Role of in-stream processes in shaping P exports to Lake Erie during low and high flows.

Jim Hood

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Translation Data Analytics Institute

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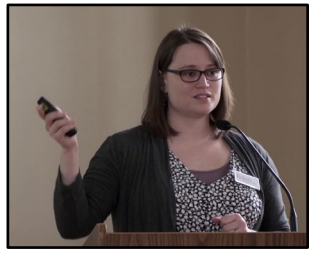
THE OHIO STATE UNIVERSITY COLLEGE OF ARTS AND SCIENCES

OHIO STATE

Audrey Sawyer
(OSU)

Tanja Williamson
(USGS)



Laura Johnson
(Heidelberg)

Margaret Kalcic
(OSU)

Becky Kreiling
(USGS)

Chris Spiese
(ONU)

Kevin McCluney
(BGSU)

And numerous students and technicians!

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HARMFUL ALGAL BLOOM
RESEARCH INITIATIVE

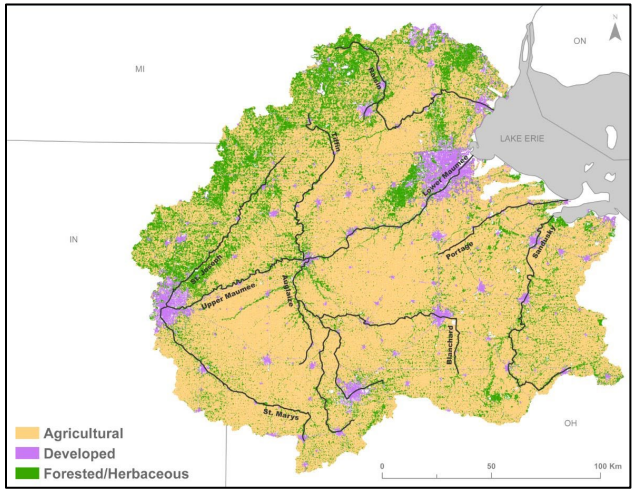
ROADMAP

- Background: importance of river P cycling in context of HABS
- River P cycling in the western Lake Erie basin
  - Sediment P apportionment (Williamson, USGS)
  - Instream: High flows (W. King & Hood, OSU)
  - Instream: Low flows (Sawyer & Hood, OSU)
- Key knowledge gaps & next steps

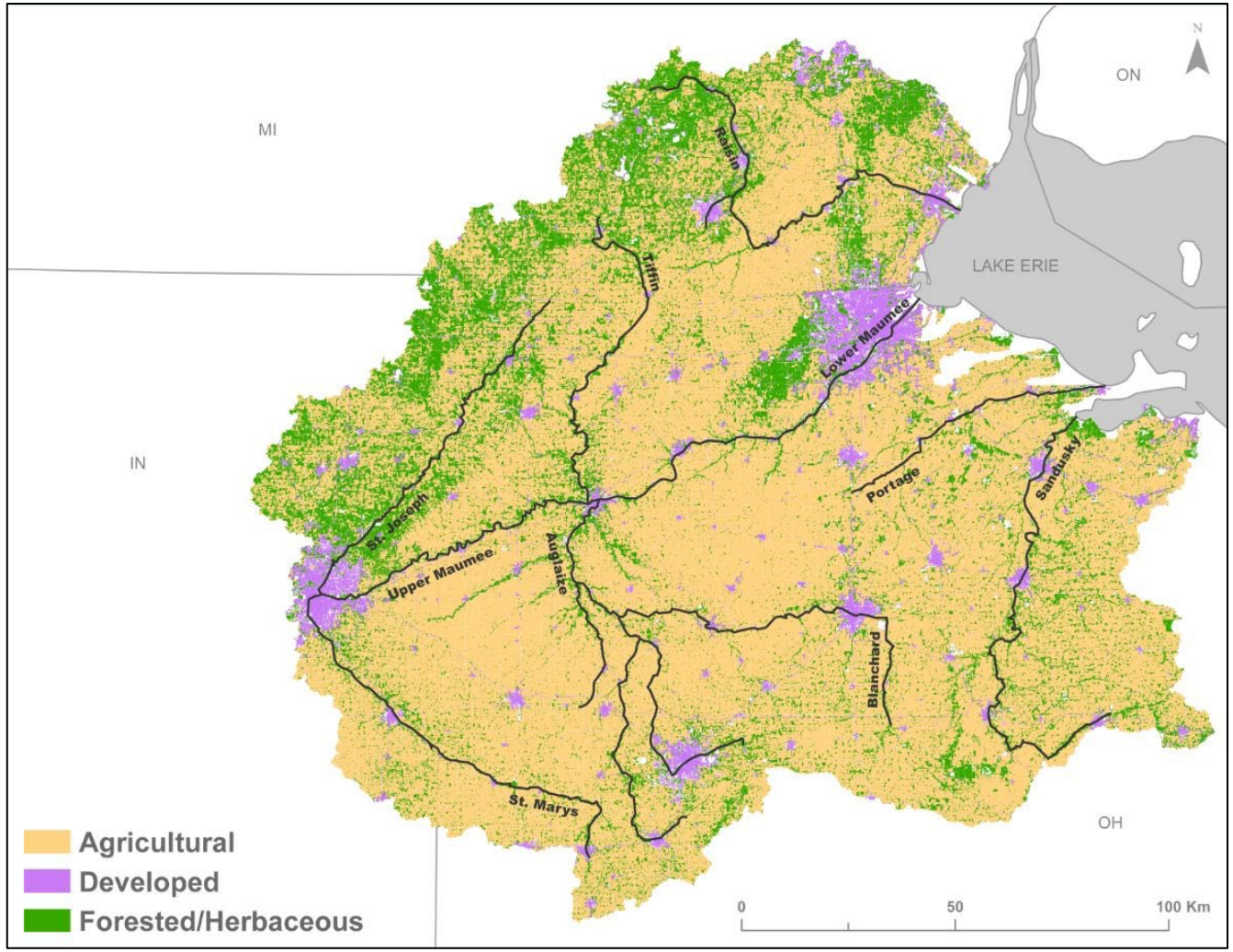
Spring loading from the Maumee River basin drives HABS

- Key facts of reoccurr
  - Driven by spring
    (DRP) loading fro
    (…but N is impor
  - Most of the sprin
    high flow events
  - The Maumee basin is ~90% agricultural lands, putting the focus for reducing P loads on agricultural lands.
  - This framework assumes that particulate and dissolved P ”passively” moves downstream from fields to the lake.

What happens to particulate and dissolved P during transport from fields to ditches, rivers, western Lake Erie?



What happens to P as it moves downstream?



do rivers passively transport P downstream or are they a P source or sink?

If they are a source and sink, through which mechanisms and how much?

Does this dynamic vary in space and time?

Phosphorus cycling in flowing waters shapes P exports

Streambanks can be important source of sediment P, even in low-gradient watersheds

Suspended sediment supply dominated by bank erosion in a low-gradient agricultural watershed, Wildcat Slough, Fisher, Illinois, United States

JOURNAL OF SOIL AND WATER CONSERVATION
MAY/JUNE 2015—VOL. 70, NO. 3 | 145

C.W.M. Neal and A.M. Anders

Ditches & rivers retain and transform P during transport.

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Science of the Total Environment

Delivery and cycling of phosphorus in rivers: A review

P.J.A. Withers[a,*], *H.P. Jarvie*[b]

[a]*Environment Group, ADAS UK Limited, Gleadthorpe, Meden Vale, Mansfield, Nottinghamshire NG20 9PF, United Kingdom*
[b]*Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB, United Kingdom*

Sandusky River retains up to 48% of P inputs on an annual basis

Quantifying Phosphorus Retention and Release in Rivers and Watersheds Using Extended End-Member Mixing Analysis (E-EMMA)

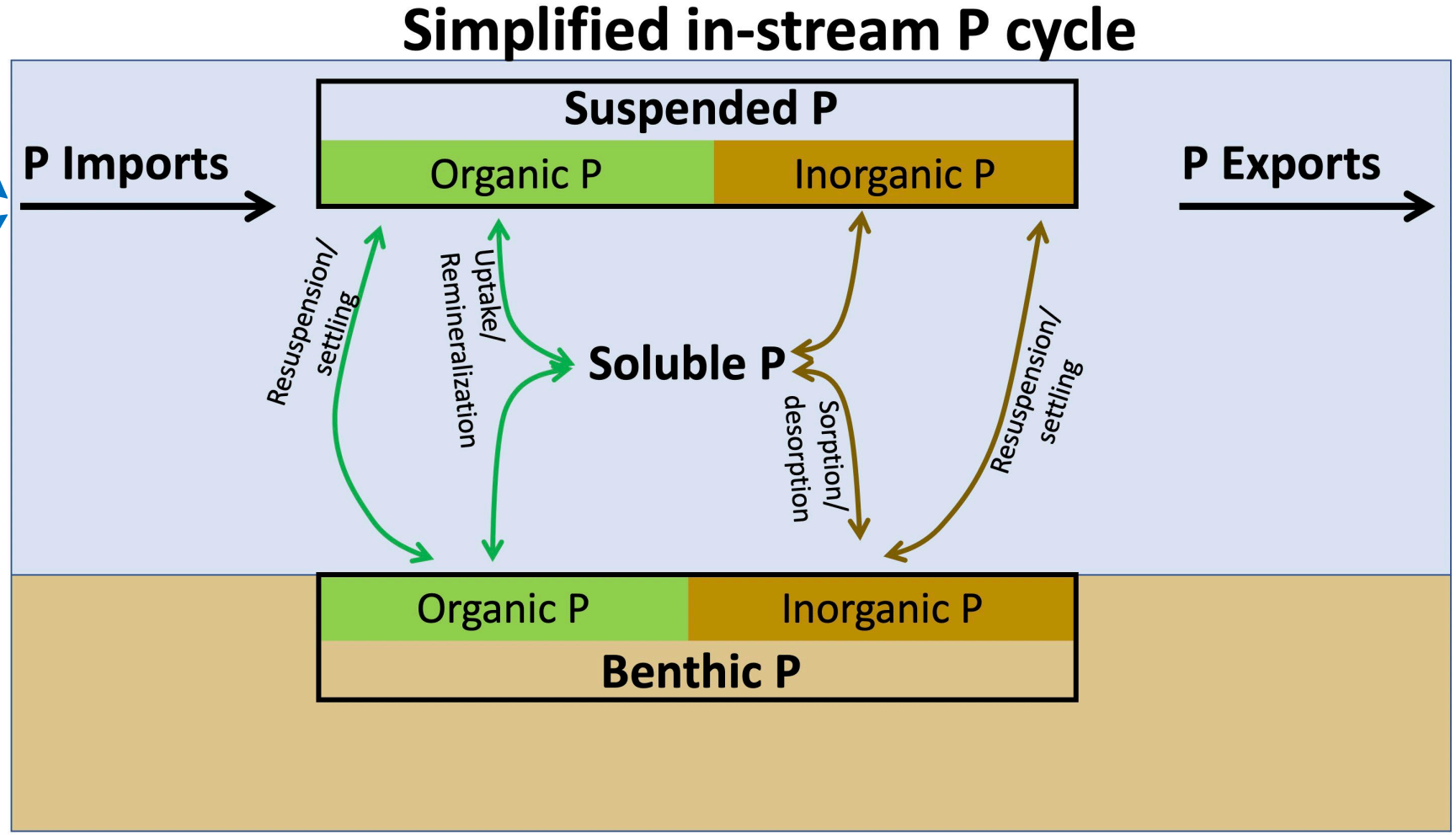
Helen P. Jarvie,* Colin Neal, Paul J.A. Withers, David B. Baker, R. Peter Richards, and Andrew N. Sharpley

