
# What's Going On at Lake Carmi?

# Update on Vermont's Lake in Crisis

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Vermont Department of Environmental Conservation

Thursday April 13, 2023

# Presentation Overview

I. Lake Carmi Context
II. TMDL & Crisis Response Plan
III. Funding & Partners
IV. Watershed Interventions (external loading)
V. Aeration System (internal loading)
VI. Water Quality Monitoring Results
VII. Alum Treatment Feasibility Study
VIII. Conclusions & Next Steps

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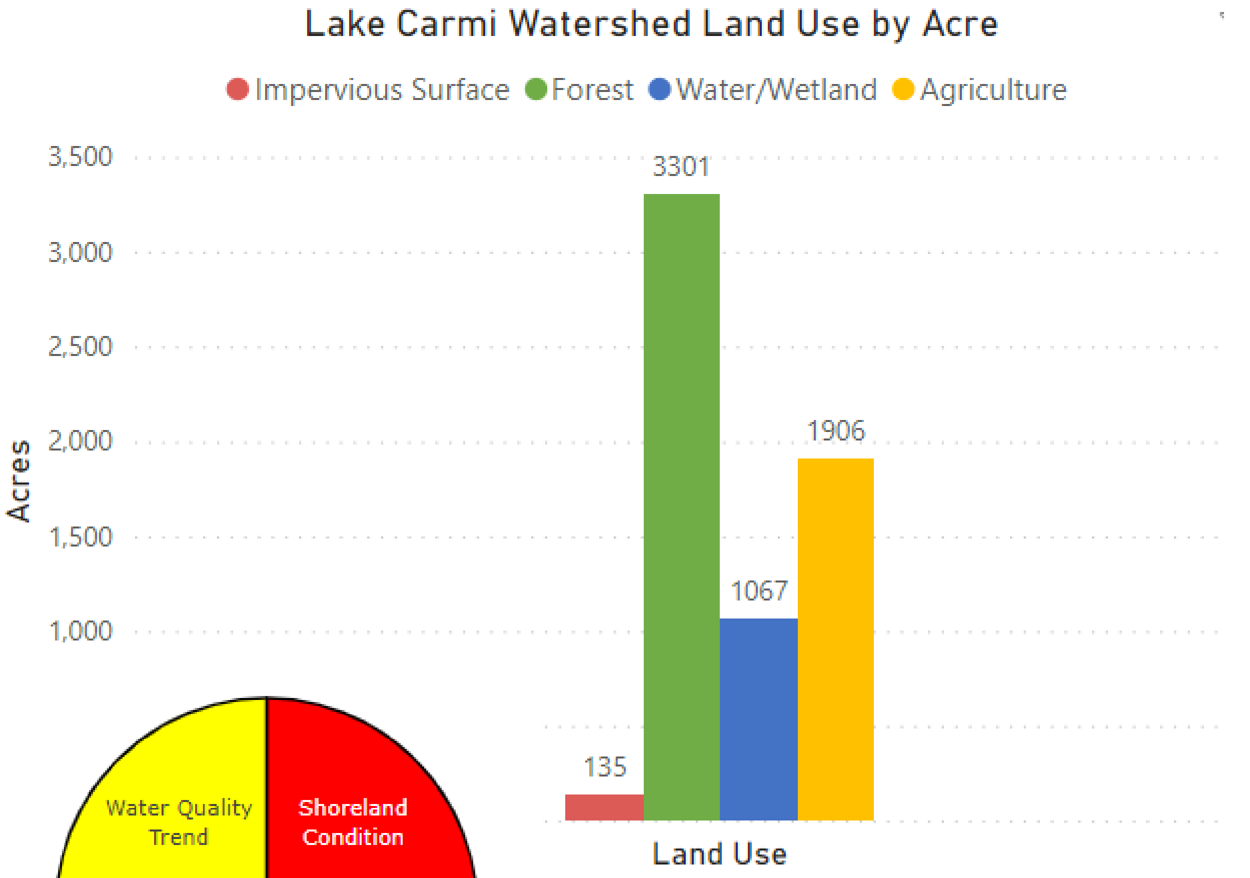
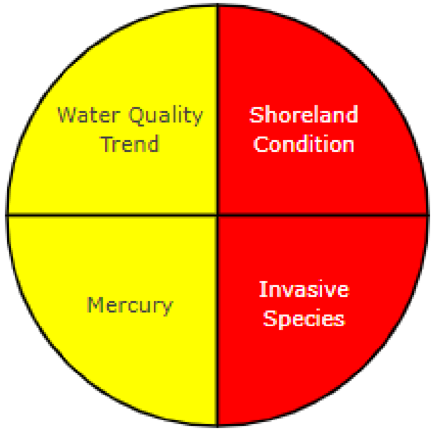
WATERSHED MANAGEMENT DIVISION
LAKES & PONDS PROGRAM

# Lake Carmi Context

- Large, shallow lake in NW Vermont
- Lake Champlain Basin (Missisquoi)
- High TP Concentrations = blooms, low clarity, heavy aquatic plant growth
- 40% of watershed in agricultural use, rest is wooded or developed lakeshore
- Lake is impaired for phosphorus, watershed highly disturbed, high TP
- Water Quality negatively impacts recreation, property values, habitat
- Cyanobacteria blooms = health risk
- Trends mixed, recent TP increase




| | |
|---|---|
| Watershed: | Highly Disturbed |
| WQ Standards: | Impaired |

- Lake Area: 1,415 Acres
- Watershed Area: 5,989 Acres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Phosphorus Total Maximum Daily Load (TMDL)

for

Lake Carmi

Waterbody VT05-02L01

October 2008

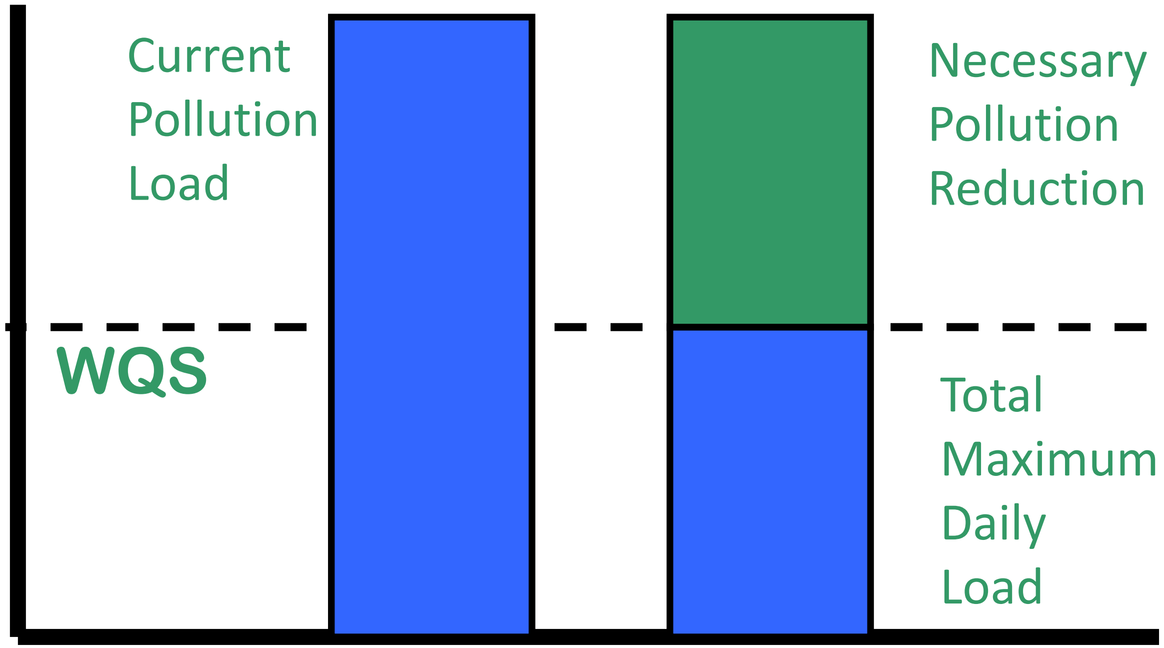
-Approved by EPA Region 1 on April 8, 2009-

Prepared by the Vermont Agency of Natural Resources
103 South Main St.
Waterbury, VT 05671-0408

with guidance from:

Franklin Watershed Committee
Lake Carmi Campers Association
Natural Resources Conservation Service
Missisquoi River Basin Association

# Lake Carmi TMDL




- Science: Establishes a loading target
- Policy: Sets up implementation plan

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# Lake Carmi TMDL

- Sources of loading estimated
  - 85% of external load from ag
  - Internal Loading 6% of overall load

- 2008: TMDL development & approval
  - Reduce P loading by 611 kg/yr from 1535 kg/yr to 924 kg/yr
  - In lake P Target of 22 ug/l

- 2009: TMDL Implementation Plan launched, watershed P loading reduction projects underway

Table 1. Total phosphorus export, by land use, from the Lake Carmi watershed.

| Land Use | Acres | Export coefficient kg/ha/yr | Initial load (kg/yr) | Corrected load kg/yr | Loading % |
|---|---|---|---|---|---|
| Agriculture | 2,748 | 1.78 | 1979 | 1188 | 85% |
| Urban – lakeshore | 100 | 2.52 | 102 | 61 | 5% |
| Urban – low density | 62 | | 63 | 38 | 2% |
| Forest | 2,090 | 0.04 | 34 | 20 | 1% |
| Wetlands[1] | 722 | 0.15 | 44 | 26 | 2% |
| Other water[2] | 586 | 0 | 0 | 0 | 0% |
| Lake Surface[1] | 1,402 | -- | 88 | 88 | 5% |
| Total | 7,710 | -- | 2,310 | 1,421 | 100% |

Table 4. Estimated annual phosphorus loads to Lake Carmi by source category.

| Source of phosphorus load | Value used to calculate this TMDL (kg/yr) |
|---|---|
| Watershed tributaries[1] | 1,421 |
| Septic loads | 15 |
| Internal loads | 97 |
| Load from Lake Carmi State Park WWTF[2] | 2 |
| Total annual load | 1,535 |

Table 6. Lake Carmi TMDL Summary

| TMDL Component | kg/yr | |
|---|---|---|
| Current load | 1,535 | |
| Wasteload allocation | 0 | |
| Load allocation | 924 | |
| Margin of safety | 103 | |
| Total loading capacity | 1,027 | |
| Load reduction required | 611 | 40% |

# Crisis Designation & Response

- WQ Problems: 50-day bloom in 2017
  - Exacerbated by climate change?
- Significant advocacy from residents
- 2018 Lake in Crisis statute passed
- SOV Crisis Response Plan Developed
  - Identified Critical Path Projects to improve water quality in 5 sectors
  - Reinforced loose coalition of organizations working in watershed
  - State Leg & CWIP allocate funding
- Critical Path section updated twice
- Roadmap for future implementation

