# The Application of the Phosphorus Bioavailability Concept in Policy and Management

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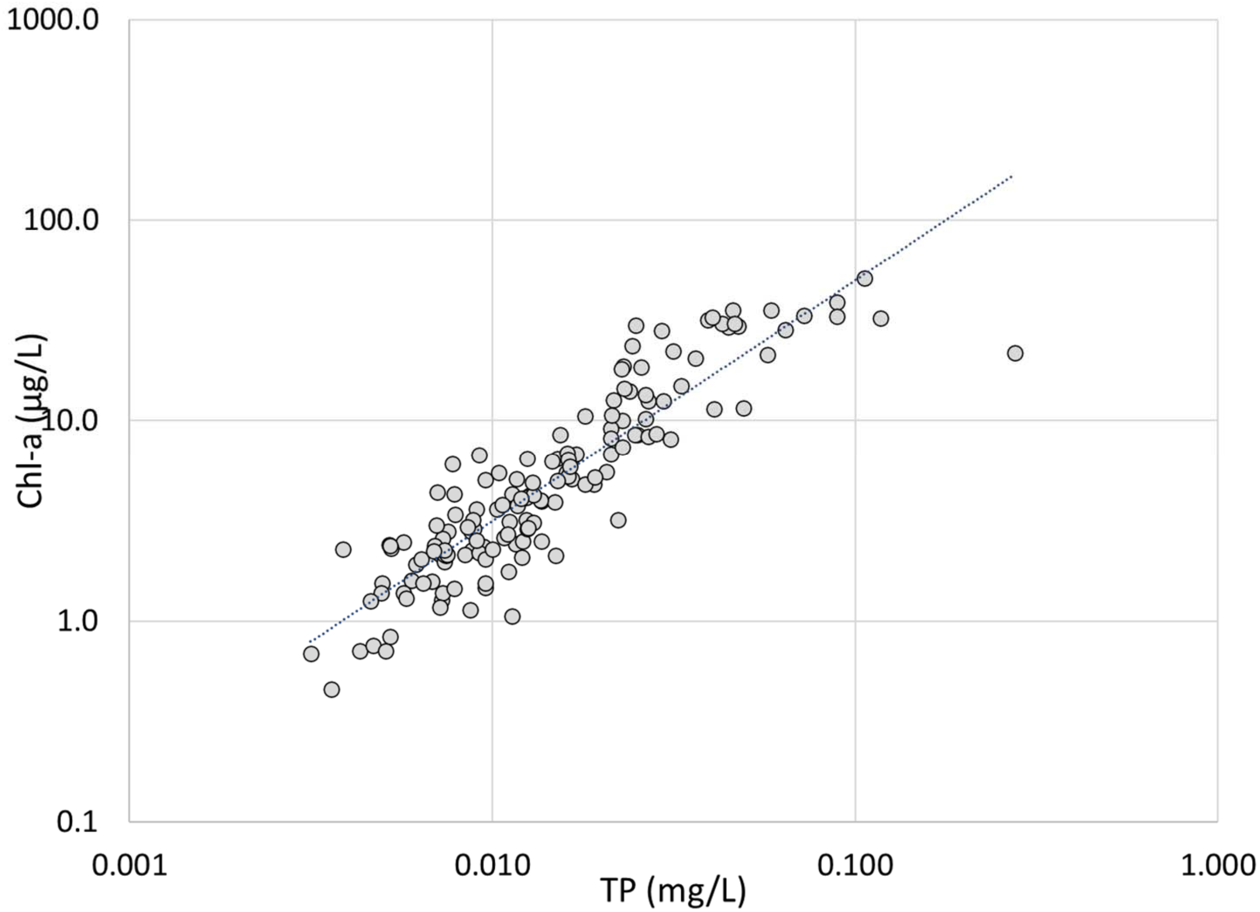
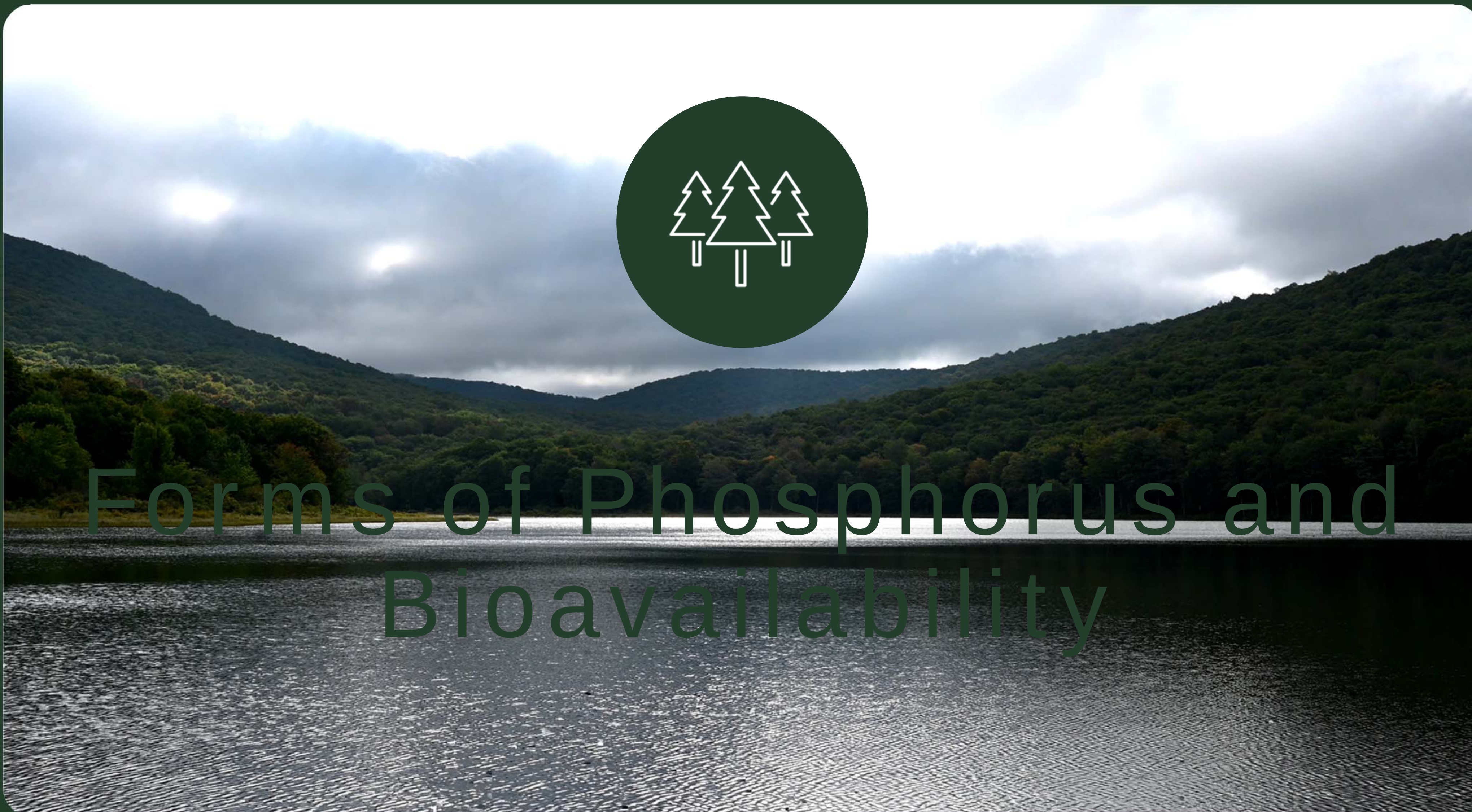
# Why is Phosphorus Important?

