Water Resources Report

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
2021 ANNUAL REPORT

Photo Credit: Elizabeth Myer, Lake Riley

protect. manage. restore.

Executive Summary

The Riley Purgatory Bluff Creek Watershed District (RPBCWD) had a successful water quality sampling season in 2021, 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 2021 sampling effort are presented in this report.

2021 LAKE SUMMARY

During the 2021 monitoring season, 13 lakes and two high value 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 2,177 common carp from the District in 2021, 1,930 of which were removed from the Purgatory Creek system. The District also monitored public access points and analyzed water samples for the presence of zebra mussels in 14 of the 15 waterbodies. Zebra mussel veligers and adults were found on Lake Riley in 2021 which was expected. Water samples processed for eDNA tested positive for the presence of zebra mussels on Lotus Lake in 2021. Lotus has tested positive each year since being added to the Minnesota Department of Natural Resources Infested Waters List in 2019. In 2021, point intercept vegetation surveys were conducted on Hyland Lake (Three Rivers Park District (TRPD)), Duck Lake (Eden Prairie) Lake Susan, Redrock Lake, Lake McCoy, Lake Idlewild, Lake Staring, and Lake Riley. In the spring of 2021, herbicide treatments occurred on Lotus Lake, Mitchell Lake, Riley Lake, Lake Susan, 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 2021 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 Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake) (MPCA 2016).

In 2021, Lake Ann, Lake Lucy, Lake Riley, Rice Marsh Lake, Silver Lake, Round Lake, and Lake Idlewild met all three MPCA standards. Overall, water quality improved in 2021 and all lakes met the MPCA water clarity standard. The Riley Chain of Lakes 2021 water quality remained relatively unchanged from 2020. Lake Riley had the highest recorded summertime secchi disk average (4.82 m) since data collection began in the 1970s. Rice Marsh Lake continued to meet all standards following the alum treatment which occurred in 2018. Similar to 2020, Lake Susan did not meet the TP and Chl-a standard in 2021. Mitchell Lake improved from 2020 by meeting the water clarity standard while still not meeting the Chl-a and TP, although concentrations decreased. Silver Lake and Lake Idlewild of the Purgatory Chain of Lakes improved and met all standards in 2021. Hyland Lake had improved water quality in 2020 and 2021 which likely can be attributed to the alum treatment in 2019. Both Red Rock Lake and Lotus Lake did not meet any of the MPCA standards in 2020 but improved to meeting all but the Chl-a standard in 2021. All lakes met the proposed nitrate/nitrite water quality standard and chloride standard.

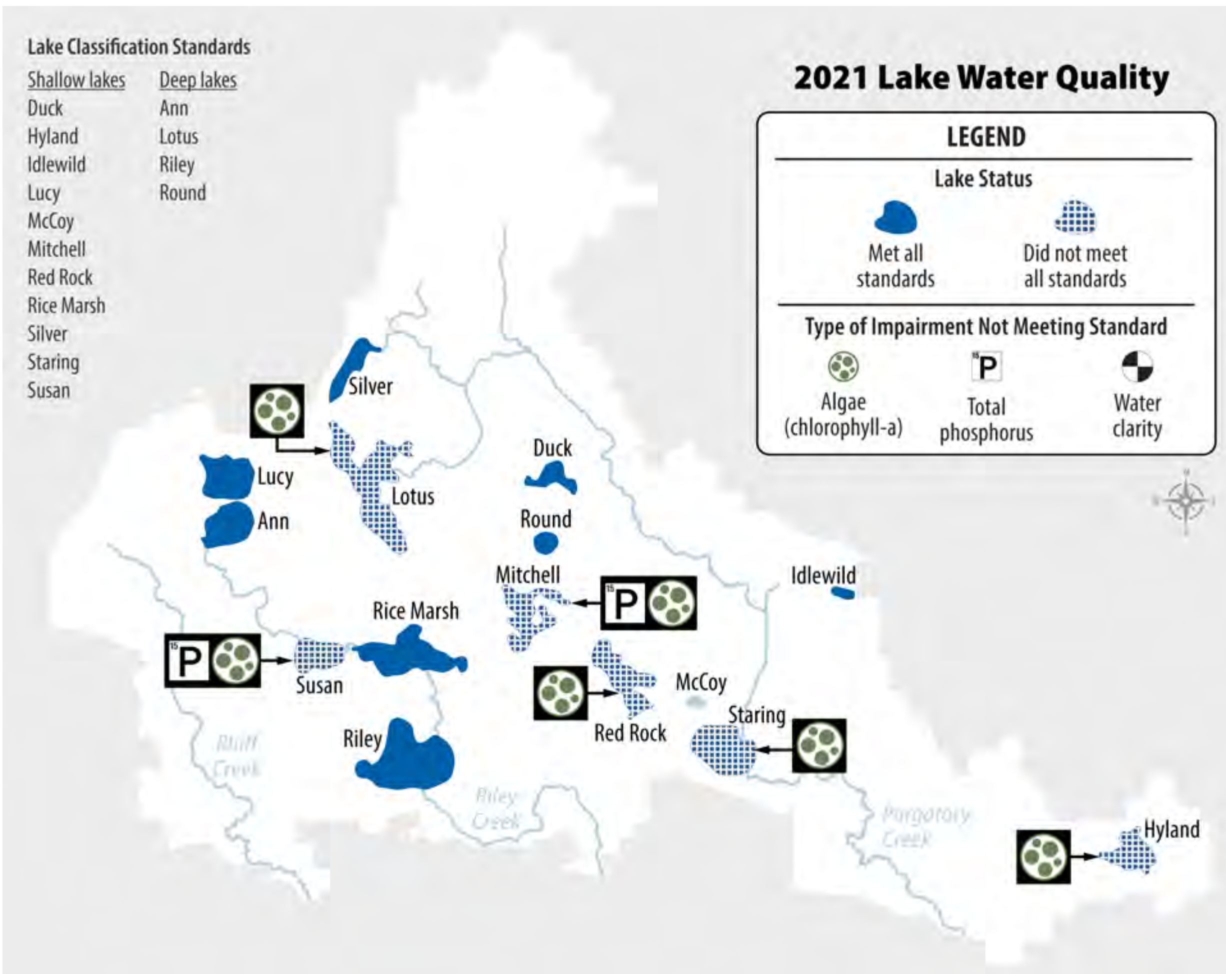

Figure i 2021 Lake Water Quality

Summary of the lake water quality data collected in 2021 by the Riley Purgatory Bluff Creek Watershed District 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.

2021 STREAM SUMMARY

In 2021, the District and its partners collected water quality samples and performed data analysis on 30 different sampling sites along Riley Creek (seven sites), Bluff Creek (eight sites), and Purgatory Creek (fifteen sites). During the 2021 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 nutrient (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 upper Bluff Creek, Purgatory Creek near Staring Lake, and the upper Lotus Lake ravine to assess pollutant loads and the potential for restoration projects. Enviro DIY units were installed on lower Bluff, Upper Purgatory, and two locations near highway 101 on lower Purgatory Creek to assess under monitored areas and to update the District's Hydraulic and Hydrology Model. 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 five Riley Creek regular water quality monitoring sites in 2021, however due to the low water levels only three sites were sampled. The middle sections of Bluff Creek were assessed, and stability and habitat scores were updated using the Creek Restoration Action Strategy (CRAS) evaluation. Overall, most stream sections scored by the CRAS were similar or slightly improved from years past.

The summary for all three creeks is based on water quality parameters developed by the MPCA in 2014 for Eutrophication and TSS as well as impairment status for fish 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).

Overall, stream water quality remained relatively the same across the District. The number of water quality standard impairments overall increased slightly from 2020 to 2021; Bluff had nine (previously ten), Riley had eleven (previously five), and Purgatory had nine (previously eleven). No regular creek sampling sites met all MPCA water quality standards assessed in 2021 (Figure ii), down from two sites in 2020 (R5 and R3). Like previous years, TP was the water quality standard causing the most impairments in 2021 with 11 of the 18 sites not meeting the standard. TSS impairments were slightly reduced from 2020. Five (previously 6) sites were impaired. Riley Creek surpassed Bluff Creek as the stream with the most impaired water quality sites in 2021. Prior to 2021, Bluff Creek generally had the most impairments. Riley was also the most degraded from 2020. Impairments on Riley Creek were relatively similar compared to 2020, however DO was impaired across three sites compared to zero in 2020. This was most likely attributed to the low water levels and lack of precipitation. The extremely low flows seen in 2022 led to reduced oxygen levels and concentrated nutrients in the stream. These factors combined led to the increase in impairments. This is also what likely caused chloride concentrations to be above the MPCA chloride standard at B4 and R4 in May, June, and July. Both of these sites are downstream of Highway 5 which receives significant salt application in the winter. All sites met the pH and Chl-a water quality limits in 2021. MPCA macroinvertebrate impairments included lower reaches of Riley and Purgatory Creek. Lower reaches of Riley and Bluff Creek had fish impairments.

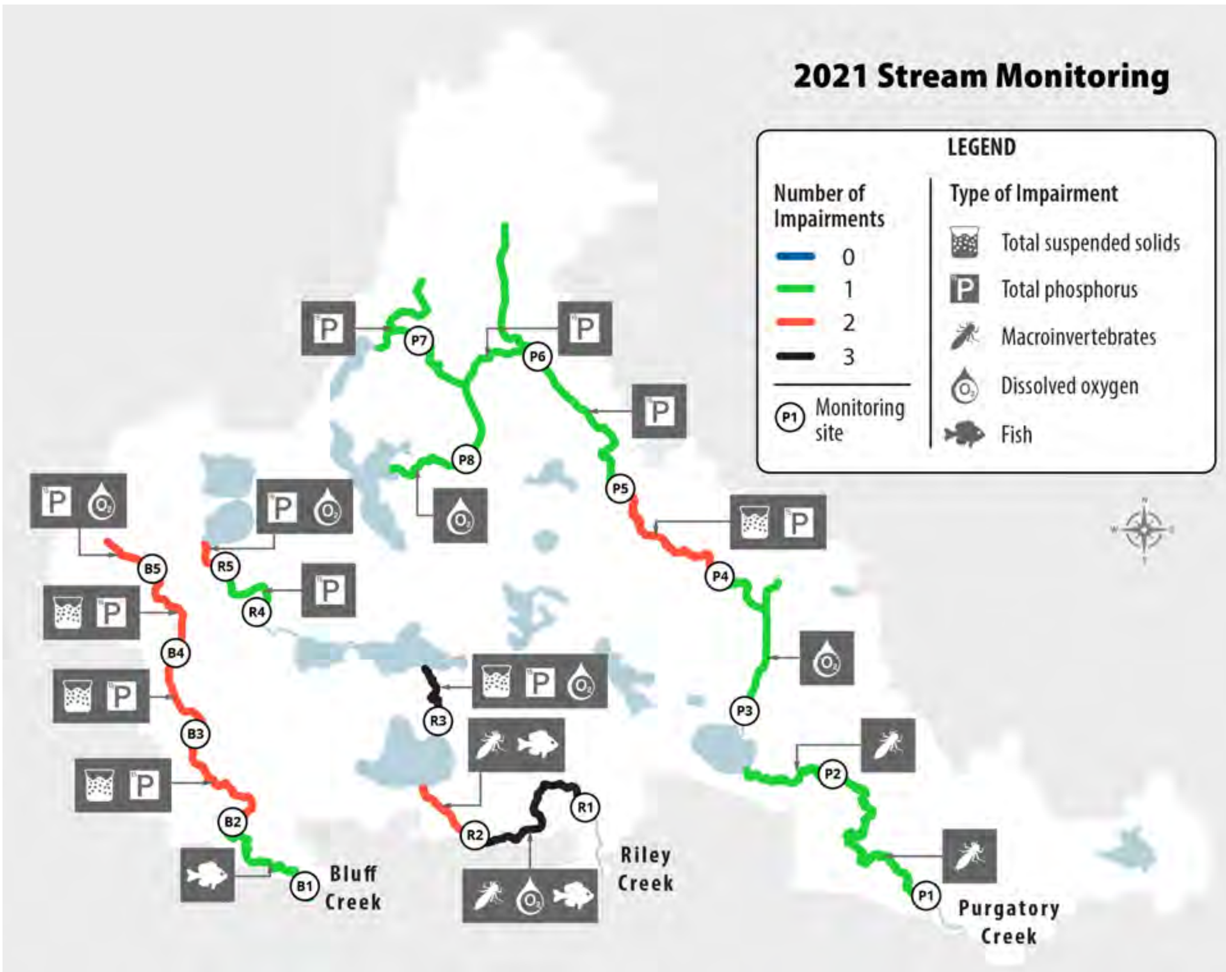

Figure ii   2021 Stream Water Quality

2021 stream water quality data from Bluff Creek, Riley Creek, and Purgatory Creek in 2021 by 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.

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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
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

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 located 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.

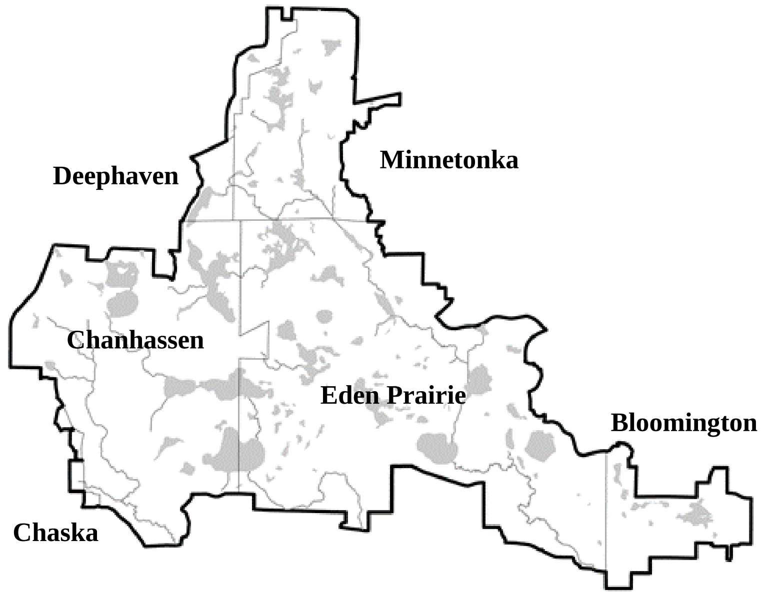


Figure 1-1 Riley Purgatory Bluff Creek Watershed District Boundary

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.

Through partnerships with various cities, Three Rivers Park District (TRPD), the University of Minnesota (UMN), Metropolitan Council (METC), and Carver County, water quality data was collected on 13 lakes and two high value wetlands (Lake Idlewild and Lake McCoy). In 2021, the District and its partners collected water quality samples and performed data analysis on 30 different sampling sites along Riley Creek (seven sites), Bluff Creek (eight sites), and Purgatory Creek (fifteen sites). Neil Lake, which is within the watershed boundaries, has not been part of the District's sampling regime. 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 (Figure 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 collected on Bluff Creek at all regular water quality sites in September.

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. 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. In the summer of 2021, four stormwater ponds were also monitored and sampled bi-weekly as a part of a cooperative study with the University of Minnesota and partner cities. Winter monitoring occurred on the Riley Chain of Lakes as well as four separate stormwater ponds in 2020. 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 1-1. 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 1-1 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	■		■	■	

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					■	■	■	■	■	■		
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 2021 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 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 install 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. A list of the variety of parameters monitored during each sampling event can be seen in Table 2-1.

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 meter depths except for the bottom sample, which is collected 0.5 meters from the lake bottom to prevent disrupting the sediment. 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. Water quality information collected in the winter 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 Intervals Collect Water Samples from Top, Thermocline, and Bottom
Summer Lake – Biological	Collect Zooplankton Tow (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 of the University of Minnesota and all phytoplankton samples were sent to Margaret Rattei at Barr Engineering 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

3 Water Quality Standards

In 1974, the Federal Clean Water Act set forth the requirements 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. 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 improve water quality within the watershed, the District 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 water quality data the District has collected in 2021.

4.1 2021 Lakes Eutrophication Water Quality Summary

More information about 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 F. Sonde lake profile data can be seen in Exhibit H.

Chlorophyll-a

The 2021 growing season Chl-a mean concentrations for all lakes sampled within the District are shown in Figure 4-1. Like 2020, of the three main eutrophication lake water quality standards (Chl-a, TP, Secchi), Chl-a was the nutrient with the most impairments in 2021. Lake McCoy values were not applied in 2021 due to extreme low water conditions. Overall, eight of 14 lakes sampled in 2021 met the MPCA Chl-a standards for their lake classification (nine lakes in 2020 and six lakes in 2018 and 2019): Lake Ann, Lake Riley, Round Lake, Duck Lake, Lake Idlewild, Lake Lucy, Rice Marsh Lake, and Silver Lake.

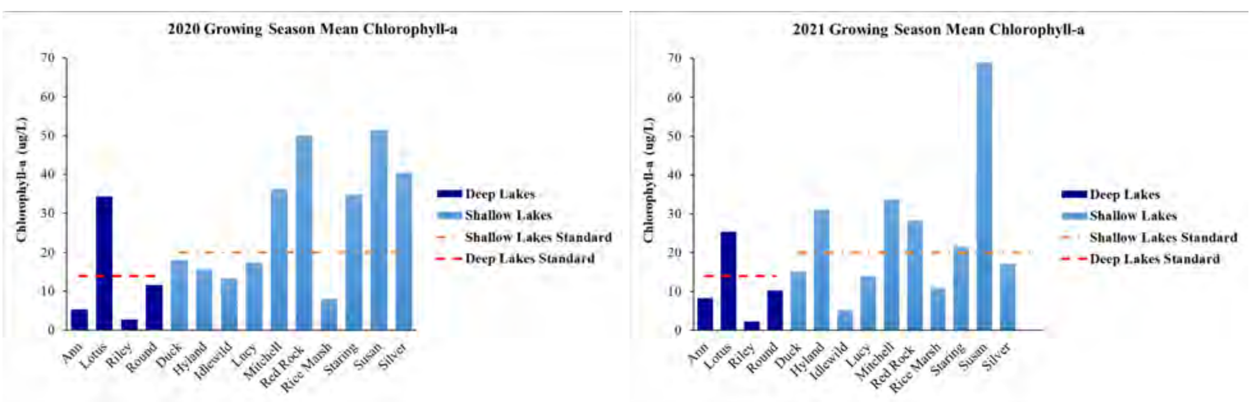


Figure 4-1 2020-2021 Lake Growing Season Mean Chlorophyll-a

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 2020 and 2021. 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. Following the alum treatment, Lake Riley had the lowest summer Chl-a average of all lakes sampled in 2021 at 2.3 ug/L (2.8 ug/l in 2020). Similar to 2019 and 2020, Lotus Lake did not meet the standard and had Chl-a average concentrations at 25.3 ug/L (a decrease of 8 and 9 ug/L from 2019 and 2020). The remainder of the lakes sampled in 2021 are categorized as 'shallow' by the MPCA (<15 ft deep, >80% littoral area): Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Lake Mitchell, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake. Water quality metrics on Lake Idlewild, which is classified as a high-value wetland, were compared to MPCA shallow lake standards. The water quality standard for shallow lakes (< 20 ug/L) was met by Duck Lake, Lake Idlewild, Lake Lucy, Rice Marsh Lake, and Silver Lake. Although Hyland Lake met the MPCA standard in 2020 (15.8 ug/L), it failed to meet the standard in 2021 (31.1 ug/L). Similar to 2020, Mitchell Lake, Red Rock Lake, and Staring all did not meet the MPCA standard in 2021 although all showed improvement. Lake Susan continued to have the highest Chl-a concentrations. Concentrations increased from 51.5 ug/L in 2020 to 69 ug/L in 2021. Silver Lake showed the most improvement across lakes with concentrations decreasing from 40.4 ug/L in 2020 to meeting the MPCA standard with a summertime average concentration of 17.1 ug/L.

Total Phosphorus

The TP growing season averages for all lakes sampled within the District in 2021 are shown in Figure 4-2. Overall, twelve of the 14 lakes sampled met the MPCA total phosphorus standard for their lake classification in 2021: Lake Ann, Lotus Lake, Lake Riley, Round Lake, Duck Lake, Lake Hyland, Lake Idlewild, Lake Lucy, Red Rock, Rice Marsh Lake, Staring Lake, and Silver Lake. This represents an increase from eight lakes in 2020 and 11 lakes in 2019 that met the standard.

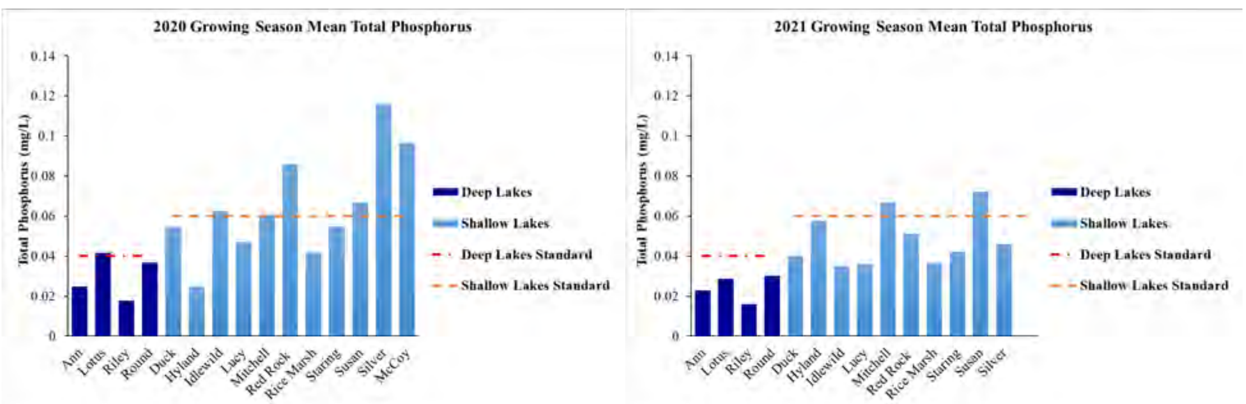


Figure 4-2 2020-2021 Lakes Growing Season Mean Total Phosphorus

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 2020 and 2021. 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 2021. Lotus Lake TP concentrations improved in 2021(0.029 mg/L) from 2020 (0.0416 mg/L), which allowed it to meet the MPCA standard 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 across all lakes sampled (2020 -0.0178 mg/L: 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, Rice Marsh Lake, Staring Lake, and Silver Lake in 2021. Lake Susan and Mitchell Lake both did not meet the MPCA standard in 2020 (0.067 mg/L and 0.061 mg/L) and 2021. They did see slight increases Chl-a concentrations in 2021 (0.072 mg/L and 0.067 mg/L). Lake Idlewild and Red Rock Lake did not achieve the standard in 2020 (0.062 mg/L and 0.086 mg/L) but improved and met the standard in 2021 (0.035 mg/L and 0.051 mg/L). Silver Lake improved the most from 2020 (0.116 mg/L) to 2021 (0.046 mg/L) with a reduction of average summertime TP concentrations of 60%.

Secchi Disk
The 2021 secchi disk growing season means for all District lakes sampled are shown in Figure 4-3. Overall, water clarity improved in 2021 with all lakes achieving the MPCA secchi disk standard for their lake classification. This occurred in 2019 and is an increase from 11 lakes in 2020.

The MPCA standard for secchi disk depth/water clarity for deep lakes (> 1.4 m) was met by all lakes. Lotus did not meet the standard in 2020 (1.24 m) but met the standard in 2021 (1.51 m). Lake Riley had the highest summer average for all lakes sampled in 2021 and the average was the highest recorded since 1971 on the lake (4.82 m). For shallow lakes, the MPCA standard was not met by Mitchell and Red Rock in 2020. Red Rock had the lowest (worst) secchi reading at 0.66 m in 2020 but improved 1.5 m in 2021. Duck, Idlewild, Silver, and Lucy had secchi readings near 2 m and Hyland was reduced from 2.05 m in 2020 to 1.14 m in 2021. Mitchell Lake and Redrock lake did not meet the standard in 2020 (0.93 m and 0.66 m) but improved in 2021 and met the standard (1.13 m and 1.5 m). Lake McCoy had max depths less than 1 m or was dry and was not included in 2021.

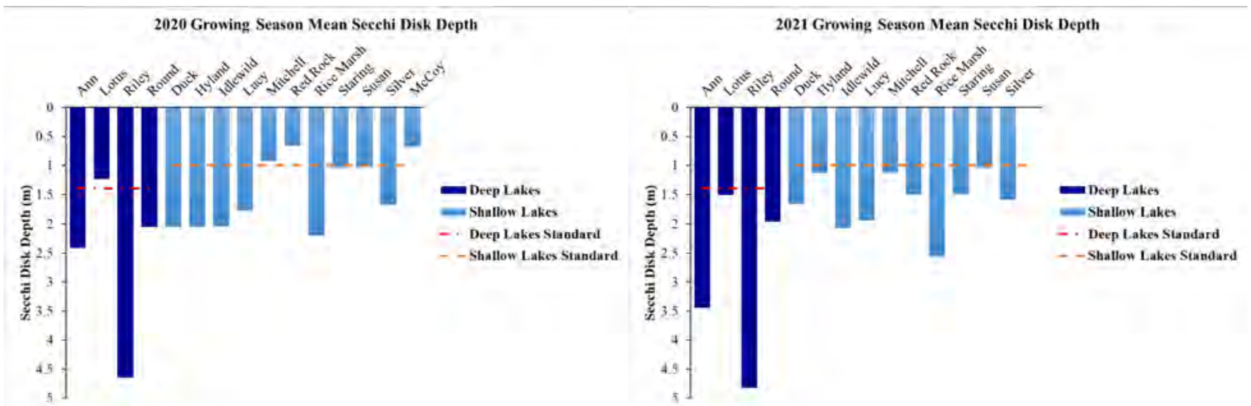


Figure 4-3 2020-2021 Lakes Growing Season Mean Secchi Disk Depth

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 2020 and 2021. 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. 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. 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 F.

Table 4-1 Aluminum Sulfate Treatments in RPBCWD

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

Figure 4-4 through Figure 4-8 illustrate total phosphorus (TP) levels prior to treatment, through the end of 2021 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 Round Lake and 2020 Lotus Lake). In addition, often both Secchi and Chlorophyll-a levels were improved which led to some lakes meeting all three water quality standards after treatment (Hyland, Rice Marsh, Riley, and Round). 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 three years of post-treatment data, it appears Rice Marsh and Hyland Lake were very effective alum treatments with phosphorus reductions of 54% and 51% respectively. 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 92% (dose 2) for Round Lake). 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 in 2020 and 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 64% at surface and 93% near the lake bottom phosphorus. After the first dose, water quality in Lotus Lake did not respond as well as the other lakes (only 34% surface and 53% bottom). This may be due to the very 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. Both basins had similar summer average surface concentrations (0.03 and 0.029 mg/L respectively). Bottom summer averages were slightly different with the south bay (normal monitoring location) having higher concentrations at 0.185 mg/L vs 0.146 measured in the east bay. Additional sediment coring will be needed before the second alum application.

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	2009-2021	0.0457	0.0267	41	0.0164	64
Lotus	2016-2021	0.054	0.0354	34	Not Complete	
Rice Marsh	2016-2021	0.0745	0.0363	51		
Round	2008-2021	0.0415	0.0388	6	0.0326	21
Hyland	2016-2021	0.0819	0.0375	54	Not Complete	

Bottom TP		Dose 1			Dose 2	
Lake	Years	Average TP Pre	Average TP Post	% Reduction	Average TP Post	% Reduction
Riley	2009-2021	0.5334	0.1684	68	0.0368	93
Lotus	2016-2021	0.3797	0.1775	53	Not Complete	
Rice Marsh	2016-2021	0.1122	0.0355	68		
Round	2008-2021	0.9270	0.1376	85	0.0741	92
Hyland	No Data					

*D1=dose 1; D2= dose 2

Staff will be collecting sediment cores on Lotus Lake and Rice Marsh Lake in 2022 to assess alum effectiveness and prepare for a second application. In addition, staff will be looking at the possibility of treating the southwest wetland draining to Lake Susan. It is thought that treating this wetland would reduce the extremely high levels of phosphorus being released and assist the spent lime treatment system

(Section 4.9) with treating its effluent. Overall, the results indicate that alum applications are effective and can drastically reduce phosphorus levels within a lake. Staff will continue to monitor each lake to determine second dose application and gauge temporal success of each treatment.

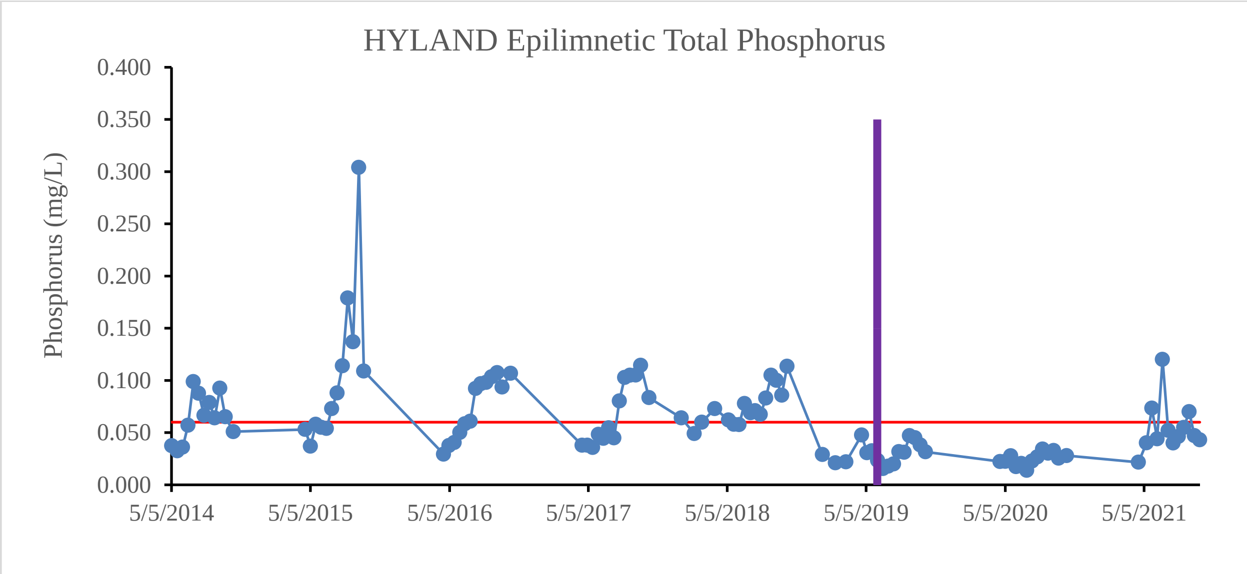


Figure 4-4 Hyland Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Hyland Lake between May 5, 2014 and September 28, 2021. The aluminum sulfate (Alum) treatment occurred on June 3, 2019 (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).

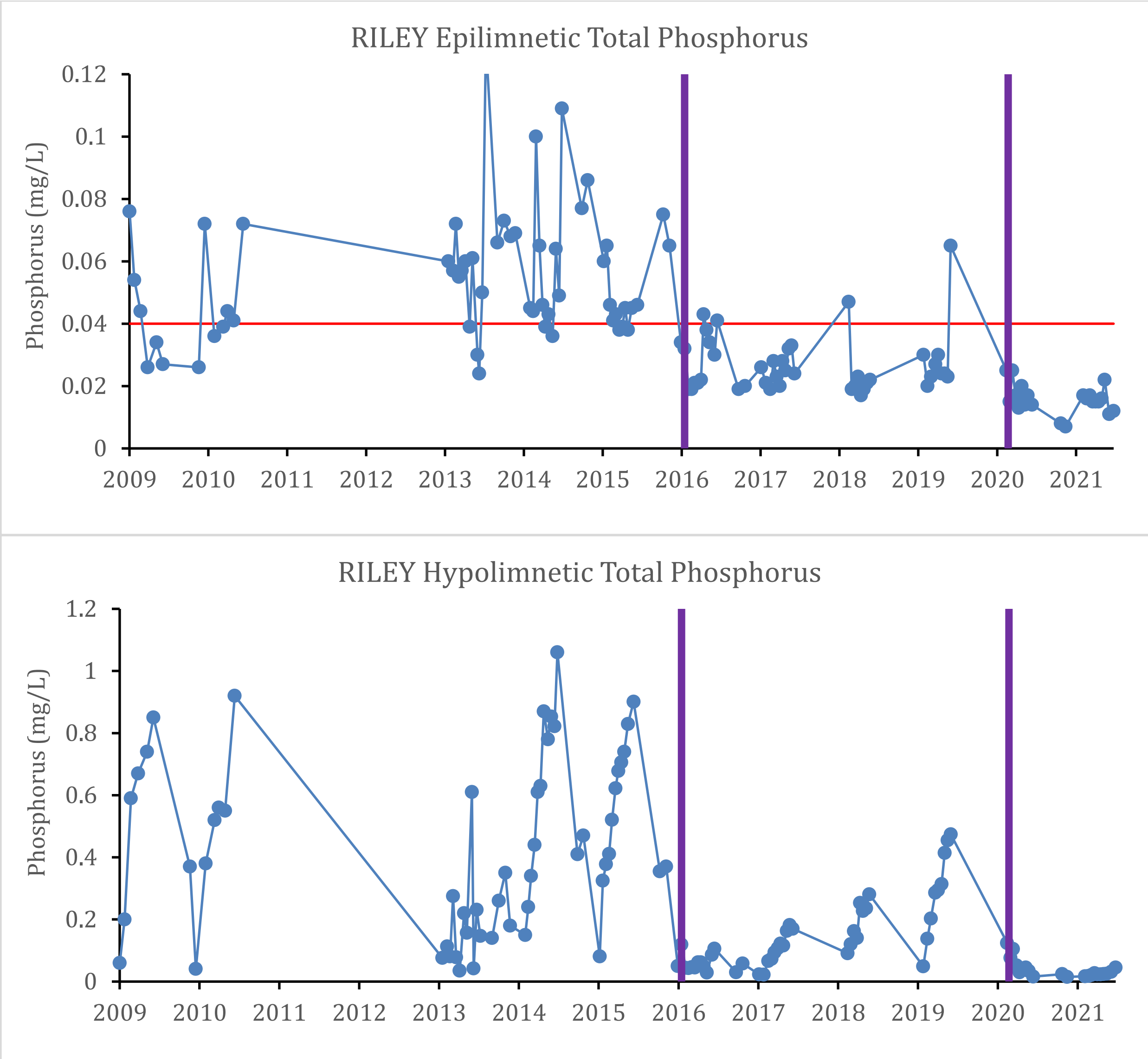


Figure 4-5 Lake Riley Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lake Riley between April 22, 2009 and October 10, 2021. 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).

