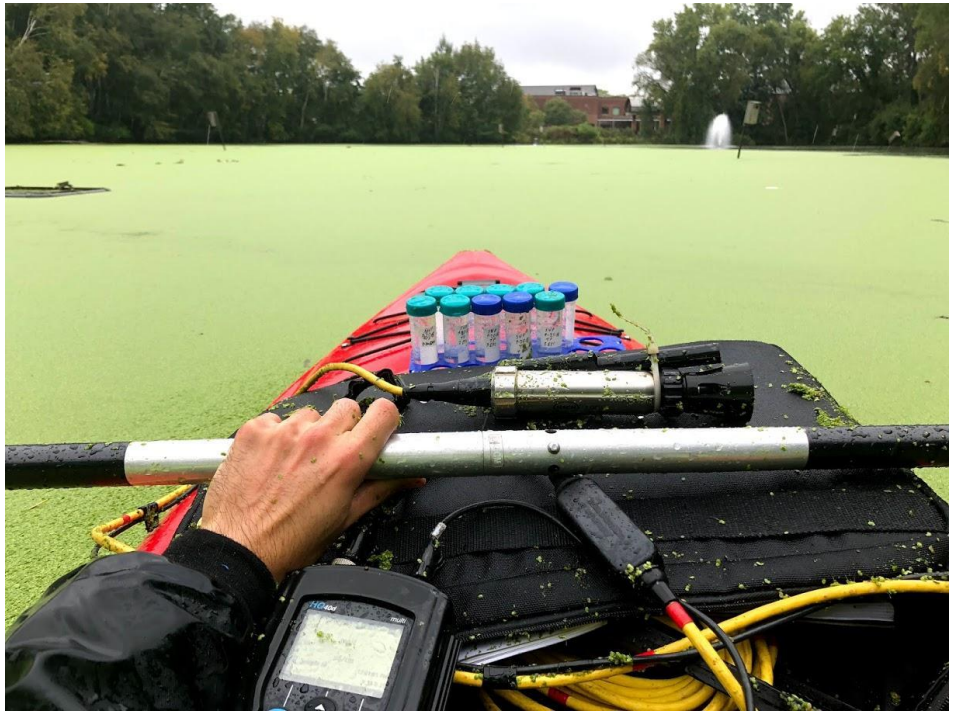
Phosphorus Exports from Ponds



Vinicius Taguchi, Stormwater Extension Associate

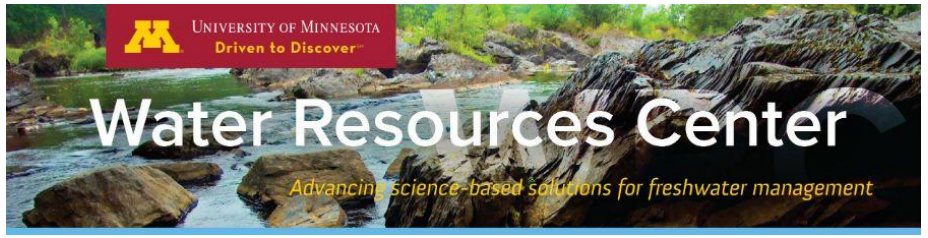
Collaborators and Funding Sources

UNIVERSITY OF MINNESOTA
Driven to Discover℠

ST. ANTHONY FALLS LABORATORY

- John Gulliver
- Jacques Finlay
- Ben Janke
- Poornima Natarajan
- Tyler Olsen
- Heinz Stefan
- Bill Herb
- Andy Erickson
- *and many undergrads!*

COLLEGE OF Science & Engineering



MINNESOTA POLLUTION CONTROL AGENCY

DEPARTMENT OF TRANSPORTATION

Riley Purgatory Bluff Creek Watershed District

RWMWD
Ramsey-Washington Metro Watershed District

NSF

Grant # 00039202

CITY OF SHOREVIEW
EST. 1957

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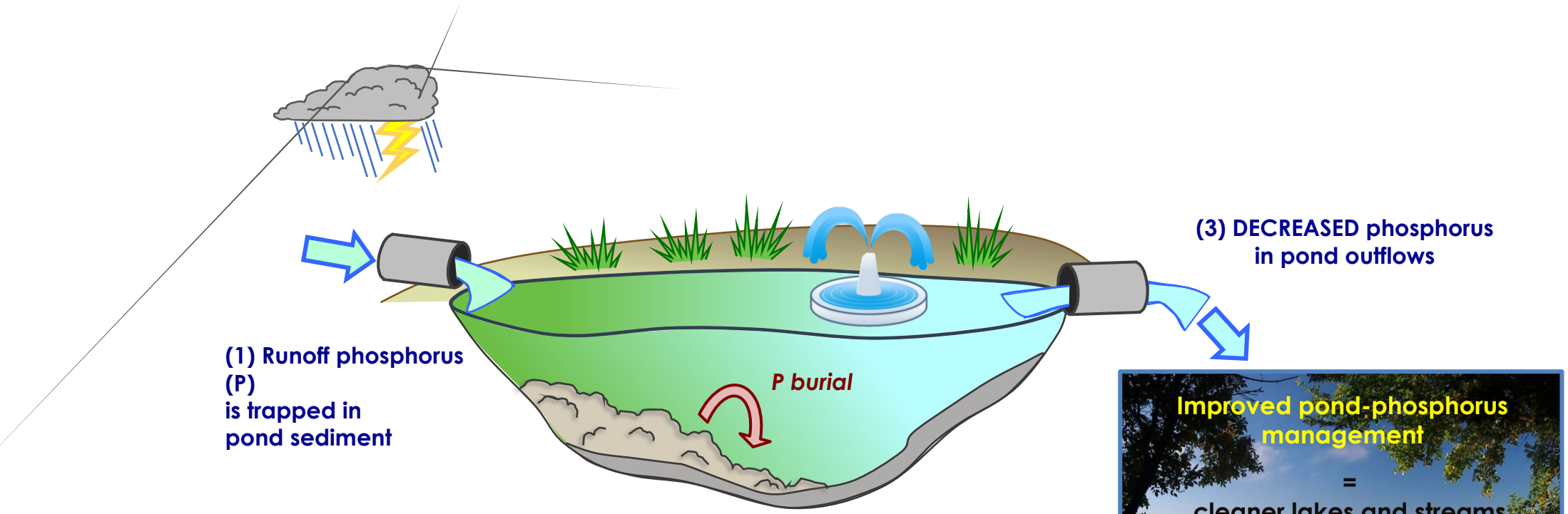
Well-Maintained Ponds Improve Water Quality



Graphic courtesy of Dr. Ben Janke

Modified from Janke et al. 2022. *Hydrologic processes regulate nutrient retention in stormwater detention ponds.* Science of the Total Environment.

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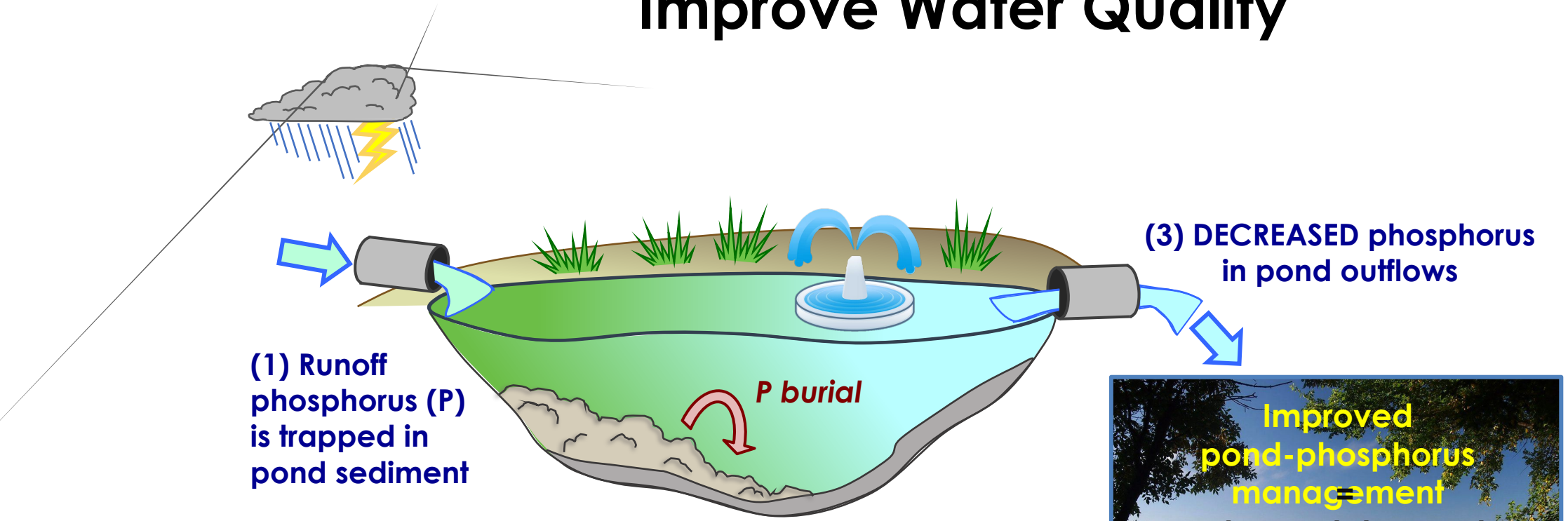
Well-Maintained Ponds Improve Water Quality



Modified from Janke et al. 2022. *Hydrologic processes regulate nutrient retention in stormwater detention ponds.* Science of the Total Environment.

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Photo credit: Poornima Natarajan

Photo credit: Peter Olson

Algae?

Duckweed

Filamentous Algae

Cyanobacteria

http://help.bioworldusa.com/kb/algae-treatment/is-this-algae-or-watermeal-duckweed

Photo credit: Andy Erickson

Don’t try this!

LOCAL

Marietta couple shares warning on toxic algae after dog dies less than an hour after visit to Lake Allatoona

This was the first time they had taken their border collie, Arya, to the lake. It would be the dog's last.

Author: Elwyn Lopez
Published: 12:19 AM EDT August 12, 2019
Updated: 10:16 AM EDT August 12, 2019

A dog died after swimming in a Texas lake. Should Michigan pet owners be concerned?

Where does that blue-green algae come from, and can it form in Michigan lakes?

Author: Nina DeSarro
Published: 5:24 PM EDT August 9, 2019
Updated: 5:24 PM EDT August 9, 2019

CNN US Crime + Justice Energy + Environment Extreme Weather Space + Science LIVE TV Edition

A North Carolina woman took her three dogs to a pond to play. Within hours, her pups had died from toxic algae

By Scottie Andrew and Melissa Gray, CNN
Updated 11:33 AM ET, Mon August 12, 2019

https://www.wzzm13.com/article/life/pets/a-dog-died-after-swimming-in-a-texas-lake-should-michigan-pet-owners-be-concerned/69-90357d2b-d405-47fb-9b97-418a69574917
https://www.cnn.com/2019/08/11/us/three-dogs-died-algae-trnd/index.html
https://www.11alive.com/article/news/local/marietta-couple-shares-warning-on-toxic-algae-after-dog-dies-less-than-an-hour-after-visit-to-lake-allatoona/85-b8c44ca2-a390-4c4e-82a2-0e67ab29dd94

https://stormwater.bae.ncsu.edu/

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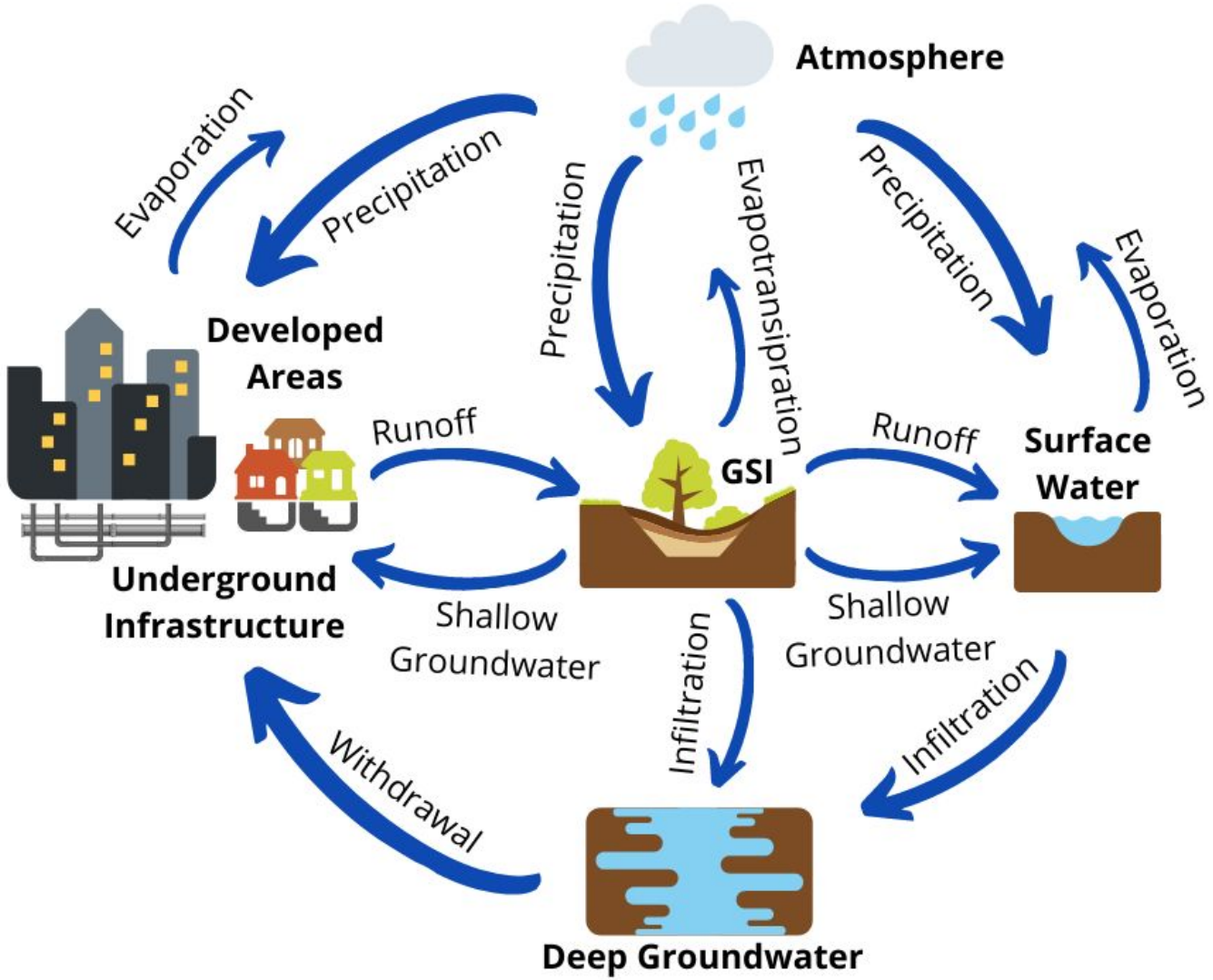

Modified from Taguchi et al. 2020. *It Is Not Easy Being Green: Recognizing Unintended Consequences of Green Stormwater Infrastructure.* Water.

https://stormwater.bae.ncsu.edu/

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Science of the Total Environment 823 (2022) 153722

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Hydrologic processes regulate nutrient retention in stormwater detention ponds

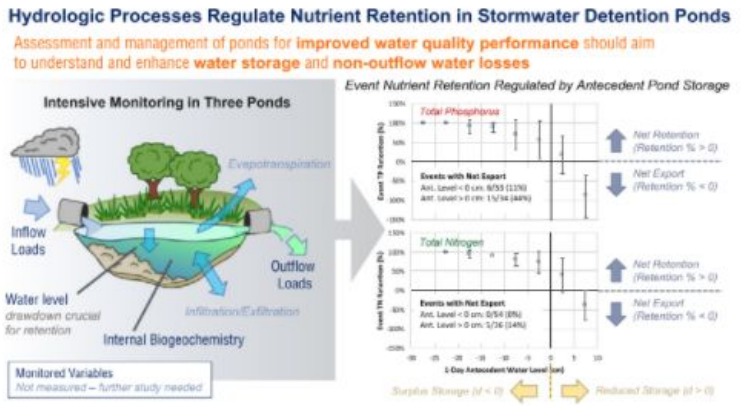
Benjamin D. Janke [a,b,*], Jacques C. Finlay [a,b], Vinicius J. Taguchi [b], John S. Gulliver [b]

[a] Dept. of Ecology, Evolution, and Behavior, University of Minnesota, 1986 Upper Buford Circle, St. Paul 55108, MN, USA
[b] St. Anthony Falls Laboratory, Dept. of Civil, Environmental, and Geo-Engineering, University of Minnesota, 2 Third Ave SE, Minneapolis 55414, MN, USA

