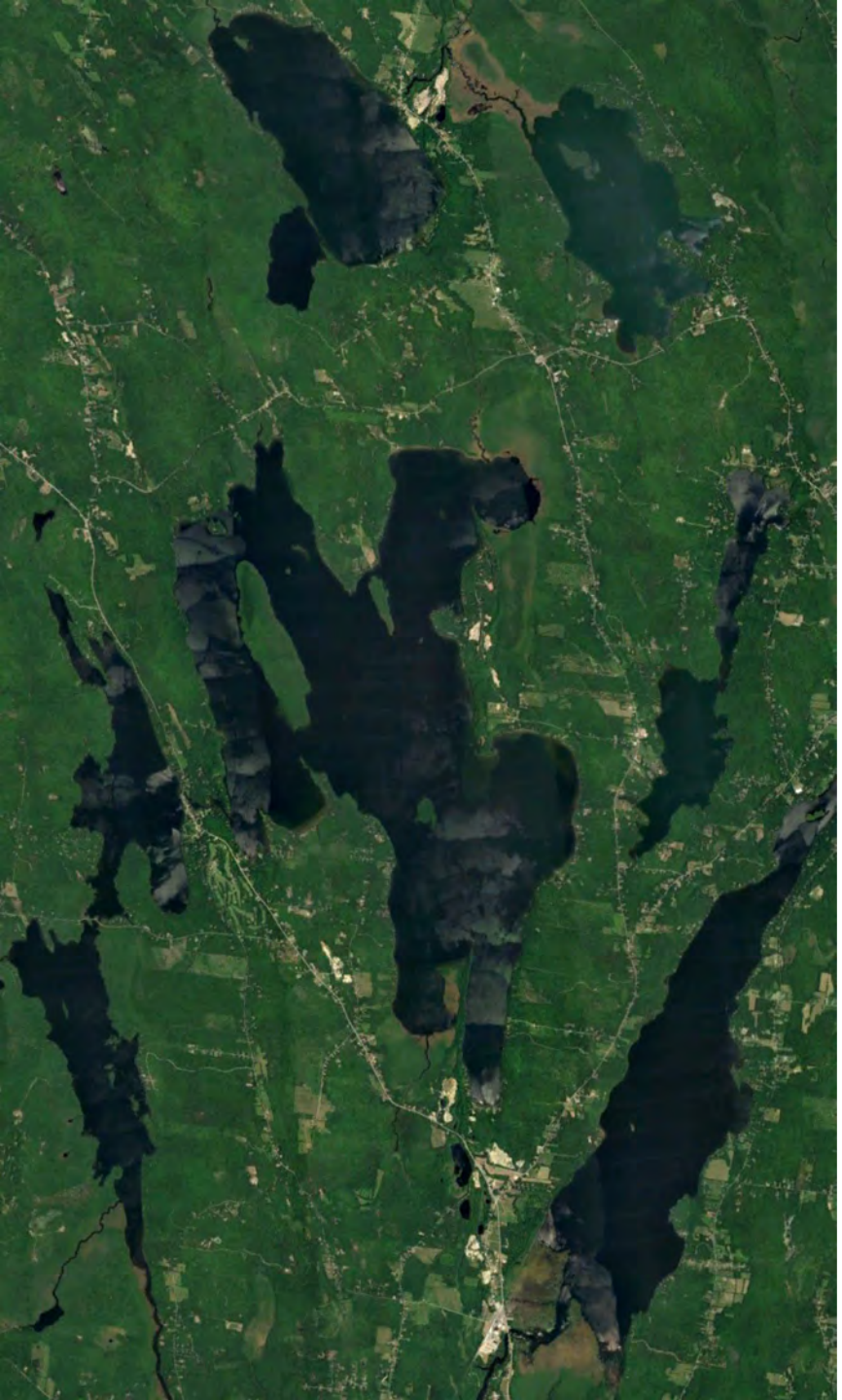


Early indications of climate impacts on Maine lakes

A case study from the Belgrades

Dr. Danielle Wain
7 Lakes Alliance

Dr. Whitney King
Colby College

Dr. Pete Kallin
Maine Lakes Society

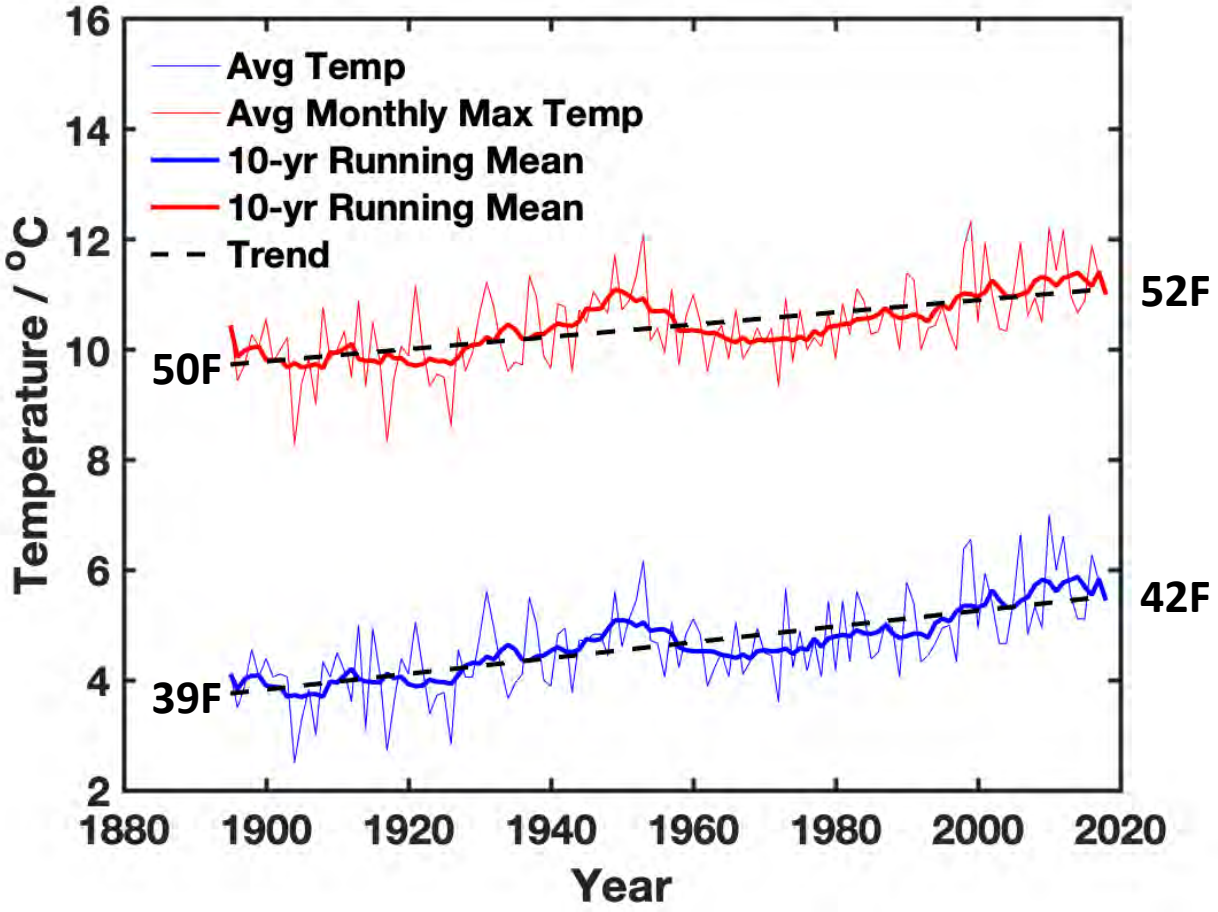
7 LAKES ALLIANCE
Ensuring Our Future

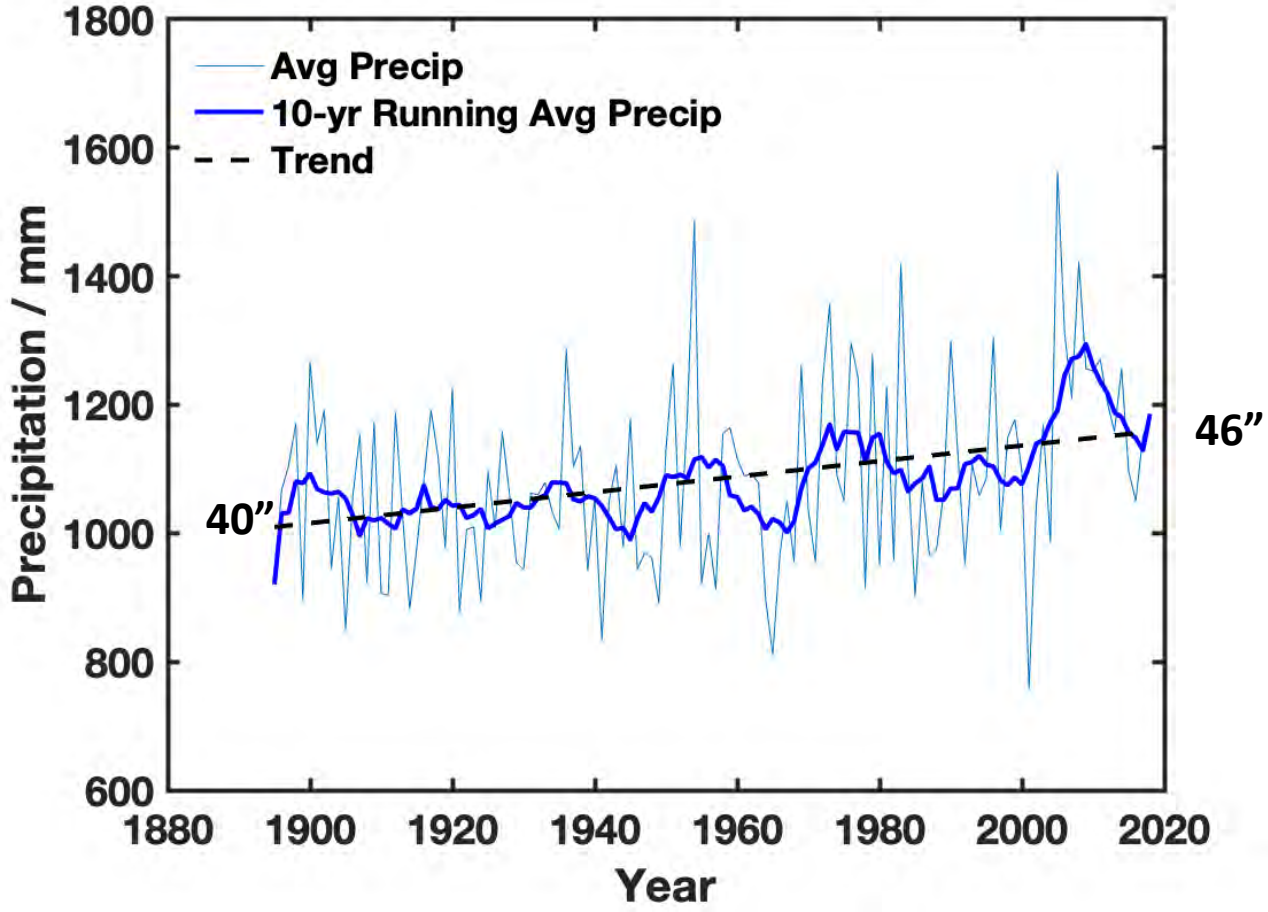
COLBY COLLEGE 1813
LUX · MENTIS · SCIENTIA

Maine Lakes Society

Climate Change in Maine

Data below from NOAA





Increasing temperatures

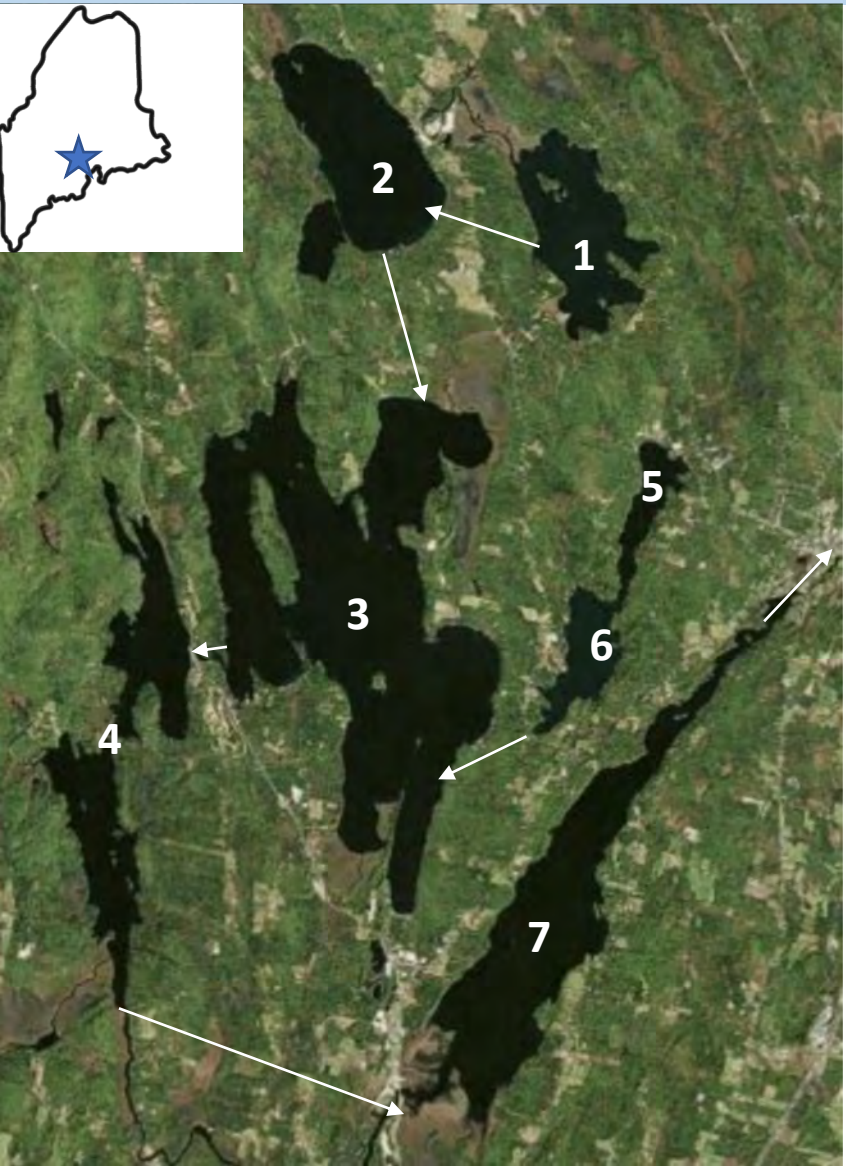
→ Stronger and longer stratification in lakes

