GUN LAKE

2021 Lake Management Update

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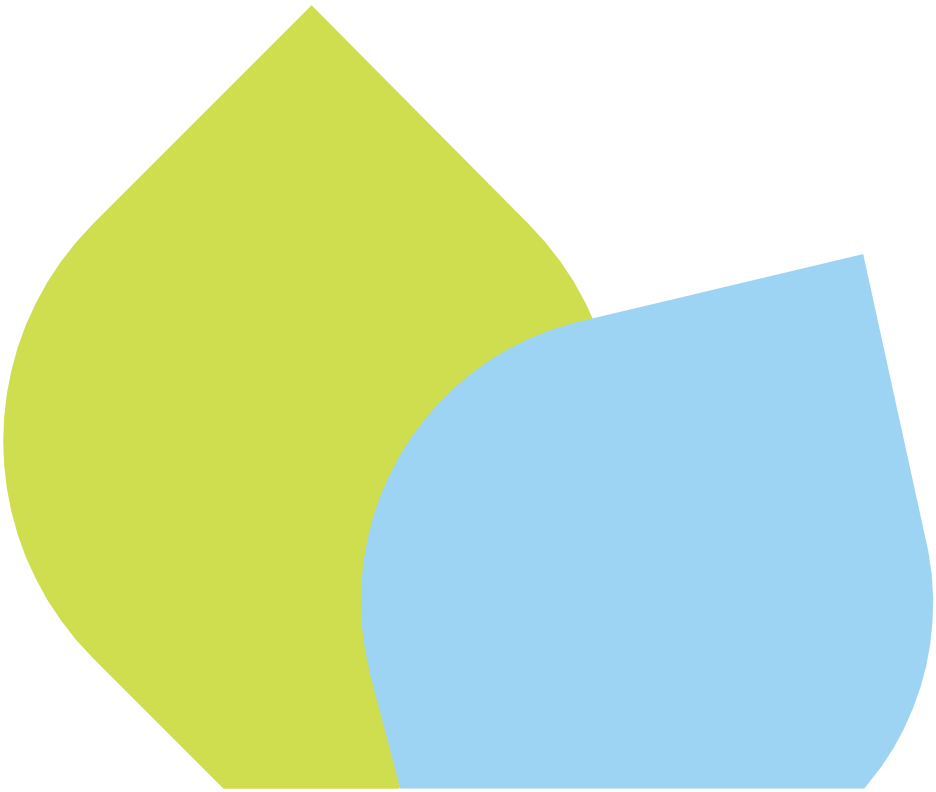

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Executive Summary

Healthy, native ecosystems are active and ever-changing, but their changes occur within a range of natural variability. Certain types of non-native plants and animals can cause havoc when, accidentally or intentionally, they are released outside their normal range into a new region.

Managing the quality of both surface water and groundwater is vital for sustaining healthy aquatic ecosystems, which is important to protect diversity of our waterways.

Routine monitoring water quality allows us to understand how the levels of nutrients, dissolved oxygen, and temperature change over time and how best to manage these conditions. We use water quality information to assess current condition and patterns over time and space to understand and manage changes in environment, habitat, and land use.

Gun Lake is 2,680 acres, located in Yankee Springs and Orangeville Township in Barry County, and in Wayland and Martin townships in Allegan County. The lake is approximately 11 miles west of Hastings, 27 miles southeast of Grand Rapids, and 32 miles northeast of Kalamazoo. Gun Lake has approximately 24.4 miles of shoreline, with a maximum depth of 68 feet and an average depth of 9.8 ft. The land use around Gun Lake is mostly residential, with a small portion of marshy area on the east side of the waterbody. The east and west basins of the lake have very different characteristics. The east basin has a marl bottom, with a few small areas of peat. Some areas have gravel present and many of the submerged and emergent islands are surrounded by gravel bars and boulders. The west portion of the lake is shallow with a maximum depth of 5 feet. The bottom is marl, and the shoreline is mostly sandy. Good water quality has been the attraction to Gun Lake for users from around the state of Michigan. Water quality had been impaired in the past due to bacterial contamination but has vastly improved after 1980 when a sewer system was installed to serve the Gun Lake community.

Problem Statement

Gun Lake historically has treated Eurasian watermilfoil (Myriophyllum spicatum) and Starry stonewort (Nitellopsis obtusa). In 2021, 241.5 acres were identified for treatment. Gun Lake has also historically monitored dissolved oxygen, pH, total alkalinity, and total phosphorus at three sites (Figure 1) due to water quality concerns.

Goals and Objectives

The management goals of the Gun Lake Aquatic Lake Management Plan are:

- Maintain a stable, diverse aquatic plant community that supports a good balance of predator and prey fish and wildlife species, good water quality, and is resistant to minor habitat disturbances and invasive species
- Direct efforts to prevent and control the negative impacts of aquatic invasive species
- Provide reasonable public recreational access while minimizing the negative impacts on plant, fish, and wildlife resources

Aquatic Plant Management

Treatment History

The morphology of Gun Lake includes extensive shallow areas; accordingly, a large percentage of the lake can become infested with heavy growth of invasive and nuisance species that negatively impact boating, fishing, swimming, and property value. In 2021, multiple inspections yielded need for treatments from May through August. Year to date, 241.5 total acres were treated for nuisance algae, starry stonewort, Eurasian watermilfoil, curly-leaf pondweed, variable-leaf pondweed, eelgrass, and a mix of nuisance algae and invasive plants (Table 1).

Table 1. Gun Lake 2021 Treatment History

Date	Targeted Species	Acres	Treatment
5/12/2021	Nuisance algae, starry stonewort, Eurasian watermilfoil, and curly-leaf pondweed	15.9	Flumioxazin, diquat dibromide, and chelated copper algaecide
5/18/2021	Nuisance algae, starry stonewort, Eurasian watermilfoil, and curly-leaf pondweed	34.8	Flumioxazin, diquat dibromide, and chelated copper algaecide
5/26/2021	Eurasian watermilfoil and variable-leaf watermilfoil	28.5	ProcellaCOR
6/21/2021	Nuisance algae and macro-algae	27.0	Chelated copper algaecide and endothall
6/21/2021	Starry stonewort, and a mix of nuisance and invasive plants	22.5	Diquat dibromide, flumioxazin, and chelated copper algaecide
7/13/2021 & 7/19/2021	Eurasian watermilfoil	23.0	Triclopyr granular
8/5/2021	Macro-algae, starry stonewort, Eurasian watermilfoil, eelgrass	48.0	Flumioxazin, chelated copper algaecide, endothall, diquat dibromide, and flumioxazin
9/13/2021	Eurasian watermilfoil, starry stonewort	10.0	Flumioxazin, chelated copper algaecide, and ProcellaCOR

The first treatment took place on May 12, 2021, to treat algae, starry stonewort, Eurasian watermilfoil, and curly-leaf pondweed. A second treatment took place on May 18th, 2021, to treat nuisance algae and starry stonewort (Figure 1).

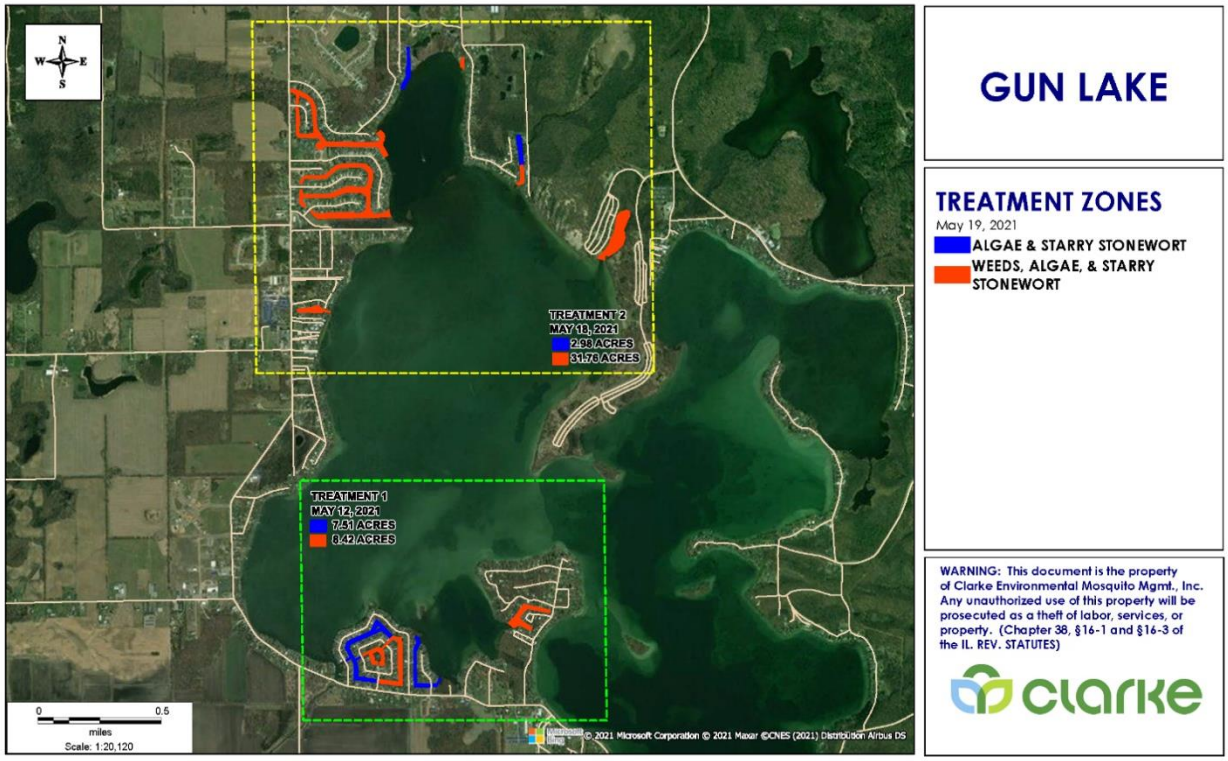

Figure 1. Gun Lake May 12th and May 18th, 2021, Treatments.

