RILEY
PURGATORY
BLUFF CREEK
WATERSHED DISTRICT

Water Resources Report

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
2022 ANNUAL REPORT

protect. manage. restore.

Executive Summary

The Riley Purgatory Bluff Creek Watershed District (RPBCWD) had a successful water quality sampling season in 2022, 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 2022 sampling effort are presented in this report.

2022 LAKE SUMMARY

During the 2022 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). In addition to regular lake sampling, the district monitored water levels on each lake, assessed carp populations on seven waterbodies, and collected zooplankton and phytoplankton populations in five lakes. Staff were able to remove 440 common carp (1,581 lbs.) from the district in 2022, 376 of which were removed from the Purgatory Creek system. An estimated 23,852 goldfish were removed from stormwater ponds this past year most of which were from Kerber Pond west of Lotus Lake. The district also monitored public access points and analyzed water samples for the presence of zebra mussels in 14 waterbodies. Zebra mussel veligers and adults were found on Lake Riley in 2022 which was expected. A boat lift with desiccated mussels was found onshore on Lotus Lake. Water samples processed for eDNA on Carver County lakes tested negative for the presence of zebra mussels in 2022. This is the first time Lotus Lake has not tested positive since being added to the Minnesota Department of Natural Resources Infested Waters List in 2019. In 2022, point intercept vegetation surveys were conducted on Hyland Lake (Three Rivers Park District (TRPD)), Round Lake, Mitchell Lake, Red Rock, Rice Marsh (Eden Prairie) Lake Susan, Lake Riley, Lake Lucy, Lotus Lake, and Staring Lake (district). In the spring of 2022, herbicide treatments occurred on Lotus Lake, Staring Lake, Mitchell Lake, Riley Lake, Lake Susan, Hyland Lake, and Red Rock for curly leaf pondweed.

Surface water samples were collected, analyzed, and compared to standards set by the Minnesota Pollution Control Agency (MPCA) to assess overall lake health. Figure i displays lakes sampled in 2022 that met or exceeded the MPCA lake water quality standards for Chlorophyll-a (Chl-a), Total Phosphorus (TP), and Secchi Disk depth during the growing season (June-September). The MPCA has specific standards for both ‘deep’ lakes (Lake Ann, Lotus Lake, Lake Riley, and Round Lake) and ‘shallow’ lakes (Duck Lake, Hyland Lake, Lake Idlewild*, Lake McCoy*, Neill Lake*, Lake Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake) (MPCA 2016).

In 2022, lake water quality improved across the district with Lake Ann, Lake Lucy, Lake Riley, Rice Marsh Lake, Silver Lake, Round Lake, Duck Lake, Hyland Lake, and Lake Idlewild meeting all three MPCA standards. The Riley Chain of Lakes 2022 water quality remained unchanged from 2021. Following the past aluminum sulfate treatments, both Lake Riley and Rice Marsh Lake continued to meet all MPCA standards. Lake Susan had the most degraded water quality in 2022 and did not meet any of the standards. Of the Purgatory Chain of Lakes, Mitchell Lake improved from 2021 by meeting the TP while still not meeting the Chl-a standard. Following the 2022 alum treatment, Hyland Lake improved from 2021 by meeting all the standards. Staring Lake saw a decrease in water clarity and had significant increases in TP and Chl-a. This is due to a combination of the low water levels and the reduction in nonnative vegetation following the whole lake fluridone herbicide treatment. This led to increased suspension of sediment which should only improve as native plants expand in the lake. All lakes met the proposed nitrogen water quality standard and only Idlewild (wetland) did not meet the chloride standard.

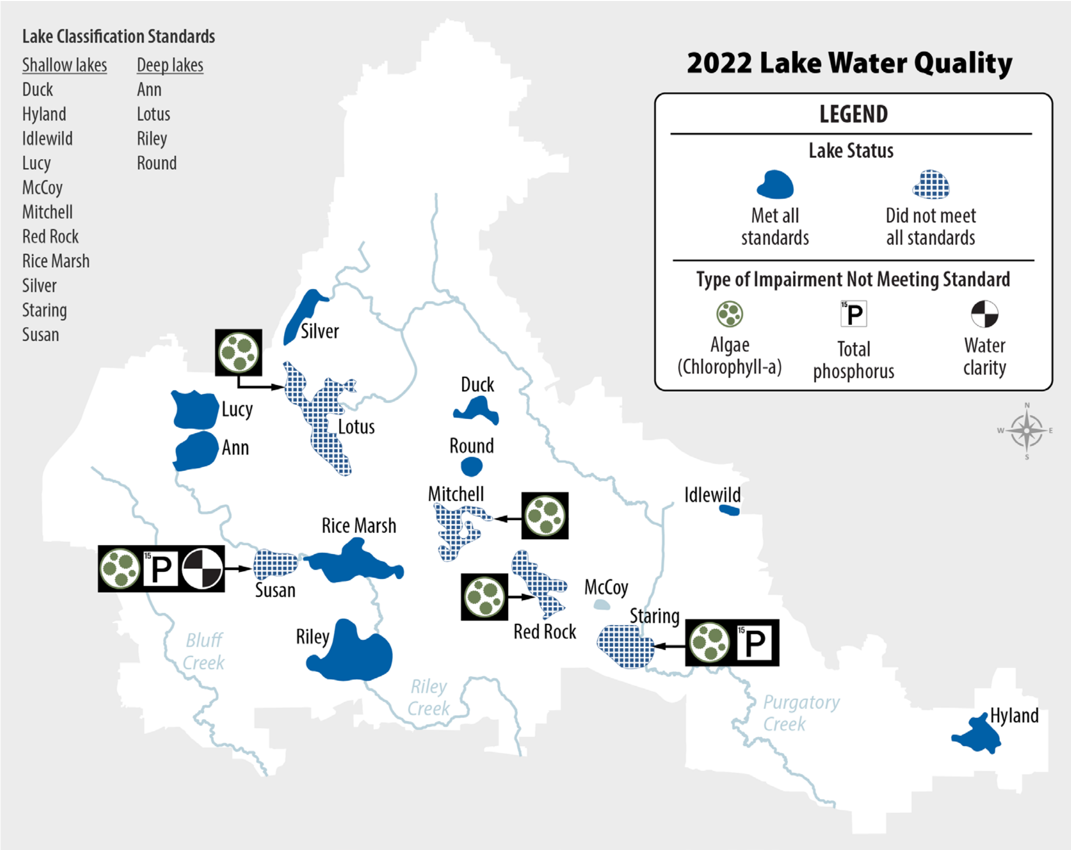


Figure i 2022 Lake Water Quality

Summary of the lake water quality data collected within the Riley Purgatory Bluff Creek Watershed District in 2022 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.

2022 STREAM SUMMARY

In 2022, the district and its partners collected water quality samples and performed data analysis on twenty-six different sampling sites along Riley Creek (six sites), Bluff Creek (seven sites), and Purgatory Creek (thirteen sites). During the 2022 creek monitoring season, (April-September) water chemistry and turbidity were regularly measured at the 18-regular water quality creek monitoring sites every two weeks. Water samples were collected to assess nutrients (TP, Ortho-Phosphorus (OP), Chloride (CL), and Chl-a) and total suspended sediment (TSS) concentrations. 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 near Staring Lake and two units along the upper Lotus Lake ravine to assess pollutant loads and the potential for restoration projects. An Enviro DIY unit was installed on middle Bluff to aid in potential project data gathering. Data was also collected on all three creeks near the confluence with the Minnesota River at the Metropolitan Councils Watershed Outlet Monitoring Stations. The district attempted to collect macroinvertebrates at all Purgatory Creek regular water quality monitoring sites in 2022, however due to the low water levels this year was skipped. All the past (four sites) and currently proposed stream restoration sites (Bluff Reach 5 and Riley Reach 4) in addition to Reach 1 of Riley Creek, Reach 2 of Riley Creek, both western Bluff tributaries, and Bluff Subreach B1A health were reassessed and updated using the Creek Restoration Action Strategy (CRAS) evaluation. Overall, most stream sections scored by the CRAS slightly improved from years past. The exceptions were Bluff Tributary 2, Riley Creek Reach 1 and 4, and Bluff Creek Subreach B1A which all declined in health.

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 and macroinvertebrates. The parameters measured during from April to September and the associated MPCA water quality limits for streams located in the Central River Region include Dissolved Oxygen (DO) daily minimum > 4 mg/L, summer season average TP < 0.1 mg/L, TSS < 10% exceedance of 30 mg/L limit during the summer season, summer season average Chl-a <18 ug/L, and summer season average pH < 9 su and >6 su (MPCA, 2016).

In 2022, the drought significantly impacted the streams. Of the 18 regular sampling sites, 11 went dry or became stagnant at some point. From 2021 to 2022, stream water quality remained relatively the same across the district. Excluding the dissolved oxygen impairment, the number of water quality standard impairments overall increased slightly from 2021 to 2022; Bluff had 11 (previously nine), Riley has had 11 the past two years, and Purgatory had nine the past two years. No regular creek sampling sites met all MPCA water quality standards assessed in 2022 (Figure ii). Like previous years, TP was the water quality standard causing the most impairments in 2022 with 12 of the 18 sites not meeting the standard. TSS impairments were slightly reduced from 2021. Seven (previously five) sites were impaired. Prior to 2021, Bluff Creek has had the most impairments. The extremely low flows seen in 2022 led to reduced oxygen levels and concentrated nutrients in the stream. These factors combined led to the slight increase in impairments. MPCA macroinvertebrate impairments included lower reaches of Riley and Purgatory Creek. Lower reaches of Riley and Bluff Creek had fish impairments.

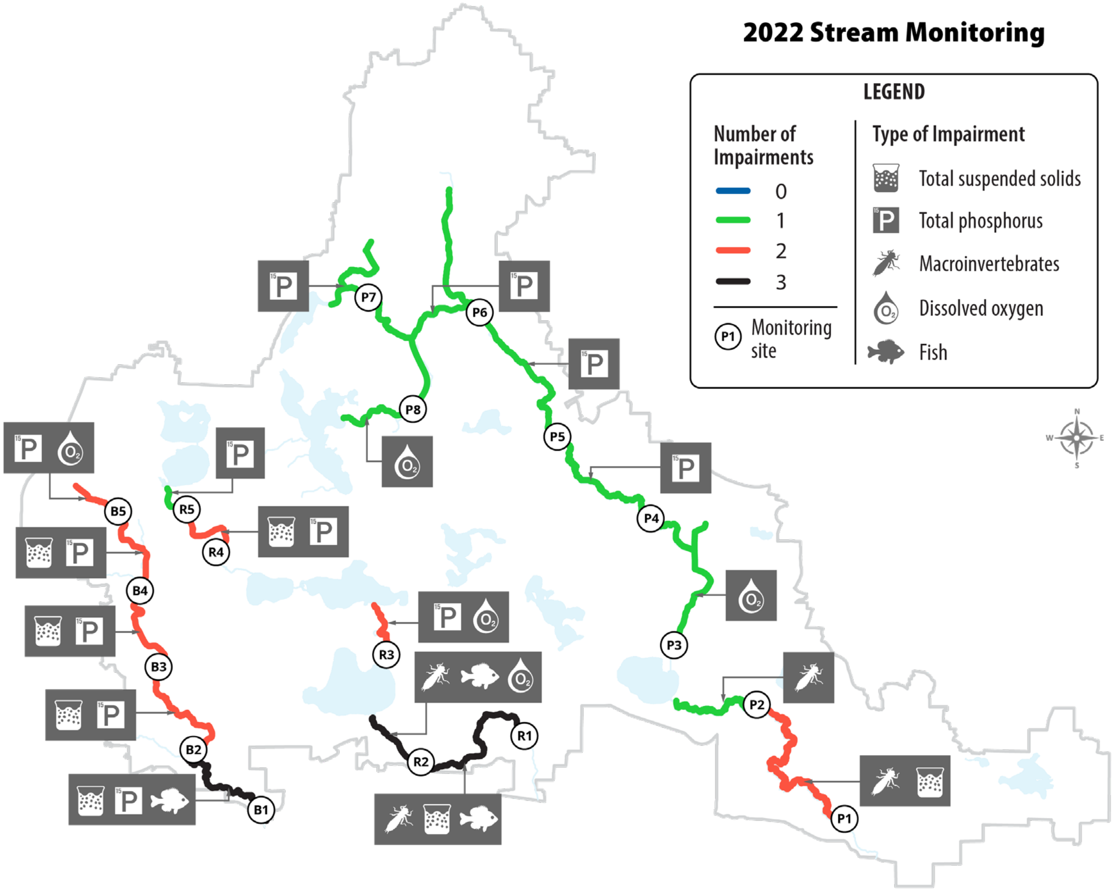


Figure ii 2022 Stream Water Quality

2022 stream water quality data from Bluff Creek, Riley Creek, and Purgatory Creek in the Riley Purgatory Bluff Creek Watershed District as compared to the Minnesota Pollution Control Agency (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 ug/L, average pH < 9 su and > 6 su. The corresponding labels next to each stream section indicate which water quality standards were not met.

Table of Contents

List of Figures

List of Tables

List of Exhibits

Acronyms & 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*
EP	Eden Prairie
EPA	Environmental Protection Agency
EWM	Eurasian Watermilfoil
Ft	Foot/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
NH_3	Ammonia
NO_2	Nitrite
NO_3	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 pattern)
RPBCWD/District	Riley Purgatory Bluff Creek Watershed District
Sec	Second
Sp.	Species

SRP	Soluble Reactive Phosphorus
TDP	Total Dissolved Phosphorus
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TPA	Total Phytoplankton Abundance
TP	Total Phosphorus
TRPD	Three Rivers Park District
TSS	Total Suspended Solids
UAA	Use and Attainability Assessment
UMN	University of Minnesota-St. Paul Campus
WD	Watershed District
WIDNR	Wisconsin DNR
WHO	World Health Organization
WMO	Watershed Management Organization
YOY	Young of Year

1 Introduction and Overview

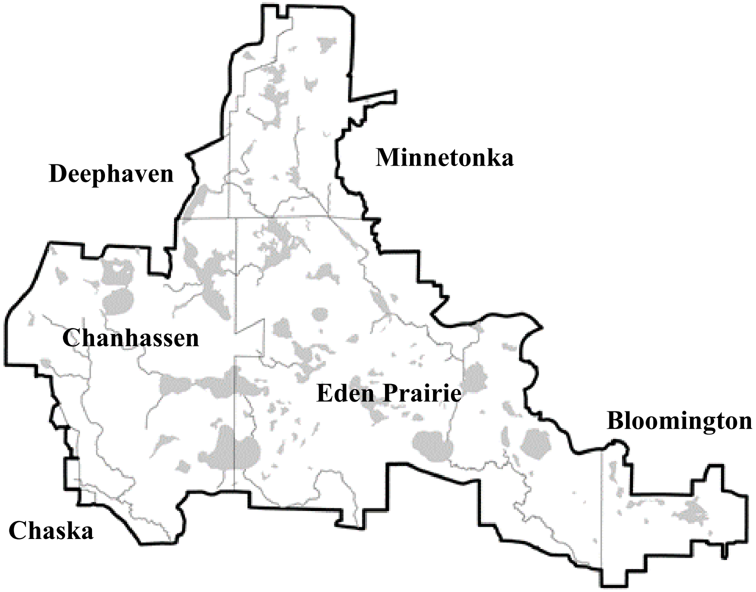


Figure 1-1 Riley Purgatory Bluff Creek Watershed District Boundary

The Riley Purgatory Bluff Creek Watershed District was established on July 31st, 1969, by the Minnesota Water Resources Board acting under the authority of the watershed law. The district is in the southwestern portion of the 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 1-1*). This total area for the watershed is close to 50 square miles located in both Hennepin and Carver Counties and includes three smaller sub watersheds: Riley Creek Watershed, Purgatory Creek Watershed, and Bluff Creek Watershed.

Data collection and reporting are the foundation for the RPBCWD's work. Regular, detailed water quality monitoring provides the district with scientifically reliable information that is needed to decide if water improvement projects are needed and how effective they are in the watershed. Data collection remains a key component of the district's work as we strive to de-list, protect, and improve the water bodies 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.

Table 1-1 Water Resources Sampling Partnerships

Water Resource	RPBCWD	Three Rivers Park District	Eden Prairie	Metropolitan Council	Carver County
Duck Lake	■				
Hyland Lake	■	■			
Lake Ann	■				■
Lake Idlewild	■				
Lake Lucy	■				
Lake Riley	■				
Lake Susan	■				■
Lotus Lake	■				■
McCoy	■				
Mitchell Lake	■		■		
Red Rock Lake	■		■		
Rice Marsh Lake	■				
Round Lake	■		■		
Silver Lake	■				
Staring Lake	■				
Bluff Creek	■			■	
Purgatory Creek	■			■	
Riley Creek	■		■	■	

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 2022, the district and its partners collected water quality samples and performed data analysis on 26 different sampling sites along Riley Creek (six sites), Bluff Creek (seven sites), and Purgatory Creek (thirteen sites). Each partner was responsible for monitoring certain parameters of their respective lakes/streams and reporting their findings, allowing for more time and attention to be given to each individual water resource (*Table 1-1).* Monitoring frequency and intensity depended on the reasoning behind each site being monitored.

Water quality and water quantity was monitored at each regular stream site during the field season (April-September) approximately 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 (WOMP) or long-term monitoring program which identifies pollutant loads entering the Minnesota River. District EnviroDIY stations were also installed at some stream locations to gather more information. In addition to water quality monitoring, creek walks were also conducted to gather more information about the current stream conditions in the district. This information was included in the Creek Restoration Action Strategy (CRAS), which was developed by the district to identify and prioritize future stream restoration sites. Bank pin data was collected near each of the water quality monitoring sites to measure generalized sedimentation and erosion rates across all three streams. Macroinvertebrates were not collected in 2022 due to the low water levels.

Lakes were also monitored bi-weekly during the summer growing season (June-September) for water quality. Lake levels were continuously recorded from ice out to ice in. Lake water samples were also 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 also 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 plant community and to search/treat for invasive plants. Common Carp have been identified as being detrimental to lake health and are continually monitored by the district. Winter monitoring occurred on the Riley Chain of Lakes as well as three separate stormwater ponds in 2022. Extending the monitoring activities into the 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 and can be seen in *Table 1-2*. 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 1-2 Monthly Field Data Collection Locations

Water Resource	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Ann	■	■	■		■	■	■	■	■	■		
Duck Lake	■	■	■		■	■	■	■	■	■		
Hyland Lake					■	■	■	■	■	■		
Lake Idlewild					■	■	■	■	■	■		
Lotus Lake					■	■	■	■	■	■		
Lake Lucy	■	■	■		■	■	■	■	■	■		
McCoy												
Mitchell Lake					■	■	■	■	■	■		
Neil Lake					■	■	■	■	■	■		
Red Rock Lake					■	■	■	■	■	■		
Rice Marsh Lake	■	■	■		■	■	■	■	■	■		
Round Lake					■	■	■	■	■	■		
Lake Riley	■	■	■		■	■	■	■	■	■		
Staring Lake	■	■	■		■	■	■	■	■	■		
Lake Susan	■	■	■		■	■	■	■	■	■		
Silver Lake					■	■	■	■	■	■		
Bluff Creek	■	■	■	■	■	■	■	■	■	■	■	■
Purgatory Creek	■	■	■	■	■	■	■	■	■	■	■	■
Riley Creek	■	■	■	■	■	■	■	■	■	■	■	■

*Water Level Sensors were placed on all lakes.

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 the water quality and quantity data during the field-monitoring season. *Table 2-1* identifies many of the different chemical, physical, and biological variables analyzed to assess overall water quality.

Table 2-1 Sampling Parameters

Parameter	Analysis	Summer Lakes	Winter Lakes	Streams	Reason for Monitoring
Total Phosphorus	Wet	■	■	■	Nutrient, phosphorus (P) controls algae growth
Orthophosphate	Wet	■	■	■	Nutrient, form of P available to algae
Total Dissolved Phosphorus	Wet			■	Fraction of total phosphorus in solution
Chlorophyll-a, pheophytin	Wet	Surface	Surface	■	Measure of algae concentration
Ammonia as N	Wet	■	■		Nutrient, form of nitrogen (N) available to algae
Nitrate + Nitrite as N	Wet	■	■		Nutrient, also oxygen substitute for bacteria
Total Kjeldahl Nitrogen	Wet	■			Nutrient, sum of nitrogen bound in organics
Calcium	Wet	■			Measure of water hardness
Total Alkalinity, adjusted	Wet	Surface	Surface		Measure of ability to resist drop in pH
Total Suspended Solids	Wet			■	Measure of the solids in water (block light)
Chloride	Wet	■	■	■	Measure of chloride ions, salts in water
Temperature	Sonde	■	■	■	Impacts biological and chemical activity in water
pH	Sonde	■	■	■	Impact chemical reactions (acidic or basic)
Conductivity	Sonde	■	■	■	Ability to carry an electrical current (TSS & Cl)
Dissolved Oxygen	Sonde	■	■	■	Oxygen for aquatic organisms to live
Macroinvertebrates	Wet			■	Organisms fluctuate due to environmental variables
Oxidation Reduction Potential	Sonde	■	■	■	Tracks chemistry in low or no oxygen conditions
Phycocyanin	Sonde	■	■		Pigment, measures cyanobacteria concentration
Phytoplankton	Wet	■			Organisms fluctuate due to environmental variables
Photosynthetic Active Radiation	Sonde	■	■		Measure of light available for photosynthesis
Turbidity	Sonde			■	Measure of light penetration in shallow water
Secchi disk depth	Observation	■	■		Measure of light penetration in deeper water
Transparency Tube	Observation			■	Measure of light penetration into shallow water
Zooplankton	Wet	■			Organisms fluctuate due to environmental variables
Zebra Mussel Veligers	Wet	■			Larval form of zebra mussels/plate checks (AIS)

2.1 Water Quality Sampling

The data collection and monitoring program supports the district’s 10-year water management plan to delist waters from the MPCA's 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.

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, photosynthetic active radiation (PAR), oxidation reduction potential (ORP), and phycocyanin. Secchi disk depth readings were recorded at the same time as sonde readings were collected 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, or 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 the shallow depths (2-3 m). 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 (>1-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 2 m 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 0.5 meters 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 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 2-2*.

Table 2-2 Basic 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 (steadily pulling a net) from Lake Bottom to Top Collect Phytoplankton (2 m surface composite sample) Collect Zebra Mussel Veliger Tow (pulling a 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

2.2 Analytical Laboratory Methods

RMB Environmental Labs, located in Bloomington, MN, is the third-party company that is responsible for conducting analytical tests on the water samples that were collected by the district staff. The methods used by the laboratory to analyze the water samples for the specified parameters are noted in *Table 2-3*.

Additional samples were sent to the Metropolitan Council (METC), St. Paul, MN. These samples included quality samples for the Watershed Outlet Monitoring Program (WOMP) and general samples that were not able to be sent to RMB Labs. Macroinvertebrate samples were sent to Dean Hansen formerly of the University of Minnesota and all phytoplankton samples were sent to Green Water Labs for identification. Zebra mussel veliger samples were processed by Kylie Cattoor.

Table 2-3 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 Standards

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 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 water bodies 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 water bodies from being added to the 303d Impaired Water Bodies list (MPCA). The district is also charged with the responsibility to take appropriate actions to improve the water quality in water bodies that are currently listed for impairments.

There are seven ecoregions within Minnesota; the 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. Water bodies 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's 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 specific standards for both ‘deep’ lakes (lakes >15 ft deep and < 80% of the total lake surface area able to support aquatic plants – littoral area), and ‘shallow’ lakes (lakes <15 ft deep and >80% littoral area. Except for chlorides, summer growing season (June-September) averages of the parameters listed in *Table 3-1* 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 water bodies. Water samples are collected and sent to an analytical lab to assess concentrations of TP, Chl-a, and chlorides. If result values are greater than the standards listed in *Table 3-1*, 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 MN, especially during the winter when road salt is heavily used. Targeted sampling occurs during the winter, early spring melting periods when salts are being flushed through our waterbodies, and monthly during the summer to set a base line. The Cl standard is the same for both deep lakes and shallow lakes. *Table 3-1* includes both the Cl chronic standard (CS) and a maximum standard (MS). The CS is the highest water concentration of Cl to which aquatic life, humans, or wildlife can be exposed to indefinitely without causing chronic toxicity. The MS is the highest concentration of Cl in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality.

Table 3-1 MPCA Water Quality Standards for Shallow and Deep Lakes

Parameter	Shallow Lakes Criteria	Deep Lakes Criteria
Total Phosphorus (mg/L)	≤ 0.060	≤ 0.040
Chlorophyll-a (ug/L)	≤ 20	≤ 14
Secchi Disk (m)	≥ 1	≥ 1.4
Chloride Chronic Standard (mg/L)	230	230
Chloride Maximum Standard (mg/L)	860	860

3.2 Streams

Table 3-2 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 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 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 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 ug/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.

Table 3-2 MPCA Stream Water Quality Standards

MPCA Standard	Parameter	Criteria
Eutrophication	Phosphorus	≤ 100 ug/L
	Chlorophyll-a (seston)	≤ 18 ug/L
	Diel Dissolved Oxygen	≤ 3.5 mg/L
	Biochemical Oxygen Demand	≥ 2 mg/L
	pH Max	≤ 9 su
	pH Min	≥ 6.5 su
Total Suspended Solids	TSS	≤ 30 mg/L

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.

4 Water Quality 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 in 2022.

4.1 2022 Lakes Eutrophication Water Quality Summary

More information about lake nutrient and water clarity data can be seen in the Fact Sheets which are located on the district website (rpbcwd.org) and Nutrient Summary Table in *Exhibit E*. Sonde lake profile data can be viewed in *Exhibit G*.

Chlorophyll-a

The 2022 growing season Chl-a mean concentrations for all lakes sampled within the district are shown in Figure 4-1 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 2022. Lake McCoy values were not applied in 2022 due to extreme low water conditions. Overall, eight of 14 lakes sampled in 2022 met the MPCA Chl-a standards for their lake classification (eight lakes in 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.

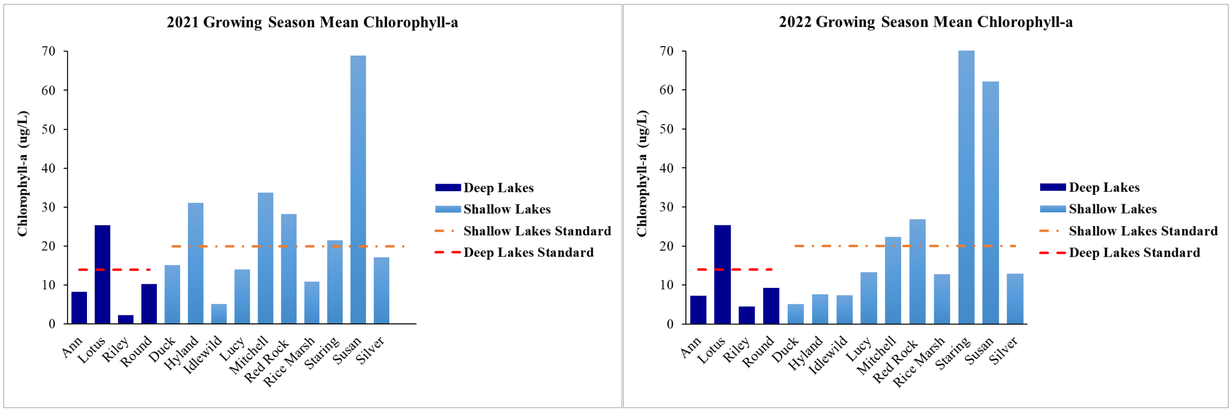


Figure 4-1 2021-2022 Lakes Growing Season Mean Secchi Depth

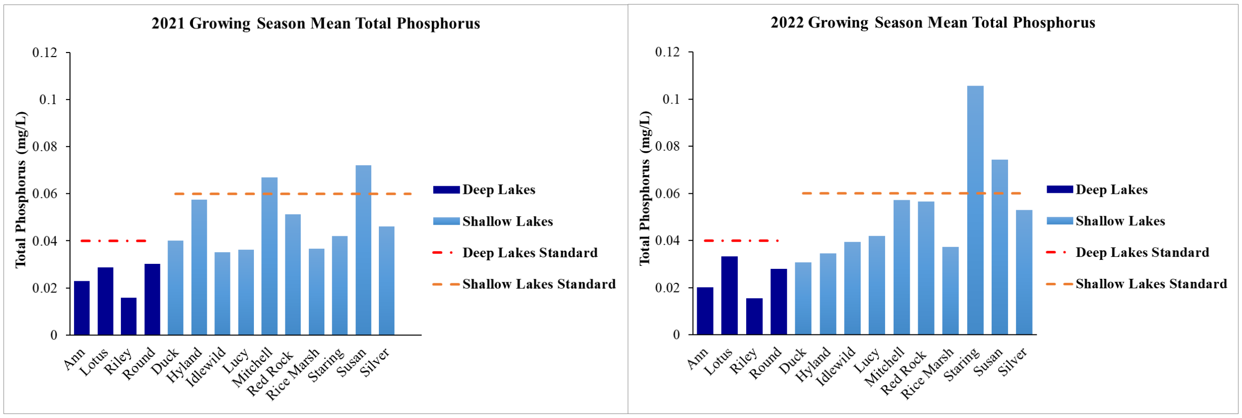
Lakes growing season (June-September) mean chlorophyll-a concentrations (ug/L) for shallow (lakes <15 ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15 ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2021 and 2022. The dashed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

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. Due to the past alum treatment, Lake

Riley had the lowest summer Chl-a average of all lakes sampled in 2022 at 4.5 ug/L. (2.3 ug/L in 2021 and 2.8 ug/l in 2020). Similar to 2019-2021, Lotus Lake did not meet the standard and had Chl-a average concentrations at 25.35 ug/L (an improvement of 8 and 9 ug/L from 2019 and 2020). The remainder of the lakes sampled in 2022 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 Hyland Lake and were well below the MPCA standard in 2022 (7.6 ug/L). These concentrations were also significantly below 2021 concentrations (31.1 ug/L). Idlewild, Lucy, Red Rock, Rice Marsh, and Silver remained similar to what was seen in 2021 with only Red Rock Lake not meeting the standard of that list (26.93 ug/L). Similar to 2021, Mitchell Lake and Lake Susan did not meet the MPCA standard in 2022 although they both showed a slight improvement. Lake Susan continued to have high Chl-a concentrations (62.2 ug/L) similar to what has been seen in the past (51.5 ug/L in 2020, 69 ug/L in 2021. Duck Lake had reduced Chl-a levels decreasing from 15.18 ug/L in 2021 to 5.19 ug/L in 2022. Staring Lake Chl-a levels increased significantly from 2021 (21.52 ug/L) and had 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.

Total Phosphorus

The TP growing season averages for all lakes sampled within the district in 2022 are shown in Figure 4-2. Overall, twelve of the 14 lakes sampled met the MPCA total phosphorus standard for their lake classification in 2022: Lake Ann, Lotus Lake, Lake Riley, Round Lake, Duck Lake, Lake Hyland, Lake Idlewild, Lake Lucy, Mitchell Lake, Red Rock, Rice Marsh Lake, and Silver Lake. This is the same number of lakes as 2021 but represents an increase from eight lakes not achieving the TP standard in 2020 and 11 lakes in 2019.



2021 Growing Season Mean Total Phosphorus

2022 Growing Season Mean Total Phosphorus

Figure 4-2 2021-2022 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 2021 and 2022. 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).

The MPCA standard for TP in deep lakes (<0.040 mg/L) was met by Lake Ann, Lotus Lake, Lake Riley, and Round Lake in 2022. All deep lake TP concentrations in 2022 remained relatively the same from what was seen in 2021. Following the second dose of the alum treatment in May of 2020, Lake Riley continues to have the lowest summertime average TP concentration (0.015 mg/L) across all lakes sampled (2020-0.0178 mg/, 2021-0.016 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, Rice Marsh Lake, and Silver Lake in 2022. Lake Susan and Staring Lake both did not meet the MPCA TP standard in 2022. Susan had concentrations similar to 2020 (0.073 mg/L), while Staring Lake significantly increased from 2021 (0.042 mg/L) to 2022 (0.106 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). 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.

Secchi Disk

The 2022 secchi disk growing season means for all district lakes sampled are shown in Figure 4-3. Overall, water clarity in most lakes stayed the same or improved 2022 except for Lake Susan which declined.

The MPCA standard for secchi disk depth/water clarity for deep lakes (> 1.4 m) was met by all deep lakes in 2022. Lotus did not meet the standard in 2020 (1.24 m) but met the standard in 2021 and 2022 (1.51 m). Lake Riley had the highest summer average for all lakes sampled in 2022 and the average was only slightly down (3.96 m) from 2021. The 2021 secchi of 4.82 m was the highest recorded since data collection began in 1971 on the lake. For shallow lakes, the MPCA standard was not met by only Lake Susan. Red Rock had the lowest (worst) secchi reading at 0.66 m in 2020 but improved 1.5 m in 2021 and was sustained in 2022 (1.48 m). Duck, Rice Marsh, and Lucy had secchi readings near 2 m and Hyland was reduced from 2.05 m in 2020 to 1.14 m in 2021 but increased to 1.67 m in 2022 following the spring alum treatment. Mitchell Lake did not meet the standard in 2020 (0.93 m) but improved in 2021 and met the standard (1.13 m) which further improved in 2022 (1.76 m).

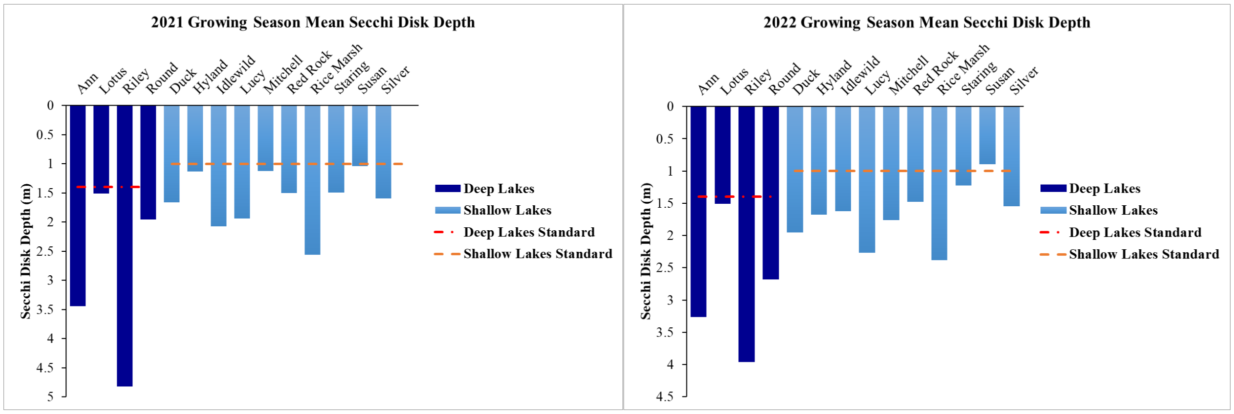


Figure 4-3 2021-2022 Lakes Growing Season Mean Secchi Disk Depth

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 2021 and 2022. 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 actively 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 as 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 in the district can be found in *Table 4-1*. 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 to evaluate their success 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 Fact Sheets located on the district website (rpbcwd.org) and Nutrient Summary Table in *Exhibit E*.

Table 4-1 Aluminum Sulfate Treatments in RPBCWD

Lake	First Dose	Second Dose
Riley	5/5/2016	6/11/2020
Lotus	9/18/2018	2023
Rice Marsh	9/21/2018	TBD
Round	11/15/2012	10/24/2018
Hyland	6/3/2019	5/18/2022

Figure 4-4 through Figure 4-8 illustrate epilimnetic and hypolimnetic 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 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 and Chlorophyll-a levels were improved which led to most lakes meeting all three water quality standards after treatment (exception Lotus Lake). In *Table 4-2* 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 four years of post-treatment data, it appears Rice Marsh and Hyland Lake were very effective alum treatments with phosphorus reductions of surface phosphorous 51% and 54% respectively. Hyland Lake was treated with the second dose in the spring of 2022 and had a reduction and the percent decrease increased slightly to 56%. Rice Marsh will be treated with the second dose in 2024. Despite having a smaller reduction in total phosphorus at the surface, Round Lake had reductions in lake bottom total phosphorus comparable with the other treated lakes (85% (dose 1) and 87% (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 m. Overall, comparing pre and post treatment years, Lake Riley had a reduction of total phosphorus of 68% at surface and 92% near the lake bottom phosphorus. After the first dose of alum in Lotus Lake, water quality did not respond as well as seen across other lakes (only 35% surface and 64% bottom). This may be due to the high phosphorus release rates observed from the sediment cores taken and because the untreated, shallower areas 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 more robust results. The district monitored TP and OP in both deep-water basins that received alum (south and east) in Lotus Lake to gauge phosphorus release rates 2021 and 2022. Both basins had similar summer average surface concentrations (0.032-0.033 and 0.03-0.035 mg/L respectively). Bottom summer averages were slightly different with the south bay (normal monitoring location) having higher concentrations at 0.185 mg/L in 2021 and 0.238 mg/L in 2022 vs 0.146 mg/L in 2021 and 0.171 mg/L in 2022 measured in the east bay.

Table 4-2 Aluminum Sulfate Effectiveness on Lake Surface and Bottom Total Phosphorus

Surface TP		Dose 1		Dose 2		
Lake	Years	Average TP Pre	Average TP Post	% Reduction	Average TP Post	% Reduction
Riley	2009-2022	0.0457	0.0267	41	0.0160	65
Lotus	2014-2022	0.0540	0.0349	35	Not Complete	
Rice Marsh	2015-2022	0.0745	0.0366	51		
Round	2008-2022	0.0415	0.0388	6	0.0313	24
Hyland	2016-2022	0.0819	0.0375	54	0.0360	56

Bottom TP		Dose 1		Dose 2		
Lake	Years	Average TP Pre	Average TP Post	% Reduction	Average TP Post	% Reduction
Riley	2009-2022	0.5334	0.1684	68	0.0418	92
Lotus	2014-2022	0.5423	0.1925	64	Not Complete	
Rice Marsh	2015-2022	0.1217	0.0362	70		
Round	2008-2022	0.8945	0.1376	85	0.1184	87
Hyland	No Data					

*D1=dose 1; D2= dose 2

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 second dose application and gauge temporal success of each treatment.

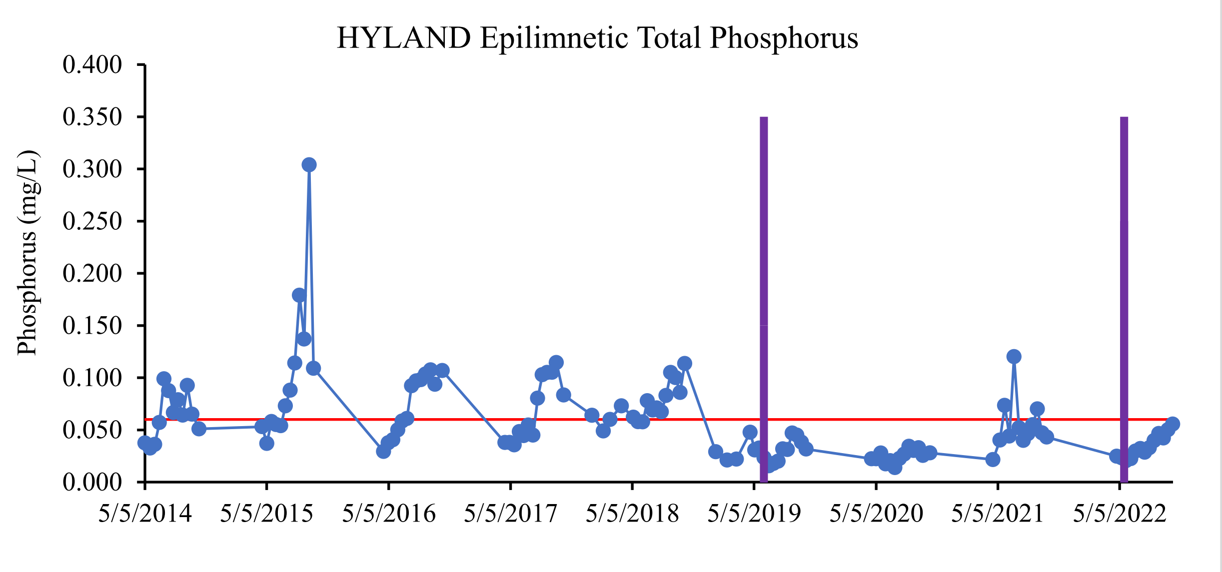


Figure 4-4 Hyland Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Hyland Lake between May 5, 2014 and October 11, 2022. 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).

