Modeling and Regulatory Support Workgroup Meeting
November 1, 2022

Agenda

- Opening Comments, Agenda Review/Revisions
- Watershed Model Report Status
- WARMF Lake Modeling Status
- EFDC Lake Modeling Status
- Lake Reporting Status

Watershed Model Report Status
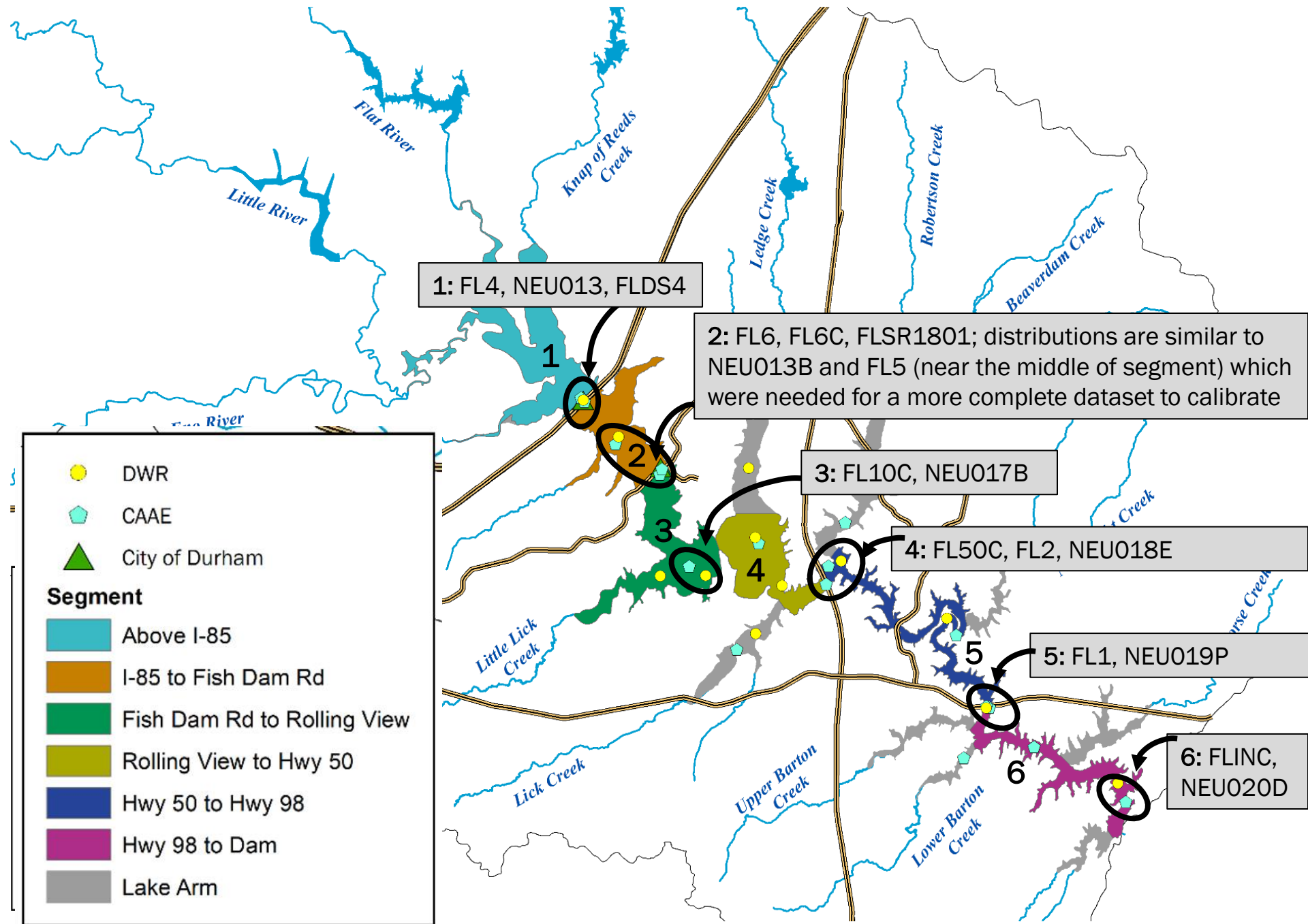
Watershed Model Report Status

- The draft WARMF watershed modeling report was distributed to the MRSW on June 30, 2022.
- We have received comments from several MRSW members as well as DWR.
- The modeling team continues to compile and address comments in a revised report to be submitted to the Path Forward Committee (PFC).
- Following PFC review and input, the report will be finalized for submittal to DWR for their formal review along with the modeling files and executable.
- Prior to delivery of the watershed model files, the modeling team will conduct a training workshop with DWR and others interested in running the model.

WARMF Lake Development and Calibration Status

WARMF Lake Development and Calibration

- During the August MRSW meeting
  - The modeling team reviewed past decisions regarding WARMF Lake development
  - The MRSW reviewed draft WARMF Lake calibration
  - Third-party reviewers suggested applying uniform model coefficients when feasible
- The modeling team has revised the calibration to use uniform chemical and biological reaction rates throughout the lake and retained segment-specific net settling rates
- A summary of the revised model coefficients and performance statistics follow.
- The MRSW will have the opportunity to provide feedback on the calibration.