On May 26th, 2021, a ProcellaCOR treatment of 28.5 acres took place to treat Eurasian watermilfoil, outlined in blue (Figure 2).

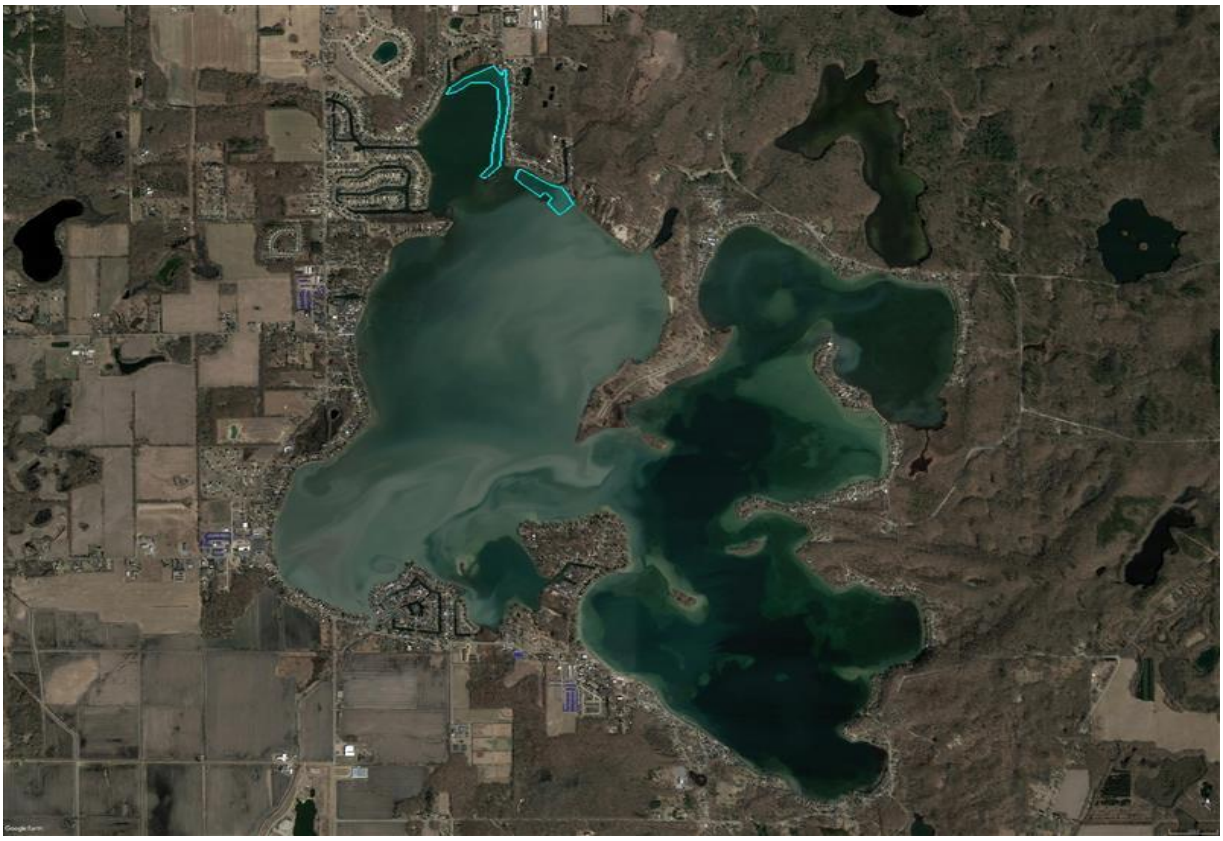

Figure 2. Gun Lake May 26th, 2021, ProcellaCOR Treatment.

Clarke surveyed the lake on June 9, June 15, and June 17. During these surveys, nuisance, and invasive plants in different areas of the lake. Based on the results of these surveys, it was recommended treating areas shown in yellow and blue. The yellow areas were recommended for treatment for nuisance algae and macroalgae. The blue areas were recommended for treatment for nuisance algae, invasive starry stonewort, and a mix of nuisance and invasive plants (Figure 3). Treatments occurred on June 21, 2021.

Figure 3. Gun Lake June 21st, 2021, Treatments.

In July, the areas in pink were treated for invasive Eurasian watermilfoil using a systemic herbicide on July 13th and 19th, 2021 and totaled 23.0 acres (Figure 4).

Figure 4. Gun Lake July 13th and 19th, 2021 Eurasian watermilfoil Treatments.

In August, areas outlined in blue had nuisance aquatic vegetation that impeded navigation and recreation. The area outlined in green had invasive starry stonewort. The areas outlined in pink had a variety of nuisance plants, including algae, macroalgae, starry stonewort, and invasive Eurasian watermilfoil. The areas outlined in yellow had a variety of nuisance plants, including algae, starry stonewort, invasive Eurasian watermilfoil, and Eelgrass (Figure 5). This treatment took place on August 5th, 2021, and totaled 48.0 acres.

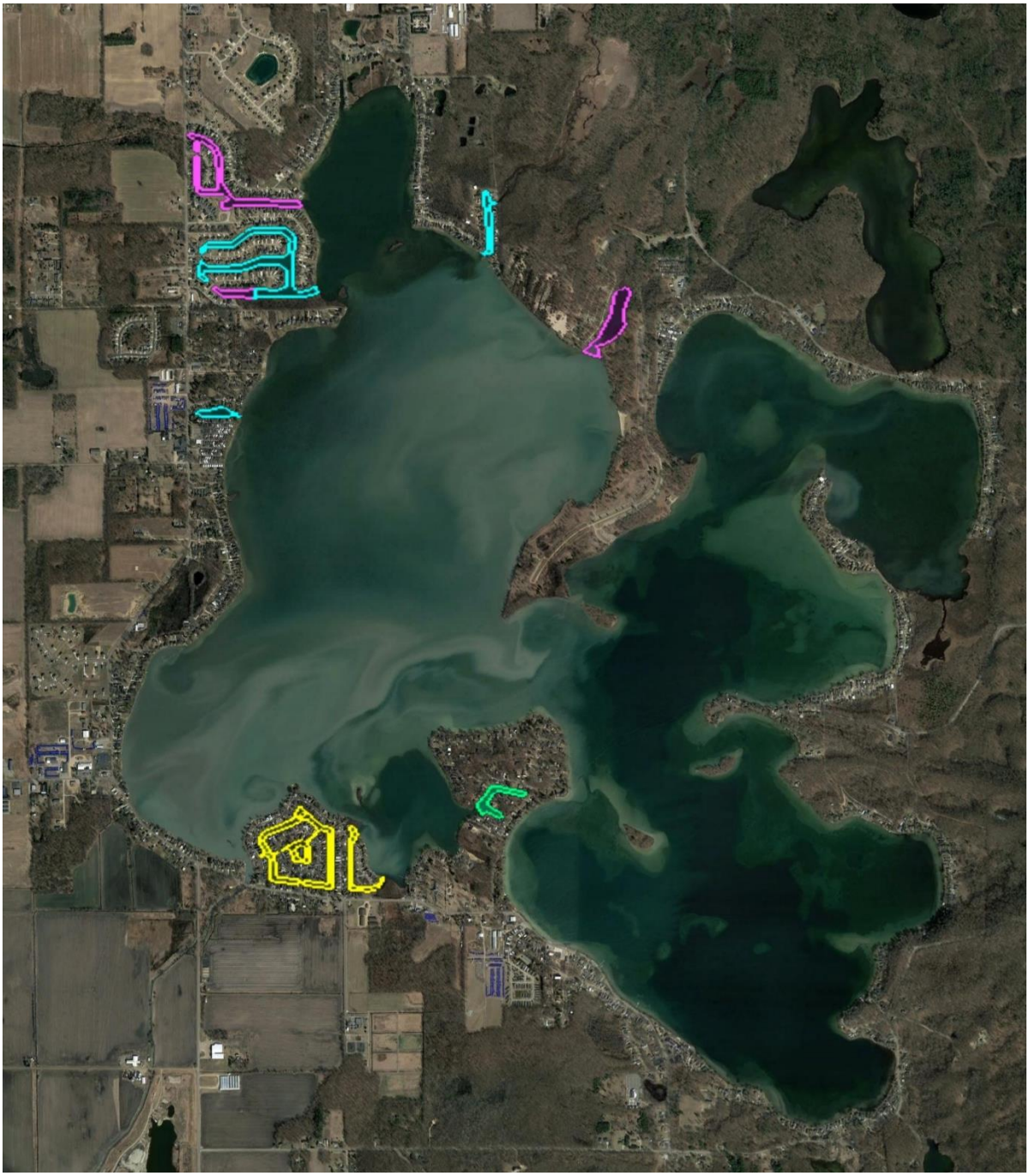

Figure 5. Gun Lake August 5, 2021, Treatment.

