PFAS Foam Formation on Muskegon Lake

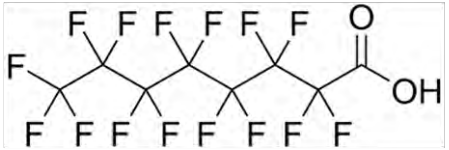
Richard R. Rediske, Ph.D

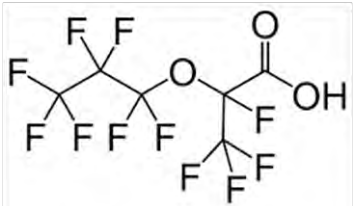
What are Per- and Polyfluoroalkyl Substances (PFAS)?

Total number of PFAS >10,000 chemicals

- Includes products, impurities, precursors, and degradation products
- Many unknown formulations
- PFAS compounds have been in commercial use since the 1950s.
- Resistant to grease, water & oil
  - Surfactants, stain repellants
  - Fire suppression - AFFF
- Persistent, mobile and bioaccumulative
- Emergence of short-chain alternatives - less well studied
  - Similar effects as long chains

Perfluorooctanesulfonoic acid PFOS





GenX

PFAS Uses

ADOD 2022

Lithium Ion Batteries and Semiconductors use fluorinated compounds

Dispersants and impurities in containers

Makes paint flow better and increases durability

Ski wax

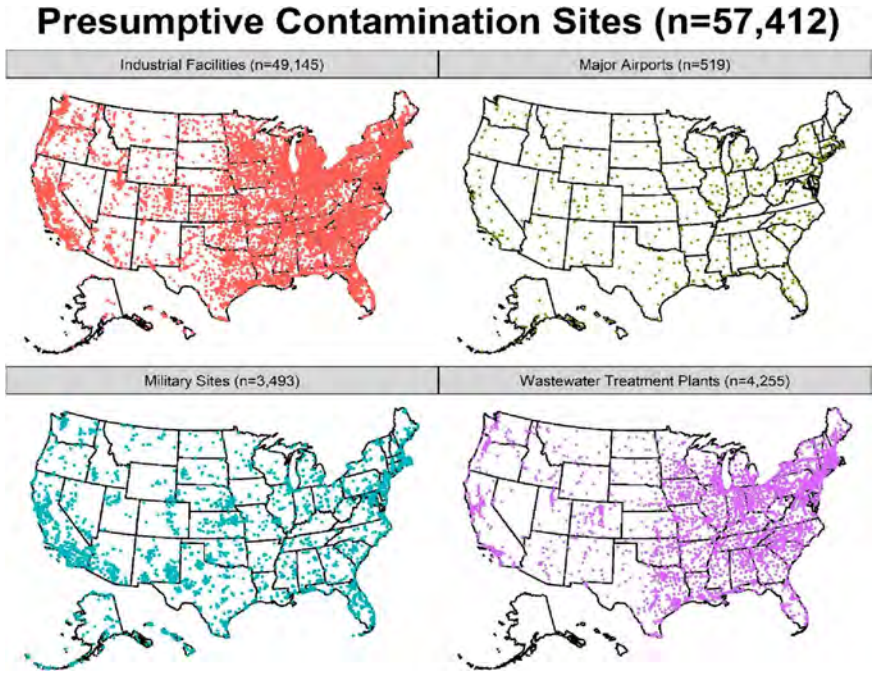
For Leather

Where can we find PFAS Sites

Scientists say 'forever chemicals' may be contaminating 57,000 US sites– The Hill

https://pubs.acs.org/doi/10.1021/acs.estlett.2c00502

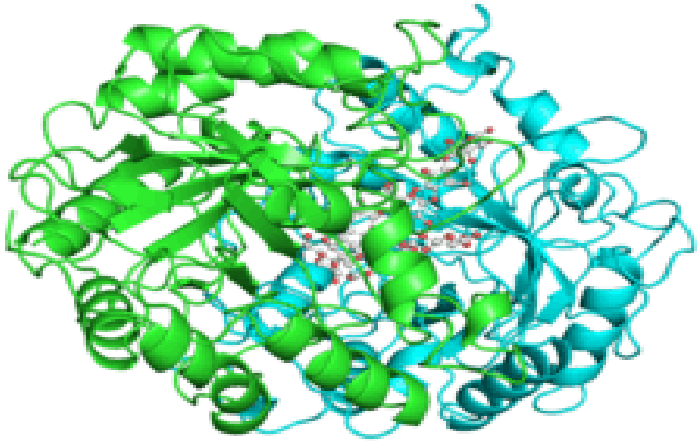
Michigan has 298 PFAS Sites



Wastewater Treatment Plants do not "treat" PFAS. The chemicals pass through or accumulate in biosolids. WWTP plants have accepted landfill leachate

