SAUK RIVER CHAIN OF LAKES 2022 MONITORING SUMMARY

Cedar Island, Horseshoe, Knaus, Krays, Schneider, Zumwalde

Overview

This monitoring summary provides 2022 water quality sample results for six lakes within the chain, and a review of historical data at those sites. Lakes within the chain that were monitored in 2022 included: Horseshoe, Cedar Island, Zumwalde, Schneider, Krays, and Knaus Lakes. Information regarding SRWD river monitoring sites upstream and downstream of the chain of lakes system has also been included, along with flow measurements and rainfall totals.

Sauk River Chain of Lakes Association, Inc. (SRCLA) has been actively monitoring and collecting water quality information regarding the chain of lakes system since it was established in 1982. The SRCLA was instrumental to the creation of the Sauk River Watershed District (SRWD) in 1986, and the organizations have worked together over the years to create and initiate water quality improvement projects along the Sauk River.

The vision of the Sauk River Chain of Lakes Association, Inc. is, “to be a passionate group of volunteers that strive to be good stewards of the Sauk River Chain of Lakes by working with all of its stakeholders to preserve and protect water quality, wildlife, and lake life while also promoting improvements through learning, education, and assistance. "

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SRCL Water Quality Standards

The Sauk River Chain of lakes is made up of 14 connected lakes and the Sauk River entering the lake system at Richmond and leaving at the dam at Cold Spring. The Chain is located in the North Central Hardwood Forest (NCHF) ecoregion, which stretches across central Minnesota and is defined by distinctive geography, annual solar energy, and moisture patterns.

There are various methods for analyzing and reporting water quality data, and the Minnesota Pollution Control Agency (MPCA) has determined both ecoregion specific water quality standards, as well as site-specific standards, for many lakes in the Sauk River Chain. Water quality standards (WQS) can be set for a pollutant at a statewide level, by ecoregion, or be site-specific. WQS are numeric pollutant level standards which are used to describe the desired condition of a water body and to protect beneficial uses. To create WQS, consideration is taken of average water depth, watershed area, biological communities present, and natural water chemistry. An ecoregion standard may be modified on a site-specific basis to account for unique characteristics such as lake depth and temperature, flowage or non-flowage classification, watershed activities, and distance from other ecoregion borders.

The MPCA and the Sauk River Watershed District (SRWD) proposed site-specific standards for some Sauk River Chain of Lakes in 2012. The proposal was created in response to several issues that arose during the development of the Total Maximum Daily Load (TMDL) study for the SRCL.

The issues that prompted the MPCA and the SRWD to propose site specific standards include, but are not limited to:

1. The SRCL is a flowage or reservoir system and the Minnesota Administrative Rules allow for the development of site-specific standards for reservoirs;
2. Lakes directly on the flowage of the river have very short water residence time (overall <7 days) and their water quality is largely driven by the Sauk River; and
3. Several deep lake basins in the chain are influenced by their connection to river and lake flowage. This influence can vary greatly from lake to lake, and so site-specific water quality standards that are more representative of the waterbody are needed to ensure recreational and aquatic life uses throughout the chain.

The table below contains the ecoregion standards and site specific standards for total phosphorus (TP), chlorophyll A (chl-a), and secchi disk readings in the Sauk River Chain of Lakes. The lakes monitored in 2022, and in past years, have been distributed throughout the chain to encompass the different lake classifications. In 2022, the lakes monitored were: Cedar Island (non-flowage), Horseshoe South (non-flowage), Knaus (flowage), Krays (flowage), Schneider (NCHF Ecoregion Standards), and Zumwalde (flowage). See the table below for WQS for each lake.

Lakes	TP (µg/L)	Chl-a (µg/L)	Secchi Disk (ft)
North Central Hardwood Forest General	<40	<14	>4.6
Sauk River Chain of Lakes Site Specific Standards			
Flowage Lakes: Zumwalde, Krays, Knaus	<90	<45	>2.6
Non-Flowage Lakes: Cedar Island Main, Horseshoe South	<55	<32	>4.6
Schneider Lake	<40	<14	>4.6
Rivers	**TP** (µg/L)	**TSS** (mg/L)	**Secchi Tube** (cm)
Central River Nutrient Region (RNR)	100	30	>35

The photo below provides an examples of secchi disk visibility during the 4 different trophic conditions described using the Carlson Trophic State Index (TSI).

The four main TSI classifications are:

oligotrophic - clear water, water bottom may be visible

mesotrophic - mostly clear water, temporary algal and aquatic plant growth

eutrophic - Water appears cloudy, persistent algal and aquatic plant growth

hypereutrophic - Water appears cloudy with scum, severe algae and plant growth

As can be seen, water clarity and visibility is greatly reduced in eutrophic and hypertrophic conditions. The Carlson TSI is used throughout this report to discuss annual water trends.

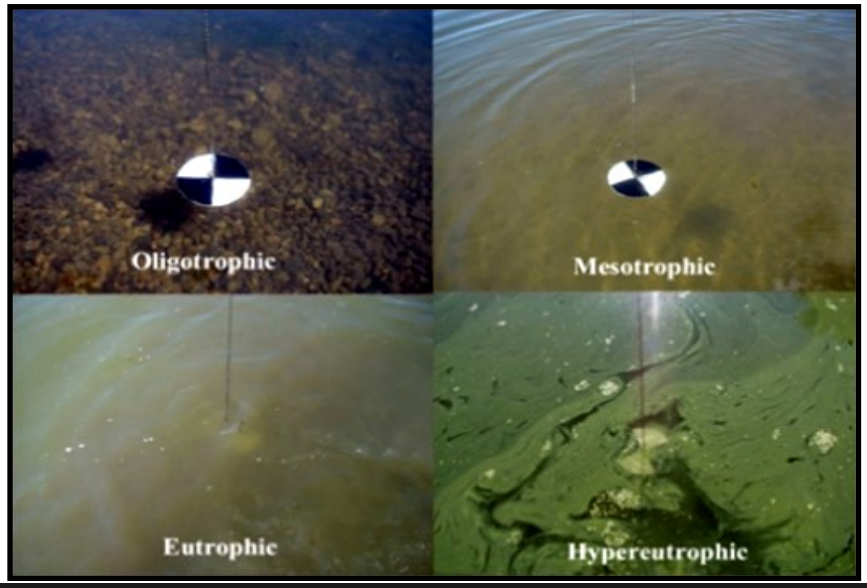


Photo Courtesy of the Minnesota Pollution Control Agency (MPCA)

River and Lake Sampling

SRWD intern demonstrating the use of a lake surface integrated sampler.

The river/stream monitoring samples presented in this report are taken of the surface water only. The SRWD river surface sampling device, called a Van Dorn, is submerged to a maximum depth of 1 - 2 feet below the water surface. This differs from lake surface sampling methods. The lake samples were collected by a SRCLA volunteer and taken with an integrated sampler, which is a 2-meter long pipe that is plunged into the lake vertically until just submerged, then a stopper is placed in the top of the pipe and the pipe is quickly pulled from the water. The sample pipe's contents are quickly released into a pitcher to allow the water to mix before filling sample bottles. This sampling method was performed at all lake monitoring sites, with the exception of Zumwalde Lake. The water depth of Zumwalde Lake at the sampling location was less than 2-meters (~6.6 feet) at certain times of the year, which is the length of the integrated sampler. Samples taken at Zumwalde Lake were taken at a depth ranging from 1-5 feet.

The Sauk River does not stop flowing when in reaches the chain of lakes, but the residence time of the flowing water increases between it's path coming in at Richmond and flowing out through the dam at Cold Spring. The aerial map above shows the predominant flow path of the river as it moves through the chain (flowing from left to right). The river enters the chain near Horseshoe Lake and follows a circuitous path through Zumwalde, Krays, and Knaus Lake, among others. These lakes are considered flowage lakes, and the average hydraulic residence time is around 7 days. Horseshoe and Cedar Island are not considered to reside in flowage, but instead very slowly drain to the flowage zone. This has led to the development of different WQS for flowage vs. non-flowage lakes within the chain. Schneider Lake is considered to be a natural lake and the general WQS for the North Central Hardwood Forest ecoregion have been assigned. These standards can be seen in the table on page 3.

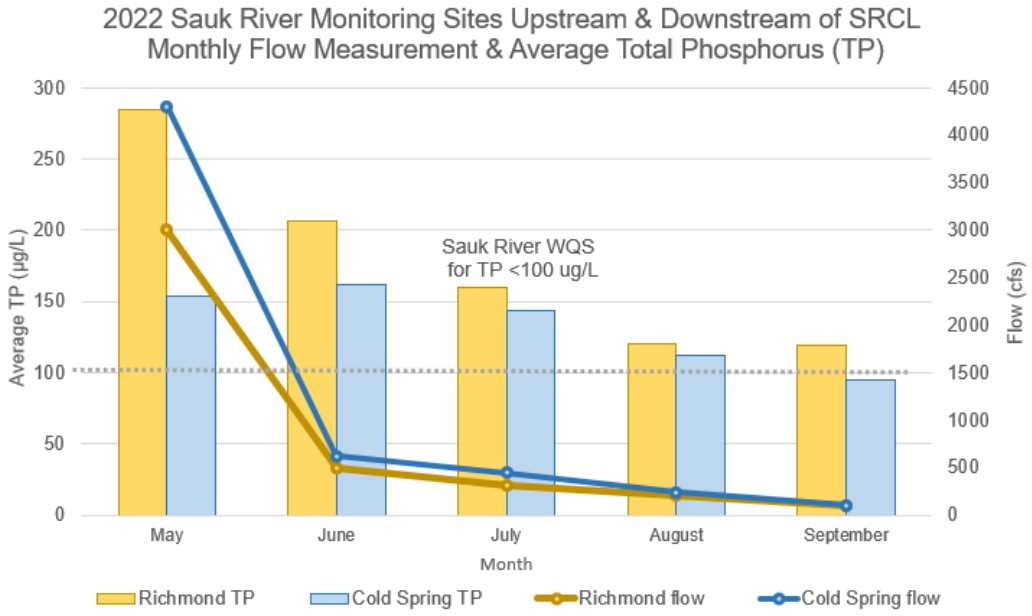
2022 Sauk River
Upstream and Downstream of SRCL