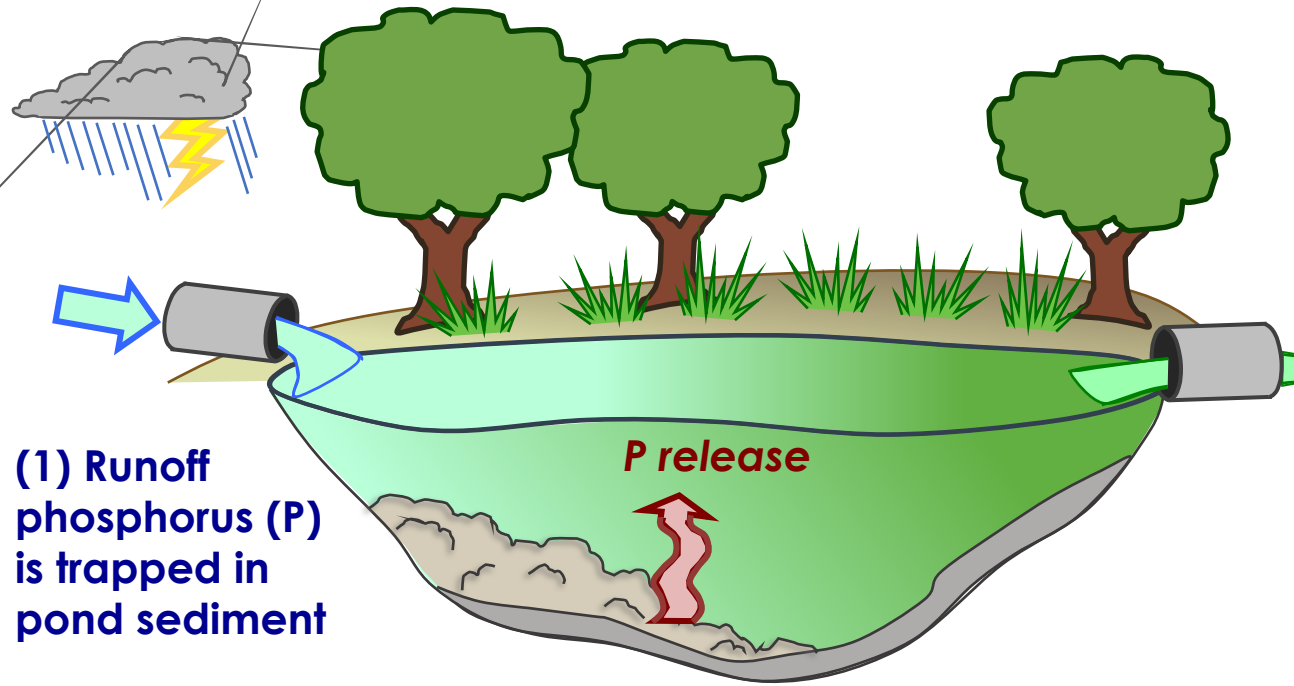
HIGHLIGHTS

- We assessed annual water and nutrient budgets for 3 ponds with intensive monitoring.
- Ponds were anoxic and eutrophic, indicating risk for poor nutrient retention.
- Concentration reduction was poor for many forms but mass reduction met expectations.
- Nutrient retention was enhanced by natural water losses (e.g., evapotranspiration).
- Pond retention performance could be improved by enhancing storage and water loss.

GRAPHICAL ABSTRACT



Old or Failing Wet Ponds Can Pollute Lakes and Streams



(1) Runoff phosphorus (P) is trapped in pond sediment

(2) Phosphorus released from sediment in old or failing ponds

(3) Increased phosphorus in pond outflows

"Pea soup" water
Algae releases toxins

Modified from Janke et al. 2022. *Hydrologic processes regulate nutrient retention in stormwater detention ponds.* Science of the Total Environment.

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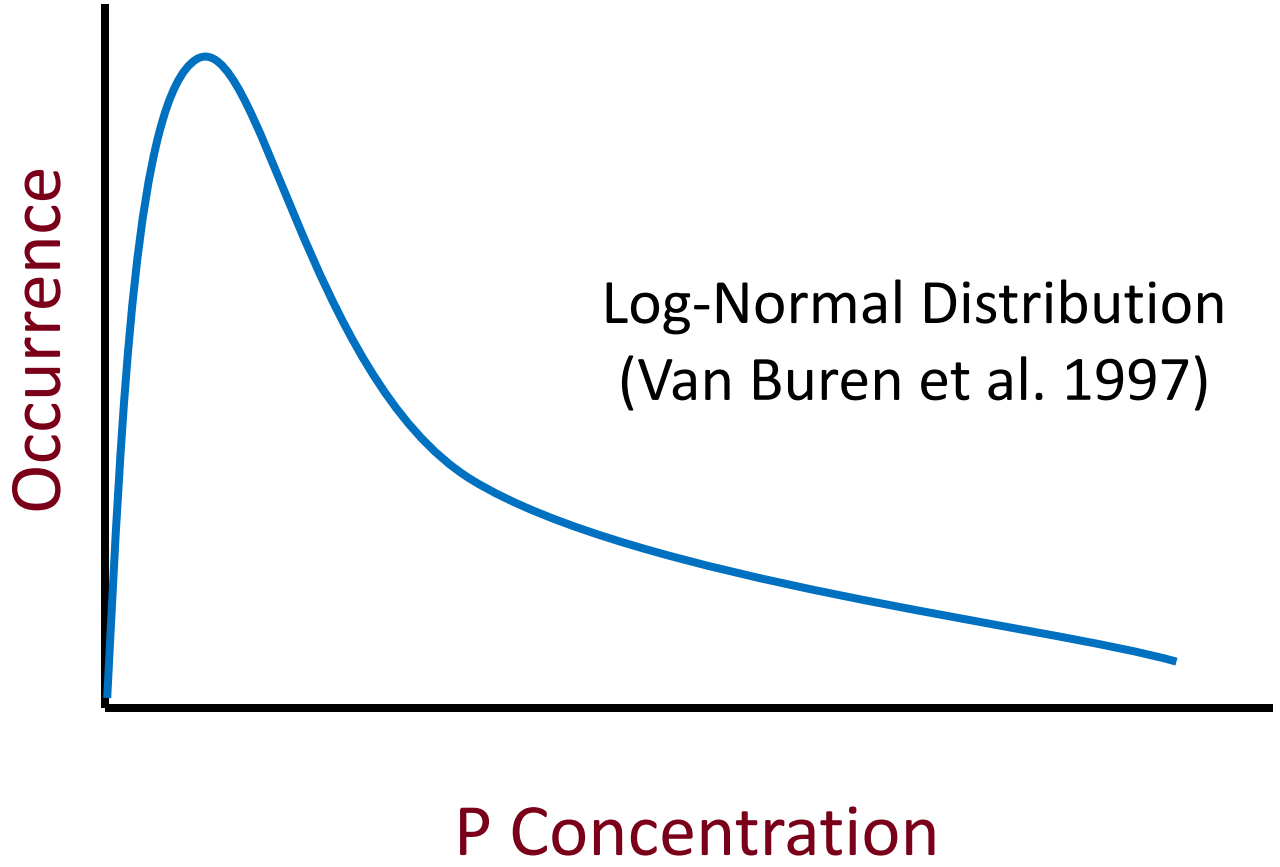
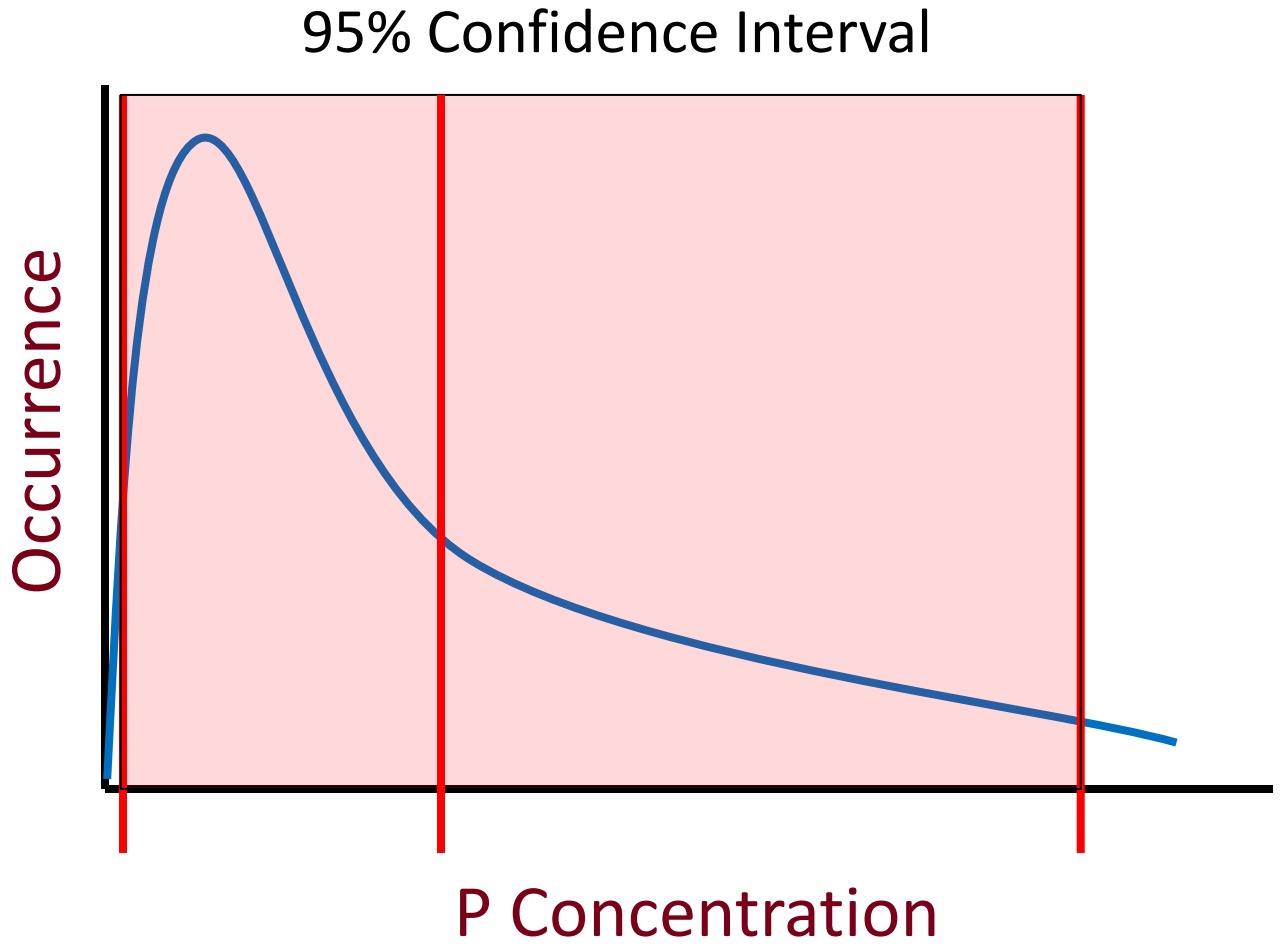
Stormwater Characterization



Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

Stormwater Characterization



Taguchi et al. 2020.
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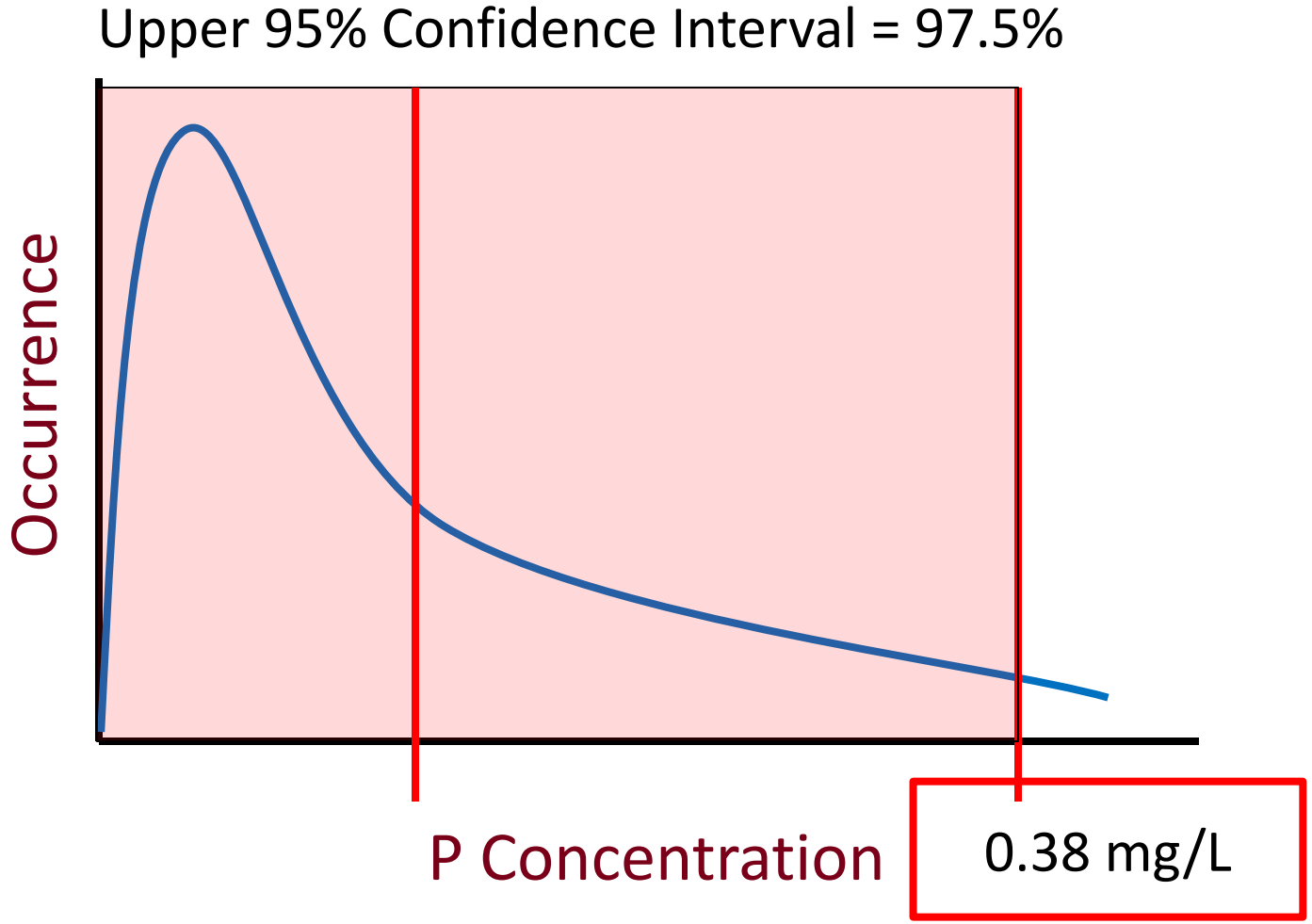
Limnology and Oceanography Letters.

