be implemented in quantities that range from 10 to 85. The height of the structures and the channel slope determine where an upstream BDA becomes redundant. Charnna Gilmore also stated that the number of BDAs implemented is dependent on the gradient of the area and the backwater created. For this reason and for the basis of the modeling data, 13 BDAs were chosen, which is on the lower end of the case studies analyzed. Current modeling data, displayed in Appendix A, shows water levels will raise slightly but will remain below the FEMA defined 100-year floodplain elevation. The locations for the BDAs were chosen based on the surrounding areas, and the ideal locations were based on parts of the inlet stream that were straight. This will allow the BDAs to naturally meander the stream. The second criteria for choosing the location were based on the surrounding area. As aforementioned, the BDAs will divert and slow down the water in the inlet stream and because of this, there is a chance of minor flooding occurring around the BDAs. The wetlands and prairie in the Management District's properly will be efficient at controlling the excess water according to the data recorded from the modeling in WinSLAMM, as shown in Appendix A. The locations were also determined by placing the BDAs in areas that will be able to handle the excess water without flooding concerns, such as areas with minimal houses and roads.

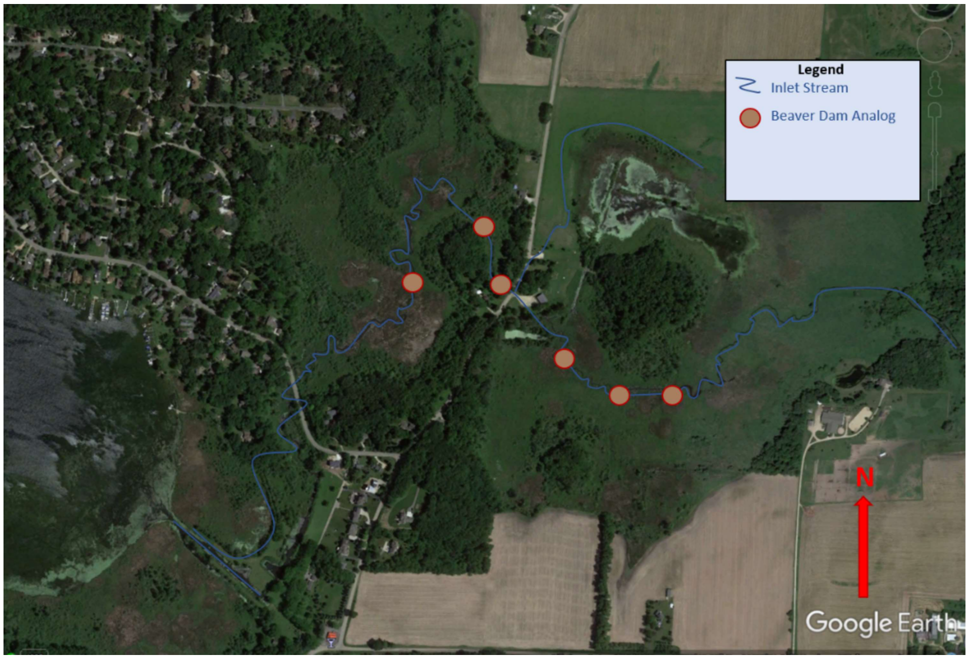


Figure 9. Map showing the west most side of the inlet stream to Lake Ripley and where the beaver dam analogs will be implemented along the stream.

Figure 10. Map showing the east most side of the inlet stream to Lake Ripley and where the beaver dam analogs will be implemented along the stream.

Modeling

RRC chose to utilize three modeling systems for initial designs – WinSLAMM, HEC-RAS, and WinTR-55. WinTR-55 has location-based storm water data and general land use data built into the system, making it an easy choice for modeling storm events in the watershed. WinSLAMM, a source loading and management modeling system, uses land use, a range of rainfall levels and storm events, and a selection of control practices to determine runoff and pollutant reduction. HEC-RAS was used for the flood modeling capabilities. Watershed land uses were determined using data from the Lake Ripley Management District and further modeled based on online maps and a site visit. The BMPs, BDAs, and stormwater pond designed by RRC were included in detail, routing appropriate runoff from each land use to respective control methods as depicted in the maps, Figures 3-9. The implemented BMPs can withstand common storm events and nutrient loading, however, they will become flooded when experiencing a 25-year storm or greater. The stormwater pond, with proper maintenance, can withstand up to the 100-year storm event and remain effective. The BDAs were modeled as weirs based on the cross-section measurements found in the Wisconsin DNR's Lake Ripley Inlet database.

The stormwater pond was modeled based on specifications stated above, including the pooling depth, pond side slope, and safety shelf slope. Orifice specifications were based on storm event water elevation levels (see Appendix A, Table 14) for the 10-year and 25-year storms. The outlet standpipe was set to the 100-year storm elevation. The best management practices were also modeled off the specifications stated in the above section, detailing sediment depths to be removed, native plants to be planted, mulch that will be added, and the maintenance required. The beaver dam analogs were modeled as shallow weirs along the width of the inlet stream. This was the method recommended by the Executive Director of the Scott River Watershed Council in Etna, California, and by the Principal Hydrologist/Geologist for Balance Hydraulics, Inc. in Truckee, California.

Data from HEC-RAS, as well as FEMA, designed floodplain maps, shown in Figures 19 and 20 in Appendix A, showed that implementing the designed alternatives would not cause a concerning rise in the water level for the area. Most of the area is of minimal flood risk, further proved through modeling, as well as speaking with professionals who specialize with the respective alternatives. Sediment and Phosphorus reduction were compared for each alternative. The stormwater pond, BMPs, and BDAs did not reach the desired reduction of 19% when implemented independently. Individual results for the stormwater pond, BMPs and BDAs are shown in Tables 10, 11, and 12, found in Appendix A. Phosphorus was a key environmental issue that was considered when determining the better alternative through a decision matrix, shown in Table 1 below.

Design Alternative Assessment

Assessing the design of each of the three alternatives and comparing specific details within each design is important because it helps to ensure which design will be best for the Lake Ripley Management District and the community that lives around Lake Ripley. The criteria's that were considered include multi-disciplinary engineering fields such as construction, geotechnical, hydraulic, and hydrological, and environmental engineering. Evaluating each of the options through the lenses of each of these engineering disciplines allows RRC to determine the best alternative.

Alternative 1: Stormwater Pond

Construction: The stormwater pond requires a lot of construction because the existing site will need to be excavated to create a pond. The depth of the pond will need to be constructed, and the gradings of the slopes of the pond will also need to be constructed based on the proposed design standards. Additionally, the aeration fountain will also need to be installed once excavation is complete, and a geosynthetic liner will be added to the bottom of the pond. Finally, the inlet and outlet structure piping will be installed for the intake of water into the pond, as well as the drainage of water that exits the pond.

Geotechnical: This design requires the largest area for construction. A one-acre stormwater pond will be constructed, and soil will be excavated up to a depth of 5 feet. The elevation in this location is about 840 ft. Based on the generalized stratigraphy of the watershed region, a 5 ft excavation would result in the bottom of the stormwater pond to be submerged in a SM classified soil. This region will be able to withstand the construction of the pond, and the pound should not collapse on itself. The construction area will need to be reached from Ripley Rd, as the soil near the inlet stream is a wooded marsh region. Obstructions should be removed over the 1-acre region.

Hydraulic/Hydrological: Looking at the stormwater pond from the hydraulic and hydrological perspective, understanding stormwater runoff levels is extremely important. The pond itself must have the capacity to take on a 24-hour – 2, 10, 25, and even up to a 100-year storm event. These runoff levels are calculated through using the NOAA Atlas 14 Point Precipitation Frequency Estimates. With this, piping dimensions will be accounted for based on how much runoff an inlet can take in or how much an outlet can release. In addition, there are hydrological aspects in the float switch of the aerating fountain. As the water level of the pond rises during a storm event, the float switch shuts off the fountain. When the pond returns to its permanent pool depth, the switch turns the fountain back on. Since the premise of the project specifically addresses the flows of water, understanding hydraulic and hydrological aspects is paramount to determining a viable solution. Projected storm event flood elevation levels (see Appendix A, Table 14) were considered when designing the pond to ensure proper flow with minimal overflow. The pond will work to divert excess storm flow into the pond, promoting sedimentation and decreasing phosphorus concentration, shown in Figure 12 and Table 10.

Environmental: Environmentally, the stormwater pond is effective at removing Phosphorus loading from entering Lake Ripley because it acts as a storage basin for the stormwater run-off. When the run-off enters the pond, it is stored, and excess run-off can be removed with the outflow piping structure. The pond itself will be designed with Polymer Floc Logs which help maintain the sediments within the pond, and this will help capture excess fine particles and reduce turbidity. The environmental downfalls of the stormwater pond design include waterfowl and mosquito concerns since it is a body of water that is structurally sound year-round. Waterfowl can fly into the pond and eat the vegetation, and mosquitos can breed and utilize the open-source water for their nests. Another environmental concern is that the water quality decreases depending on the permanent pool level, and the level will be high or low from rain-storm fluctuations. Overall, the stormwater pond is an effective design that can help mitigate sediment and nutrient loading from entering Lake Ripley; however, it is important to be aware of the few environmental concerns that are associated with this design.

Alternative 2: Best Management Practices

Construction: For the best management practices, there is minimal construction work needed for the three designs. For the raingardens, there will be low depression excavation for each of the six 10,890 square feet gardens. Mulch and fertilizer will also be added as part of the construction labor for the base of the raingarden. For the biofilters, there is more construction needed for the 91 square foot concrete systems. After the concrete systems are installed, additional construction is needed for the stormwater underdrain system that allows excess stormwater to flow out of the biofilter system. Finally, a layer of mulch and media will be added into the concrete system and the trees will be planted for each of the six biofilter systems. For the final BMP, vegetative buffers, the most construction that is needed for the design is site excavation and adding mulch and plants into the six 1-acre vegetative strips along the inlet stream.

Geotechnical: The BMPs proposed will require moist, peaty soil for the vegetation to thrive. The land surface in which the BMP's will be placed will have a shallow groundwater table depth. These proposed locations have an abundance of PT and SM classified soil. Therefore, the plants are expected to thrive in these corresponding regions. The construction of the biofilters and raingardens will require a small amount of excavation of 1 ft depth. The proposed locations of the raingardens have elevations of about 840 ft. The bottom of the raingarden will generally be submerged in the SM classified soil. Excess soil obtained from excavation will be used for the vegetative buffer. The vegetative buffers along the inlet of the stream will withstand as the stream has a low velocity feeding into the lake. The plant roots will extend to limit stream erosion.

Hydraulic/Hydrological: For hydraulic and hydrological engineering, the BMPs are effective at reducing stormwater runoff during rain-storm events. For the raingardens, the grading slope is designed to trap stormwater, and keep sediment contained within the perimeters of the garden. This is an effective way to reduce stormwater runoff and maintain clean water that flows into the lake. For the biofilters, the stormwater run-off flows through the concrete biofiltration system going through the mulch, the media, and the energy dissipator stones. Eventually, the excess runoff reaches the bottom of the system and the water will be drained out with the stormwater underdrain piping. This is also an effective management of stormwater because it stores the stormwater initially and relocates the excess water out of the system and into the inlet. Finally, for the vegetative buffers, the stormwater is collected similarly to the raingardens. The slight grades allow the run-off to flow into the buffer, and the vegetation will absorb the stormwater as well as trap sediments to prevent soil loss. Overall, the BMPs are highly effective with the management of run-off water and do an effective job at storing the water.

Environmental: The three BMPs that will be designed are highly effective at collecting nutrients and preventing them from entering Lake Ripley. The raingardens will be installed with native vegetative species, and the upkeep throughout the year is minimal. Once the raingardens begin to grow, they can be left alone, and the plants will store stormwater run-off and prevent soil erosion from occurring. Another environmental benefit is that raingardens are great habitats for birds and insects, such as butterflies. For total phosphorus, the biofilters have a 70% median removal efficiency. Additionally, they are aesthetically pleasing and the maple trees that grow within the biofilter concrete system absorb stormwater run-off efficiently. Finally, the vegetative buffers are like raingardens and once the plants are fully grown, they efficiently absorb stormwater runoff and collect extra sediment from the inlet stream. To conclude, all three of the BMP's are aesthetically pleasing with the vegetation and will work efficiently to reduce phosphorus levels.

Alternative 3: Beaver Dam Analogs

Construction: The beaver dam analogs require minimal construction for site excavation and minimal construction labor for the installation of the wooden posts. The site must be cleared for access across the stream from one bank to another. The wooden posts should be pounded straight into the ground. It is important that the posts are not significantly slanted and are pounded in enough that they are able to withstand the force of the stream water during all times of the year, as well as during storm events. The brush and sticks are then added to the posts and set up in a way to mimic a beaver pile. The brush and sticks should be held up by the force of the water in the stream, so they do not float downstream. Weaving between the posts with brush and sticks can also be done to ensure that the structural integrity of the dam stays sound. The more submerged the dam is within the water, the longer the life will be for the BDA.

Geotechnical: The construction of the beaver dam analogs will require posts to be driven into the streambed. The posts will be cylindrical with a pointed cone shape at one end, which will be driven into the soil. The dominant soil at the bottom of the streambed has an SM classification, which consists of stratified sand and gravel. This proposed design is acceptable as the weight of each individual structure is below the ultimate and allowable bearing capacity of the streambed soil. There is expected to be less than a half of an inch in settlement from these structures. The analogs will withstand the hydrostatic pressures imposed on the system, as the stream velocity is low. The insertion of the wooden piles will need to occur during the winter.

Hydraulic/Hydrological: The beaver dam analogs will provide natural dams in the inlet stream to slow the water flow, and push excess water into the surrounding wetlands. This slowed streamflow will allow more nutrients to be taken up and the dam structure will force sediment to be collected by the dam. Pushing the water onto the wetlands allows the wetlands to absorb the excess water and nutrients. The dams will force the stream to create natural meandering by diverting the water. This will prevent erosion of the stream banks, as there will be more uniform flow directed towards one side. The dams have been placed in straight areas of the stream where meandering will be beneficial. During large storm events, the dams will prevent runoff from entering the lake. The runoff contains sediments and excess nutrients, so having the dams divert the water into surrounding wetlands while slowing the flow of the water will prevent the nutrients from entering the lake. The average stream width of 0.58 ft yields a hydrostatic pressure of 1167.6 $\frac{lb}{ft \cdot s^2}$. The minimum and maximum stream width of 0.35 ft, and 1.38 ft yield 702.6 $\frac{lb}{ft \cdot s^2}$ and 2770.2 $\frac{lb}{ft \cdot s^2}$, respectively.

Environmental: The BDAs are designed to mimic natural beaver dams and therefore, the environmental impact should be minimal. The structures will be designed by using the natural brush in the area, as well as wooden posts. This will ensure that the materials used for the dams are native to the area as we will not be introducing invasive species. The dams provide a natural habitat to the area and therefore, we anticipate minimal disturbance to any animals. The use of natural materials also ensures that there will be no chemicals added to the stream and lake, and that in the event of a disaster, there will be no contamination. Phosphorus and sediment will be mitigated from entering the lake by slowing down the stream. This will prevent excess nutrient loading and will give the surrounding wetlands of the area more opportunity to filter out the phosphorus in the water. The dam will be beneficial for utilizing the wetlands of the area and are also aesthetically pleasing because they fit into the surrounding environment.

Decision Matrix

To further evaluate each of the three alternatives, a decision matrix was created. The decision matrix is broken down into four main categories: economic factors, environmental factors, construction factors, and social factors. For the economic factors, the construction cost, life cycle cost, operation and maintenance, and salvage costs were weighted, and each design was scored on a scale of 1 to 5. The environmental factors that were considered include the materials being used for each design, the effectiveness of phosphorus reduction, and the overall degradation of each design. Regarding the Phosphorus reduction, this was weighed and scored according to the modeling in WinSLAMM and WinTR-55. The Phosphorus reduction was quantified as a percentage and was accounted for from the pollutants yielded with controls, as well as the total concentration of Phosphorus with or without controls, as shown in Figure 12. For construction factors, each design is ranked and weighted based on the spatial limitations, the geotechnical limitations, and the accessibility of each of the designs. Finally, for social factors, the aesthetics were considered as well as the community approval of the design and the community's interaction with the design itself. The summary table of the decision matrix is shown in Table 1 below. Based on the weights and rated scores of each of the designs, BMP’s and the Stormwater Pond scored the highest, at 3.40 and 3.45, respectively.

Table 1. Outline of the Decision Matrix.

The Alternative Analysis Decision Matrix		**Score (1-5)**					
Considerations	**Weight**	**Stormwater Pond**	**Weighted Scores**	**BMP's**	**Weighted Scores**	**BDA**	**Weighted Scores**
Economic Factors							
Construction Cost	0.1	1	0.1	3	0.3	5	0.5
Life Cycle Cost	0.1	5	0.5	1	0.1	2	0.2
O&M	0.05	4	0.2	1	0.05	5	0.25
Salvage Costs	0.1	5	0.5	3	0.3	1	0.1
Environmental Factors							
Materials	0.1	3	0.3	4	0.4	5	0.5
Phosphorus Reduction	0.1	5	0.5	2	0.2	3	0.3
Degradation	0.05	4	0.2	5	0.25	1	0.05
Construction Factors							
Space Limitations	0.1	4	0.4	3	0.3	5	0.5
Geotechnical Limitations	0.05	3	0.15	5	0.25	2	0.1
Accessibility	0.1	3	0.3	5	0.5	2	0.2
Social Factors							
Aesthetics	0.05	2	0.1	5	0.25	3	0.15
Community Approval	0.05	1	0.05	5	0.25	3	0.15
Community Interaction	0.05	3	0.15	5	0.25	2	0.1
TOTAL	1		**3.45**		**3.40**		**3.30**

Project Cost and Financing

RRC has provided a detailed evaluation of probable cost, including a life cycle cost analysis, for the Lake Ripley project. The purpose of the life cycle cost is to evaluate and compare alternatives, as well as determine the cost of ownership. Capital costs, operation and maintenance costs, salvage value, equipment costs, installation costs, and recurring costs are the main components being evaluated. With this, a present worth analysis is detailed below, which is utilized to compare alternatives in a "fair" manner. Present worth analysis is a commonly applied technique in civil and environmental engineering economics, which gives an optimal alternative based on the maximization of net benefits. This analysis is useful for projects with long lives, like Lake Ripley, and requires assumptions on interest rates and inflation. RRC strives to focus on the social and environmental aspects of the triple-bottom-line theory, while also providing adequate detail to the economic aspect.

Capital Costs

The capital costs associated with each alternative are shown in Table 2 below. A capital cost is the initial cost of the project. These fixed expenses that are incurred at the start of a project. For each alternative, the total capital cost is the sum of the construction fees, engineering fees, and contingency (20%). The engineering fees were evaluated separately for each given alternative. The costs consider associated fees for all design and consultant work (in-scope services), as well as all bidding and construction phase service fees (additional scope services). The BDA's engineering fees consist of a standard detail, field staking, and inspections. This compares to a significantly higher engineering fee with the BMPs and stormwater pond, which consider pre-construction services, permitting, construction oversight, and final documentation. Engineering fees for each given alternative range between 9-15% of the overall construction cost. Construction fees vary between alternatives due to the differing complexity and additional products required. Tables 3, 4, and 5 provide a summary of all additional products required for each respective alternative, along with the total construction fees associated with each. Solely reviewing the capital costs for the three alternatives, RRC has found the Beaver Dam Analogs to be the least costly ($5,500), followed by Best Management Practices ($277,000) and Stormwater Pond ($500,000), respectively.

Table 2. Capital cost breakdown for each alternative.

Alternatives	Beaver Dam Analogs	Best Management Practices	Stormwater Pond
Construction Costs	$4,000	$210,000	$381,000
Engineering Fees	$500	$21,000	$36,000
Contingency (20%)	$1000	$46,000	$83,000
Total Capital Costs	$5,500	$277,000	$500,000

Table 3. Construction cost breakdown for the Beaver Dam Analogs.

Construction Component	Unit Price		Quantity	Cost
Site Excavation	$900	SF	-	$900
Wooden Posts	$7	EA	120	$840
Branches and Brush Collection	$1,200	LS	-	$1,200
Structure Assembly	$1,060	LS	-	$1,060
			Subtotal	**$4,000**

Table 4. Construction cost breakdown for the Best Management Practices.

Construction Component	Unit Price		Quantity	Cost
Fertilizer	$13	SF	-	$8494
Mulch	$30	SF	-	$8061
Plants	$5303	LS	-	$31820
Site Excavation	$5220	SF	6	$31,320
Concrete System	$21,000	SF	6	$126,000
Buffer Site Design	$300	SF	6	$1800
Planting Machine Labor	$400	LS	6	$2400
Herbicide	$45	SF	-	$270
			Subtotal	**$210,000**

Table 5. Construction cost breakdown for the Stormwater Pond.

Construction Component	Unit Price		Quantity	Cost
Excavation/Site Grading	$300,000	LS	-	$300,000
Geosynthetic Liner	$0.50	SF	40,000	$20,000
Inlet Structure/Piping	$5,000	LS	-	$5,000
Outlet Structure/Piping	$10,000	LS	-	$10,000
Vegetation (Erosion Control)	$0.50	SF	16,000	$8,000
Rip-Rap (Erosion Control)	$6.00	SF	5,300	$32,000
Aerating Fountain	$6,000	LS	1	$6,000
			Subtotal	**$381,000**

O&M Costs

Operations and maintenance (O&M) costs are accounted for in Table 6 below, summarizing each alternative, product life span, and yearly fees associated. The scope of O&M costs includes activities, processes, and workflows required to keep each alternative functioning properly. Operations includes yearly costs of utilities and labor, whereas maintenance covers site inspections, sampling, repairs, and replacements. With this, differing alternative and product life spans must also be considered while comparing costs. For example, the overall projected life span of a Beaver Dam Analog is five years with proper maintenance, compared to a Stormwater Pond which ranges from eighty to one hundred years. Alternatives and products with shorter life spans then activate repair and replacement costs. Total yearly O&M costs are the highest for Best Management Practices ($78,000), followed by the Stormwater Pond ($7,000) and Beaver Dam Analogs ($1,200), respectively.

Table 6. Operations and maintenance cost breakdown for each alternative.

Alternatives	Beaver Dam Analogs	Best Management Practices	Stormwater Pond
Estimated Life Span	5 years	N/A	20 years*
Replacement Costs	$4,000	N/A	$30,000*
Yearly O&M Costs	$1,200	$78,000	$7,000

**Denotes dredging of pond every 20 years, with a fee of $30,000.*

LCCA

RRC has prepared a life cycle cost analysis, which evaluates and compares each alternative over a 20-year period. Present worth analysis is utilized in calculating life cycle costs, which is an equivalence method of analysis in which each alternative's cash flows are discounted to a single present value. Table 7 provides a detailed summary of the project life cycle costs, considering both present worth capital costs and O&M costs. Table 8 gives an annualized breakdown of each design alternative, again considering a 20-year life cycle cost analysis. Table 7 and Table 8 utilize engineering economics equations and interest rate values specified in Appendix B. The salvage value, which is the estimated book value of an asset after depreciation is complete, is also an important aspect in life cycle cost analysis. For each of the three alternatives proposed, little to no salvage value is prevailing for the associated assets. All calculations for the life cycle cost analysis are provided in Appendix B. BMPs is shown to possess the highest life cycle cost at $1,377,000 (PW) and $98,000 (annualized). The BMPs are followed by the Stormwater Pond at $609,000 (PW) and $45,000 (annualized). Finally, the Beaver Dam Analogs are shown to be the least costly alternative over the 20-year life span at $40,000 (PW) and $3,000 (annualized).