Problems with PFAS

- **Water Soluble g/l**
- **Bioaccumulates in the plants and animals**
- **Not biodegradable**
- **Binds to proteins and DNA**
- **Circulate in the blood bound to albumen, the major carrier protein in our bodies**
- **Reabsorbed by the kidney; resulting in long half-lives (4-9 yrs) and difficulties in the interpretation of data from studies with animals that have more rapid clearance rates (C8 Compounds)**
- **Toxicity effects are additive**
- **We are dealing with historical releases involving decades of human exposure over multiple generations and life stages**



https://bestanimations.com/gifs/Metabolism.html

PFAS Health Effects

Epidemiological evidence suggests associations between increases in exposure to PFAS and certain health effects

- **Increases in cholesterol levels**
- **Small decreases in birth weight**
- **Lower antibody response to some vaccines**
- **Kidney, prostate, ovarian, and testicular cancer**
- **Pregnancy-induced hypertension or preeclampsia**
- **Changes in liver enzymes**
- **Delayed puberty, decreased fertility, early menopause**
- **Thyroid disruption**

The risk of health effects associated with PFAS depends on

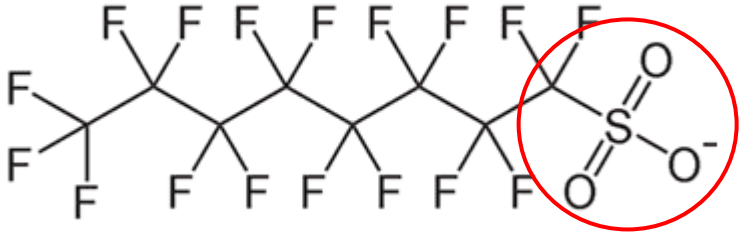
- **Exposure factors (e.g., dose, stage of development, frequency, route, and duration)**
- **Individual factors (e.g., sensitivity and chronic disease burden)**
- **Other determinants of health (e.g., access to safer water and quality healthcare)**

Birnbaum 2021

PFAS Foam

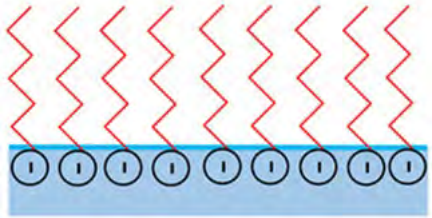
- **High Concentrations of PFOS and PFOA (1,000-250,000 ppt)**
- **Measured as water concentrations in collapsed foam.**
- **PFAS in foam is not absorbed through the skin.**
- **Can be washed off.**

PFAS Foam Formation



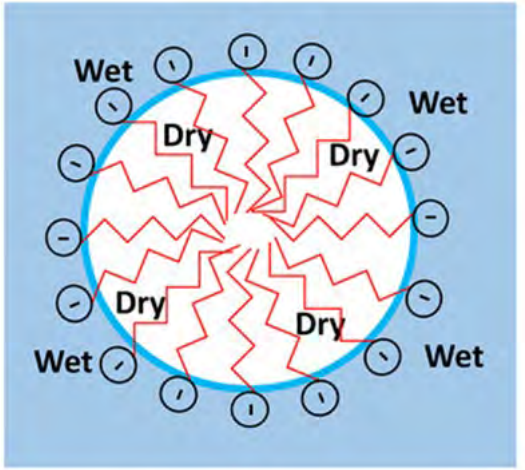
Hydrophilic head
(dissolves in water)

Hydrophobic/oleophobic Tail
(repels water and oil)



In water, PFOS can orient itself at the surface with the head in water and the tail in the air