J. Environ. Qual. 40:492–504 (2011)
JEQ JOURNAL OF ENVIRONMENTAL QUALITY

Phosphorus cycling in flowing waters

Dissolved & particulate P inputs from wastewaters and runoff

Sediment P from riverbanks



ROADMAP

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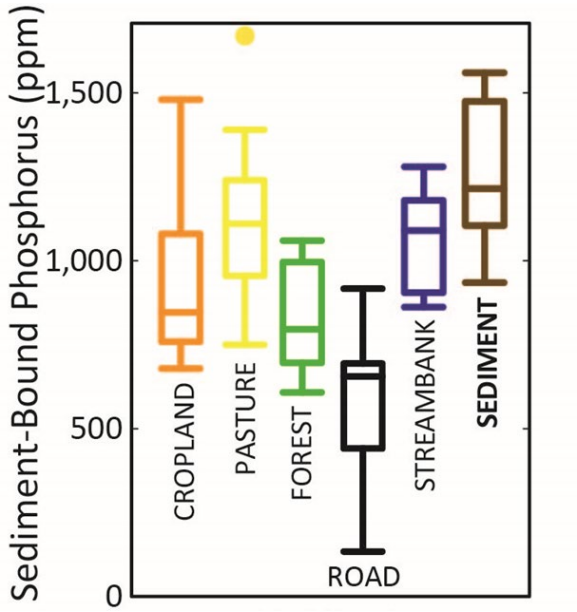
  - Instream: Low flows (Sawyer & Hood, OSU)
- Key knowledge gaps & next steps

What is the source of suspended sediment?

Land cover

- 66% cropland
- 19% pasture
- 7% forest
- 5% roads

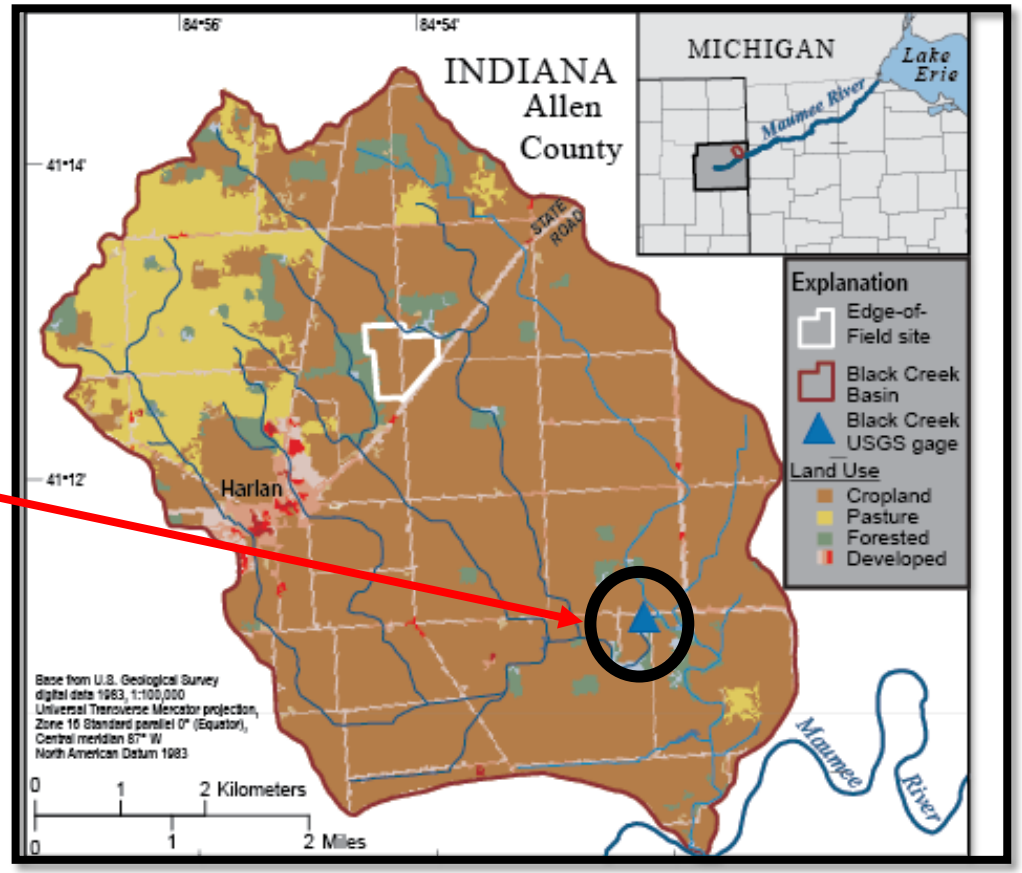


Streamflow and water-quality monitoring began October 2015 (WY 2016)

Monthly sampling for sediment source attribution WY 2018

Monthly samples of suspended sediment are time and flow integrated

Black Creek basin
32 km^2



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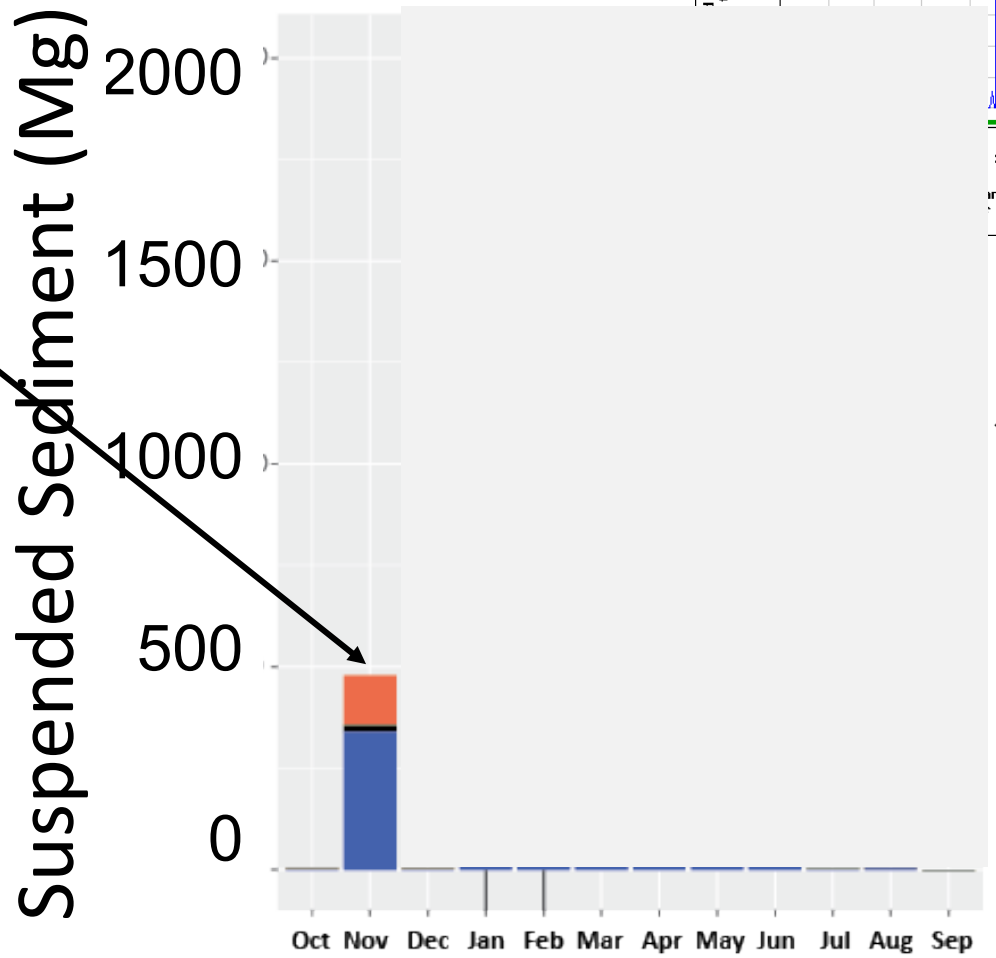
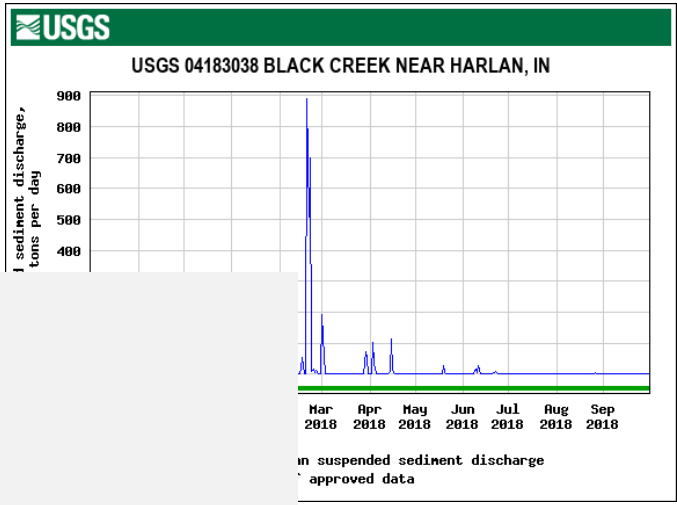
Streambanks contribute 70-90% of suspended sediment in key months

- **November 2017:**
  - 123 Mg sediment from cropland
  - 340 Mg sediment from streambank
- **Streambanks**: 40-100 % of monthly suspended sediment.
  - ➢ Great Potential Here
- **Cropland**: keep doing those BMPs – most in bare soil months.