Phosphorus is often the nutrient that limits algae growth in freshwaters

# Relationship Between P and Chlorophyll-a in NY Lakes

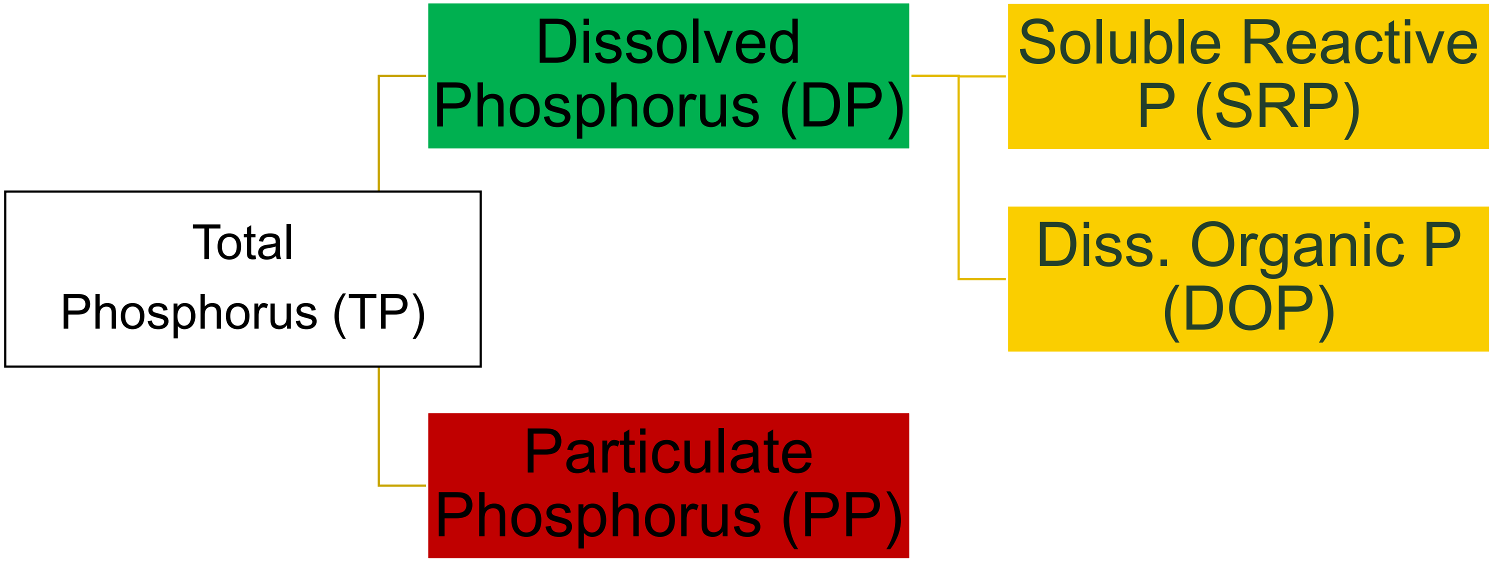




# Forms of Phosphorus and Bioavailability

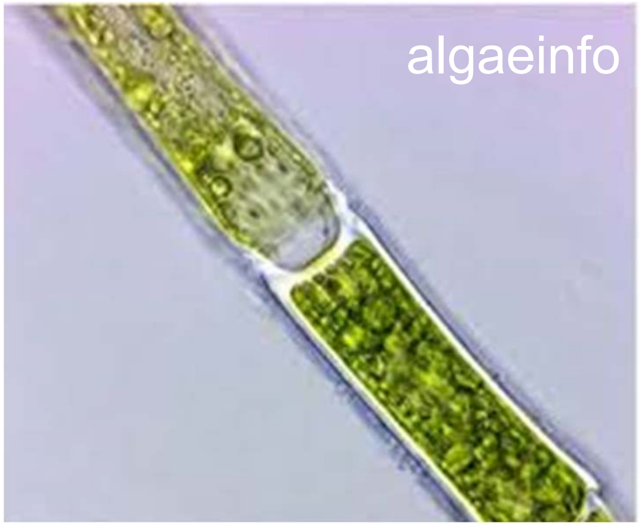
# Some Different Forms of Phosphorus

- Total phosphorus (TP) is the total amount of elemental P in a sample (all forms)



