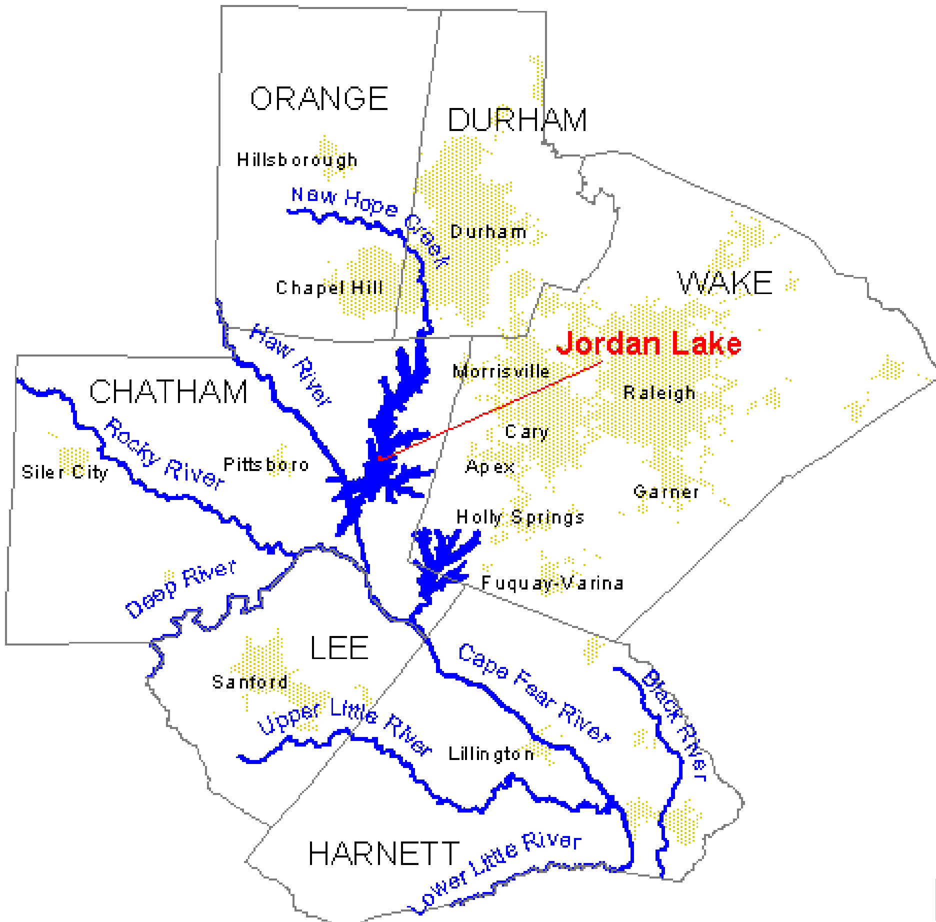
Multi-dimensional mechanistic modeling of Jordan Lake – Project Description



James Bowen, Assoc. Professor, Assoc. Chair

Civil and Environmental Engineering Dept.

NSAB Meeting, Durham, NC
November 2, 2018

UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE *of* ENGINEERING

Project Overview

Project Duration: Aug. 2018 – Dec. 2019

Objectives:

1. Setup and calibrate a mechanistic, multi-dimensional model of Jordan Lake, NC based on current monitoring data
2. Run scenario tests to investigate system sensitivity to potential management actions (nutrient load reduction, circulation modification, others TBD)

Project Tasks and Timeline

1 July – 30 Sep. 2018
Initial Consultation with NC DWR, Jordan Lake Monitoring Project Team, Stakeholders

1 Sep. – 31 Dec. 2018
Data Gathering, Initial Model Setup and Testing

1 Jan. – 30 Apr. 2019
Model Calibration

1 May – 31 July 2019
Scenario Testing with Calibrated Model

1–31 Aug.
Presentation of Initial Model Project Results to DWR, Stakeholders, Jordan Lake Project Team: August 1- 31, 2019