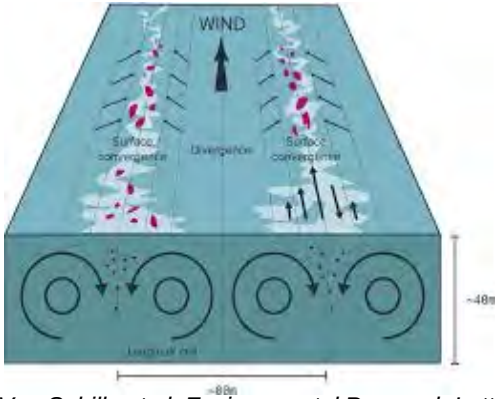
Waves or turbulence will force PFOS molecules together, break the surface tension, and form bubbles or micelles



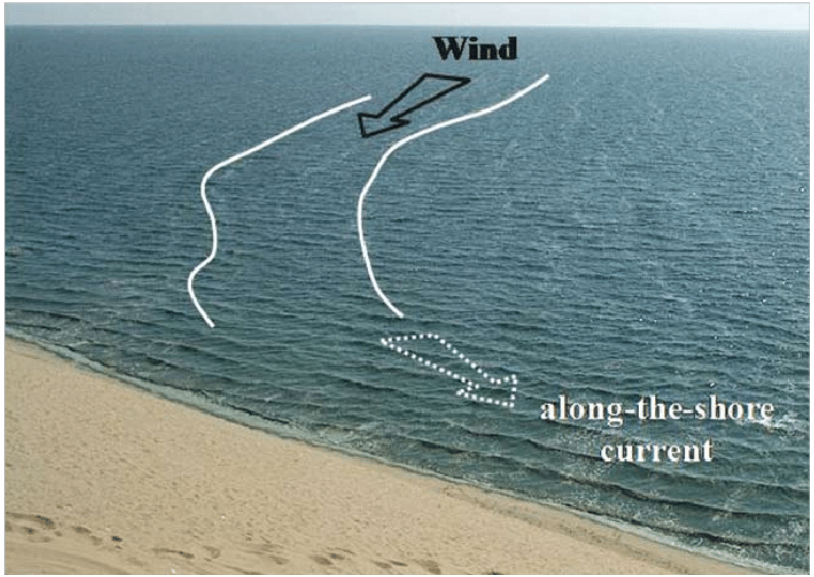
The PFAS tails stick together, trap air, and form foam

https://doi.org/10.1002/rem.21552

Langmuir Cells



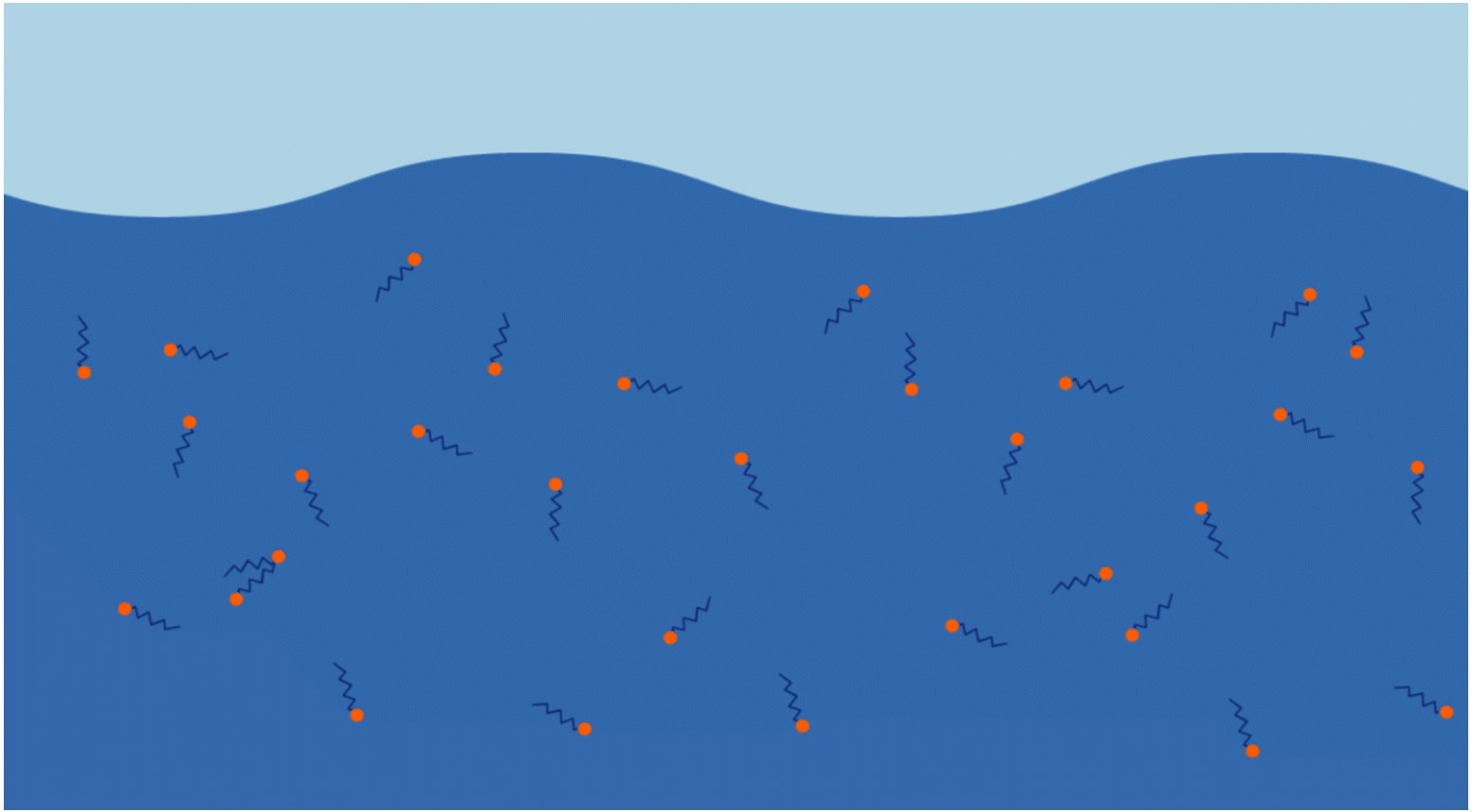
Van Sebille et al. Environmental Research Letters (2020)



