The Effect of Agriculture on Harmful Algal Blooms

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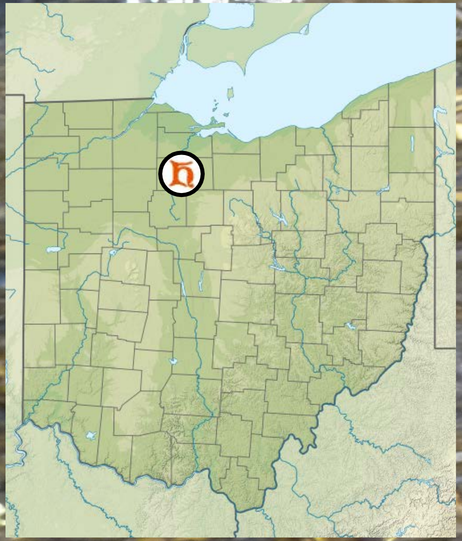

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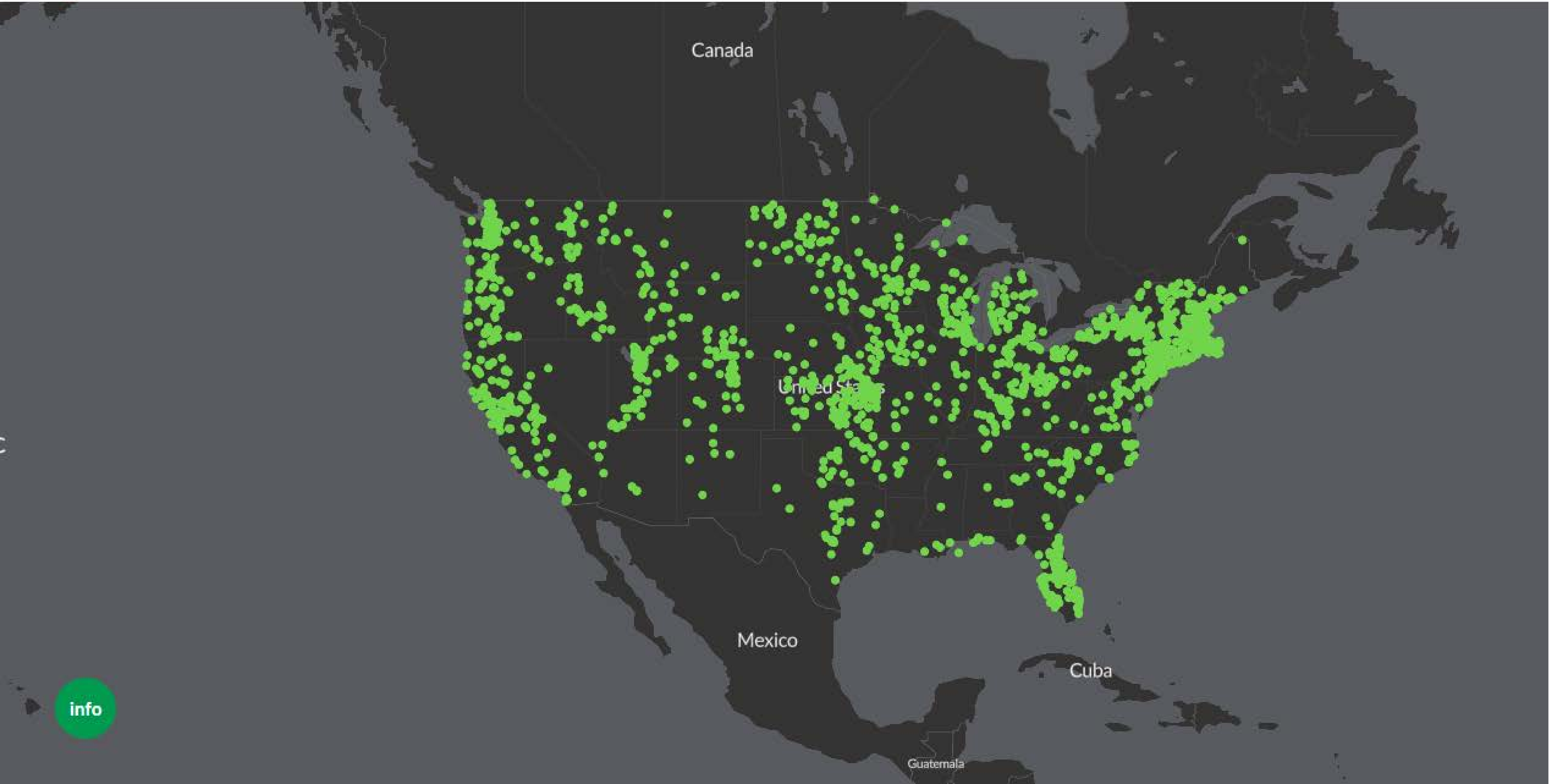
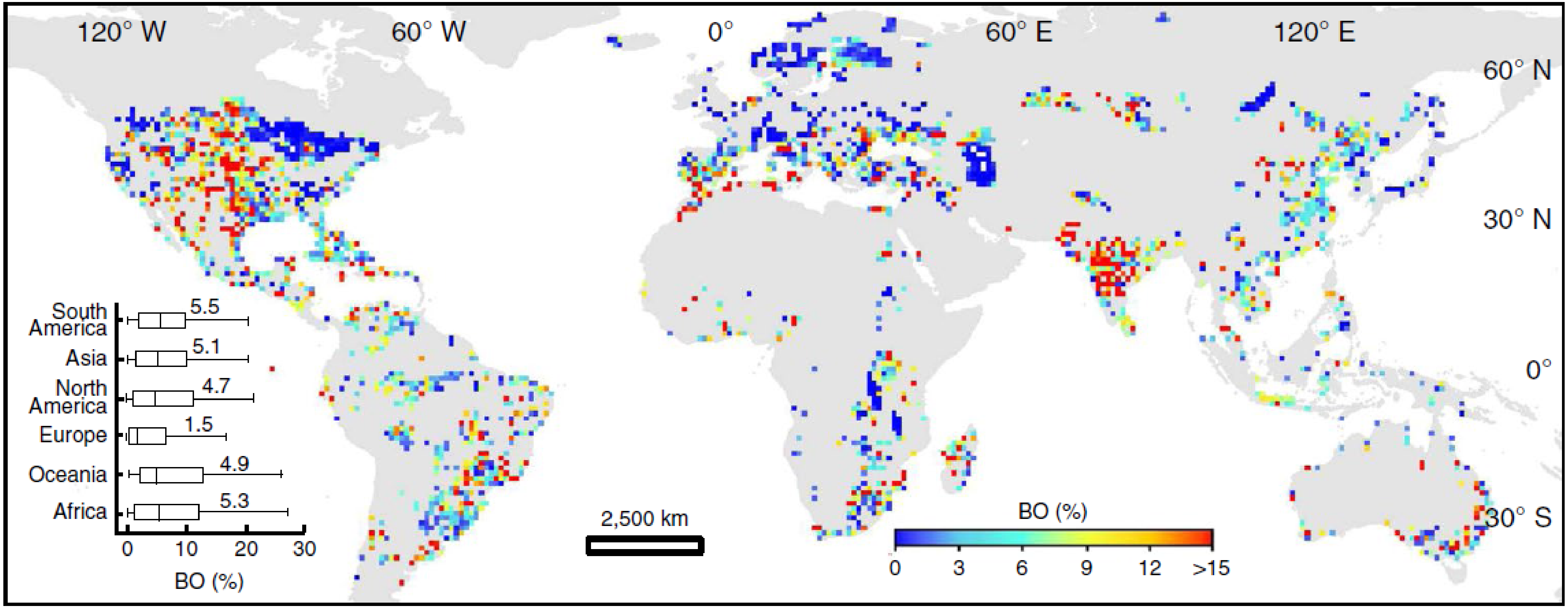
Algal blooms are common in Ohio

News Reports of Algae Blooms, 2010 to Present



Algal blooms are common globally and are intensifying



Global patterns of lacustrine algal blooms between 1982 and 2019

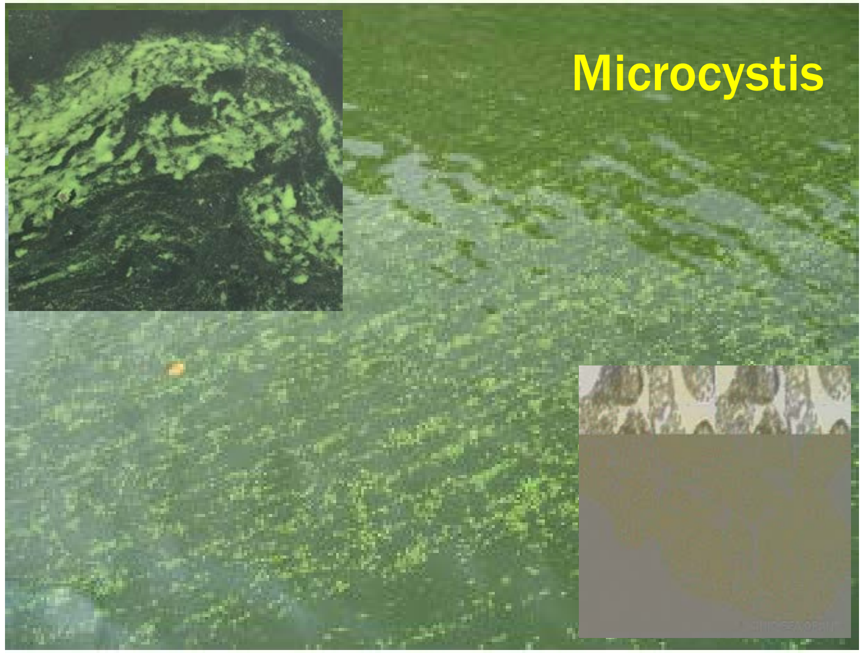
(BO; that is, the frequency of which algal blooms were detected)

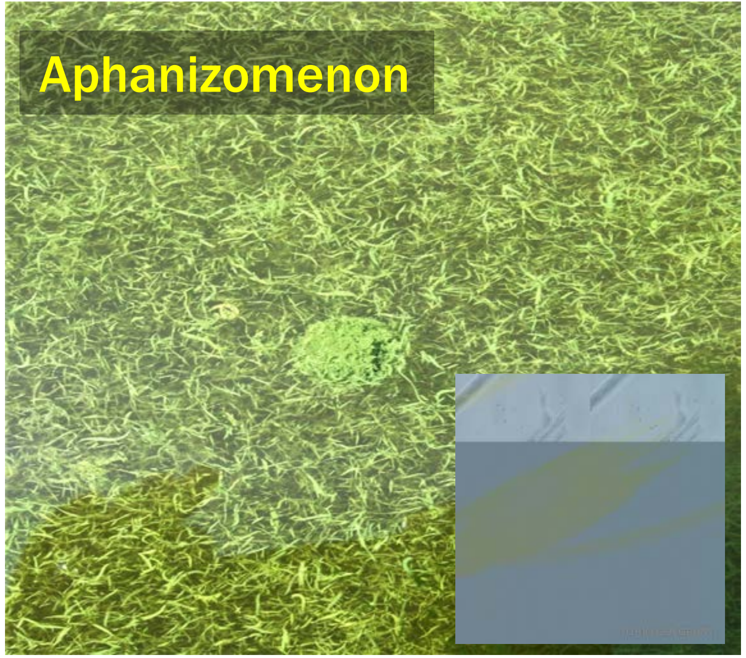
What are harmful algal blooms?

**produce a toxin*

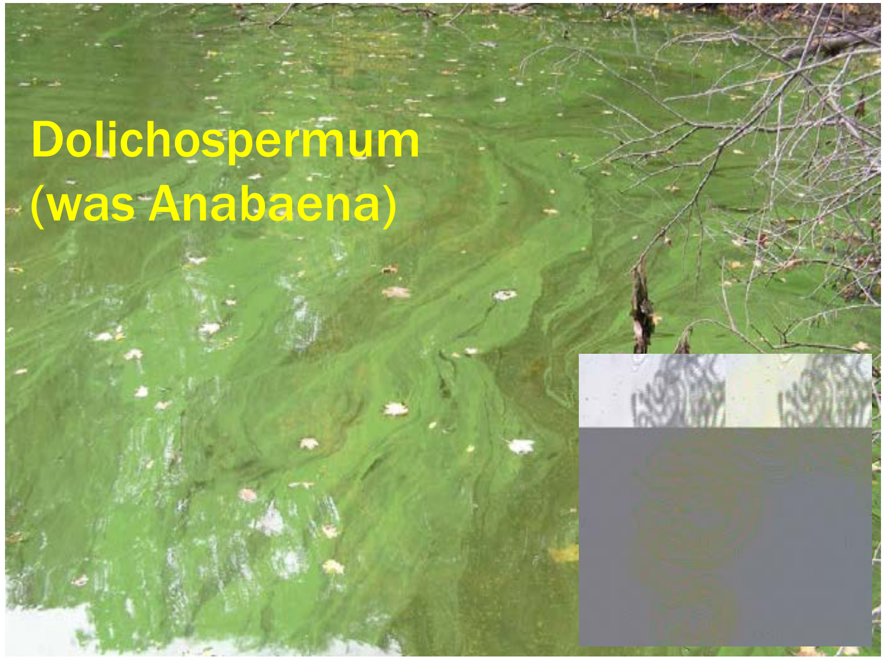
**often cyanobacteria*

Lake Erie, 2019
Aerial Associates Photography

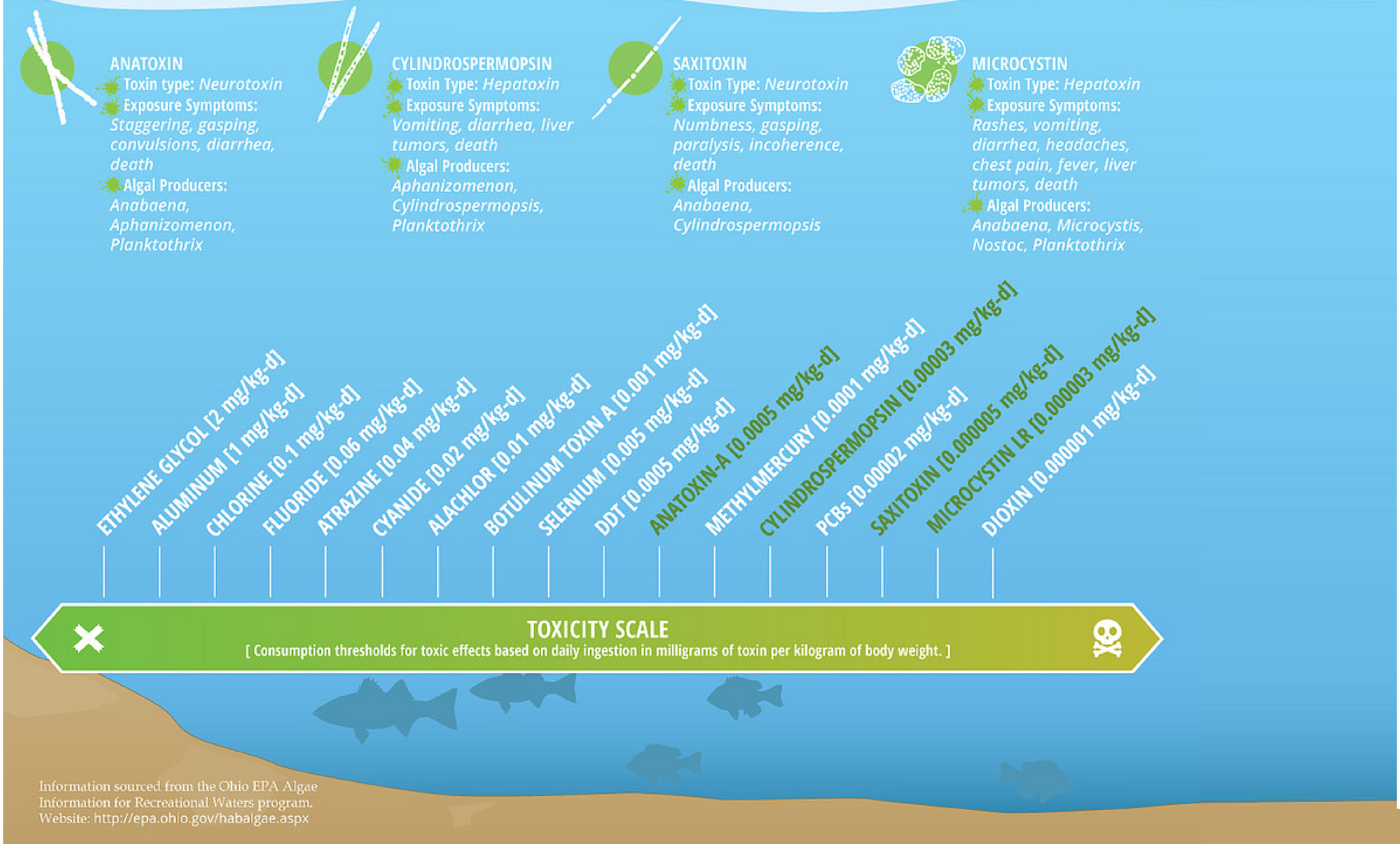




Toxin-producing cyanobacteria common to Ohio

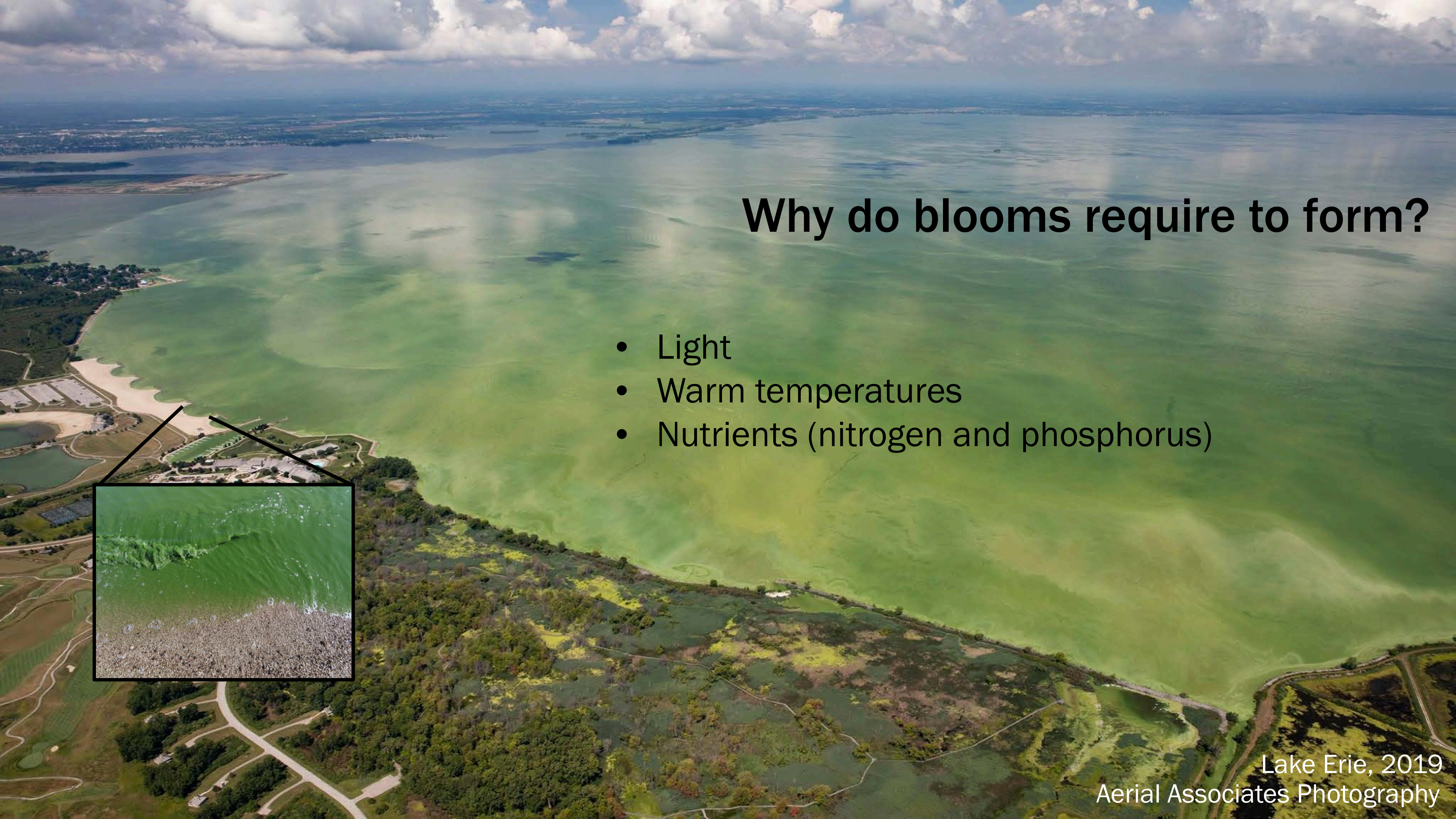


Cyanobacterial Toxins



Why do blooms require to form?

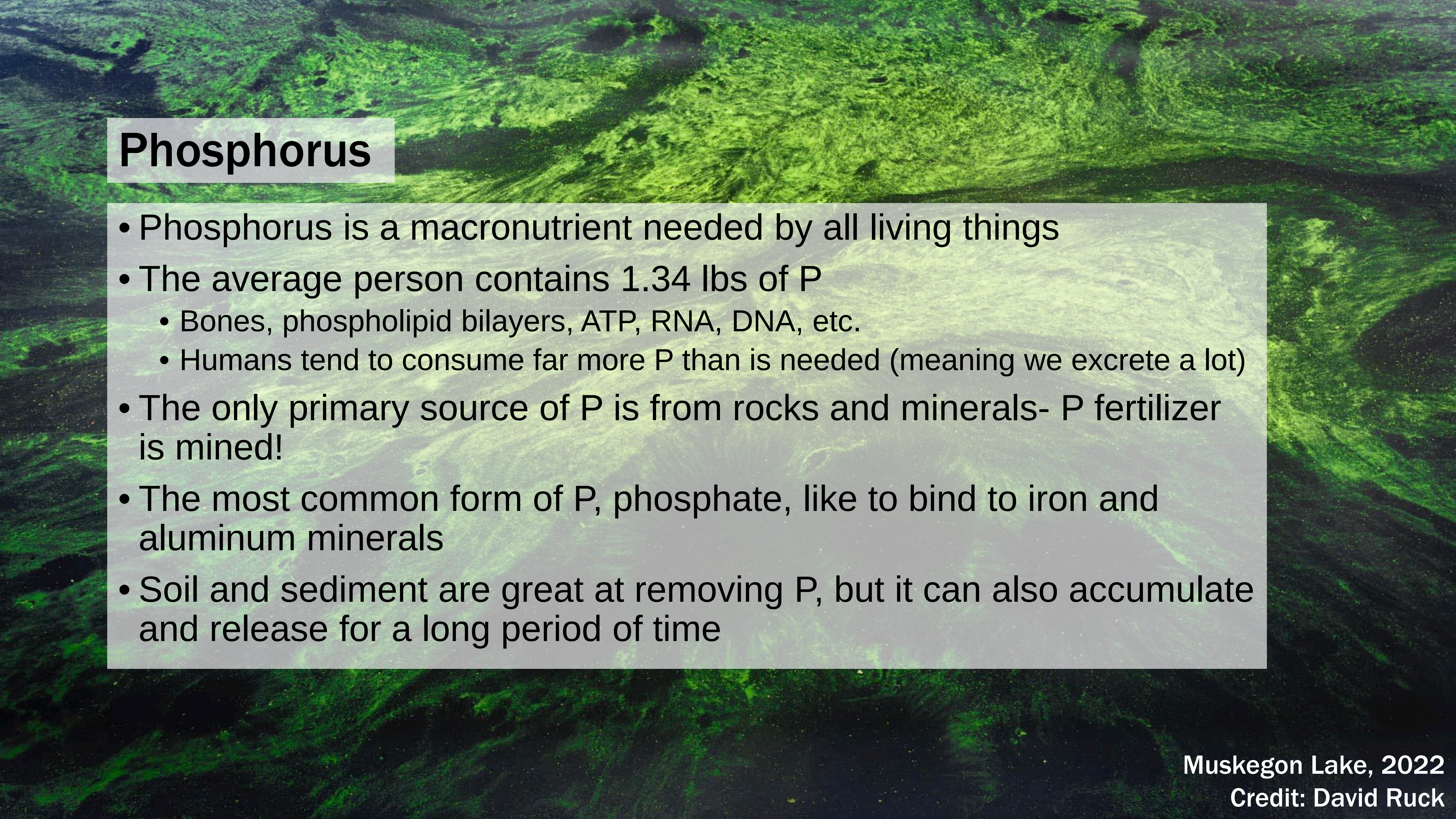
- Light
- Warm temperatures
- Nutrients (nitrogen and phosphorus)



Lake Erie, 2019
Aerial Associates Photography

Phosphorus

- Phosphorus is a macronutrient needed by all living things
- The average person contains 1.34 lbs of P
  - Bones, phospholipid bilayers, ATP, RNA, DNA, etc.
  - Humans tend to consume far more P than is needed (meaning we excrete a lot)
- The only primary source of P is from rocks and minerals- P fertilizer is mined!
- The most common form of P, phosphate, like to bind to iron and aluminum minerals
- Soil and sediment are great at removing P, but it can also accumulate and release for a long period of time

