Jordan Lake Watershed and Water Quality Modeling to Assess Eutrophication Trends under Historical and Projected Scenarios

Nutrient Scientific Advisory Board meeting

2 Nov 2018

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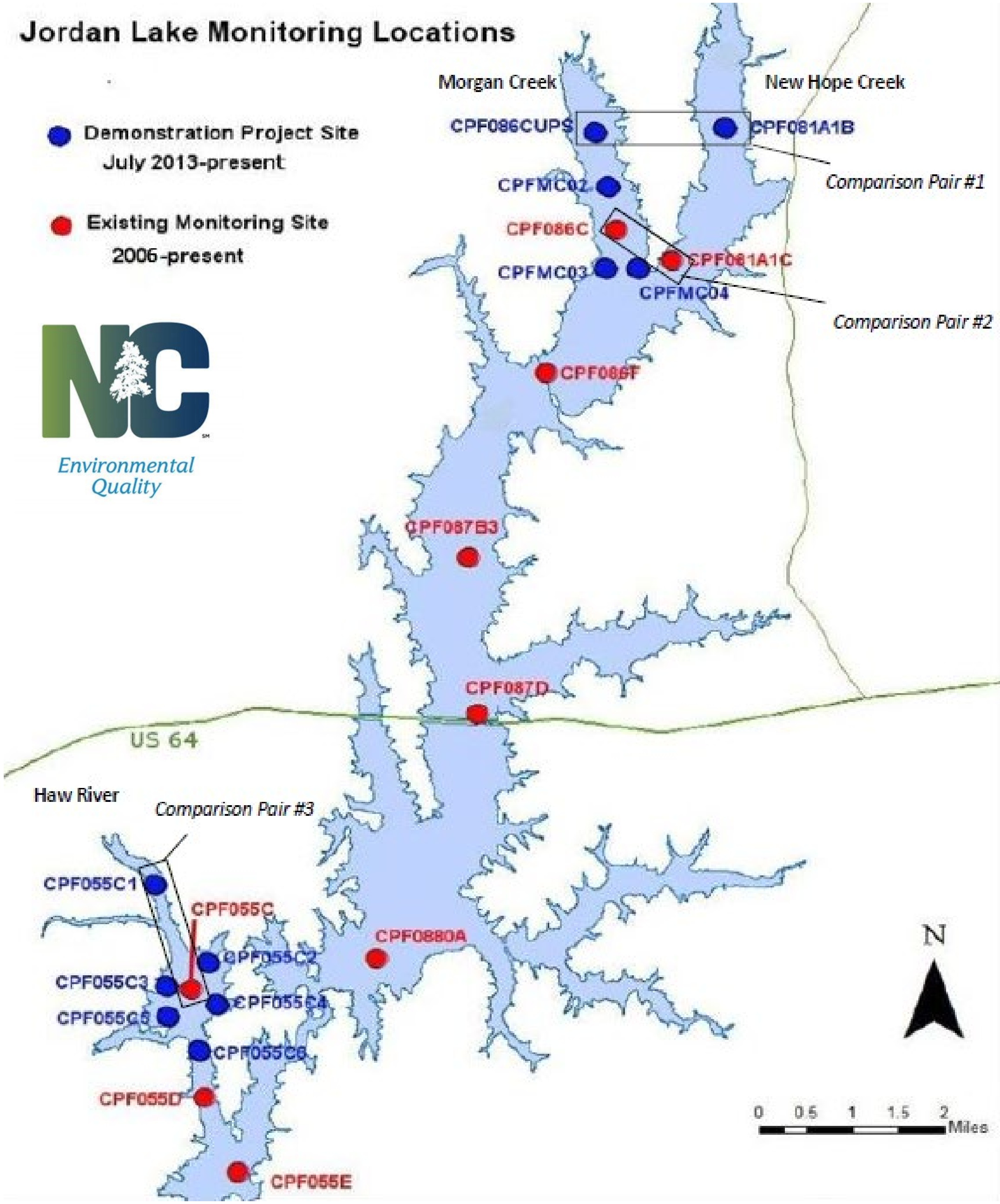
Presenter: Jonathan Miller

Outline

- Previous Jordan Lake research
- Bayesian modeling framework
- Hybrid Watershed modeling
- Jordan Lake water quality modeling

Previous Work (2015-2018)

Solar-powered surface-layer circulator on Jordan Lake



Environmental Quality

Characterizing Vertical Mixing in northern Jordan Lake (2015-2017)

Primary field team:
D. Obenour, R. Smyth,
J. Smithheart, T. Aziz.

Physical Measurements:

- SCAMP: Self-Contained Autonomous Micro Profiler.
- Dye Study: Rhodamine WT dye releases.
- Thermistor Strings: Continuous temperature profile monitoring.

Water Quality Measurements:

- Sonde: CTD, O_2, pH, chlorophyll, and phycocyanin
- NCDEQ DWR coordination (+nutrients +phytoplankton community)

Major findings

SCAMP Analysis of Diffusion

- SCAMP results showed circulators have a ~ 10m radius footprint.

Mechanistic Vertical Diffusion Model

- On average, natural (wind-induced) mixing overwhelms artificial mixing in all seasons.
- Artificial mixing can theoretically suppress cyanobacteria, but the degree of mixing required may not be realistic for large reservoirs.

Statistical Algal Bloom Prediction Model

- Vertical mixing (primarily natural) is negatively related to cyanobacteria biovolume, but positively related to overall chlorophyll concentration.

Bayesian modeling framework

1) Systematic approach to incorporate prior information

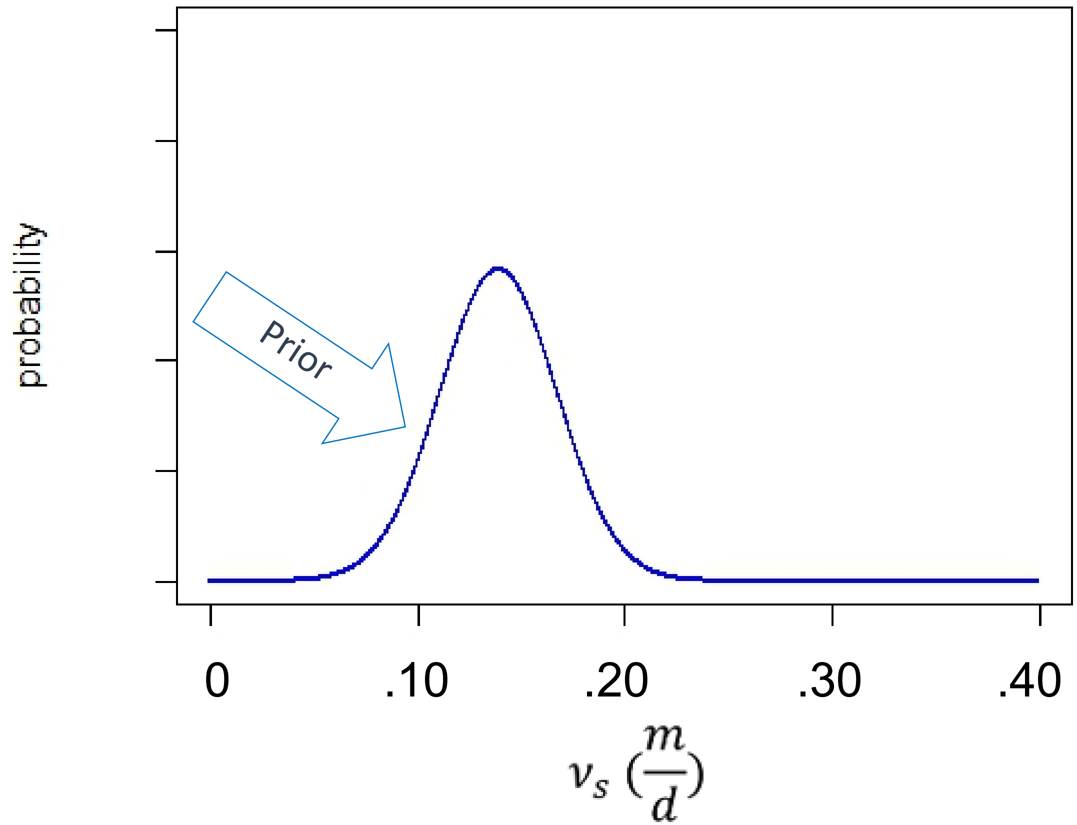
2) Rigorous uncertainty quantification

3) Flexibility to incorporate mechanistic (non-linear and dynamic) relationships

4) Probabilistically test hypothesis about water quality drivers.

