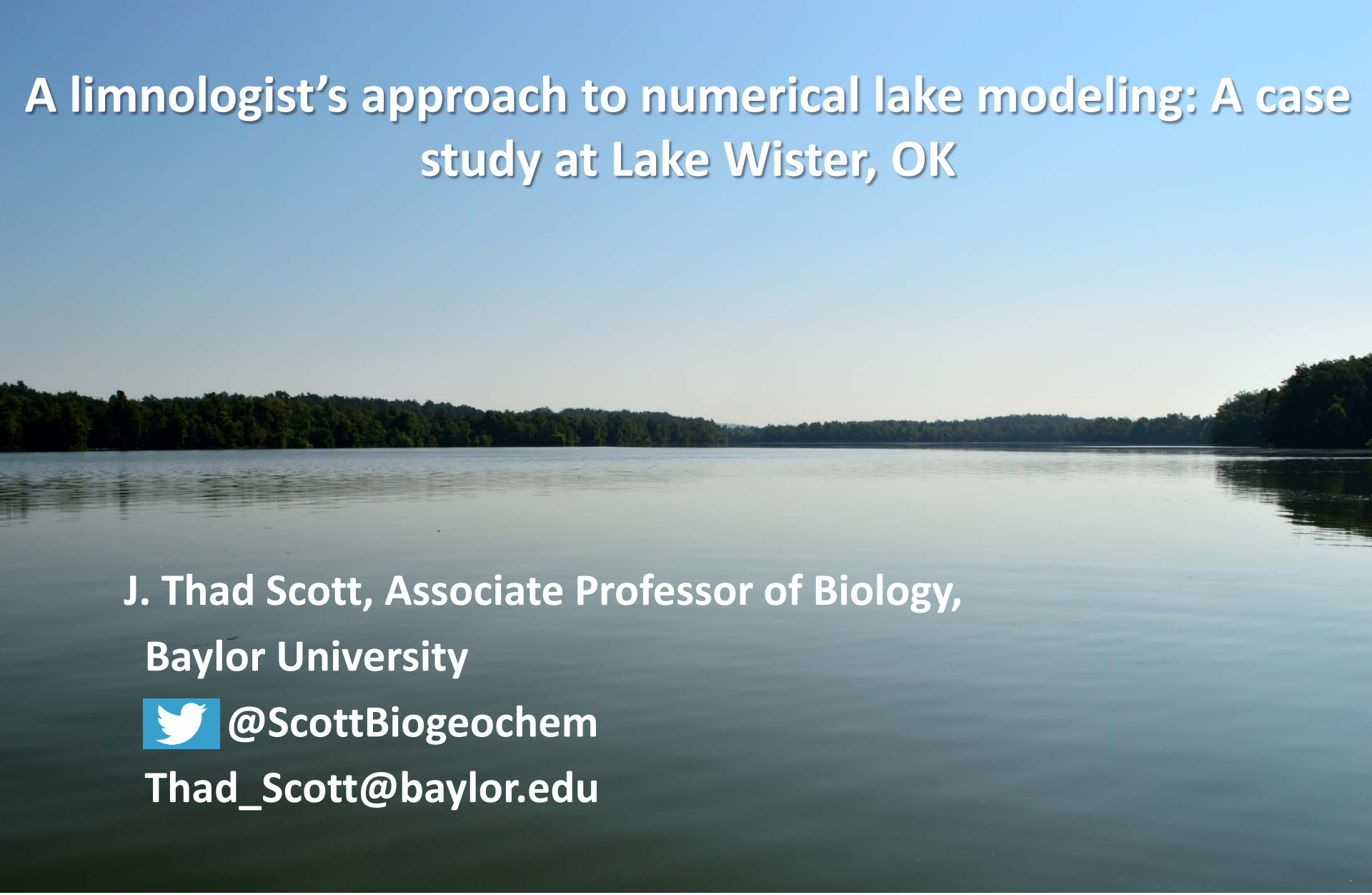
A limnologist's approach to numerical lake modeling: A case study at Lake Wister, OK



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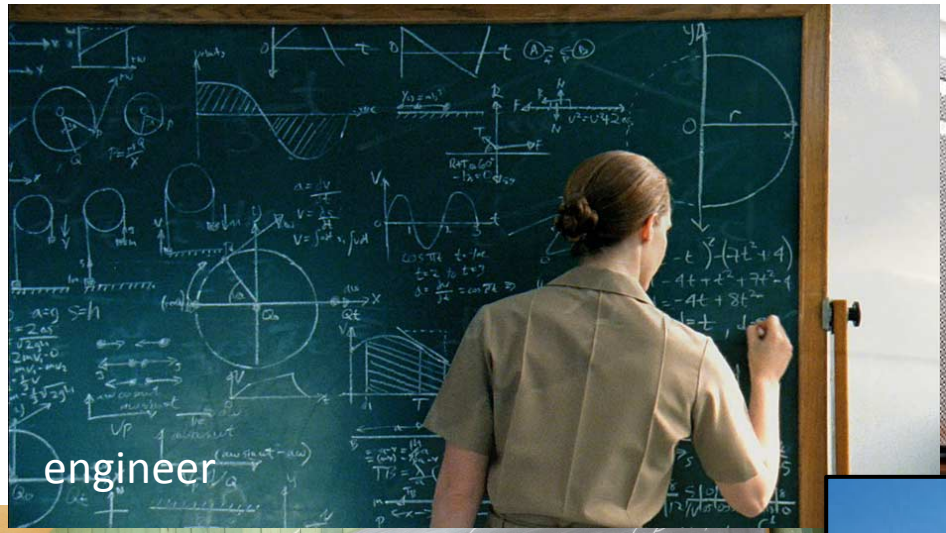
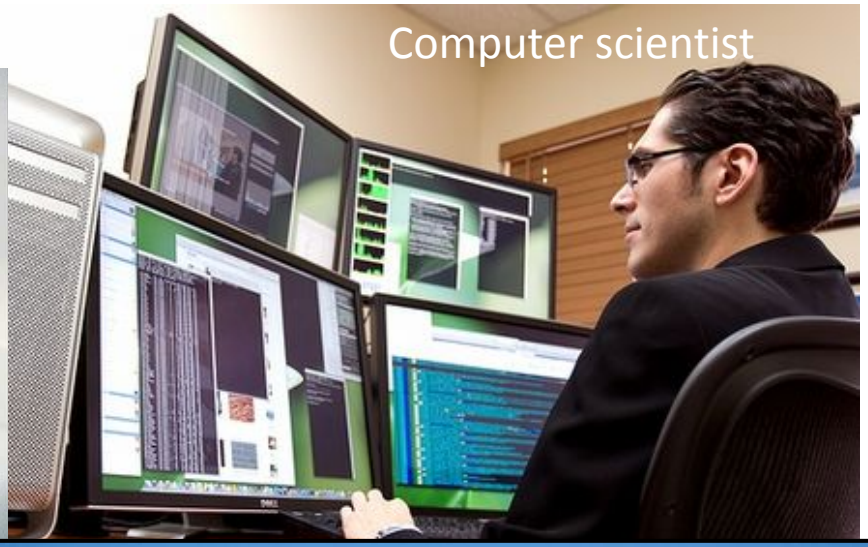
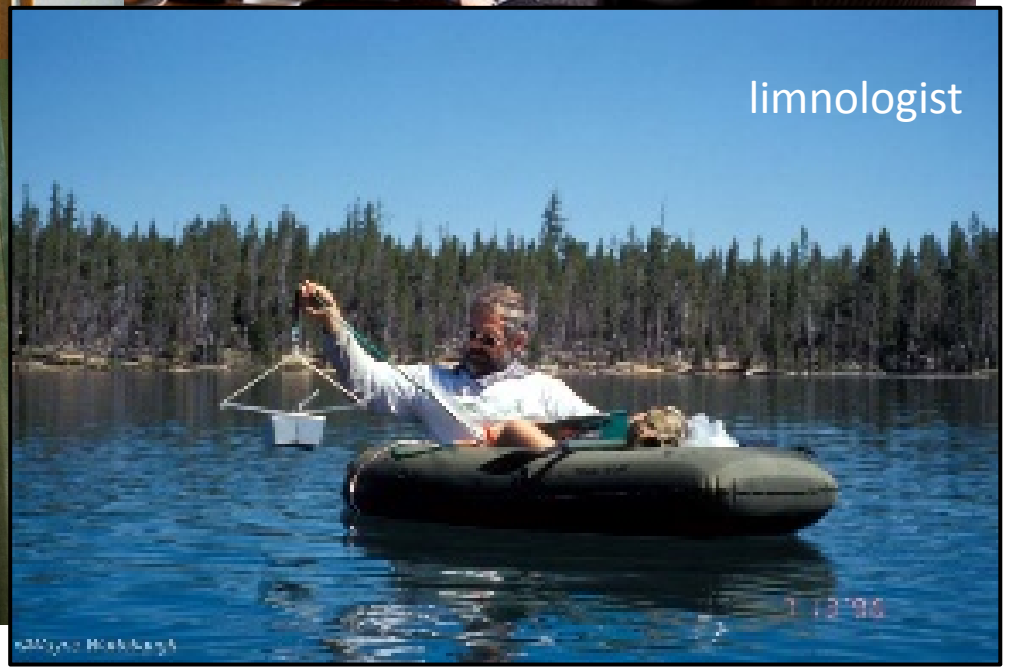
- Lake models are a tool to perform the science of limnology (not vice-versa)







Lake Wister

State of Oklahoma 303d List of Impaired Waterbodies:

- Chlorophyll-a
- Dissolved Oxygen
- Total Phosphorus
- Turbidity

2013 – Contracted with Poteau Valley Improvement Authority:

1. Sediment analysis
2. Water quality model
   a) Modeling Plan
   b) Model development and simulations

Modeling Platforms:

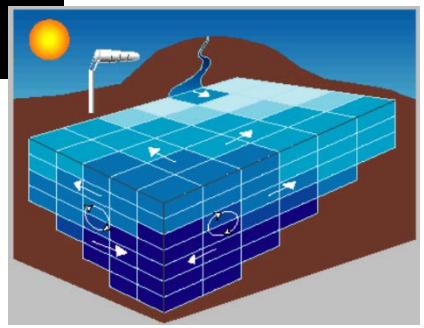
Centre for Water Research

Hydrodynamics

- Estuary, Lake and Coastal Ocean Model **(ELCOM)** (3D)

Ecology

- Computational Aquatic Ecosystem Dynamics Model **(CAEDYM)**



ELCOM-CAEDYM Simulation Capacity

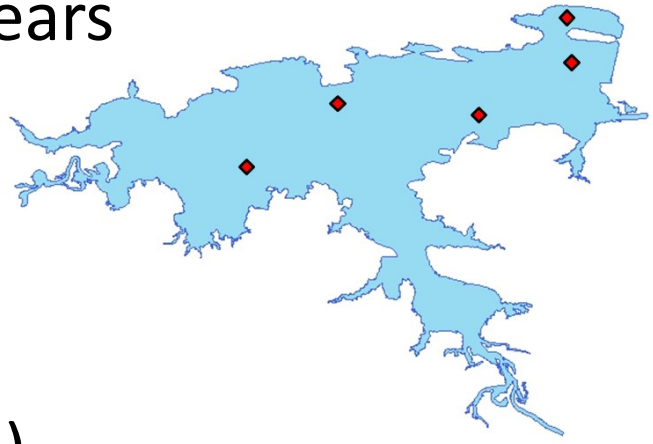
- Light (NIR, PAR, UVA, UVB)
- Suspended sediment ($SS_{1...6}$)
- Dissolved oxygen (DO)
- Organic nutrients (POM, DOM)
- Inorganic nutrients (NH_4, NO_3, PO_4, SiO_2, DIC)
- Heterotrophic bacteria (BAC)
- Phytoplankton (Chl-a/C, Internal N/P, ~~toxins~~)
- ~~Higher biology (zooplankton, fish, eggs & larvae)~~
- ~~Benthic biology (macroalgae, bivalves, macroinvertebrates)~~
- ~~Pathogens & indicator organisms (crypto, coliforms, phages)~~
- Geochemistry (pH, ions, ~~metals~~)
- Sediment diagenesis