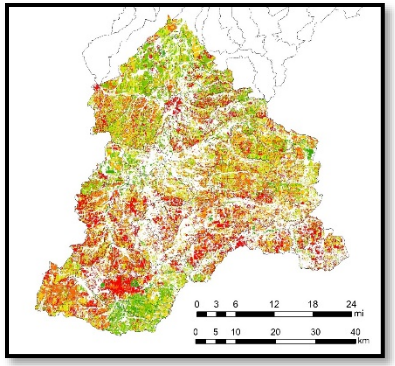


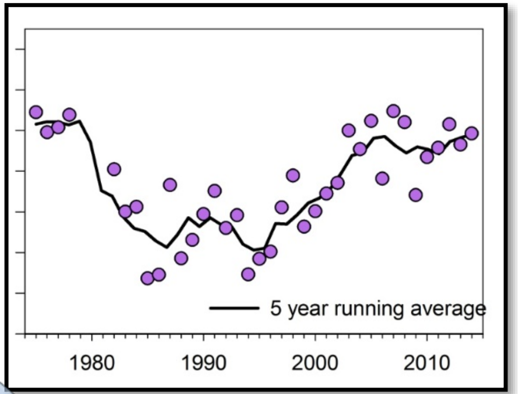
Muskegon Lake, 2022
Credit: David Ruck

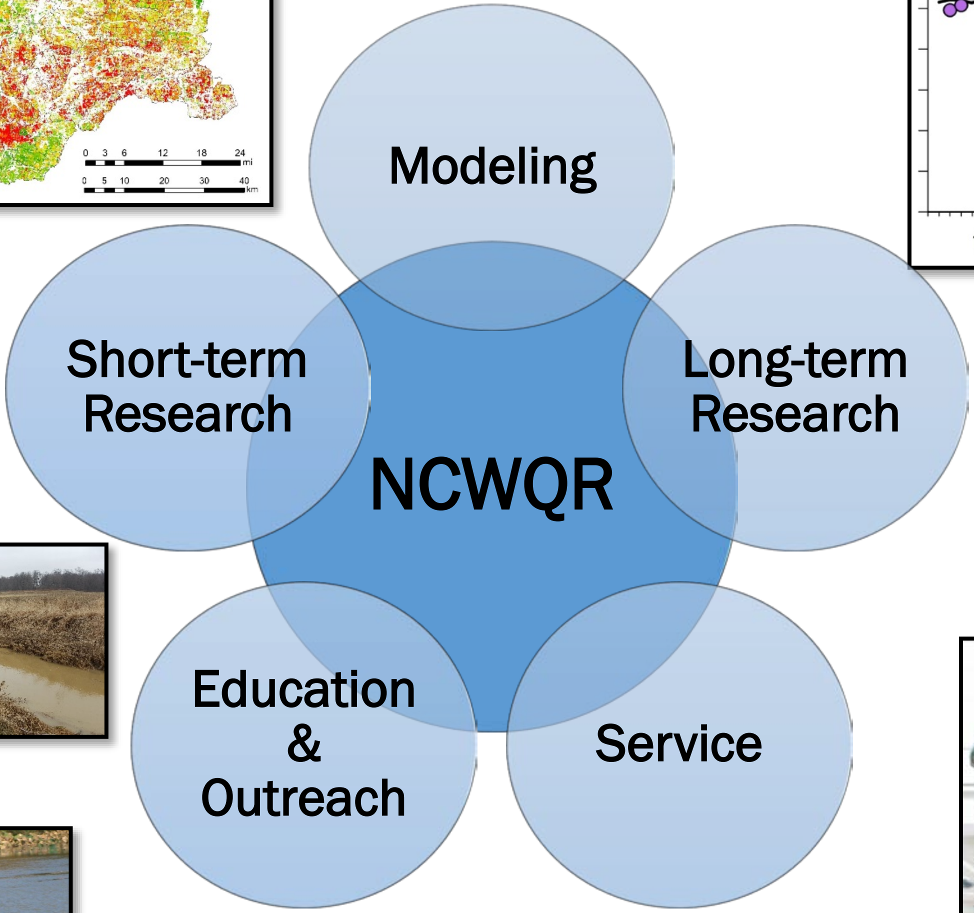
Nitrogen

- Nitrogen is also a macronutrient needed by all living things
- The average person contains 5.4 lbs of N
  - Proteins and amino acids, ATP, RNA, DNA, etc.
  - Humans tend to consume far more N than is needed (meaning we excrete a lot)
- Nitrogen gas makes up 78% of Earth's atmosphere
- Microbes can breathe oxidized forms of N (i.e., nitrate) and return it to the atmosphere; therefore N rarely accumulates in freshwaters
- Nitrate-N is a drinking water contaminant that can impact the ability of hemoglobin to bind oxygen

Muskegon Lake, 2022
Credit: David Ruck



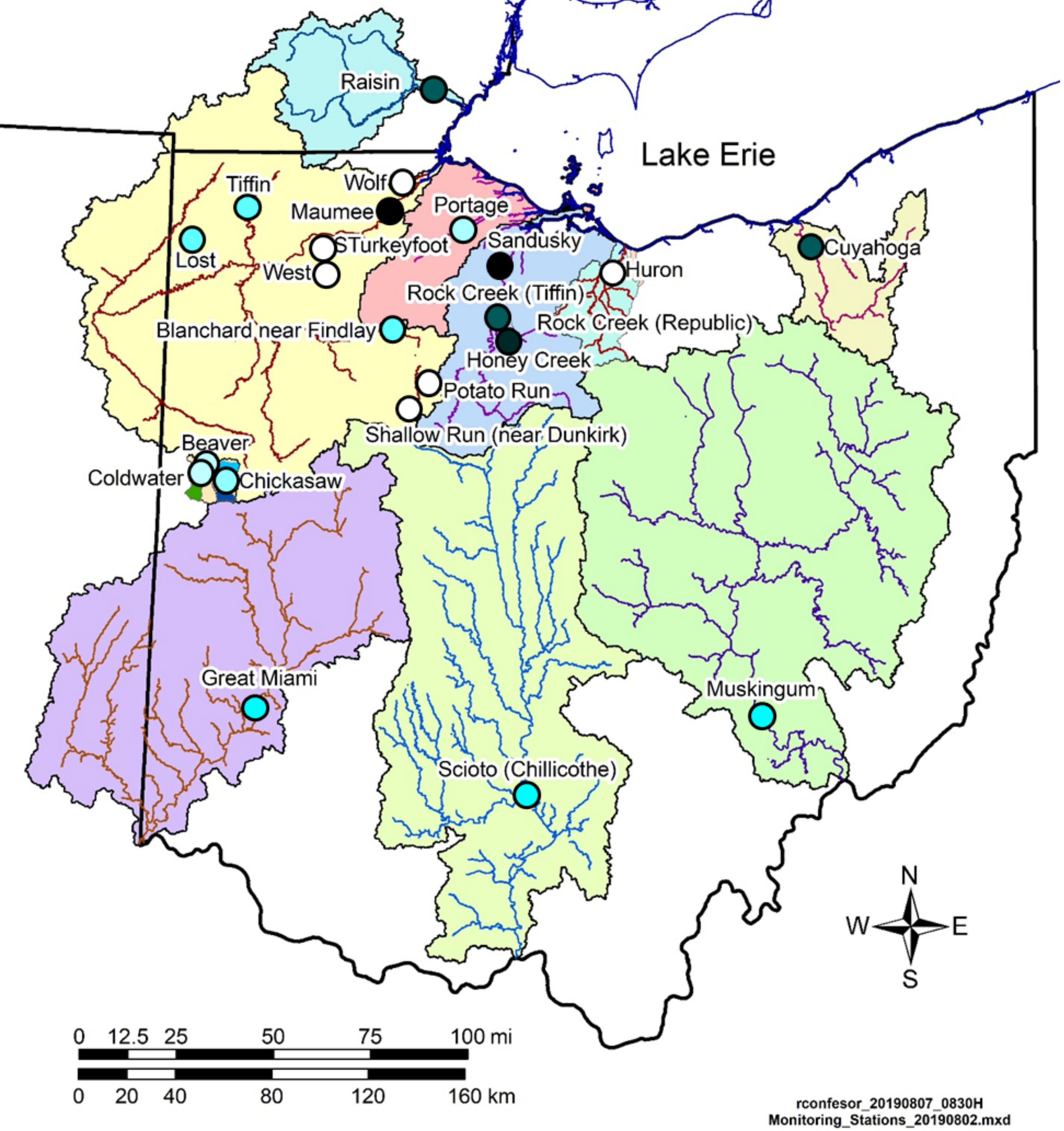


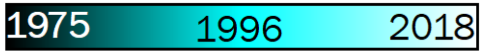


SANDUSKY RIVER Watershed Coalition

To generate knowledge about the dynamics of water and soil resources in order to improve water quality and availability

Heidelberg Tributary Loading Program





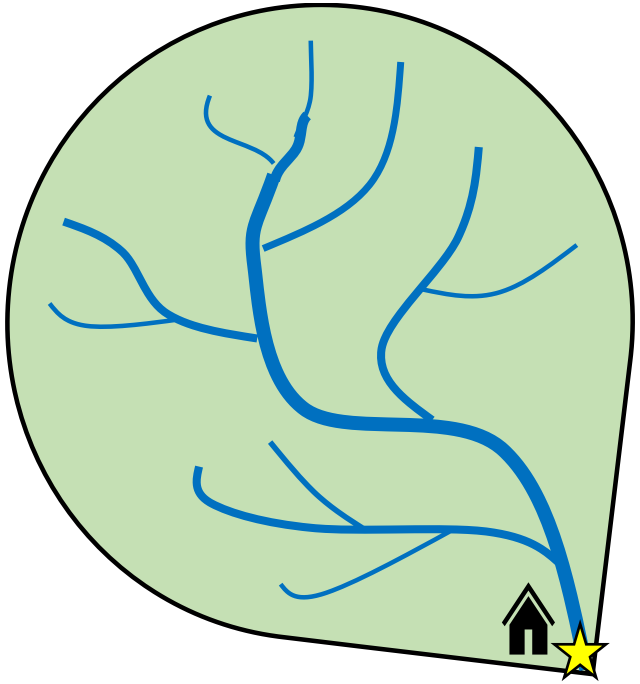
GOAL: quantify the loads (or mass) of contaminants from watersheds draining different land uses

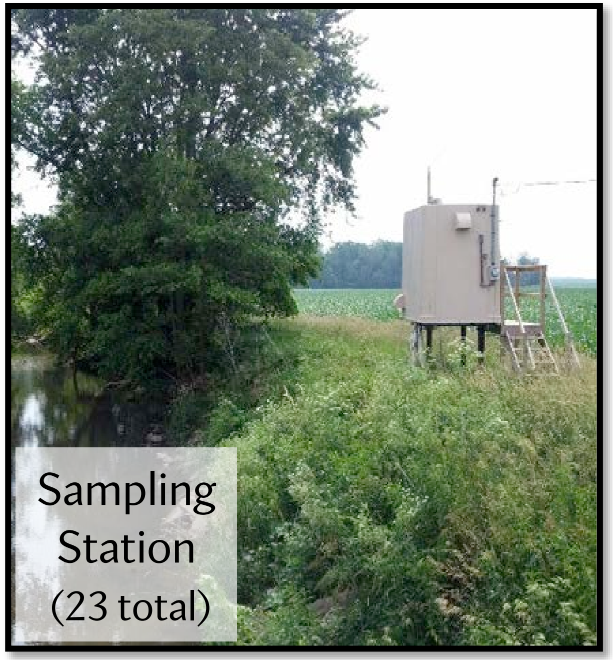
We currently sample from 23 locations

The HTLP began in 1974 with the Sandusky and Maumee

The newest stations are smaller watersheds to help test practice effectiveness

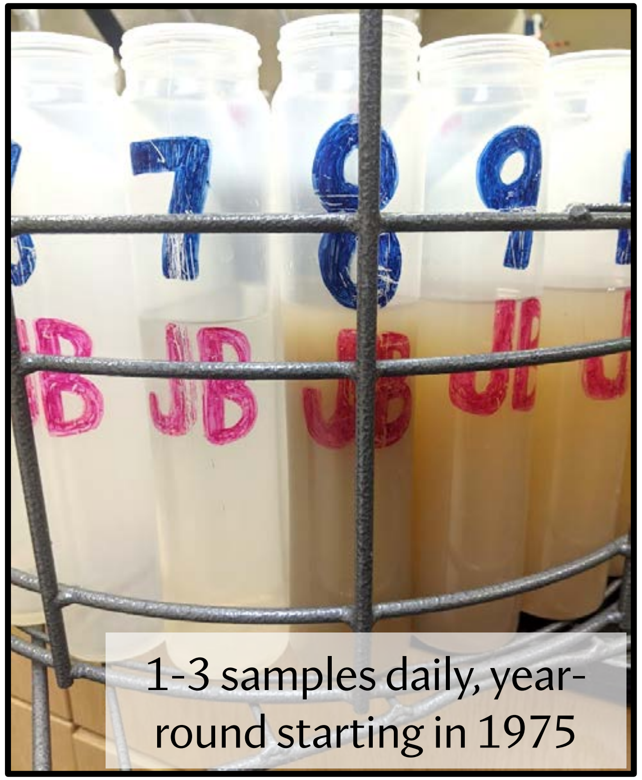
NCWQR





Sampling Station (23 total)

Refrigerated Automatic Sampler



1-3 samples daily, year-round starting in 1975

Samples retrieved weekly

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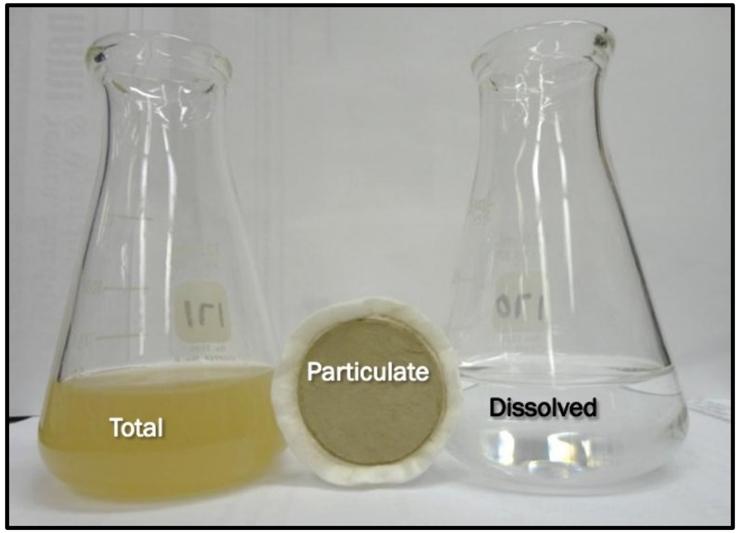
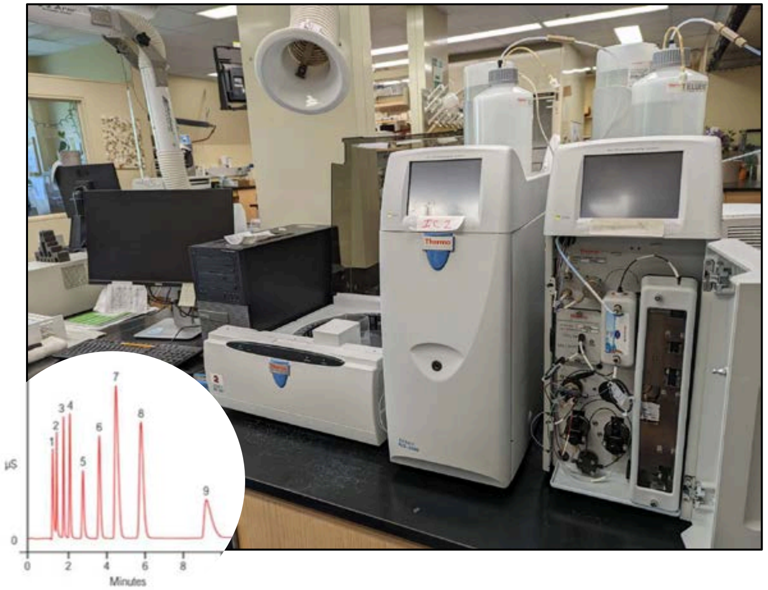
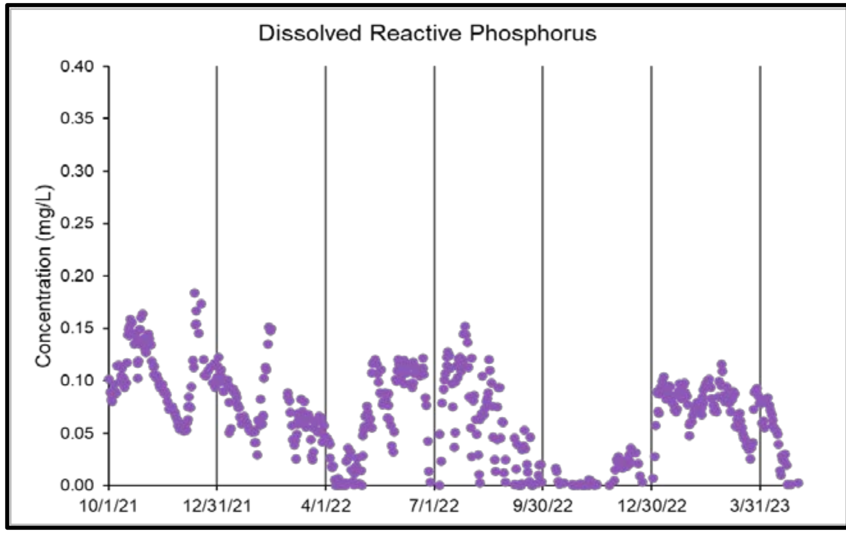
Sample processing



Sample analysis

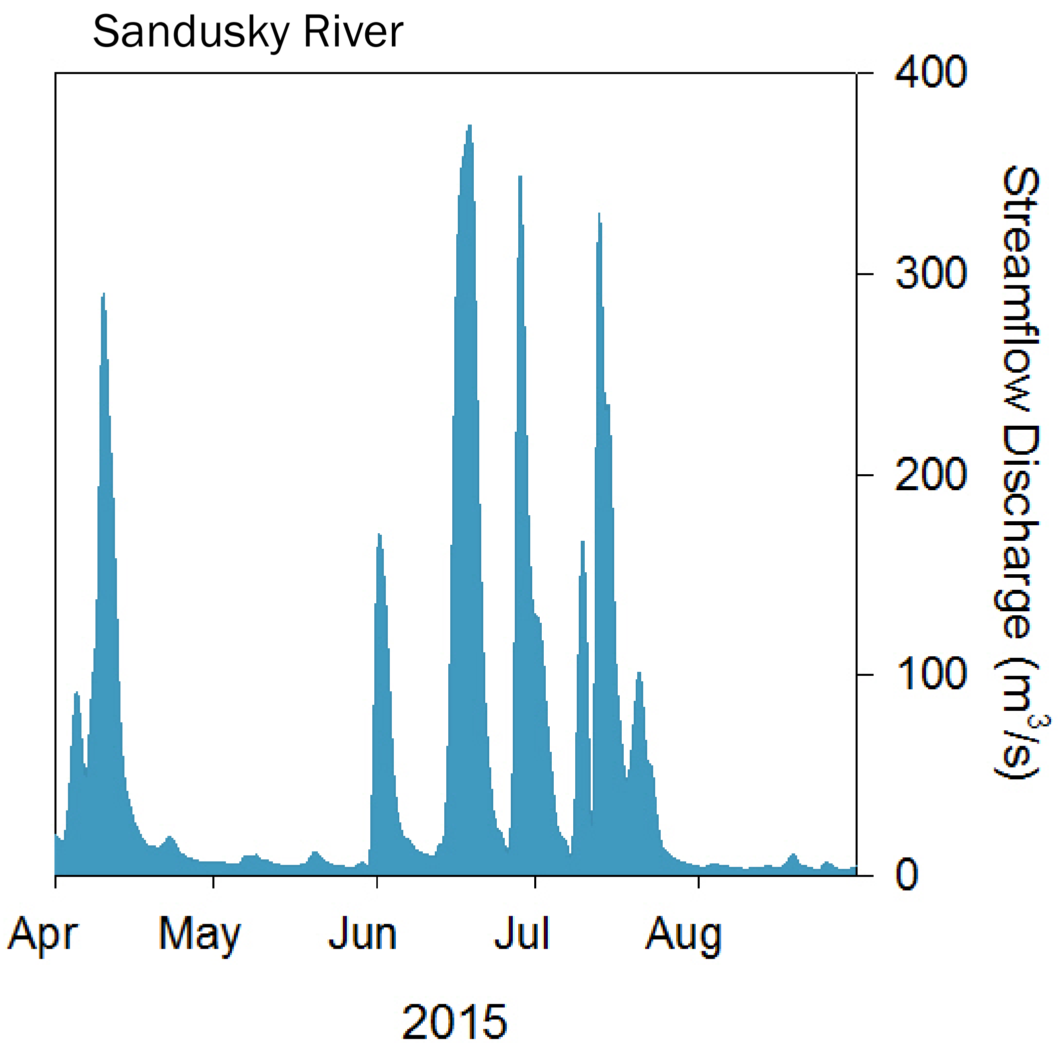


Data!



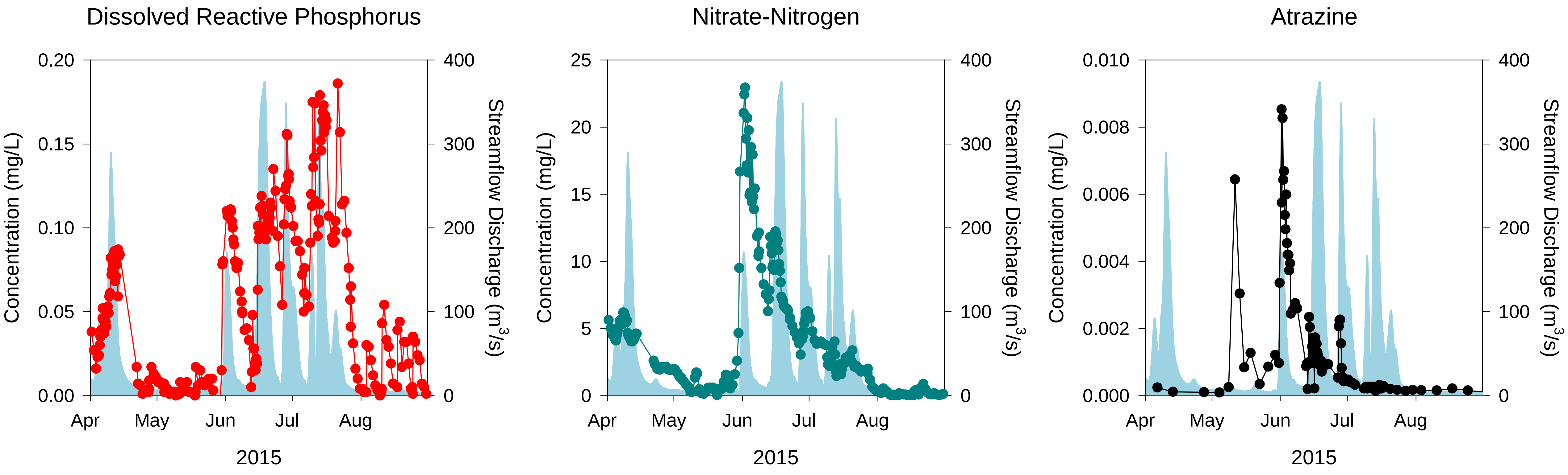
Why do we need this approach to accurately assess sediments and nutrients in stormwater?