WARMF Lake Calibration Stations (approved 10/5/2021)

Legend:

- DWR
- CAAE
- City of Durham

Segment
- Above I-85
- I-85 to Fish Dam Rd
- Fish Dam Rd to Rolling View
- Rolling View to Hwy 50
- Hwy 50 to Hwy 98
- Hwy 98 to Dam
- Lake Arm

1: FL4, NEU013, FLDS4

2: FL6, FL6C, FLSR1801; distributions are similar to NEU013B and FL5 (near the middle of segment) which were needed for a more complete dataset to calibrate

3: FL10C, NEU017B

4: FL50C, FL2, NEU018E

5: FL1, NEU019P

6: FLINC, NEU020D

Performance Criteria

- WARMF Lake uses the same performance criteria as the watershed model for water quality evaluations in the six main stem segments
- Measurements in Falls Lake at each station selected for calibration are compared to the segment output for the 6-hour time step that contains the observation

Model Performance Targets

Parameter	Percent Bias Criteria		
	Very Good	Good	Fair
Sediment	< ± 20	± 20-30	± 30-45
Water Temperature	< ± 7	± 8-12	± 13-18
Water Quality/Nutrients	< ± 15	± 15-25	± 25-35

Initial Conditions – Sediment Depth by Segment

Segment	Segment Type	Average Sediment Depth (cm)
Above I-85	Main	1.43
I-85 to Fish Dam Rd	Main	2.75
Fish Dam Rd to Rolling View	Main	3.40
Rollingview to Hwy 50	Main	6.77
Hwy 50 to Hwy 98	Main	6.76
Hwy 98 to Dam	Main	13.55
Beaverdam Impoundment	Arm	8.82
Honeycutt Arm	Arm	12.37
Horse Creek Arm	Arm	6.30
Ledge Creek Arm	Arm	3.04
Lick Creek Arm	Arm	3.52
Lower Barton Creek Arm	Arm	5.99
New Light Creek Arm	Arm	5.68
Upper Barton Creek Arm	Arm	6.65

Based on UNRBA Sediment Depth Special Study

No change from
August presentation

Adsorption Isotherms and Initial Sediment Bed Conditions – All Segments

N & P sediment adsorption isotherms set using sediment core and pore water concentration data:	
Phosphate*	10,000 L/kg
Ammonia	60 L/kg
N & P initial sediment concentrations set using sediment core data:	
Ammonia	0.7 mg/g N
Phosphate	0.9 mg/g P
Organic Carbon	25.6 mg/g
Initial concentration of detritus (provides a pool of organic matter to break down into N, P, Org. C, etc.)	
Detritus	3.7 mg/g C

Primarily based on UNRBA Sediment Quality Special Study. Parameters marked with a "" indicate these were adjusted for model calibration.*

Sediment Bed Reaction and Diffusion Rates – All Segments

Rate (applied to all segments)	Value
BOD Decay, 1/d	0.5
Denitrification, 1/d	0.5
Sulfate Reduction, 1/d	0.05
Organic Carbon Decay, 1/d*	0.01
Nitrification, 1/d*	0.015
Detritus Decay, 1/d*	0.01
Settled Detritus Decay, 1/d*	0.01

Parameters marked with a "" indicate these were adjusted for model calibration. Bold rates were changed since August MRSW meeting (made uniform across segments).*

Reservoir Wide Parameters

Water Column Diffusion Parameters:			
Density Gradient Max (m²/sec)	0.0005		
Wind Diffusion Max (m²/sec)	0.0005		

Algae Growth Parameters:			
Parameter	Blue-Green Algae	Diatoms	Other Algae (Greens, Prym., Eugl., etc.)
Nitrogen Half-Saturation, mg/L*	0.005	0.005	0.005
Phosphorus Half-Saturation, mg/L	0.005	0.005	0.005
Silica Half-Saturation, mg/L	0.005	0.005	0.005
Light Half-Saturation, W/m^2 *	200	55	150
Lower Growth Temperature, C *	10	0	5
Upper Growth Temperature, C *	40	30	40
Optimum Growth Temperature, C *	31	8	17

Parameters marked with a "" indicate these were adjusted from model defaults.*

No change from
August presentation

Water Column Reaction Rates – All Segments

Reaction Rate	Value
BOD Decay, 1/d	0.5
Detritus Decay, 1/d*	0.01
Organic Carbon Decay, 1/d*	**0.01**
Nitrification, 1/d*	**0.015**
Denitrification, 1/d	0.5
Sulfate Reduction, 1/d	0.05
Periphyton Mortality, 1/d	0.05
Net Sand Settling/Resuspension, m/d*	1036.8
Blue-green, Diatom, Other Algae Respiration, 1/d*	0.01
Blue-green and Other Algae Mortality, 1/d*	0.02
Diatom Mortality, 1/d*	0.1
Blue-green and Other Algae Growth, 1/d*	**0.9**
Diatom Growth, 1/d*	**1.8**

Parameters marked with a "" indicate these were adjusted for model calibration.*
Bold rates were changed since August MRSW meeting (made uniform across segments).

Water Column Net Settling Rates – By Segment

Reaction Rate	Seg1	Seg2	Seg3	Seg4	Seg5	Seg6
Blue-green Settling, m/d	0.02	0.02	0.02	0.02	0.02	0.02
Diatom Settling, m/d	0.20	0.20	0.20	0.20	0.20	0.20
Other Algae Settling, m/d	0.06	0.06	0.06	0.06	0.06	0.06
Detritus Settling, m/d	0.25	0.25	0.25	0.25	1	1
Net Clay Settling, m/d	0.001	0.1	0.21	0.1	0.8	1
Net Silt Settling, m/d	0.001	3	3	3	3	3

Bed Sediment Diffusion Rate – By Segment

Reaction Rate	Seg1	Seg2	Seg3	Seg4	Seg5	Seg6
Diffusion, m^2/d	8E-06	8E-06	8E-06	3E-05	3E-05	3E-05

Each of these parameters were adjusted for model calibration.