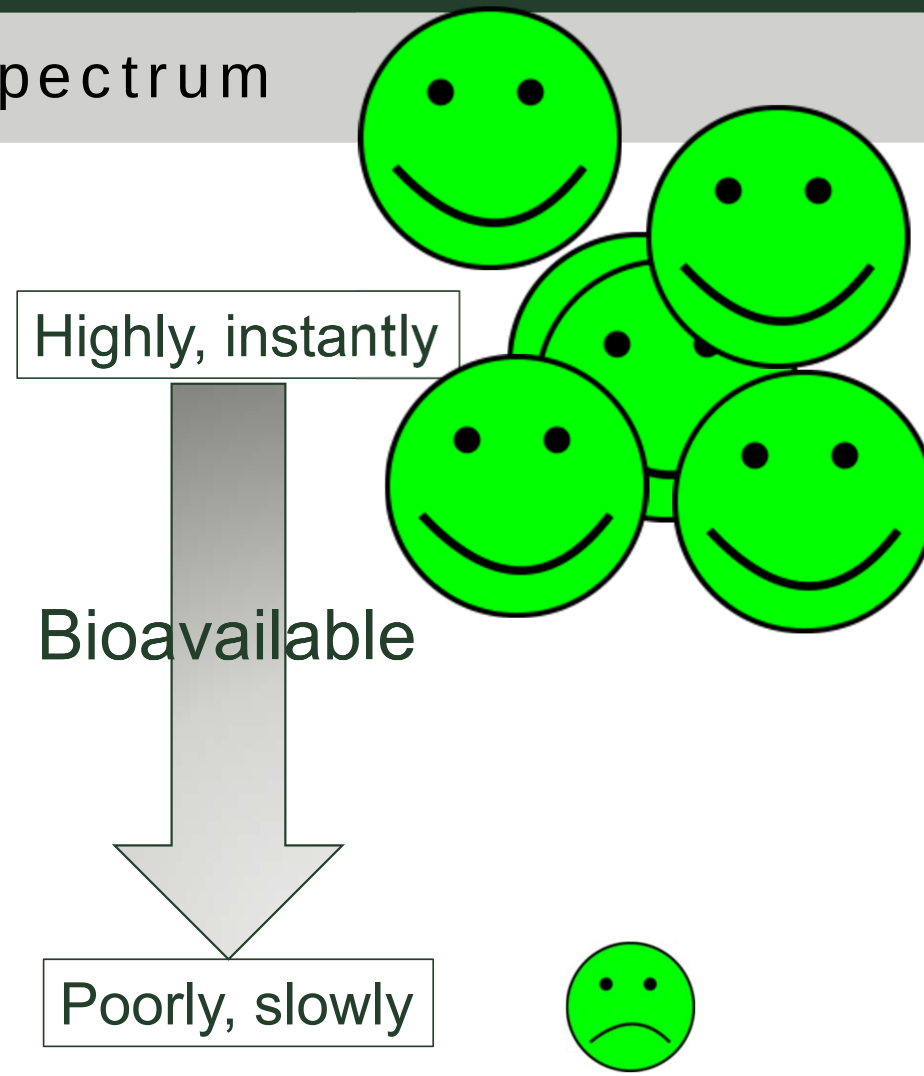
# Phosphorus Bioavailability, The Concept

1. P exists in multiple forms and those forms differ in their ability to support primary production
2. Those forms that are useable by algae, phytoplankton for assimilation and growth are called ***bioavailable***



# Phosphorus Bioavailability: A spectrum

- Soluble Reactive P (SRP)
- Dissolved Organic P (DOP)
- Particulate P (PP)



# Phosphorus Forms and Bioavailability

SRP


PP

# Quantifying Bioavailability: Algal Bioassays

Algal Bioassays

- Measure algal uptake of P over time to quantify usability (soluble P and particulate P)

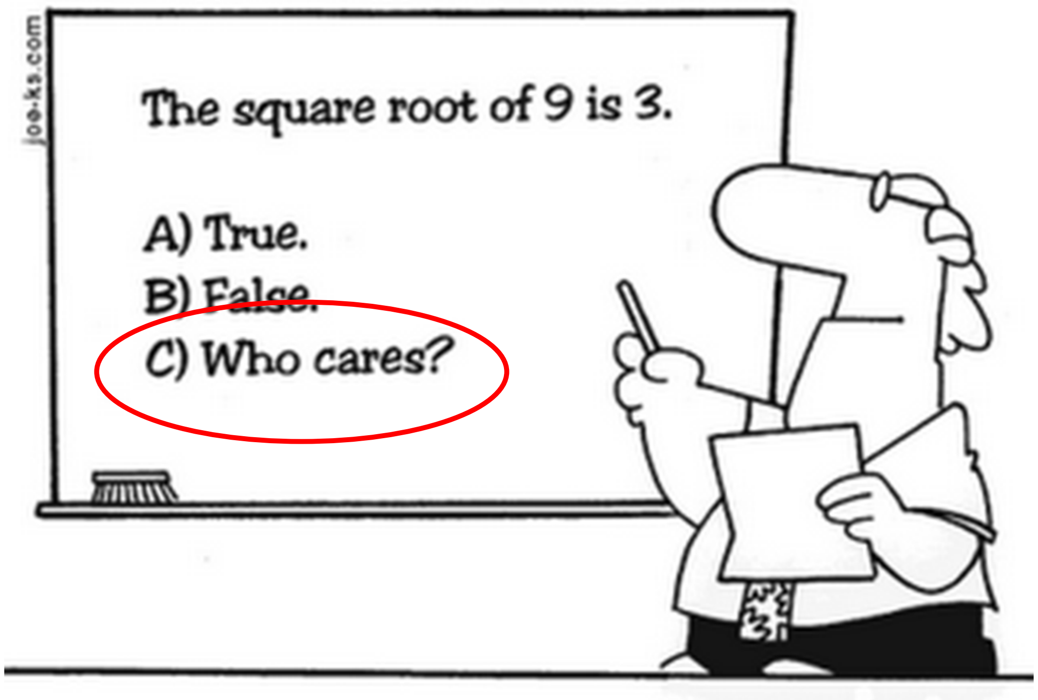
\+ Direct estimates based on algal response

\- Labor intensive
  - sample collection, filtering (hours), assays (multiple days), multiple analytical tests

\- Expensive
  - labor costs, lab analysis, shipping (specialty lab)