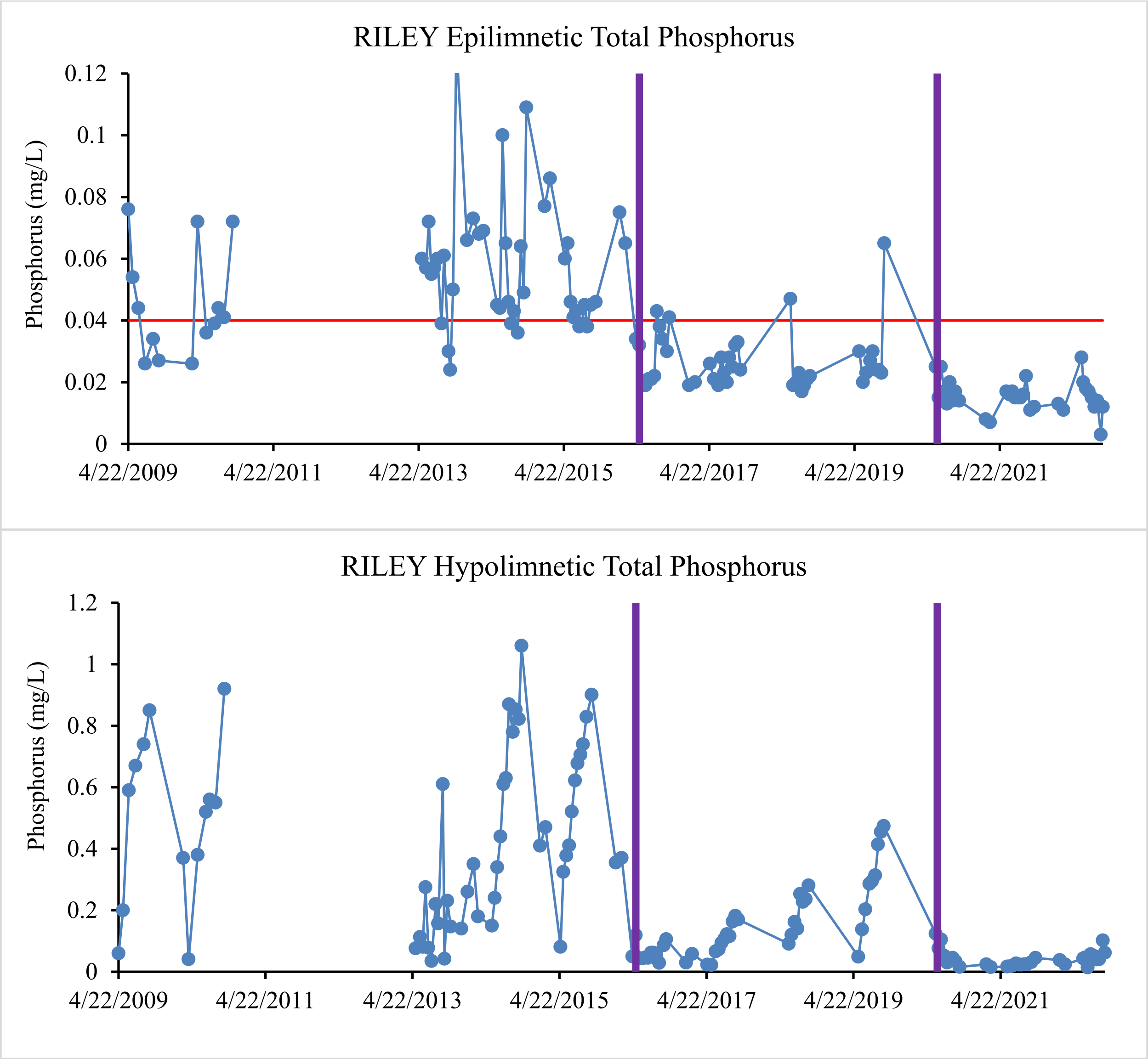
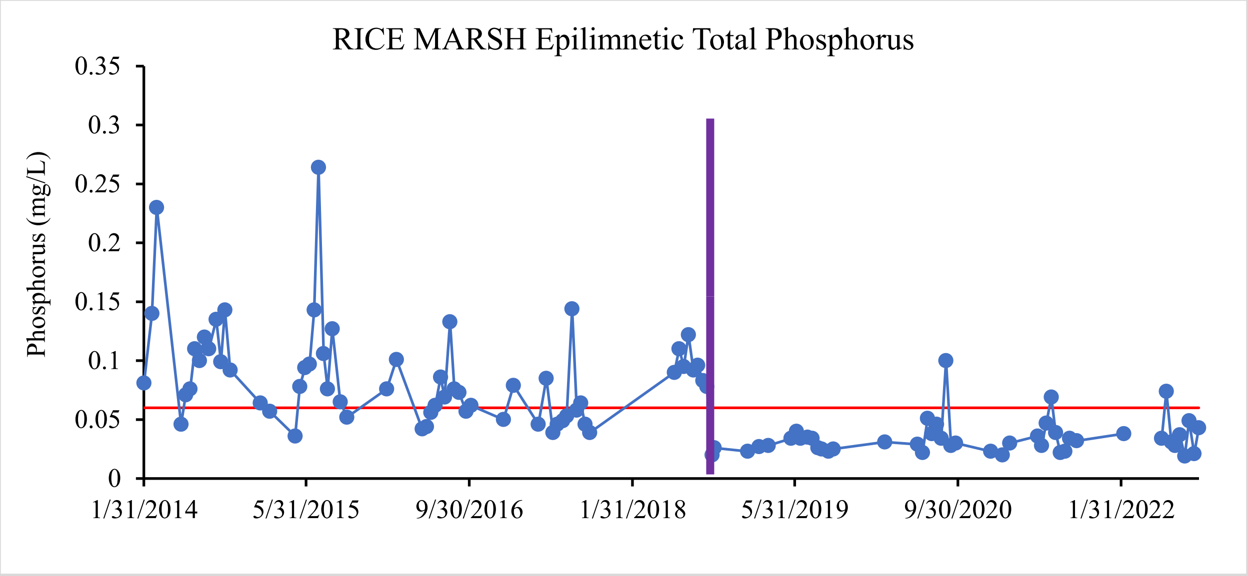


Figure 4-5 Lake Riley Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lake Riley between April 22, 2009 and September 22, 2022. 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).



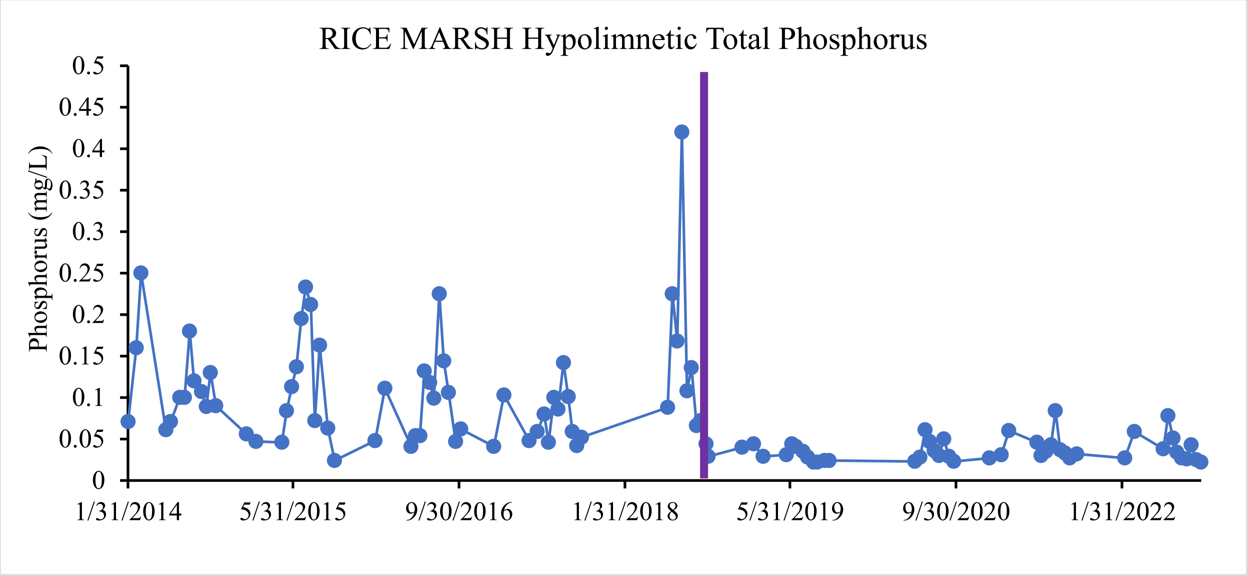
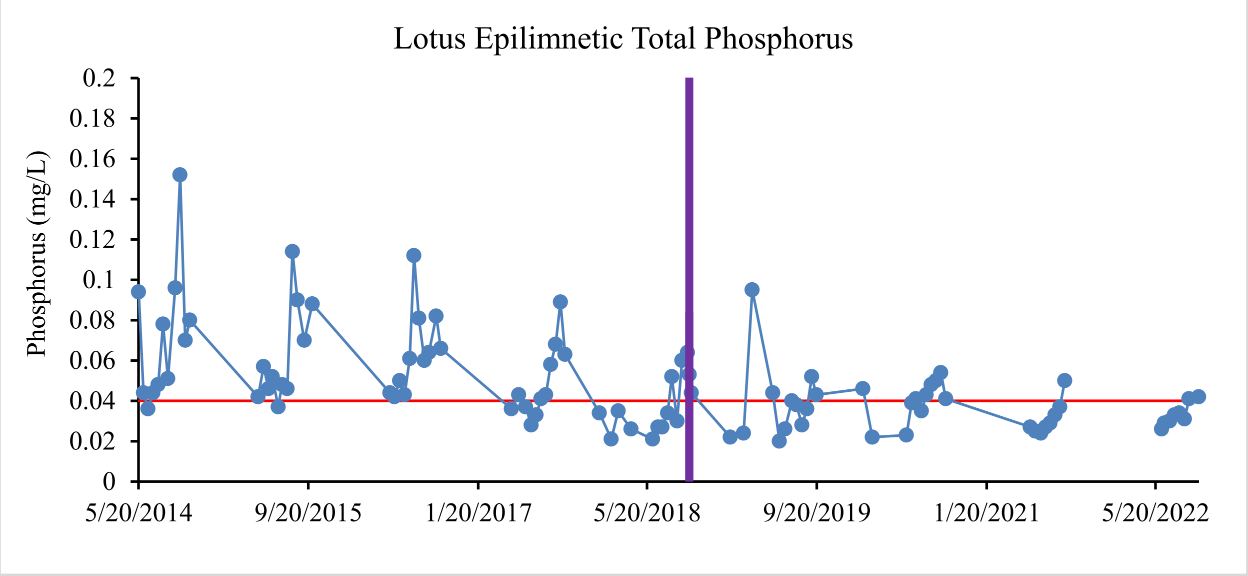


Figure 4-6 Rice Marsh Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Rice Marsh Lake between January 31, 2014 and September 20, 2022. 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).



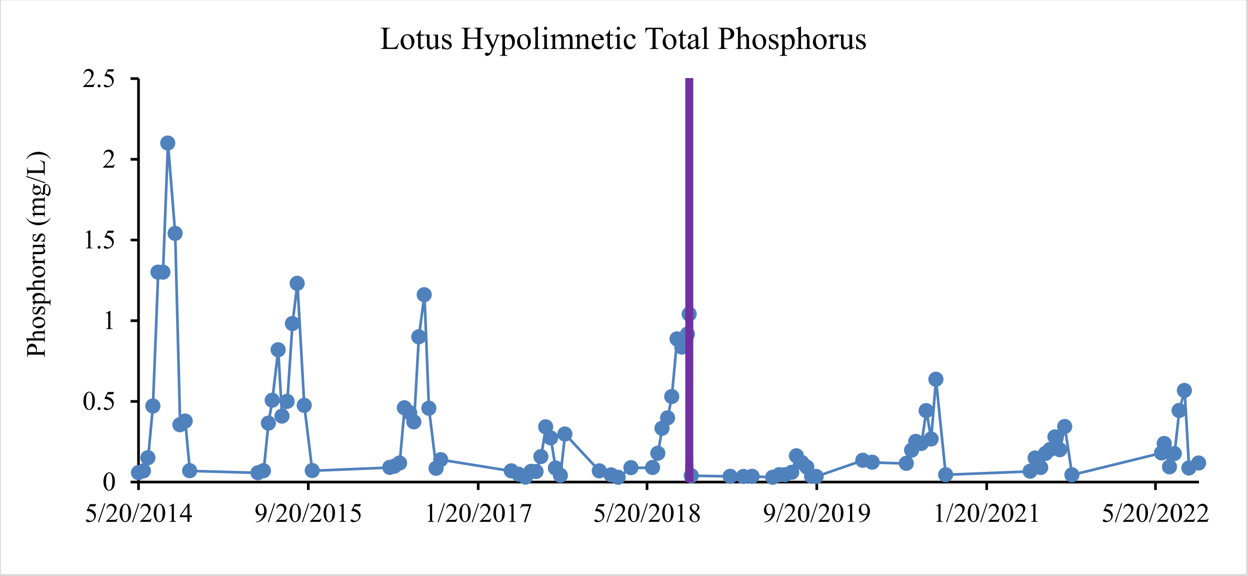


Figure 4-7 Lotus Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lotus Lake between May 20, 2014 and September 21, 2022. 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).

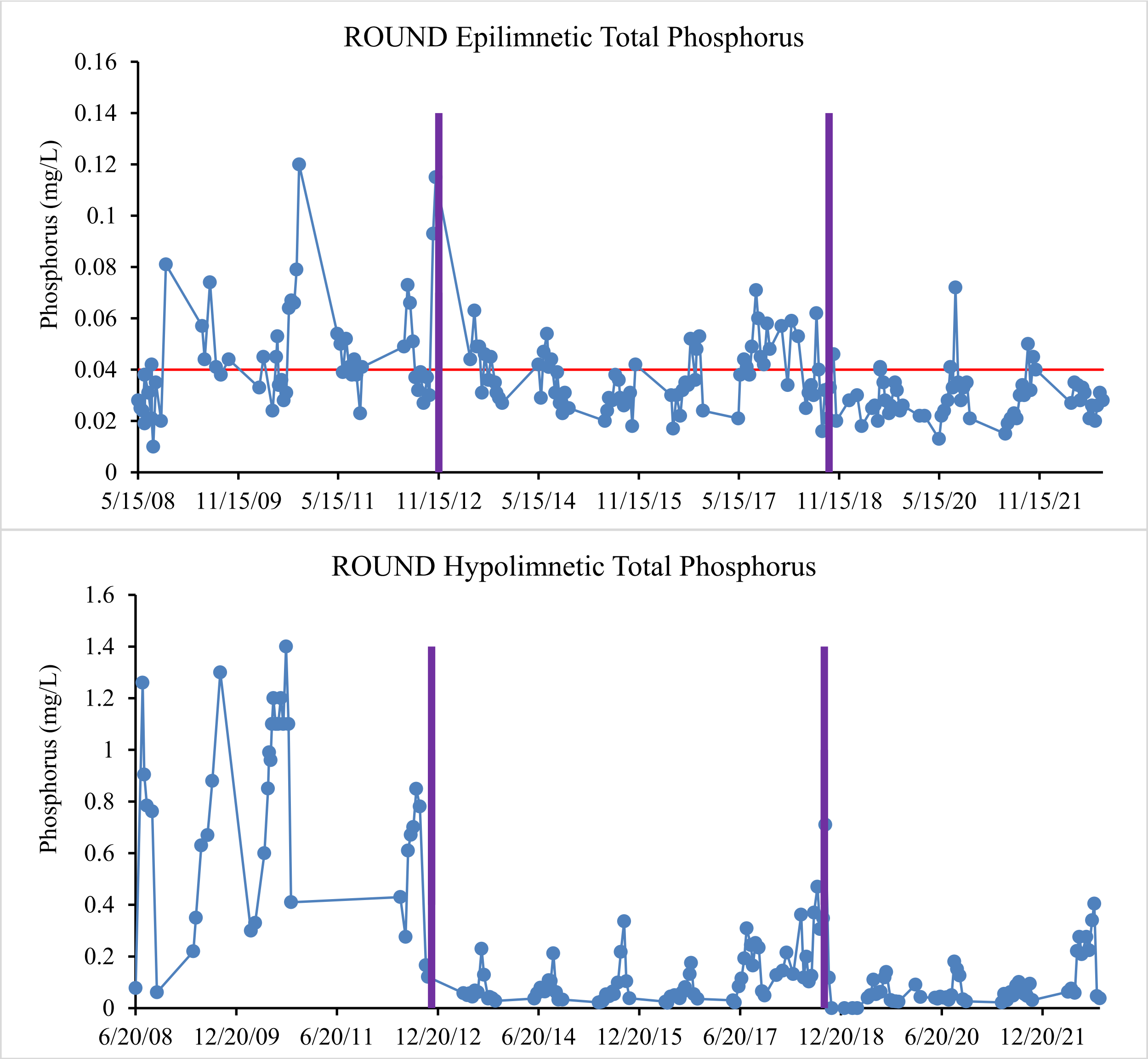


Figure 4-8 Round Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Round Lake between May 15, 2008 and October 27, 2022. 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


Figure 4-9 Heavy Salt Application

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, Cl 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 2019, staff carried out Cl sampling in lakes and streams every other week during the spring, switching to monthly sampling in summer/fall/winter. In 2022, 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 2 m composite sample (when possible) and a bottom water sample to be analyzed for Cl.

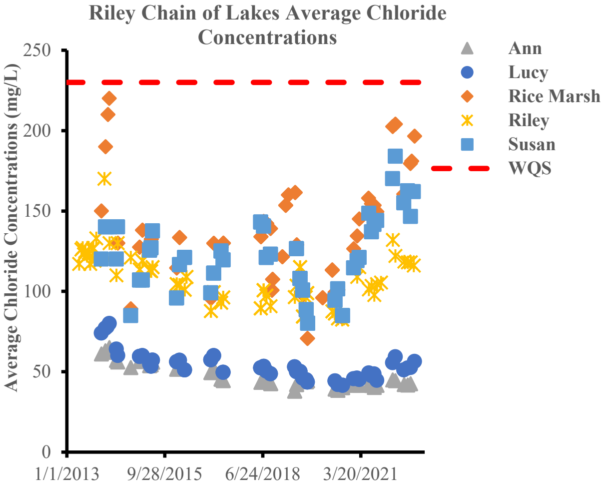


Figure 4-11 2013-2022 Chloride Levels within the Riley Chain of Lakes

All average chloride sampling results (mg/L) on the Riley Chain of Lakes from 2013-2022. The MPCA chloride chronic standard for class 2B waters (230 mg/L) is indicated by the red line.

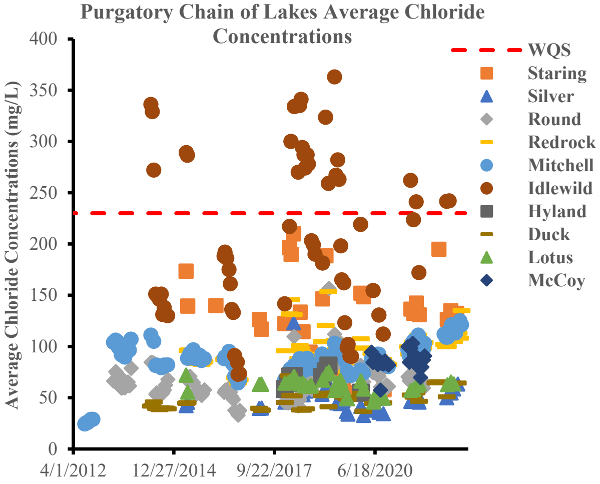


Figure 4-10 2013-2022 Chloride Levels within the Purgatory Chain of Lakes

All average chloride sampling results (mg/L) on the Purgatory Chain of Lakes from 2013-2022. The MPCA chloride chronic standard for class 2B waters (230 mg/L) is indicated by the red line.

Since 2012, except for multiple samples taken from Lake Idlewild, the average Cl levels from the RCL and PCL have fallen below the MPCA CS of 230 mg/L (Figure 4-10, Figure 4-11). In 2022, Lake Idlewild did not meet the chloride CS standard, which has often occurred in the past. The maximum concentration measured in Idlewild was from a bottom sample taken in March of 2019 which measured 390 mg/L. The only other lake that had chloride concentrations above the standard was Staring Lake in 2018 and 2022. Multiple bottom concentrations exceeded the standard, however the average (top/bottom) did not. Overall, Cl levels within the PCL system, except for Idlewild, were below the MPCA water quality standard and have stayed relatively consistent within lakes year-to-year. In the RCL system, no lake exceeded the water quality standard. However, for the bottom three lakes within the chain (Susan, Rice Marsh, and Riley) there appears to be a recent rising trend.

Figure 4-12 shows Cl levels within the four stormwater ponds, which includes all sampling events since 2013. Except for two sampling events, all samples taken from Pond K (top of the chain) exceed the class 2B MS. This includes 2013 samples which exceeded the maximum chloride concentrations the lab equipment could measure. Most samples taken from Eden Pond greatly exceed 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. 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 even during melting events. This is preventing high chloride levels from reaching Purgatory Creek. During significant rain events in the spring, chloride is most likely being flushed downstream at a larger scale than in the winter or during normal water level periods.

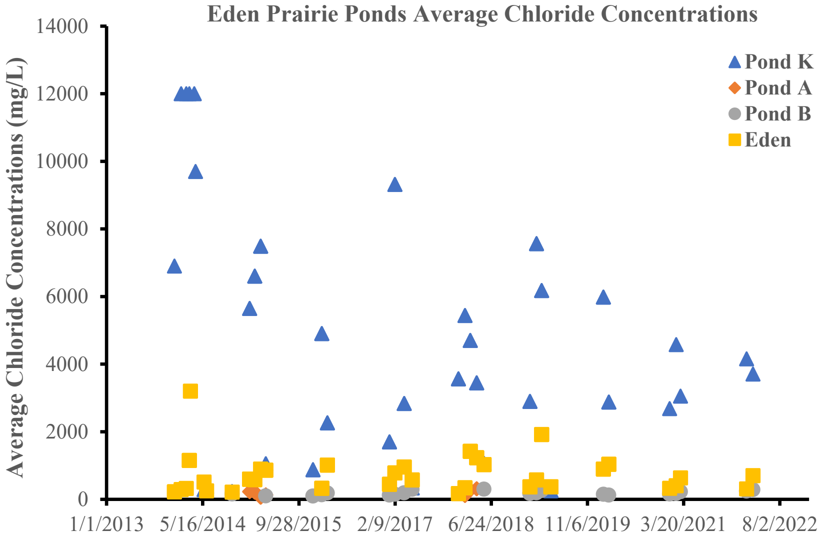


Figure 4-12 2013-2022 Chloride Levels within EP Stormwater Ponds

All average chloride results (mg/L) on stormwater ponds draining the City of Eden Prairie City Center to Purgatory Creek from 2013-2022.

Regular stream monitoring sites have had chloride samples collected monthly from 2018-2022. Samples collected during the open water season act as a baseline of standard chloride levels. They can also alert staff of any chloride level spikes during this period. In 2021, only sites R4 and B4 exceeded the MPCA CS water quality standard in May, June, and July. R4 also exceeded the standard in 2022. Previously no sites exceeded the standard across all sites. In 2021 and 2022, 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 along with the fact that both sites are closest to Highway 5 which is one of the larger road systems draining to district streams. Winter and early spring monitoring, specifically after melting events, is often the time to capture maximum chloride levels from each stream. Our 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 4-13) and Bluff Creek (Figure 4-14) 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 RCL in 2023 which will include: Lucy, Ann, Susan, Rice Marsh, and Lake Riley, along with the stormwater ponds draining Eden Prairie Center. This is the final year of monitoring within the three-year cycle before staff shift to the PCL. Once-a-month Cl 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 Table in *Exhibit F* and stream conductivity readings can be seen in *Exhibit D*.

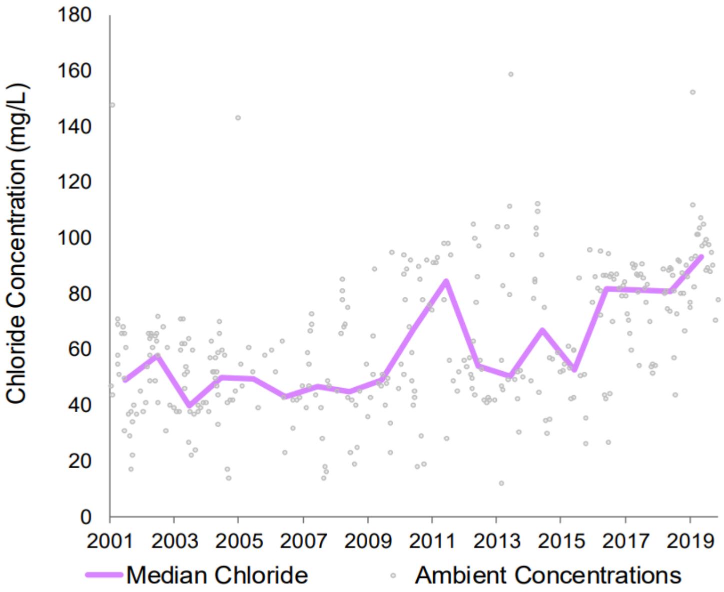


Figure 4-13 Ambient and Annual Median Chloride Concentration in Riley Creek (Metropolitan Council).

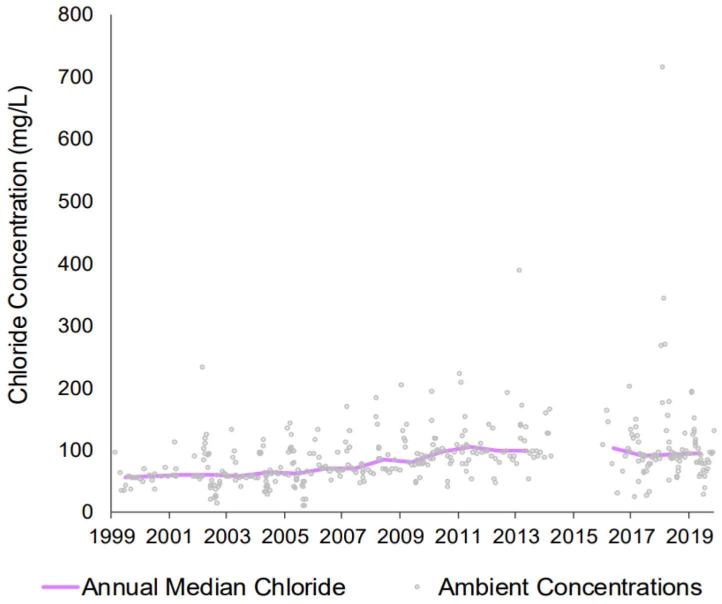


Figure 4-14 Ambient and Annual Median Chloride Concentration in Bluff Creek (Metropolitan Council).

4.4 Nitrogen Monitoring

The toxicity of nitrates to aquatic organisms has been a growing concern in MN over the last decade. Nitrate (NO_3), 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 (still in the draft stage for external review) to address concerns of the toxicity of nitrate in freshwater systems and develop nitrate standards for class 2B and 2A systems. Sources of excess nitrate in freshwater systems are linked to human activities that release nitrogen into water. The draft chronic standard (CS) is 4.9 mg/L nitrate-N.

Once a month during regular sampling, staff collects a surface 2 m 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 2022 was 0.74 mg/L (1.099 mg/L in 2021). 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). This lab also tests for ammonia in the form of ammonia+ammonium. As seen in *Table 4-3*, 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 (*Table 4-3*).

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 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 MPCA does have standards 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 4-3* 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 4-3* 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 2022 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.

Table 4-3 2022 Lakes Summer Average of Nitrogen

2022 growing season (June-September) averages of nitrate+nitrite, ammonia, and total kjeldahl nitrogen levels for District lakes. The MPCA proposed chronic standards (CS) are in orange. The NH4 (CS) standard should not be directly compared to lake values (see text). Lower limit of lab analysis of nitrate+nitrite is 0.03 mg/L and ammonia+ammonium is 0.04 mg/L.

Lake	Average Nitrate-N	Average Ammonia+Ammonium	Total Kjeldahl Nitrogen
MPCA	4.90 mg/L	*0.04 mg/L NH4	-
Ann	0.030	0.682	1.482
Duck	0.052	0.025	0.718
Hyland			0.74
Idlewild	0.030	0.023	0.568
Lotus	0.032	1.293	2.066
Lucy	0.030	0.411	1.506
Mitchell	0.040	0.129	1.306
Neil	0.030	0.023	0.867
Red Rock	0.040	0.140	1.364
Rice Marsh	0.057	0.047	0.865
Riley	0.033	0.43	0.959
Round	0.040	0.099	0.863
Silver	0.030	0.049	1.245
Staring	0.030	0.124	1.860
Susan	0.030	1.377	2.806

4.5 Lake Water Levels and Precipitation

In-Situ Level Troll 500, 15-psig water level sensors, as well as 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 4-15 and Figure 4-16 displays daily precipitation totals across at the two stations from March 1, through December 1 for 2021 and 2022. Overall, precipitation levels were very low in 2021. In 2022, we continued to be in a drought condition with even less precipitation than seen in 2021. During this period, rainfall at the Flying Cloud Airport and National Weather Service Station totaled 16.78 inches (19.12 inches in 2021) and 23.49 inches (19.95 inches in 2021) respectively. In 2022, The max rainfall event at Flying Cloud Airport occurred on 5/11/22, totaling 1.32 inches of rain (8/27/21, 1.49 inches). At the National Weather Service Station, the max rainfall total occurred on 5/11/22, totaling 2.13 inches of rain (8/28/21, 1.71 inches).

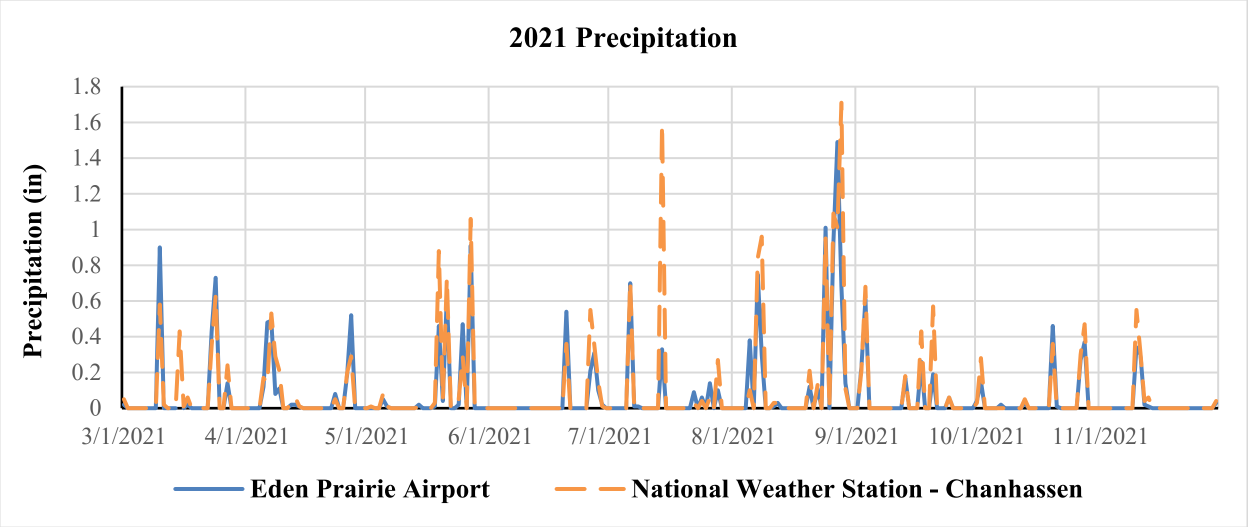


Figure 4-15 2021 Precipitation Levels

2021 precipitation daily totals in inches for Flying Cloud Airport in Eden Prairie, MN and the National Weather Service Station in Chanhassen, MN.

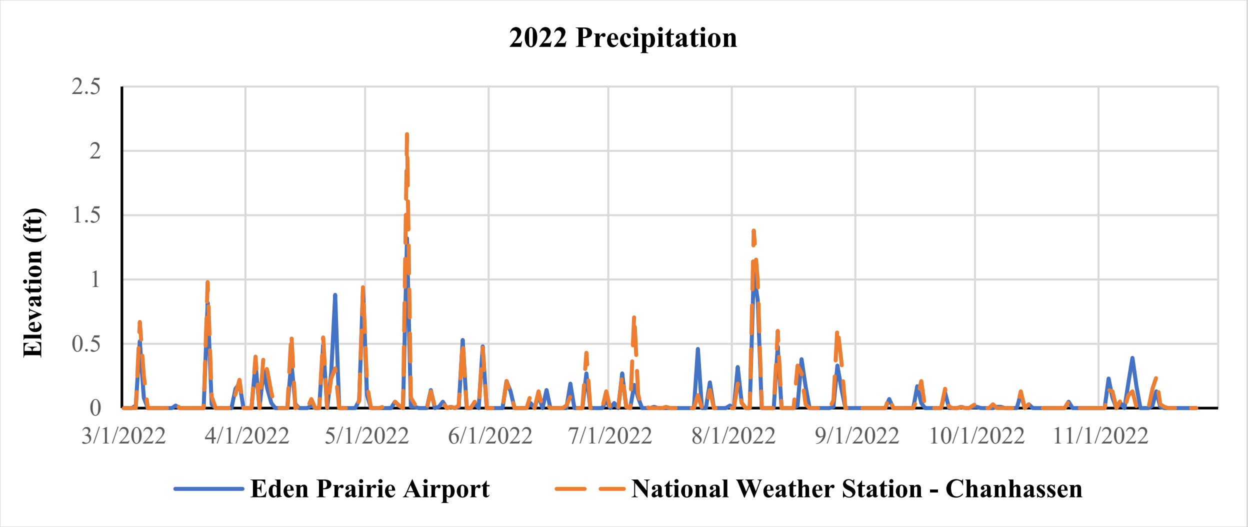


Figure 4-16 2022 Precipitation Levels

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

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 (located in section 4.8). 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. See *Exhibit A* for figures showing historical lake level data and 2022 lake level data compared with precipitation data. In both the 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.

Figure 4-17 Round Lake Level Sensor High & Dry

In 2022, lake level measurements were collected on 13 lakes in the district and three wetlands (Lake Idlewild, Lake McCoy, Eden Lake) (*Table 4-4*). This was the third year Lake McCoy had water levels monitored and second for Eden. Round Lake experienced the greatest seasonal water level change over the 2022 season, decreasing 3.04 ft from spring sensor placement to the last day of recording. Like 2021, Round Lake had the largest range of fluctuation through 2022. During the 2022 season, Round Lake had a low elevation of 875.167 ft, and a high of 878.518 ft (3.351 ft difference). Round Lake also had the lowest recorded water level according to past district data and MN DNR Lakefinder data. The previous low was recorded on 7/25/1977 and measured 875.290. Round Lake water levels are highly influenced by precipitation events within the watershed which is why it commonly has the highest flux (Figure 4-17). Lake Susan had the least seasonal flux (0.694 ft) and flux range (0.954 ft) across all district lakes. This is likely from a beaver dam which was located between Lake Susan and Rice Marsh Lake which artificially raised the water levels through the 2022 season. On average, lake levels seasonal flux was 1.747 ft in the PCL and 1.468 in RCL in 2022. The average fluctuation range across PCL was 1.952 and 1.636 ft for RCL.

Table 4-4 2022 Lake Water Levels Summary

The 2022 (March-November) and historical recorded lake water levels (ft) 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.

	2022 Lake Water Level Data				Historical Lake Water Levels			
Lake	Seasonal Flux	Flux Range	High Level	Low Level	Highest Level	Date	Lowest Level	Date
Duck	1.641	1.654	913.854	912.200	915.317	6/20/2014	911.260	11/10/1988
Eden	1.220	1.690	810.698	809.008	854.324	8/27/2021	809.008	10/12/2022
Hyland	1.608	2.101	814.391	812.290	818.733	6/23/2014	811.660	12/2/1977
Idlewild	1.228	1.445	854.036	852.591	860.780	3/29/1976	853.100	1/7/1985
Lotus	1.509	1.693	896.189	894.497	897.080	7/2/1992	893.180	12/29/1976
McCoy	1.560	1.560	823.516	821.956	823.902	8/16/2020	821.956	11/4/2022
Mitchell	2.599	2.635	871.974	869.339	874.210	6/25/2014	865.870	7/25/1977
Red Rock	1.625	1.829	840.534	838.705	842.702	7/13/2014	835.690	9/28/1970
Round	3.040	3.351	878.518	875.167	884.260	8/17/1987	875.167	11/4/2022
Silver	1.764	1.772	898.969	897.197	901.030	6/20/2012	894.780	6/6/1972
Staring	1.421	1.738	815.111	813.373	820.000	7/24/1987	812.840	2/12/1977
Average	1.747	1.952						

	2022 Lake Water Level Data				Historical Lake Water Levels			
Lake	Seasonal Flux	Flux Range	High Level	Low Level	Highest Level	Date	Lowest Level	Date
Ann	1.604	1.608	956.408	954.800	957.930	2/18/1998	952.800	9/28/1970
Lucy	1.393	1.459	956.581	955.122	957.683	6/20/2014	953.290	11/10/1988
Rice Marsh	1.778	1.932	876.123	874.191	877.250	5/28/2012	872.040	8/27/1976
Riley	1.872	2.227	865.274	863.047	866.855	6/20/2014	862.000	2/1/1990
Susan	0.694	0.954	881.912	880.958	884.226	6/19/2014	879.420	12/29/1976
Average	1.468	1.636						

4.7 Purgatory Creek Auto-Sampling Units

Within the Purgatory Creek Chain of Lakes, both Lotus Lake and Staring Lake consistently failed to achieve the water quality standards set forth by the MPCA including total phosphorus (TP) chlorophyll-a, and water clarity (secchi disk depth). Additionally, both lakes were 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 these lakes.

- (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 lbs. alone (Figure 4-18). 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.

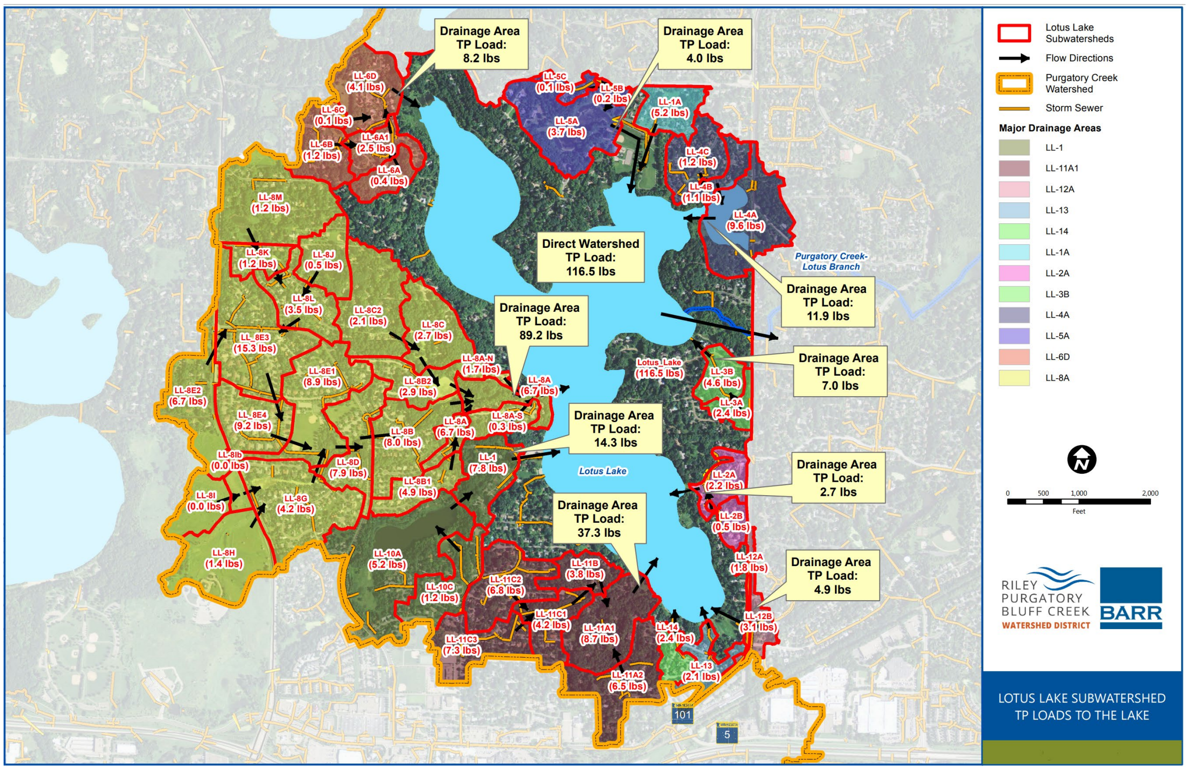


Figure 4-18 Lotus Lake Sub watershed Estimated Total Phosphorus Loading

- (STL_17) For Staring Lake, a creek restoration and stabilization project of a 1,000-foot reach between the Recreation Area and Staring Lake (behind Oak Point Elementary School) would reduce the phosphorus load in Purgatory Creek and to Staring Lake by 4% and provide increased education and outreach to residents.

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 2022, staff placed an automated sampling unit at the grated access site downstream of Kerber Boulevard, the culvert under the recreational trail connected to the end of Carver Beach Road (Lotus Lake), and the culvert under Staring Lake Parkway. 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), ortho-phosphorus (OP), 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.

In 2021 and 2022, total phosphorus levels on the upper Lotus Lake ravine during storm events were high compared to the MPCA standards, as seen in Figure 4-19 and *Table 4-5*. The average TP coming from upstream of Kerber Blvd. (LL_3) averaged 0.505 mg/L and the average TP leaving the stormwater pond upstream of the recreational trail (LL_7) measured 0.424 mg/L in 2022 (*Table 4-5*). The reduction in 2022 from 2021 (0.534 mg/L) for LL_7 was likely due to the reduced amount of precipitation seen in 2022. Regardless, the 2022 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 storm event TP samples collected 7 out of 8 samples from LL_3 and 6 out of 10 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 in early May which corresponded with the largest rain event (Figure 4-19). This would have likely also occurred for station LL_3 but it was installed later in the year. In 2022, the average TDP concentration was just over the 2021 value of 0.106 mg/L across both stations. The OP average varied across the stations with LL_3 double the concentration (0.1 mg/L) of station LL_7 (0.053 mg/L) in 2022.

