ENVIRO-SHIELD
SOLUTIONS

Evaluation of Watershed-Level and In-Lake Options to Improve Lake Thunderbird Water Quality

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Prepared for

Central Oklahoma Master Conservancy District (COMCD)

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List of Abbreviations

BMP	Best Management Practices
BOR	Bureau of Reclamation
CA	Catchment Area
CBOD	Carbonaceous Biochemical Oxygen Demand
Chl-a	Chlorophyll-a
CGR	Coir Geotextile Rolls
COMCD	Central Oklahoma Master Conservancy District
DO	Dissolved Oxygen
NLCD	National Land Cover Data
OCC	Oklahoma Conservation Commission
ODEQ	Oklahoma Department of Environmental Quality
ODWC	Oklahoma Department of Wildlife Conservation
OWRB	Oklahoma Water Resources Board
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
WWAC	Warm Water Aquatic Communities

1 Executive Summary

Enviro-Shield Solutions worked to provide the Central Oklahoma Master Conservancy District (COMCD) with two design alternatives to address eutrophication in Lake Thunderbird. First, an extensive data analysis of twenty years of data from the Oklahoma Water Resources Board (OWRB) determined that phosphorus was the limiting nutrient in the lake and that there were positive correlations between Total Phosphorus (TP) and Chlorophyll-a (Chl-a), as well as TP and Total Suspended Solids (TSS), and TP and turbidity throughout the lake. It was also determined, using a combination of TP measurements and flow data from StreamStats, that TP loading was highest at the Little River branch of Lake Thunderbird.

Then, an extensive literature review identified 29 potential watershed BMPs and in-lake technologies. Through a qualitative analysis, this list was shortened to 11 viable technologies. Evaluation criteria were established by Enviro-Shield Solutions, consisting of objectives, sub-objectives, and performance measures, and sent to COMCD for a weighted ranking of the objectives. Then, each technology was scored on a scale of 1-5 based on how well it performed in each sub-objective. By considering these weighted objectives, Enviro-Shield Solutions was able to perform a completely objective evaluation of all the possible design solutions and present the best final recommendation that meets the specific preferences of COMCD.

The final recommendation for watershed BMPs are bioretention basins dispersed throughout the Little River and Hog Creek watersheds with a present-day cost (i=6%, n=60 yrs) of **$2,596,737**.

The final recommendation for in-lake technologies are constructed wetlands at the Little River and Hog Creek branches with a present-day cost (i=6%, n=20 yrs) of **$18,199,962** without a sedimentation basin upstream and **$10,795,842** with a sedimentation basin upstream.

2 Introduction

2.1 Background

Lake Thunderbird is located in south-central Oklahoma in the Cross Timbers Ecoregion where it serves as a water supply reservoir for Norman, Del City, and Midwest City (OWRB 2019). The Cross Timbers ecoregion consists of dense oak forests with some open woodlands and soils are typically sandy (Julian et al. 2015). While Lake Thunderbird lies in the Cross Timbers Ecoregion, the watershed covers parts of the Central Great Plains Ecoregion, consisting of mixed-grass prairie, riparian woodlands, scattered hills, and clay-rich soils (Julian et al. 2015). The lake covers approximately 2456 hectares, with mean and maximum depths of approximately 6 and 18 m (20 and 58 feet), respectively (USACE 2020). Lake Thunderbird has a volume of 105,838 acre-feet and 59 miles (95km) of shoreline (Horton 2018). The major tributaries interacting with the lake are the Little River connecting from the West side and Hog

Creek which connects from the North side. Figure 1 shows the municipalities that lie in the approximate 25.5 mi^2 ($66km^2$) Lake Thunderbird watershed.

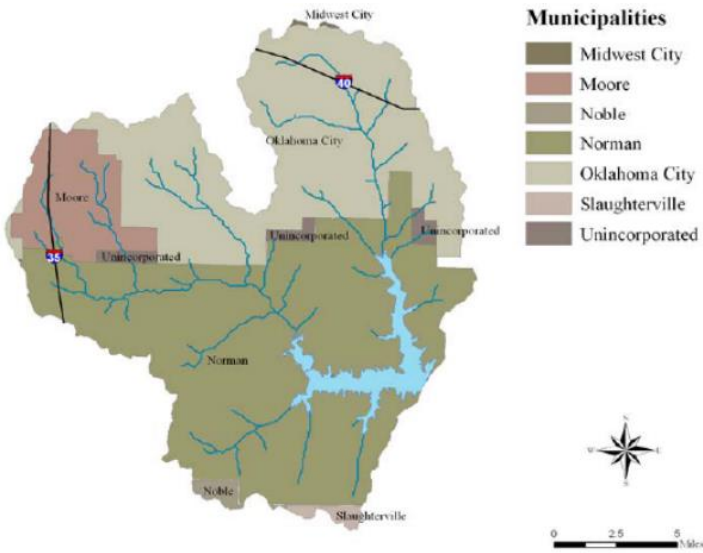

Figure 1: Municipalities located in the Lake Thunderbird watershed (Vieux and Vieux 2007)

The Lake Thunderbird Watershed is a mixed-use watershed that includes portions of Midwest City, Oklahoma City, Moore, and Norman. More than 40 percent of the watershed is affected by highly impervious surface areas due to residential use. Figure 2 demonstrates the varaious land use categories nd the respective areas they cover. Population growth is expected to drive the need for new housing and infrastructure developments for the foreseeable future (Martin-Mikle 2015).

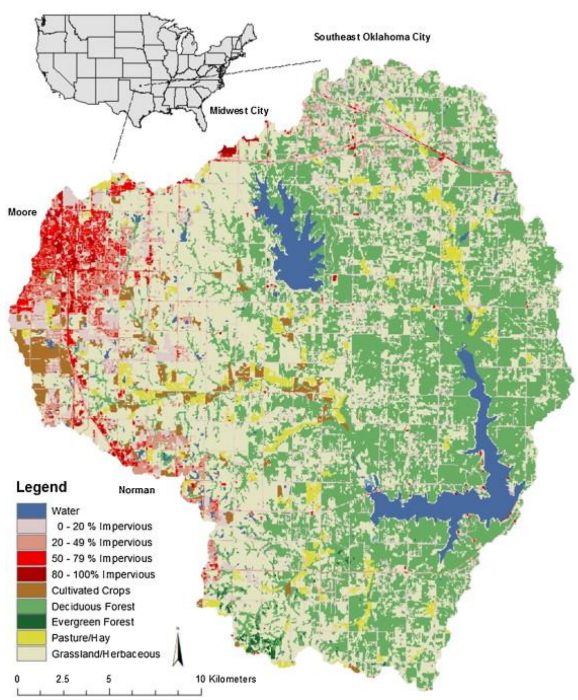

Figure 2: Lake Thunderbird Watershed land use depicted by NLCD (Fry et al. 2011)

The US Army Corps of Engineers (USACE) first evaluated the potential for development on the Little River in 1936 (Simonds 1999). It was determined that the Little River did not have the sufficient water supply to meet the demands of the community; however, after many investigations, a plan for the construction of a reservoir to meet these needs was released in 1954. Originally called the Norman Project, Lake Thunderbird was authorized by an act of Congress, Public Law 86-529, on June 27, 1960. In 1961, the United States and the District formed by decree of the District Court of Cleveland County, signed a contract for the construction, operation, and maintenance of the Lake Thunderbird project and for the reimbursement of all appropriate costs under Reclamation Law (COMCD 2020). Funds for planning were made available through the 1961 Public Works Appropriation Bill. Construction began the following year, funded by the 1962 Public Works Appropriation Bill. By the summer of 1965, construction of the dam, pipelines, and pumping stations was complete and potable water arrived at homes by February 1966 (Simonds 1999). Lake Thunderbird is a federally owned water resource administered by the United States Bureau of Reclamation (BOR). The Central Oklahoma Master Conservancy District (COMCD) is responsible for operation and maintenance of the reservoir on behalf of the BOR (Evenson 2019).

Lake Thunderbird also provides flood control for the surrounding region. Flood control operations are carried out according to regulations developed by the USACE and since the completion of Lake Thunderbird and Norman Dam, have prevented more than $33,250,000 in flood damage (Simonds 1999). In addition, members of the community are invited to enjoy Lake Thunderbird State Park, a large park that includes hiking and biking trails, two swimming beaches, a nature center, and activities such as fishing and birdwatching. The lake has two marinas and is open to boating, kayaking, and jet skiing (OWRB 2019). Both sport fish and endemic fish are present in Lake Thunderbird. Sport fish species in the lake include largemouth bass, black crappie, blue catfish, saugeye, and bluegill sunfish. The endemic fish species include common carp, spotted gar, longear sunfish, yellow bullhead, blunt nose minnow, and mosquito fish (ODWC 2008).

Lake Thunderbird is of the upmost importance to the community as a reliable and safe drinking water source. The reservoir also has many other designated beneficial uses such as Aesthetics, Warm Water Aquatic Community (WWAC), Primary Body Contact Recreation, and Fish Consumption (OCC 2010). Further action must be taken to achieve full attainment of these designated beneficial uses in the watershed.

2.2 Site Status

Lake Thunderbird has a history of water quality issues and was designated as a Sensitive Water Supply (SWS) lake by the state of Oklahoma in 2002 (ODEQ 2013). This designation was assigned due to high levels of pollutants in the water. Specific parameters of concern that are related to excessive nutrient loading are total phosphorus (TP), total nitrogen (TN), dissolved oxygen (DO), chlorophyll-a (Chl-a), and turbidity. These were mainly determined to be the result of agricultural practices, excessive fertilizer application, and other contributing urban and rural factors (Olsson n.d).

Over the next decade water quality continued to worsen. In 2010, Lake Thunderbird was placed on the Oklahoma Department of Environmental Quality's (ODEQ) 303(d) List of Impaired Waterbodies for impaired beneficial uses of public/private water supply and WWAC. By 2013, the ODEQ responded by establishing a Total Maximum Daily Load (TMDL) for nutrients, turbidity, and DO but did not stipulate specific regulatory controls or management practices necessary to reduce nutrients within the watershed. The ultimate recommendation was that watershed-specific controls and best management practices (BMPs) be chosen and put in use through a process involving all stakeholders (BOR 2019). Lastly, water quality aesthetics, such as taste and odor, have received major complaints from the surrounding communities, resulting in the installation of ozone treatment at the City of Norman Water Treatment Plant (City of Norman 2021).

2.3 History of Attempted Solutions

Studies involving Lake Thunderbird such as Gross and Pfiester's 1988 analysis on blue-green algae growth and Allen's 2001 shoreline erosion assessment have contributed to an understanding of the sources of impairment. Government entities such as the Oklahoma Water Resources Board (OWRB) and ODEQ have also contributed to a deeper understanding of the sources and parameters of impairment through water quality and TMDL reports (ODEQ 2013).

2.3.1 Attempted Watershed BMPs

After Allen's assessment in 2001, the OWRB attempted a demonstration of two BMPs that were suggested by Allen along the Southern shore of Lake Thunderbird, just east of Calypso Cove marina shown in Figure 3 (OWRB 2005). The BMPs installed were fixed breakwater BMPs in the form of branch boxes and coir geotextile rolls (CGR). The intent of installing BMPs at this site was to allow for vegetative growth to establish and propagate behind the BMPs to prevent further shoreline erosion. Branch boxes shown in Figure 4a are a series of branches stacked horizontally and fixed in place with stakes. CGRs are coconut husk fibers that are packed, rolled, or woven into a cylindrical shape and bound by a fibrous material. Similar to branch boxes, CGRs are also fixed in place using stakes as shown in Figure 4b.

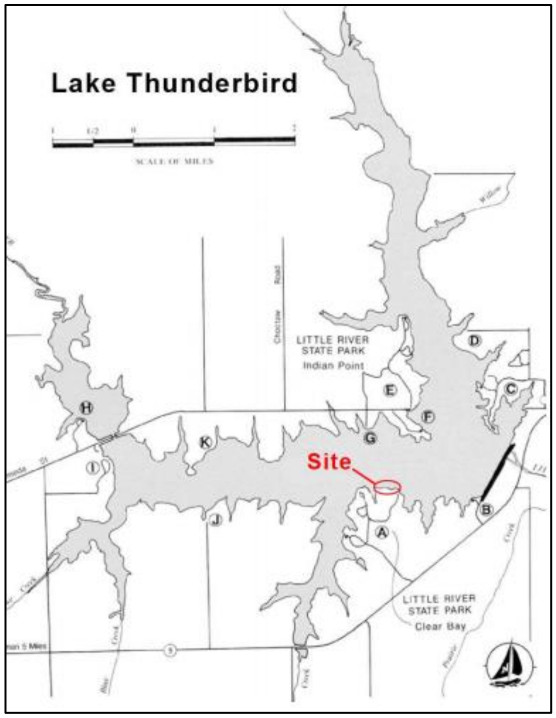

Figure 3: Site of branch box and coir log BMP demonstration (OWRB 2005)

Figures 4a and 4b: Branch box (4a) and fixing a CGR with stakes (4b) at Lake Thunderbird (OWRB 2005)

The results of this demonstration were that the OWRB deemed branch boxes and CGRs as suitable BMPs, although they may encounter several problems during their design life. An example of one issue encountered was that a storm in July 2004 dislodged the CGR from its stakes and the log subsequently disintegrated into fibers. To remedy this, the OWRB suggests that special care be given to securing the logs with stakes, and that CGRs be bound with a heavy duty 3/16" vinyl cable rather than the baling wire originally used. The study also documented poor plant survival behind the BMPs but attributed that to a lack of continued plantings over several months. The branch boxes performed well and had no issues other than the initial installation being labor intensive, which may affect capital costs.

2.3.2 Trailwoods Neighborhood BMPs

The Trailwoods was a housing development project that began in 2009 and was completed in 2011 as shown in Figure 5. The intent of the project was to establish BMPs in an entry-level housing development to reduce runoff into Lake Thunderbird's watershed. The Trailwoods project was a collaborative effort between the Oklahoma Conservation Commission (OCC), the University of Oklahoma, the City of Norman, Ideal Homes Development, as well as the consulting firms, CH Guernsey and SMC Engineering. The project included several watershed level BMPs in the form of curbside raingardens, rain barrels, porous pavement, and downspout diversions (Coffman 2014). The primary conclusion from the Trailwoods project was that more communication with residents is required to maintain the rain gardens. In addition to communicating with residents, robust planning regarding lot installation sequencing, as well as the developer prioritizing communication with contractors regarding BMPs, were critical to successful installation of BMPs. Finally, Coffman notes that although the evidence is anecdotal, pre-excavated rain gardens used as a sediment catch basin during construction functioned to reduce cleanup costs after construction (Coffman 2014).

Figure 5: Aerial view of Trailwoods development (Coffman 2014)

2.3.3 Floating Wetlands

In 2018, a project was undertaken to install floating wetlands in Lake Thunderbird with the goals of reducing shoreline erosion, improving bank stabilization, reducing turbidity caused by erosion, and evaluating wetland prototypes for dissipating wave action (Evenson 2015). Although improved water quality was not directly targeted by this project as wave reduction to reduce erosion was the primary goal, the wetlands had the potential for side benefits of increasing nutrient settlement and water purification. Because the wetlands enhance particle settling, some nitrogen reduction was a possibility, but 10 percent lake coverage would be necessary to significantly reduce nutrients. Other ecological benefits of the floating wetlands include serving as fish habitats. To construct the floating wetlands, sealed PVC pipe frames were used with a plastic erosion control mat topped by coir. The coir provides a buoyant quality and is nutrient dense, making it an ideal material for helping keep the constructed wetland afloat and to help feed fledgling plants (Hampton 2017). Implementing and maintaining the project have proved to be challenging. Due to their size and weight, the constructed wetlands were difficult to transport to the desired location. Although they were initially anchored in place, over time several of the units have either capsized or separated from neighboring units. Difficulties in removing the floating wetlands from the lake are also anticipated due to size and weight. Figure 6 shows a current photo (March 2021) of the floating wetlands installed at Lake Thunderbird. The performance of this current version of floating wetlands has led to concerns that any benefits received from the project may be outweighed by maintenance costs and application logistics. To date, there has not been a follow up study to provide definitive results on the efficacy of the current floating wetlands project installed in the lake. Modifications to the floating wetlands design that use a combination of lighter weight materials and a more robust anchoring system would decrease installation and maintenance labor in the future.

Figure 6: Current condition of floating wetlands in Lake Thunderbird (Photo: Peter Wolbach 2021)

2.4 Project Scope

Despite multiple attempts at improving the water quality of Lake Thunderbird, the reservoir remains a eutrophic water supply that does not satisfactorily meet the needs of the communities it serves.

Therefore, the goal of this project is to provide COMCD with a recommended conceptual design to improve the water quality of Lake Thunderbird. This goal was achieved by evaluating the existing environmental dataset from OWRB, identifying the major water quality parameters affecting Lake Thunderbird, reviewing and assessing available in-lake and watershed-based technologies, and comparing these technologies based on site-specific conditions in order to determine a sustainable recommendation to COMCD.

1) ***Analysis of available data***
    a) COMCD contracted OWRB to perform routine water quality sampling at numerous locations across Lake Thunderbird over the past 20 years. This 20-year dataset was analyzed to identify trends in various water quality parameters.
2) ***Identification of candidate watershed and in-lake technologies***
    a) Evaluation of results from analysis of OWRB Dataset to determine most effective solution
    b) Review of available technologies and their applicability to achieve the site-specific water quality goals for Lake Thunderbird
3) ***Evaluation of technologies relative to specific criteria***
    a) Quantitative comparison of in-lake technologies and watershed BMPs using the following main objectives:
        i) Affordability
        ii) Efficacy
        iii) Environmental Stewardship
        iv) Timely Implementation and Certainty
        v) Lifetime Assessment
        vi) Community Values
        vii) Water Quality Aesthetics
    b) Direct comparison of targeted watershed BMPs against intensive in-situ technology options. A list of viable solutions for in-situ technologies and watershed BMPs were identified based on the results of the objective evaluation process.
4) ***Selection of preferred option***
    a) Includes methodology ascribed to the final recommended solutions
5) ***Provision of conceptual designs for selected solutions.***
    a) Includes conceptual models, designs, and diagrams of preferred solution

3 Evaluating Water Quality Data

3.1 Enviro-Shield Data Collection

A field sampling event was conducted on March 20, 2021, with all students of the OU Environmental Engineering and Science Capstone course. In-lake sampling was coordinated by Kyle Arthur with the COMCD, while sampling near the Alameda bridge was led by Dr. Robert Nairn and Dr. Robert Knox. All sampling procedures and safety measures were followed as outlined in the Health and Safety Plan (HSP), Sampling and Analysis Plan (SAP), and Quality Assurance and Analysis Plan (QAAP) presented in Appendix E . Data was collected at Sites 1, 3, 4, 5, 6, and 11 as defined in the OWRB 2019 Report to obtain values for a range of lacustrine, riverine, and transitional zones. Data collected from the YSI probe and field analyses including turbidity, alkalinity, hardness, and Secchi disk depth are presented in Table 15, Appendix B. Data from laboratory analyses conducted on the day of sampling are also presented in Appendix B, including TN (Table 13) and TP (Table 14). The TSS data is not included due to concerns regarding quality assurance. Photos from the sampling event are presented in Figure 7 and 8.

Figure 7: Team Member Peter Wolbach conducting in-situ alkalinity sampling

Figure 8: COMCD Board Member Kyle Arthur with students

For the purposes of this report, the extensive, 20-yr dataset provided by the OWRB was used instead of the data collected at the singular capstone sampling event. This is to ensure a better understanding of seasonal and annual fluctuations in sediment and nutrient loading.

3.2 OWRB Data Analysis

EnviroShield Solutions hypothesized that phosphorus was the limiting nutrient in Lake Thunderbird, in turn controlling the extent of eutrophication. To validate this assumption, data analysis was used to look for and identify direct correlations between parameters such as TP and Chl-a. Also, determining the nature of the relationship between TSS and TP was helpful in providing the most cost effective and viable recommendations for preventing eutrophication (Horton 2018).

Pearson's correlation coefficient was used to measure the statistical relationship, or association, between two continuous variables. It is known as a viable method of measuring the association between variables of interest because it is based on the method of covariance (Adler 2010). It gives information about the magnitude of correlation, as well as the direction of the relationship.

3.2.1 Determining the Limiting Nutrient

While a variety of techniques are available for determining the algal-limiting nutrient in a waterbody, the procedure that appears to be most reliable and readily usable is the measurement of algal available forms of N and P at the time of water quality concerns. In this case the readily available form of phosphorus is orthophosphate, while the most readily available form of nitrogen is nitrate. Using the 2000-2015 OWRB nutrient data set for Lake Thunderbird, the N:P ratios from 2008 to 2013 were determined (data set did not have nitrate/nitrite measurements before 2008 and after 2013). Figure 9 illustrates the N:P ratios from 2008 to 2013 at Site 1. Since most of the ratios were above 10, (N:P average of 13 over 5 years), the limiting nutrient driving eutrophication in the watershed is phosphorus.

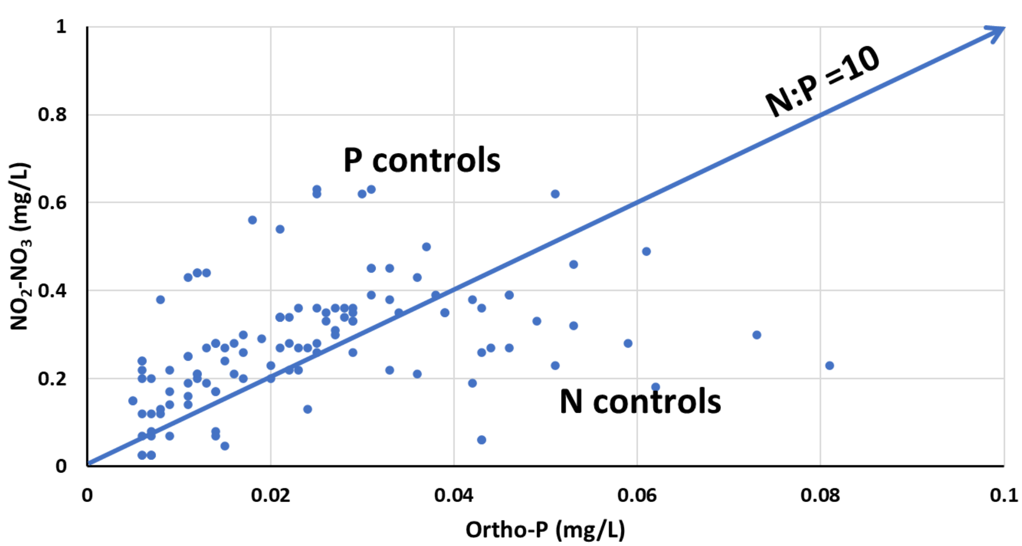

Figure 9: N:P Ratios at Site 1 based on the 2008-2015 OWRB data set

3.2.2 Total Phosphorus (TP) and Chlorophyll-a (Chl-a) Relationship

The relationship between TP and Chl-a was also evaluated. The 2016-2019 data set (Appendix A, Hyperlink 1) provided water quality measurements for several sites on the lake, but only Sites 1 and 6 had Chl-a and TP measurements. Site 1 provided the most accurate measurements that were taken on the same day; therefore Site 1 was used to validate the relationship between Chl-a and TP. The data set provided four TP measurements for each day, so the average was used to plot against the corresponding Chl-a measurements. The relationship between Ortho-P and Chl-a was also analyzed.

As Figure 10 illustrates, there is a direct linear relationship between the TP and Chl-a concentrations in the lake after performing linear regression, so the Pearson analysis can be conducted. The Pearson values obtained from the data set, represented as "R" on the graphs, confirmed that there is a moderate to strong (0.39-0.59) relationship between Chl-a and TP concentrations in the lake. The Pearson value was calculated to be 0.53, which indicates that there is a high degree of correlation between Chl-a and TP concentrations at Site 1. Figure 11 shows the data for Site 6, which also validates that a linear relationship exists between the two variables. Site 6 represents Little River, which is one of the main feeding streams into Lake Thunderbird. Figure 12 shows the linear relationship between Ortho-P and Chl-a at Site 1. The Pearson value for the data set was calculated to be 0.378, indicating a strong correlation.