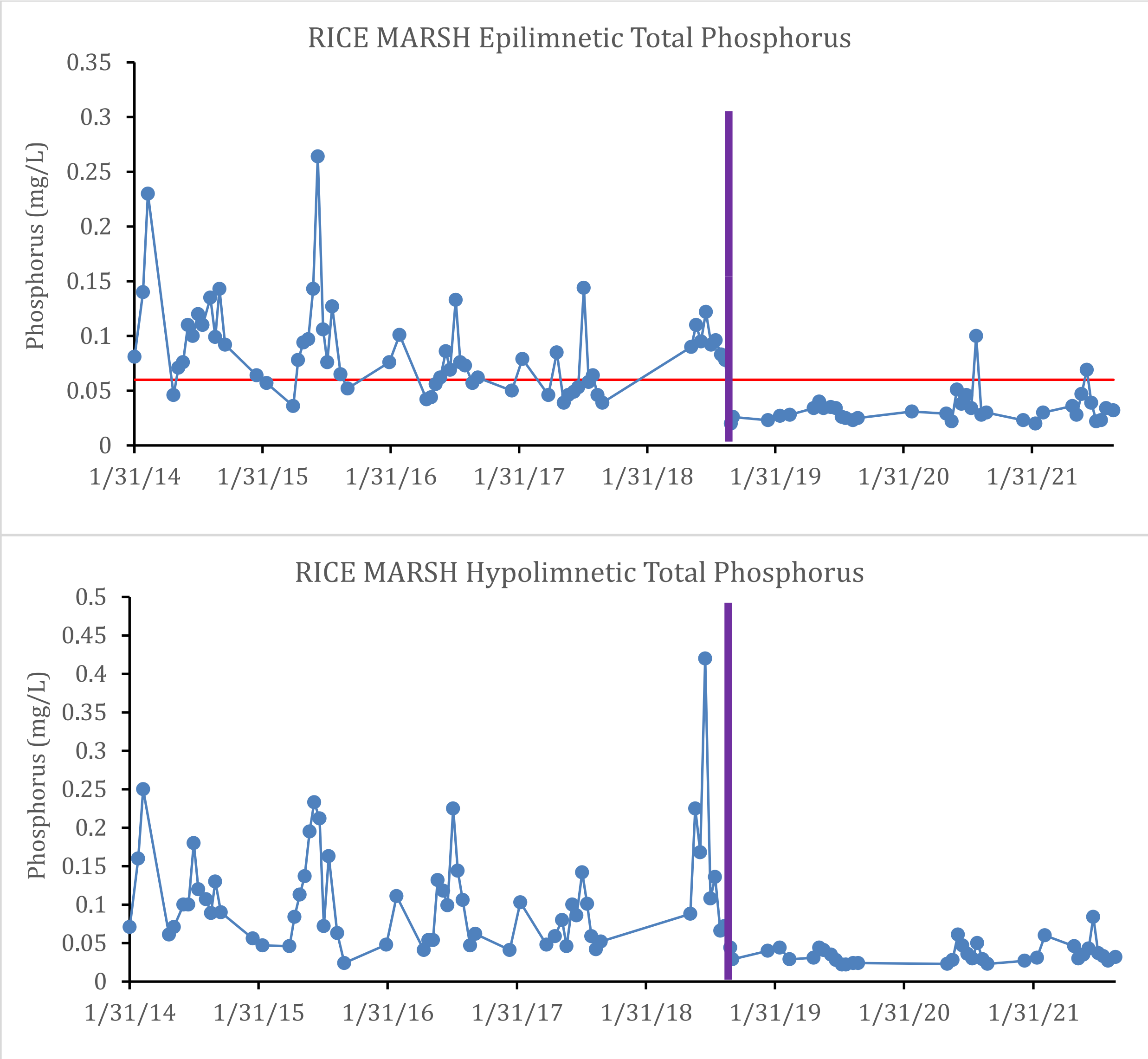


Figure 4-6 Rice Marsh Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Rice Marsh Lake between January 31, 2014 and September 21, 2021. 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).

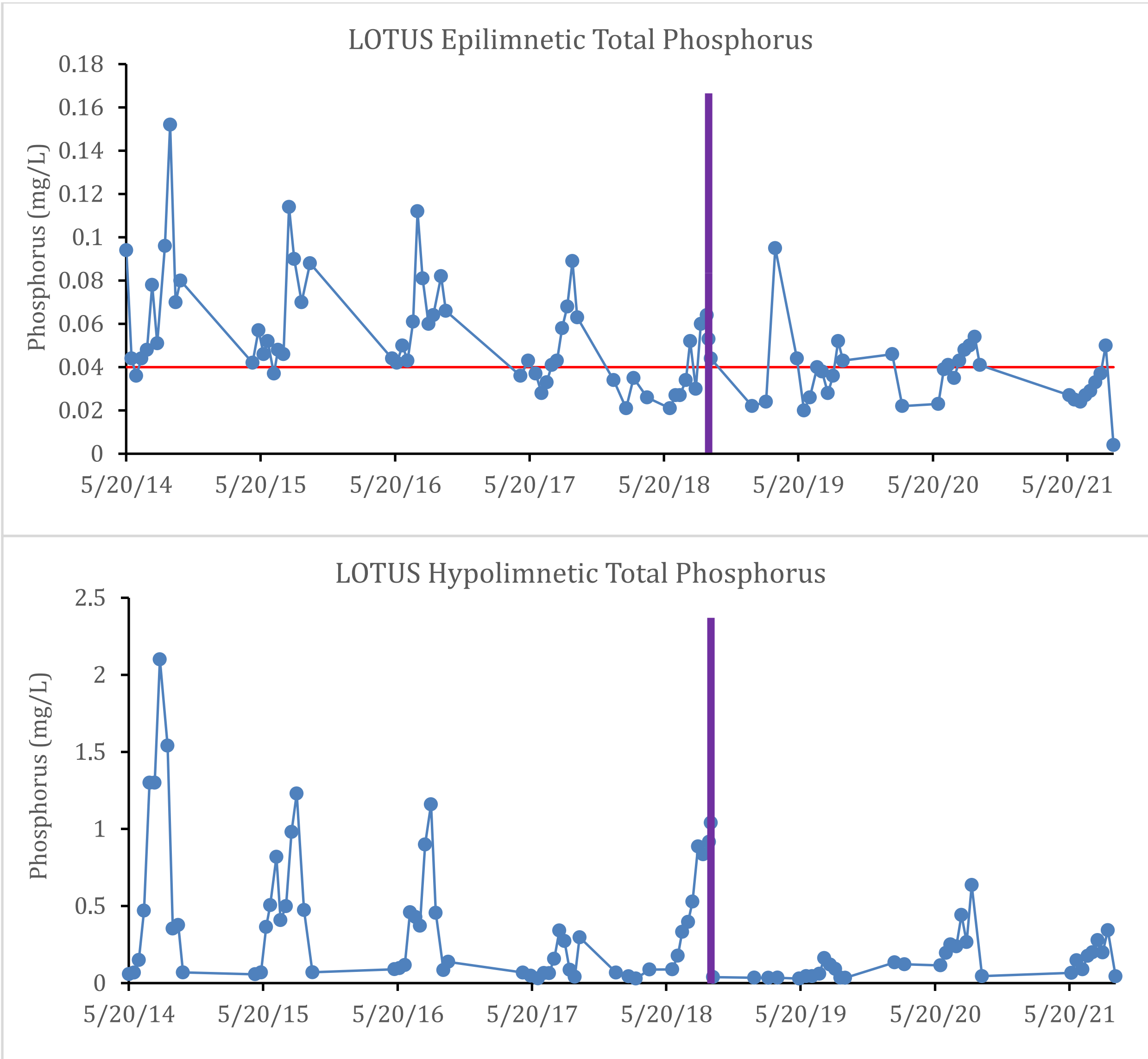


Figure 4-7 Lotus Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lotus Lake between May 6, 2014 and September 22, 2021. 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).

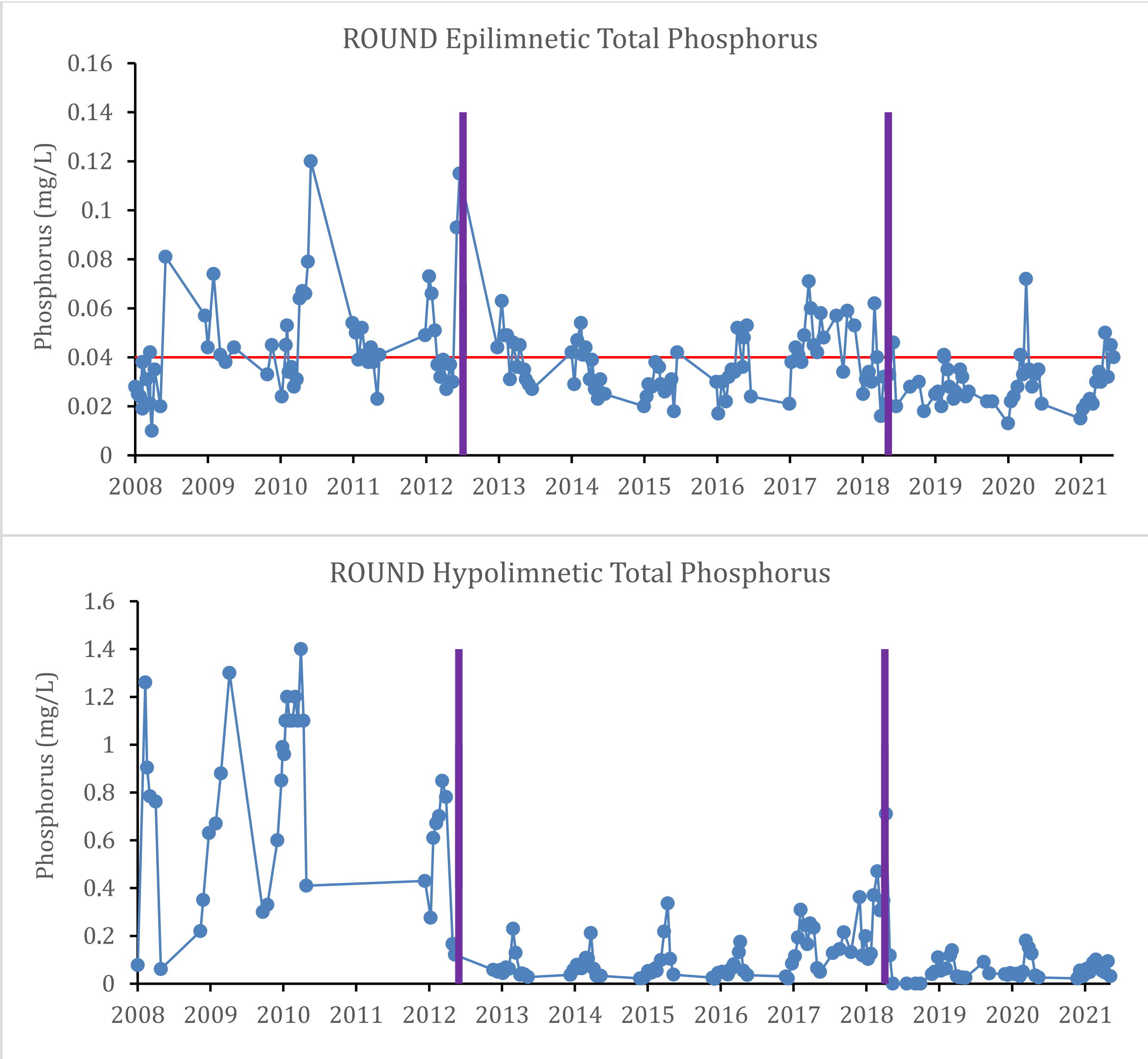


Figure 4-8 Round Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Round Lake between May 15, 2008 and October 30, 2020. 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 2021, 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. Since 2012, except for multiple samples taken from Lake Idlewild, the average cl level from the RCL and PCL has fallen below the MPCA CS of 230 mg/L (Figure 4-11, Figure 4-10). In 2021, Idlewild did meet the chloride standard, but it often exceeded the standard 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. Multiple bottom concentrations exceeded the standard, however the average (top/bottom) did not. Overall, Cl levels were below the MPCA water quality standard and have stayed relatively consistent within lakes year-to-year.

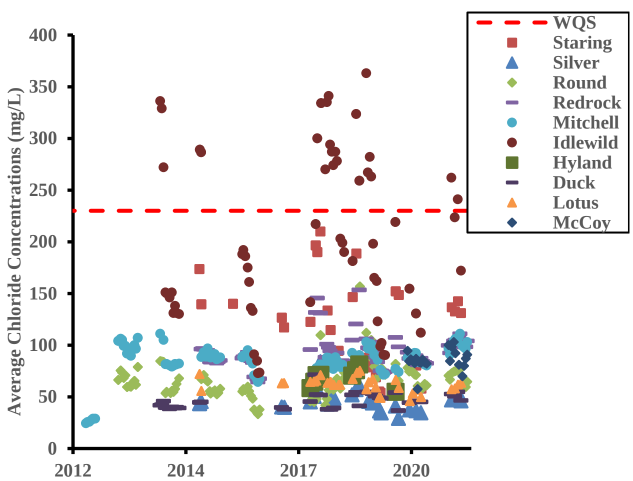


Figure 4-11 2013-2021 Chloride Levels within the Purgatory Chain of Lakes

All average chloride sampling results (mg/L) on the Purgatory Chain of Lakes from 2013-2021. The MPCA chloride chronic standard for class 2B waters (230 mg/L) is indicated by the red line.

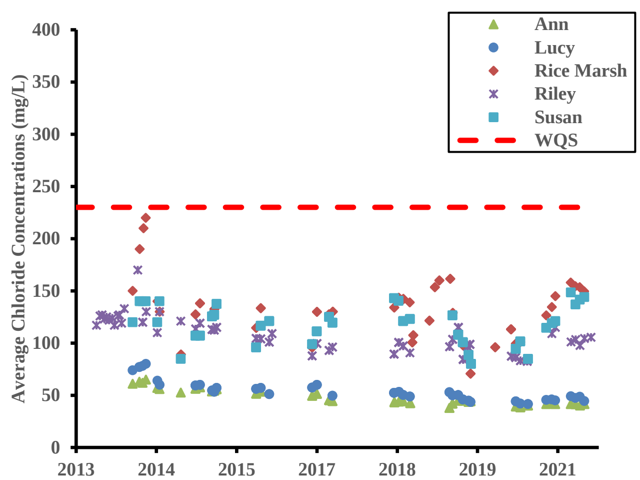


Figure 4-10 2013-2021 Chloride Levels within the Riley Chain of Lakes

All average chloride sampling results (mg/L) on the Riley Chain of Lakes from 2013-2021. The MPCA chloride chronic standard for class 2B waters (230 mg/L) is indicated by the red line.

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. 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 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.

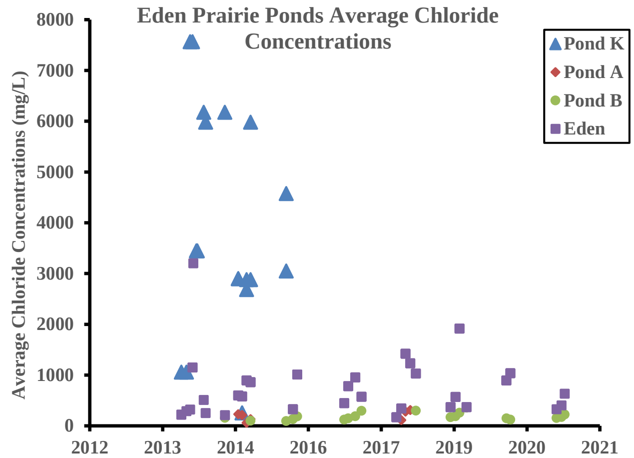


Figure 4-12 2013-2021 Chloride Levels within EP Stormwater Ponds

All average chloride results (mg/L) on stormwater ponds draining the City of Eden Prairie City Center to Purgatory Creek from 2013-2021.

Regular stream monitoring sites have had chloride samples collected monthly from 2018-2021. 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 time period. In 2021, only sites R4 and B4 exceeded the MPCA water quality standard in May, June, and July. Previously no sites exceeded the standard across all sites. In 2021, 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 out 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 4-14) and Bluff Creek (Figure 4-13) 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 2022 which will include: Lucy, Ann, Susan, Rice Marsh, and Lake Riley, along with the stormwater ponds draining Eden Prairie Center. This is the second 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.

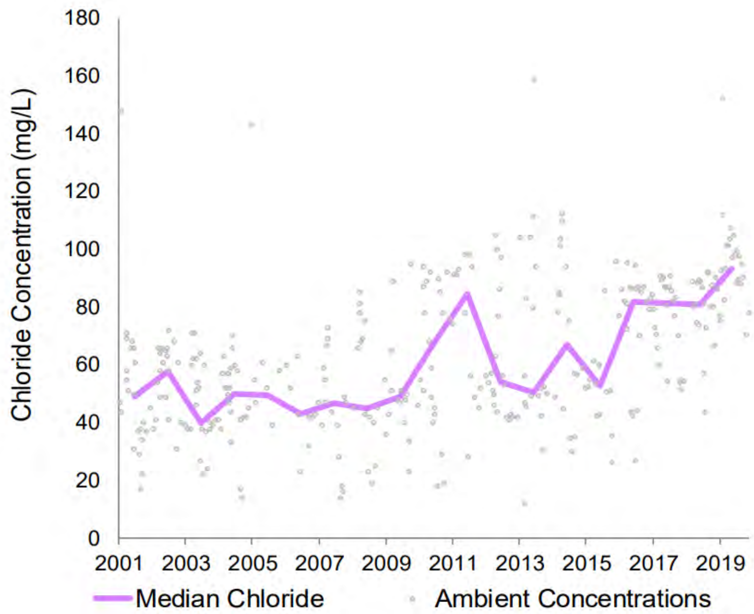


Figure 4-13 Ambient and Annual Median Chloride Concentration in Riley Creek (Metropolitan Council).

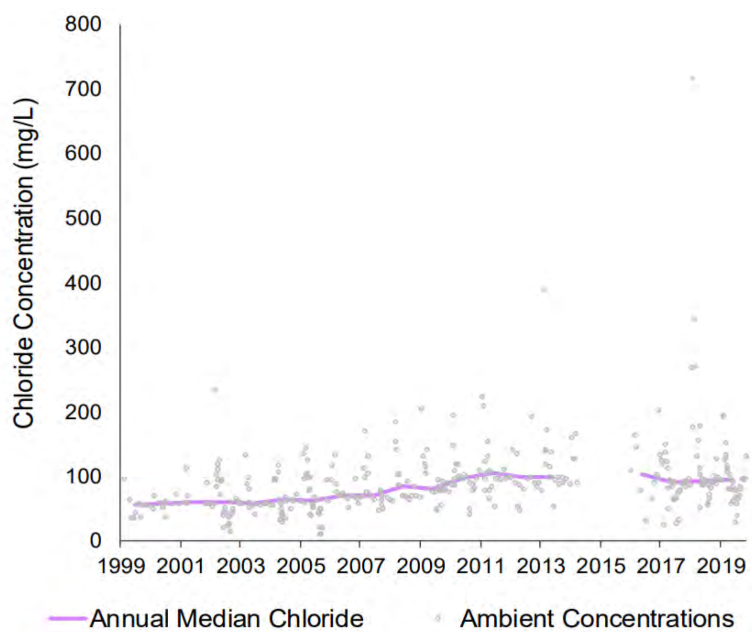


Figure 4-14 Ambient and Annual Median Chloride Concentration in Bluff Creek (Metropolitan Council).

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 nitrate has 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 Nitrate: 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 2021 was 1.099 mg/L. The District monitors nitrates in lakes as a part of its regular sampling regime. The District tests for nitrates in the form of nitrate+nitrite (the combined total of nitrate and nitrite, Table 4--3). 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, McCoy, and Mitchell Lakes is 0.16 mg/L. Due to these limits, some of the average levels of Ammonia+Ammonium provided in Table 1-1 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 2021 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 2021 Lakes Summer Average of Nitrogen

2021 growing season (June-September) averages of nitrate+nitrite, ammonia, and total kjeldahl nitrogen levels for District lakes. The MPCA proposed chronic standard (CS) is included in the table (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	0.794	1.513
Duck	0.030	0.063	0.821
Hyland			0.663
Idlewild	0.030	0.060	0.591
Lotus	0.030	1.377	3.200
Lucy	0.030	1.578	1.745
McCoy	0.050	0.160	1.475
Mitchell	0.050	0.194	1.688
Red Rock	0.050	0.169	1.863
Rice Marsh	0.030	0.069	0.840
Riley	0.032	0.541	0.970
Round	0.050	0.160	1.100
Silver	0.030	0.095	1.127
Staring	0.030	0.304	1.463
Susan	0.033	0.566	1.588

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 Maxbotic 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 data analysis throughout the following report. Figure 4--15 displays daily precipitation totals across at the two stations from March 1, 2021, through December 1, 2021. Overall, precipitation levels were low in 2021. During this time period, rainfall at the Flying Cloud Airport and National Weather Service Station totaled 19.12 inches and 23.49 inches respectively. The max rainfall event at Flying Cloud Airport occurred on 8/27, totaling 1.49 inches of rain. At the National Weather Service Station, the max rainfall total occurred on 8/28, totaling 1.71 inches of rain.

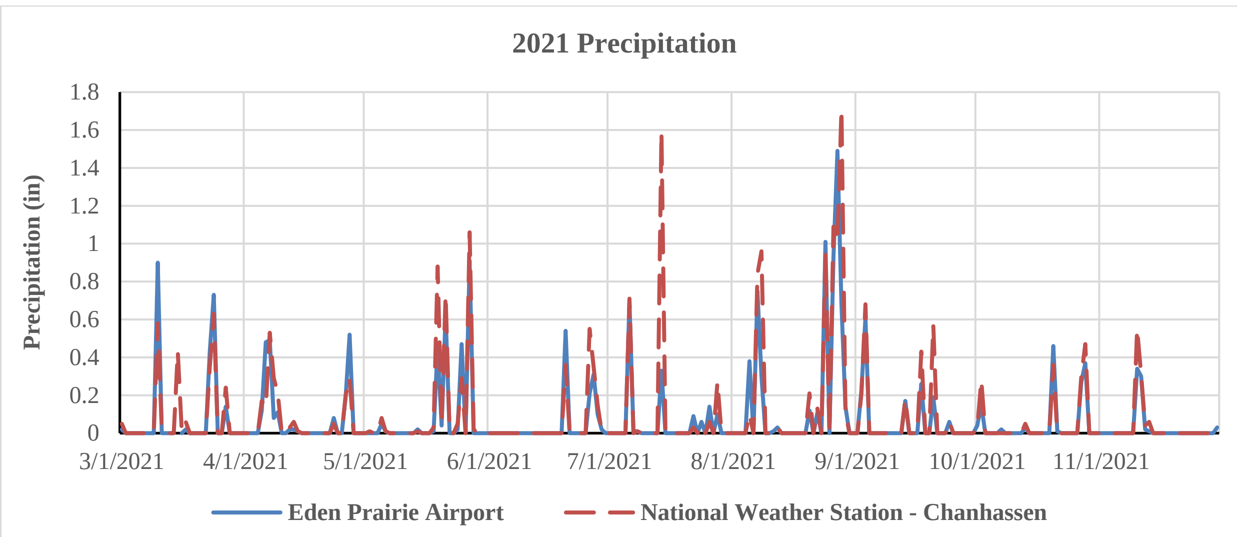


Figure 4--15 2021 Precipitation Levels

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

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. 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.

In 2021, lake level measurements were collected on 13 lakes in the District and two high value wetlands (Lake Idlewild and Lake McCoy) (Table 4--4). This was the second year Lake McCoy had water levels monitored. Silver Lake experienced the greatest seasonal water level change over the 2021 season, increasing 1.463 ft from sensor placement to the last day of recording (Nov. 18). Round Lake had the largest range of fluctuation through 2021, having a low elevation of 876.712 ft, and a high of 879.069 ft (2.357 ft difference). On average, lake levels seasonal flux was 0.521 ft over the 2021 season. The average fluctuation range across all lakes was 1.32 ft.

Table 4--4 2021 Lake Water Levels Summary

The 2021 (March-November) and historical recorded lake water levels (ft) for all monitored lakes within the Riley Purgatory Bluff Creek Watershed District. 2021 data includes the overall change in water level, the range of elevation fluctuation, and the highest and lowest recorded elevations. Historical data includes the highest and lowest historical recorded levels and the date they were taken.

	2021 Lake Water Level Data				Historical Lake Water Levels			
Lake	**Seasonal Flux**	**Flux Range**	**High level**	**Low level**	**Highest Level**	**Date**	**Lowest Level**	**Date**
Ann	0.626	1.089	956.497	955.408	957.93	2/18/1998	952.800	9/28/1970
Duck	0.684	1.091	913.777	912.686	915.32	6/20/2014	911.260	11/10/1988
Hyland	1.449	1.582	815.362	813.780	818.73	6/23/2014	811.660	12/2/1977
Eden	0.626	1.159	854.324	853.165	854.32	8/27/2021	809.100	5/11/1994
Idlewild	0.626	1.159	854.324	853.165	860.78	3/29/1976	853.100	1/7/1985
Lotus	-0.013	1.104	894.966	893.862	897.08	7/2/1992	893.180	12/29/1976
Lucy	0.555	1.195	956.580	955.385	957.68	6/20/2014	953.290	11/10/1988
McCoy	0.192	0.924	823.286	822.362	823.90	8/16/2020	822.362	8/4/2021
Mitchell	0.454	1.411	871.462	870.051	874.21	6/25/2014	865.870	7/25/1977
Red Rock	0.487	1.128	840.380	839.252	842.70	7/13/2014	835.690	9/28/1970
Rice Marsh	0.219	1.333	876.451	875.119	877.25	5/28/2012	872.040	8/27/1976
Riley	0.191	1.106	864.925	863.819	866.86	6/20/2014	862.000	2/1/1990
Round	0.732	2.357	879.069	876.712	884.26	8/17/1987	875.290	7/25/1977
Silver	1.463	2.223	899.777	897.554	901.03	6/20/2012	894.780	6/6/1972
Staring	0.807	1.221	815.019	813.798	820.00	7/24/1987	812.840	2/12/1977
Susan	0.271	1.114	882.200	881.086	884.23	6/19/2014	879.420	12/29/1976
UPCRA	0.265	1.587	821.234	819.647	818.42	5/16/1991	818.420	5/16/1991
Average	0.586	1.325						

*UPCRA = Upper Purgatory Creek Recreational Area

4.6 Upper Bluff Auto-Sampling Units

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

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

In 2019 and 2020, total phosphorus levels at the upper Bluff Creek site during storm events were high compared to the MPCA standards, as seen in Figure 4--16. As seen in Table 4--5, the average TP across 17 samples was 0.525 mg/L in 2019 and 0.425 mg/L in 2020. This level is over four times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP). Across both years, all TP samples collected measured above the MPCA standard. The highest TP concentration in 2019 occurred in early August (1.77 mg/L). The highest concentration in 2020 occurred in mid-October (1.12 mg/L). The TDP average in 2019 was 0.135 mg/L with a high measurement of 0.237 mg/L (Table 4--5). OP average in 2020 was 0.094 mg/L with a high measurement of 0.168 mg/L. The average amount of TSS across the 17 samples taken in 2019 was 84.6 mg/L. The average amount of TSS across the 15 samples taken in 2020 was 26.4 mg/L. To achieve the MPCA TSS stream water quality standard, a stream may not exceed 30 mg/L TSS more than 10% of the time. Across all the sampling events, nine of the 17 samples taken in 2019 were above 30 mg/L TSS and only five of the fifteen samples taken in 2020 were above the standard (Figure 4-17). Four of the six in 2019 and five of six in 2020 Chl-a samples collected were less than the MPCA eutrophication water quality standard of ≤ 18 ug/L Chl-a (Figure 4--16).

Table 4--5 2021 Highway 5 Bluff Creek Crossing Nutrient Loading Summary

	GALPIN		HIGHWAY 5	
Parameter	**2019 Average**	**2020 Average**	**2021 Average**	**MPCA Water Quality Standards**
TP (mg/L)	0.525	0.425	0.365	≤ 0.1
TDP (mg/L)	0.135		0.074	
OP (mg/L)		0.094	0.062	
Chl-a (ug/L)	11.562	32	9.7	≤ 18
TSS (mg/L)	84.6	26.4	99.4	≤ 30

In 2021 total phosphorus levels on Bluff Creek downstream of highway 5 during storm events were high compared to the MPCA standards, as seen in Figure 4-18 and Table 4--5. As seen in Figure 4-17, the average TP across 19 samples was 0.365 mg/L 2021. Although it is less than 2019 and 2020 concentrations at Galpin Boulevard, this level is close to four times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP). All storm event TP samples collected measured above the MPCA standard. The highest TP concentration occurred at the end of August (similar to 2019 and 2020). In 2021, the average TDP concentration was 0.074 mg/L and the OP average was 0.062 mg/L. The average amount of TSS across the 17 samples taken was 99.4 mg/L in 2021, up from 2019 and 2020. Across all the sampling events, 10 of the 17 samples taken in 2021 were above 30 mg/L TSS (Figure 4-18). It is important to note that these samples are targeted samples, representative of the initial flush of water and pollutants that occurs during a rain event, and do not represent season-long pollutant levels in Bluff Creek. Therefore, a direct comparison to the MPCA water quality standards is cautioned.

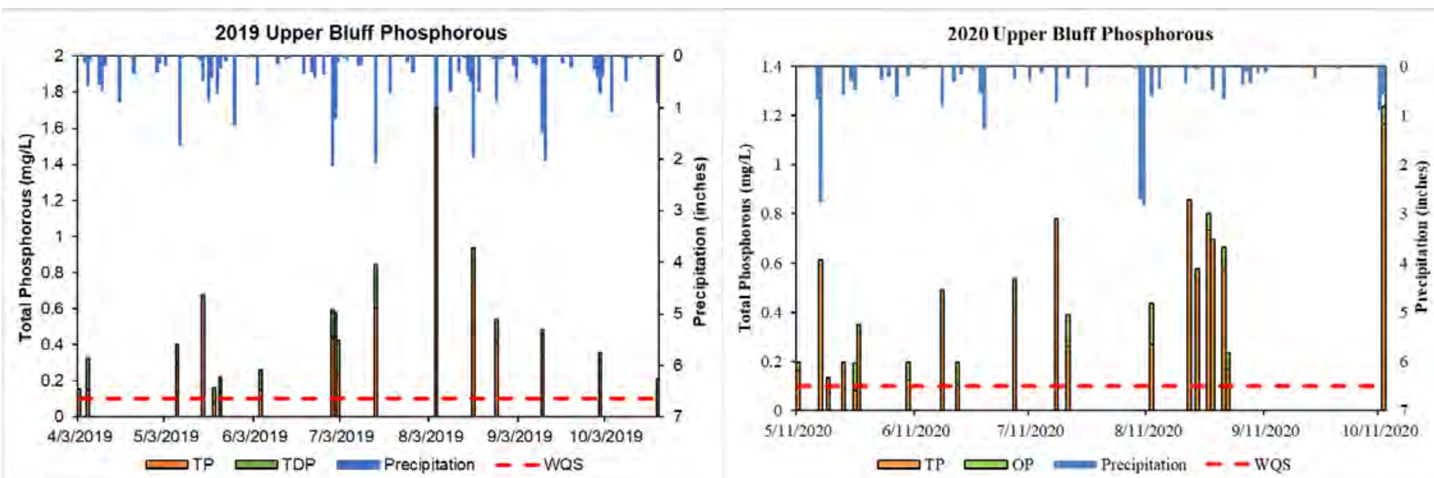


Figure 4--16 2019 and 2020 Galpin/Bluff Creek Phosphorus

The Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) concentrations (mg/L) from Bluff Creek under Galpin Blvd from 2019 and 2020 automated, level triggered, flow-paced samples. Dashed line represents the Minnesota Pollution Control Agency standard for TP in class 2B creeks (≤ 0.1 mg/L).

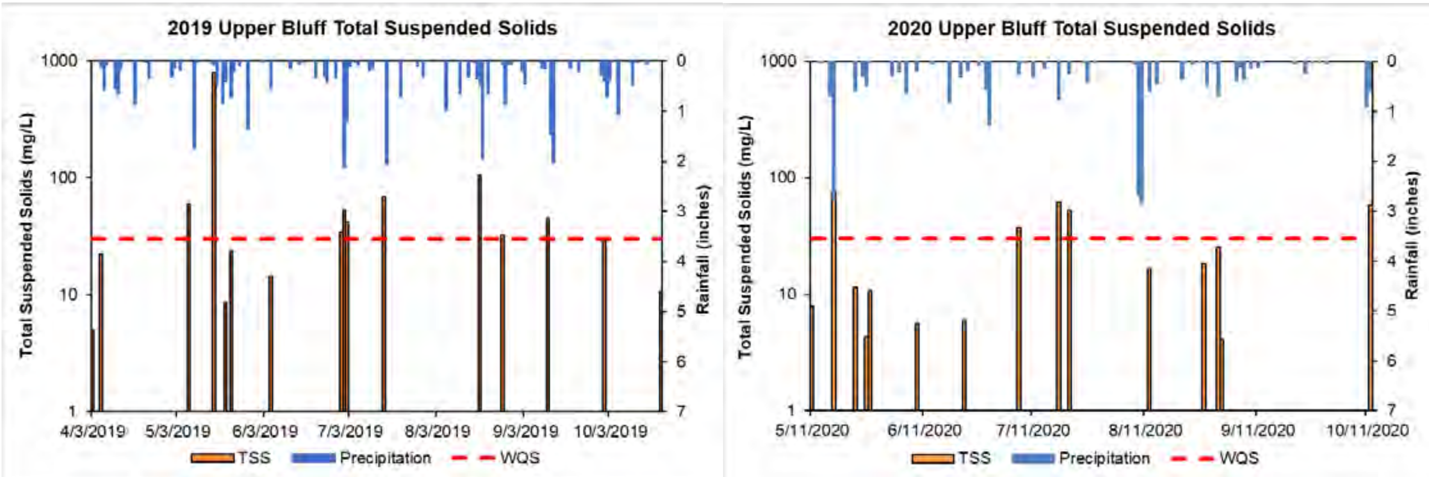


Figure 4-17 2019 and 2020 Galpin/Bluff Creek Total Suspended Solids

Total Suspended Solids (TSS) concentrations (mg/L) from Bluff Creek under Galpin Blvd from 2019 and 2020 automated, level triggered, flow-paced sampler. Dashed line represents the Minnesota Pollution Control Agency standard for TSS in class 2B creeks (≤ 30 mg/L TSS no more than 10% of the time).

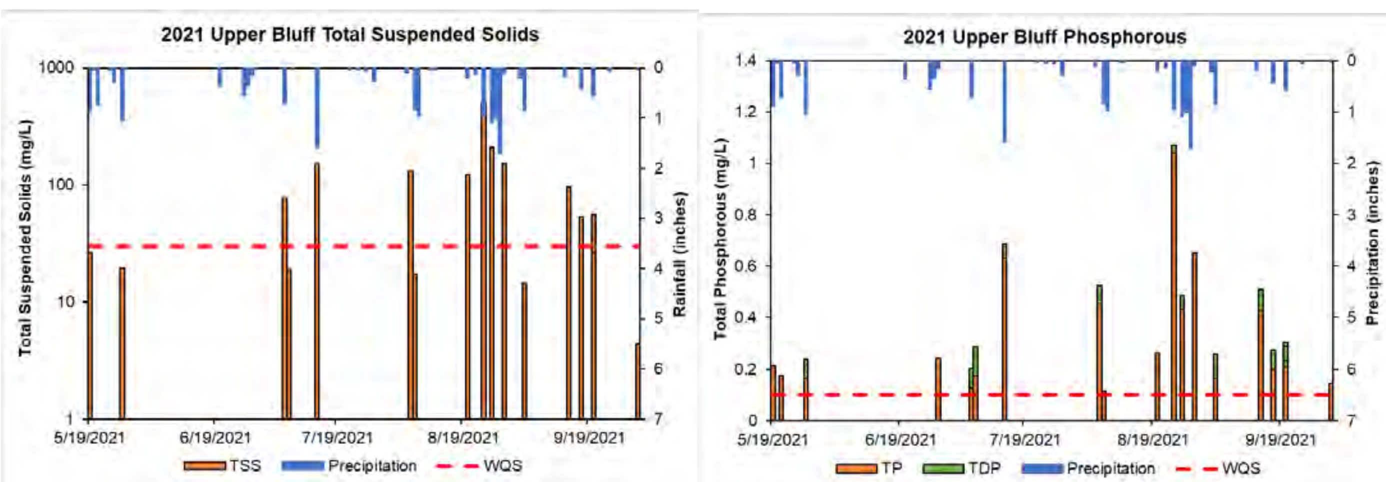


Figure 4-18 2021 Highway 5/Bluff Creek Total Suspended Solids and Phosphorous

Total Suspended Solids (TSS), Total Dissolved Phosphorus (TDP), and Total Phosphorus (TP) concentrations (mg/L) from Bluff Creek downstream of highway 5 from 2021 automated, level triggered, flow-paced sampler. Dashed line represents the Minnesota Pollution Control Agency standard for TSS (≤ 30 mg/L TSS no more than 10% of the time) and TP (≤ 0.1 mg/L) in class 2B creeks.