Model Inputs:

- Inflow/outflow rates (USGS and USACE)
- Inflow concentrations for suspended sediment, TP, TN, etc… (USGS)
- Sediment P (Haggard, Scott, and Patterson 2012)
- Meteorological data (Oklahoma Mesonet)

Modeling Periods:

- 2011, 2013, 2015 calibration years
- 2012, 2014 “validation” years



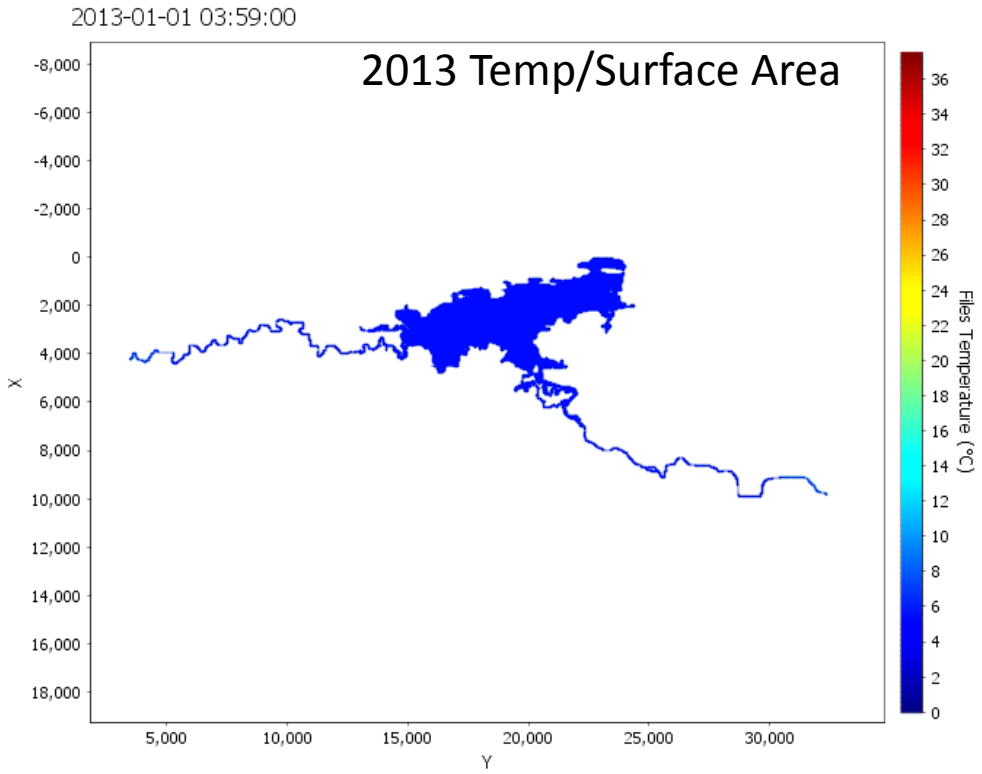
Calibration data:

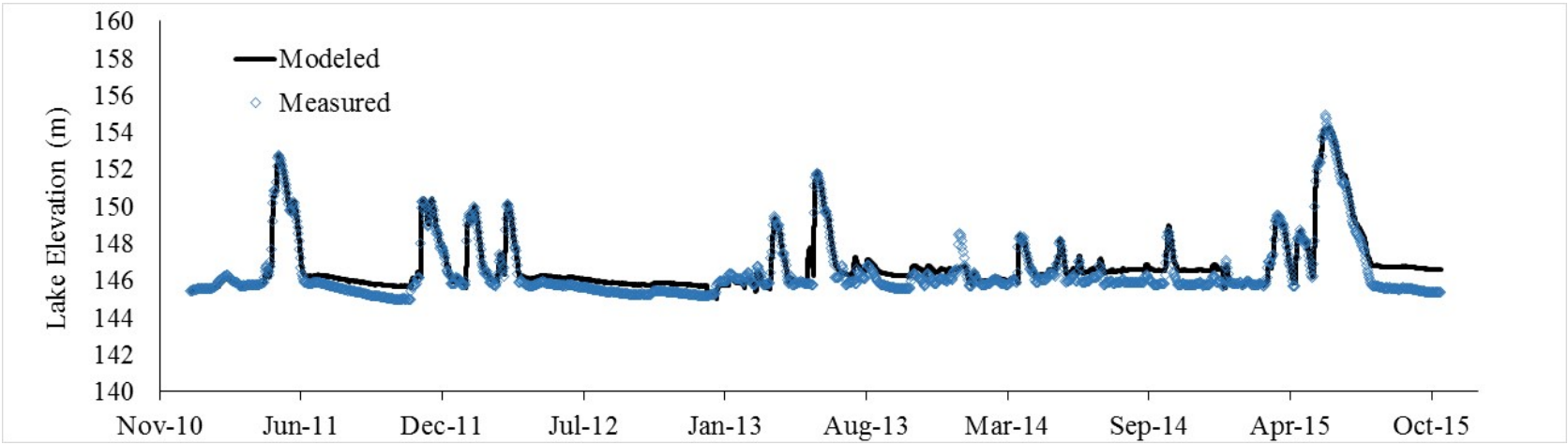
- Daily lake elevation (USACE)
- Monthly lake monitoring (PVIA)

A limnologist's list of non-negotiable accuracy requirements for eutrophication model:

- Hydrologic mass balance
- Seasonal thermal regime
- Seasonal dissolved oxygen concentrations
- Seasonal nitrate trends (as indicator of biological activity)
- Phytoplankton biomass (as chlorophyll-a AND accessory pigments)

Hydrologic mass balance:





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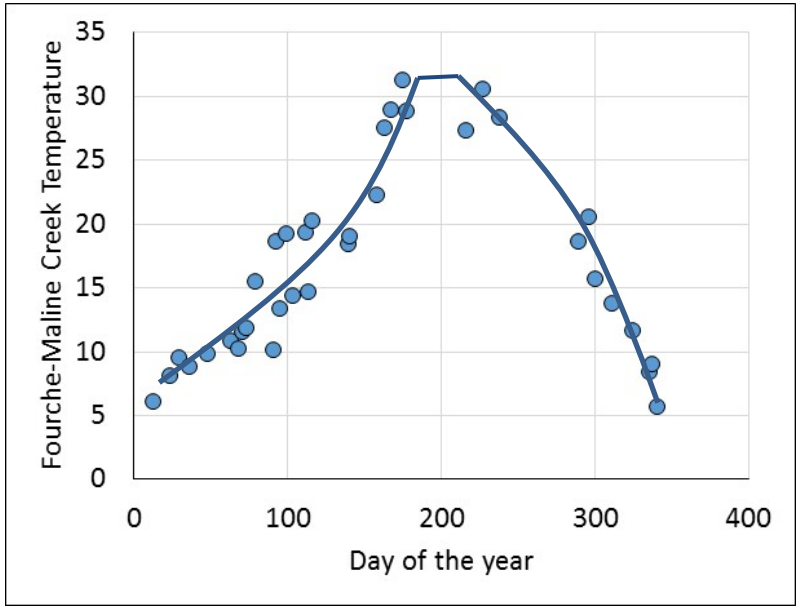
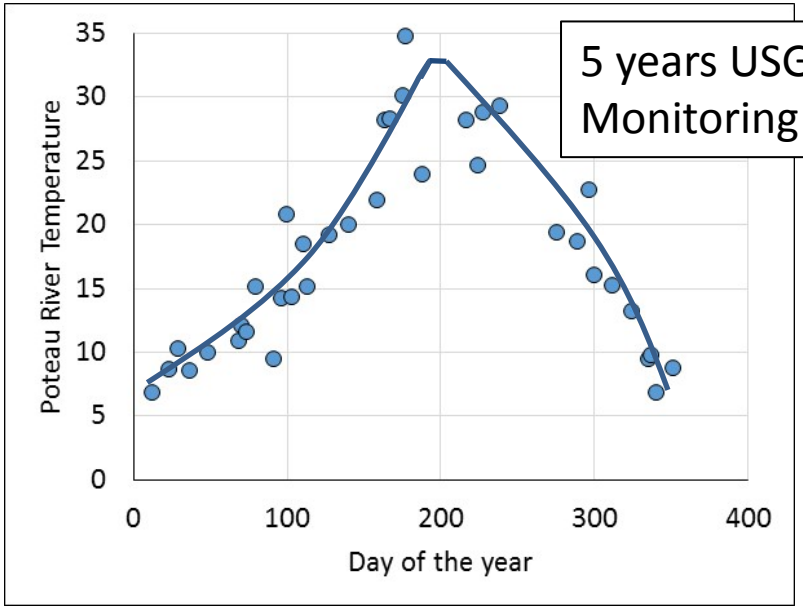
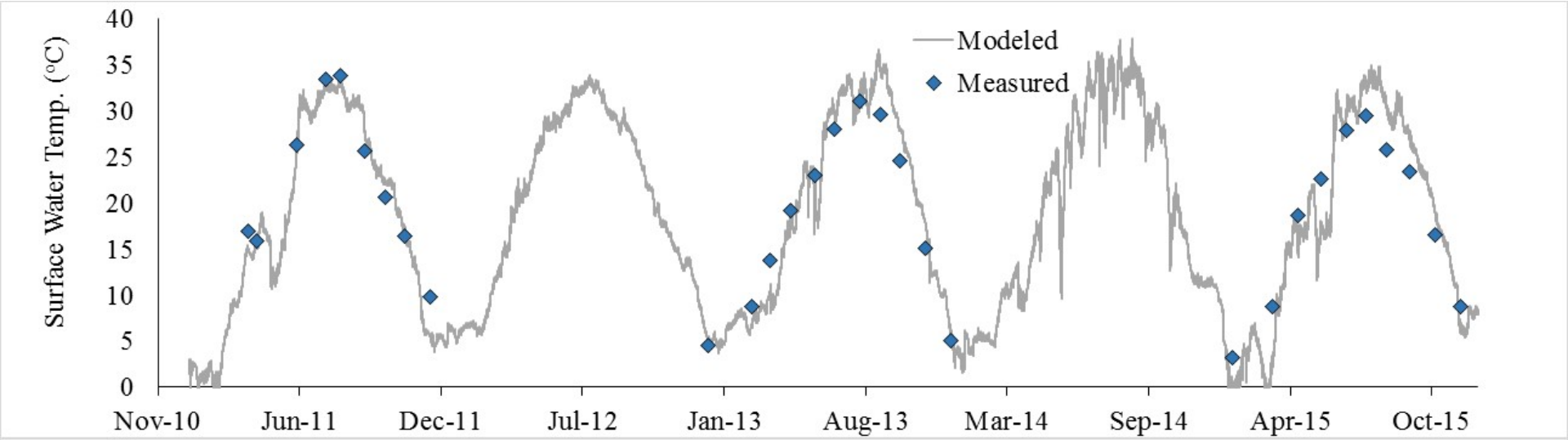
ELCOM-CAEDYM Sensitive to Inflow Temperature