The average amount of TSS across 2022 was 180 mg/L for station LL_3 and 107 mg/L for LL_7. This is up from 76 mg/L for station LL_7 in 2021. Across all the sampling events, 6 out of 7 for LL_3 and 7 of the 10 samples taken in 2022 were above 30 mg/L TSS water quality standard for streams (Figure 4-19). From the limited Chl-a samples collected, concentrations at LL_7 averaged just above the MPCA standard with two out of three sampling events greater than the MPCA standard (<18 ug/L).

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. 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 cleanout 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 at the beginning of the year. 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. Staff will walk the upstream site to assess if any of the ravine is eroding significantly.

Table 4-5 2022 Purgatory Creek First Flush Auto Sampling Units Average Nutrient Summary

Parameter	STL_17	LL_3	LL_7	MPCA WQS
TP (mg/L)	0.337	0.505	0.424	≤ 0.1
TDP (mg/L)	0.045	0.117	0.108	
OP (mg/L)	0.036	0.100	0.053	
Chl-a (ug/L)	12.2	20.9	14.9	≤ 18
TSS (mg/L)	99.3	180.7	107.5	≤ 30

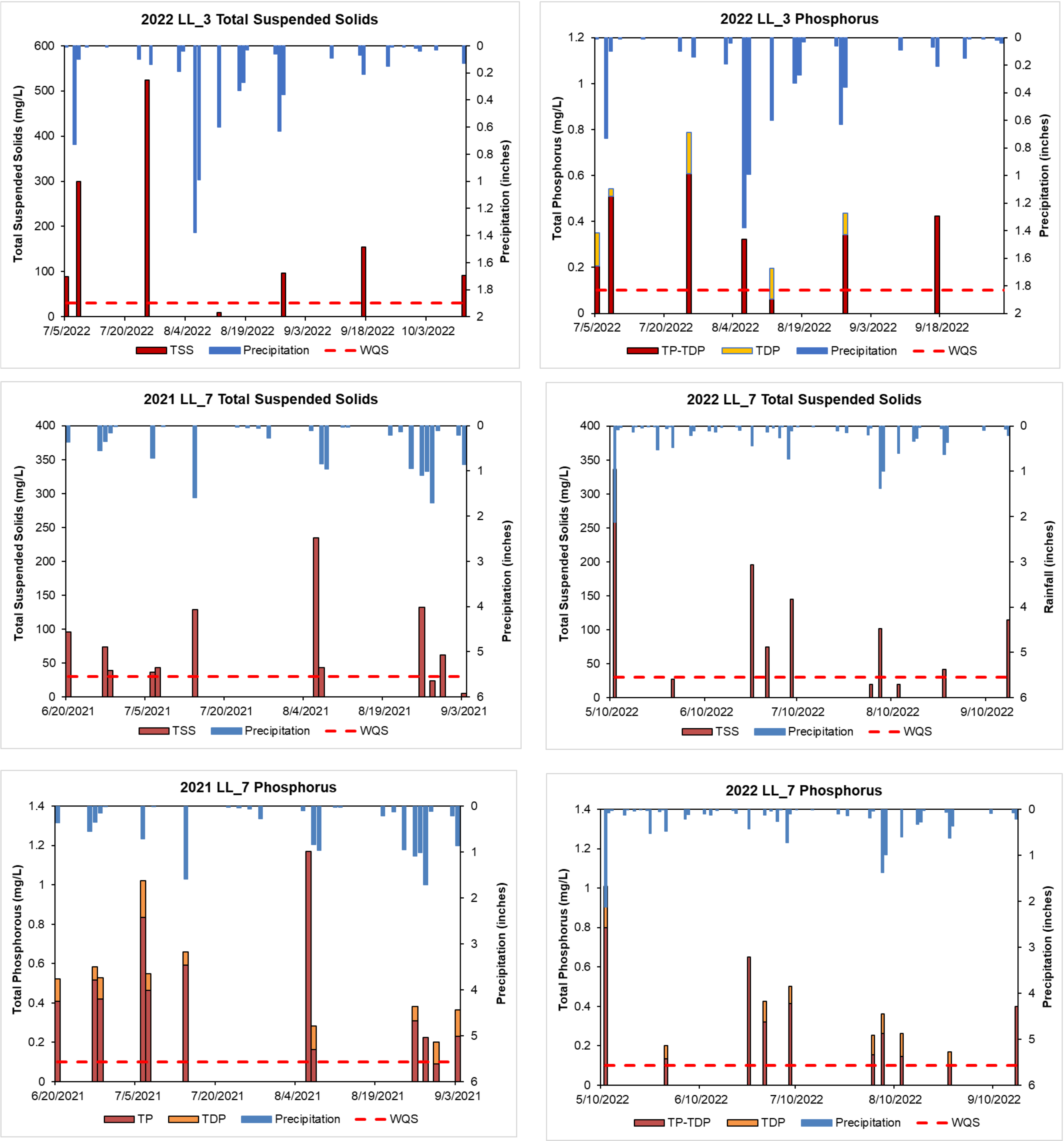


Figure 4-19 2022 Lotus Upper Ravine Total Suspended Solids and Phosphorus

Total Suspended Solids (TSS), Total Dissolved Phosphorus (TDP), and Total Phosphorus (TP) first flush concentrations (mg/L) from 2022 Lotus Lake Upper Ravine downstream of Kerber Blvd (LL_3) and from 2021-2022 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).

At the Staring Lake Road Purgatory Creek Crossing, total phosphorus levels were high compared to the MPCA standards, as seen in Figure 4-20 and Table *4-5*. In *Table 4-5*, the average TP at that site on Purgatory Creek across four samples was 0.337 mg/L in 2022. This is nearly twice the average TP across 19 samples in 2021 (0.197 mg/L). This level is nearly four times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP), but these measurements only include rain events. All four storm event TP samples collected measured above the MPCA stream standard. The highest TP concentration occurred on 7/23/22 (0.544 mg/L), which was up from 0.466 mg/L in 2021. In 2022, the average TDP concentration was 0.045 mg/L and the OP was 0.036 mg/L (0.043 mg/L and 0.029 mg/L in 2021).

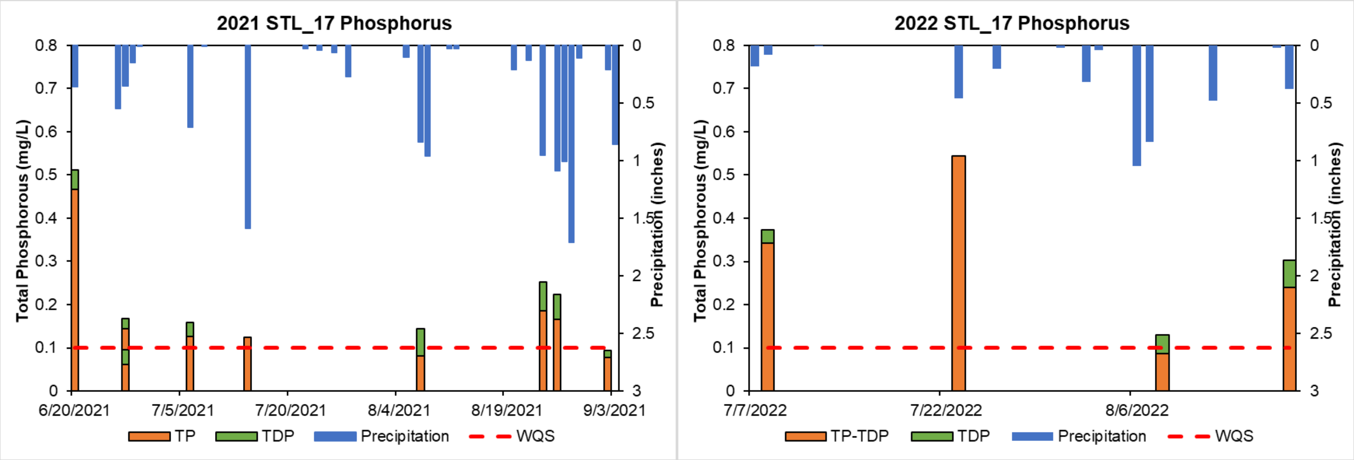


Figure 4-20 2021-2022 Purgatory Creek/Staring Lake Road Phosphorus

The Total and Dissolved Phosphorus first flush concentrations (mg/L) from the Staring Lake Road/Purgatory Creek automated, level triggered, flow-paced auto sampling unit in 2021 and 2022. Precipitation data is from the Flying Cloud Airport. Dashed line represents the Minnesota Pollution Control Agency standard for TP (≤ 0.1 mg/L).

The average amount of TSS across the four sampling events was nine samples taken was 99.3 mg/L which is double what was found in 2021 (52.9 mg/L). Across all the sampling events, samples taken in 2022 were above the MPCA water quality standard for streams which is 30 mg/L for TSS (Figure 4-21). It is important to note that these samples are targeted samples, representative of the initial flush of water and pollutants that occur during a rain event, and do not represent season-long pollutant levels in Purgatory Creek. With the low water levels, this site may have met the TSS, TP, and Chl-a stream standards if continuous monitoring and baseline sampling occurred. Therefore, a direct comparison to the MPCA stream standards is cautioned.

Overall, the limited precipitation in 2022 may have concentrated nutrients in Purgatory Creek and the Lower Purgatory Creek Recreational Area. These concentrations were likely transported downstream during the few rain events that occurred, which could explain the elevated levels seen in 2022.

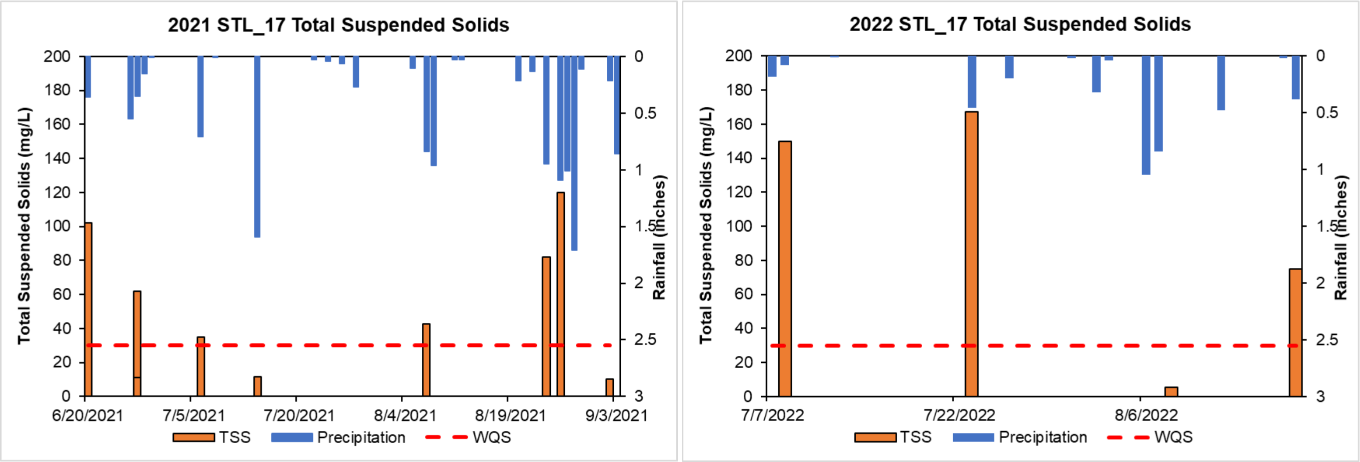


Figure 4-21 2021-2022 Purgatory Creek/Staring Lake Road Total Suspended Solids

The Total Suspended Solids first flush concentrations (mg/L) from the Staring Lake Road/Purgatory Creek culvert from a 2021-2022 automated, level triggered, flow-paced auto sampling unit. Precipitation data is from the Flying Cloud Airport. Dashed line represents the Minnesota Pollution Control Agency standard for TSS (≤30 mg/L).

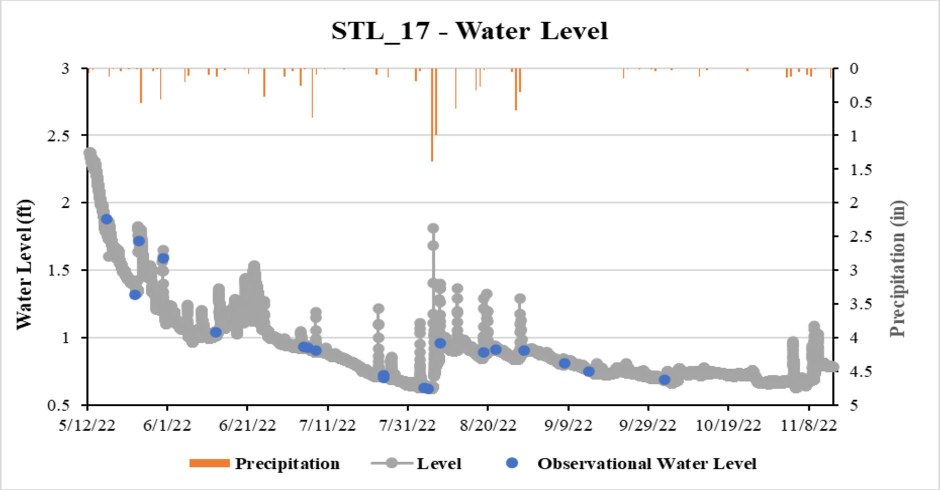


Figure 4-22 2022 Purgatory Creek/Staring Lake Road Water Level

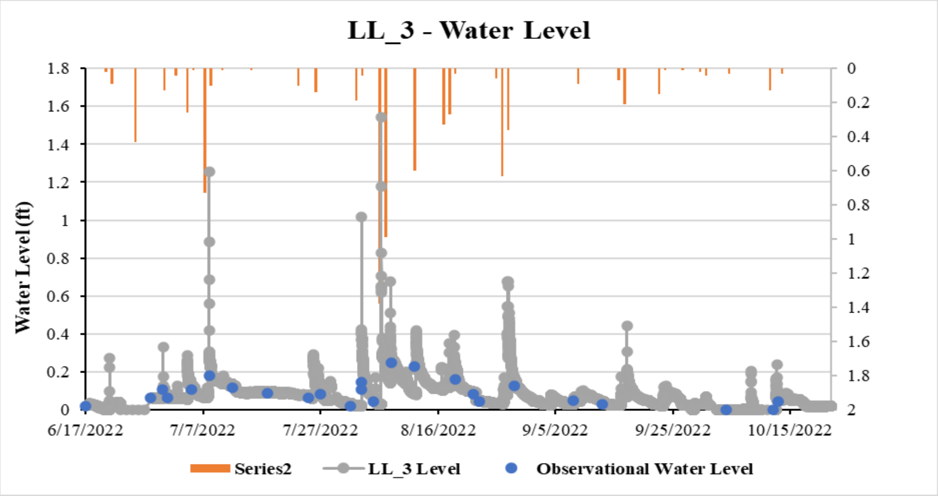


Figure 4-23 2022 Kerber Blvd/Upper Lotus Lake Ravine Water Level

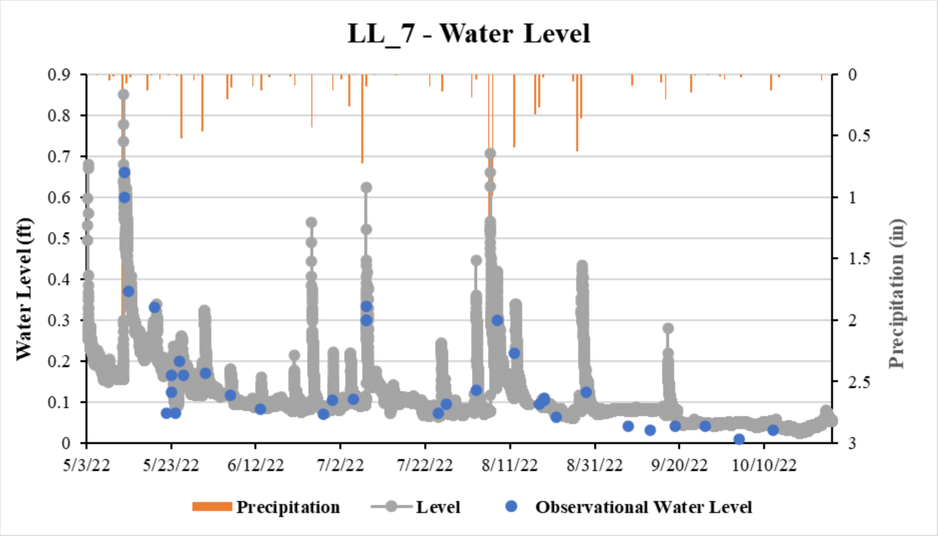


Figure 4-24 2022 Carver Beach Road/Upper Lotus Lake Ravine Water Level

4.7 The Creek Restoration Action Strategy

The RPBCWD developed the Creek Restoration Action Strategy (CRAS) to prioritize creek reaches, sub-reaches, or sites, in need of stabilization and/or restoration. The district has 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. More information on the CRAS can be found on the district's website (rpbcwd.org). 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 4-6*) and a CRAS Map (*Exhibit H*) were updated to include results from 2022.

Table 4-6 Severe Reaches Identified by the Creek Restoration Action Strategy

Reach	Sub-reach	Tier 2 Rank	Tier 2 Score	Tier 1 Rank	Tier 1 Score	Location	Restoration Status
R4	R4E	1	48	4	22	Powers Boulevard to Lake Susan	Planning
R4	R4D	2	44	8	22	Railroad Bridge to Powers Boulevard	Planning
B1	B1D	3	42	9	26	475 feet Upstream of Great Plains Boulevard to Great Plains Boulevard	
R4	R4C	4	42	1	22	Park Road to Railroad Bridge	Planning
B5	B5C	5	40	3	22	Galpin Boulevard to West 78th Street	Planning
B1	B1B	6	38	7	22	2,150 feet Downstream of Pioneer Trail to 300 feet Upstream of Bluff Creek Park	
R2	R2D	7	36	2	24	Upper Third between Dell Road and Eden Prairie Road	
R2	R2C	8	36	5	22	720 feet Upstream of Dell Trail to Dell Road	

Streams are monitored biweekly between May and September for nutrients and flow. This data is used to assess water quality across each stream which is then incorporated into the CRAS. Results from the 2022 data can be seen in *Exhibit D 2022 Creek Seasonal Sonde & Flow Data* and *Exhibit F 2022 Stream Summary Table*. As part of the CRAS, stream reaches are walked on a rotational basis after the initial assessment was completed. This allows staff to evaluate changes in the streams and update the CRAS accordingly. In 2022 staff walked, P6B Restoration Site, Reach 1 of Riley Creek, Reach 4 of Riley Creek (excluding R4F), subreach R2E, Reach 2 of Bluff Creek, Reach 5 of Bluff Creek, the Southwest Bluff Creek Tributary, North West Bluff Creek Tributary, and subreach B1A. 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 which were 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 2022 creek walks can be seen in *Table 4-7*, in our Fact Sheets on the District website (rpbcwd.org), and in (*Exhibit H*).

Overall, scores were slightly improved across most sites from 2015 to 2022. Reach 4 of Riley Creek saw significant degradation across all sites which may be partially attributed to head cutting that occurred after the replacement of the culvert under Park Road. R1C near Fredrick Miller Spring had an increased score (more degraded) but was still in the same previous Tier I category – poor. The bottom three sites in *Table*

4-7 show improvements in the CRAS scoring from restorations that occurred. Significant improvements occurred as expected after all the creek restoration projects.

Table 4-7 2022 Creek Restoration Action Strategy Updates

Tier I and Tier II scores for the Creek Restoration Action Strategy for 2015 and the corresponding updates from 2022 for subreaches within P1, P2, and B5. Bottom four sites are an evaluation pre and post stream restoration utilizing the CRAS (Eden Prairie restored R1A).

Reach	Subreach	Location	Old Tier I Scores	2022 Tier I Scores	Tier II Scores
B1	B1A	Pioneer Trail to 2,150 feet Downstream of Pioneer Trail	16	18	34
B2	B2A	Lyman Boulevard to Bluff Creek Boulevard	16	10	22
B2	B2C	1,750 feet Upstream of Highway 212 to Highway 212	14	14	24
B2	B2D	Highway 212 to 830 feet Downstream of Highway 212	14	14	22
B2	B2E	830 feet Downstream of Highway 212 to Pioneer Trail	16	12	20
B5	B5A	Ridgeview Road Recreational Trail to 985 feet Upstream of Galpin Blvd	16	12	26
B5	B5B	985 feet Upstream of Galpin Boulevard to Galpin Boulevard	22	20	38
B5	B5C	Galpin Boulevard to West 78th Street	24	22	40
BT2	BT2A	380 feet Upstream of Galpin Road to Galpin Boulevard	16	12	24
BT2	BT2B	Galpin Boulevard to Bluff Creek	18	20	40
BT3	BT3B	Pioneer Trail to Bluff Creek Drive	18	14	34
BT3	BT3C	Bluff Creek Drive to Bluff Creek	20	18	30
R1	R1A	Eden Prairie Road to Prospect Road	18	14	20
R1	R1B	Prospect Road to Spring Road	20	18	24
R1	R1C	Spring Road to Flying Cloud Drive	18	20	38
R4	R4A	Highway 5 to Park Drive	18	20	42
R4	R4B	Park Drive to Park Road	14	16	38
R4	R4C	Park Road to Railroad Bridge	18	22	42
R4	R4D	Railroad Bridge to Powers Boulevard	20	22	44
R4	R4E	Powers Boulevard to Lake Susan	18	22	48

BT3	BT3A	Audubon Road to Pioneer Trail	22	10	18
P6	P6B	200 feet Upstream of Highway 101 to Highway 62	18	8	16
R2	R2E	Middle Third between Dell Road and Eden Prairie Road	26	14	22

Red – Severe
Orange – Poor
Yellow – Fair
Blue – Good

Staff also attempted to collect macroinvertebrates at all eight Purgatory Creek sites in 2022 (Riley Creek in 2021 and Bluff Creek in 2020). However, due to drought conditions samples were not collected. 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. Purgatory macro collection will occur in 2023.

Staff will finish the assessment on Reach 1 Bluff Creek next year and update accordingly. CRAS updates and potential additional monitoring for 2023 include:

- Placement of additional bank pins at sites that align with upcoming projects.
- Walk additional first order tributaries that have not been 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.

Bank Pins

In addition to creek walks, staff have also checked bank pins yearly since they were installed in 2015 near all the regular water quality sites. The bank pins were installed at "representative" erosion sites to evaluate erosion rates for each reach. Staff measured the amount of exposed bank pin or sediment accumulation (if pin was buried) in 2016 through current (2018-2022 measurements shown in *Table 4-8*). From this, staff can 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 loss and quantify lateral recession rates (Wenck, 2017). From their monitoring results, 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.

- 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, reach 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 ft3). 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 in/year) and the highest bank volume loss per one yard stretch of creek (4.62 ft3). Due to the low water levels in 2021 and 2022, erosion appeared to be reduced across most sites.

Table 4-8 2018-2022 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 2018-2022. Negative values denote areas of bank where there was sediment deposition. Empty cells denote sites where pins were not found. Yellow highlighted 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.

	Average Lateral Loss (in/year)					Estimated bank loss per one yard stretch of creek (ft3)				
	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
R5	7.75	8.03	1.58	1.38	5.61	4.81	3.93	1.69	1	4.62
R4	0.42	3.63	1.77	0.5	0.43	0.25	2.93	1.31	0.13	0.27
R3	5.31	14.9	5.69	1.63	1.82	6.36	11.42	4.84	1.64	1.66
R2	--	6.45	2.15	0.69	1.03	--	13.3	4.24	1.41	2.2
R1	2.96	4.88	1.79	1	1.13	1.23	4.29	1.57	1.04	1.03
P8	0.55	3.16	0.63	0.25	0.01	0.24	1.65	0.45	0.14	0.02
P7	2.02	2.02	--	1.56	0.05	4.96	5.17	0	2.34	-0.21
P6	0.83	3.7	2	1.45	0.38	0.7	2.41	1.57	1.54	0.51
P5	0.77	3.07	1.58	0.83	0.25	0.81	3.82	1.77	0.94	0.31
P4	0.78	1.8	1.2	0.25	0.25	0.53	0.33	0.3	0.09	0.09
P3	0.94	1.96	0.66	0.42	0.42	1.02	2.77	0.89	0.61	0.61
P2	0.50	3.15	3.6	2.8	0.91	0.47	3.99	3.74	2.05	0.72
P1	0.38	3.52	3.35	7.33	1.2	0.92	6.38	10.98	18.82	3.12
B5	-0.79	0.89	1.16	0	1.35	-0.46	0.87	1.13	0	2.2
B4	5.58	12.06	12.02	2.96	2.44	3.66	12.81	11.49	2.77	2.51
B3	--	3.29	1.77	0.23	0.87	--	3.67	1.66	0.21	0.83
B2	3.00	7.00	5.56	1.6	1.95	1.25	4.08	3.19	1.51	2.11
B1	-0.67	5.54	--	3.81	1.08	-0.44	6.62	--	4.48	-1.39

4.8 Zooplankton

In 2022, 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. The 2022 phytoplankton results were not available in time for this report.

Healthy zooplankton populations are characterized by having balanced densities (number per m^2) 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 fowl 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).

Lake Riley

In 2022, all three groups of zooplankton were captured in Lake Riley (*Exhibit C*). About 11% of the zooplankton captured were Cladocera, up from 6% in 2021 but down from 18% from 2020. Rotifers were the most abundant zooplankton sampled across all sampling events but the June sample. (Figure 4-25). In 2022, all zooplankton groups were at their highest levels in June and decreased throughout the year. The largest number of Copepods captured were Nauplii which are the larval stage of Copepods. Cladocera numbers were relatively high averaging 87 thousand across the year, while only averaging 17 thousand across the five sampling events in 2021. This temporal reduction through the year may be due to the continued excellent water clarity caused by alum treatment, which can lead to increased predation on zooplankton populations. Zebra mussels were discovered in 2018 which could also be contributing to the increase in water clarity and the removal of phytoplankton (a Cladoceran food source). The most numerous Cladocera found in Riley was *Daphnia galeata mendotae,* which are common in the northern part of the United States, especially in common in glaciated regions such as MN.

Cladocera consume algae and have the potential to improve water quality if they are abundant in large numbers. Due to the lower numbers of Cladocera in 2022, grazing rates were low across all sampling events. The maximum grazing rate of around 11% occurred in June and corresponded with the highest Cladocera numbers seen across the year.

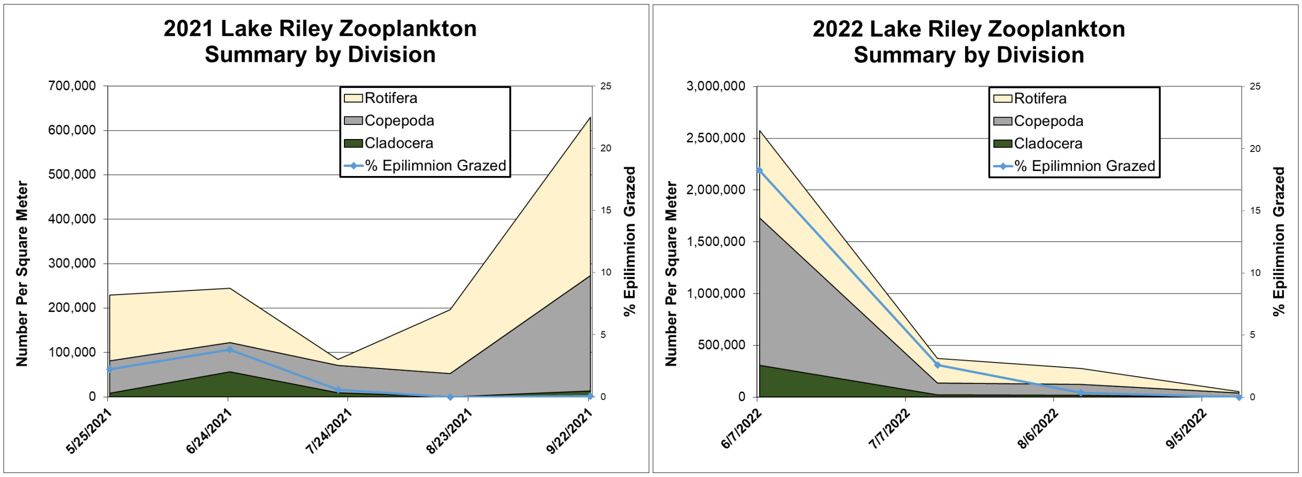


Figure 4-25 2021 & 2022 Lake Riley Zooplankton Counts (#/m²).

Lotus Lake

In 2022, all three groups of zooplankton were present in Lotus Lake (*Exhibit C*). Rotifers were the most abundant zooplankton sampled making up 61% of the total zooplankton captured in 2022, which was the same as 2021 (Figure 4-26). Copepod numbers were relatively stable across sampling events averaging 281 thousand after the June sample which was 734 thousand. Cladoceran populations were stable from June through August (average 155 thousand) before bottoming out in September at 24 thousand. The most common Cladocera were *Daphnia galeata mendotae* in the spring and *Daphnia retrocurva* in August. *Daphnia retrocurva* is known for its large, curved helmet it develops in late spring-to-summer to reduce predation by planktivorous fish and invertebrates.

Large Cladocera consume algae and, if enough are present in a lake, they have the potential to improve water quality. The estimated epilimnetic grazing rates in ranged from 6% to 19% in 2018, near 0% to under 5% in 2019, and were near 0% in 2020. In 2021, grazing rates increased, ranging from 0% to 4% (Figure 4-26.) and further increased to 0% to 7% in 2022.

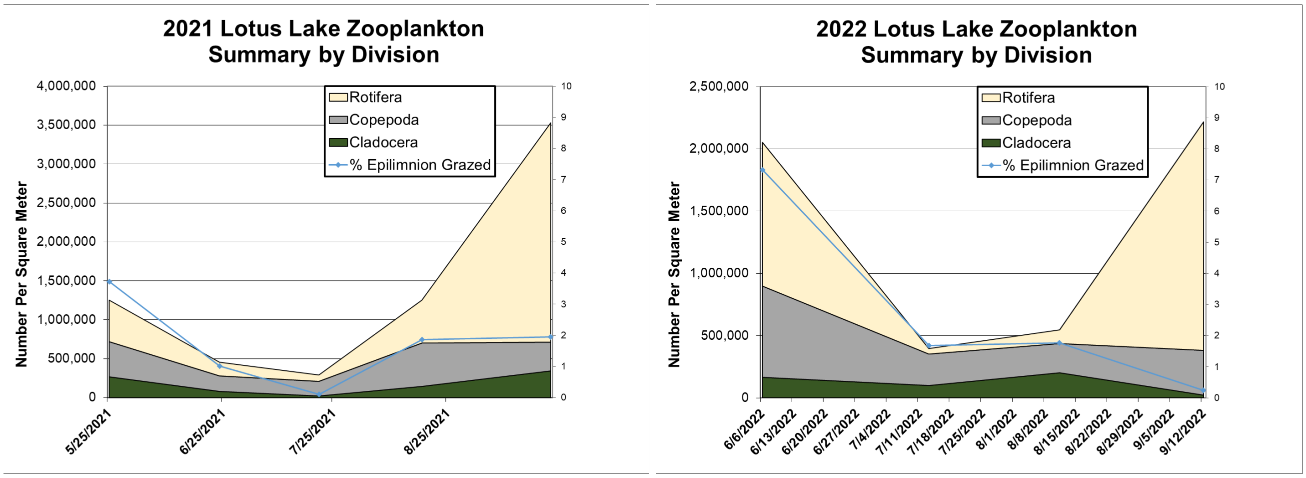


Figure 4-26 2021 & 2022 Lotus Lake Zooplankton Counts (#/m²).

Lake Susan

In 2022, Copepoda were the most abundant zooplankton captured in Lake Susan (*Exhibit C*). The Copepoda population was variable with the highest level occurring in August at 1.26 million and the lowest the following month at 85 thousand. Except for a smaller population in June (117 thousand), the rotifer population was relatively stable across the remaining sampling events averaging 491 thousand (Figure 4-27). Overall, Cladocera numbers comprised 21% of the total zooplankton captured. This is up from 2021 which was 11.6%. The highest Cladocera population recorded in 2022 was in June when *Daphnia galeata mendotae* were captured in high numbers. *Daphnia galeata mendotae* are common in the northern part of the United States, especially in common in glaciated regions such as MN.

The estimated epilimnetic grazing rates upon algae in 2018 ranged from 0% to 11%. They were around 1% in 2019 and 2020. In 2021 and 2022, grazing rates were less than 1% across all sampling dates. This is due to the limited number of Cladocera present in all the samples collected.

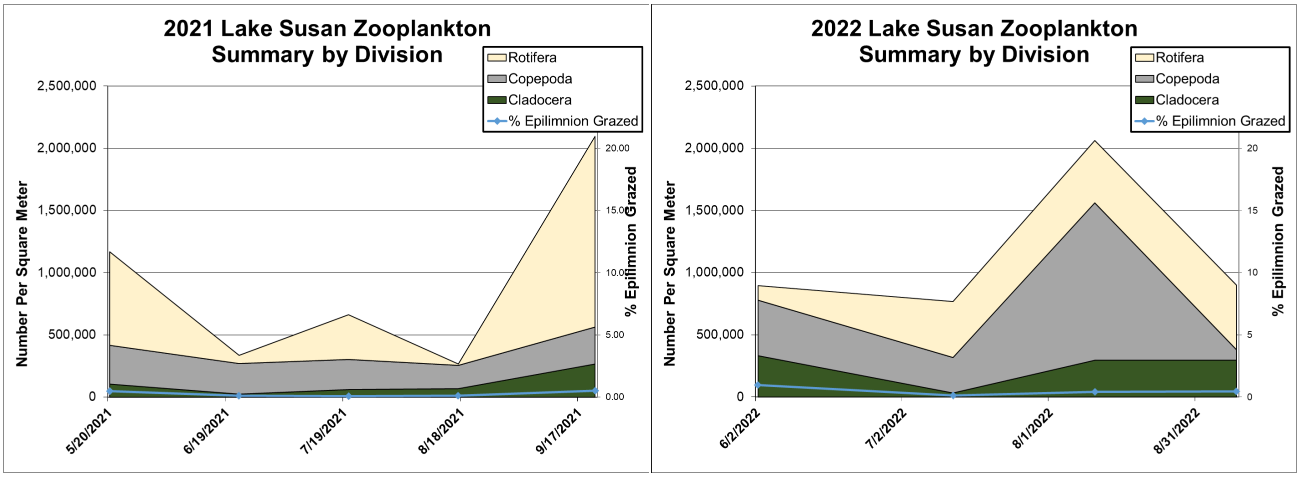


Figure 4-27 2021 & 2022 Lake Susan Zooplankton Counts (#/m²).

Rice Marsh Lake

In 2022, all three groups of zooplankton were captured in Rice Marsh Lake (*Exhibit C*), of which 42% of the population was comprised of Cladocerans. This number is up from 24% in 2021, 17% in 2020, 8% in 2019, and 13% in 2018. Rotifers were not the most abundant zooplankton sampled in 2021 and 2022 (Figure 4-28). Rotifer numbers were over 300 thousand in the spring and fall, while numbers dwindled during the peak of summer. Copepod densities were highly variable across the year with the highest density in August at 458 thousand. Across all sampling dates the Cladoceran community was dominated by small-bodied zooplankton, consisting of mainly *Bosmina longirostris, Ceriodaphnia sp*., and *Chydorus sphaericus*.

The estimated epilimnetic grazing rates of Cladocera ranged from near 0% to 23% in 2018, 2% to 39% in 2019, 0 to 11 % in 2020 and 0 to 8% in 2021 (Figure 4-28). In 2022, the highest August grazing rate of 6% was linked with the highest density of smaller Cladocerans and the presence of the larger bodied *Diaphanosoma leuchtenbergianum*.

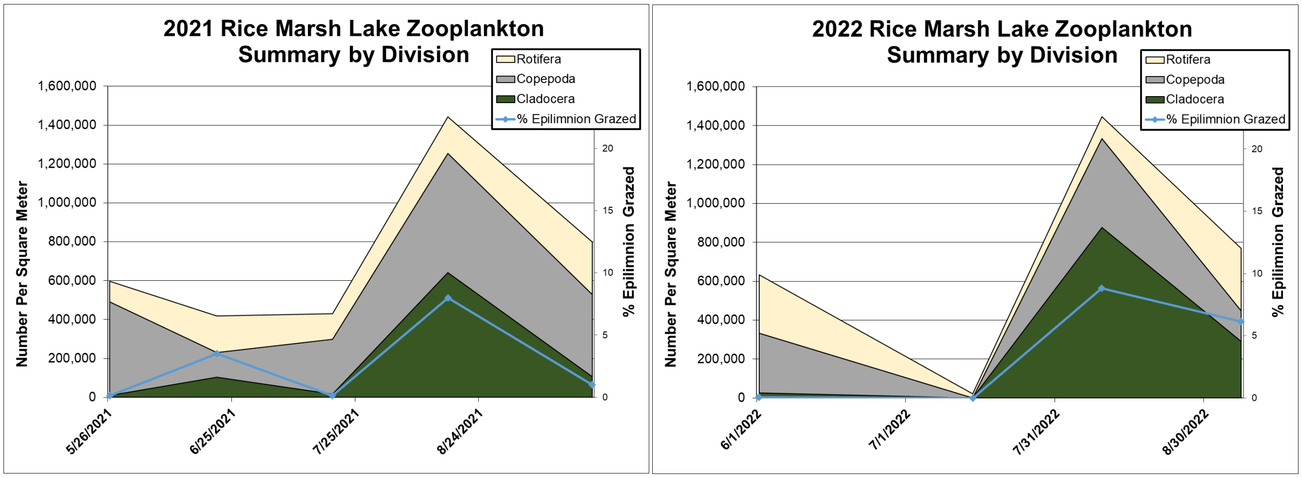


Figure 4-28 2021 & 2022 Rice Marsh Lake Zooplankton Counts (#/m²).

Staring

In 2022, all three groups of zooplankton were present in Staring Lake (*Exhibit C*). Similar to 2019 through 2021, the 2022 June sampling event had the highest number of organisms present (Figure 4-29). In 2022, rotifers were highly variable across the year with the highest abundance occurring in June at 1.09 million. The dominant Rotifer species was Keratella cochlearis, which occurs worldwide in virtually all bodies of water whether fresh, marine, or brackish. Copepod numbers were also highly variable and comprised 48% of the total zooplankton abundance across the year. Cladocera species made up 16% of the total zooplankton population and averaged 129 thousand across the year. In 2021 they made up 23% of the zooplankton and averaged 253 thousand. In 2020, the Cladocera population was lower, averaging only 75 thousand. In 2022, the Cladocera population was highest in August (221 thousand) and lowest in July (21 thousand). The most abundant Cladocera were Bosmina longirostris which are common in ponds and lakes throughout the continent.

Large Cladocera consume algae and may have the potential to improve water quality when present in high densities. The estimated epilimnetic grazing rates ranged from 2% to 24% in 2018, 1% to 4% in 2019, 0% to 1.4% in 2020, and 1 to 6% in 2021. Grazing rates increased in 2022, ranging from 0% to 20%.

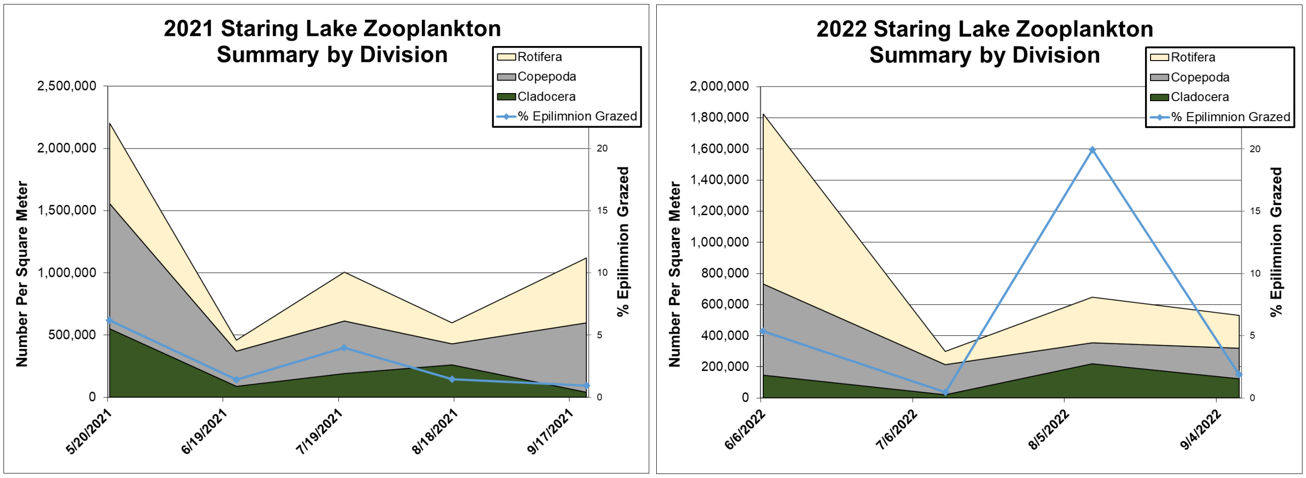


Figure 4-29 2021 and 2022 Staring Lake Zooplankton Counts (#/m²).