Table 7. Present worth life cycle cost analysis for each alternative over a 20-year life span.

Alternatives	Beaver Dam Analogs	Best Management Practices	Stormwater Pond
PW Capital Costs	$9,600	$277,000	$500,000
PW O&M Costs	$16,400[2]	$1,060,000[2]	$95,000[2]
PW Replacement Costs	$10,000[1]	N/A	$14,000[1]
Total PW Cost	$40,000	$1,337,000	$609,000

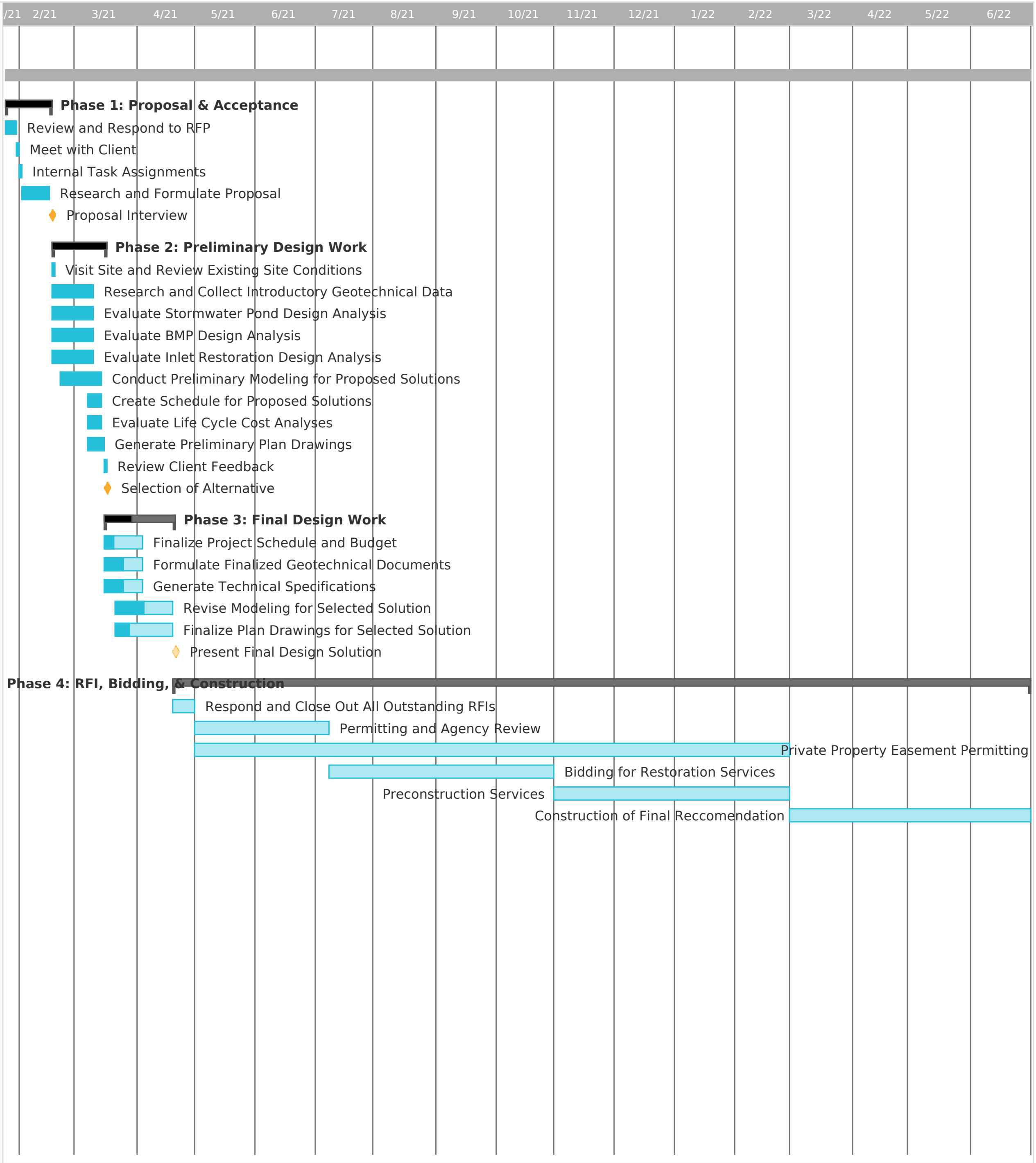
[1,2,3,4] *Denotes specified equations with calculations shown in Appendix B.*

Table 8. Annualized life cycle cost analysis for each alternative over a 20-year life span.

Alternatives	Beaver Dam Analogs	Best Management Practices	Stormwater Pond
Annualized Capital Costs	$400[3]	$20,000[3]	$37,000[3]
Annualized O&M Costs	$1,200	$78,000	$7,000
Annualized Replacement Costs	$1,400[4]	N/A	$1,000[4]
Total Annualized Cost	$3,000	$98,000	$45,000

[1,2,3,4] *Denotes specified equations with calculations shown in Appendix B.*

Lake Ripley Management Di...	start	end	20%
Phase 1: Proposal & Acceptance	**01/25/21**	**02/16/21**	**100%**
Review and Respond to RFP	01/25	01/28	100%
Meet with Client	01/29	01/29	100%
Internal Task Assignments	02/01	02/01	100%
Research and Formulate Proposal	02/02	02/15	100%
Proposal Interview	02/16	02/16	100%
Phase 2: Preliminary Design Work	**02/17/21**	**03/16/21**	**100%**
Visit Site and Review Existing Site C...	02/17	02/17	100%
Research and Collect Introductory G...	02/17	03/09	100%
Evaluate Stormwater Pond Design A...	02/17	03/09	100%
Evaluate BMP Design Analysis	02/17	03/09	100%
Evaluate Inlet Restoration Design An...	02/17	03/09	100%
Conduct Preliminary Modeling for Pr...	02/22	03/12	100%
Create Schedule for Proposed Soluti...	03/08	03/12	100%
Evaluate Life Cycle Cost Analyses	03/08	03/12	100%
Generate Preliminary Plan Drawings	03/08	03/15	100%
Review Client Feedback	03/16	03/16	100%
Selection of Alternative	03/16	03/16	100%
Phase 3: Final Design Work	**03/16/21**	**04/20/21**	**39%**
Finalize Project Schedule and Budget	03/16	04/02	25%
Formulate Finalized Geotechnical Do...	03/16	04/02	50%
Generate Technical Specifications	03/16	04/02	50%
Revise Modeling for Selected Solution...	03/22	04/19	50%
Finalize Plan Drawings for Selected S...	03/22	04/19	25%
Present Final Design Solution	04/20	04/20	0%
Phase 4: RFI, Bidding, & Construct...	**04/20/21**	**06/30/22**	**0%**
Respond and Close Out All Outstandi...	04/20	04/29	0%
Permitting and Agency Review	04/30	07/07	0%
Private Property Easement Permitting	04/30	02/28	0%
Bidding for Restoration Services	07/08	10/29	0%
Preconstruction Services	11/01	02/28	0%
Construction of Final Reccomendation	03/01	06/30	0%



Historical Considerations

Lake Ripley and the surrounding Cambridge area, prior to European development, consisted of oak savannas and extensive wetlands. Wetlands in Wisconsin have been drained and filled throughout history, destroying half of the wetlands that used to exist within the state. The Lake Ripley watershed was no exception. Agricultural and urban development took over the watershed, creating large impervious areas that increased surface runoff and decreased groundwater recharge. The village of Cambridge, including lakeshore properties, previously had individual septic systems. In 1984, a municipal sewer system was installed, which manages the wastewater outside of the watershed. Septic leachate is not a concern due to this previous change. The 13-year Priority Lake Project that took place between 1993 and 2007 reduced sediment loading to the lake by 2100 tons per year through yard waste control, installing rain gardens, shoreline restoration, wetland remediation, and implementing slow-no-wake restrictions on the lake. The Wisconsin DNR's lake project actively worked to reduce erosion effects on yards and shorelines and increase wetland area. While water quality has improved, it can still be upgraded. The LRMD reports a mean surface Phosphorus level of 20.3 µg/L and bottom Phosphorus level of 70.0 µg/L. Phosphorus levels will be addressed by RRC through further remediation efforts, implementing BMPs, and constructing a retention pond. This would not only reduce loading to the lake, but also diminish the effects of storm events and provide more habitat to native populations, all of which are focuses of the LRMD.

Sustainability Impact Assessment

Economic

The economic sustainability of this project is assessed on the state and local level. The economy is impacted by Lake Ripley because it is a place where the community and visitors can use the lake recreationally. Lake Ripley brings tourists to the area and adds to the value of the real estate as well. If the lake is clean and appealing, more people will utilize the lake, and this will increase spending on beach passes and concessions at the Lake Ripley park. A clean and appealing lake can also bring new tourists or residents to the area, boosting the economy of the area. The biggest pitfall of the economic sustainability of the project is if eutrophication occurs in the lake. This would have a negative impact on the recreational activities that occur at Lake Ripley, such as fishing and boating. A negative impact on these activities would affect the economy and small businesses of Oakland, as less people would be inclined to use the lake. Implementing our designs will mitigate run-off pollution from entering the lake, which will in turn, also mitigate the possibility of eutrophication from occurring. The more effective our designs can be to improving lake water quality, the more economic sustainability it can provide to the community around Lake Ripley. More people will consider the property value of the estates along the shoreline, which will in turn, increase spending on housing and grow the economy of the area. These long-term improvements to the lake will improve the economic sustainability of the area.

Environmental

The purpose of focusing on environmental sustainability is to improve the environment so that it can continue to be used for future generations. All three designs have environmental sustainability in mind because they improve the inlet stream and add natural solutions to capturing stormwater run-off and its excess nutrients and sediments. The three alternatives were chosen to enhance the surrounding environment and cause minimal disruptions. For instance, the BMPs and BDAs will both be adding native plants and brush to the area. This will have a positive environmental impact by helping native habitats thrive in these sites rather than introducing new species. They will provide additional habitats for wildlife in the area and improve the water quality of the lake allowing aquatic plants and animals to thrive. The designs were created with the intention that they would become natural parts of the area once implemented. Natural and native materials were used, which will prevent contamination and invasive species being introduced to the area. This will be important in extreme flooding events or other natural disasters. Additionally, the carbon footprint of all three alternatives is minimal, especially once the alternatives have been constructed. Once implemented, all three alternatives will be naturally working to reduce Phosphorus without the need of fuel. This will also prevent the possibility of leaking contaminants into the lake or inlet stream. Not only will the alternatives be improving the inlet area where they are implemented, they will also have a positive effect on Lake Ripley. The alternatives will be reducing excess nutrients which will result in optimal water quality for the aquatic species and vegetation in the lake without the addition of harmful chemicals.

Social

Social Sustainability is an important design impact that RRC has considered. This pillar of sustainability includes concern for human health equity, social and cultural responsibility, and community development. Lake Ripley is used for many recreational purposes such as boating, fishing, and swimming. All these activities would not be possible if the lake faced serious algal blooms that also cause eutrophication from the Phosphorus nutrient loading. These activities are a part of the culture around Lake Ripley and are important to community members and visitors of the area. Algal blooms are dangerous for human health, and they are very aesthetically unpleasing. By implementing the stormwater pond or BMPs, less Phosphorus would enter the lake, and therefore, the spread of algal blooms would be mitigated. Another social aspect that RRC must consider is the community that lives along the shores of the lake. For these residents, the lake can be a common place for social interaction and getting together within the community. Additionally, RRC has considered the need for installing trails and including a board signage to educate the community and visitors on watershed dynamics and stormwater control. Educating the community on how the designs benefit the lake will provide more political community support towards the LRMD projects and similar restoration project. Our designs must look professional and natural, while maintaining zero public disturbance. Our designs must also incorporate the native plants to the area of Cambridge, Wisconsin, and by doing so, we hope to promote the wellbeing of the community and provide education on native Wisconsin wildlife.

The native plants added will also bring value to the Management District's property and the public hiking trail, further enhancing the social sustainability of the project.

Summary of Public Input

The Lake Ripley watershed and Management District residents have participated in two surveys, and results for each are recorded through the LRMD. Both surveys showed a great appreciation for the lake and awareness of the importance of restoring and maintaining the native habitat and wildlife populations in the area for recreational, aesthetic, and environmental reasons. All respondents were highly supportive of cost sharing for projects, lake monitoring, invasive species control, acquiring conservancy areas, and furthering lake protection policies. Reservoir Reserve Consultants have taken all responses into consideration while designing solutions for the current project. We have focused on low-cost projects that promote native plant growth, increase wildlife habitat potential, and appeal to the community aesthetically.

Beyond the immediate community, the Cambridge and Lake Ripley area has a high seasonal population and high tourist traffic. Beneficial changes to the lake, inlet, and surrounding wetland would increase the areas value to seasonal property owners and increase tourist traffic to the area. This would lead to an overall increase in revenue for the city. The implementation of BDA's is not something that RRC has been able to find record of in Wisconsin. This introduction, as well as other alternatives, could encourage the public to implement similar practices in their own watersheds. This would have statewide and national benefits to watersheds and native wildlife while remaining within appropriate federal and state standards. The RRC designs would have global effects due to their low carbon footprint and minimal environmental impacts.

Uncertainties in Design

The designs Reservoir Reserve Consultants implemented were created to encounter changing environmental conditions, however, there are still uncertainties to consider. The uncertainties can be considered as knowledge-based or data-based. Knowledge-based uncertainties describes the lack of information or the assumptions made about the project that causes design decisions to be made from current knowledge. Data-based uncertainties describe the lack of precision or detail in aspects of the project that cause decisions to be made based off surrounding data.

The project consists of knowledge-based uncertainties, such as the current standards and codes relating to the project and how those could change. As seen in the schedule, this project will be constructed over a prolonged period. Code changes could be made during the construction, such as stricter water quality standards. There is also uncertainty on how the Phosphorus concentrations from nearby farms could change over time. This would be dependent on the practices farmers utilize on their private property. While the Town of Oakland works closely with farmers to keep Phosphorus levels at a minimum, an increase in phosphorus would need to be handled to preserve the water quality of the lake.

There are also data-based uncertainties involved, such as whether the Phosphorus in the inlet stream is legacy Phosphorus, or how much there is. Legacy Phosphorus is a type of Phosphorus that has accumulated in soils after long-term cultivation. The area around Lake Ripley has a history of agriculture, so it is possible that legacy Phosphorus is present. Our Phosphorus data from the inlet stream and surrounding area is not precise enough to determine whether legacy Phosphorus is present. We are assuming the Phosphorus is runoff from stormwater and farms, thus we have designed engineering solutions to filter this runoff. Legacy Phosphorus on the District Management's property would be more difficult to control. Like legacy Phosphorus, the form of Phosphorus present can also cause uncertainty. Our modeling software provided estimates for the particulate and filterable forms of Phosphorus entering the inlet stream, however samples of runoff entering the inlet stream have not been laboratory tested and therefore may not be precise.

The uncertainties could change the performance of the proposed design alternatives. The alternatives have been modeled to show the amount of Phosphorus that will be decreased from the stream, and final recommendations have been made off that data. The two different forms could also affect how the design solutions manage the phosphorus. For instance, if there is more filterable Phosphorus in the water then the designs may not be as effective, as filterable Phosphorus can be more difficult to uptake in the environment. Lastly, changes in codes and regulations could affect the construction processes of the alternatives.

Final Recommendation

In conclusion, the final recommendation includes the Stormwater Pond alternative design in-full, as well as a reduced implementation of BMPs and BDAs. Figure 10 depicts a map of all proposed locations for the modified final recommendation. The stormwater pond reduces the most Phosphorus out of all three designs, at a rate of 15.96%. The quantities of each of the BMPs and BDAs were modified and derived from the modeling in WinSLAMM. Each alternative was modeled individually, and the Phosphorus concentrations that were removed were quantified. For the BMPs, each raingarden removed up to 0.27% of Phosphorus, with the proposed six BMPs removing 1.69%. When the BDAs were modeled individually, each removed up to 3.61%, with the average being 0.02%, of Phosphorus. This reduction of BMPs will consist of (6) – 1/4-acre rain gardens. The vegetative buffers and biofilters were removed due to negligible Phosphorus removal concentrations. When the site was assessed in-person by RRC, it was determined that several of the proposed BMPs were not placed in optimal locations. The number of the raingardens and the locations of each in the modified final recommendation optimize reduction in nutrient loading because they are each placed in locations where excess run-off accumulates. RRC has pinpointed high flood risk zones and condensed the BMPs to those specified areas. In addition, instead of (13) BDAs, the final recommendation includes (4), which is based off the modeling as well as location. The Phosphorus reduced from the BDAs was quantified to 5.53%. This reduction of BDAs came about following a site assessment that was inspected by RRC as well as modeling each individual BDA to achieve a maximum reduction in Phosphorus. The four BDAs contribute to a maximum reduction of nutrient loading, which is quantified to be 21.53%.

Table 9 gives a summarized cost breakdown of the modified final recommendation, which is under the initial $2,000,000 budget for both the total capital cost and the 20-year LCCA present worth analysis. Results following modeling showed that, while effective, the rain gardens were unable to handle large storms (25-year, 50-year, and 100-year storms). The stormwater pond, with regular maintenance, was able to properly handle most storms that will affect the area. The beaver dam analogs will require observation and potential maintenance when first installed, then twice annually for their lifespan. The BDAs can control most natural flows in the inlet stream without exceeding FEMA determined floodplains. The final design resulted in a 6.16% runoff volume reduction, 24.01% sediment reduction, and a 21.79% particulate Phosphorus reduction. This meets the 19% Phosphorus and/or sediment reduction that the client, LRMD, has requested. The final recommendation reduction value exceeds the project goal of a total annual Phosphorus loading reduction of at least 19%.

Figure 11. Map detailing proposed quantities and locations of alternatives within the modified final recommendation.

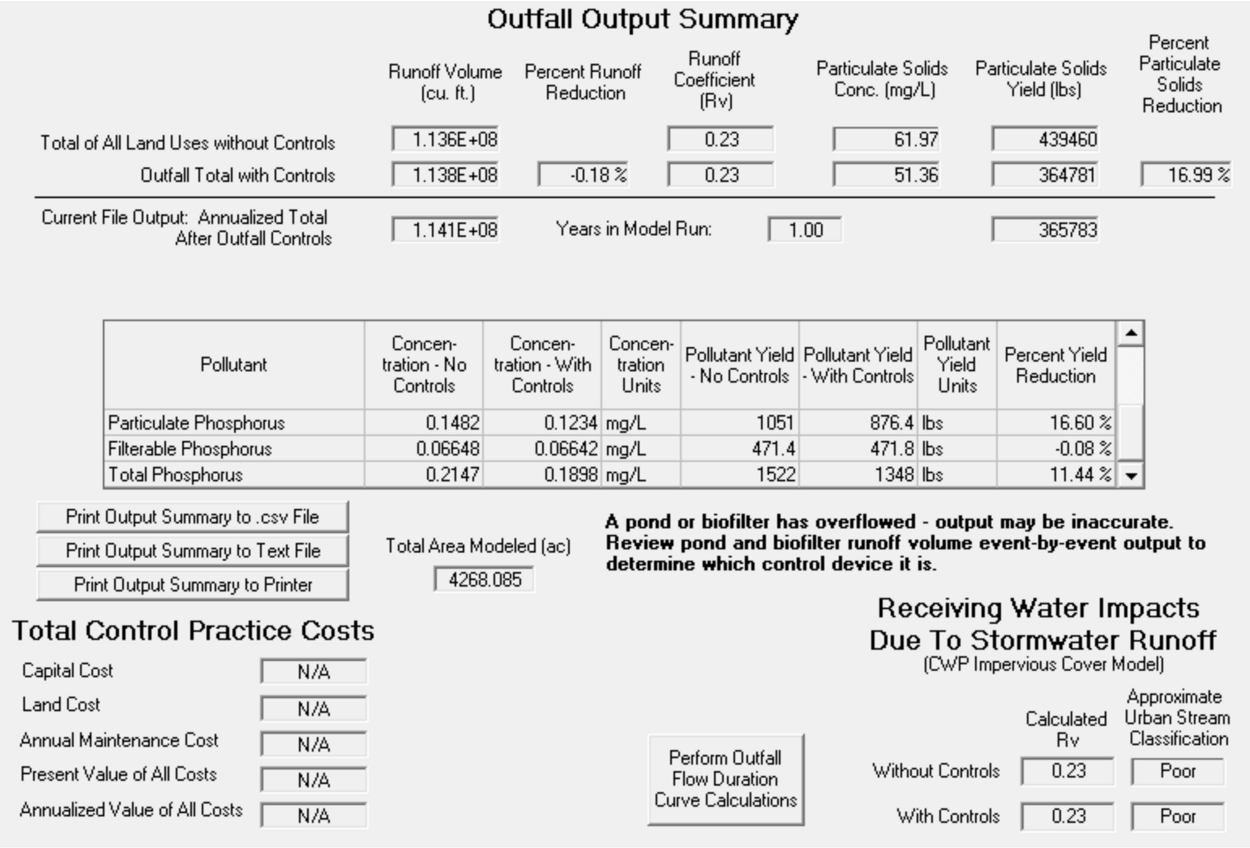
Table 9. Summarized cost breakdown of the modified final recommendation.

Component of Final Recommendation	Capital Cost	Yearly O&M Cost	Present Worth Analysis
(4) - BDAs	$1,500	$500	$9,000[7]
(6) – ¼-acre Raingardens	$40,000	$49,000	$706,000[7]
Stormwater Pond	$500,000	$7,000	$609,000
Total	$541,500	$56,500	$1,324,000

[7] *Denotes specified equations with calculations shown in Appendix D.*

Appendix A (Modeling)

WinSLAMM Watershed Land Use Modeling



Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	1.136E+08		0.23	61.97	439460	
Outfall Total with Controls	1.138E+08	-0.18 %	0.23	51.36	364781	16.99 %

Current File Output: Annualized Total After Outfall Controls: 1.141E+08

Years in Model Run: 1.00

365783

Pollutant	Concen-tration - No Controls	Concen-tration - With Controls	Concen-tration Units	Pollutant Yield - No Controls	Pollutant Yield - With Controls	Pollutant Yield Units	Percent Yield Reduction
Particulate Phosphorus	0.1482	0.1234	mg/L	1051	876.4	lbs	16.60 %
Filterable Phosphorus	0.06648	0.06642	mg/L	471.4	471.8	lbs	-0.08 %
Total Phosphorus	0.2147	0.1898	mg/L	1522	1348	lbs	11.44 %

Total Area Modeled (ac): 4268.085

A pond or biofilter has overflowed - output may be inaccurate. Review pond and biofilter runoff volume event-by-event output to determine which control device it is.