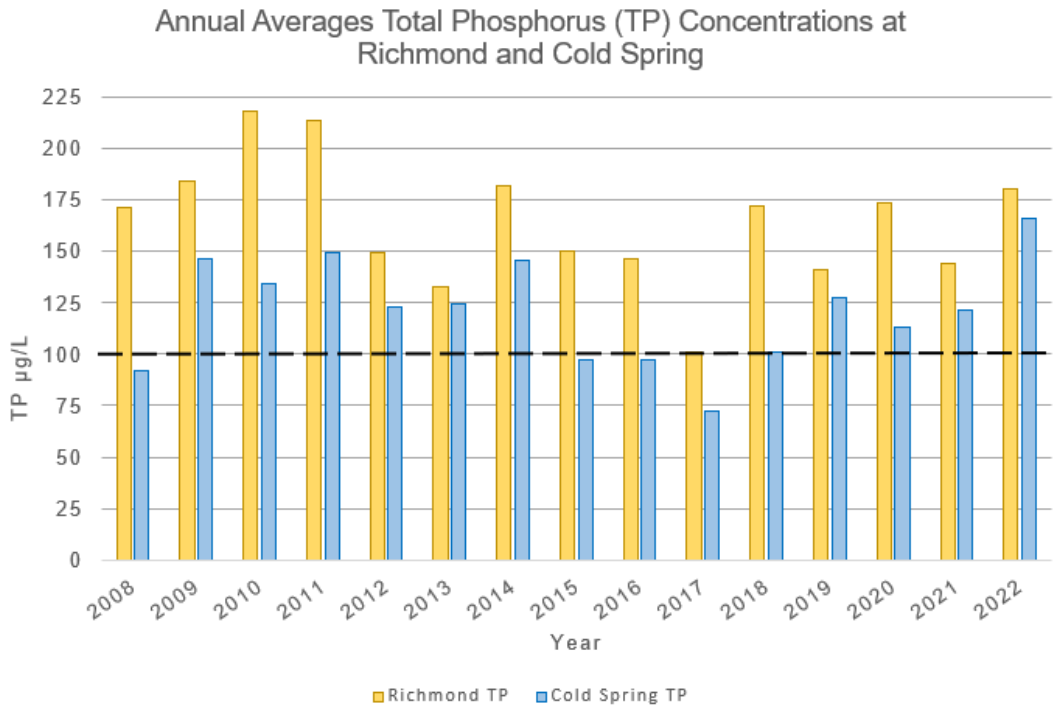
Sauk River Total Phosphorus

The top graph shows the monthly 2022 average concentrations of total phosphorus (TP) at the upstream and downstream sampling locations (left vertical axis and bar graphs) and the monthly flow measurements (right vertical axis and line graphs) together. The intense rain in May 2022 led to extreme high flows of just 4,300 cfs that brought with it high levels of TP into the chain. The TP WQS for the Sauk River is 100 µg/L. All 2022 Richmond (upstream) samples exceeded the WQS, and 2022 Cold Spring (downstream) samples exceeded the WQS until late September. It can be seen that TP concentrations upstream of the chain are higher than downstream concentrations, even though downstream flows are higher. This is indicative of TP settling out in the chain of lakes system and collecting in lake bottoms.

The bottom graph contains the annual average TP concentrations for Richmond and Cold Spring over the last 15 years. The Richmond site has exceeded the WQS each year, and the Cold Spring site has exceeded the standard the majority of the time. The upstream total phosphorus concentrations of the Sauk River will make it difficult to meet the WQS in the chain of lakes system. Upstream water quality improvement projects are needed to reduce TP loading to the chain.

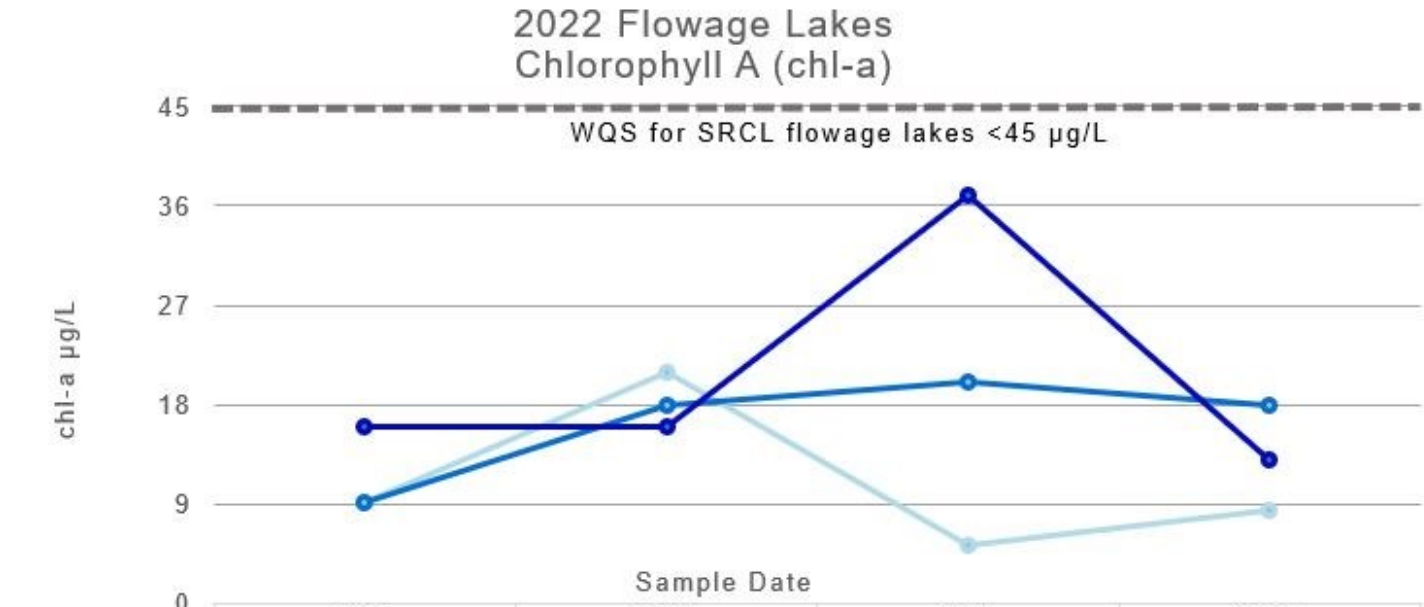
The SRWD has maintained Sauk River monitoring sites upstream of the chain of lakes on County Road 111 near the city of Richmond, and downstream in the city of Cold Spring on Red River Road. River monitoring sites are visited regularly from March to September, and water quality (WQ) samples are taken bimonthly. The 2022 monitoring year had some of the highest flow measurements taken by SRWD. Rainfall amounts for the May storms totaled ~6 inches over just a few days, and flow measurements increased by 1,000 cubic feet per second (cfs) from the upstream river monitoring site at Richmond to the downstream site at Cold Spring. This intense inundation of water flooded much of the chain, delayed the annual fishing opener, and led to no wake orders to be put of for weeks following the event.



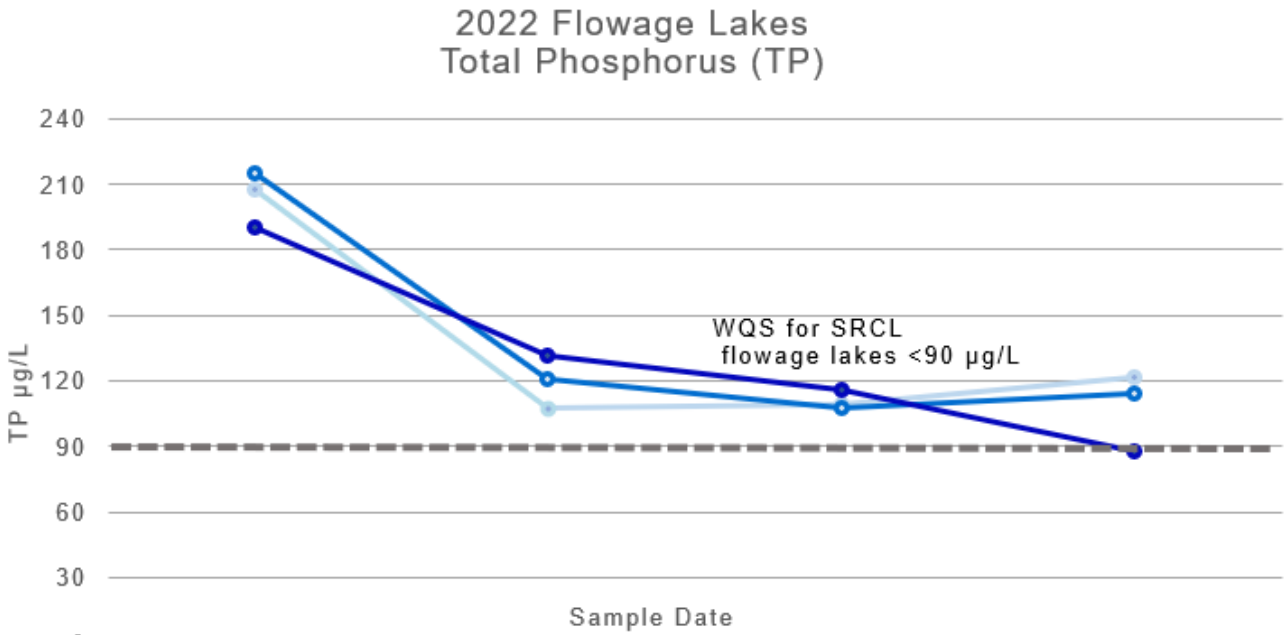


2022 Flowage Lakes

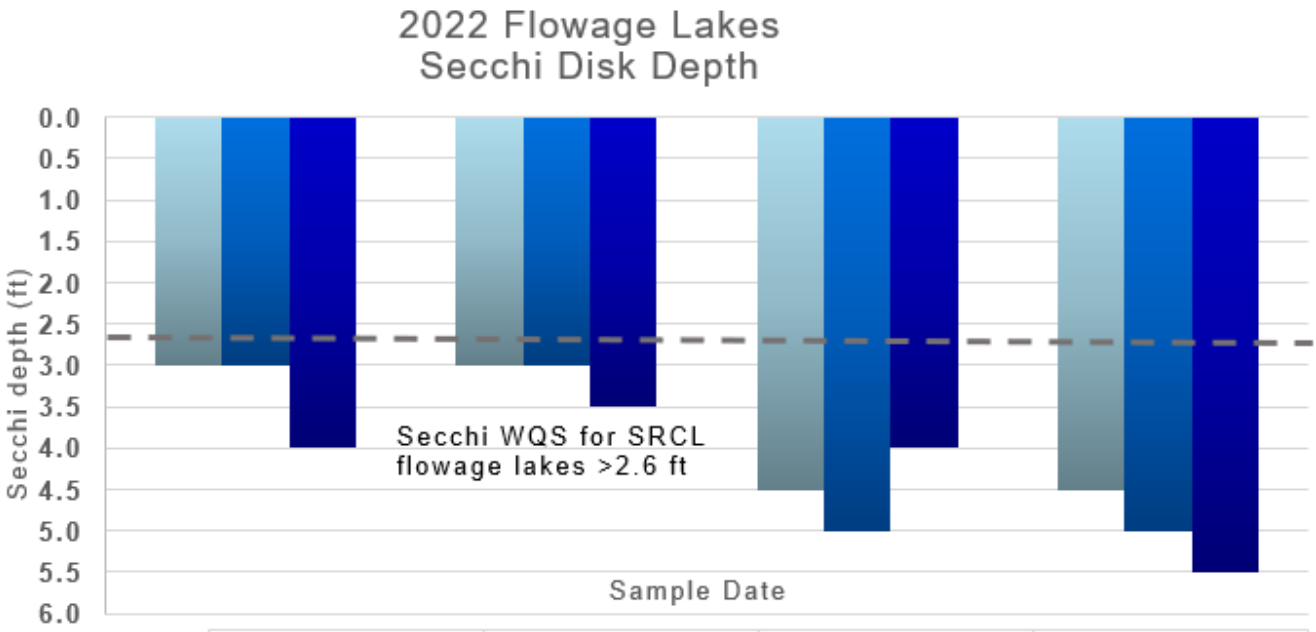
Krays, Knaus, and Zumwalde Lake



	6/21	7/28	8/30	9/20
Zumwalde	9.1	21	5.3	8.5
Krays	9.1	18	20	18
Knaus	16	16	37	13



	6/21	7/28	8/30	9/20
Zumwalde	208	108	109	122
Krays	215	121	108	114
Knaus	190	132	116	88



	6/21	7/28	8/30	9/20
Zumwalde	3.0	3.0	4.5	4.5
Krays	3.0	3.0	5.0	5.0
Knaus	4.0	3.5	4.0	5.5