4.9 Lake Susan Spent-Lime Treatment System

Figure 4-30 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 land around it, 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 south-west corner of Lake Susan (Figure 4-30). 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 4-31 Spent Lime/Sand Mixture Column Testing

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 4-31 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 appears 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 where generally higher the larger the content of spent lime in the mixture (Figure 4-32).

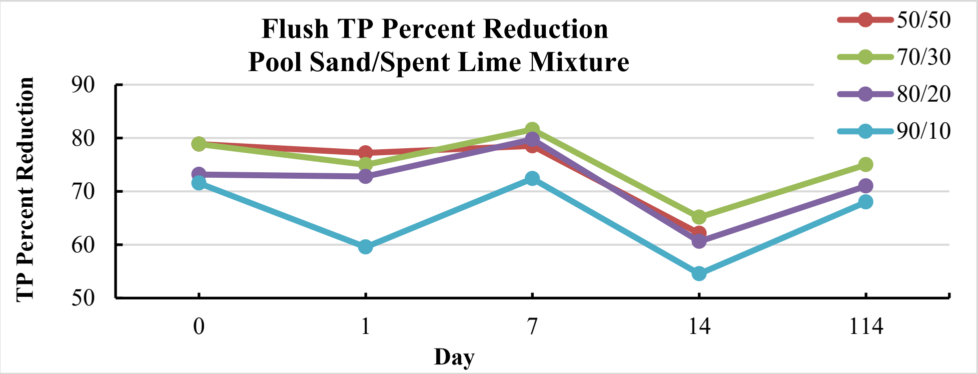


Figure 4-32 Pool Sand/Spent Lime Mixture Column Testing Phosphorus Removals

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 5-hour periods. In 2021, the unit was brought online 5/14/2021 and allowed flow on Mondays, Wednesdays, and Fridays for 7-hour periods. This schedule was also followed in 2022 after the unit was started on 5/26/2022. 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 4-33). The average TP reduction in 2021 was 40% (Figure 4-34). 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 4-9*). 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.

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. The long dry period in 2022, may also increase system performance in 2023. 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.

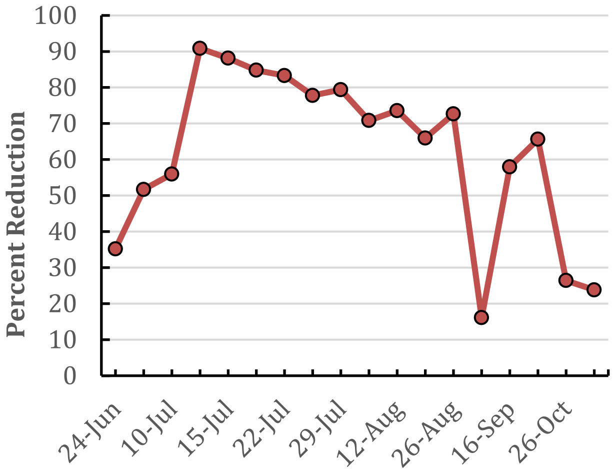


Figure 4-33 2020 Lake Susan Spent Lime Treatment System Total Phosphorous Percent Reduction

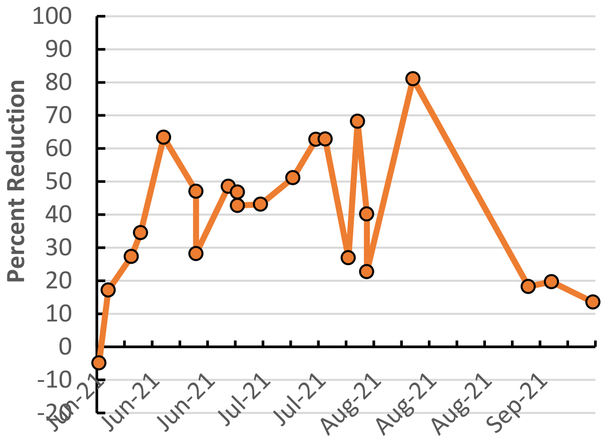


Figure 4-34 2021 Lake Susan Spent Lime Treatment System Total Phosphorous Percent Reduction

Table 4-9 2020-2022 Average TSS and Nutrient Percent Removals from the Spent Lime Treatment System

Analyte	2020	2021	2022
TDP (mg/l)	50	37	6
TP (mg/l)	62	40	16
TSS (mg/l)	46	28	48
OP (mg/l)	59	51	1
CHLA (mg/l)	53	55	25

*Actual values - only one sample collected in 2022 due to drought.

4.10 Stormwater Ponds

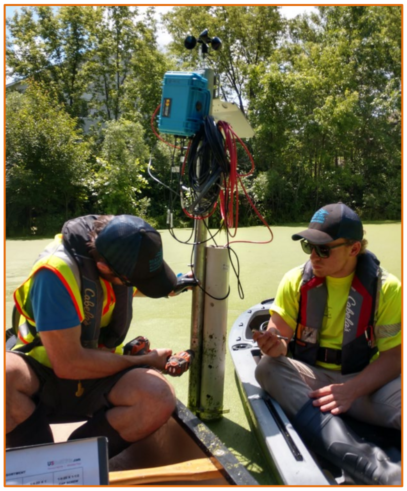


Figure 4-35 EnviroDIY Pond Continuous Monitoring Station

Stormwater ponds are the most commonly used method for controlling pollutant loading into natural water bodies. Phosphorus pollution is the primary component influencing eutrophication in freshwater resources. Excess phosphorus can lead to increased algal growth, turbid water, and loss of biodiversity and desirable aquatic habitat. Urban watersheds, like the Riley-Purgatory-Bluff Creek Watershed, typically export an amount of phosphorus five to 20 times more than that of less developed watersheds due to an increase in the amount of impervious cover (streets, sidewalks, and driveways) and surface runoff for a watershed (Athayde et al. 1983, Dennis 1985). Potential sources of phosphorus pollution in the Riley Purgatory Bluff Creek Watershed District include stormwater runoff, sediment erosion, grass clippings, lawn fertilizer, and pet waste.

The Riley-Purgatory-Bluff Creek Watershed District stormwater pond project (RPBCWD 2014) began in 2010, with initial data collection conducted in the summers of 2010 and 2011 and a second phase beginning in 2012-2013. The purpose of the project was to ascertain if stormwater ponds were possible sources of pollution within the district and identify ponds with exceptionally high total phosphorus concentrations that could be targeted for remediation projects. With assistance of city partners, a total of 119 ponds were sampled across Bloomington, Chanhassen, Eden Prairie, Minnetonka, and Shorewood. In both 2012 and 2013, average total phosphorus levels were higher than the MPCA estimated typical total phosphorus range (0.1 mg/L to 0.25 mg/L) for effluent (outgoing) stormwater in all five of the cities sampled. This data served as a baseline for the intensive research carried out in 2019 and 2020 on eight different stormwater ponds.

The University of Minnesota, City of Eden Prairie (Wenck), and Limnotech used the previous stormwater pond study to launch additional research projects in 2018-2020 in attempt to understand the chemical/ physical/biological complexity of stormwater ponds. On January 24th, 2020, RPBCWD held its first stormwater pond summit to get all interested/invested partners together to discuss current, ongoing, and future stormwater pond research. On January 20th, 2021, the second stormwater summit was held. This summit expanded upon what was learned from the original studies and helped guide the direction of future studies. In 2021, staff intensively monitored four additional ponds that were part of a hydraulic and hydrology model update in the Purgatory Creek watershed. This allowed them to expand the number and diversity of stormwater ponds that have been monitored while completing the update. Overall, the four ponds monitored in 2021 measured within the expected range for stormwater ponds.

Staff and partners had similar approaches to monitoring; ponds were selected and monitored biweekly to collect nutrient and pond vertical profile data. The selected ponds varied in size, design, depth, and watershed load, and encompassed a good representation of what currently exists in the district. Sediment cores were collected on many ponds to evaluate phosphorus release and identify the chemical makeup of each sediment layer. Continuous monitoring also occurred on a number of ponds. This included monitoring the surface and bottom of each pond for some or all of the following parameters: wind speed, water level, conductivity, temperature, and DO. RPBCWD staff worked with staff from the environmental engineering/science consultant firm Limnotech to implement EnviroDIY technology into everyday district water monitoring and data collection (Figure 4-35). The following information is a summary of the research being carried out in the district and associated published papers.

John Gulliver Lab – University of MN - Internal Phosphorus Loading in Stormwater Ponds - Remediation Utilizing Iron Filings – Sediment Phosphorus Release and Characterization

Poornima, N. & J. S. Gulliver. 2022. Assessment of Internal Phosphorus Release and Treatment with Iron Filings in five RPBCWD Ponds. Prepared for Riley Purgatory Bluff Creek Watershed District. St. Anthony Falls Laboratory, University of Minnesota, 2 Third Avenue SE Minneapolis, MN 55455.

- Ponds are stratified at a depth of 1-2 feet and the bottom sediment is pulling oxygen out of the water (zero oxygen at the bottom for 85% of the year in most ponds). Sediment releases phosphorus because of lack of oxygen. Many of the ponds that are stratified are sheltered which suggests the trees are reducing pond mixing. TP might not be the best way to measure phosphorus in the pond, because of duckweed soaking it up and concentrating phosphorus (duckweed and/or watermeal present across all five study ponds).
- The three study ponds all released phosphorus under anoxic conditions with two of the ponds also releasing phosphorus when oxygen was available. 40%-60% of phosphorus available from sediments in all the ponds was considered mobile (readily able to be used by algae or move out of system), highlighting the importance of mobile phosphorus in driving internal phosphorus loading during anoxia in the ponds.
- Possible remediation options include treating ponds (iron filings), artificial mixing (aeration), selective withdrawal (water draining from different locations within the water column), reduce sheltering (tree removal), and/or dredging and source control (removing phosphorus from landscape before it reaches the pond).
- Results from 15 different ponds show there is a significant range of phosphorus release possible based upon seasonal changes in oxic and anoxic flux. In 2020, ponds released significantly more phosphorus than in 2019 which is hypothesized to be the result of drier conditions.
- The use of iron filings in stormwater ponds has been successfully tested by the University of Minnesota in improving water quality under lab conditions. The District, Cities, and the UMN worked together and applied iron filings to three ponds. Initial results from 2020 monitoring data show variability in the results. Some ponds appeared to have some reductions, but others had little change. This variability can be partially explained by the seasonal variability in stormwater ponds which may be caused by different climatic conditions. Treatment of the ponds will likely require a combination of remediation techniques such as sealing the sediments from phosphate flux, aeration to enhance mixing and watershed-based phosphorus control actions to reduce the inflow of TP.

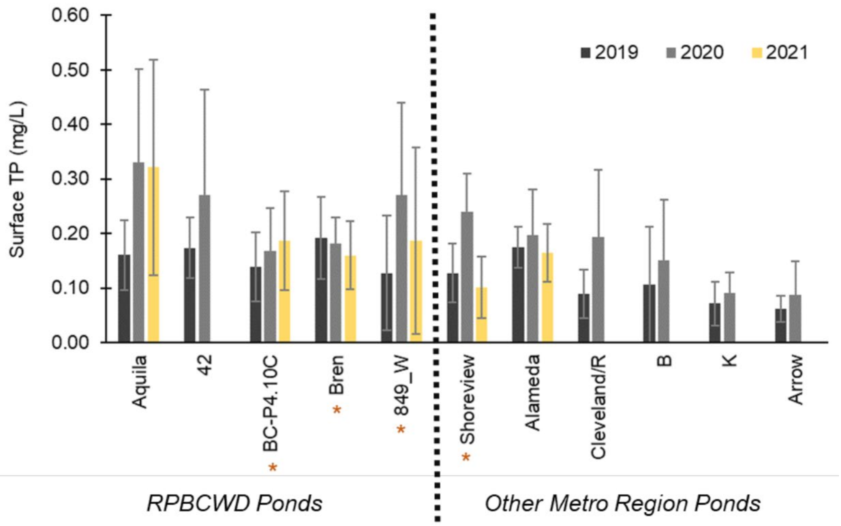


Figure 4-36 Pre & Post Iron Filing TP Concentrations

May through October mean surface TP concentrations in the five RPBCWD ponds and other ponds in the Twin Cities Metro area during 2019-2021. Error bars represent standard deviation of the mean. The ponds treated with iron filings are marked with an asterisk (dates of iron application are 2/19/20 in BC-P4.10C, 2/21/20 in 849_W, 2/24/21 in Bren Pond and Shoreview Commons Pond).

Jacque Finlay – University of Minnesota – Understanding Phosphorus Release in Urban Ponds - Stormwater Pond Research Overview

- Ponds are unexpectedly anoxic, promoting phosphorus release. Road salt accumulation may be part of why ponds stratify. Road salt sinks, accumulates, and persists. In ponds less than 3 ft deep there is no spatial chloride variation across the pond. However, deeper ponds have considerable spatial variations with high chloride concentrations common from January to July. Some variability in chloride concentrations depend on precipitation patterns (i.e., lots of snow = lots of salt application). Ponds located in commercial areas had the highest salt concentrations.
- Water temperature stratification occurs early in the spring in ponds – not a lot of wind caused mixing throughout the year. Ponds with 100% coverage by duckweed had very low oxygen levels. New ponds that are open and shallow had mixing occurring. Older and saltier ponds had low oxygen levels.
- Phosphorus concentrations are highly variable temporally (examples from MWMO-Kasota East Pond). Mass phosphorus balance testing was conducted on three ponds to determine how each pond was performing (inputs and outputs of phosphorus). Ponds variated in retention of phosphorus, were all anoxic almost all year, and were variable in phosphorus inputs and outputs. Overall, two ponds decreased and one increased in total phosphorus concentrations from inlet to outlet.
- Vinicius Taguchi discussed his literature review of fountain impacts on stormwater ponds to aerate and eliminate stratification. The literature review found that fountains do not serve as functional aeration units as only the area immediately around the fountain is affected.
- Duckweed and phosphorus - Finlay suggested that a feedback loop between duckweed and phosphorus does exist and that they are not independent.
- Duckweed in several ponds was measured for phosphorus (mass of P per mass of dried duckweed). This was used to come up with a total mass of duckweed P for the whole pond based on the ratio of sampled area to pond surface area (sampled area = net sampler size [area] * number of samples). With the assumption that the duckweed could access P in the upper ~0.5 m of the water column (concentration of duckweed TP mg/L = total mass of duckweed P / volume of the pond from water surface to depth of 0.5 m), it was estimated that ~50% of the pond's upper water column TP was contained within the duckweed and the other half was in the water. This has implications in sampling by underestimating TP in ponds as currently the duckweed is "moved", or water is sampled under the duckweed layer. In the original pond study, water was grabbed at the surface, which included duckweed, and then was filtered through a screen. This may have captured a more complete TP picture in ponds. Ben Janke redesigned a pond outlet to essentially skim the duckweed to prevent it from moving downstream to reduce phosphorus loading.
- An undergrad removed duckweed on a very small/shallow pond to see the effect on pond stratification and phosphorus. The pond responded with an immediate increase in oxygen down to sediment surface and phosphorus concentration were reduced.

Anthony Aufdenkampe – Limnotech - Mechanisms Driving Phosphorus Recycling in Constructed Stormwater Ponds: Implications for Management (stormwater.pca.state.mn.us)

- Anthony Aufdenkampe conducted a literature search investigating if ponds export phosphorus, if phosphorus removal efficiencies are less than design targets, and if influent/effluent studies were available (very limited). For the last three decades, stormwater pond design recommendations have been based on models of P removal for ponds studied by EPA's Nationwide Urban Runoff Program (NURP, 1983), using a simple model that only considered sedimentation and resuspension processes (Walker 1987). However, we know that other mechanisms within a pond (fluxes) are important to understand and include in pond design. These fluxes include inputs to the pond, sedimentation, mixing in the pond, sediment resuspension, internal loading, biological uptake and decay, groundwater exchange, and finally what is exported from the pond.

- Is it time to rethink pond design? Incorporate physical/geochemical/biological processes, consider temporal dynamics (storm events), and optimize mean annual load reductions in ponds rather than single inter-storm interval. Focus on inlet outlet loads with continuous monitoring stations to capture all pond dynamics.
- Adapt the General Lake Model (GLM) and Aquatic Ecodynamics v2 (AED2) to fit ponds with continuous pond data provided by EnviroDIY units and continuous nitrate and phosphorus analyzer at pond inlet and outlets. The goal is to develop a defensible designed model and provide maintenance recommendations for constructed stormwater ponds to maximize phosphorus retention. The model will have a sensitivity analysis of different drivers & factors to ensure performance and will eventually be used to simulate different design, retrofit and maintenance scenarios w/ input from stormwater practitioners. Develop a pond phosphorus management web tool for everyone to use.

Joe Bischoff – Barr – Ann Wilkinson – Stantec - RPBCWD Pond Assessment and Harmful Algae

Wenck Associates, Inc. 2021. Technical Report: 2021. Mitchell Lake, Rice Marsh Lake, and Lake Riley Subwatershed Assessment. Prepared for Riley Purgatory Bluff Creek Watershed District. Maple Plain, MN.

- Mitigating the HAB risk could be done by discouraging public access, increasing public outreach, promoting short water residence time, reducing DP and internal loading, and increasing mixing potential. More research is needed in this field to better understand the extent of risks of HAB in stormwater ponds.
- Stormwater pond systems are preferred by Harmful Algal Blooms (HAB) because they are high in nutrients, warm, and have limited mixing. In this assessment, it was found that stormwater ponds experienced cyanobacteria blooms in late summer (the presence of cyanobacteria does not necessarily indicate toxicity). District staff measured Chlorophyll-a and Phycocyanin during field monitoring which was used to gauge HAB presence. Chl-a samples and phycocyanin levels indicate ponds have harmful algal blooms (Figure 4-37).

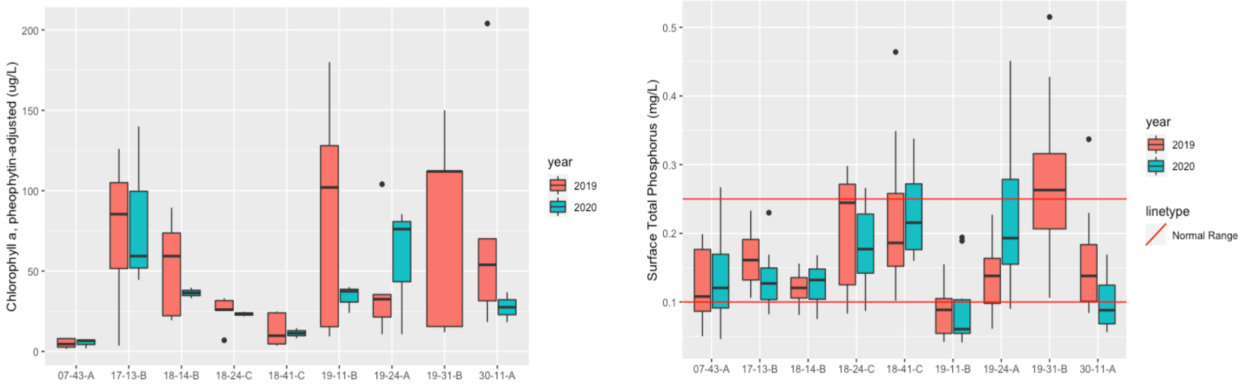


Figure 4-37 2019-2020 Stormwater Pond Surface Total Phosphorus and Chlorophyll A.

- Pond phosphorus levels averaged concentrations of around 200 ug/L (Figure 4-37) but had maximum concentrations that were very high. This suggests levels are highly dependent on episodic events (i.e., rain events or lack thereof). High phosphorus levels could be driven by high particulate seen within the ponds. All nine ponds sampled were anoxic for a significant portion of the year, even large ponds that should have a better chance of mixing. Sheltering around the ponds may be a main driver in reducing pond mixing and therefore increasing anoxia.

- Measured anaerobic phosphorus release in sediment cores and did not see much variation across all ponds, including other pond studies that have previously been conducted in the area. Sediment P release ranged from 2 to 9 mg/m2 /day resulting in an additional 1.2 to 7.7 pounds of P loading to surface waters and most phosphorus was iron bound.
- Overall, the ponds are still effective at removing P, but some are better than others and could be improved. The ponds with higher release rates could be targeted for BMPs to improve removal efficiencies. Developing a framework to determine which ones are performing poorly for targeted treatment is needed. In most cases, more than 75% of the released P load could be addressed by restoring P retention in ponds greater than 2 acres in size.
- A CE-QUAL model has been developed to identify drivers of pond anoxia and develop hypotheses to determine the role of re-aeration, biochemical oxygen demand (BOD), and sediment oxygen demand (SOD). Using measured sediment P release and P8 estimated settling, all ponds in the study demonstrated net retention of P, albeit at a reduced rate when factoring in sediment sources of P (Figure 4-38). When these factors were applied at a watershed scale, watershed P retention was reduced by as much as 50% and the Lake Riley watershed has the potential to be a net source of P even when accounting for all of the P sedimentation in the watershed. Based on these results, addressing sediment P release in the watershed will improve the efficiency of the stormwater ponds.

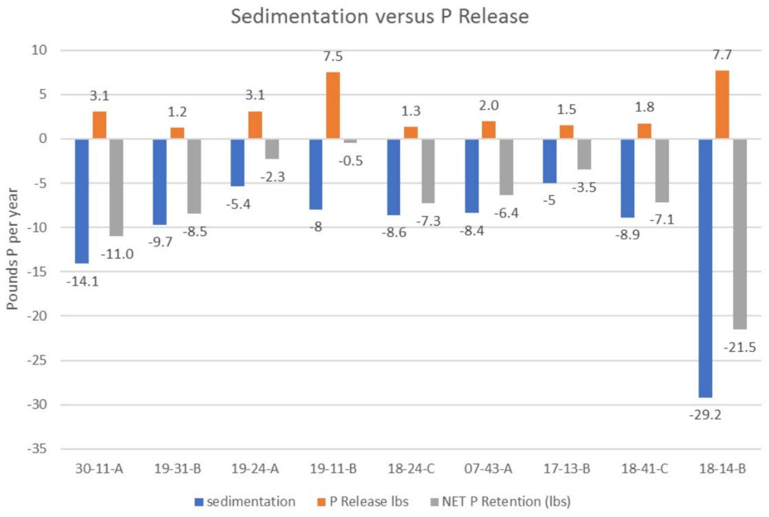


Figure 4-38 Stormwater Mass P Flux using P8 and Sediment Release.

Stormwater Pond Research Avenues

- Creation of a Stormwater Pond Decision Tree
- Quick Assessment for Identifying High Risk Ponds
- More Efficient Stormwater Pond Function – Design and Retrofits/Mitigation
- Assessment/Revision of Current Nationwide Urban Stormwater Ponds (NURP) Standards
- Refinement of Current Stormwater Pond Modeling
- More Investigation of Biological and Sediment Oxygen Demands Role in the Functionality of Stormwater Ponds.
- Constructed Ponds vs Converted Natural Wetlands and the Relevance Sediment Plays

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 5-1*). 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 exist in RPBCWD waterbodies, but to be an early detection tool for new infestations of AIS. Figure 5-1 identifies AIS monitoring/management that occurred in 2022, excluding common carp management.

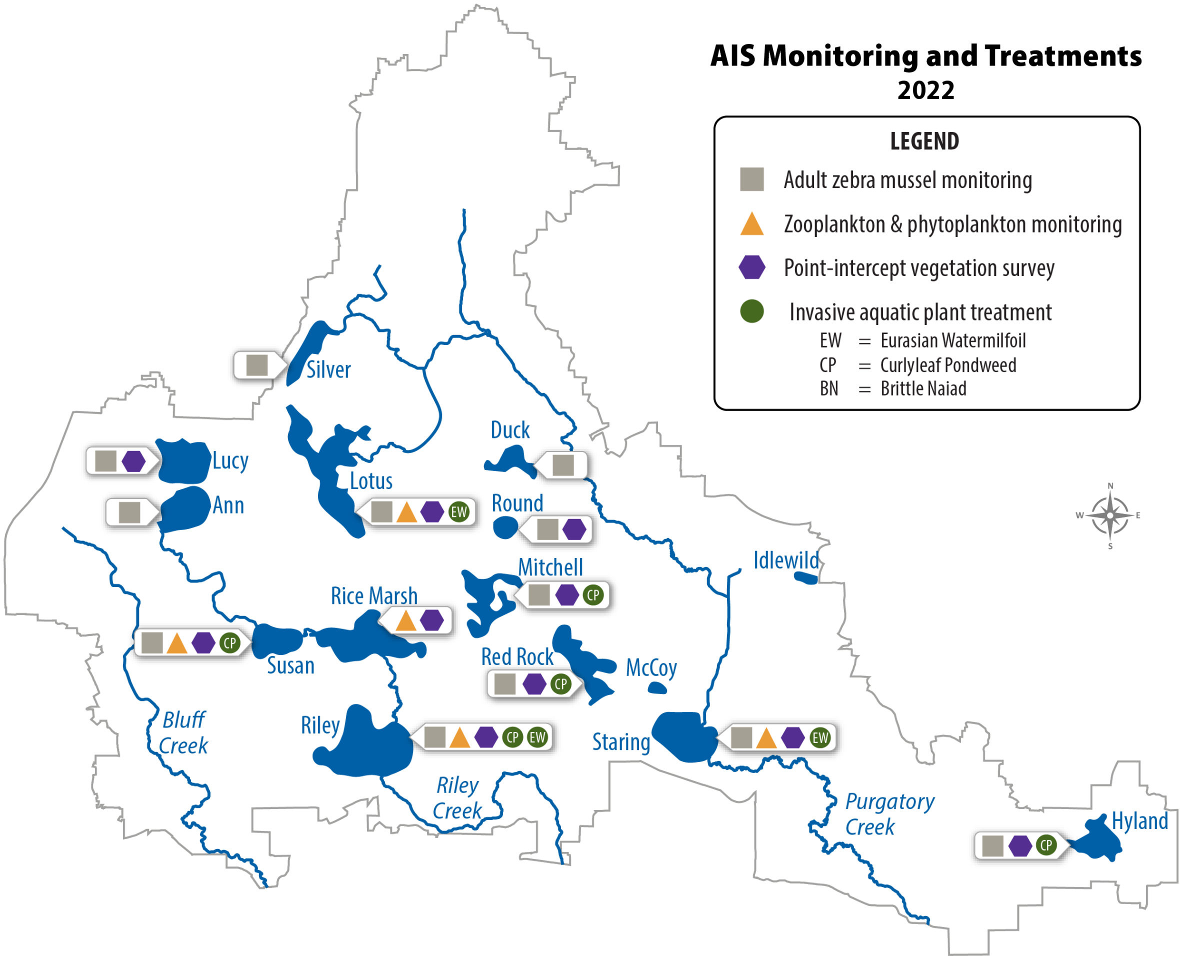


Figure 5-1 2022 Aquatic Invasive Species Summary

Aquatic Invasive Species (AIS) work conducted in 2022 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 5-1 Aquatic Invasive Species Infested Lakes

Lake Names	Brittle Naiad	Eurasian Watermilfoil	Curlyleaf Pondweed	Purple Loosestrife	Common Carp	Zebra Mussels
Ann	x	x	x	x	x	
Lotus	x	x	x	x	x	x
Lucy		x	x	x	x	
Red Rock		x	x	x		
Rice Marsh			x	x	x	
Riley		x	x	x	x	x
Silver			x	x		
Staring	x	x	x	x	x	
Susan	x	x	x	x	x	
Duck		**x**	x	x		
Mitchell		x	x	x		
Round	x	x	x			
Hyland			x			

X– Indicates new infestation.

5.2 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 they 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, and 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 2022, point intercept surveys were conducted Hyland Lake (TRPD), Mitchell, Rice Marsh (EP), Lake Susan, Lake Lucy, Lotus Lake, Staring Lake, and Lake Riley (district). Aquatic plant reports can be provided upon request. Figure 5-2 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 25 species which is followed by Silver with 18 species. Most lakes have between 10-15 species of native plants with Hyland and Round with the least native plant diversity (4 species). The district will continue to monitor the aquatic plant communities 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.

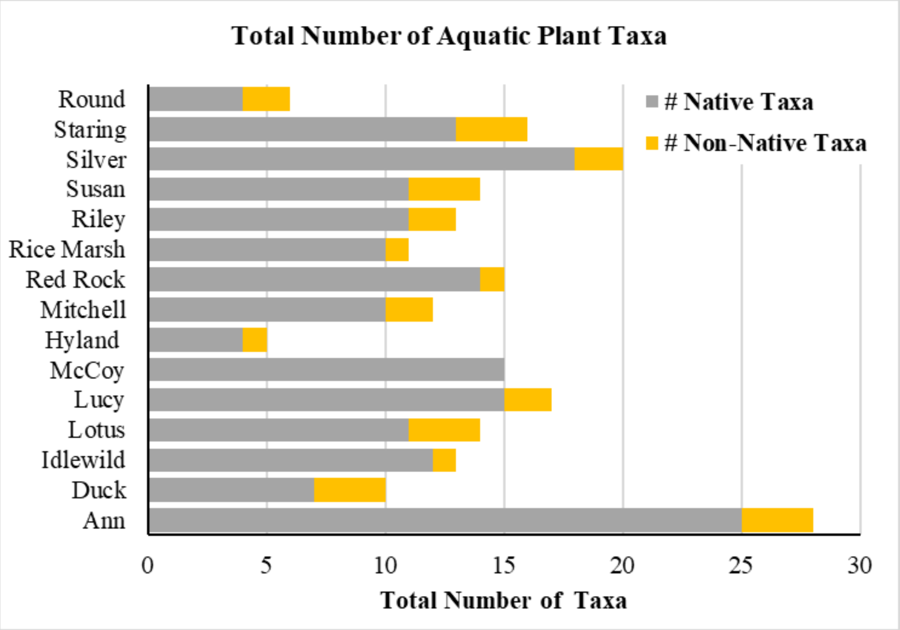


Figure 5-2 Total Number of Aquatic Plant Taxa

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

- HYLAND: A turion survey in 2022 showed an increase in the number of turions in the lake which is due to the improved water clarity from the alum treatment. In 2022, the herbicide Fluridone was used again to treat CLP immediately after ice-off. CLP density was at 70% during the pre-treatment survey and was reduced to 0% post treatment. CLP density was 3% during the late summer survey, indicating that CLP is continuing to germinate throughout the late season which is unusual. The native plant community has continued to decline. The late summer survey had a native plant frequency of only 5%, which is the lowest since 2008. Water levels were at the lowest level since 1979, which might be influencing the native plant community.

- LOTUS: A late summer point intercept survey indicated that the percent littoral area vegetated has declined since the 2017 and 2019 surveys. Coontail was the most common native plant species while Eurasian watermilfoil has been steadily increasing since 2017.

- LUCY: Submersed coontail (50% frequency of occurrence) and floating white waterlily (30% frequency of occurrence) are the dominant vegetation in the lake. Since the 2019 survey, the number of species was reduced from 20 species to 15 in 2022, while the percent vegetated littoral remained relatively the same around 60%. Low water levels may have led to the decline in the number of species.

- MITCHELL: Coontail was the dominant plant in Mitchell Lake and was found growing at 54% of the sites. The number of species observed at each site ranged from 1 to 6 species with the most occurring in the northeast arm.

- RICE MARSH LAKE: Coontail was the most common plant found at 94% of sites and flatstem pondweed was the second most common plant, found at 62% of sites. Overall, plant growth in Rice Marsh covered 100% of the lake area. Watermeal and duckweed covered approximately 50% of the lake.

- RILEY: In June, 13 species were observed, 11 that were native. In August, 12 species were observed, 10 that were native. Due to the lake management in and around the lake, native plants have steadily increased in frequency of occurrence and have been able to expand into deeper depths because of the increased water quality. A turion survey in 2022 showed a slight increase in the number of turions in the lake. Turion densities remained low indicating the success of the herbicide treatments.

- ROUND: In the July point intercept survey, Eurasian watermilfoil growth was found at 47% of the sites at a range of densities from light to heavy growth. Plants were observed growing out to a depth of 10 feet in summer. Submerged plants, dominated by native coontail, covered more than 22 acres of the lake bottom. White water lilies were relatively widespread at a moderate density along much of the shoreline.

- STARING: In 2022, the herbicide Fluridone was used to treat Eurasian watermilfoil and was successful. Unfortunately, the reduced vegetation from the treatment combined with the low water levels led to reduced water quality. Nutrient levels should decline as native vegetation expands across the lake. A turion survey in 2022 yielded no turions indicating the herbicide treatment was effective.

- SUSAN: Native plant frequency of occurrence and number of species remained low due to poor water quality. The number of projects planned for the lake along with projects already in the ground should improve the lake. A turion survey in 2022 showed a similar number of turions as seen in 2020 (35).

In the spring of 2022, herbicide treatments were carried out by PLM Lake and Land Management Corporation on district lakes. Curly leaf pondweed was treated on Mitchell Lake (12.85 acres), Lake Riley (16.7 acres), Lake Susan (8.25 acres), and Red Rock (13 acres) for curly leaf pondweed. These survey maps can be seen in *Exhibit I*. Eurasian watermilfoil was treated on Riley (8.1 acres) and both Eurasian watermilfoil and curlyleaf pondweed were targeted with a single treatment Lotus Lake (20.8 acres) and Staring Lake (whole lake fluridone). A MNDNR Traditional AIS Control Grant in the amount of $10,000 was awarded and utilized for the Staring Lake whole lake fluridone treatment. A summary of the 2022 lake vegetation monitoring and management can be seen in *Table 5-2* and *Exhibit I*.

Table 5-2 2022 Lake Vegetation Monitoring & Management

Lake	PI Surveyor	Delineation	Delineation Surveyor	Herbicide	Acreage
Red Rock	EP	CLP	District	Aquathol	13
Mitchell	EP	CLP	District	Diquat	12.85
Lotus	District	CLP/EWM	District	Diquat	20.8
Riley	UMN	CLP	District	Diquat	16.7
Riley		EWM	District	Procellacor	8.1
Susan	UMN	CLP	District	Diquat	8.25
Staring	UMN	CLP/EWM	District	Fluridone	whole
Hyland	TRPD	CLP	TRPD	Fluridone	whole
Lucy	District				
Rice Marsh	EP				
Round	EP				

*All aquatic herbicide treatments were directed and financed by the RPBCWD and executed by PLM Lake and Land Management Corporation.

Red Rock Lake Turion Survey

In 2022, District staff completed a curly leaf pondweed turion survey on Red Rock 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 cm2 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. Upon retrieving each sediment sample, the sampler contents were emptied into a sifting bucket (1 mm screen) and searched for turions. The turions found were placed into a labeled plastic bag with lake water 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 were not included in the final turion counts. We calculated 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.

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 d 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 d at 20 C with 14 h of light per day from a bank of four fluorescent 20-watt grow lamps. After 90 d of warm incubation, we 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/m2) in each lake for each year. The results from the survey are below:

Table 5-3 2022 Red Rock Lake CLP Turion Statistics

Total Number of Sample Points	40
Total Number of Live Turions/Total Turions	11/106
Total Number of Points with Viable Turions/Total Points with Turions	9/22
Frequency of Occurrence	23
Number of points above potential impairment (+50/m2)	12
Number of points above predicted nuisance level (+200/m2)	8
Maximum Turions/m^2	905.17
Mean Turions/m^2	114.22
Standard deviation/m2	68.78

Table 5-3 summarizes the results from the 2022 Red Rock Lake CLP Turion Survey. On October 25, 2022, survey, District staff found 106 total CLP turions; 9 of 40 points had live turions (23% occurrence). This is the first turion survey conducted on Red Rock Lake so no temporal comparisons could be made. Turions appeared to be concentrated in the shallow southern basin (Figure 5-3). The overall mean density within the study areas was 114.22 turions/m2 with a standard deviation of 68.78 turions/m2. This mean value was significantly higher than other lakes sampled in 2022. Overall, the number of turions are low in the area that has received consecutive herbicide treatments (along the west side of the northern basin). For herbicide applications, from 2015-2017 endothall was used and from 2018-2022 diquat was used. Yearly aquatic plant harvesting has occurred on Red Rock for navigational purposes. Twelve of the survey points topped an estimated 50 turions/m2 which indicates a low potential for navigation impairment (Johnson 2012) (50% of points with turions). Eight points exceeded the expected “nuisance level” of 200/m2 with three points >350/m2 which is extremely high (Figure 5-3). District staff will continue to monitor the CLP pondweed on Red Rock Lake to assess if treatment is needed moving forward.

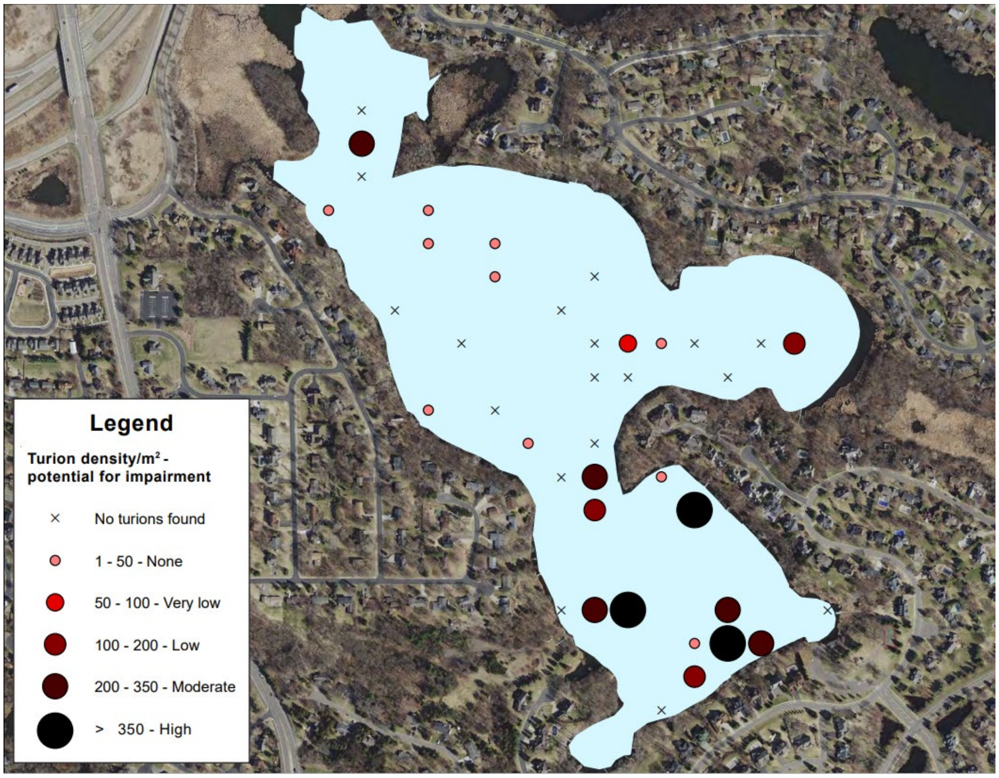


Figure 5-3 2022 Fall Red Rock Lake CLP Turion Survey Density and Distribution

5.3 Common Carp Management

The 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. At that point, the district would also consider further management action. In 2022, 440 carp or 1,581 lbs. of fish were removed from RPBCWD (*Table 5-4*).

Figure 5-4 Electrofished Common Carp

Table 5-4 2022 Total Carp Removed

System	# Of Fish	Weight (lbs.)
RCL	64	227.16
PCL	376	1353.4
Total	**440**	**1580.56**

Trap Netting

District staff completed trap net surveys on Staring Lake, Lake Lotus, Lake Ann, and the Upper (UPCRA) and Lower Purgatory Creek Recreational Area (LPCRA) in 2022. Of the lakes sampled, the UPCRA had the most fish captured (n=1,099). Staring Lake had the most diverse fish population in 2022 (n=10). Previously the UPCRA had the highest at 10 different species were captured in 2021 and 11 species were captured in 2020. 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. Staring Lake had the highest number of bluegills captured, averaging 102 fish per net. This is up from 2021 (n=39) and historically on the higher end of bluegill numbers. The LPCRA had the lowest bluegill abundance at around 10.67 bluegills/net. This is down from 53.25 bluegills/net in 2021. Other species that were abundant included pumpkinseed sunfish, black crappies, and bullhead species. UPCRA had the highest number of black crappies by far (242.25 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

Figure 5-5 Staring Lake Trap Net

in low numbers across the lakes. A full summary table of the fish captured for each lake can be found in *Exhibit B*.

In 2022, a total of four YOY carp were captured via trap net surveys. All of which were captured in the LPCRA. The lack of young individuals captured across all other sampled lakes indicates that 2022 was a poor recruitment year for common carp. YOY carp numbers were down in the LPCRA from 2020 (n=17) but up slightly since 2021 (n=0). In 2022, the four YOY carp captured here, indicate limited recruitment. This is most likely due to a combination of a winterkill and the extremely low summer water levels within this area, leading to increased predation.

Electrofishing

Lake Lucy and LSPP were the only RCL waterbodies electrofished in 2022. Rice Marsh Lake was planned to be sampled but extremely low water levels made it difficult to access. No carp were captured in Lake Lucy across the three sampling events. Since 2008, Lake Lucy has hovered around the 100 kg/ha biomass threshold (Figure 5-6). The last time Lake Lucy was sampled was in 2017 and in winter of 2018/2019 a winter kill occurred. This may explain the reduction in common carp in the system to the lowest levels seen. LSPP continues to be a congregation area for common carp within the RCL system. In 2017 the biomass estimate for carp was 404 k/ha which has steadily declined since (Figure 5-6). In 2022, the biomass estimate was well above the biomass threshold of 100 kg/ha at 165 kg/ha (*Table 5-5*). 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 it. 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 to prevent carp movement into the pond to prevent recruitment. The district will continue monitoring and removing carp from LSPP in addition to the recommended management actions established in the RCL management plan.

