RILEY
PURGATORY
BLUFF CREEK
WATERSHED DISTRICT

Water Resources Report

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
2019 ANNUAL REPORT

protect. manage. restore.

Executive Summary

The Riley Purgatory Bluff Creek Watershed District (RPBCWD) had a successful water quality sampling season in 2019, 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 2019 sampling effort are presented in this report.

2019 LAKE SUMMARY

During the 2019 monitoring season, 13 lakes and one high value wetland were monitored throughout the District. 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 441 common carp from the Purgatory Creek Recreation Area during the spring spawning run in attempt to reduce overall carp numbers in the system. The District also monitored public access points and analyzed water samples for the presence of zebra mussels in these 14 waterbodies. Unfortunately, zebra mussels veligers were found in Lotus Lake and mussel shells were found on a dock on shore, which makes Lotus the second lake within the District to be listed as infested. A successful alum treatment occurred on Hyland Lake in 2019. Herbicide treatments for curly leaf pondweed were conducted on Lotus Lake and Red Rock Lake. In 2019, brittle naiad was found at two locations in Lake Susan; this represents the first appearance of this invasive aquatic plant in the lake.

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 2019 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).

Overall lake water quality across the District improved in 2019. This is the first time since data has been collected that all lakes within the watershed district have met the water clarity standard in the same year. Lake Ann, Lake Idlewild, Lake Riley, Rice Marsh Lake, Round Lake, and Duck Lake met all three MPCA standards in 2019; Rice Marsh Lake did not previously meet the Chl-a and TP standards in 2018, but the alum treatment at the end of 2018 cut the concentrations of both in half. Silver Lake met all standards in 2018, but just missed meeting the Chl-a and TP standards in 2019. Red Rock and Staring also all exceeded both the Chl-a and TP standards in 2019. Both Hyland Lake and Mitchell Lake failed to meet any of the standards in 2018 but met all standards except the Chl-a standard in 2019. Lucy and Susan also did not meet the Chl-a standard 2019. All lakes met the nitrate/nitrite water quality standard and only Lake Idlewild did not meet the chloride standard for lakes.

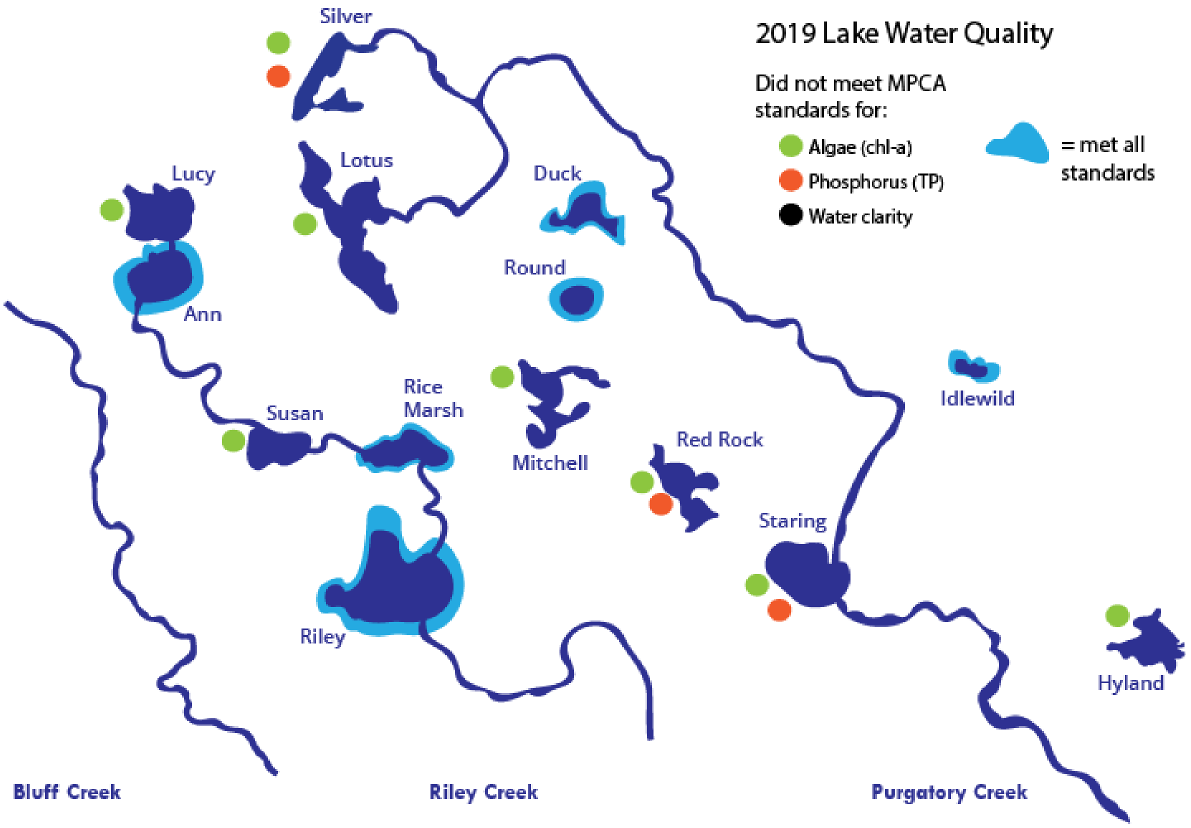

Figure i 2019 Lake Water Quality

Summary of the lake water quality data collected in 2019 by the Riley Purgatory Bluff Creek Watershed District as compared to the Minnesota Pollution Control Agency Water Quality Standards. Chlorophyll-a (green), Total Phosphorus (orange), and Secchi Disk depth (black) were assessed during the growing season (June-September) for both 'deep' lakes or lakes >15 ft deep and < 80% littoral area (Lake Ann, Lotus Lake, Lake Riley, and Round Lake), and 'shallow' lakes or lakes <15 ft deep and >80% littoral area (Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake). The corresponding dots next to each lake indicate which water quality standard was not met and lakes surrounded by blue met all water quality standards.

2019 STREAM SUMMARY

In 2019, the District collected water quality samples and performed data analysis on 23 different sampling sites along Riley Creek (six sites), Bluff Creek (six sites), and Purgatory Creek (eleven sites). During the 2019 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, OP, CL, and Chl-a) and total suspended sediment (TSS) concentrations. Creek flow was calculated from velocity measurements taken at consistent creek cross sections at each water quality monitoring location. Staff deployed automated sampling units on upper Bluff and Riley Creek to assess pollutant loads and the potential for restoration projects. The District collected macroinvertebrates at all eight Purgatory Creek regular water quality sites in 2019. Sections of Purgatory Creek were assessed and updated using the Creek Restoration Action Strategy (CRAS) evaluation, which identifies the stream reaches most in need of restoration. Overall, the 2019 CRAS scores of subreaches previously walked remained very similar to past scores.

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

Regular creek sampling sites P3, P4, P5 and R3 met all MPCA water quality standards assessed in 2019 (Figure ii). The overall number of water quality standard impairments decreased from 2018 to 2019; Bluff had nine (previously 10), Riley had seven (previously eight), and Purgatory had seven (previously nine). Bluff Creek remained the stream with the most impaired water quality, as previously seen between 2015-2018, with TP impairments at all sites, as well as TSS impairments at two sites, a Chl-a impairment at B5, and a fish impairment at B1. Once again, TP was the water quality standard causing the most impairments in 2019 with seven of the 18 sites not meeting the standard (summer average <0.1 mg/L). TSS impairments decreased from nine impairments in 2018 to seven 2019. The dissolved oxygen standard (daily minimum of 4mg/L) was impaired at only site P8. All sites met the pH water quality standard (< 9su and >6su). Similar to 2016-2018, P2 did not meet the Chl-a standard (summer average <18ug/L). Macroinvertebrate impairments by the MPCA were added to this year’s analysis and included lower Purgatory and Riley Creek.

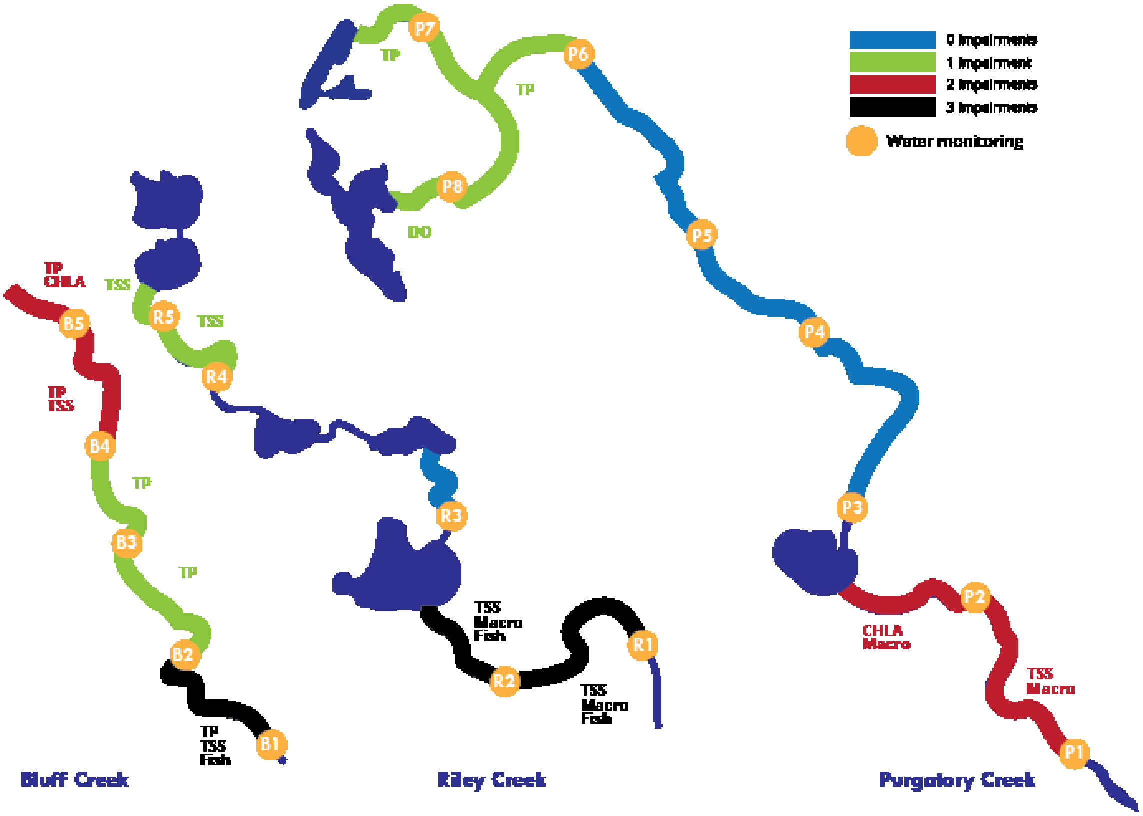

Figure ii 2019 Stream Water Quality

Summary of stream water quality data collected on Bluff Creek, Riley Creek, and Purgatory Creek in 2019 by the Riley Purgatory Bluff Creek Watershed District as compared to the Minnesota Pollution Control Agency (MPCA) Water Quality Standards. A total of 18 water monitoring locations (orange circles) were sampled and information gathered 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 > 4mg/L, average Total Phosphorus (TP) < 0.1mg/L, Total Suspended Solids (TSS) < 10% exceedance of 30mg/L limit, average Chlorophyll-a (CHLA) <18ug/L, average pH < 9su and > 6su. The corresponding labels next to each stream section indicate which water quality standard were not met.

Table of Contents

List of Figures

List of Tables

List of Exhibits

Exhibit A	Lake Water Levels
Exhibit B	Fyke Net Data
Exhibit C	Zooplankton Summary Data
Exhibit D	Phytoplankton Summary Data
Exhibit E	Lake and Creek Fact Sheets

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
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
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
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
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**). This total area for the watershed is close to 50 square miles located in both Hennepin and Carver Counties and includes three smaller subwatersheds: Riley Creek Watershed, Purgatory Creek Watershed, and Bluff Creek Watershed.

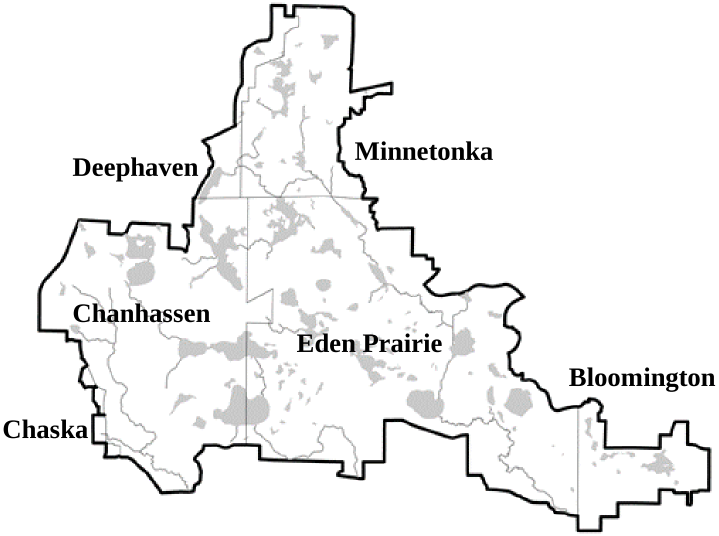

Figure 1 Riley Purgatory Bluff Creek Watershed District Boundary

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 (Eden Prairie=EP), Three Rivers Park District (TRPD), the University of Minnesota (UMN), Metropolitan Council (METC), and Carver County, water quality data was collected on 13 lakes, one high value wetland (Lake Idlewild), and 23 creek sites in the District. The 23 creek sites include six on Bluff Creek, six on Riley Creek, and eleven on Purgatory Creek. Lake McCoy and Neil Lake, which are within the watershed boundaries, have 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 (**Table 1**).

Table 1 District Water Resource Sampling Partnerships

Water Resource	RPBCWD	TRPD	EP	UMN	METC	Carver Co.
Duck Lake	■					
Hyland Lake	■	■				
Lake Ann	■					■
Lake Idlewild	■		■			
Lake Lucy	■					
Lake Riley	■			■		
Lake Susan	■			■		■
Lotus Lake	■					■
Mitchell Lake	■		■	■		
Red Rock Lake	■		■			
Rice Marsh Lake	■					
Round Lake	■		■			
Silver Lake	■					
Staring Lake	■			■		
Bluff Creek	■				■	
Purgatory Creek	■				■	
Riley Creek	■		■		■	

Water quality and water quantity was monitored at each stream site during the field season (April-September) approximately twice a month. The METC also has continuous monitoring stations near the outlet of each creek as part of its long-term monitoring program which identifies pollutant loads entering the Minnesota

River. 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 at all Purgatory Creek 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 2019, nine stormwater ponds were also monitored and sampled bi-weekly as a part of a cooperative study with the University of Minnesota and the city of Eden Prairie. Winter monitoring occurred on the Purgatory Chain of Lakes as well as four separate stormwater ponds in 2019. 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 2**. Data was not collected in November and December due to unsafe ice conditions. In addition to lakes and streams, multiple stormwater ponds and other specialty projects were monitored to evaluate their effectiveness at preventing or contributing pollutant loads to the watershed.

Table 2 RPBCWD 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				■	■	■	■	■	■	■		
Mitchell Lake	■	■	■	■	■	■	■	■	■	■		
Red Rock Lake	■	■	■	■	■	■	■	■	■	■		
Rice Marsh Lake	■	■	■	■	■	■	■	■	■	■		
Round Lake	■	■	■									
Lake Riley				■	■	■	■	■	■	■		
Staring Lake	■	■	■	■	■	■	■	■	■	■		
Lake Susan				■	■	■	■	■	■	■		
Silver Lake	■	■	■	■	■	■	■	■	■	■		
Bluff Creek **(5 sites)**				■	■	■	■	■	■	■		
Purgatory Creek **(8 sites)**				■	■	■	■	■	■	■		
Riley Creek **(5 sites)**				■	■	■	■	■	■	■		

*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 2019 field-monitoring season. **Table 3** identifies many of the different chemical, physical, and biological variables analyzed to assess overall water quality.

Table 3 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
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 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/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 as well. 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 *3***.

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 (2-3m). For all other lakes within the District, water samples were collected at the surface, middle, and bottom of the lake. Lakes are monitored at the same location on each sampling trip, typically at the deepest part 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 using 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 2m 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 raised 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 recorded, 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 4**.

Table 4 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 Tow (2m 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 one 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 the 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 5**. Zebra mussel veliger samples were also sent to RMB Labs for analysis.

Additional samples were sent to the Metropolitan Council (METC), St. Paul, MN. These samples included quality control duplicate samples and special water quality monitoring project samples. METC allows staff to bring samples in on a Friday which is not possible with RMB because samples must be shipped. Additionally, macroinvertebrate samples were sent to Dean Hansen of the University of Minnesota for identification and 10% of zooplankton and all phytoplankton samples were sent to Margaret Rattei at Barr Engineering for quality control duplicate samples.

Table 5 RMB Environmental Laboratories Parameters and Methods Used for Analyses

Parameter	Standard Method
Alkalinity	EPA 310.2
Ammonia	EPA 350.1 Rev 2.0
Nitrogen, Nitrate & Nitrite	EPA 353.2 Rev 2.0
Chlorophyll-a	SM 10200H
Total Phosphorus	EPA 365.3
Orthophosphate	EPA 365.3
Chloride	SM 10200H
Total Kjeldahl Nitrogen	EPA 351.2 Rev 2.0

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 characterize the ecoregion. 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.

3.1 Lakes

The MPCA has specific standards for both 'deep' lakes or lakes >15ft deep and < 80% of the total lake surface area able to support aquatic plants (littoral area), and 'shallow' lakes or lakes <15ft deep and >80% littoral area. Except for chlorides, summer growing season (June-September) averages of the parameters listed in **Table 6** for each lake and 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 or 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 6**, the lake is considered impaired. Secchi disk readings are collected to measure the transparency, or 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, especially during the winter when road salt is heavily used. Targeted sampling occurs during the winter, during early spring melting periods when salts are being flushed through our waterbodies, and monthly during the summer. The Cl standard is the same for both deep lakes and shallow lakes. **Table 6** 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 6 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 7 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 phosphorus levels but do not exceed the Chl-a (seston), cBOD, diel DO flux, or pH levels meet the eutrophication standard. The District added Chl-a to its monthly sampling regime in 2015 to account for the polluted condition when Chl-a (periphyton) concentration exceeds 18ug/L. The daily minimum DO concentration for all Class 2B Waters cannot dip below 4mg/L to achieve the MPCA standard, which was used in the analysis for the Annual Report.

Table 7 MPCA Stream Water Quality Standards

MPCA Standard	Parameter	Criteria
Eutrophication	Phosphorus	≤ 100ug/L
	Chlorophyll-a (seston)	≤ 18ug/L
	Diel Dissolved Oxygen	≤ 3.5mg/L
	Biochemical Oxygen Demand	≥ 2mg/L
	pH Max	≤ 9su
	pH Min	≥ 6.5su
Total Suspended Solids	TSS	≤ 30mg/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 30mg/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 2019.

4.1 2019 Lakes Water Quality Summary

The 2019 growing season Chl-a mean concentrations for all lakes sampled within the District are shown in **Figure 2**. Of the three main lake water quality standards (Chl-a, TP, Secchi), Chl-a was the nutrient with the most site impairments in 2019. Overall, six of the 14 lakes sampled in 2019 met the MPCA Chl-a standards for their lake classification (six lakes also met standard in 2018): Lake Ann, Duck Lake, Lake Idlewild, Round Lake, Lake Riley, and Rice Marsh Lake.

Four lakes sampled within the District are categorized as 'deep' by the MPCA (>15ft deep, < 80% littoral area): Lake Ann, Lotus Lake, Lake Riley, and Round Lake. The MPCA standard for Chl-a in deep lakes (< 14ug/L) was met by Lake Ann, Lake Riley and Round Lake. Similar to 2018, Lotus Lake did not meet the standard with Chl-a average concentrations were more than twice the MPCA standard at 33ug/l (an increase of 10ug/L from 2018). The remainder of the lakes sampled in 2019 are categorized as 'shallow' by the MPCA (<15ft deep, >80% littoral area): Duck Lake, Hyland Lake, Lake Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake. Water quality metrics on Lake Idlewild, classified as a high-value wetland, were compared to MPCA shallow lake standards. The water quality standard for shallow lakes (< 20ug/L) was met by Duck Lake, Lake Idlewild, and Rice Marsh Lake in 2019. Lake Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, and Staring Lake did not meet the standard. Hyland Lake and Lake Susan also did not meet the MPCA standard but had significantly reduced chlorophyll levels from 2018.

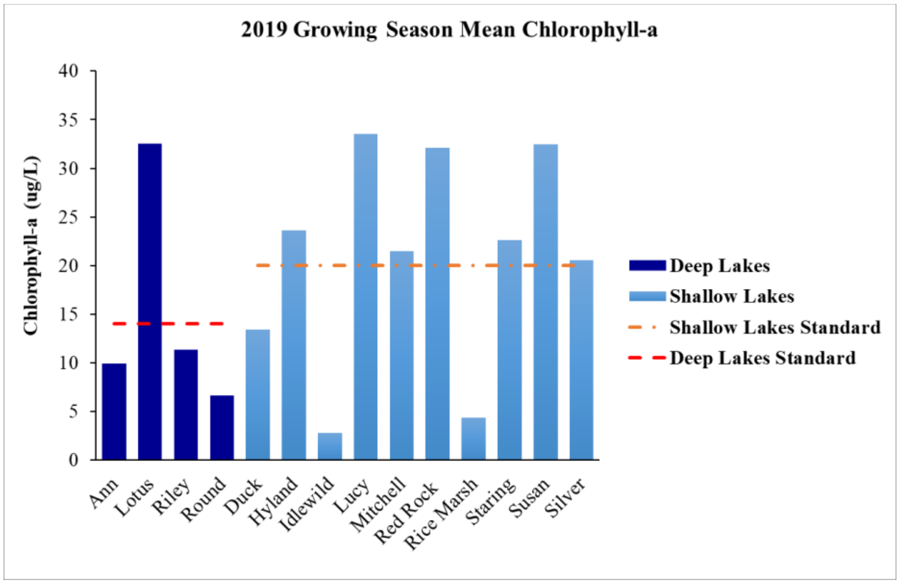

Figure 2 2019 Lake Growing Season Mean Chlorophyll-a

Lakes growing season (June-September) mean chlorophyll-a concentrations (ug/L) for shallow (lakes <15ft. 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 2019. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for Chlorophyll-a for shallow (<20ug/L-orange dashed line) and deep lakes (<14ug/L-red dashed line).

Overall, six of the 14 lakes sampled met the MPCA chlorophyll-a standard for their lake classification in 2019: Lake Ann, Lake Riley, Round Lake, Duck Lake, Lake Idlewild, and Rice Marsh Lake. This represents no change from 2018.

The TP growing season averages for all lakes sampled within the District in 2019 are shown in **Figure 3**. The MPCA standard for TP in deep lakes (<0.040mg/L) was met by Lake Ann, Lake Riley, Round Lake, and Lotus Lake. TP concentrations in Lotus Lake, which had failed to meet the standard in 2018, decreased by 20% in 2019. TP levels in both Lake Riley and Lake Ann increased slightly from 2018 (increases of 0.006 mg/L and 0.003 mg/L, respectively). The increase in Lake Riley represents a reversal of a trend of decreasing TP levels year-to-year since the application of the aluminum sulfate treatment in 2016. For shallow lakes, the MPCA TP standard (<0.060mg/L) was met by Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Mitchell Lake, Rice Marsh Lake, and Lake Susan in 2019. Despite having exceeded the standard in 2018, Hyland Lake, Lake Mitchell, Lake Susan and Rice Marsh Lake met the standard in 2019 due to decreases in TP levels (0.05mg/L, 0.03mg/L, 0.03mg/L, and 0.06mg/L, respectively). Red Rock Lake TP levels were down slightly from 2018, but still exceeded the standard. Silver Lake, Duck Lake, and Staring Lake saw increases in TP levels from 2018; Silver and Staring Lake both exceeded the standard despite meeting it 2018.

Overall, 11 of the 14 lakes sampled met the MPCA total phosphorus standard for their lake classification in 2019: Lake Ann, Duck Lake, Lake Idlewild, Lake Lucy, Lake Riley, Round Lake, Lotus Lake, Hyland Lake, Mitchell Lake, Rice Marsh Lake, and Lake Susan. This represents an increase from eight of 14 sampled lakes that met the standard in 2018.

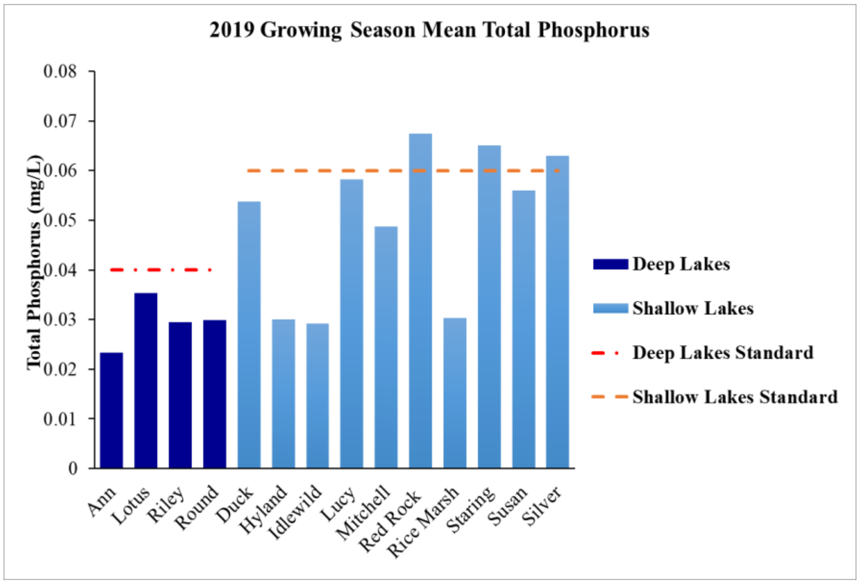

Figure 3 2019 Lakes Growing Season Mean Total Phosphorus

Lakes growing season (June-September) mean total phosphorus concentrations (mg/L) for shallow (lakes <15ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2019. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for Total Phosphorus for shallow (<0.060mg/L-orange dashed line) and deep lakes (<0.040mg/L-red dashed line).

The 2019 secchi disk growing season means for all District lakes sampled are shown in **Figure 4**. The MPCA standard for secchi disk depth/water clarity for deep lakes (> 1.4m) was met by all deep lakes in the District (Ann, Lotus, Riley, and Round). Ann, Lotus, and Riley all decreased in clarity (1.01m, 0.18m, and 0.98m respectively). Round Lake increased 0.25m in average clarity. For shallow lakes, all ten lakes monitored achieved the MPCA secchi disk depth water quality standard (>1m), an increase from eight of ten lakes monitored in 2018. All the shallow lakes except Duck, Idlewild, and Silver, which experienced minor decreases, showed improvements in water clarity. Particularly notable were large increases in clarity on Hyland (1.965m) and Rice Marsh Lakes (1.012m), which received alum treatments in 2019 and 2018, respectively.

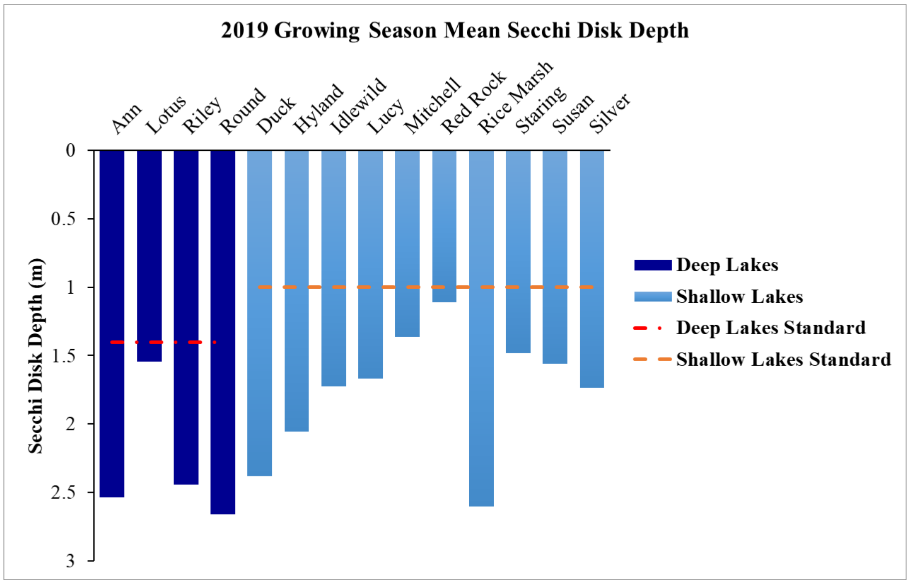

Figure 4 2019 Lakes Growing Season Mean Secchi Disk Depth

Lakes growing season (June-September) mean secchi disk depths (m) for shallow (lakes <15ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2019. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for secchi disk depths for shallow (>1m-orange dashed line) and deep lakes (>1.4m-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 the alum to improve their water quality. An alum treatment provides a safe, effective and long-term control of the quantity of algae in our lakes, by trapping the nutrient 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 the sediments of the lake bottom. 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 kind of 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 10–15 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 for a longer period.