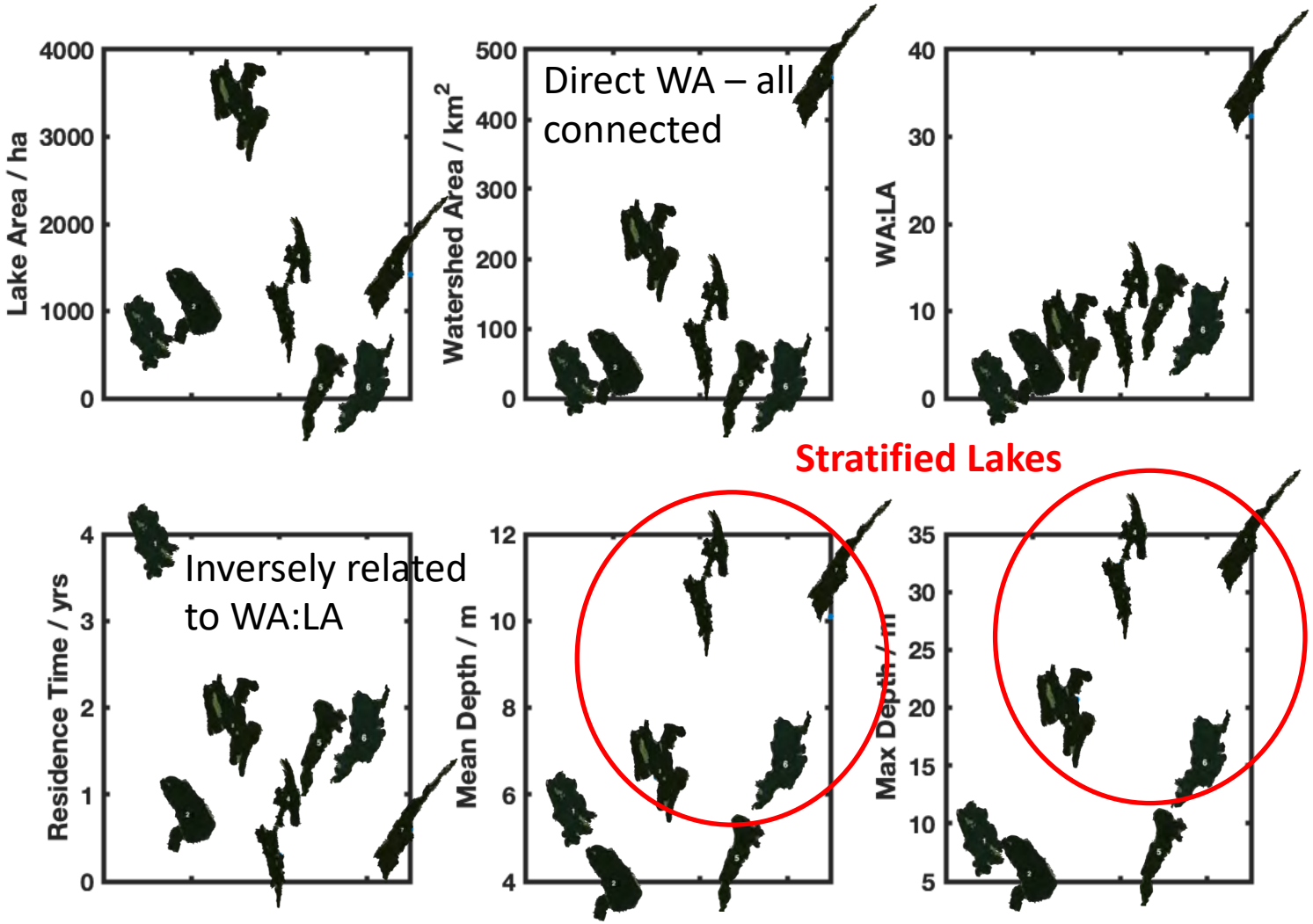
Increasing precipitation

→ More runoff of nutrients from the watershed

The Belgrade Lakes

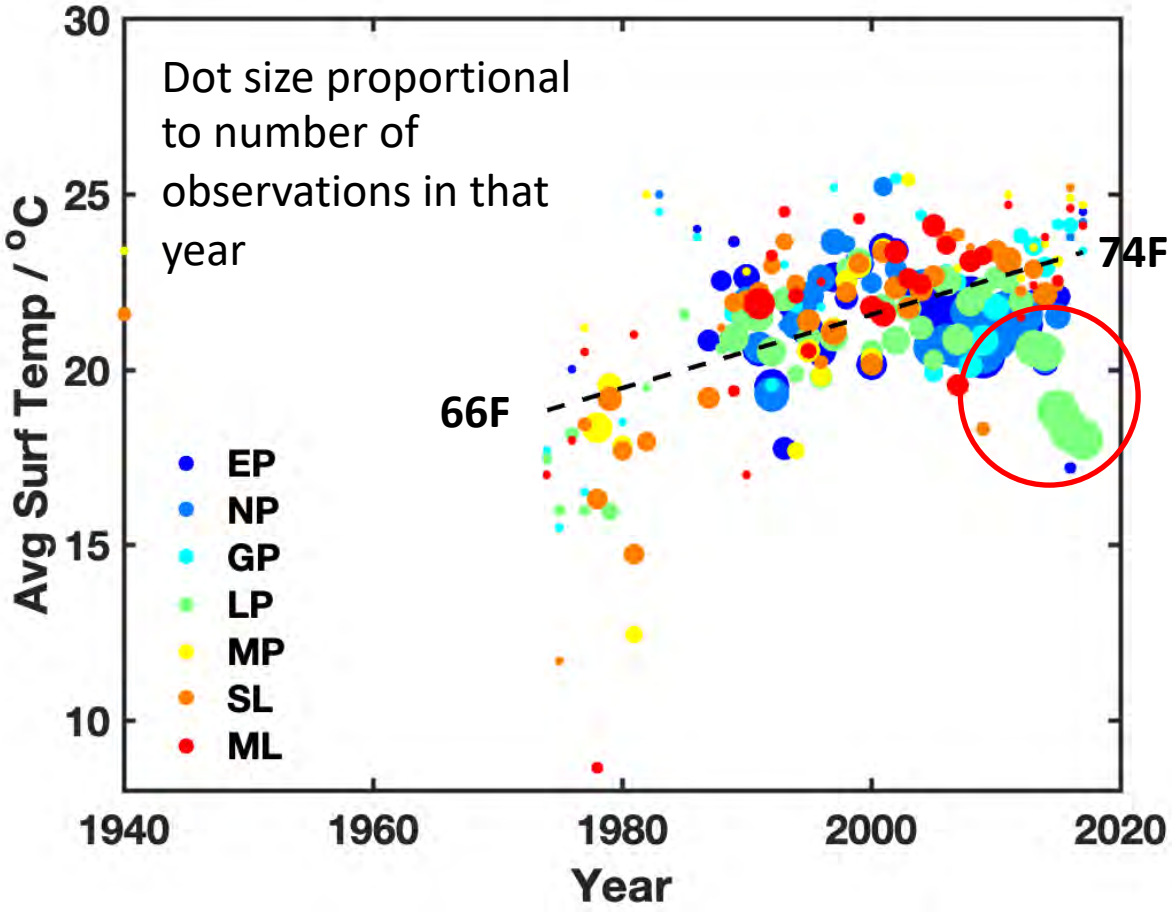
1 = East Pond
2 = North Pond
3 = Great Pond
4 = Long Pond
5 = McGrath Pond
6 = Salmon Pond
7 = Messalonskee Lake

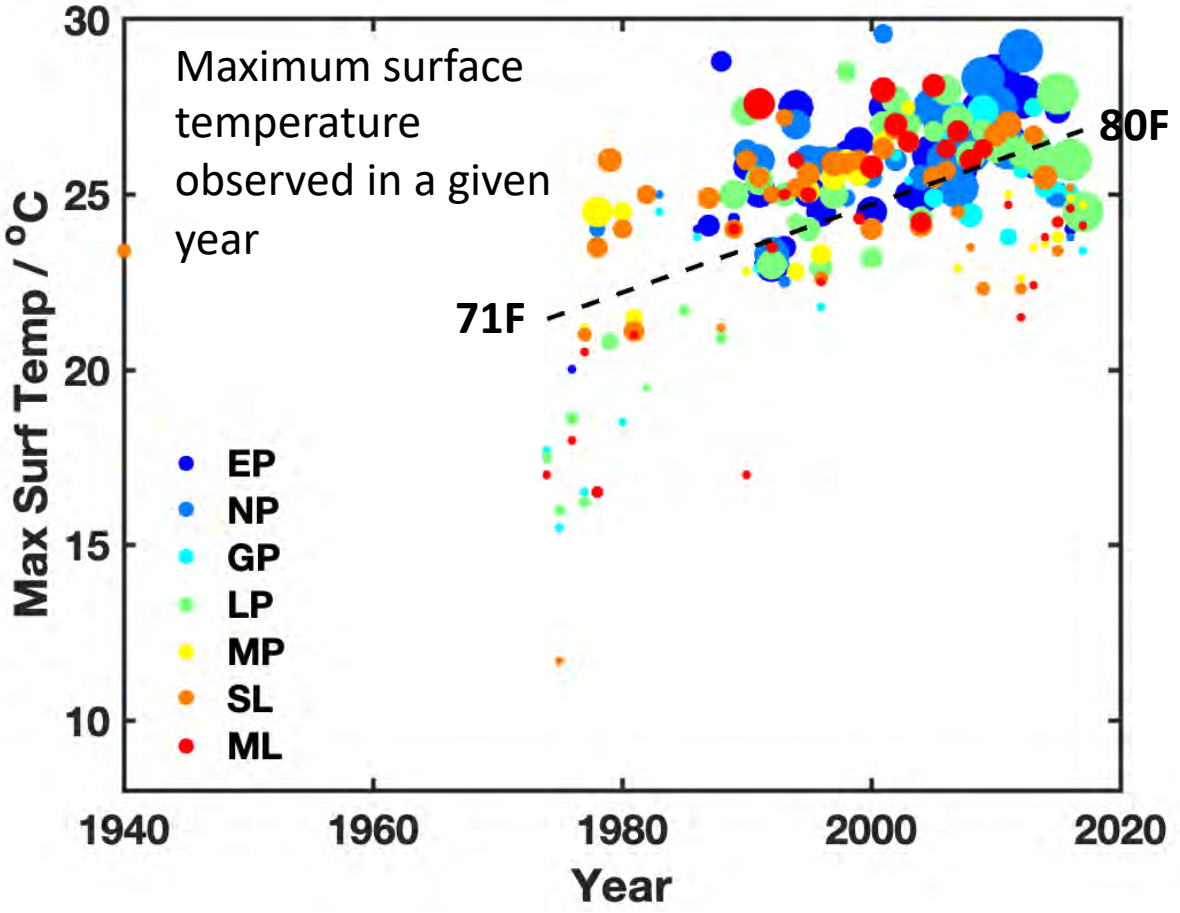




Surface Water Temperatures

Data below from Maine DEP, Lake Stewards of Maine



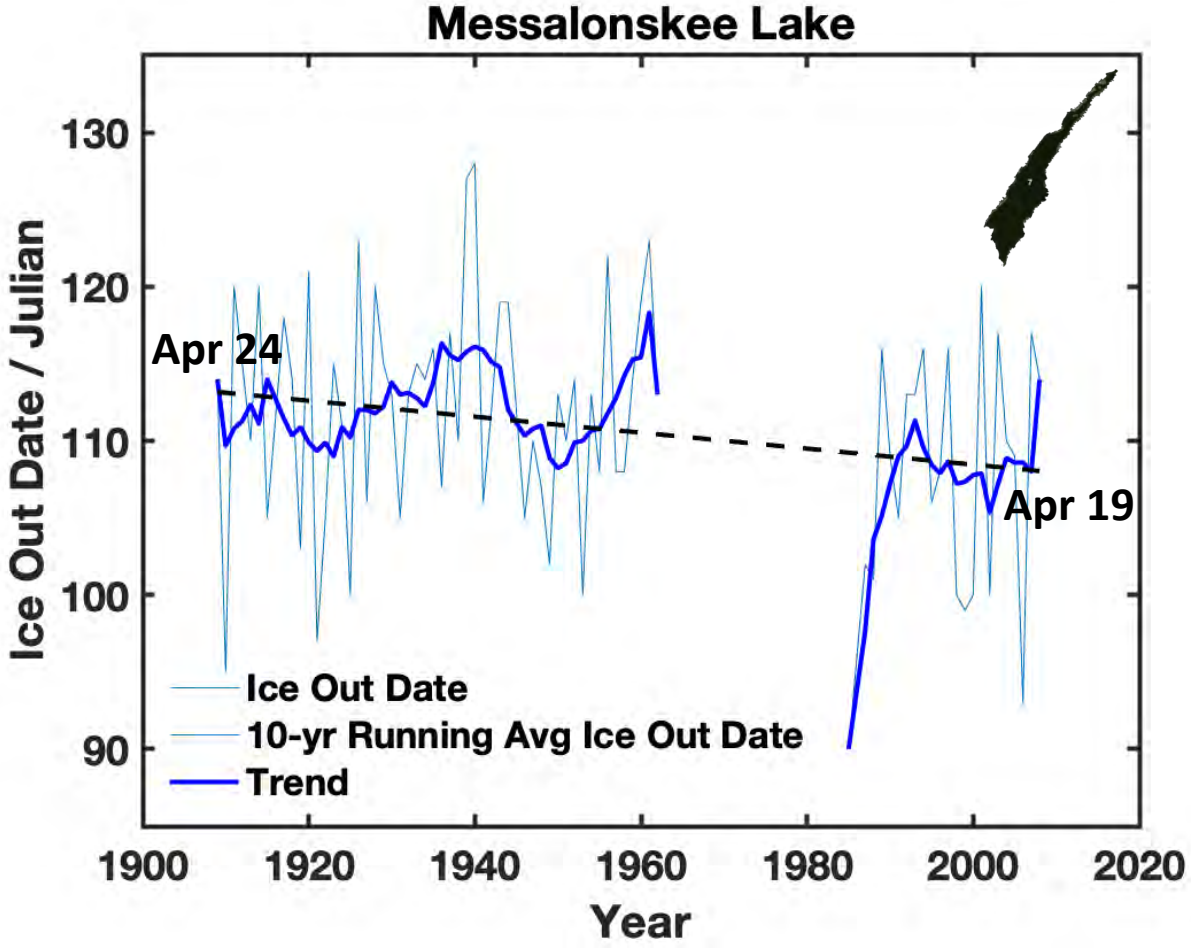


Average yearly surface temperature and maximum measured surface temperature appears to be increasing