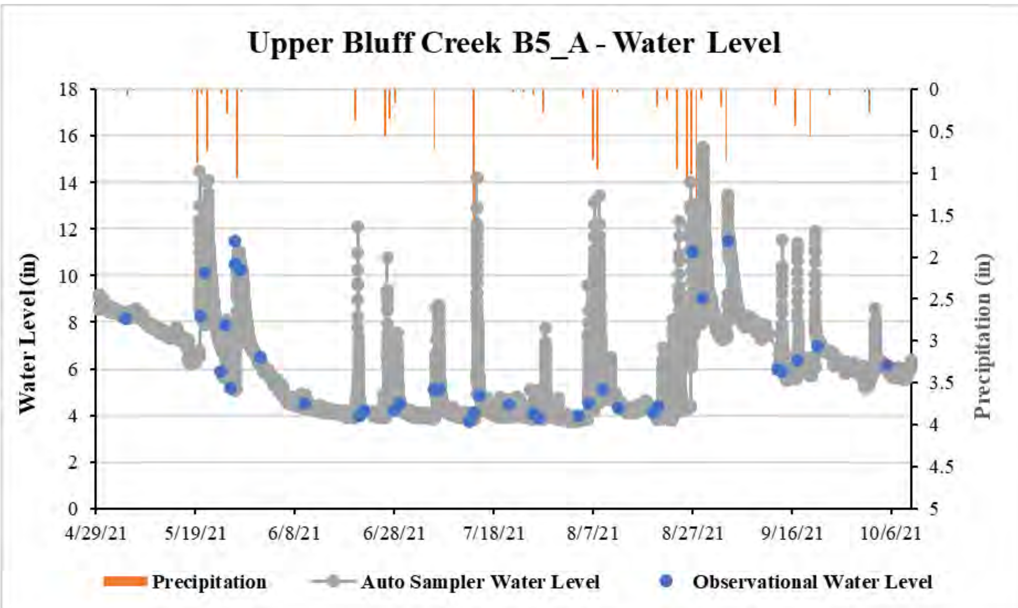


Figure 4-19 2021 Highway 5/Bluff Creek Water Levels

Water levels recorded from the autosampler and visual staff gage readings from Bluff Creek under Highway 5 in 2021.

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_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 4-20). 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.

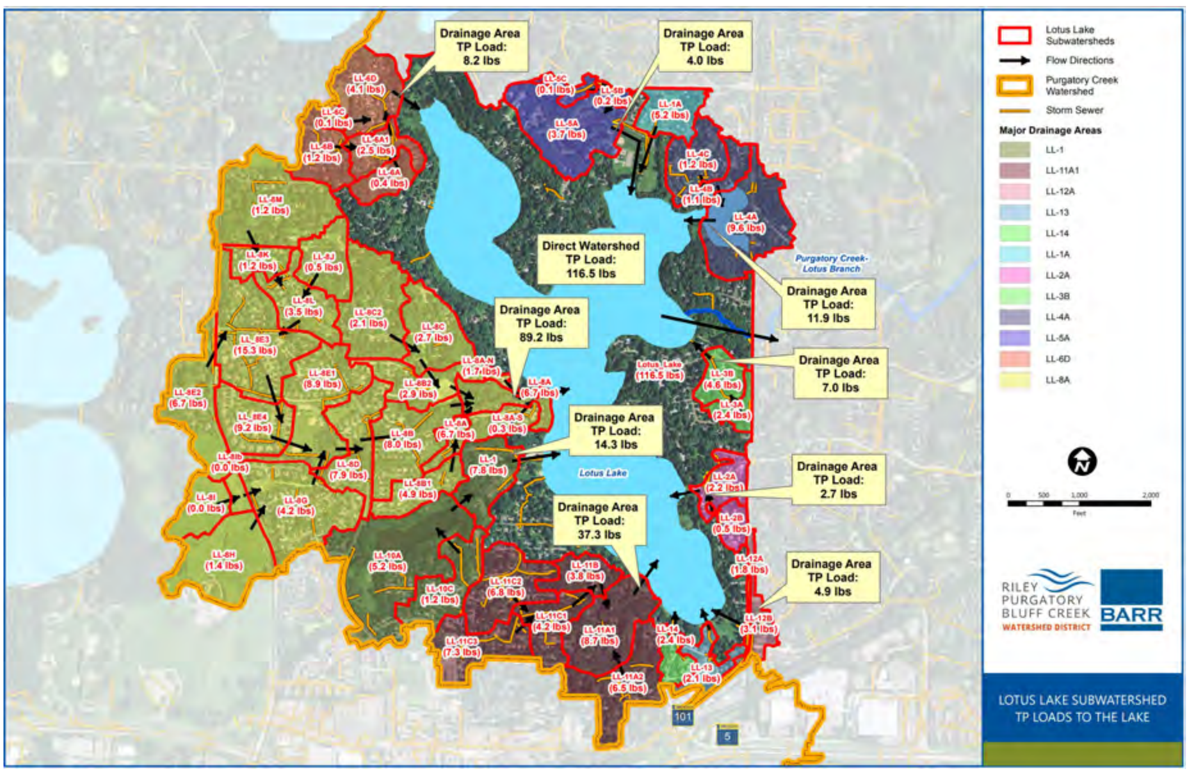


Figure 4-20 Lotus Lake Sub watershed Estimated Total Phosphorus Loading

- (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 2021, staff placed an automated sampling unit at 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) in 2020. The automated water-sampling units also estimated flow of the creek or drainage channel at that point.

In 2021 total phosphorus levels on the upper Lotus Lake ravine during storm events were high compared to the MPCA standards, as seen in Figure 4-21 and Table 4--6. As seen in Table 4 9 the average TP leaving the stormwater pond upstream of the recreational trail across 12 samples was 0.534 mg/L in 2021. This level is over five times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP) and more than double the MPCA estimated typical total phosphorus range (0.1 mg/L to 0.25 mg/L) for effluent (outgoing) stormwater. All storm event TP samples collected measured above the MPCA stream standard and all but two measured above the MPCA stormwater effluent standard. The highest TP concentration occurred in early August which is likely when the pond is the most stagnant/anoxic and the highest level of phosphorus release from the pond sediment is occurring. In 2021, the average TDP concentration was 0.106 mg/L and the OP average was 0.039 mg/L. The average amount of TSS across the 12 samples taken was 76.6 mg/L in 2021. Across all the sampling events, 10 of the 12 samples taken in 2021 were above 30 mg/L TSS (Figure 4 17). Chl-a concentrations at this site averaged above the MPCA standard with four of seven sampling events greater than the MPCA standard (<18 ug/L). 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 Lotus Ravine. With the low water levels, this site would have likely met the TSS standard if continuous monitoring occurred, although these results suggest that a bmp placement at this location would likely reduce loading to Lotus Lake, specifically phosphorus loading. Additionally, this site is specifically measuring effluent directly after a stormwater pond, so stream standards are used as a comparison. Therefore, a direct comparison to the MPCA stream water quality standards is cautioned.

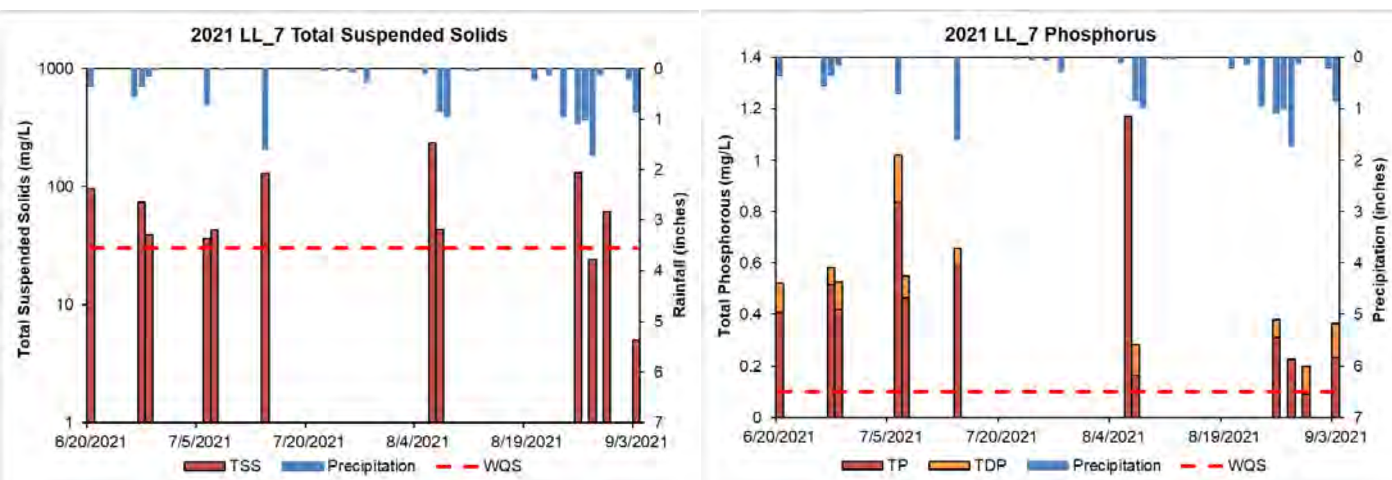


Figure 4-21 2021 Lotus Upper Ravine Total Suspended Solids and Phosphorus

The Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) concentrations (mg/L) from Bluff Creek under Galpin Blvd from 2019 and 2020 automated, level triggered, flow-paced samples. Dashed line represents the Minnesota Pollution Control Agency standard for TP in class 2B creeks (≤ 0.1 mg/L).

Table 4--6 2021 Purgatory Creek Auto Sampling Units Nutrient Loading Summary

Parameter	STL_17	LL_7	MPCA Water Quality Standards
TP (mg/L)	0.197	0.534	≤ 0.1
TDP (mg/L)	0.043	0.106	
OP (mg/L)	0.020	0.039	
Chl-a (ug/L)	-	18.5	≤ 18
TSS (mg/L)	52.9	76.6	≤ 30

At the Staring Lake Road Purgatory Creek Crossing total phosphorus levels were high compared to the MPCA standards, as seen in Figure 4-18 and Table 4--6. As seen in Table 4--6, the average TP at that site on Purgatory Creek across 19 samples was 0.197 mg/L in 2021. This level is nearly twice the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1 mg/L TP), but these measurements only include rain events. Six of nine storm event TP samples collected measured above the MPCA stream standard. The highest TP concentration occurred near the end of June (0.466 mg/L). In 2021, the average TDP concentration was 0.043 mg/L and the OP average was 0.029 mg/L. The average amount of TSS across the nine samples taken was 52.9 mg/L in 2021. Across all the sampling events, six of the nine samples taken in 2021 were above 30 mg/L TSS (Figure 4-22). 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 would likely meet 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.

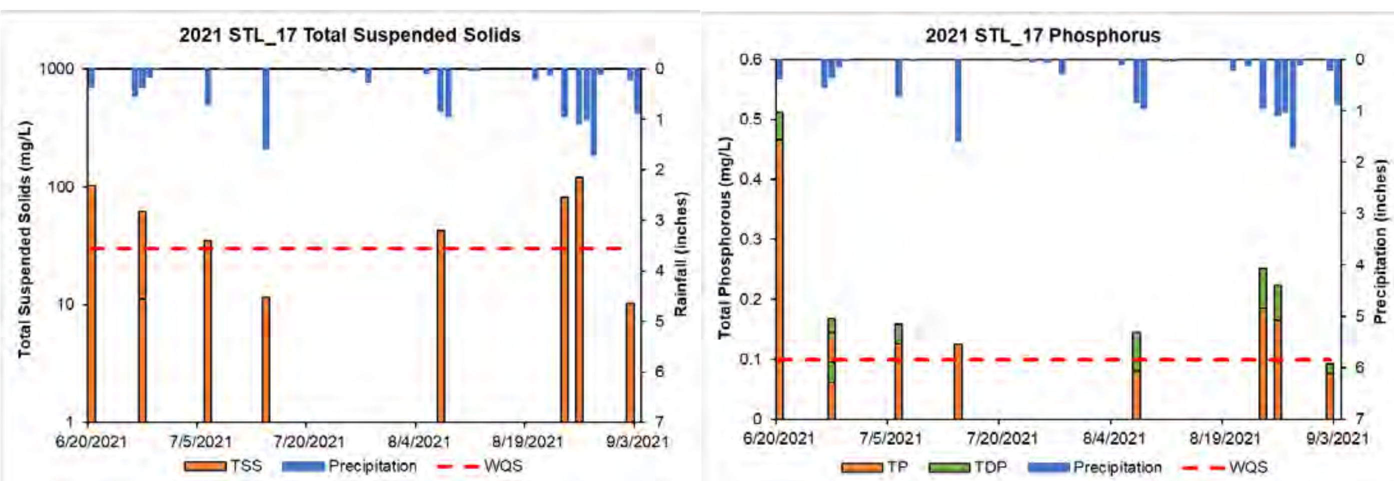


Figure 4-22 2021 Purgatory Creek/Staring Lake Road Total Suspended Solids and Phosphorus

The Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) concentrations (mg/L) from Purgatory Creek under Staring Lake Road from 2021 automated, level triggered, flow-paced samples. Dashed line represents the Minnesota Pollution Control Agency standard for TP in class 2B creeks (≤ 0.1 mg/L).

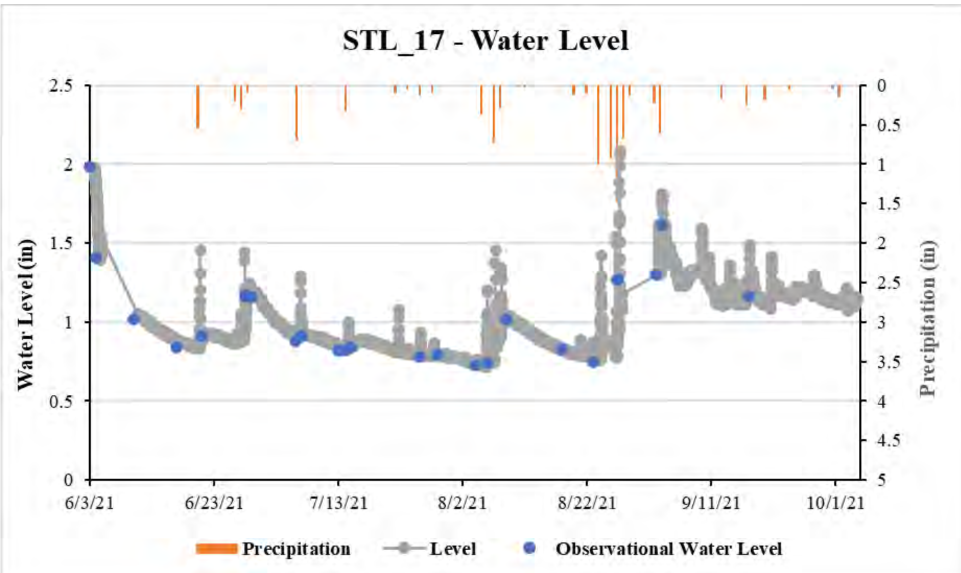


Figure 4-23 Purgatory Creek/Staring Lake Road Water Levels

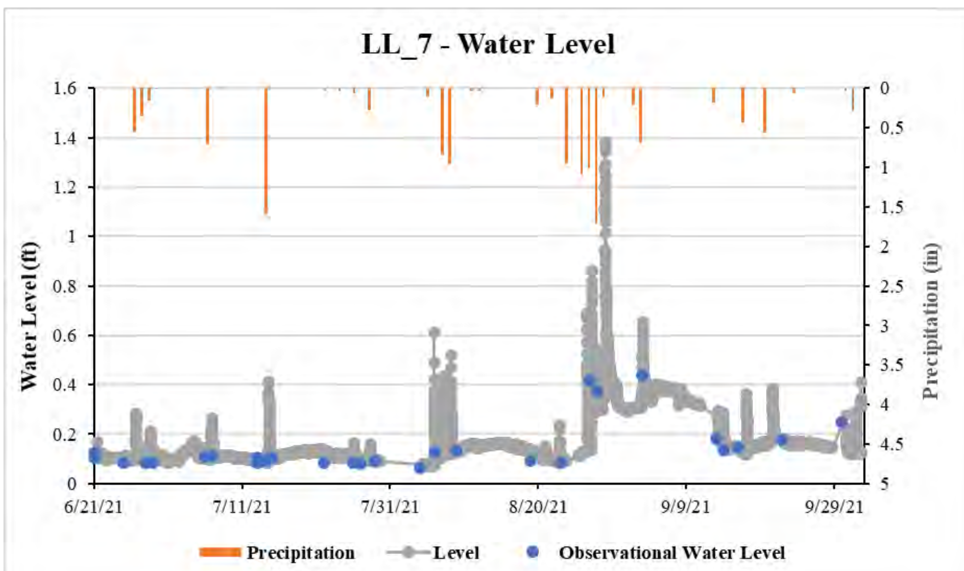


Figure 4-24 Upper Lotus Lake Ravine Water Level

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--7) and a CRAS Map (Exhibit I) were updated to include results from 2021.

Table 4--7 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
R2	R2E	1	44	2	26	Middle Third between Dell Road and Eden Prairie Road	Complete
P1	P1E	2	44	4	22	1,350 feet DS of Wild Heron Point to Burr Ridge Lane	
B1	B1D	3	42	1	26	475 feet US of Great Plains Blvd to Great Plains Blvd	
R4	R4D	4	42	7	22	Railroad Bridge to Powers Blvd	Planning
B5	B5C	5	40	3	24	Galpin Boulevard to West 78th Street	Planning
B1	B1B	6	38	8	22	2,150 feet DS of Pioneer Trail to 300 feet US of Bluff Creek Park	
BT3	BT3A	7	38	5	22	Audubon Road to Pioneer Trail	Complete
R2	R2D	8	34	6	22	Upper Third between Dell Road and Eden Prairie Road	Complete

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 2021 data can be seen in Exhibit E 2021 Creek Seasonal Sonde & Flow Data and Exhibit G 2021 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 2021 staff walked Reach 3 and 4 of Bluff Creek. 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. Overall, scores remained very similar from 2015 to 2021. Only sub-reach B4A had a rating change, moving from moderate to good. Staff also checked bank pins which were installed in 2015 and 2018 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 2021 creek walks can be seen in Table 4--8 and in our Fact Sheets on the District website (rpbcwd.org). A summary of the 2021 creek walks can be seen in the section below.

In addition to CRAS scoring and measuring bank pins, staff also attempted to collect macroinvertebrates at all five Riley Creek sites in 2021 (Bluff Creek in 2020). However, due to dry conditions samples were only collected at R1, R3, and R4. 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. The 2021 data was not available for this report.

Table 4--8 2021 Creek Restoration Action Strategy Updates

Tier I and Tier II scores for the Creek Restoration Action Strategy for 2015 and the corresponding updates from 2021 for subreaches within P1, P2, and B5.

Reach	Subreach	Location	2015 Tier I Scores	2020 Tier I Scores	Tier II Scores
B3	B-3A	750 feet Downstream of Railroad to 860 feet Downstream of Railroad	20	18	38
B3	B-3B	860 feet Downstream of Railroad to 1,675 feet Upstream of Audubon Road	16	16	30
B3	B-3C	1,675 feet Upstream of Audubon Road to Lyman Boulevard	20	18	40
B4	B-4A	West 78th Street to 485 feet Downstream of Recreational Trail South of Highway 5	14	12	28
B4	B-4C	Stone Creek Drive to 350 feet Downstream of Stone Creek Drive	14	14	28
B4	B-4D	350 feet Downstream of Stone Creek Drive to 950 feet Downstream of Stone Creek Drive	16	16	38
B4	B-4F	530 feet Upstream of Railroad to 750 feet Downstream of Railroad	16	16	36
BT-1	BT-1A	Arboretum Boulevard to Bluff Creek	18	18	36

BLUE=Good
GREEN=Moderate
RED=Poor
BLACK=Severe

Staff will finish the assessment on Reach 1 and 2 of Bluff Creek in the spring of 2022 and update accordingly. CRAS updates and potential additional monitoring for 2022 include:

- Placement of additional bank pins at sites that align with upcoming projects.
- Walk additional 1st 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.

Bluff Creek – Reach 3 – Subreach A/B/C
Walking trail ~ 1350 ft downstream of railroad, west of Lake Drive West to Lyman Boulevard
This reach of the stream passes through wet prairie/wet meadow floodplain wetlands dominated by reed canary and other wetland grasses, as well as cattails. The gradient through most of the reach is nearly flat, (0-5%). Prior to the end of sub-reach B-3C, the reach passes through a lightly wooded area with higher grades (~10-20%). Most of the substrate within the reach consists of sand and some silt. The amount of silt increases as the reach progresses, getting closer to a one-to-one ratio by the end of sub-reach B-3C.

There are areas with heavier amounts of sand and gravel, such as in the few riffles and around culverts. The stream crosses under a walking path and Audobon Road before ending at Lyman Blvd. Erosion was moderate-to-heavy within sub-reach B-3A, due mostly to sloughing on both banks. There are patches of bare eroded banks, but much of the raw banks are shielded by overhanging vegetation. Sub-reach B-3C also had a moderate-to-heavy amount of sloughing and some bare banks measuring 0.5-1.1 m high. Habitat in sub-reaches B-3A and B-3B was fair, but poor in B-3C. Sinuosity and Channel development (riffle, run, pool) are good in the first sub-reach, but are poor in the last two. Sinuosity is fair in B-3B. Habitat in the first two sub-reaches is fair, mostly consisting of heavy overhanging vegetation and deeper pools, but poor in sub-reach B-3C. There is no major concern facing infrastructure. There is a beaver dam instream before Audobon Road that should be watched.

Bluff Creek – Reach 4 – Sub-reach A/B/C/D/E/F
West 78th Street to walking trail ~ 1350 ft downstream of railroad, west of Lake Drive West
This section of the stream passes through deciduous woods and prairie as well as more urban areas (wooded residential/urban landscapes). The gradient through the first part of the reach (B-4A through B-4C) is lower, usually around 10-20%. Through B-4D and B-4F, grades increase, ranging from about 5% on low ends, to areas where it is consistently 30-40%. Sub-reaches B-4B and B-4E pass through wet prairie wetlands, in both of which the channel disperses into the wetland for the majority of the reaches (0-5% gradient); both were not scored because of the lack of channel to assess. Substrate in this reach starts out dominated by sand with moderate amounts of silt and gravel mixed in. There is a shift to more of a sand silt mixture through B-4B through B-4D, but transitions to a sand-gravel mixture in B-4F with heavier amounts of silt in the one major pooling area. The stream crosses under Highway 5, Coulter Boulevard, Stone Creek Drive, and a walking trail crosses the stream multiple times. The stream is paralleled by a recreational trail along the right bank for almost the entirety of all the sub-reaches. The creek is fairly straight with limited channel development (riffle, run, pool). At the time of the walk the stream was narrow and had low flows. The banks are moderately incised in B-4A. With the exception of the wetland areas and B-4C, the stream was heavily incised continuing downstream from Stone Creek Drive. There is an instance of mass wasting upstream of the railroad (above the culvert that passes under it) as well as an area on the upper bank just downstream of the railroad. Habitat is poor-to-fair, most of the viable habitat being in the overhanging wetland grasses. There is one spot where there might be some infrastructure risk in B-4C, where a stormwater pipe draining into a pond is fully exposed and crosses the channel at the start of the sub-reach.

Bluff Creek – Sub-reach BT-1A
Enters main channel ~ 65 ft east of the walking trail, east of Stone Creek Drive, starting on north side of MN-5
This tributary of the stream passes through deciduous woods, prairie, and agricultural fields, as well as some residential areas. The gradient is fairly steep, starting at 30-40% and increasing up to 50% in some areas. The majority of the sediment is sand and silt, although there are several areas with moderate amounts of riprap and gravel. The stream crosses under Coulter Blvd and a walking path. The reach is fairly straight, and channel development (riffle, run, pool) is fair, with a few riffles and limited areas of pooling. Most of the reach is incised, the eroded areas being quite heavy; several areas of erosion are very severe (one area marked with GPS point). There is no major concern facing infrastructure, although the mass wasting of the upper bank upstream by the railroad should be monitored.

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 2021 (2018-2021 measurements shown in **Table 4-9**). 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. In 2018, staff added pins at representative erosion sites near the following regular creek monitoring sites (if pins were installed on the left bank, it is denoted here as LB; RB denotes pins installed on the right bank): 2 pins on LB at R4, 3 pins on RB and 3 pins on LB at R2, 3 pins on RB at B4, 3 pins on RB and 3 pins on LB at B3, 2 pins on RB at B2, and 1 pin on LB at P6. 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.

Table 4-9 2018-2021 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 2018-2020. 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	2018	2019	2020	2021
R5	7.75	8.03	1.58	1.38	4.81	3.93	1.69	1
R4	0.42	3.63	1.77	0.5	0.25	2.93	1.31	0.13
R3	5.31	14.9	5.69	1.63	6.36	11.42	4.84	1.64
R2	--	6.45	2.15	0.69	--	13.3	4.24	1.41
R1	2.96	4.88	1.79	1	1.23	4.29	1.57	1.04
P8	0.55	3.16	0.63	0.25	0.24	1.65	0.45	0.14
P7	2.02	2.02	--	1.56	4.96	5.17	0	2.34
P6	0.83	3.7	2	1.45	0.7	2.41	1.57	1.54
P5	0.77	3.07	1.58	0.83	0.81	3.82	1.77	0.94
P4	0.78	1.8	1.2	0.25	0.53	0.33	0.3	0.09
P3	0.94	1.96	0.66	0.42	1.02	2.77	0.89	0.61
P2	0.50	3.15	3.6	2.8	0.47	3.99	3.74	2.05
P1	0.38	3.52	3.35	7.33	0.92	6.38	10.98	18.82
B5	-0.79	0.89	1.16	0	-0.46	0.87	1.13	0
B4	5.58	12.06	12.02	2.96	3.66	12.81	11.49	2.77
B3	--	3.29	1.77	0.23	--	3.67	1.66	0.21
B2	3.00	7.00	5.56	1.6	1.25	4.08	3.19	1.51
B1	-0.67	5.54	--	3.81	-0.44	6.62	--	4.48

4.8 Zooplankton and Phytoplankton

In 2021, five lakes were sampled for both zooplankton and phytoplankton: Lake Riley, Rice Marsh Lake, Lake Susan, Lotus Lake, and Staring Lake. Zooplankton plays an important role in a lake's ecosystem, specifically in fisheries and bio control of algae. Healthy zooplankton populations are characterized by having balanced densities (number per 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 2021, all three groups of zooplankton were captured in Lake Riley (Exhibit C). Only 6% of the zooplankton captured were Cladocera, down from 18% from 2020 and tied with 2019. Similar to 2019, rotifers were the most abundant zooplankton sampled in 2021. (Figure 4-25). In 2021, rotifers were at their lowest levels in July and at their highest during the last September sampling event. Copepods were very stable in 2021, averaging 63 thousand before jumping to 260 thousand during the last September sampling event. Cladocera numbers were relatively low and averaged 17 thousand across the five sampling events. This is less than half of what was seen in 2020. This reduction may be due to the continuing increase in 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 2021, grazing rates were low across all sampling events. The maximum grazing rate of around 4% occurred at the end of June and corresponded with the highest Cladocera numbers seen across the year.

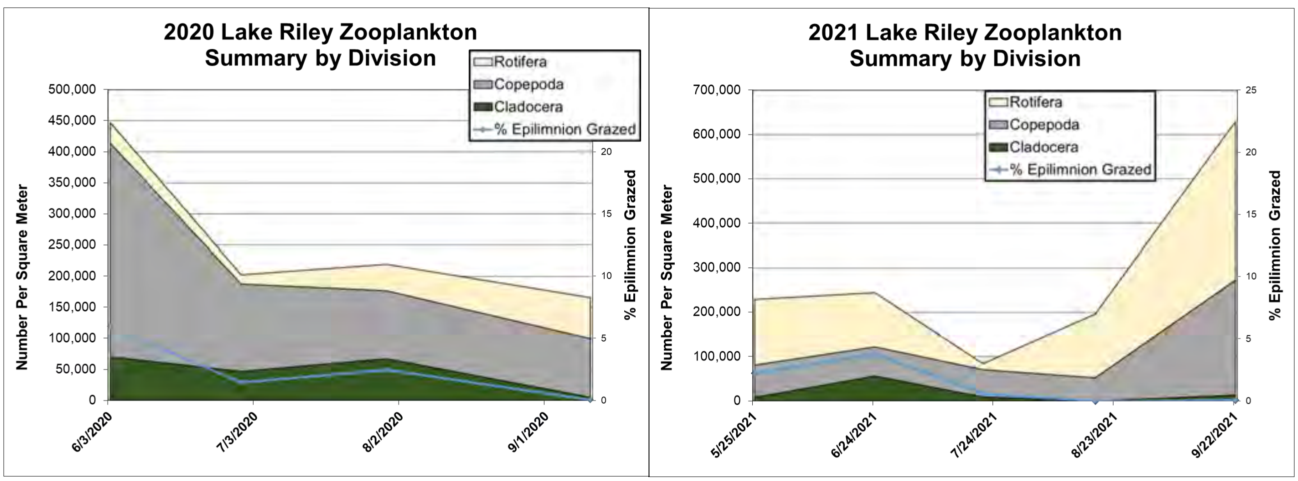


Figure 4-25 2020 & 2021 Lake Riley Zooplankton Counts (#/m²).

During the summer of 2021, staff collected five phytoplankton samples on Lake Riley (Exhibit D). The 1997 to 2021 total historical abundance and the 2021 seasonal abundance of phytoplankton is presented in Figure 4-26. The dominant phytoplankton in 2021 was Chlorophyta, specifically Chlamydomonas globose or green algae. Both Cryptophyta and Cyantophyta were the second most abundant classes of phytoplankton. Cyanophytes, also known as cyanobacteria or blue-green algae, are a group of free-living bacteria that obtain energy through photosynthesis. Under favorable conditions large, toxic blooms of cyanobacteria can occur. In 2020, Chlorophyta (primarily *Chlamydomonas globose*) was also the most dominant class of phytoplankton.

Historically, phytoplankton numbers have been declining since 2019 and are now significantly lower than previously seen. This is likely due to the zebra mussel population expansion and alum treatment which first occurred in 2018. Before 2019, potentially harmful blue-green algae were the dominant phytoplankton in Lake Riley. This has now changed, transitioning to a more balanced community following the alum treatment.

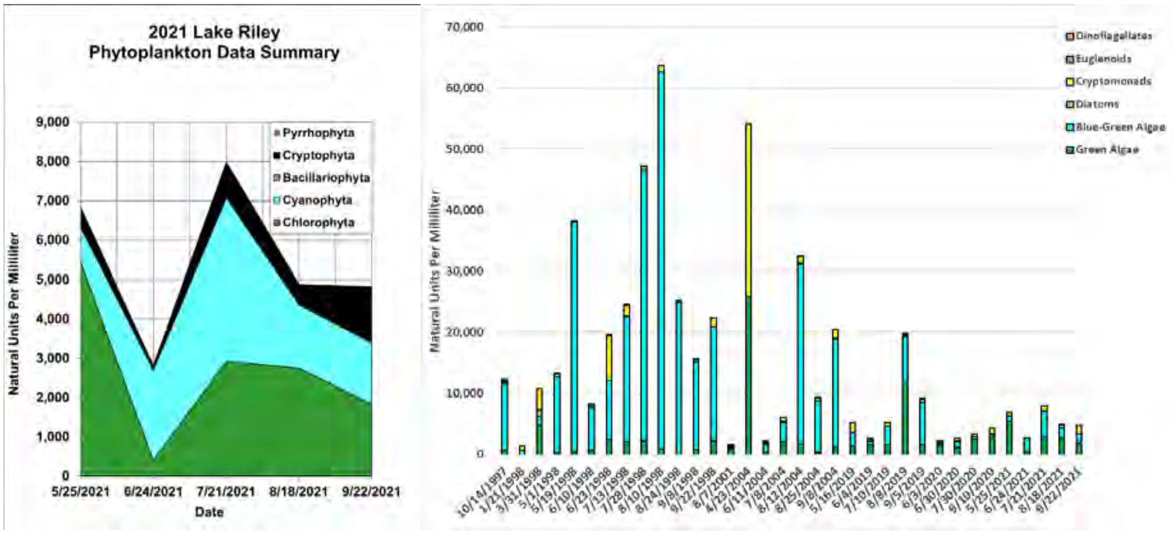


Figure 4-26 1997-2021 Lake Riley Phytoplankton Historical & Seasonal Abundance (#/mL).

Lotus Lake

In 2021, all three groups of zooplankton were present in Lotus Lake (Exhibit C). Similar to 2020, rotifers were the most abundant zooplankton sampled making up 61.5% of the total zooplankton captured in 2021 (Figure 4-27). Copepod numbers varied between sampling events throughout 2021 with the highest number captured in May and August (around 400 thousand). Cladoceran populations were variable over the year. The highest numbers were recorded in spring and fall (around 300 thousand). The increased fall Cladocera numbers can be attributed to an abundance of *Daphnia galeata mendotae* in the spring and *Daphnia retrocurva* in the fall. *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 observed in 2018 ranged from 6% to 19%. In 2019 the rates were very low ranging from near 0% to under 5%. Rates were near 0% in 2020. In 2021, grazing rates increased, ranging from 0% to 4% (Figure 4-27.). The fall increase in *Daphnia retrocurva* is what drove the increase the 68% grazing rate.

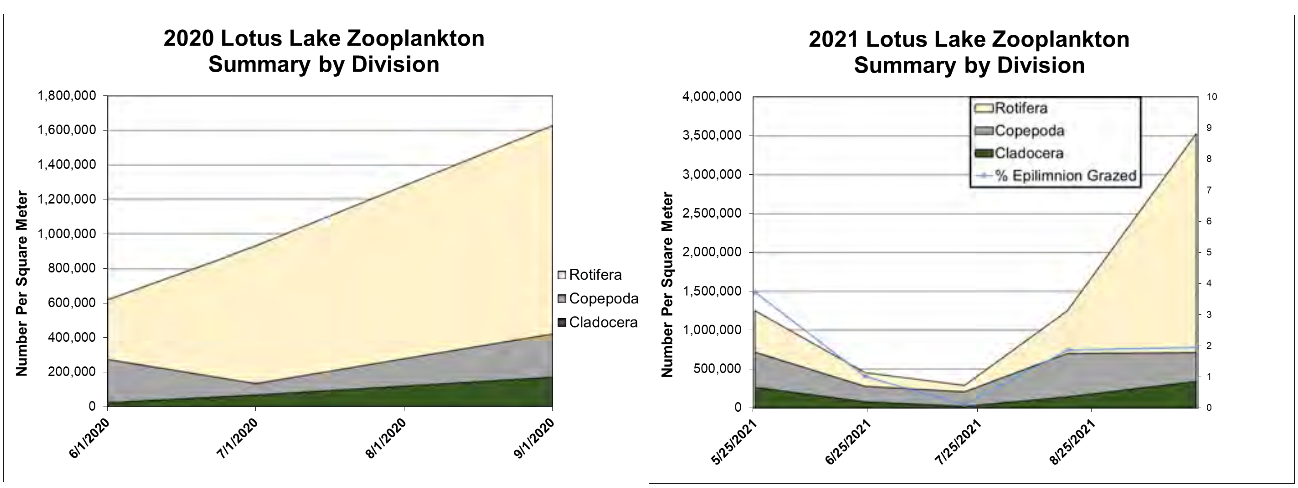


Figure 4-27 2020 & 2021 Lotus Lake Zooplankton Counts (#/m²).

During the summer of 2021, staff collected five phytoplankton samples on Lotus Lake (Exhibit D). The abundance of phytoplankton across all sampling dates is presented Figure 4-28. In 2019 Cyanophyta (primarily *Aphanizomenon flos-aquae*) was dominant in August and September, spiking in early August. Aphanizomenon are a potential producer of cylindrospermopsin, anatoxins, and saxitoxins. This trend matched what was seen in 2020 and 2021 with *Aphanizomenon flos-aquae* being the most consistently dominant species and a spike of *Cylindrospermopsis raciborskii and Anabaenopsis raciborskii* in August and September. These species can produce similar toxins to Aphanizomenon. Historically, blue green algae have comprised a large population of phytoplankton sampled, but since 2004 have they have been the dominant phytoplankton group observed (Figure 4-28).