Table 8 Aluminum Sulfate Treatments in RPBCWD

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

A list of the alum treatments completed and proposed second doses in the District can be found in **Table 8**. 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 phosphorous levels within treatment lakes to evaluate the success of the treatment and to assess when a second dose might be needed. More information about Lake Riley, Lotus Lake, Rice Marsh Lake, Round Lake, and Hyland Lake nutrient and water clarity data can be seen in the Fact Sheets located in 8 Exhibits E.

Figure 5 through **Figure 9** illustrates total phosphorus (TP) levels prior to treatment, through the end of the 2019 growing season for all lakes that received an alum treatment. As seen across all lakes, after alum was applied, TP levels within each lake declined considerably for both the surface and lake bottom. In all cases, in the years following the alum treatment, lakes met the MPCA water quality standard for TP (exception – 2013 surface Round 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 (Rice Marsh, Riley, and Round). In **Table 9** the percent reduction of surface and bottom growing season values of total phosphorous from an equal number of years pre and post alum treatment can be seen across all lakes. Utilizing one year of data, it appears Rice Marsh and Hyland Lake were very effective alum treatments with phosphorus reductions of 67% and 62% respectively. Despite having smaller reductions in total phosphorus at the surface, both Lotus Lake and Round Lake had reductions in lake bottom total phosphorus comparable with the other treated lakes (86% for Lotus Lake and 91% (dose 1) and 88% (dose 2) for Round Lake). Looking at a broader range of years pre and post alum treatment, the Lake Riley treatment also was effective at a 41% surface and 86% bottom phosphorus reduction. The results indicate that alum applications are effective and can drastically reduce phosphorous levels within a lake. Staff will continue to monitor each lake to determine second dose application and gauge temporal success of each treatment.

Table 9 Phosphorous Response to Alum Treatment

		Surface			Bottom		
Lake	Years	Avg. TP Before (mg/L)	Avg. TP After (mg/L)	Percent Reduction	Avg. TP Before (mg/L)	Avg. TP After (mg/L)	Percent Reduction
Riley	2009-2019	0.0458	0.0270	41	0.6357	0.0891	86
Lotus	2017-2019	0.0500	0.0380	24	0.4954	0.0702	86
Rice Marsh	2017-2019	0.0894	0.0291	67	0.1483	0.0316	79
Round (D1)	2008-2016	0.0420	0.0363	14	0.9504	0.0874	91
Round (D2)	2018-2019	0.0335	0.0299	11	0.3183	0.0388	88
Hyland	2018-2019	0.0797	0.0300	62	No Data		

*D1=dose 1; D2=dose 2

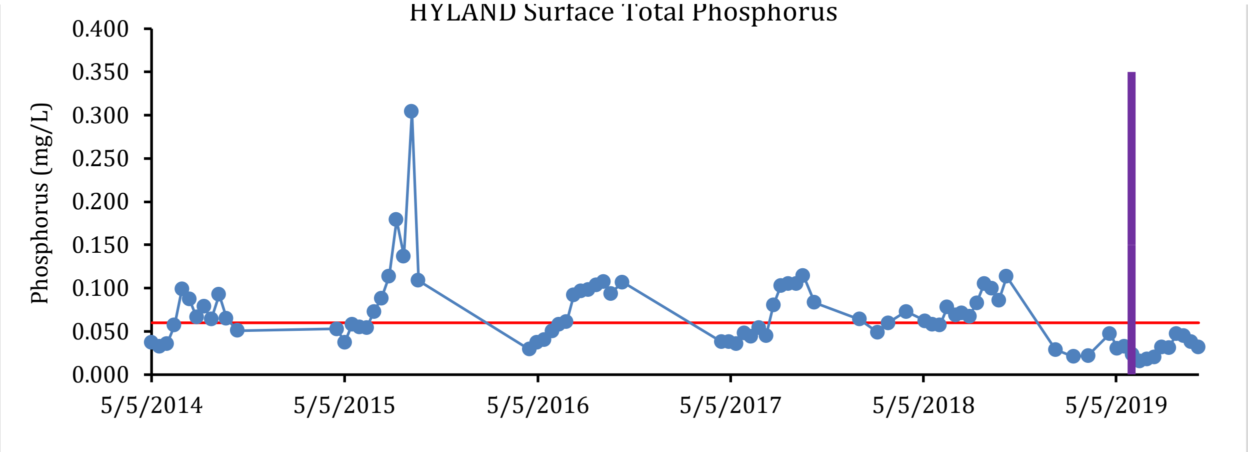

Figure 5 Hyland Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Hyland Lake between May 5, 2014 and October 10, 2019. The aluminum sulfate (Alum) treatment carried out in June 3, 2019 (indicated by vertical bar). The graph displays TP levels (mg/L) measured from 2m composite samples taken at the lake surface and the MPCA water quality standard for TP is represented by the horizontal red line (0.06mg/L).

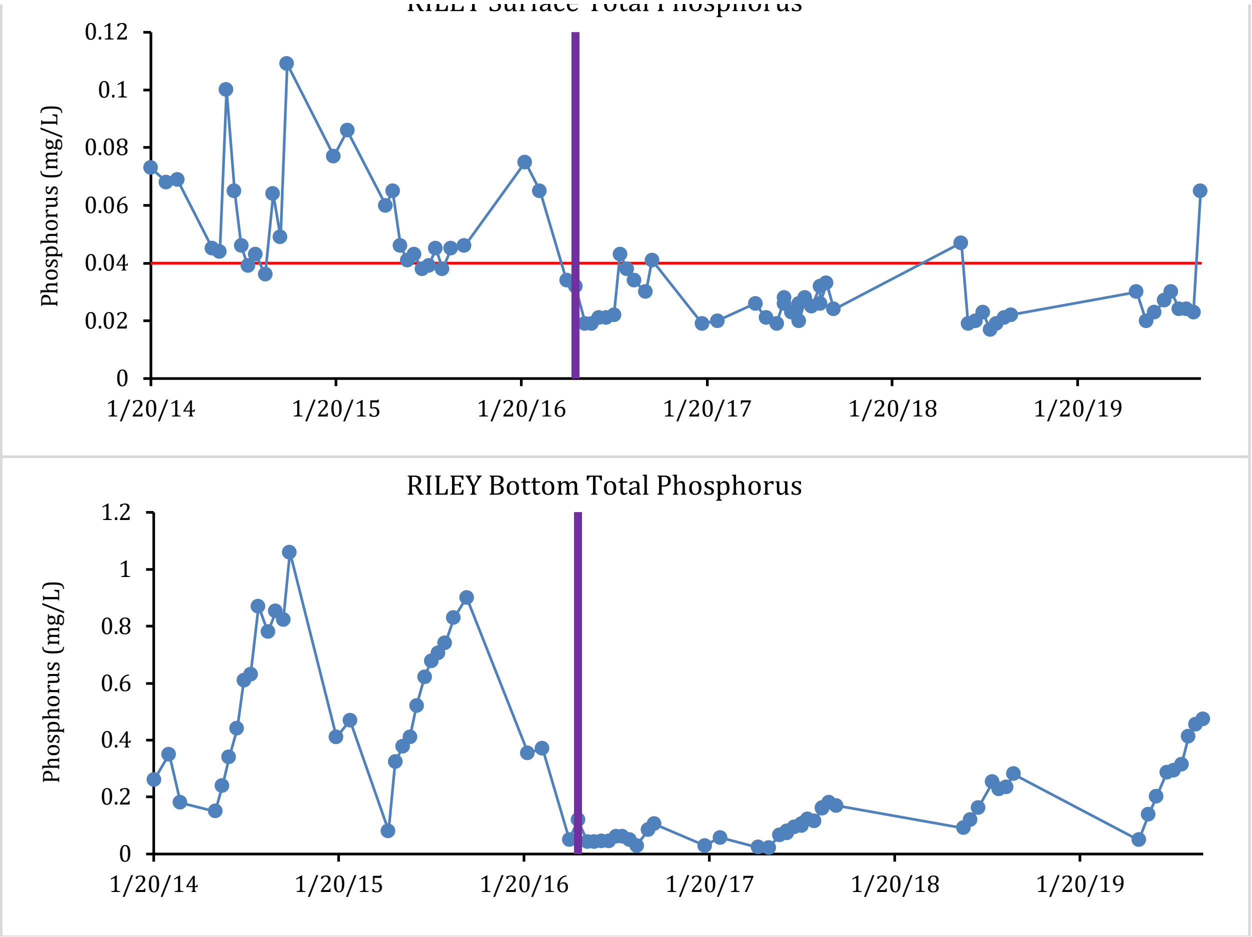

Figure 6 Lake Riley Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lake Riley between January 20, 2014 and September 19, 2019. The aluminum sulfate (Alum) treatment carried out in May 5, 2016 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 2m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1m 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 (0.04mg/L).

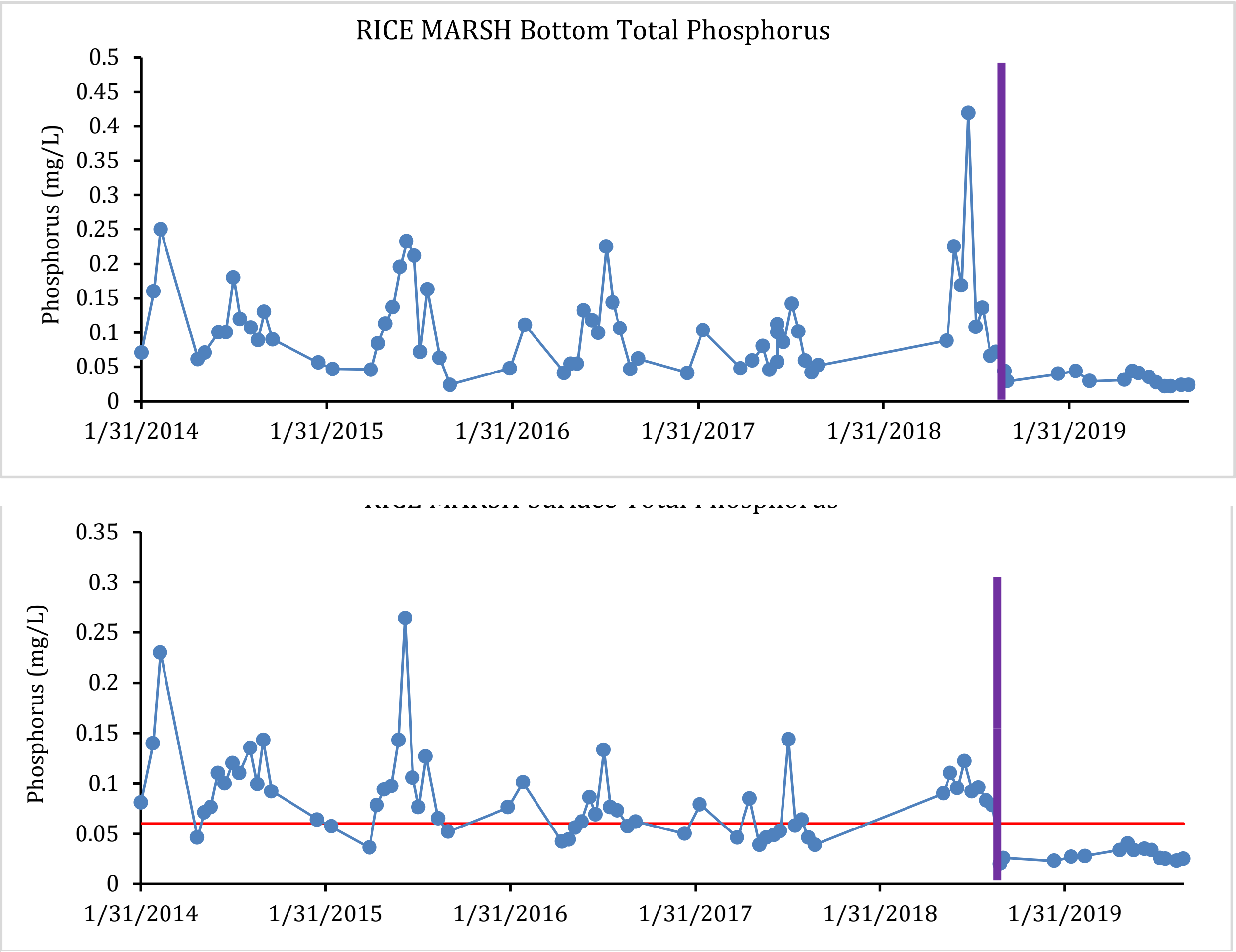

Figure 7 Rice Marsh Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Rice Marsh Lake between January 31, 2014 and September 23, 2019. The aluminum sulfate (Alum) treatment carried out in September 21, 2018 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 2m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1m 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 (0.06mg/L).

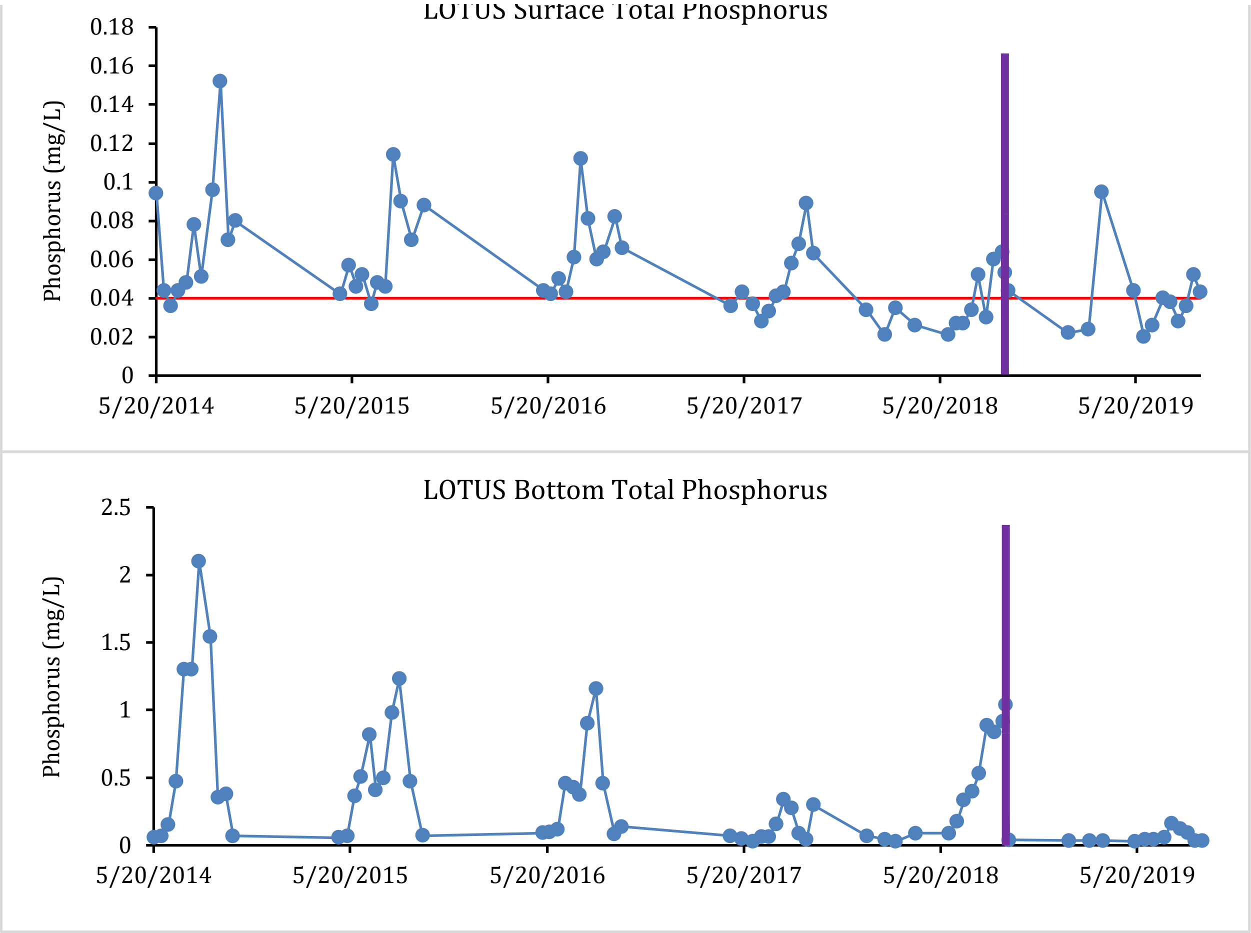

Figure 8 Lotus Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lotus Lake between May 6, 2014 and September 18, 2019. The aluminum sulfate (Alum) treatment carried out in September 18, 2018 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 2m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1m 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 (0.04mg/L).

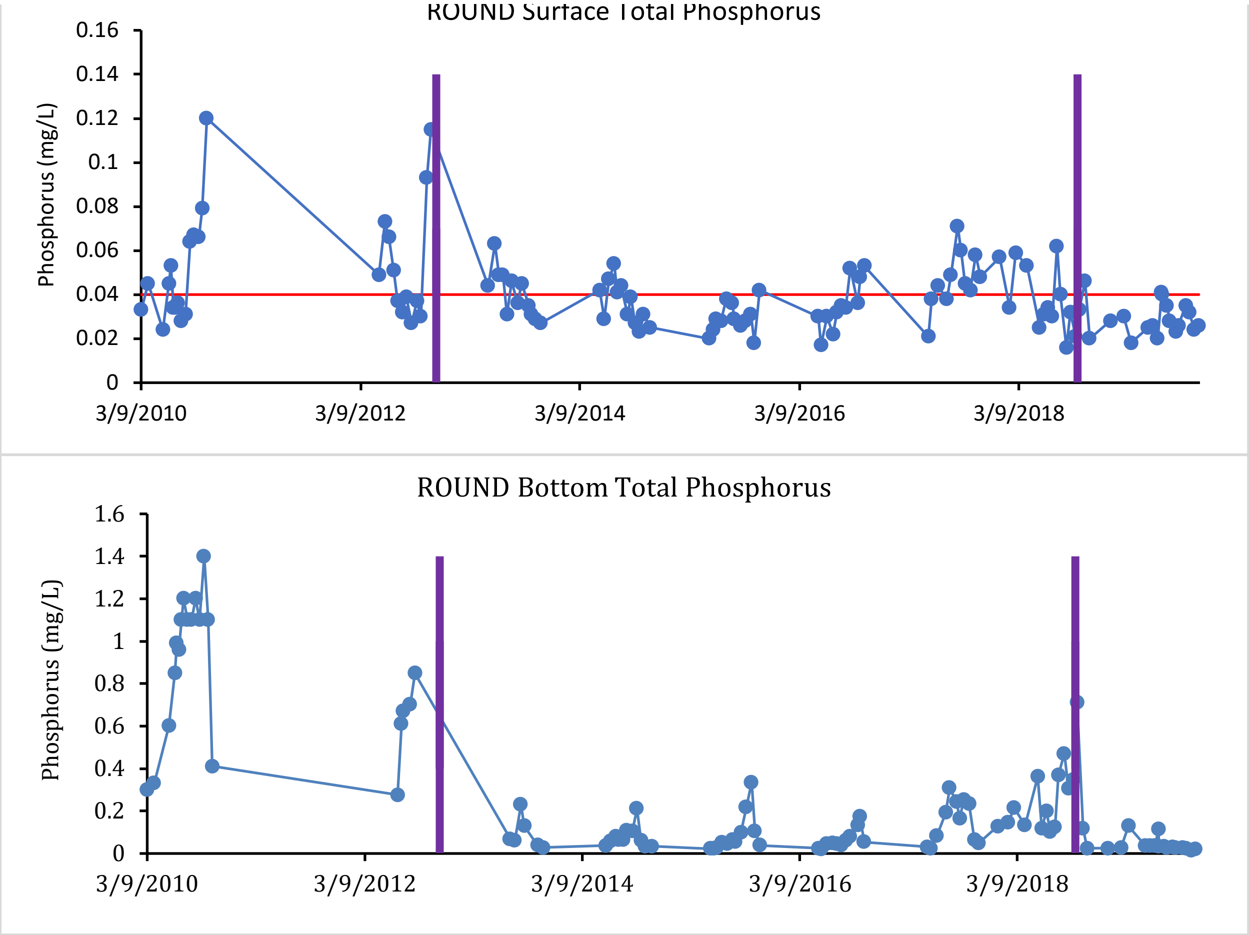

Figure 9 Round Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Round Lake between March 9, 2010 and October 29, 2019. The aluminum sulfate (Alum) treatment carried out in November 15, 2012 and October 24, 2018 (indicated by vertical bars). The upper graph displays TP levels (mg/L) measured from 2m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1m 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 (0.04mg/L).

4.3 Lake Water Levels

In-Situ Level Troll 500, 15-psig water level sensors, as well as METER Environment Hydros 21 water level sensors, have been placed on most lakes throughout the watershed district to monitor water quantity and assess yearly and historical water level fluctuations. These sensors are mounted inside a protective PVC pipe that are attached to a vertical post and placed in the water. 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. New in 2018, staff built and deployed two EnviroDIY stations run by EnviroDIY Mayfly circuit boards on Rice Marsh Lake and Lake Riley. These units were housed in a Pelican brand waterproof case which were mounted to one of the District's standard level sensor posts/staff gauges. These stations were outfitted with the Hydros 21 water level sensors, a solar panel, as well as a radio which allowed for remote communication with the station for real-time viewing of elevation/data.

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 4.9). 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 8 Exhibits A for 2019 level sensor results. Lake Levels for 2018 are also provided for a year-to-year comparison. In both the Lakefinder database and in 8 Exhibits 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. National Oceanic and Atmospheric Administration (NOAA) precipitation data collected from the area was also included in 8 Exhibits A to evaluate how rain events influenced lake levels. Rain data recorded at the Flying Cloud Drive Airport, Eden Prairie, MN is included alongside lake level data from lakes in Hennepin County (including Lake Riley). A combination of rain data from Meteorological Station Chanhassen WSFO and Chanhassen 1.0 ESE is included alongside lake level data from lakes in Carver County.

In 2019, lake level measurements were collected on 13 lakes in the District and one high value wetland, Lake Idlewild (**Table 10**). Silver Lake experienced the greatest seasonal water level change over the 2019 season, increasing 0.567ft from sensor placement to the last day of recording (Oct. 29). Staring Lake had the largest range of fluctuation through 2019, having a low elevation of 814.499ft, and a high of 816.344ft (1.845ft difference). On average, lake levels decreased by 0.165ft over the 2019 season. The average fluctuation range across all lakes was 1.121ft.

Table 10 Lake Water Levels Summary

The 2019 (March-November) and historical recorded lake water levels (ft) for all monitored lakes within the Riley Purgatory Bluff Creek Watershed District. 2019 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.

	2019 Lake Water Level Data				Historical Lake Water Levels			
Lake	**Seasonal Flux**	**Flux Range**	**High level**	**Low level**	**Highest Level**	**Date**	**Lowest Level**	**Date**
Ann	-0.419	0.782	956.743	955.961	957.93	2/18/1998	952.80	9/28/1970
Duck	-0.155	0.892	915.303	914.411	916.12	6/20/2014	911.26	11/10/1988
Hyland	-0.295	1.068	817.299	816.231	818.68	8/11/1987	811.66	12/2/1977
Idlewild	-0.224	1.031	854.497	853.466	860.78	3/29/1976	853.10	1/7/1985
Lotus	-0.193	0.958	896.353	895.395	897.08	7/2/1992	893.18	12/29/1976
Lucy	-0.453	0.744	956.807	956.063	957.67	6/20/2014	953.29	11/10/1988
Mitchell	-0.351	1.063	872.636	871.573	874.21	6/25/2014	865.87	7/25/1977
Red Rock	0.191	1.041	841.317	840.276	842.69	7/13/2014	835.69	9/28/1970
Rice Marsh	0.531	1.135	876.582	875.447	877.25	5/28/2012	872.04	8/27/1976
Riley	-1.145	1.447	865.559	864.112	866.74	7/6/1993	862.00	2/1/1990
Round	0.145	1.252	881.067	879.815	884.26	8/17/1987	875.29	7/25/1977
Silver	0.567	1.021	900.089	899.068	901.03	6/20/2012	894.78	6/6/1972
Staring	-0.136	1.845	816.344	814.499	820.00	7/24/1987	812.84	2/12/1977
Susan	-0.378	1.419	882.288	880.0869	883.77	6/21/2014	879.42	12/29/1976
Average	-0.165	1.121						

4.4 Powers Blvd Riley Creek Crossing

In 2013, the Lake Susan Use and Attainability Analysis (UAA) identified Lake Susan Park Pond as a significant contributing source of nutrient pollution to Lake Susan, however sampling results indicated it was less than the UAA. In 2017, the District proposed actions to improve the water quality in Lake Susan through implementing the Lake Susan Park Pond Iron Sand Bench and Stormwater Reuse Enhancement Project which was completed in 2019. As part of the project, staff placed an automated water-sampling unit on Riley Creek at the culvert passing under Powers Blvd, just upstream of Lake Susan and Lake Susan Park Pond. This was done to better quantify rain event nutrient loading from upstream sources in upper Riley 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. Additionally, this information could potentially guide efforts to reduce nutrient loading from upstream sources (i.e. creek restoration sites). Additionally, the Creek Restoration Action Strategy suggested parts of upper Riley Creek were degraded and causing nutrient and sediment loading downstream, eventually to Lake Susan. Water samples were collected and analyzed for total dissolved phosphorus (TDP), total phosphorus (TP), total suspended solids (TSS), and Chlorophyll-a (Chl-a) between 2017-2019. The automated water-sampling unit also estimated flow of the creek at that point.

In 2019, total phosphorus levels at the sampling site during storm events were high compared to the MPCA standard, but the first flush average TP level was down from 2017 but up from 2018. As seen in **Table 11**, the average TP across 12 samples collected in 2019 was 0.497mg/L (highest average level occurred in 2017-0.681mg/L). This level is still about four times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1mg/L TP). The highest TP reading in 2019 occurred in August at 1.08mg/L (highest sampled TP values were 1.62mg/L-2017 and 1.04mg/L-2018; **Figure 9**). The 2019 TDP average across the sampling events was similar to 2018 (0.058mg/L) at 0.053mg/L (up from 0.034mg/L in 2017). The highest TDP 2019 measurement was 0.17mg/L, up from both 2018 (0.076mg/L) and 2017 (0.066mg/L) (**Figure 9**; **Table 11**). TSS concentrations at the sampling site were considered very high, but the average was less than half of the average in 2017 (659.5mg/L). The average amount of TSS across the 12 samples taken in 2019 was 396.07mg/L which is up from 310.61mg/L in 2018 (**Table 11**). To achieve the MPCA TSS stream water quality standard, a stream may not exceed 30mg/L TSS more than 10% of the time. None of the 12 samples taken in 2019 fell below 30mg/L TSS (**Figure 10**). All three Chl-a samples collected in 2019 were less than the MPCA eutrophication water quality standard (≤ 18ug/L Chl-a) which is similar to what was seen in 2017 and 2018 (**Table 11**). It is important to remember 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 Riley Creek. Therefore, a direct comparison to the MPCA water quality standards is cautioned.

Table 11 2017-2019 Powers Blvd Riley Creek Crossing Nutrient Summary

Powers Blvd Riley Creek Crossing Total Dissolved Phosphorus (mg/L), Total Phosphorus (mg/L), Chlorophyll-a (ug/L), and Total Suspended Solids (mg/L) average concentrations from 2017-2019 automated, level triggered and flow-paced samples. The table also includes the Minnesota Pollution Control Agency water quality standards.