LAKE CARMI
CRISIS RESPONSE PLAN
Version 3.0 Issued June 1, 2022


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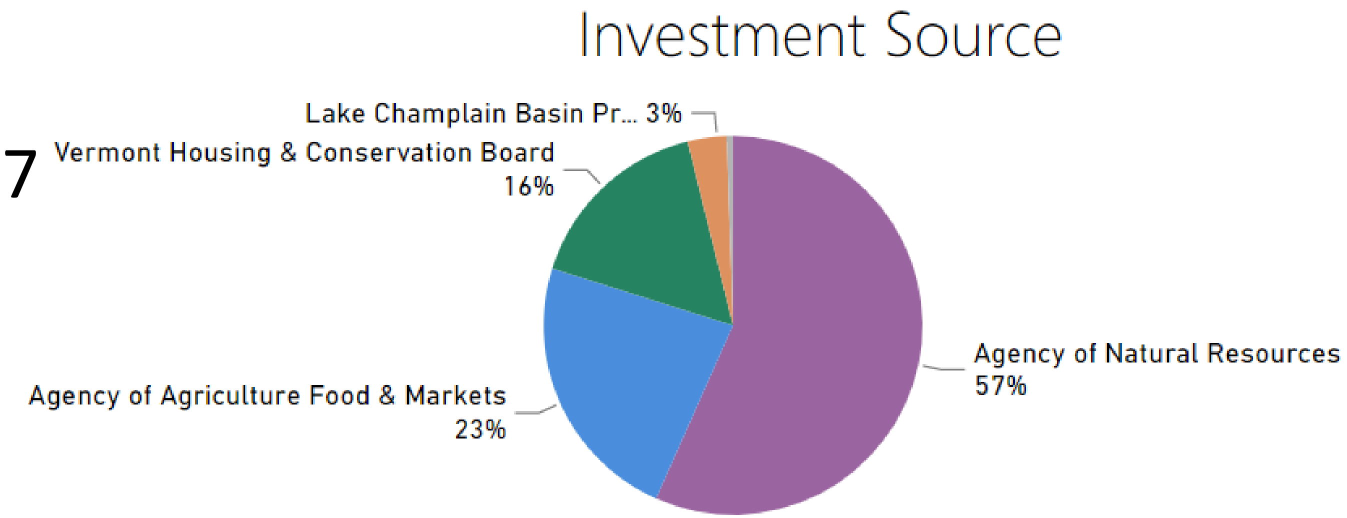
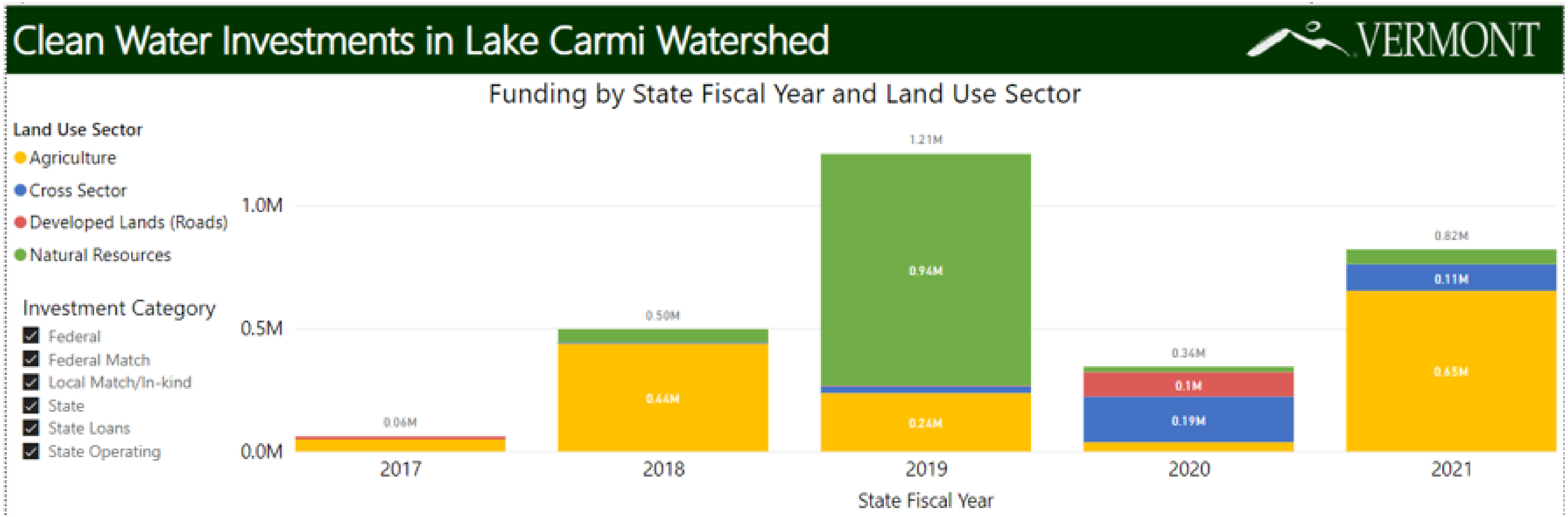
AGENCY OF TRANSPORTATION

# Funding & Partners

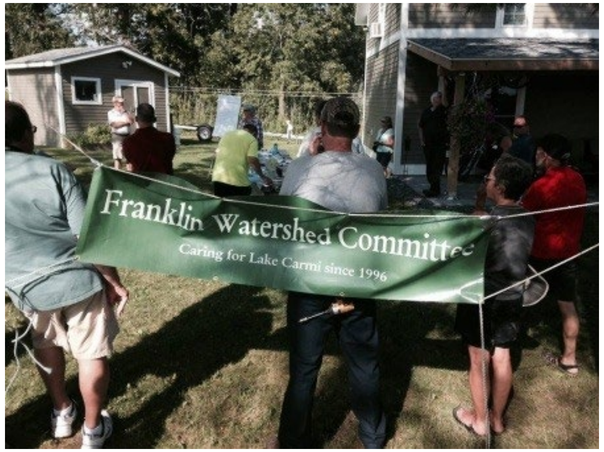
- SOV: Over $2.5M invested since 2017
- Federal: Over $500K via USDA-NRCS matching funds & LCBP project



# Funding & Partners

- State of Vermont led effort
  - ANR, AAFM, AOT
  - Planning, Executing, Implementing
  - Quarterly Coordination Meeting
  - Actively maintained website
- Local Organizations (CCA, FWC)
- Farmers, Town of Franklin
- Service Providers
  - NRCD, NRPC, UVM, Everblue
- Funding Organizations: LCBP, CWIP
- Federal Partners: EPA, USDA-NRCS

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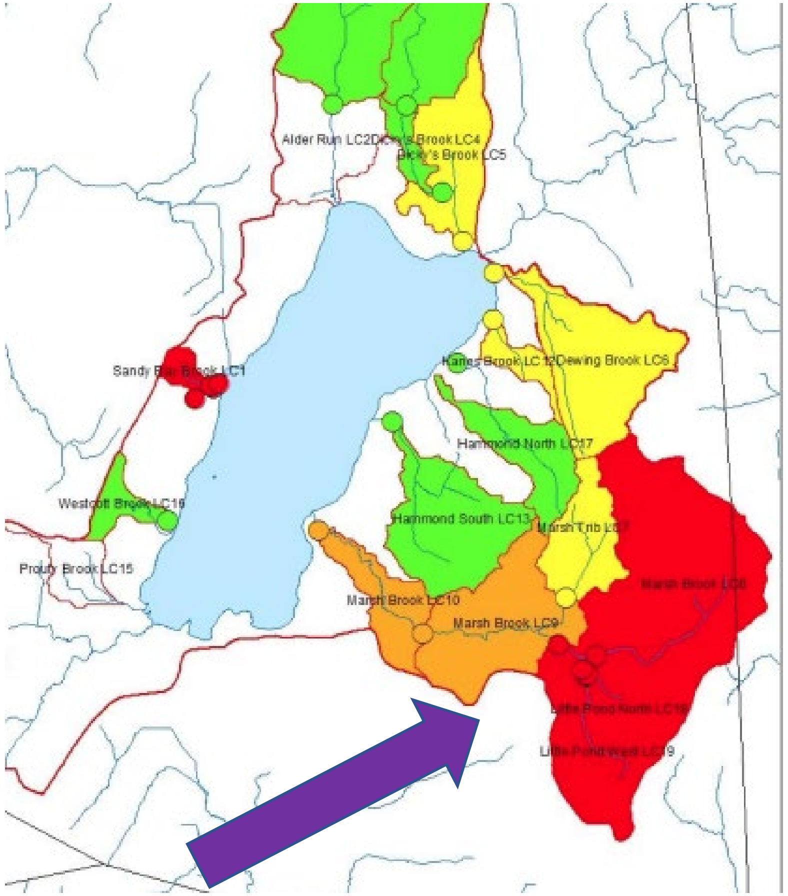
# Watershed Interventions

- Stressors: channel erosion, land erosion & nutrient loading

- 6 categories of interventions
  - **Agriculture**: SOV Required Ag Practices & BMPS, including manure injection
  - **Roads**: Upgrades to reduce erosion, runoff
  - **Lakeshore**: Lake Wise Program -> BMPs
  - **Wastewater**: Zero discharge wastewater system at State Park, Septic Socials
  - **Natural Resources**: Buffers, wetland restoration, reforestation
  - **Groundwater**: Assessing contribution of groundwater to lake's P budget

# Marsh Brook Case Study

- DEC-supported volunteer water quality sampling -> hot spot, high P
- Marsh Brook is largest sub-watershed
- Targeted for projects in all 5 sectors
  - Stream geomorphic assessment
  - Floodplain restoration planning
  - Woody Riparian Planting
  - Snowmobile Crossing improved
  - Rt 136 Crossing improved; new culverts
  - State Park Beach Parking Lot improved
  - Ag BMP Implementation
- Reductions in Total Phosphorus since 2019, but Dissolved Phosphorus remains high



# BMP Identification Contract

- DEC awarded a Lake Carmi BMP Assessment & Design Contract to Franklin NRCD using Lakes in Crisis Funds
- Work will identify and design BMPs that can reduce external phosphorus loading to Lake and tee them up for Act 76 Funding from CWSP

## Summer 2022 Progress

- Project kickoff meeting at Franklin Homestead
- Boat tour around Lake Carmi
- 14 Lake Wise evaluations
- Stream walks on 7 lake tributaries
- Prioritization matrix
- BMP Project Inventory
    - 28 Potential, 16 Completed or In Progress

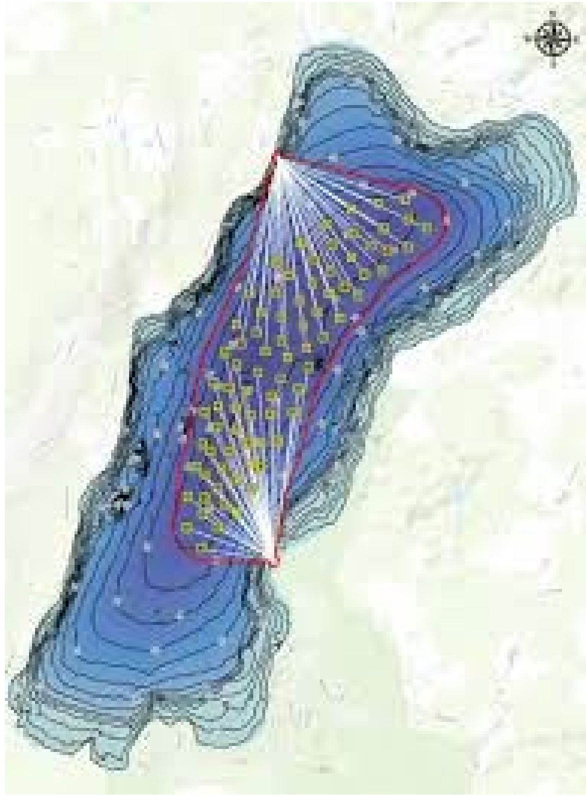
## Next Steps

- Identify potential agricultural stream and wetland projects
- Additional Lake Wise evaluations in early summer 2023
- Finalize BMP project database
- Prioritize identified natural resources, agriculture, and shoreline projects
- 30% designs

# Aeration System

- System installed to
  - prevent oxygen depletion in hypolimnion during summer stratification
  - decrease release of legacy phosphorus from sediments
  - create physical conditions that hinder cyanobacteria blooms.
- System w/ 2 compressors and 80 diffusers installed in early June 2019
- **Targets**: Maintain water temp within 2.5 C, minimum dissolved oxygen level of 2.5 mg/l
- $12K annual electricity costs

- **$1M?:** Was system effective in preventing O2 depletion, reducing internal loading & blooms?