2022 Flowage Lakes Summary

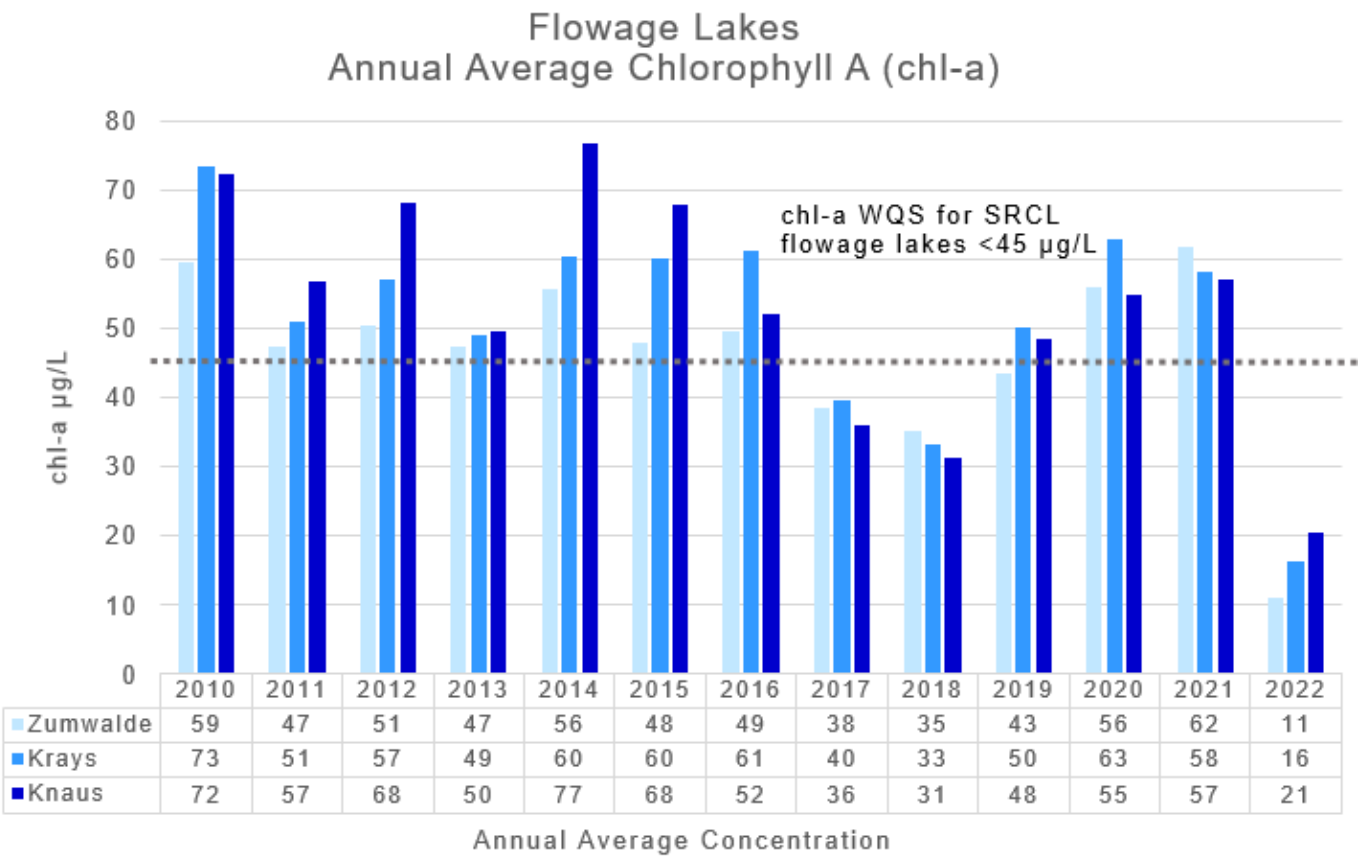
All lake sites met the WQS of 45 µg/L for chlorophyll-a (chl-a) and >2.6 feet for Secchi disk, but total phosphorus (TP) concentrations were above the WQS of 90 µg/L at all sites all year. Sampling did not occur in May due to high water and safety concerns.

Using concentrations of TP, chl-a, and Secchi disk depth, the Carlson trophic state index (TSI) calculation was applied. The TSI is used to indicate how much aquatic plant and animal life a waterbody can sustain, and the likelihood of observing poor water quality conditions. The table to the right shows that all 2022 flowage lakes were considered to be in the eutrophic range, with TSI values improving as the months progressed. This is not the "normal" seasonal progression, as usually the year begins with a lower TSI and increases as the weather warms. This is likely due to the extreme weather event in May effecting lake dynamics and phosphorus loading.

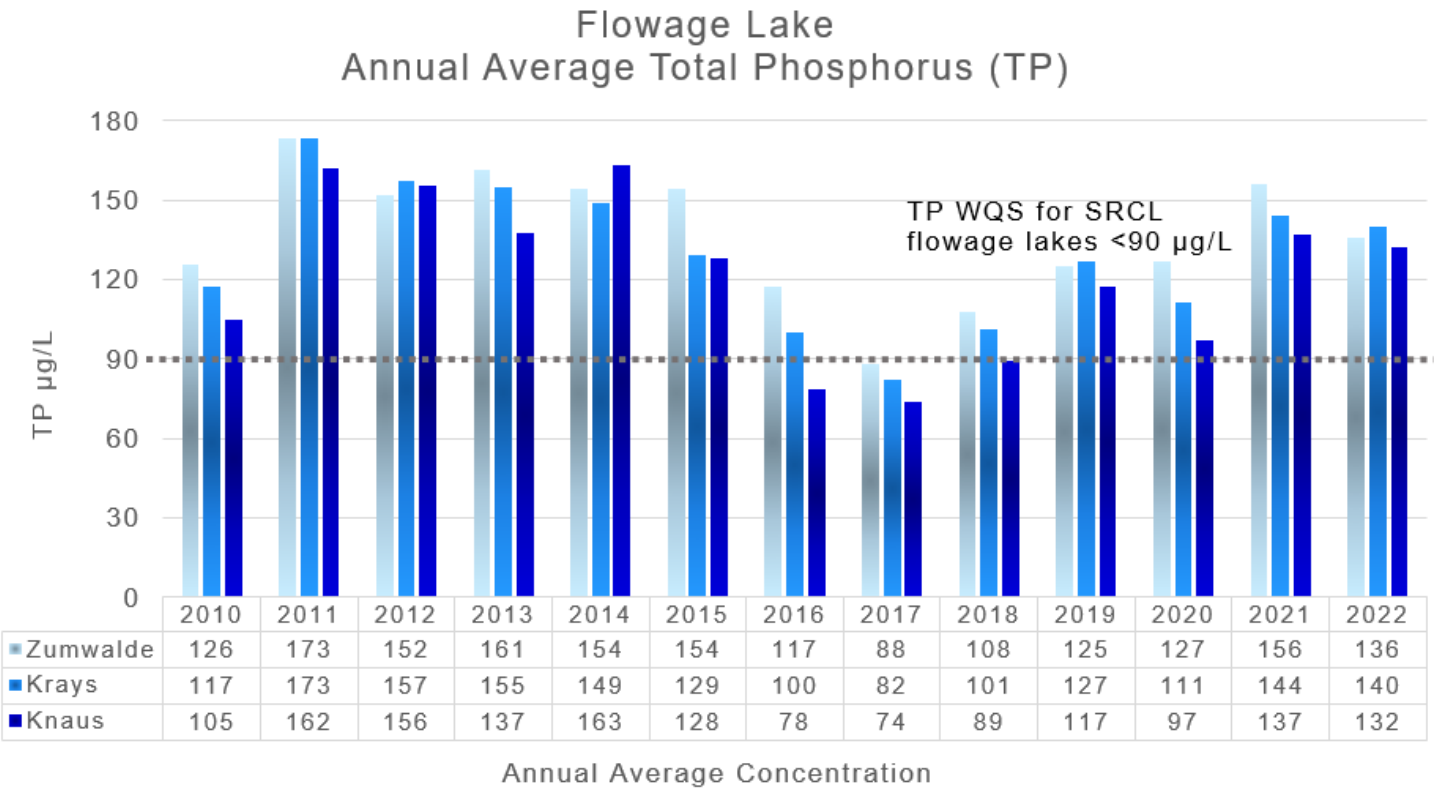
Observation Date	Zumwalde CTSI	Krays CTSI	Knaus CTSI
6/21/22	65	65	65
7/28/22	64	65	64
8/30/22	58	62	65
9/20/22	60	62	59
Annual Average	62	63	63

Annual Averages - Flowage Lakes

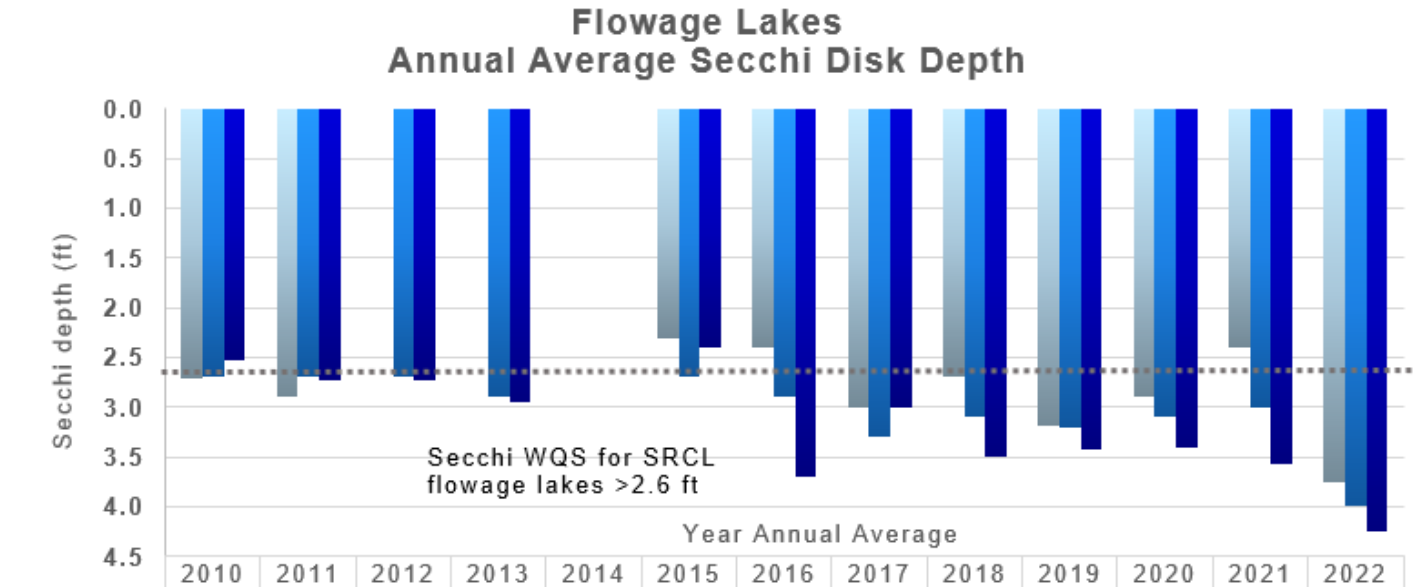
Zumwalde, Krays, and Knaus Lakes



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zumwalde	59	47	51	47	56	48	49	38	35	43	56	62	11
Krays	73	51	57	49	60	60	61	40	33	50	63	58	16
Knaus	72	57	68	50	77	68	52	36	31	48	55	57	21