Parameter	2019 Average	2018 Average	2017 Average	MPCA Water Quality Standards
TP (mg/L)	0.497	0.331	0.681	≤ 0.1mg/L
TDP (mg/L)	0.053	0.058	0.034	-
Chl-a (ug/L)	6.39	6.00	*41.04/5.62	≤ 18ug/L
TSS (mg/L)	396.07	310.61	659.50	≤ 30mg/L

* Suspect point caused high average

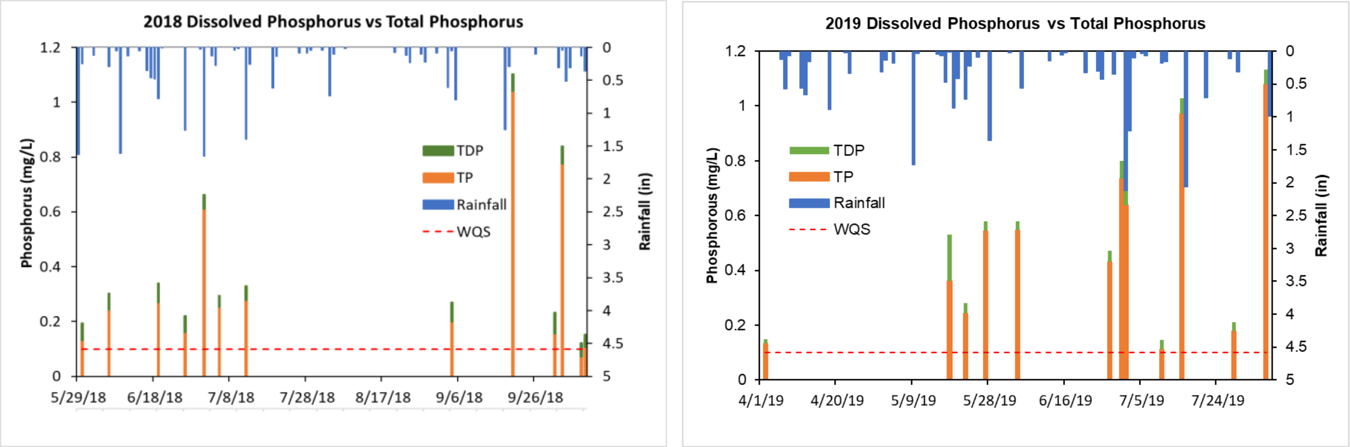

Figure 11 2018 and 2019 Upper Riley Creek Phosphorus

The Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) concentrations (mg/L) from Riley Creek under Powers Blvd from 2018 and 2019 automated, level triggered, flow-paced samples. Dashed line represents the Minnesota Pollution Control Agency standard for TP in class 2B creeks (≤ 0.1mg/L).

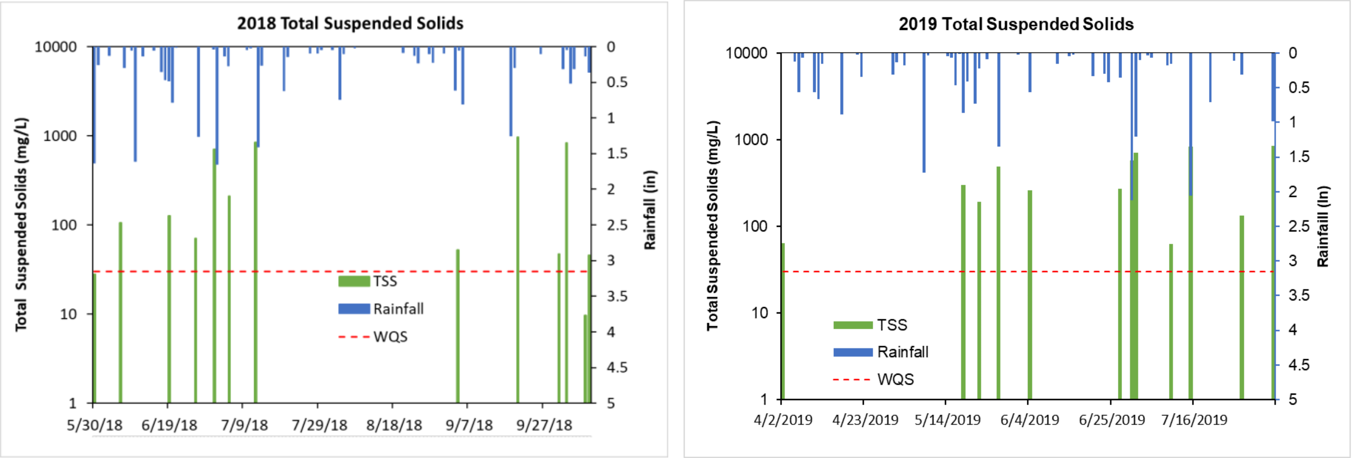

Figure 10 2018 and 2019 Upper Riley Creek Total Suspended Solids

Total Suspended Solids (TSS) concentrations (mg/L) from Riley Creek under Powers Blvd from 2018 and 2019 automated, level triggered, flow-paced samples. Dashed line represents the Minnesota Pollution Control Agency standard for TSS in class 2B creeks (≤ 30mg/L TSS no more than 10% of the time).

4.5 Galpin Blvd Bluff Creek Crossing

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 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 loadings, mobilized by stormwater runoff from the watershed under high flow conditions. In addition, total phosphorous levels across all five Bluff Creek water quality sites are consistently above then MPCA water quality standard from year to year (≤ 0.1mg/L). The Creek Restoration Action Strategy identified subreaches 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 is to confirm a project is warranted and to monitor the effectiveness of a project. In 2019, 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 from Bluff Creek. Analyzing the “first flush” of a storm event is important because these events are when water pollution entering storm drains in areas with high proportions of impervious surfaces is typically more concentrated compared to the remainder of the storm. Water samples were collected and analyzed for total dissolved phosphorus (TDP), total phosphorus (TP), total suspended solids (TSS), and Chlorophyll-a (Chl-a) in 2019. The automated water-sampling unit also estimated flow of the creek at that point.

In 2019, total phosphorus levels at the upper Bluff Creek site during storm events were high compared to the MPCA standards, as seen in **Figure 12**. As seen in **Table 12**, the average TP across 17 samples was 0.525mg/L. This level is over five times the MPCA eutrophication water quality standard for class 2B streams (≤ 0.1mg/L TP). All TP samples collected measured above the MPCA standard with the highest TP concentration having occurred in early August at 1.77mg/L. The 2019 TDP average across the sampling events was 0.135mg/L. The highest measurement was 0.237mg/L (**Table 12**). The average amount of TSS across the 17 samples taken was 84.625mg/L. To achieve the MPCA TSS stream water quality standard, a stream may not exceed 30mg/L TSS more than 10% of the time. Across all the sampling events, nine of the 17 samples taken in 2019 were above 30mg/L TSS (**Figure 13**). Four of the six Chl-a samples collected in 2019 were less than the MPCA eutrophication water quality standard of ≤ 18ug/L Chl-a (**Table 12**). It is important to remember 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.

Table 12 2019 Galpin Road Bluff Creek Crossing Nutrient Summary
Galpin Road Bluff Creek Crossing Total Dissolved Phosphorus (mg/L), Total Phosphorus (mg/L), Chlorophyll-a (ug/L), and Total Suspended Solids (mg/L) max, min, and average concentrations in 2019 automated, level triggered and flow-paced samples. The table also includes the Minnesota Pollution Control Agency water quality standards.

Parameter	Minimum	Maximum	2019 Average	MPCA Water Quality Standards
TP (mg/L)	0.154	1.77	0.525	≤ 0.1mg/L
TDP (mg/L)	0.025	0.237	0.135	-
Chl-a (ug/L)	3.34	24	11.562	≤ 18ug/L
TSS (mg/L)	5	800	84.625	≤ 30mg/L

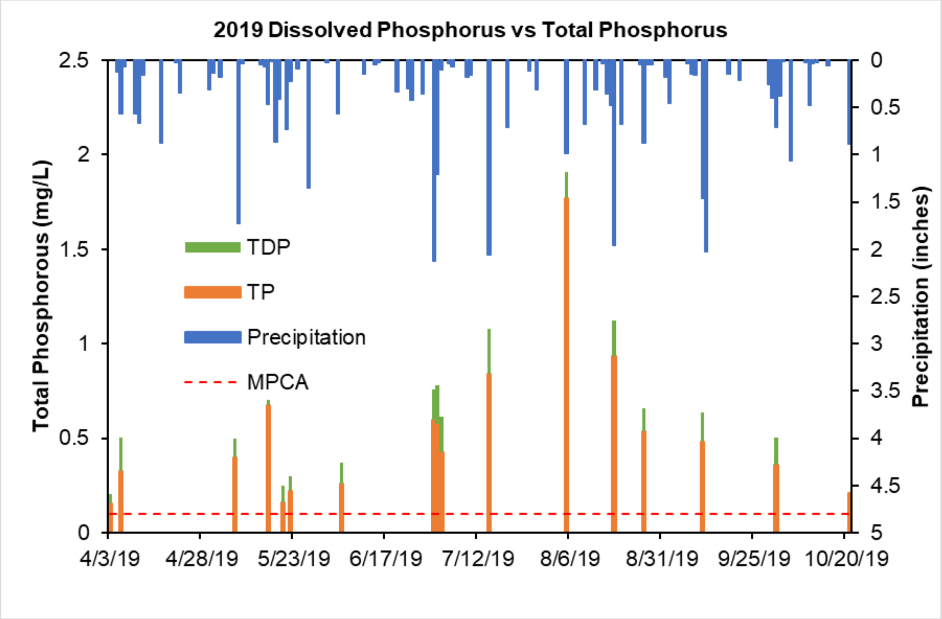

Figure 12 2019 Upper Bluff Creek Phosphorus

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

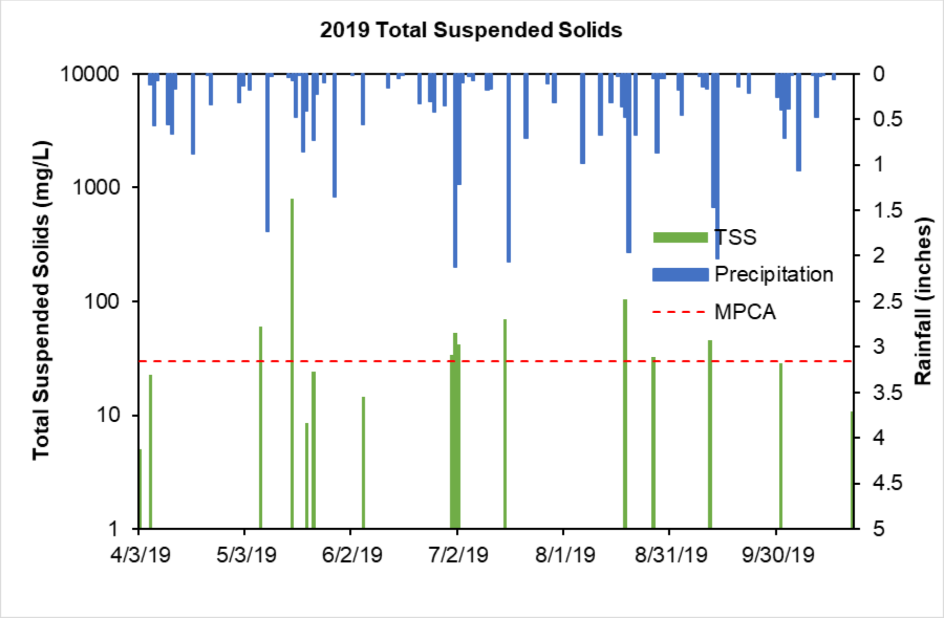

Figure 13 2019 Upper Bluff Creek Total Suspended Solids

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

4.6 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: www.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 was developed which includes subreaches from all three creeks (**Table 13**).

Table 13 Severe Reaches Identified by the Creek Restoration Action Strategy

Stream	Tier II Rank	Tier I Rank	Reach	Subreach	Location
Purgatory	1	9	P7	P7E	Covington Road to Pond in Covington Park
Riley	2	2	R2	R2E	Middle 1/3 between Dell Road and Eden Prairie Road
Bluff	3	5	BT3	BT3A	Audubon Road to Pioneer Trail
Purgatory	4	4	P1	P1E	1,350 feet DS of Pioneer Trail to Burr Ridge Lane
Bluff	5	1	B1	B1D	475 feet US of Great Plains Blvd to Great Plains Blvd
Bluff	6	7	B3	B3A	750 feet DS of Railroad to 860 feet DS of Railroad
Bluff	7	10	B3	B3C	1,675 feet US of Audubon Road to Lyman Blvd
Bluff	8	6	R2	R2D	Upper 1/3 between Dell Road and Eden Prairie Road
Bluff	9	3	B5	B5C	Galpin Blvd to West 78th Street
Bluff	10	8	B5	B5B	985 feet US of Galpin Blvd to Galpin Blvd

Note: US = Upstream; DS = Downstream

As part of CRAS, stream reaches are walked on a rotational basis after the initial assessment was completed. This will allow staff to evaluate changes in the streams and update the CRAS accordingly. In 2019 staff walked Reach 7 of Purgatory Creek and parts of Reach 3, 4, and 5. Staff conducted Modified Pfankuch Stream Stability Assessments, MPCA Stream Habitat Assessments (MSHA), took photos, and recorded notes of each subreach to assess overall stream conditions. In addition to creek walks, 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 2019 creek walks can be seen in **Table 14** and in our Fact Sheets. A summary of the 2019 creek walks can be seen in the section below.

In addition to CRAS scoring and measuring bank pins, staff also collected macroinvertebrates at all eight sites on Purgatory Creek. 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. A summary of the macroinvertebrate results will be available in the 2020 annual report as the data was not available for this report.

Table 14 2019 Creek Restoration Action Strategy Updates

Tier I and Tier II scores for the Creek Restoration Action Strategy for 2017 and the corresponding updates from 2019 for subreaches within P7, P5, P4, and P3.

Reach	Subreach	Location	2017 Tier I Scores	2019 Tier I Scores	Tier II Scores
P3	P3A	Mitchell Road to 1,375 feet upstream of Highway 212	16	14	24
P3	P3B	1,375 feet Upstream of Highway 212 to Purgatory Creek Conservation Area	14	14	24
P4	P4A	Valley View Road to Bent Creek Golf Club	14	12	22
P4	P4B	Bent Creek Golf Club to Mitchell Road	18	17	33
P5	P5B	Eden Prairie Road to Railroad	12	12	20
P5	P5C	Railroad to 1500 feet Downstream	12	14	22
P5	P5D	1500 feet Downstream of Railroad to 3550 feet Downstream	14	14	26
P5	P5E	3550 feet Downstream of Railroad to Valley View Road	12	12	20
P7	P7A	Silver Lake to Covington Road	14	12	22
P7	P7C	Vine Hill Road to Covington Road	14	14	26
P7	P7D	Covington Road to Pond in Covington Park	22	18	46

BLUE=GOOD
YELLOW=MODERATE
ORANGE=POOR
RED=SEVERE

In 2020, staff will finish the second complete walk of Purgatory Creek and update accordingly. CRAS updates and potential additional monitoring for 2020 include:

- Placement of additional bank pins at sites that align with upcoming projects.
- Walk additional 1st order tributaries that have not been assessed.
- LRAS
- 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.

Purgatory Creek – P3

Reach 3 of Purgatory Creek begins at Mitchell road and ends at Highway 212. The reach stretches across subreaches P3A and P3B and encompasses approximately 1.02 stream miles. The culvert under Mitchell road was replaced and stabilized in 2014 and was in good shape. Substrate at the beginning of the reach consisted of predominantly gravel/cobble but began shifting to sand silt as staff moved downstream. For the last quarter of the reach the substrate again shifted to primarily sand/gravel/detritus with cobble and boulders sparsely distributed. Similarly, woody debris was relatively common early, but quickly faded out with a slight increase in the last quarter of the reach. Overall, stream sinuosity in this reach was very good. Chanel development, on the other hand, was relatively poor (riffle/run/pool/sequences). The bank vegetation near Mitchell Road consisted of deciduous trees and sparse patches of terrestrial grasses which stretched about 10m in width from both stream banks. Beyond the 10m riparian zone the landscape was mainly an industrial/urban environment. Both banks had slope gradients between 20%-30% which flattened out about 100m downstream but increased to 40-50% for the last quarter of the reach. Downstream of Mitchell Road stream was approximately 3m wide and had depths ranging from 0.4-1m. Near Mitchell Road, staff observed an eroding stormwater culvert which was suspended about 1m above the outflow channel water surface and has been undercut about 1m. About 100m downstream of Mitchell Road the upland vegetation shifted to grasses/sedges and the riparian zone also increased in width to about 50m. In this stream section, undercutting was almost continuous along both banks, however, the banks were considered stable as it was a wetland stream. There was some bank sloughing occurring throughout this section. The channel displayed a high level of connectivity to the floodplain. As the stream shifted east along Highway 212 the surrounding vegetation changed to mostly buckthorn and deciduous trees. In the last quarter, the average stream depth was approximately 0.5m with an average channel width of 5m. The stream erosion increased in this section as the stream was incised about 0.5m with a few larger erosion areas present. Both Pfankuch and MSHA habitat scores were similar to 2017 scores.

Purgatory Creek – P4

Reach 4 of Purgatory Creek begins at Valley View Road and ends at Mitchell Road. The reach stretches across P4A and P4B which encompasses approximately 0.73 stream miles. Bank shaping/channel re-directing has occurred across the entirety of the reach. Starting downstream of the culvert under Valley View Road, the stream was approximately 6m wide and had a shallow depth, ranging from 0.2-0.6m. Slope gradients were less than 45%. The riparian zone on the right stream bank was wide while the left bank bordering Valley View Road was very narrow. The immediate vegetation consisted of wetland marsh grasses but shifted to deciduous trees shortly downstream. Substrates consisted of sand/silt/muck in the wetland reach. Moving downstream into the wooded area, substrate shifted to gravel/sand. Erosion (incision) increased as staff moved towards the bridge, measuring 0.75m in height. The Minnesota River Bluffs LRT Regional Trail culvert is 5m wide and has signs of wear including cracks and missing chunks.

At the beginning of subreach B, the stream enters the Bent Creek Golf Course. Buffer zones along the stream banks in P4B were absent. Mowed turf grass extended to the edge of the stream in most areas. These practices have increased/caused considerable bank erosion/sloughing, measuring 0.5m-0.75 in height on both banks. Areas where the bank erosion was most severe, small rock had been placed. This rock has the potential to erode and be moved downstream in high/swift water conditions. In slow areas around stream bends, cattails were growing in patchy stands. Staff also observed considerable deposition of silt and muck at these points. The main substrate was comprised of muck/silt and mucky backwaters were present along the channel. Below the first golf course bridge a 3in diameter irrigation pipe crossed the channel. Moving downstream a stormwater culvert was present on the right bank and extended 3m into the stream channel. Near the end of the golf course on a right bank steep slope, a landscape tarp with cobble size riprap was added in attempt to stabilize the bank.

Purgatory Creek – P5 B/C/D/E

The assessment began immediately downstream from Hwy 62 extending to Valley View Road (approximately 2.4 stream miles). The reach includes five subreachs, of which the lower four were walked in 2019. Reach 5 of Purgatory Creek runs through grassy wetlands and a few areas of mixed deciduous forests. The stream was surrounded by residential housing and had a low slope gradient

(<30%). The stream crosses under Eden Prairie Road, Rainbow Drive, a railroad bridge, and a walking trail bridge in subreach P5D upstream of Valley View Road. The creek was fairly straight and had limited channel development (riffle, run, pool). Erosion in this section was relatively low overall with sparse woody debris present within the channel. Overall, Reach 5 was a relatively stable section with some erosion occurring mainly below the choke points at culverts/bridges. After the railroad bridge choke point in P5C, it appears the channel erosion increased since the 2017 analysis. Subreach D had the most continuous erosion with banks incision ranging between 0.25-0.5m. No immediate infrastructure risk was apparent across all the subreaches. MSHA scores indicated limited to moderate habitat availability for aquatic organisms across all subreaches.

Purgatory Creek – P7

Reach P7 of Purgatory Creek originates from Silver Lake and ends at Highway 101 (approximately 1 stream mile). The reach includes five subreachs, of which P7B and P7E are ponding/wetland areas that were not scored by the CRAS. The stream upland vegetative communities in this section consisted of grass prairies, deciduous forests, and cattail marshes. Most banks along the stream were gradually sloped and had moderate-to-no erosion. The creek generally has low flows in this reach. Substrates were made up mostly of sand/silt. P7D did have a considerable amount of gravel/cobble with mixed boulders present. This stream reach was overall in good condition except for P7D. P7D was extremely incised with raw eroding banks up to 2m in height. A few mass wasting sites where also present and contributing sediment nearly all year long. P7D improved in Tier 1 scoring due to an increased MSHA habitat score and because the culvert under Covington Road was replaced and surrounding area stabilized in 2018. This stream enhancement eliminated a major mass wasting site and reduced the infrastructure risk to a score of three. The scoring was only dropped to a three because of a suspended and eroded stormwater culvert downstream of Covington Road was still present.

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 buried in 2016 through 2019 (2018 and 2019 measurements shown in **Table 15**). From this, staff can quantify estimates of lateral bank recession rates. 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 2019, reach R3 had the highest estimated lateral loss (in/year) while reach R2 had the highest bank loss per one yard stretch of creek (ft3).

Table 15 2018-2019 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 in 2019. Negative values denote areas of bank where there was sediment deposition. Empty cells denote sites where pins were not found. Orange-highlighted cells denote sites where bank pins were added on one or both banks in 2018. * Values in these cells are averages from the left bank; right bank pins were not found at these sites. ** The right bank heights used to calculate these values were taken from 2018 measurements.

Site	Average Lateral Loss (in/year)		Estimated bank loss per one yard stretch of creek (ft3)	
	2018	2019	2018	2019
R5	8.99	9.45	2.41	2.58
R4	0.42	4.44	0.25	1.97
R3	5.31	12.96	3.18	5.71
R2	--	6.45	--	6.93
R1	2.96	5.35	1.23	2.71
P8	0.55	2.99	0.12	0.93
P7	2.02	3.40	2.48	3.22
P6	0.73	5.39	0.35	1.95
P5	0.77	3.41	0.41	2.09
P4	0.83	2.09	0.27	**0.69
P3	0.94	1.96	0.51	1.38
P2	0.50	6.36	0.24	3.21
P1	0.38	*0.83	0.46	*0.82
B5	-0.79	1.78	-0.23	0.89
B4	5.58	11.45	3.66	6.59
B3	--	3.29	--	1.84
B2	3.00	*7.00	1.25	*4.08
B1	-0.67	5.54	-0.25	3.45

4.7 Chloride Monitoring

Increasing chloride (Cl) levels in water bodies are becoming of greater concern within the state of Minnesota. It takes only one teaspoon of road salt to permanently pollute five gallons of water, as chlorides do not break down over time. At high concentrations, 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 230mg/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 860mg/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 2019, winter monitoring included the Purgatory Chain of Lakes (Lotus, Silver, Duck, Round, Mitchell, Red Rock, Staring, and Hyland), the Upper and Lower Purgatory Creek Recreation Area (UPCRA and LPCRA), Rice Marsh Lake, and a chain of ponds that drain the City of Eden Prairie Center to Purgatory Creek. During sampling, staff collected a surface 2m composite sample and a bottom water sample to be analyzed for Cl. Since 2013, except for some samples taken from Idlewild, every sample taken from the RCL and PCL, has fallen below the MPCA CS of 230mg/L (**Figure 14**; **Figure 15**). Cl levels have stayed relatively consistent within lakes year-to-year.

Figure 16 shows Cl levels within the four stormwater ponds, which includes all sampling events since 2013. In the spring of 2015, staff were no longer able to take accurate water samples on Pond A due to low water levels, so, sampling began on Pond B, directly upstream. In 2018, due to inconsistencies with getting samples without disturbing sediment, staff reverted to sampling Pond A in place of Pond B for several monitoring events. Most samples taken from Eden Pond greatly exceed the class 2B CS, some exceeding the class 2B MS. Except for two sampling events, all samples taken from Pond K exceed the class 2B MS, although, there has been a noticeable drop in Cl levels since sampling began in 2013. It is important to note that these stormwater ponds are not classified as class 2B surface waters by the MPCA; the CS is given in the figure to demonstrate the much higher Cl levels accumulating within these ponds before water moves into Purgatory creek.

Staff will continue the winter monitoring of Cl in the Purgatory Chain of Lakes in 2020 which will include: Lotus, Silver, Duck, Round, Mitchell, Red Rock, PCRA, Staring, and Hyland Lake. Rice Marsh Lake will also be monitored for Cl in the 2020 winter, along with the stormwater ponds draining Eden Prairie Center, UPCRA, and LPCRA. Once-a-month Cl sampling will continue as part of sampling SOP's during the regular growing season on both lakes and streams.

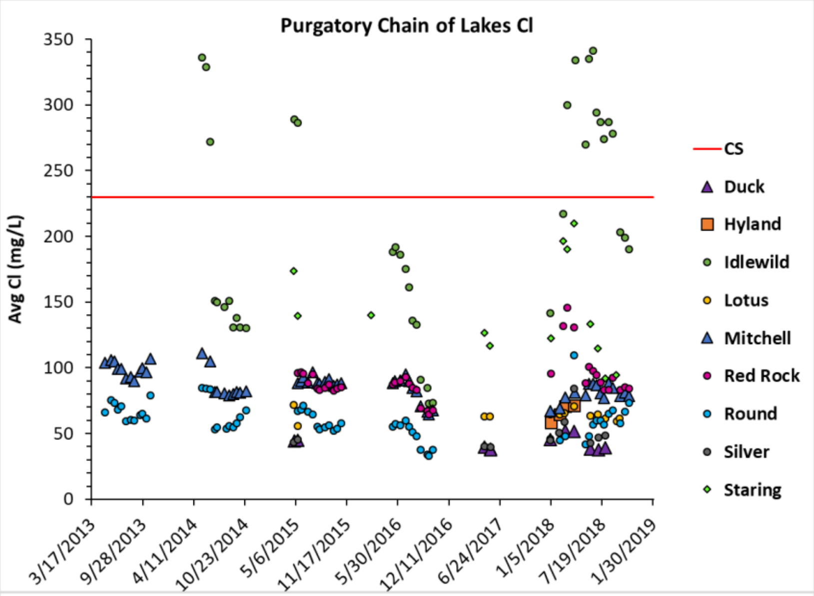

Figure 14 2013-2019 Chloride Levels within the Purgatory Chain of Lakes

All chloride sampling results (mg/L) on the Purgatory Chain of Lakes from 2013-2019. The MPCA chloride chronic standard for class 2B waters (230mg/L) is indicated by the red line.

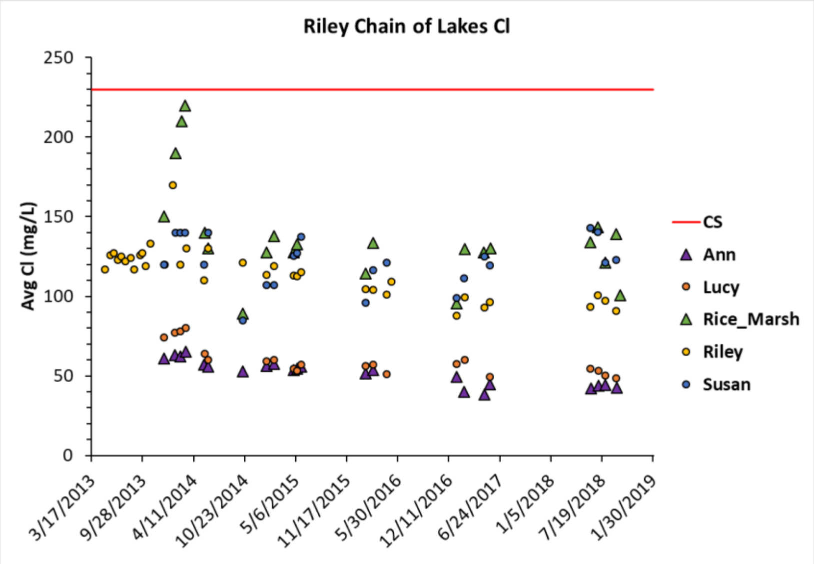

Figure 15 2013-2019 Chloride Levels within the Riley Chain of Lakes

All chloride sampling results (mg/L) on the Riley Chain of Lakes from 2013-2019. The MPCA chloride chronic standard for class 2B waters (230mg/L) is indicated by the red line.

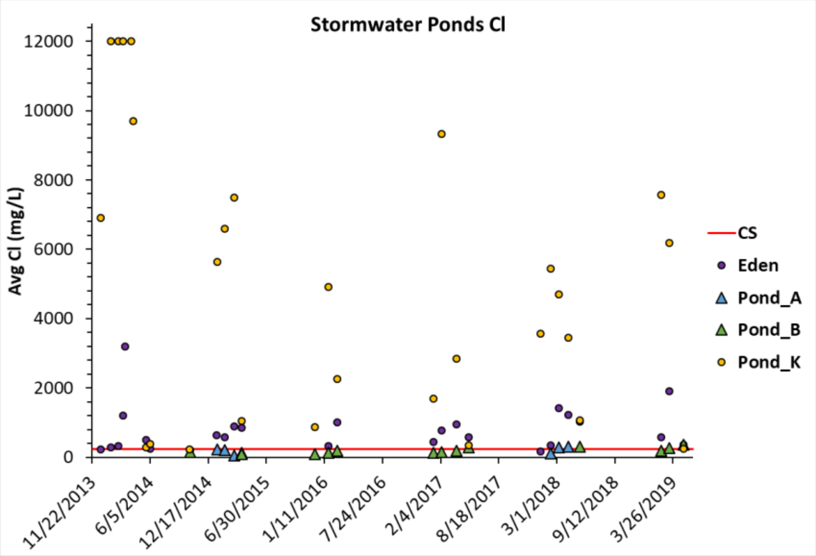

Figure 16 2013-2019 Chloride Levels within EP Stormwater Ponds

All chloride results (mg/L) on stormwater ponds draining the City of Eden Prairie Center to Purgatory Creek from 2013-2019. The MPCA chloride chronic standard (230mg/L) for class 2B waters indicated by the red line.