Sediment Thickness Map and Diffusion Rates

The average sediment depths in segments to the left of the line range from 0.6 to 1.3 inches and to the right range from 1.4 to 5.3 inches. Lower sediment depths may not provide adequate habitat for some benthic organisms like worms that may extend 6 inches down into sediments (White and Miller 2008). Benthic organisms also prefer habitats where the water depth is ~1.5 times the depth of the photic zone (White and Miller 2008).
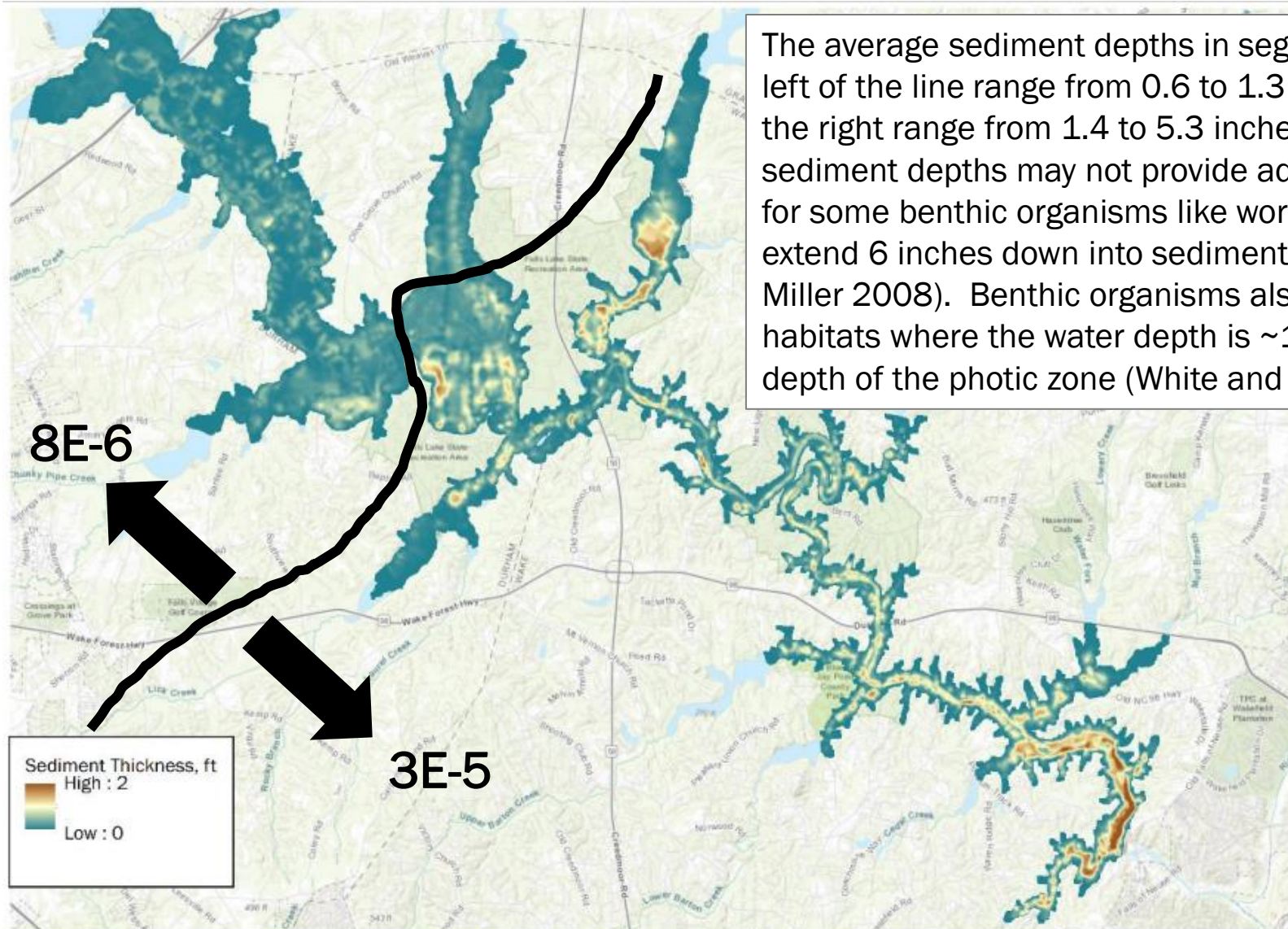
8E-6

3E-5

Sediment Thickness, ft
High : 2

Low : 0

0   0.5   1   2 Miles

N

Falls Lake Sediment Thickness
Upper Neuse River Basin Association
North Carolina

Brown AND Caldwell

Performance Criteria, Final WARMF Lake Calibration (5th Run)