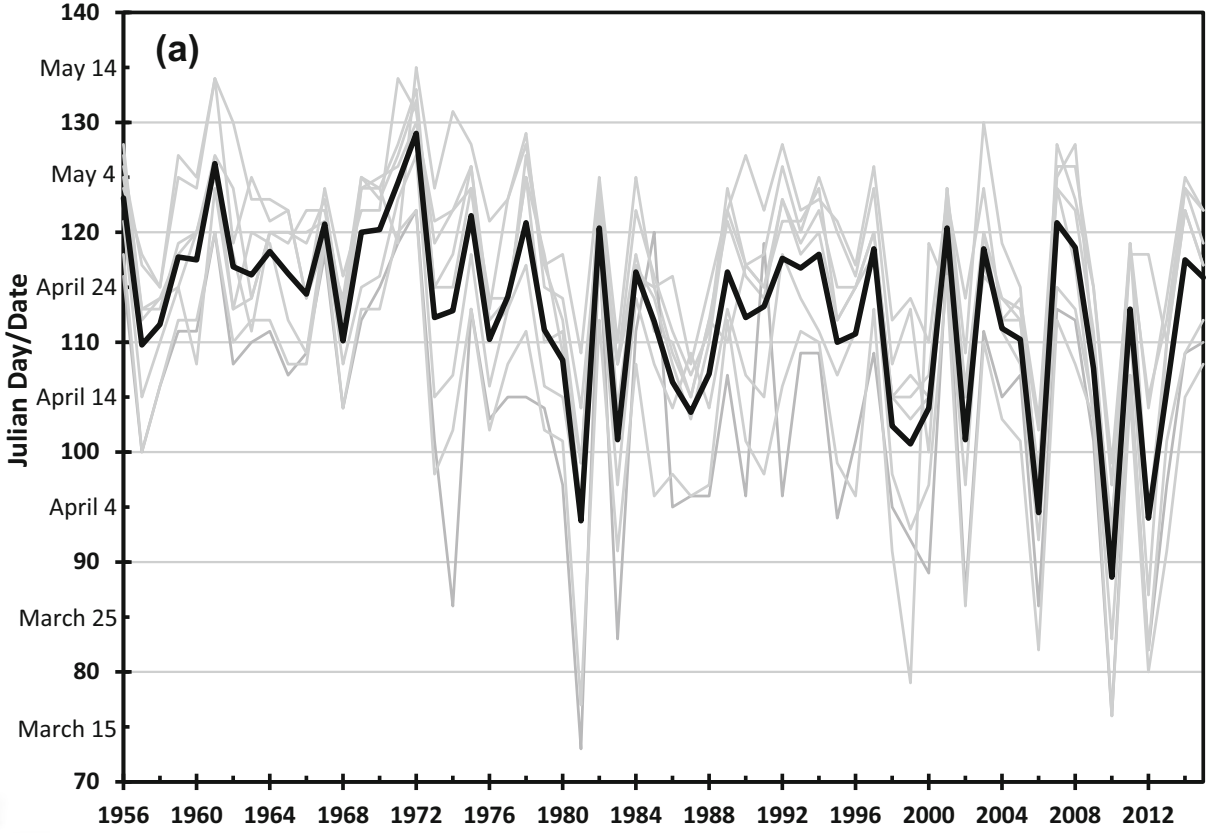
- Data has a bias towards the summer, which needs to be kept in mind

Ice Out Dates

Data below from USGS



Ellis and Greene (2019), Climactic Change – 8 lakes across Maine

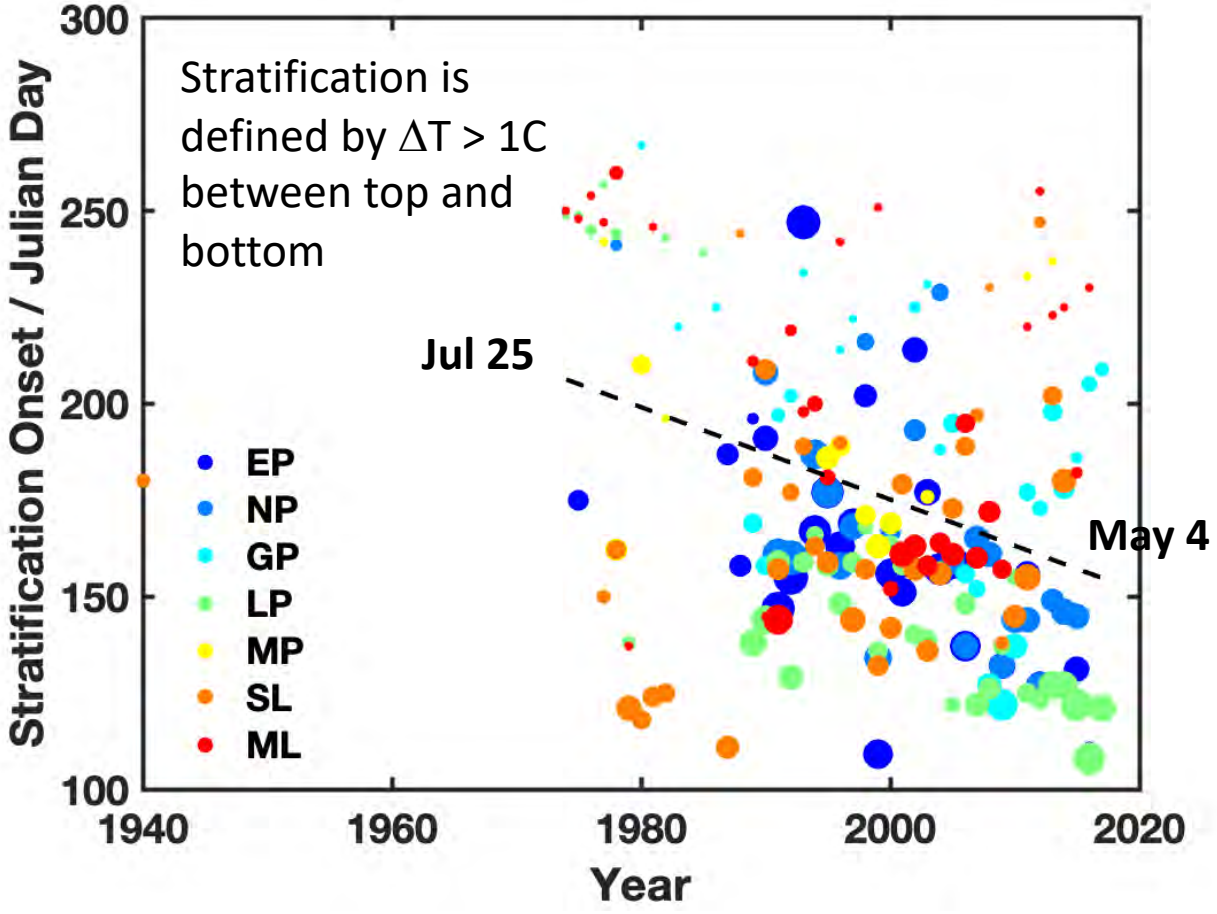


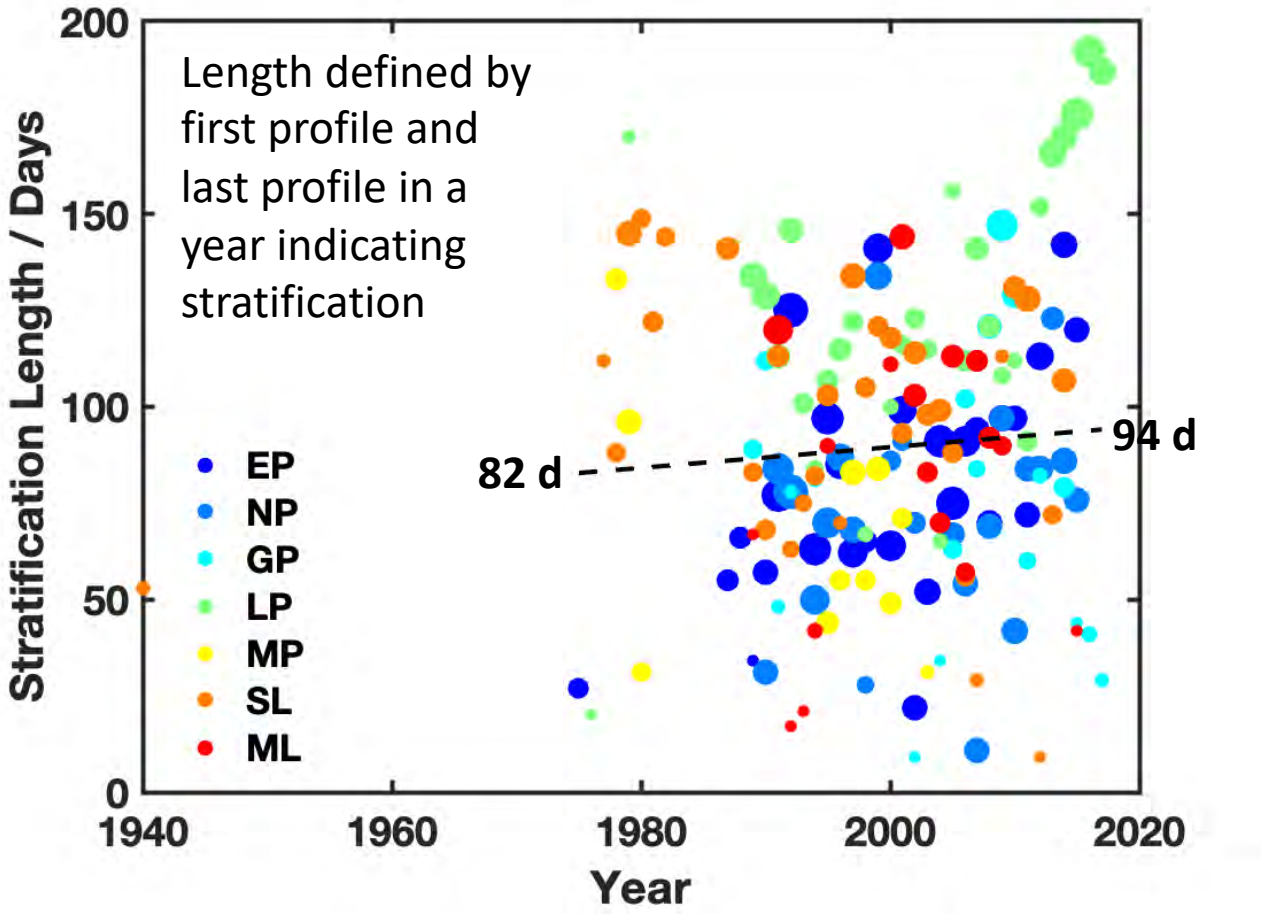
Ice out date on Messalonskee has become earlier in the last century, consistent with patterns seen across Maine

This allows warming of the surface waters starting earlier in the year, leading to earlier stratification