Journal of Great Lakes Research
Available online 14 July 2020
In Press, Corrected Proof

Monthly suspended-sediment apportionment for a western Lake Erie agricultural tributary

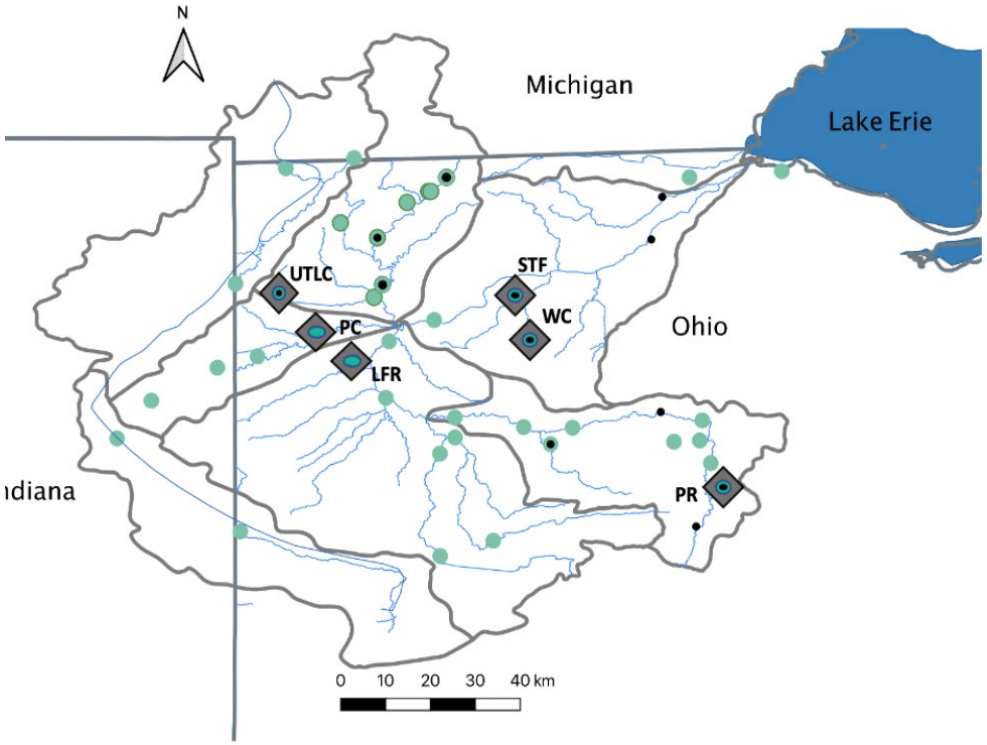
Tanja N. Williamson [a], Edward G. Dobrowolski [b], Allen C. Gellis [c], Timur Sabitov [d], Lillian Gorman Sanisaca [c]

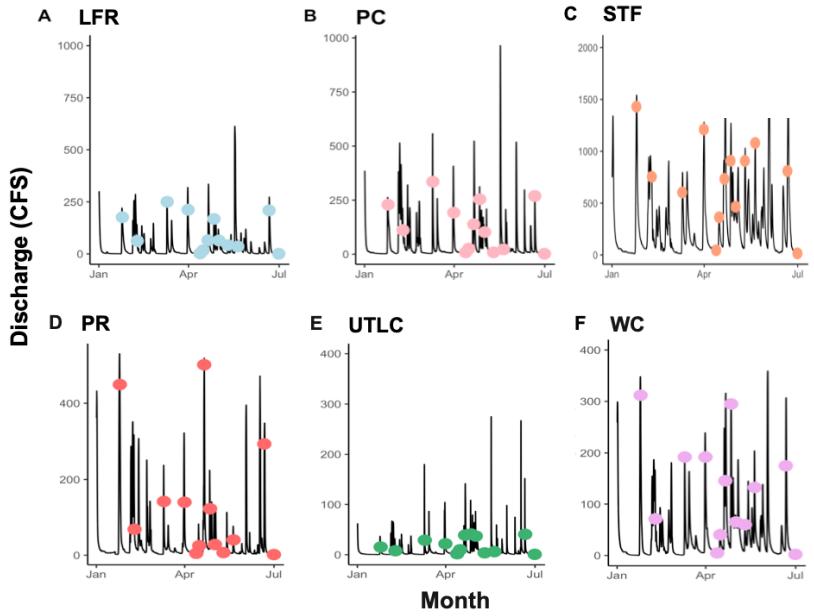
DRP to sediment P transformations at high flow

Whitney King

Sampled 13 storm events between January and June 2019

Measured P sorption by suspended sediments & their physiochemical composition

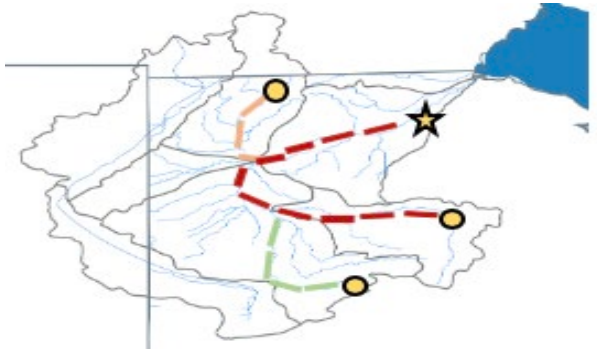




Rapid P sorption during high flow events

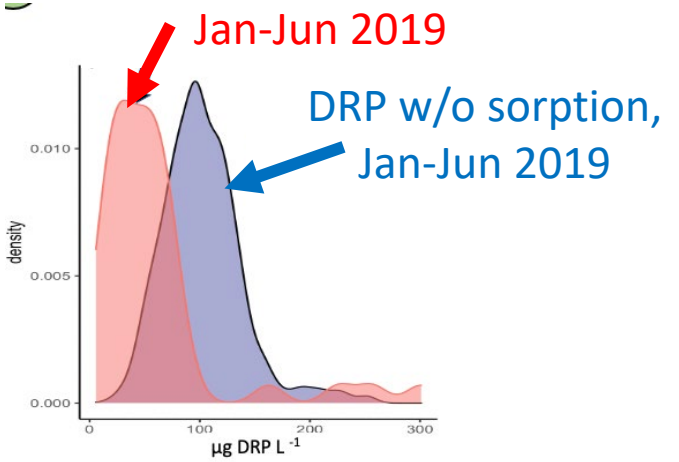
- Sorption observed in 77 of 78 measurements.
- Sorption rates varied widely among streams, related to discharge, particle size, and percent organic matter.
- Preliminary scaling calculations suggest that DRP sorption might be reducing DRP loading to Lake Erie during high flow events.

Without sorption DRP concentrations would be ~87% higher at Waterville



DRP at flows > 90th %, Jan-Jun 2019

DRP w/o sorption, Jan-Jun 2019



King et al. *in prep*

Instream processes during low flow

Sawyer Computational Hydrogeology Group (OSU)

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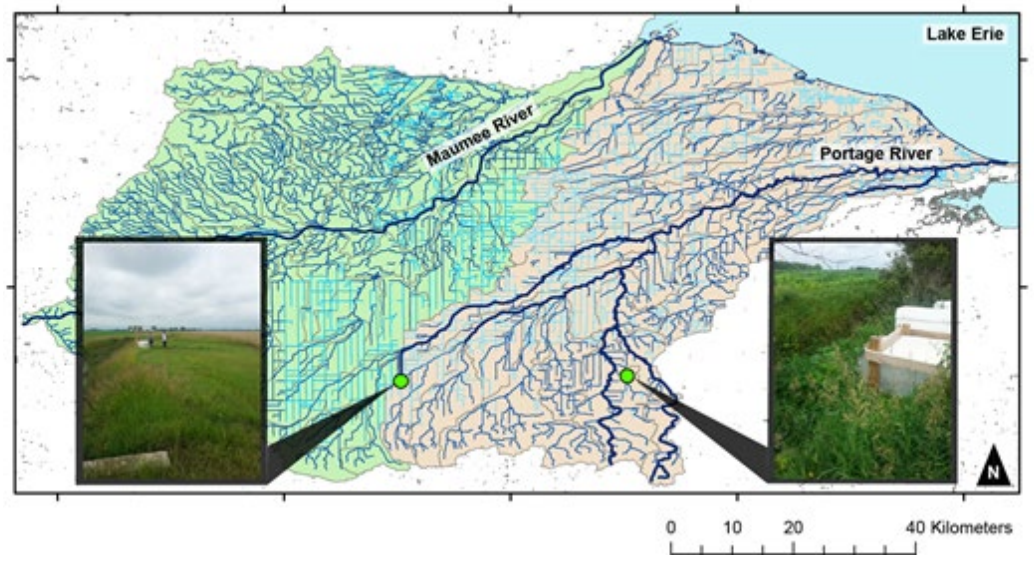

