RILEY PURGATORY BLUFF CREEK
WATERSHED DISTRICT

2023
Water Resources Report

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Photo of Rice Marsh Lake by Tom Duevel

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EXECUTIVE SUMMARY

The Riley Purgatory Bluff Creek Watershed District (RPBCWD) had a successful sampling season in 2023, completing a full year of sample collection and data analysis. This effort was made possible through multiple partnerships with municipalities and organizations based within the watershed. The results from the 2023 sampling effort are presented in this report. Table 1 provides an overview of water quality parameters. For a list of commonly used acronyms and abbreviations used in this report, see Exhibit K.

2023 LAKE SUMMARY

During the 2023 monitoring season, 13 lakes and two open-water wetlands were intensively monitored. Regular water quality lake sampling was conducted on each lake approximately every two weeks throughout the growing season (June-September). Surface water samples were collected, analyzed, and compared to standards set by the Minnesota Pollution Control Agency (MPCA) to assess overall lake health. Figure 1 displays lakes sampled in 2023 that met or exceeded the MPCA lake water quality standards.

In 2023, lake water quality remained relatively the same across the district with Lake Ann, Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Rice Marsh Lake, Lake Riley, and Round Lake meeting all three MPCA standards. Following the past aluminum sulfate treatments, both Lake Riley and Rice Marsh Lake continued to meet all MPCA standards and are in the process of being delisted from the MPCA Impaired Waters List for nutrients. Lake Susan had the most degraded water quality of all Riley chain lakes but did improve to meet the total phosphorous standard in 2023. Of the Purgatory Chain of Lakes, Red Rock Lake and Mitchell both improved from 2022 by meeting the TP standard, but neither meet the Chl-a standard. Silver had an increase in TP and is now just above the threshold from 2023. Hyland Lake continued to meet the standards in 2023 following the completed alum treatment in 2022. Staring Lake saw a decrease in water clarity and is now below all three MPCA standards. All lakes met the proposed nitrate water quality standard. Rice Marsh Lake and Idlewild were above the chloride standard in 2023. Susan and Staring have shown increasing chloride levels in 2023 and are approaching the standard.

Staff removed 394 Common carp (735 pounds) from the district in 2023, 365 of which were removed from the Purgatory Creek system during the spring migration. Following the winterkill in Staring Lake, a significant carp recruitment event occurred which is the first time since 2015. The district also monitored public access points and analyzed water samples for the presence of Zebra Mussels in 13 waterbodies. Zebra Mussel veligers and adults were found on Lake Riley in 2023, which was expected. During an intensive Zebra Mussel survey, adult Zebra Mussels were found on Lake Ann and a rapid response copper sulfate treatment was conducted to try and eliminate them from the lake. During an end of the year Zebra Mussel scan a boat lift

Table 1. Water quality parameter indications.

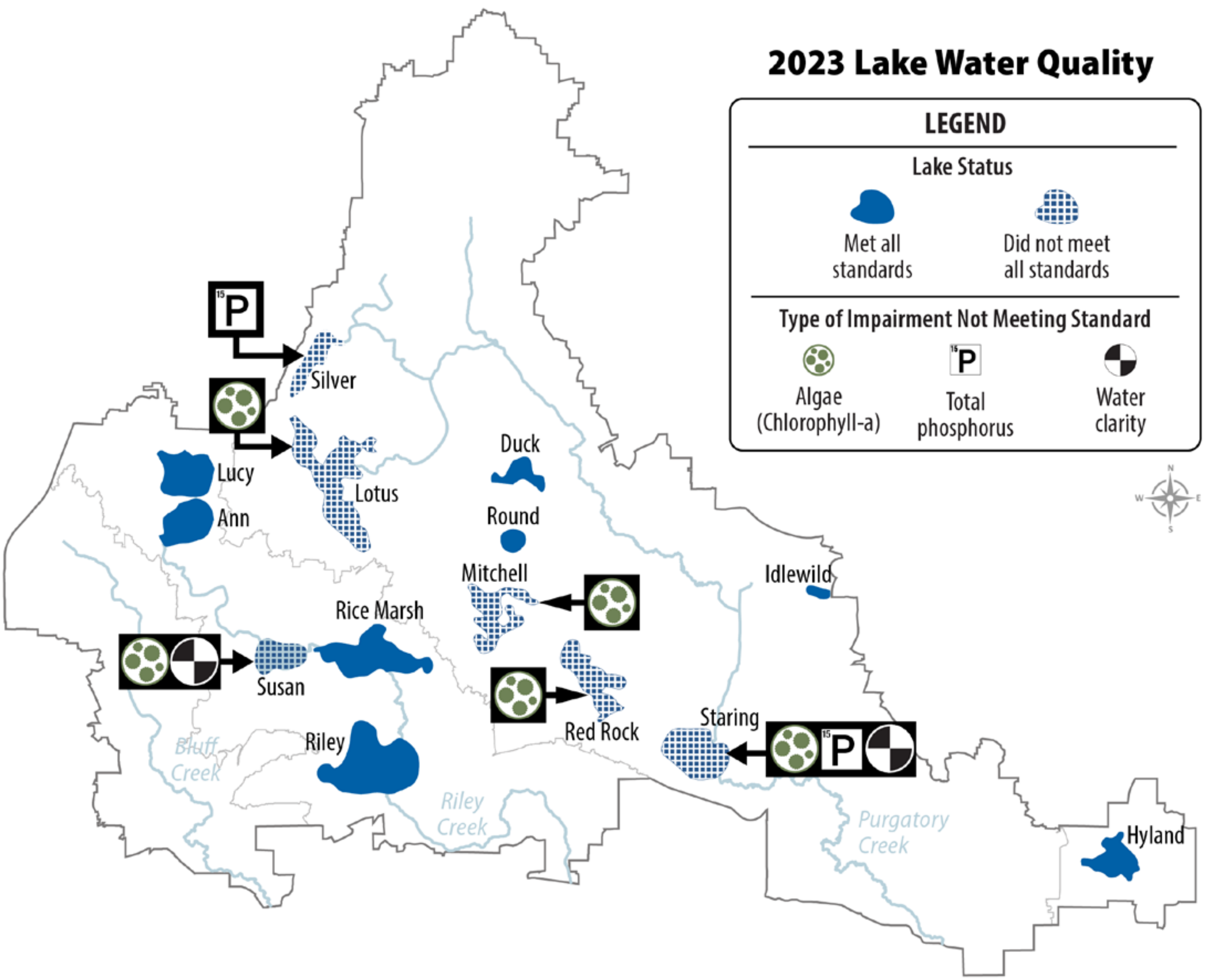
Abbreviation	What is stands for	What it indicates
Chl-a	Chlorophyll-a	Level of algae growth
CL	Chloride	Level of salt pollution
DO	Dissolved oxygen	Oxygen level of water
TP	Total phosphorus	Level of all phosphorus
TDP	Total dissolved phosphorus	Level of all available phosphorus
OP	Ortho phosphorus	Level of biologically available phosphorus
TSS	Total suspended solids	Level of silt/sediment suspended in water

with desiccated mussels was found onshore on Lotus Lake. Water samples processed for eDNA on Carver County lakes tested positive for the presence of Zebra Mussels in Lotus Lake and Lake Ann and veligers were also found on Lotus Lake. In 2023, point-intercept surveys were conducted on Hyland Lake (Three Rivers Park District), Mitchell Lake, Red Rock Lake (Eden Prairie), Lake Susan, Lake Riley, Staring Lake, Duck Lake, Silver Lake, and Lake Ann (RPBCWD). In the spring, Curly-leaf Pondweed was treated on Mitchell Lake (12.9 acres), Lake Riley (9 acres), Lake Susan (5.35 acres), and Red Rock (13 acres). Both Eurasian Watermilfoil and Curly-leaf Pondweed were targeted with a single treatment on Lotus Lake (22.92 acres).


Staff Maxwell collects water samples from Lake Susan.

Figure 1. Summary of lake water quality in 2023 within RPBCWD.

Summary of the lake water quality data collected within the Riley Purgatory Bluff Creek Watershed District in 2023 as compared to the Minnesota Pollution Control Agency Water Quality Standards. Chlorophyll-a, Total Phosphorus, and Secchi Disk depth during the growing season (June-September) for both "deep lakes" or lakes >15 ft deep and < 80% littoral area and "shallow lakes" or lakes <15 ft deep and >80% littoral area. The corresponding symbols next to each lake indicate which water quality standard was not met and lakes remaining blue met all water quality standards.



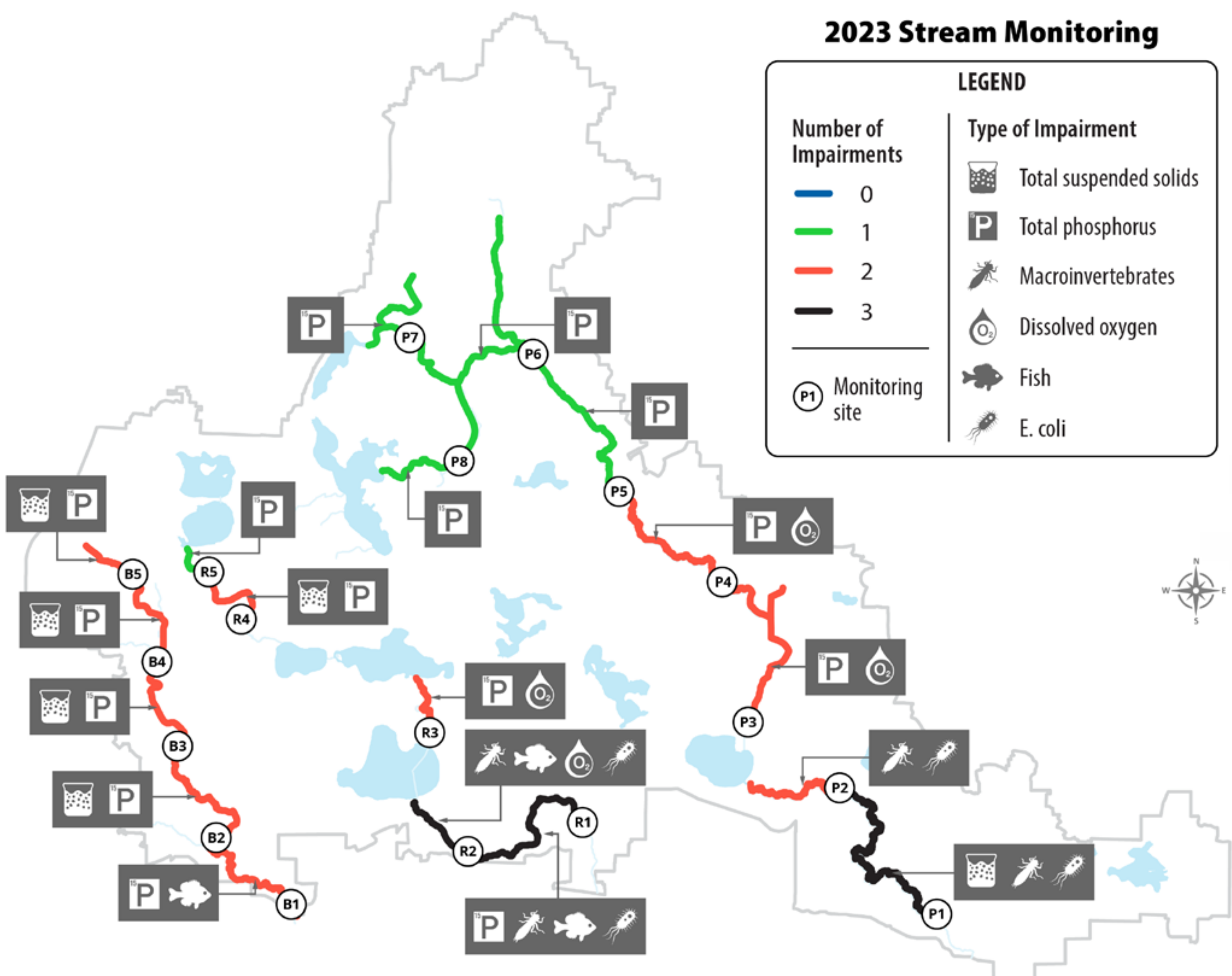
2023 STREAM SUMMARY

In 2023, RPBCWD and its partners collected water quality samples and performed data analysis on 28 different sampling sites along Riley Creek (six sites), Bluff Creek (eight sites), and Purgatory Creek (14 sites). During the 2023 creek monitoring season, (April-September) water chemistry, nutrients, and turbidity were regularly measured at the 18 regular water quality creek monitoring sites every two weeks. Creek flow was calculated by taking velocity measurements from consistent creek cross sections at each water quality monitoring location. Staff deployed automated sampling units on Purgatory Creek

Staff collect data for Bluff Creek.

Figure 2. Summary of stream water quality in 2023 within RPBCWD.

2023 stream water quality data from Bluff Creek, Riley Creek, and Purgatory Creek in the Riley Purgatory Bluff Creek Watershed District as compared to MPCA Water Quality Standards. Eighteen water monitoring locations (white circles) were sampled every other week and data from the individual sites were applied upstream to the next monitoring location. The summer season (April-September) eutrophication and total suspended solids water quality standards used in this assessment included: Dissolved Oxygen (DO) daily minimum > 4 mg/L, average Total Phosphorus (TP) < 0.1 mg/L, Total Suspended Solids (TSS) < 10% exceedance of 30 mg/L limit, average Chlorophyll-a (CHLA) <18 µg/L, average pH < 9 su and > 6 su. The corresponding labels next to each stream section indicate which water quality standards were not met.



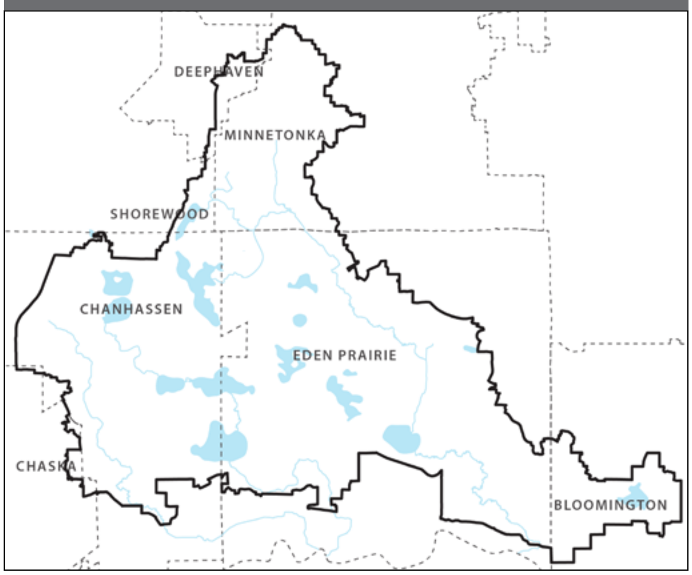
on the upper Lotus Lake ravines and Bluff Creek on the upper reach to assess pollutant loads and assess the potential for restoration projects. Data was also collected on all three creeks near the confluence with the Minnesota River at the Metropolitan Council's Watershed Outlet Monitoring Stations (WOMP). District staff attempted to collect macroinvertebrates at all Purgatory Creek regular water quality monitoring sites in 2023, however due to the low water levels only five sites were able to be sampled. Staff walked and assessed lower Bluff Creek and upper Riley Creek. Overall, most stream sections had Creek Restoration Action Strategy (CRAS) scores slightly improved from years past.

The summary for all three creeks is based on water quality parameters developed by the MPCA in 2014 for Eutrophication and TSS as well as impairment status for fish, macroinvertebrates, and E. coli can be seen in Figure 2. In 2023, the continued drought significantly impacted the streams. Of the 18 regular sampling sites, 14 went dry or became stagnant at some point. From 2022 to 2023, stream water quality was reduced slightly across the district. Excluding the dissolved oxygen impairment, the number of water quality standard exceedances remained relatively the same from 2022. Bluff had 10, Riley has had 13, and Purgatory had 13 water quality standard exceedances. No regular creek sampling sites met all MPCA water quality standards assessed in 2023 . Like previous years, TP was the water quality standard causing the most impairments in 2023 with 15 of the 18 sites not meeting the standard. TSS impairments were slightly reduced from 2022, which is likely related to the low flows. In 2023, Riley Creek had the most water quality exceedances with 13. MPCA macroinvertebrate and E. coli impairments included the lower reaches of Riley and Purgatory Creeks. The lower reaches of Riley and Bluff creeks had fish impairments.

1: INTRODUCTION

The Riley Purgatory Bluff Creek Watershed District (RPBCWD) was established on July 31, 1969, by the Minnesota Water Resources Board acting under the authority of the watershed law. The district is located in the southwestern Twin Cities Metropolitan Area. It consists of a largely developed urban landscape and encompasses portions of Bloomington, Chanhassen, Chaska, Deephaven, Eden Prairie, Minnetonka, and Shorewood (Figure 3). The watershed district includes portions of both Hennepin and Carver counties. The total district area is about 50 square miles and includes three creek subwatersheds: Riley Creek, Purgatory Creek, and Bluff Creek.

Figure 3. Cities with land within the RPBCWD boundary.



Data collection and reporting are the foundation of the District's work. Regular, detailed water quality monitoring provides staff with scientifically reliable information needed to decide if water improvement projects are needed and how effective they are in watershed improvement. Data collection remains a key component of the district's work as we strive to de-list, protect, and improve the waterbodies within the watershed. The purpose of this report is to summarize the water quality and quantity results collected over the past year, which can be used to direct the district in managing our water resources.

Through partnerships with various cities, Three Rivers Park District (TRPD), the University of Minnesota (UMN), Metropolitan Council (METC), and Carver County, data was collected on 13 lakes and two wetlands (Lake Idlewild and Neill Lake). In 2023, the district and its partners collected water quality samples and performed data analysis on 28 different sampling sites along Riley Creek (six sites), Bluff Creek (eight sites), and Purgatory Creek (fourteen sites). Each partner was responsible for monitoring particular parameters of their respective lakes and/or streams and reporting their findings, allowing for more time and attention to be given to each individual water resource (see Table 2). Monitoring frequency and intensity depended on monitoring purpose(s).

Water quality and quantity were monitored at each regular stream monitoring site during the field season (April-September) typically twice a month. The district assisted METC with collecting data at continuous monitoring stations near the outlet of each creek as part of its Watershed Outlet Monitoring Program

Table 2. Water resources sampling partnerships.

Name	RPBCWD	Three Rivers Park District	City of Eden Prairie	Carver County	Met Council
LAKES					
Ann	💧			💧	
Duck	💧				
Hyland	💧	💧			
Idlewild	💧				
Lotus	💧			💧	
Lucy	💧				
McCoy	💧				
Mitchell	💧		💧		
Neill	💧				
Red Rock	💧		💧		
Rice Marsh	💧				
Riley	💧				
Round	💧		💧		
Silver	💧				
Staring	💧				
Susan	💧			💧	
CREEKS					
Bluff	💧				💧
Purgatory	💧				💧
Riley	💧		💧		💧

(WOMP) or long-term monitoring program which identifies pollutant loads entering the Minnesota River.

In addition to water quality monitoring, staff conducted creek walks to gather more information about current stream conditions. The information was included in the Creek Restoration Action Strategy (CRAS), which was developed by the district to identify and prioritize future stream restoration sites. More information about CRAS is available in Chapter 4.9. Bank pin data was collected near each of the creek water quality monitoring sites to measure generalized sedimentation and erosion rates. In 2023, macroinvertebrates were collected from Purgatory Creek but only five of eight sites could be sampled due to low water levels.

Lakes were also monitored bi-weekly during the summer growing season (June-September), and lake levels were continuously recorded from ice-out to ice-in. Lake water samples were collected in early summer and analyzed for the presence of Zebra Mussel veligers. Additionally, during every sampling event, boat launch areas and Zebra Mussel monitoring plates were scanned for adult Zebra Mussels and other aquatic invasive species (AIS).

Zooplankton and phytoplankton samples were collected on five lakes to assess the overall health of the population as it applies to fishery health and water quality. Plant surveys and herbicide treatments were also conducted to assess overall health of the aquatic plant community and to reduce the number of invasive aquatic plants.

Common carp have been identified as being detrimental to lake health and are continually monitored by the district. In 2023, winter monitoring occurred on the Riley Chain of Lakes as well as three separate stormwater ponds. Extending monitoring activities into winter months can provide key insights into ways to improve water quality during the summer months. Winter monitoring also allows us to evaluate the influence of chloride levels in our lakes. The data collection and reporting events were tracked throughout the year (see summary in Table 3).

In addition to lakes and streams, multiple specialty projects were monitored to evaluate their effectiveness at preventing or contributing pollutant loads to the watershed.

Table 3. Monthly field data collection locations.

Waterbody name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
LAKES												
Ann	💧	💧	💧		💧	💧	💧	💧	💧	💧		
Duck	💧	💧	💧		💧	💧	💧	💧	💧	💧		
Hyland					💧	💧	💧	💧	💧	💧		
Idlewild					💧	💧	💧	💧	💧	💧		
Lotus					💧	💧	💧	💧	💧	💧		
Lucy	💧	💧	💧		💧	💧	💧	💧	💧	💧		
McCoy					💧							
Mitchell					💧	💧	💧	💧	💧	💧		
Neill					💧	💧	💧	💧	💧	💧		
Red Rock					💧	💧	💧	💧	💧	💧		
Rice Marsh	💧	💧	💧		💧	💧	💧	💧	💧	💧		
Riley	💧	💧	💧		💧	💧	💧	💧	💧	💧		
Round					💧	💧	💧	💧	💧	💧		
Silver					💧	💧	💧	💧	💧	💧		
Staring	💧	💧	💧		💧	💧	💧	💧	💧	💧		
Susan	💧	💧	💧		💧	💧	💧	💧	💧	💧		
CREEKS												
Bluff	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧
Purgatory	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧
Riley	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧

2: METHODS

Water quality and quantity monitoring entails the collection of multi-probe sonde data readings, water samples, zooplankton samples, phytoplankton samples, macroinvertebrate samples, Zebra Mussel veliger samples, and physical readings, as well as recording the general site and climactic conditions at the time of sampling. Listed in the following sections are the methods and materials, for both lake and stream monitoring, used to gather water data during the field monitoring season Table 4 identifies many of the different chemical, physical, and biological variables analyzed to assess overall water quality.

2.1. Water Quality Sampling

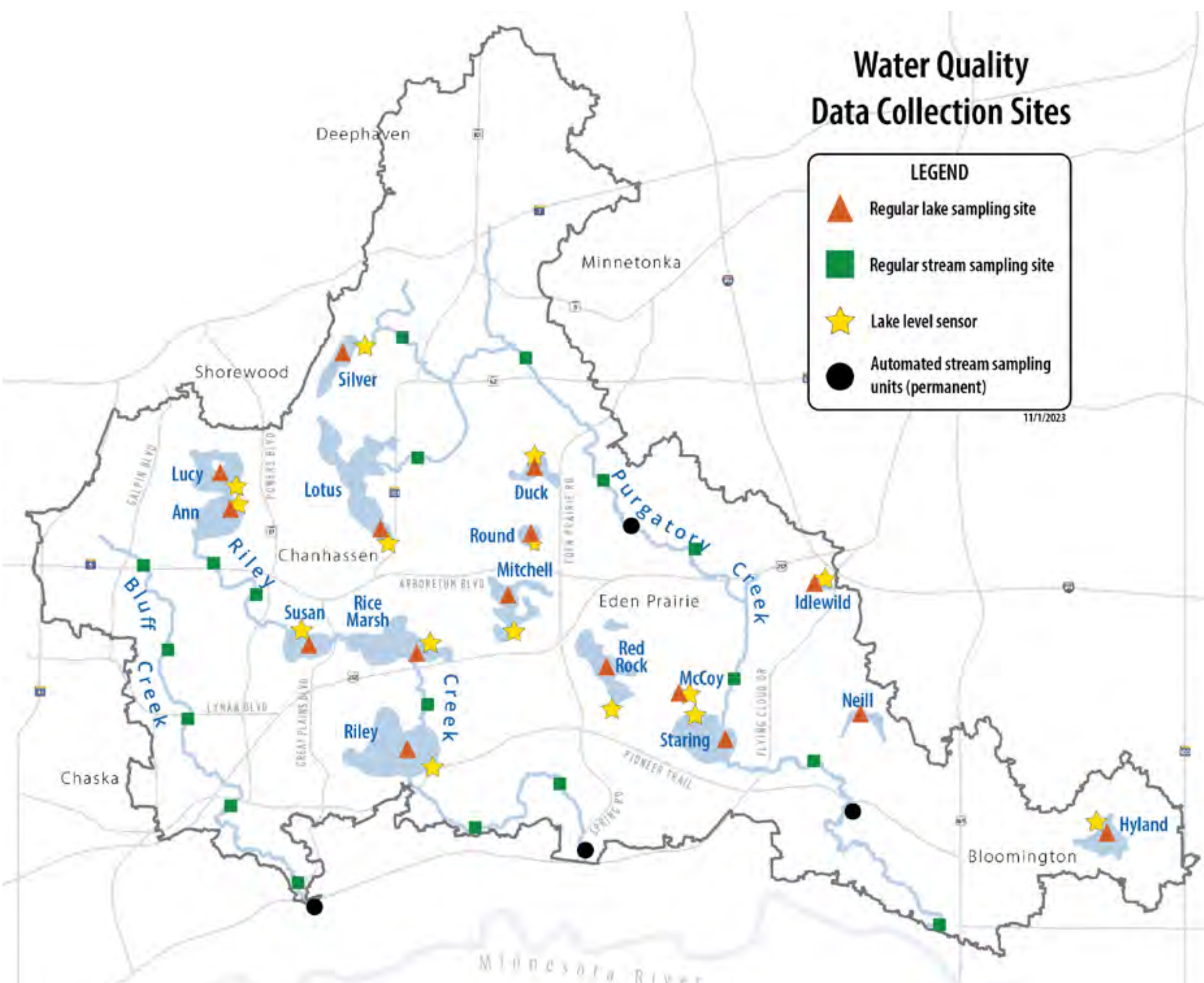
The data collection and monitoring program supports the District's 10-year management plan to delist waters from the MPCA 303d Impaired Waters list. The parameters monitored during the field season help determine the sources of water quality impairments and provide supporting data that is necessary to best design and implement water quality improvement projects. Table 5 provides an overview of

Table 4. Water quality sampling parameters.

Parameter	How data is collected	Where and when data is collected			Reason for monitoring the parameter
		Lakes - Summer	Lakes - Winter	Streams	
Total Phosphorus (TP)	Water sample	💧	💧	💧	Nutrient that controls algae growth
Orthophosphate	Water sample	💧	💧	💧	Nutrient; form of phosphorus (P) available to algae
Total Dissolved Phosphorus	Water sample	--	--	💧	Fraction of total phosphorus (P) in solution
Chlorophyll-a, pheophytin	Water sample	💧	💧	💧	Measure of algae concentration
Ammonia as N	Water sample	💧	💧	--	Nutrient; form of nitrogen (N) available to algae
Nitrate + Nitrite as N	Water sample	💧	💧	--	Nutrient and oxygen substitute for bacteria
Total Kjeldahl Nitrogen	Water sample	💧	--	--	Nutrient; sum of nitrogen bound in organics
Calcium (Ca)	Water sample	💧	--	--	Measure of water hardness
Total Alkalinity, adjusted	Water sample	💧	💧	--	Measure of ability to resist drop in pH
Total Suspended Solids (TSS)	Water sample	--	--	💧	Measure of solids in water (solids block light)
Chloride (Cl)	Water sample	💧	💧	💧	Measure of chloride ions (salts) in water
Temperature	Sonde	💧	💧	💧	Impacts biological and chemical activity in water
pH	Sonde	💧	💧	💧	Acidity/alkalinity level impacts chemical reactions
Conductivity	Sonde	💧	💧	💧	Indicates ability to carry an electrical current (TSS and Cl)
Dissolved Oxygen (DO)	Sonde	💧	💧	💧	Oxygen available to aquatic organisms
Macroinvertebrates	Water sample	--	--	💧	Organisms that fluctuate due to environmental conditions
Oxidation Reduction Potential	Sonde	💧	💧	💧	Tracks chemistry in low- or no-oxygen conditions
Phycocyanin	Sonde	💧	💧	--	Indicates measure of cyanobacteria concentration based on pigment
Phytoplankton	Water sample	💧	--	--	Organisms that fluctuate due to environmental conditions
Turbidity	Sonde	--	--	💧	Measure of light penetration in shallow water
Secchi disk depth	Observation	💧	💧	--	Measure of light penetration in deep water
Transparency tube	Observation	--	--	💧	Measure of light penetration in shallow water
Zooplankton	Water sample	💧	--	--	Organisms that fluctuate due to environmental conditions
Zebra Mussel veligers (larvae)	Water sample	💧	--	--	Use of monitoring plates tracks presence/abundance of Zebra Mussels (AIS)

Table 5. An overview of water quality data collection sites.

Type	Purpose	Data collected	Number of sites/units
Regular lake sampling site ▲	Staff collect bi-weekly samples at the same locations to allow comparison from year-to-year and trends over time.	TP, OP, Cl, Chl-a, TSS	*One site each at these lakes*: Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Rice Marsh, Red Rock, Riley, Round, Silver, Staring, Susan *One site each at these waterbodies*: Idlewild, McCoy, Neill
Regular stream sampling site ■	Staff collect bi-weekly samples at the same locations to allow comparison from year-to-year and trends over time.	TP, OP, Cl, Chl-a, TSS, water flow rate	Bluff Creek: 5 sites Riley Creek: 5 sites Purgatory Creek: 8 sites
Lake level sensor ☆	In-lake sensors collect lake level data.	Lake level	*One each at these lakes*: Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Rice Marsh, Red Rock, Riley, Round, Silver, Staring, Susan *One each at these waterbodies*: Idlewild, McCoy
Automated stream sampling unit - *Permanent* ●	Units collect data continuously and collect water samples during storm events. Permanent locations allow comparison.	*Continuous*: Water level, temperature, flow rate, conductivity *Storm events*: TP, OP, Chl-a, TDP, TSS	Bluff Creek: 1 site near RPBCWD southern boundary Riley Creek: 1 site near RPBCWD southern boundary Purgatory Creek: 1 site east of Round Lake; 1 site near Pioneer Trail
Automated stream sampling unit - *Temporary*	Units collect data continuously and collect water samples during storm events. Temporary units installed as needed at project sites to collect data before/ during/after project installation.	*Continuous*: Water level, temperature, flow rate, conductivity *Storm events*: TP, OP, Chl-a, TDP, TSS	Varies and is based upon project site monitoring needs.



sampling locations and purpose.

Multi-probe sondes (Hach Lake DS-5 and Stream MS-5; YSI EXO3) were used for collecting water quality measurements across both streams and lakes. Sonde readings measured include temperature, pH, dissolved oxygen, conductivity, oxidation reduction potential (ORP), and phycocyanin. Secchi disk depth readings were recorded at the same time as sonde readings at all lake sampling locations. When monitoring stream locations, transparency, turbidity (Hach 2100Q), and flow measurements (Flow Tracker) were collected. General site conditions related to weather and other observations were recorded as well.

At each lake monitoring location, multiple water samples are collected using a Van Dorn, and a depth integration sampler, for analytical laboratory analysis. For Duck, Idlewild, Rice Marsh, Silver, and Staring Lakes, water samples were collected at the surface and bottom due to their shallow depths of two to three meters. For all other lakes within the District, water samples were collected at the surface, middle (when stratified), and bottom of the lake. Lakes are monitored at the same location on each sampling trip, typically at the deepest location of the lake. All samples are collected from whole or half-meter depths to the lake bottom. The surface sample is a composite sample of the top two meters of the water column. The middle sample is collected from the approximate midpoint of the temperature/ dissolved oxygen change (greater than one degree Celsius change) or thermocline. Pictures and climatic data are collected at each monitoring site. Winter water quality information is collected utilizing the same procedures as in the summer. Zooplankton samples were collected using a 63 micrometer Wisconsin style zooplankton net and Phytoplankton samples were collected using a two-meter integrated water sampler on Lake Susan, Lotus Lake, Staring Lake, Lake Riley, and Rice Marsh Lake. Zooplankton are collected by lowering the net to a depth of one-half meter from the bottom at the deepest point in the lake and raising it slowly. Zebra Mussel veliger samples were collected on all lakes using the same zooplankton sampling procedures but collected at three sites and consolidated before being sent to a lab for analysis. A Zeiss Primo Star microscope

Table 6. Water Quality Monitoring Activities.

Pre-Field Work Activities	• Calibrate Water Quality Sensors (sonde) • Obtain Water Sample Bottles and Labels from Analytical Lab • Prepare Other Equipment and Perform Safety Checks • Coordinate Events with Other Projects and Other Entities
Summer Lake – Physical and Chemical	• Navigate to Monitoring Location • Read Secchi Disk Depth and Record Climatic Data • Record Water Quality Sonde Readings at Meter/Half Meter Intervals • Collect Water Samples from Top, Thermocline, and Bottom
Summer Lake – Biological	• Collect Zooplankton Tow (steady pull of net) from Lake Bottom to Top • Collect Phytoplankton (2 m surface composite sample) • Collect Zebra Mussel Veliger Tow (steady pull of net) from Lake Bottom to Top at Multiple Sites
Winter Lakes	• Navigate to Monitoring Location • Record Ice Thickness • Read Secchi Disk Depth and Record Climatic Data • Record Water Quality Sonde Readings at Meter Intervals • Collect Water Samples from Top and Bottom
Streams – Physical, Chemical, and Biological	• Navigate to Monitoring Location • Measure Total Flow by Measuring Velocity at 0.3 to 1 Foot Increments across Stream • Record Water Quality Sonde Measurements from Middle of Stream • Read Transparency Tube and Perform Turbidity Test • Collect Water Samples from Middle of Stream • Collect macroinvertebrate samples (D-net collection across representative habitat types) • Collect Climatic Data and Take Photos
Post-Field Work Activities	• Ship Water Samples to Analytical Lab • Enter Data, Perform Quality Control Checks, and Format Data for Database • Clean and Repair Equipment • Reporting and Summarizing Data for Managers, Citizens, Cities, and Others

with a Zeiss Axiocam 100 digital camera was used to monitor zooplankton populations, scan for invasive zooplankton, and to calculate Cladoceran-grazing rates on algae.

Water quality samples collected during stream monitoring events were collected from the approximate middle (width and depth) of the stream in ideal flow conditions or from along the bank when necessary. Both water quality samples and flow monitoring activities were performed in the same section of the creek during each sampling event. Stream velocity was calculated at 0.3 to 1.5-foot increments across the width of the stream using the FlowTracker Velocity Meter at each sampling location. If no water or flow was observed, only pictures and climatic data were collected. Macroinvertebrate samples were collected on one stream per year on a rotating basis. A D-net was used to sample macroinvertebrates and each habitat type was sampled proportional to the amount of habitat in each reach. The activities associated with the monitoring program are described in Table 6.

2.2. Analytical Lab Methods

RMB Environmental Labs, located in Burnsville, Minnesota, is the third-party company that is responsible for conducting analytical tests on the water samples that were collected by district staff. The methods used by the laboratory to analyze the water samples for the specified parameters are noted in Table 7.

Additional samples were sent to the Metropolitan Council (METC), Saint Paul, Minnesota. These samples included quality samples for the Watershed Outlet Monitoring Program (WOMP) and other permanent auto sampling stream units. Macroinvertebrate samples were sent to RMB, and all phytoplankton samples were sent to Barr Engineering. Zebra Mussel veliger samples were processed by Kylie Cattoor, an independent consultant.

Table 7. RMB Environmental Laboratories Parameters and Methods used for Analyses.

PARAMETER	STANDARD METHOD
Alkalinity	EPA 310.2, SM 2320 B-2011
Ammonia	EPA 350.1 Rev 2.0 or Timberline Ammonia-001
Nitrogen, Nitrate & Nitrite	EPA 353.2 Rev 2.0
Chlorophyll-a	SM 10200H
Total Phosphorus	EPA 365.3
Orthophosphate	EPA 365.3
Chloride	SM 4500-Cl E-2011
Total Kjeldahl Nitrogen	EPA 351.2 or Timberline Kjeldahl Nitrogen-001
Calcium	EPA 200.7
Total Dissolved Phosphorus	365.3_LF_(DL)
Total Suspended Solids	USGS_(BL)

3: WATER QUALITY

In 1974, the Federal Clean Water Act set forth the requirement for states to develop water quality standards for surface waters. In 2014, specific standards were developed for eutrophication and Total Suspended Solids (TSS) for rivers and streams. In Minnesota, the agency in charge of regulating water quality is the Minnesota Pollution Control Agency (MPCA). Water quality monitoring and reporting is a priority for the District to determine the overall health of the waterbodies within the watershed boundaries. The District's main objectives are to prevent a decline in the overall water quality within lakes and streams and to prevent waterbodies from being added to the MPCA 303(d) Impaired Waters list. The District is also charged with the responsibility to take appropriate actions to improve the water quality in waterbodies that are currently listed for impairments.

There are seven ecoregions in Minnesota. RPBCWD is within the Northern Central Hardwood Forest (NCHF) Ecoregion. Rural areas in the NCHF are dominated by agricultural land and fertile soils. For most water resources in the region, phosphorus is the limiting (least available) nutrient within lakes and streams, meaning that the available concentration of phosphorus often controls the extent of algal growth. The accumulation of excess nutrients (i.e., TP and Chl-a) in a waterbody is called eutrophication. This relationship has a direct impact on the clarity and recreational potential of our lakes and streams. Waterbodies with high phosphorus concentrations and increased levels of algal production have reduced water clarity and limited recreational potential.

All lakes sampled in the District are considered Class 2B surface waters. The MPCA states that this class of surface waters should support the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. They should also be suitable for aquatic recreation of all kinds, including bathing. This class of surface water is not protected as a source of drinking water. For more detailed information regarding water quality standards in Minnesota, please see the MPCA Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment, 305(b) Report, and 303(d) List of Impaired Waters. These resources provide information to better understand the water quality assessment process and the reasoning behind their implementation (MPCA 2021).

3.1. Lakes

The MPCA has standards for lakes based upon their maximum depth and percent of littoral zone (surface area able to support aquatic plants. "Deep lakes" are defined as more than 15 feet

Figure 4. MPCA water quality standards used for waterbodies in RPBCWD.

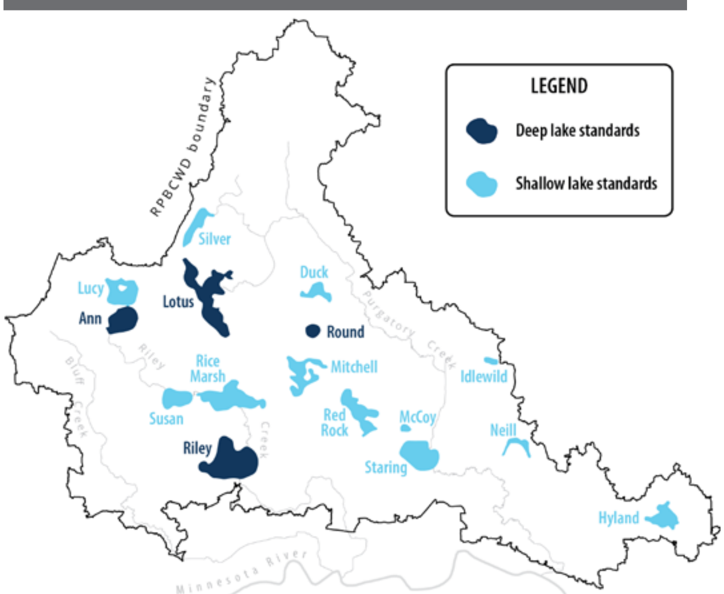


Table 8. MPCA Water Quality Standards for Lakes.

PARAMETER	SHALLOW LAKES CRITERIA (<15 ft deep)	DEEP LAKES CRITERIA (>15 ft deep)
Total Phosphorus (mg/L)	≤ 0.060	≤ 0.040
Chlorophyll-a (µg/L)	≤ 20	≤ 14
Secchi Disk (m)	≥ 1	≥ 1.4
Chloride Chronic Standard (mg/L)	230	230
Chloride Maximum Standard (mg/L)	860	860

deep and less than 80 percent of littoral zone. "Shallow lakes" are defined as less than 15 feet deep and greater than 80 percent littoral zone. See Figure 4 for lake classifications within RPBCWD. Except for chlorides, summer growing season (June-September) averages of the parameters listed in Table 8 for each lake are compared to the MPCA standards to determine the overall state of the lake. The standards are set in place to address issues of eutrophication (excess nutrients) in local waterbodies. Staff collect water samples and send them to a laboratory to assess concentrations of TP, Chl-a, and chlorides. If result values are greater than the standards listed in Table 8, the lake is considered impaired. Secchi disk readings are collected to measure the transparency (visibility) in each lake. A higher individual reading corresponds to increased clarity within the lake (this indicates the Secchi Disk was visible at a deeper depth in the water column).

Chlorides (Cl) are of increasing concern in Minnesota, especially during the winter when de-icing salt is heavily used. Targeted sampling occurs during the winter and early spring melting periods when salts are being flushed through our waterbodies. Monthly samples are collected during the summer to establish a baseline for chloride in our lakes and streams. The chloride standard is the same for both deep and shallow lakes. Table 8 includes both the Chloride chronic standard (CS) and a maximum standard (MS). The CS is the highest water concentration of Chloride to which aquatic life, humans, or wildlife can be exposed to indefinitely without causing chronic toxicity. The MS is the highest concentration of Chloride in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality.

3.2. Streams

Table 9 displays water quality parameters developed by the MPCA in 2014 for eutrophication and TSS in streams. The standards include some parameters the District has not yet incorporated into their monitoring procedures that may eventually be added in the future. All streams sampled in the District are considered Class 2B surface waters. The MPCA states that this class of surface waters should support the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. They should also be suitable for aquatic recreation of all kinds including bathing. This class of surface water is not protected as a source of drinking water. For more detailed information regarding water quality standards in Minnesota, please see the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment, 305(b) Report and the 303(d) List of Impaired Waters. These resources provide information to better understand the water quality assessment process and the reasoning behind their implementation.

Eutrophication pollution is measured based upon the exceedance of the summer growing season average (May-September) of Total Phosphorus (TP) levels and Chl-a (seston), five-day biochemical oxygen demand (cBOD, amount of DO needed by organisms to breakdown organic material present in a given water sample at a certain temperature over a five-day period), diel DO flux (difference between the maximum DO concentration and the minimum daily DO concentration), or summer average pH levels. Streams that exceed the phosphorus standard but do not exceed the Chl-a (seston), cBOD, diel DO flux, or pH standard meet the eutrophication

Table 9. MPCA Water Quality Standards for Streams.

MPCA STANDARD	PARAMETER	CRITERIA
Eutrophication	Phosphorus	≤ 100 µg/L
	Chlorophyll-a (seston)	≤ 18 µg/L
	Diel Dissolved Oxygen	≤ 3.5 mg/L
	Biochemical Oxygen Demand	≥ 2 mg/L
	pH Maximum	≤ 9 su
	pH Minimum	≥ 6.5 su
Total Suspended Solids	TSS	≤ 30 mg/L

standard. The District added Chl-a to its monthly sampling regime in 2015 to account for the polluted condition that occurs when Chl-a (periphyton) concentration exceeds 18 µg/L. The daily minimum DO concentration for all Class 2B waters cannot dip below 4 mg/L to achieve the MPCA standard, which was used in the analysis for this report.

TSS is a measure of the amount of particulate (soil particles, algae, etc.) in the water. Increased levels of TSS can be associated with many negative effects including nutrient transport, reduced aesthetic value, reduced aquatic biota, and decreased water clarity. For the MPCA standard, TSS concentrations are assessed from April through September and cannot exceed 30 mg/L more than 10 percent of the time during that period.

Photo of Lake Lucy by Sharon McCotter.

4: DATA COLLECTION

To assess and improve water quality within the watershed, the District continues to collect long-term data from specific locations on waterbodies to monitor temporal changes or gage the success or need of a water quality project. The District also conducts studies to root out key sources of pollution or other negative variables that impact our lakes and streams. Once identified, the District will often monitor these locations and eventually act to improve the water resource if the data confirms the suspicion. Below is a summary of each special project/monitoring and an overall summary of the long-term water quality data the District has collected.

4.1. 2023 Lakes Eutrophication Summary

More information about lake nutrient and water clarity data can be seen in the water quality factsheets located on the District website (rpbcwd.org/factsheets). Nutrient summary tables and Sonde lake profile data is located in the Exhibit G and Exhibit H.

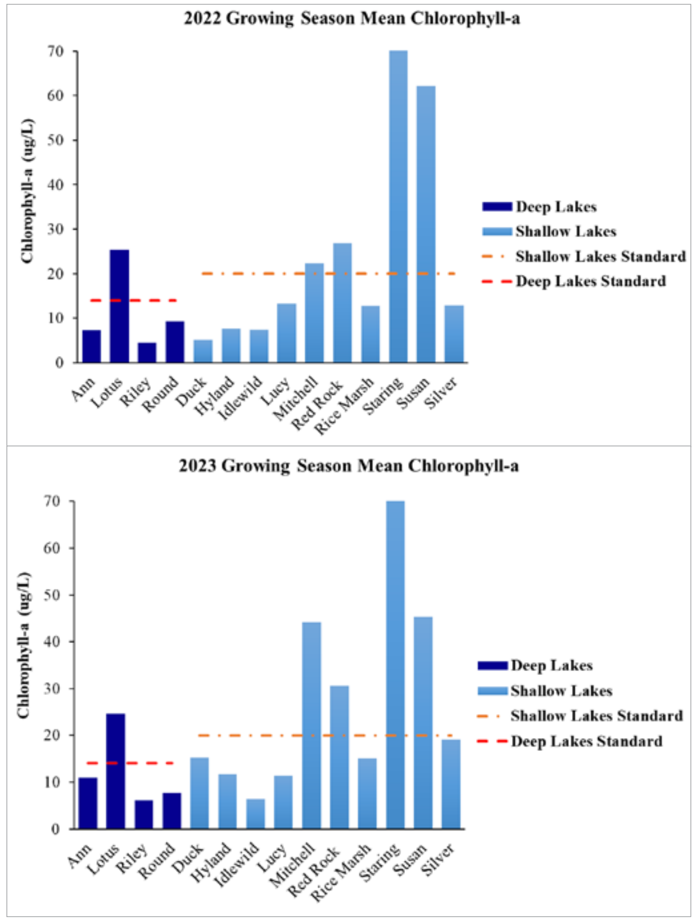
Chlorophyll-a

The 2023 growing season Chl-a mean concentrations for all lakes sampled within the District are shown in Figure 5. As seen in previous years, of the three main eutrophication lake water quality standards (Chl-a, TP, Secchi), Chl-a was the nutrient with the most impairments in 2023. Overall, nine of the 14 lakes sampled in 2023 met the MPCA Chl-a standards for their lake classification (eight lakes in 2022 and 2021, nine in 2020, and six lakes in 2018 and 2019): Lake Ann, Lake Riley, Round Lake, Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Rice Marsh Lake, and Silver Lake.

Four lakes sampled within the district are categorized as "deep" by the MPCA (>15 ft deep, < 80% littoral area): Lake Ann, Lotus Lake, Lake Riley, and Round Lake. The MPCA standard for Chl-a in deep lakes (<14 ug/L) was met by Lake Ann, Lake Riley, and Round Lake. Lake Ann has met the Chl-a standard since data collection began in the 1970s and continues to have some of the best water quality in the district. Due to the past alum

Figure 5. 2022-2023 Lakes Growing Season Mean Secchi Depth.

Lakes growing season (June-September) mean chlorophyll-a concentrations (µg/L) for shallow (lakes <15 ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15 ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2021 and 2022. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for Chlorophyll-a for shallow (<20 µg/L-orange dashed line) and deep lakes (<14 µg/L-red dashed line).

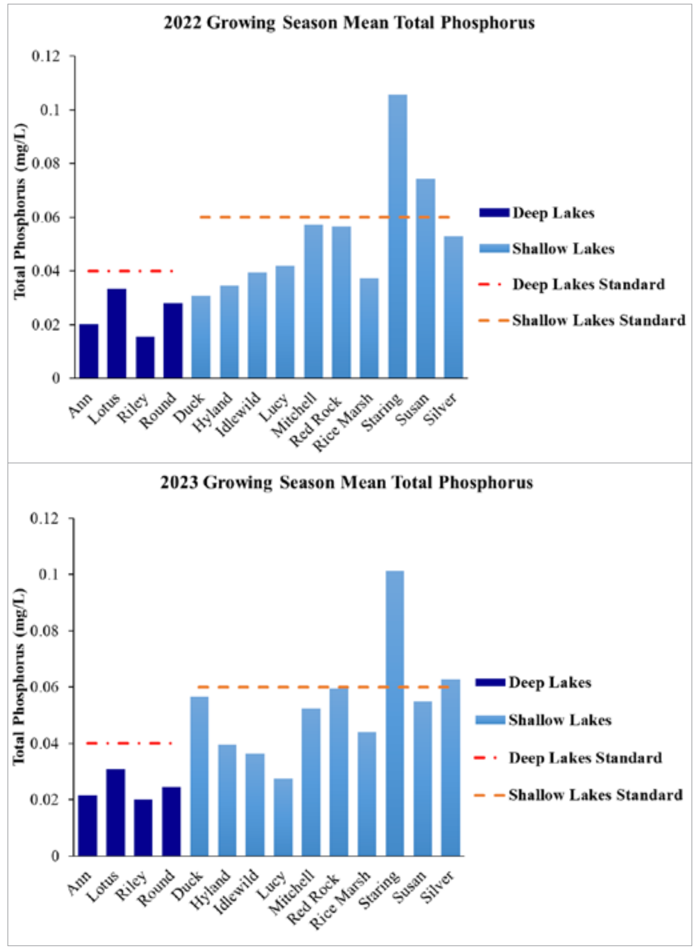


treatment, Lake Riley had the lowest summer Chl-a average of all lakes sampled in 2023 at 6.1 ug/L. (4.5 ug/L in 2022, 2.3 ug/L in 2021, and 2.8 ug/l in 2020). Similarly, Round Lake has also met the standard since the first alum treatment in 2012. Lotus Lake did not meet the standard in 2023 and had Chl-a average concentrations at 24.6 ug/L (consistent with 25.4 in 2022 and 25.3 in 2021).

The remainder of the lakes sampled in 2023 are categorized as "shallow" by the MPCA (<15 ft deep, >80% littoral area): Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Lake Mitchell, Neill Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake. Water quality metrics on Lake Idlewild and Neill Lake, which are classified as open water wetlands, were compared to MPCA shallow lake standards. The water quality standard for shallow lakes (< 20 ug/L) was met by Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Rice Marsh Lake, and Silver Lake. Chl-a concentrations improved in Lake Lucy and were well below the MPCA standard in 2023 (11.3 ug/L), and Hyland remained below the standard for the second year in a row. Silver Lake increased slightly and is now above the standard for chl-a. Duck, Idlewild, Red Rock, and Rice Marsh remained similar to what was seen in previous years with only Red Rock Lake not meeting the standard of that list (30.6 ug/L). Lake Susan had a decrease in chlorophyll-a from 2022, (62.2 ug/L) but is still well above the standard (45.3 ug/L). Mitchell Lake Chl-a concentrations increased to 44.1 ug/L which is double the standard. Staring Lake had the highest concentration of chl-a in the district (87.6 ug/L). This is a significant increase from 2021 (21.52 ug/L) and in 2022 when it began to have the highest concentrations across all lakes (70.38 ug/L). This is likely from a combination of very low water levels, increasing sediment resuspension via wind mixing, and the reduced vegetation following the whole lake fluridone treatment meant to reduce Eurasian Watermilfoil. These values will likely decline as native vegetation increases in abundance.

Figure 6. 2022-2023 Lakes Growing Season Mean Total Phosphorus

Lakes growing season (June-September) mean total phosphorus concentrations (mg/L) for shallow (lakes <15 ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15 ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2022 and 2023. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for Total Phosphorus for shallow (<0.060 mg/L-orange dashed line) and deep lakes (<0.040 mg/L-red dashed line).



Total Phosphorus

The TP growing season averages for all lakes sampled within the district in 2023 are shown in Figure 6. Overall, twelve of the 14 lakes sampled met the MPCA total phosphorus standard for their lake classification in 2023: Lake Ann, Lotus Lake, Lake Riley, Round Lake, Duck Lake, Lake Hyland, Lake Idlewild, Lake Lucy, Mitchell Lake, Red Rock, Rice Marsh Lake, and Lake Susan from 2021-2023, 12 lakes have achieved the standard, an increase from eight lakes not achieving the TP standard in 2020 and 11 lakes in 2019.

The MPCA standard for TP in deep lakes (<0.040 mg/L) was met by all deep lakes in 2023. All deep lake TP concentrations in 2023 remained relatively the same from what was seen in 2022. Following the second dose of the alum treatment in May of 2020, Lake Riley continues to have the lowest summertime average TP concentration (0.020 mg/L) across all lakes sampled (2022-0.015 mg/L, 2021-0.016 mg/L, 2020-0.0178 mg/L) followed by lake Ann (0.022 mg/L). For shallow lakes, the MPCA TP standard (<0.060 mg/L) was met by Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Red Rock Lake, Mitchell Lake, Rice Marsh Lake, and Lake Susan in 2023. Silver Lake and Staring Lake both did not meet the MPCA TP standard in 2023. Silver Lake had barely met the standard the previous two years and slightly increased back above it in 2023. Staring Lake significantly increased from 2021 (0.042 mg/L) to 2022 (0.106 mg/L) and then decreased slightly in 2023 (0.104 mg/L). This is likely from a combination of very low water levels, increasing sediment resuspension via wind mixing, and the reduced vegetation following the whole lake fluridone treatment meant to reduce Eurasian Watermilfoil. These values will likely decline as native vegetation increases in abundance. Mitchell Lake did not achieve the standard in 2021 (0.067 mg/L) but improved and met the standard in 2022 (0.057 mg/L) and 2023 (0.052 mg/L.) Following the second spring alum application in Hyland Lake in 2022, average concentrations were reduced for 0.054 mg/L in 2021 to 0.034 mg/L in 2022 and 0.044 mg/L in 2023. Duck Lake had an increase in TP concentration from 0.0301 mg/L in 2022 to 0.0565, just below the standard.

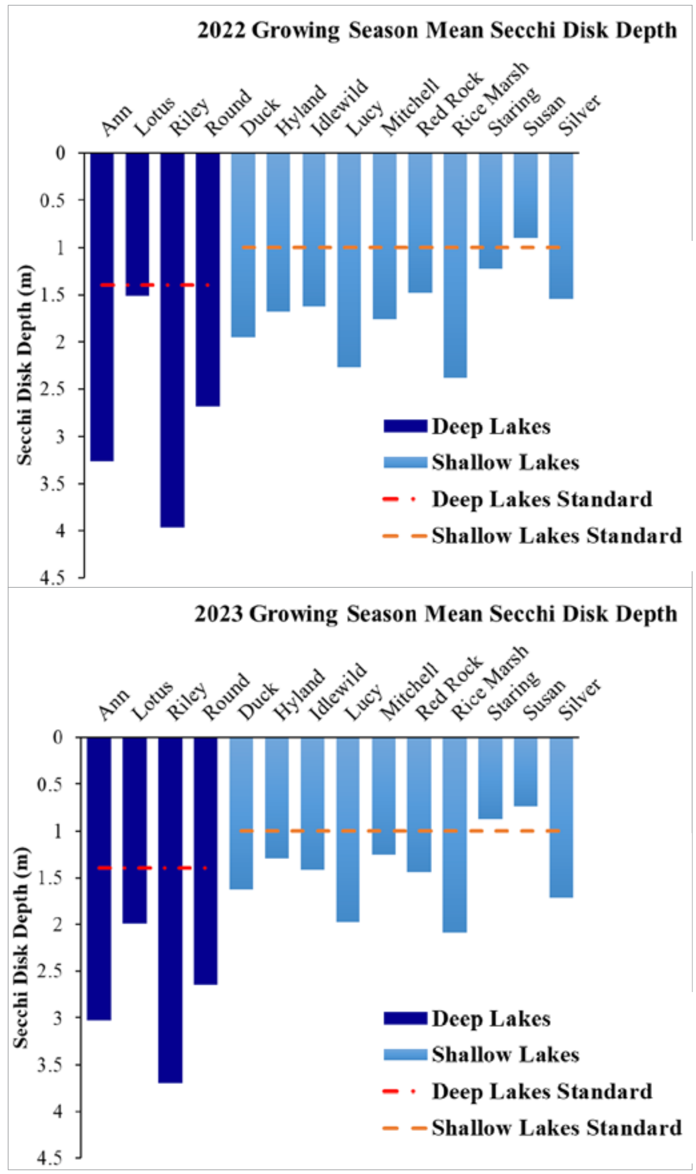
Secchi Disk

The 2023 Secchi disk growing season means for all district lakes sampled are shown in Figure 7. Overall, water clarity in most lakes stayed the same from 2022 except for Staring Lake which declined below the standard.

The MPCA standard for Secchi disk depth/water clarity for deep lakes (> 1.4 m) was met by all deep lakes in 2023. Lotus did not meet the standard in 2020 (1.24 m) but met the standard in 2021 and 2022 (1.51 m). In 2023 Lotus continued to improve with an average of 1.99 m. Lake Riley had the highest summer average for all lakes sampled in 2023 (3.7 meter) and the average was only slightly down (3.96 meter) from 2022. For shallow lakes, the MPCA standard was not met by only Staring Lake and Lake Susan. Staring Lake met the standard in 2022 with a reading of 1.23 m, but fell below the standard in 2023 with a mean Secchi depth of only 0.87 m. Susan had a mean Secchi depth of 0.74 in 2023, a decrease from 0.89 in 2022, marking its second year in a row below the water quality standard. Red Rock had the shallowest average secchi reading at 0.66 meter in 2020 but improved to 1.5 meter in 2021. This was sustained in 2022 and 2023 at 1.48 m and 1.4 m respectively. Lucy and Rice Marsh both had Secchi readings near 2 m (1.98 and 2.09), and Duck and Silver averaged around 1.65 m (1.63 and 1.70). Hyland was reduced from 2.05 m in 2020 to 1.14 meters in 2021 but increased to 1.67 meter in 2022 following the spring alum treatment. It recorded its 4th consecutive year meeting the standard in 2023 (1.29 m). Mitchell Lake did not meet the standard in 2020 (0.93 m) but improved in 2021 and met the standard (1.13 m). This continued to further improve in 2022 (1.53 m) and continued to meet the standard in 2023 with a mean depth of 1.25 meters.

Figure 7. 2022-2023 Lakes Growing Season Mean Secchi Disk Depth.

Lakes growing season (June-September) mean Secchi disk depths (m) for shallow (lakes <15 ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15 ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2022 and 2023. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for Secchi disk depths for shallow (>1 m-orange dashed line) and deep lakes (>1.4 m-red dashed line).



4.2. Alum Treatments

Alum (aluminum sulfate) is a compound derived from aluminum, the earth's most abundant metal. Alum has been used in water purification and wastewater treatment for centuries and in lake restoration for decades. Many watershed management plans recommend that some lakes be treated with alum to improve their water quality. Alum treatments provide a safe, effective, and long-term control of the quantity of algae in our lakes by trapping phosphorus in sediments. Algal growth is directly dependent on the amount of phosphorus available in the water. Phosphorus enters the water in two ways:

- **Externally** from surface runoff entering the water or from groundwater.
- **Internally** from the sediments on the bottom of the lake.

Phosphorus already in the lake settles to the bottom and is periodically re-released from the sediments back into the water under anoxic conditions. Even when external sources of phosphorus have been significantly reduced through best management practices, the internal recycling of phosphorus within a lake can still support explosive algal growth. Alum is used primarily to control this internal loading of phosphorus from lake bottom sediments. The treatment is most effective when it occurs after external sources of phosphorus have been or are in the process of being controlled. Internal phosphorus loading is a large problem in Twin Cities Metropolitan Area lakes because of historic inputs of phosphorus from the urban storm water runoff and past agriculture practices. Phosphorus in runoff has concentrated in the sediments of urban lakes and successive years of algal blooms have died and settled to the lake bottoms. This phosphorus is recycled from the lake sediments into the overlying waters, primarily during summer periods, when it contributes to the growth of nuisance algal blooms.

Alum is applied by injecting it directly into the water several feet below the surface. On contact with water, alum becomes floc, or aluminum hydroxide (the principal ingredient in common antacids such as Maalox). This fluffy substance settles to the bottom of the lake. On the way down, it interacts with phosphorus to form an aluminum phosphate compound that is insoluble in water. Phosphorus in the water is trapped as aluminum phosphate and can no longer be used as food by algae. As the floc settles downward through the water, it also collects other suspended particles in the water, carrying them down to the bottom and leaving the lake noticeably clearer.

On the bottom of the lake, the floc forms a layer that acts as a phosphorus barrier by combining with (and trapping) the phosphorus as it is released from the sediments. This reduces the amount of internal recycling of phosphorus in the lake. An alum treatment can last 10–20 years or even longer, depending on the level of external phosphorus loading to the lake. The less phosphorus that enters the lake from external sources after it is applied, the more effective the treatment will be over a longer period.

A list of the alum treatments completed/partially completed in the district can be found in Table 10. Treatments are split into two doses to ensure the entirety of the lake is being treated effectively. District staff and its partners have continued to monitor phosphorus levels within treatment lakes and sediment cores to evaluate the effectiveness of each alum treatment and to assess when a second dose might be needed. More information about Lake Riley, Lotus Lake, Rice Marsh Lake, Round Lake, and Hyland Lake nutrient and water clarity data can be seen in the factsheets located at rpbcwd.org/factsheets and Nutrient Summary Table in the (Exhibit G).

Figures 9 through 13 illustrate epilimnetic (surface) and hypolimnetic (bottom) total phosphorus (TP) levels prior to treatment, through the end of this current year for all lakes that received alum treatments. As seen across all lakes, after alum was applied, TP levels declined considerably throughout the water column in the year immediately succeeding the treatment. In the years following the alum treatment, all these lakes met the MPCA water quality standard for TP (exception – 2013 & 2017 Round Lake and 2020 Lotus Lake). In addition, often both Secchi readings and Chlorophyll-a levels were improved which led to most lakes meeting all three water

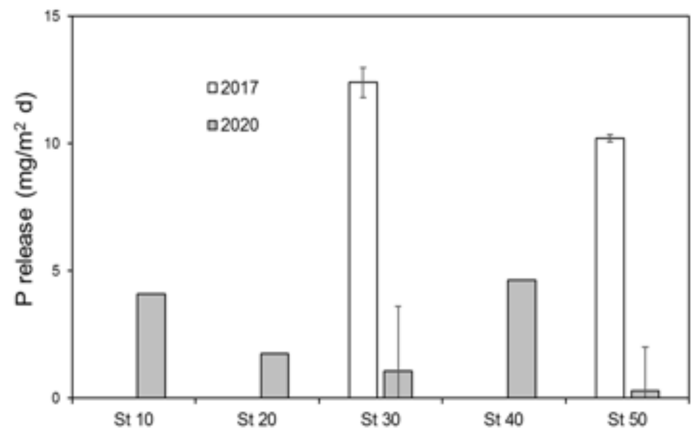
Table 10. Aluminum sulfate (alum) treatments.

LAKE	FIRST DOSE	SECOND DOSE
Riley	5/5/2016	6/11/2020
Lotus	9/18/2018	Fall 2024
Rice Marsh	9/21/2018	2025
Round	11/15/2012	10/24/2018
Hyland	6/3/2019	5/18/2022

quality standards after treatment. Exceptions include Lotus Lake, which did not meet chlorophyll-a and Secchi standards in 2020, and Hyland Lake, which did not meet the chlorophyll-a standard in 2021.

In Table 11 the percent reduction of surface and bottom growing season values of total phosphorus pre and post-alum treatment can be seen across all lakes. Utilizing five years of post-treatment data, it appears Rice Marsh and Hyland Lake had very effective alum treatments with phosphorus reductions of surface phosphorus with a reduction of over 55% on both lakes. Hyland Lake was treated with the second dose in the spring of 2022 and the surface TP concentration decreased to 57%. Rice Marsh will be treated with a second dose likely in 2025. Despite having a smaller reduction in total phosphorus at the surface (9%), Round Lake had reductions in lake bottom total phosphorus comparable with the other treated lakes (85% for dose 1 and 83% for dose 2). In 2020, Lake Riley received the second dose of alum which led to a historically good water quality year with record secchi disk depths of 4.6 m which was followed by another record year in 2021 at 4.8 meters with a slight decline in secchi depth since then. Overall, comparing pre and post treatment years, Lake Riley had a reduction in total phosphorus of 63% at the surface and 91% near the lake bottom.

Figure 8. Lotus Lake Sediment release rates in 2017 and 2020.



After the first dose of alum in Lotus Lake, water quality did not respond as well as seen across other lakes, however the surface and bottom phosphorus concentrations did match with what we have seen across other lakes (only 40% surface and 61% bottom). The lakewide limited water quality response may be due to the high phosphorus release rates observed from the sediment cores taken outside of the treatment areas (Figure 8). These shallower areas (15 feet) of the lake may be contributing more phosphorus release than first thought. Although a second dose would further reduce the release rates, expanding some of the treatment areas may produce a more robust water quality response. The district monitored TP and OP in both deep-water basins that received alum (south and east) in Lotus

Table 11. Aluminum sulfate (alum) treatment effectiveness at lake surface and lake bottom.