Lake Segment:	Average of pBias: 1	2	3	4	5	6	Average of Observations by period (n), 1	2	3	4	5	% below reporting limit (full period) 6
Ammonia Nitrogen as N, mg/l							64%	65%	11%	47%	23%	27%
Full Period	38	21	8	64	-37	-54	0.029 (232)	0.031 (215)	0.019 (54)	0.019 (139)	0.045 (56)	0.06 (57)
Calibration	22	14	-26	38	-36	-38	0.029 (113)	0.03 (107)	0.022 (33)	0.022 (61)	0.046 (34)	0.051 (36)
Validation	54	27	101	95	-39	-64	0.029 (119)	0.033 (108)	0.013 (21)	0.015 (78)	0.043 (22)	0.069 (21)
Nitrate-Nitrite as N, mg/l							35%	37%	7%	46%	17%	28%
Full Period	33	-20	-46	18	-46	-51	0.077 (234)	0.08 (218)	0.06 (54)	0.031 (139)	0.053 (56)	0.06 (57)
Calibration	68	-14	-77	-40	-59	-48	0.064 (115)	0.06 (109)	0.081 (33)	0.049 (61)	0.069 (34)	0.067 (36)
Validation	9	-23	100	168	-17	-55	0.091 (119)	0.101 (109)	0.027 (21)	0.014 (78)	0.034 (22)	0.053 (21)
Total Kjeldahl Nitrogen as N, mg/l							0%	0%	0%	0%	0%	0%
Full Period	-10	-7	2	-2	-1	-4	0.96 (204)	0.83 (190)	0.76 (54)	0.72 (139)	0.67 (56)	0.62 (57)
Calibration	-8	-9	6	4	3	5	0.94 (115)	0.81 (109)	0.73 (33)	0.68 (61)	0.65 (34)	0.58 (36)
Validation	-13	-5	-5	-6	-5	-12	0.98 (89)	0.85 (81)	0.8 (21)	0.76 (78)	0.68 (22)	0.65 (21)
Total N - calculated, mg/l					Calculated parameter							
Full Period	-7	-9	-3	-2	-5	-9	1.03 (204)	0.9 (190)	0.82 (54)	0.75 (139)	0.72 (56)	0.68 (57)
Calibration	-4	-11	-3	0	-3	-1	1.01 (115)	0.87 (109)	0.81 (33)	0.73 (61)	0.72 (34)	0.65 (36)
Validation	-11	-7	-2	-4	-7	-15	1.06 (89)	0.94 (81)	0.83 (21)	0.77 (78)	0.71 (22)	0.71 (21)

- Values on the right side of the table in **black font**: average of the observations (number of samples)
- Values in blue font: percent of samples less than the reporting limit for the full period
- Different organizations sample different segments, and segments 1 and 2 have the most data
- Meeting the performance criteria (left side of table) is more difficult when concentrations are very low
- Ammonia and nitrate are generally underpredicted downstream of Highway 50
- Most of the total nitrogen is in the organic nitrogen form (TKN minus ammonia)
- TKN and TN are very good in all segments/periods except one (just over cutoff)

Highway 50 is downstream of Segment 4

Performance Criteria, Final WARMF Lake Calibration (5th Run)

Lake Segment:	Average of pBias:						Average of Observations by period (n), % below reporting limit (full period)					
	1	2	3	4	5	6	1	2	3	4	5	6
Chlorophyll-a, ug/l							0%	0%	0%	0%	0%	0%
Full Period, n=2	-5	-6	-10	-18	-5	10	42.2 (284)	36.5 (277)	35.3 (111)	32.3 (243)	27 (57)	20.6 (57)
Calibration, n=1	7	14	4	-6	20	16	39.6 (169)	31.2 (147)	31.4 (69)	28.6 (146)	21.3 (35)	18.2 (36)
Validation, n=1	-20	-22	-27	-32	-22	0	45.8 (115)	42.4 (130)	41.1 (42)	37.6 (97)	33.4 (22)	24.5 (21)
Total Organic Carbon, mg/l							0%	0%	0%	0%	0%	0%
Full Period	2	-5	0	-12	-15	-19	8.1 (235)	8.1 (219)	7.6 (54)	7.8 (139)	7.5 (57)	7.2 (57)
Calibration	1	-8	0	-8	-11	-14	8.5 (116)	8.3 (109)	7.8 (33)	7.6 (61)	7.5 (35)	7 (36)
Validation	4	-1	0	-14	-18	-24	7.8 (119)	7.8 (110)	7.3 (21)	7.9 (78)	7.6 (22)	7.3 (21)
Total Phosphorus as P, mg/l							30%	47%	0%	0%	0%	0%
Full Period	-21	-5	-7	-2	-2	12	0.097 (225)	0.053 (212)	0.06 (54)	0.048 (139)	0.04 (56)	0.031 (57)
Calibration	-23	-9	-12	-11	0	8	0.1 (114)	0.05 (106)	0.064 (33)	0.052 (61)	0.039 (34)	0.033 (36)
Validation	-18	-1	3	6	-3	16	0.093 (111)	0.057 (106)	0.054 (21)	0.045 (78)	0.042 (22)	0.03 (21)
Total Suspended Solids, mg/l					Calculated (TSS minus VSS)							
Full Period	7	-33	4	61	1	-2	19.5 (35)	13.9 (36)	6.2 (37)	5 (37)	3.1 (36)	2.2 (36)
Calibration	45	-27	1	36	-17	-9	16.7 (15)	12.6 (16)	6.2 (16)	5.5 (16)	3.2 (14)	2.2 (15)
Validation	-15	-36	7	84	14	3	21.6 (20)	14.9 (20)	6.2 (21)	4.6 (21)	3.1 (22)	2.2 (21)
Water Temperature, C							0%	0%	0%	0%	0%	0%
Full Period	3	6	7	9	12	11	22 (60)	22.4 (54)	17.8 (53)	17.8 (57)	17.7 (57)	17.5 (56)
Calibration	3	5	5	9	13	11	21.5 (37)	22 (34)	17.4 (32)	17.4 (36)	16.9 (35)	17 (35)
Validation	2	7	9	8	10	9	22.6 (23)	22.8 (20)	18.5 (21)	18.6 (21)	19.2 (22)	18.3 (21)