4.8 Nitrate 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 a 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) of 4.9mg/L nitrate-N.

Once a month during regular sampling, staff collects a surface 2m 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 (**Figure 17**). 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 TKN. The District monitors for 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 16**). This lab also tests for ammonia in the form of ammonia+ammonium (**Figure 18**). As seen in **Table 16**, 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 0.03mg/L. Therefore, it is possible that some of the samples contained less than 0.03mg/L nitrate; because of this, actual average nitrate levels in District lakes may be lower than what measured (**Table 16**).

Lake	Average Nitrate+Nitrite (mg/L)
CS	**4.90mg/L**
Ann	0.03
Duck	0.03
Hyland	N/A
Idlewild	0.05
Lucy	0.03
Lotus	0.03
Mitchell	0.05
Red Rock	0.05
Rice Marsh	0.03
Riley	0.03
Round	0.05
Silver	0.03
Staring	0.03
Susan	0.03

Table 16 2019 Lakes Summer Average Nitrate+Nitrite

2019 growing season (June-September) average nitrate+nitrite levels for District lakes. The MPCA proposed chronic standard (CS) is included in the table (orange). Lower limit of lab analysis of nitrate+nitrite is 0.03mg/L.

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 0.04mg/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 0.04mg/L. The lower limit for sample data provided by the City of Eden Prairie for Red Rock, Round, Idlewild, and Mitchell Lakes is 0.16mg/L. Due to these limits, some of the average levels of Ammonia+Ammonium provided in **Figure 18** may actually 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). **Figure 18** 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 2019 growing season and because lab testing measures the combination of ammonia and ammonium. This suggesting that most of nitrogen found in these tests was from the less toxic compound ammonium.

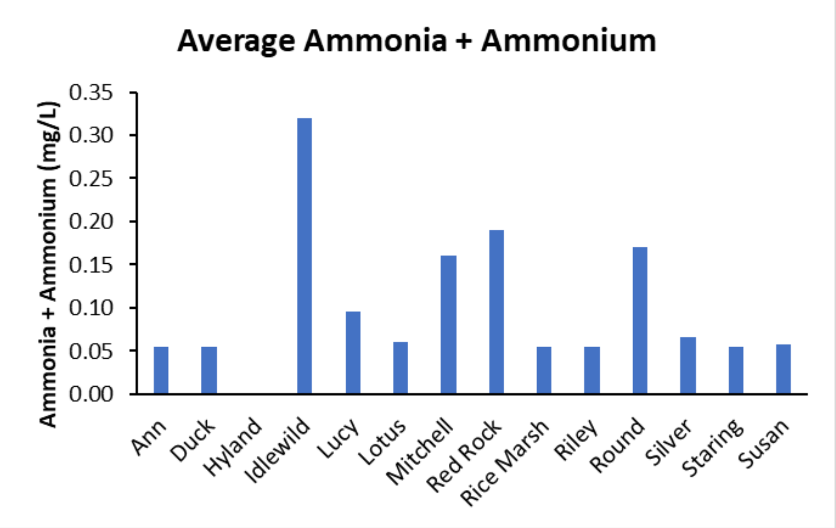

Figure 18 2019 Lakes Summer Average Ammonia+ Ammonium

Average levels of ammonia+ammonium from samples taken on each lake during regular sampling within the growing season (June-September).

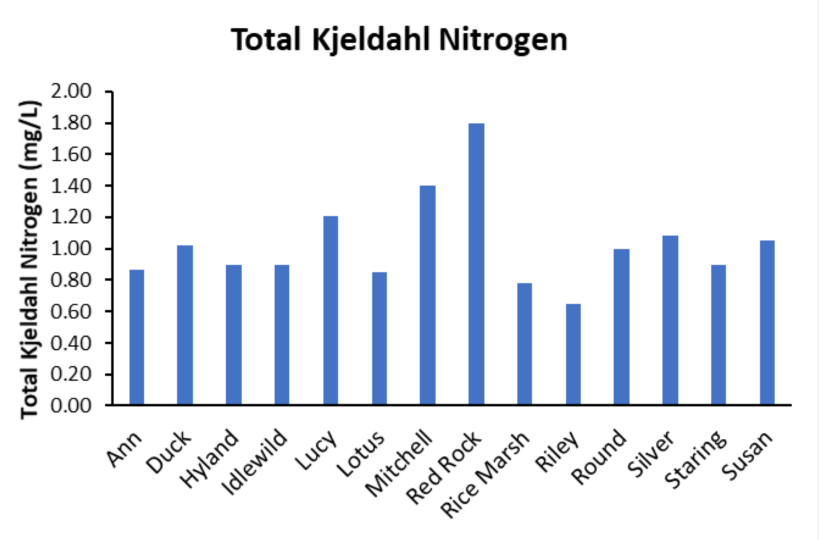

Figure 17 2019 Lakes Summer Average Total Kjeldahl Nitrogen

Average levels of Total Kjeldahl Nitrogen from samples taken on each lake during regular sampling within the growing season (June-September).

4.9 Zooplankton and Phytoplankton

In 2019, five lakes were sampled for both zooplankton and phytoplankton: Lake Riley, Rice Marsh Lake, Lake Susan, Lotus Lake, and Staring Lake. Zooplankton play 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. The Sedgwick-Rafter Chamber (SRC) was used for zooplankton counting and species identification. A two mL sub-sample was prepared in which all zooplankton 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 Sedgwick-Rafter Chamber (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 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 necessary and identify possible sources of pollution. Just because toxic algae are found in a lake does mean it could cause harm. Specific conditions must be met for the algae to become toxic.

Lake Riley

In 2019, all three groups of zooplankton were captured in Lake Riley (8 Exhibits C), however only 5.6% of the population was comprised of Cladocera. As expected, rotifers were the most abundant zooplankton sampled (**Figure 19**). The number of rotifers identified in 2019 steadily decreased over sampling events to a low point in August, followed by a sharp increase in September. Copepod numbers increased between the first two sampling events, then followed roughly the same pattern as Rotifera. Cladoceran numbers decreased over the course of the season. Total Cladoceran counts in 2019 were up slightly from 2018, but still less than what was seen in 2016 and 2017 (around 450 thousand). This reduction may be due to the continuing increase in water clarity caused by alum treatment, which leads to increased predation on zooplankton populations. Additionally, zebra mussels were discovered in 2018 which could also be contributing to the increase in water clarity and are removing phytoplankton (Cladoceran food source). The most numerous Cladocera found in Riley was *Chydorus sphaericus*, a species tolerant of widely ranging environmental conditions.

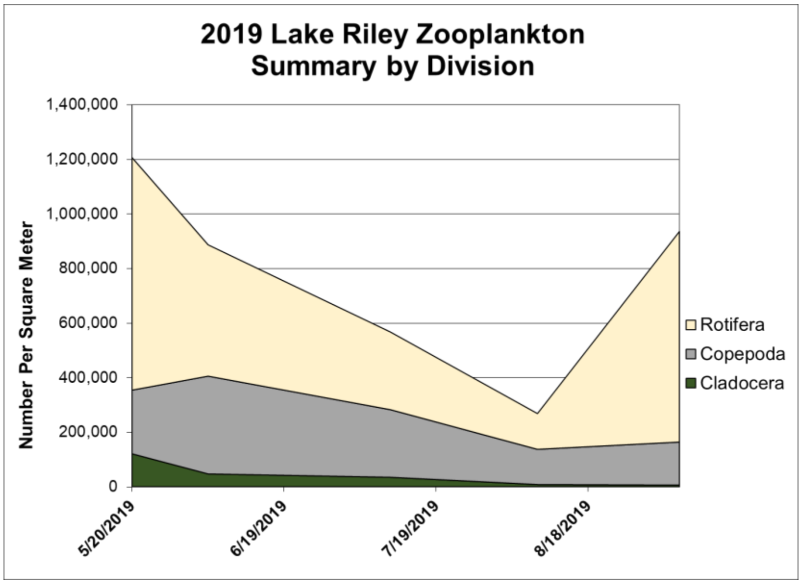

Figure 19 2019 Lake Riley Zooplankton Counts (#/m²)

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 as seen in 2019, grazing rates were near 0% across all sampling dates.

During the summer of 2019, staff collected five phytoplankton samples on Lake Riley (8 Exhibits D). The seasonal abundance of phytoplankton is presented in **Figure 20**. The dominant phytoplankton in May, July, and September were Cyanophyceae cells which made up 41%, 59%, and 63% of the total phytoplankton abundance (TPA), respectively. 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. *Aphanizomenon sp*. was the predominant cyanobacteria found and is known as a possible toxin producer that may potentially produce cylindrospermopsin, anatoxins, and saxitoxins. These toxic compounds have the potential to pose serious threats to human and environmental health via contamination of drinking water, recreational exposure to waterborne toxins and possible accumulation of toxins in the food-web. Chlorophyceae dominated the phytoplankton population in June and August (60% and 59% TPA, respectively).

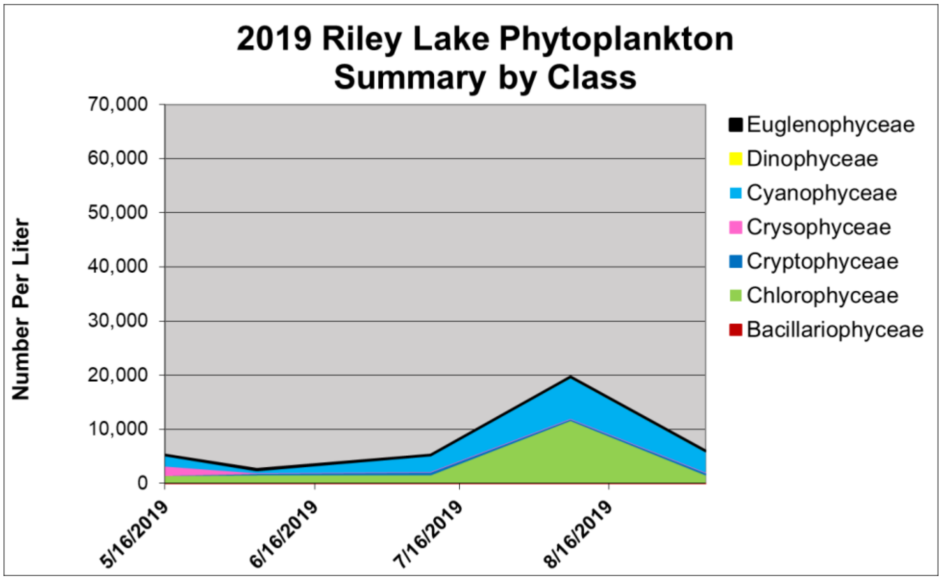

Figure 20 2019 Lake Riley Phytoplankton Abundance (#/L) by Class.

Lotus Lake

In 2019, all three groups of zooplankton were present in Lotus Lake (8 Exhibits C). In 2019 Rotifers were the least abundant zooplankton sampled (**Figure 21**) which is in contrast with 2018 when Rotifers were the most abundant overall. Copepod numbers varied significantly between sampling events throughout 2019. Cladoceran numbers began at 210 thousand in May before decreasing to less than 100 thousand for the June, July, and August. Cladocerans reached their highest numbers in September, at 362 thousand. The spring Cladocera numbers can be attributed to an abundance of *Daphnia galeata*, while *Daphnia retrocurva* was dominant in late 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.

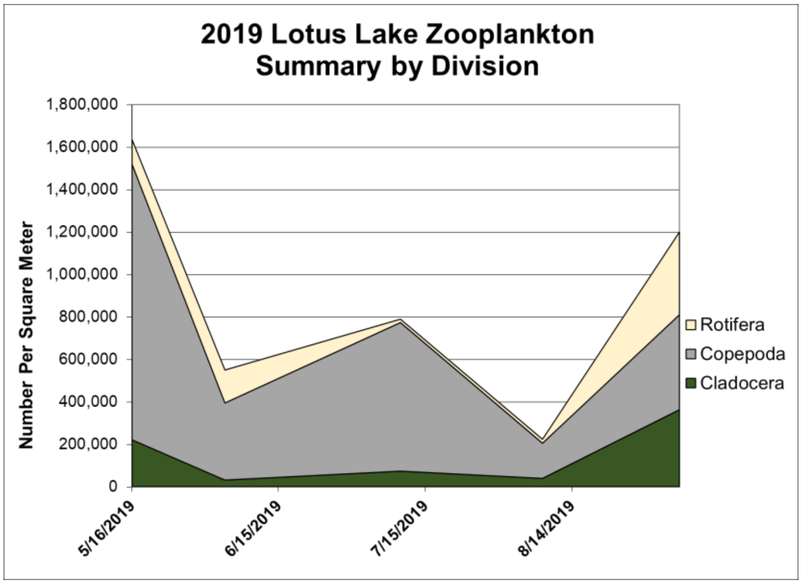

Figure 21 2019 Lotus Lake Zooplankton Counts (#/m²)

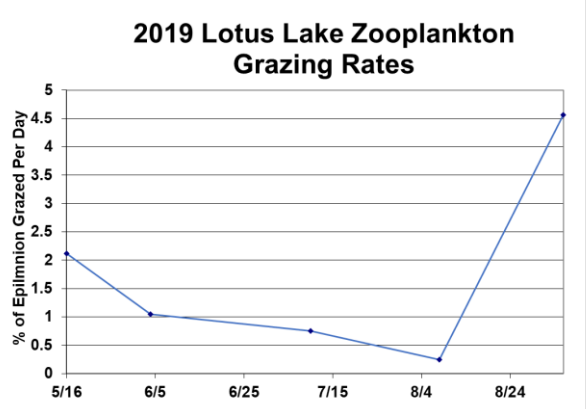

Figure 22 2019 Lotus Lake Epilimnetic Grazing Rates

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% (**Figure 22**). As expected, grazing rates followed a similar trend to what was seen in the population fluctuations; the largest grazing rate occurred on in September when the spike in *Daphnia retrocurva* numbers occurred.

During the summer of 2019, staff collected five phytoplankton samples on Lotus Lake (8 Exhibits D). The abundance of phytoplankton across all sampling dates is presented in **Figure 23**. In July Cryptomonas erosa was briefly dominant, followed closely by Cyanobacteria (55% and 43% total phytoplankton abundance, respectively). Cryptomonas spp. are not known to produce toxins and are an important food source for zooplankton. Cyanobacteria was the dominant species on the May, June, August, and September sampling dates (58%, 59%, 87%, and 72% total phytoplankton abundance by sampling event). Aphanizomenon sp. was the dominant species of cyanobacteria in August and September, with a massive spike occurring in early August. Aphanizomenon are a potential producer of cylindrospermopsin, anatoxins, and saxitoxins.

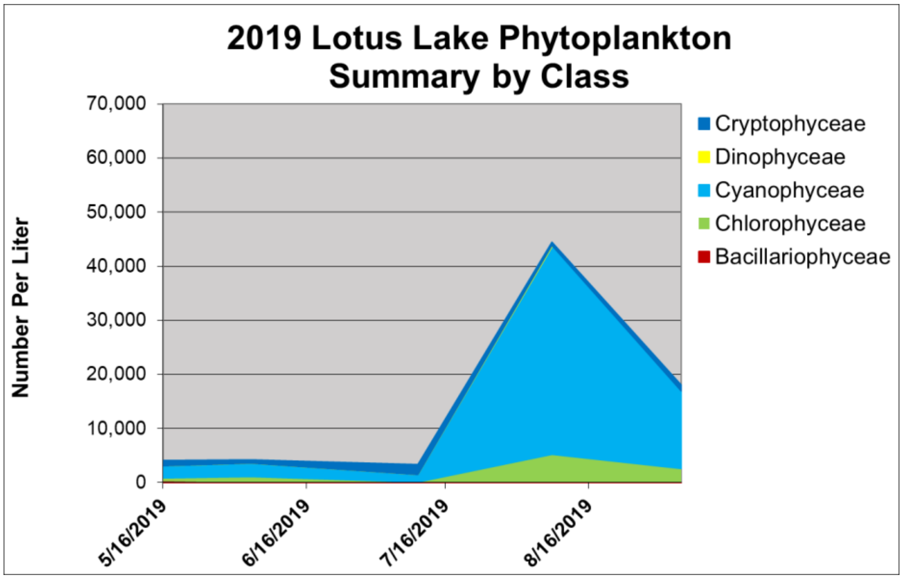

Figure 23 2019 Lotus Lake Phytoplankton Abundance (#/L) by Class.

Lake Susan

Similar to 2018, Rotifers were the most abundant zooplankton captured in Lake Susan in 2019 (8 Exhibits C). The rotifer population was variable over the sampling events with a notable decrease in rotifer numbers occurring in June and July. Copepod numbers declined from an early high of 872 thousand, dropping to an average of around 300 thousand for the rest of the season (**Figure 24**). Overall, Cladocera numbers were low relative to the other taxa, around 100 thousand individuals per sampling event, but were still around 5 times higher than Cladocera numbers in 2018 (<20 thousand per sampling event). The lowest Cladocera population recorded in 2019 was in early August when no individuals were captured.

The Cladocera population in Lake Susan was dominated by species in the genus *Daphnia*, of which *D. pulex* was most common.

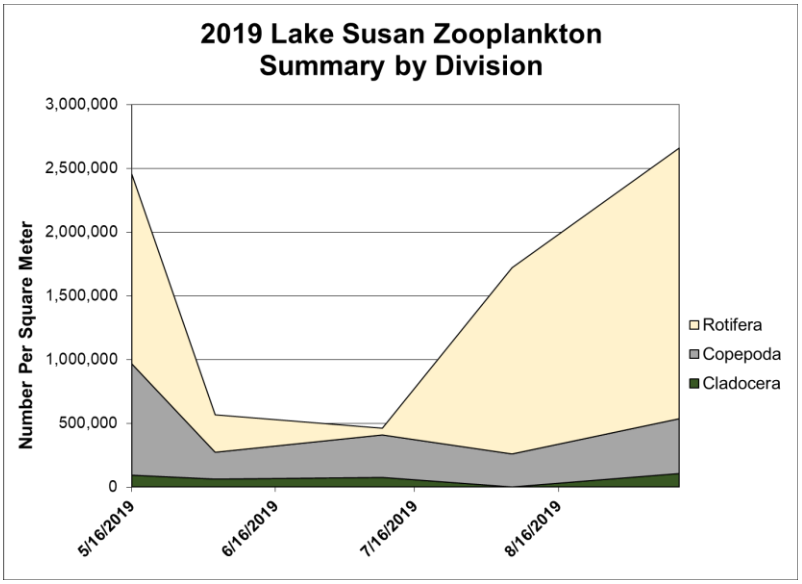

Figure 24 2019 Lake Susan Zooplankton Counts (#/m²)

The estimated epilimnetic grazing rates upon algae observed in 2018 were, ranging from 0.1% to 11%. However, in 2019, the epilimnetic grazing rate was only around 1% (**Figure 25**). This is mainly due to the very limited number of Cladocera present in all the samples collected. The highest grazing rate was observed in early June when *Daphnia pulex* were more numerous in the zooplankton community.

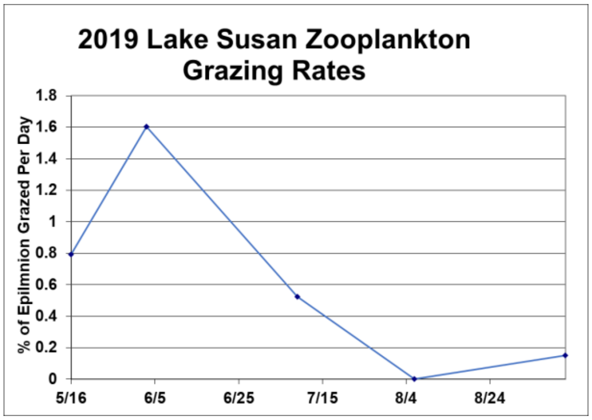

Figure 25 2019 Lake Susan Epilimnetic Grazing Rates

During the summer of 2019, staff collected five phytoplankton samples on Lake Susan (8 Exhibits D). The abundance of phytoplankton by Class is presented in **Figure 26**. From mid-May to mid-July, Cryptophytes and Chlorophytes were the co-dominate phytoplankton groups. Cryptophytes are motile unicellular algae that grow photosynthetically and are broadly distributed in lakes, usually preferring nutrient-rich environments. Chlorophytes, or green algae, are like Cryptophytes, but are non-motile. A large spike in the population of Cyanobacteria caused it to become the dominant phytoplankton species in August with a TPA values 64%. *Pseudanabaena limnetica* was the most common species of cyanobacteria during this event. *Pseudanabaena sp.* are filamentous, bloom forming organisms. They produce compounds that can impart muddy or moldy flavors to drinking water during large blooms. By mid-September the Cyanophytes had disappeared and been replaced as the dominant phytoplankton group by the Dinophyceae species *Ceratium hirundinella*. This unicellular species is known for its spiked shell formed of armored plates. Though generally harmless, blooms of *Ceratium* species can occur under the right conditions. The resulting oxygen depletion caused by these blooms can potentially result in fish kills.

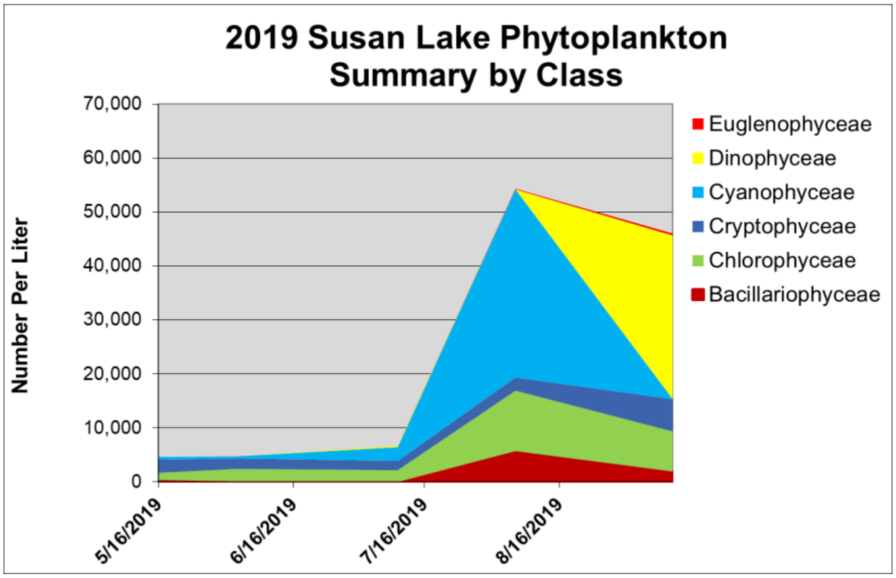

Figure 26 2019 Lake Susan Phytoplankton Abundance (#/L) by Class.

Rice Marsh Lake

In 2019, all three groups of zooplankton were captured in Rice Marsh Lake (8 Exhibits C), of which 8% of the population was comprised of Cladocerans, down from 13% in 2018 and 27% in 2017. As expected, rotifers were the most abundant zooplankton sampled in 2019 (**Figure 27**). However, 90% of Rotifers counted were sampled in May and June. Copepod densities were highest in May and remained relatively stable thereafter. Across all sampling dates the Cladoceran community was dominated by small-bodied zooplankton, consisting of mainly *Bosmina longirostris, Ceriodaphnia sp*., and *Chydorus sphaericus.*

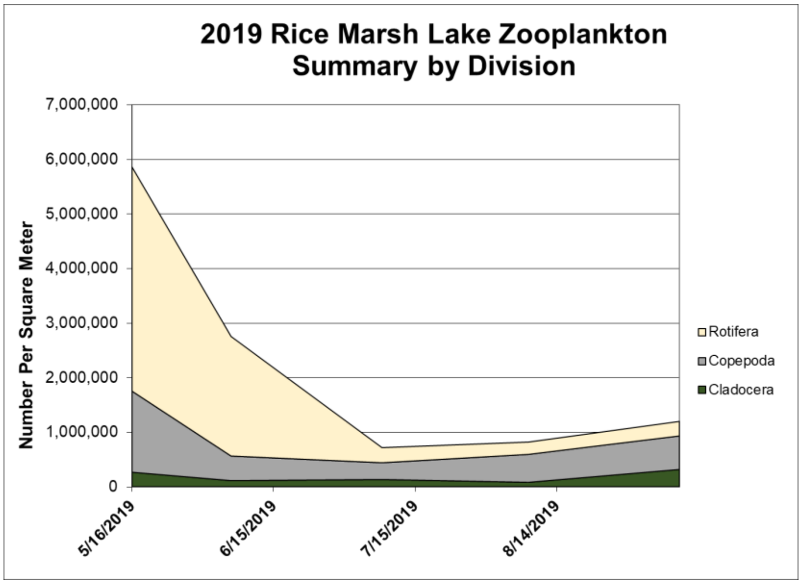

Figure 27 2019 Rice Marsh Lake Zooplankton Counts (#/m^2)

The estimated epilimnetic grazing rates of Cladocera observed in 2018 ranged from near 0% to 23% on Rice Marsh Lake. In 2019, the epilimnetic grazing rate was highest during the May sample at 39% (**Figure 28**). After the first May sampling event, grazing rates averaged near 5% for the remainder of the year. The highest May grazing rate was linked with the presence of the larger bodied Cladocera *Daphnia pulex*. The most common Cladocera present was *Bosmina longirostris* which are commonly found in bog lakes such as Rice Marsh Lake.

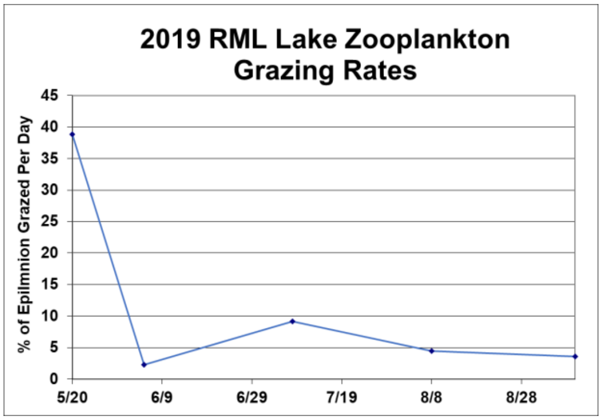

Figure 28 2019 Rice Marsh Lake Epilimnetic Grazing Rates

During the summer of 2019, staff collected five phytoplankton samples on Rice Marsh Lake (8 Exhibits D). Abundance of phytoplankton by Class for Rice Marsh Lake is presented in **Figure 29**. In 2019, there was a notable steep decline in Cyanobacteria as a percent of total phytoplankton abundance (TPA), from 82% in 2018 to just 9% in 2019. *Chlamydomonas globosa* (Chlorophyceae) was the dominant species of all five sampling events (83%, 60%, 37%, and 53% TPA).

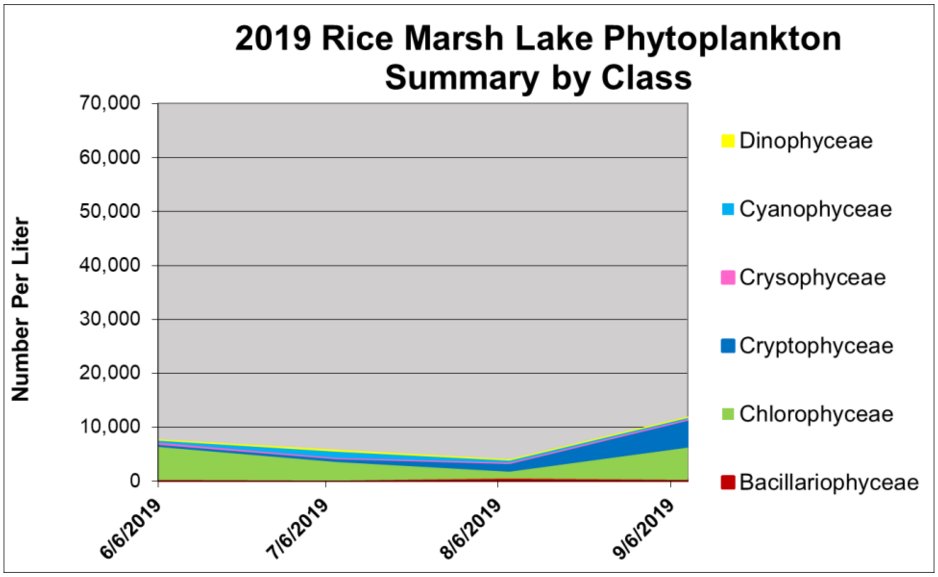

Figure 29 2019 Rice Marsh Lake Phytoplankton Abundance (#/L) by Class.