Casillas-Ituarte et al. ES&T (2019)

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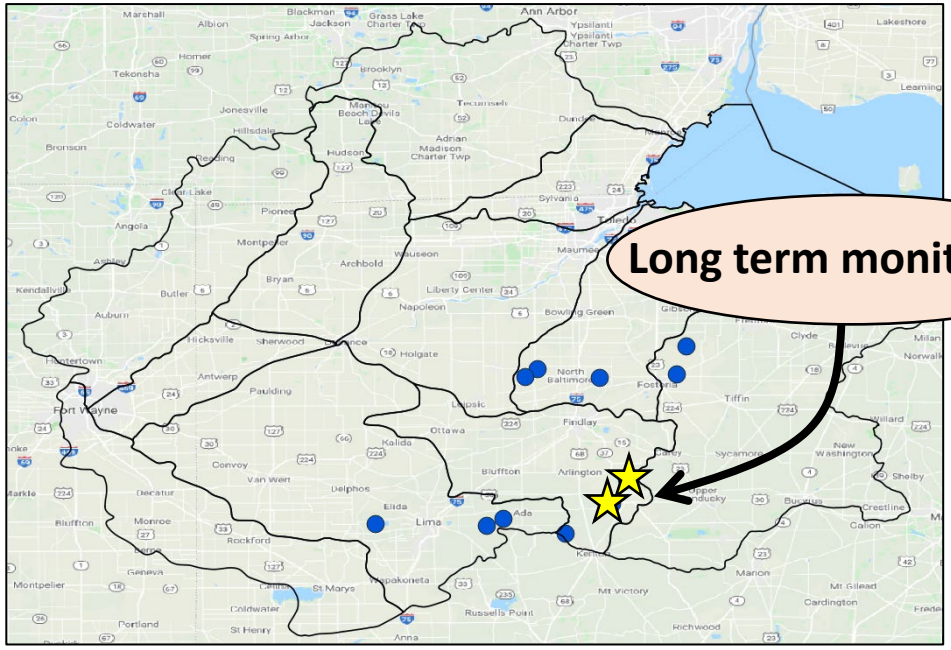
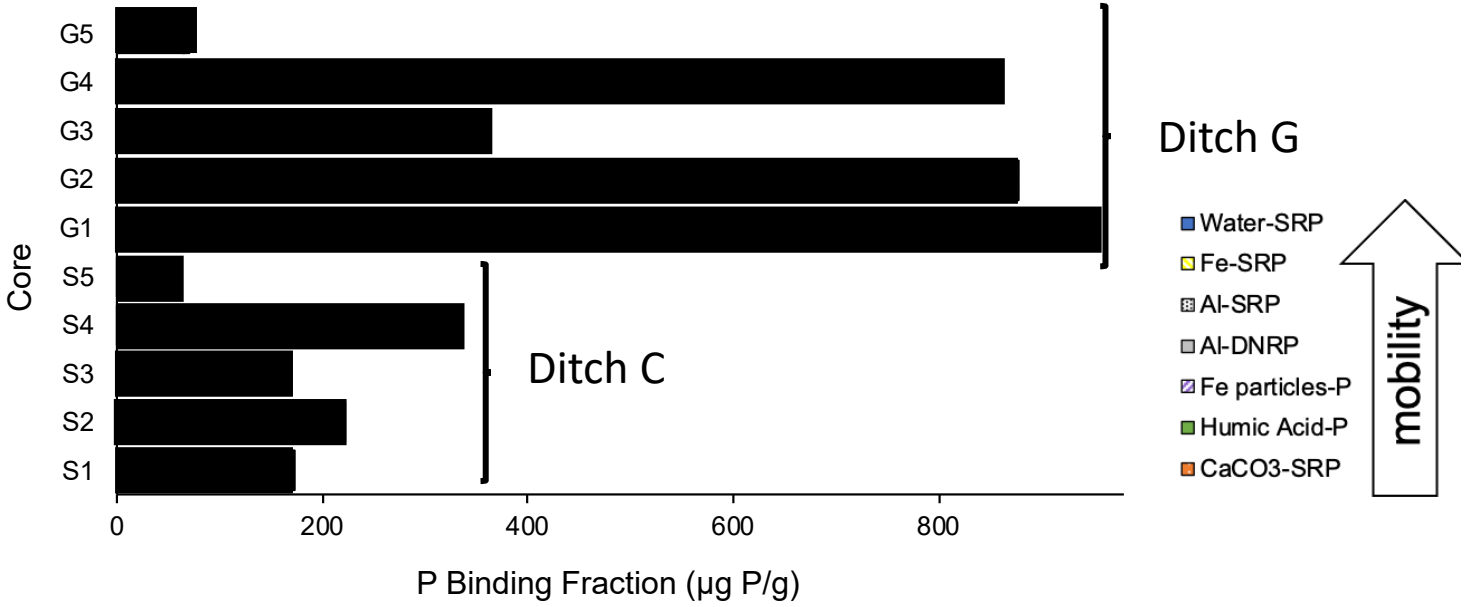
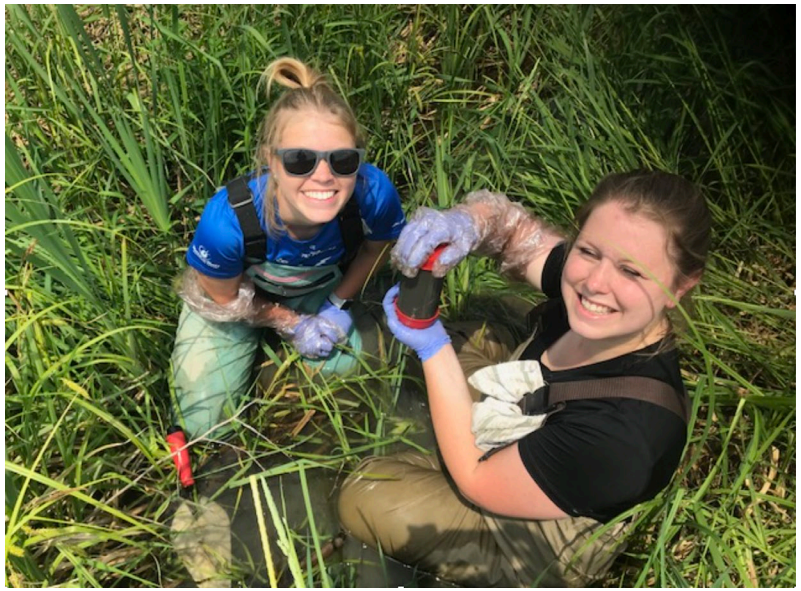


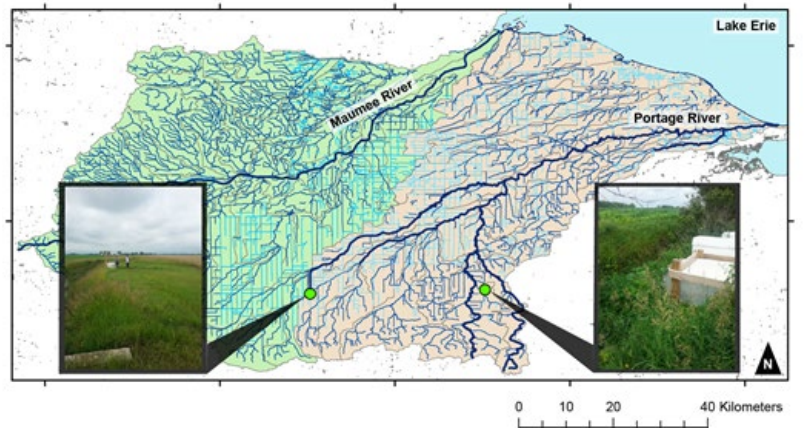
Hood et al. in prep

Benthic sediment P: high spatial variation

- P content at ditch G is higher and more variable





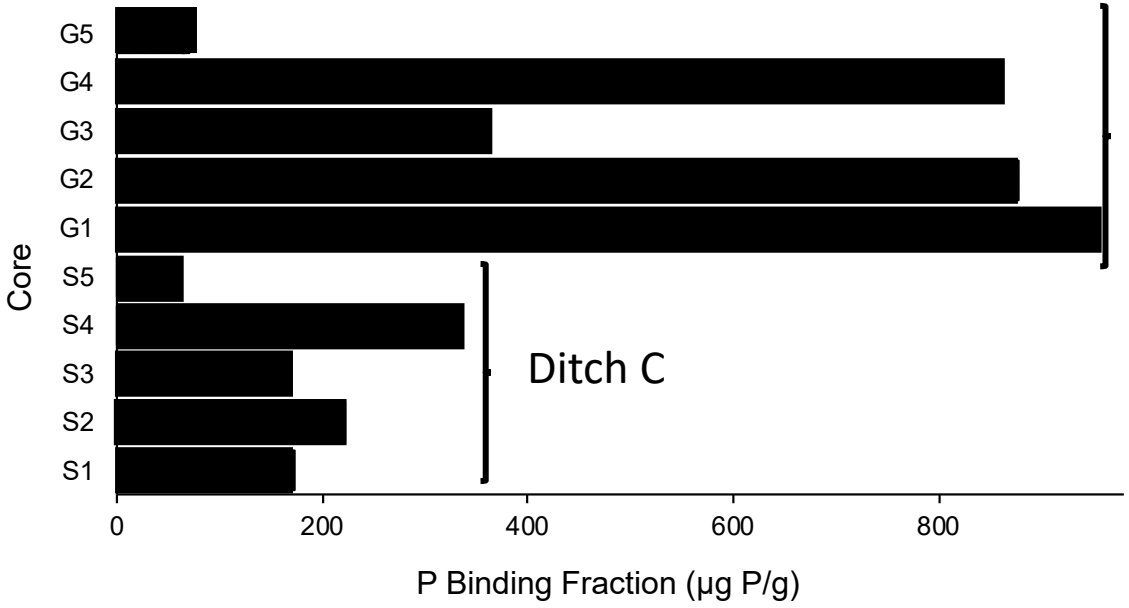


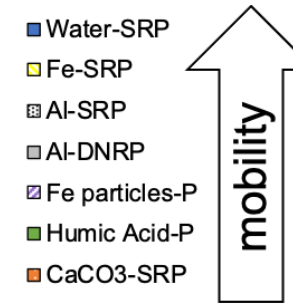
Casillas-Ituarte et al. ES&T (2019)