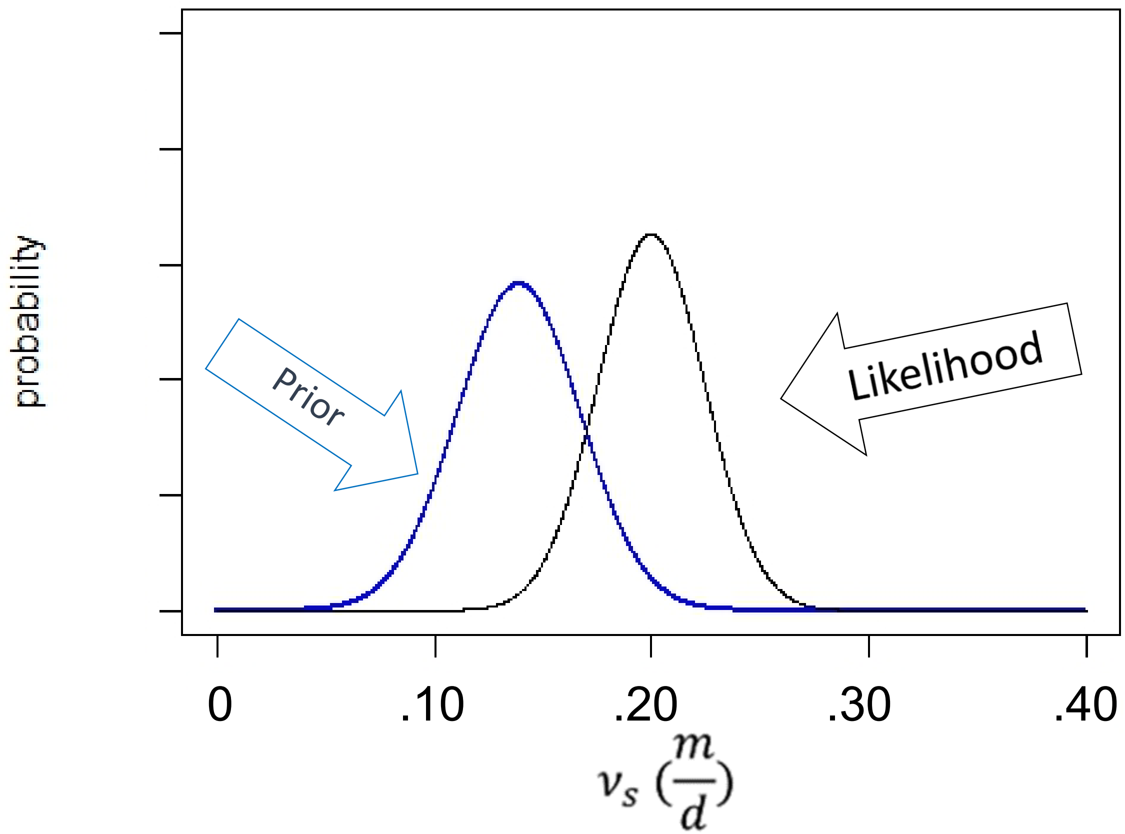
Bayesian modeling

Prior belief – distribution previous research implies for a parameter (e.g., export coefficient)



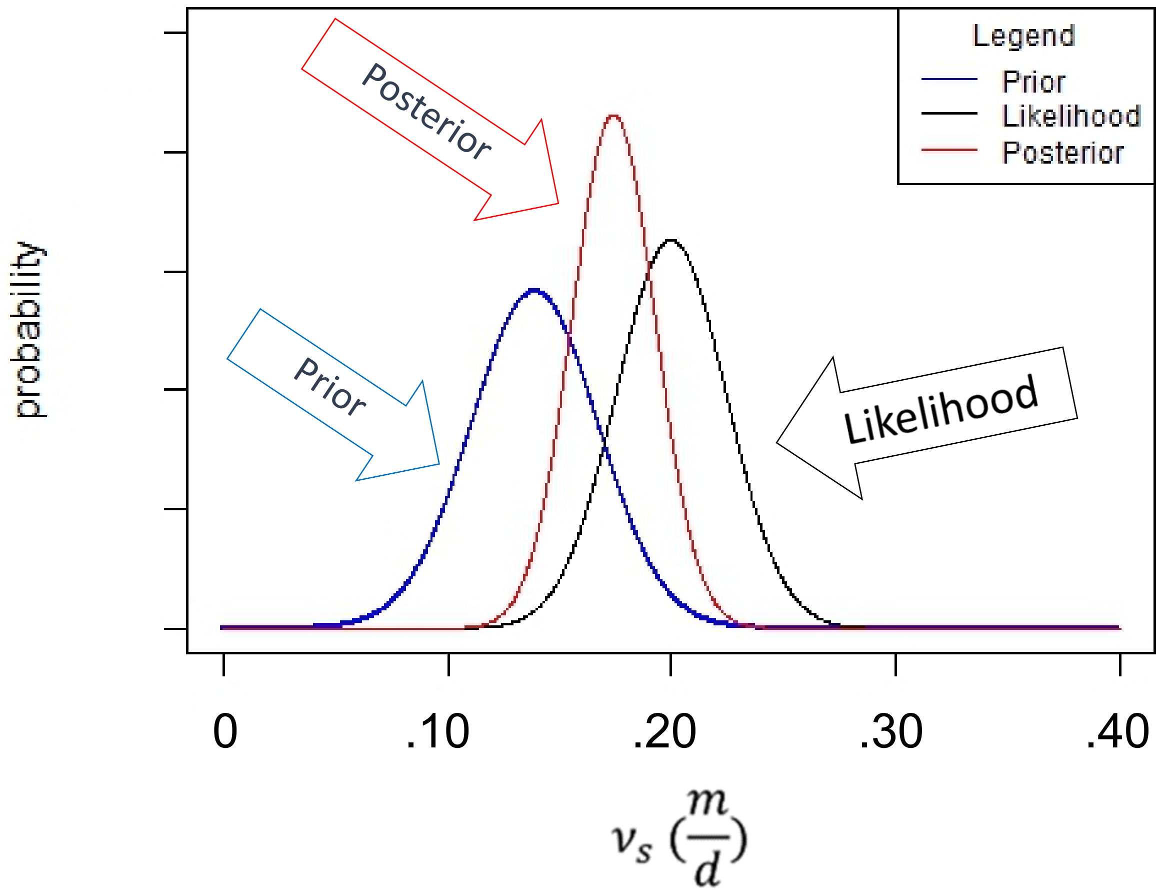
Bayesian modeling

Prior belief – distribution previous research implies for a parameter (e.g., export coefficient)
Likelihood – distribution that model and data imply about the parameter

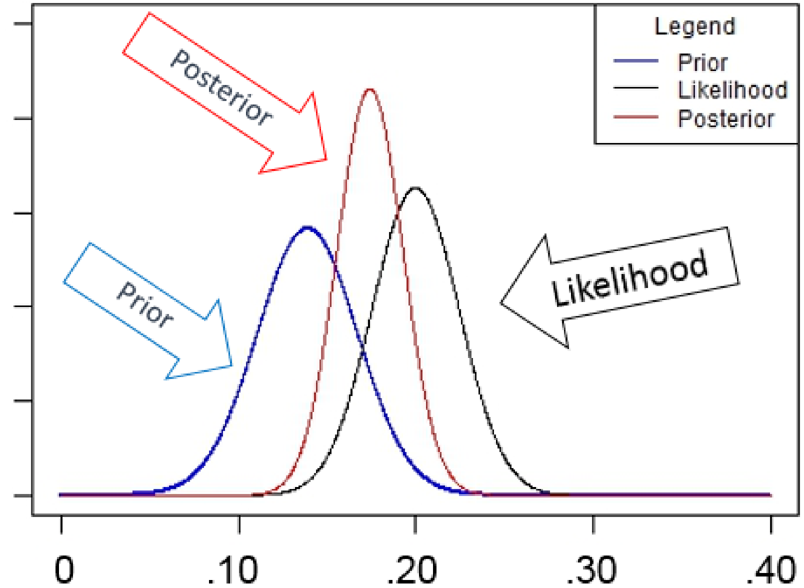


Bayesian modeling

Prior belief – distribution previous research implies for a parameter (e.g., export coefficient)
Likelihood – distribution that model and data imply about the parameter
Posterior – final distribution for the parameter