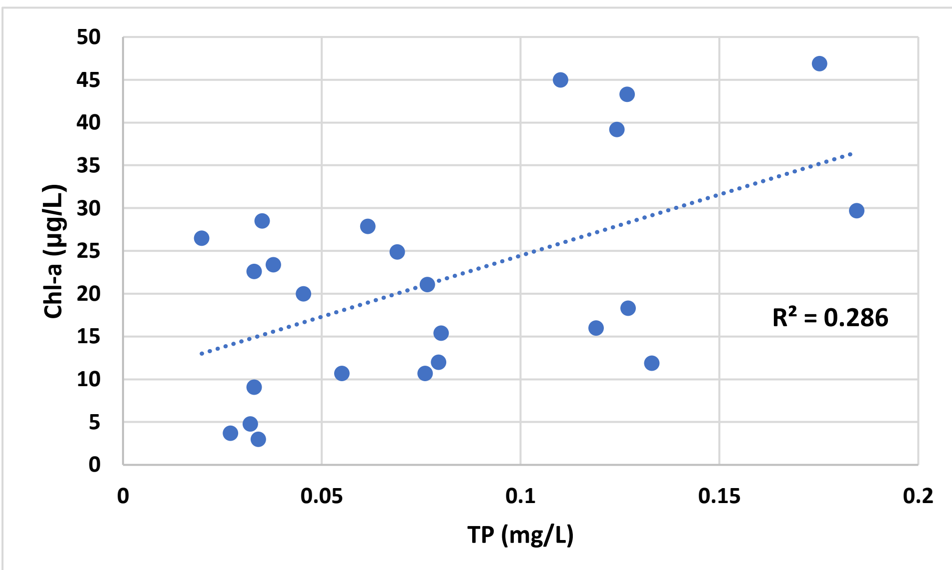

Figure 10: Correlation between TP and Chl-a for Site 1 based on the 2016-2019 OWRB data set

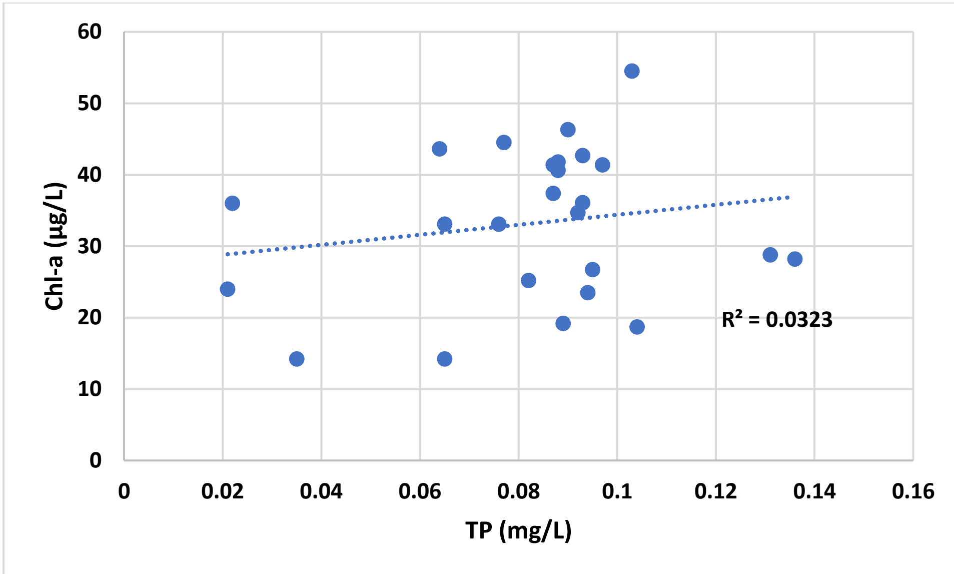

Figure 11: Correlation between TP and Chl-a for Site 6 based on the 2016-2019 OWRB data set

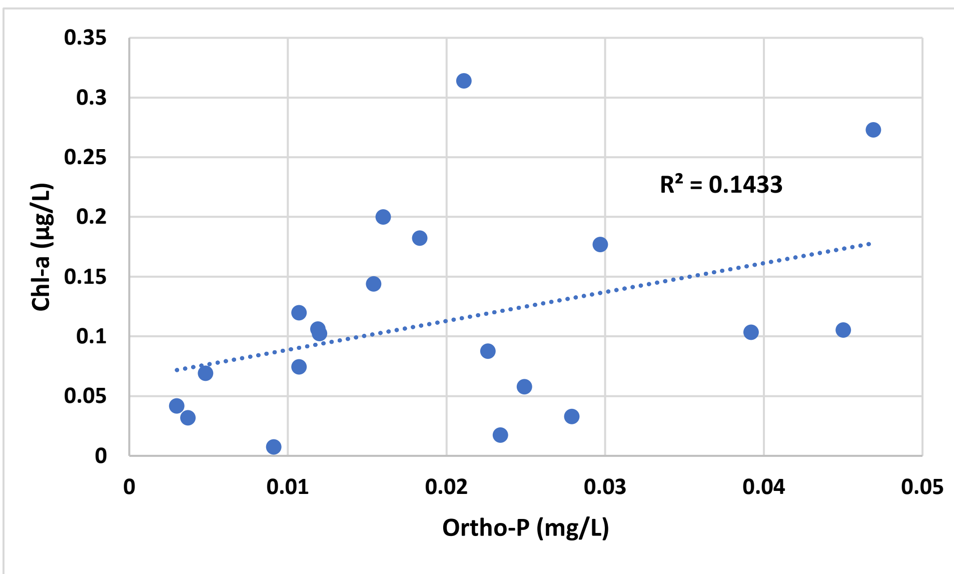

Figure 12: Correlation between Ortho-P and Chl-a for Site 1 based on the 2016-2019 OWRB data set

The 2000-2015 data set provided by the OWRB was also incorporated in the analysis. This data allowed for the analysis of the relationship over a 15-year period (20 years all together) for Sites 1, 2, 3, 4, 5 and 6. Figures 13 – 17 are linear plots illustrating the relationship between Chl-a and TP from 2000 to 2015. Site 3 did not have enough data points to establish a linear relationship between the two parameters. The smallest Pearson value obtained from all data sets was 0.179 while the largest value was 0.591, falling in the "high degree" correlation range. While the 2016-2019 dataset provides the more recent data, analyzing the 2000-2015 dataset allowed Enviro-Shield Solutions to consider any significant fluctuations over time.

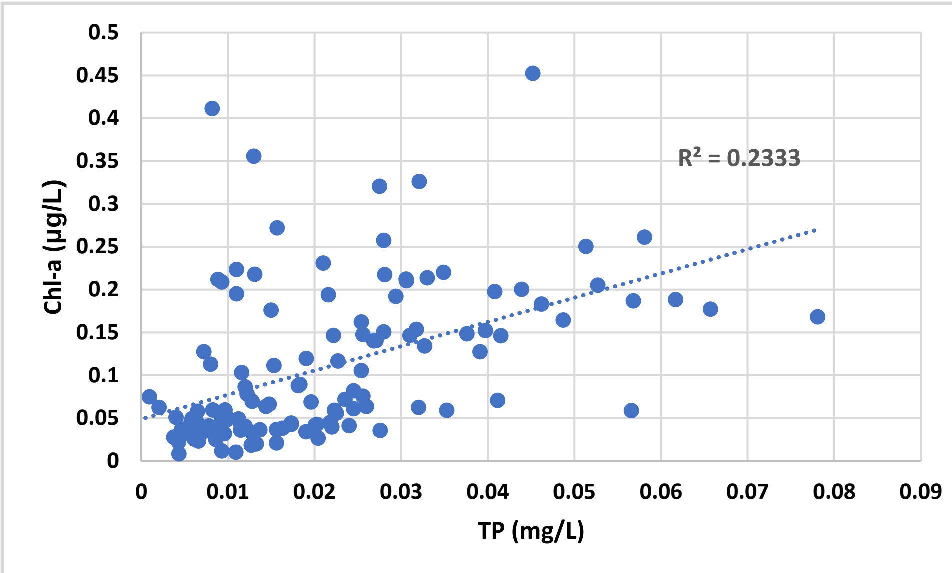

Figure 13: Correlation between TP and Chl-a for Site 1 based on the 2016-2019 OWRB data set

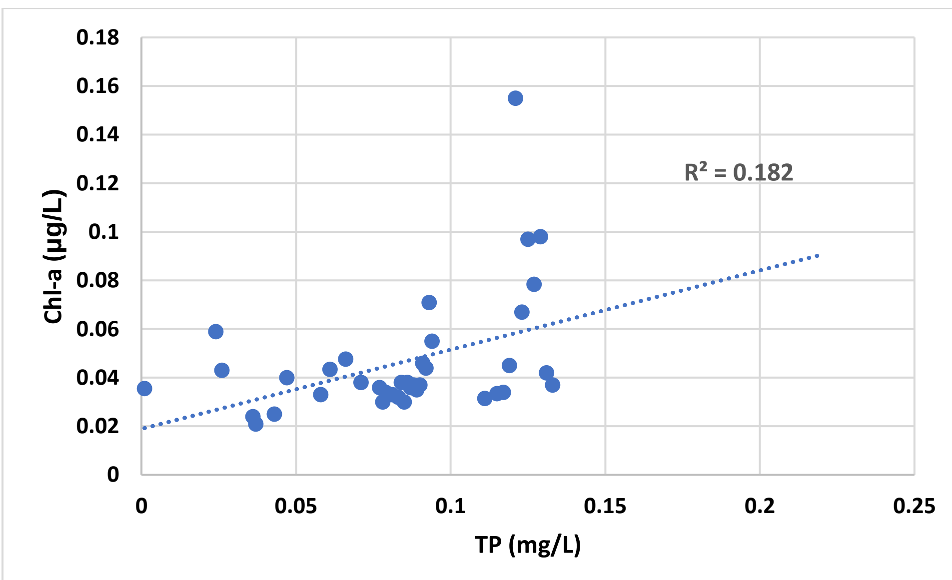

Figure 14: Correlation between TP and Chl-a for Site 2 based on the 2000-2015 OWRB data set

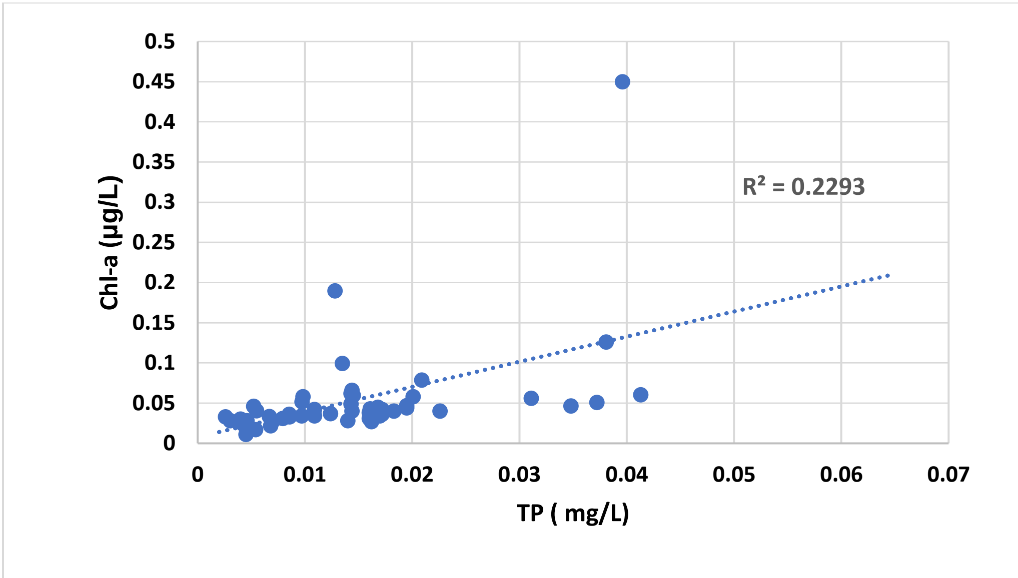

Figure 15: Correlation between TP and Chl-a for Site 4 based on the 2000-2015 OWRB data set

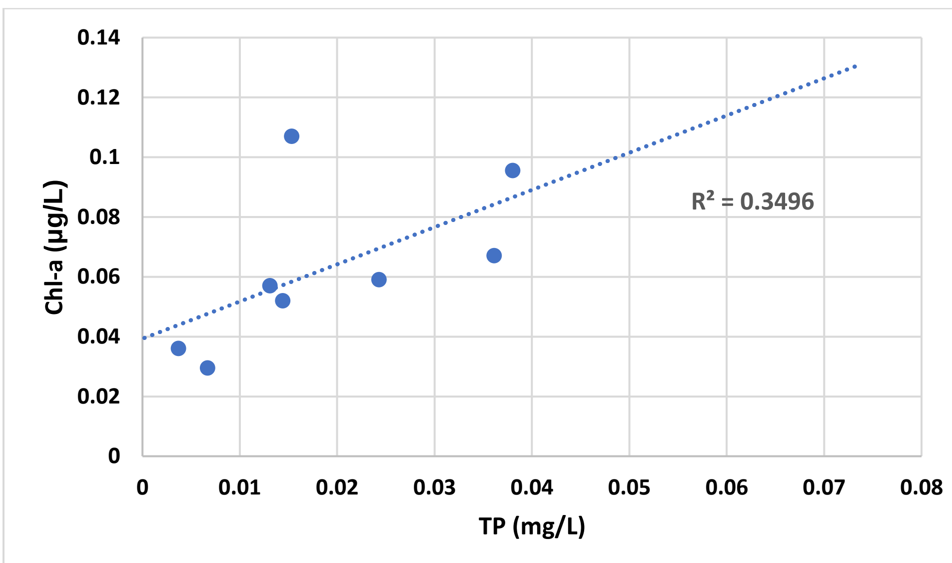

Figure 16: Correlation between TP and Chl-a for Site 5 based on the 2000-2015 OWRB data set

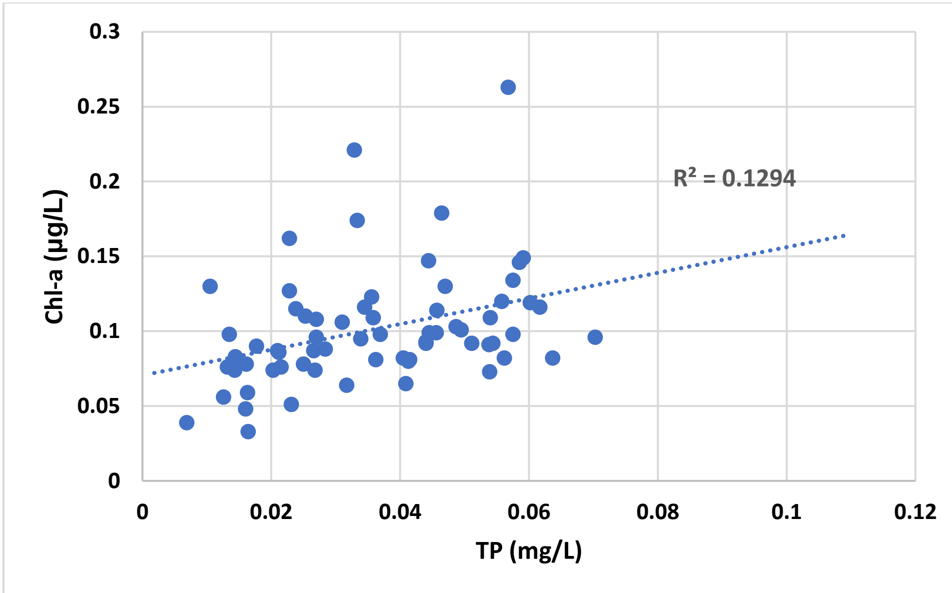

Figure 17: Correlation between TP and Chl-a for Site 6 based on the 2000-2015 OWRB data set

3.2.3 Total Phosphorus (TP) and Total Suspended Solids (TSS) Relationship

The relationship between TSS and TP was evaluated using the 2000-2015 data set provided by the OWRB (Appendix A, Hyperlink 2). A strong linear relationship between TSS and TP was determined at all sites. The linear relationships for Sites 11, 8, 4, and 6 are represented in Figures 18-21. Sites 8, 6, and 4 had moderate to strong Pearson values of 0.414, 0.309, and 0.439, respectively. The other sites provided in the data set also had positive Pearson values and can be found in Appendix A, Hyperlink 2.

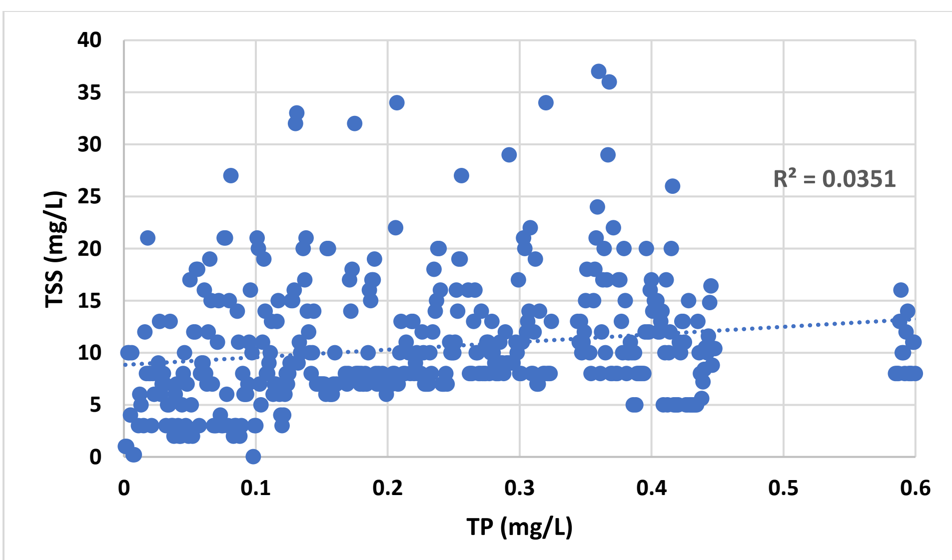

Figure 18: Correlation between TP and TSS for Site 11 based on the 2000-2015 OWRB data set

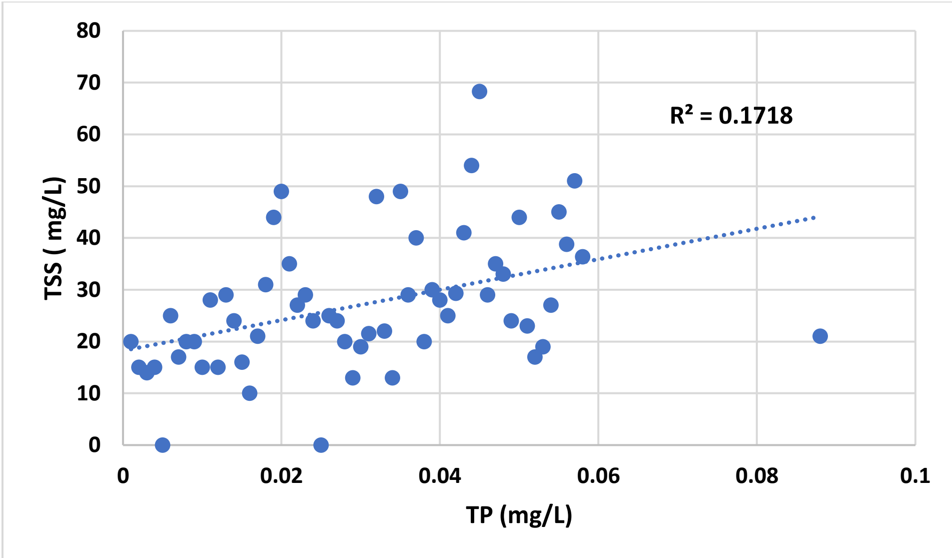

Figure 19: Correlation between TP and TSS for Site 8 based on the 2000-2015 OWRB data set

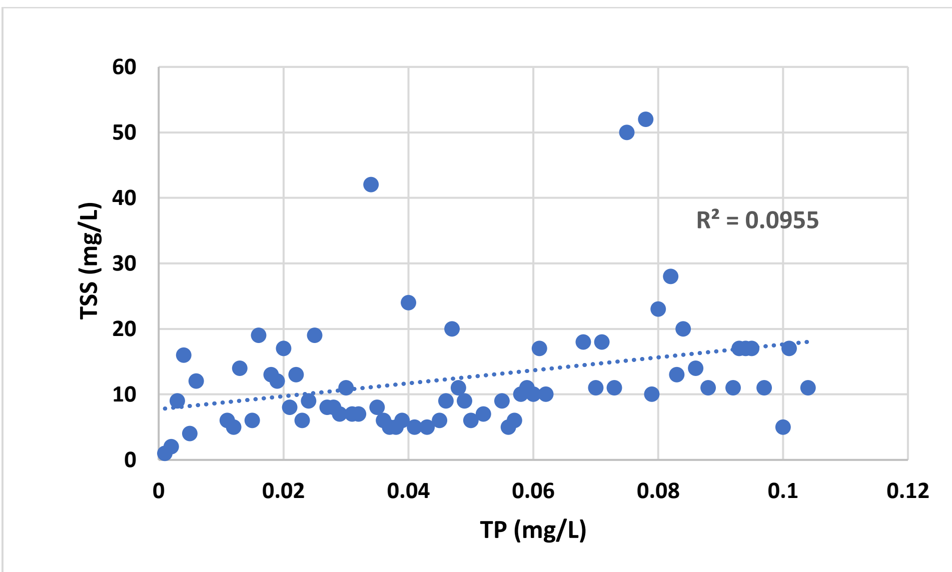

Figure 20: Correlation between TP and TSS for Site 4 based on the 2000-2015 OWRB data set

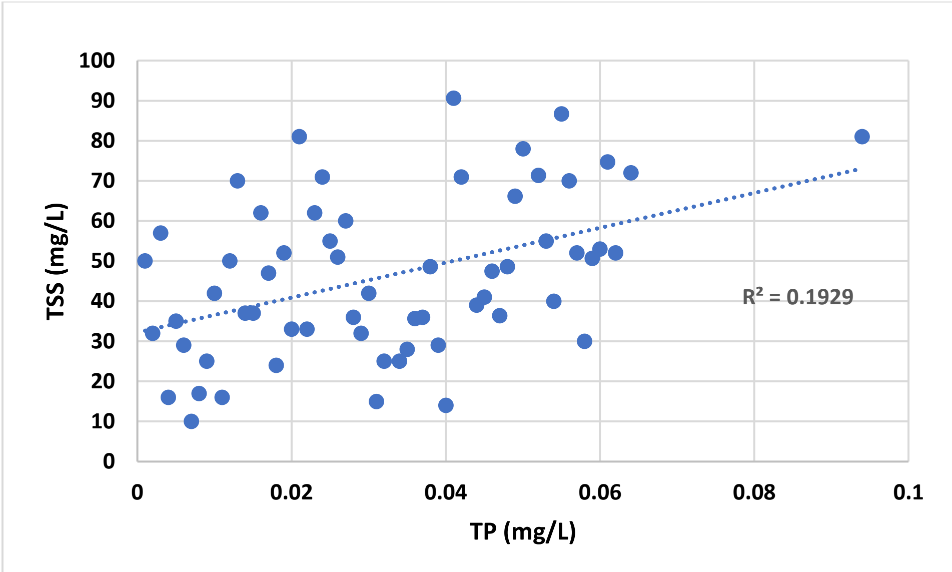

Figure 21: Correlation between TP and TSS for Site 6 based on the 2000-2015 OWRB data set

The relationship between measured turbidity and TP was also evaluated at Sites 1 and 6 using the 2016-2019 data set. Since it is confirmed that phosphorus is the limiting nutrient in the lake, verifying how the phosphorus is entering the watershed is important for developing a solution to decrease TP loadings. Figures 22 and 23 illustrate the relationships between TP and turbidity for Sites 1 and 6. The Pearson values calculated for both plots verified that there is a strong correlation between turbidity and TP.