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zumwalde	126	173	152	161	154	154	117	88	108	125	127	156	136
Krays	117	173	157	155	149	129	100	82	101	127	111	144	140
Knaus	105	162	156	137	163	128	78	74	89	117	97	137	132



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zumwalde	2.7	2.9				2.3	2.4	3.0	2.7	3.2	2.9	2.4	3.8
Krays	2.7	2.7	2.7	2.9		2.7	2.9	3.3	3.1	3.2	3.1	3	4
Knaus	2.5	2.7	2.7	3.0		2.4	3.7	3.0	3.5	3.4	3.4	3.6	4.3

Annual Averages - Flowage Lakes Summary

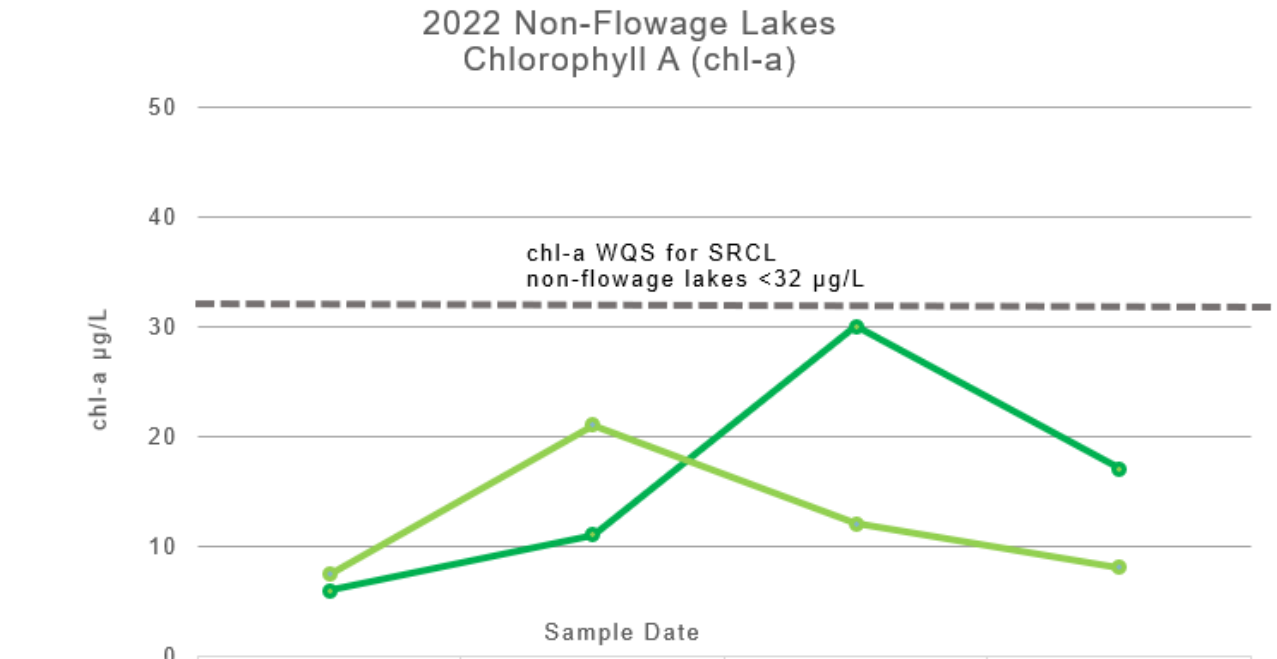
The flowage lakes annual averages presented on page 8 and 9 span from 2010 to 2022, with a few years where secchi readings were not taken. It can bee seen that the annual average values for chlorophyll-a were much lower in 2022 than other years, and Secchi disk depth was much deeper. As low levels of algae mean improved water visibility, the correlation in these results makes sense. Total phosphorus on the other hand, is well above the water quality standard in 2022, as well as most years. It is not the highest average the flowage lakes has seen, and is comparable to results seen in 2021. It is important to remember that sampling in May 2022 did not occur, so these average results are missing the first month of the season.

YEAR	Zumwalde CTSI	Krays CTSI	Knaus CTSI
2010	69	69	69
2011	70	70	70
2012	-	70	71
2013	-	69	69
2014	-	-	-
2015	70	69	70
2016	69	68	65
2017	65	65	64
2018	67	66	64
2019	67	68	67
2020	69	68	67
2021	71	69	68
2022	62	63	64

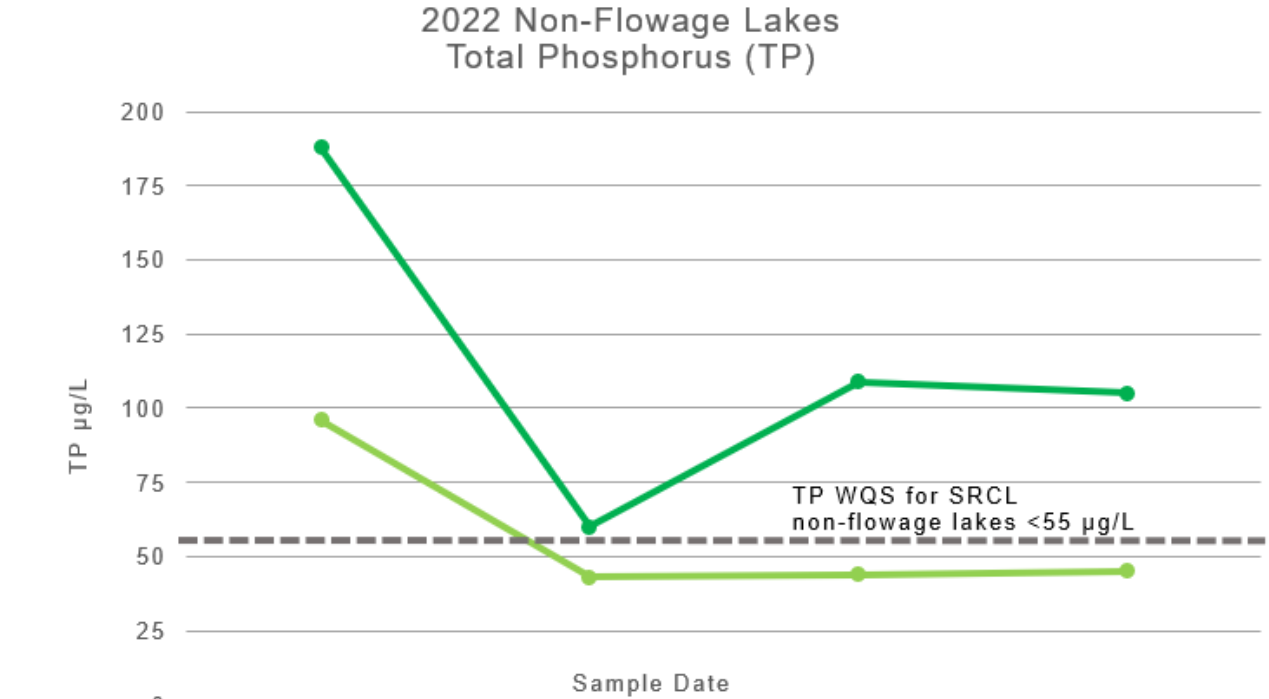
Using the annual averages for chlorophyll-a, total phosphorus, and Secchi disk readings, the Carlson Trophic State Index (TSI) was calculated for each flowage lake from 2010 to 2022 (see table to the right). Zumwalde, Krays, and Knaus Lake had TSI's ranging from 64-71, indicating that over the last decade the lakes reach eutrophic conditions each year. The 2022 TSI averages are low compared to the previous years. Although the annual average TSI is characterized as eutrophic, it is a good sign that there does not appear to be an increasing trend in the annual averages, but no trend is to be noticed. This indicates that conditions are at least holding steady in the flowage lakes and are not deteriorating at present.