Chubarenko, et al. Baltica 23.1 (2010)

K. Lynnes

PFAS Attachment to Air Bubbles



CDM 2024

Foam Formation in Rockford

Mlive 2019

Mean Discharge of the Rogue River is

244 cubic ft/sec or

6,899 liters/sec

Water Concentration of PFAS at the Dam is 10 ppt = 12 Trillion molecules/liter

North Muskegon Water Sports Park 8/28/24

R. Tardani

Bluffton Bay Marina 9/6/24

R. Tardani

Grand Trunk Boat Launch 8/19/24

M. Hassett

Harbour Towne Beach
9/6/24

R. Tardani

6th St Outfall near AWRI
8/28/24

A. Steinman

Muskegon Lakeshore Trail Park 9/1/24

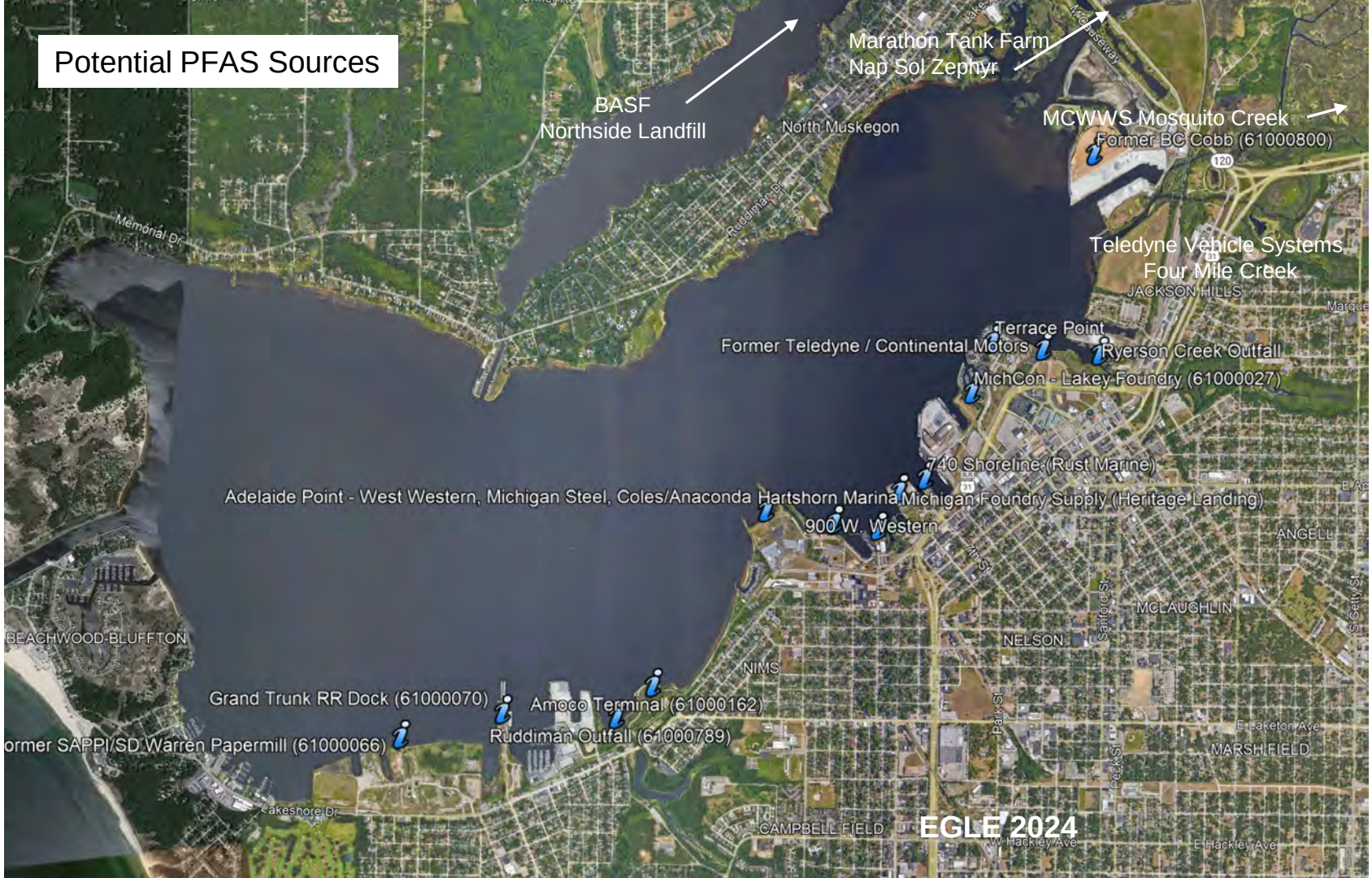
K. Lynnes

Foam Blowing Across Muskegon Lake 9/1/24

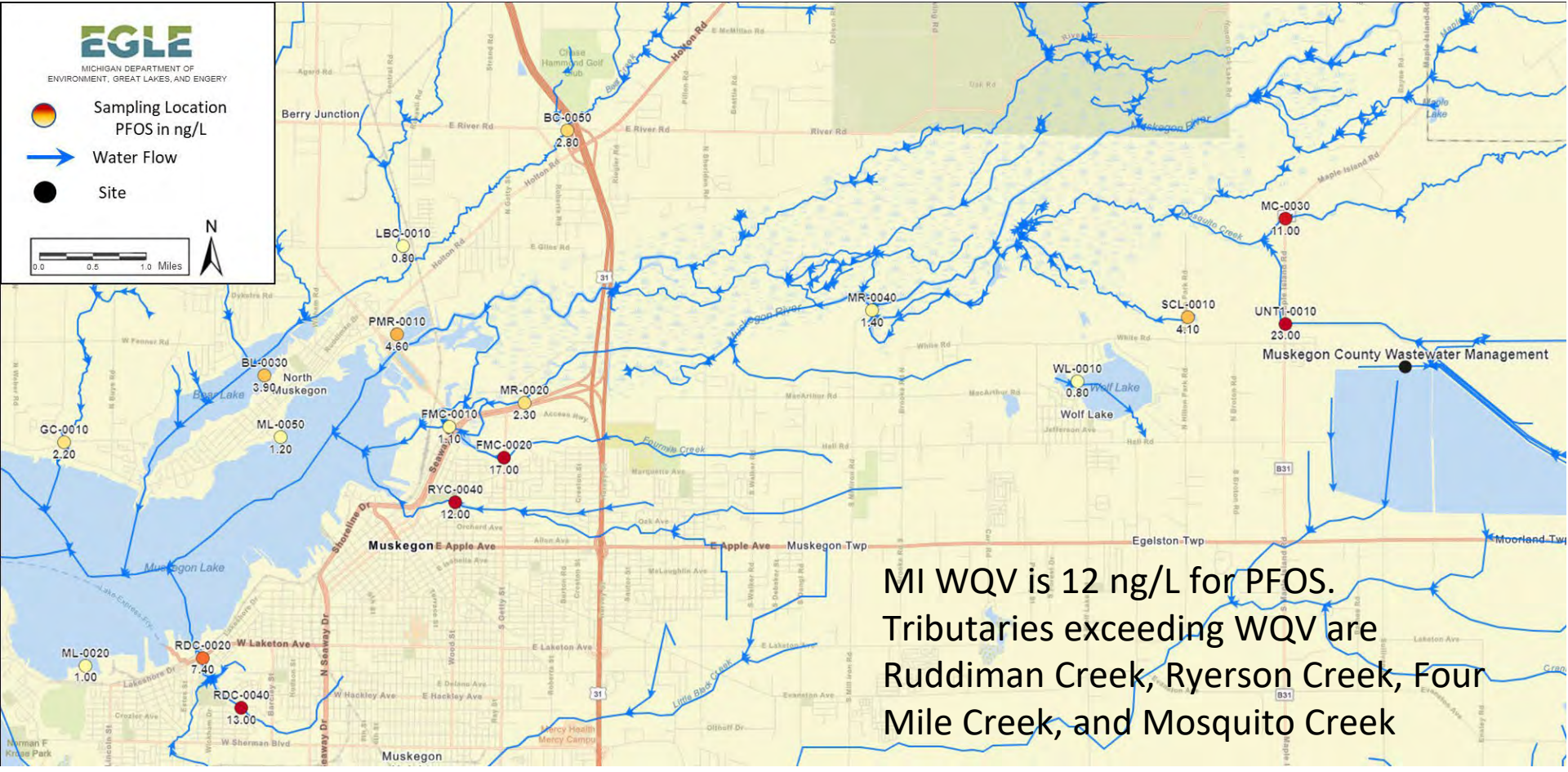
K. Lynnes

Foam Formation on Muskegon Lake

- **Wave action in the open water and on the shoreline**