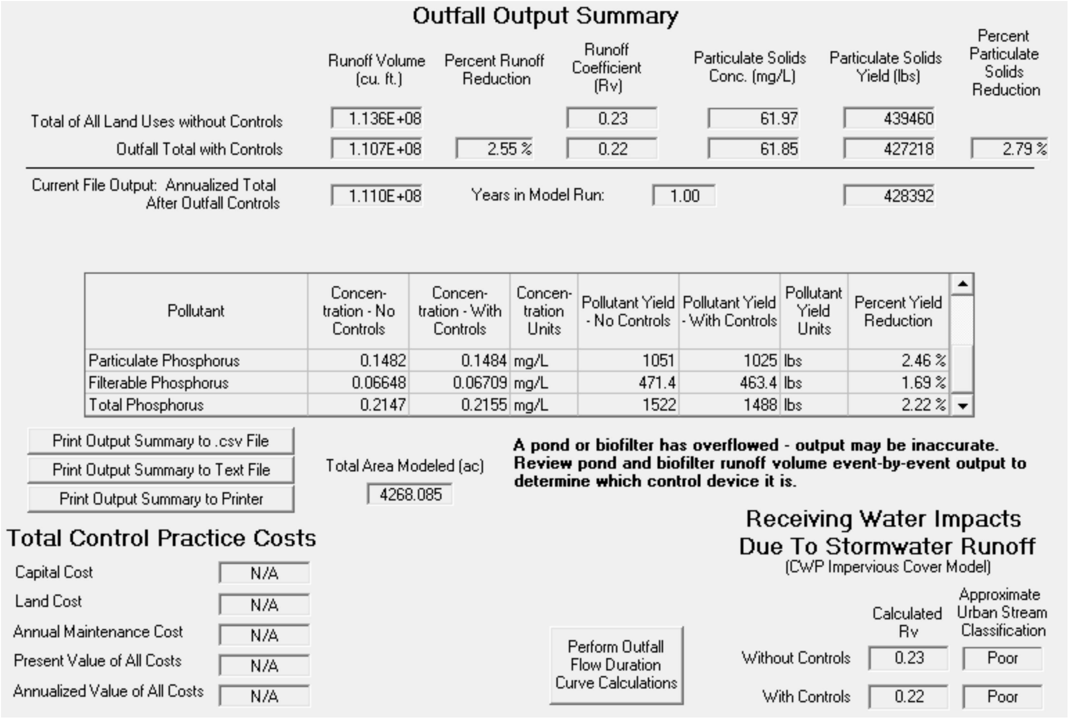
Total Control Practice Costs

Capital Cost	N/A
Land Cost	N/A
Annual Maintenance Cost	N/A
Present Value of All Costs	N/A
Annualized Value of All Costs	N/A

Receiving Water Impacts Due To Stormwater Runoff (CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.23	Poor
With Controls	0.23	Poor

Figure 12. Model Results – Retention pond alternative runoff, sediment, and phosphorus reductions



Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	1.136E+08		0.23	61.97	439460	
Outfall Total with Controls	1.107E+08	2.55 %	0.22	61.85	427218	2.79 %
Current File Output: Annualized Total After Outfall Controls	1.110E+08	Years in Model Run:	1.00		428392	

Pollutant	Concen-tration - No Controls	Concen-tration - With Controls	Concen-tration Units	Pollutant Yield - No Controls	Pollutant Yield - With Controls	Pollutant Yield Units	Percent Yield Reduction
Particulate Phosphorus	0.1482	0.1484	mg/L	1051	1025	lbs	2.46 %
Filterable Phosphorus	0.06648	0.06709	mg/L	471.4	463.4	lbs	1.69 %
Total Phosphorus	0.2147	0.2155	mg/L	1522	1488	lbs	2.22 %

Total Area Modeled (ac) 4268.085

A pond or biofilter has overflowed - output may be inaccurate. Review pond and biofilter runoff volume event-by-event output to determine which control device it is.

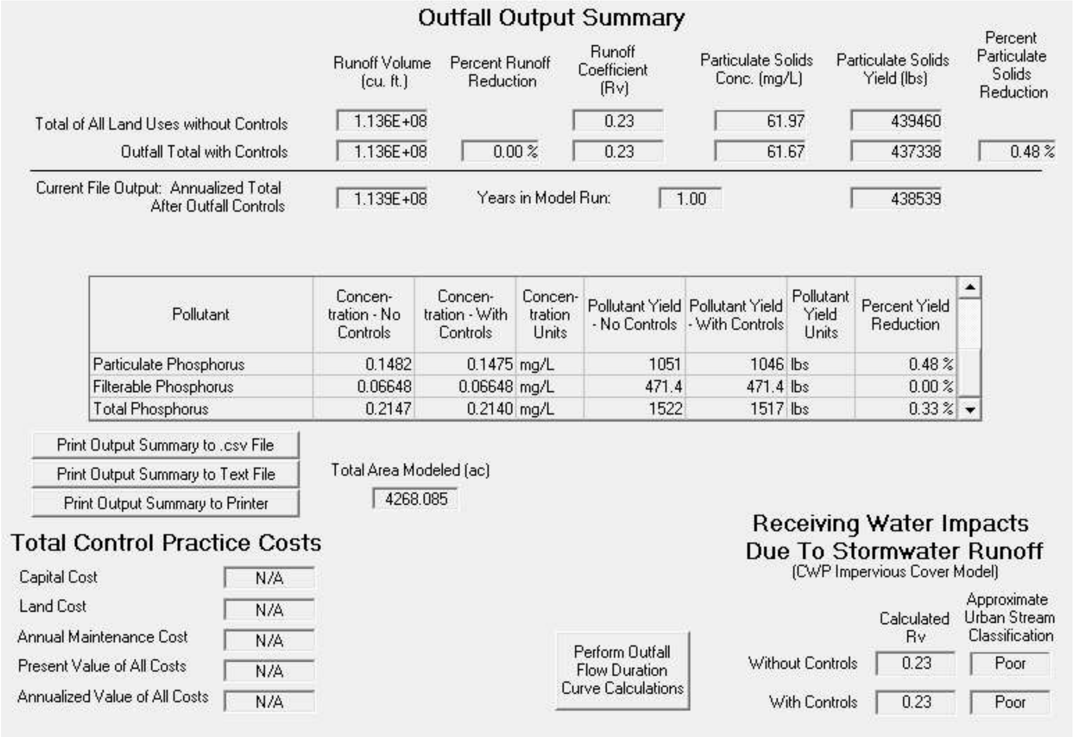
Total Control Practice Costs

Capital Cost	N/A
Land Cost	N/A
Annual Maintenance Cost	N/A
Present Value of All Costs	N/A
Annualized Value of All Costs	N/A

Receiving Water Impacts Due To Stormwater Runoff
(CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.23	Poor
With Controls	0.22	Poor

Figure 13. Model Results – BMP alternative runoff, sediment, and phosphorus reductions



Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	1.136E+08		0.23	61.97	439460	
Outfall Total with Controls	1.136E+08	0.00 %	0.23	61.67	437338	0.48 %
Current File Output: Annualized Total After Outfall Controls	1.139E+08	Years in Model Run:	1.00		438539	

Pollutant	Concen-tration - No Controls	Concen-tration - With Controls	Concen-tration Units	Pollutant Yield - No Controls	Pollutant Yield - With Controls	Pollutant Yield Units	Percent Yield Reduction
Particulate Phosphorus	0.1482	0.1475	mg/L	1051	1046	lbs	0.48 %
Filterable Phosphorus	0.06648	0.06648	mg/L	471.4	471.4	lbs	0.00 %
Total Phosphorus	0.2147	0.2140	mg/L	1522	1517	lbs	0.33 %

Total Area Modeled (ac) 4268.085

Total Control Practice Costs

Capital Cost	N/A
Land Cost	N/A
Annual Maintenance Cost	N/A
Present Value of All Costs	N/A
Annualized Value of All Costs	N/A

Receiving Water Impacts Due To Stormwater Runoff
(CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.23	Poor
With Controls	0.23	Poor

Figure 14. Model Results – BDA alternative runoff, sediment, and phosphorus reductions

Table 10. Model Results – Retention pond result details.

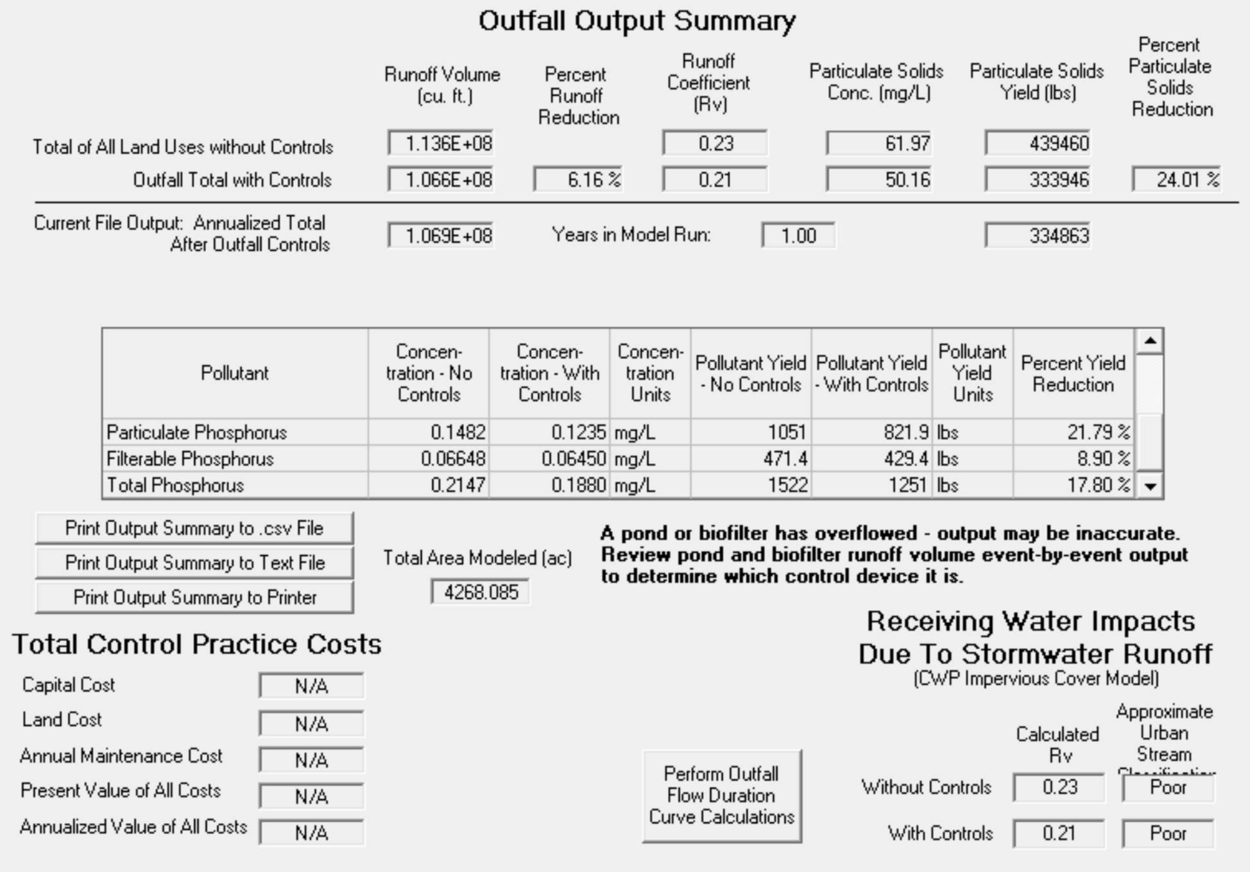
Design Detail	Model Results
Maximum Stage	5.07 feet – highest water levels will overflow onto safety shelf
Minimum Volume	68,105 cubic feet – volume below designed outlet
Phosphorus Reduction	Particulate: 16.66% Total: 11.44%
Sediment Reduction	Particulate: 16.99% Total: 9.88%

Table 11. Model results – BMP individual reduction progression: percent reduction caused by individual BMP additions.

BMP Alternative		Phosphorus Reduction	Sediment Reduction	Runoff Reduction
Rain Gardens	1	0.28%	0.34%	0.53%
	2	+0.27%	+0.32%	+0.44%
	3	+0.27%	+0.33%	+0.44%
	4	+0.27%	+0.33%	+0.53%
	5	+0.27%	+0.32%	+0.44%
	6	+0.27%	+0.32%	+0.44%
Biofilters	1	0.01%	0.01%	0.0%
	2	+0.01%	+0.01%	0.0%
	3	+0.01%	+0.01%	0.0%
	4	+0.01%	+0.01%	0.0%
	5	+0.01%	+0.02%	0.0%
	6	+0.01%	+0.02%	0.0%
Vegetative Buffers	1	0.0%	0.0%	0.0%
	2	+0.02%	+0.01%	0.0%
	3	+0.03%	+0.02%	0.0%
	4	+0.03%	+0.03%	0.0%
	5	+0.04%	+0.02%	0.0%
	6	+0.01%	+0.01%	0.0%

Table 12. Model results – BDA individual reduction progression: percent reduction caused by individual BMP additions.

BDA	Incremental Phosphorus Reduction	Cumulative Phosphorus Reduction	Incremental Sediment Reduction	Cumulative Sediment Reduction
1	3.61%	3.61%	3.62%	3.62%
2	-0.73%	2.88%	-1.05%	2.57%
3	+0.18%	2.90%	+0.01%	2.58%
4	**+0.92%**	**3.82%**	**+0.76%**	**3.34%**
5	-2.95%	0.87%	-2.60%	0.74%
6	-0.47%	0.40%	-0.35%	0.39%
7	-0.21%	0.19%	-0.21%	0.18%
8	+0.45%	0.64%	+0.37%	0.55%
9	-0.07%	0.57%	-0.06%	0.49%
10	-0.21%	0.36%	-0.14%	0.35%
11	-0.16%	0.20%	-0.17%	0.18%
12	+0.16%	0.36%	+0.13%	0.31%
13	-0.03%	0.33%	-0.03%	0.28%



Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	1.136E+08		0.23	61.97	439460	
Outfall Total with Controls	1.066E+08	6.16 %	0.21	50.16	333946	24.01 %

Current File Output: Annualized Total After Outfall Controls 1.069E+08
Years in Model Run: 1.00
334863

Pollutant	Concen-tration - No Controls	Concen-tration - With Controls	Concen-tration Units	Pollutant Yield - No Controls	Pollutant Yield - With Controls	Pollutant Yield Units	Percent Yield Reduction
Particulate Phosphorus	0.1482	0.1235	mg/L	1051	821.9	lbs	21.79 %
Filterable Phosphorus	0.06648	0.06450	mg/L	471.4	429.4	lbs	8.90 %
Total Phosphorus	0.2147	0.1880	mg/L	1522	1251	lbs	17.80 %

Total Area Modeled (ac) 4268.085

A pond or biofilter has overflowed - output may be inaccurate. Review pond and biofilter runoff volume event-by-event output to determine which control device it is.

Total Control Practice Costs

Capital Cost N/A
Land Cost N/A
Annual Maintenance Cost N/A
Present Value of All Costs N/A
Annualized Value of All Costs N/A

Receiving Water Impacts Due To Stormwater Runoff

(CWP Impervious Cover Model)

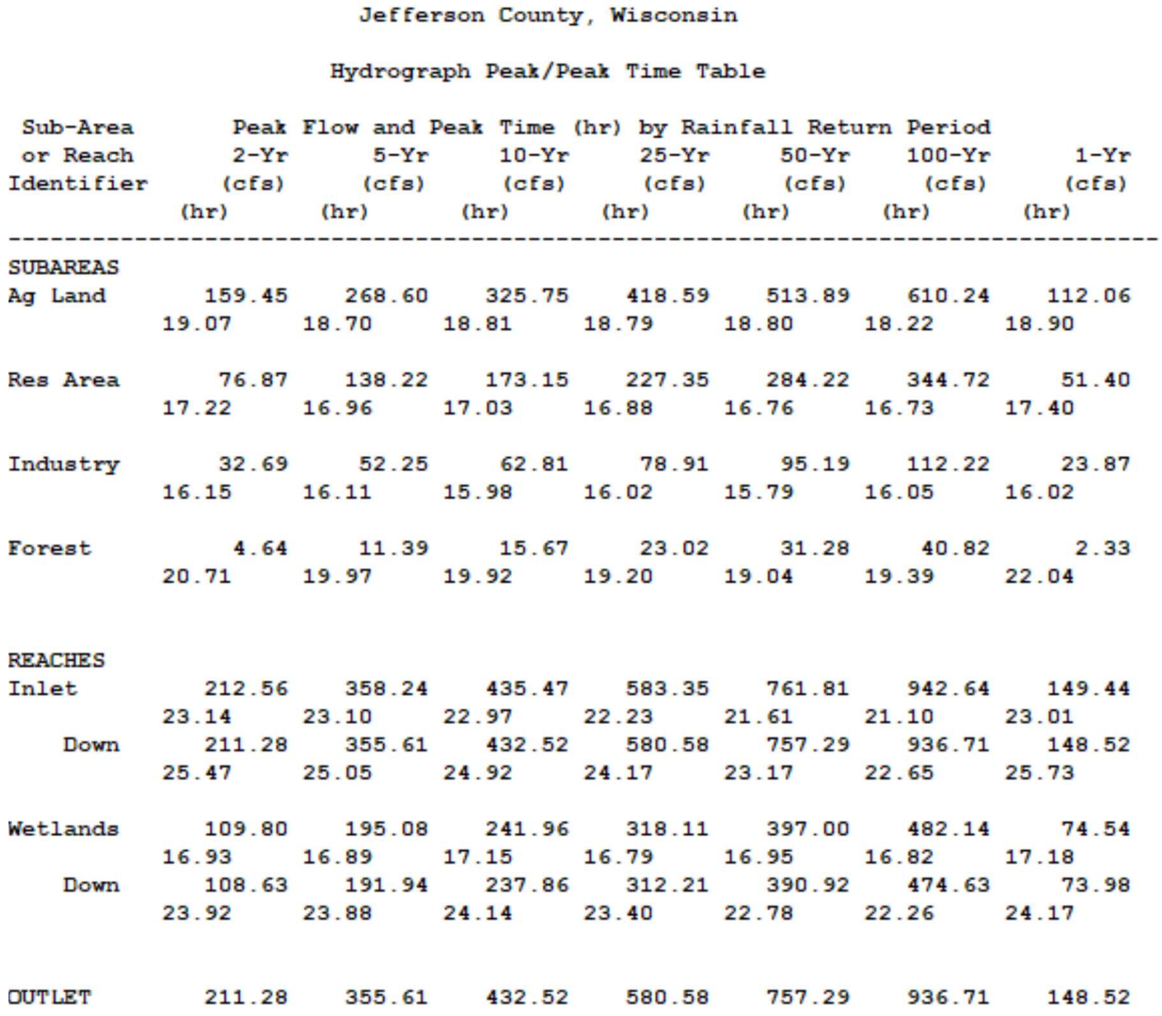
	Calculated Rv	Approximate Urban Stream
Without Controls	0.23	Poor
With Controls	0.21	Poor

Figure 15. Model Results – Final design runoff, sediment, and phosphorus reductions.

Table 13. Model Results – Final design result details.

	Total Phosphorus Reduction	Total Sediment Reduction	Particulate Phosphorus Reduction	Particulate Sediment Reduction	Runoff Reduction
Retention Pond	11.44%	9.88%	16.60%	16.99%	-0.08%
BMPs	1.63%	1.96%	1.69%	1.95%	2.82%
BDAs	3.82%	3.34%	5.53%	5.72%	0.00%
MODELED TOTAL	17.80%	19.87%	21.79%	24.01%	6.16%

WinTR-55 Land Use Hydrology Modeling



```
                       Jefferson County, Wisconsin

                      Hydrograph Peak/Peak Time Table

 Sub-Area       Peak Flow and Peak Time (hr) by Rainfall Return Period
 or Reach       2-Yr      5-Yr      10-Yr     25-Yr     50-Yr     100-Yr      1-Yr
Identifier     (cfs)     (cfs)     (cfs)     (cfs)     (cfs)     (cfs)     (cfs)
            (hr)      (hr)      (hr)      (hr)      (hr)      (hr)      (hr)
---------------------------------------------------------------------------------
SUBAREAS
Ag Land       159.45    268.60    325.75    418.59    513.89    610.24    112.06
           19.07     18.70     18.81     18.79     18.80     18.22     18.90

Res Area       76.87    138.22    173.15    227.35    284.22    344.72     51.40
           17.22     16.96     17.03     16.88     16.76     16.73     17.40

Industry       32.69     52.25     62.81     78.91     95.19    112.22     23.87
           16.15     16.11     15.98     16.02     15.79     16.05     16.02

Forest          4.64     11.39     15.67     23.02     31.28     40.82      2.33
           20.71     19.97     19.92     19.20     19.04     19.39     22.04


REACHES
Inlet         212.56    358.24    435.47    583.35    761.81    942.64    149.44
           23.14     23.10     22.97     22.23     21.61     21.10     23.01
    Down      211.28    355.61    432.52    580.58    757.29    936.71    148.52
           25.47     25.05     24.92     24.17     23.17     22.65     25.73

Wetlands      109.80    195.08    241.96    318.11    397.00    482.14     74.54
           16.93     16.89     17.15     16.79     16.95     16.82     17.18
    Down      108.63    191.94    237.86    312.21    390.92    474.63     73.98
           23.92     23.88     24.14     23.40     22.78     22.26     24.17


OUTLET        211.28    355.61    432.52    580.58    757.29    936.71    148.52
```

Figure 16. Model Results - multiple storm event peak flow rate for each subarea and outlet.

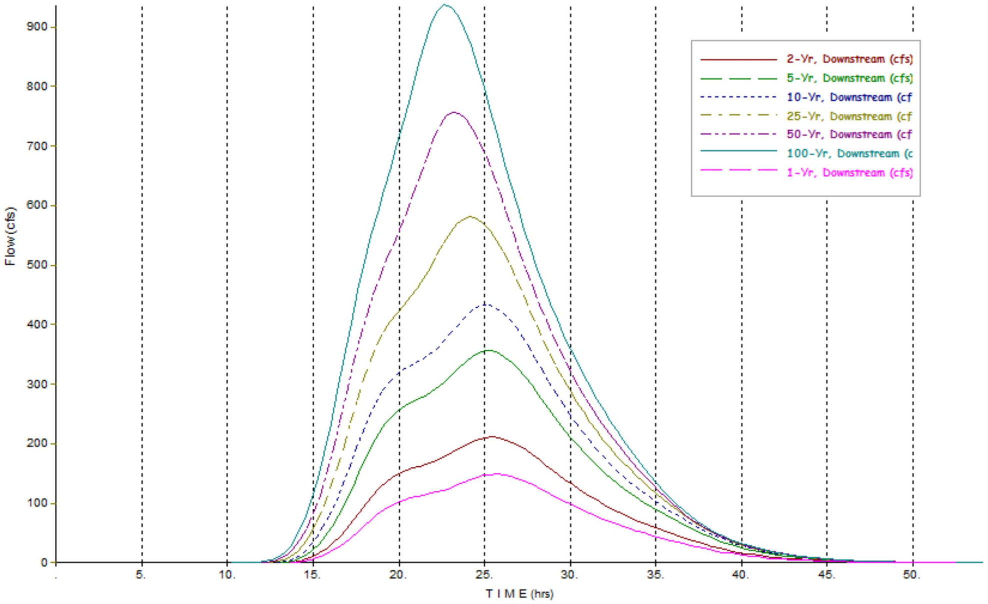
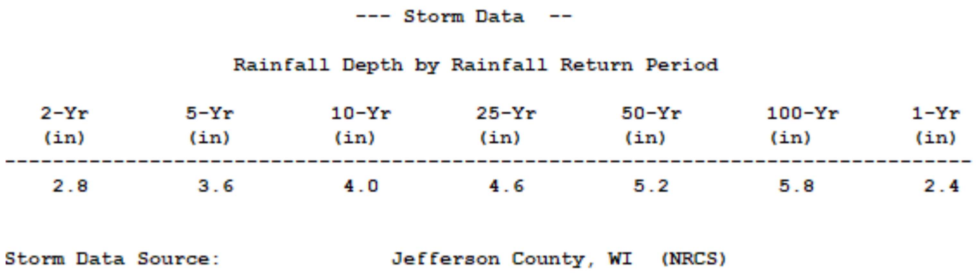


Figure 17. Model Results – downstream inlet stream hydrograph for multiple storm events.



```
                         --- Storm Data  --

                  Rainfall Depth by Rainfall Return Period

   2-Yr        5-Yr        10-Yr       25-Yr       50-Yr       100-Yr      1-Yr
   (in)        (in)        (in)        (in)        (in)        (in)        (in)
--------------------------------------------------------------------------------
    2.8         3.6         4.0         4.6         5.2         5.8         2.4


Storm Data Source:              Jefferson County, WI   (NRCS)
```

Figure 18. Model Results – rainfall depth for multiple storm events.