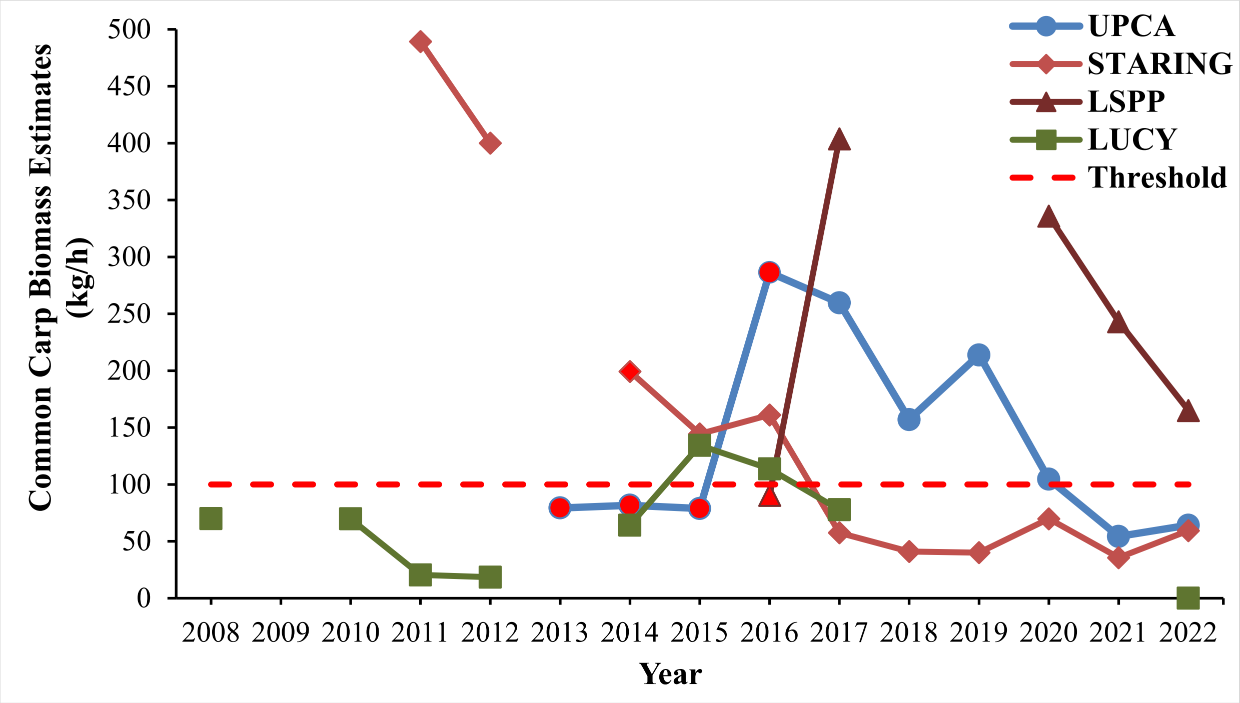


Figure 5-6 2008-2022 Common Carp Biomass Estimates
*Red markers indicate partial sampling year.

The PCL waterbodies surveyed via electrofishing in 2022 were Staring Lake and the UPCRA. As seen in (Figure 5-6), the adult common carp biomass estimates have been decreasing in Staring Lake since management began. The 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 60 kg/ha (Figure 5-6). 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. Electrofishing does not regularly occur in the LPCRA due to access issues and the amount of brittle naiad present in the system. In 2022, the UPCRA carp biomass estimate was below the threshold at 64 kg/ha (*Table 5-5*). 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 system and fish migrating between the systems. 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 flow through wetlands (UPCRA and LPCRA are shallow water wetlands). The low water levels seen in 2021 and 2022 may have also led to decreased carp populations due to increased predation and will likely lead to a significant if not complete winterkill this winter. Staff will continue to monitor the carp population and remove fish.

Table 5-5 2022 Common Carp Biomass Estimates

Lake	Fish per Hour	Density per Hectare	Average Weight (kg)	Carp Biomass (kg/ha)
Lake Susan Park Pond	21.12	102.53	1.61	165.07
Lucy	0	3.04	0	0
Staring	4.23	22.96	2.59	59.46
Upper PCRA	9.92	49.77	1.29	64.2

PCL 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, the physical carp barrier was closed all year. Due to the low water levels in 2022, the City of Eden Prairie rarely opened, cleaned, and closed the fish barrier during high water levels in the Purgatory Creek Recreational Area. Only once was the barrier held open for an extended period (2.5 weeks) in late March through April 14th. During this time, fish could move freely throughout the system.

During the spring of 2022 spawning run, staff utilized a backpack electrofishing unit combined with block nets to remove common carp. Springtime boat electrofishing was added in UPCRA in 2020 to attempt to remove carp seen congregating in large groups, however this method was not utilized in 2022. Backpack electrofishing and block nets were utilized in the channel upstream and downstream of the barrier

Figure 5-7 PCRA Spring Removal Site Map

and at the breach in the berm that separates the Upper and Lower Purgatory Creek Recreational Area (Figure 5-7). 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 2022, 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. It is also assumed that the berm has further eroded and/or subsided, making it easier for fish to move freely at the site.

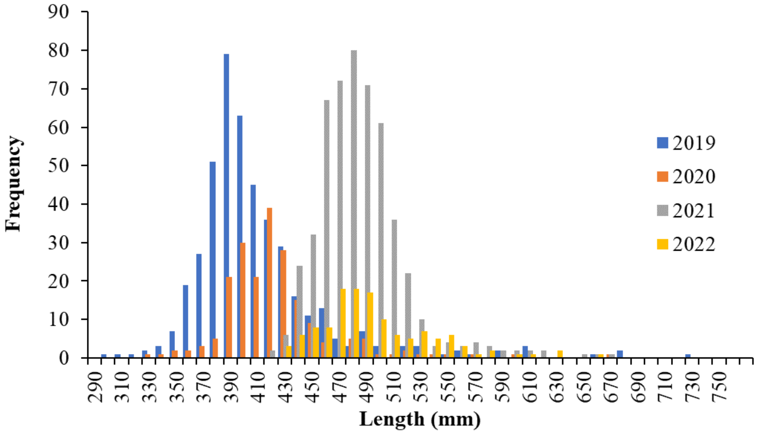


Figure 5-8 2019-2022 Length Frequency of PCRA Spring Removals

In 2022, the backpack electrofishing below the barrier combined with a block net across two sampling events yielded a total 315 carp removed or 1,145 lbs. By sex, 30% were males and 70% were females Utilizing all spring gear types in the past, a total of 511 carp were removed in 2021, 201 in 2020, 441 carp 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 thus far Figure 5-8. In 2022, most of the carp were removed on April 22 when water temperature was near 7 degrees Celsius. April 19th when upstream barrier water levels were 57.4 inches (based on the installed staff gauge) and water temperatures at 7.8 degrees Celsius (Figure 5-9). This is compared to April 19th, 2021, at 57.4 inches and 7.8 degrees; May 7th, 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 possibly conduct electrofishing after dark in 2023 to improve capture efficiency.

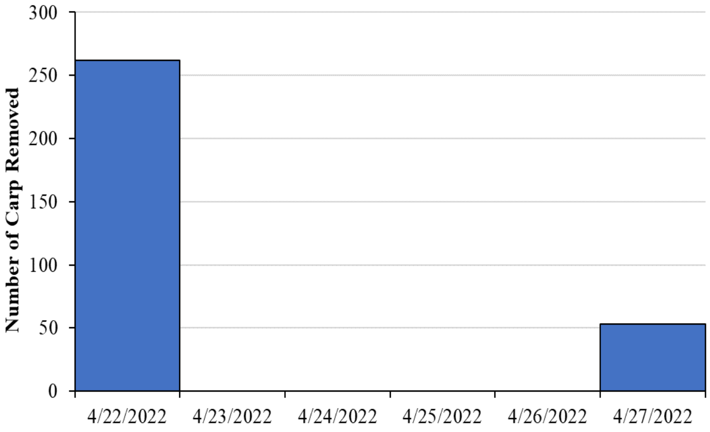


Figure 5-9 Purgatory Creek Recreational Area Common Carp Removal

Goldfish Removals

The RPBCWD is aware that goldfish (*Carassius auratus*) are present in the district and are becoming a concern to residents. Significant populations have been noted in multiple stormwater ponds and within Duck Lake. Goldfish are most likely introduced to these waterbodies in the form of people releasing pets. They then can reproduce successfully because there are limited predators to control them due to the frequent winterkills that occur in these systems. Winterkill refers to the loss of fish that can occur during winter because oxygen levels fall below 2 mg/L for an extended period. Goldfish can survive in these conditions for months by shifting their physiology and producing ethanol through fermentation as lactic acid builds under anoxic conditions (Shoubridge & Hochachka 1980 & 1983). Goldfish are a non-native species and are in the carp family. Like common carp, goldfish can cause water quality problems by disturbing lake sediments and damaging aquatic vegetation. While it's clear that goldfish cause less damage to aquatic ecosystems than common carp, limited data is available on the magnitude of their impacts. Trying to tease out water quality impacts of goldfish is difficult because water systems are very complex and little research has been done on this topic.

Figure 5-10 Goldfish Removal from Kerber Pond

The district did conduct an experimental removal event on Kerber Pond in Chanhassen using a seine net combined with backpack electrofishing this spring. Staff were able to surround the goldish with a large seine and direct others into the net. An estimated 23,310 goldfish were removed from Kerber Pond which took limited time and effort. Backpack electrofishing via kayak was also tried on a stormwater pond on Stone Creek Drive in partnership with the City of Chanhassen but had limited success (542 fish removed). Both methods were used on Duck Lake in 2021 (133 fish removed) and a stormwater pond near the Staring Lake Outdoor Center (127 fish removed) but had limited success. This strategy is more successful on smaller stormwater ponds because goldfish could be targeted more easily Figure 5-10.

The district is currently working with Carver County which has begun a goldfish control program. The district is consulting with them about different gear and techniques that have been the most successful in their own operations. The use of herding goldfish into shallow culverts and into box nets has been successful in Carver County when conducted in smaller, shallow stream channels. The use of rotenone (fish toxin) is currently being considered as a tool to use in stormwater ponds where we see large goldfish populations. This could possibly be done in stormwater ponds since no other fish/very few fish can access or survive in these ponds. Rotenone would kill all fish within the pond. Using this in Duck

Lake presents more challenges since it is a public lake and would essentially kill every fish in the lake. Additionally, a more complex system such as Duck Lake (depth variability, bays, etc.) can reduce the chances of a complete kill leaving some goldfish behind to reproduce. Any treatment of this type would occur in the winter and would need to be approved by the MN DNR which has had a varying success using this technique to control carp. The district was also looking into utilizing drawdowns within stormwater ponds. Instead of removing individuals via netting/electrofishing/etc., it would be more cost effective, have a better chance of complete removal, and would be easier overall to utilize winter drawdowns. The other option would be to combine rotenone with a drawdown. Using drawdowns alone may be just as effective without the use of chemicals. Benefits of drawdowns include:

- Most ponds are not within the ordinary high-water level and not considered public waters.
- No chemicals or need to block outlets.
- Limited native species mortality due to the already harsh conditions within stormwater ponds (often goldfish are the only fish able to survive).
- Many ponds are located entirely within city property.
- There are less safety and general public concerns.

A drawdown works by utilizing large pumps already in the possession of our city partners to pump all or most of the water out of ponds (the district would target ponds with large goldfish populations). This would be done late fall or during winter to maximize chances of a complete kill. The pumps would be fitted with mesh socks and water would be pumped downstream. This management strategy could potentially be applied to larger ponds (Kerber Pond) or small lakes (Duck Lake) in the future. A TAC or separate meeting would most likely need to be held to discuss the topic further.

5.4 Zebra Mussels

Zebra mussels are native to Eastern Europe and Western Russia and were introduced to 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's 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. The district continued to monitor for adult and veliger zebra mussels in 2022. The district conducted veliger sampling from June to July on 13 lakes and a wetland to detect the presence of zebra mussels. Each lake was sampled once, apart from Lotus Lake and Lake Ann which were sampled twice. Kylie Cattoor processed the samples and only found zebra mussel veligers on Lake Riley in 2022. Adult zebra mussel presence was assessed using monitoring plates 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 2022. Public accesses were scanned monthly for approximately five to ten minutes during the regular water quality sampling period. 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 searched. Adult zebra mussels were only found at Lake Riley in 2022. Carver County also submitted water samples to process for zebra mussel eDNA on Lotus, Ann, and Susan. No lakes had a positive eDNA hit which is the first time Lotus had a not tested positive since the initial listing of the lake.

Figure 5-11 Lake Riley Zebra Mussel Sizes

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, zebra mussels were found on all plates deployed ranging in number from 4,015 mussels to 29,959 mussels/plate. This indicates a robust population that is well established across the lake. The increase in 2022 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).

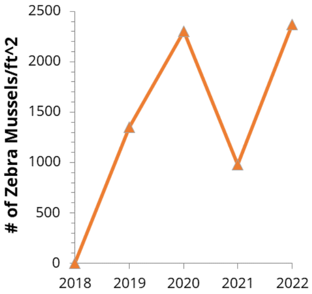


Figure 5-12 2018-2022 Zebra Mussel Density on Lake Riley

Lotus

On August 30, 2019, 5 zebra mussel veligers were found in veliger tows collected by Carver County from the public access of Lotus Lake (*Figure 5-1*). 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 5 zebra mussels ranging in size from 6-16 mm on a single boat lift footing in the east bay (*Figure 5-1*). 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 MN DNR. Similar to 2020 and 2021, veliger tows were collected twice in the spring but yielded no zebra mussel veligers in 2022. Both boat launch and mussel plate checks (5 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. Thousands of desiccated mussels were found on a lift on shore near where the mussels were found in 2019 during the fall survey, but none were found in the lake or elsewhere. The eDNA results for 2022 was the first negative result since 2019 when mussels were found for Lotus Lake. Staff will continue to monitor for zebra mussels in 2022.

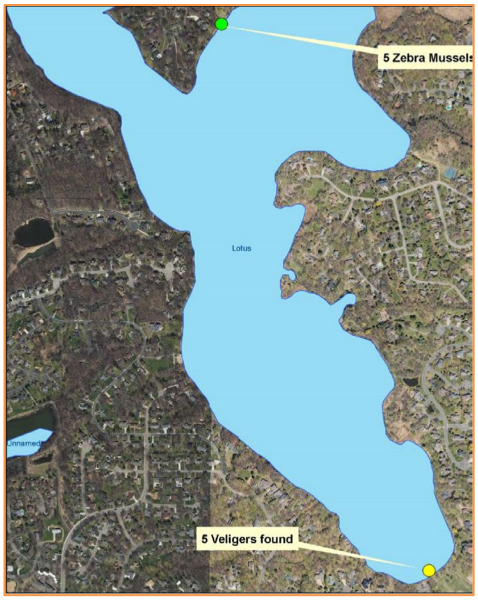


Figure 5-13 2019 Lotus Lake Zebra Mussel Map

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 within a system. *Table 5-6* lists the different variables associated with zebra mussels measured by the district in 2022 for Lake Riley and for Lotus Lake. In *Table 5-6*, the criteria 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. The estimated calcium concentrations in Lotus Lake and Lake Riley were similar to actual calcium concentrations collected from all other lakes in the Riley Chain. 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 both lakes. The nutrient variables for Lake Riley were at moderate to high levels for zebra mussel suitability. Lotus Lake nutrient data indicates minimal growth parameters for zebra mussels. This indicates the zebra mussel population may not be as significant if they invade Lotus Lake. Steve McComas 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 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 for zebra mussels in both lakes. In 2016, it was found that 98% 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 smaller, but dense groups of adults spread on isolated hard structure in slightly deeper portions of the lake. Hard structure in both lakes included predominantly rock and woody debris and is hypothesized to not be limiting for zebra mussels.

Based on the results in *Table 5-6* 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. In Lotus Lake *Table 5-6* indicates a slow growing or restricted population limited by minimal growth nutrient levels.

Table 5-6 Suitability for Zebra Mussels in Lake Riley and Lotus Lake

	LAKE	**Little**	**Mod**	**Max**	**RILEY**	**LOTUS**
Shell Formation	Calcium (mg/L)	8-15	15-30	30-80	44	56
	Alkalinity (mg/L)	30-55	55-100	100-280	140.5	173
	pH	7-7.8;9-9.5	7.8-8.2;8.8-9	8.2-8.8	8.51	8.65
Trophic Variables	TP (ug/L)	5-10;35-50	10-25	25-35	15	33
	Chl-a (ug/L)	2-2.5;20-25	8-20	2.5-8	4.5	25.4
	Secchi (m)	1-2;6-8	4-6	2-4	4	1.5
Physical Variables	Temp (deg C)	26-32	10-20	20-26	23.8	24.2
	DO (mg/L)	3-7	7-8	>8	8.79	8.82
	Cond (uS/cm)	0-60	60-110	>110	589	483
	Hard Structure	Little	Mod	Max	Mod	Mod

*Mackie and Claudi 2010
BLUE=Minimal Infestation Potential
ORANGE= Moderate Infestation Potential
RED=Maximum Infestation Potential
*Summer (June-Sept) averages across 0-2m depth profile

6 Lake and Creek Fact Sheets

The Riley Purgatory Bluff Creek Watershed District has included on the website (rpbcwd.org) informational fact sheets for the lakes and creeks that were monitored during the 2022 sampling season. The lake fact sheets include Lake Ann, Duck Lake, Hyland Lake, Lake, Lotus Lake, Lake Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Lake Riley, Round Lake, Silver Lake, Staring Lake, and Lake Susan. The creek fact sheets include Bluff Creek, Purgatory Creek, and Riley Creek.

Each lake fact sheet includes a summary of the historical water quality data collected as related to the MPCA water quality parameters: Secchi Disk depth, Total Phosphorus, and Chlorophyll-a. Each creek fact sheet includes a summary of the most current Creek Restoration Acton Strategy assessment, which includes the analysis of infrastructure risk, water quality, stream stability/erosion, and habitat. Lake or creek characteristics, stewardship opportunities, and information about district activities in and around local water bodies are also described in each fact sheet.

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8 Exhibits

Exhibit A *Historical and 2022 Lake Level Graphs (NAVD1929)*

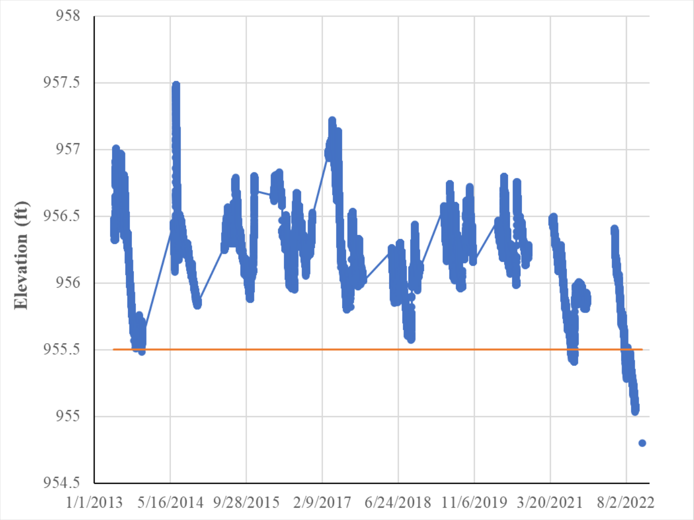


Figure A-1: Water surface elevation on Lake Ann from 2013 to 2022 & Ordinary High-Water Level (955.5 ft).

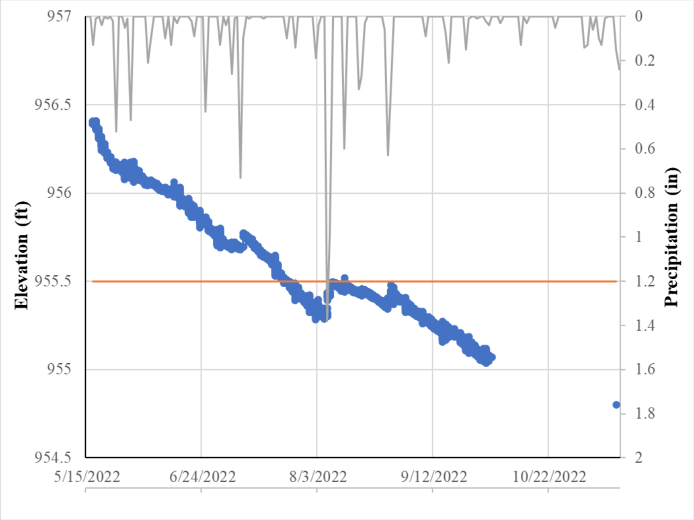


Figure B-1: Water surface elevation, precipitation & Ordinary High-Water Level on Lake Ann 2022 (955.5 ft).

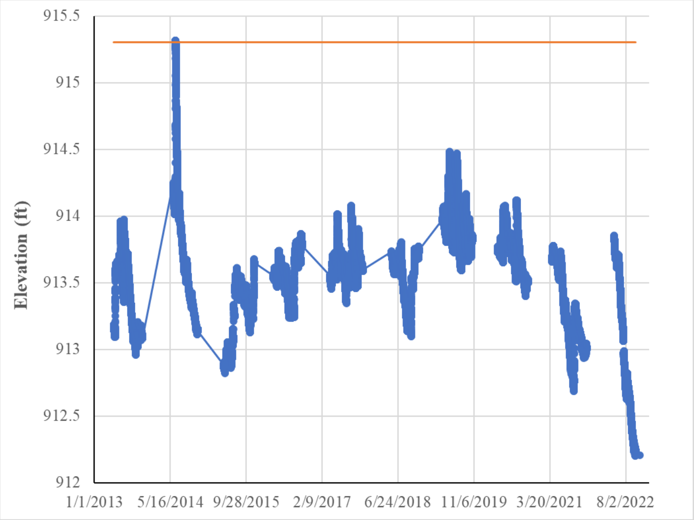


Figure A-2: Water surface elevation on Duck Lake from 2013 to 2022 & Ordinary High-Water Level (915.3 ft).

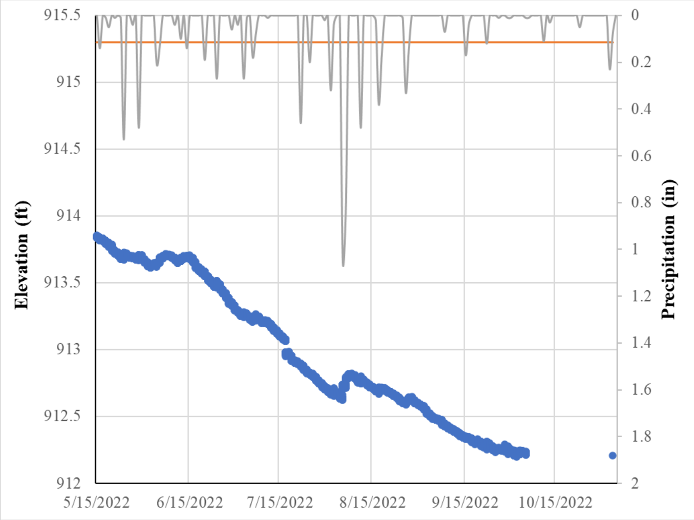


Figure B-2: Water surface elevation, precipitation & Ordinary High-Water Level on Duck Lake 2022 (915.3 ft).

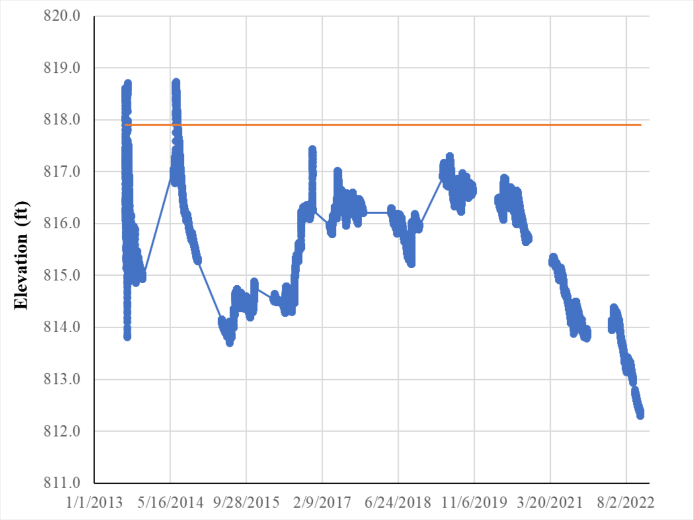


Figure A-3 Water surface elevation on Hyland Lake from 2013 to 2022 & Ordinary High-Water Level (817.9 ft).

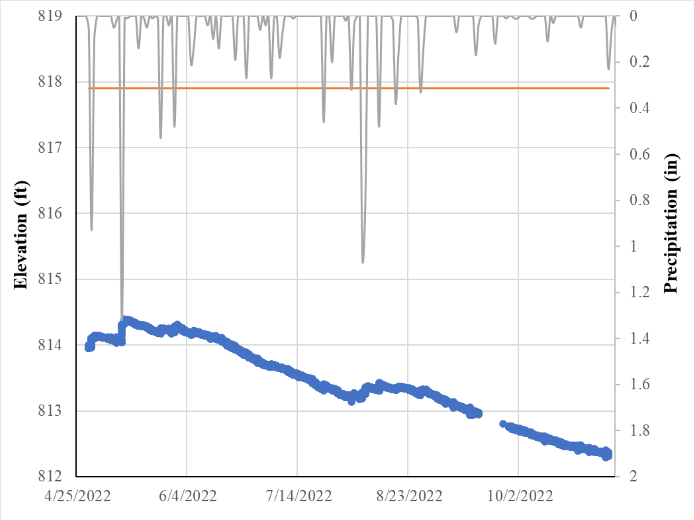


Figure B-3 Water surface elevation, precipitation & Ordinary High-Water Level on Hyland Lake 2022 (817.9 ft).

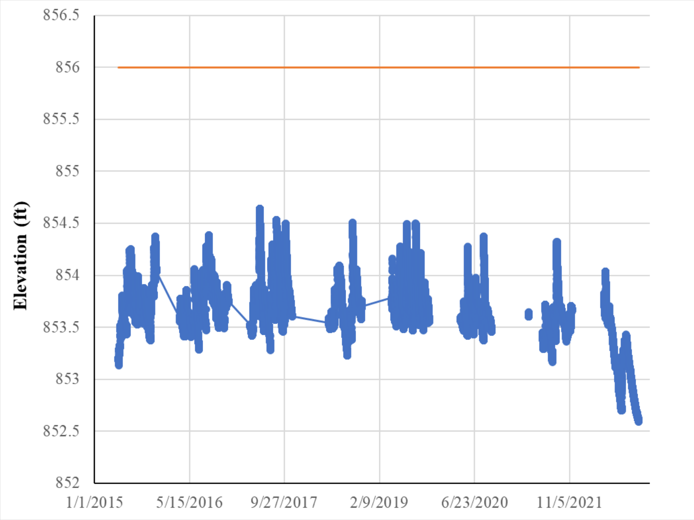


Figure A-4: Water surface elevation on Lake Idlewild from 2015 to 2022 & Ordinary High-Water Level (856 ft).

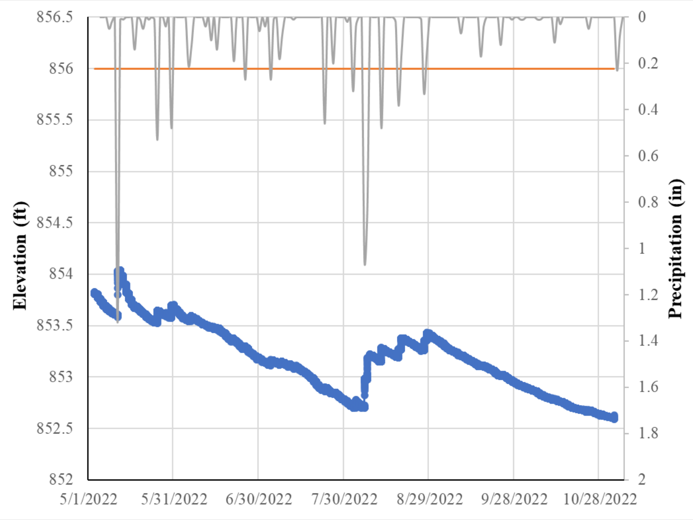


Figure B-4: Water surface elevation, precipitation & Ordinary High-Water Level on Lake Idlewild 2022 (856 ft).

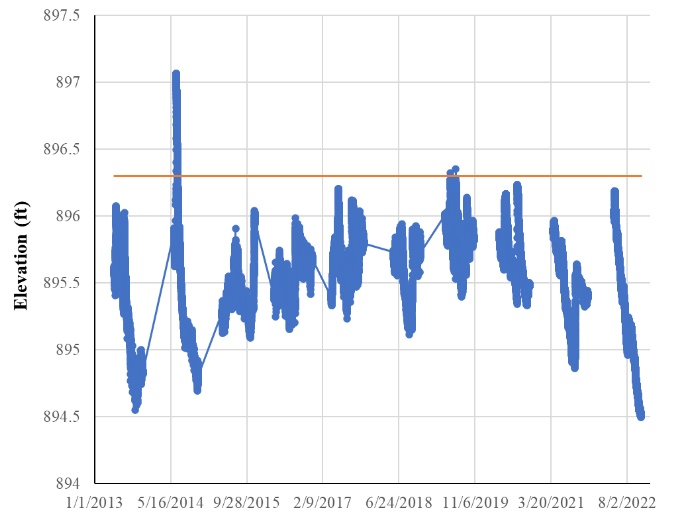


Figure A-5: Water surface elevation on Lotus Lake from 2013 to 2022 & Ordinary High-Water Level (896.3 ft).

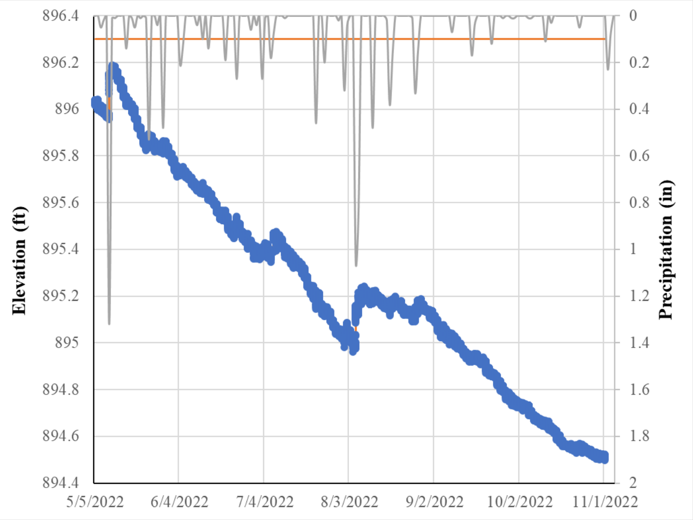


Figure B-5: Water surface elevation, precipitation & Ordinary High-Water Level on Lotus Lake 2022 (896.3 ft).

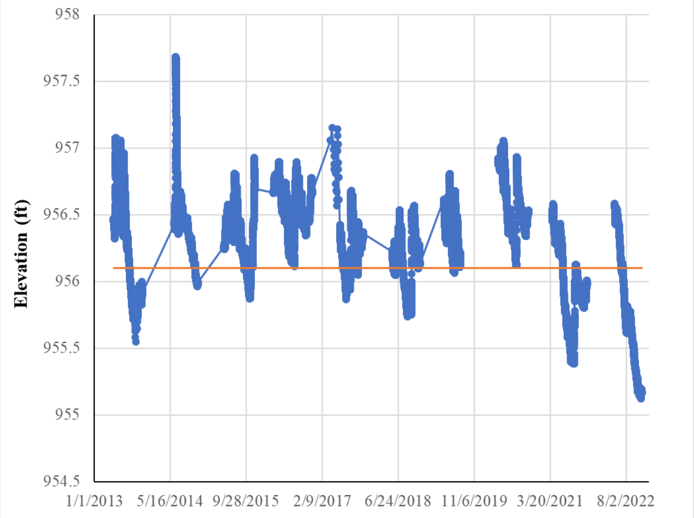


Figure A-6: Water surface elevation on Lake Lucy from 2013 to 2022 & Ordinary High-Water Level (956.1 ft).

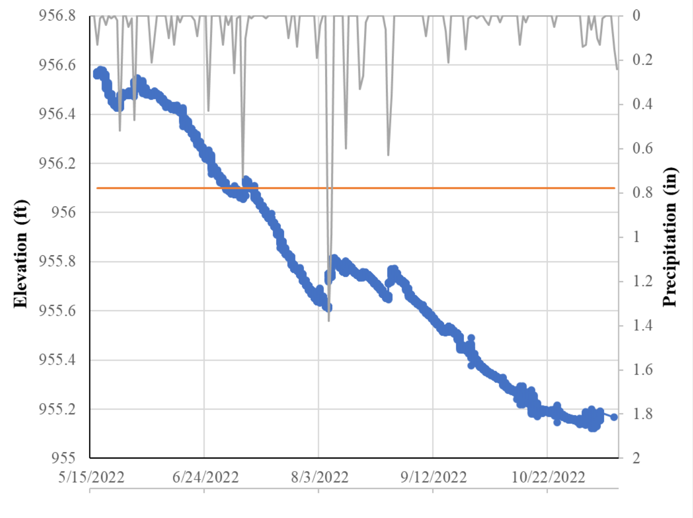


Figure B-6: Water surface elevation, precipitation & Ordinary High-Water Level on Lake Lucy 2022 (896.3 ft).

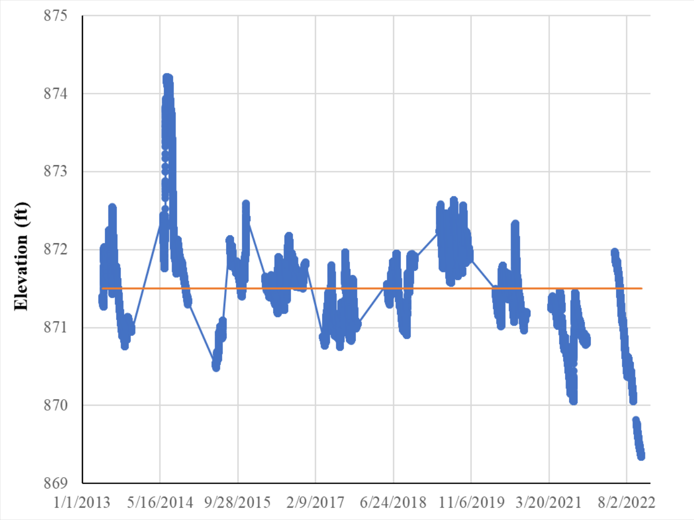


Figure A-7: Mitchell Lake water surface elevation from 2013 to 2022 & Ordinary High-Water Level (815.3 ft).

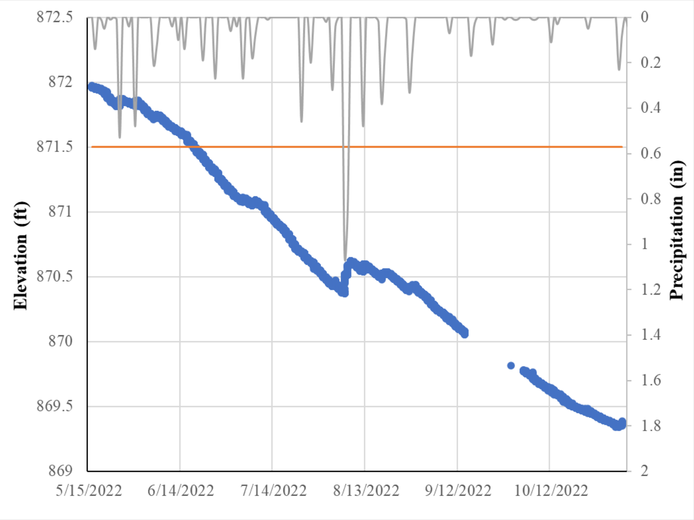


Figure B-7: Water surface elevation, precipitation & Ordinary High-Water Level Mitchell Lake 2022 (815.3 ft).

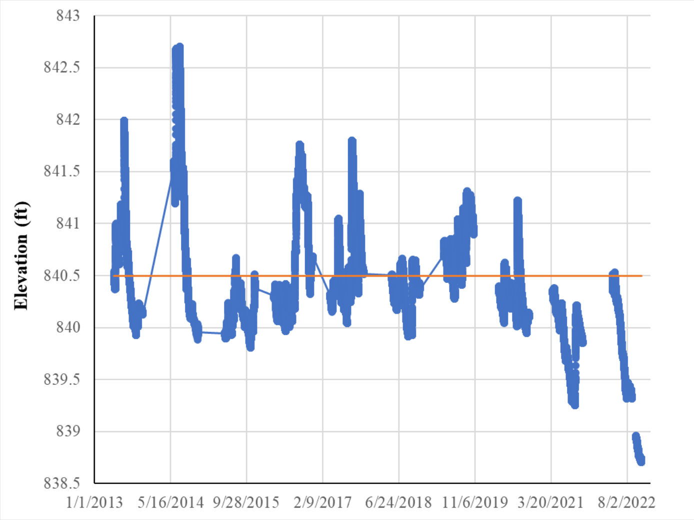


Figure A-8: Red Rock Lake water surface elevation from 2013 to 2022 & Ordinary High-Water Level (840.5 ft).

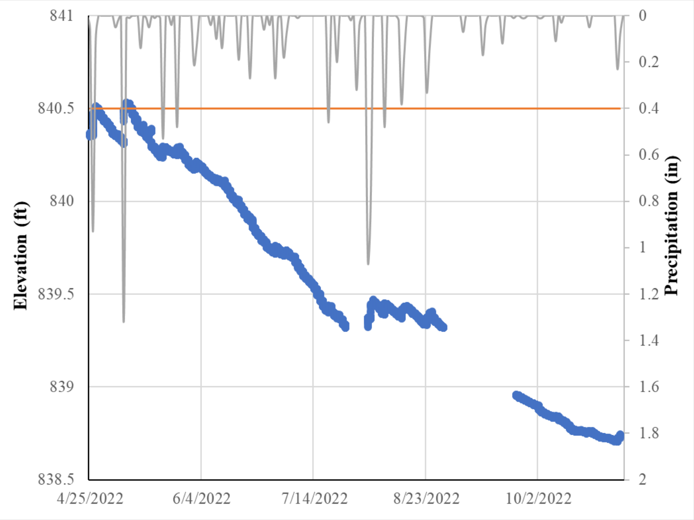


Figure B-8: Water surface elevation, precipitation & Ordinary High-Water Level Red Rock Lake 2022 (840.5 ft).

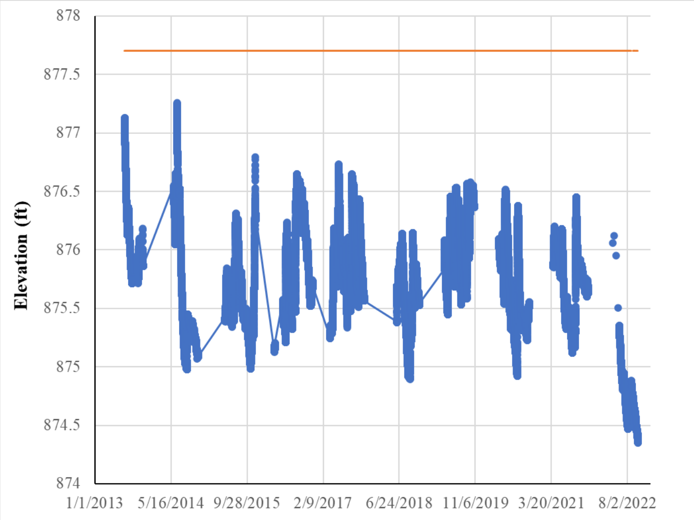


Figure A-9: Water surface elevation on Rice Marsh Lake from 2013 to 2022 & Ordinary High-Water Level (877 ft).

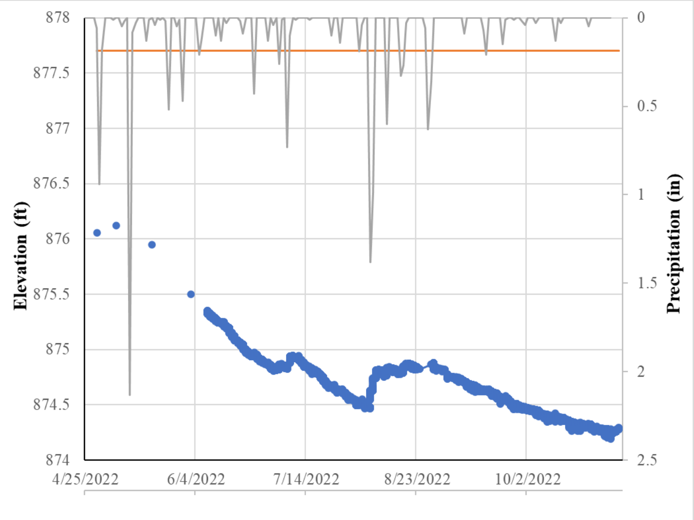


Figure B-9: Water surface elevation, precipitation & Ordinary High-Water Level Rice Marsh Lake 2022 (877 ft).

