# 2023 Shadow Lake Water Quality Monitoring Results: Lay Monitoring Program and LaRosa Partnership Program

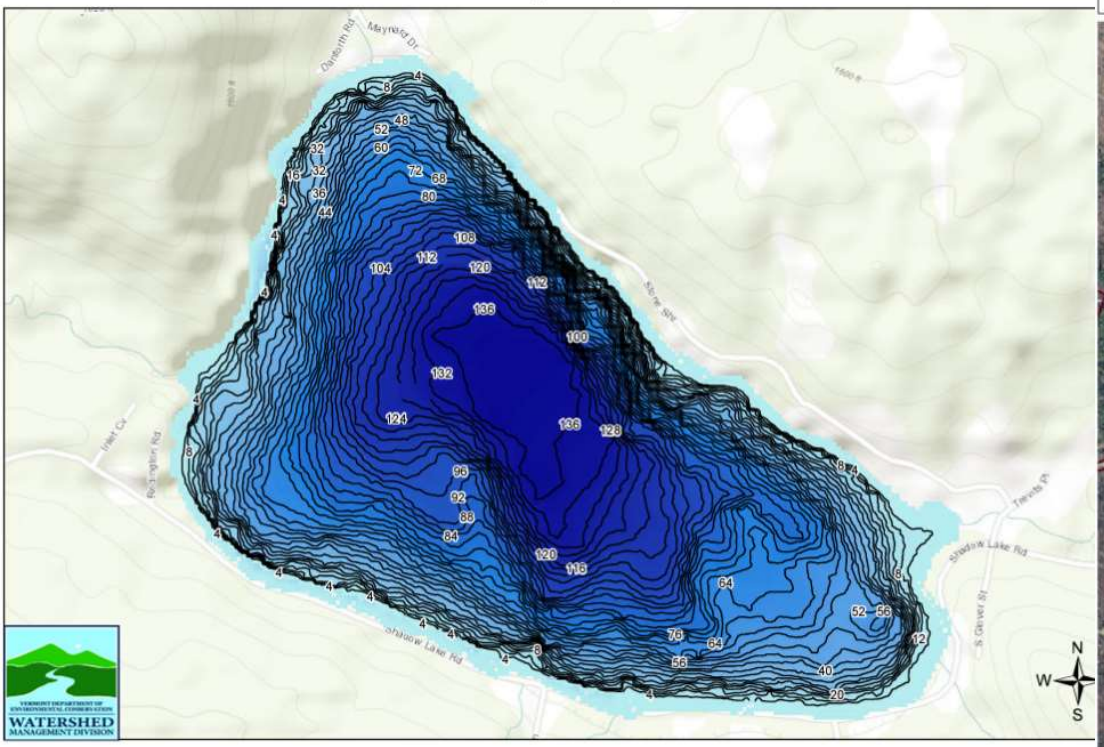
Mark Mitchell, Lake Monitoring and Community Outreach Coordinator
VT Department of Environmental Conservation, UVM Lake Champlain Sea Grant

# Lay Monitoring Program (LMP) Lake Sampling Overview

- Biweekly from June through August (total of 6 samples for summer mean):
  - *Basic Sampling:* Measure Secchi disk transparency depth (clarity)
  - *Supplemental Sampling:* Collect water samples with hose at twice Secchi depth that are lab tested for total phosphorus (nutrient) concentration and chlorophyll-a (algae) concentration
  - Pilot caffeine sampling (wastewater)
  - Complete a lake sampling webform (and report cyanobacteria conditions)

https://dec.vermont.gov/watershed/lakes-ponds/monitor/lay-monitoring

Shadow Lake, Barton VT
Depth Map




**Legend**

**Shadow Lake Depth (Feet)**

**Value**

High : -0.213579

Low : -139.284

Scale : 1:8,000
Map Created : 6/10/2019
Source Data Collected : 8/3/2018
Map Author : Tim Cassese

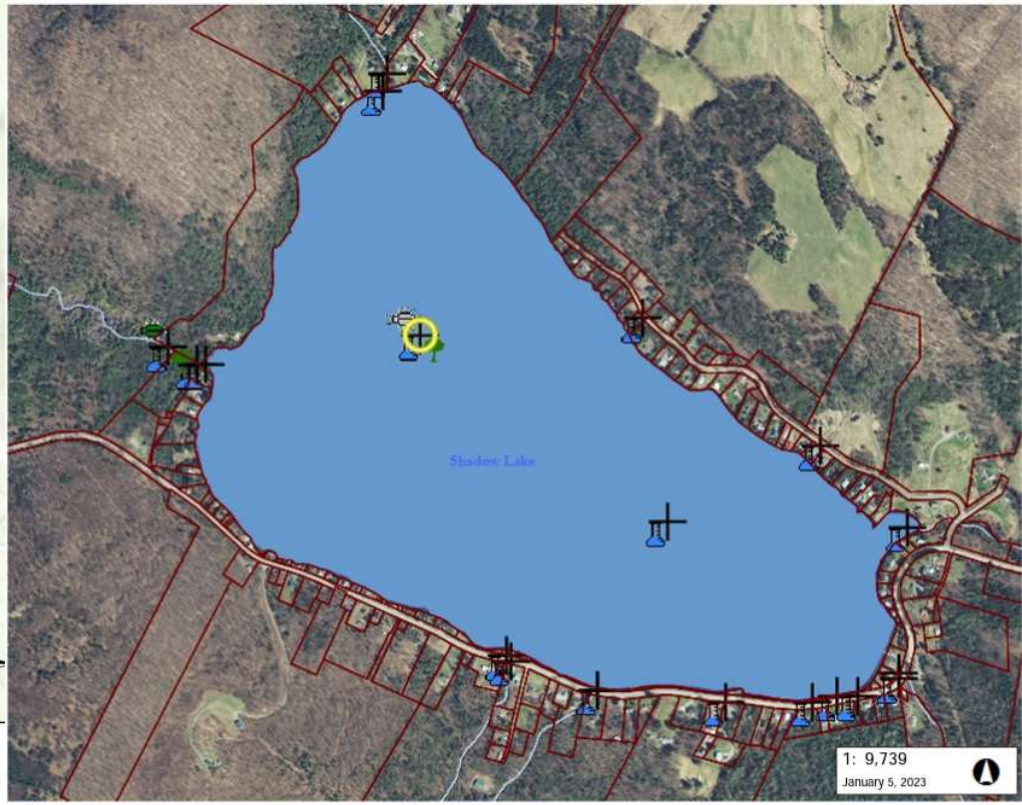
0 0.1 0.2 0.4

0 0.125 0.25 0.5 Kilometers

VERMONT

**Shadow Lake (Glover) Monitoring Station #1**
Vermont Agency of Natural Resources

vermont.gov




495.0 0 248.00 495.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere 1" = 812 Ft. 1cm = 97 Meters

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THIS MAP IS NOT TO BE USED FOR NAVIGATION

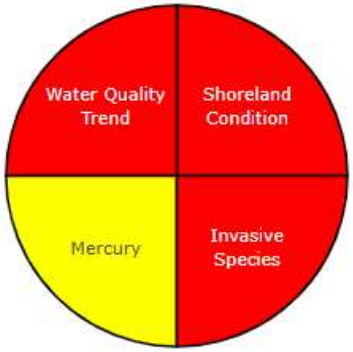
DISCLAIMER: This map is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. ANR and the State of Vermont make no representations of any kind, including but not limited to, the warranties of merchantability, or fitness for a particular use, nor are any such warranties to be implied with respect to the data on this map.

# Vermont Lake Score Card

## Shadow Lake

https://dec.vermont.gov/watershed/lakes-ponds/data-maps/scorecard

Scores | Water Quality Data | Lake Information



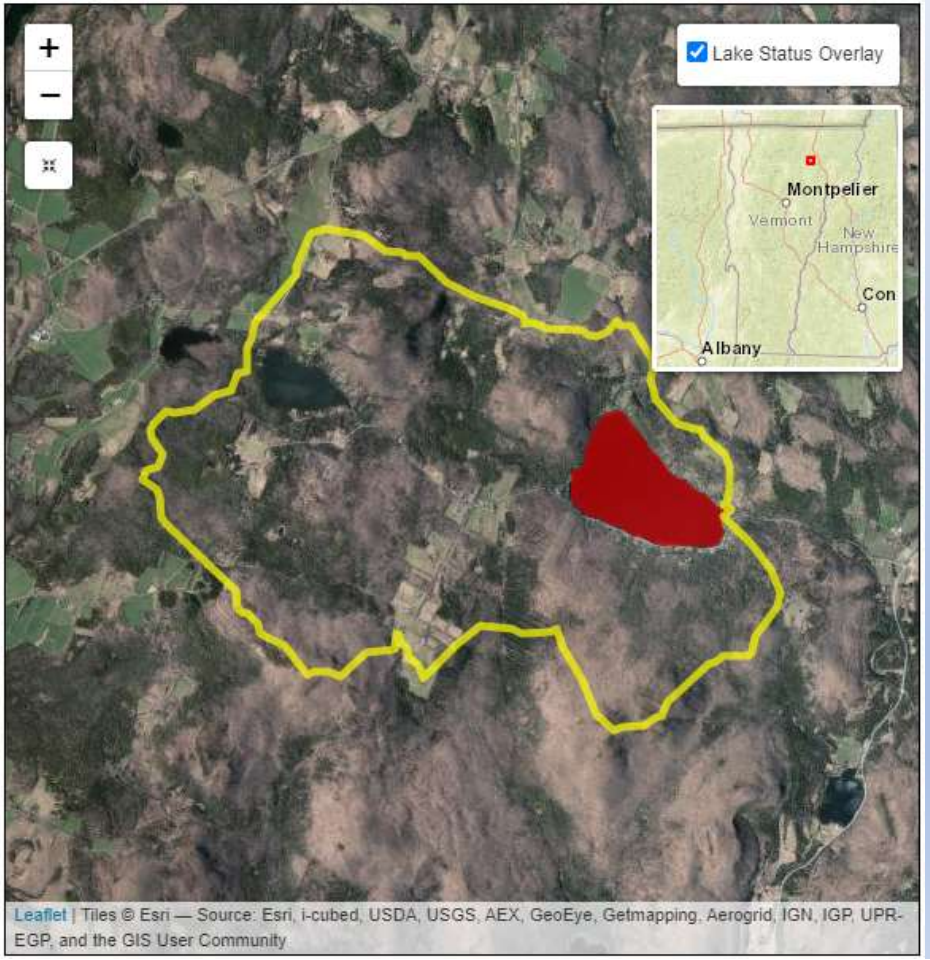

| | |
|---|---|
| Watershed: | Moderately Disturbed |
| WQ Standards: | Altered |

Details

Altered – Flow alteration

Color Scoring System
- Good Conditions
- Fair Conditions
- Poor Conditions
- Insufficient Data

Learn How Lakes Are Scored



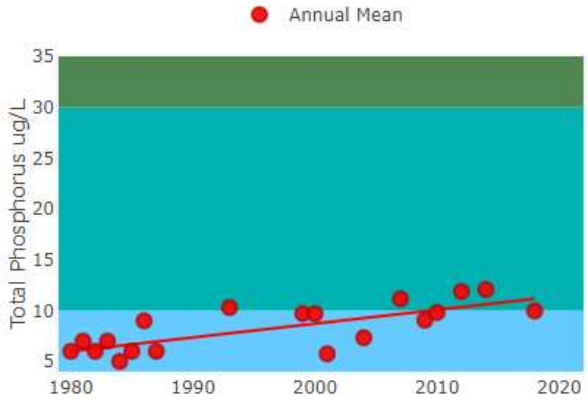
■ Hypereutrophic ■ Eutrophic ■ Mesotrophic ■ Oligotrophic

Click on “Daily Mean” or “Annual Mean” to toggle on or off the data layer.