Stormwater Characterization



Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

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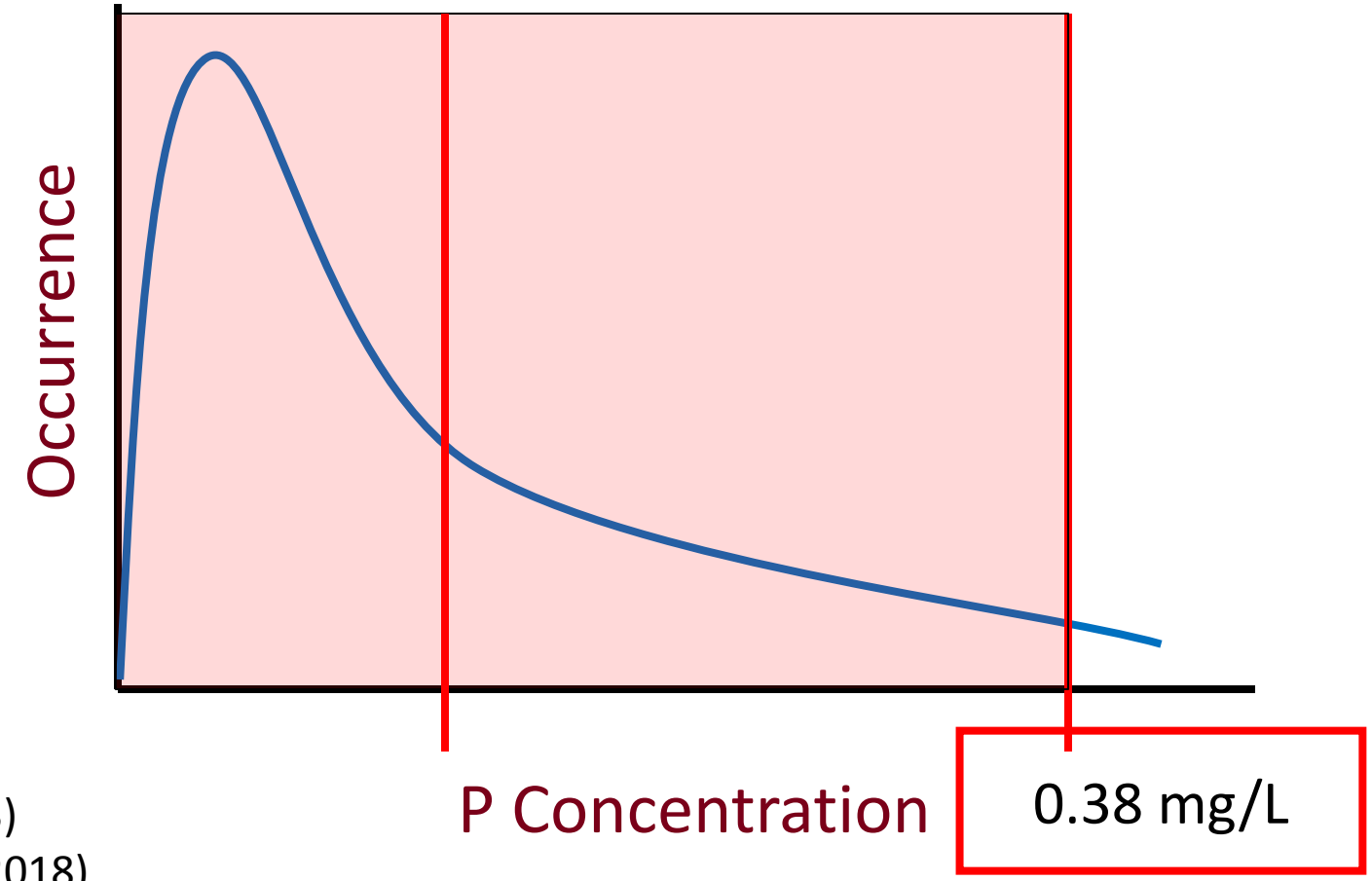
Stormwater Characterization

Upper 95% Confidence Interval = 97.5%



For reference:
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0.10 mg/L (Anderson et al. 2018)

Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

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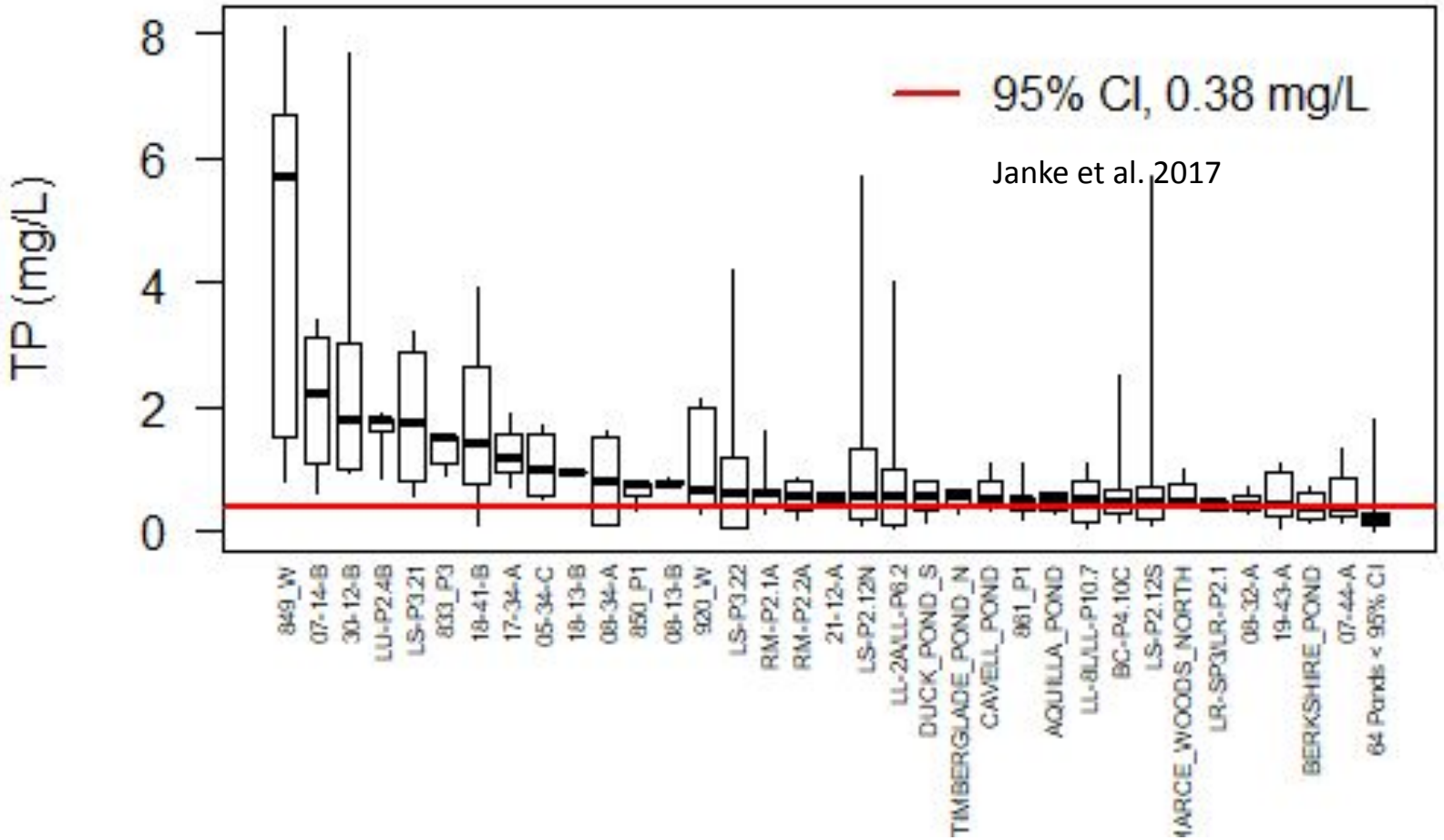
RPBCWD Surface Samples



Taguchi et al. 2020.
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Limnology and Oceanography Letters.

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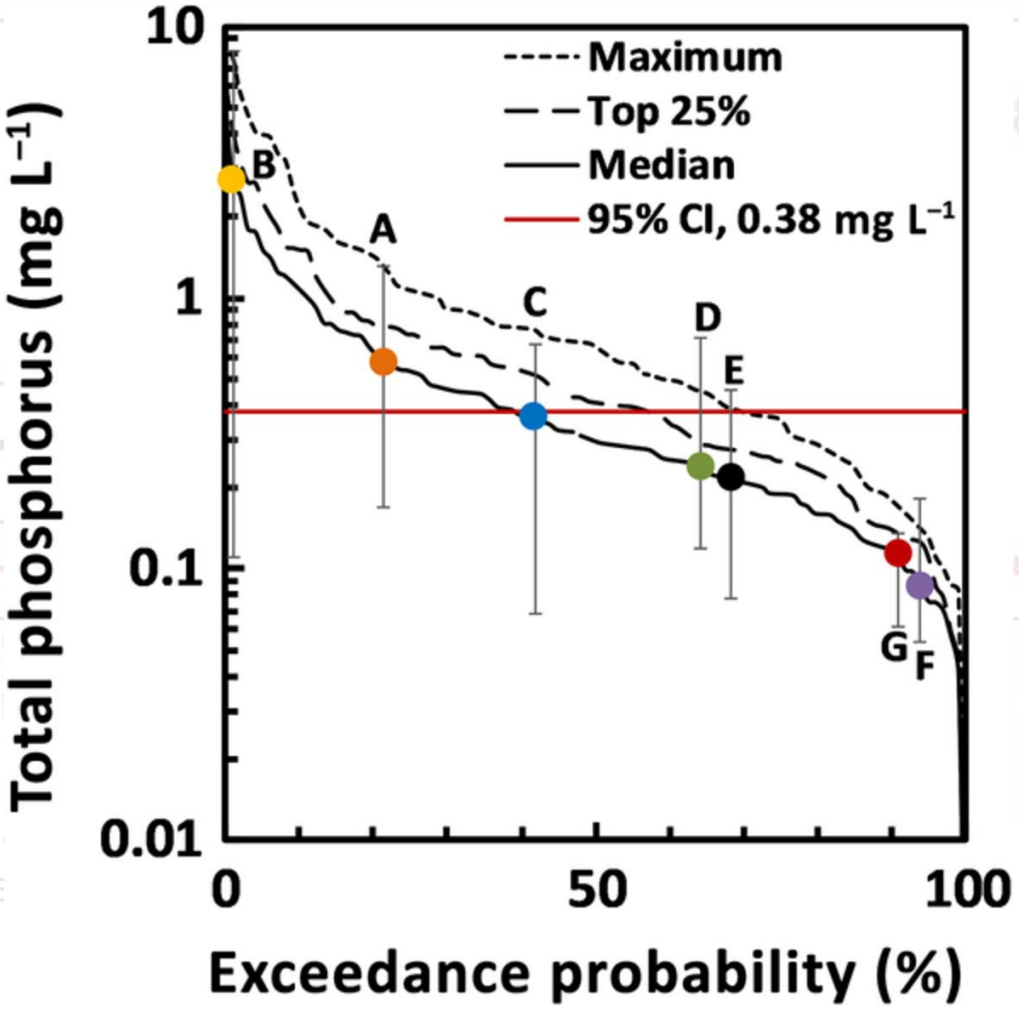

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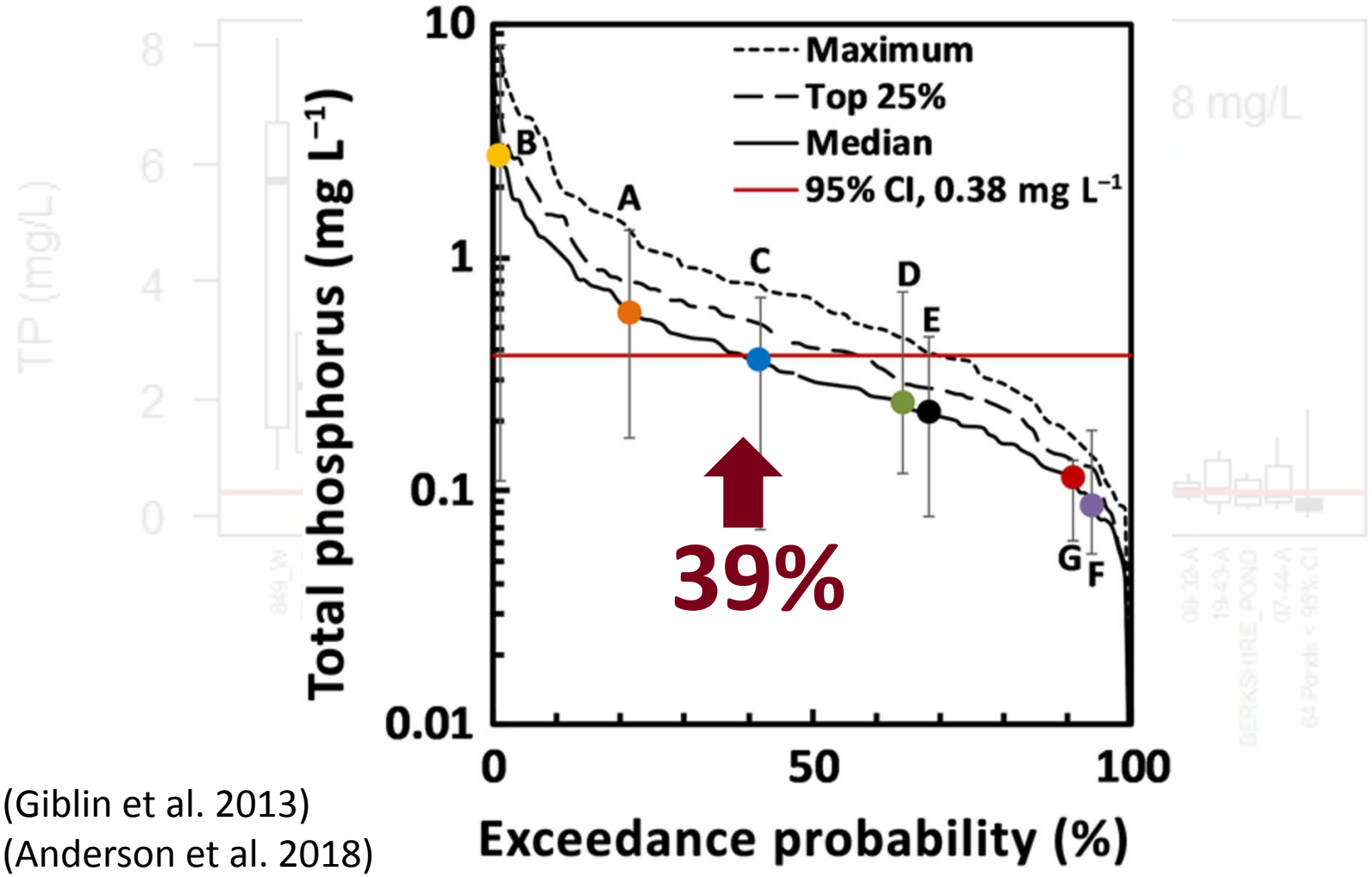

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Taguchi et al. 2020.
Internal loading in stormwater ponds as a phosphorus source to downstream waters.
Limnology and Oceanography Letters.

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Why does this happen?

Recent Research

LIMNOLOGY AND OCEANOGRAPHY
Letters

ASLO up
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Limnology and Oceanography Letters 2020

doi: 10.1002/lol2.10155

LETTER

Internal loading in stormwater ponds as a phosphorus source to downstream waters

Vinicius J. Taguchi[1,2*] *Tyler A. Olsen*[1,2] *Poornima Natarajan*[1] *Ben D. Janke*[1,3] *John S. Gulliver*[1,2] *Jacques C. Finlay*[1,3] *Heinz G. Stefan*[1,2]

[1]St. Anthony Falls Laboratory, University of Minnesota, Twin Cities, Minneapolis, Minnesota; [2]Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, Twin Cities, Minneapolis, Minnesota; [3]Department of Ecology, Evolution, and Behavior, University of Minnesota, Twin Cities, St. Paul, Minnesota

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Publication Research Sites

Taguchi et al. 2020.
Internal loading in stormwater ponds as a phosphorus source to downstream waters.
Limnology and Oceanography Letters.