HEC-RAS Modeling

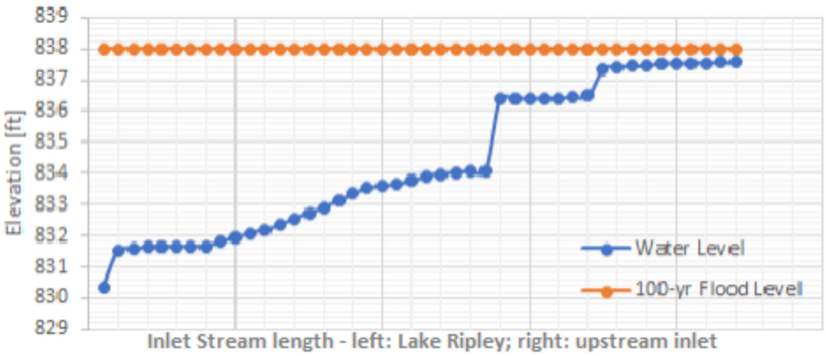


Figure 19. Model Results – water level after BDA alternative implementation along the inlet stream length.

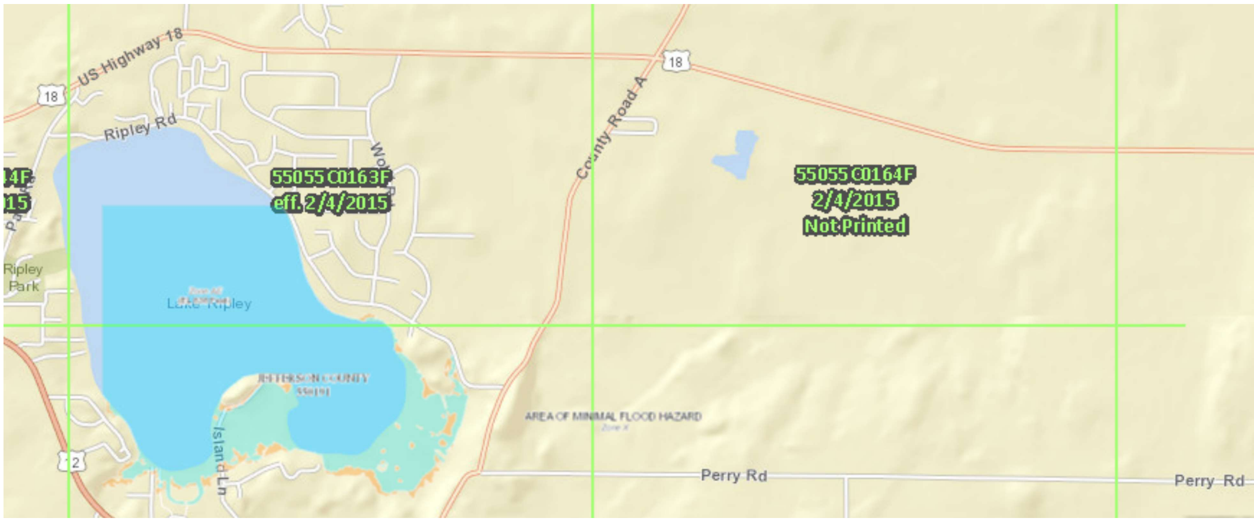


Figure 20. FEMA 100-year floodplain map – floodplain in light blue; beige area shows minimal flood hazard.

Table 14. Lake Ripley storm event elevations, from Jefferson County's Flood Insurance Study.

Storm Event	10-year	25-year	50-year	100-year	500-year
Elevation [ft]	837.1	837.4	837.6	837.9	838.7

Appendix B (LCCA Calculations)

Equation 1: Single Payment Present Worth[1]

- $P = (1+i)^{-n}$
- $\left(\frac{P}{F}, i\%, n\right)$
- BDAs: $P = 4000 * \left(\frac{P}{F}, 4\%, 5\right) + 4000 * \left(\frac{P}{F}, 4\%, 10\right) + 4000 * \left(\frac{P}{F}, 4\%, 15\right) + 4000 * \left(\frac{P}{F}, 4\%, 20\right)$
    - $P = 4000 * (0.8219) + 4000 * (0.6756) + 4000 * (0.5553) + 4000 * (0.4564) = \$10{,}037$
- Pond: $P = 30{,}000 \left(\frac{P}{F}, 4\%, 20\right) = 30{,}000(0.4564) = \$13{,}692$

Equation 2: Uniform Series Present Worth[2]

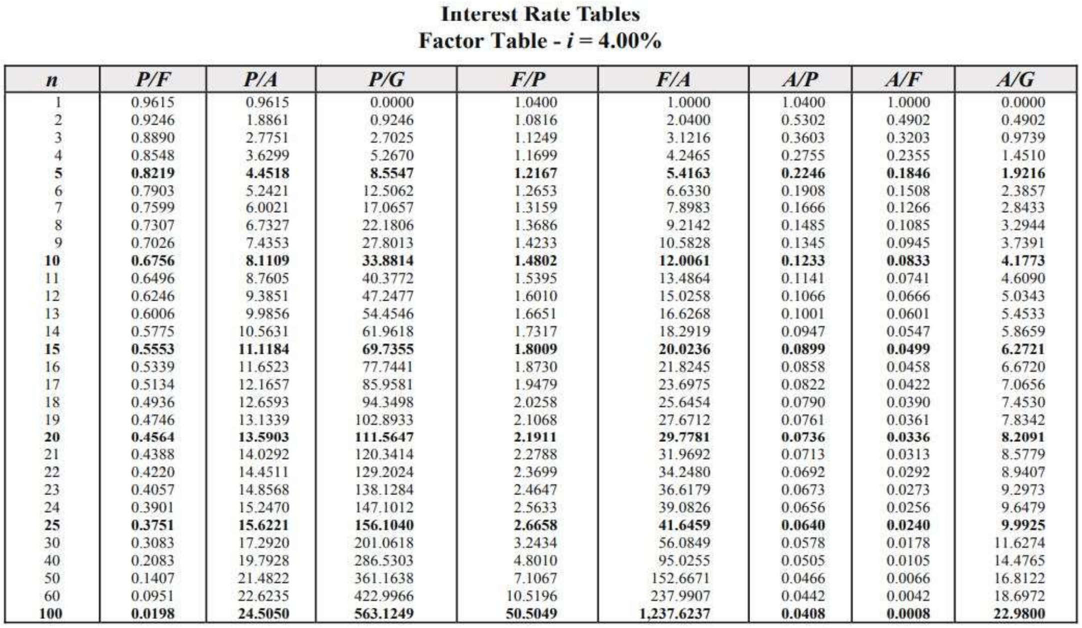
- $P = \frac{(1+i)^n - 1}{i(1+i)^n}$
- $(\frac{P}{A}, i\%, n)$
- BDAs: $P = 1200 \left(\frac{P}{A}, 4\%, 20\right) = 1200(13.5903) = \$16{,}308$
- BMPs: $P = 78{,}000 \left(\frac{P}{A}, 4\%, 20\right) = 78{,}000(13.5903) = \$1{,}060{,}043$
- Pond: $P = 7000 \left(\frac{P}{A}, 4\%, 20\right) = 7000(13.5903) = \$95{,}132$

Equation 3: Capital Recovery[3]

- $A = \frac{i(1+i)^n}{(1+i)^n - 1}$
- $(\frac{A}{P}, i\%, n)$
- BDAs: $A = 5500 \left(\frac{A}{P}, 4\%, 20\right) = 5500(0.0736) = \$405$
- BMPs: $A = 277{,}000 \left(\frac{A}{P}, 4\%, 20\right) = 277{,}000(0.0736) = \$20{,}387$
- Pond: $A = 500{,}000 \left(\frac{A}{P}, 4\%, 20\right) = 500{,}000(0.0736) = \$36{,}800$

Equation 4: Uniform Series Sinking Fund[4]

- $A = \frac{i}{(1+i)^n - 1}$
- $(\frac{A}{F}, i\%, n)$
- BDAs: $A = 4000 \left(\frac{A}{F}, 4\%, 5\right) + 4000 \left(\frac{A}{F}, 4\%, 10\right) + 4000 \left(\frac{A}{F}, 4\%, 15\right), +4000(\frac{A}{F}, 4\%, 20)$
    - $A = 4000(0.1846) + 4000(0.0833) + 4000(0.0499), +4000(0.0336) = \$1406$
- Pond: $A = 30{,}000 \left(\frac{A}{F}, 4\%, 20\right) = 30{,}000(0.0336) = \$1008$



Interest Rate Tables
Factor Table - *i* = 4.00%

n	*P/F*	*P/A*	*P/G*	*F/P*	*F/A*	*A/P*	*A/F*	*A/G*
1	0.9615	0.9615	0.0000	1.0400	1.0000	1.0400	1.0000	0.0000
2	0.9246	1.8861	0.9246	1.0816	2.0400	0.5302	0.4902	0.4902
3	0.8890	2.7751	2.7025	1.1249	3.1216	0.3603	0.3203	0.9739
4	0.8548	3.6299	5.2670	1.1699	4.2465	0.2755	0.2355	1.4510
5	**0.8219**	**4.4518**	**8.5547**	**1.2167**	**5.4163**	**0.2246**	**0.1846**	**1.9216**
6	0.7903	5.2421	12.5062	1.2653	6.6330	0.1908	0.1508	2.3857
7	0.7599	6.0021	17.0657	1.3159	7.8983	0.1666	0.1266	2.8433
8	0.7307	6.7327	22.1806	1.3686	9.2142	0.1485	0.1085	3.2944
9	0.7026	7.4353	27.8013	1.4233	10.5828	0.1345	0.0945	3.7391
10	**0.6756**	**8.1109**	**33.8814**	**1.4802**	**12.0061**	**0.1233**	**0.0833**	**4.1773**
11	0.6496	8.7605	40.3772	1.5395	13.4864	0.1141	0.0741	4.6090
12	0.6246	9.3851	47.2477	1.6010	15.0258	0.1066	0.0666	5.0343
13	0.6006	9.9856	54.4546	1.6651	16.6268	0.1001	0.0601	5.4533
14	0.5775	10.5631	61.9618	1.7317	18.2919	0.0947	0.0547	5.8659
15	**0.5553**	**11.1184**	**69.7355**	**1.8009**	**20.0236**	**0.0899**	**0.0499**	**6.2721**
16	0.5339	11.6523	77.7441	1.8730	21.8245	0.0858	0.0458	6.6720
17	0.5134	12.1657	85.9581	1.9479	23.6975	0.0822	0.0422	7.0656
18	0.4936	12.6593	94.3498	2.0258	25.6454	0.0790	0.0390	7.4530
19	0.4746	13.1339	102.8933	2.1068	27.6712	0.0761	0.0361	7.8342
20	**0.4564**	**13.5903**	**111.5647**	**2.1911**	**29.7781**	**0.0736**	**0.0336**	**8.2091**
21	0.4388	14.0292	120.3414	2.2788	31.9692	0.0713	0.0313	8.5779
22	0.4220	14.4511	129.2024	2.3699	34.2480	0.0692	0.0292	8.9407
23	0.4057	14.8568	138.1284	2.4647	36.6179	0.0673	0.0273	9.2973
24	0.3901	15.2470	147.1012	2.5633	39.0826	0.0656	0.0256	9.6479
25	**0.3751**	**15.6221**	**156.1040**	**2.6658**	**41.6459**	**0.0640**	**0.0240**	**9.9925**
30	0.3083	17.2920	201.0618	3.2434	56.0849	0.0578	0.0178	11.6274
40	0.2083	19.7928	286.5303	4.8010	95.0255	0.0505	0.0105	14.4765
50	0.1407	21.4822	361.1638	7.1067	152.6671	0.0466	0.0066	16.8122
60	0.0951	22.6235	422.9966	10.5196	237.9907	0.0442	0.0042	18.6972
100	**0.0198**	**24.5050**	**563.1249**	**50.5049**	**1,237.6237**	**0.0408**	**0.0008**	**22.9800**

Figure 21. 4% interest rate engineering economics table utilized in LCCA calculations.

Appendix C (AutoCAD)

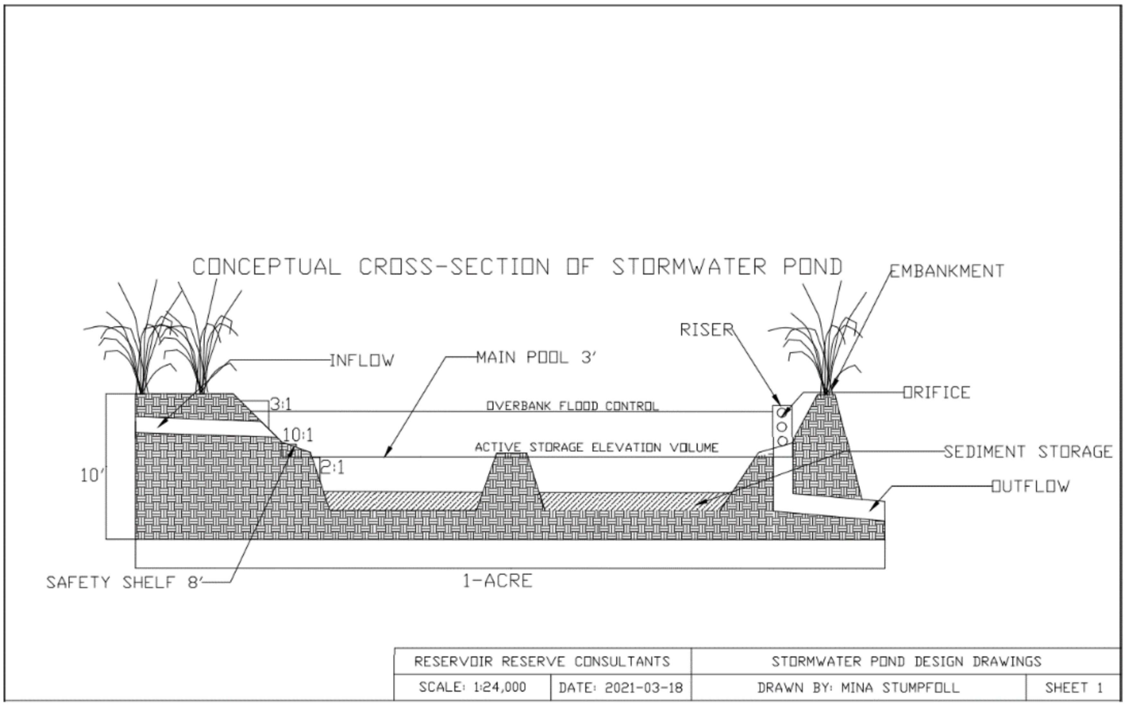


Figure 22. AutoCAD drawing of proposed Stormwater Retention Pond.

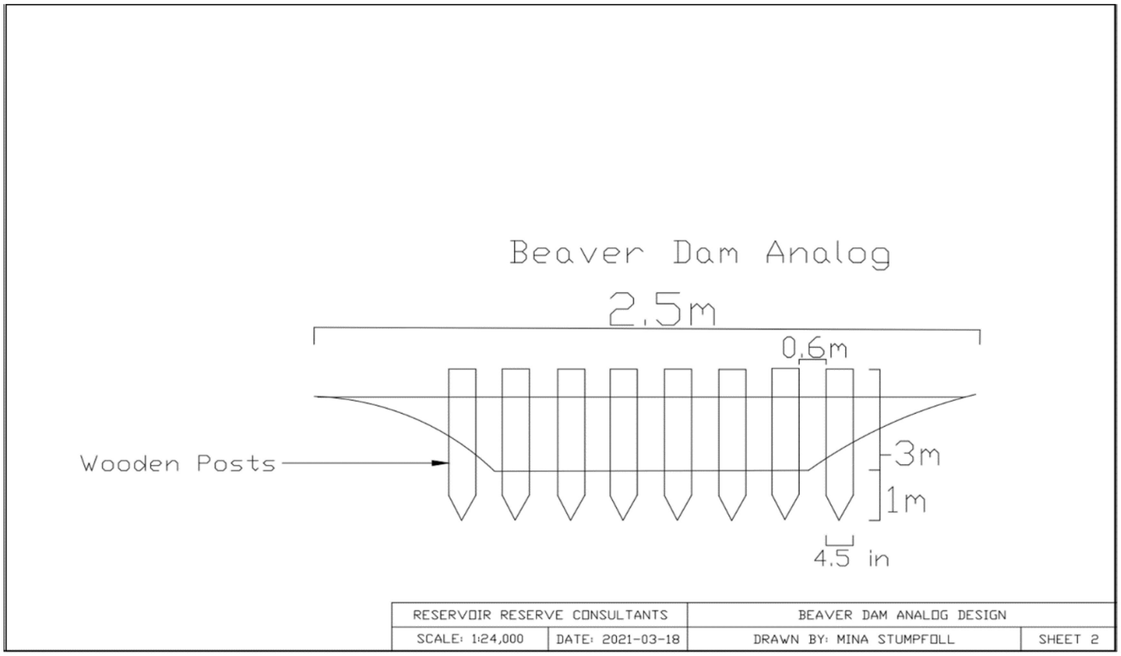


Figure 23. AutoCAD drawing of proposed Beaver Dam Analog structure.

Appendix D (Additional Equations)

Equation 5:

- $S_a = 1.2 * \left(\frac{q_o}{v_s}\right) = 43{,}403\ ft^2 = \sim 1 - acre$
    - $S_a = permanent\ pool\ surface\ area\ (ft^2)$
    - $1.2 = EPA\ recommended\ safety\ factor$
    - $q_o = post - construction\ peak\ outflow\ during\ 1 - yr, 24 - hour\ design\ storm\ (\frac{ft^3}{sec})$
        - $q_o = 10.67\ \frac{ft^3}{sec}$
    - $v_s = particle\ settling\ velocity\ \left(\frac{ft}{sec}\right) = 2.95 * 10^{-4} (12\ micron)$

Equation 6:

- $Q = V * A$
    - $Q = streamflow\ rate\ \left(\frac{ft^3}{sec}\right) = 4.5\ \frac{ft^3}{sec}$
    - $V = average\ velocity\ of\ streamflow\ \left(\frac{ft}{sec}\right) = 0.952 \frac{ft}{sec}$
    - $A = \left(\frac{\pi * d^2}{4}\right)$
        - $d = diameter\ of\ pipe = 2.45\ ft = 29.44\ in = \sim 30\ in$

Equation 7: [Final Recommendation – Present Worth Analysis]

- BDAs: $P = 1500 + 500\left(\frac{P}{A}, 4\%, 20\right) + 1140 * \left(\frac{P}{F}, 4\%, 5\right) + 1140 * \left(\frac{P}{F}, 4\%, 10\right) + 1140 * \left(\frac{P}{F}, 4\%, 15\right) + 1140 * \left(\frac{P}{F}, 4\%, 20\right) = 1500 + 500(13.5903) + 1140 * (0.8219) + 1140 * (0.6756) + 1140 * (0.5553) + 1140 * (0.4564) = \$8{,}696$
- BMPs: $P = 40{,}000 + 49{,}000\left(\frac{P}{A}, 4\%, 20\right) = 40{,}000 + 49{,}000(13.5903) = \$705{,}925$

Appendix E (Additional Product Data)

SURFACE AERATOR

Introduce More Oxygen with a Kasco Surface Aerator

High performance surface aerators dramatically push high volumes of water into the air. This process increases the overall health of your water and keeps it thoroughly mixed. These self-contained units deliver up to 3.0 lbs of O_2 per horsepower per hour of operation, making Kasco surface aerators the most dependable and efficient units on the market.

- Proven performance for continuous, supplemental or emergency aeration
- 1/2HP, 3/4HP and 1HP sizes can easily be moved and installed by 1 person
- ETL listed as complete package to UL and CSA safety standards
- 2 year warranty on 1/2HP, 3/4HP and 1HP
- 3 year for the 2HP, 3HP and 5HP

EFFICIENT/LOW POWER USE

Kasco surface aerators feature the highest efficiency design to ensure low power consumption. This attention to efficiency combined with lower monthly power bills, low maintenance, and a very affordable initial purchase price allows our surface aerators to have a very low total cost of ownership.

RUGGED MOTOR

Manufactured with robust components ensures the most dependable unit motor on the market. Featuring hard-face internal mechanical seals for leak protection, long-life top and bottom ball bearings and environmentally friendly mineral oil lubrication for excellent heat dissipation.

CORROSION RESISTANT

These units thrive in corrosive and salt water environments. All external metal, motor, and hardware components are of stainless steel composition and protected by a sacrificial zinc anode. Units with stainless steel tops and double mechanical seals are available for harsher environments.

LOW MAINTENANCE

Kasco surface aerators are maintained by simply cleaning the motor housing once or twice per year and replacing the sacrificial zinc anode when visibly corroded.

MODEL NUMBERS AND SPECIFICATION

60 HZ MODELS	SIZE (HP)	VOLT (V)	PHASE	AMPS	OPTIONAL CONTROL PANEL	MINIMUMV OPERATING DEPTH (IN)
2400AF	1/2	120	1	5.7	C-25	15
3400AF	3/4	120	1	7	C-25	17.5
3400HAF	3/4	208-240	1	3.5	C-220	17.5
4400AF	1	120	1	9.1	C-25	19
4400HAF	1	208-240	1	4.5	C-220	19
8400AF	2	208-240	1	9	C-220	20
2.3AF	2	230	3	4.5	CA-3235	20
2.3HAF	2	460	3	2.8	Inquire	20
3.1AF	3	208-240	1	10.7	C-230	24
3.3AF	3	230	3	8.2	CA-3235	24
3.3HAF	3	460	3	4.1	Inquire	24
5.1AF	5	208-240	1	18	C-230	26
5.3AF	5	230	3	18	CA-3235	26
5.3HAF	5	460	3	6.5	Inquire	26

Product Notes

- AF model numbers have 50 ft., 100 ft., 150 ft., and 200 ft., cord lengths available
- HAF model numbers have 50 ft., 100 ft., 150 ft., 200 ft., 250 ft., 300 ft., 400., and 500 ft., cord lengths available
- 2 and 5HP units available with NSF certification
- Bottom screens are optional for all units
- 50Hz units available for the international market.

COMMON APPLICATIONS

- Commercial aquaculture
- Residential ponds and lakes
- Retention ponds
- Leachate ponds
- Industrial lagoons
- Waste water lagoons
- Marina entrance and navigation

Commercial aquaculture

Residential pond

Pair your surface aerator with a Kasco LED light kit for an added effect. Choose from the RGB color changing lights, composite lights or stainless steel lights.