Bayesian modeling



A) Prior information (rates)
- Bioassays of N and P limitation (Paerls)
- Benthic fluxes (Alperin)
- Effect of LID on nutrient export (Hunt)

B) Likelihood (model and calibration data)
- Water quality data (NC DEQ and USGS)
- Flow data (USGS)
- Flow velocity profiles (Luettich)
- Revised bathymetry (Rodriguez)

Hybrid Watershed Modeling

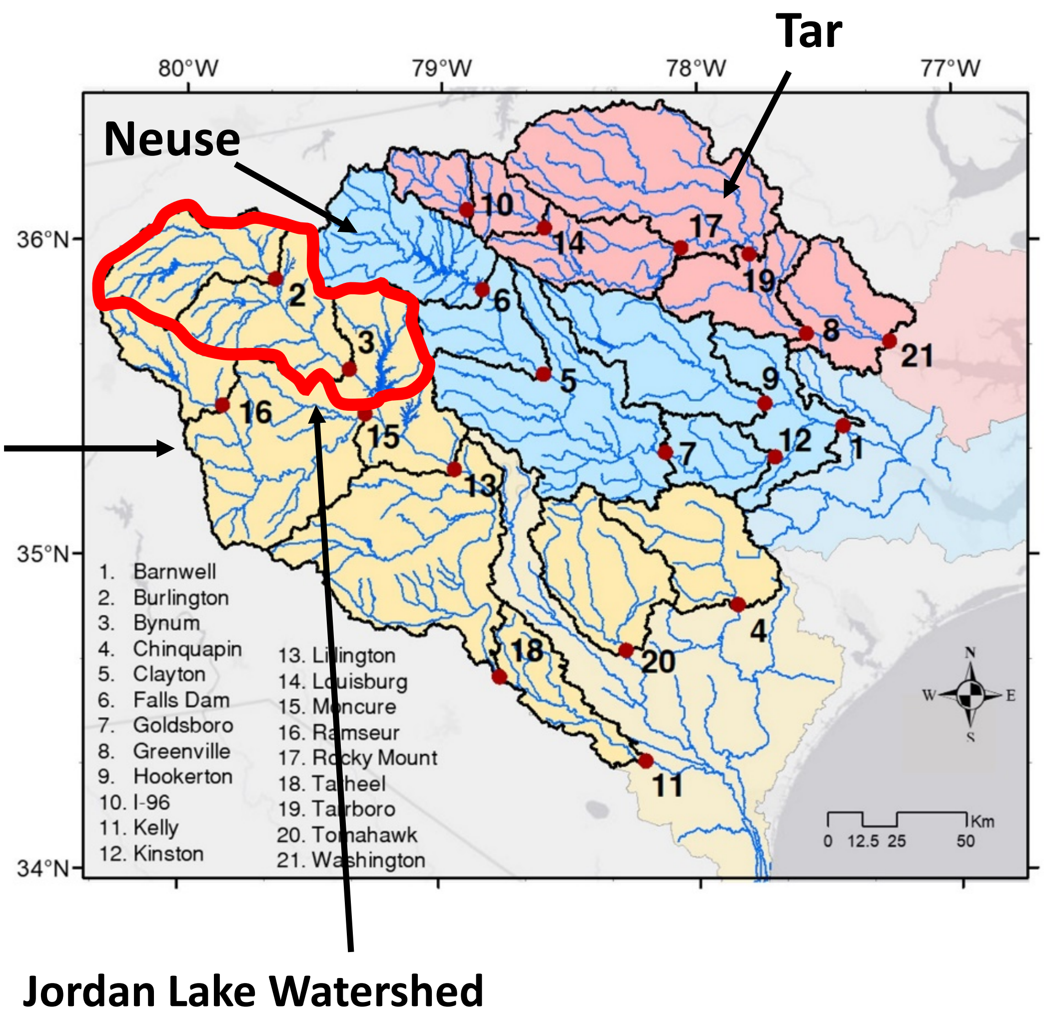
Modeling Approach:

- Leverage 30+ years of historical flow, concentration, land use, etc. data to refine source characterization and constrain uncertainties
- Incorporate all relevant data for Jordan Lake tributaries
- Leverage past export coefficients and nutrient loss values from previous research as prior knowledge

Previous Hybrid Watershed Modeling

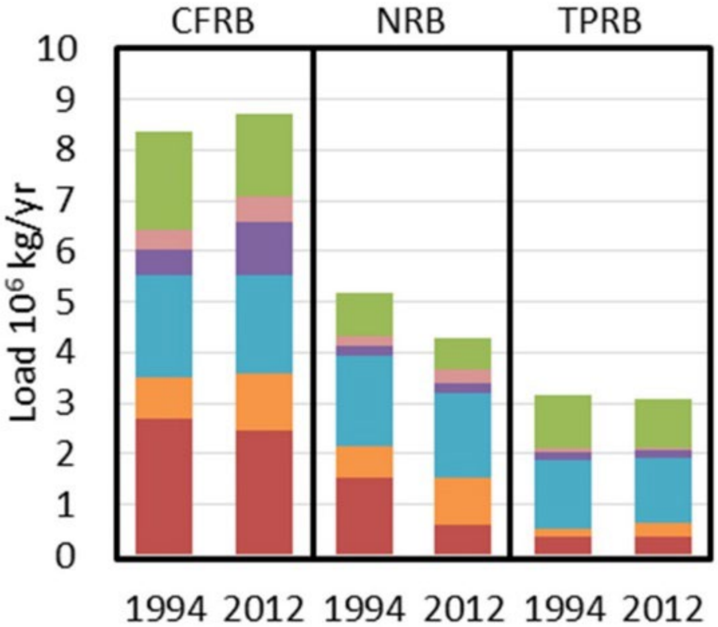
(Strickling & Obenour, 2018)

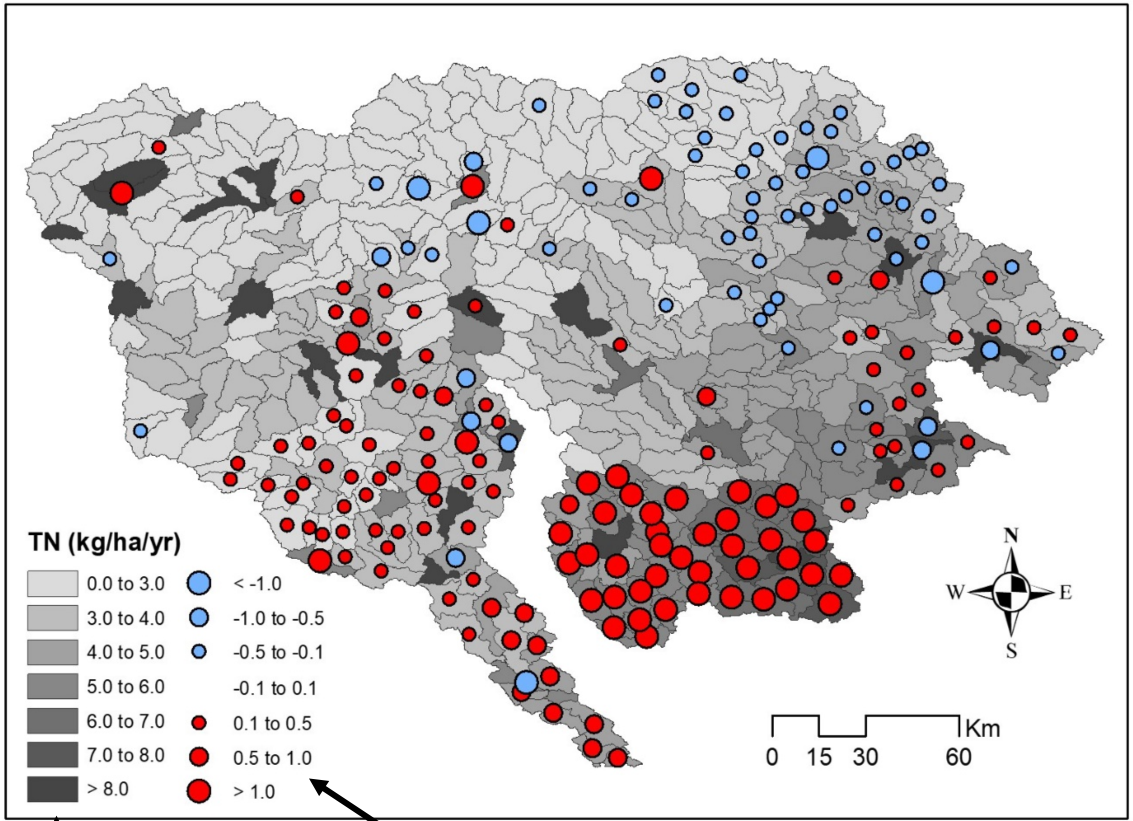
- Build on hybrid empirical-mechanistic modeling concepts (e.g., USGS SPARROW).
- Enhance model to consider temporal dynamics (Strickling & Obenour, *WRR*, 2018).