During earlier inspections, 10 acres of starry stonewort, Eurasian watermilfoil, and nuisance native plants were detected and GLPA notified when the lake outflow was minimal to allow treatment just above the dam at the Gun Lake outlet. In such a situation, the MDEGLE ANC permit would allow Clarke Aquatic Services to treat within the 1,000-foot setback area. After board approval and site inspection confirmed there was no outflow, treatment took place on September 13, 2021, when water was no longer flowing over the dam (Figure 6).

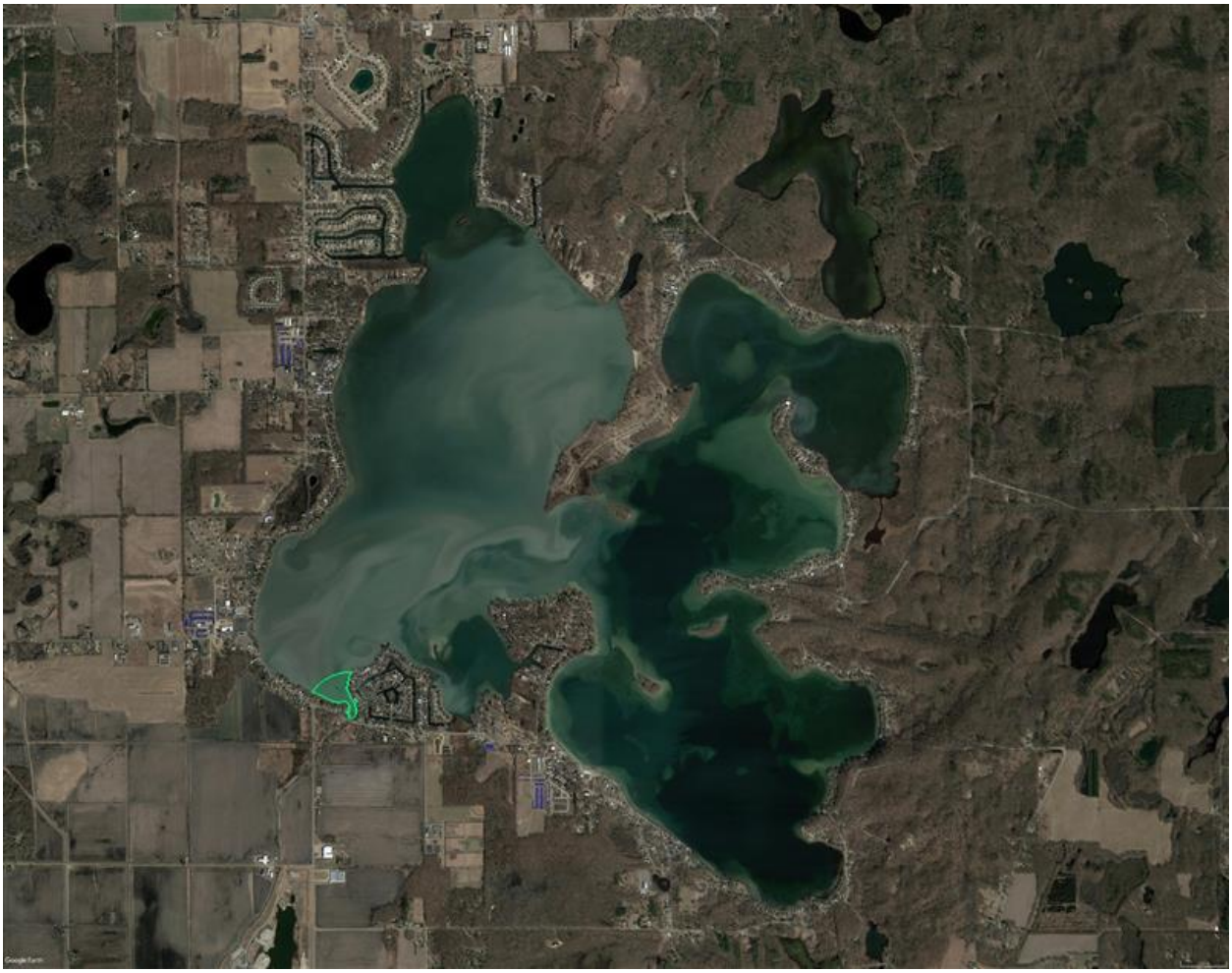

Figure 6. Gun Lake September 13, 2021, Treatment.

Treatment areas are outlined in yellow took place in 2020. The areas in yellow did not need retreatment in 2021 (Figure 7). This is the strategy of using systemic herbicides to reduce the overall population of invasive Eurasian watermilfoil. Furthermore, ProcellaCOR is selective for Eurasian watermilfoil and does not harm the native pondweeds in these areas. Except for one small area in the canal east of Harmony Drive. But this 2020 treatment polygon was not large enough to qualify for the extended control guarantee, so this 0.2-acre area was treated in 2021.

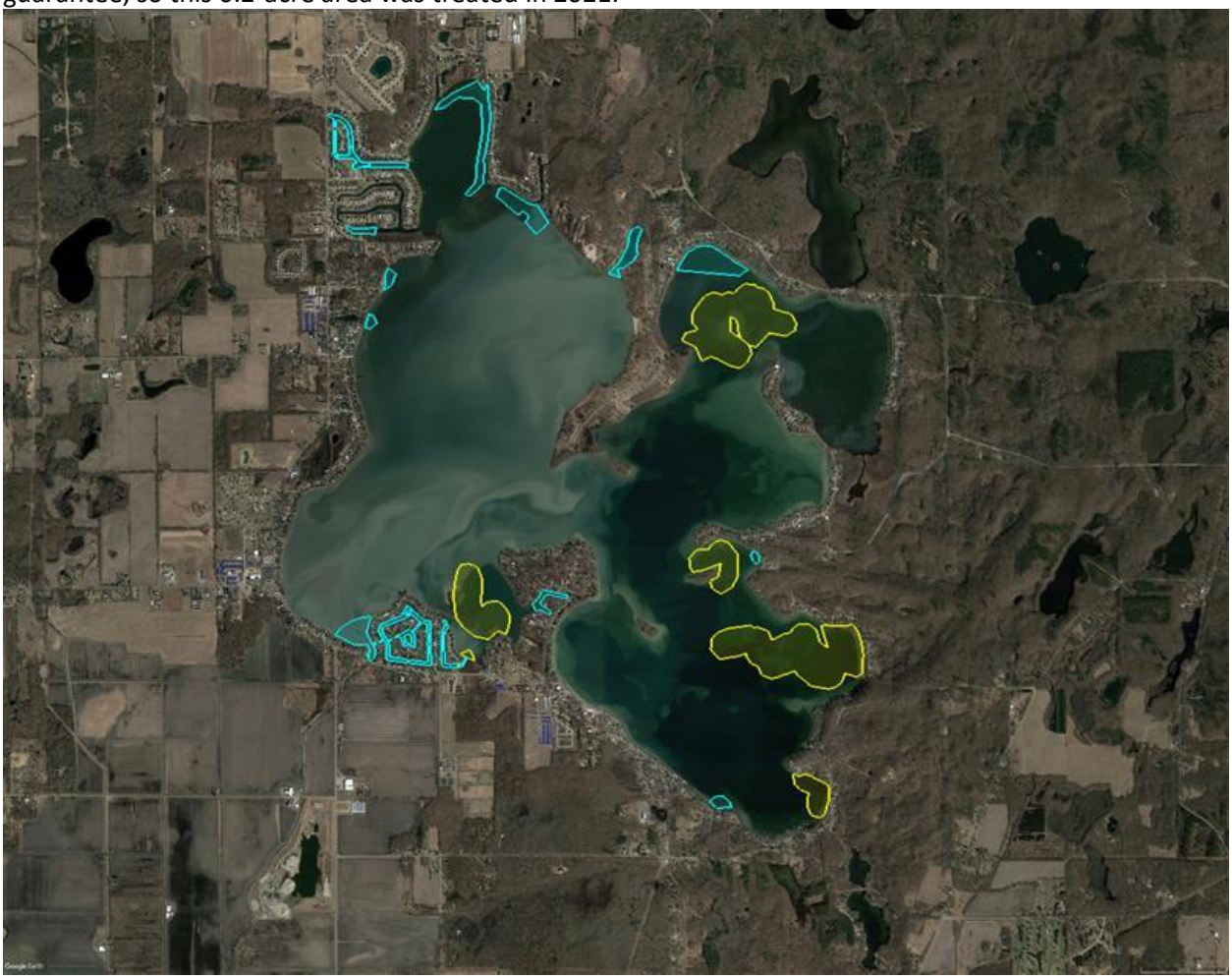

Figure 7. Gun Lake ProcellaCOR 2020 Treatments vs. 2021 Eurasian watermilfoil Treatments.