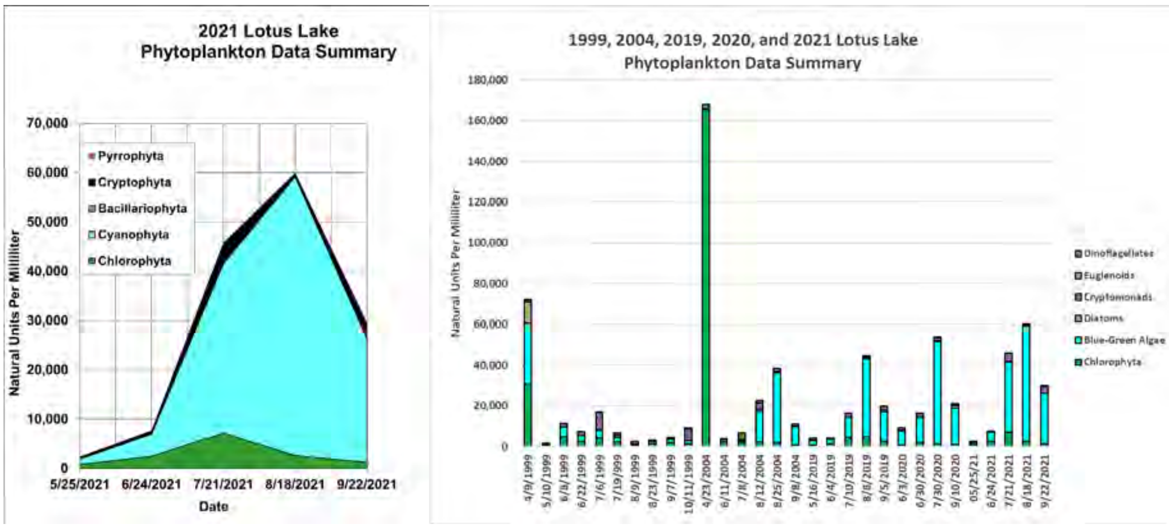


Figure 4-28 1999-2021 Lotus Lake Phytoplankton Historical & Seasonal Abundance (#/mL).

Lake Susan

In 2021, rotifers were the most abundant zooplankton captured in Lake Susan with *Keratella sp.* being dominant. (Exhibit C). The rotifer population was highly variable over the 2021 sampling events with the highest abundances observed in September (1.5 million). Copepod numbers declined from an early high of 411 thousand in May to 60 thousand in June, July, and August before expanding to 296 thousand in September (Figure 4-29). Overall, Cladocera numbers comprised 11.6% of the total zooplankton captured, averaging around 100 thousand per month. This number is up from 2019 when individuals per sampling event averaged around 50 thousand. The highest Cladocera population recorded in 2021 was in September when *Chydorus sphaericus* were captured in high numbers. *Chydorus sphaericus* is the most common of all Cladocera and currently found within all the great lakes states.

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

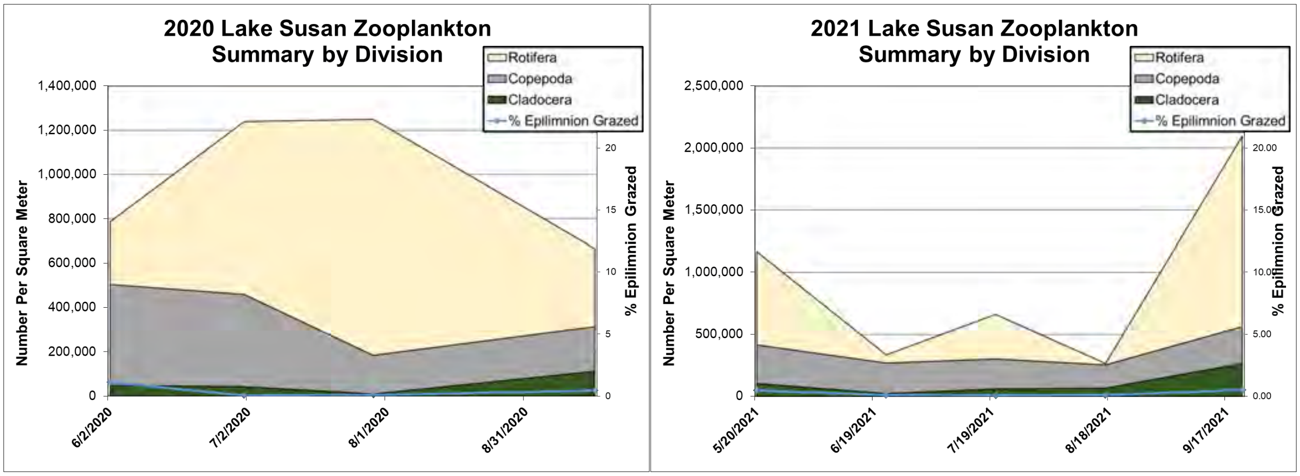


Figure 4-29 2020 & 2021 Lake Susan Zooplankton Counts (#/m²).

During the summer of 2021, staff collected five phytoplankton samples on Lake Susan (Exhibit D). The abundance of phytoplankton by Class is presented in Figure 4-30. Similar to 2019 and 2020, Cyanophyta and Chlorophytes were the co-dominate phytoplankton groups in 2021. Chlorophyta are a division of green, mostly unicellular, or simple filamentous algae, which are free-floating or are present in large aggregations in stagnant water, such as ponds and lakes. Cyanobacteria from the end of June through August were the dominant phytoplankton species making up 88% of the Total Phytoplankton Abundance (TPA). The 2021 blue-green numbers in Lake Susan were the highest to date as shown in Figure 4-30. Lake Susan blue-green numbers during June and August exceeded the World Health Organization (WHO) threshold for moderate probability of adverse health effects (>100,000 units/mL). This threshold indicates when blue-green algal toxins may be high enough to cause adverse health effects. Although the presence of algae able to produce toxins within Lake Susan is known, the concentration of algal toxins cannot be known unless samples are collected. The climatic conditions in 2021 seemed to support higher blue-green algal numbers in many shallow lakes across the metro area (personal communication - Margaret Rattei). Since Lake Susan exceeded this threshold in 2021, in the future staff may send samples from Lake Susan to be analyzed shortly after collection to assess blue-green numbers and potentially post warnings for recreational use. *Cylindrospermopsis raciborskii*, *Anabaenopsis raciborskii* and *Aphanizomenon flos-aquae* were the most abundant phytoplankton overall. These phytoplankton are a potential producer of cylindrospermopsin, anatoxins, and saxitoxins.

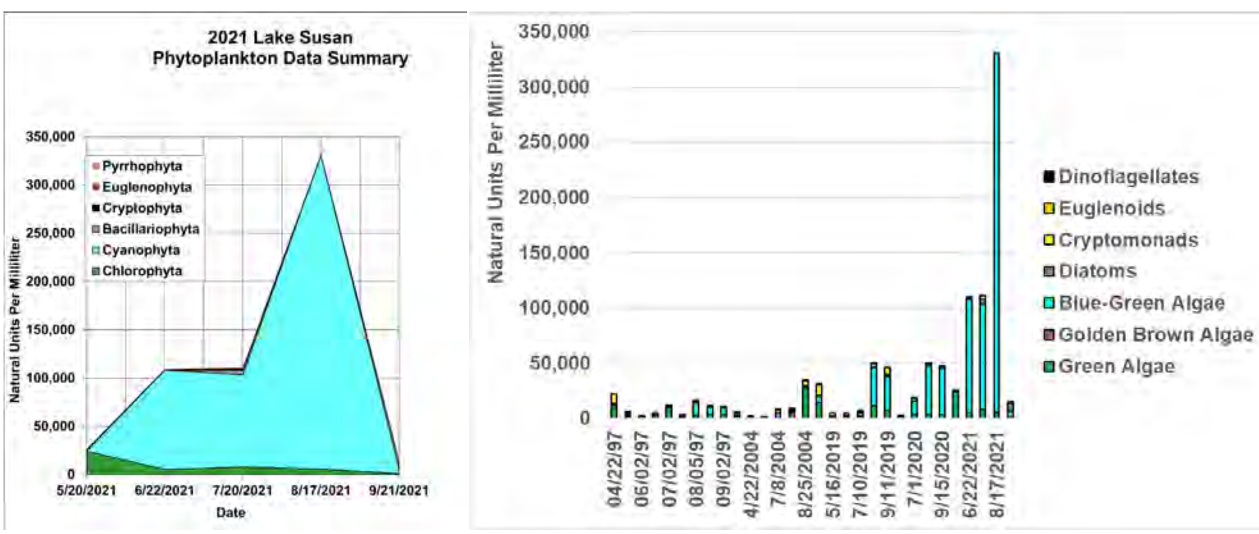


Figure 4-30 1997-2021 Lake Susan Phytoplankton Historical & Seasonal Abundance (#/mL).

Historically, the trend of Chlorophyta and Cyanobacteria being the two dominant types of phytoplankton has persisted. Cryptomonads were also commonly found across most years. Between 2019 and 2021, Blue Green Algae populations have increased significantly, which is of concern. Numerous water quality projects have been implemented around Lake Susan and others are projected to be completed soon. These water quality improvements will hopefully reduce potentially harmful algal blooms as seen in other lakes.

Rice Marsh Lake

In 2021, all three groups of zooplankton were captured in Rice Marsh Lake (Exhibit C), of which 24% of the population was comprised of Cladocerans. This number is up from 17% in 2020, 8% in 2019, and 13% in 2018. Rotifers were not the most abundant zooplankton sampled in 2021 (Figure 4-32). Unlike 2019 and 2020 when the majority of the rotifers captured were from the first sampling event (May-June 90% in 2019 and June 67% in 2020), most in 2021 were captured in the fall in 2021 (270 thousand). Copepod densities were highly variable across the year with the highest density in August at 611 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, and 0 to 11 % in 2020 (Figure 4-32). In 2021, the highest July grazing rate of 8% was linked with the highest density of smaller Cladocerans and the presence of the larger bodied *Diaphanosoma leuchtenbergianum*.

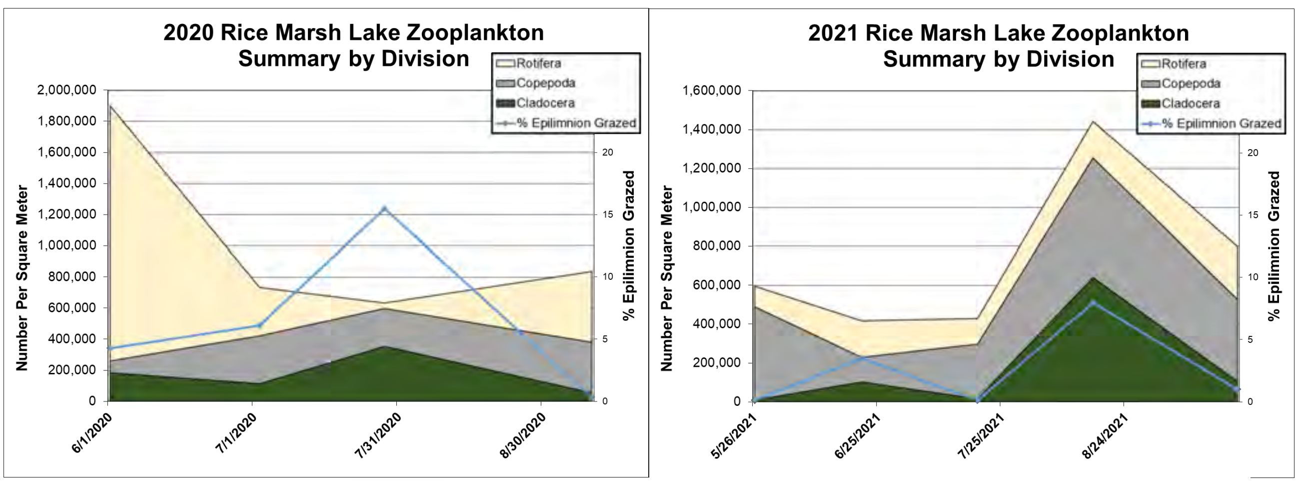


Figure 4-31 2020 & 2021 Rice Marsh Lake Zooplankton Counts (#/m²).

During the summer of 2021, staff collected five phytoplankton samples on Rice Marsh Lake (Exhibit D). Abundance of phytoplankton by Class for Rice Marsh Lake is presented in Figure 4-32. Historically, the phytoplankton community has been balanced with limited numbers of Cyanobacteria. Cryptomonads and Green Algae have and continue to dominate the phytoplankton community. *Chlamydomonas globosa* and *Cryptomonas erosa* were the most dominant species in 2021. Generally, all phytoplankton species counts steadily declined from the beginning to the end of the year.

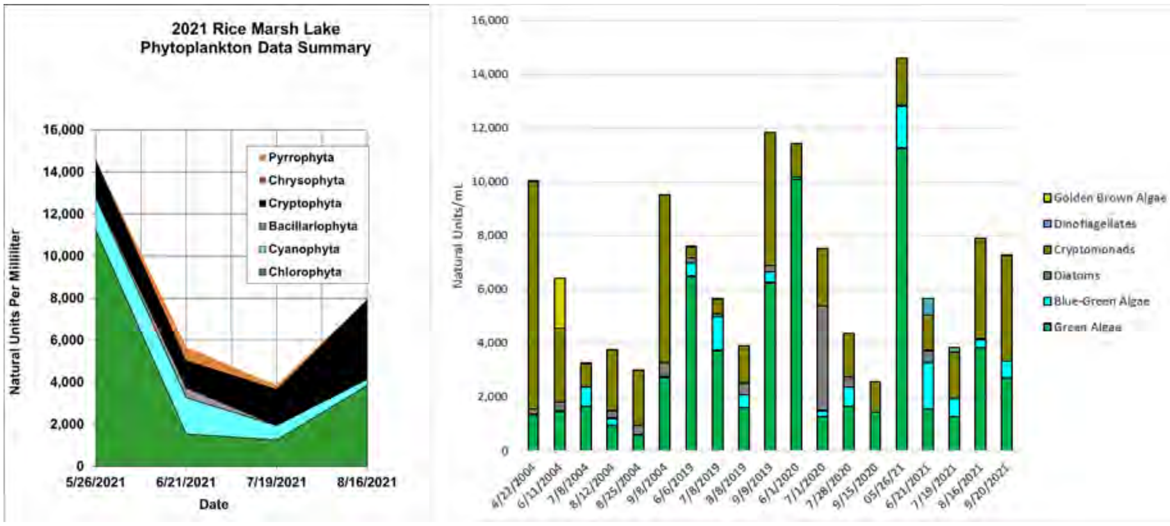


Figure 4-32 2004-2021 Rice Marsh Lake Phytoplankton Historical & Seasonal Abundance (#/mL).

Staring

In 2021, all three groups of zooplankton were present in Staring Lake (Exhibit C). Similar to 2019 and 2020, the 2021 June sampling event had the highest number of organisms across all groups (Figure 4-34). In 2021, rotifers were highly variable across the year with the highest abundance occurring in June at 646 thousand. 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 44% of the total zooplankton abundance across the year. Cladocera species made up 23% of the total zooplankton population. In 2020, the Cladocera population was lower than in 2021, averaging only 75 thousand. In 2021, the Cladocera population was highest in spring (603 thousand) and lowest in September (13 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. Grazing rates increased in 2021 but were still low, ranging from 1% to 6%.

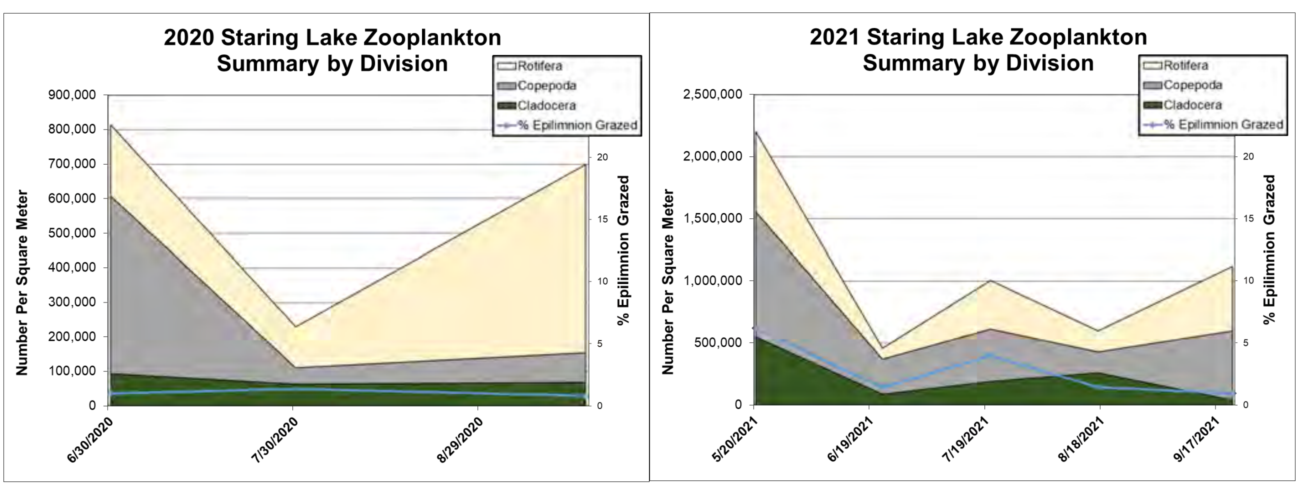


Figure 4-33 2020 and 2021 Staring Lake Zooplankton Counts (#/m²).

During the summer of 2021, staff collected five phytoplankton samples on Staring Lake **(Exhibit D)**. Abundance of phytoplankton by Class are presented in Figure 4-34. Cyanophyta was the most dominant zooplankton across all sampling events in 2021. This has been the case historically as well. As seen in other lakes, blue green algae dominated Staring Lake. In August and September, they made up 63% of the Total Phytoplankton Abundance. Cylindrospermopsis raciborskii and Anabaenopsis raciborskii were the most prevalent species.

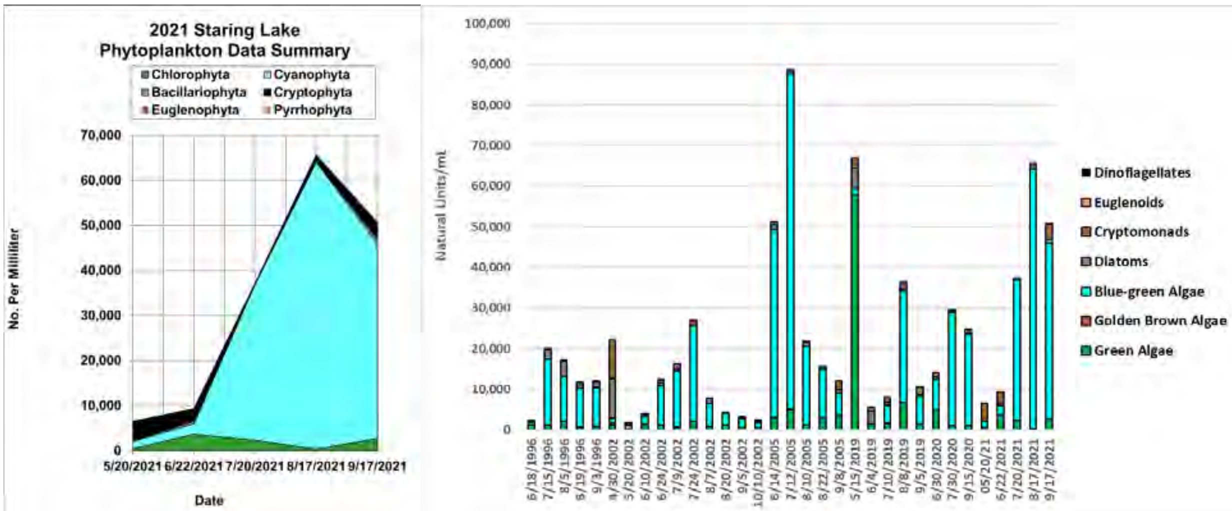


Figure 4-34 1996-2021 Staring Lake Phytoplankton Historical & Seasonal Abundance (#/mL).

4.9 Lake Susan Spent-Lime Treatment System

Figure 4-35 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 4-36). 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 4-36 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 4-37 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 4-38).

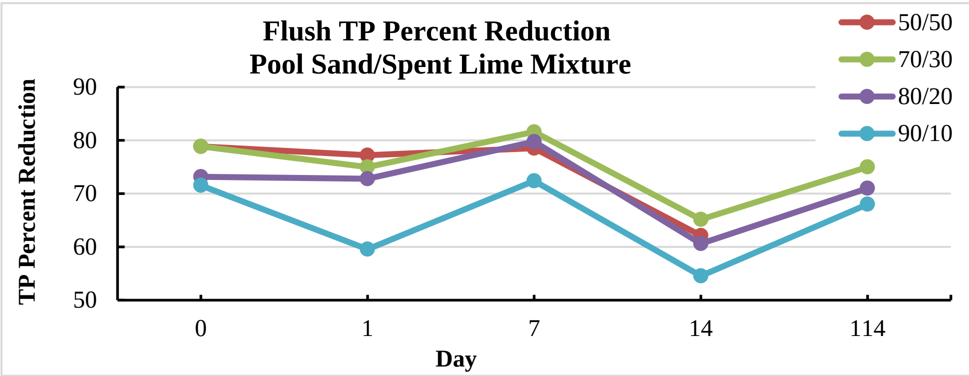
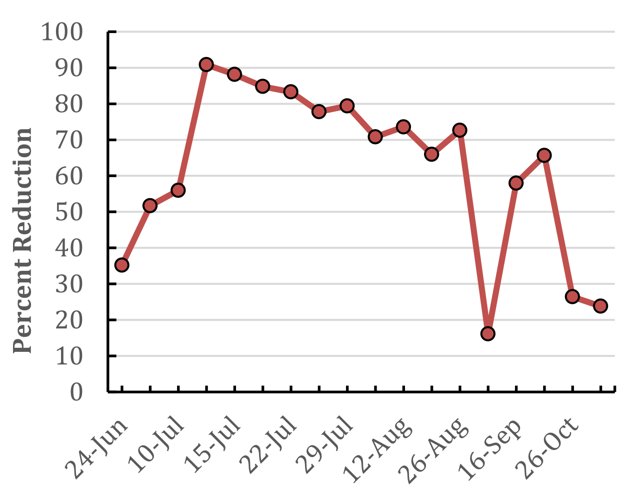


Figure 4-37 Pool Sand/Spent Lime Mixture Column Testing Phosphorus Removals

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 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 4-40). There was a 41% reduction across samples in 2021 (Figure 4-39). 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 4-10).



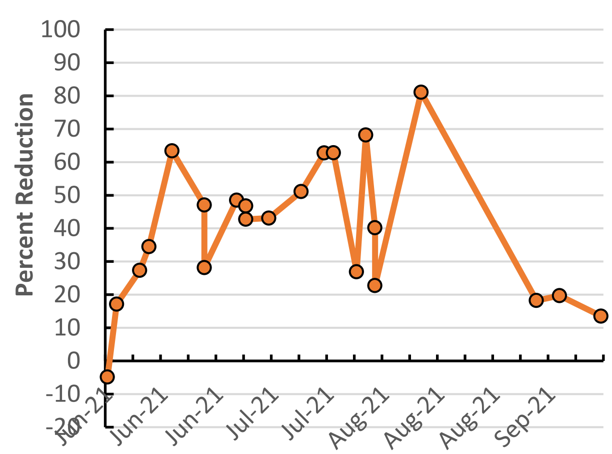


Figure 4-39 2020 Lake Susan Spent Lime Treatment System Total Phosphorous Percent Reduction

Figure 4-38 2021 Lake Susan Spent Lime Treatment System Total Phosphorous Percent Reduction

The reduced TP removal efficiencies in 2021 could be linked to the need for additional mixing or “fluffing” of the sand/spent lime mixture. The District has been manually mixing the material once a year, but additional mixing may be needed to prevent media from compacting over time and to break up preferential flow paths within the BMP. Another explanation could be that the system 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 may be needed to address the nutrient impairment. Overall, the spent lime treatment system removes phosphorus and other nutrients.

Table 4-10 2020-2021 Average TSS and Nutrient Removals from the Spent Lime Treatment System

Analyte	2020	2021
TDP (mg/l)	53	37
TP (mg/l)	49	51
TSS (mg/l)	46	29
OP (mg/l)	59	55
CHLA (mg/l)	53	37

4.10 Stormwater Ponds

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.

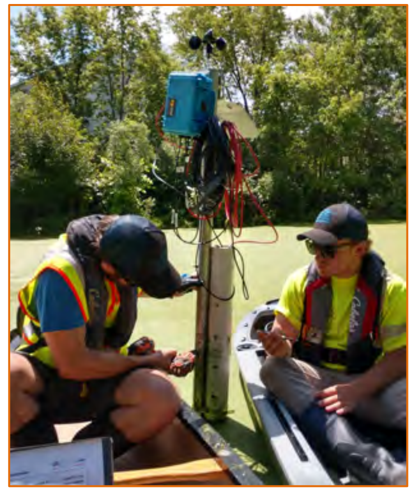


Figure 4-40 EnviroDIY Pond Continuous Monitoring Station

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 critical baseline for research carried out in 2019 and 2020.

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. A quick highlighted summary of the 2021 results can be seen in Figure 4--16. 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 4-41). Most of the data from each study is currently being evaluated, but the following information is a summary of the research being carried out in the District:

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

- 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 most likely 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.
- The three study ponds all released phosphorus under anoxic conditions with two of the ponds also releasing phosphorus when oxygen was available. 30%-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).
- 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.
- Poornima Natarajan discussed possible predictors of the phosphorus flux from the sediment. They included measuring redox sensitive phosphorus, total releasable phosphorus, total sedimentary phosphorus, sediment oxygen exposure, and total organic content.
- 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 (Figure 4-42). 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. The UMN will be producing a final report in 2022.

Figure 4-41 Minnetonka Iron Filings Application

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 had 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.
- Last summer 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 dropped.

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 over three decades, constructed stormwater ponds have been designed and maintained to maximize sedimentation and minimize scour during storm periods (EPA's Nationwide Urban Runoff Program (NURP)). 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.
- Is it time to rethink pond monitoring? Focus on inlet outlet loads with continuous monitoring stations to capture all pond dynamics.
- Adapt the GLM (general lakes model)-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.

Anne Wilkinson – Wenck – Harmful Algal Blooms 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.
- 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.
- Wilkinson stated that because duckweed blocks all the sunlight from penetrating below the pond's surface, even the most buoyant algae are not able to compete with high duckweed cover.

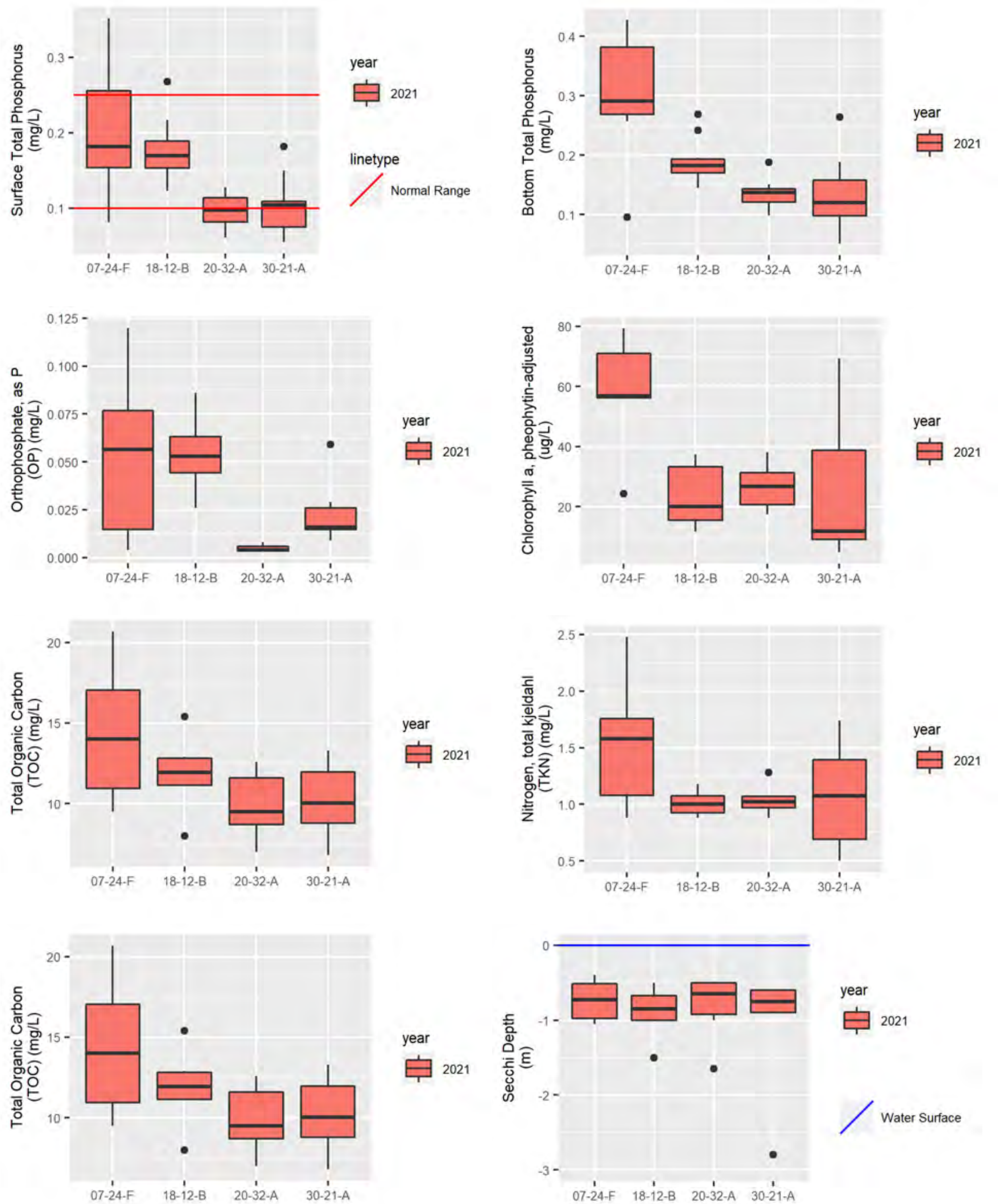
Joe Bischoff – Barr – RPBCWD Pond Assessment

- Pond phosphorus levels averaged concentrations of around 200 ug/L 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. Chl-a samples and phycocyanin levels indicate ponds have harmful algal blooms. 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. Pond sediment phosphorus release rates were between 4-8 mg/m2/day and most phosphorus is 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. Need to develop framework to determine which ones are performing badly so we can target treatment.
- 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). This modeling, while not intended for scenario analysis, could develop hypotheses to manage drivers of anoxia- mainly BOD and SOD in larger ponds- and determine the role of sheltering- particularly in smaller ponds.

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

Figure 4-42 2021 Stormwater Pond Summary



4.11 Fish Kills and Stocking

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

- Winterkills (oxygen depletion)
- Columnaris Bacteria

In 2021 a springtime fish kill was observed and reported by residents around Red Rock Lake. The likely cause was columnaris bacteria. The fish species reported (crappie and bass) were spawning at the time of the kill. Spawning weakens the fish's immune system, causing them to be more susceptible to bacterial or fungal infections that, if contracted, can kill them. The columnaris bacterium exists naturally in lakes and can cause disease during stressful conditions. The primary fish stressors triggering columnaris infection are rapid springtime increases in water temperature, coupled with spawning activity and low energy reserves from the previous winter. Fish infected with or killed by Flexibacter columnaris show signs of eroded fin edges, skin lesions, eroded gill tissue, and a grey/white to yellow skin slime. External symptoms might not be obvious. This is fairly common and regularly occurs on Lotus Lake, Lake Susan, and many other lakes across the metro. The herbicide treatment (Diquat) that was used on the lake for the herbicide treatment this year may have been an additional stressor contributing to the fish kill. Most fish kills associated with bacterial and fungal infections have limited impacts on overall fish numbers, as is the case with Red Rock Lake.

Winterkills are common across the state of Minnesota, especially in shallow, eutrophic (nutrient-rich) lakes with muck bottoms and an abundance of aquatic plants. Many shallow lakes within the District have had a history of winterkills. A winterkill occurs when dissolved oxygen (DO) levels within a lake drop below 4 mg/L for an extended period, causing fish to suffocate and perish. During the summer season, oxygen is added to lakes through wind action and photosynthesis by phytoplankton and macrophytes. In the winter, if there is limited persisting snow to block sunlight, phytoplankton and some macrophytes may continue to photosynthesize and help prevent a winterkill from occurring. Microorganisms near the lake bottom and in the sediment of a lake are continuously decomposing material, consuming DO in the process. If a large snow event occurs or snow coverage has been present for an extended period, it becomes too dark below the ice for photosynthesis to occur. The high organic content in shallow lakes provides an abundance of food for the decomposers which can deplete DO levels. This can cause a fish kill.

In late February of 2021, RPBCWD staff noticed low DO levels on Rice Marsh Lake during regular lake sampling (2.61 mg/L at the surface: 0.64 mg/L near the bottom). Staff conducted a regular water quality sampling event in March which confirmed that a fish kill occurred. DO levels in Rice Marsh Lake were less than 1 mg/l across all depths. At this time dead bluegills were observed. The District aeration unit on Rice Marsh Lake was successfully operating and a large open water area was present all winter in 2021. Another winterkill occurred on Rice Marsh in the winter of 2017/2018, but prior to this no others had occurred since the aeration unit was installed in 2010. Residents of Duck Lake also reported a winter kill on the lake in the spring of 2021.

Preventing a winterkill in Rice Marsh Lake is a critical part of the Common Carp Management Plan for the RCL. Common carp have been known to move from various lakes in the RCL into Rice Marsh Lake to spawn. Before the aeration unit was operational, Rice Marsh Lake would winterkill every few years. This eliminated all predators of common carp in the system, allowing carp to successfully spawn. These successful spawning events caused large carp populations to form in all lakes within the RCL. Since operation of the unit in 2010, winterkills have occurred in 2017/2018 and 2020/2021. The most important predator of common carp is the bluegill sunfish which can suppress a carp population by consuming eggs and larval stages of carp. A well-established bluegill population in a lake can control a carp population and prevent it from becoming a problem.

Fish stocking following a winterkill is a common practice to reestablish a population. Due to the importance of Rice Marsh Lake in combating carp within the RCL, bluegill sunfish were stocked in the lake. After the 2019/2020 winterkill in Lake Lucy, stocking occurred there in order to quickly re-establish a base bluegill population. Bluegills have also been stocked in the Upper and Lower Purgatory Creek Recreational Area and Staring Lake. These water bodies have variable carp populations that are not under full control. Stocking bluegills in these waterbodies has been used in the past to aid in common carp control, the hope being to eliminate carp recruitment. Duck lake was stocked by the MN DNR in 2018. Bluegill stocking rates can be seen in Table 4-11. Figure 4-43 displays the total number of bluegills captured in each trap net survey for the lakes that have been stocked with bluegills. Corresponding winterkill years are indicated in the figure by the red arrows. Staff will monitor lakes of concern through the winter to see if 2022 bluegill stocking is warranted.

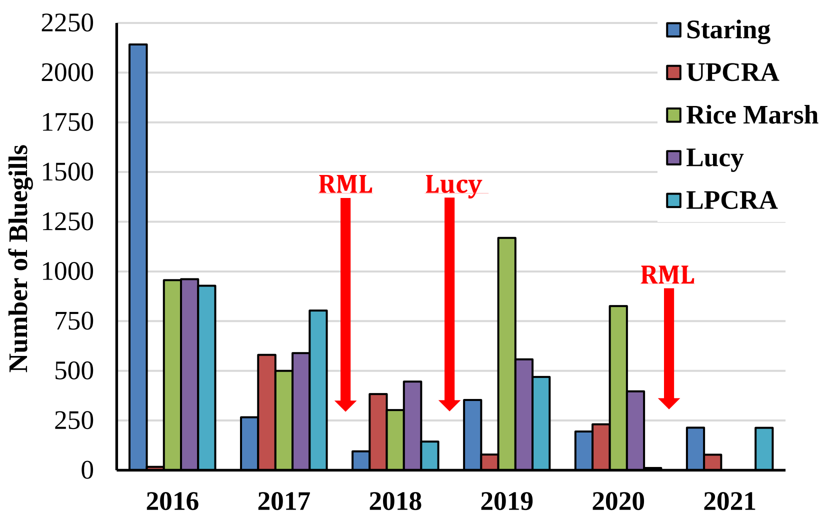


Figure 4-43 2016-2021 Total Bluegill Trap Net Numbers

Table 4-11 2018-2021 Bluegill Stocking Numbers

	Number of Bluegill Stocked			
Lake	**2018**	**2019**	**2020**	**2021**
Rice Marsh Lake	1000	300	0	800
Staring	300	200	0	0
UPCRA	200	100	0	100
LPCRA	500	100	0	100
Lucy	0	300	0	0
Duck	20	0	0	0
TOTAL	2020	1000	0	1000

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 5-2). 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. Table 5-1 identifies AIS monitoring/management that occurred in 2021, excluding common carp management.