2022 Non-Flowage Lake

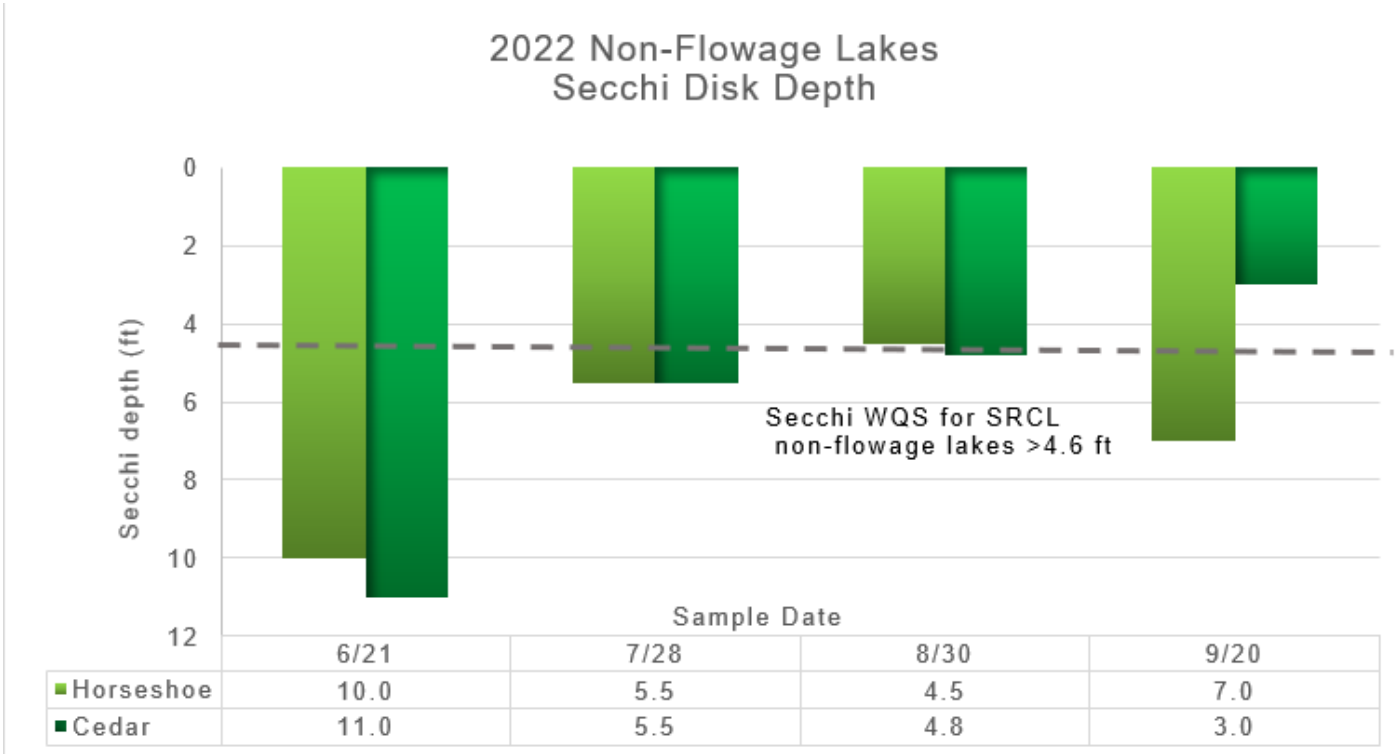
Cedar and Horseshoe Lake



	6/21	7/28	8/30	9/20
Horseshoe	5.9	11	30	17
Cedar	7.4	21	12	8



	6/21	7/28	8/30	9/20
Horseshoe	188	60	109	105
Cedar	96	43	44	45



2022 Non-Flowage Lakes Summary

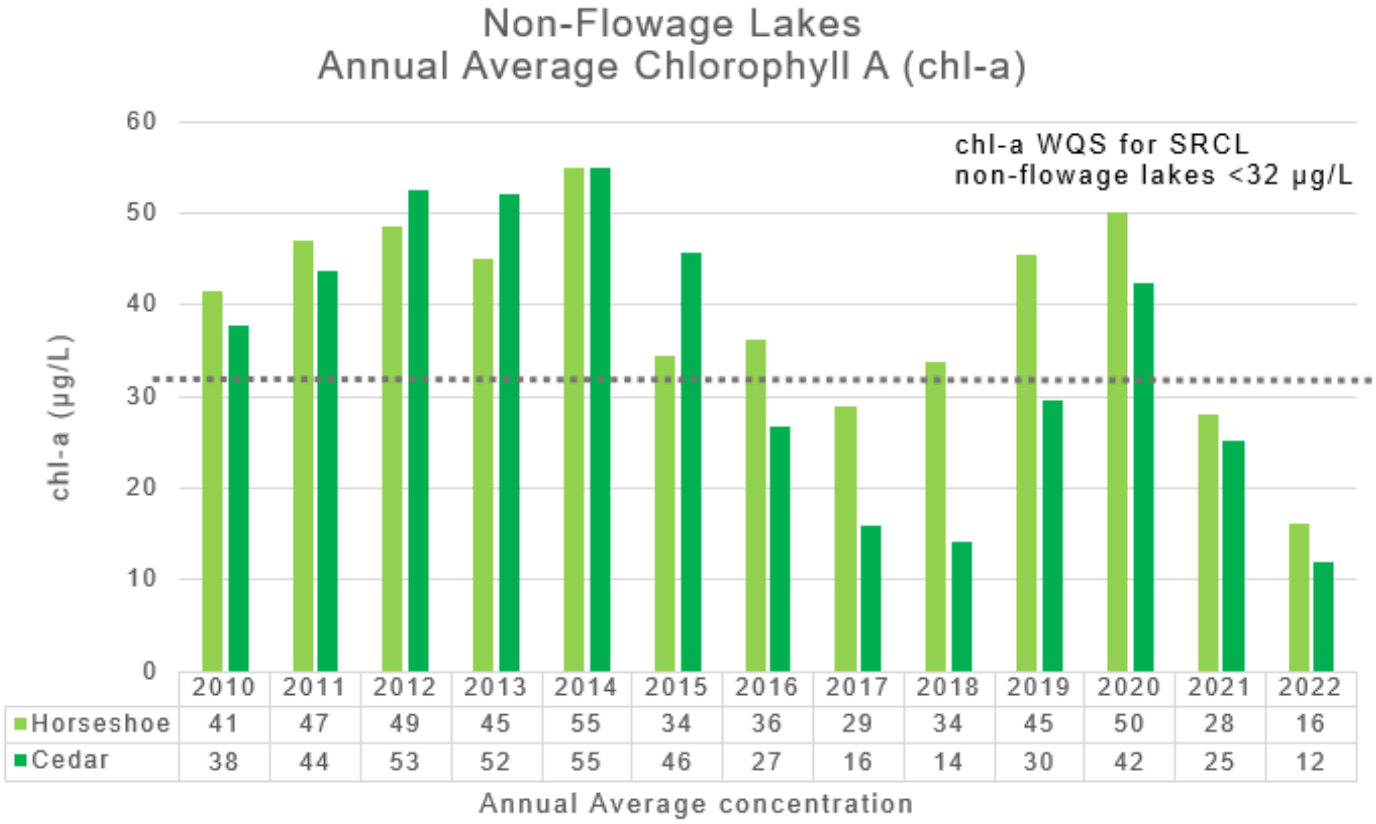
Non-flowage lakes Horseshoe and Cedar Island have lower water quality standards for chlorophyll-a and total phosphorus and a greater standard for Secchi disk depth measurements than flowage lakes. This is due to their longer hydraulic residence time. The sample concentrations for chl-a were below the water quality standard of 32 µg/L in both lakes. TP concentrations in Horseshoe Lake were higher than at Cedar Island at each sampling event, with all samples for Horseshoe Lake above the water quality standard of 55 µg/L. Secchi disk depth measurements for Cedar Island decreased as the summer progressed to less than the WQS of >4.6 feet, and Cedar Island results varied.

Using the 2022 data for TP, chl-a, and Secchi disk depth, the Carlson trophic state index (CTSI) calculation was applied. The table to the right shows that the TSI values ranged from 57-64 at Horseshoe Lake, and Cedar Island ranged from 51-54, which falls in the eutrophic range. Eutrophic conditions in this range indicate moderately clear water with increased probability of low oxygen concentrations as the summer progresses. The monthly results for the non-flowage lakes are better than what was seen in the flowage lakes in 2022, and were variable as the summer progressed.

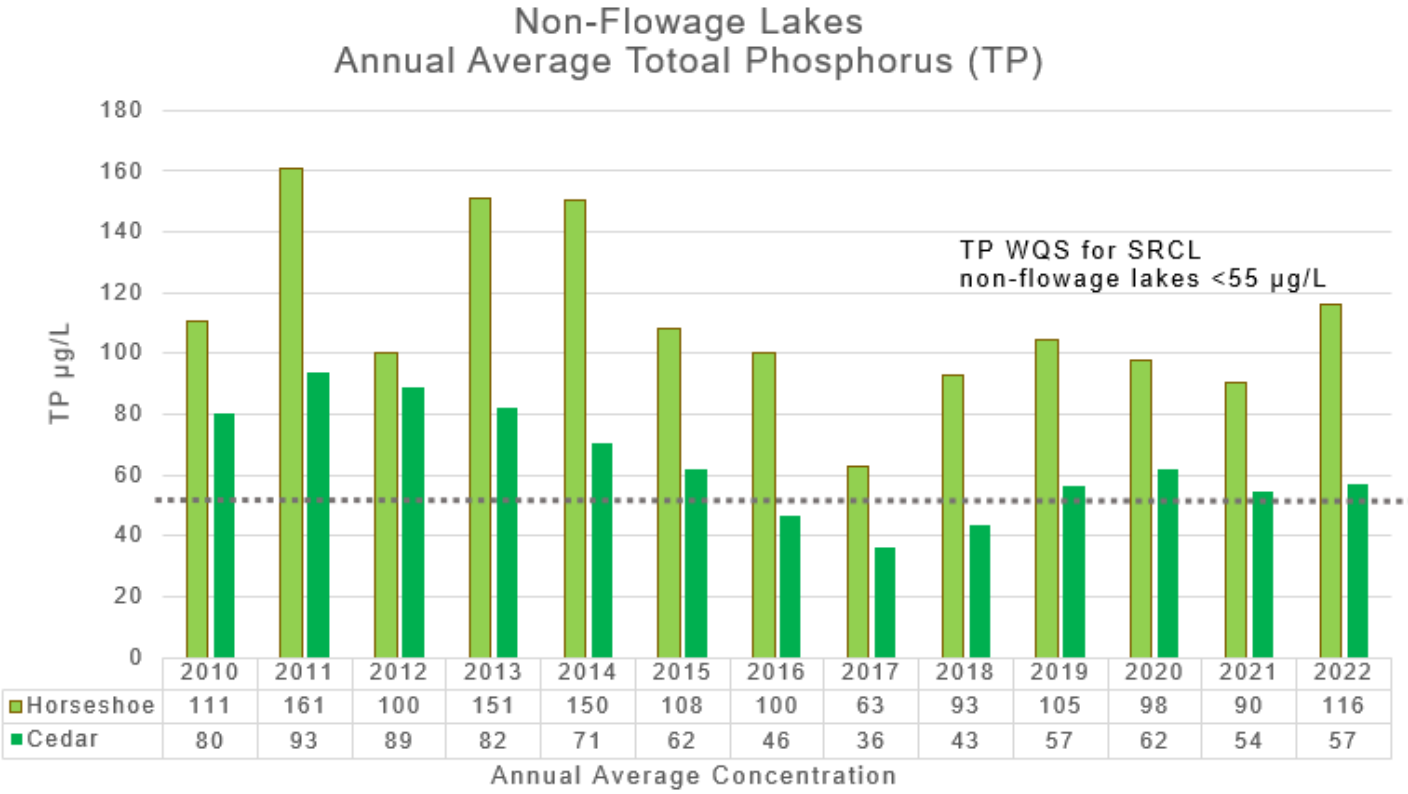
Observation Date	Horseshoe CTSI	Cedar CTSI
6/21/22	57	54
7/28/22	57	55
8/30/22	64	54
9/20/22	60	51
Annual Average	59	53

Annual Averages - Non-Flowage Lakes

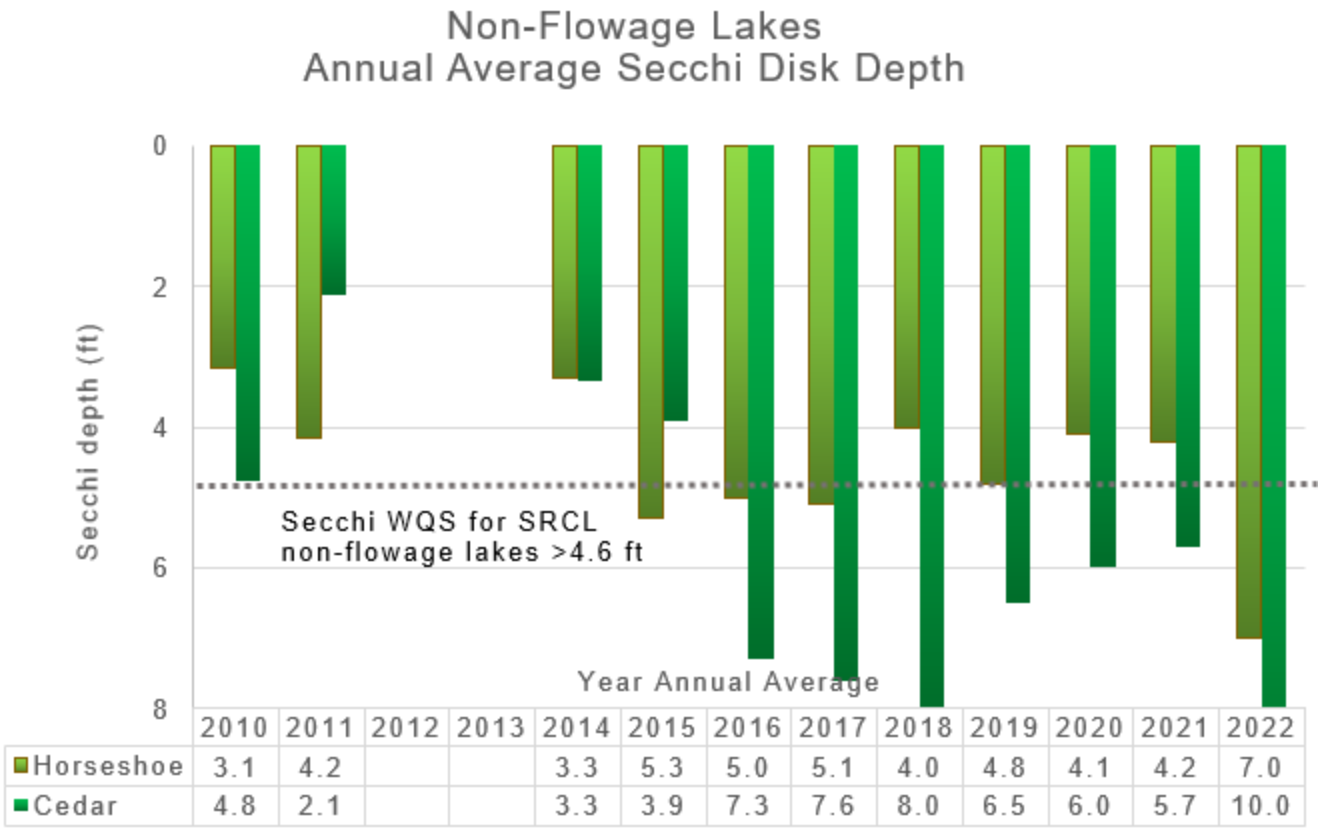
Horseshoe & Cedar Island



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Horseshoe	41	47	49	45	55	34	36	29	34	45	50	28	16
Cedar	38	44	53	52	55	46	27	16	14	30	42	25	12