Water Quality Results and Discussion

Water Quality Monitoring

The most common dissolved substances in water are minerals or salts that, as a group, are referred to as dissolved solids. Dissolved solids include common elements such as calcium, sodium, and chloride; plant nutrients such as nitrogen and phosphorus; and trace elements such as selenium, chromium, and arsenic. In general, the common elements are not considered harmful to human health, although some can affect the taste, smell, or clarity of water. Plant nutrients (such as nitrogen and phosphorus) and trace elements in water can be harmful to human health and aquatic life if they exceed standards or guidelines. Dissolved gases such as oxygen and radon are common in natural waters. Adequate oxygen levels in water are a necessity for fish and other aquatic life. Consistent water quality monitoring is essential to note trends in water quality and ecosystem health.

Sampling Methods

Gun Lake was sampled using a deep-water submersible pump with a flexible hose to obtain water samples below the surface across the three sampling locations. Water samples were stored on ice in coolers and shipped to SRTC Laboratory for third party analysis using standard laboratory procedures for EPA methods including Chlorophyll a (ug/L) EPA 445, Phosphorus (ug/L) EPA 365.3, Alkalinity (mg/L as CaCO3) EPA 310.2, and pH EPA 150.1. Tributary monitoring was conducted during a storm flow and a base flow sampling event. Stream discharge was measured at three locations, Gun Lake outlet, just below the dam, Intercuddy drain, and Payne Lake Outlet Tributary at Vista Point Ave. Stream discharge was measured using methods outlined by the US EPA for Stream Monitoring:

Stream flow, or discharge, is the volume of water that moves over a designated point over a fixed period. It is often expressed as cubic feet per second (ft3/sec).

$$\text{Flow} = ALC / T$$

Where:

A=Average cross-sectional area of the stream (stream width multiplied by average water depth).

L =Length of the stream reach measured (usually 20 ft.)

C=A coefficient or correction factor (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams). This allows you to correct for the fact that water at the surface travels faster than near the stream bottom due to resistance from gravel, cobble, etc. Multiplying the surface velocity by a correction coefficient decreases the value and gives a better measure of the stream's overall velocity.

T=Time, in seconds, for the float to travel the length of L

Inlet and Outlet Flow Data

The flow of a stream is affected by weather, increasing during rainstorms, and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground. August and September are usually the months of lowest flow for most streams and rivers in most of the country (Mitchell and Stapp 1997).

Flow is a function of water volume and velocity. It is important because of its impact on water quality and on the living organisms and habitats in the stream. Large, swiftly flowing rivers can receive pollution discharges and be little affected, whereas small streams have less capacity to dilute and degrade wastes (Adopt-A-Stream Foundation 1996). The Gun River below the Dam, Payne Lake outlet and the Intercuddy drain outlet were sampled on June 9, 2021, and September 23, 2021.

Flow from Payne Lake Outlet Tributary was 3.76 ft3/sec. Discharge for Gun Lake outlet was 12.91 ft3/sec. for base flow. Flow from Payne Lake Outlet Tributary for Storm flow was 10.4 ft3/sec. Flow from Inter Cuddy Drain for storm flow was 2.82 ft3/sec (Table 2). It was also noted at the Gun Lake outlet site, south of Marsh Road, there is a substantial amount of construction and a significant amount of erosion occurring, causing sedimentation on the west side of the stream

Table 2. Tributary Discharge Data 2021.

Sample Date	Location	Total Suspended Solids (mg/L)	Total Phosphorus (ug/L)	Discharge (ft3/sec)	Sampling Event
9-Jun-21	Dam	10	13.5	12.91	Base
9-Jun-21	Payne Lake Outlet	< 4.0	12.6	3.76	Base
23-Sep-21	Inter Cuddy	<4.0	17	10.4	Storm
23-Sep-21	Payne Lake Outlet	<4.0	14.1	2.82	Storm

Lake Assessment Data

A lake is usually classified as being in one of three possible classes: oligotrophic, mesotrophic or eutrophic. Lakes with extreme trophic indices may also be considered hyper oligotrophic or hypereutrophic. Table 3 below demonstrates how the index values translate into trophic classes (USEPA 2007).

Oligotrophic lakes exhibit low productivity, with few nutrients and high-water clarity, and consequently, generally host very little aquatic vegetation. On the other hand, eutrophic lakes are more productive, with more nutrients available for algae, plant, and fish growth and typically have lower water clarity. Each trophic class supports different types of fish and other organisms, as well. Due to increased algal productivity eutrophic and hypereutrophic lakes are more at risk for fish kills. If the algal biomass in a lake or other water body reaches too high a concentration, fish die-offs may occur as decomposing algal biomass depletes the oxygen in the lake. In past surveys, Gun Lake has had a relatively low phosphorus, high secchi depth readings, and Chlorophyll <10, placing it in the oligotrophic class.

Table 3. Trophic State Index Classification

Trophic State Index	Chlorophyll (ug/L)	Phosphorus (ug/L)	Secchi Depth (ft)	Trophic Class
<30-40	0-2.6	0-12	>8-4	Oligotrophic
40-50	2.6-20	12-24	4-2	Mesotrophic
50-70	20-56	24-96	2-0.5	Eutrophic
70-100	56-155+	96-384+	0.5-<0.25	Hypereutrophic

Natural water quality varies from place to place, with the seasons, climate, and the types of soils and rocks through which water moves. When water from rain or snow moves over the land and through the ground, the water may dissolve minerals in rocks and soil, percolate through organic material such as roots and leaves, and react with algae, bacteria, and other microscopic organisms. Water may also carry plant debris, sand, silt, and clay to rivers and streams making the water appear “muddy” or turbid.

Three locations (Figure 8) within Gun Lake were sampled on June 24, 2021 (Table 4), July 21, 2021 (Table 5), and September 23, 2021 (Table 6). Location 1 is in the southeast portion of Gun Lake and is described by site 1 and depth indicated by numerical value following the location. Location 2 is in the western portion of Gun Lake and only a surface water sample was taken due to the shallowness of the site. Location 3 is in the northeast portion of Gun Lake and is described by site 3 and depth indicated by numerical value following the location. Due to lab equipment issues at SRTC Laboratory, Chlorophyll a was not analyzed in July and September sampling events.

Figure 8. Gun Lake Water Quality Sampling Locations 2021.

Table 4. Gun Lake June 24, 2021, Water Quality Monitoring Data.

Sample Date	Location	Total Phosphorus (ug/L)	Alkalinity (mg/L as CaCO3)	pH	Chlorophyll a (ug/L)	Temp (F)	DO (mg/L)	Secchi (ft)
24-Jun-21	1-0	<10.0	153.4	8.4	<10.0	74.2	8.7	10.6
24-Jun-21	1-10	10.8	151.5	8.5		73.2	8.8	
24-Jun-21	1-20	10.4	154.7	8.5		64.1	11.0	
24-Jun-21	1-30	<10.0	156.5	8.4		57.6	8.5	
24-Jun-21	1-40	10.7	156.5	8.2		52.1	2.1	
24-Jun-21	1-50	11.5	161.8	7.9		49.5	0.1	
24-Jun-21	1-60	28.5	167.4	7.7		43.7	0.0	
24-Jun-21	2-0	11.8	140.0	8.6	<10.0	69.1	9.3	5.5
24-Jun-21	3-0	10.0	148.1	8.4	<10.0	71.0	8.4	8.4
24-Jun-21	3-10	17.3	165.0	7.8		70.6	8.4	
24-Jun-21	3-20	10.7	146.9	8.4		65.3	8.1	
24-Jun-21	3-30	10.2	160.3	8.2		57.6	4.1	
24-Jun-21	3-40	11.2	160.8	8.1		54.4	2.3	

Table 5. Gun Lake July 21, 2021, Water Quality Monitoring Data.

Sample Date	Location	Total Phosphorus (ug/L)	Alkalinity (mg/L as CaCO3)	pH	Chlorophyll a (ug/L)	Temp (F)	DO (mg/L)	Secchi (ft)
21-Jul-21	1-0	10.9	138.0	8.4	NA	77.5	8.98	9.7
21-Jul-21	1-10	32.0	138.4	8.5	NA	77.6	9.02	
21-Jul-21	1-20	11.8	143.4	8.2	NA	71.9	6.35	
21-Jul-21	1-30	13.1	156.7	7.8	NA	63.5	2.99	
21-Jul-21	1-40	11.3	157.4	7.8	NA	55.1	2.01	
21-Jul-21	1-50	12.8	158.5	7.8	NA	51.7	0.4	
21-Jul-21	1-60	38.6	164.1	7.9	NA	49.4	0.14	
21-Jul-21	2-0	11.2	129.8	8.5	NA	77.8	8.84	5.0
21-Jul-21	3-0	11.9	135.8	8.4	NA	76.7	8.7	4.5
21-Jul-21	3-10	10.9	137.0	8.4	NA	77.1	8.7	
21-Jul-21	3-20	11.9	144.5	8.2	NA	59.9	0.62	
21-Jul-21	3-30	13.1	158.2	7.9	NA	57.0	0.24	
21-Jul-21	3-40	14.2	159.8	7.8	NA	57.5	0.15	

Table 6. Gun Lake September 23, 2021, Water Quality Monitoring Data.