# SHADOW LAKE (GLOVER) SCORE CARD WATER QUALITY ANNUAL MEANS

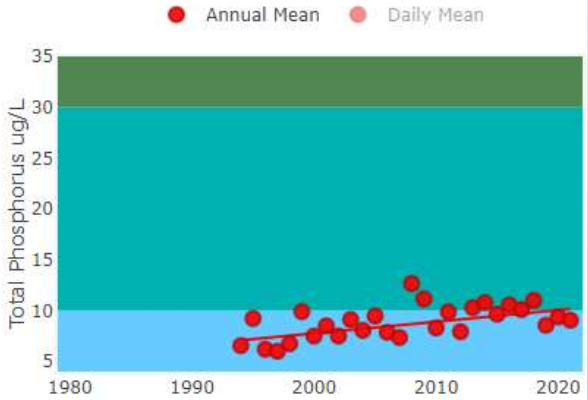
## Spring Phosphorus

Trend: Highly Significantly Increasing (p-value=0.0014)



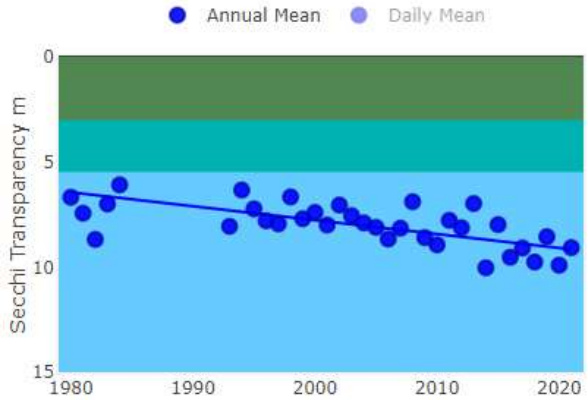

## Summer Phosphorus

Trend: Highly Significantly Increasing (p-value=0.0032)



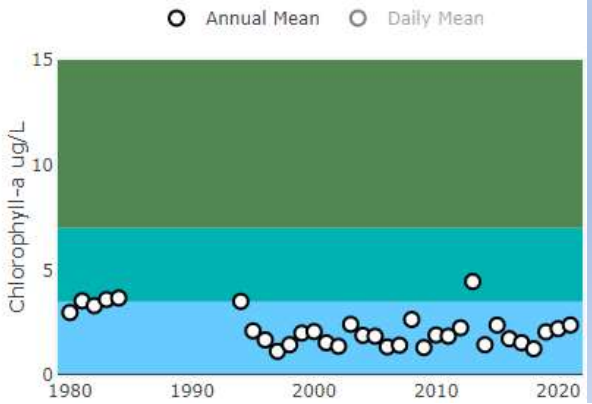

## Summer Secchi

Trend: Highly Significantly Increasing (p-value=0)




## Summer Chlorophyll-a

Trend: Stable (p-value=0.1289)



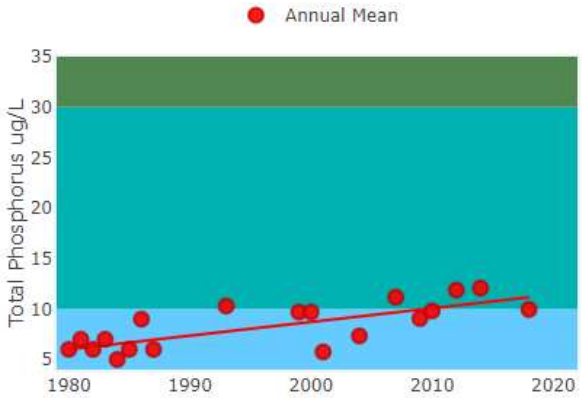
■ Hypereutrophic ■ Eutrophic ■ Mesotrophic ■ Oligotrophic

Click on “Daily Mean” or “Annual Mean” to toggle on or off the data layer.

# SHADOW LAKE (GLOVER) SCORE CARD WATER QUALITY ANNUAL RANGE

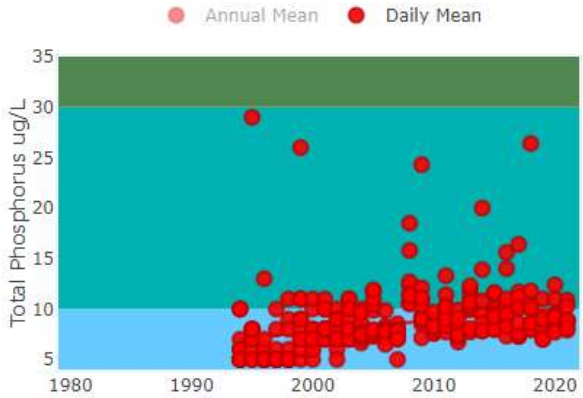
## Spring Phosphorus

Trend: Highly Significantly Increasing (p-value=0.0014)



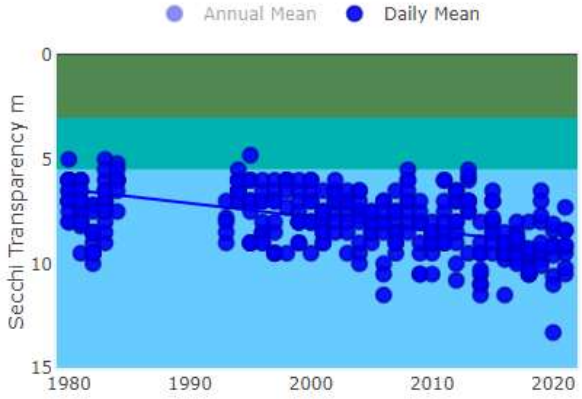

## Summer Phosphorus

Trend: Highly Significantly Increasing (p-value=0.0032)



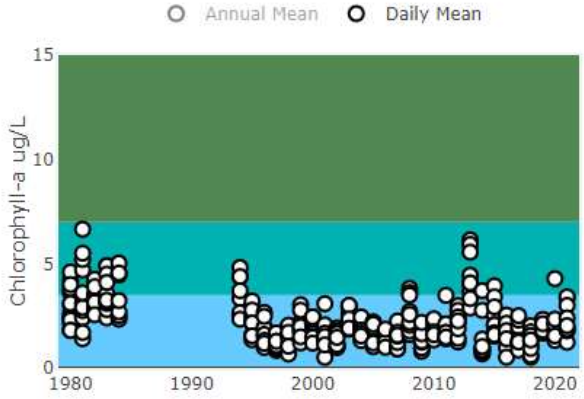

## Summer Secchi

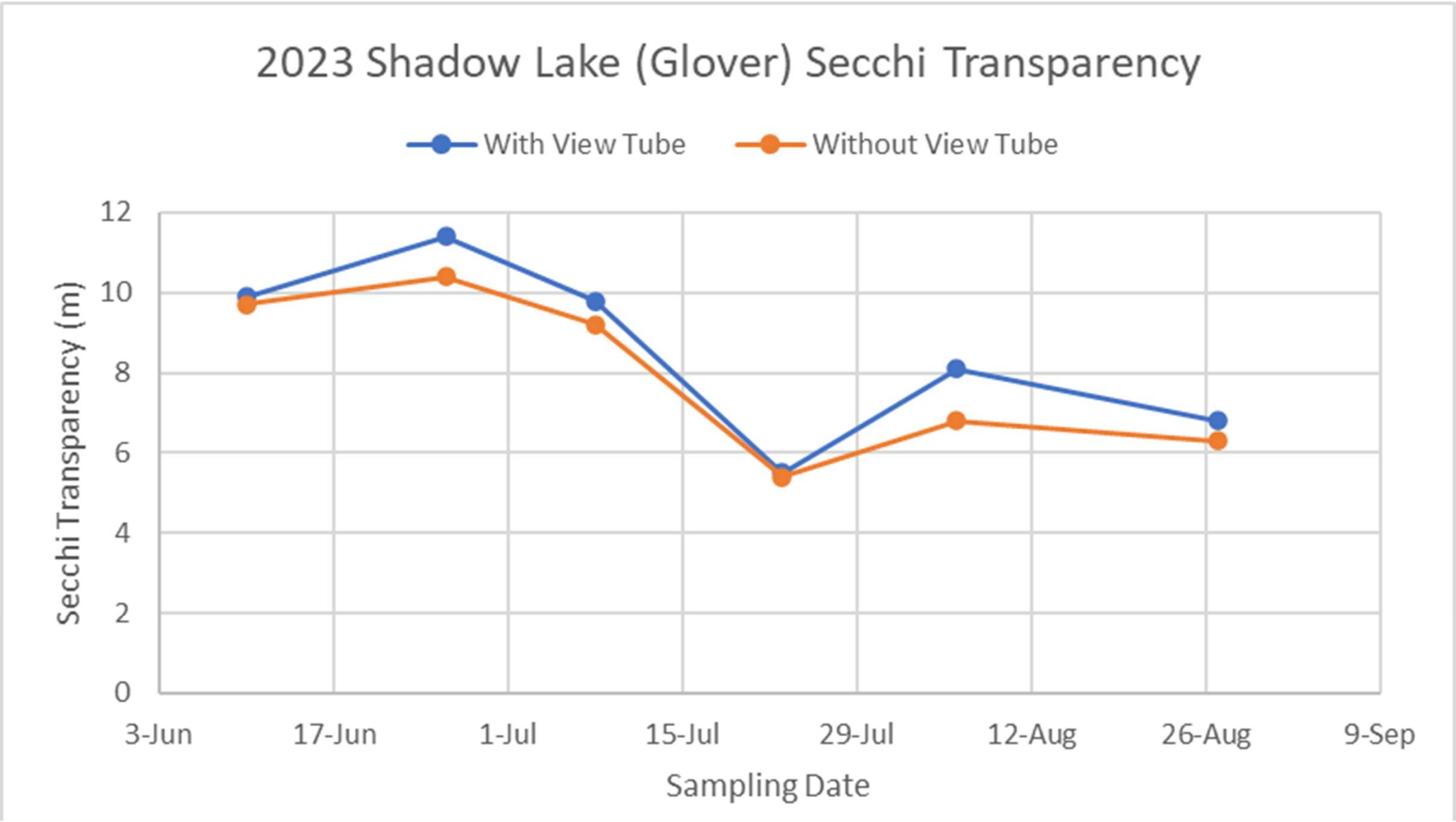
Trend: Highly Significantly Increasing (p-value=0)

