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STUDENT FOCUSED • LAND GRANT • RESEARCH UNIVERSITY

North Dakota Water Resources Research Institute Overview and Smart Water Management Research

Xinhua Jia, Professor, Ph.D., P.E.
Agricultural and Biosystems Engineering
Director of North Dakota Water Resources Research Institute
North Dakota State University

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North Dakota Water Resources Research Institute (NDWRRI)

- Founded in 1965 by Congress as one of the 54 Institutes or Centers, one in each state, plus four in other regions.
- Administered through the United States Geological Survey
- Located at North Dakota State University
- Supported by ND Department of Water Resources
- Housed in the Office of the Vice President for Research and Creative Activity

The United States Geological Survey Water Resources Research Act Program (usgs.gov)
https://water.usgs.gov/wrri/index.php

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NDWRRI Overview

- **Director:** Dr. Xinhua Jia, Professor of Agricultural and Biosystems Engineering, NDSU, 1-2 months time annually.
- **Affiliate faculty members:** 45 total – 35 from NDSU and 10 from UND.
- **Advisory board:** Dr. Karen Ryberg of USGS, Mr. Andrew Nygren of ND Department of Water Resources, and Mr. Peter Wax of ND Department of Environmental Quality.
- **Funding:** USGS 104b base funds ($146,840) and DWR matching funds ($25,000) - Awarded 24 graduate student fellowships in 2023.

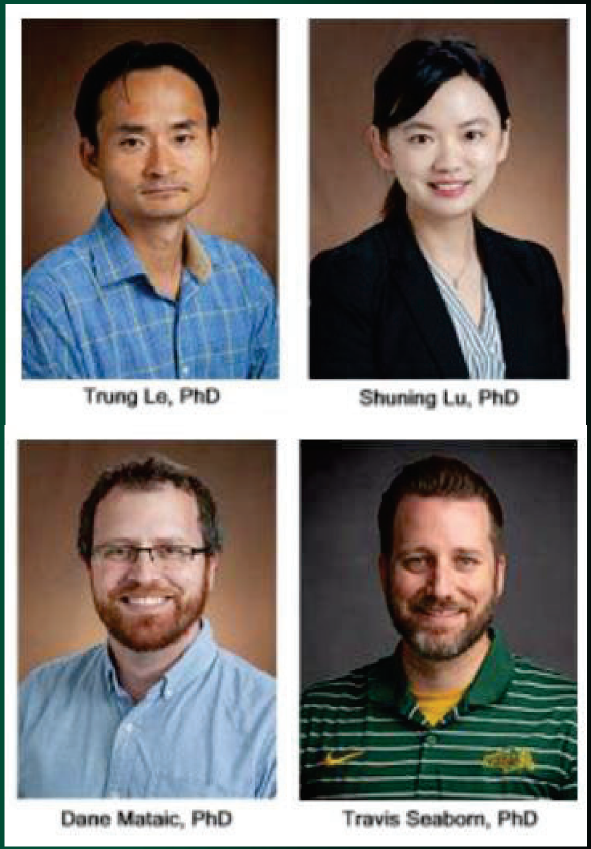
Water Fellows - Brand new program supported by NDSU VPR to foster cross-disciplinary water research

- **Trung Le,** NDSU assistant professor of civil and environmental engineering, specializing in floods, drinking water supply, industrial use, irrigation use and recreation.

- **Shuning Lu,** NDSU assistant professor of communications, specializing in public communication about water-related research issues and policy.

- **Dane Mataic,** NDSU assistant professor of sociology and anthropology, specializing in law and society, social movements and social groups perspectives.

- **Travis Seaborn,** NDSU assistant professor of applied ecology, specializing in a range of big data challenges in aquatic systems including the interface of genomics, the environment, landscape and social-ecological systems.



Trung Le, PhD
Shuning Lu, PhD
Dane Mataic, PhD
Travis Seaborn, PhD

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Current NDWRRI Research Topics

- **Agricultural Processes:** Drain Tile Management, Irrigation, Soil Moisture Measurement, Nutrient Management
- **Hydrology:** Surface Water, Groundwater, Modeling
- **Water Quality:** Emerging Contaminants (PFAS, PCBs, Mercury, Microplastics, Neonics), Contamination Mitigation
- **Basin Issues:** Red River, Upper & Lower Missouri River, Souris River, and James River
- **Other:** Energy Development, Wetland Ecosystems, Data Sharing, Weather Extremes/Climate, Monitoring & Assessment

Focused Research

- **PFAS research and outreach in spring 2024:**
  - **LINK: ND PFAS Conference**
  - Overview of PFAS in the US
  - Identifying and measuring PFAS
  - Remediating PFAS contamination
  - Assessing risks to humans, animals, and ecosystems
  - Impact of water and food sources
  - Recent research at NDSU and UND
  - Panel discussion and Q&A
- **Fargo-Moorhead Flood Diversion research and education in fall 2024**

Water Resources Certificate Program

- Four courses (12 credits) from a course catalogue of 26 courses (79 credits)
- Topics include hydrology, soil and water quality and technology
- Certificate will prepare students to enter careers in hydrology and water resource management.
- The program will draw from students in CCEE, ABEN, NRM
- Prepare students for careers in local, state, and federal agencies as well as industry

Jia’s Smart Water Management Research

- Automatic
- Sensor Incorporated
- Remote controlled
- Precise with higher efficiency
- Flexible irrigation scheduling
- Labor/cost saving

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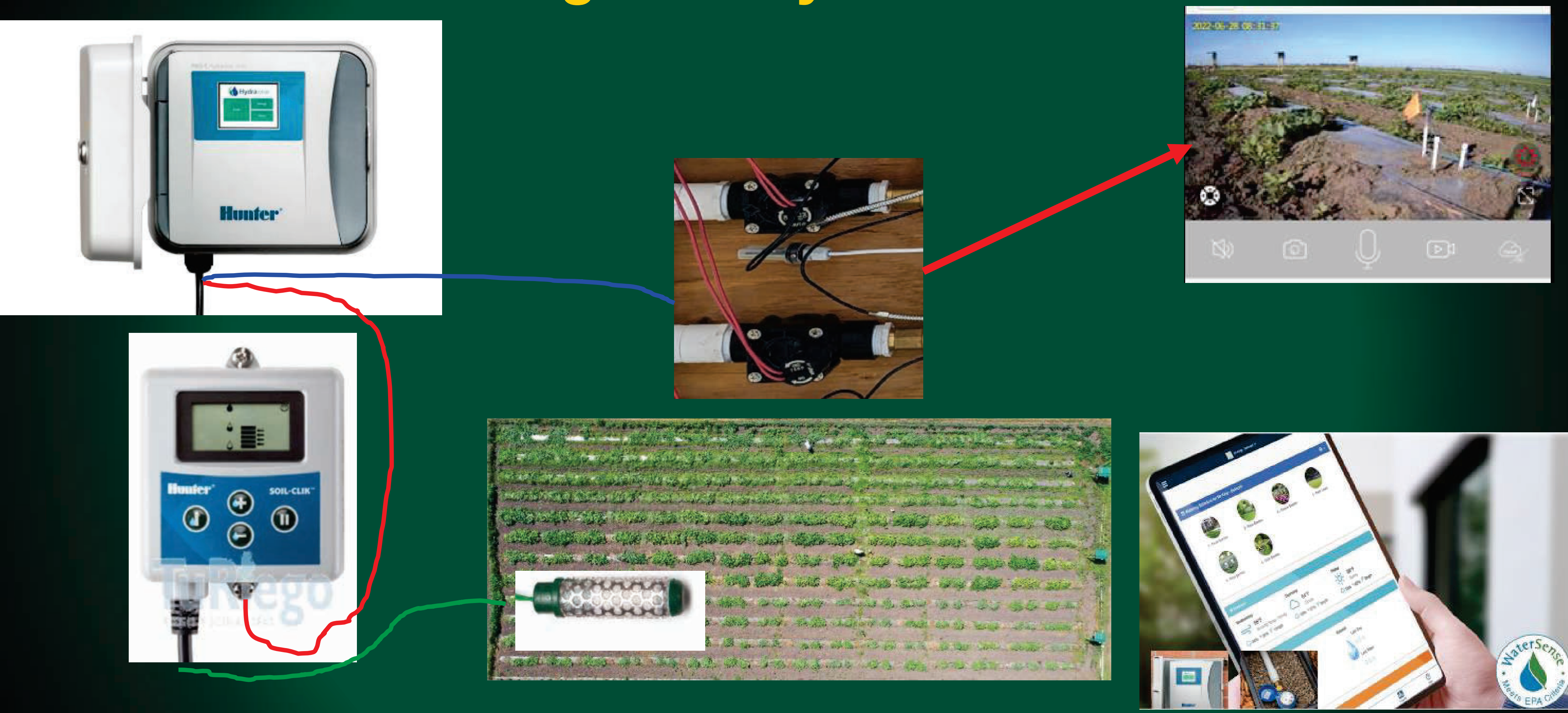
Smart irrigation system in the field



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Smart irrigation system in other applications

Greenhouse

Vertical Indoor farming

High tunnel

Presenters

Syeed Iskander, PhD
Assistant professor in Civil, Construction and Environmental Engineering, PFAS in Fargo Yard Waste Compost

Jiale Xu, PhD
Assistant professor in Civil, Construction and Environmental Engineering, Novel electrochemical technologies for industrial wastewater treatment: PFAS and produced water

Trung Le, PhD
Assistant professor in Civil, Construction and Environmental Engineering, Ice-covered flows in the Red River

Christina Hargiss, PhD
Director and professor in School of Natural Resource Sciences, Understanding North Dakota's water use, stormwater, and harmful algal blooms

PFAS in Fargo Yard Waste Compost

Presented by
Syeed Md Iskander, Ph.D., PE
Assistant Professor
Civil, Construction and Environmental Engineering
North Dakota State University
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Research conducted by
Biraj Saha
Ph.D. Student
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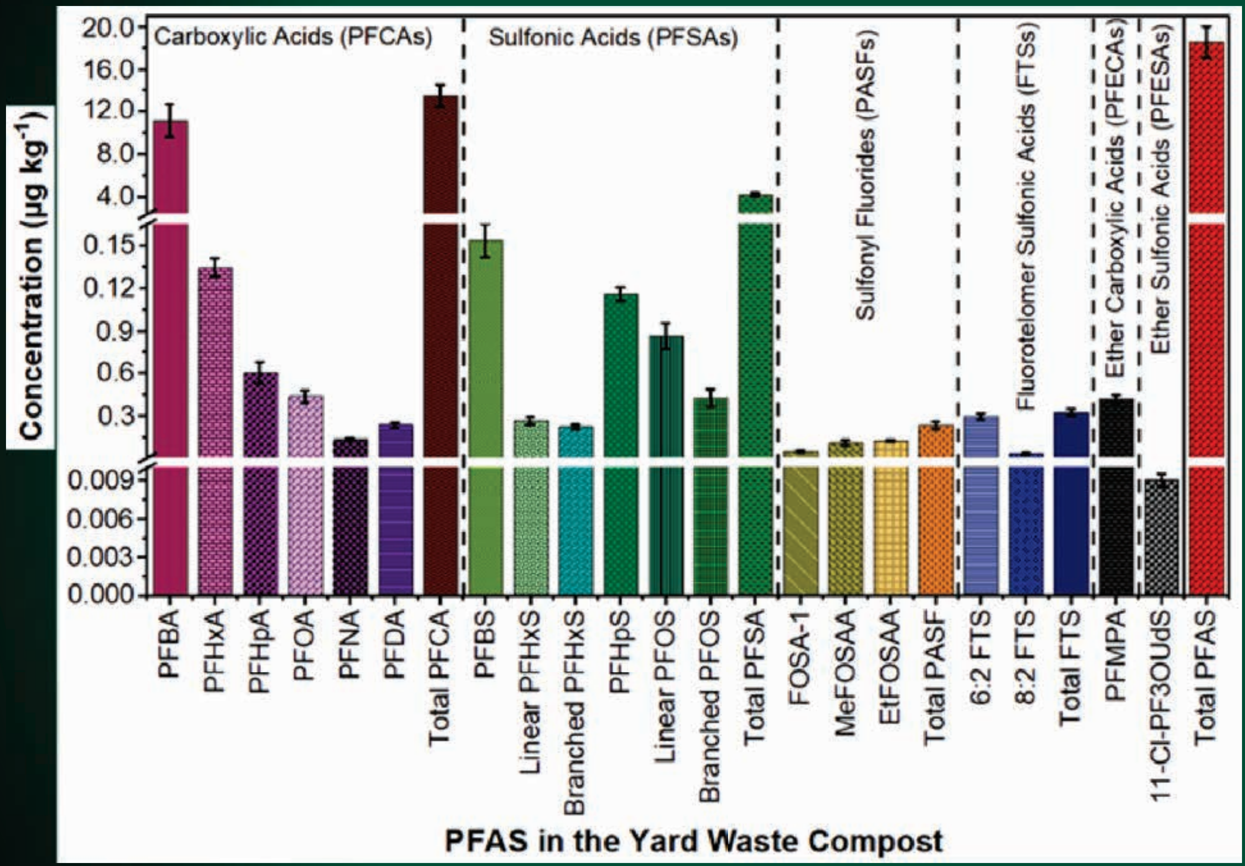
Yard Waste Compost