1 Sep. – 31 Oct. 2019
Additional Work as Needed on Model Inputs, Calibration, and Scenario Tests

1 Nov. – 31 Dec. 2019
Project Reporting

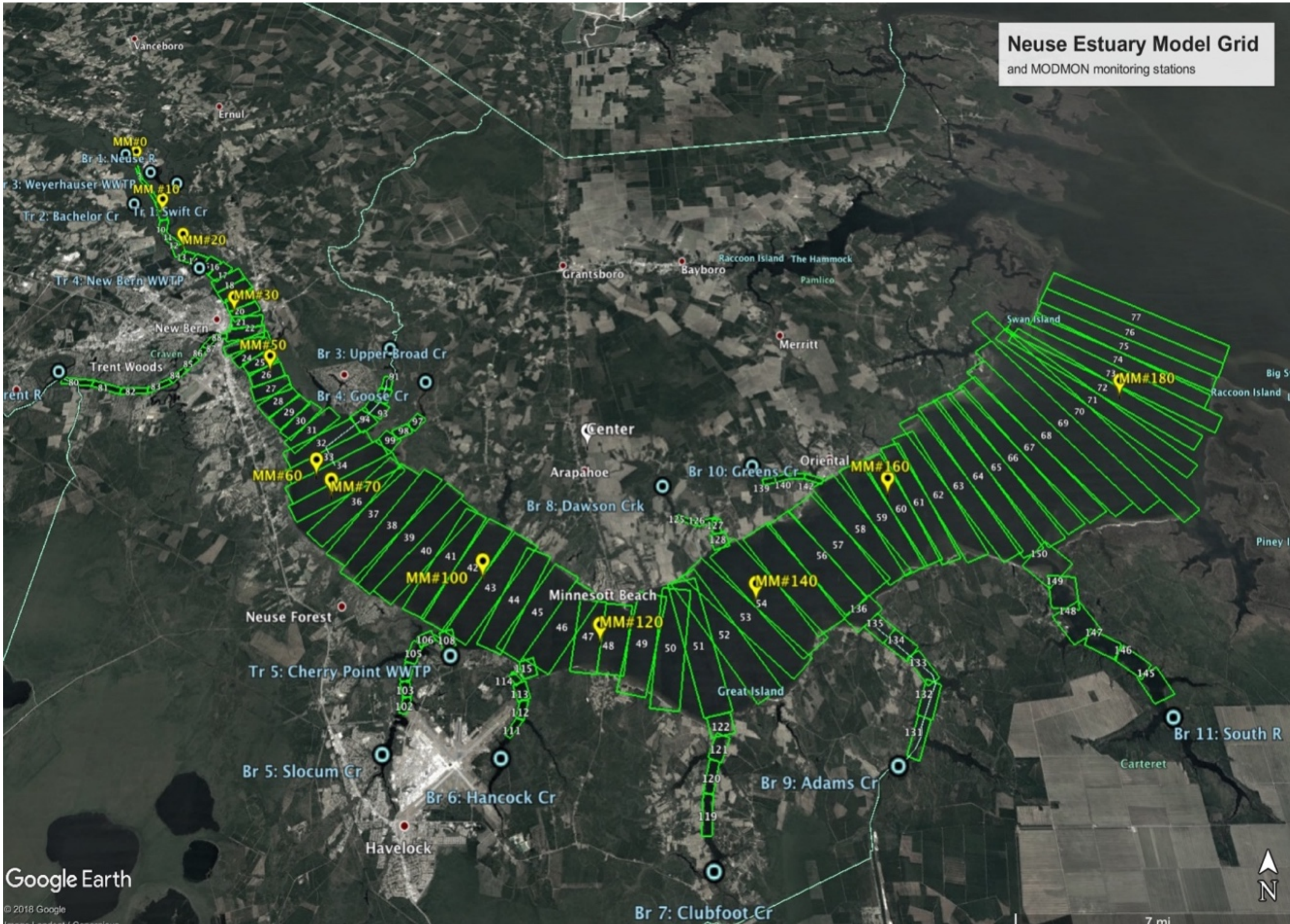
But first, a little about me

- PhD from MIT, 1990 - Modeled interaction between a phytoplankton cell and nearby motile bacteria, simulated effects of turbulent shear on microscale nutrient distributions and bacterial chemotaxis
- Worked in consulting in Boston area until 1996 doing surface water monitoring and modeling work
- Moved to NC in '96 to take position as an Assistant Professor at UNC Charlotte, began work on Neuse R. almost immediately (w/ help from Rick Luettich)
- Interim Chair of Civil & Environmental Engr. (CEE) Dept. in 2017 & 1st half of 2018
- Now CEE dept. graduate program director and associate chair, Nutrient Criteria Development SAC member

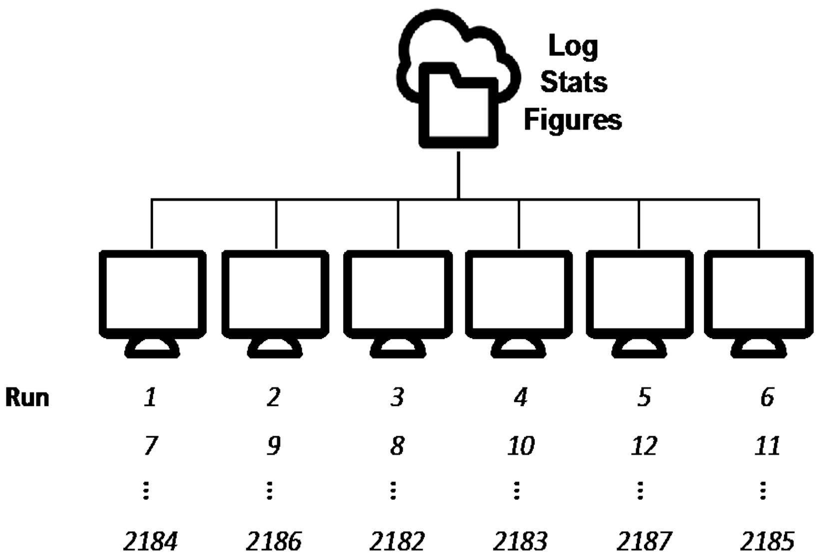
Mechanistic Modeling Experience in North Carolina – Neuse River Estuary

- Research funded by NC WRRI ('97, '99, '16, '18)
- Developed a 2-d laterally averaged model of Neuse River Estuary (using CE-QUAL-W2)
- Added a sediment submodel to simulate denitrification in estuary
- Used as part of nutrient TMDL analysis of estuary in 1999, 2002
- Latest work refines model grid, automates calibration, extends model run to 2016, adds full sediment diagenesis submodel

Neuse River Estuary Model Grid

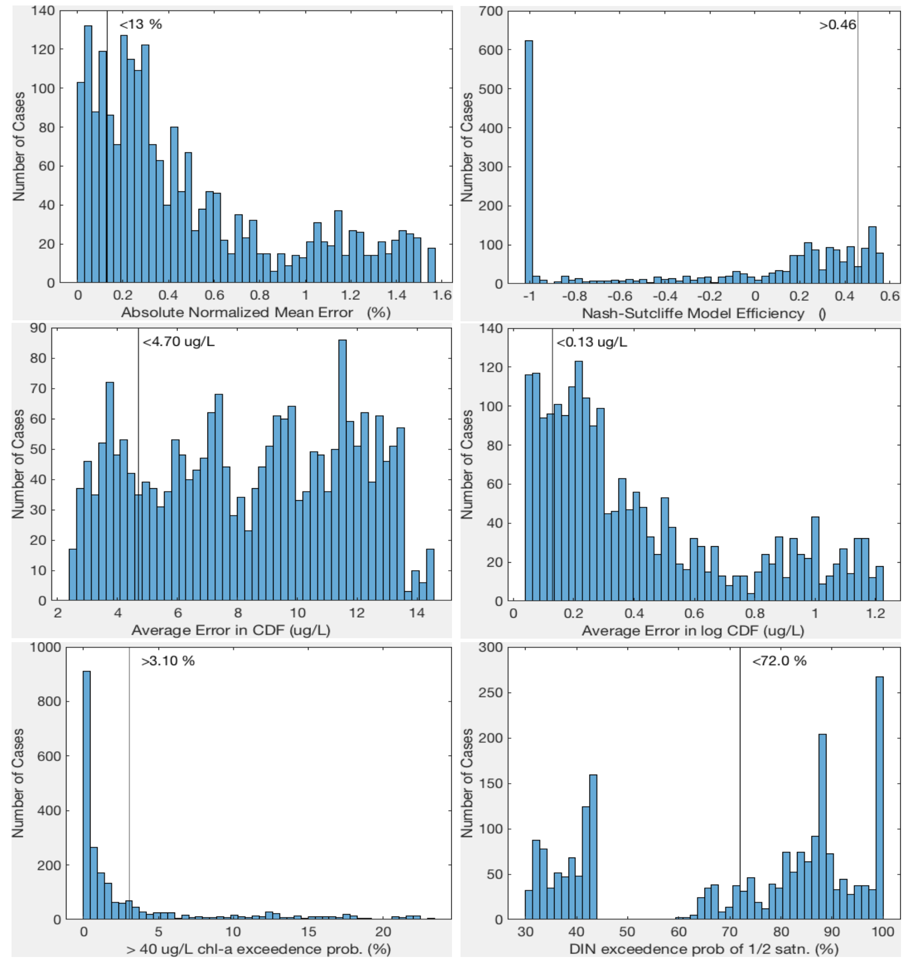


Automated model calibration w/ computer cluster



Computer Cluster Running Model in Parallel Thousands of Times

Histograms of Six Numeric Calibration Criteria



Mechanistic Modeling Experience in North Carolina – Cape Fear River Estuary

- Research funded by NC DWR (2006-2009)
- Developed a 3-d laterally averaged model of lower Cape Fear River Estuary (below lock & dam 1) using EFDC
- Used long-term BOD tests of WWTP effluent to quantify OM decay rates
- Used attenuation of progressive wave in estuary to calibrate effective exchange volume w/ fringing marshes
- Model used by DWR to estimate DO impact of point and non-point organic matter inputs to estuary