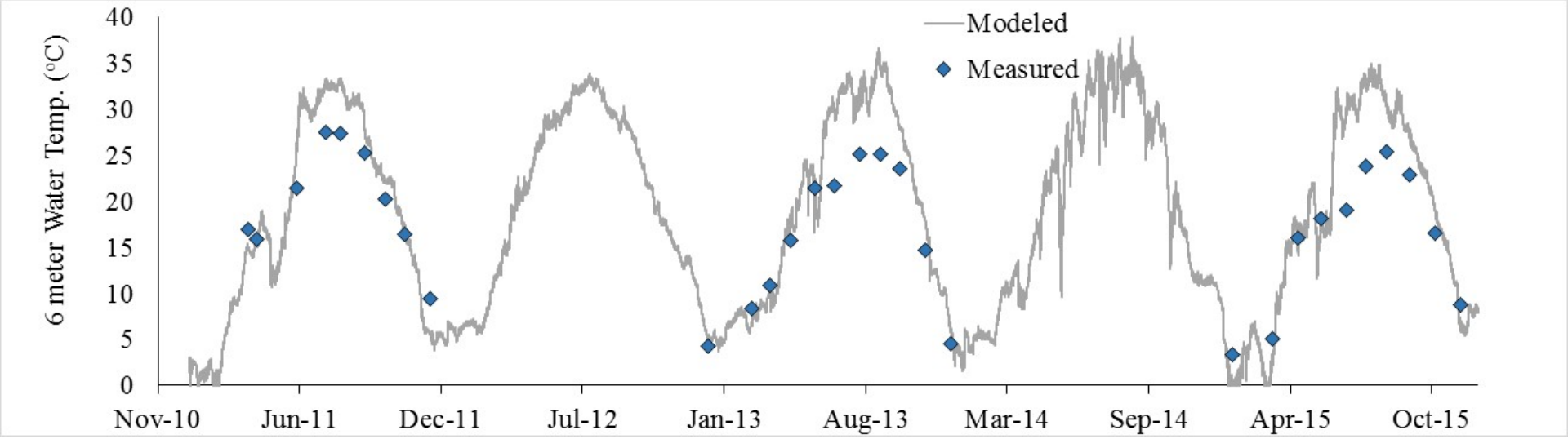




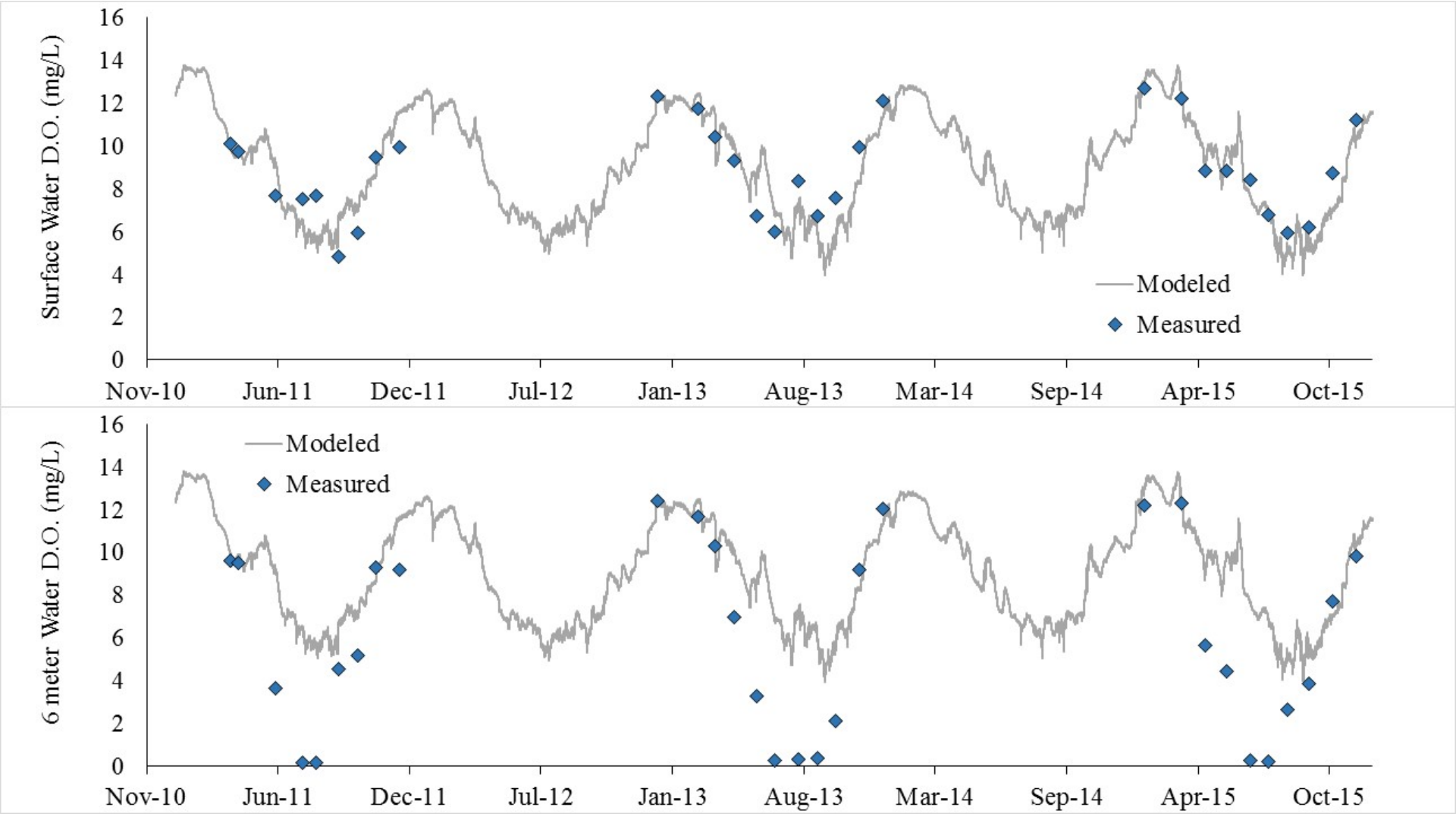
5 years USGS Monitoring Data

Modeling weak thermal stratification





Thermal stratification influences D.O.



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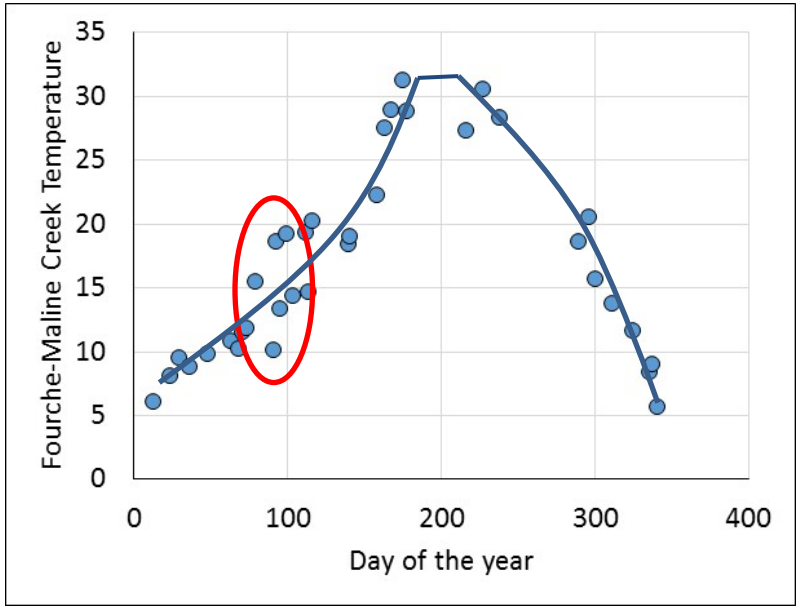
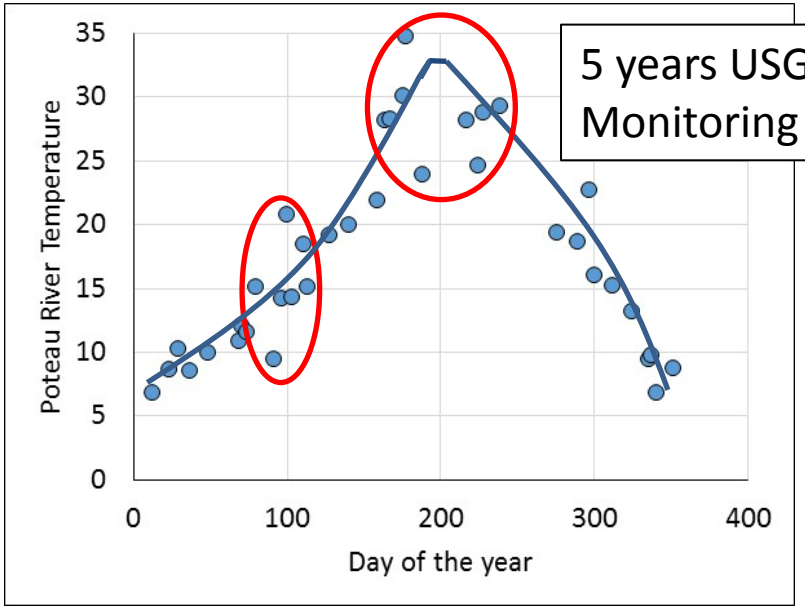
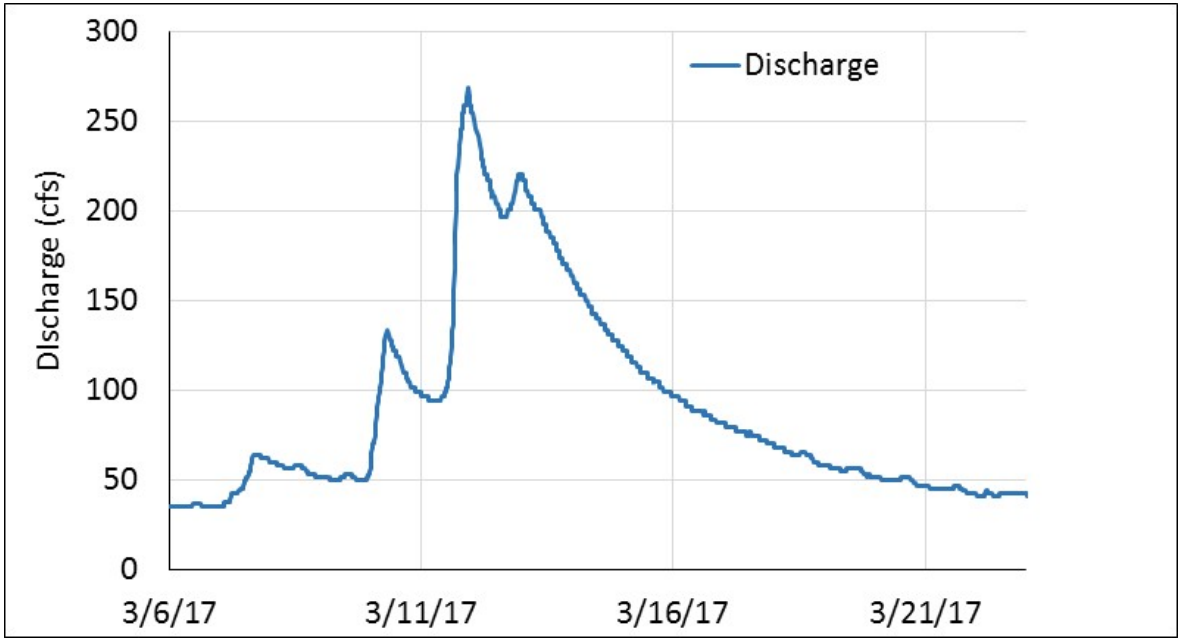