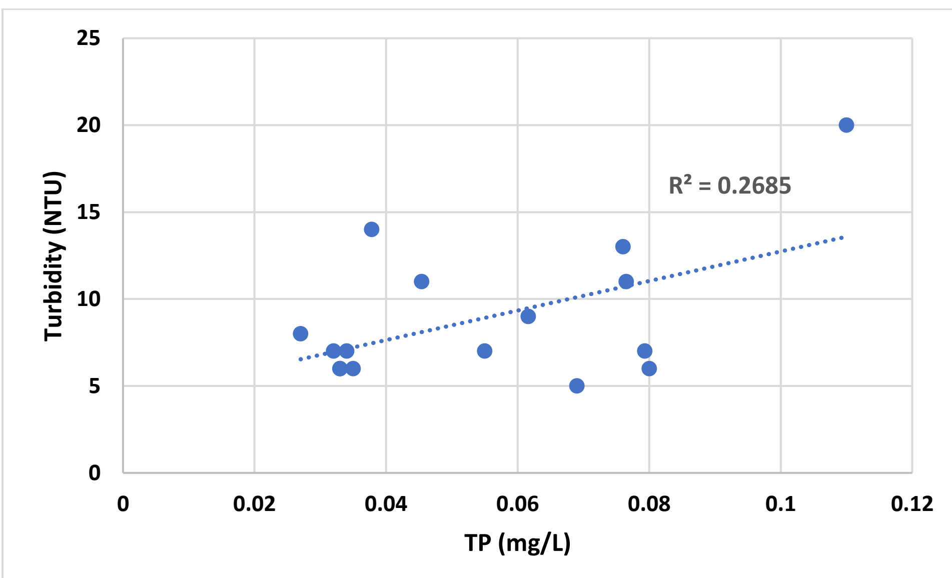

Figure 22: Correlation between TP and turbidity for Site 1 based on 2016-2019 OWRB data set.

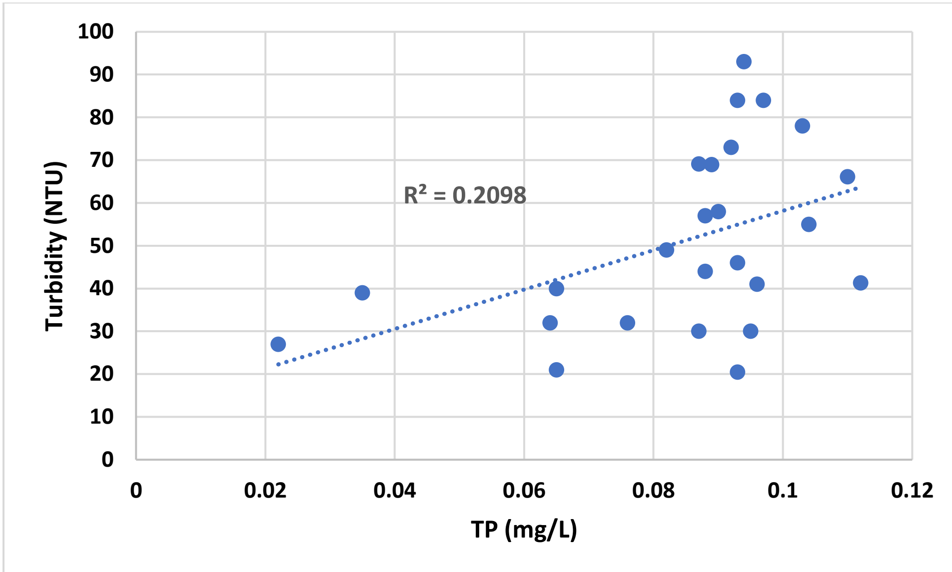

Figure 23: Correlation between TP and turbidity for Site 6 based on 2016-2019 OWRB data set

3.3 Water Quality Parameter Design Values

The TMDL report conducted by Dynamic Solutions, LLC for ODEQ determined average annual values of TSS, Carbonaceous Biochemical Oxygen Demand (CBOD), TP and TN (kg/yr), that, if achieved, will meet water quality targets for Chl-a, DO, and turbidity (Dynamic Solutions, LLC 2013). These values are based on a total 35% reduction required for TN, TP, and TSS. Table 4 summarizes the values that were used in the final design to ensure that adequate treatment was achievable.

Table 1: TMDL design parameters (Dynamic Solutions, LLC 2013)

Water Quality Constituent	TMDL (kg/day)
TN	807.7
TP	158.4
CBOD	2,408.8
TSS	76,950.8

3.4 TP Loadings in Hog Creek and Little River

StreamStats is a map-based web application that uses a Geographic Information System (GIS) with the intent of providing the user with analytic tools that pertain to water resource management, planning, and design. In the case of this project, StreamStats was used to delineate the area of the primary drainage basins and provide inflow estimates. The significance of delineating the area of drainage basins is that catchment areas can be estimated for pervious and impervious flow. It is also important to note that the method StreamStats uses to provide estimates for streamflow statistics is a specific equation solving process called regionalization. Regionalization relates streamflow statistics from stream gages to physical basin characteristics by utilizing regression analysis (McCarthy n.d.). The StreamStats visual depiction of the drainage basins is highlighted in yellow in Figures 24 and 25. The pin displayed in the figures show the manually selected points that StreamStats used to delineate the drainage basin.

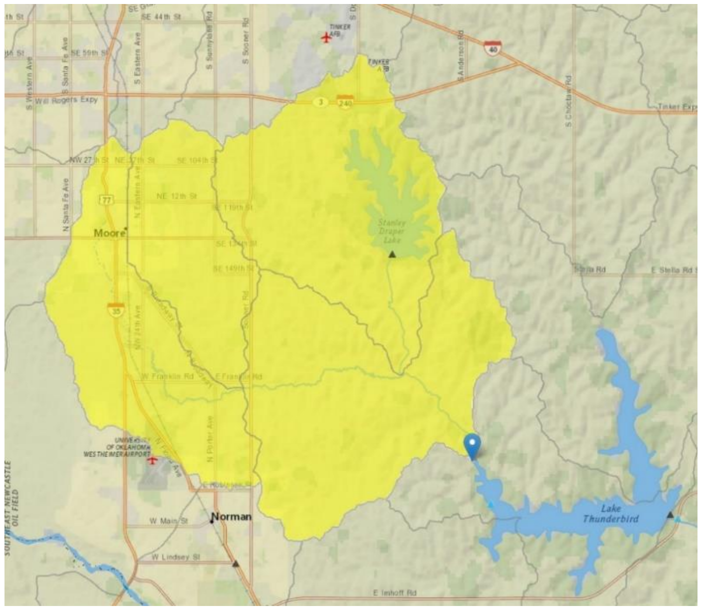

Figure 24: StreamStats delineation of Little River drainage basin

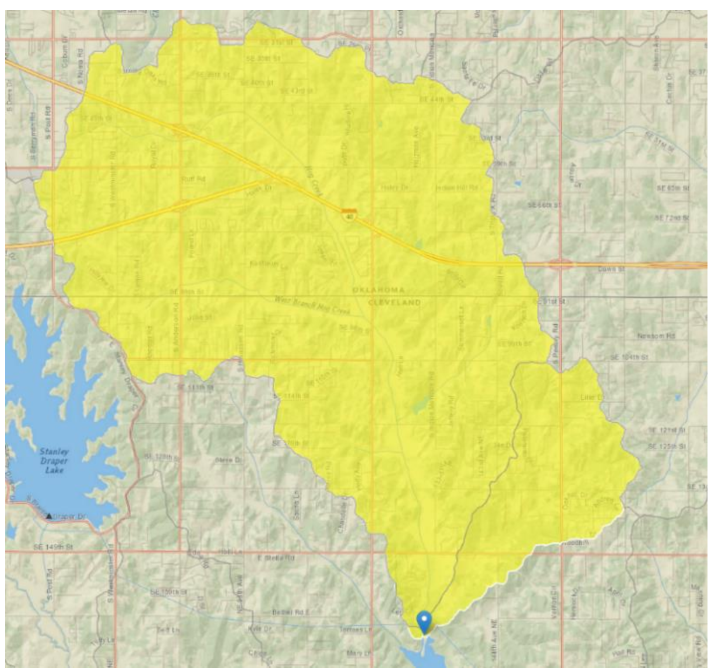

Figure 25: StreamStats delineation of Hog Creek drainage basin

Using current flow data provided by StreamStats for Hog Creek and Little River, along with the average TP concentrations at Site 8 and Site 6 obtained from the OWRB data sets, an approximate value for the TP loading can be calculated. StreamStats provided both the average flow and the 100-year peak flow for both streams, and these values can be used to determine the average and the peak loading rates. The flow values generated by Streamstats for Little River and Hog Creek are shown in Tables 1 and 2 abd can be used to estimate mass loading. They also serve as sizing values for the conceptual design of the recommended solution.

Table 2: Streamstats Little River drainage basin

Parameter Description	**Value**	**Unit**
Area that contributes flow to a point on a stream	110.36	mi^2
Percentage of impervious area determined from NLCD 2001 dataset	6.8	percent
Average daily streamflow	39.9	ft^3/s
Controlled 100 Year Peak Flood	29400	ft^3/s

Table 3: Streamstats Hog Creek drainage basin

Parameter Description	**Value**	**Unit**
Area that contributes flow to a point on a stream	48.34	mi^2
Percentage of impervious area determined from NLCD 2001 impervious dataset	2.36	percent
Average daily streamflow	18.5	ft^3/s
Controlled 100 Year Peak Flood	18800	ft^3/s

Table 3 shows the peak and average loadings from both streams with TP data from the OWRB dataset and flow data from StreamStats. The TP loading at the lake is estimated to be 124.35 mg/s, while the TMDL is 5.01 mg/s (158 kg/day) meaning that a reduction of 95.97% is required.

Table 4: Peak and average TP loadings for Hog Creek and Little River

Hog Creek TP Loading		
100-year peak flow	18800	ft^3/s
Average flow	18.5	ft^3/s
(2000-2015) Avg. TP	0.05	mg/L
(2016-2019) Avg. TP	0.05	mg/L
Peak Loading	26851	mg/s
Average Loading	26.42	mg/s

Little River TP Loading		
100-year peak flow	29400	ft^3/s
Average flow	39.9	ft^3/s
(2000-2015) Avg. TP	0.09	mg/L
(2016-2019) Avg. TP	0.08	mg/L
Peak Loading	72162	mg/s
Average Loading	97.93	mg/s

The calculated TP loading only accounts for the average concentrations in the lake from 2000 to 2019. As urbanization increases in the area, the amount of predicted TP loading is set to increase. Using SWAT

(Soil & Water Assessment Tool) modeling, Vieux was able to predict the TP loadings in the watershed if 50% of the agricultural land was converted to residential property by 2040. SWAT is a watershed to river basin-scale numerical model used to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. The program estimated that the TP loading by 2040 (if 50% of the local land is urbanized) will be 24,907 kg/year or 790 mg/s (Vieux and Vieux 2007).

4 Initial Assessment of Available Technologies

First, an extensive literature review determined all the in-lake technologies and watershed BMPs that are currently available and were considered for this project. Topical reports were conducted by EnviroShield Solutions, H_2OU Engineering, and Jay Engineering to identify costs, performance, and maintenance requirements for a wide range of watershed BMPs and in-lake technologies. Based on this information, a qualitative analysis conducted by EnviroShield Solutions determined which technologies should be further considered based on an analysis of benefits and limitations of each technology. The results of this initial assessment are summarized in Appendix C.

4.1 Watershed BMPs

For the remainder of this document, watershed BMPs will be defined as technologies intended to address conditions in the larger watershed, such as urban stormwater runoff, that adversely impact water quality. The majority of these BMPs primarily address sediment loading, which has the beneficial secondary effect of reducing nutrient loading that are often bound to sediment, as determined by the analysis of the OWRB dataset. Most of the watershed BMPs that were selected for further consideration directly address erosion control and excess nutrient loading simultaneously. There are several BMPs that do not directly address both parameters but require further consideration. These BMPs are intended to work in tandem with other watershed or in-lake BMPs. They will be deployed near areas of urbanization and are expected to have lower capital costs. Table 16 in Appendix C lists the qualitative benefits and limitations of each BMP. Based on these considerations, EnviroShield Solutions has decided to further consider Coir Geotextile Rolls, Shoreline Revegetation, Bioretention Basins, Infiltration Basins, and Log Vanes. Other BMPs that can be classified as “Low-Impact Development” that are not previously mentioned, such as Green Roofs, Rainwater Harvesting, Pervious Pavement, etc. are not further considered because they would consist of several, small-scale projects throughout the Lake Thunderbird Watershed that would be difficult for COMCD to maintain and operate, and, as was seen with the Trailwoods Project, are dependent on communities that naturally fluctuate and may not wish to continue the project.

4.2 In-Lake Technologies

In-Lake Technologies may have higher capital costs but result in more direct treatment of water as they are located within the lake. An extensive literature review gathered all relevant and available technologies, and an initial qualitative assessment was conducted to determine which technologies EnviroShield Solutions would further consider. The benefits and limitations of each technology were identified, and technologies worthy of further consideration were identified. Table 17 in Appendix C summarizes the results of this evaluation process. Based on this initial qualitative assessment the following technologies will be further considered: Constructed Wetlands, Floating Wetlands, Hydrogen Peroxide, Speece Cones, Ultrasonic Irradiation, and Phoslock®.

5 Evaluation Criteria and Process

To compare a wide range of solutions, Enviro-Shield Solutions followed a similar method as outlined in the city of Norman "Strategic Water Supply Plan" (Carollo 2014). The method clearly identifies objectives and sub-objectives of the project, as well as performance measures which help quantify the ability of the proposed solution to meet the objectives. Table 6 shows the evaluation criteria developed by Enviro-Shield Solutions. A score of 1-5 was assigned to each subobjective and represents relative performance when compared to the other options. These values were then averaged to determine an overall score for each respective objective.

Table 5: Evaluation criteria for performance comparisons

Objective	**Sub-objective**	**Performance Measure**
Affordability	Minimize capital cost	Unit capital cost
	Minimize life-cycle cost	$/yr
Efficacy	Reduction in volume runoff	%
	Reduction in total nitrogen (TN)	%
	Reduction in total phosphorus (TP)	%
	Reduction in total suspended solids (TSS)	%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Amount of land disturbed during construction (qualitative score)
	Minimize permanent ecosystem impacts	Environmental impacts (qualitative score)
Timely Implementation and Certainty	Reduce institutional complexity and increase COMCD control	Number of facility owners and/or project co-participants (qualitative score)

	Reduce barriers met by negative public perception and increase potential for community engagement	Public/political acceptability (qualitative score)
Lifetime Assessment	Temporal reliability	Lifetime (yr)
Community Values	Minimize impact on non-water supply benefits	Perceived impacts to recreation and aesthetics (qualitative score)
	Reduce reliance on traditional infrastructure	Amount of green infrastructure vs. traditional infrastructure (qualitative score)
	Maintain protection of property rights	Potential impact to property rights (qualitative score)
	Contribute to environmental equity	Potential to locate projects in low income/minority areas (qualitative score)
	Improve access to nature	Accessibility to public (qualitative score)
Water Quality Aesthetics	Minimize taste and odor potential	Expected chlorophyll-a reduction
	Address DO levels	Expected increase in DO

Since not all objectives are equally important, and the importance placed on each objective may vary from stakeholder to stakeholder, it is important to weight objectives to better reflect the preferences and values of this specific project (Carollo 2014). Collaboration with COMCD was done prior to beginning the evaluation process to determine the weight that each objective should receive to reflect the specific preferences for this particular project. Since there are seven total objectives, a total of seventy points were allocated to be distributed. If the evaluator believed that all objectives were equally important, they would award ten points to each objective. The points were distributed accordingly by three board members of the COMCD and then the averages were taken to obtain an overall weight for each objective. The results of the individual point distributions, as well as the aggregate values, are presented in Table 6 and Figure 26. The score for each objective is multiplied by its relative weight to determine a final score that adequately reflects the preferences of the COMCD. A higher score indicates that the solution performed best compared to other solutions relative to the objectives.

Table 6: Summary of points distributions per COMCD board members

Objective	**Board Member 1**	**Board Member 2**	**Board Member 3**	**Average Points**	**Percentage**
Affordability	9	12	11	11	15%
Efficacy	12	16	11	13	19%
Environmental Stewardship	11	5	10	9	12%
Timely Implementation and Certainty	8	6	10	8	11%
Lifetime Assessment	7	16	9	11	15%
Community Values	12	4	7	8	11%
Water Quality Aesthetics	11	11	12	11	16%

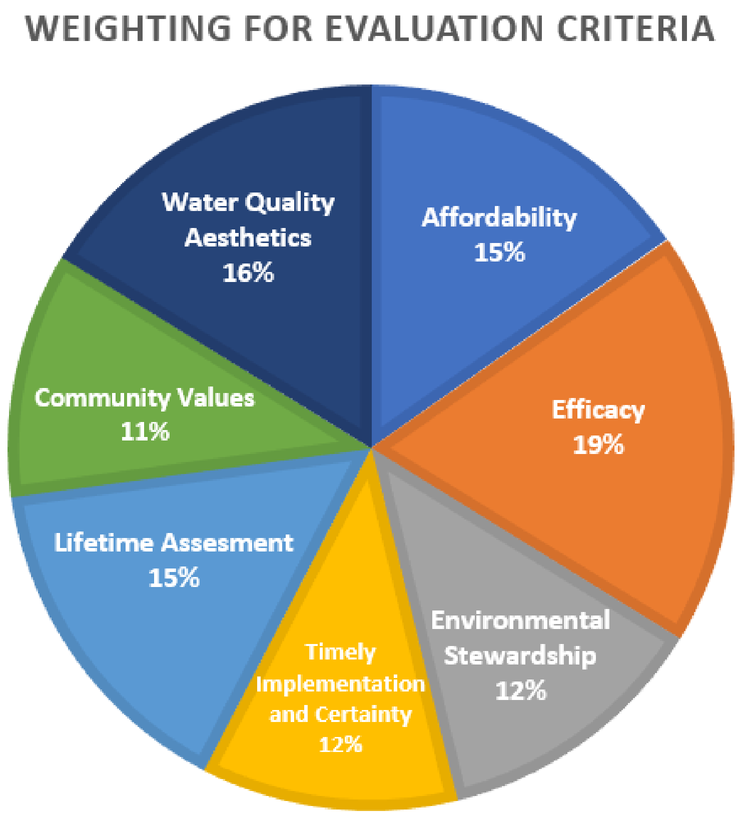

Figure 26: Weighting for evaluation criteria per COMCD input

As seen above, the objectives rank in order from most important to least important as follows: Efficacy, Water Quality Aesthetics, Lifetime Assessment/Affordability, Environmental Stewardship/Timely Implementation and Certainty/Environmental Stewardship, and Community Values; however, the distribution of weight is relatively equal. By considering these weighted objectives, Enviro-Shield Solutions was able to perform a completely objective evaluation of all the possible design solutions and present the best final recommendation that meets the specific preferences of COMCD.

6 Results of Evaluation

Following an initial qualitative assessment of available technologies, a quantitative analysis was conducted of the 11 remaining technologies. This evaluation followed the template presented in Table 6 and the completed tables for each solution are presented in Appendix D. A color scale was used to better visualize the numerical results: 1 (red), 2 (orange), 3 (yellow), 4 (light green), and 5 (green) with 1 being the lowest score and 5 the highest score.). The following abbreviations are used as well: Bioretention Basin (BB), Coir Geotextile Rolls (CGR), Log Vanes (LV), Infiltration Basin (IB), Hydrogen Peroxide (H_2O_2), Speece Cones (SC), Phoslock (P), Ultrasonic Irradiation (UI), Shoreline Revegetation

(SRv), Constructed Wetlands (CW), and Floating Wetlands (FW). The ‘raw scores’ reflect the results before applying the weighted preferences. The bolded numbers reflect the highest scoring solutions.

The results of the ‘raw scores’ would result in the preferred in-lake technology being constructed wetlands and equivalent scores for infiltration basins and bioretention basins. However, upon applying the weights, Enviro-Shield Solutions was able to identify bioretention basins as the preferred watershed BMP solution, with constructed wetlands remaining the preferred in-lake solution. Bioretention basins scored better in sub-objectives such as “Access to Nature” and “Environmental Equity” as they bring aesthetic enhancements to communities previously lacking access to outdoor spaces. Floating wetlands also received a high score yet have been attempted before in Lake Thunderbird as wave breakers and have proven to have significant operation and maintenance requirements. Therefore, bioretention basins are the preferred watershed BMP, while constructed wetlands are the preferred in-lake technology.

Table 7: Results of evaluation of in-lake technologies and watershed BMPs

Objective	Sub-objective	BB	CGRs	LV	IB	H_2O_2	SC	P	UI	SRv	CW	FW
Affordability	Minimize capital cost Minimize lifecycle cost	4	5	5	4	1	2	1	2	3	3	5
Efficacy	Reduction in volume runoff	5	1	1	5	1	1	1	1	2	1	1
	Reduction in total nitrogen (TN)	2	1	1	4	4	5	1	4	4	3	2
	Reduction in total phosphorus (TP)	2	1	1	4	1	3	5	4	4	5	3
	Reduction in total suspended solids (TSS)	4	5	1	5	4	1	1	4	4	5	3
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	3	5	5	4	5	2	5	5	4	4	3
	Minimize permanent ecosystem impacts	5	5	5	4	1	4	4	3	3	4	3
Timely Implementation and Certainty	Number of facility owners and/or project co-participants	2	4	2	2	1	1	5	4	3	2	1
	Public/political acceptability	3	5	5	3	2	5	2	3	5	3	3
Lifetime Assessment	Temporal reliability	5	4	2	4	3	3	3	4	2	5	5
Community Values	Impact on non-water supply benefits	5	4	4	3	1	4	4	3	5	3	5
	Reliance on natural infrastructure	4	3	4	4	1	1	1	1	5	5	4
	Protection of property rights	2	3	3	2	5	4	5	5	3	1	5
	Environmental Equity	5	1	1	3	1	1	1	1	1	1	2
	Access to Nature	5	2	2	3	5	5	2	2	4	5	4
Water Quality Aesthetics	Minimize taste and odor potential	3	1	1	1	4	5	3	4	1	3	3
	Address DO levels	4	1	1	1	4	5	1	3	1	3	3
Raw Scores		**3.71**	3.00	2.59	**3.29**	2.59	3.06	2.65	3.12	3.18	**3.29**	3.24
Weighted Scores		**3.77**	3.32	2.73	3.33	2.54	3.08	2.55	3.24	2.87	**3.46**	3.45

6.1 Watershed BMP Result of Evaluation: Bioretention Basins

Bioretention basins are designed to retain stormwater runoff which is then filtered through native plants to remove pollutants (USEPA 2013). Filtration, chemical, and biological processes all aid in the removal of contaminants and make bioretention basins more effective than wet ponds or infiltration basins. Removal efficiencies for bioretention basins are 32% for TN, 31% for TP, and 60% for TSS (Austin 2012). The location of bioretention basins should be strategically placed in hydrologically sensitive areas (HSAs) to ensure maximum efficiency (Martin-Mikle 2015). HSAs were determined from a multi-variable topographic index, considering factors such as slope, drainage area, soil conductivity, and modified depth to restrictive layer (Martin-Mikle 2015). These HSA can then be used to identify sites where expected stormwater runoff accumulates and low-impact development techniques should be placed for maximum efficacy.

The ability to plant native species in the basin contributes positively to the aesthetics and biodiversity of a city. Furthermore, if placed in low-income areas, or areas typically prone to having low access to nature, bioretention basins can contribute to the environmental equity. Bioretention basins are more expensive than other forms of low impact development but are more effective and are more centralized, making it easier for the city to negotiate property rights, ensure efficacy, and conduct maintenance. Figure 27 shows a picture of a bioretention basin installed in Denver, CO. The complete evaluation table of bioretention basins can be found in Appendix D, Table 18.

Figure 27: Bioretention basin during a stormwater event (USEPA 2013)

6.2 In-Lake Technology Result of Evaluation: Constructed Wetlands

Constructed wetlands are shallow basins that treat stormwater inputs through gravitational settling, filtration by biomass, biological uptake, and microbial activity. They are designed to resemble self-sustaining natural wetlands, are generally low-cost, and are considered one of the most reliable stormwater treatment practices (Sample et al. 2020). Expected removal efficiencies are 50-75% TP, 25-55% TN, and 95% TSS (Chesapeake Stormwater Network 2013). The constructed wetland will ideally be placed closer to Lake Thunderbird, effectively minimizing the need for extensive property rights. The constructed wetland would ideally serve as an addition to the Lake Thunderbird State Park, hosting a range of educational activities for K-12 students as well as university students to learn about this unique form of water treatment. Figure 28 is an example of a constructed wetland in Virginia.

