Understanding Sediment Oxygen Demand in the Delaware River Estuary
Impacts, Insights and Uncertainties

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The following slides describe ongoing staff research as of February 10, 2025, and do not necessarily reflect policies or proposals of the Delaware River Basin Commission.

This presentation is provided as a contribution to an ongoing dialogue in the spirit of advancing collective understanding of environmental processes.
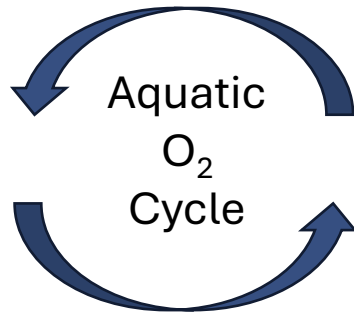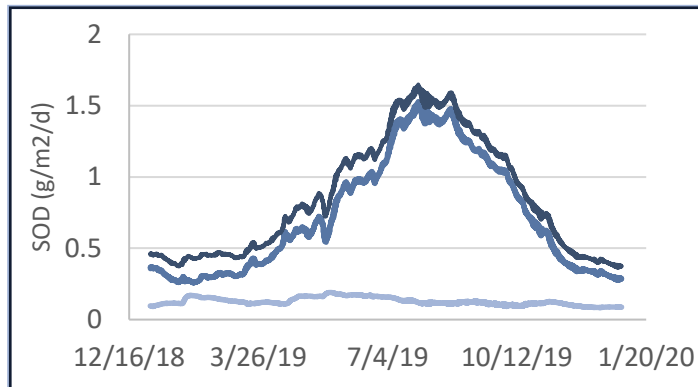
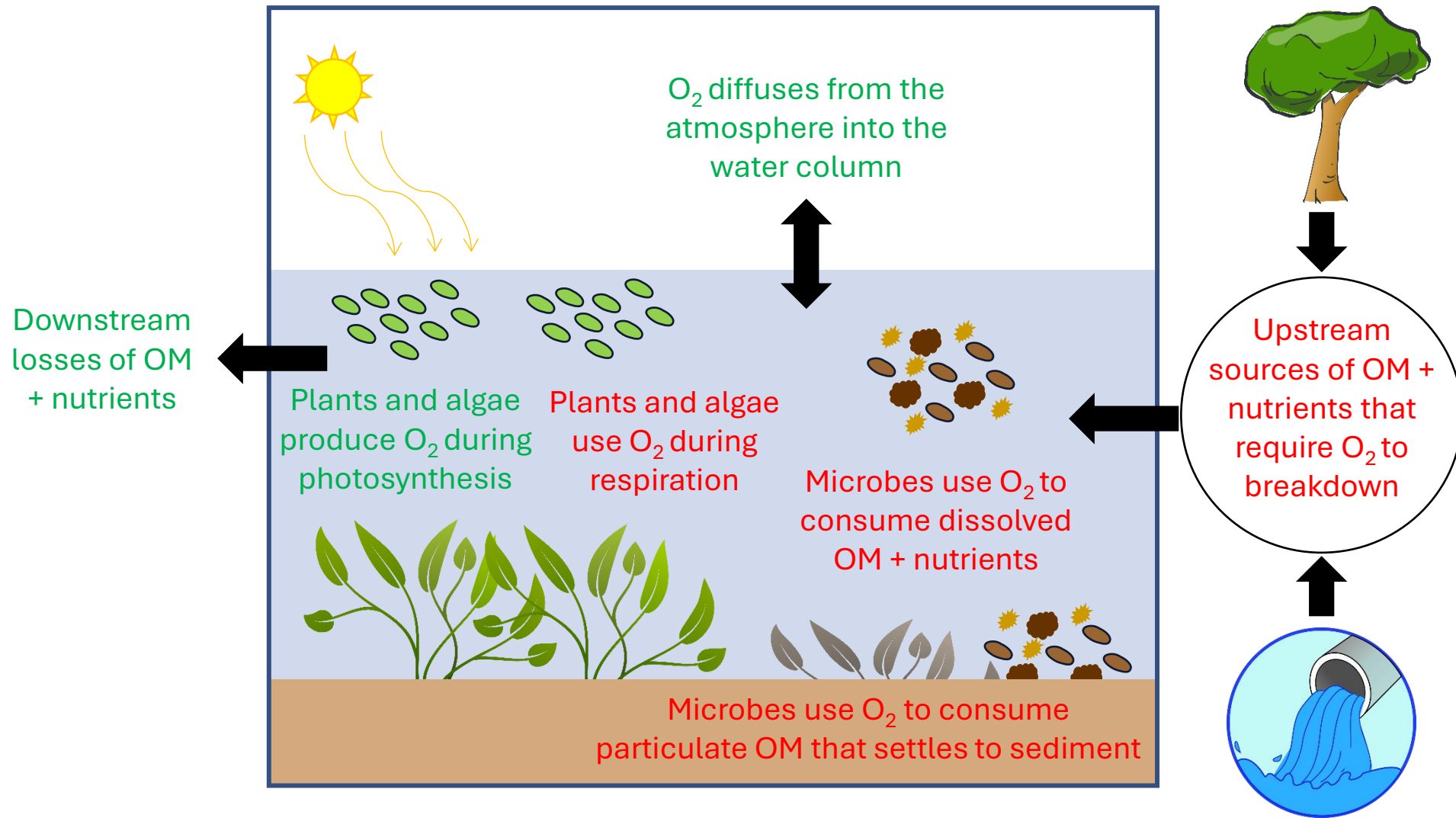What is SOD? What are its drivers? How is it represented in WQ models?
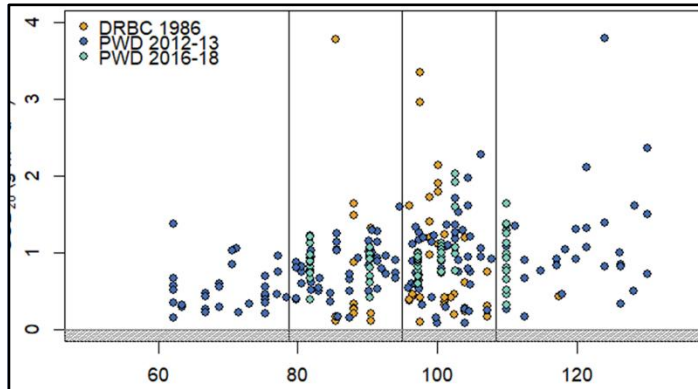
What do we know about SOD in the Delaware River Estuary? Has it changed over time?