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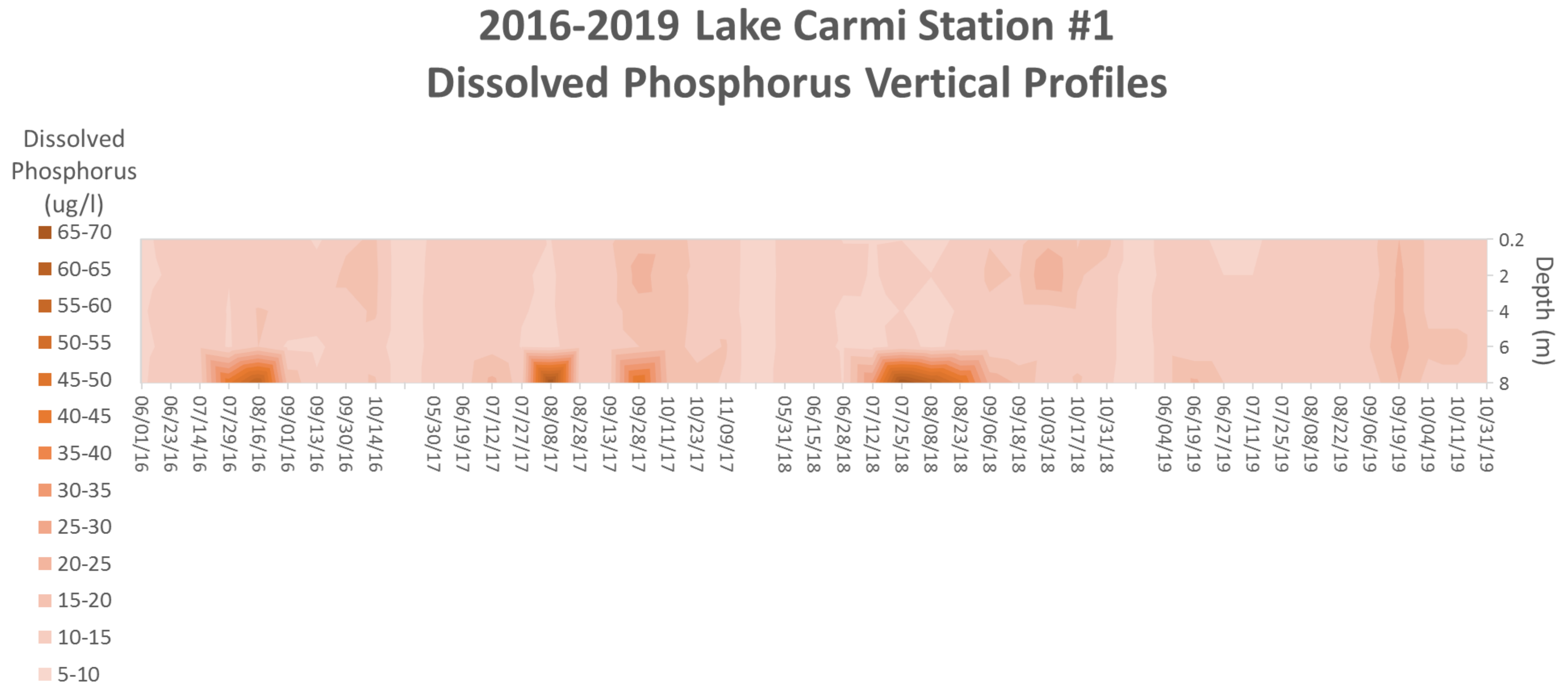
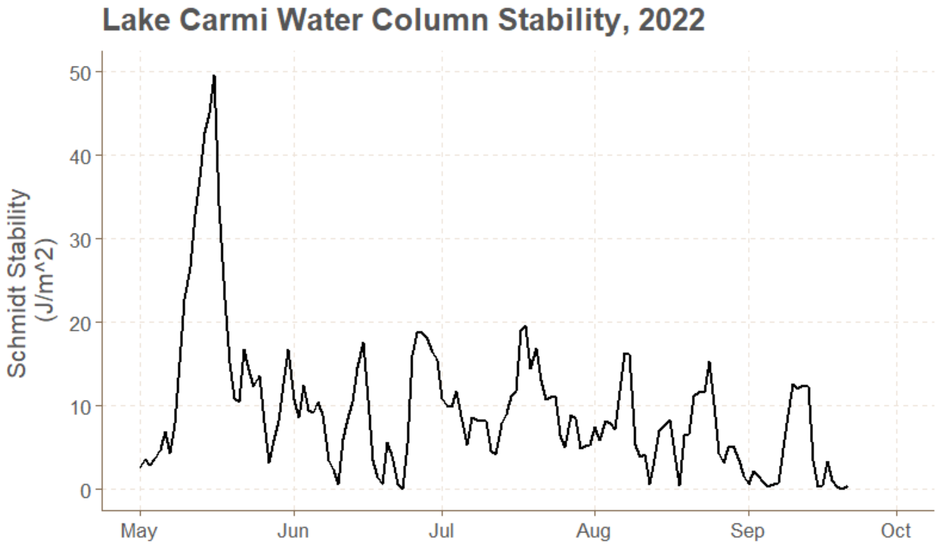


# Aeration System

- DEC & UVM monitor system to assess its performance and lake's response
- System struggled in 2020-2021 with technical problems (outages) but worked in 2022
- Outages can lead to period of anoxia at depth and internal loading of phosphorus
- System reduces internal loading when operational, BUT doesn't eliminate it
- System makes lake prone to wind mixing
- Turning system back after outages or wind-driven lake mixing can lead to P fluxes
- 2023: Reconfigure system, final attempt
- http://epscor.uvm.edu/LakeCarmi/




The lower the number, the less wind energy needed to mix the system

# Water Quality Monitoring Results

- Regional Climate Data
- Modeled P Loading Results in Watershed
- Tributary TP and DP Concentration Data
- Groundwater Data
- Cyanobacteria Data
- In-Lake Data

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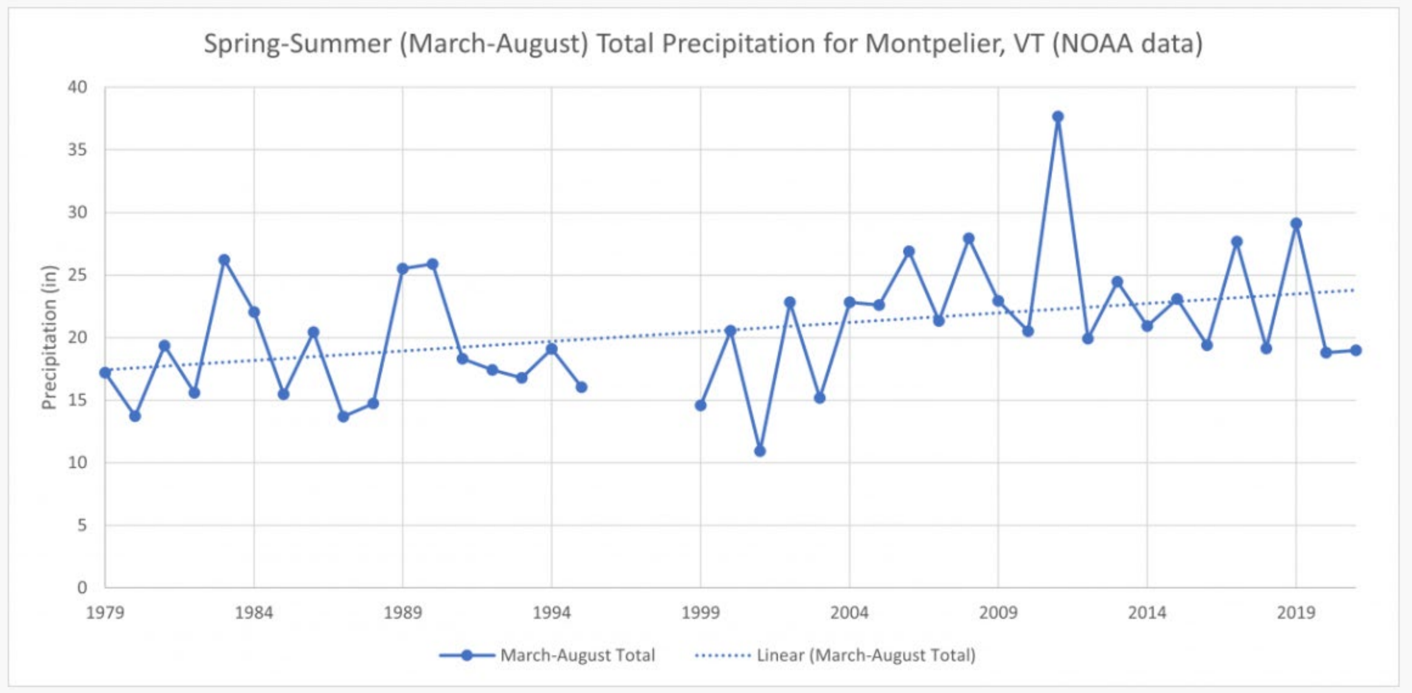
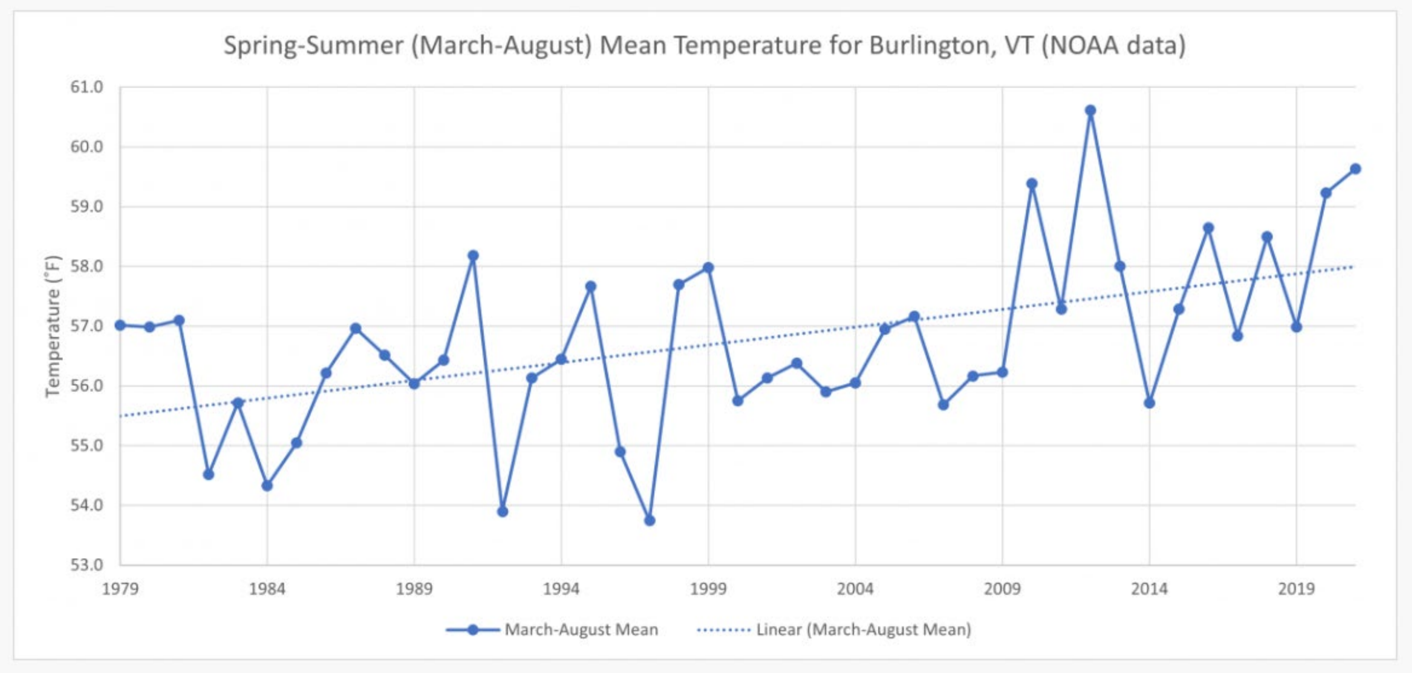
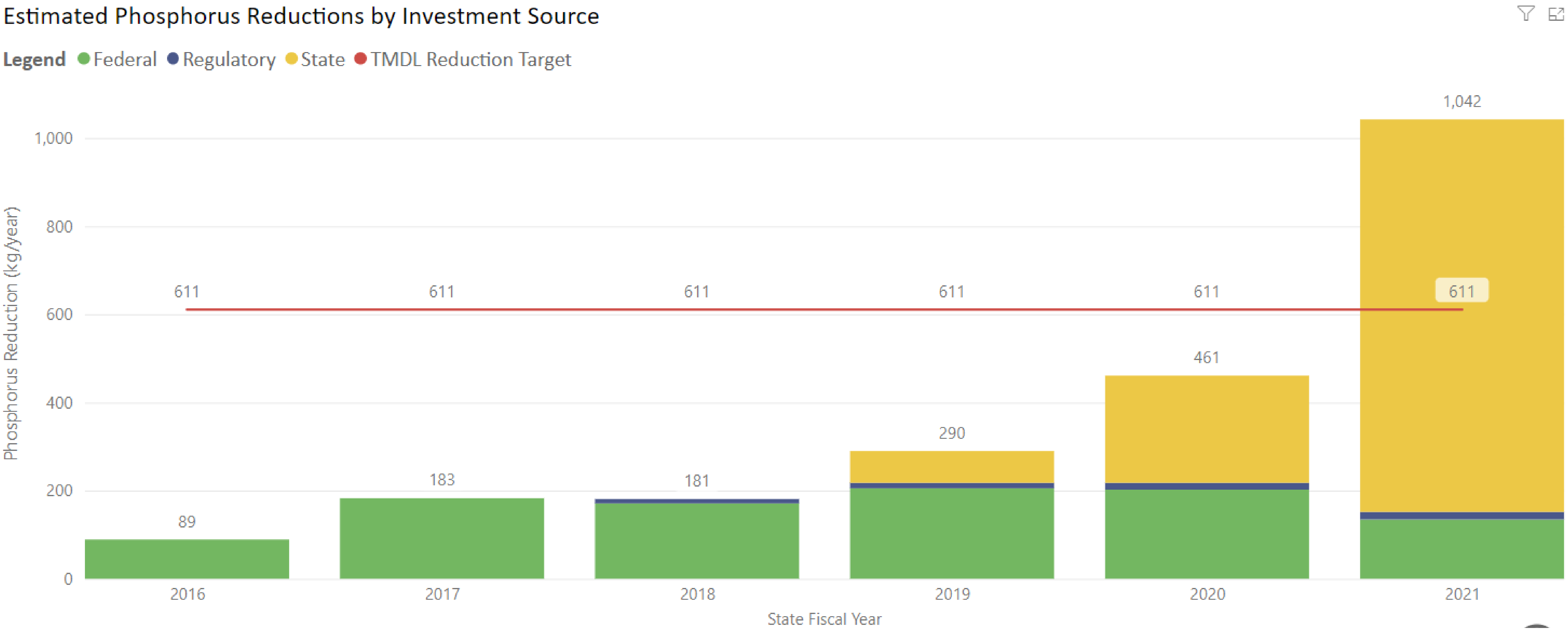
# Regional Climate Data