Figure 28: Example of a constructed wetland (Chesapeake Stormwater Network 2013)

7 Final Recommendation and Conceptual Design

7.1 Watershed BMP: Bioretention Basins

The type of bioretention basin recommended typically has an area of 5% to 8% of the catchment area (Austin 2012). Minimum suggested dimensions are 10 feet wide by 20 feet long with a recommended 2:1 length to width ratio (LSS 2019). Suggested maximum widths are 25 feet and maximum surface pond depth should be between six and eighteen inches. The surface pond depth should drop at a rate of about 1 inch per hour and a freeboard distance between six and twelve inches is necessary. Beneath the water ponding area should be a 24-inch layer of well-drained planting soil mixture. Most current specifications require 80% to 88% sand for the main filter layer, but many variations are suitable. Small quantities of shredded bark, mulch, and loam soil are generally specified, but silt and clay are limited to 7%. This thick soil layer is followed by a two-inch sand layer on top of a 24-inch gravel bed. All gravel should be triple washed and only low phosphorus index media should be used. Native plants should be used to enhance the local biodiversity (Austin 2012). A simple pond shape helps keep flows from being interrupted or short-circuited (Pitt n.d.). Bioretention basins should be placed in hydrologically sensitive areas because these specific areas are prone to generating runoff. Drainage areas used for design should not exceed five acres (LSS 2019). Figure 29 is a general schematic of a bioretention basin.

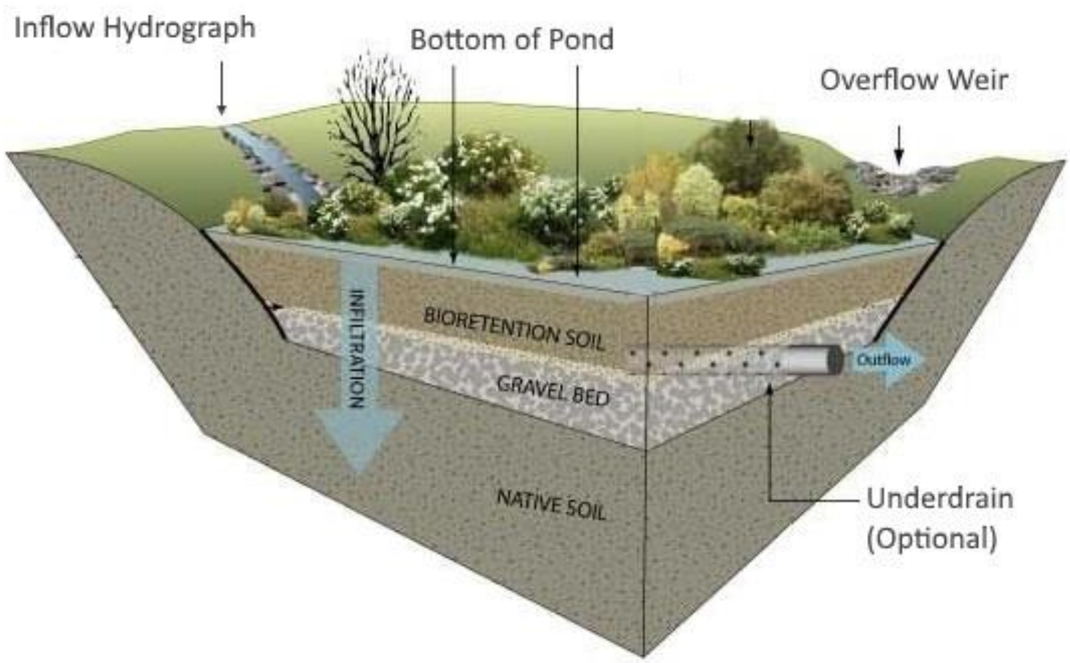

Figure 29: General schematic of a bioretention basin (Hydrology Studio n.d.)

To calculate the area required for the recommended bioretention basins, 5% of the catchment area was used as a basis for the design. For the Little River, a total drainage area of approximately 110 mi^2 and 6.8% of that area being impervious, 5% of the catchment area was calculated to be about 240 acres. Taking the same approach for Hog Creek, which has a total drainage area of approximately 48 mi^2, yielded a catchment area of about 105 acres. The result is a total drainage area of 345 acres. Because drainage areas used for design should not exceed five acres, multiple basins will be necessary to cover the total surface area recommended. Bioretention basins are typically placed within small land areas with residential usage or with parking lots where the islands become aesthetically pleasing stormwater treatment centers (LSS 2019). Housing and commercial developments result in high sediment runoffs and contribute to imperviousness in the watershed so these would be the preferred locations for bioretention basin placement. The guidelines provided allow for a wide variety of possible basin dimensions and locations. Table 8 provides specific information for sample basin designs.

Table 8: Recommended design for bioretention basins in Little River and Hog Creek watersheds

Little River					
Drainage (ft^2)	Catchment (%)	Catchment (ac)	Width (ft)	Length (ft)	Depth (in)
110.36	5	239.4	15	30	15
Hog Creek					
Drainage (ft^2)	Catchment (%)	Catchment (ac)	Width (ft)	Length (ft)	Depth (in)
48.34	5	105	20	40	12

After assessing cost components such as site preparation, site formation, structural components, and site restoration, the proposed bioretention basins were calculated to have an average cost of $7,500 per acre drained (LSS 2019). Estimated costs for each area-specific bioretention basin, along with total capital costs are given in Table 9. Performance expectations for TP, TN, and TSS removal are also included.

Table 9: Total cost of bioretention basins in Little River and Hog Creek watersheds

TP Decrease (%)	TN Decrease (%)	TSS Decrease (%)	Little River CA (acres)	Hog Creek CA (acres)	Total CA (acres)	Little River Cost	Hog Creek Cost	Total Capital Cost
31	32	60	240	105	345	$1,795,500	$787,000	$2,583,000

Considering an operation and maintenance cost of $850/year, the total present-day cost (i = 6%, n=20 yrs) is **$2,596,737** (LSS 2019).

7.2 In-Lake Technology: Constructed Wetlands

The recommended type of constructed wetland possesses hydrology similar to Figure 30. To optimize temporal performance and reduce the costs of maintenance, constructed wetlands should include design plans for a sediment forebay. Sediment forebays are placed upstream of major inflow points to the constructed wetland where they function as an initial sediment capture. In addition to being placed upstream, the forebay and the constructed wetland must be physically separated by a weir or similar structure to promote settling in the forebay. The forebay should be sized to contain 10 to 15 percent of the total volume of the constructed wetland pool. In terms of depth, the forebay should be at least four feet deep or a similar depth to open water portions of Lake Thunderbird (Department of Environmental Protection 2006).

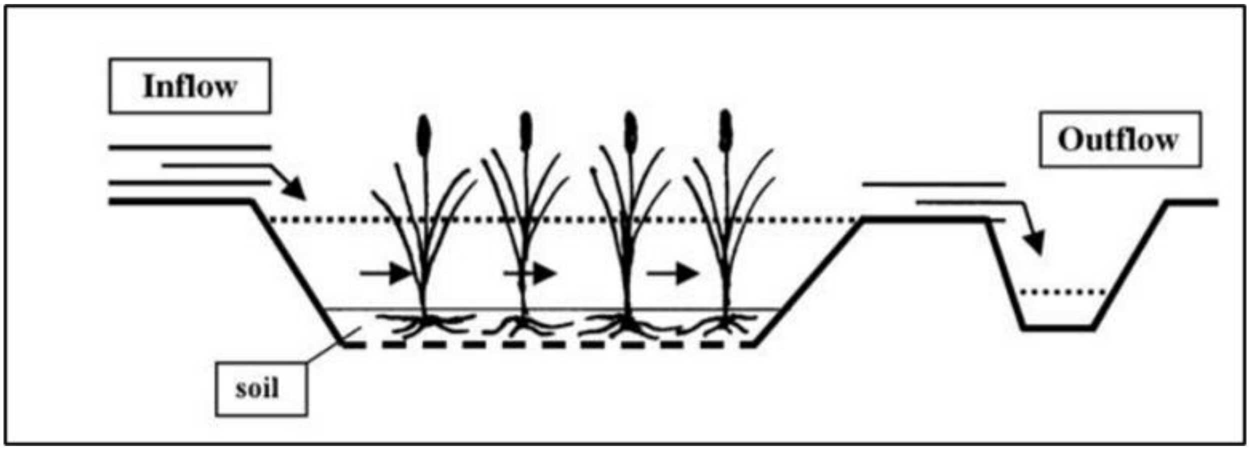

Figure 30: Free water surface and emergent macrophytes constructed wetland (Vymazal 2007)

To calculate the total area of wetland needed at Hog Creek and Little River, a ratio of wetland surface area (SA) and TP loading from the study conducted by Han and Huang was used and multiplied by the TP load at each tributary. The ratio determined was 1.0476 (acres)/(mg/s). Two TP loading scenarios were provided, one for average conditions and one for 40-year model predicting increase in loading due to urbanization. SWAT modeling estimated TP loading will be 24,907 kg/year (789.79 mg/s) by 2040 if 50% of the local land is urbanized (Vieux and Vieux 2007).

A study conducted by O'Geen and referenced in the Victoria report concluded the ideal constructed wetland size is between 0.3% and 6% of the catchment (Ziegler 2014). A different study conducted by Reinhardt also referenced in the Victoria report concluded that a constructed wetland was able to retain about half of its agricultural nutrient load. Typically, constructed wetlands require a surface area that equals about 4% of its pervious catchment area and a 7-day residence time, but percentages as low as 0.2% have shown significant results (Ziegler 2014).

70,646 acres of the watershed contribute to the loadings at Little River, with 6.8% being impervious. The surface area calculated for Little River using the ratio was 519 acres, which accounts for 0.8% of the pervious catchment area. The surface area calculated for Hog Creek was 312 acres which accounts for 1.01% of the catchment area. Based on existing topography, approximately 500 and 750 acres of wetlands could be established on the Little River and Hog Creek arms of the lake (Nairn 2014). The water depth for the wetland suggested by the department of agriculture is 3 feet (USDA n.d.). Table 9 summarized the design recommendation for the constructed wetlands at Little River and Hog Creek

Table 9: Recommended design for constructed wetlands in Little River and Hog Creek watersheds

Little River					**Hog Creek**				
Q (ft^3/s)	SA (acres)	Catchment (%)	HDT (days)	Depth (ft)	Q (ft^3/s)	SA (acres)	Catchment (%)	HDT (days)	Depth (ft)
39.9	518	0.08	19	3	18.5	312	1.01	25	3

A study conducted by The Nature Conservancy determined that a hydraulic detention time (HDT) of 7-10 days resulted in 50% reduction of TP loading (Ziegler 2014). Typically, the longer the HDT, the greater the nutrient removal. Local aquatic plants and organisms will be used in the wetland so that the system resembles local ecology, therefore a full analysis on local plant/animal species is needed (Ziegler 2014).

Tables 10 and 11 summarize the expected removal efficiencies and contain the calculated surface areas and associated cost for the two scenarios. It is suggested that the scenario accounting for increased loadings be considered over the average scenario as urbanization is expected to increase. The cost of the second system accounting for the predicted loading over 40 years is $8,328,282 with an annual maintenance cost of $246,742.

Table 10: Cost of constructed wetlands for average TP loadings in Little River and Hog Creek

TP Reduction (%)	TN Reduction (%)	Q, Little River (ft^3/s)	Q, Hog Creek (ft^3/s)	TP, Little River (mg/L)	TP, Hog Creek (mg/L)	Area, Little River (acres)	Area, Hog Creek (acres)	Total (acres)	Total Capital Cost
50	80	39.9	18.5	0.084	0.0508	99.27	27.84	127.11	$1,273,855

Table 11: Cost of constructed wetlands for 40-year max TP loading in Little River and Hog Creek

TP Reduction (%)	TN Reduction (%)	Q, Little River (ft^3/s)	Q, Hog Creek (ft^3/s)	TP, Little River (mg/L)	TP, Hog Creek (mg/L)	Area, Little River (acres)	Area, Hog Creek (acres)	Total (acres)	Total Capital Cost
50%	80%	39.9	18.5	0.44	0.57	519	312	831	$8,328,282

The annualized per-acre cost over a 40-year lifespan for a constructed wetland is $785 per acre (Tyndall and Bowman 2016). Most of the maintenance consists of removing accumulated sediment from the filtration bed or revegetating the wetland, but by implementing sedimentation basins that reduce sediment loadings by 75% to 80%, operational costs decrease substantially (Miranda, 2017). Table 12 shows the related annual maintenance cost of the constructed wetland system proposed.

Table 12: Annual Maintenance cost over 40-year lifespan

Without Sed. Basin	With Sed. Basin
$246,792	$61,689

In conclusion, the total cost for a lifetime of 40 years would be **$18,199,962** without a sedimentation basin and **$10,795,842** with a sedimentation basin.

8 Opportunities

On March 29th, 2021, the EPA released the Sewer Overflow and Stormwater Reuse Municipal Grants Program which contains $40 million USD in appropriations for the fiscal year 2021. In accordance with the Clean Water State Revolving Fund (CWSRF), states are required to allocate 20% of funds for green infrastructure, water and energy efficiency improvements, and other environmentally innovative activities (USEPA 2021). Therefore, the implementation of bioretention basins and a constructed wetland would fall within this category and this could perhaps be a means of obtaining funding. A bio-retention cell funded by CWSRF was implemented in Bixby, OK in 2011 (OWRB n.d.). More information can be obtained at www.owrb.ok.gov/CWSRF.

Figure 31: CWSRF Loan Program Bioretention roundabout in Bixby, OK (OWRB, n.d.)

In addition, the American Jobs Plan, which was released March 31st, proposes a total of $56 billion (out of a $2 trillion infrastructure plan) towards “upgrading and modernizing America’s wastewater, stormwater and drinking water systems through grant and low-cost loans (waterfm.com). While the bill has not yet been approved, this could prove to be a potential avenue for funding.

Overall, with the proven dedication by the surrounding municipalities to reduce their TMDLs, as well as the history of attempts made to improve the water quality of Lake Thunderbird, EnviroShield Solutions believes this project would be a good candidate for either of these federal funding programs.

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10 Appendix

10.1 Appendix A: OWRB Data Analysis

Hyperlink 1: Lake Thunderbird 2016-2019 Nutrient Data

https://sooners-my.sharepoint.com/:x:/r/personal/peter_j_wolbach-1_ou_edu/_layouts/15/Doc.aspx?sourcedoc=%7B0E66D0BA-4A8D-482C-87B3-45B69C9B4765%7D&file=CAPSTONE%202016-2019%20data%20analysis.xlsx&action=default&mobileredirect=true

Hyperlink 2: Lake Thunderbird 2000-2015 Data (TSS vs. TP)

https://sooners-my.sharepoint.com/:x:/r/personal/peter_j_wolbach-1_ou_edu/_layouts/15/Doc.aspx?sourcedoc=%7B90D23A0D-7D55-41B0-96C9-FA28B954B977%7D&file=CAPSTONE%202000-2015%20data%20analysis.xlsx&action=default&mobileredirect=true

Hyperlink 3: Lake thunderbird 2000-2015 Data (Chl-a vs. TP)

https://sooners-my.sharepoint.com/:x:/r/personal/peter_j_wolbach-1_ou_edu/_layouts/15/Doc.aspx?sourcedoc=%7BB2FB7307-2DDD-45BD-82E8-FC0D517D79AA%7D&file=2000-2015%20data%20analysis%20TP%20vs.%20Chl-a%20.xlsx&action=default&mobileredirect=true

10.2 Appendix B: Capstone Data Sampling Event

Table 13 represents the results of the TN analysis. The values highlighted in red signify the values that were outside the detectible range as designed by the test kit (1-16 mg/L).

Table 13: Results of TN analysis from capstone sampling event

Sample Name	mg/L N
Lab Blank	14.5
Site 5	7.45
Site 1	26.8
Site 6 Field Dup	22.5
Field Blank	24.4
Site 11	14.7
Site 6	7.74
Site 2 Lab Dup	43.9
Site 4 Field Dup	16.1
Site 2	10
Site 4	12.4

Table 14: Results of TP analysis from capstone sampling event

Site	1	2	4	Field Dup (4)	5	6 (West Bridge)	6 (East Bridge)	11	Field blank	Lab Dup (2)	Lab blank
Time	9:23	10:16	11:20	11:25	11:53	9:12	12:00	12:16	12:00	-	15:28
mg/L	0.027	0.022	0.021	0.013	0.015	0.026	0.017	0.03	-0.027	-0.016	-0.036

Table 15 reflects the data collected with the YSI probe, alkalinity kit, hardness kit, turbidimeter and Secchi disk. For the purposes of this document , the three replicates collected for turbidity, alkalinity, and hardness were averaged.

Table 15: Data collection during field sampling event on March 20, 2021

(red cells: data not collected, yellow cells: data not valid)

Site	Temp (F)	Depth (ft)	Coordinates	Secchi Disk (ft)	Turbidity (NTU)	Alkalinity (mg/L)	Hardness (mg/L)	Time	Specific Conductivity (mS)	Conductivity (uS)
1	43	63	33 deg 22 min N, 97 deg 22 min W	3	11.7	143.3	333.3	9:39	0.531	391
3	50	21	35 deg 26 min N, 97 deg 23 min W	3	10.7	167.3	306.7	10:27	0.429	319
4	54	40	35 deg 13.631 min N, 97 deg 15.362 min W	2.54	10.7	191.3	226.7	11:25	0.423	316
5	54	11	35 deg 13.283 N, 97 deg 17.249 min W	1.9	13.3	191.7	206.7	11:57	0.44	332
West Bridge	44		35 deg 13.646 min N, 97 deg 18.360 min W		24	165	273.3	9:18	0.481	359
East Bridge	57		35 deg 13 min, 71 sec N, 97 deg 18 min 17 sec W		21	187	280.0	12:06	0.483	360
11	54	7.3	35 deg 12.811 min N, 97 deg 18.14 min W	1	23	208	233.0	12:26	0.449	342
Site	**Resist (ohm'cm)**	**TDS (g/L)**	**Salinity (ppt)**	**ODO_{sat} (%)**	**ODO (mg/L)**	**pH**	**pH (mV)**	**Orp (mV)**	**Chl-a (ug/L)**	**Chl (RFU)**
1	2558.06	0.345	0.26	0	0	8.16	-102.3	741.3	653.9	156.8
3	3138.86	0.279	0.21	0	0	8.23	-106	741.4	628	150.6
4	3161.18	0.275	0.2	101.2	10.95	8.45	-80.4	254.2	8.8	2.1
5	3015.53	0.286	0.21	102.6	11.02	8.56	-86.5	244.4	13.5	3.2
West Bridge	2785.98	0.312	0.23	97.2	10.52	8.47	-81.7	219	19.7	4.7
East Bridge	2779.65	0.314	0.23	0	0	8.24	-106.8	740.5	652.3	156.4
11	2923.67	0.292	0.22	104.4	11.1	8.6	-89.2	253.2	14.1	3.4

10.3 Appendix C: Qualitative Analysis of Watershed BMPs and In-Lake Technologies

Table 16: Initial watershed BMPs qualitative assessment

Name	Functionality	Benefits/Limitations	Limitations	Further Consideration? (Y/N)
Fascines	Slow runoff with small check dams	Addresses TSS, erosion control	Requires considerable area	N
Coir Geotextile Rolls (CGR)	Erosion and runoff prevention through functioning as a sediment block, sediment sequester, and breakwater tool	Versatile use addressing TSS and TN/TP nutrient loading	Bulky and requires substantial initial maintenance.	Y
Shoreline Revegetation with Geotextile Mats	Erosion – anchoring vegetation and sequestering sediment	Allows for vegetative reestablishment in adverse conditions Addresses TSS and nutrient uptake	Typically requires tandem use of another BMP	Y
Branch Box	Erosion – Breakwater structures for reducing shoreline erosion	Hardier than CGR breakwaters	Only addresses TSS from shoreline erosion	N
Brush layering	erosion – plant material layered in successive trenches to assist in repairing bank slopes	Addresses TSS through bank stabilization	Used in tandem with ripraps or geotextile mats, cheap	N
Plant Rolls	Erosion -technique using plants soil in burlap strip with embedded vegetation	Addresses TSS from stormwater runoff. Effective in areas with poor soil quality	Requires multiple plantings and maintenance to be effective	N
Brush Mattress	Bank erosion - provides direct protective cover for steeper degrading banks	Reduces TSS through sedimentation and provides protection for establishing vegetation	May require heavy maintenance throughout lifetime.	N
A-jacks	Rigid concrete structures placed in rows with vegetation established behind them	Addresses TSS through reducing toe scouring and bank undercutting	Requires stable bank, cost, material and is labor intensive	N

Name	Functionality	Benefits/Limitations	Limitations	Further Consideration? (Y/N)
Log/tree breakwater	Shoreline/bank Erosion - functions as a sediment block and breakwater tool	Similar to CGR without sequestration and not as versatile, but much cheaper	Labor installation costs may be higher due to the weight of moving logs	N
Bioretention Basin	Vegetative impoundments that infiltrate design volume in under 48 hours	Addresses TSS and nutrient loading through filtering runoff through basin.	Requires significant area and several different forms of maintenance	Y
Wet Detention Basin	Impoundment that retains a design volume of water and allows for runoff	Use settling for pollutant removal and can use vegetation to augment nutrient loading reduction	Substantial initial costs and maintenance, not as directly effective as other methods.	N
Infiltration Basin	Excavated trench backfilled with stones to act as a temporary runoff storage	Addresses sediment loading by reducing stormwater runoff velocity	Expensive, site specific, requires large area	Y
Log Vanes	Logs are anchored into the bank and directed at an angle perpendicular to the bank that directs flow away from the eroding bank.	Addresses TSS and only significant costs would be capital costs	Could wash away	Y

Table 17: Initial in-lake technologies qualitative assessment

Name	Functionality	Benefits	Limitations	Further Consideration? (Y/N)
Biomanipulation	Control populations of fish species to reduce algae biomass	Reduces Chl-a, reduces turbidity, relatively cheap	Requires extensive monitoring	N
Constructed Wetlands (CW)	Shallow, wet detention basin with vegetative covering. Treats water through contact time with vegetation	Vertical CWs: remove NH_3-N Subsurface CWs: remove CODMn and Chl-a Surface CWs: increase DO content, cheapest	Require maintenance and future dumping, require large area	Y
Shoreline Revegetation	Planting native plants to stabilize soil	Stabilize soil, uptake nutrients, release oxygen	Attempted before, take 40+ years to reach full potential	N
Escarpment Treatment	Treats eroded banks with vertical barriers	Prevents further shoreline erosion, cheap	Requires heavy maintenance	N
Floating Wetlands	Small-scale water treatment and breakwater	Lower COD, Mn, P, NO_3-N, and NO_2-N, increase DO and redox potential	Already existing in lake as wave breakers	Y
Phosphorus Inactivation (Alum, Iron, Calcium, Modified Clays)	Surface application of coagulant to bind P and settle	Immobilizes P even in internal cycling	Must also reduce external P loading, reduces storage volume of lake	N
Sediment Oxidation	Injection of chemical oxidizers in sediments to remove organic matter	Less toxic than phosphorus inactivation, reduces phosphorus	Only effective in shallow lakes, costly, requires iron redox reactions	N
Coagulation-Magnetic Separation	Surface application of acid-modified fly-ash to physically absorb P	Cost-effective, reuse of byproduct (fly ash), high removal efficiencies of COD, TN, and TP	Could result in formation of iron hydroxides	N
Algicides/Herbicides	Implores hydrogen peroxide to oxidize cyanobacteria	Directly targets cyanobacteria	Could result in new algae blooms, potential for toxic byproduct, requires monitoring	N