Storms happen rapidly and can be difficult to predict



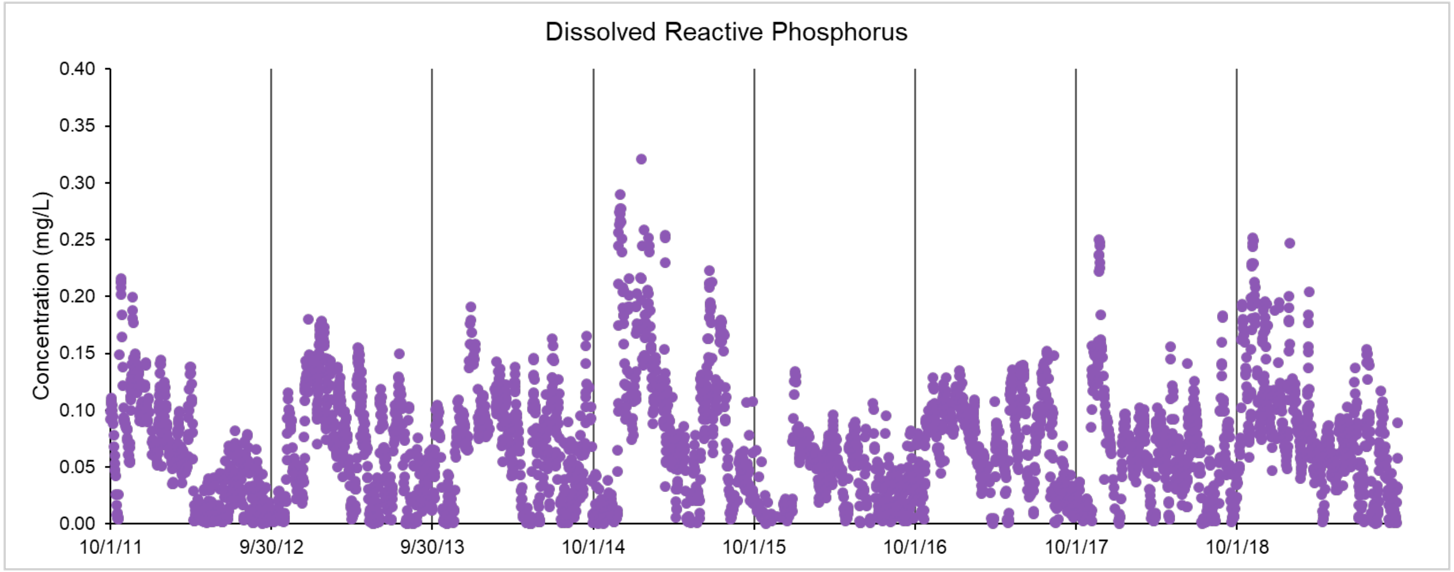
Water pollution from land runoff increases with storms

Sandusky River

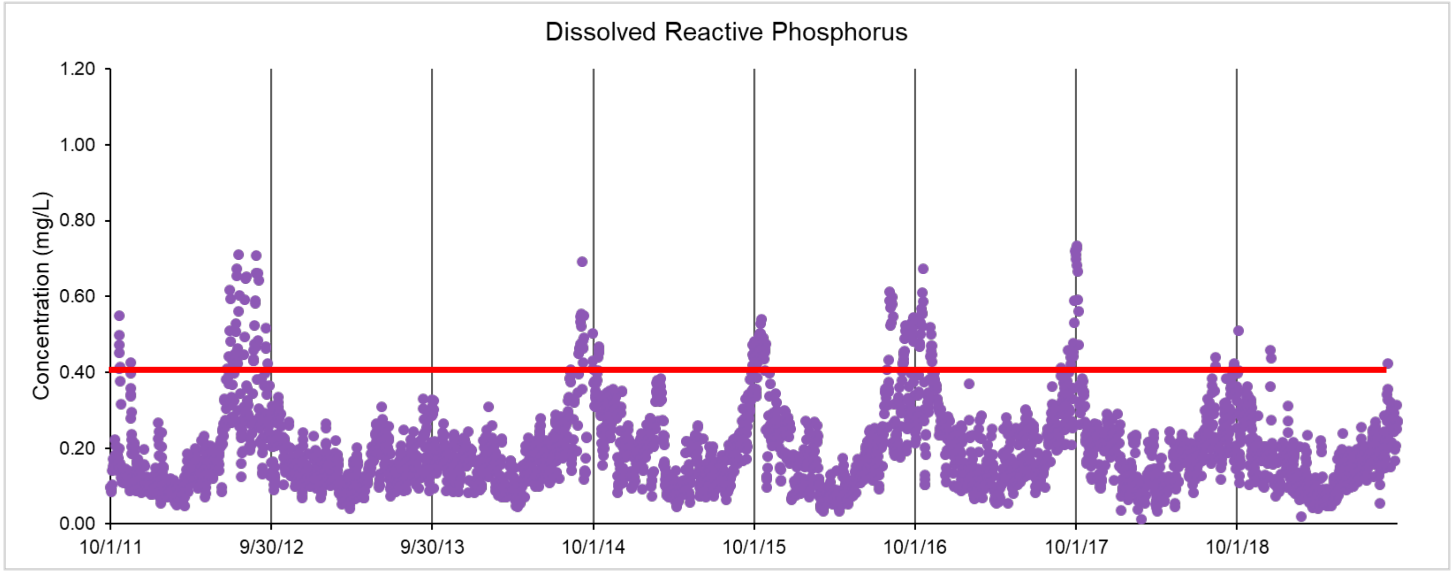


The response of water pollution to storms varies by river

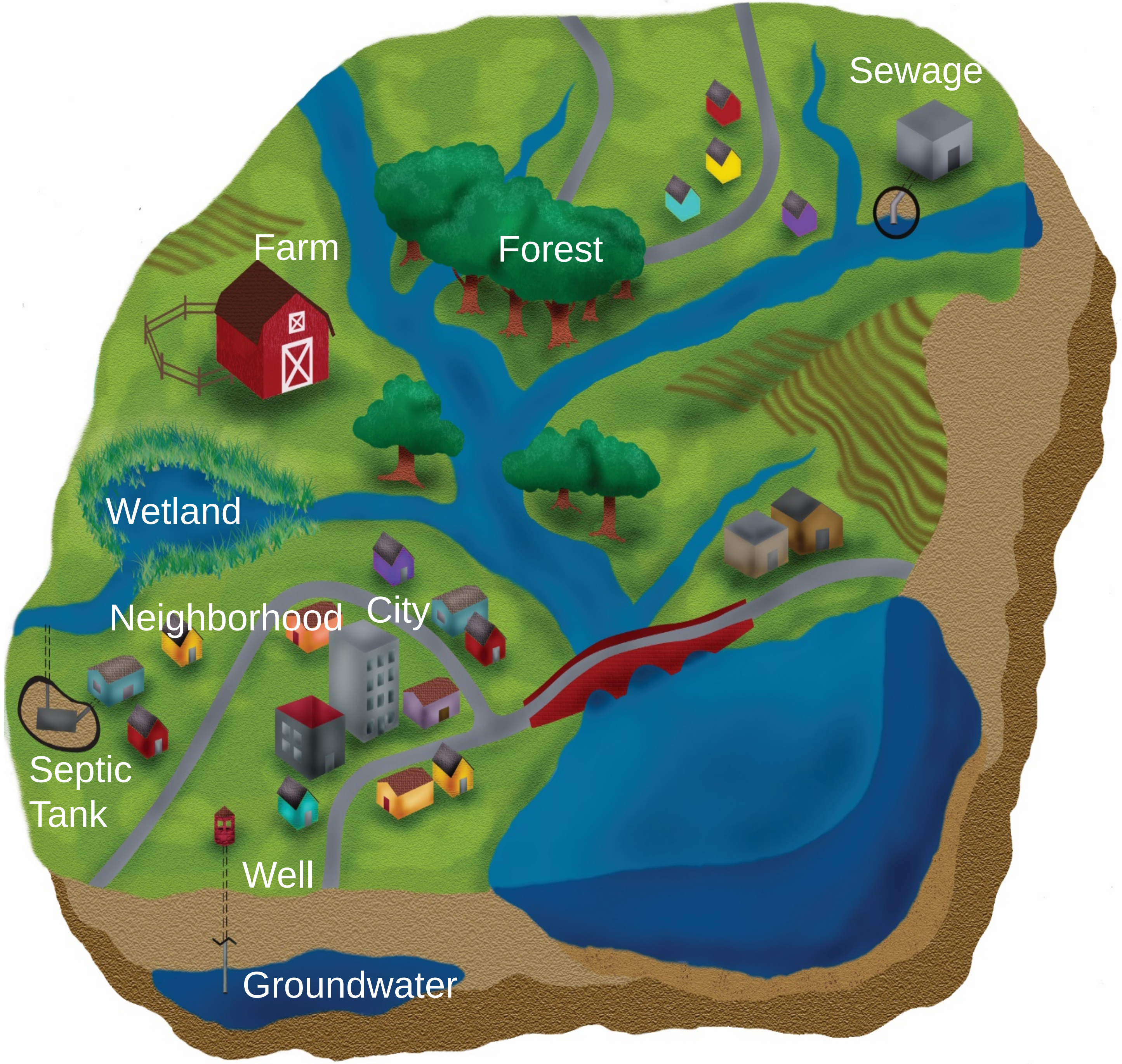
Maumee



Blanchard




How do nutrients enter our
rivers and streams?



What is a watershed?

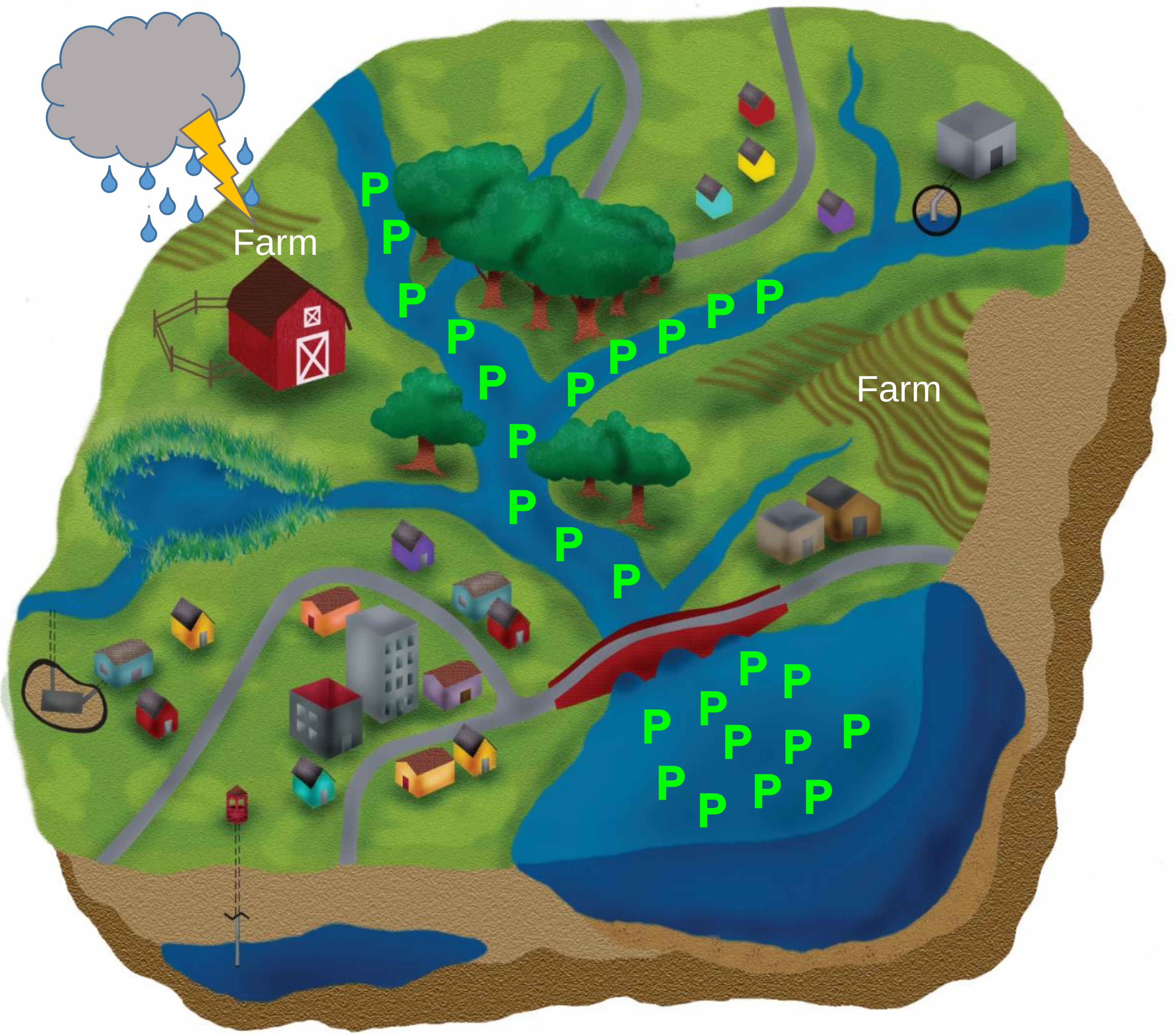
an area of land that drains all the streams and rainfall to a common outlet

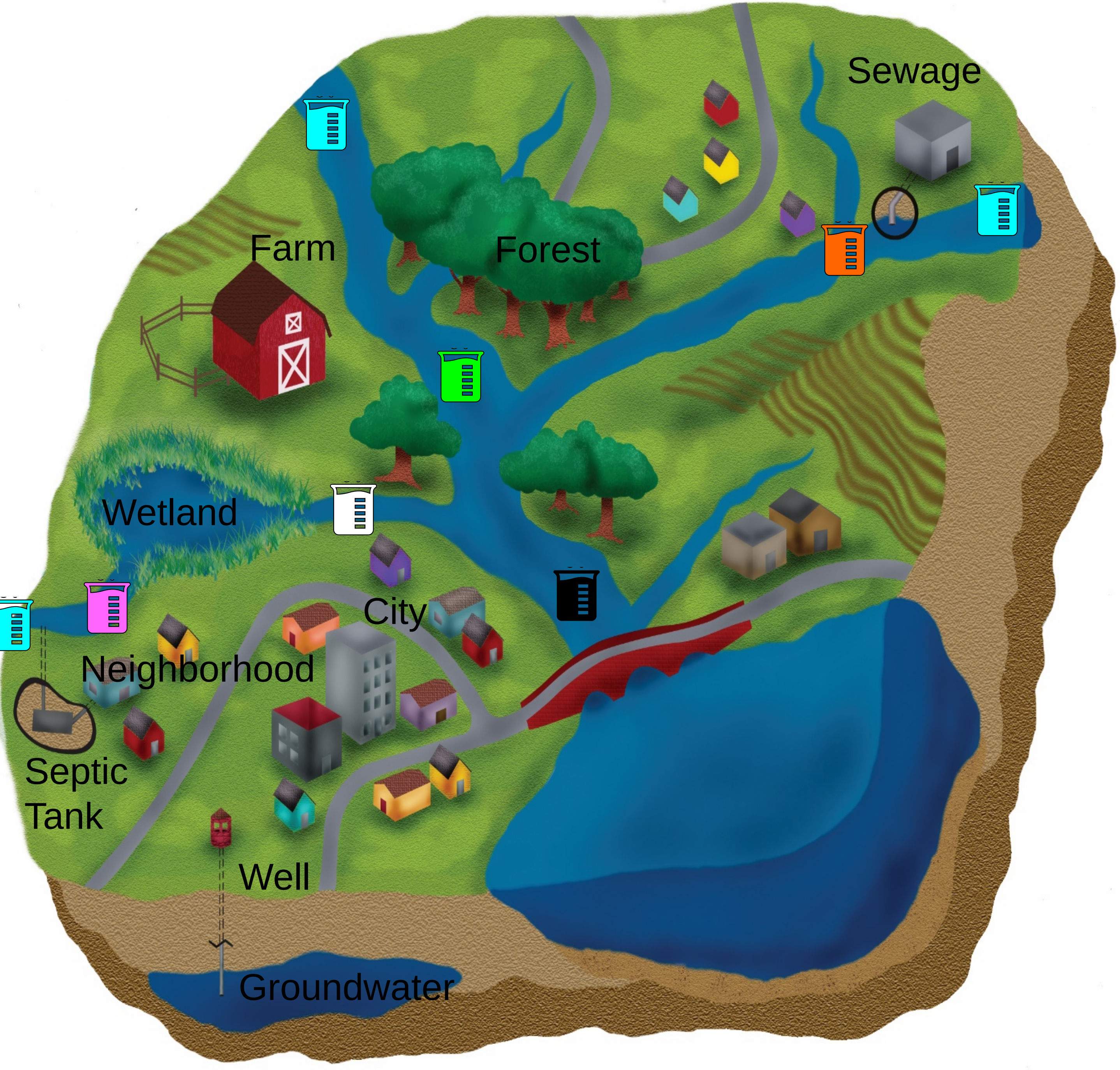
Point sources

- Point sources tend to have higher concentrations during low flow
- Blooms from point sources tends to be localized near the input rather than at a distance

Nonpoint sources

- Nonpoint sources tend to have higher concentrations during high flow
- Blooms from nonpoint sources tends to occur in the downstream receiving waterbodies where water velocity is slower (lakes, estuaries, stormwater ponds, reservoirs, etc)





TIME TO BE A WATER DETECTIVE

Location	Sediment (mg/L)	Phosphorus (µg/L)
up		
sewage		
farm/forest		
septic/ neighborhood		
wetland		
all		

WHAT IS THE SOURCE OF THE HIGHEST CONCENTRATION?

Location	Sediment (mg/L)	Phosphorus (µg/L)
up	10	10
sewage	15	800
farm/forest	40	50
septic/ neighborhood	40	100
wetland	5	5
all	25	200

WHAT IS THE SOURCE OF THE HIGHEST CONCENTRATION?

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up	10	10
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TIME TO BE A WATER DETECTIVE

Location	Sediment (mg/L)	Phosphorus (µg/L)
up		
sewage		
farm/forest		
septic/ neighborhood		
wetland		
all		

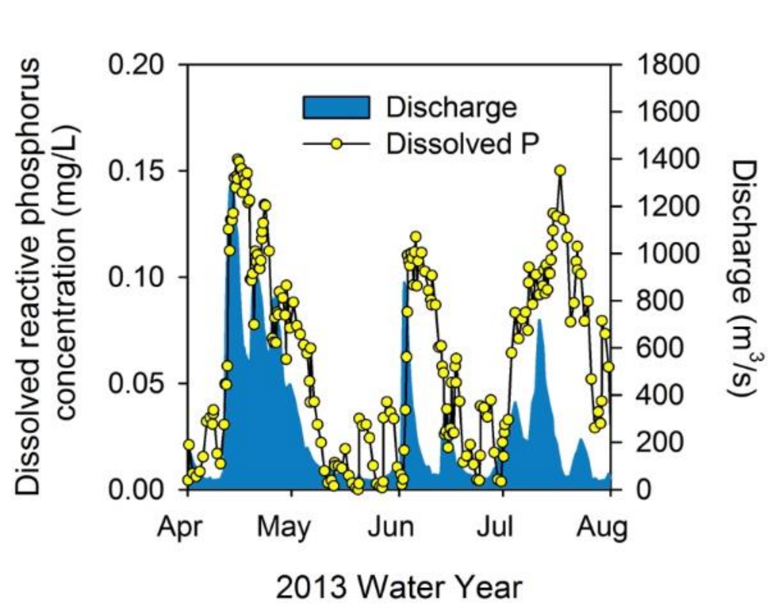
WHAT IS THE SOURCE OF THE HIGHEST CONCENTRATION?

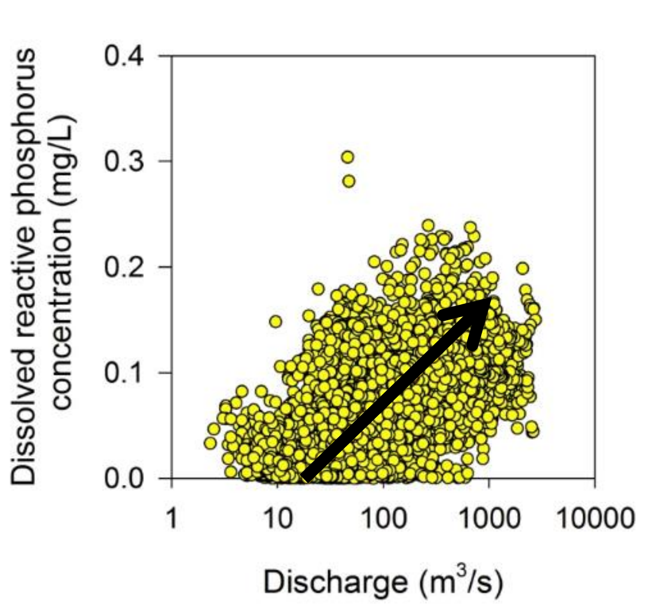
Location	Sediment (mg/L)	Phosphorus (µg/L)
up	100	50
sewage	100	55
farm/forest	750	200
septic/ neighborhood	300	55
wetland	30	15
all	450	150

HOW DOES PHOSPHORUS ENTER SURFACE WATER?

Maumee River: Nonpoint Sources

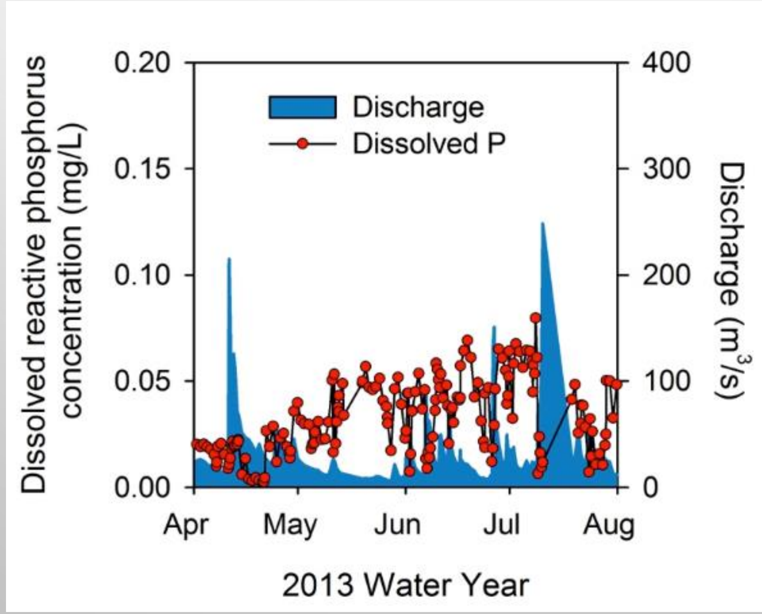
- P inputs dominated by agricultural runoff
- Concentrations increase with flow

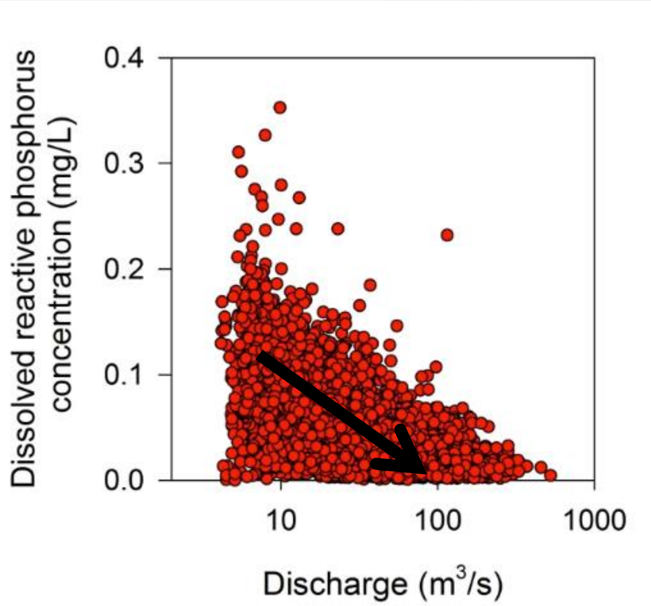




Cuyahoga River: Point Sources

- P inputs dominated by sewage effluent
- Concentrations decrease with flow





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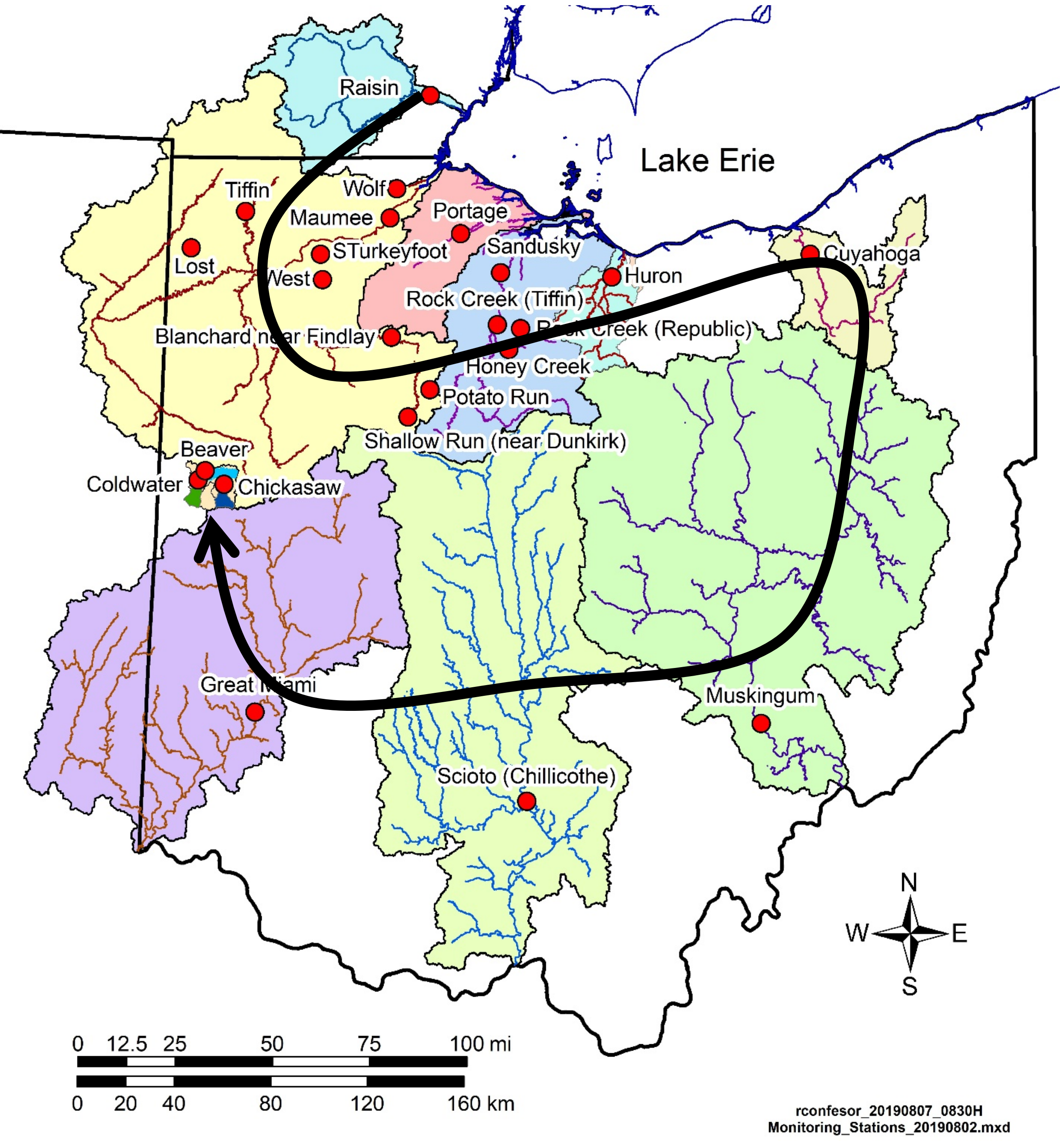
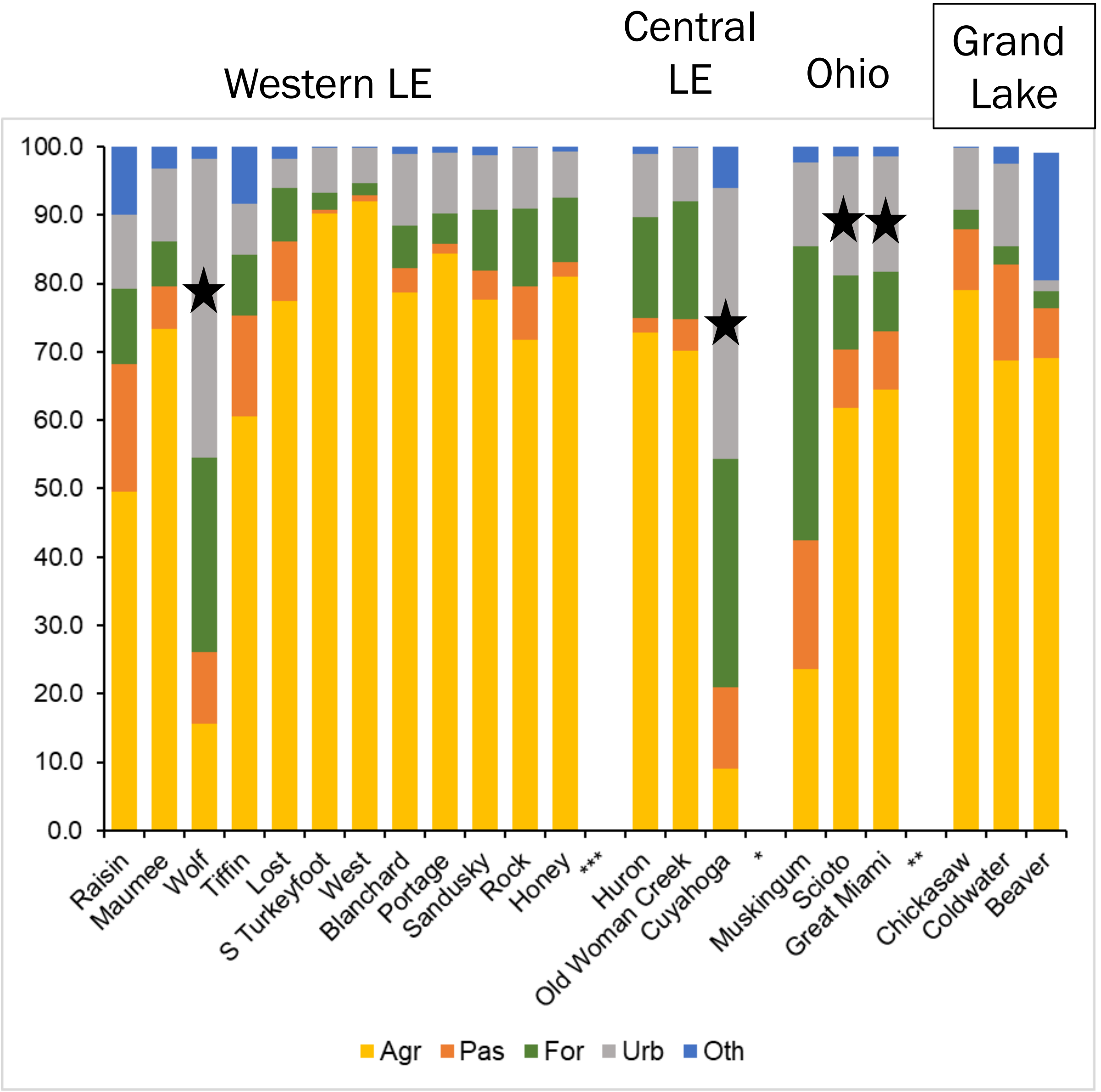
How do phosphorus loads vary by watershed?