- Chlorophyll-a model performance is good to very good during calibration and validation at segments 1, 2, 5, and 6. It is very good at segments 3 and 4 during the calibration period and fair at both in the validation period.
- Total organic carbon model performance is good to very good for each segment and period
- Total phosphorus model performance is good to very good for each segment and period.
- There are fewer TSS observations due to lack of VSS measurements for comparison to WARMF output [WARMF TSS (silt plus clay) corresponds to observed TSS minus observed VSS]. TSS model performance is fair to very good except in segment 4.
- Water temperature model performance is usually good to very good with one segment/period that is fair.

Performance Criteria and Sediment Nutrient Fluxes (5th Run)

Lake Segment:	Average of pBias: 1	2	3	4	5	6	Average of Observations by period (n), % below reporting limit (full period) 1	2	3	4	5	6
Ammonia Nitrogen as N, mg/l							64%	65%	11%	47%	23%	27%
Full Period	38	21	8	64	-37	-54	0.029 (232)	0.031 (215)	0.019 (54)	0.019 (139)	0.045 (56)	0.06 (57)
Calibration	22	14	-26	38	-36	-38	0.029 (113)	0.03 (107)	0.022 (33)	0.022 (61)	0.046 (34)	0.051 (36)
Validation	54	27	101	95	-39	-64	0.029 (119)	0.033 (108)	0.013 (21)	0.015 (78)	0.043 (22)	0.069 (21)
Total Phosphorus as P, mg/l							30%	47%	0%	0%	0%	0%
Full Period	-21	-5	-7	-2	-2	12	0.097 (225)	0.053 (212)	0.06 (54)	0.048 (139)	0.04 (56)	0.031 (57)
Calibration	-23	-9	-12	-11	0	8	0.1 (114)	0.05 (106)	0.064 (33)	0.052 (61)	0.039 (34)	0.033 (36)
Validation	-18	-1	3	6	-3	16	0.093 (111)	0.057 (106)	0.054 (21)	0.045 (78)	0.042 (22)	0.03 (21)