LAKE	SAMPLE YEARS	SAMPLE LOCATION	FIRST DOSE			SECOND DOSE	
			Average TP Pre-treatment	Average TP Post-treatment	Percent Reduction	Average TP Post-treatment	Percent Reduction
Riley	2009-2023	Surface	0.0457	0.0267	41%	0.0170	63%
	2009-2023	Bottom	0.5334	0.1684	68%	0.0465	91%
Lotus	2014-2023	Surface	0.0540	0.0349	40%	*Not treated yet*	*n/a*
	2014-2023	Bottom	0.5423	0.2088	61%	*Not treated yet*	*n/a*
Rice Marsh	2014-2023	Surface	0.0745	0.0380	56%	*Not treated yet*	*n/a*
	2014-2023	Bottom	0.1210	0.0413	66%	*Not treated yet*	*n/a*
Round	2008-2023	Surface	0.0415	0.0388	9%	0.0274	34%
	2008-2023	Bottom	0.8945	0.1376	85%	0.1491	83%
Hyland	2016-2023	Surface	0.0819	0.0375	58%	0.0377	57%
		Bottom	*No data*				

Lake to gauge phosphorus release rates. The south basin had a concentration of 0.032 mg/L in 2021, 0.033 mg/L in 2022, 0.031 mg/L in 2023. The east basin had a concentration of 0.03 mg/L in 2021, 0.035 mg/L in 2022, and 0.031 mg/L in 2023. Bottom summer averages were slightly different with the south bay (normal monitoring location) having higher concentrations at 0.185 mg/L in 2021, 0.238 mg/L in 2022, and 0.273 mg/L in 2023 vs 0.146 mg/L in 2021, 0.171 mg/L in 2022, and 0.106 mg/L measured in the east bay. Overall, both locations have averages well below the pretreatment conditions indicating the first dose was successful.

Overall, the water quality results pre and post alum treatment indicate that alum applications are effective and can drastically reduce phosphorus levels caused by internal loading within a lake. Staff will continue to monitor each lake to determine the second dose application and gauge the temporal success of each treatment. Total Phosphorus levels before and after alum treatment are included for the following lakes:

- Hyland, Figure 9
- Riley, Figure 10
- Rice Marsh, Figure 11
- Lotus, Figure 12
- Round, Figure 13

Figure 9. Hyland Lake Total Phosphorus Levels pre and post-alum treatment.

Total phosphorus levels (TP) in Hyland Lake between May 5, 2014, and October 10, 2023. The aluminum sulfate (alum) treatments occurred on June 3, 2019, and May 18, 2022 (indicated by vertical bar). The graph displays TP levels (mg/L) measured from 0-2 m composite samples and the MPCA water quality standard for TP is represented by the horizontal red line (0.06 mg/L).

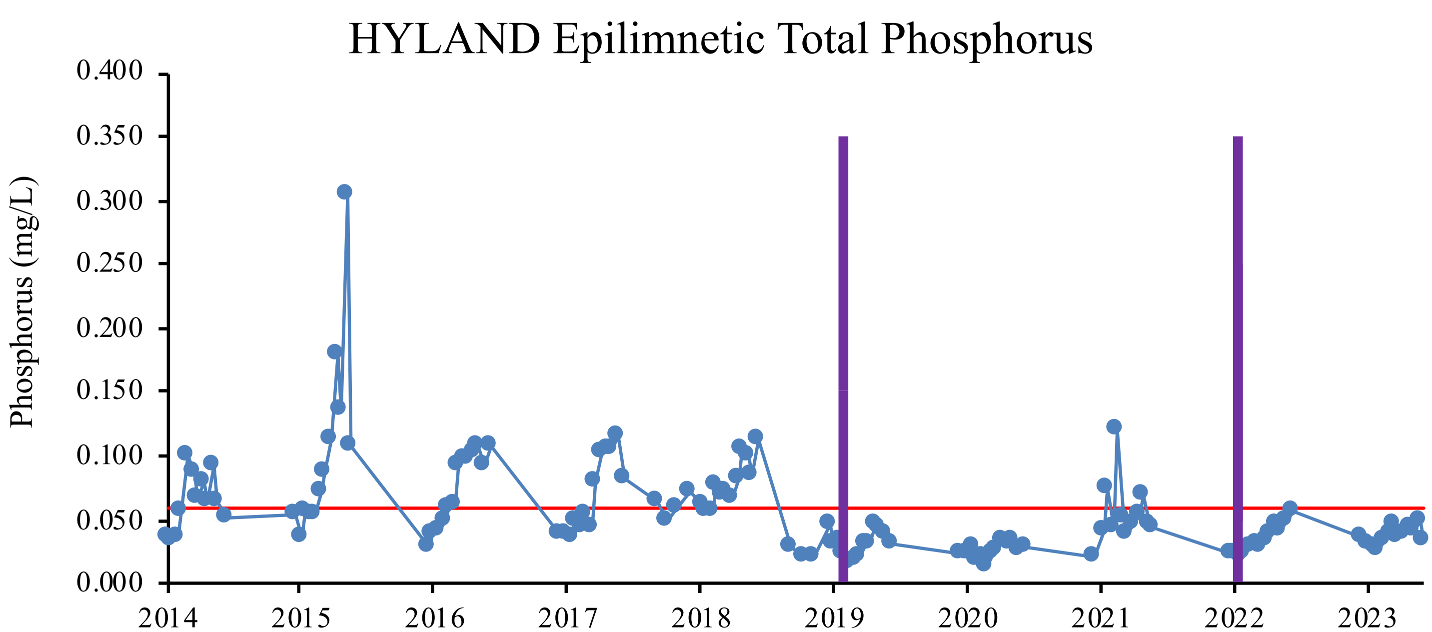
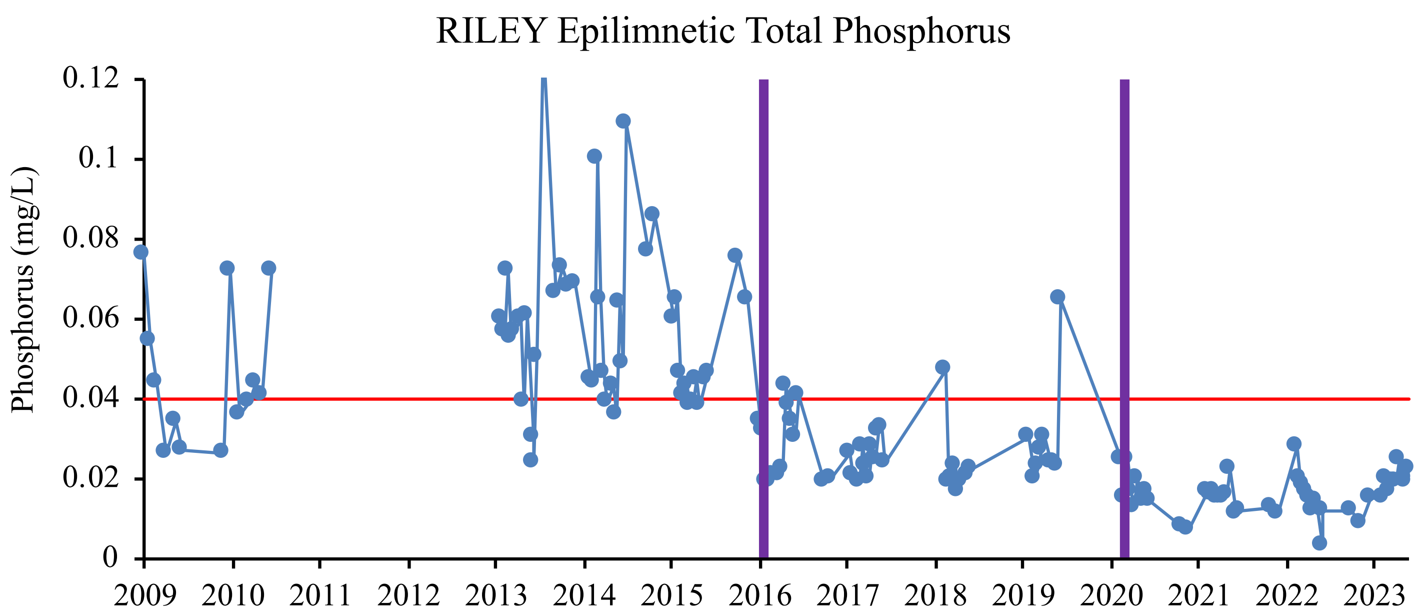


Figure 10. Lake Riley Total Phosphorus Levels pre and post-alum treatment.

Total phosphorus levels (TP) in Lake Riley between April 22, 2009, and September 12, 2023. The aluminum sulfate (alum) treatments occurred on May 5, 2016, and June 11, 2020 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 0-2 m composite samples and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.04 mg/L).



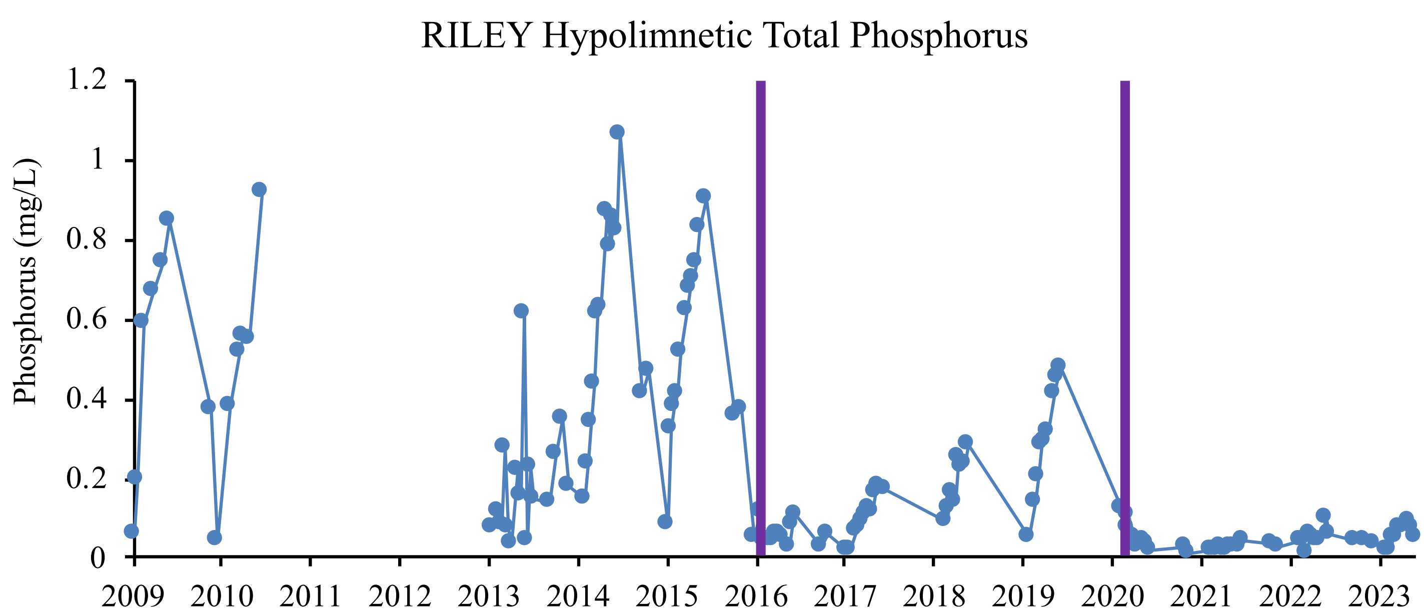
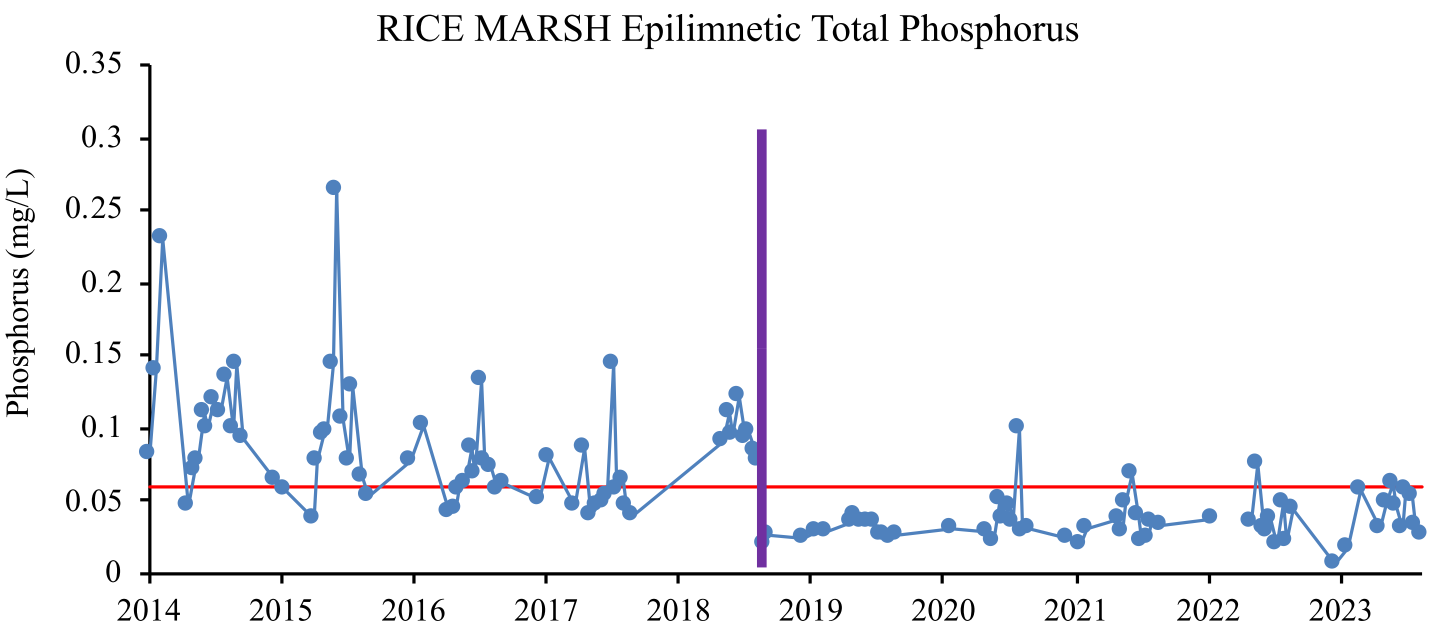


Figure 11. Rice Marsh Lake Total Phosphorus Levels pre and post-alum treatment.

Total phosphorus levels (TP) in Rice Marsh Lake between January 31, 2014, and September 14, 2023. The aluminum sulfate (alum) treatment occurred on September 21, 2018 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 0-2 m composite samples and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.06 mg/L).



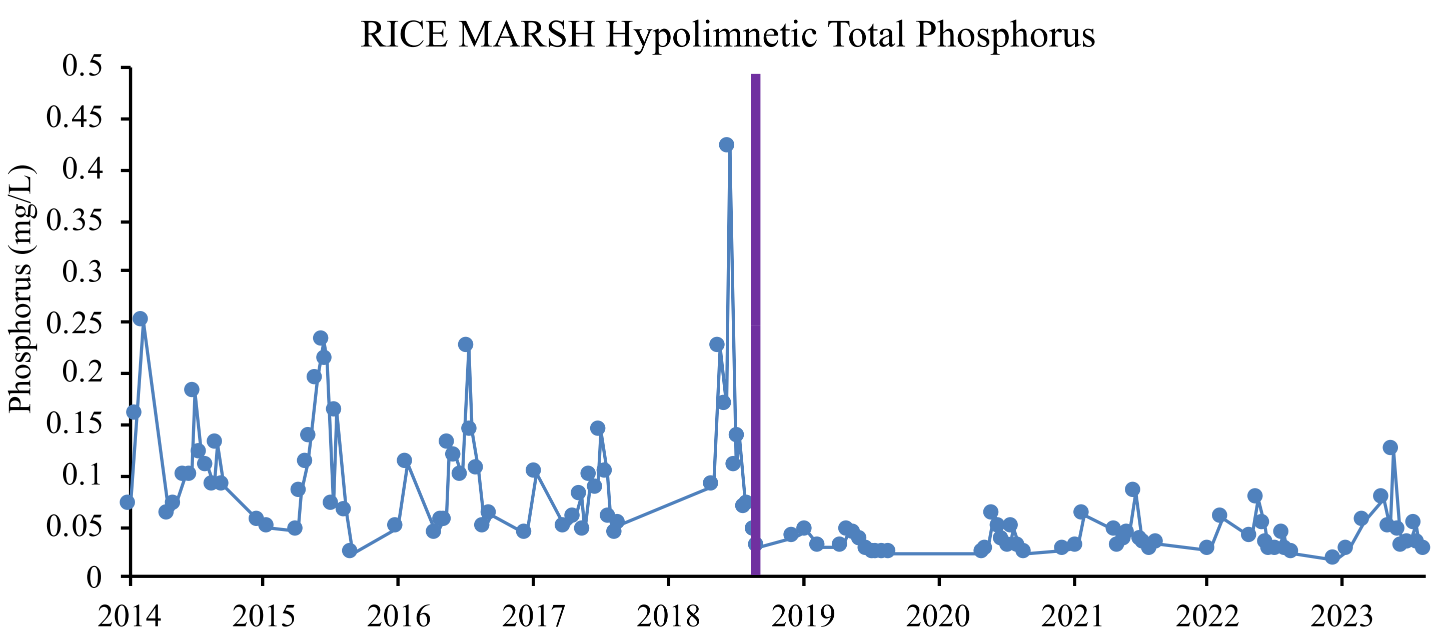
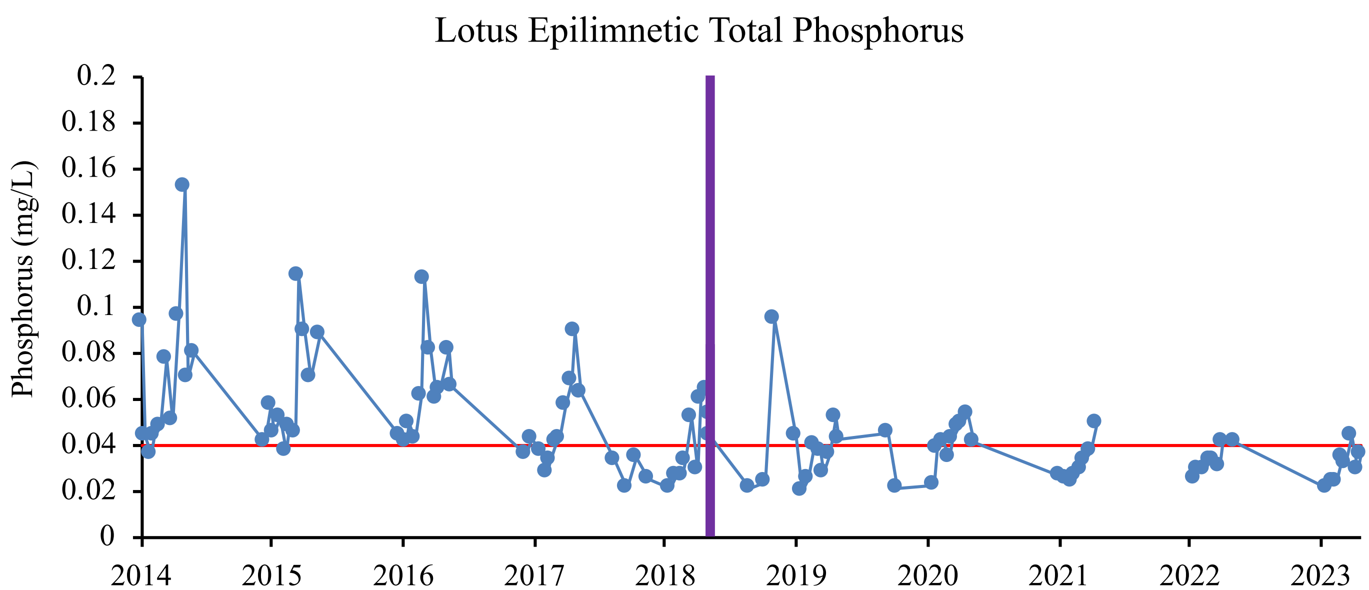


Figure 12. Lotus Lake Total Phosphorus Levels pre and post-alum treatment.

Total phosphorus levels (TP) in Lotus Lake between May 20, 2014, and September 11, 2023. The aluminum sulfate (alum) treatment occurred on September 18, 2018 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 0-2 m composite samples and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.04 mg/L).



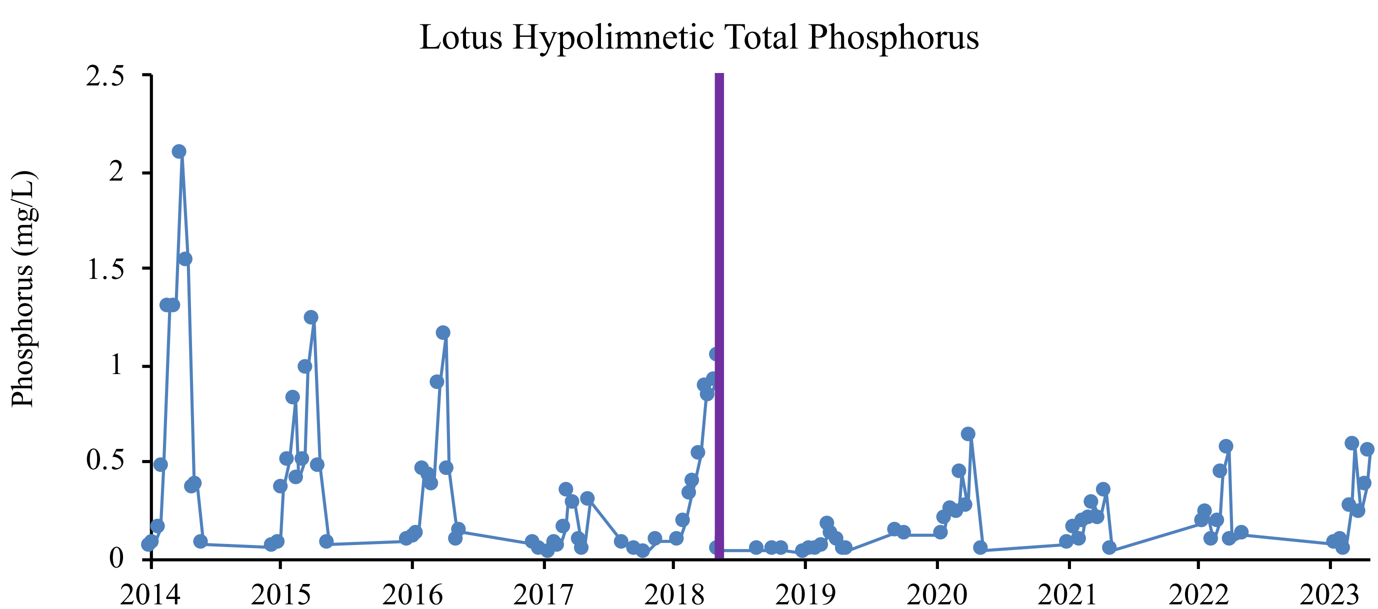
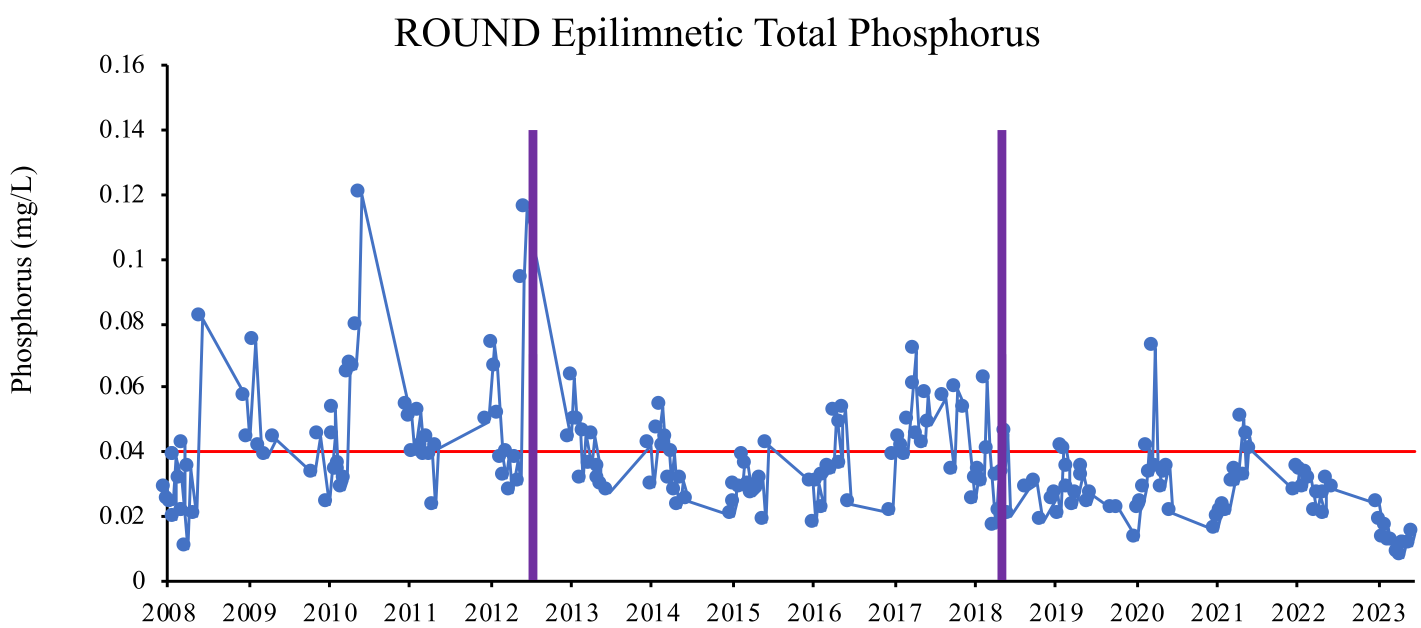
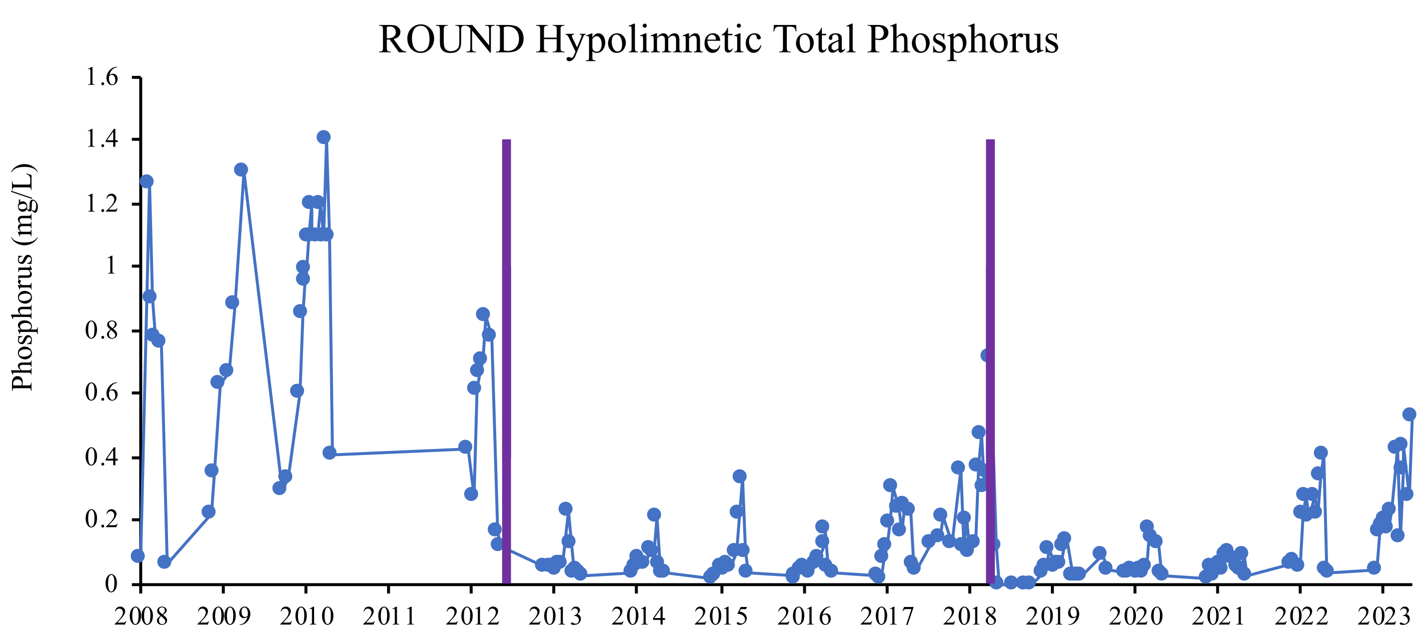


Figure 13. Round Lake Total Phosphorus Levels pre and post-alum treatment.

Total phosphorus levels (TP) in Round Lake between May 15, 2008 and October 26, 2023. The aluminum sulfate (alum) treatments occurred on November 15, 2012 and October 25, 2021 (indicated by vertical bars). The upper graph displays TP levels (mg/L) measured from 0-2 m composite samples and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.04 mg/L).





4.3. Chloride Monitoring

Increasing chloride (Cl) levels in water bodies are becoming of greater concern within the state of Minnesota. It takes only one teaspoon of road salt to permanently pollute five gallons of water, as chlorides do not break down over time. At high concentrations, chloride can also be harmful to fish, aquatic plants, and other aquatic organisms. The MPCA Cl Chronic Standard (CS, highest water concentration of Cl to which aquatic life, humans, or wildlife can be indefinitely exposed without causing chronic toxicity) is 230 mg/L for class 2B surface waters (all waters sampled within the District, excluding storm water holding ponds). The MPCA Cl Maximum Standard (MS, highest concentration of Cl in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality) is 860 mg/L for class 2B surface waters.

The District has been monitoring salt concentrations in our lakes and ponds since 2013 and will continue monitoring efforts to identify high salt concentration areas and to assess temporal changes in salt concentrations. In 2016, staff carried out Cl sampling in lakes and streams every other week during the spring, switching to monthly sampling in summer/winter. In 2022-2023, winter monitoring included the Riley Chain of Lakes (Lucy, Ann, Susan, Rice Marsh, and Riley) and a chain of ponds that drain the City of Eden Prairie Center to Purgatory Creek. During sampling, staff collected a surface two-meter composite sample (when possible) and a bottom water sample to be analyzed for Cl.

Since 2012, except for multiple samples taken from Lake Idlewild (high value wetland), the average chloride levels from the PCL are below the MPCA CS of 230 mg/L (Figure 14, Figure 15). Similar to previous years, Lake Idlewild did not meet the chloride CS standard in 2023. Previously, the maximum concentration measured in Idlewild was from a bottom sample taken in March of 2019 which measured 390 mg/L. In 2023, summertime chloride levels were nearly double what has been seen in the past, with the max concentration occurring on 6/25/2023 from a bottom sample (639 mg/L). The location of Lake Idlewild is likely the cause of elevated chloride levels as much of the receiving water is drainage from the heavily developed and

Figure 14. Riley Creek Chain of Lakes chloride levels 2013-2023.

All average chloride sampling results (mg/L) on the Riley Chain of Lakes from 2013-2023. The MPCA chloride chronic standard for class 2B waters (230 mg/L) is indicated by the red line.

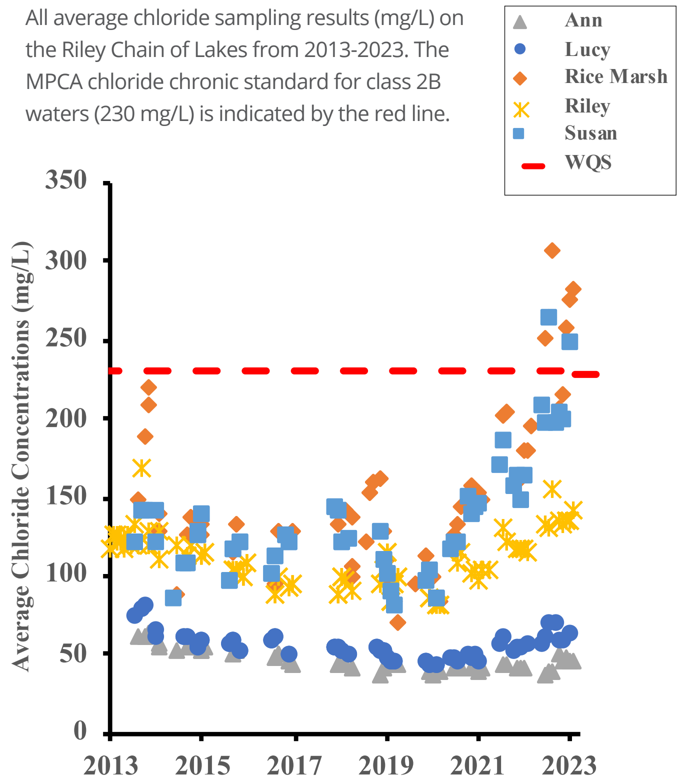
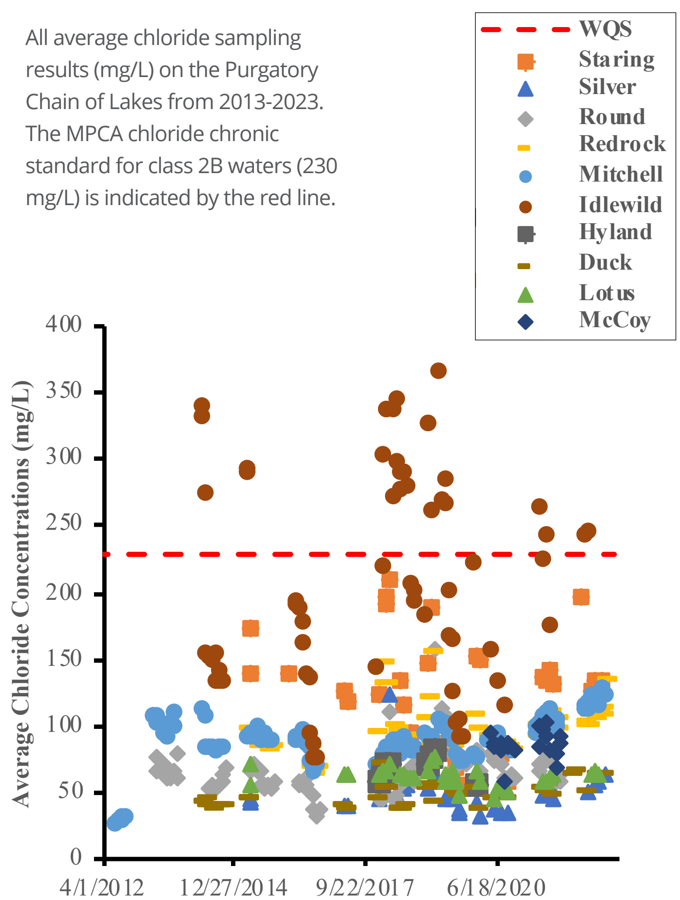


Figure 15. Purgatory Creek Chain of Lakes average chloride levels 2013-2023.

All average chloride sampling results (mg/L) on the Purgatory Chain of Lakes from 2013-2023. The MPCA chloride chronic standard for class 2B waters (230 mg/L) is indicated by the red line.



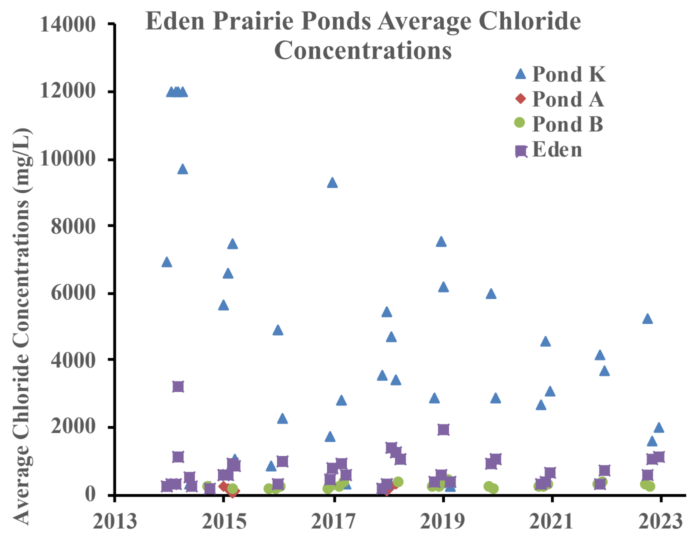
impervious area near the City of Eden Prairie City Center. The only other lake in the Purgatory Chain that had chloride concentrations above the standard was Staring Lake in 2018, 2022 and 2023. Previously, multiple lake bottom concentrations exceeded the standard, however the average (top/bottom) did not. In 2023, one sample average on 3/28/23 did not meet the MPCA standard (390 mg/L). The remainder of the PCL lakes had Cl levels below the MPCA water quality standard and have stayed relatively consistent within lakes year-to-year. There are however signs of slight increases in the past two to three years.

In the RCL system, no lake exceeded the water quality standard from 2013-2022. In 2023, both Rice Marsh Lake and Lake Susan exceeded the standard on multiple dates. Both lakes are downstream of Highway 5 and are smaller in size which may explain partially why they do not meet the standard. Unfortunately, Susan, Rice Marsh, and Riley have been on an increasingly alarming trend for the past three years which, if continued, could lead to all lakes exceeding the standard soon. Rice Marsh Lake had the highest average chloride concentration in RCL, measuring 306 mg/L (3/28/2023). At the top of RCL. Lucy and Ann have remained relatively flat with low concentrations near 50 mg/L but have seen subtle increases as well.

Figure 16 shows chloride levels within the four stormwater ponds, which includes all sampling events since 2013. All samples taken from Pond K (top of the chain) exceed class 2B CS. This includes 2013 samples which exceeded the maximum chloride concentrations the lab equipment could measure. All but three samples from Pond K were below the class 2B MS of 860 mg/L. Additionally, most samples taken from Eden Pond exceeded the class 2B CS, some exceeding the class 2B MS of 860 mg/L. In the spring of 2015, staff were no longer able to take accurate water samples on Pond B due to low water levels, so, sampling began on Pond A located directly upstream. In 2018, due to inconsistencies with getting samples without disturbing sediment, staff reverted again to sampling Pond A in place of Pond B for multiple monitoring events. It is important to note that these stormwater ponds are not classified as class 2B surface waters by the MPCA and so the standards do not apply but are simply a gauge to what is being seen in the watershed.

Figure 16. Chloride levels 2013-2023 in Eden Prairie stormwater ponds.

All average chloride results (mg/L) on stormwater ponds draining the City of Eden Prairie City Center to Purgatory Creek from 2013-2023.



The highest chloride concentration in 2023 occurred in January on Pond K at 5,265 mg/L which is over six times the maximum standard. Moving from upstream to downstream (Pond K - Eden Lake - Pond A - Pond B) it appears that the ponds are retaining much of the chloride they are receiving from the surrounding watershed during the winter and even during melting events. This is preventing high chloride levels from reaching Purgatory Creek. During significant rain events, specifically in the spring, chloride is most likely being flushed downstream at a larger scale than in the winter or during normal water level periods.

Regular stream monitoring sites have had chloride samples collected monthly from 2018-2023. Samples collected during the open water season act as a baseline of standard chloride levels within the watershed. They can also alert staff of any chloride level spikes during this period. From 2018-2021, no sites had chloride levels above the CS. In 2021, only sites R4 and B4 exceeded the MPCA CS water quality standard in May, June, and July. R4, B2, and P6 exceeded the CS in 2022 and R4, B3, B4, and P3 exceeded the CS in 2023. In the drought period between 2021-2023, water levels were very low and there was limited spring rainfall which generally flushes streams of chloride. This may explain why concentrations exceeded the standard well into the summer months. Sites B3, B4, and R4 which consistently do not meet the MPCA CS are the stream locations nearest to Highway 5. Even with the data limitations both Bluff Creek and Purgatory Creek appear to have rising trends.

Winter and early spring monitoring, specifically after melting events, is often the time to capture maximum chloride levels from each stream. The district's regular monitoring often does not completely capture these events, so we rely on and assist with the Metropolitan Council's (METC) Watershed Outlet Monitoring Program. These continuous monitoring stations are sampled biweekly for a variety of parameters including chloride, and capture storm and melting events. The METC released findings (METC 2020a; METC 2020b) on both Riley (Figure 17) and Bluff Creek (Figure 18) indicating Chloride concentrations have increased since 1999. Bluff Creek is at high risk of chloride impairment. Flow in both creeks has generally increased since 1999 although it has been extremely variable. Chloride varied seasonally across both creeks with higher values occurring in the spring and early summer, indicating salt use for winter de-icing is likely the major source for chloride in the stream. Other sources, such as synthetic fertilizer, are not well understood and should be investigated.

Staff will continue winter monitoring of Cl in the PCL in 2024 which will include: Silver, Lotus, Mitchell, Red Rock, Duck, Staring, Round, and Hyland, along with the stormwater ponds draining Eden Prairie Center. The PCL will be monitored over a three-year cycle before staff shift to the RCL. Once-a-month chloride sampling will continue as part of the monthly sampling SOP's during the regular growing season on both lakes and streams. Continuing data collection and analysis will allow us to guide more comprehensive and effective chloride pollution reduction projects and initiatives. More information on chloride concentrations can be seen in the Nutrient Summary Tables in the Exhibit F and Exhibit G in the Appendix.

Figure 17. Ambient and Annual Median Chloride Concentration in Riley Creek (Metropolitan Council).

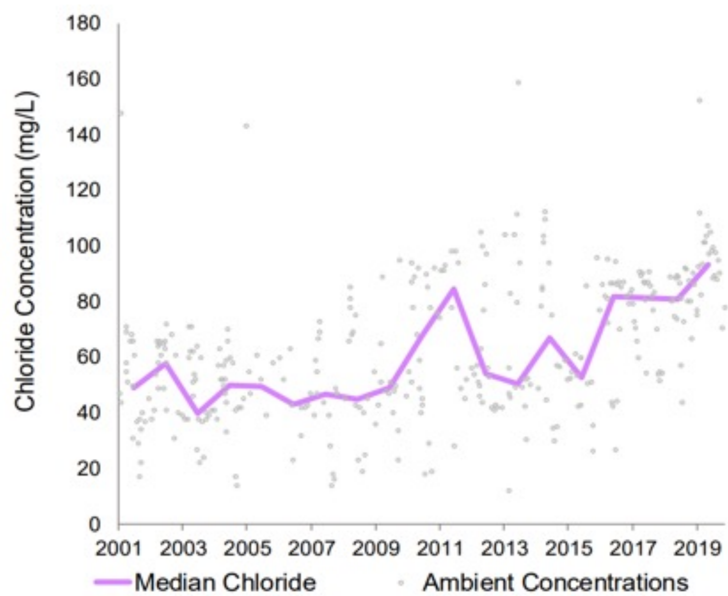
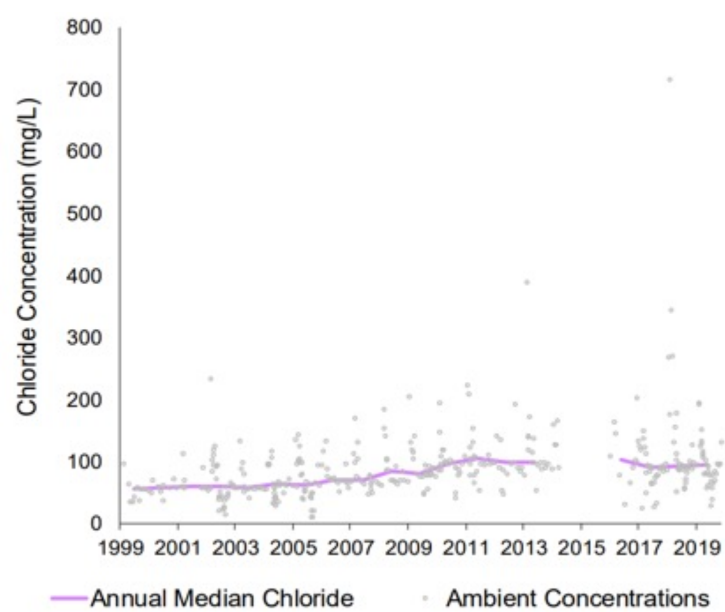


Figure 18. Ambient and Annual Median Chloride Concentration in Bluff Creek (Metropolitan Council).



4.4. Nitrogen Monitoring

Toxicity of nitrates to aquatic organisms is a growing concern in Minnesota over the last decade. Nitrate (NO3), the most available form of nitrogen for use by plants, can accumulate in lakes and streams since aquatic plant growth is not limited by its abundance. While nitrates have not been found to directly contribute to eutrophication of surface waters (phosphorus is the main cause of eutrophication) and is not an MPCA water quality standard, studies have found that nitrate can cause toxicity in aquatic organisms. In 2010, the MPCA released the Aquatic Life Water Quality Standards Technical Support Document for Nitrates: Technical Water Quality Standard Amendments to Minn. R. chs. 7050 and 7052 to address concerns of the toxicity of nitrate in freshwater systems and develop nitrate standards for class 2B and 2A systems. This document was updated in 2020 (still in the draft stage for external review). The draft acute value (maximum standard) calculated is 60 mg/L N:NO_3 for a one-day duration concentration for all Class 2 waters, and the draft chronic values are 8 mg/L N:NO_3 mg/L for Class 2B and 2Bd waters and 5 mg/L for class 2A waters Draft Aquatic Life Water Quality Standards Draft.

Once a month during regular sampling, staff collects a surface two-meter composite and a bottom water sample to be analyzed for nitrate+nitrite and ammonia+ammonium. In 2019, staff added Total Kjeldahl Nitrogen (TKN) to its monthly sampling regime. Organic-N levels are determined in a laboratory method called Total Kjeldahl Nitrogen (TKN). This measures the combination of organic N and ammonia+ammonium. Organic-N can be biologically transformed to ammonium and then to nitrate and nitrite forms. Because of this, monitoring for TKN could provide important supplemental data if staff observe increases in harmful forms of N in the future. Three Rivers Park District conducts water sampling on Hyland Lake and shares data with the District. Their lab tests do not specifically test for nitrogen as nitrate+nitrite or ammonia, therefore, nitrogen data on Hyland only includes Total Nitrogen. The average total Nitrogen for Hyland in 2023 was 0.98 mg/L).

The District monitors nitrates in lakes as a part of its regular sampling regime. The District tests for nitrates in the form of nitrate+nitrite (the combined total of nitrate and nitrite) and tests for ammonia in the form of ammonia+ammonium. As seen in Table 12, all the lakes in the District met the draft nitrate CS. It is also important to note that the lab equipment used to test for nitrate has a lower limit of 0.03 mg/L. Therefore, it is possible that some of the samples contained less than 0.03 mg/L nitrate; because of this, actual average nitrate levels in District lakes may be lower than what was measured.

Ammonia (NH_3), a more toxic nitrogen-based compound, is also of concern when discussing toxicity to aquatic organisms. It is commonly found in human and animal waste discharges, as well

Table 12. 2023 Lakes Summer Average of Nitrogen

2023 growing season (June-September) averages of nitrate+nitrite, ammonia+ammonium, and total kjeldahl nitrogen levels for District lakes. The MPCA proposed chronic standards (CS) are in gold near the top of the table. The lower limit of lab analysis of nitrate+nitrite is 0.03 mg/L and ammonia+ammonium is 0.04 mg/L.

LAKE	AVERAGE NITRATE [NO_3] + NITRITE [N] (mg/L)	AVERAGE AMMONIA [NH_3] + AMMONIUM [NH_4^+] (mg/L TAN)	TOTAL KJELDAHL NITROGEN (mg/L)
MPCA Proposed Chronic Standard (CS)	**5.0 mg/L**	**1.9 mg/L TAN***	**none**
Ann	0.03	0.99	1.84
Duck	0.03	0.03	0.90
Hyland	--	--	0.97
Idlewild	0.03	0.02	0.65
Lotus	0.03	1.55	2.56
Lucy	0.03	0.99	2.05
Mitchell	0.03	0.05	1.11
Neill	0.03	0.06	1.15
Red Rock	0.03	0.03	0.09
Rice Marsh	0.03	0.03	1.06
Riley	0.06	0.40	1.02
Round	0.03	0.10	0.66
Silver	0.03	0.03	1.12
Staring	0.03	0.18	1.80
Susan	0.03	0.34	1.50

*The NH_4 (CS) standard should not be directly compared to lake values (as mg/L TAN (pH=7, T=20°C).

as agricultural fertilizers in the form of ammonium nitrate. When ammonia builds up in an aquatic system, it can accumulate in the tissues of aquatic organisms and eventually lead to death. The new proposed acute water quality standard for Classes 2B, 2Bd, and 2D is defined by the set of numeric values at an example pH of 7 and temperature of 20°C, the proposed chronic standards for Class 2 waters are 1.9 mg/L TAN (30-day rolling average) and 4.8 mg/L TAN (highest 4-day average within a 30-day averaging period), applied uniformly across all subclasses. The MPCA current standard for assessing toxicity of ammonia; the CS of ammonia in class 2B is 0.04 mg/L. RMB Environmental Lab water sample testing methods measures for ammonia in the form of ammonia+ammonium. The lab lower limit for these samples is 0.02 mg/L. The lower limit for sample data provided by the City of Eden Prairie for Red Rock, Round, and Mitchell Lakes is 0.16 mg/L. Due to these limits, some of the average levels of ammonia+ammonium provided in Table 12 may be lower than what is given. In lakes and streams, ammonium (NH_4^+) is usually much more predominant than ammonia (NH_3) under normalized pH ranges. Ammonium is less toxic than ammonia, and not until pH exceeds 9 will ammonia and ammonium be present in about equal quantities in a natural water system (as pH continues to rise beyond 9, ammonia becomes more predominant than ammonium). Table 12 shows ammonia+ammonium average levels in each lake during the growing season. These numbers are not of concern at this point seeing that pH levels were normal throughout the 2023 growing season and because lab testing measures the combination of ammonia and ammonium. This suggests that most of nitrogen found in these tests was from the less toxic compound ammonium.

4.5. Lake Water Levels and Precipitation

In-Situ Level Troll 500, 15-psig water level sensors, METER Environment Hydros 21 water level sensors, and MaxBotix MB7389 HRXL-MaxSonar water level sensors were placed on all lakes throughout the watershed District to monitor water quantity and assess yearly and historical water level fluctuations. The pressure sensors are mounted inside a protective PVC pipe that are attached to a vertical post and placed in the water. The sonars are placed on a vertical post above the water surface. The Hydros 21 pressure sensors and MaxBotix Sonars were outfitted with solar panels and radios which allows for remote communication with the station for real-time viewing of elevation/data. A staff gauge, or measuring device, is also mounted to the vertical post, and surveyed by District staff to determine the elevation for each level sensor. Once the water elevation is established, the sensors record continuous water level monitoring data every 15 minutes from ice out until late fall.

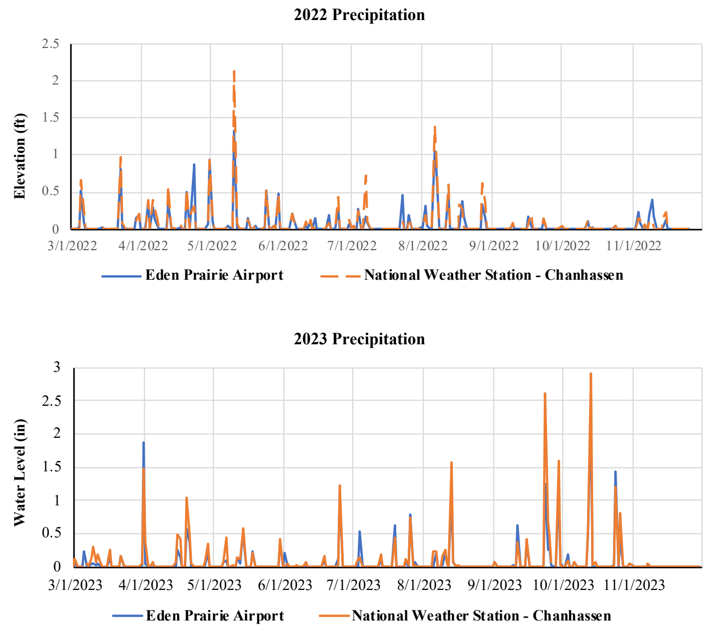
Precipitation data from the Flying Cloud Airport (Pioneer Trail, Eden Prairie) and the National Weather Service Station (Lake Drive West, Chanhassen) was used for precipitation data throughout the following report. Figure 19 displays daily precipitation totals across the two stations from March 1 through December 1 in 2022 and 2023. Overall, precipitation levels were very low in 2023, and the District continued to be in drought condition. During this period, rainfall at the Flying Cloud Airport and National Weather Service Station totaled 20.73 inches (16.78 inches in 2022 and 19.12 inches in 2021) and 26.82 inches (23.49 inches in 2022 and 19.95 inches in 2021) respectively. In 2023, the max rainfall event at Flying Cloud Airport occurred on 10/13/2023 at 2.33 inches of rain (5/11/22, 1.32 inches in 2022) of rain. At the National Weather Service Station, the max rainfall total occurred on 10/13/2023, totaling 2.92 inches of rain (5/11/2022, 2.13 inches). The 2023 autumn rains helped increase water levels going into winter.

Lake level data is used for developing and updating the District's models, which are used for stormwater and floodplain analysis. Monitoring the lake water levels can also help to determine the impact that climate change may have on lakes and land interactions in the watershed. Lake level data is also used to determine epilimnetic zooplankton grazing rates (Chapter 4.10). Lake level data is submitted to the Minnesota Department of Natural Resources (MNDNR) at the end of each monitoring season and historical data specific to each lake can be found on MNDNR website using the LakeFinder database. Exhibit A in the Appendix shows historical lake level data and current year lake level data compared with precipitation data. In both the DNR LakeFinder database and in Exhibit A, the Ordinary High-Water Level (OHWL) is displayed so water levels can be compared to what is considered the "normal" water level for each lake. The OHWL is used by governing bodies like the RPBCWD for regulating activities that occur above and below this zone.

In 2023, lake level measurements were collected on 13 lakes in the District and three wetlands (Lake Idlewild, Lake McCoy, Eden Lake) (Table 13). Idlewild experienced the greatest seasonal water level change over the 2023 season, decreasing 1.07 feet from spring sensor placement to the last day of recording. In 2022, Round Lake experienced the greatest seasonal water level change, decreasing 3.04 feet.

Figure 19. Daily precipitation levels in 2022 and 2023.

2022 and 2023 precipitation daily totals in inches for Flying Cloud Airport in Eden Prairie, MN and the National Weather Service Station in Chanhassen, Minnesota.



Like 2022, Round Lake had the largest range of fluctuation through 2023. During the 2023 season, Round Lake had a low elevation of 874.752 feet above sea level (FASL) and a high of 877.119 FASL (2.34-foot difference). Round Lake also had the lowest recorded water level according to past district data and DNR LakeFinder data. The previous low was recorded on 7/25/1977 and measured 875.290 FASL compared to a low of 874.752 on 9/5/2023. Round Lake water levels are highly influenced by precipitation events within the watershed which is why it commonly has the highest flux (Table 13). Staring Lake had the least seasonal flux (0.065 feet) across all district lakes. On average, lake levels seasonal flux or change in water levels was 0.351 ft in PCL and 0.286 in RCL in 2023. The average fluctuation range across PCL was 1.755 and 1.645 ft for RCL.

Table 13. Summary of 2023 Lake Water Levels.

The 2023 (March-November) and historical recorded lake water levels (feet above sea level or FASL) for all monitored lakes within the Riley Purgatory Bluff Creek Watershed District. The overall change in water level, the range of elevation fluctuation, and the highest and lowest recorded elevations are included. Historical data includes the highest and lowest historical recorded levels and the date they were taken. Lake levels are represented by flux in feet and high/low level in FASL.

	2023 LAKE WATER LEVEL DATA				HISTORIC LAKE WATER LEVELS			
Lake	Seasonal Flux (feet)	Flux Range (feet)	High level (FASL)	Low level (FASL)	Highest Level (FASL)	Date	Lowest Level (FASL)	Date
Riley Creek Chain of Lakes (RCL)								
Ann	0.356	1.465	956.373	954.908	957.930	2/18/1998	952.800	9/28/1970
Lucy	-0.153	1.613	956.731	955.118	957.683	6/20/2014	953.290	11/10/1988
Rice Marsh	-0.204	1.879	876.492	874.613	877.250	5/28/2012	872.040	8/27/1976
Riley	-0.289	1.890	865.434	863.544	866.855	6/20/2014	862.000	2/1/1990
Susan	0.430	1.378	882.317	880.939	884.226	6/19/2014	879.420	12/29/1976
AVERAGE	**0.286**	**1.645**	--	--	--	--	--	--
Purgatory Creek Chain of Lakes (PCL)								
Duck	0.429	1.493	913.242	911.749	915.317	6/20/2014	911.260	11/10/1988
Eden	-0.184	1.778	810.647	808.869	811.046	8/27/2021	809.008	10/12/2022
Hyland	0.407	1.949	813.839	811.890	819.800	8/11/1987	811.660	12/2/1977
Idlewild	-1.071	2.178	854.764	852.586	860.780	3/29/1976	852.586	9/23/2023
Lotus	0.136	1.358	895.943	894.585	897.080	7/2/1992	893.180	12/29/1976
McCoy	-0.240	1.168	823.223	822.055	823.902	8/16/2020	821.956	11/4/2022
Mitchell	0.222	2.045	871.283	869.238	874.210	6/25/2014	865.870	7/25/1977
Red Rock	0.684	1.640	840.288	838.648	842.702	7/13/2014	835.690	9/28/1970
Round	-0.356	2.367	877.119	874.752	884.260	8/17/1987	874.752	9/5/2023
Silver	-0.071	1.417	899.291	897.874	901.030	6/20/2012	894.780	6/6/1972
Staring	0.065	1.911	815.445	813.534	820.000	7/24/1987	812.840	2/12/1977
AVERAGE	**0.351**	**1.755**	--	--	--	--	--	--

4.6. **Lake Shoreline Assessment**

In 2021, Riley Purgatory Bluff Creek Watershed District staff began a district-wide assessment of lake shoreland health. Staff followed the Score the Shore (STS) methodology outlined in the DNR Minnesota Lake Plant Survey Manual (Perleberg et al. 2016) with adaptations to allow for generation of individual property scores as well as an overall lake score.

As with the original STS methodology, RPBCWD staff evaluated shoreland in three zones: upland, shoreline, and aquatic (Figure 20). The score from each zone was equally weighted and combined to provide an overall score for each survey point (in the RPBCWD approach, each individual property served as a survey point). Within each zone, the evaluator scored for three metrics, resulting in a total of nine metrics assessed for each property. The metrics used in the assessment primarily relate to habitat value and include density of trees, shrubs, and natural ground cover; overhanging wood; woody debris within the water, amount of human-built structure (e.g. docks), and openings in aquatic plant beds. See comparison between a low and moderate scoring property in Figure 21.

Figure 20. Score The Shore (STS) property zones (MN DNR) shown with a bird's-eye view (top) and side view (bottom).

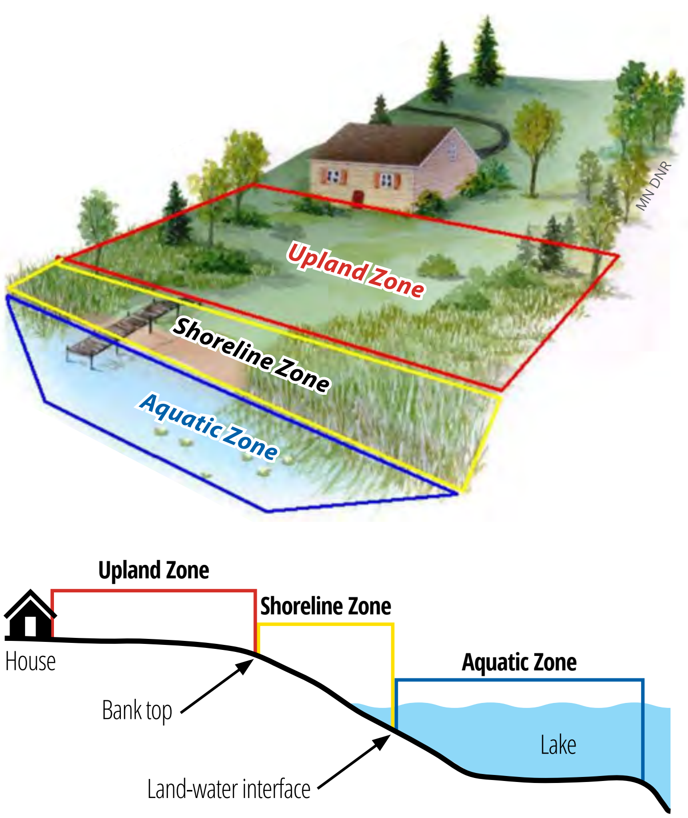


Figure 21. Example of a STS low scoring property (top) and STS high scoring property (bottom).

STS is an intuitive rapid assessment survey designed to be completed by boat. See Table 14 for the DNR STS scoring form. The upland zone should be judged as the area from the house/cabin to the top of the lake bank (area where land begins slope to water). If there is no clearly defined bank on the property (which is frequently the case), the best judgment of the assessor must be used. The shoreline zone extends from the bank to the land-water interface. This zone fluctuates depending on the water level. When necessary, the shoreline can be defined by the assessor as the first one-third of the lot toward the house and the upland zone the remaining two-thirds. The aquatic zone is the area extending from the land-water interface into the water body for 50 feet. For scoring purposes, trees are defined as larger woody plants that have a canopy. Shrubs are tree saplings or other small woody plants. Groundcover includes natural vegetative cover, wetland shrubs, shoreline grasses, and leafy debris.

Eleven of thirteen lakes in the District were scored in 2021 through 2023 (Figure 23). These lakes included Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Red Rock, Riley, Silver, Staring, and

Table 14. Original Score The Shore (STS) scoring form developed by the MnDNR to assess lake shoreland health.

FEATURE	FEATURE DESCRIPTION	COVERAGE	POINTS	SCORE (%)
UPLAND ZONE - *House to lake bank*				
1	Percent of frontage with trees	75-100%	20	$13.3\overline{3}$ %
		50-74%	15	10 %
		25-49%	10	$6.6\overline{7}$ %
		1-24%	5	$3.3\overline{3}$ %
		0%	0	0%
2	Percent of frontage with shrubs	75-100%	20	$13.3\overline{3}$ %
		50-74%	15	10 %
		25-49%	10	$6.6\overline{7}$ %
		1-24%	5	$3.3\overline{3}$ %
		0%	0	0 %
3	Percent of frontage with natural ground cover	75-100%	10	$6.6\overline{7}$ %
		50-74%	7.5	5 %
		25-49%	5	$3.3\overline{3}$ %
		1-24%	2.5	$1.6\overline{7}$ %
		0%	0	0 %
SHORELINE ZONE - *Lake bank to waterline*				
4	Percent of frontage with trees, shrubs, and/or wetland	75-100%	20	$13.3\overline{3}$ %
		50-74%	15	10 %
		25-49%	10	$6.6\overline{7}$ %
		1-24%	5	$3.3\overline{3}$ %
		0%	0	0%
5	Percent of frontage with natural ground cover or wetland	75-100%	20	$13.3\overline{3}$ %
		50-74%	15	10 %
		25-49%	10	$6.6\overline{7}$ %
		1-24%	5	$3.3\overline{3}$ %
		0%	0	0 %
6	Overhead woody habitat	Yes	10	$6.6\overline{7}$ %
		No	0	0 %
AQUATIC ZONE - *Waterline to 50 feet into water*				
7	Human-made openings in plant beds	No	20	$13.3\overline{3}$ %
		Yes	0	0 %
8	Downed woody habitat	Yes	10	$6.6\overline{7}$ %
		No	0	0 %

9	STRUCTURE				
	Number of docks	**Number of Rafts**	**Number of Lifts**	**Number of Marinas**	**Points**	**Score**
	None	None or many	None	None	20	$13.3\overline{3}$ %
	One simple	None or many	None	None	15	10 %
	At least 1 simple or 1 complex	None or many	None to 2	None	10	$6.6\overline{7}$ %
		None or many	More than 2	None	5	$3.3\overline{3}$ %
	None to many	None or many	None or many	One or more	0	0%

Susan. Round and Rice Marsh lakes did not receive shoreland evaluations from RPBCWD staff. More developed shorelines generally received lower scores compared to more natural shorelines, which have less disturbed vegetation and habitat throughout each zone. A healthy shoreline has a wide variety of vegetation, which provides stabilization, reduces runoff, and decreases water pollution. A healthy shoreline also has downed woody debris with undisturbed plant beds providing habitat for aquatic macroinvertebrates and fish and trees that shade the water and provide habitat. An unhealthy shoreline is typically dominated by turf grass maintained by mowing. Shoreline armoring (e.g. riprap) in place of naturally vegetated banks also lowers a shoreline's score.

Not to be Confused with Score Your Shore

Score the Shore (STS) is easy to confuse with the name of another DNR tool, Score Your Shore (SYS) (MNDNR 2023). SYS is used by an individual with limited experience and equipment (e.g. homeowner) to assess one or more lake properties. While similar to STS, SYS is primarily a hands-on educational tool for lake residents, the DNR does not generally collect SYS scores for statewide comparison of lakes.

Overview of RPBCWD Adaptations of STS

Most lakes within the district have shoreland largely developed as residential properties. To allow for more detailed assessment and more effective outreach with shoreland property owners, RPBCWD adapted DNR methodology in three primary ways:

1. **Selection of survey points:** RPBCWD used individual properties as a survey point so that each property received its own score. The DNR utilizes a standard-length method based on lake size with survey points distributed evenly around the lake. Because of the difference in how survey points were selected, RPBCWD calculated a weighted lakewide average that considers shoreline length for comparison with the DNR lakewide average.