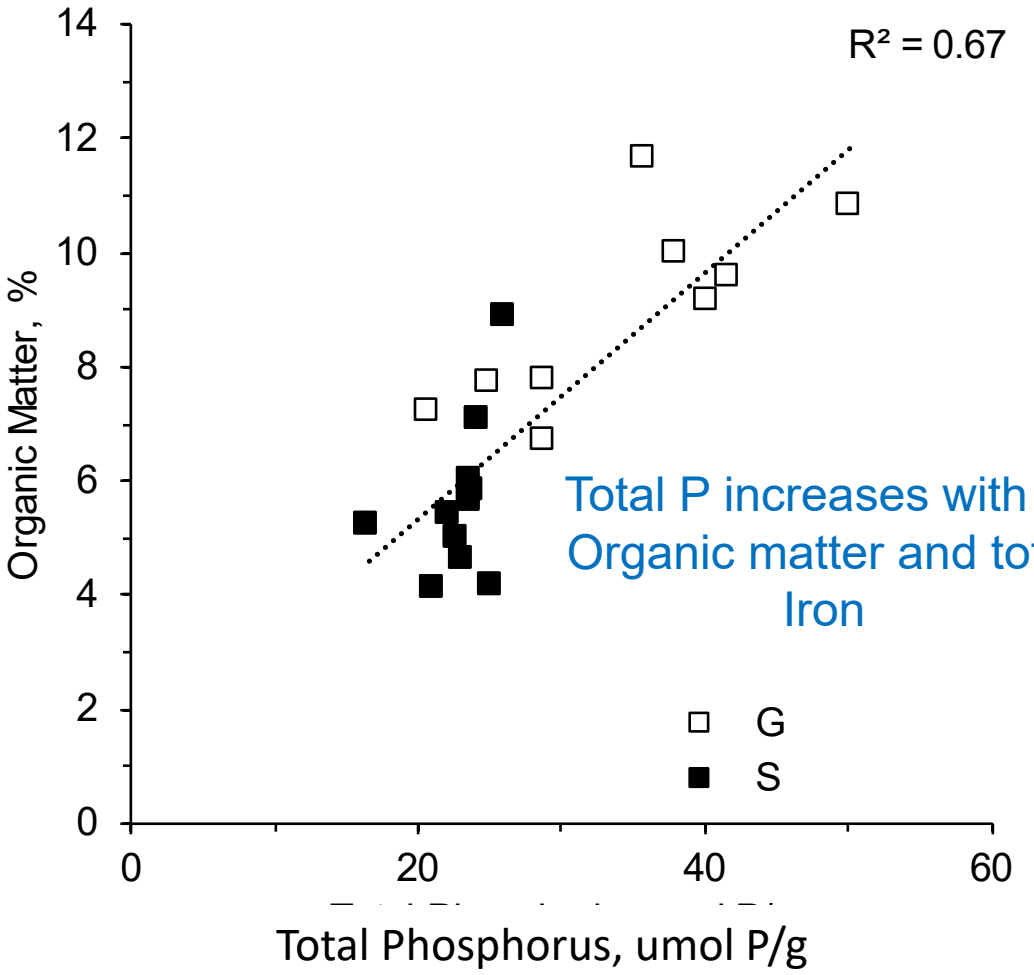
Benthic sediment P: high spatial variation

Sediment properties affect P storage

- P content at ditch G is higher and more variable





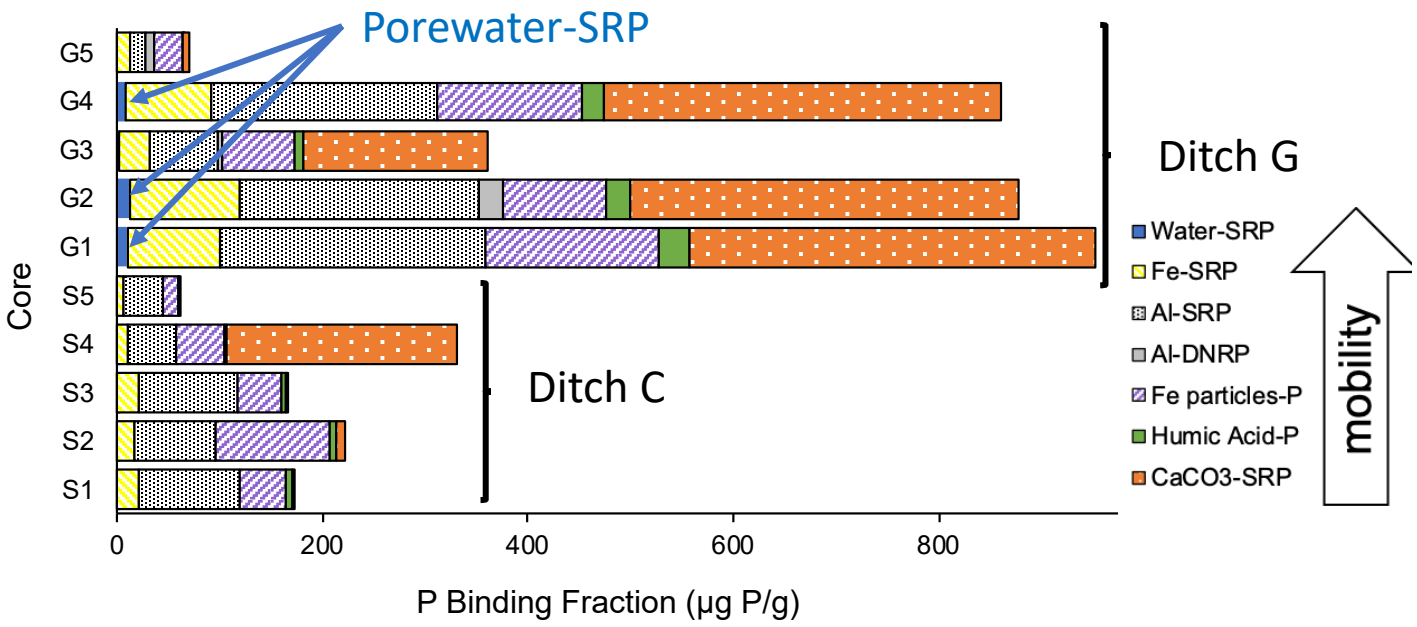


Total P increases with % Organic matter and total Iron

Casillas-Ituarte et al. ES&T (2019)

Benthic sediment P: high spatial variation

- P content at ditch G is higher and more variable
- Mobile fractions (Water, Fe) are small piece of the total