- **Muskegon Lake has a complex shoreline and is prone to the accumulation of surface scum from HABs**
- **Muskegon Lake has numerous known and potential PFAS sites**
- **Muskegon Lake has complex hydrodynamics due to the influence of the Muskegon River, Bear Lake, and the Lake Michigan Channel**
- **What does the existing data tell us?**
  - **EGLE 2022 PFAS Investigation**
  - **EGLE Fish Data**


Potential PFAS Sources
BASF
Northside Landfill
Marathon Tank Farm
Nap Sol Zephyr
MCWWS Mosquito Creek
Former BC Cobb (61000800)
Teledyne Vehicle Systems
Four Mile Creek
Terrace Point
Former Teledyne / Continental Motors
Ryerson Creek Outfall
MichCon - Lakey Foundry (61000027)
740 Shoreline (Rust Marine)
Adelaide Point - West Western, Michigan Steel, Coles/Anaconda
Hartshorn Marina
Michigan Foundry Supply (Heritage Landing)
900 W. Western
Grand Trunk RR Dock (61000070)
Amoco Terminal (61000162)
Ruddiman Outfall (61000789)
ormer SAPPI/SD Warren Papermill (61000066)
North Muskegon
JACKSON HILLS
ANGELL
MCLAUGHLIN
NELSON
NIMS
BEACHWOOD-BLUFFTON
MARSH FIELD
CAMPBELL FIELD
Memorial Dr
Ruddiman Dr
Lakeshore Dr
Sanford St
Park St
Peck St
E Laketon Ave
W Hackley Ave
E Hackley Ave
EGLE 2024

EGLE 2022 PFAS Survey



MI WQV is 12 ng/L for PFOS. Tributaries exceeding WQV are Ruddiman Creek, Ryerson Creek, Four Mile Creek, and Mosquito Creek

PFOS in Fish

Species	Collection Date	Count	Min PFOS (ppb)	Max PFOS (ppb)	Avg PFOS (ppb)
Rock Bass	04-Aug-23	10	3.43	8.44	5.18
Largemouth Bass	04-Aug-23	10	4.22	16.81	8.62
Bluegill	15-Jun-23	5	3.32	7.54	5.16
Pumpkinseed	15-Jun-23	5	1.52	7.17	3.72
Lake Herring	15-Jan-22	10	1.87	16.13	8.40
Yellow Perch	07-Feb-22	10	10.17	21.44	15.33

The data for Bear Lake are below.