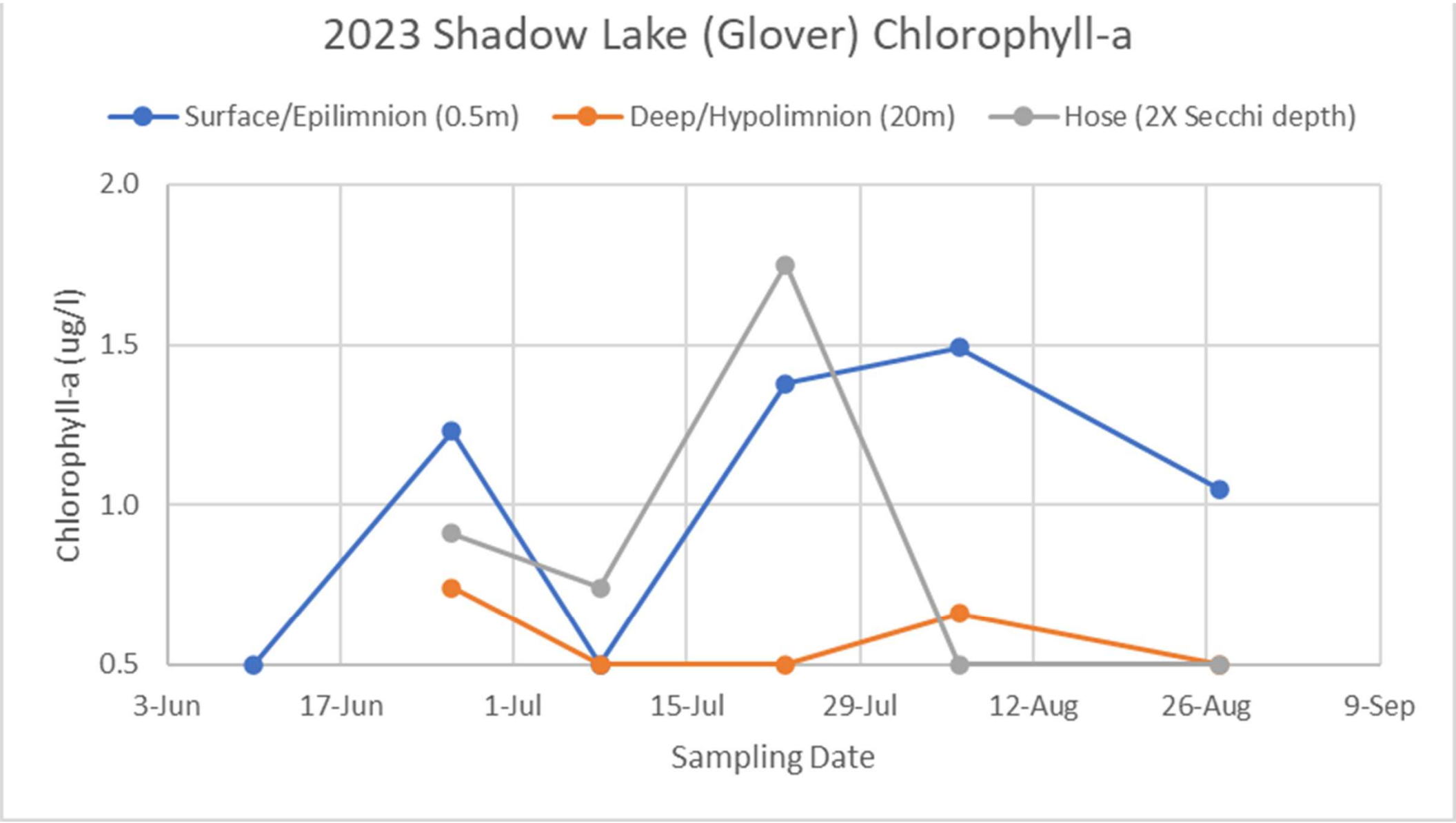


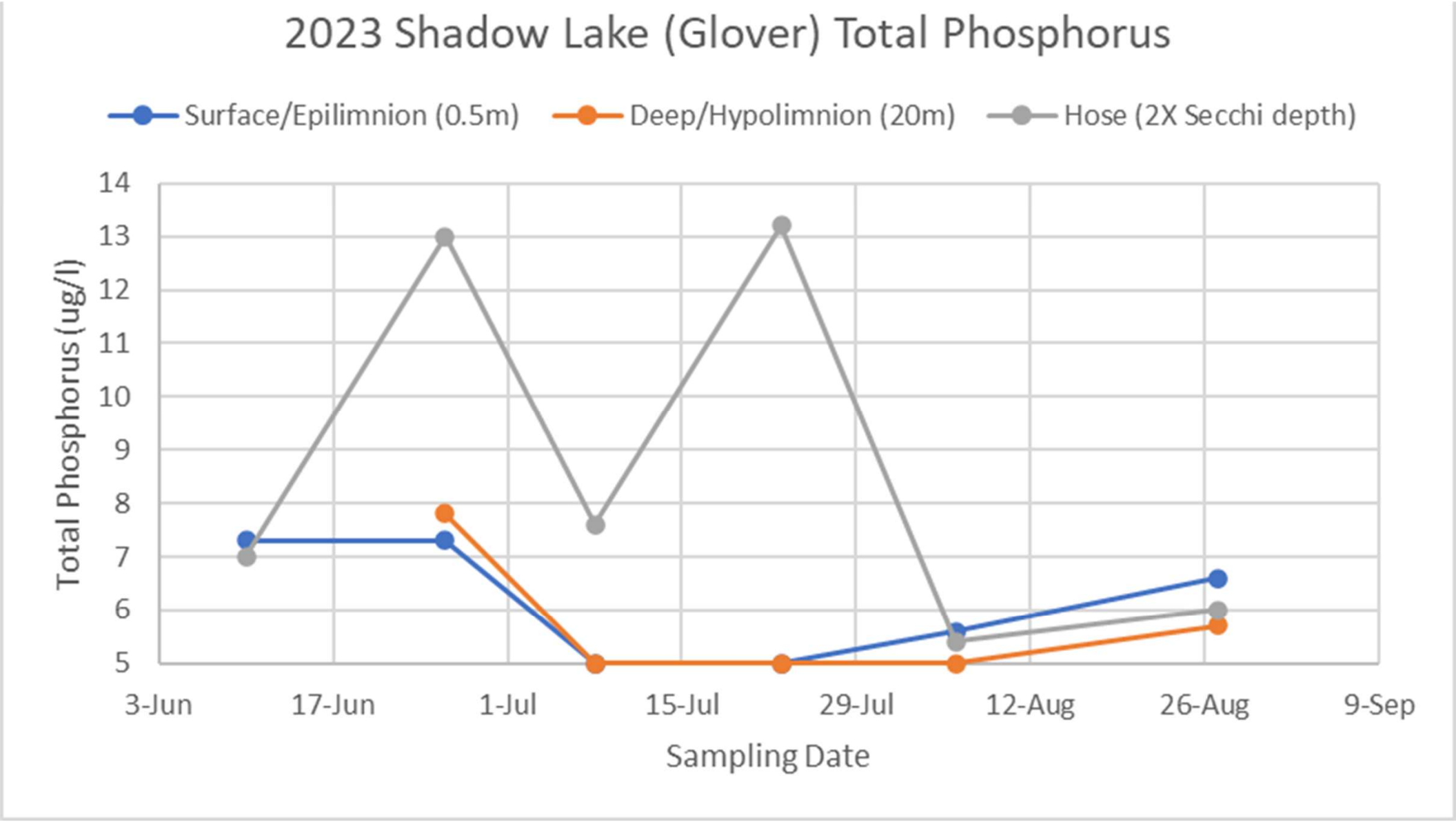

## Summer Chlorophyll-a

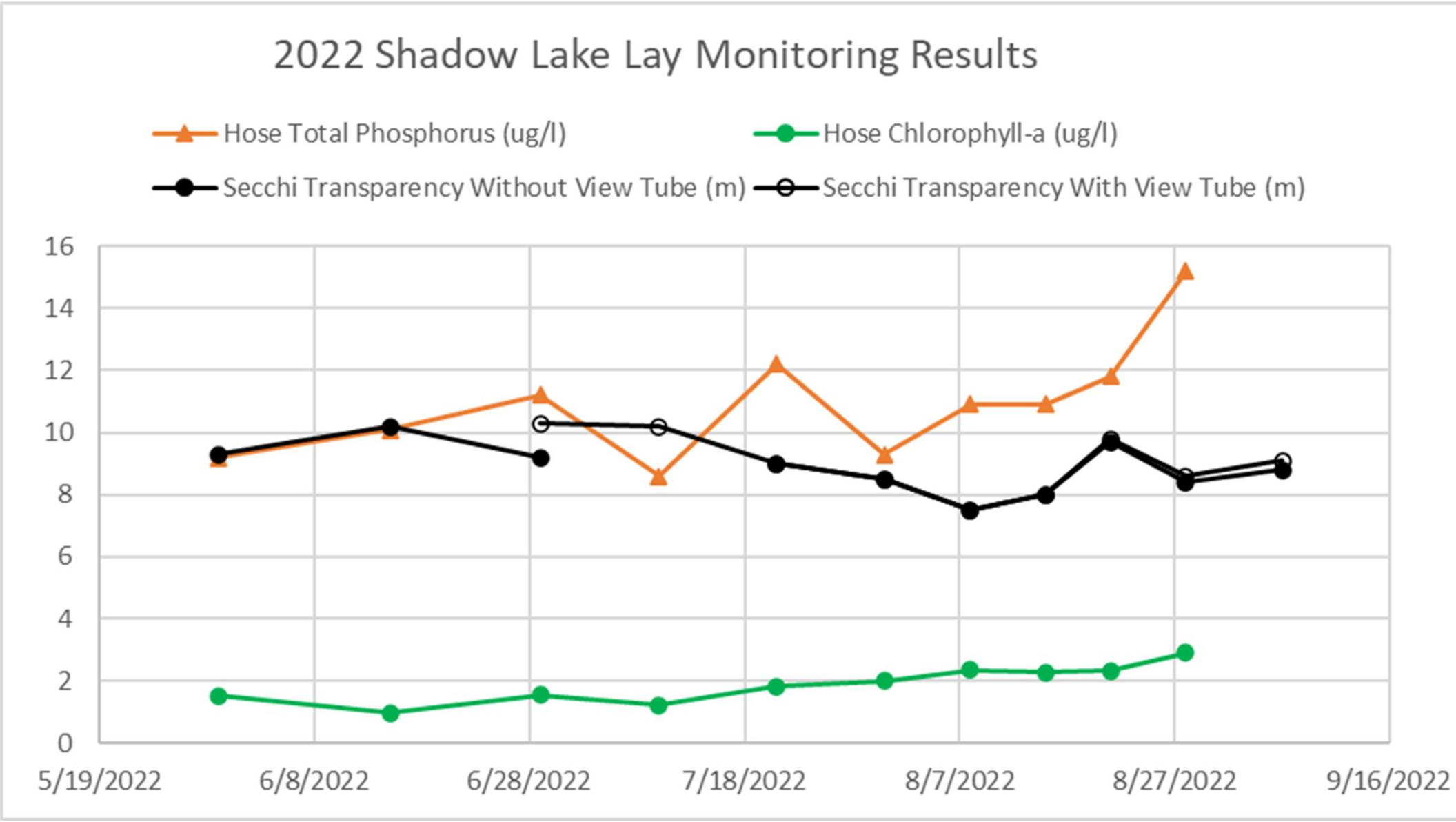
Trend: Stable (p-value=0.1289)