Lower Cape Fear River Model Grid

Figure 6. Model Grid Showing Location and Size of Marsh Cells

DOC (top) and NH4 (bot) load to LCFR estuary by source

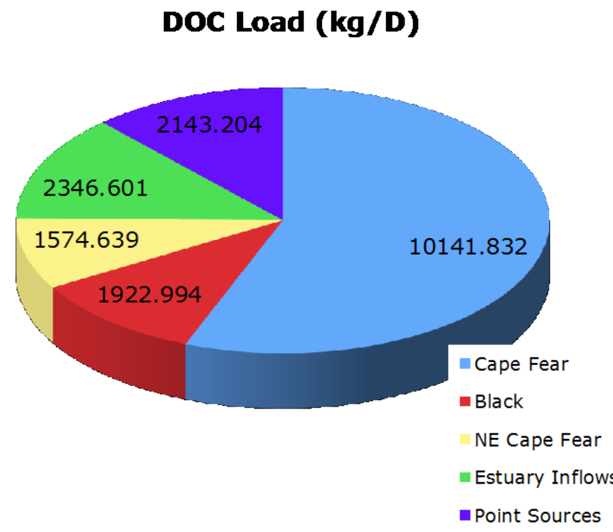


Figure 44. Average Daily Load of Dissolved Organic Carbon to the Model Region from Various Sources

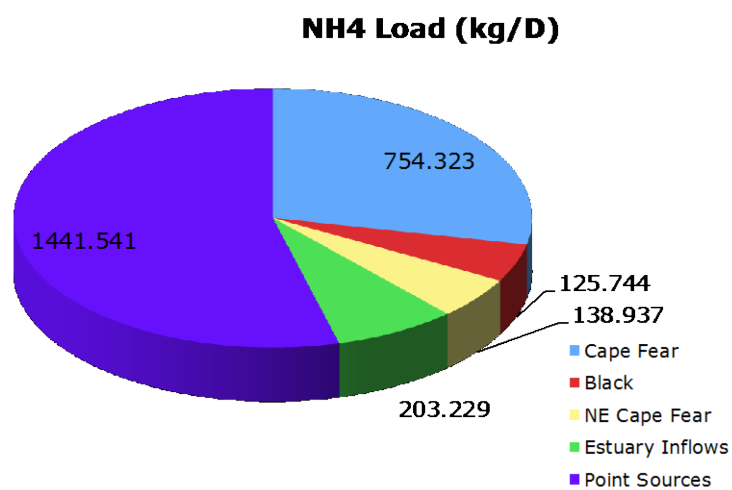


Figure 45. Average Daily Load of Ammonia to the Model Region from Various Sources.

Model Predicted & Observed DO’s in Lower Cape Fear River

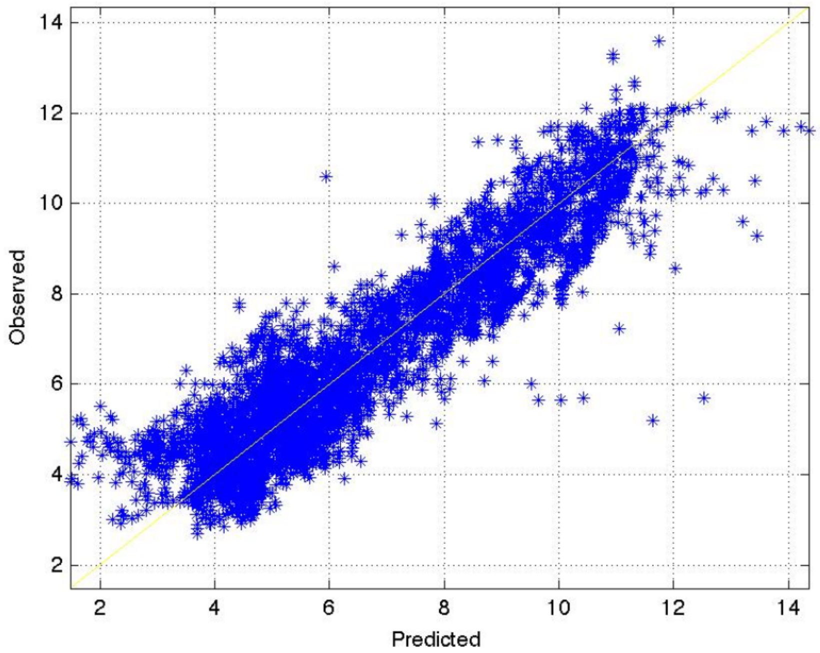


Figure 51. Scatter Plot of Predicted Dissolved Oxygen Concentrations (mg/L, x-axis Corresponding Observed Dissolved Oxygen Concentrations (mg/L, y-axi 2004 Calibration Period.

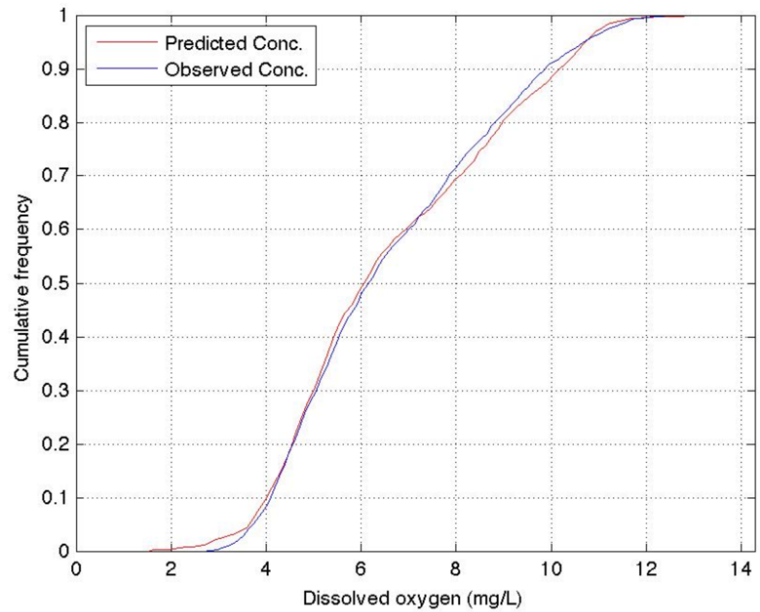


Figure 52. Percentile Plot of Observed and Model Predicted Dissolved Oxygen Concentrations During the Calibration Period. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x -axis.

