UNRBA
Monitoring Program Development and Implementation

Path Forward Committee
Feb. 17, 2014

Overview of Three Draft Technical Memoranda

- Modeling Framework TM
  - Requested by DWR
  - Describes how data collected by UNRBA monitoring program will be used to update Falls Lake Nutrient Response Model
- Model Sensitivity TM
  - Explores use of United States Geological Survey LOADEST model for estimating daily nutrient loads
  - Assesses how increases and decreases in nutrient loads from individual tributaries influences water quality predictions in Falls Lake based on the existing Falls Lake Nutrient Response Model
  - Evaluates influence of model input time step and flow and water quality concentration estimation method on model predictions
- Flow Estimation TM
  - Reviews a number of methods that could be used to estimate flows in ungaged tributaries and at jurisdictional boundaries

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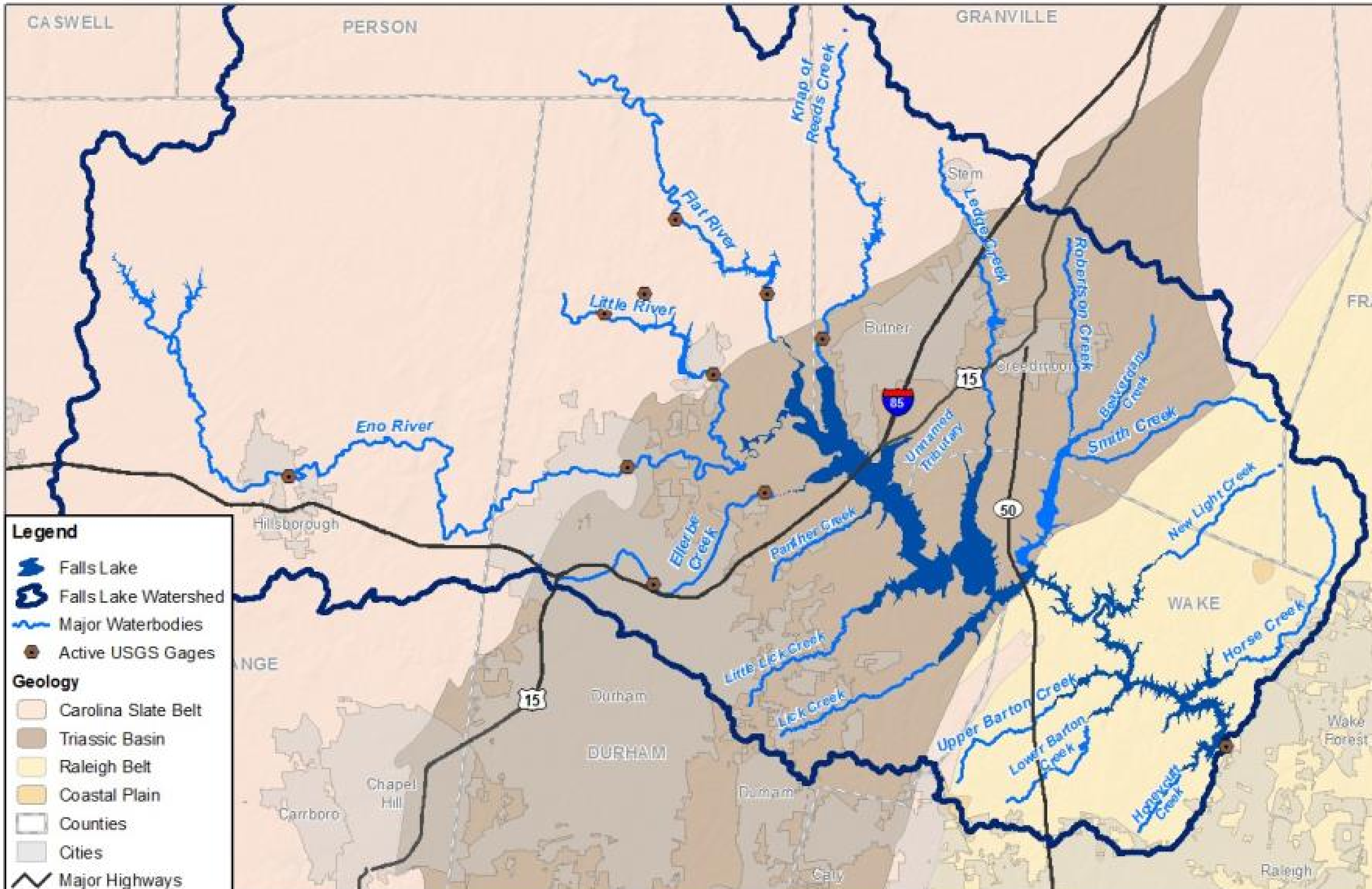

Geology of the Falls Lake Watershed

0 3 6 Miles

Sources: North Carolina Geological Survey, USGS.

Upper Neuse River Basin Association
North Carolina

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5400 Glenwood Ave, Suite G-03, Raleigh, NC 27612 USA
Phone (+1) 919-239-8900 Fax (+1) 919-239-8913
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Modeling Framework

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Falls Rules Require DWR approval of Monitoring Study Plan and Modeling Framework

A person shall obtain Division review and approval of any monitoring study plan and description of the modeling framework to be used prior to commencement of such a study. The study plan and modeling framework shall meet any Division requirements for data quality and model support or design in place at that time. Within 180 days of receipt, the division shall either approve the plan and modeling framework or notify the person seeking to perform the supplemental modeling of changes to the plan and modeling framework required by the Division;

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Discussions with DWR

- Kathy Stecker referenced the Falls Rules noting that a modeling framework is needed to supplement the monitoring plan
- DWR was very clear that the Falls Lake Nutrient Response Model will be used for lake water quality predictions
- Forrest discussed with DWR staff that the modeling framework should be short and straightforward
- UNRBA Monitoring program Quality Assurance Project Plan (QAPP) under development so that DWR accepts UNRBA's data for model development and WQ standards compliance assessment

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UNRBA Objectives for Revised Falls Lake Model

- Reduce uncertainty in relationship between tributary loading and water quality predictions within Falls Lake
- Reduce uncertainty in loading estimates
- Replace modeling assumptions with actual data
- Use defensible methods and statistical approaches to refine assumptions previously used by DWR if actual data is not available

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UNRBA will Use DWR's Existing Model Framework

- UNRBA will start with DWR's model
- Calibrate model with Falls Lake water quality data collected by DWR
- Update model inputs using data collected by the UNRBA monitoring program under an approved QAPP
- Model recalibration and corroboration based on the metrics developed by the Falls Lake technical advisory group and used previously by DWR

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Updates to Existing Model Proposed in the Modeling Framework

- The modeling period will be based on a range of typical hydrologic conditions for the watershed rather than a single year.
- Reduce the uncertainty in pollutant loading estimates for all tributaries.
- Use actual tributary concentrations of chlorophyll *a* and TOC collected in free flowing waters to calculate inputs to Falls Lake.
- Conduct special studies to obtain an improved understanding of the spatial variability in Falls Lake modeling parameters such as background light extinction and benthic flux rates.

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Model Review

[NOTE to PFC: From the Model Framework Guidance: "This section should describe any intended plan to obtain an independent third party or peer review of the draft model. This is generally appropriate only for the more complex models where independent review will provide additional confidence in the model's capability to address the stated goals."]

Does the UNRBA want to support additional outside model review or work with DWR as the reviewer?

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Tasks	2013	2014	2015	2016	2017	2018	2019	2020
Complete Monitoring Program QAPP								
Conduct Monitoring								
Optional 5th year of Monitoring								
Preliminary Revisions to EFDC Model and inputs								
Final Revisions to EFDC model and inputs								
Recalculate Stage II Load Reductions using Revised EFDC model								
NCDWR Review of Model Revisions								

Falls Lake Nutrient Response Model (EFDC) Sensitivity Analyses

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Evaluation of Sensitivity of Falls Lake Nutrient Response Model

- Does the method used to estimate daily nutrient loading change modeled Lake water quality?
- How do changes in nutrient loads from different tributaries or groups of tributaries influence water quality predictions throughout Falls Lake?
- How does the use of different loading estimation methods impact overall nutrient loads and model response?

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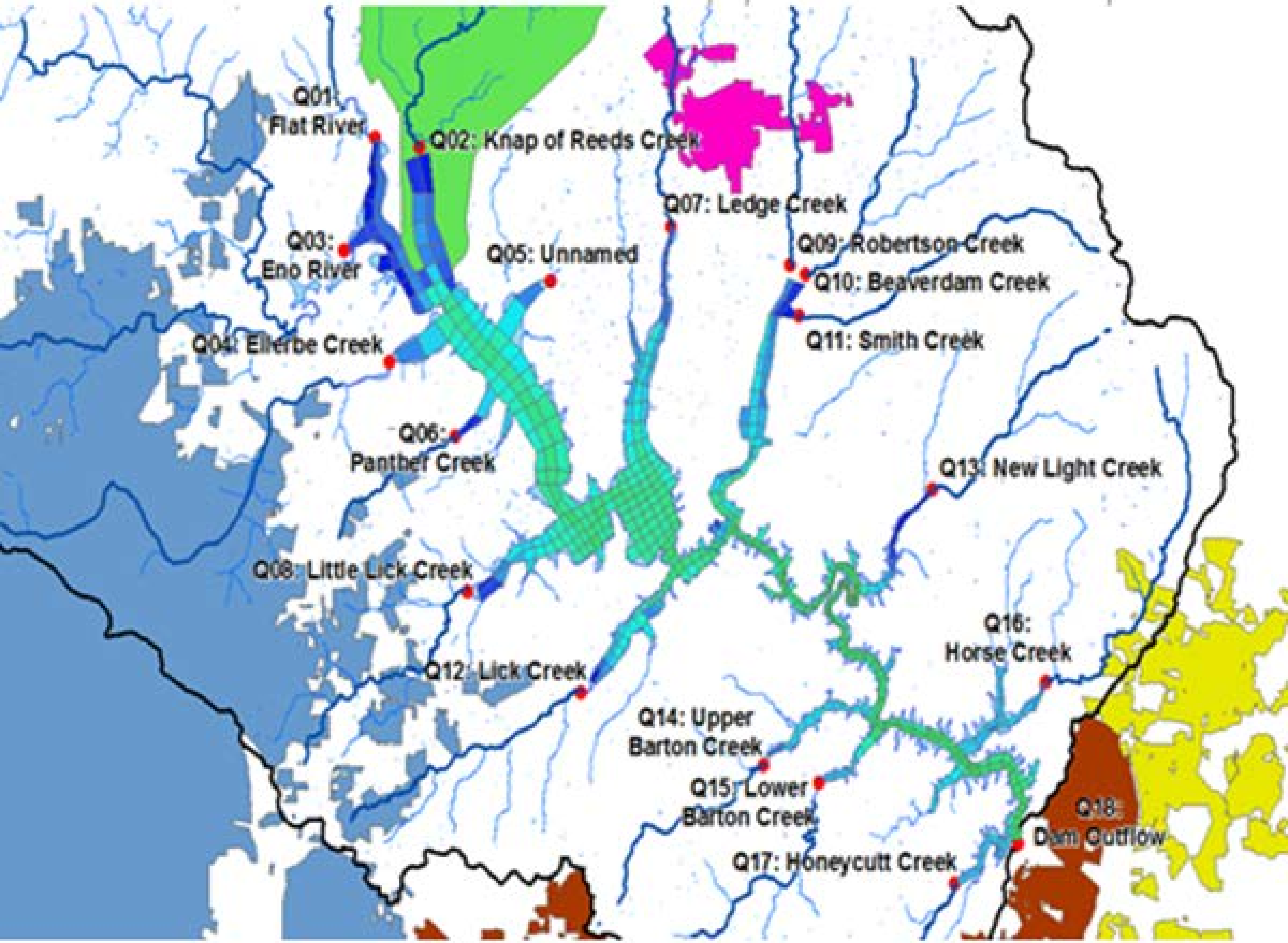
Q01:
Flat River
Q02: Knap of Reeds Creek
Q03:
Eno River
Q04: Ellerbe Creek
Q05: Unnamed
Q06:
Panther Creek
Q07: Ledge Creek
Q08: Little Lick Creek
Q09: Robertson Creek
Q10: Beaverdam Creek
Q11: Smith Creek
Q12: Lick Creek
Q13: New Light Creek
Q14: Upper
Barton Creek
Q15: Lower
Barton Creek
Q16:
Horse Creek
Q17: Honeycutt Creek
Q18:
Dam Outflow

How sensitive is the model to the method used to generate a daily time series of nutrient inputs?

- The EFDC model requires daily inputs of flow and nutrient concentrations from all tributaries
- Water quality data collection was biweekly or monthly
- DWR used a linear interpolation between two sampling dates to estimate daily loads
- The USGS LOADEST can more accurately predict daily concentrations than a linear interpolation between two sampling points

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How does flow data time step influence loading calculations?