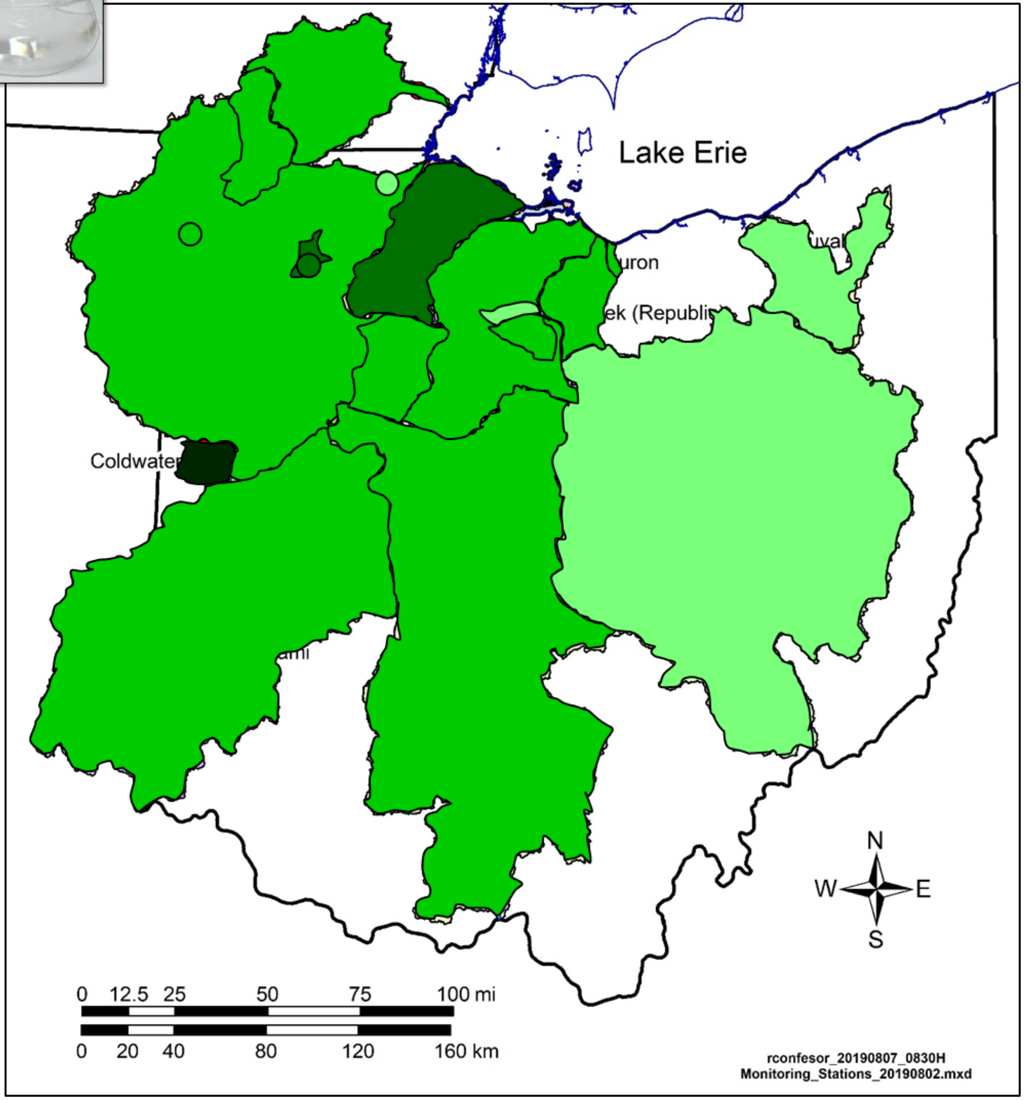
Watershed Land Use

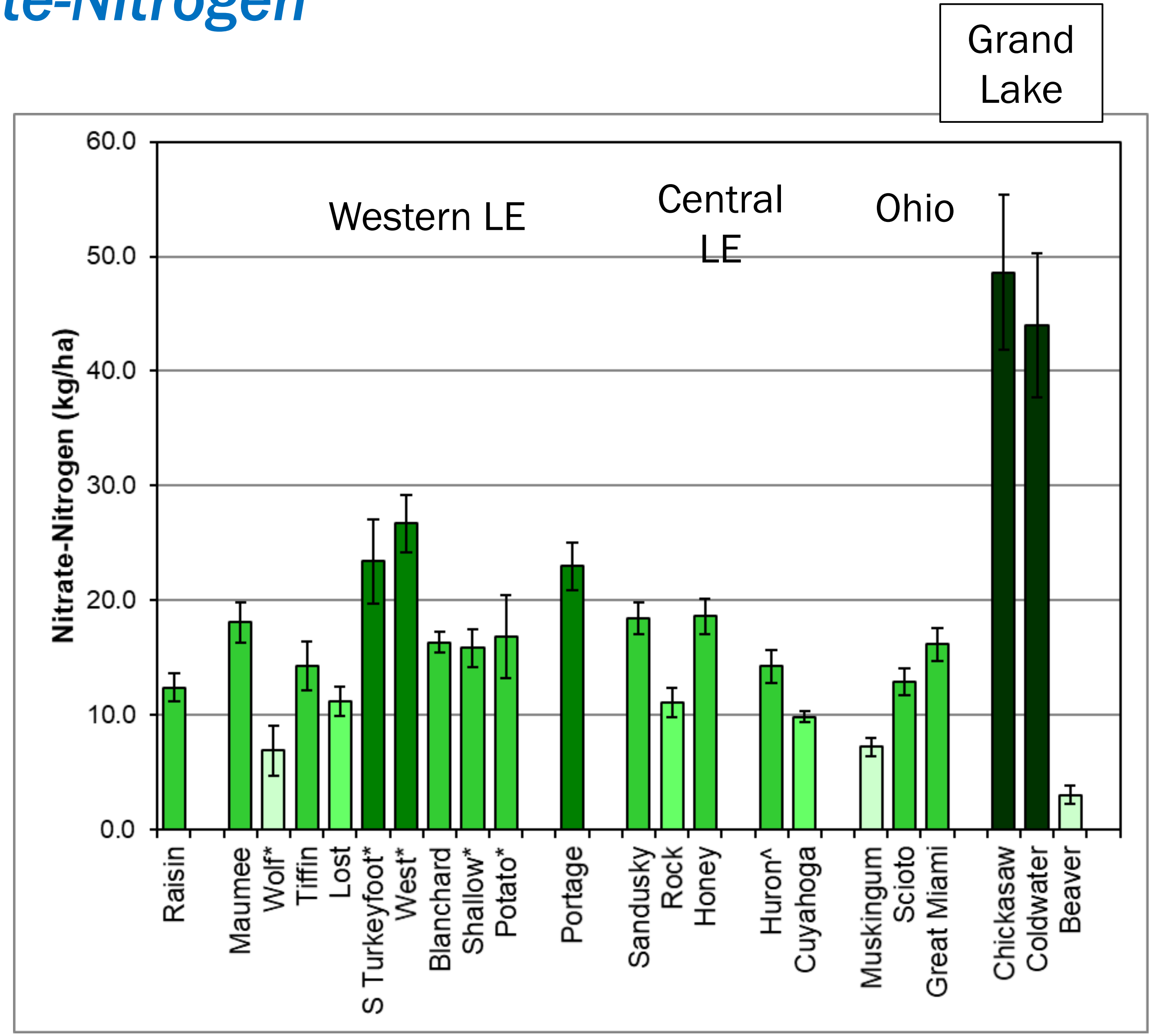




Comparing watersheds: Unit Area Loads

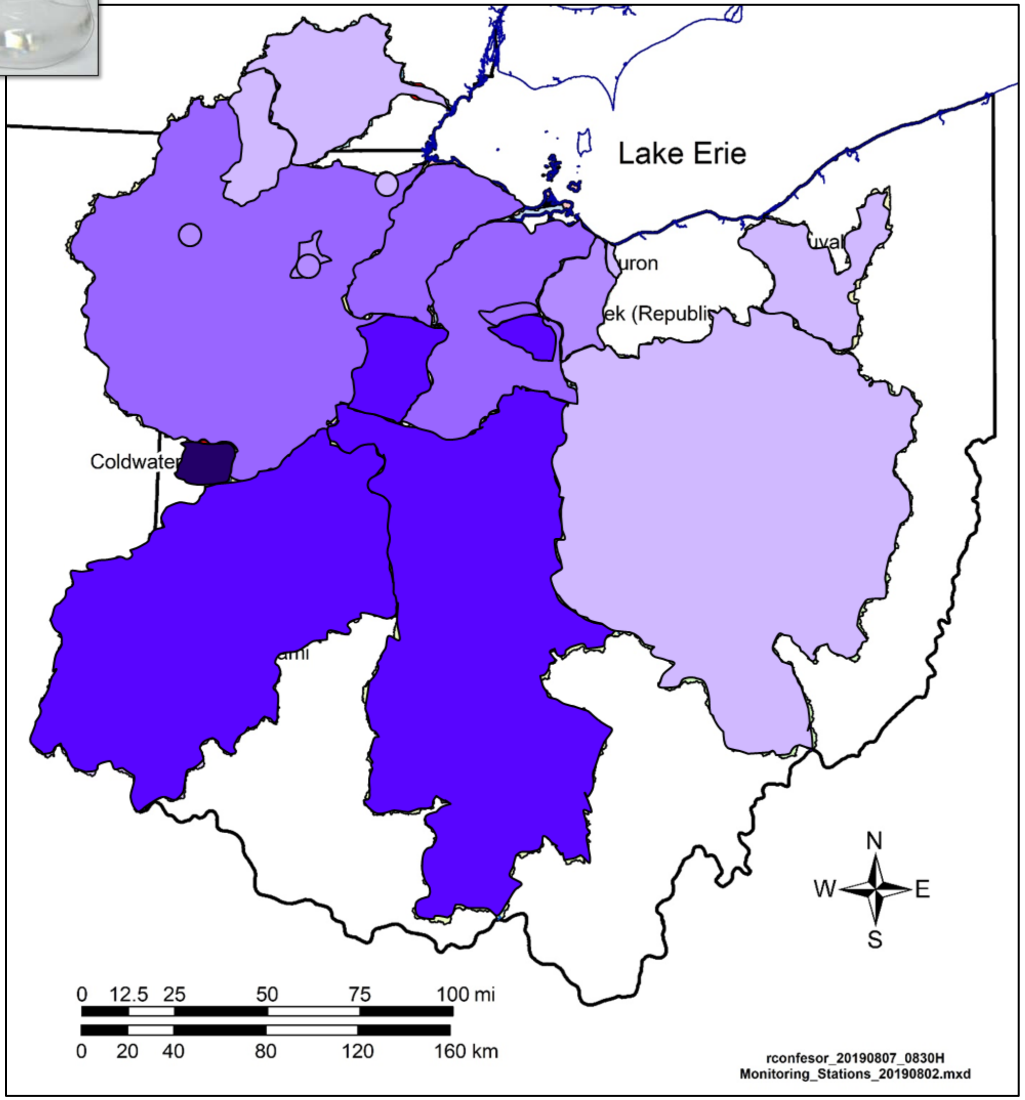
Nitrate-Nitrogen



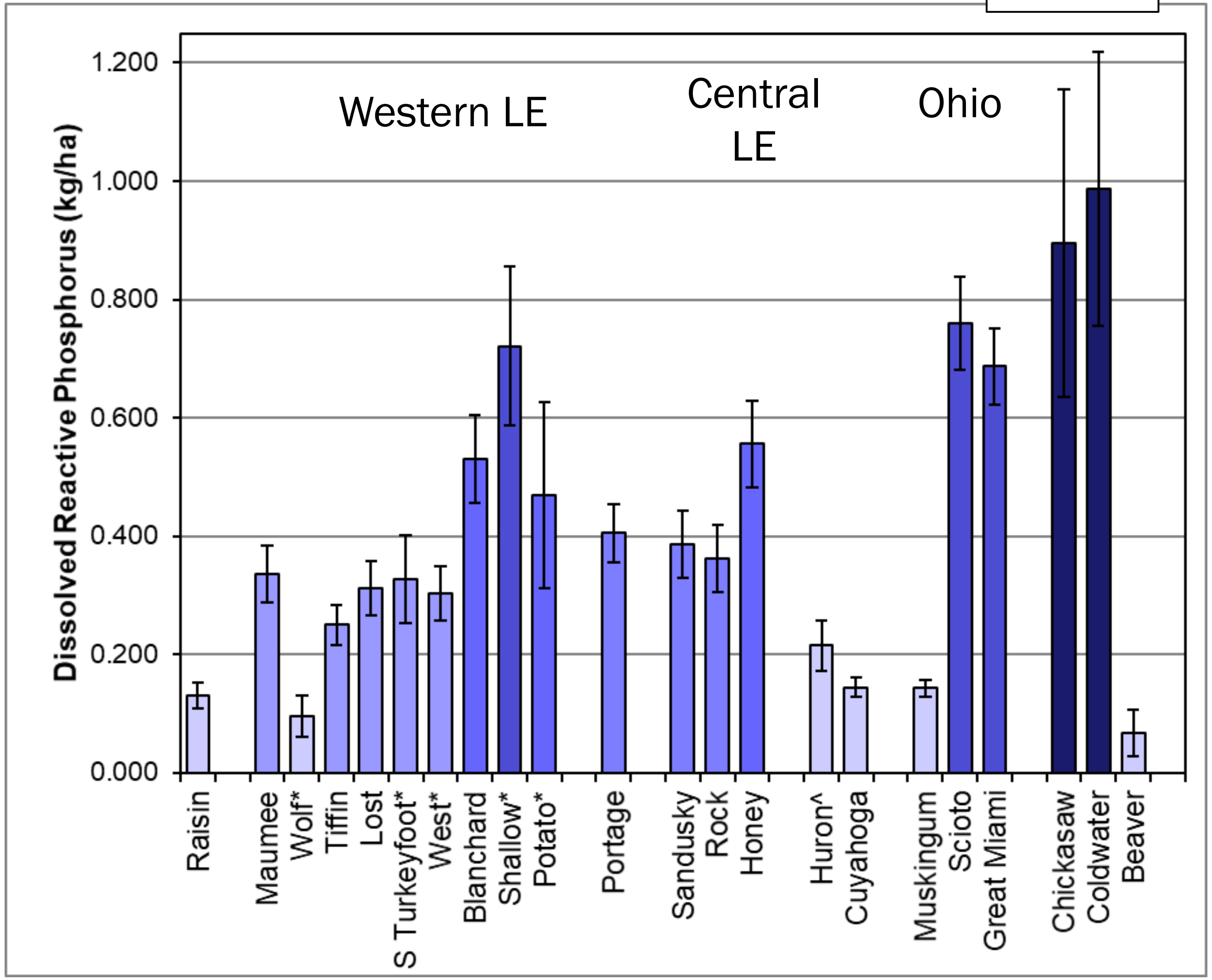


Comparing watersheds: Unit Area Loads

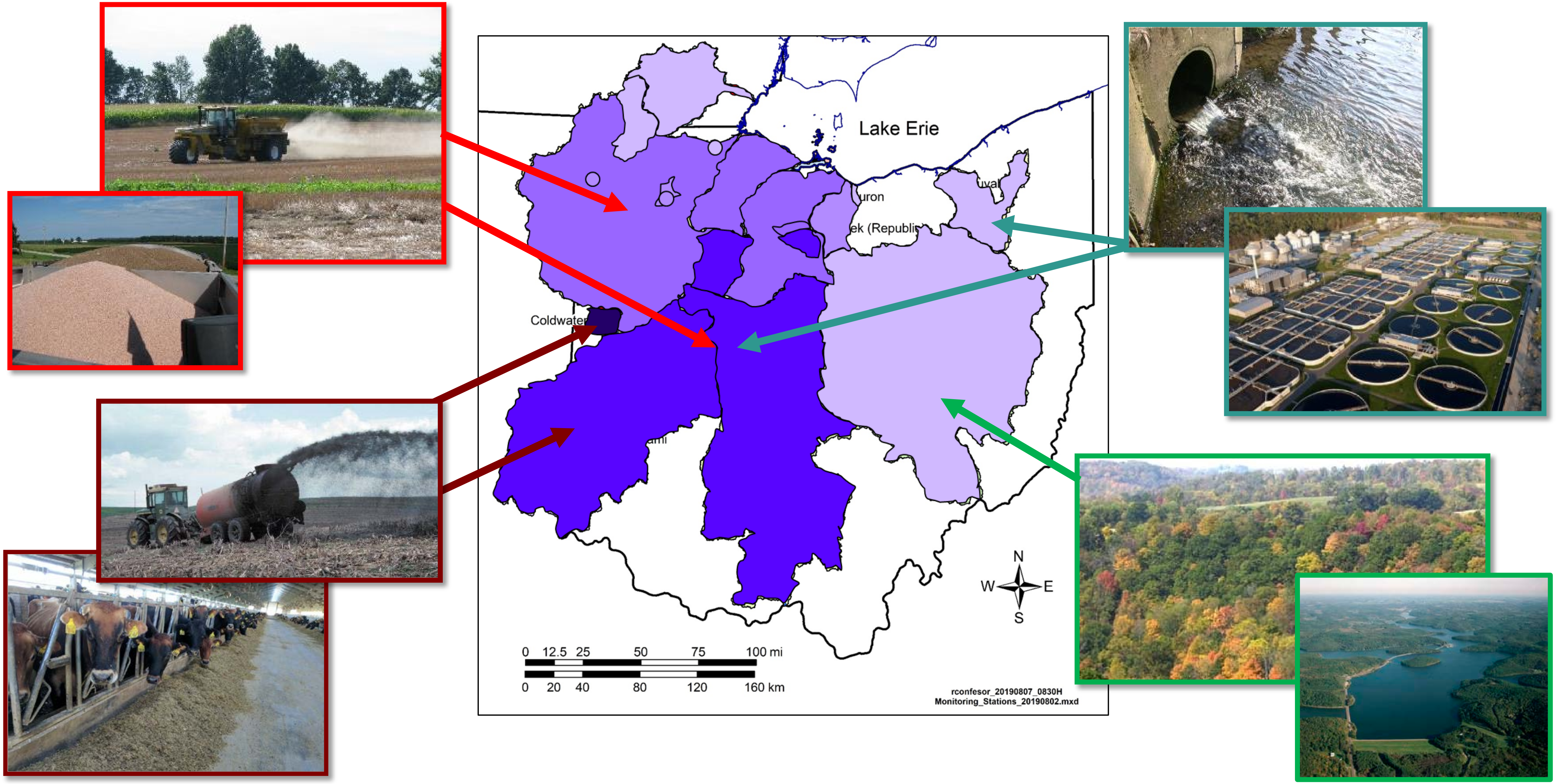
Dissolved Reactive Phosphorus



Grand Lake



Why are there differences across the watersheds?