- Regionally, temperature and precipitation are both increasing in Northern VT
- 2020 and 2021 saw below average precipitation at Lake Carmi; precipitation just below average in 2022
- 2020 – 2022 have all had above average temperatures



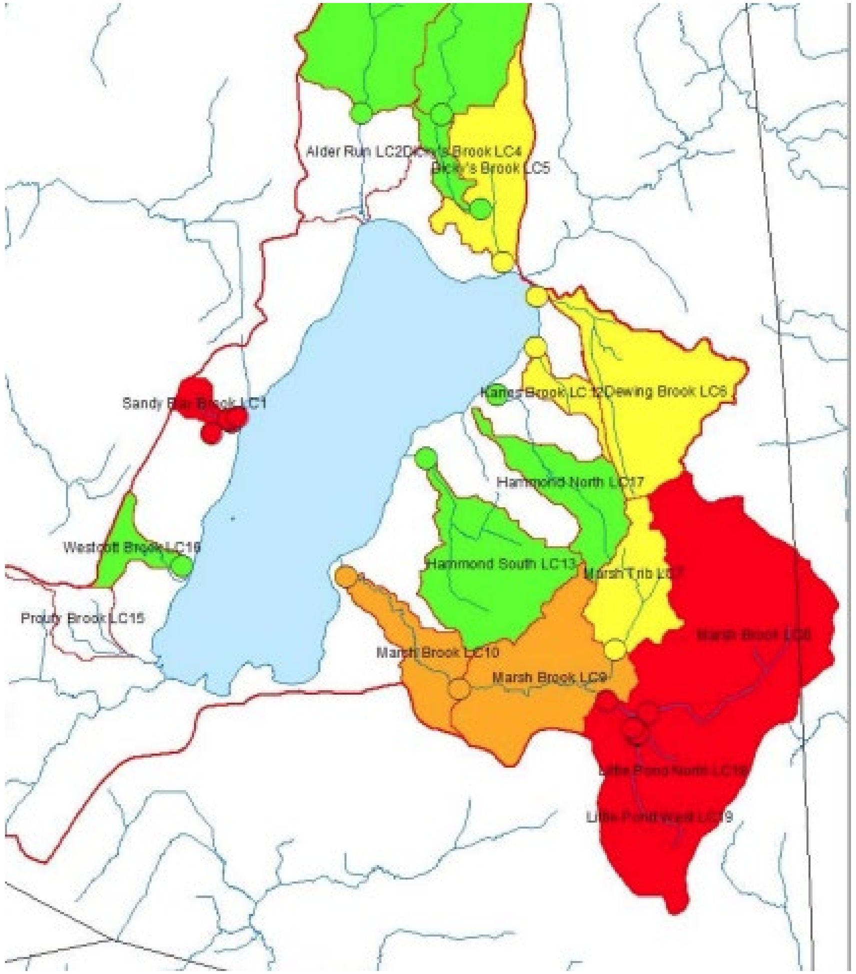



# Modeled Results in Watershed to reduce P loading




- In 2021, estimated P reductions in watershed exceeded TMDL goal of 611 kg, reducing P loading below the TMDL load allocation of 924 kg/year

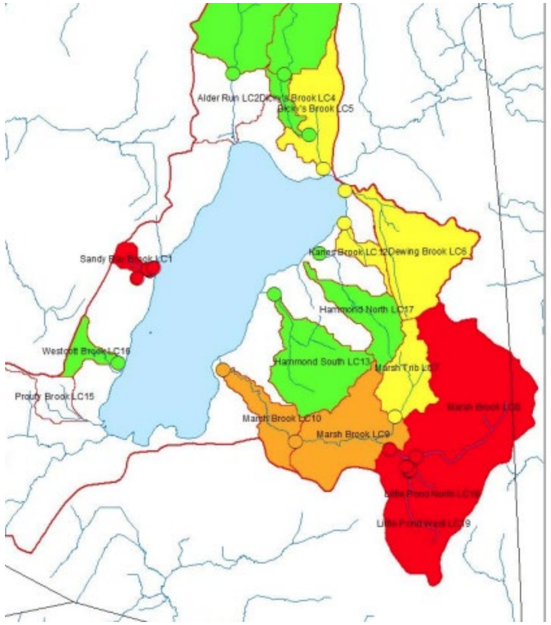
# 2022 Tributary TP and DP Concentration Data

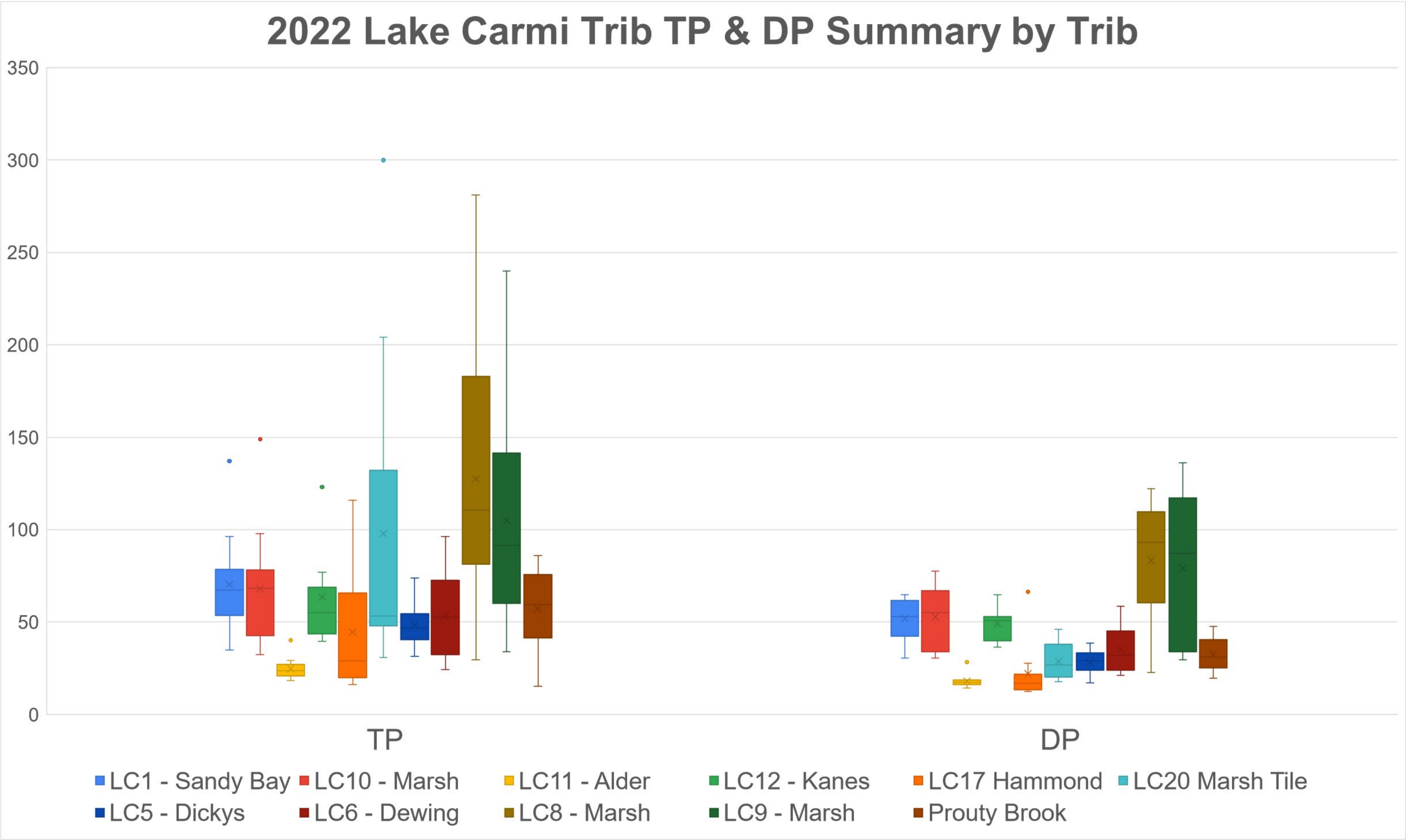



| Total Phosphorus | Min | Mean | Max |
|---|---|---|---|
| LC1 - Sandy Bay | 34.9 | 70.3 | 137.0 |
| LC5 - Dickys | 31.3 | 48.5 | 73.9 |
| LC6 - Dewing | 24.2 | 53.4 | 96.1 |
| LC8 - Marsh | 29.6 | 127.4 | 281.0 |
| LC9 - Marsh | 33.9 | 104.9 | 240.0 |
| LC10 - Marsh | 32.2 | 68.1 | 149.0 |
| LC11 - Alder | 18.4 | 24.6 | 40.0 |
| LC12 - Kanes | 39.4 | 63.5 | 123.0 |
| LC17 Hammond | 16 | 44.5 | 116.0 |
| LC20 Marsh Tile | 30.7 | 81.0 | 204.0 |
| Prouty Brook | 47.7 | 62.5 | 85.9 |