2. **Addition of partial credit for aquatic plant beds:** The RPBCWD approach allowed partial credit when assessing aquatic plant bed openings (Feature 7/Aquatic Plant Zone). With a three-point scale (20/10/0 points), a lakeshore owner receives points if the aquatic plant bed along their property has only minimal disturbance such as a narrow boat path cleared to open water. The DNR all or nothing (20/0 points) scoring option does not allow partial credit to lakeshore owners with mostly intact aquatic plant beds.

3. **Finer-scaled rating system:** The DNR rating scale uses four categories: Excellent (91-100 percent), Good (81-90 percent), Average (71-80 percent), and Poor (less than 70 percent). Based on the DNR rating scale, most residential lakeshore properties in the District score as Poor. The DNR scoring scale is designed to be used for all Minnesota waterbodies, ranging from completely natural to heavily developed. Considering the mostly developed nature of lakes within RPBCWD, staff developed a finer scale with ten categories instead of the DNR's four. This allowed for a finer scale of assessment for shorelines scoring 70 percent or lower. See Figure 22 for a comparison between the DNR and RPBCWD scales.

Table 15 provides an overview of RPBCWD modifications to the original STS approach.

DNR and District Lakewide Score Comparison

Figure 22. Comparisons between the original STS rating scale and modified version used by RPBCWD.

MNDNR Rating Scale

MEAN LAKEWIDE SCORE	MEAN SHORELAND SCORE	MEAN SHORELINE SCORE	MEAN AQUATIC SCORE	RATING
90-100%	30 - 33.3 %	30 - 33.3 %	30 - 33.3 %	**Excellent**
80-89%	25 - 29 %	25 - 29 %	25 - 29 %	**Good**
70-79%	20 - 24 %	20 - 24 %	20 - 24 %	**Fair**
<70%	<20 %	<20 %	<20 %	**Poor**

The DNR's standard Score The Shore method uses a shoreline rating of four categories. The rating scale does not allow for a finer level of assessment below a score of 70 percent, which is the category where most fully developed suburban lakes fall within.

RPBCWD Rating Scale

SCORE RANGE	COLOR CODE	RATING
90-100%		**Healthy**
80-89%		↑
70-79%		
60-69%		
50-59%		
40-49%		
30-39%		
20-29%		
10-19%		↓
0-9%		**Degraded**

RPBCWD staff use a modified version of the Score The Shore rating scale. Instead of the DNR's four categories, the RPBCWD rating method has 10 rating categories (of 10 points each) along a continuum from healthy to degraded. The addition of a corresponding color scale (green to red) allows for visual representation of scores on GIS-generated maps.

Table 15. Overview RPBCWD modifications to the original DNR Score The Shore (STS) methods.

METHOD	Original STS developed by DNR	Modified STS used by RPBCWD
Features assessed	9 feature categories	*Same as DNR*
Survey points	Number of survey points based upon lake shoreline length; points spaced evenly	Number of survey points based upon property lines (one survey point per parcel)
Zone scoring	Points based upon percent coverage or presence/absence of feature	*Same as DNR except* addition of partial credit for minimal human-made openings in plant beds (Feature 7 in Aquatic Zone): scoring option changed to 0/10/20 from 0/20
Overall rating scale	4 rating categories with variable percent ranges (10%, 10%, 10%, and 70%)	10 rating categories divided evenly between percent ranges (10% each)

The DNR calculates a lakewide score by averaging the STS scores collected at points evenly distributed around the lake; the number of survey points per lake is based upon lake size. As RPBCWD survey locations were based upon property lines and not lake size, the RPCWD lakewide scores were weighted to make a reasonable comparison to the DNR lakewide scores.

To calculate the RPBCWD lakewide score, each individual property score was multiplied by the property's shoreline length. The sum of this value was then divided by the length of the lake shoreline. The formula for this calculation is shown below:

$$lake\ weighted\ average = \frac{\Sigma\,(property\ score \times property\ length)}{\Sigma\,property\ length}$$

As of this report, five lakes located within the district boundary had STS scores from the DNR. Scores by property were used to map in ArcGIS and then converted to lakewide weighted average scores for comparison to DNR STS scores. This allowed a more direct comparison to the standard width scoring method that the DNR utilizes.

Differences can arise upon comparing scoring processes due to variation in property sizes. For instance, park and city land can skew property averages as they are typically larger than residential lots and generally have limited disturbance. The scoring by property and weighted average scoring provides a much finer level of detail than what is captured with the DNR method. The DNR scoring is geared towards a fast and general assessment of the lake as a whole and does not assess individual properties as accurately. Regardless, the scoring of RPBCWD lakes can show lakeshore residents the difference in shoreline health between a natural/undeveloped shore and their own.

RPBCWD average lakewide scores (straight and weighted averages) and the corresponding DNR lakewide score is shown in the Table 17. Lake weighted scores displayed along the RPBCWD rating scale is shown on Figure 24. Lakes with less developed properties scored higher and had smaller range of property scores.

Figure 23. Distribution of RPBCWD individual property shoreland scores and overall average property score (unweighted).

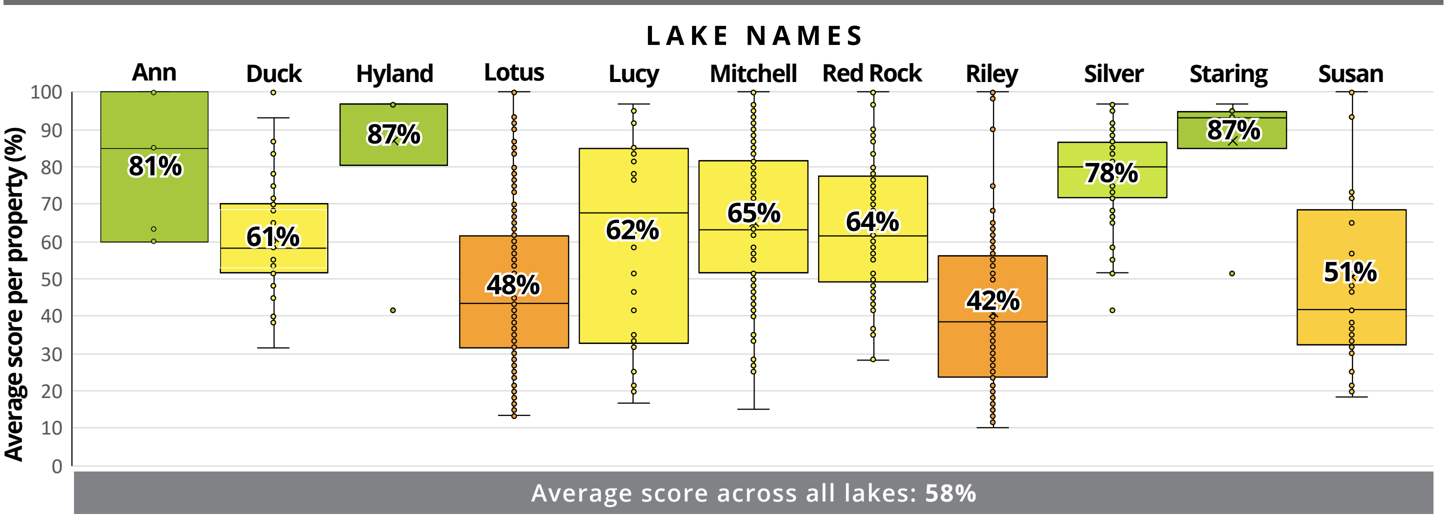


Table 16. Overview of RPBCWD Score The Shore (STS) averages for each lake, each zone within a lake, and all lakes combined (unweighted averages).

LAKE NAME	SCORE PER ZONE			OVERALL LAKE SCORE
	UPLAND ZONE	SHORELINE ZONE	AQUATIC ZONE	
Ann	27%	29%	26%	**81%**
Duck	14%	20%	27%	**61%**
Hyland	30%	29%	28%	**87%**
Lotus	18%	16%	14%	**48%**
Lucy	21%	20%	21%	**62%**
Mitchell	21%	22%	23%	**65%**
Red Rock	18%	21%	26%	**65%**
Riley	18%	13%	10%	**41%**
Silver	22%	24%	31%	**78%**
Staring	27%	31%	29%	**87%**
Susan	18%	17%	16%	**50%**
Combined lakes average	19%	19%	20%	**58%**

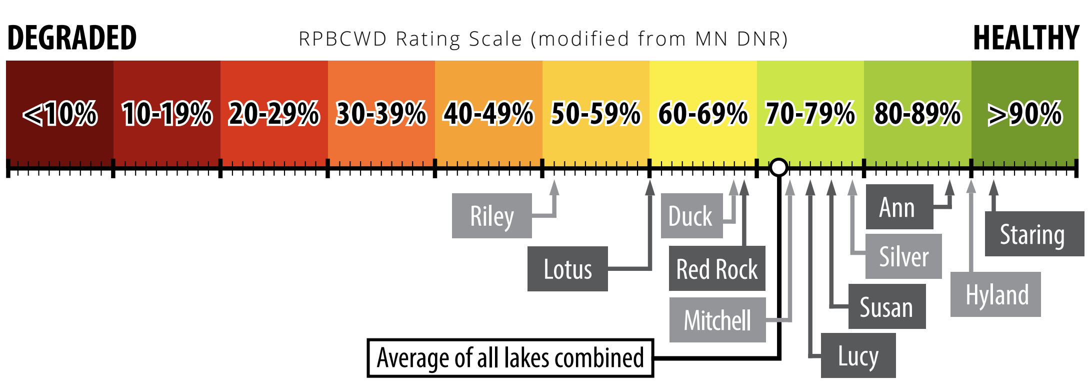
Table 17. Comparison of lakewide Score the Shore (STS) scores between RPBCWD and the DNR.

	RPBCWD Lakewide Score		DNR Lakewide Score
Lake	STRAIGHT AVERAGE (average of property scores)	WEIGHTED AVERAGE (accounts for shoreline length)	Average score considers lake size
Ann	81	88	92
Duck	61	68	*unavailable*
Hyland	87	90	*unavailable*
Lotus	48	60	75
Lucy	62	75	*unavailable*
Mitchell	65	73	89
Red Rock	65	69	*unavailable*
Riley	41	51	55
Silver	78	79	*unavailable*
Staring	87	91	97
Susan	50	77	*unavailable*
All-lake average	58	72	--

RPBCWD Shoreland Scoring Results

The average individual property shoreland score for all lakes in the District was 58 percent (Table 16 and Table 17). The weighted average of all shoreline in the district is higher, at 72 percent. This can be explained in part by larger average shoreland scores from higher scoring public land properties. Although the DNR method for shoreline scoring is standardized, the subjectivity in scoring still allows for judgment differences by the scorer and can explain some of the differences between scores. The weighted average scores by property are more accurate and precise on fully developed lakes than the DNR standard method because there is more definition (each property is scored compared to its property length). On less developed lakes, the inverse is true where the DNR standard scoring method has more definition (more scored transects per parcel). This is because less developed lakes have much larger parcels such as parks or other public land, which are only scored once using in the RPBCWD approach. However, there is typically not much change in score within larger, undeveloped properties which generally have better scores. The higher definition garnered by the DNR scoring in larger properties is generally not needed to achieve the same lakewide score. Evidence of this

Figure 24. Comparison of RPBCWD Score The Shore weighted lake scores along the modified rating scale.



can be seen in the closeness in scoring between the weighted lakewide average score and DNR lakewide average score for less developed lakes such as Ann and Staring. These lake scoring differences had some of the least variability between methods at 3 percent and 5 percent respectively. If additional DNR surveys are performed on other lakes in the future, it could provide enough data for more in-depth comparisons between the DNR and RPBCWD scoring approaches.

Several lakes (Duck, Lotus, Red Rock, and Riley) have a lower weighted average than the weighted average for all lakes. This is likely due to these lakes containing a higher proportion of developed property and subsequently a higher percentage of deteriorated shoreline. All lakes had a weighted average that was higher than their property average. Susan had the highest difference, with a weighted average 26 percent higher than the individual property score. Lake Susan has one side of the lake dominated by natural parkland and the other side as heavily developed private property. Lake Lucy has a similar case, with a property average of 62 and a weighted average of 75. For these lakes, the individual property score is skewed and the average is a gross underestimation of the overall shoreline health. All other lakes had a difference of 11 percent or less. Lake Riley is the most developed lake within the district and had similar scores comparing the DNR and weighted method (four percent difference). Both Lotus and Mitchell scores were significantly different between the district and DNR scoring with differences greater than 15 percent.

Scoring by property leads to scores that are lower than the comparable lake wide average created from scoring set intervals in DNR methodology. However, with the standard STS scoring performed by the District, the ability for the homeowner to see their individual property score is realized. A homeowner seeing a lower score for their property may be called to action and aim to improve their individual score. The weighted average allowed for a better comparison with the standard methodology and fully took into consideration the different lengths and associated scores of individual properties.

After completing all surveys, commonalities on solutions to improve shoreline scores were found. Residents can improve their scores by increasing the percentage of their upland and shoreland areas covered by trees, shrubs, and groundcover. One of the simplest ways to increase a score is by leaving woody habitat in the water, as having no downed woody habitat eliminates 10 points from the total score (6.67 percent of the total score). Another simplistic way to increase score is to avoid treating/removing aquatic plant beds. By not clearing a swimming area or boat path, a maximum score of 20 points (13.3 percent) can be obtained for this category. If they do modify their aquatic vegetation (<25 percent disturbance as with a boat path and no other clearing) the district modified scoring allows them to still gain 10 points (6.67 percent). If a resident leaves their aquatic zone natural (with the exception of their dock) and does not remove plants or woody debris in any capacity their score can increase by 30 points (20 percent).

Overall, the STS assessment suggests there is room for ecological improvement in the form of shoreline restoration, upland restorations, and aquatic improvements across all lakes within the district. It is understood that we are in an urban setting and people want to utilize their lakeshore. With this study, District staff hope to start constructive conversations about how lakeshore owners can take small steps to improve their shorelines. Developing a district wide or individual goal residential property average may engage residents to improve their shorelines.

District staff are discussing the potential of adapting the grant program to allow for targeted grants to residents to specifically increase their STS score. This could include tree/shrub planting, buffer plantings, etc. Follow up surveys will be conducted on a rotational basis moving forward to assess changes in shoreline health over time.

More information about Score Your Shore including individual property scores will be available at rpbcwd.org in late spring 2024.

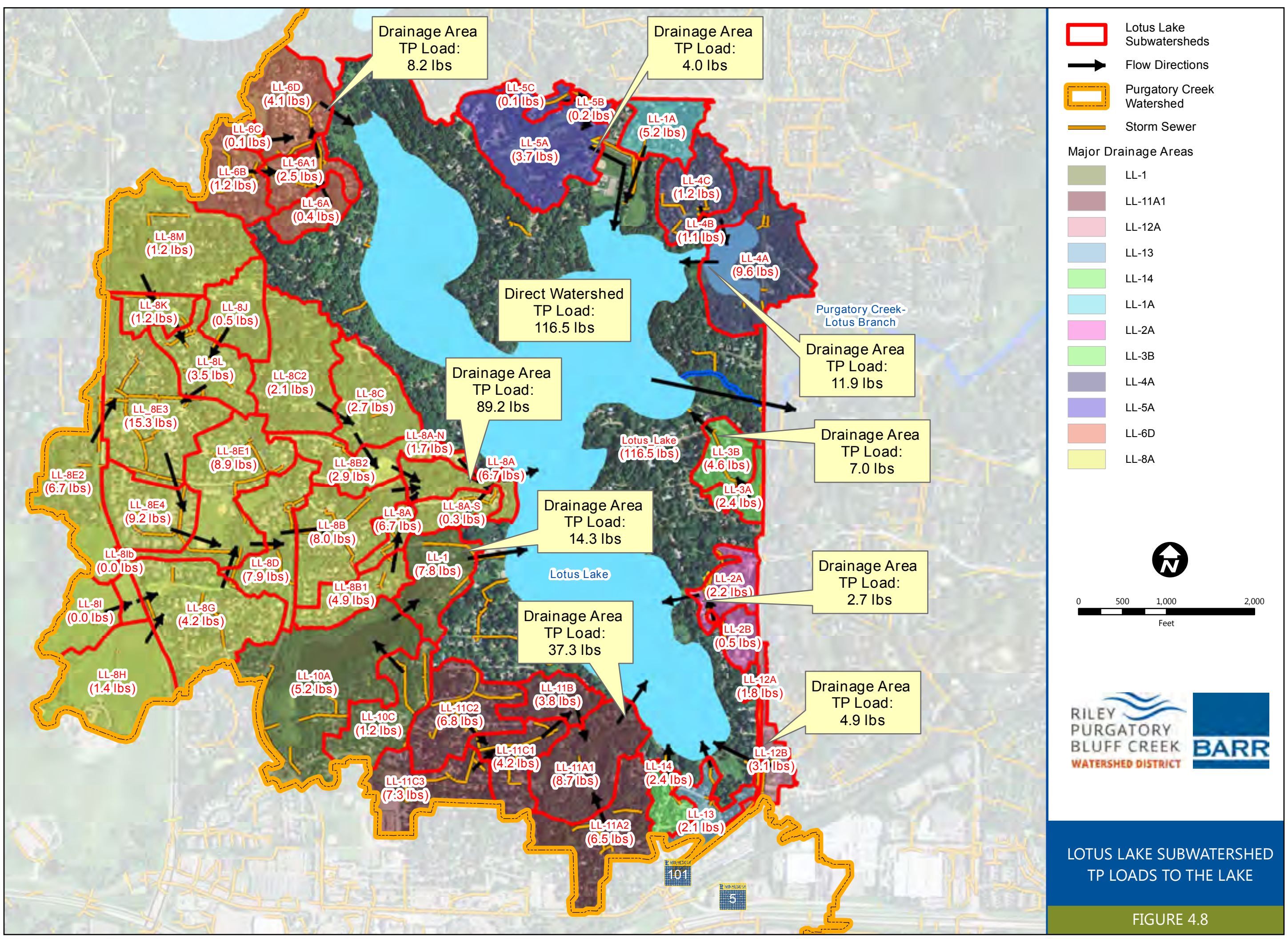
4.7. **Purgatory Creek Auto-Sampling Units**

Within the Purgatory Creek Chain of Lakes, Lotus Lake consistently fails to achieve the water quality standards set forth by the MPCA including total phosphorus (TP) chlorophyll-a, and water clarity (Secchi disk depth). Additionally, Lotus Lake was listed on the MPCA 2002 Minnesota Section 303(d) List of Impaired Waters due to nutrients. In 2017, an updated Use Attainability Analysis (UAA) for most of the Purgatory Creek watershed was completed which further identified sources and potential solutions for correcting the nutrient loading to the lake.

- (LL_3 & LL_7) For Lotus Lake, the three ravines on the west side of the lake were estimated to be contributing 140.8 lbs. of TP. The uppermost ravine contributed 89.2 pounds alone (Figure 25). This is the largest estimated loading drainage area besides the direct runoff from the area around the lake which could potentially be addressed by the installation of a BMP.
- (LL_1/Kerber 1 and Kerber 2) For Lotus Lake, the three ravines on the west side of the lake were estimated to be contributing 140.8 lbs. of TP. The middle ravine is estimated to contribute 14.3 lbs. but there is likely more as the City of Chanhassen must clean out sediment from the modified culvert near the lake multiple times a year. (Figure 25). Since the upper site is being studied, the middle and lower ravines will also have samples collected to potentially gain cost savings for project implementation.

Figure 25. Estimated subwatershed Total Phosphorus loading to Lotus Lake .

Image below is "Figure 4.8" from the *Lotus, Silver, Duck, Round, Mitchell, Red Rock Use Attainability Analysis Update; Lake Idlewild and Staring Lake Use Attainability Analysis; and Lower Purgatory Creek Stabilization Study* (Revised March 2017).



When a project is identified, RPBCWD staff will often monitor the site before and after the project is implemented. This helps confirm if a project is warranted and assess the effectiveness of a project once it is in place. In the Lotus subwatershed, staff placed an automated sampling units at the grated access site downstream of Kerber Boulevard (upper tributary), the culvert under the recreational trail connected to the end of Carver Beach Road (upper tributary), the culvert draining Kerber Pond (middle tributary), and the culvert under frontier trail (middle tributary). This was done to better quantify rain event nutrient loading from upstream sources. Analyzing the "first flush" of a storm event is important because these events are when water pollution entering storm drains in areas with high proportions of impervious surfaces is typically more concentrated compared to the remainder of the storm. Water samples were collected and analyzed for total dissolved phosphorus (TDP), total phosphorus (TP), total suspended solids (TSS), and Chlorophyll-a (Chl-a). The automated water-sampling units also estimated flow of the creek or drainage channel at that point.

From 2021-2023, total phosphorus levels on the upper Lotus Lake ravine during storm events were high compared to the MPCA standards, as seen in Figure 26 and Table 18. In 2023, the average TP coming from upstream of Kerber Blvd. (LL_3) averaged 0.506 mg/L and the average TP leaving the stormwater pond upstream of the recreational trail (LL_7) measured 0.442 mg/L in (Table 18). Water at LL_3 is piped from upstream to a stormwater pond just upstream of the sampling location LL_7. The average percent reduction of 13% (16% in 2022). This slight reduction in TP suggests the stormwater pond is undersized for the hydrology at this location and is likely not effectively treating much of the water. When comparing the individual storm events this becomes more apparent. The overall reduction in TP in 2022 and 2023 from 2021 (0.534 mg/L) for LL_7 was likely due to the reduced amount of precipitation seen in 2022 and 2023. Regardless, the 2023 TP levels were over four times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP) and double the MPCA estimated typical total phosphorus range (0.1 mg/L to 0.25 mg/L) for effluent (outgoing) stormwater. Of the 13 storm event TP samples collected 11 out of 13 samples from LL_3 and 8 out of 11 samples from LL_7 measured above the MPCA stormwater effluent standard, but all measured above the MPCA stream standard. The highest TP concentration for LL_7 occurred on 9/11/23 which corresponded with a relatively small rain event 0.37 inches (Figure 26). This followed a month-long dry period and could be linked with an internal loading release event from the pond. The highest concentration for LL_3 occurred on 9/24/23 which corresponded with the largest storm event. In 2023, the average TDP concentration was reduced from the previous years to 0.085 mg/L, previously 0.106 mg/L in 2021 and 0.108 mg/L in 2022.

The average amount of TSS across 2023 storm events was 142.7 mg/L for station LL_3 and 89.7 mg/L for LL_7. This is down from 180.7 mg/L for station LL_3 and 107.5 mg/L for station LL_7 in 2022. Across all the sampling events, 12 out of 13 for LL_3 and 8

Table 18. Lotus Lake Northern Tributary First Flush Auto Sampling Units Average Nutrient Summary (2021-2023).

		SITE LL_3		SITE LL_7			AVERAGE PERCENT REDUCTION	
PARAMETER	**MPCA WQS**	**2022**	**2023**	**2021**	**2022**	**2023**	**2022**	**2023**
TP (mg/L)	≤ 0.1	0.505	0.506	0.534	0.424	0.442	16.04%	12.65%
TDP (mg/L)	--	0.117	0.105	0.106	0.108	0.085	7.69%	19.05%
Chl-a (µg/L)	≤ 18	20.9	24.9	18.5	14.9	15.8	28.71%	36.55%
TSS (mg/L)	≤ 30	180.7	142.7	76.6	107.5	89.7	40.51%	37.14%

of the 10 samples taken in 2023 were above 30 mg/L TSS water quality standard for streams (Figure 26). The average percent reduction from LL-3 to LL_7 was around 40 percent indicating the upstream pond from LL_7 is settling out suspended solids. From the limited Chl-a samples collected, concentrations at LL_3 both averaged just above the MPCA standard while LL_7 averaged just below.

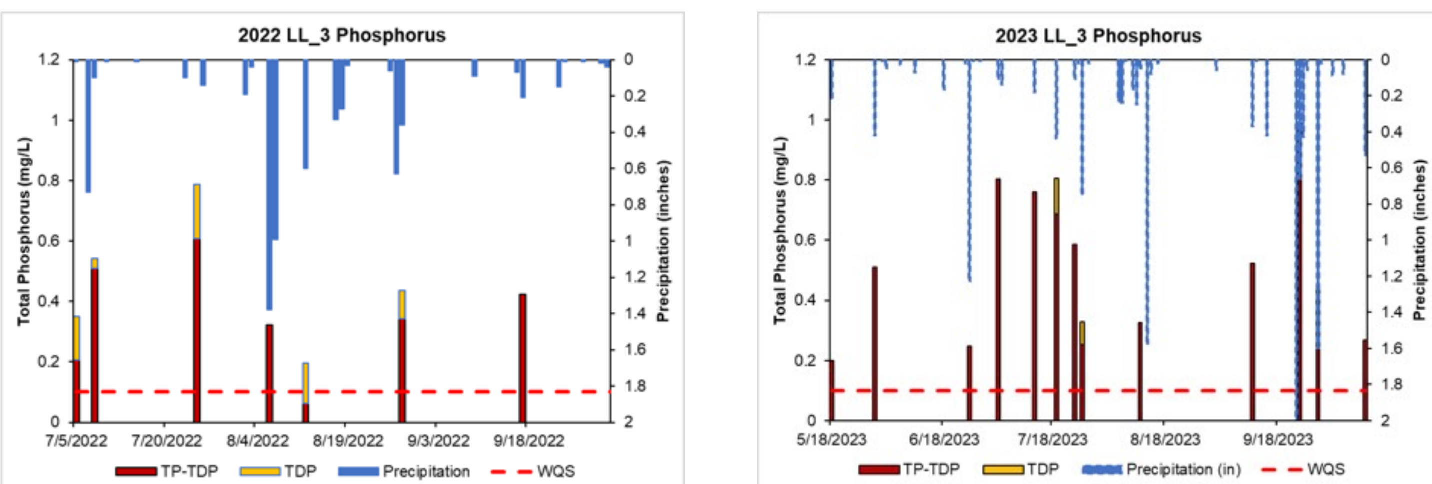
It is important to note that these samples were targeted samples, representative of the initial flush of water and pollutants that occur during rain events, and do not represent season-long pollutant levels in the Lotus Lake Ravine. Precipitation graphs are shown in Figure 27, Figure 28, and Figure 29. With the low water levels, this site may have met the TSS and Chl-a MPCA standard for streams if more continuous or consistent nutrient monitoring occurred. Regardless, the results suggest that a bmp placement or upstream clean out of the ravine at this location would likely reduce loading to Lotus Lake. Additionally, the LL_7 site is specifically measuring effluent directly after a stormwater pond and LL_3 is an intermittent non navigable stream. Therefore, a direct comparison to the MPCA stream water quality standards is cautioned. The high nutrient levels at the downstream site indicates the stormwater pond is likely undersized for the volume of water it receives.

Site LL_3 levels may have been elevated due to the upstream sediment that was cleared upstream of Kerber Blvd in 2022. This clearing caused the down cutting upstream of the culvert which contributed TP and TSS downstream. This excess material is likely from the upstream pond cleanout, outlet reconstruction, and stabilization that occurred recently.

Kerber site 1 and 2 were installed later in the year during the drought conditions so limited nutrient and flow data was collected. Only two samples were collected for site Kerber 2 and none were collected for Kerber 1. Both samples indicated high TP and TSS loading. All sites will again be monitored in 2024 to assess nutrient loading to Lotus Lake.

Figure 26. 2022-2023 Lotus Upper Ravine Total Suspended Solids and Phosphorus

Total Suspended Solids (TSS), Total Dissolved Phosphorus (TDP), and Total Phosphorus (TP) first flush concentrations (mg/L) from 2022-2023 Lotus Lake Upper Ravine downstream of Kerber Blvd (LL_3) and from 2022-2023 Lotus Lake Upper Ravine off end of Carver Beach Road (LL_7) from an automated sampling unit. Precipitation data is from the Chanhassen MN National Weather Service Station. Dashed line represents the Minnesota Pollution Control Agency standard for TSS (≤30 mg/L) TP in class 2B creeks (≤ 0.1 mg/L).



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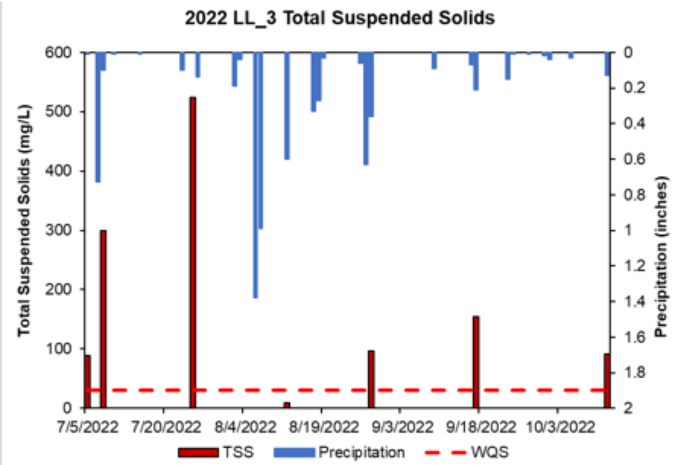
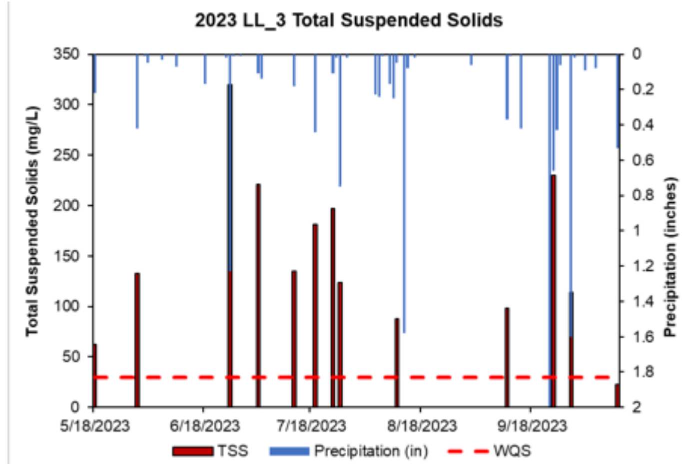
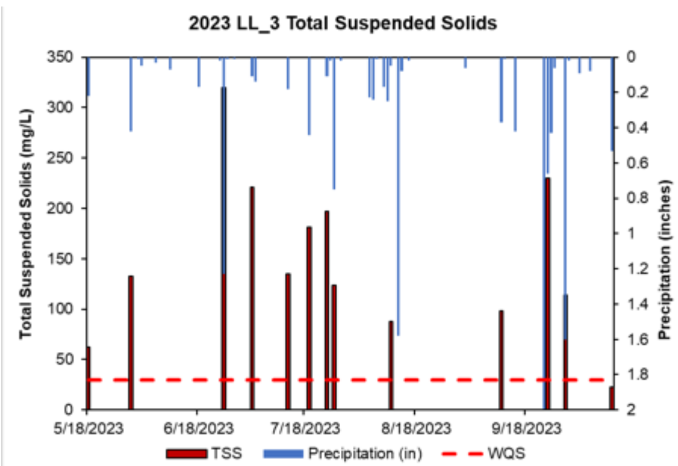
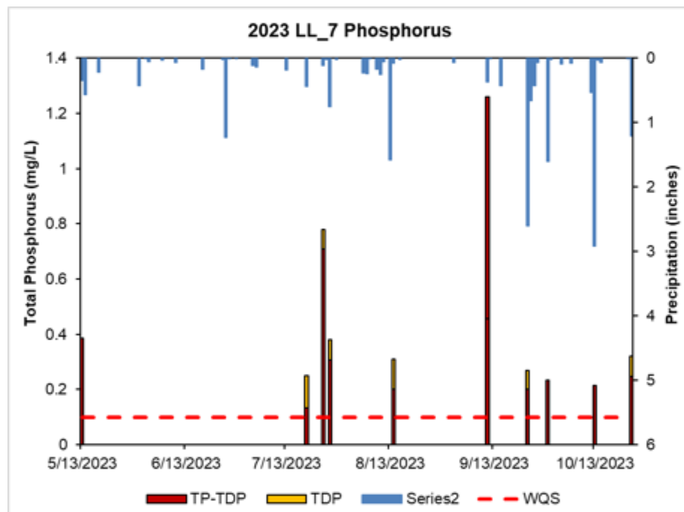

2022 LL_3 Total Suspended Solids
Total Suspended Solids (mg/L)
Precipitation (inches)
7/5/2022 7/20/2022 8/4/2022 8/19/2022 9/3/2022 9/18/2022 10/3/2022
TSS
Precipitation
WQS


2023 LL_3 Total Suspended Solids
Total Suspended Solids (mg/L)
Precipitation (inches)
5/18/2023 6/18/2023 7/18/2023 8/18/2023 9/18/2023
TSS
Precipitation (in)
WQS


2023 LL_3 Total Suspended Solids
Total Suspended Solids (mg/L)
Precipitation (inches)
5/18/2023 6/18/2023 7/18/2023 8/18/2023 9/18/2023
TSS
Precipitation (in)
WQS


2023 LL_7 Phosphorus
Total Phosphorus (mg/L)
Precipitation (inches)
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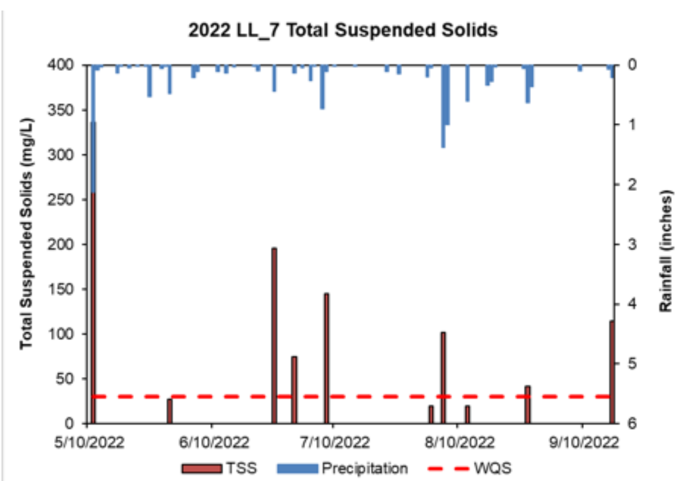
TP-TDP
TDP
Series2
WQS


2022 LL_7 Total Suspended Solids
Total Suspended Solids (mg/L)
Rainfall (inches)
5/10/2022 6/10/2022 7/10/2022 8/10/2022 9/10/2022
TSS
Precipitation
WQS

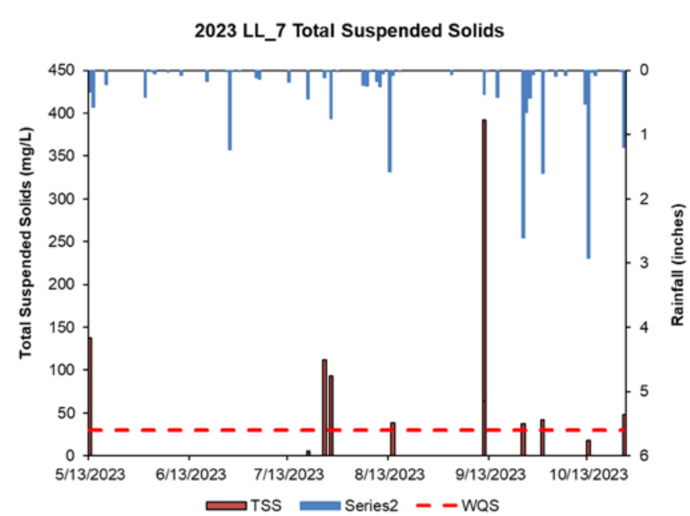

2023 LL_7 Total Suspended Solids
Total Suspended Solids (mg/L)
Rainfall (inches)
5/13/2023 6/13/2023 7/13/2023 8/13/2023 9/13/2023 10/13/2023
TSS
Series2
WQS

Figure 27. 2023 Kerber 2 Lotus Lake Middle Ravine water level.

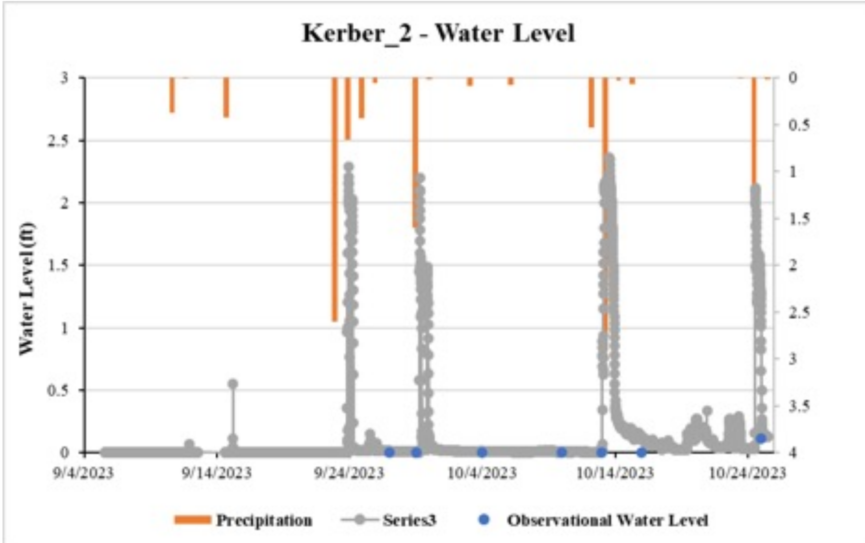


Figure 28. 2023 Kerber Blvd/Upper Lotus Lake Ravine Water Level

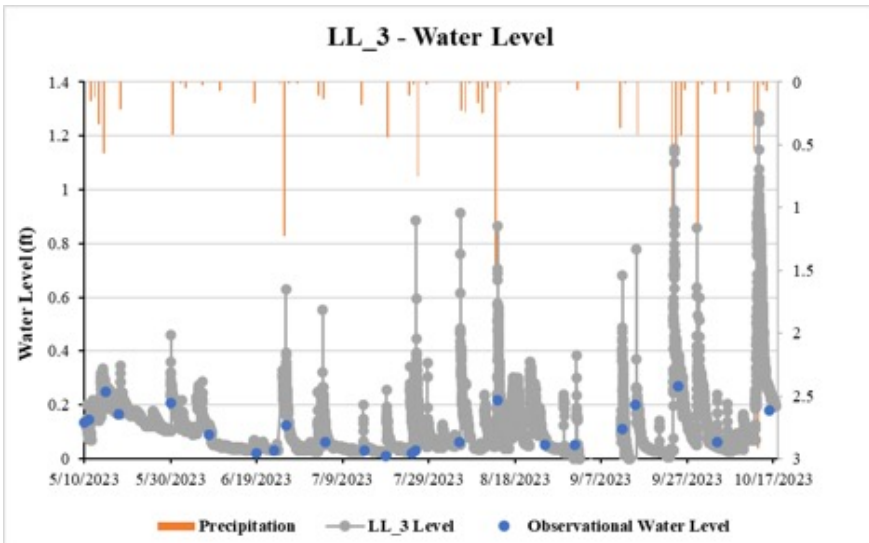
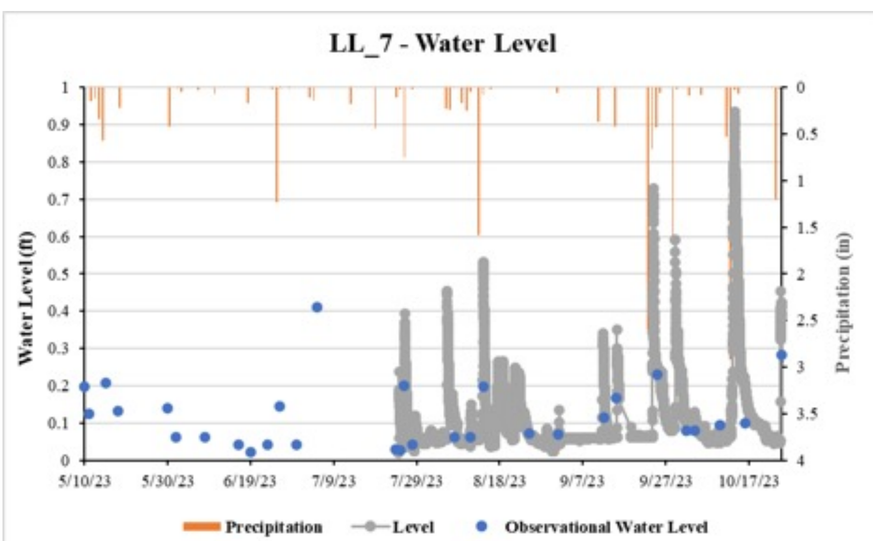


Figure 29. 2023 Carver Beach Road/Upper Lotus Lake Ravine Water Level



4.8. Upper Bluff Creek Auto-Sampling Units

Bluff Creek is listed on the 2002 and 2004 Minnesota Section 303(d) List of Impaired Waters due to impairment of turbidity and low fish Index of Biological Integrity (IBI) scores. Turbidity in water is caused by suspended sediment, organic material, dissolved salts, and stains that scatter light in the water column making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, can harm aquatic life, and have greater thermal impacts from increased sediment deposition in the stream. Primary sources contributing to TSS within the Bluff Creek Watershed are streambank and bluff erosion, as well as poorly vegetated ravines and gullies (Barr 2013). These sources of sediment are contributing to excess TSS loading mobilized by stormwater runoff from the watershed under high flow conditions. In addition, total phosphorus levels across all five Bluff Creek water quality sites are consistently above the MPCA water quality standard from year to year (≤ 0.1 mg/L). The Creek Restoration Action Strategy identified sub-reaches B5B and B5C near Galpin Road as sites that could benefit from restoration/stabilization and therefore reduce downstream nutrient and sediment loading.

When a project is identified RPBCWD staff will often monitor a site before and after the project is implemented. This helps confirm if a project is warranted and monitor the effectiveness of a project once it is in place. In 2019, 2020, 2021, and 2023, staff placed an automated sampling unit at the culvert under Galpin Road and the culvert under Highway 5 on Bluff Creek. This was done to better quantify rain event nutrient loading from upstream sources of Bluff Creek. Analyzing the "first flush" of a storm event is important because these events are when water pollution entering storm drains in areas with high proportions of impervious surfaces is typically more concentrated compared to the remainder of the storm. Water samples were collected and analyzed for total dissolved phosphorus (TDP), total phosphorus (TP), total suspended solids (TSS), and Chlorophyll-a (Chl-a). The automated water-sampling unit also estimated the flow of the creek at that point.

In 2019, 2020, and 2023 total phosphorus levels at the Galpin Bluff Creek site during storm events were high compared to the MPCA standards, as seen in Figure 30. As seen in Table 19, the average TP has been consistent at 0.525 mg/L in 2019, 0.425 mg/L in 2020, and 0.434 mg/L in 2023. This level is over three times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP). All TP samples across three years measured above the MPCA standard.

The highest TP concentration in 2019 occurred in early August (1.77 mg/L). The highest concentration in 2020 occurred in mid-October (1.12 mg/L) and the highest in 2023 occurred in mid-September (1.05 mg/L). The TDP average in 2019 was 0.135 mg/L with a high measurement of 0.237 mg/L and the and the only measurement in 2023 was 0.127 mg/L (Table 19). The average amount of TSS across the 17 samples taken in 2019 was 84.6 mg/L. It was reduced in 2020 was 26.4 mg/L (15 samples) and then the average increased across the 5 samples in 2023 to 33.5 mg/L. To achieve the MPCA TSS stream water quality standard, a stream may not exceed 30 mg/L TSS more than 10% of the time. Across all the sampling events, nine of the 17

Table 19. Upper Bluff Creek Crossing Nutrient Loading Summary.

		Galpin Boulevard			Highway 5	
PARAMETER	**MPCA WQS**	**2019 Average**	**2020 Average**	**2023 Average**	**2021 Average**	**2023 Average**
TP (mg/L)	≤ 0.1	0.525	0.425	0.434	0.365	0.811
TDP (mg/L)	--	0.135	--	0.127*	0.074	0.081
Chl-a (µg/L)	≤ 18	11.56	32	1*	9.7	11.53
TSS (mg/L)	≤ 30	84.6	26.4	33.5	99.4	109.2

*Only one sample collected.

samples taken in 2019 were above 30 mg/L TSS, only five of the fifteen samples taken in 2020, two of the five samples in 2023 were above the standard (Figure 31). Four of the six in 2019, five of six in 2020, and the only Chl-a samples collected were less than the MPCA eutrophication water quality standard of ≤18 ug/L Chl-a indicating Chl-a is not loading downstream from the upper wetland.

In 2021 and 2023 total phosphorus levels on Bluff Creek downstream of Highway 5 during storm events were high compared to the MPCA standards (Table 19). The average TP across 19 samples was 0.365 mg/L 2021. Of the 15 samples in 2023, the average total phosphorus doubled to 0.811 mg/L. Concentrations at the Highway 5 site were over seven times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP). All storm event TP samples collected measured above the MPCA standard across both years. The highest TP concentration occurred at the end of August at 1.07 mg/L in 2021 and the first sample taken in 2023 (June) at 2.43 mg/L. In 2021, the average TDP concentration was 0.074 mg/L which remained similar in 2023 at 0.081 mg/L (Figure 33).

Figure 30. 2020 and 2023 Galpin/Bluff Creek Phosphorus

The Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) concentrations (mg/L) from Bluff Creek under Galpin Blvd from 2020 and 2023 automated, level triggered, flow-paced samples. Dashed line represents the Minnesota Pollution Control Agency standard for TP in class 2B creeks (≤ 0.1 mg/L).

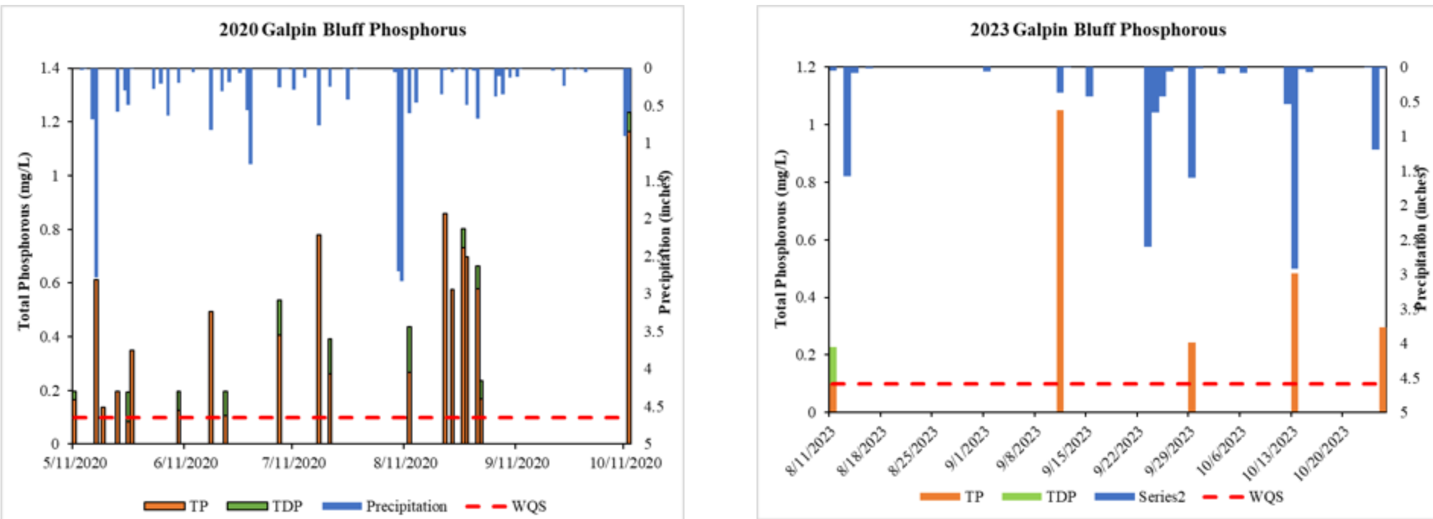
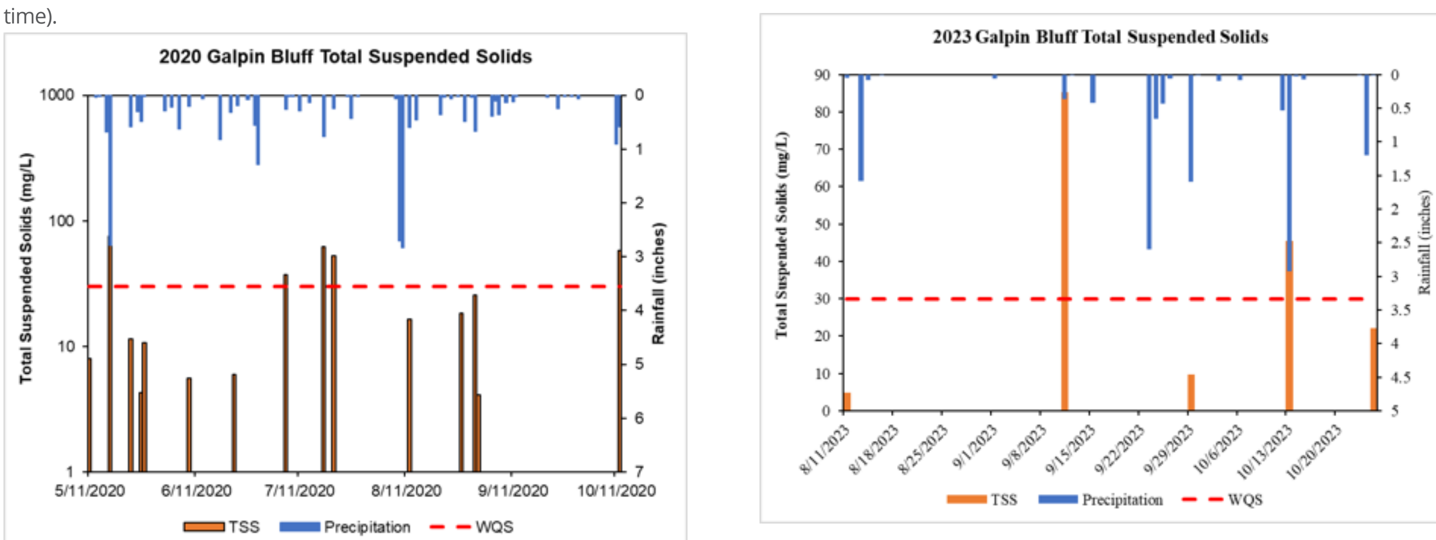


Figure 31. 2020 and 2023 Galpin/Bluff Creek Total Suspended Solids

Total Suspended Solids (TSS) concentrations (mg/L) from Bluff Creek under Galpin Blvd from 2020 and 2023 automated, level triggered, flow-paced sampler. Dashed line represents the Minnesota Pollution Control Agency standard for TSS in class 2B creeks (≤ 30 mg/L TSS no more than 10% of the time).

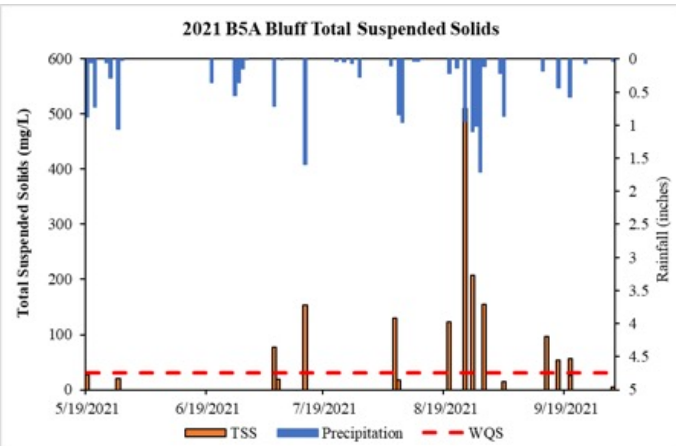


The average amount of TSS was 99.4 mg/L in 2021 which increased slightly to 109.2 mg/L in 2023. Across all the sampling events, 10 of the 17 samples taken in 2021 were above 30 mg/L TSS (Figure 32) while all 15 samples were above the standard in 2023. Water level graphs are shown in Figure 34 and Figure 35.

It is important to note that these samples are targeted samples, representative of the initial flush of water and pollutants that occurs during a rain event, and do not represent season-long pollutant levels in Bluff Creek. Therefore, a direct comparison to the MPCA water quality standards is cautioned.

Figure 32. 2021 and 2023 Highway 5/Bluff Creek Total Suspended Solids

Total Suspended Solids (TSS) concentrations (mg/L) from Bluff Creek downstream of highway 5 from 2021 and 2023 automated, level triggered, flow-paced sampler. Dashed line represents the Minnesota Pollution Control Agency standard for TSS (≤ 30 mg/L TSS no more than 10% of the time).



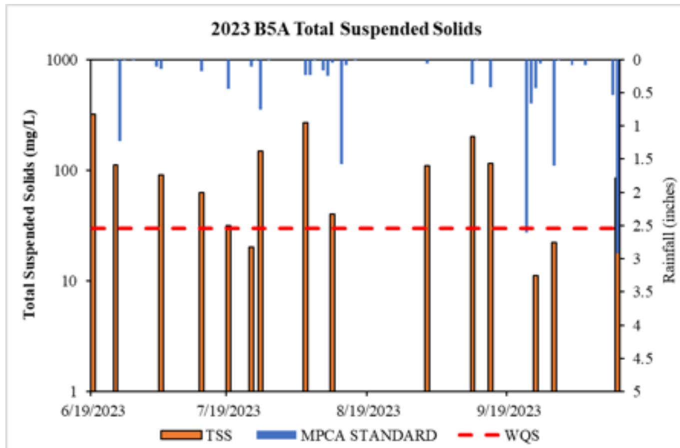
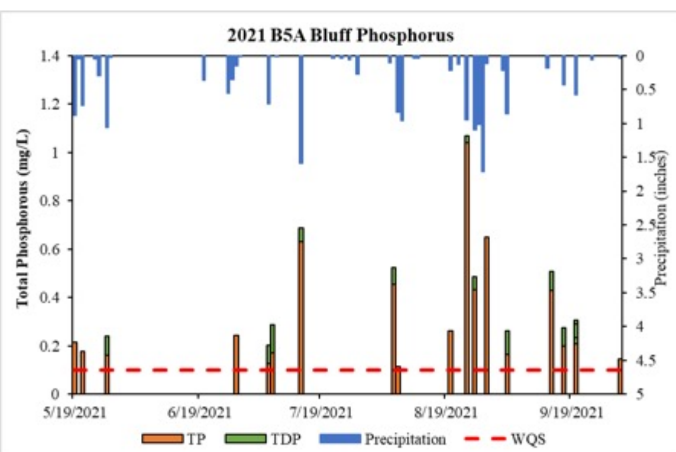


Figure 33. 2021 and 2023 Highway 5/Bluff Creek Phosphorous

Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) concentrations (mg/L) from Bluff Creek downstream of highway 5 from 2021 and 2023 automated, level triggered, flow-paced sampler. Dashed line represents the Minnesota Pollution Control Agency standard for TP (≤ 0.1 mg/L) in class 2B creeks.



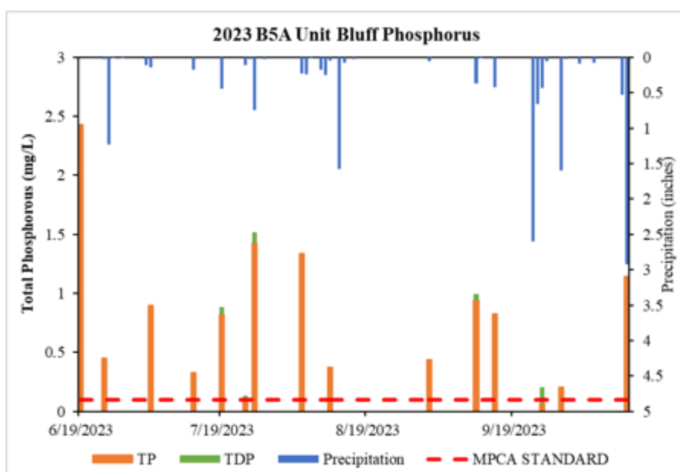


Figure 34. 2023 Highway 5/Bluff Creek Water Levels at Galpin Blvd.

Water levels recorded from the autosampler and visual staff gauge readings from Bluff Creek under Galpin Boulevard in 2023.

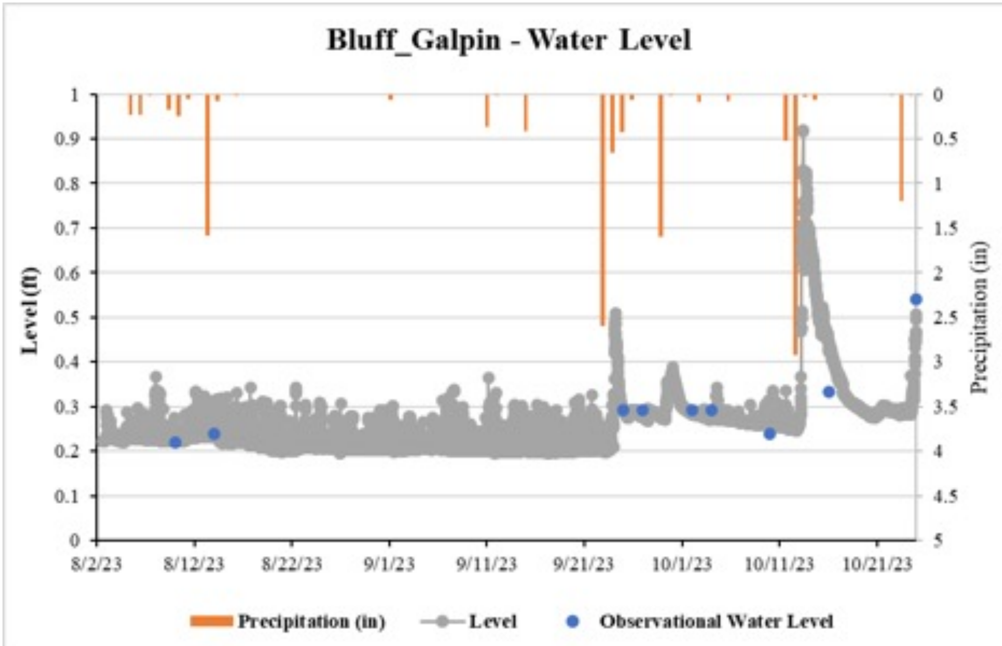
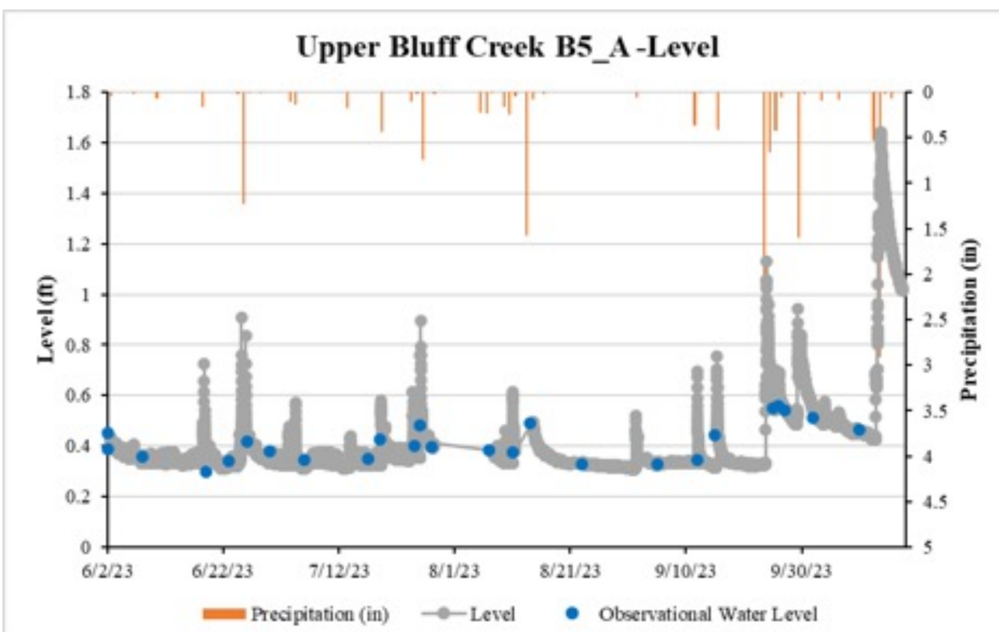


Figure 35. 2023 Highway 5/Bluff Creek Water Levels at Highway 5.

Water levels recorded from the autosampler and visual staff gauge readings from Bluff Creek under Highway 5 in 2023.



4.9. Creek Restoration Action Strategy

RPBCWD developed the Creek Restoration Action Strategy (CRAS) to prioritize creek reaches, subreaches, or sites in need of stabilization and/or restoration. The District identified eight categories of importance for project prioritization including: infrastructure risk, erosion and channel stability, public education, ecological benefits, water quality, project cost, partnerships, and watershed benefits. These categories were scored using methods developed for each category based on a combination of published studies and reports, erosion inventories, field visits, and scoring sheets from specific methodologies. Final tallies of scores for each category, using a two-tiered ranking system, were used to prioritize sites for restoration/remediation. The CRAS was finalized/adopted in 2015, updated in April of 2017, and published in the Center for Watershed Protection Science Bulletin in 2018. A severe site list (Table 21) and a CRAS Map (Figure 36) were updated to include results from 2023.

Streams are monitored biweekly between May and September for nutrients and flow. The data is used to assess water quality across each stream which is then incorporated into the CRAS. Results from the 2023 data can be seen in Exhibit E and Exhibit F in the Appendix. As part of the CRAS, stream reaches are walked on a rotational basis after initial assessment was completed. This allows staff to evaluate changes in the streams and update the CRAS accordingly. In 2023 staff walked: Reach 5 of Riley Creek (Lake Ann to Hwy 5), subreach R4F of Riley Creek (Lake Susan to Rice Marsh Lake), and Reach B1 excluding B1A (downstream of Pioneer Trail). Staff conducted Modified Pfankuch Stream Stability Assessments, MPCA Stream Habitat Assessments (MSHA), took photos, and recorded notes of each sub-reach to assess overall stream conditions. Staff also checked bank pins (Table 22) originally installed in 2015 near all the regular water quality sites. The bank pins were installed at representative erosion sites to evaluate general erosion rates for each reach. Changes to the CRAS based upon 2023 creek walks and updated water quality scores can be seen in Table 20. Overall, scores remained relatively the same across most sites from 2016 to 2023.

Staff attempted to collect macroinvertebrates at all eight Purgatory Creek sites in 2023. However, due to drought conditions only five sites had adequate to water to sample. Biological monitoring can often detect water quality problems that water chemistry analysis misses or underestimates. Chemical pollutants, agricultural runoff, hydrologic alterations, and other human activities have cumulative effects on biological communities over time. The condition of these communities represents the condition of their aquatic environment. Bluff Creek macroinvertebrate collection will occur in 2024.

In 2024, staff will finish the CRAS assessment on Riley Creek and begin Purgatory Creek assessment. CRAS updates and potential additional monitoring for 2024 include:

- Placement of additional bank pins at sites that align with upcoming projects.
- Walk additional first order tributaries not yet assessed.
- Assessing additional ravine erosion areas.
- Using the stream power index (SPI) to identify and assess potential areas of erosions upstream of wetland, creeks, and lakes.
- Installing EnviroDIY stations near areas of concern or where information is lacking.
- Utilize CRAS2 to advance creek stability assessments.
- Potentially add macroinvertebrates Index of Biotic Integrity to CRAS scoring methodology.
- Identify spring locations along channel.

Bank Pins

In addition to creek walks, staff have checked bank pins yearly since installation in 2015 near all the regular water quality sites. Bank pins were installed at representative erosion sites to evaluate erosion rates for each reach. Staff measurement of the amount of exposed bank pin or sediment accumulation (if pin was buried) has been ongoing since 2016 (see Table 22). Staff can use the measurements to quantify estimates of lateral bank recession rates and total annual bank loss. Engineering firm Wenck Associates, Inc. also installed bank pins at 11 sites on lower Riley Creek (south of Lake Riley) and Purgatory Creek (south of Riverview Road) in 2008 and 2010 to monitor bank

Table 20. 2023 Creek Restoration Action Strategy Updates.

Staff reassess a portion of subreaches each year. The table below shows subreaches revaluated in 2023 along with their original Tier I scores from 2015.

Reach	Subreach	Location	Original Tier I Scores (2015)	Updated Tier I Scores (2023)	Updated Tier II Scores (2023)
B1	**B1B**	2,150 feet downstream of Pioneer Trail to 300 ft US of Bluff Creek Park	22	20	36
B1	**B1C**	300 feet upstream of Bluff Creek Park to 475 ft US of Great Plains Blvd	18	20	36
B1	**B1D**	475 feet upstream of Great Plains Blvd to Great Plains Blvd	26	24	42
R4	**R4F**	Lake Susan to Rice Marsh Lake	14	12	28
R5	**R5**	Lake Ann to Highway 5	16	14	28

KEY: Severe, Poor, Fair, Good

Table 21. Updated 2023 Creek Restoration Action Strategy severe site list.

Every year the list of most degraded creek subreaches is updated to reflect any CRAS score reassessments done that year.