Name	Functionality	Benefits	Limitations	Further Consideration? (Y/N)
Hydrogen Peroxide (H_2O_2)	Addition of H_2O_2 to inactive photosynthesis of cyanobacteria	Reduces Chl-a and COD, no effect on aquatic life	Expensive	Y
Hypolimnetic Aeration/Oxygenation Systems	Injects oxygen into anoxic hypolimnion	Raises DO levels	Attempted before (SDOX)	N
Speece Cones (or downflow bubble contact system, DBCS)	Inverted cone that oxygenates the hypolimnion	Raises DO levels, decreases Chl-a and soluble phosphate, does not disturb thermal stratification, minimizes environmental disturbances	5 years to notice difference in similar study	Y
Sediment Dredging	Removes bottom sediment from lake to address internal cycling	Relatively quick solution	Requires off-site waste disposal, non-ideal for large lakes, intrusive, decreases pool elevation	N
Hooper Dredge	Skims bottom of lake, like a vacuum, removing sediment	Addresses internal loading, less disturbance than sediment dredging, ideal for silty clay, addresses turbidity and chl-a formation	Requires off-site waste disposal, removes water	N
Ultrasonic or Ultrasound Irradiation	High frequency soundwave that deactivates algal cells	Results in 4-5 weeks with 24-hour exposure, Rapid decrease in Chl-a conc., reduces pH, DO, TN and TP, low maintenance unless turned off	Increases water temperature, conductivity, and orthophosphate, requires solar or line voltage, equipment life of 10 years	Y
Phoslock ® or thermally treated calcium-rich attapulgite)	Geoengineered materials that solidify surface sediment and reduce internal P loading	Address internal P loading (reduces SRP in study), have addressed eutrophication in cases where all else failed	Internal loading of P in Lake Thunderbird is not well understood	Y

10.4 Appendix D: Results of Evaluation Process for Individual Design Solutions

Table 18: Evaluation of Bioretention Basins

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$2,583,000
	Minimize life-cycle cost	$850/year
	Total present-day cost (i=6%, n=60)	**$2,596,737**
Efficacy	Reduction in volume runoff	82-96%
	Reduction in total nitrogen (TN)	32%
	Reduction in total phosphorus (TP)	31%
	Reduction in total suspended solids (TSS)	60%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Average impact
	Minimize permanent ecosystem impacts	Low impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Some dependence
	Public perception	Average acceptance
Life-Time Assessment	Temporal reliability	50-60 years
Community Values	Impact on non-water supply benefits	Positive impact
	Reliance on natural infrastructure	More natural
	Protection of property rights	More impact
	Environmental Equity	High potential
	Access to Nature	High access
Water Quality Aesthetics	Minimize taste and odor potential	31%
	Address DO levels	Expected increase

Table 19: Evaluation of Coir Geotextile Rolls

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$12,000
	Minimize life-cycle cost	$350/yr
	Total present-day cost (i=6%, n=10)	**$14,576**
Efficacy	Reduction in volume runoff	No direct measurement
	Reduction in total nitrogen (TN)	No direct measurement
	Reduction in total phosphorus (TP)	No direct measurement
	Reduction in total suspended solids (TSS)	85%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Low impact
	Minimize permanent ecosystem impacts	Low impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Average complexity
	Public perception	High acceptance
Life-Time Assessment	Temporal reliability	3-10 years
Community Values	Impact on non-water supply benefits	Minimal disturbance
	Reliance on natural infrastructure	Mixed infrastructure
	Protection of property rights	Low impact
	Environmental Equity	Low potential
	Access to Nature	No increased access
Water Quality Aesthetics	Minimize taste and odor potential	No direct measurement
	Address DO levels	No direct measurement

Table 20: Evaluation of Log Vanes

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$7,000
	Minimize life-cycle cost	$350/yr
	Total present-day cost (i=6%, n=5)	**$71,464**
Efficacy	Reduction in volume runoff	No direct measurement
	Reduction in total nitrogen (TN)	No direct measurement
	Reduction in total phosphorus (TP)	No direct measurement
	Reduction in total suspended solids (TSS)	No direct measurement
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Low impact
	Minimize permanent ecosystem impacts	Low impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	More dependent
	Public perception	High acceptance
Life-Time Assessment	Temporal reliability	5 years
Community Values	Impact on non-water supply benefits	Minimal disturbance
	Reliance on natural infrastructure	More natural
	Protection of property rights	Average impact
	Environmental Equity	No potential
	Access to Nature	No increased access
Water Quality Aesthetics	Minimize taste and odor potential	No direct measurement
	Address DO levels	No direct measurement

Table 21: Evaluation of Infiltration Basins

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$31,500
	Minimize life-cycle cost	$585/yr
	Total present-day cost (i=6%, n=15)	**$37,182**
Efficacy	Reduction in volume runoff	70-90%
	Reduction in total nitrogen (TN)	62%
	Reduction in total phosphorus (TP)	62%
	Reduction in total suspended solids (TSS)	75-100%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	More impact
	Minimize permanent ecosystem impacts	Moderate impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	More dependence
	Public perception	Average acceptance
Life-Time Assessment	Temporal reliability	15 years
Community Values	Impact on non-water supply benefits	Average impact
	Reliance on natural infrastructure	More natural
	Protection of property rights	More impact
	Environmental Equity	More potential
	Access to Nature	Average access
Water Quality Aesthetics	Minimize taste and odor potential	No direct measurement
	Address DO levels	No direct measurement

Table 22: Evaluation of Hydrogen Peroxide Treatment

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$6,372,865,227
	Minimize life-cycle cost	No maintenance
	Total present-day cost	**$6,372,865,227**
Efficacy	Reduction in volume runoff	N/A
	Reduction in total nitrogen (TN)	70%-85%
	Reduction in total phosphorus (TP)	11%
	Reduction in total suspended solids (TSS)	79%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Low impact
	Minimize permanent ecosystem impacts	High impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Completely independent
	Public perception	Some resistance
Life-Time Assessment	Temporal reliability	2 years
Community Values	Impact on non-water supply benefits	High disturbance
	Reliance on natural infrastructure	Highly traditional
	Protection of property rights	No impact
	Environmental Equity	No potential
	Access to Nature	No increased access
Water Quality Aesthetics	Minimize taste and odor potential	Expected decrease in Chl-a concentration
	Address DO levels	40-50% reduction

Table 23: Evaluation of Speece Cones

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$1,875,000
	Minimize life-cycle cost	$152,000/yr (additional $122,000 at yr 10)
	Total present-day cost (i=6%, n=20 yrs)	**$3,686,550**
Efficacy	Reduction in volume runoff	N/A
	Reduction in total nitrogen (TN)	88%
	Reduction in total phosphorus (TP)	58%
	Reduction in total suspended solids (TSS)	No direct measurement
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	More impact
	Minimize permanent ecosystem impacts	Moderate impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Highly dependent
	Public perception	High acceptance
Life-Time Assessment	Temporal reliability	20 years
Community Values	Impact on non-water supply benefits	Minimal disturbance
	Reliance on natural infrastructure	Highly traditional
	Protection of property rights	Fewer impacts
	Environmental Equity	No potential
	Access to Nature	Removal of access
Water Quality Aesthetics	Minimize taste and odor potential	79% reduction in Chl-a
	Address DO levels	60-71% increase

Table 24: Evaluation of Phoslock

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$95,964,074
	Minimize life-cycle cost	No maintenance
	Total present-day cost	**$95,964,074**
Efficacy	Reduction in volume runoff	N/A
	Reduction in total nitrogen (TN)	N/A
	Reduction in total phosphorus (TP)	80%
	Reduction in total suspended solids (TSS)	N/A
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Low impact
	Minimize permanent ecosystem impacts	Moderate impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Completely independent
	Public perception	Some resistance
Life-Time Assessment	Temporal reliability	Unknown
Community Values	Impact on non-water supply benefits	Minimal disturbance
	Reliance on natural infrastructure	Highly traditional
	Protection of property rights	No impact
	Environmental Equity	No potential
	Access to Nature	No increased access
Water Quality Aesthetics	Minimize taste and odor potential	Expected chlorophyll-a reduction
	Address DO levels	No direct measurement

Table 25: Evaluation of Ultrasonic Irradiation

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$4,043,500
	Minimize life-cycle cost	$10,000
	Final present-day cost (i = 6%, n= 10 yr)	**$4,117,101**
Efficacy	Reduction in volume runoff	N/A
	Reduction in total nitrogen (TN)	68%
	Reduction in total phosphorus (TP)	73%
	Reduction in total suspended solids (TSS)	60%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Low impact
	Minimize permanent ecosystem impacts	Average impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Some dependence
	Public perception	Average acceptability
Life-Time Assessment	Temporal reliability	10 years
Community Values	Impact on non-water supply benefits	Average impact
	Reliance on natural infrastructure	Highly traditional
	Protection of property rights	No impact
	Environmental Equity	No potential
	Access to Nature	No increased access
Water Quality Aesthetics	Minimize taste and odor potential	75% reduction in Chl-a
	Address DO levels	No direct measurement

Table 26: Evaluation of Shoreline Revegetation

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$98,000
	Minimize life-cycle cost	$13000/year
	Final present-day cost (i=6%, n=5)	**$152,761.20**
Efficacy	Reduction in volume runoff	30%
	Reduction in total nitrogen (TN)	56-87%
	Reduction in total phosphorus (TP)	41-93%
	Reduction in total suspended solids (TSS)	58-100%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Low impact
	Minimize permanent ecosystem impacts	Average impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Average dependence
	Public perception	High acceptance
Life-Time Assessment	Temporal reliability	Infinite
Community Values	Impact on non-water supply benefits	Positive impact
	Reliance on natural infrastructure	Highly natural
	Protection of property rights	Average impact
	Environmental Equity	No potential
	Access to Nature	More access
Water Quality Aesthetics	Minimize taste and odor potential	No direct measurement
	Address DO levels	N/A

Table 27: Evaluation of Constructed Wetlands

Objective	**Sub-objective**	**Performance Measure**
Affordability	Minimize capital cost	$1,273,855 - $8,328,282
	Minimize life-cycle cost	$785 per acre/yr
	Final present-day cost	**$18,199,962 (w/o sed. basin)** **$10,795,842 (w/ sed. basin)**
Efficacy	Reduction in volume runoff	N/A
	Reduction in total nitrogen (TN)	49%
	Reduction in total phosphorus (TP)	79%
	Reduction in total suspended solids (TSS)	95%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Low impact
	Minimize permanent ecosystem impacts	Moderate impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	More dependent
	Public perception	Average acceptance
Life-Time Assessment	Temporal reliability	40 yrs
Community Values	Impact on non-water supply benefits	Average impact
	Reliance on natural infrastructure	Highly traditional
	Protection of property rights	More impact
	Environmental Equity	Low potential
	Access to Nature	High access
Water Quality Aesthetics	Minimize taste and odor potential	Expected chlorophyll-a reduction
	Address DO levels	Expected increase in DO

Table 28: Evaluation of Floating Wetlands

Objective	Sub-objective	Performance Measure
Affordability	Minimize capital cost	$9,600
	Minimize life-cycle cost	$480/yr
	Final present-day cost (i=6%, n=60 yrs)	**$17,357.47**
Efficacy	Reduction in volume runoff	N/A
	Reduction in total nitrogen (TN)	17%
	Reduction in total phosphorus (TP)	53%
	Reduction in total suspended solids (TSS)	80%
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	Average impact
	Minimize permanent ecosystem impacts	Average impact
Timely Implementation and Certainty	Minimize number of facility owners and/or project co-participants	Highly dependent
	Public perception	Average acceptance
Life-Time Assessment	Temporal reliability	50 - 60 yrs
Community Values	Impact on non-water supply benefits	Positive impact
	Reliance on natural infrastructure	More natural
	Protection of property rights	No impact
	Environmental Equity	Low potential
	Access to Nature	More access
Water Quality Aesthetics	Minimize taste and odor potential	31% TP reduction
	Address DO levels	Expected increase

10.5 Appendix E: HSP, SAP, QAPP, and PWP

ENVIRO-SHIELD
SOLUTIONS

Health and Safety Plan

Evaluation of Watershed-Level and In-Lake Options to Improve
Lake Thunderbird Water Quality

Prepared by

Enviro-Shield Solutions

Prepared for

Central Oklahoma Master Conservancy District (COMCD)

April 30, 2021

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1 Introduction

The purpose of the Health and Safety Plan (HSP) is to ensure the health and safety of each person working on the proposed remediation efforts for the Lake Thunderbird project directed by Enviro-Shield Solutions. Contact and hazard information is also included.

2 Project and Site Information

2.1 Site History and Current Status

Lake Thunderbird is located in the Cross Timbers Ecoregion of south-central Oklahoma and was completed in 1965 by the U.S. Bureau of Reclamation. The lake is formed by an earth dam 7300 feet long and up to 144 feet high (USGS 2019). It has a surface area of 5439 acres with a capacity of 105838 acre-feet. Near the dam, the maximum depth of the lake is 58 feet, with an average water depth of 15.4 feet (OWRB 2020). The lake was created to aid in flood control and provide water supply, recreational opportunities, and fish and wildlife habitat.

Lake Thunderbird is an important and popular recreation destination for water activities such as fishing, boating, and kayaking. In addition, members of the community are invited to enjoy the large state park, hiking and biking trails, two swimming beaches, and the nature center. A 256 square mile drainage area from the lake covers parts of Norman, Moore, and Oklahoma City. Lake Thunderbird has a history of water quality issues and was designated as a Sensitive Water Supply (SWS) lake by the state of Oklahoma in 2002 (ODEQ 2013). This designation was assigned due to high levels of pollutants in the water. Excess nutrients, such as nitrogen, phosphorous and chlorophyll-a, along with insufficient dissolved oxygen and unacceptable turbidity levels were the main concerns and were determined to be the result of agricultural practices, excessive fertilizer application, and other contributing urban and rural factors (Olsson n.d).

Over the next decade water quality continued to worsen. In 2010, Lake Thunderbird was placed on the Oklahoma Department of Environmental Quality's 303(d) List of Impaired Waterbodies for impaired beneficial uses of public/private water supply and warm water aquatic communities (WWAC). By 2013, the Oklahoma Department of Environmental Quality (ODEQ) responded by establishing a Total Maximum Daily Load (TMDL) for nutrients, turbidity, and dissolved oxygen but did not stipulate specific regulatory controls or management practices necessary to reduce nutrients within the watershed. The ultimate recommendation was that watershed-specific controls and best management practices be chosen and put in use through a process involving all stakeholders (BOR 2019).

In an effort to improve water quality and quantity at Lake Thunderbird, many projects and studies have been conducted. For example, in 2009, the Oklahoma Tourism and Recreation Department and Bureau of Reclamation (BOR) worked with Oklahoma State University on a Resource Management Plan for Lake

Thunderbird and the Norman Project (USBR 2009). In 2012, the BOR awarded the Central Oklahoma Master Conservancy District (COMCD) a grant for the "COMCD Lake Thunderbird Water Reuse Feasibility Study", which identified the need for additions to the raw water supply in Lake Thunderbird with highly treated municipal reuse water. After the ODEQ completed a TMDL study and report on Lake Thunderbird in 2013, the City of Norman hired Olsson Engineering to create a compliance and monitoring plan that would reduce the load of pollutants discharged into the lake. The idea was to slow the rate of pollutants going into the lake so that it could begin to fix itself. The City of Norman did eventually implement the plan from Olsson (Olsson).

In 2017, the Lake Thunderbird Watershed Partnership (LTWP) was created by the cities of Oklahoma City, Moore, and Norman with the goal of educating the public about the Lake Thunderbird watershed and ways to help improve the lake through collaborative efforts and community events. The ODEQ required each city in the LTWP to develop compliance and monitoring plans which describe how they will meet requirements to reduce the amount of nitrogen, phosphorus, and sediment in stormwater runoff. These plans include a 5-year schedule of monitoring and other activities to ensure requirements are met (LTWP 2019).

Another project funded in 2018 was undertaken to install floating wetlands in Lake Thunderbird with the intention of reducing shoreline erosion, improving bank stabilization, reducing turbidity caused by erosion, and evaluating wetland prototypes for dissipating wave action (USBR 2019). As recently as this year, a pilot study led by Garver and funded by the BOR hopes to modify Lake Thunderbird into a drought-resilient water supply. This project, the Lake Thunderbird Water Reuse – Field Research Project for Inland Indirect Potable Reuse (IPR), will determine if IPR is feasible at the lake and will help the city expand its current water reclamation and reuse efforts, while also addressing reliability concerns and cutting demand on groundwater supply. The project is scheduled for completion in 2022 (Garver 2020).

Although much has been done to address problems at Lake Thunderbird, continually poor water quality and the rising demand for freshwater for multiple beneficial uses makes it critical to continue working on the future health of the reservoir.

2.2 Scope of Work

Oklahoma does not have many urban federal lakes and has only one urban state park. Lake Thunderbird is unique in that it includes both factors. As a result, remediation of this special recreational area is a worthwhile endeavor with potential impacts on a large number of visitors and the surrounding ecosystem of the lake.

The purpose of this project is to find a solution or a suite of solutions to the Lake Thunderbird water quality impairments through analysis of the existing environmental data sets and identification of potential remedial technologies. Comparisons will be made between watershed-level and in-lake technologies. The final report will include conceptual designs for the appropriate solutions and will be presented to the Central Oklahoma Master Conservancy District (COMCD). In carrying out the project, Enviro-Shield Solutions is committed to avoiding any significant or unnecessary disruption of ecosystems and natural processes.

3 Emergency Contact Information

3.1 Project Team Contact and Emergency Information

Emergency contact information for each team member is provided in Table 1.

Table 1: Emergency Contact Information for Enviro-Shield Solutions Team Members and Advisors

Name	Address	Phone Number	Emergency Contact	Emergency Contact Number
Heath Orcutt	830 W Eufaula St. Norman, OK 73069	(405) 664-1095	Kendra Orcutt	(405) 664-1095
Peter Wolbach	1902 Christie Dr. Midwest City, OK 73110	(405) 819-9451	Morgan Wolfe	(405) 589-8486
Cameo Holland	3301 Warrior Ct. Oklahoma City, OK 73121	(405) 208-2766	Nancy Spivey	(903) 806-8898
Oscar Tavarez	1601 E. Imhoff Rd. Norman, OK	(580) 791-2200	Benard Padilla	(405) 368-2124
Robert Knox	823 S. Flood Norman, OK 73069	(405) 550-2355	Linda Goeringer	(405) 249-8893
Robert Nairn	1629 Wilderness Dr. Norman, OK 73071	(405) 388-8819	Kathryn Amanda Nairn	(405) 664-0989

3.2 Emergency Contact and Facility Directions

Table 2 provides the nearest locations and departments for emergency services if help is needed.

Table 2: Emergency Service Department Information

Name	Address	Phone Number
Little Axe Volunteer Fire Department	17777 S Harrah Rd Newalla, OK 74857	(405) 386-7700
Norman Regional Hospital	901 N Porter Ave Norman, OK 73071	(405) 307-1000
Cornerstone Hospital of Shawnee	1900 Gordon Cooper Shawnee, OK 74801	(405) 395-5800

3.3 Emergency Directions

Figures 1, 2, and 3 provide emergency directions to the Little Axe Fire Department, Norman Regional Hospital, and Cornerstone Hospital in Shawnee, OK, respectively.

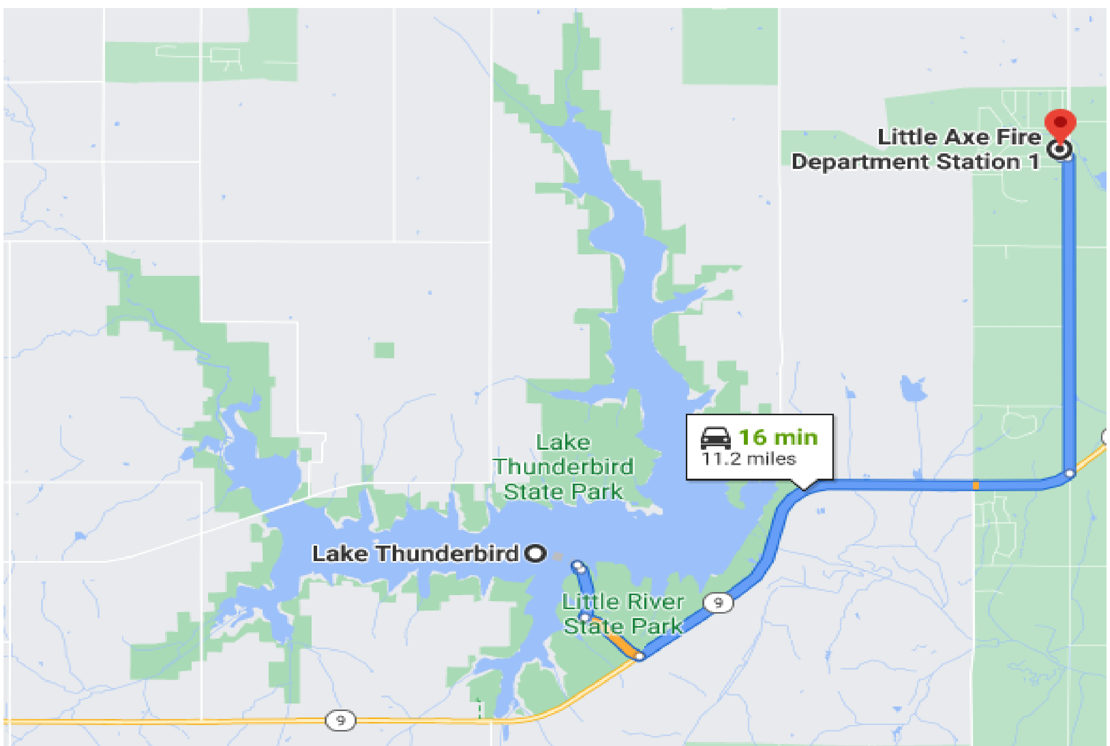

Figure 1: Directions to Little Axe Fire Department

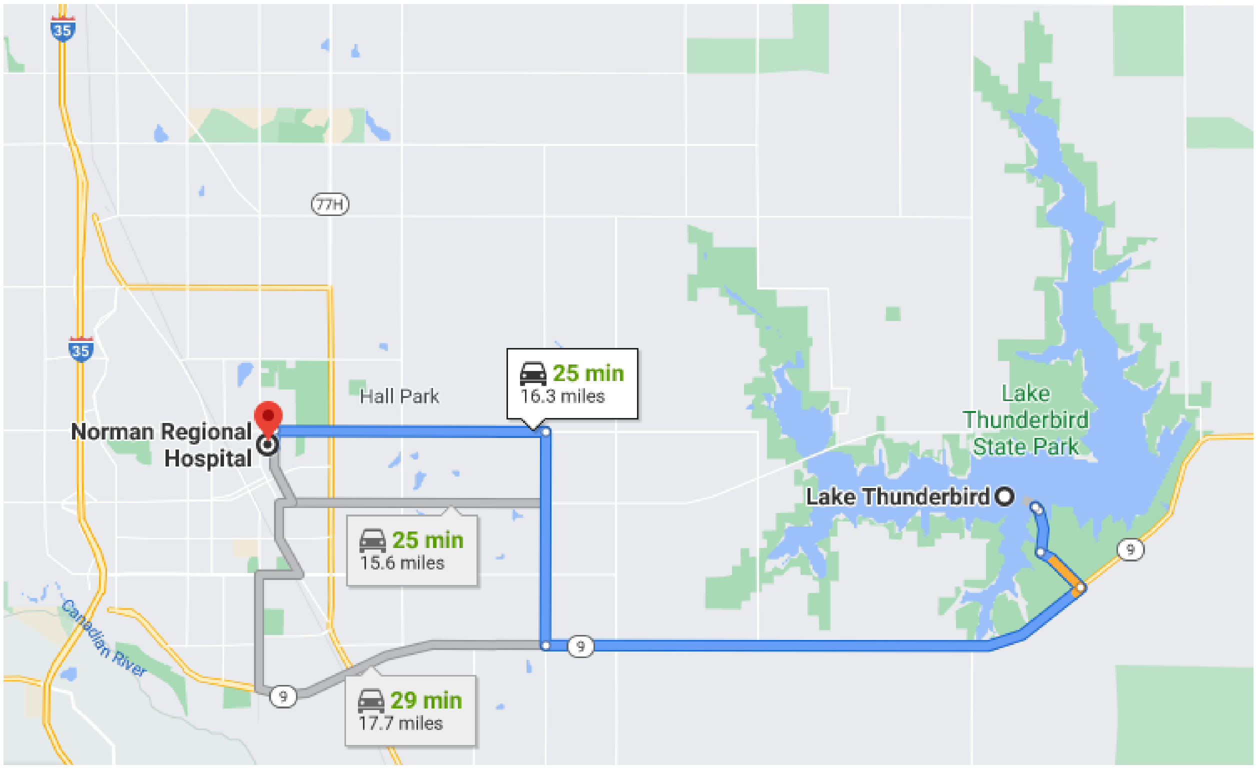

Figure 2: Directions to Norman Regional Hospital

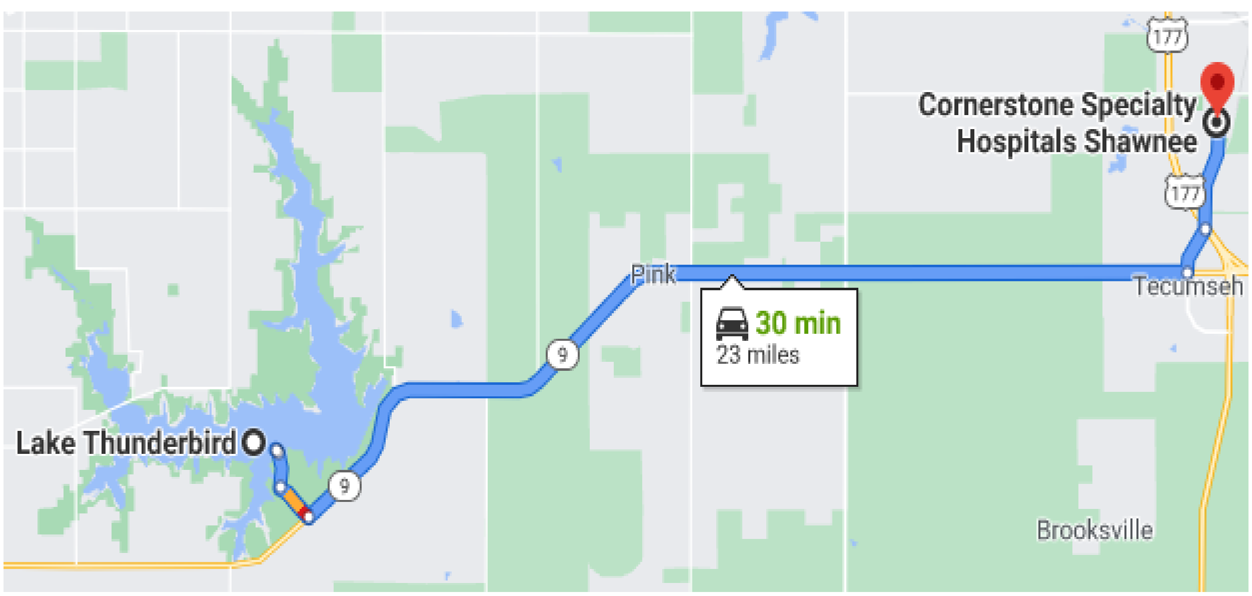

Figure 3: Directions to Cornerstone Hospital in Shawnee

4 Field Hazards

Each team member will follow general housekeeping procedures, including cleaning up after themselves, alerting others to any dangers they notice or encounter, and seeking help in a timely manner for themselves or any other personnel should the need arise. If a threat to their safety should occur, they are responsible for notifying their supervisor. Proper attire will be worn, and only closed-toed shoes will be allowed. A proper "tailgate" meeting will occur at the beginning of any sampling or laboratory work to ensure that all team members are aware of the potential hazards and are equipped with the appropriate PPE.