Previous Hybrid Watershed results

(Strickling & Obenour, 2018)





Cape Fear **Neuse** **Tar**

Mean export

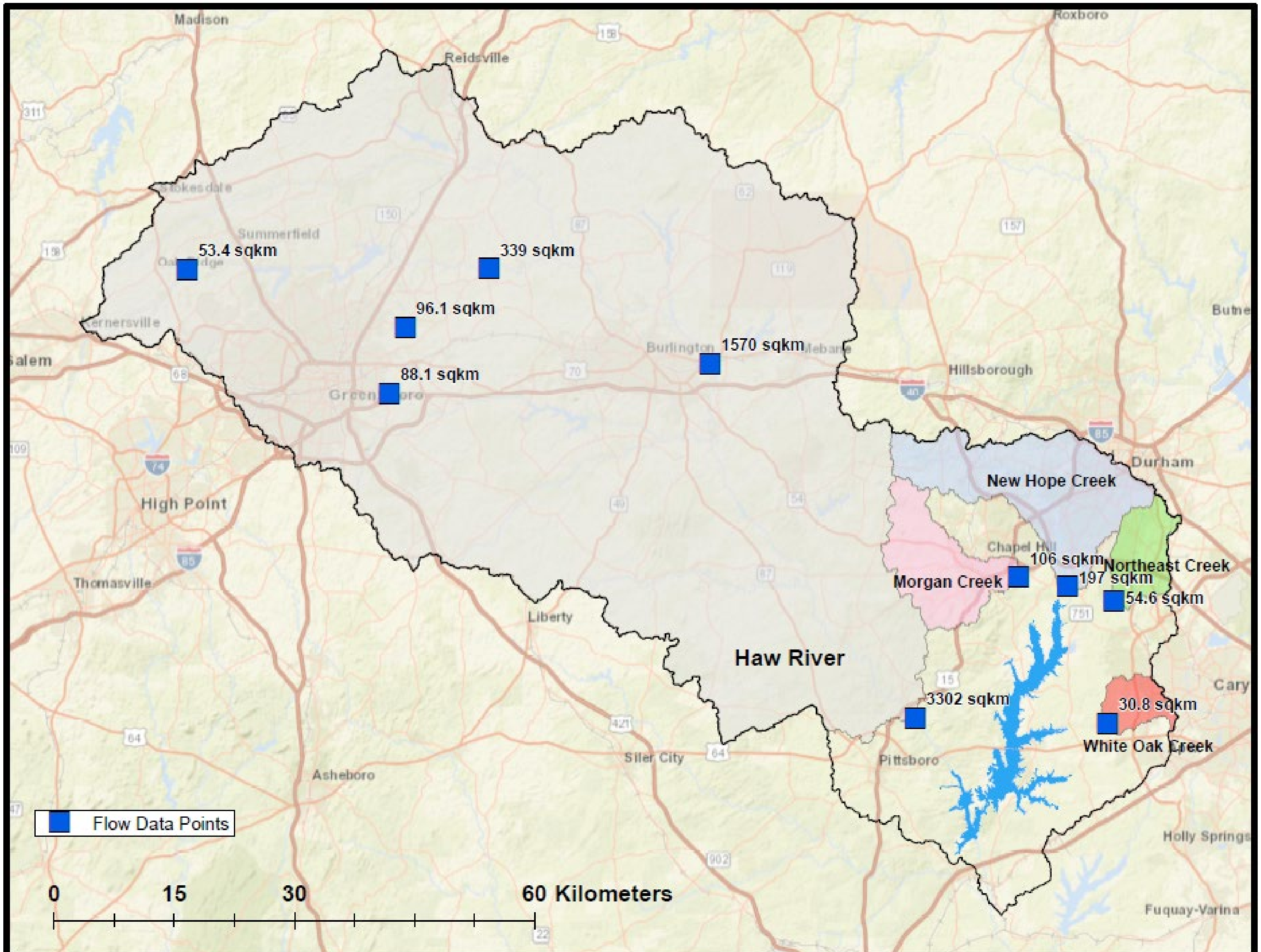
Δ Export from 1994-2012

Hybrid Watershed Modeling

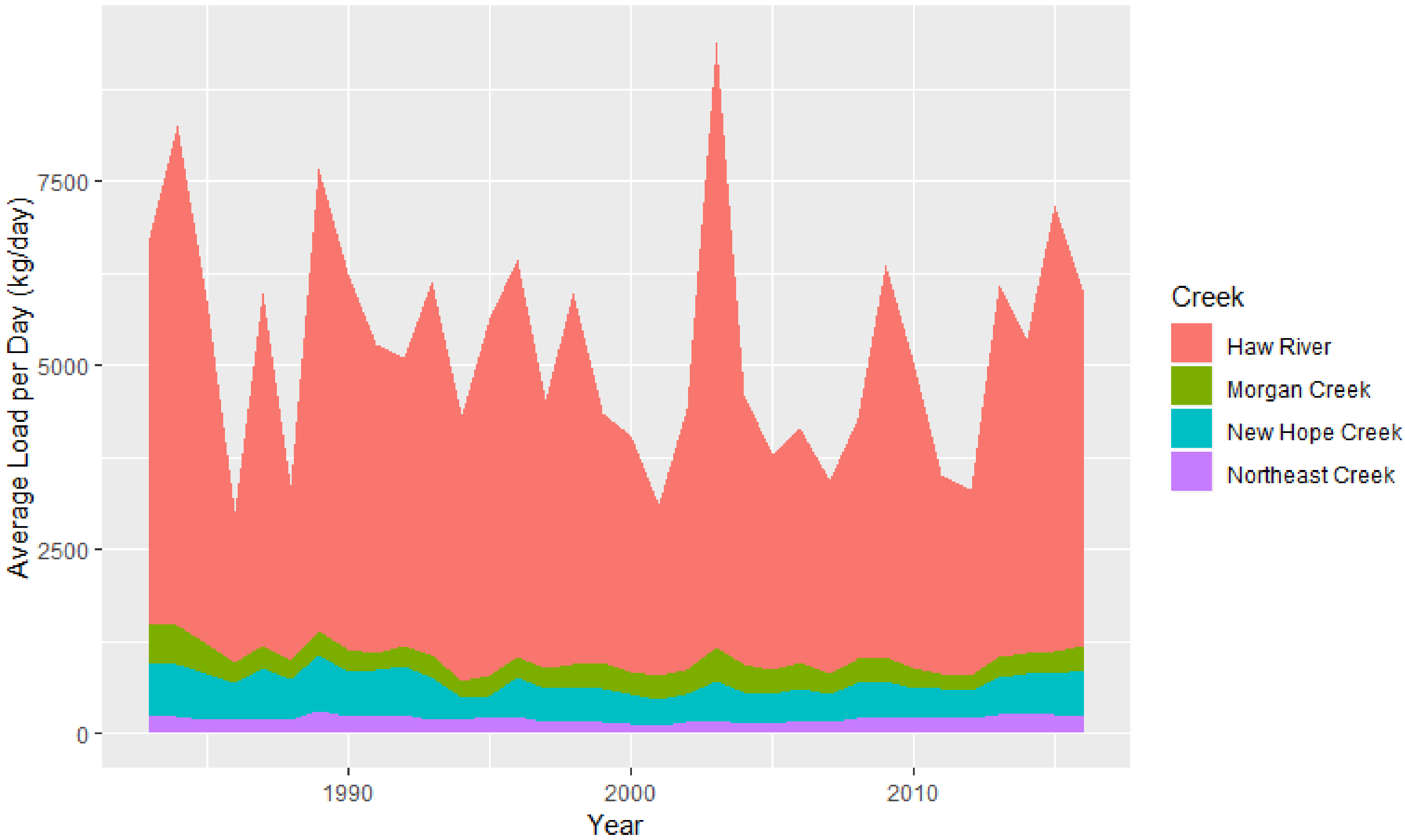
Objectives:

- Understand long-term temporal drivers of nutrient loading (land covers, point sources, etc.)
- Assess the relative influence of Jordan lake tributaries on loadings.
- Forecast future loading scenarios for watershed management and climate variability

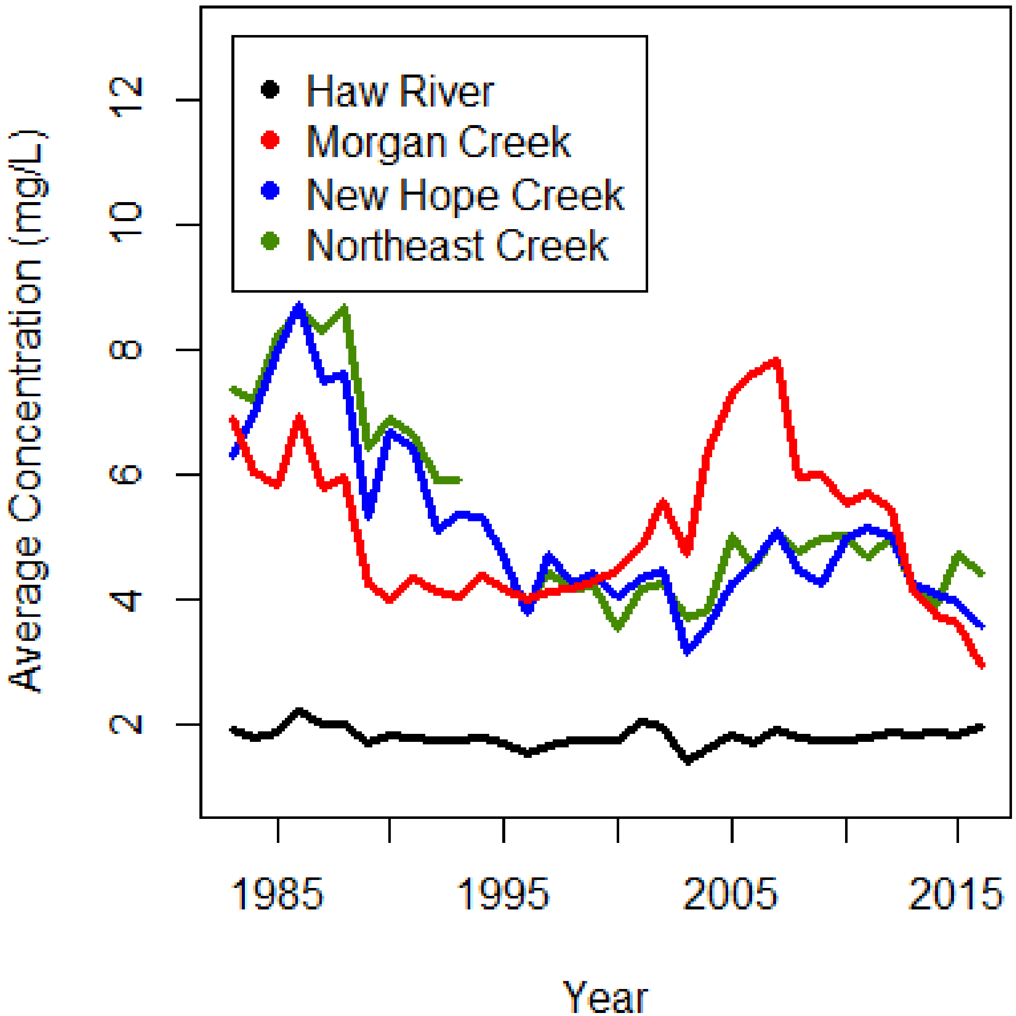
Preliminary data collection for Jordan Lake watershed



Jordan Lake TN loadings- WRTDS



Mean TN concentrations by tributary



Jordan Lake Modeling

- Build on long-term phenomenological modeling of nutrient dynamics (e.g., Chapra & Canale, 1991).

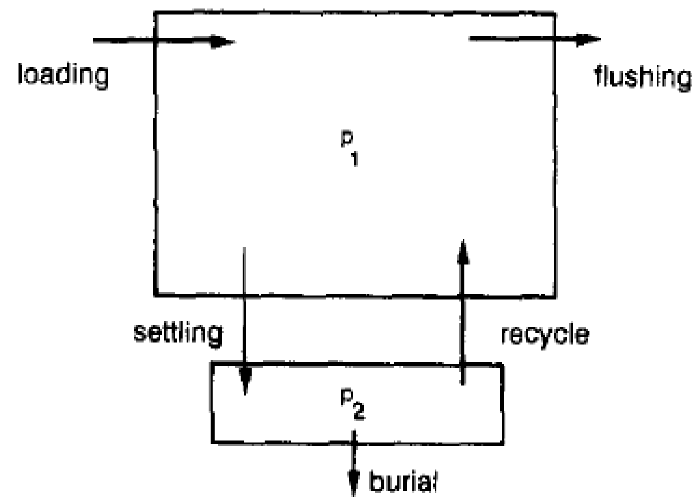


Fig. 2. Schematic diagram of a phosphorus budget model for a lake underlain by sediments.

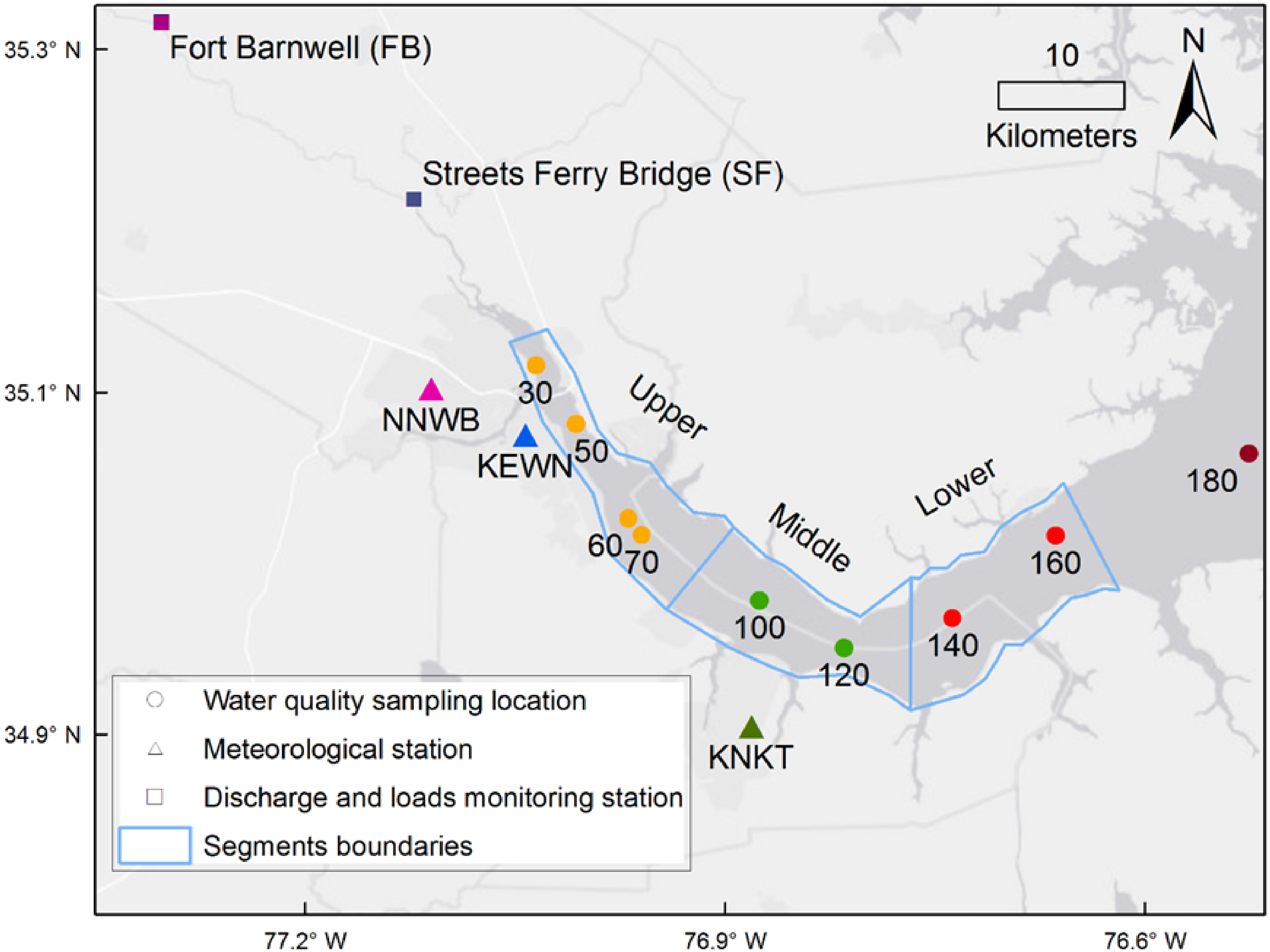
- Enhance model with Bayesian parameter estimation/uncertainty quantification (e.g., Obenour et al., 2015; Katin et al., submitted; Del Giudice et al., in prep.)