Reach	Subreach	Location	Tier I Score	Tier II Score	Tier II Rank	Restoration Status
R4	**R4E**	Powers Blvd to Lake Susan	22	48	1	Planning
P1	**P1E**	1,350 feet downstream of Wild Heron Point to Burr Ridge Lane	22	44	2	--
R4	**R4D**	Railroad Bridge to Powers Blvd	22	44	3	Planning
R4	**R4C**	Park Rd to Railroad Bridge	22	42	4	Planning
B1	**B1D**	475 feet upstream of Great Plains Blvd to Great Plains Blvd	24	40	5	--
B5	**B5C**	Galpin Blvd to West 78th Street	22	40	6	Planning
R2	**R2D**	Upper Third between Dell Rd and Eden Prairie Rd	24	36	7	--
R2	**R2C**	720 feet upstream of Dell Trail to Dell Rd	22	36	8	--

loss and quantify lateral recession rates (Wenck, 2017). Wenck was able to track the potential effectiveness of upstream bank repairs on bank-loss-reduction at the Purgatory Creek sites. Results from monitoring the Riley Creek bank pins informed Wenck's recommendation to the City of Eden Prairie to prioritize several reaches for stabilization. District staff will continue to monitor the bank pins/bank loss at our 18 regular monitoring sites and major erosion sites as needed.

- In 2018, reach R5 had the highest estimated lateral loss (7.75 in/year) while reach P7 had the highest bank volume loss per one yard stretch of creek (4.96 ft3).
- In 2019, B4 had the highest estimated lateral loss (12.06 in/year) and the highest bank volume loss per one yard stretch of creek (12.81 ft3).
- In 2020, reach B4 had the highest estimated lateral loss (12.02 in/year) and the highest bank volume loss per one yard stretch of creek (11.49 ft3).
- In 2021, reach P1 had the highest estimated lateral loss (7.33 in/year) and the highest bank volume loss per one yard stretch of creek (18.82 ft^3). Due to the low water levels in 2021, erosion appeared to be reduced across most sites.
- In 2022, reach R5 had the highest estimated lateral loss (5.61 inch/year) and the highest bank volume loss per one yard stretch of creek (4.62 ft^3). Due to the low water levels in 2021 and 2022, erosion appeared to be reduced across most sites.
- In 2023, reach R3 had the highest estimated lateral loss (1.38 in/year) while reaches R3 and B4 had the highest bank volume loss per one yard stretch of creek (1.28 ft^3). Due to the low water levels in 2021, 2022, and 2023, erosion appeared to be reduced across most sites.

Figure 36. 2023 Creek Restoration Action Strategy (CRAS) Prioritization Map of 2023.

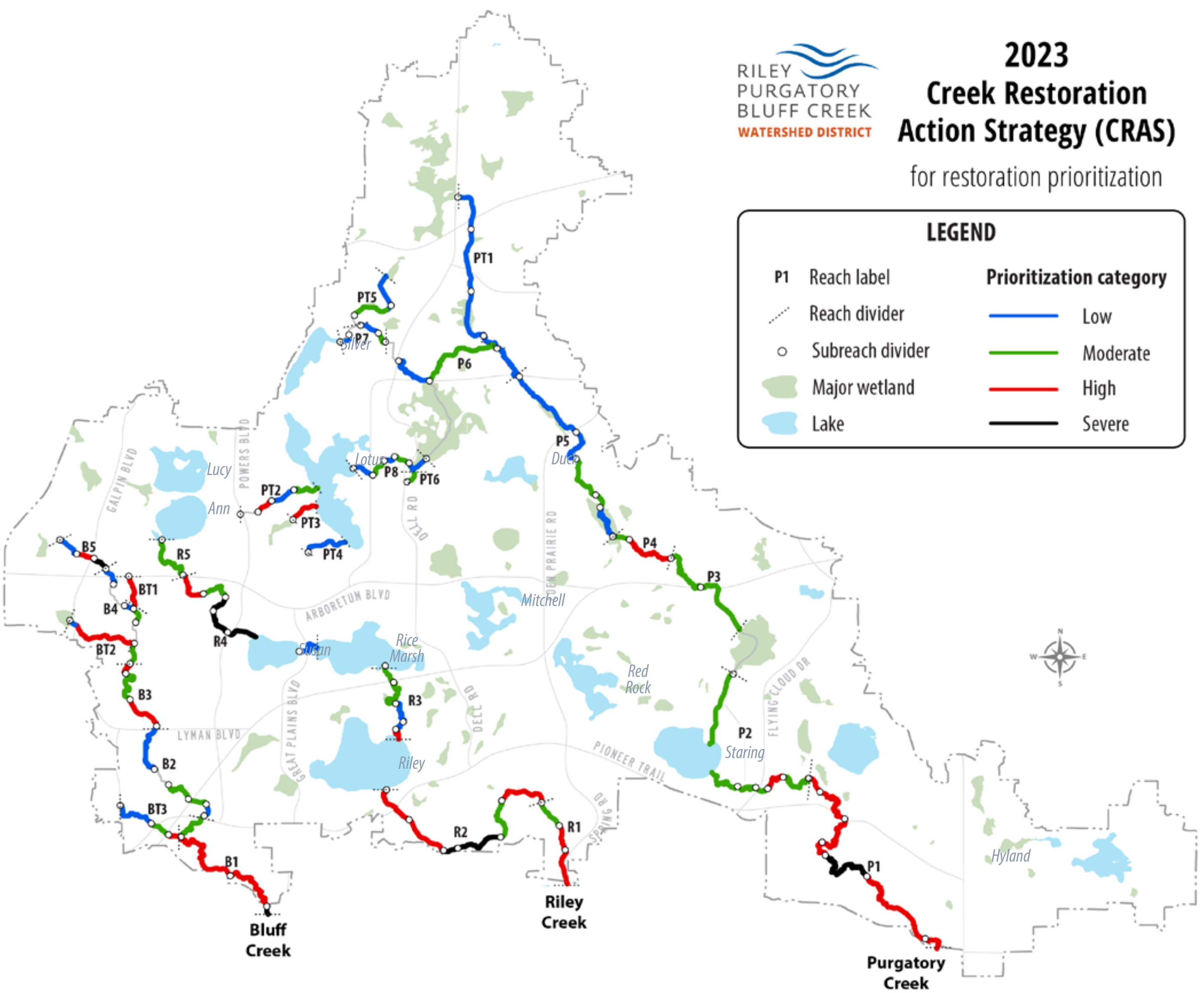


Table 22. 2018-2023 Bank Pin Data

Average lateral stream bank loss per year and the estimated bank volume loss for a one-yard section of streambank at each of the 18 regular creek monitoring sites from 2018-2023. Negative values denote areas of bank where there was sediment deposition. Empty cells denote sites where pins were not found. Red text in cells indicate only pins from one bank were found. P1 calculations in 2019 and 2020 were estimated across both years as the banks were in the process of collapsing.

Reach	Average Lateral Loss (in/year)						Estimated bank loss per one yard stretch of creek (cubic feet)					
	2018	2019	2020	2021	2022	2023	2018	2019	2020	2021	2022	2023
R5	7.75	8.03	1.58	1.38	5.61	0.7	4.81	3.93	1.69	1	4.62	0.36
R4	0.42	3.63	1.77	0.5	0.43	0.7	0.25	2.93	1.31	0.13	0.27	0.57
R3	5.31	14.9	5.69	1.63	1.82	1.38	6.36	11.42	4.84	1.64	1.66	1.28
R2	--	6.45	2.15	0.69	1.03	0.47	--	13.3	4.24	1.41	2.2	0.98
R1	2.96	4.88	1.79	1	1.13	0	1.23	4.29	1.57	1.04	1.03	0
P8	0.55	3.16	0.63	0.25	0.01	0.25	0.25	0.50	0.75	1.25	2.01	0.05
P7	2.02	2.02	--	1.56	0.05	0.30	4.96	5.17	0	2.34	-0.21	0.35
P6	0.83	3.7	2	1.45	0.38	0.54	0.7	2.41	1.57	1.54	0.51	0.52
P5	0.77	3.07	1.58	0.83	0.25	0.71	0.81	3.82	1.77	0.94	0.31	0.89
P4	0.78	1.8	1.2	0.25	0.25	1.12	0.53	0.33	0.3	0.09	0.64	0.70
P3	0.94	1.96	0.66	0.42	0.42	-0.06	1.02	2.77	0.89	0.61	0.61	-0.03
P2	0.5	3.15	3.6	2.8	0.91	0.18	0.47	3.99	3.74	2.05	0.72	0.11
P1	0.38	3.52	3.35	7.33	1.2	-0.45	0.92	6.38	10.98	18.82	3.12	-1.24
B5	-0.79	0.89	1.16	-0.03	1.35	-0.03	-0.46	0.87	1.13	0	2.2	0.03
B4	5.58	12.06	12.02	2.96	2.44	1.28	3.66	12.81	11.49	2.77	2.51	1.28
B3	--	3.29	1.77	0.23	0.87	1.34	--	3.67	1.66	0.21	0.83	0.87
B2	3	7	5.56	1.6	1.95	1.18	1.25	4.08	3.19	1.51	2.11	1.04
B1	-0.67	5.54	--	3.81	1.08	-0.19	-0.44	6.62	--	4.48	-1.39	0.10

4.10. Phyto and Zooplankton

In 2023, five lakes were sampled for both zooplankton and phytoplankton: Lake Riley, Rice Marsh Lake, Lake Susan, Lotus Lake, and Staring Lake. Zooplankton plays an important role in a lake's ecosystem, specifically in fisheries and bio control of algae.

Healthy zooplankton populations are characterized by having balanced densities (number per m2) of three main groups of zooplankton: Rotifers, Cladocerans, and Copepods. A Sedgwick-Rafter Chamber (SRC) was used for zooplankton counting and species identification. A two mL sub-sample was prepared. All zooplankton in the sample were counted and identified to the genus and/or species level. The sample was scanned at 10x magnification to identify and count zooplankton using a Zeiss Primo Star microscope. Cladocera images were taken using a Zeiss Axiocam 100 digital camera and lengths were calculated in Zen lite 2012. The District analyzed zooplankton populations for the following reasons:

1. **Epilimnetic Grazing Rates** (Burns 1969): The epilimnion is the uppermost portion of the lake during stratification where zooplankton feed. Zooplankton can be a form of bio control for algae that may otherwise grow to an out-of-control state and therefore influence water clarity.
2. **Population Monitoring** (APHA, 1992): Zooplankton are a valuable food source for planktivorous fish and other organisms. The presence or absence of healthy zooplankton populations can determine the quality of fish in a lake. Major changes in a lake (significant reduction in common carp, winter kills, large scale water quality improvement projects, etc.) can change zooplankton populations drastically. By ensuring that the lower parts of the food chain are healthy, we can protect the higher ordered organisms.
3. **Aquatic Invasive Species Monitoring:** Early detection of water fleas is important to ensure these organisms are not spread throughout the District. These invasive species outcompete native zooplankton for food and grow large spines which make them difficult for fish to eat.

The SRC was used for phytoplankton counting and species identification. A one mL aliquot of the sample was prepared using a Sedgewick Rafter cell. Phytoplankton were identified to genus level. The sample was scanned at 20x magnification to count and identify phytoplankton species using a Carl Zeiss Axio Observer Z1 inverted microscope equipped with phase contrast optics and digital camera. Higher magnification was used as necessary for identification and micrographs. The District analyzed phytoplankton populations for the following reasons:

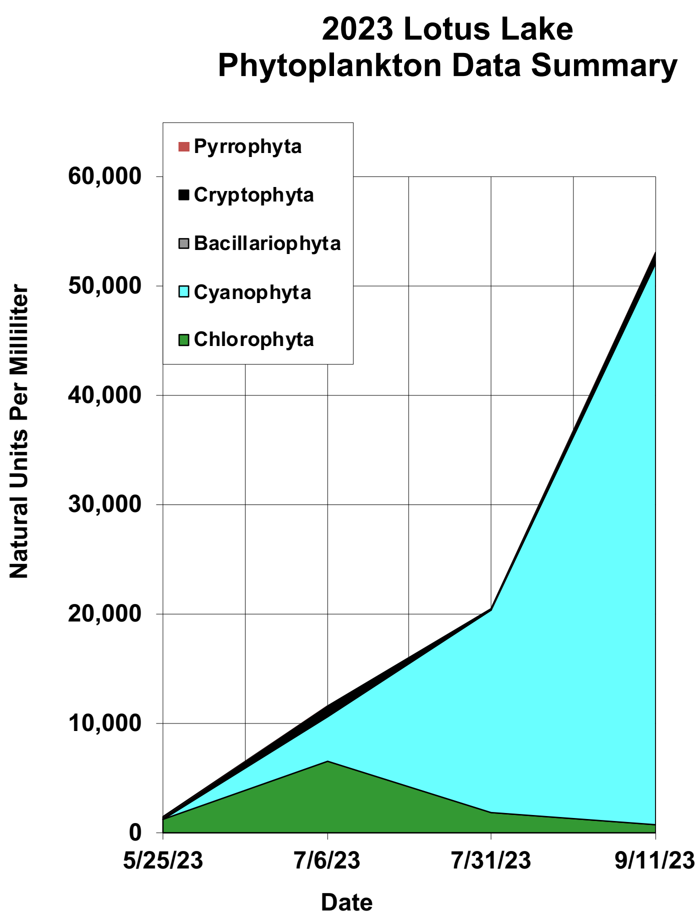
1. **Population Monitoring:** Phytoplankton are the base of the food chain in freshwater systems and populations fluctuate throughout the year. By ensuring that the lower parts of the food chain are healthy, we can protect the higher ordered organisms such as macroinvertebrates and fish.
2. **Toxin Producers and Algae Blooms:** Some phytoplankton produce toxins that can harm animals and humans, or cause water to have a foul taste or odor (Microcystis, Aphanizomenon, Dolichospermum, Planktothrix, and Cylindrospermopsis). Monitoring these organisms can help us take the proper precautions and identify possible sources of pollution. The presence of toxin producing algae in a lake does present a health risk. Specific conditions must be met for the algae to become toxic. The World Health Organization provides threshold guidance for the probability of adverse health risks related to blue-green algal counts for, slight to no risk (0-20,000 mg/L) low risk (>20,000 cells/mL), moderate risk (>100,000 cells/mL) probabilities of adverse health risks for people or pets (WHO 2003).

Lotus Lake

During the summer of 2023, staff collected four phytoplankton samples on Lotus Lake (Exhibit D). The abundance of phytoplankton across all sampling dates is presented Figure 37. In 2023, the most abundant division was Cyanophyta, characterized by a high number of *Aphanizomenon flos-aquae* in July, followed by an increase in *Aphanizomenon flos-aquae* and the addition of *Aphanocapsa* sp. in August. *Raphidopsis raciborskii* was the most abundant taxon in the division, with the highest count of all species. Aphanizomenon species are a potential producer of cylindrospermopsin, anatoxins, and saxitoxins. This trend matched what was seen in 2020 and 2021 with *Aphanizomenon flos-aquae* being the most consistently dominant species with a spike of *Cylindrospermopsis raciborskii* and *Anabaenopsis raciborskii* in August and September (Figure 39). These species can produce similar toxins to Aphanizomenon. Historically, blue-green algae have comprised a large proportion of phytoplankton sampled in Lotus Lake but have been the dominant phytoplankton group since 2004 (Figure 39).

In 2023, all three groups of zooplankton were present in Lotus Lake (Exhibit D). Similar to past years (Figure 40), Rotifers were the most abundant clade of zooplankton. Rotifers made up 56% of the total zooplankton captured, with Copepods at 39% and

Figure 37. 2023 Lotus Lake Phytoplankton Summary by Order (units/mL)



Cladcerans at 5%. All three groups had their highest population in May and their lowest in June. Cladocerans and Copepods had their second highest concentration in July contrasting with the second highest abundance of Rotifers in September (Figure 38). Copepods numbers reached a high of 2.1 million and a low of 72 thousand, averaging 619 thousand. Rotifers had a maximum of 2.9 million and a minimum of 34 thousand, averaging 902 thousand. Cladocerans had a maximum of 156 thousand and a minimum of 27 thousand, averaging 75 thousand.

Large Cladocera consume algae and, if enough are present in a lake, they have the potential to improve water quality. Estimated grazing rates for 2023 ranged from 59.7% in May to 1.1% in September, averaging 16.3%. Cladocerans of considerable size (greater than 1mm) in high abundance can highly impact the grazing rate. The 2023 grazing rates are higher than previous years (2022-0 to 7% 2021-0 to 4%, 2020-0%, 2019-0 to 5%, 2018-6 to 19%) (Figure 38). The high grazing rate in May is associated with an increased abundance of large bodies cladoceran *Daphnia galeata mendotae* which are most commonly found in mesotrophic to eutrophic lakes such as Lotus.

Figure 38. 2023 Lotus Lake Zooplankton Summary by Division (number/m²).

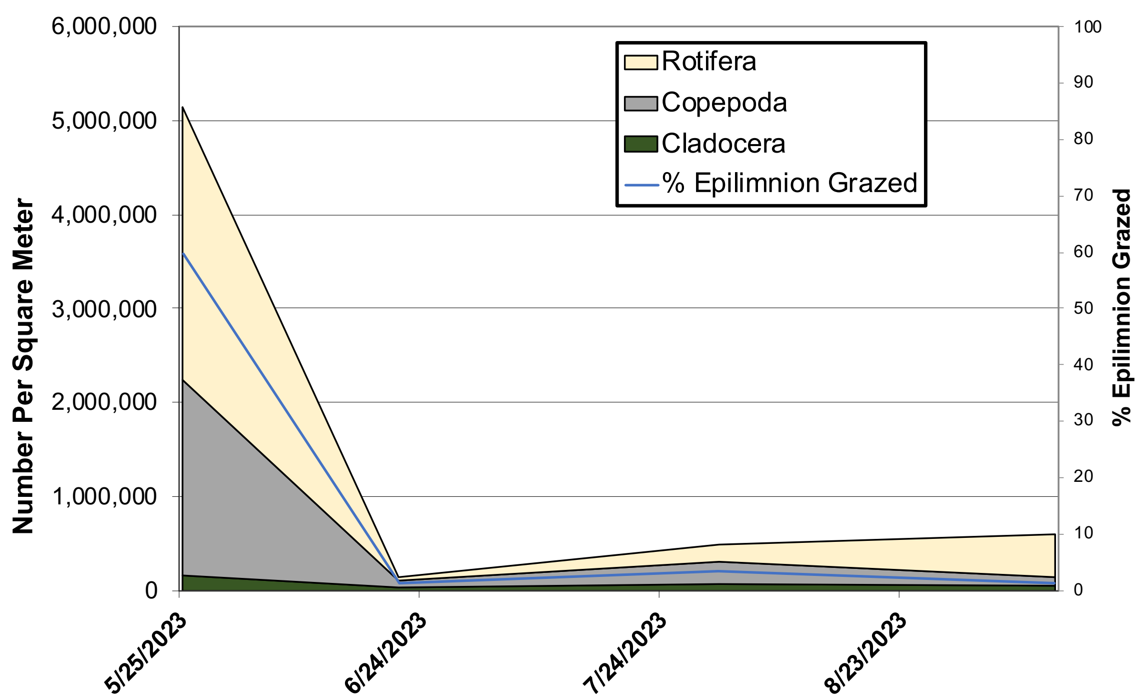


Figure 39. 1999-2023 Lotus Lake Phytoplankton Historical Abundance (units/mL).

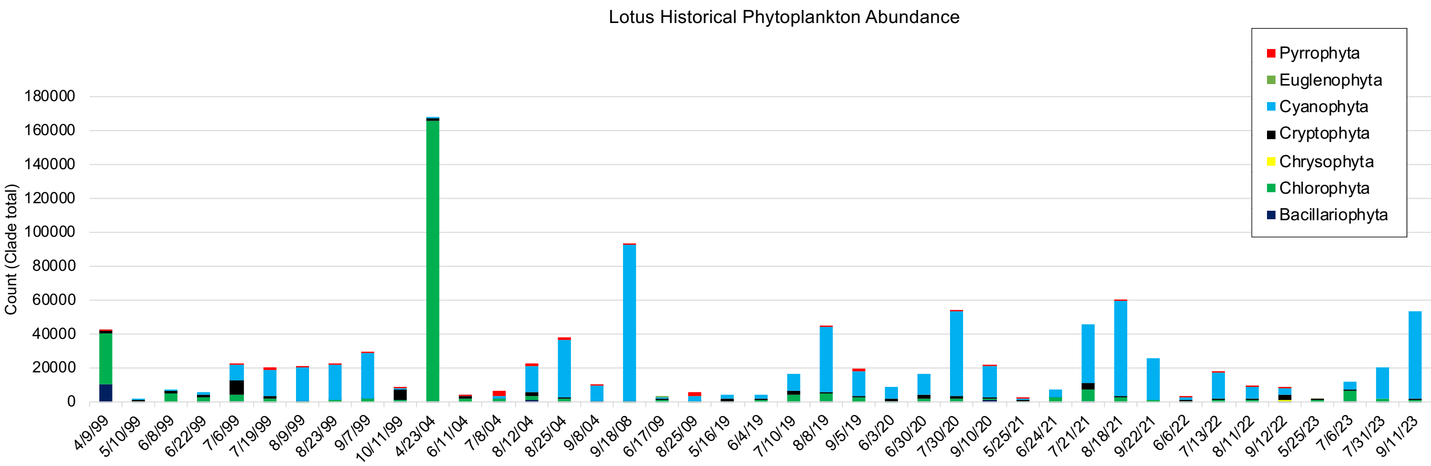
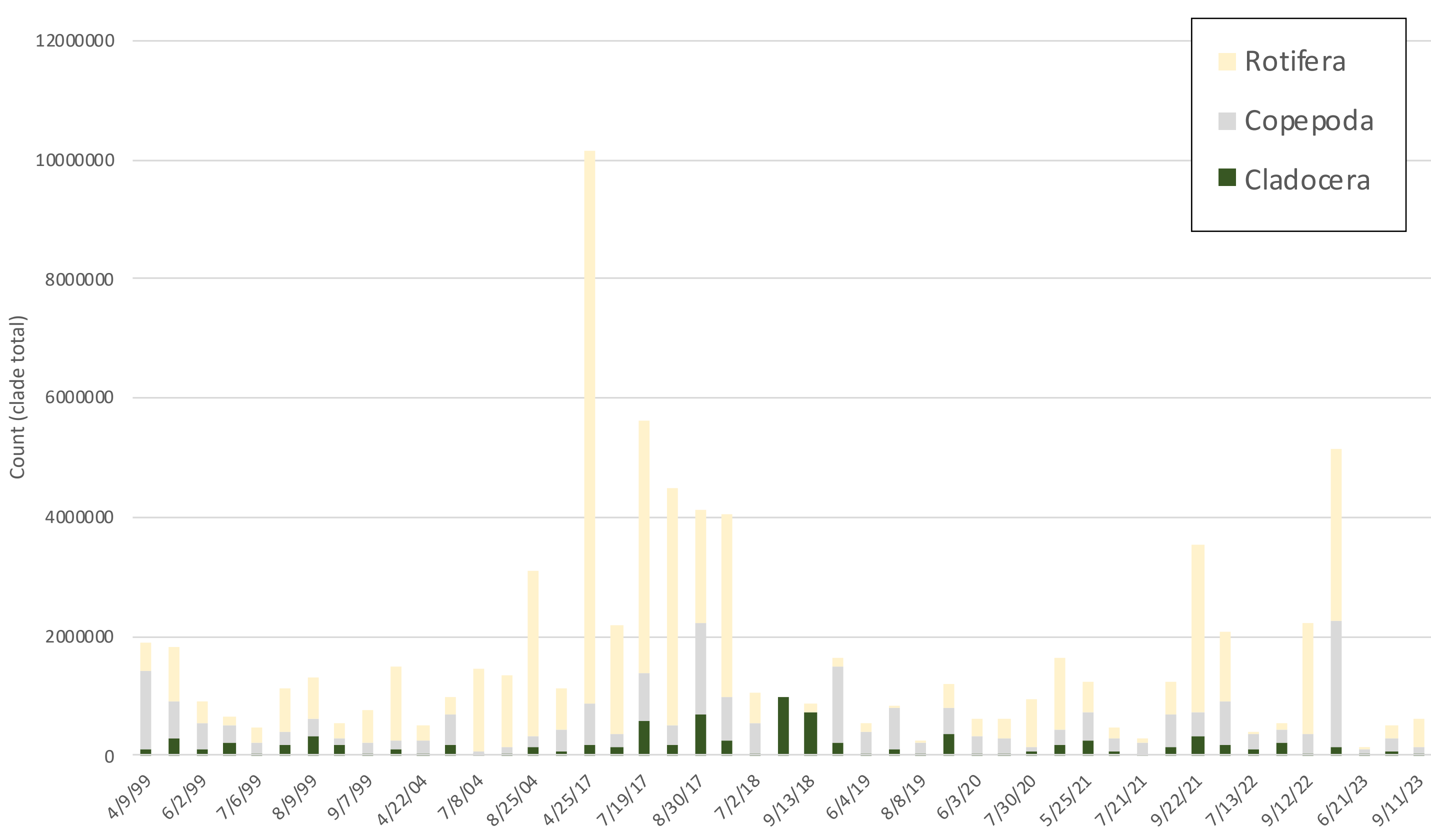


Figure 40. 1999-2023 Lotus Lake Zooplankton Historical Abundance (number/m²).



Rice Marsh Lake

During the summer of 2023, staff collected four phytoplankton samples on Rice Marsh Lake (Exhibit C). Chlorophyta and Cryptophyta were the most dominant division, mostly due to *Chlamydomonos globosa* and *Cryptomonas erosa* respectively. This trend is similar to what has been observed since 2019. Abundance of phytoplankton by Class for Rice Marsh Lake is presented in Figure 41. Historically, the phytoplankton community has been balanced with limited numbers of Cyanobacteria except for 2018 and 1997 (Figure 42).

In 2023, all three groups of zooplankton were captured in Rice Marsh Lake, of which Cladocerans comprised 13.5% of the total population collected, Copepods 54.2% of the population, and Rotiferans 32.3% (Figure 43). The Cladoceran population peaked in September at 185 thousand, with a minimum of 23 thousand in June, and an average of 103 thousand. This overall percentage of 13.5% is down from 2021-2022 (22% in 2022, 24% in 2021) but consistent with previous years (17% in 2020, 8% in 2019, and 13% in 2018 Figure 44. Copepod populations collected peaked at 559 thousand in May, with a minimum of 45 thousand in June, and an average of 415 thousand. Rotifers had

Figure 41. 2023 Rice Marsh Lake Phytoplankton Summary by Division.

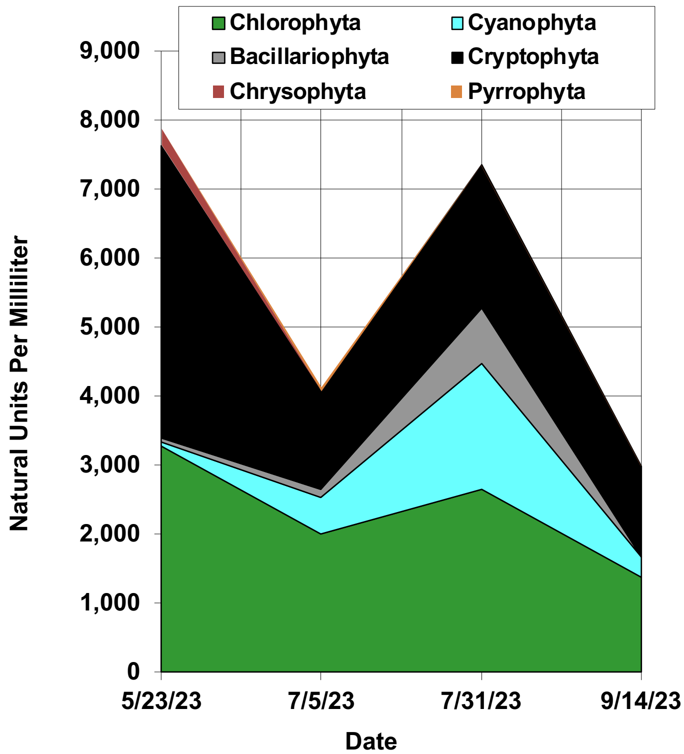
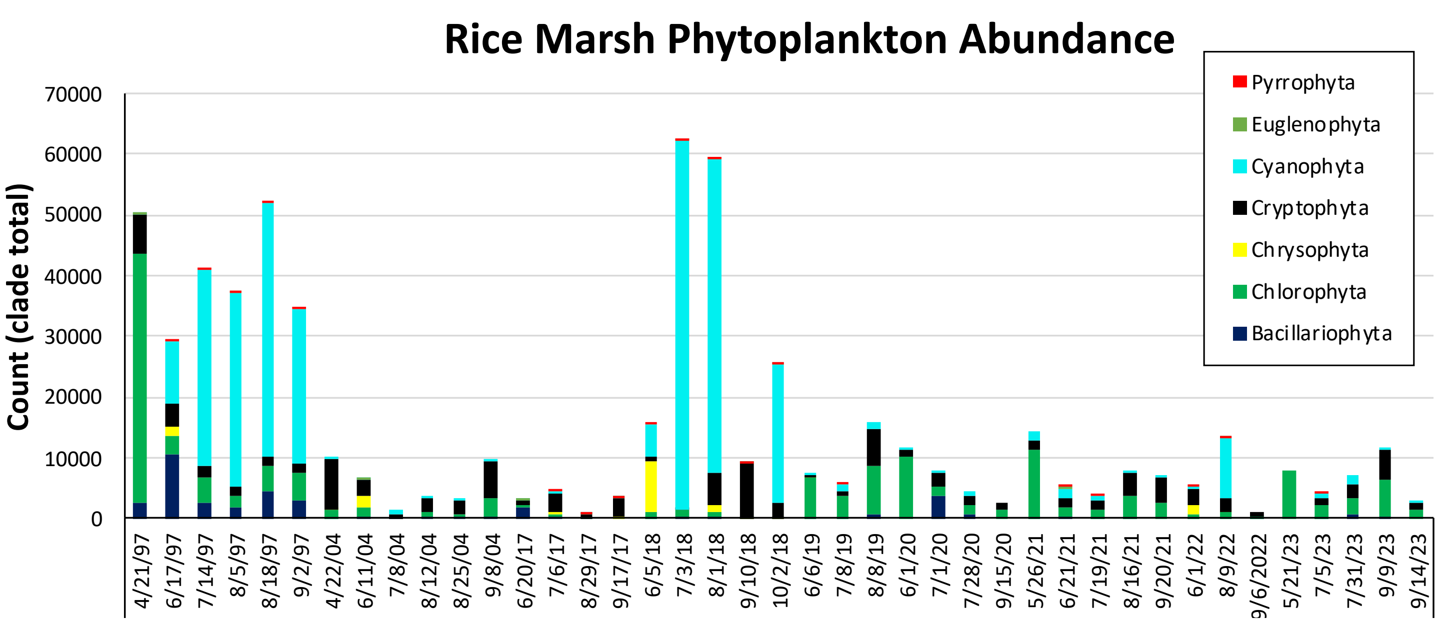


Figure 42. 1997 to 2023 Rice Marsh Lake Phytoplankton Historical Abundance (number/m²)



a maximum of 466 thousand, a minimum of 14 thousand, and an average of 247 thousand. The estimated grazing epilimnetic grazing rate was 5.2% in May, 0.3% in June, 2.5% in August, and 2.3% in September. The highest overall zooplankton density corresponded with the highest Cladoceran populations in August (Figure 43). The most abundant Cladoceran were the smaller *Ceriodaphnia* sp. and *Chydorus sphaericus*.

Figure 43. 2023 Rice Marsh Lake Zooplankton Summary by Division (number/m²).

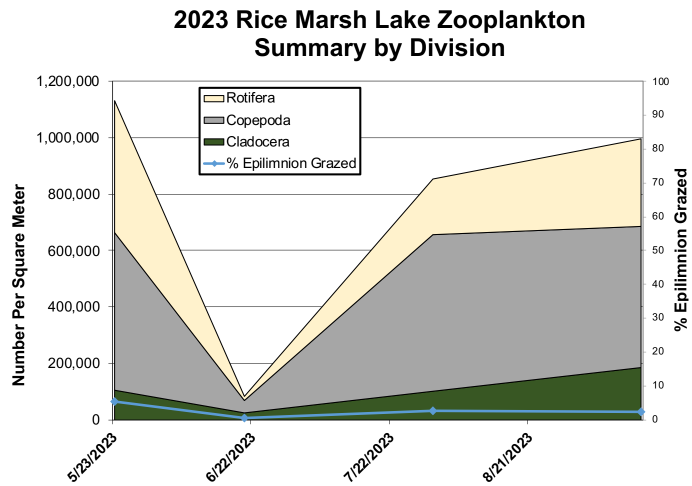
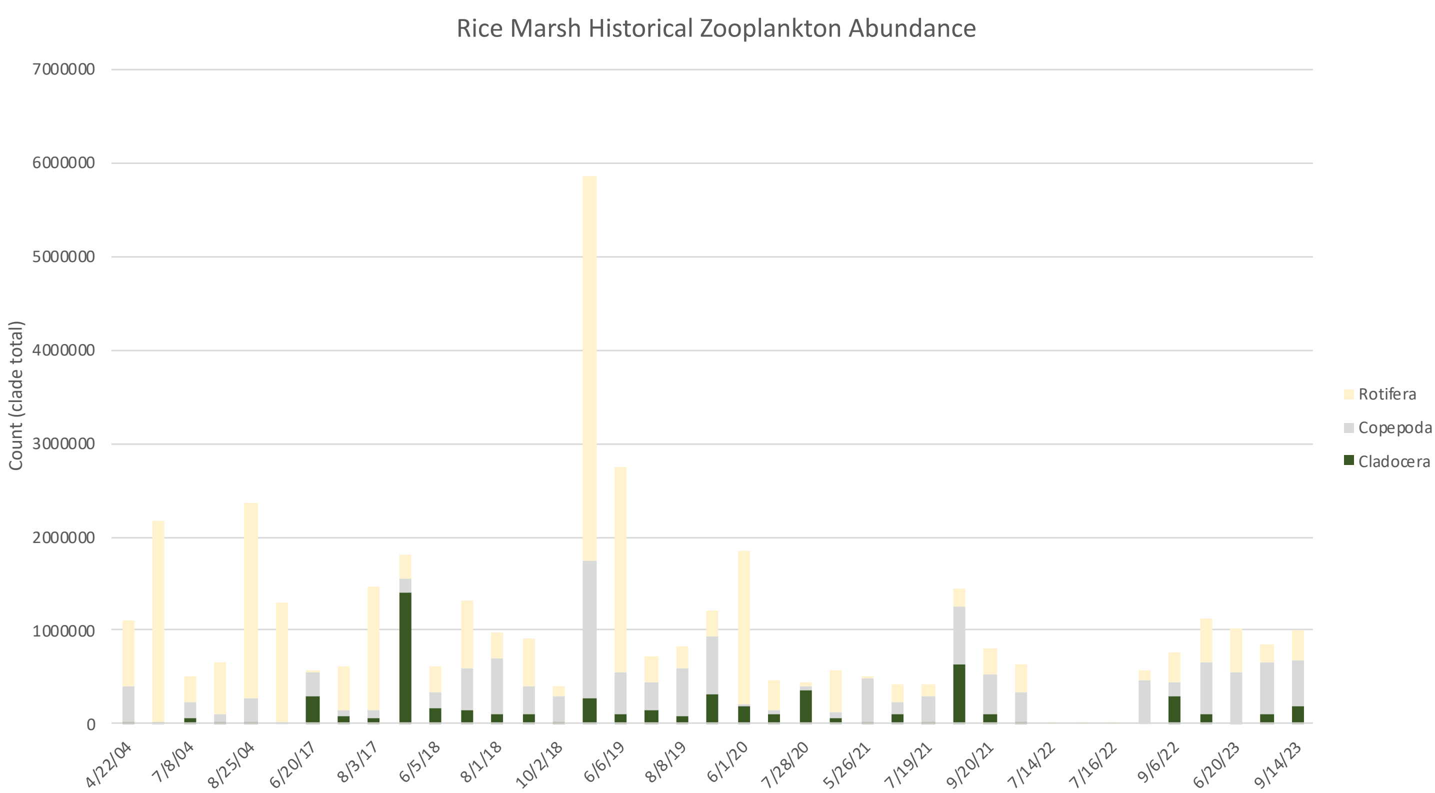


Figure 44. 2004-2023 Rice Marsh Lake Zooplankton Historical Abundance (number/m²).



Lake Riley

During the summer of 2023, staff collected four phytoplankton samples on Lake Riley (Exhibit C). The dominant phytoplankton in 2023 was Chlorophyta, specifically *Chlamydomonas globosa* or green algae (Figure 45). Cyanophyta was the second most abundant class of phytoplankton. Cyanophytes, also known as cyanobacteria or blue-green algae, are a group of free-living bacteria that obtain energy through photosynthesis. Under favorable conditions large, toxic blooms of cyanobacteria can occur.

The 1997 to 2023 total historical abundance is presented in Figure 47. Phytoplankton numbers in Lake Riley have been declining since 2019 and are now lower than previously seen. The reduction can be explained by the significant reduction in cyanobacteria which had previously dominated the phytoplankton population. The total of all other classes of phytoplankton has remained relatively unchanged. The reduction in cyanobacteria is likely related to the success of the alum treatment which improved water quality and reduced the severity of harmful algal blooms seen in the past. A secondary consideration is the introduction of Zebra Mussels which are filter feeders and can reduce phytoplankton numbers. Before 2019, potentially harmful blue-green algae were the dominant phytoplankton in Lake Riley. This has now changed, transitioning to a more balanced community.

In 2023, all three groups of zooplankton were captured in Lake Riley (Exhibit D). Around 7.7% of the zooplankton captured were Cladocera which is similar to 2022 (11%) and 2021 (6%), but still low in comparison to the 18% from 2020 and 2019 (Figure 48). Copepods were the most abundant zooplankton sampled, at around 46.7% slightly above the 45.6% abundance of rotifers (Figure 46). In 2023, September had the lowest abundance for all three groups of zooplankton in Lake Riley. Cladocerans experienced a downward trend of abundance throughout the four samples taken. Rotiferans had the highest populations in May followed by the second highest abundance in August. Cladocerans were slightly less abundant than in 2022, with an average of 78 thousand in comparison to 87 thousand. Copepods and Rotiferans had high averages in 2023 compared to previous years averaging roughly 470 thousand for both groups. The most numerous Cladoceran found in Riley was *Daphnia galeata mendotae*, which are common in the northern part of the United States, especially in glaciated regions such as MN. The most common Copepods found were Nauplius larvae.

Figure 45. 2023 Lake Riley Phytoplankton Summary by Division (units/mL).

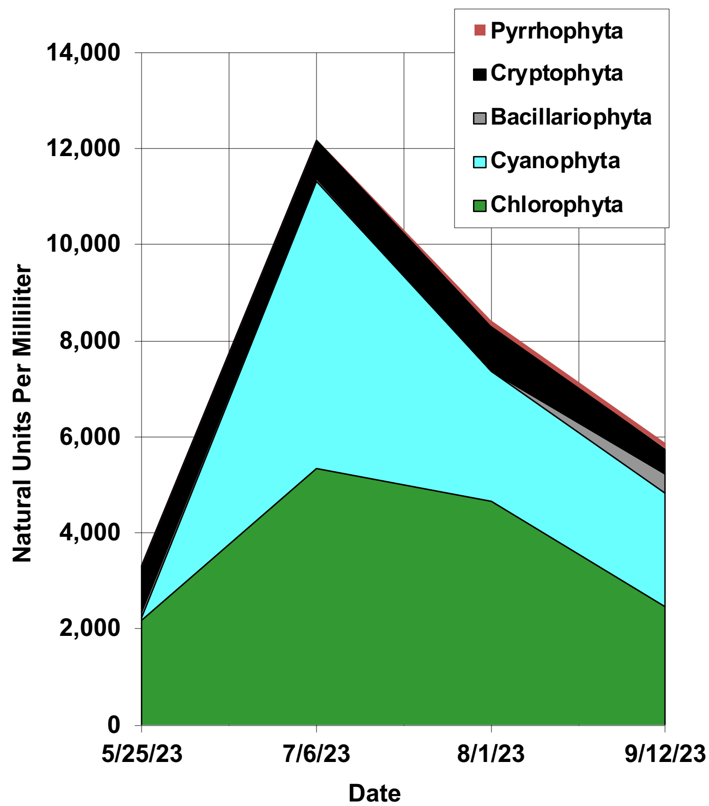


Figure 46. Lake Riley Zooplankton Summary by Division (number/m²)

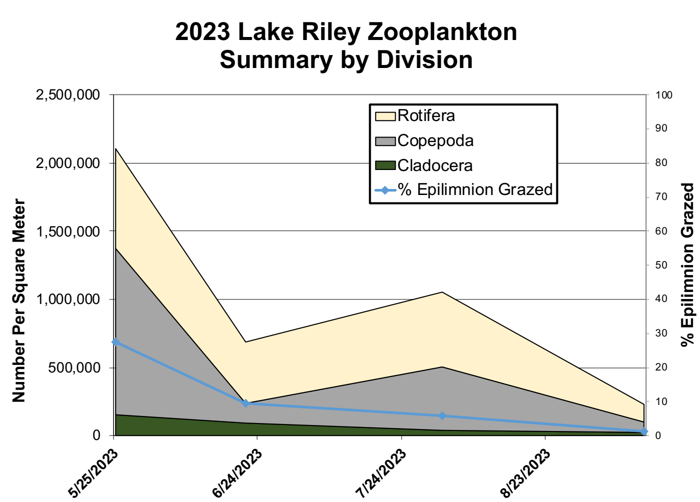


Figure 47. 1997-2023 Lake Riley Phytoplankton Historical Abundance (units/mL).

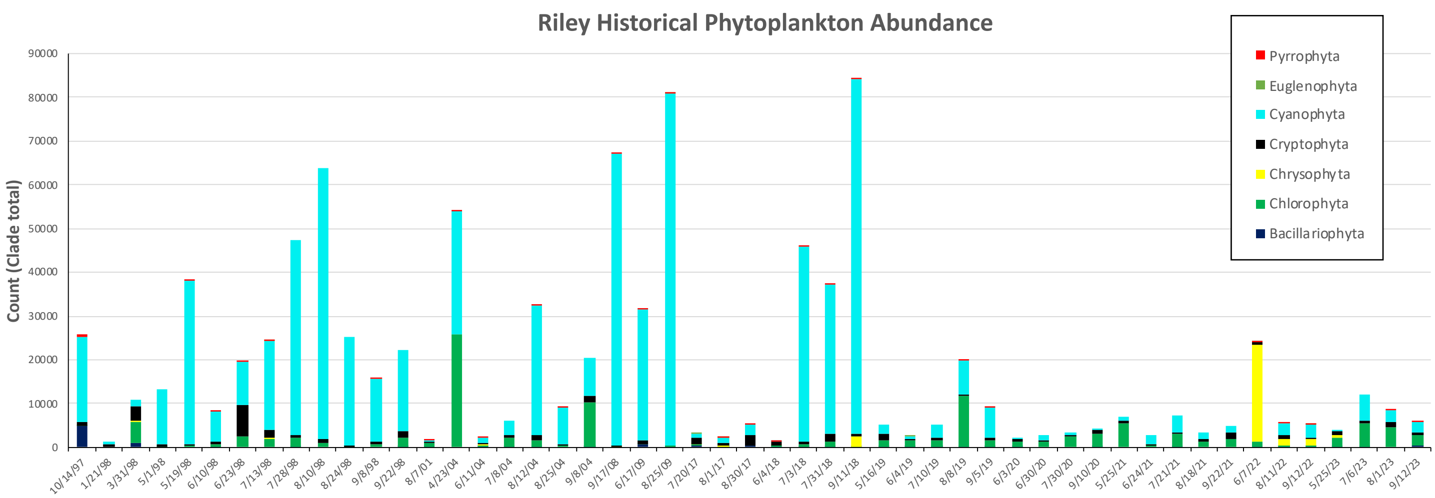
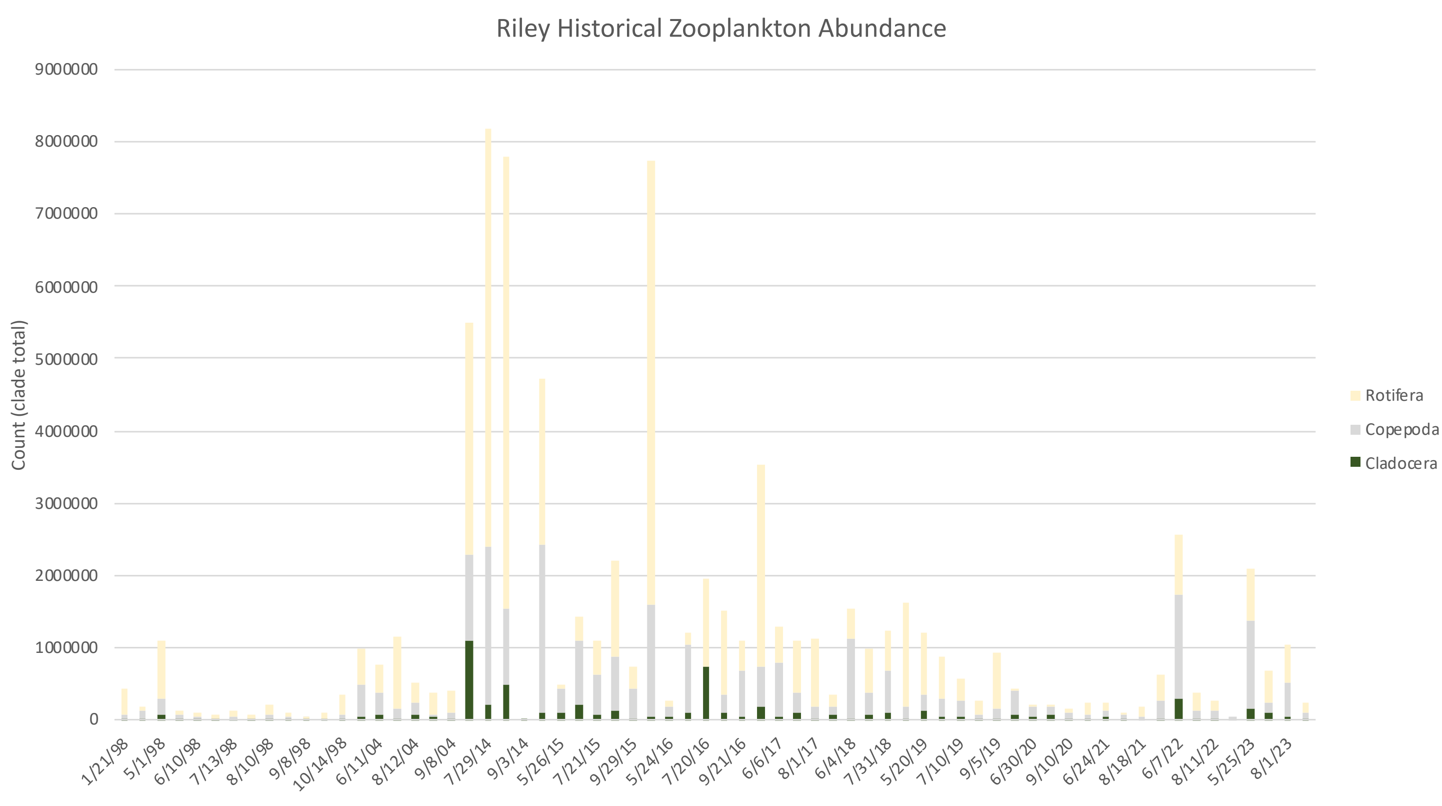


Figure 48. 1998-2023 Lake Riley Historical Abundance (number/m²)

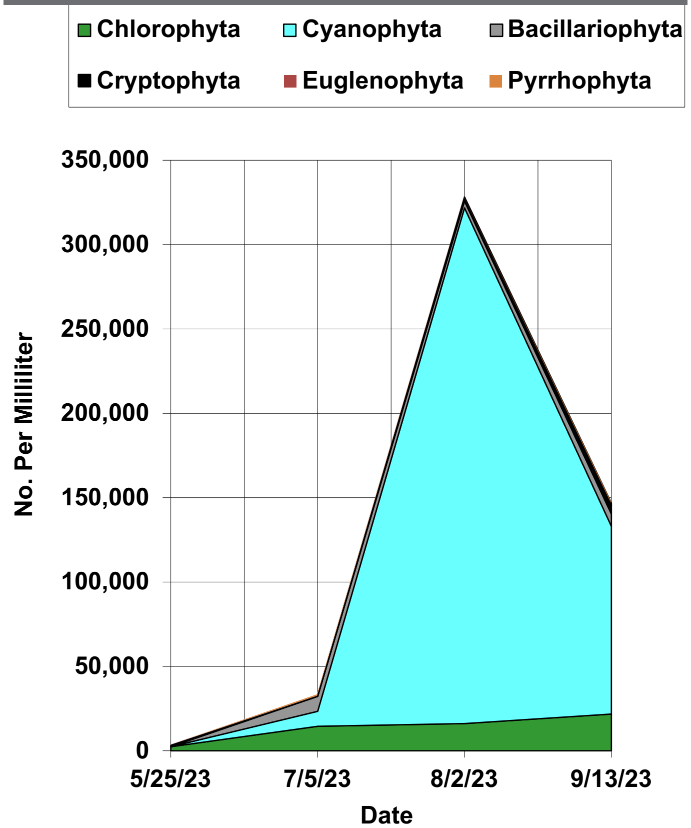


Cladocerans consume algae and have the potential to improve water quality if they are abundant in large numbers. The average grazing rate on Riley for 2023 was 11.1%, ranging from a maximum of 27.6% in May to a minimum of 1.3% in September. This trend matched the Cladoceran population fluctuations with the highest grazing rate being equal to the highest abundance (Figure 46).

Staring Lake

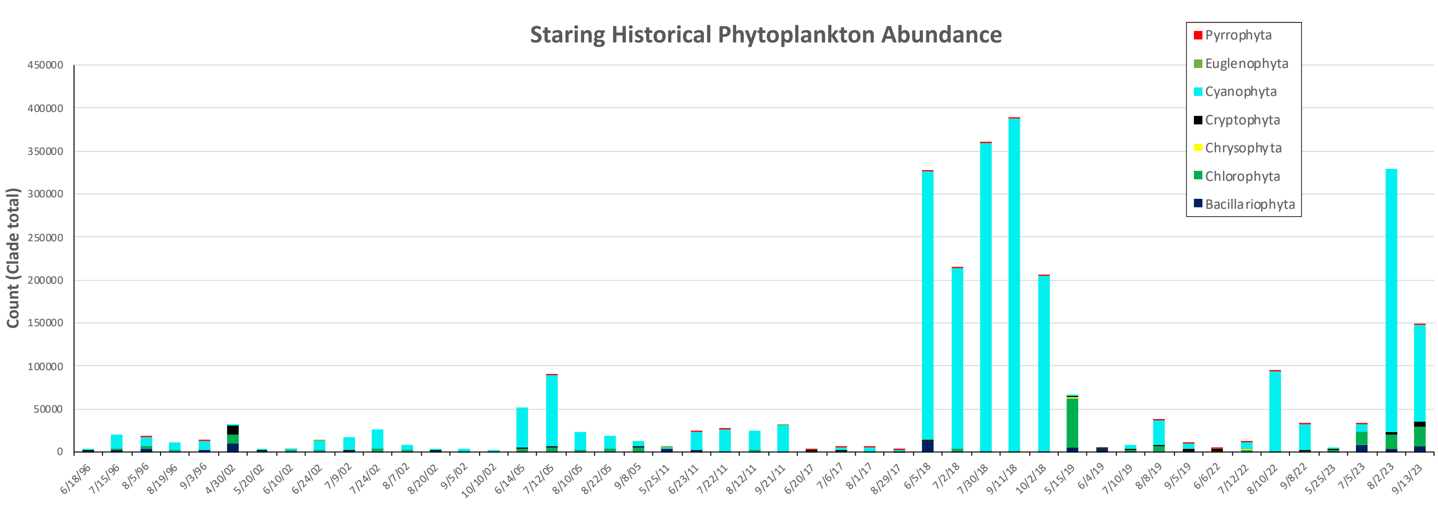
During the summer of 2023, staff collected four phytoplankton samples on Staring Lake (Exhibit C). Abundance of phytoplankton by Class are presented in Figure 49. Cyanophyta was the most dominant phytoplankton across all sampling events in 2023. Cyanobacteria populations reached such high levels in August that *Raphidiopsis raciborski* represented 88% of the total phytoplankton population. This matches historical data, with August samples containing populations of blue-green algae taking up a majority proportion of total phytoplankton (Figure 50). The blue-green algae numbers in Staring Lake in August and September were 305 thousand and 111 thousand respectively, which is above the WHO threshold (>100,000 units/mL) for moderate probability of adverse health impacts. This is also one of the highest blue-green numbers to date. Continued yearly monitoring of these plankton populations is necessary in order to monitor potentially toxic blooms.

Figure 49. 2023 Staring Phytoplankton Summary by Order (units/mL)



In 2023, all three groups of zooplankton were found in Staring Lake. Out of the total population collected, 54.3% were Rotiferans, 33.1% were Copepods, and 12.6% were Cladocerans (Figure 51). The Rotifer population peaked at 1.2 million in September, were lowest at 177 thousand in May, and averaged 705 thousand across the four samples. Copepod populations were 573 thousand at a maximum in August, 258 thousand at minimum, and averaged 430 thousand. Cladoceran populations were 351 thousand at a maximum in

Figure 50. 1996-2023 Staring Lake Phytoplankton Historical Abundance (units/mL).



August, 72 thousand at a minimum in June, and averaged 163 thousand. Historical changes in zooplankton population are shown in (Figure 52).

The estimated percentage of the epilimnion grazed is 9.7% for May, 21.9% for June, 1.3% for August, and 0.3% in September. A high presence of *Daphnia galeata mendotae* collected in June accounts for the highest grazing rate. May and July had a higher presence of Cladocerans, but smaller organisms that lack the filtering capacity of *Galeata mendotae* (Figure 51).

Figure 51. 2023 Staring Lake Zooplankton Summary by Division (number/m²)

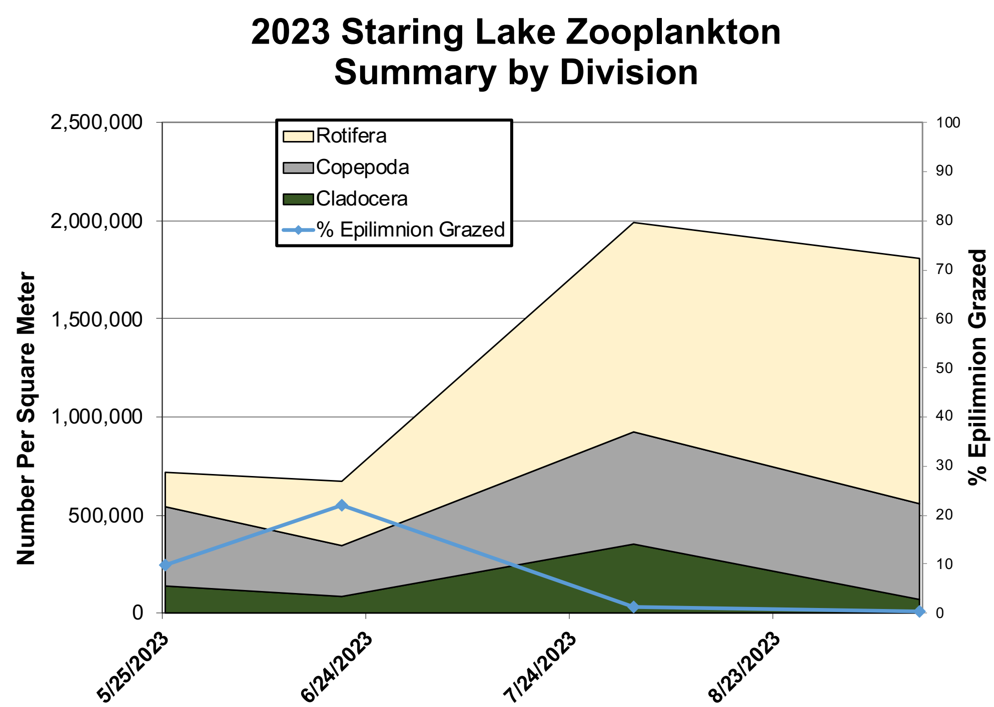
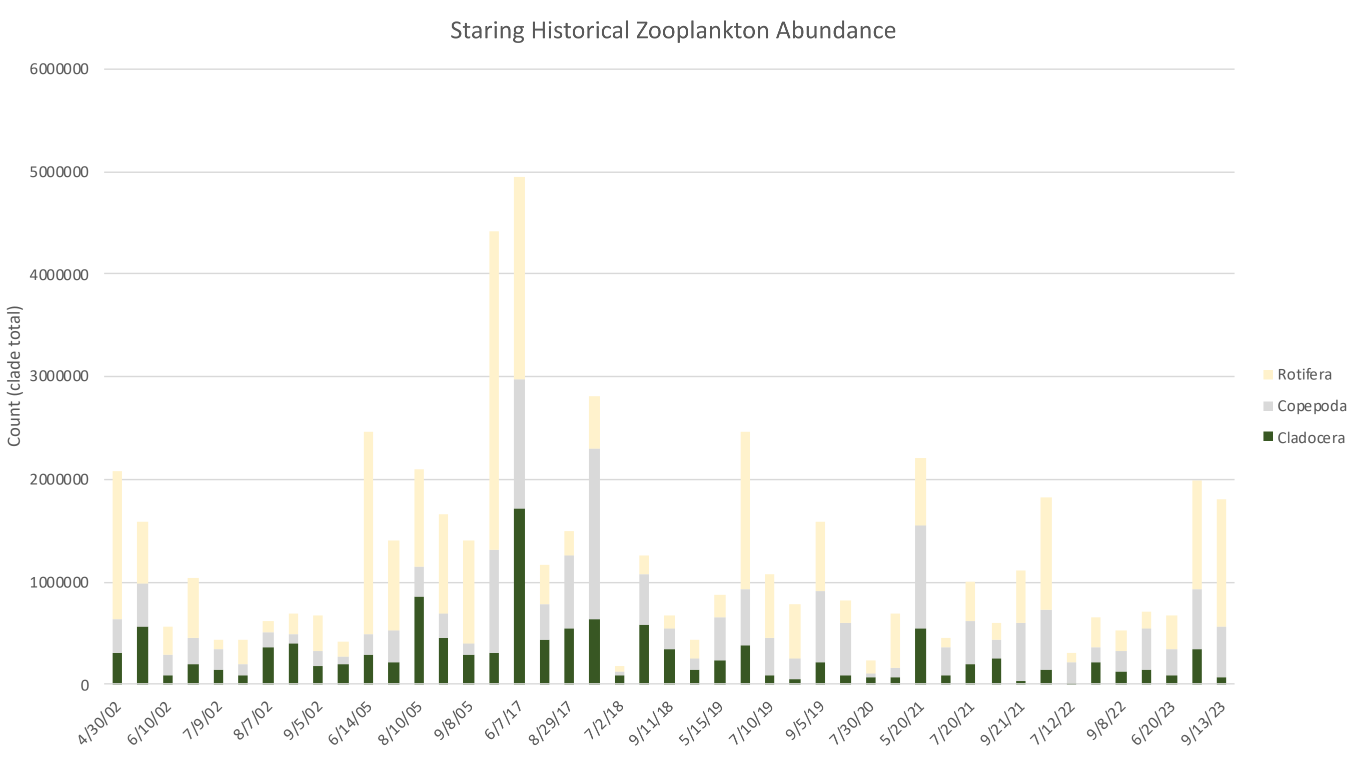


Figure 52. 2002-2023 Staring Lake Historical Zooplankton Abundance (number/m²)



Lake Susan

During the summer of 2023, staff collected four phytoplankton samples on Lake Susan (Exhibit C). The abundance of phytoplankton by Class is presented in Figure 53. Similar to previous years, Cyanophytes were the dominant phytoplankton groups in 2023. Cyanophytes such as *Raphidiopsis raciborskii*, *Amphanizmenon flos-aqauae*, and *Pseudanabaena limnetica* began to grow in numbers, and the populations eventually culminated with a bloom in August and September. The 2023 blue-green numbers in Lake Susan were one of the highest to date as shown in Figure 55. Lake Susan blue-green algae numbers during July (215 thousand) and August (160 thousand) exceeded the World Health Organization (WHO) threshold for moderate probability of adverse health effects (>100,000 units/mL). This threshold indicates when blue-green algal toxins may be high enough to cause adverse health effects. Although the presence of algae able to produce toxins within Lake Susan is known, the concentration of algal toxins cannot be known unless samples are collected. The climatic conditions in 2023 seemed to support higher blue-green algal numbers in many shallow lakes across the metro area (personal communication - Margaret Rattei). Since Lake Susan exceeded this threshold in 2023, in the future staff may send samples from Lake Susan to be analyzed shortly after collection to assess blue-green numbers and potentially post warnings for recreational use.

Historically, the trend of Chlorophyta and Cyanobacteria being the two dominant types of phytoplankton has persisted (Figure 53). Cryptomonads were also commonly found across most years. Since 2008, Blue Green Algae populations have increased significantly, which is of concern. Numerous water quality projects have been implemented around Lake Susan and others are projected to be completed soon. These water quality improvements will hopefully reduce potentially harmful algal blooms moving forward.

In 2023, Rotifers were the most abundant zooplankton in Susan with *Keretella* sp. being dominant. Rotifers made up 48.7% of the total zooplankton, Copepods with 46.0%, and Cladocerans with 5.3% (Figure 54). The Cladoceran population peaked at 66 thousand in May, had a minimum of 4 thousand in June, and had an average of 27 thousand. The copepod population peaked at 461 thousand in August, had a minimum of 8 thousand in June, and an average of 233 thousand. The Rotifer population peaks at 497 thousand in August, a minimum of 8 thousand in June, and an average of 246 thousand.

Estimated grazing rates of 2023 ranged from 1.8% to 0.1%. This is slightly greater than 2022 and 2021, neither of which had a maximum grazing rate higher than 1%. Averages of around 1% were seen in 2019 and 2020. More Cladocerans found in lake Susan would result in a higher estimated grazing rate (Figure 54). While historically Cladoceran numbers have been low, this years numbers have been even lower (Figure 56).

Figure 53. 2023 Lake Susan Phytoplankton Summary by Division (unit/mL)

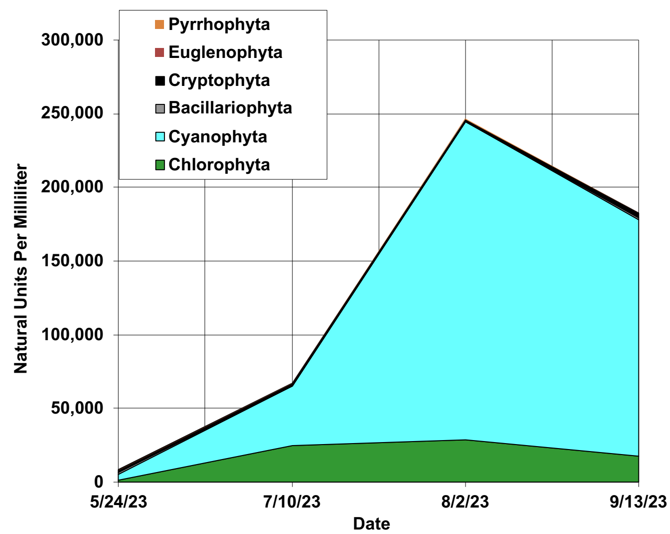


Figure 54. 2023 Lake Susan Zooplankton Counts by Division (number/m^2).

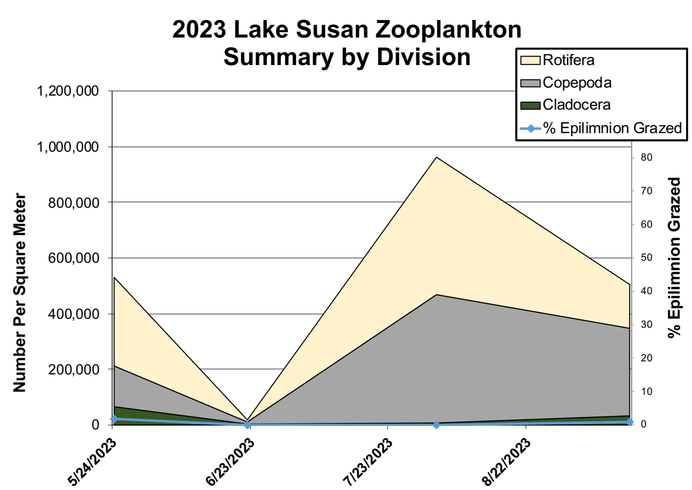


Figure 55. 1997-2023 Lake Susan Phytoplankton Historical Abundance (number/mL).