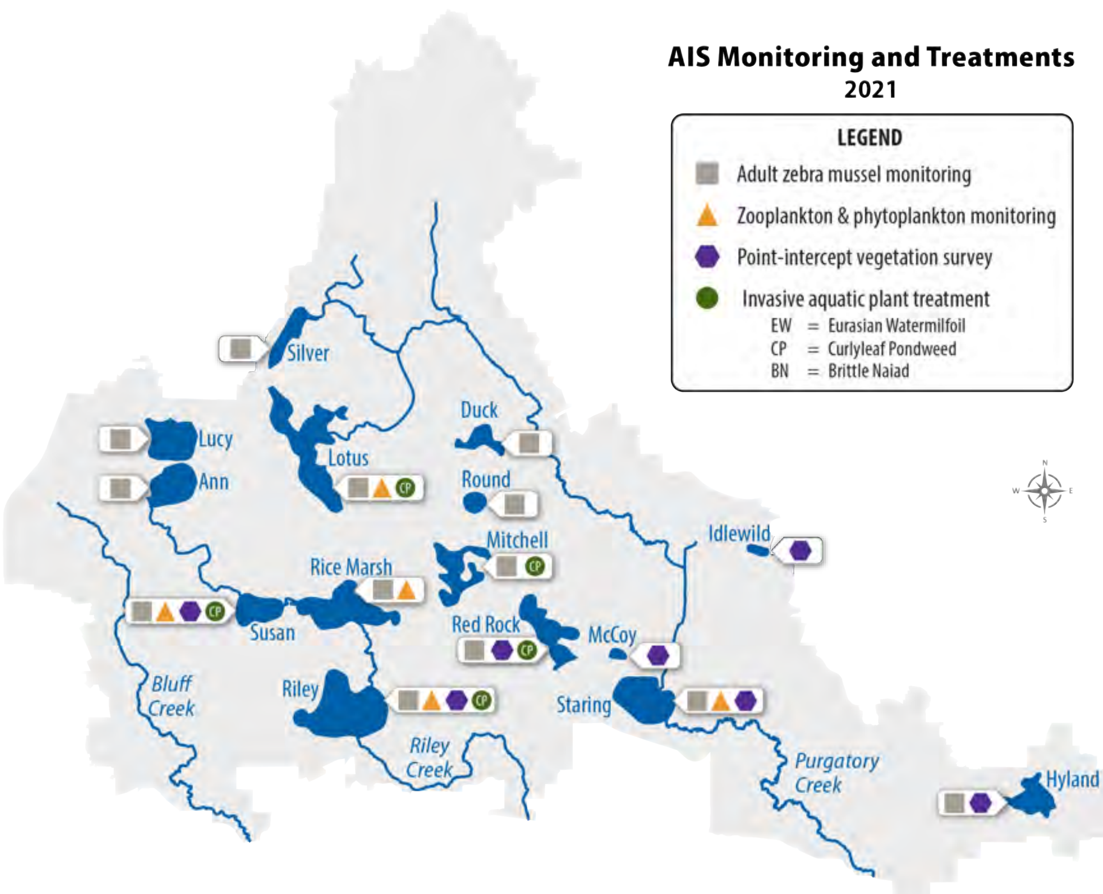


Table 5-1 2021 Aquatic Invasive Species Summary

Aquatic Invasive Species (AIS) work conducted in 2021 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 5-2 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 Plant Management

Aquatic plant surveys are important because they allow the District to map out invasive plant species for treatment, locate rare plants for possible 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. 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 2021, point intercept surveys were conducted Hyland Lake (TRPD), Duck Lake (EP), Lake Susan, Red Rock Lake, Lake McCoy, Lake Idlewild, Staring Lake, and Lake Riley. Aquatic plant reports can be provided upon request. 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. In the early spring of 2021, herbicide treatments were carried out by PLM Lake and Land Management Corporation on Lotus Lake (22.8 acres), Mitchell Lake (12.8 acres), Lake Riley (22.3 acres), Lake Susan (8.64 acres), and Red Rock (13.04 acres) for curly leaf pondweed. These survey maps can be seen in Exhibit J. No Eurasian watermilfoil or brittle naiad treatments occurred.

Mitchell Lake Turion Survey

In 2021, District staff completed a curly leaf pondweed turion survey on Mitchell Lake. Turions are the primary reproductive structure of curly leaf pondweed. Research suggests approximately 50% of turions germinate in a growing season while the rest remain dormant until the following growing season when another 50% will germinate (Johnson 2012). Depending on the level of turions at a given location (knowing that latent turions may be able to survive for over five years in the sediment), it may take several years of control to exhaust the “turion bank” (R. Newman – U of M unpublished data). Evaluating the turions in a lake can help researchers evaluate the effectiveness of treatments.

Staff followed procedures outlined by the UMN (Johnson, 2012). In October the abundance of curly leaf turions in littoral sediment was measured. A petite Ponar dredge (225 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 (53 points surveyed in 2021). 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 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 2021 Mitchell Lake CLP Turion Statistics

Total Number of Sample Points	53
Total Number of Live Turions/Total Turions	9/17
Total Number of Points with Live Turions/Total Turions	5/10
Frequency of Occurrence	19
Number of points above potential impairment (+50/m2)	5
Number of points above predicted nuisance level (+200/m2)	0
Maximum Turions/m^2	129
Mean Turions/m^2	16
Standard deviation/m2	8.77

Table 5-3 summarizes the results from the 2021 Mitchell Lake CLP Turion Survey. During the October 14, 2021 survey, District staff found 17 total CLP turions; 10 of 53 points had live turions (19% occurrence). This an overall decrease from 2017 (12 out of 40 points with live turions, a 30% occurrence). This is also well below the occurrence of live turions first sampled in 2013 (29 out of 40 points with live turions, a 73% occurrence). Turions appeared to be scattered throughout the lake at very low densities (Figure 5-1). The overall mean density within the study areas was 13.57 turions/m2 with a standard deviation of 8.77 turions/m2. This is a significant decline from 2013 (190.73 turions/m2 with a standard deviation of 85.81 turions/m2). It has remained relatively unchanged since the last survey in 2017 (12.93 turions/m2 with a standard deviation of 15.8 turions/m2). Overall, the total number of turions has been reduced with the application of consecutive herbicide treatments. No herbicide treatments occurred in 2013 and 2014, but the herbicide endothall was applied to the lake in 2015, 2016, and 2017. Diquat was applied in 2018, 2020, and 2021. Turion surveys show a clear reduction in viable turions following herbicide applications. Five of the survey points topped an estimated 50 turions/m2. This indicates a low potential for navigation impairment (Johnson 2012) (50% of points with turions). However, none of these points exceeded the expected “nuisance level” of 200/m2 (Figure 5). District staff will continue to monitor the CLP pondweed on Mitchell Lake to assess if treatment is needed moving forward.

Table 5-4 CLP 2013-2021 Mitchell Lake CLP Turion Survey Results

Date	Turions/m^2	Viability	Viable Turion Density (turions/m^2)
Oct-13	177	77%	137
Oct-14	152	44%	72
Oct-15	13	80%	11
Oct-16	25	38%	10
Oct-17	12	49%	5
21-Oct	17	50%	7

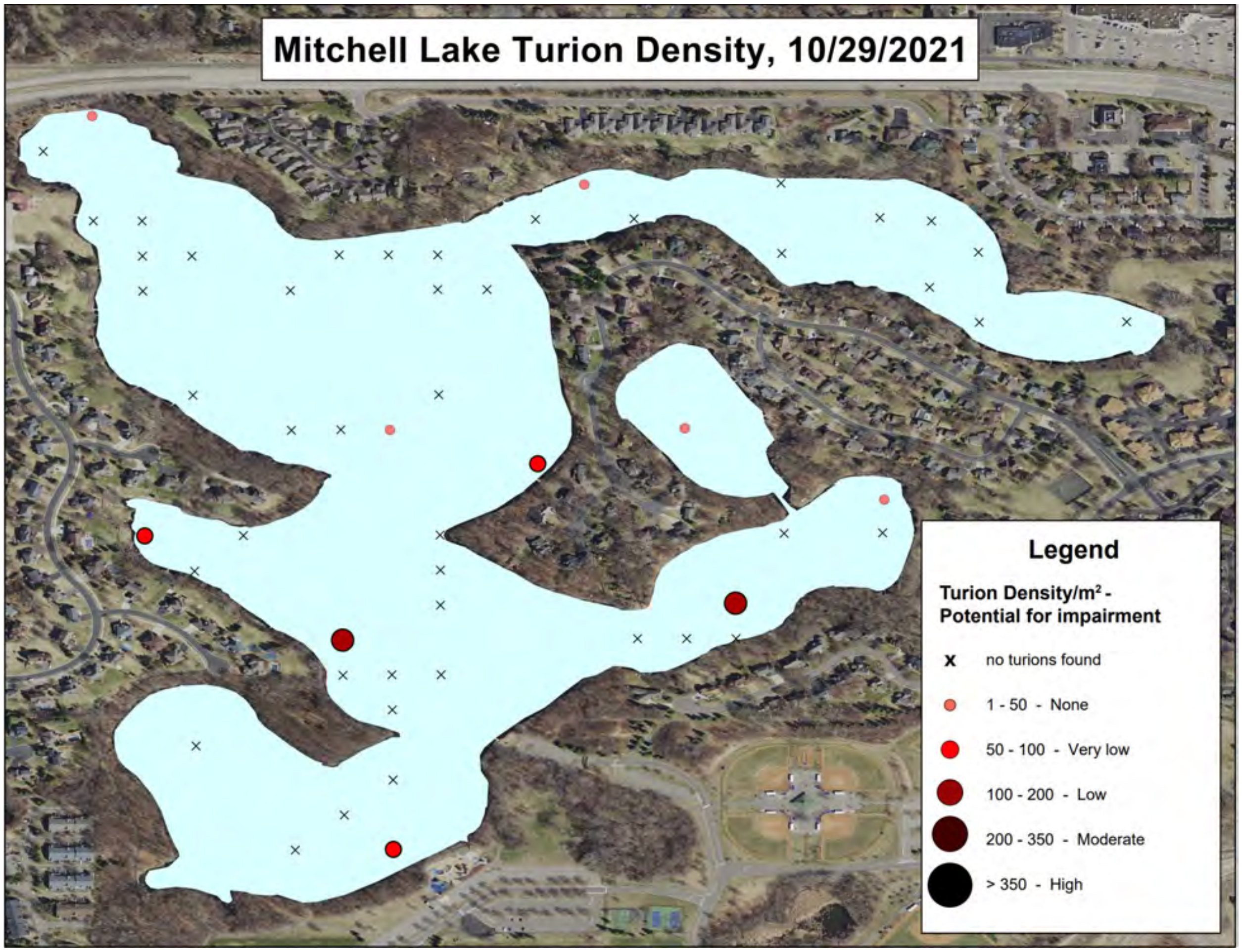


Figure 5-1 2021 Fall Mitchell Lake CLP Turion Survey Density and Distribution

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.

Figure 5-2 Electrofished Common Carp

Adult carp are monitored within RPBCWD by conducting electrofishing events on each lake, three times each year between late July and early October. Each event consists of three, 20-minute transects (totaling three hours per lake). If the total biomass estimate of carp is above 100 kg/h, the population is considered harmful to lake water quality and the District would need to consider management. Young of the year (YOY) carp are monitored by conducting 24-hour small mesh trap net sets between August and September. Each sampling event consists of five nets set per lake. Capture of YOY carp during this sampling suggests successful recruitment has occurred, and monitoring efforts should be increased on that water body. At that point, the District would also consider further management action. In 2021, 644 carp or 2,177 lbs. of fish were removed from RPBCWD (Table 5-5).

Table 5-5 2021 Total Carp Removed

System	# of Fish	Weight (lbs.)
RCL	70	247
PCL	574	1930
Total	**644**	**2177**

Trap Netting

District staff completed trap net surveys on Staring Lake, Lake Riley, Lake Susan, Lake Susan Park Pond (LSPP), the Upper Purgatory Creek Recreational Area (UPCRA), and the Lower Purgatory Recreation Area (LPCRA) in 2021. Of the lakes sampled, LSPP and Lake Susan had the most fish captured (423 and 384 fish respectively). The UPCRA had the most diverse fish population sampled over the past two years. 12 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. Lake Susan had the highest number of bluegills captured, averaging 68.8 fish per net. This is slightly down from the last sampling event, 98.4 fish/net in 2018. The UPCRA had the lowest bluegill abundance. Only 19.5 bluegills/net were captured, down from 57.75 in 2020. Other species that were abundant included pumpkinseed sunfish, black crappies, and bullhead species. LSPP also had the highest number of black crappies by far (48.25 fish/net captured). Large predatory fish including northern pike and largemouth bass were captured via trap netting in low numbers across the lakes. The largest pike was captured in UPCRA, measuring 39.45 inches. A total of 14 pike were captured in the UPCRA which was the highest CPUE. A full summary table of the fish captured for each lake can be found in Exhibit B.

Figure 5-3 Staring Lake Trap Net

In 2021, a total of 14 YOY carp were captured via trap net surveys. One was captured in Staring Lake and 13 were captured in Lake Susan Park Pond. The lack of young individuals captured in Staring Lake and all other sampled lakes indicates that 2021 was a poor recruitment year for common carp. The presence of YOY carp in Lake Susan Park is slightly alarming; recruitment had not been seen in the pond before 2021. Staff had been utilizing this pond as a removal area but may rethink allowing carp to move up into the pond if it continues to become a nursery. In 2020, 17 YOY carp were captured during trap netting on the LPCRA which had been the most seen since pre carp management. In 2021, no YOY carp were captured here, indicating no or limited recruitment occurred. 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 Ann and LSPP were the only RCL waterbodies electrofished in 2021. Lake Ann was only sampled over two dates which yielded only one YOY common carp. Since 2008, Lake Ann has consistently seen biomass estimates near 0 kg/h (Figure 5-4). 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, and in 2020 it was 336 kg/ha (Figure 5-4). In 2021, the biomass estimate was well above the biomass threshold of 100 kg/ha at 243 kg/ha (Table 5-6). Fish move into LSPP during spring high water and are trapped as water levels recede. This has presented 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, 25 YOY carp were captured via electrofishing. This coupled with the 2021 trap net data suggest that a winterkill may have occurred, and common carp were able to utilize LSPP as a nursery in the resulting absence of egg predators such as bluegill. Although the pond does offer some removal potential, this may be outweighed by the potential for carp to reproduce. District staff may investigate a temporary spring barrier to prevent migration into the pond. District will continue monitoring and removing carp from LSPP in addition to the recommended management actions established in the RCL management plan.

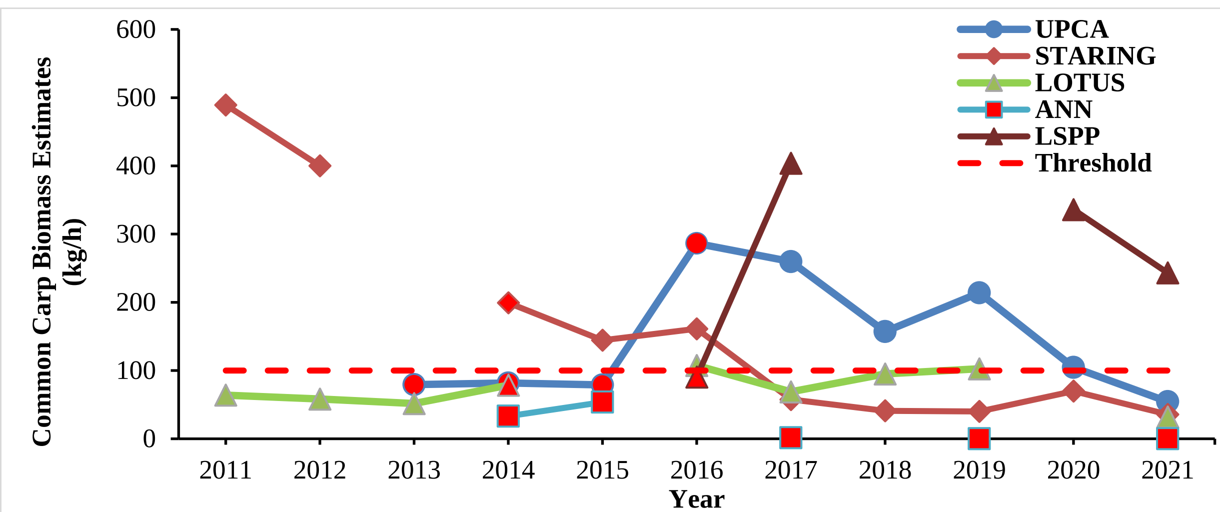


Figure 5-4 2011-2021 Common Carp Biomass Estimates
*Red markers indicate partial sampling event.

The PCL waterbodies surveyed via electrofishing in 2021 were Lotus Lake, Staring Lake, and the UPCRA. The common carp biomass estimate was 32 kg/ha in Lotus Lake (Table 5-6), which is the lowest biomass estimate to date. As seen in (Figure 5-4), the adult common carp biomass estimates have been decreasing in Staring Lake since management began. In 2017 the carp biomass estimate was below the threshold at 62 kg/ha. In 2018, it was lower still at 41 kg/ha. In 2019 the estimate was 40 kg/h. In 2020, the population estimate did increase to 69 kg/ha but was reduced in 2021 to 36 kg/ha (Figure 5-4). The fish captured consisted of individuals from the 2014/2015-year class, which was the last major recruitment year for common carp in this system. Electrofishing has not occurred in the LPCRA the past few years due to access issues and the amount of brittle naiad present in the system. In 2021, the UPCRA carp biomass estimate was below the threshold at 54 kg/ha (Table 5-6). Since 2016, the UPCRA has exceeded the biomass estimate. 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). Staff will continue to monitor the carp population and remove fish.

Table 5-6 2021 Common Carp Biomass Estimates

Lake	Fish per Hour	Density per Hectare	Average Weight (kg)	Carp Biomass (kg/ha)
Upper Purgatory Creek	8.06	41	1.33	54.35
Lotus	1.36	9.44	3.39	31.99
Ann	0	3.04	0	0
Lake Susan Park Pond	28.27	136.19	1.79	243.11
Staring	3.37	18.91	1.89	35.69

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 2021, the physical carp barrier was closed all year. Due to the low water levels in 2021, the City of Eden Prairie rarely opened, cleaned, and closed the fish barrier during high water levels in the Purgatory Creek Recreational Area. Only one time was the barrier held open for an extended period (1 week). During this time, fish could move freely throughout the system

Figure 5-5 PCRA Spring Removal Site Map

During the spring of 2021 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 2021. Backpack electrofishing and block nets were utilized in the channel upstream and downstream of the barrier and at the breach in the berm that separates the Upper and Lower Purgatory Creek Recreational Area (Figure 5-5). 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 2021, water levels were either too high or too low for this method to be successful. Additionally, the 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.

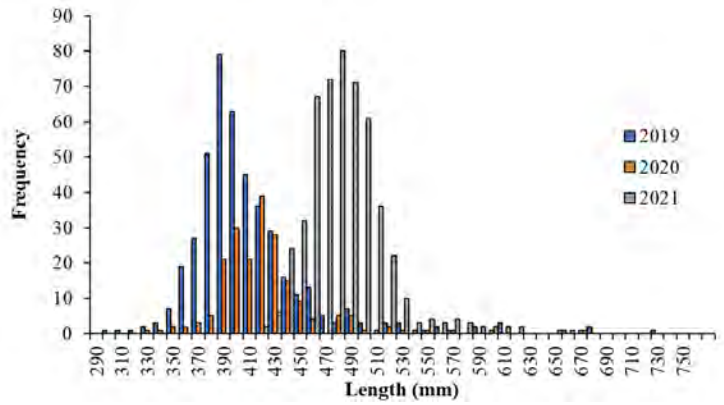


Figure 5-6 2019-2021 Length Frequency of PCRA Spring Removals

In 2021, the backpack electrofishing above and below the barrier combined with block nets across four sampling events yielded a total 511 carp removed or 1,732 lbs. By sex, 281 males and 229 females were removed. Utilizing all gear types in the past, a total of 201 carp were removed 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 5-6. In 2021, most of the carp were removed on 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 5-7). This is compared to 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 2022 to improve capture efficiency.

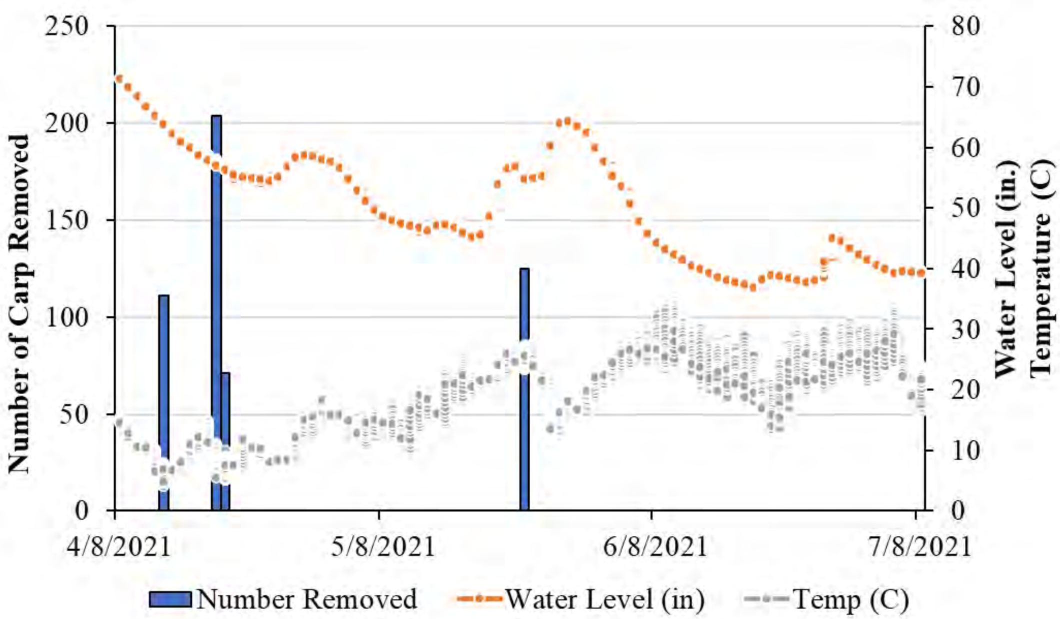


Figure 5-7 Purgatory Creek Recreational Area Common Carp Removal vs Environmental Variables

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 a number of 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. 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 lake systems are very complex and little research has been done on this topic.

The District did conduct experimental removal events this spring on Duck Lake (133 fish removed) and a stormwater pond near the Staring Lake Outdoor Center (127 fish removed) using a seine net combined with backpack electrofishing but had limited success. This technique was determined to not be sustainable on Duck Lake due to the limited number caught vs the number observed and the high demand on staff time and energy. This strategy was more successful on smaller stormwater ponds because goldfish could be targeted more easily Figure 5-8.

Figure 5-8 Goldfish Removal from Staring Lake Outdoor Center Pond

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. Doing 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 essentially 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 (provided by the District) 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, however two trial ponds have been identified for preliminary trials, one in both Chanhassen and Eden Prairie. Locations are below:

- Eden Prairie - Staring Lake Outdoor center - 44.841362, -93.448438
- Chanhassen - Stone Creek Drive/High School - 44.851331, -93.571668

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 2021. The District conducted veliger sampling from June to July on 13 lakes and a high-value wetland to detect the presence of zebra mussels. Each lake was sampled once, apart from Lotus Lake and Lake Ann which were sampled twice. RMB Environmental Labs processed the samples and only found zebra mussel veligers on Lake Riley in 2021. 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 2021. 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 2021. Carver County also submitted water samples to process for zebra mussel eDNA on Lotus, Ann, and Susan. Only Lotus had a positive eDNA hit.

Figure 5-9 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 appears to have maxed out at 2,623 mussels per plate in 2020. In 2021 zebra mussels were found on all plates deployed ranging in number from 1,583 mussels to 4,930 mussels/plate. This indicates a robust population that is well established across the lake. The reduction in 2021 indicates a partial collapse in the population that should cycle up and down in the future similar to what has been seen on Lake Minnetonka (McComas 2018).

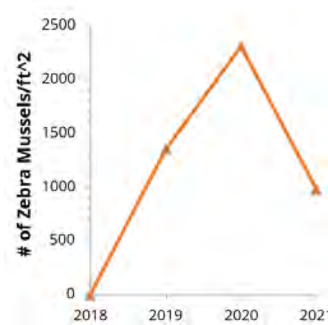


Figure 5-10 2018-2021 Zebra Mussel Density on Lake Riley

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 5-11). 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 5-11). 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, in 2021 veliger tows were collected twice in the spring but yielded no zebra mussel veligers. Both boat launch and mussel plate checks (expanded to 11 plates) yielded no adult mussels. Staff visually searched multiple areas of the lake for mussels twice in 2021, once in august and once in October after docks were pulled. No mussels were found. The eDNA results for 2021 was positive for the deep-water area near the boat launch only. Staff will continue to monitor for zebra mussels in 2022.

Figure 5-11 2019 Lotus Lake Zebra Mussel Map

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 5-7, lists the different variables associated with zebra mussels measured by the District in 2018 for Lake Riley and in 2019 for Lotus Lake. In Table 5-7, 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 levels for zebra mussel suitability, however both TP and Chl-a concentrations were near the upper end of the moderate infestation threshold. Lotus Lake nutrient data indicates minimal growth parameters for zebra mussel growth. This indicates the zebra mussel population may not be as significant. Steve McComas found Chlorophyll 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 5-7, 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 5-7 indicates a slow growing or restricted population limited by minimal growth nutrient levels.

Table 5-7 Suitability for Zebra Mussels in Lake Riley and Lotus Lake

	LAKE	RILEY	LOTUS
Shell Formation	Calcium (mg/L)	44	56
	Alkalinity (mg/L)	112	158
	pH	8.69	7.88
Trophic Variables	TP (mg/L)	0.018	0.042
	Chl-a (ug/L)	28	34.3
	secchi (m)	4.64	1.2
Physical Variables	Temp (deg C)	24.69	22.74
	DO (mg/L)	8.79	8.82
	Cond (uS/cm)	483.7	461.73
	Hard Structure	n/a	n/a

*Mackie and Claudi 2010
BLUE=Minimal Infestation Potential
ORANGE= Moderate Infestation Potential
RED=Massive Infestation Potential

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 2021 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 Lake Level Graphs (NAVD1929)*

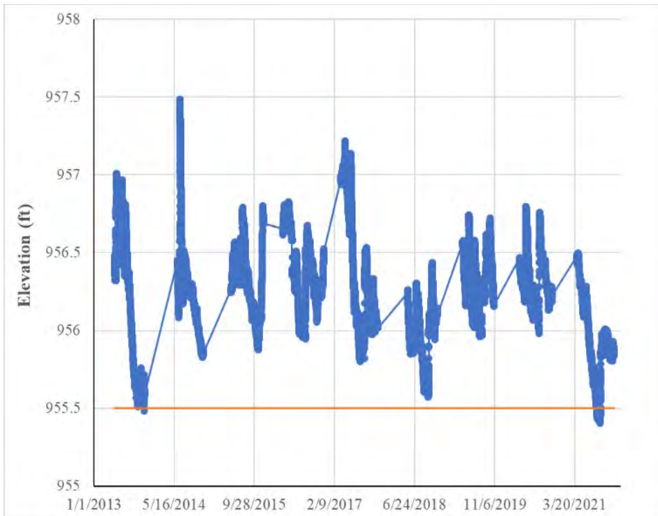


Figure A-1: Water surface elevation on Lake Ann from 2013 to 2021 & Ordinary High-Water Level (955.5 ft).

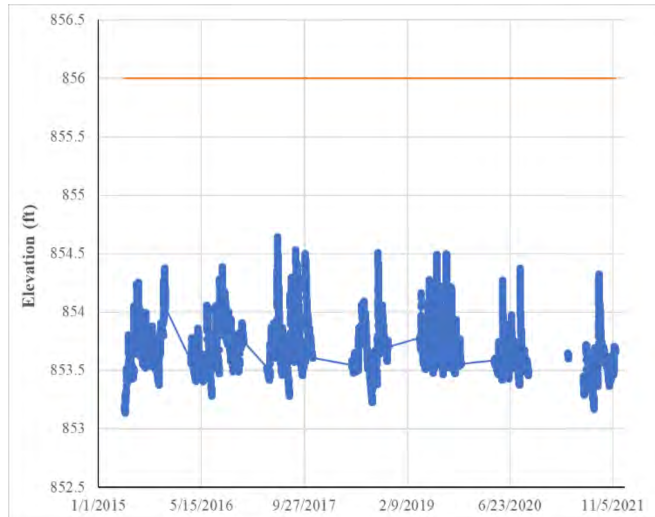


Figure A-2: Water surface elevation on Lake Idlewild from 2015 to 2021 & Ordinary High-Water Level (856 ft).

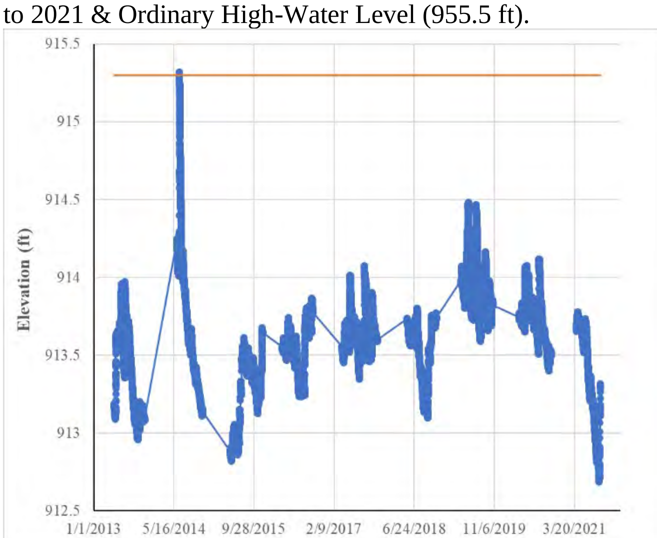


Figure A-3: Water surface elevation on Duck Lake from 2013 to 2021 & Ordinary High-Water Level (915.3 ft).

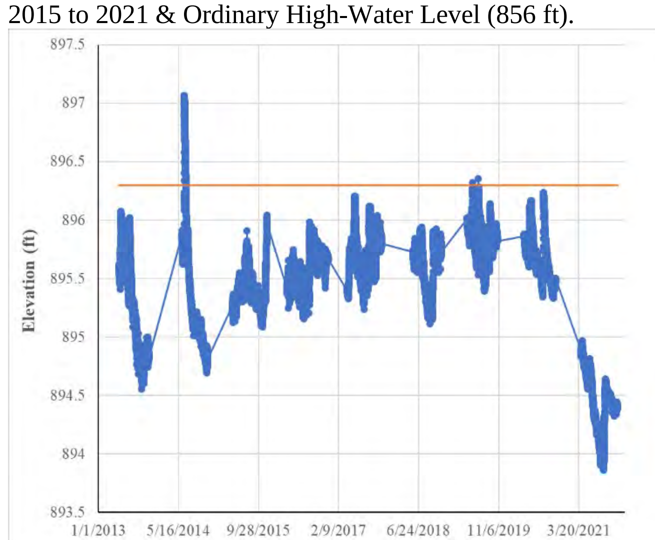


Figure A-4: Water surface elevation on Lotus Lake from 2013 to 2021 & Ordinary High-Water Level (896.3 ft).

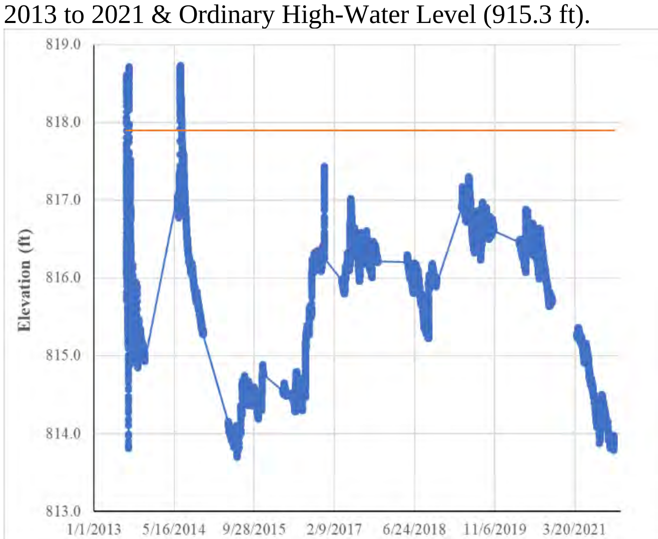


Figure A-5 Water surface elevation on Hyland Lake from 2013 to 2021 & Ordinary High-Water Level (817.9 ft).

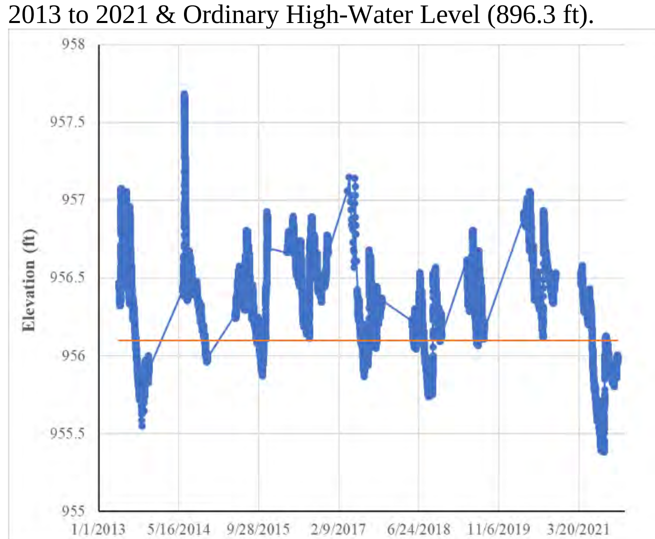


Figure A-6: Water surface elevation on Lake Lucy from 2013 to 2021 & Ordinary High-Water Level (956.1 ft).

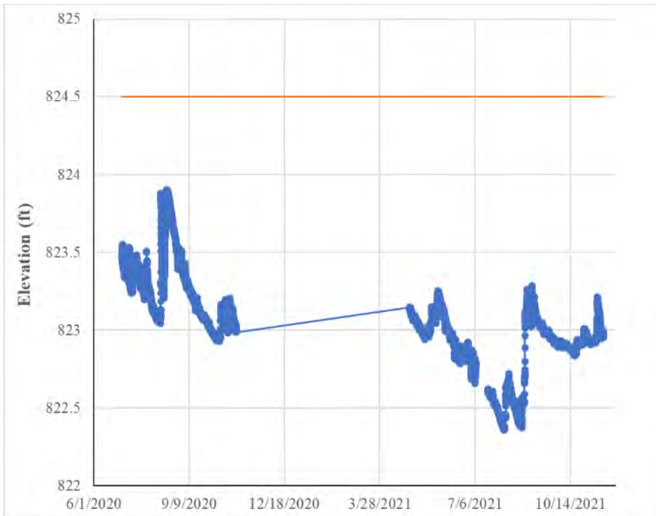


Figure A-7: Water surface elevation on Lake McCoy during 2021 & Ordinary High-Water Level (824.5 ft).

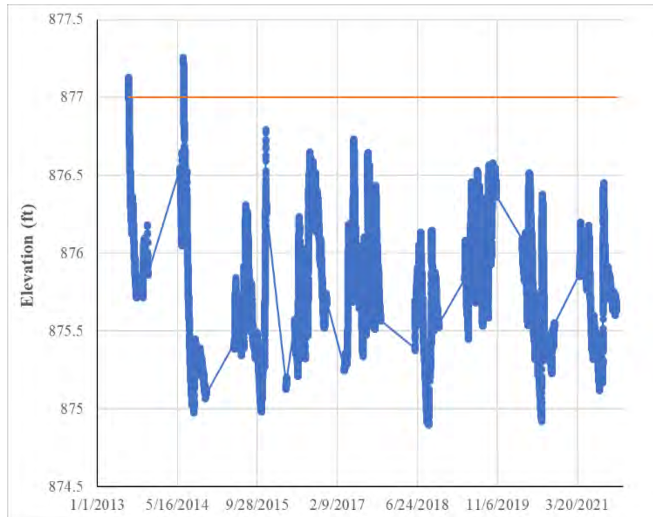


Figure A-8: Water surface elevation on Rice Marsh Lake from 2013 to 2021 & Ordinary High-Water Level (877 ft).