Jordan Lake Model Plan, Some Thoughts

- Previous model (EFDC/WASP) was developed using data from almost 20 years ago

EFDC Hydrodynamic Grid

Original Tetratech Jordan Lk. Model

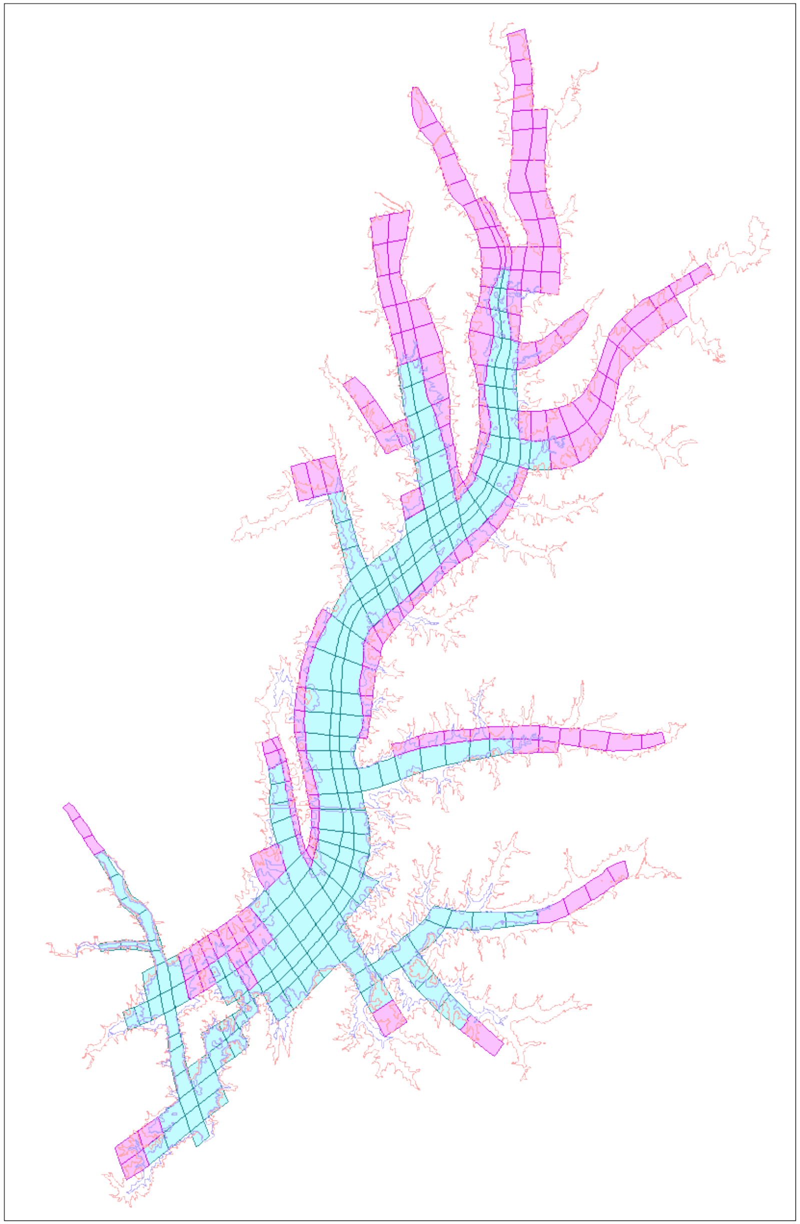


Figure 3-2. EFDC Simulation Grid for Jordan Lake. Cells shown in pink are repres dry at lake normal pool elevation.

WASP Water Quality Grid

Original Tetratech Jordan Lk. Model

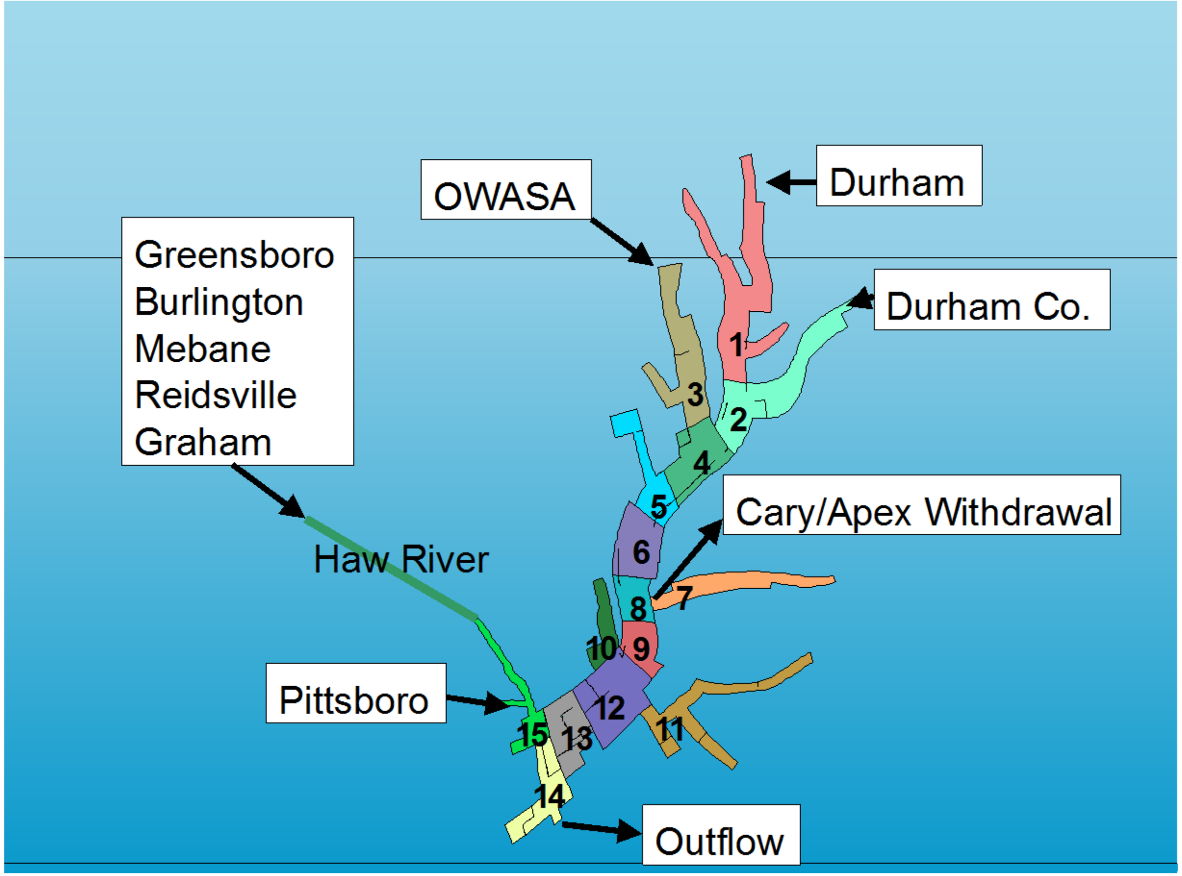
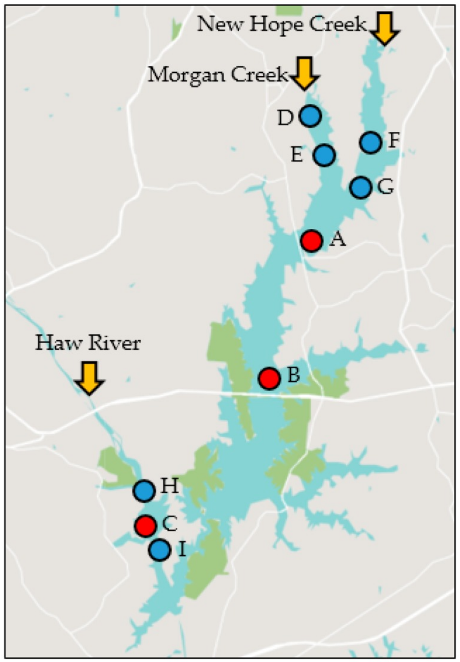