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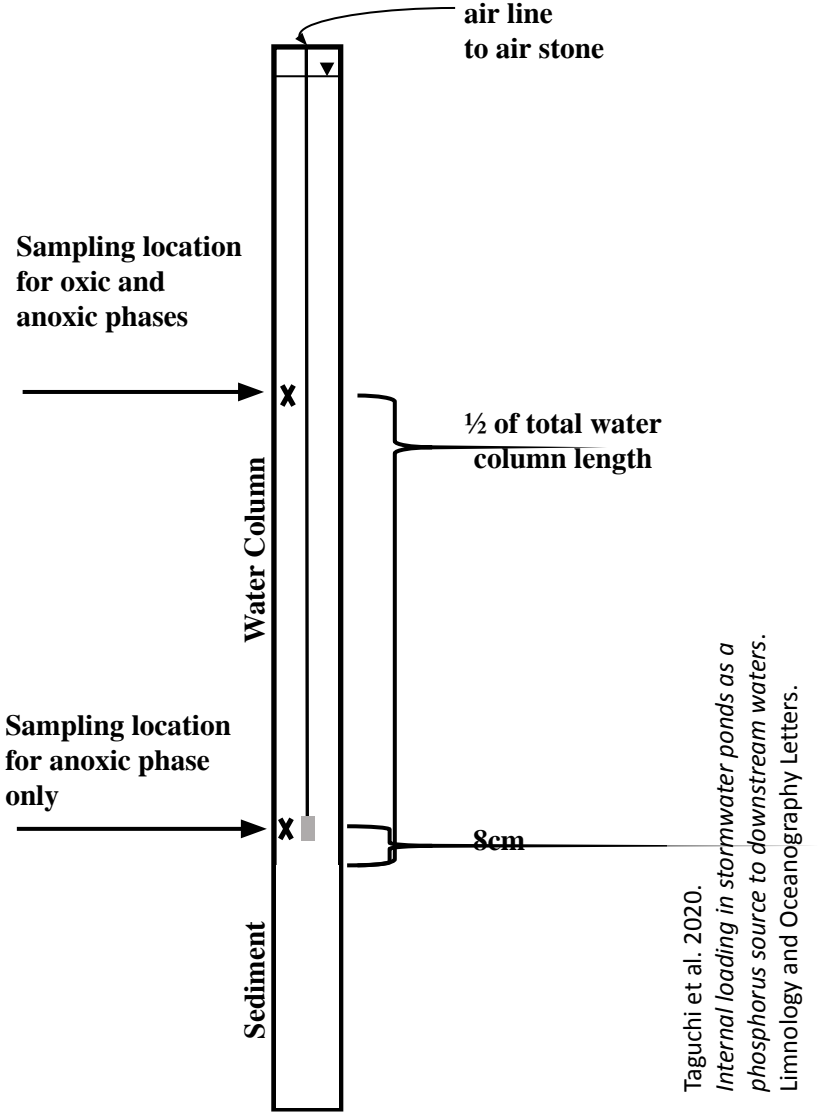
Intact Sediment Cores

Photo credit: Peter Corkery

Photo credit: Poornima Natarajan

Experimental Setup



Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

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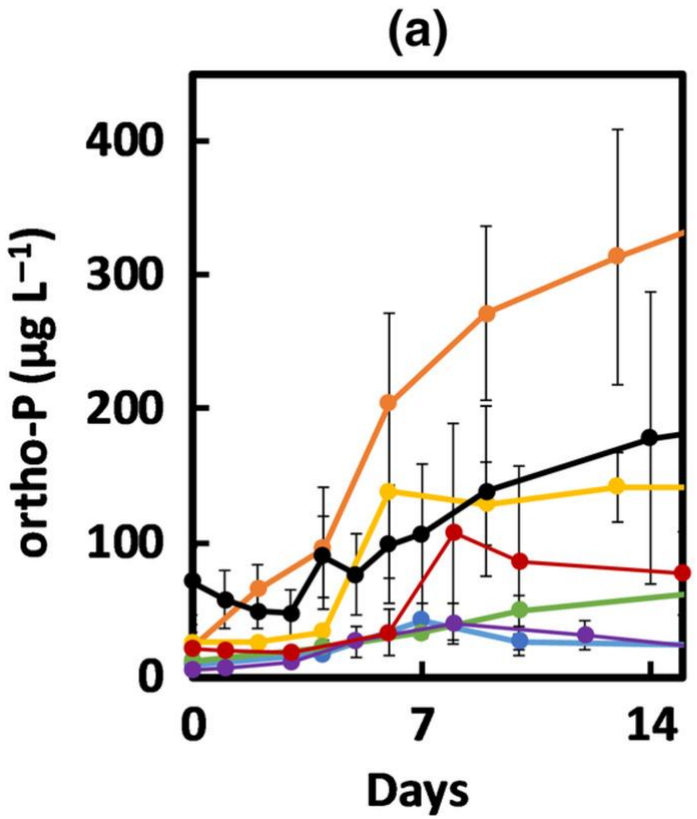
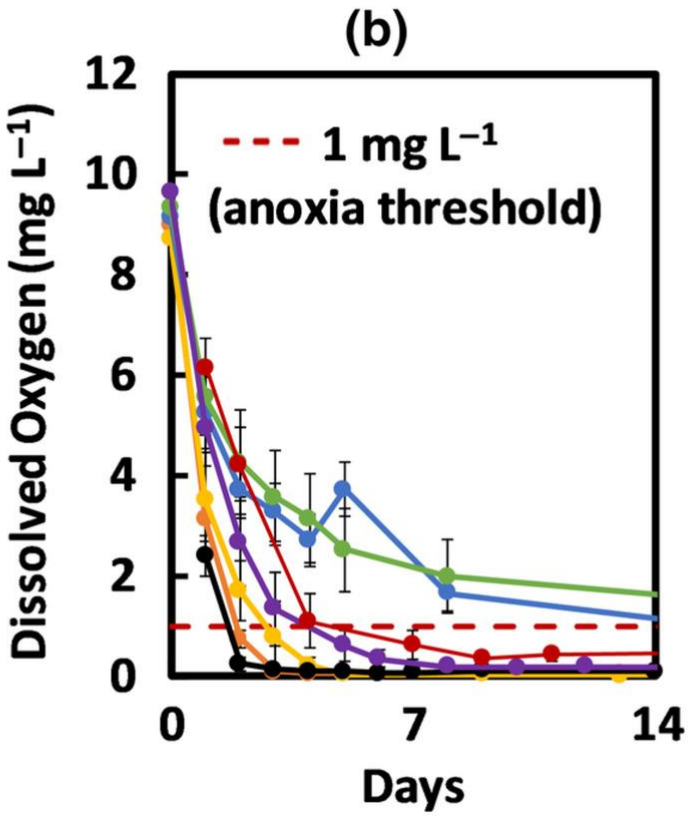
Sediment Oxygen Demand and Phosphorus Release





(c)

	Ortho-P Flux ($mg\ m^{-2}\ day^{-1}$)	S_{max} ($g\ m^{-2}\ day^{-1}$)
A	7.51 ± 2.93	4.21 ± 0.47
B	5.62 ± 1.80	4.23 ± 0.95
C	1.09 ± 0.26	1.94 ± 0.19
D	2.27 ± 0.49	1.85 ± 0.63
E	3.18 ± 2.76	5.19 ± 0.59
F	1.16 ± 0.45	3.07 ± 0.48
G	1.07 ± 1.18	2.09 ± 0.33

Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

https://stormwater.bae.ncsu.edu/

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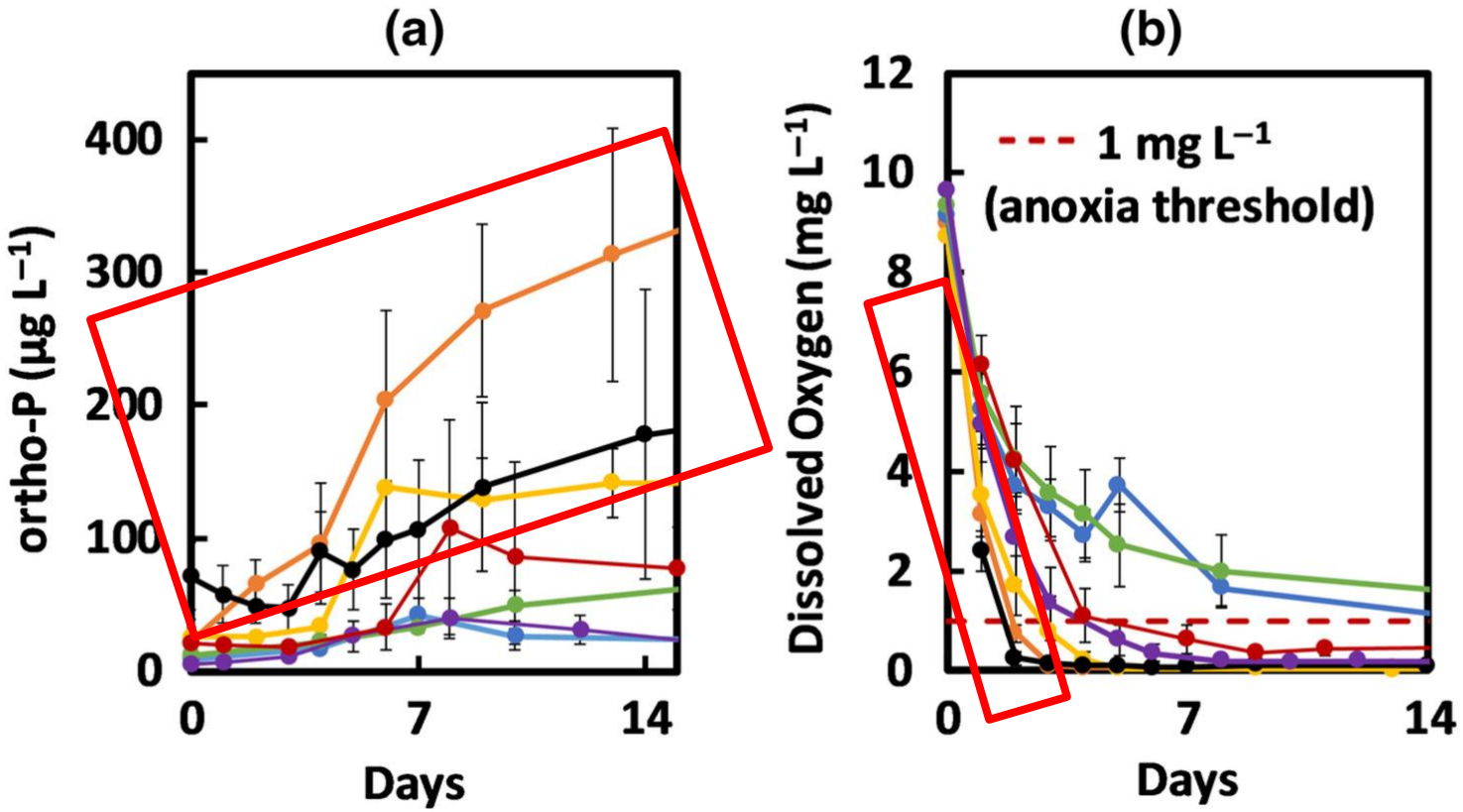
Sediment Oxygen Demand and Phosphorus Release

A B E



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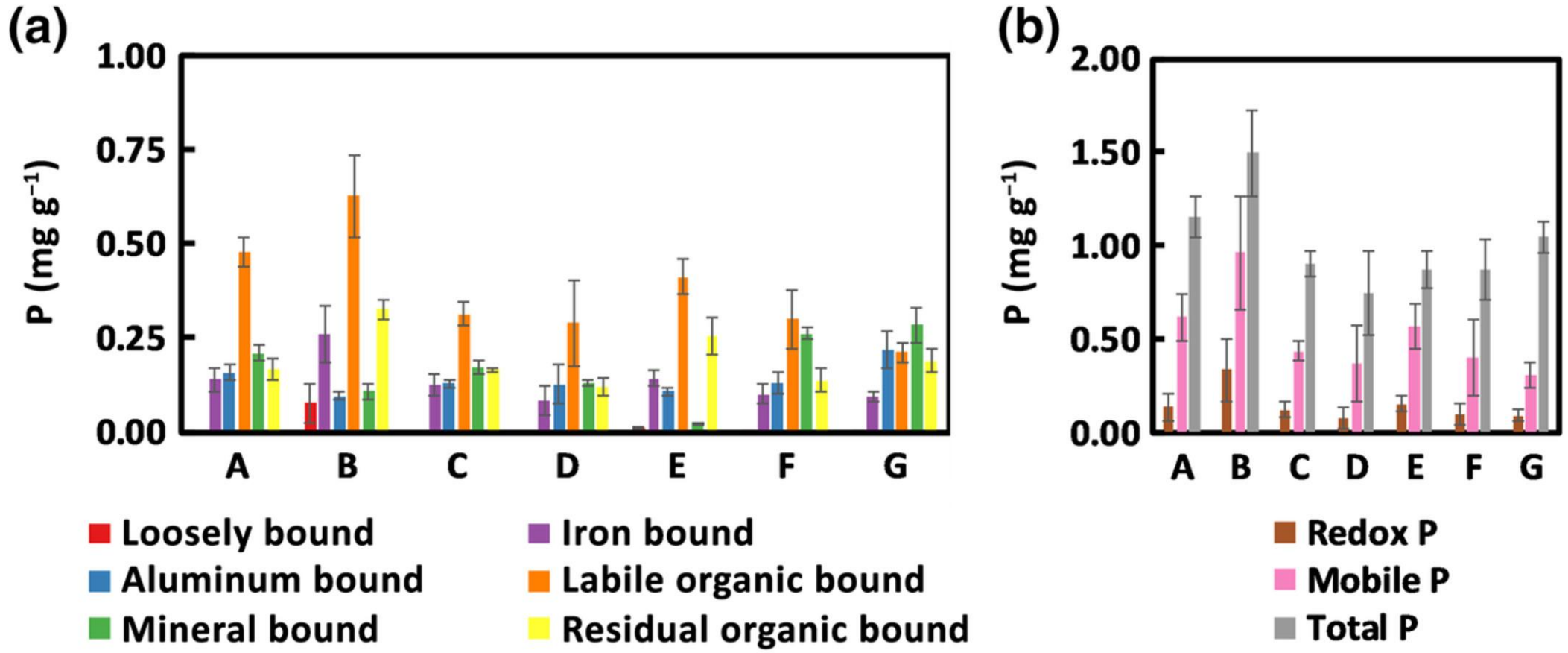
Sediment Phosphorus Fractionation

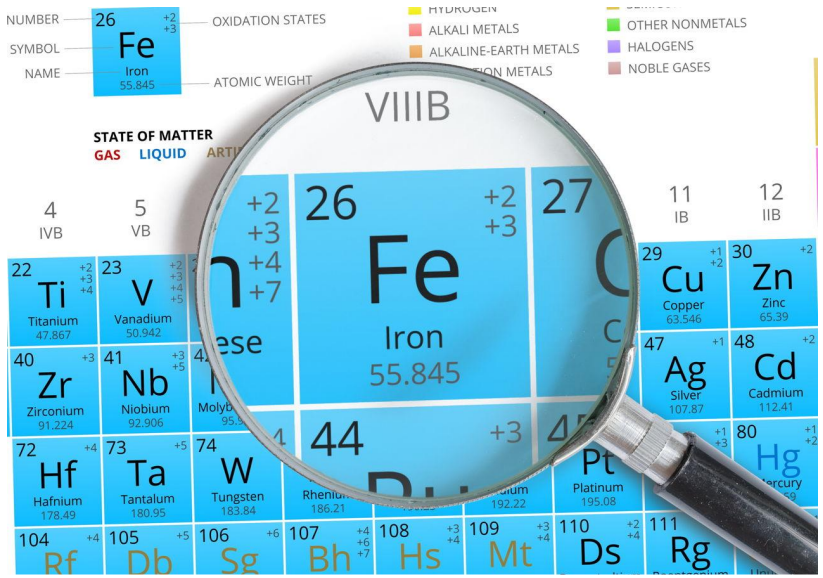


Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

Redox-Sensitive Phosphorus Dynamics

Oxic (≥1 mg/L DO)

$Fe^{3+}(aq) + PO_4^{3-}(aq) \Rightarrow FePO_4(s)$



https://pixfeeds.com/images/science/chemistry/1280-516796706-fe-element-of-the-periodic-table.jpg

Anoxic (<1 mg/L DO)

$FePO_4(s) + e^- \Rightarrow Fe^{2+}(aq) + PO_4^{3-}(aq)$

https://stormwater.bae.ncsu.edu/

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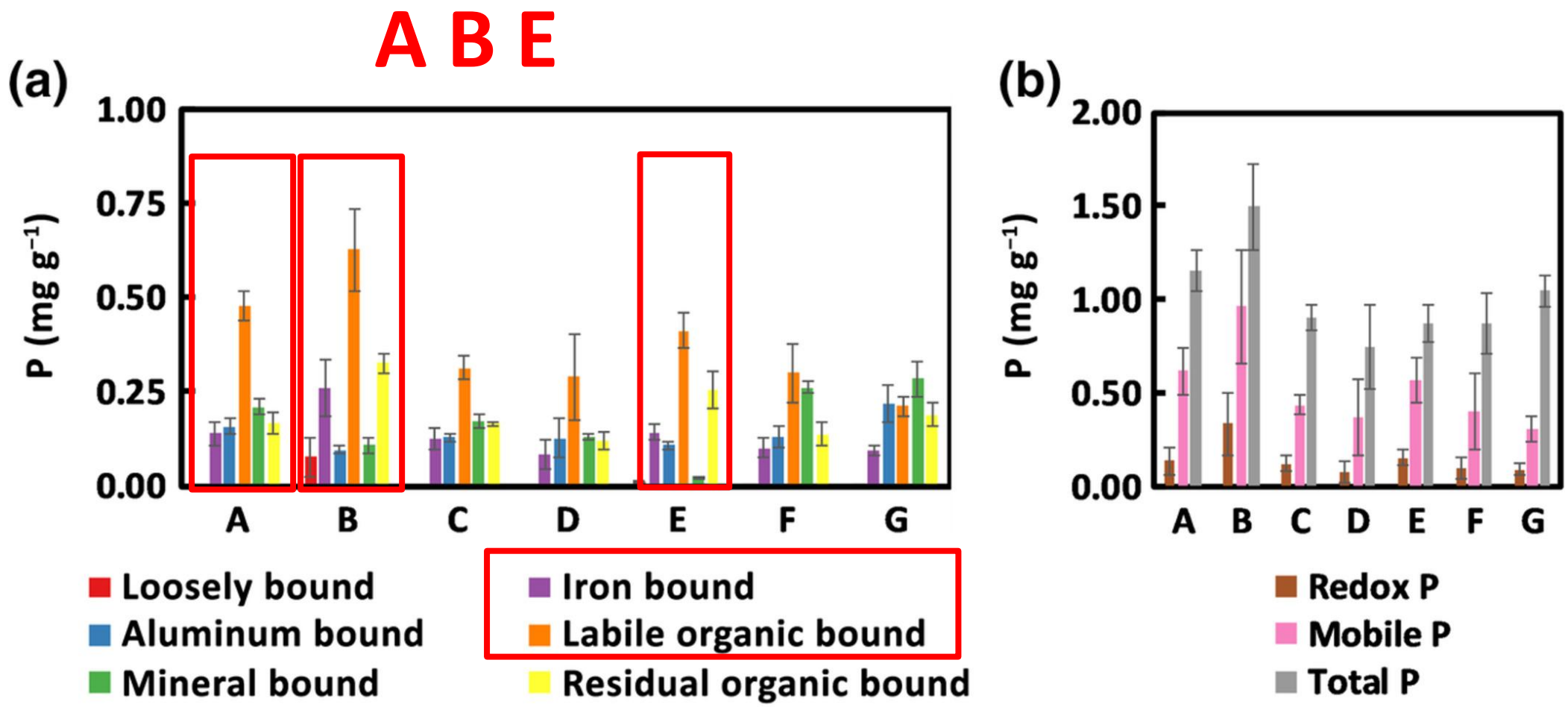
Sediment Phosphorus Fractionation