- Use LOADEST models to predict variance in load estimates
  - Pair water quality samples with daily average flow and 15- minute flows
  - Compare predictions from the 9 different LOADEST models to actual data

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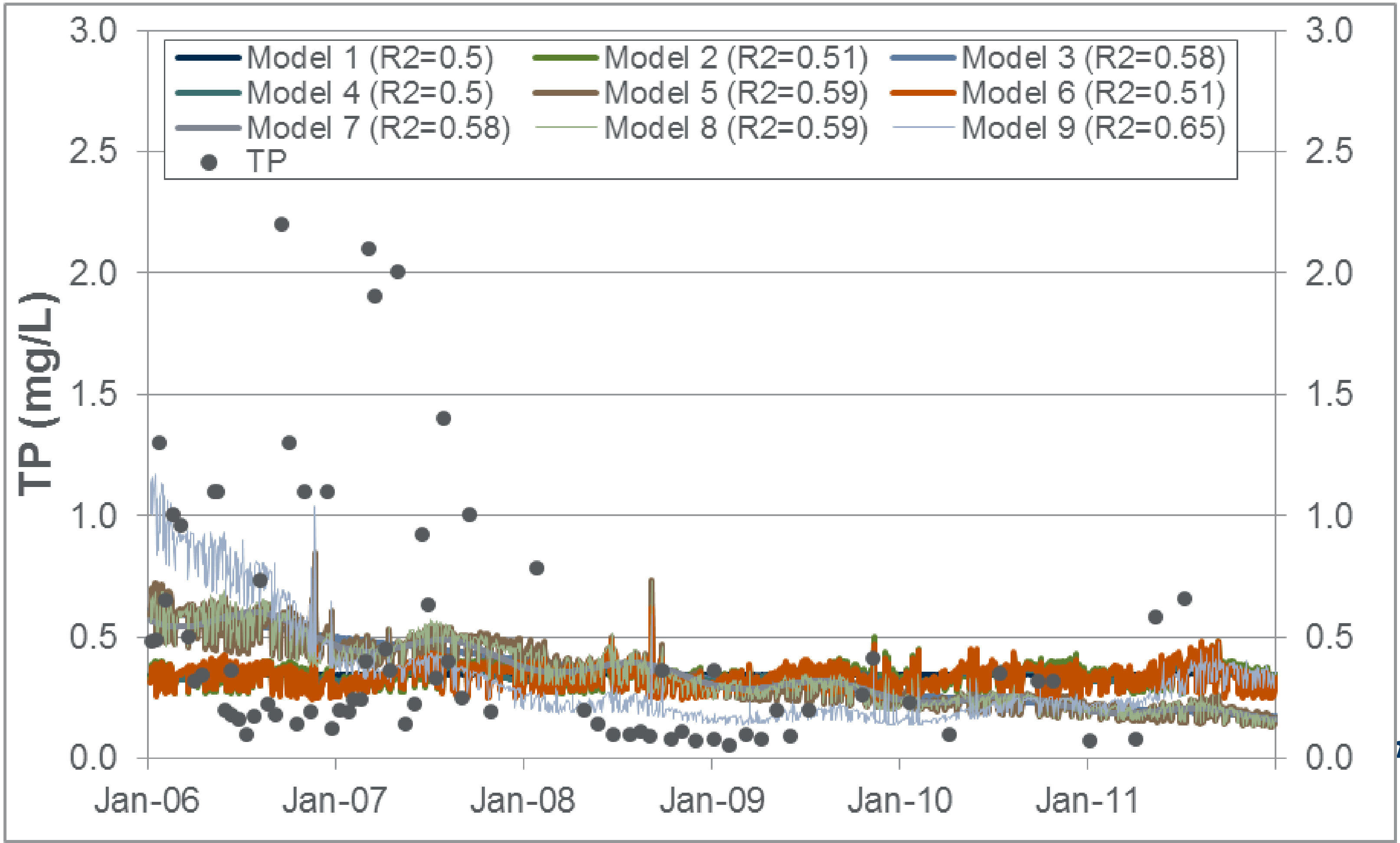
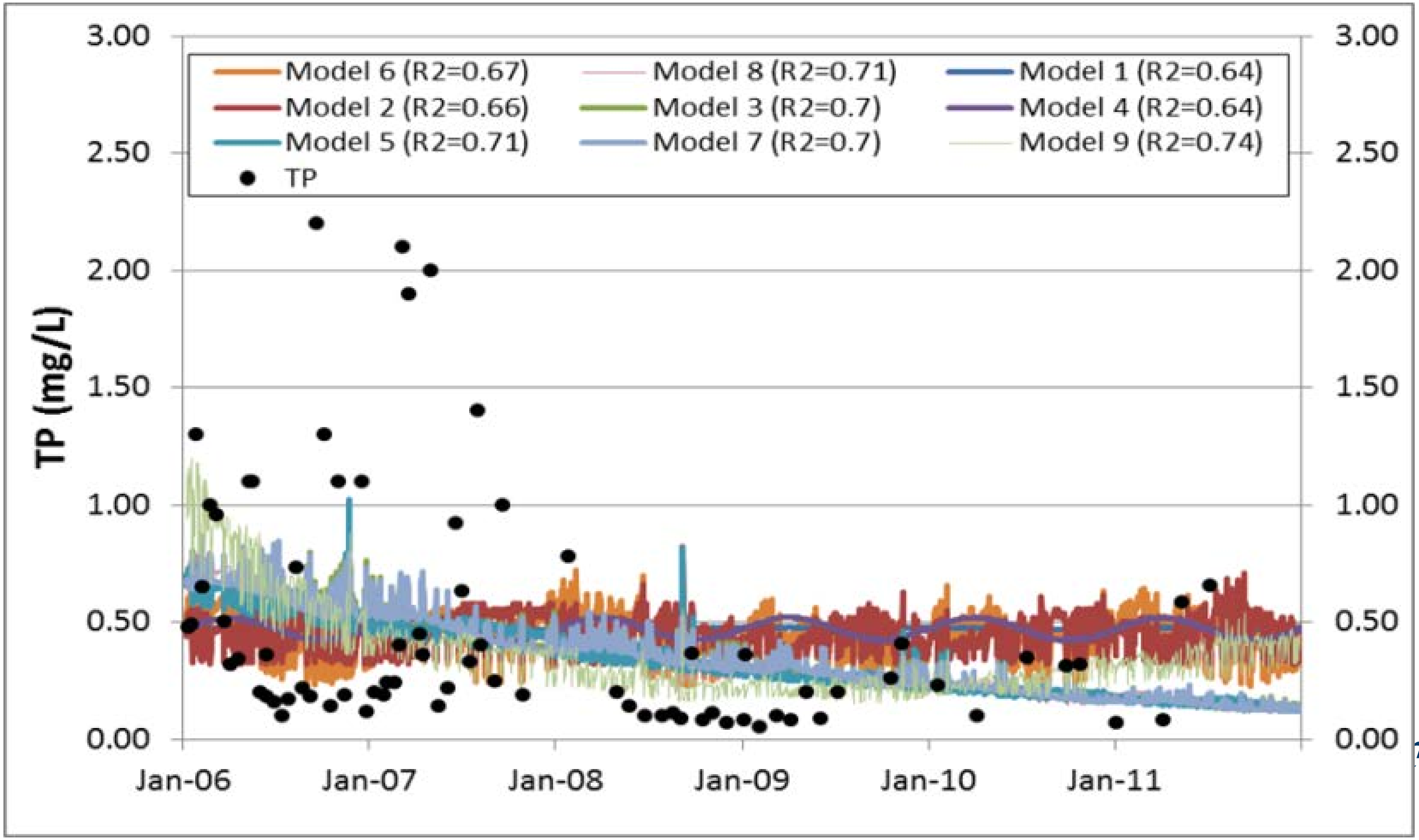
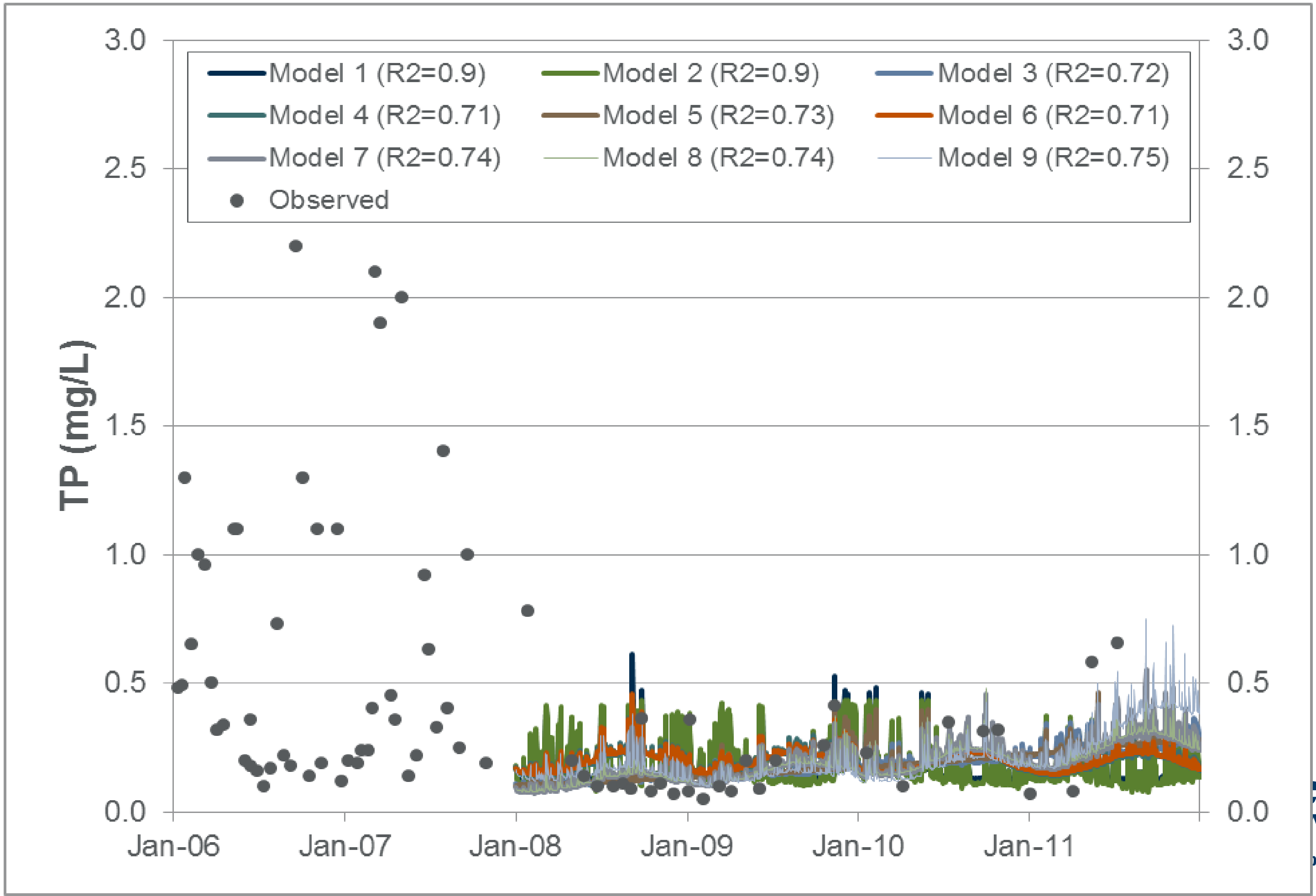
Ellerbe Creek LOADEST: TP, 2006-2011, daily flow



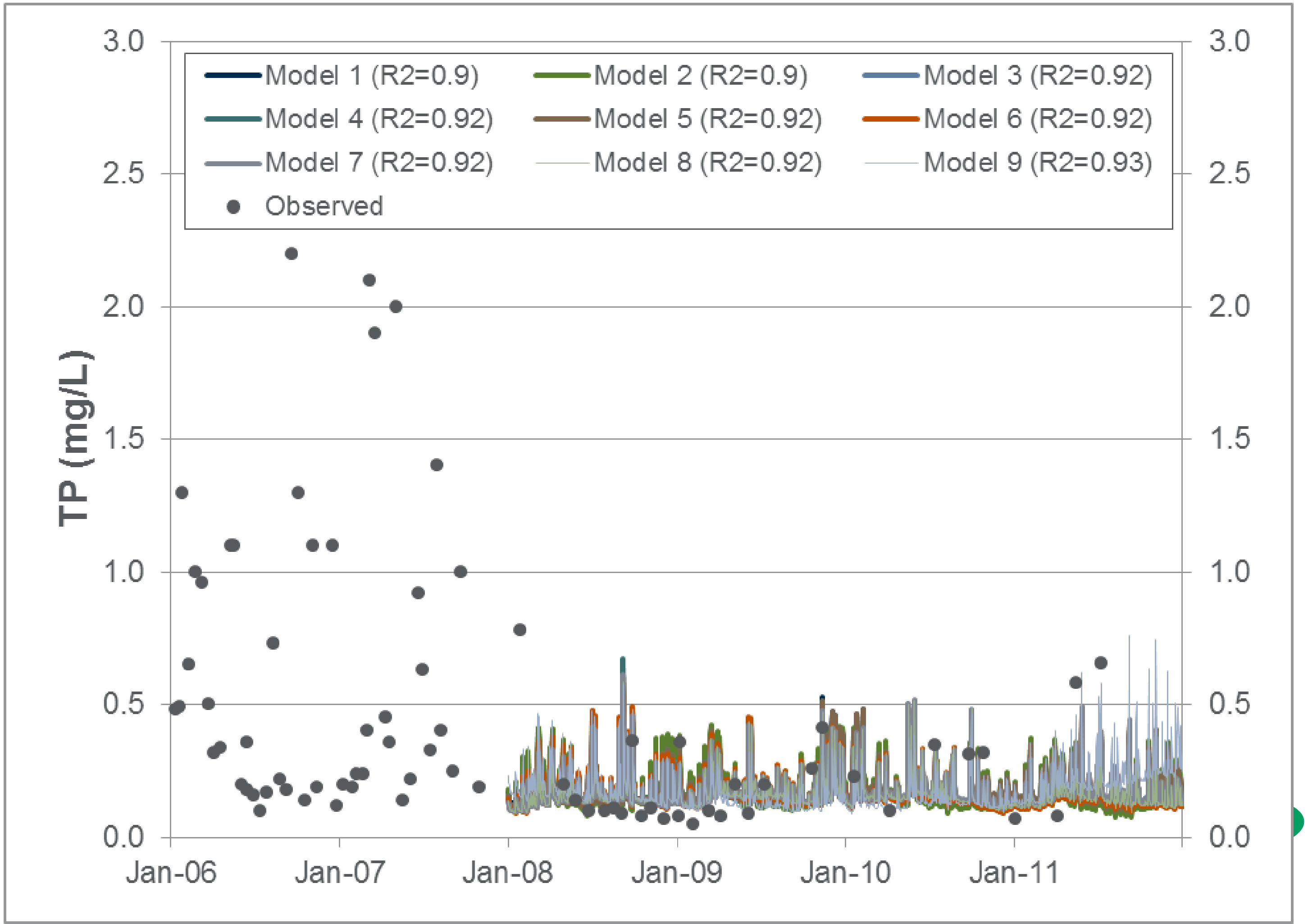
Ellerbe Creek LOADEST: TP, 2006-2011, 15-min flow