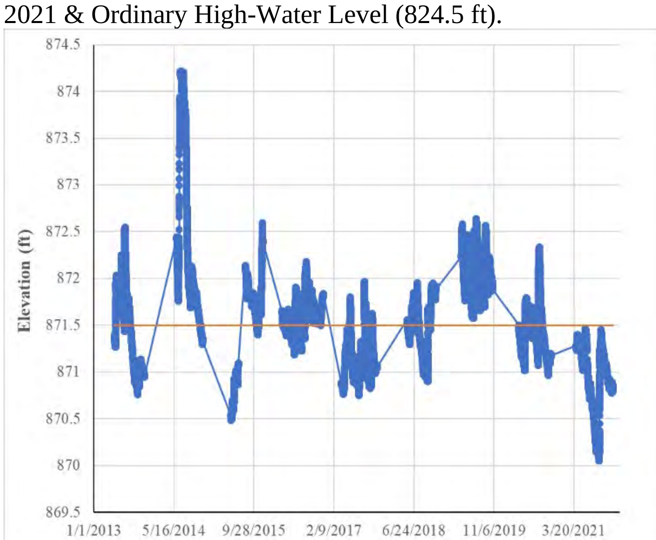


Figure A-9: Mitchell Lake water surface elevation from 2013 to 2021 & Ordinary High-Water Level (815.3 ft).

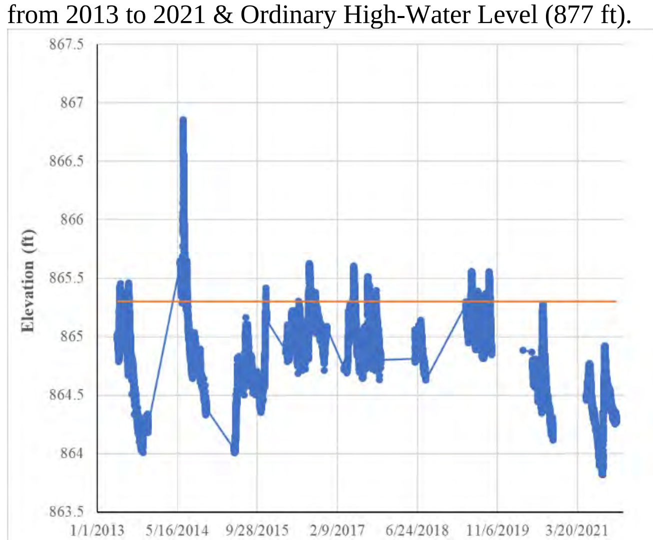


Figure A-10: Water surface elevation on Lake Riley from 2013 to 2021 & Ordinary High-Water Level (865.3 ft).

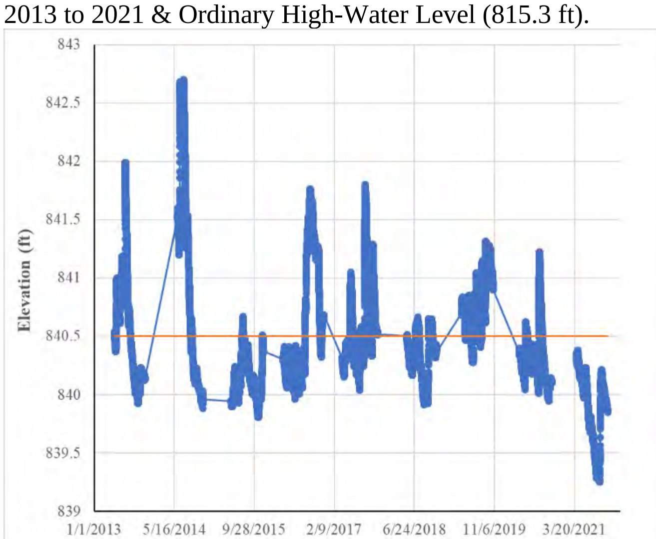


Figure A-11: Red Rock Lake water surface elevation from 2013 to 2021 & Ordinary High-Water Level (840.5 ft).

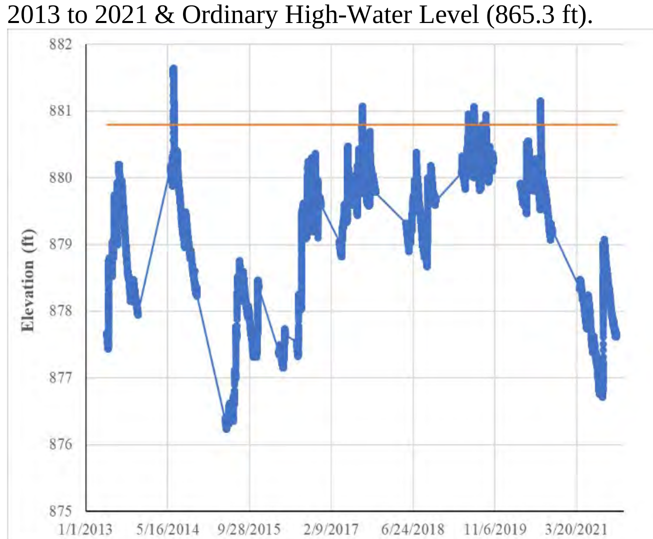


Figure A-12: Water surface elevation on Round Lake from 2013 to 2021 & Ordinary High-Water Level (880.8 ft).

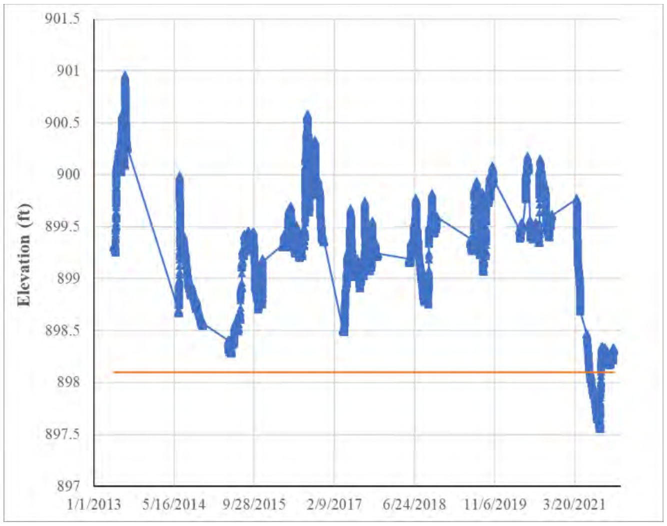


Figure A-13: Water surface elevation on Silver Lake from 2013 to 2021 & Ordinary High-Water Level (898.1 ft).

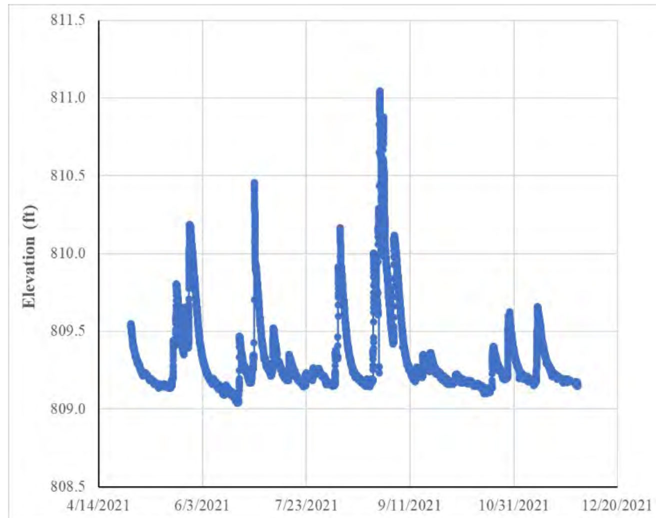


Figure A-14: Water surface elevations on Lake Eden in 2021.

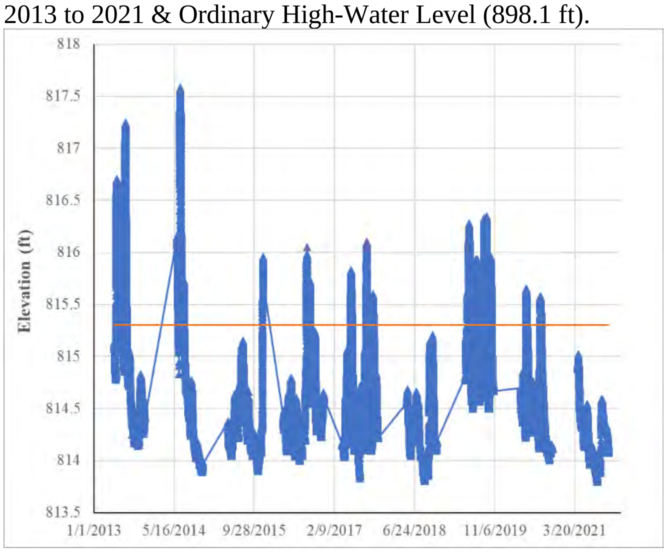


Figure A-15: Water surface elevation on Staring Lake from 2013 to 2021 & Ordinary High-Water Level (815.3 ft).

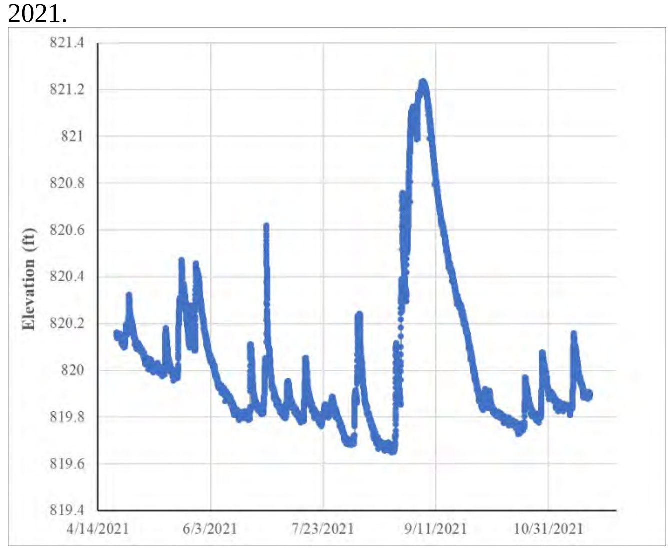


Figure A-16: Water surface elevations on the Upper Purgatory Creek Rec Area in 2021.

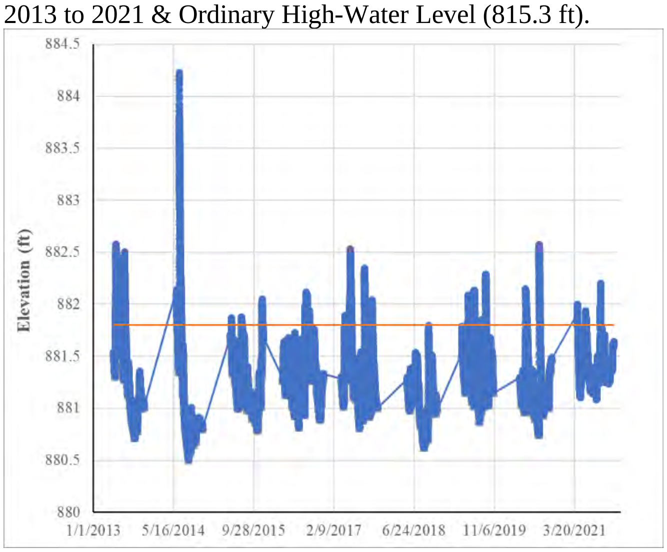


Figure A-17: Water surface elevation on Lake Susan from 2013 to 2021 & Ordinary High-Water Level (881.8 ft).

Exhibit B *2021 Trap Net Summary Data*

Table B1: 2021 **Lake Susan Park Pond** 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	2021 Fish/Net
Black Bullhead		1										1	0.25
Black Crappie	156	35	1	1								193	48.25
Bluegill Sunfish	109	18										127	31.75
Common Carp	12											12	3
Green Sunfish	14	4	3									21	5.25
Golden Shiner	15	13	1									29	7.25
Hybrid Sunfish		1	1									2	0.5
Largemouth Bass				1								1	0.25
Pumpkinseed	2											2	0.5
Yellow Bullhead	2	17	10	1								30	7.5
Yellow Perch	3	1	1									5	1.25

Table B2: 2021 **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	2021 Fish/Net
Black Bullhead	2	9	13	2								26	6.5
Black Crappie	3	18	4		1							26	6.5
Bluegill Sunfish	166	47										213	53.25
Common Carp				2	1	7						10	2.5
Green Sunfish	1											1	0.25
Hybrid Sunfish	8	4										12	3
Largemouth Bass					2							2	0.5
Pumpkinseed	5											5	1.25
Yellow Bullhead		2	7	2	1							12	3
Yellow Perch			1									1	0.25

Table B3: 2021 **Lake Susan** 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	2021 Fish/Net
Black Bullhead			1									1	0.2
Black Crappie		5	1									6	1.2
Bluegill Sunfish	162	179	3									344	68.8
Common Carp						1	1					2	0.4
Hybrid Sunfish	1											1	0.2
Largemouth Bass	1					1						2	0.4
Northern Pike									1			1	0.2
Pumpkinseed	10											10	2
Yellow Bullhead	1		1	9	4							15	0.55
Yellow Perch	1		1									2	0.4

Table B4: 2021 **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	2021 Fish/Net
Black Bullhead	2	1	3									6	1.5
Black Crappie	43	18	9	1								71	17.75
Bluegill Sunfish	76	2										78	19.5
Common Carp			1			12	4					17	4.25
Freshwater Drum						1			1			2	0.5
Golden Shiner	2											2	0.5
Largemouth Bass					1							1	0.25
Northern Pike						1	8	2	1	2		14	3.5
Pumpkinseed	1											1	0.25
Walleye						1						1	0.25
Yellow Bullhead			2	1	1							4	1
Yellow Perch	3											3	0.75

Table B5: 2021 **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	2021 Fish/Net
Black Crappie	5	1										6	1.2
Bluegill Sunfish	208	6										214	42.8
Common Carp	1			1								2	0.4
Green Sunfish	18											18	3.6
Hybrid Sunfish	19											19	3.8
Largemouth Bass				1	1							2	0.4
Pumpkinseed	10											10	2
White Sucker					1							1	0.2
Yellow Bullhead	3	1	8	7								19	3.8
Yellow Perch	3	1										4	0.8

Table B6: 2021 **Lake Riley** 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	2021 Fish/Net
Black Crappie	1	2	1									4	0.8
Bluegill Sunfish	162	172	2									336	67.2
Common Carp		1										1	0.2
Green Sunfish		1										1	0.2
Largemouth Bass	2	1										3	0.6
Northern Pike									1			1	0.2
Pumpkinseed	3	2										5	1
Walleye					1	2						3	0.6
Yellow Bullhead				1								1	0.2

Exhibit C *2021 Zooplankton Summary Data*

Table C1: 2021 **Lake Riley** Zooplankton Counts (#/m²)

DIVISION	TAXON	5/25/2021 #/m2	6/24/2021 #/m2	7/21/2021 #/m2	8/18/2021 #/m2	9/22/2021 #/m2
CLADOCERA	*Bosmina Longirostris*	0	0	0	0	13,222
	Daphnia galeata mendotae	0	47,087	9,417	0	0
	Daphnia pulex	8,174	9,417	0	0	0
	Immature Cladocera	0	0	0	0	0
	CLADOCERA TOTAL	**8,174**	**56,505**	**9,417**	**0**	**13,222**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	32,697	28,252	9,417	7,572	74,925
	Nauplii	32,697	37,670	37,670	45,430	101,370
	Calanoida	8,174	0	14,126	0	83,740
	COPEPODA TOTAL	**73,569**	**65,922**	**61,214**	**53,001**	**260,035**
ROTIFERA	*Keratella sp.*	89918	75340	4709	37858	255628
	Kellicottia sp.	49046	0	0	0	4407
	Polyarthra sp.	8174	0	9417	98431	96962
	Conochilus sp.	0	47087	0	7572	0
	Monostyla sp.	0	0	0	0	0
	ROTIFERA TOTAL	**147,138**	**122,427**	**14,126**	**143,861**	**356,997**
	TOTALS	**228,882**	**244,854**	**84,757**	**196,863**	**630,254**

Table C2: 2021 **Staring Lake** Zooplankton Counts (#/m²)

DIVISION	TAXON	5/20/2021 #/m2	6/22/2021 #/m2	7/20/2021 #/m2	8/17/2021 #/m2	9/21/2021 #/m2
CLADOCERA	*Bosmina longirostris*	358,316	8,852	4,445	185,637	0
	Ceriodaphnia sp.	0	17,705	26,670	0	0
	Chydorus sphaericus	17,479	0	0	8,438	6,592
	Daphnia galeata mendotae	174,788	8,852	0	0	6,592
	Daphnia retrocurva	0	0	0	0	0
	Diaphanosoma leuchtenbergianum	52,436	318,687	35,560	33,752	0
	CLADOCERA TOTAL	**603,019**	**354,097**	**66,676**	**227,827**	**13,184**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	131,091	17,705	44,450	16,876	131,845
	Nauplii	760,329	168,196	186,692	109,695	362,572
	Calanoida	113,612	97,377	191,137	42,190	65,922
	COPEPODA TOTAL	**1,005,032**	**283,277**	**422,279**	**168,761**	**560,339**
ROTIFERA	*Asplanchna priodonta*	0	44,262	0	16,876	0
	Brachionus sp.	0	0	4,445	0	0
	Filinia longiseta	0	0	4,445	8,438	0
	Monostyla sp.	0	8,852	0	0	65,922
	Keratella cochlearis	568,062	17,705	337,823	126,571	382,349
	Kellicottia sp.	0	0	8,890	0	0
	Polyarthra sp.	78,655	17,705	31,115	16,876	72,514
	Trichocerca sp.	0	0	4,445	0	0
	ROTIFERA TOTAL	**646,716**	**88,524**	**391,164**	**168,761**	**520,786**
	TOTALS	**2,254,767**	**725,898**	**880,119**	**565,349**	**1,094,310**

Table C3: 2021 **Lotus Lake** Zooplankton Counts (#/m²)

DIVISION	TAXON	5/25/2021 #/m2	6/24/2021 #/m2	7/21/2021 #/m2	8/18/2021 #/m2	9/22/2021 #/m2
CLADOCERA	*Bosmina longirostris*	0	9,041	4,709	15,369	113,537
	Chydorus sphaericus	16,499	4,520	4,709	7,685	20,643
	Daphnia galeata mendotae	247,491	63,285	4,709	0	0
	Daphnia retrocurva	0	0	0	23,054	175,466
	Diaphanosoma leuchtenbergianum	0	0	4,709	99,900	30,965
	CLADOCERA TOTAL	**263,990**	**76,847**	**18,835**	**146,008**	**340,611**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	32,999	22,602	23,544	84,531	61,929
	Nauplii	329,988	94,928	136,553	199,801	144,502
	Calanoida	90,747	81,367	28,252	268,963	165,145
	COPEPODA TOTAL	**453,733**	**198,897**	**188,349**	**553,295**	**371,576**
ROTIFERA	*Asplanchna sp.*	16,499	0	0	0	0
	Filinia longiseta	0	0	0	7,685	41,286
	Keratella sp.	412,485	13,561	14,126	284,332	1,806,270
	Kellicottia sp.	107,246	0	4,709	238,224	20,643
	Polyarthra sp.	0	9,041	9,417	7,685	10,322
	Conochilus sp.	0	158,213	56,505	15,369	0
	UID Rot	0	0	0	0	939,260
	ROTIFERA TOTAL	**536,230**	**180,815**	**84,757**	**553,295**	**2,817,781**
	TOTALS	**1,253,954**	**456,559**	**291,941**	**1,252,598**	**3,529,968**

Table C4: 2021 **Lake Susan** Zooplankton Counts (#/m²)

DIVISION	TAXON	5/20/2021 #/m2	6/22/2021 #/m2	7/20/2021 #/m2	8/17/2021 #/m2	9/21/2021 #/m2
CLADOCERA	*Bosmina longirostris*	35,259	0	8,702	34,204	8,476
	Ceriodaphnia sp.	0	0	0	0	0
	Chydorus sphaericus	0	0	0	0	119,187
	Daphnia galeata mendotae	70,518	24,523	0	8,551	76,960
	Daphnia retrocurva	0	0	0	8,551	60,121
	Diaphanosoma leuchtenbergianum	0	0	52,210	17,102	0
	CLADOCERA TOTAL	**105,777**	**24,523**	**60,912**	**68,408**	**264,744**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	52,888	49,046	26,105	8,551	78,316
	Nauplii	246,813	147,138	156,631	179,572	174,788
	Calanoida	11,753	49,046	60,912	0	43,697
	COPEPODA TOTAL	**311,454**	**245,231**	**243,649**	**188,123**	**296,801**
ROTIFERA	*Asplanchna priodonta*	41,135	0	0	0	0
	Filinia longiseta	0	0	34,807	0	0
	Keratella sp.	475,996	65,395	321,964	8,551	1,517,719
	Keratella quadrata	0	0	0	0	0
	Kellicottia sp.	41,135	0	0	0	0
	Polyarthra sp.	193,924	0	0	0	17,931
	Conochilus sp.	0	0	0	0	0
	UID Rot	0	0	0	0	0
	ROTIFERA TOTAL	**752,192**	**65,395**	**356,771**	**8,551**	**1,535,650**
	TOTALS	**1,169,423**	**335,149**	**661,332**	**265,083**	**2,097,194**

Table C5: 2021 **Rice Marsh Lake** Zooplankton Counts (#/m²)

DIVISION	TAXON	5/26/2021 #/m2	6/21/2021 #/m2	7/19/2021 #/m2	8/16/2021 #/m2	9/20/2021 #/m2
CLADOCERA	*Bosmina longirostris*	8,777	0	8,777	156,707	12,582
	Ceriodaphnia sp.	0	83,627	8,777	211,554	37,745
	Chydorus sphaericus	0	20,907	0	227,225	56,618
	Acroperus sp.	0	0	0	7,835	0
	Diaphanosoma leuchtenbergianum	0	0	0	39,177	0
	CLADOCERA TOTAL	**8,777**	**104,534**	**17,554**	**642,497**	**106,945**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	122,879	16,725	8,777	125,365	31,454
	Nauplii	280,866	108,715	236,981	477,955	390,034
	Calanoida	78,994	0	35,108	7,835	0
	COPEPODA TOTAL	**482,739**	**125,441**	**280,866**	**611,156**	**421,488**
ROTIFERA	*Asplanchna priodonta*	8,777	4,181	52,662	0	6,291
	Lecane sp.	0	0	8,777	7,835	0
	Lepadella sp.	0	4,181	0	0	0
	Monostyla sp.	0	16,725	0	15,671	0
	Keratella cochlearis	87,771	137,985	17,554	7,835	0
	Platyias sp.	0	0	0	47,012	0
	Polyarthra vulgaris	8,777	25,088	52,662	109,695	264,216
	ROTIFERA TOTAL	**105,325**	**188,161**	**131,656**	**188,048**	**270,507**
	TOTALS	**596,841**	**418,135**	**430,077**	**1,441,701**	**798,940**

Exhibit D *2021 Phytoplankton Summary Data*

Table D1: 2021 **Lotus Lake** Phytoplankton #/mL

Class	**5/25/2021 #/mL**	**6/24/2021 #/mL**	**7/21/2021 #/mL**	**8/18/2021 #/mL**	**9/22/2021 #/mL**
Chlorophyta	804	2,470	7,179	2,647	1,264
Chrysophyta	0	0	0	0	0
Cyanophyta	1,149	4,480	34,404	56,509	24,985
Bacillariophyta	0	57	287	102	0
Cryptophyta	402	632	3,848	611	3,159
Euglenophyta	0	0	0	0	0
Pyrrophyta	115	0	0	102	287
Total	2,470	7,639	45,719	59,971	29,694

Table D2: 2021 **Staring Lake** Phytoplankton #/mL

Class	**5/20/2021 #/mL**	**6/22/2021 #/mL**	**7/20/2021 #/mL**	**8/17/2021 #/mL**	**9/17/2021 #/mL**
Chlorophyta	459	3,676	2,355	379	2,744
Chrysophyta	0	0	0	0	0
Cyanophyta	1,666	2,297	34,634	63,729	43,214
Bacillariophyta	57	574	57	0	943
Cryptophyta	4,308	2,814	287	1,514	3,773
Euglenophyta	0	0	0	0	0
Pyrrhophyta	0	0	0	0	86
Total	6,490	9,362	37,333	65,622	50,759

Table D3: 2021 Lake **Riley** Phytoplankton #/mL

Class	**5/25/2021 #/mL**	**6/24/2021 #/mL**	**7/21/2021 #/mL**	**8/18/2021 #/mL**	**9/22/2021 #/mL**
Chlorophyta	5,456	402	2,929	2,757	1,838
Chrysophyta	0	57	0	0	0
Cyanophyta	862	2,297	4,135	1,608	1,551
Bacillariophyta	0	0	57	0	0
Cryptophyta	517	115	862	517	1,436
Euglenophyta	0	0	0	0	0
Pyrrhophyta	0	0	0	0	0
Total	6,835	2,872	7,984	4,882	4,825

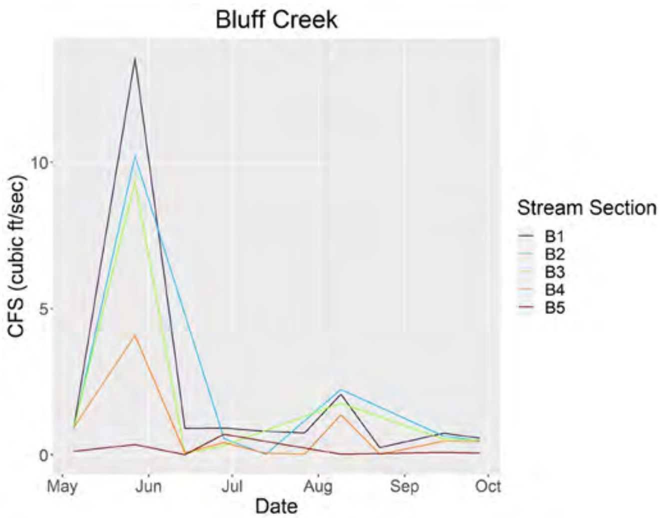
Table D4: 2021 **Rice Marsh Lake** Phytoplankton #/mL

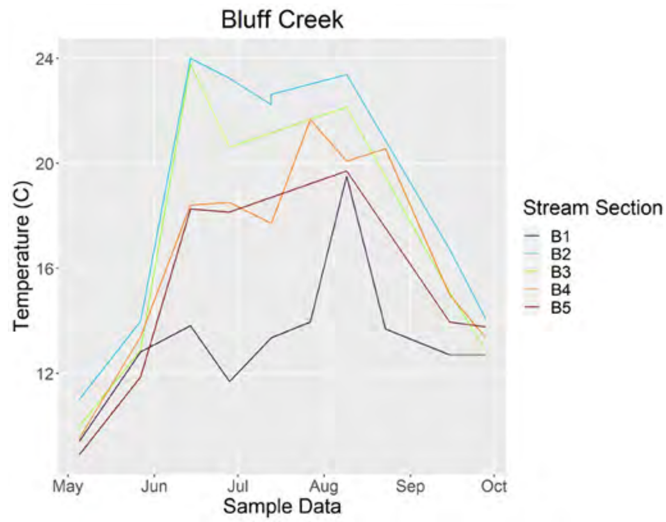
	5/26/2021	6/21/2021	7/19/2021	8/16/2021	9/20/2021
Class	**#/mL**	**#/mL**	**#/mL**	**#/mL**	**#/mL**
Chlorophyta	11,257	1,551	1,264	3,848	2,699
Chrysophyta	0	0	0	0	0
Cyanophyta	1,551	1,723	689	287	632
Bacillariophyta	57	459	0	57	0
Cryptophyta	1,723	1,321	1,723	3,733	3,963
Euglenophyta	0	0	0	0	0
Pyrrophyta	0	632	172	0	0
Total	14,589	5,686	3,848	7,926	7,294

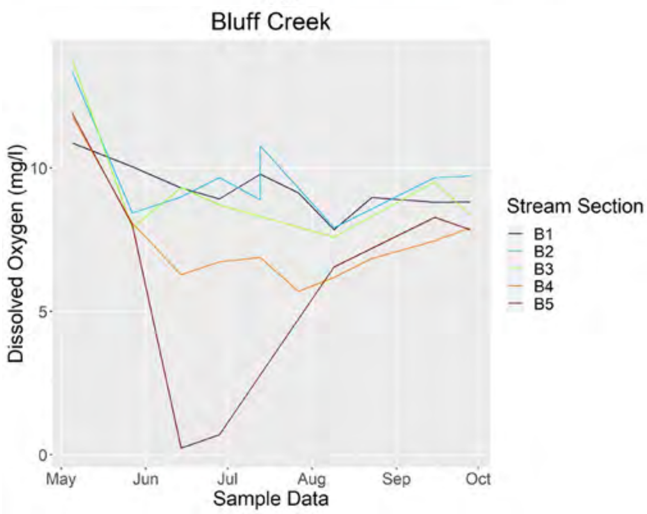
Table D4: 2021 **Lake Susan** Phytoplankton #/mL

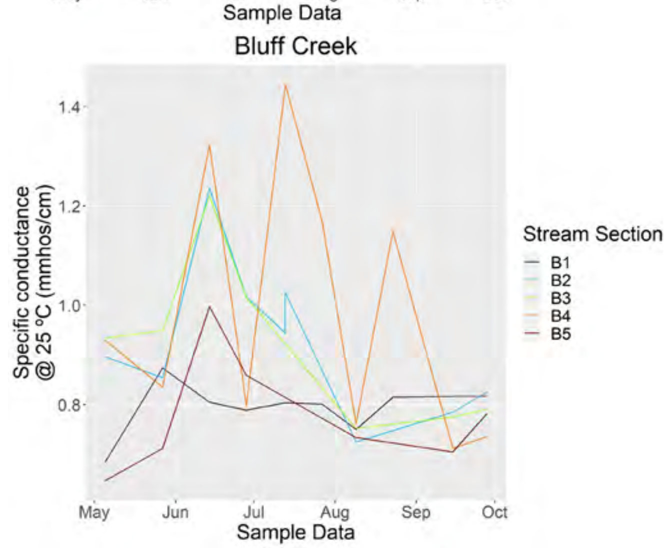
	5/20/2021	6/22/2021	7/20/2021	8/17/2021	9/21/2021
Class	**#/mL**	**#/mL**	**#/mL**	**#/mL**	**#/mL**
Chlorophyta	24,295	5,203	8,041	5,744	1,378
Chrysophyta	0	0	0	0	0
Cyanophyta	57	102,895	95,343	325,087	4,767
Bacillariophyta	57	0	4,595	0	7,639
Cryptophyta	1,608	963	2,297	0	402
Euglenophyta	0	0	0	0	0
Pyrrhophyta	0	385	1,149	0	804
Total	26,018	109,447	111,425	330,830	14,991

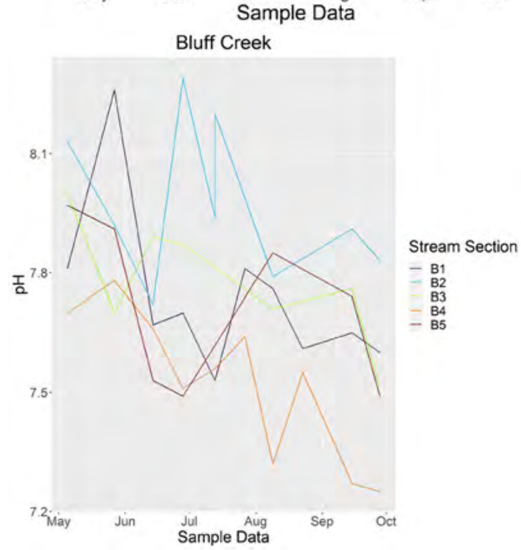
Exhibit E *2021 Creek Seasonal Sonde & Flow Data*

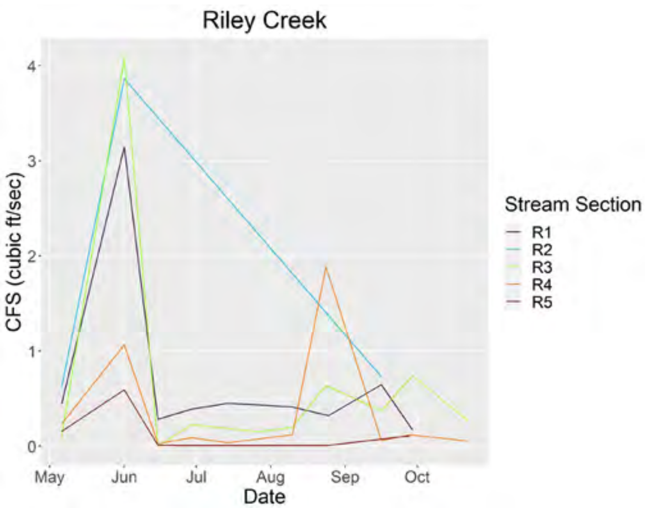


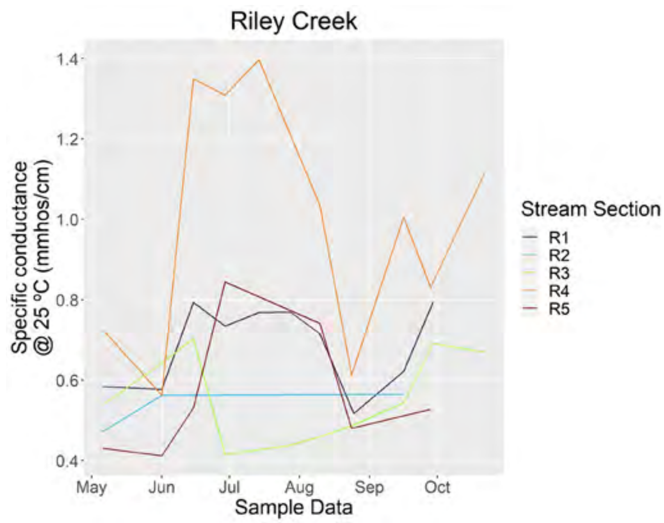


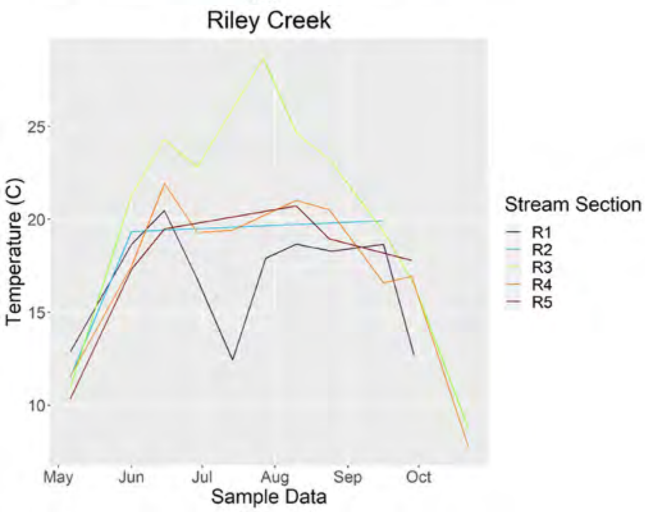


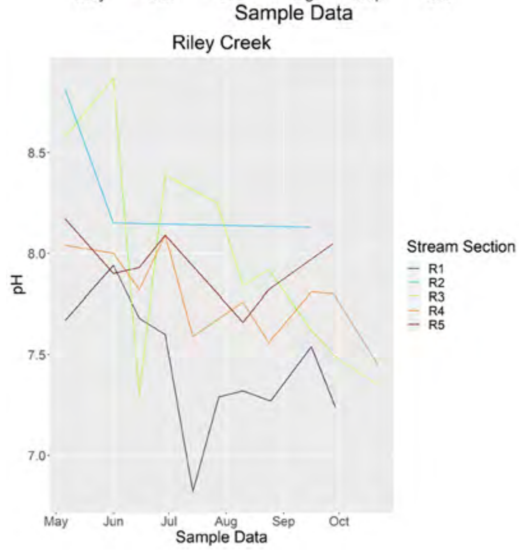


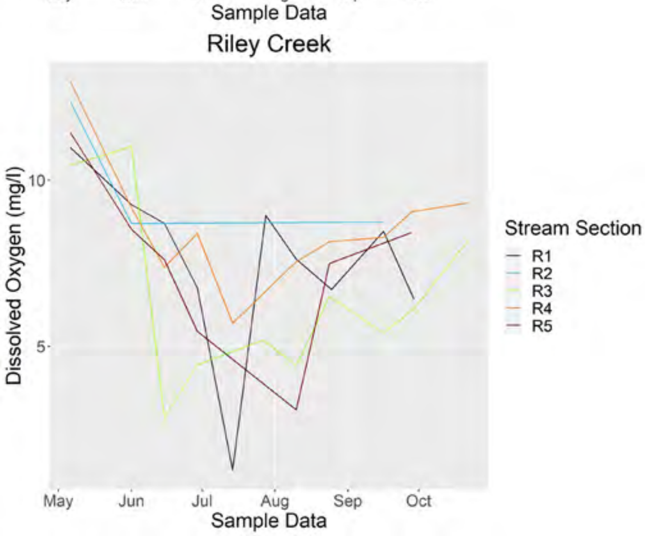


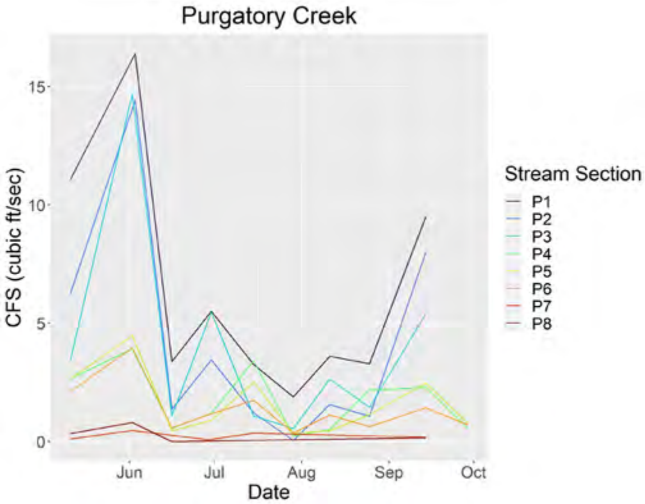

Riley Creek
CFS (cubic ft/sec)
0
1
2
3
4
May
Jun
Jul
Aug
Sep
Oct
Date
Stream Section
R1
R2
R3
R4
R5