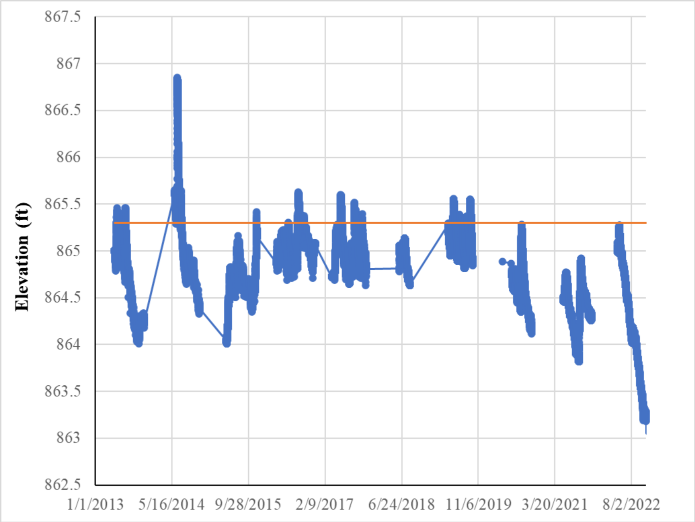


Figure A-10: Water surface elevation on Lake Riley from 2013 to 2022 & Ordinary High-Water Level (865.3 ft).

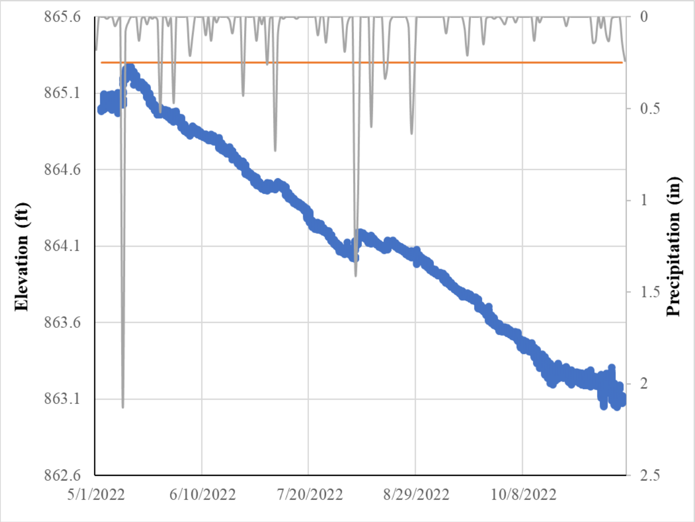


Figure B-10: Water surface elevation, precipitation & Ordinary High-Water Level Lake Riley 2022 (865.3 ft).

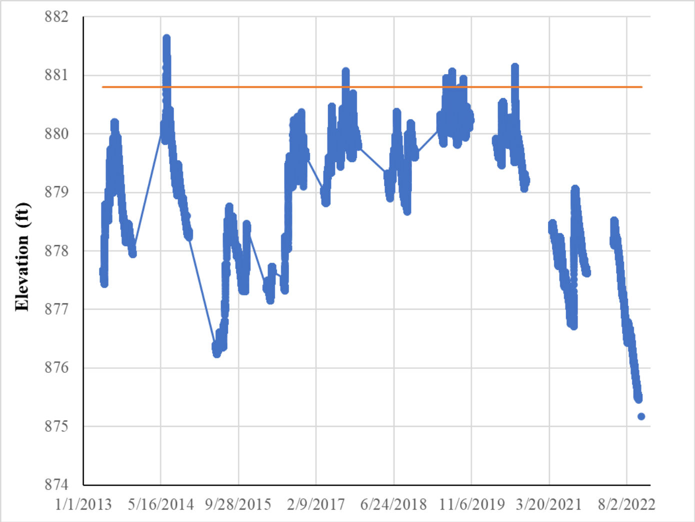


Figure A-11: Water surface elevation on Round Lake from 2013 to 2022 & Ordinary High-Water Level (880.8 ft).

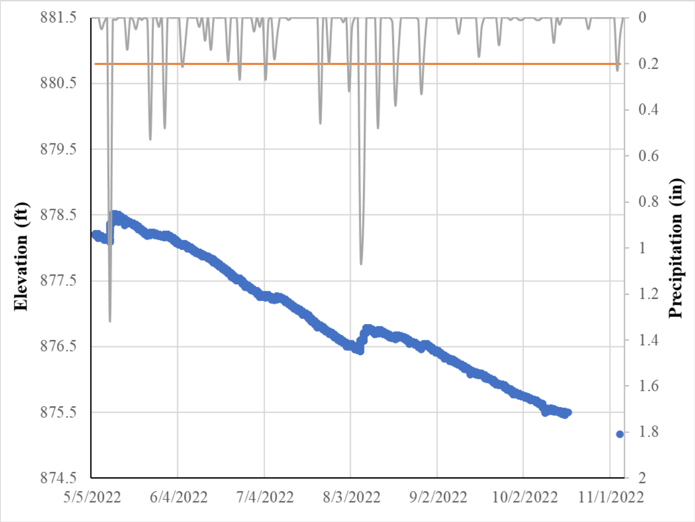


Figure B-11: Water surface elevation, precipitation & Ordinary High-Water Level Round Lake 2022 (880.8 ft).

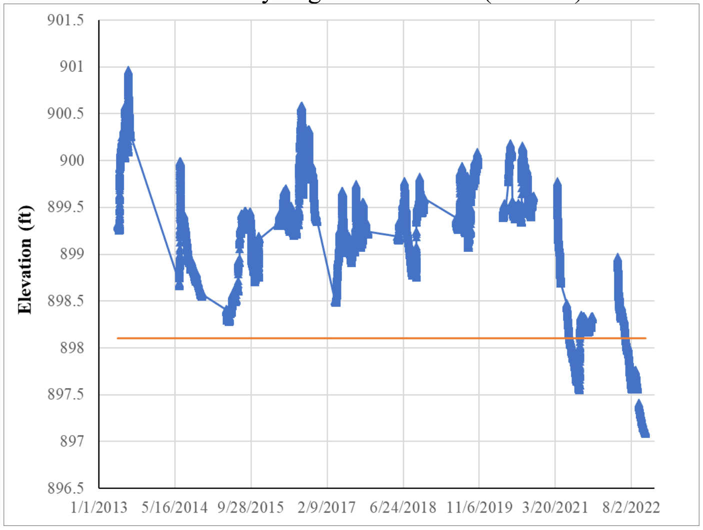


Figure A-12: Water surface elevation on Silver Lake from 2013 to 2022 & Ordinary High-Water Level (898.1 ft).

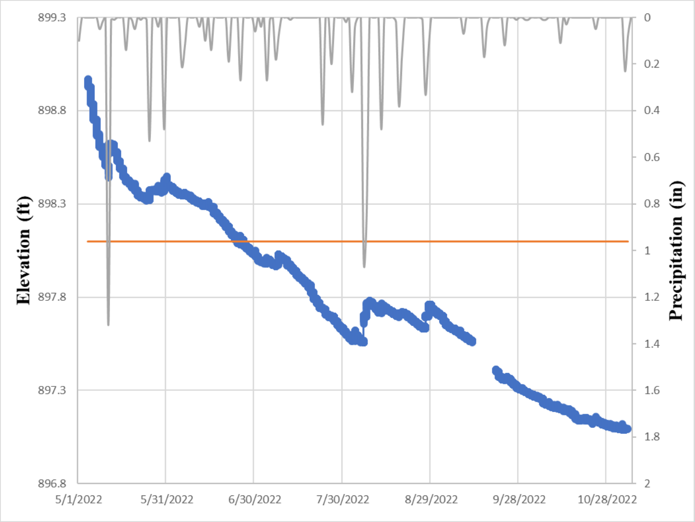


Figure B-12: Water surface elevation, precipitation & Ordinary High-Water Level Silver Lake 2022 (898.1 ft).

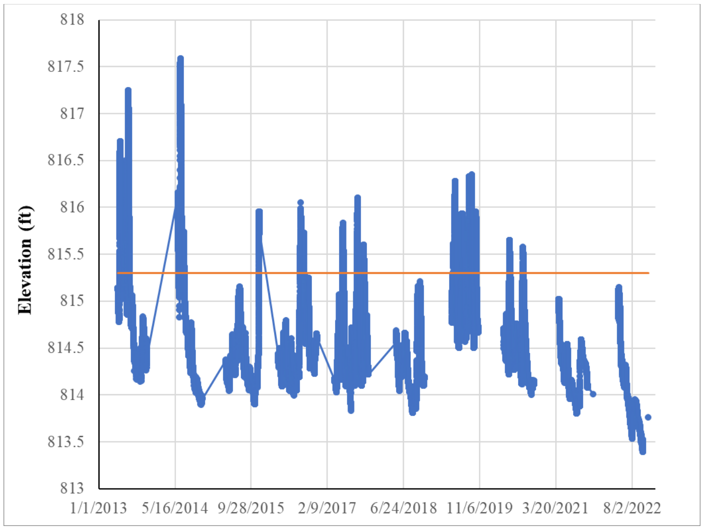


Figure A-13: Water surface elevation on Staring Lake from 2013 to 2022 & Ordinary High-Water Level (815.3 ft).

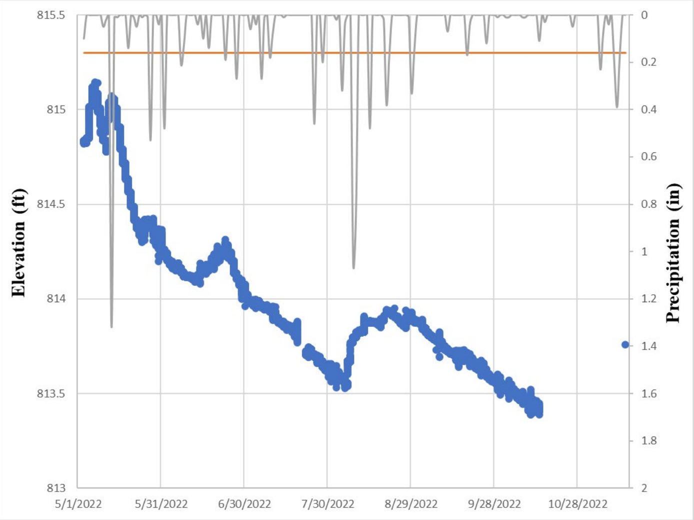


Figure B-13: Water surface elevation, precipitation & Ordinary High-Water Level Staring Lake 2022 (815.3 ft).

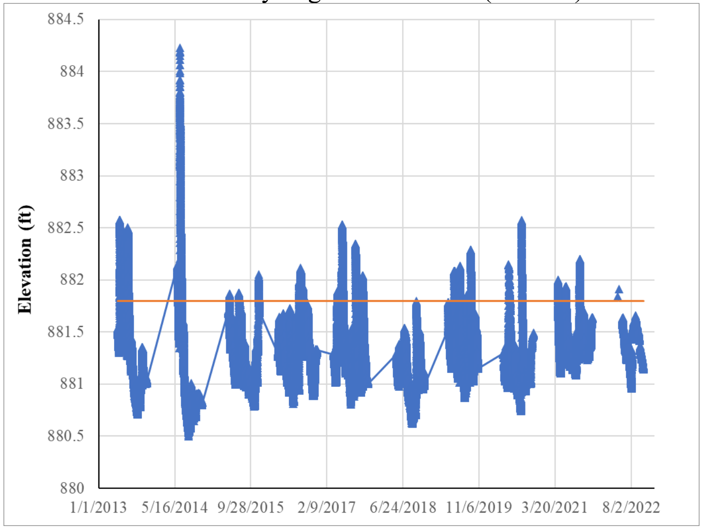


Figure A-14: Water surface elevation on Lake Susan from 2013 to 2022 & Ordinary High-Water Level (881.8 ft).

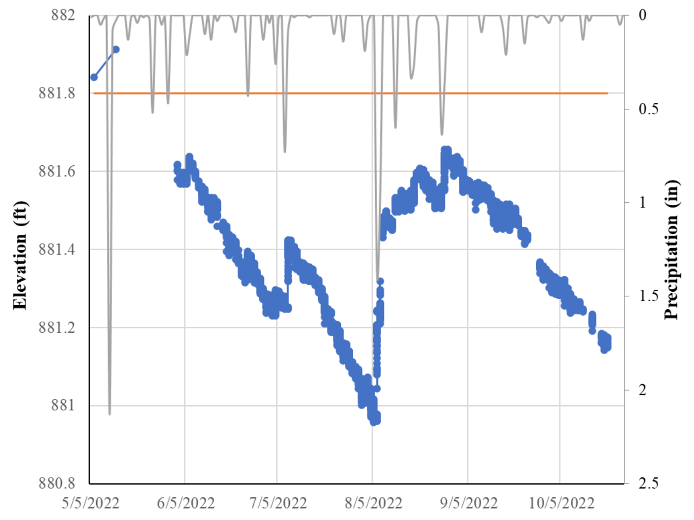


Figure B-14: Water surface elevation, precipitation & Ordinary High-Water Level Lake Susan 2022 (881.8 ft).

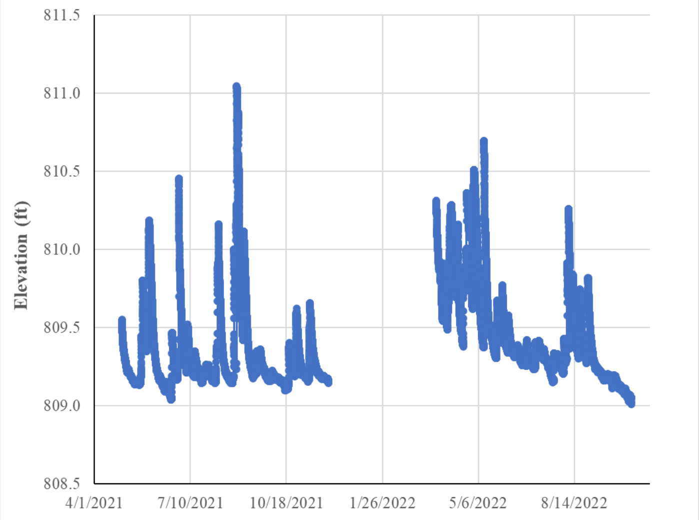


Figure A-15: Water surface elevations on Lake Eden from 2021-2022.

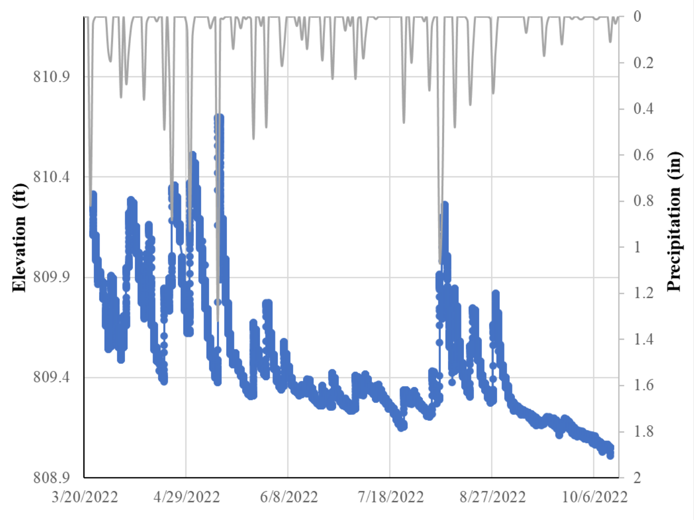


Figure B-15: Water surface elevation & precipitation from 2022.

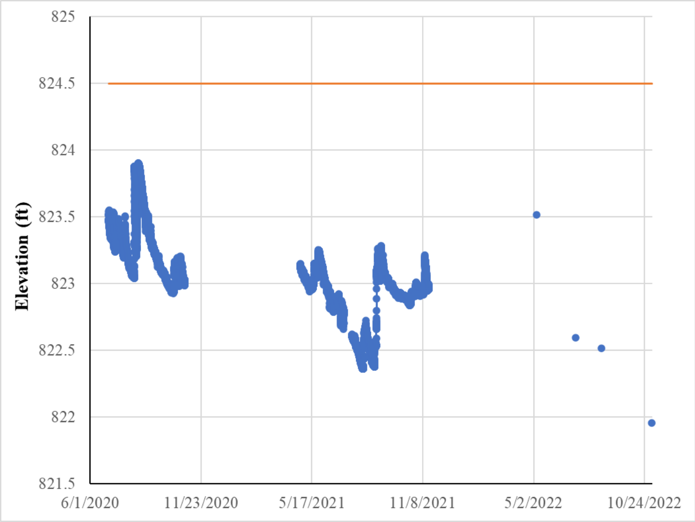


Figure A-16: Water surface elevation on Lake McCoy from 2020 to 2022 & Ordinary High-Water Level (824.5 ft).

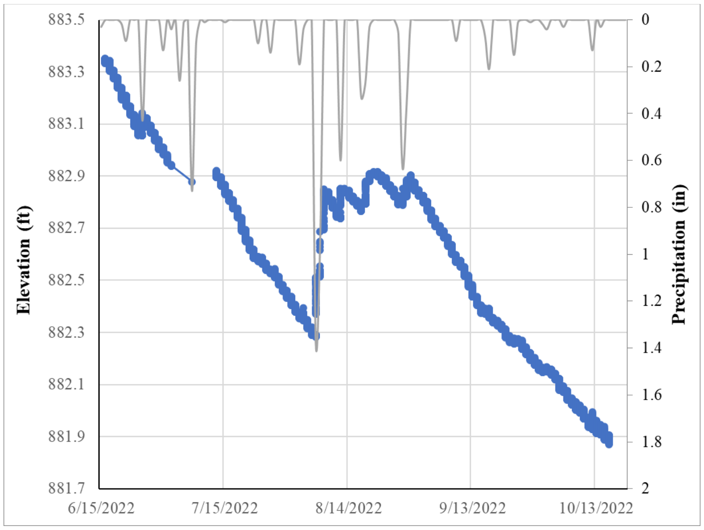


Figure A-17: Water surface elevation on Lake Susan Wetland from 2020 to 2022 & Ordinary High-Water Level.

Exhibit B *2022 Trap Net Summary Data*

Table B1: 2022 **Lake Ann** 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	2022 Fish/Net
Black Crappie			1									1	0.2
Bluegill Sunfish	234	12	4	1								251	50.2
Brown Bullhead				1	3							4	0.8
Green Sunfish	6											6	1.2
Hybrid Sunfish	5	1										6	1.2
Largemouth Bass	4											4	0.8
Northern Pike						1	1					2	0.4
Pumpkinseed	66	5										71	14.2
Yellow Bullhead	1	2	17	10	23							53	10.6

Table B2: 2022 **Lotus** 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	2022 Fish/Net
Black Crappie	7	12	20									39	7.8
Bluegill Sunfish	203	196										409	81.8
Green Sunfish		2										2	0.4
Hybrid Sunfish	1	3	1									5	1
Largemouth Bass	1											1	0.2
Northern Pike									1			1	0.2
Pumpkinseed		1										1	0.2
Walleye					1	3						4	0.8
Yellow Bullhead				1	4							5	1
Yellow Perch	3											3	0.6

Table B3: 2022 **Lower Purgatory Creek Recreational 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	2022 Fish/Net
Black Bullhead	15	3	3									21	7.0
Black Crappie	65											65	21.7
Bluegill Sunfish	25	7										32	10.7
Common Carp	4	1				1						6	2.0
Green Sunfish	42											42	14.0
Hybrid Sunfish	101	2										103	34.3
Largemouth Bass	41											41	13.7
Pumpkinseed	199											199	66.3
Yellow Bullhead	3	2	8	1								14	4.7
Yellow Perch	1											1	0.3

Table B4: 2022 **Upper Purgatory Creek Recreational 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	2022 Fish/Net
Black Crappie	327	3	6									969	242.25
Bluegill Sunfish	87	3										95	23.75
Brown Bullhead			1									1	0.25
Hybrid Sunfish	4											4	1
Largemouth Bass	6	1				1						8	2
Northern Pike							5	2		1		8	2
White Sucker						2						2	0.5
Yellow Bullhead	6	1		1	1							9	2.25
Yellow Perch	3											3	0.75

Table B5: 2022 **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	2022 Fish/Net
Black Bullhead			1	5								6	1.2
Black Crappie		4	2		2							8	1.6
Bluegill Sunfish	484	26										510	102
Brown Bullhead					1							1	0.2
Common Carp						2	9					11	2.2
Green Sunfish	10	3										13	2.6
Hybrid Sunfish	15											15	3
Largemouth Bass	2		2	1								5	1
Pumpkinseed	22											22	4.4
Yellow Bullhead		4	7	13	2							26	5.2
Yellow Perch	16	4										20	4

Exhibit C

2022 Zooplankton Summary Data

Table C1: 2022 **Lake Riley** Zooplankton Counts (#/m^2)

DIVISION	TAXON	9/12/2022 #/m2	8/11/2022 #/m2	7/13/2022 #/m2	6/7/2022 #/m2
CLADOCERA	*Bosmina longirostris*	0	6,592	0	3,805
	Chydorus sphaericus	0	0	0	30,437
	Daphnia ambigua/parvula	0	0	0	106,530
	Daphnia galeata mendotae	0	6,592	7,233	152,186
	Daphnia pulex	0	0	3,616	11,414
	Diaphanosoma leuchtenbergianum	0	6,592	10,849	0
	Immature Cladocera	0	0	0	3,805
	CLADOCERA TOTAL	**0**	**19,777**	**21,698**	**308,177**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	32,434	32,961	0	239,693
	Nauplii	4,633	59,330	79,559	1,145,201
	Calanoida	4,633	13,184	36,163	38,047
ROTIFERA	**COPEPODA TOTAL**	**41,701**	**105,476**	**115,722**	**1,422,941**
	Asplanchna sp.	0	0	0	121749
	Keratella sp.	13900	39553	47012	677229
	Kellicottia sp.	0	0	0	30437
	Polyarthra sp.	0	112068	191664	15219
	ROTIFERA TOTAL	**13,900**	**151,621**	**238,676**	**844,634**
	TOTALS	**55,601**	**276,873**	**376,096**	**2,575,752**

Table C2: 2022 **Staring Lake** Zooplankton Counts (#/m^2)

DIVISION	TAXON	6/6/2022 #/m2	7/12/2022 #/m2	8/10/2022 #/m2	9/8/2022 #/m2
CLADOCERA	*Bosmina longirostris*	15,821	7,157	102,839	39,930
	Ceriodaphnia sp.	21,095	0	0	3,993
	Chydorus sphaericus	0	0	0	31,944
	Daphnia galeata mendotae	84,380	0	15,821	0
	Daphnia retrocurva	26,369	0	87,017	19,965
	Diaphanosoma leuchtenbergianum	0	14,315	15,821	27,951
	CLADOCERA TOTAL	**147,666**	**21,472**	**221,499**	**123,783**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	79,107	42,944	47,464	27,951
	Nauplii	448,271	114,516	63,285	159,720
	Calanoida	58,012	35,786	23,732	7,986
	COPEPODA TOTAL	**585,390**	**193,246**	**134,481**	**195,657**
ROTIFERA	*Brachionus sp.*	0	0	0	0
	Filinia longiseta	0	0	15,821	11,979
	Keratella cochlearis	1,054,756	71,573	268,963	199,650
	Keratella quadrata	0	0	0	0
	Kellicottia sp.	0	0	7,911	0
	Polyarthra sp.	36,916	14,315	0	0
	ROTIFERA TOTAL	**1,091,673**	**85,887**	**292,695**	**211,629**
	TOTALS	**1,824,728**	**300,606**	**648,675**	**531,070**

Table C3: 2022 **Lotus Lake** Zooplankton Counts (#/m^2)

DIVISION	TAXON	6/6/2022 #/m2	7/13/2022 #/m2	8/11/2022 #/m2	9/12/2022 #/m2
CLADOCERA	*Bosmina longirostris*	22,602	42,379	20,266	0
	Ceriodaphnia sp.	0	0	0	0
	Chydorus sphaericus	5,650	4,709	0	0
	Daphnia galeata mendotae	129,961	14,126	0	14,239
	Daphnia retrocurva	5,650	37,670	151,998	4,746
	Diaphanosoma leuchtenbergianum	0	0	30,400	4,746
	CLADOCERA TOTAL	**163,864**	**98,883**	**202,664**	**23,732**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	84,757	28,252	30,400	66,450
	Nauplii	559,397	136,553	162,131	208,842
	Calanoida	90,408	89,466	40,533	80,689
	COPEPODA TOTAL	**734,562**	**254,272**	**233,063**	**355,980**
ROTIFERA	*Asplanchna sp.*	209,068	0	0	0
	Brachionus sp.	0	0	0	0
	Filinia longiseta	0	0	10,133	9,493
	Keratella sp.	389,883	28,252	81,066	1,727,691
	Keratella quadrata	0	0	0	0
	Kellicottia sp.	553,747	0	0	61,703
	Polyarthra sp.	0	14,126	20,266	37,971
	ROTIFERA TOTAL	**1,152,698**	**42,379**	**111,465**	**1,836,858**
	TOTALS	**2,051,124**	**395,534**	**547,192**	**2,216,570**

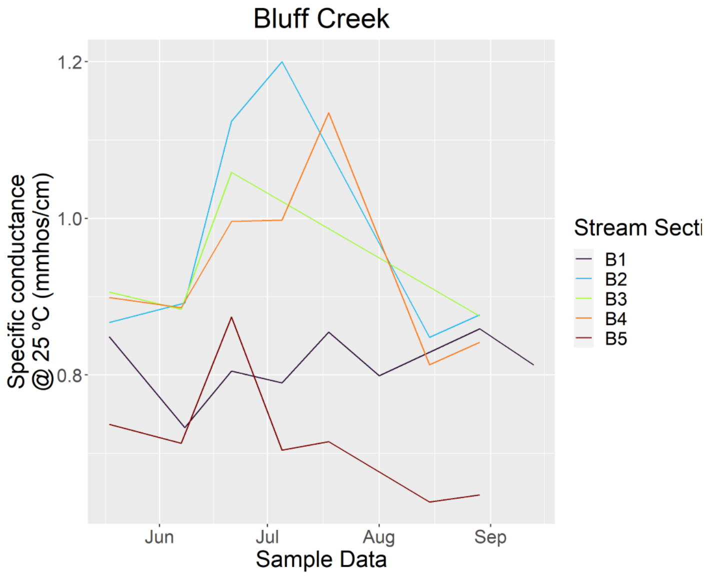
Table C4: 2022 **Lake Susan** Zooplankton Counts (#/m^2)

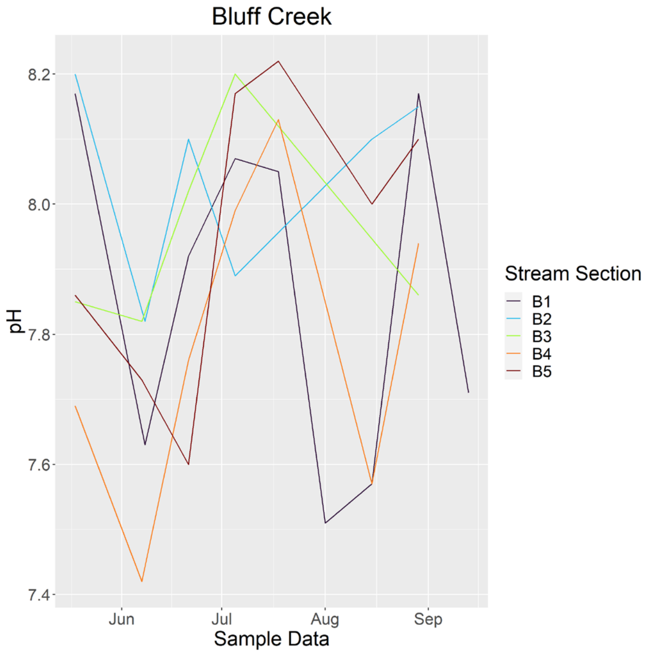
DIVISION	TAXON	6/2/2022 #/m2	7/12/2022 #/m2	8/10/2022 #/m2	9/8/2022 #/m2
CLADOCERA	*Bosmina longirostris*	58,539	0	31,040	170,644
	Ceriodaphnia sp.	0	0	0	0
	Chydorus sphaericus	0	0	38,800	39,817
	Daphnia galeata mendotae	273,182	0	0	0
	Daphnia retrocurva	0	33,903	108,640	73,946
	Diaphanosoma leuchtenbergianum	0	0	116,400	11,376
	CLADOCERA TOTAL	**331,721**	**33,903**	**294,880**	**295,784**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	68,295	39,553	263,840	34,129
	Nauplii	360,990	231,670	985,519	51,193
	Calanoida	19,513	11,301	15,520	0
	COPEPODA TOTAL	**448,799**	**282,524**	**1,264,879**	**85,322**
ROTIFERA	*Asplanchna priodonta*	19,513	0	0	0
	Brachionus sp.	0	0	15,520	0
	Filinia longiseta	0	0	23,280	11,376
	Keratella sp.	78,052	440,737	465,600	329,913
	Kellicottia sp.	0	0	0	176,333
	Trichocerca multicrinis	19,513	11,301	0	0
	ROTIFERA TOTAL	**117,078**	**452,038**	**504,399**	**517,622**
	TOTALS	**897,597**	**768,465**	**2,064,158**	**898,728**

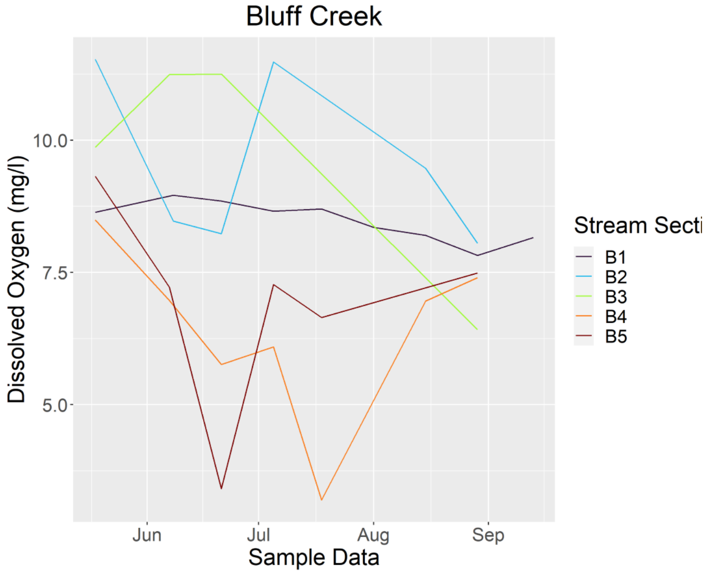
Table C5: 2022 **Rice Marsh Lake** Zooplankton Counts (#/m^2)

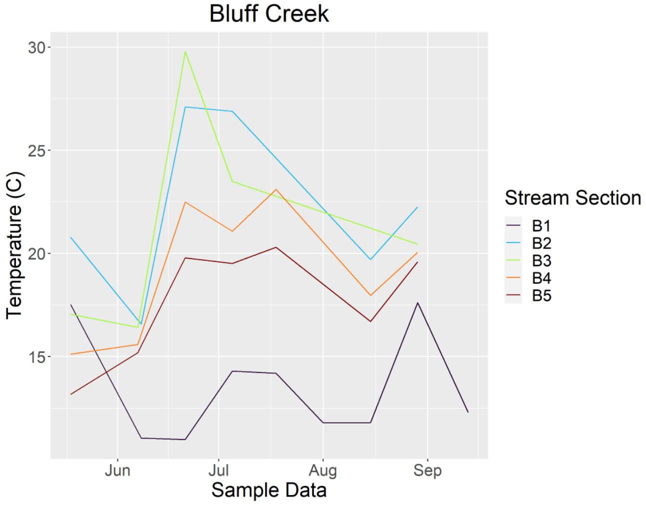
DIVISION	TAXON	6/1/2022 #/m2	7/14/2022 #/m2	8/9/2022 #/m2	9/6/2022 #/m2
CLADOCERA	*Bosmina longirostris*	15,821	0	293,825	45,204
	Ceriodaphnia sp.	5,274	0	468,990	97,942
	Chydorus sphaericus	5,274	0	0	0
	Acroperus sp.	0	0	0	0
	Diaphanosoma leuchtenbergianum	0	0	113,010	146,912
	CLADOCERA TOTAL	**26,369**	**0**	**875,824**	**290,058**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	52,738	0	101,709	37,670
	Nauplii	242,594	0	248,621	105,476
	Calanoida	10,548	0	107,359	15,068
	COPEPODA TOTAL	**305,879**	**0**	**457,689**	**158,213**
ROTIFERA	*Keratella cochlearis*	279,510	7,534	62,155	3,767
	Keratella quadrata	0	0	0	0
	Kellicottia sp.	0	0	0	0
	Platyias sp.	0	7,534	0	0
	Polyarthra vulgaris	21,095	7,534	50,854	301,359
	Trichocerca multicrinis	0	0	0	3,767
	UID Rot	0	0	0	11,301
	ROTIFERA TOTAL	**300,606**	**22,602**	**113,010**	**320,194**
	TOTALS	**632,854**	**22,602**	**1,446,523**	**768,465**

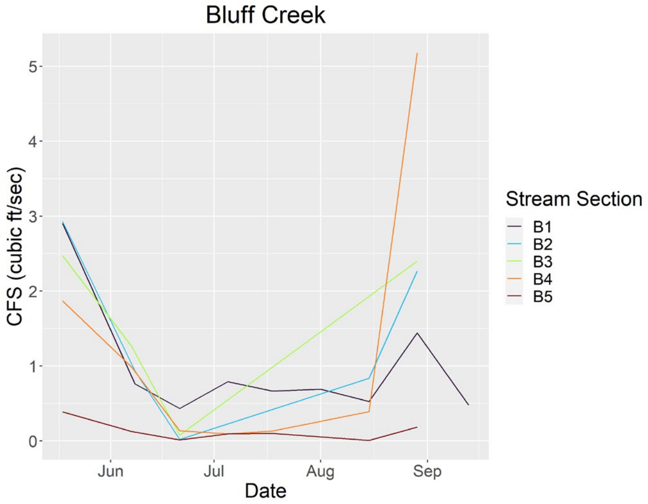
Exhibit D *2022 Creek Seasonal Sonde & Flow Data*

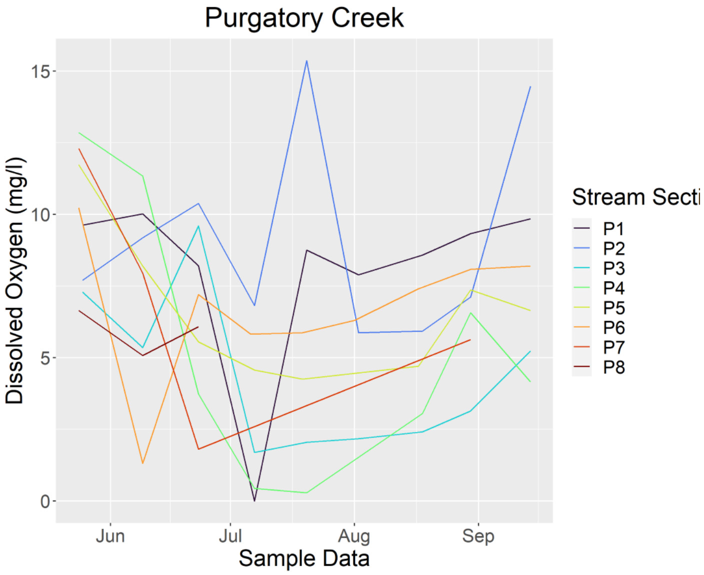


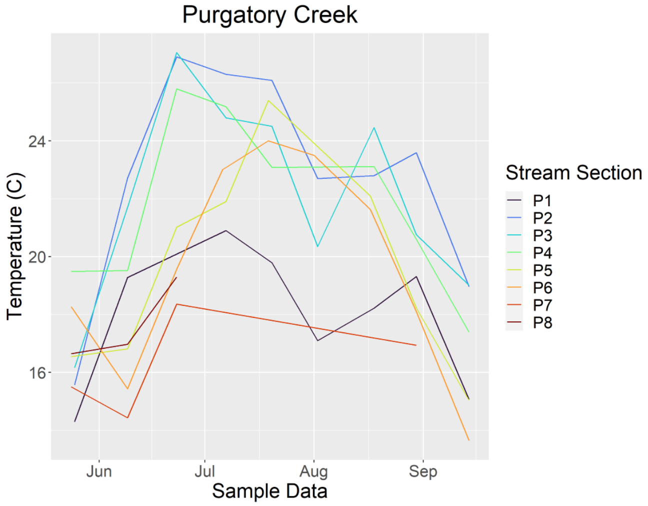


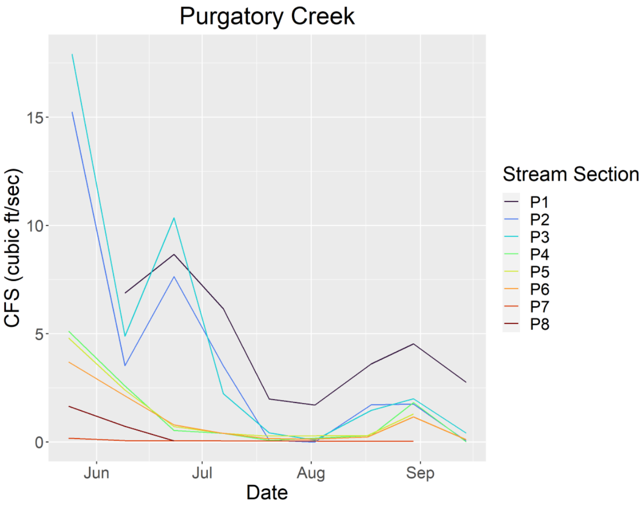


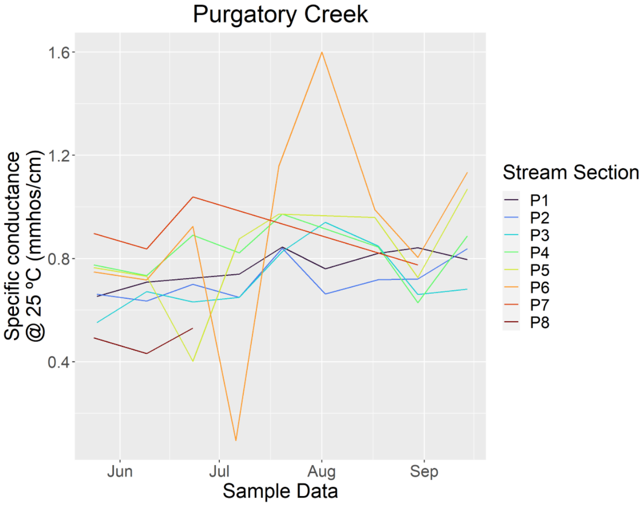


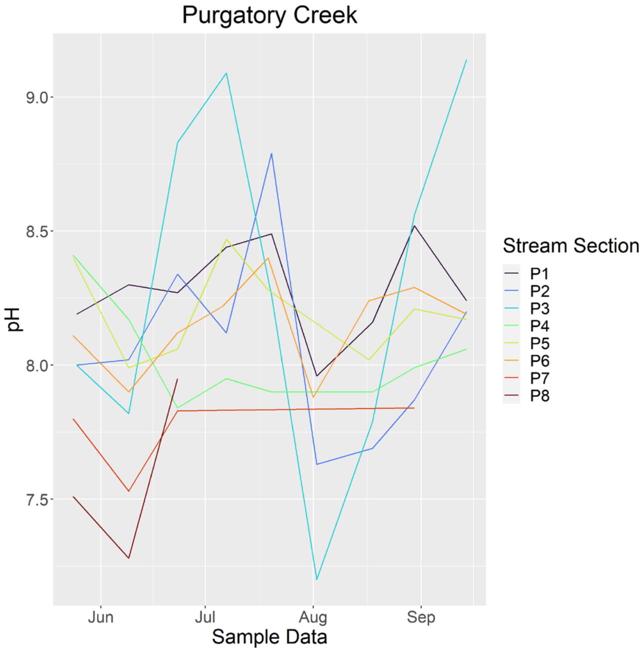


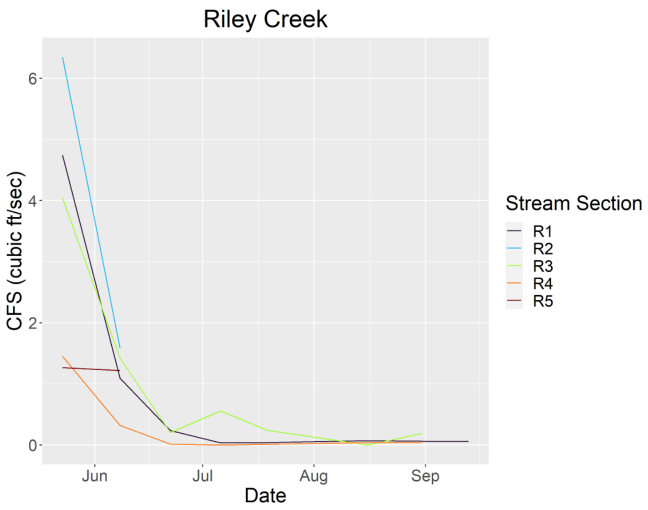

Purgatory Creek
Dissolved Oxygen (mg/l)
15
10
5
0
Jun
Jul
Aug
Sep
Sample Data
Stream Secti
P1
P2
P3
P4
P5
P6
P7
P8