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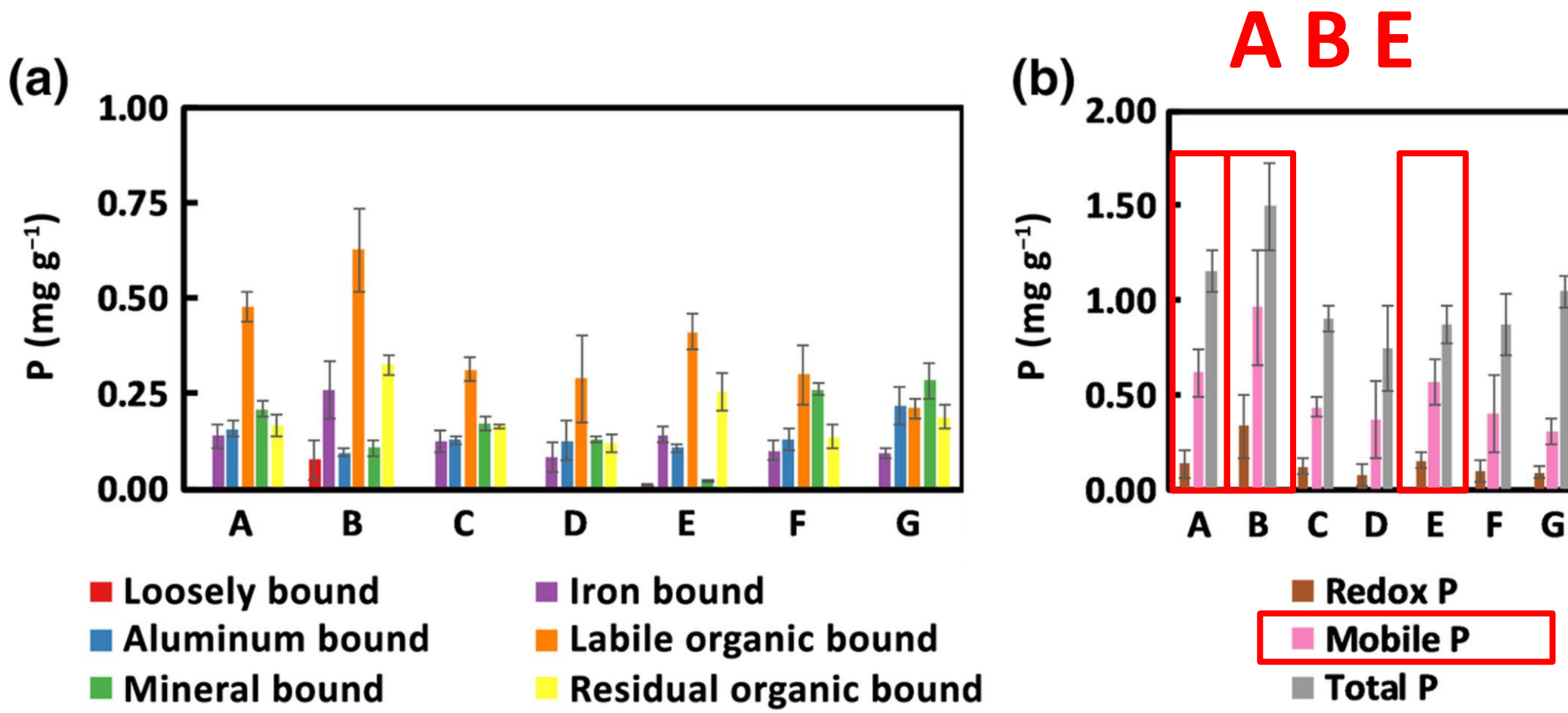

Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

Redox-P = Loosely-Bound P + Iron-Bound P
Mobile-P = Redox-P + Labile-P

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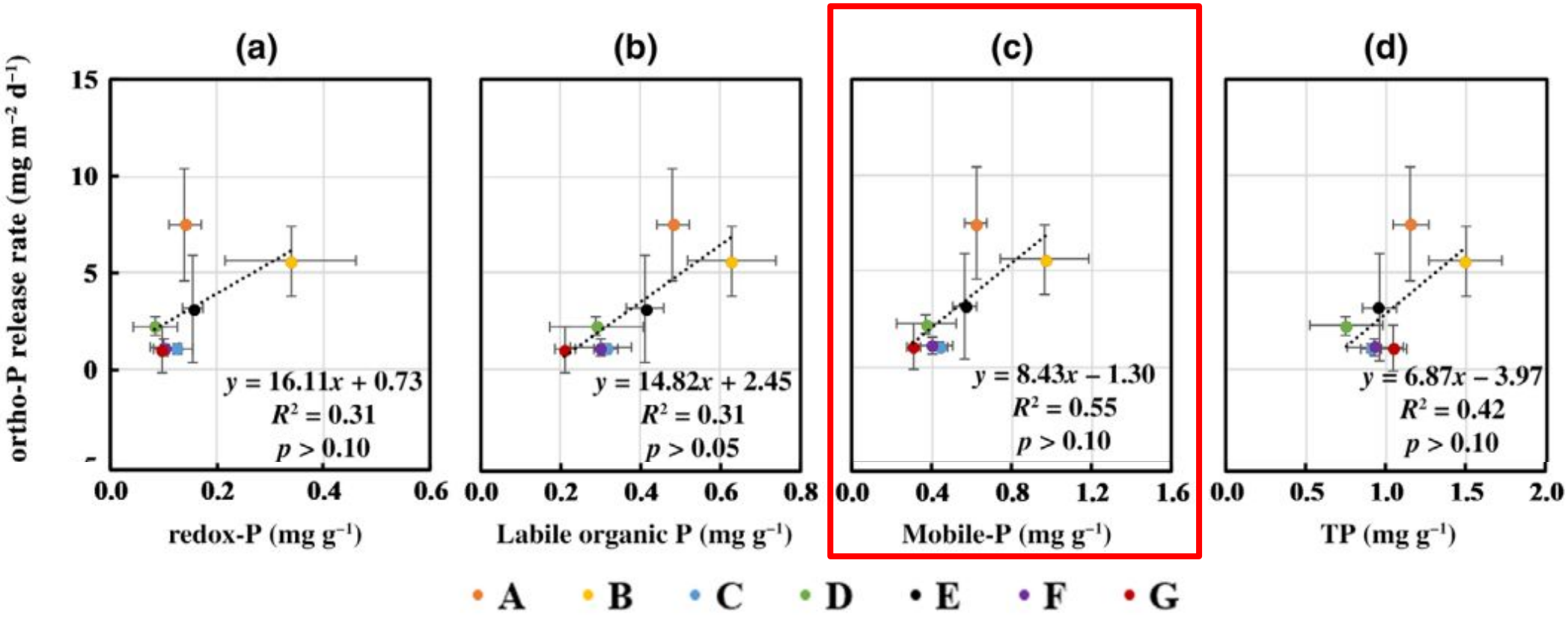

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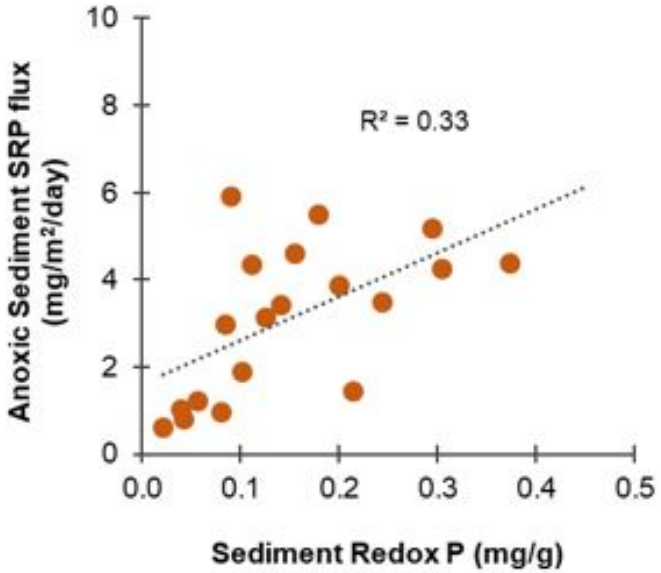
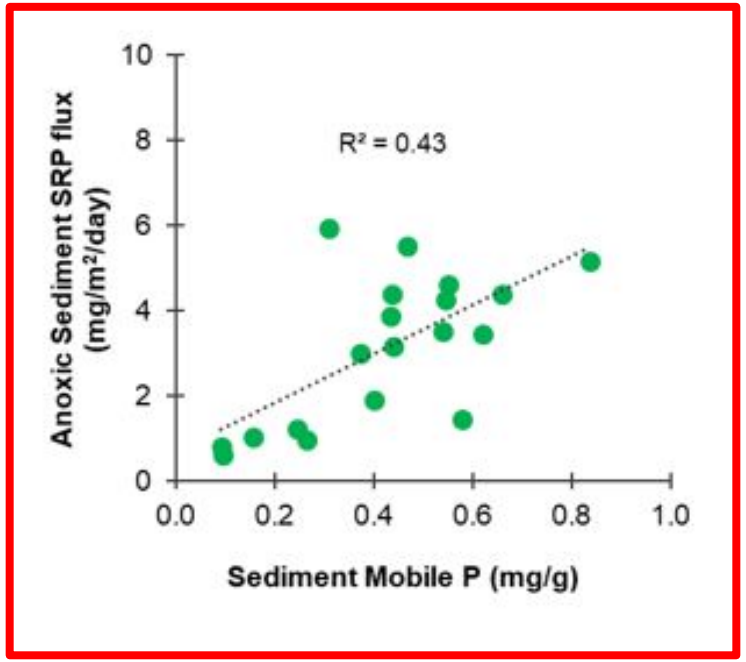
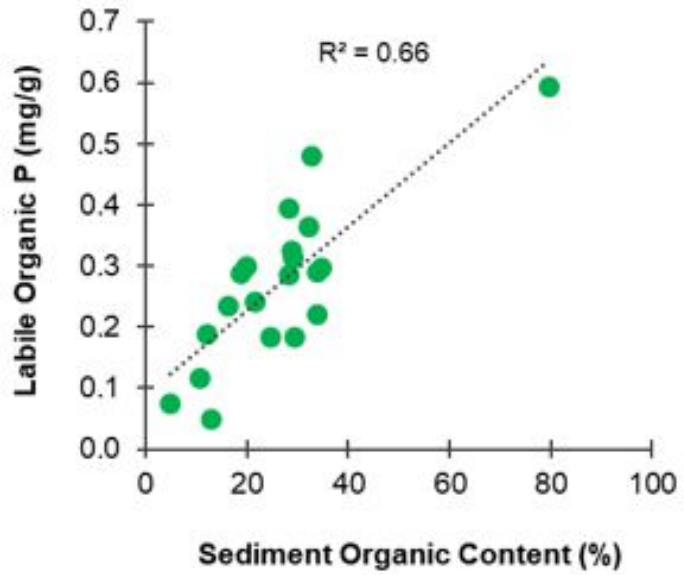
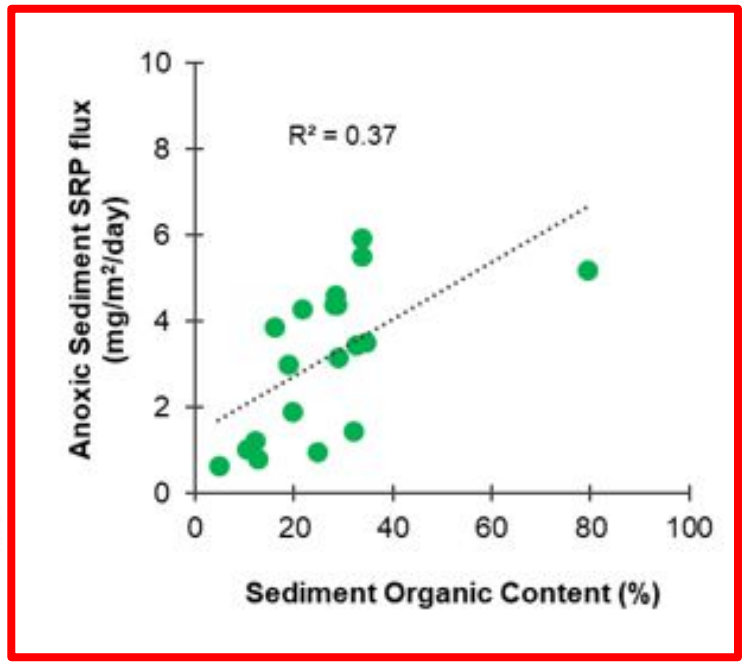








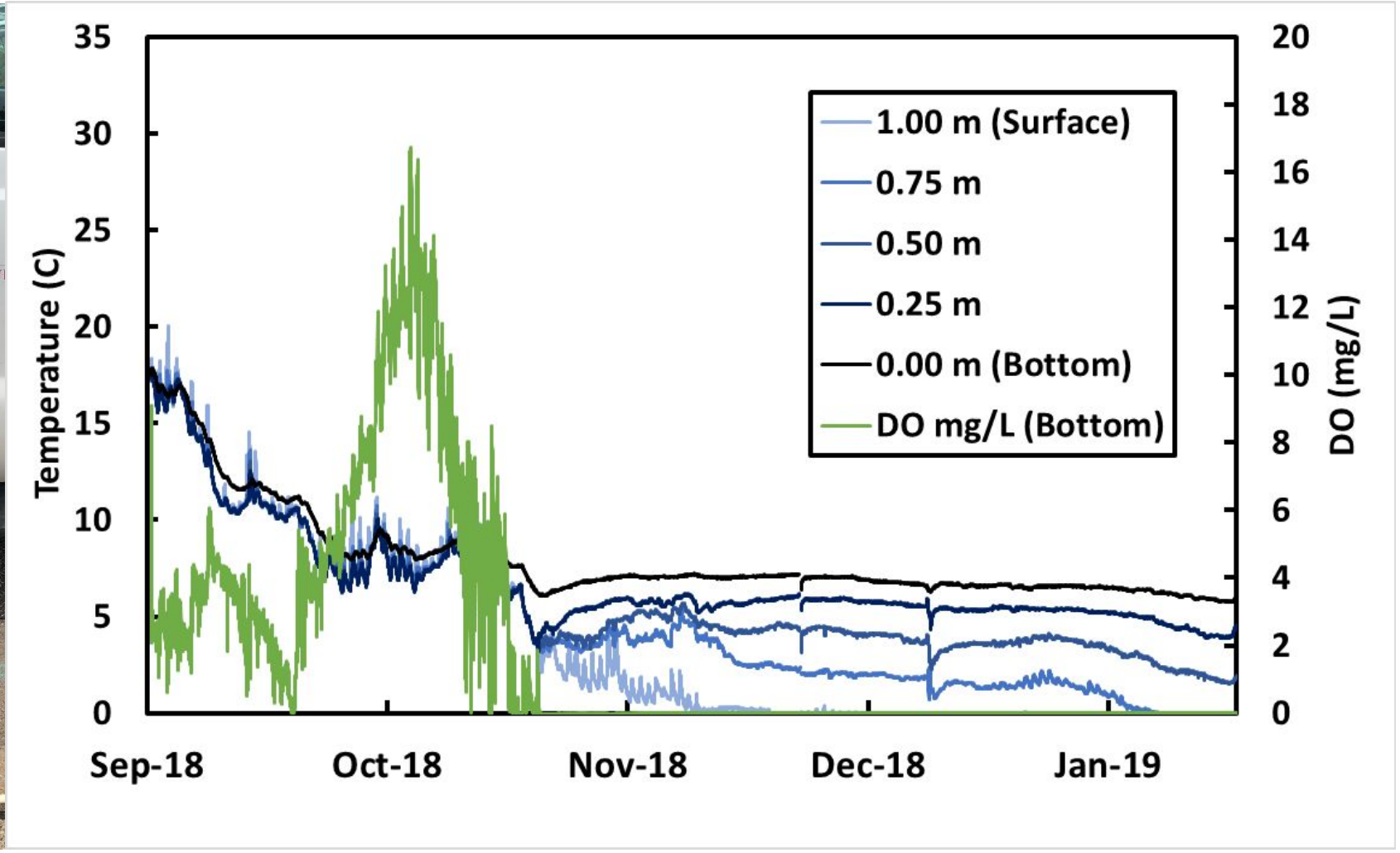
Natarajan et al. 2022.
Stormwater Pond Maintenance and Wetland Management for Phosphorus Retention.
LRRB 2020 NS 596.
Minnesota Department of Transportation
Local Roads Research Board.