What information do we need to model SOD? Where are the largest sources of uncertainty?
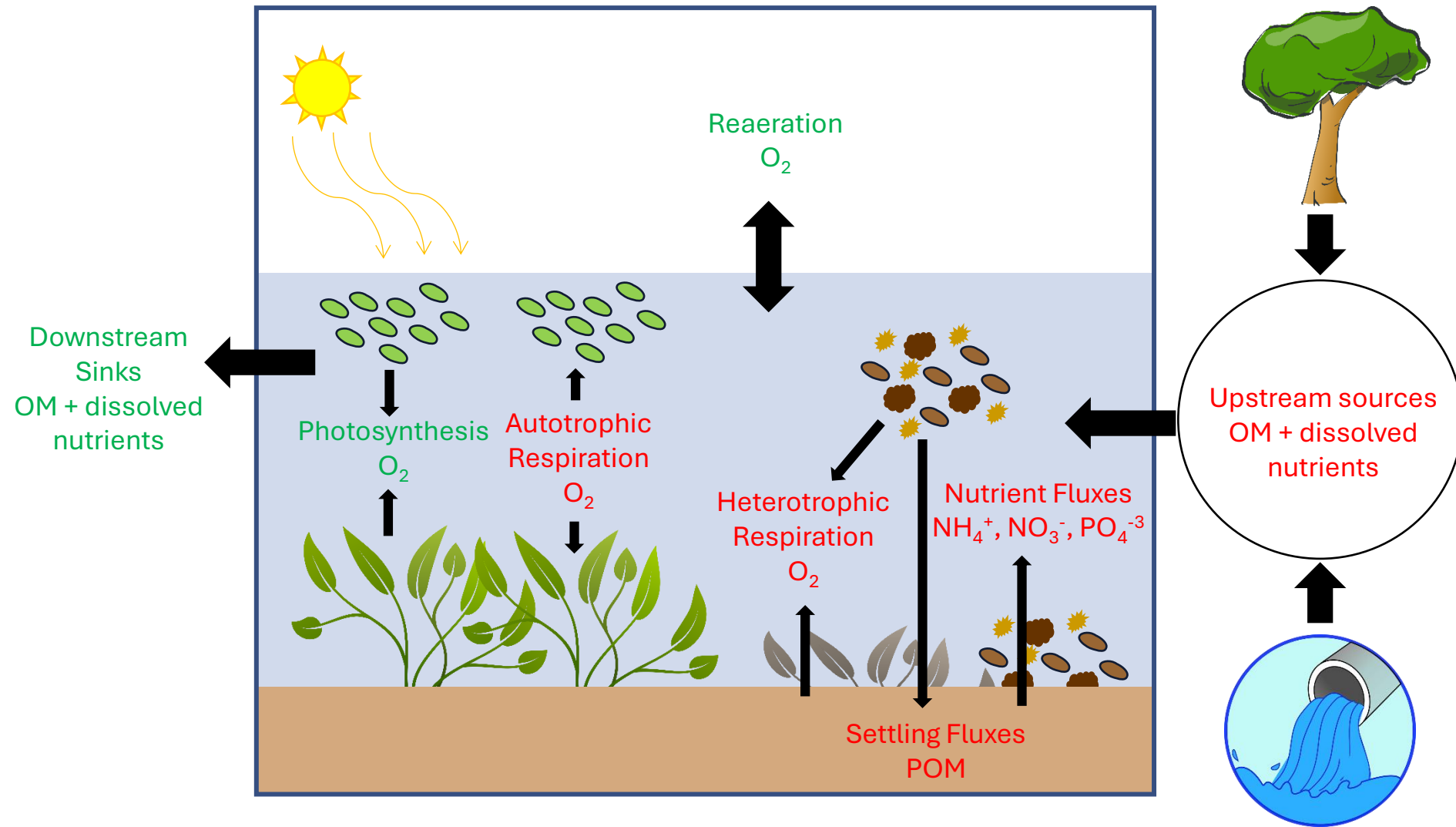
O$_2$ Cycle in Aquatic Environments

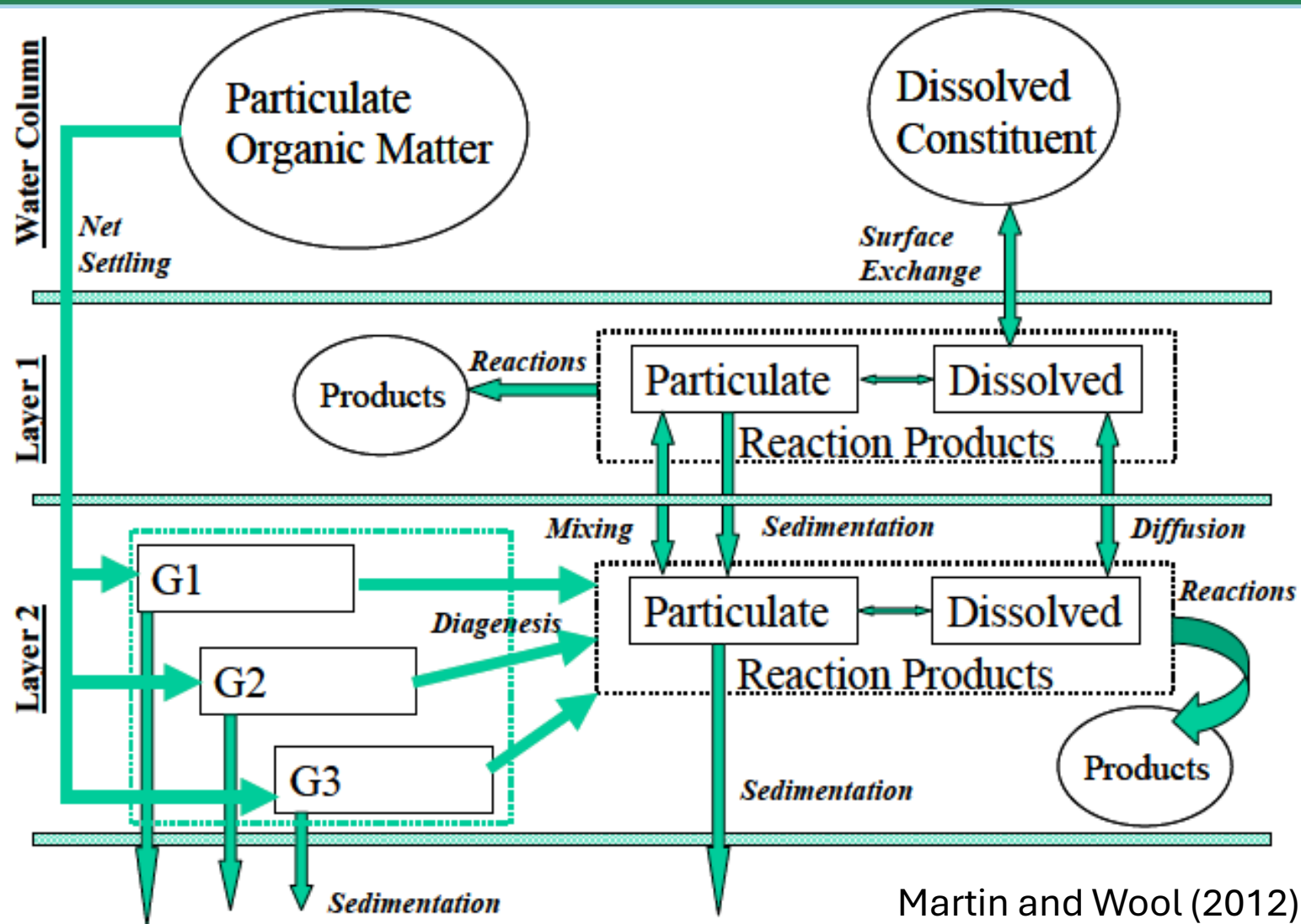Sediment organic matter is a major sink of O$_2$ and source of nutrients in aquatic environments

O$_2$ diffuses from the atmosphere into the water column

Downstream losses of OM + nutrients

Plants and algae produce O$_2$ during photosynthesis

Plants and algae use O$_2$ during respiration

Microbes use O$_2$ to consume dissolved OM + nutrients

Microbes use O$_2$ to consume particulate OM that settles to sediment

Upstream sources of OM + nutrients that require O$_2$ to breakdown

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O$_2$ Cycle in Aquatic Environments

SOD is driven by settling fluxes of internally- and externally-sourced organic matter

Reaeration O$_2$

Downstream Sinks OM + dissolved nutrients

Photosynthesis O$_2$

Autotrophic Respiration O$_2$

Heterotrophic Respiration O$_2$

Nutrient Fluxes NH$_4^+$, NO$_3^-$, PO$_4^{-3}$

Settling Fluxes POM

Upstream sources OM + dissolved nutrients

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Dynamic SOD predictions enable understanding of future changes (i.e., wasteload allocations)


Martin and Wool (2012)

Dynamic SOD predictions enable understanding of future changes (i.e., wasteload allocations)