Yard Waste Compost

Yard Waste Compost

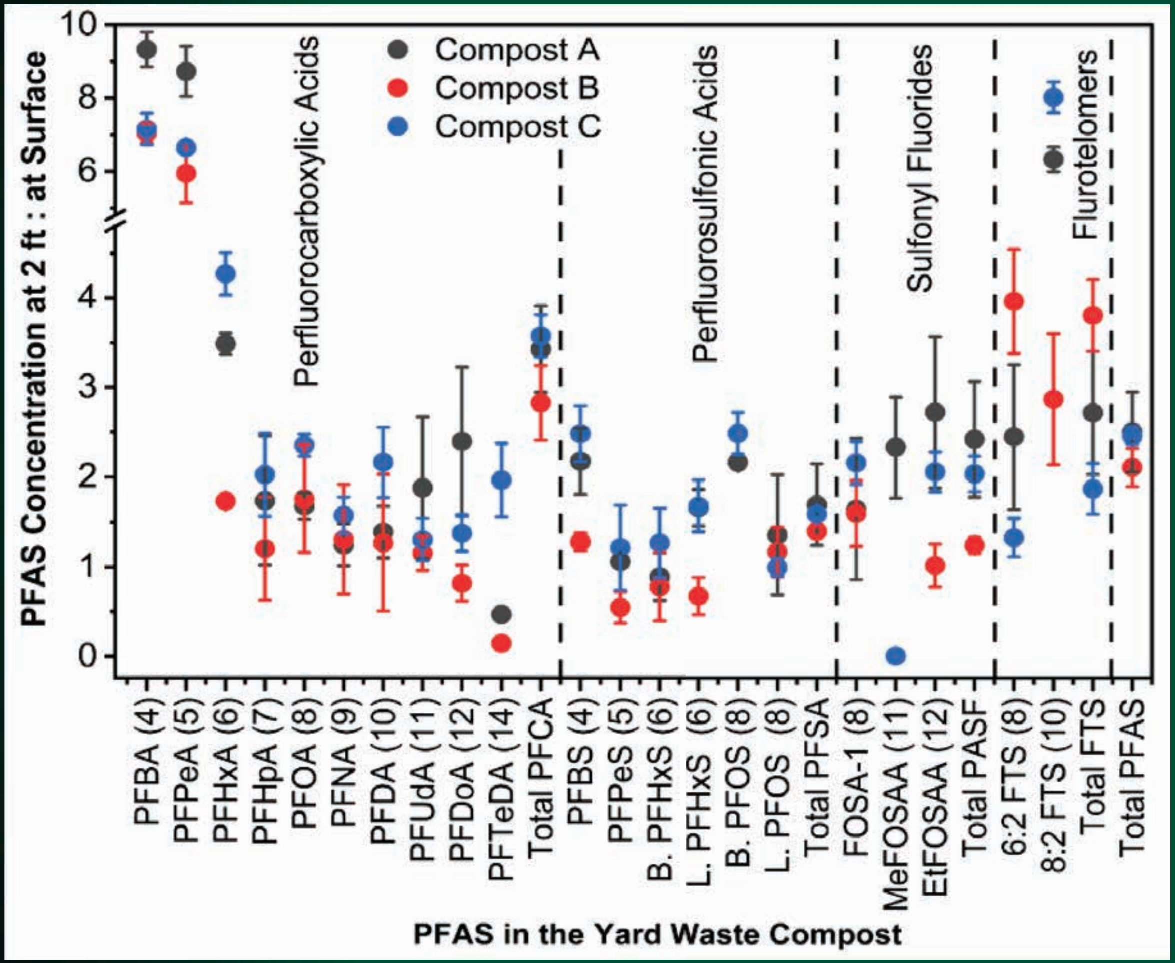
Yard Waste Compost

PFAS in Yard Waste Compost



- Total measured PFAS concentrations range from 16 – 18 μg kg^{-1}
- PFCAs and PFSAs are the dominant classes, comprising approximately 72.5% and 22.1% of the total measured PFAS

PFAS Distribution in Yard Waste Compost



The total PFAS concentration at 2-ft depth was 2.5, 2.1, and 2.5 times the total PFAS concentrations at the surface level for Composts A, B, and C

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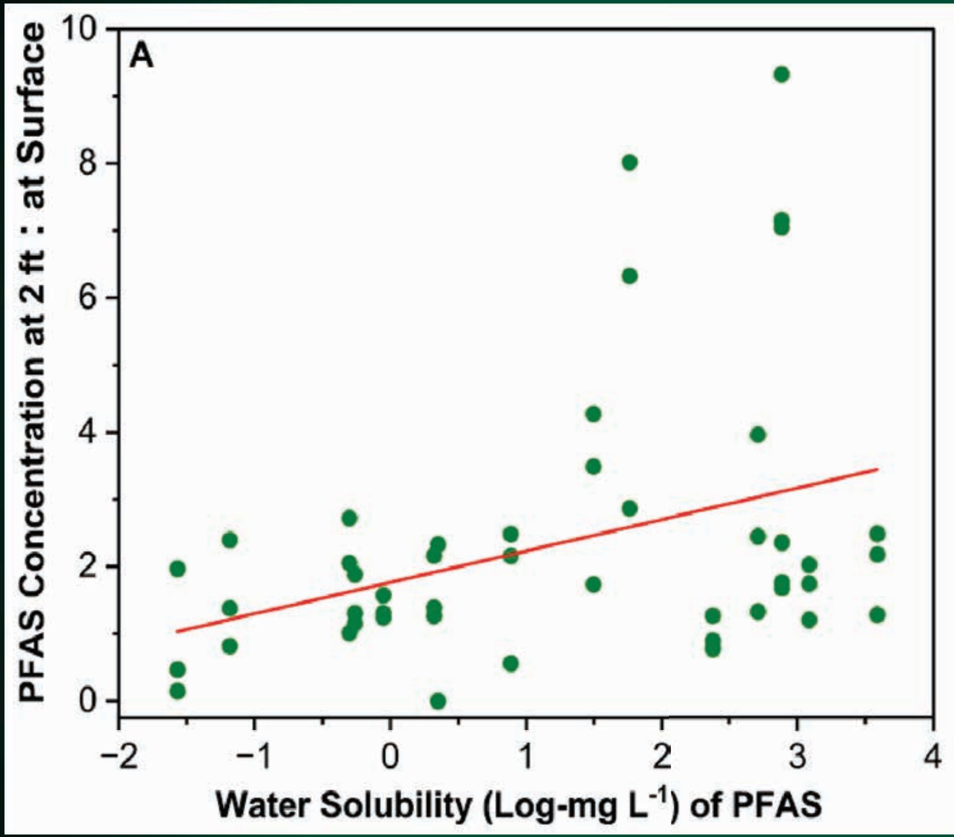
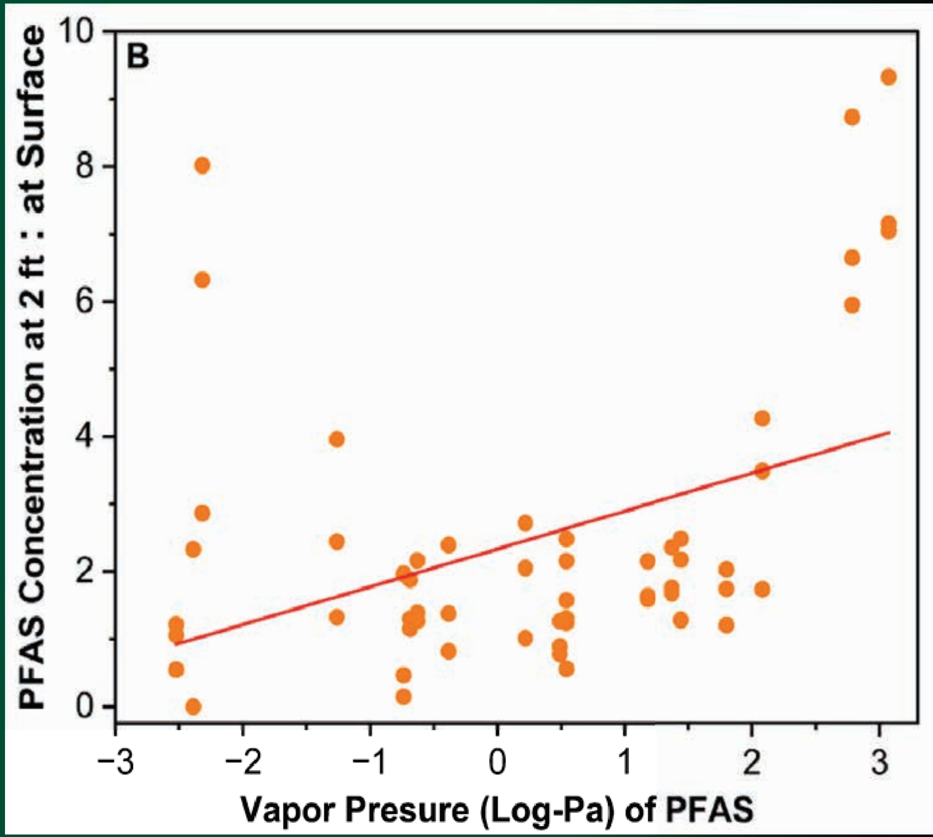
PFAS Distribution in Yard Waste Compost





Water solubility and vapor pressure of PFAS impact their distribution!