Ellerbe Creek LOADEST: TP, 2008-2011, daily flow



Ellerbe Creek LOADEST: TP, 2008-2011, 15 min flow



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Comparison of LOADEST R^2 Values for TP and TN at other Tributaries

Waterbody	Highest R^2 Value for Phosphorus Using Daily Flows	Highest R^2 Value for Phosphorus Using 15-minute Flows	Highest R^2 Value for Nitrogen Using Daily Flows	Highest R^2 Value for Nitrogen Using 15-minute Flows
Ellerbe Creek	0.9 (2008-2011)	0.9 (2008-2011)	0.81 (2006-2011)	0.88 (2006-2011)
Eno River	0.93	0.93	0.96	0.96
Flat River	0.99	0.99	0.99	0.99
Knap of Reeds Creek	NA	NA	0.48	0.46
Little River	0.9	0.9	0.98	0.98

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How sensitive is the Falls Lake EFDC model to changes in inputs from different tributaries?

- Increased and decreased individual tributary loads and groups of tributaries by 50 percent
- Compared model output to baseline predictions at I-85, Highway 50, and the Dam
- Used the simpler BATHTUB model to verify the relative importance of upper, middle and lower lake tributaries on predicted water quality at I-85, Highway 50, and the Dam

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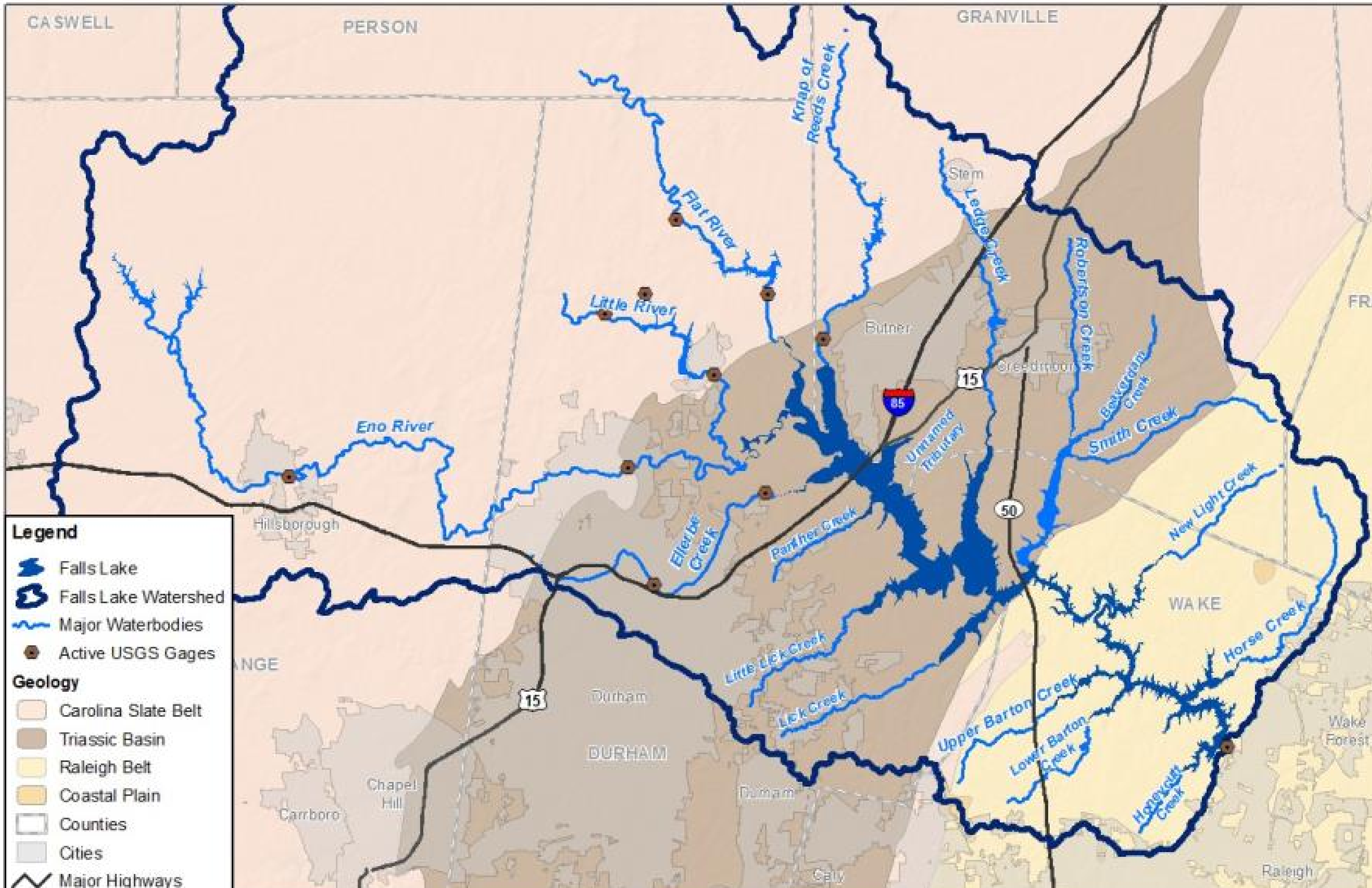

Geology of the Falls Lake Watershed

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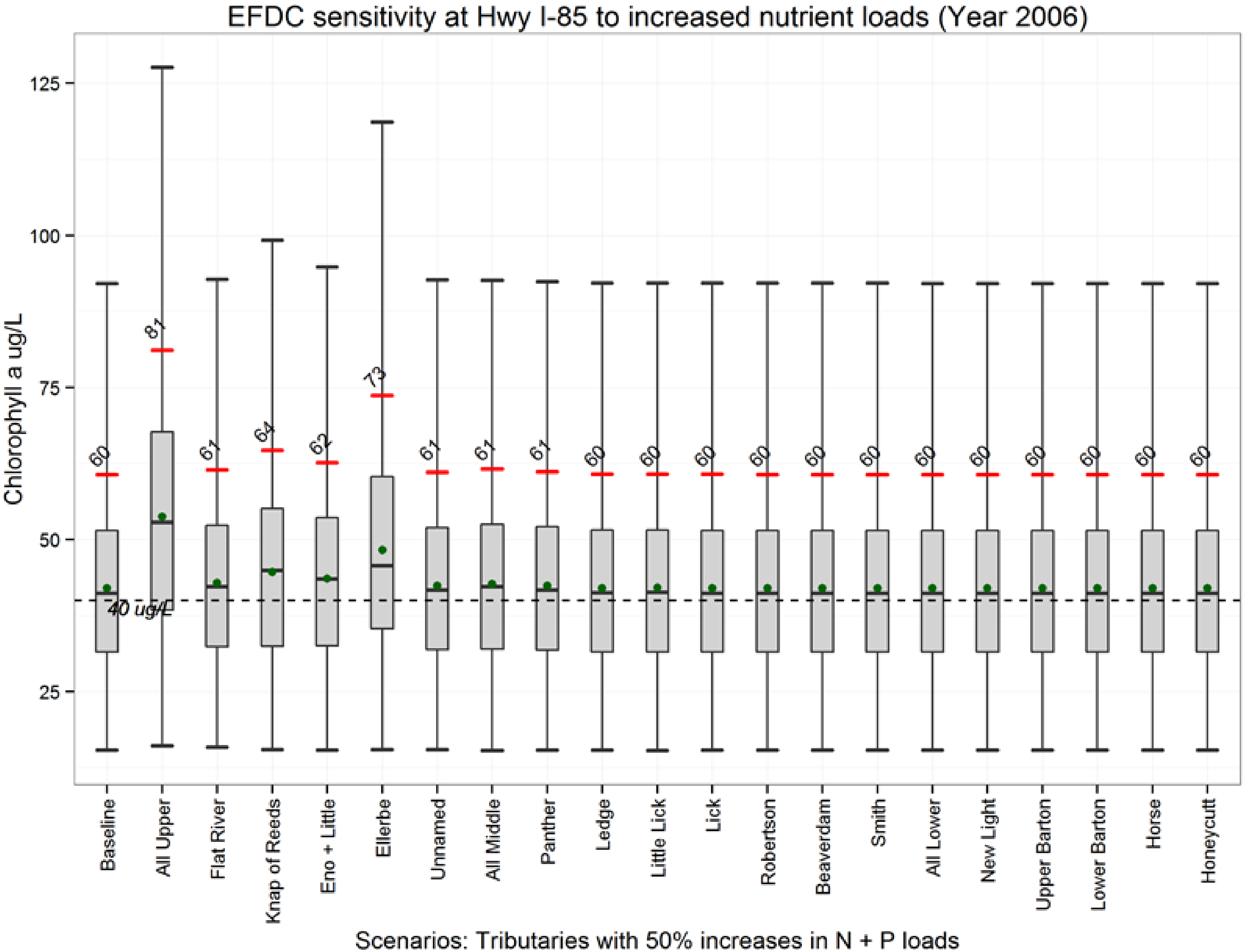
Model Sensitivity at Interstate 85



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Chlorophyll *a* concentrations at I-85 – 50% increase in nutrient loading from upstream tributaries

Scenario	Minimum	25th percentile	Median	75th percentile	90th percentile	Maximum
Baseline	15.4	31.5	41.1	51.5	60.7	92.1
All Upper	16.1	38.4	52.8	67.7	81.1	127.6
Flat River	15.8	32.3	42.2	52.4	61.5	92.7
Knap of Reeds	15.5	32.5	44.9	55.1	64.7	99.2
Eno + Little	15.4	32.6	43.5	53.6	62.6	94.8
Ellerbe	15.5	35.4	45.7	60.3	73.6	118.6
Unnamed	15.5	31.9	41.7	51.9	61.1	92.7

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Chlorophyll a predictions at I-85

- The largest increase in chlorophyll a concentrations was associated with the increase in nutrient loading from all 5 upper tributaries (61 µg/L for baseline vs. 81 µg/L)
- Increases in loading of 50 percent from Ellerbe Creek and Knap of Reeds Creek cause the greatest increase in the simulated 90th percent concentration (73 µg/L and 64 µg/L, respectively) based on changing loading at a single tributary location