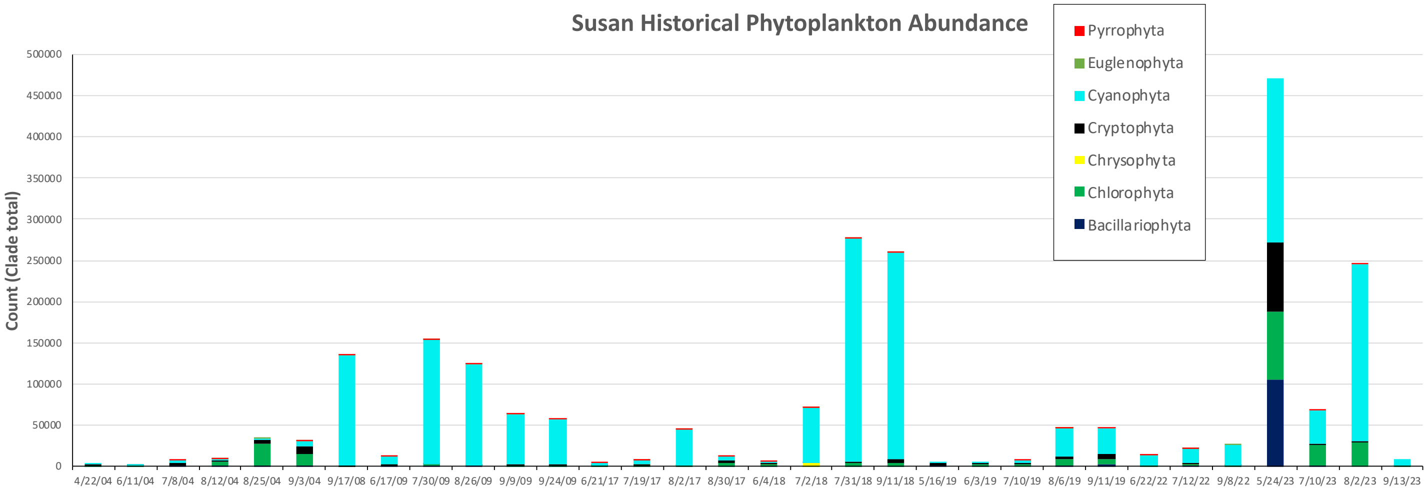
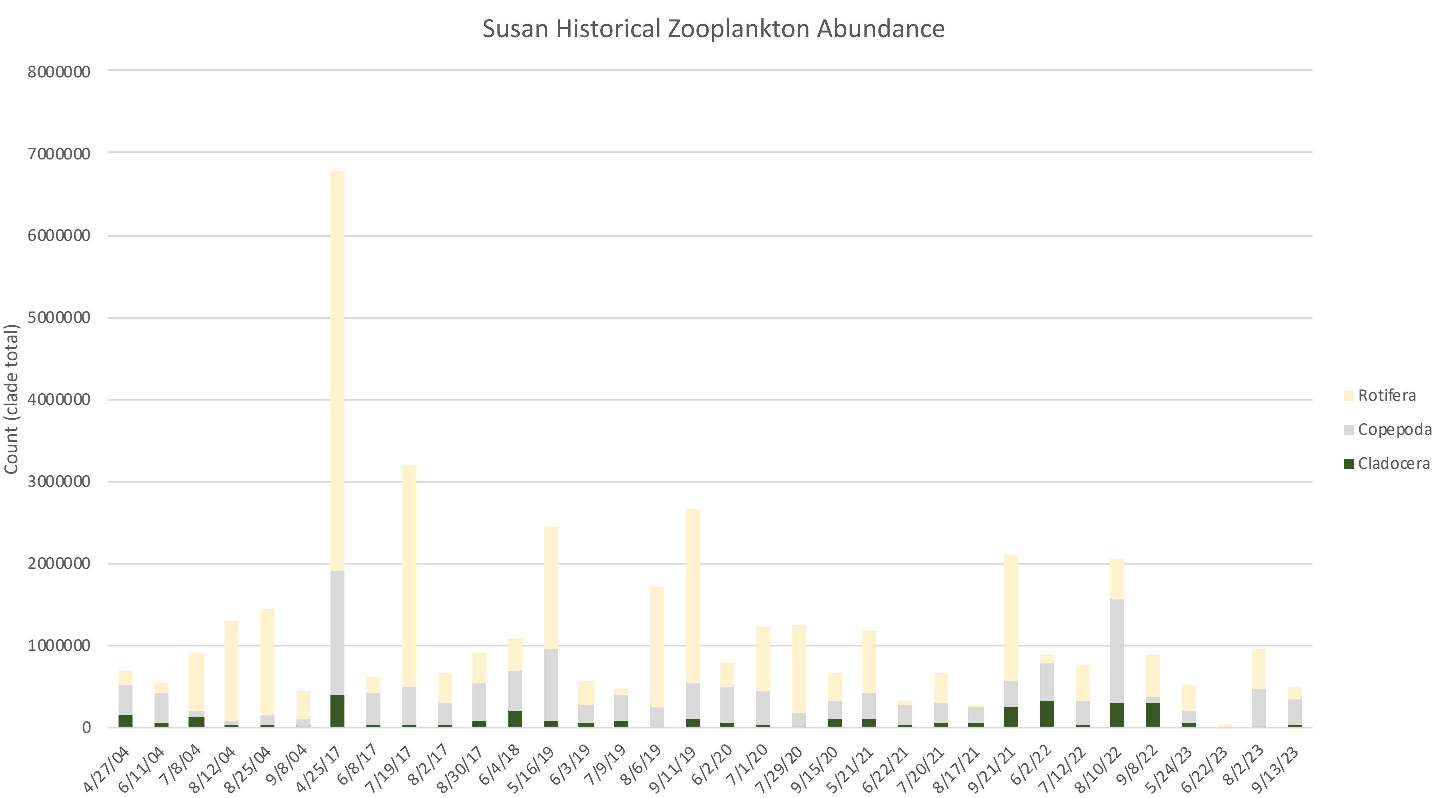


Figure 56. 2004-2023 Lake Susan Historical Zooplankton Abundance (number/m^2)



4.11. Lake Susan Spent-Lime Treatment System

Lake Susan is an 88-acre lake next to Lake Susan Park. It is an important resource in the City of Chanhassen and the Riley Purgatory Bluff Creek Watershed District. The lake is a popular recreational water body used for boating and fishing. Lake Susan is connected to four other lakes by Riley Creek. It receives stormwater runoff from 66 acres of surrounding land, as well as stormwater that enters two upstream lakes (Lake Ann and Lake Lucy). The stormwater entering the lake carries debris and pollutants, including the nutrient phosphorus. Phosphorus is a nutrient that comes from sources such as erosion, fertilizers, and decaying leaves and grass clippings. Excess phosphorus can cause cloudy water and algal blooms in lakes. Removing phosphorus from stormwater is a proven way to improve the water quality of lakes and streams.

In 2016, an innovative spent lime filtration system was constructed along a tributary stream draining a wetland on the southwest corner of Lake Susan (Figure 57). Based on system performance of the one other experimental spent lime filter site in the eastern Twin Cities area, modeling simulations based on available water quality measurements suggested the Lake Susan system had the potential to remove up to 45 pounds of phosphorus annually from water entering the lake. This would result in improved water quality and recreational opportunities. Spent lime is calcium carbonate that comes from drinking-water treatment plants as a byproduct of treating water. Instead of disposing of it, spent lime can be used to treat stormwater runoff. When nutrient-rich water flows through the spent lime system, the phosphorus binds to the calcium. The water flows out of the spent lime system, leaving the phosphorus behind.

Figure 57. Spent Lime Treatment System

Figure 58. Column testing for lime/sand mixture.

Observation and monitoring data collected by District staff in 2016 - 2018 indicated inconsistent system performance and periods of extended inundation, which deviated from the original design parameters. District staff worked with Barr to review monitoring data and identify potential shortcomings of the system (e.g., monitoring, materials, influent, changed conditions, etc.) It was discovered that the spent lime media appeared to be significantly restricting flow of water through the filter. District and Barr staff conducted field testing of the filtration capacity of the spent lime and discovered that the spent lime structure had degraded into a clay-like consistency, thus essentially preventing water from filtering through the media. During the summer of 2019, District staff completed laboratory column testing for mixtures of spent lime and sand. Column testing indicated that mixing spent lime with sand improves the filtration capacity of the media, while still removing phosphorus. Figure 58 is a photograph of the column testing completed by District staff during 2019. The testing revealed the following key points:

- Filtering water through sand washed to MnDOT standard specifications (washed sand) results in phosphorus export from the test columns.
- Water filtered through the various spent lime/pool sand mixtures elevated the pH in the effluent water, thus supporting the chemical reaction to precipitate phosphorus (i.e., remove phosphorus).
- Filtration rates through the various spent lime/pool sand mixtures appear relatively unchanged after 114 days of inundation and continuous flow for 10 days did not reduce

drain times.

- Initial testing of plaster sand obtained from a local pit also results in phosphorus export from the material.
- Total phosphorus removals were generally higher the larger the content of spent lime in the mixture (Figure 59).

The laboratory testing completed by District staff was used to guide modifications to the spent lime system to improve filtration capacity and performance of the system. Modifications included the replacement of the deteriorated spent lime with a mixture of 70% plaster sand and 30% spent lime, replacement of the underdrain slotted piping, and the installation of an automated water control structure and solar panel.

Water samples were collected and analyzed from the inlet and outlet of the treatment system for total dissolved phosphorus (TDP), total phosphorus (TP), total suspended solids (TSS), ortho phosphorus (OP), and Chlorophyll-a (Chl-a). In 2020, the automated water control structure unit was brought online on 5/28/2020 and allowed to flow on Mondays and Fridays for 4 hours. On 6/23/2020, after a month of testing and the addition of a stop log, the unit was changed to remain open on Mondays, Wednesdays, and Fridays for five-hour periods. In 2021 (5/14/2021) and 2022 (5/26/2022), the unit was brought online and allowed flow on Mondays, Wednesdays, and Fridays for seven-hour periods. This schedule was increased to a nine-hour period (8am-5pm) in 2023 after the unit was started on 5/15/2023. This was to increase the amount of water being treated through the system.

Overall, a total of 18 samples were collected in 2020 and 22 samples were collected in 2021. The average TP reduction across all samples collected in 2020 was 62% (Figure 60). The average TP reduction in 2021 was 40% (Figure 61). In 2020, the maximum reduction was measured during a July sampling event and was 91%. In 2021, the maximum reduction occurred in early August and removed 81% of the phosphorus. For TDP, TSS, OP, Chl-a, reductions were around 50% in 2020. Similar to 2020, OP and Chl-a, reductions in 2021 were around 50%, but TDP and TSS removals were reduced to 30-40% removals (Table 23). Due to the extremely low water levels in 2022, the units last significant flow through event was on 6/17/22. Because of the low water only a single sample was collected in 2022. Drought

Figure 59. Pool Sand/Spent Lime Mixture Column Testing Phosphorus Removals

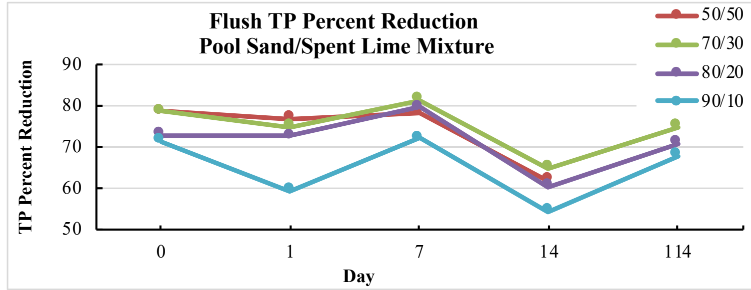


Figure 60. 2020 Lake Susan Spent Lime Treatment System Total Phosphorous Percent Reduction

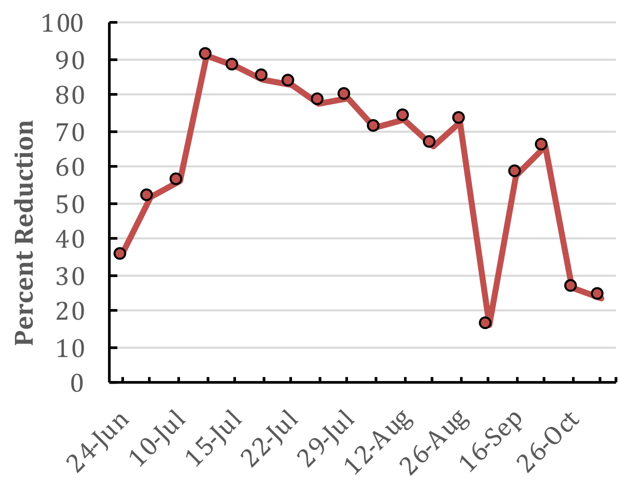
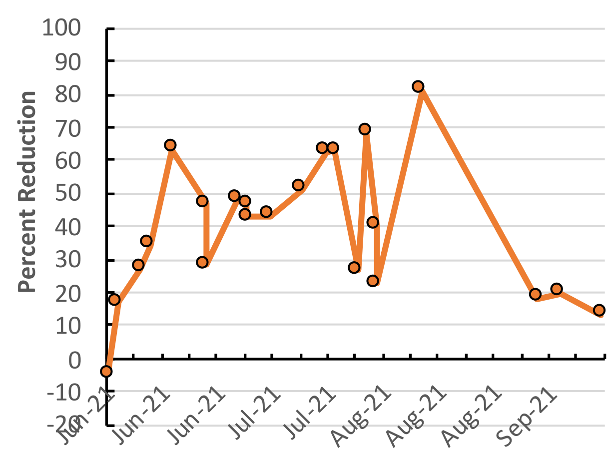


Figure 61. 2021 Lake Susan Spent Lime Treatment System Total Phosphorous Percent Reduction



conditions continued in 2023, which only allowed 6 samples to be collected in the spring and fall. Nutrient reductions were limited, but the small number off samples collected did not allow for an accurate performance evaluation of the unit.

The reduced TP removal efficiencies in 2021 could be linked to the need for additional mixing or "fluffing" of the sand/spent lime mixture. The District has been manually mixing the material once a year, but additional mixing may be needed to prevent media from compacting over time and to break up preferential flow paths within the BMP. Another explanation of reduced performance of the system could be that it may be overloading due to high upstream TP concentrations. The average inlet TP concentrations ranged from 0.099 to 1.41 mg/l across both years with averages well above the MPCA estimated typical total phosphorus range (0.1 mg/L to 0.25 mg/L) for effluent (outgoing) stormwater. These extremely high TP levels might be limiting system performance and additional treatments of the upstream wetland may be needed to address the nutrient impairment. Overall, the spent lime treatment system effectively removes phosphorus and other nutrients.

Table 23. 2020-2023 Average TSS and Nutrient Percent Removals from the Spent Lime Treatment System

Analyte	2020	2021	2022*	2023*
TDP (mg/l)	50	37	6	5
TP (mg/l)	62	40	16	14
TSS (mg/l)	46	28	48	No change
OP (mg/l)	59	51	1	7
CHLA (mg/l)	53	55	25	61

*Actual values - Limited samples collected due to drought.

4.12. **Rice Marsh Lake Water Quality Improvement Project: Kraken Filter**

The Use Attainability Assessment (UAA) undertaken by the District and the City of Chanhassen in 2016 found that the majority of pollutant loading to Rice Marsh Lake is due to runoff within the watershed (44%), with internal loading accounting for an additional 35% of the pollutant load. The remaining load is from upstream water bodies or atmospheric deposition. Further, the UAA concluded that Rice Marsh Lake Subwatershed RM-12A (232 acres) was the largest contributor to external pollutant loading to Rice Marsh Lake (Figure 62). In the fall of 2018, Rice Marsh Lake was treated with aluminum sulfate (alum) to treat the internal loading , but the external load still needed to be addressed. This led to the Kraken Filtration Project..

This project consisted of two manufactured treatment devices (MTDs) used in parallel along with a rain garden, soil amendments, and prairie restoration. These practices will result in the removal of approximately one-third of the load from the watershed or around 90 pounds of total phosphorus per year. The Kraken Filter by BioClean was the MTD selected; it is an engineered stormwater membrane filter that provides treatment for high flow rates (up to 2.9 cfs) using a number of filter cartridges. Runoff first passes through a pre-treatment chamber, moving to the membrane filter where it fills up the outer chamber. Once water reaches the top of the chamber, it flows down through the filter membrane, collecting in the underdrain, and flowing to the discharge chamber. High flow conditions cause water to pass over the high-flow weir, directly into the discharge chamber. The manufacturer evaluation indicates that the device can remove 63% of TP and 85% of TSS from influent runoff.

Construction began in fall 2021 with the installation of the two Kraken filters and ancillary storm sewer improvements. Vegetative restoration occurred in the spring 2022. Monitoring of the system began in 2023. Parameters monitored included total phosphorus, total dissolved phosphorus, chlorophyll-a, and total suspended solids. Continuous water level on the inlet and outlet along with inlet flow was collected (Figure 63). Nutrient data was not processed in time for the report and will be included in the next water resources report. Initial data review

Figure 62. Rice Marsh Lake RM-12A Watershed & Flow Patterns

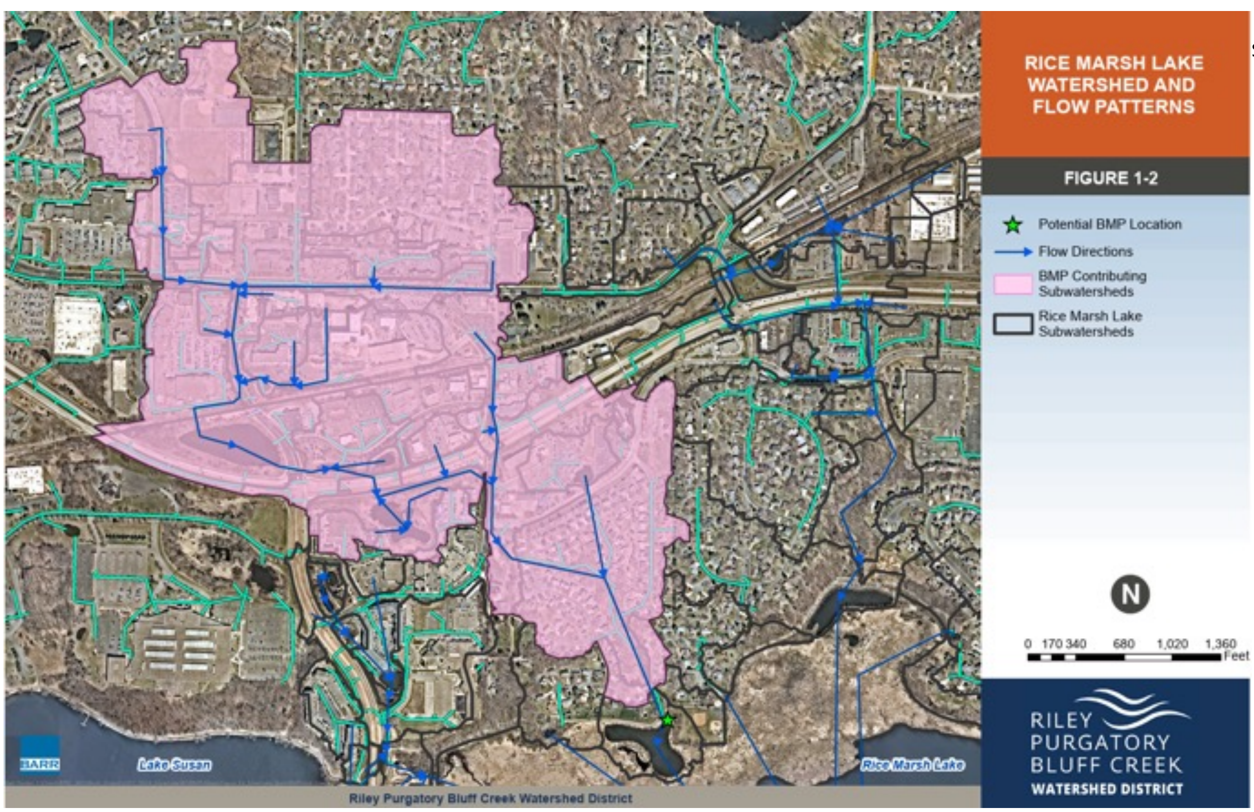


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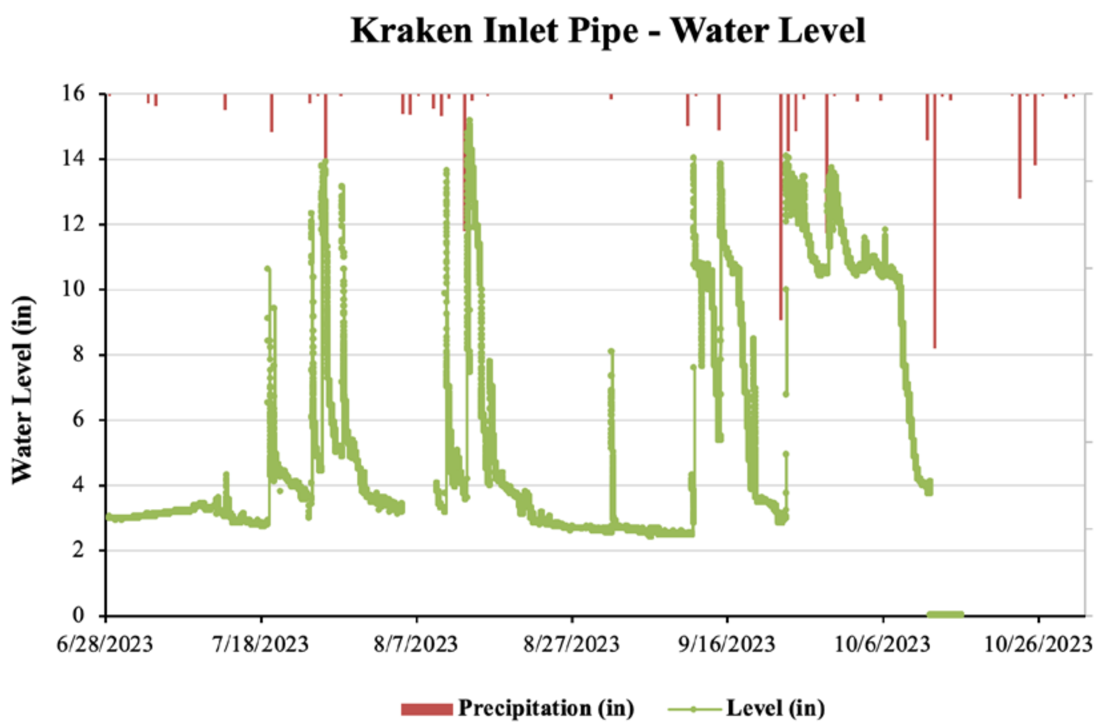
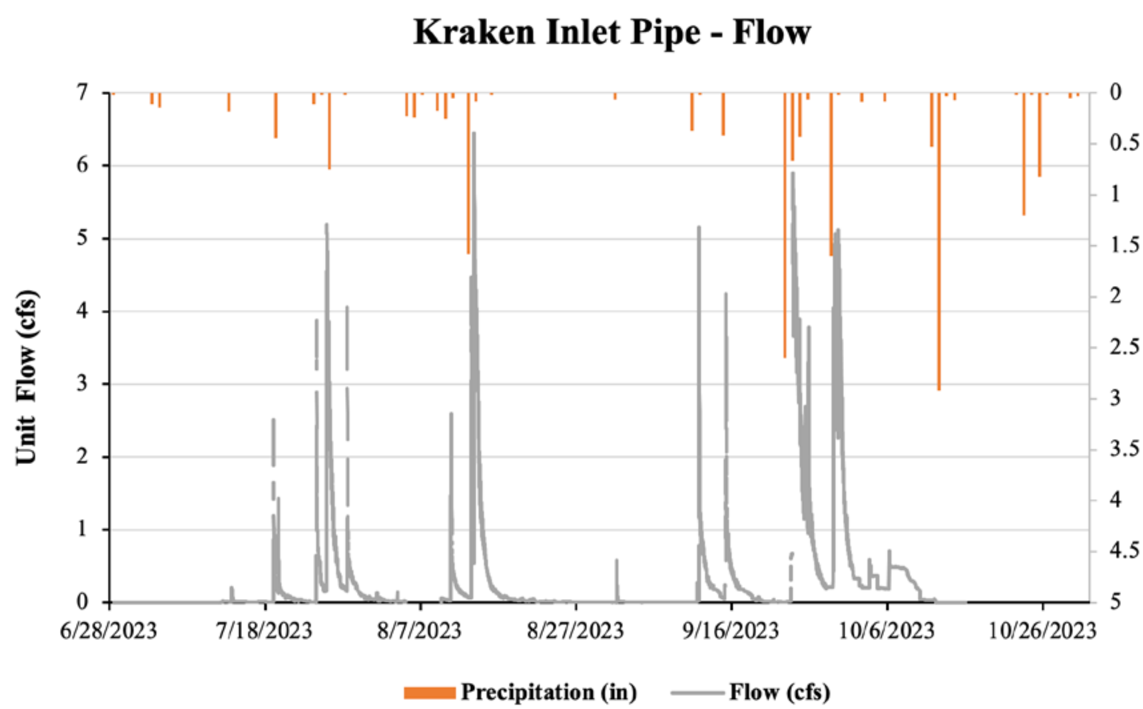
Figure 63. Rice Marsh Lake Kraken Inlet Water Level and Flow





4.13. Fish Kills and Stocking

Fish kills have commonly been recorded within the Riley Purgatory Bluff Creek Watershed District and generally have two causes:

- Winterkills (oxygen depletion)
- Columnaris Bacteria

In 2023 a summertime fish kill was observed and reported by residents around Lake Riley. Eden Prairie Parks staff counted just under 80 dead fish of all species ranging in size from 1-18inches. The cause of the fish kill was unknown and was reported to the DNR Fisheries Office. The number of fish was relatively small and the kill was considered minor.

Winterkills are common across the state of Minnesota, especially in shallow, eutrophic (nutrient-rich) lakes with muck bottoms and an abundance of aquatic plants. Many shallow lakes within the District have had a history of winterkills. A winterkill occurs when dissolved oxygen (DO) levels within a lake drop below 2 mg/L for an extended period, causing fish to suffocate and perish. During the summer season, oxygen is added to lakes through wind action and photosynthesis by phytoplankton and macrophytes. In the winter, if there are limited amounts of persisting snow-blocking sunlight, phytoplankton and some macrophytes may continue to photosynthesize and help prevent a winterkill from occurring. Microorganisms near the lake bottom and in the sediment of a lake are continuously decomposing material, consuming DO in the process. If a large snow event occurs or snow coverage has been present for an extended period, it becomes too dark below the ice for photosynthesis to occur. The high organic content in shallow lakes provides an abundance of food for the decomposers which can deplete DO levels. This can cause a fish kill.

In the winter of 2022/2023, winterkills occurred on Rice Marsh Lake, Lake Lucy, Silver Lake, and String Lake. The significant drought conditions that persisted in the summer of 2022, along with the record winter snowfalls can likely explain the number and severity of some of the winterkills. Table 24 shows DO levels for all lakes sampled across all sampling dates. At some point during the winter season, each lake measured below 2 mg/L from top to bottom, indicating a winterkill occurred. In most cases, staff also verified a fish kill by discovering dead fish on the perimeter of the lake as the ice receded, on the lake bottom, and/or near the openings. This includes the aeration opening on Rice Marsh Lake and the multiple holes which formed on Silver Lake. The District operates only a single aeration unit on Rice Marsh Lake which was operating all winter in 2023 but this still did not prevent a partial winterkill. Additionally, bird species (osprey, crows, eagles) were also observed in numbers eating deceased fish on Rice Marsh Lake and Silver Lake. Residents were often the first to detect a winterkill and observed these winterkill signs before contacting the District.

Preventing a winterkill in Rice Marsh Lake is a critical part of the Common Carp Management Plan for the RCL. Common carp have been known to move from various lakes in the RCL into Rice Marsh Lake to spawn. Before the aeration unit was operational, Rice Marsh Lake would winterkill every few years. This eliminated all predators of common carp in the system, allowing carp to successfully spawn. These successful spawning events caused large carp populations to form in all lakes within the RCL. Since operation of the unit in 2010, partial winterkills have occurred in 2017/2018, 2020/2021, and 2022/2023. Lake Lucy is also the top of the RCL and has similar reasons for maintaining a healthy bluegill population. The most important predator of common carp is the bluegill sunfish which can suppress a carp population by consuming eggs and larval stages of carp. A well-established bluegill population in a lake can control a carp population and prevent it from becoming a problem. Staring lake and the Purgatory Creek Recreation Area also act as a chain of lakes. Similarly, to Rice Marsh Lake in the RCL, carp migrate into the Rec Area to spawn and have free range when a winterkill occurs if the barrier is not in place or has to be removed. This is why maintaining healthy bluegill populations in this system is critical. For shallow lakes such as Duck Lake and Silver Lake, winterkills are common and often reset the lake. The Duck Lake and Silver Lake fisheries are not regularly sampled as part of the Districts carp management plan and are lower priority lakes for the DNR sampling, so fisheries data is limited.

Table 24. 2023 Dissolved Oxygen (DO) profiles on winterkill lakes.

Winter dissolved oxygen profiles (mg/L) for all 2023 winterkill lakes for each date sampled. Blue indicates good (>3mg/L), yellow indicates critical (2 mg/L), and red indicates winterkill DO levels (<2mg/L).

Dissolved Oxygen Level Status	Good	Critical	Winterkill

	LUCY			**STARING**			**RICE MARSH**			**DUCK**		**SILVER**
	Sample dates			Sample dates			Sample dates			Sample dates		Sample dates
Depth (m)	1/11/2023	2/16/2023	3/28/2023	1/11/2023	2/25/2023	3/28/2023	1/12/2023	2/16/2023	3/28/2023	1/12/2023	2/15/2023	2/28/2023
0.5							2.82	2.57	1.54	1.86	3.25	1.61
1.0	7.73	3.45	1.02	1.59	3.3	10.41	2.51	1.87	1.27	1.42	2.29	1.4
1.5					2.53	7.52	2.34	1.73	0.94	1.26	1.6	1.2
2.0	5.07	2.91	0.85	1.37	2.0	4.29	1.59	1.66	0.5	1.11	1.47	1.14
2.5	5.07	2.91	0.85		1.69	1.68	1.38	1.78	0.14			
3.0	4.74	2.32	0.13	1.32	1.54	0.55						
4.0	4.87	1.82	0		1.44	0.21						
5.0	4.32	1.58	0	1.35		0.14						
6.0	1.05	1.41	0									

Fish stocking following a winterkill is a common practice to reestablish a population. Due to the importance of Rice Marsh Lake in combating carp within the RCL, bluegill sunfish were stocked in the lake. After both the 2019/2020 and 2022/2023 winterkill in Lake Lucy, stocking occurred to quickly re-establish a base bluegill population. Bluegills have also been stocked in the Upper and Lower Purgatory Creek Recreational Area and Staring Lake. These water bodies have variable carp populations that are not under full control. Stocking bluegills in these waterbodies has been used in the past to aid in common carp control, the hope being to eliminate carp recruitment. Duck lake was stocked by the DNR in 2021 and 2023. Bluegill stocking rates can be seen in Table 25. Figure 64 displays the total number of bluegill/net captured in each trap net survey for the lakes that have been stocked with bluegills. Corresponding winterkill years are indicated in the figure by the red arrows. From this figure it clearly shows a reduction in bluegill numbers in most lakes with winterkills. Staff will monitor lakes of concern through the winter and will likely stock bluegills in 2024 as needed.

Figure 64. 2016-2023 Total Bluegill Trap Net Numbers

The number of bluegill caught per net for each of the five winterkill lakes from 2016-2023. Each arrow indicates a winterkill. Rice Marsh Lake and Lake Lucy are not sampled yearly.

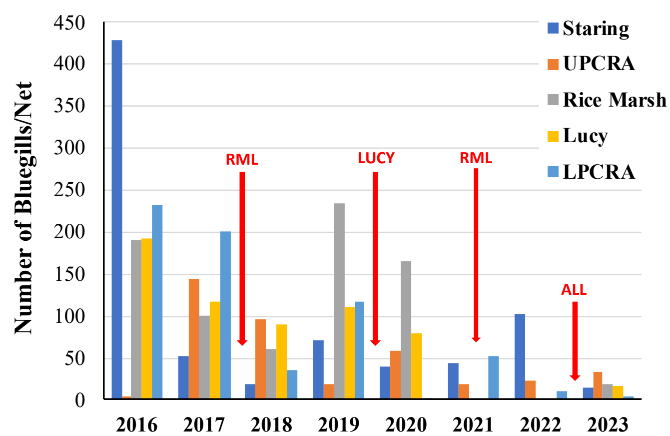


Table 25. 2018-2023 Bluegill Stocking Numbers

Lake	Number of Bluegill Stocked					
	2018	2019	2020	2021	2022	2023
Rice Marsh Lake	1,000	300	0	800	0	300
Staring	300	200	0	0	0	300
Upper Purgatory Creek Recreation Area (UPCRA)	200	100	0	100	0	50
Upper Purgatory Creek Recreation Area (LPCRA)	500	100	0	100	0	50
Lucy	0	300	0	0	0	300
Duck (stocked by DNR)	20	0	0	18	0	20
TOTAL	**2,020**	**1,000**	**0**	**1,018**	**0**	**1,020**

5: AQUATIC INVASIVE SPECIES

Due to the increase in spread of Aquatic Invasive Species (AIS) throughout the state of Minnesota, staff completed an AIS early detection and management plan in 2015. As part of the plan, an AIS inventory for all waterbodies within the District was completed. A foundation was also set up to monitor invasive species that are currently established within District waters (Table 26). Early detection is critical to reduce the negative impacts of AIS and to potentially eliminate an invasive species before it becomes fully established within a waterbody. Effective AIS management of established AIS populations will also reduce negative impacts and control their further spread. The RPBCWD AIS plan is adapted from the Wisconsin Department of Natural Resources (WIDNR, 2015), Minnehaha Creek Watershed District (MCWD, 2013), and the Minnesota Department of Natural Resources (MNDNR, 2015a) Aquatic Invasive Species Early Detection Monitoring Strategy. The goal is to not only assess AIS that currently reside in RPBCWD waterbodies, but to be an early detection tool for new infestations of AIS. Figure 65 identifies AIS monitoring/management that occurred in 2023, excluding common carp management.

Figure 65. 2023 AIS monitoring and treatment summary

Aquatic Invasive Species (AIS) work conducted in 2023 within the Riley-Purgatory-Bluff Creek Watershed District. Symbols indicate Zebra Mussel monitoring plates and/or monthly public boat launch scans (grey), zooplankton and phytoplankton sampling conducted (orange), herbicide treatments occurred (green), point-intercept vegetation surveys (purple). All lakes received juvenile mussel sampling.

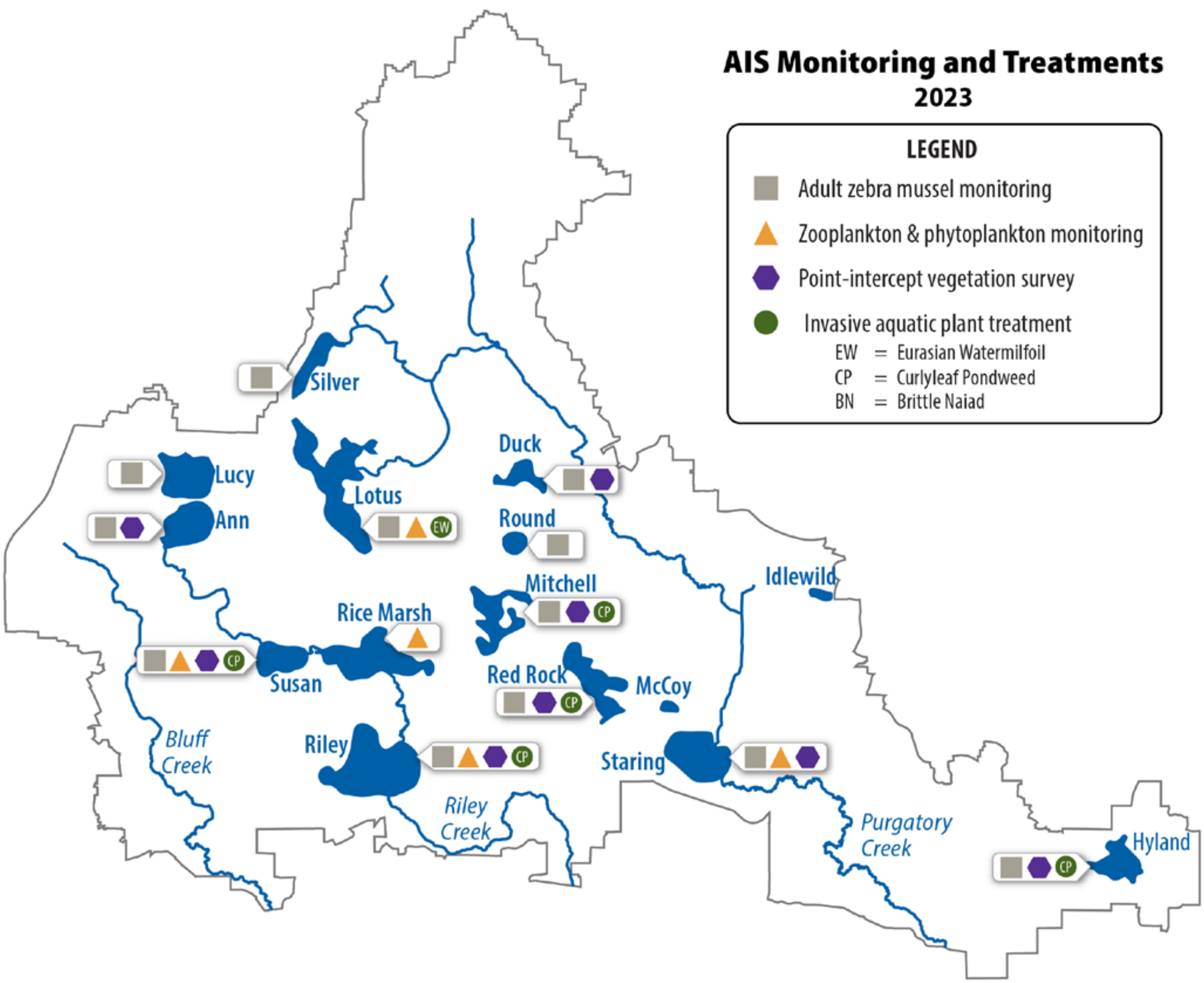


Table 26. Aquatic Invasive Species Infested Lakes

Lake Names	Brittle Naiad	Eurasian Watermilfoil	Curly-leaf Pondweed	Purple Loosestrife	Common Carp	Zebra Mussels
Ann	✓	✓	✓	✓	✓	✓ (new)
Lotus	✓	✓	✓	✓	✓	✓
Lucy	--	✓	✓	✓	✓	--
Red Rock	--	✓	✓	✓	--	--
Rice Marsh	--	--	✓	✓	✓	--
Riley	--	✓	✓	✓	✓	✓
Silver	--	--	✓	✓	--	--
Staring	✓	✓	✓	✓	✓	--
Susan	✓	✓	✓	✓	✓	--
Duck	--	✓	✓	✓	--	--
Mitchell	✓ (new)	✓	✓	✓	--	--
Round	✓	✓	✓	--	--	--
Hyland	--	--	✓	--	--	--

✓ (red) Indicates new infestation

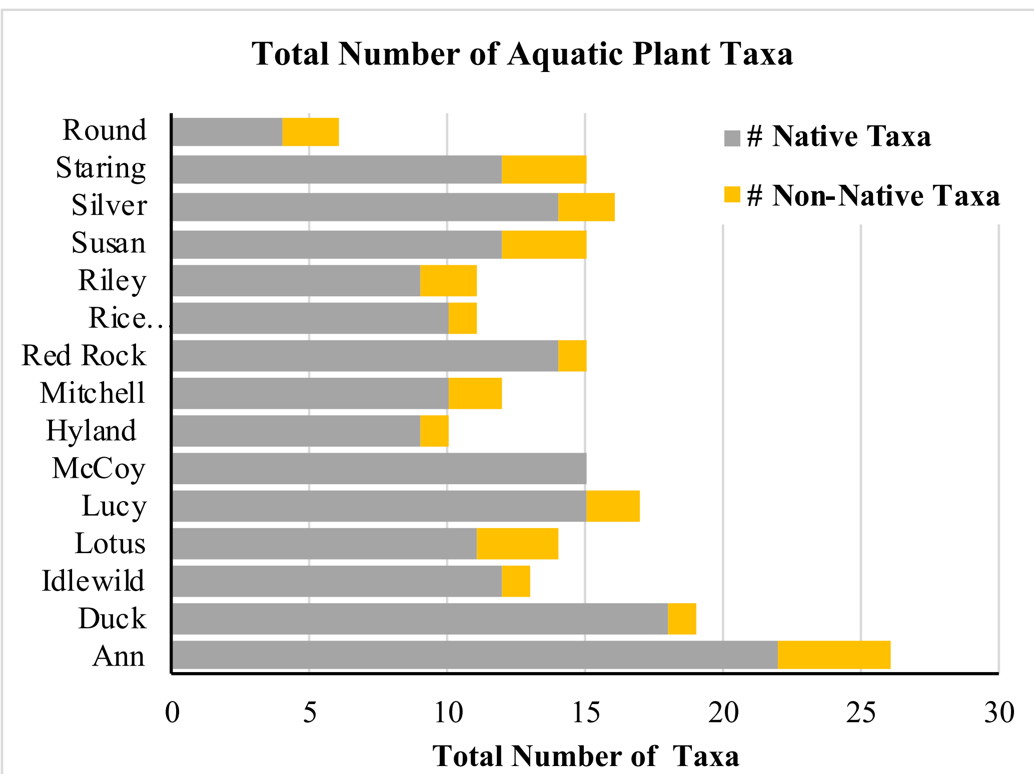
5.1. Aquatic Vegetation Monitoring & Management

Aquatic plant surveys are important because they allow the District to map out invasive plant species for treatment, locate rare plants for protection, create plant community/density maps which evaluate temporal changes in vegetation community, identify the presence of new AIS within water bodies, and can assess the effectiveness of herbicide treatments. Aquatic plant surveys have been conducted on a rotational basis within RPBCWD to ensure all lakes have received adequate assessments. As projects arise, or issues occur, additional plant surveys are conducted to aid in the decision-making process. The most comprehensive aquatic plant survey is called a point-intercept method. This survey utilizes sample points arranged in a uniform grid across the entire lake which can vary in number depending on the lake size. At each designated sample location, plants are collected using a double-headed, 14-tine rake on a rope. For each rake sample, the rake is dragged over the lake bottom for approximately 5 ft before it is retrieved. Roving surveys are also used when species of concern are in question. This survey method involves driving around the lake, visually scanning the shallows, tossing rakes, and marking every plant found using a handheld GPS device. The other type of aquatic plant survey is a delineation survey which guides and directs herbicide treatments. Herbicide treatments have been shown to reduce and control aquatic invasive plants to a manageable level, which may in turn allow for native plants to increase in abundance.

In 2023, point-intercept surveys were conducted Hyland Lake (TRPD), Mitchell Lake, Red Rock Lake (EP), Lake Susan, Lake Riley, Staring Lake (UMN), Duck Lake, Silver Lake, and Lake Ann (District). Aquatic plant reports can be provided upon request. Figure 66 shows the number of native and non-native taxa from each lake within the District based on the latest completed point-intercept survey. Lake Ann continues to have the greatest number of native taxa with 22 species (reduction from 25 species in 2020) which is followed by Duck with 19 species. Most lakes have between 10-15 species of native plants with Round Lake having the least native plant diversity (four species). The District will continue to monitor the aquatic plant communities

Figure 66. Total Number of Aquatic Plant Taxa

Total number of native and non-native taxa across all lakes within the RPBCWD based on their most recent point-intercept survey.



within our lakes and use herbicide treatments to manage aquatic invasive plants to sustain healthy aquatic communities into the future. A list of highlights from each point-intercept survey is below.

- **HYLAND:** For the third consecutive year, the herbicide Fluridone was used to treat Curly-leaf Pondweed immediately after ice-off on Hyland Lake. In 2023, the number of native species increased to nine species from a previous high of six species in 2019 and 2020. The combined herbicide treatments and aluminum sulfate (alum) treatment by Three Rivers Park District has allowed plants to expand to 50% of the littoral area.
- **SILVER:** Submersed Coontail (94% frequency of occurrence) and floating White Waterlily (50% frequency of occurrence) are the dominant vegetation in the lake. Since the 2013 survey, the number of species has increased from 10 species to 16 in 2020 and 14 in 2023. Most plant species have increased in abundance and density due to the increased water clarity. This includes Northern Wild Rice which has increased from 5% in 2013 and 1% in 2020 to 13% in 2023.
- **MITCHELL:** Coontail was the dominant plant in Mitchell Lake and was found growing at 52% of the sites. Eurasian Watermilfoil was found at 15 sites at mostly light growth and Curly-leaf Pondweed was present. Brittle naiad, an AIS, was discovered and determined to be established in the northeast end of Mitchell Lake. The acreage of aquatic submerged plants in Mitchell Lake in late summer was about 68 acres (61% of the lake). The number of species observed at each site ranged from 1 to 5 species.
- **DUCK:** Coontail was the most common plant found at 96% of sites followed by Flatstem Pondweed at 52% of sites. Overall, plant growth in Duck Lake covered 100% of the lake surface. The number of plants increased from six in 2020 to 16 in 2023. This is partially due to the inclusion of the west bay and very low densities of additional floating and emergent native species that previously were not found (Longleaf Pondweed, Arrowhead, American Lotus, and Hardstem Bullrush)
- **RILEY:** Lake Riley was treated for Curly-leaf Pondweed (9 acres). The University of Minnesota conducted three point-intercept plant surveys in 2023 to track aquatic vegetation populations. In August, 11 species were observed, 9 were native, and native richness declined slightly from previous years with a high of 1.3 natives per point. Throughout all survey years, most plants were in water < 2m deep. However, with the improved water clarity, from 2016 through 2023, plants were observed in sites up to 5.0 meters deep. Eurasian Watermilfoil greatly decreased in 2023, with all three sampling months having less than 3% observed frequency. Frequency of Curly-leaf Pondweed increased slightly from June 2020 to June 2023, from 25% to 29% but has not expanded further. Turion density was sampled in 2022 and 2023 and remained low at 8 turions/m^2 in 2022 which increased slightly to 25 turions/m^2 in 2023, well below the abundance prior to the start of invasive control.

Table 27. Lake Vegetation Monitoring and Management in 2023.

Species delineated for treatment included Curly-leaf Pondweed (CLP) and Eurasian Watermilfoil (EWM). All aquatic herbicide treatments were directed and financed by the RPBCWD and executed by PLM Lake and Land Management Corporation except for Red Rock which was carried out by Midwest AquaCare.

Lake	Point-Intercept Surveyor	Delineation Species	Delineation Surveyor	Herbicide	Acreage Treated
Red Rock	EP	CLP	RPBCWD	Aquathol	13
Mitchell	EP	CLP	RPBCWD	Flumioxazin	12.9
Lotus	RPBCWD	CLP/EWM	RPBCWD	Diquat	22.92
Riley	UMN	CLP	UMN	Diquat	9
Susan	UMN	CLP	UMN	Flumioxazin	5.35
Hyland	TRPD	CLP	TRPD	Fluridone	Whole-lake
Staring	UMN	--	--	--	--
Ann	RPBCWD	--	--	--	--
Duck	RPBCWD	--	--	--	--
Silver	RPBCWD	--	--	--	--

EP = City of Eden Prairie; UMN = Univesity of Minnesota; TRPD = Three Rivers Park District

- **ANN:** At 22 species, Lake Ann has the highest plant diversity of all lakes in the District. Coontail was the most common plant found at 67% of sites followed by Flatstem Pondweed at 55% of sites. White Water Lily was the most dominant floating plant at 28% frequency of occurrence. In the 2023 survey, no Eurasian Watermilfoil was sampled. However, for the first time, Brittle Naiad was at a detectable level (4% frequency of occurrence) since its initial discovery in 2017.
- **STARING:** In 2022, the herbicide Fluridone was used to treat Eurasian Watermilfoil and was successful; no Eurasian Watermilfoil was observed in 2023. Unfortunately, the reduced vegetation from the treatment combined with the low water levels for 2022 and 2023 has led to reduced water quality. Nutrient levels should decline as native vegetation expands across the lake. The University of Minnesota conducted three point-intercept plant surveys in 2023 to track aquatic vegetation populations. Native plant coverage decreased to 25% in August 2023 down from > 50% in 2016-2022. In 2023, 13 total species were found throughout the year, with 12 total natives. In 2023, Curly-leaf Pondweed was found at 20% of points in peak season. White Water Lily, Sago Pondweed, and Star Duckweed were all found at the highest frequency in 2023 since sampling started.
- **SUSAN:** Lake Susan was treated via herbicide for Curly-leaf Pondweed in 2023 (5.3 acres). The University of Minnesota conducted three point-intercept plant surveys in 2023 to track aquatic vegetation populations. In 2023, May maximum depth of growth was 3.1 and decreased to 1.5 in August. The invasive Eurasian Watermilfoil declined in frequency since 2011 and was not observed on any rake tosses during the aquatic vegetation surveys of 2018 through 2023. Brittle Naiad although present in the lake, has not been detected in point-intercept surveys. Turion density decreased in 2023 to 20 turions/m^2 and viability was 87%.

2023 Herbicide Treatments

In the spring 2023, herbicide treatments were carried out by PLM Lake and Land Management Corporation and Midwest AquaCare (Red Rock Lake) on District lakes. Curly-leaf Pondweed was treated on Mitchell Lake (12.9 acres), Lake Riley (9 acres), Lake Susan (5.35 acres), and Red Rock (13 acres). The survey maps can be seen in Exhibit J. Both Eurasian Watermilfoil and Curly-leaf Pondweed were targeted with a single treatment on Lotus Lake (22.92 acres). A DNR Traditional AIS Control Grant in the amount of $3,000 was awarded and utilized for a Lake Riley Diquat treatment for Curly-leaf Pondweed and to cover the early season point-intercept survey. A summary of the 2023 lake vegetation monitoring and management can be seen in Table 27 and Exhibit I.

Curly-leaf Pondweed Flumioxazin Treatment

The herbicide Flumioxazin was used for the first time in the District and was part of a study to evaluate its effectiveness. This collaborative study between the UMN, DNR, and the District involved the submission of water samples to test the time the herbicide was in the water and extensive pre and post point-intercept surveys of the area to gauge control of the Curly-leaf Pondweed and damage to native plants. The Mitchell Lake Flumioxazin treatment monitoring included a pre-treatment point-intercept survey on May 15 before the application was administered on May 17. The follow-up point-intercept survey was conducted on June 20. A control area was surveyed in addition to the treatment area to identify any variability to what was seen in the treatment area. Pre-treatment frequency of occurrence was 67% in the control area and 69% in the treatment area. In the post treatment PI survey, Curly-leaf Pondweed frequency of occurrence declined 22% in the control area and 99% in the treatment area (Figure 67). Native plants declined 19% in the treatment area while increasing 13% in the control area. Overall, the Flumioxazin treatment seems to be a highly effective treatment for Curly-leaf Pondweed in Mitchell Lake with a drastic reduction in occurrence following the treatment.

Lake Susan also had a Flumioxazin treatment applied on 5/17/2023. The UMN conducted a pre-treatment survey was conducted on 5/15/2023, and a post-treatment survey on 6/13/2023. Pretreatment Curly-leaf Pondweed frequency of occurrence declined from 53% to 7% in the treatment area or an 87% decline overall (Figure 68). Native plant density declined 21%. Overall, Flumioxazin performed well and will likely be utilized moving forward.

Figure 67. 2023 Curly-leaf Pondweed Pre and Post Treatment Densities on Mitchell Lake (source: DNR).

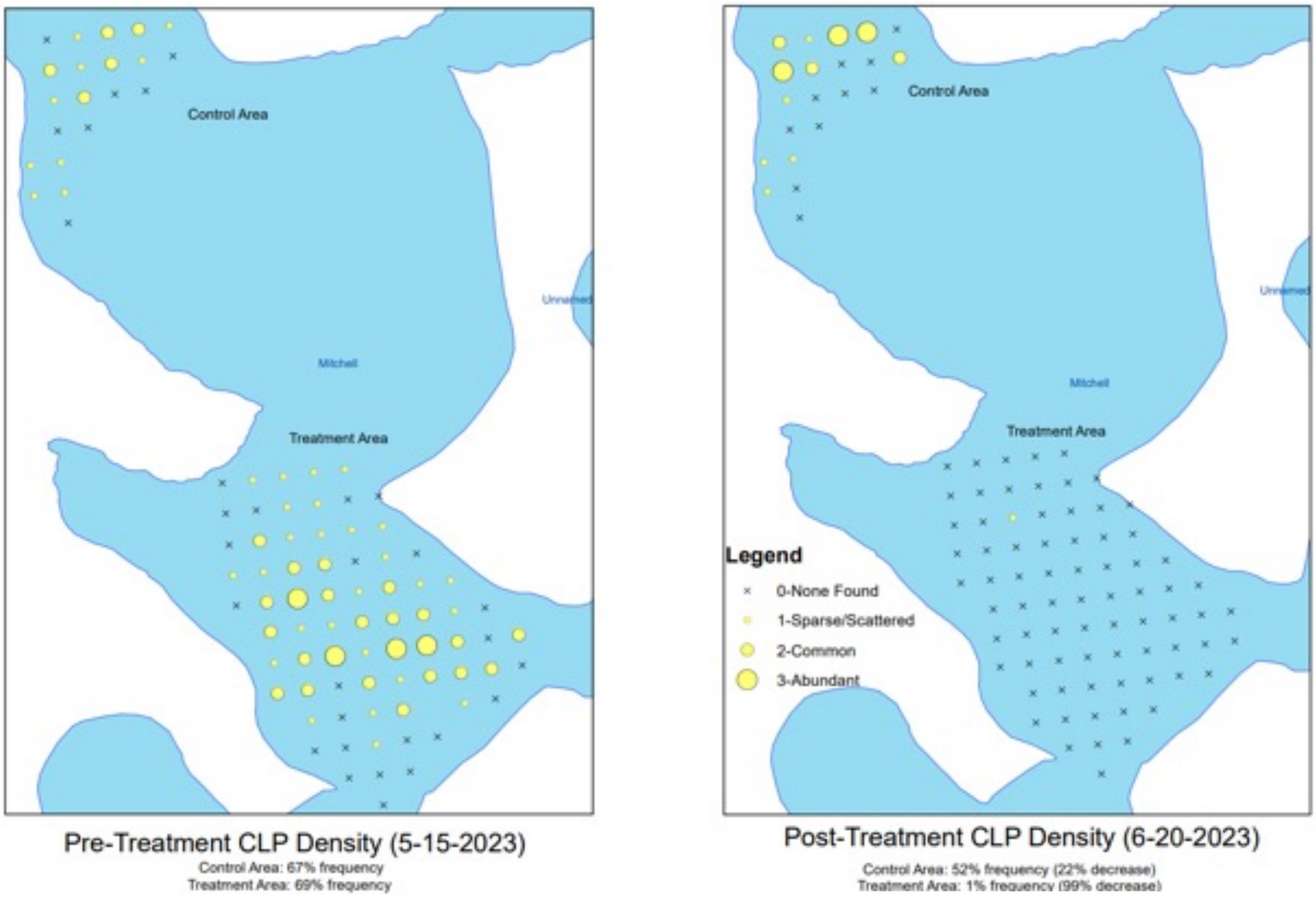
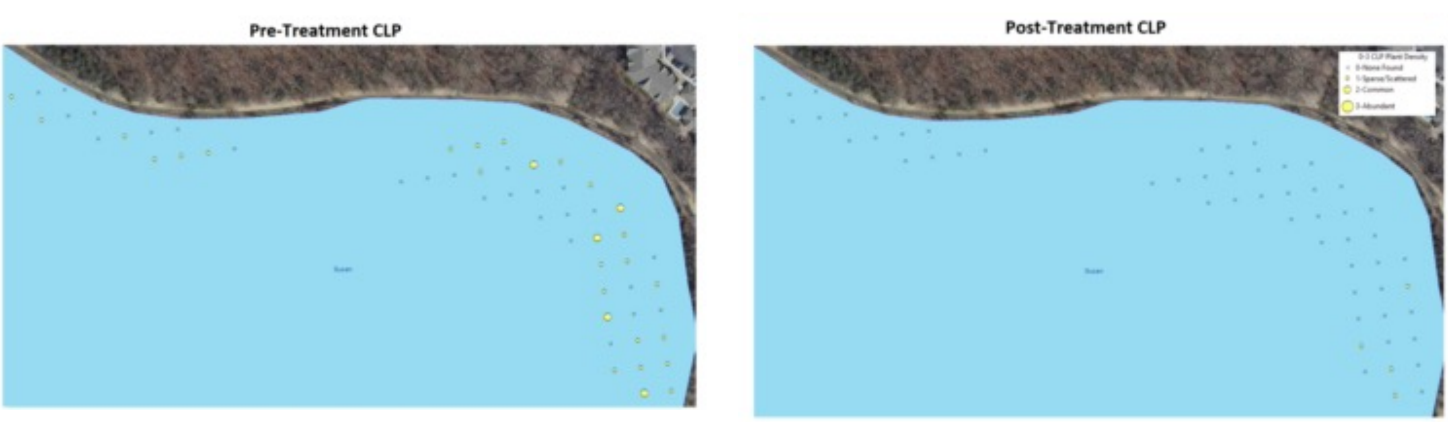


Figure 68. 2023 Curly-leaf Pondweed Pre and Post Treatment Densities on Lake Susan (source: DNR)



Mitchell Lake Turion Survey

In 2023, District staff completed a Curly-leaf Pondweed turion survey on Mitchell Lake. Turions are the primary reproductive structure of Curly-leaf Pondweed. Research suggests approximately 50% of turions germinate in a growing season while the rest remain dormant until the following growing season when another 50% will germinate (Johnson 2012). Depending on the level of turions at a given location (knowing that latent turions may be able to survive for over five years in the sediment), it may take several years of control to exhaust the "turion bank" (R. Newman – U of M unpublished data). Evaluating the turions in a lake can help researchers evaluate the effectiveness of treatments.

Staff followed procedures outlined by the UMN (Johnson, 2012). In October, the abundance of Curly-leaf turions in littoral sediment was measured. A petite Ponar dredge (225 cm^2 basal area; sample depth ~10 cm) was used to collect one sediment sample at each of the same 40 locations where biomass (point-intercept surveys) was collected (40 points surveyed in 2023). Upon retrieving each sediment sample, the sampler contents were emptied into a sifting bucket with a 1-millimeter screen and searched for turions or spread thinly across the boat deck and hand-sifted. Turions were placed into a labeled plastic bag and stored in a cooler while in the field. Small turion fragments (those that did not include a portion of a central turion stem) and severely decayed turions (those that did not retain their shape when lightly squeezed) were discarded and not included in final turion counts. Turion abundance at each sampled site (N of turions ÷ 0.0225 m^2; N/m^2) and yearly mean littoral turion abundance for each lake was calculated.

Turion viability was also assessed. Turions found sprouting at the time of sample processing were tallied as viable and then discarded. Remaining unsprouted turions from each lake were placed into clear sealable plastic bags with a small amount of water and stored in the dark at 5°C for 30 days to simulate typical fall conditions in surface sediments of Minnesota lakes to break turion dormancy (Sastroutomo 1981). During this period of cold storage, bagged turions were inspected weekly and any sprouted turions were tallied and discarded. After this period of cold storage, remaining unsprouted turions were incubated for an additional 90 days at 20 $^\circ$C with 14 hours of light per day from a bank of four fluorescent 20-watt grow lamps. After 90 days of warm incubation, staff calculated final turion viability (proportion sprouted) by dividing the total number of sprouted turions (in-lake + cold-storage + warm incubation) by the total number of turions collected (sprouted + unsprouted) from each lake and calculated the abundance of viable turions (turion abundance × proportion sprouted; N/m^2) in each lake for each year. The results from the survey are shown in Table 28.

Table 28. 2023 Mitchell Lake CLP Turion Statistics

Total Number of Sample Points	40
Total Number of Live Turions/Total Turions	7/17
Total Number of Points with Viable Turions/Total Points with Turions	6/10
Frequency of Occurrence	25%
Number of points above potential impairment (+50/m^2)	4
Number of points above predicted nuisance level (+200/m^2)	0
Maximum Turions/m^2	129.31
Mean Turions/m^2	17.24
Standard deviation/m^2	11.04

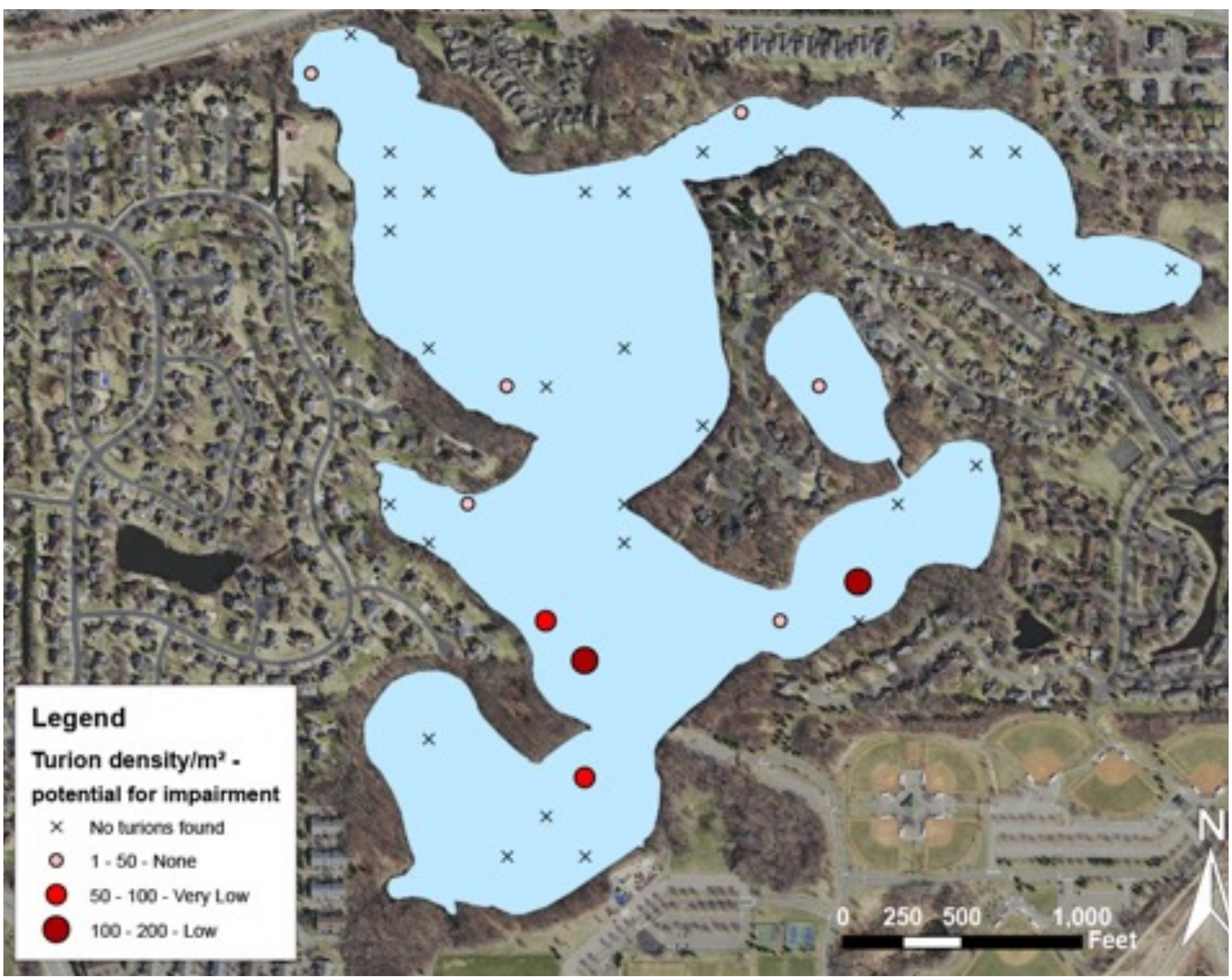
Table 29 summarizes the results from the 2023 Mitchell Lake turion survey. During the October 5, 2023, survey, District staff found 17 total CLP turions; 6 of 40 points had live turions (25% occurrence). In the 2021 survey, District staff found 17 total CLP turions; 10 of 53 points had live turions (19% occurrence), an overall decrease from 2017 (12 out of 40 points with live turions, a 30% occurrence). This is also well below the occurrence of live turions first sampled in 2013 (29 out of 40 points with live turions, a 73% occurrence). Turions appeared to be scattered throughout the lake at very low densities (Figure 69).

The overall mean density within the study areas was 17.24 turions/m^2 with a standard deviation of 11.04 turions/m^2 slightly higher than the 2021mean density of 13.57 turions/m2 with a standard deviation of 8.77 turions/m2. This is a significant decline from 2013 (190.73 turions/m2 with a standard deviation of 85.81 turions/m2). It has remained relatively unchanged since the last survey in 2017 (12.93 turions/m2 with a standard deviation of 15.8 turions/m^2). Overall, the total number of turions has been reduced with the application of consecutive herbicide treatments. No herbicide treatments occurred in 2013 and 2014, but the herbicide endothall was applied to the lake in 2015, 2016, and 2017. Diquat was applied in 2018, 2020, 2021, and 2023. In 2023, the herbicide flumioxazin was used. Turion surveys show a clear reduction in viable turions following herbicide applications. Four of the survey points topped an estimated 50 turions/m2. This indicates a low potential for navigation impairment (Johnson 2012) (50% of points with turions). However, none of these points exceeded the expected "nuisance level" of 200/m^2 (Figure 67). District staff will continue to monitor the CLP pondweed on Mitchell Lake to assess if treatment is needed moving forward.