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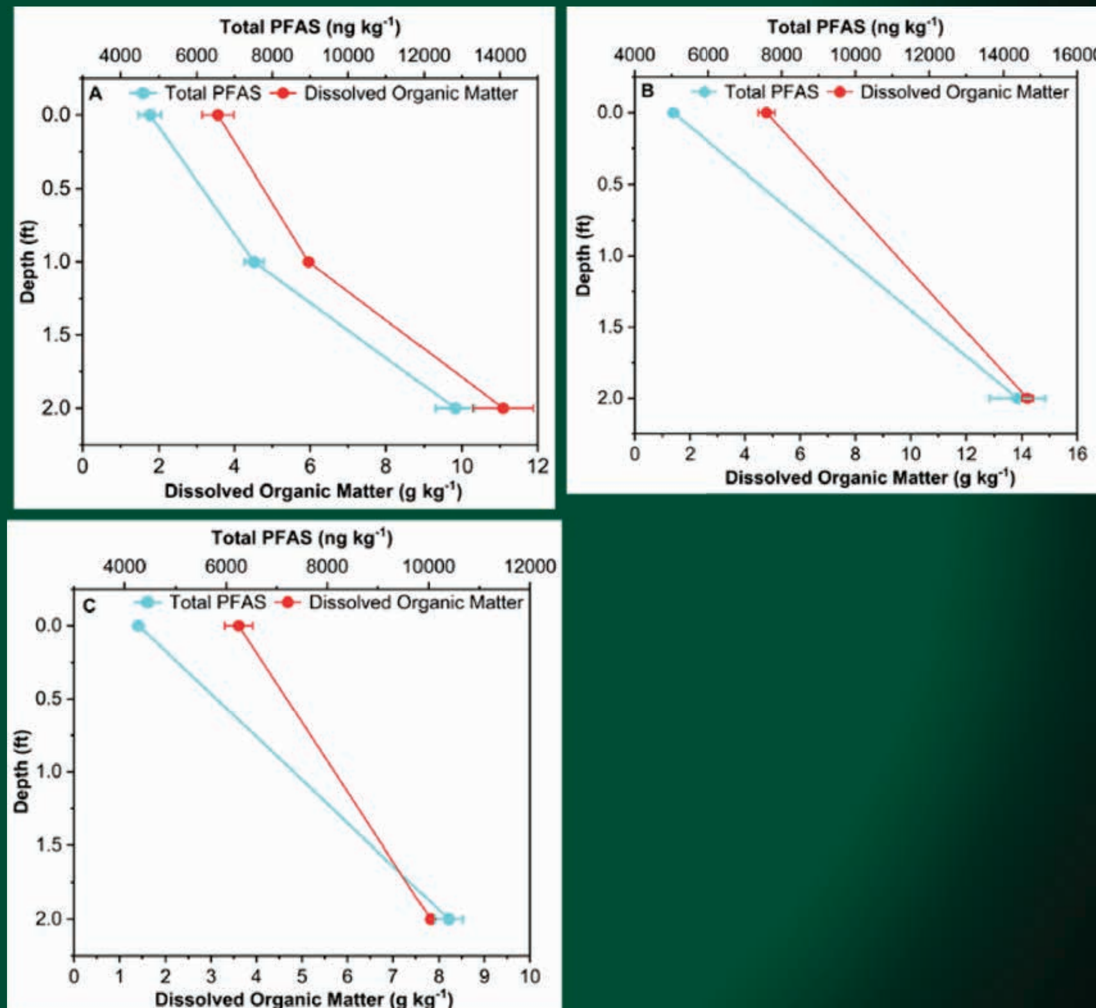
PFAS Distribution in Yard Waste Compost

The dissolved organic matter content of compost showed a strong correlation with PFAS distribution



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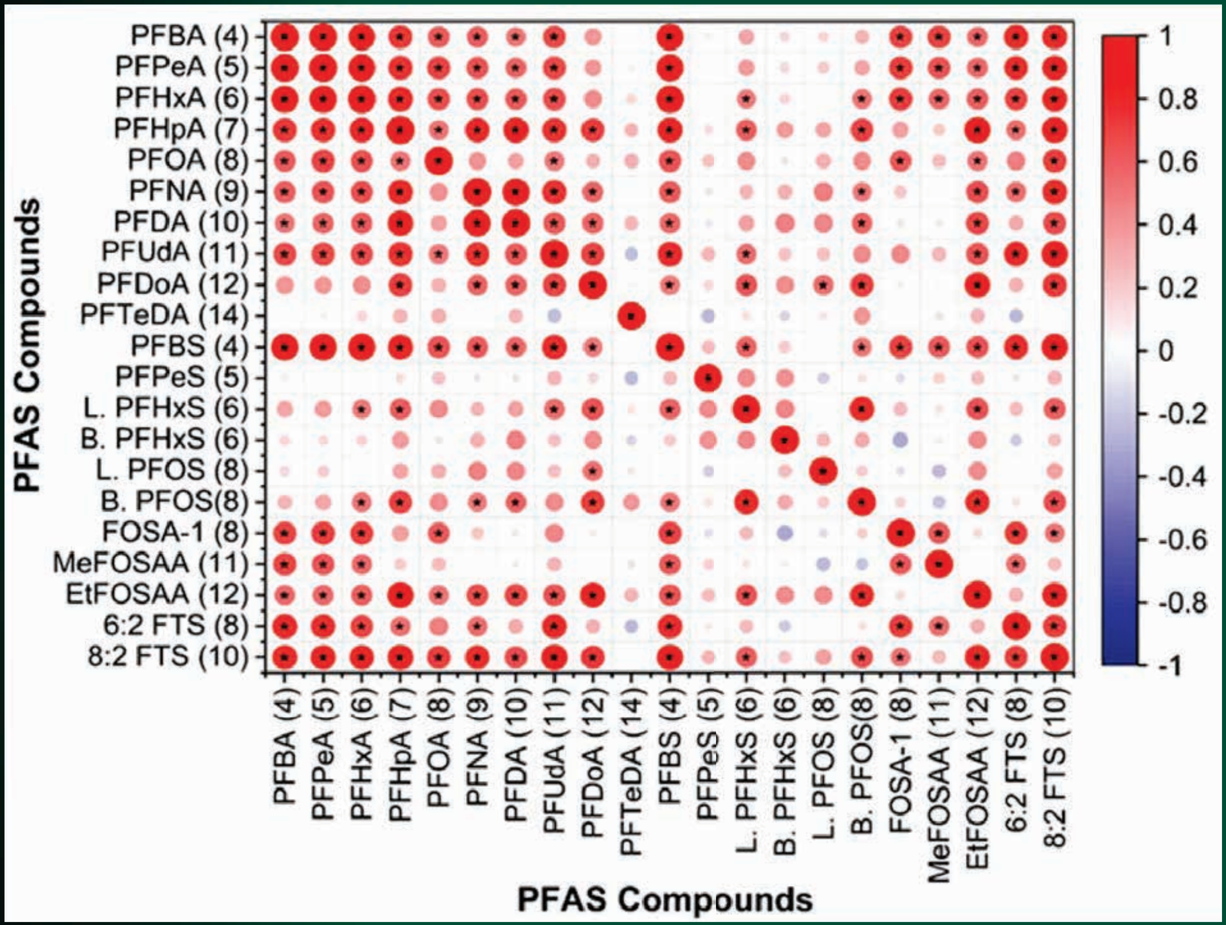
Sources of PFAS in Yard Waste Compost



Shared source of origin for many PFAS!

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Plastics in Yard Waste Compost






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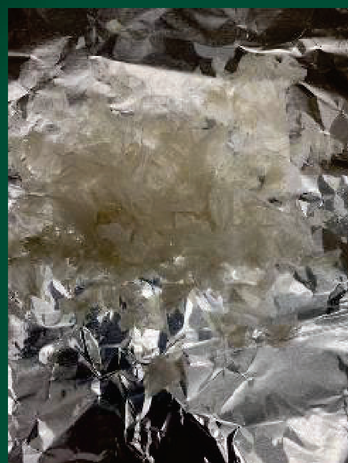
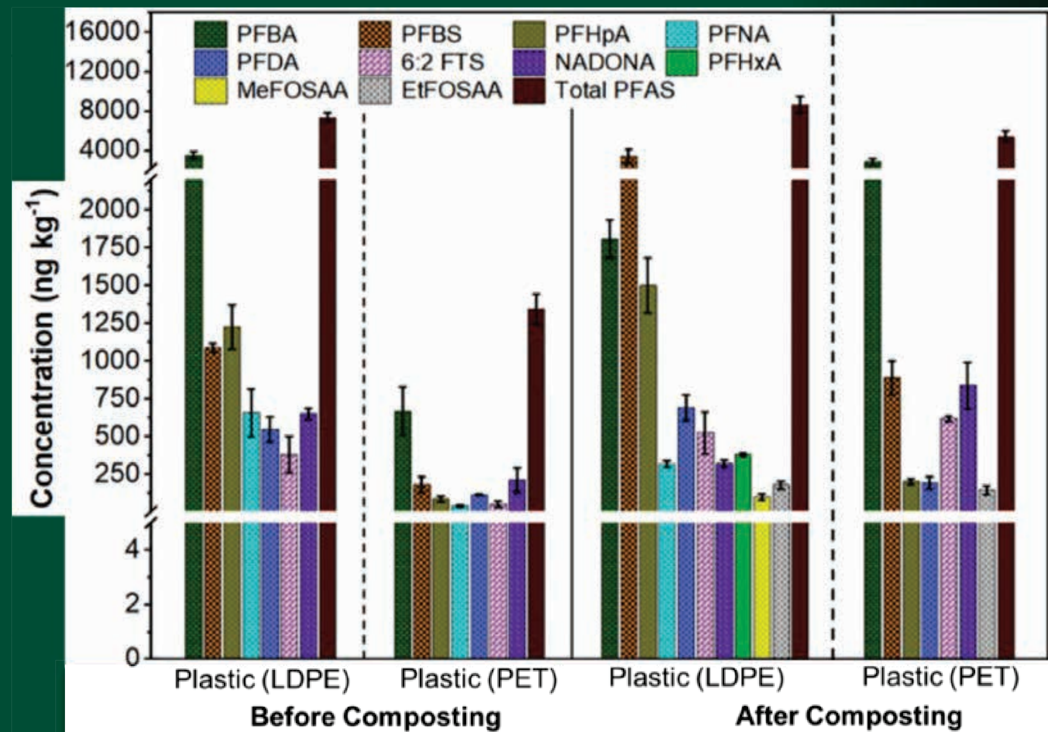
Plastics as a Source of PFAS in Yard Waste Compost





	LDPE	PET
Before composting	**7.41** µg kg^{-1}	**1.35** µg kg^{-1}
After composting	**8.66** µg kg^{-1}	**5.44** µg kg^{-1}

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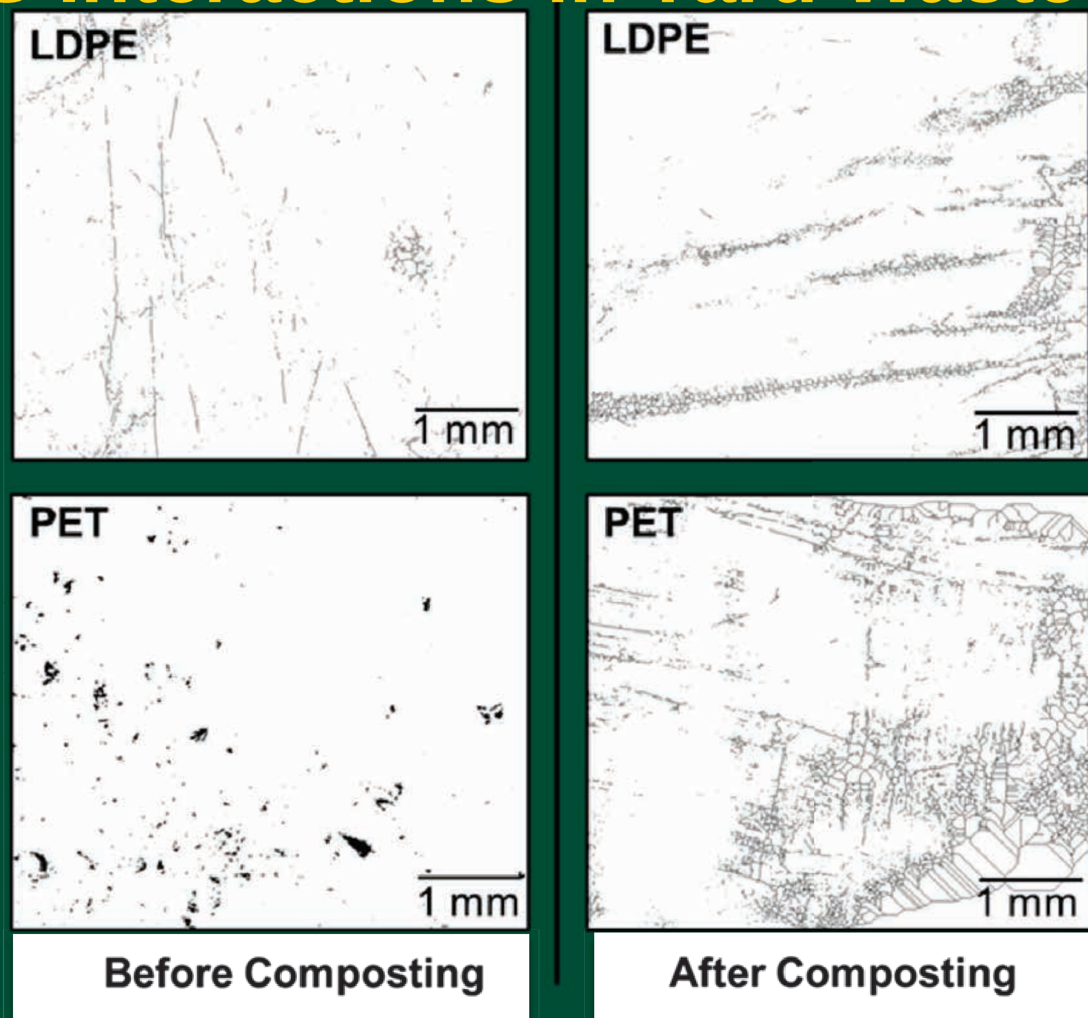
Plastics-PFAS Interactions in Yard Waste Compost



An increased amount of cracks after composting!