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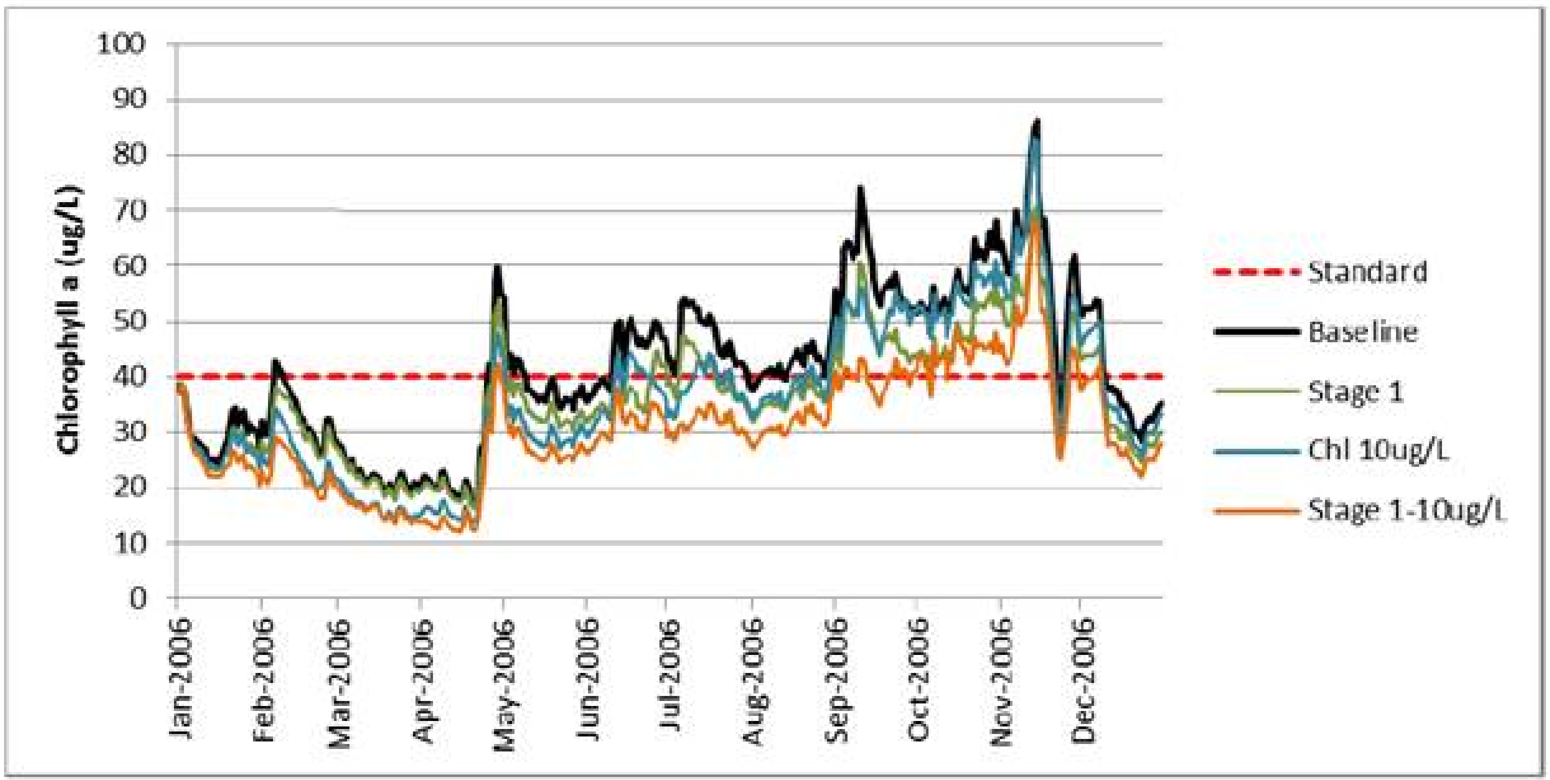
EFDC Sensitivity – Predicted Chl a at I-85 with Chl a inputs reduced to 10 ug/l, with and without Stage I reductions in TN and TP (20%↓ TN, 40%↓ TP)



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Model Sensitivity at Highway 50 (Creedmoor Road)

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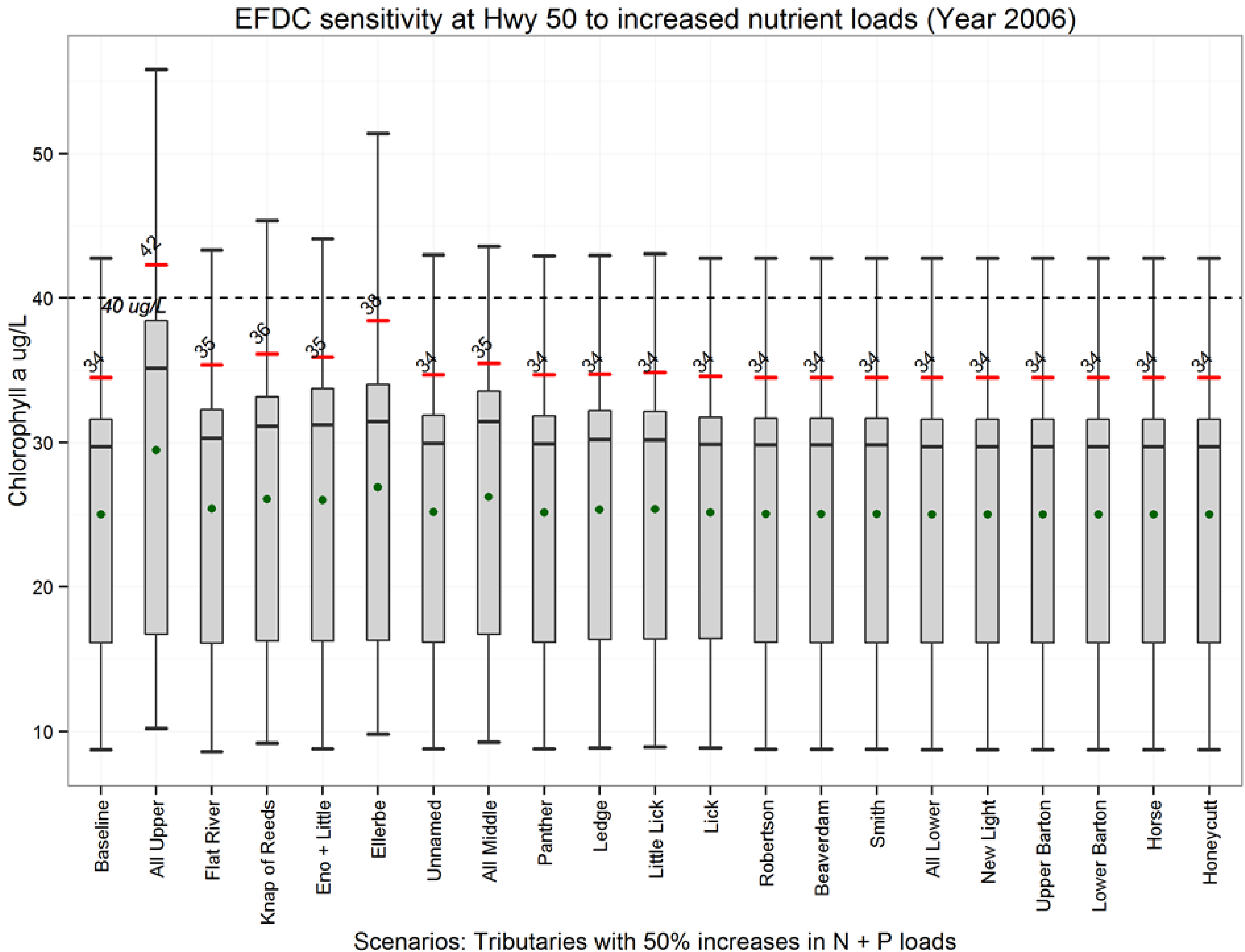
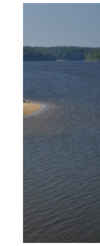


EFDC sensitivity at Hwy 50 to increased nutrient loads (Year 2006)
Chlorophyll a ug/L
50
40
30
20
10
40 ug/L
34
42
35
36
35
38
34
35
34
34
34
34
34
34
34
34
34
34
34
34
34
Baseline
All Upper
Flat River
Knap of Reeds
Eno + Little
Ellerbe
Unnamed
All Middle
Panther
Ledge
Little Lick
Lick
Robertson
Beaverdam
Smith
All Lower
New Light
Upper Barton
Lower Barton
Horse
Honeycutt
Scenarios: Tributaries with 50% increases in N + P loads



Predicted Daily Average Chlorophyll *a* at Highway 50

Scenario	Minimum	25th percentile	Median	75th percentile	90th percentile	Maximum
Baseline	8.7	16.1	29.7	31.6	34.5	42.8
All Upper	10.2	16.7	35.1	38.4	42.3	55.8
Flat River	8.6	16.1	30.3	32.3	35.4	43.3
Knap of Reeds	9.2	16.3	31.1	33.2	36.1	45.4
Eno + Little	8.8	16.3	31.2	33.7	35.9	44.1
Ellerbe	9.8	16.3	31.4	34.0	38.4	51.4
Unnamed	8.8	16.2	29.9	31.9	34.7	43.0
All Middle	9.2	16.7	31.4	33.6	35.5	43.6
Panther	8.8	16.1	29.9	31.8	34.7	42.9
Ledge	8.8	16.4	30.2	32.2	34.7	43.0
Little Lick	8.9	16.4	30.2	32.1	34.8	43.0
Lick	8.9	16.4	29.9	31.7	34.6	42.8
Robertson	8.7	16.1	29.8	31.7	34.5	42.8
Beaverdam	8.7	16.1	29.8	31.7	34.5	42.8
Smith	8.7	16.1	29.8	31.7	34.5	42.8

Chlorophyll *a* predictions at Highway 50

- Minor increases in chl a were observed for most scenarios
- The only scenario that caused a compliance issue was increasing nutrient loading by 50 percent in all of the upper lake tributaries (34.5 µg/L to 42 µg/L).
- Increasing all of the middle lake tributaries by 50 percent only raised the 90th percentile relative to baseline levels by 1 µg/L
- Larger uncertainty with respect to the loading from the middle lake tributaries compared to the upper lake tributaries is likely acceptable, at least with the current version of the lake response model

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Model Sensitivity at the Falls Lake Dam

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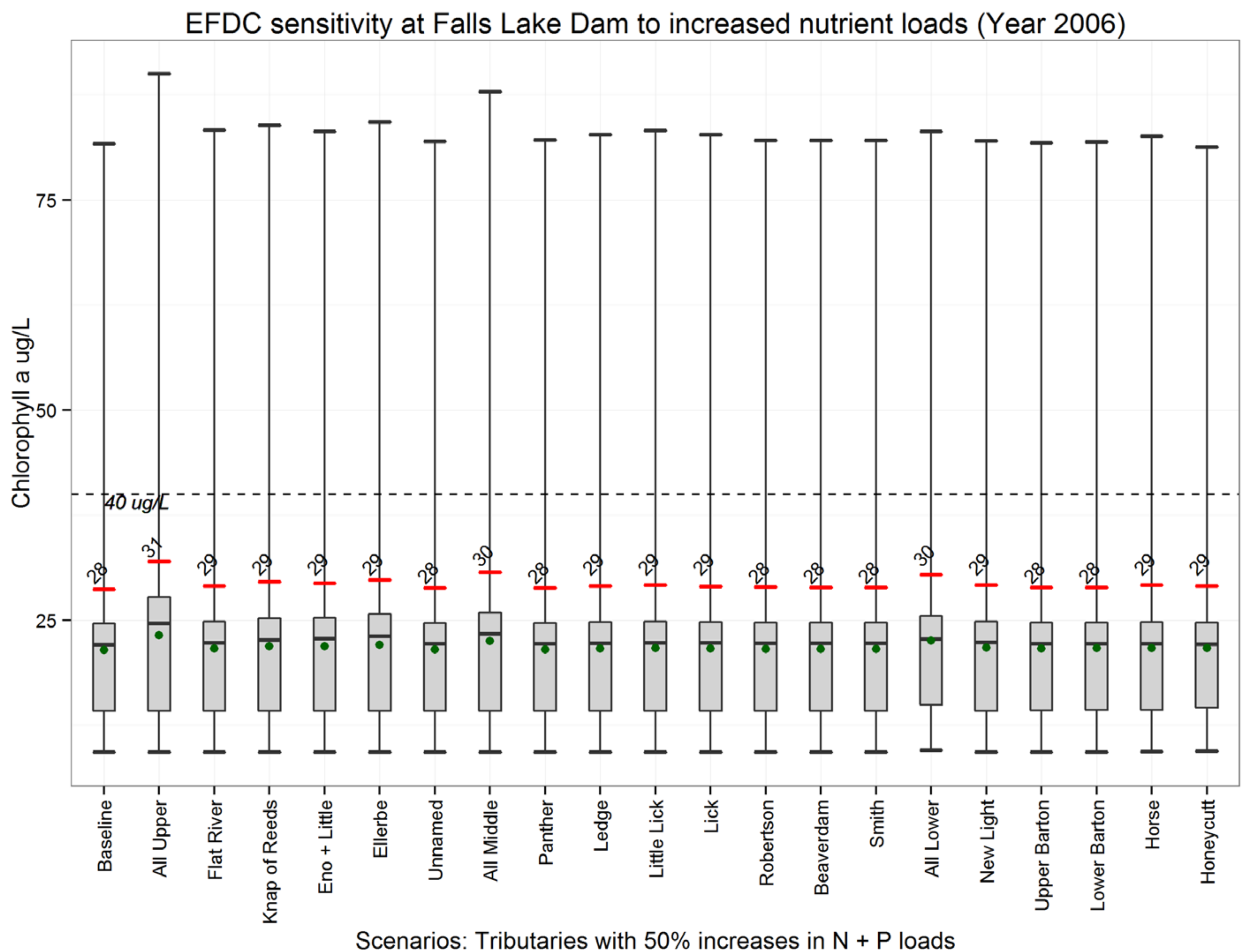
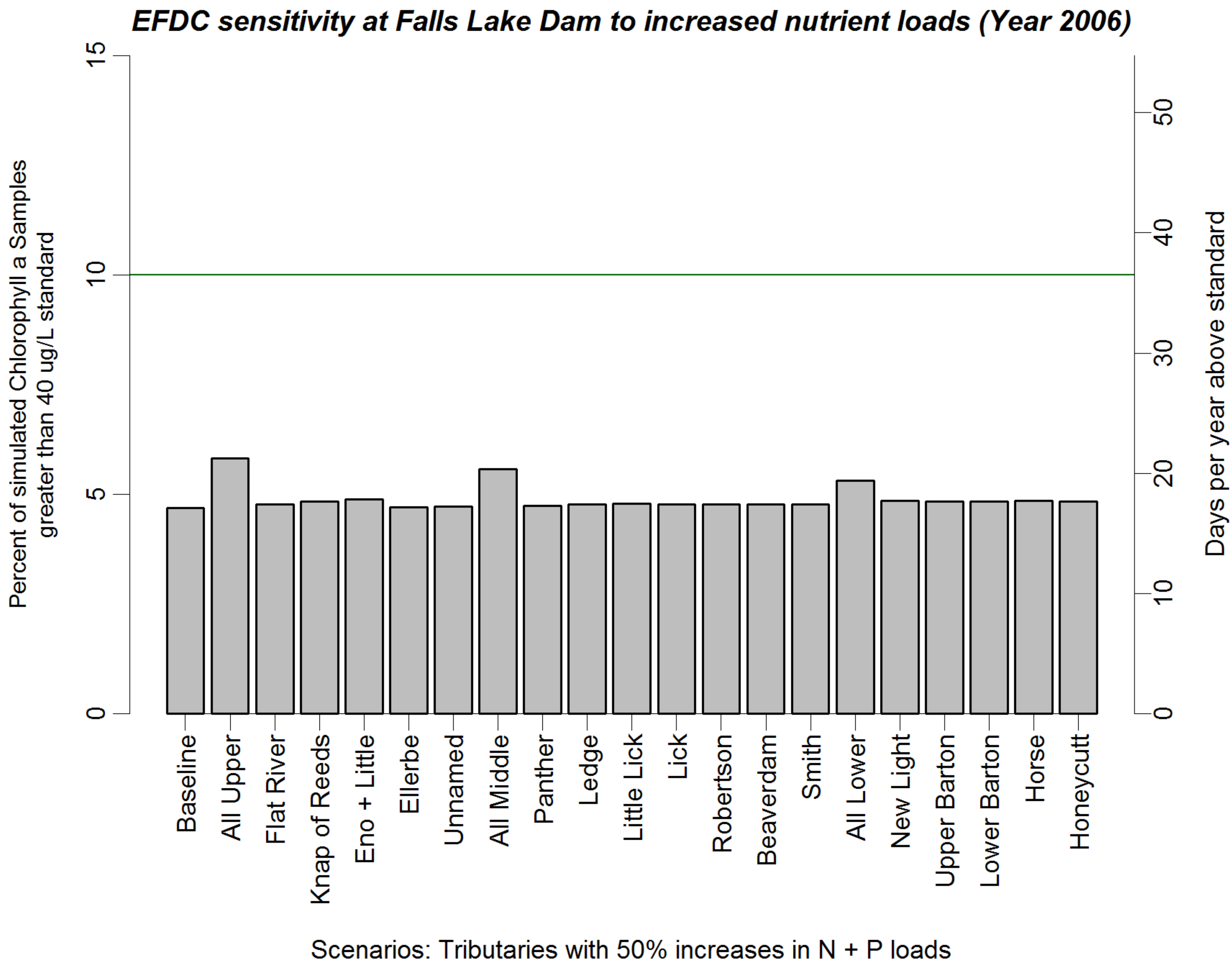