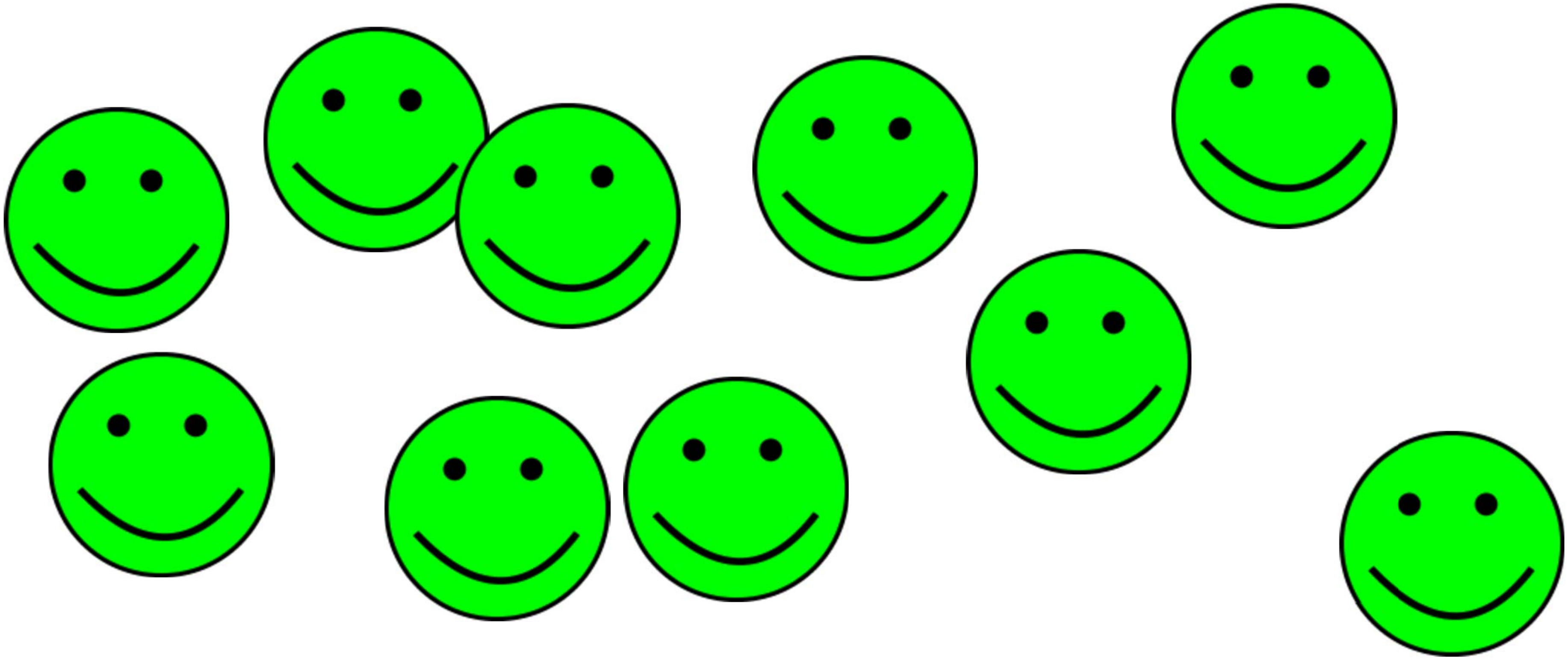
Soluble Phase Assay Setup

Dual Culture Diffusion Apparatus

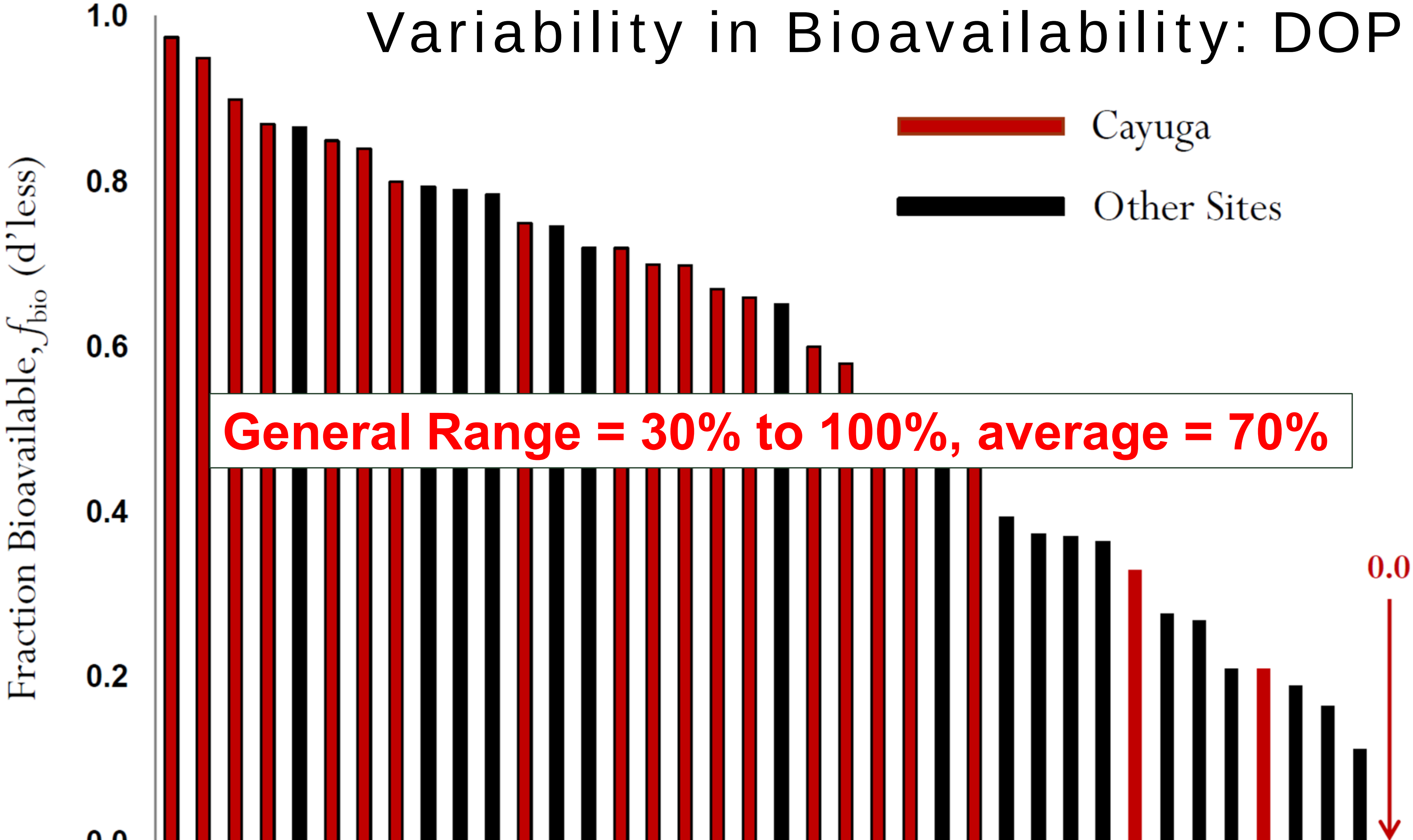



bioavailability has real value in watershed, lake management

SRP is immediately and 100% bioavailable!

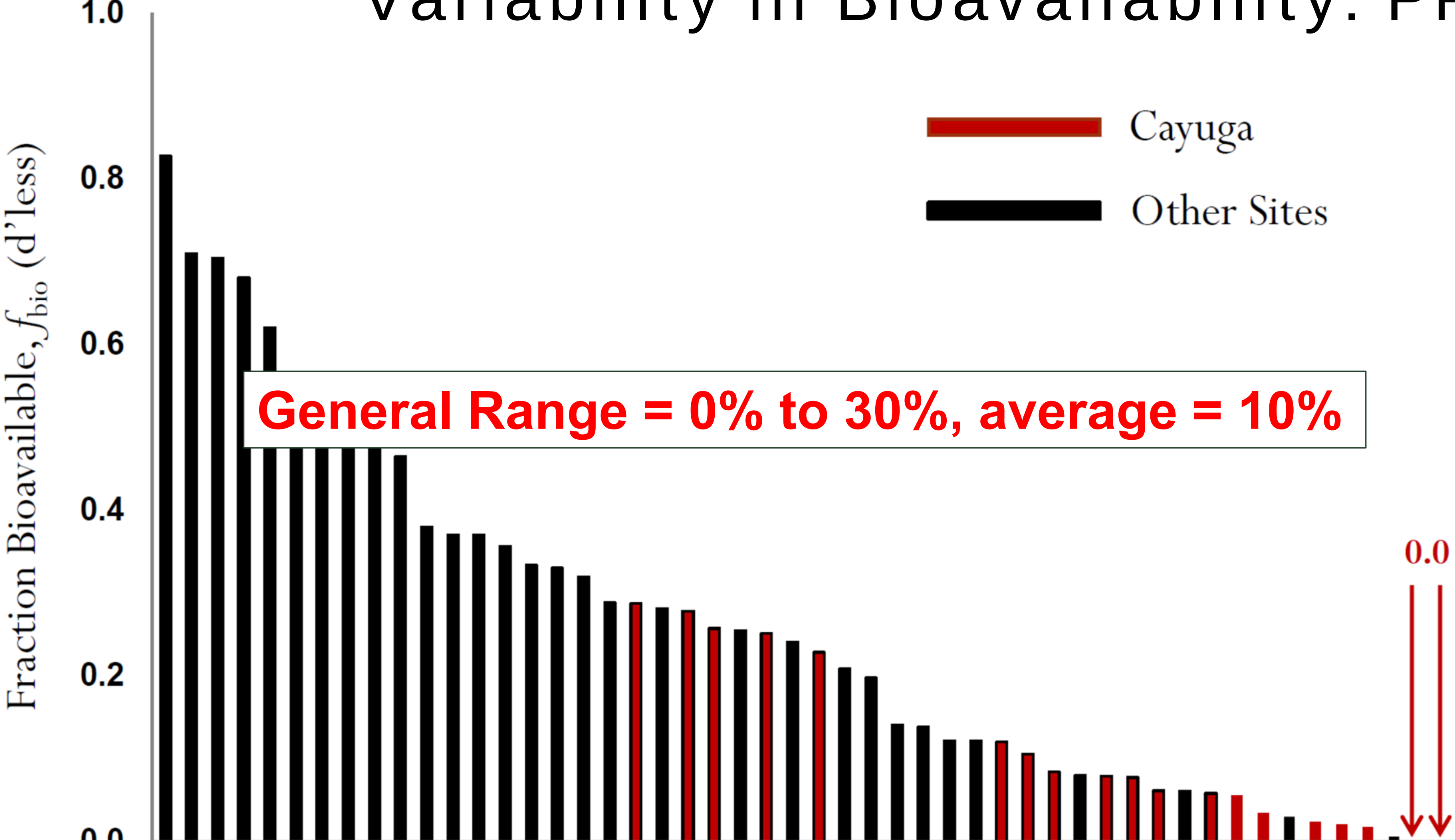


# Variability in Bioavailability: DOP




Courtesy of M. Auer, MTU

# Variability in Bioavailability: PP




Courtesy of M. Auer, MTU

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Technical Paper

# Apportionment of bioavailable phosphorus loads entering Cayuga Lake, New York†

Anthony R. Prestigiacomo, Steven W. Effler, Rakesh K. Gelda, David A. Matthews, Martin T. Auer, Benjamin E. Downer, Anika Kuczynski, M. Todd Walter

First published: 14 November 2015 | https://doi.org/10.1111/1752-1688.12366 | Citations: 23

† Paper No. JAWRA-14-0155-P of the *Journal of the American Water Resources Association* (JAWRA).
‡ **Discussions are open until six months from issue publication.**