Species	Collection Date	Count	Min PFOS (ppb)	Max PFOS (ppb)	Avg PFOS (ppb)
Bluegill	01-Mar-22	10	8.41	27.85	16.59
Yellow Perch	01-Mar-22	10	11.57	29.37	21.95

EGLE 2024

MDHHS 2016

Meal Category	PFOS
meals per month	*µg/g (ppm)[a]*
16	≤ 0.009
12	>0.009 to 0.013
8	>0.013 to 0.019
4	>0.019 to 0.038
2	>0.038 to 0.075
1	>0.075 to 0.15
6 meals per year	>0.15 to 0.3
Limited	NA
Do Not Eat	>0.3

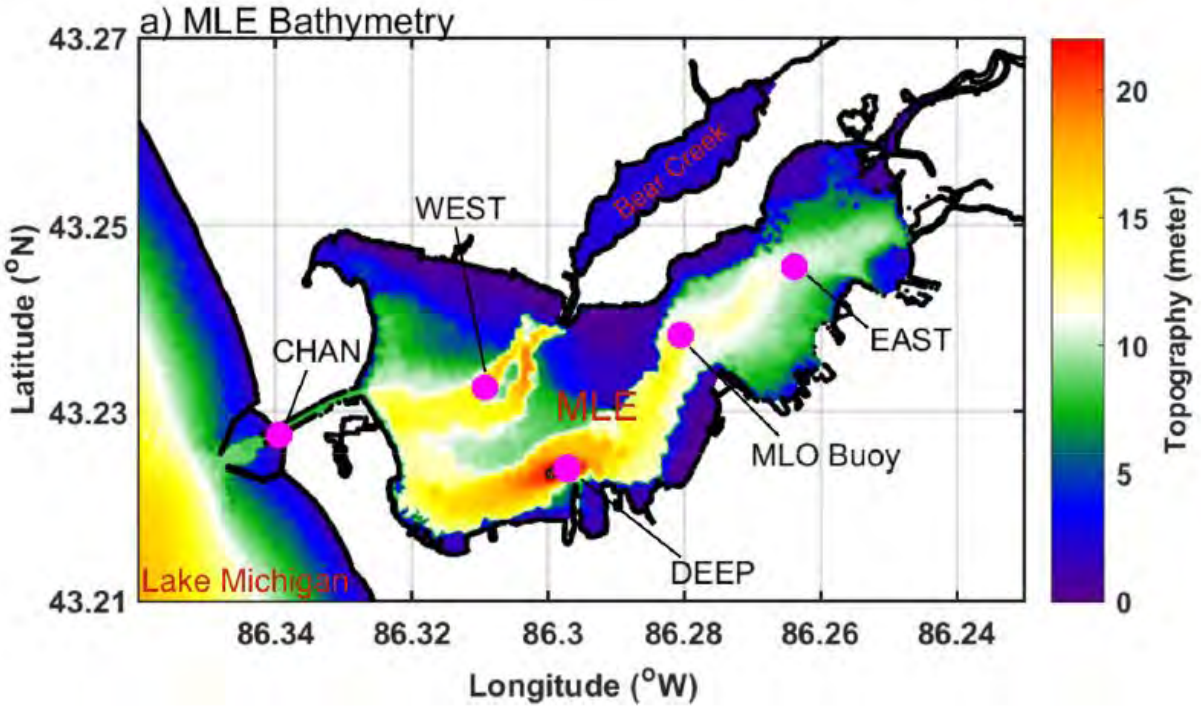
Muskegon Lake

MDHHS 2023

Type of Fish	Chemicals of Concern	Size of Fish (length in inches)	MI Servings per Month*
Carp	PCBs	Any	Do Not Eat▲
Largemouth Bass	PCBs	Any	6 Per Year[2x]
Northern Pike	PCBs & Mercury	Any	2
Rock Bass	Mercury	Any	4
Smallmouth Bass	PCBs	Any	6 Per Year[2x]
Walleye	Mercury	Under 18"	4
	PCBs	18" to 22"	6 Per Year[2x]
		Over 22"	Limited▲
All Other Species	PCBs	Any	6 Per Year[2x]

PFAS Fish Consumption Advisories would not be recommended based on these data.