Stratification Onset and Length

Temperature Data from Maine DEP, Lake Stewards of Maine





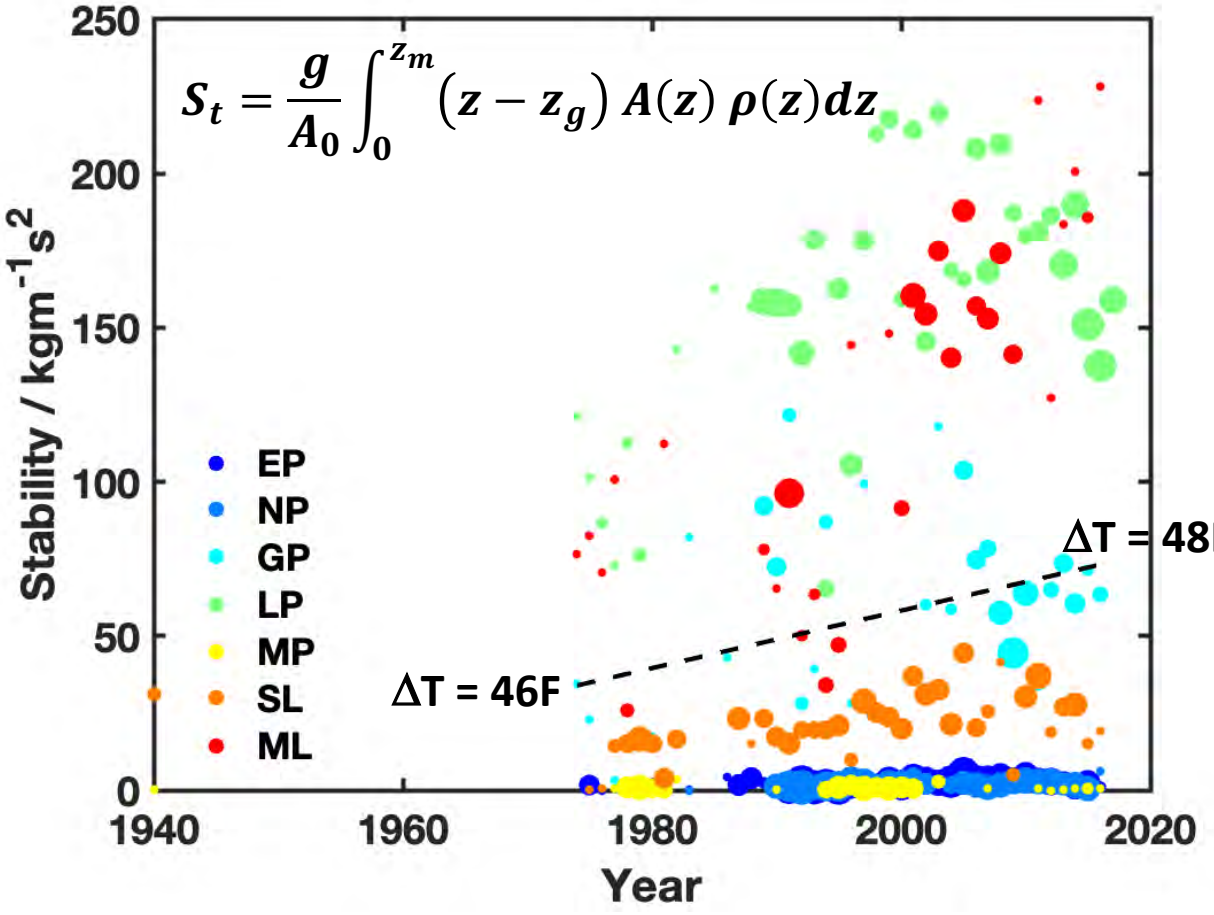
Stratification is beginning earlier and lasting longer.

➡ This isolates the lower layers of the lake from the atmosphere, preventing reoxygenation until mixing occurs

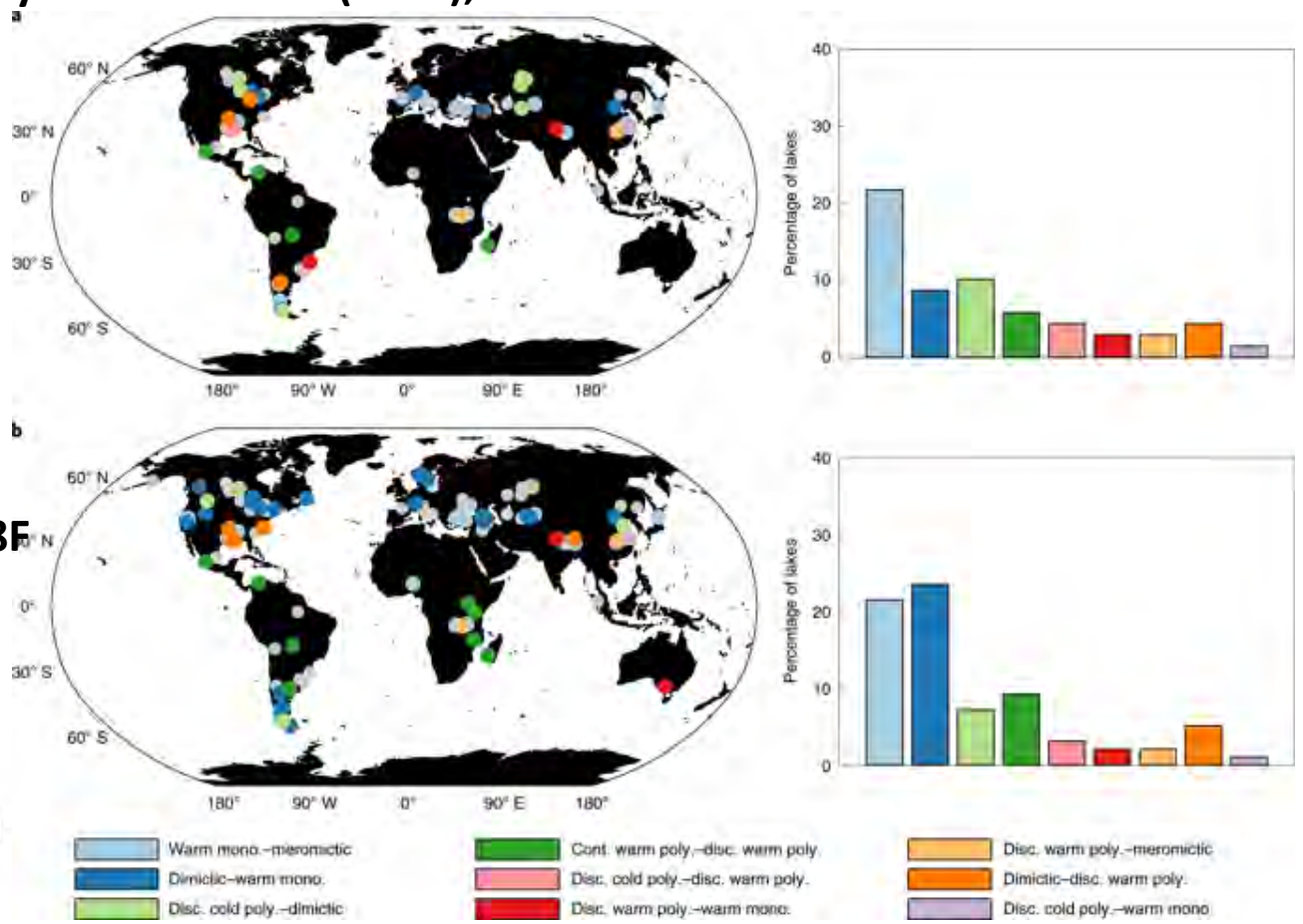
Stratification Strength (Stability Index)

Temperature Data from Maine DEP, Lake Stewards of Maine

$$S_t = \frac{g}{A_0}\int_0^{z_m}(z - z_g)\,A(z)\,\rho(z)dz$$



Woolway and Merchant (2019), Nature Geosciences – 635 lakes worldwide

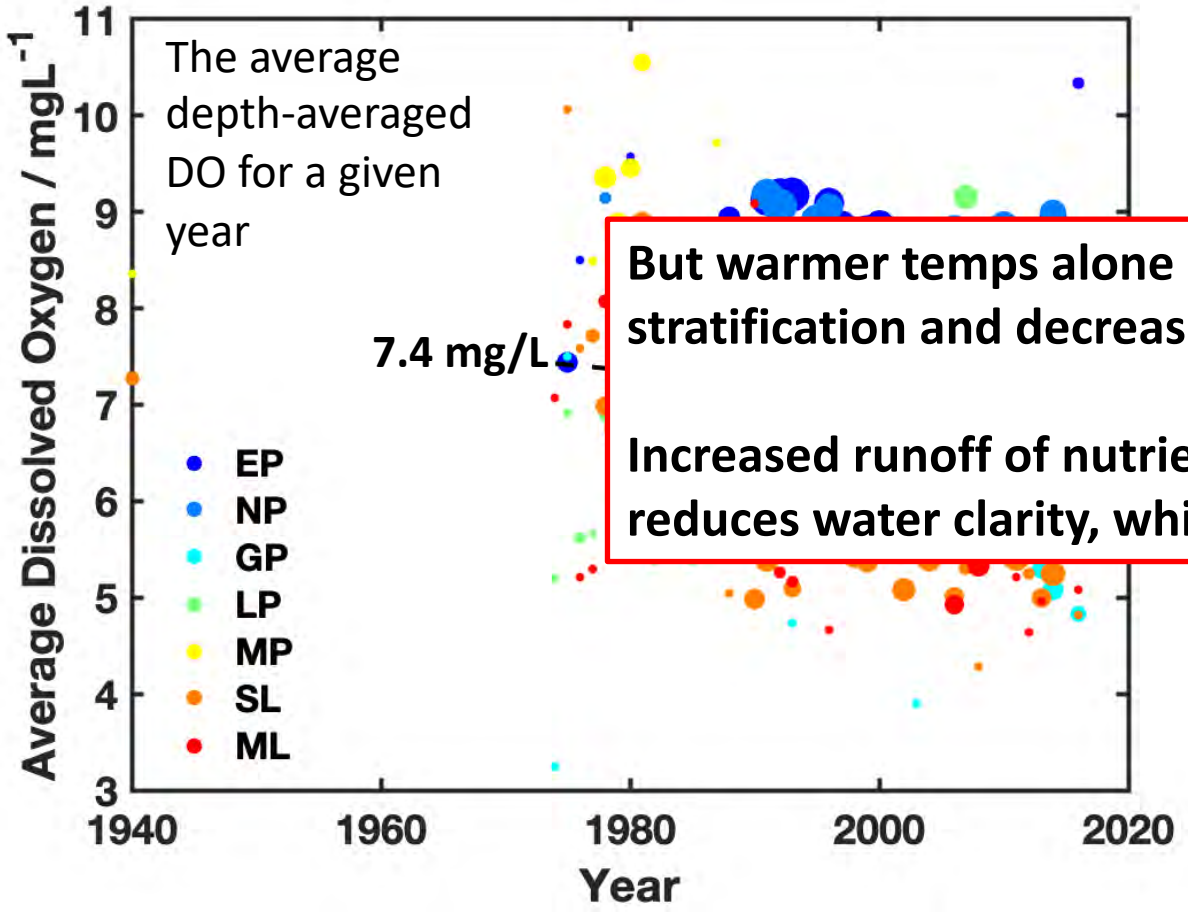


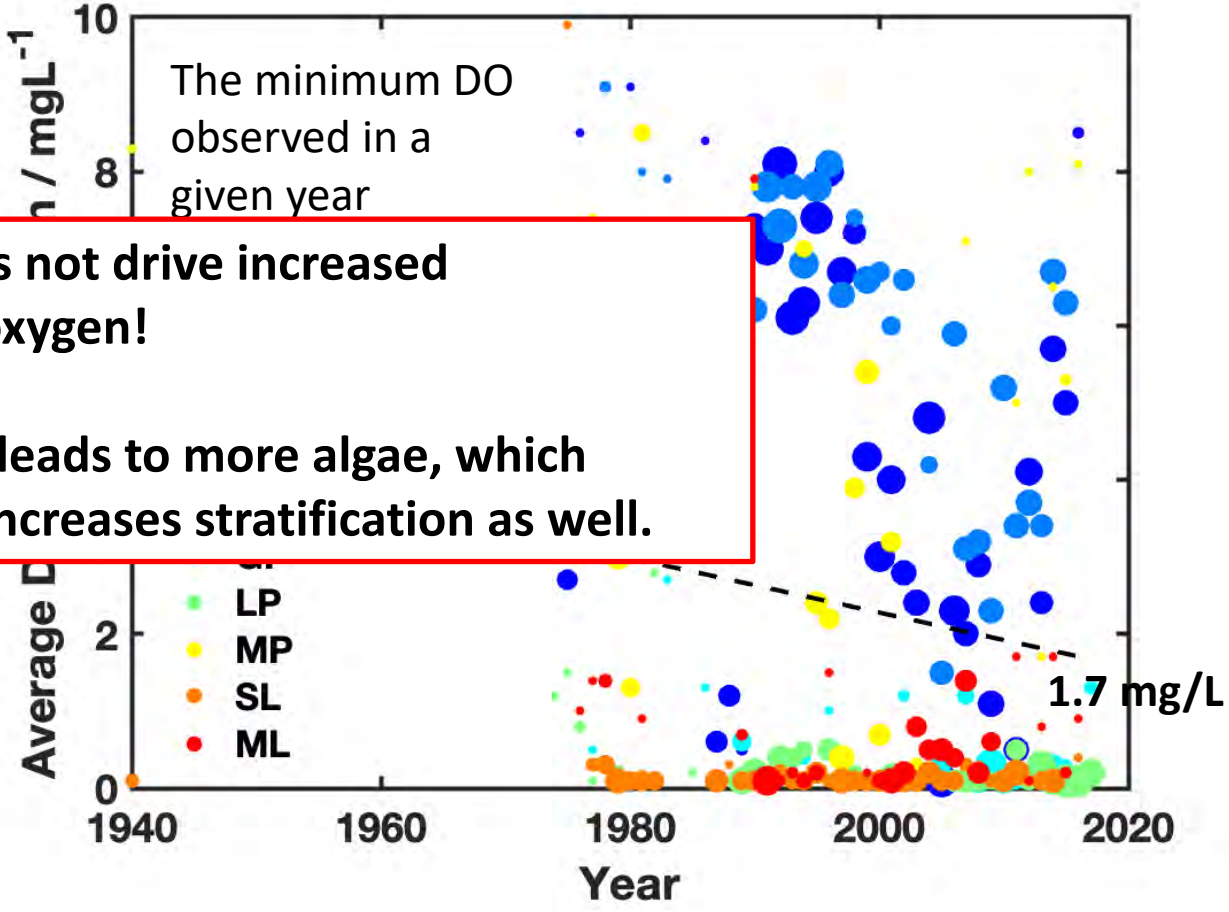
Stratified deep lakes will become more strongly stratified, while shallow lakes will have more stratified periods