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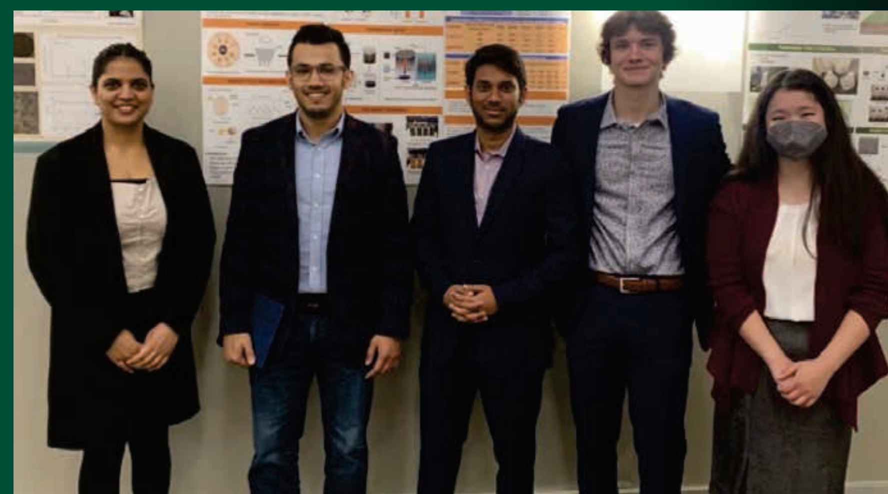
Acknowledgment

- ND Water Resources Research Institute
- Civil, Construction and Environmental Engineering, NDSU
- NDSU Electron Microscopy Center (NSF Grant 0923354)
- Coating and Polymeric Materials Department, NDSU
- NDSU RCA Research Support Services Award (RSS21-14)
- ND EPSCoR (FAR 0031773 and FAR 0033911)
- NDSU College of Engineering
- US EPA P3 Award
- Environmental Research and Education Foundation (EREF)

ND EPSCoR
Established Program to
Stimulate Competitive Research



NDSU Research Group

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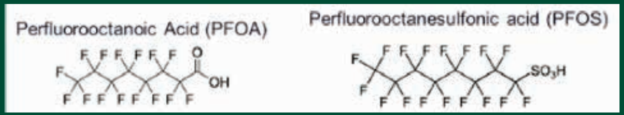
WATER TOPICS MEETING

Novel Electrochemical Technologies for Industrial Wastewater Treatment: PFAS and Produced Water

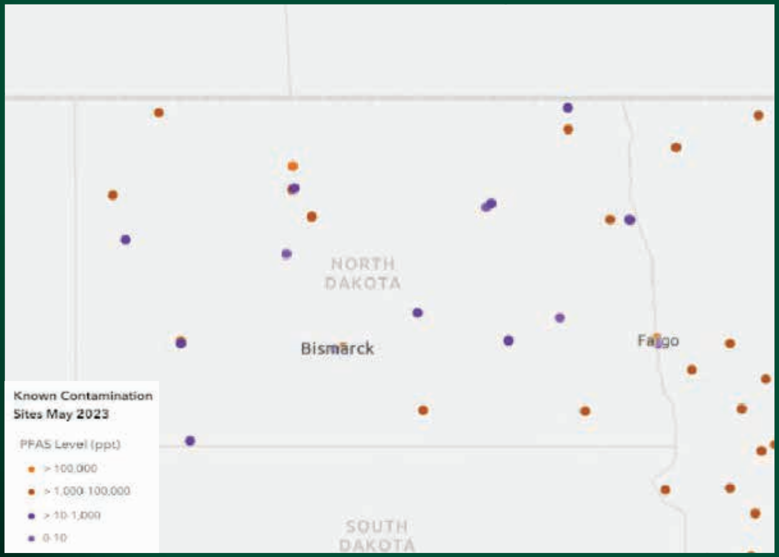
Jiale Xu, Ph.D., Assistant Professor
Environmental Engineering
North Dakota State University

PFAS in ND Water

- Sources: military bases (fire fighting) and industrial wastewater
- EPA proposed MCL regulations (PFOA 4 ng/L and PFOS 4 ng/L)



PFAS Sites and Community Resources



Air Force Base Groundwater:

PFOS 35000 - 440000 ng/L

PFOA 20000 - 40000 ng/L

Landfill Leachate:

PFOS 7.4 - 580 ng/L

PFOA 78 - 1700 ng/L

Municipal Wastewater Effluents:

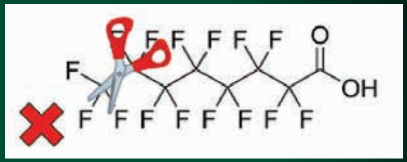
PFOS 3.6 - 29 ng/L

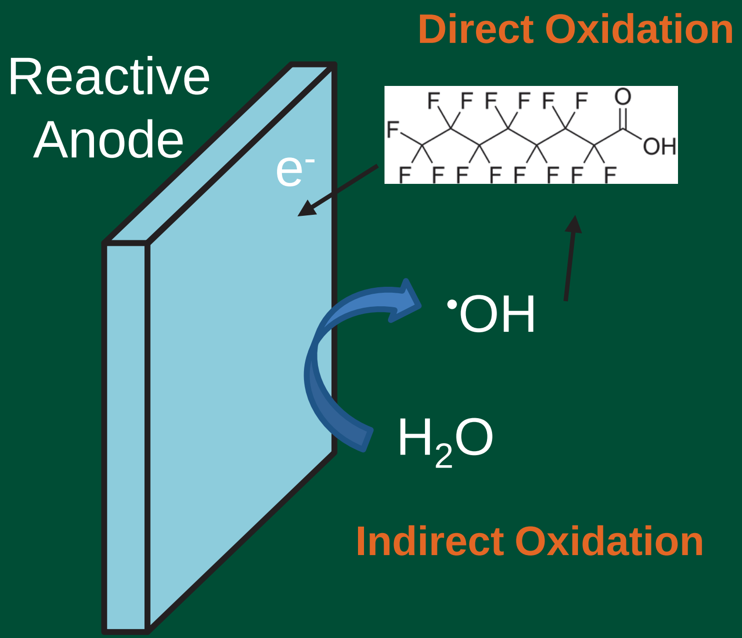
PFOA 6.3 - 35 ng/L

https://experience.arcgis.com/experience/12412ab41b3141598e0bb48523a7c940/page/Page-1/?views=Known-Contamination

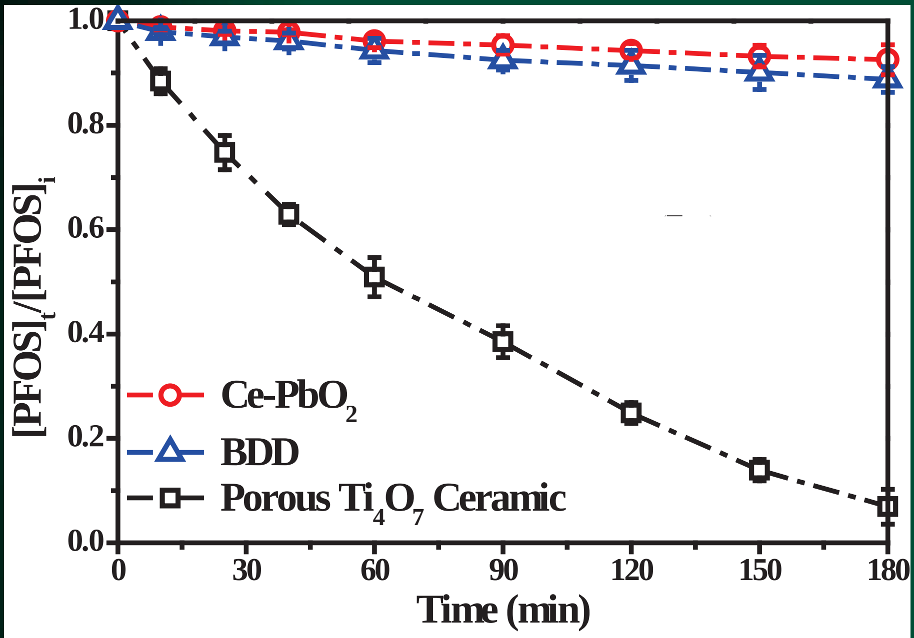
Electrochemical Advanced Oxidation Processes (EAOP)

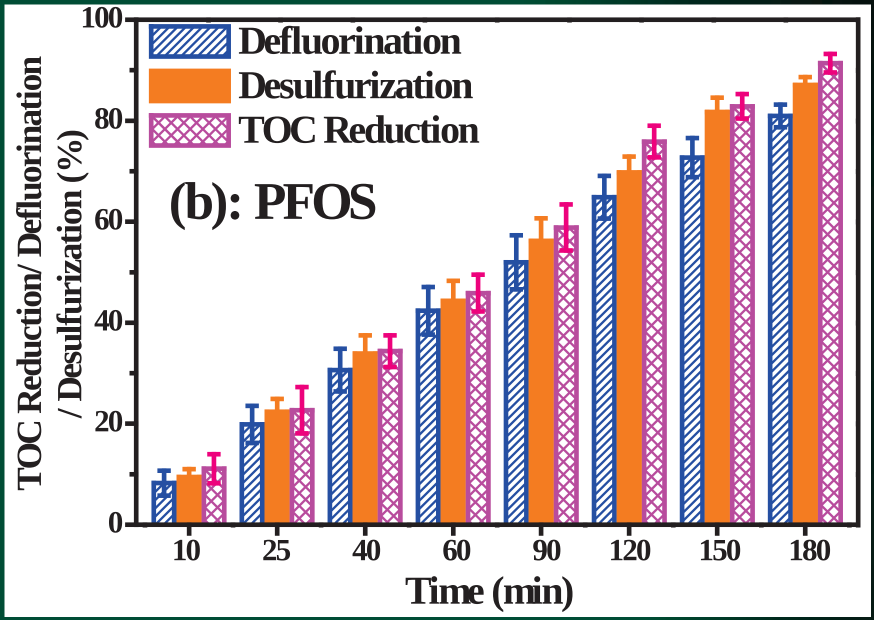
- **Resistant to traditional treatment: strong carbon-fluorine bond**
- **EAOP mechanism for PFAS degradation**



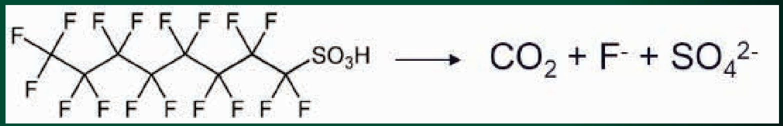


Degradation and Mineralization of PFOS





Experimental conditions
0.5 mM PFOA and 0.1 mM PFOS in 20 mM $NaClO_4$
stir at 800 rpm; current density of 5 mA/cm^2