5 years USGS Monitoring Data

Big Creek near Mt. Judea, AR



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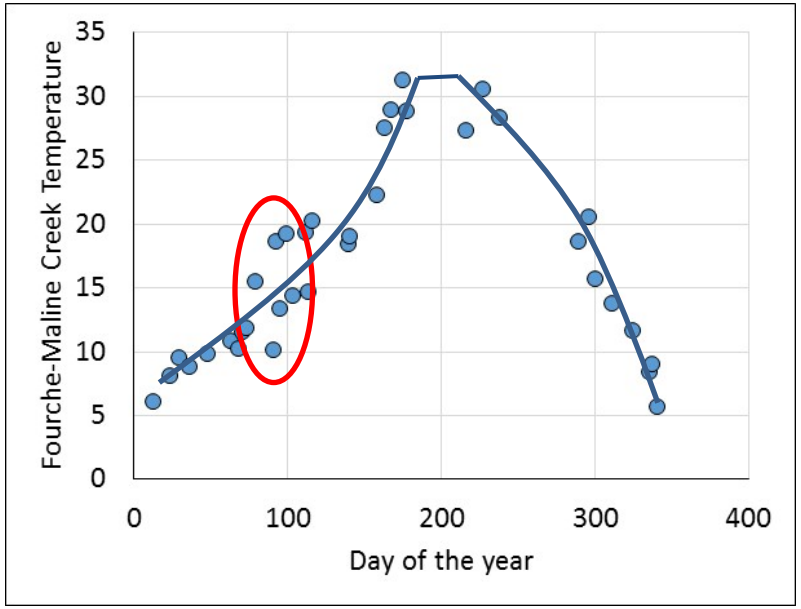

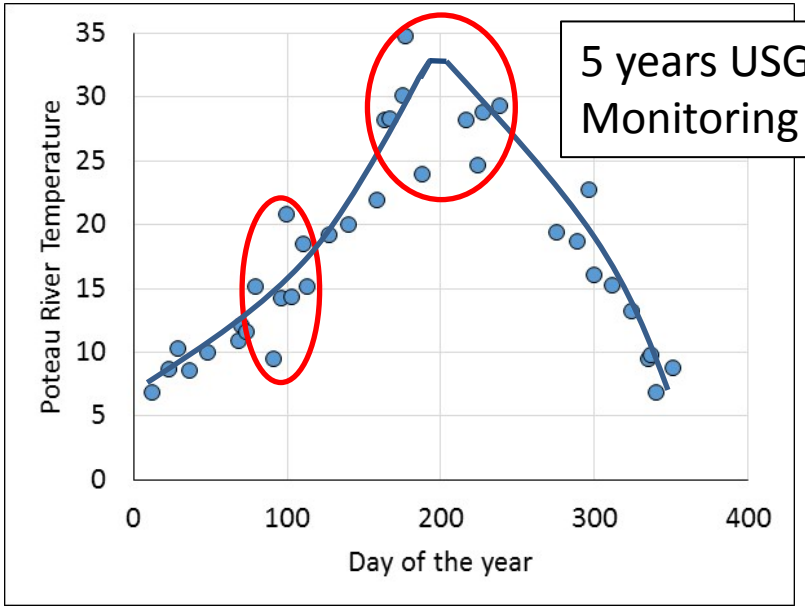

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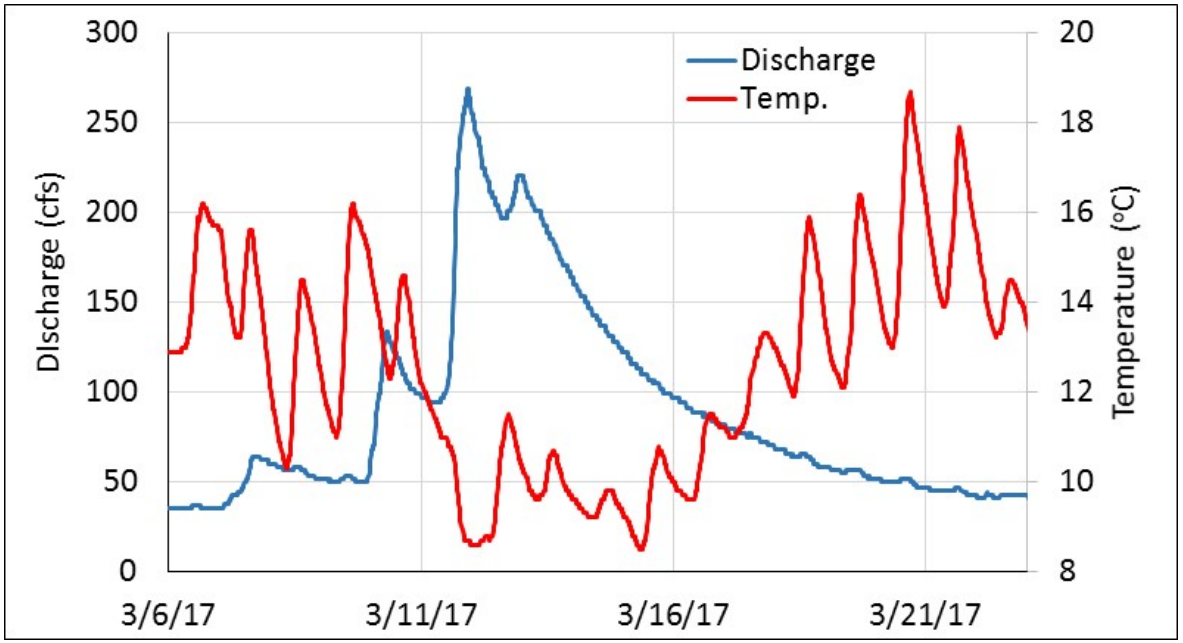

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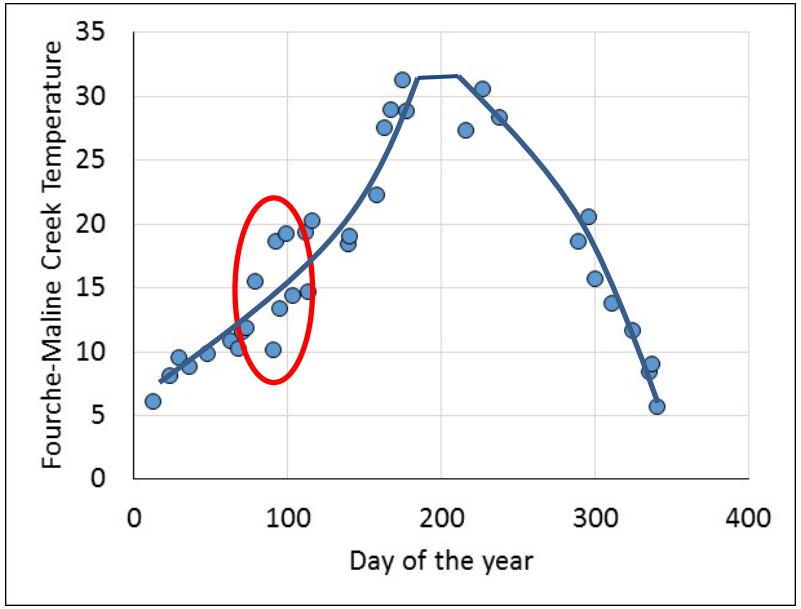
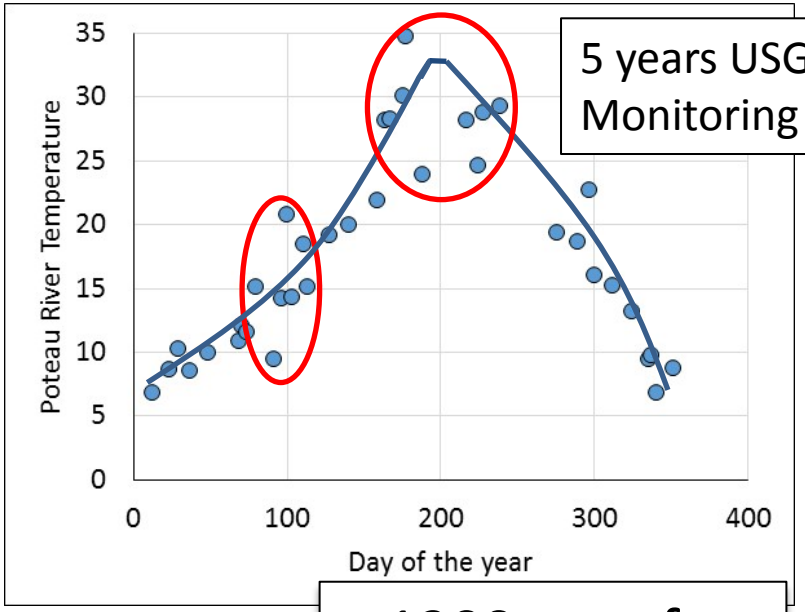
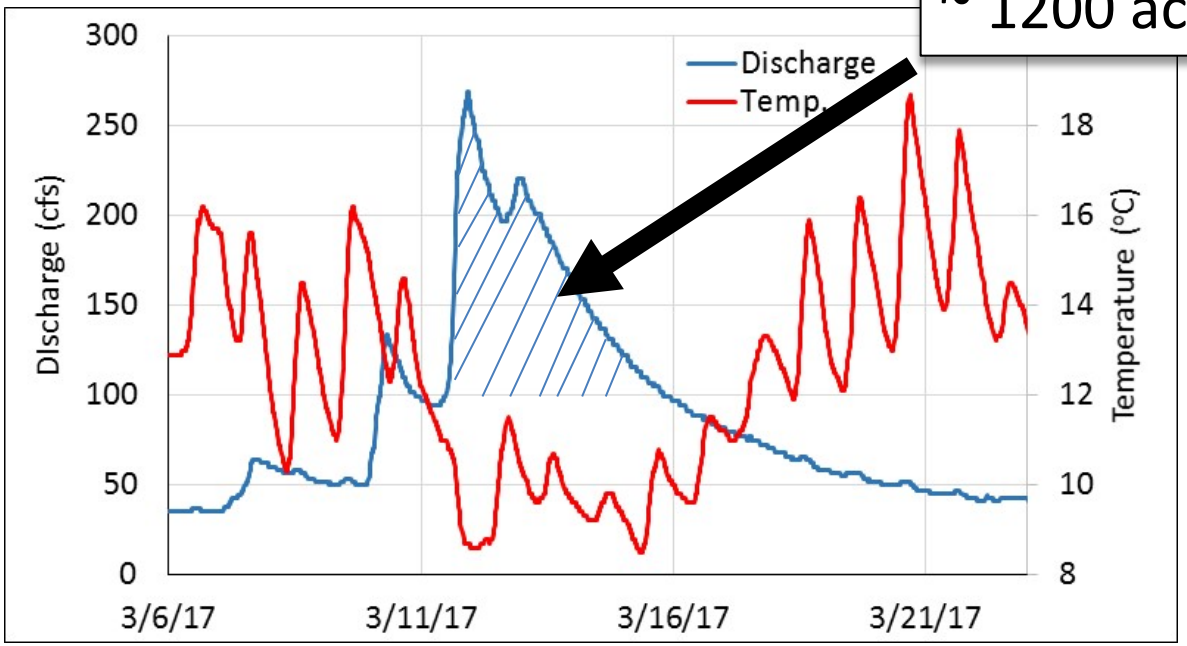