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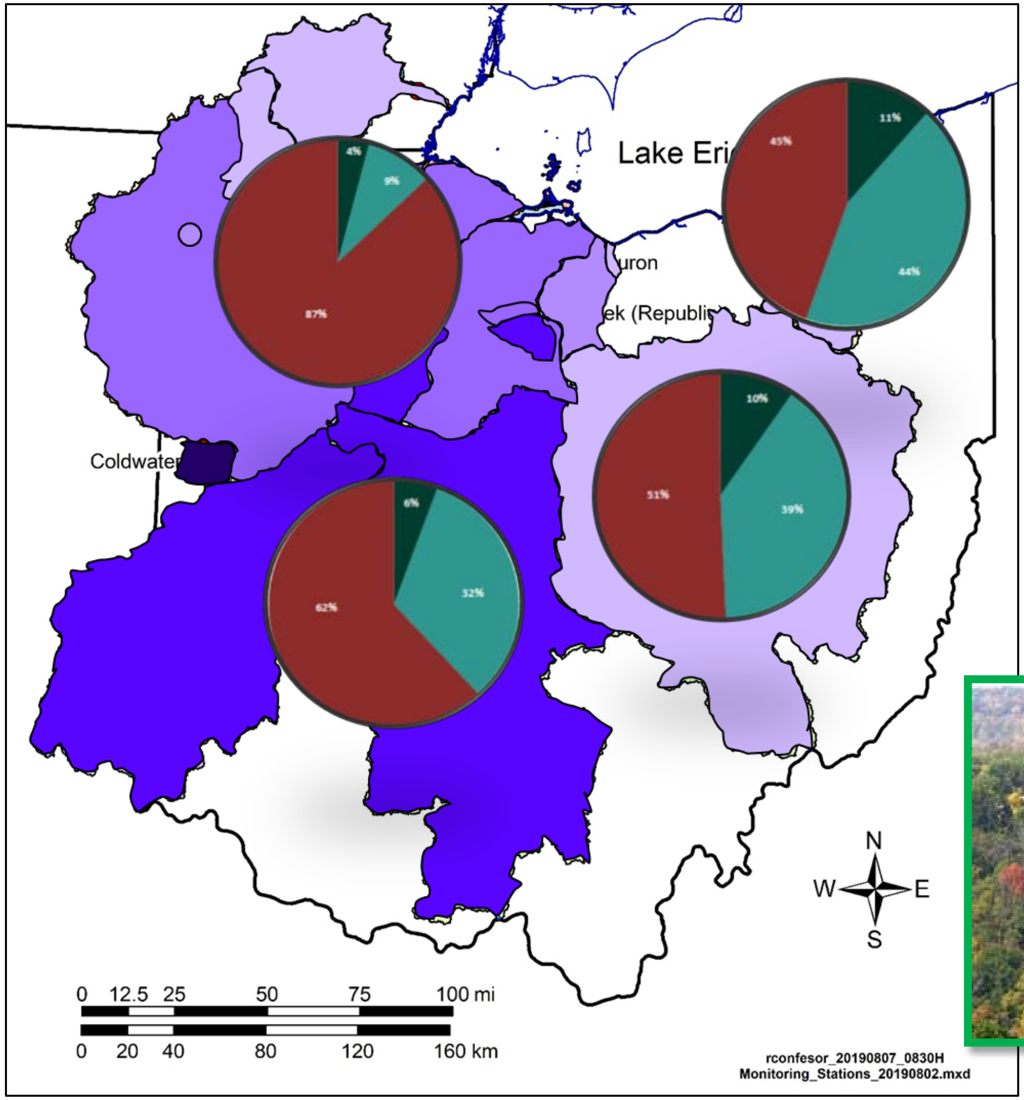
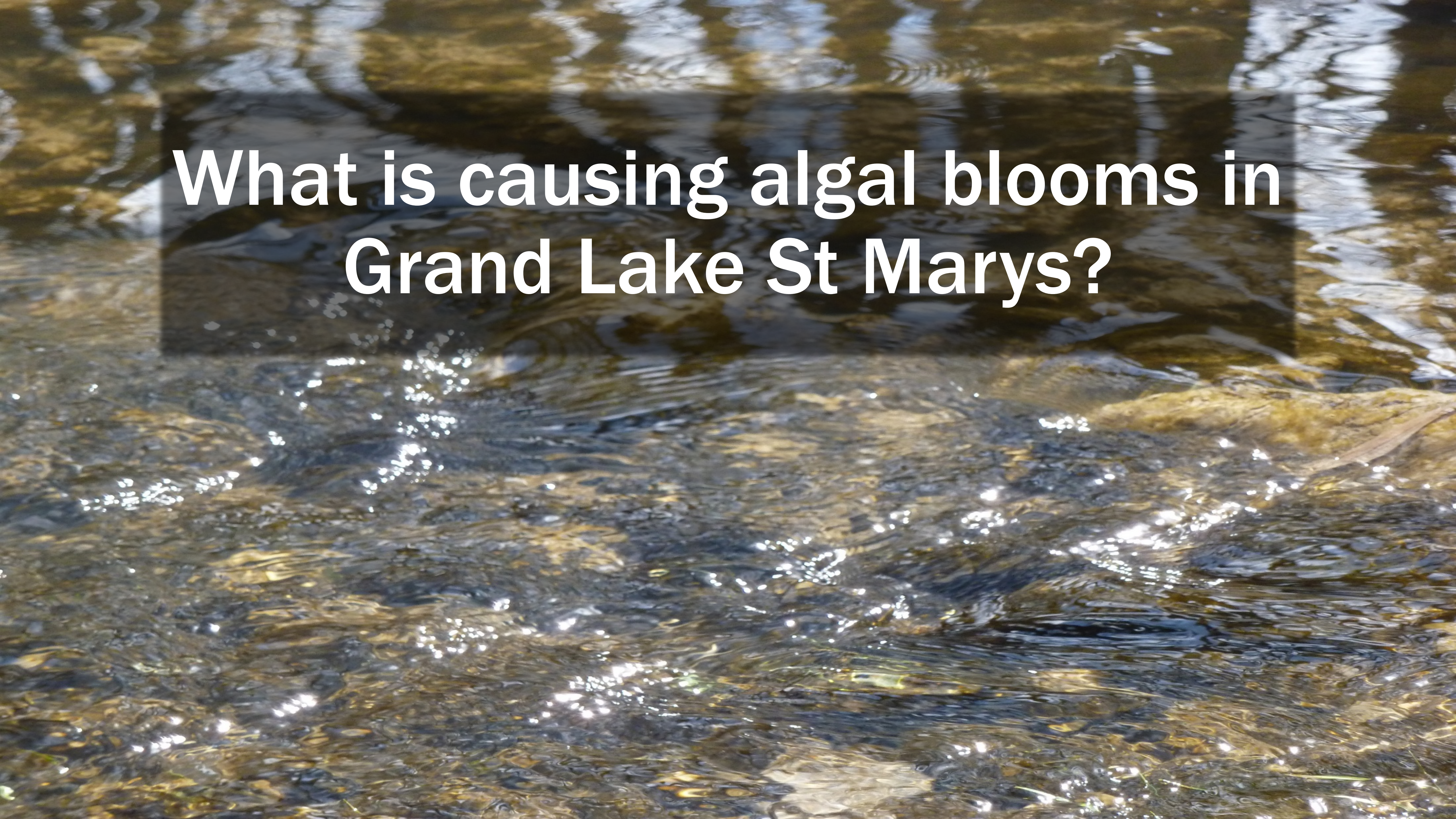
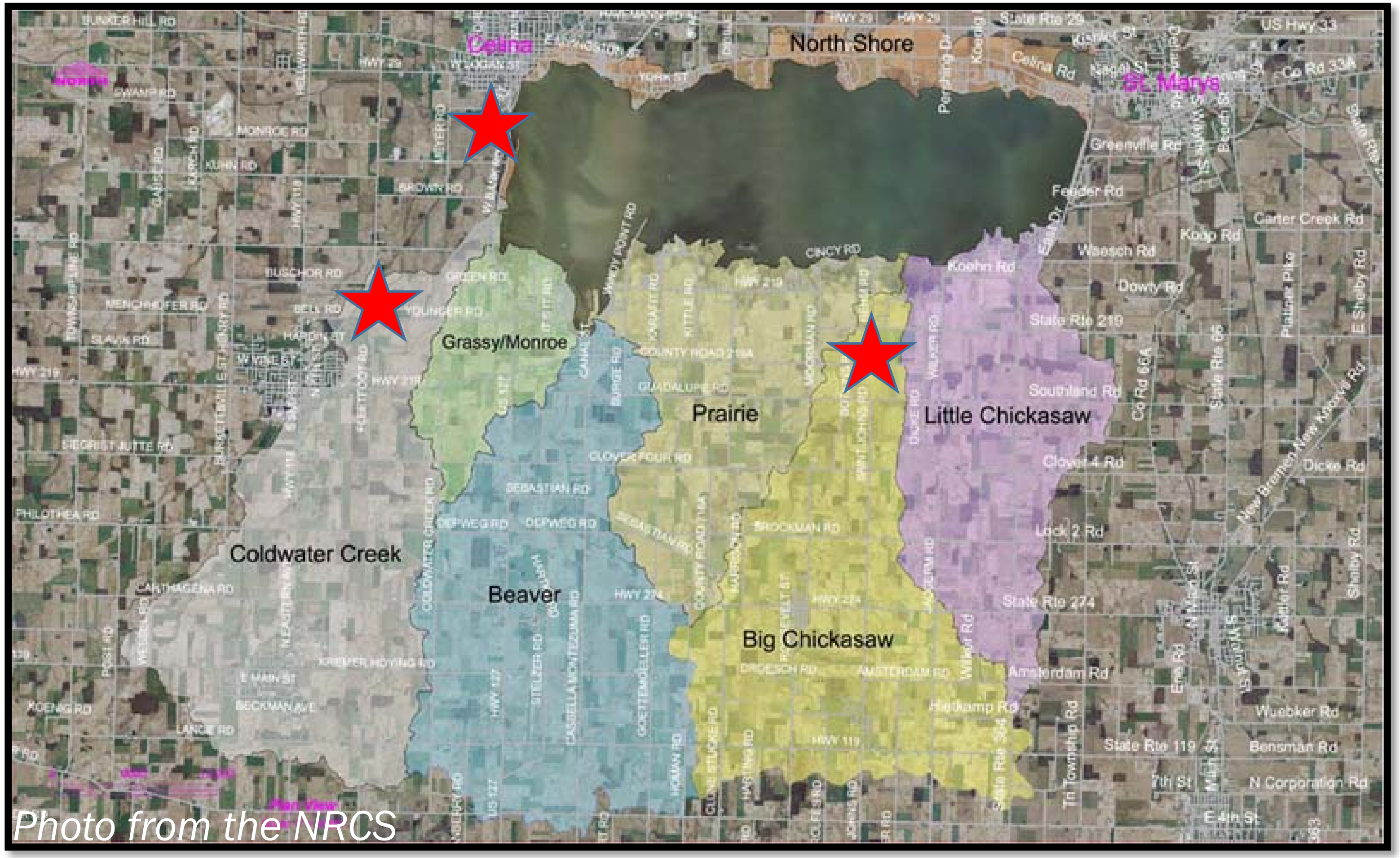


SEPTIC POINT NONPOINT

What is causing algal blooms in Grand Lake St Marys?

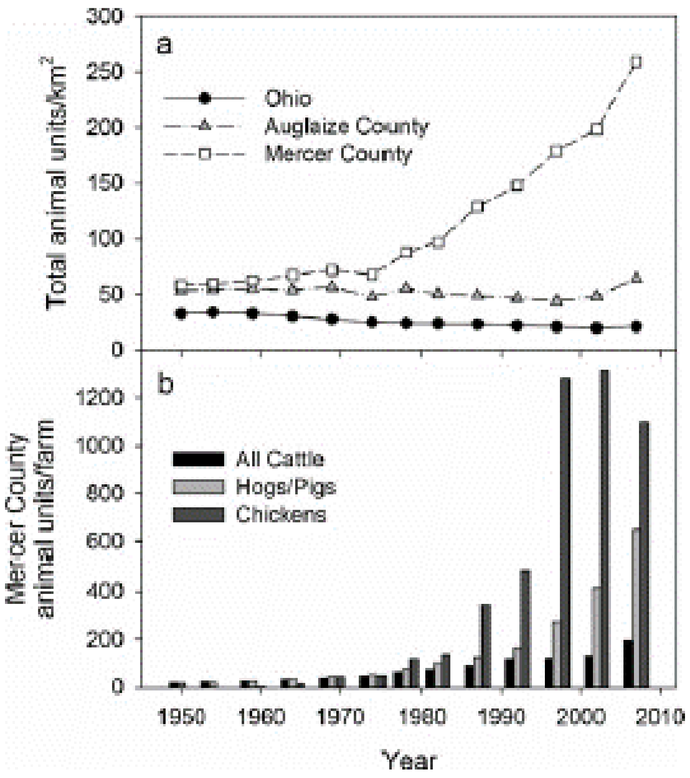




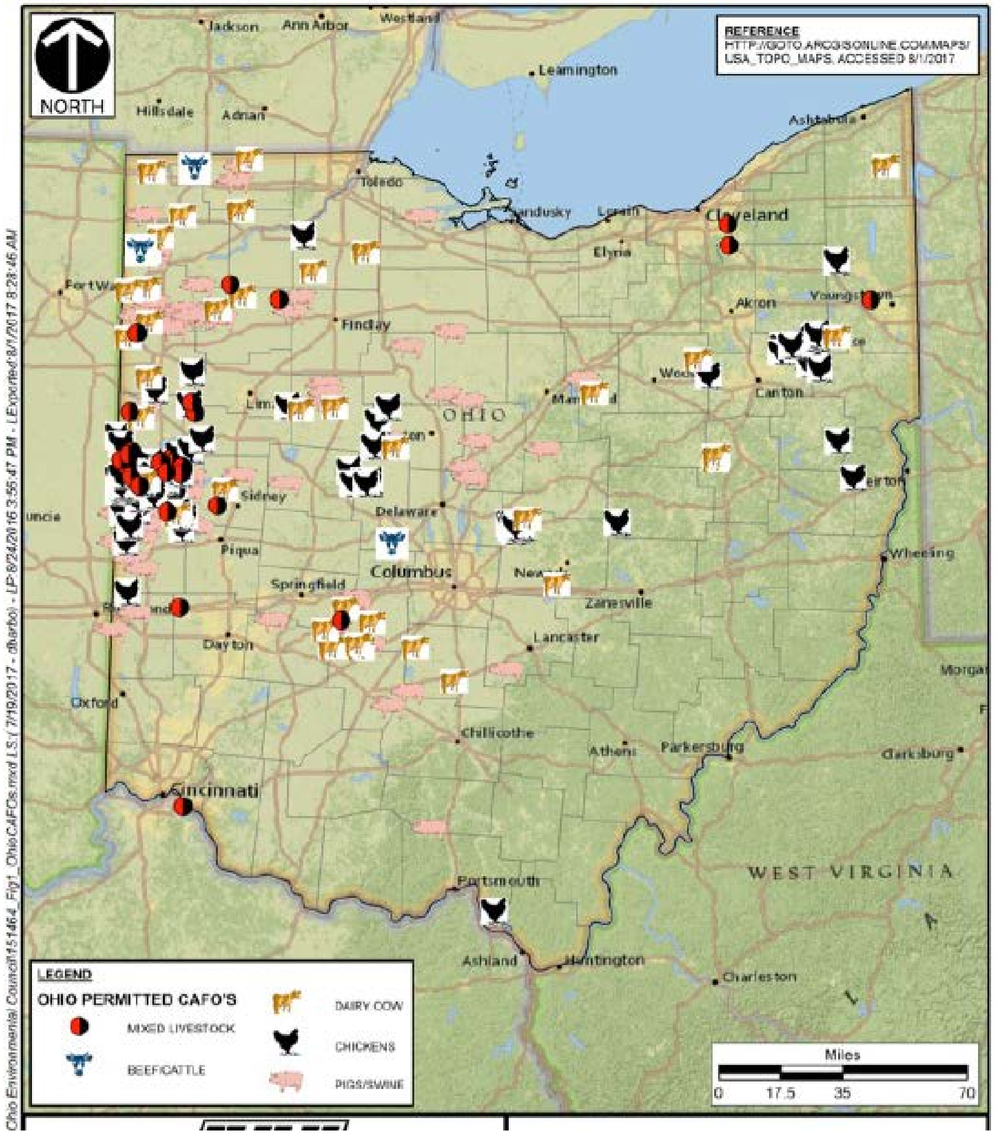
Chickasaw started in 2008
Coldwater started in 2012
Beaver (outflow) started in 2013

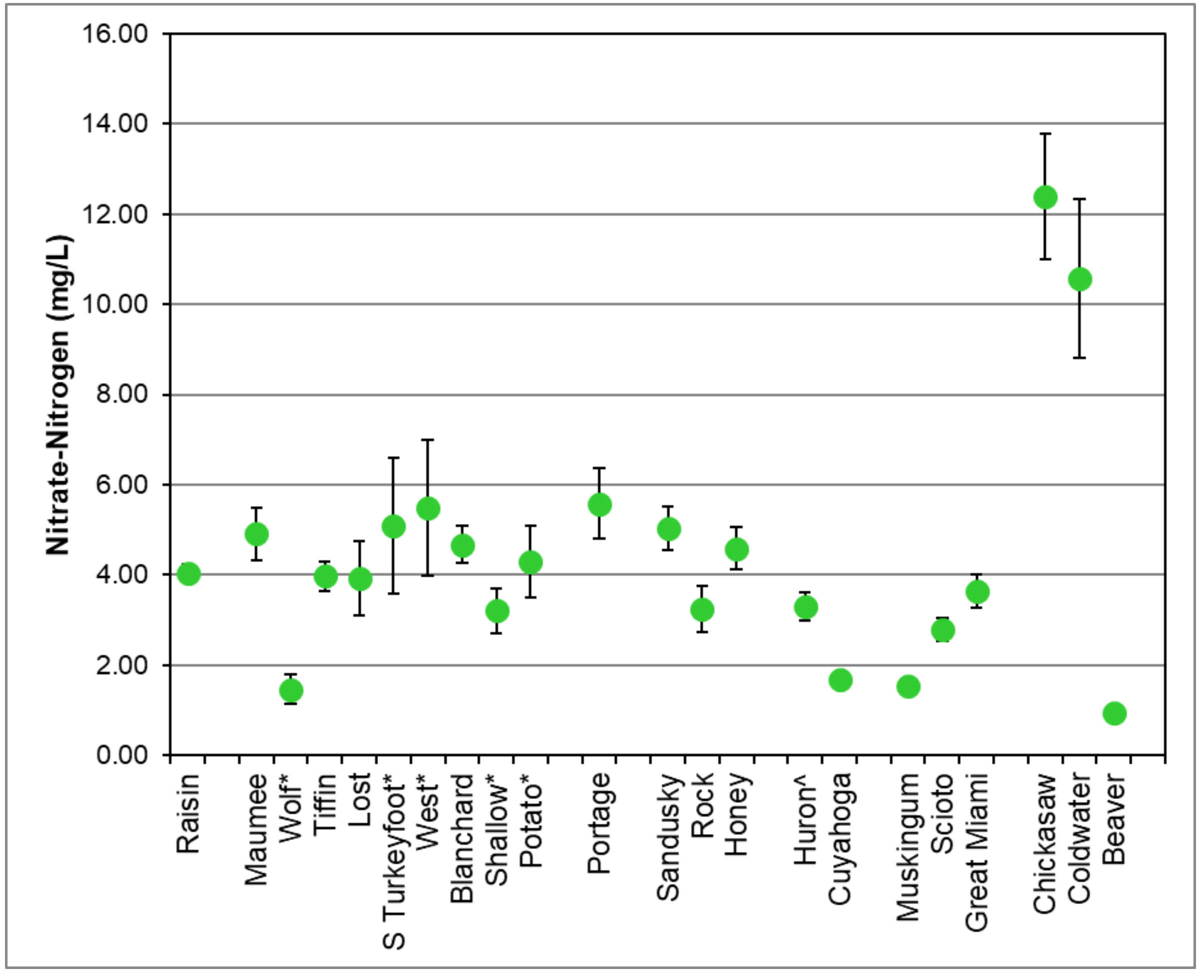
Grand Lake St Marys

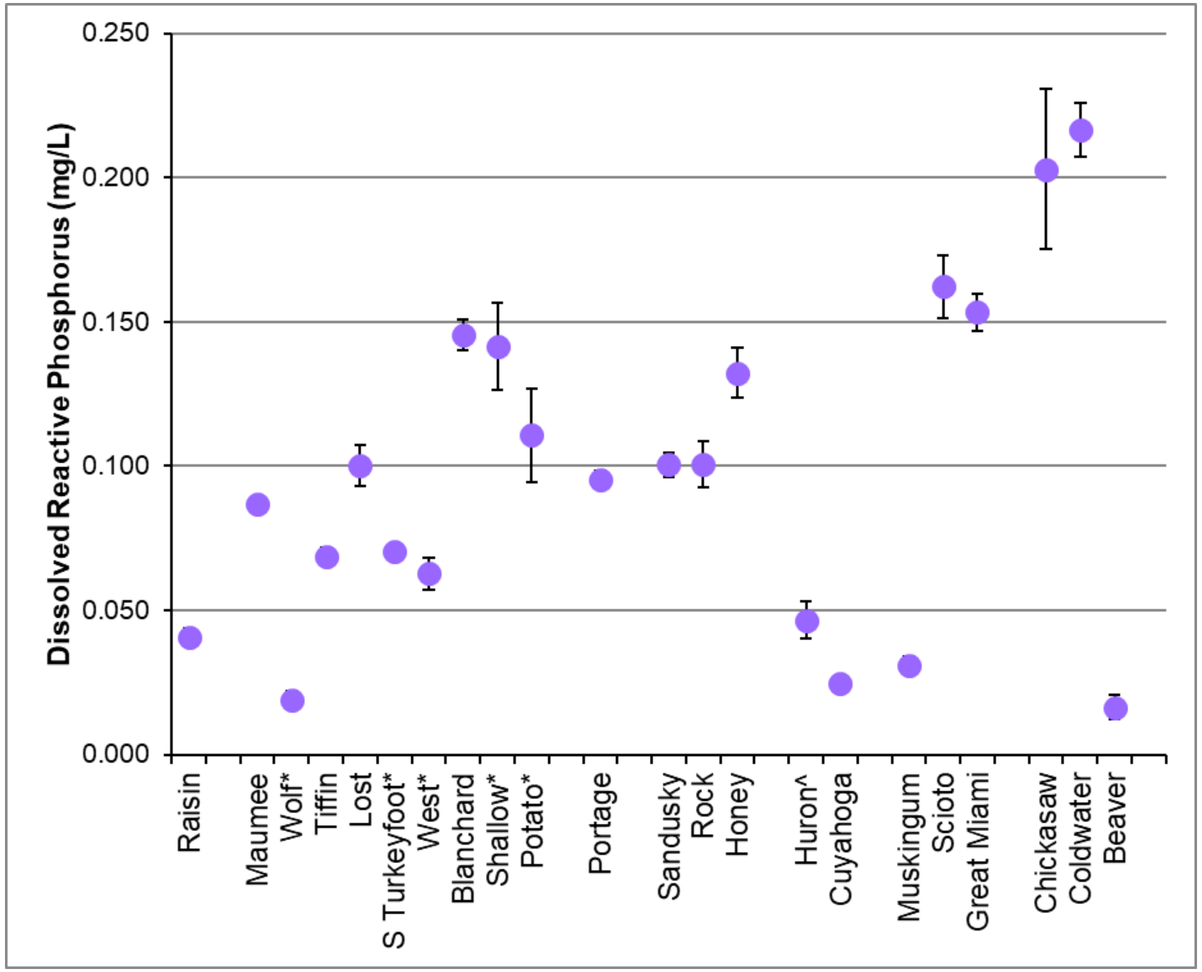
- 2007 National Lakes Assessment
  - Of 1252 lakes sampled, GLSM was in 97th percentile for chlorophyll a, and 3rd highest microcystin levels
- Why all the problems?
  - Lots of livestock in the basin
- Classified as a distressed watershed in 2011
- 99% of livestock producers and 90% of the cropland has a nutrient management plan
- ~20% of the watershed has received EQIP funding for cover crops
- No manure application after Dec 15th (in effect 2013) without approval to Mar 1st



From Filbrun et al. 2013

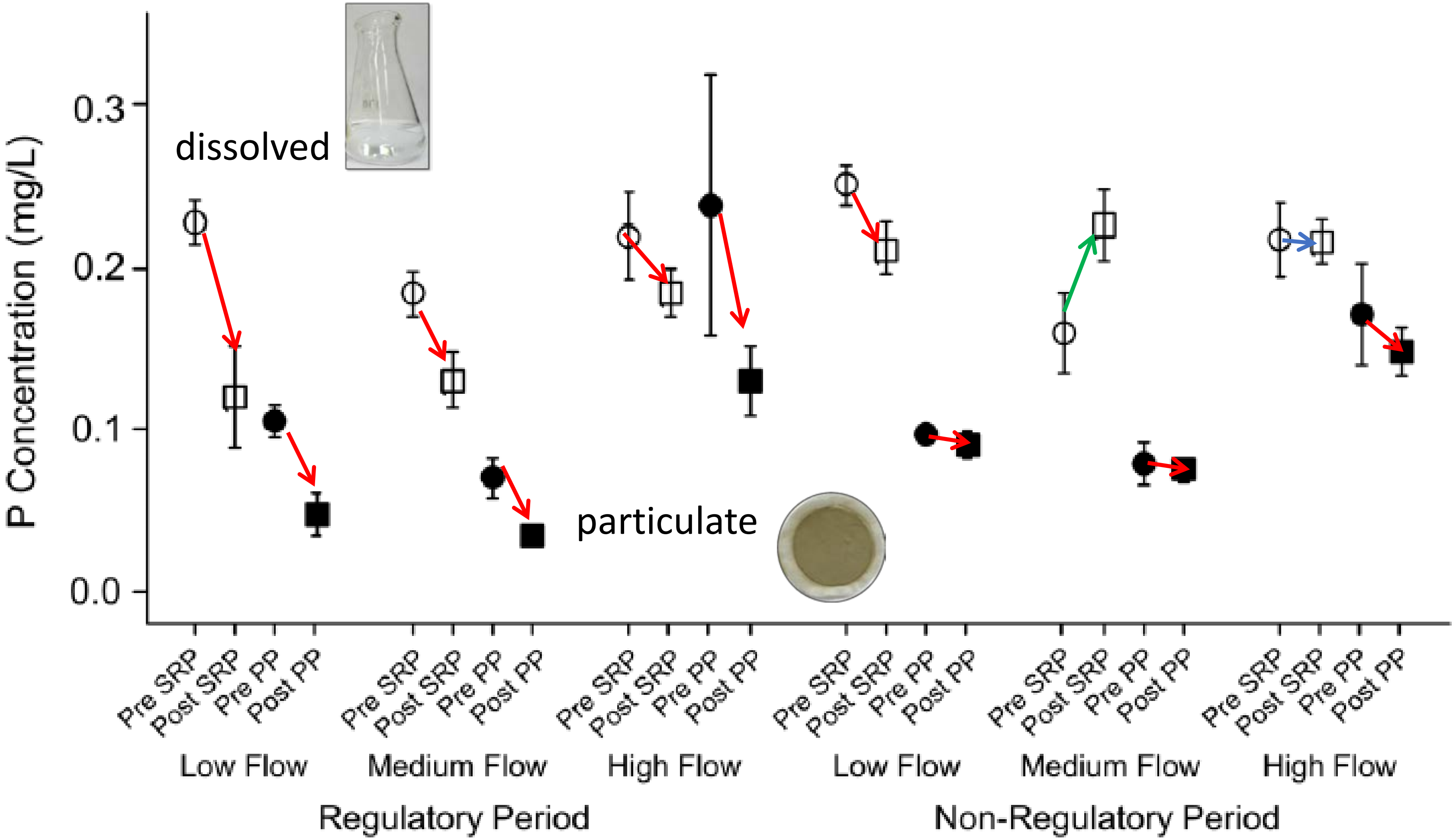






Grand Lake St Marys inflow tributaries have very high average annual concentrations

Change in phosphorus concentrations in Chickasaw Creek due to distressed GLSM watershed designation in 2011