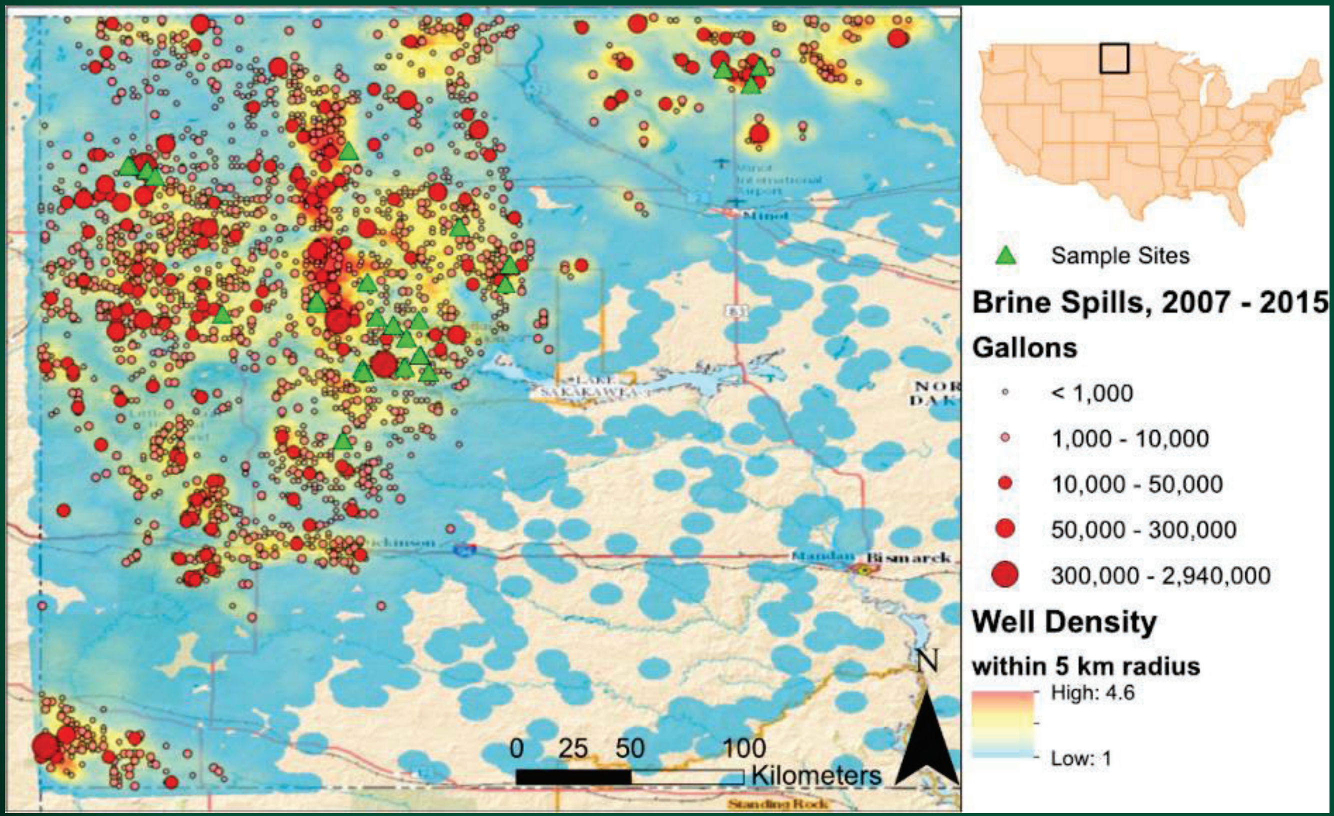


Ti_4O_7 ceramic electrode provided excellent degradation of PFOS

Lin et al. *Chem Eng Technol*, 2018; H. Lin*, **J. Xu***, et al. *Water Res,* 2021; X. Xie, **J. Xu**, et al. *Electrochim Acta*, 2023; H. Peng, **J. Xu**, et al. *ACS ES&T Water*, 2023; W. Li, **J. Xu**, et al. *Water Res,* 2022; K. Yang, **J. Xu**, et al. *J. Hazard. Mater.*, 2022

Produced Water Contamination

- **Brine spill from oil and gas industry is a serious problem in ND**



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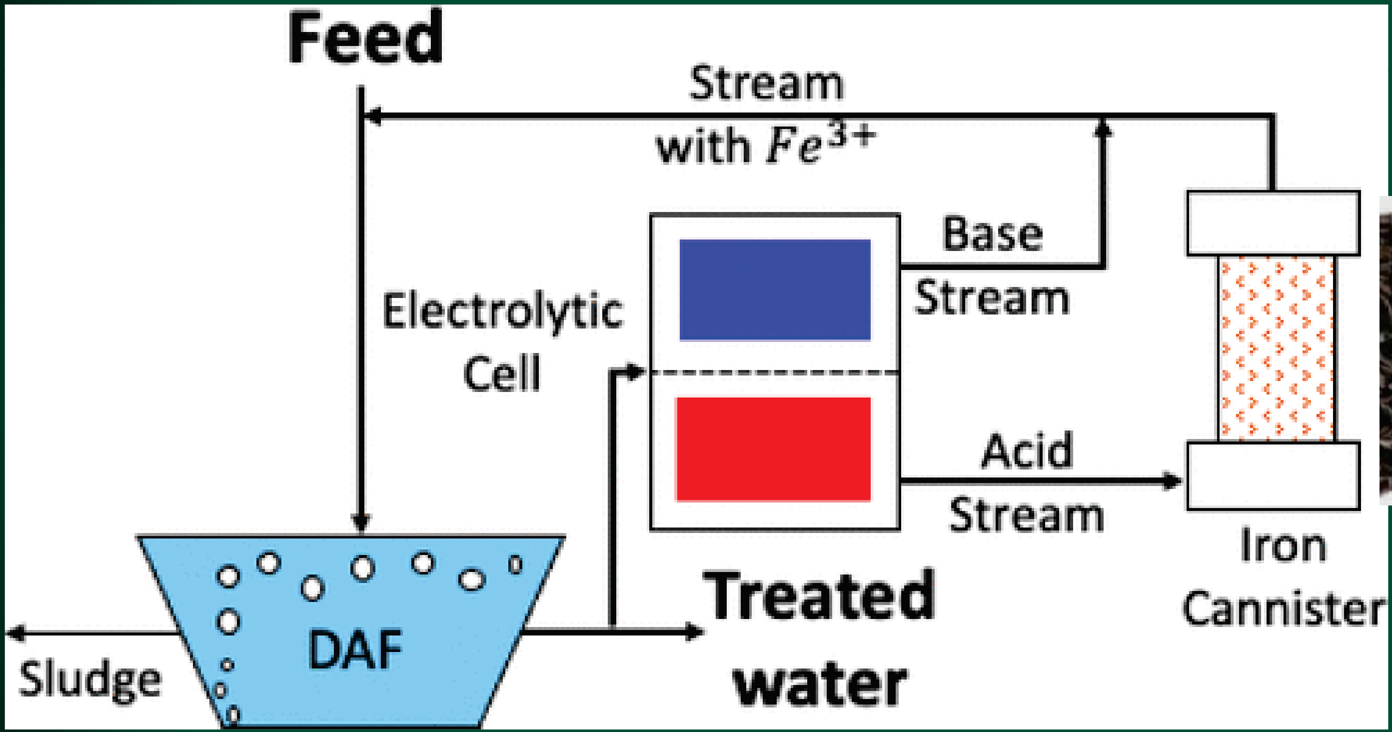
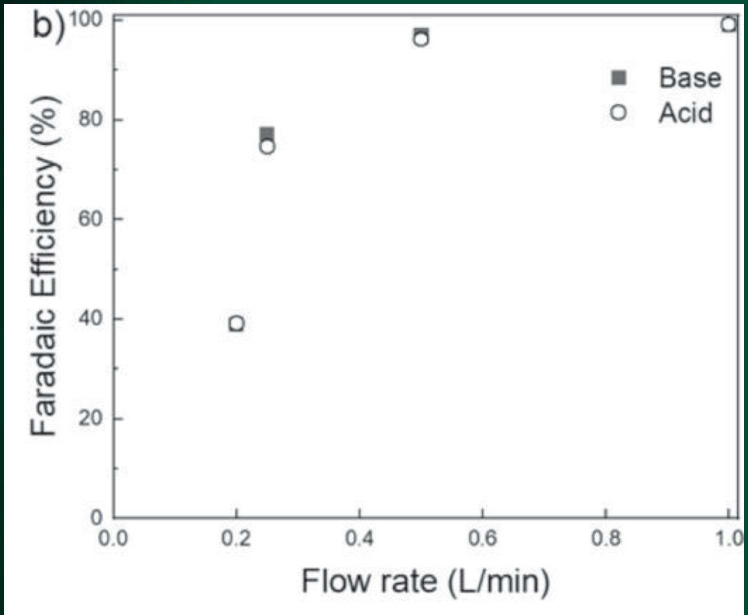
Nancy E. Lauer, Jennifer S. Harkness, and Avner Vengosh. *Environmental Science & Technology* **2016** *50* (10), 5389-5397

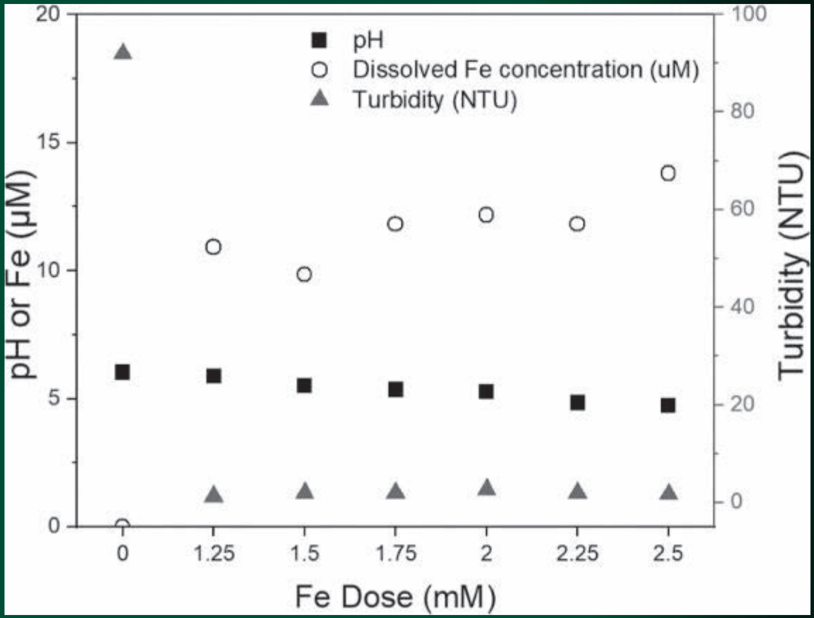
Onsite Treatment and Reuse of Produced Water



Efficient Produced Water Treatment



Close to 100% generation of acid and base



Over 99% removal of turbidity

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Low-cost Treatment

Table 3. Treatment costs for operating the system at 190 Lpm over a 10-year period with a coagulant dose of 2 mM-Fe^{3+}.