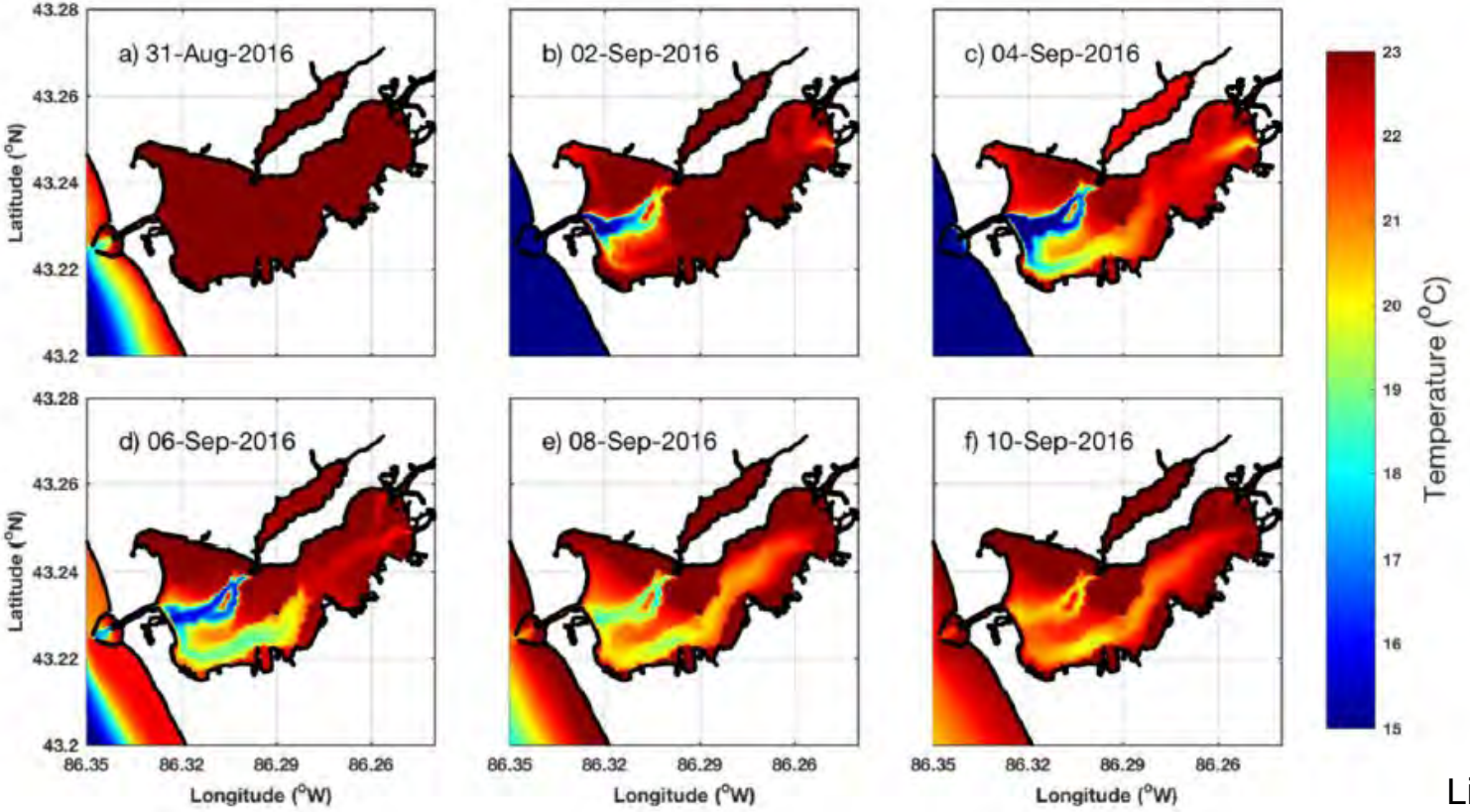
Muskegon Lake Bathymetry



AWRI Muskegon Lake Long Term Monitoring Stations in Pink

Liu et al 2018

Model results for the cold-water intrusion event at the beginning of September 2016.



Liu et al 2018

Potential Next Steps

Is the 2024 foam event from increased PFAS concentrations or unusual meteorological conditions?

- **Review the meteorological data and compare it to previous years.**
- **If foam events persist, repeat the EGLE 2022 study of Muskegon Lake to determine if PFAS levels have increased. Include the AWRI Long Term Monitoring Sites.**
- **Collect another set of fish samples to see if they are comparable or higher.**
- **Review the status of 201 sites and recent areas with heavy construction to determine if PFAS data are available.**