- Sediment nutrient fluxes are simulated by sediment diffusion rates and adsorption isotherms.
- Simulated diffusion rates are lower in segments 1-3 which have less accumulated sediment.
- This represents the 5th model run or 20+ years of model stabilization with current inputs;
- Ammonia concentrations have a positive percent bias (overestimated) above Highway 50 and negative percent bias downstream.
- Total phosphorus concentrations have a negative percent bias (underestimated) at the upper part of the lake and progressively increase such that they are positive in segment 6.
- Refining the calibration may improve one parameter but make the other parameter worse.
- The WARMF Lake simulated flux rates are lower than previous estimates (UNRBA and Dr. Alperin)
  - The WARMF Lake model simulates approximately 80,000 pounds per year of ammonia released from the sediments (for the 5th model run) compared to previous estimates of approximately 200,000 pounds per year. For the initial model run, ammonia flux is 192,000 pounds per year.
  - The WARMF Lake model simulates approximately 2,000 pounds per year of phosphate released from the sediments compared to previous estimates approximately 14,000 pounds per year. For the initial model run, phosphate flux is 7,000 pounds per year. Note that WARMF simulates the diffusion processes only; not the oxygen-chemistry component.
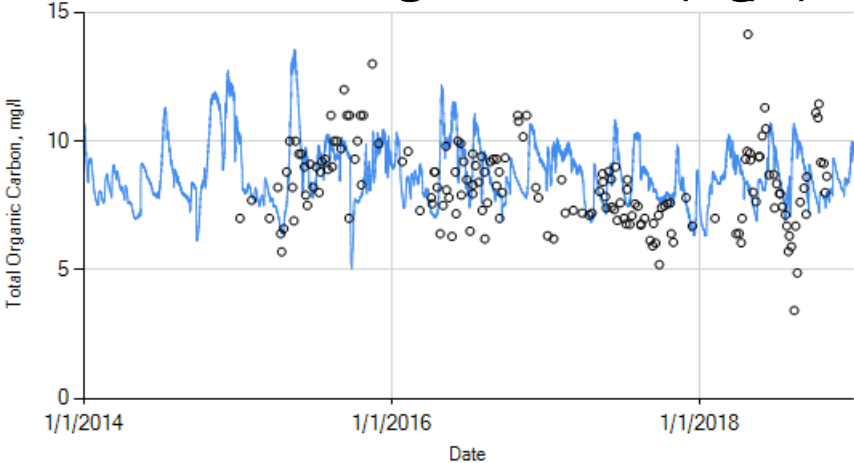
Falls Lake Water Quality – Segment 1 (above I-85)
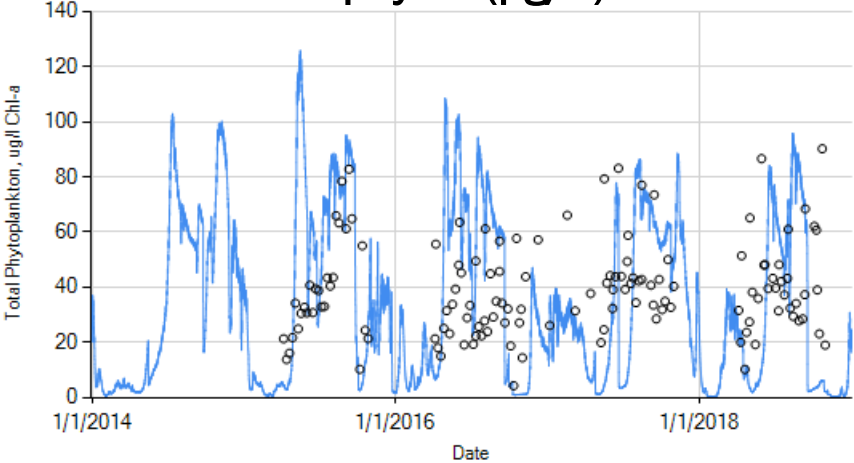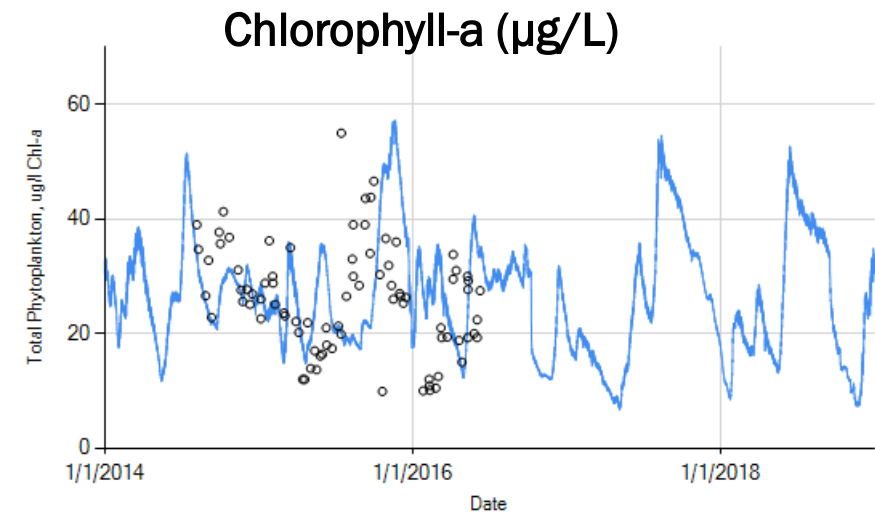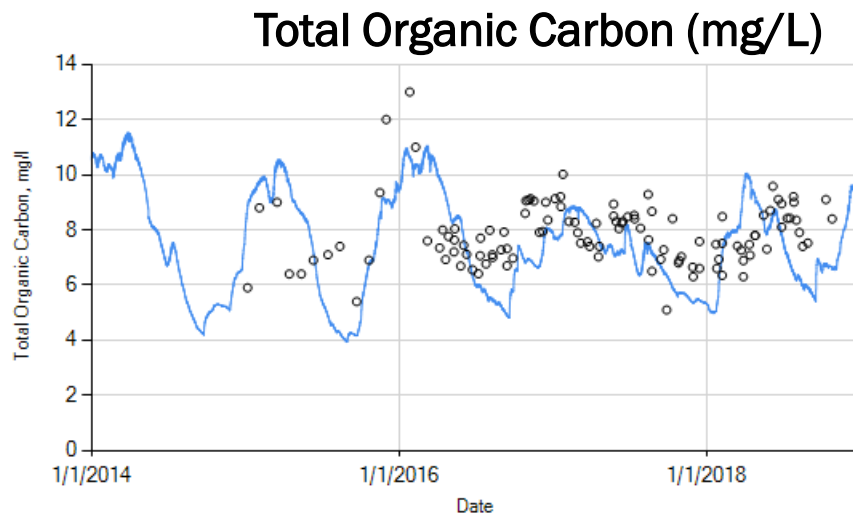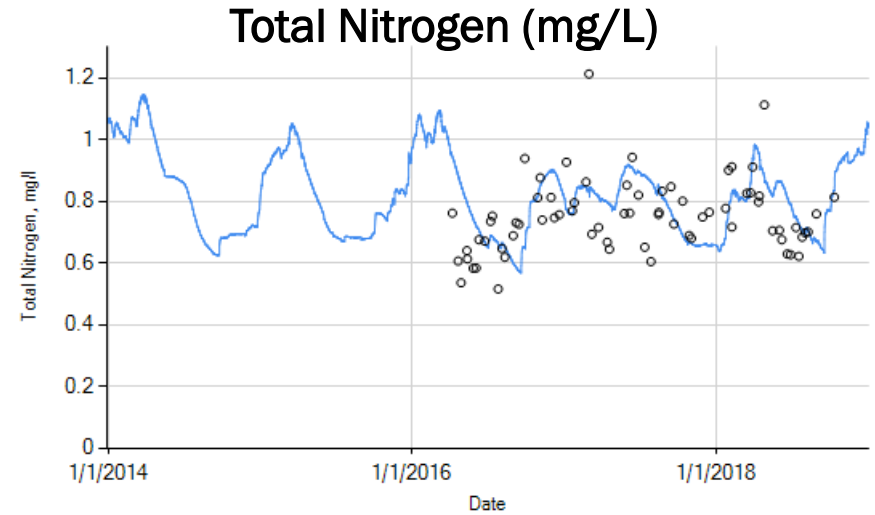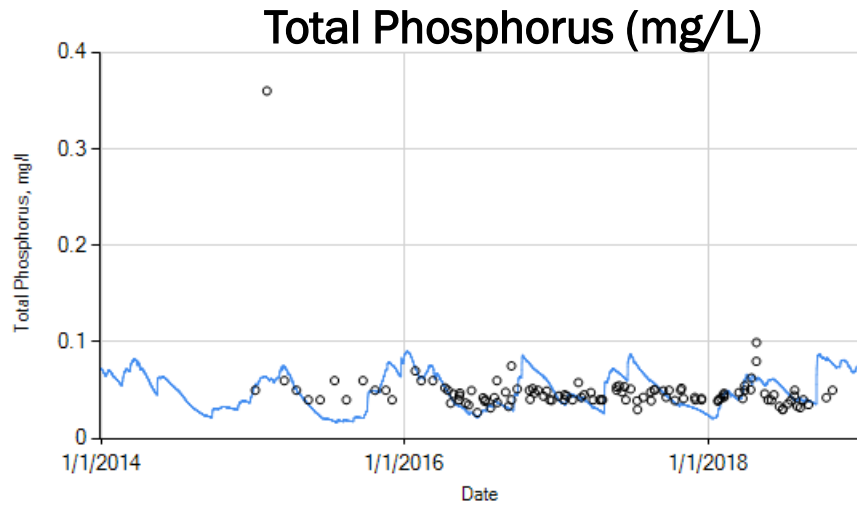