Kasco®

kascomarine.com

BTL
LINERS
GEOMEMBRANE SYSTEMS

RPEL™-30

Single Scrim Laminated LDPE with LLDPE Film (polyethylene)

LOW TEMPERATURE - HYDROCARBON STABLE

DESCRIPTION	BLACK 12 X 12 COUNT PER INCH	
FABRICATION & WAREHOUSE	PRINEVILLE, OREGON	
WEIGHT	14.7 OZ./SQ.YD. (+/-5%)	ASTM D751
THICKNESS	30 MIL (+/-10%)	ASTM D1777
COATING THICKNESS	2.4 MIL EACH (+/-5%)	
TENSILE STRENGTH (GRAB METHOD)	MD 410 LBS. TD 400 LBS.	ASTM D7004
STRIP TENSILE	MD 260LBS. TD 260 LBS.	ASTM D7003
TONGUE TEAR	MD 79 LBS. TD 81 LBS.	ASTM D5884
BURSTING STRENGTH (MULLEN)	622 PSI	ASTM D3786
MVTR	0.33 g/m^2- 24hr (0.05 perms)	ASTM E96
HYDROSTATIC RESISTANCE	635 PSI	ASTM D751
PUNCTURE RESISTANCE	195 LBS.	ASTM D4833
CBR STATIC PUNCTURE	1272 lb (5658 N)	ASTM D6241
CARBON BLACK CONTENT	3%	ASTM D4218
DIMENSIONAL STABILITY	MD -2.9% TD -1.0%	ASTM D1204
LOW TEMPERATURE COLD CRACK	-85º F	ASTM D2136
HP-OIT	3048 minutes	ASTM D5885
UV RESISTANCE	>90% STRENGTH RETAINED ASTM G-151 AFTER 2000 HRS.	

NSF®
Certified to
NSF/ANSI 61-G & 372

ALL DATA IS DRAWN FROM U.S. TESTING AND PRECISION LABORATORIES. AVAILABLE ON REQUEST.

Applied Polymer Systems
519 Industrial Drive, Woodstock, GA 30189
www.siltstop.com
Phone: 678-494-5998
Toll-free: 866-200-9868
Fax: 678-494-5298

APS 700 Series Floc Logs®

Polyacrylamide Sediment and Turbidity Control Applicator Logs

APS 700 Series Floc Logs are a group of soil-specific tailored log-blocks that contain blends of water treatment components and polyacrylamide co-polymer for water clarification. They reduce and prevent fine particles and colloidal clays from suspension in stormwater. There are several types of Floc Logs designed to treat most water and soil types. Contact Applied Polymer Systems, Inc. or your local distributor for free testing and site-specific application information.

Primary Applications

- Mine tailings and waste pile ditches
- Stormwater drainage from construction and building sites
- Road and highway construction runoff ditches
- Ditch and treatment system placement for all forms of highly turbid waters (less than 4% solids)
- Dredging operations as a flocculent

Features and Benefits

- Removes solubilized soils and clay from water
- Prevents colloidal solutions in water within ditch systems
- Binds cationic metals within water, reducing solubilization
- Binds pesticides and fertilizers within runoff water
- Reduces operational and cleanup costs
- Reduces environmental risks and helps meet compliance

Specifications / Compliances

- ANSI/NSF Standard 60 Drinking water treatment chemical additives
- 48h or 96h Acute Toxicity Tests (*D. magna* or *O. mykiss*)
- 7 Day Chronic Toxicity Tests *(P. promealas* or *C. dubia*

Packaging

APS 700 Series Floc Logs are packaged in boxes of four (4)

Technical Information

Appearance - semi-solid block
Biodegradable internal coconut skeleton
Percent Moisture - 40% maximum
pH 0.5% Solution - 6-8
Shelf Life – up to 5 years when stored out of UV rays

Applied Polymer Systems
519 Industrial Drive, Woodstock, GA 30189
www.siltstop.com
Phone: 678-494-5998
Toll-free: 866-200-9868
Fax: 678-494-5298

Placement

Floc Logs are designed for placement within ditches averaging three feet wide by two feet deep. Floc log placement is based on gallon per minute flow rates. Note: actual GPM or dosage will vary based on site criteria and soil/water testing.

Directions for Use

(Water and Floc Log Mixing is Very Important!)

APS 700 Series Floc Logs should be placed within the upper quarter to half of a *stabilized* ditch system or as close as possible to active earth moving activities. Floc Logs have built in ropes with attachment loops which can be looped over stakes to ensure they remain where placed. Mixing is key! If the flow rate is too slow, adding sand bags, cinder blocks, etc., can create the turbulence required for proper mixing. Floc Logs are designed to treat dirty water, not liquid mud; when the water contains heavy solids (exceeding 4%), it will be necessary to create a sediment or grit pit to let the heavy solids settle before treating the water.

Floc Logs must not be placed in areas where heavy erosion would result in the Floc Logs becoming buried. Where there is heavy sedimentation, maintenance will be required.

APS 700 Series Floc Logs can easily be moved to different locations as site conditions change. Water quality will be improved with the addition of a dispersion field or soft armor covered ditch checks below the Floc Log(s) to collect flocculated particulate. Construction of mixing weirs may be required in areas where short ditch lines, swelling clays, heavy particle concentrations, or steep slopes may be encountered.

Cleanup:

Latex or rubber gloves are recommended for handling during usage. Use soap and water to wash hands after handling.

Precautions / Limitations

- APS 700 Series Floc Logs are extremely slippery when wet.
- Clean up spills quickly. Do not use water unless necessary as extremely slippery conditions will result and if water is necessary, use pressure washer.
- APS Floc Log will remain viable for up to 5 years when stored out of UV rays.
- APS 700 Series Floc Logs have been specifically tailored to specific water and soil types and samples must be tested. Testing is necessary and is free.
- For product information, treatment system design assistance, or performance issues, contact Applied Polymer Systems.

RRC

Reservoir Reserve Consultants
324 Wendt Commons
215 North Randall Avenue
Madison, WI 53715

Tuesday, April 6th, 2021

Mark Oleinik, PE Adjunct Professor
2346 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

RE: 100% Geotechnical Report for Team 7 – Lake Ripley Watershed

Dear Mr. Mark Oleinik,

Reservoir Reserve Consultants has completed the geotechnical investigation for three potential site locations for the Lake Ripley Management District Flood and Nutrient Control Project. These locations were selected to decrease phosphorus loading from flooding into Lake Ripley.

Power Tools, Inc. performed the subsurface exploration and provided the boring log data for these potential site locations.

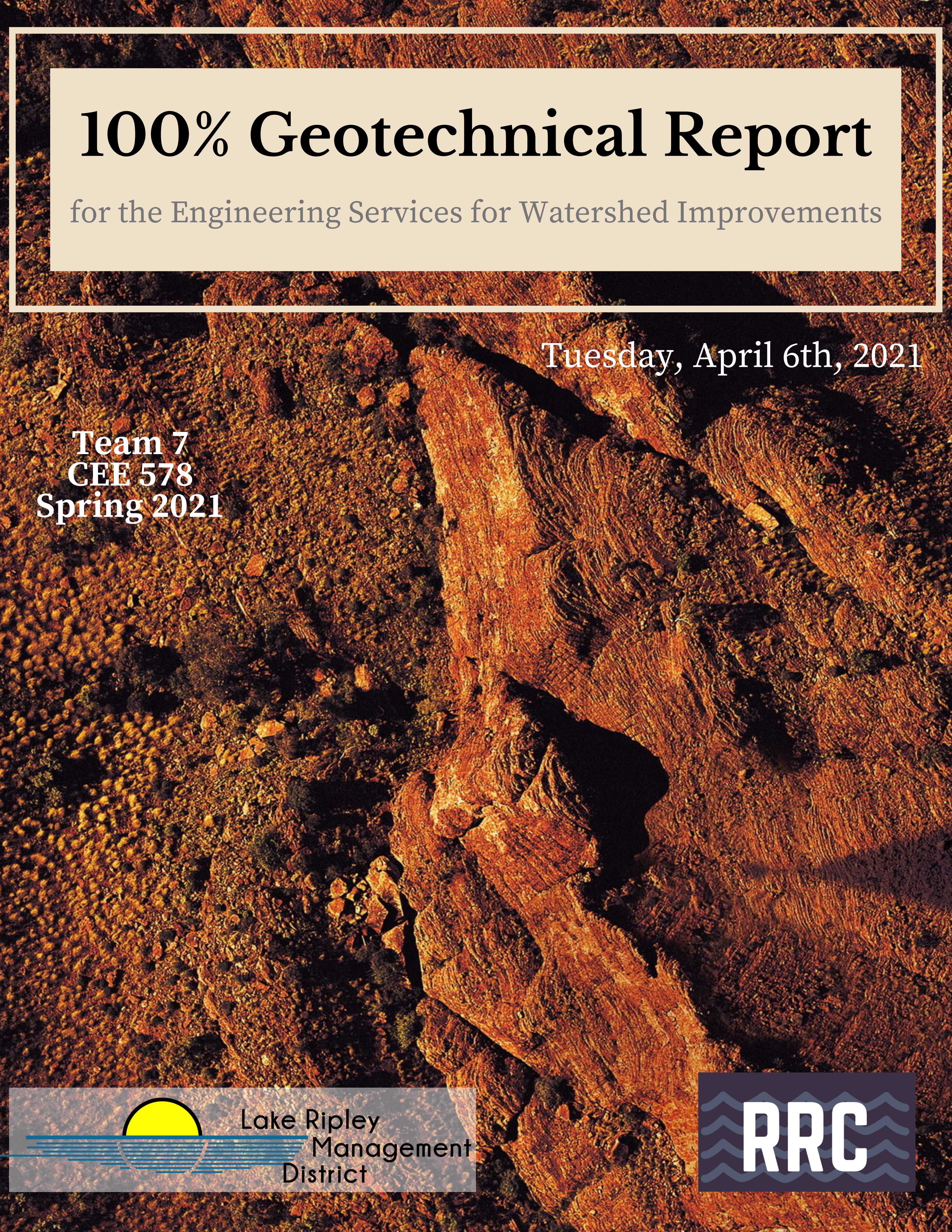
This report contains a description of the testing services that were conducted and geotechnical findings that were necessary to provide recommendations for each site. Reservoir Reserve Consultants will verify and approve the recommendations provided in this report during the construction phase of the project.

Please feel free to contact Tea Jackson-Strong via email at jacksonstron@wisc.edu if you have any questions or comments regarding the following report.

Sincerely,

Tea Jackson-Strong

Tea Jackson-Strong
Geotechnical Engineer
Reservoir Reserve Consultants



100% Geotechnical Report

for the Engineering Services for Watershed Improvements

Tuesday, April 6th, 2021

Team 7
CEE 578
Spring 2021

Lake Ripley
Management
District

RRC

Disclaimer

The concepts, drawings and written materials detailed in this document were prepared by students in the Department of Civil & Environmental Engineering at the University of Wisconsin-Madison through the Civ Engr 578 – Senior Capstone Design/GLE 479 – Geological Engineering Design course. This document does not represent the work of a licensed Professional Engineer and is not for construction purposes.

Table of Contents

Introduction

Reservoir Reserve Consultants has prepared this geotechnical report for the Lake Ripley Management District in Cambridge Wisconsin, concerning the Lake Ripley project focused on decreasing the phosphorus loading that enters the lake. This presents the geotechnical information necessary for the implementation of vegetative buffers, raingardens, and biofilters, as well as construction of a retention basin and Beaver Dam Analogs (BDA).

Vegetative buffers, raingardens and biofilters required an analysis of drainage properties for the necessary soils required for vegetation settings. The implementation of raingardens and biofilters will require slight excavation of 1 ft. The retention basin required a slope analysis and detailed site preparation plans. The retention basin requires the largest excavation of 5 ft over a 1-acre surface. Excess soil may be used for the embankment and vegetative buffers. BDA structure required analysis of the foundation embedment, settlement and hydrostatic pressure. Accessing the retention basin and BDA sites will need cleared pathways to place timber mats, so that the machinery necessary for construction will not sink or get stuck in the marshy wetland areas.

The purpose of this geotechnical report is to recommend the following: locations in which the vegetative buffers, raingardens, and biofilters will thrive based on soil stratigraphy, maximum slopes in the construction of the retention pond, and depth and spacing of wooden piles for the BDA structures. Additionally, this report will provide other engineering and construction related recommendations for the Lake Ripley Management District Flood and Nutrient Control Project. The boring logs and data used in this report were provided by Power Tools, Inc.

Project Background

Lake Ripley is currently surrounded by both an agricultural and residential area. There are three main roads that incase the lake region - Highway 18, Highway 12 and County Road A. This region has predominately been used for agricultural purposes. While agricultural areas along Highway 18, Highway 12 and the inlet stream have been lost from 1993-2011 [11], the residential use of the area has increased. Structures such as residential homes, boathouses, commercial buildings and fire pits have developed over the years, thus, increasing the impervious surfaces around the lake and inlet stream regions [11].

The Best Management Practice (BMP) designs are located within the Houghton muck (Ht) and WtA boundary regions. The retention basin is located within a Casco loam (CaC2) rich area with the bottom submerging into the Watseka sand (WtA) bed. The Beaver Dam Analogs (BDA) will be driven into the streambed, which consists of stratified sand. The stream has an average width of 7 yards, and average depth of 0.58 ft. Reservoir Reserve Consultants is currently preparing the preliminary designs for each of these alternatives.

The proposed locations of these designs are shown in Figure 4. As discussed with the Lake Ripley Management District, these locations were approved and selected to target the phosphorus levels from entering Lake Ripley along the inlet stream.

Scope of Subsurface Exploration

Two standard penetration test (SPT) borings were drilled by Power Tools, Inc. Power Tools, Inc. performed the SPT in accordance with ASTM D 1586, using a continuous split spoon sampler. A Hollow-Stem auger was used with a 4-inch diameter and 10-foot length.

Boring No. 1 was drilled in the northern area of Lake Ripley, near Highway 18, and Boring No. 2 was drilled in the southern area of Lake Ripley, near the Highway 12 inlet. These locations are shown in Figure 2. These two locations were selected as they are within the watershed boundary, and in fields, rather than residential areas. Boring No. 1 is located on the Lake District Preserve; and Boring No. 2 is located within the Lake Ripley District Management property. Boring No. 1 was performed on Monday, February 1st, 2021 at an elevation of 861.8 ft and Boring No. 2 was performed one week later, on Monday, February 8th, 2021 at an elevation of 865.8 ft. The depth to groundwater table was obtained during this subsurface exploration. Boring No. 1 displayed the depth to groundwater table at 8.0 ft below the surface, and Boring No. 2 displayed the depth at 7.5 ft. The detailed borings are included in Appendix A.

Soil samples were collected and classified using the Unified Soil Classification System (USCS).

Site Description

Reservoir Reserve Consultants conducted a subsurface exploration in the watershed region of Lake Ripley, as shown in Figure 2 and Figure 3.

Regional Geology

The geology in Jefferson County, Wisconsin resembles end moraine glacial geology [5]. This is formed through the melting and moving of glaciers; and typically deposits a range of particle sizes from clay to boulders; as well as stratified sand and gravel [5]. The dominate parent material in this region is loamy alluvium over calcareous stratified sandy and gravelly outwash. The northern region of Lake Ripley has a 750 ft depth to bedrock: and an 800 ft depth in the southern region [5]. The bedrock identified in the north is St. Peter sandstone; and quartzite, a crystalline rock, in the south [5]. The soil near Lake Ripley is primarily made of sand, muck, and gravel [2]. It generally consists of sandy loam, silty loam, and muck with gravel pit areas. The bottom of Lake Ripley is made of 45% organic silt, 35% sand and 20% gravel [8].

The National Resources Conservation Survey (NRCS) soil maps are presented in Appendix A, Figures 9-12. The area of interest (AOI) indicated in the NRCS soil maps was selected to represent the land surface of the proposed alternative locations shown in Figure 4. The AOI includes regions Lake Ripley District Management property near the inlet stream, the Lake Ripley District Preserve and watershed area along the inlet stream.

Surface Characteristics

Figure 1. shows a topographic map of Lake Ripley and the surrounding land. The elevations range from 830 – 920 feet. Figure 3. shows the watershed boundary, Lake Ripley Management District preserve and property. Lake Ripley has a 423.3-acre surface area. The area surrounding the lake contains a 1.7-acre ditch area, and a dredged inlet channel of 2.5 acres [10]. The inlet steam that feeds into Lake Ripley is 4.25-mile-long. The lake has an average depth of 18 feet, and maximum depth of 44 feet [10]. The stream creates a valley type of structure which contains the lowest elevations, below 840 ft, leading into the lake.

Lake Ripley is currently an agricultural and residential area. There are roads and residential homes surrounding the lake. Historically, the region around Lake Ripley was primarily farmlands, and the land was used for agricultural purposes.

Subsurface Conditions

The northern region of the AOI is near Highway 18 where boring No. 1 was obtained. The southern region is near Highway 12 where boring No. 2 was obtained. These locations are shown in Figure 2. Figure 5 shows a generalized stratigraphic column of the AOI. This was constructed using boring log data, regional geology, topography and soil maps. The boring log data indicates that the northern region of the Lake Ripley watershed has a 0.75 ft layer of topsoil, a 3.25 ft layer of Fox loam (FoC2), 3 ft layer of Matherton silt loam (MmA); followed by Casco loam (CaC2). The southern region has a 1.25 ft layer of topsoil, an 8.25 ft layer of MmA; followed by CaC2. The detailed borings are located in Appendix A.

Fox silt loam/Fox loam (FsB/FoC2) are found in the higher elevation regions. Thus, a layer of FsB/FoC2 could be found within the general elevation range from 870 ft to 880 ft. FsB/FoC2 are categorized together as they have the same soil properties. Layers of MmA are located in the elevations from 855 ft to 870 ft. Layers of CaC2 range from 840 ft to 855 ft. Adrian muck (Ad) is found close to the inlet of the lake near the southern bay region. Ad and Ht are located in the shallow regions of this area, found between 835 ft to 840 ft in elevation, which is typically near the stream valley and inlet. Below 835 ft elevation, the underlying sediment consists of stratified sand. Watseka sand (WtA) is found at the bottom of the streambed between 830 ft to 835 ft in elevation. NRCS soil maps are included in Appendix A.

FsB/FoC2 is a well-drained material with a SM classification from the Unified Soil Classification System (USCS); this soil has a unit weight of 98.0 $\frac{lb}{ft^3}$. Fs/FoC2 is a compact soil with a corresponding N value of 13. MmA is a somewhat poorly drained material with a SM classification and unit weight of 96.1 $\frac{lb}{ft^3}$. MmA is also a compact soil with a corresponding N value of 11. CaC2 is somewhat drainable material with a SM classification and unit weight of 92.4 $\frac{lb}{ft^3}$. CaC2 compact and dense soil with a corresponding N value of 26. Ht has a PT classification, and unit weight of 17.5 $\frac{lb}{ft^3}$. WtA is a somewhat poorly drained material with a SM classification, and unit weight of 115.5 $\frac{lb}{ft^3}$. The properties of each soil are summarized in Table 2.

The particle size distribution report was derived from boring No. 2, as shown in Appendix A. Table 1. summarizes the findings of this report. The overall gradation of the soil in this region is dominantly clays, silts and fine sands.

Laboratory and Field Testing

During the subsurface exploration, as in accordance with ASTM D 1586, the standard penetration number (N) was recorded. This value defines the number of blows required to drive the sampling spoon over a depth interval of 1.5 feet. As previously stated, the length of the auger was 10-feet, with a 4-inch diameter. The samples were recovered to the surface for further laboratory testing by Power Tools, Inc.

In both areas, the topsoil is a moist fill. Each soil presented in Boring No. 1 was moist. The FoC2 layer was very moist with a 13% water content. Each soil presented in Boring No. 2 was moist. MmA had a water content of 11%. The organic contents are much higher in the PT soil compared to that of the SM soil. The Plastic Limit (PL), for SM classified soil, is typically around 22-23%, the Liquid Limit (LL) is between 35-50%, and the Plasticity Index (PI) is between 7-20%. For the PT classified soil, the PL is roughly 20%, the LL is 40-65%, and the PI is 10-15%. The detailed boring logs are in Appendix A.

Groundwater Conditions

In Jefferson County, the groundwater generally flows from east to west [8]. This is a continuous condition of the groundwater in this area. Lake Ripley is a drainage lake with the stream flow being the main water source [8]. About 30% of the water contributing to Lake Ripley is due to groundwater [11]. Generally, the depth to the groundwater table near Lake Ripley is less than 10 feet [5]. Boring No. 1 and No. 2, display the water table to be below the surface at 8.0 ft, and 7.5 ft, respectively. The groundwater table depth is relatively shallow in the wetlands, near the stream and regions around lake. The average surface elevation of Lake Ripley is 835 ft [8], which is an indication of the expected groundwater table depth in the surrounding areas.

The topography of the lake itself is generally less than 5 ft deep around the perimeter, with the inlet depth of 0-3 ft. The maximum depth of the lake is 44 ft. The average stream depth is 0.58 ft.

The minimum depth of the stream is 0.35 ft, and maximum depth is 1.38 ft. The average stream width is 8.2 ft, and has an inlet flow is 5 $\frac{ft^3}{s}$; and outlet flow of 8 $\frac{ft^3}{s}$ [8].

The construction of raingardens and the retention basin will cause the groundwater table to rise in the locations shown in Figure 4. Water will fill the pool created. Since these locations are within the watershed boundary near stream surfaces, it will not have a significant effect on the overall groundwater table gradient in surrounding areas.

Engineering Recommendations

Foundation

A shallow foundation system will be recommended for the alternatives outlined in this report. The round wooden piles needed to construct the BDA would be of 0.37 ft diameter, and 6.95 ft length. The piles should be spaced 2 ft apart in the channel. The piles will be driven 3.3 ft below the surface and should not extend 3.3 ft above the channel bed. An image of a BDA structure is shown in Figure 7. The bottom of the wooden piles will be driven into the streambed. The soil properties of the Watseka sand (WtA) are outlined in Table 3. The total weight of each BDA structure yields 137.0 $\frac{lb}{ft^2}$ across the area of the stream. The piles can be driven into WtA as it is below the ultimate and allowable bearing capacity of WtA. The estimated settlement of 0.005 ft will not affect the recommended dimensions of the wooden piles.

Slope

The retention pond has a permanent pool surface area of 1 acre and depth of 5 ft. The proposed location of the basin has an elevation of 835 ft. Therefore, the bottom of the basin will be in the WtA bed. This material is somewhat poorly drained. A geosynthetic liner such as reinforced polyethylene (RPE) or reinforced polypropylene (RPR) will be used to create a waterproof layer that is puncture resistant. An AutoCAD drawing of the retention basin is shown in Figure 6. The safety shelf around the pond will be 8 ft. in width and have a 10:1 slope. The regions above and below the shelf will have a 3:1 and 2:1 slope, respectively. These soils in this area have been tested and are suitable to withstand these slopes. The thickness of the embankment shown in Figure 6 is enough so that hydrostatic pressures will not affect the design. The geosynthetic liner would prevent the slopes from failing that could occur from saturated soils.

Bearing Capacity

The expected bearing capacity and allowable bearing pressures were obtained using Equations 1 and 2. Table 2 summarizes the measured and calculated properties of the generalized soil types found in the Lake Ripley watershed region. The ultimate bearing capacity for the Fox (silt) loam, Matherton silt loam, Casco loam, Houghton muck and Watseka sand were calculated to be 1566.5 psi, 1536.6 psi, 1476.7 psi, 30.6 psi, and 1761.5 psi, respectively. The allowable bearing pressures were 915.9 psi, 898.4 psi, 863.4 psi, 13.9 psi, and 1036.1 respectively. These calculations utilized a factor of safety of 2.