EFDC sensitivity at Falls Lake Dam to increased nutrient loads (Year 2006)
Chlorophyll a ug/L
75
50
25
40 ug/L
28
31
29
29
29
29
28
30
28
29
29
29
28
28
28
30
29
28
28
29
29
Baseline
All Upper
Flat River
Knap of Reeds
Eno + Little
Ellerbe
Unnamed
All Middle
Panther
Ledge
Little Lick
Lick
Robertson
Beaverdam
Smith
All Lower
New Light
Upper Barton
Lower Barton
Horse
Honeycutt
Scenarios: Tributaries with 50% increases in N + P loads


EFDC sensitivity at Falls Lake Dam to increased nutrient loads (Year 2006)
Percent of simulated Chlorophyll a Samples greater than 40 ug/L standard
Days per year above standard
0
5
10
15
0
10
20
30
40
50
Baseline
All Upper
Flat River
Knap of Reeds
Eno + Little
Ellerbe
Unnamed
All Middle
Panther
Ledge
Little Lick
Lick
Robertson
Beaverdam
Smith
All Lower
New Light
Upper Barton
Lower Barton
Horse
Honeycutt
Scenarios: Tributaries with 50% increases in N + P loads

Chlorophyll a predictions at the Falls Lake Dam

- The model results at the dam are rather insensitive to increases in upstream nutrients
- The majority of the nutrient loading entering the lake originates from the five upper lake tributaries. By the time these loads travel to the lower end of the lake, they have been largely removed from the water column by sedimentation and uptake in the upper and middle sections of the lake
- The nutrient loading from the lower tributaries is relatively small compared to the pool of water that is present in the lower section of the lake

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Will Updated Falls Lake EFDC model be as Sensitive to Changes in inputs?

- Model is currently calibrated with large inputs of chl a coming from the tributaries.
  - Even if we reduce the chl a inputs and rerun the model, its calibration affects how the model will respond
  - The sensitivity of an improved and recalibrated model is unknown at this time, but is unlikely to show the same sensitivity to nutrient inputs as the existing model
  - The upper portions of Falls Lake are most sensitive to changes in nutrient inputs

Evaluate Whether a Similar Lake Response is Seen when using the BATHTUB model

- Given the issues with the existing Falls Lake Nutrient Response Model, does the USACE BATHTUB model predict a similar degree of sensitivity to variations in tributary loading?

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BATHTUB Model

- BATHTUB is a steady state model developed with three segments for Falls Lake
- Many of the tributaries were grouped together within a segment.
- The USACE BATHTUB model predicts growing season average chlorophyll *a* concentrations and the percent of time during the growing season that the 40 µg/L chlorophyll *a* standard would be exceeded

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Scenario	Avg. Chl a at I-85	Percent Exceed. at I-85	Avg. Chl a at Hwy 50	Percent Exceed. at Hwy 50	Avg Chl a at Dam	Percent Exceed. at Dam
Baseline	60.5	63	30.8	19	21.1	10
All Upper	88.6	79	37.1	35	23.4	13
Flat River	65.3	67	32.0	22	21.5	11
Knap of Reeds	65.7	68	32.1	22	21.6	11
Eno + Little	67.9	69	32.6	23	21.8	11
Ellerbe	71.5	71	33.4	25	22.1	12
All Middle	60.5	63	34.0	27	22.9	13
Panther/Little Lick/Lick	60.5	63	32.9	24	21.9	11
Ledge/Robertson/ Beaverdam/Smith	60.5	63	31.9	22	22.1	12
All Lower	60.5	63	30.8	19	23.4	13
New Light/Horse	60.5	63	30.8	19	21.8	11
Upper Barton/Lower Barton/ Honeycutt	60.5	63	30.8	19	22.6	12

BATHTUB Model Results

- Although BATUTHB results are not directly comparable to the Falls Lake Nutrient Response Model sensitivity analyses, the general trends in model sensitivity to changes in nutrient inputs are similar
- Increasing loading from any single tributary around the lake, or group of tributaries (upper, middle, and lower), has a similar impact on simulated chlorophyll a values at the dam.
- For the tributaries in the middle and lower part of the lake where relatively less data is currently collected, there is no single tributary that “stands out” in its effect on simulated chlorophyll a values at Highway 50 or the dam

Evaluation of Falls Lake EFDC model sensitivity to changes in loading time step

- Compared annual nutrient loading generated by 4 different approaches using LOADEST and different flow time steps
- Falls Lake Nutrient Response Model was modified using hourly nutrient and flow inputs
- Nitrogen and phosphorus concentrations at each assessment point are averaged over the four model layers. Chlorophyll *a* results are presented for the top layer only.