5 years USGS Monitoring Data

~ 1200 acre-feet

Big Creek near Mt. Judea, AR



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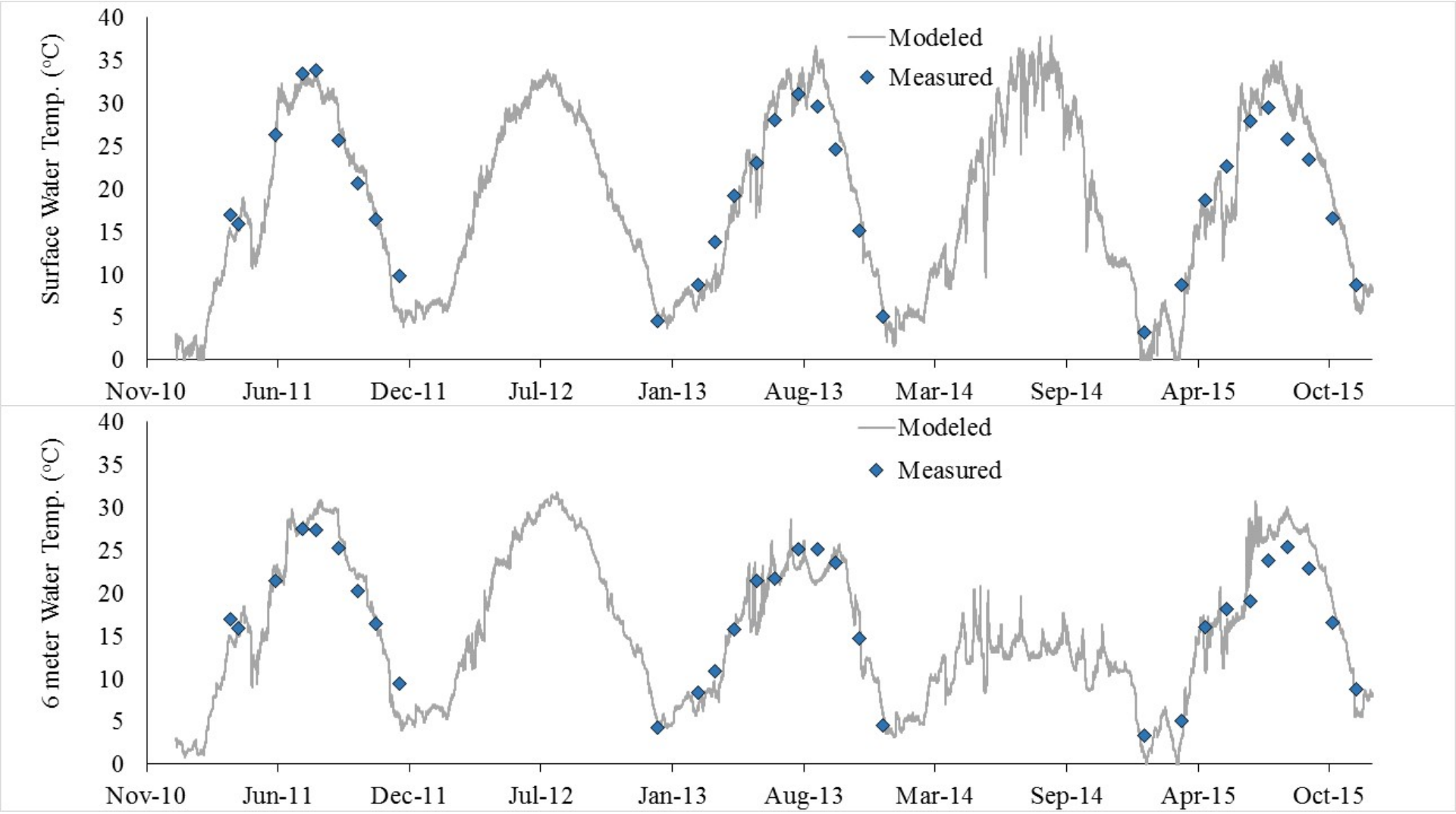

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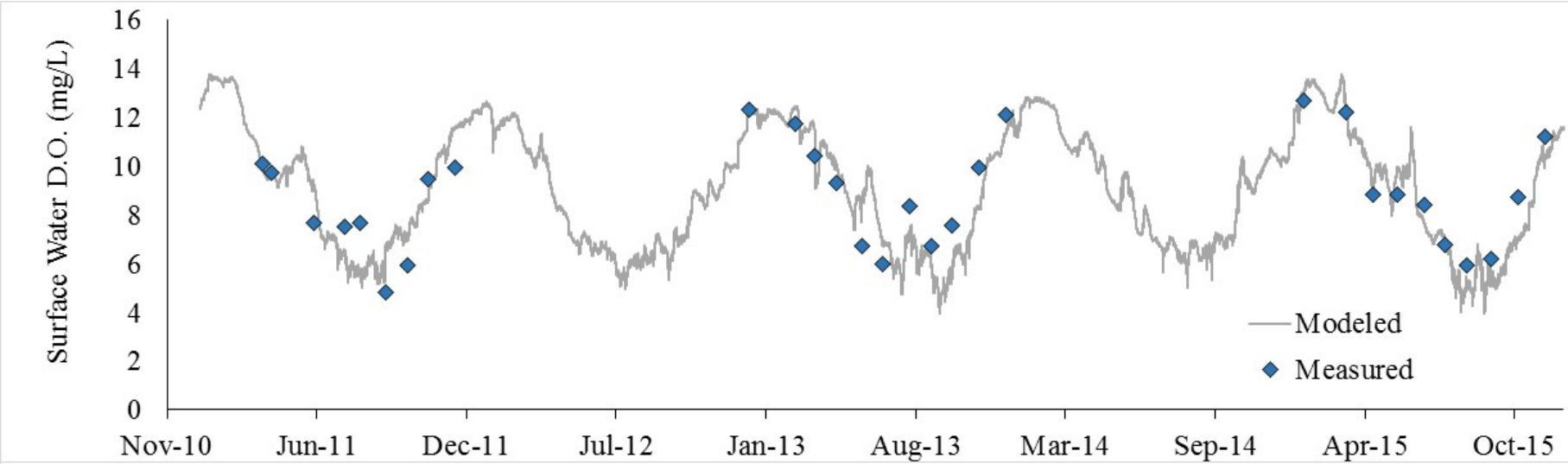

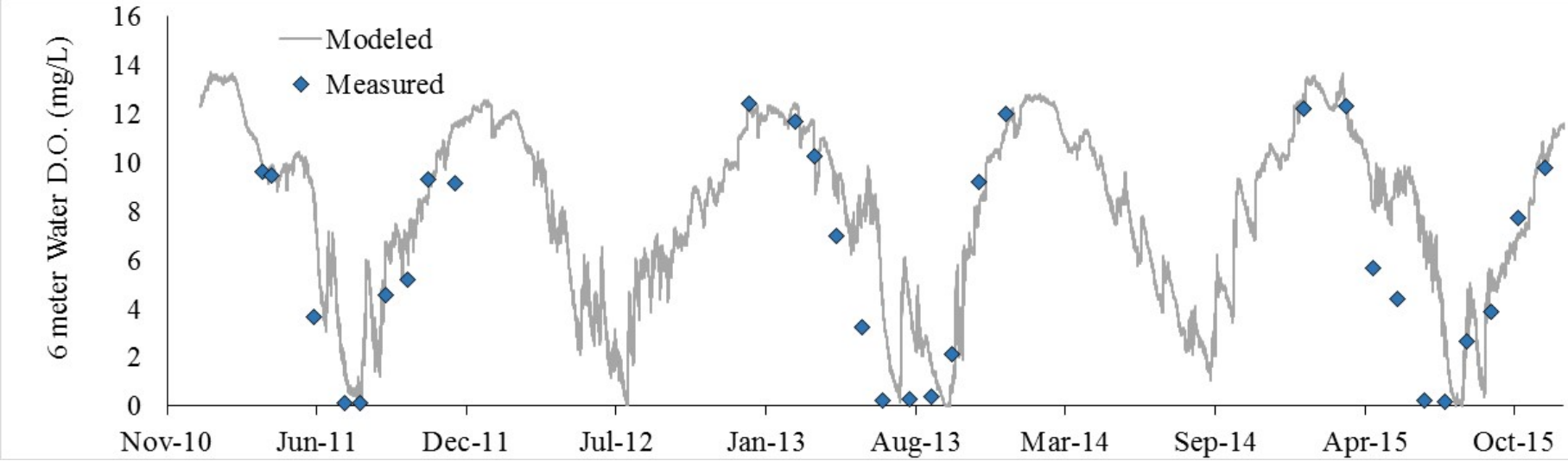

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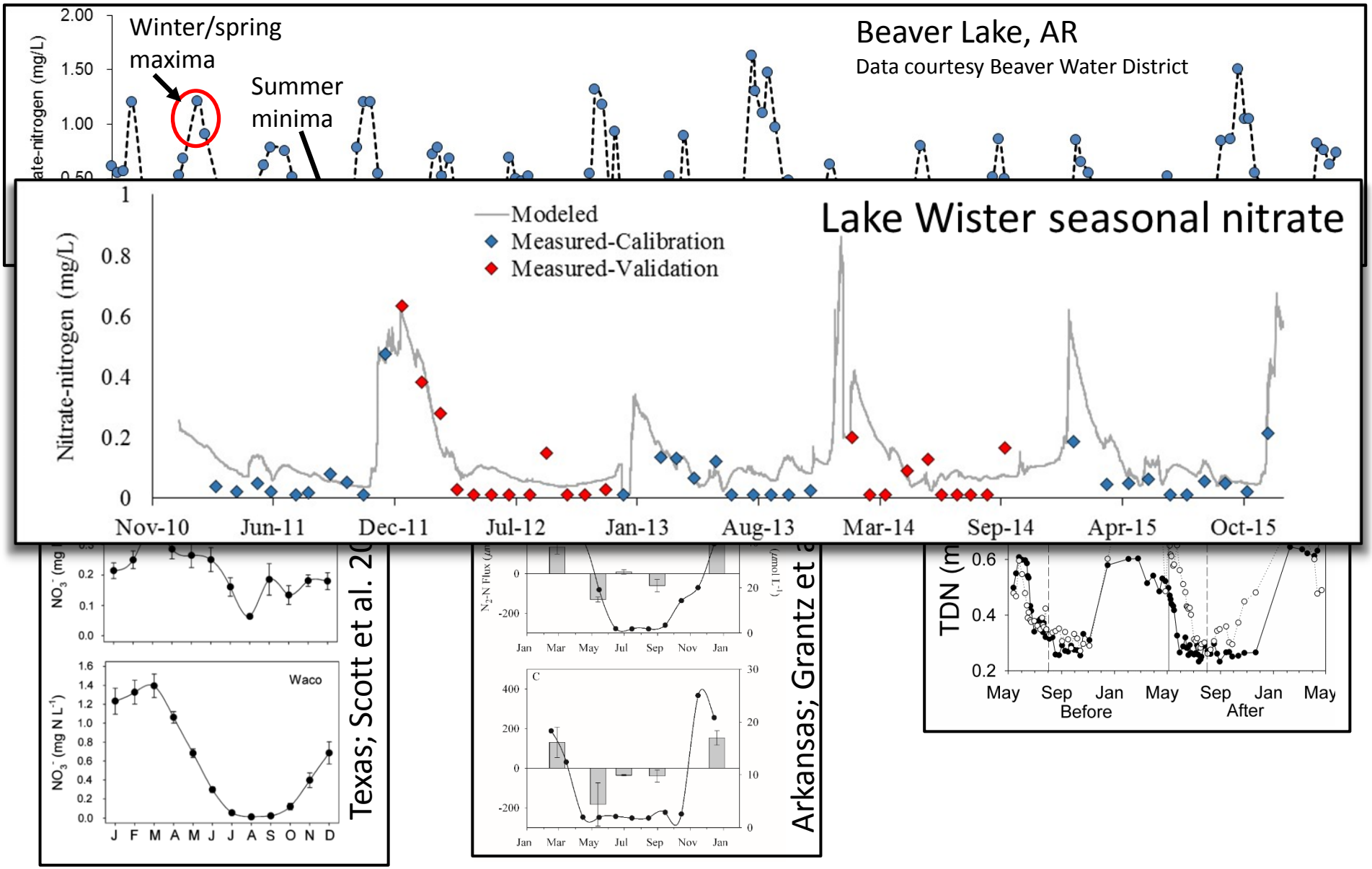
Seasonal nitrate dynamics in warm-temperate lakes and reservoirs