Item	Amount
Capital Cost (actual cost from this project)	$368,750
Interest Expense @ 5%/yr	$184,375
Capital plus Interest	$553,125
Operational Expense @$0.087/mM-Fe/$m^3$	$172,967
Total Cost for 10 years	$726,092
Volume of FPW Treated @ 190 Lpm gpm	994,064 m^3
Cost per m^3 FPW Treated	$0.73/$m^3$
Cost per bbl FPW Treated	**$0.12/bbl**

- **Cheap iron filings**
- **Utilize salt from brine**

Pilot System

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Acknowledgement and Contact

Funding Sources

Collaborators:

Shahidul Islam, Assistant professor, NDSU
Ying Huang, Professor, NDSU
Kalpana Katti, Professor, NDSU
Dinesh Katti, Professor, NDSU
Hui Lin, Associate professor, Dongguan University of Technology, China

Students: Tajrin Alom Nizhum and Md. Atik Fayshal

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River flows in ice-covered conditions

Trung Le, PhD, Assistant Professor
Civil, Construction, and Environmental Engineering
North Dakota State University

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Motivation

Understanding river flow dynamics is important for many purposes

FM Flood diversion

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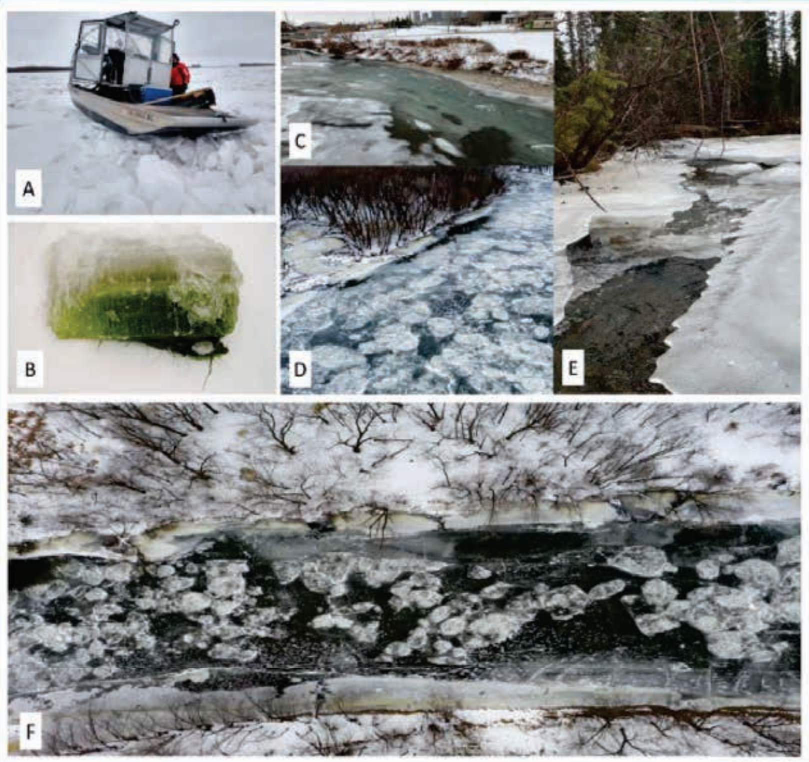
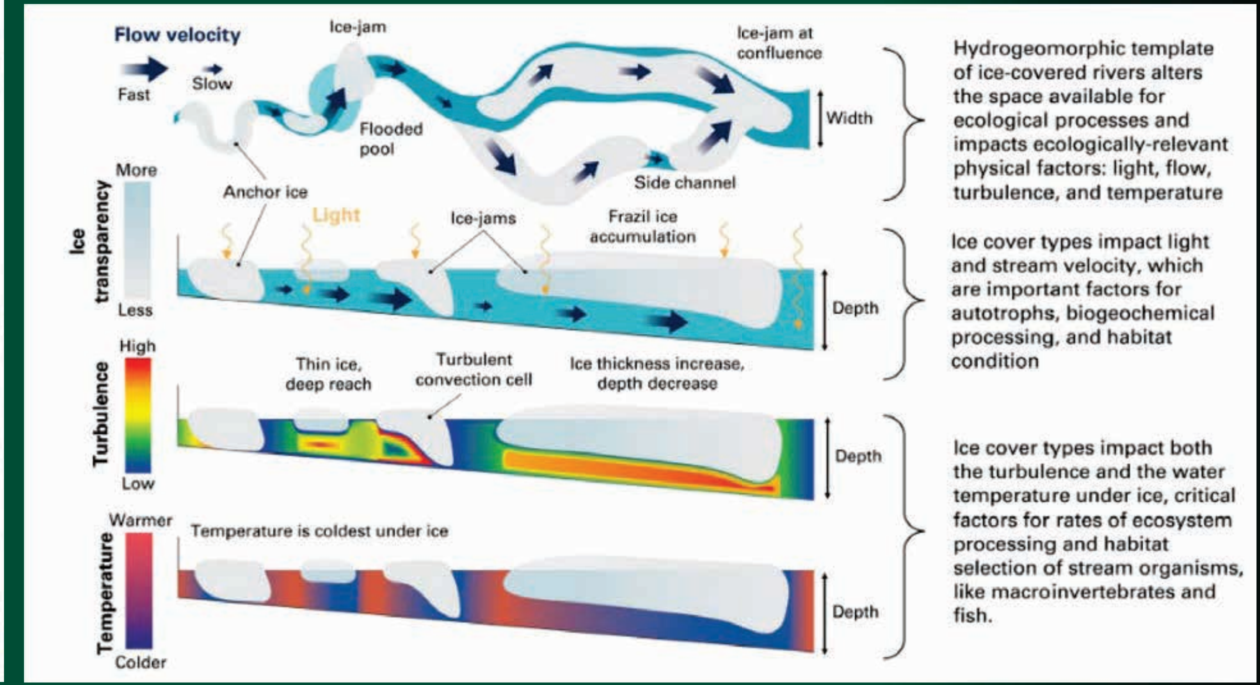
Turbulent flows in ice-covered rivers



Common ice formations (Thellman et al. 2020)



How does ice cover impact the river flow and dynamics? (Thellman et al. 2020)

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Field measurements of icy flows under full coverage

- Winter measurement challenges:
- Safety (ice thickness to walk on ice and safety equipment)
- Minimum ice thickness for a 200-lbs person is suggested as 0.30 ft (~ 4 inch)
- During all our measurements, minimum ice thickness is measured as 0.75ft (10 inch)
- Extremely low temperature (generally -20oC to -10oC) makes the sensor difficult to operate
- Signal interference near the river bed (for both surface conditions)
- Difficult to derive shear velocity because profile assumption is required

Winter measurements on Feb/18/2020 (Trung on the left, and Berkay on the right)

Goals

The main goal is to understand the flow structures under the ice cover:

- Investigate the changes in flow profiles as the surface condition changes from ice-free to ice-covered conditions.
- Examine the cross-stream distribution of bed shear stress
- Evaluate the impacts of the ice-cover on the secondary flow structures in the bend
- Demonstrate the ability of Large-Eddy Simulation in replicating the dynamics of ice-covered flows
- Examine the impacts of the ice-covered on the flow planform

Field measurements of flow characteristics of a bend of the Red River

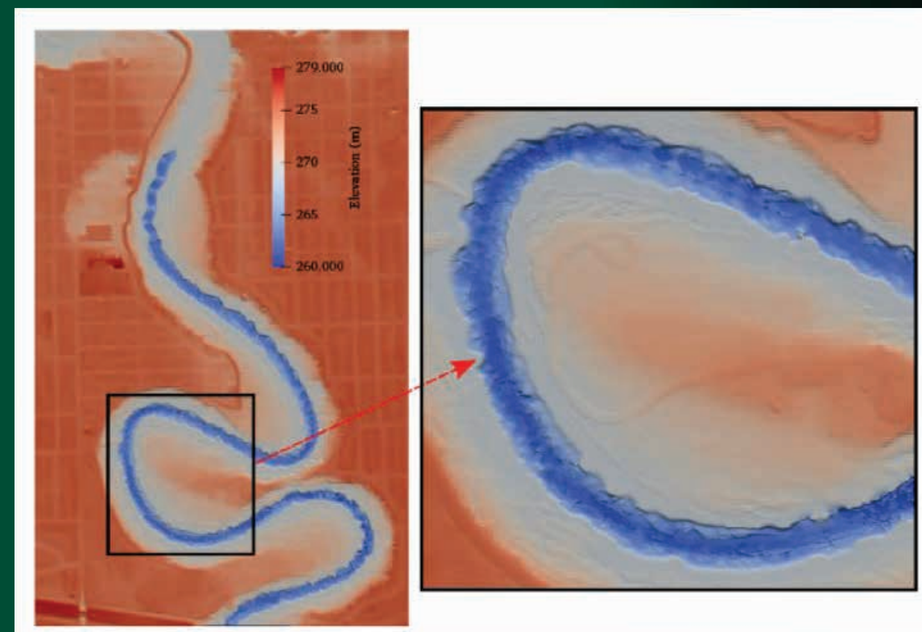
Modeled Red River Reach:

Downstream

Flow Direction

Upstream

Study site (Google Earth Image: 03/17/2021)



Three-dimensional model of the Red River reach

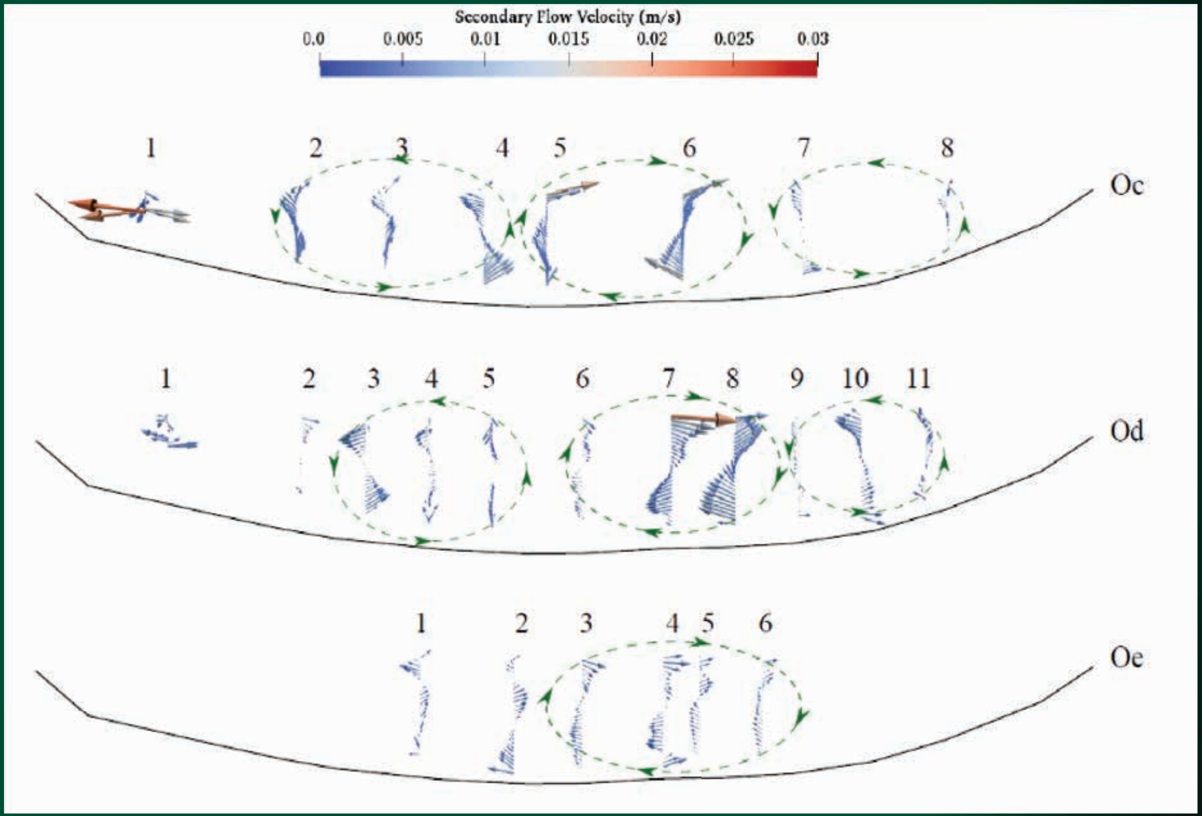
Field measurements under ice-free condition

Secondary Flow Patterns: rotation-based Rozovskii approach

Jun/22/2021: Q = 14.30m^3/s

Jun/24/2021: Q = 12.20m^3/s

Jun/30/2021: Q = 6.82m^3/s



Secondary flow patterns using rotation-based Rozovskii method

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Field measurements of icy flows under full coverage