Settlement Estimation and Hydrostatic Pressure

The estimated settlement used Equations 3 and 4, and Figure 15. The estimated settlement of the BDA structure submerged into the WtA sand is 0.005 ft (or 0.06 in.). Table 3 outlines these properties. Appendix A contains the elastic settlement graphs used in this analysis.

The hydrostatic pressure of the inlet stream against the BDA structure was obtained using Equation 5. The average stream width of 0.58 ft yields a hydrostatic pressure of 1167.6 $\frac{lb}{ft \cdot s^2}$. Whereas, minimum and maximum stream width of 0.35 ft, and 1.38 ft yield 702.6 $\frac{lb}{ft \cdot s^2}$ and 2770.2 $\frac{lb}{ft \cdot s^2}$, respectively. Table 4 summarizes the hydrostatic pressures. This calculation was necessary to determine the stability of the BDA structure. With the recommended embedment depth of the wooden piles, the BDA will withstand the hydrostatic pressures caused by the river. The Earth pressure coefficient does not apply to this project.

Geotechnical-Related Construction

Site Preparation

BMPs

Vegetative buffers will require the excess excavated soil from the retention basin, raingardens and biofilter construction can be used as native material. The plants proposed will require moist, peaty soil for the vegetation to thrive. Raingardens will require excavation of 1 ft over a 0.25-acre surface area. The plants proposed will prefer well-drained soil layers so the roots can quickly spread. The excavation of these proposed locations will be placed in the CaC2 bed, which has drainable characteristics. Lastly, biofilters are concrete systems which will require slight excavation of 1 ft depth. Figure 8 shows the initial locations of all BMP designs. The vegetative buffer, shown with solid green lines, are placed along the inlet stream. The proposed locations of the biofilters, shown with pink dots, are near Ripley Rd. This area is marshy with low stream velocity. The groundwater is shallow near in all proposed locations as they are placed near the inlet stream. Obstructions over the raingarden and biofilter area will need to be removed.

Retention Basin

PT soil is a very compressible material, is not suited for construction purposes; therefore, it will need to be removed prior to construction. Construction of the retention pond will require the area to be excavated. Obstructions should be removed over the 1-acre surface area, and 5 ft depth.
A backhoe-excavator with low ground pressure (LGP) tracks will be needed in this wetland area. Backhoes are smaller and weigh less than an excavator. LGP tracks will allow the weight of the

machine to be distributed over a larger track area. The backhoe will use a smooth-edged bucket for the excavation. A pump will be needed to keep the excavated area as dry as possible.

The site will need to be accessed from Ripley Rd. A path from Ripley Rd to the retention basin site will need to be cleared for timber mats to be placed down. The distance from Ripley Rd to the site is 0.125 miles, which requires 33 20-foot-long timbers to be placed and connect via cable. Figure 4 shows the 0.125-mile path needed for access to the retention basin site using a black dashed line. These timber mats and the LGP tracks will prevent the backhoe-excavator from sinking.

The volume being filled is the same volume being cut; therefore, the excavated soil will be utilized for the embankment of the pond. The best soil to hold water behind a dam or embankment will have low seepage potential [15]; thus, will have a low saturated hydraulic conductivity. WtA soil has been tested and shown to be suitable for this purpose given the low saturated hydraulic conductivity. Rip rap will be added around the safety shelf to provide bank stabilization and prevent erosion. Additional excess soil not used for the embankment will be used for the vegetative buffers.

Beaver Dam Analogs

The bottom of the wooden piles will be driven into the streambed. This consists of the Watseka sand, other stratified sands, and gravel. A 1-mile path will need to be cleared from County Road A, along the inlet stream where the BDA structures will be placed. Figure 4 shows the 1-mile path needed for access to the BDA locations using a black dashed line. This will require 132 timbers to be placed and connected via cables. The posts will be set in the winter using the Geoprobe Model 8040DT hollow stem auger, with a 10-feet length and 4.5-inch diameter. The hollow stem auger will temporarily encase the hole so the piles can be directly driven into the streambed. The branches will need to be added in the spring, once the ice has melted.

Potential Environmental Issues/Limitations

The boring logs do not indicate any contaminates. Groundwater pollution is a potential issue that is dependent on the use of the land. Fertilizer and pesticides can contaminate the groundwater as runoff flows downstream [11]. The risk of pollution is increased if the soil is used for waste disposal [5]. Sewer lines could also degrade which would cause leaking, thus, contaminating the groundwater [11].

Appendix A: Figures

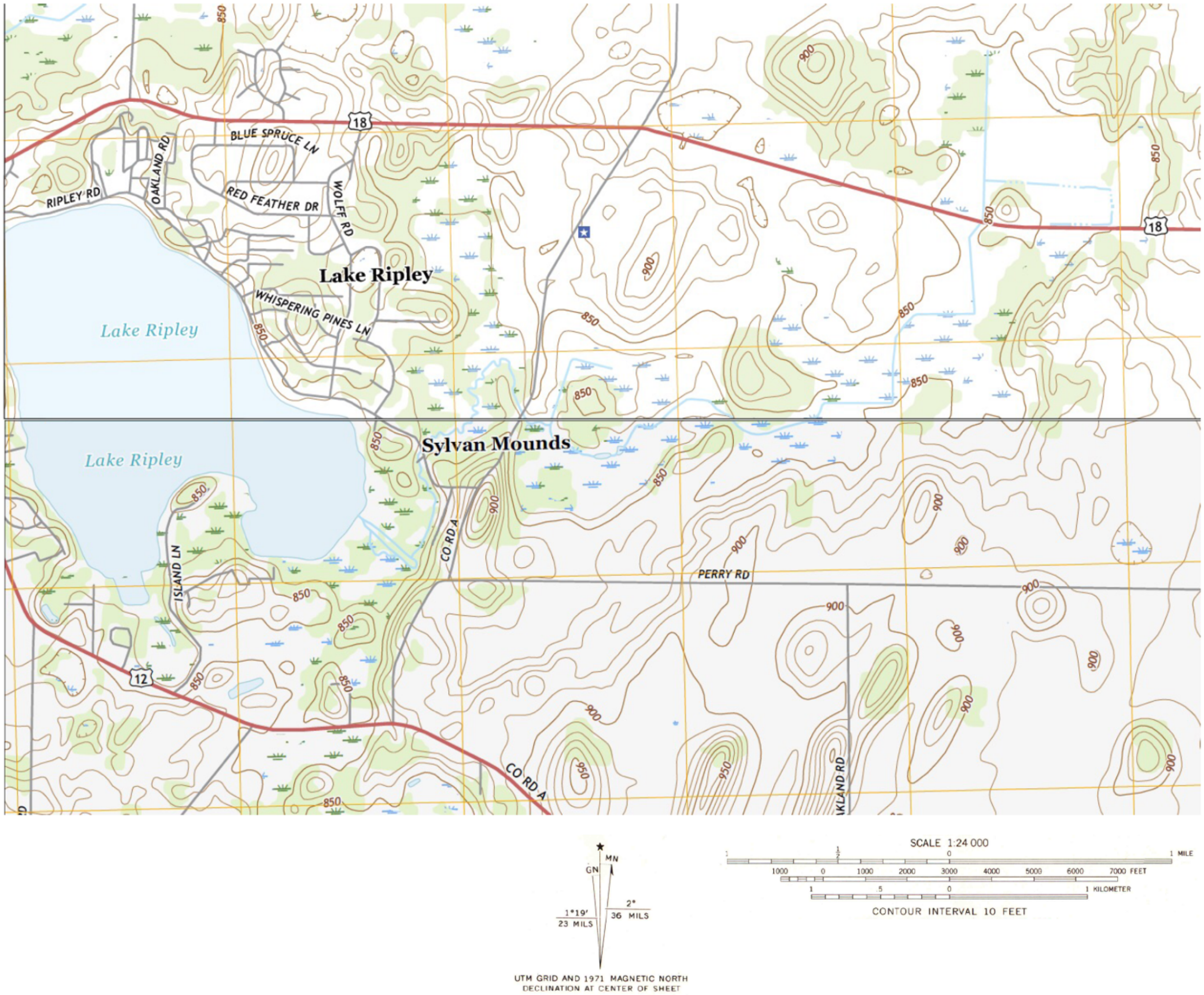


Figure 1. Topography of Lake Ripley. Constructed using two USGS maps [9].

Figure 2. Boring log locations [1]. Boring No. 1 is located near Highway 18, and Boring No. 2 is located near Highway 12.

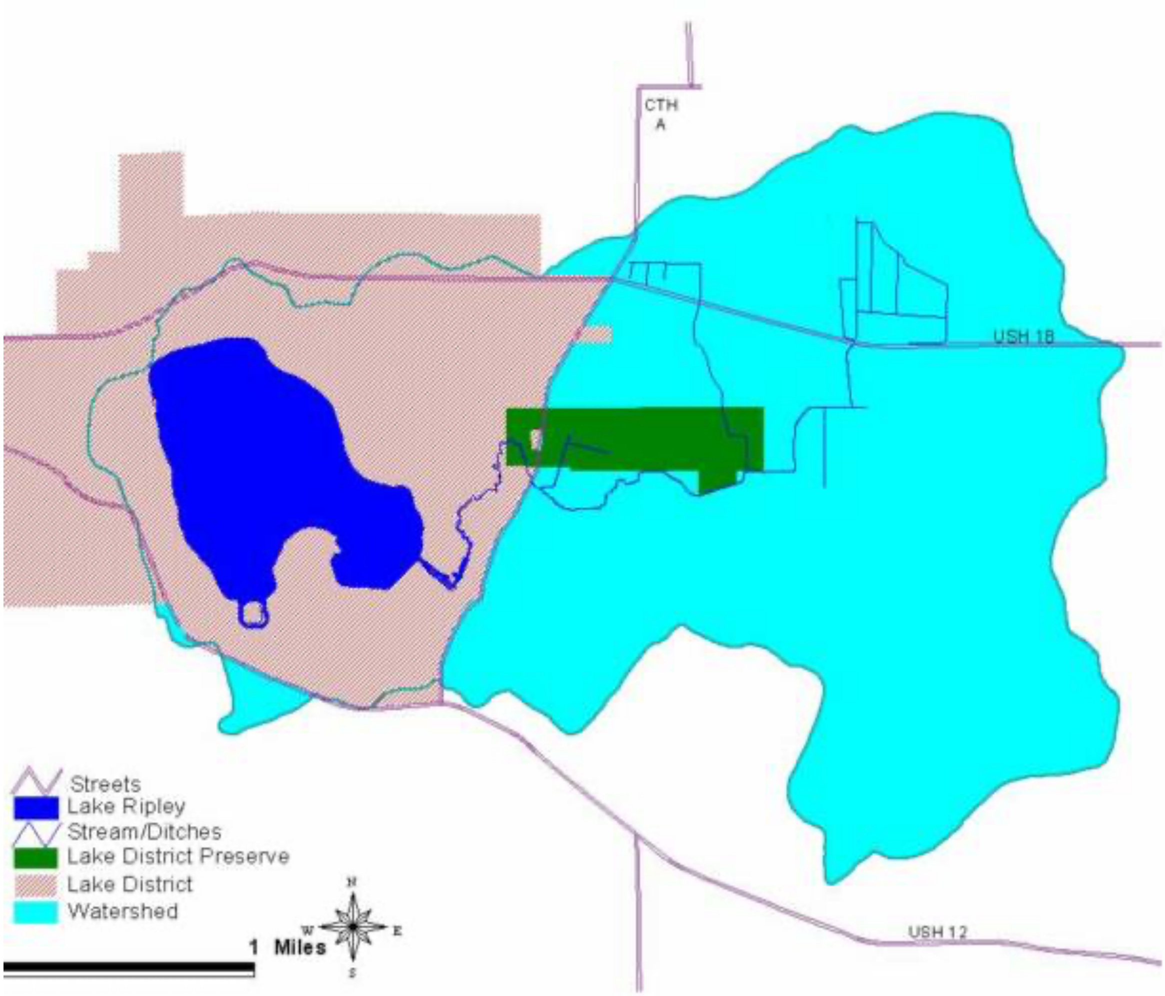


Figure 3. Map of Lake Ripley with outlined watershed boundary and Lake Ripley Management district property and preserve [3].

Figure 4. Locations of proposed solutions with outlined access paths.

Generalized Stratigraphic Column with Elevations

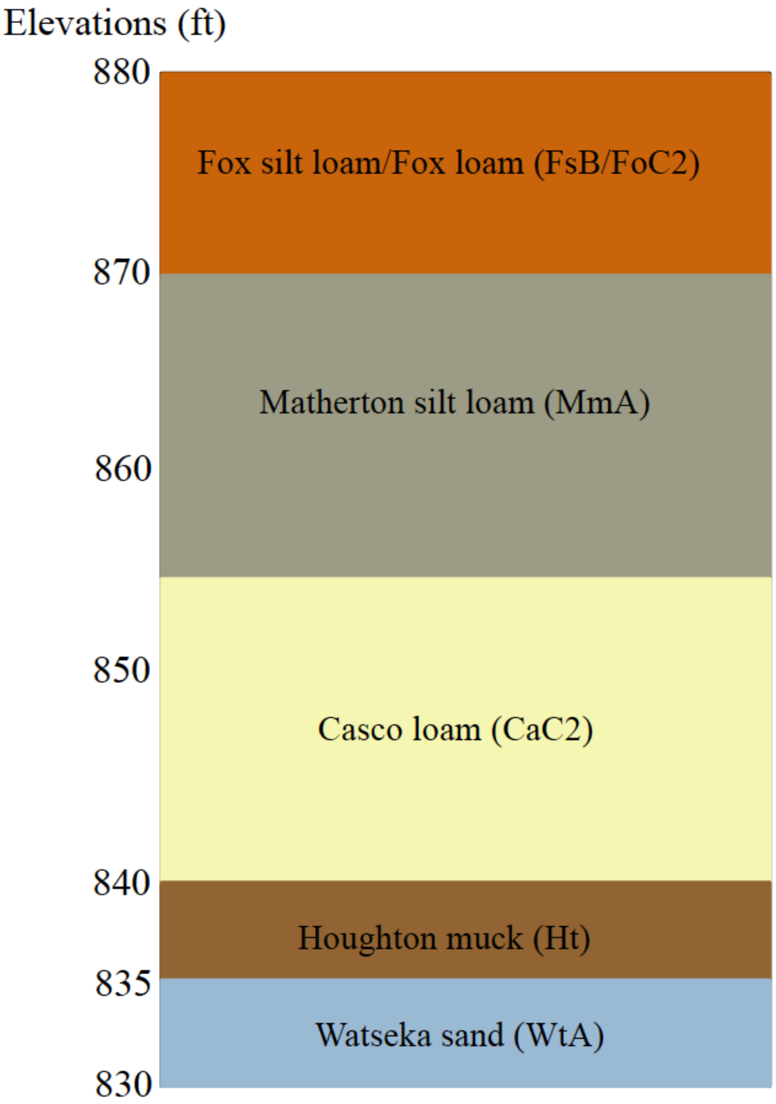


Figure 5. Generalized stratigraphic column based boring log data, regional geology, topography and soil maps.

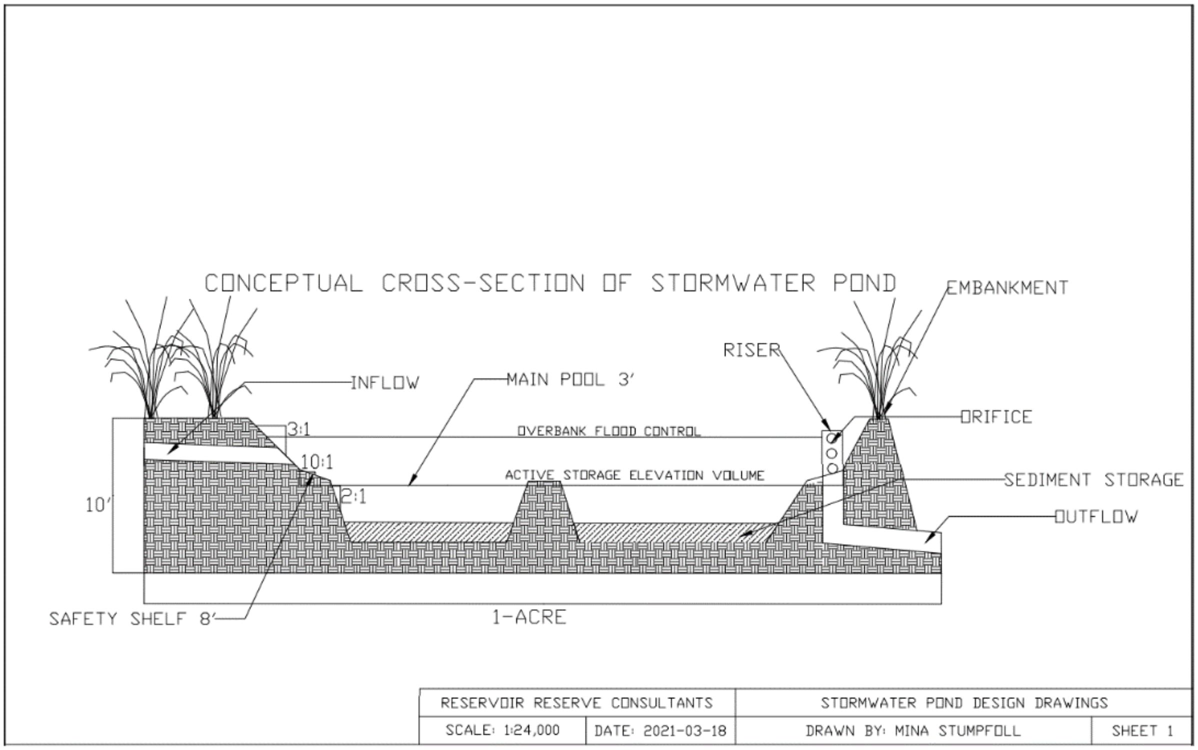


Figure 6. AutoCAD drawing of proposed Stormwater Retention Pond.

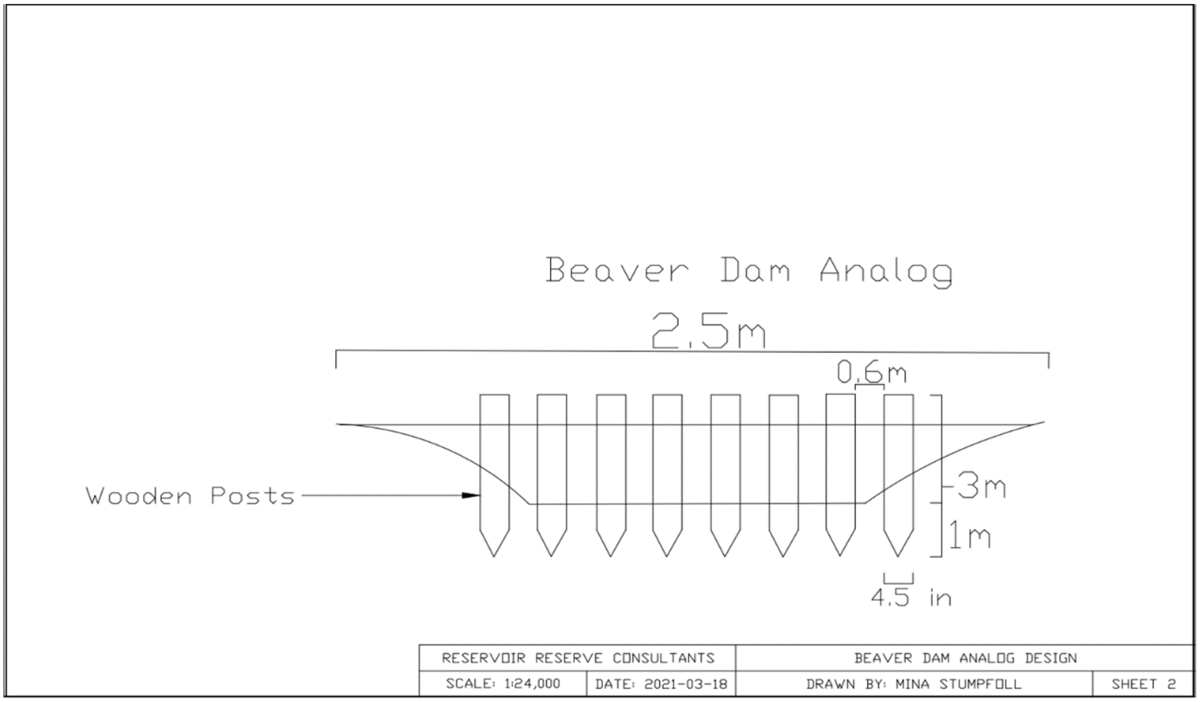


Figure 7. AutoCAD drawing of proposed Beaver Dam Analog structure.

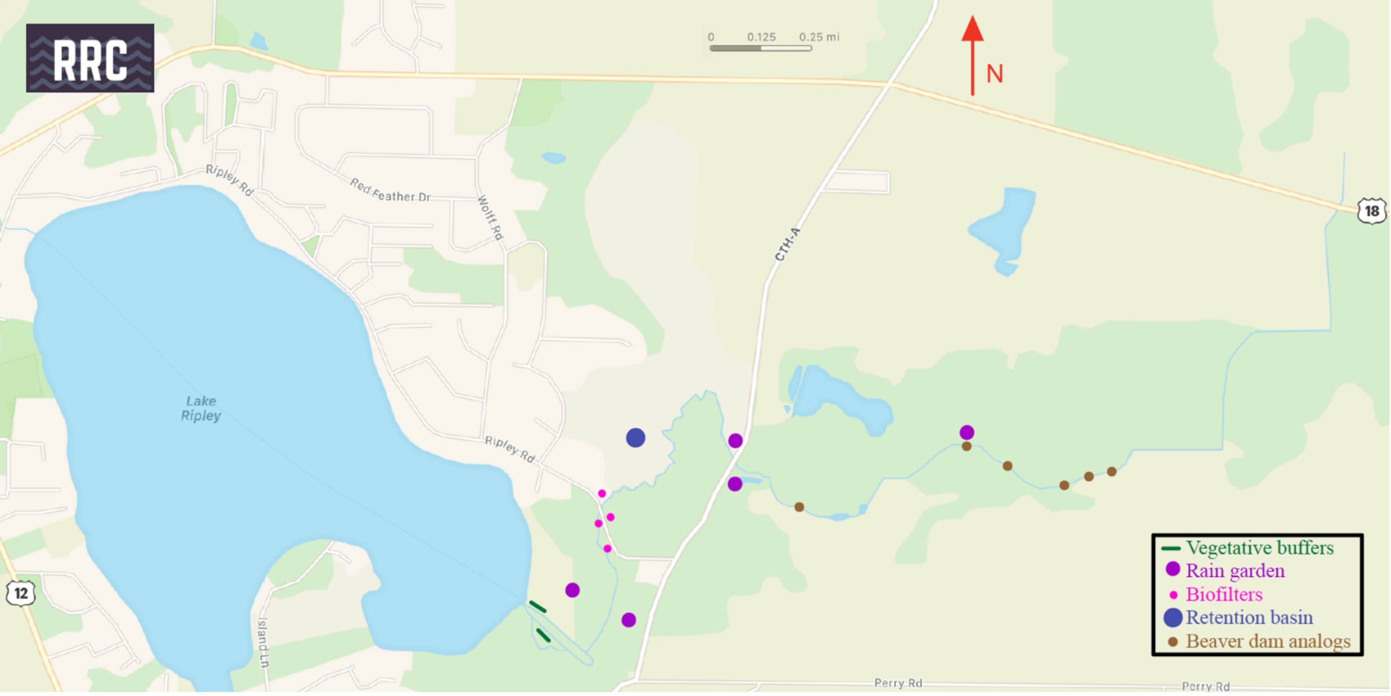


Figure 8. Initial locations of all BMP alternatives with retention basin and BDA locations.