Jordan Lake modeling

Modeling Approach:

- Parameterize a mechanistic model within a Bayesian statistical framework.
- Include past research (e.g., N:P ratios, benthic fluxes) as prior knowledge
- Couple with watershed model to leverage 30+ years of historical loading data
- Predict effects of watershed management and climate variability on system productivity.

Example hybrid water quality modeling
(Katin et al. submitted)



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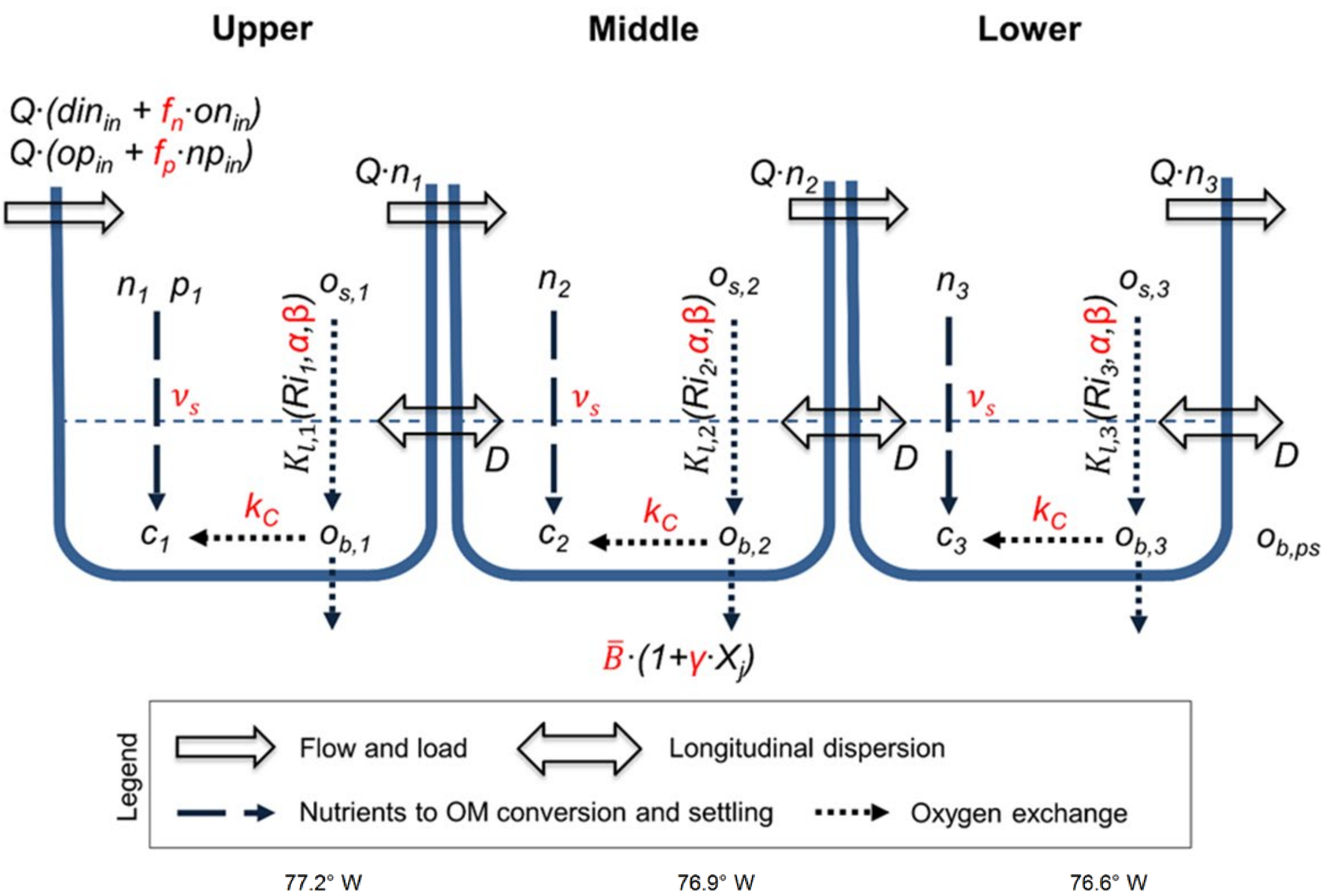
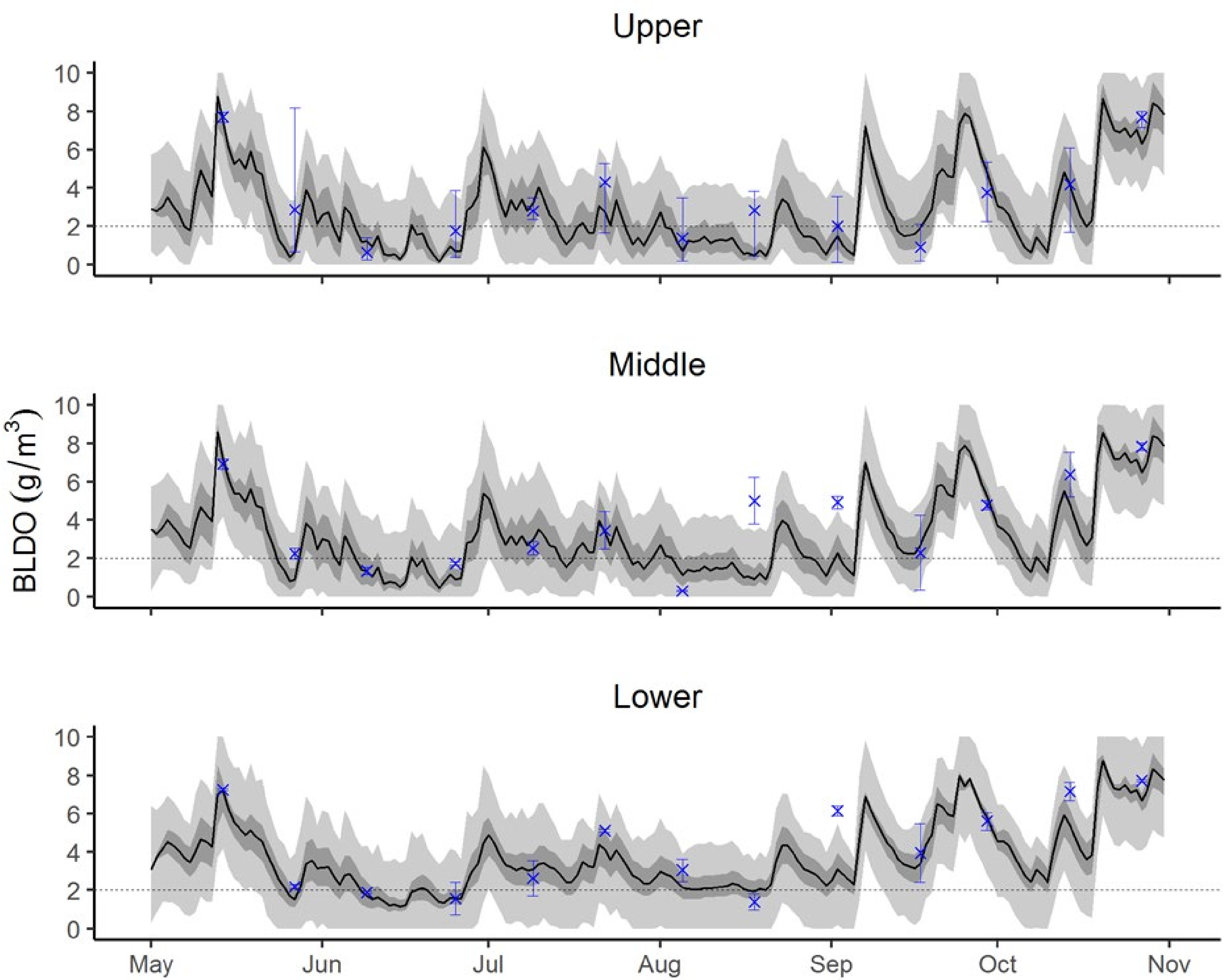