Figure 3-13. Relationship of WASP Model Segments, Major Dischargers, and Withdrawal from Jordan Lake.

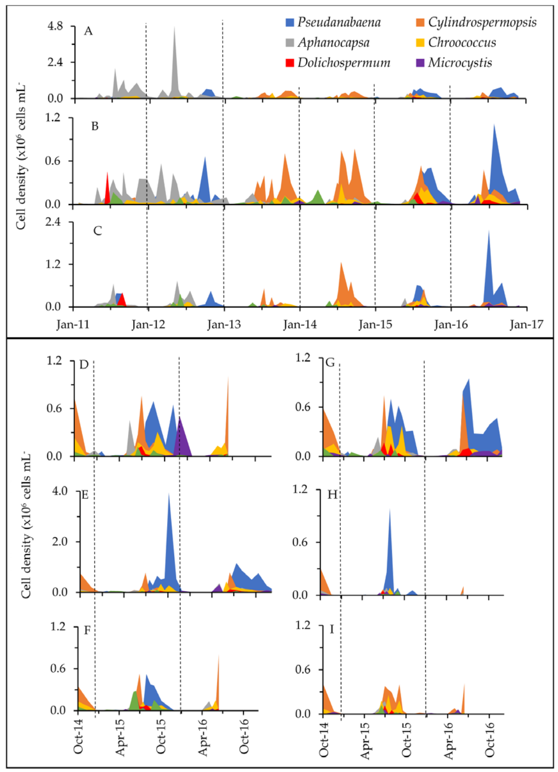
Jordan Lake Model Plan, Some Thoughts

- Recent monitoring efforts (DWR, UNC policy collaboratory, UNC & NCSU faculty) provide data neeed to run and calibrate model

e.g. “Algal Blooms and Cyanotoxins in Jordan Lake, North Carolina” (2018, Schnetzer lab, NCSU)



Sampling Stations



B-G Algae Abundance vs. time

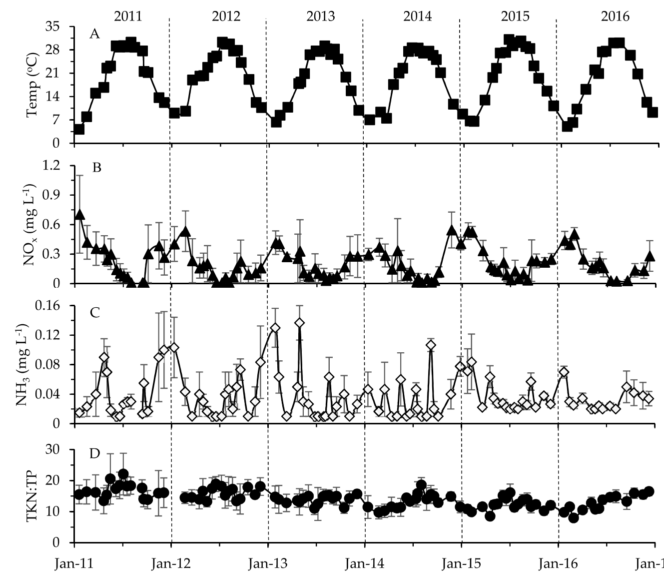


Figure 5. Changes in (**A**) temperature, (**B**) NO_x, (**C**) NH_3 concentration and (**D**) Total Kjeldahl nitrogen (TKN):TP ratio averaged for each sampling event. Standard error bars are included. Vertical dashed lines separate years.

Water quality constituents vs. time

Jordan Lake Model Plan, Some Thoughts

- Data collection underway, tentative plan is to model some or all of 2014 – 2017 time period
- Implementing a 3-d model (EFDC) for both hydrodynamics and water quality
- EFDC model will include sediment transport sub-model