Table 29. Mitchell Lake turion survey results (2013-2023)

Date	Turions/m^2	Viability	Viable Turion Density (turions/m^2)
Oct 2013	177	77%	137
Oct 2014	152	44%	72
Oct 2015	13	80%	11
Oct 2016	25	38%	10
Oct 2017	12	49%	5
Oct 2021	17	50%	7
Oct 2023	17	44%	6

Figure 69. 2023 Fall Mitchell Lake CLP Turion Survey Density and Distribution



5.2. Common Carp Management

RPBCWD, in cooperation with the University of Minnesota (UMN), has been a key leader in the development of successful carp management strategy for lakes within the state of Minnesota. Following the completion of the Riley Chain of Lakes (RCL) Carp Management Plan drafted by the UMN in 2014 (Bajer et al., 2014), and the Purgatory Creek Carp Management Plan drafted in 2015 (Sorensen et al., 2015), the District took over monitoring duties from UMN. Carp can be detrimental to lake water quality. They feed on the bottom of the lake, uprooting aquatic plants and resuspending nutrients found in the sediment.

Adult carp are monitored within RPBCWD by conducting three electrofishing events per lake each year, between late July and early October. Each event consists of three 20-minute transects (totaling three hours per lake). The population is considered harmful to lake water quality if the total biomass estimate of carp is above 100 kg/h; at this point the District would need to consider management. Young of the year (YOY) carp are monitored by conducting 24-hour small mesh trap net sets between August and September. Each sampling event consists of five nets set per lake. Capture of YOY carp during this sampling suggests successful recruitment has occurred, and monitoring efforts should be increased on that water body. At that point, the District would also consider further management action. In 2023, 394 carp or 735 lbs. of fish were removed from RPBCWD (Table 30).

Table 30. Total Common Carp removed in 2023.

System	Number of Fish	Weight (pounds)
Riley Chain of Lakes (RCL)	29	121.13
Purgatory Chain of Lakes (PCL)	365	613.80
Total	**394**	**734.93**

Trap Netting

District staff completed trap net surveys on Staring Lake, Lake Lucy, Rice Marsh Lake, and the Upper (UPCRA) and Lower Purgatory Creek Recreational Area (LPCRA) in 2023. Of the lakes sampled, Staring Lake had the most fish captured (n=2,782). Similar to 2022, Staring Lake had the most diverse fish population in 2023 (n=13). Previously, Staring Lake had 10 different species in 2022 and the UPCRA had the highest in 2021 (n=10) and 2020 (n=11). As is true with many lakes during late summer located within the Twin Cities' metro area, the RCL and PCL inshore fish community was dominated by bluegill sunfish. The Upper Purgatory Recreation Area had the highest number of bluegills captured, averaging 33.5 fish per net. This is up from 2022 (n=23.75) and historically on the higher end of bluegill numbers. The LPCRA had the lowest bluegill abundance at around 4.75 bluegills/net. This is down from 10.7 bluegills/net in 2022. Other species that were abundant included pumpkinseed sunfish, black crappies, and bullhead species. LPCRA had the highest number of black crappies by far (200 fish/net captured), which was primarily made up of YOY crappies. Large predatory fish including northern pike and largemouth bass were captured via trap netting in low numbers across the lakes. A full summary table of the fish captured for each lake can be found in Exhibit B.

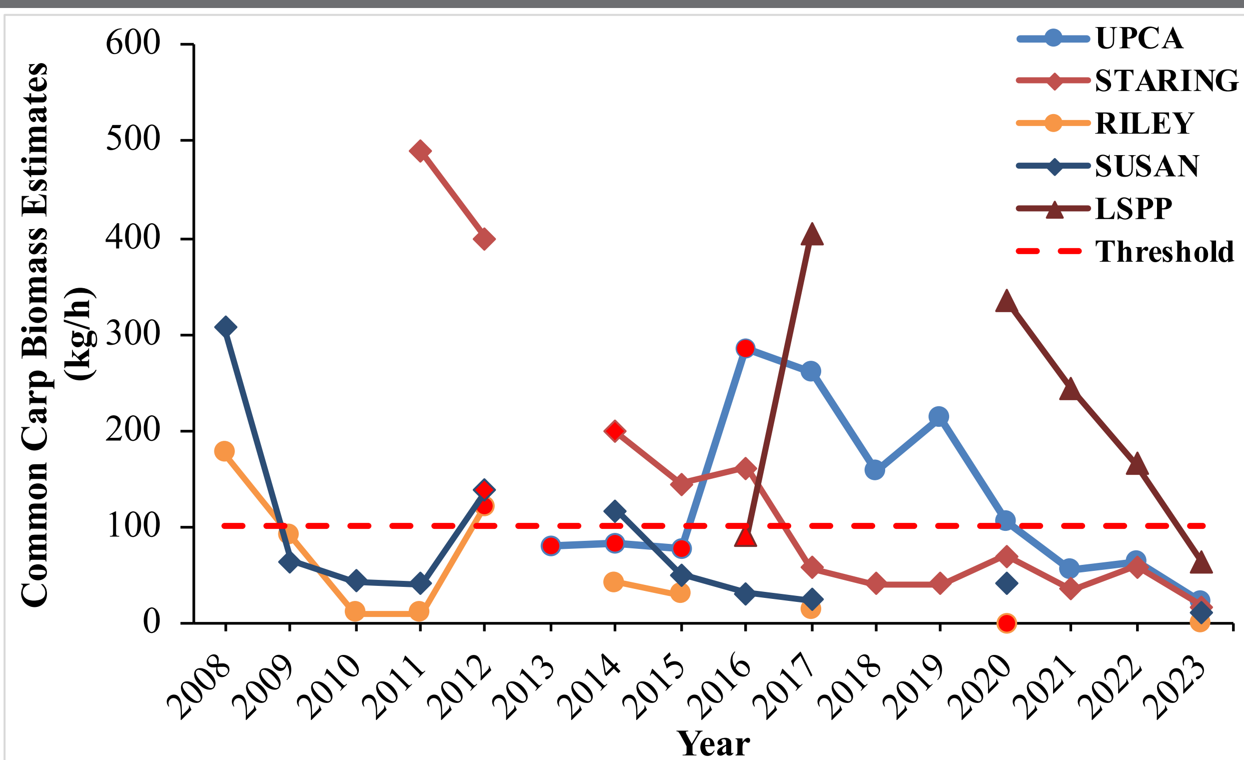
In 2023, a total of 107 YOY carp were captured via trap net surveys. Of the 107 YOY found in fyke nets, 92 were captured in the LPCRA, and 15 were found in Staring Lake. The abundance of YOY carp found in trap net surveys combined with 55 YOY carp found electrofishing on Staring indicates a full recruitment year. This recruitment is directly related to the decreased predation pressure resulting from winterkill in both Staring and the LPRCA. Although bluegills were stocked, they were only available later in the spring and the sheer numbers of YOY carp were not able to be exploited. This recruitment event marks the first time since 2015 that largescale reproduction has occurred. The amount of YOY carp in LPRCA (n=92) is a large increase from 2022 (n=4) and 2020 (n=17).

Electrofishing

Lake Susan, LSPP, and Lake Riley were the RCL waterbodies electrofished in 2023. For 2023, Lake Susan had a biomass estimate of 11.28 kg/h, well below the threshold and consistent with past estimates. LSPP continues to be a congregation area for common carp albeit reduced within the RCL system. Despite this, the 2023 biomass estimate was below the biomass threshold of 100 kg/ha at 63.54 kg/ha (Table 31). Fish move into LSPP during spring high water and are trapped as water levels recede. This was thought to be a management opportunity within the RCL lakes as carp in LSPP are more easily captured due to the pond's limited depth and area. This is also a likely explanation as to why the biomass estimates are so high, suggesting an overestimation of the population within the pond. Although the pond was suspected to be deep enough to prevent winterkill, in 2021 25 YOY carp were captured. Although the pond does offer some removal potential, staff put up a barrier at the beginning of spring in 2022 to prevent carp movement into the pond to reduce the chance of recruitment occurring. The overall reduction in adult carp in the system is likely due to the District's removal efforts. The District will continue monitoring and removing carp from LSPP in addition to the recommended management actions established in the RCL management plan. Lake Riley had no carp captured, yielding an estimate of 0 kg/ha. The carp population in Riley is comprised of a few large adults that are able to visually detect and flee surveyors because of the clear water conditions.

The PCL waterbodies surveyed via electrofishing in 2023 were Staring Lake and the UPCRA. As seen in (Figure 70), the adult common carp biomass estimates have been decreasing in Staring Lake since management began. The adult carp biomass estimate fell below the threshold for the first time in 2017, at 62 kg/ha. Since then, the population has been maintained around 40-60 kg/ha. The fish captured each year have primarily consisted of individuals from the 2014/2015-year class, which was the last major recruitment year for common carp in this system. In 2023 the adult carp biomass was the lowest ever at 18 kg/ha. Electrofishing does not regularly occur in the LPCRA due to access issues and the amount of brittle naiad present in the system. In 2023, the UPCRA carp biomass estimate was below the threshold at 23 kg/ha (Table 31). The UPCRA biomass estimate has exceeded the threshold every year from 2016 until 2020, before falling below the threshold in 2021. Since the UPCRA area is essentially the top of the system (fish cannot travel to Silver Lake and Lotus Lake), and has a deeper-water refuge, fish move to this location. The fluctuations in Staring and UPCRA can be explained by removals happening in the

Figure 70. Common Carp Biomass Estimates (2008-2023)



system and fish migrating between the watetbodies. Due to the shallowness of the system, winter seining would have limited effectiveness at capturing carp in UPCRA and LPCRA. Success of winter seining may also be limited in Staring Lake due to the low number of carp estimated in the system. Capture rates in the recreational area can be highly variable as the UMN biomass estimates were based on lakes and not wetlands/ponds (UPCRA and LPCRA are shallow water wetlands).

Unfortunately, in 2023, both Staring Lake and the Recreational Area experienced a significant winterkill with signs of low dissolved oxygen levels present even in December of 2022. This is extremely early for winterkill to occur. The winterkill was likely linked to the near record low water year which led to near zero flows in Purgatory Creek. With these conditions most native predators of carp were eliminated and a recruitment event occurred. Staff are discussing the possible placement of an aeration unit on Staring Lake to prevent such an event from happening again. Staff will attempt to remove carp in the spring of 2024 and may need to conduct other removal events to try and eliminate much of the 2023-year class.

Table 31. Common Carp Biomass Estimates for 2023.

Body of water name	Fish per Hour	Density per Hectare	Average Weight (kg)	Carp Biomass (kg/ha)
Lake Susan Park Pond	8.95	45.18	1.41	63.54
Susan	0.30	4.45	2.54	11.28
Staring	0.92	7.37	2.43	17.91
Riley	0.00	3.04	0.00	0.00
Upper PCRA	3.36	18.85	1.24	23.44

PCRA Spring Removals

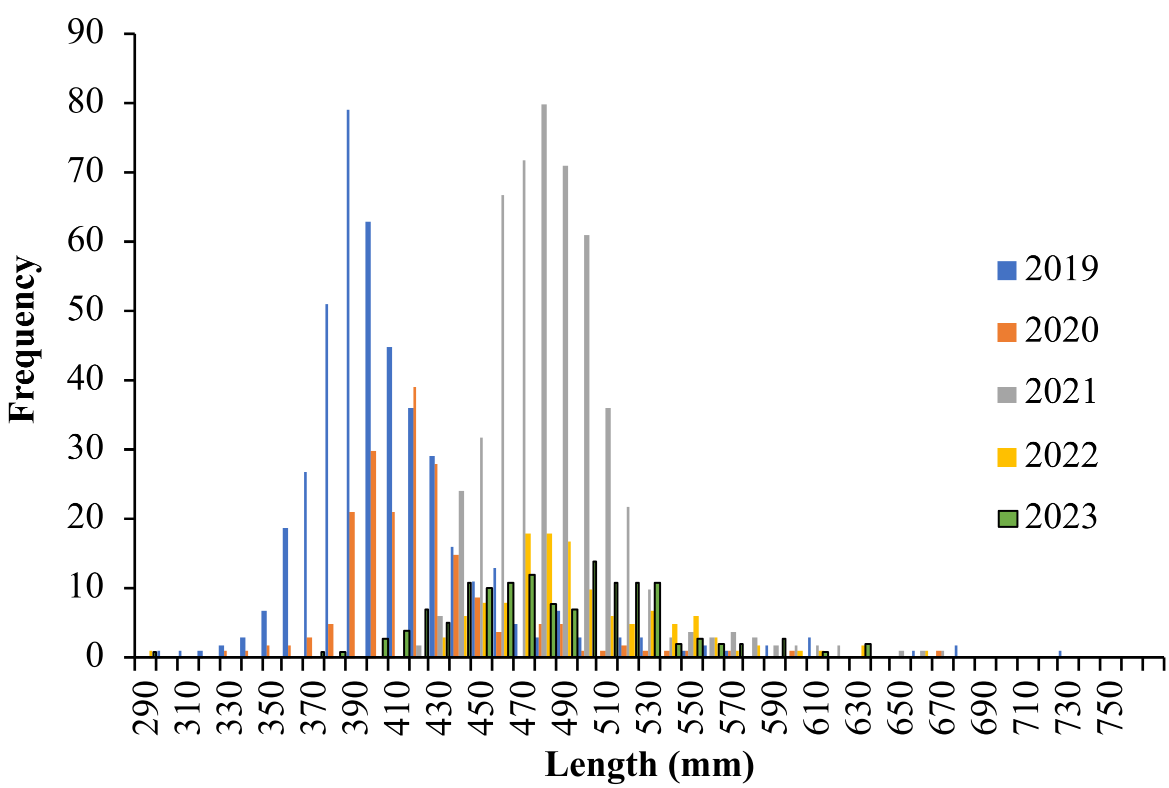
In 2014, a metal fish barrier was installed in Purgatory Creek at the outlet of the LPCRA. This was installed to prevent carp from moving into the recreational area to spawn in the spring. It was also used to trap carp in the LPCRA over winter in hopes of a complete winterkill. In 2022 and 2023, the physical carp barrier was closed all year. Due to the low water levels, the City of Eden Prairie rarely opened, cleaned, and closed the fish barrier during high water levels in the Purgatory Creek Recreational Area. The barrier was opened twice for an extended period (two weeks) in April 11-April 25 and once in late fall. During this time, fish could move freely throughout the system. Staff utilized a backpack electrofishing unit combined with block nets to remove common carp during the spring spawning run.

Backpack electrofishing and block nets were utilized in the channel upstream and downstream of the barrier and at the breach in the berm that separates the Upper and Lower Purgatory Creek Recreational Area (Figure 72). In the past, most of the fish had been captured/removed via backpack electrofishing at the breached berm site. This breach allows water to short circuit the overflow structure. Water is always flowing at this location which leads to carp concentrating in the shallow water near the breach before trying to move upstream. The sheet piling, combined with the consistent flow, has eroded the downstream side of the berm, causing a drop that impedes carp movement. A block net is anchored on the downstream side of the flow at the breach, stretched around the congregating carp, trapping them between the berm and net. During the heavy spawning run, staff repeated the process, sometimes up to three times a day, taking about an hour each time from installation of the net to completion of removal. In 2023 only one successful removal event occurred at the berm. Water levels were either too high or too low for this method to be successful. Additionally, a majority of the carp in this system are now larger in size and able to navigate the berm more easily. Upon visual inspection, it appears that the berm has further eroded and/or subsided, making it easier for fish to move freely at the site.

In 2023, the backpack electrofishing below the barrier combined with a block net across two sampling events yielded a total 144 carp removed or 416 lbs. By sex, 26% were males and 74% were females Utilizing all spring gear types in the past, a total of 315 carp were removed in 2022, 511 in 2021, 201 in 2020, 441 in 2019, and 1,901 carp in 2018. Most of the fish removed were from the 2015-year class, in which approximately 3000 YOY carp had entered Staring Lake from LPCRA and started to grow rapidly (Sorensen et al., 2015). This year class was a result of the last major recruitment event that occurred in the system until 2023 (Figure 71). In 2023, most of the carp were removed on May 23rd and 26th when water was over the top of the staff gauge and the water temperature was 20.2 degrees Celsius (May 26th). This is compared to April 19, 2022, when upstream barrier water levels were 57.4 inches (based on the installed staff gauge) and water temperatures at 7.8 degrees Celsius; April 19th, 2021, at 57.4 inches and 7.8 degrees; May 7, 2019, at 37.5 inches and 17.2 degrees; and June 29th, 2020, at 39 inches and 22 degrees Celsius. District staff have been working with the City of Eden Prairie to stabilize the berm and correct/improve the regular overflow location to allow staff to utilize the berm location for future carp removal events. Staff will utilize all the same techniques and potentially conduct electrofishing after dark in 2024 to improve capture efficiency.

Figure 72. PCRA Spring Removal Site Map

Figure 71. Length Frequency of PCRA Spring Removals (2019-2023).



5.3. Zebra Mussels

Zebra Mussels (*Dreissena polymorpha*) are native to Eastern Europe and Western Russia and introduced in the United States. Zebra Mussels can cover submerged equipment, clog water intakes, cut bare feet, smother native mussels by covering them, and they can fundamentally change the food web of a lake by extensively filtering out the phytoplankton on which many aquatic animal diets depend (MNDNRb 2015). Treatment methods available to date are considered experimental and have not been effective in eradicating Zebra Mussels from a lake once they are introduced.

Figure 73. A range of Zebra Mussel sizes have been found on monitoring plates.

The District continued to monitor for adult and veliger Zebra Mussels in 2023. The District conducted veliger sampling from June to July on 13 lakes to detect the presence of Zebra Mussels. Each lake was sampled once, apart from Lotus Lake and Lake Ann which were sampled twice. Consultant Kylie Cattoor processed the samples and only found Zebra Mussel veligers on Lake Riley in 2023. Carver County veliger testing also yielded veligers on Lotus Lake. Adult Zebra Mussel presence was assessed using monitoring plates (Figure 73) that were hung from all public access docks, as well as some private docks of residents participating in the District's Adopt-a-Dock program. Monitoring plates were checked monthly, and no mussels were found across all lakes except for Lake Riley in 2023.

Public accesses were scanned monthly for approximately five to ten minutes during the regular bi-weekly water quality sampling events. Staff visually searched anchoring sites such as rocks, docks, sticks, and vegetation for adult Zebra Mussels. Expanded visual surveys were conducted on Lotus Lake and Lake Ann, where multiple locations on each lake were intensively searched. During these intensive scans adult Zebra Mussels were only found on Lake Ann and a copper sulfate treatment occurred. Carver County also submitted water samples to process Zebra Mussel eDNA on Lotus and Ann.

Lake Ann

After a single adult Zebra Mussels was found on a swimming buoy 9/21/20, monitoring efforts were increased in attempt to make sure this was only an isolated event. On 7/12/2023, district staff conducted an intensive Zebra Mussel scan on Lake Ann. This scan occurred over a 150m area in the NE part of the lake and over a 300m area in the southern end. In the southern transects four adult Zebra Mussels were found attached to woody debris in shallow water. A rapid response survey with partners including the district, Carver County, and the DNR occurred on 7/14/2023. During this survey, divers and snorkelers intensively searched for mussels from 0-18 feet of water for a total of 14.25 hours. Five more mussels were found at the original discovery location.

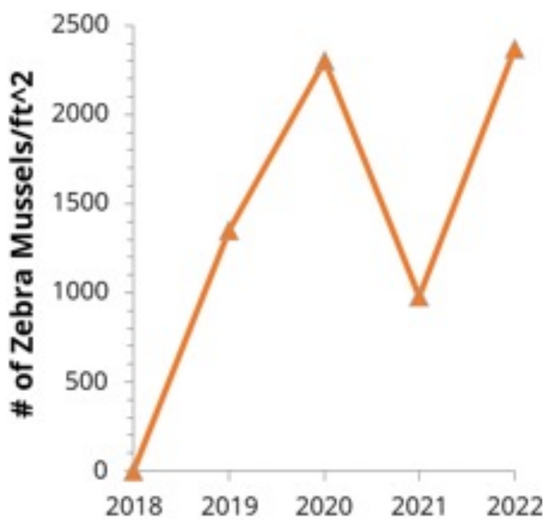
On 8/4/2023 a barricade was set up to concentrate the treatment, and on 8/7/2023 the copper sulfate treatment (EarthTechQZ) was applied to about an acre by PLM Lake and Land Management. Ideally, the treatment will eliminate mussels from the lake although there have been no known eradication events from a lake to date. At minimum the treatment will slow the spread of mussels through the lake.. No Zebra Mussels were found on attached boat launch deployed adult mussel monitoring plate. Lake Ann will be monitored in the same fashion as the other infested lakes in the district, with continued eDNA, veliger, adult mussel monitoring plates and visual surveys for population monitoring. An additional SCUBA/snorkel survey will likely be added in 2024 as well.

Lake Riley

On October 22, 2018, RPBCWD staff confirmed Zebra Mussels on Lake Riley after a lake service provider discovered some Zebra Mussels while pulling docks and lifts. Previously, no Zebra Mussels had been found in the lake during the regular monitoring season, which included all the different monitoring efforts. The Zebra Mussels appeared to be widespread across the lake at low densities. Mussels were found of varying sizes suggesting that reproduction in Lake Riley had occurred.

In 2018 Zebra Mussels were estimated at four mussels per plate and the population appeared to have peaked at 2,623 mussels per plate in 2020. In 2022, the mussels were found on all plates ranging in number from 4,015 mussels to 29,959 mussels/plate (Figure 74). This indicates a robust population that is well established across the lake. The increase in 2022 and 2023 indicates a rebound in the population that should cycle up and down in the future similar to what has been seen on Lake Minnetonka (McComas 2018).

Figure 74. Zebra Mussel density on Lake Riley, 2018-2023.



Lotus Lake

On August 30, 2019, five Zebra Mussel veligers were found in veliger tows collected by Carver County from the public access of Lotus Lake (Figure 75). No Zebra Mussel veligers were found in samples collected on June 20, 2019, or on September 10, 2019, by the RPBCWD. Additional in-lake searching occurred on October 9, 2020, by RPBCWD staff. No adult Zebra Mussels were found during the search. An additional veliger tow was collected on October 10, 2019, and eDNA samples were taken at four locations. On October 24, 2019, staff from DNR, Carver County and the RPBCWD surveyed pulled docks on shore around the lake and found five Zebra Mussels ranging in size from 6-16 millimeters on a single boat lift footing in the east bay (Figure 73). After the October survey, the eDNA results were complete and indicated Zebra Mussel eDNA was present near the boat launch sample and the east bay sample near where the adults were captured. Based on the collected information, Lotus Lake was added to the Infested Waters List for Zebra Mussels in 2019 by the MNDNR.

Similar to 2020 and 2021, veliger tows were collected twice in spring 2022 but yielded no Zebra Mussel veligers. Both boat launch and mussel plate checks (five plates, previously 10 plates) yielded no adult mussels. Staff visually searched multiple areas of the lake for mussels twice in 2022, once in August and once in October after docks were pulled. Many desiccated mussels were found on boat lifts at different locations in the east bay in 2019 and in 2022 during the fall surveys, but none were found in the lake or elsewhere. The eDNA results for 2022 were the first negative result since 2019 when mussels were found in Lotus

Figure 75. Lotus Lake Zebra Mussel summary map.

Lake. Several hundered Zebra Mussels were found dessicated on a lift in 2023 during the fall survey on the north end of the lake. Staff will continue to monitor for Zebra Mussels in 2024.

Lake Suitability for Zebra Mussels

The chemical and physical makeup of a lake determines the suitability of that lake to support Zebra Mussels. Like many organisms, there is a wide range of suitable conditions in which Zebra Mussels can survive. Optimal conditions are conditions in which there are no limiting variables that are controlling an organism's ability to grow and reproduce. Table 32 lists the different variables associated with Zebra Mussels measured by the District in 2023 for Lake Riley, Lotus Lake, and Lake Ann. The criteria in Table 32 used to determine the level of infestation by Zebra Mussels in North America (Mackie and Claudi 2010) with the variables being arranged from greatest to least importance for determining suitability for Zebra Mussels. For consistency, all variables included in the analysis were measured during the summer growing season (June-September) and include only the top two meters for the lakes. The different variables can be grouped into three categories:

- Chalk variables which are needed for shell formation.
- Trophic (nutrient) variables which are associated with growth and reproductive success.
- Physical variables or basic lake variables that limit where Zebra Mussels can live in a lake.

Calcium concentrations were estimated based on average monthly alkalinity samples. Comparing all lakes in the District with the calcium threshold established by Mackie and Claudi 2010, only Round and Hyland have less than optimal calcium concentrations (>30 mg/L) for Zebra Mussels. Alkalinity and pH are associated with calcium concentrations and were both highly suitable for sustaining Zebra Mussels in the three lakes. The nutrient variables for Lake Riley and Lake Ann were at moderate to high levels for Zebra Mussel suitability. Lotus Lake nutrient data indicates minimal growth parameters for Zebra Mussels because of lower Secchi disk depths and higher Chlorophyll-a concentrations. This indicates the Zebra Mussel population may not be as significant if they invade Lotus Lake. Steve McComas of Blue Water Science found Chlorophyll-a concentrations directly impacted Zebra Mussel populations in Lake Minnetonka bays. Areas of the lake with optimal chlorophyll conditions experienced significant reductions in chlorophyll concentrations after infestation. This was followed by a Zebra Mussel dieback, occurring three to four years after the first mussels were found (McComas 2018). Physical variables all scored moderate to high for Zebra Mussel suitability in Riley and Lotus. These variables all change with depth, however optimal conditions for each were present in both lakes. Hard structure suitability was estimated as moderately suitable in both lakes but had low suitability in Lake Ann due to the lack of hard structure. In 2016, it was found that 98 percent of the Zebra Mussel population in Lake Minnetonka were mostly juveniles and were found on submerged aquatic plants (McComas 2018). That said, it was hypothesized that many of those individuals died off and the main source of Zebra Mussel year to year recruitment may be from small but dense groups of adults spread on isolated hard structure in slightly deeper portions of the lake. Hard structure in Riley and Lotus lakes included predominantly rock and woody debris and is hypothesized to not be limiting for Zebra Mussels.

Based on the results in Table 32 the suitability of Lake Riley to support a robust and expansive Zebra Mussel population is high. These results were confirmed by mussel counts on plates placed by Adopt-a-Dock volunteers. Once large Zebra Mussel populations become established, it is hypothesized that Chl-a and TP will decrease, and water clarity will increase due to Zebra Mussel filtering rates. Table 32 indicates that in Lotus Lake a slow growing or restricted population limited by minimal growth nutrient levels. Lake Ann would likely have moderate growth.

Table 32. Suitability of lake conditions to support a robust and expansive Zebra Mussel population.

	Variable	Suitability Ranges			Lake Suitability by Variable		
		Low	Moderate	Maximum	ANN	LOTUS	RILEY
Shell formation	Calcium (mg/L)	8-15	15-30	30-80	41	56	44
	Alkalinity (mg/L)	30-55	55-100	100-280	145.5	173	140.5
	pH	7-7.8; 9-9.5	7.8-8.2; 8.8-9	8.2-8.8	8.53	8.65	8.51
Trophic variables	TP (µg/L)	5-10; 35-50	10-25	25-35	22	33	15
	Chl-a (µg/L)	2-2.5; 20-25	8-20	2.5-8	11.0	25.4	4.5
	Secchi (m)	1-2; 6-8	4-6	2-4	2.8	1.5	4
Physical variables	Temp (° C)	26-32	10-20	20-26	24.8	24.2	23.8
	DO (mg/L)	3-7	7-8	>8	8.98	8.82	8.79
	Cond (uS/cm)	0-60	60-110	>110	317	483	589
	Hard Structure	Low	Moderate	Max	Low	Moderate	Moderate

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7: APPENDIX

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Exhibit A. Historical and 2023 Lake Level Graphs (NAVD 1929)

Figure A-1: Water surface elevation on Lake Ann from 2013 to 2023 & Ordinary High-Water Level (955.5 ft).

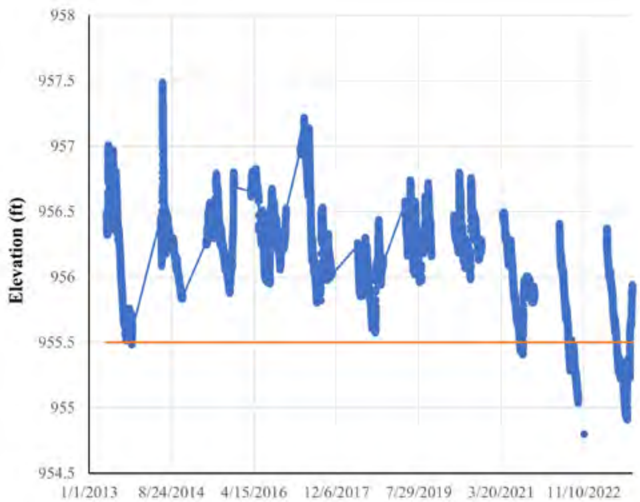


Figure A-2: Water surface elevation, precipitation & Ordinary High-Water Level on Lake Ann 2023 (955.5 ft).

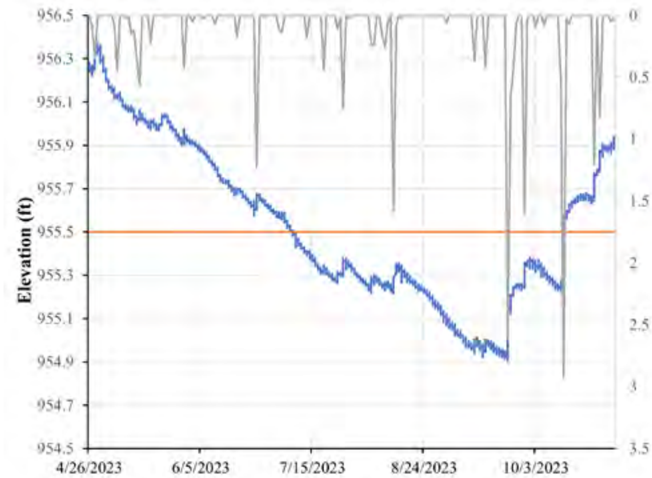


Figure A-3: Water surface elevation on Duck Lake from 2013 to 2023 & Ordinary High-Water Level (915.3 ft).

Figure A-4: Water surface elevation, precipitation & Ordinary High-Water Level on Duck Lake 2023 (915.3 ft).

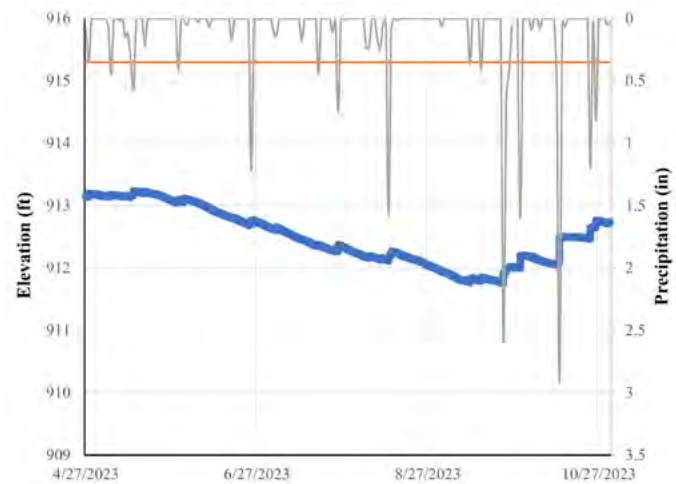


Figure A-5: Water surface elevation on Hyland Lake from 1970 to 2023 & Ordinary High-Water Level (817.9 ft).

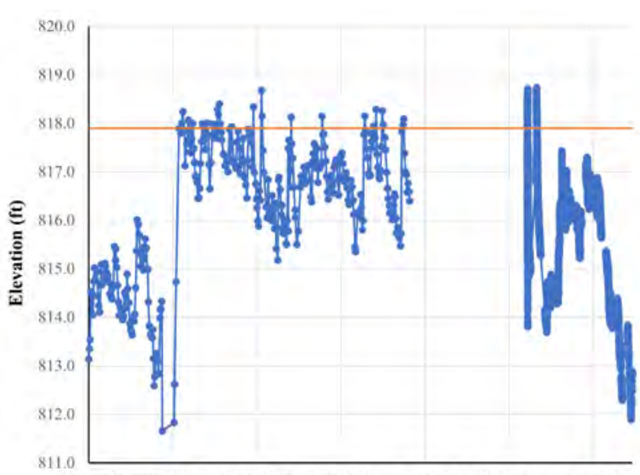


Figure A-6: Water surface elevation, precipitation & Ordinary High-Water Level on Hyland Lake 2023 (817.9 ft).

Figure A-7: Water surface elevation on Lake Idlewild from 2015 to 2023 & Ordinary High-Water Level (856 ft).

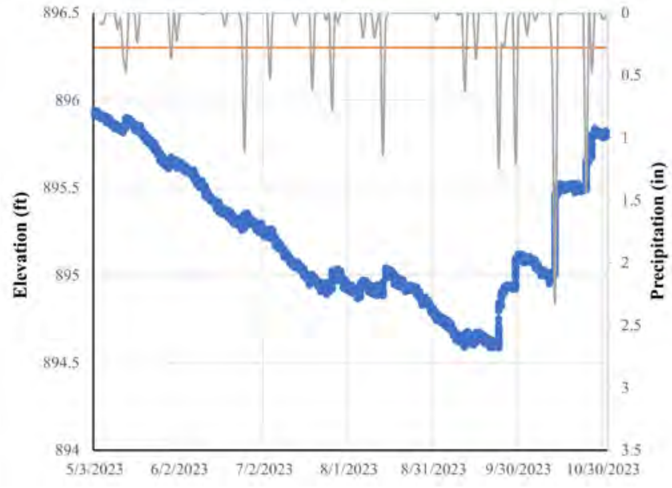


Figure A-8: Water surface elevation, precipitation & Ordinary High-Water Level on Lake Idlewild 2023 (856 ft).

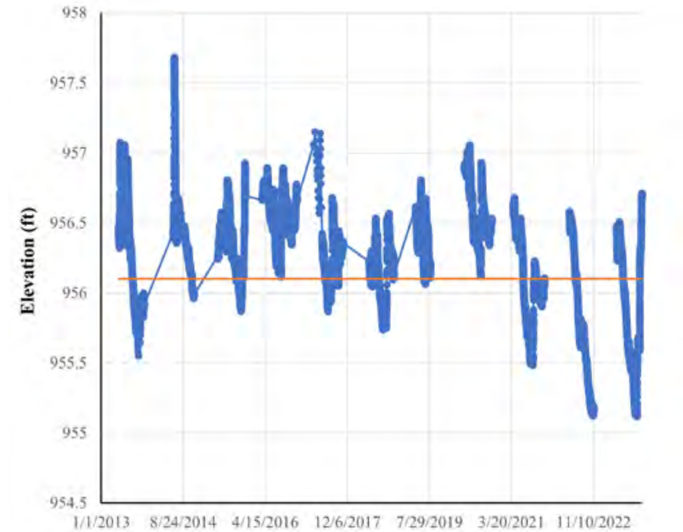


Figure A-9: Water surface elevation on Lotus Lake from 2013 to 2023 & Ordinary High-Water Level (896.3 ft).

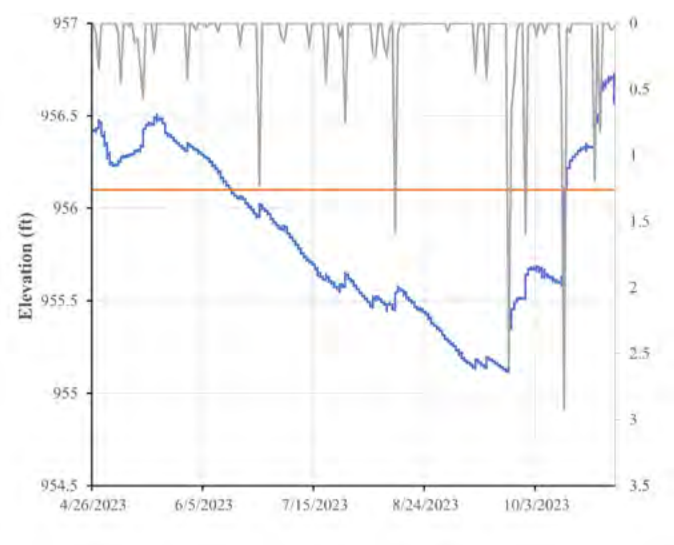


Figure A-10: Water surface elevation, precipitation & Ordinary High-Water Level on Lotus Lake 2023 (896.3 ft).

Figure A-11: Water surface elevation on Lake Lucy from 2013 to 2023 & Ordinary High-Water Level (956.1 ft).

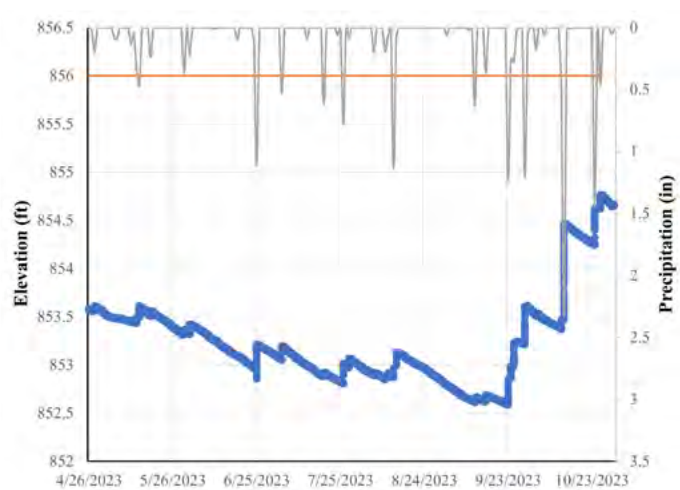


Figure A-12: Water surface elevation, precipitation & Ordinary High-Water Level on Lake Lucy 2023 (956.1 ft).

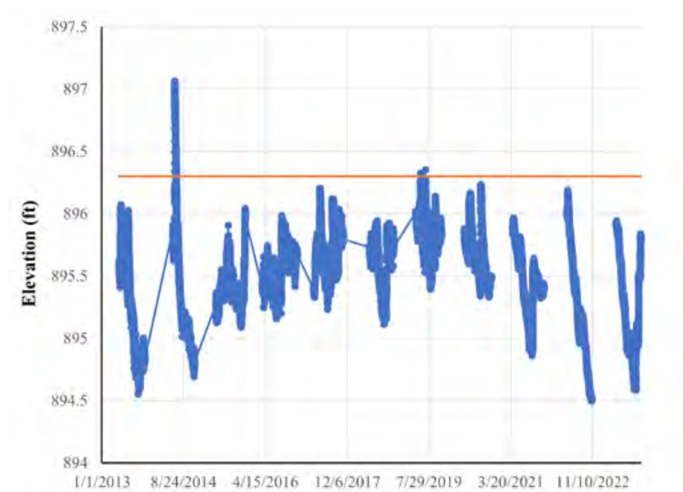


Figure A-13: Water surface elevation on Mitchell Lake from 2013 to 2023 & Ordinary High-Water Level (815.3 ft).

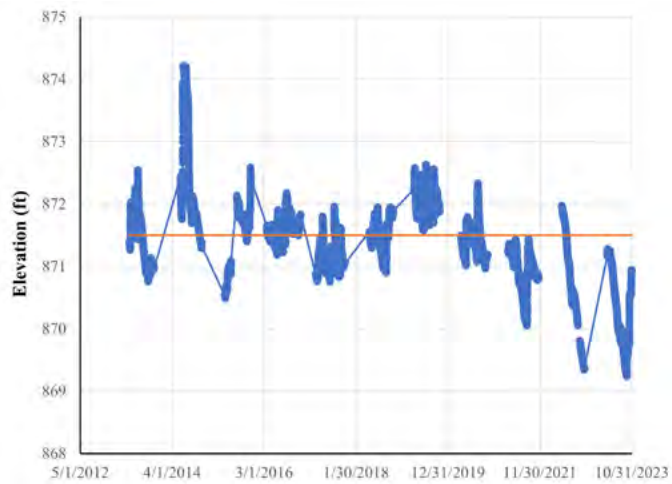


Figure A-14: Water surface elevation, precipitation & Ordinary High-Water Level Mitchell Lake 2023 (815.3 ft).

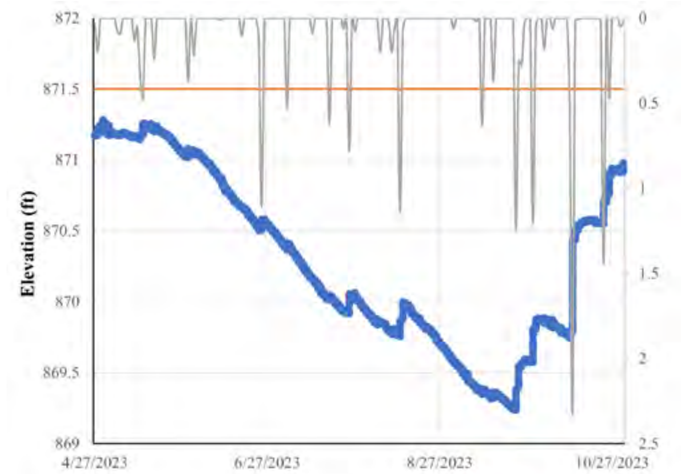


Figure A-15: Water surface elevation on Red Rock Lake from 2013 to 2023 & Ordinary High-Water Level (840.5 ft).

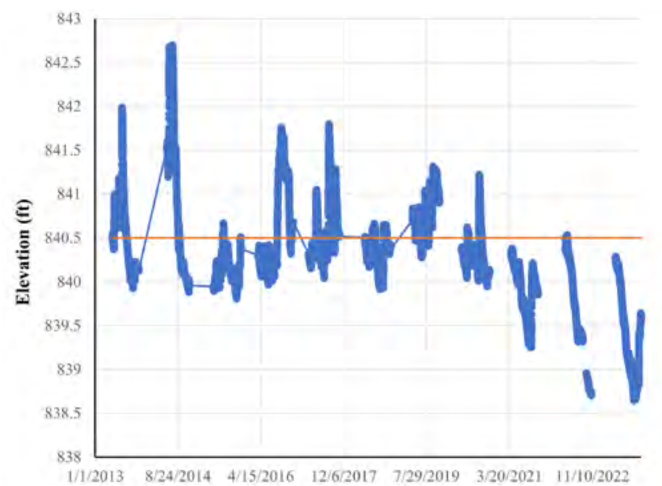


Figure A-16: Water surface elevation, precipitation & Ordinary High-Water Level Red Rock Lake 2023 (840.5 ft).

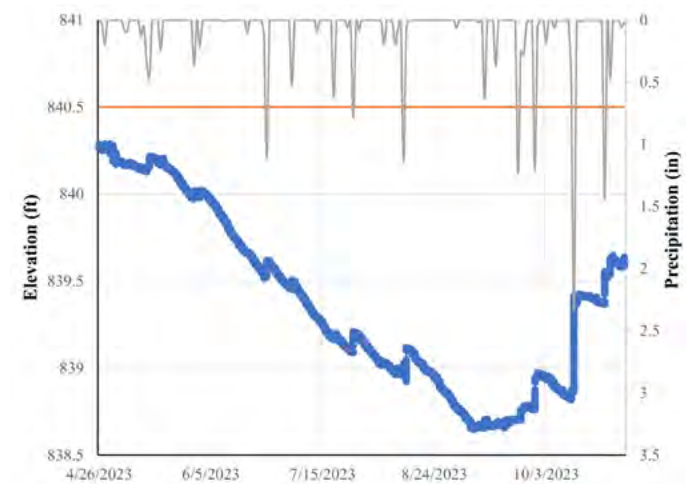


Figure A-17: Water surface elevation on Rice Marsh Lake from 2013 to 2023 & Ordinary High-Water Level (877 ft).

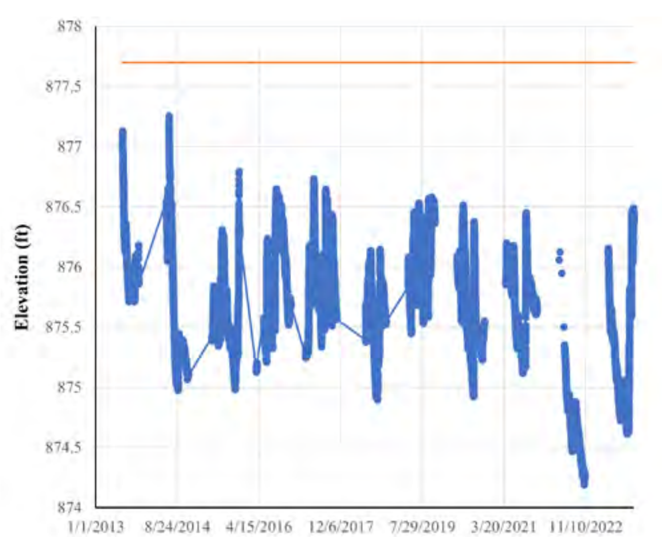


Figure A-18: Water surface elevation, precipitation & Ordinary High-Water Level Rice Marsh Lake 2023 (877 ft).

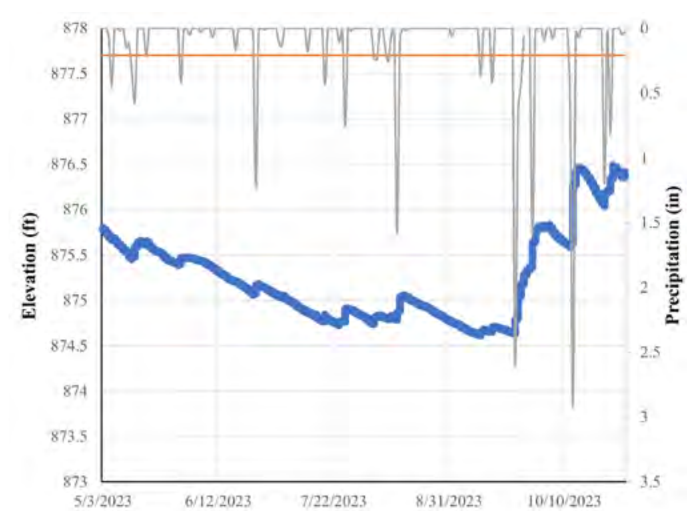


Figure A-19: Water surface elevation on Lake Riley from 2013 to 2023 & Ordinary High-Water Level (865.3 ft).

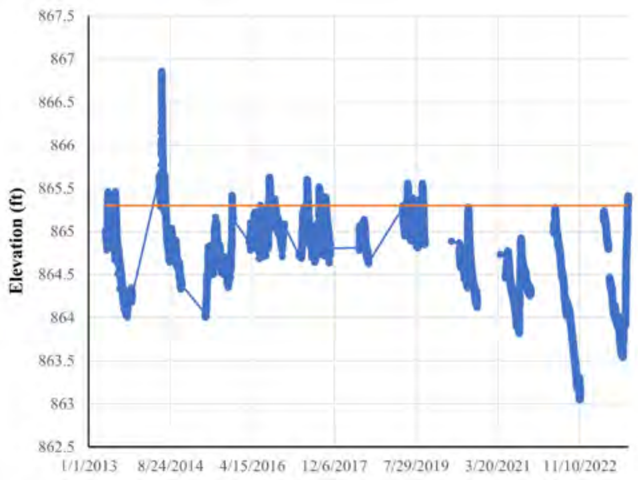


Figure A-20: Water surface elevation, precipitation & Ordinary High-Water Level Lake Riley 2023 (865.3 ft).

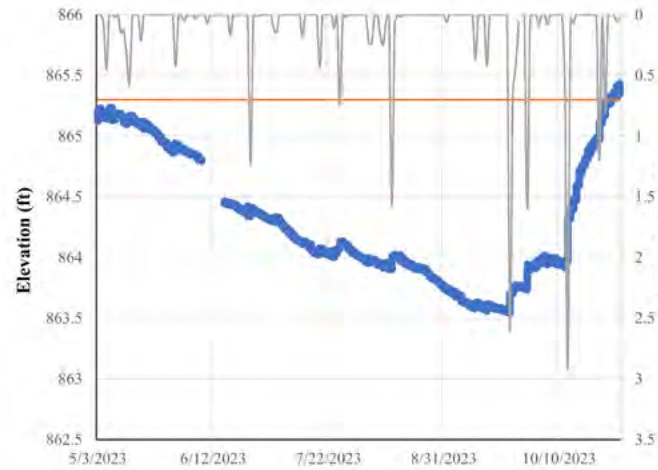


Figure A-21: Water surface elevation on Round Lake from 2013 to 2023 & Ordinary High-Water Level (880.8 ft).

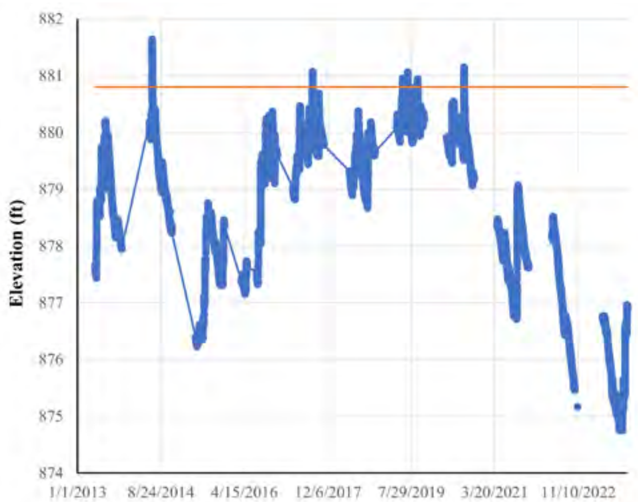


Figure A-22: Water surface elevation, precipitation & Ordinary High-Water Level Round Lake 2023 (880.8 ft).

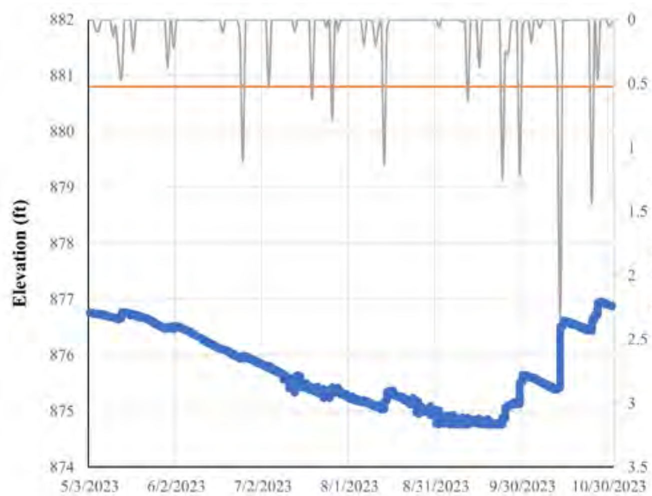


Figure A-23: Water surface elevation on Silver Lake from 2013 to 2023 & Ordinary High-Water Level (898.1 ft).

Figure A-24: Water surface elevation, precipitation & Ordinary High-Water Level Silver Lake 2023 (898.1 ft).

Figure A-25: Water surface elevation on Staring Lake from 2013 to 2023 & Ordinary High-Water Level (815.3 ft).

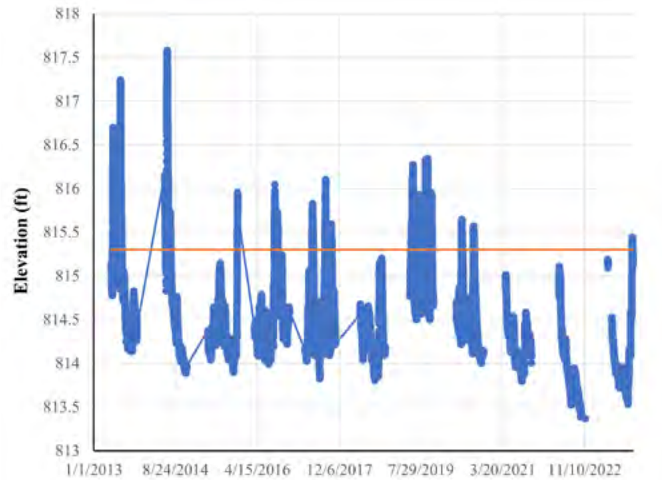


Figure A-26: Water surface elevation, precipitation & Ordinary High-Water Level Staring Lake 2023 (815.3 ft).

Figure A-27: Water surface elevation on Lake Susan from 2013 to 2023 & Ordinary High-Water Level (881.8 ft).

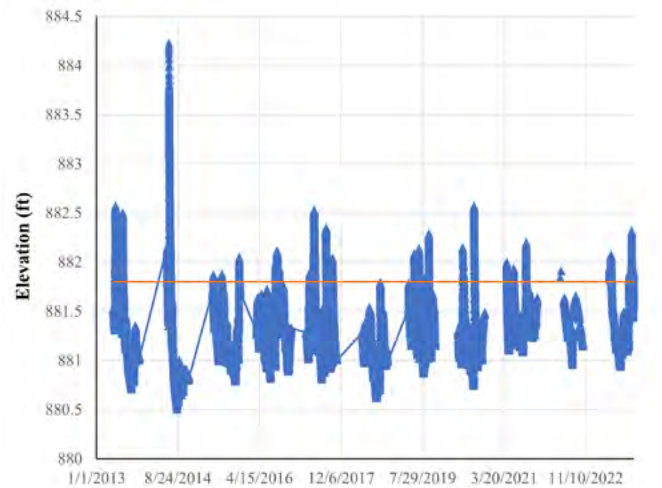


Figure A-28: Water surface elevation, precipitation & Ordinary High-Water Level Lake Susan 2023 (881.8 ft).

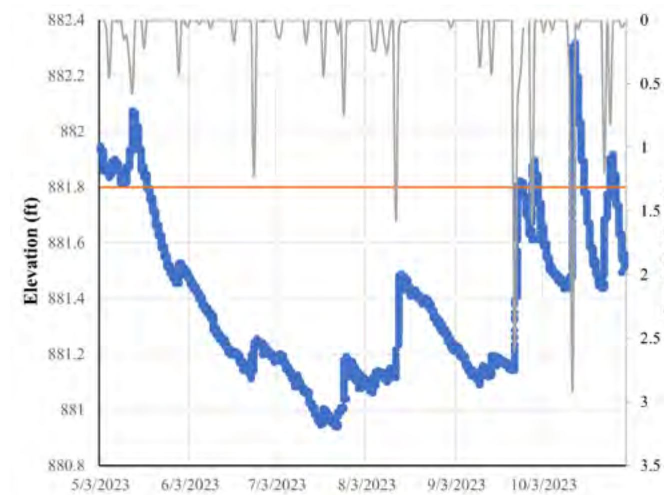


Figure A-29: Water surface elevations on Lake Eden from 2021 to 2023.

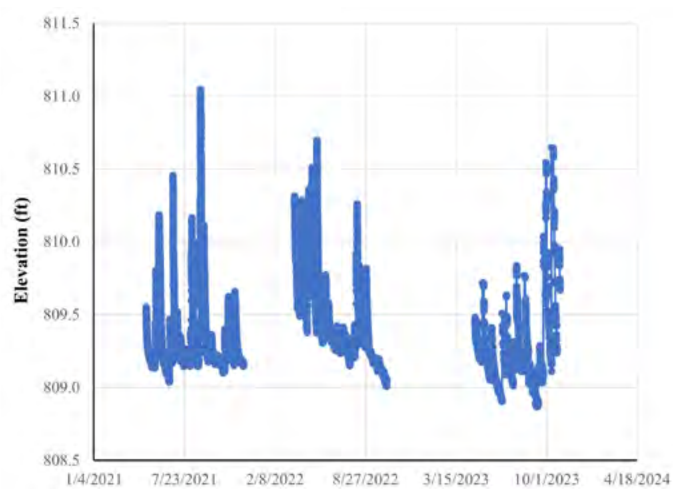


Figure A-30: Water surface elevation & precipitation Lake Eden 2023.

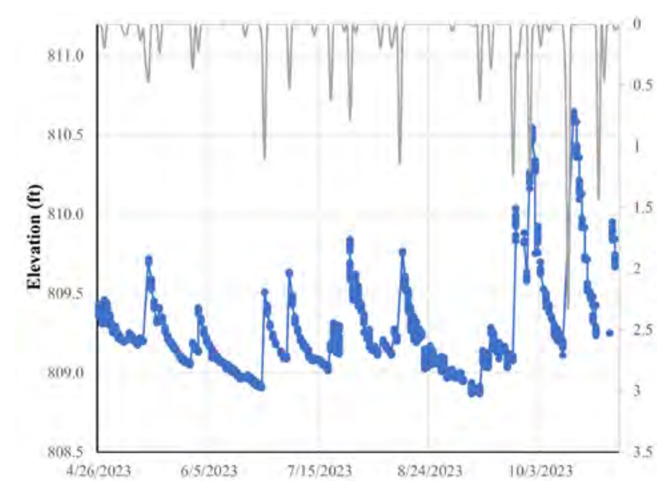


Figure A-31: Water surface elevation on Lake McCoy from 2020 to 2023 & Ordinary High-Water Level (824.5 ft).

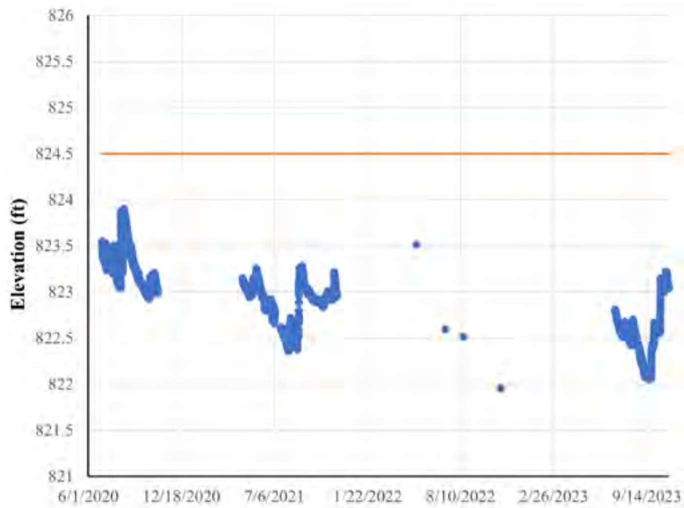


Figure A-32: Water surface elevation, precipitation & Ordinary High-Water Level Lake McCoy 2023 (824.5 ft).

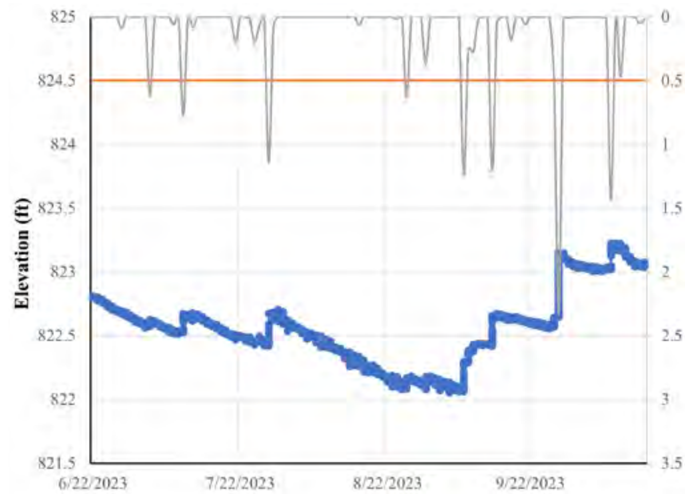


Exhibit B. 2023 Trap Net Summary Data

Table B-1: 2023 **Lower Purgatory Recreation Area** trap net data.

Species	Number of fish caught in each category (inches)												
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	2023 Fish/Net
Black bullhead	842	44	3									889	222.25
Black crappie	791	6	3	2								800	200
Bluegill sunfish	19											19	4.75
Bigmouth buffalo	12	1										13	3.25
Common carp	89	3	1			23	6		1			123	30.75
Green sunfish	24											24	6
Golden shiner	7											7	1.75
Hybrid sunfish	22	1										23	5.75
Largemouth bass	6	2				1						9	2.25
Pumpkinseed sunfish	33											33	8.25
Yellow bullhead	14	5	11	2								32	8
Yellow perch	1											1	0.25
Total												**1973**	**493.25**

Table B-2: 2023 **Lake Lucy** trap net data.

Species	Number of fish caught in each category (inches)												
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	2023 Fish/Net
Black crappie	13	1	14	3								31	6.2
Bluegill sunfish	64	18	1									83	16.6
Common carp							6	3				9	1.8
Green sunfish	5											5	1
Hybrid sunfish	15	16										31	6.2
Largemouth bass	2											2	0.4
Northern pike			1	1								2	0.4
Pumpkinseed	85	4										89	17.8
Yellow bullhead	14	10	13	7								44	8.8
Yellow perch	1	1										2	0.4
Total												**298**	**59.6**

Table B-3: 2023 **Rice Marsh Lake** trap net data.

Species	Number of fish caught in each category (inches)												
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	2023 Fish/Net
Black crappie	16	1	1									18	3.6
Bluegill sunfish	21	68	1									90	18
Brown bullhead					1							1	0.2
Largemouth bass	1											1	0.2
Northern pike						1						1	0.2
Pumpkinseed sunfish	4	1										5	1
Yellow bullhead			1	3								4	0.8
Total												**120**	**24**

Table B-4: 2023 **Staring Lake** trap net data.

Species	Number of fish caught in each category (inches)											
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	2023 Fish/Net
Black bullhead	2582	7	5	9								2603	520.6
Black crappie	21	17	13	1								52	10.4
Bluegill sunfish	41	14	11				2					68	13.6
Bigmouth buffalo		4										4	0.8
Common carp	7	8					5					20	4
Green sunfish		4										4	0.8
Hybrid sunfish	2	3										5	1
Largemouth bass	8	3										11	2.2
Northern pike					4							4	0.8
Pumpkinseed sunfish	2											2	0.4
Walleye						1						1	0.2
Yellow bullhead		1										1	0.2
Yellow perch	4	3										7	1.4
Total												**2782**	**556.4**

Table B5: 2023 **Upper Purgatory Creek Recreation Area** trap net data.