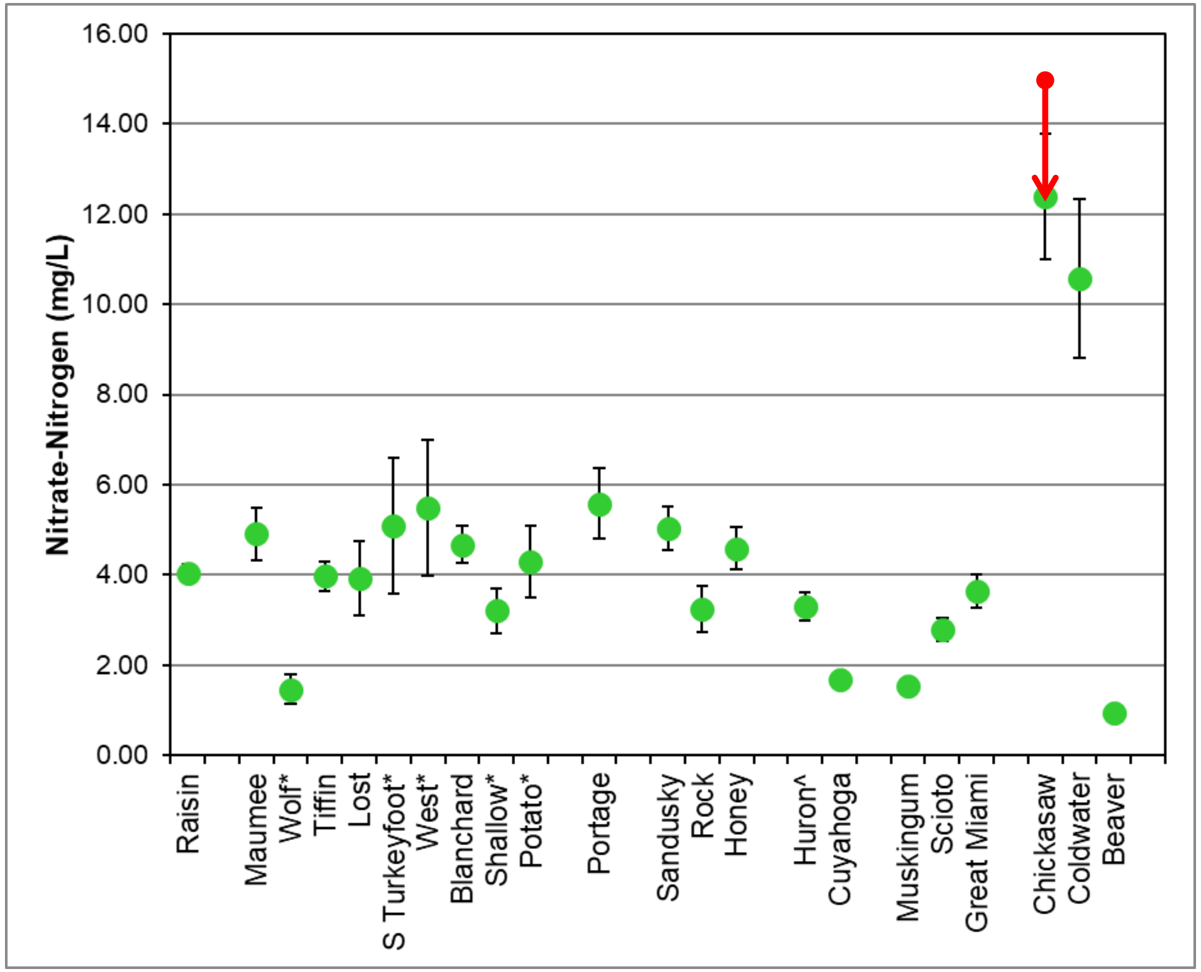


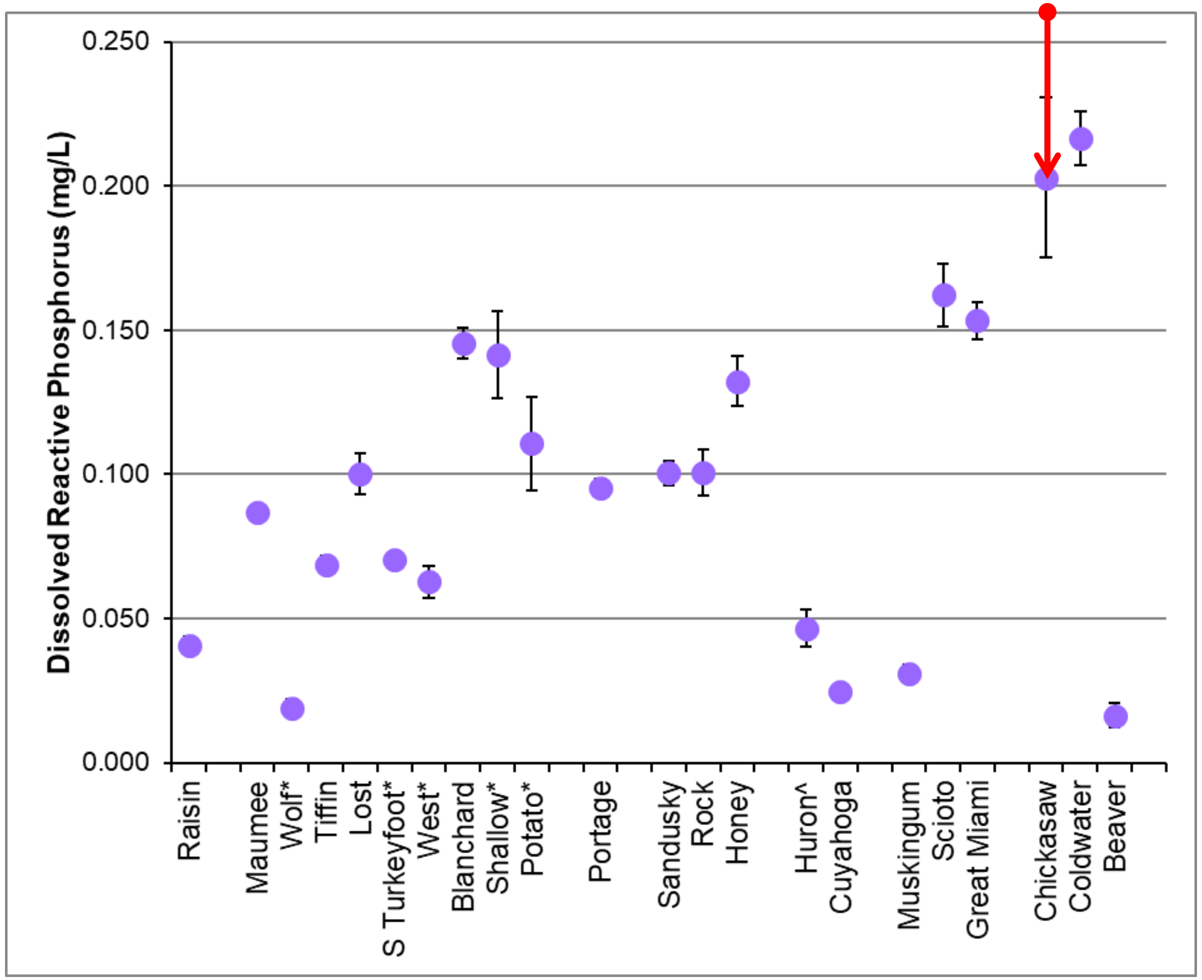
Dec 15 – Mar 1

Mar 1 – Dec 15

Pre = 2008 – 2011
Post = 2012 – 2016

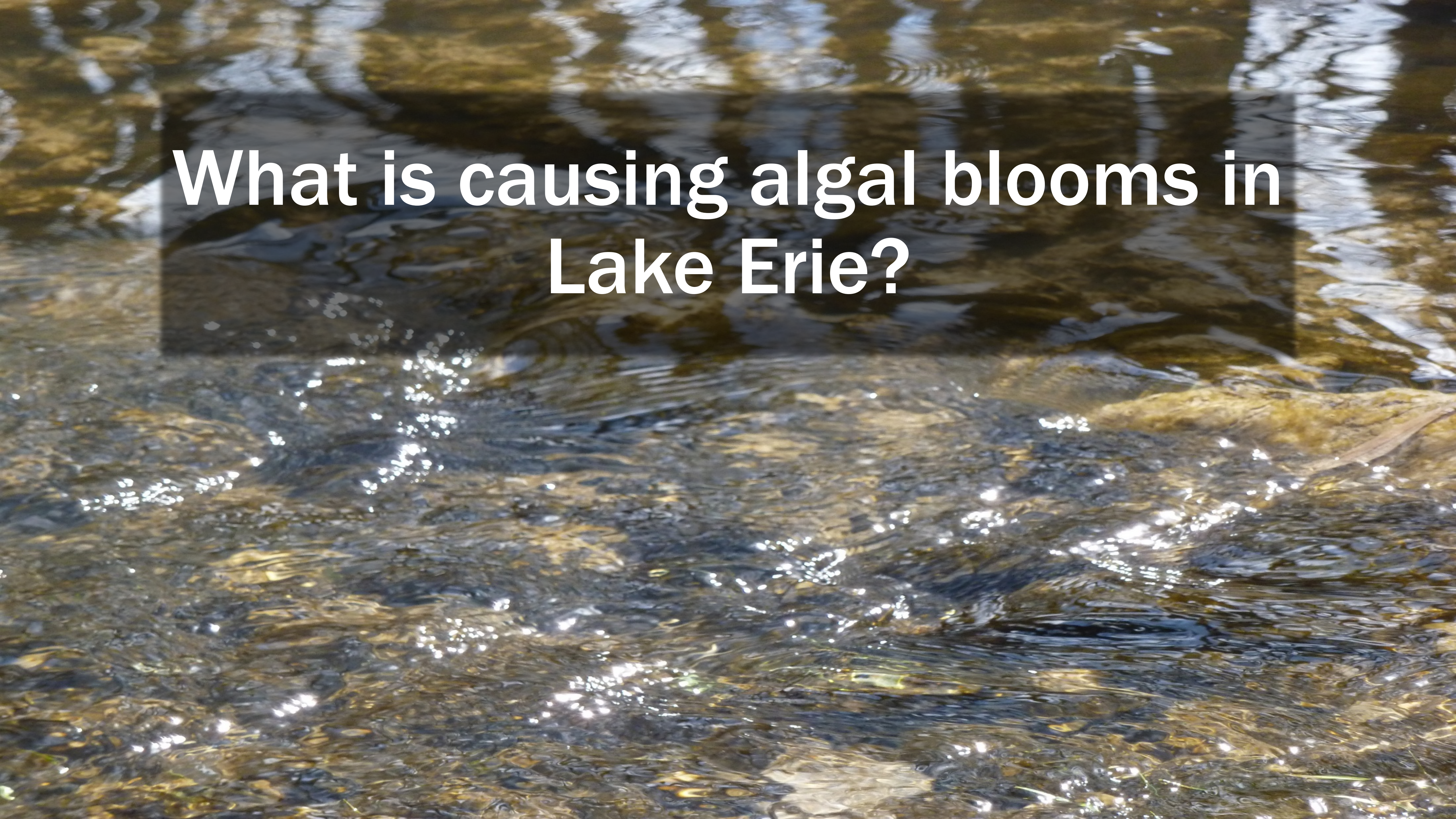
Jacquemin et al. 2018



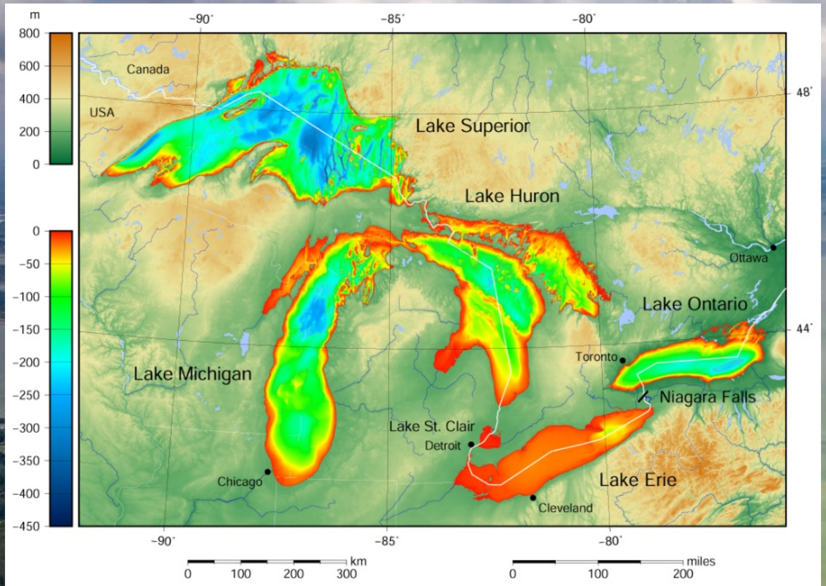


Nitrate-N	Average Annual Concentration (mg/L)	Percent decrease from 2008-2011
2008-2011 (pre-manure ban)	15.4	
2012-2016	10.8	30 %
2017-2023	12.3	20 %

Dissolved P	Average Annual Concentration (mg/L)	Percent decrease from 2008-2011
2008-2011 (pre-manure ban)	0.265	
2012-2016	0.253	4 %
2017-2023	0.196	26 %



What is causing algal blooms in Lake Erie?

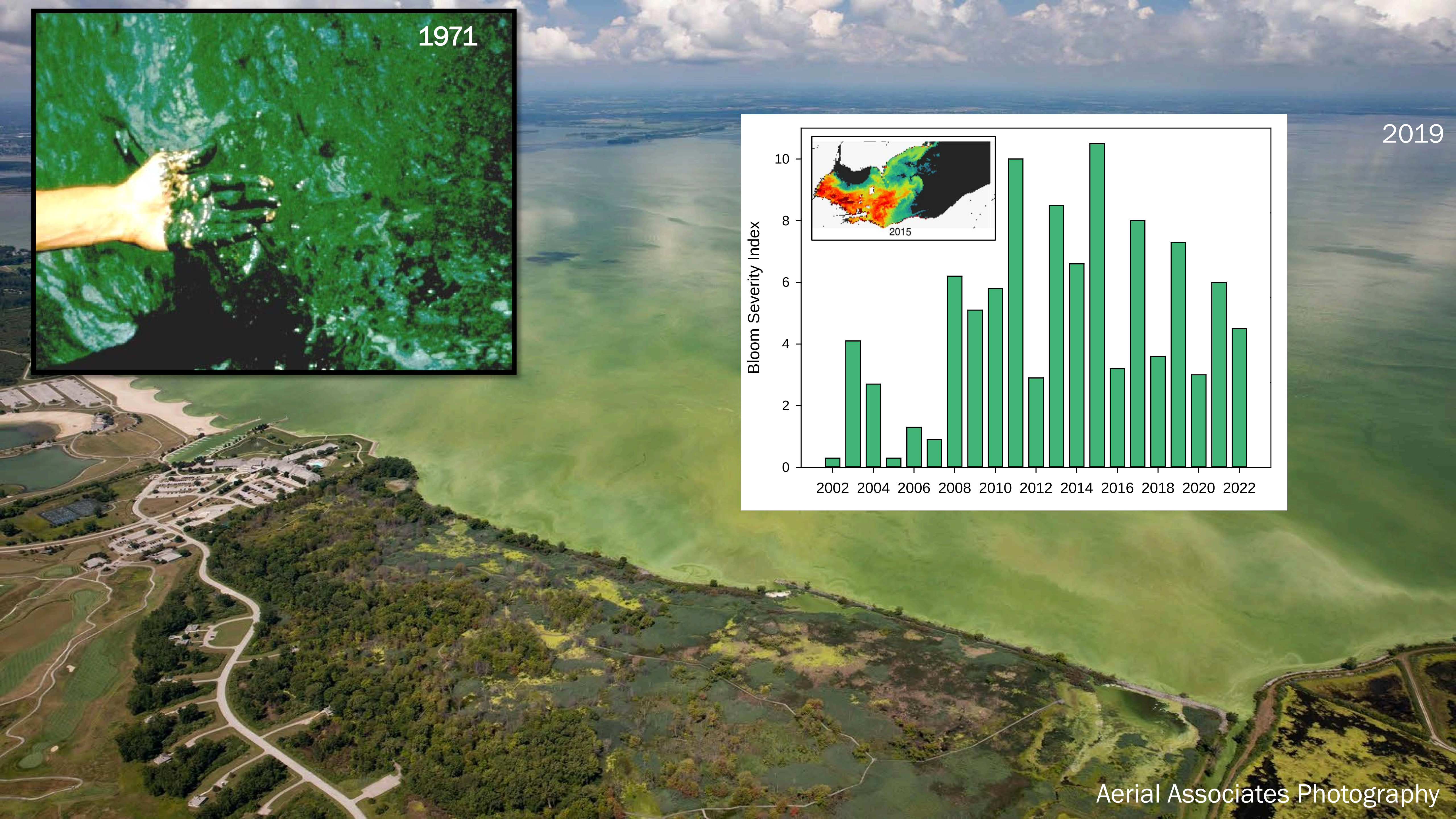


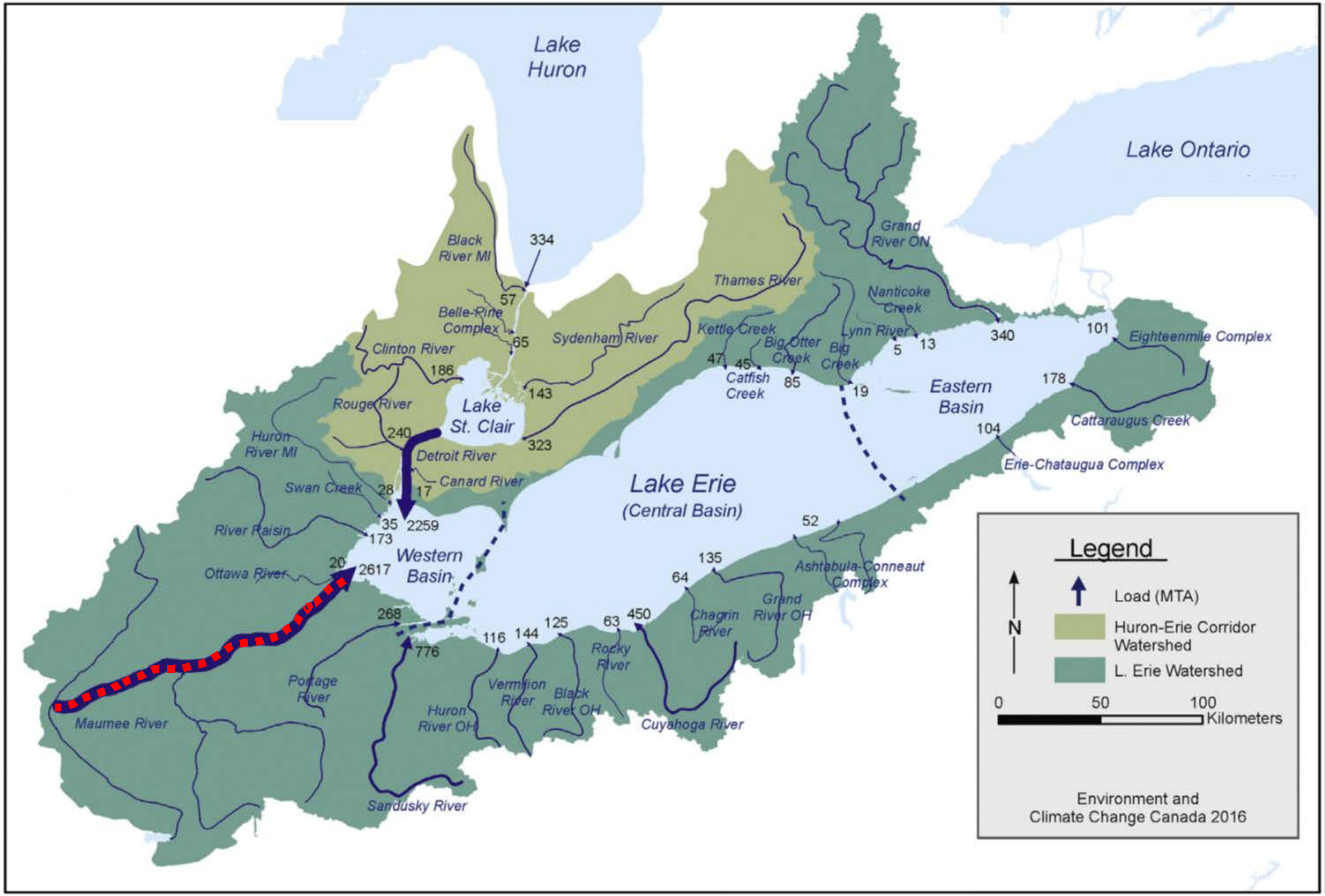
What are harmful algal blooms?

**produce a toxin*
**Microcystis, spp.*

- Light
- Warm temperatures
- Nutrients (nitrogen and phosphorus)

2019
Aerial Associates Photography

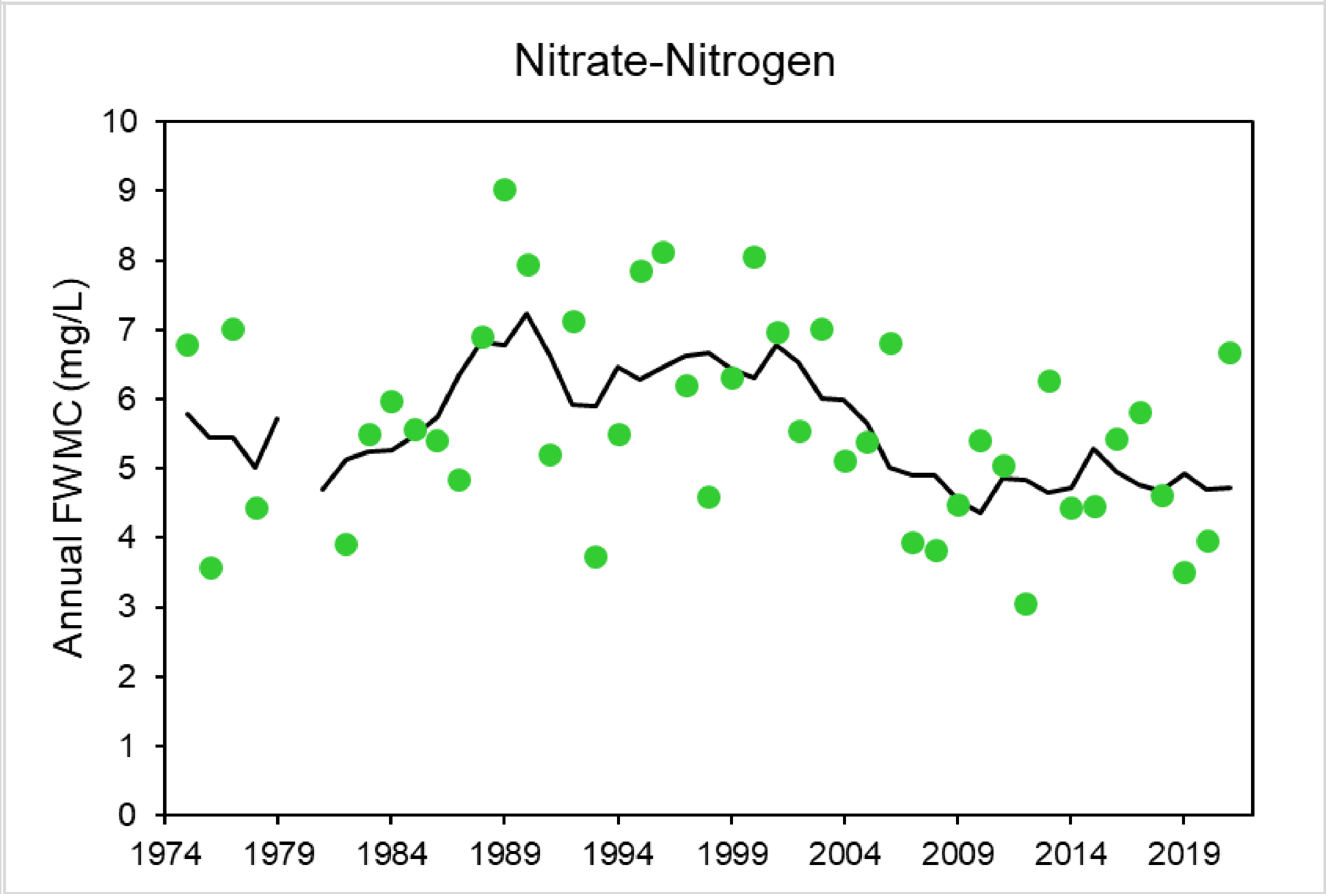

1971
2019
Bloom Severity Index
2015
0
2
4
6
8
10
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Aerial Associates Photography

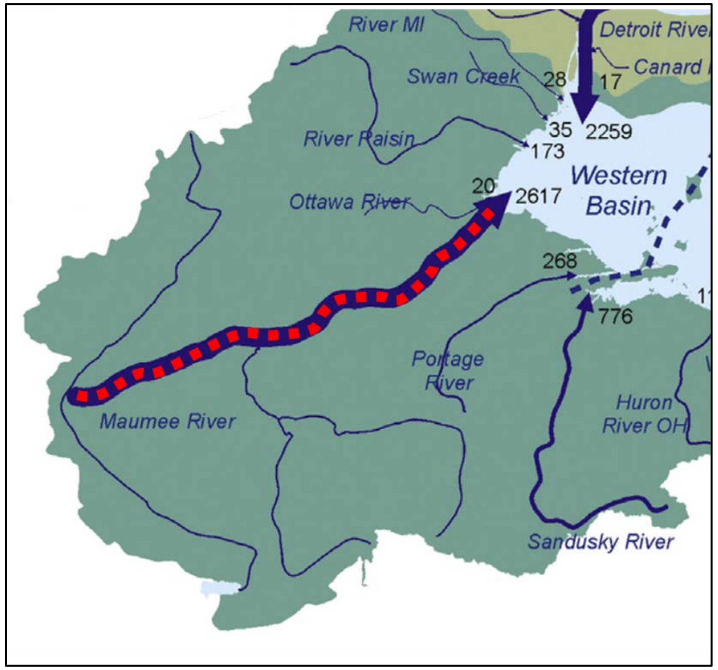


Mean total phosphorus loadings (MTA) to Lake Erie (2003–2013)