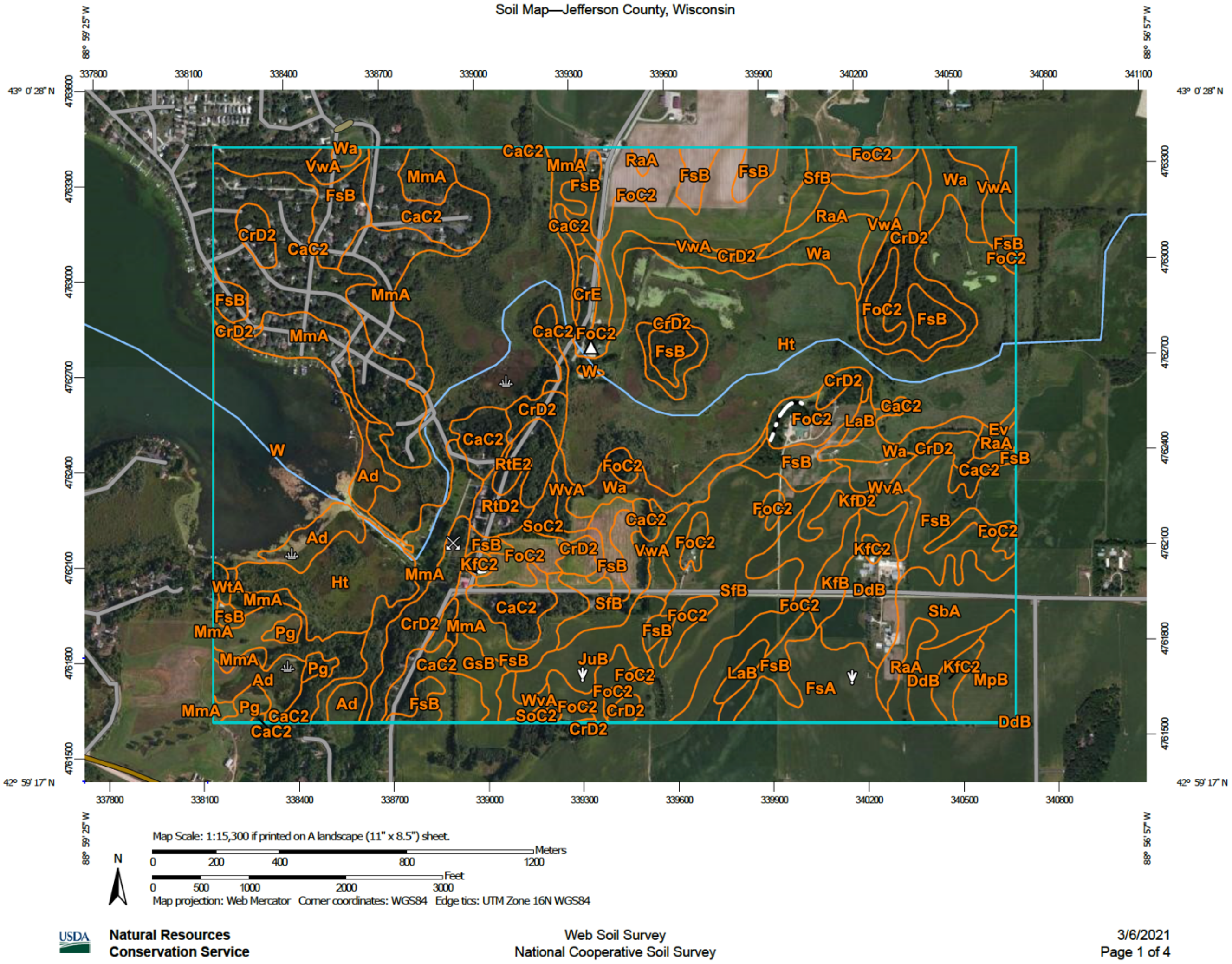
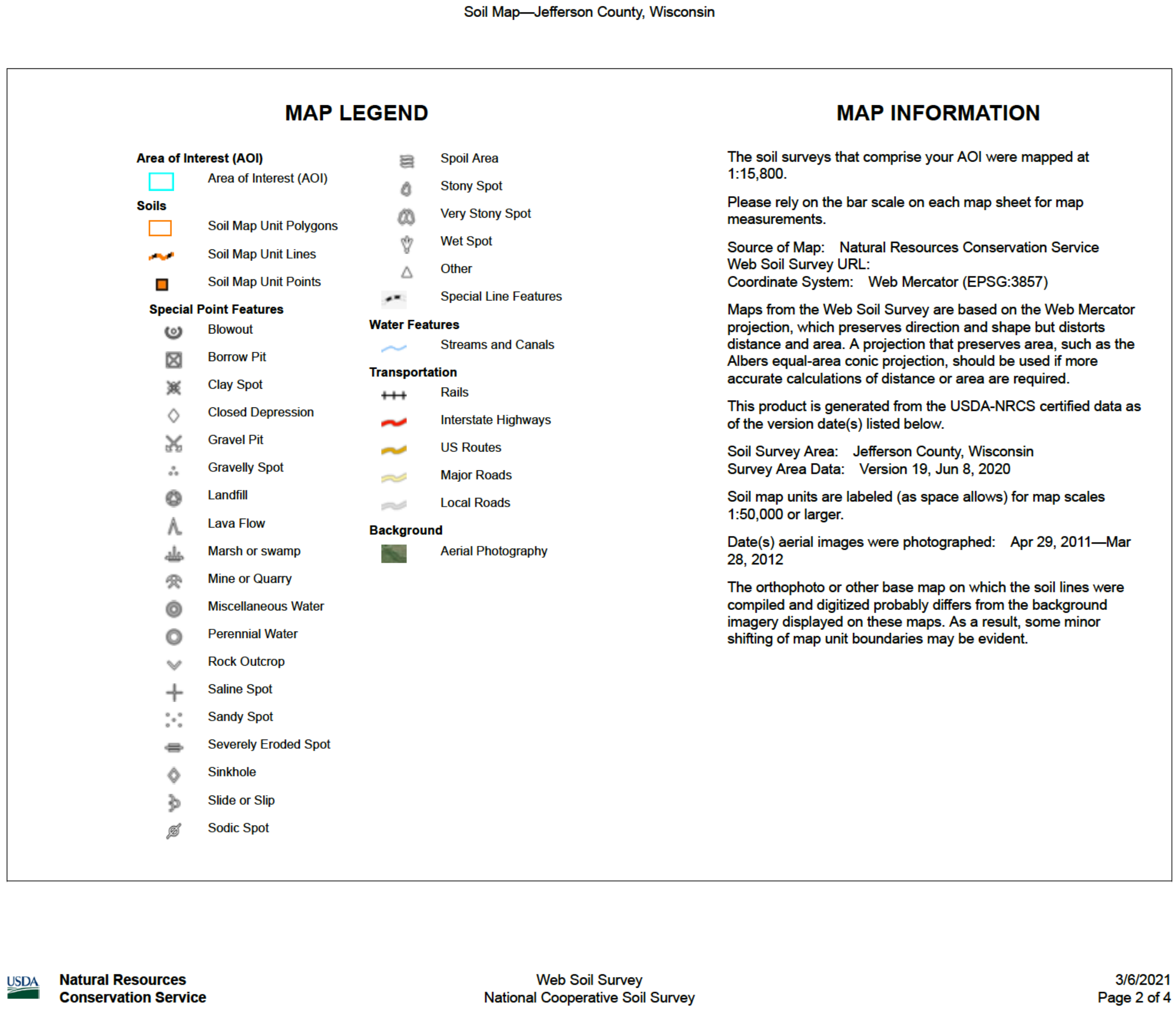


Figure 9. Soil map (pg. 1) of Lake Ripley's inlet stream with the AOI defined around the proposed alternative locations [14].



Soil Map—Jefferson County, Wisconsin

MAP LEGEND

Area of Interest (AOI)
Area of Interest (AOI)

Soils
Soil Map Unit Polygons
Soil Map Unit Lines
Soil Map Unit Points

Special Point Features
Blowout
Borrow Pit
Clay Spot
Closed Depression
Gravel Pit
Gravelly Spot
Landfill
Lava Flow
Marsh or swamp
Mine or Quarry
Miscellaneous Water
Perennial Water
Rock Outcrop
Saline Spot
Sandy Spot
Severely Eroded Spot
Sinkhole
Slide or Slip
Sodic Spot

Spoil Area
Stony Spot
Very Stony Spot
Wet Spot
Other
Special Line Features

Water Features
Streams and Canals

Transportation
Rails
Interstate Highways
US Routes
Major Roads
Local Roads

Background
Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Jefferson County, Wisconsin
Survey Area Data: Version 19, Jun 8, 2020

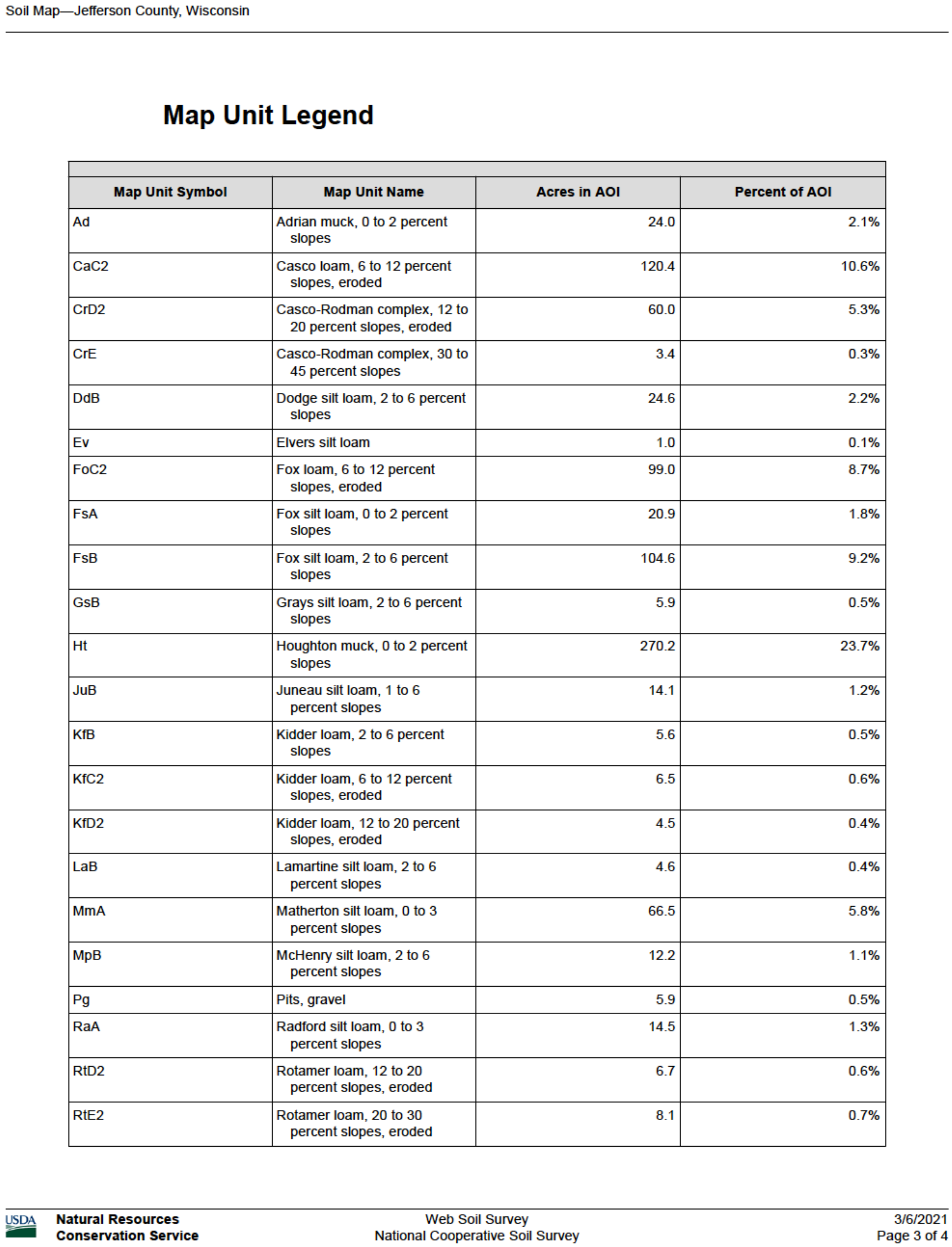
Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 29, 2011—Mar 28, 2012

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Natural Resources Conservation Service
Web Soil Survey
National Cooperative Soil Survey
3/6/2021
Page 2 of 4

Figure 10. Soil map (pg. 2) of Lake Ripley's inlet stream with the AOI defined around the proposed alternative locations [14].



Soil Map—Jefferson County, Wisconsin

Map Unit Legend

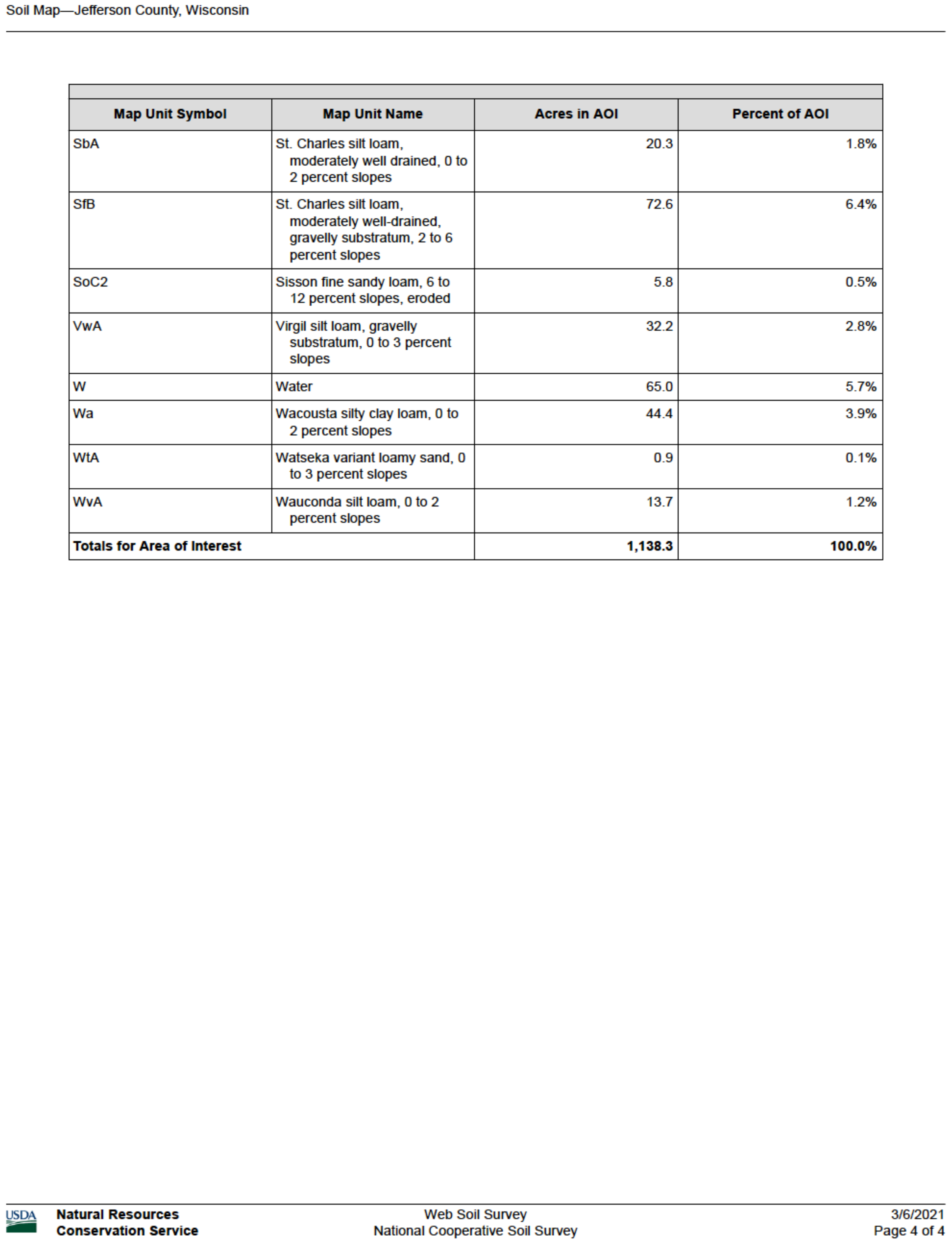
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ad	Adrian muck, 0 to 2 percent slopes	24.0	2.1%
CaC2	Casco loam, 6 to 12 percent slopes, eroded	120.4	10.6%
CrD2	Casco-Rodman complex, 12 to 20 percent slopes, eroded	60.0	5.3%
CrE	Casco-Rodman complex, 30 to 45 percent slopes	3.4	0.3%
DdB	Dodge silt loam, 2 to 6 percent slopes	24.6	2.2%
Ev	Elvers silt loam	1.0	0.1%
FoC2	Fox loam, 6 to 12 percent slopes, eroded	99.0	8.7%
FsA	Fox silt loam, 0 to 2 percent slopes	20.9	1.8%
FsB	Fox silt loam, 2 to 6 percent slopes	104.6	9.2%
GsB	Grays silt loam, 2 to 6 percent slopes	5.9	0.5%
Ht	Houghton muck, 0 to 2 percent slopes	270.2	23.7%
JuB	Juneau silt loam, 1 to 6 percent slopes	14.1	1.2%
KfB	Kidder loam, 2 to 6 percent slopes	5.6	0.5%
KfC2	Kidder loam, 6 to 12 percent slopes, eroded	6.5	0.6%
KfD2	Kidder loam, 12 to 20 percent slopes, eroded	4.5	0.4%
LaB	Lamartine silt loam, 2 to 6 percent slopes	4.6	0.4%
MmA	Matherton silt loam, 0 to 3 percent slopes	66.5	5.8%
MpB	McHenry silt loam, 2 to 6 percent slopes	12.2	1.1%
Pg	Pits, gravel	5.9	0.5%
RaA	Radford silt loam, 0 to 3 percent slopes	14.5	1.3%
RtD2	Rotamer loam, 12 to 20 percent slopes, eroded	6.7	0.6%
RtE2	Rotamer loam, 20 to 30 percent slopes, eroded	8.1	0.7%

USDA **Natural Resources Conservation Service**

Web Soil Survey
National Cooperative Soil Survey

3/6/2021
Page 3 of 4

Figure 11. Unit map legend (pg. 3) of Lake Ripley's inlet stream with the AOI defined around the proposed alternative locations [14].



Soil Map—Jefferson County, Wisconsin

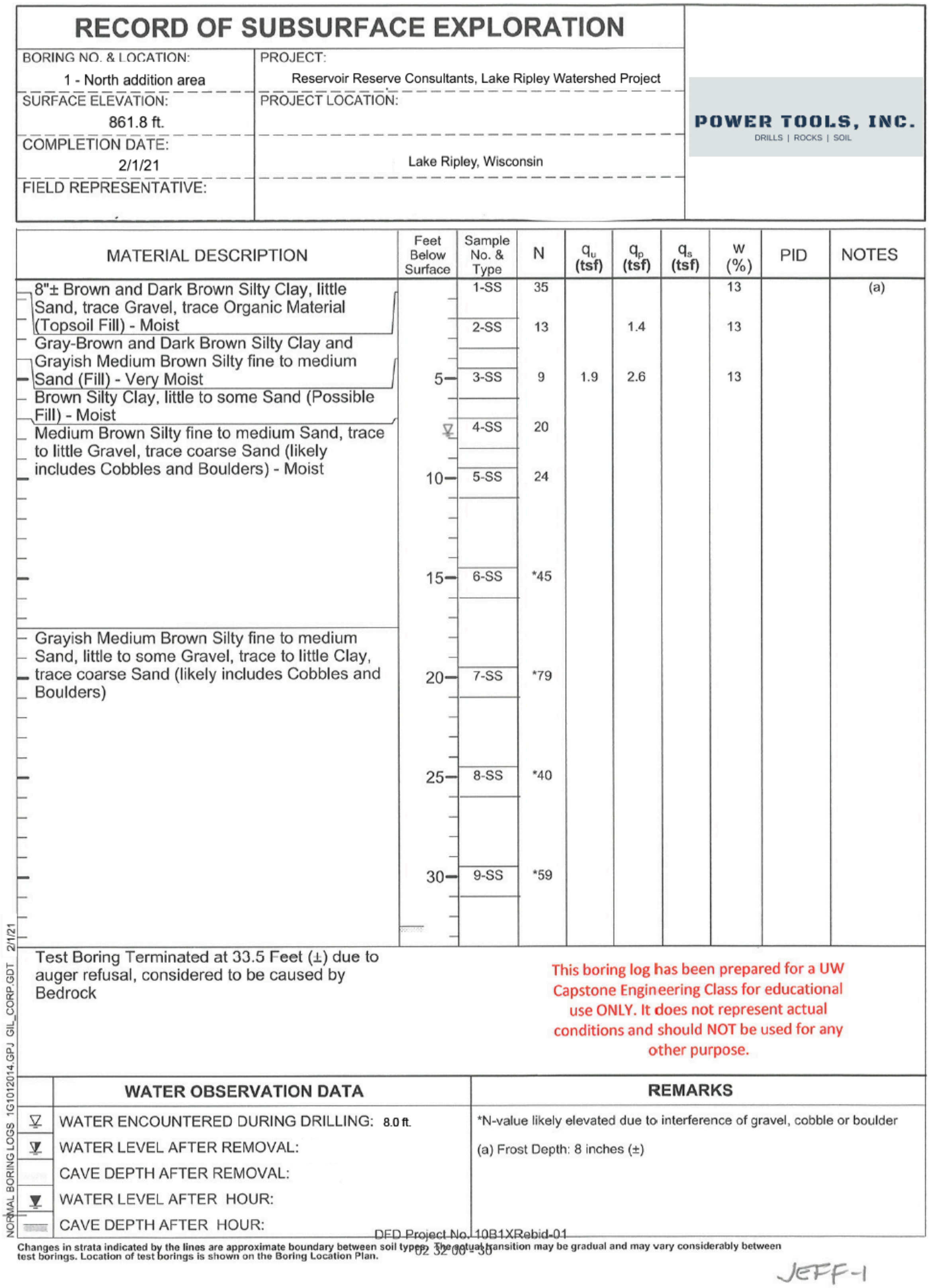
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
SbA	St. Charles silt loam, moderately well drained, 0 to 2 percent slopes	20.3	1.8%
SfB	St. Charles silt loam, moderately well-drained, gravelly substratum, 2 to 6 percent slopes	72.6	6.4%
SoC2	Sisson fine sandy loam, 6 to 12 percent slopes, eroded	5.8	0.5%
VwA	Virgil silt loam, gravelly substratum, 0 to 3 percent slopes	32.2	2.8%
W	Water	65.0	5.7%
Wa	Wacousta silty clay loam, 0 to 2 percent slopes	44.4	3.9%
WtA	Watseka variant loamy sand, 0 to 3 percent slopes	0.9	0.1%
WvA	Wauconda silt loam, 0 to 2 percent slopes	13.7	1.2%
Totals for Area of Interest		**1,138.3**	**100.0%**

USDA **Natural Resources Conservation Service**

Web Soil Survey
National Cooperative Soil Survey

3/6/2021
Page 4 of 4

Figure 12. Unit map legend (pg. 4) of Lake Ripley's inlet stream with the AOI defined around the proposed alternative locations



RECORD OF SUBSURFACE EXPLORATION

POWER TOOLS, INC.
DRILLS | ROCKS | SOIL

BORING NO. & LOCATION: 1 - North addition area	PROJECT: Reservoir Reserve Consultants, Lake Ripley Watershed Project
SURFACE ELEVATION: 861.8 ft.	PROJECT LOCATION:
COMPLETION DATE: 2/1/21	Lake Ripley, Wisconsin
FIELD REPRESENTATIVE:	

MATERIAL DESCRIPTION	Feet Below Surface	Sample No. & Type	N	q_u (tsf)	q_p (tsf)	q_s (tsf)	w (%)	PID	NOTES
8"± Brown and Dark Brown Silty Clay, little Sand, trace Gravel, trace Organic Material (Topsoil Fill) - Moist		1-SS	35				13		(a)
		2-SS	13		1.4		13		
Gray-Brown and Dark Brown Silty Clay and Grayish Medium Brown Silty fine to medium Sand (Fill) - Very Moist	5	3-SS	9	1.9	2.6		13		
Brown Silty Clay, little to some Sand (Possible Fill) - Moist									
Medium Brown Silty fine to medium Sand, trace to little Gravel, trace coarse Sand (likely includes Cobbles and Boulders) - Moist	▽	4-SS	20						
	10	5-SS	24						
	15	6-SS	*45						
Grayish Medium Brown Silty fine to medium Sand, little to some Gravel, trace to little Clay, trace coarse Sand (likely includes Cobbles and Boulders)	20	7-SS	*79						
	25	8-SS	*40						
	30	9-SS	*59						

Test Boring Terminated at 33.5 Feet (±) due to auger refusal, considered to be caused by Bedrock

This boring log has been prepared for a UW Capstone Engineering Class for educational use ONLY. It does not represent actual conditions and should NOT be used for any other purpose.