| Dissolved Phosphorus | Min | Mean | Max |
|---|---|---|---|
| LC1 - Sandy Bay | 30.6 | 52.0 | 64.8 |
| LC5 - Dickys | 17.1 | 28.2 | 38.7 |
| LC6 - Dewing | 21 | 35.1 | 58.6 |
| LC8 - Marsh | 22.8 | 83.2 | 122.0 |
| LC9 - Marsh | 29.5 | 79.1 | 136.0 |
| LC10 - Marsh | 30.3 | 52.8 | 77.5 |
| LC11 - Alder | 14.1 | 17.9 | 28.2 |
| LC12 - Kanes | 36.3 | 49.1 | 64.8 |
| LC17 Hammond | 12.5 | 21.9 | 66.3 |
| LC20 Marsh Tile | 17.7 | 28.6 | 46.0 |
| Prouty Brook | 15.3 | 25.9 | 33.0 |

# 2022 Tributary TP and DP Concentration Data



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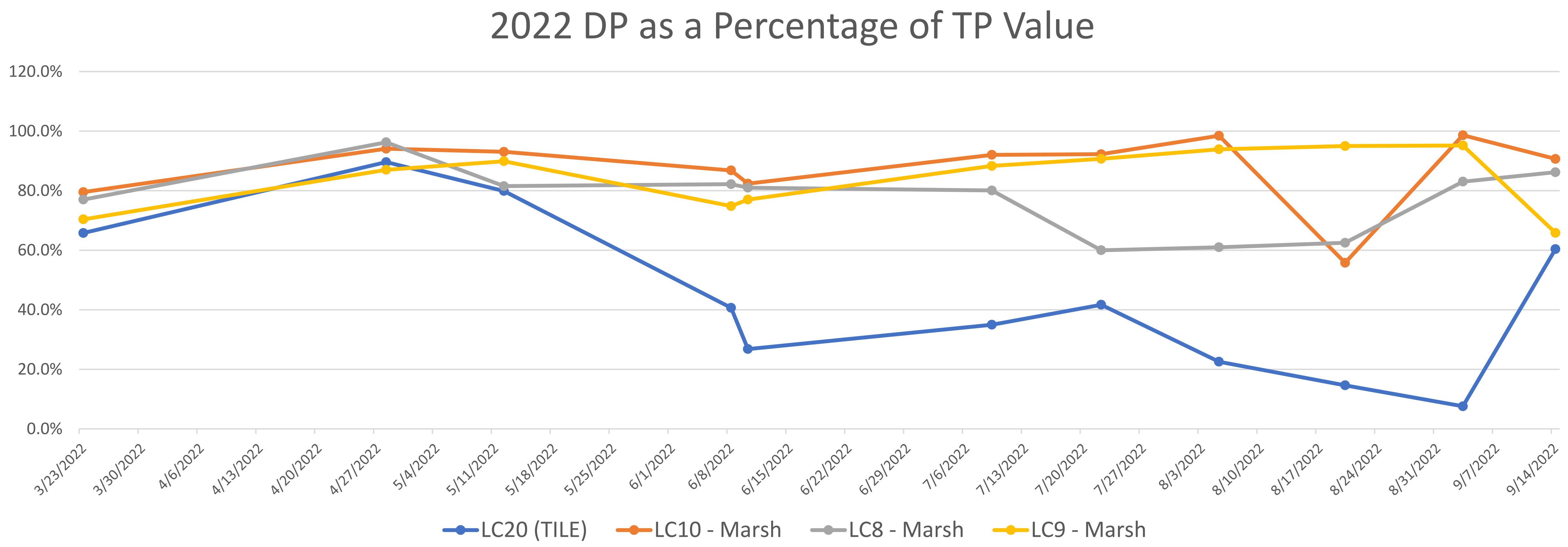
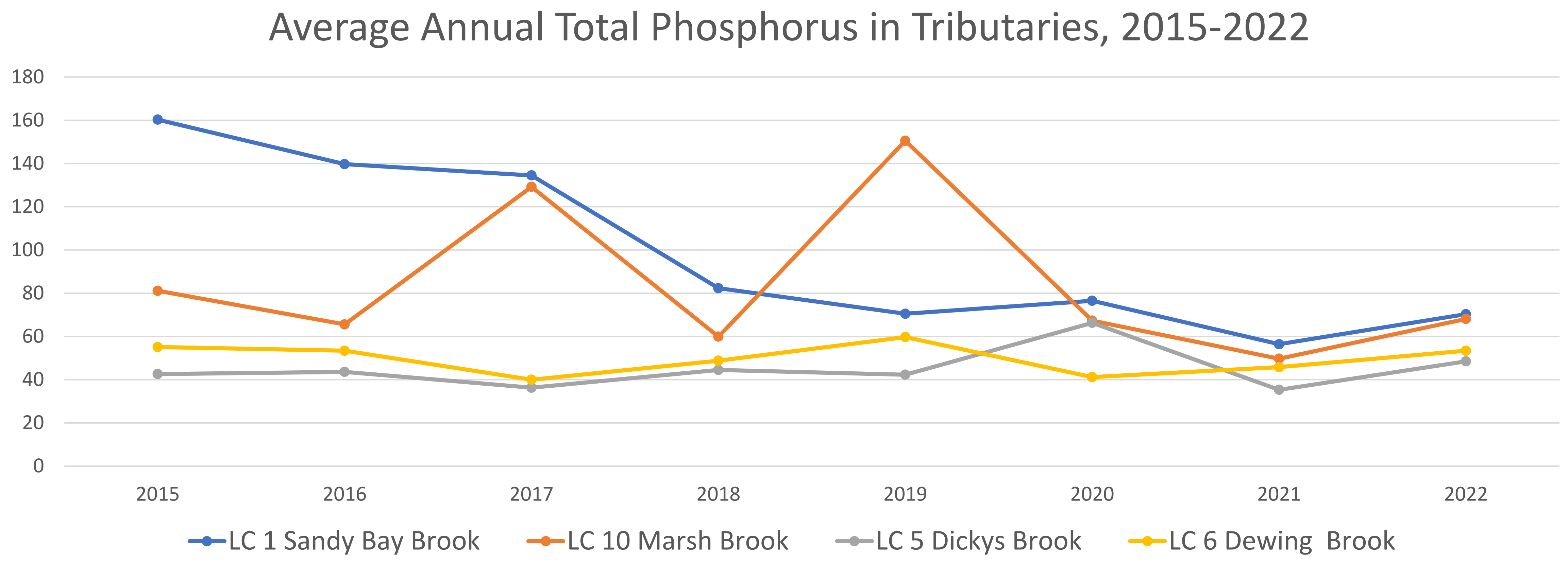



- Marsh Brook TP and DP concentrations highest, Sandy Bay & Kanes are next
- DP remains persistently high percentage of TP in Marsh Brook (70% to 80%)

# Tributary TP and DP Concentration Data




- Sandy Bay Brook decreases over time, Dickys and Dewing relatively constant, and Marsh Brook has fluctuated

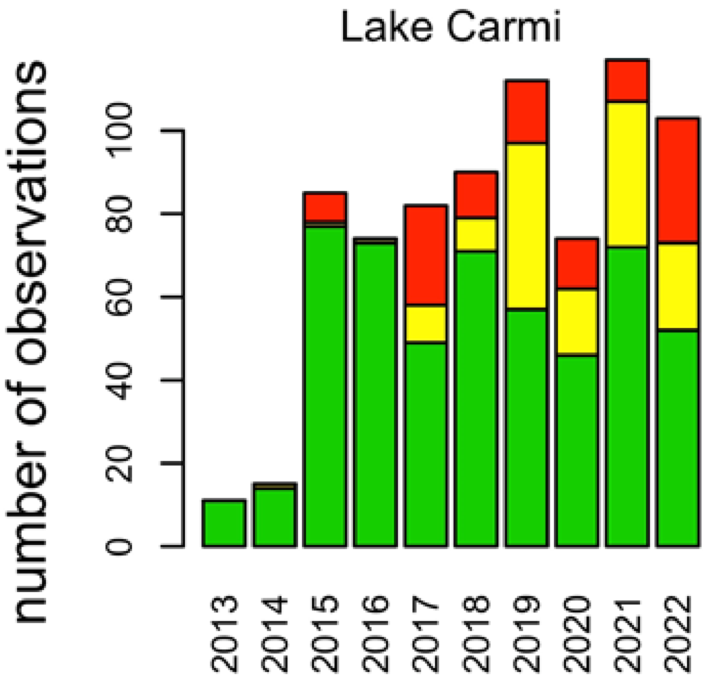
# Groundwater Data

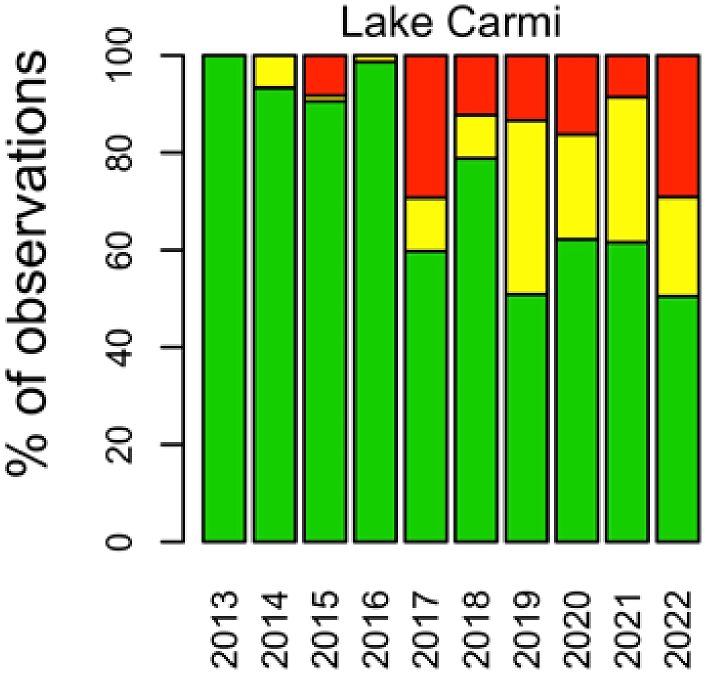
| Kg of TP in Lake Carmi (late spring to late summer 2022) | | | | | |
|---|---|---|---|---|---|
| Lake area | 1402 | ac | 5.67E+06 | $m^2$ | 5.67E+02 |
| Depth avg | 13 | ft | 3.96 | m | |
| Lake Volume | | | 2.25E+10 | L | |
| TP (June) | 25 | ug/L | **562** | kg | |
| TP (Aug) | 50 | ug/L | **1124** | kg | |

- In other words, between mid-June and mid-August, P in lake water increases by 562 kg over 2 months = 281 kg / month.
- This increase occurs when surface water is delivering little P and groundwater trickling into the lake appears to deliver on the order of 1 to 10 kg P per month
- Or, groundwater is not a major P contributor to Lake (same as TMDL)