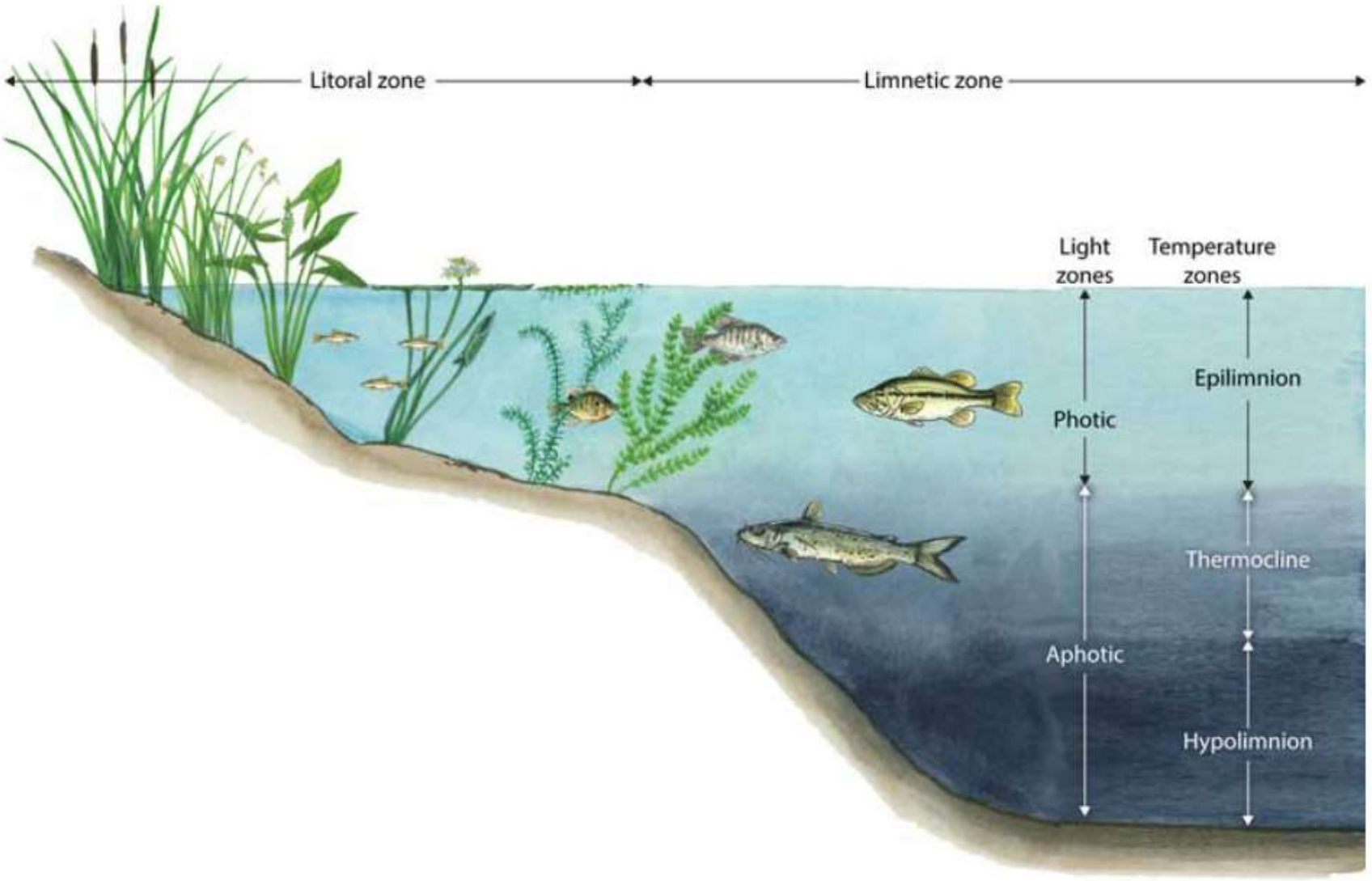



2023 Shadow Lake (Glover) Secchi Transparency
With View Tube
Without View Tube
Secchi Transparency (m)
12
10
8
6
4
2
0
3-Jun
17-Jun
1-Jul
15-Jul
29-Jul
12-Aug
26-Aug
9-Sep
Sampling Date


2023 Shadow Lake (Glover) Chlorophyll-a
Surface/Epilimnion (0.5m)
Deep/Hypolimnion (20m)
Hose (2X Secchi depth)
Chlorophyll-a (ug/l)
2.0
1.5
1.0
0.5
3-Jun
17-Jun
1-Jul
15-Jul
29-Jul
12-Aug
26-Aug
9-Sep
Sampling Date


2023 Shadow Lake (Glover) Total Phosphorus
Surface/Epilimnion (0.5m)
Deep/Hypolimnion (20m)
Hose (2X Secchi depth)
Total Phosphorus (ug/l)
14
13
12
11
10
9
8
7
6
5
3-Jun
17-Jun
1-Jul
15-Jul
29-Jul
12-Aug
26-Aug
9-Sep
Sampling Date


2022 Shadow Lake Lay Monitoring Results
Hose Total Phosphorus (ug/l)
Hose Chlorophyll-a (ug/l)
Secchi Transparency Without View Tube (m)
Secchi Transparency With View Tube (m)
16
14
12
10
8
6
4
2
0
5/19/2022
6/8/2022
6/28/2022
7/18/2022
8/7/2022
8/27/2022
9/16/2022

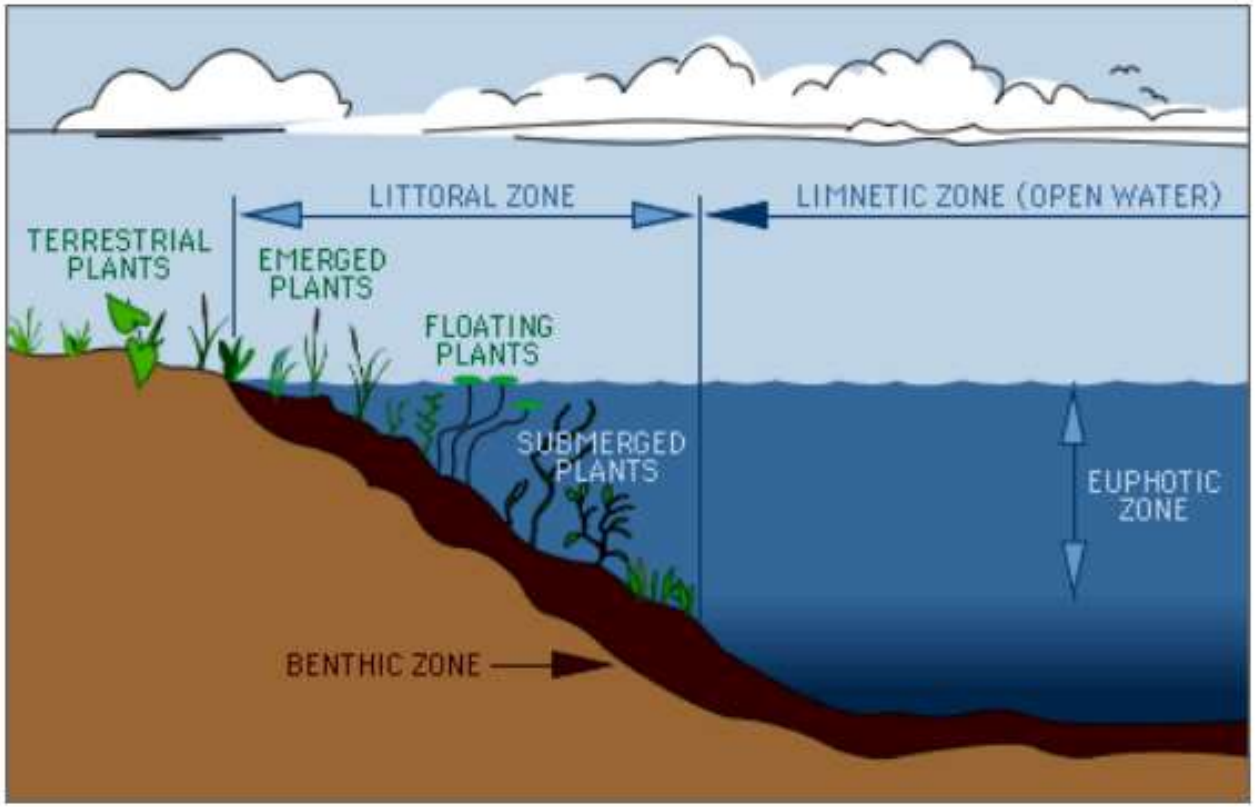



(Image courtesy of Kasco Marine)

https://kascomarine.com/blog/pond-lake-zone-identification/

## Lake Zones

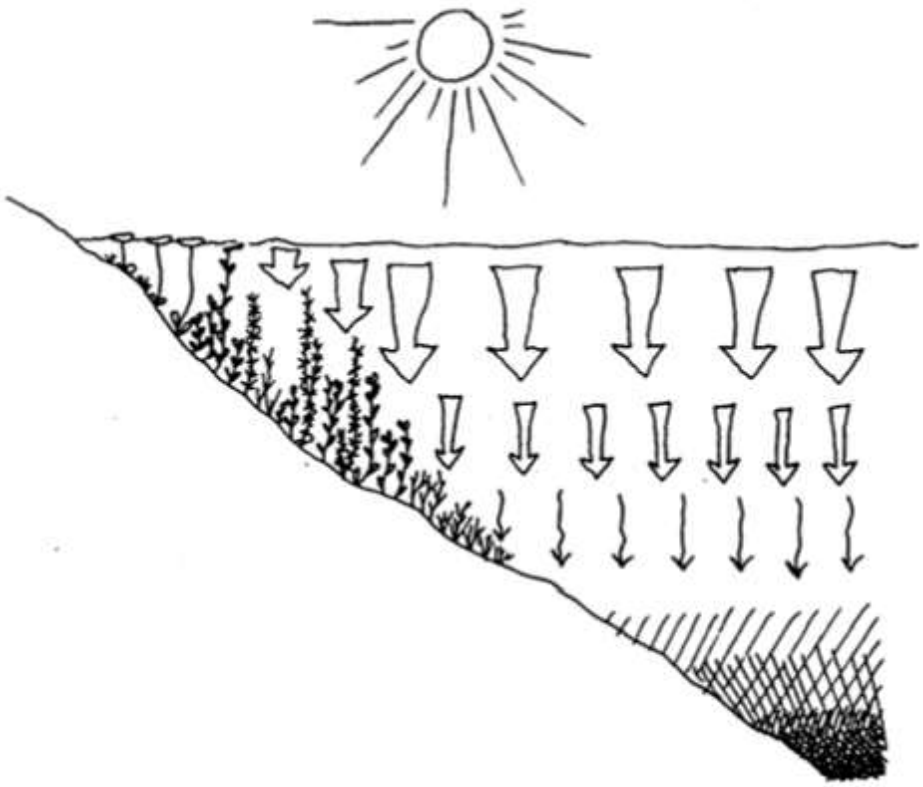
A typical lake has distinct zones of biological communities linked to the physical structure of the lake (Figure 10). The **littoral** zone is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (**macrophytes**) to grow. Light levels of about 1% or less of surface values usually define this depth. The 1% light level also defines the **euphotic zone** of the lake, which is the layer from the surface down to the depth where light levels become too low for **photosynthesizers**. In most lakes, the sunlit euphotic zone occurs within the **epilimnion**.