Total Phosphorus (mg/L)
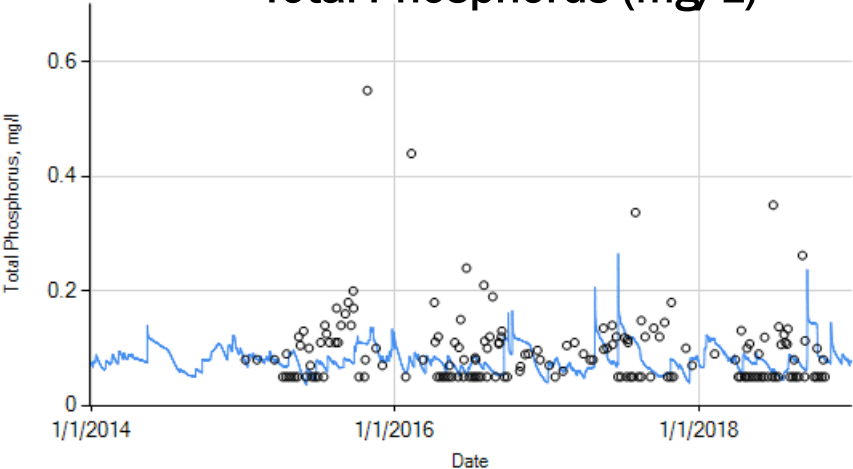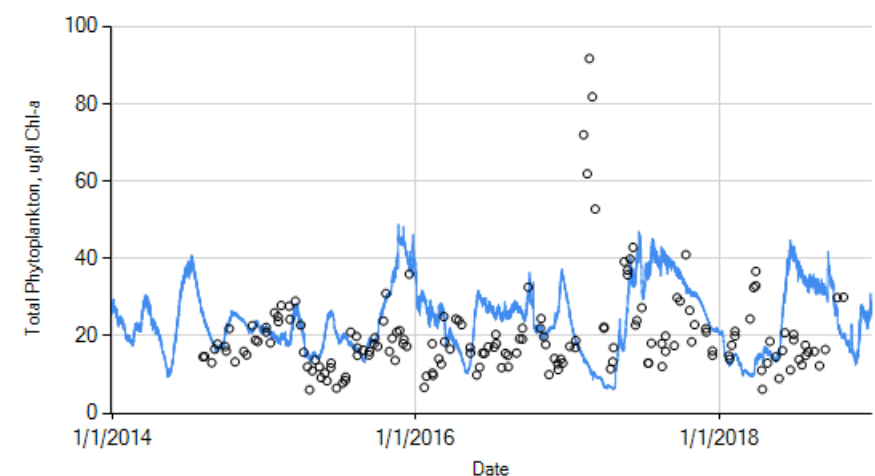

Total Nitrogen (mg/L)
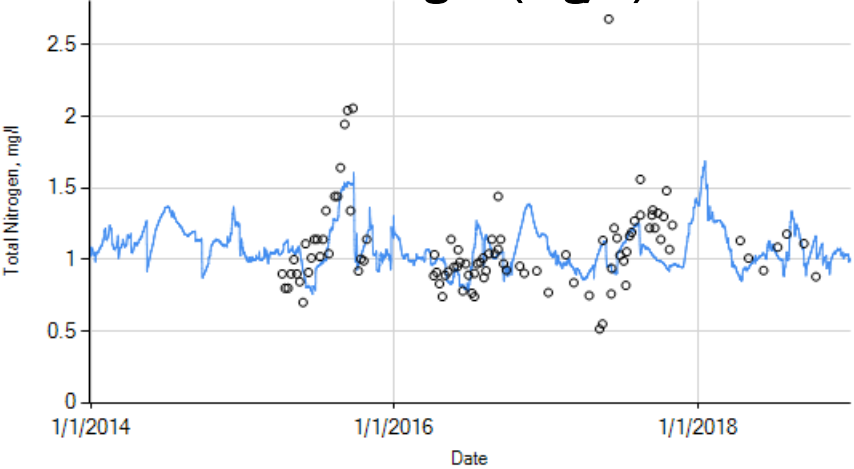
Total Organic Carbon (mg/L)

Chlorophyll-a (µg/L)

Falls Lake Water Quality – Segment 4 (Rolling View to Hwy. 50)