Reaeration

Water Column Oxygen Demand

Sediment Oxygen Demand(?)
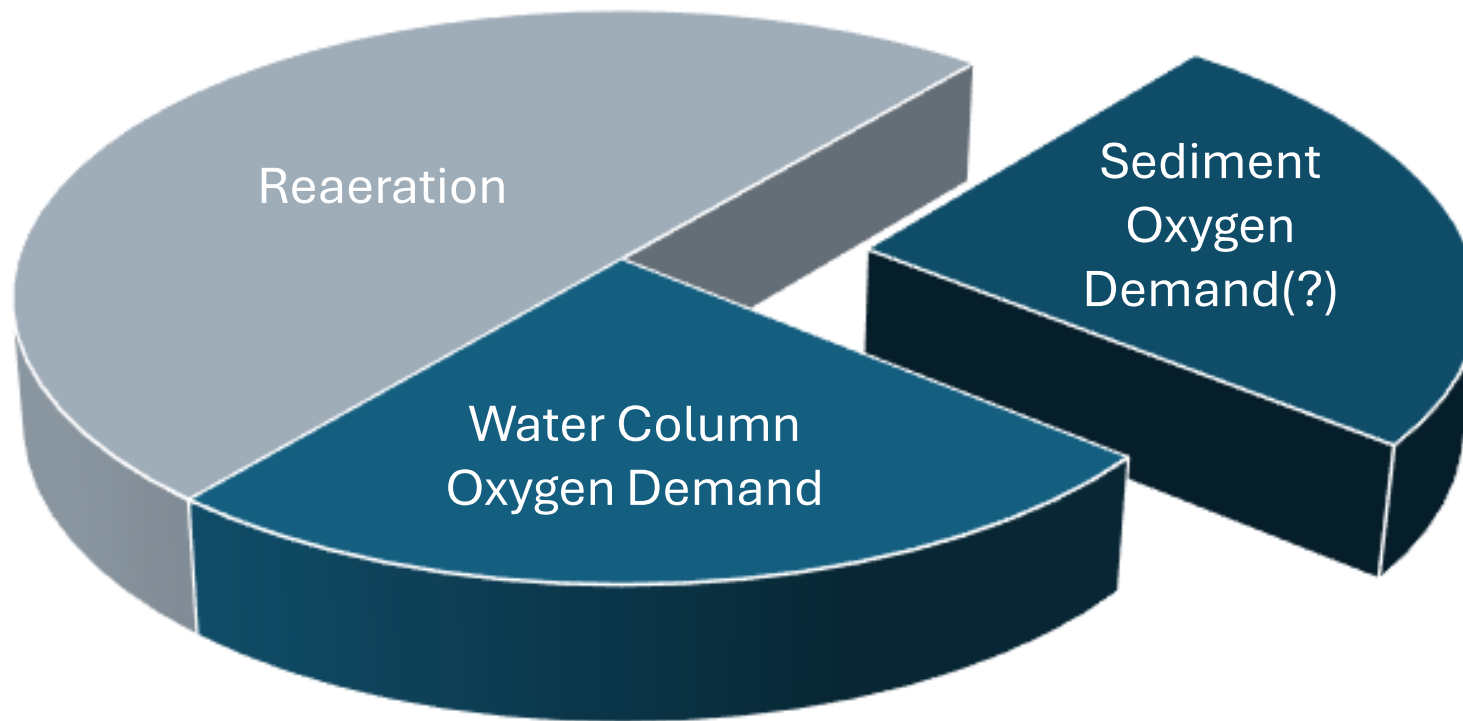
Alternative is to prescribe SOD based on measurements (expensive) or calibrate to water column DO (common)