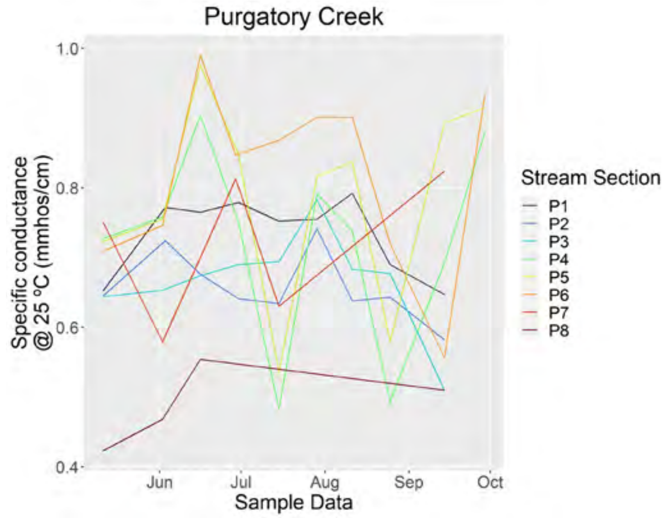

Riley Creek
Specific conductance @ 25 °C (mmhos/cm)
0.4
0.6
0.8
1.0
1.2
1.4
May
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
R1
R2
R3
R4
R5

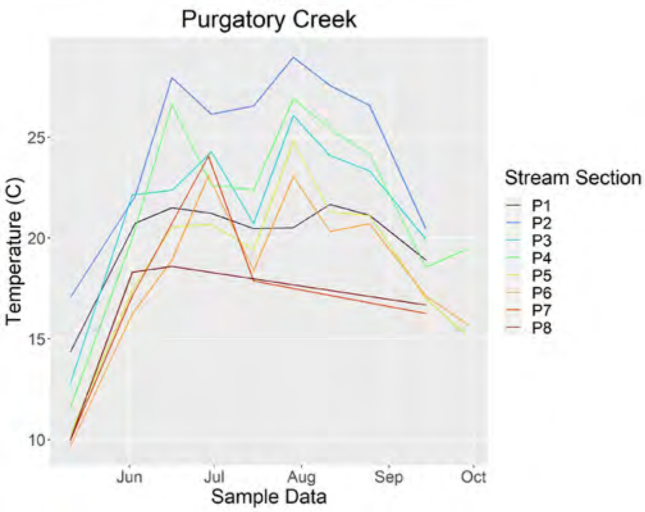

Riley Creek
Temperature (C)
10
15
20
25
May
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
R1
R2
R3
R4
R5

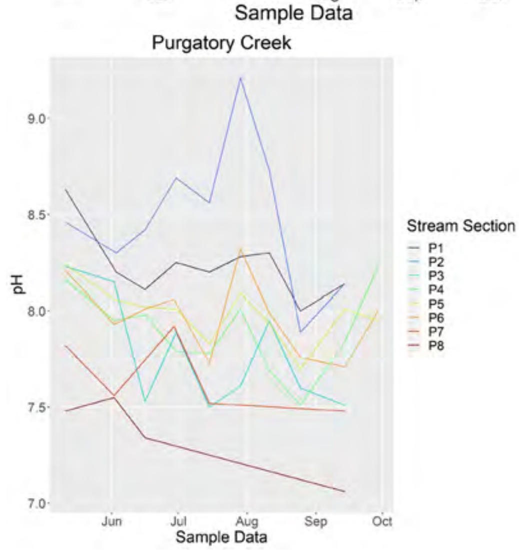

Riley Creek
pH
7.0
7.5
8.0
8.5
May
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
R1
R2
R3
R4
R5


Riley Creek
Dissolved Oxygen (mg/l)
5
10
May
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
R1
R2
R3
R4
R5


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


Purgatory Creek
Specific conductance @ 25 °C (mmhos/cm)
0.4
0.6
0.8
1.0
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8


Purgatory Creek
Temperature (C)
10
15
20
25
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8


Purgatory Creek
pH
7.0
7.5
8.0
8.5
9.0
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8

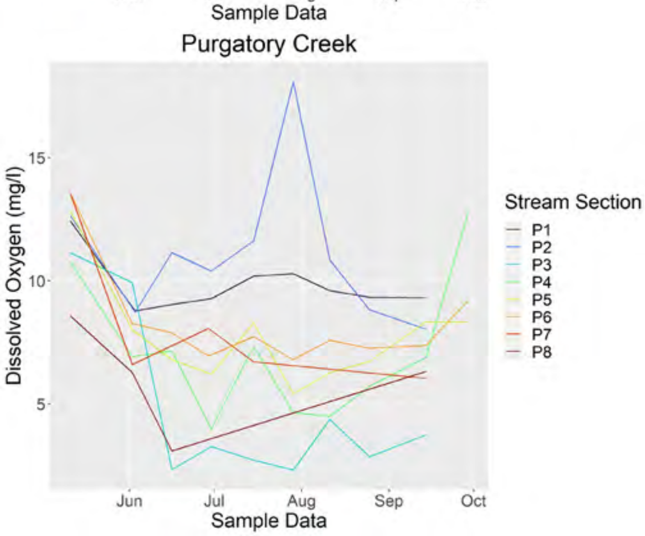

Purgatory Creek
Dissolved Oxygen (mg/l)
5
10
15
Jun
Jul
Aug
Sep
Oct
Sample Data
Stream Section
P1
P2
P3
P4
P5
P6
P7
P8

Exhibit F *2021 Lake Nutrient Data Summary Table*

Figure F-1. Shows the average values for all nutrients analyzed in lakes during the growing season (June-September) 2021. Each lake is separated by top, middle, and bottom and all values are in mg/l.

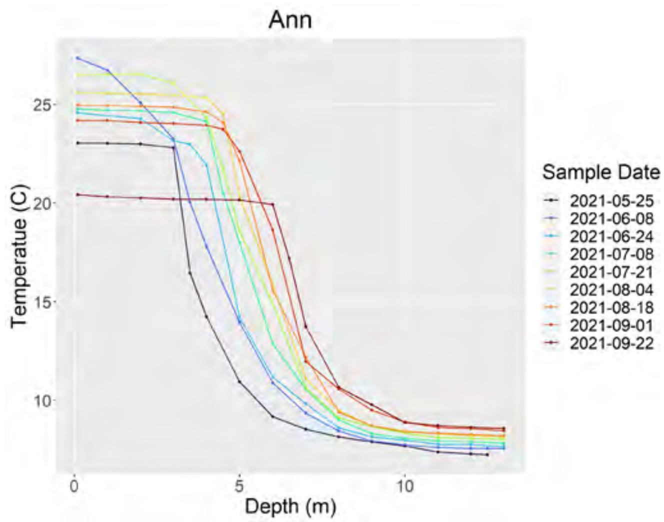
Lake	Location	Total ALK	Ca	Cl-	Chl a	Fe	NH3	NO2/ NO3	TKN	OP	TP	TSS
Ann	Top	157	33.3	41.93	0.008		0.02	3.6	1.093	0.006	0.023	
Ann	Middle									0.005	0.021	
Ann	Bottom		48.2	40.45			1.655	0.03	2.843	0.039	0.405	
Duck	Top	82.45	15.5	51.33	0.015		0.02	0.03	0.855	0.005	0.04	
Duck	Middle		15.2	50.93			0.02	0.03	0.675	0.005	0.034	
Hyland	Top				0.032				1.259	0.007	0.058	
Idlewild	Top	64	16.3	232	0.005		0.025	0.03	0.595	0.008	0.035	
Idlewild	Bottom		16.3	217.3			0.04	0.033	0.405	0.007	0.057	
Lotus	Top	163.3	39.5	60.18	0.025		0.023	1.913	1.047	0.005	0.029	
Lotus	Middle									0.005	0.029	
Lotus	Bottom		55.7	60.18			3.458	0.03	4.807	0.052	0.155	
Lucy	Top	183.8	44.1	48.35	0.014		0.023	0.03	1.05	0.006	0.036	
Lucy	Middle									0.006	0.036	
Lucy	Bottom		48.8	46.5			1.693	0.03	3.47	0.012	0.368	
McCoy	Top	127.8		87.37	0.017	3.032	1.362	0.05	4.367	0.063	0.372	122.4
Mitchell	Top	106.1		103.8	0.034	0.186	0.246	0.05	1.763	0.005	0.067	8.714
Mitchell	Middle				0.032					0.005	0.073	
Mitchell	Bottom				0.02					0.008	0.201	
Red Rock	Top	121.8		103.5	0.028	0.162	0.266	0.05	1.525	0.005	0.051	7.143
Red Rock	Middle				0.024					0.006	0.064	
Red Rock	Bottom				0.015					0.006	0.111	
Rice Marsh	Top	105.8	38.6	150.3	0.011		0.025	0.03	0.945	0.007	0.037	
Rice Marsh	Middle		39.1	157.5			0.028	0.03	0.785	0.007	0.04	
Riley	Top	177.8	34.9	103.2	0.002		0.028	0.033	0.683	0.004	0.016	
Riley	Middle									0.006	0.015	
Riley	Bottom		44.1	100.2			0.84	0.035	1.298	0.005	0.02	
Round	Top	48		71.08	0.01	0.042	0.199	0.05	1.213	0.005	0.03	3.857
Round	Middle				0.009					0.005	0.031	
Round	Bottom				0.016					0.005	0.064	
Silver	Top	111	20.8	49.2	0.017		0.085	0.03	1.165	0.006	0.046	
Silver	Bottom		22.2	49.65			0.06	0.03	1.02	0.006	0.048	
Staring	Top	124.8	25.7	134.8	0.022		0.04	0.03	1.077	0.006	0.042	
Staring	Bottom		24.9	136.5			0.37	0.03	1.27	0.016	0.086	
Susan	Top	122.8	27.1	143	0.069		0.2	0.03	1.507	0.008	0.072	
Susan	Middle									0.013	0.118	
Susan	Bottom			142.3			1.737	0.03	3.67	0.01	0.372	

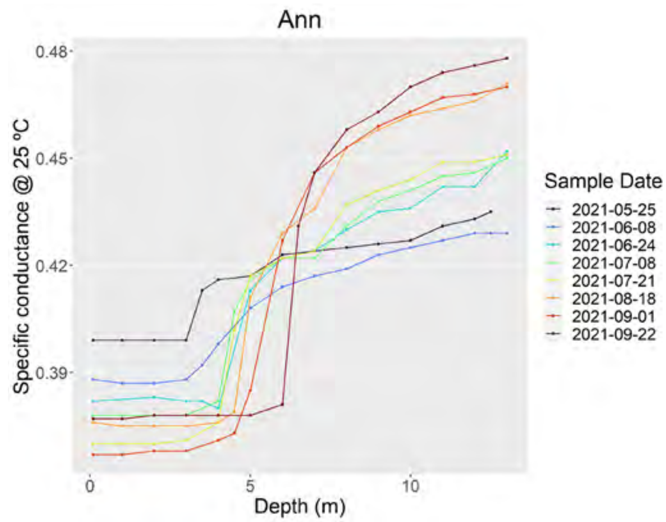
Exhibit G *2021 Stream Summary Table*

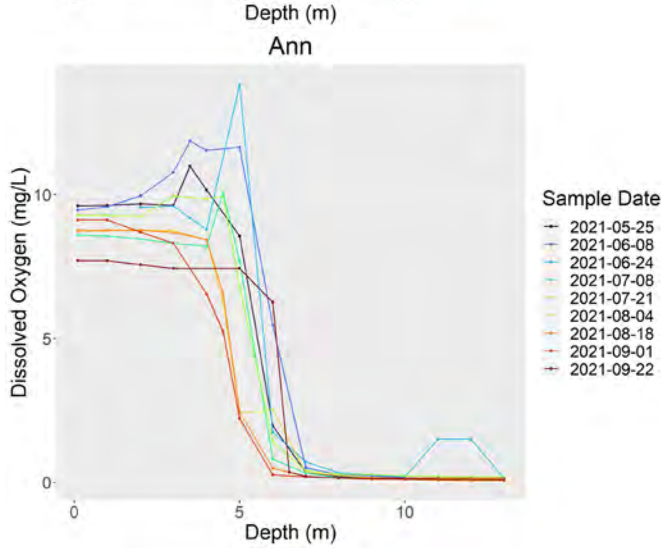
Figure G-1. The 2021 average values for all lab water quality parameters sampled for creeks by each major stream reach specified. Chlorophyll a (Chl a), Orthophosphate (OP) and Total Phosphorus (TP) are the averages of all values collected from May through September. Total suspended solids (TSS) are the average of values collected from April through September. Chloride (Cl-) is the average of all values collect year-round.

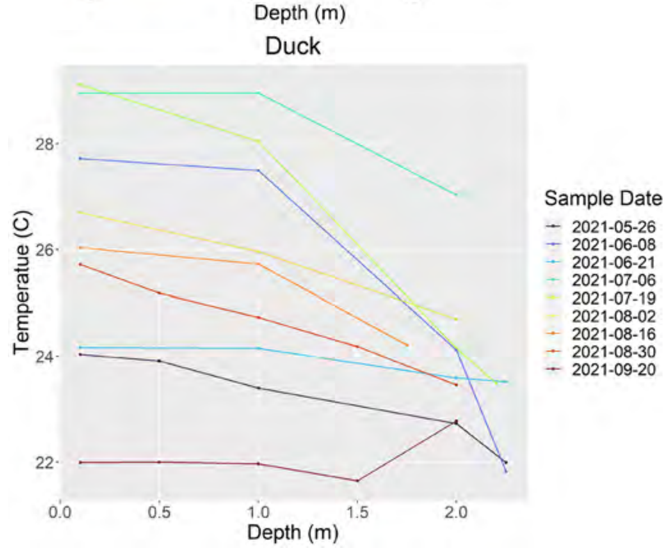
Stream	Stream Reach	Cl- (mg/l)	Chl a (ug/l)	OP (mg/l)	TP (mg/l)	TSS (mg/l)
Bluff	B5	86.6	6.5	0.111	0.232	25.3
Bluff	B4	218.8	4.7	0.074	0.180	13.6
Bluff	B3	184.7	4.4	0.081	0.177	20.9
Bluff	B2	175.5	12.5	0.080	0.169	20.5
Bluff	B1	92.8	2.7	0.045	0.074	27.2
Purgatory	P8	63.0	6.7	0.034	0.091	18.2
Purgatory	P7	100.7	4.0	0.057	0.110	9.1
Purgatory	P6	128.0	4.2	0.062	0.139	10.2
Purgatory	P5	124.1	3.6	0.102	0.171	11.3
Purgatory	P4	112.5	25.3	0.084	0.200	16.3
Purgatory	P3	146.3	3.5	0.026	0.062	6.1
Purgatory	P2	140.3	6.5	0.018	0.057	3.9
Purgatory	P1	116.7	9.6	0.032	0.059	14.2
Riley	R5	41.3	2.9	0.049	0.108	18.1
Riley	R4	232.2	6.6	0.062	0.141	12.2
Riley	R3	144.3	4.9	0.050	0.128	13.4
Riley	R2	109.0	4.5	0.011	0.020	2.3
Riley	R1	52.7	3.5	0.026	0.080	9.0

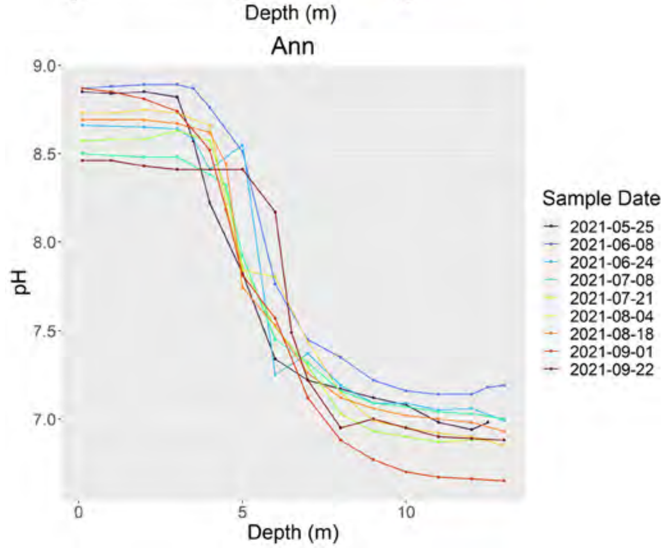
Exhibit H *2021 Lake Profile Data*

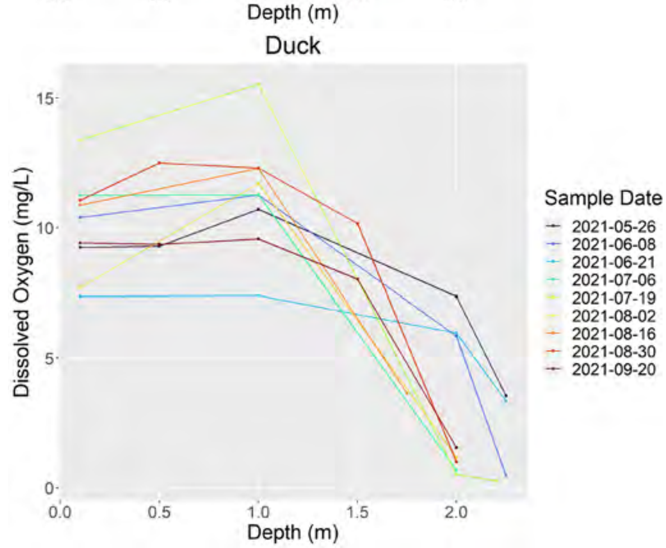


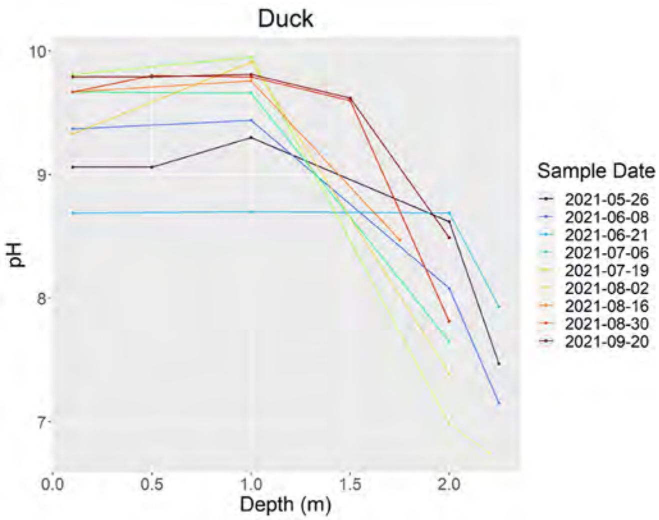


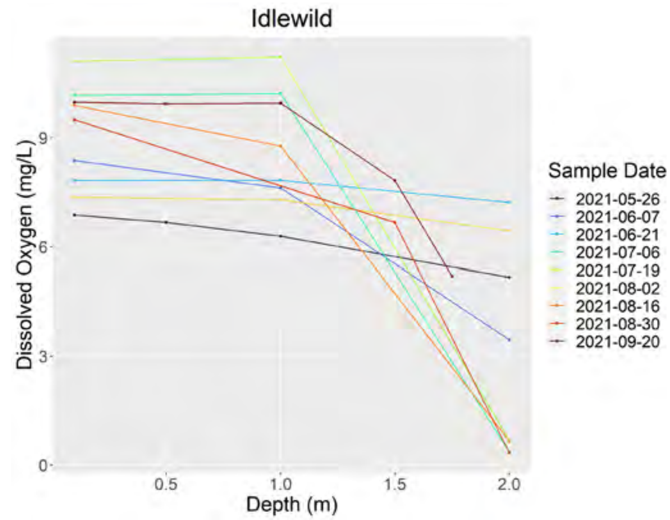


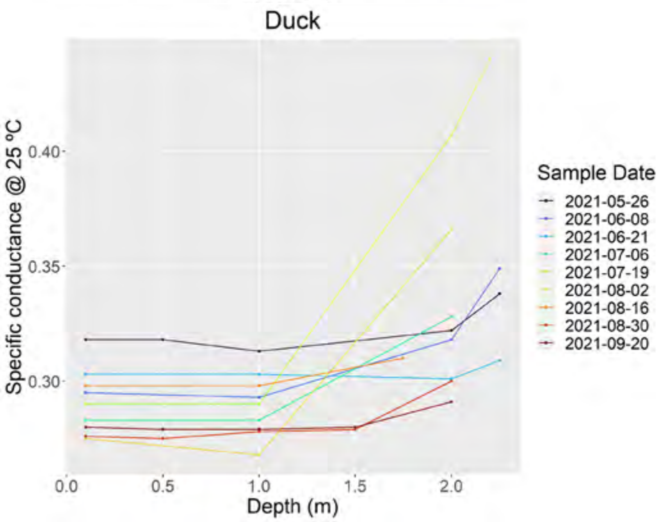


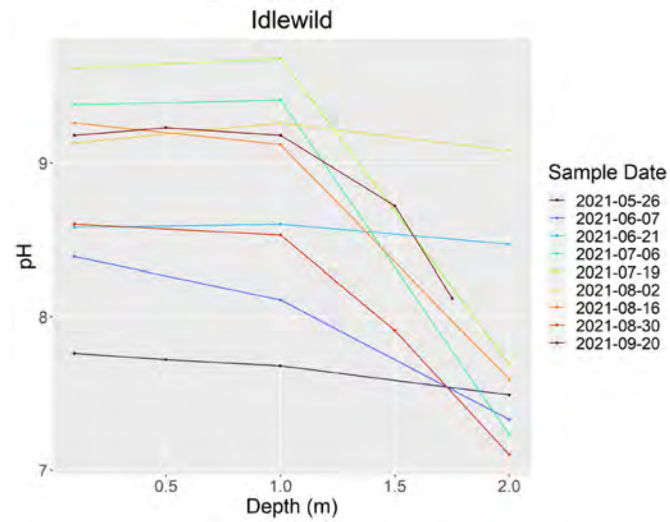


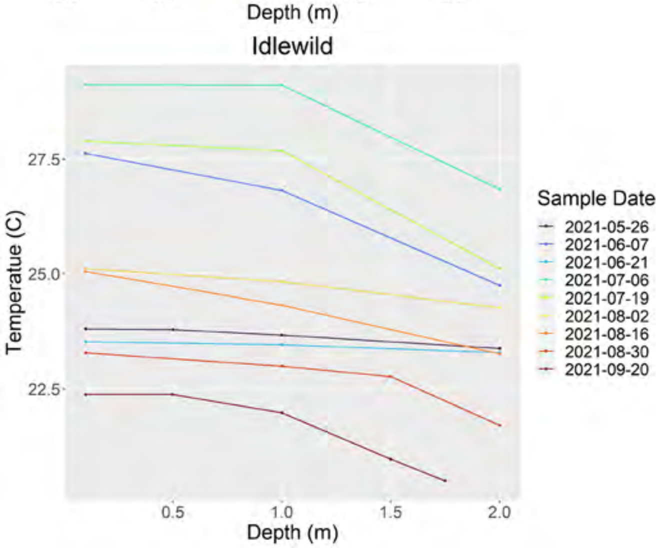


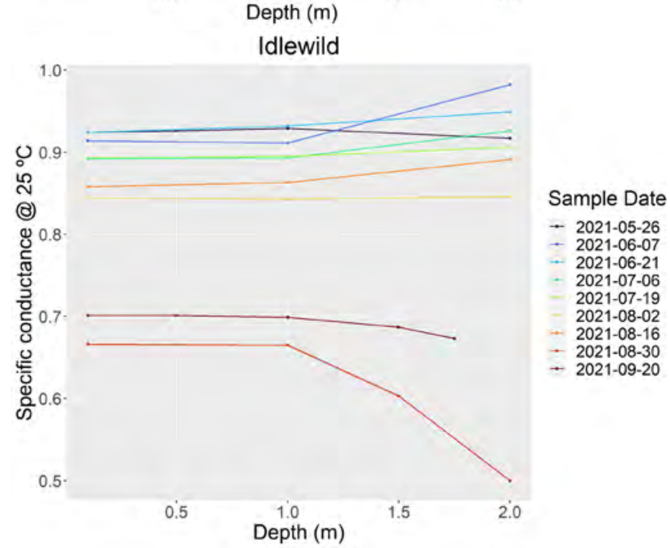

Duck
pH
10
9
8
7
0.0 0.5 1.0 1.5 2.0
Depth (m)
Sample Date
2021-05-26
2021-06-08
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

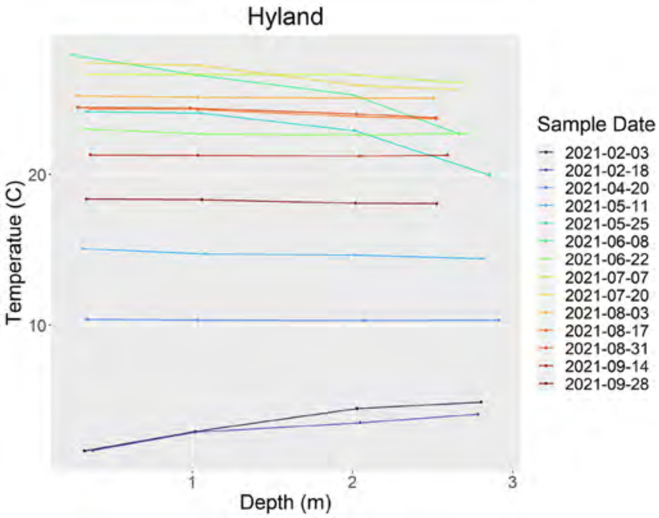

Idlewild
Dissolved Oxygen (mg/L)
9
6
3
0
0.5 1.0 1.5 2.0
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

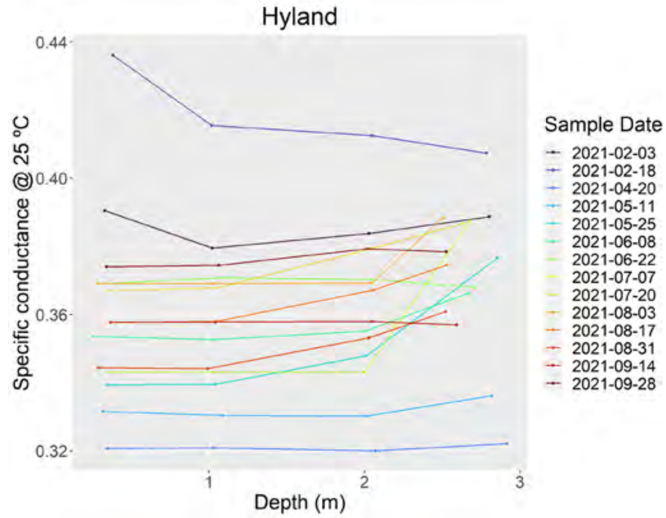

Duck
Specific conductance @ 25 °C
0.40
0.35
0.30
0.0 0.5 1.0 1.5 2.0
Depth (m)
Sample Date
2021-05-26
2021-06-08
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

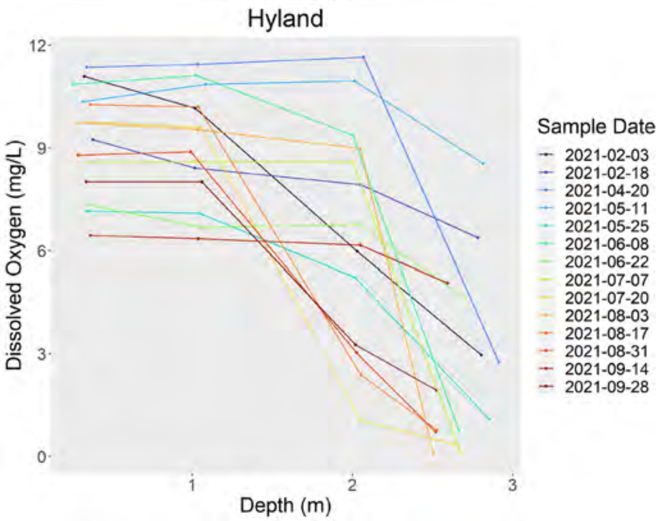

Idlewild
pH
9
8
7
0.5 1.0 1.5 2.0
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

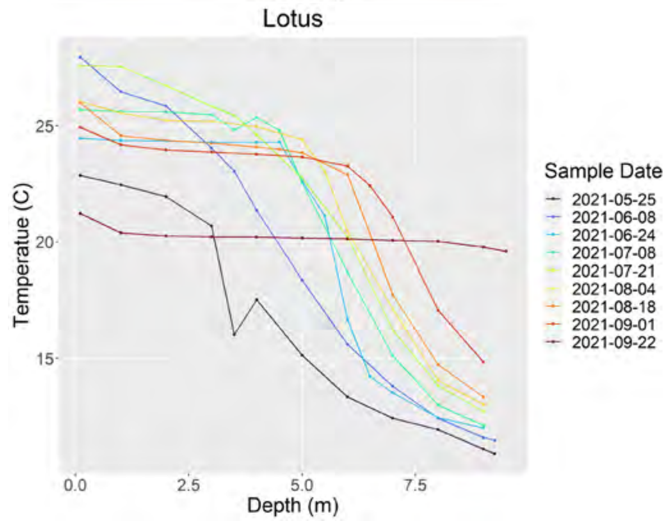

Idlewild
Temperatue (C)
27.5
25.0
22.5
0.5 1.0 1.5 2.0
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

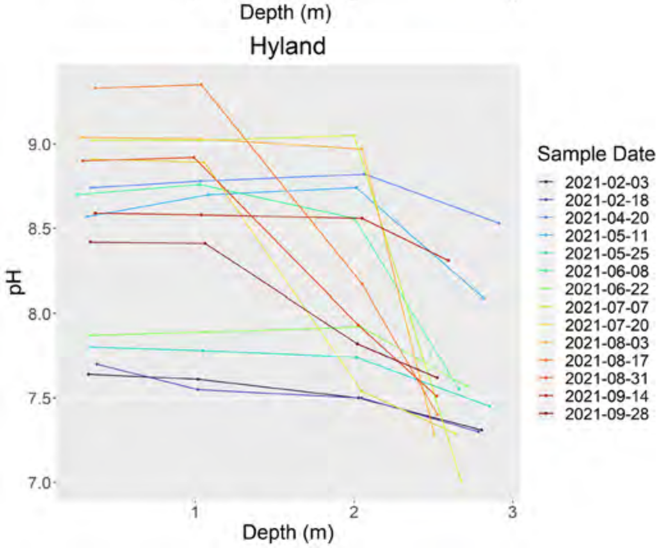

Idlewild
Specific conductance @ 25 °C
1.0
0.9
0.8
0.7
0.6
0.5
0.5 1.0 1.5 2.0
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

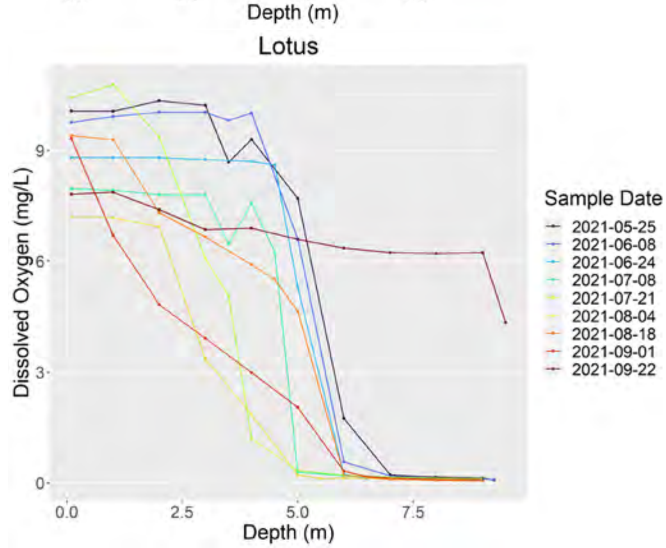

Hyland
Temperatue (C)
10
20
Depth (m)
1
2
3
Sample Date
2021-02-03
2021-02-18
2021-04-20
2021-05-11
2021-05-25
2021-06-08
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-14
2021-09-28

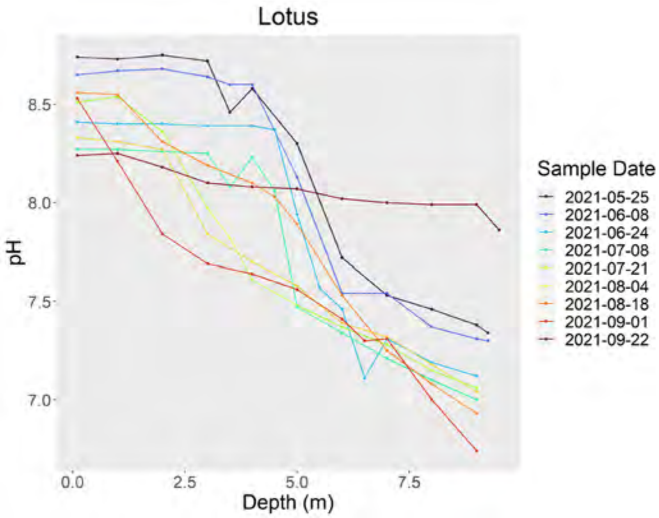

Hyland
Specific conductance @ 25 °C
0.32
0.36
0.40
0.44
Depth (m)
1
2
3
Sample Date
2021-02-03
2021-02-18
2021-04-20
2021-05-11
2021-05-25
2021-06-08
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-14
2021-09-28

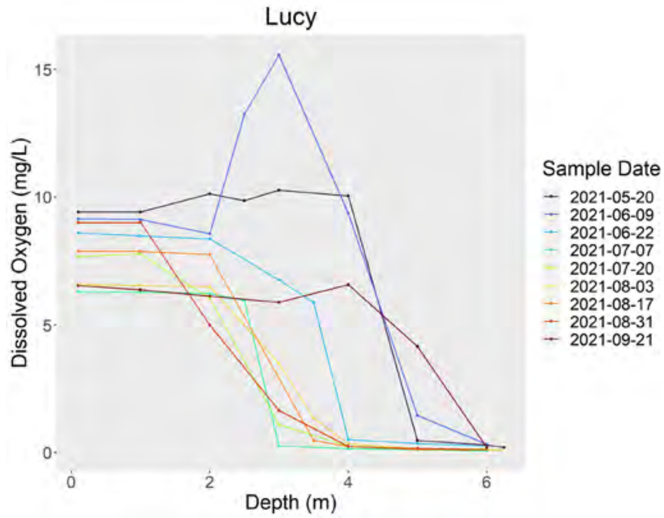

Hyland
Dissolved Oxygen (mg/L)
0
3
6
9
12
Depth (m)
1
2
3
Sample Date
2021-02-03
2021-02-18
2021-04-20
2021-05-11
2021-05-25
2021-06-08
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-14
2021-09-28