http://waterontheweb.org/under/lakeecology/10_biological_lakezones.html

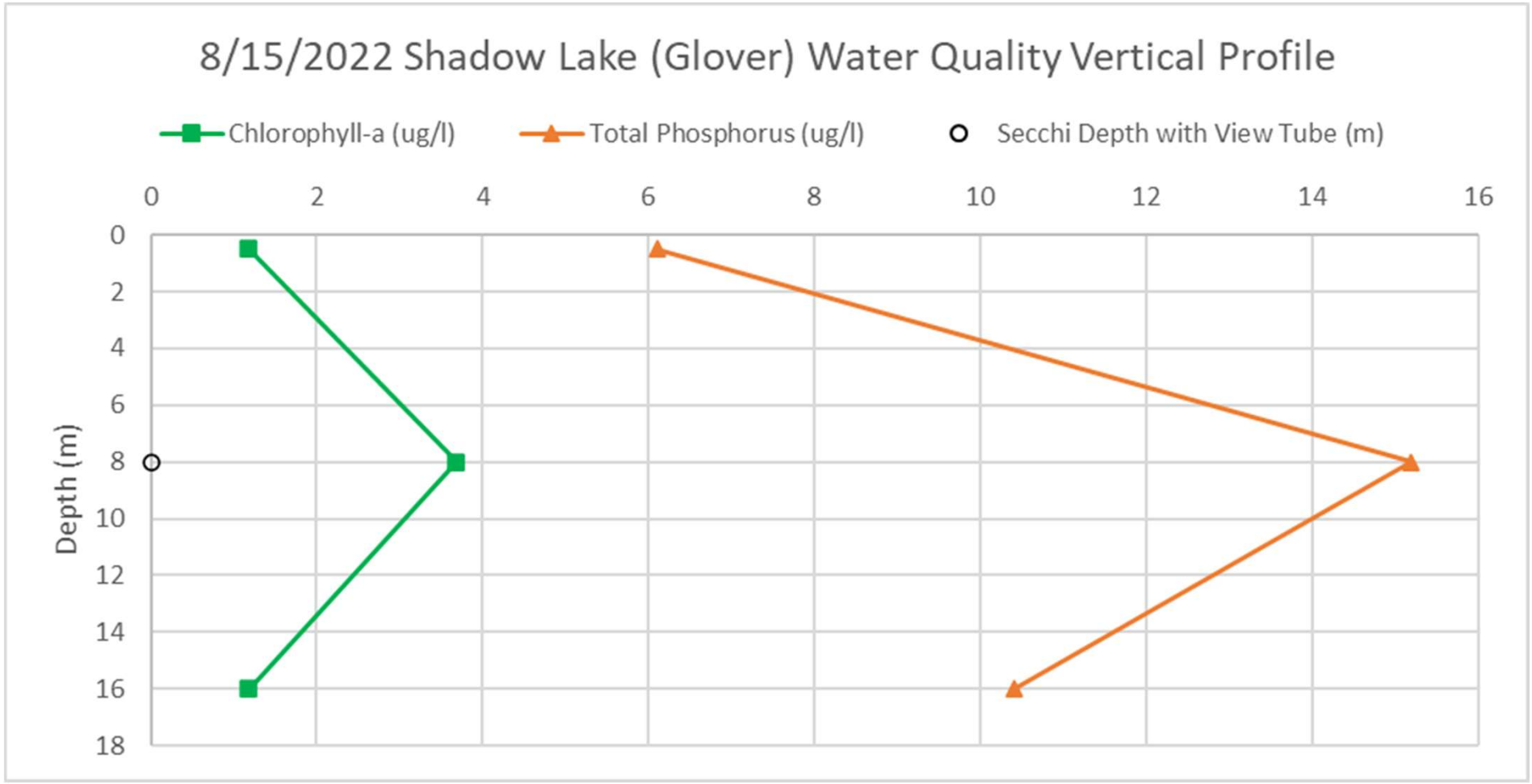
4. *Light*

Plants need light to grow. Many lakes have deep water areas where rooted plants can't get enough light to survive. The maximum depth at which plants grow in a lake depends on the water clarity. In Vermont lakes, plants can generally be found growing out to water depths of 25 feet.



https://dec.vermont.gov/sites/dec/files/wsm/lakes/ans/docs/Lake%20and%20Pond%20Plants%20Booklet.pdf

**From Lake Champlain Long-Term Monitoring Protocol**:
During stratified conditions, two samples will be obtained, representing the epilimnion and hypolimnion, respectively.
https://dec.vermont.gov/sites/dec/files/wsm/docs/20200605%20LTM%205yr%20QAPP-Workplan.pdf



| Sampling Date | Hose Sample Depth (m) | Hose Total Phosphorus (ug/l) | Hose Chlorophyll-a (ug/l) | Secchi Transparency Without View Tube (m) | Secchi Transparency With View Tube (m) |
|---|---|---|---|---|---|
| 5/30/2022 | 18.6 | 9.2 | 1.52 | 9.3 | |
| 6/15/2022 | 20.4 | 10.1 | 0.98 | 10.2 | |
| 6/29/2022 | 20.6 | 11.2 | 1.55 | 9.2 | 10.3 |
| 7/10/2022 | 20.4 | 8.6 | 1.22 | | 10.2 |
| 7/21/2022 | 18 | 12.2 | 1.81 | 9 | 9 |
| 7/31/2022 | 17 | 9.3 | 2 | 8.5 | 8.5 |
| 8/8/2022 | 15 | 10.9 | 2.34 | 7.5 | 7.5 |
| 8/15/2022 | 16 | 10.9 | 2.27 | 8 | 8 |
| 8/21/2022 | 20 | 11.8 | 2.32 | 9.7 | 9.8 |
| 8/28/2022 | 17 | 15.2 | 2.88 | 8.4 | 8.6 |
| 9/6/2022 | | | | 8.8 | 9.1 |
| **Mean** | **18.3** | **10.9** | **1.89** | **9.3** | **9** |
| **A1 Critieria** | **Euphotic Zone** | **12** | **2.6** | **5** | **5** |

# SHADOW LAKE

## **Annual Data** (Station 1)

| Year | Days Sampled | Secchi (m) | Secchi View Tube (m) | Chloro-a (µg/l) | Summer TP (µg/l) | Spring TP (µg/l) |
|---|---|---|---|---|---|---|
| 1979 | 17 | 7.3 | | 4.5 | | 4.0 |
| 1980 | 14 | 6.7 | | 3.0 | | 6.0 |
| 1981 | 13 | 7.4 | | 3.5 | | 7.0 |
| 1982 | 13 | 8.7 | | 3.3 | | 6.0 |
| 1983 | 13 | 7.0 | | 3.6 | | 7.0 |
| 1984 | 9 | 6.1 | | 3.7 | | 5.0 |
| 1985 | | | | | | 6.0 |
| 1986 | | | | | | 9.0 |
| 1987 | | | | | | 6.0 |
| 1993 | 5 | | | | | 10.3 |
| 1994 | 9 | 6.3 | | 3.5 | 6.3 | |
| 1995 | 10 | 7.2 | | 2.1 | 9.0 | |
| 1996 | 10 | 7.8 | | 1.7 | 6.1 | |
| 1997 | 9 | 7.9 | | 1.1 | 6.0 | |
| 1998 | 8 | 6.7 | | 1.4 | 6.6 | |
| 1999 | 10 | 7.7 | | 2.0 | 9.9 | 9.7 |
| 2000 | 10 | 7.4 | | 2.1 | 7.5 | 9.7 |
| *VT Standard** | | *2.6* | | *7.0* | *18.0* | |

** VT Water Quality Standards Nutrient Criteria for Class B2 Lakes > 20 acres.*

## **Annual Data** (Station 1)

| Year | Days Sampled | Secchi (m) | Secchi View Tube (m) | Chloro-a (µg/l) | Summer TP (µg/l) | Spring TP (µg/l) |
|---|---|---|---|---|---|---|
| 2001 | 10 | 8.0 | | 1.5 | 8.5 | 5.7 |
| 2002 | 10 | 7.1 | | 1.4 | 7.5 | |
| 2003 | 9 | 7.6 | | 2.4 | 9.1 | |
| 2004 | 10 | 7.9 | | 1.9 | 8.1 | 7.3 |
| 2005 | 9 | 8.1 | | 1.9 | 9.5 | |
| 2006 | 9 | 8.7 | | 1.3 | 7.9 | |
| 2007 | 10 | 8.2 | | 1.4 | 7.4 | 11.2 |
| 2008 | 9 | 6.9 | | 2.6 | 12.7 | |
| 2009 | 10 | 8.6 | | 1.3 | 11.2 | 9.1 |
| 2010 | 9 | 8.9 | | 1.9 | 8.3 | 10.1 |
| 2011 | 10 | 7.8 | | 1.9 | 9.9 | |
| 2012 | 10 | 8.1 | | 2.3 | 7.9 | 11.9 |
| 2013 | 9 | 7.0 | | 4.5 | 10.3 | |
| 2014 | 9 | 10.0 | | 1.4 | 10.8 | 12.1 |
| 2015 | 10 | 8.0 | | 2.4 | 9.6 | |
| 2016 | 9 | 9.5 | | 1.7 | 10.6 | |
| 2017 | 10 | 9.1 | | 1.5 | 10.1 | |
| 2018 | 10 | 9.8 | | 1.3 | 11.0 | 9.5 |
| 2019 | 9 | 8.6 | | 2.1 | 8.6 | |
| 2020 | 8 | 9.9 | | 2.2 | 9.4 | |
| 2021 | 8 | 9.1 | | 2.4 | 9.1 | |
| *VT Standard** | | *2.6* | | *7.0* | *18.0* | |

** VT Water Quality Standards Nutrient Criteria for Class B2 Lakes > 20 acres.*

# LaRosa Partnership Program Tributary Sampling Overview

- Tributaries first sampled in 2021 ~biweekly (8X) from April/May to August + ~2 storm events
- Baseline total phosphorus and total nitrogen concentrations
- 522768-Trib 1 Town
- Beach522761-Town Beach Culvert
- 522769-Trib 2 Cermak
- 522766-Trib 3 Dudley
- 522770-Trib 4 Inlet
- 522767-Trib 5 Lussier

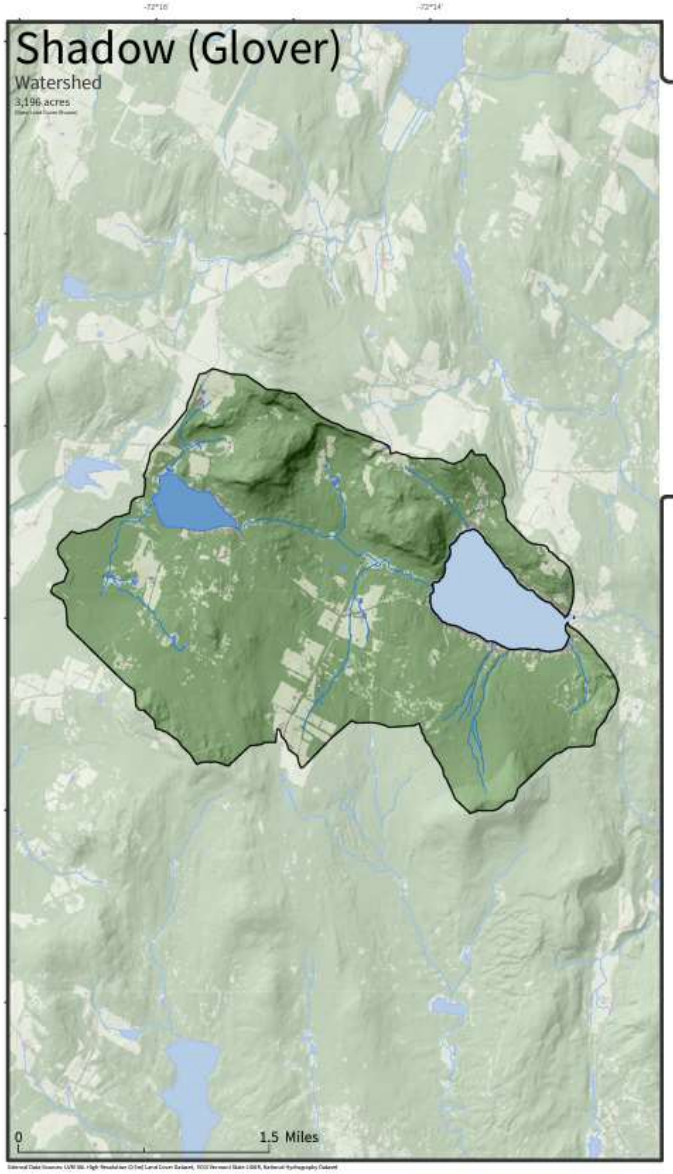
# LPP Sample Parameters Overview

## Total Phosphorus

- *Impacts*
  - Feeds plants, algae and cyanobacteria
  - Aquatic Biota, Aesthetics, Recreation Uses
- *Human Sources*
  - Runoff from roads, lawns, agriculture, logging
  - Malfunctioning septic systems
- *Vermont Water Quality Standards Nutrient Criteria for Aquatic Biota Use (+ Biological Criteria)*
  - Not to be exceeded at low median monthly flow (baseflow) during June through October
  - 12 ug/L for small high gradient streams (SHG)
  - 15 ug/L for medium high gradient streams (MHG)
  - 27 ug/L for warm-water medium gradient streams and rivers (WWMG)