# 2013-2021 Cyanobacteria Monitoring

- Blooms are highly variable
- Surface & subsurface accumulations moved by wind, waves & currents
- Summer 2022 marked by below average precipitation and above average temperatures (new normal?), conducive to bloom formation
- 2022: First Bloom at Carmi Recorded on June 24, steady blooms from mid July to October
- Data doesn't show significant increase in high alert (Category 3) Blooms between 2013-22, but 2022 had a high number of reports

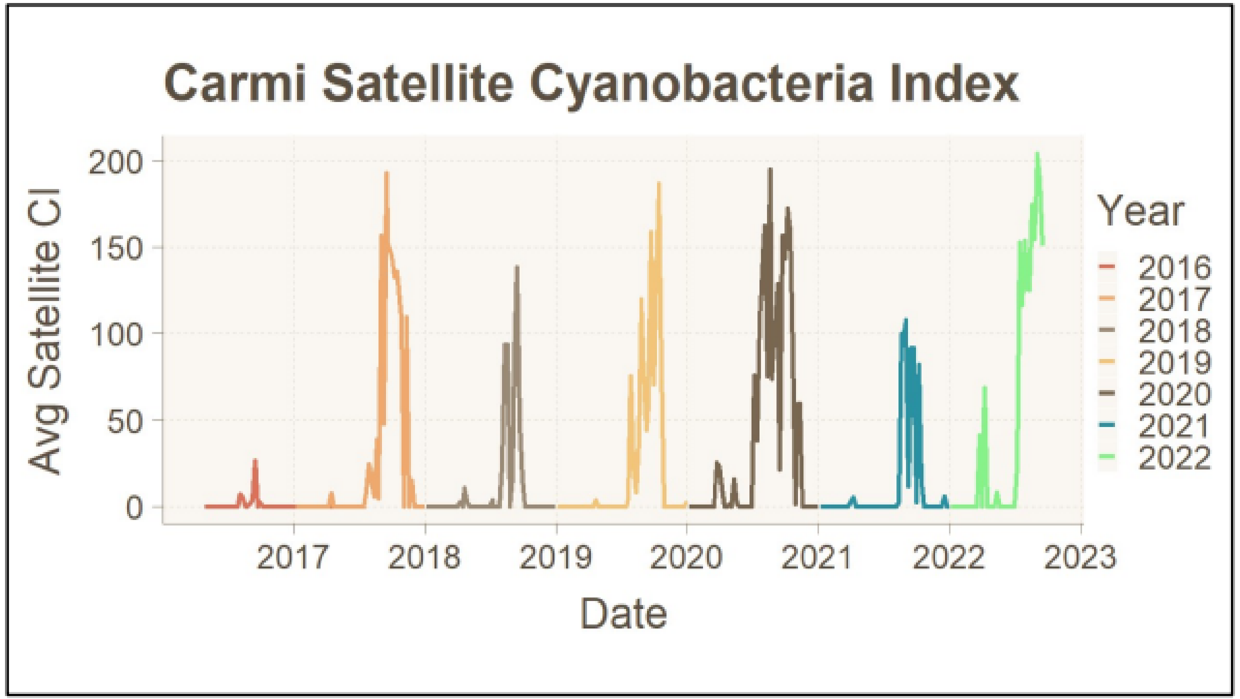


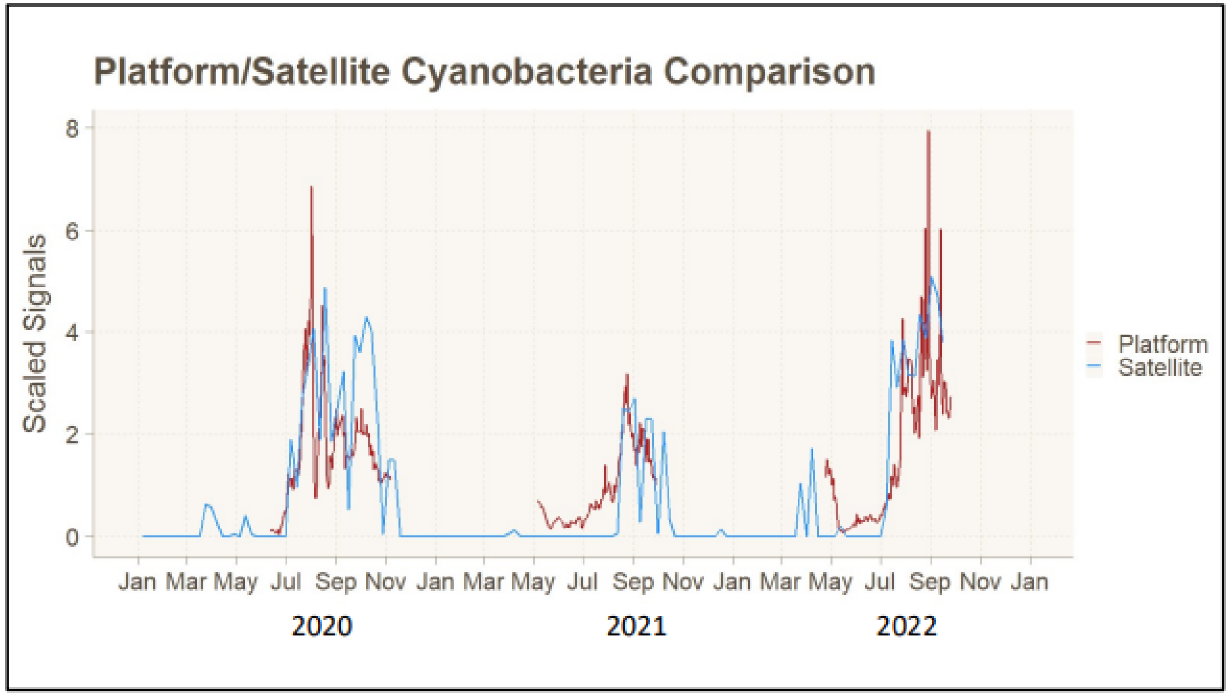



# Cyanobacteria Remote Sensing

- Work by Ashton Kirol, UVM using NOAA satellite images
- Cyanobacteria Index is calculated based on reflectance of wavelengths of light off blue-green algae

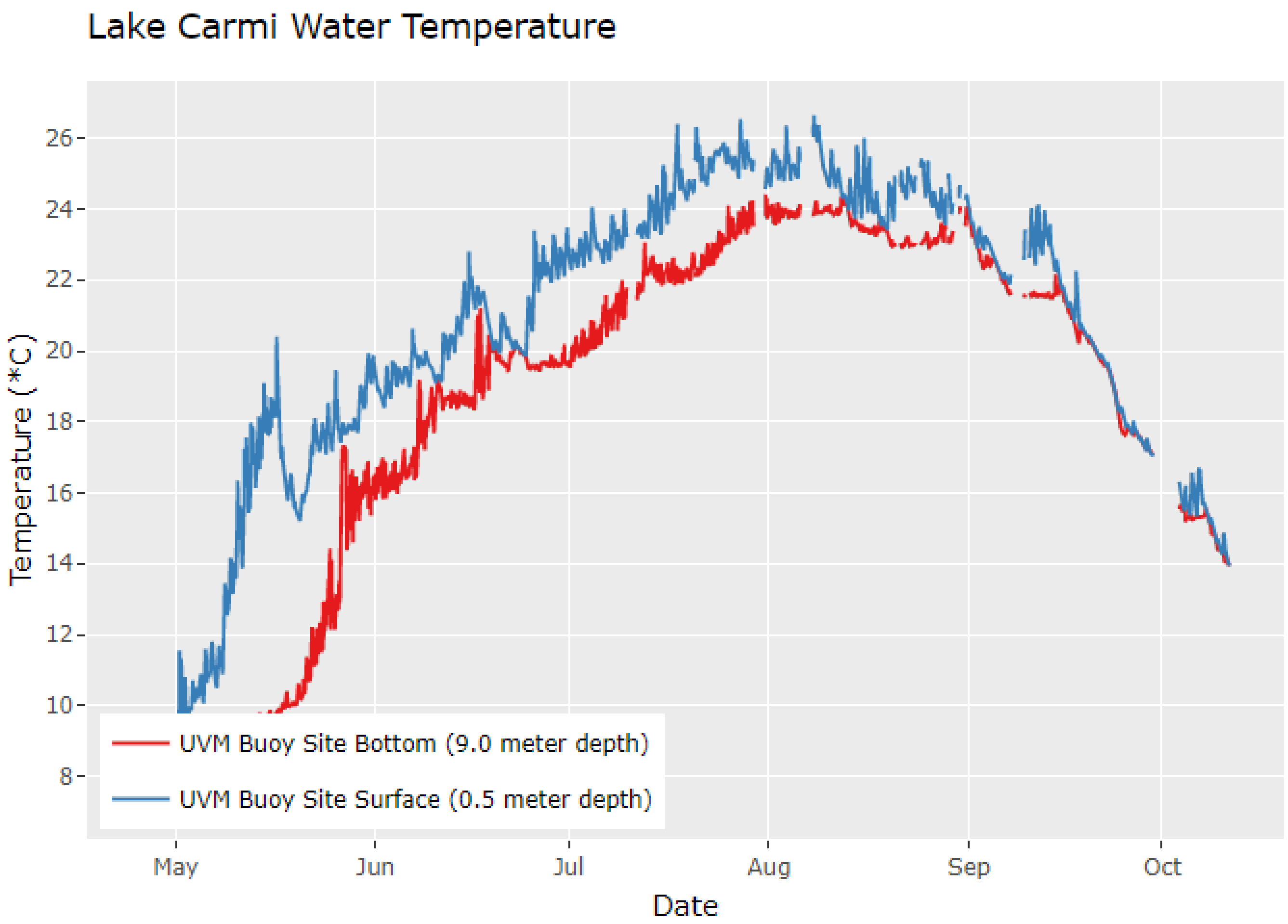
**Results**:
- Pre-Aeration: 2017 quiet, 2018 severe
- Bloom in 2020 began almost a month earlier than 3 years prior
- 2021 typical, slightly better
- 2022 early blooms and more severe
- Platform & Satellite show same timing and relative severity of blooms