Species	Number of fish caught in each category (inches)												
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	2023 Fish/Net
Black crappie	439	1					5	6	43			494	123.5
Bluegill sunfish	130						4					134	33.5
Common carp				4								4	1
Green Sunfish	1											1	0.25
Golden shiner	1											1	0.25
Northern pike			1		4	5						10	2.5
Yellow perch	6						1					7	1.75
Total												**651**	**162.75**

Exhibit C. 2023 Phytoplankton Summary Data

Table C-1: 2023 **Lotus Lake** Phytoplankton #/mL

	5/25/2023	7/6/2023	7/31/2023	9/11/2023
Class	#/mL	#/mL	#/mL	#/mL
Chlorophyta	1,206	6,548	1,838	796
Chrysophyta	0	0	0	0
Cyanophyta	57	4,021	18,494	51,371
Bacillariophyta	0	172	0	100
Cryptophyta	172	919	115	896
Euglenophyta	0	0	0	0
Pyrrophyta	0	0	0	0
Total	1,435	11,660	20,447	53,063

Table C-2: 2023 **Rice Marsh Lake** Phytoplankton #/mL

	5/23/2023	7/5/2023	7/31/2023	9/14/2023
Class	#/mL	#/mL	#/mL	#/mL
Chlorophyta	3,274	2,010	2,642	1,378
Chrysophyta	230	0	0	0
Cyanophyta	57	517	1,838	287
Bacillariophyta	57	115	804	0
Cryptophyta	4,250	1,436	2,068	1,321
Euglenophyta	0	0	0	0
Pyrrophyta	0	57	0	0
Total	7,869	4,135	7,352	2,987

Table C-3: 2023 **Lake Riley** Phytoplankton #/mL

	5/25/2023	7/6/2023	8/1/2023	9/12/2023
Class	#/mL	#/mL	#/mL	#/mL
Chlorophyta	2,183	5,342	4,652	2,470
Chrysophyta	459	0	0	0
Cyanophyta	57	5,973	2,699	2,355
Bacillariophyta	115	57	0	402
Cryptophyta	976	804	976	517
Euglenophyta	0	0	0	0
Pyrrhophyta	0	0	115	115
Total	3,791	12,176	8,443	5,858

Table C-4: 2023 **Staring Lake** Phytoplankton #/mL

	5/25/2023	7/5/2023	8/2/2023	9/13/2023
Class	#/mL	#/mL	#/mL	#/mL
Chlorophyta	2,355	14,761	16,082	21,826
Chrysophyta	115	230	0	0
Cyanophyta	57	8,788	305,558	111,425
Bacillariophyta	230	8,328	4,595	6,892
Cryptophyta	632	689	2,297	6,892
Euglenophyta	0	115	0	0
Pyrrhophyta	0	345	0	1,149
Total	3,389	33,255	328,533	148,184

Table C-5: 2023 **Lake Susan** Phytoplankton #/mL

	5/24/2023	7/10/2023	8/2/2023	9/13/2023
Class	#/mL	#/mL	#/mL	#/mL
Chlorophyta	1,436	24,783	28,718	17,231
Chrysophyta	0	0	0	0
Cyanophyta	3,475	40,161	215,959	160,820
Bacillariophyta	1,838	254	0	1,149
Cryptophyta	1,465	1,779	1,149	3,446
Euglenophyta	0	0	0	0
Pyrrhophyta	0	127	1,149	0
Total	8,213	67,105	246,974	182,646

Exhibit D. 2023 Zooplankton Summary Data

Table D-1: 2023 Lotus Lake Zooplankton (number/m²)

DIVISION	TAXON	5/25/2023 #/m²	6/21/2023 #/m²	7/31/2023 #/m²	9/11/2023 #/m²
CLADOCERA	*Bosmina longirostris*	0	0	18,986	6,253
	Ceriodaphnia sp.	0	3,428	0	0
	Chydorus sphaericus	0	0	0	0
	Daphnia galeata mendotae	134,670	13,712	4,746	0
	Daphnia retrocurva	21,547	10,284	18,986	28,139
	Diaphanosoma leuchtenbergianum	0	0	23,732	15,633
	CLADOCERA TOTAL	**156,217**	**27,424**	**66,450**	**50,026**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	1,352,084	6,856	85,435	28,139
	Nauplii	624,868	41,135	109,167	37,519
	Diaptomus sp.	113,123	23,996	33,225	18,760
	COPEPODA TOTAL	**2,090,075**	**71,987**	**227,827**	**84,418**
ROTIFERA	*Asplanchna sp.*	5,387	0	0	0
	Brachionus sp.	0	0	0	0
	Filinia longiseta	37,708	0	0	0
	Keratella sp.	2,704,169	17,140	113,914	221,989
	Keratella quadrata	0	3,428	0	0
	Keratella bostoniensis	134,670	6,856	61,703	9,380
	Kellicottia sp.	0	0	0	0
	Polyarthra sp.	21,547	6,856	18,986	21,886
	Conochilus sp.	0	0	4,746	215,735
	ROTIFERA TOTAL	**2,903,480**	**34,280**	**199,349**	**468,990**
	TOTALS	**5,149,772**	**133,690**	**493,626**	**603,434**

Table D-2: 2023 Rice Marsh Lake Zooplankton (number/m²)

DIVISION	TAXON	5/23/2023 #/m²	6/20/2023 #/m²	7/31/2023 #/m²	9/14/2023 #/m²
CLADOCERA	*Bosmina longirostris*	5,274	22,602	0	22,602
	Ceriodaphnia sp.	0	0	11,301	139,378
	Chydorus sphaericus	52,738	0	90,408	22,602
	Acroperus sp.	0	0	0	0
	Daphnia galatea mendotae	47,464	0	0	0
	Diaphanosoma leuchtenbergianum	0	0	0	0
	CLADOCERA TOTAL	**105,476**	**22,602**	**101,709**	**184,582**
COPEPODA	*Cyclops sp. / Mesocyclops sp*	5,274	0	118,660	67,806
	Diaptomus sp.	0	0	0	290,058
	Nauplii	553,747	45,204	435,087	143,145
	Copepodid	0	0	0	0
	COPEPODA TOTAL	**559,021**	**45,204**	**553,747**	**501,009**
ROTIFERA	*Asplanchna priodonta*	0	0	0	7,534
	Brachionus sp.	0	0	5,650	0
	Conochilus sp.	0	0	0	7,534
	Filinia longiseta	0	0	25,314	0
	Monostyla sp.	0	0	2,110	0
	Keratella cochlearis	0	0	0	0
	Keratella sp.	455,956	13,561	16,876	66,713
	Kellicottia sp.	0	0	0	0
	Platyias sp.	0	0	0	0
	Polyarthra vulgaris	10,058	0	145,556	229,146
	Trichocerca multicrinis	0	0	0	0
	UID Rot	0	0	0	0
	ROTIFERA TOTAL	**466,014**	**13,561**	**195,507**	**303,393**
	TOTALS	**1,130,510**	**81,367**	**850,962**	**988,985**

Table D-3: 2023 Lake Riley Zooplankton (number/m^2)

DIVISION	TAXON	5/25/2023 #/m²	6/21/2023 #/m²	8/1/2023 #/m²	9/12/2023 #/m²
CLADOCERA	*Bosmina longirostris*	0	6,329	19,438	2,486
	Ceriodaphnia sp.	0	0	0	0
	Chydorus sphaericus	0	0	0	0
	Daphnia ambigua/parvula	0	0	0	0
	Daphnia galeata mendotae	155,388	56,957	4,859	17,403
	Daphnia pulex	0	28,478	14,578	0
	Daphnia retrocurva	0	0	0	2,486
	Diaphanosoma leuchtenbergianum	0	0	4,859	0
	Immature Cladocera	0	0	0	0
	CLADOCERA TOTAL	**155,388**	**91,764**	**43,735**	**22,376**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	122,427	41,135	58,313	22,376
	Diaptomus sp.	32,961	25,314	29,156	19,890
	Nauplii	1,059,465	82,271	374,175	34,807
	Calanoida	0	0	0	0
ROTIFERA	**COPEPODA TOTAL**	**1,214,853**	**148,721**	**461,644**	**77,073**
	Asplanchna sp.	9,417	6,329	0	4,972
	Keratella sp.	197,767	259,470	92,329	0
	Keratella quadrata	9,417	0	0	0
	Kellicottia sp.	230,728	79,107	4,859	87,017
	Polyarthra sp.	287,233	101,257	21,8674	39,779
	Conochilus sp.	0	0	228,392	0
	ROTIFERA TOTAL	**734,562**	**446,162**	**544,254**	**131,769**
	TOTALS	**2,104,804**	**686,646**	**1,049,633**	**231,218**

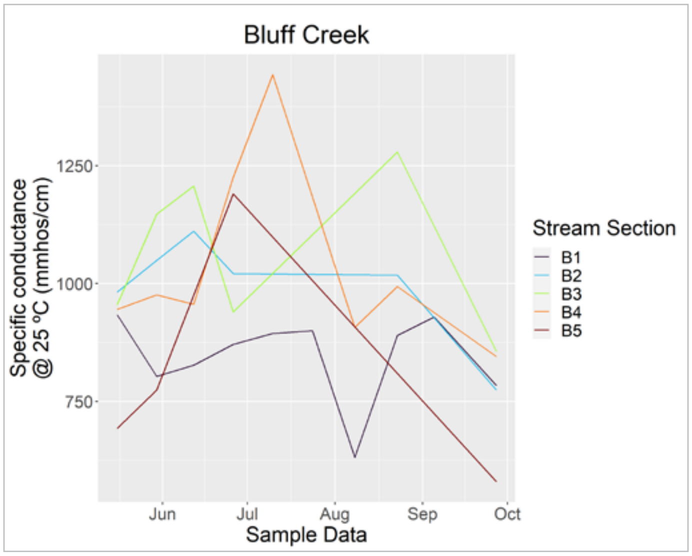
Table D-4: 2023 Staring Lake Zooplankton (number/m^2)

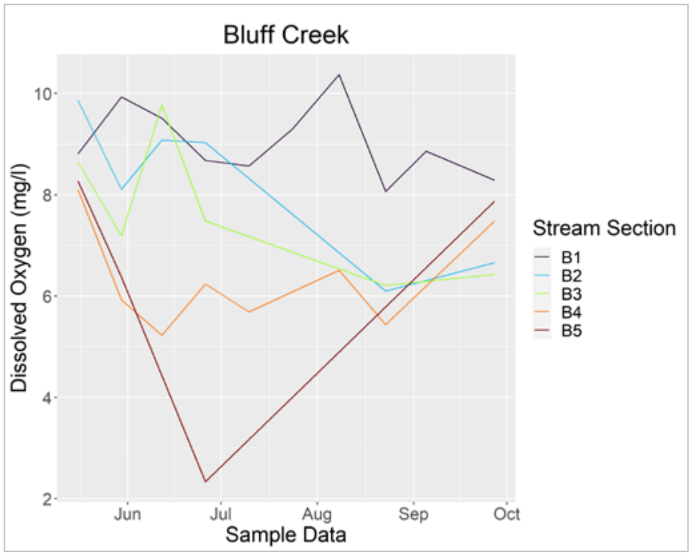
DIVISION	TAXON	5/25/202 #/m²	6/20/2023 #/m²	8/2/2023 #/m²	9/13/2023 #/m²
CLADOCERA	*Bosmina longirostris*	18,082	0	338,577	72,326
	Ceriodaphnia sp.	0	0	3,164	0
	Chydorus sphaericus	0	0	0	0
	Daphnia parvula	28,930	0	0	0
	Daphnia galeata mendotae	50,628	88,901	0	0
	Daphnia retrocurva	43,396	0	0	0
	Diaphanosoma leuchtenbergianum	0	0	9,493	0
	CLADOCERA TOTAL	**141,036**	**88,901**	**351,234**	**72,326**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	108,489	88,901	148,721	62,683
	Nauplii	289,305	160,022	420,848	419,492
	Diaptomus sp.	3,616	8,890	3,164	7,233
	COPEPODA TOTAL	**401,410**	**257,813**	**572,733**	**489,407**
ROTIFERA	Asplanchna sp.	25,314	93,346	6,329	0
	Brachionus angularis	0	17,780	15,821	4,822
	Brachionus havanaensis	0	0	0	57,861
	Filinia longiseta	0	0	0	0
	Lecane sp.	0	0	37,971	0
	Monostyla sp.	0	0	3,164	0
	Keratella cochlearis	144,652	195,582	348,070	547,268
	Keratella quadrata	0	0	0	0
	Kellicottia sp.	0	0	0	0
	Polyarthra sp.	7,233	22,225	655,004	636,470
	ROTIFERA TOTAL	**177,199**	**328,933**	**1,066,358**	**1,246,420**
	TOTALS	**719,645**	**675,647**	**1,990,325**	**1,808,153**

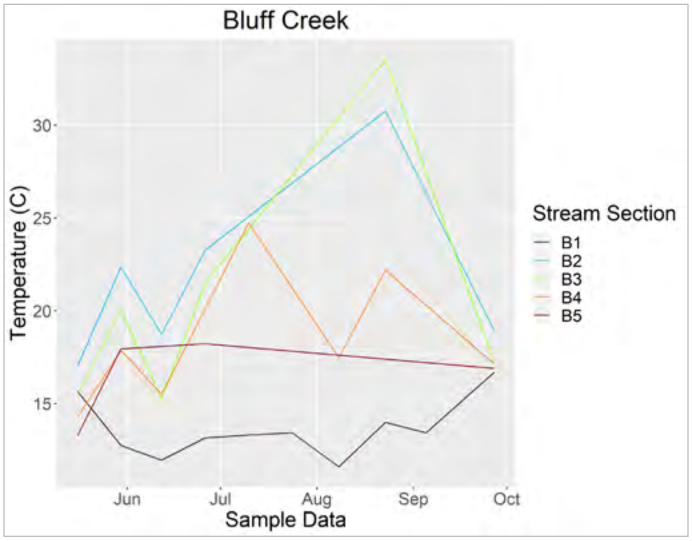
Table D-5: 2023 Lake Susan Zooplankton (number/m^2)

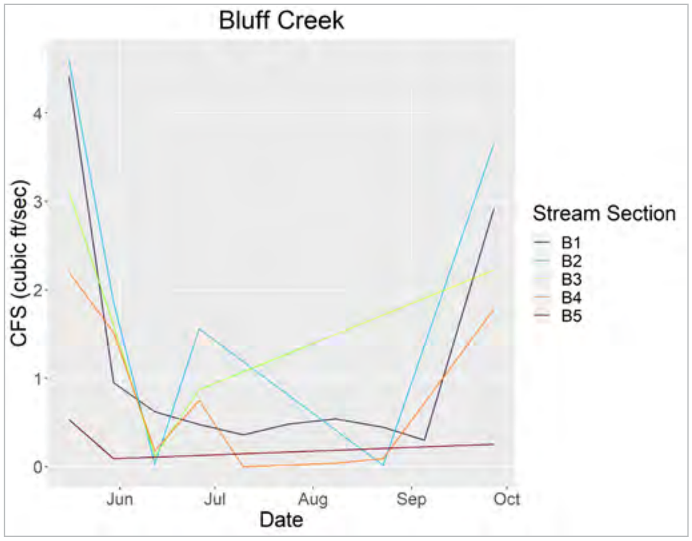
DIVISION	TAXON	5/24/22 #/m^2	6/22/22 #/m^2	8/2/22 #/m^2	9/13/22 #/m^2
CLADOCERA	*Bosmina longirostris*	0	0	0	0
	Ceriodaphnia sp.	0	0	0	0
	Chydorus sphaericus	0	0	0	0
	Daphnia galeata mendotae	42,379	3,955	0	0
	Daphnia pulex	23,544	0	0	0
	Diaphanosoma leuchtenbergianum	0	0	5,876	28,328
	Leptodora kindtii	0	0	0	3,541
	CLADOCERA TOTAL	**65,922**	**3,955**	**5,876**	**28,328**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	47,087	3,955	52,888	24,787
	Nauplii	75,340	3,955	393,725	262,032
	Diaptomus Sp.	23,544	0	14,691	28,328
	COPEPODA TOTAL	**145,971**	**7,911**	**461,305**	**315,146**
ROTIFERA	*Asplanchna priodonta*	0	0	0	0
	Brachionus havanaensis	0	0	23,506	0
	Filinia longiseta	0	0	20,568	0
	Lecane sp.	0	0	0	0
	Monostyla sp.	0	0	0	0
	Keratella sp.	301,359	7,911	449,552	159,344
	Keratella quadrata	18,835	0	0	0
	Keratella bostoniensis	0	0	2,938	0
	Kellicottia sp.	0	0	0	0
	Trichocerca multicrinis	0	0	0	0
	ROTIFERA TOTAL	**320,194**	**7,911**	**496,564**	**159,344**
	TOTALS	**532,087**	**19,777**	**963,746**	**502,817**

Exhibit E. 2023 Creek Seasonal Sonde & Flow Data : **BLUFF CREEK**









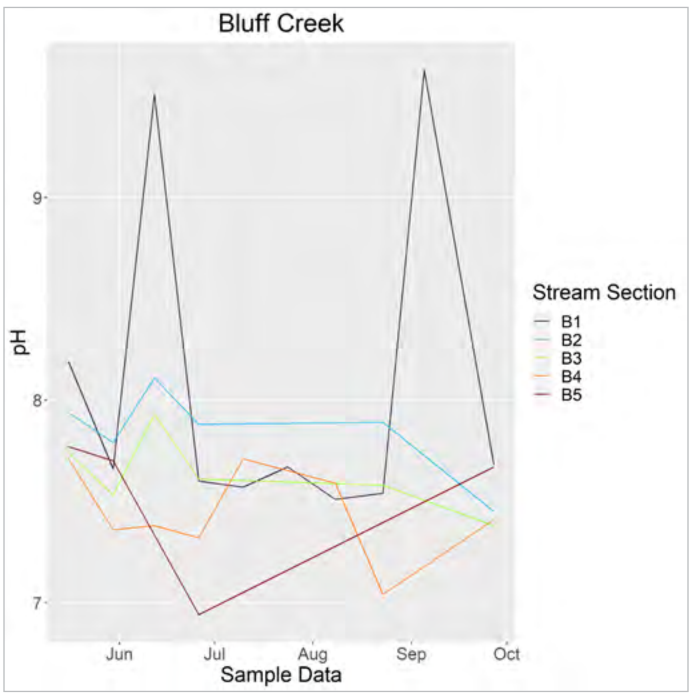
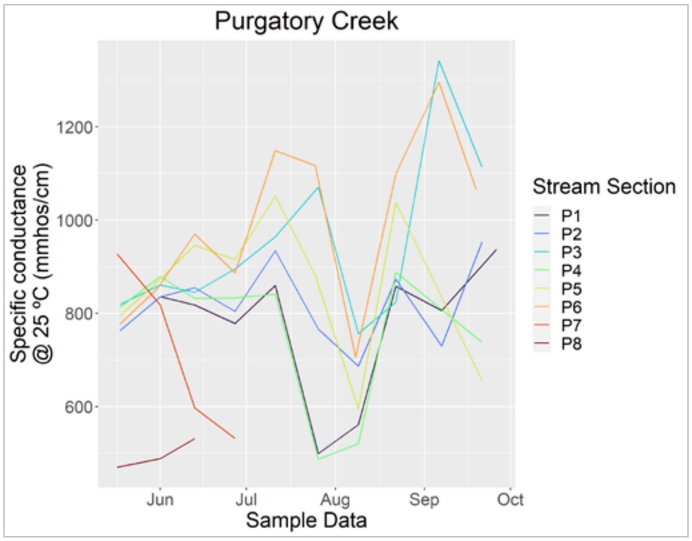
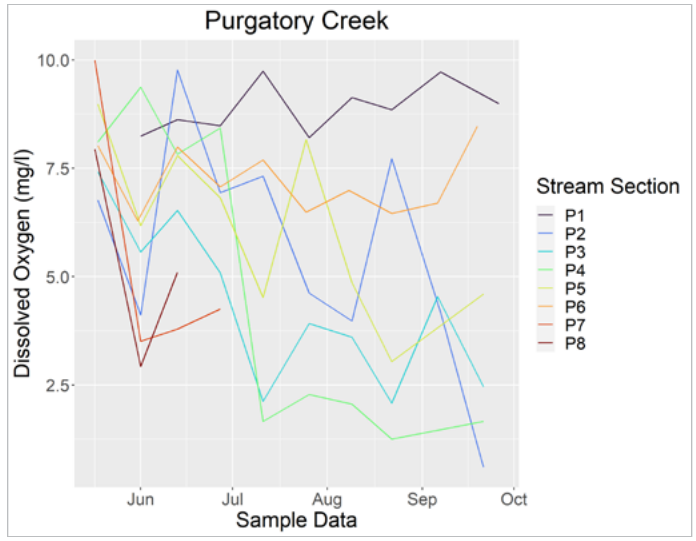
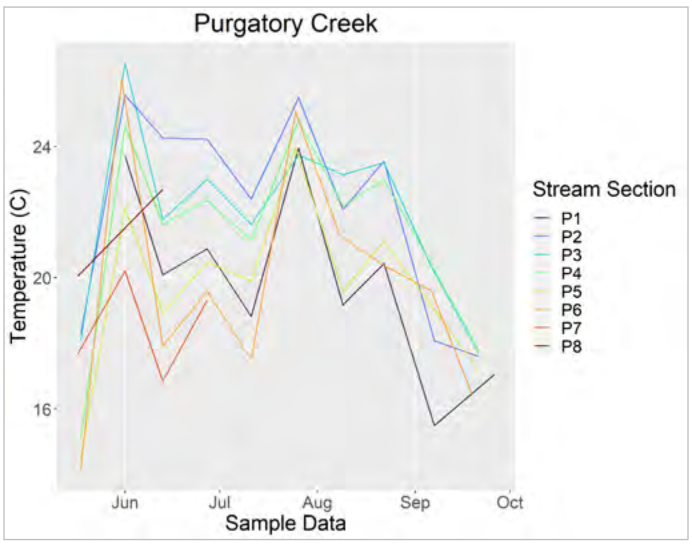
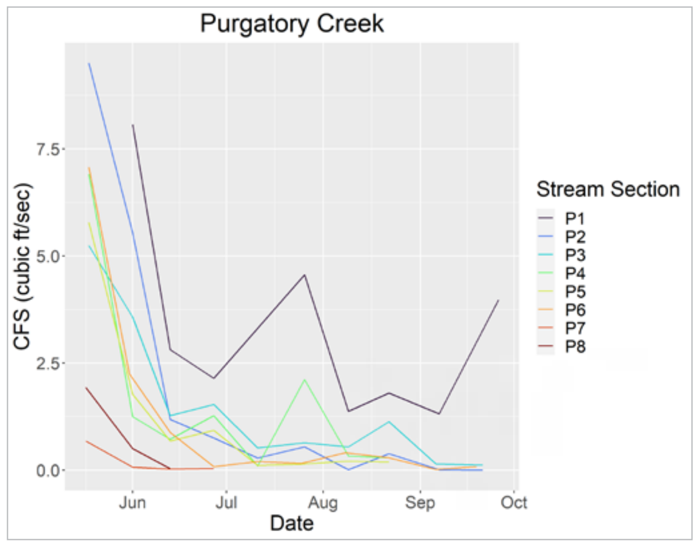


Exhibit E. 2023 Creek Seasonal Sonde & Flow Data: **PURGATORY CREEK**









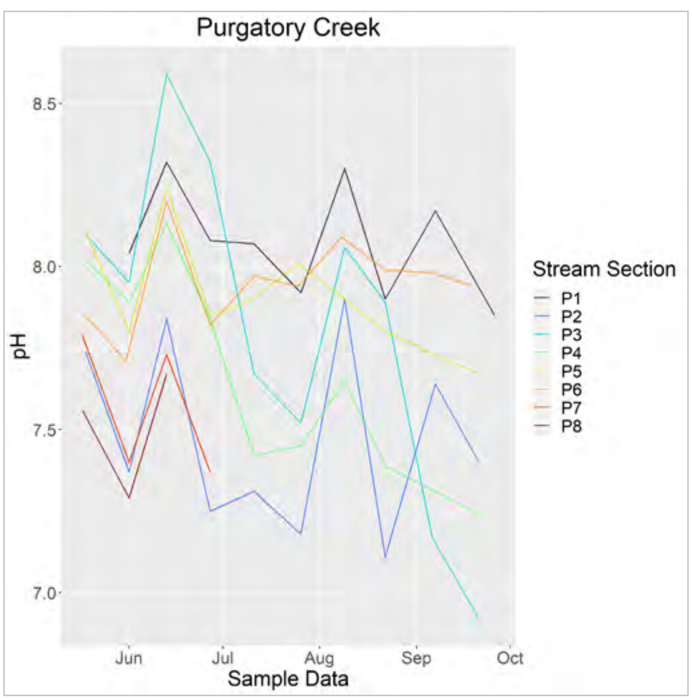
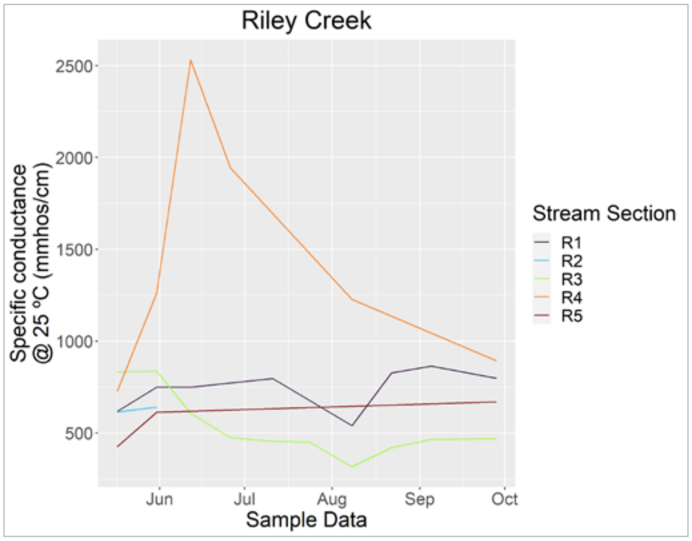
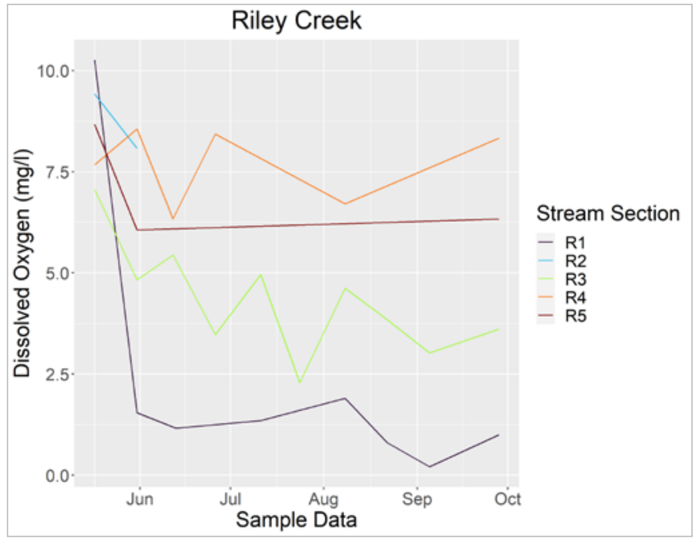
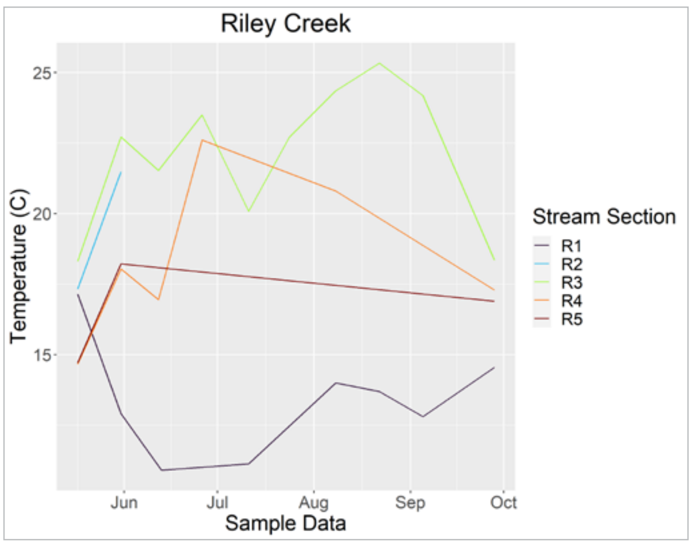
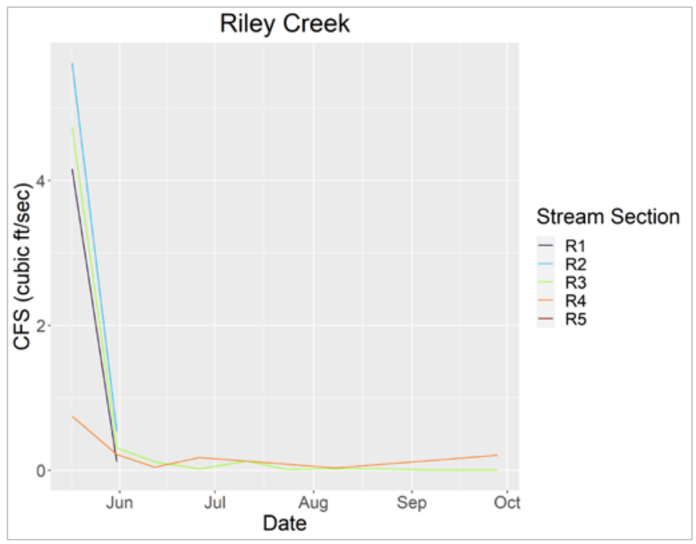


Exhibit E. 2023 Creek Seasonal Sonde & Flow Data: **RILEY CREEK**









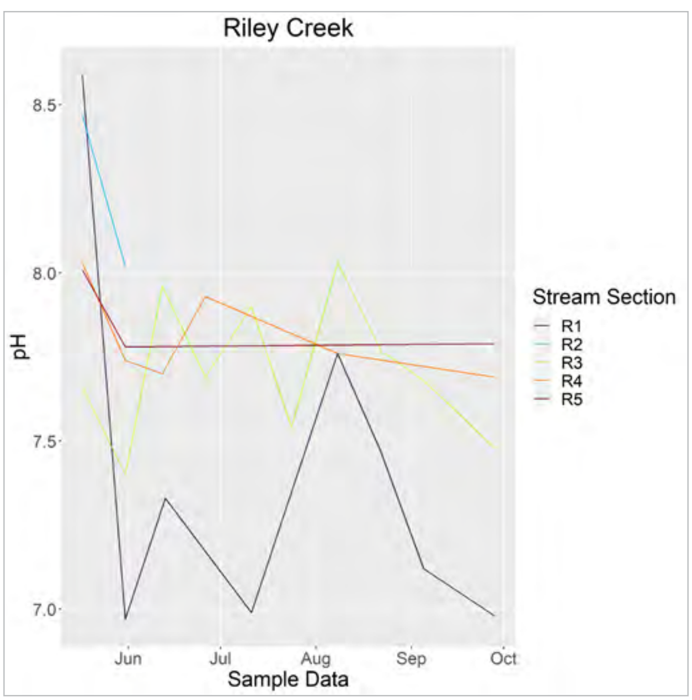


Exhibit F. 2023 Creek Nutrient Data Summary Table

Stream	Stream Section	Cl- (mg/l)	Chl a (ug/l)	OP (mg/l)	TP (mg/l)	TSS (mg/l)
Bluff	B5	94.6500	1.875000	--	0.19600000	19.500000
Bluff	B4	225.7500	4.730000	--	0.20750000	6.850000
Bluff	B3	247.0000	4.967500	--	0.10287500	4.975000
Bluff	B2	196.6667	5.990000	--	0.13700000	5.175000
Bluff	B1	147.3333	2.170000	0.0360	0.03778571	2.028571
Purgatory	P8	67.9000	6.800000	--	0.21233333	37.766667
Purgatory	P7	119.0000	3.957500	--	0.11412500	11.125000
Purgatory	P6	177.7500	6.398571	0.1315	0.13264286	7.342857
Purgatory	P5	159.0000	6.273333	0.2130	0.17466667	9.300000
Purgatory	P4	152.0000	7.971667	0.1460	0.14233333	2.800000
Purgatory	P3	222.7500	62.950000	0.0270	0.11358333	17.416667
Purgatory	P2	179.3333	2.695000	0.0470	0.07191667	3.783333
Purgatory	P1	120.4000	5.364000	0.0400	0.07020000	4.540000
Riley	R5	65.5000	3.500000	--	0.06600000	17.800000
Riley	R4	309.0000	2.448000	--	0.08080000	14.820000
Riley	R3	111.1000	11.940000	0.0730	0.13400000	5.171429
Riley	R2	130.0000	3.320000	--	0.02525000	4.300000
Riley	R1	76.5000	3.446667	--	0.06783333	9.066667

Exhibit G. 2023 Lake Nutrient Data

All values given in mg/L

Lake	Location	Alk	Ca	Cl	Chl-a	Fe	NH_3	NO_2/NO_3	TN	TKN	OP	TP	TSS
Ann	Top	151.5		48.50	0.003138333		0.03750000	0.05250000		0.830000	0.005333333	0.02050000	
Ann	Middle										0.005833333	0.02700000	
Ann	Bottom			46.83			1.45500000	0.03750000		2.540000	0.203500000	0.48050000	
Duck	Top	81.0	25.7	66.85	0.014426667		0.02250000	0.03000000		0.787500	0.003500000	0.04000000	
Duck	Bottom		25.5	66.48			0.02000000	0.03000000		0.632500	1.016600000	0.02420000	
Hyland	Middle				9.393333333				1.065		0.007085000	0.03517000	
Idlewild	Top	66.0	32.3	528.25	0.004415000		0.02000000	0.03000000		0.652500	0.004000000	0.03333333	
Idlewild	Bottom		32.6	565.75			0.02000000	0.03000000		0.597500	0.003600000	0.03220000	
Lotus	Top	160.5	41.8	70.93	0.009636667		0.04750000	0.03000000		0.830000	0.005500000	0.02783333	
Lotus	Middle			72.90			2.37000000	0.03000000		4.520000	0.011428571	0.09285714	
Lotus	Bottom		48.5	68.60			1.93666667	0.03000000		2.753333	0.045400000	0.21300000	
Lucy	Top	176.0		62.60	0.007974000		0.02666667	0.03000000		0.935000	0.004800000	0.02720000	
Lucy	Middle										0.005600000	0.04500000	
Lucy	Bottom			60.63			0.45000000	0.03000000		1.840000	0.038800000	0.33620000	
McCoy	Top	186.0	69.0	118.00	0.003340000		0.07000000	0.03000000		0.990000	0.025000000	0.09700000	
Mitchell	Top	141.6		155.20	0.014080000	0.1480	0.02000000	0.03200000		0.740000	0.003200000	0.03680000	3.88
Mitchell	Middle				0.019740000						0.004600000	0.05100000	
Mitchell	Bottom				0.014780000						0.009200000	0.07900000	

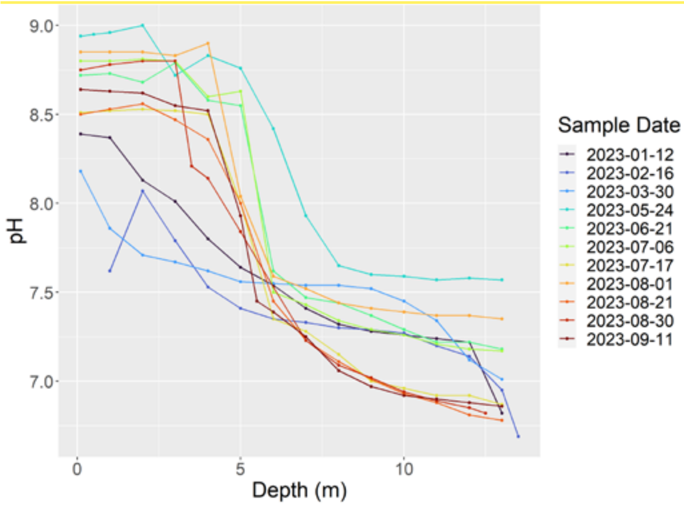
Exhibit H. 2023 Lake Nutrient Data (continued)

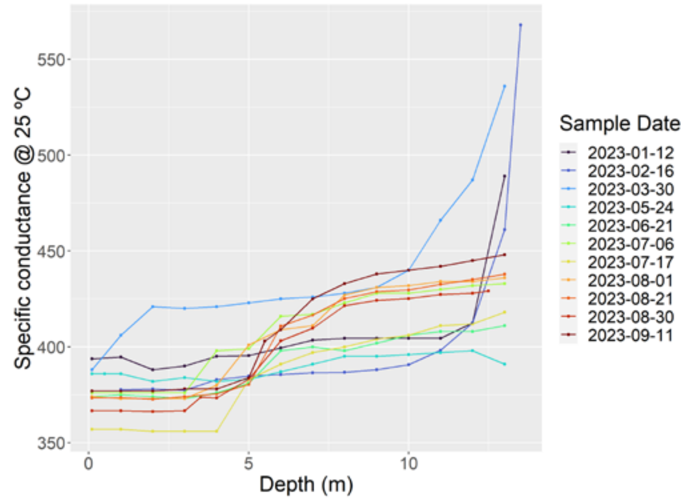
All values given in mg/L

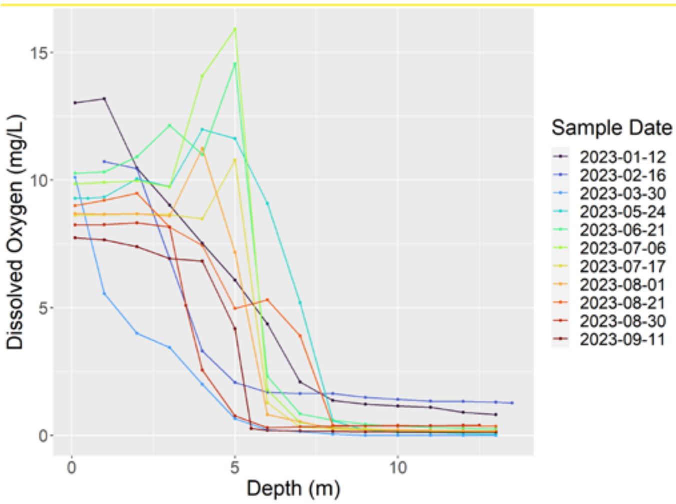
Lake	Location	Alk	Ca	Cl	Chl-a	Fe	NH_3	NO_2/NO_3	TN	TKN	OP	TP	TSS
Neill	Top	102.0		237.67	0.033074000		0.06333333	0.03000000		1.193333	0.004200000	0.06840000	
Neill	Bottom	108.0	35.2	232.00	0.003050000		0.05333333	0.03000000		1.043333	0.004200000	0.05240000	
Red Rock	Top	152.4		125.00	0.010560000	0.1134	0.02600000	0.03000000		0.694000	0.004200000	0.03280000	3.08
Red Rock	Middle				0.010480000						0.005800000	0.04440000	
Red Rock	Bottom				0.013980000						0.011000000	0.05040000	
Rice Marsh	Top	114.0		239.75	0.015291667		0.03000000	0.03000000		0.940000	0.004000000	0.04533333	
Rice Marsh	Bottom			238.50			0.03000000	0.03000000		0.940000	0.004000000	0.05966667	
Riley	Top	138.0	44.2	133.75	0.004203333		0.02750000	0.06500000		0.697500	0.004666667	0.01916667	
Riley	Middle							0.15000000			0.005000000	0.02066667	
Riley	Bottom		43.7	136.50			0.47750000	0.10250000		1.050000	0.030666667	0.04866667	
Round	Top	62.4		92.48	0.004880000	0.1052	0.02800000	0.03000000		0.672000	0.003400000	0.02500000	1.72
Round	Middle				0.012160000						0.005200000	0.04560000	
Round	Bottom				0.024800000						0.052800000	0.19280000	
Silver	Top	120.0		66.13	0.018978333		0.02500000	0.03000000		1.192500	0.004333333	0.07516667	
Silver	Bottom			66.88			0.02000000	0.03000000		1.042500	0.004400000	0.04260000	
Staring	Top	180.0	64.0	166.00	0.038436000		0.05333333	0.03000000		1.116667	0.010000000	0.07760000	
Staring	Bottom		68.4	166.67			0.51333333	0.03000000		1.873333	0.225200000	0.34160000	
Susan	Top	150.0		199.33	0.025448000		0.03333333	0.03000000		0.980000	0.004000000	0.04460000	
Susan	Bottom			198.67			0.69666667	0.03333333		1.995000	0.039375000	0.18337500	