➡ Climate mode projections indicate many lakes will see a shift in their mixing regimes by 2100

Dissolved Oxygen

Oxygen Data from Maine DEP, Lake Stewards of Maine





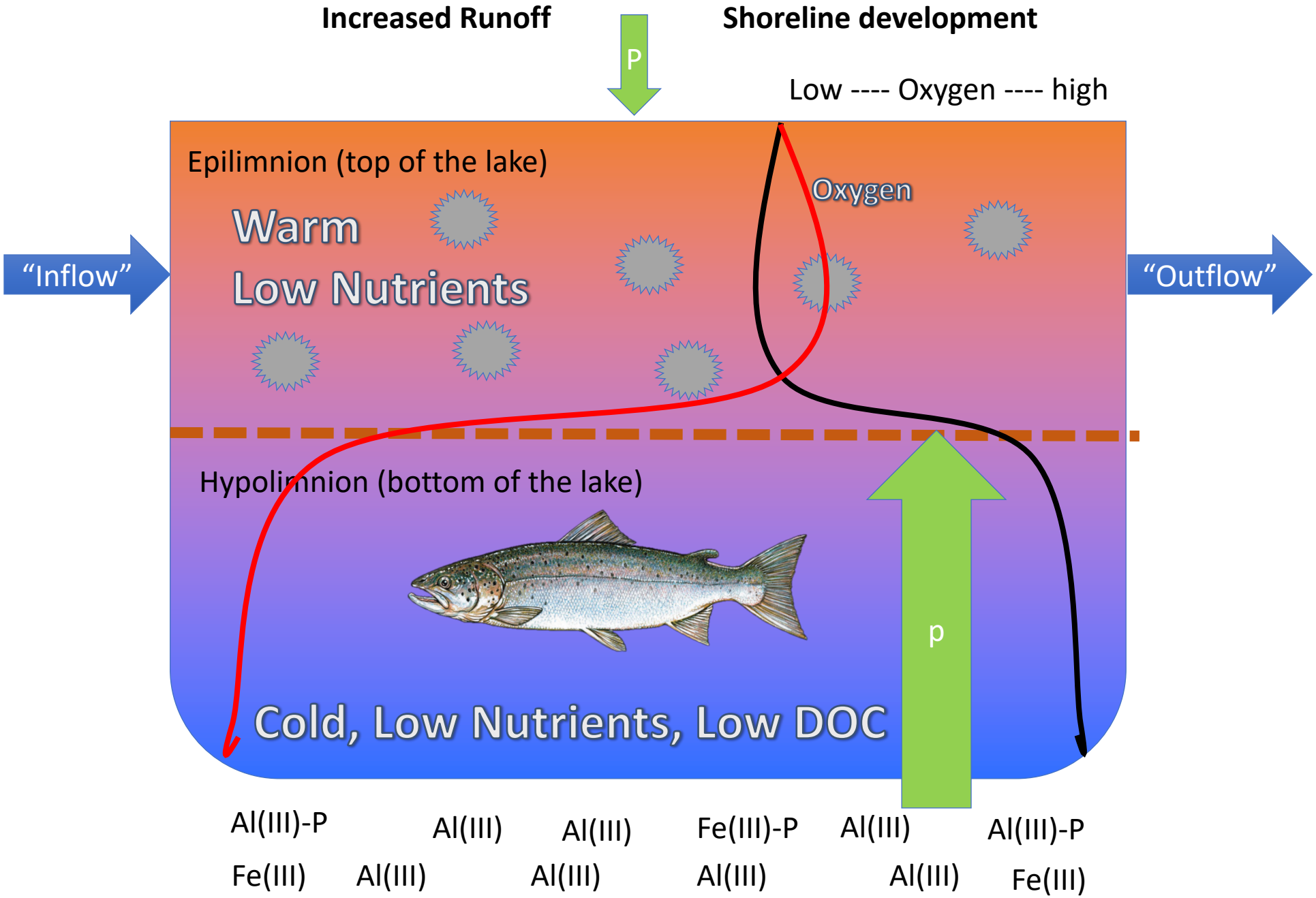
But warmer temps alone does not drive increased stratification and decreased oxygen!

Increased runoff of nutrients leads to more algae, which reduces water clarity, which increases stratification as well.

While average DO has declined, the minimum DO observed has declined more significantly

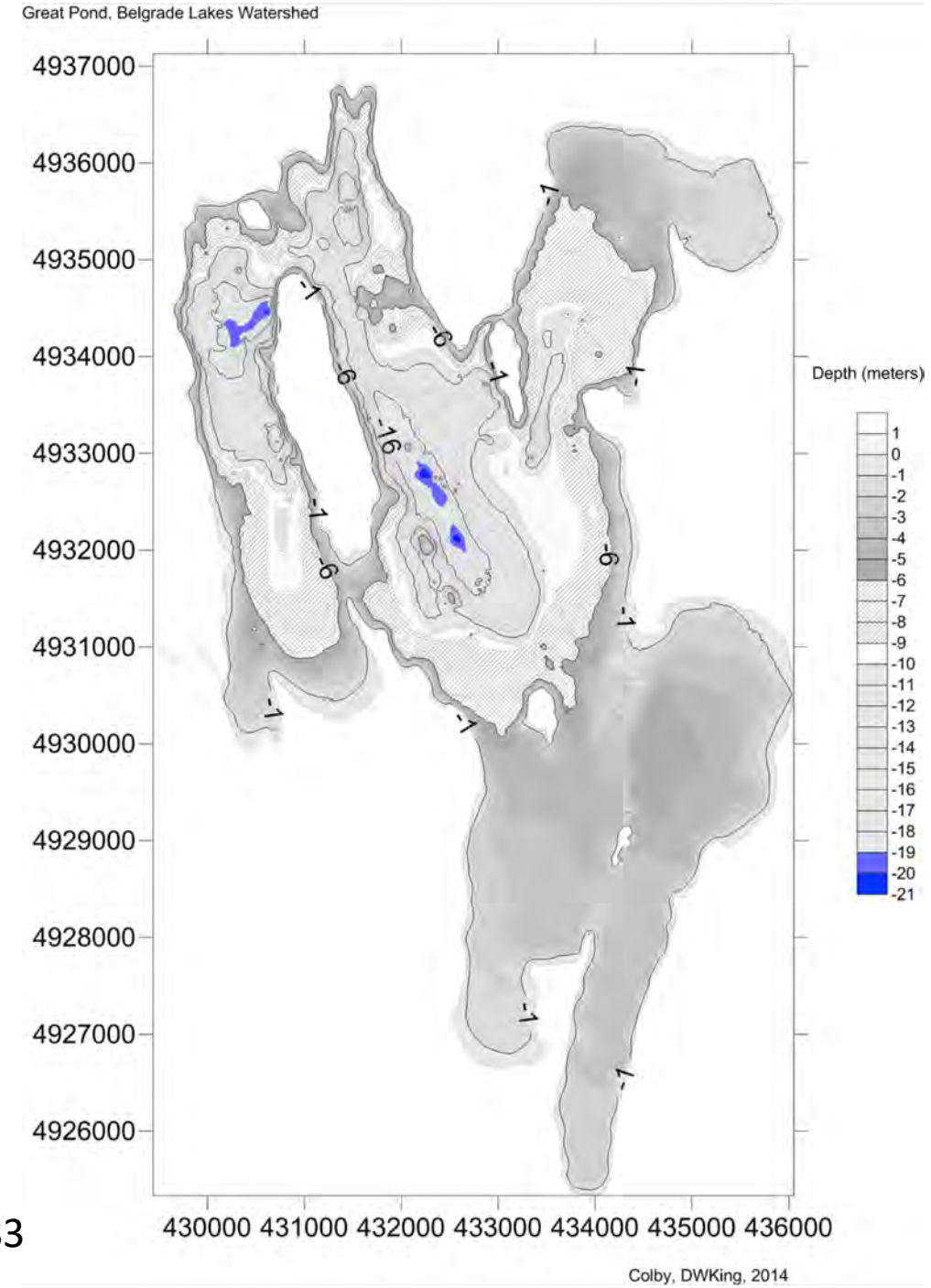
The difference between 3.2 and 1.7 mg/L is significant for water quality!

Lake Feedbacks



Has the water quality in the Belgrades Lakes declined in the last 20 years?

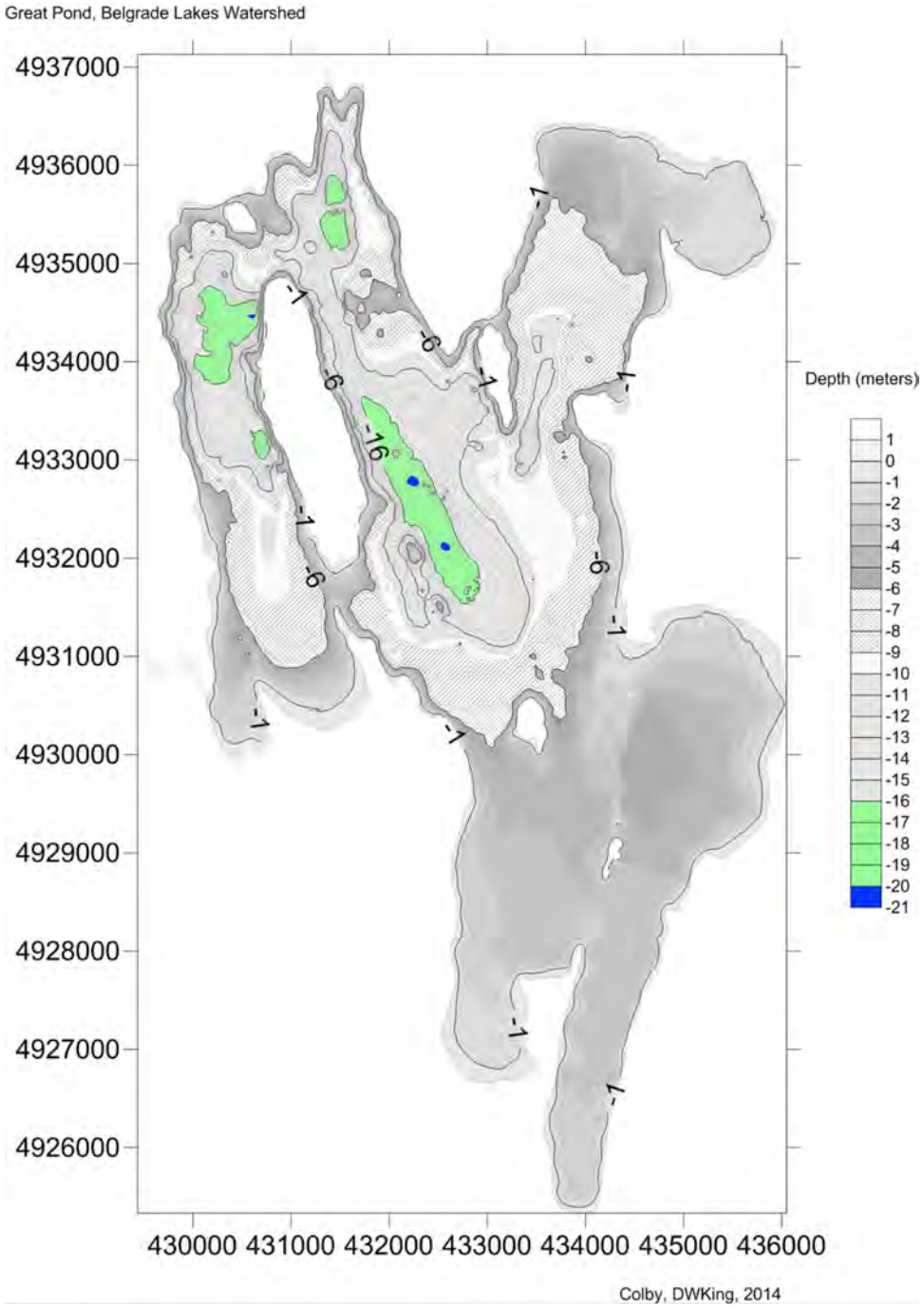
YES



Dead (Anoxic) Areas of Great Pond in 1983

Has the water quality in the Belgrades Lakes declined in the last 20 years?