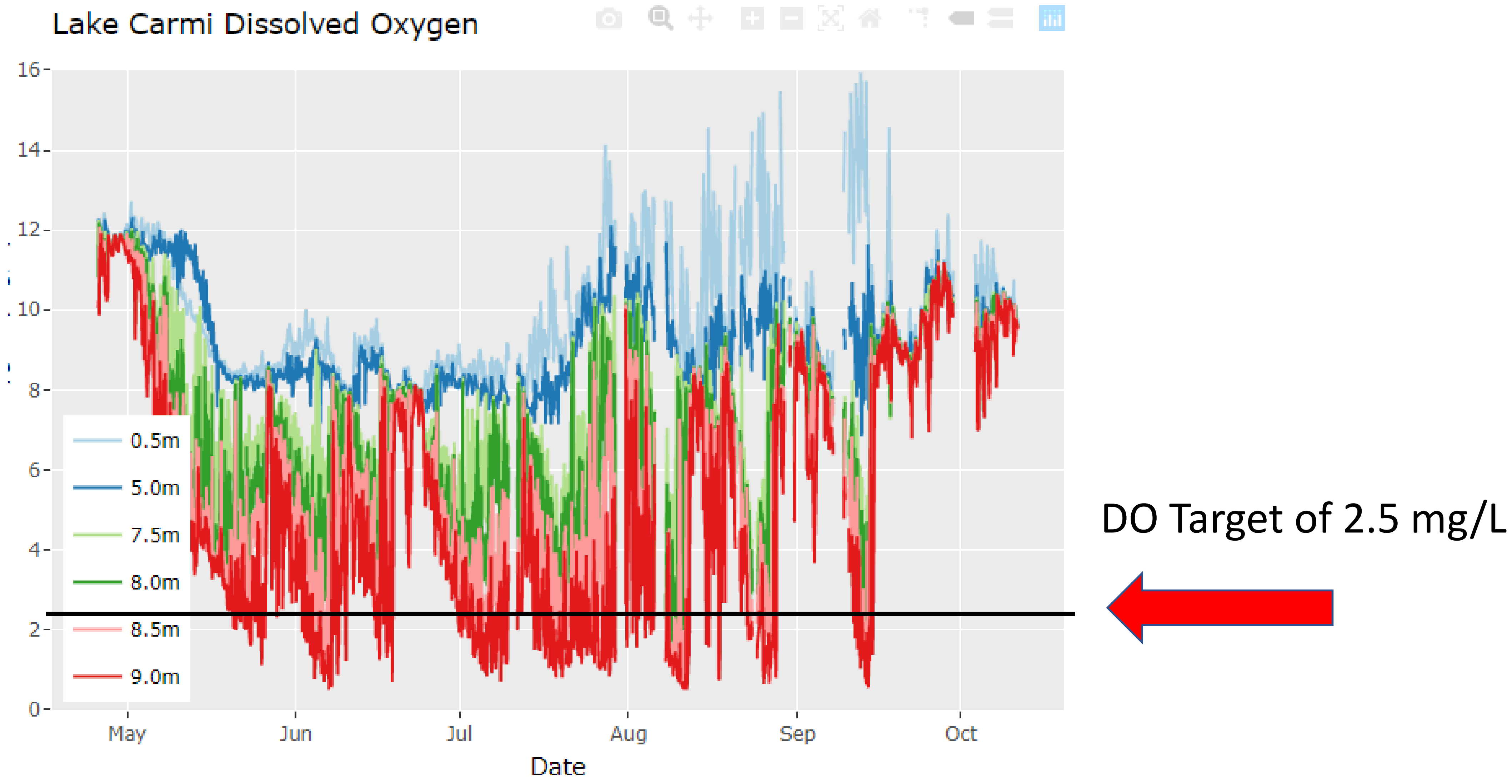
# In-Lake Water Quality Data

Summer 2022 Temperature Data shows good mixing, within targets



# In-Lake Water Quality Data

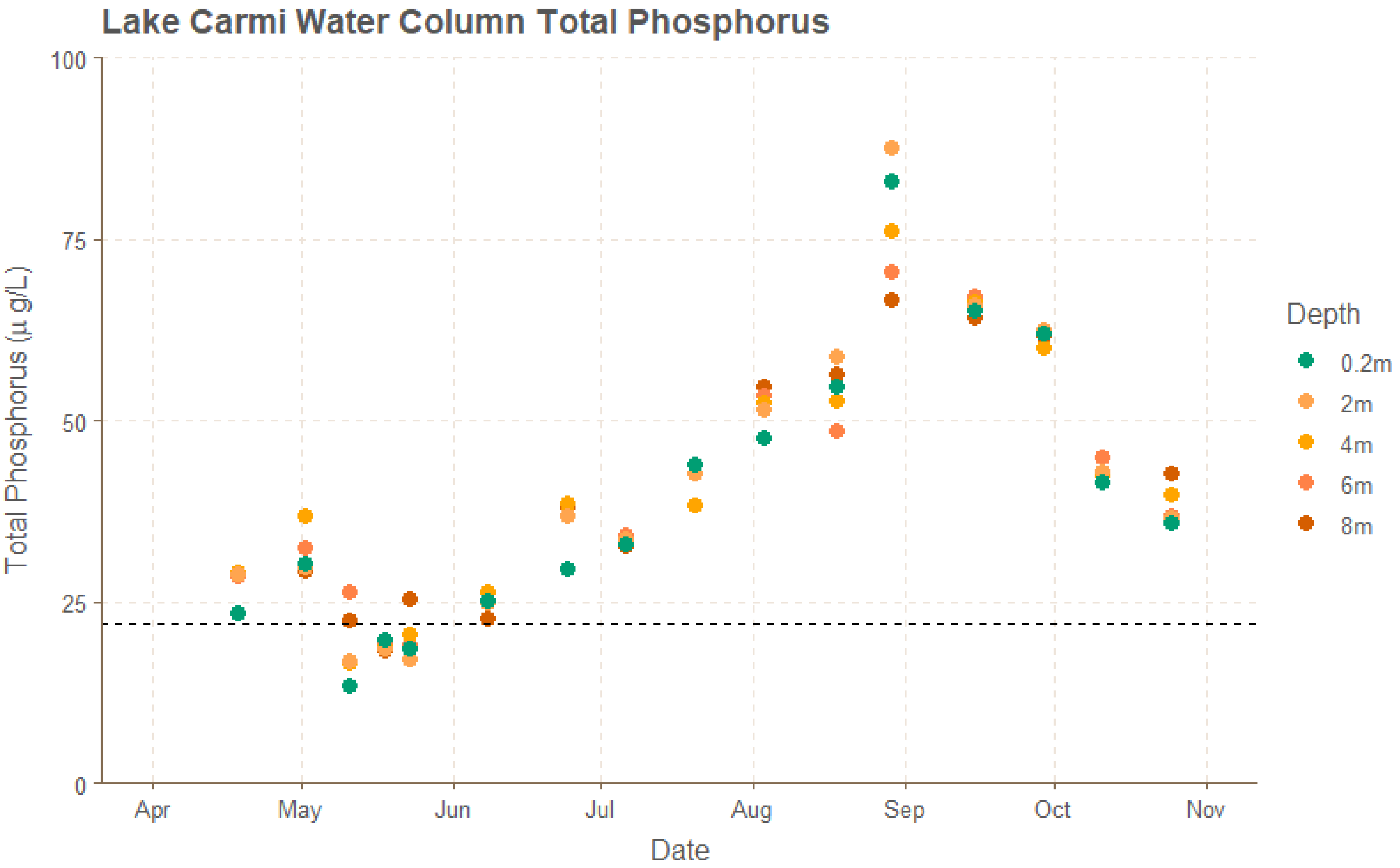
2022 Dissolved Oxygen Data: Mostly above 2.5 mg/L target at 8.5 m but not 100%



# In-Lake Water Quality Data

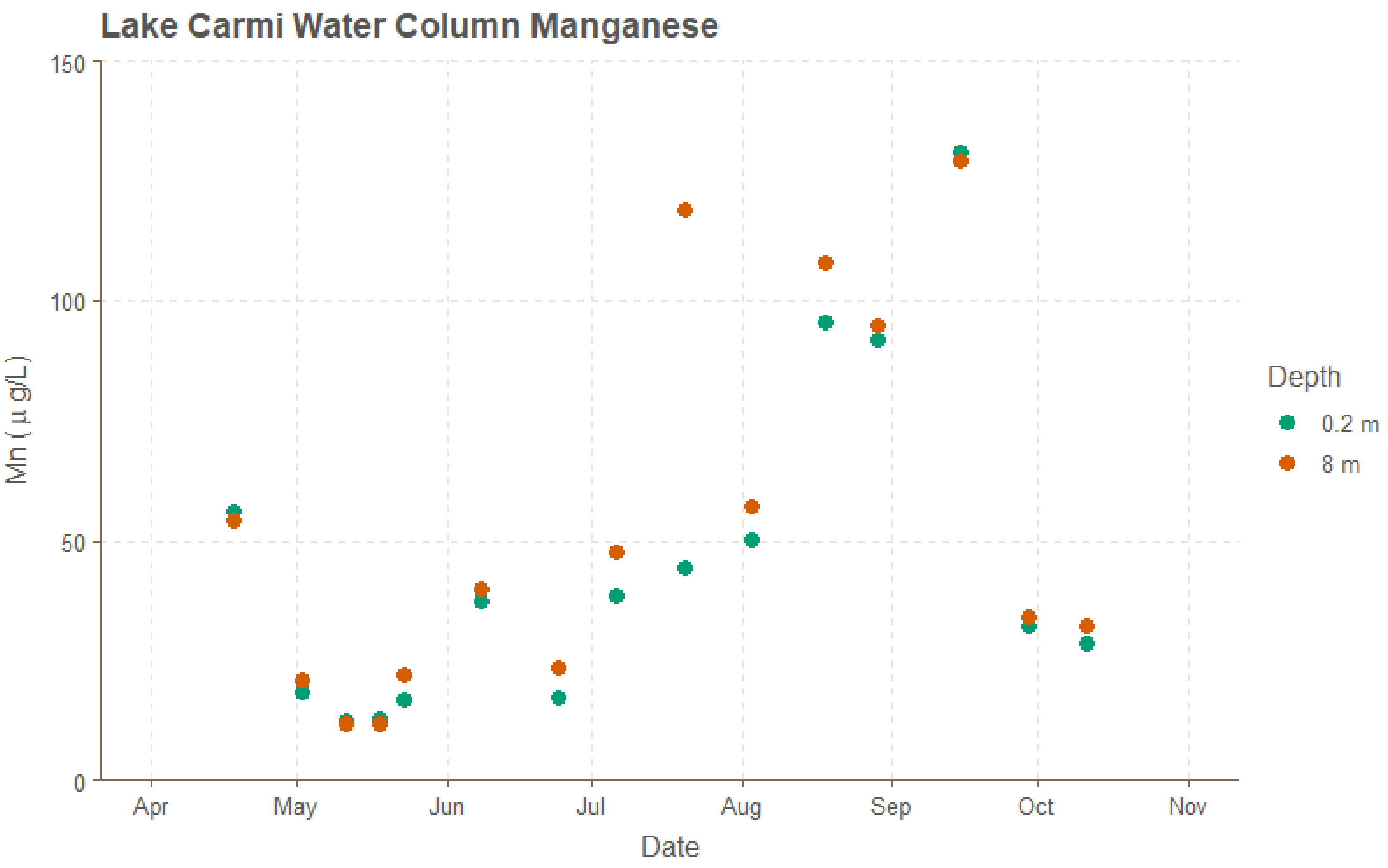
2022 TP Data: Substantial evidence that internal loading is the dominant source of summer water column P enrichment observed under aeration

TMDL Target of 22 ug/L



# In-Lake Water Quality Data

2022 Manganese Data: Elevated concentrations of mangenese can be indicative of a phosphorus source in low oxygen conditions at the sediment water interface

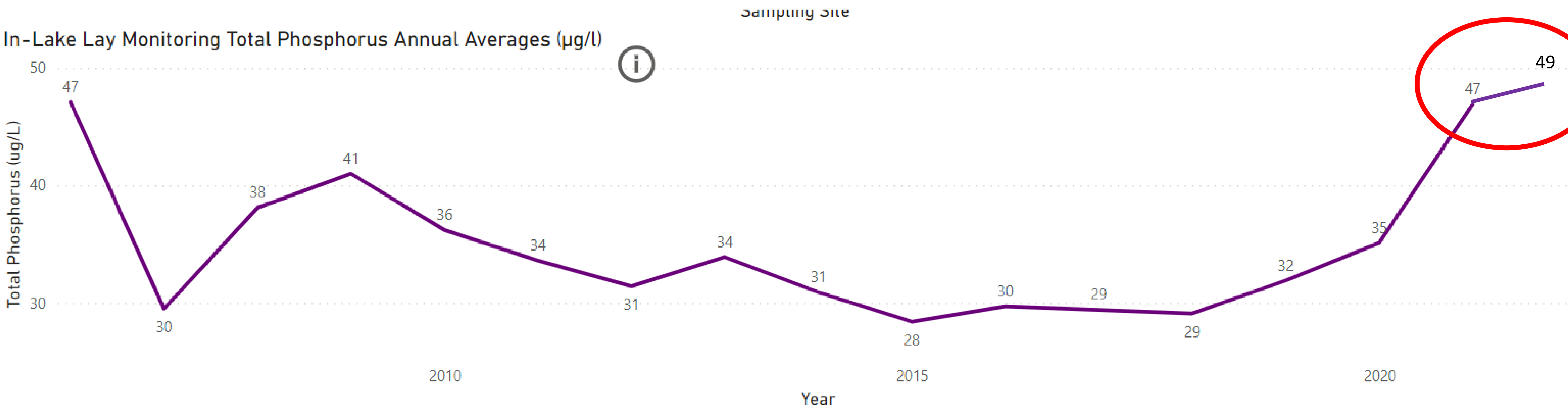


# In-Lake Water Quality Data

Aeration System

- 2022 Operations: No outages, system stayed on entire summer
- 2020-2021 Operational Challenges, In-Lake P Concentrations increases