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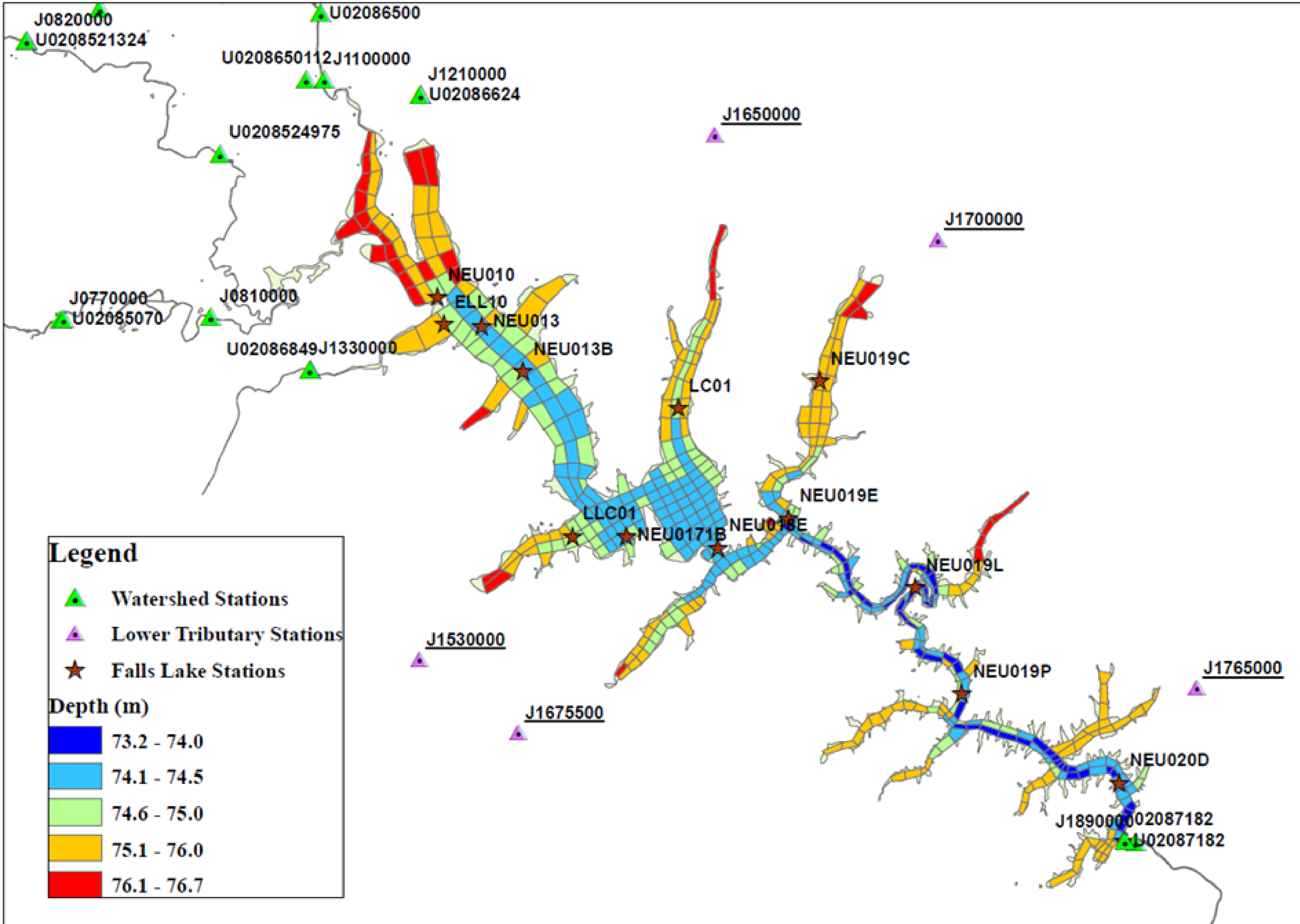
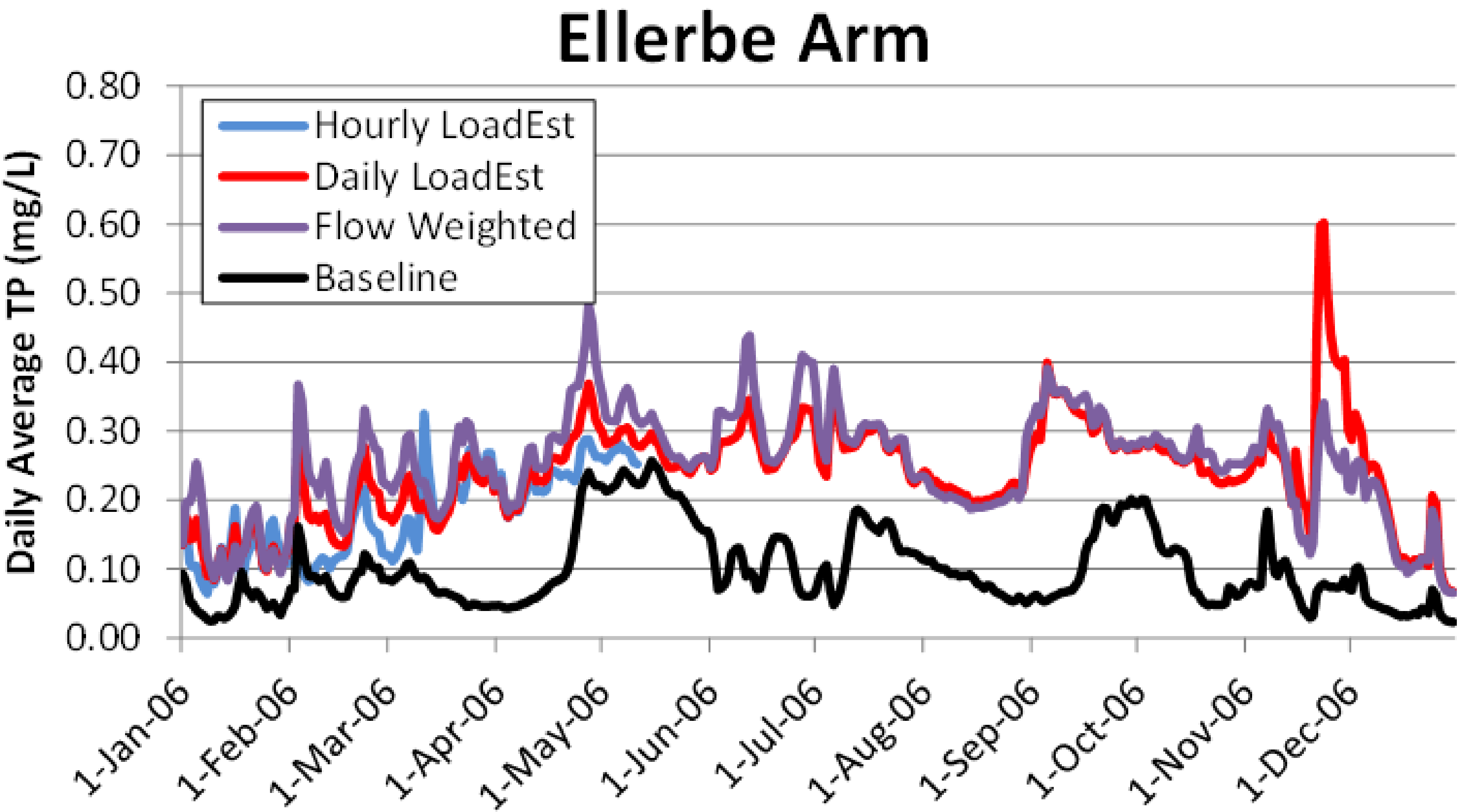
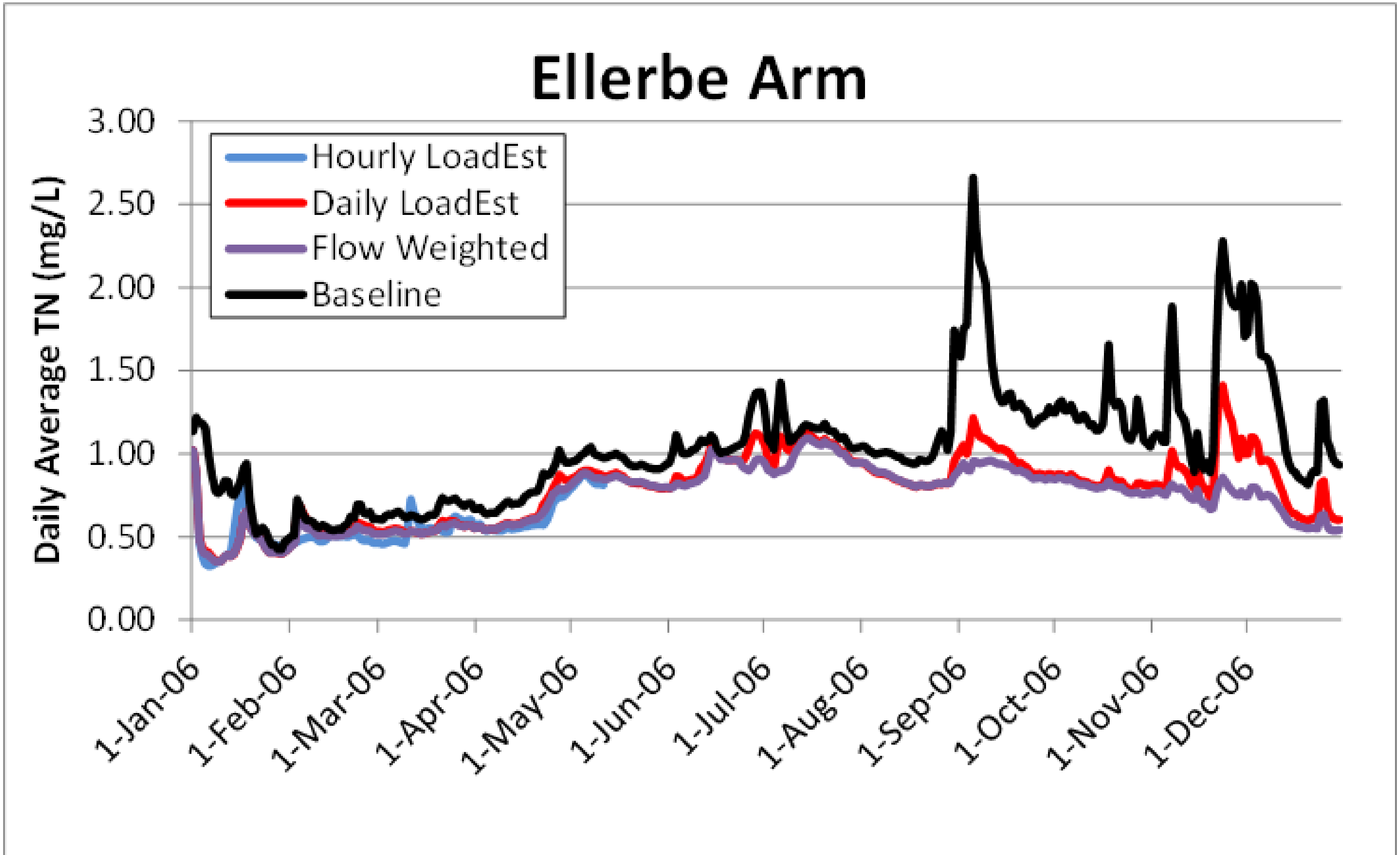
Ellerbe Creek Scenario	Flow Input	Water Quality Concentration	Total Nitrogen Load (lb/yr)	Total Phosphorus Load (lb/yr)
Baseline	Daily time step using USGS daily flows	Daily time step based on linear interpolation between weekly to monthly grab samples	432,293	42,731
Daily LoadEst	Daily time step using USGS daily flows	Daily time step based on daily flows input to the LOADEST regressions*	317,213	77,861
Hourly LoadEst	Hourly time step calculated by averaging USGS 15-min flows	Hourly time step based on hourly flows input to the LOADEST regressions *	177,947	32,642
Flow Weighted	Daily time step using USGS daily flows	Daily time step based on flow weighting the hourly time step values (see row above)*	556,062	67,300



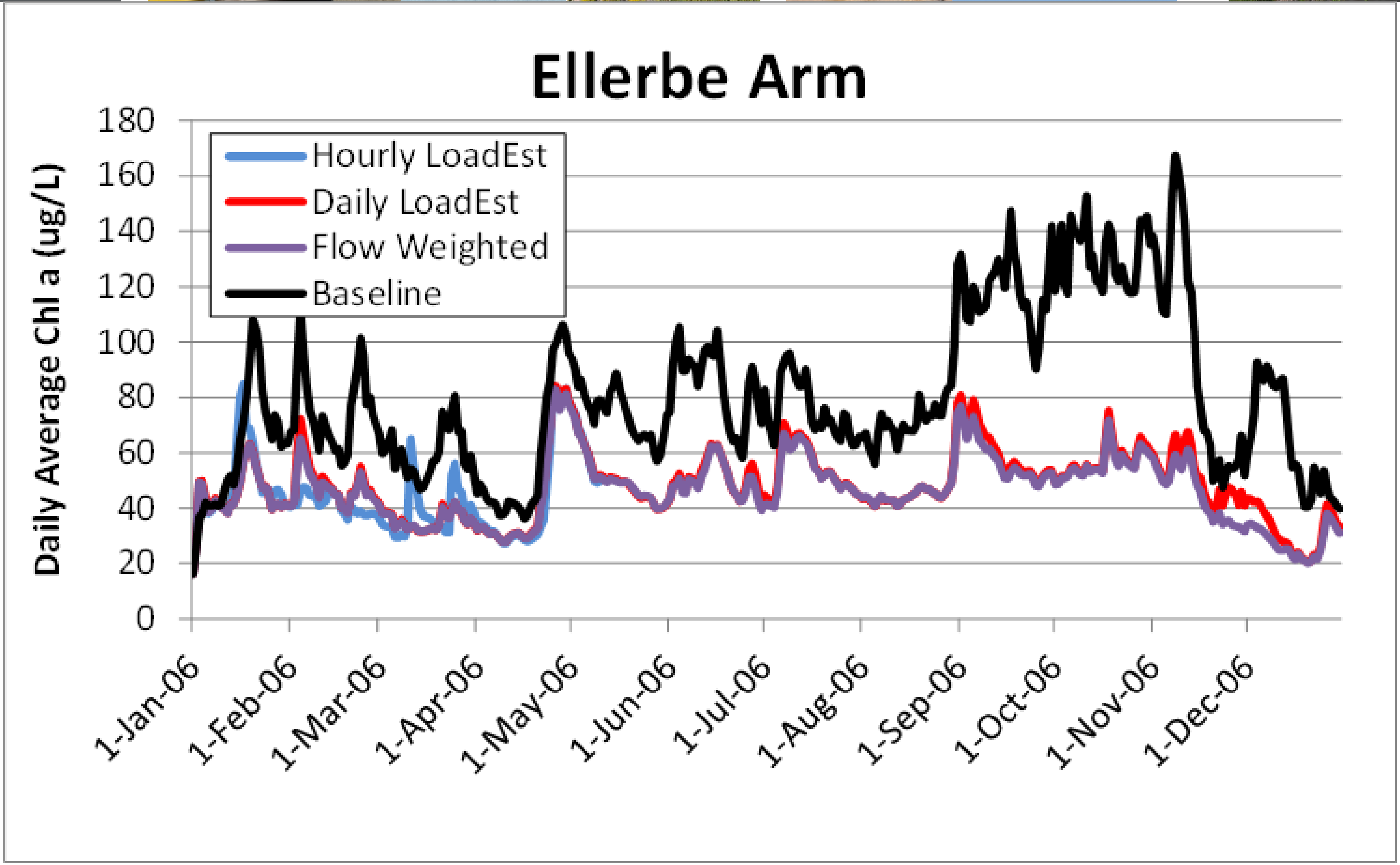
J0820000
U0208521324
U02086500
U0208650112
J1100000
J1210000
U02086624
J1650000
U0208524975
J1700000
NEU010
ELL10
J0770000
U02085070
J0810000
NEU013
U02086849
J1330000
NEU013B
NEU019C
LC01
NEU019E
LLC01
NEU018E
NEU0171B
NEU019L
Legend
Watershed Stations
Lower Tributary Stations
Falls Lake Stations
Depth (m)
73.2 - 74.0
74.1 - 74.5
74.6 - 75.0
75.1 - 76.0
76.1 - 76.7
J1530000
NEU019P
J1765000
J1675500
NEU020D
J1890000
02087182
U02087182