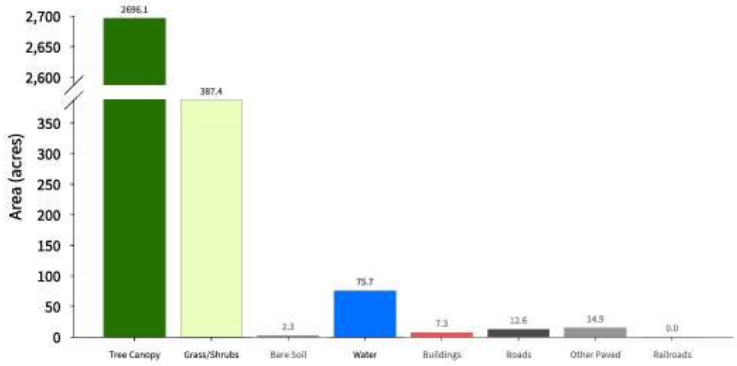
## Total Nitrogen

- *Impacts*
  - Feeds plants, algae and cyanobacteria
  - Aquatic Biota, Aesthetics, Recreation Uses
- *Human Sources*
  - Runoff from roads, lawns, agriculture, logging
  - Malfunctioning septic systems
- *Vermont Water Quality Standards*
  - Not to exceed 5.0 mg/l as NO3-N at flows exceeding low median monthly flows, in Class B(1) and B(2) waters.
  - Not to exceed 2.0 mg/l as NO3-N at flows exceeding low median monthly flows, in Class A(1) and A(2) waters at or below 2,500 feet elev.



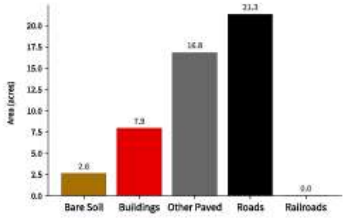

# High-Resolution Land Cover Summary

## Base Land Cover (Top-Down*)

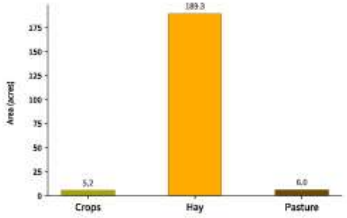



## Supplemental Land Cover

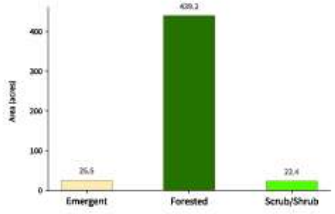
### Impervious Surfaces (48.64 acres - 1.5 % of total)
(Bottom-Up**)



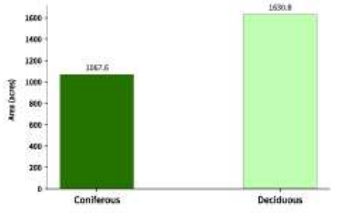

### Agriculture (200.6 acres - 6.3 % of total)

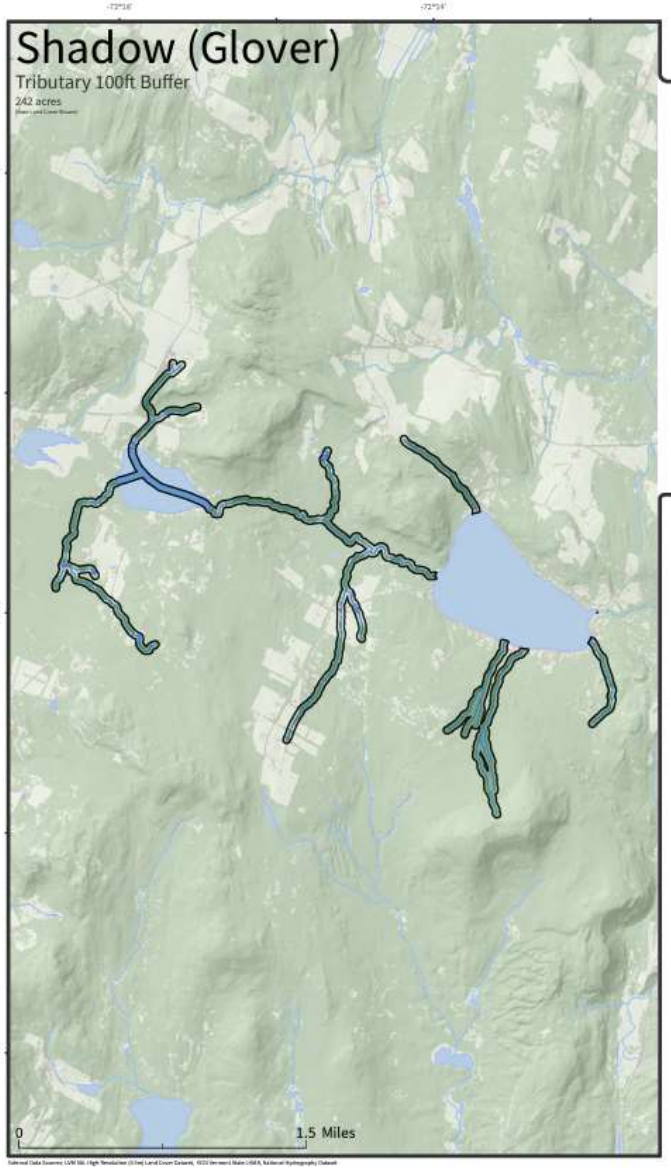



### Wetlands (487.09 acres - 15.2 % of total)



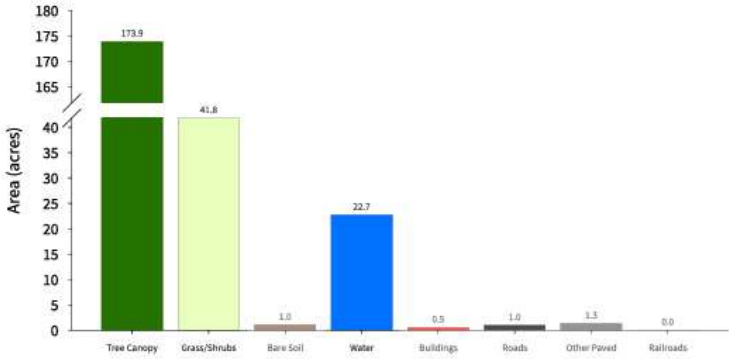

### Tree Canopy (2,698.34 acres - 84.4 % of total)





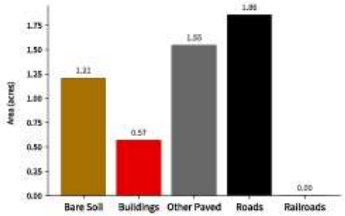

# High-Resolution Land Cover Summary

## Base Land Cover (Top-Down*)

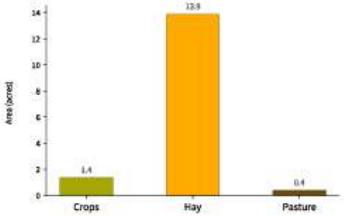



## Supplemental Land Cover

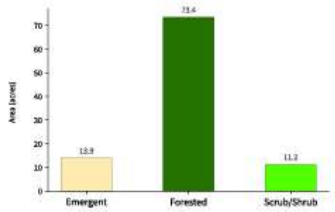
### Impervious Surfaces (5.18 acres - 2.1 % of total)
(Bottom-Up**)