When does P-Release Occur

Design Assumptions

- ~~Indefinite phosphorus retention in sediments~~
- Shallow (<10 m; often 0.5-3.0 m)
- Well-mixed (by wind and stormflows)
- Daily destratification (nighttime cooling)

Lasting Thermal Stratification and Low Dissolved Oxygen



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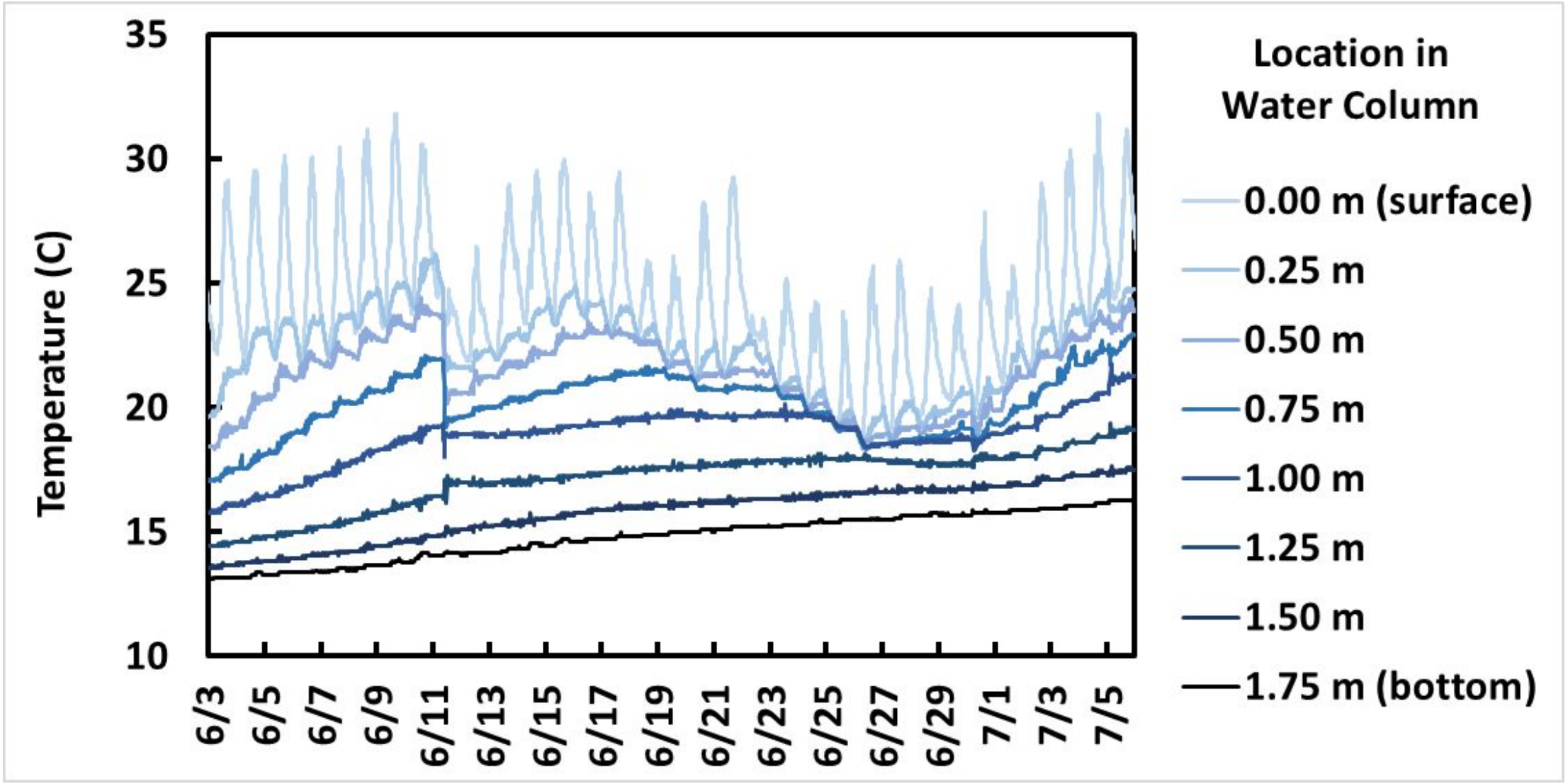
Lasting Thermal Stratification



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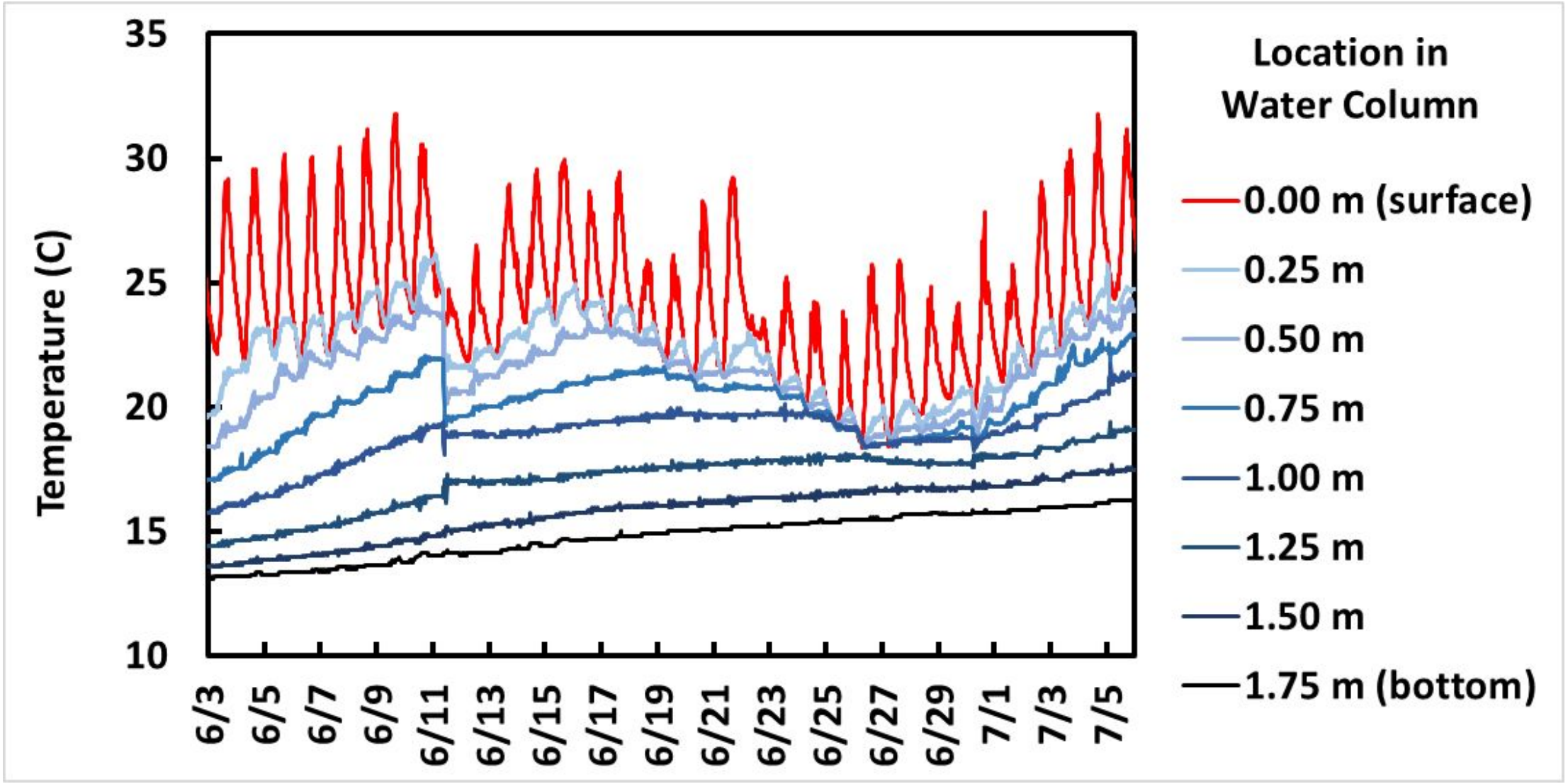

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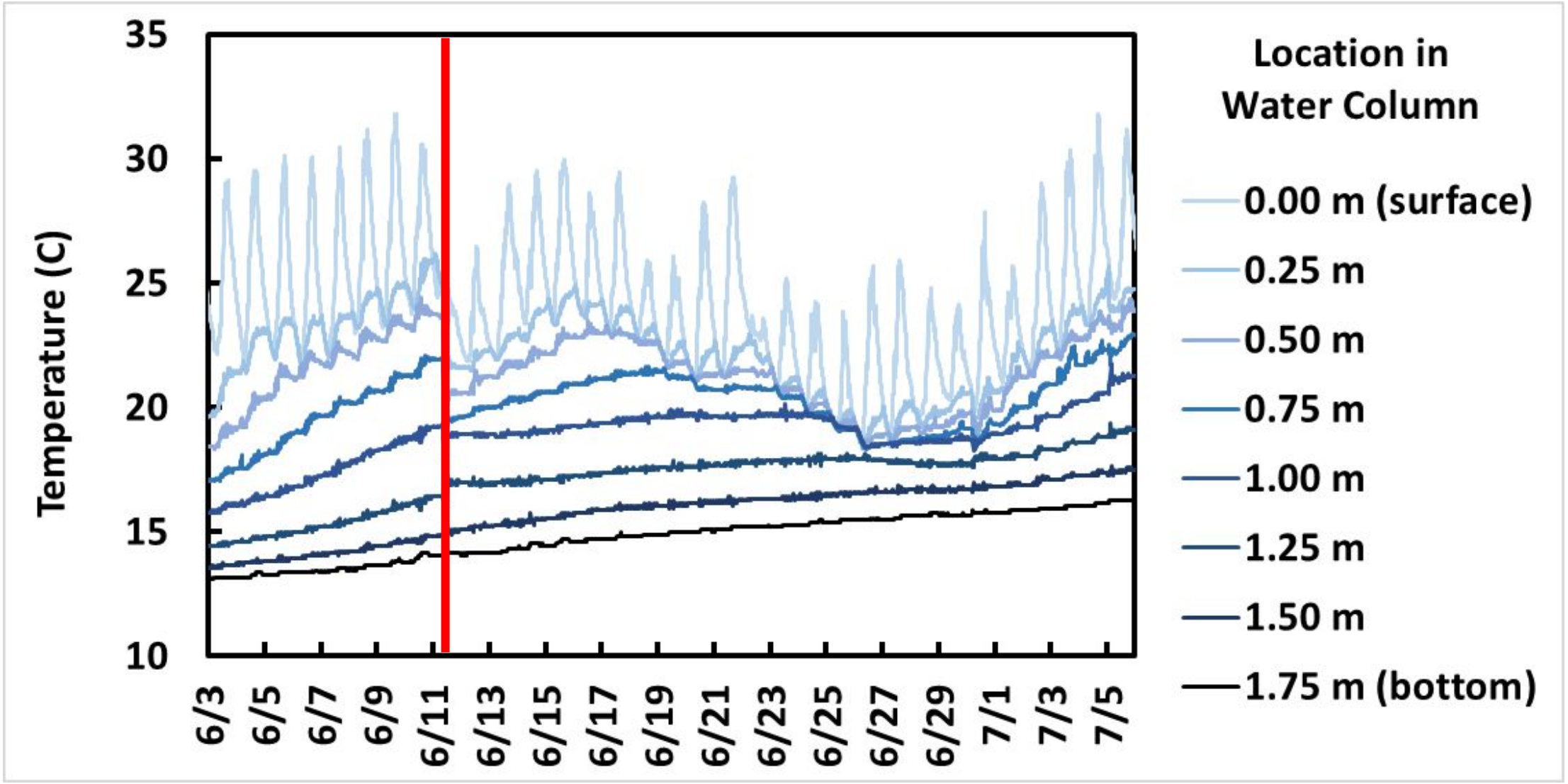

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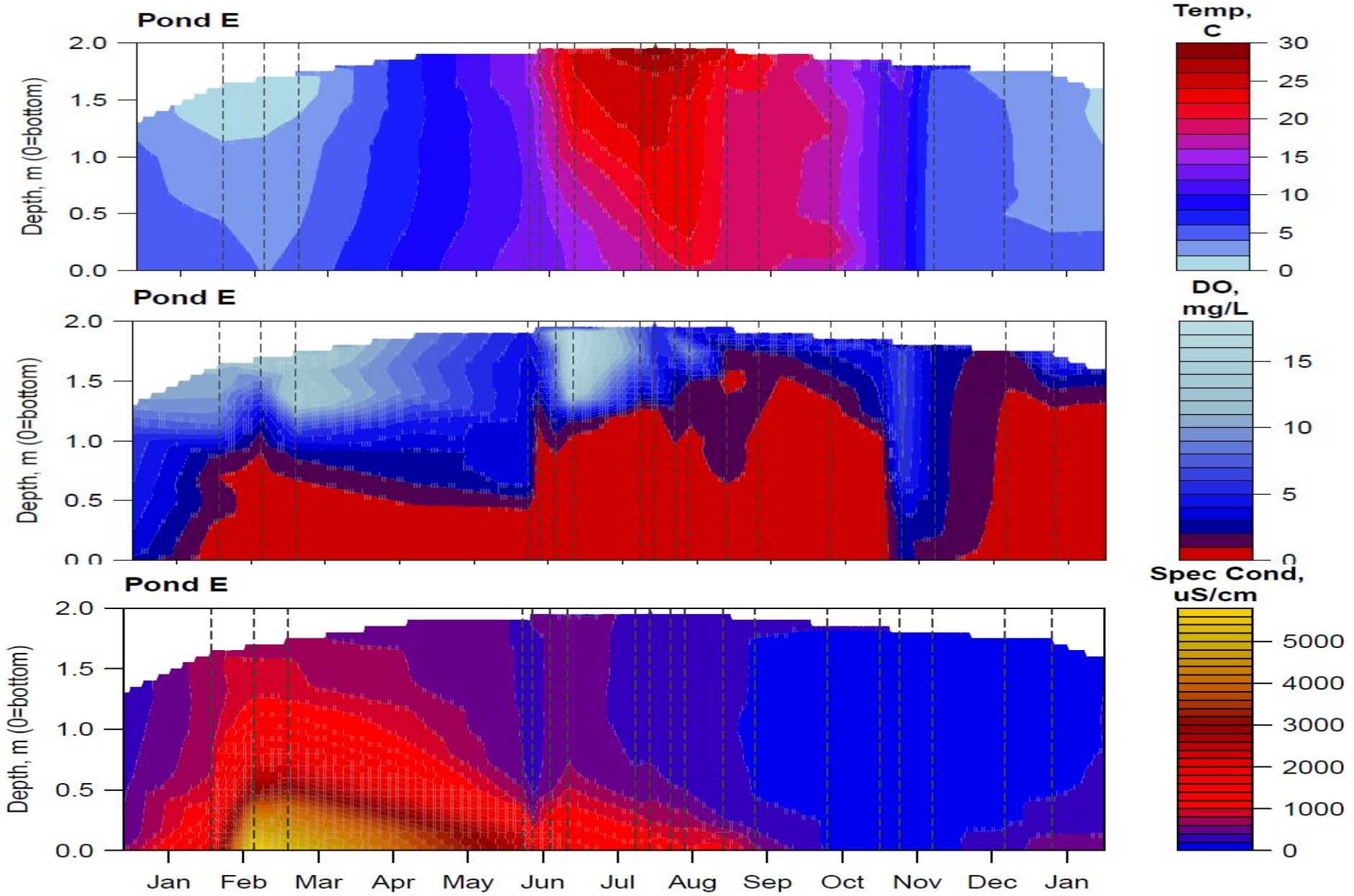
Substantial Chlorides from Winter Deicing