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Horseshoe	111	161	100	151	150	108	100	63	93	105	98	90	116
Cedar	80	93	89	82	71	62	46	36	43	57	62	54	57



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Horseshoe	3.1	4.2			3.3	5.3	5.0	5.1	4.0	4.8	4.1	4.2	7.0
Cedar	4.8	2.1			3.3	3.9	7.3	7.6	8.0	6.5	6.0	5.7	10.0

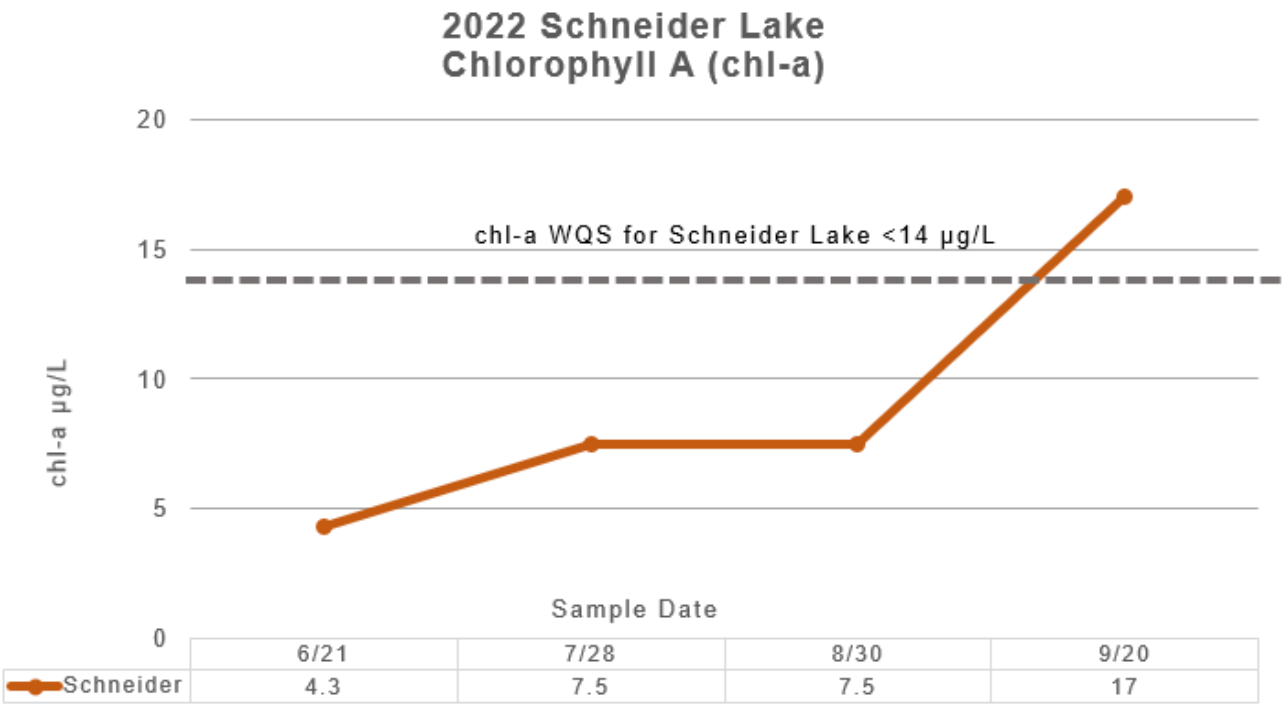
Non-Flowage Lakes Data Summary

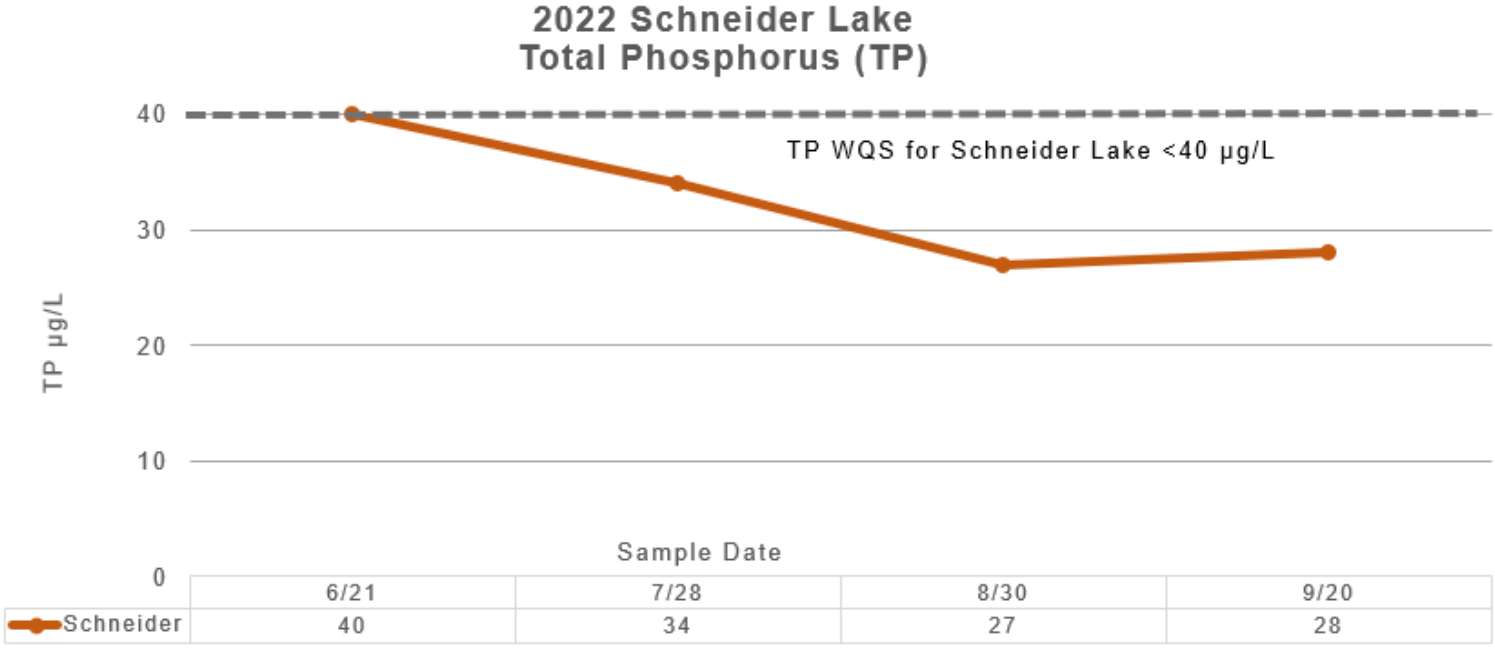
The non-flowage lakes annual averages presented here span from 2010 to 2021, though no secchi readings were taken in 2012 and 2013. It can be seen that annual average values for all parameters at Horseshoe Lake fail to meet WQS the vast majority of the time, and Cedar Island regularly exceeds WQS for TP and chl-a as well. The average secchi reading's at Cedar Island have met the WQS of disk visibility greater than 2.6 feet (0.8 meters) since 2016. It is important to remember that sampling in May 2022 did not occur, so the 2022 annual average results are missing the first month of the season.

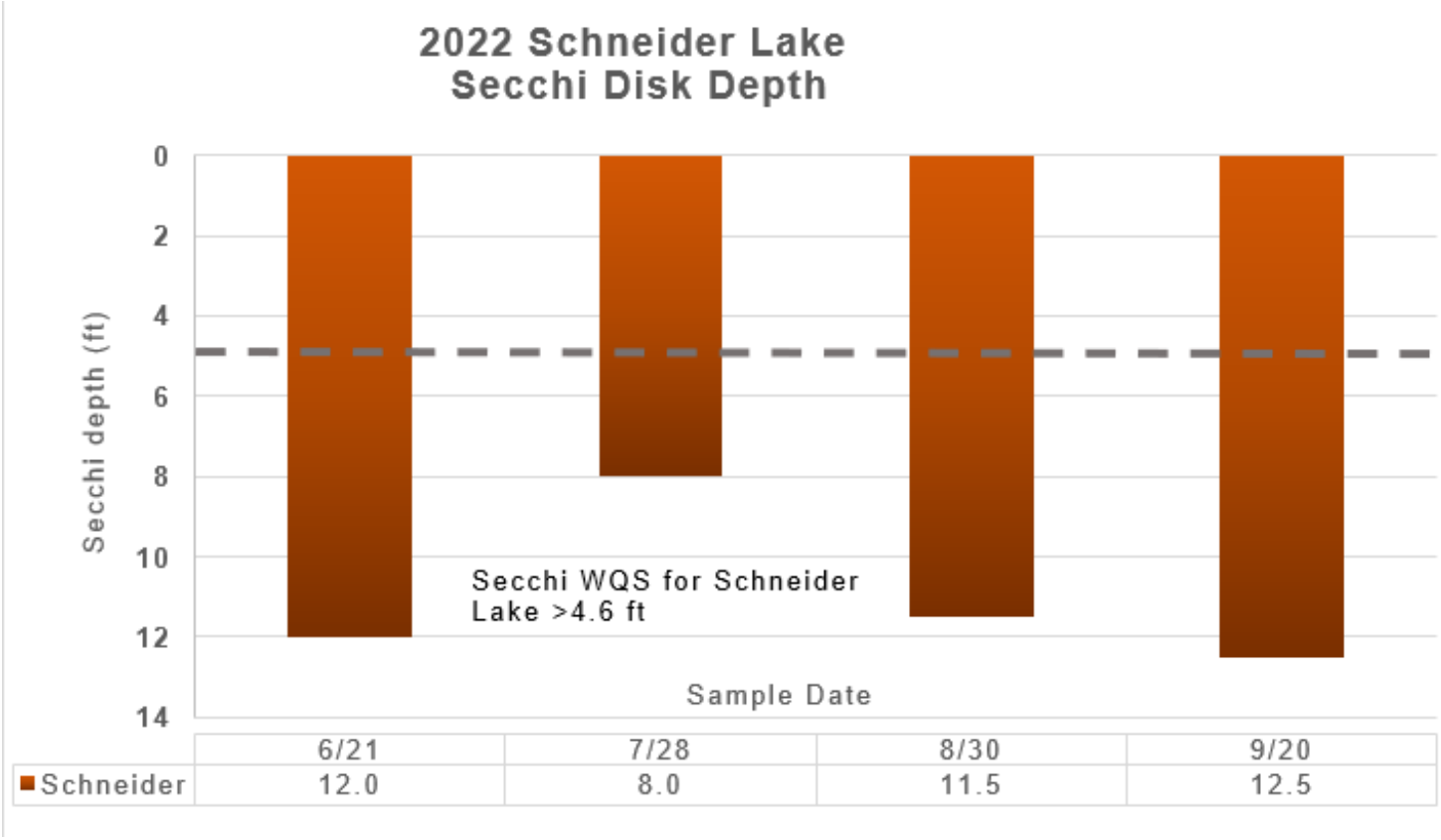
Using the annual averages for chlorophyll a, total phosphorus, and secchi disk readings, the Carlson Trophic State Index (TSI) was calculated for each flowage lake (see table to right). From 2010 to 2022, Horseshoe Lake had a TSI ranging from 60-69, and Cedar Island ranged from 54-68. These results indicate that each year the lake's reach eutrophic conditions, with decreased water visibility, extensive aquatic plant growth, algal scum, and low oxygen conditions as the summer progresses. These conditions likely stress aquatic species, reduce recreational and visual enjoyment of the lakes, and lead to plant overgrowth. Although the annual average TSI is considered eutrophic for Horseshoe Lake and Cedar Island, there does not appear to be an increasing trend in the values from year to year. This indicates that conditions are at least holding steady in the non-flowage lakes and not deteriorating at present.