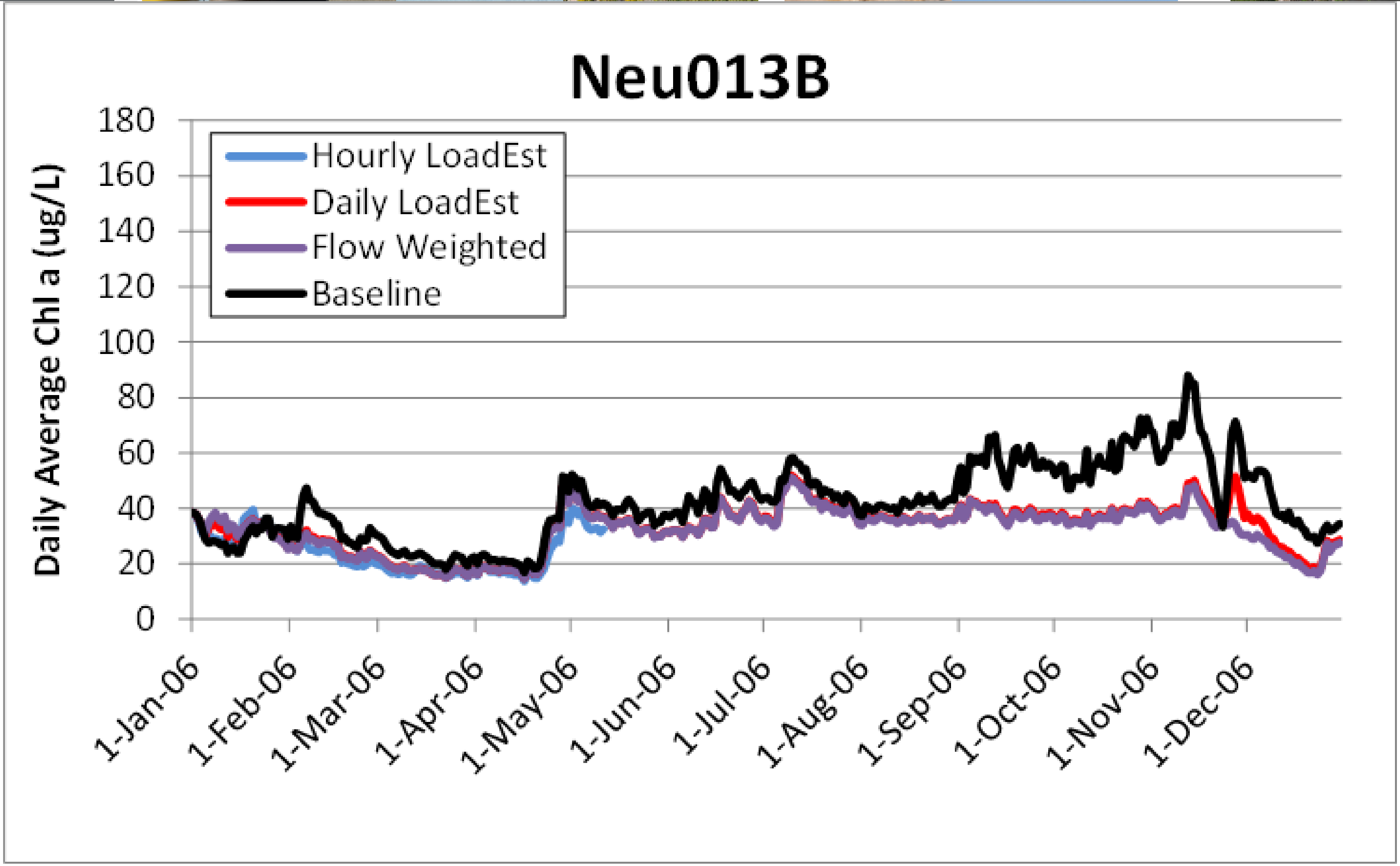


Ellerbe Arm
Daily Average TP (mg/L)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Hourly LoadEst
Daily LoadEst
Flow Weighted
Baseline
1-Jan-06
1-Feb-06
1-Mar-06
1-Apr-06
1-May-06
1-Jun-06
1-Jul-06
1-Aug-06
1-Sep-06
1-Oct-06
1-Nov-06
1-Dec-06



Ellerbe Arm
Hourly LoadEst
Daily LoadEst
Flow Weighted
Baseline
Daily Average TN (mg/L)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1-Jan-06
1-Feb-06
1-Mar-06
1-Apr-06
1-May-06
1-Jun-06
1-Jul-06
1-Aug-06
1-Sep-06
1-Oct-06
1-Nov-06
1-Dec-06


Ellerbe Arm
Daily Average Chl a (ug/L)
180
160
140
120
100
80
60
40
20
0
Hourly LoadEst
Daily LoadEst
Flow Weighted
Baseline
1-Jan-06
1-Feb-06
1-Mar-06
1-Apr-06
1-May-06
1-Jun-06
1-Jul-06
1-Aug-06
1-Sep-06
1-Oct-06
1-Nov-06
1-Dec-06



Neu013B
Hourly LoadEst
Daily LoadEst
Flow Weighted
Baseline
Daily Average Chl a (ug/L)
0
20
40
60
80
100
120
140
160
180
1-Jan-06
1-Feb-06
1-Mar-06
1-Apr-06
1-May-06
1-Jun-06
1-Jul-06
1-Aug-06
1-Sep-06
1-Oct-06
1-Nov-06
1-Dec-06

Load Estimation Methods - Summary

- For total nitrogen and chlorophyll *a*, the baseline input methodology estimates much higher concentrations in the Ellerbe arm and downstream than different approaches using LOADEST.
- The baseline method generates much lower total phosphorus concentrations than the LOADEST approaches.
- Predicted chlorophyll *a* concentrations in the lake are fairly sensitive to the method used to estimate daily nutrient and flow inputs. The baseline method tended to produce the highest simulated concentrations of chlorophyll a.
- The hourly time step for flow inputs did not significantly impact simulated chlorophyll *a* concentrations using the existing lake response model. Given the level of effort associated with setting up and running hourly inputs, one of the daily input methods is likely the best approach for future model revisions.

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UNRBA Monitoring Plan Implications

- Continue to support water quality monitoring and USGS gages on the uppermost tributaries to Falls Lake
- Existing Nutrient Response Model Chlorophyll a predictions are much less sensitive to loading from the middle and lower tributaries
  - Flow estimation methods for calculating loading for these tributaries should be considered as an alternative to USGS gage installation
  - Water Quality monitoring frequency can be lower in these areas

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Review Flow Estimation Methods

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Is there a cost effective tool available to predict flows in areas where we do not have flow gages?

- Methods/Models under evaluation
  - OASIS,WARMF, RTI Waterfall
  - USGS Streamflow Regionalization Method (Archfield method), Basin Proration
- Identifying model strengths and limitations
- Comparing flow predictions from several methods at gaged locations
- Compare basin proration method to selected method at an ungaged location

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Cape Fear / Neuse OASIS Model – Major Limitations

- The model covers only the main stem of the river and parts of main tributaries where surface water withdrawals, discharges or reservoir operations take place.
- The tributaries in Falls Lake are not included individually in the OASIS model. All the flows from these tributaries are calculated as a mass balance.
- The model is calibrated to monthly flows.
- Many inputs are monthly averages.
- The model will not provide daily flows for the ungaged tributaries to Falls Lake.

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RTI Waterfall Model

- RTI Waterfall has been developed for Neuse River Basin using a GWLF modeling platform.
- Unknown cost for model license.
- Has not been used to predict daily flows to drive a hydrodynamic model.
- Unable to find documented peer review.

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WARMF Model

- Existing DWR WARMF Model
- Incorporates wastewater discharge into model flow predictions
- Durham's updated WARMF model may provide improved flow predictions because of the hourly time step for the middle tributaries Lick, Little Lick, and Panther Creeks

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Basin Proration Method

- Flows at a gaged location (referred to as the donor gage) are scaled by a ratio of drainage areas to predict flows at an ungaged location
- The ratio is calculated as drainage area of the non-gaged location divided by drainage area of the gaged location:

$$Ungaged\ Flow = \text{Gaged}\ Flow \times \frac{Drainage\ Area\ at\ Ungaged\ Location}{Drainage\ Area\ at\ Gage}$$

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USGS Streamflow Regionalization Method

- The USGS streamflow regionalization approach expands the basin proration method by using catchment characteristics such as geology, land use, slope, etc. to identify the donor gages
- Multiple gages and their catchment traits are used to create a set of regression models that estimate a flow duration curve for an ungauged location

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USGS Streamflow Regionalization Method

- Advantages
  - Uses watershed characteristics and observed flows to create a flow prediction model
  - The purpose of the model is to predict flows in ungaged locations
  - Has been through peer review process
  - Publicly available at no cost to UNRBA

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USGS Streamflow Regionalization Method

- Considerations and Limitations
  - This method uses gage data from outside the Upper Neuse Basin
  - Limited to use in watersheds without significant reservoir withdrawals or major wastewater discharges
  - Has not been used in NC

USGS Streamflow Regionalization Method

- Includes three main steps:
  - development of a flow duration curve for the ungaged site using a quantile regression method;
  - selecting the best donor gage using the map-correlation method; and
  - using the predicted flow duration curve to identify daily flow based on the observed flow percentile at the donor gage.

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WARMF Flow Prediction Results for 2007 – Model Validation Year

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Statistic	Reco-mmended Criteria	Knap of Reeds	Flat River above Lake Michie	Little River above Reservoir	Eno near Hills-borough	Eno near Durham	Ellerbe Creek at Gorham
Total predicted instream flow volume	±10%	5.6%	1.7%	-8.5%	-19.5%	13.4%	-7.6%
Total volume of highest 10%of flows	±15%	6.8%	-3.0%	13.9%	-13.2%	18.7%	-7.6%
Total volume of lowest 50%of flows	±10%	15.9%	115.6%	60.8%	62.5%	115.2%	-10.5%
Total 1st quarter flow volume	±30%	9.6%	606.8%	10.5%	-15.6%	16.5%	-4.6%
Total 2nd quarter flow volume	±30%	-3.9%	-0.5%	-55.8%	-39.2%	-10.8%	-15.8%
Total 3rd quarter flow volume	±30%	16.1%	-10.0%	193.9%	140.4%	365.7%	2.4%
Total 4th							

Basin Proration Flow Prediction Results Eno River at Hillsborough using two different donor gages

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		Observed	Basin Proration		
	Target Criteria	(mean daily cfs)	SevenMile Creek(MC[1])	Little River	Eno River at Hillsb.
Coefficient of Efficiency		--	0.856	0.877	--
Total instream flow volume	+/- 10%	63.6	0.63%	1.47%	--
Highest 10% of flows	+/- 15%	--	-1.35%	0.041%	--
Lowest 50% of flows	+/- 10%	--	10.7%	6.15%	--
Total 1st quarter flow volume	+/- 30%	118	1.31%	2.99%	--
Total 2nd quarter flow volume	+/- 30%	65.1	-2.64%	-5.23%	--
Total 3rd quarter flow volume	+/- 30%	31.2	-3.26%	7.35%	--
Total 4th quarter flow volume	+/- 30%	41.1	-0.974%	3.19%	--

USGS Streamflow Regional Method Results for Multiple Tributary Locations

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Prediction Site:	Target Criteria	Sevenmile Creek	Eno River at Hillsb.	Eno River near Durham	Little River above Reservoir	Mountain Creek
Statistic						
Coefficient of Efficiency		0.864	0.856	0.357	0.671	0.774
Total predicted instream flow volume	+/- 10%	1.87%	2.78%	31.9%	16.6%	14.8%
Total volume of highest 10% of flows	+/- 15%	-1.11%	1.28%	17.3%	6.32%	-0.003%
Total volume of lowest 50% of flows	+/- 10%	17.3%	25.1%	81.7%	93.7%	139.%
Total 1st quarter flow volume	+/- 30%	1.7%	4.07%	26.9%	11.7%	15.3%
Total 2nd quarter flow volume	+/- 30%	3.23%	0.16%	26.8%	17.4%	16.2%
Total 3rd quarter flow volume	+/- 30%	1.91%	3.11%	44.%	34.%	0.336%
Total 4th quarter flow volume	+/- 30%	0.284%	2.97%	38.9%	12.3%	25.8%

Comparison of Basin Proration and USGS Method at two Eno River Locations

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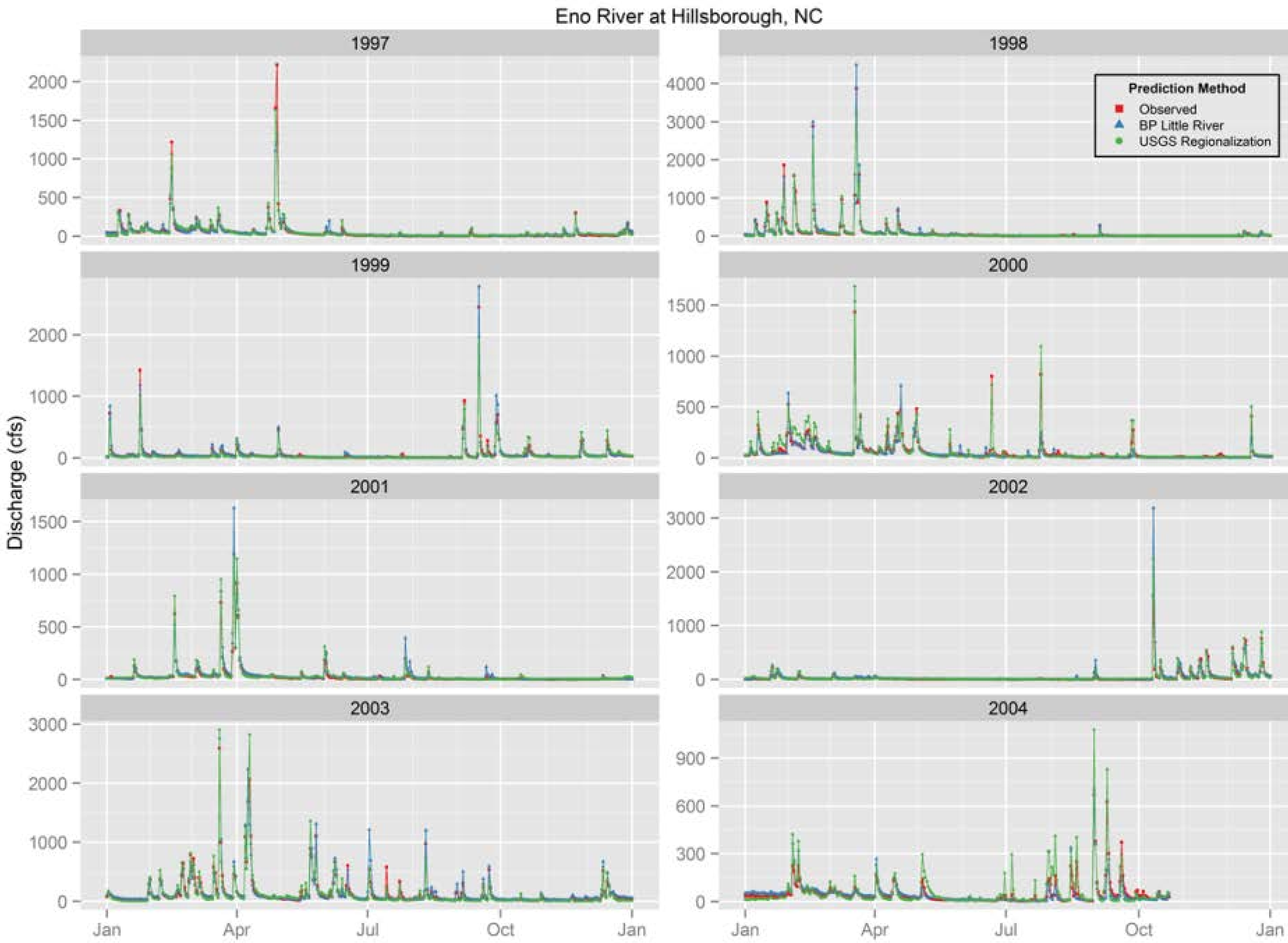