Staring

In 2019, all three groups of zooplankton were present in Staring Lake (8 Exhibits C). The June sampling event had the highest number organisms across all groups (**Figure 30**). Rotifer numbers experienced a significant spike to near 2.5 million in June, and an average of 500 thousand for the remainder of the year. The dominant Rotifer species was *Keratella cochlearis*, which occurs worldwide in virtually all bodies of water whether fresh, marine, or brackish. Copepod numbers were roughly steady at an average of 440 thousand per sampling event. Cladoceran numbers generally remained above 200 thousand except in July and August when they dipped below 100 thousand. The most abundant Cladocera were *Bosmina longirostris* which are common in lakes and ponds across the United States.

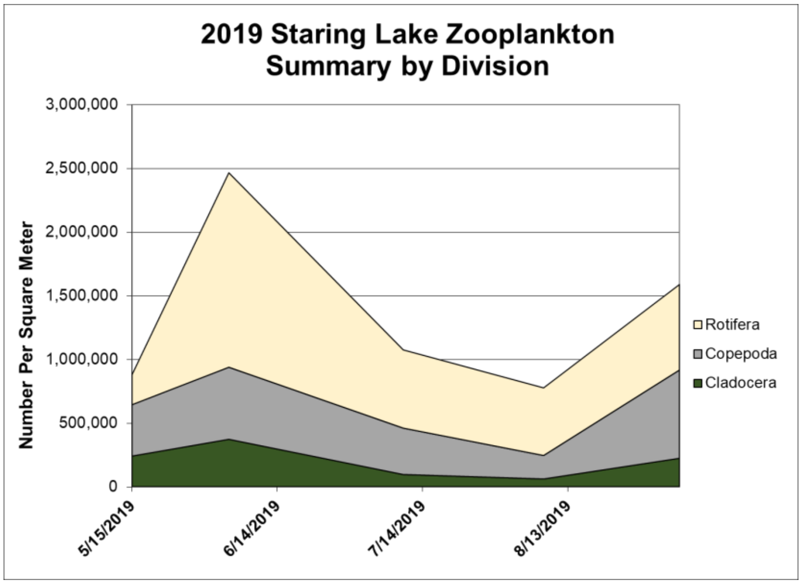

Figure 30 2019 Staring Lake Zooplankton Counts (#/m^2)

Large Cladocera consume algae and may have the potential to improve water quality when present in large densities. The estimated epilimnetic grazing rates observed in 2018 ranged from 2% to 24%. The 2019 were much lower at 1-4% (**Figure 31**). The max grazing rate in May corresponded optimal feeding temperatures near 21 degrees Celsius.

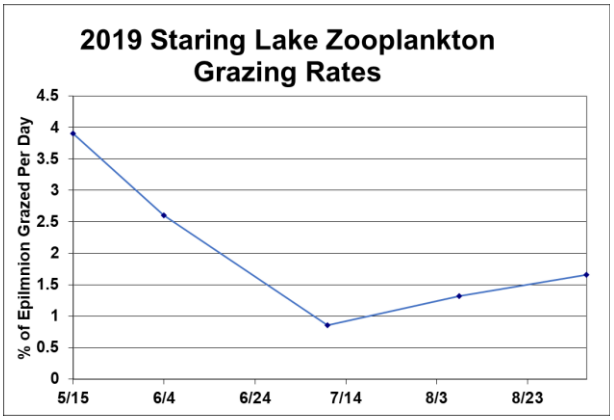

Figure 31 2019 Staring Lake Grazing Rates

During the summer of 2019, staff collected five phytoplankton samples on Staring Lake (8 Exhibits D). Abundance of phytoplankton by Class are presented in **Figure 32**. In May, the dominant class of phytoplankton, with 87% of the total phytoplankton abundance (TPA), was the Chlorophyceae (green algae). The June sampling event was dominated by Bacillariophyceae, the diatoms, with 56% of the TPA. Cyanophyceae, commonly known as cyanobacteria or blue-green algae, began to dominate in July (56%) and spiked in August with 75% of the TPA. Blue-green algae was absent in the September sample, being replaced by Cryptophyceae as the dominant class with 85% of the TPA.

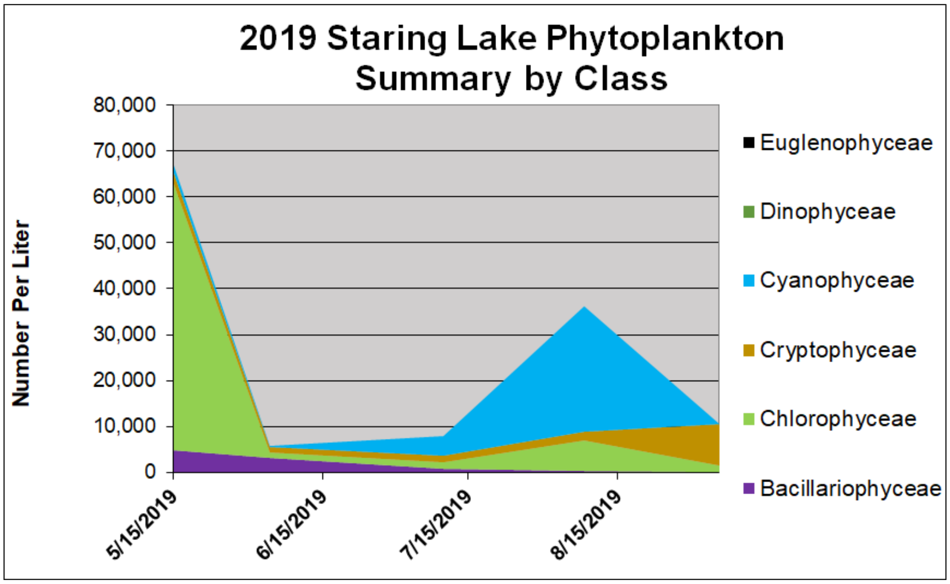

Figure 32 2019 Staring Lake Phytoplankton Abundance (#/L) by Class.

4.10 Winterkills and Fish Stocking

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 Riley Purgatory Bluff Creek Watershed 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 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 and consume DO in that 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 provide an abundance of food for the decomposers which can cause DO levels to become depleted and a fish kill can occur.

In late March of 2018, RPBCWD staff were notified about a possible winterkill on Rice Marsh Lake by a resident who contacted the City of Chanhassen. Staff went out and conducted a regular water quality sampling event and confirmed that a fish kill occurred. DO levels in Rice Marsh Lake across all depths were less than 2 mg/l and dead bluegills were observed. Staff had been operating an aeration unit on Rice Marsh Lake successfully and a large open water area was present all winter in 2017-2018. No winterkills had previously occurred on Rice Marsh Lake since the aeration unit was installed in 2010. After sampling Rice Marsh Lake, staff also sampled Duck Lake, where similar conditions were observed, indicating a winterkill had occurred. The surface DO level was at 8 mg/L, while the remaining levels were below 2 mg/L. Lake residents attempted to prevent a winterkill by plowing away strips of snow totaling four to five acres to increase photosynthesis but were unsuccessful.

Additionally, during spring of 2019 staff were alerted by residents around the lake that a fish kill had occurred on Lake Lucy. The fish kill was near a complete kill. Fish of all sizes and species were found dead, including low oxygen tolerant fish such as common carp. Staff rotate winter monitoring between the Riley Chain of Lakes (RCL) and Purgatory Chain of Lakes (PCL) every year, so no oxygen data was available to assess the winterkill on Lucy in 2019.

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, eliminating 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, no winterkills, and subsequently, no major recruitment events of common carp occurred within the Riley Creek system. 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 fish population. Due to the importance of Rice Marsh Lake in combating carp within the RCL, and the need to quickly establish a base bluegill population in Lake Lucy after the 2019 winterkill, it was decided that bluegill sunfish would be stocked into these lakes. Since the certified private hatchery was delivering bluegill to Rice Marsh Lake and Lake Lucy, staff also directed the stocking of bluegills 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 and stocking bluegill has been used in the past to aid in common carp control. The stocking was used to bolster bluegill populations within the PCL system with the hope of eliminating carp recruitment. Duck lake was stocked by the MN DNR in 2018 and 2019. Bluegill stocking rates can be seen in **Table 17**. **Figure 33** displays the average number of bluegill/net for the lakes sampled in 2019 and the corresponding winterkill years indicated by the red arrows. Due to the recovery of bluegills in both Rice Marsh Lake and Lake Lucy, no fish will be stocked in 2020 unless another significant winterkill occurs. No spring fish kills were identified in 2019 as a result of the bacterial infection Flexibacter columnaris which, has occurred in previous years on Lotus Lake and Lake Susan.

Table 17 2018 & 2019 Bluegill Stocking Rates

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

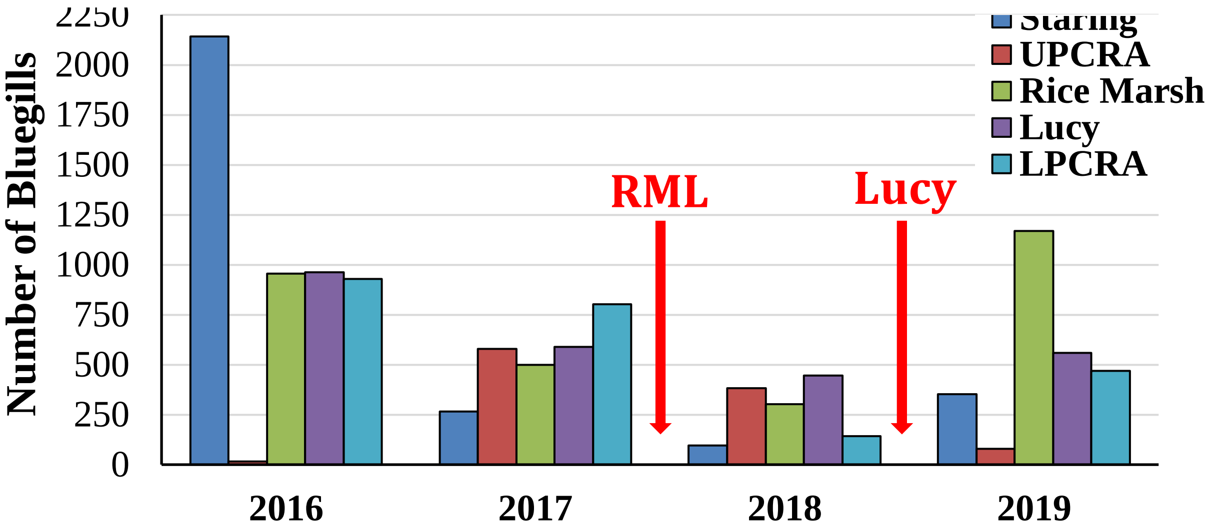

Figure 33 2019 Bluegill Catch/Net from 2016-2019

The red arrows indicate the winters in which winter kills occurred on the corresponding lakes.

4.11 Lake Susan Spent-Lime Treatment System

Figure 34 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 34**). 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.

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 the system (e.g., monitoring, materials, influent, changed conditions, etc.) During 2018, 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.

Figure 35 Spent Lime/Sand Mixture Column Testing

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 35** 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 (**Figure 37**; **Figure 38**).
- Initial testing of plaster sand obtained from a local pit also results in phosphorus export from the material.
- Total phosphorus removals where generally high the larger the content of spent lime in the mixture (**Figure 36**).

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. Staff will monitor the spent lime system to see if the system is performing. Modifications will be installed in 2020 which include:

- Replace the deteriorated spent lime with a mixture of 70% plaster sand and 30% spent lime.
- Improve control of water flow through installing various valves and gates and replacing the underdrain slotted piping.

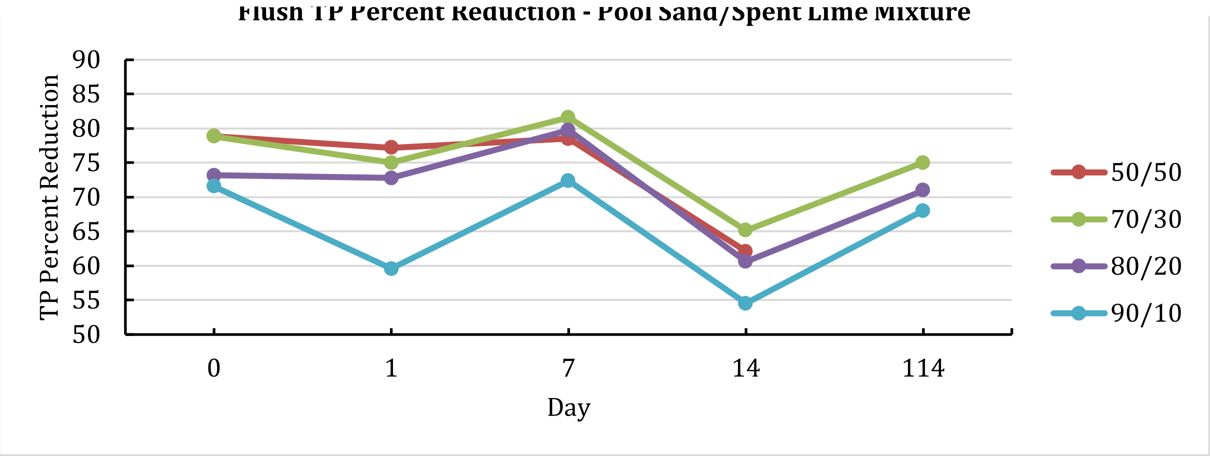

Figure 36 Pool Sand/Spent Lime Mixture Column Testing Phosphorus Removals

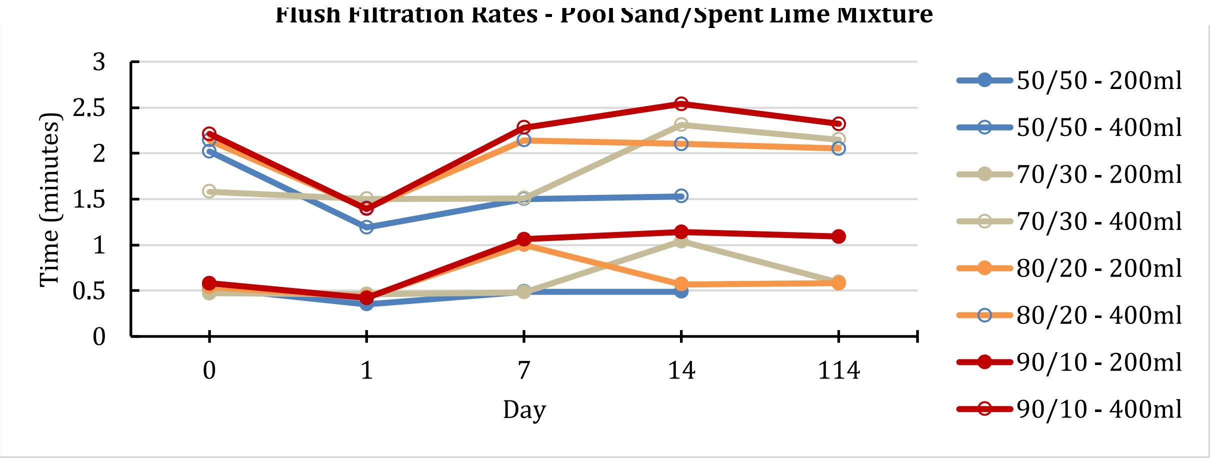

Figure 37 Pool Sand/Spent Lime Mixture Column Testing Filtration Rates

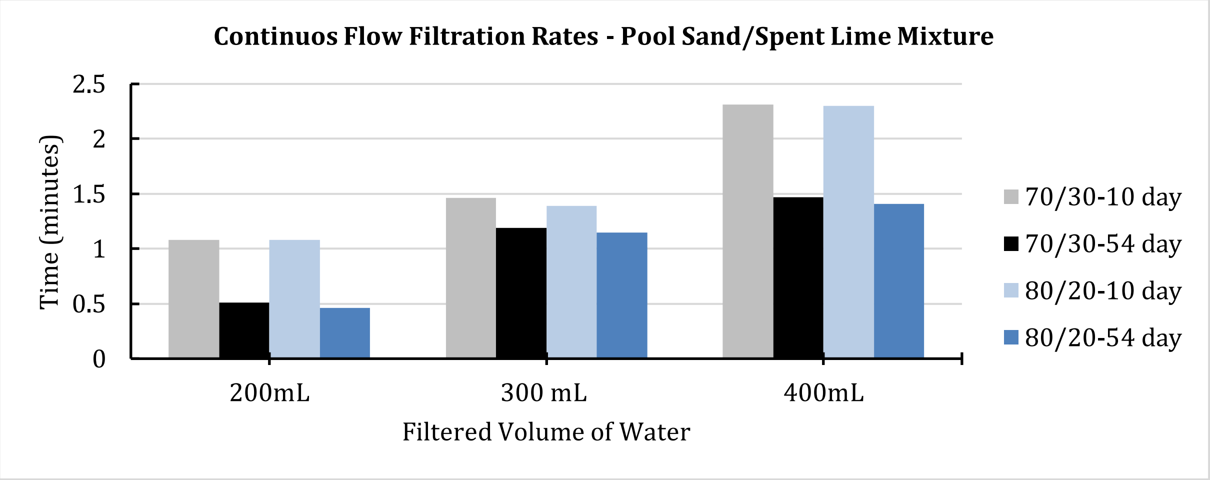

Figure 38 Pool Sand/Spent Lime Mixture Column Testing Continuous Flow Results

4.12 LSPP Iron Enhanced Sand Filter Bench

Figure 39 Lake Susan Park Pond Iron Sand Bench

In 2013, the Lake Susan Use and Attainability Analysis (UAA) identified Lake Susan Park Pond as a significant contributing source of nutrient pollution to Lake Susan. In 2015 and 2016, staff conducted sampling on Lake Susan Park Pond and at the Lake Susan Park Pond outlet to confirm the UAA findings. Results indicated the pond was contributing nutrient pollution, but at a lesser level then indicated by the UAA (surface water total phosphorous concentrations ranged from 0.043 to 0.084 mg/L). In addition to the goal to improve water quality, the District has been looking at ways to decrease the use of groundwater for irrigation. In 2017, the District proposed actions to improve the water quality in Lake Susan, increase water storage along Riley Creek, and reduce potable water use through implementing the Lake Susan Park Pond Iron Sand Bench and Stormwater Reuse Enhancement Project which was completed in 2019 (**Figure 39**).

Iron-enhanced filtration consists of mixing iron filings with a filtration media (i.e., sand). Filtration through the sand removes the particulate phosphorus, while the iron filings, which form iron oxide when rusted, increase the removal of dissolved phosphorus. When water containing dissolved phosphorus contacts the iron oxide, the dissolved phosphorus is removed from the stormwater through surface sorption. A stormwater harvesting and use system is a constructed system that captures and retains stormwater for beneficial use at a different time or place than when or where the stormwater was generated. To reduce potable water use from which the city of Chanhassen supplies irrigation to the Lake Susan Park ballfield, stormwater already captured in Lake Susan Park Pond was used for irrigation.

Due to the difficulty of catching the unit in operation and communication challenges with the contractor of the project, staff were only able to capture two water quality samples in 2019 from the unit. Surface water samples were collected from the northeast corner of LSPP and from the manhole access of the iron enhanced outlet near the pond outlet located on the southeast corner. This data allowed for a general comparison for pre and post treatment. Water samples were collected and analyzed for ortho phosphorus (OP) total dissolved phosphorus (TDP), total phosphorus (TP), and Chlorophyll-a (Chl-a) in 2019. **Table 18** indicates the amount of removals for each nutrient sampled in 2019. Although only two samples were collected early results indicate the iron enhanced sand bench is removing nutrients effectively. Reductions of over 70-80%% for OP and TP, with reductions near 30% for TDP and Chl-a. Staff will monitor the treatment system in 2020 and capture an entire year of data to evaluate the removal efficiencies of the system.

Table 18 2019 LSPP Iron Enhanced Sand Bench Results

Nutrient	Average % Reduction
Ortho-P	79.3
Dissolved-P	38.0
Total-P	72.7
Chl-a	26.6

4.13 Stormwater Ponds

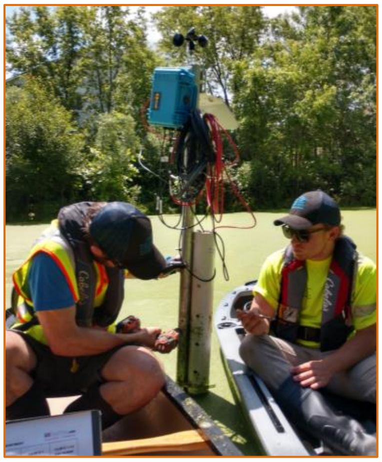

Figure 40 EnviroDIY Fixed Pond Continuous Monitoring Station

Stormwater ponds are the most commonly used method for controlling pollutants, such as phosphorus, which are found in stormwater runoff. 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 5 to 20 times the amount of phosphorus than less developed watersheds due to an increase in the amount of impervious cover (streets, sidewalks, and driveways) and surface runoff for a watershed (Athayde et al. 1983, Dennis 1985). Potential sources of phosphorus pollution in the Riley Purgatory Bluff Creek Watershed District include stormwater runoff, sediment erosion, grass clippings, lawn fertilizer, and pet waste.

The Riley-Purgatory-Bluff Creek Watershed District stormwater pond project (RPBCWD 2014) began in 2010, with initial data collection conducted in the summers of 2010 and 2011 and the 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 projected 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, 2019, RPBCWD held its first stormwater pond summit to get all interested/invested partners together to discuss current/ongoing/future research going on with stormwater ponds. Most of these studies are addressing the stratification occurring within the ponds which is leading to anoxic (no oxygen) conditions near the sediments, but across the entirety of the ponds in many cases. Anoxia in ponds can allow phosphorous to become released from the sediments which could eventually find its way downstream to the nearest waterbody.

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 most ponds to evaluate phosphorus release and identify the chemical makeup of each sediment layer. Continuous monitoring also occurred on a number of ponds which included monitoring the surface and bottom of each pond for some or all the following parameters: wind, 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 40**). EnviroDIY is a part of WikiWatershed, a web toolkit designed to help citizens, conservation practitioners, municipal decision-makers, researchers, educators, and students advance knowledge and stewardship of fresh water (EnviroDIY 2019). Staff built/programmed these stations from the ground up, paired them with professional grade water sensors, and deployed them in nine ponds. 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 - Remediation of Internal Phosphorus Loading in Stormwater Ponds with Iron Filings

- 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 phosphorous.
- Laboratory phosphorous release and sediment chemistry is currently being analyzed. All three ponds released phosphorus under anoxic conditions with two of the ponds also releasing phosphorus when oxygen is 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 includes 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 phosphorous from landscape before it reaches the pond).

Joe Bischoff – Wenck – RPBCWD Pond Assessment

- Pond phosphorous levels averaged concentrations around 300-350 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 of). 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. HAB's have been shown to cause human/pet health issues, but the risk in stormwater ponds is unknown. All nine ponds sampled were anoxic significant portion of the year. Sheltering around the ponds may be a main driver in reducing pond mixing and therefore increasing anoxia.
- Measured anaerobic phosphorous 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 phosphorous release rates were between 4-8mg/m2/day and most phosphorous 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 BMP's to improve removal efficiencies. Need to develop framework to determine which ones are performing badly so we can target treatment.

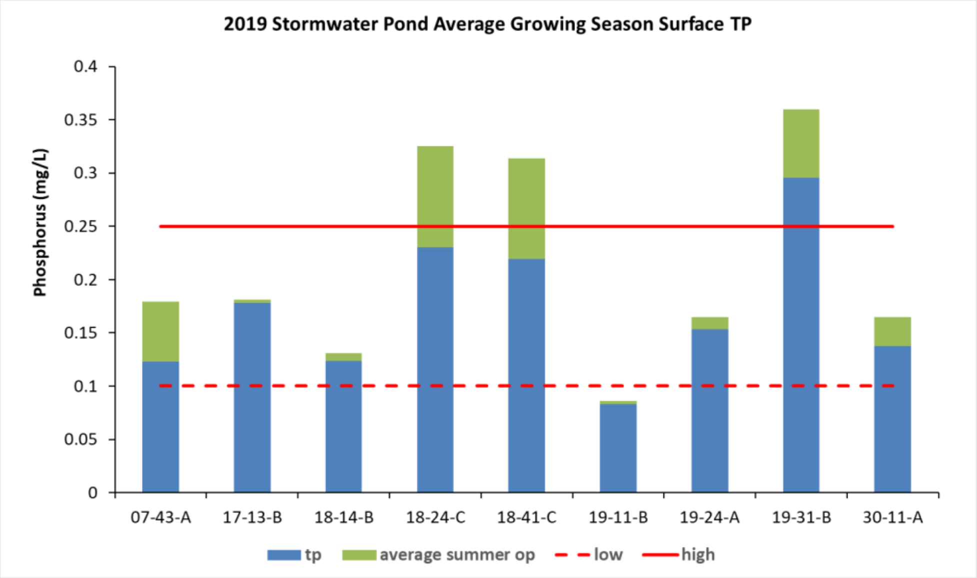

Figure 41 2019 Stormwater Pond Average Growing Season Surface Phosphorous Results

Jacque Finlay – University of Minnesota - Stormwater Pond Research Overview (part II)

- Ponds are unexpectedly anoxic, promoting phosphorus release. Road salt causation may be part of why ponds stratify. Road salt sinks accumulates and persists. In ponds less than 3ft 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 on in the spring in ponds– not a lot of wind caused mixing throughout the year. Ponds with 100% coverage by pondweed 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 phosphorous balance testing was conducted on three ponds to determine how each pond was performing (inputs and outputs of phosphorous). 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 phosphorous concentrations from inlet to outlet.

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

- They conducted a literature search on if ponds export phosphorous, if phosphorous 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) that are important to understand and include. 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 EnvioDIY units and continuous nitrate and phosphorous 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.

5 Aquatic Invasive Species

5.1 AIS Management

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 and a foundation was set up to monitor invasive species that are currently established within District waters (**Table 19**). Early detection is critical to reduce the negative impacts of AIS and to potentially eliminate an invasive species before it becomes fully established within a waterbody. Effective AIS management of established AIS populations will also reduce negative impacts and control their further spread. The RPBCWD AIS plan is adapted from the Wisconsin Department of Natural Resources (WIDNR, 2015), Minnehaha Creek Watershed District (MCWD, 2013), and the Minnesota Department of Natural Resources (MNDNR, 2015a) Aquatic Invasive Species Early Detection Monitoring Strategy. The goal is to not only assess AIS that currently exist in RPBCWD waterbodies, but to be an early detection tool for new infestations of AIS. **Figure 42** identifies AIS monitoring/management that occurred in 2019, excluding common carp management.