Sample Date	Location	Total Phosphorus (ug/L)	Alkalinity (mg/L as CaCO3)	pH	Chlorophyll a (ug/L)	Temp	DO (mg/L)	Secchi (ft)
23-Sep-21	1-0	<10.0	138.1	8.3	NA	67.3	8.5	8.0
23-Sep-21	1-10	<10.0	136.5	8.28	NA	67.5	8.3	
23-Sep-21	1-20	<10.0	138.3	8.27	NA	67.5	8.4	
23-Sep-21	1-30	<10.0	132.0	8.27	NA	67.5	8.3	
23-Sep-21	1-40	<10.0	137.0	8.23	NA	58.5	8.2	
23-Sep-21	1-50	15.9	165.3	8.26	NA	57.2	5.3	
23-Sep-21	1-60	<10.0	160.8	7.47	NA	55.8	2.6	
23-Sep-21	2-0	25.6	132.4	8.43	NA	61.2	9.5	5.0
23-Sep-21	3-0	<10.0	140.0	8.05	NA	66.2	7.3	8.0
23-Sep-21	3-10	13.9	137.4	8.02	NA	66.2	7	
23-Sep-21	3-20	<10.0	145.2	7.8	NA	65.1	5.8	
23-Sep-21	3-30	<10.0	157.4	7.41	NA	61.9	2.3	
23-Sep-21	3-40	14.2	160.1	7.26	NA	58.1	0.4	

Total phosphorus is one of the key elements necessary for growth of plants and animals and in lake ecosystems it is the growth limiting nutrient. The presence of phosphorus is often scarce in well-oxygenated lakes and low levels of phosphorus limit the production of freshwater systems. Unlike nitrogen, phosphorus is retained in the soil by a complex system of biological uptake, absorption, and mineralization. Phosphates are not toxic to people or animals unless they are present in very high levels.

As phosphorus enters a lake, it can result in an increase in the growth of plankton and aquatic plants that provide food for larger organisms, including zooplankton, fish, humans, and other mammals. However, too much phosphorus entering the system over time can accelerate the aging process of the lake known as eutrophication. Gun Lake had total phosphorus levels ranging between <10.0 ug/L and 38.6 ug/L during the sampling events.

USEPA regulations recommend a max of 76 ug/L. While a numeric value has not been established by the state of Michigan some watersheds have established a Total Maximum Daily Limit (TMDL) of 200 ug/L. Gun Lake water samples only exceeded the recommended in one sample, which was a deep-water sample. A high concentration of phosphorus at the bottom of the lake could be caused by years of nutrients settling into the sediment.

Alkalinity is a property of water that is dependent on the presence of certain chemicals in the water, such as bicarbonates, carbonates, and hydroxides. In a surface waterbody, such as a lake, the alkalinity in the water comes mostly from the rocks and land surrounding the lake. Precipitation falls in the watershed surrounding the lake and most of the water entering the lake comes from runoff over the landscape. If the landscape is in an area containing rocks such as limestone, then the runoff picks up chemicals such as calcium carbonate (CaCO3), which raises the pH and alkalinity of the water. In areas where the geology contains large amounts of granite, for instance, lakes will have a lower alkalinity. The alkalinity of most lakes in the Upper Midwest is within the range of 23 to 148 milligrams per liter, or parts per million, as calcium carbonate. Alkalinity ranged between 132 – 167.4 mg/L CaCO3 in Gun Lake during sampling events.

Chlorophyll *a* is a measure of the number of algae growing in a waterbody. It can be used to classify the trophic condition of a waterbody. Although algae are a natural part of freshwater ecosystems, too many algae can cause aesthetic problems such as green scums and bad odors and can result in decreased levels of dissolved oxygen. Some algae also produce toxins that can be of public health concern when they are found in high concentrations. One of the symptoms of degraded water quality condition is the increase of algae biomass as measured by the concentration of chlorophyll a. Waters with high levels of nutrients from fertilizers, septic systems, sewage treatment plants and urban runoff may have high concentrations of chlorophyll a and excess amounts of algae. Chlorophyll a was recorded at <10 ug/L at surface locations during the June 24, 2021, sampling event. Chlorophyll a was to be tested at both summer and late sampling events, however due to lab constraints beyond reasonable measures, chlorophyll a was unable to be tested.

Total suspended solids (TSS) are solid materials, both organic and inorganic, that are suspended in water including silt, plankton, and industrial wastes. High concentrations of suspended solids can lower water quality by absorbing light. Waters then become warmer and lessen the ability of the water to hold oxygen necessary for aquatic life. Because aquatic plants also receive less light, photosynthesis decreases, and less oxygen is produced. The combination of warmer water, less light, and less oxygen makes it impossible for some forms of life to exist. Suspended solids can result from erosion from urban runoff and agricultural land, industrial wastes, bank erosion, bottom feeders (such as carp), algae growth, or wastewater discharges (Oliva et al 1980).

Most people consider water with a TSS concentration less than 20 mg/l to be clear. Water with TSS levels between 40 and 80 mg/l tends to appear cloudy, while water with concentrations over 150 mg/l usually appears dirty. The nature of the particles that comprise the suspended solids may cause these

numbers to vary. Michigan's rules do not contain numerical limits for total suspended solids. The U.S. Environmental Protection Agency has announced treatment technology-based limits for total suspended solids for municipal wastewater treatment plants and many industrial categories. Municipal wastewater treatment plants must provide treatment to meet TSS limits of 30 mg/l as a monthly average and 45 mg/l as a 7-day average. Some industrial categories have treatment technology-based concentration limits. Others have production-based loading limits, which are expressed in lbs./day or lbs./year.

Total suspended solids were sampled in June and September at the Dam, Intercuddy, and Payne Lake Outlet and did not exceed 10 mg/L with most samples <4 mg/L, indicating high water quality, even during storm events when higher levels of TSS are to be expected.

pH is a measure of the amount of acid or base in the water. The pH scale ranges from 0 (acidic) to 14 (alkaline or basic) with neutrality at 7. The pH of most lakes in the Upper Midwest ranges from 6.5 to 9.0 (MDEQ 2012). pH significantly affects the chemical and biological interactions in the aquatic environment. This is of particular concern in considering the effects of toxic substances on aquatic organisms, especially the release of metals from sediments. At certain pH levels, a particular toxicant may increase in toxicity or become more soluble, and thus is more likely to affect aquatic organisms. The problems of acidic deposition and the acidification of lakes and streams have gained widespread attention. However, certain biological communities are adapted to acidic conditions (e.g., blackwater stream systems, where pH ranges from 4 to 5) or to slightly alkaline conditions (e.g., spring runs, where pH values of 8 are not unusual) and are endangered only when the natural conditions are altered. The Michigan Water Quality Standard (Part 4 of Act 451) states that pH shall be maintained within the range of 6.5 to 9.0 in all waters of the state. pH did not exceed 8.6 during all sampling events.

When pollution results in higher algal and plant growth (e.g., from increased temperature or excess nutrients), pH levels may increase, as allowed by the buffering capacity of the lake. Although these small changes in pH are not likely to have a direct impact on aquatic life, they greatly influence the availability and solubility of all chemical forms in the lake and may aggravate nutrient problems. For example, a change in pH may increase the solubility of phosphorus, making it more available for plant growth and resulting in a greater long-term demand for dissolved oxygen. The pH at Gun Lake ranged between 7.41 and 8.6 for all sampling events. These numbers align with most lakes in the upper Midwest.

Dissolved oxygen (DO) and temperature are two fundamental measurements of lake productivity. The amount of dissolved oxygen in the water is an important indicator of overall lake health. A lake's oxygen and temperature patterns not only influence the physical and chemical qualities of a lake but the sources and quantities of phosphorus, as well as the types of fish and animal populations. By measuring dissolved oxygen and temperature, scientists can gauge the overall condition of a waterbody. Aquatic organisms need dissolved oxygen for their survival, while water temperature also directly influences aquatic organisms' growth and survival.

Higher dissolved oxygen concentrations are correlated with high primary productivity and little pollution. Oxygen saturation is temperature dependent, and cold water generally has higher dissolved oxygen concentrations than warm water. As the surface water temperature rises throughout the spring and summer, the denser cold water becomes trapped below the warm water and the lake becomes stratified. At deeper depths, oxygen is consumed by decomposition of organic material faster than it can be produced. Fish usually need a minimum DO of 4 mg/L to survive, indicated by the grey line on the figures below (United States Department of the Interior 2010b).