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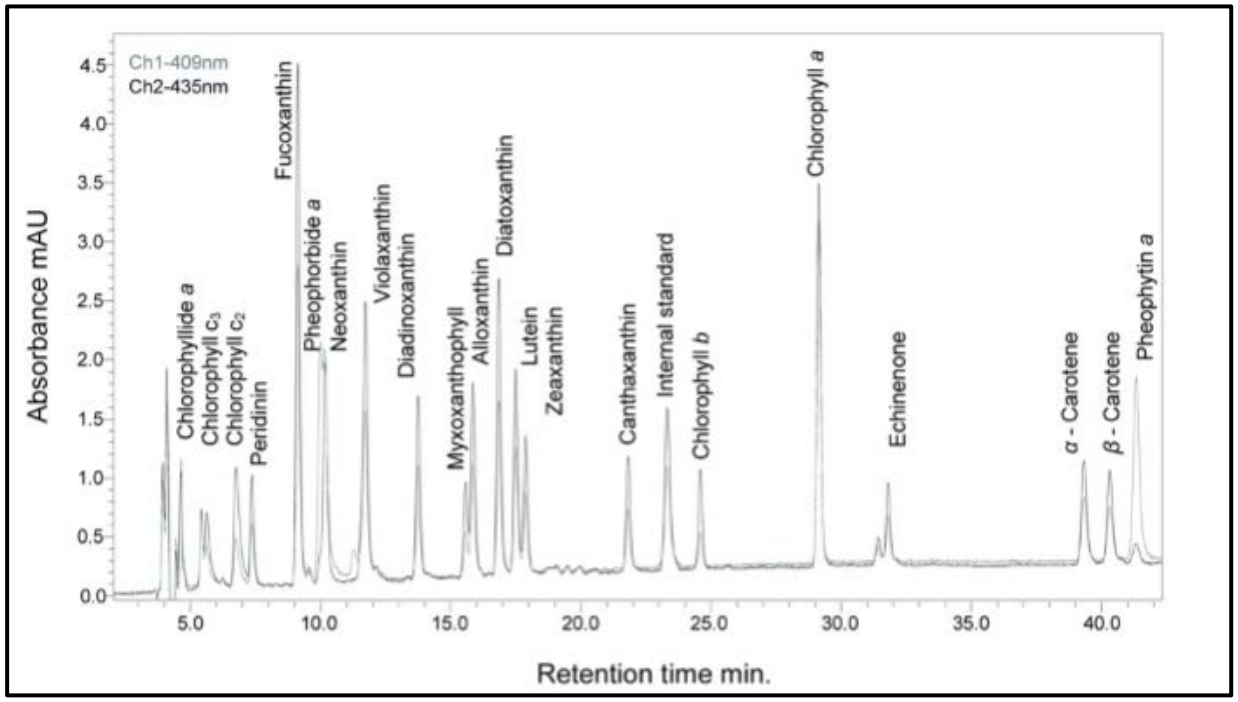
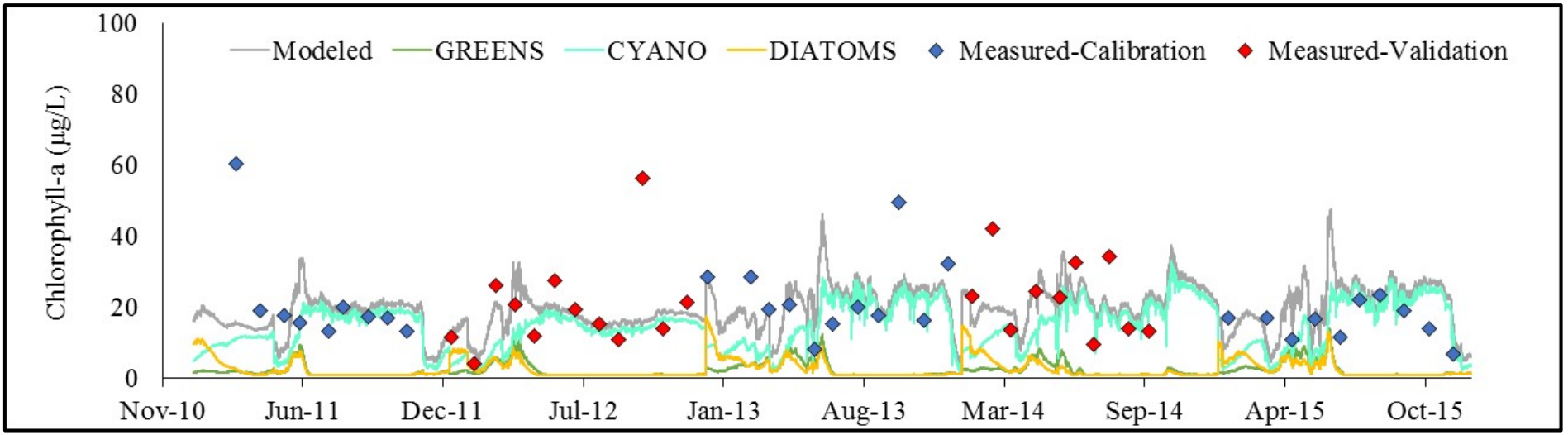
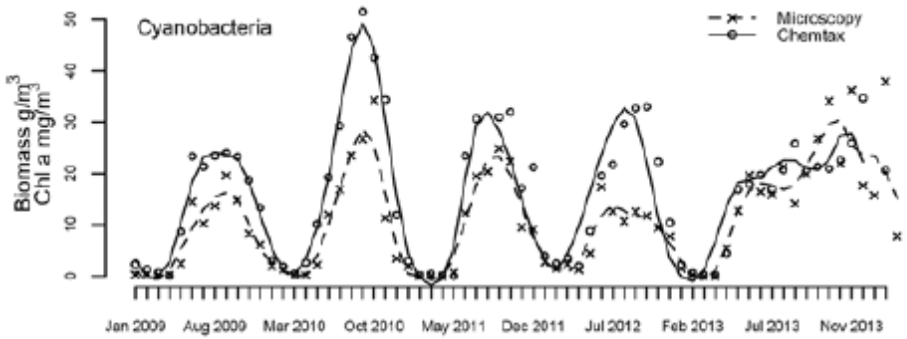
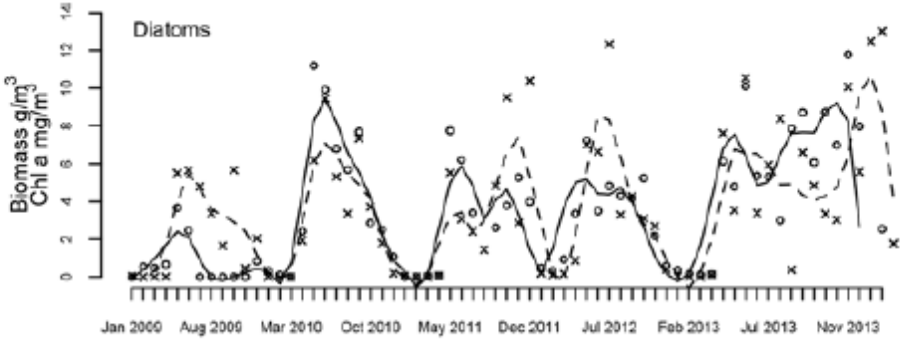
Calibrate phytoplankton biomass to pigment-specific data