If we prescribe SOD, we assume it will not change with changing organic fluxes!!
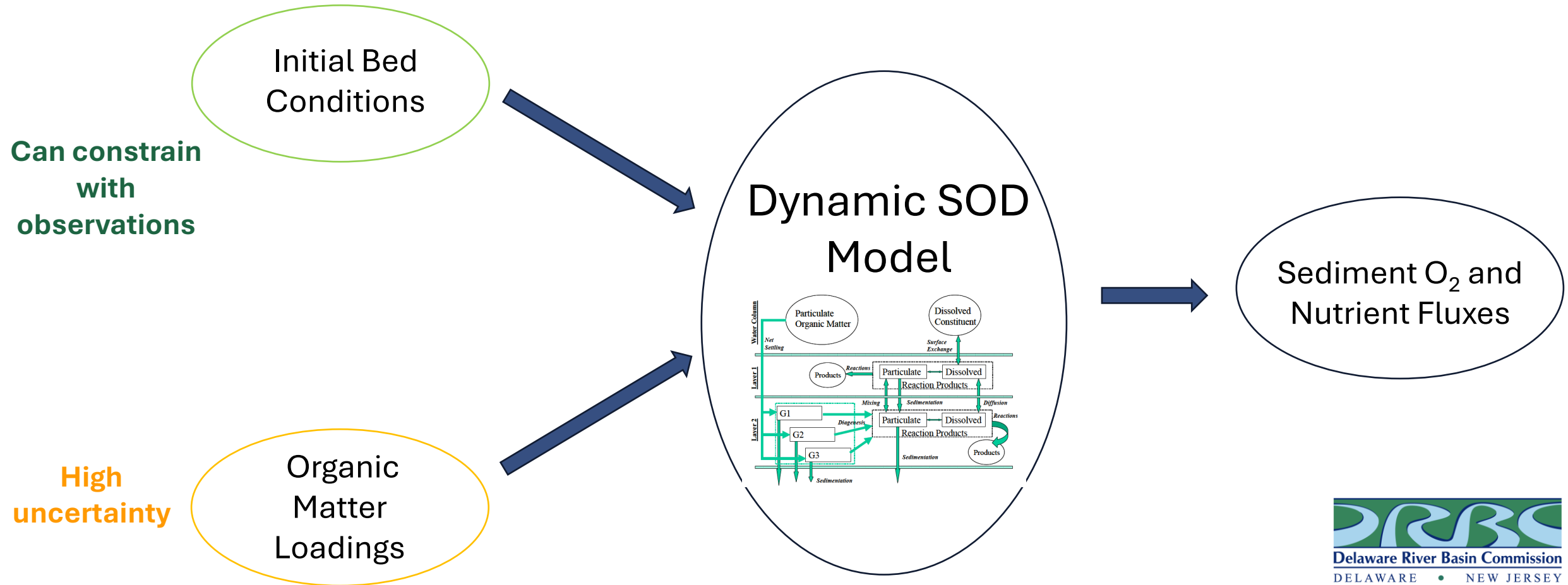
On average, SOD increases as you move upstream, but the trend has not changed much over the last 30+ years
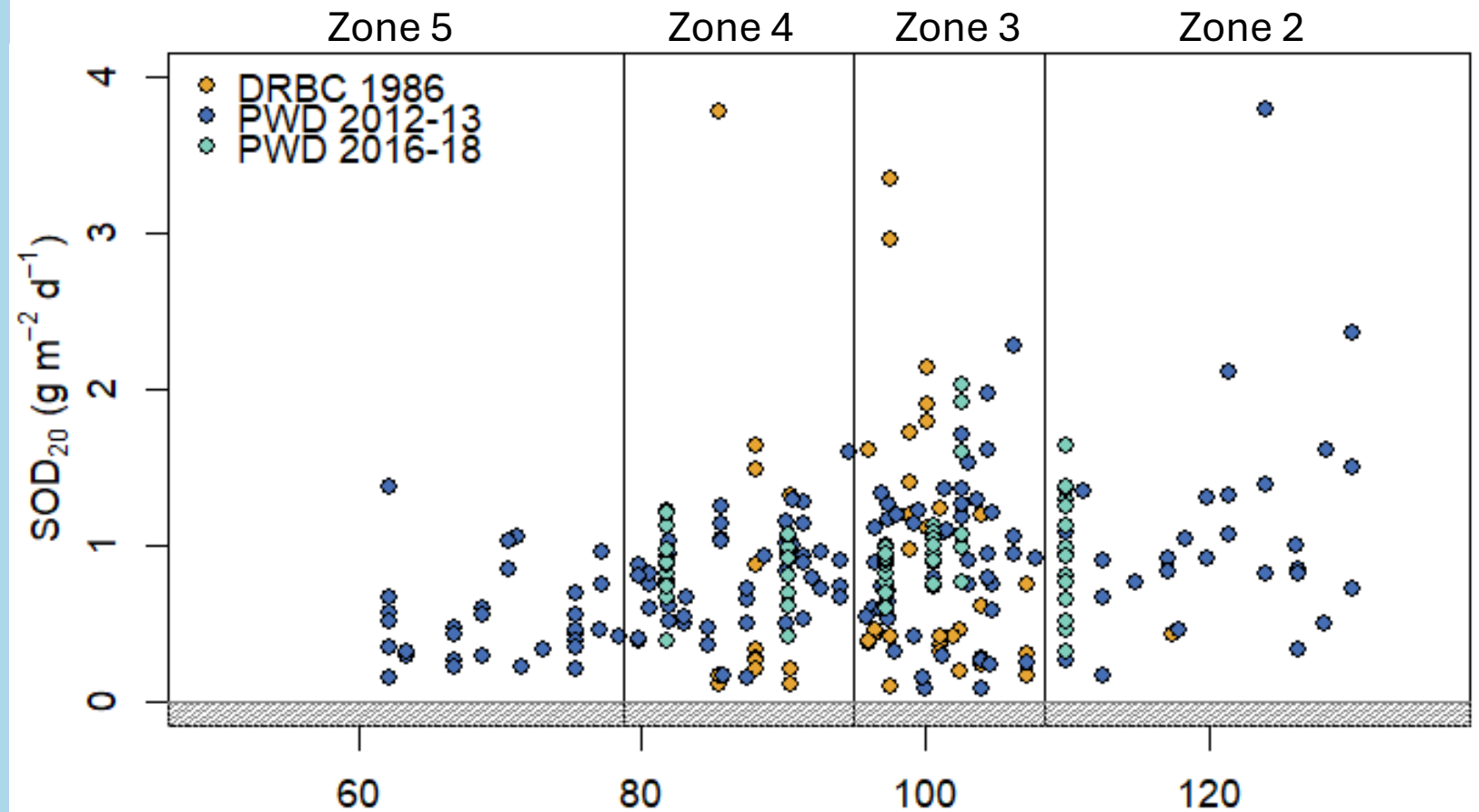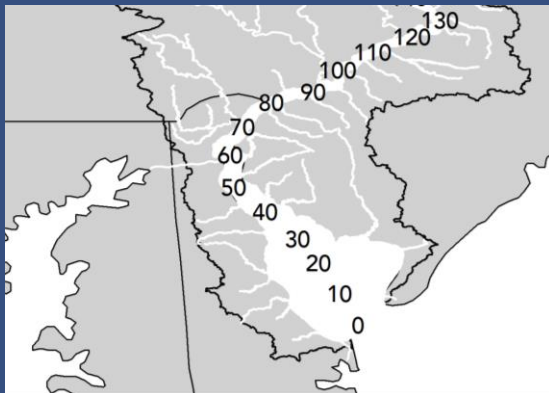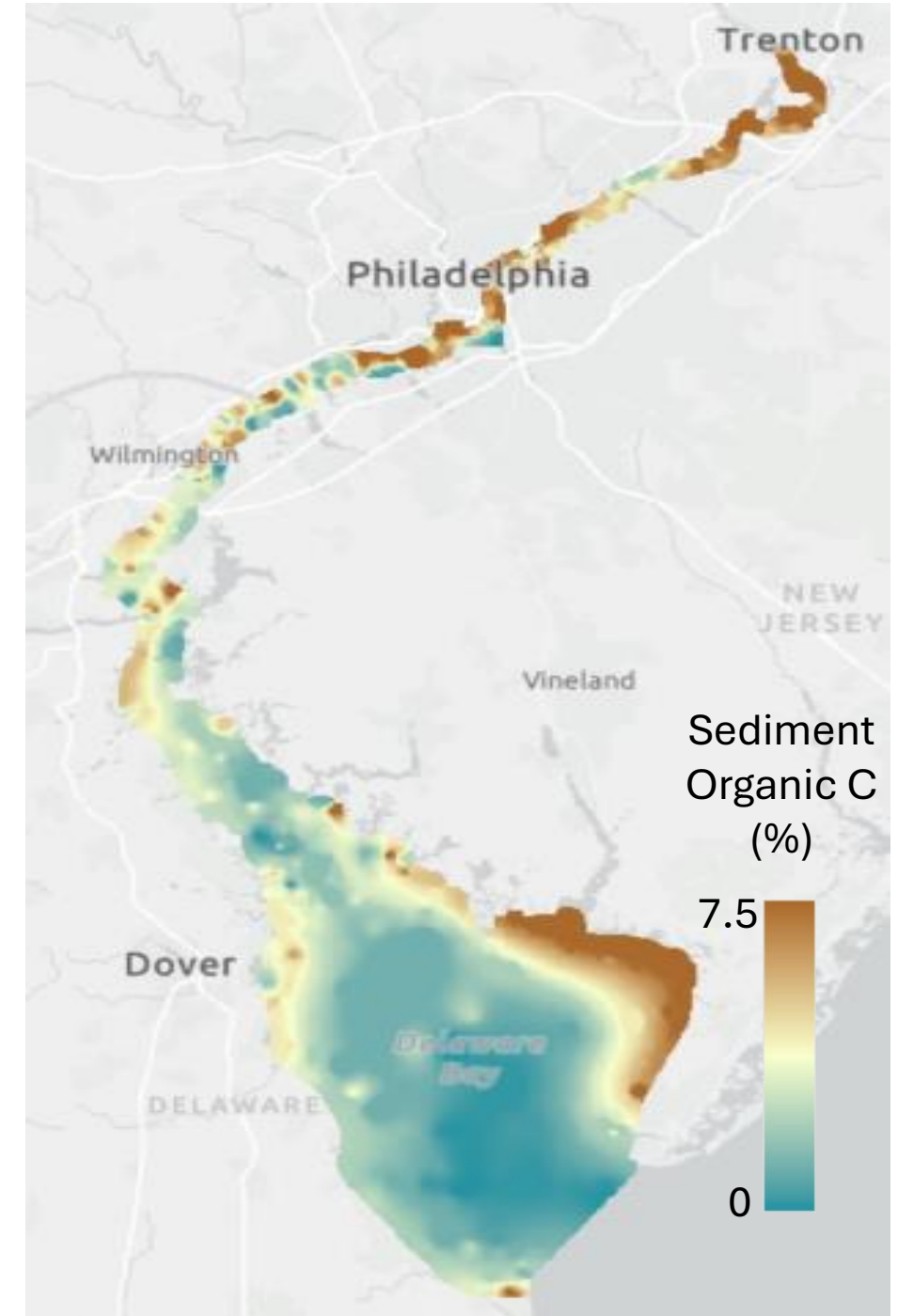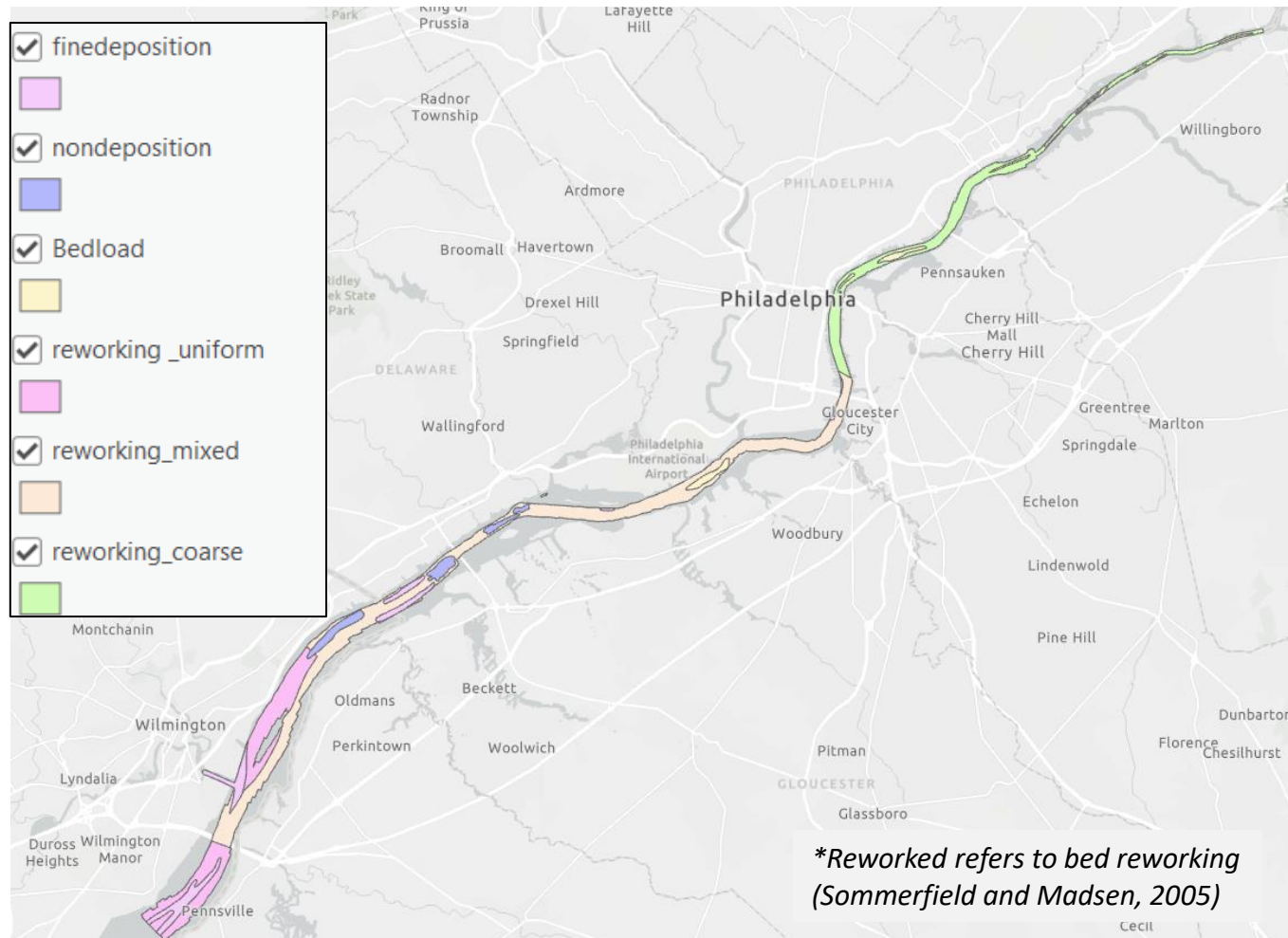