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## Abstract

# Current Work

# What Determines the BAP of a Source?

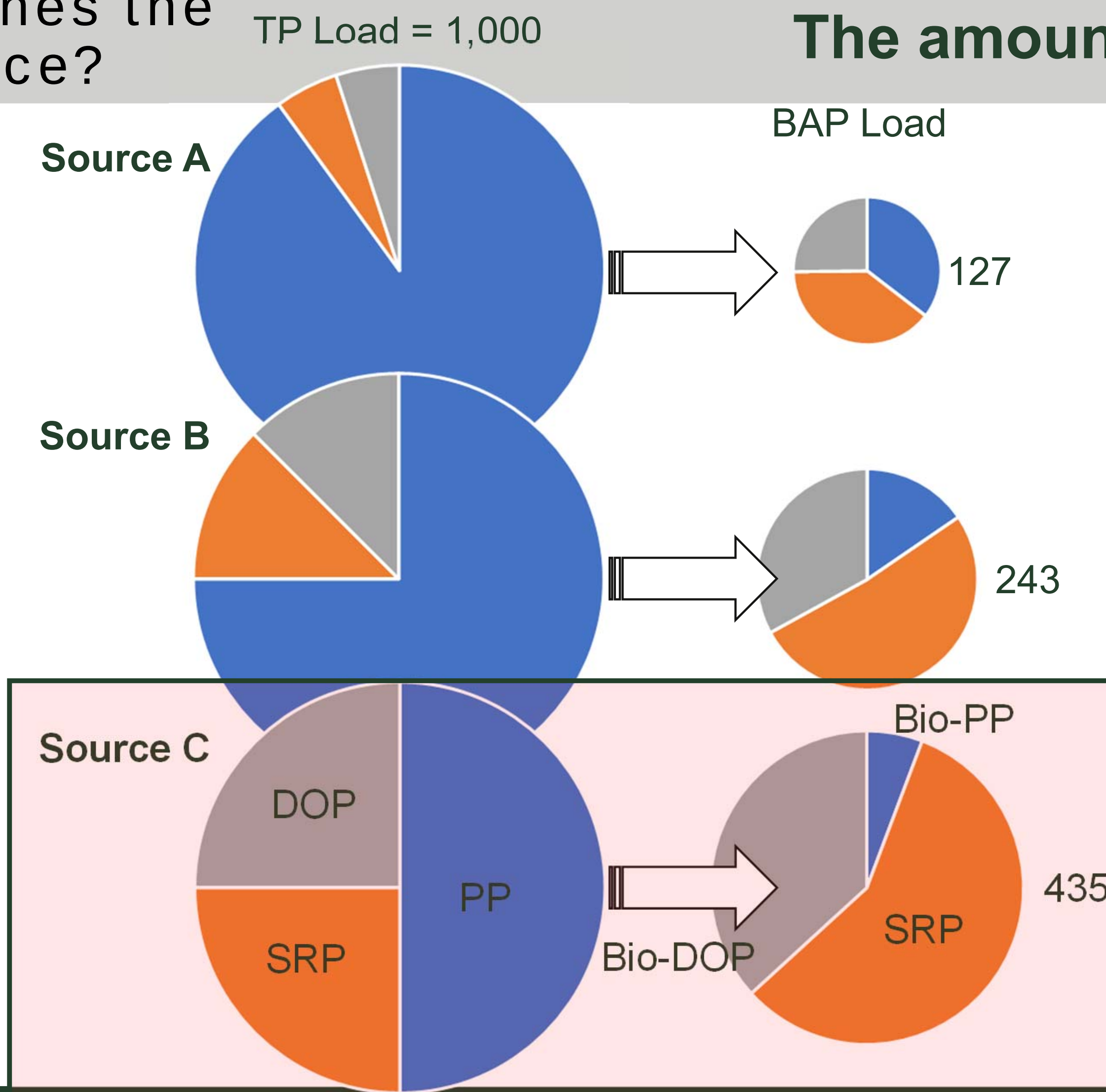
## The amounts of DP vs PP

(1) total phosphorus concentration

(2) the proportion of total phosphorus that is dissolved,

(3) the bioavailability of dissolved phosphorus, and

(4) the bioavailability of particulate phosphorus




BAP Load

- Source B is 2x higher than Source A
- Source C is 3.5x higher than Source A
  - 1.8x higher than Source B

Target for BMPs!

# What Determines the BAP of a Source?

## The bioavail. of the components

(1) total phosphorus concentration

(2) the proportion of total phosphorus that is dissolved,

(3) the bioavailability of dissolved phosphorus, and

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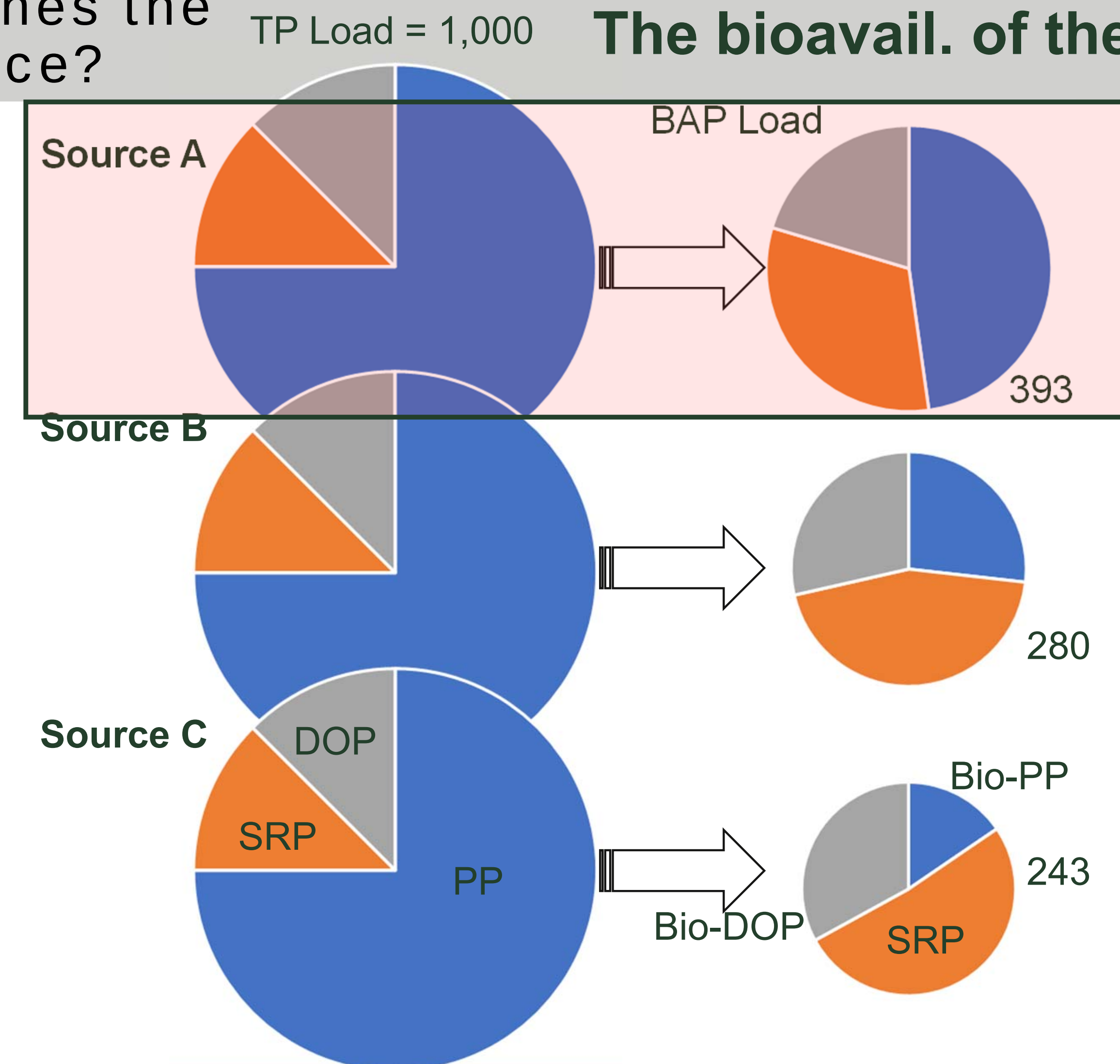