Bell Museum 2018

Heat

Oxygen

Salt



Modified from Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

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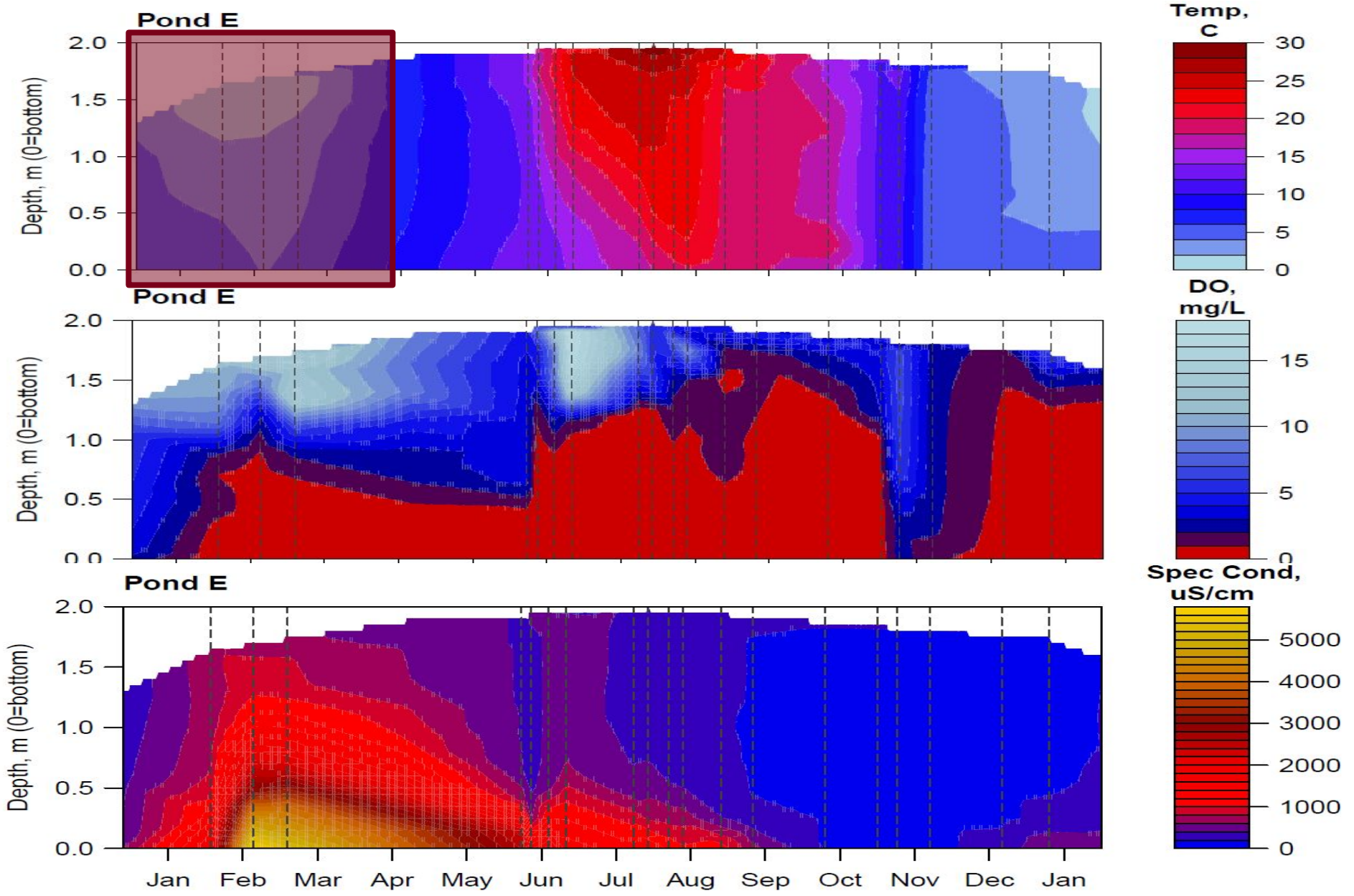
Heat

Oxygen

Salt



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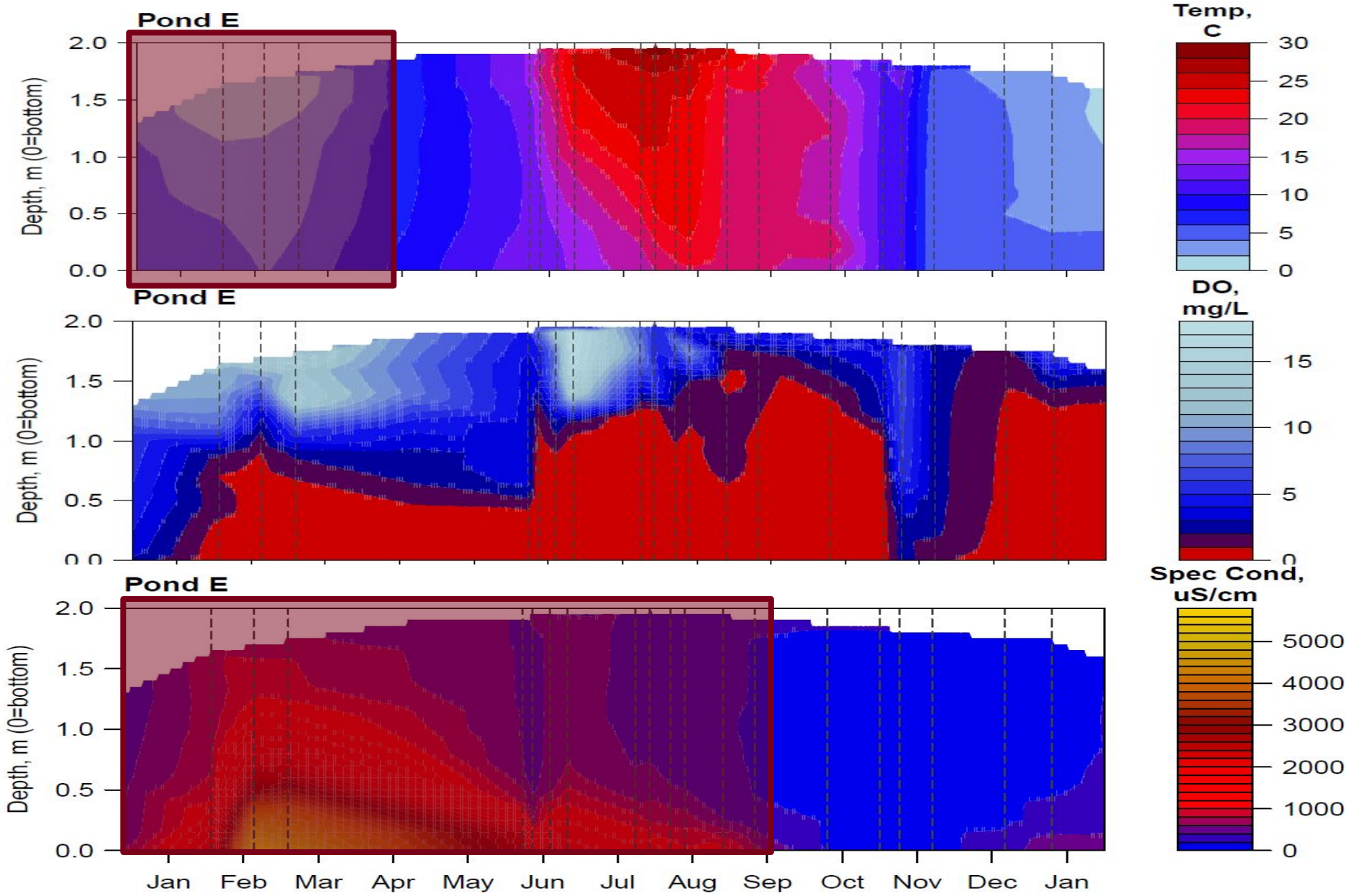
Heat

Oxygen

Salt



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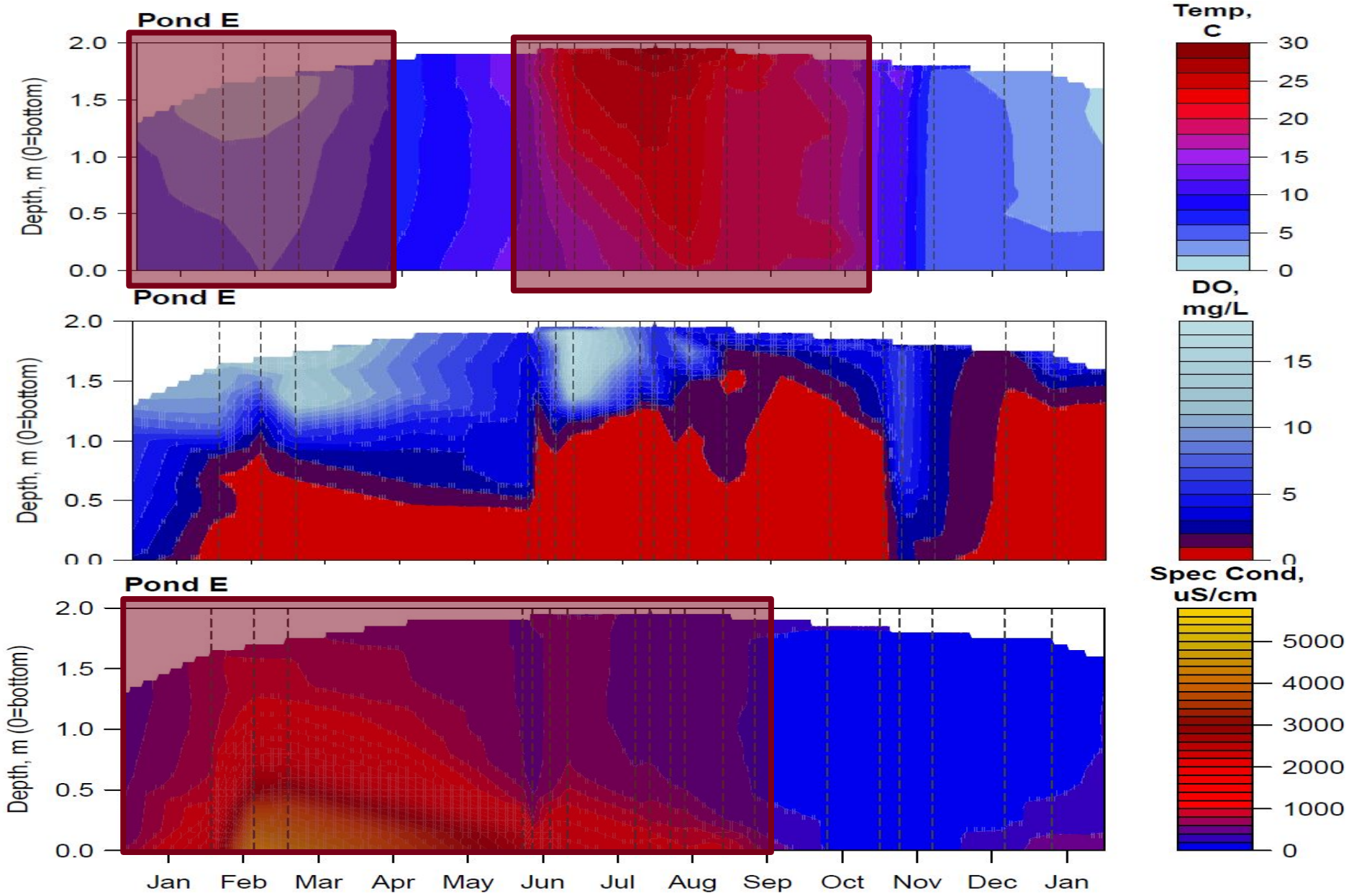
Heat

Oxygen

Salt



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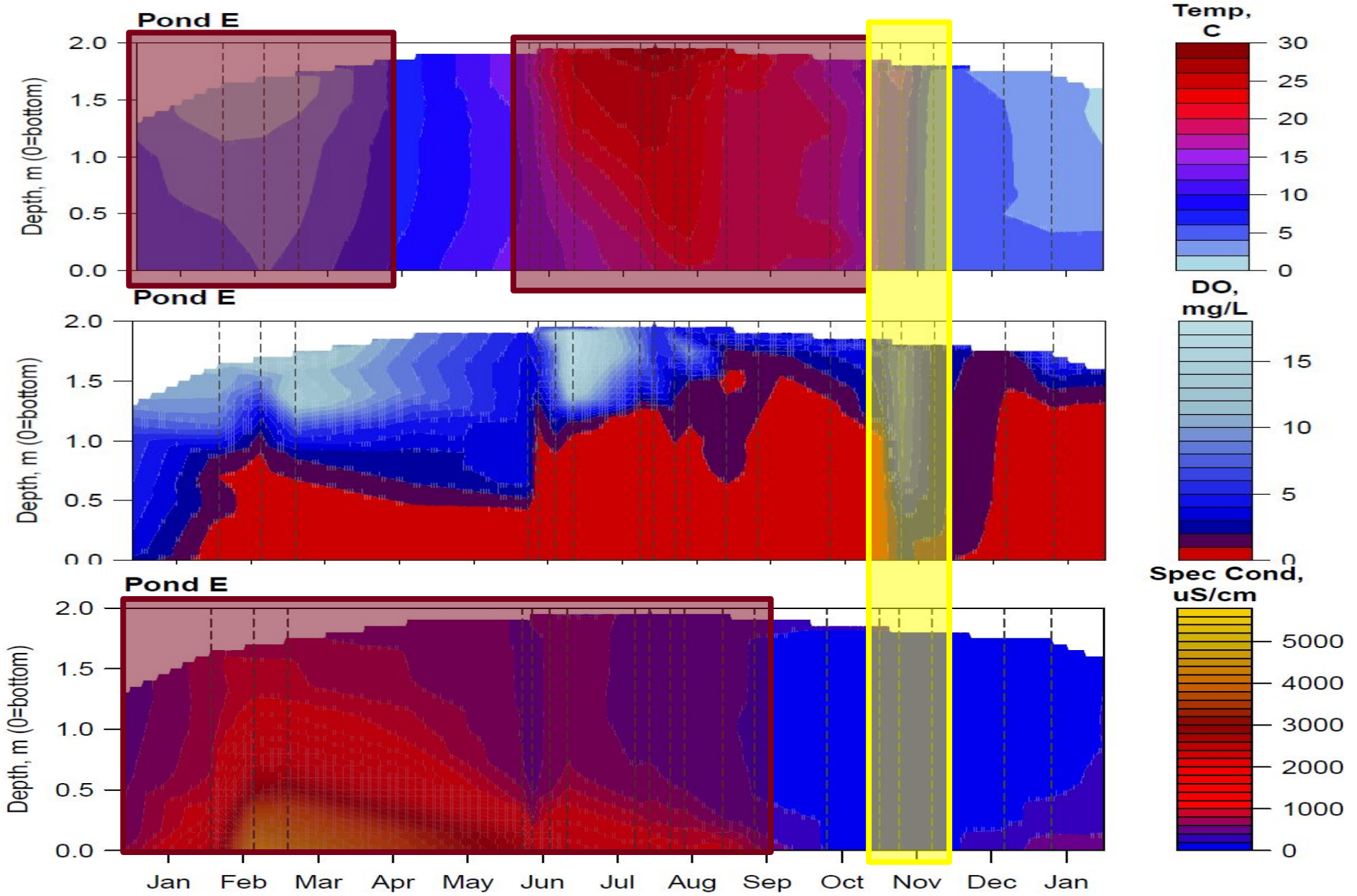
Heat