It is important that team members be able to communicate during sampling events in the case of an emergency. Two-way radios will be used at the site to ensure that communication can occur regardless of phone service.

4.1 General Hazards

4.1.1 COVID-19

Due to the current global pandemic, appropriate social distancing and facial coverings will be required at all times.

4.1.2 Site Visits

Project duties such as sampling and site assessments will be performed during the daytime to avoid any dangers associated with attempting to work onsite in the dark.

4.1.3 Lifting

Some lifting of 10lb or less may be required and proper lifting techniques that prevent weight bearing on the back are expected to be used. Individual limitations are the responsibility of the individual completing the task.

4.2 Weather Hazards

4.2.1 Heat

Extreme heat can cause numerous complications including heat exhaustion, heat stroke, and sunburns. Team members will drink plenty of fluids, take any necessary rest breaks, and stay in shaded areas when necessary. To mitigate the harmful effects of UV radiation, hats, long sleeves, and sunscreen will be required.

4.2.2 Cold

Extreme cold can lead to hypothermia and frostbite. Limited mobility and precipitation induced by very cold temperatures can accelerate these conditions, making it essential for team members to wear warm clothing. Some precipitation events can also lessen overall visibility. Eye protection, warm hats, and gloves will be required.

4.2.3 Wind

High winds can compound most of the hazards previously addressed and must be considered. Winds can also cause movement of debris that could result in damage to the face or eyes. Allergies can also be aggravated by winds by increasing or transporting concentrations of materials that affect some individuals adversely. While working downwind is ideal, it is often not possible. Team members will use face and eye protection and will be responsible for any onsite allergy medication. Before leaving for the site, the HSP leader will be informed of the need or intent to use allergy medication while performing project duties.

4.3 Physical Hazards

4.3.1 Water

Lake depth and flow could be potentially hazardous. Since the majority of samples will need to be collected from the center of the lake, samplers will need to use a boat to reach the location sites. Sampling should occur only when the boat has been anchored. Extra care should be taken when collecting and storing samples in the cooler to maintain an equal distribution of weight in the boat. When samplers are leaning over the side of the boat to collect samples, they should not be standing, and another team member should be holding their feet or legs to prevent them from falling out of the boat. All team members involved in sampling should be experienced swimmers, be wearing a flotation device, and always abide by the buddy system. The buddy system requires 2 team members to stay together while working in or on the water and assist the other in the event of an accident.

4.3.2 Loss of Footing

The worksite contains many potential hazards such as uneven ground, holes, large rocks, and other debris that could facilitate falls, trips, or slips. Team members will be expected to wear appropriate footwear and be as careful as possible.

4.3.3 Plants and Animals

Working in a natural environment allows the opportunity to encounter potentially dangerous plants and animals. Team members should wear long pants and sleeves and close-toed shoes to help avoid any adverse reactions to plants they may come in contact with and also to deter insects.

5 Laboratory Hazards

5.1 Housekeeping

Team members will clean up after themselves and keep their laboratory work areas clean and safe. When appropriate, laboratory equipment will be cleaned with deionized water and then left to dry completely before being put away in the correct storage location. Team members will be careful to keep chemical containers closed when not in use and return the containers to their assigned location.

5.2 Chemicals

Proper laboratory attire and PPE will be required, including close-toed shoes, long pants, goggles, and laboratory coats. Before using any chemicals in the laboratory, team members will review the procedure and any associated hazards with the chemicals required for the procedure. In the event of a chemical spill, a supervisor will be notified. Safety Data Sheets (SDS) for all chemicals used in the laboratory will be available and cleanup will be handled according to guidelines provided in the SDS.

5.3 Glassware

Laboratory equipment made of glass can become hazardous if it is chipped or broken. Team members will be careful not to expose glassware to unnecessarily extreme temperatures or pressures and to take care when handling the items. If any glass is broken, it will be cleaned up immediately and a supervisor will be notified.

6 Personal Protective Equipment (PPE)

6.1 COVID-19

Appropriate use of social distancing and PPE will be required at all times due to the current global pandemic.

6.2 Field Work

Team members will wear long pants and closed-toed shoes when doing any fieldwork. Overall attire should be comfortable, safe, and suited for whatever the current weather conditions at the site may be. Jackets, coats, hats, and gloves are examples of potentially necessary seasonal accessories. Nitrile gloves will be provided to team members performing sampling procedures. Life jackets will also be provided to any team member performing duties in or on the water.

6.3 Laboratory

Team members will wear long pants and closed-toed shoes when working in the laboratory. Additional PPE including gloves, eye protection, laboratory coats and face shields will be provided when necessary.

7 Safety Documents

7.1 Personnel Contact Information

Contact information for every member of Enviro-Shield Solutions and the project managers is listed in Table 3.

Table 3: Personnel information for Enviro-Shield Solutions members and advisors

Name	Position	Email Address	Phone Number
Dr. Robert Knox	Project Advisor	rknox@ou.edu	(405) 550-2355
Dr. Robert Nairn	Project Advisor	nairn@ou.edu	(405) 888-3812
Heath Orcutt	Team Leader	heathorcutt@ou.edu	(405) 664-1095
Peter Wolbach	Quality Assurance	peter.j.wolbach-1@ou.edu	(405) 589-8486
Cameo Holland	Health & Safety	cameo.j.holland-1@ou.edu	(405) 208-2766
Oscar Tavarez	Water Quality	oscartavarez1017@ou.edu	(405) 368-2124

Team Member Signatures:

Name *Date*

Name *Date*

Name *Date*

Name *Date*

8 References

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ENVIRO-SHIELD
SOLUTIONS

Sampling and Analysis Plan

Evaluation of Watershed-Level and In-Lake Options to Improve Lake Thunderbird Water Quality

Prepared by

Enviro-Shield Solutions

Prepared for

Central Oklahoma Master Conservancy District (COMCD)

April 30, 2021

Table of Contents

1 Background

Lake Thunderbird is a manmade reservoir which serves as the primary drinking water supply for Del City, Midwest City, and the City of Norman. Located in south-central Oklahoma in Cleveland County, the lake is part of the Cross Timbers Ecoregion. It has a surface area of 5,439 acres and a capacity of 105,838-acre feet (OWRB, 2020). The lake is host to numerous recreational activities such as camping, boating, jet skiing, fishing, hiking, and more. Due to water quality concerns, monitoring of the water quality standards in Lake Thunderbird gained attention and observations confirm that the lake does not meet the criteria for turbidity, chlorophyll-a and Dissolved Oxygen, while high levels of nutrients continue to drive algal growth. The city of Norman had previously installed a Suppressed Dissolved Oxygen System (SDOX) system to address the water quality concerns in 2011, but the system was ineffective. (OWRB,2020).

2 Objective

The water quality issues at Lake Thunderbird need to be addressed and a solution must be developed. In order to develop a solution, the water quality of Lake Thunderbird must be fully assessed. Testing will be conducted to determine total phosphorous and nitrogen, turbidity, chlorophyll-a, total hardness, alkalinity, and dissolved oxygen concentrations at multiple locations (zones) in the lake. Data provided by OWRB will also be incorporated. This will allow Enviro-Shield Solutions to identify potential loading points in the lake, determine which parts of the lake need the most attention through the year, and allow our team to develop an adequate solution. Other chemical parameters of the lake will be recorded, such as pH, temperature, and specific conductivity.

3 Sampling Plan

3.1 Sampling Area Description

Lake Thunderbird has a surface area of 5,439 acres and a volume of 105,838 acre-ft. The major tributaries interacting with the lake are the Little River connecting from the west side and Hog Creek which connects from the north side. The lake has a lacustrine region which is the deepest part of the lake at a depth of 58 feet, along with several riverine regions. The average depth of the lake is estimated to be 15.4 feet and is surrounded by light vegetation. Figure 1 shows an aerial image of the lake (OWRB, 2020).

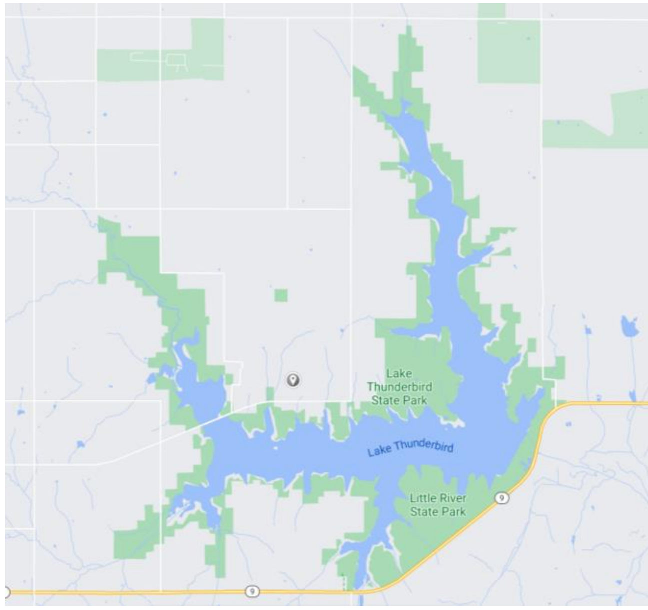

Figure 1: Arial view of Lake Thunderbird (Image courtesy of Google Maps).

3.2 Stratification Patterns

Typical thermal stratification patterns in the lake consist of complete stratification occurring in May (summer) and mixing occurring in October (fall). The Oklahoma Water Resources Board (OWRB) reported that the hypolimnion experiences anoxic conditions in the summer season and that the metalimnion experiences anoxic conditions from July to September (OWRB, 2020).

3.3 Sampling Rationale

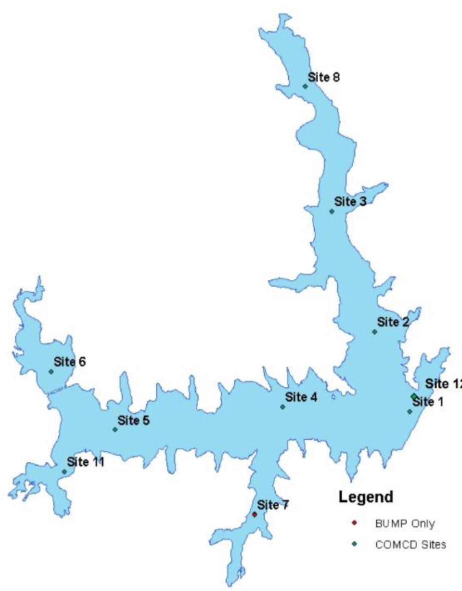

Figure 2: Sampling locations (Image courtesy of OWRB).

Taking into consideration the thermal stratification patterns of the lake reported by the OWRB, sampling would ideally occur between April and September during the complete stratification period (EPA 2010). For the purpose of time, Enviro-Shield Solutions will conduct sampling and analysis in the month of March. As shown in Figure 2, the OWRB identified the most promising and relevant sampling locations on the lake, in order to get a full understanding of the lake's water quality and allow for determination of potential loading zones (OWRB 2020). The riverine regions of the lake are located at the mouth of the tributaries and are represented by Sites 6, 8 and 11. Site 8 is where Hog Creek connects, Site 6 is where the Little River connects, and Site 11 is where Jim Blue Creek and Dave Blue Creek connect to the lake. The riverine regions have been determined to have a greater nutrient concentration in the summer, leading to external nutrient loading from runoff into the lake. The lacustrine regions of the lake are represented by Sites 1, 2, and 4. Since these regions are open water zones, they have consistent stratification in the summer and serve as good monitoring sites. The transition zones between the lacustrine zone and the riverine zones are represented by Sites 3 and 5. For this project, we have decided to sample Sites 6, 5, 4, 1 and 3 (if time permits) to cover a variety of riverine, lacustrine, and transition sites. To get an idea of the stratification of the lake, we will take three readings at different depths with the YSI at Site 1. We will conduct a one-time sampling event and will use a combination of the obtained data and data provided by the OWRB for a complete analysis of Lake Thunderbird water quality.

3.4 Sampling Strategy

3.4.1 Surface Water Sampling

3.4.1.1 Sampling Schedule

The samples will be collected in March. We will begin collecting samples early in the morning and will continue through the day until complete. We will be performing a one-time analysis of the parameters previously listed and will compare with data provided by the OWRB.

3.4.1.2 Sampling Procedures

All sampling methods and equipment selected are in accordance with the EPA's Operating Procedures for sampling surface water bodies (US EPA 2016). The sampling methods used will be the "*Dipping Using Sample Container"* (for the shallow riverine zones), and "*Discrete Depth Sampler"* (for deep zones). Below are descriptions and procedures of the sampling methods provided by the EPA.

"Dipping Using Sample Container Method"

Sample is to be collected directly with container, when surface water source is accessible by wading or other methods. EPA states that the sampler should face upstream if there is a current and collect the sample without disturbing the bottom sediment. This is the ideal testing methods for shallow riverine zones since it is the cheapest, but since the average water depth of the lake is 15.4 feet, this method will likely not be used but will be an option if depth permits (US EPA 2016).

“Discrete Depth Sampler”

When discrete samples are desired from a specific depth, and the parameters to be measured do not require a Teflon®-coated sampler, a standard Kemmerer or Van Dorn sampler may be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the ends of the sampler open while being lowered in a vertical position, thus allowing free passage of water through the cylinder. The Van Dorn sampler is plastic and is lowered in a horizontal position. In each case, a messenger is sent down a rope when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill respective sample containers. With a rubber tube attached to the valve, dissolved oxygen sample bottles can be properly filled by allowing an overflow of the water being collected. With multiple depth samples, care should be taken not to disturb the bottom sediment, thus biasing the sample (US EPA 2016).

3.4.2 Sampling Equipment

Table 1 illustrates the equipment needed for the water sampling and analysis (reagents for analytical analysis are not included).

Table 1: Sampling equipment for March sampling event

Method	Equipment Needed
Buckets and Dripping	5- gal bucket, 25 ft Rope
Scoops	Steel scoops with bar
Discrete Depth Sampler	Discrete depth sampler
N/A	Plastic Sampling Containers
In-situ analysis	YSI probe
Deep water	Sechi disk
Alkalinity	Titration Kit
Hardness	Titration Kit
Turbidity	Turbidimeter

YSI probe procedure

The YSI probe is a portable instrument that measures multiple critical water quality parameters. The YSI probe will be used to record the dissolved oxygen, turbidity, pH, oxygen redox potential, specific conductivity, total dissolved solids, total suspended solids, temperature, and chloride. We will take three separate measures at different depths, to get an idea of regional stratification. To obtain the most accurate readings, it is important that the instrument is calibrated before taking measurements and the manufacturer's procedures are followed.

Alkalinity and Hardness

We will follow instructions provided by manufacturers of titration kits to determine total hardness and alkalinity. These will be performed separately with separate kits.

Turbidity

The turbidimeter will be calibrated prior to use, and instructions provided by the manufacturer will be used.

Secchi Disk

A Secchi disk will be used to measure the transparency or turbidity of the deep water. A Secchi disk is a white, circular disk twelve inches in diameter. The disc is mounted on a pole or line and lowered slowly down in the water. It will be lowered from the boat. Observations should be made during mid-day, without sunglasses and from the shady side of the boat. The observer makes the reading by looking as close as possible to the water to minimize glare. Drop the Secchi disk down until it is no longer visible. Bring the Secchi disk up until you can just barely see it. Record the depth at which the Secchi disk is again visible. Repeat the above procedure and average the two readings for the final Secchi disk depth. We will take two measurements at every site.

Phosphorous and Nitrogen

To measure total phosphorus in the water, we will be using HACH TNT843-Method 10209/10210 and DR3800 spectrophotometer. To measure total nitrogen, we will use HACH TNT826-Method 10208 and a DR3800 spectrophotometer.

3.4.3 Sample Labeling and Duplicates

Samples collected will be clearly labeled on the outside and will be given their own specific identification number with the prefix “LTB”. The label will contain the name of the lake, the specific sampling site, and the time and date of sampling. The label will also contain the name of the individuals collecting the sample, along with the method used to collect the sample. The label will also contain the main analytical parameters of interest. A duplicate will be taken every 10 samples collected. Three measurements will be taken with the YSI at different depths at the first location and one at every other site. Three samples will be taken for alkalinity, three for turbidity, and three for hardness.

3.4.4 Transport and Storage

The samples that need to go to the lab will be placed and stored in sealed coolers, with clear labeling. The coolers will be transported to Carson Engineering Center, where they will be stored until analyzed.

3.4.5 Equipment Decontamination Procedure

Since this water analysis focuses on identifying classical parameter such as nutrients, dissolved oxygen, alkalinity, and hardness the water sampling equipment will be rinsed out with deionized water between sampling zones. This complies with the US EPA 2020 methods.

The geographic location of each sample site will be recorded. A handheld GPS device will be used, and longitude and latitude coordinates will be called out and recorded in real time on a field notebook.

4 Analytical Approach

4.1. Specified Parameters

Table 2 shows the parameters of interest for the samples collected.

Table 2: Parameters to be recorded in March sampling event

Parameters	
Chlorophyll-a (YSI)	DO (YSI)
Nitrogen as NO_2 (lab)	Temperature (YSI)
Ammonia as NH_3 (YSI)	pH (YSI)
Nitrate as NO_3 (YSI)	Oxidation Reduction Potential (YSI)
Harness (kit)	Air Temperature
Turbidity (turbidimeter) TSS (YSI), TDS (lab)	Cloud Cover
Total Phosphorus (lab)	Precipitation
Alkalinity (kit)	BOD/COD (lab)

4.2 Containers, Preservatives and Holding Times

Table 3 lists the volume of the sample to be collected, the container material, preservative requirements, and the maximum holding time for water quality samples.

Table 3: Containers, holding times, and volumes to be collected for analysis of particular parameters

Analytical Parameter	Sample Volume (mL)	Containers	Preservative Requirements (preservative. temp)	Max Holding Time
TOC	300	plastic	H_2SO_4 to pH<2	5 months
Total Phosphorus	500	plastic	4° C	7 days
Nitrogen as NO_2	150	plastic	H_2SO_4 to pH <2	24 hours
Nitrate (NO_3)	150	plastic	H_2SO_4 to pH <2	24 hours
Ammonia as NH_3	150	plastic	H_2SO_4 to pH <2	24 hours
TSS	100	plastic	4° C	7 days
TDS	100	plastic	4° C	7 days
BOD	500	plastic	4° C	6 hours
COD	300	Plastic	H_2SO_4 to pH <2	7 days

4.3 Special Precautions and Considerations

The following are precautions provided by the EPA to be considered when collecting water samples (US EPA 2016).

- Special care must be taken not to contaminate samples. This includes storing samples in a secure location to preclude conditions which could alter the properties of the sample. Samples shall be custody sealed during long-term storage or shipment.
- Collected samples are in the custody of the sampler or sample custodian until the samples are relinquished to another party.
- If samples are transported by the sampler, they will remain under his/her custody or be secured until they are relinquished.
- Shipped samples shall conform to all U.S. Department of Transportation (DOT) rules of shipment found in Title 49 of the Code of Federal Regulations (49 CFR parts 171 to 179), and/or International Air Transportation Association (IATA) hazardous materials shipping requirements found in the current edition of IATA's Dangerous Goods Regulations.
- Documentation of field sampling is done in a bound logbook.
- Chain-of-custody documents shall be filled out and remain with the samples until custody is relinquished.
- All shipping documents, such as air bills, bills of lading, etc., shall be retained by the project leader and stored in a secure place.

4.4 Disposal of Residual Material

The following are procedures listed under US EPA 2020, for investigation of derived wastes. Table 4 outlines the proper disposal procedures for the generated waste.

Types of Investigation Derived Waste:

- Personal protective equipment (PPE) - This includes disposable coveralls, gloves, booties, respirator canisters, splash suits, etc.
- Disposable equipment and items - This includes plastic ground and equipment covers, aluminum foil, conduit pipe, composite liquid waste samplers (COLIWASAs), Teflon® tubing, broken or unused sample containers, sample container boxes, tape, etc.

Table 4: Disposal procedure of IDW outlined in the US EPA Operating Procedure: Management of Investigation Derived Waste

TYPE	HAZARDOUS	NON - HAZARDOUS
PPE-Disposable	Containerize in plastic 5-gallon bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise return to FEC for proper disposal	Place waste in trash bag. Place in dumpster with permission of site operator, otherwise return to FEC for disposal in dumpster.

PPE-Reusable	Decontaminate as per SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, if possible. If the equipment cannot be decontaminated, containerize in plastic 5-gallon bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise return to FEC for proper disposal	Decontaminate as per SESDPROC-205, and return to FEC.
Spent Solvents	Containerize in original containers. Clearly identify contents. Leave on-site with permission of site operator and arrange for proper disposal.	N/A
Disposable Equipment	Containerize in DOT-approved container or 5-gallon plastic bucket with tightfitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with program site manager for testing and disposal.	Containerize in an appropriate container with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with program site manager for testing and disposal. If unfeasible, return to FEC for disposal in dumpster.
Trash	N/A	Place waste in trash bag. Place in dumpster with permission of site operator, otherwise return to FEC for disposal in dumpster.