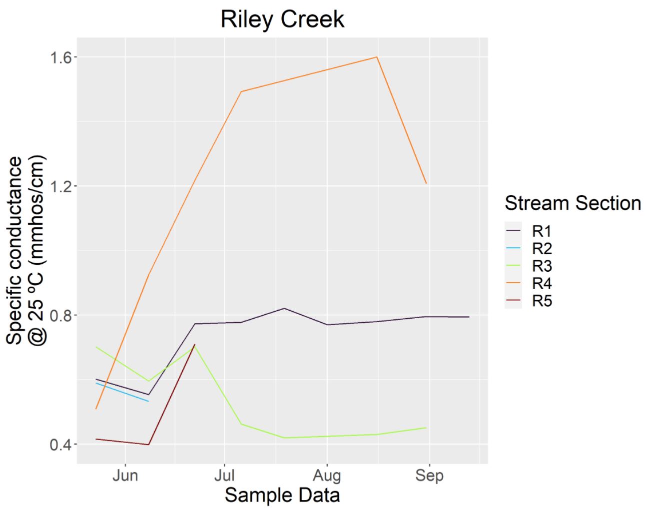

Purgatory Creek
Temperature (C)
24
20
16
Jun
Jul
Aug
Sep
Sample Data
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8

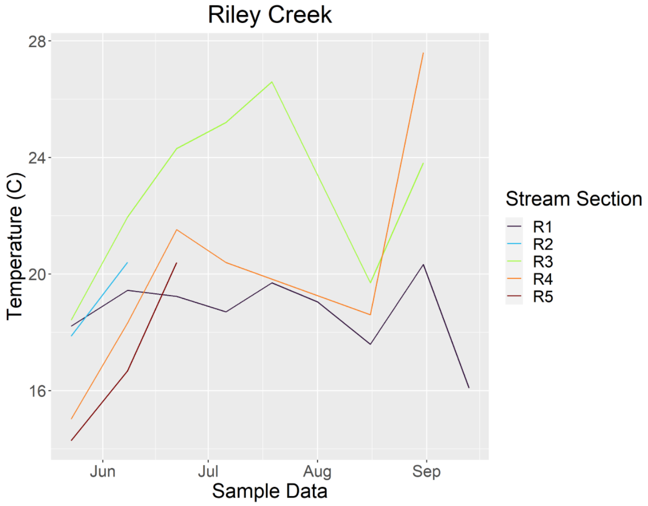

Purgatory Creek
CFS (cubic ft/sec)
15
10
5
0
Jun
Jul
Aug
Sep
Date
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8

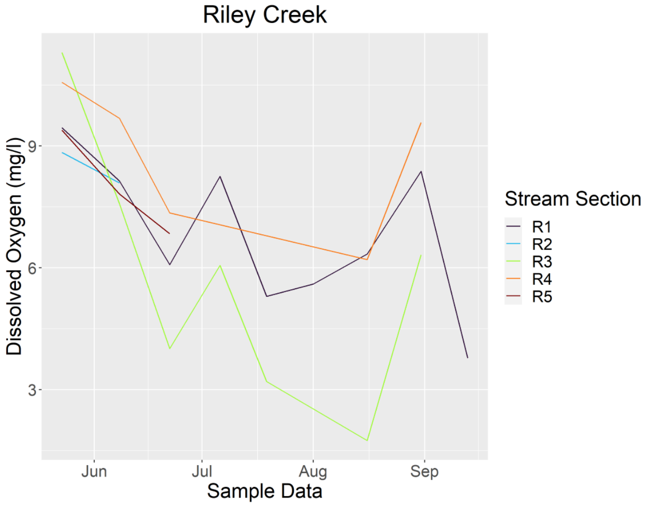

Purgatory Creek
Specific conductance @ 25 °C (mmhos/cm)
1.6
1.2
0.8
0.4
Jun
Jul
Aug
Sep
Sample Data
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8


Purgatory Creek
pH
9.0
8.5
8.0
7.5
Jun
Jul
Aug
Sep
Sample Data
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8


Riley Creek
CFS (cubic ft/sec)
6
4
2
0
Jun
Jul
Aug
Sep
Date
Stream Section
R1
R2
R3
R4
R5


Riley Creek
Specific conductance @ 25 ºC (mmhos/cm)
1.6
1.2
0.8
0.4
Jun
Jul
Aug
Sep
Sample Data
Stream Section
R1
R2
R3
R4
R5


Riley Creek
Temperature (C)
28
24
20
16
Jun
Jul
Aug
Sep
Sample Data
Stream Section
R1
R2
R3
R4
R5


Riley Creek
Dissolved Oxygen (mg/l)
9
6
3
Jun
Jul
Aug
Sep
Sample Data
Stream Section
R1
R2
R3
R4
R5

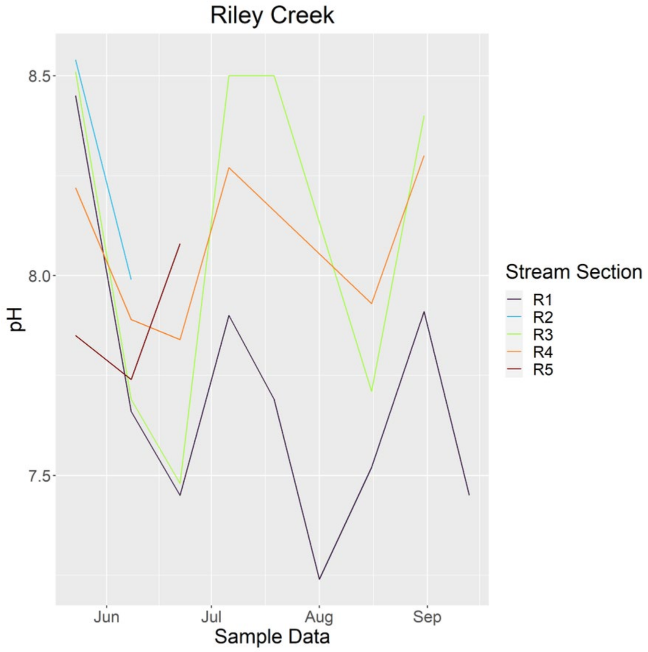

Riley Creek
pH
8.5
8.0
7.5
Jun
Jul
Aug
Sep
Sample Data
Stream Section
R1
R2
R3
R4
R5

Exhibit E *2022 Lake Nutrient Data Summary Table*

Figure F-1. Shows the average values for all nutrients analyzed in lakes during the growing season (June-September) 2022.

Each lake is separated by top, middle, and bottom and all values are in mg/l.

Lake	Location	Total ALK	Ca	Cl-	Chl a	Fe	NH3	NO2/NO3	TKN	OP	TP	TSS
Ann	Top	182.33		42.77	0.007		0.023	0.030	0.84	0.004	0.020	
Ann	Middle									0.004	0.031	
Ann	Bottom			41.37			1.340	0.030	2.13	0.058	0.291	
Duck	Top	83.40	14.60	61.43	0.019		0.020	0.073	0.75	0.004	0.031	
Duck	Bottom			57.97			0.030	0.030	0.68	0.004	0.030	
Hyland	Middle				9.596				0.74	0.007	0.036	
Idlewild	Top	66.50	16.50	241.00	0.007		0.020	0.030	0.60	0.003	0.036	
Idlewild	Bottom			242.50			0.025	0.030	0.54	0.004	0.038	
Lotus	Top	173.00		64.90	0.025		0.023	0.033	0.95	0.005	0.033	
Lotus	Middle									0.004	0.042	
Lotus	Bottom			63.07			2.563	0.030	3.74	0.065	0.238	
Lucy	Top	192.50	38.80	53.80	0.013		0.020	0.030	1.02	0.075	0.042	
Lucy	Middle									0.006	0.053	
Lucy	Bottom		42.20	52.28			0.803	0.030	1.99	0.007	0.260	
Mitchell	Top	123.00		116.50	0.027	0.191	0.129	0.040	1.31	0.025	0.062	9.81
Mitchell	Middle				0.029					0.010	0.067	
Mitchell	Bottom				0.025					0.009	0.093	
Neill	Top	86.80	21.40	210.50	0.009		0.023	1.196	0.87	0.014	0.060	
Neill	Bottom			209.00	0.009		0.020	0.030	0.90	0.004	0.042	
Red Rock	Top	134.00		108.75	0.033	0.218	0.140	0.040	1.36	0.005	0.064	6.50
Red Rock	Middle				0.026					0.005	0.065	
Red Rock	Bottom				0.023					0.009	0.111	
Rice Marsh	Top	136.73	35.10	179.50	0.013		0.040	0.083	0.88	0.004	0.037	
Rice Marsh	Bottom			178.67			0.053	0.030	0.85	0.006	0.038	
Riley	Top	140.50	40.00	121.75	0.005		0.020	0.030	0.59	0.004	0.015	
Riley	Middle								0.47	0.003	0.020	
Riley	Bottom			113.50			0.084	0.035	1.33	0.025	0.051	
Round	Top	52.70		73.08	0.011	0.053	0.099	0.040	0.86	0.004	0.027	4.04
Round	Middle				0.027					0.008	0.031	
Round	Bottom				0.016					0.068	0.179	
Silver	Top	114.80	19.10	56.65	0.013		0.027	3.698	1.25	0.004	0.566	
Silver	Bottom			56.63			0.065	9.648	1.24	0.004	0.054	
Staring	Top	171.25	42.40	132.25	0.086		0.043	0.030	1.88	0.007	0.106	
Staring	Middle									0.004	0.075	
Staring	Bottom		38.60	126.33			0.233	0.030	1.84	0.011	0.144	
Susan	Top	147.00	33.30	159.50	0.062		0.023	0.030	1.61	0.005	0.074	
Susan	Middle									0.005	0.074	
Susan	Bottom		47.30	153.50			2.947	0.030	4.09	0.054	0.624	

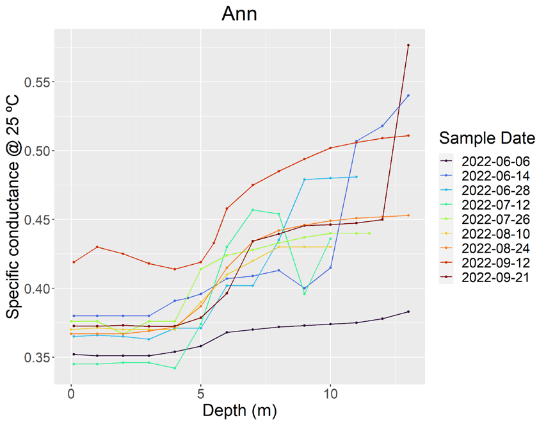
Exhibit F

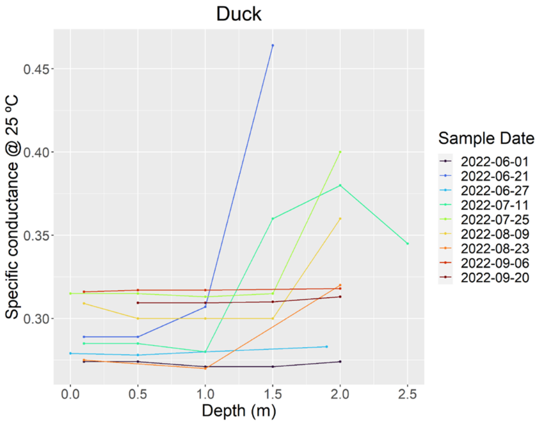
2022 Stream Summary Table

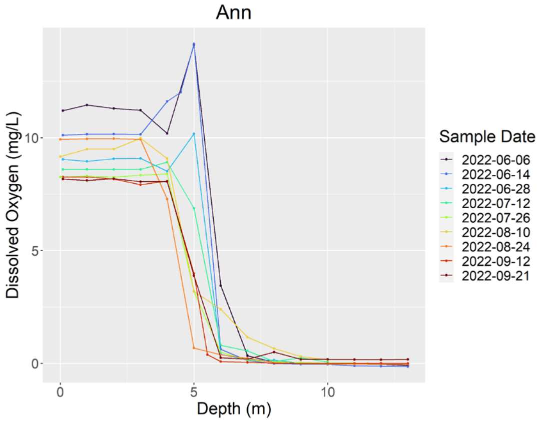
Figure G-1. The 2022 average values for all lab water quality parameters sampled for creeks by each major stream reach specified. Chlorophyll a (Chl a), Orthophosphate (OP) and Total Phosphorus (TP) are the averages of all values collected from May through September. Total suspended solids (TSS) are the average of values collected from April through September. Chloride (Cl-) is the average of all values collect year-round.

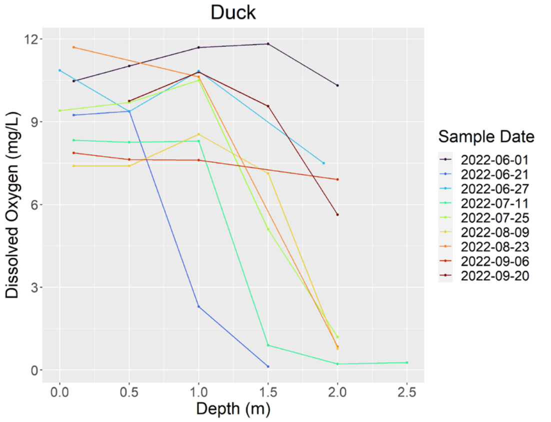
Stream	Stream Section	Cl- (mg/l)	Chl a (ug/l)	OP (mg/l)	TP (mg/l)	TSS (mg/l)
Bluff	B5	57.13	5.13	0.119	0.263	8.69
Bluff	B4	166.67	5.01	0.105	0.234	14.39
Bluff	B3	167.00	9.31	0.167	0.233	15.65
Bluff	B2	182.50	22.24	0.089	0.217	13.75
Bluff	B1	102.34	2.24	0.041	0.074	7.39
Purgatory	P8	63.80	1.98	0.028	0.117	76.70
Purgatory	P7	121.00	2.91	0.064	0.111	6.00
Purgatory	P6	186.62	2.38	0.087	0.147	9.62
Purgatory	P5	141.40	3.05	0.133	0.209	8.41
Purgatory	P4	145.75	15.87	0.116	0.234	14.84
Purgatory	P3	161.12	6.02	0.043	0.114	4.91
Purgatory	P2	123.40	4.72	0.034	0.098	5.14
Purgatory	P1	88.10	4.85	0.040	0.073	13.03
Riley	R5	44.00	2.08	0.032	0.109	29.30
Riley	R4	212.95	4.02	0.069	0.141	24.35
Riley	R3	58.00	14.15	0.068	0.143	9.14
Riley	R2	112.00	10.20	0.006	0.026	3.55
Riley	R1	60.86	4.30	0.031	0.091	7.44

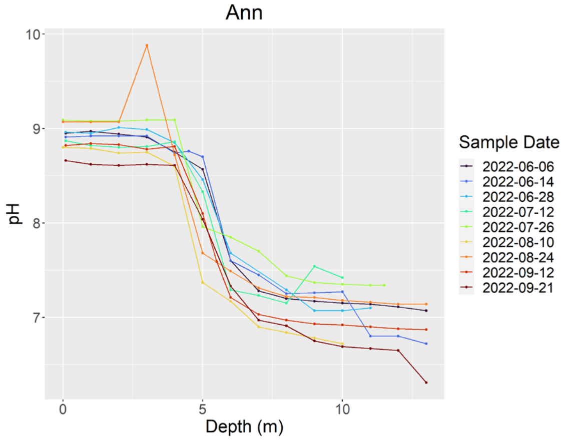
Exhibit G *2022 Lake Profile Data*

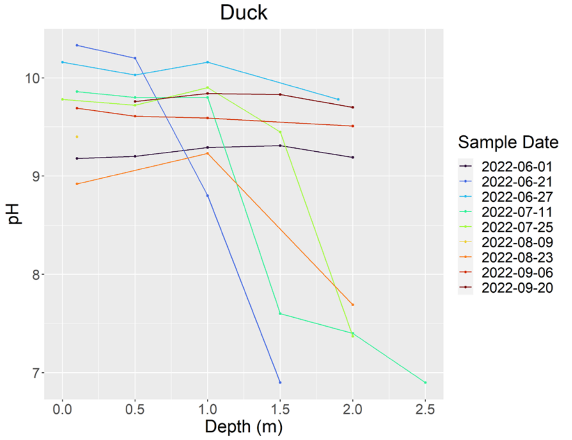


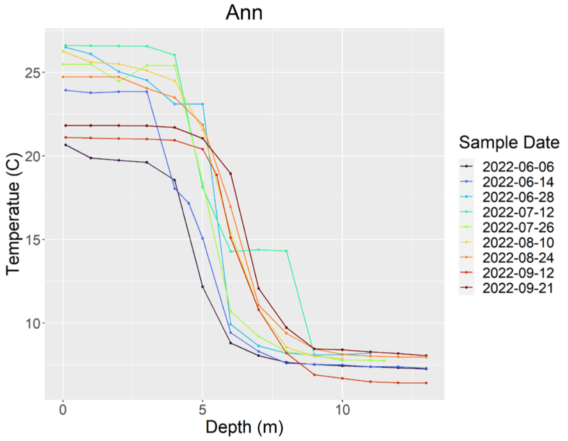


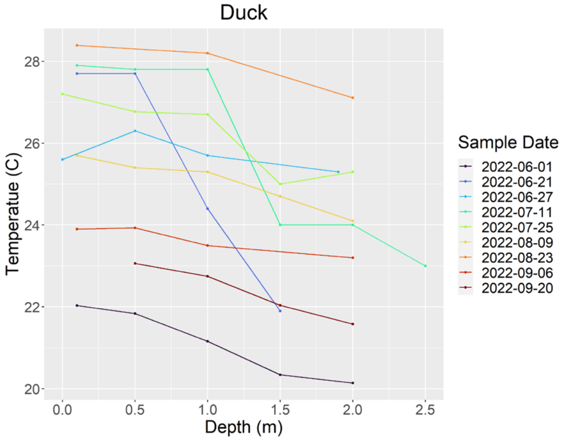


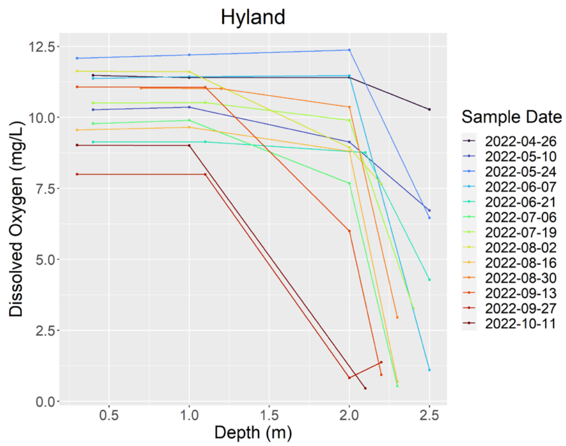


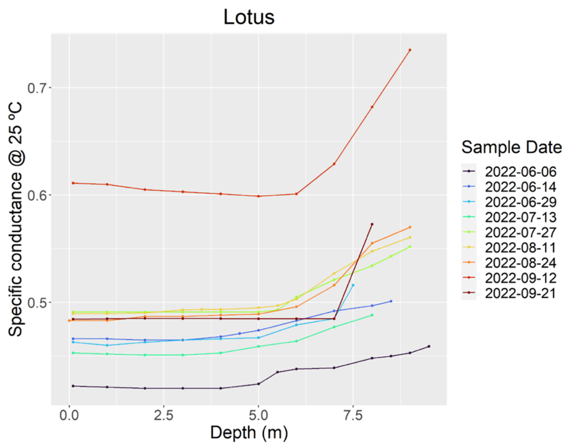









Hyland
Dissolved Oxygen (mg/L)
12.5
10.0
7.5
5.0
2.5
0.0
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-04-26
2022-05-10
2022-05-24
2022-06-07
2022-06-21
2022-07-06
2022-07-19
2022-08-02
2022-08-16
2022-08-30
2022-09-13
2022-09-27
2022-10-11


Lotus
Specific conductance @ 25 °C
0.7
0.6
0.5
0.0
2.5
5.0
7.5
Depth (m)
Sample Date
2022-06-06
2022-06-14
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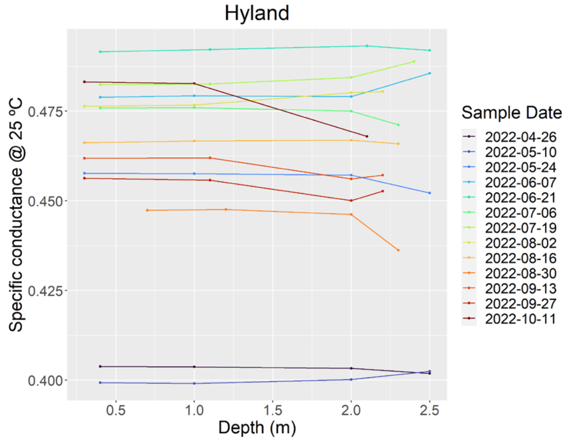
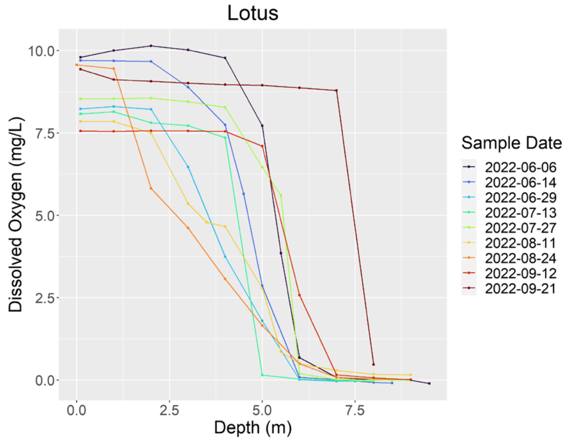
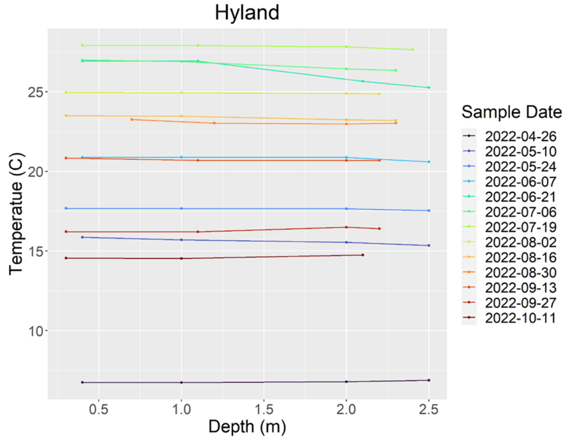
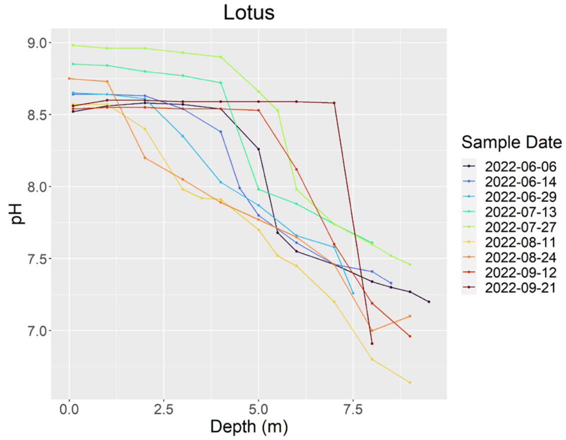
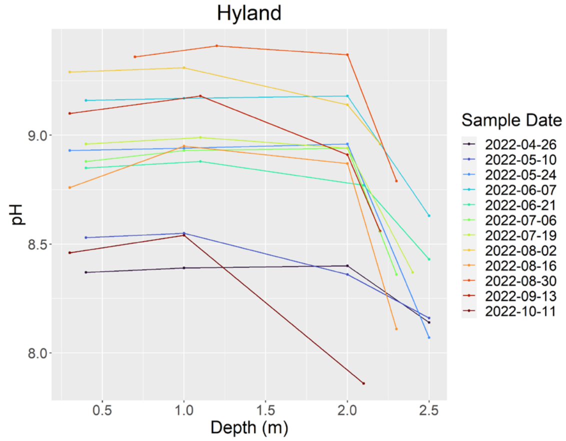
2022-09-12
2022-09-21

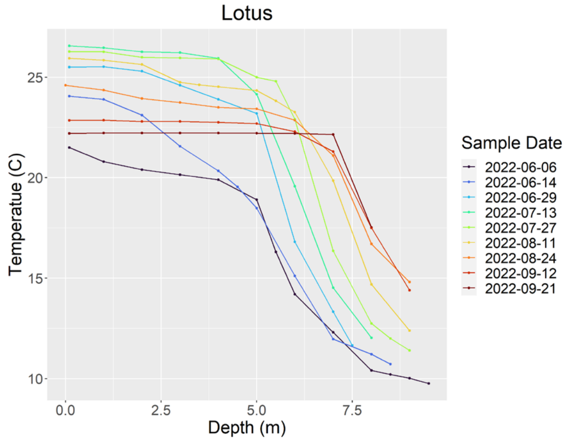

Hyland
Specific conductance @ 25 °C
0.475
0.450
0.425
0.400
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-04-26
2022-05-10
2022-05-24
2022-06-07
2022-06-21
2022-07-06
2022-07-19
2022-08-02
2022-08-16
2022-08-30
2022-09-13
2022-09-27
2022-10-11

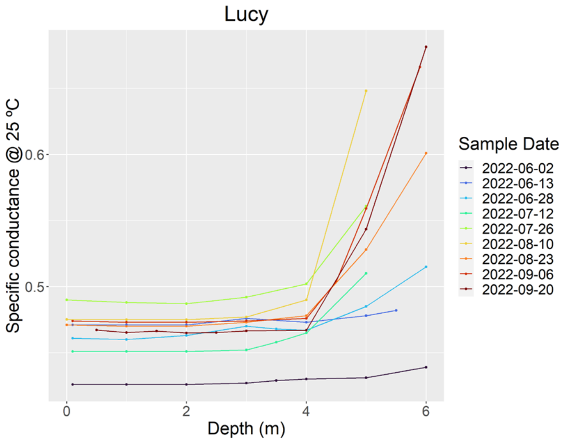

Lotus
Dissolved Oxygen (mg/L)
10.0
7.5
5.0
2.5
0.0
0.0
2.5
5.0
7.5
Depth (m)
Sample Date
2022-06-06
2022-06-14
2022-06-29
2022-07-13
2022-07-27
2022-08-11
2022-08-24
2022-09-12
2022-09-21

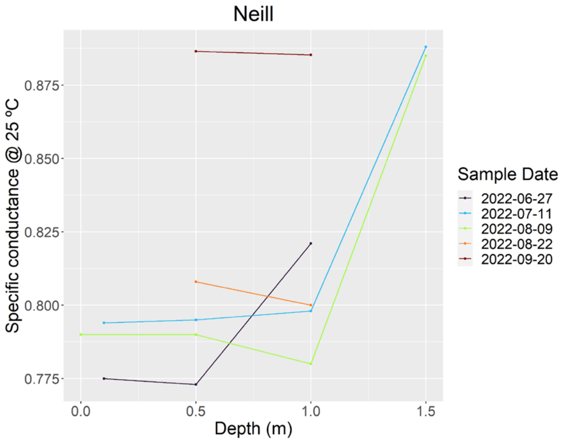

Hyland
Temperatue (C)
25
20
15
10
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-04-26
2022-05-10
2022-05-24
2022-06-07
2022-06-21
2022-07-06
2022-07-19
2022-08-02
2022-08-16
2022-08-30
2022-09-13
2022-09-27
2022-10-11

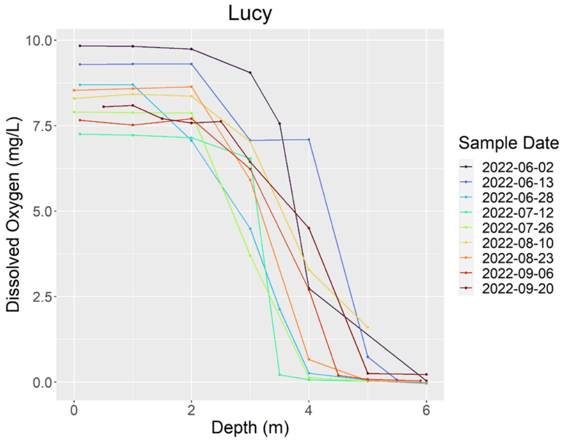

Lotus
pH
9.0
8.5
8.0
7.5
7.0
0.0
2.5
5.0
7.5
Depth (m)
Sample Date
2022-06-06
2022-06-14
2022-06-29
2022-07-13
2022-07-27
2022-08-11
2022-08-24
2022-09-12
2022-09-21

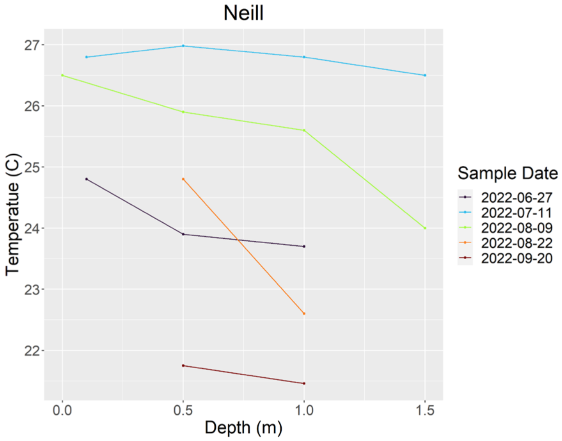

Hyland
pH
9.0
8.5
8.0
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-04-26
2022-05-10
2022-05-24
2022-06-07
2022-06-21
2022-07-06
2022-07-19
2022-08-02
2022-08-16
2022-08-30
2022-09-13
2022-09-27
2022-10-11

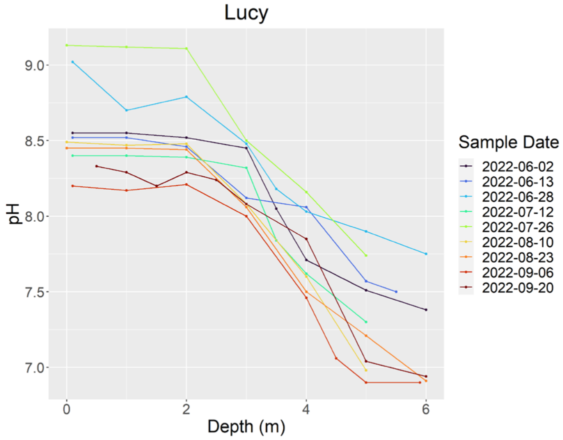

Lotus
Temperatue (C)
25
20
15
10
0.0
2.5
5.0
7.5
Depth (m)
Sample Date
2022-06-06
2022-06-14
2022-06-29
2022-07-13
2022-07-27
2022-08-11
2022-08-24
2022-09-12
2022-09-21

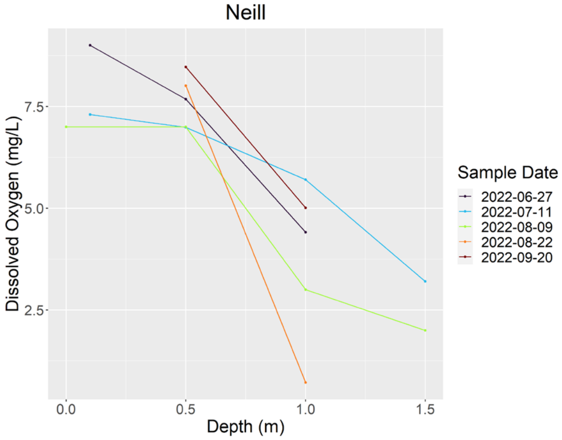

Lucy
Specific conductance @ 25 °C
0.5
0.6
Depth (m)
0
2
4
6
Sample Date
2022-06-02
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-06
2022-09-20

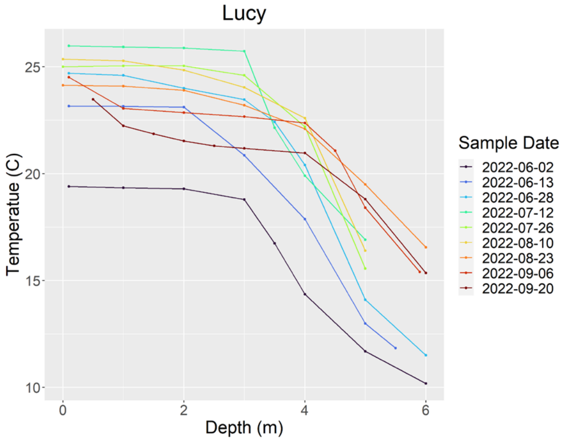

Neill
Specific conductance @ 25 °C
0.775
0.800
0.825
0.850
0.875
Depth (m)
0.0
0.5
1.0
1.5
Sample Date
2022-06-27
2022-07-11
2022-08-09
2022-08-22
2022-09-20

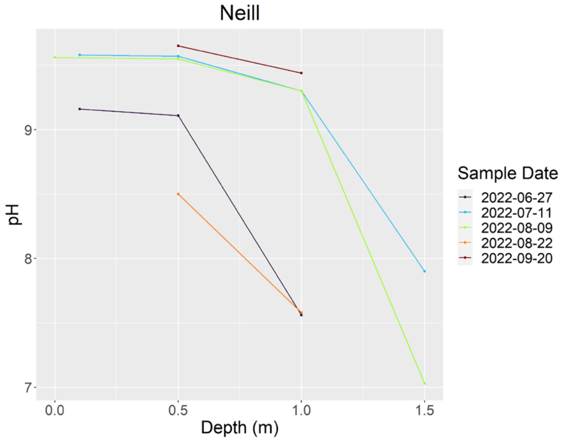

Lucy
Dissolved Oxygen (mg/L)
0.0
2.5
5.0
7.5
10.0
Depth (m)
0
2
4
6
Sample Date
2022-06-02
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-06
2022-09-20

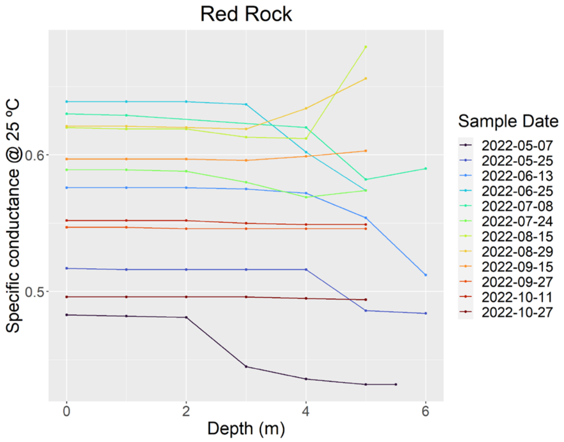

Neill
Temperatue (C)
22
23
24
25
26
27
Depth (m)
0.0
0.5
1.0
1.5
Sample Date
2022-06-27
2022-07-11
2022-08-09
2022-08-22
2022-09-20

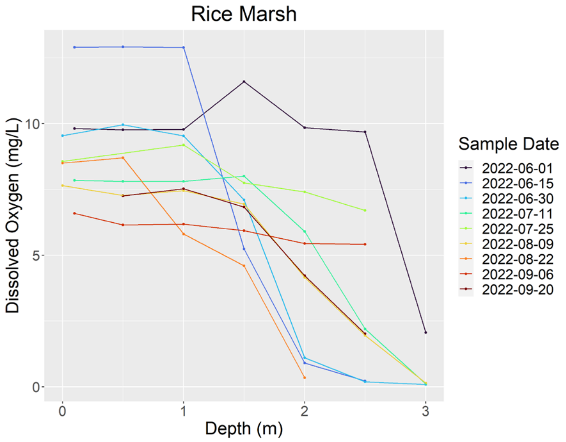

Lucy
pH
7.0
7.5
8.0
8.5
9.0
Depth (m)
0
2
4
6
Sample Date
2022-06-02
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-06
2022-09-20

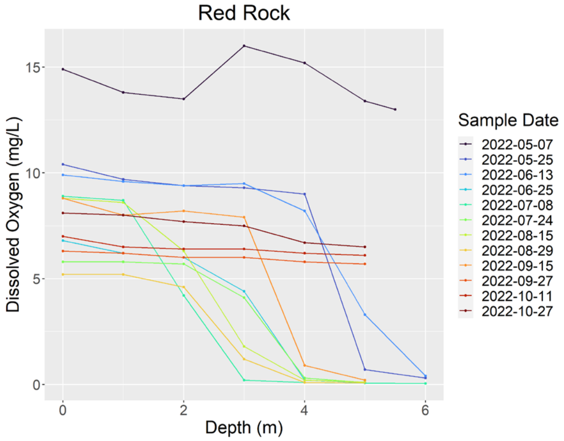

Neill
Dissolved Oxygen (mg/L)
2.5
5.0
7.5
Depth (m)
0.0
0.5
1.0
1.5
Sample Date
2022-06-27
2022-07-11
2022-08-09
2022-08-22
2022-09-20

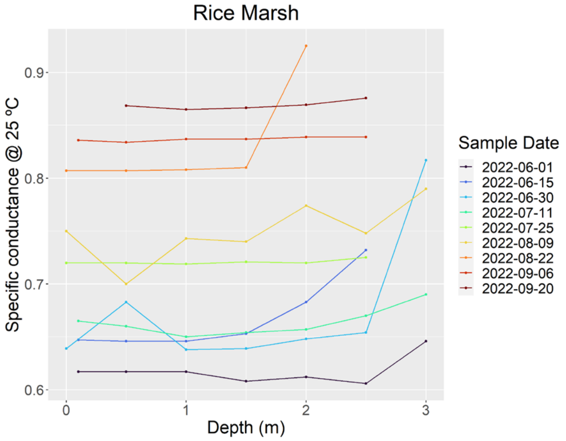

Lucy
Temperatue (C)
10
15
20
25
Depth (m)
0
2
4
6
Sample Date
2022-06-02
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-06
2022-09-20

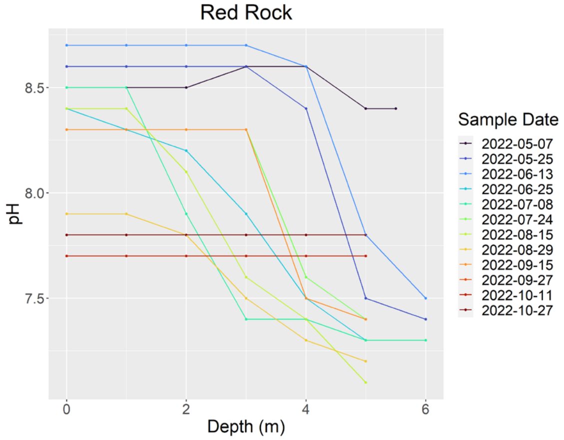

Neill
pH
7
8
9
Depth (m)
0.0
0.5
1.0
1.5
Sample Date
2022-06-27
2022-07-11
2022-08-09
2022-08-22
2022-09-20

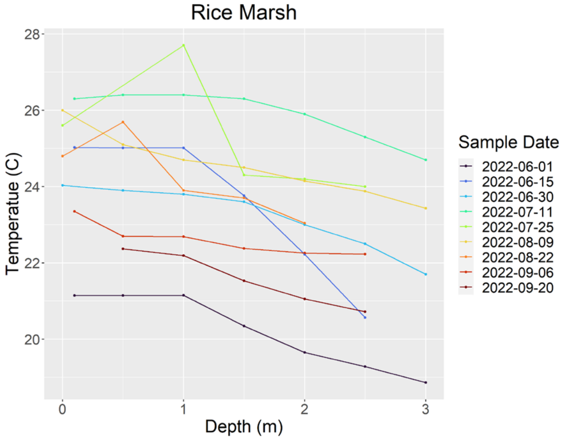

Red Rock
Specific conductance @ 25 °C
0.5
0.6
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-29
2022-09-15
2022-09-27
2022-10-11
2022-10-27

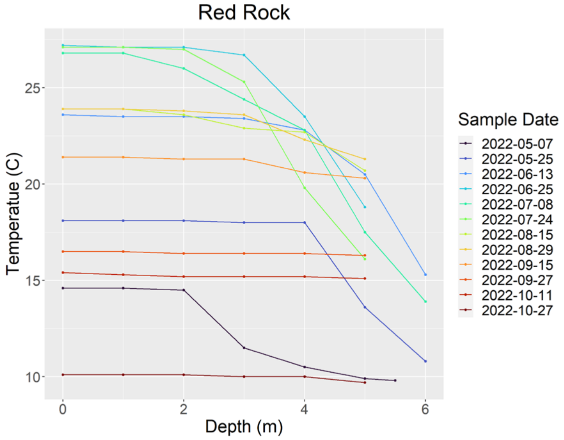

Rice Marsh
Dissolved Oxygen (mg/L)
0
5
10
0
1
2
3
Depth (m)
Sample Date
2022-06-01
2022-06-15
2022-06-30
2022-07-11
2022-07-25
2022-08-09
2022-08-22
2022-09-06
2022-09-20

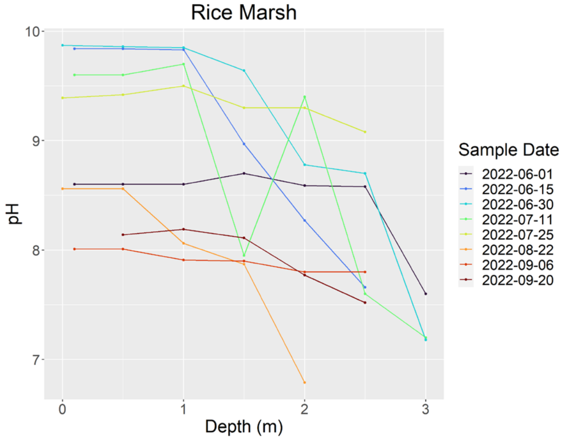

Red Rock
Dissolved Oxygen (mg/L)
0
5
10
15
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-29
2022-09-15
2022-09-27
2022-10-11
2022-10-27