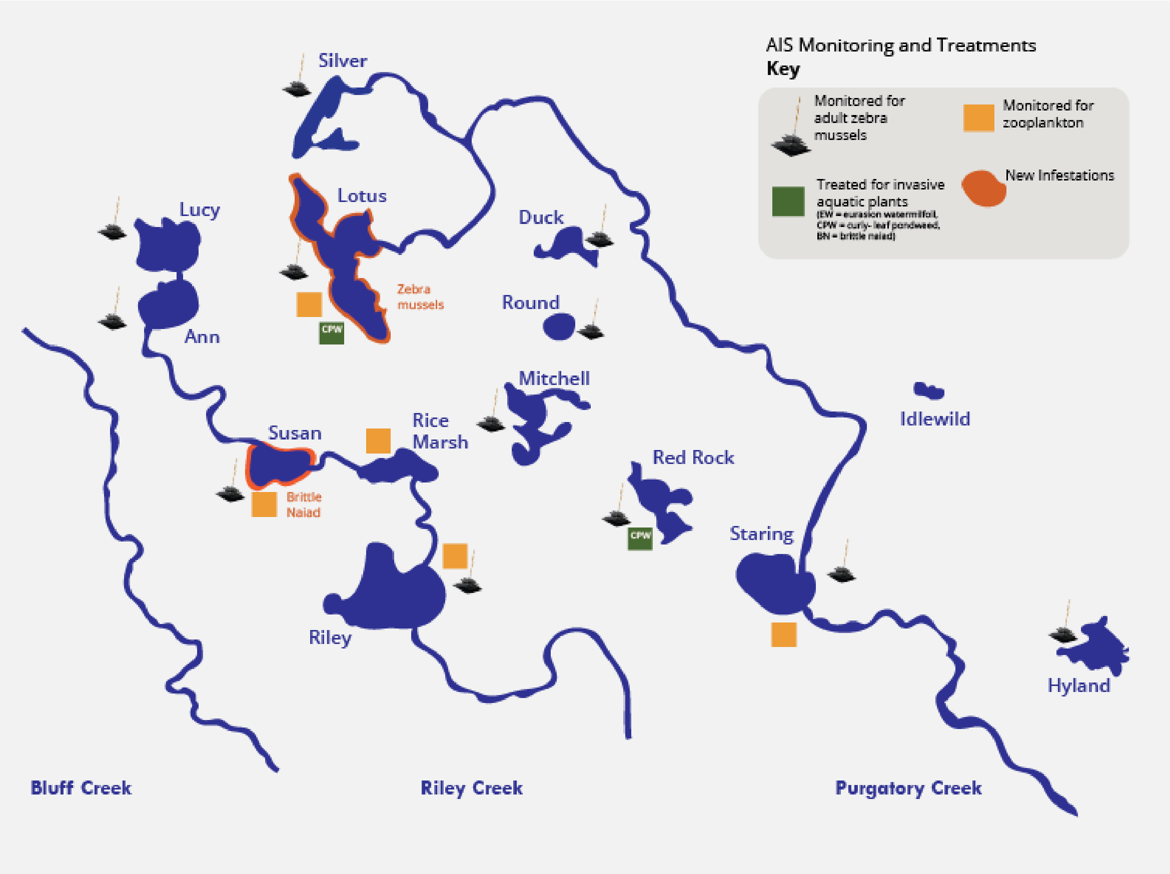

Figure 42 2019 Aquatic Invasive Species Summary

Aquatic Invasive Species (AIS) work conducted in 2019 within the Riley-Purgatory-Bluff Creek Watershed District. Zebra mussel plate symbol indicates the installation of monitoring plates and bi-weekly public boat launch scans. Lakes that received zooplankton and phytoplankton sampling are identified by orange squares and lakes that received herbicide treatments are identified by green squares (CPW=curly-leaf pondweed; BN=Brittle Naiad; EW=Eurasian watermilfoil). The orange outline around a lake indicates a new AIS found; Lotus-zebra mussels; Susan-BN. All lakes received juvenile mussel sampling; none were found by the District.

Table 19 Aquatic Invasive Species Infested Lakes

Lake Names	Infested Waters	Brittle Naiad	Eurasian Watermilfoil	Curlyleaf Pondweed	Purple Loosestrife	Common Carp	Zebra Mussels
Ann	x	x	x	x	x	x	
Lotus	x	x	x	x		x	x
Lucy	x		x	x	x	x	
Red Rock	x		x	x	x		
Rice Marsh	x			x	x	x	
Riley	x		x	x	x	x	x
Silver	x			x	x		
Staring	x	x	x	x		x	
Susan	x	x	x	x	x	x	
Duck	x			x	x		
Mitchell	x		x	x	x		
Round	x	x	x	x			
Hyland	x			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. 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. 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 early the spring of 2019, herbicide treatments were carried out on Lotus Lake and Red Rock for curly leaf pondweed. No Eurasian watermilfoil or brittle naiad treatments occurred.

Brittle Naiad

Brittle naiad (*Najas minor*) is a species native to Europe, western Asia, and northern Africa that has been introduced to the United States. The concern with Brittle Naiad is that it can form dense mats that can outcompete native plants. These dense communities can disrupt fish and waterfowl habitat, choking out plants which animals depend on for survival and potentially decreasing dissolved oxygen levels upon its decomposition. Brittle naiad is a resilient plant; it can survive in some polluted and eutrophic waters and can reproduce by fragmentation. The plant is most apparent in early fall when most recreational boaters are off the water. With that said, brittle naiad is a very new AIS and not much is known about its effects especially in Minnesota. So far the plant has appeared in small, dispersed stands across the infested lakes, but has had limited expansion to date. The exception is in the Lower Purgatory Creek Recreational Area where the plant has taken over. It may have been more successful in the LPCRA due to the good water clarity, shallow and uniform depths, highly organic sediments, and the highly fluctuating water levels. The highly fluctuating water levels make it difficult for many native plants to establish, which does not occur in relatively stable lake water levels. In the RPBCWD, Lotus, Staring, and Susan were scanned for the plant. The results from these surveys can be seen in this section.

Lotus Lake Brittle Naiad

On September 26, 2017, Riley Purgatory Bluff Creek Watershed District staff found brittle naiad located on both sides of the public boat access on the south side of Lotus Lake. The plants were found during a routine aquatic invasive species (AIS) inspection of the boat launch. These inspections, conducted bimonthly, consist of staff searching the area around the boat launch for various types of aquatic invasive species for 5-10 minutes. The searches are conducted at each regular water quality sampling event. Since most AIS enter a lake through the public access this is the most likely location to find AIS. Staff immediately reported the occurrence of brittle naiad to Aquatic Invasive Species Specialist Keegan Lund of the Minnesota Department of Natural Resources. Staff extended the inspection to a full scan of the lake, mapping the position of every observed brittle naiad occurrence with a handheld GPS device. An effective treatment area was determined in the fall, an herbicide was applied to the lake in an area totaling 2.42 acres across.

On September 24th and 26th of 2018, RPBCWD staff conducted brittle naiad surveys to determine the effectiveness of the herbicide and to see if the plant had spread throughout the lake. During the scan staff drove a lap around the lake and every brittle naiad plant found was marked with a handheld GPS device. Results of the survey can be seen in **Figure 43**. Based on the 2018 brittle naiad scan, it appeared the overall plant distribution had been reduced in the treatment areas. Plants were found on both sides of the public access, similar to where stands of plants were most dense in 2017, however the number and area occupied by the plants was reduced considerably. Additionally, no rooted plants were found on the southwest side of the lake. More plants were found scattered along the south east shoreline and into the east bay which may have been missed during the 2017 survey. Brittle naiad was observed growing between 0.5 to three feet of water. Its absence from deeper water was likely due to limited water clarity in Lotus Lake.

Figure 43 2018(left) & 2019(right) Brittle Naiad Maps

District staff again carried out the visual roving survey in 2019, marking each plant discovered. This was done to assess if brittle naiad expanded its range or growing depth due to increased clarity following the fall 2018 alum treatment. The results of the scan can be seen in **Figure 43**. Overall, the 2019 results were very similar to what was seen in 2018. The plant was found in almost all areas where it was found in 2018, however it again appeared to be reduced in density. It has not been determined what would cause reductions in density. Staff will conduct another scan in 2020 to assess brittle naiad population.

Staring Lake Brittle Naiad

In 2015 Brittle Naiad was first discovered on Staring Lake at a single location along the northwest corner of the lake as indicated in **Figure 44**. It is not surprising that this occurred due to the fact that the species was found extensively in Purgatory Creek Recreation Area which is located upstream of Staring Lake. This fact, combined with the increased water clarity due to carp control may have allowed the plant to become established. After the discovery, the immediate area was treated in attempt to eliminate the plant from the lake. The following years after the lake was surveyed by the Unversity of MN via point intercept survey and no brittle naiad plants were found.

In the fall of 2019, staff decided to conduct a roving survey as we had completed on multiple other lakes to see if we could detect brittle naiad. **Figure 44** shows the results of that survey. Staff did locate a number of plants scattered across the lake. The most brittle naiad was located in the northwest corner near the Purgatory Creek outlet and 2015 plant location. In ths location the plant was the most abundant plant and was dense, limiting other native vegeatation growth. It should be noted that the sediment found in this location was rich in organic matter which matches what can be seen in the Purgatory Creek Recreational Area where brittle naiad in dominant. In addition, there was a smaller location of dense plants located along the south shoreline. Staff may conduct another survey in 2020 to see if the population expands.

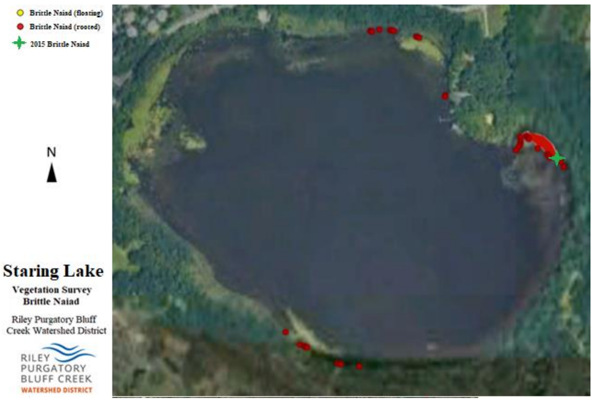

Figure 44 2019 Staring Lake Brittle Naiad Map

Lake Susan Brittle Naiad

During the University of MN 2019 August point intercept plant survey of Lake Susan, brittle naiad was detected at two points on Lake Susan. Both points were on the southern-most shore but relatively far apart (**Figure 45**).

In September, RPBCWD staff went out and conducted a roving survey and searched to collect a voucher specimen in order to list the lake as infested. Staff completed a survey and only found four small brittle naiad plants on the southwest location. Staff will conduct a survey in 2020 to assess if the population expands.

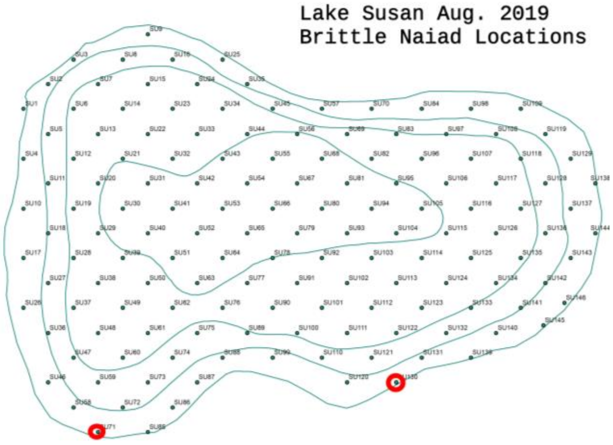

Figure 45 2019 Lake Susan Brittle Naiad Map

5.3 Common Carp Management

Figure 46 RPBCWD Common Carp

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 the University. Carp can be detrimental to lake water quality. They feed on the bottom of the lake, uprooting aquatic plants and resuspending nutrients in the sediment. Adult carp are monitored within RPBCWD by conducting three, 20-minute electrofishing transects on each lake, three times between late July and early October (totaling nine transects per lake). If the total biomass estimate of carp is above 100kg/h, the population is considered harmful to lake water quality and the District would need to consider removing carp. Young of the year (YOY) carp are monitored by conducting five, 24-hour small mesh fyke net sets between August and September. If YOY carp are captured during this sampling, it suggests successful recruitment has occurred, and monitoring efforts should be increased on that water body. At that point, the District would also consider the removal of excess carp.

District staff completed fyke net surveys on Staring Lake, Lake Lucy, Lake Susan Park Pond, Rice Marsh Lake, the Upper Purgatory Creek Recreational Area (UPCRA), and the Lower Purgatory Recreation Area (LPCRA) in 2019. 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. Other species that were abundant included pumpkinseed sunfish, black crappies, and bullhead species. Of the lakes sampled in 2019, Lake Susan Park Pond had highest number of bluegills captured averaging 295 fish per net, which was closely followed up by Rice Marsh Lake with 234 fish/net. The UPCRA had the lowest bluegill abundance with only 20 bluegills/net captured. Larger predatory fish including northern pike and largemouth bass were also captured via fyke netting in low numbers. The most diverse fish population was observed in LPCRA where 15 different species were captured. A full summary table of the fish captured for each lake can be found in 8 Exhibits B. Similar to 2018 and 2017, no YOY carp were captured in any of the lakes during fyke net surveys in 2019. The lack of young individuals captured in lakes indicates that 2019 was a poor recruitment year for common carp overall. Five YOY carp were captured during fyke netting on the LPCRA indicating little recruitment occurred.

The PCL lakes (Staring and Lotus) and the Purgatory Recreation Area were surveyed via electrofishing in 2019. Lake Ann located in the RCL was also sampled via electrofishing in 2019 but was only electrofished on one date which yield no carp. In 2019, the common carp biomass estimate was 103 kg/ha on Lotus Lake (**Table 20**), which is up from the 2017 (69 kg/ha) and 2018 (95 kg/ha). This number is slightly above the carp biomass threshold of 100 kg/ha. Comparing the past four years of electrofishing data (**Figure 47**) the carp population has remained stable, with slight year to year variability around the 100 kg/ha threshold. With no YOY carp captured, combined with stable carp biomass estimates for a number of past years, the resident carp population in Lotus Lake is of limited concern in relation to the degradation water quality. As seen in (**Figure 47**), the adult common carp biomass estimates have been decreasing in Staring Lake over the past four years. In 2017 the carp biomass estimate was below the threshold at 62 kg/ha. In 2018, it was lower still at 41 kg/ha and in 2019 the estimate was 40 kg/h (**Table 20**). These fish captured consisted of individuals from the 2014/2015-year class, which was the last successful recruitment year for common carp in the system.

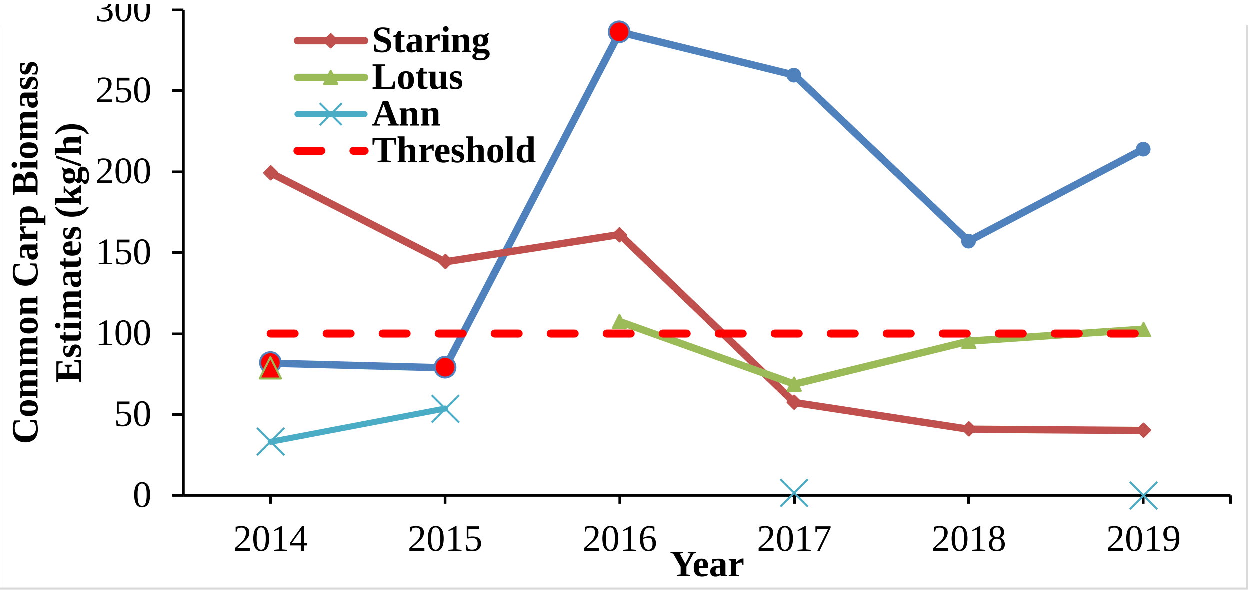

Figure 47 2019 Common Carp Biomass Estimates

The LPCRA was not electrofished in 2019 due to access issues and the amount of brittle naiad present in the system. In 2019, the UPCRA again had a carp biomass estimate that exceeded the biomass threshold at 214 kg/ha (**Table 20**). This number is down from the 260 kg/ha estimate in 2017, but up from the 2018 estimate of 157 kg/ha (**Figure 47**). 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. Due to the shallowness of the system, winter seining would have limited effectiveness at capturing carp. Additionally, winter seining may yield limited success in Staring Lake due to the low number of carp captured. The 2017-2018 reduction in biomass estimates seen in Purgatory Creek Recreational Area may not have been as significant as thought as indicated by the increase in carp abundance seen in 2019. However, capture rates in the rec area can be highly variable as the U of MN biomass estimates were based on lakes and not flow through wetlands. In 2019, UPCRA carp levels still exceeded the threshold and carp could reduce water quality in the system. Additionally, fyke nets captured five YOY carp which suggests a very low level of recruitment occurred in the recreation area. Staff will continue to monitor the carp population and remove fish in 2020.

Table 20 2019 Common Carp Biomass Estimates

Lake	Fish per Hour	Density per Hectare	Average Weight (kg)	Carp Biomass (kg/ha)
Ann	0	0	0	0
Lotus	6.01	31.33	3.27	102.53
Staring	6.22	32.32	1.24	40.12
Upper Purgatory Wetland	40.31	192.88	1.11	213.84
Lower Purgatory Wetland	-	-	-	-

*Lower Purgatory Creek Recreational Area not sampled.

PCL Spring Removals

In the spring of 2019, staff placed a large floating trap net below the barrier in Purgatory Creek during peak spawning runs to capture common carp as an experimental gear. This net was checked daily; staff sorted fish, releasing natives and removing carp. In 2019, the barrier was closed on April 20th after northern pike could move upstream into the recreational area to spawn and return to Staring Lake (as suggested by Chizinski et al., 2016). The floating trap net was deployed in early May. The City of Eden Prairie opened, cleaned, and closed the fish barrier multiple times during the spring and late summer due to high water levels in the Purgatory Creek Recreational Area. At times the barrier was held open for an extended period (up to 2 weeks) numerous times this year. During this time, fish could move freely throughout the system when the trap net wasn't present or overwhelmed. The net did not perform well in 2019 due to the high water and the continual creation of holes by what was suspected to be muskrats and turtles. The total number of carp removed via floating trap net was only 4 fish (48-2018; 139-2017). Staff hoped a larger number of fish would have been captured by the trap net, but this net is an experimental gear and it was unsure how many would be captured. With the poor capture efficiency combined with the declining numbers since first deployed, the trap net will be limited to emergency deployments only moving forward from 2019.

Figure 49 Common Carp Removal at the PCRA Berm

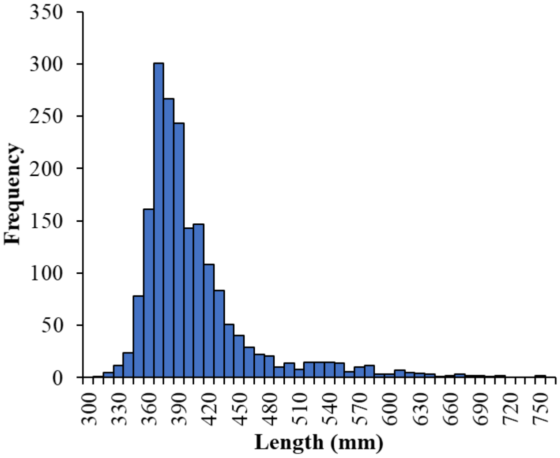

Figure 48 Length Frequency of PCRA Spring Removals

In 2019 staff also utilized a backpack electrofishing unit and block nets to remove common carp during the spring spawning run (**Figure 49**). These two gears were deployed in the channel upstream of the barrier to trap carp between the net and at the breach in the berm that separates the Upper and Lower Purgatory Creek Recreational Area. Most of the fish captured via backpack electrofishing were captured at the breached berm site. This breach allows water to short circuit the overflow structure. Water was always flowing at this location which led to carp concentrating in the shallow water near the breach before they tried to move upstream. The sheet piling, combined with the consistent flow, eroded the downstream side of the berm, causing a drop that impeded carp movement. A block net was anchored on one side of the flow at the breach and then stretched around the congregating carp, trapping them against the berm and net. Staff used an electrofishing backpack to easily remove the trapped fish. 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 sampling. Utilizing both the trap net and backpack electrofishing, a total of 441 carp were removed in 2019 vs 1,901 carp in 2018. Most of the fish removed were from the 2015 year class, in which approximately 3000 YOY carp had entered Lake Staring 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 48**. The major removal rate discrepancy between 2018 and 2019 can be attributed to the very high-water levels seen in 2019. This allowed fish to move freely between the two basins without congregating at the overflow. Most of the carp were removed on May 7th, when the water level at the barrier was 37.5 inches in depth (based on the installed staff gauge), and when the temperature was 17.2 degrees Celsius (**Figure 50**). Unfortunately, after this removal event, water level increased to a point that allowed fish to move freely between the two basins. 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 location for future carp removal events.

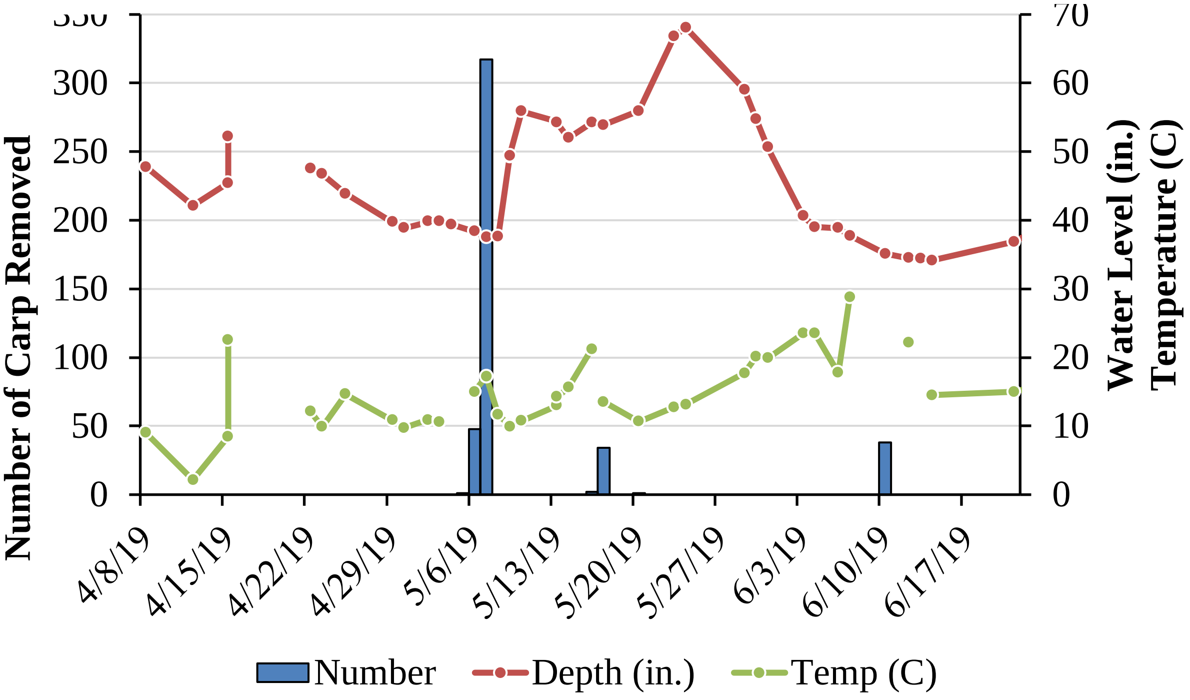

Figure 50 Purgatory Creek Recreational Area Common Carp removal vs Environmental Variables

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 equipment in the water, 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 phytoplankton to which many aquatic animals need (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 2019. 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 Lake Riley and Lotus Lake, each of which were sampled twice due to the amount of summer traffic on these lakes. RMB Environmental Labs processed the samples and found zebra mussel veligers on only lake Riley in 2019. 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 2019. Additionally, public accesses were scanned for approximately ten minutes during each regular water quality sampling period (bi-weekly). Staff visually searched rocks, docks, sticks, and vegetation for adult zebra mussels. Only a few adult zebra mussels were found during public access searches on Lake Riley in 2019.

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. Most zebra mussels were found on rock, wood, and items placed in the water, including pvc pipes and bricks. In discussion with our AIS specialist, it was determined that a rapid response would not be effective and was not recommended. Following the confirmation of zebra mussels in Lake Riley staff distributed MN DNR zebra mussel fact sheets to all lakeshore owners (MNDNRb, 2015) and hosted an informational zebra mussel workshop in December of that year. In 2019 zebra mussels were found on all plates deployed ranging in number from 69 mussels to 5,717 mussels/plate. This indicates a relatively robust population that is well established across the lake.

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 51**). No zebra mussel veligers were found in samples collected on June 20 or September 10 by the RPBCWD. Water samples were submitted to RMB Environmental Laboratories for processing. Additional in-lake searching occurred on October 9 by RPBCWD staff. No adult zebra mussels were found during the search. An additional veliger tow was collected on October 10th and eDNA samples were taken at 4 locations. On October 24 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 51**; **Figure 52**). 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 for 2019.

Figure 51 Lotus Lake Zebra Mussel Map

Figure 52 Zebra Mussels Found on Lotus Dock on Shore

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 21**, the different variables associated with zebra mussels that the District currently measured in 2018 for Lake Riley and in 2019 for Lotus Lake. In **Table 21**, 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 Lake Riley. 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 in were estimated based on average monthly alkalinity samples. The estimated calcium concentrations in Lotus and 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 (>30mg/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 21**, the suitability of Lake Riley to support a robust and expansive zebra mussel population is high. These results were confirmed by mussel counts on 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 21** indicates a slow growing or limited population to the minimal growth nutrient levels.

Table 21 Suitability for Zebra Mussels in Lake Riley and Lotus Lake

	LAKE	**RILEY (2018)**	**LOTUS (2019)**
Shell Formation	Calcium (mg/L)	🟥 48.7	🟥 45.55
	Alkalinity (mg/L)	🟥 121.75	🟥 129.2
	pH	🟥 8.69	🟧 7.88
Trophic Variables	TP (mg/L)	🟧 0.024	🟦 0.035
	Chl-a (ug/L)	🟧 7.98	🟦 32.51
	secchi (m)	🟥 3.43	🟦 1.45
Physical Variables	Temp (degC)	🟥 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 in this report informational fact sheets for the lakes and creeks that were monitored during the 2019 sampling season (See 8 Exhibits E). The lake fact sheets include: Lake Ann, Duck Lake, Hyland Lake, Lake Idlewild (high value wetland), 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 what the District is doing in and around local water bodies is also described in each fact sheet.

7 References

American Public Health Association (APHA). 1992. Standard Methods for the Examination of Water and Wastewater, 18th Edition. American Water Works Association and Water Pollution Control Federation. New York.

Athayde, D.N., P.E. Shelly, E.D. Driscoll, D. Gaboury, and G. Boyd. 1983. Results of the Nationwide Urban Runoff Program: Volume I - Final Report. Water Planning Division, U.S. Environmental Protection Agency. Washington, DC.

Bajer, P.G., M. Headrick, B.D. Miller, and P.W. Sorensen. 2014. Development and implementation of a sustainable strategy to control common carp in Riley Creek Chain of Lakes. Prepared for Riley Purgatory Bluff Creek Watershed District. University of Minnesota, Saint Paul, MN.

BARR Engineering Co. [BARR]. 2013. Bluff Creek Watershed Total Maximum Daily Load Implementation Plan: Turbidity and Fish Bioassessment Impairments. Minneapolis, MN

BARR Engineering Co. [BARR]. 2016. Rice Marsh Lake and Lake Riley: Use Attainability Analysis Update. Minneapolis, MN

BARR Engineering Co. [BARR] and Riley Purgatory Bluff Creek Watershed District [RPBCWD]. 2017. Creek Restoration Action Strategy: 2017 report. Minneapolis, MN.

Burns, Carolyn W. 1969. Relation between Filtering Rate, Temperature, and Body Size in Four Species of Daphnia. Limnology and Oceanography, 14:696-700.

Chizinski, C. J., P. Bajer, M. Headrick, and P. Sorensen. 2016. Different Migratory Strategies of Invasive Common Carp and Northern Pike in the American Midwest Suggest an Opportunity for Selective Management Strategies. North American Journal of Fisheries Society, 36:769-779.

Dennis, J. 1985. Phosphorus export from a low density residential watershed and an adjacent forested watershed. Pages 401-7 in Lake and Reservoir Management, Volume II. Proc. 5th Ann. Conf., N. Am. lake Manage. Soc. Lake Geneva, WI.

Duncan, R. R, R. N. Carrow, and M. Huck. 2000. Understanding Water Quality Management. USGA Green Section Record. September-October, pp. 14-24.

Edmondson, W.T. editor. 1966. Freshwater Biology. Second edition. John Wiley & Sons, Inc. New York, NY.

EnviroDIY. 2019. EnviroDIY homepage. Accessed online from: https://www.envirodiy.org/

Environmental Protection Agency [EPA]. 2002. Federal water pollution control act (as amended through P.L. 107-303, November 27, 2002). Washington, DC. Accessed online from: http://www.epw.senate.gov/water.pdf

International Association of Plumbing and Mechanical Officials [IAPMO]. 2017. Minnesota Plumbing Code: Code 21, Chapter 17, Nonpotable Rainwater Catchment Systems. Ontario CA. Accessed online from: http://www.iapmo.org/Pages/MinnesotaPlumbingCode.aspx.