*** These materials may be placed on the ground if doing so will not endanger human health or the environment or violate federal or state regulations (US EPA 2020).*

4.5 Sample Analysis

The collected samples will be transported to the laboratory in the Carson Engineering building for chemical analysis. The following are analysis parameters.

The following parameters will be measured in-situ using the YSI probe: conductivity, specific conductance, total dissolved solids (TDS), pH, ORP, pH/ORP combination, ammonium (ammonia), nitrate as NO_3, nitrogen as NO_2, chloride, temperature, chlorophyll-a, and dissolved oxygen (YSI 2019).

A discrete depth finder will be used to measure the depth of the lake.

To measure total phosphorus in the water, we will be using HACH TNT843-Method 10209/10210 and DR3800 spectrophotometer. To measure total nitrogen, we will use HACH TNT826-Method 10208 and a DR3800 spectrophotometer.

5 Quality Assurance and Control

To ensure the quality of the data collected and minimize potential error, duplicate samples will be collected at every site. Field equipment will also be rinsed between sample collections and containers will be cleaned and sealed. We will take three measurements at different depths using the YSI at the first location to get an idea of local stratification, and one measurement at the other sites. Three samples will be collected at each site for the hardness test, three for the turbidimeter, and three will be collected for the alkalinity test separately. We will also take a duplicate sample every 10 samples collected. Data provided by the OWRB will be incorporated into our analysis to ensure the accuracy of our results. Several statistical methods to quantify data will be used such as t-distribution and relative error. This will allow us to find inconsistencies in our data and remove outliers, so that we may present our data with confidence.

6 References

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ENVIRO-SHIELD
SOLUTIONS

Quality Assurance Project Plan

Evaluation of Watershed-Level and In-Lake Options to Improve Lake Thunderbird Water Quality

Prepared by

Enviro-Shield Solutions

Prepared for

Central Oklahoma Master Conservancy District (COMCD)

April 30, 2021

Table of Contents

1 Project Management

1.1 Approval Signatures and Distribution List

The contents of this document are to be approved by the individuals with a signature line below. Regardless of the approval status of this document, a live copy may be distributed to any of the individuals listed in Table 1.

Table 1: Distribution list for Enviro-Shield Solutions members and advisors

Name	Position	Contact Information
Robert Knox	Project Advisor	rknox@ou.edu
Robert Nairn	Project Advisor	nairn@ou.edu
Heath Orcutt	Team Leader	heathorcutt@ou.edu
Cameo Holland	Health and Safety Specialist	Cameo.J.Holland-1@ou.edu
Oscar Tavarez	Water Quality Specialist	oscartavarez1017@ou.edu
Peter Wolbach	Quality Assurance Specialist	peter.j.wolbach-1@ou.edu

____ Date: ___________________

Robert C. Knox, Ph.D., P.E. (Project Advisor)

____ Date: ___________________

Robert W. Nairn, Ph.D. (Project Advisor)

____ Date: ___________________

Heath Orcutt (Team 3 Leader)

1.2 Project Organization

Heath Orcutt – Team Leader

As shown in Figure 1, Heath acts as the chief editor for all documentation, as well as the head of communications and planning. While serving as the head of communications and planning, Heath communicates with advisors and students to produce a comprehensive Project Work Plan (PWP). Heath also serves in the roles of a water quality technician for sampling/analysis, as well as the sustainability lead for choosing in-lake technologies. and as the team leader of Enviro-Shield Solutions, Heath is responsible for the final submission of documents to project advisors, Dr. Knox and Dr. Nairn.

Cameo Holland – Health and Safety Expert

In this project, Cameo is responsible for the health and safety of team members during laboratory and field work. In addition to this responsibility, Cameo also serves as a data analyst and presentation developer for Enviro-Shield Solutions. In addition to health and safety responsibilities, Cameo is responsible for the operation and maintenance guidelines for in-lake technologies and watershed best management practices (BMPs). Cameo is in charge of development of the Health and Safety Plan (HSP)

Oscar Tavarez – Water Quality Expert

Oscar is responsible for developing the sampling and analysis plan (SAP) that not only coincides with the EPA's guidelines, but also considers how Oklahoma's climatic effects on the thermal stratification of Lake Thunderbird's water would affect sampling in the spring of 2021. Oscar and Heath are Enviro-Shield Solutions water quality technicians, and Oscar is also responsible for the cost estimates that accompanies implementing new in-lake technologies and their maintenance.

Peter Wolbach – Quality Assurance Expert

Peter is responsible for ensuring any field sampling procedures and laboratory analyses are executed within project guidelines. This includes compiling the results from field and laboratory work, as well as compiling documentation for Heath to review and/or submit. Peter will be focused on development of the Quality Assurance Project Plan (QAPP), as well as ensuring the project adheres to the guidelines in this document. Other responsibilities include sediment data analysis and graphic design for documents and presentations.

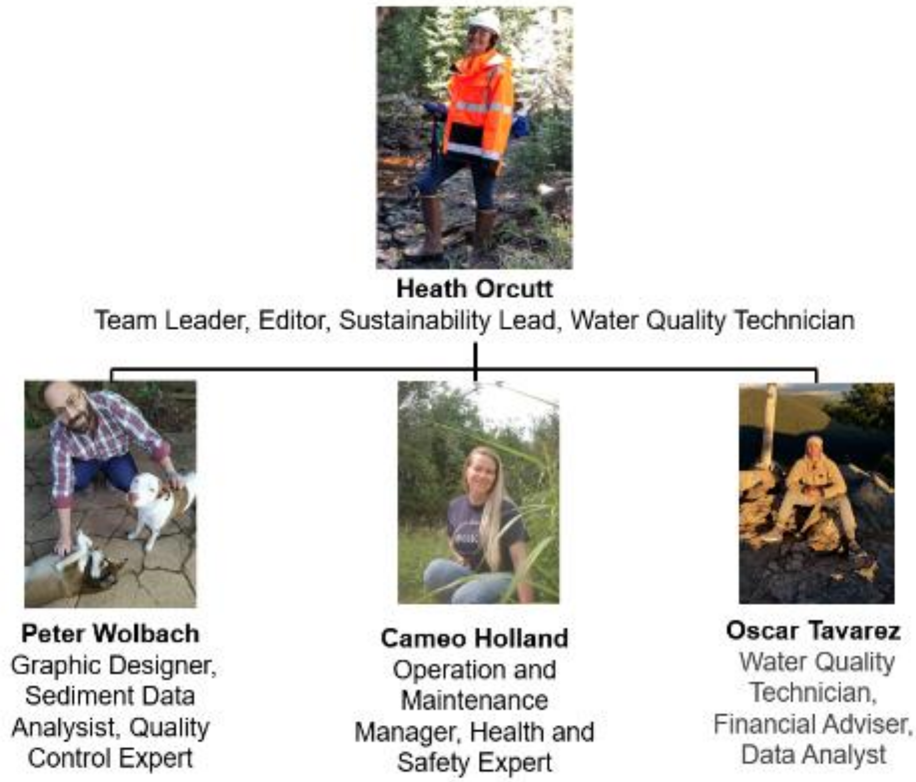

Figure 1. Enviro-Shield Solutions Team Roles

1.3 Project Background

Lake Thunderbird is located in south-central Oklahoma in the Cross Timbers Ecoregion where it serves as a water supply reservoir for Norman, Del City, and Midwest City (OWRB 2019). Figure 2 shows all of the municipalities that lie in the Lake Thunderbird watershed. The lake covers approximately 2456-hectares, with mean and maximum depths of 6 and 18 m (20 and 58 feet), respectively (USACE 2020). The reservoir was originally conceived to meet the needs of the growing population following the opening of Oklahoma Indian Territory to settlement, the discovery of oil, and the development of farming operations. The Army Corps of Engineers first evaluated the potential of development on the Little River in 1936 (Simonds 1999). It was determined that the Little River did not have the sufficient water supply to meet the demands of the community; however, after many investigations, a plan for the construction of a reservoir to meet the needs of Midwest City, Del City, Moore, Tinker Air Force Base, and Norman was released in 1954. Construction began in 1962 and potable water arrived at homes by February 1966 (Simonds 1999). Since then, the Central Oklahoma Master Conservancy District (COMCD) has been responsible for operation and maintenance of the reservoir.

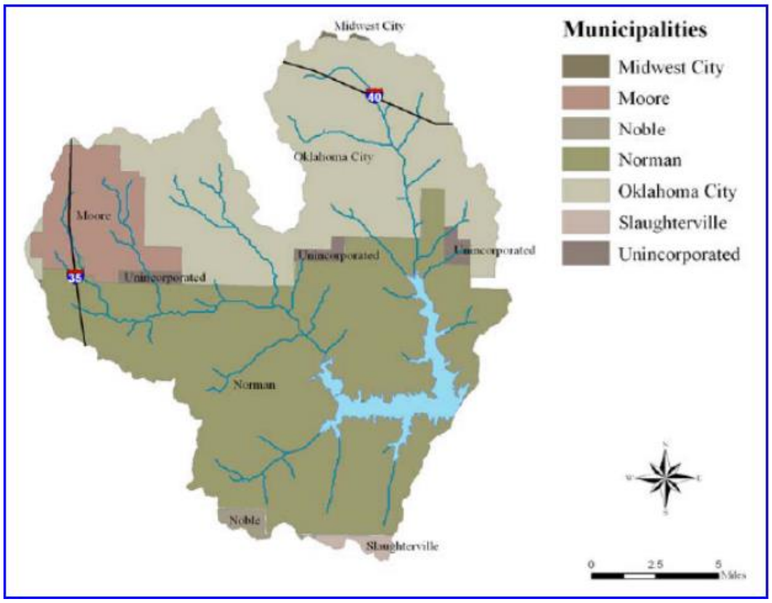

Figure 2: Municipalities in Lake Thunderbird Watershed

Lake Thunderbird also provides flood control for the surrounding region. In addition, members of the community are invited to enjoy the large state park which offers birdwatching, hiking and biking trails, the two swimming beaches, and the nature center. The lake has two marinas and is open to boating, fishing, kayaking, and jet skiing. In conclusion, Lake Thunderbird is of the upmost importance as a reliable and safe drinking water source.

1.4 Current Status

The Oklahoma Water Resources Board (OWRB) has extensive data showing the long history of water quality issues in Lake Thunderbird. Primarily, the lake is subject to excessive nutrient loading from the surrounding watershed, leading to problems such as eutrophication. This leads to significant taste and odor issues which have been documented by complaints from community members (OCC 2010). In addition, Lake Thunderbird is included on the State of Oklahoma List of Impaired Waters due to its inability to meet public/private water supply and warm water aquatic community beneficial uses (DEQ 2018). In 2013, the Oklahoma Department of Environmental Quality (DEQ) responded by establishing a Total Maximum Daily Load (TMDL) for total nitrogen, total phosphorus, carbonaceous biological oxygen demand, and total suspended solids. However, DEQ did not stipulate specific regulatory controls or management practices necessary to reduce nutrients within the watershed. The ultimate recommendation was that watershed-specific controls and best management practices be chosen and put in use through a process involving all stakeholders (BOR 2019).

In an effort to improve water quality and quantity at Lake Thunderbird, many projects and studies have been conducted. For example, in 2009, the Oklahoma Tourism and Recreation Department and Bureau of Reclamation (BOR) worked with Oklahoma State University on a Resource Management Plan for Lake Thunderbird and the Norman Project (BOR 2009). In 2012, the BOR awarded the Central Oklahoma Master Conservancy District (COMCD) a grant for the “COMCD Lake Thunderbird Water Reuse Feasibility

Study", which identified the need for additions to the raw water supply in Lake Thunderbird with highly treated municipal reuse water (BOR 2012). After the DEQ completed a TMDL study and report on Lake Thunderbird in 2013, the City of Norman hired Olsson Engineering to create a compliance and monitoring plan that would reduce the amount of pollutants discharged into the lake. The idea was to slow the rate of pollutants going into the lake so that it could begin to self-regulate. The City of Norman did eventually implement the plan from Olsson (Olsson).

In 2017, the Lake Thunderbird Watershed Partnership (LTWP) was created by the cities of Oklahoma City, Moore, and Norman, with the goal of educating the public about the Lake Thunderbird watershed (Figure 3) and ways to help improve the lake through collaborative efforts and community events. The DEQ required each city in the LTWP to develop compliance and monitoring plans which describe how they will meet requirements to reduce the amount of nitrogen, phosphorus, and sediment in stormwater runoff. These plans include a 5-year schedule of monitoring and other activities to ensure requirements are met (LTWP 2019).

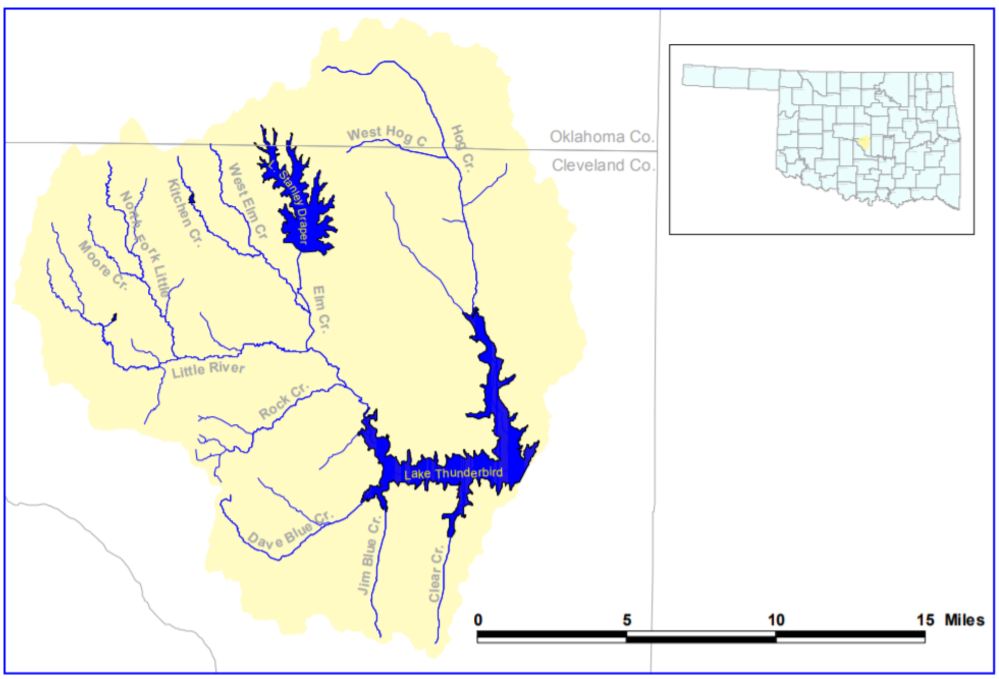

Figure 3: Lake Thunderbird watershed (OCC 2010)

Another project funded in 2018 was undertaken to install floating wetlands in Lake Thunderbird with the intention of reducing shoreline erosion, improving bank stabilization, reducing turbidity caused by erosion, and evaluating wetland prototypes for dissipating wave action (BOR 2019). As recently as 2020, a pilot study led by Garver and funded by the BOR hopes to modify Lake Thunderbird into a drought-resilient water supply. This project, the Lake Thunderbird Water Reuse – Field Research Project for Inland Indirect Potable Reuse (IPR), will determine if IPR is feasible at the lake and will help the city expand its current water reclamation and reuse efforts, while also addressing reliability concerns and cutting demand on groundwater supply. The project is scheduled for completion in 2022 (Garver 2020).

Although much has been done to address problems at Lake Thunderbird, continually poor water quality and the rising demand for freshwater for multiple beneficial uses makes it critical to continue working on the future health of the reservoir.

1.5 Project Description

The scope of the work to be performed is divided into five major tasks. An important note in this QAPP is that the environmental sampling data has already been collected by the COMCD (Central Oklahoma Master Conservancy District) over the course of twenty years.

1) ***Evaluating existing environmental data sets*** **– Complete by February 1, 2021**
   a) While twenty years of environmental datasets are provided by the COMCD, the Oklahoma Water Resources Board (OWRB) was the party contracted and responsible for executing the sampling for different parameters across many areas of Lake Thunderbird. For this reason, information from the data generation portion of the QA project plan is taken from the available information from OWRB sampling and procedures.

2) ***Assessment of technologies to address identified problems*****. Complete by February 5, 2021**
   a) Evaluation and assessment of site-specific information from the data-sets provided by the COMCD.
   b) Assessment of state-of-the-art technologies and their applicability to the site-specific information of Lake Thunderbird.

3) ***Direct Comparison of watershed-level vs. in-lake technologies*****. Complete by March 11, 2021**
   a) Retroactive evaluation of both, in-lake technologies and land use (BMPs).
   b) Direct comparison of targeted watershed BMPs against intensive in-situ technology options. A list of viable solutions for in-situ technologies and watershed BMPs is chosen based on the information listed below.
      i) Cost analysis
      ii) Implementation
      iii) Environmental Impact

4) ***Primary recommendation of preferred solution(s).*** **Complete by March 11, 2021**
   a) Includes methodology ascribed to the final recommended solutions

5) ***Provision of conceptual designs for selected solutions.*** **Complete by March 18, 2021**
   a) Includes conceptual models, designs, and diagrams of preferred solution(s).

1.6 Quality Objectives and Criteria for Data Measurement

1.6.1 Primary Objectives

In general terms, the quality objective of this project is to supply the COMCD with viable solutions to address Lake Thunderbird water quality concerns. If the COMCD does not choose any of the solutions proposed, then criteria used to determine the recommended solutions retain value as the basis for third-party analysis of the provided datasets. The analysis provided from this project could be used in a future analytical triage to determine solutions that may become viable in the future.

1.6.2 Action Limits/Levels

Regulatory Standards and Goals

The causes of impairment are attributed to turbidity, increased levels of chlorophyll-a, and low dissolved oxygen. In analysis, values for these parameters are compared to the Total Maximum Daily Loads (TMDL) specified in the Clean Water Act (Copeland 2016). A secondary comparison is used for comparing the parameter TMDL from the Clean Water Act against the TMDL targets set by Oklahoma Department of Environmental Quality.

Data Quality Needs

Quantitative

- Precision – To ensure the data from sampling and analysis tools represent the sites with greater precision, the following general measures will be taken.
  - Field blanks – A 500 ml or 1 L jar willl be taken at each sampling site.
  - Field duplicates – every ten samples, a duplicate field sample will be taken.
  - Secchi disk – When water depth of a site allows for a secchi disk reading, two readings will be taken with the results averaged.

- Accuracy – Due to the eutrophic nature of Lake Thunderbird, the quantitative measure of what is present in the sample changes over time. Therefore, noting the climatic and seasonal conditions are paramount in analysis.

Qualitative

- Comparability– The proposed solutions need to be at least as effective as the technologies in place. Therefore, the data from measurements after implementing a solution need to be obtained using the same procedures and sites initially used by the OWRB.

1.7 Project Schedule

This project officially started in September of 2020 and is scheduled to be completed by May of 2021. There are two large phases of the project that are divided into the Fall of 2020 and Spring of 2021. The

Fall project timeline begins with a literature review and ends with submission of the final project documents that include the PWP, HSP, SAP, and QAPP. Figure 4 provides a more detailed description of the fall phase timeline. The spring phase of the project is detailed in Figure 5.

Precapstone Team 3 Gantt Chart

Enviro-Shield Solutions

FALL 2020

Project Start: Tue, 9/8/2020

Today:

Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Precapstone Project				
Preliminary Literature Review Sources	ALL	100%	9/8/2020	9/17/2020
5 Literature Review Sources	ALL	100%	9/8/2020	9/22/2020
Literature Review - Draft	ALL	100%	9/22/2020	11/3/2020
Literature Review - Water Quality	OT	100%	9/8/2020	11/3/2020
Literature Review - Regulatory Drivers and Community Issues	HO	100%	9/8/2020	11/3/2020
Literature Review - Watershed BMP	AP, PW	100%	9/8/2020	11/3/2020
Literature Review - Improvement Technologies	CH	100%	9/8/2020	11/3/2020
Draft - Health and Safety Plan	CH	100%	9/22/2020	11/3/2020
Draft - Sampling and Analysis Plan	OT	100%	9/22/2020	11/3/2020
Draft - Quality Assurance Plan	AP, PW	100%	9/22/2020	11/3/2020
Draft - Project Work Plan	TBD	100%	9/22/2020	11/3/2020
2/3 Completion Meeting - More Drafting Time or Final Review Decisions	ALL	100%	10/20/2020	10/20/2020
Finalizing Draft	ALL	100%	10/20/2020	11/3/2020
Final Draft Review	ALL	75%	11/3/2020	11/9/2020

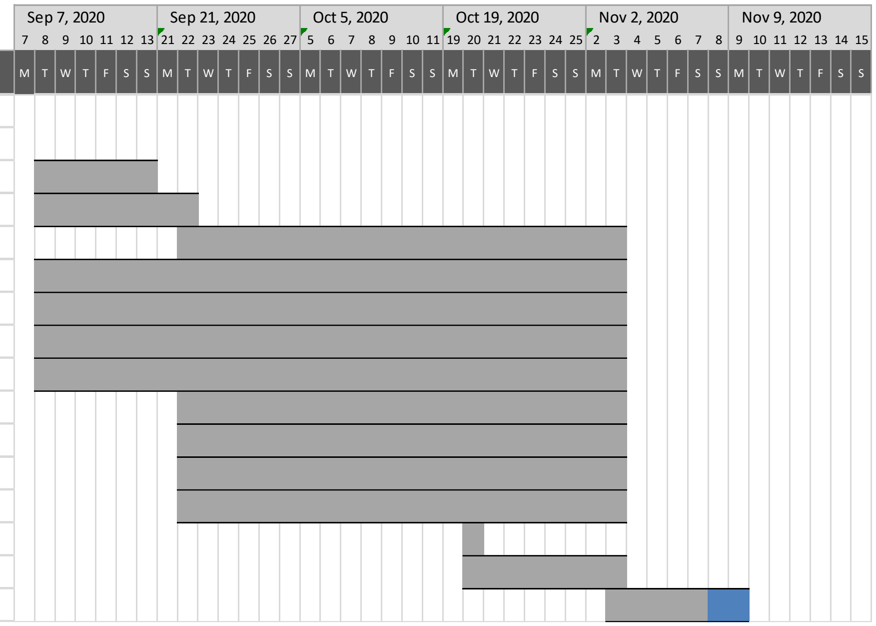

Figure 4. Fall Phase Timeline for Enviro-Shield Solutions

Precapstone Team 3 Gantt Chart

Enviro-Shield Solutions

SPRING 2021

Project Start: Wed, 1/20/2021

Today:

Display Week: 1-Jan

TASK	ASSIGNED TO	PROGRESS	START	END
Precapstone Project				
Project Document Feedback			2/21/2021	2/21/2021
Prepare for revised document turnin: SAP, HSP, QAPP, WP	ALL	100%	2/22/2021	2/22/2021
Evaluating - Existing environmental data (TENTATIVE START DATE)	ALL	0%	2/25/2021	3/20/2021
Topical Reports	ALL	100%	1/19/2021	2/18/2021
Peer evaluations due	ALL	100%	2/23/2021	2/23/2021
33% Written report due	ALL	15%	3/4/2021	3/4/2021
Peer evaluations due	ALL	0%	3/4/2021	3/4/2021
66% - Written report due	ALL	0%	3/25/2021	3/25/2021
66% - Oral report due	ALL	0%	3/25/2021	3/25/2021
Peer evaluations due	ALL	0%	3/25/2021	3/25/2021
100% - Oral presentation due	ALL	0%	4/15/2021	4/15/2021
100% - Final written report due	ALL	0%	4/27/2021	4/27/2021
Final oral presentations to COMCD	ALL	0%	5/4/2021	5/4/2021

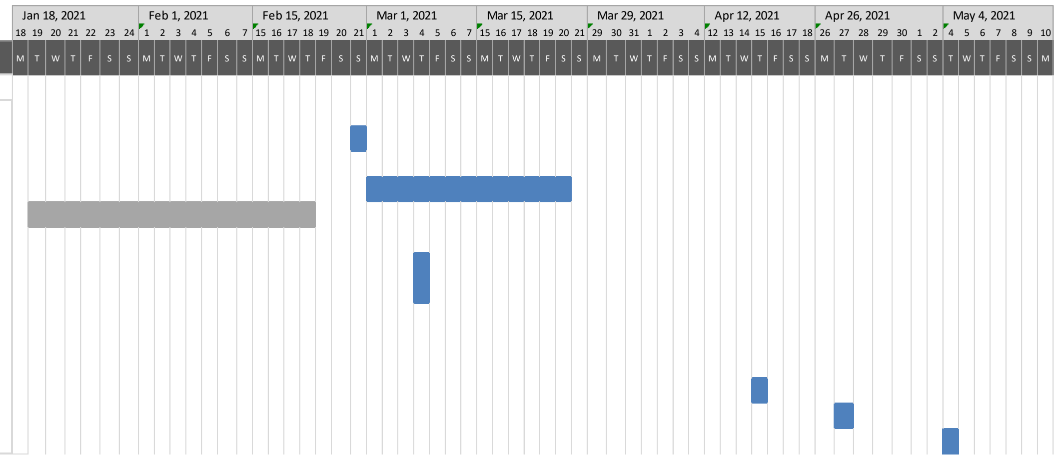

Figure 5. Spring Phase Timeline for Enviro-Shield Solutions

2 Data Collection

2.1 Sampling Methods

Ideally, sampling would take place during the summer from May through July when the lake has not turned over. However, due to the time constraints for this project, the samples taken by Enviro-Shield Solutions will be sometime in March of 2021. The sampling methods used at this time will be dipping with a sample container in shallow riverine zones near the lake and a discrete depth sampler when a sample from a specific depth is desired. All the sampling methods will be done in accordance with the Inland Lakes Sampling Procedure Manual from the Environmental Protection Agency (EPA, 2010). To ensure the quality of the samples collected and minimize error, at least three replicate samples will be taken in accordance with the quality control requirements detailed in Section 2.4 of this plan.