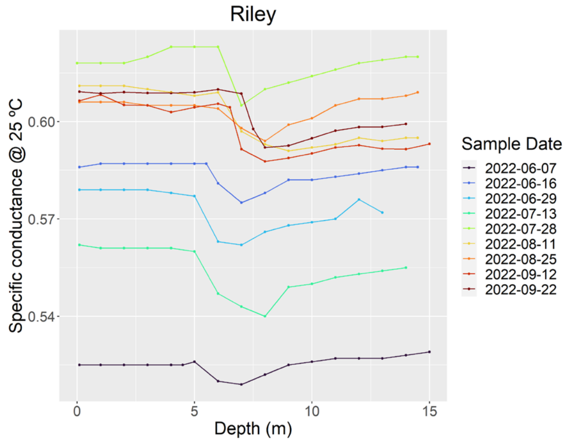

Rice Marsh
Specific conductance @ 25 °C
0.6
0.7
0.8
0.9
0
1
2
3
Depth (m)
Sample Date
2022-06-01
2022-06-15
2022-06-30
2022-07-11
2022-07-25
2022-08-09
2022-08-22
2022-09-06
2022-09-20

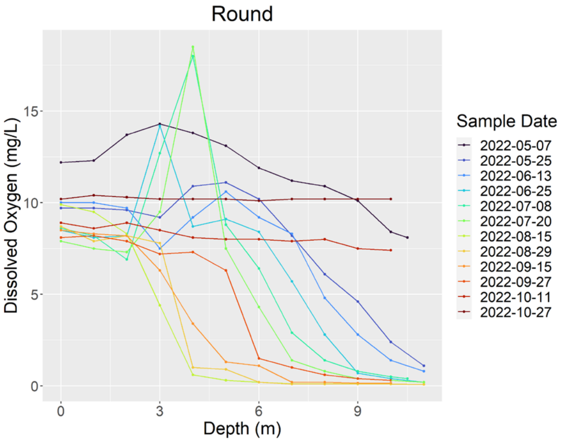

Red Rock
pH
7.5
8.0
8.5
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-29
2022-09-15
2022-09-27
2022-10-11
2022-10-27

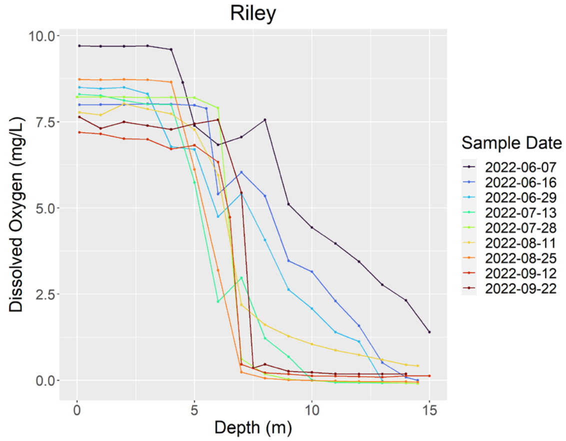

Rice Marsh
Temperatue (C)
20
22
24
26
28
0
1
2
3
Depth (m)
Sample Date
2022-06-01
2022-06-15
2022-06-30
2022-07-11
2022-07-25
2022-08-09
2022-08-22
2022-09-06
2022-09-20

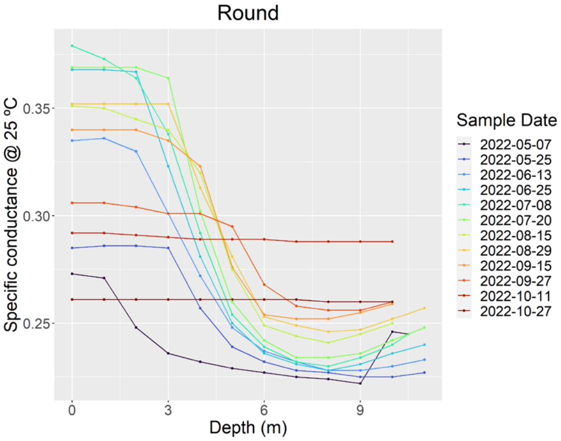

Red Rock
Temperatue (C)
10
15
20
25
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-29
2022-09-15
2022-09-27
2022-10-11
2022-10-27

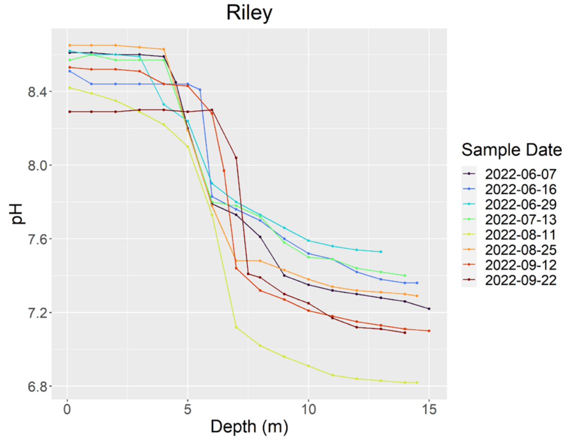

Rice Marsh
pH
7
8
9
10
0
1
2
3
Depth (m)
Sample Date
2022-06-01
2022-06-15
2022-06-30
2022-07-11
2022-07-25
2022-08-22
2022-09-06
2022-09-20

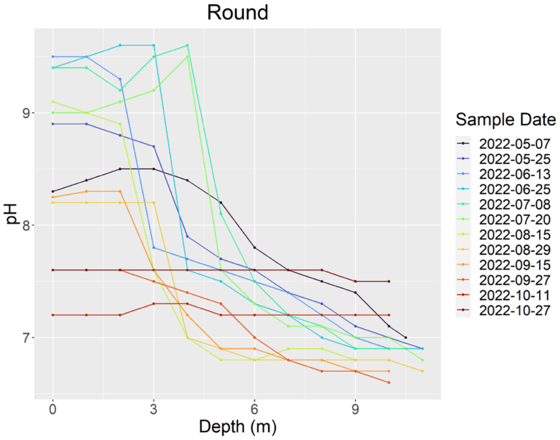

Riley

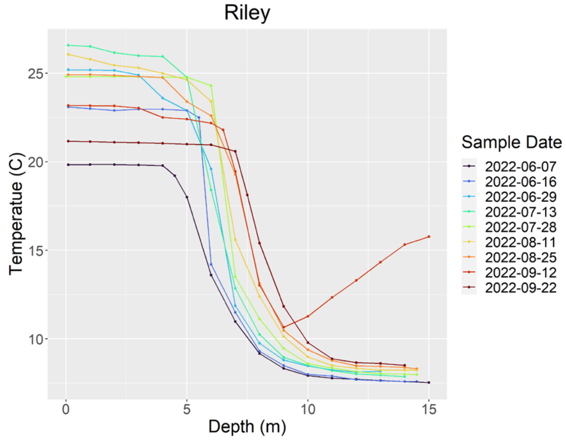

Round

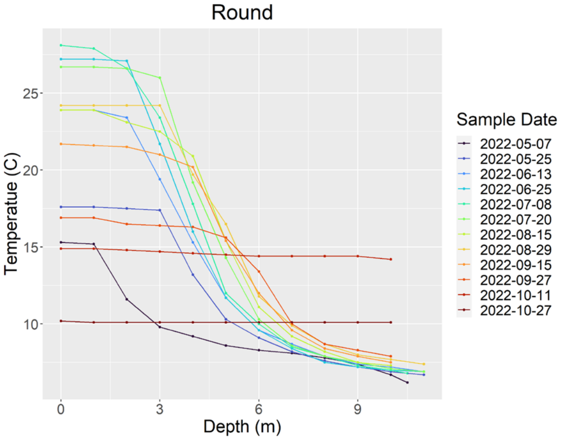

Riley

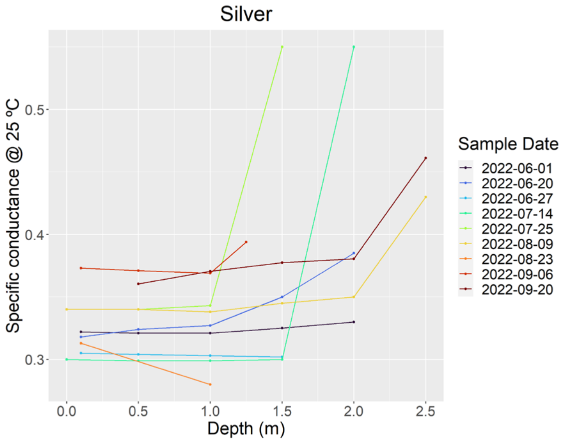

Round

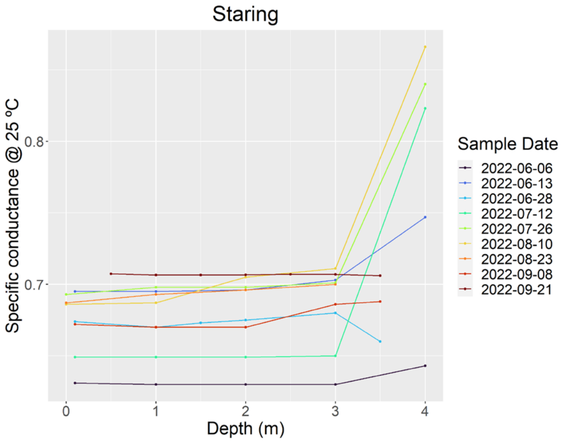

Riley

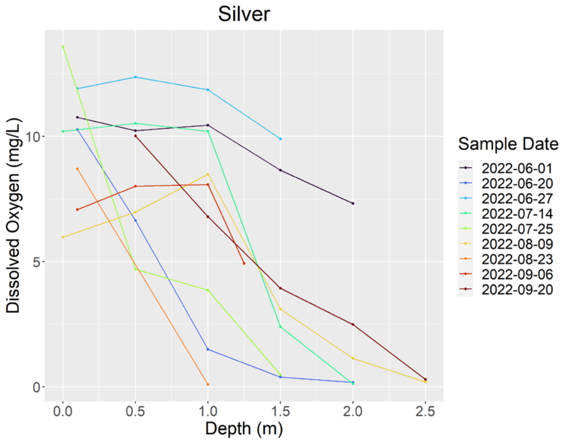

Round

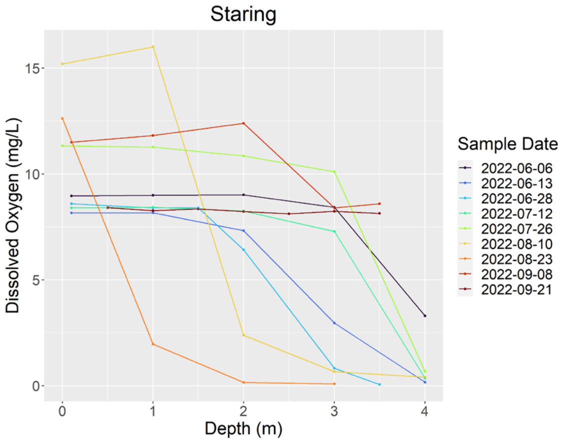

Riley

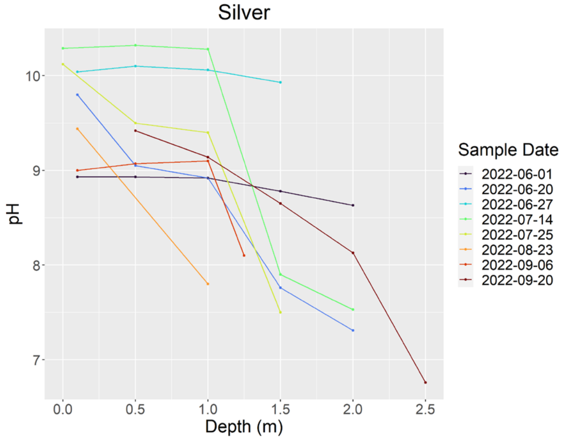

Round

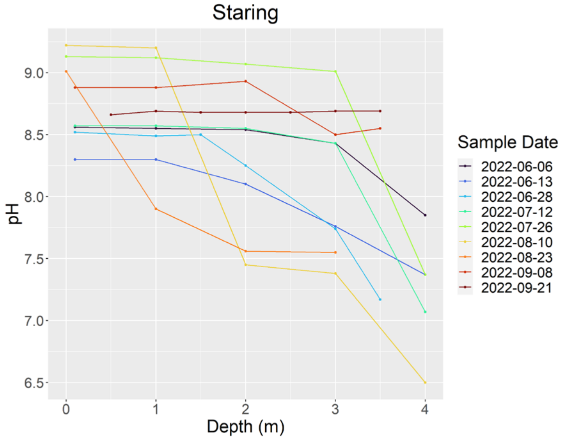

Silver
Specific conductance @ 25 °C
0.3
0.4
0.5
0.0
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-06-01
2022-06-20
2022-06-27
2022-07-14
2022-07-25
2022-08-09
2022-08-23
2022-09-06
2022-09-20

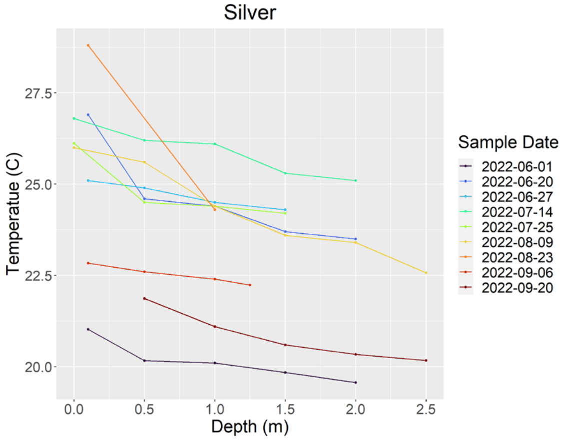

Staring
Specific conductance @ 25 °C
0.7
0.8
0
1
2
3
4
Depth (m)
Sample Date
2022-06-06
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21

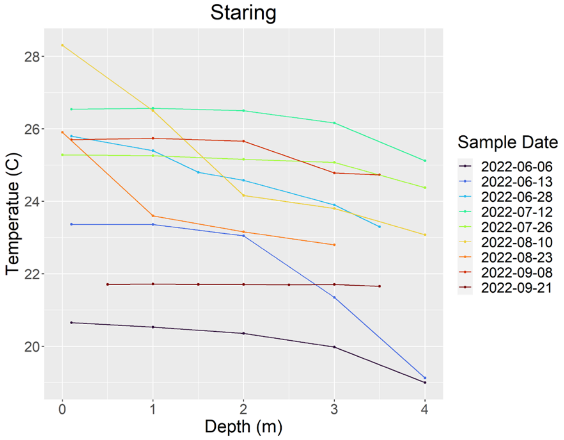

Silver
Dissolved Oxygen (mg/L)
0
5
10
0.0
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-06-01
2022-06-20
2022-06-27
2022-07-14
2022-07-25
2022-08-09
2022-08-23
2022-09-06
2022-09-20

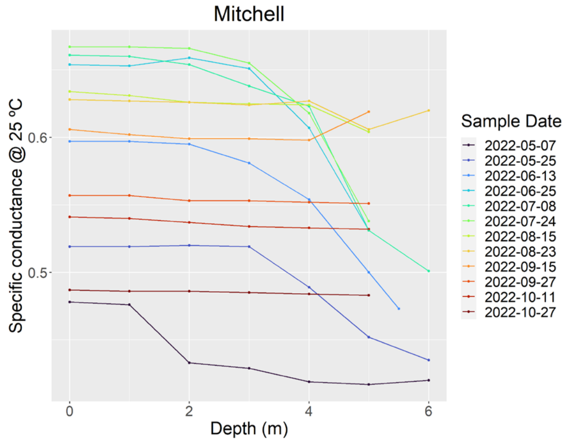

Staring
Dissolved Oxygen (mg/L)
0
5
10
15
0
1
2
3
4
Depth (m)
Sample Date
2022-06-06
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21

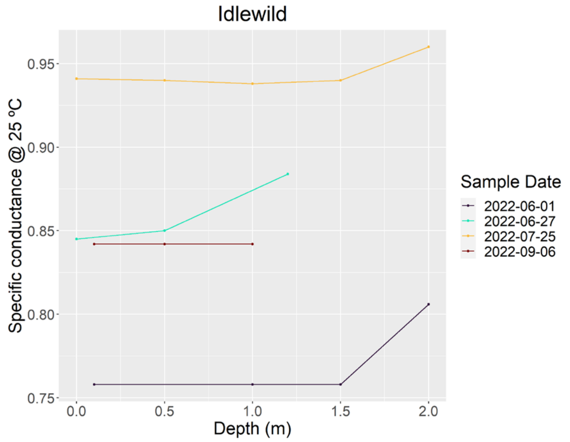

Silver
pH
7
8
9
10
0.0
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-06-01
2022-06-20
2022-06-27
2022-07-14
2022-07-25
2022-08-23
2022-09-06
2022-09-20

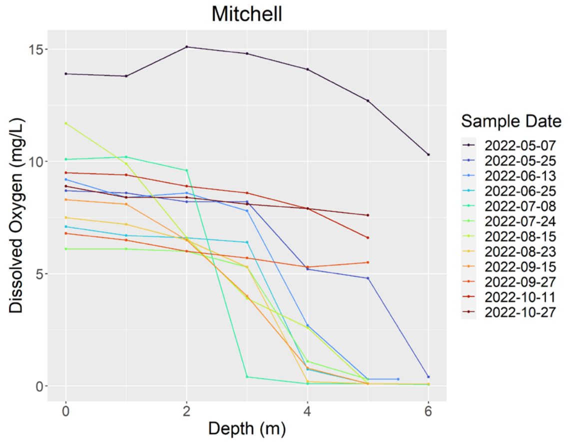

Staring
pH
6.5
7.0
7.5
8.0
8.5
9.0
0
1
2
3
4
Depth (m)
Sample Date
2022-06-06
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21

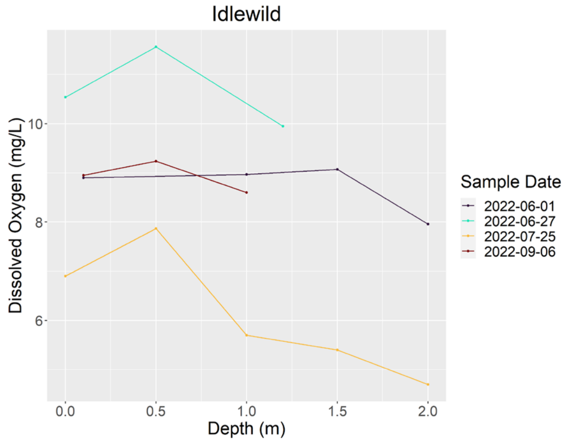

Silver
Temperatue (C)
20.0
22.5
25.0
27.5
0.0
0.5
1.0
1.5
2.0
2.5
Depth (m)
Sample Date
2022-06-01
2022-06-20
2022-06-27
2022-07-14
2022-07-25
2022-08-09
2022-08-23
2022-09-06
2022-09-20

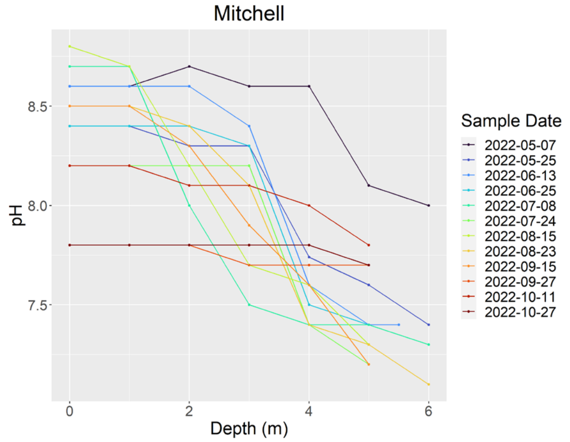

Staring
Temperatue (C)
20
22
24
26
28
0
1
2
3
4
Depth (m)
Sample Date
2022-06-06
2022-06-13
2022-06-28
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21

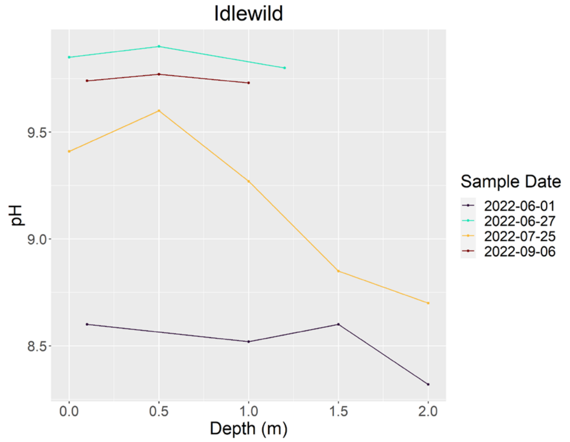

Mitchell
Specific conductance @ 25 °C
0.5
0.6
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-23
2022-09-15
2022-09-27
2022-10-11
2022-10-27

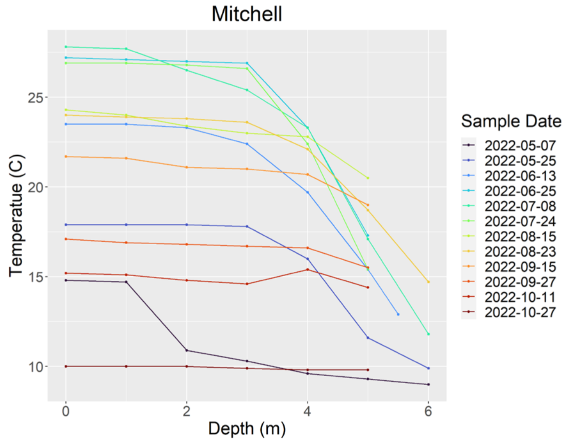

Idlewild
Specific conductance @ 25 °C
0.75
0.80
0.85
0.90
0.95
0.0
0.5
1.0
1.5
2.0
Depth (m)
Sample Date
2022-06-01
2022-06-27
2022-07-25
2022-09-06

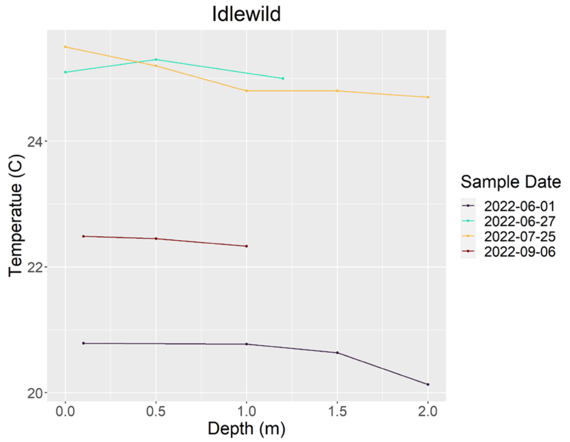

Mitchell
Dissolved Oxygen (mg/L)
0
5
10
15
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-23
2022-09-15
2022-09-27
2022-10-11
2022-10-27

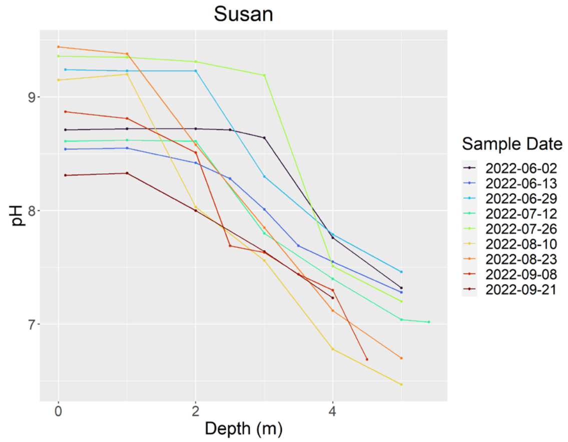

Idlewild
Dissolved Oxygen (mg/L)
6
8
10
0.0
0.5
1.0
1.5
2.0
Depth (m)
Sample Date
2022-06-01
2022-06-27
2022-07-25
2022-09-06

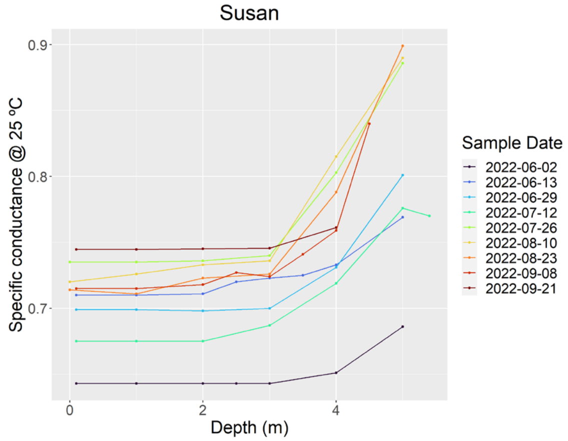

Mitchell
pH
7.5
8.0
8.5
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-23
2022-09-15
2022-09-27
2022-10-11
2022-10-27

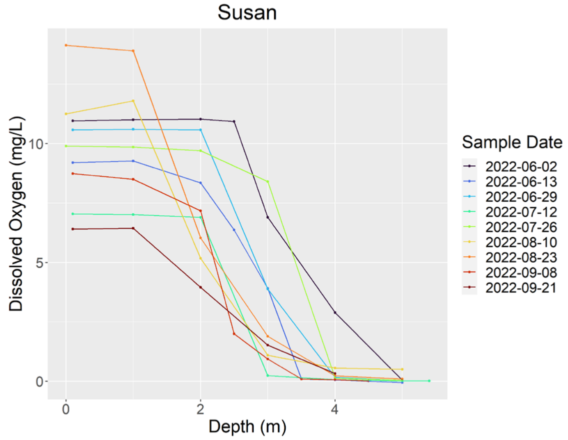

Idlewild
pH
8.5
9.0
9.5
0.0
0.5
1.0
1.5
2.0
Depth (m)
Sample Date
2022-06-01
2022-06-27
2022-07-25
2022-09-06


Mitchell
Temperatue (C)
10
15
20
25
0
2
4
6
Depth (m)
Sample Date
2022-05-07
2022-05-25
2022-06-13
2022-06-25
2022-07-08
2022-07-24
2022-08-15
2022-08-23
2022-09-15
2022-09-27
2022-10-11
2022-10-27


Idlewild
Temperatue (C)
20
22
24
0.0
0.5
1.0
1.5
2.0
Depth (m)
Sample Date
2022-06-01
2022-06-27
2022-07-25
2022-09-06


Susan
pH
9
8
7
0
2
4
Depth (m)
Sample Date
2022-06-02
2022-06-13
2022-06-29
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21


Susan
Specific conductance @ 25 °C
0.9
0.8
0.7
0
2
4
Depth (m)
Sample Date
2022-06-02
2022-06-13
2022-06-29
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21


Susan
Dissolved Oxygen (mg/L)
10
5
0
0
2
4
Depth (m)
Sample Date
2022-06-02
2022-06-13
2022-06-29
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21

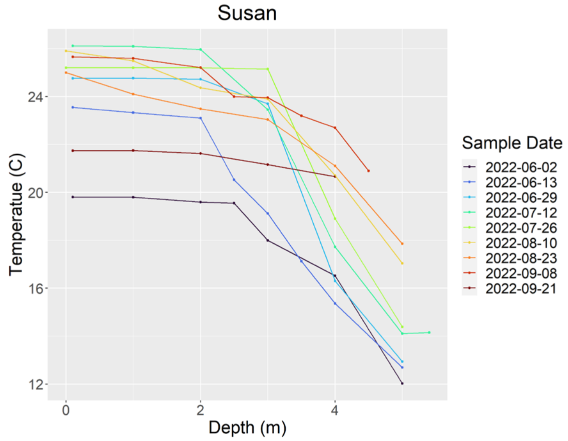
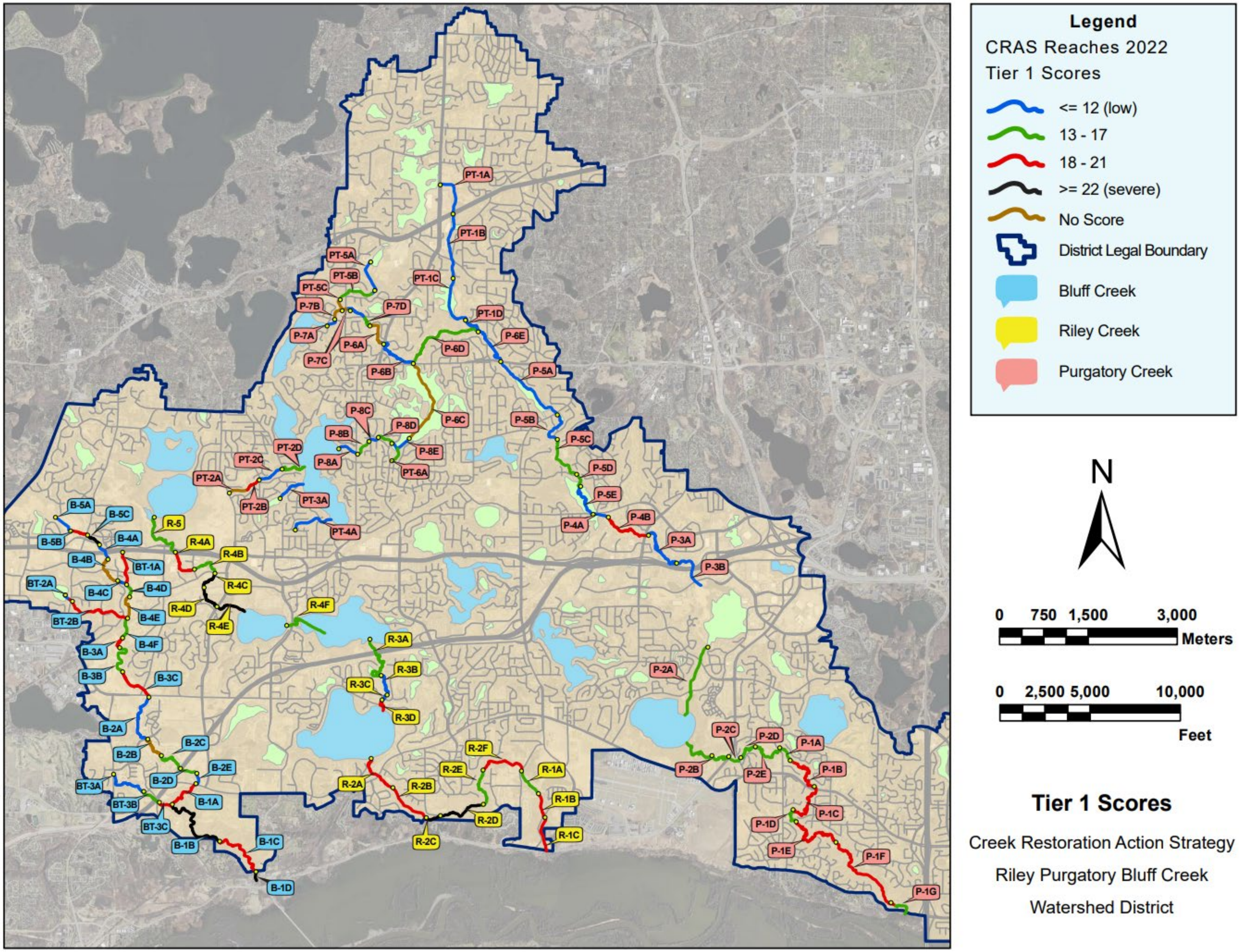

Susan
Temperatue (C)
24
20
16
12
0
2
4
Depth (m)
Sample Date
2022-06-02
2022-06-13
2022-06-29
2022-07-12
2022-07-26
2022-08-10
2022-08-23
2022-09-08
2022-09-21

Exhibit H
2022 Creek Restoration Action Strategy

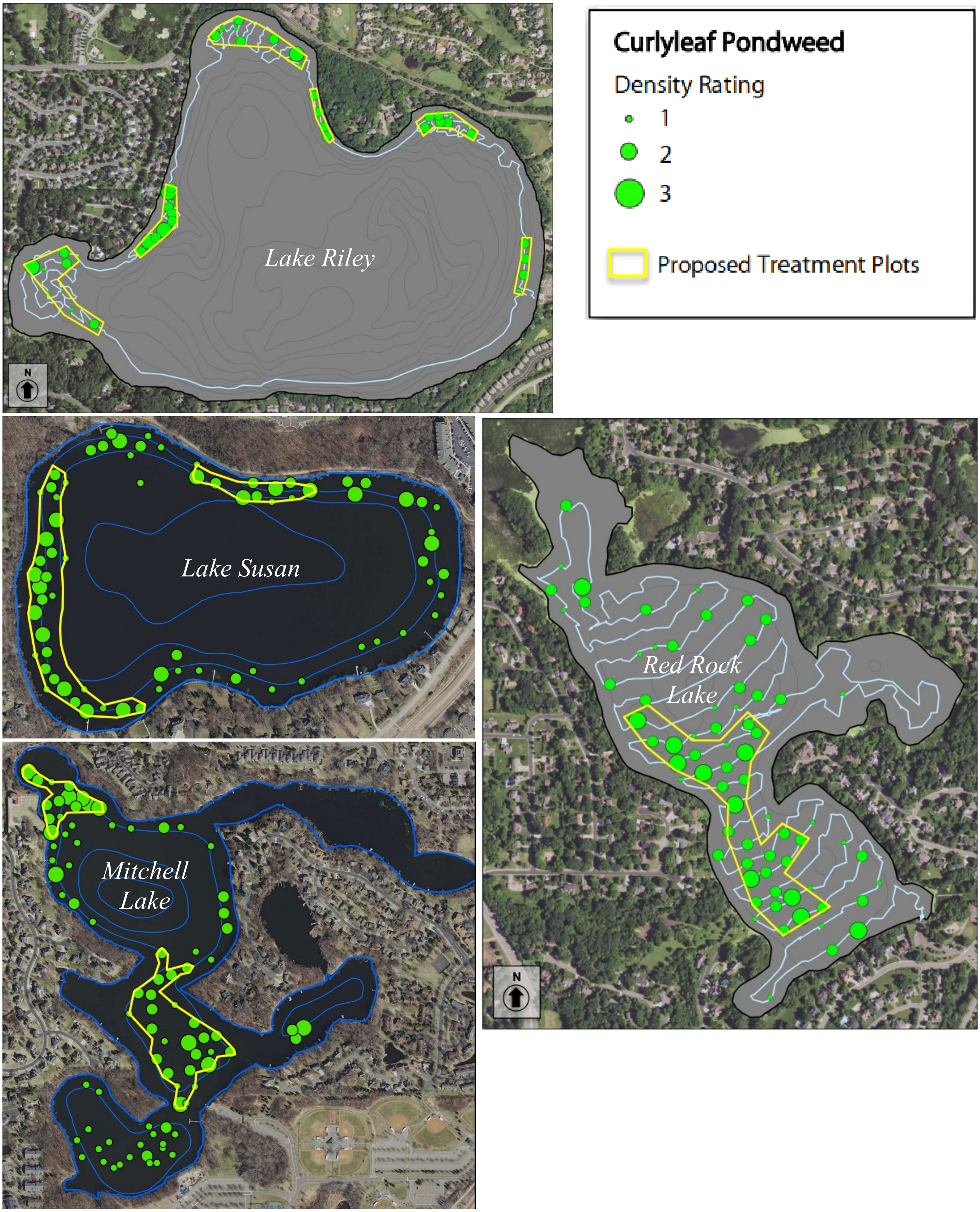


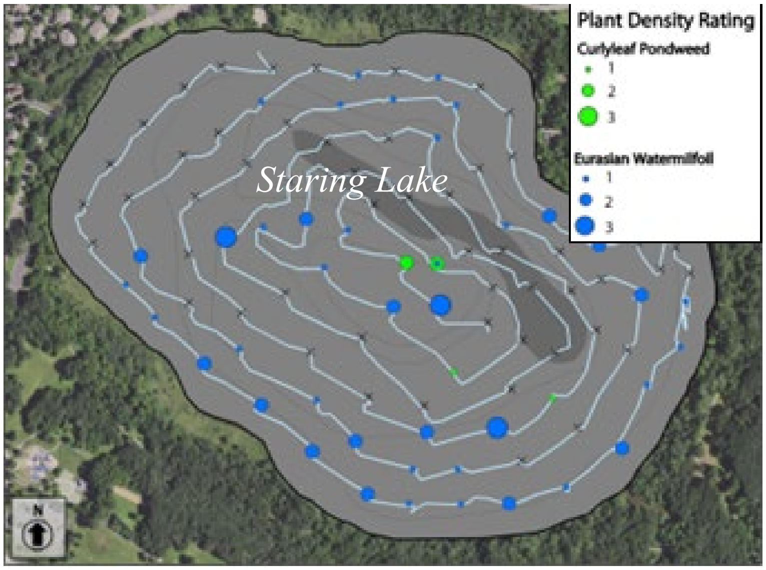
Tier 1 Scores

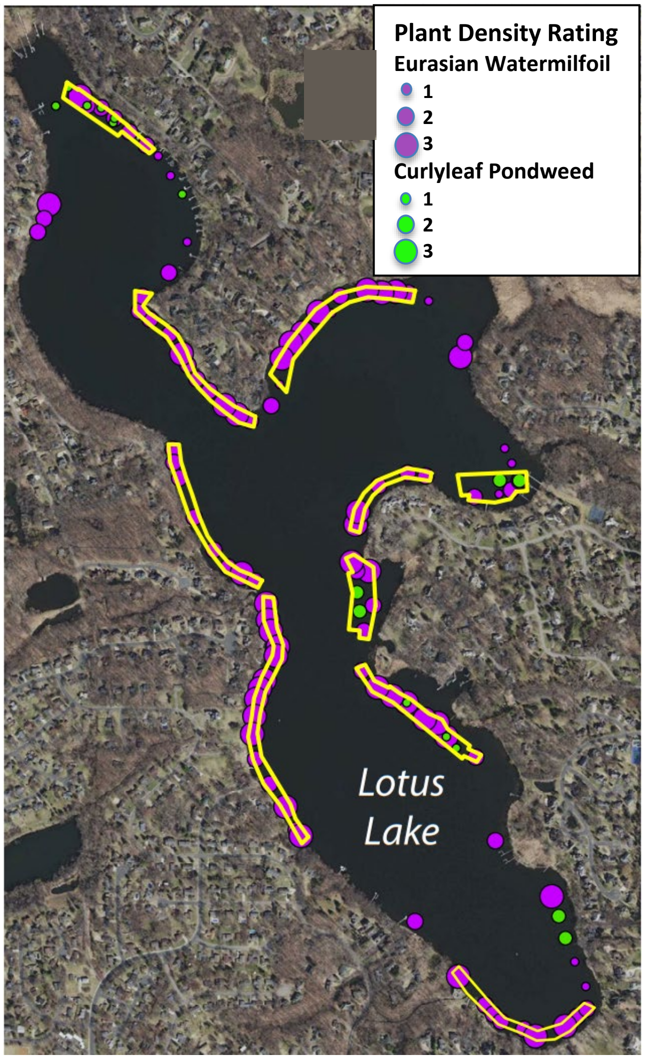
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

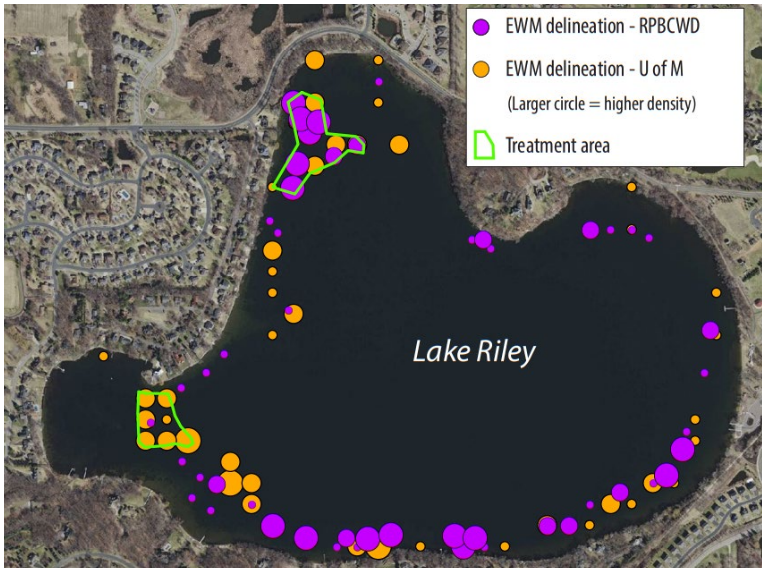
Exhibit I

2022 RPBCWD Curly-leaf Pondweed and Eurasian Watermilfoil Treatment Areas




Plant Density Rating
Curlyleaf Pondweed
1
2
3
Eurasian Watermilfoil
1
2
3
Staring Lake
N


Plant Density Rating
Eurasian Watermilfoil
1
2
3
Curlyleaf Pondweed
1
2
3
Lotus Lake


EWM delineation - RPBCWD
EWM delineation - U of M
(Larger circle = higher density)
Treatment area
Lake Riley