Total Phosphorus (mg/L)

Total Nitrogen (mg/L)

Total Organic Carbon (mg/L)

Chlorophyll-a (µg/L)

Falls Lake Water Quality – Segment 6 (Hwy. 98 to dam)
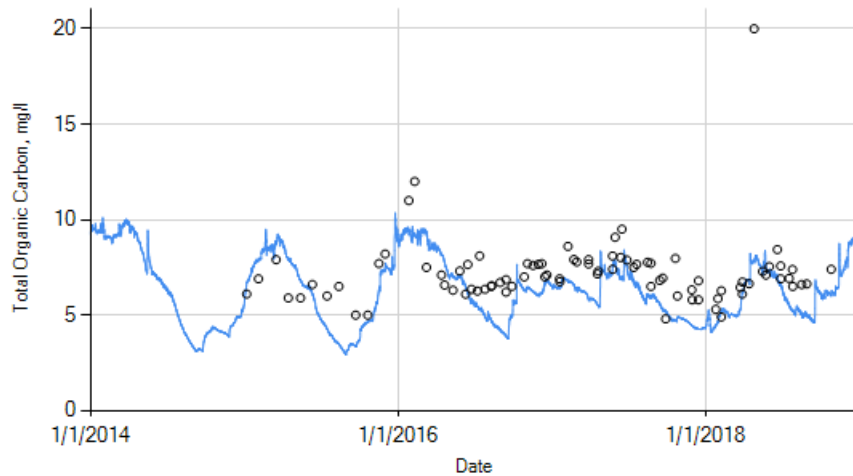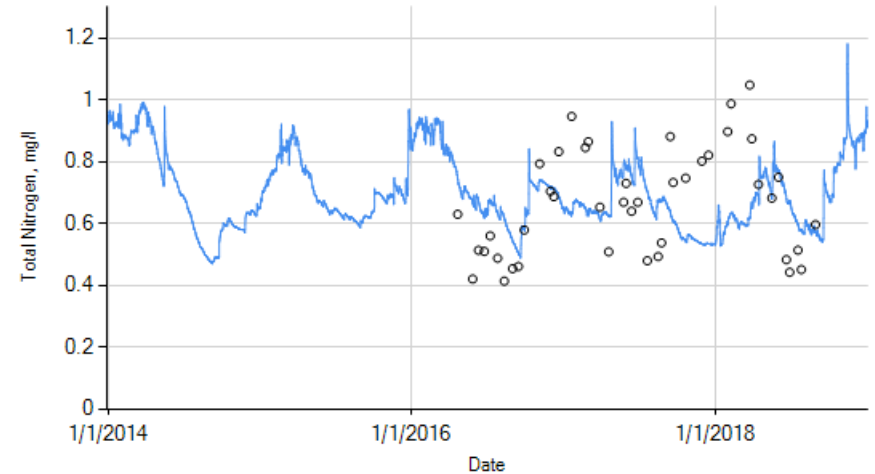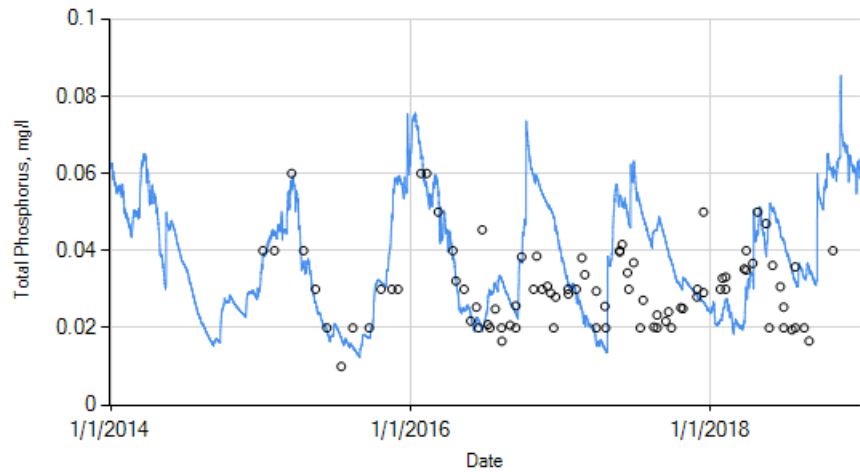
Summary

- The latest calibration applies uniform chemical and biological model coefficients
- Sediment diffusion rates vary above and below Rolling View
- Settling rates vary by segment
- Further refinements may improve one parameter or location at the expense of others
- The modeling team recommends approval of the model calibration by the MRSW and to proceed with sensitivity analyses and scenario analyses
- MRSW Discussion

EFDC Lake Modeling Status

EFDC Lake Modeling Status

- During the May and August MRSW meetings, the modeling team presented comparisons of observed biovolume and chlorophyll-a data in Falls Lake and discussed calibration challenges
- Modeling team has continued to discuss model calibration with subject matter experts and DWR modeling staff
  - September 26, 2022 (with DWR and SMEs)
  - October 13, 2022 (with SMEs)
- Further refinements have been made and model performance has improved
- We have scheduled a meeting with DWR to discuss model calibration on November 17th and will present the calibration to the MRSW on December 6th

Lake Reporting Status

Lake Reporting Status

- The modeling team is continuing to draft sections and appendices of the lake modeling report.
- Will work with subject matter experts and DWR regarding time series comparisons to observed data
- Current focus is on responding to comments on the watershed modeling report

Closing Comments
Additional
Discussion