YES

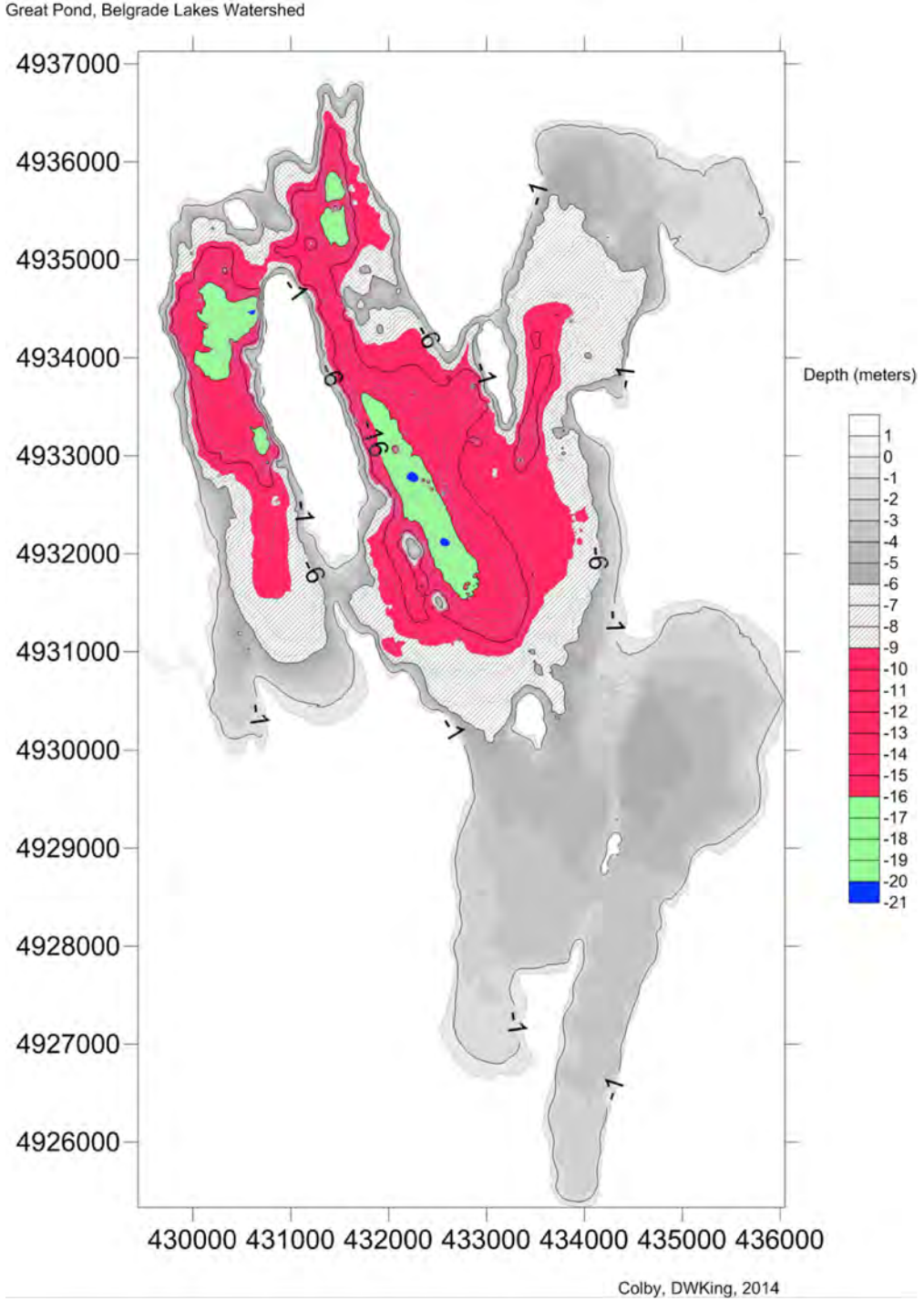


Dead (Anoxic) Areas of Great Pond in 1988

Has the water quality in the Belgrades Lakes declined in the last 20 years?

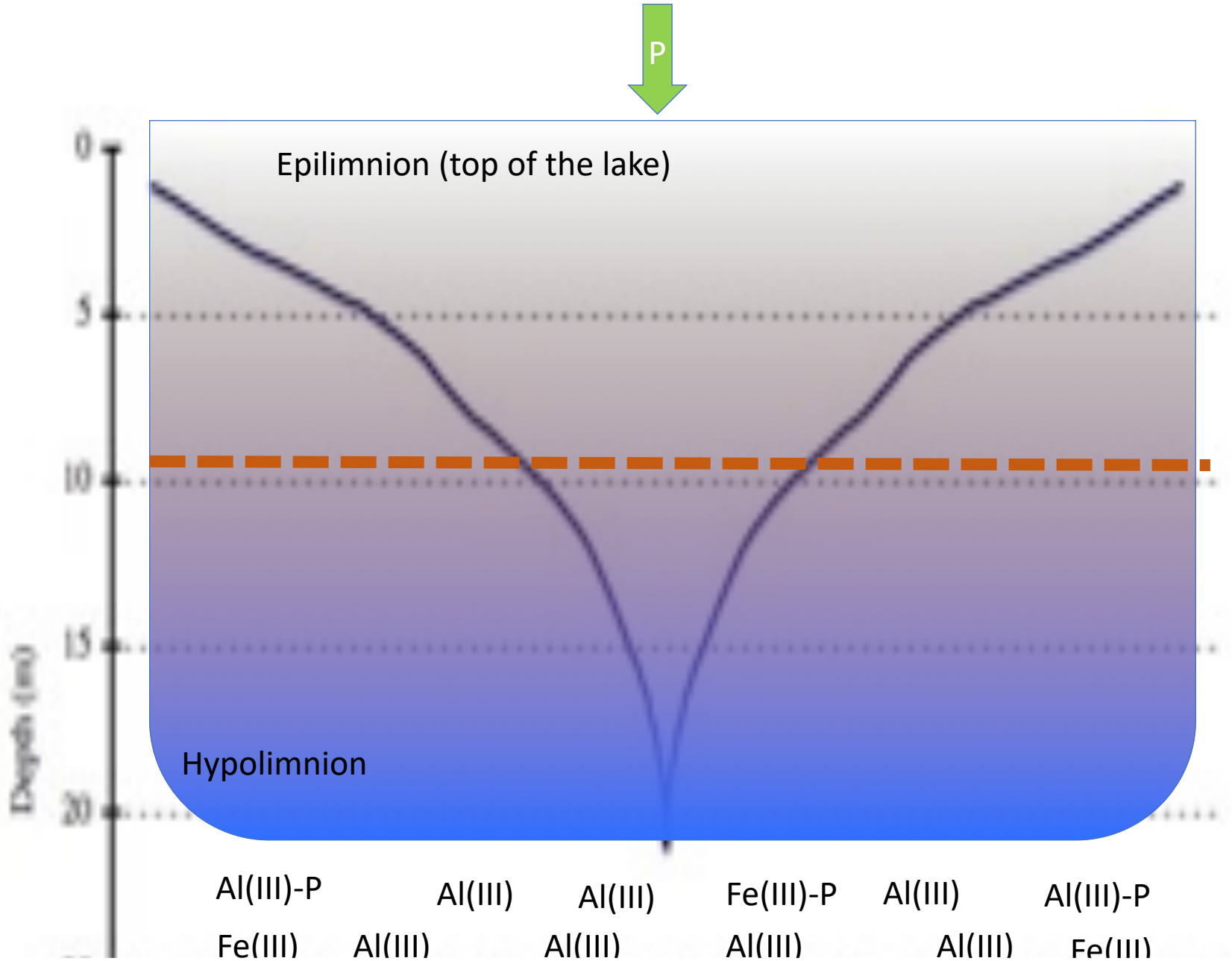
YES

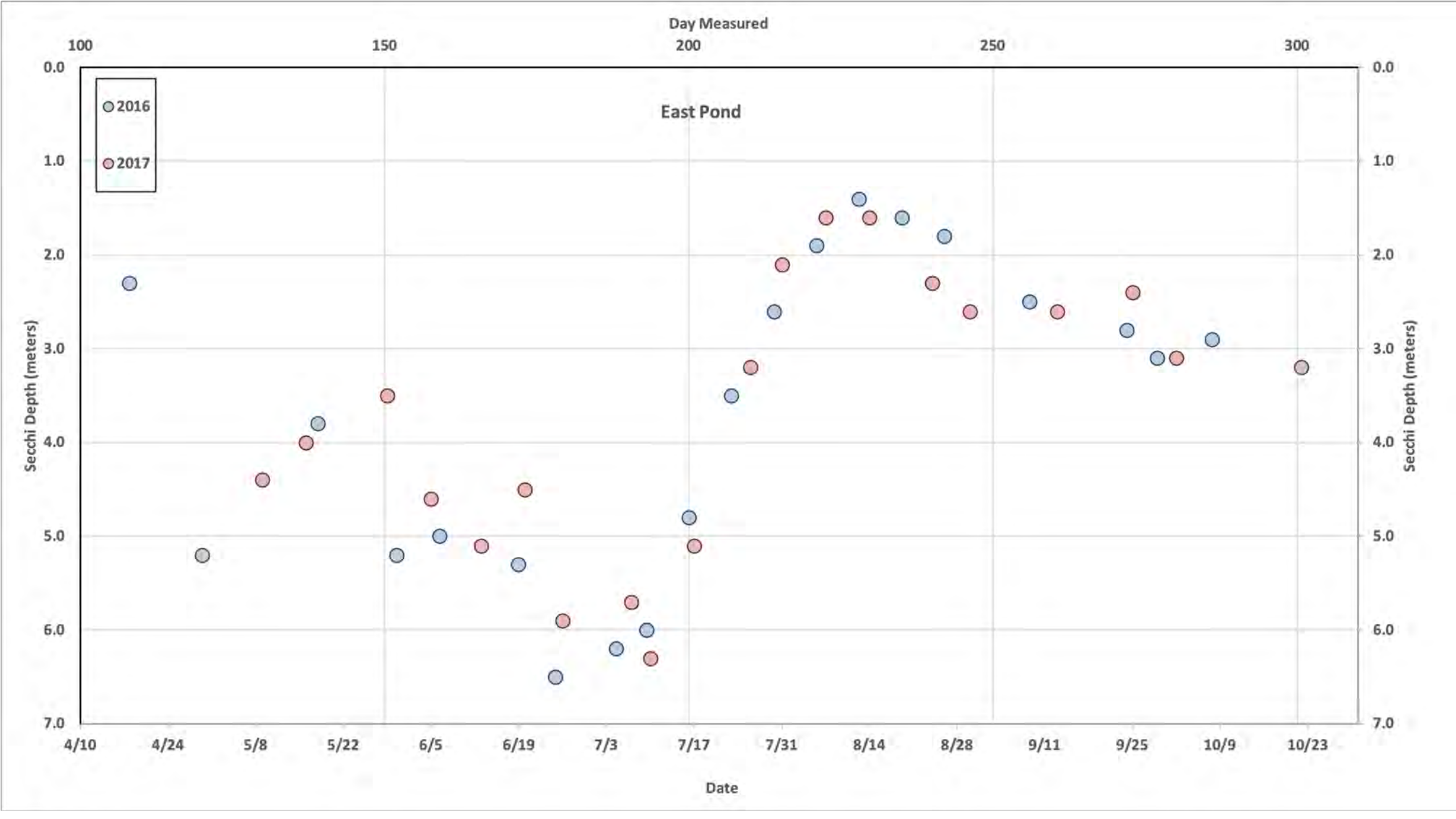
Anoxic extent is 35 times larger than 1989



Dead (Anoxic) Areas of Great Pond in 2015

Lake Feedbacks – Lakes are not LINEAR SYSTEMS




Day Measured
100
150
200
250
300
East Pond
2016
2017
Secchi Depth (meters)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
4/10
4/24
5/8
5/22
6/5
6/19
7/3
7/17
7/31
8/14
8/28
9/11
9/25
10/9
10/23
Date