The DO levels at Gun Lake are sufficient to support fish down to 40 feet during summer stratification at site 1. Site 3 had DO levels sufficient to support fish down 30 feet in the spring and the fall, but the summer sample was only down to 20 feet. Site 2 was only sampled at the surface due to the shallow water level. Gun Lake tends to host relatively high dissolved oxygen numbers, which can generally indicate high water quality as seen in this recent year (Figures 9-14).

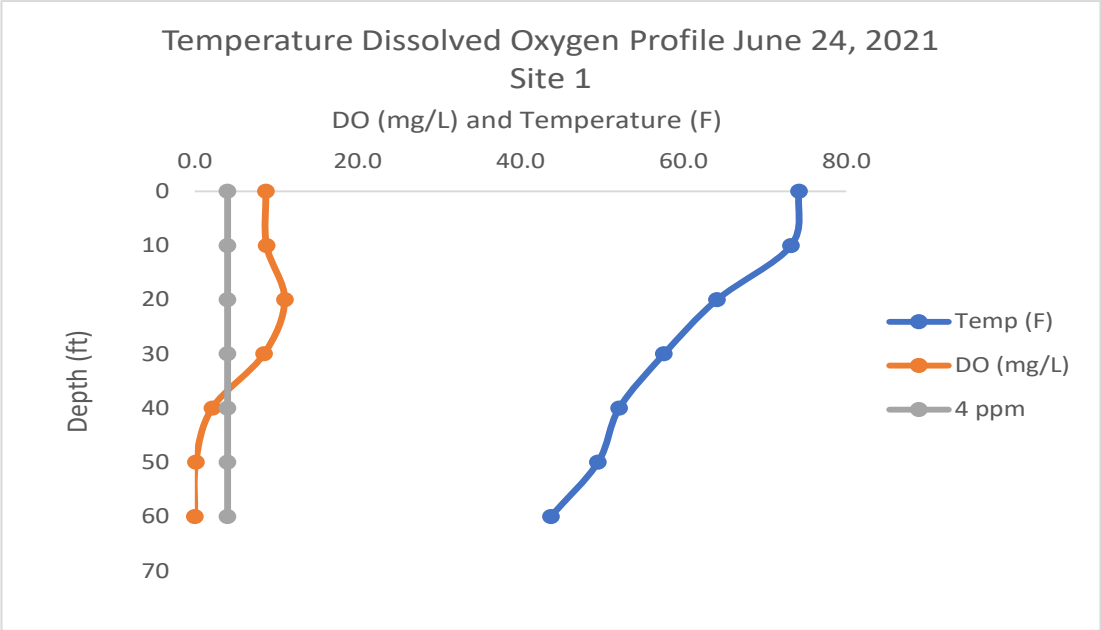

Figure 9. Temperature and Dissolved Oxygen profile for Gun Lake Site 1 June 24, 2021.

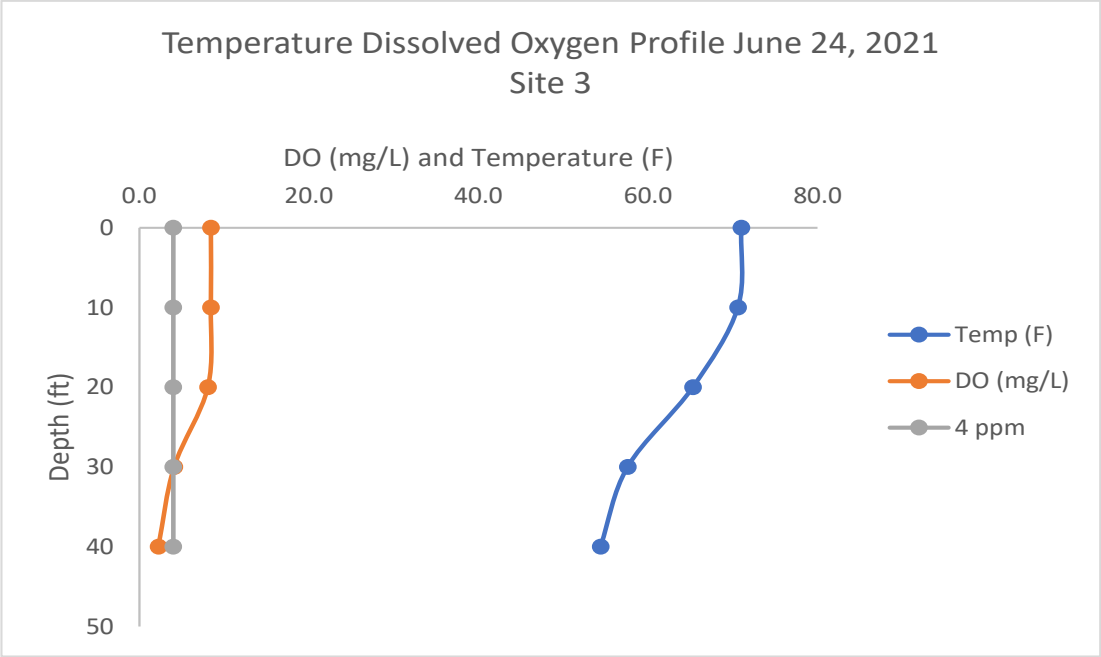

Figure 10. Temperature and Dissolved Oxygen profile for Gun Lake Site 3 June 24, 2021.

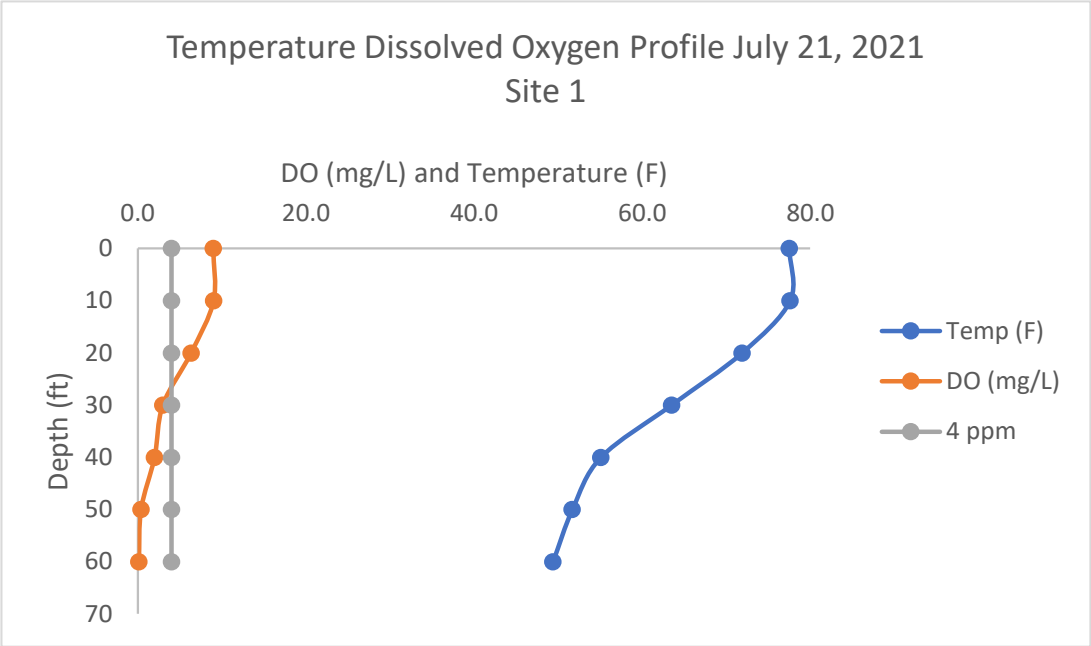

Figure 11. Temperature and Dissolved Oxygen profile for Gun Lake Site 1 July 21, 2021.

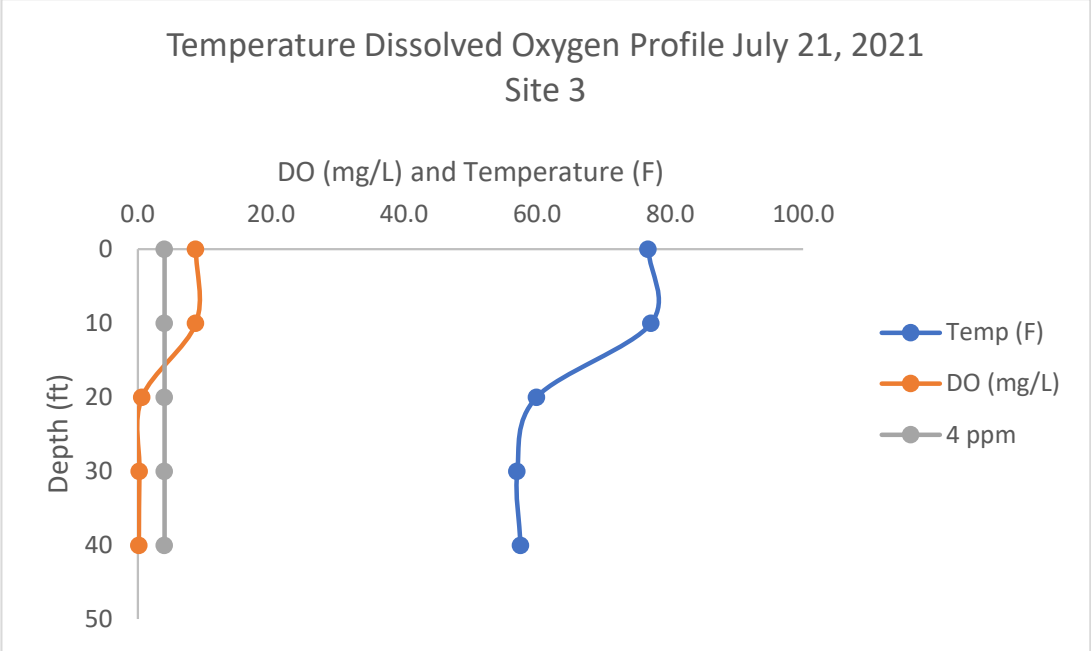

Figure 12. Temperature and Dissolved Oxygen profile for Gun Lake Site 3 July 21, 2021.