Target for BMPs!

BAP Load

- Source A is 30% more than Source B
- Source A is 40% more than Source C

# Calculations

Performed numeric exercises to estimate reductions in BAP from three P management strategies to meet TP load reduction targets

- Same initial TP load
- Random cases of P-bioavailability and particulate/dissolved TP composition (based on literature ranges)
- 5,000 iterations
- What was the resulting BAP load for each Strategy?

<u>The three strategies were:</u>

1. Reduce PP only; 2. Reduce PP and DP; 3. Reduce DP only.

## Results

| Strategy | BAP Load Reduction |
|---|---|
| 1. Reduce PP only (SRP, DOP constant) | Worst |
| 2. Reduce PP, SRP, and DOP | Moderate |
| 3. Reduce SRP, DOP only (PP constant) | Best* |

*In many cases, reducing SRP, SUP would not achieve desired TP reductions

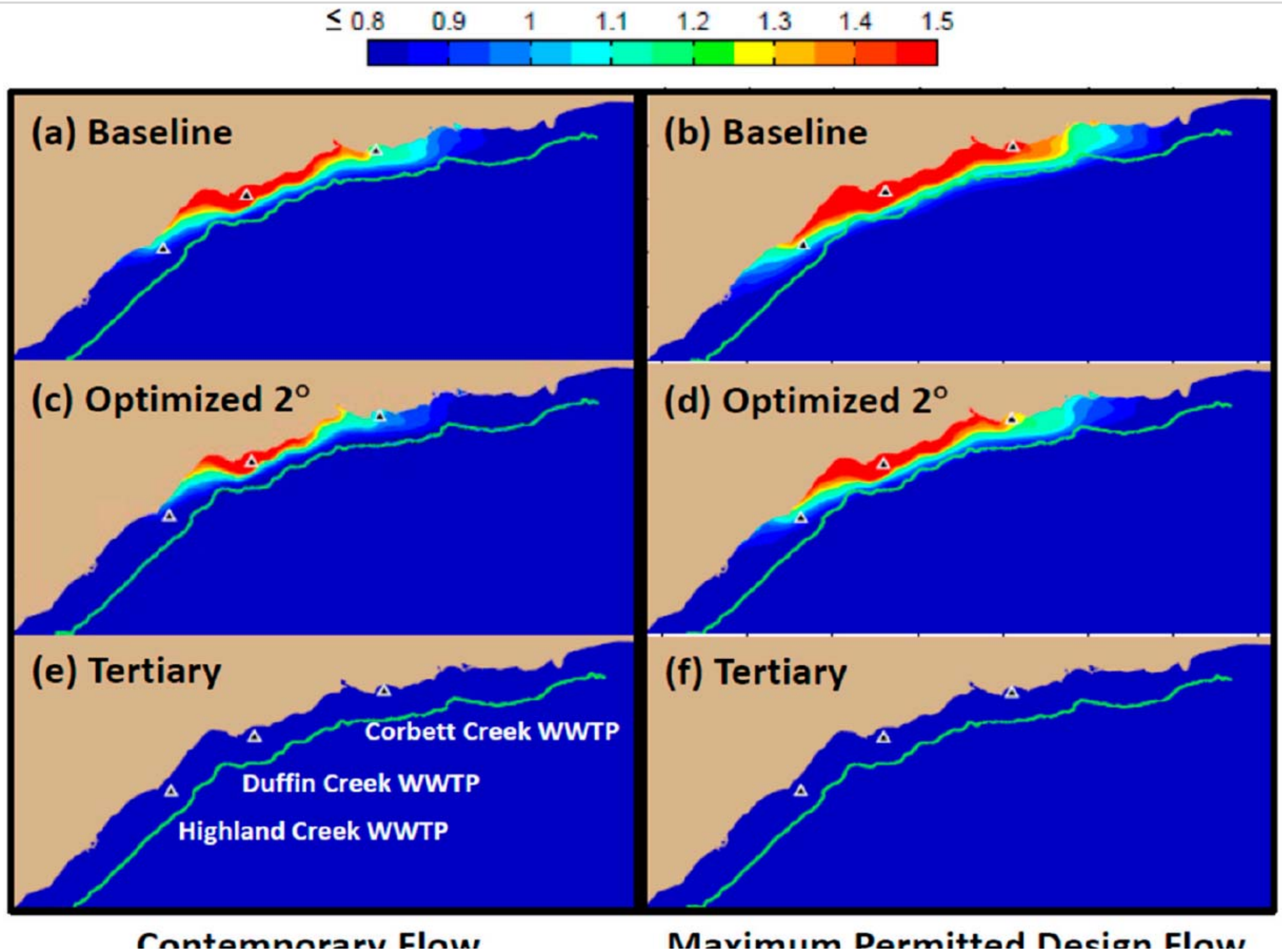
- Focusing on DP is critical to reduce bioavailable P to meet water quality goals
- Adopting a DP management strategy alone is impractical:
  - erosion controls will always be an important part of watershed management