2.2 Sampling Handling and Custody

The primary water quality parameters of concern are dissolved oxygen concentration, total nitrogen, total phosphorus, total suspended solids, and turbidity. In addition to the previous parameters, the collection of alkalinity and hardness data will assist in providing detailed analysis of Lake Thunderbird's aquatic chemistry. In consideration of these parameters, sample containers can be rinsed in-between measurements with deionized water to remain in compliance with EPA sampling standards (EPA 2010). Once a sample has been taken, it's temperature will be logged before being transferred to a sealable container with a clear label. The sample is then placed in a sealed cooler for transportation back to the laboratory in Carson Engineering Center at the Norman campus of the University of Oklahoma.

2.3 Analytical Methods

Specific parameters that will be analyzed from samples are, total nitrogen, total phosphorus, turbidity, alkalinity, hardness, Secchi disk depth, optical dissolved oxygen, and chlorophyll a. The data gathered from Enviro-Shield Solutions sampling in February or March for the parameters of concern will be compared to twenty years of historical data provided by the OWRB. The analytical methods used will be in accordance with the EPA's 2016 Surface Water Sampling and Science guidelines (EPA, 2016).

2.4 Quality Control Requirements

To assure the resulting recommendations from this project adhere to the highest quality of standards applicable, quality control measures as they pertain to the EPA and OWRB will be assessed and implemented throughout timeline of the project. To analyze total phosphorous from samples taken, HACH TNT843-Method 10209/1021 will be used. To analyze total nitrogen from samples taken, HACK TNT826-Method 1020 will be used. Both total phosphorous and total nitrogen will use a dR3800 spectrophotometer to analyze samples. A YSI 6000 series sonde will be used at each sampling site a single time to measure conductivity, total dissolved solids, oxidation reduction potential, pH, depth, temperature, optical dissolved oxygen, and chlorophyll a. In relation to the hand sampling quality control requirements, the following bulleted list provides replicate and time sensitive information for sampling and testing procedures.

- Alkalinity – At least three field titrations using alkalinity kits taken at each site.

- Hardness – At least three field measurements using hardness kits taken at each site.
- Turbidity – Turbido-meter will take three readings from a sample taken at each site. readings must be within 10% of each other.
- Total Phosphorus – Samples will be returned to the lab and tested immediately after all sites have been sampled. Will use ascorbic acid method for evaluating the parameter requires sample blanks for each site if the turbidity varies more than 10%. A spectrophotometer is needed for this test.
- Total Nitrogen – Samples will be returned to the lab and tested immediately after all sites have been sampled. At least one sample from each site will be used in a spectrophotometric total nitrogen test.

3 Oversight

3.1 Assessment and Response Actions

The assessment and response actions relevant to the production of project documents relate to analyzing data outside of the field. This is done using digital resources available to the general public, as well as document resources provided by advisors and found in the research databases the University of Oklahoma student body has access to. The assessments and response actions come in three forms, a Gantt chart for detailing the time-scaled layout of the Project, which details when actions need to be done. Peer evaluation and assessment is done in teams where each team member is responsible for different aspects of the project. The intended response actions to peer evaluations and assessments is collaboration and discussion of elements in the project. This has the effect of producing a more cohesive document with multiple inputs. Finally, the last form of assessment is grading by the project advisors with extensive experience in similar projects. In addition to grading by project advisors, this project will also be presented to the COMCD on May 4th, 2021.

4 Data Review and Usability

4.1 Data Review, Verification, and Validation Requirements

Sampling data from Enviro-Shield Solutions will be compiled into Microsoft Excel for spreadsheet analysis. The sampling data will then be shared using OneDrive to each team member. Using OneDrive allows for the use of a control copy and a live copy that can be edited by any members in real time. Changes in the live copy can then be reviewed, and an updated control copy can then be saved for referencing in the future. Control copies will be saved by the date all changes were approved by Oscar, Cameo, and Peter. Using this method of data review allows for peer-review of all changes, as well as documenting progress from control copies.

5 References

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ENVIRO-SHIELD
SOLUTIONS

Project Work Plan

Evaluation of Watershed-Level and In-Lake Options to Address Lake Thunderbird Water Quality

Prepared by

Enviro-Shield Solutions

Prepared for

Central Oklahoma Master Conservancy District (COMCD)

April 30 2021

Table of Contents

1 Introduction

The purpose of the Project Work Plan (PWP) is to ensure coordination between all the personnel on this project. This document will serve as a resource to manage workflow and ensure the completion of tasks in a timely manner. The Sampling and Analysis Plan (SAP), the Health and Safety Plan (HSP), and Quality Assurance Project Plan (QAPP) will ensure a safe and efficient work atmosphere throughout the duration of the project.

2 Project Overview

2.1 Site History

Lake Thunderbird is located in south-central Oklahoma in the Cross Timbers Ecoregion where it serves as a water supply reservoir for Norman, Del City, and Midwest City (OWRB 2019). Figure 1 shows all of the municipalities that lie in the Lake Thunderbird watershed. The lake covers approximately 2456-hectares, with mean and maximum depths of 6 and 18 m (20 and 58 feet), respectively (USACE 2020). The reservoir was originally conceived to meet the needs of the growing population following the opening of Oklahoma Indian Territory to settlement, the discovery of oil, and the development of farming operations. The Army Corps of Engineers first evaluated the potential of development on the Little River in 1936 (Simonds 1999). It was determined that the Little River did not have the sufficient water supply to meet the demands of the community; however, after many investigations, a plan for the construction of a reservoir to meet the needs of Midwest City, Del City, Moore, Tinker Air Force Base, and Norman was released in 1954. Construction began in 1962 and potable water arrived at homes by February 1966 (Simonds 1999). Since then, the Central Oklahoma Master Conservancy District (COMCD) has been responsible for operation and maintenance of the reservoir.

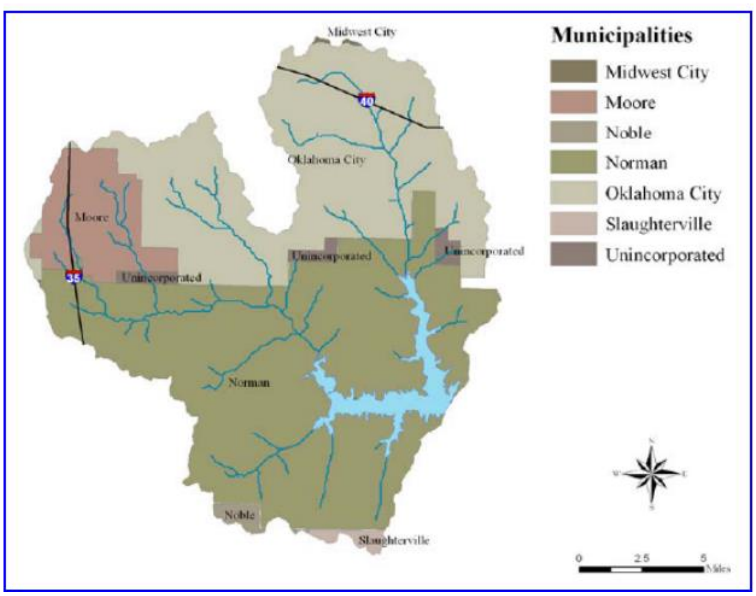

Figure 1: Municipalities located in the Lake Thunderbird Watershed (Vieux 2007)

Lake Thunderbird also provides flood control for the surrounding region. In addition, members of the community are invited to enjoy the large state park, the hiking and biking trails, the two swimming beaches, the nature center, and activities such as fishing and birdwatching. The lake has two marinas and is open to boating, kayaking, and jet skiing. In conclusion, Lake Thunderbird is of the upmost importance as a reliable and safe drinking water source.

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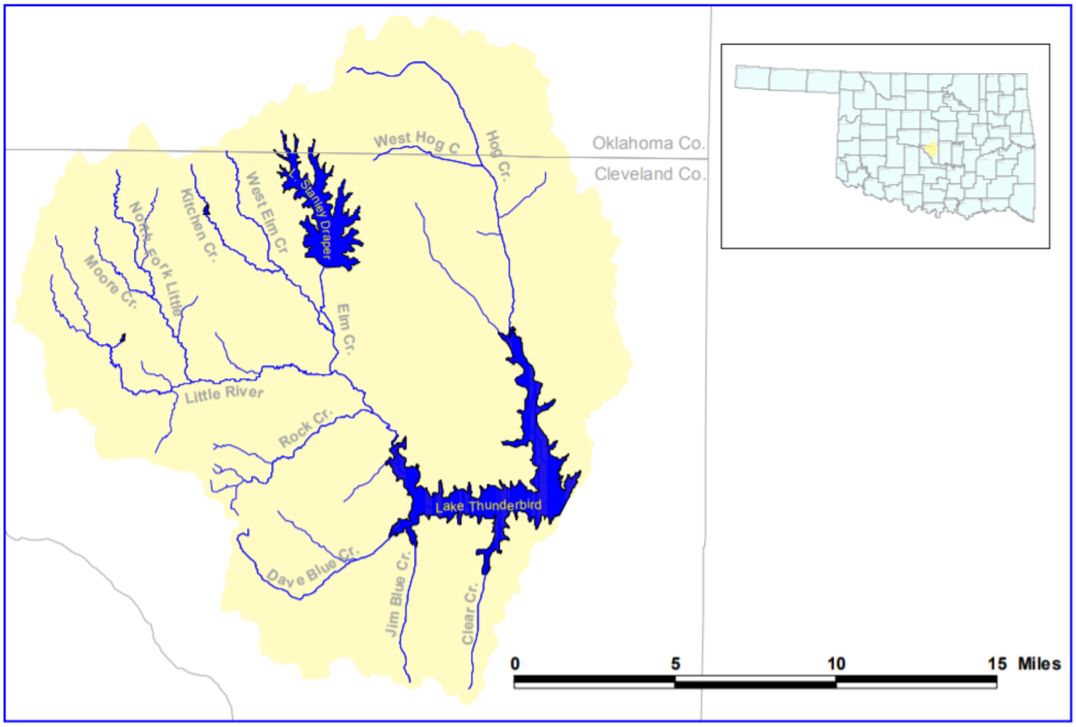

Figure 2: Lake Thunderbird watershed (OCC 2010).

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Although much has been done to address problems at Lake Thunderbird, continually poor water quality and the rising demand for freshwater for multiple beneficial uses makes it critical to continue working on the future health of the reservoir.

2.3 Purpose and Scope

Despite multiple attempts at improving the water quality of Lake Thunderbird, the reservoir remains a eutrophic water supply that does not satisfactorily meet the needs of the communities it serves. Therefore, a combination of in-lake technologies and watershed management measures are being considered by Enviro-Shield Solutions to provide the communities with a long-term solution. This project will include field sampling, an extensive research effort to determine the most appropriate in-lake technology and watershed best management practices (BMPs), a thorough review of all previously attempted projects, and an analysis of the OWRB water quality data gathered over the past two decades. Final deliverables will include a written report and a presentation to key stakeholders.

2.4 Issues of Concern

In 2002, the State of Oklahoma deemed Lake Thunderbird a Sensitive Water Supply, meaning that it requires more care as it is a water body particularly subject to pollution events (OWRB 2020). In addition, Lake Thunderbird is included on the State of Oklahoma List of Impaired Waters due to its inability to meet public/private water supply and warm water aquatic community beneficial uses (DEQ 2018). Specifically, Lake Thunderbird is subject to excessive nitrogen and phosphorus loading from the surrounding watershed. In addition to eutrophication, the lake is subject to thermal stratification which can lead to significant taste and odor complaints from the water users when the lake effectively “turns over” in October and algal growth is at its peak (OWRB 2019). Other water quality parameters of concern are elevated chlorophyll-a concentrations, low dissolved oxygen concentrations, and turbidity. Following two decades of data collection, OWRB has determined that a combination of intensive watershed best management practices (BMPs) and in-lake technologies are necessary to achieve water quality standards for turbidity, chlorophyll-a, and dissolved oxygen.

2.5 Identification of Key Stakeholders

2.5.1 Central Oklahoma Master Conservancy District (COMCD)

The COMCD is the client for this project and is primarily responsible for the operation and maintenance of the Lake Thunderbird reservoir and the municipal and industrial water supplies of Del City, Midwest City, and Norman, Oklahoma. The COMCD was originally formed following a concerted and persistent effort led by local interests to develop surface water resources.

2.5.2 Surrounding Municipalities

Del City, Midwest City, and Norman, Oklahoma all receive drinking water from Lake Thunderbird and their residents are directly impacted by poor water quality. Furthermore, portions of the city of Norman lie within the watershed of the lake, meaning that a portion of non-point source load comes from the city of Norman.

2.5.3 Oklahoma Water Resources Board (OWRB)

The OWRB has conducted monitoring on Lake Thunderbird for the past two decades. OWRB is the primary water agency for the state of Oklahoma and is committed to improving the state’s water resources.

2.5.4 Oklahoma Conservation Commission (OCC)

The OCC is the lead state agency for erosion control, upstream flood control programs, and soil conservation. OCC developed a Watershed Based Plan in 2008 for the Lake Thunderbird Watershed (OCC 2008).

2.5.5 Oklahoma Department of Environmental Quality (DEQ)

The DEQ is responsible for the regulation of Lake Thunderbird and the enforcement of water quality standards. As such, DEQ developed a TMDL report for Lake Thunderbird and submitted the final report to the Environmental Protection Agency (EPA) for approval under the Clean Water Act (CWA).

3 Project Goals

3.1 Safety Goals

The safety and wellbeing of all involved parties must be held paramount throughout the entire duration of the project. The HSP outlines any and all potential hazards, emergency response procedures, and emergency contact information. The purpose of preparing the HSP before the beginning of a project, is to minimize response time in the case of an accident. The members of Enviro-Shield Solutions and any other party involved in sampling procedures will be required to review the HSP before beginning sampling.

3.2 Sample Collection

Sampling is subject to random and/or systematic errors. The purpose of the QAPP is to minimize these errors in order to provide data sets that are as accurate as possible. Due to the current situation with COVID-19, sampling opportunities will be limited, and it is of upmost importance that all sampling procedures follow the QAPP.

3.3 Final Document and Presentation Goals

A final document and oral presentation will provide COMCD with a comprehensive analysis of the current status of Lake Thunderbird and present feasible solutions.

4 Resources and Constraints

Completion of this project will depend on successful collaboration among Enviro-Shield Solutions, as well as with Dr. Robert Nairn and Dr. Robert Knox of the University of Oklahoma. In addition, data must be obtained from the OWRB and collaboration will ultimately be needed among all stakeholders for significant improvements to be made. The laboratories at the Center for Restoration of Ecosystems and Watersheds (CREW) at the University of Oklahoma will be made available to conduct water quality analyses.

Due to the current global pandemic, there are some restrictions regarding social distancing and minimized exposure that will complicate sampling events and group collaboration. To combat these constraints, effective means of communication via Zoom will be established and proper social distancing and face coverings will be enforced during all sampling events to ensure the safety of the samplers. In addition, the limited number of individuals in the Enviro-Shield Solutions team may limit the number of samples collected. Data will be supplemented by OWRB database. Careful considerations will be made regarding the differences in sampling procedures before the two data sets are fully incorporated together.

Lastly, the project must be completed by May 2021. The time constraint is more relevant than the distance constraint, as Lake Thunderbird is located only 14 miles from the University of Oklahoma Norman campus.

5 Project Tasks and Timeline

Specific project roles have been assigned based upon past experiences and individual strengths; however, all group members will work collaboratively to accomplish the majority of tasks. Assigning roles ensures that each individual can perform at their highest potential. Figure 3 shows the group structure and the team member roles.

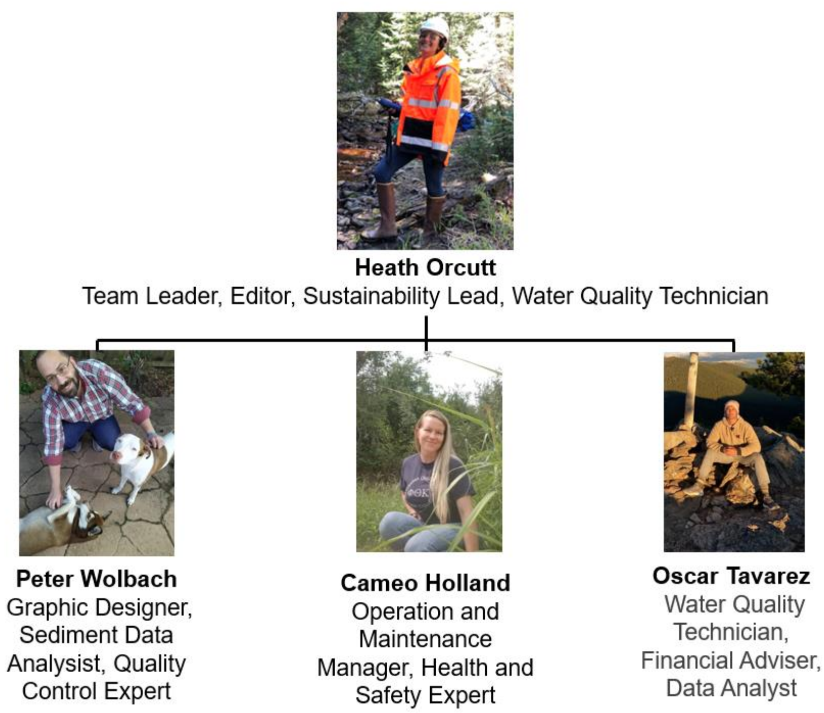

Figure 3: Group structure and team member roles

5.1 Sampling Tasks

Sampling will take place during a single sampling event at the end of January. Being that Lake Thunderbird is within close proximity to the University of Oklahoma Norman Campus, sampling should be completed within one day. As the leading Water Quality Technician, Oscar Tavarez developed the sampling plan and such, will lead all sampling events. As team leader, Heath Orcutt will be responsible for coordinating transportation, meeting times and places, and ensuring the sampling event runs smoothly. Cameo Holland is the lead Health and Safety Expert, and as such, will enforce all safety precautions, such as Personal Protective Equipment (PPE), and will conduct a safety meeting before sampling begins to remind all samplers of the potential hazards. Lastly, Peter Wolbach will ensure that sampling procedures follow the QAPP for accurate and consistent data collection. All team members will contribute to ensuring the success of the sampling event, the safety of all members, and minimal impact on the environment.

5.2 Laboratory Tasks

All team members will participate in laboratory analyses. Oscar Tavarez will inform all team members on the different hazardous and non-hazardous wastes before sampling begins to ensure proper disposal. Cameo Holland will ensure that all team members have the proper PPE and that safety is of the upmost importance. Peter Wolbach will be responsible for ensuring that analysis of the samples is done in the most precise manner with minimal error. Lastly, Heath Orcutt will be responsible for documenting results and coordinating laboratory times with all team members and the directors of the laboratory.

5.3 Report and Presentation Tasks

The content for final deliverables will be developed by the team members throughout the project. The final report will provide COMCD with 2-3 potential solutions that would address the poor water quality of Lake Thunderbird. In addition, it will detail the history of the project and any previous attempts to address the issue at hand. Heath Orcutt will be primarily responsible for ensuring the formality and uniformity of the final written report. Peter Wolbach will be responsible for designing key visuals that clearly represent technical information and design solutions. All team members are expected to contribute equally to the project and to always provide high quality work. The final presentation made to COMCD will be conducted in a professional manner with input from all team members.

5.4 Timeline

Enviro-Shield Solutions first began work in September 2020 with the guidance of Dr. Robert Knox. By December 2020, the HSP, SAP, QAPP, and PWP were developed. The bulk of the project will be conducted in the Spring of 2021, and the important milestone tasks are outlined in Figure 4. By March 4th, 33% of the project must be completed. The next milestone is March 25th when 66% of the project must be completed. Finally, 100% of the project must be completed and a draft report submitted by April 15th. The final presentation and final report will be completed by April 27th. Final presentations will be made to COMCD on May 4th.

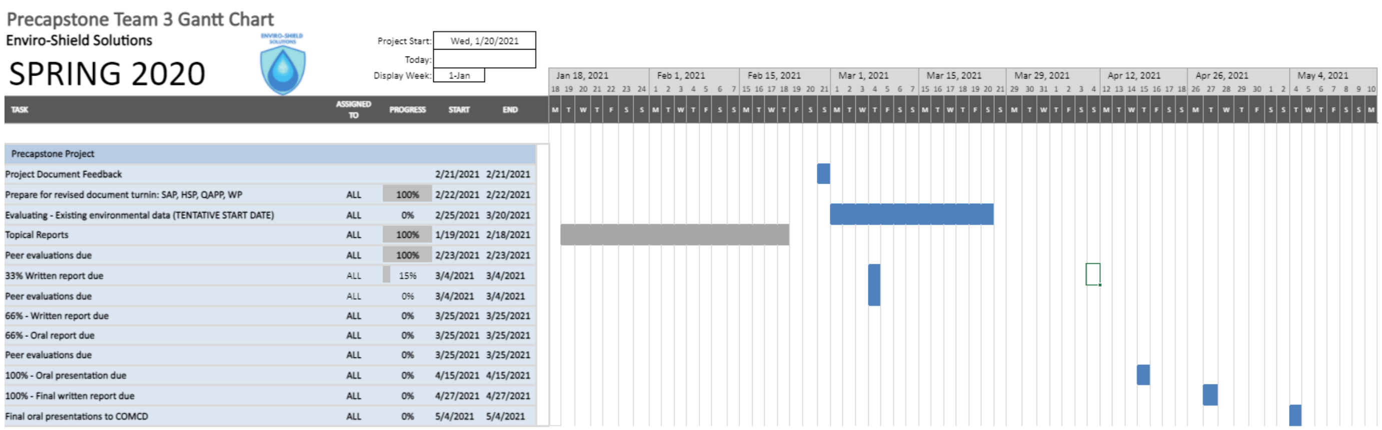

Figure 4: Spring 2021 Project Gantt Chart for Enviro-Shield Solutions

6 Strategy

With the current status of COVID-19, the entire world is experiencing unprecedented times that require different tactics of teamwork and effective leadership. As always, safety and the wellbeing of all parties involved must be held paramount; however, extra precautions must be taken to minimize routes of transmission for COVID-19. The onset of symptoms and/or any team member being exposed to the virus may result in a mandatory quarantine and thus, extra time should be built into every deliverable. In addition, communication is of the upmost importance since the majority of meetings will take place virtually. Team members will be encouraging and engaged during all team interactions to promote good team ethics and morale. The team leader will be responsible for enforcing the 33%, 66%, and 100% draft milestones so that the project may be completed in a timely manner. It will be the responsibility of each team member that work be completed in a professional and high-quality fashion.

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