	WATER OBSERVATION DATA	REMARKS
▽	WATER ENCOUNTERED DURING DRILLING: 8.0 ft.	*N-value likely elevated due to interference of gravel, cobble or boulder
▽	WATER LEVEL AFTER REMOVAL:	(a) Frost Depth: 8 inches (±)
	CAVE DEPTH AFTER REMOVAL:	
▼	WATER LEVEL AFTER HOUR:	
▨	CAVE DEPTH AFTER HOUR:	

DFD Project No. 10B1XRebid-01

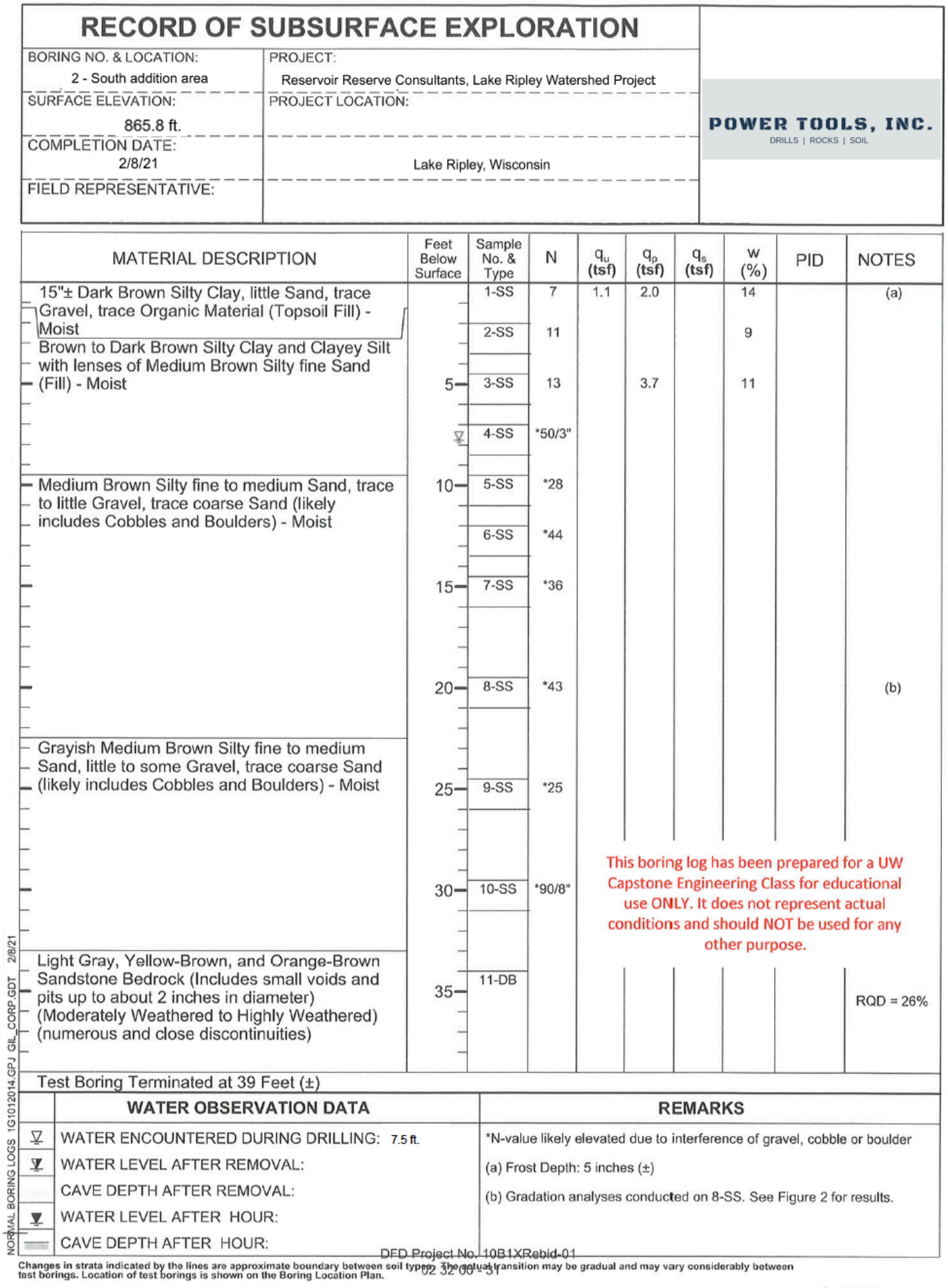
Changes in strata indicated by the lines are approximate boundary between soil types. The actual transition may be gradual and may vary considerably between test borings. Location of test borings is shown on the Boring Location Plan.

02 32 00 - 30

NORMAL BORING LOGS 1G1012014.GPJ GIL_CORP.GDT 2/1/21

JEFF-1

Figure 13. Boring No. 1



RECORD OF SUBSURFACE EXPLORATION

POWER TOOLS, INC.
DRILLS | ROCKS | SOIL

BORING NO. & LOCATION: 2 - South addition area	PROJECT: Reservoir Reserve Consultants, Lake Ripley Watershed Project
SURFACE ELEVATION: 865.8 ft.	PROJECT LOCATION:
COMPLETION DATE: 2/8/21	Lake Ripley, Wisconsin
FIELD REPRESENTATIVE:	

MATERIAL DESCRIPTION	Feet Below Surface	Sample No. & Type	N	q_u (tsf)	q_p (tsf)	q_s (tsf)	w (%)	PID	NOTES
15"± Dark Brown Silty Clay, little Sand, trace Gravel, trace Organic Material (Topsoil Fill) - Moist		1-SS	7	1.1	2.0		14		(a)
Brown to Dark Brown Silty Clay and Clayey Silt with lenses of Medium Brown Silty fine Sand (Fill) - Moist		2-SS	11				9		
	5	3-SS	13		3.7		11		
	▽	4-SS	*50/3"						
Medium Brown Silty fine to medium Sand, trace to little Gravel, trace coarse Sand (likely includes Cobbles and Boulders) - Moist	10	5-SS	*28						
		6-SS	*44						
	15	7-SS	*36						
	20	8-SS	*43						(b)
Grayish Medium Brown Silty fine to medium Sand, little to some Gravel, trace coarse Sand (likely includes Cobbles and Boulders) - Moist	25	9-SS	*25						
	30	10-SS	*90/8"						
Light Gray, Yellow-Brown, and Orange-Brown Sandstone Bedrock (Includes small voids and pits up to about 2 inches in diameter) (Moderately Weathered to Highly Weathered) (numerous and close discontinuities)	35	11-DB							RQD = 26%

This boring log has been prepared for a UW Capstone Engineering Class for educational use ONLY. It does not represent actual conditions and should NOT be used for any other purpose.

Test Boring Terminated at 39 Feet (±)

WATER OBSERVATION DATA		REMARKS
▽	WATER ENCOUNTERED DURING DRILLING: 7.5 ft.	*N-value likely elevated due to interference of gravel, cobble or boulder
▼	WATER LEVEL AFTER REMOVAL:	(a) Frost Depth: 5 inches (±)
	CAVE DEPTH AFTER REMOVAL:	(b) Gradation analyses conducted on 8-SS. See Figure 2 for results.
▼	WATER LEVEL AFTER HOUR:	
▨	CAVE DEPTH AFTER HOUR:	

NORMAL BORING LOGS 1G1012014.GPJ GIL_CORP.GDT 2/8/21

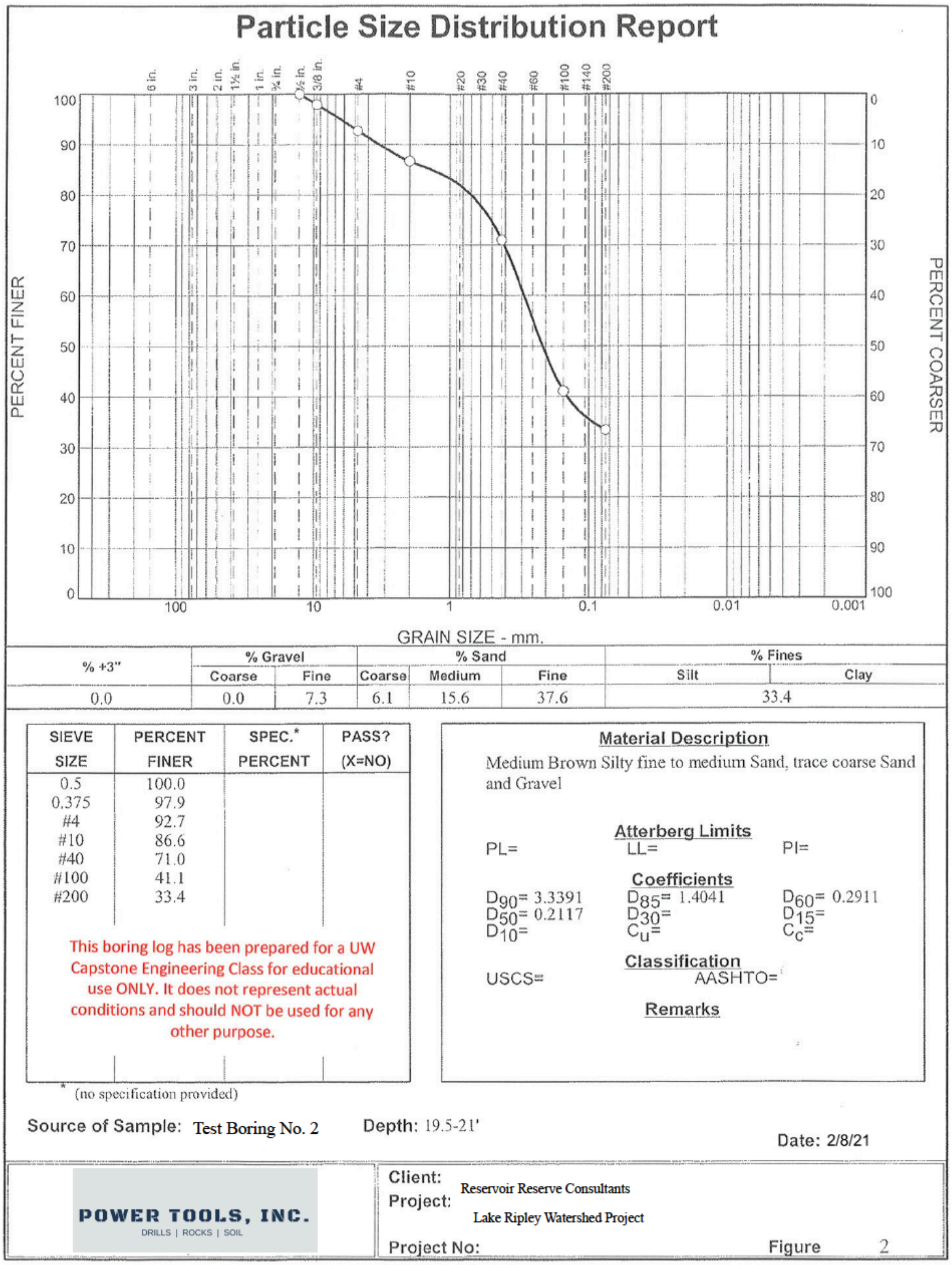
DFD Project No. 10B1XRebid-01

02 32 00 - 31

Changes in strata indicated by the lines are approximate boundary between soil types. The actual transition may be gradual and may vary considerably between test borings. Location of test borings is shown on the Boring Location Plan.

JEFF-1

Figure 14. Boring No. 2



Particle Size Distribution Report

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	7.3	6.1	15.6	37.6	33.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.5	100.0		
0.375	97.9		
#4	92.7		
#10	86.6		
#40	71.0		
#100	41.1		
#200	33.4		

This boring log has been prepared for a UW Capstone Engineering Class for educational use ONLY. It does not represent actual conditions and should NOT be used for any other purpose.

* (no specification provided)

Material Description

Medium Brown Silty fine to medium Sand, trace coarse Sand and Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 3.3391 D_{85}= 1.4041 D_{60}= 0.2911
D_{50}= 0.2117 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: Test Boring No. 2 **Depth:** 19.5-21'

Date: 2/8/21

POWER TOOLS, INC.
DRILLS | ROCKS | SOIL

Client: Reservoir Reserve Consultants
Project: Lake Ripley Watershed Project
Project No: **Figure** 2

JEFF-1

Figure 15. Particle Distribution Report

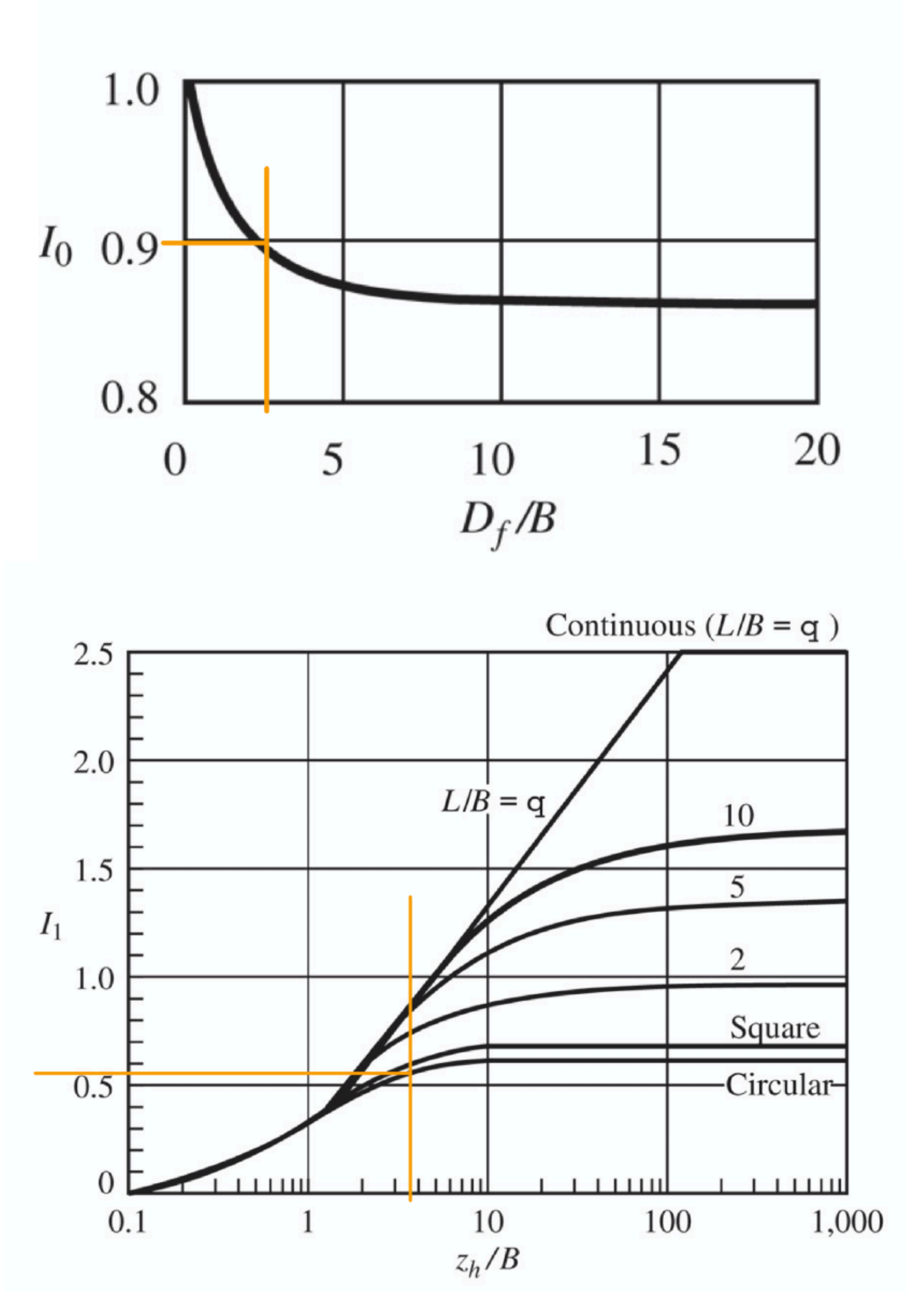


Figure 16. Elastic Settlement graphs [13].

Appendix B: Tables

Table 1. Particle size distribution data extracted from Boring No. 2

% Gravel		**% Sand**			**% Fines**	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	7.3	6.1	15.6	37.6	33.4	
[redacted]						
[redacted]			D_{90}	D_{85}	D_{60}	D_{50}
			3.3391	1.4041	0.2911	0.2117

Table 2. Summary of measured and calculated soil properties

Soil	Avg. N	$\gamma\left(\frac{lb}{ft^3}\right)$[6]	ϕ [4]	E (psi) [4]	N_q	N_γ	q_u (psi)	q_a(psi)
Fox (silt) loam (SM)	13	98.0	30	2900.65	18.4	22.4	1566.5	915.9
Matherton silt loam (SM)	11	96.1	30	2900.65	18.4	22.4	1536.6	898.4
Casco loam (SM)	26	92.4	30	2900.65	18.4	22.4	1476.7	863.4
Houghton muck (PT)	N/A	17.5	5	725.2	1.57	0.45	30.6	13.9
Watseka sand (SM)	N/A	115.5	32	3625.8	23.2	30.2	1761.5	1037.1

Table 3. Settlement properties for Watseka sand (WtA)

q_u (kip/ft^2)	q_a(kip/ft^2)	q_{net}(kip/ft^2)	I_0	I_1	δ (ft)
253.7	149.3	1.2	0.9	0.55	0.005

Table 4. Hydrostatic pressure summary

Depth of stream	Hydrostatic Pressure $\left(\frac{lb}{ft \cdot s^2}\right)$
Minimum depth: 0.35 ft	702.6
Average depth: 0.58 ft	1167.6
Maximum depth: 1.38 ft	2770.2

Appendix C: Calculations

Equation 1: Vesic's Ultimate Bearing Capacity Formula

$$q_u = \gamma D_f \left(N_q - 1\right) s_q d_q + \frac{1}{2}\gamma B' N_\gamma s_\gamma$$

Where γ is the unit weight of soil, D_f is the depth to the bottom of the foundation, N_q and N_γ are Terzaghi's parameters; s_q, d_q, s_γ are shape factors, and B' is the width of the foundation.

Equation 2: Allowable Bearing Capacity

$$q_a = \frac{q_u}{FS} + \gamma D_f$$

Where q_u is the ultimate bearing capacity, FS is the factor of safety, γ is the unit weight of soil, and D_f is the depth to the bottom of the foundation.

Equation 3: Ultimate Net Bearing Capacity

$$q_{net} = \frac{P}{A} - \gamma D_f$$

Where P is the vertical load applied to the foundation, A is the surface area of the footing, γ is the unit weight of soil, and D_f is the depth to the bottom of the foundation.

Equation 4: Elastic Settlement

$$\delta = I_0 I_1 \frac{q_{net} B'}{E}$$

Where I_0 and I_1 are the influence factors, q_{net} is the ultimate net bearing capacity, B' is the width of the foundation, and E is the elastic modulus of the soil.

Equation 5: Hydrostatic Pressure

$$P = \rho_w g h$$

Where ρ_w is the density of water, g is the gravitational acceleration and h is the depth of the streambed.

Appendix D: References

[1] “TNM Elevation.” https://apps.nationalmap.gov/elevation/##bottom (accessed Mar. 01, 2021).

[2] “Lake Ripley.” https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=809600&page=facts (accessed Feb. 27, 2021).

[3] “Area Maps – Lake Ripley Management District.” https://lakeripley.org/area-maps/ (accessed Feb. 27, 2021).

[4] Muni Budhu, *Soil Mechanics and Foundations*, Second. John Wiley & Sons, Inc.

[5] “Ground-Water Resources and Geology of Jefferson County, Wisconsin - Ground-Water Resources and Geology of Jefferson County, Wisconsin - WGNHS.” https://wgnhs.wisc.edu/catalog/publication/000283/resource/ic33 (accessed Mar. 2, 2021).

[6] “Physical Soil Properties---Jefferson County, Wisconsin,” *Natural Resources*, p. 20.

[7] “Engineering Properties---Jefferson County, Wisconsin,” *Natural Resources*, p. 21.

[8] L. Ripley, “LAKE RIPLEY WATERSHED,” p. 393.

[9] “TNM Download v2.” https://apps.nationalmap.gov/downloader/#/ (accessed Mar. 06, 2021).

[10] “History – Lake Ripley Management District.” https://lakeripley.org/history/ (accessed Mar. 06, 2021).

[11] K. Whalley, W. Luo, and Department of Geography, Northern Illinois University, 218 Normal Rd, DeKalb, IL 60115, USA, “The Pressure of Society on Water Quality: A Land Use Impact Study of Lake Ripley in Oakland, Wisconsin,” *AIMS Geosciences*, vol. 3, no. 1, pp. 14–36, 2017, doi: 10.3934/geosci.2017.1.14.

[12] T. Nelson, “Units of Measure and Conversion Factors for Forest Products,” p. 8.

[13] “2020 Serviceability Limits.pptx: GLE401: Special Topics in Geological Engineering (002) FFE SP20.” https://canvas.wisc.edu/courses/181000/files/11810987?module_item_id=2535580 (accessed Mar. 08, 2021).

[14] “Web Soil Survey - Home.” https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm (accessed Mar. 08, 2021).

[15] Clarence J. Milfred and Francis D. Hole, “Soils of Jefferson County, Wisconsin,” p. 177.