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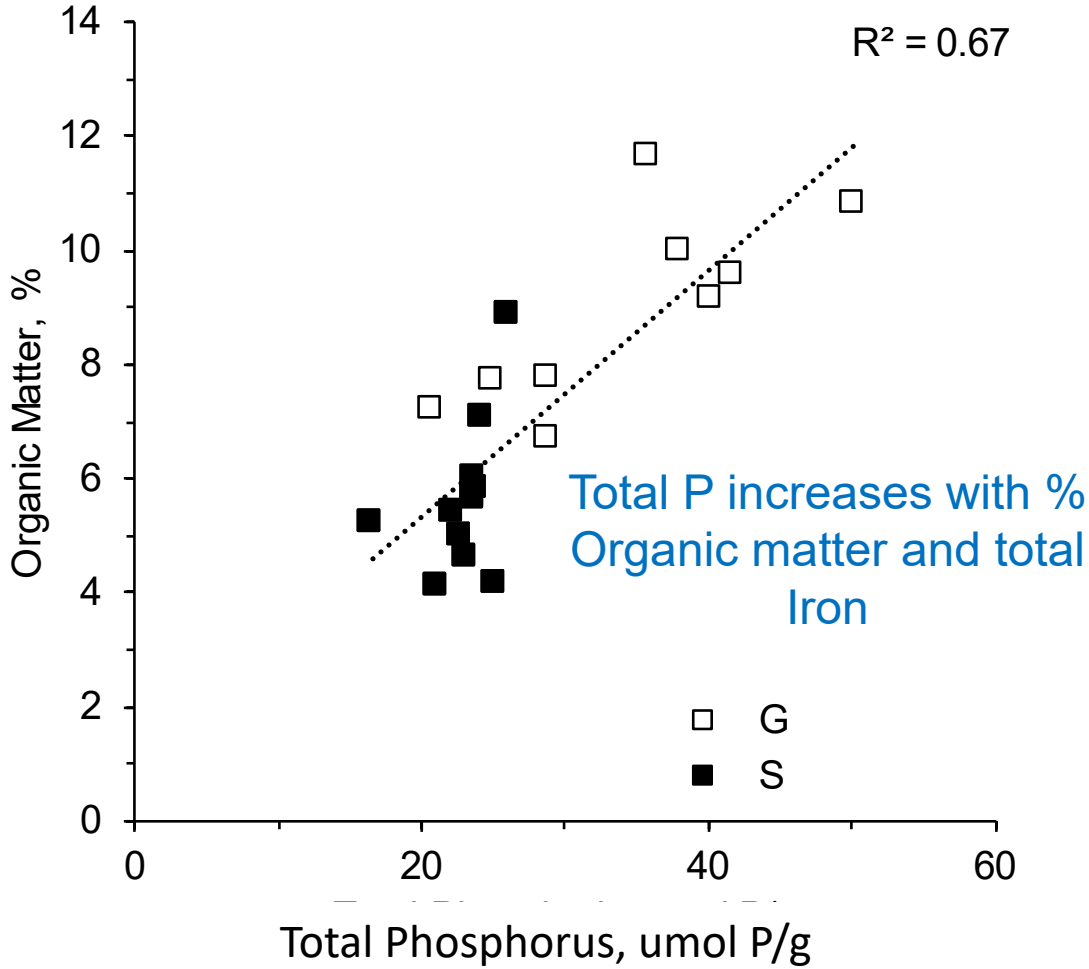
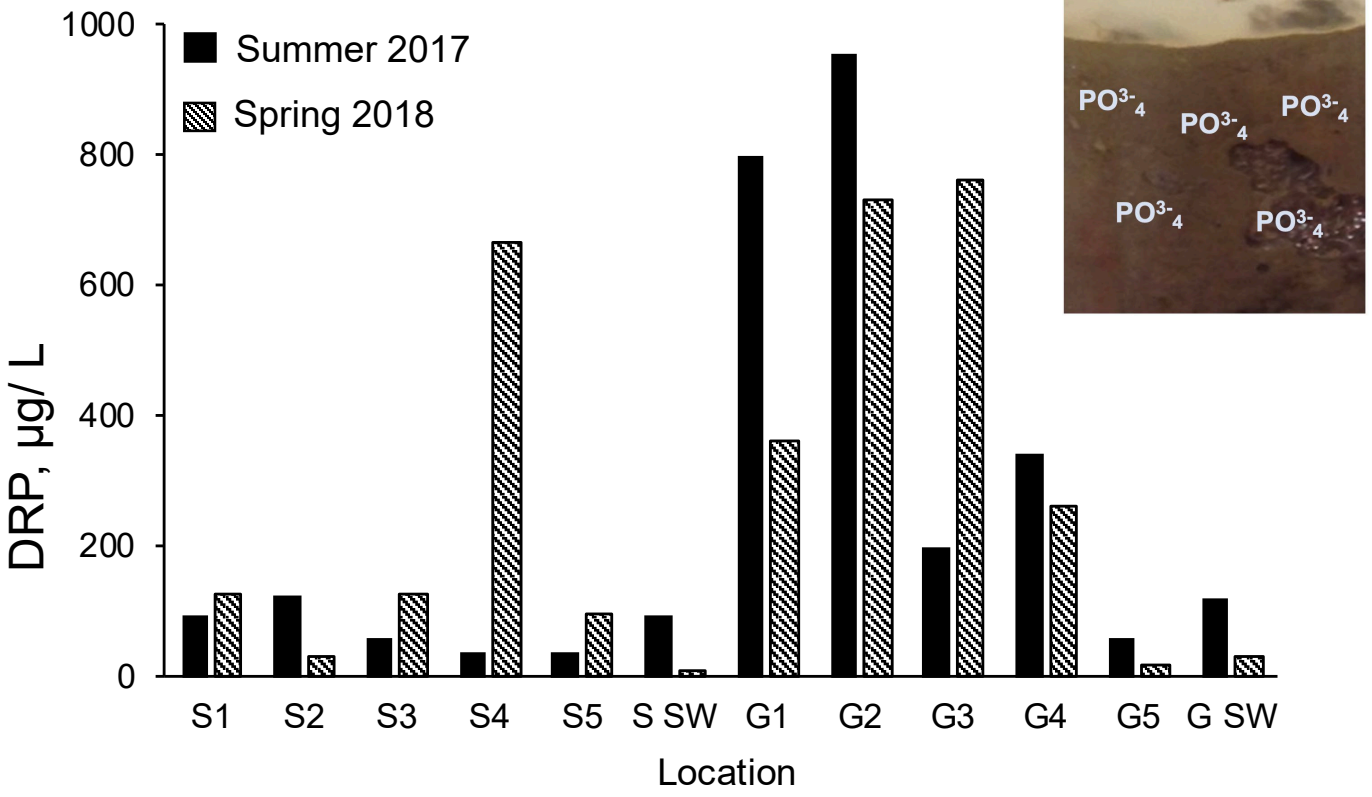
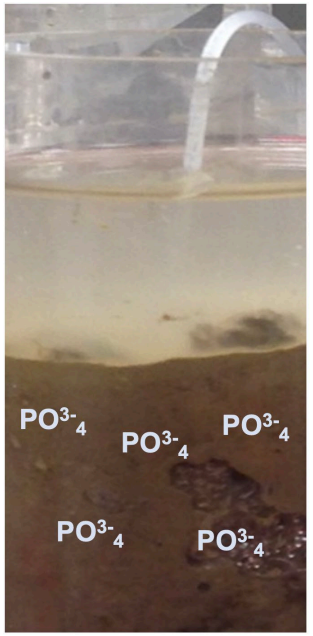


Casillas-Ituarte et al. ES&T (2019)

Sediment Porewater-SRP (most mobile fraction)

- Porewater is a source of DRP to surface water – average DRP in porewater is up to 20x greater than surface water
- If this P were mobilized over 1 year, it would represent 8 - 27% of the total DRP load of the Portage river into Lake Erie (and this is only a tiny fraction of total P in sediments!)

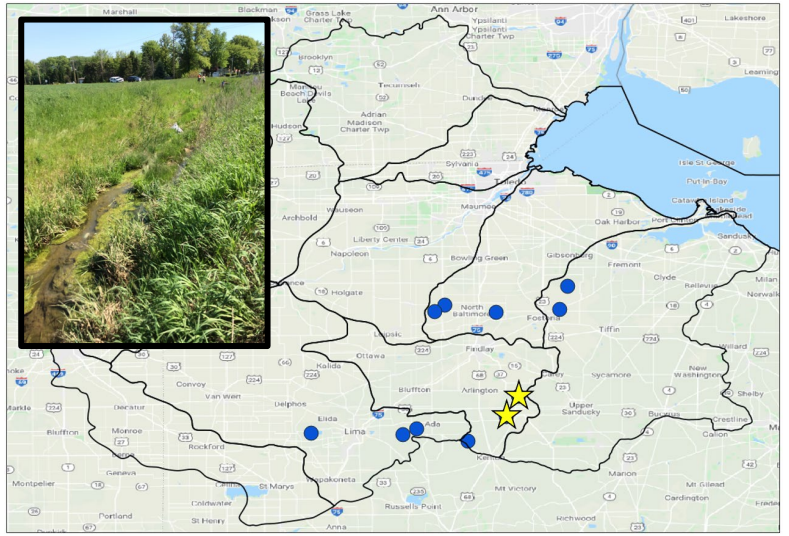




Casillas-Ituarte et al. ES&T (2019)

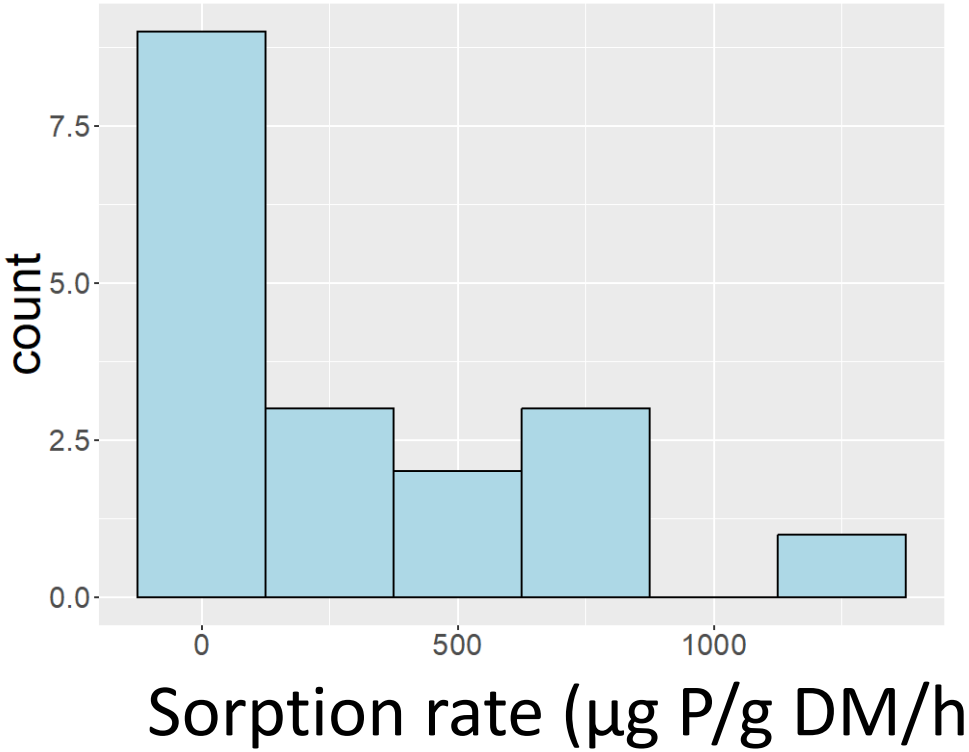
Sorption rates

- **Approach:** 11 sites sampled 2 times May to July
- Sorption at all sites, no desorption
- Sorption rates ranged widely from near zero to > 1000 µg P/g DM/h
- No clear patterns in sorption rate with ditch management or spatial location.