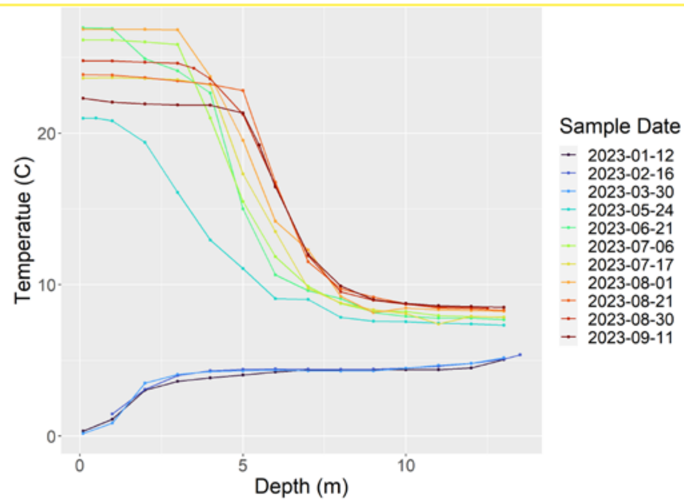
Exhibit I. 2023 Lake Profile Data

Lake Profile: ANN

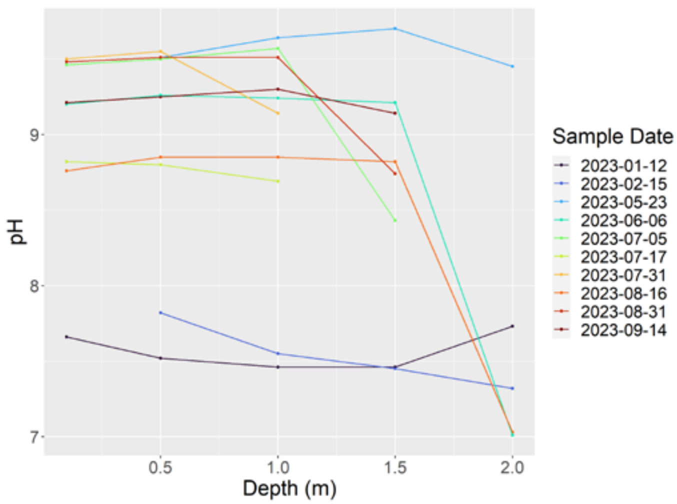


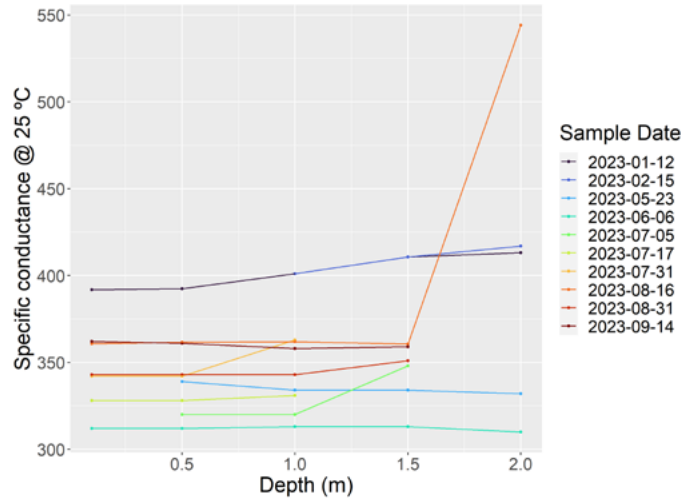


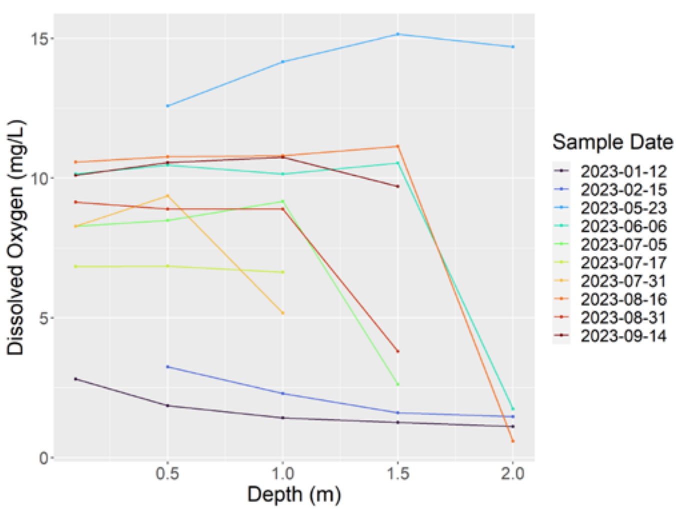


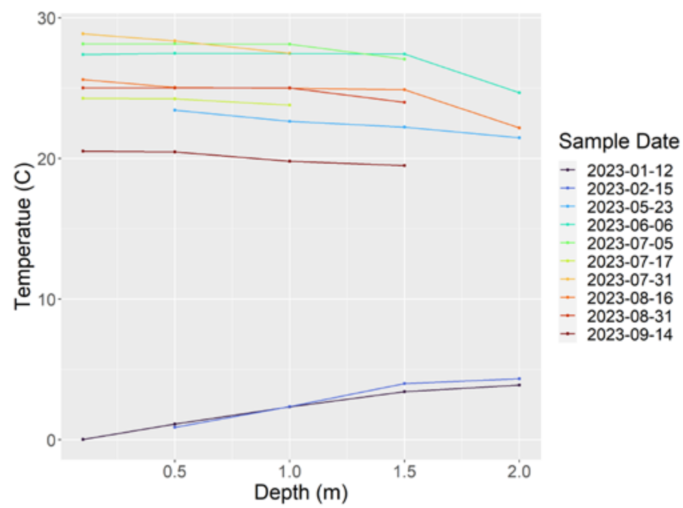


Lake Profile: DUCK

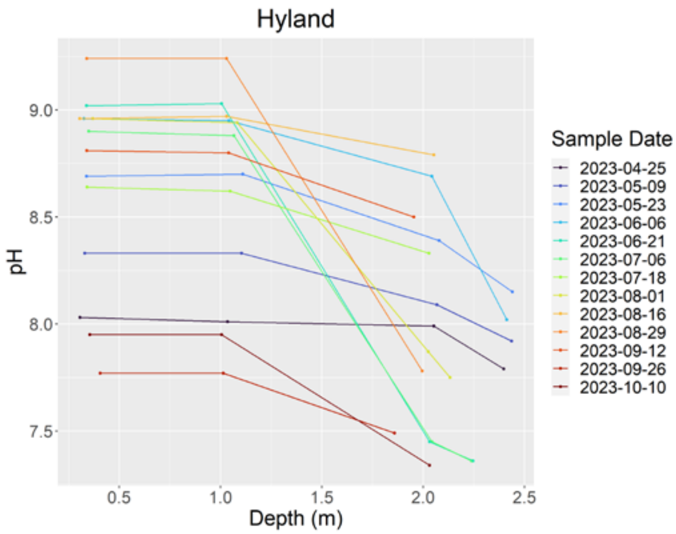


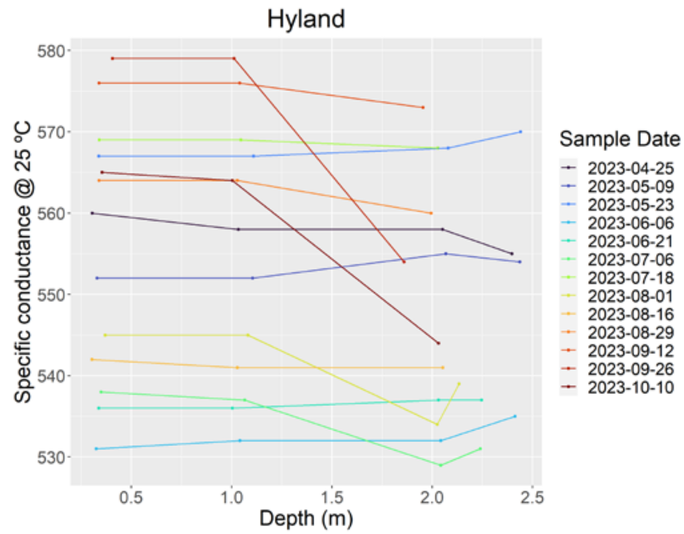


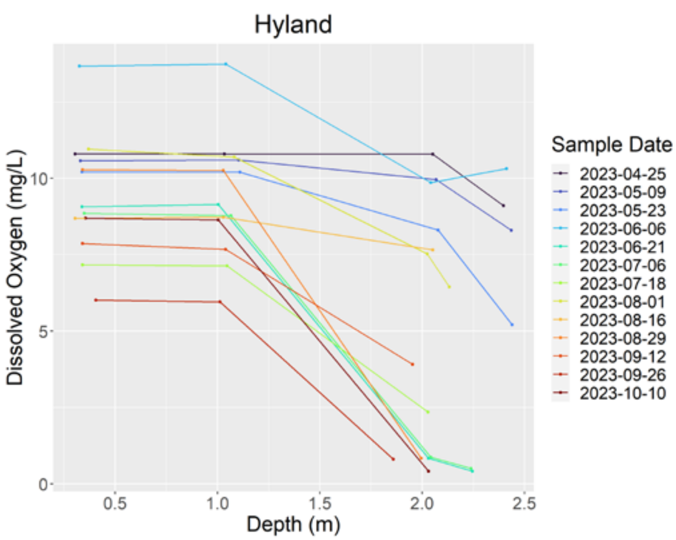


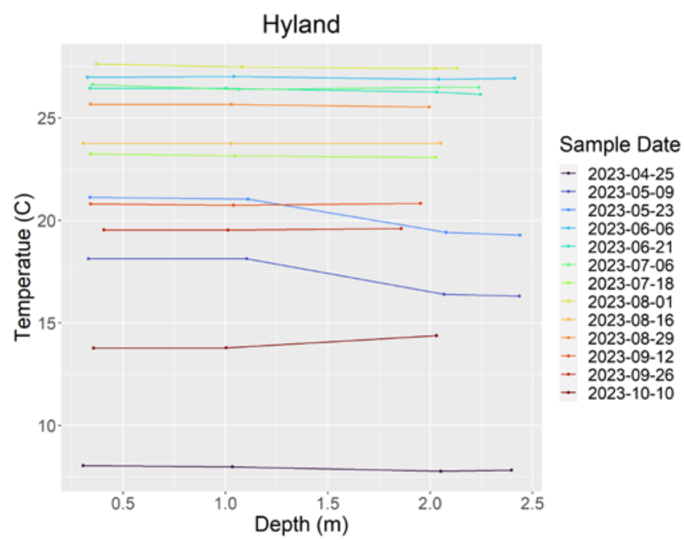


Lake Profile: HYLAND

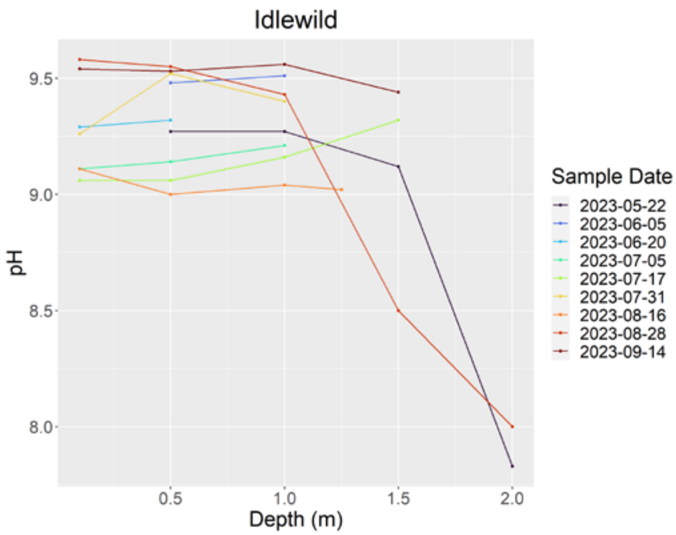


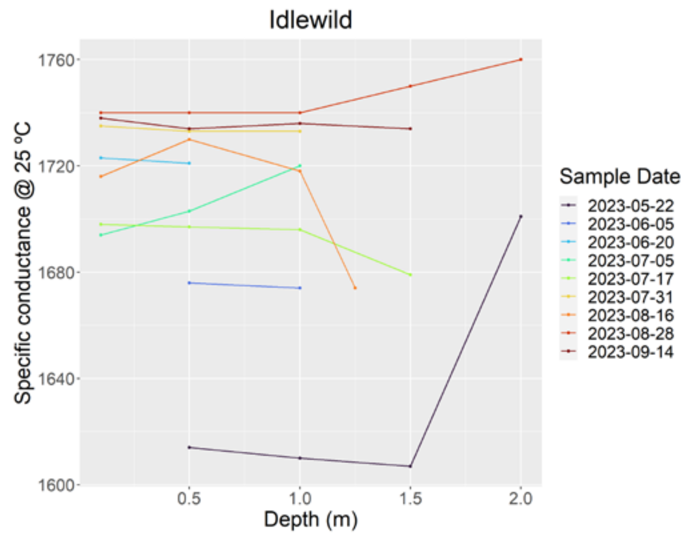


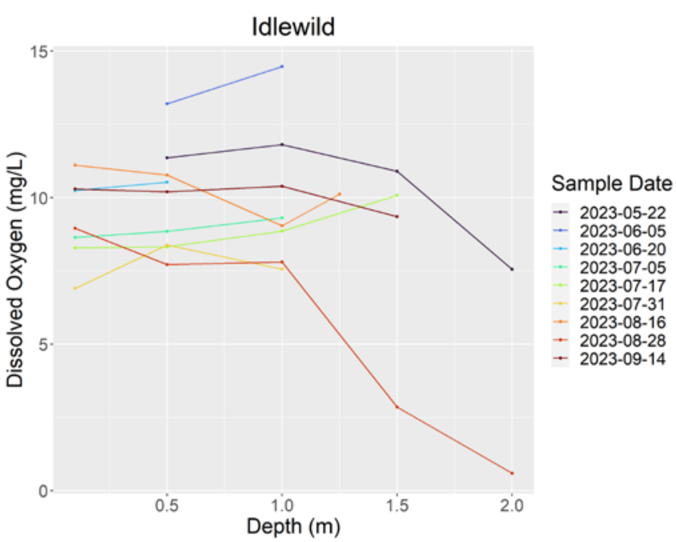


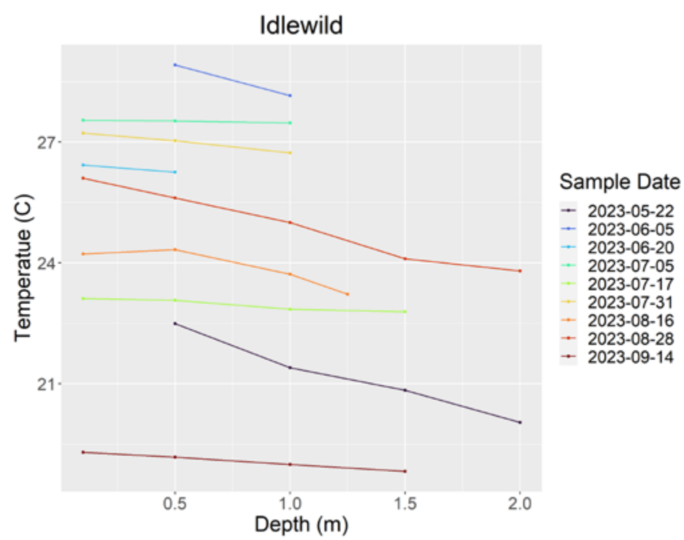


Lake Profile: IDLEWILD

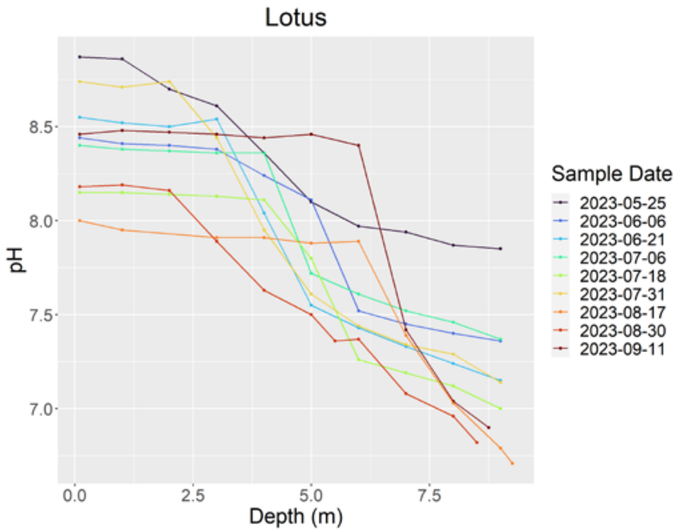


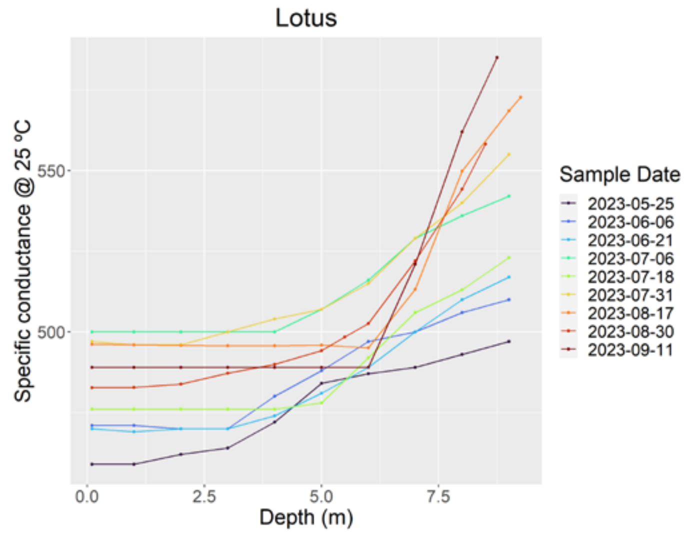


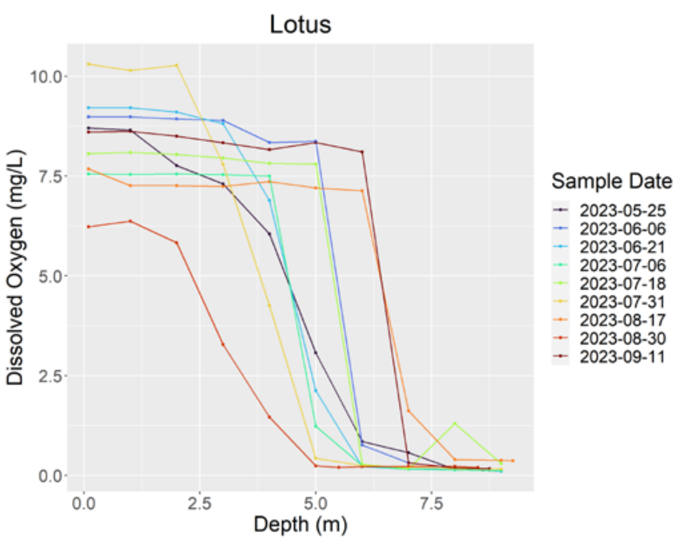


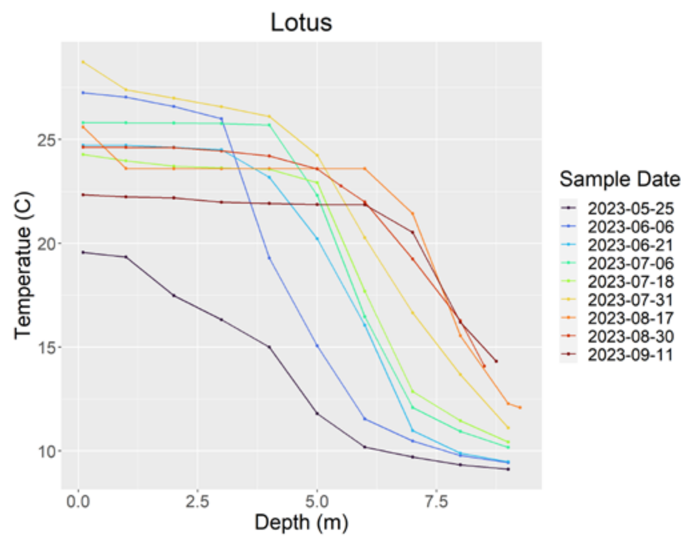


Lake Profile: LOTUS

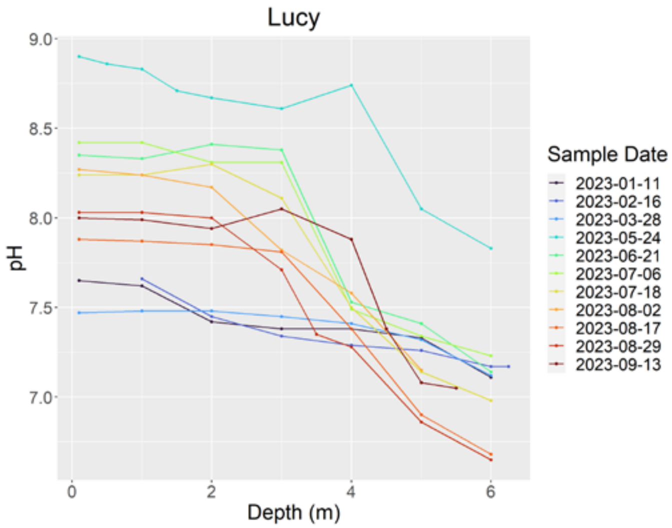


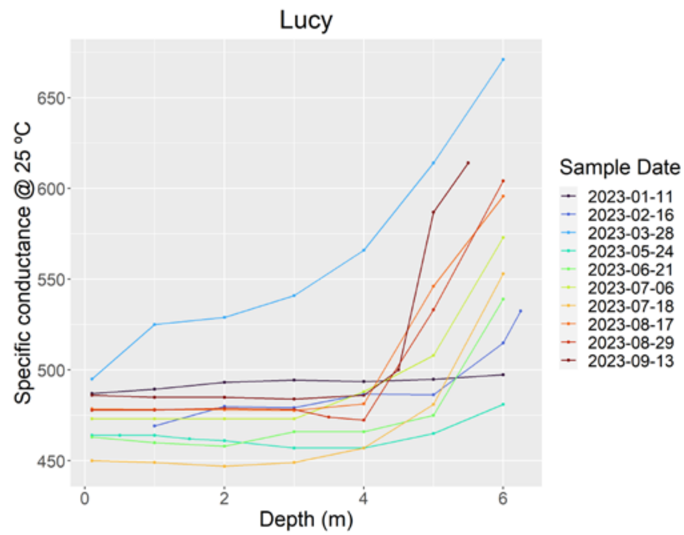


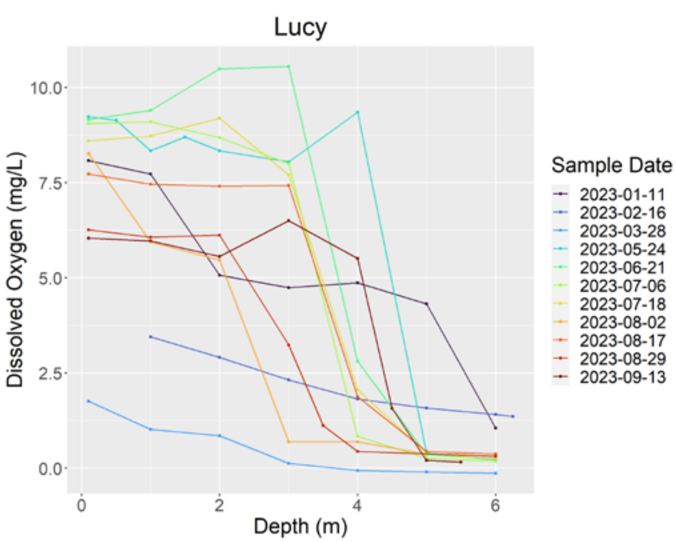


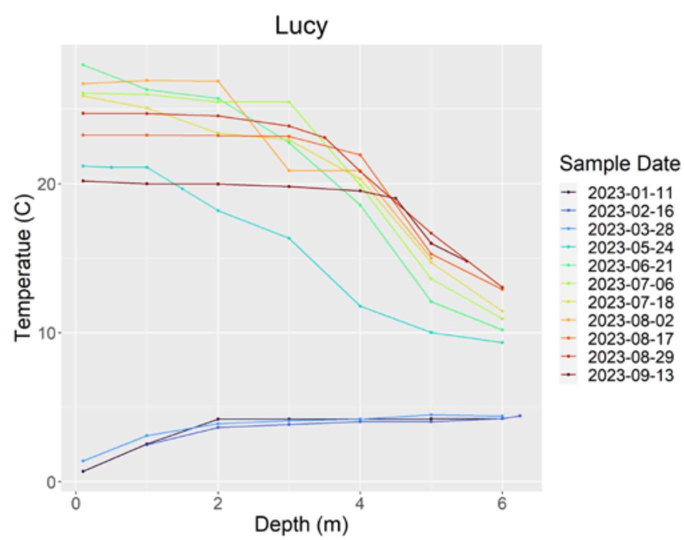


Lake Profile: LUCY

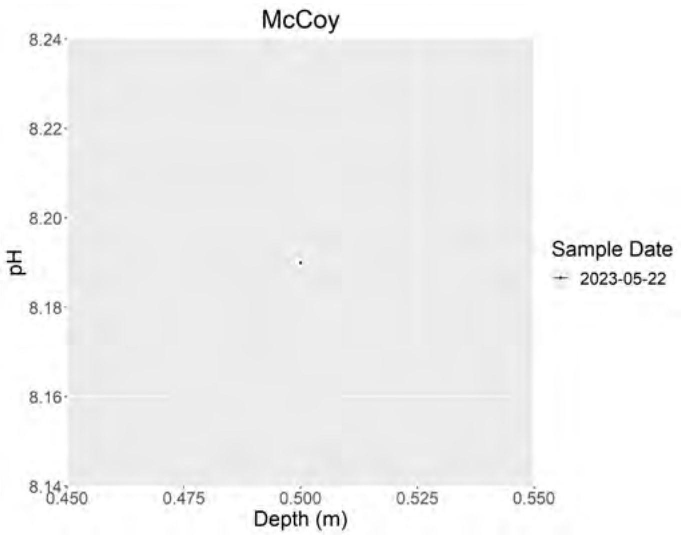


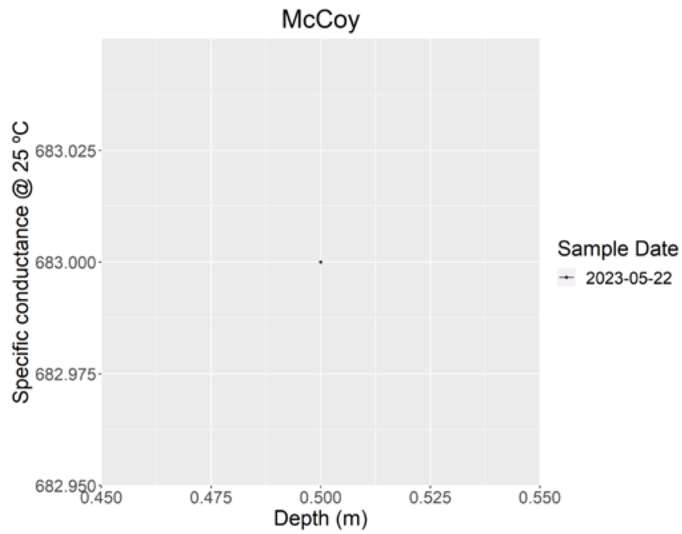


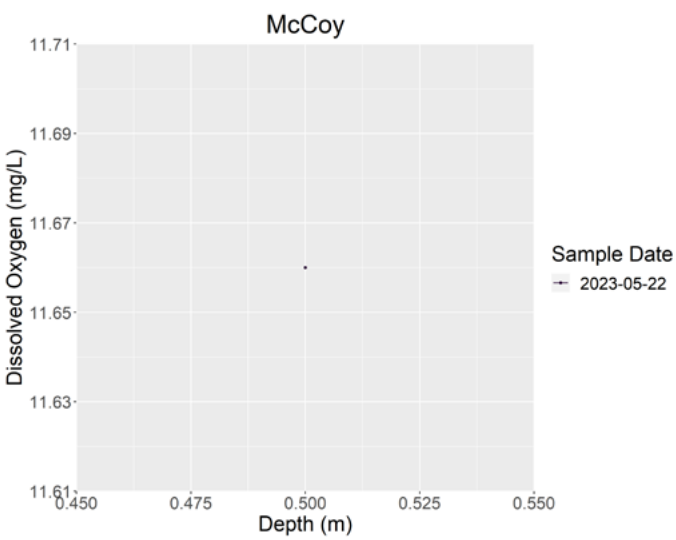


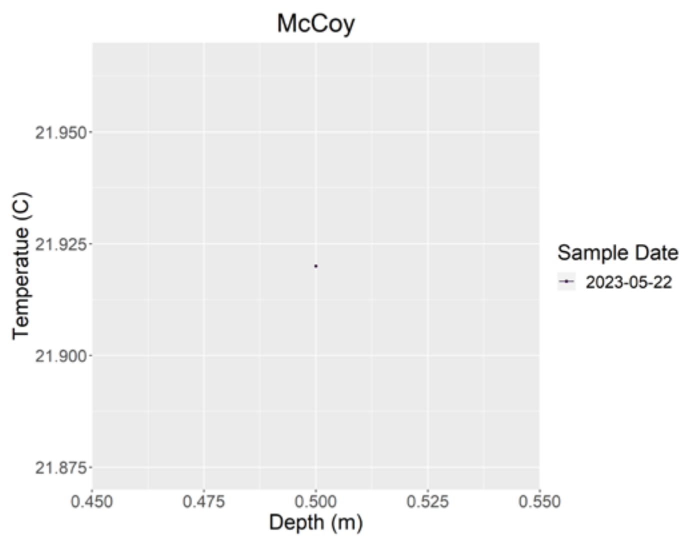


Lake Profile: MCCOY

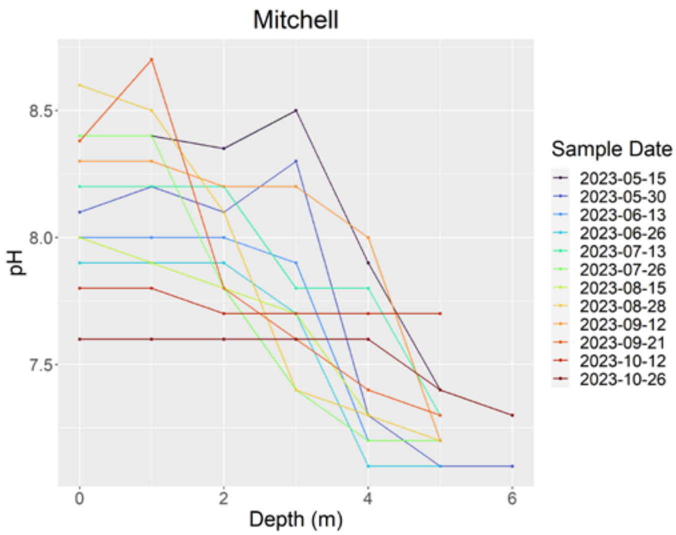


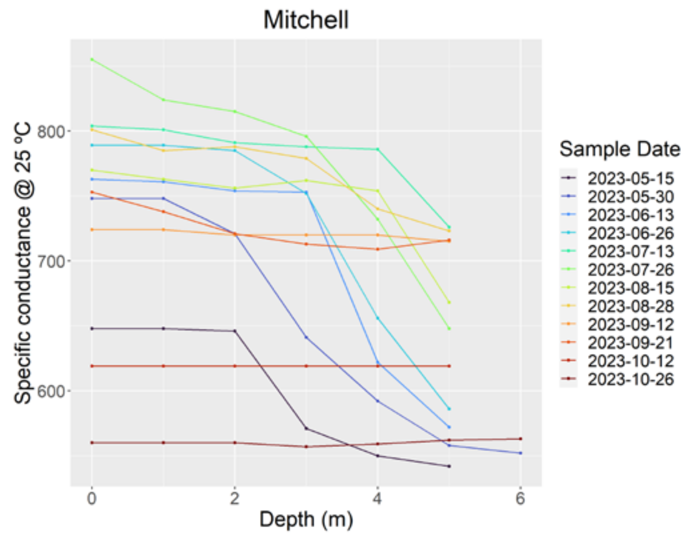


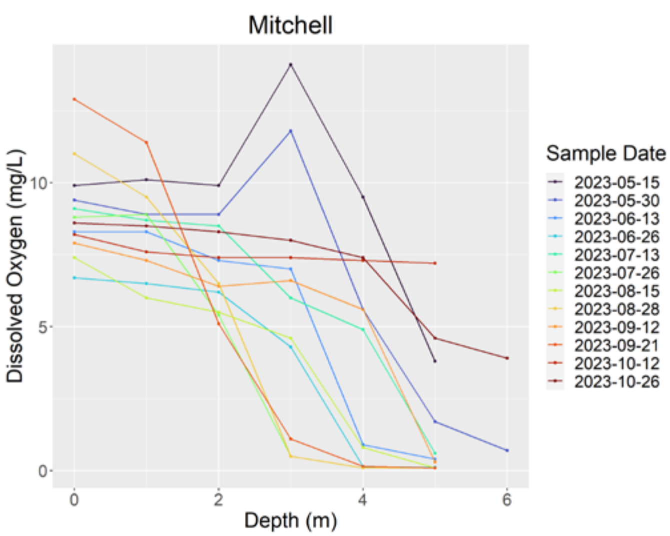


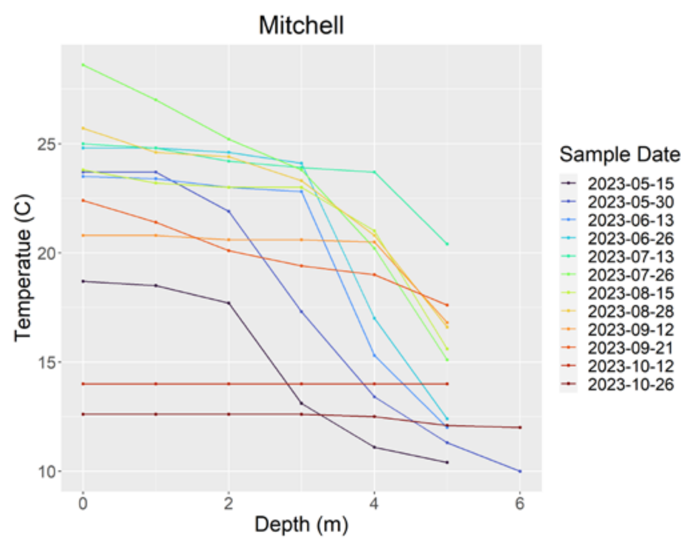


Lake Profile: MITCHELL

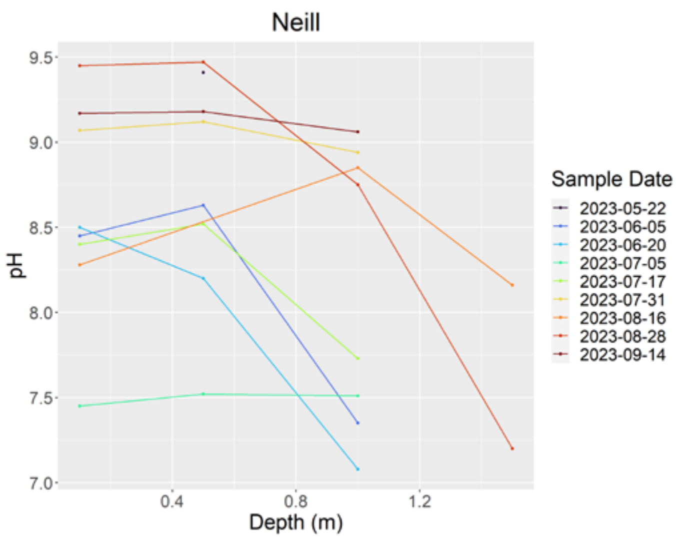


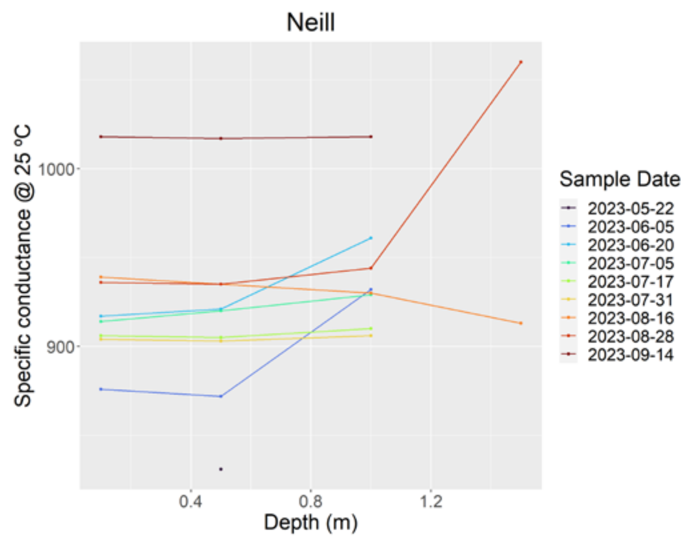


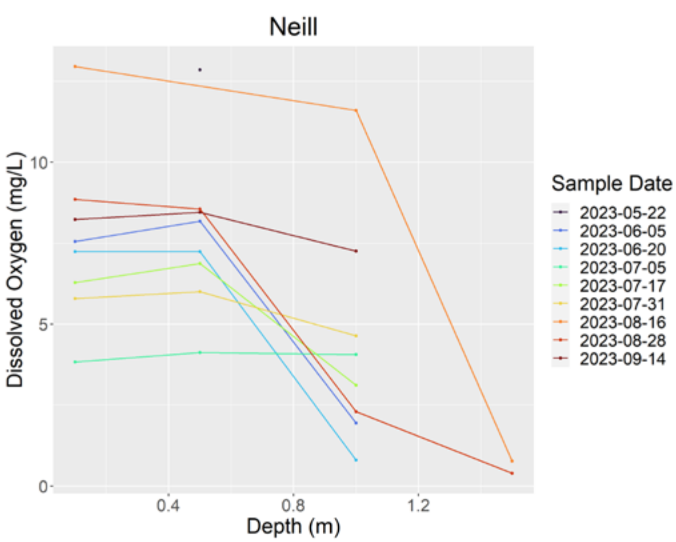


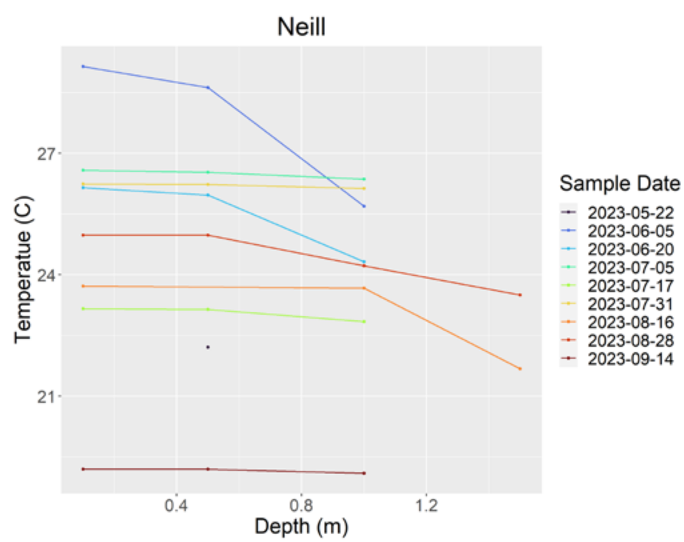


Lake Profile: NEILL

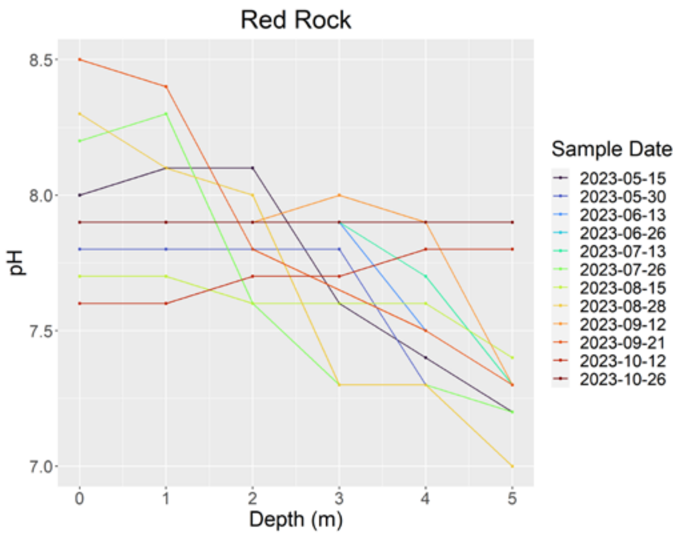


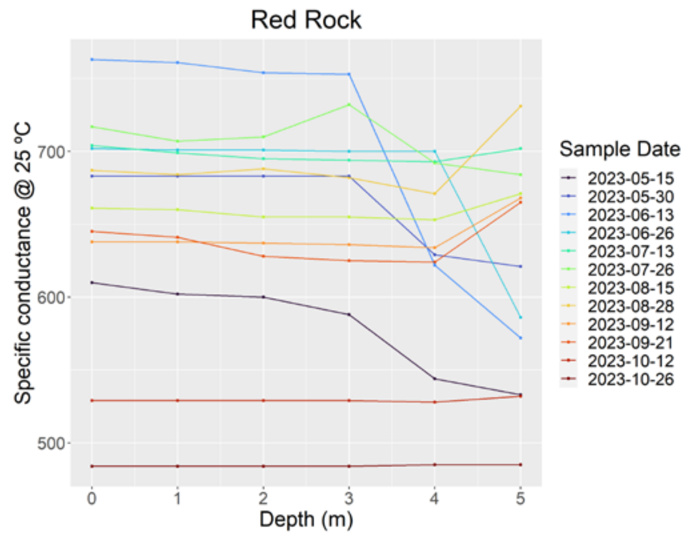


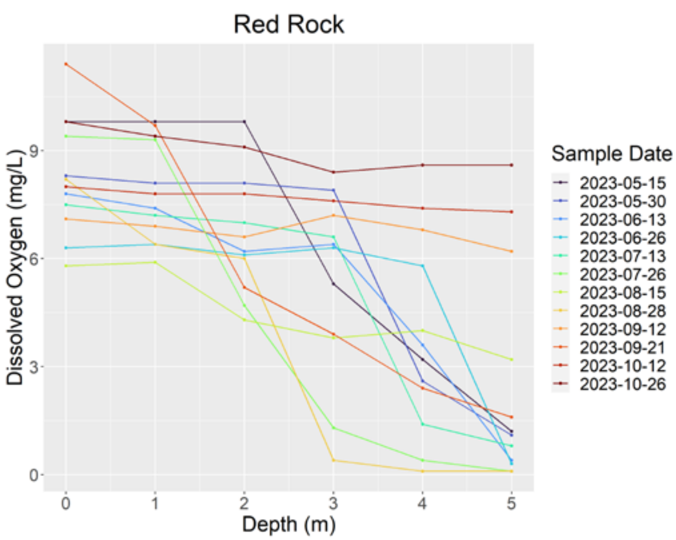


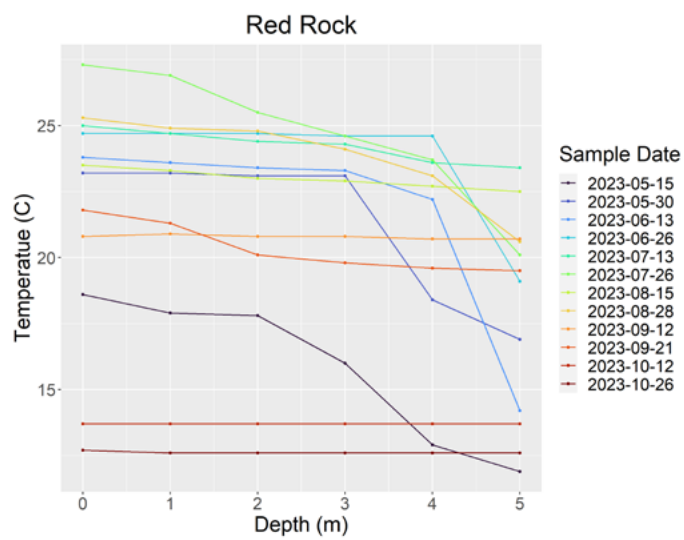


Lake Profile: RED ROCK

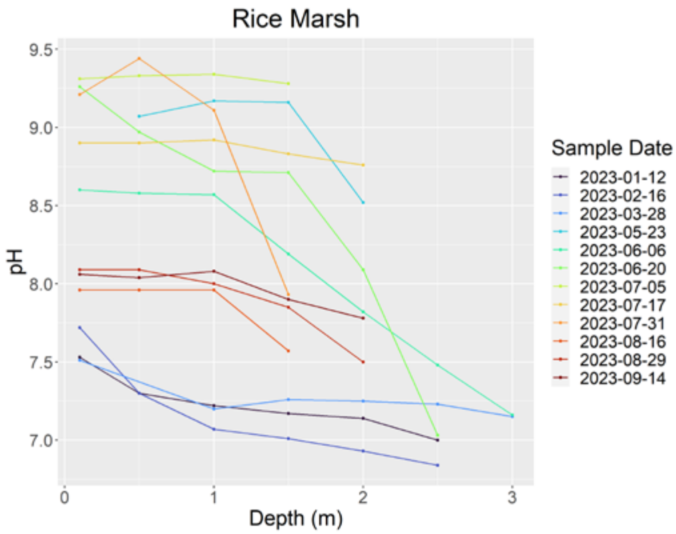


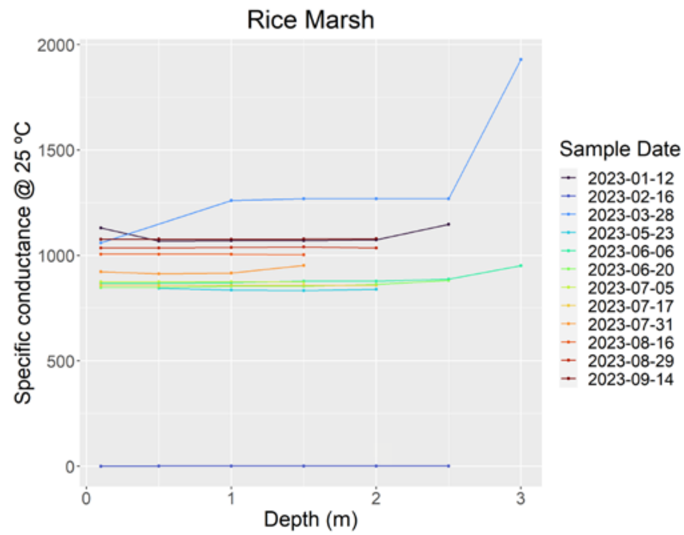


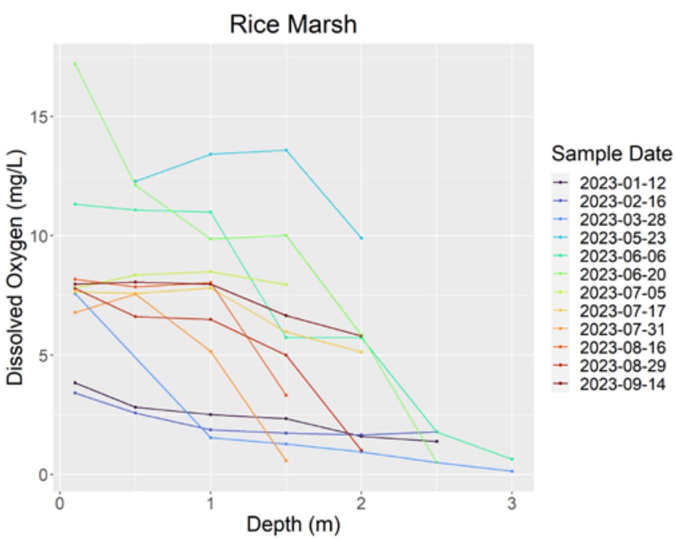


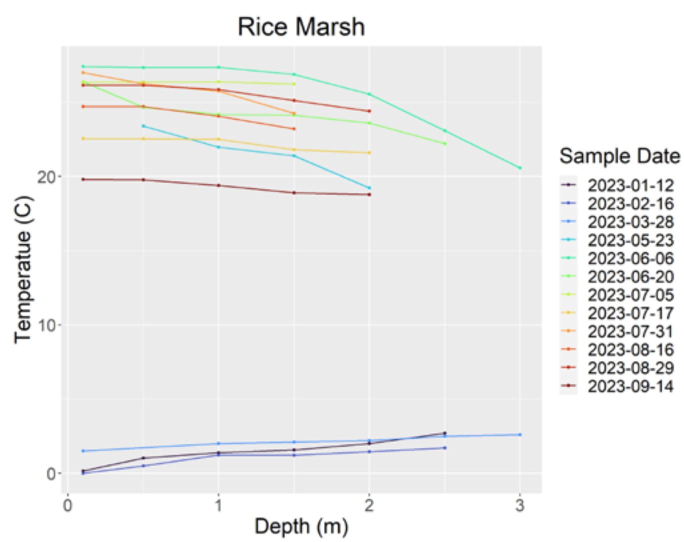


Lake Profile: RICE MARSH

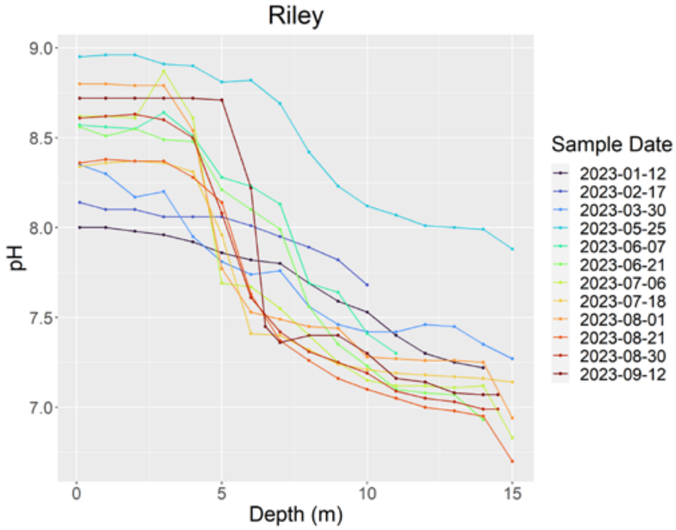


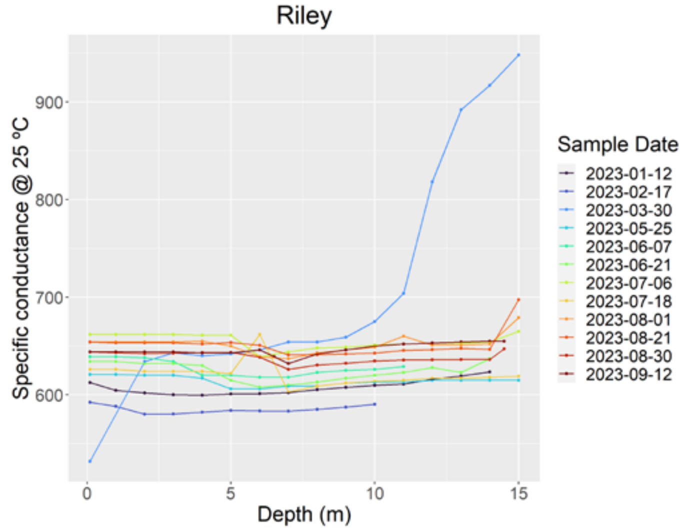


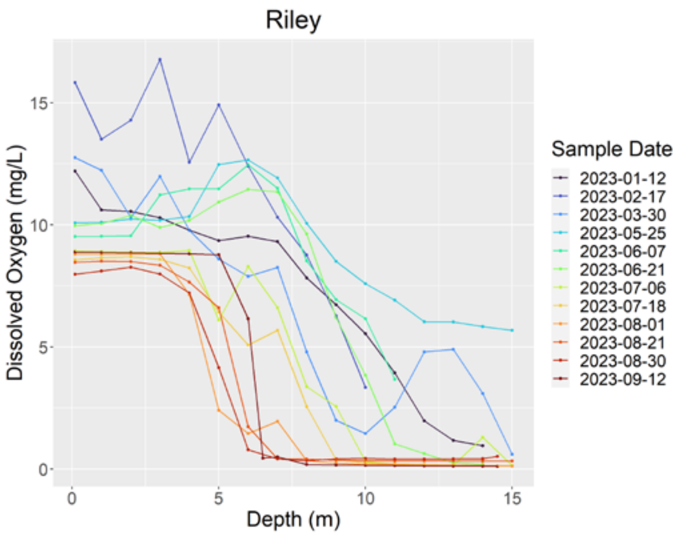


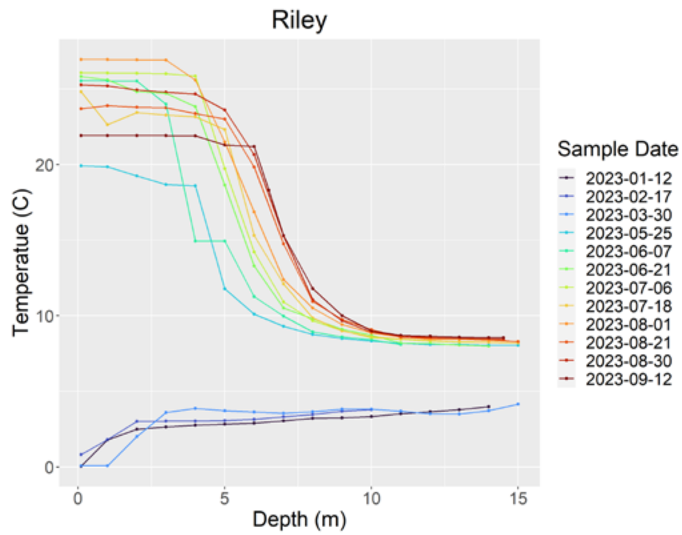


Lake Profile: RILEY

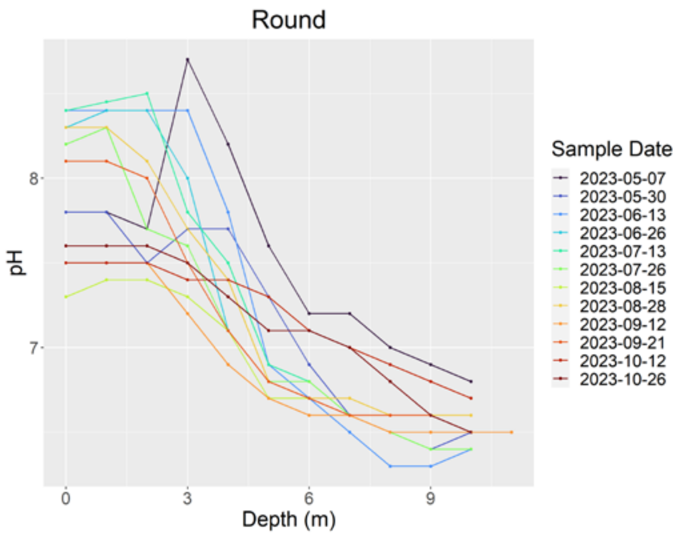


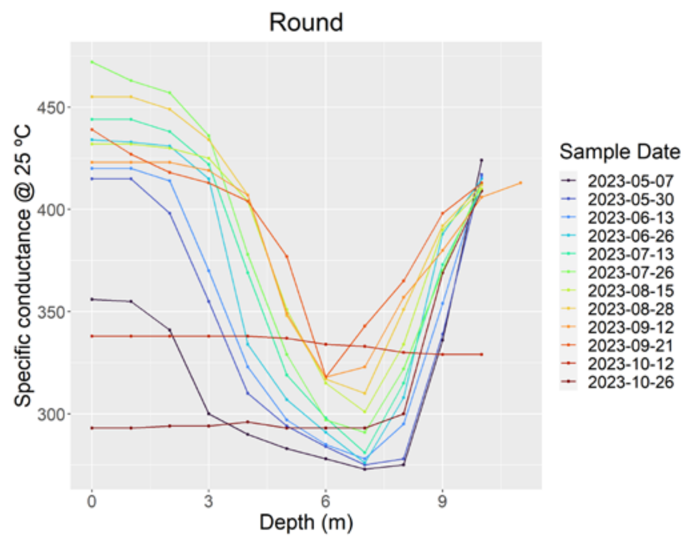


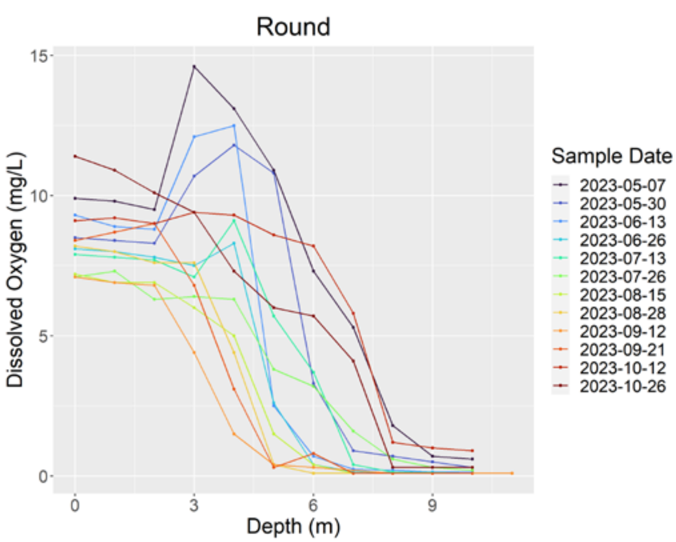


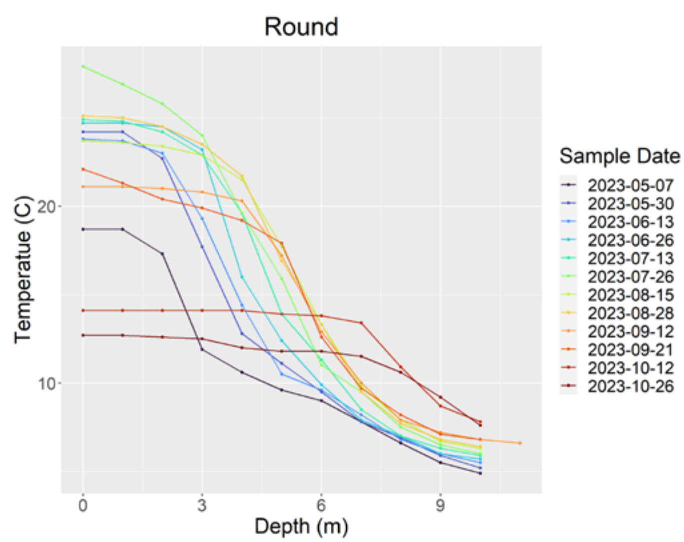


Lake Profile: ROUND

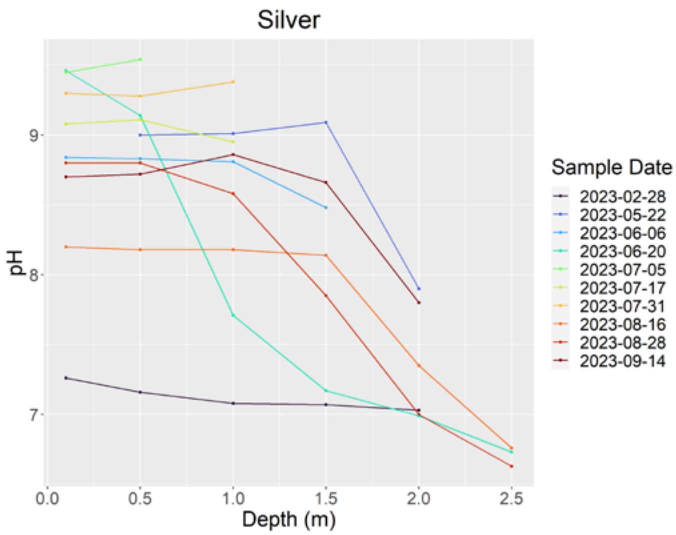


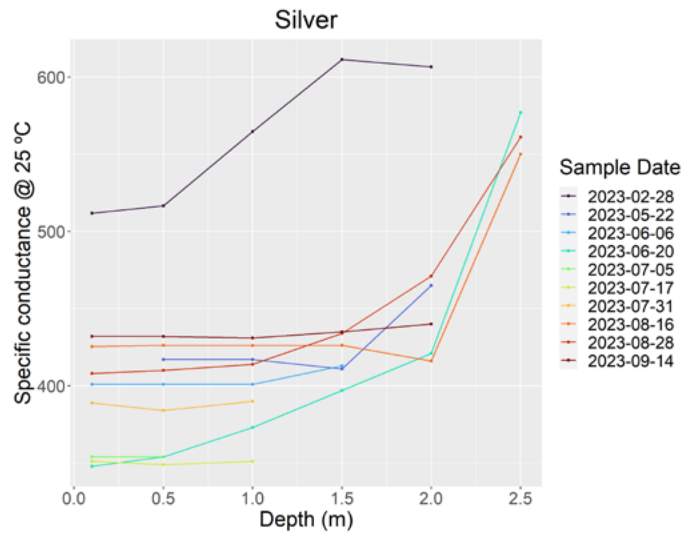


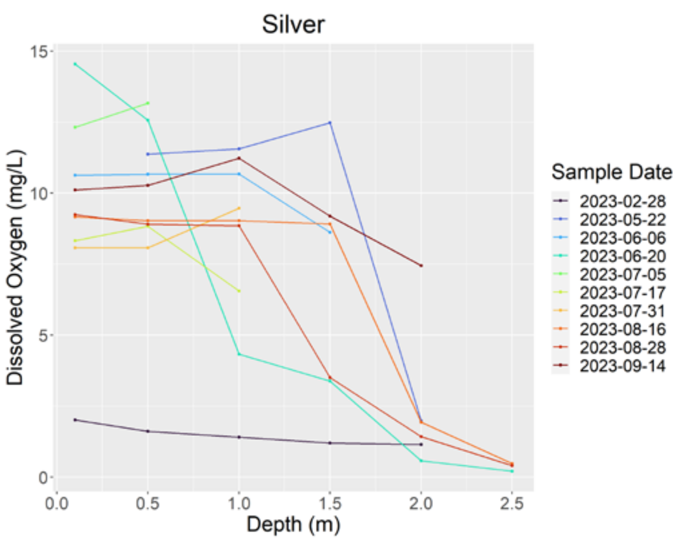


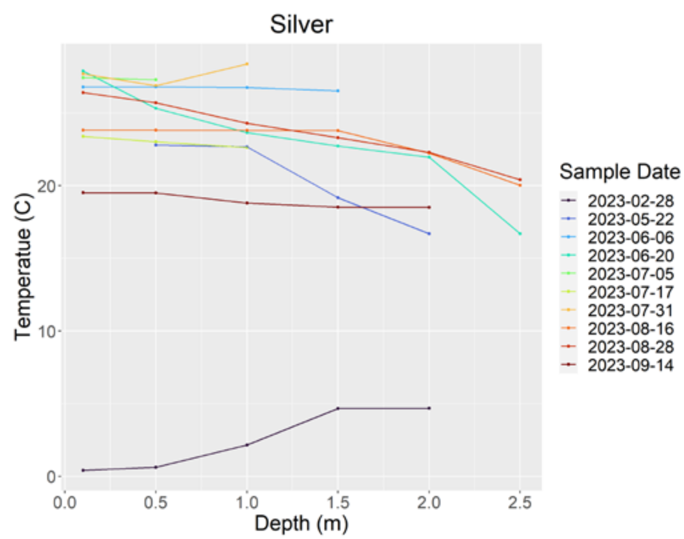


Lake Profile: SILVER

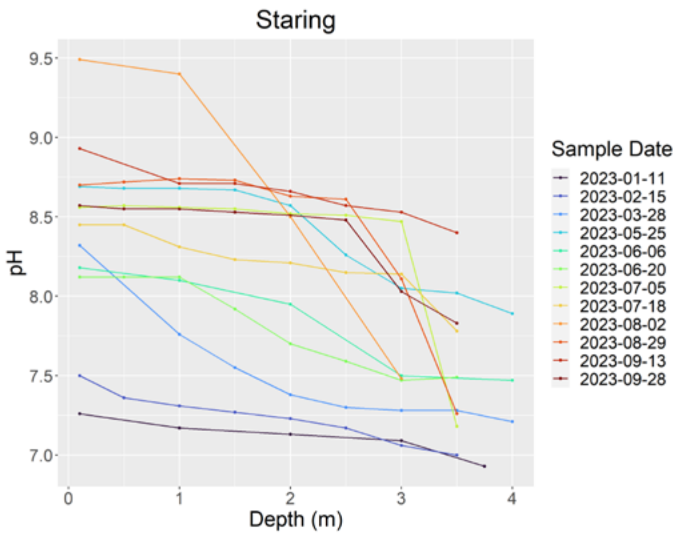


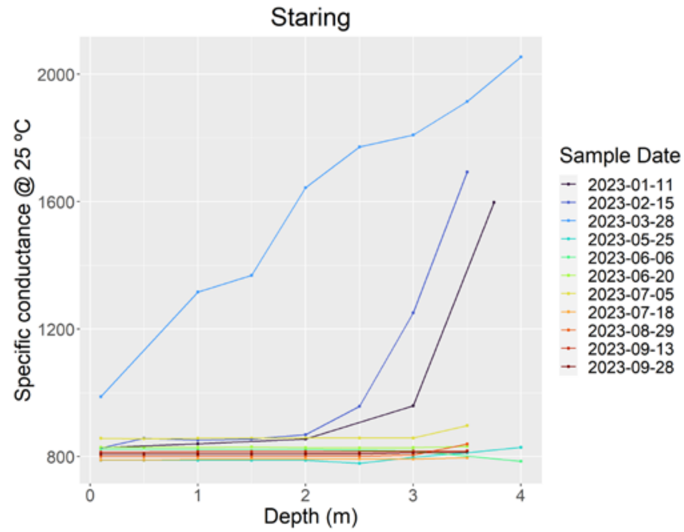


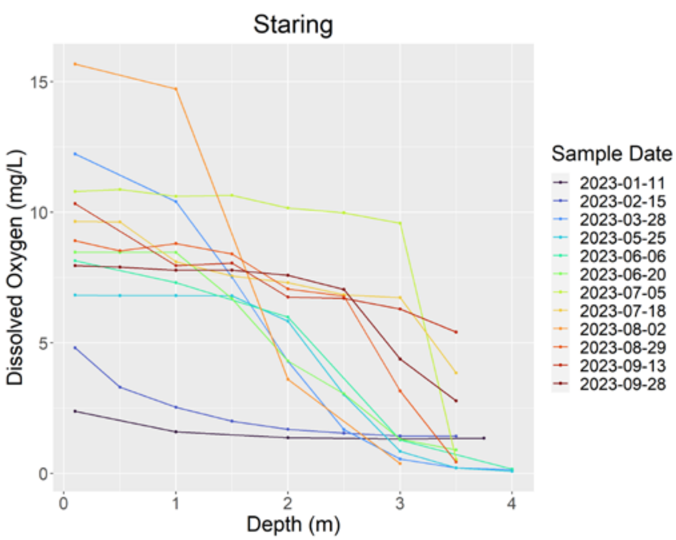


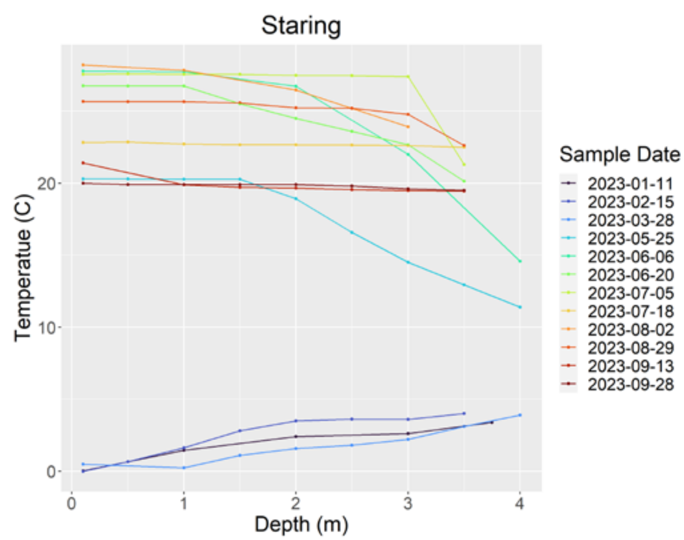


Lake Profile: STARING

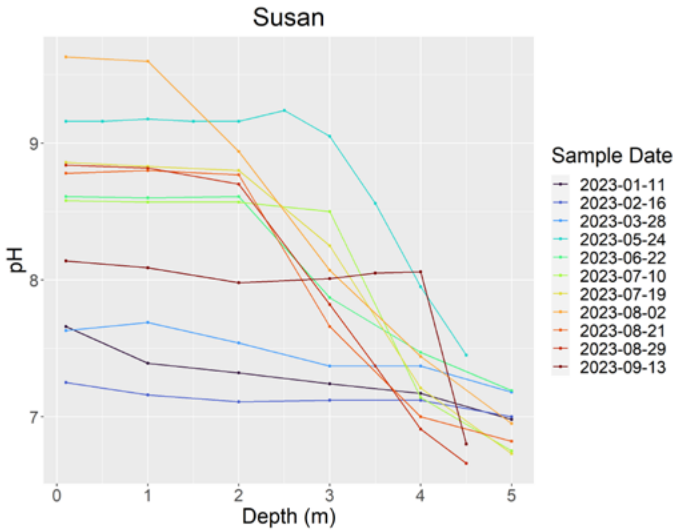


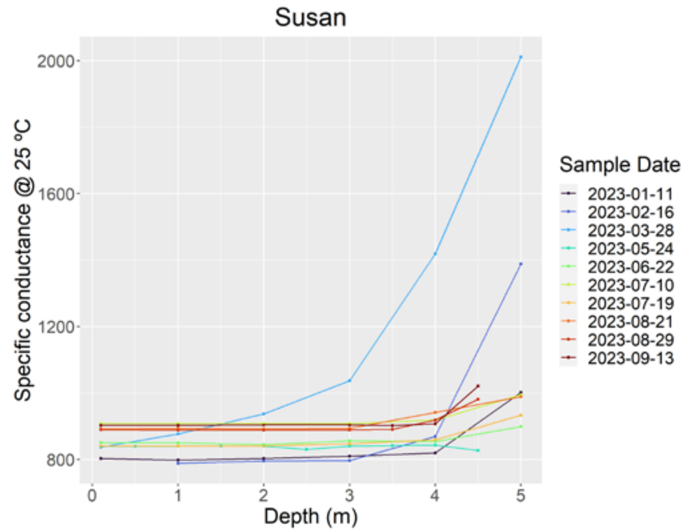


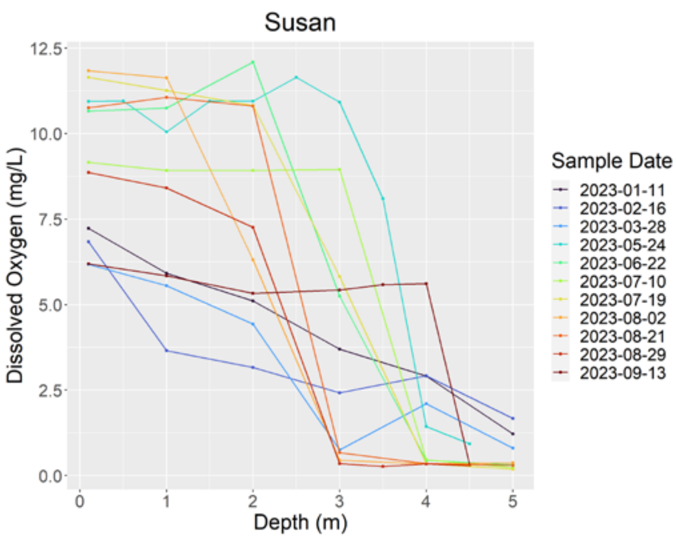




Lake Profile: SUSAN







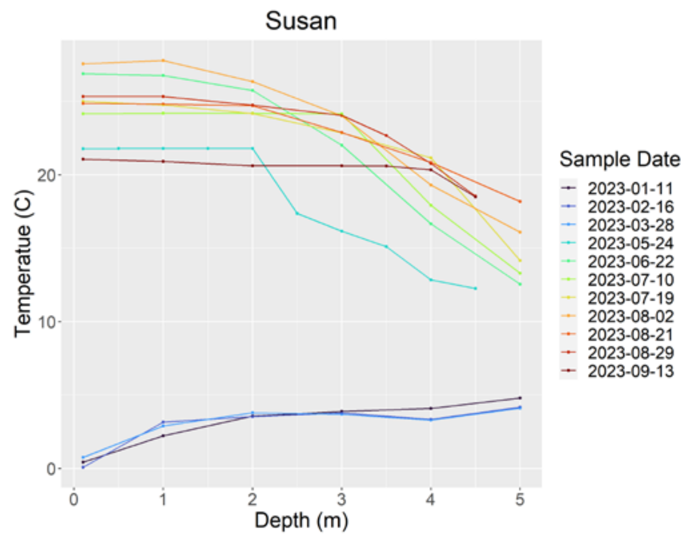


Exhibit J. 2023 Invasive Aquatic Plant Treatment Areas.

Figure I-1. **Mitchell Lake** Curly-leaf Pondweed delineation and treatment area (12.9 acres).

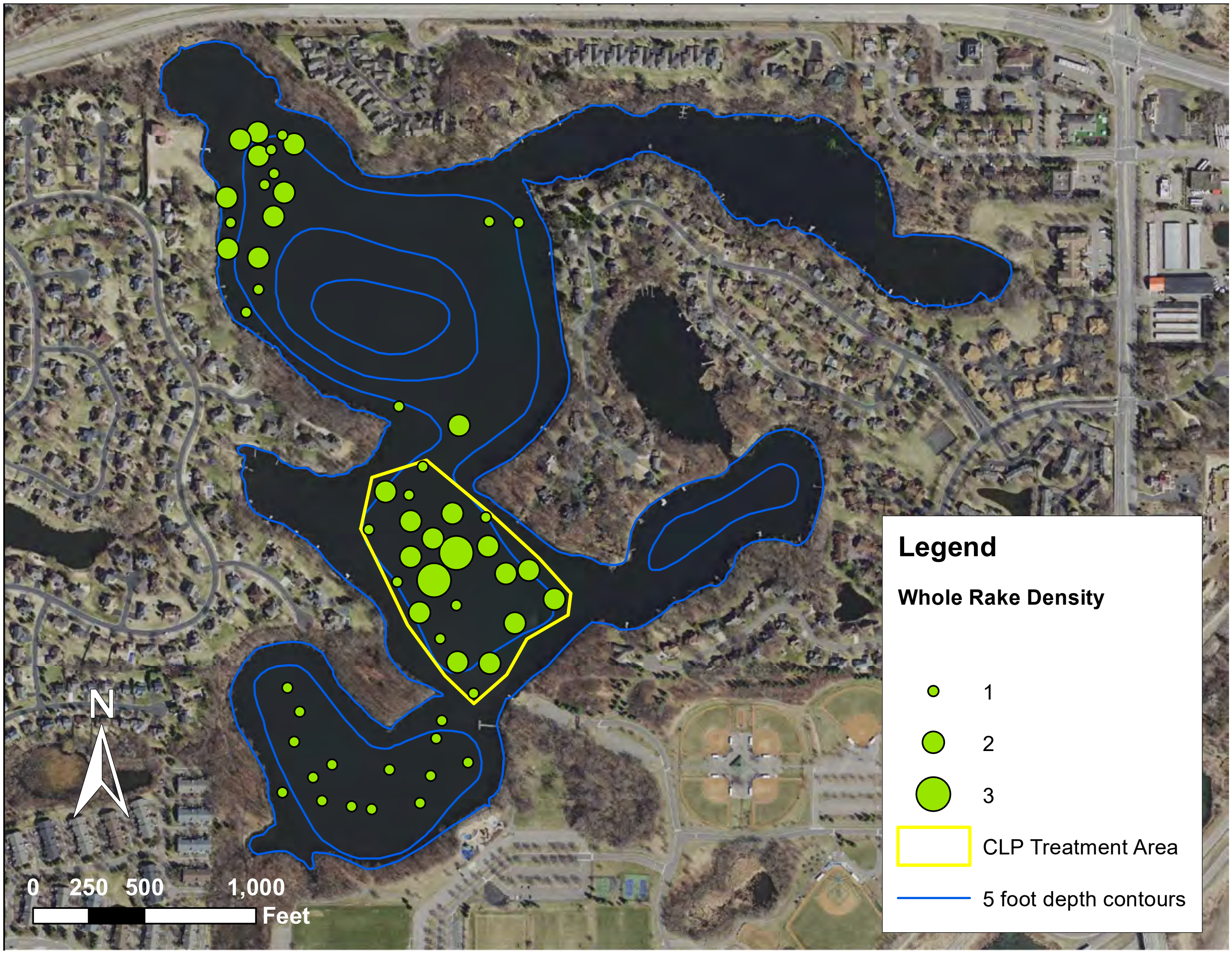


Figure I-2. **Lake Susan** Curly-leaf Pondweed delineation and treatment area (5.3 acres).

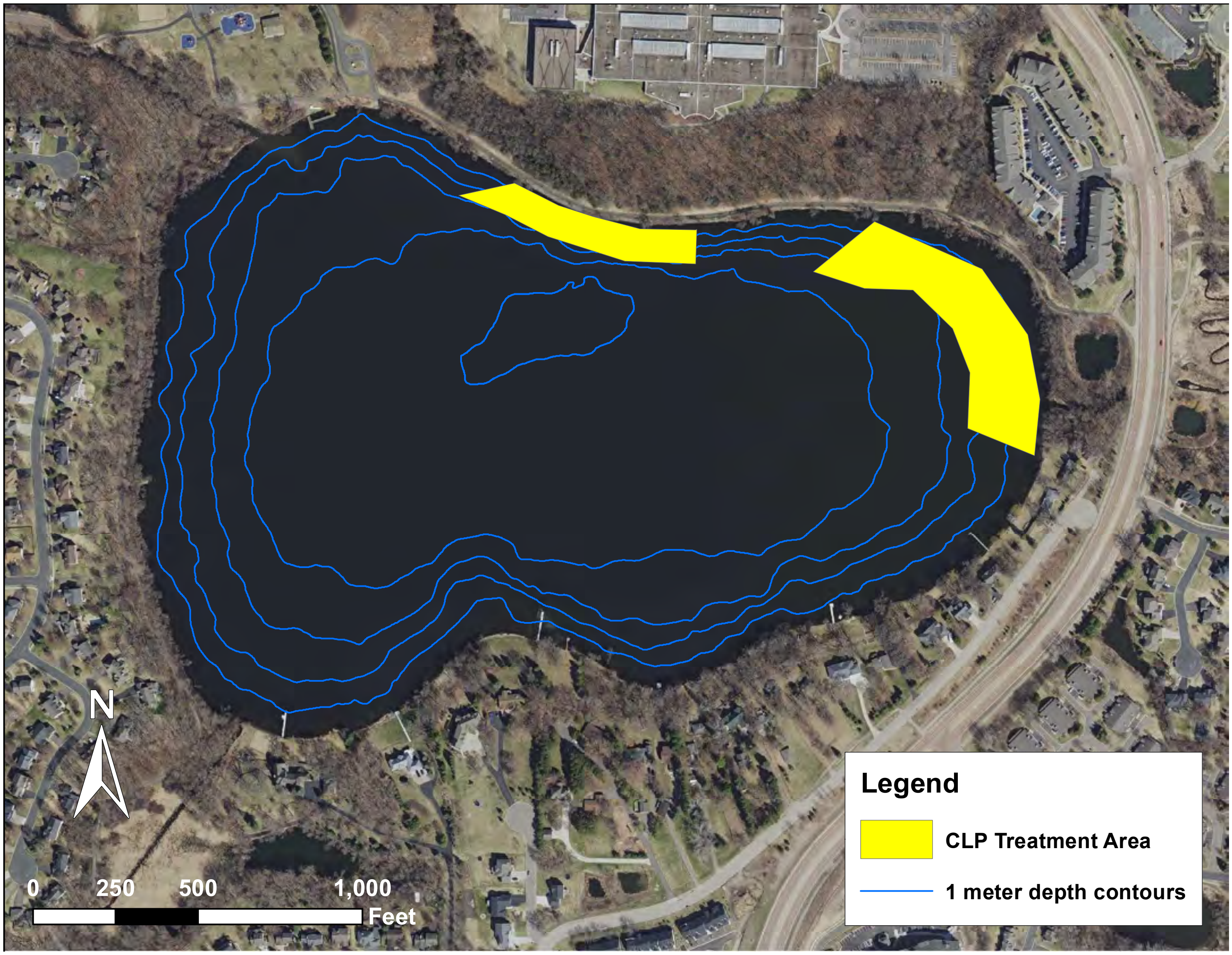


Figure I-3. **Red Rock Lake** Curly-leaf Pondweed delineation and treatment area (13 acres).

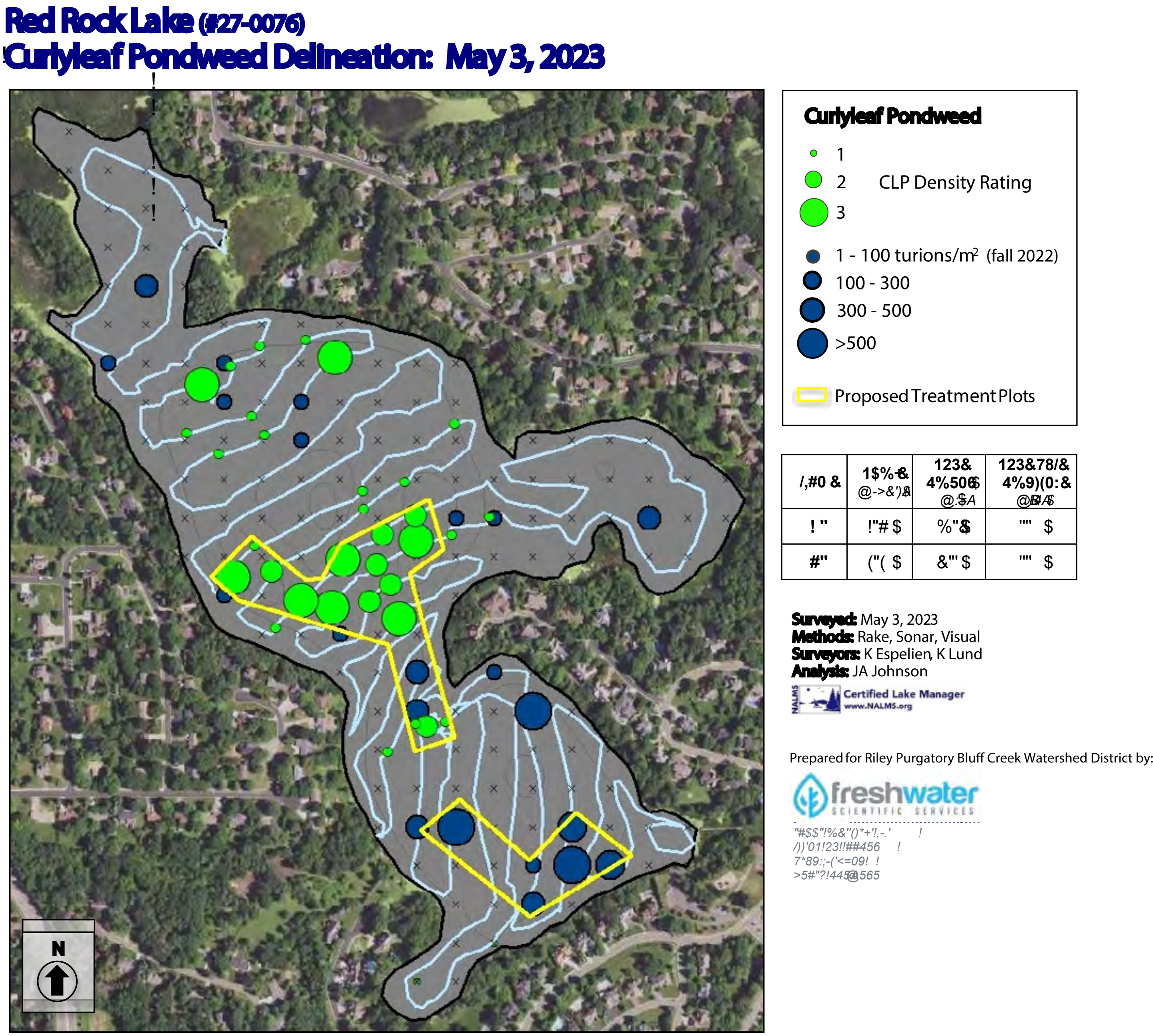


Figure I-4. **Lake Riley** Lake Curly-leaf Pondweed delineation and treatment area (9 acres).

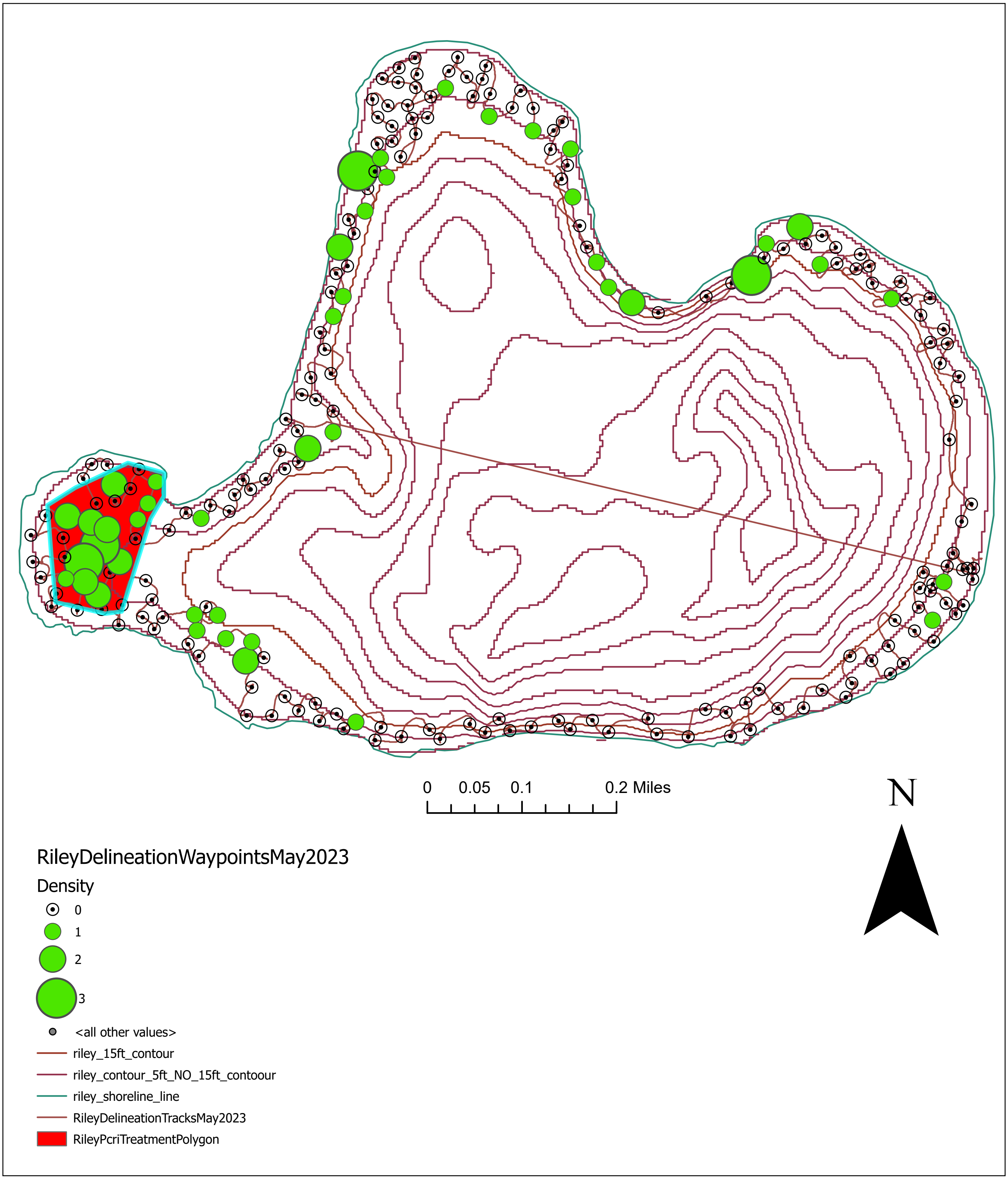


Figure I-5. **Lotus Lake** Eurasian Watermilfoil delineation and treatment area (22.92 acres).

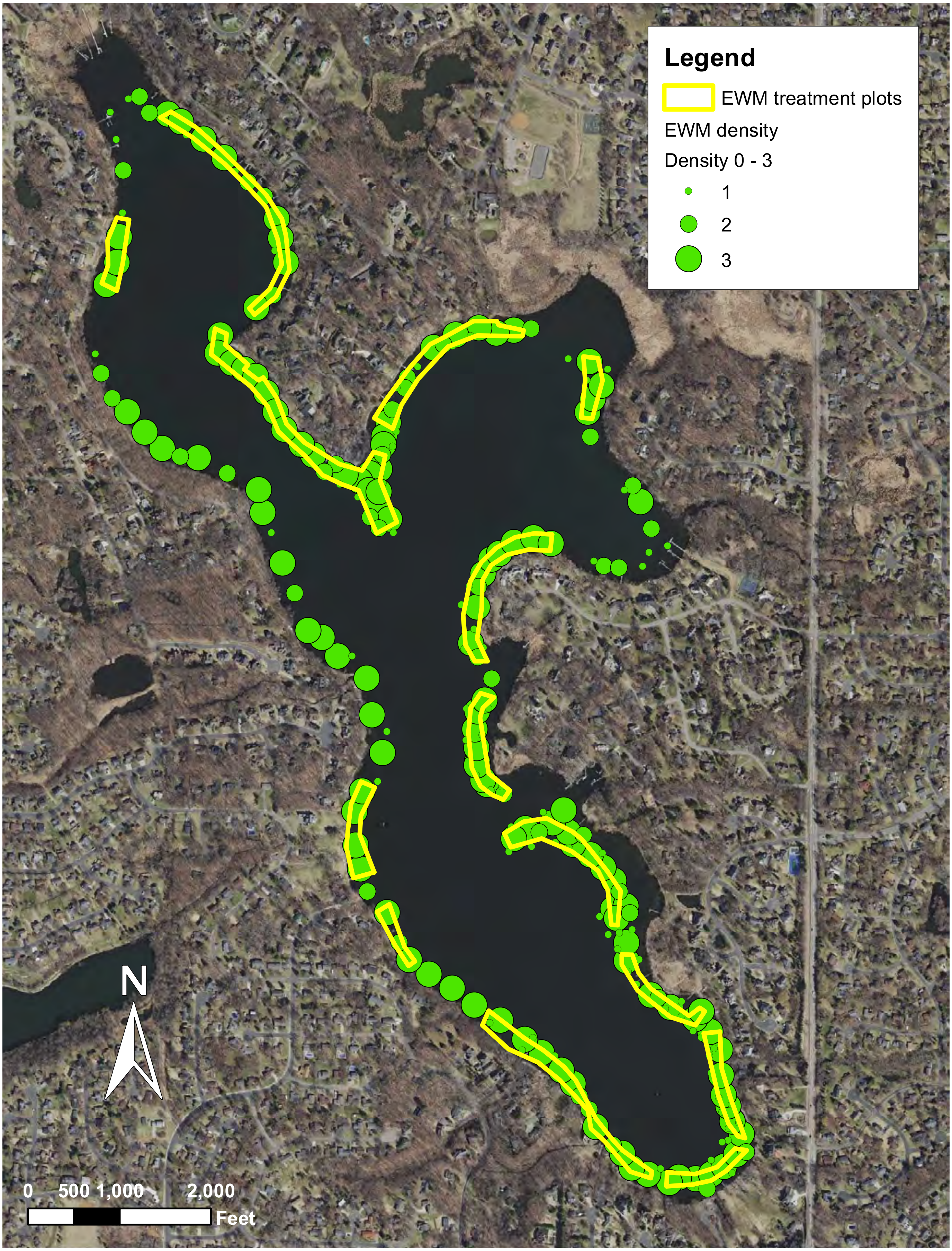


Exhibit K. Acronyms and Abbreviations

ac	acre
BMP	Best Management Practice
cBOD	5-day Carbonaceous Biochemical Oxygen Demand
cf	cubic feet
cfs	cubic feet per second
Chl-a	Chlorophyll-a
Cl	Chloride
CPUE	Catch Per Unit Effort
CRAS	Creek Restoration Action Strategy
CS	Chronic Standard
DO	Dissolved Oxygen
E. coli	*Escherichia coli* (bacteria)
EP	Eden Prairie
EPA	Environmental Protection Agency
EWM	Eurasian Watermilfoil
Ft	feet
FWSS	Freshwater Scientific Services
GPS	Global Positioning System
Ha	hectare
HAB	Harmful Algal Bloom
IBI	Index of Biological Integrity
in	inch
kg	kilogram
L	liter
lb	pound
m	meter
MCWD	Minnehaha Creek Watershed District
METC	Metropolitan Council
Mg	milligram
mL	milliliter
MNDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS	Maximum Standard
MS4	Municipal Separate Storm Sewer System
NA	Not available
NCHF	North Central Hardwood Forest
NH3	ammonia
NO2	Nitrite
NO3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NURP	National Urban Runoff Program
NWS	National Weather Service
OHWL	Ordinary High-Water Level
ORP	Oxidation Reduction Potential
Ortho-P	Orthophosphate
PAR	Photosynthetic Active Radiation
PCL	Purgatory Chain of Lakes
RCL	Riley Chain of Lakes
PI Survey	Point-intercept survey (approach to aquatic plant surveying using a grid sampling pattern)
RPBCWD/ District	Riley Purgatory Bluff Creek Watershed District
sec	second (unit of time)
sp	species