Mackie, M. L. and Claudi R. 2010. Monitoring and Control of Macrofouling Mollusks in Fresh Water Systems. CRC Press. Boca Raton, FL, 93-145pp.

McComas, Steve. 2018. Status of Zebra Mussel Densities and Water Quality Impacts in Lake Minnetonka DRAFT. Prepared for Minnehaha Creek Watershed District. Blue Water Science. St. Paul, MN.

Minnehaha Creek Watershed District [MCWD]. 2013. Aquatic invasive species management program. Minnetonka, MN. Accessed online from: http://minnehahacreek.org/sites/minnehahacreek.org/files/attachments/Adopted%20Plan%20COMBINED.pdf

Minnesota Department of Natural Resources [MNDNRa]. 2015. Guidance for conducting aquatic invasive species early detection and baseline monitoring in lakes. Saint Paul, MN. Accessed online from: http://files.dnr.state.mn.us/natural_resources/invasives/prevention/ais_detection-baseline-monitoring.pdf

Minnesota Department of Natural Resources [MNDNRb]. 2015. Zebra mussel fact sheet. Accessed online from: http://files.dnr.state.mn.us/natural_resources/invasives/aquaticanimals/zebramussel/fact_sheet-zebra_mussels.pdf

Minnesota Department of Natural Resources [MNDNR]. 2016. Lake finder. Saint Paul, MN. Accessed online from: http://www.dnr.state.mn.us/lakefind/index.html

Minnesota Department of Natural Resources [MNDNR]. 2019. Eurasian watermilfoil (Myriophyllum spicatum). Saint Paul, MN. Accessed online from: https://www.dnr.state.mn.us/invasives/aquaticplants/milfoil/index.html

Minnesota Pollution Control Agency [MPCA]. 2010. Aquatic Life Water Quality Standards Technical Support Document for Nitrate: Triennial water quality standard amendments to Minn. R. chs. 7050 and 7052: DRAFT for external review. Saint Paul, MN. Accessed online from: https://www.pca.state.mn.us/water/water-quality-standards#draft-technical-documents-b1ac9611

Minnesota Pollution Control Agency [MPCA]. 2014. Guidance Manual for assessing the quality of Minnesota surface waters for determination of impairment: 305(b) report and 303(d) list. Saint Paul, MN. Accessed online from: https://www.pca.state.mn.us/sites/default/files/wq-iw1-04.pdf

Minnesota Pollution Control Agency [MPCA]. 2016. EDA: Guide to typical Minnesota water quality conditions. Saint Paul, MN. Accessed online from: https://www.pca.state.mn.us/quick-links/eda-guide-typical-minnesota-water-quality-conditions

Minnesota Pollution Control Agency [MPCA]. 2017. Salty water a growing problem in Minnesota. Saint Paul, MN. Accessed online from: https://www.pca.state.mn.us/water/salty-water-growing-problem-minnesota

National Oceanic and Atmospheric Administration [NOAA]. 2016. National Centers for Environmental Information: Climate data online: dataset discovery. Asheville, NC. Accessed online from: https://www.ncdc.noaa.gov/cdo-web/datasets

National Oceanic and Atmospheric Administration [NOAA]-Great Lakes Environmental Research Laboratory. 2016. Great Lakes Aquatic Nonindigenous Species Information System [GLANSIS]: GLANSIS search portal. Ann Arbor, MI. Accessed online from: https://nas.er.usgs.gov/queries/greatLakes/FactSheet.aspx?SpeciesID=1118&Potential=N&Type=0&HUCNumber=DGreatLakes

The Office of the Reviser of Statutes. 2016a. Minnesota Pollution Control Agency [MPCA]. Minnesota Administrative Rules: Chapter 7050, Waters of the State. Saint Paul, MN. Accessed online from: https://www.revisor.mn.gov/rules/?id=7050&view=chapter#rule.7050

The Office of the Reviser of Statutes. 2016a. Minnesota Pollution Control Agency [MPCA]. Minnesota Administrative Rules: Chapter 7050.0222, Waters of the State. Saint Paul, MN. Accessed online from: https://www.revisor.mn.gov/rules/?id=7050.0222

The Office of the Reviser of Statutes. 2016b. Minnesota Pollution Control Agency [MPCA]. Minnesota Administrative Rules: Chapter 7053, state waters discharge restrictions. Saint Paul, MN. Accessed online from: https://www.revisor.mn.gov/rules/?id=7053&view=chapter

Riley Purgatory Bluff Creek Watershed District [RPBCWD]. 2011. Riley Purgatory Bluff Creek Watershed District 10-year watershed management plan. Eden Prairie, MN. Accessed online from: http://rpbcwd.org/library/wmp/

Riley Purgatory Bluff Creek Watershed District [RPBCWD]. 2016. Riley Purgatory Bluff Creek Watershed District about us page. Eden Prairie, MN. Accessed online from: http://rpbcwd.org/about/.

RMB Environmental Laboratories, Inc. 2016. Sample collection and preservation list. Detroit Lakes, MN. Accessed online from: http://rmbel.info/wp-content/uploads/2013/05/Sample-Collection-and-Preservation-List.pdf

Schemel, L., United States Geological Survey [USGS]. 2001. Simplified conversions between specific conductance and salinity units for use with data from monitoring stations. Menlo Park, CA.

Sorensen, P., P. Bajer, and M. Headrick. 2015. Development and implementation of a sustainable strategy to control common carp in the Purgatory Chain of Lakes. Prepared for Riley Purgatory Bluff Creek Watershed District. University of Minnesota, Saint Paul, MN.

United States Environmental Protection Agency: Office of Water [EPA] 2013. Aquatic Life Ambient Water Quality Criteria for Ammonia- Freshwater. Washington, D.C. Accessed online from: https://www.epa.gov/wqc/aquatic-life-criteria-ammonia#how

Wenck Associates, Inc. 2017. Technical Memo: 2017 Purgatory Creek erosion monitoring. Maple Plain, MN.

Wenck Associates, Inc. 2017. Technical Memo: 2017 Riley Creek erosion monitoring. Maple Plain, MN.

Wenck Associates, Inc. 2013. Lake Susan use attainability assessment update. Prepared for Riley Purgatory Bluff Creek Watershed District. Maple Plain, MN. Accessed online from: http://www.rpbcwd.org/files/4013/8426/4706/Lake_Susan_Report_FINALred1.pdf

Wisconsin Department of Natural Resources [WIDNR]. 2015. Wisconsin's water monitoring strategy, 2015-2020: a roadmap for understanding, protecting and restoring Wisconsin's water features. Madison, WI. Accessed online from http://dnr.wi.gov/topic/SurfaceWater/monitoring/strategy/Strategy_2015_2020.pdf

8 Exhibits

Exhibit A	2018 & 2019 Lake Level Sensor Graphs
Exhibit B	2019 Fyke Net Summary Data
Exhibit C	2019 Zooplankton Summary Data
Exhibit D	2019 Phytoplankton Summary Data
Exhibit E	2019 Lake and Creek Fact Sheets

Exhibit A

2018 & 2019 Lake Level Sensor Graphs

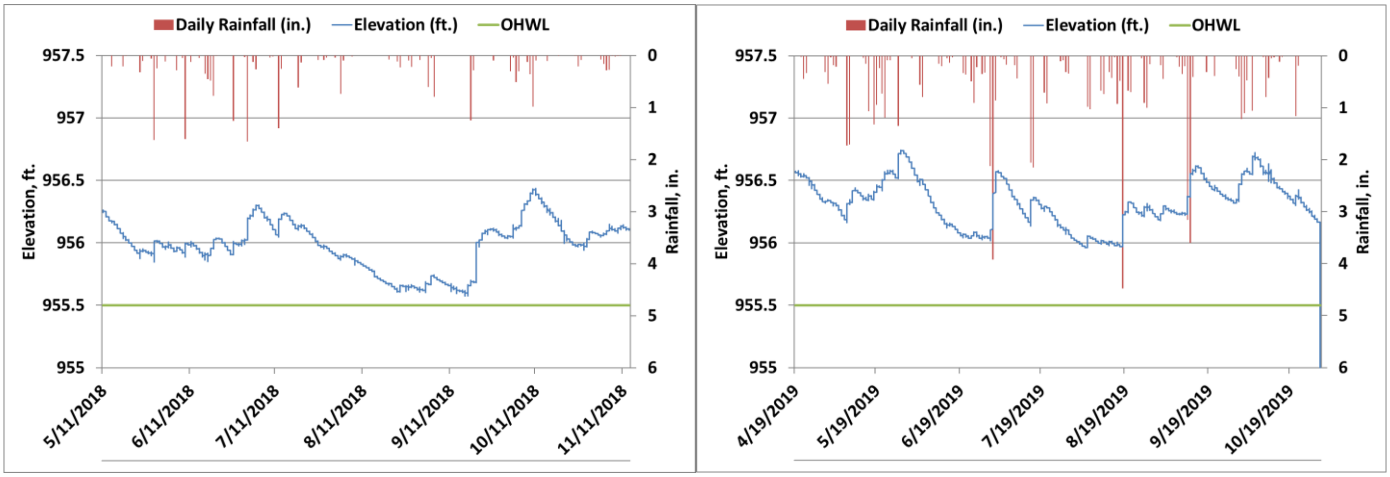

Figure A-1. **Lake Ann** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

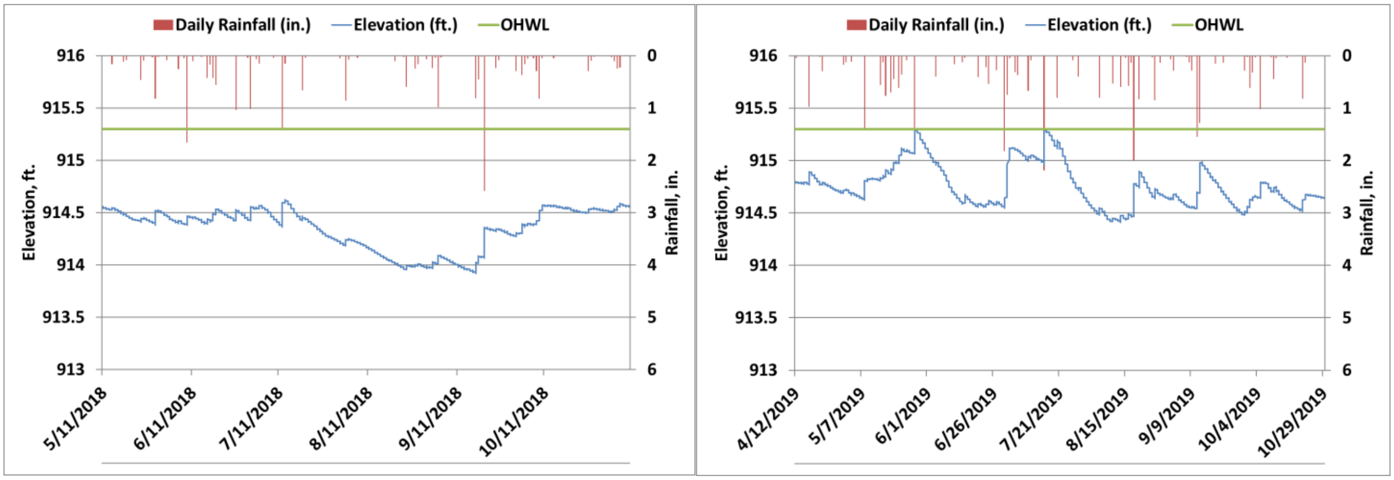

Figure A-2**. Duck Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

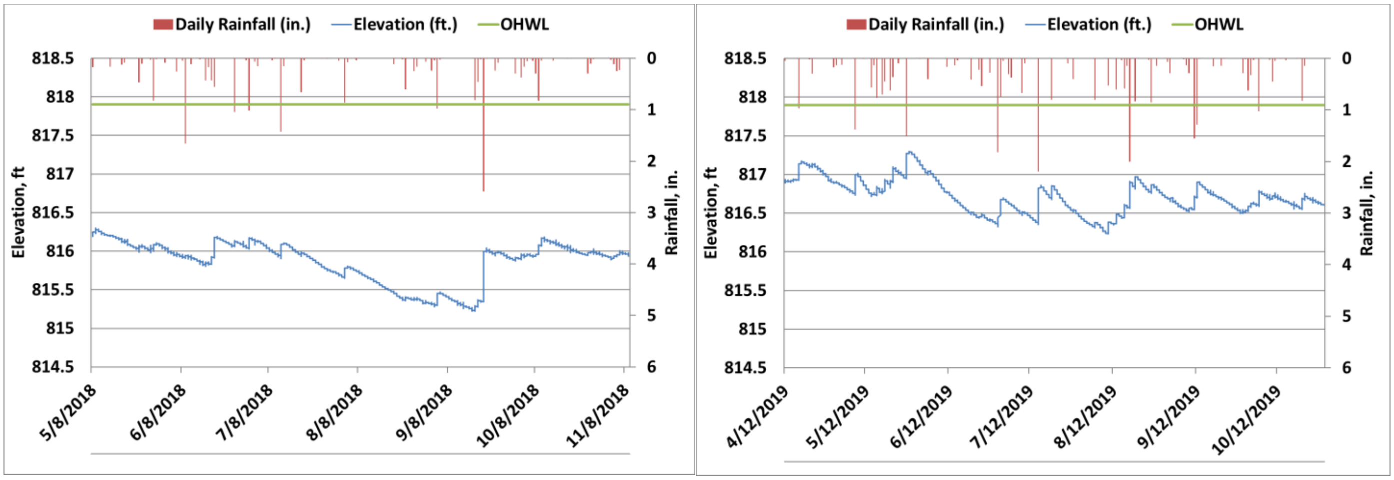

Figure A-3. **Hyland Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

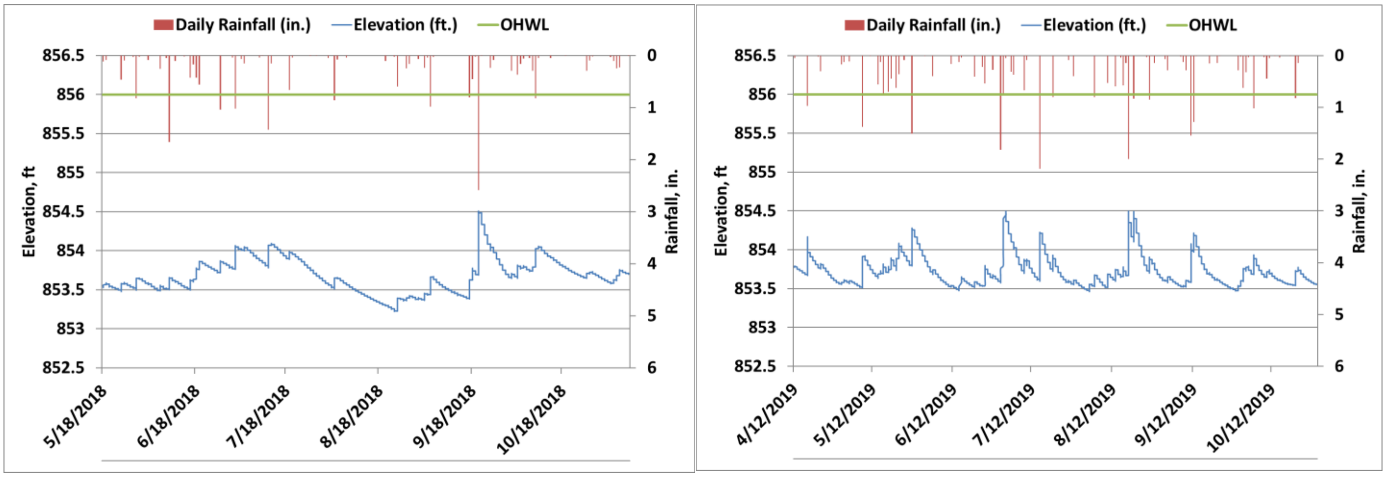

Figure A-4. **Lake Idlewild** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