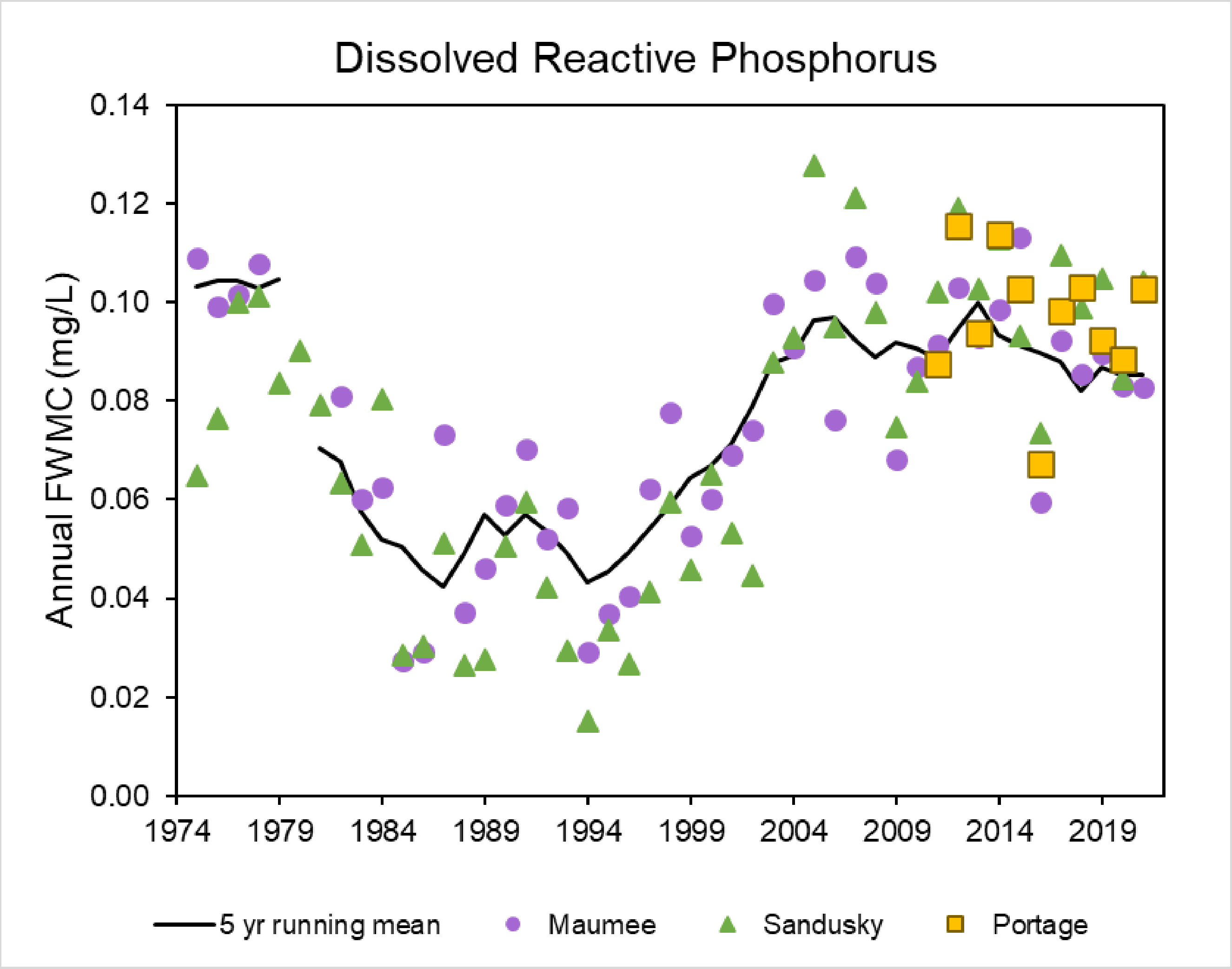
Maccoux et al. 2016, JGLR

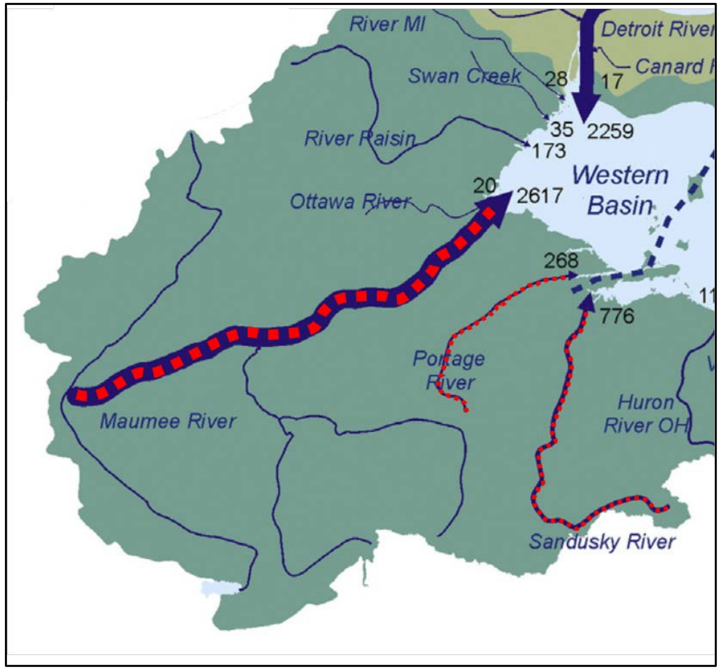
Long-term trends in annual nutrient concentrations from the Maumee River





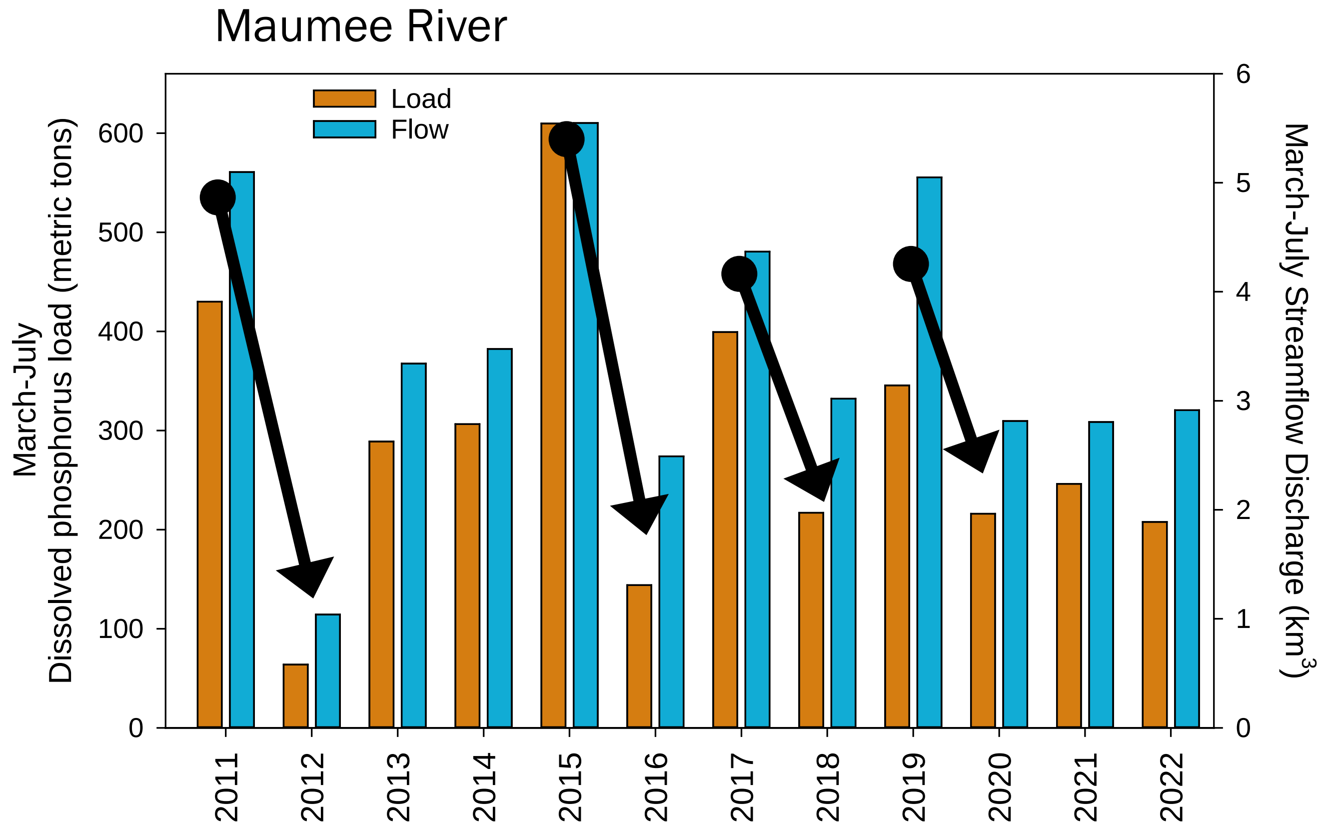
Similar increases in dissolved phosphorus are found in other WLEB tributaries

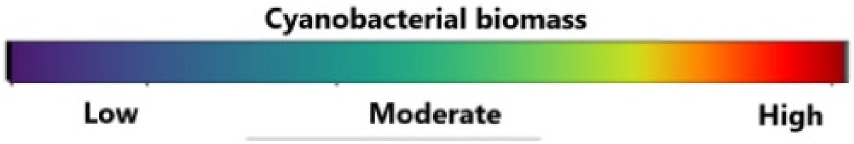


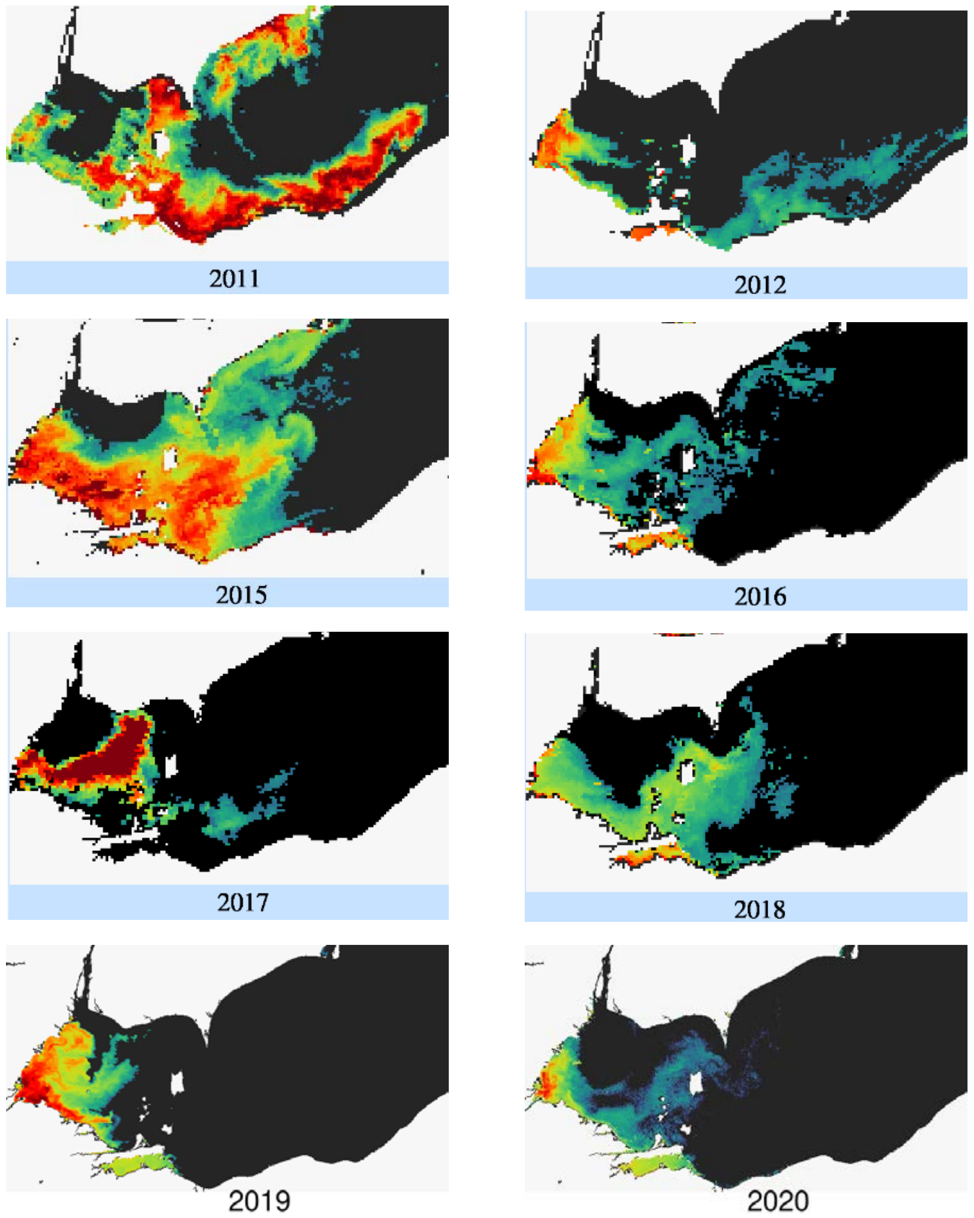


NCWQR

March to July P loads are linked to bloom severity



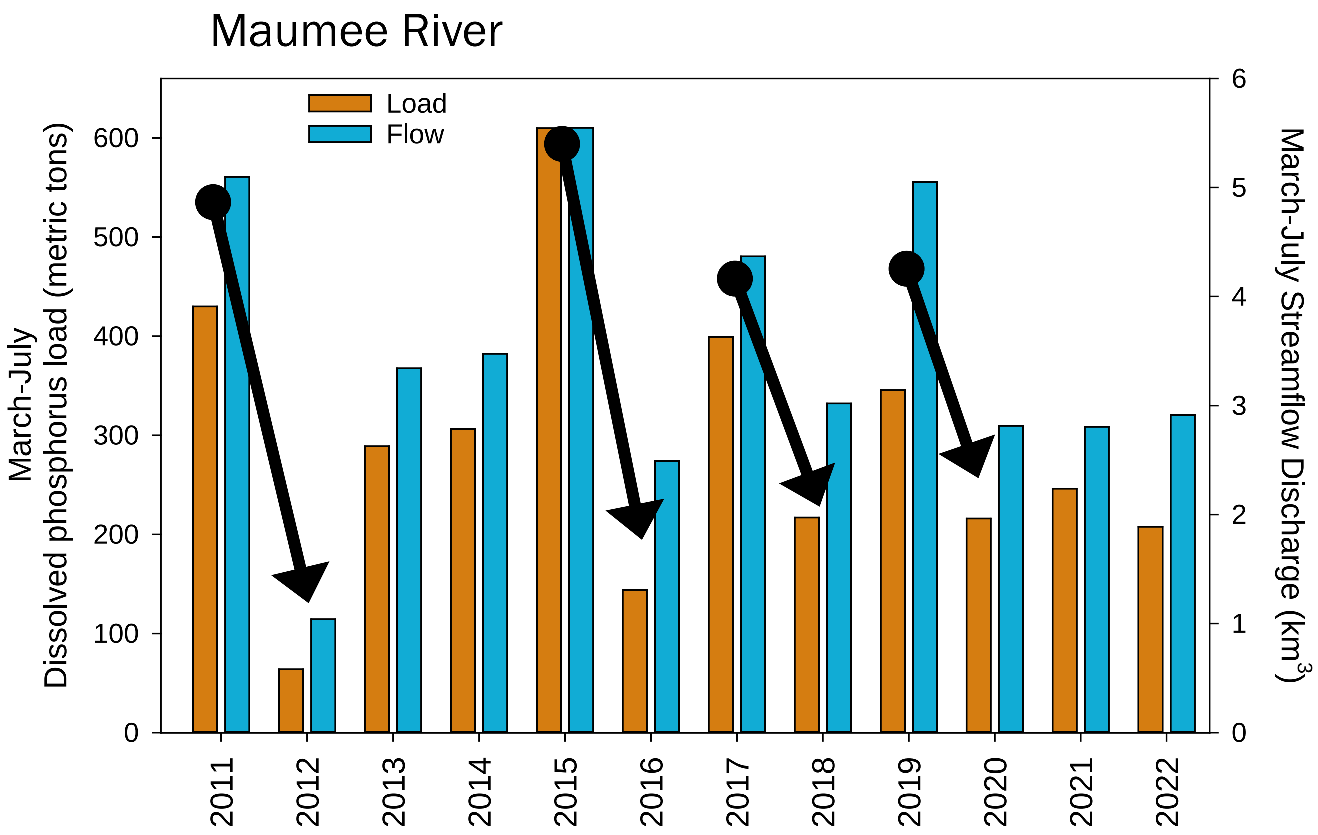


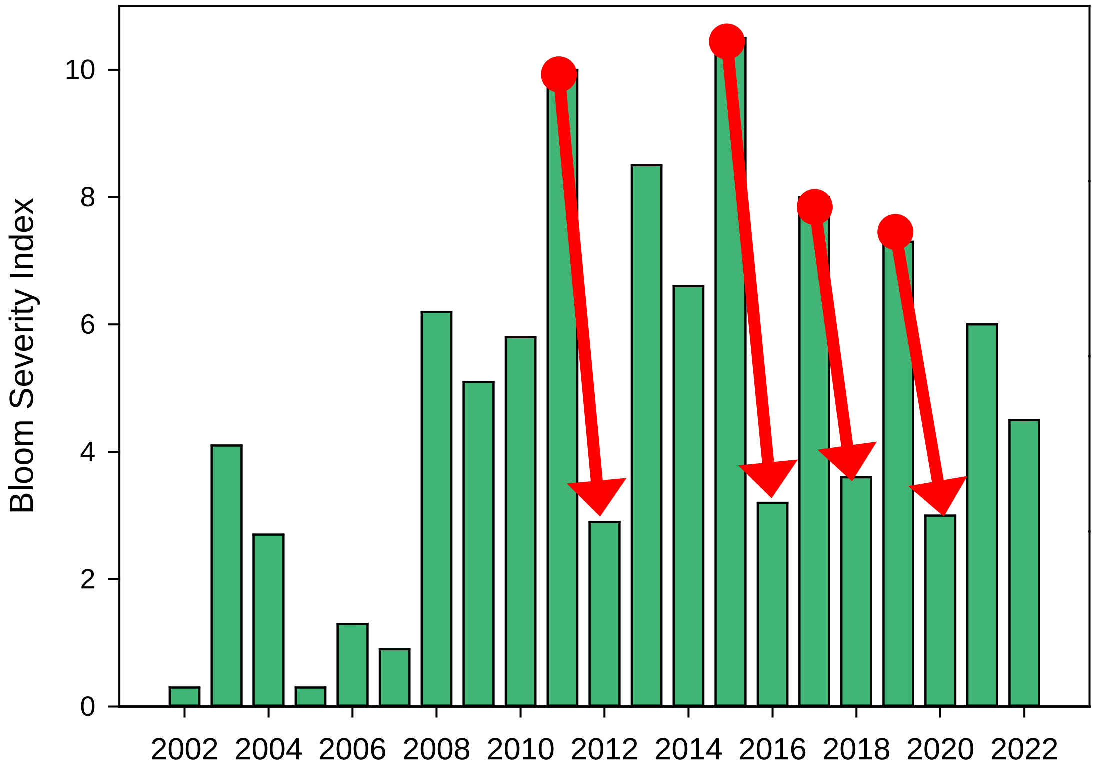


NCWQR

NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

March to July P loads are linked to bloom severity





Each summer we use this relationship to forecast bloom severity for Lake Erie

https://coastalscience.noaa.gov/science-areas/habs/hab-forecasts/lake-erie/

NCWQR

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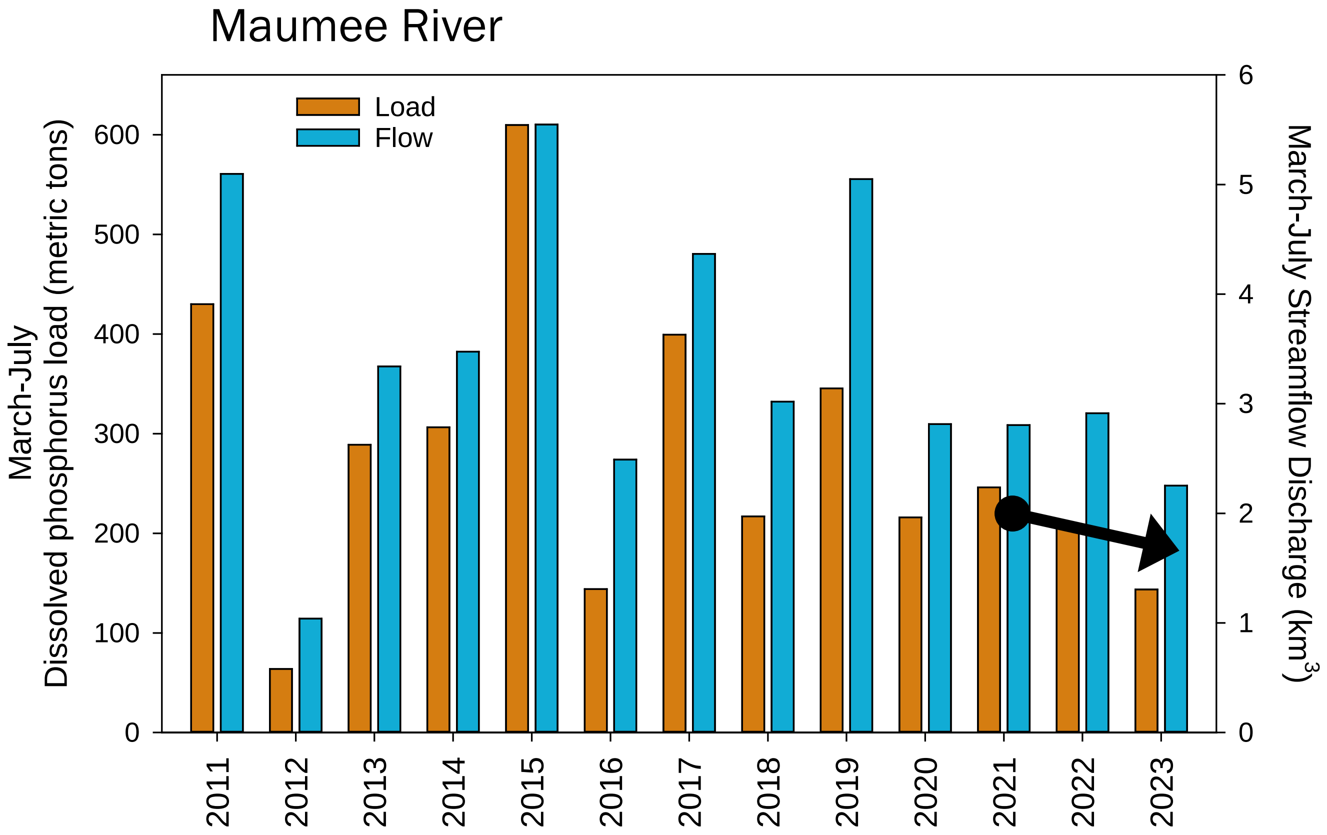
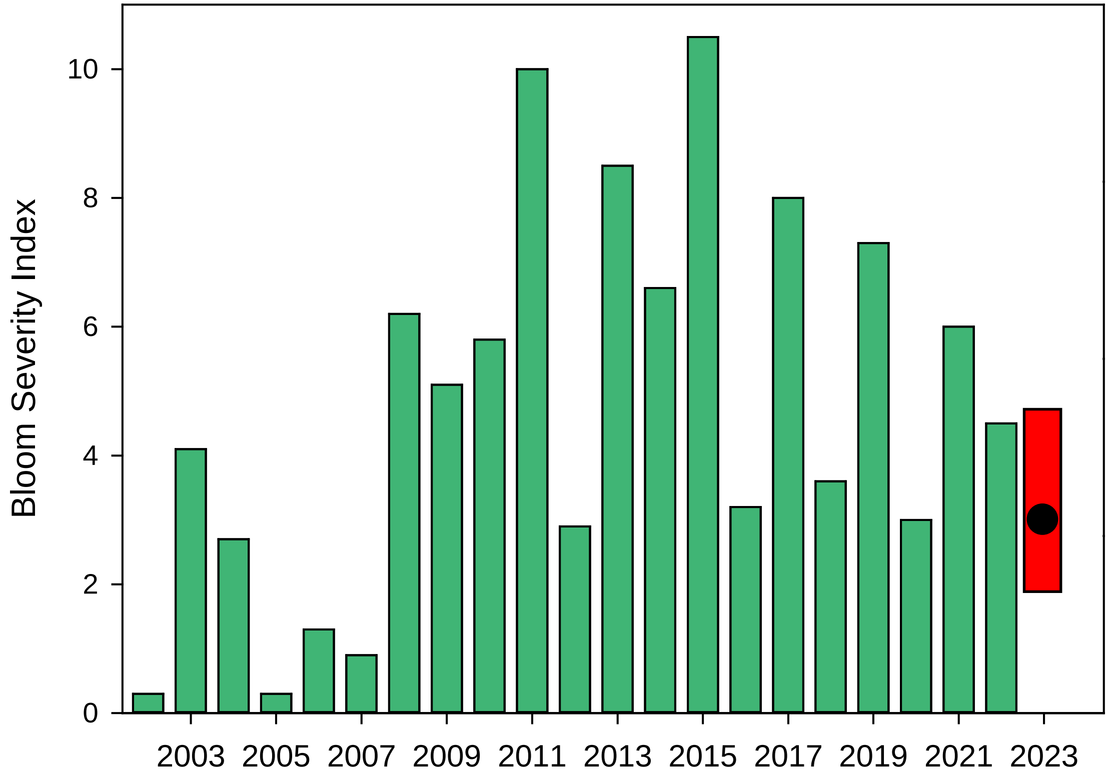
The 2023 bloom is expected to be mild (3; 2-4.5)