**Table 1.** Summary of current modeled conditions and TP load reduction scenarios in the Owasco Lake Model. Modified from Table 7-5, UFI 2021.

| **Description** | **Lake Chl-a (ug/L) *** | **Lake TP (ug/L)** | **Cyano. (ug/L)** | **Strategy Findings** |
|---|---|---|---|---|
| Current Modeled Conditions | 3.2 ± 0.3 | 8.1 ± 0.9 | 0.14 ± 0.04 | - |
| A. 30% TP reduction achieved from particulate P reductions | 3.1 ± 0.3 | 7.5 ± 0.6 | 0.14 ± 0.09 | Least beneficial |
| B. 30% TP reduction achieved dissolved and particulate P reductions | 2.8 ± 0.3 | 6.8 ± 0.6 | 0.10 ± 0.05 | Moderately beneficial |
| C. 30% TP reduction achieved dissolved P reductions | 2.3 ± 0.2 | 5.9 ± 0.6 | 0.07 ± 0.03 | Most beneficial |

* presented as an upper waters, summer average of multiple annual predictions

Auer et al. 2021



# Management: What to Do?

# Best Management Practices: Cayuga Lake TMDL

**Table 31.** Agricultural BMPs and the TP pounds reduced and cost to reduce TP. (X = applicable, Unknown = not enough information to determine applicability)

| | | | **Targeted Nutrient Form**[1] | |
|---|---|---|---|---|
| **BMP Name** | **TP Pounds Reduced** | **Cost to Reduce Pound of TP** | **Sediment bound pollutants (particulate) and nutrients** | **Dissolved pollutants and nutrients** |
| Riparian Forest Buffer on Pasture with Exclusion Fencing | High | Low | X | X |
| Riparian Herbaceous Cover on pasture with fencing | High | Low | X | |
| Riparian Forest Buffer Narrow with Exclusion Fencing | Medium | Low | X | |
| Heavy Use Area Protection | Medium | Low | X | |
| Riparian Herbaceous Cover-Narrow on pasture with Exclusion Fencing | Medium | Low | X | |
| Roof Runoff Structure | Medium | Low | X | |
| Riparian Herbaceous Cover Narrow on cropland | Low | Low | X | |

https://dec.ny.gov/sites/default/files/2024-08/tmdl_phos_cayuga.pdf

https://stormwater.pca.state.mn.us/index.php?title=Phosphorus_in_stormwater

WIKI

Minnesota Stormwater Manual

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## Phosphorus in stormwater

This page provides general information

The United States Geological Survey states: "Phosphorus is a common constituent of agricultural fertilizers, manure, [urban runoff], and organic wastes in sewage and industrial effluent. It is an essential element for plant life, but when there is too much of it in water, it can speed up eutrophication (a reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients) of rivers and lakes." Phosphorus in stormwater runoff can generally be divided into the fraction associated with sediment, called particulate phosphorus, and the fraction dissolved in water, called dissolved or soluble phosphorus. Total phosphorus is the sum of particulate and dissolved phosphorus and includes the total amount of phosphorus in both organic and inorganic forms. Orthophosphate measures phosphorus that is most immediately biologically available. Most of the soluble phosphorus in stormwater is usually present in the orthophosphate form.

Photo of a eutrophic lake, a result of excessive phosphorus loading.

This article provides information on phosphorus in urban stormwater, including a discussion of sources of phosphorus and management strategies for minimizing phosphorus loading from urban stormwater runoff to surface water. For more information on phosphorus in water, click on these links: [1], [2], [3], [4], [5].

## Conclusions

1. P is a key nutrient that often limits algae and cyanobacteria growth
2. Generally, soluble forms of P are more bioavailable than particulate forms
3. Bioavailability is highly variable within and between non-point sources and point sources;
4. Bioavailability in clean water planning is an emerging area of management;
5. Reducing soluble forms of phosphorus to waterbodies is always a better strategy to reduce bioavailable P, but
6. Particulate phosphorus reductions will always be necessary to prevent erosion losses and meet water quality goals and targets;

Advancing the bioavailability concept into future monitoring and management programs for effective, efficient watershed management to control algae and cyanobacteria is supported


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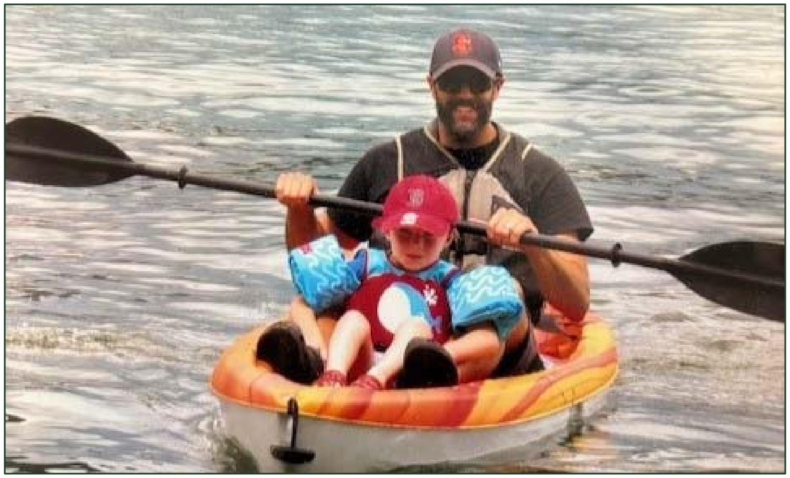

NEW YORK STATE

Department of Environmental Conservation

# Quantifying Bioavailability

from Baker et al. 2014

<u>Chemical Extractions</u>

- TP → six categories!
- Based on ease of extraction

\+ Cost-effective

\+ Less labor, analysis time

\- Not a direct measure of algal response

\- Can be limited analytically