Hybrid water quality modeling-results
(Katin et al. submitted)



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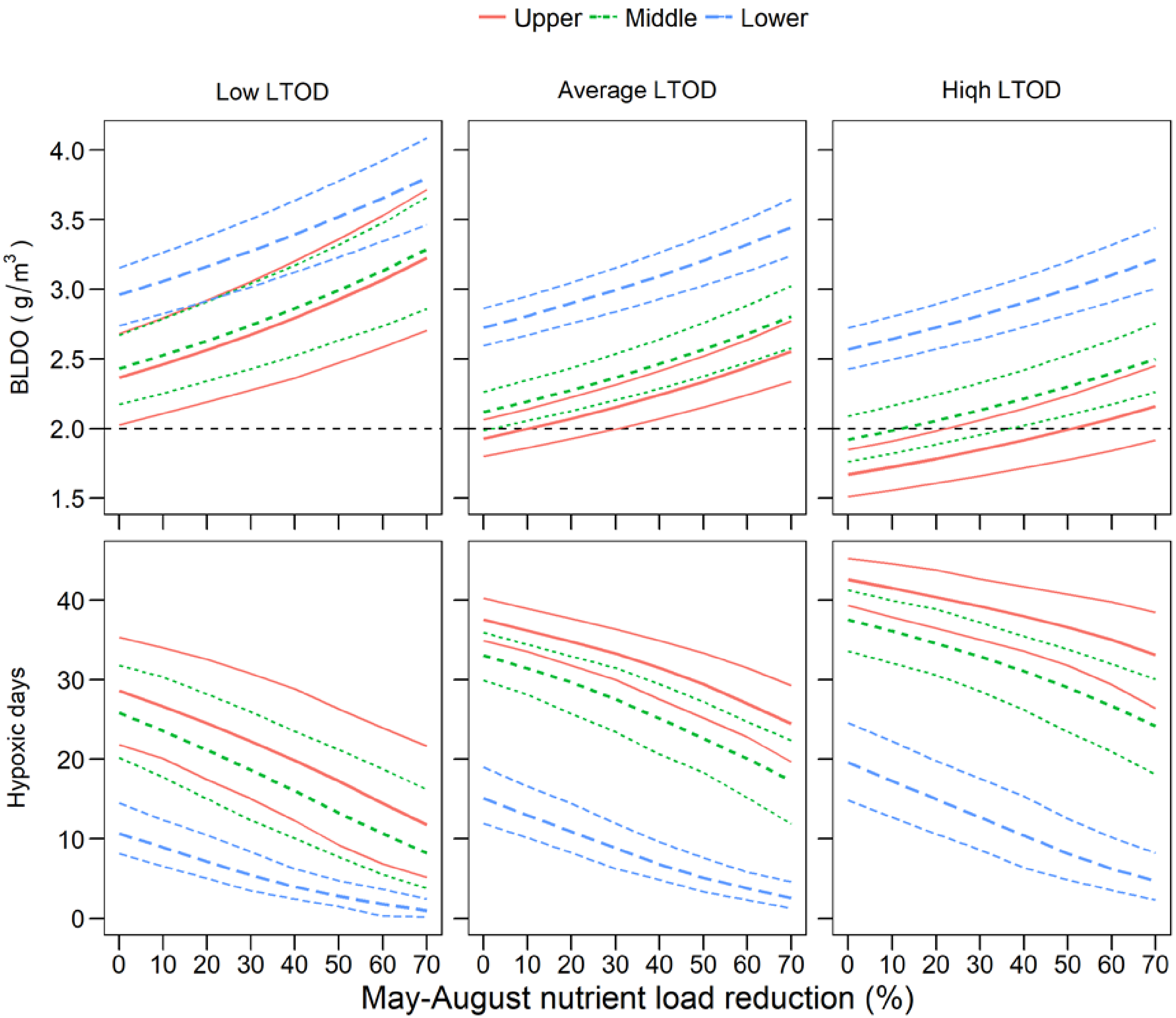

Hybrid water quality modeling-results

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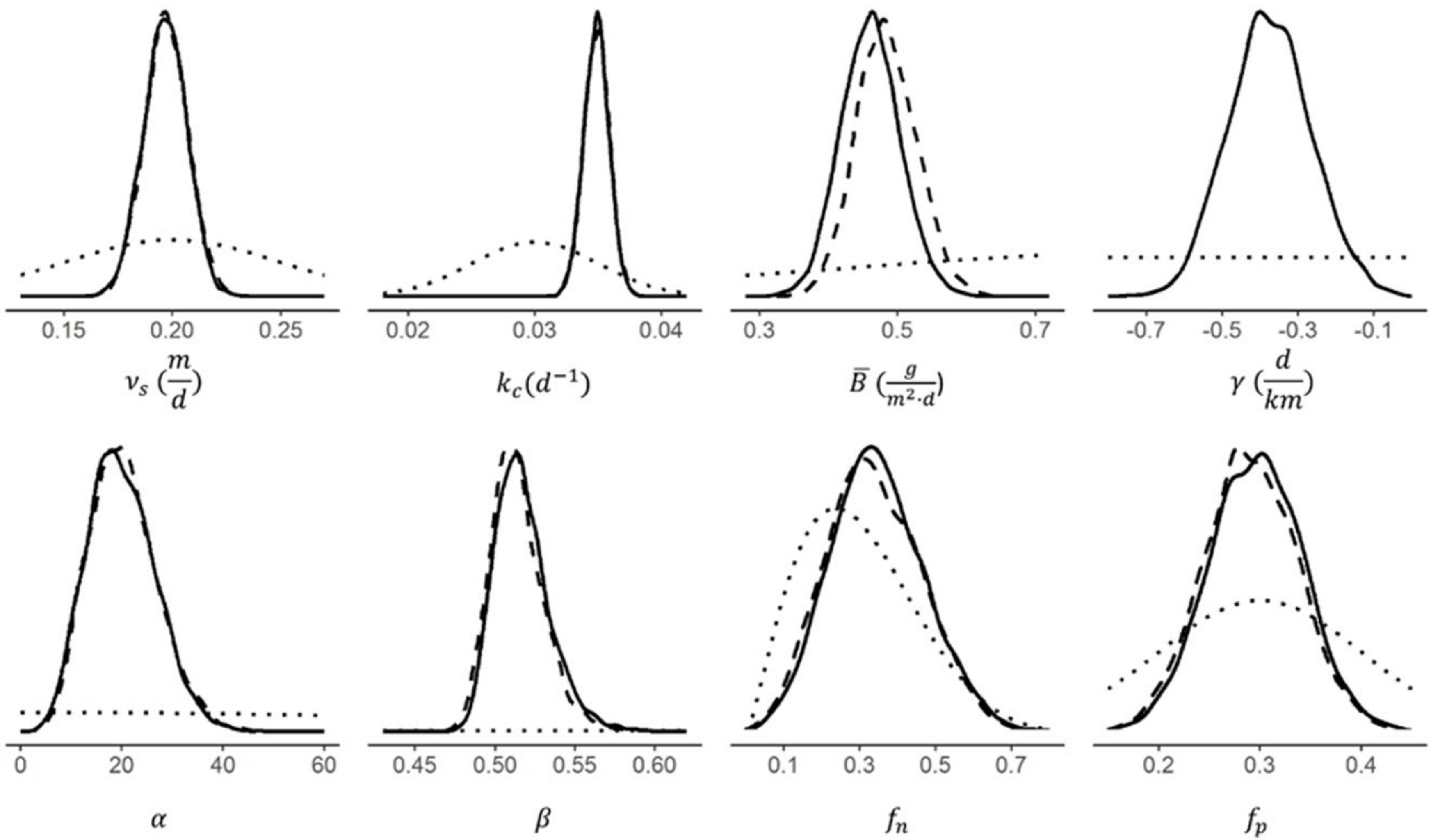
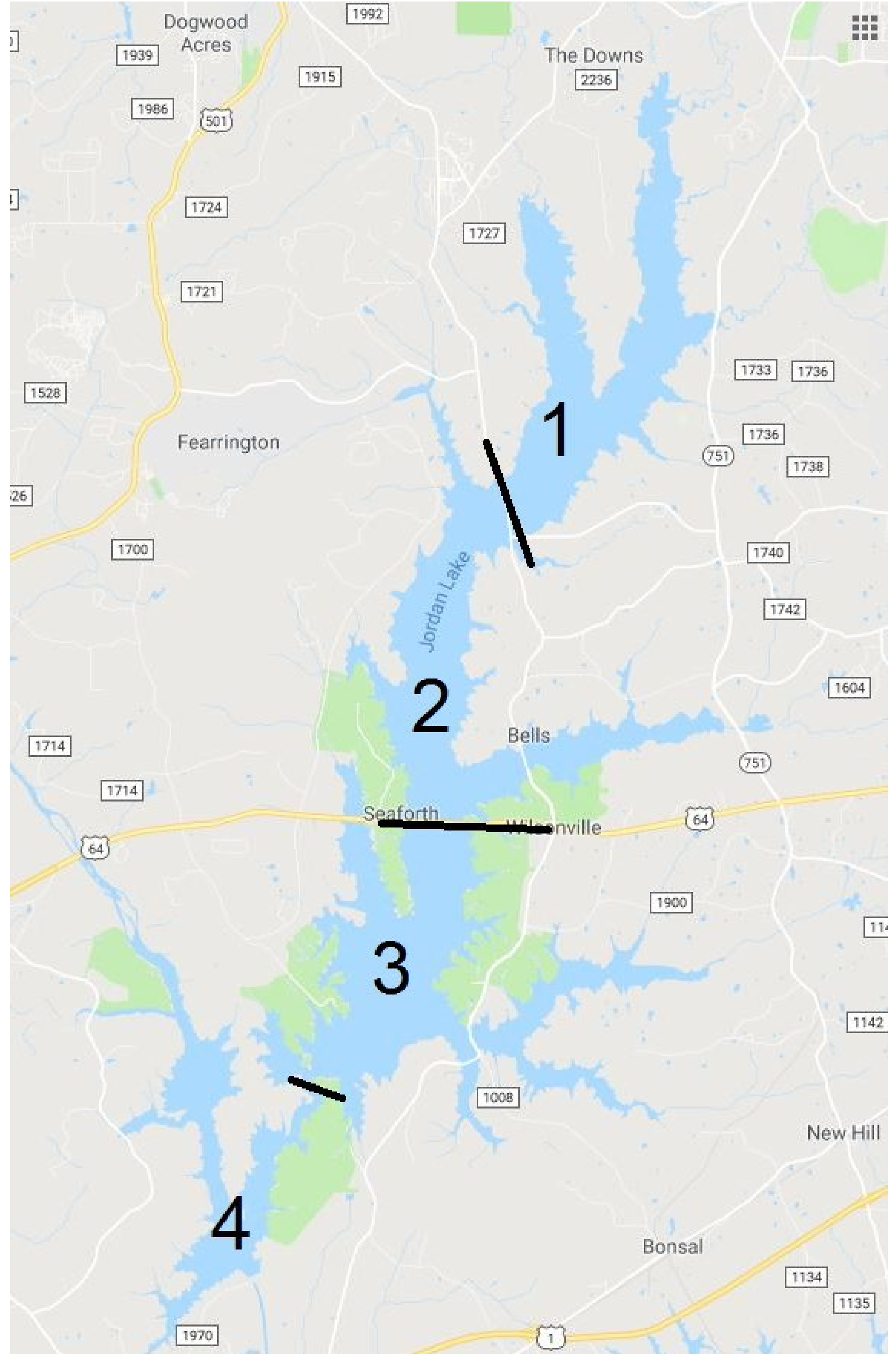