EFDC water column, water quality state variables

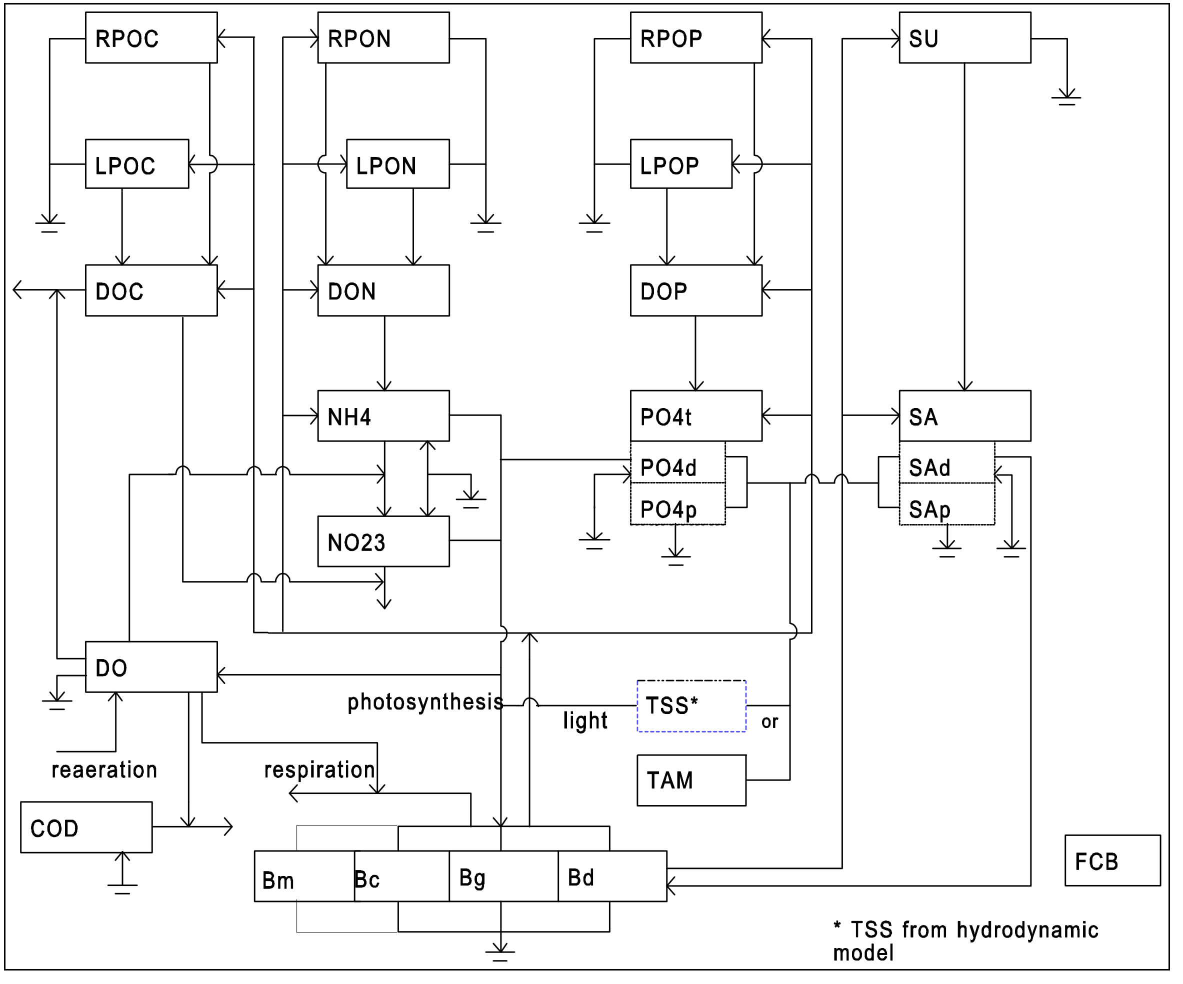
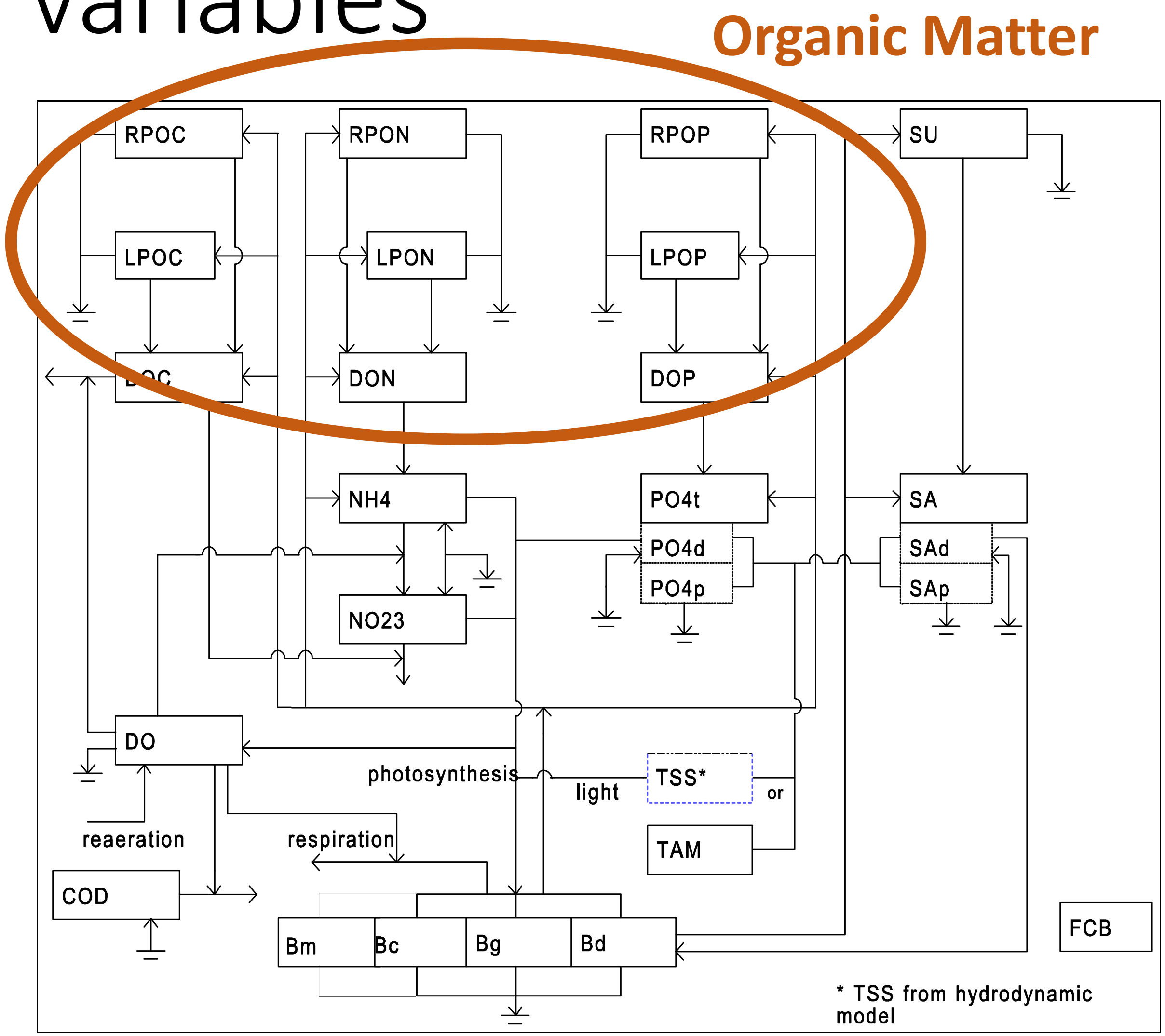


Figure 2.1 Schematic diagram of EFDC Water Quality Model Structure.