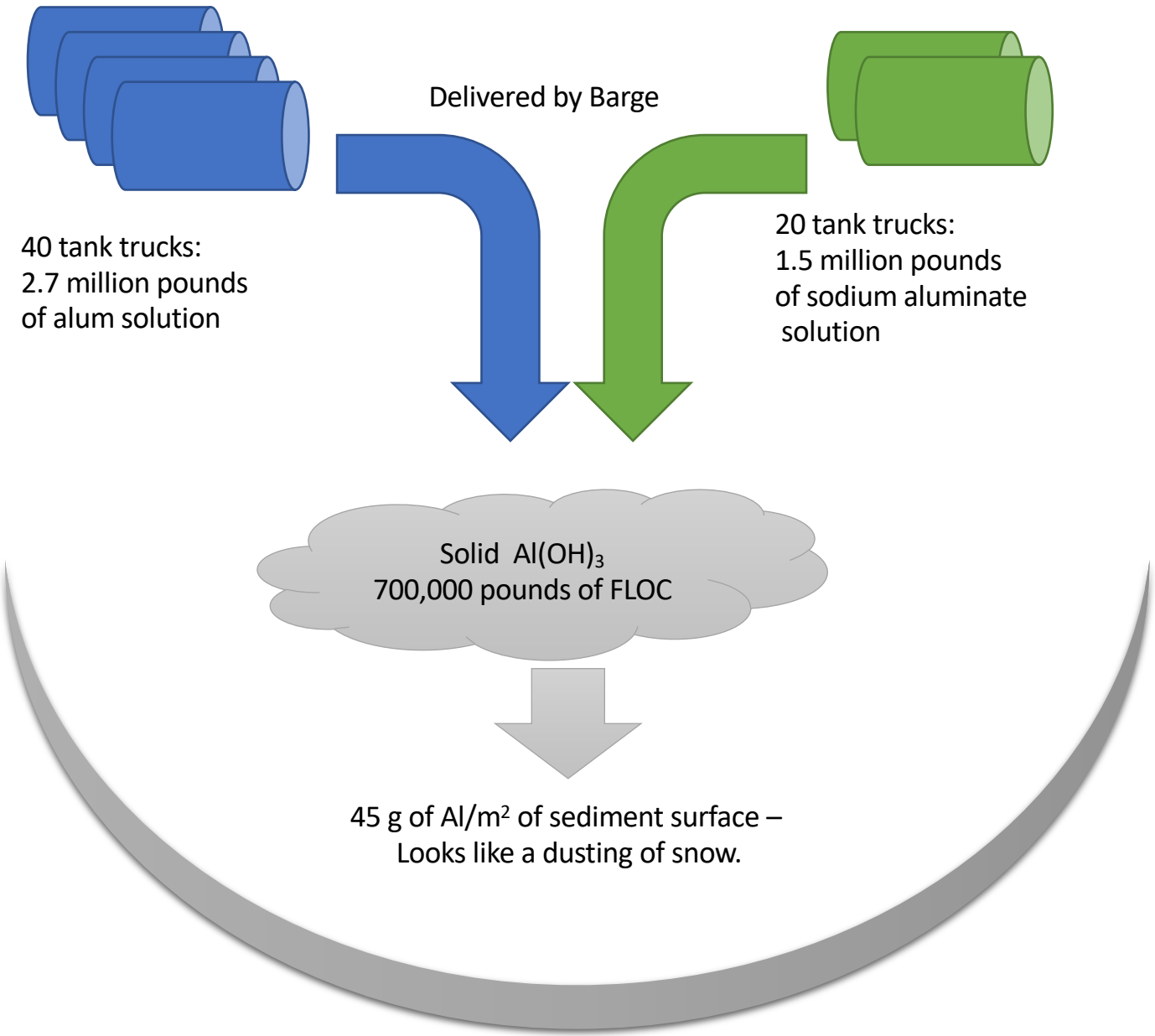
Phosphate retention mechanisms

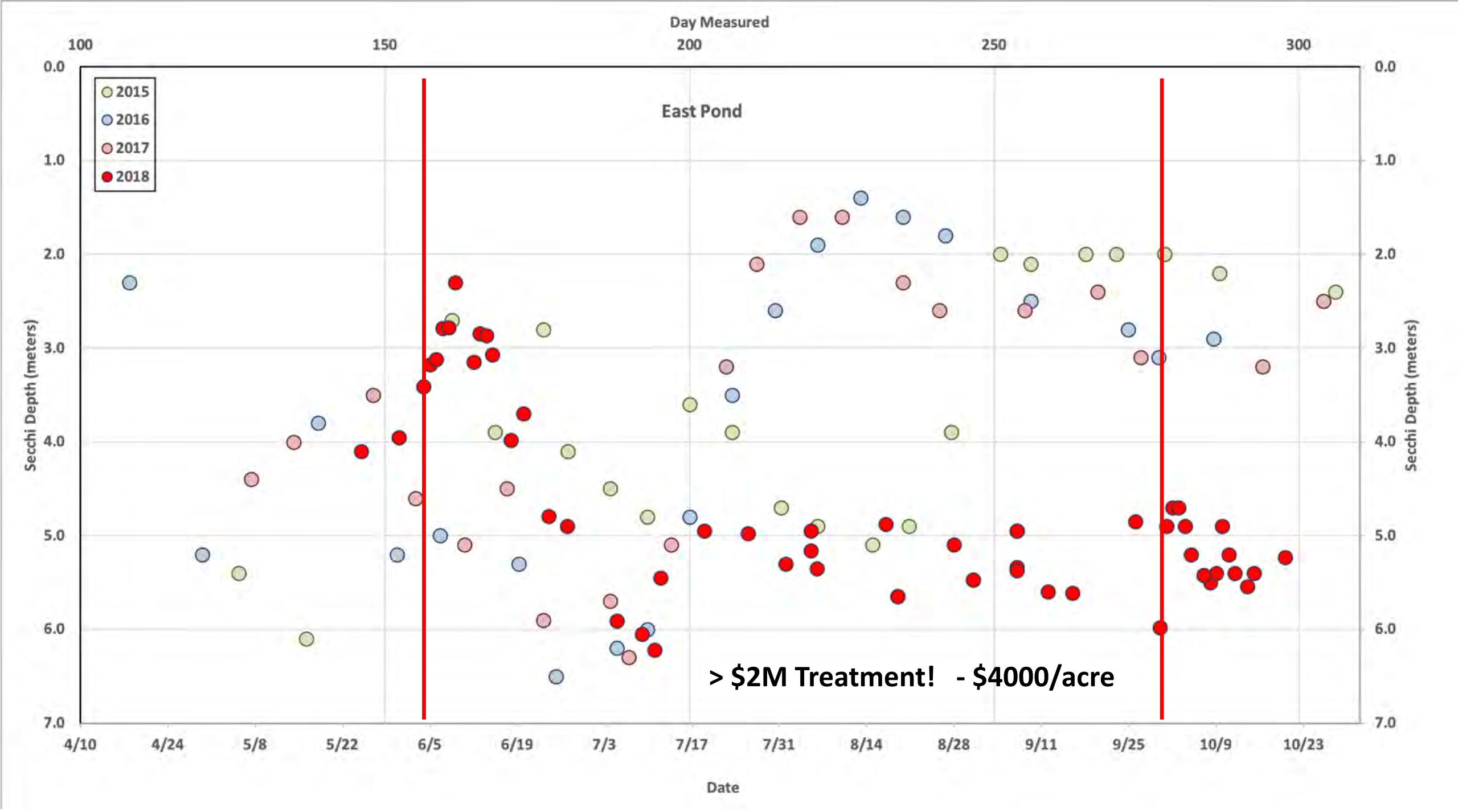
- East Pond's lake sediment has naturally present iron (III) and aluminum (III)
  - Both compounds are good Lewis acids, and bind to phosphate compounds, which controls the amount available to cyanobacteria
    - $Fe(OH)_3 + PO_4^{-3} \rightarrow Fe(OH)_3 * PO_4(s)$
    - $Al(OH)_3 + PO_4^{-3} \rightarrow Al(OH)_3 * PO_4(s)$
  - However, not all Lewis acids are equally effective – we used the redox inactive meteal Al(III).

Wagner, K. J. *The practical guide to lake management in Massachusetts: a companion to the final generic environmental impact report on eutrophication and aquatic plant management in Massachusetts*; Commonwealth of Massachusetts, Executive Office of Environmental Affairs: Boston, 2004.

Amirbahman A, Lake BA, Norton SA (2012) Seasonal phosphorus dynamics in the surficial sediment of two shallow temperate lakes: a solid-phase and pore-water study. Hydrobiologia 701:65–77. doi: 10.1007/s10750-012-1257-z

Alum by the Numbers




Day Measured
100
150
200
250
300
East Pond
2015
2016
2017
2018
Secchi Depth (meters)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
4/10
4/24
5/8
5/22
6/5
6/19
7/3
7/17
7/31
8/14
8/28
9/11
9/25
10/9
10/23
Date
> $2M Treatment! - $4000/acre

Climate Change in Maine's Lakes:
Possible Policy Implications

Climate Issues

- Changes in precipitation
  - Decreasing pH , more frequent intense storms, increased DOC, flood events, higher stormwater flows and sediment loading
- Ice in-Ice out, warming temperatures
  - Longer growing season, longer stronger stratification, hypolimnetic anoxia, decreased coldwater refugia for salmonids, enhanced likelihood of internal loading, cyanobacteria, invasive species

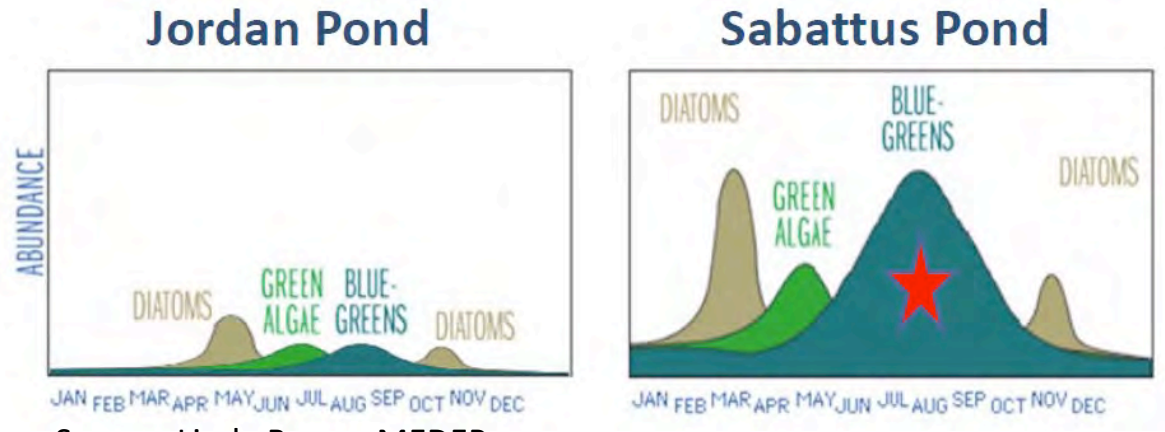
Invasive Aquatic Species strategies

- Expand Courtesy Boat Inspections (CBI) and mitigation
  - More hours, longer season
  - More species (plants, fish, mollusks)
  - Advanced decontamination (e.g., bleach, vinegar)
  - Riparian threats (e.g., Hemlock woolly adelgid)

- LD 235- Increases sticker fee
  - $10 to $15 for Residents $25 to $45 for Nonresidents
- LD 945- Increased funding to VLMP and MLS
  - Potential integration of LakeSmart and “Eyes on the water” and “Adopt-a-shoreline.”

Harmful Algal Blooms

- Cyanobacteria
  - Potential neurotoxins, hepatotoxins
  - BMAA possible ALS association



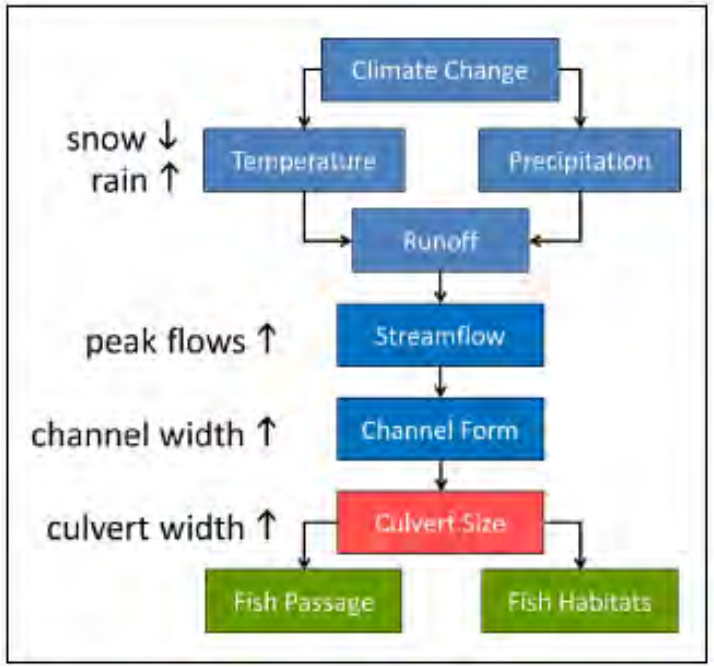
Source: Linda Bacon MEDEP

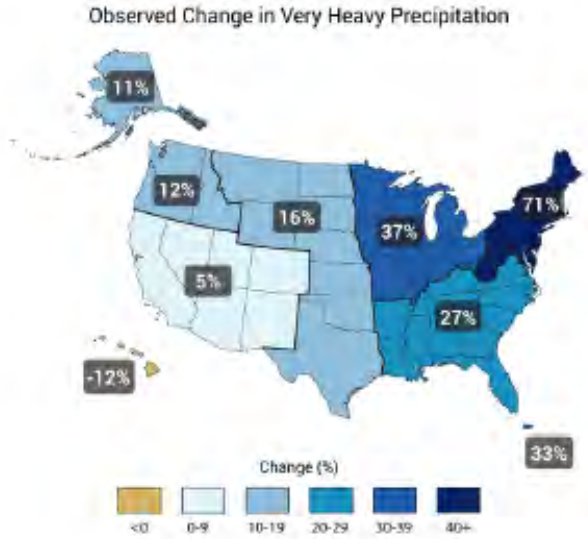
- Prevention: reduce nutrient loading, especially P and N
- Detection: Need enhanced and more monitoring (Drinking water/recreational standards)
  - USEPA Region 1 Tiered monitoring program (Hilary Snook)
    - **Bloomwatch APP** (Smartphone app to submit photos of blooms)
    - **Cyanoscope** (Fluorometer kit to collect samples and upload photos for ID)
    - **Cyanomonitoring** by network of citizen scientists to identify factors and vulnerabilities
- Advisory warnings: Need refined reporting and warning system

Get involved with Lake Stewards of Maine VLMP
Contact congressional representatives to restore proposed EPA budget cuts and protect the Clean Water Rule!
Comment on proposed changes to Waters of the United States (WOTUS).