Depth-averaged velocity vectors:

Pedestrian bridge during winter

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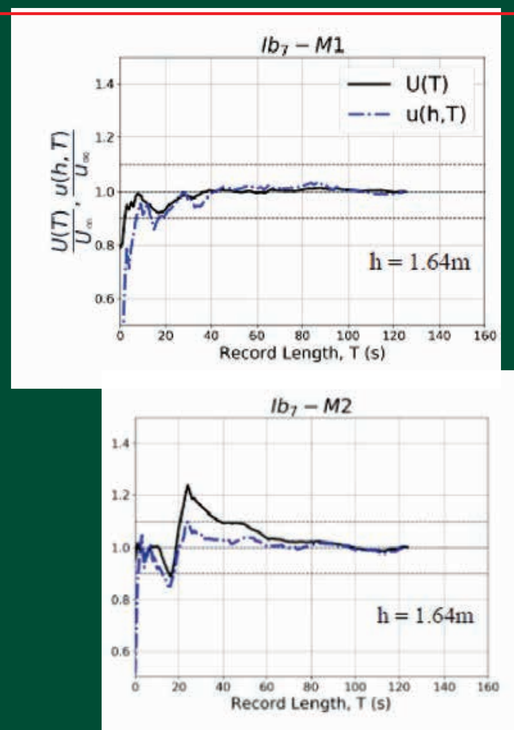
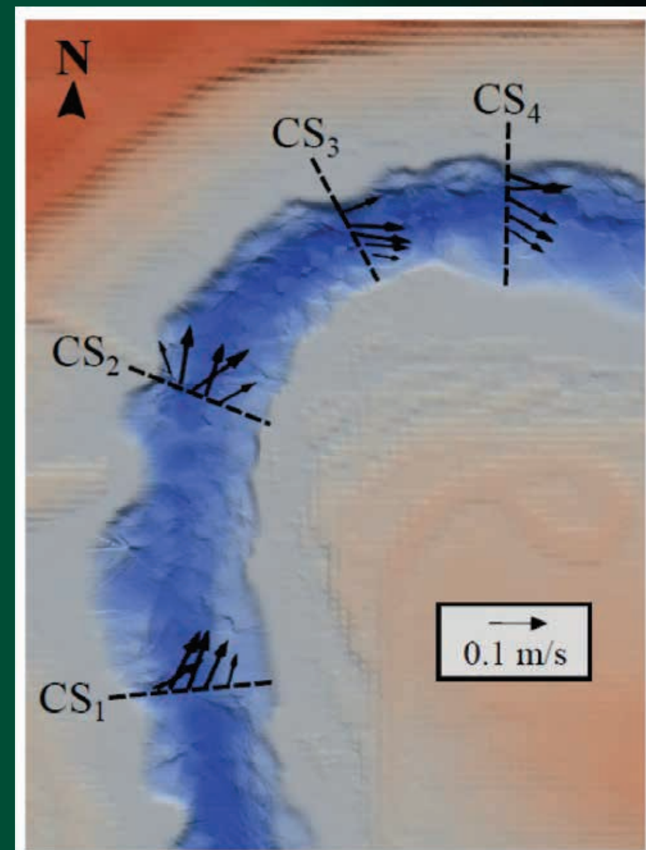
Stationary (fixed-vessel) deployment:

- ~2 to 4 min under ice coverage



Long-term statistics of data sets



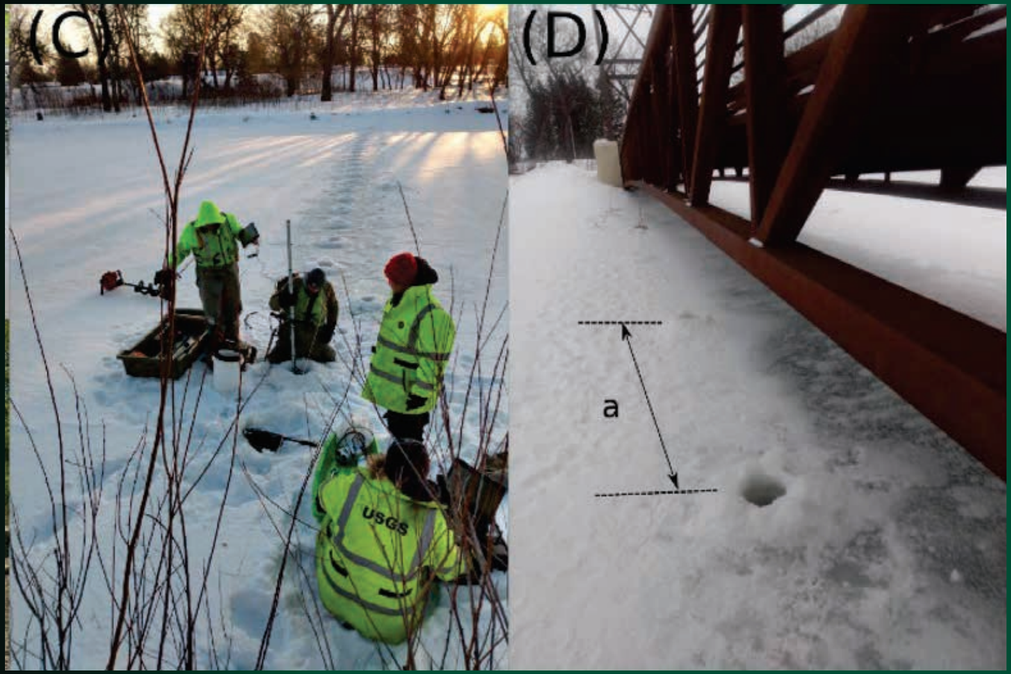
Depth-averaged velocity vectors at measured cross-sections (Feb/08/2022)

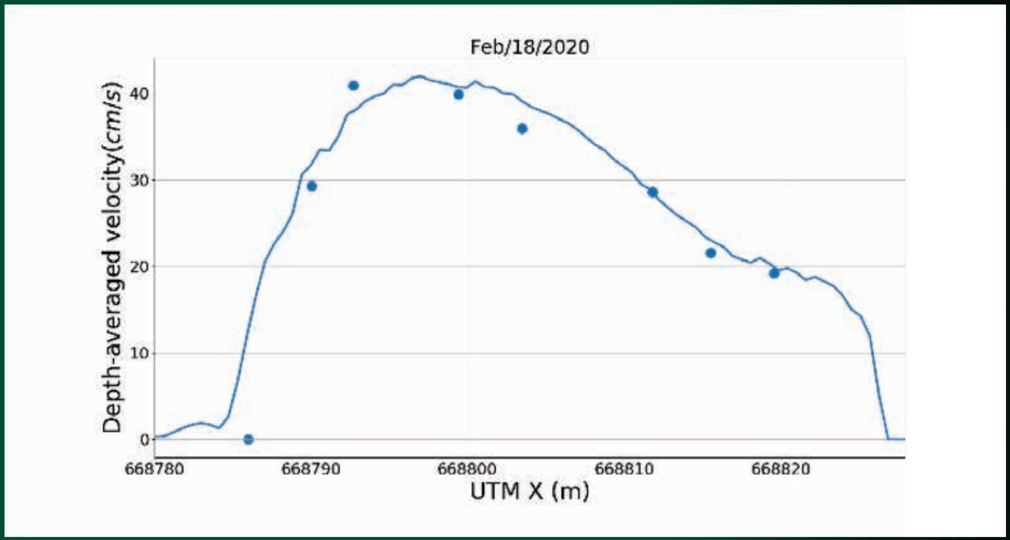
LES of river flows

LARGE-EDDY SIMULATION (LES):

- A structured grid is used with approximately 80M grid points
- Dynamic Smagorinsky model for the eddy viscosity
- Wall modeling for solid surfaces
- Assumed uniform flow at the inlet, fully developed flow at the outlet
- Using immersed boundary method (CURVIB) to handle complex bathymetry
- High performance computing (HPC) centers at NDSU (CCAST) and Pittsburgh Super Computing (XSEDE)
- LES model has been validated with field measurements (Le et al., 2019)

LES validation





Comparison between the depth-averaged velocity of LES (line) and measurements (dots)

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Conclusions

- Under open-surface condition, the logarithmic layer can extend up to 50% of the total depth.
- Under ice-covered condition, the logarithmic layer is restricted in 20% of the total depth.
- The quartic solution (Guo et al., 2017) is helpful in determining these shear velocities. It is sensitive to the determination of maximum velocity, which might result in an underestimation of the shear stresses.
- The spatial distribution of the bed shear stress across the cross-section is changed by ice cover
- Under open-surface condition, the secondary flow pattern is dependent on the flow discharge. At high discharge, a single circulation dominates the overall pattern. At low discharge, two counter-rotating circulations, which have reverse senses of rotation to the high discharge one, mutually exist.
- Under ice-covered condition, the secondary flow pattern becomes highly complex. Multiple circulations are found simultaneously with alternating senses of rotation.

Understanding North Dakota’s Water Use, Stormwater, and Harmful Algal Blooms

Christina Hargiss, PhD, Professor
Natural Resources Management
Director School of Natural Resource Sciences
North Dakota State University

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Water Use Projects with ND Dept of Water Resources (NDDWR) and USGS

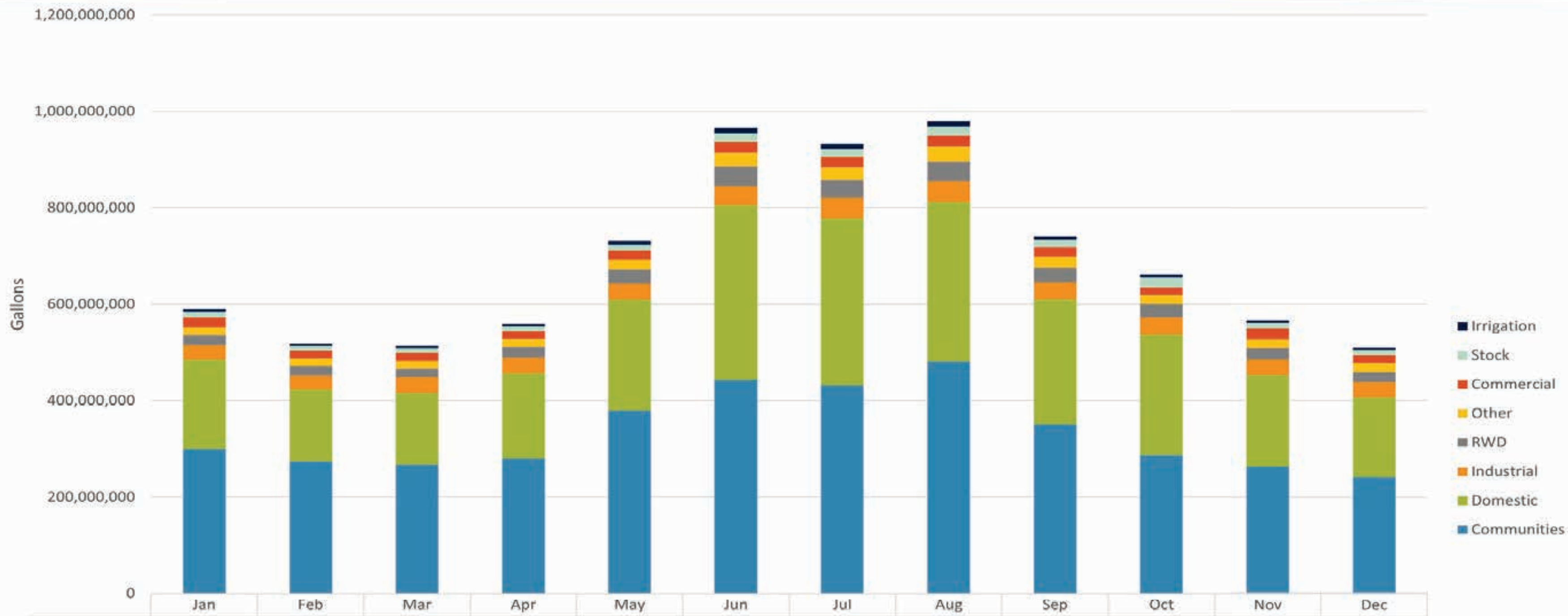
Four projects 2015-2023

- Set North Dakota priorities for understanding water use
- Assessed cities of all sizes across the state
- Per capita coefficients
- Assessed pre-oil boom, boom, and post-boom industrial and municipal water use in Bakken Region (2000-2018)
- Municipal and industrial water use
- Rural Water Use