EFDC water column, water quality state variables



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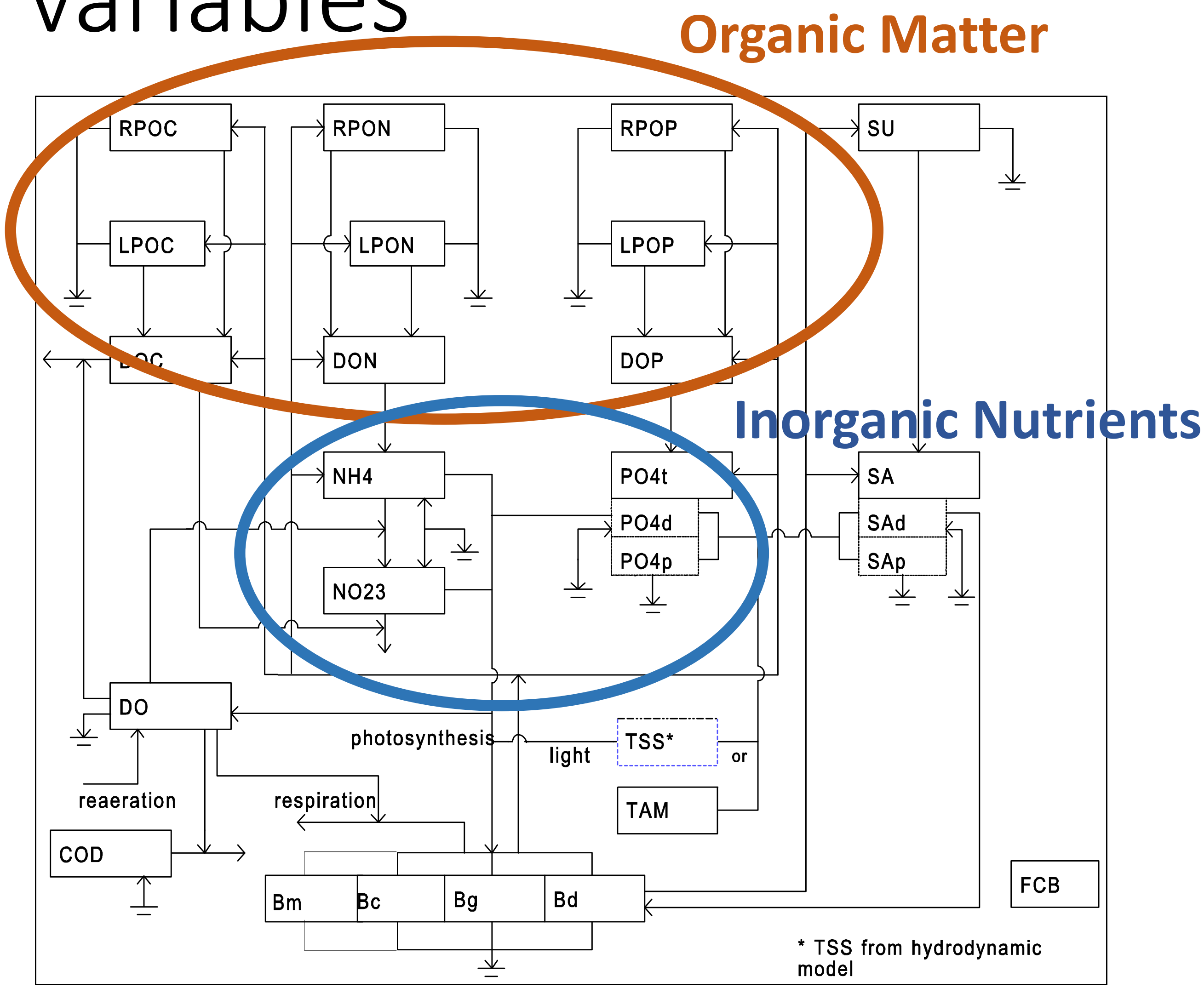

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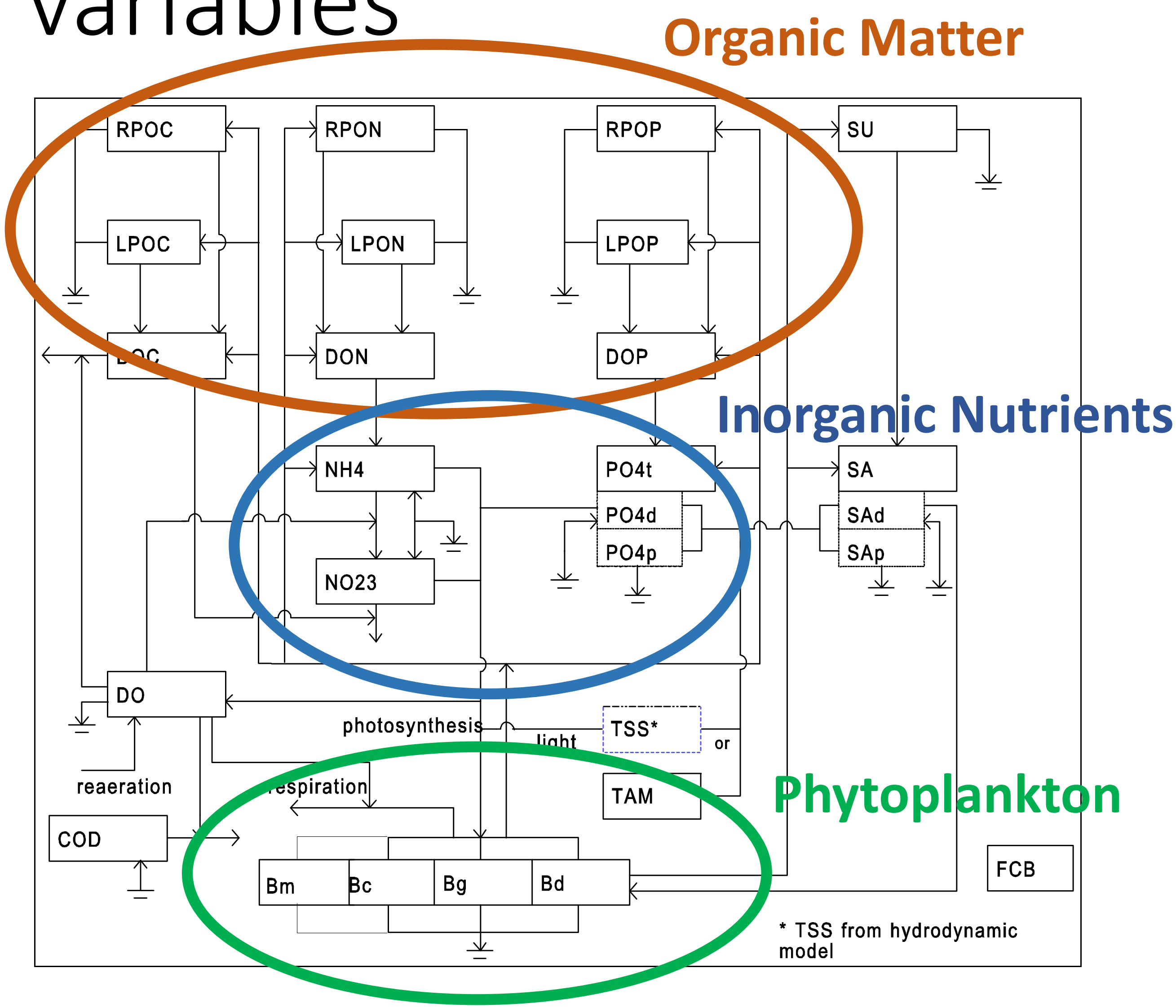