Coping with Increased Stormwater Runoff

- Need bigger, wider culverts
- Fish passage!
- Need wider, more biodiverse riparian buffers
- More emphasis on slowing, spreading overland flows, avoiding concentration
- Minimize impervious surfaces
- Infiltration BMPs
- More vegetation
- Conserving forest lands in lake watersheds
- Green Infrastructure



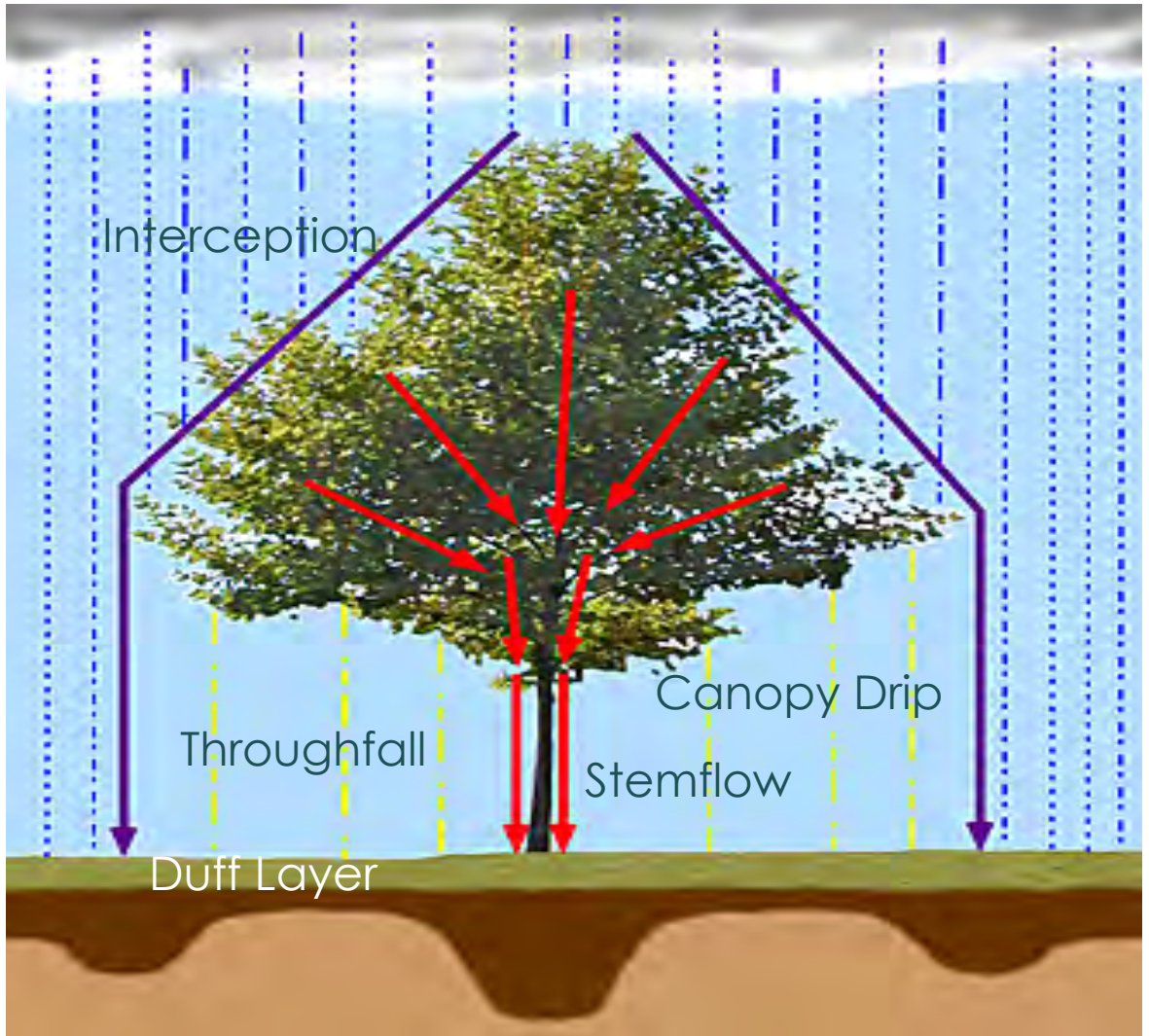


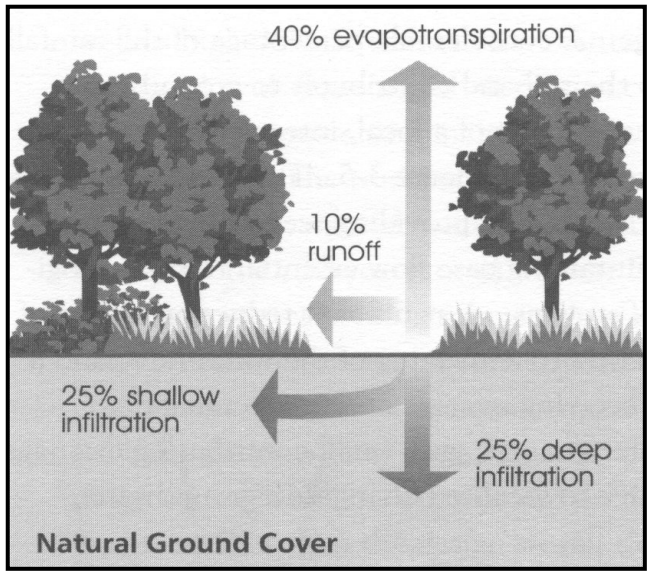
Riparian Buffer Tax Incentives

- Virginia (Forest land along waterways)
  - 25% of value of timber (25-300ft wide for 15 years) up to $17,500
- Burnett Co., WI: Shoreland Incentive Program (Property tax credit)
  - Natural shoreline (35 ft wide) $250 enrollment, $50 annually thereafter (FB)
- Maryland Buffer Incentive Program-Chesapeake Bay
  - $300/acre to plant forest buffer (65% survival) max $15,000
- Oregon Riparian Lands Tax Incentive Program (200 miles per Co) 100ft
  - Property tax exempt with approved management plan and TIP agreement
- MN State wide conservation and preservation plan
- SD Ag land valued at 66% within 120 ft of waterways, grazing restrictions
- EQIP –Natural Resources Conservation Service (NRCS)

Transpiring Recyclable Energy Efficient Stormwater System

TREES





Buffers and Shoreland Zoning

The roots of the willows do not suffer the banks of the canals to be destroyed; and the branches of the willows, nourished during their passage through the thickness of the bank and then cut low, thicken every year and make shoots continually, and so you have a bank that has life and is of one substance.

-Leonardo Da Vinci (1452-1519)

Summary

- Quality Data is key
- How we collect data matters – ice in to ice out profiles, winter data
- Shallow lakes need to be sampled at greater than 1 m with pressure sensor
- Changes in the lake are a complex nonlinear function of climate and land use
- We see different things because lakes are different!
- Don’t ignore the human dimension in developing solutions

Paying for infrastructure

- MA- Proposed 1% increase in Real Estate Transfer Tax
- ME- Clean Water State Revolving Fund (CWSRF)
  - Funded by Maine Municipal Bond Bank and USEPA ($50M approved last year)
  - ME is #46 in capital spending as a % of state budget (7%)
- NJ- NJ Environmental Infrastructure Financing Program
  - Clean Water State Revolving Fund (CWSRF) Administered by NJDEP
    - Corporate business tax- NJ Infrastructure Bank
    - Help municipalities, MUAs, Counties, Water groups
    - Coordinate with USEPA CWA funding

Technical Data Sheet

USALCO® Acid Alum

Aluminum Sulfate Solution, 7% Free Acid

USALCO Acid Alum is an aqueous solution manufactured by dissolving alumina tri-hydrate (ATH) into water and sulfuric acid. The use of only stringently selected raw materials and state-of-the-art manufacturing practices ensures that USALCO Acid Alum is of the highest quality. USALCO Acid Alum meets the specifications of the American Water Works Association Standard B403-16 and complies with the requirements of NSF/ANSI 60: Drinking Water Treatment Chemicals -Health Effects at a maximum dosage of 150 mg/L.

PROPERTIES

Appearance:	Clear to amber or light green liquid.
Specific Gravity @60°F:	1.28 - 1.30
Product Weight:	10.65 - 10.85 Lbs/Gal
pH (neat):	0.2 - 1.0
Freezing Point	0° - 10°F

SPECIFICATIONS

% Al_2O_3:	5.8 - 6.2
%Acidity	6.8 - 8.0
Total Soluble Iron (Fe_2O_3)	50 ppm max

PRINCIPAL USES

Drinking water / wastewater treatment – removal of suspended matter and phosphorus.

Wastewater treatment – coagulant / flocculent for the removal of suspended matter and phosphorus.

Pulp and paper manufacturing – retention and drainage aid, charge neutralization, pH control, improved sizing efficiency.

Catalyst manufacturing

Food industry – firming agent in pickle processing

SAFETY / HANDLING

Observe caution when handling corrosive materials. Please consult the safety data sheet (SDS) for safety and handling precautions.

DELIVERY

Tank trucks and railcars.

PRODUCTION

USALCO has production facilities in:

- Baltimore, Maryland
- Fairfield Ohio
- Michigan City, Indiana
- Gahanna, Ohio
- Port Allen, Louisiana

CUSTOMER SERVICE

If you have any questions concerning this material, please contact our Inside Sales Department at:

410-918-2230 or **info@usalco.com**

Technical Data Sheet

USALCO® 38

Sodium Aluminate Solution, 38% Solids

USALCO 38 is an economical source of highly reactive alumina manufactured by dissolving alumina tri-hydrate (ATH) into sodium hydroxide and water. USALCO 38 is also stabilized to prevent alumina from precipitating. The use of only stringently selected raw materials and state-of-the-art manufacturing practices ensures that USALCO 38 is of the highest quality. USALCO 38 meets the specifications of the American Water Works Association Standard B405-16 and complies with the requirements of NSF/ANSI 60: Drinking Water Treatment Chemicals -Health Effects at a maximum dosage of 105 mg/L.

PROPERTIES

Chemical Formula:	$Na_2Al_2O_4$
Appearance:	Amber Liquid
Specific Gravity @60°F:	1.46 - 1.49
Product Weight::	12.18 - 12.43 Lbs./Gal
pH (neat):	14
pH (1% solution):	>11.5
Viscosity (cps):	155 @25C
	80@45C

SPECIFICATIONS

% Al_2O_3:	19.5 - 20.5
% Na_2O:	17.9 - 19.1
% $Na_2Al_2O_4$:	31.4 - 33.0
Molar Ratio (Na_2O / Al_2O_3):	1.48 - 1.54
Iron:	200 ppm, max
Silica:	225 ppm, max

PRINCIPAL USES

Drinking water / wastewater treatment – removal of suspended matter and phosphorus.

Catalyst, zeolite, molecular sieve manufacturing.

Coating for titanium dioxide pigments.

Pulp and paper manufacturing – pitch control and sizing agent.

SAFETY / HANDLING

Observe caution when handling corrosive materials. Please consult the safety data sheet (SDS) for safety and handling precautions.

DELIVERY

275 gallon IBCs (totes), tank trucks and railcars

PRODUCTION

USALCO has production facilities in:

- Baltimore, Maryland
- Fairfield, Ohio
- Michigan City, Indiana
- Ashtabula, Ohio
- Port Allen, Louisiana

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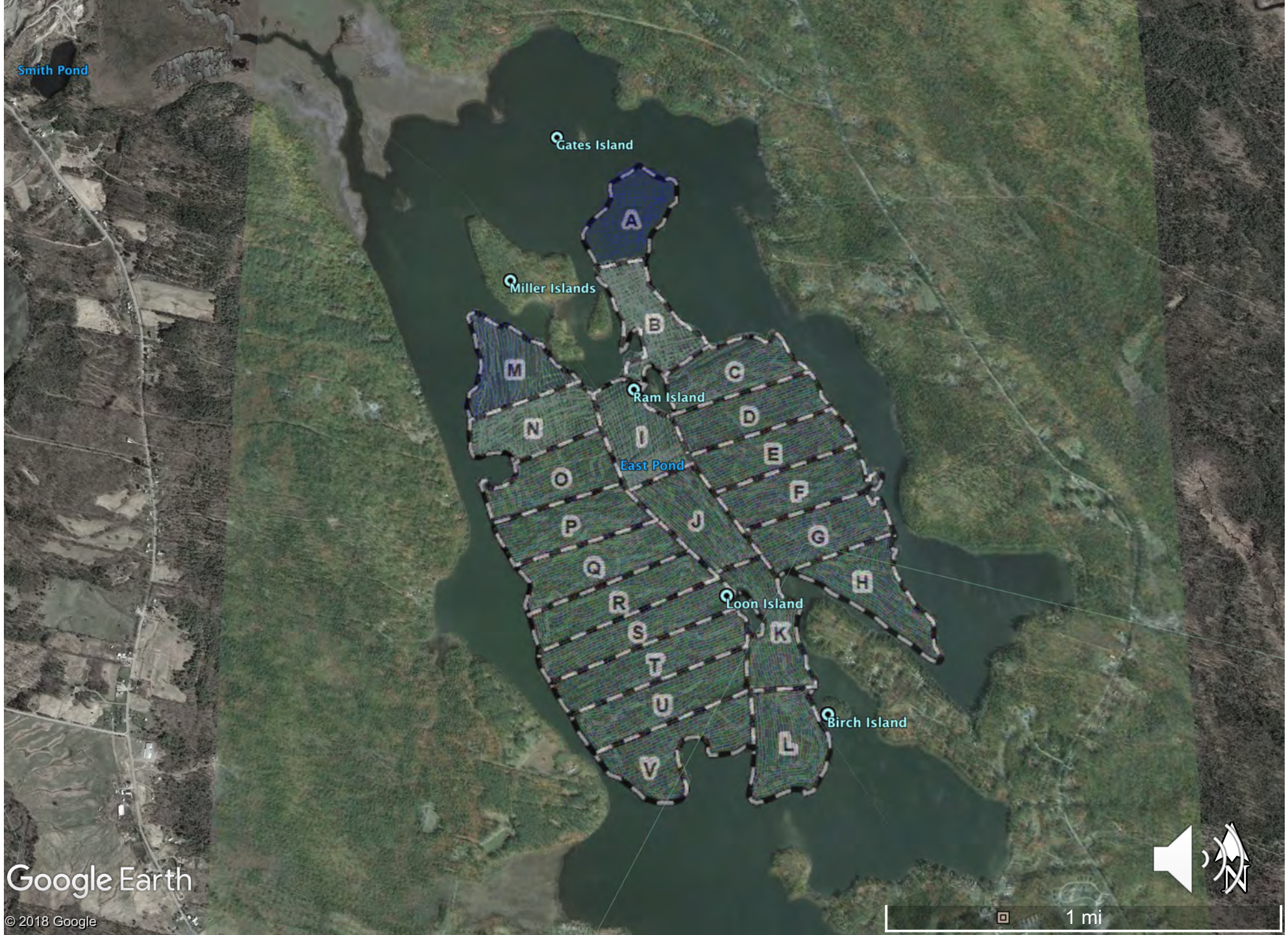
Smith Pond
Gates Island
Miller Islands
Ram Island
East Pond
Loon Island
Birch Island
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
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U
V
Google Earth
© 2018 Google
1 mi

We are not adding CHEMICALS! We are restoring Natures balance!

Acknowledgements

Abbey Sykes ’21 and Guillermo Picó Oms ‘19

Betsy and Jerry Tipper

Danielle Wain
and Charlie Baeder

East Pond Association (150 private donations)

2018 Belgrade Lakes summer research group

US EPA and Maine DEP

Team Alum 2018

7 Lakes Alliance

Ken Wagner

Harold – Alfond Foundation

Footage by Tim Stonefield