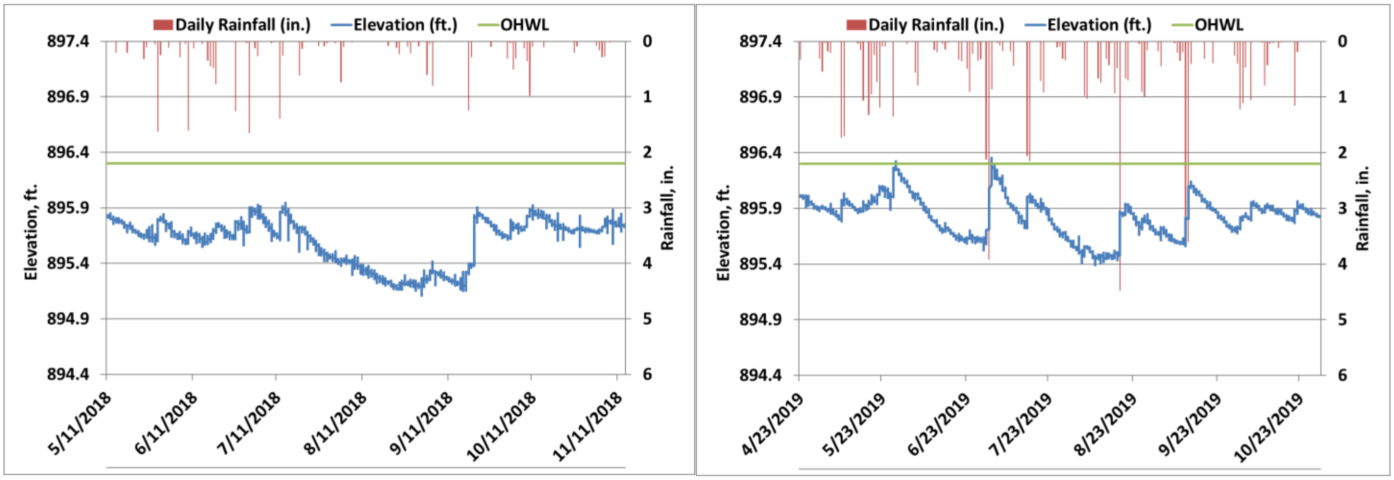

Figure A-5. **Lotus Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

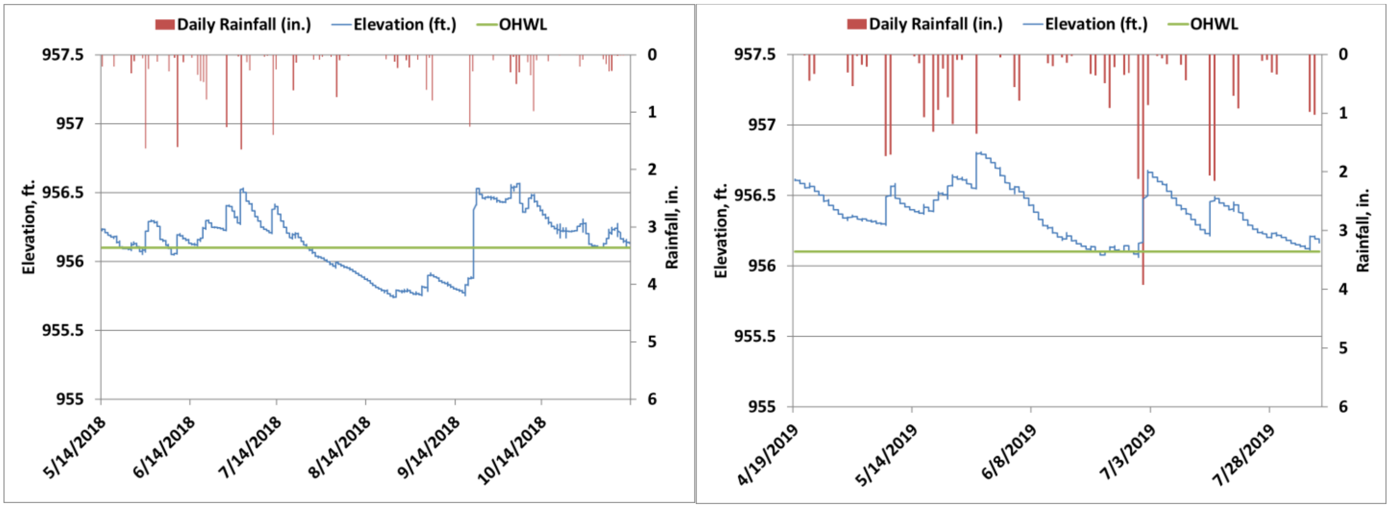

Figure A-6. **Lake Lucy** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

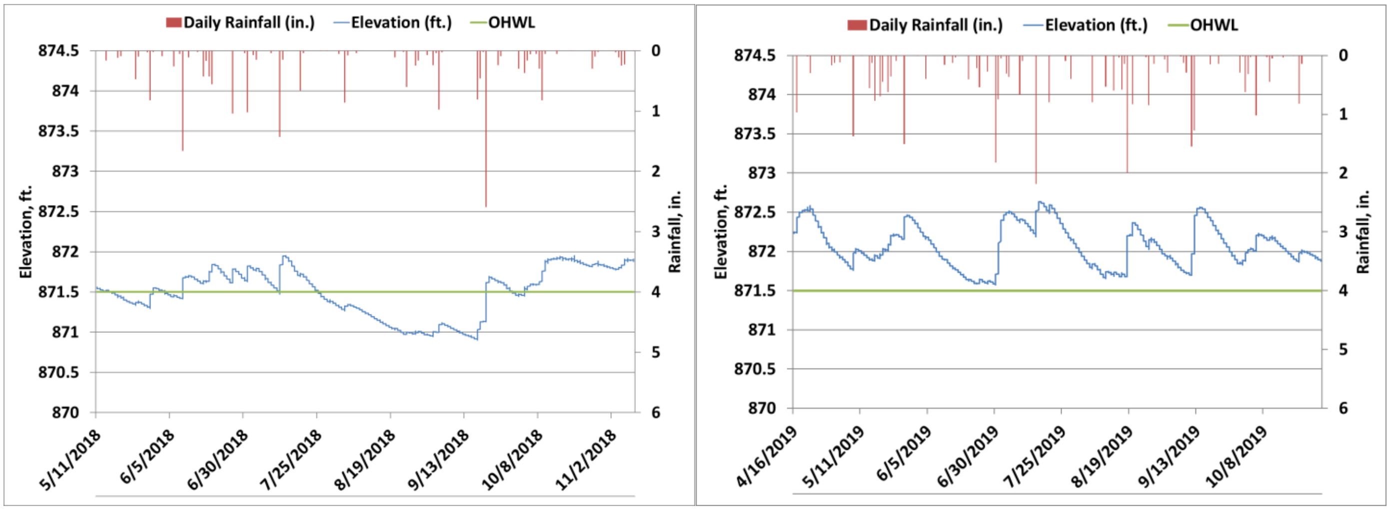

Figure A-7. **Mitchell Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

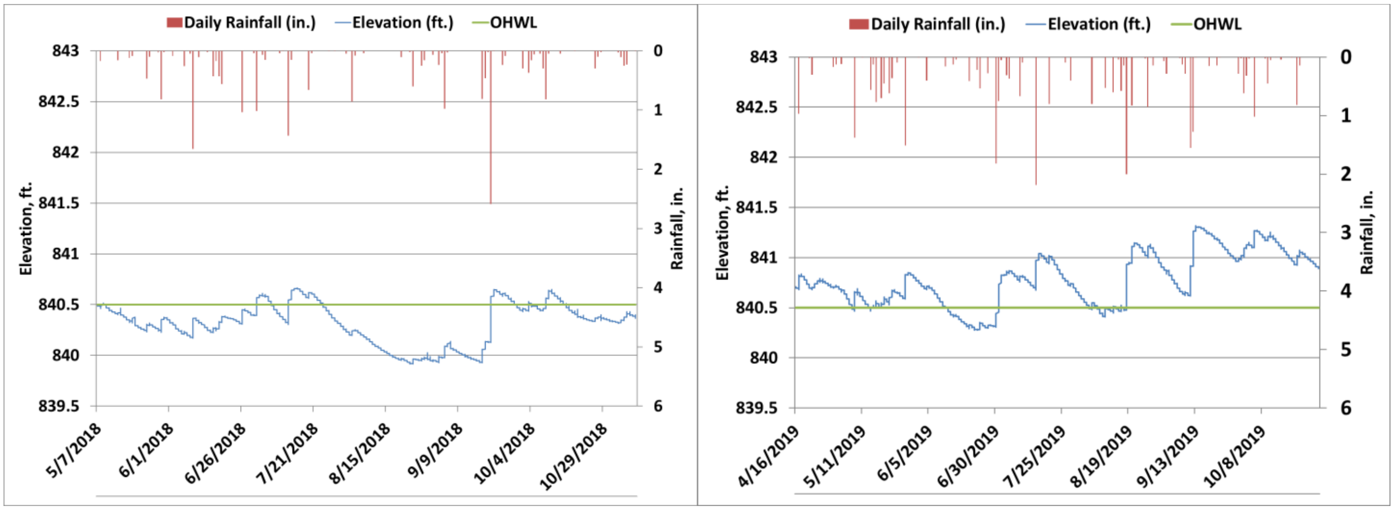

Figure A-8. **Red Rock Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

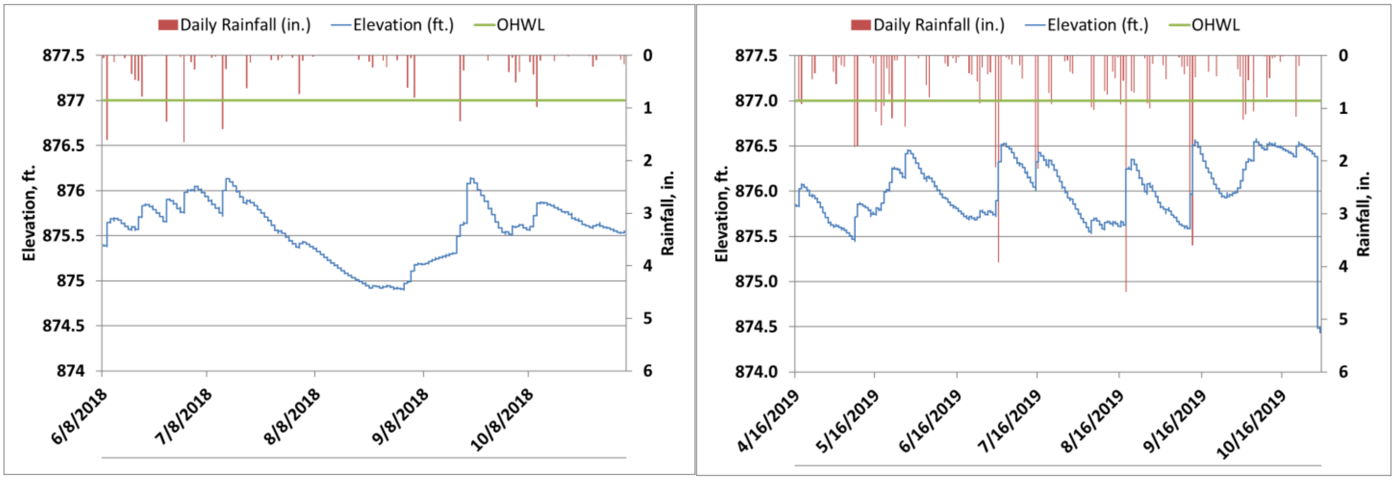

Figure A-9. **Rice Marsh Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

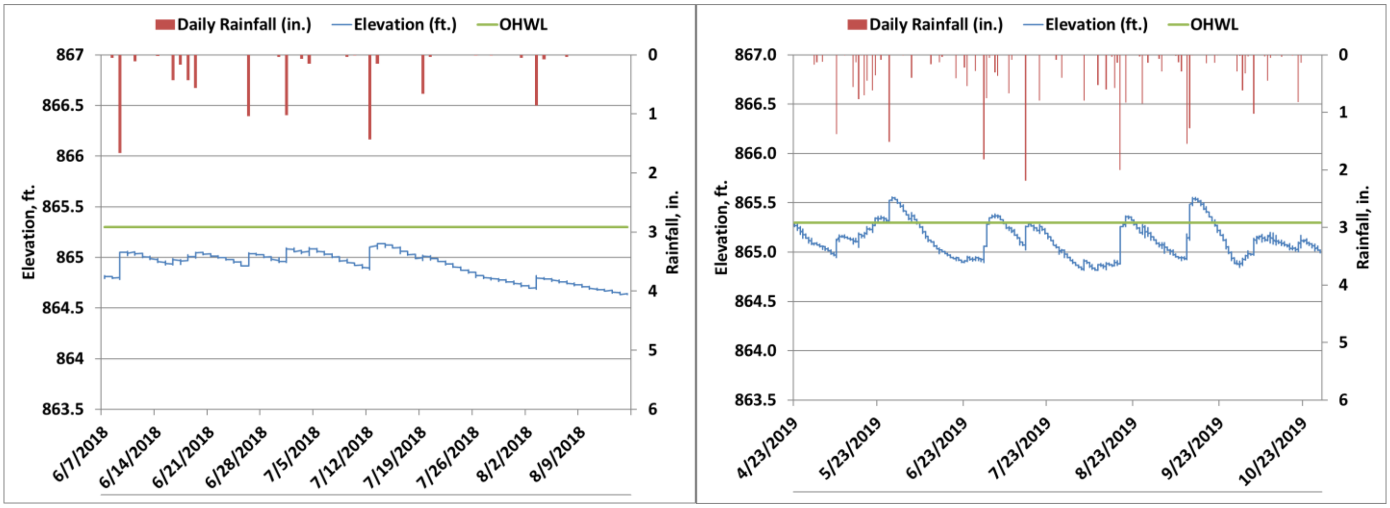

Figure A-10. **Lake Riley** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

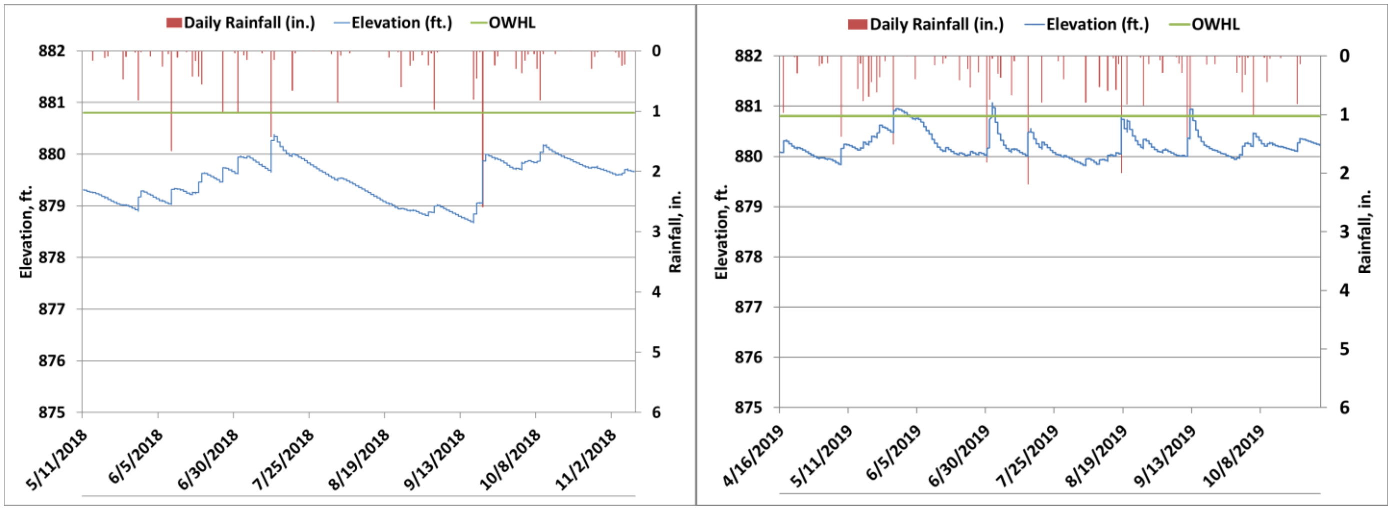

Figure A-11. **Round Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

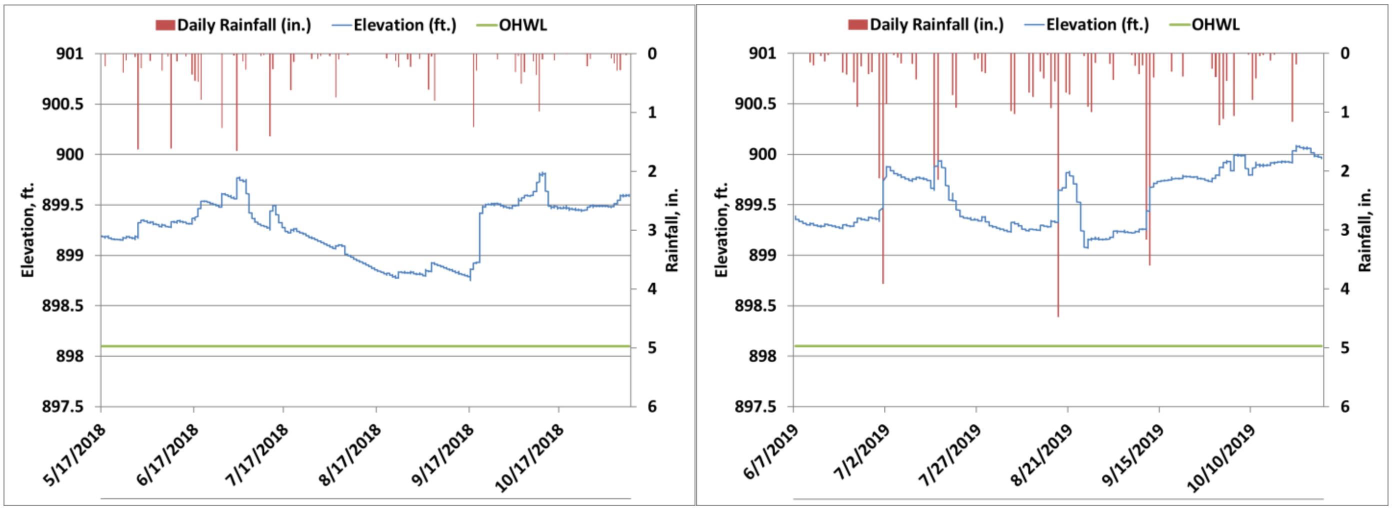

Figure A-12. **Silver Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

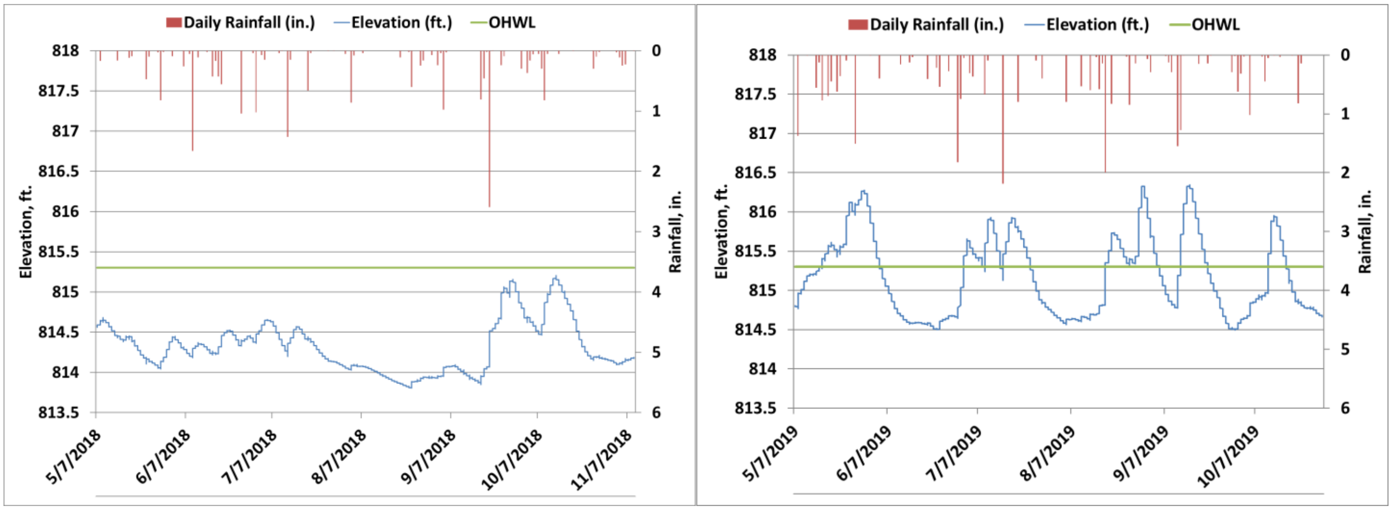

Figure A-13. **Staring Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

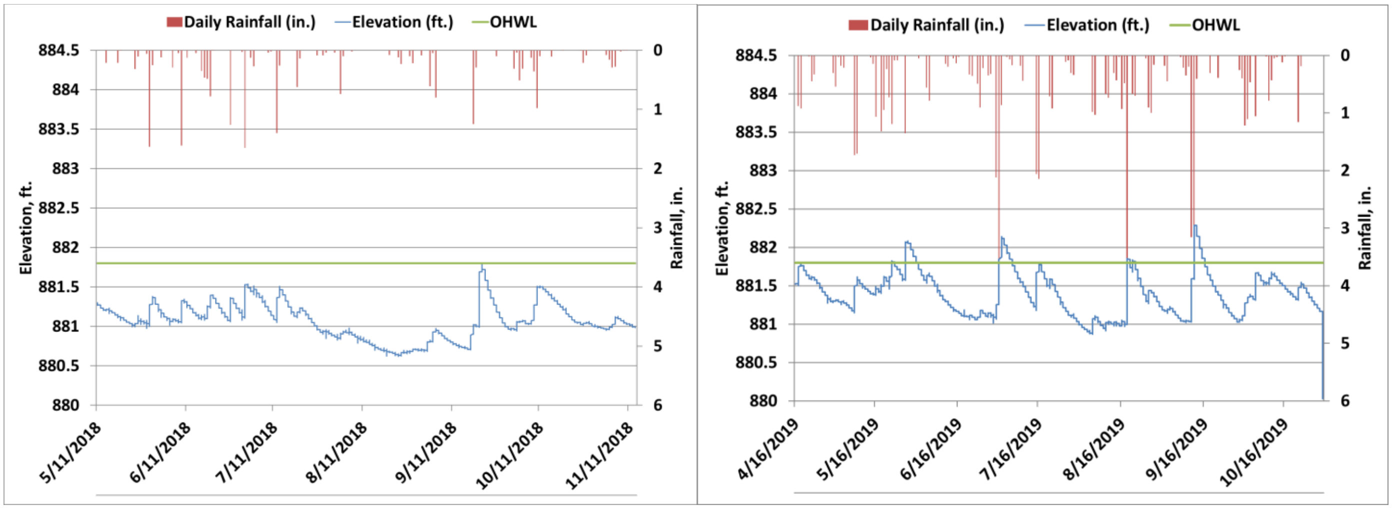

Figure A-14**. Lake Susan** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

Exhibit B

2019 Fyke Net Summary Data

Table B1: 2019 **Lake Susan Park Pond** fyke net data

Species	Number of fish caught in each category (inches)										
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	Not measured	Total	Fish/Net
Black crappie	241	51	2						66	360	90
Bluegill	384	32	1						763	1180	295
Yellow perch	95	7								102	25.5
Pumpkinseed	12	0								12	3
Golden shiner	1	5								6	1.5
Black bullhead	0	1	1							2	0.5
Green sunfish	13	2								15	3.75
Hybrid sunfish	1	4								5	1.25
Yellow bullhead	12	22	5	1						40	10
Largemouth bass	1									1	0.25
Northern pike						1				1	0.25
Painted turtle									13	13	3.25
Snapping turtle									4	4	1

Table B3: 2019 **Lake Lucy** fyke net data

Species	Number of fish caught in each category (inches)										
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	Not measured	Total	Fish/Net
Black crappie	3		3							6	1.2
Bluegill	376	7							175	558	111.6
Green sunfish	15	2								17	3.4
Hybrid sunfish	2	1								3	0.6
Largemouth bass	29	1								30	6
Northern pike		1	1		1	2				5	1
Pumpkinseed	114	10								124	24.8
Yellow bullhead	3	1								4	0.8
Yellow perch	8	1								9	1.8
Painted turtle									67	67	13.4
Snapping turtle									6	6	1.2

Table B4: 2019 **Lower Purgatory Creek Recreational Area** fyke net data

Species	Number of fish caught in each category (inches)										
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	Not measured	Total	Fish/Net
black bullhead	5	15								20	5
black crappie	54	18								72	18
bluegill	217	10							242	469	117.25
common carp	5			3		1				9	2.25
freshwater drum					1					1	0.25
green sunfish	85	3								88	22
golden shiner	8	2								10	2.5
hybrid sunfish	29	5								34	8.5
largemouth bass	36	5								41	10.25
northern pike			3	20		1				24	64
pumpkinseed	214	1							1,025	1240	310
walleye		1								1	0.25
white sucker					1					1	0.25
yellow bullhead	1	5								6	1.5
yellow perch	114	39								153	38.25
painted turtle									14	14	3.5
snapping turtle									1	1	0.25

Table B5: 2019 **Upper Purgatory Creek Recreational Area** fyke net data

Species	Number of fish caught in each category (inches)										
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	Not measured	Total	Fish/Net
Black bullhead	7	69								76	19
Black crappie	13	39	2							54	13.5
Bluegill	79									79	19.75
Common carp			1		5					6	1.5
Golden shiner	27	1								28	7
Green sunfish	14									14	3.5
Largemouth bass	10									10	2.5
Pumpkinseed	23	1								24	6
Yellow bullhead	1	7	4	1						13	3.25
Yellow perch	14	8								22	5.5
Painted turtle									2	2	0.5
Snapping turtle									4	4	1

Table B6: 2019 **Rice Marsh Lake** fyke net data

Species	Number of fish caught in each category (inches)										
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	Not measured	Total	Fish/Net
Black bullhead		1	2							3	0.6
Black crappie	20	3	5							28	5.6
Bluegill	489	146							191	826	233.8
Common carp					2					2	0.4
Central mudminnow	1									1	0.2
Hybrid sunfish		1								1	0.2
Largemouth bass		1								1	0.2
Northern pike		1			1			1		3	0.6
Pumpkinseed	3	5								8	1.6
Yellow bullhead	4	33	60	1						98	19.6
Painted turtle									39	39	7.8
Snapping turtle									2	2	0.4

Table B8: 2019 **Staring Lake** fyke net data

Species	Number of fish caught in each category (inches)										
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	Not measured	Total	Fish/Net
Black bullhead		1								1	0.2
Black crappie	2									2	0.4
Bluegill	264	27							62	353	70.6
Green sunfish	22	1								23	4.6
Hybrid sunfish	9	3								12	2.4
Largemouth bass	2	1								3	0.6
Pumpkinseed	43								1	44	8.8
White sucker				1						1	0.2
Yellow perch	1									1	0.2
Painted turtle									2	2	0.4
Snapping turtle									2	2	0.4

Exhibit C

2019 Zooplankton Summary Data

Table C1: 2019 **Lake Riley** Zooplankton Counts (#/m^2)

		5/20/2019	**6/4/2019**	**7/10/2019**	**8/8/2019**	**9/5/2019**
DIVISION	**TAXON**	**#/m2**	**#/m2**	**#/m2**	**#/m2**	**#/m2**
CLADOCERA	*Bosmina longirostris*	0	0	0	0	0
	Ceriodaphnia sp.	0	0	0	0	0
	Chydorus sphaericus	120,544	11,904	0	0	0
	Daphnia ambigua/parvula	0	0	0	0	0
	Daphnia galeata mendotae	0	11,904	17,177	0	0
	Daphnia pulex	0	23,807	8,589	0	0
	Daphnia retrocurva	0	0	8,589	8,137	6,329
	Diaphanosoma leuchtenbergianum	0	0	0	0	0
	Immature Cladocera	0	0	0	0	0
	Kindtti	0	0	0	0	0
	CLADOCERA TOTAL	**120,544**	**47,615**	**34,355**	**8,137**	**6,329**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	45,204	71,422	34,355	0	0
	Diaptomus sp.	7,534	107,133	25,766	65,094	6,329
	Nauplii	180,815	178,555	188,952	65,094	151,885
	COPEPODA TOTAL	**233,553**	**357,110**	**249,073**	**130,187**	**158,213**
ROTIFERA	*Asplanchna sp.*	0	41,663	0	0	0
	Brachionus sp.	0	0	0	0	0
	Filinia longiseta	0	0	8,589	0	0
	Lecane sp.	0	0	0	0	0
	Monostyla sp.	0	0	0	0	0
	Keratella sp.	851,339	124,989	60,121	89,504	398,698
	Keratella quadrata	0	0	0	0	0
	Kellicottia sp.	0	309,496	0	0	6,329
	Polyarthra sp.	0	5,952	154,597	24,410	145,556
	Trichocerca cylindrica	0	0	0	0	0
	Trichocera similis	0	0	0	0	0
	Trichocerca multicrinis	0	0	0	16,273	0
	Conochilus sp.	0	0	60,121	0	221,499
	Noltholca	0	0	0	0	0
	UID Rot	0	0	0	0	0
	ROTIFERA TOTAL	**851,339**	**482,099**	**283,428**	**130,187**	**772,082**

TOTALS	**1,205,436**	**886,824**	**566,856**	**268,511**	**936,623**

Table C2: 2019 **Staring Lake** Zooplankton Counts (#/m²)

DIVISION	**TAXON**	**5/15/2019 #/m2**	**6/4/2019 #/m2**	**7/10/2019 #/m2**	**8/8/2019 #/m2**	**9/5/2019 #/m2**
CLADOCERA	*Bosmina longirostris*	220,670	217,129	63,285	10,096	66,713
	Ceriodaphnia sp.	0	19,739	0	0	18,195
	Chydorus sphaericus	7,609	0	0	0	24,259
	Daphnia ambigua/parvula	0	0	0	10,096	0
	Daphnia galeata mendotae	15,219	108,565	23,732	0	72,778
	Daphnia pulex	0	0	0	0	0
	Daphnia retrocurva	0	29,609	0	0	36,389
	Diaphanosoma leuchtenbergianum	0	0	7,911	40,382	6,065
	Immature Cladocera	0	0	0	0	0
	Kindtti	0	0	0	0	0
	CLADOCERA TOTAL	**243,498**	**375,041**	**94,928**	**60,573**	**224,399**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	251,107	69,087	23,732	40,382	121,297
	Diaptomus sp.	7,609	39,478	31,643	20,191	84,908
	Nauplii	144,577	453,997	308,516	126,194	485,188
	COPEPODA TOTAL	**403,294**	**562,562**	**363,891**	**186,767**	**691,393**
ROTIFERA	*Asplanchna priodonta*	38,047	69,087	0	131,242	6,065
	Brachionus sp.	0	9,870	0	0	0
	Filinia longiseta	0	19,739	63,285	0	0
	Lecane sp.	0	0	0	0	6,065
	Monostyla sp.	0	0	7,911	0	0
	Keratella cochlearis	167,405	888,255	308,516	318,009	121,297
	Keratella quadrata	0	9,870	0	0	0
	Kellicottia sp.	30,437	187,521	0	0	66,713
	Polyarthra sp.	0	345,433	237,320	20,191	133,427
	Trichocerca cylindrica	0	0	0	0	6,065
	Trichocera similis	0	0	0	0	0
	Trichocerca multicrinis	0	0	0	0	0
	Conochilus sp.	0	0	0	0	0
	UID Rot	0	0	0	60,573	333,567
	ROTIFERA TOTAL	**235,889**	**1,529,773**	**617,032**	**530,015**	**673,198**
	TOTALS	**882,680**	**2,467,376**	**1,075,851**	**777,355**	**1,588,990**

Table C3: 2019 **Lotus Lake** Zooplankton Counts (#/m^2)

		5/16/2019	**6/4/2019**	**7/10/2019**	**8/8/2019**	**9/5/2019**
DIVISION	**TAXON**	**#/m2**	**#/m2**	**#/m2**	**#/m2**	**#/m2**
CLADOCERA	*Bosmina longirostris*	11678	0	48820	0	13184
	Ceriodaphnia sp.	0	0	0	0	0
	Chydorus sphaericus	0	0	16273	0	0
	Daphnia ambigua/parvula	0	6253	0	0	0
	Daphnia galeata mendotae	198520	25013	16273	0	0
	Daphnia pulex	0	0	0	0	0
	Daphnia retrocurva	0	0	8137	26369	243912
	Diaphanosoma leuchtenbergianum	0	0	0	13184	105476
	Immature Cladocera	0	0	0	0	0
	Leptodora kindtii	0	0	0	0	0
	CLADOCERA TOTAL	**210198**	**31266**	**89504**	**39553**	**362572**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	309458	81292	122050	26369	46146
	Diaptomus sp.	216037	68785	81367	19777	79107
	Nauplii	770725	212609	496338	118660	323019
	COPEPODA TOTAL	**1296220**	**362685**	**699755**	**164806**	**448271**
ROTIFERA	*Asplanchna sp.*	5839	62532	0	0	0
	Brachionus sp.	0	0	0	0	0
	Filinia longiseta	0	0	0	0	0
	Lecane sp.	0	0	0	0	0
	Monostyla sp.	0	0	0	0	0
	Keratella sp.	0	50026	16273	13184	171398
	Keratella quadrata	0	0	0	0	0
	Kellicottia sp.	110938	25013	0	0	217543
	Polyarthra sp.	0	18760	0	6592	0
	Trichocerca cylindrica	0	0	0	0	0
	Trichocera similis	0	0	0	0	0
	Trichocerca multicrinis	0	0	0	0	0
	Conochilus sp.	0	0	0	0	0
	UID Rot	0	0	0	0	0
	ROTIFERA TOTAL	**116777**	**156330**	**16273**	**19777**	**388941**

TOTALS	**1623194**	**550281**	**805532**	**224136**	**1199785**

Table C4: 2019 **Lake Susan** Zooplankton Counts (#/m²)

DIVISION	TAXON	5/15/2019 #/m2	6/4/2019 #/m2	7/10/2019 #/m2	8/8/2019 #/m2	9/5/2019 #/m2
CLADOCERA	*Bosmina longirostris*	220,670	217,129	63,285	10,096	66,713
	Ceriodaphnia sp.	0	19,739	0	0	18,195
	Chydorus sphaericus	7,609	0	0	0	24,259
	Daphnia ambigua/parvula	0	0	0	10,096	0
	Daphnia galeata mendotae	15,219	108,565	23,732	0	72,778
	Daphnia retrocurva	0	29,609	0	0	36,389
	Diaphanosoma leuchtenbergianum	0	0	7,911	40,382	6,065
	CLADOCERA TOTAL	**243,498**	**375,041**	**94,928**	**60,573**	**224,399**
COPEPODA	*Cyclops sp. / Mesocyclops sp.*	251,107	69,087	23,732	40,382	121,297
	Nauplii	144,577	453,997	308,516	126,194	485,188
	Diaptomus sp.	7,609	39,478	31,643	20,191	84,908
	COPEPODA TOTAL	**403,294**	**562,562**	**363,891**	**186,767**	**691,393**
ROTIFERA	*Asplanchna priodonta*	38,047	69,087	0	131,242	6,065
	Brachionus sp.	0	9,870	0	0	0
	Filinia longiseta	0	19,739	63,285	0	0
	Lecane sp.	0	0	0	0	6,065
	Monostyla sp.	0	0	7,911	0	0
	Keratella cochlearis	167,405	888,255	308,516	318,009	121,297
	Keratella quadrata	0	9,870	0	0	0
	Kellicottia sp.	30,437	187,521	0	0	66,713
	Polyarthra sp.	0	345,433	237,320	20,191	133,427
	Trichocerca cylindrica	0	0	0	0	6,065
	Trichocera similis	0	49,348	0	0	0
	UID Rot	0	0	0	0	333,567
	ROTIFERA TOTAL	**235,889**	**1,579,121**	**617,032**	**469,442**	**673,198**
	TOTALS	**882,680**	**2,516,724**	**1,075,851**	**716,782**	**1,588,990**

Table C5: 2019 **Rice Marsh Lake** Zooplankton Counts (#/m²)

DIVISION	TAXON	5/16/2019 #/m2	6/6/2019 #/m2	7/8/2019 #/m2	8/8/2019 #/m2	9/9/2019 #/m2
CLADOCERA	Bosmina longirostris	8,438	87,394	51,758	23,205	296,763
	Ceriodaphnia sp.	0	0	86,264	20,304	7,609
	Chydorus sphaericus	0	26,218	0	2,901	0
	Daphnia ambigua/parvula	0	0	0	0	0
	Daphnia galeata mendotae	210,951	0	0	0	0
	Daphnia pulex	50,628	0	0	0	0
	Daphnia retrocurva	0	0	0	0	0
	Diaphanosoma leuchtenbergianum	0	0	0	40,608	15,219
	Immature Cladocera	0	0	0	0	0
	Kindtti	0	0	0	0	0
	CLADOCERA TOTAL	**270,018**	**113,612**	**138,022**	**87,017**	**319,591**
COPEPODA	Cyclops sp. / Mesocyclops sp.	337,522	34,958	17,253	46,409	91,312
	Diaptomus sp.	84,380	0	103,517	23,205	53,265
	Nauplii	1,063,194	410,752	181,154	437,987	464,168
	COPEPODA TOTAL	**1,485,097**	**445,710**	**301,924**	**507,601**	**608,745**
ROTIFERA	Asplanchna priodonta	8,438	26,218	17,253	0	0
	Brachionus sp.	0	0	0	0	0
	Filinia longiseta	0	0	0	0	0
	Lecane sp.	0	0	0	5,801	0
	Monostyla sp.	0	0	0	8,702	0
	Keratella cochlearis	556,911	620,498	25,879	31,906	15,219
	Keratella quadrata	497,845	8,739	0	0	0
	Kellicottia sp.	2,826,747	0	0	0	0
	Polyarthra sp.	210,951	1,538,136	232,913	179,836	251,107
	Trichocerca cylindrica	0	0	0	0	0
	Trichocera similis	0	0	0	0	0
	Trichocerca multicrinis	0	0	0	0	0
	Platyias patulus	0	0	0	2,901	7,609
	Euchlaris sp.	0	0	0	0	0
	UID Rot	0	0	0	0	0
	ROTIFERA TOTAL	**4,100,892**	**2,193,591**	**276,045**	**229,146**	**273,935**

TOTALS	**5,856,006**	**2,752,914**	**715,991**	**823,765**	**1,202,271**

Exhibit D

2019 Phytoplankton Summary Data

Table D1: 2019 **Lotus Lake** Phytoplankton #/L

	5/16/2019	6/4/2019	7/10/2019	8/8/2019	9/5/2019
Class	#/L	#/L	#/L	#/L	#/L
Bacillariophyceae	230		57	172	
Chlorophyceae	574	1149		5054	2642
Cryptophyceae	919	574	1838	689	1149
Cyanophyceae	2354	2470	1436	38367	14244
Dinophyceae				230	1723
Total	4077	4193	3331	44513	19758

Table D2: 2019 **Staring Lake** Phytoplankton #/L

	5/15/2019	6/4/2019	7/10/2019	8/8/2019	9/5/2019
Class	#/L	#/L	#/L	#/L	#/L
Bacillariophyceae	4882	3159	689	230	115
Chlorophyceae	57838	1321	1608	6777	1436
Cryptophyceae	2527	1149	1264	1838	9017
Cyanophyceae	1608	57	4480	27339	
Dinophyceae				57	57
Euglenophyceae				57	
Total	66855	5686	8041	36299	10626

Table D3: 2019 **Lake Riley** Phytoplankton #/L

	5/16/2019	6/4/2019	7/10/2019	8/8/2019	9/5/2019
Class	#/L	#/L	#/L	#/L	#/L
Bacillariophyceae	56	57	115		57
Chlorophyceae	1418	1551	1551	11659	1551
Cryptophyceae		287	517	287	459
Crysophyceae	1668				
Cyanophyceae	2141	632	3102	7696	3791
Dinophyceae				57	172
Euglenophyceae		57			
Total	5284	2585	5284	19700	6031

Table D4: 2019 **Rice Marsh** Lake Phytoplankton #/L

	6/6/2019	7/8/2019	8/8/2019	9/9/2019
Class	#/L	#/L	#/L	#/L
Bacillariophyceae	172	115	459	230
Chlorophyceae	6490	3733	1608	6261
Cryptophyceae	402	517	1378	4939
Crysophyceae	57			
Cyanophyceae	517	1264	459	402
Dinophyceae		57		
Total	7639	5686	3906	11832

Table D5: 2019 **Lake Susan** Phytoplankton #/L

	5/16/2019	**6/3/2019**	**7/10/2019**	**8/6/2019**	**9/11/2019**
Class	**#/L**	**#/L**	**#/L**	**#/L**	**#/L**
Bacillariophyceae	287	57		5700	1920
Chlorophyceae	1378	2355	2125	11158	7406
Cryptophyceae	2412	1895	1781	2536	5943
Cyanophyceae	574	402	2527	34741	
Dinophyceae			230	85	30446
Euglenophyceae				85	366
Total	4652	4710	6663	54304	46080

Exhibit F

2019 Lake and Creek Fact Sheets