Evidence suggests that improvements in water quality since the 1980s may have had a positive impact in depositional areas
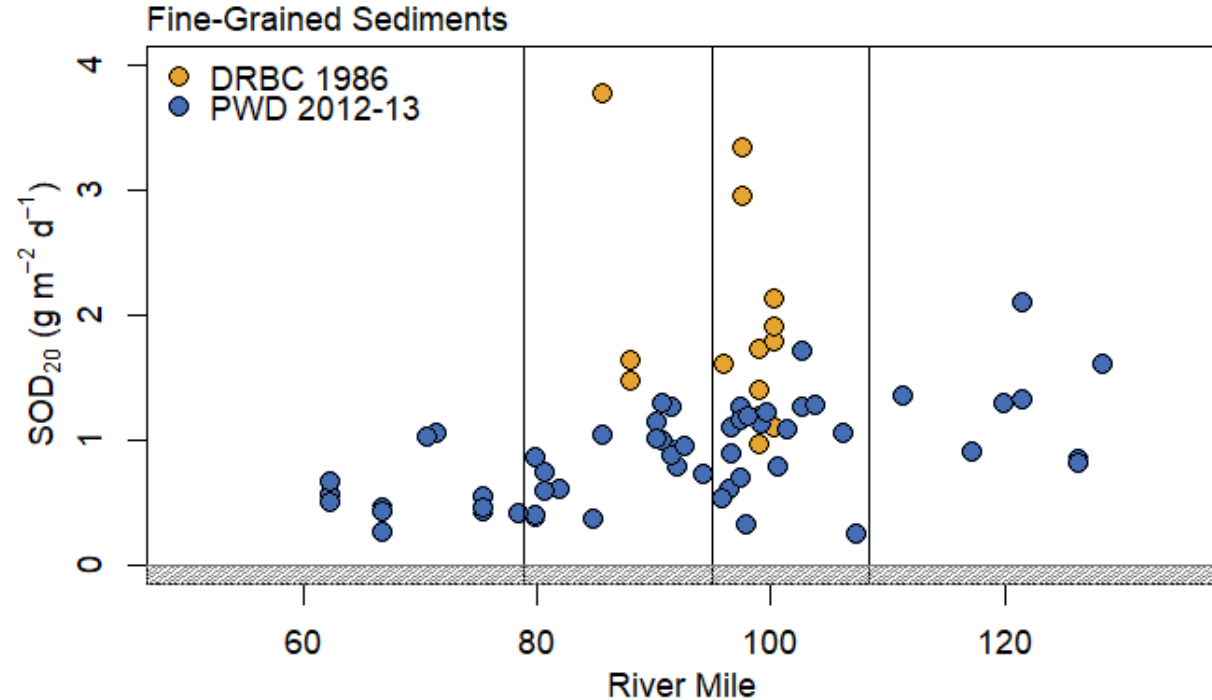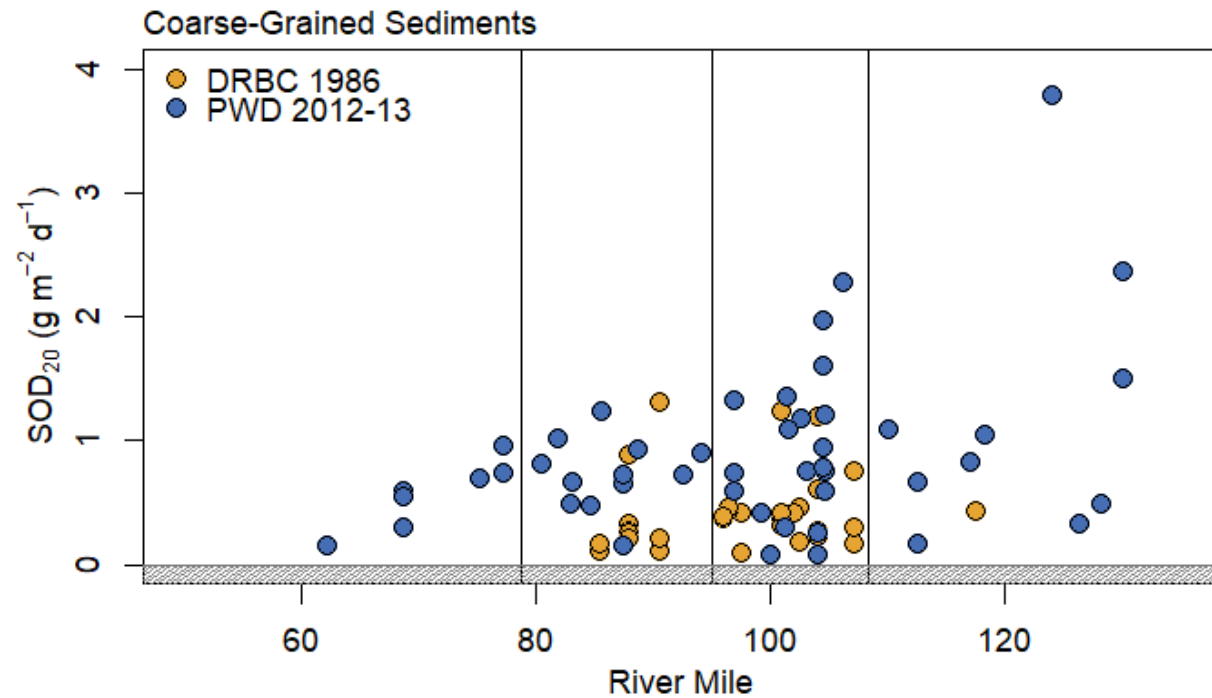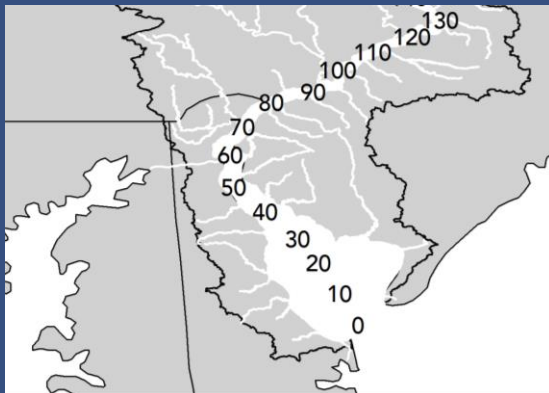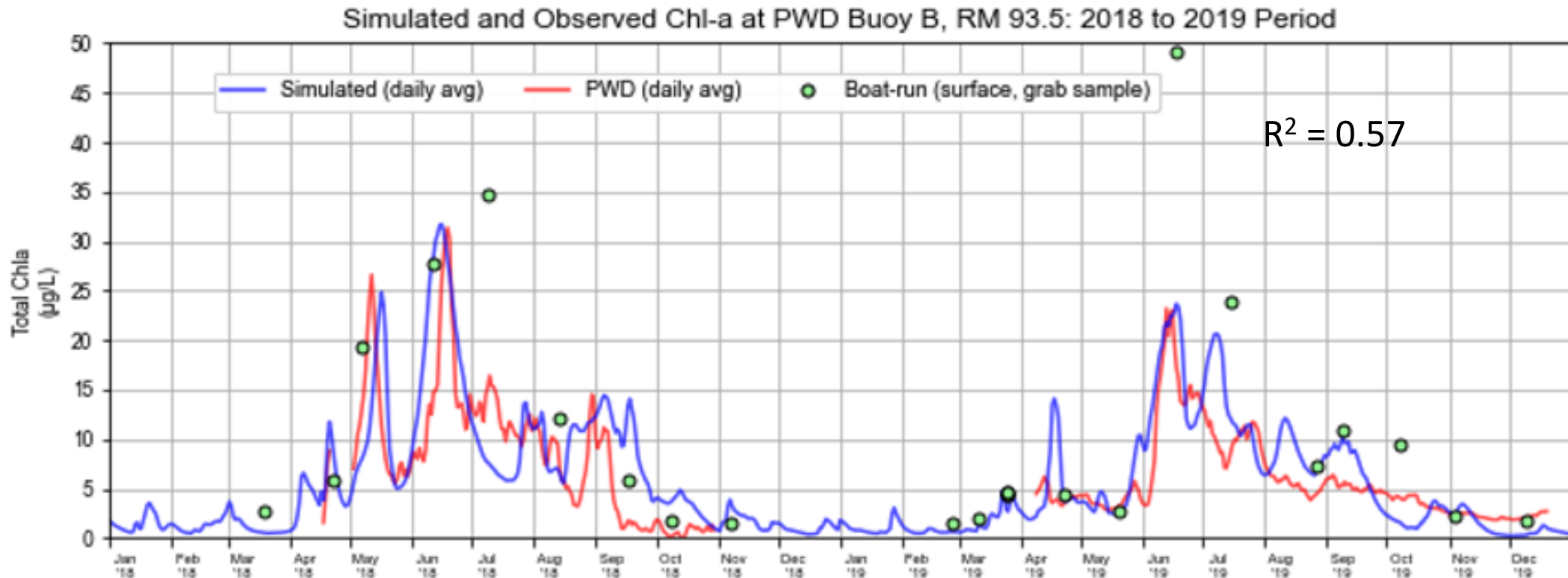
Goal is to predict SOD dynamically based on loads and bed conditions