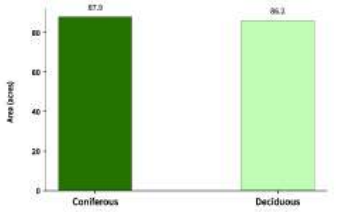

### Agriculture (15.62 acres - 6.5 % of total)



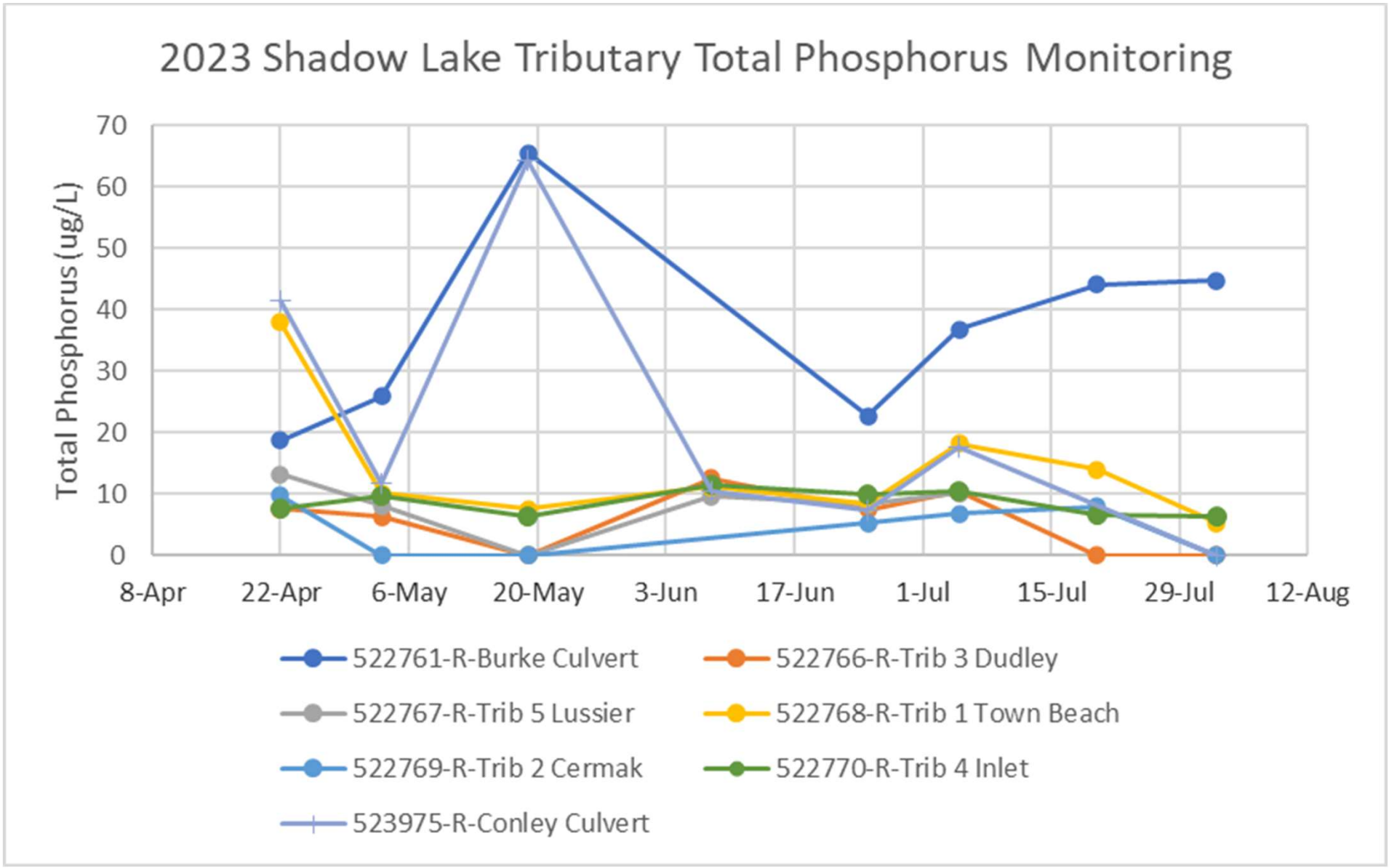

### Wetlands (98.52 acres - 40.7 % of total)

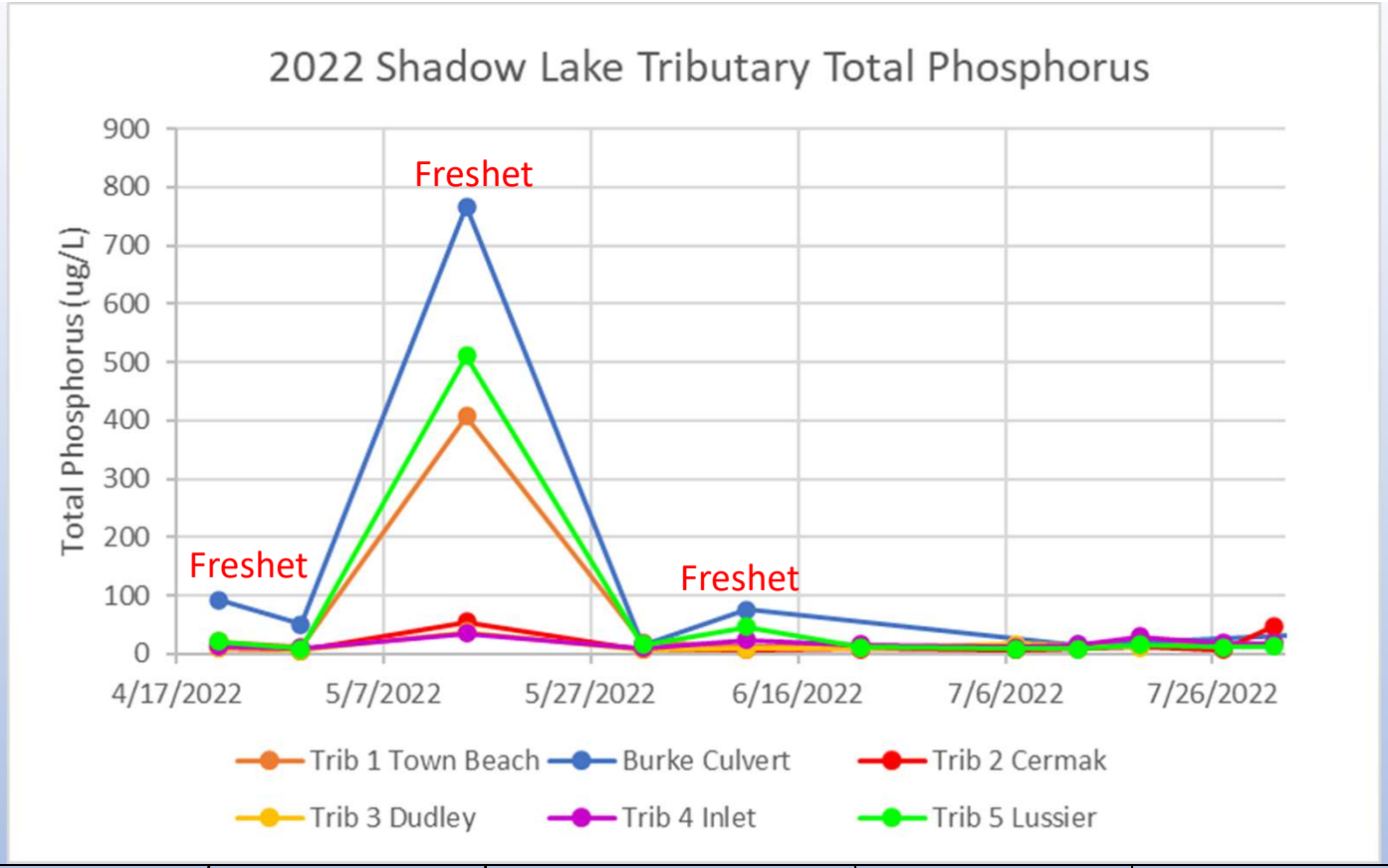



### Tree Canopy (174.13 acres - 72 % of total)

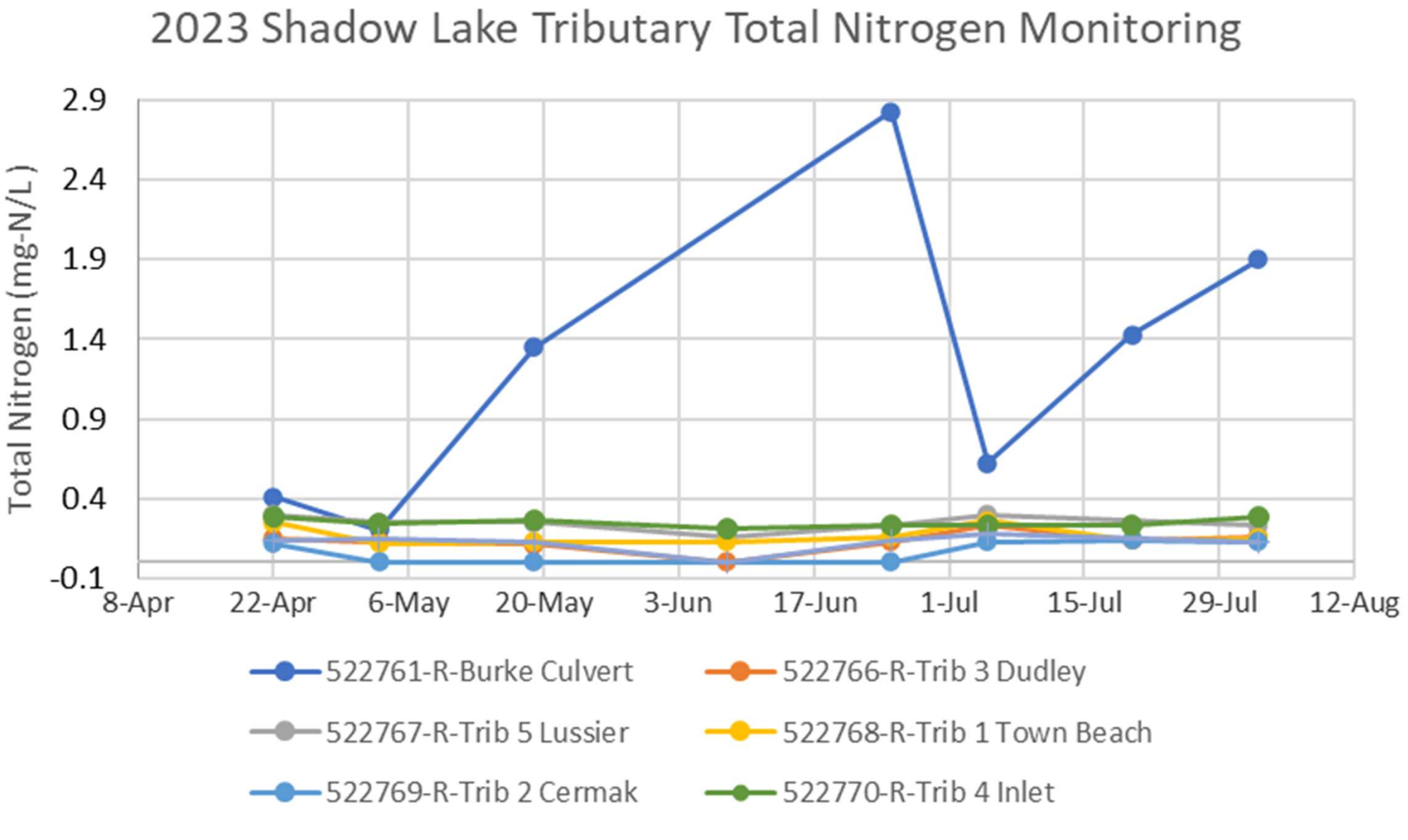


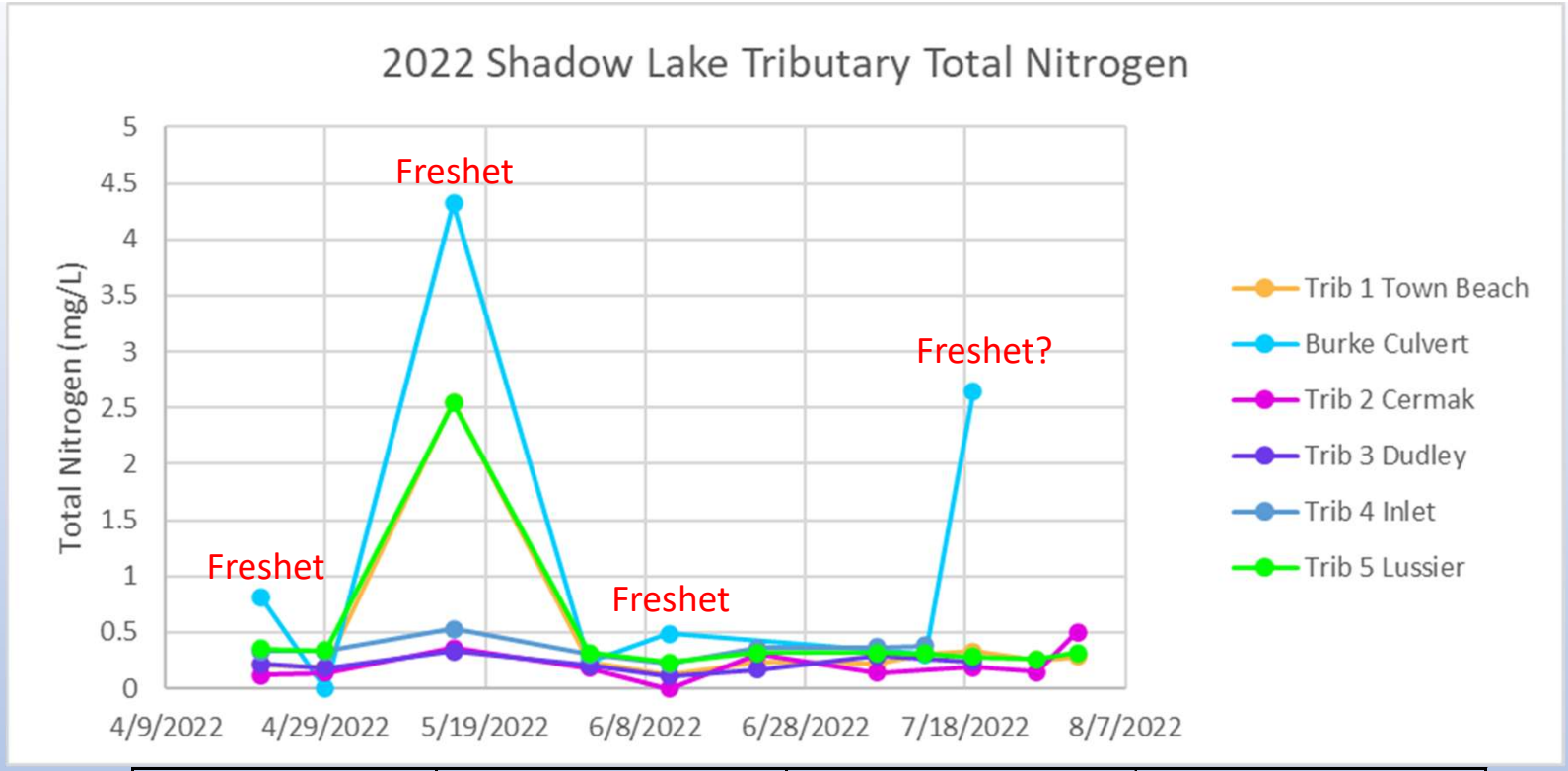

*Top-Down: A traditional land cover mapping approach - land cover is mapped as the uppermost land cover class.
**Bottom-Up: A new land cover mapping approach - land cover is mapped as the lowermost land cover class. This approach results in more land cover mapping detail as some impervious features are mapped but obscured by other features. See UVM GIC High-Resolution Land Cover 2016 Report for more detail.


2023 Shadow Lake Tributary Total Phosphorus Monitoring
Total Phosphorus (ug/L)
70
60
50
40
30
20
10
0
8-Apr
22-Apr
6-May
20-May
3-Jun
17-Jun
1-Jul
15-Jul
29-Jul
12-Aug
522761-R-Burke Culvert
522766-R-Trib 3 Dudley
522767-R-Trib 5 Lussier
522768-R-Trib 1 Town Beach
522769-R-Trib 2 Cermak
522770-R-Trib 4 Inlet
523975-R-Conley Culvert



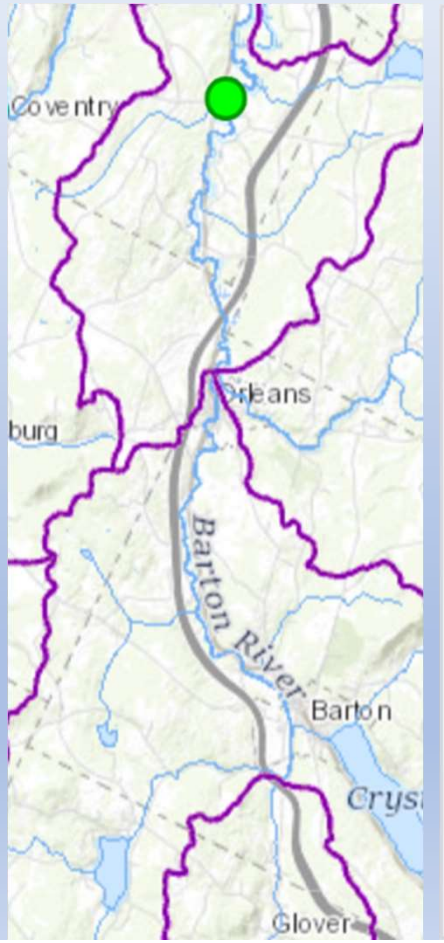

| Tributary | Minimum TP (ug/l) | | Base/Low Flow Avg. TP (ug/l) | | Average TP (ug/l) | | Maximum TP (ug/l) | |
|---|---|---|---|---|---|---|---|---|
| | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 |
| Trib 1 Town Beach | 7.6 | 7.6 | 13.4 | 11.4 | 50 | 23.4 | 407 | 78.4 |
| Burke Culvert | 15 | 15.2 | 41.7 | 45.4 | 138.7 | 54.7 | 767 | 111 |
| Trib 2 Cermak | 5.6 | 5.7 | 12.8 | 12.7 | 16.7 | 12.2 | 55.2 | 36.5 |
| Trib 3 Dudley | 6.2 | 5.4 | 9.9 | 6.7 | 13.3 | 6.9 | 37.2 | 9.2 |
| Trib 4 Inlet | 9.3 | 8.7 | 16.8 | 12.3 | 18.04 | 12.9 | 34.6 | 17.7 |
| Trib 5 Lussier | 8.2 | 7.2 | 15.2 | 8.5 | 60.71 | 8.7 | 510 | 10 |

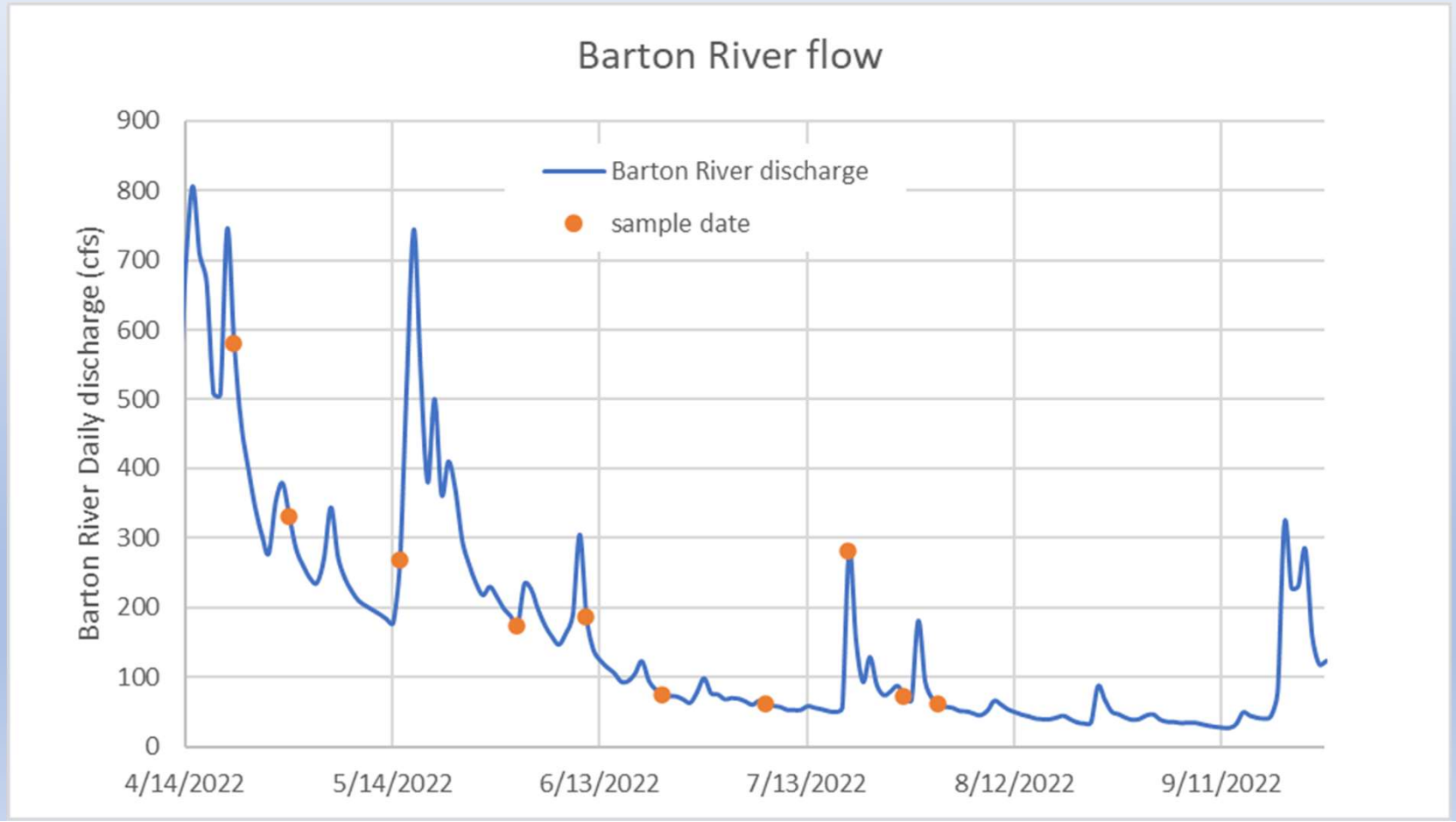

2023 Shadow Lake Tributary Total Nitrogen Monitoring
Total Nitrogen (mg-N/L)
2.9
2.4
1.9
1.4
0.9
0.4
-0.1
8-Apr
22-Apr
6-May
20-May
3-Jun
17-Jun
1-Jul
15-Jul
29-Jul
12-Aug
522761-R-Burke Culvert