Oxygen

Salt



Modified from Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

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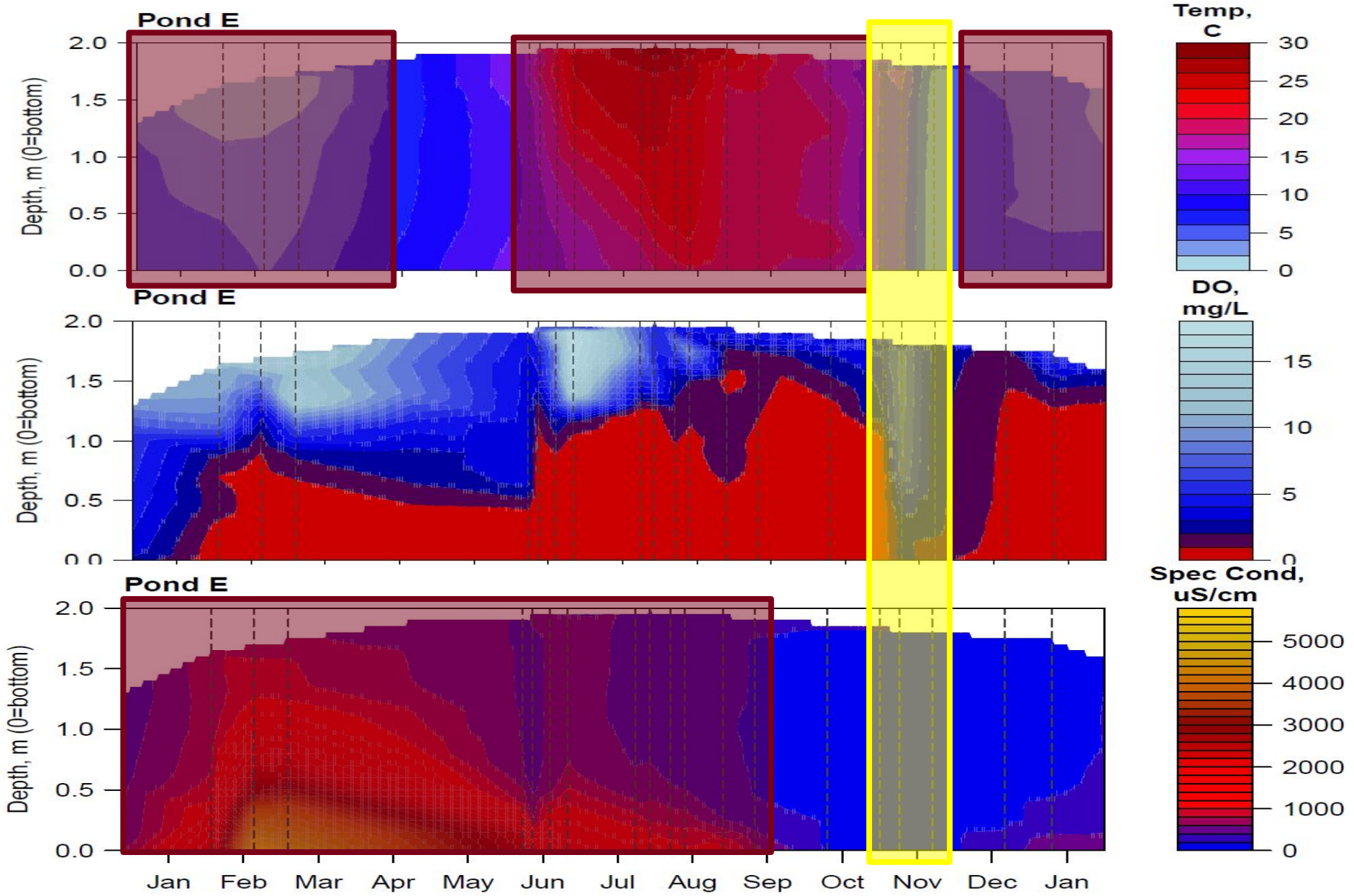
Heat

Oxygen

Salt



Modified from Taguchi et al. 2020. *Internal loading in stormwater ponds as a phosphorus source to downstream waters.* Limnology and Oceanography Letters.

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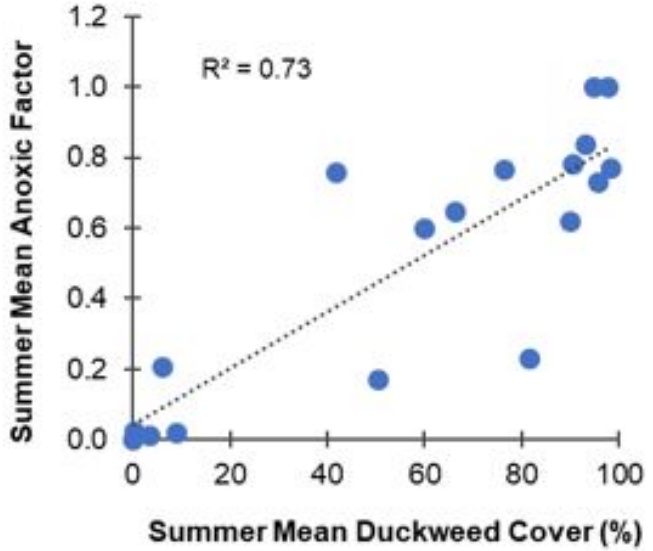
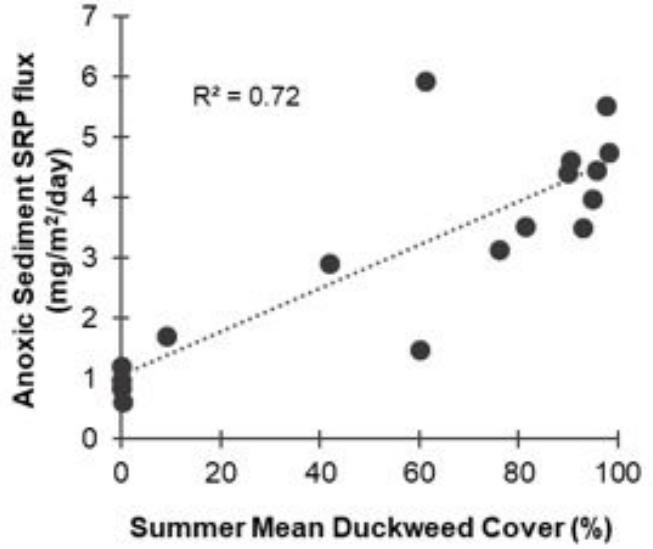
Duckweed also contributes

Photo credit: Poornima Natarajan





Natarajan et al. 2022. *Stormwater Pond Maintenance and Wetland Management for Phosphorus Retention. LRRB 2020 NS 596.* Minnesota Department of Transportation Local Roads Research Board.

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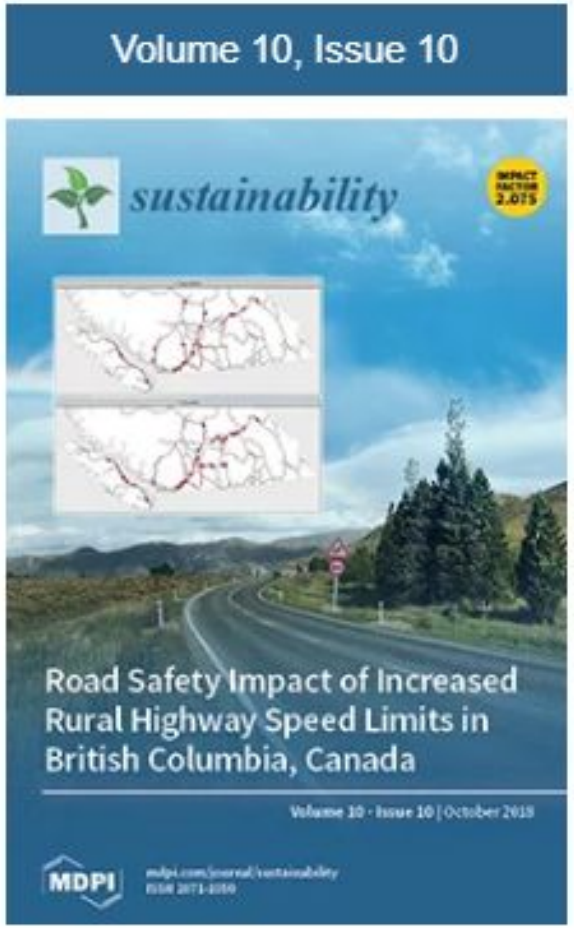
What can we do?

Maintenance Recommendations

PREVENTION is cheaper than REMEDIATION



Open Access Review

The Challenge of Maintaining Stormwater Control Measures: A Synthesis of Recent Research and Practitioner Experience

Andrew J. Erickson [1,*], Vinicius J. Taguchi [1,2] and John S. Gulliver [1,2]

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Watershed Pollutant Reduction

PREVENTION

https://www.tymco.com/sweepers/model-600/

Volume Reduction

PREVENTION

https://gardening-abc.com/rain-garden/

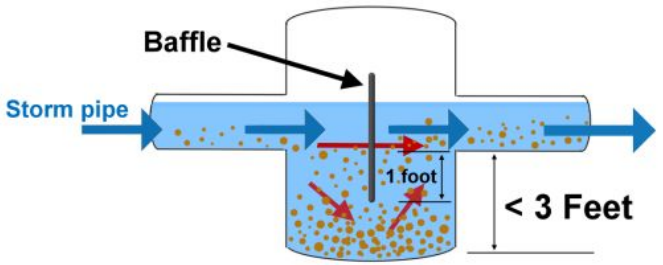
Pretreatment

PREVENTION

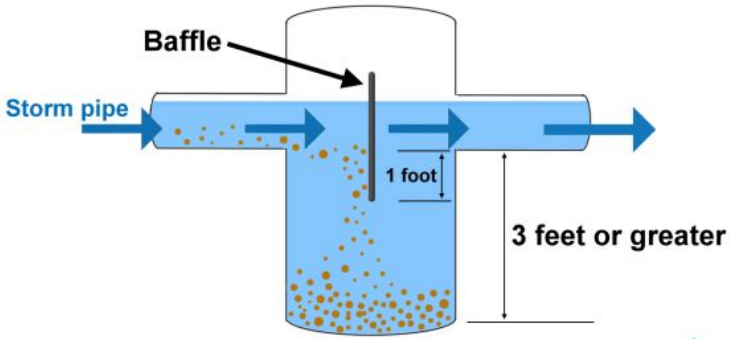
Tip #2: Sediment Retention

3 feet deep or greater

If a sump is less than 3 feet deep,
a baffle will not help remove sediment



Only install baffles in sumps that are
3 feet deep or greater

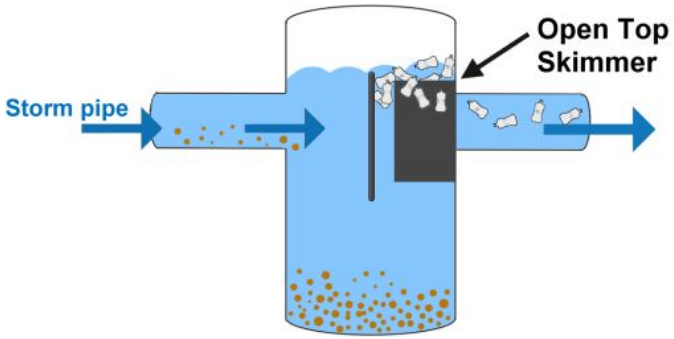


Upstream Technologies
www.upstreamtechnologies.us

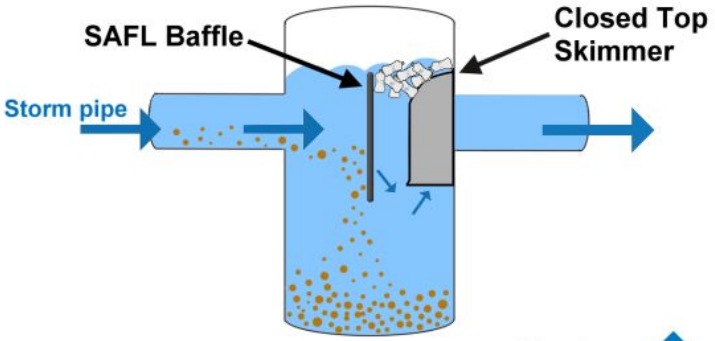
Tip 4: Trash and Oil Retention

Use Closed-Top Skimmers

During heavy rain events,
trash & oil will float over open top skimmers



Closed top skimmers retain trash and oil



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Alum Treatment

TREATMENT

Photo credit: Joe Bischoff – Stantec

Iron Filings Treatment

TREATMENT

Video credit: Poornima Natarajan

Iron Filings Treatment

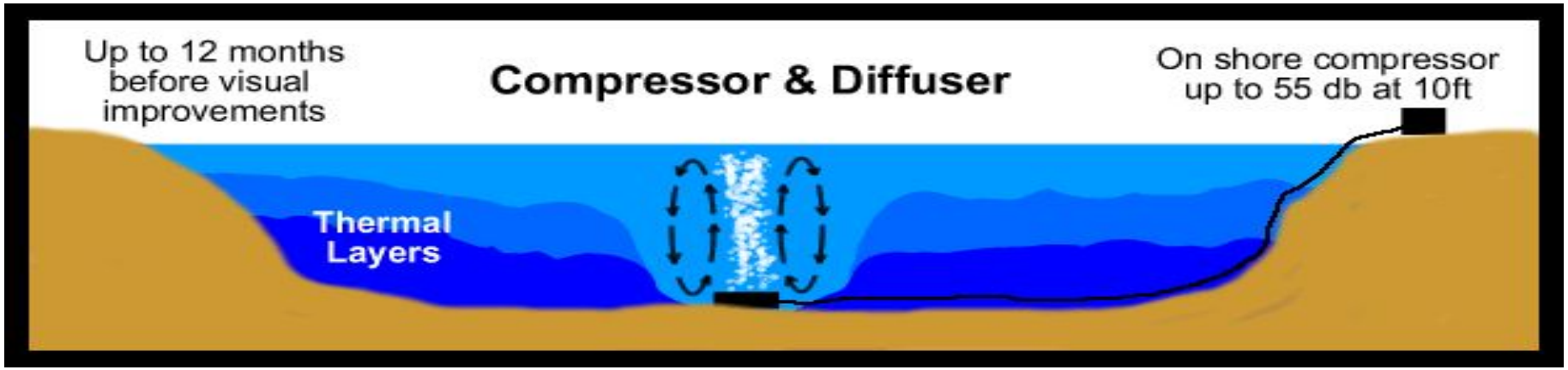
TREATMENT

Photo credit: Noah Czech – City of St. Cloud, MN

Mechanical Aeration (Not Fountains)

TREATMENT

DO



Customfountains.com

DON'T

https://stormwater.bae.ncsu.edu/

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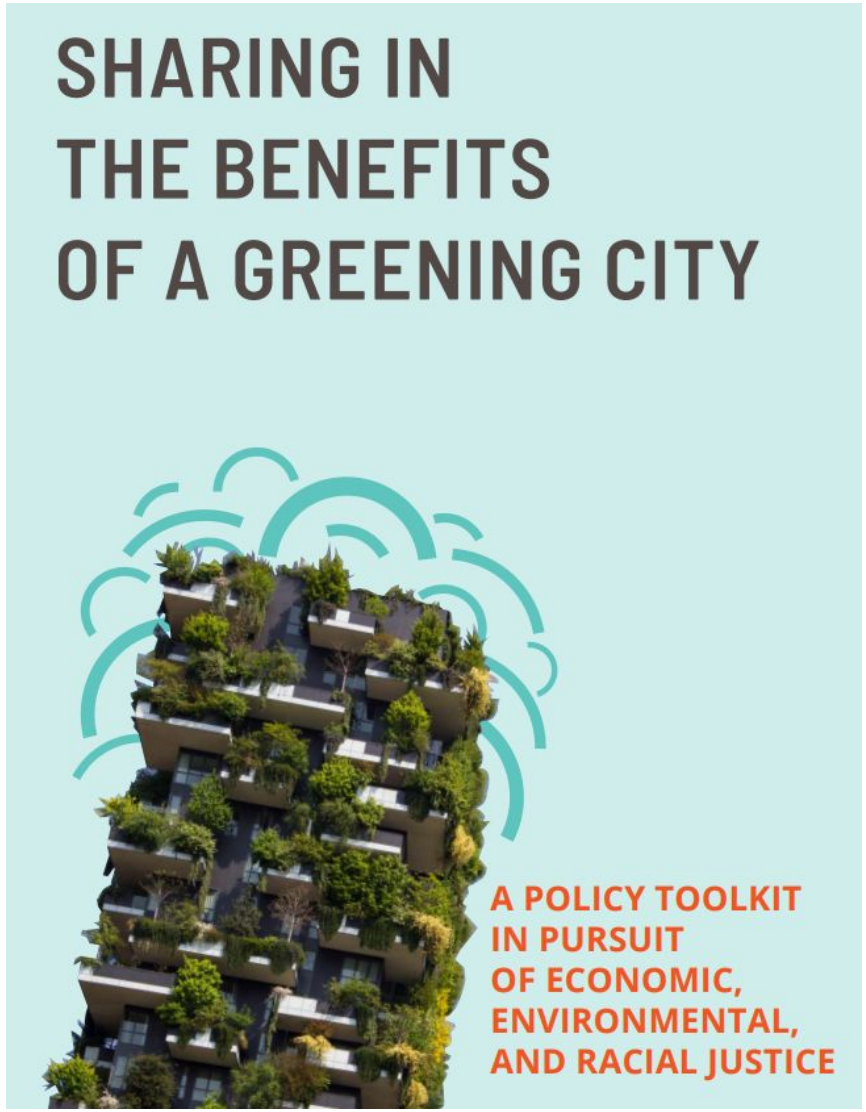
Dredging

REMEDIATION

Photo credit: John Carlon – City of Eden Prairie, MN

Human Impacts



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create.umn.edu/toolkit

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Thank you!

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