Sediment maps define long-term bed conditions

Reworked refers to bed reworking (Sommerfield and Madsen, 2005)

Our ability to simulate internal organic matter production has vastly improved

Simulated and Observed Chl-a at PWD Buoy B, RM 93.5: 2018 to 2019 Period

$R^2 = 0.57$

The explanatory power of the model near Philadelphia increased by 38% since the previous round of calibration
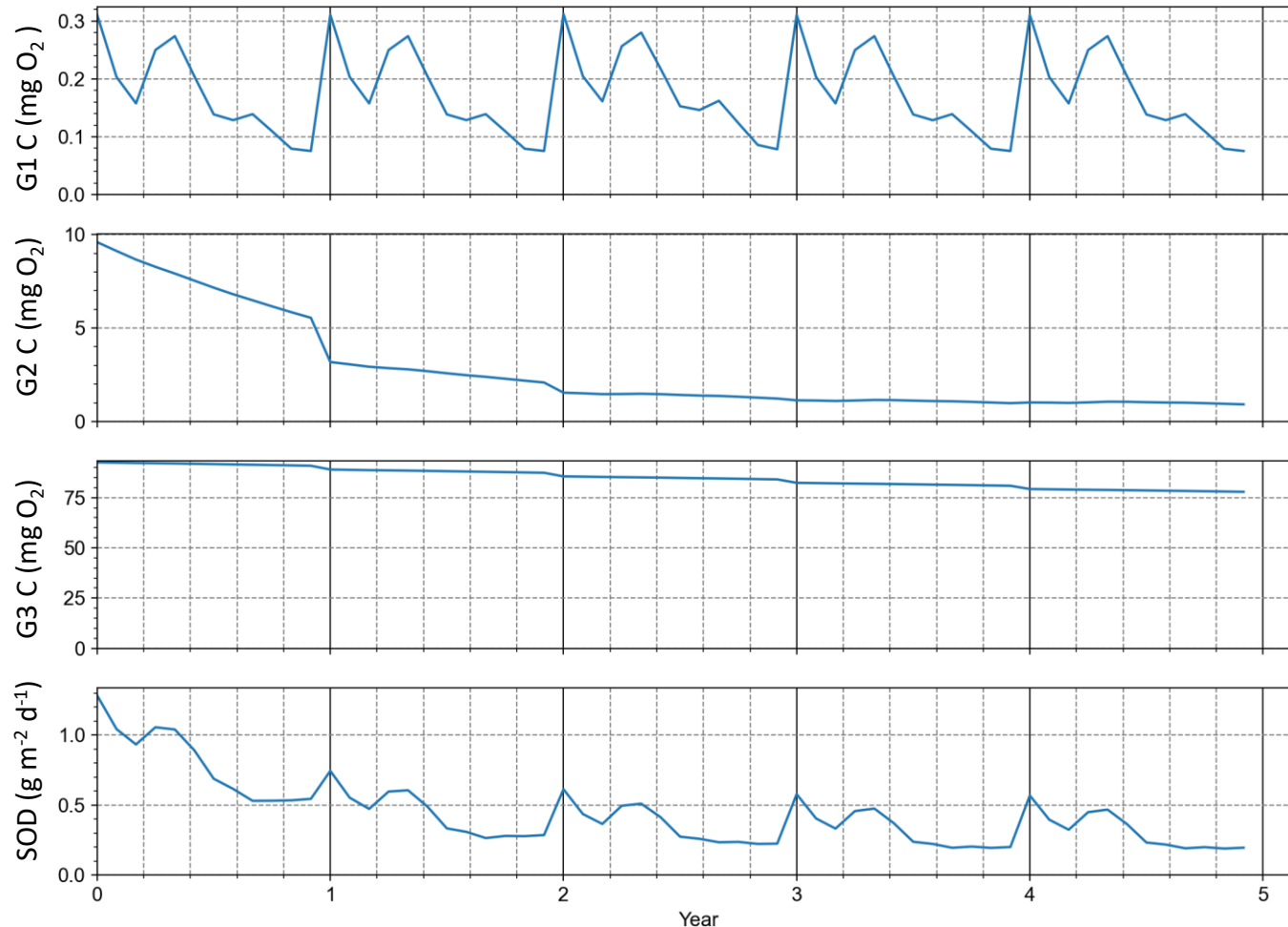
... but organic matter loads still likely underestimated as they cannot maintain SOD