Interesting Highlights

- Municipal Water Use
  - Top 10% of single family homes use approximately 25% of the water
  - Top 10% commercial water users use over 50% of commercial water
- Bakken Oil Water Use 2000-2018
  - Oil and Gas permitted water use increased in the non-Bakken region, but not in Bakken
  - Commercial water use was steady in non-Bakken, but increased significantly in Bakken
    - Commercial water used to support oil and gas industry
  - Municipal water in many large Bakken cities did not increase
    - However, rural water use did
    - Little data on how rural water used beyond yearly permit total use

Rural Water-Use Trends

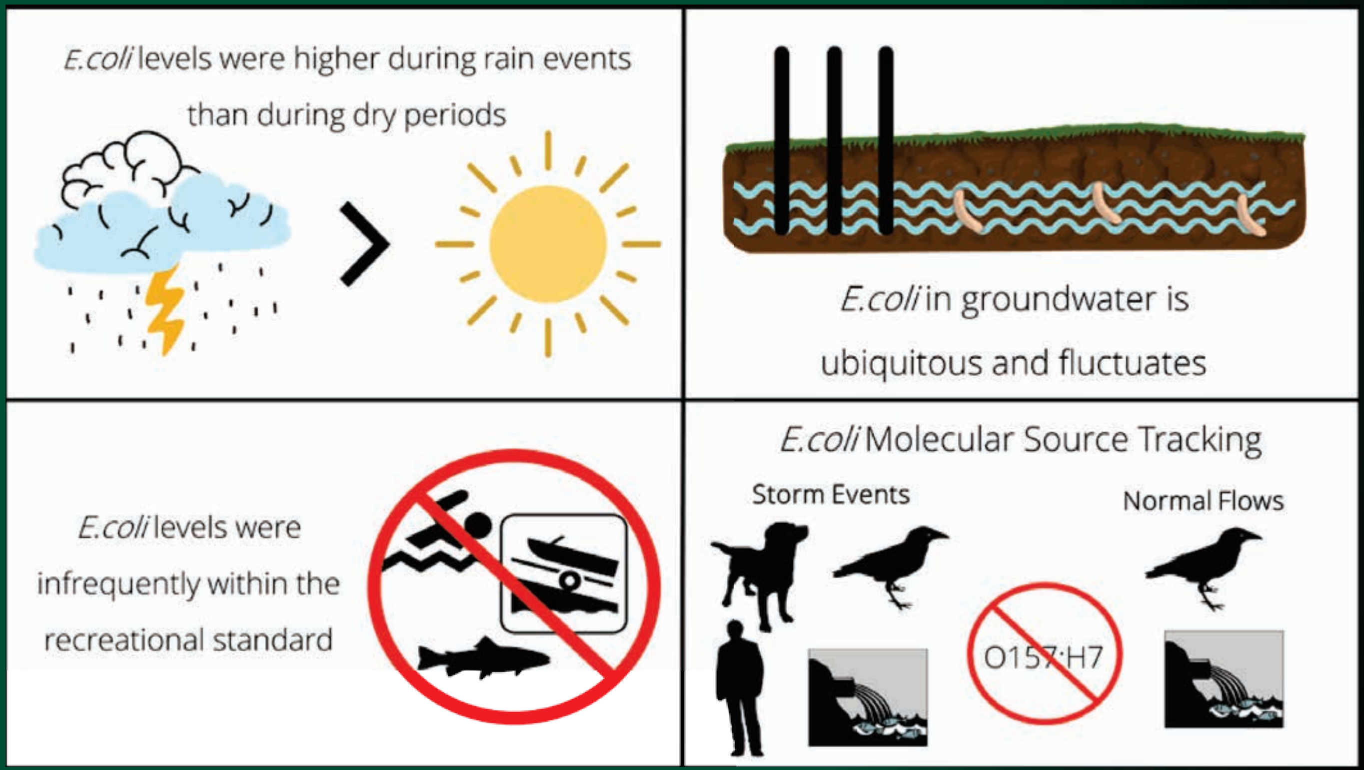


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation	4,504,944	4,366,227	4,805,906	5,418,881	7,953,630	10,983,746	10,472,489	11,124,320	7,636,800	5,904,831	4,925,945	5,261,578
Stock	11,343,521	10,154,623	9,740,934	10,625,646	12,072,261	16,624,949	16,207,580	17,839,634	14,782,364	21,309,426	11,223,427	10,528,926
Commercial	21,337,661	16,138,257	16,795,363	16,396,042	18,797,826	22,936,581	21,531,643	23,612,478	19,666,400	15,866,051	23,196,045	16,269,444
Other	16,209,026	15,610,339	15,853,626	16,860,102	20,860,897	28,244,155	25,847,448	31,045,425	22,800,989	18,560,372	18,310,049	18,219,096
RWD	20,019,881	19,005,305	17,632,951	21,431,197	29,730,892	40,357,052	37,894,021	40,712,103	30,319,673	27,146,247	23,138,855	21,428,768
Industrial	30,606,100	29,193,955	32,468,725	32,685,205	32,355,915	40,830,490	42,902,065	43,329,625	35,190,175	36,346,715	32,706,885	30,964,885
Domestic	185,221,279	148,940,357	149,869,766	176,295,669	229,623,871	361,676,795	346,747,893	330,249,971	258,807,876	249,942,061	189,531,217	166,285,989
Communities	299,830,947	274,592,910	266,412,110	280,184,011	380,016,050	443,378,302	431,037,638	481,384,993	351,631,685	286,704,029	263,516,342	240,762,732

Month

Urban Stormwater

- First flush off landscape carries largest amounts of organic material, debris, and pollutants
- Nitrogen, phosphorus, and oil and gas we assumed to be high, but they weren't
- E.coli was the big story



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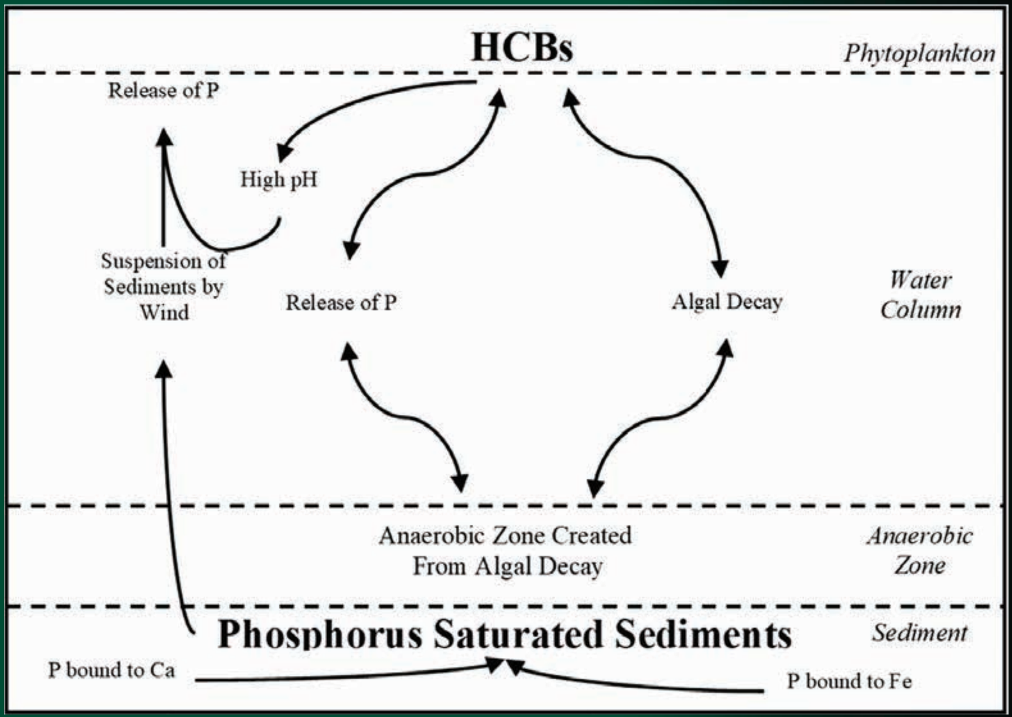
Harmful Algal Blooms

Des Lacs National Wildlife Refuge

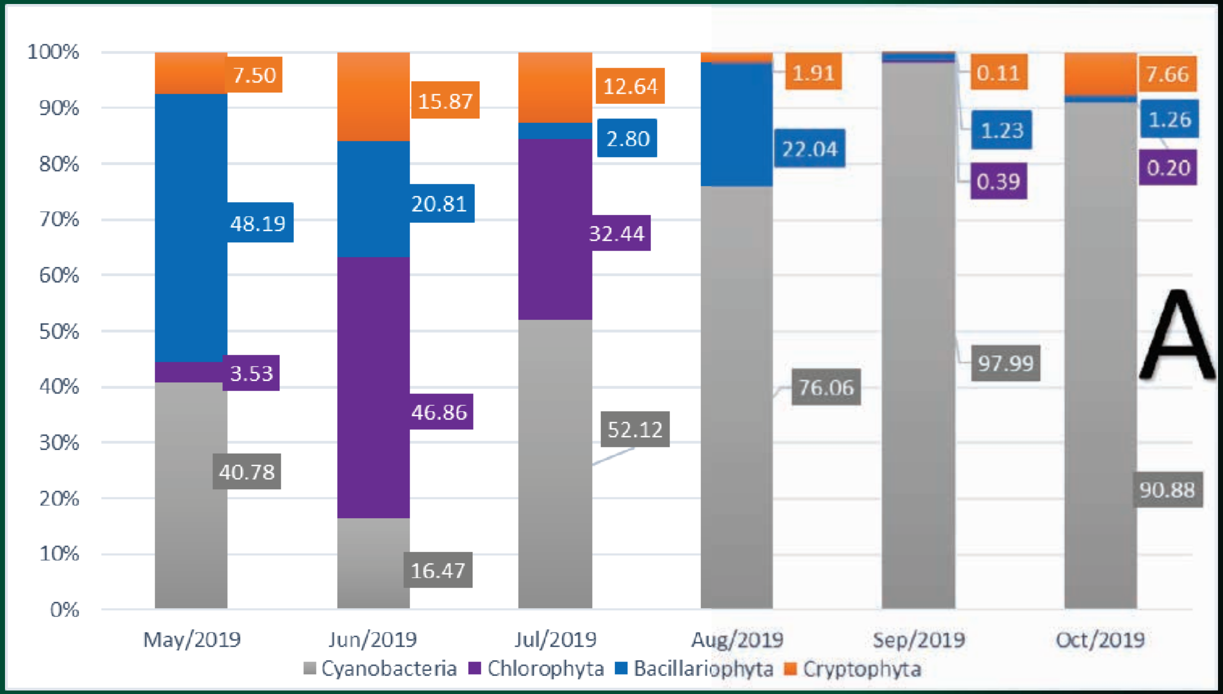
- 2014 24 head of cattle died from cyanobacteria (blue green algae poisoning – microcystin toxin)
- USFWS, NDDEQ, and NDSU collaboration
- Sampled water 2016-2019 and sediment 2019 to help understand HABS problem
- System is eutrophic and hypereutrophic
  - Large amounts of nutrients fuel blooms through summer season
- Sediment 95-100% saturated with phosphorus



Harmful Algal Blooms

Harmful algal blooms (cyanotoxins)

- Not an easy fix
- No magic bullet exists currently anywhere in US/world
- Detection and warning necessary when present
- Mitigation to reduce impacts



Questions?

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