Year	Horseshoe CTSI	Cedar CTSI
2010	67	63
2011	67	68
2012	-	-
2013	-	-
2014	69	65
2015	63	63
2016	63	57
2017	60	54
2018	64	54
2019	65	59
2020	65	61
2021	63	59
2022	60	54

2022 Schneider Lake
NCHF Standards







2022 Schneider Lake Summary

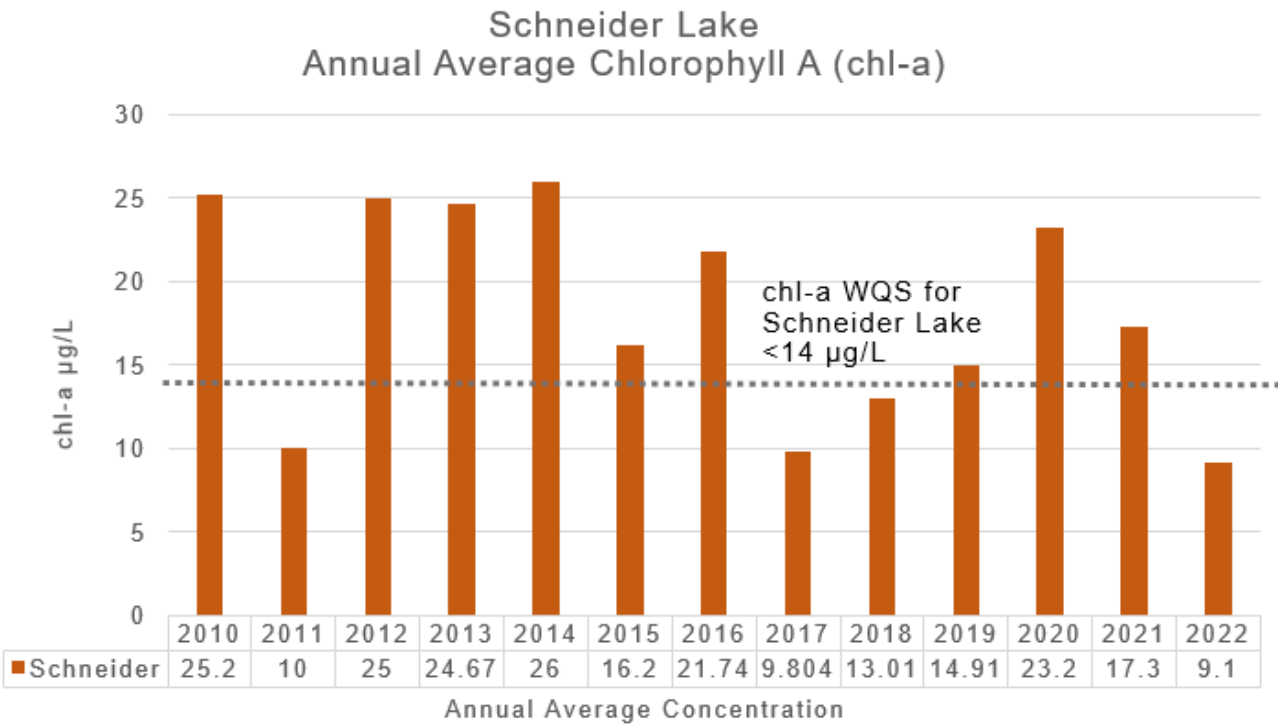
Schneider Lake is considered a natural lake and follows the North Central Hardwood Forest ecoregion water quality standards, which differs from flowage and non-flowage lakes in the chain. Chlorophyll-a levels did have one exceedance of the WQS of 14 µg/L in September, and total phosphorus levels were at the WQS of 40 µg/L in June, but crept down and the season progressed. Secchi disk visibility was deeper than the standard of 4.6 feet for all 2022 sampling visits. Overall sampling results for Schneider Lake were quite good for the season, indicating good water quality throughout the year.

Using the 2022 Schneider Lake data for TP, chl-a, and secchi disk depth readings, we are able to apply the Carlson Trophic State Index (TSI) calculation. The TSI is used to indicate how much aquatic life a waterbody can sustain and the likelihood of observing poor water quality conditions for aquatic life and recreation. The table to the right shows that the TSI values ranged from 48-51, which falls in the higher end range for mesotrphic conditions to the lower end of the eutrophic categories. This indicates waters conditions were mostly clear with temporary algal and aquatic plant growth.

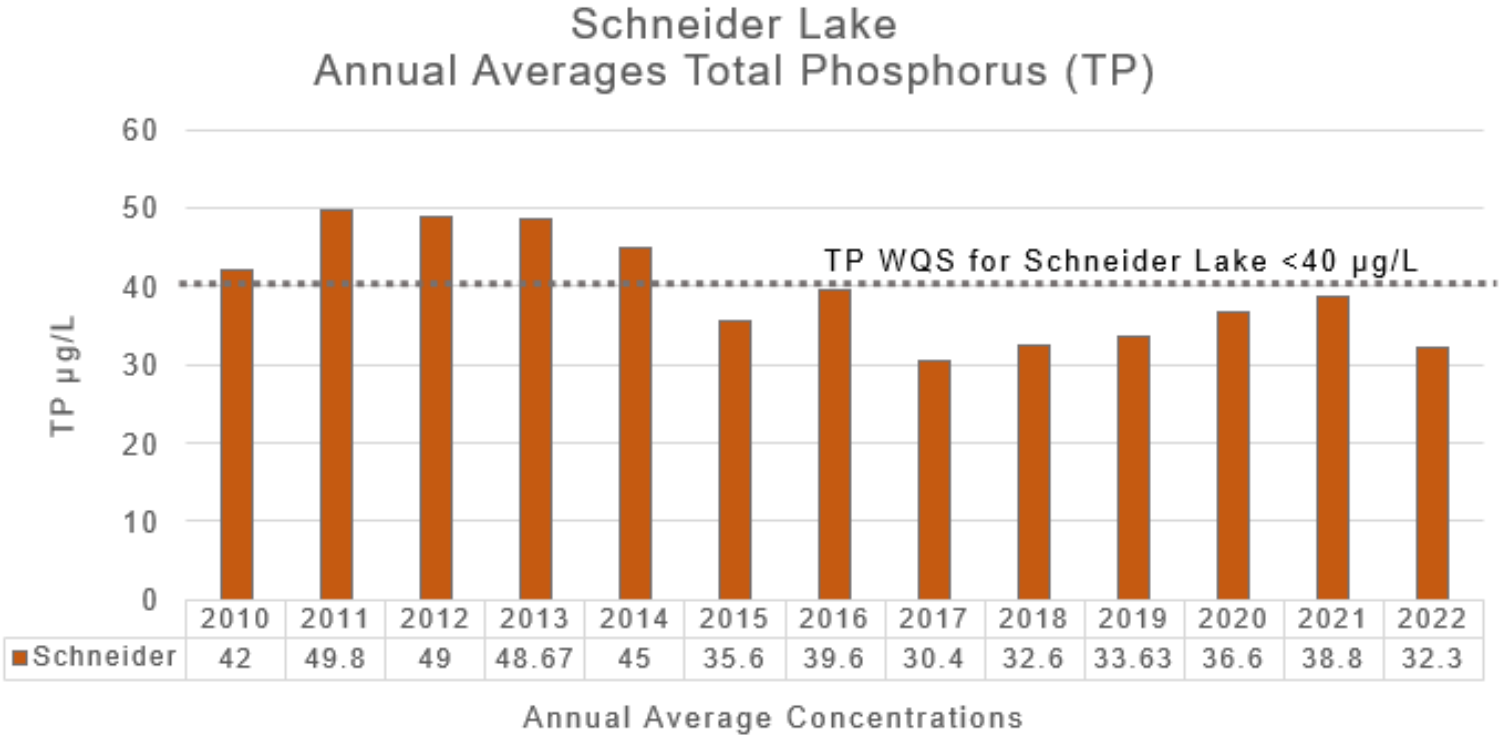
Observation Date	Schneider CTSI
6/21/22	48
7/28/22	51
8/30/22	48
9/20/22	50
Annual Average	49

Annual Averages - Schneider Lake

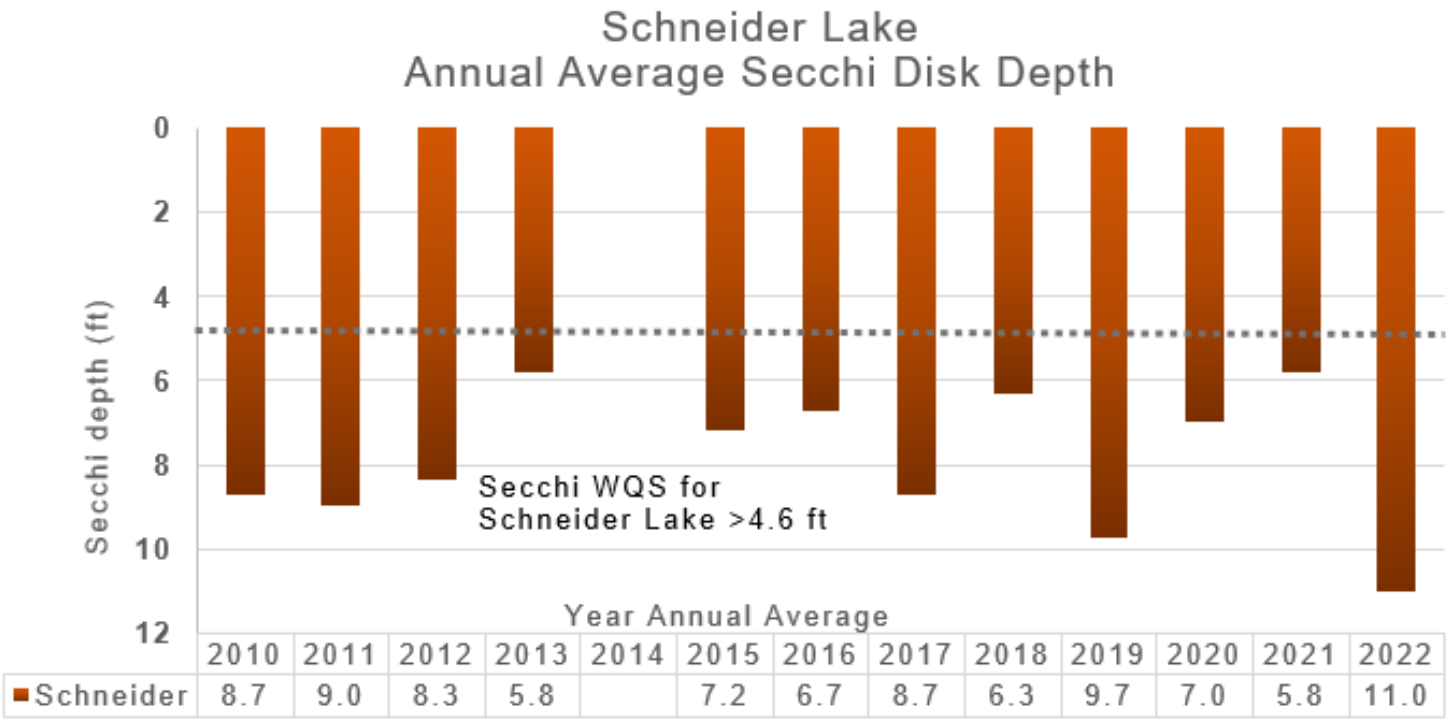
NCHF Standards



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Schneider	25.2	10	25	24.67	26	16.2	21.74	9.804	13.01	14.91	23.2	17.3	9.1