POC (G Class 1-3) and SOD Time Series at Ben Franklin, RM 100
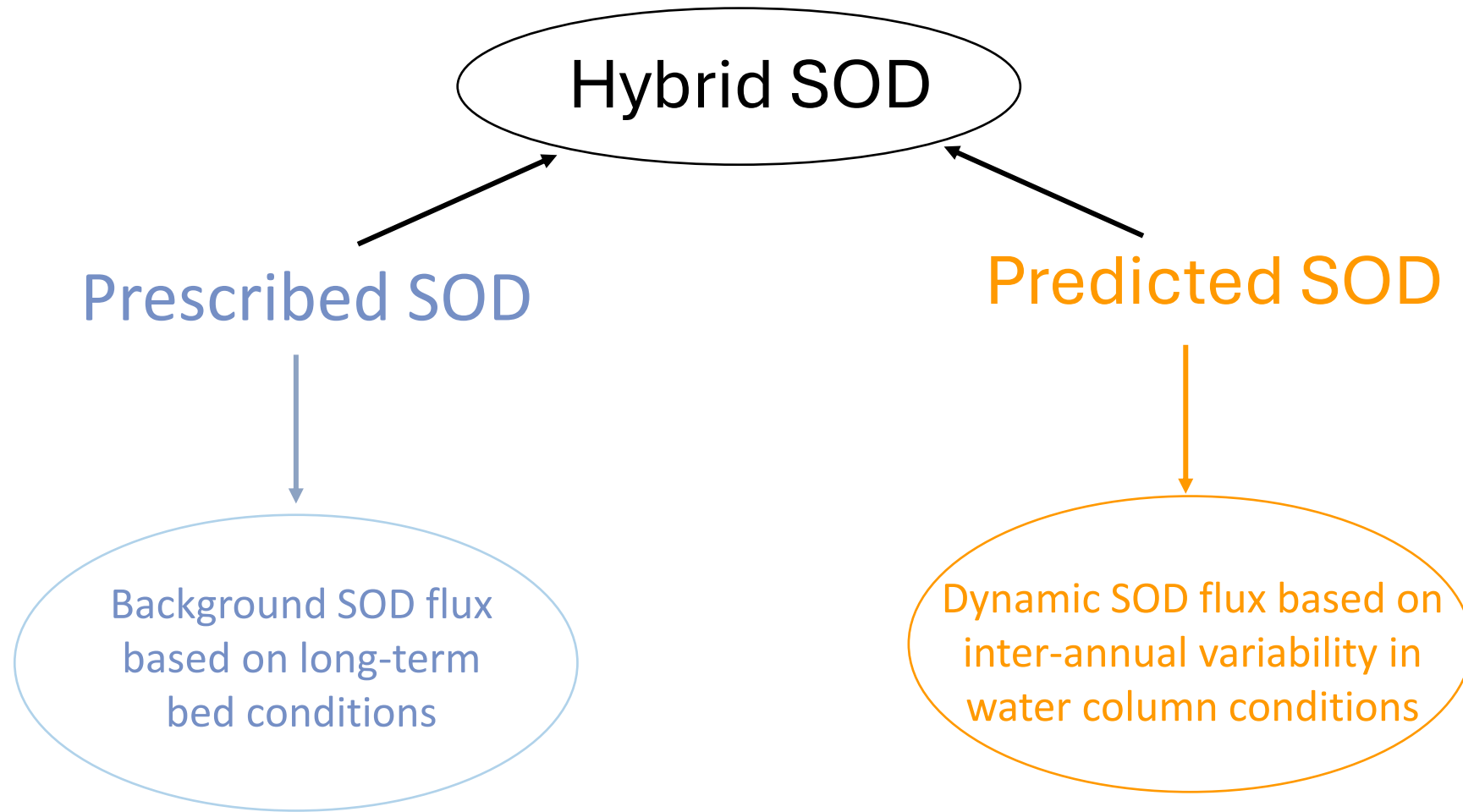
Labile OM

Refractory OM

What is missing from the model?
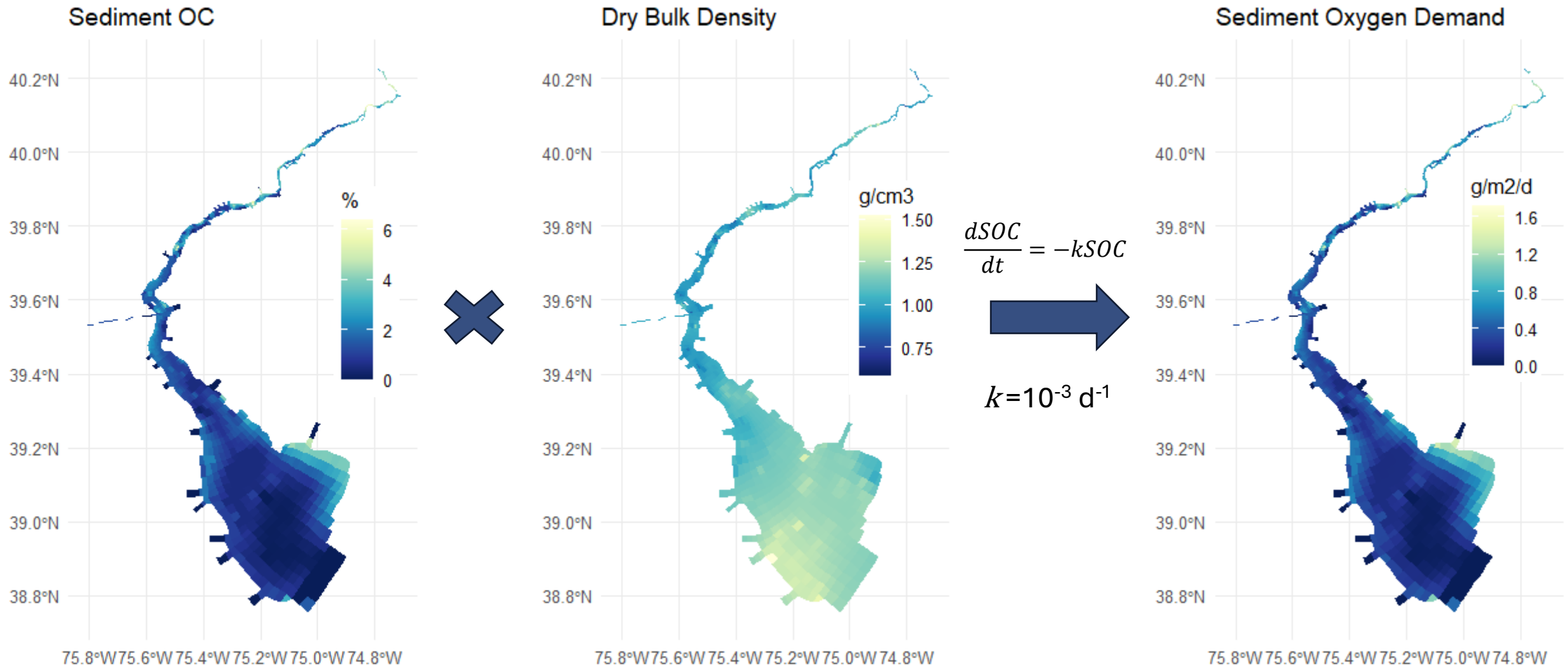1. Extreme loading events
2. Bank/Marsh loads