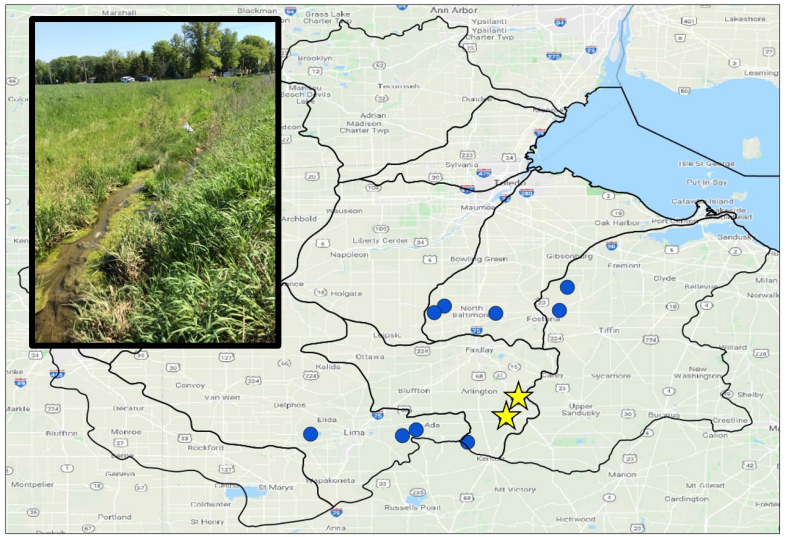
Kevin McCluney (BGSU)

May & July sorption rates

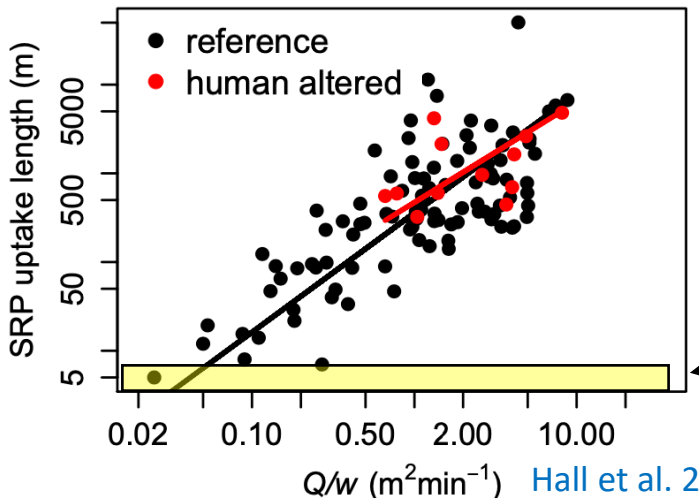


Whole-stream uptake rates

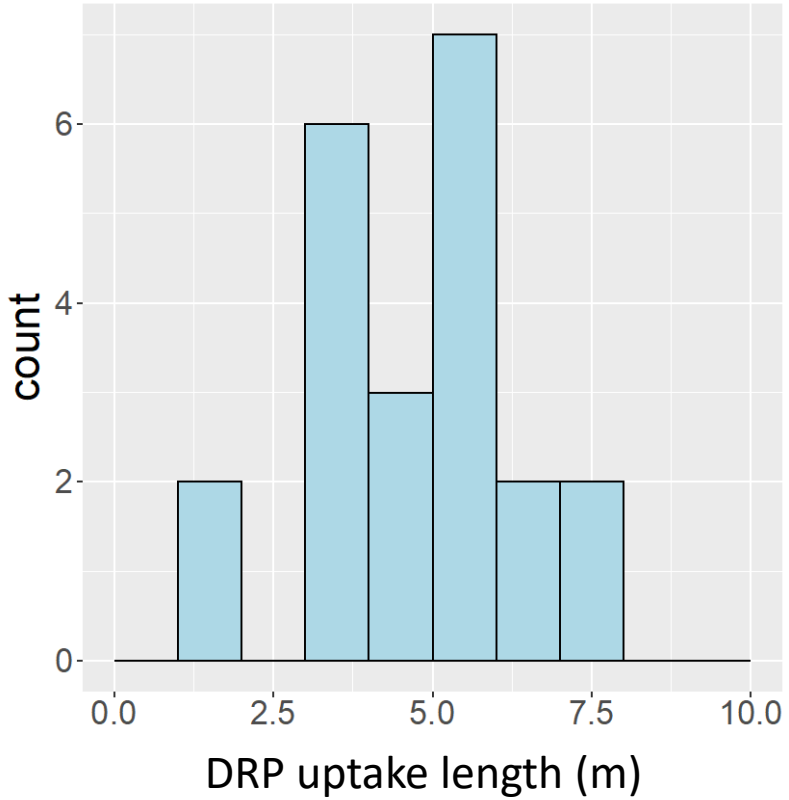
- **Approach:** Measured whole-stream P uptake rates in 11 sites in May and July. Measurements failed in some “dry” ditches.
- Uptake lengths exceptionally short



Bowling Green
Kevin McCluney



Hall et al. 2013



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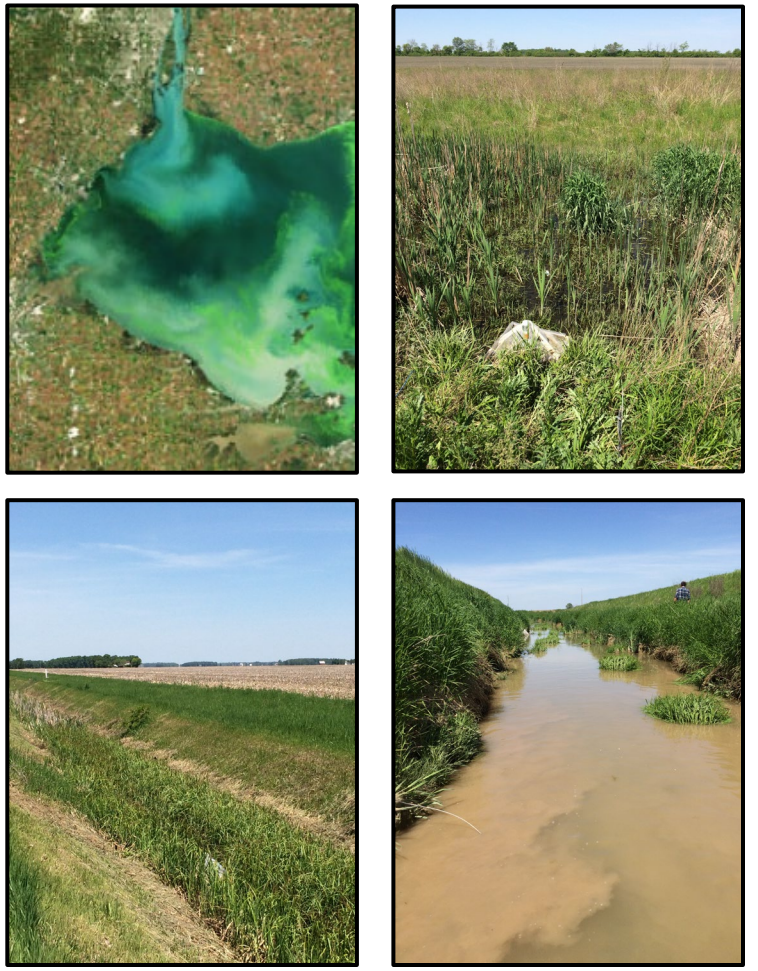
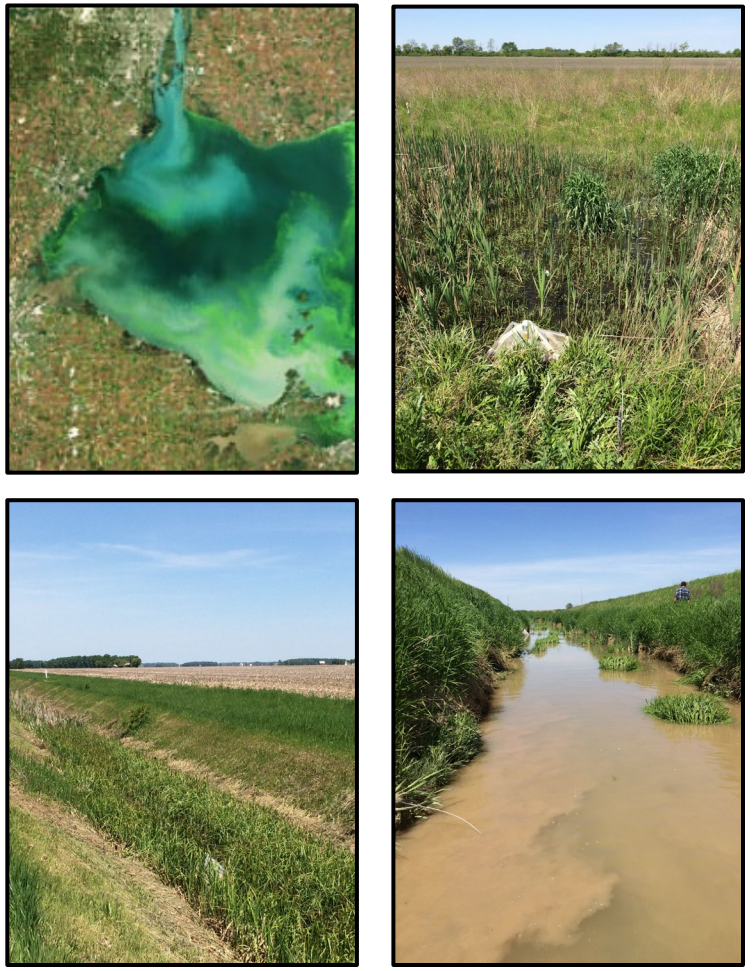
Summary: ditches are important to watershed P cycling

- In Black Ck basin, streambanks contribute 70-90% of monthly suspended sediment (& sed-P) in key months.
- **High flow**: High P sorption rates may reduce DRP loading to Lake Erie when it matters to P loading and HABs development.
- **Low flow**: P cycles rapidly with high DRP retention rates



Knowledge gaps & research needs

1. Is Black Ck. Basin representative of suspended sediment sources across the entire western Lake Erie basin?



Potential Next steps:
Is Black Ck. Basin representative?

Tanja N. Williamson
tnwillia@usgs.gov

- Link sediment apportionment with nutrient loads for Black Creek
- Determine how representative Black Creek is of Maumee tributaries by repeating study in basin south of Maumee River
- Synthesize previous sediment fingerprinting studies to:
  - Determine common chemical fingerprints of land use among study sites
  - Examine sediment-bound P as a function of land use and soils
  - Can we extend this to larger basin?