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Schneider	42	49.8	49	48.67	45	35.6	39.6	30.4	32.6	33.63	36.6	38.8	32.3



Annual Averages - Schneider Lakes Data Summary

Schneider Lake's annual averages presented here span from 2010 to 2022, with no secchi readings taken in 2014. Chl-a averages vary from year to year, and TP averages began to meet the WQS in 2015. Both Chl-a and TP concentrations had the lowest average in 2022. It is important to remember that sampling in May 2022 did not occur, so the 2022 annual average results are missing the first month of the season.

Year	Schneider CTSI
2010	55
2011	53
2012	56
2013	58
2014	-
2015	54
2016	56
2017	51
2018	54
2019	52
2020	56
2021	56
2022	48

Using the annual averages for chlorophyll a, total phosphorus, and secchi disk readings, the Carlson Trophic State Index (TSI) was calculated for Schneider Lake (see table to right). From 2010 to 2022 the TSI ranged from 48-58, which falls in the lower end of the eutrophic category. This indicates that most years late in the summer, Schneider Lake begins to reach eutrophic conditions, with moderate aquatic plant growth, some algal scum, and potentially reduced oxygen conditions. Since Schneider is tucked up to the North of the chain of lakes system and is not part of the flowage or non-flowage lakes that drain to and interact with the Sauk River, Schneider behaves more like a regular, isolated lake system. The surrounding drainage area drives the water quality results in Schneider Lake, and this is why it is classified separately from many of the other lakes on the chain. The range of Carlson TSI results over the last 12 years all fall into the expected normal range for a deep lake in the North Central Hardwood Forest Ecoregion. There was a slight upward trend in TSI results from 2027 to 2021, but at this time no trend is identifiable.

Common Terms

Average/Arithmetic Mean - The arithmetic mean is commonly referred to as the average. It is calculated by adding all given sample values together and then dividing them by the number of values (n) that were added. Sample data annual averages are commonly used in this report to summarize conditions each year.

Eutrophication - The term eutrophication comes from the Greek word eutrophos, which means well nourished. Eutrophication occurs when an excess of nutrients, particularly phosphorus and nitrogen, enters a river or lake system and cause excessive plant and algae growth. When the plants die and decompose, microbes breakdown the plant material and use up the majority of the available oxygen in the waterbody. This creates low oxygen (anoxic) conditions and will stress and even kill macroinvertebrates and fish. Additionally, recreational suitability is greatly reduced and physical contact with or ingestion of the water could result it harm.

Ecoregion - An ecoregion is a major ecosystem that can be defined by distinctive geography, annual solar energy, and moisture patterns. The Minnesota ecoregion the Sauk River resides in is the North Central Hardwood Forest (NCHF) ecoregion in the Central Minnesota River Nutrient Region (RNR).

Flowage Lakes - A flowage lake is a lake that forms upstream of a dam and can be used synonymously with reservoir lake. Water in flowage lakes acts like a very slow river, as the water keeps flowing down stream, but is slowed down markedly by the dam structure. A *Non-flowage* lake is a lake that formed without the effects of downstream damming. Water enters non-flowage lakes and resides there much, much longer than in flowage lakes.

Point Source and Nonpoint Source - These terms are used when referring to how a pollutant enters a waterbody. Point sources are single and identifiable locations, such as the end of a pipe, and are regulated by state and federal agencies. Nonpoint sources are things like rain and snow runoff, which accumulate pollutants as water drains. Things like parking lots, farmland, construction sites, and eroding streambanks are considered nonpoint sources of pollution and are harder to identify, control, and regulate.

Carlson's Trophic State Index (TSI) - The Carlson Trophic State Index (TSI) is a classification system designed to rate water bodies using concentration measurements of both chlorophyll-a and total phosphorus, combined with secchi disk readings. This rating indicates how much aquatic life, plant and animal, a waterbody can sustain. The higher the rating, the more likely it will be that poor water quality will be observed. Under the TSI scale, waterbodies may be defined as:

oligotrophic - TSI >0–35, Good water depth visibility, adequate oxygen conditions for aquatic life year round.
mesotrophic - TSI 35–50, Moderately water depth visibility, increased probability of low oxygen conditions.
eutrophic - TSI 50-70, Poor water visibility, algae scum, extensive aquatic plant growth, low oxygen conditions.
hypereutrophic - TSI 70–100+, Heavy algae and aquatic plant growth, very low oxygen conditions, summer fish kills likely.

Water Quality Monitoring Parameters

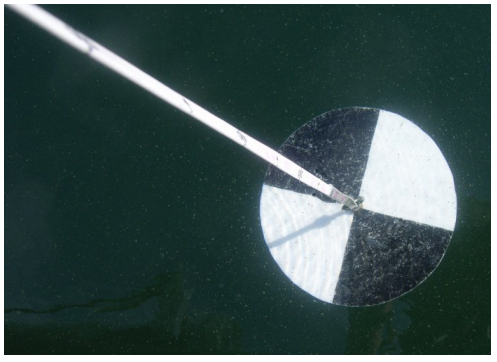
Total Phosphorus (TP)

Total phosphorus is a measure of both the organic and inorganic (orthophosphorus) forms of phosphorus in a sample. Phosphorus is an essential nutrient for plant and animal growth, but is only necessary in small concentrations to sustain life. The natural background levels of TP in a pristine Minnesota Lake is around 10 ug/L, and can be found suspended in the water or in the bottom materials. Most lakes and waterbodies have elevated TP concentrations in the United States, with point source contributions from wastewater releases and industrial cleaners, and nonpoint source contributions from agricultural fertilizers and groundwater. Minnesota is broken up into different ecoregions to account for some of the variability in landscape, land use, and weather in the state, and each region has unique water quality standards. The entire Sauk River watershed resides in the north central hardwood forest (NCHF) ecoregion, and the general eutrophication standard for total phosphorus in NCHF lakes is less than 40 µg/L. The Sauk River Chain of Lakes system has many lakes with site specific water quality standards for total phosphorus that can be found on page 75of this report. These site specific standards were created due to the unique nature of the Sauk River chain of lakes system.

Chlorophyll A (chl-a)

Chlorophyll A is a measure of the amount of algae growing in a waterbody, and can be used as an indicator of water quality. Although algae is a natural part of freshwater ecosystems, too much algae can result in decreased levels of oxygen in the waterbody and cause aesthetic problems, such as green scum and bad odors. Some algae naturally produces toxins as well, and can be a public health concern in high concentrations. Waters with high levels of nutrients from fertilizers, septic systems, and urban runoff may have high concentrations of chl-a in response to the excess nutrients. The general water quality standard for chl-a in lakes within the north central hardwood forest (NCHF) ecoregion is less than 14 µg/L. The Sauk River Chain of Lakes system has many lakes with site specific water quality standards for chl-a that can be found on page 5 of this report. . These site specific standards were created due to the unique nature of the Sauk River chain of lakes system.

Secchi Disk



Water clarity is measured using a secchi disk (also known as a transparency disk) that is lowered into the water until it can no longer be seen, and the depth of visibility is noted. Secchi disk readings are used to assess water visibility and quality. The general water quality standard for lake secchi disk readings in the north central hardwood forest (NCHF) ecoregion is greater than 4.6 feet (1.4 meters). The Sauk River Chain of Lakes system has many lakes with site specific water quality standards for secchi readings that can be found on page 5 of this report.

Summary of SRCL 2022 Monitoring Data

The intense rainfall events that occurred across the watershed in May brought about high water levels to all six lakes in the Sauk River Chain of Lakes (SRCL) system that were monitored in 2022 (Cedar Island, Knaus, Krays, Horseshoe, Schneider, and Zumwalde). This led to a reduction in the normal data collection for the year, as May samples were not taken due to no wake orders and unsafe boating conditions. Reducing the data points for the season from 5 per lake to 4 likely effected the data for the year and the annual averages for 2022.

All sampled lakes were considered eutrophic at some point in the season using the Carlson Trophic State Index (TSI). Flowage lakes (Knaus, Krays, Zumwalde) had the highest levels of total phosphorus and the highest Carlson TSI's of the sampled lakes. The non-flowage lakes (Cedar Island, Horseshoe) met their water quality standards for some of the year, but struggled early in the season with total phosphorus concentrations and Secchi disk visibility. Schneider Lake had the best overall water quality in 2022 of the lakes sampled in the chain.

The site-specific water quality standards for flowage, non-flowage, and natural lakes in the SRCL were calculated by the MPCA to describe the desired conditions of these unique waterbodies and to protect their designated beneficial uses for aquatic life and recreation.

The SRCL's largest challenges when it comes to meeting WQS in the chain are:

- Upstream river and tributary loading of total phosphorus and other usually limited nutrients entering the chain system. Upstream water quality improvement projects will be needed.

- Tributaries to the lake chain system have not been sampled since 2009, and data collected at that time shows very high levels of TP in Spring, in March in particular, from those tributaries. Additional comparative samples will be necessary to assess if lake tributaries are heavily effecting individual lake conditions, as well as the chain as a whole.

- Identifying if deeper lakes in the chain are undergoing internal nutrient loading due to lake bottom conditions. Lakes that are layered, with lower oxygen and temperature conditions at the bottom than the top of the lake, could be contributing further phosphorus and nitrogen to the system as bacteria at the lake bottom break down the settled organic matter and release those nutrients.

Continued monitoring in the Sauk River Chain of Lakes will help identify the next necessary steps to preserve and protect the invaluable resources found in our watershed. The SRWD appreciates the time and efforts of citizen scientists and volunteers with the Sauk River Chain of Lake, Inc. who support the ongoing monitoring and improvement projects in the area.

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Please Note:

The data and recommendations included in this report are based on the 2022 monitoring season. Lake samples were collected by a SRCL volunteer, and all data was reviewed by the Sauk River Watershed District. This report is not a complete picture of all conditions, but built to assess specific measurements of water quality.

Contact Allison Lightfoot, Environmental Monitoring Manager with the Sauk River Watershed District, with any questions or concerns regarding the information presented in this report.

All aerial photos taken from Google Earth in December 2021, and all water quality standard information and state statistics were gathered from Minnesota Pollution Control Agency (MPCA) documents accessed January 2023.