What is missing from our data?
1. Large OM particles (e.g., leaves)
2. High-frequency sampling
3. Bed load

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Our plan going forward…

Hybrid SOD

Prescribed SOD

Predicted SOD

Background SOD flux based on long-term bed conditions

Dynamic SOD flux based on inter-annual variability in water column conditions

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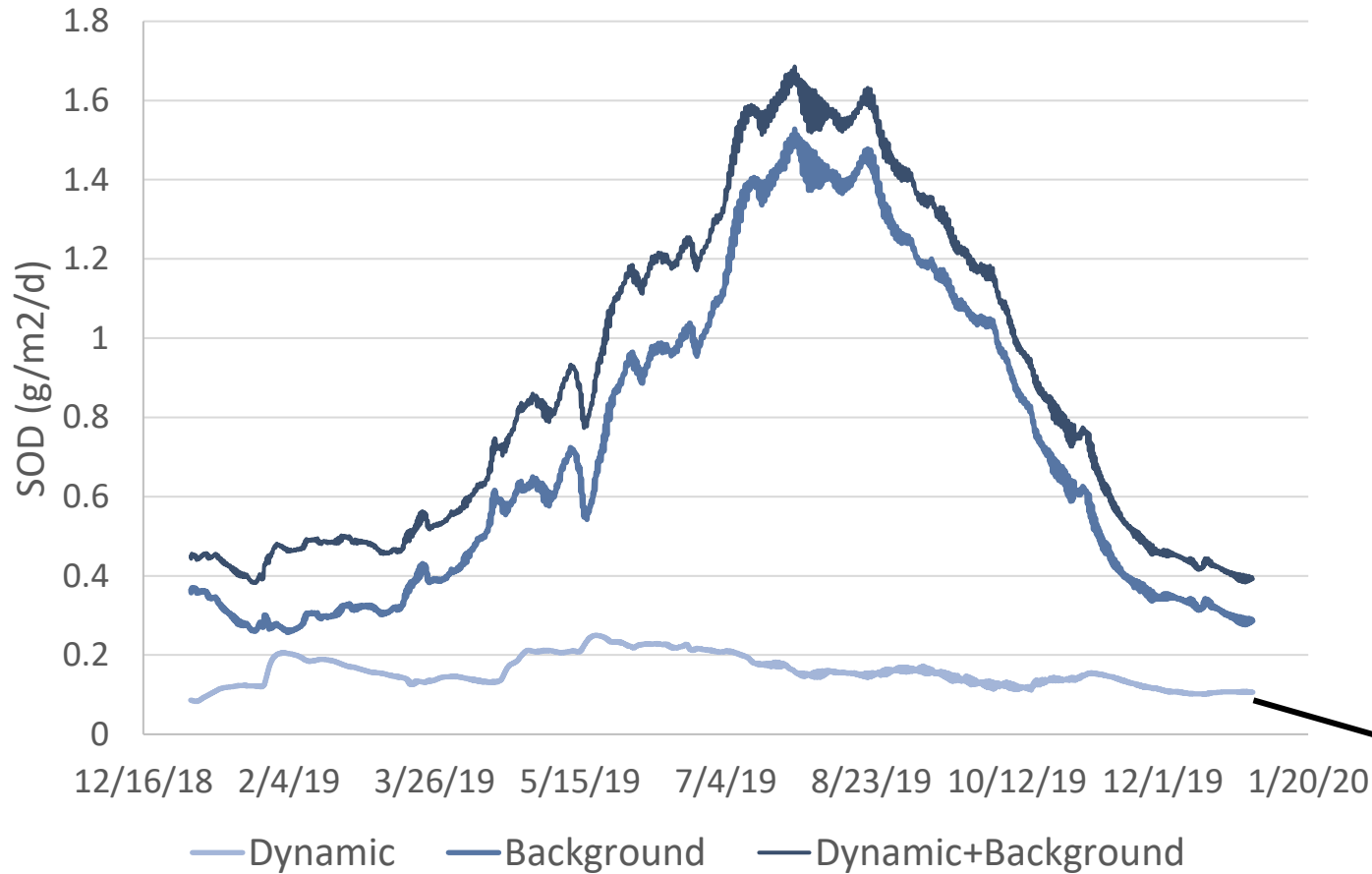
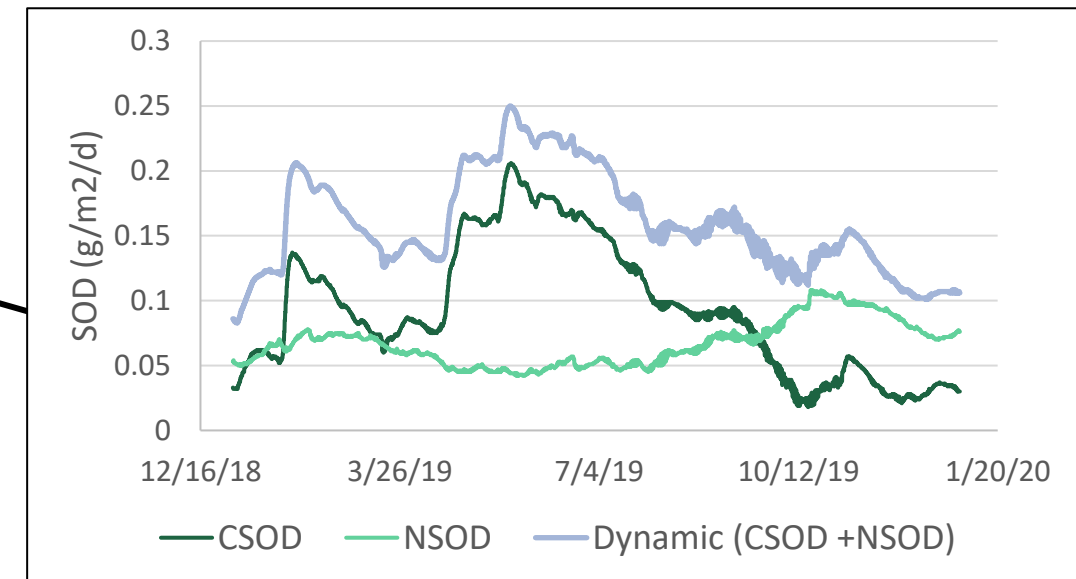# Background SOD can be constrained by sediment composition maps

SOD is the correct magnitude, but mostly due to the 'prescribed' component

Simulated SOD @ 20° C: 1.05 g $O_2/m^2/d$

Measured SOD @ 20° C : 0.953 $O_2/m^2/d$
(based on 2016-2018 data from PWD)

Recap

- **Significance:** SOD is one of the major oxygen sinks within the DRE

- **Driving Forces:** SOD is fueled by the influx of organic matter into sediments

- **Water Quality Impact:** By improving SOD predictions, we hope to better simulate the impact of management actions

- **Modeling Challenges:** Closing the mass balance of organic matter within the estuary is the top priority to accurately model SOD

- **Moving Forward:** The DRBC plans to implement a hybrid modeling approach that partitions the SOD rate into contributions from short- and long-term turnover of organic matter

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Questions?
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