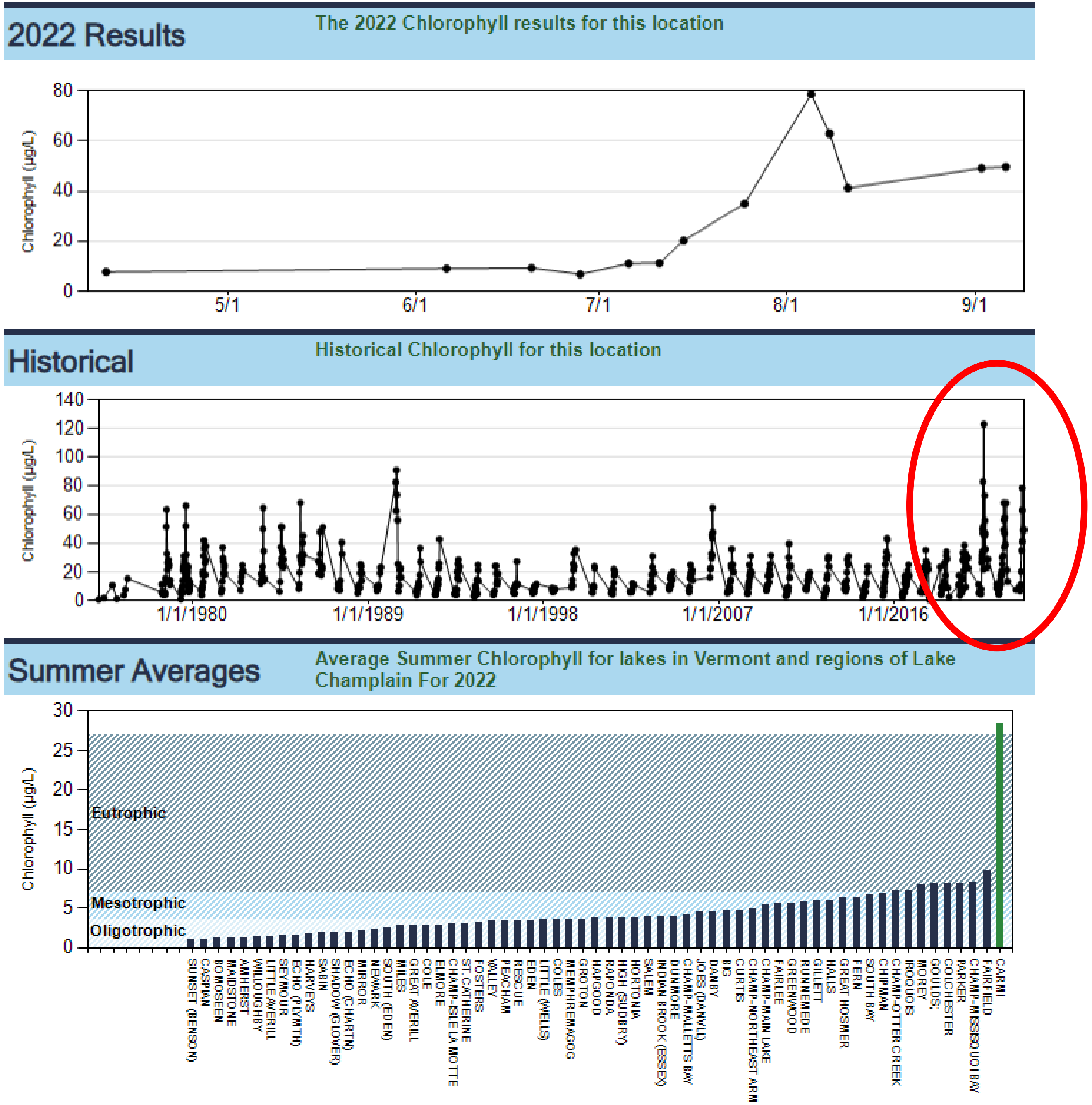
Summer Mean TP Concentration increased significantly since start of aeration



# In-Lake Water Quality Data

## Chlorophyll A

- Chlorophyll A is a pigment present in plants and cyanos, used as a proxy for the amount of algae in the water
- 2022 mean value of 31.6 ug/L was among the five highest values
- Last three years have had higher chlorophyll A values than the ten previous years, suggesting a possible correlation with aeration
- Carmi has by far the highest mean chlorophyll a in Vermont



# Alum Treatment Feasibility Study

- Alum has been used twice in Vermont to limit internal recycling of phosphorus
  - Morey (1986) & Ticklenaked (2014)
  - Treatments deemed "successful"
- Considered for Carmi in 2018 but external loading was too high -> aeration
- Today, aeration is likely not solution, and external loading reduced, creating conditions more favorable for alum
- Dec 2022: DEC advertised RFI, got three responses, one providing input on alum

SOLITUDE LAKE MANAGEMENT

December 23, 2022

Restoring Balance. Enhancing Beauty

**Lake Carmi In-Lake Phosphorus & Cyanobacteria Treatment Feasibility Study Input**

Response to Request for Information

**PREPARED FOR:**

Vermont Department of Environmental Conservation

**PREPARED BY:**

SOLitude Lake Management
590 Lake Street
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and

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144 Crane Hill Road
Wilbraham, MA 011095
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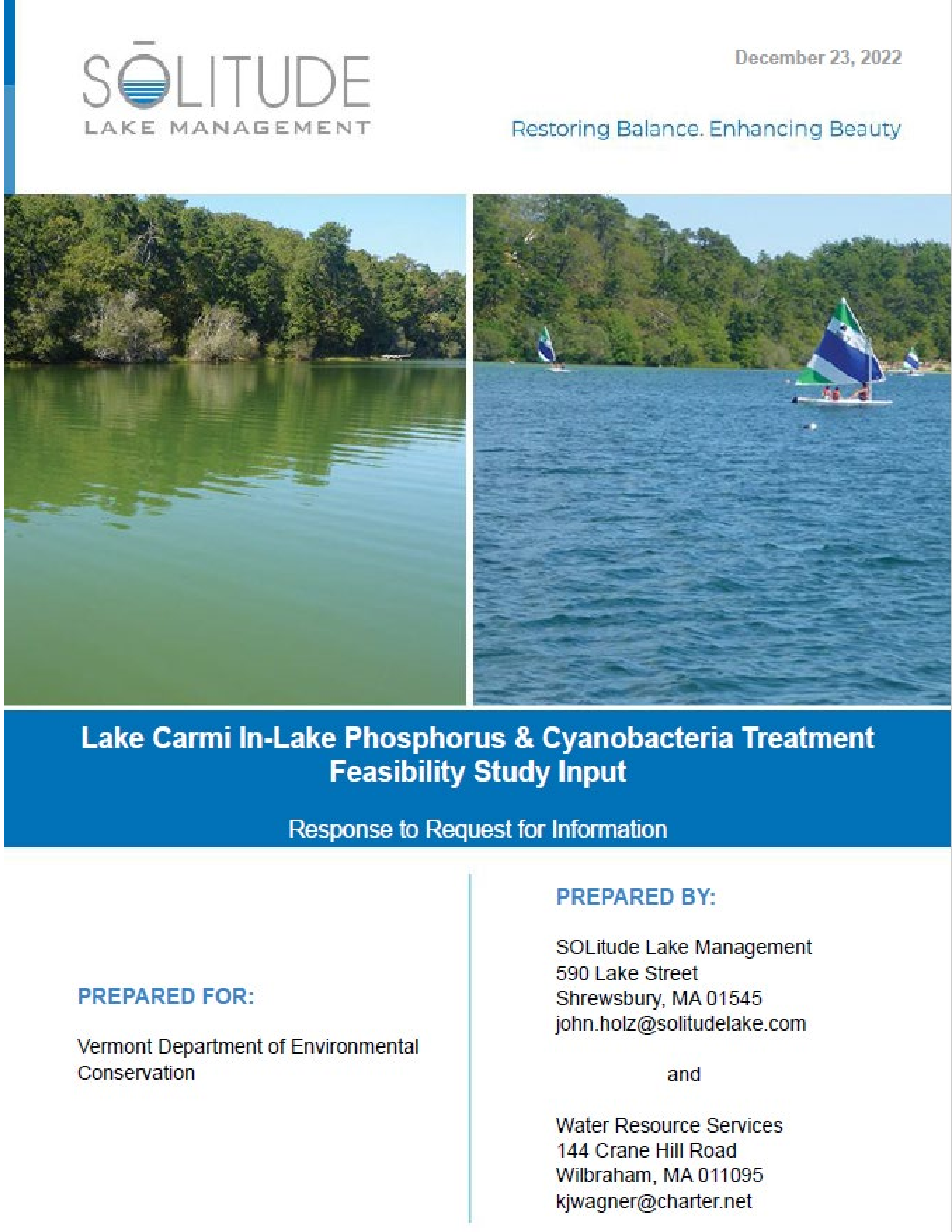
# Alum Treatment Feasibility Study

- Strategy to manage internal & external loads is to first conduct a high dose alum application that will control the existing internal load.
- Once the sediment inactivation application is complete, conduct low dose alum applications every 2-4 years to inactivate / strip P in the water column from external loading.
- Low dose applications would decrease in dose and frequency as external loading decreases, internal load is controlled
- Cost of a higher dose treatment on the full 850-acre area at the central station to 10 cm, the cost would be $2-$4 million and could be done over multiple years
- *More study needed!*



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LAKE MANAGEMENT

December 23, 2022

Restoring Balance. Enhancing Beauty

**Lake Carmi In-Lake Phosphorus & Cyanobacteria Treatment Feasibility Study Input**

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# Conclusions and Next Steps

**External P Loading**

- Drought conditions in 2020-21, very limited surface water flow into the lake, helped reduce external load
- Modeled Results show BMPs leading to decreases in external P loading
- Groundwater not a major TP source
- No related in-lake signal
- ***Legacy Phosphorus and Lag Time Concept:*** *lakes are slow to recover after high external loading is reduced*

# Conclusions and Next Steps

**Internal P Loading**

- 2008 TMDL Calculation underesti-mated internal P loading contribution
- UVM analysis show importance of internal P loading for fueling blooms in hot, dry conditions
- Aeration System 100% Operational in 2022, exacerbated internal P loading
- Significant Blooms on Lake in 2020-22
- “Crisis” situation persists

# Conclusions and Next Steps

**Plans for Summer 2023:**

- Continue BMP Identification, Design, Implementation in watershed
  - *Please work with us – Lake Wise, Agricultural BMPs, Roads*
- Maintain UVM Monitoring Platform
- Reconfiguration of Aeration System to pump more O2 to deepest part of lake where internal loading occurs
- Use SFY24 CWIP Funds for Alum Feasibility Study (Alternatives, EIA)
- If favorable, secure permits & funding

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# Thanks for your attention!
# Questions?