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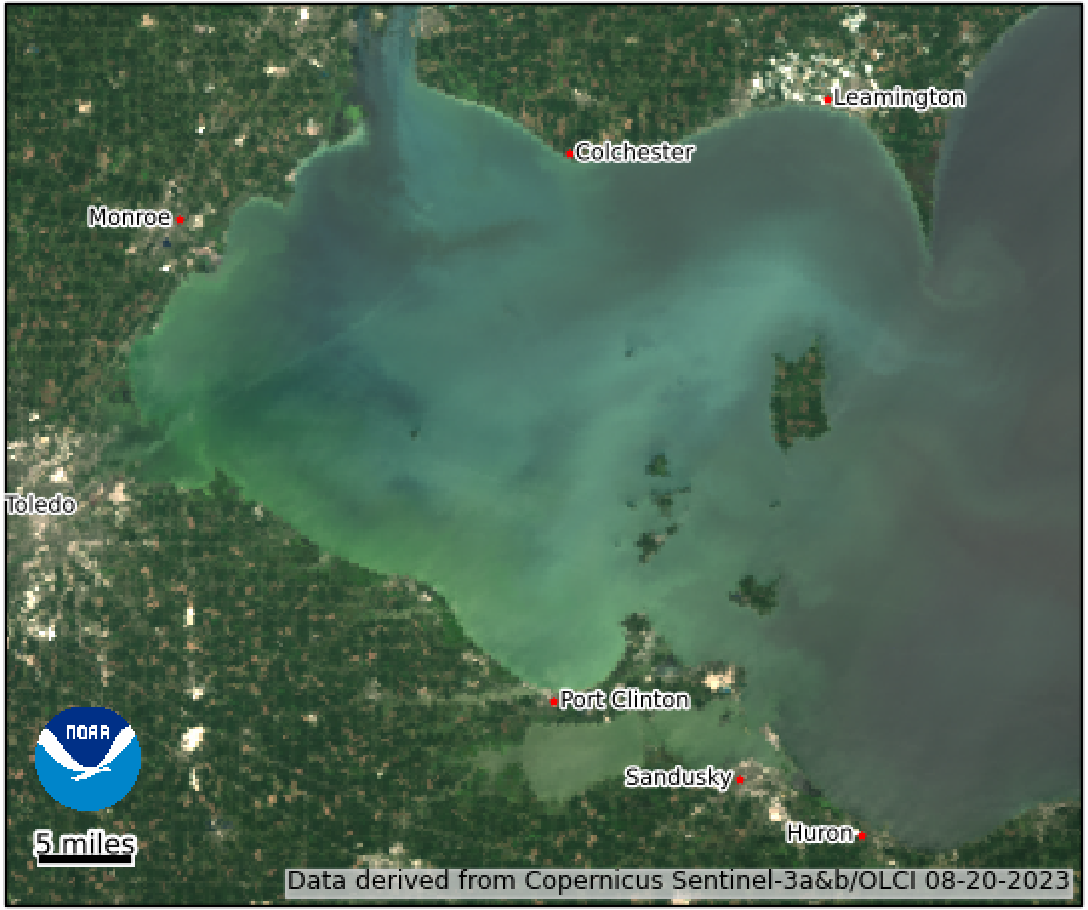
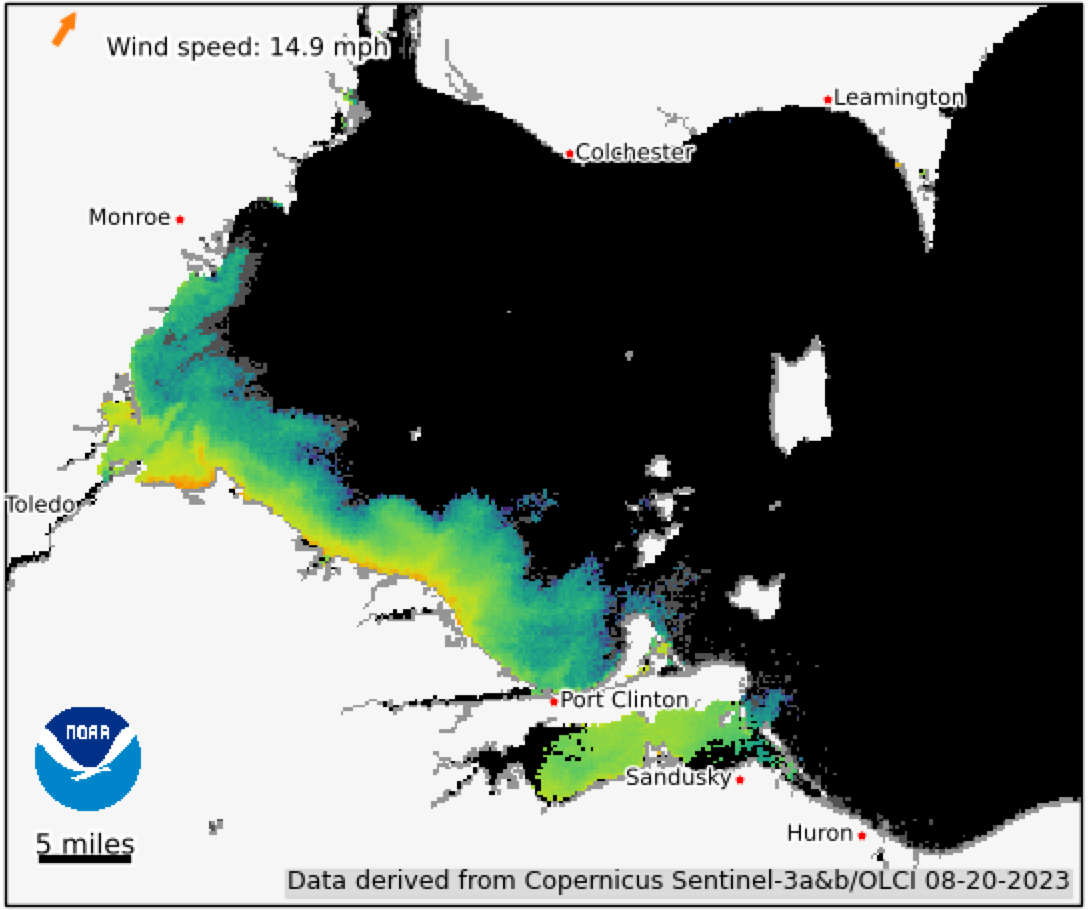
The Western Lake Erie bloom in 2023 (so far)

June 20 July 4 July 14 July 24 August 4 August 13 August 20



Composited Western Lake Erie basin true color image derived from the OLCI sensor on Copernicus Sentinel-3a&b obtained from EUMETSAT.



Composited Cyanobacteria Index (CI-CIcyano) for Western Lake Erie basin. The algal bloom is present but cloud cover or winds above 9.0 mph prevent determining an area (previous area from Aug 19 was 360 square miles). Winds above 4.0 mph may begin mixing the bloom and clouds may obscure it, leading to an underestimate of the area. Moderate and low concentrations may not be obvious to the eye. Average wind for preceding 3 hours of satellite observation from NOAA

Why did dissolved phosphorus increase?

What are some solutions?

Point sources

- Reduce nutrients in effluent through technological advances

Nonpoint sources

- Apply less fertilizer and place it below the surface of the soil
- Reduce water movement off fields

Reduce nutrient loss

Soil testing:
Testing results give farmers information on where to place fertilizer and fertilizer application rate.

Variable-rate fertilization:
Applying specific fertilizer levels based on the need of each sub-acre to reduce fertilizer application without risk of losing yield.

Subsurface nutrient application:
Applying specific fertilizer below the surface to reduce nutrient loss.

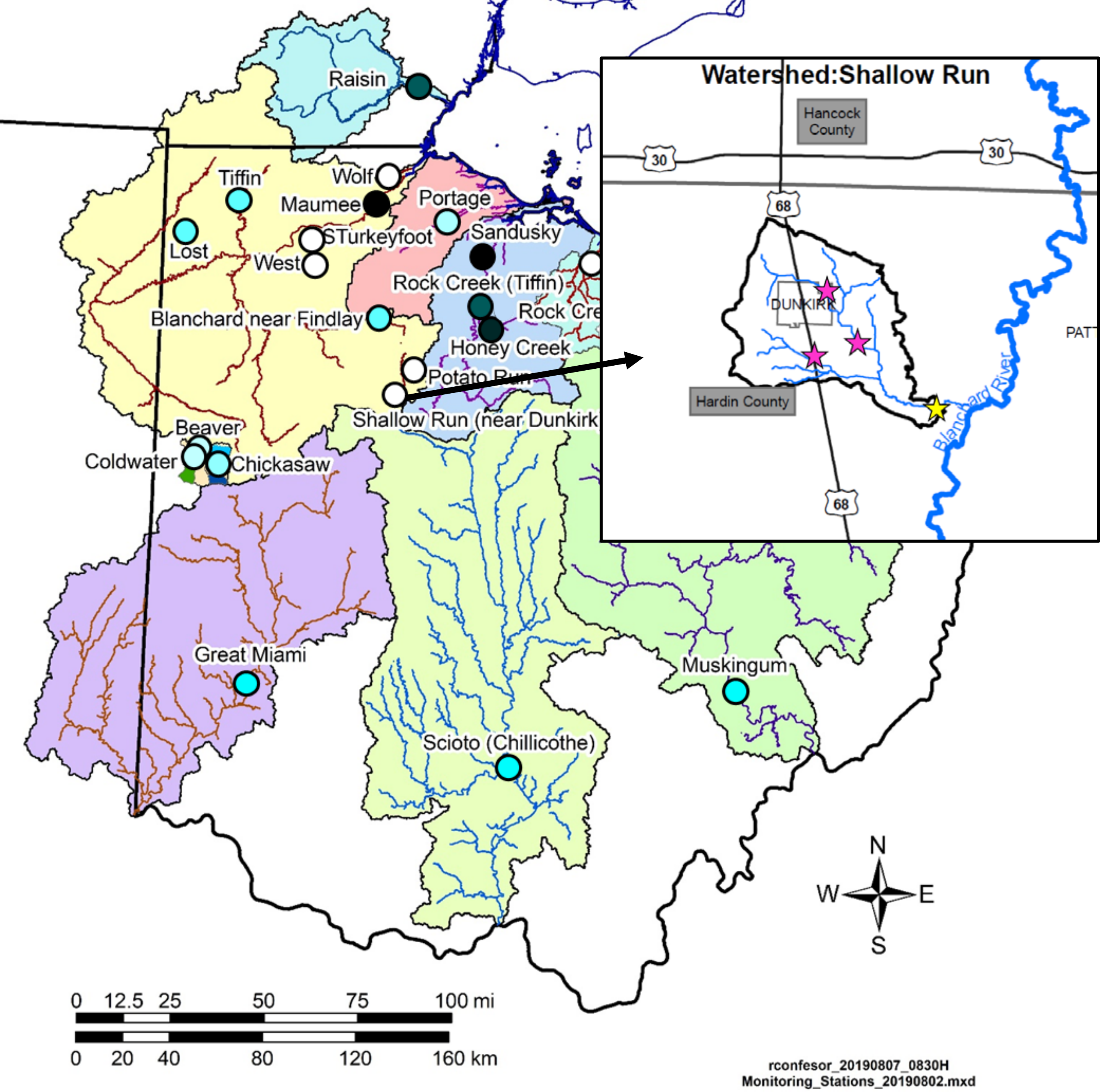
Manure incorporation:
Mixing manure into the soil to keep it in place and minimize nutrient loss.

The Ohio State University

The Pilot Watershed Approach

Reduce Scale & Increase Adoption

- Heavily invest in practices, monitoring, outreach in small sub-watershed
- GOAL: 70%+ adoption rates in Shallow Run
- Demonstrate ability of practices to increase water quality: “Can we move the needle?”
- With results, extrapolate to determine successful approaches for larger areas.
- Collaboration critical



Paired approach

- Shallow Run (5,500 acres) is the treatment
- Potato Run (11,000 acres) is the control
- Monitoring began in 2018
- Practices will focus on reducing dissolved phosphorus
- Implementation will begin this fall

Reduce erosion and slow down water

Conservation crop rotation: Planting certain crops that reduce erosion and enrich the soil thus reducing runoff and sediment delivery.

Cover crops: When planted after the main harvest, cover crops reduce erosion, hold nutrients in the soil, and improve soil health.

Drainage water management: Slowing down runoff to give phosphorus more time to settle back in the soil.

Two-stage ditch construction: Creating modified drainage ditches to slow water flow and allow the phosphorus to settle.

Edge-of-field buffers: When trees, shrubs or strips of grass are planted along farm fields in the right place, the plants hold on to phosphorus and prevent its release into the water.

Wetlands: Wetland vegetation and soils absorb phosphorus, slow down the movement of water, offer a natural filtering process, and allow phosphorus to settle.

The H2Ohio Wetland Monitoring Program

Managed by the Lake Erie and Aquatic Research Network (LEARN) and the Ohio Department of Natural Resources (ODNR)

LEARN
LAKE ERIE & AQUATIC RESEARCH NETWORK

OHIO DEPARTMENT OF NATURAL RESOURCES

GOAL OF THE PROGRAM

The ultimate goal of the H2Ohio Wetland Monitoring Program is to assess nutrient removal of wetland restoration sites to help improve future restoration and management strategies.

CORE QUESTIONS

The core questions of the program are:

- Which types of wetland structure and function provide enhanced nutrient reduction and retention?
- Which wetland restoration approaches maximize cost-effectiveness to mitigate nutrient loads to Ohio water bodies?
- How can wetland restoration be effectively implemented in the future?

Program Partners

Lake Erie and Aquatic Research Network

Ohio Department of Natural Resources

The Ohio State University College of Food, Agricultural, and Environmental Sciences

Ohio Sea Grant and Stone Lab

Kent State University

The University of Toledo

Heidelberg University National Center for Water Quality Research

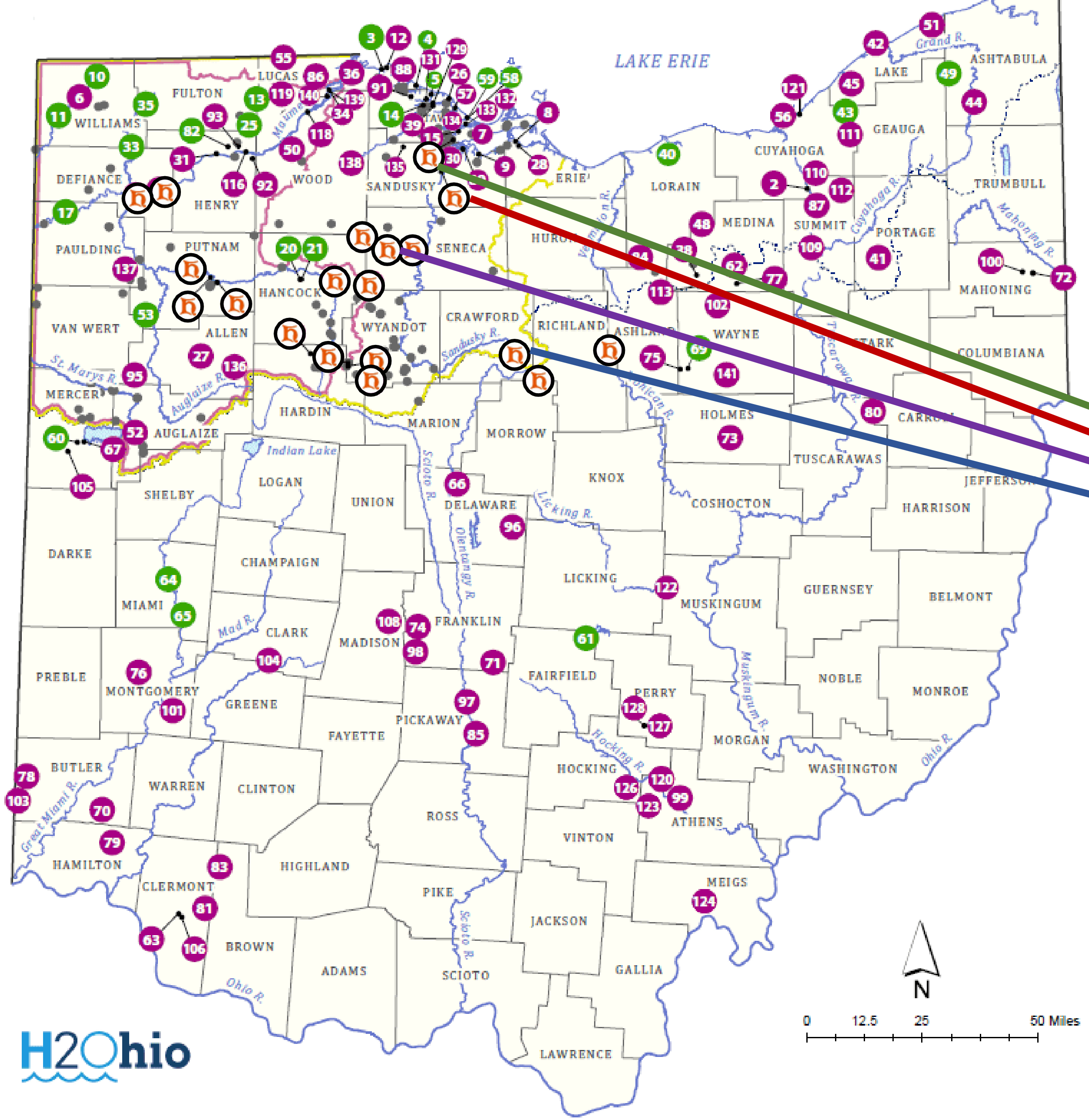
Old Woman Creek National Estuarine Research Reserve

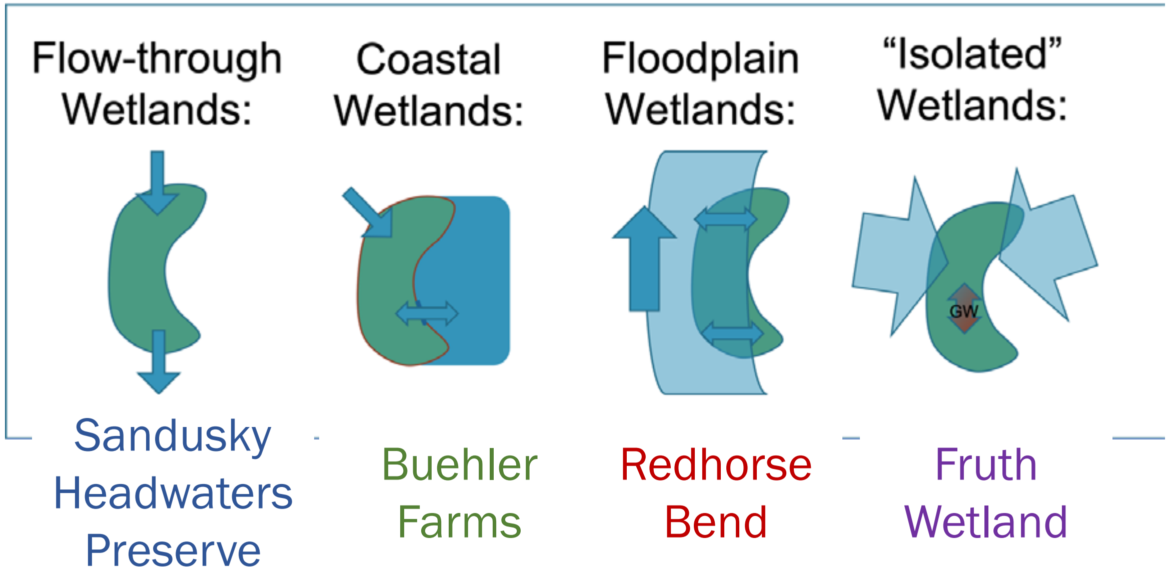
Bowling Green State University

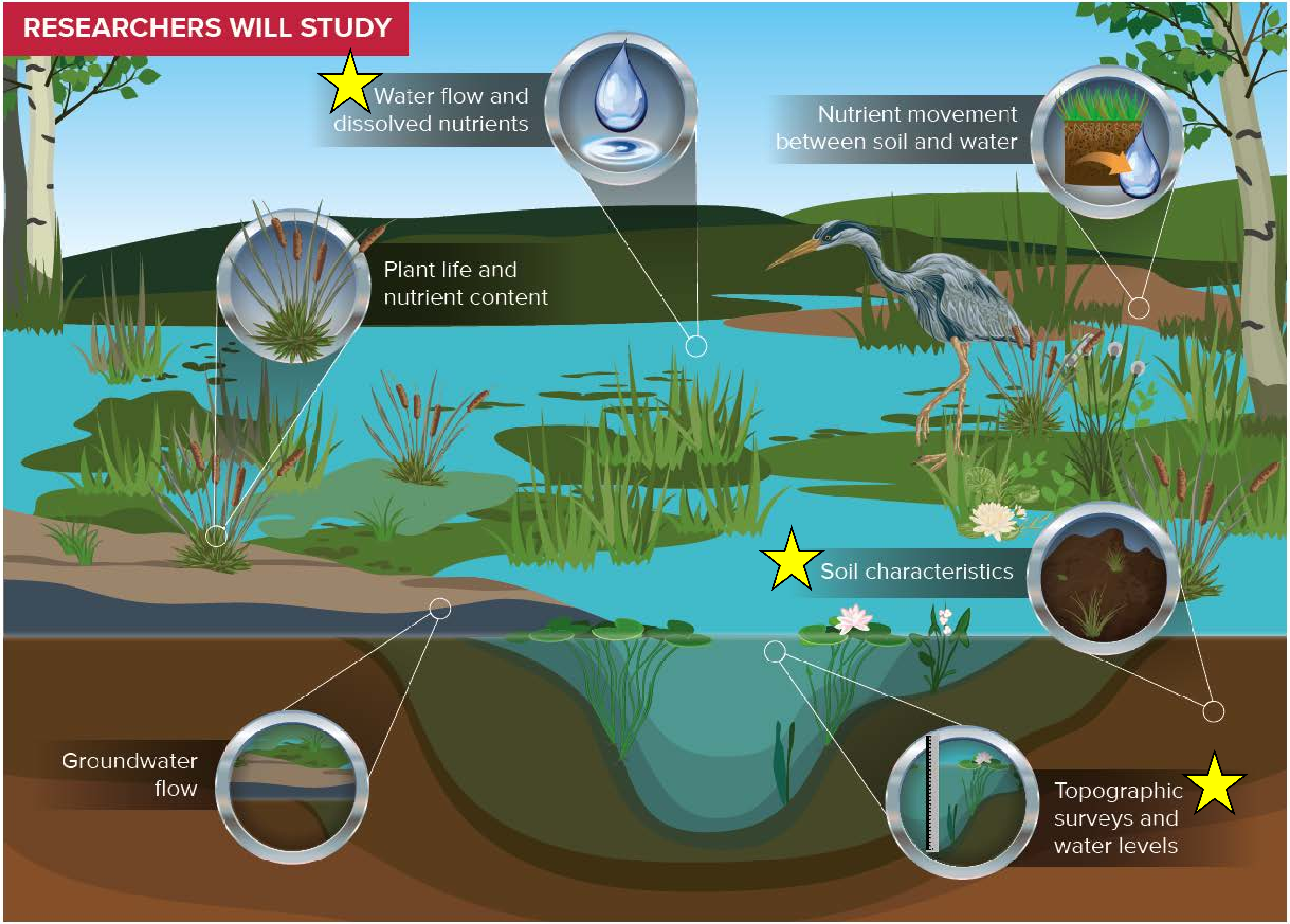
Wright State University

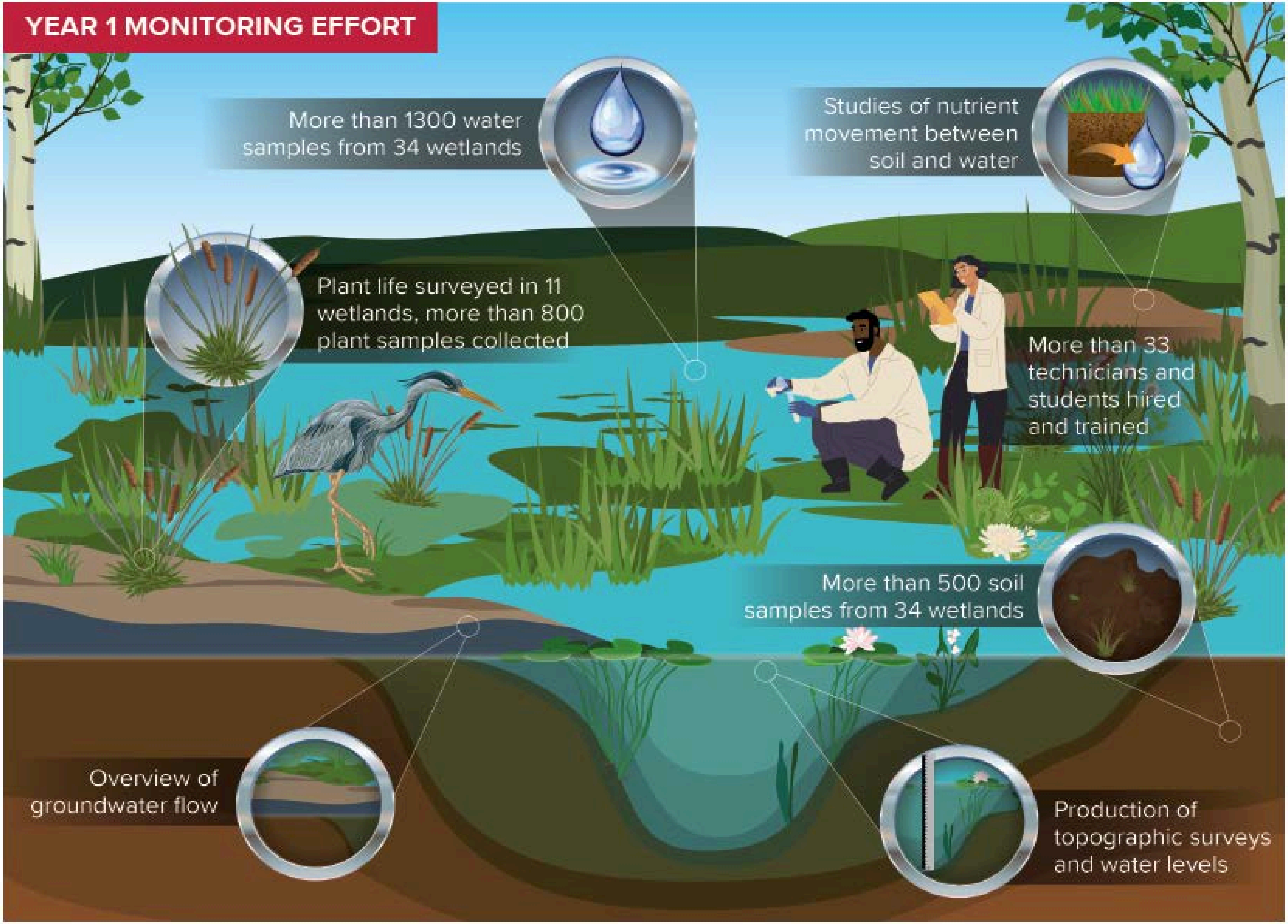
H2Ohio Statewide Projects (Status)

and Water Quality Incentive Program Projects






RESEARCHERS WILL STUDY
Water flow and dissolved nutrients
Nutrient movement between soil and water
Plant life and nutrient content
Soil characteristics
Groundwater flow
Topographic surveys and water levels


YEAR 1 MONITORING EFFORT
More than 1300 water samples from 34 wetlands
Studies of nutrient movement between soil and water
Plant life surveyed in 11 wetlands, more than 800 plant samples collected
More than 33 technicians and students hired and trained
More than 500 soil samples from 34 wetlands
Overview of groundwater flow
Production of topographic surveys and water levels

2019	2020	2021	2022	2023 +
H2Ohio Initiative Launched	H2Ohio Wetland Monitoring Program Established	Protocol Development and Preliminary Data Collection	Routine Monitoring Begins in 19 Completed Projects	Continued Monitoring, Data Synthesis, Protocol Refinement
TOTAL RESTORATION PROJECTS ▸	26	68	107	More to Come!

Take Home

- To best understand the threats and solutions to water quality issues, a rigorous water quality monitoring program is necessary
- Threats to water quality come from many different sources and vary by watershed
- Improving water quality associated with nonpoint sources can be challenging

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http://www.ncwqr.org
https://ncwqr-data.org/
https://seagull.glos.org/