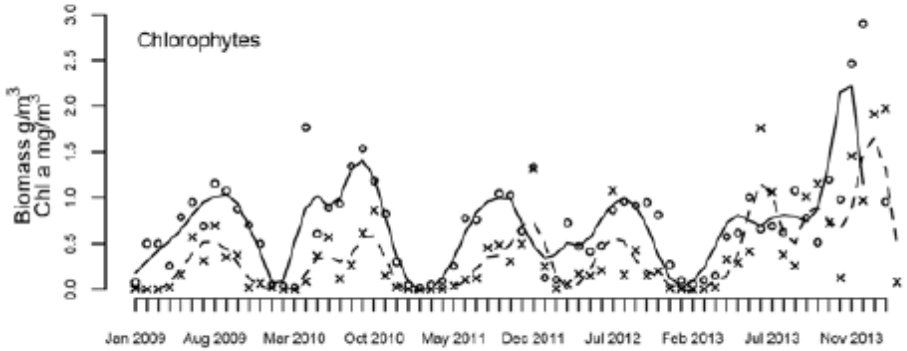
Tamm et al. 2015

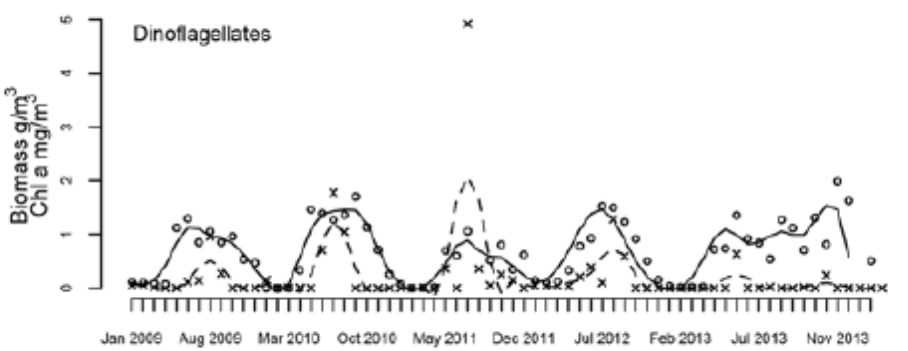


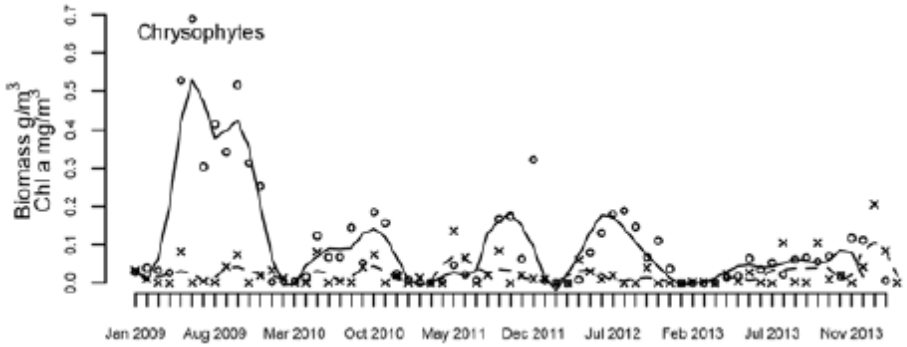


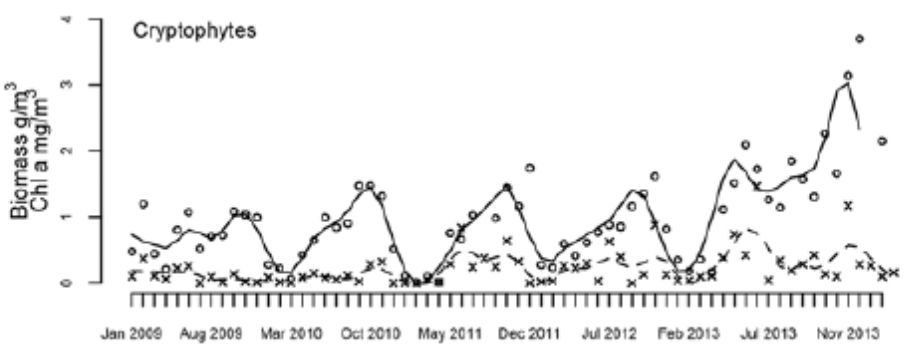












Tamm et al. 2015

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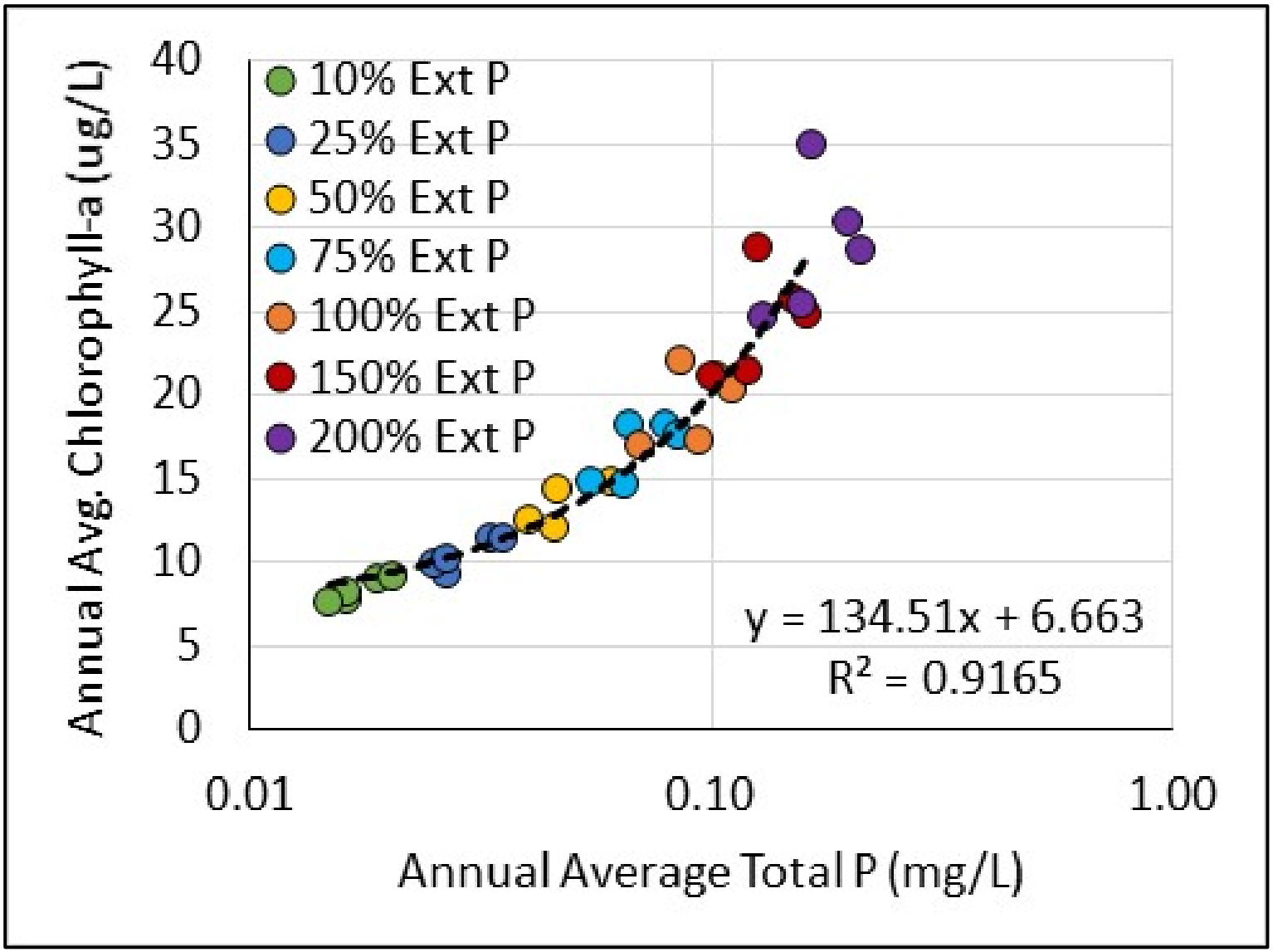
MONITOR MONITOR MONITOR MONITOR

Why model at all?

To simulate conditions to inform management



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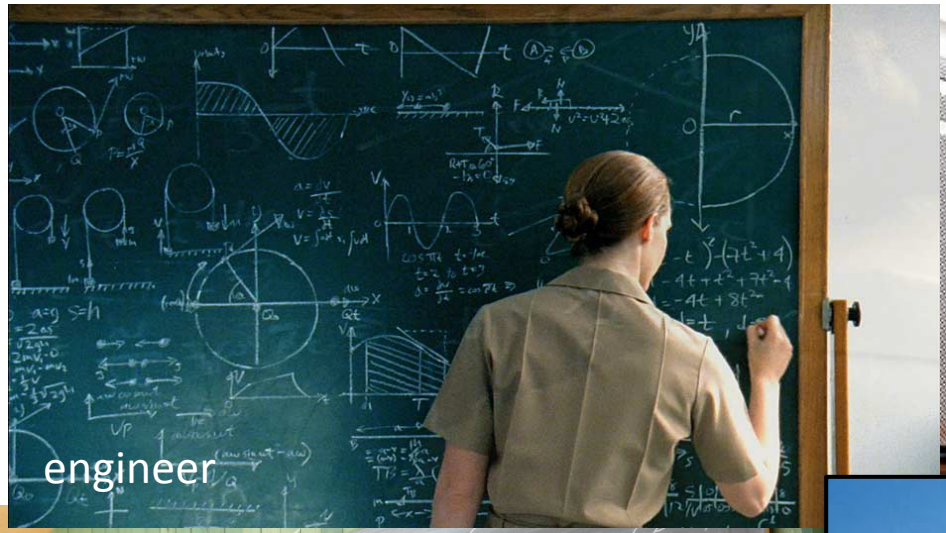

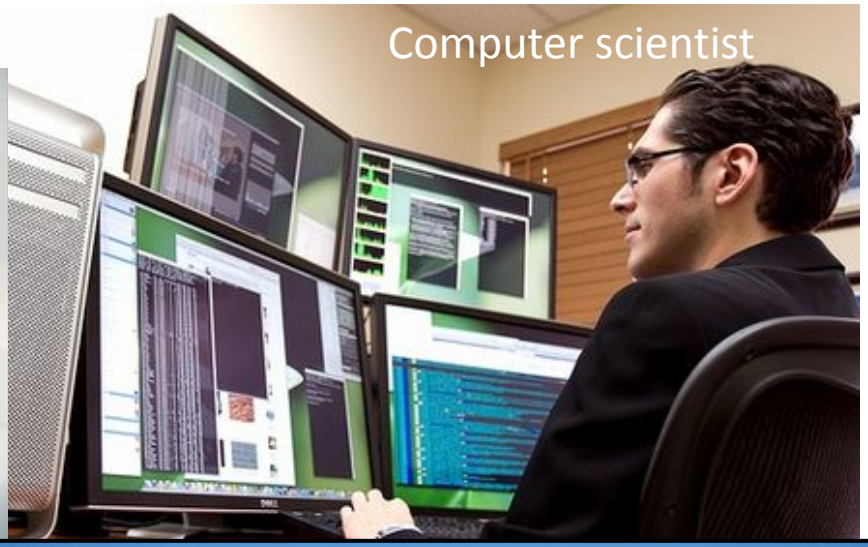

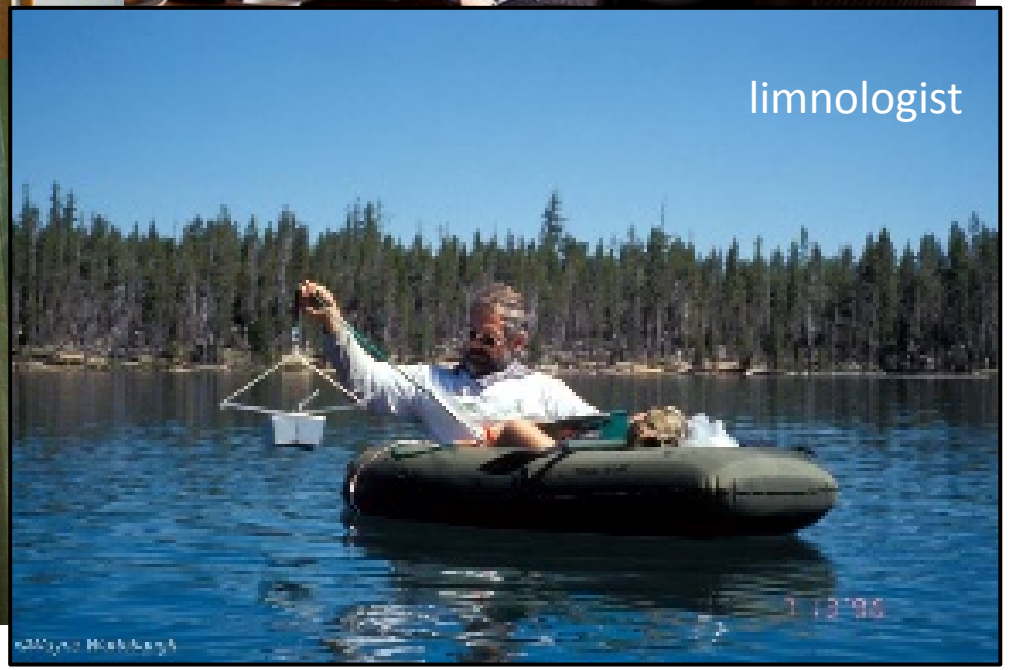

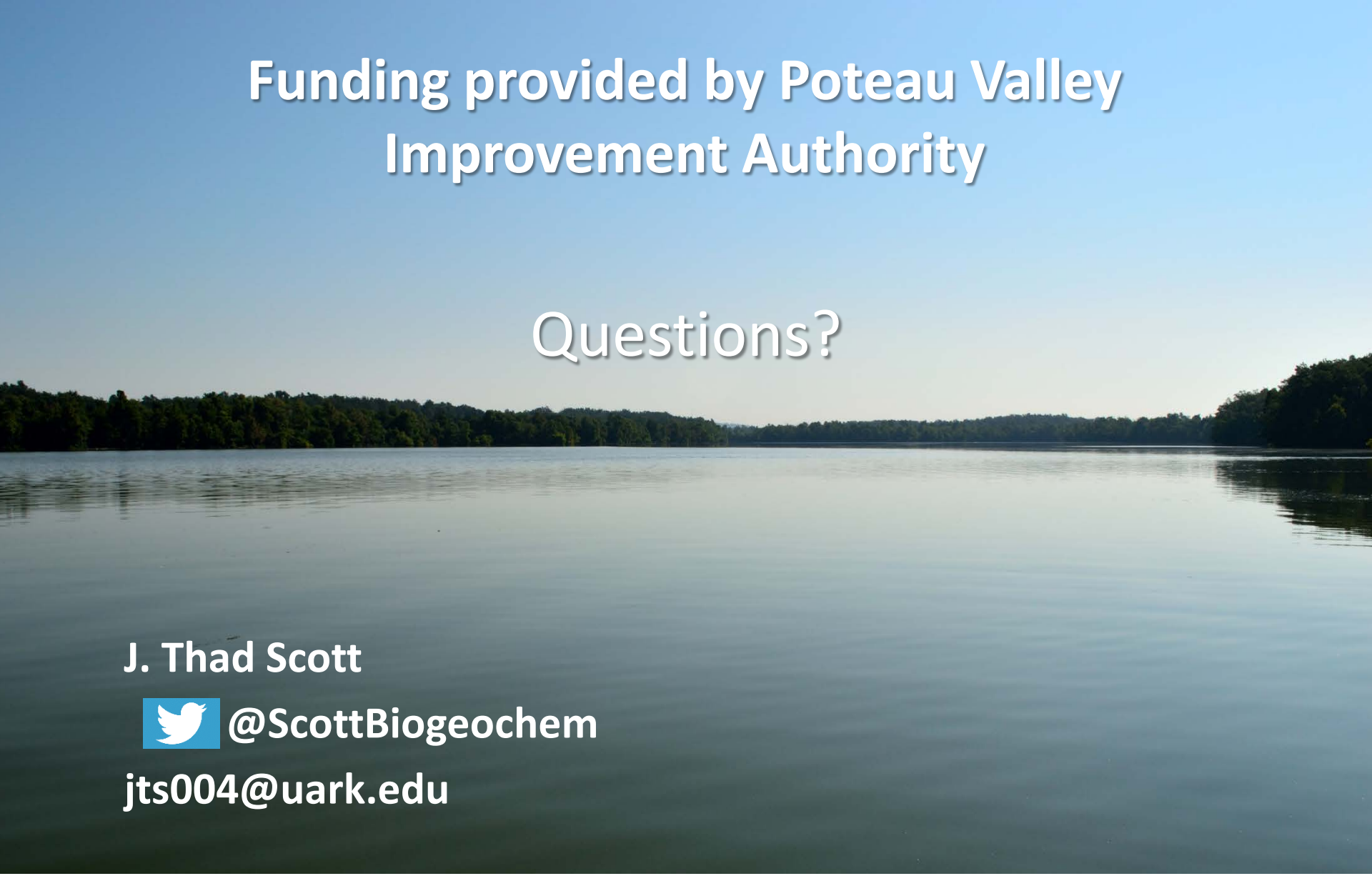

Funding provided by Poteau Valley Improvement Authority

Questions?