- Already underway

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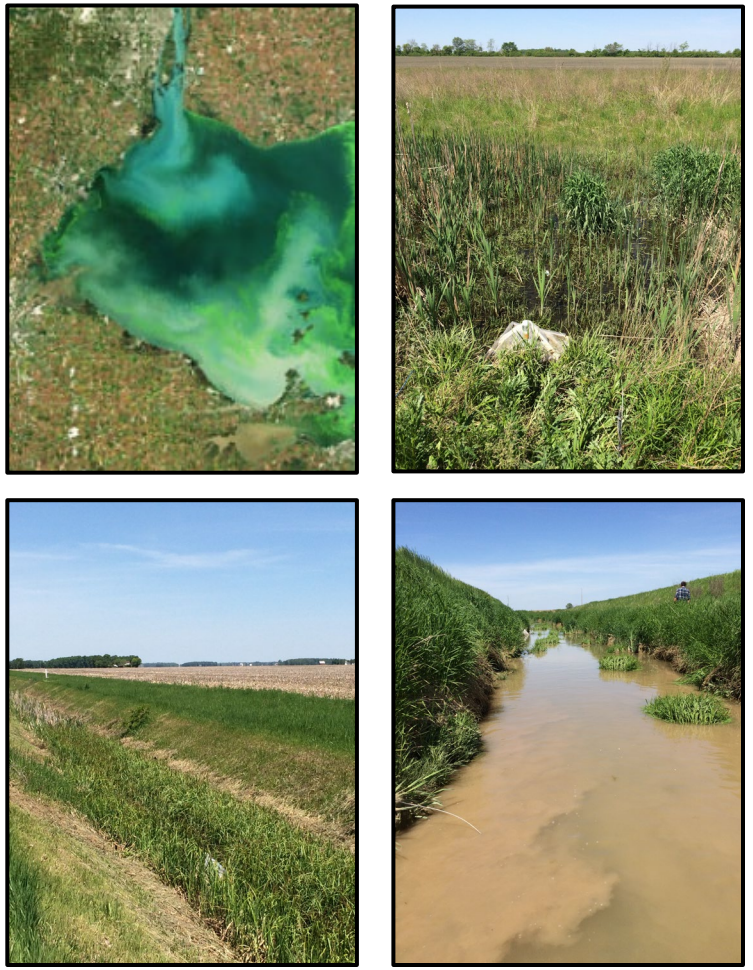
Knowledge gaps & research needs

1. Is Black Ck. Basin representative of suspended sediment sources across the entire western Lake Erie basin?
2. What is the residence time and transport distances of DRP and sediment P?



Next steps: Quantify residence times & transport lags

By: tracking SRP and sediments

Fluorescent particle tracer injections with SRP

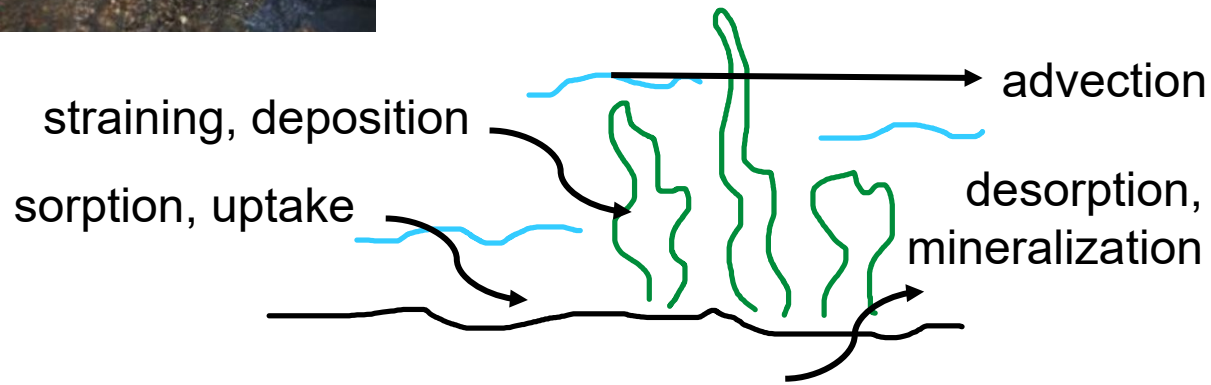
Hannah Field (MS student, OSU)

Audrey Sawyer (OSU)

Kevin King (USDA-ARS)

Brittany Hanrahan (USDA-ARS)

"Random walk" mobile-immobile zone modeling



How far does SRP travel before it's removed?
How long do sediments reside in channels?

Knowledge gaps & research needs

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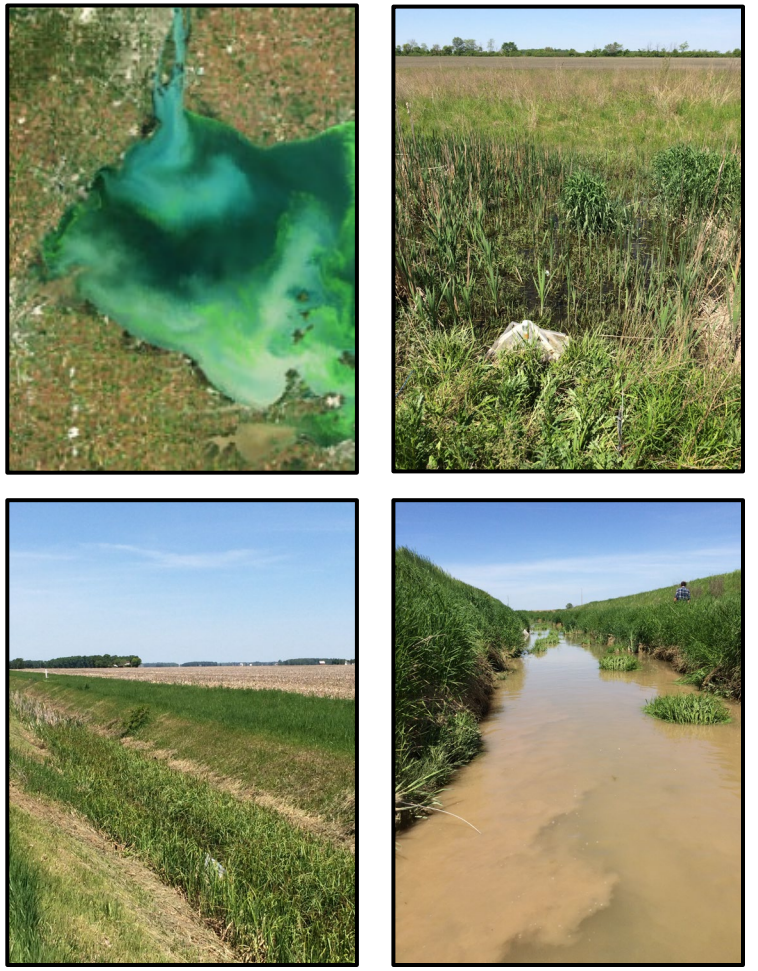
2. What is the residence time and transport distances of DRP and sediment P?
3. What are the spatial and temporal patterns of P cycling and how do they scale up to the entire western Lake Erie basin?



Next steps: spatial and temporal patterns & watershed models

- Temporal variation: use high-frequency nutrient & sensor data to identify seasonal patterns and hot moments in P cycling.
- Spatial variation
  1. Quantify spatial patterns in stream P cycling sources and sinks.
  2. Estimate impact of the Maumee River tributaries on P delivery to Lake Erie.


Sushant Mehan (Postdoc, OSU)


Laura Johnson (Heidelberg)

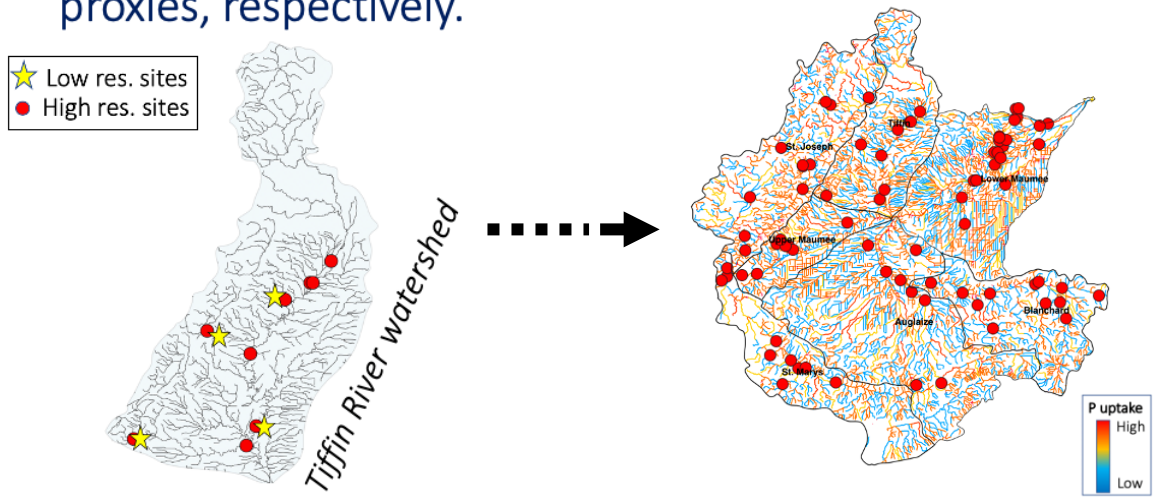

Margaret Kalcic (OSU)


Becky Kreiling (USGS)


Chris Spiese (ONU)

STEP 1 | Low & high-resolution surveys of P fluxes and P cycling proxies, respectively.

STEP 3 | Use universal kriging or other predictive process to make predictions for all reaches.



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Knowledge gaps & research needs

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4. Need to incorporate this information about river P cycling into the watershed models (e.g., SWAT) used to inform management and policy decisions.

Sushant Mehan
(Postdoc, OSU)

Margaret Kalcic
(OSU)

HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE

Knowledge gaps & research needs

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