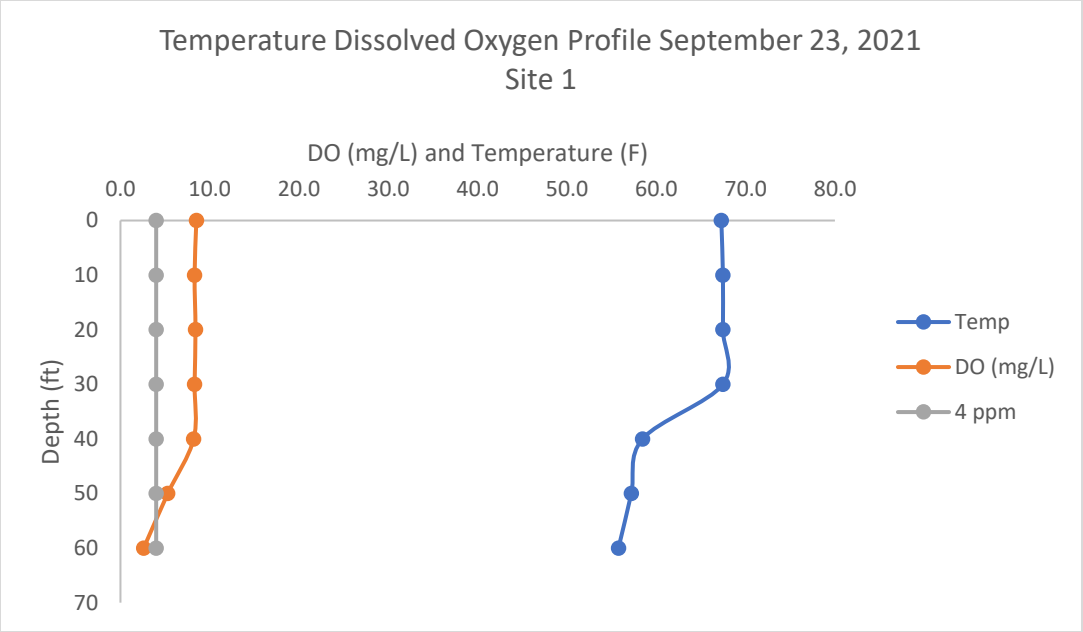

Figure 13. Temperature and Dissolved Oxygen profile for Gun Lake Site 1 September 23, 2021.

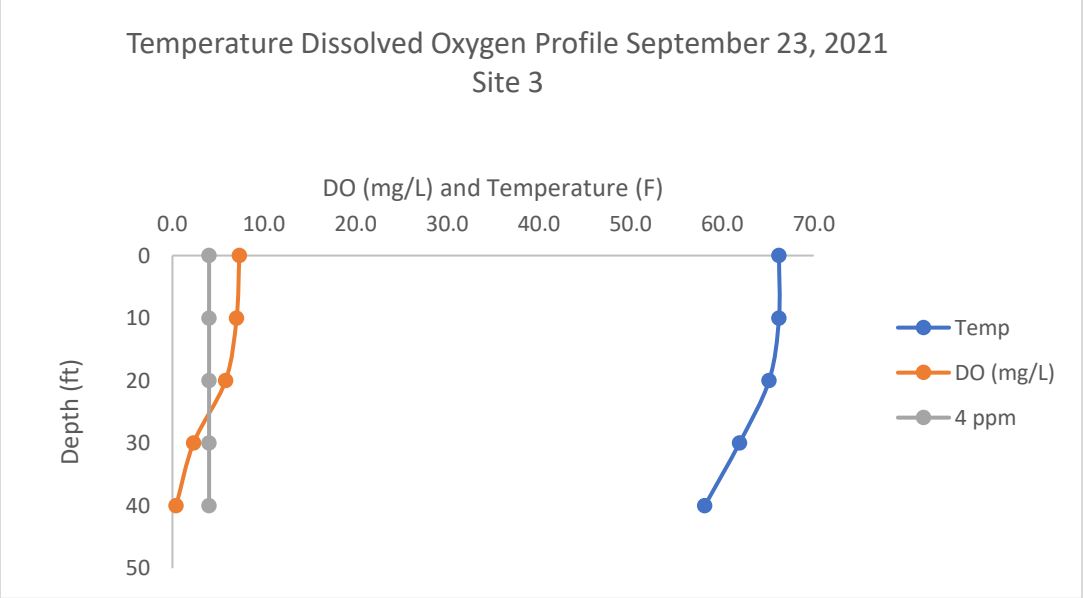

Figure 14. Temperature and Dissolved Oxygen profile for Gun Lake Site 3 September 23, 2021.

Shoreline Evaluation

Water is one of Michigan's most valuable resources and provides many benefits to its residents. It is important to protect and manage the water resource as it helps maintain and improve water quality. Water and nearshore areas are critical to health and wellbeing of fish, wildlife, and native plants and the species that depend on vegetated shorelines to provide healthy spawning areas, as well as habitat for feeding, resting, and other life stages. Gun Lake was evaluated on June 9, 2021, for undeveloped vs. developed shoreline. To categorize these areas, a developed shoreline contained a hardened surface such as a seawall or a highly altered shoreline that contained large rocks and boulders. An undeveloped shoreline was categorized as no hardened surface or seawall. Undeveloped shorelines consisted of natural areas and areas that were cleared to create water access and may have some areas of erosion. Minimal sites were observed with erosion, approximately 418 feet or 0.3% of the shoreline, while most of the Gun Lake shoreline is considered developed with hardened seawall or surfaces, this accumulated to a total of 106,487 feet or 71.7 % (Figure 15).