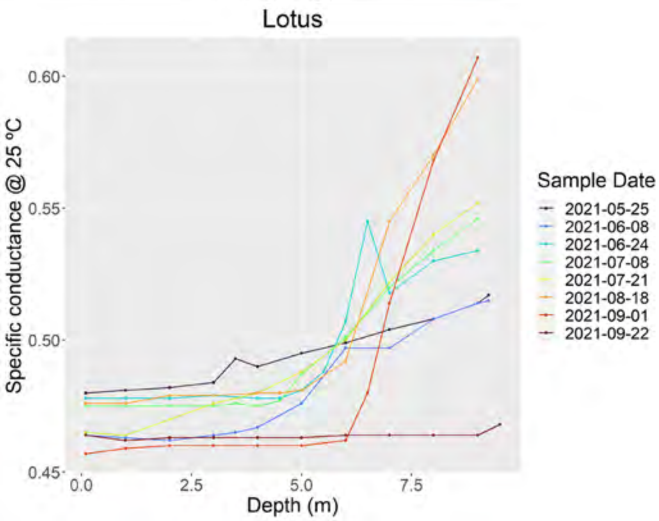

Lotus
Temperatue (C)
15
20
25
Depth (m)
0.0
2.5
5.0
7.5
Sample Date
2021-05-25
2021-06-08
2021-06-24
2021-07-08
2021-07-21
2021-08-04
2021-08-18
2021-09-01
2021-09-22

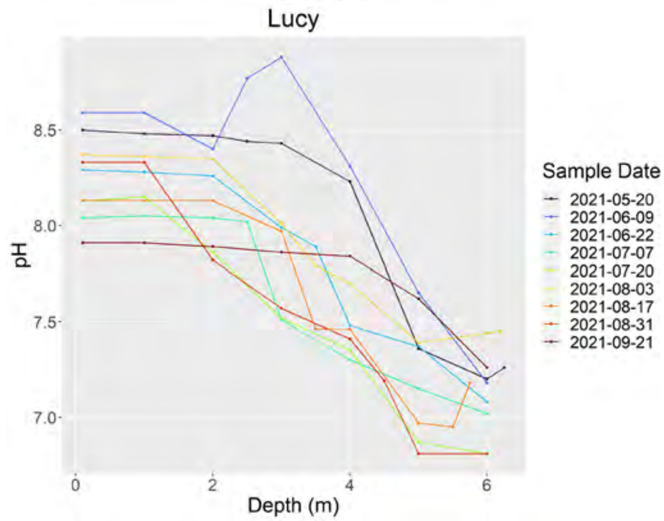

Hyland
pH
7.0
7.5
8.0
8.5
9.0
Depth (m)
1
2
3
Sample Date
2021-02-03
2021-02-18
2021-04-20
2021-05-11
2021-05-25
2021-06-08
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-14
2021-09-28

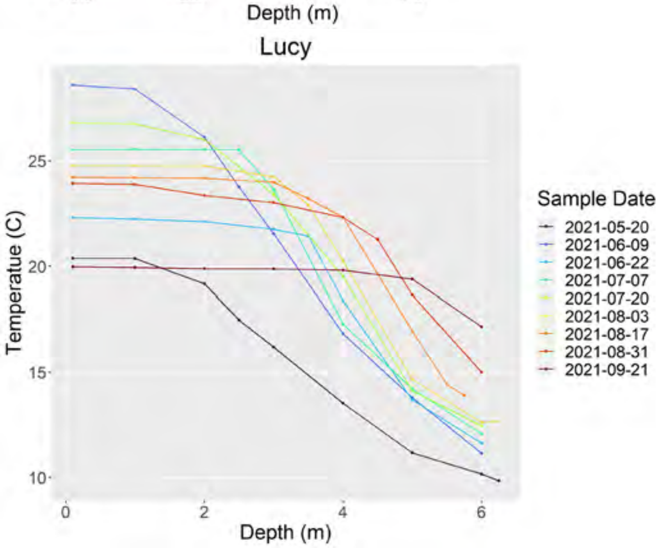

Lotus
Dissolved Oxygen (mg/L)
0
3
6
9
Depth (m)
0.0
2.5
5.0
7.5
Sample Date
2021-05-25
2021-06-08
2021-06-24
2021-07-08
2021-07-21
2021-08-04
2021-08-18
2021-09-01
2021-09-22

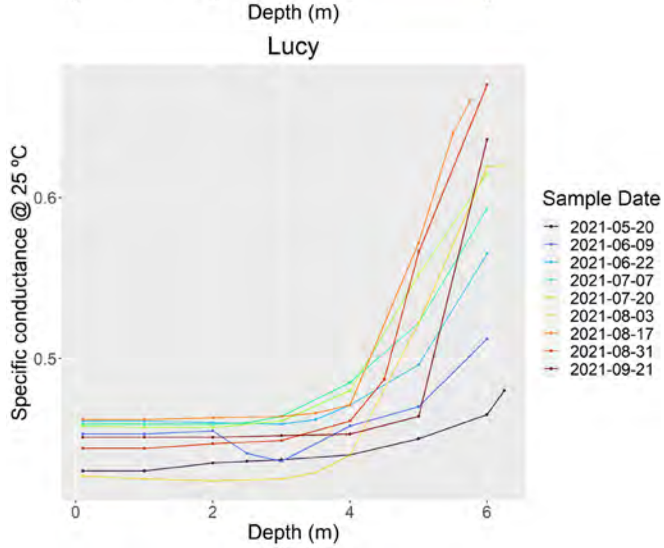

Lotus
pH
Depth (m)
Sample Date
2021-05-25
2021-06-08
2021-06-24
2021-07-08
2021-07-21
2021-08-04
2021-08-18
2021-09-01
2021-09-22

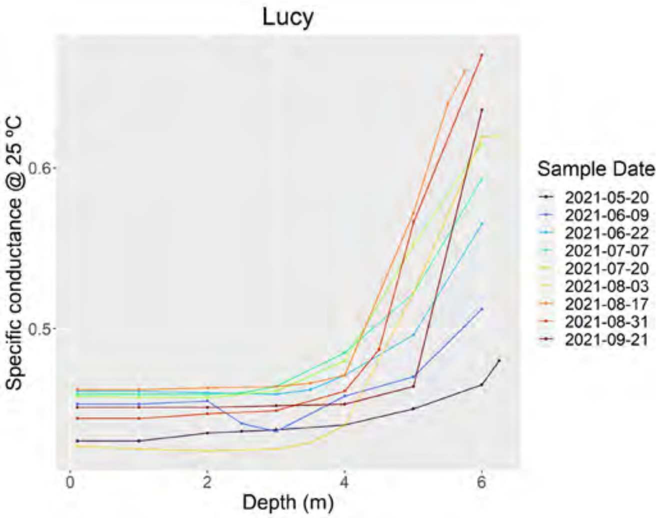

Lucy
Dissolved Oxygen (mg/L)
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

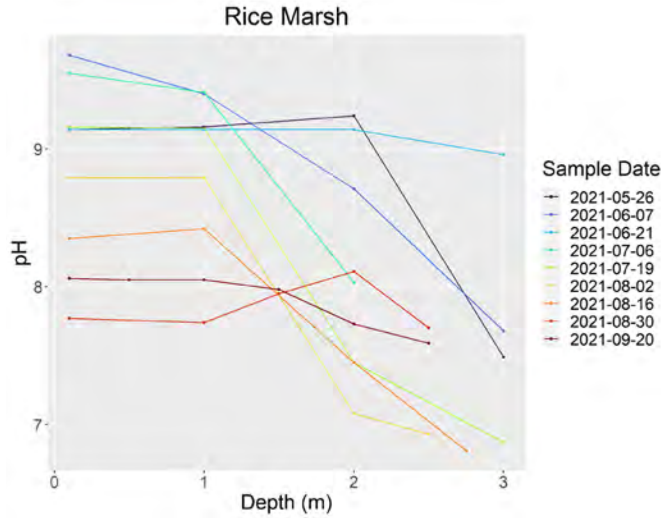

Lotus
Specific conductance @ 25 °C
Depth (m)
Sample Date
2021-05-25
2021-06-08
2021-06-24
2021-07-08
2021-07-21
2021-08-18
2021-09-01
2021-09-22

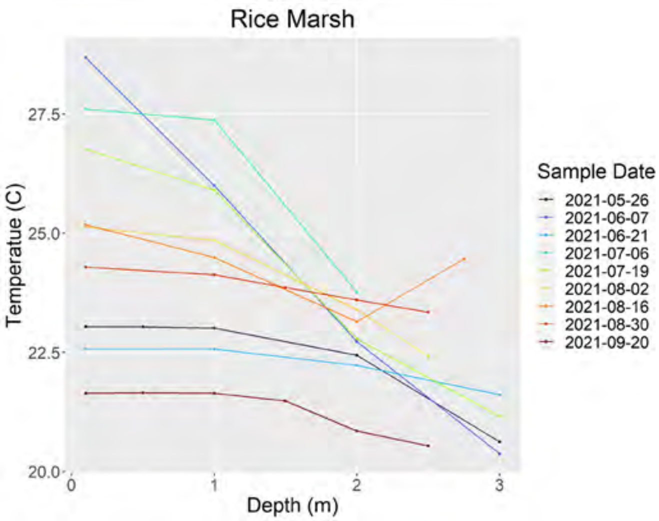

Lucy
pH
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

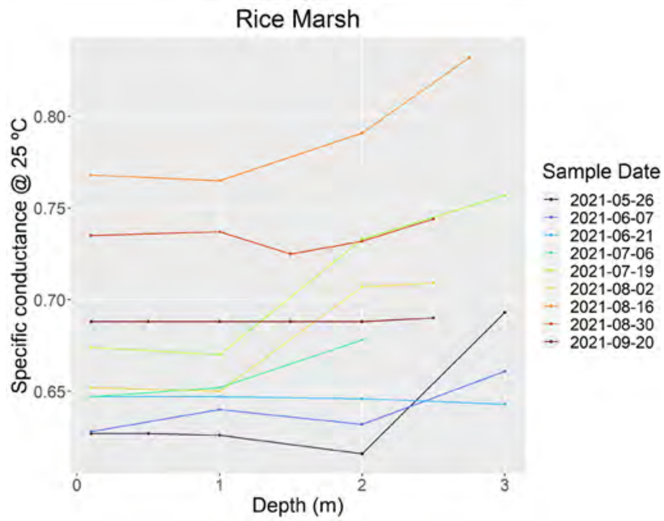

Lucy
Temperatue (C)
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

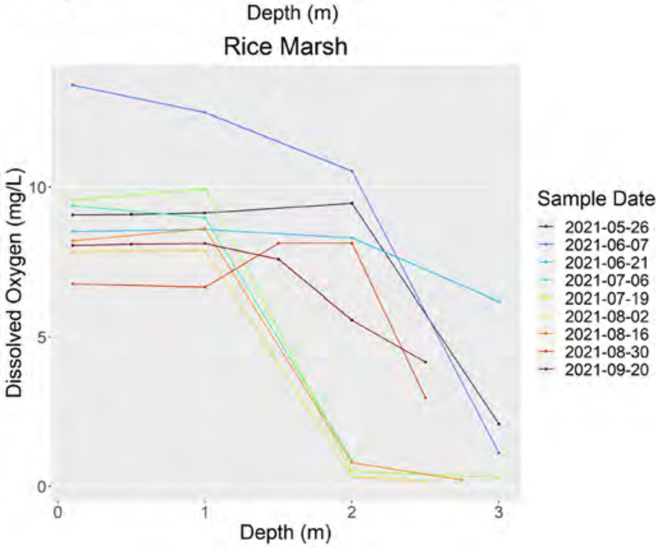

Lucy
Specific conductance @ 25 °C
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

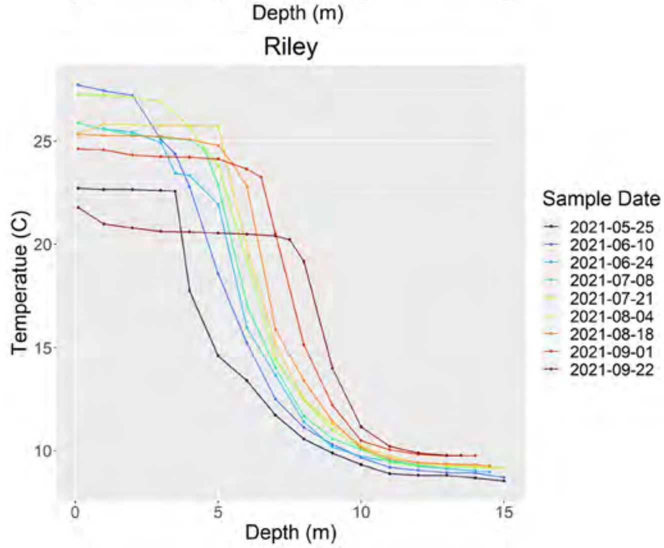

Lucy
Specific conductance @ 25 °C
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

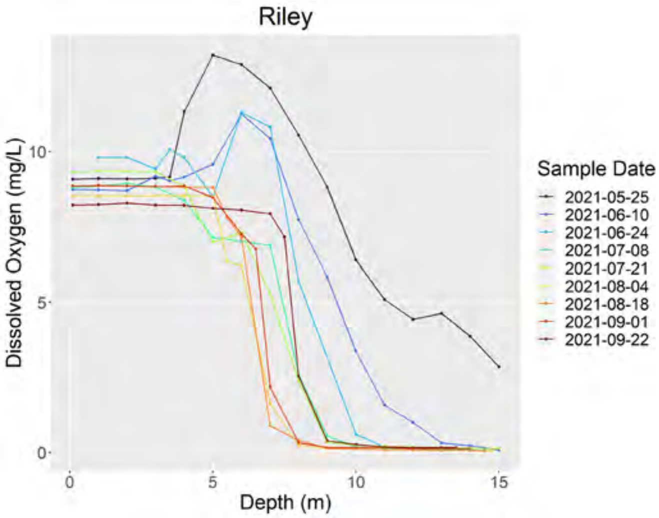

Rice Marsh
pH
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

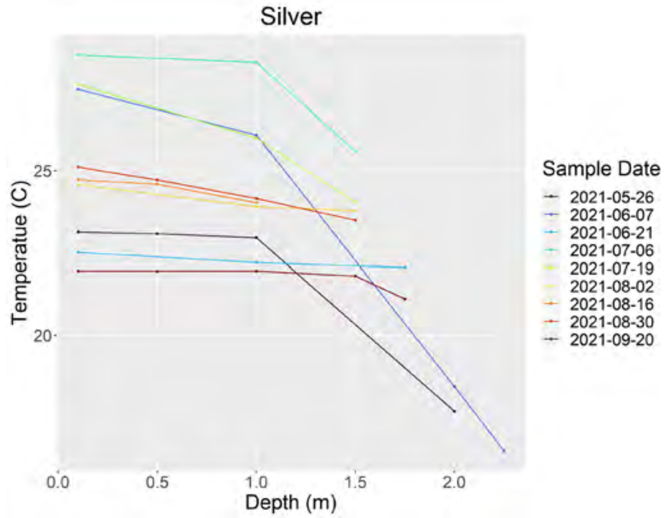

Rice Marsh
Temperatue (C)
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

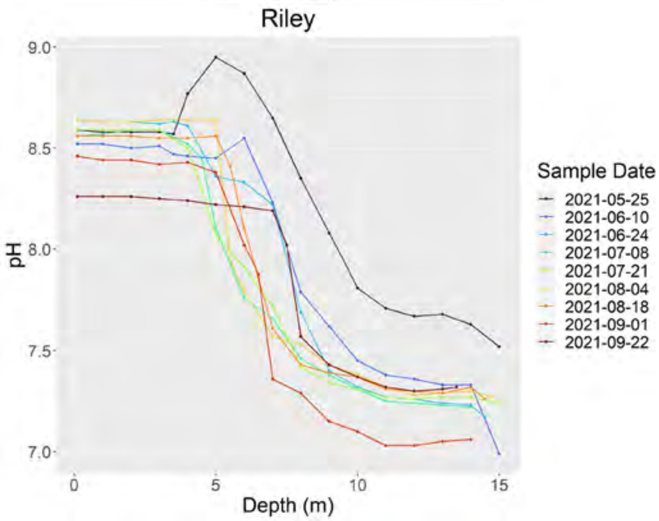

Rice Marsh
Specific conductance @ 25 °C
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

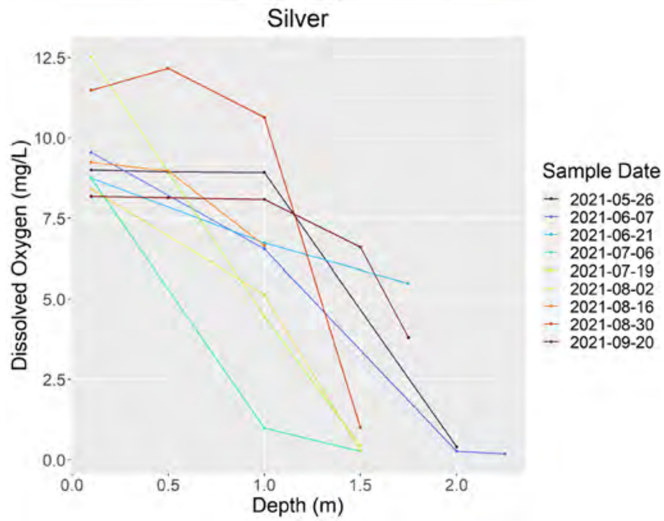

Rice Marsh
Dissolved Oxygen (mg/L)
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

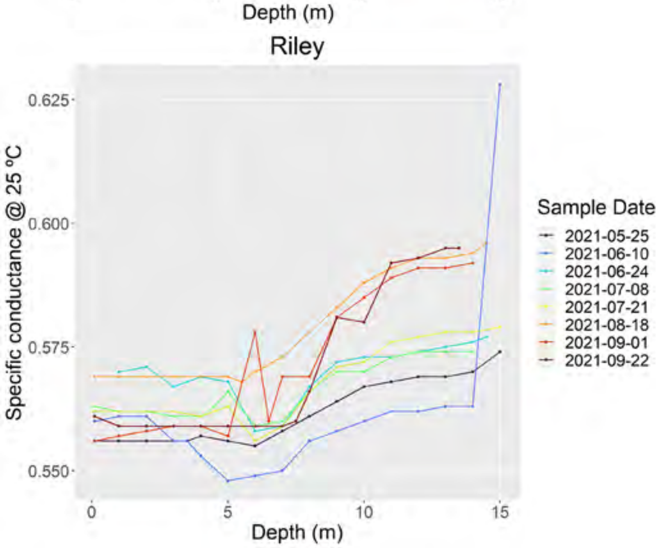

Riley
Temperatue (C)
Depth (m)
Sample Date
2021-05-25
2021-06-10
2021-06-24
2021-07-08
2021-07-21
2021-08-04
2021-08-18
2021-09-01
2021-09-22

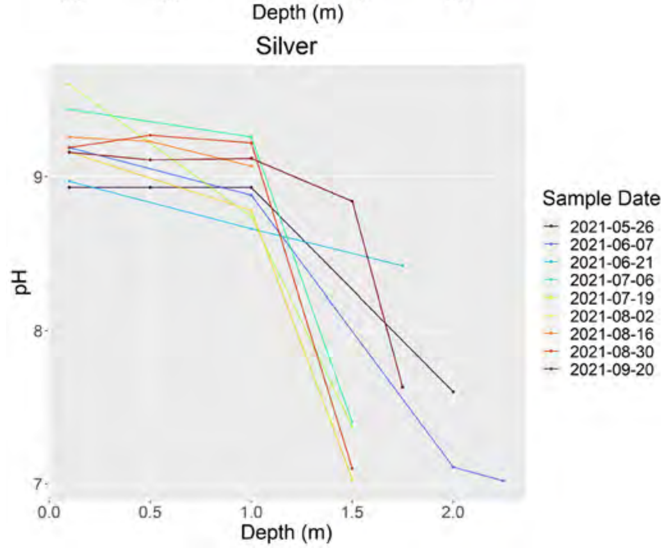

Riley
Dissolved Oxygen (mg/L)
Depth (m)
Sample Date
2021-05-25
2021-06-10
2021-06-24
2021-07-08
2021-07-21
2021-08-04
2021-08-18
2021-09-01
2021-09-22

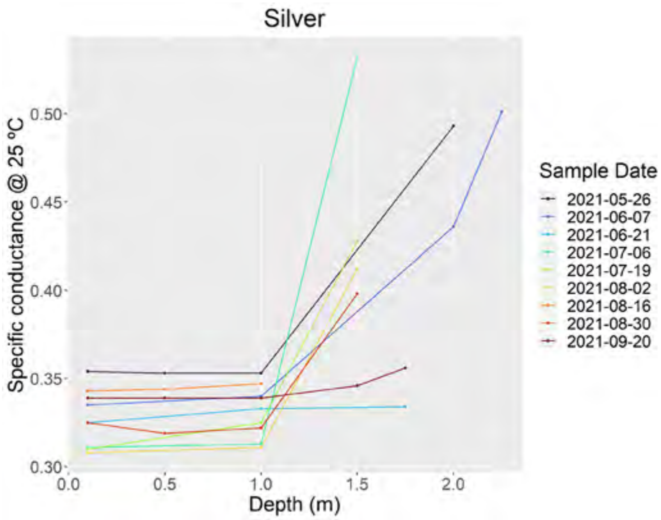

Silver
Temperatue (C)
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

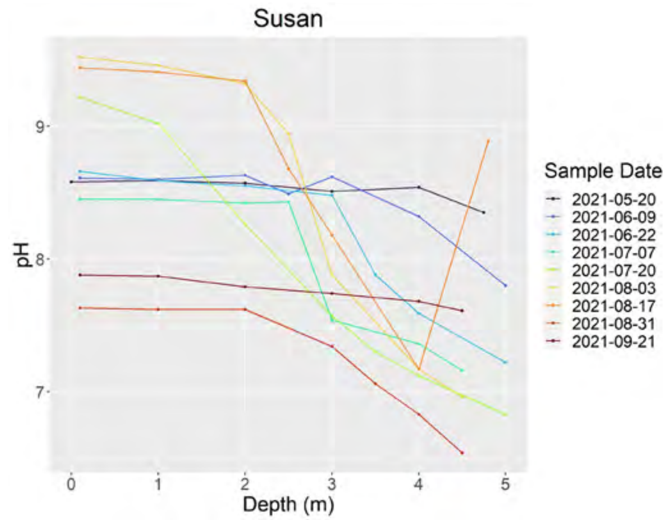

Riley
pH
Depth (m)
Sample Date
2021-05-25
2021-06-10
2021-06-24
2021-07-08
2021-07-21
2021-08-04
2021-08-18
2021-09-01
2021-09-22

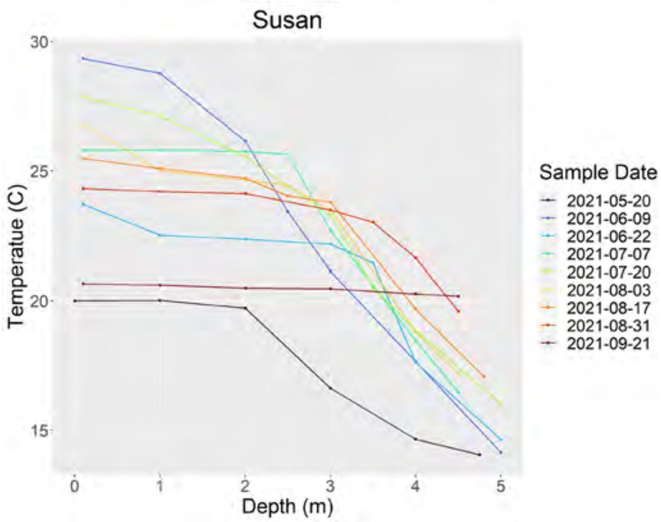

Silver
Dissolved Oxygen (mg/L)
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

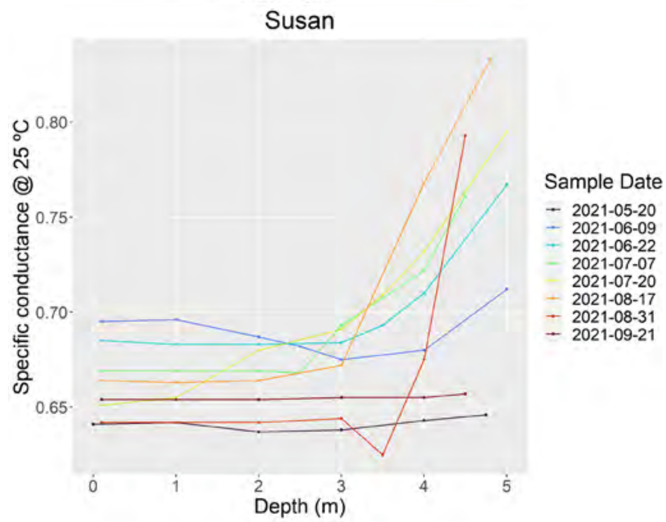

Riley
Specific conductance @ 25 °C
Depth (m)
Sample Date
2021-05-25
2021-06-10
2021-06-24
2021-07-08
2021-07-21
2021-08-18
2021-09-01
2021-09-22

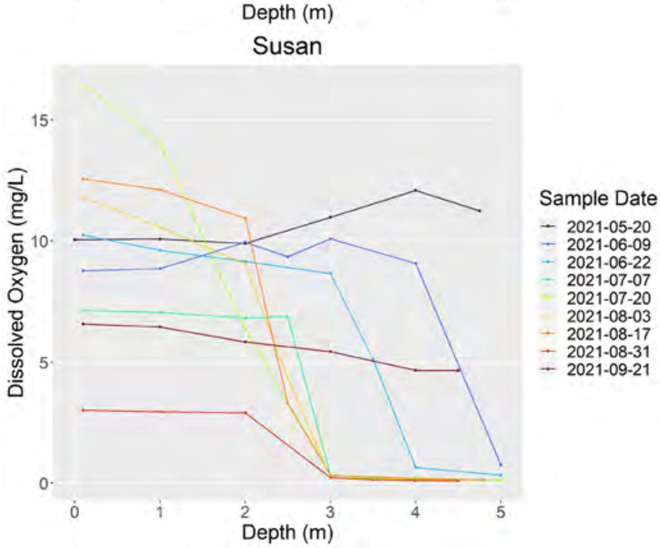

Silver
pH
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

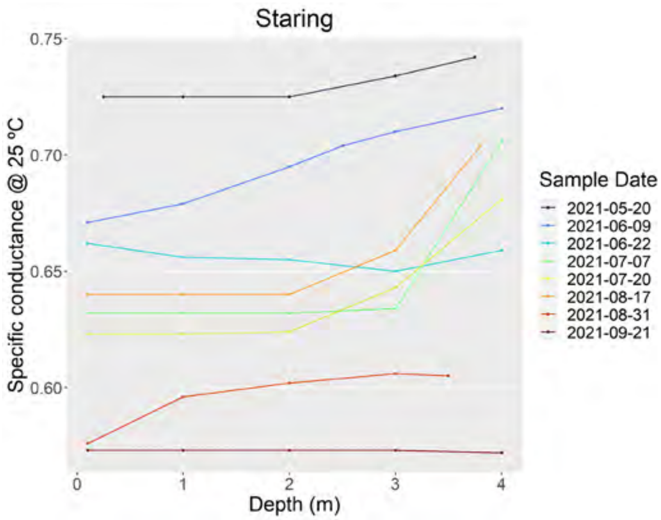

Silver
Specific conductance @ 25 °C
0.30
0.35
0.40
0.45
0.50
0.0
0.5
1.0
1.5
2.0
Depth (m)
Sample Date
2021-05-26
2021-06-07
2021-06-21
2021-07-06
2021-07-19
2021-08-02
2021-08-16
2021-08-30
2021-09-20

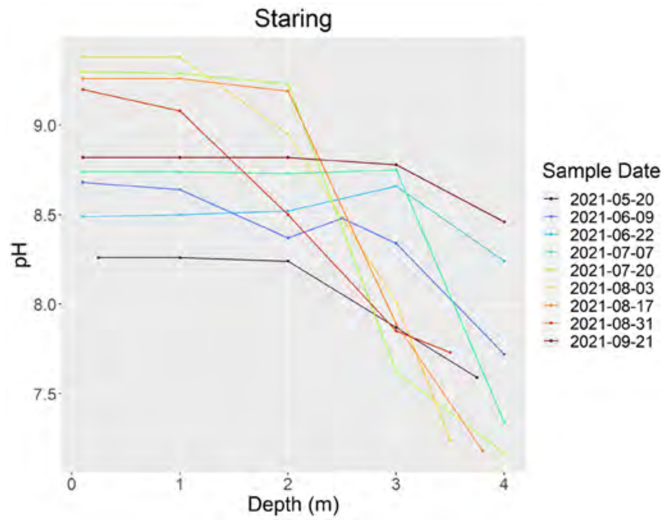

Susan
pH
7
8
9
0
1
2
3
4
5
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

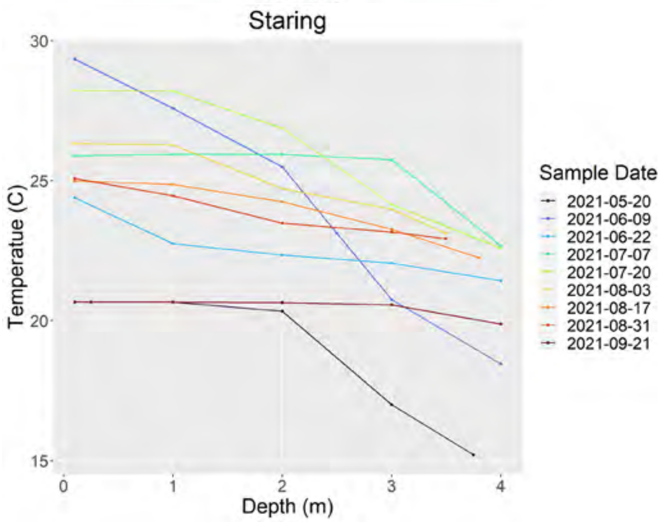

Susan
Temperatue (C)
15
20
25
30
0
1
2
3
4
5
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21


Susan
Specific conductance @ 25 °C
0.65
0.70
0.75
0.80
0
1
2
3
4
5
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-17
2021-08-31
2021-09-21


Susan
Dissolved Oxygen (mg/L)
0
5
10
15
0
1
2
3
4
5
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21


Staring
Specific conductance @ 25 °C
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-17
2021-08-31
2021-09-21


Staring
pH
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21


Staring
Temperatue (C)
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

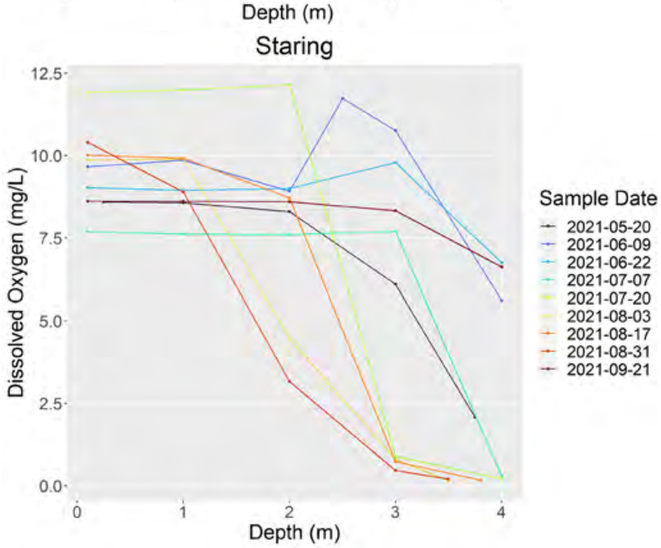

Staring
Dissolved Oxygen (mg/L)
Depth (m)
Sample Date
2021-05-20
2021-06-09
2021-06-22
2021-07-07
2021-07-20
2021-08-03
2021-08-17
2021-08-31
2021-09-21

Exhibit I *2021 Creek Restoration Action Strategy*

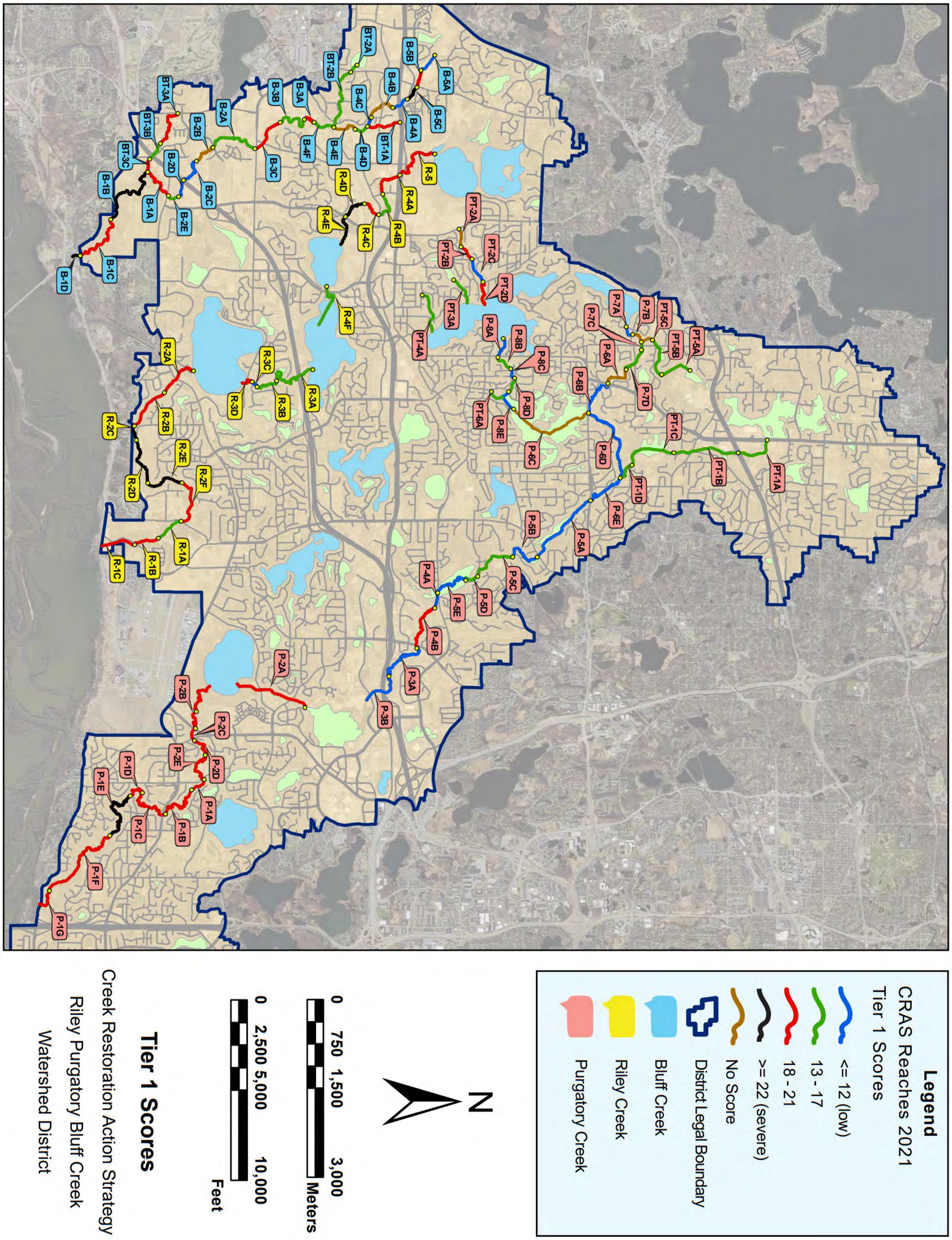


Exhibit J *2021 RPBCWD Curly-leaf Pondweed Treatment Areas*