522766-R-Trib 3 Dudley
522767-R-Trib 5 Lussier
522768-R-Trib 1 Town Beach
522769-R-Trib 2 Cermak
522770-R-Trib 4 Inlet




| Tributary | Minimum TN (mg/L) | | Average TN (mg/L) | | Maximum TN (mg/L) | |
|---|---|---|---|---|---|---|
| | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 |
| Trib 1 Town Beach | 0.12 | 0.14 | 0.45 | 0.32 | 2.55 | 0.67 |
| Burke Culvert | 0.24 | 0.4 | 1.5 | 1.9 | 4.32 | 5.85 |
| Trib 2 Cermak | 0.12 | 0.1 | 0.23 | 0.17 | 0.5 | 0.27 |
| Trib 3 Dudley | 0.11 | 0.13 | 0.22 | 0.17 | 0.33 | 0.27 |
| Trib 4 Inlet | 0.22 | 0.29 | 0.36 | 0.32 | 0.53 | 0.37 |
| Trib 5 Lussier | 0.23 | 0.21 | 0.51 | 0.27 | 2.54 | 0.36 |

# USGS Streamflow – Barton River, Coventry



# 2023 Monitoring Summary & 2024 Next Steps

https://lamotte.com/horizontal-water-sampler-1087

- Lay Monitoring Program (LMP)
  - 2023 Summary: Very high Secchi depths decreased by ~5 m after July 10th floods but recovered in early August. Chlorophyll-a was very low and then increased slightly after July 10th floods similarly with all three sampling methods (eplimnetic, hypolimnetic, and depth-integrated hose). Total phosphorus was very low with all three sampling methods except for the hose in late June and after July 10th floods, possibly due to sediment trapped in the metalimnion. All summer means qualify for A1 reclassification. All caffeine results were below the lab reporting limit (0.5 ug/L).
  - 2024 Next Steps: LMP volunteer continues collecting biweekly epilimnetic (0.5 m) and hypolimnetic (20 m) samples, while replacing hose sampling with metalimnetic (10 m) sampling. Caffeine testing will also continue at a lower lab reporting limit (≤0.1 ug/L). LMP staff collects vertical profile data during annual visit.
- LaRosa Partnership Program (LPP)
  - 2023 Summary: Highest TP in Burke Culvert (also high TN), Conley Culvert, and Trib 1 Town Beach.
  - 2024 Next Steps: LPP volunteer continues collecting biweekly samples at all sites, except now on the LMP schedule of June through August. Focus on road erosion in culverts.