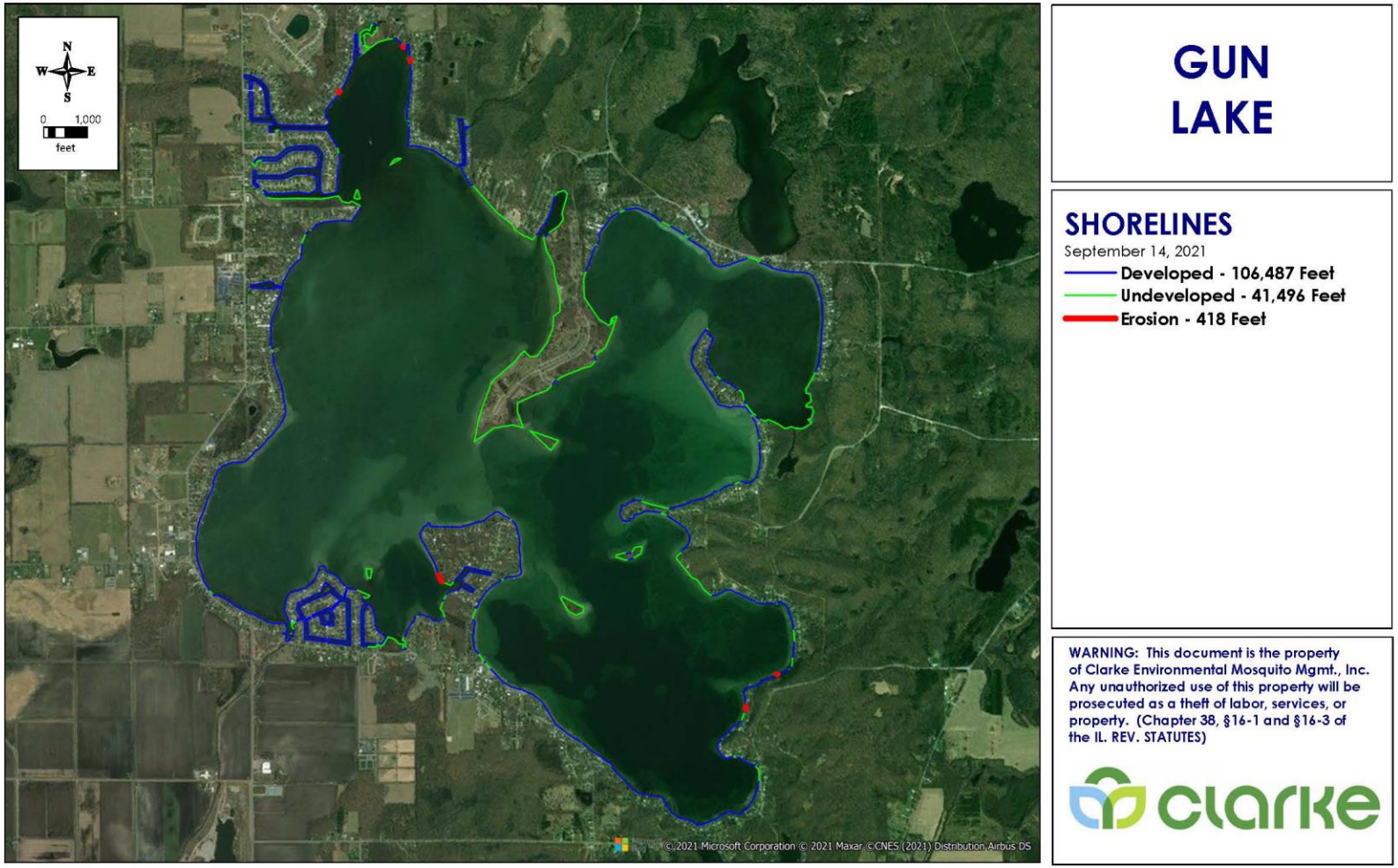

Figure 15. Gun Lake 2021 Shoreline Evaluation.

Lake Management Discussion and Action Plan

For 2022, we recommend a similar approach as in 2021. Routine monitoring and management will greatly improve the overall conditions of Gun Lake. Although throughout most of the lake submerged aquatic vegetation does not create unfavorable recreation conditions, in some areas submerged aquatic vegetation creates limitations for navigation and concerns among lake residents. Steps should be taken to manage invasive starry stonewort, Eurasian watermilfoil, and curly-leaf pondweed as they can create dense mats, clog waterways, interfere with fishing, swimming, and entangle propellers. Most invasive species can reach nuisance levels and thrive in conditions that are normally less habitable to native plant species. These invasive species can be controlled with early spring herbicide treatments and treatments as needed throughout the season.

The GLIB can authorize treatment of nuisance algae with several contact algaecides such as chelated copper. Results have been known to last longer in high alkaline waters with the use of copper chelates. It is important to treat algae as soon as they appear to prevent build up later in the season. Systemic herbicides will continue to be utilized to work toward eradication of invasive species.

The tentative schedule for 2022 services is as follows for the weeks beginning:

- April 18 — Newsletter & Treatment Notice Mailing
- April 25 — Vegetation Survey (CLPW)
Spring Water Quality Sampling
Inlet Monitoring – High Flow Sample
- May 2 — Herbicide Treatment
- May 23 — Vegetation Survey (EWM)
- May 31 — Herbicide Treatment
- June 20 — Vegetation Survey (Pre-July 4th)
- June 27 — Herbicide Treatment
- July 18 — Vegetation Survey (Nuisance native plants)
- August 1 — Herbicide Treatment
- August 22 — Vegetation Survey (Final inspection)
Summer Water Quality Sampling
Inlet Monitoring – Low Flow Sample

This schedule is designed to ideally time vegetation surveys based on the target plants and to be able to present the results at the upcoming GLIB meetings. The schedule includes herbicide treatments after the first four surveys. Herbicide treatments are dependent upon the results of the surveys, our professional recommendations, and the GLIB's approval of each treatment. Finally, this schedule may be modified based on weather, growing conditions, and aquatic vegetation community composition at the time of each service.

Gun Lake can benefit from a Biosonics hydroacoustic survey in 2022. Hydroacoustic technology has become important for assessing lake ecosystems, monitoring fish movement, and lake and stream health. The Biosonics Echosounder system consists of hydroacoustic equipment, which operates from a slow-moving boat and records bottom depth, submerged vegetation height, and submerged vegetation density. This information is coupled with geographic location coordinates from a Global Positioning System (GPS) and stored together in digital files, representing submerged aquatic vegetation (SAV) status and fish densities at points along transect lines.

Biosonics DT-XTM Echosounder and Visual Acquisition Software that provide data images and reports regarding depth and vegetation measurements within a body of water. The DT-X system consists of a surface unit (echosounder), digital transducers, a Global Positioning System GPS), and laptop computer which allows the user to control settings and functions of the surface unit and runs the software system enabling data collection. Hydroacoustic technology, according to Minnesota Department of Natural Resources, has proved to be an effective way to study various habitat influences, as well as map and monitor important physical and seasonal habitat parameters such as bathymetry, bottom character, and aquatic vegetation distribution (Hrabik et al, 2006).

BioSonics Mapping' can cover data points for all of the below in just one surveying session:

- Bathymetric mapping of submerged topography / depth levels
- Sediment analysis for dredging planning
- Surveying of aquatic and shoreline vegetation, invasive weed presence and density levels
- Treatment maps for weed and algae control with product recommendation
- Implementation of algae and weed treatment, littoral planting, and water quality management services
- Diagnostic, in-field and post-treatment mapping

Recommendations for Riparian Owners

To preserve the high level of water quality exhibited at Gun Lake, residents should monitor the amount of development within the watershed and around the lake. Increased development can cause sedimentation, displacement of soils, and increased number of pollutants entering the lake by way of surface runoff. Routine water quality monitoring will ensure early detection and remediation of any water impairments.

Lake users should take precautions to avoid spreading aquatic invasive species to or from Gun Lake. Plants such as Eurasian watermilfoil, hydrilla, and others can make waters virtually unusable and cause property values to plummet if spread. Creatures such as zebra mussels can clog drains and pipes. Fish diseases such as the emerging VHS (viral hemorrhagic septicemia) can result in large, widespread fish kills. Steps can be taken at access sites to minimize the spread of aquatic invasive species. Individuals should remove mud, plants, fish, or animals before transporting equipment, eliminate water from equipment before transporting, clean and dry anything that meets water (boats, trailers, equipment, clothing, dogs, etc.) and never release plants, fish, or animals into a body of water unless they came out of that body of water. The Stop Aquatic Hitchhikers campaign provides outreach and educational resources to lake associations. More information can be found at www.protectyourwaters.net. With these simple steps, individuals can continue to protect the water quality of Gun Lake. Gun Lake has three boat wash stations that can be utilized by lake users as they leave Gun Lake.

Residents should also consider improving or restoring shoreline habitat to that of a natural shoreline. Lake residents can consider replacing maintained lawns with native vegetation. In those areas that do not have seawalls, plants such as rushes (Juncus spp.), sedges (Carex spp.), pickerel weed (Pontederia cordata), arrowhead (Sagittaria latifolia), and blue-flag iris (Iris viginica) offer an attractive, low-profile community in wet areas. Behind existing seawalls, a variety of upland forbs and grasses that have lower fertilizer/pesticide maintenance requirements than turf grass may be planted in place of the turf grass. Plantings can even occur in front of existing seawalls. Bulrushes (Scirpus spp.) and taller emergents are recommended for this. While not providing all the functions of a natural shoreline, plantings in front of seawalls provide fish and invertebrate habitat. In addition, the restoration of natural shoreline or the planting of emergents in front of seawalls also discourages the use of these areas by Canada geese, whose droppings can increase the amount of phosphorus and nitrogen entering the lake. Geese prefer maintained lawns adjacent to shorelines as a food source because predators are clearly visible in lawns as opposed to areas of taller native vegetation. Partial or full restoration of the natural shoreline community with these measures would provide shoreline erosion control and filter runoff to the lakes, thus improving the lake's overall health without interfering with recreational uses of the lake.

To maintain excellent water quality, the Gun Lake Association should promote Best Management Practices (BMP) for homeowners, including the following:

- Reduce the frequency and amount of fertilizer and herbicide/pesticide used for lawn care.
- Use only phosphorus-free fertilizer unless a soil test indicates the need for phosphorus. This means that the middle number on the fertilizer package listing the nutrient ratio, nitrogen:phosphorus:potassium, is zero. More information can be found at https://clearchoicescleanwater.org/
- Consider re-landscaping lawn edges, particularly those along the lake, to include low profile prairie and wetland species that are capable of filtering runoff water better than turf grass.
- Consider planting native emergent vegetation along shorelines or in front of existing seawalls to provide fish and invertebrate habitat and dampen wave energy.
- Consider replacing or refacing concrete seawalls with glacial stone to dampen wave energy and provide some habitat for fish and invertebrates.
- Keep grass clippings, yard waste, and animal waste out of the lake.
- Reduce the runoff of stormwater from residential properties by disconnecting downspouts and installing rain barrels and rain gardens.
- Obey no-wake zones to minimize wave impact and reduce shoreline erosion.

By implementing the above recommendations, the residents and public can continue to enjoy the recreational and aesthetic benefits that Gun Lake provides for years to come.

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