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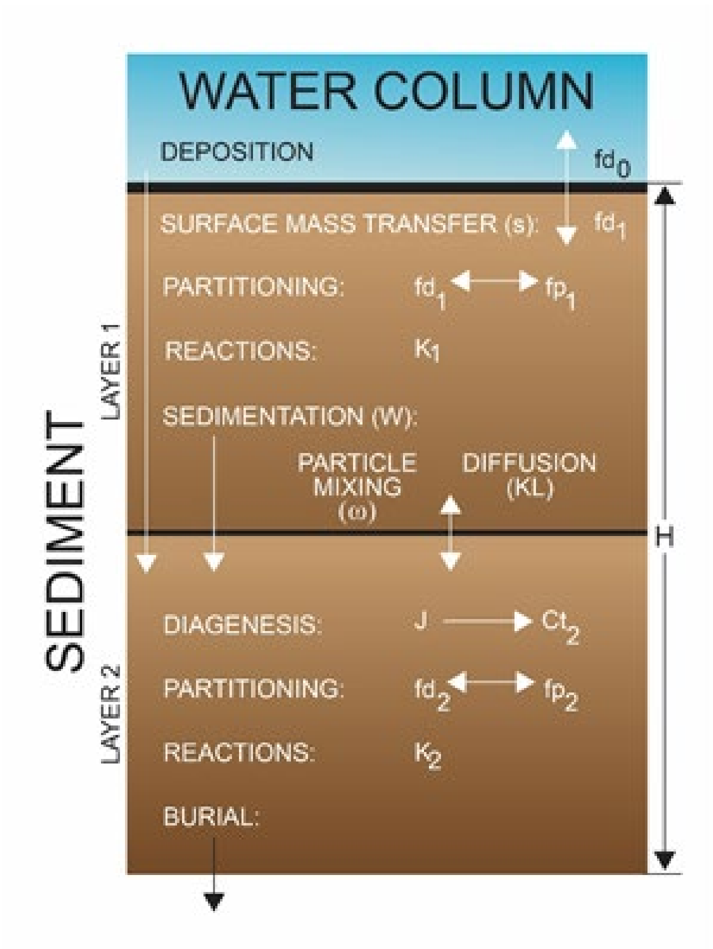
Sediment Diagenesis, conceptual model & state variables



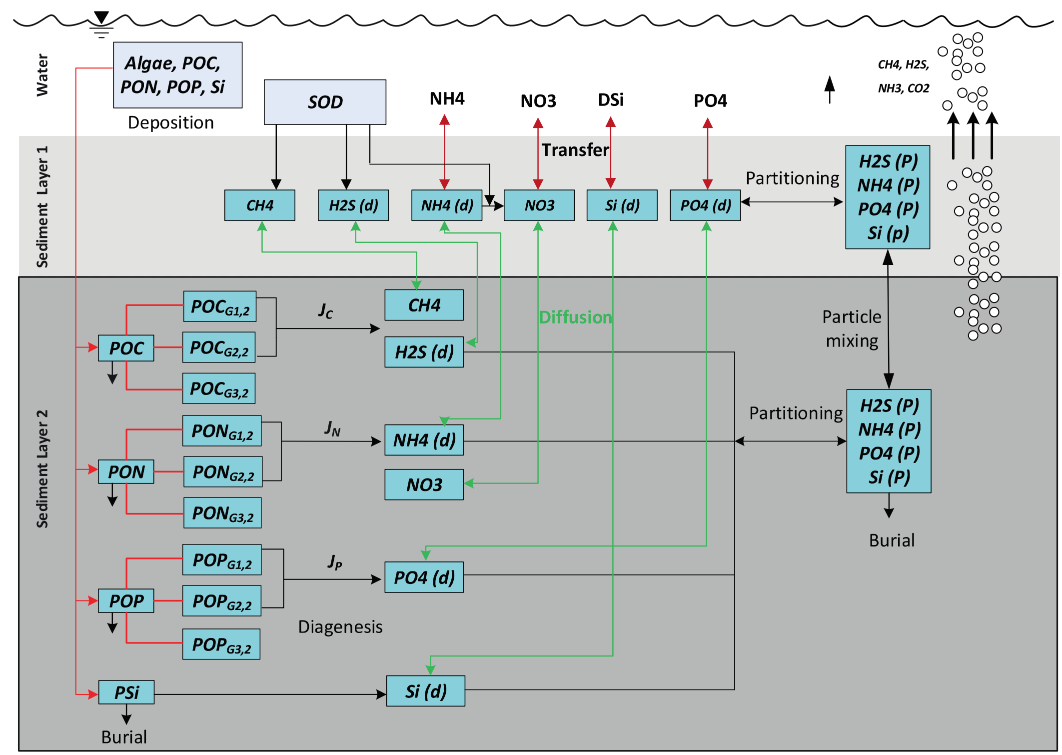


Fig. 3. Benthic sediment diagenesis modeling framework in enhanced W2.

Jordan Lake Model Plan, Some Thoughts, p. 2

- Will rely on Dan O. & Co.'s work in the watershed (WRTDS) to specify time varying nutrient load
- Water quality calibration will take advantage of automated multi-criteria approach developed for the Neuse River model
- Consultation w/ stakeholders throughout project is planned

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Questions?