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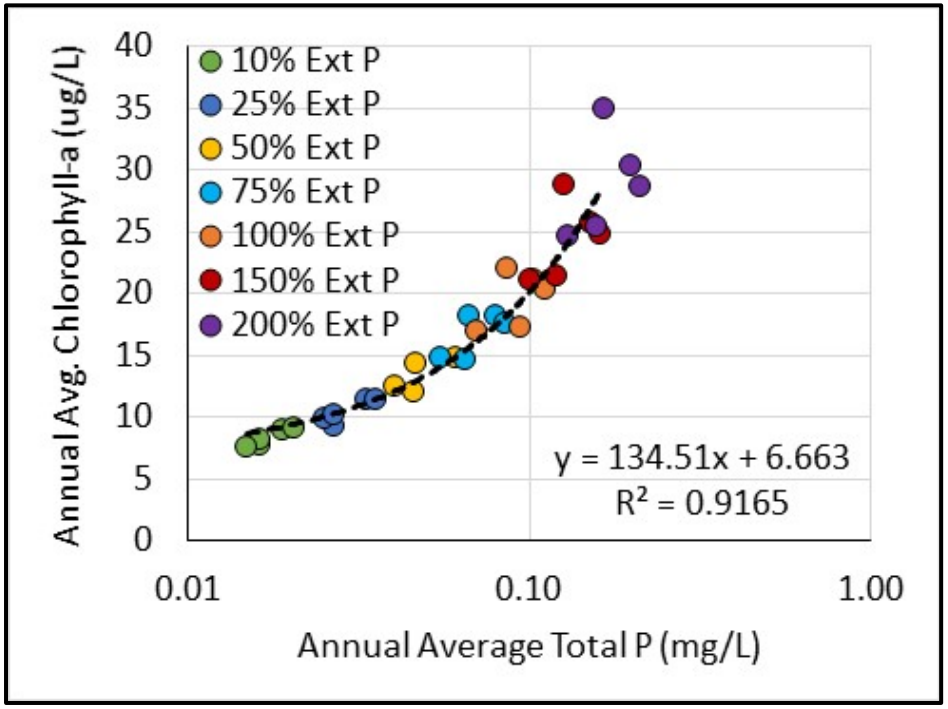
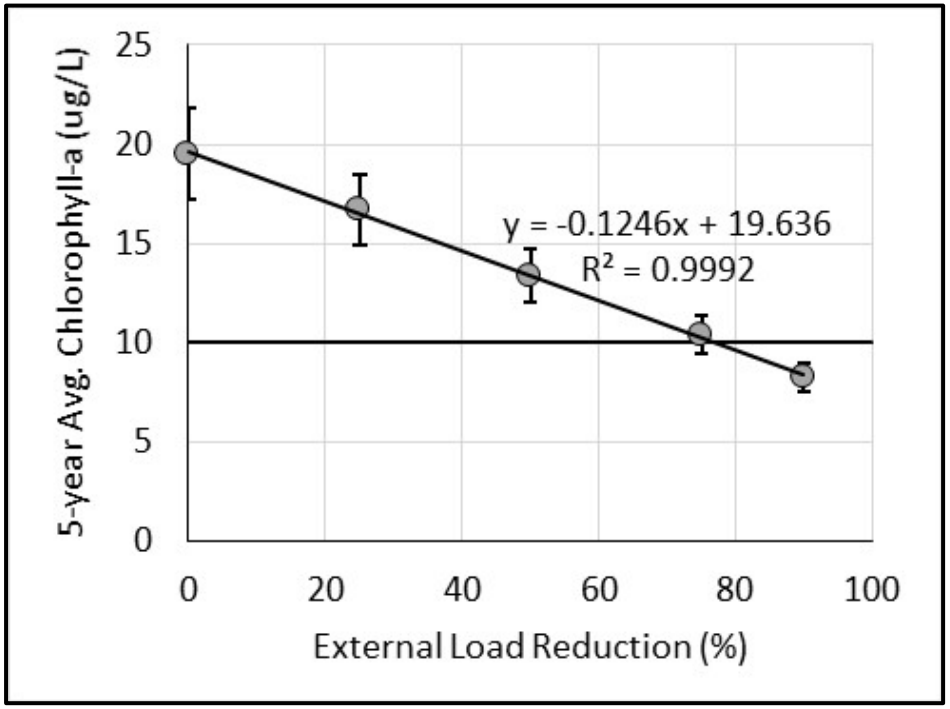
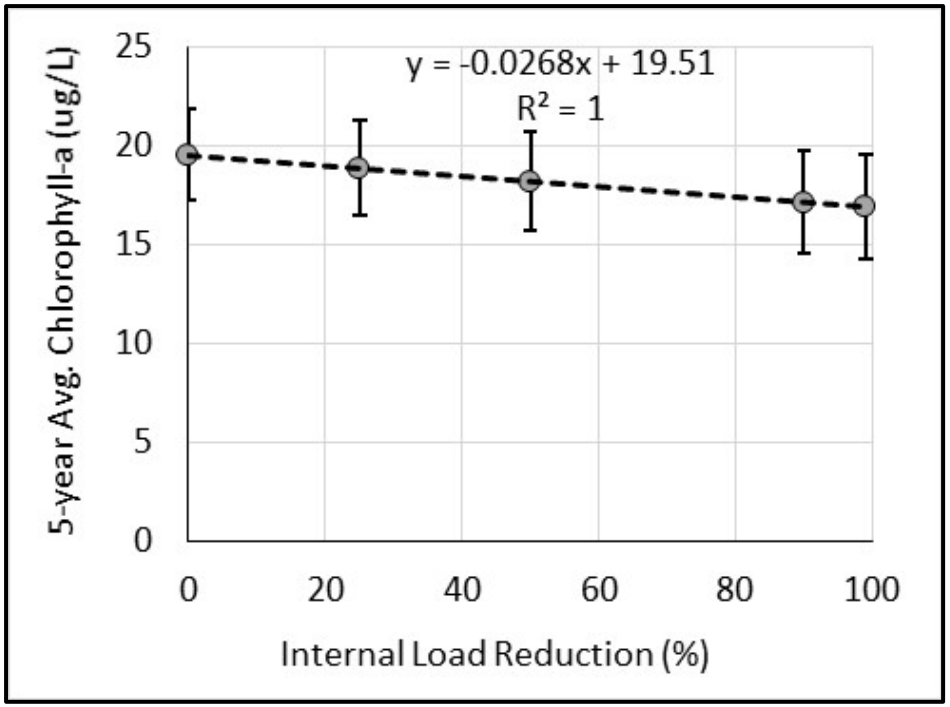
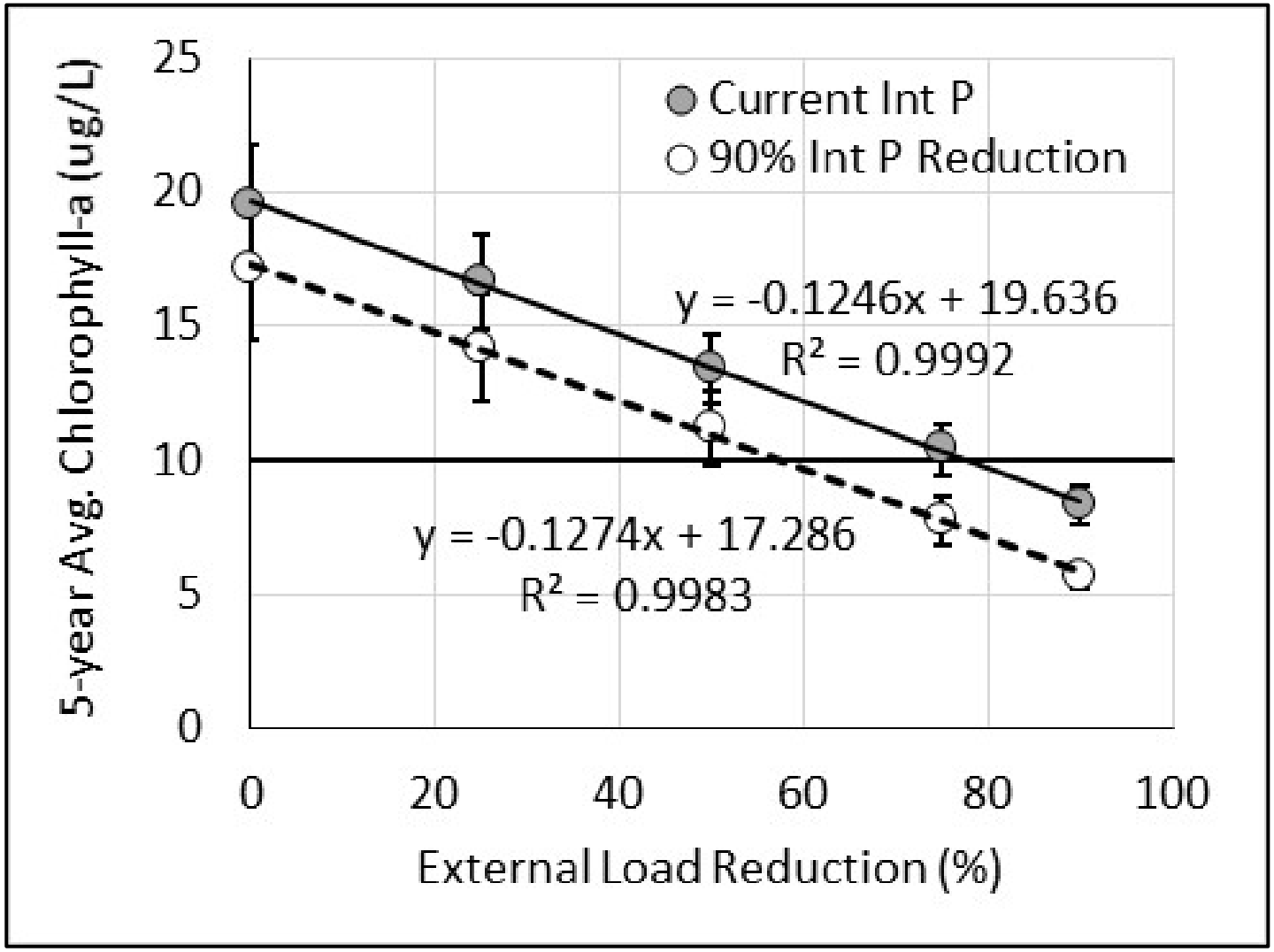

Annual Avg. Chlorophyll-a (ug/L)
40
35
30
25
20
15
10
5
0
10% Ext P
25% Ext P
50% Ext P
75% Ext P
100% Ext P
150% Ext P
200% Ext P
y = 134.51x + 6.663
R² = 0.9165
0.01
0.10
1.00
Annual Average Total P (mg/L)


5-year Avg. Chlorophyll-a (ug/L)
25
20
15
10
5
0
y = -0.1246x + 19.636
R² = 0.9992
0
20
40
60
80
100
External Load Reduction (%)


5-year Avg. Chlorophyll-a (ug/L)
25
20
15
10
5
0
y = -0.0268x + 19.51
R² = 1
0
20
40
60
80
100
Internal Load Reduction (%)


5-year Avg. Chlorophyll-a (ug/L)
25
20
15
10
5
0
0
20
40
60
80
100
External Load Reduction (%)
Current Int P
90% Int P Reduction
y = -0.1246x + 19.636
R² = 0.9992
y = -0.1274x + 17.286
R² = 0.9983