Jordan Lake segmentation



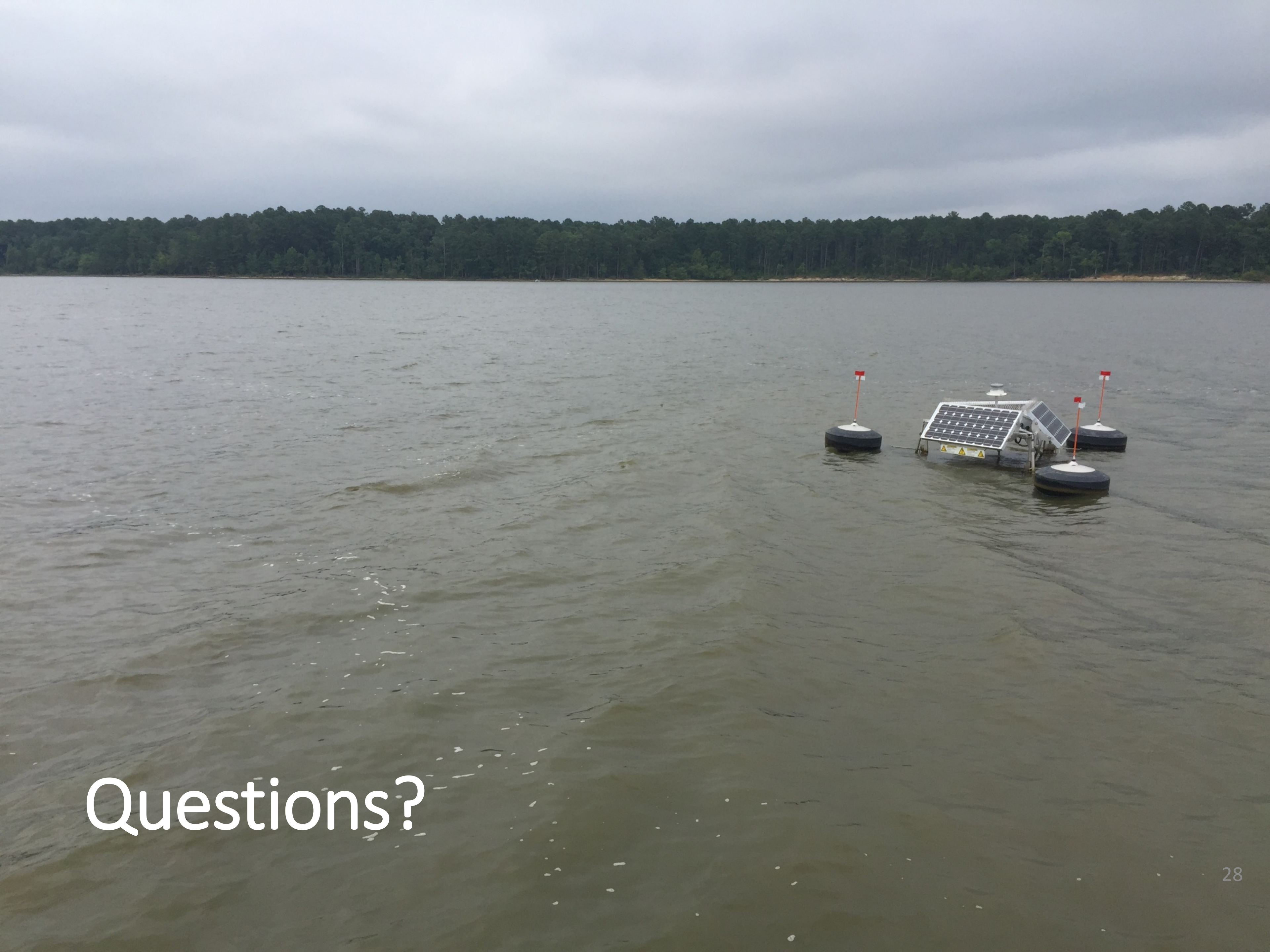
Jordan Lake modeling

Objectives:

- Characterize long-term nutrient dynamics and controls on algal production
- Simulate longitudinal concentration gradients (nutrients, chlorophyll, turbidity, etc.)
- Understand the impact of Jordan Lake tributaries on different sections of the lake.
- How responsive will Jordan Lake be to reductions in nutrient loadings? How long might it take to see a difference?

Project Timeline

- Develop WRTDS loading estimates of nitrogen and phosphorus (December 2018).
- Develop Jordan Lake watershed nutrient loading model (September 2019).
- Develop Jordan Lake reservoir water quality model (September 2019).
- Apply models for Scenario forecasts (November 2018).
- Final report (December 2019).


Questions?