Eno River at Hillsborough, NC
Prediction Method
Observed
BP Little River
USGS Regionalization
1997
1998
1999
2000
2001
2002
2003
2004
Discharge (cfs)
Jan
Apr
Jul
Oct
Jan

Comparison of three Different Flow Estimation Methods

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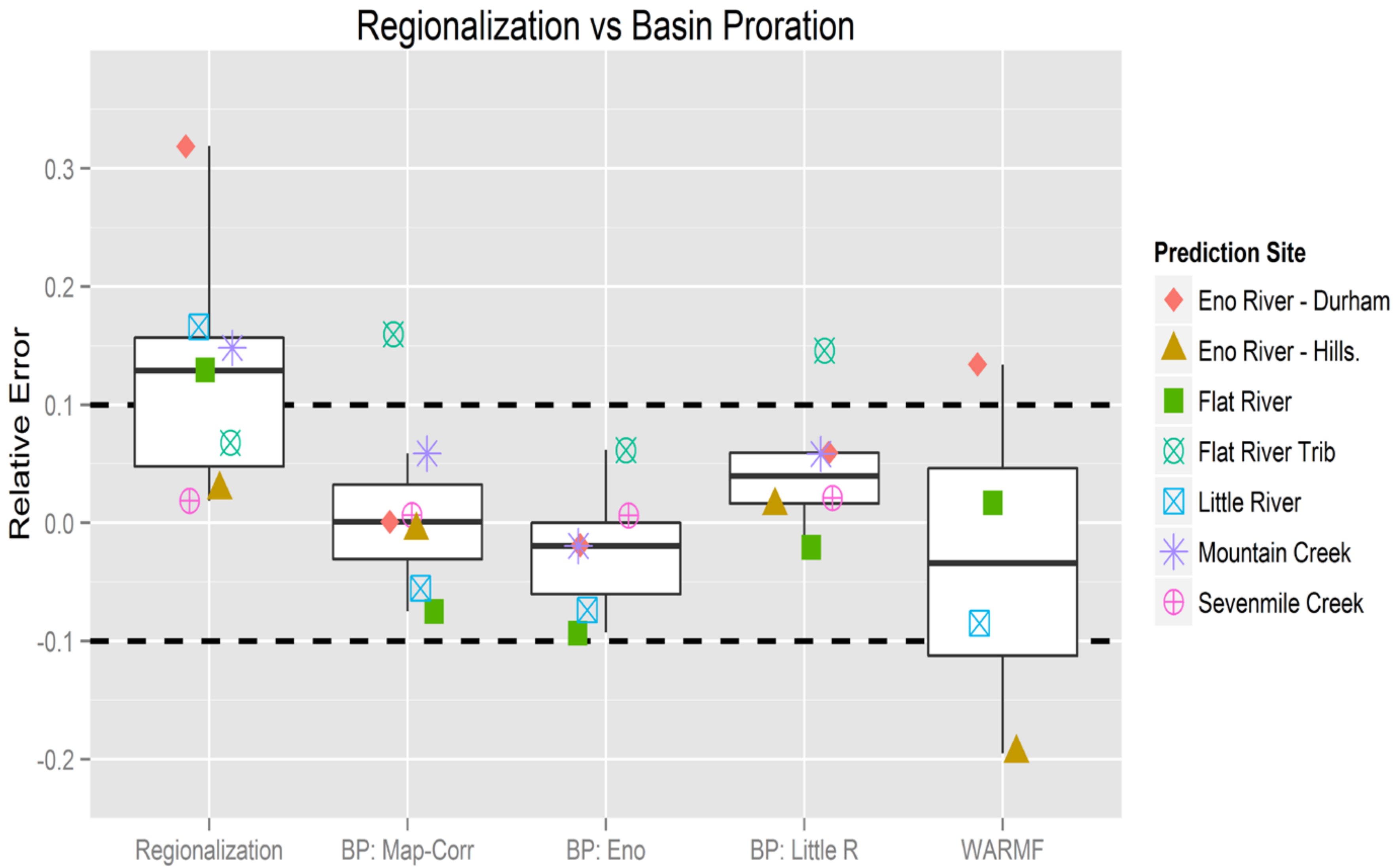

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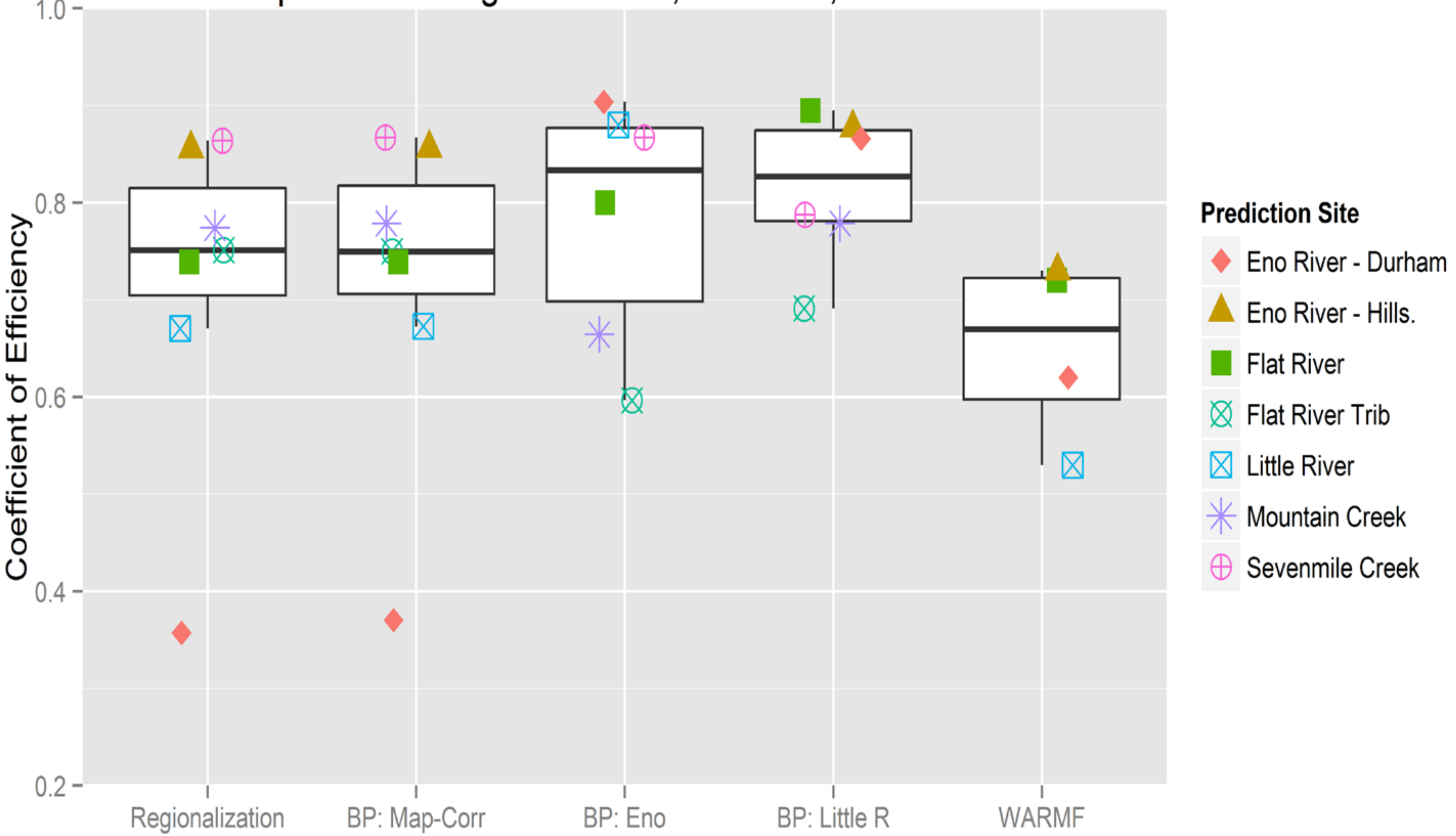
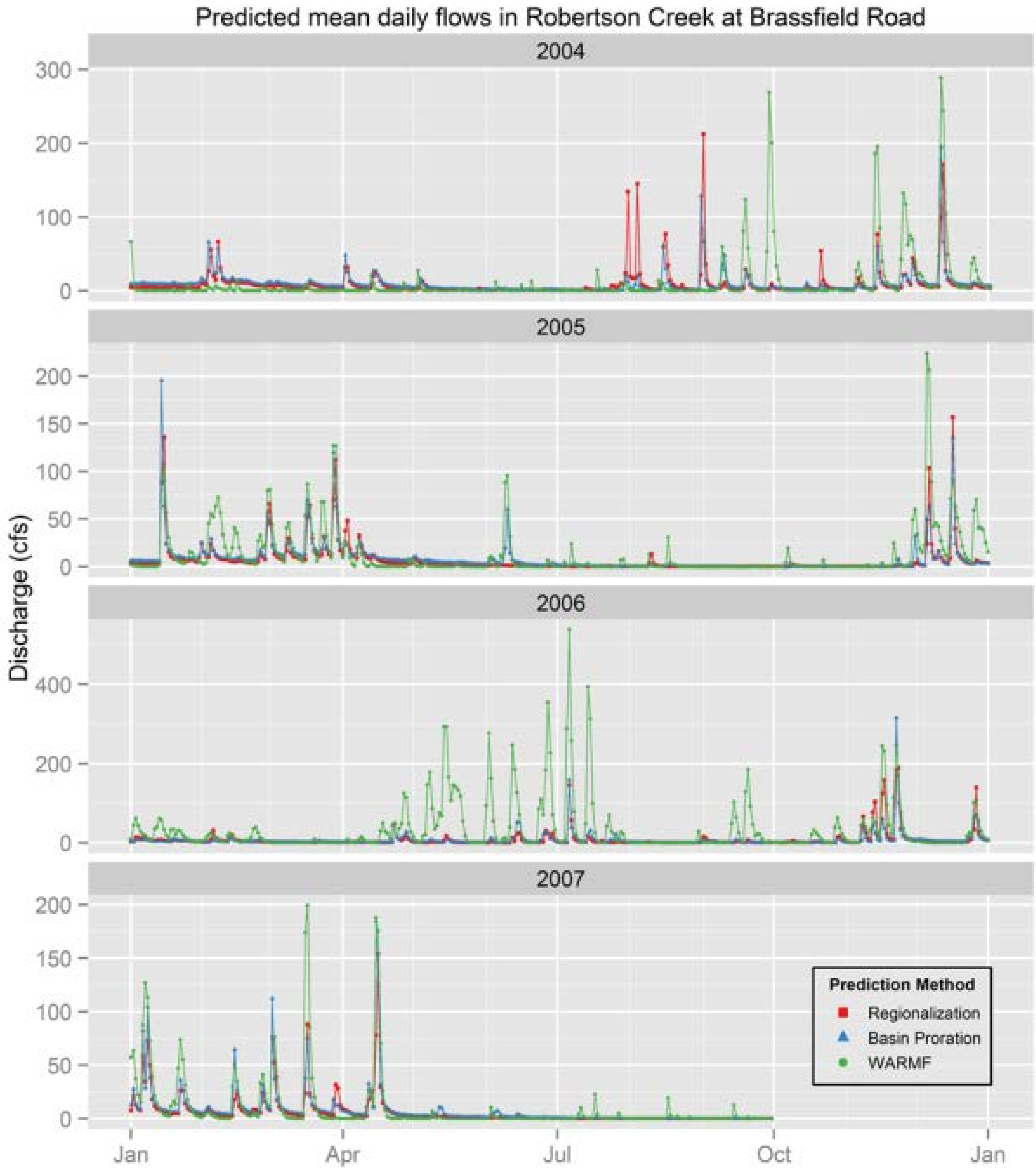
Comparison of Regionalization, Proration, and WARMF





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Suggested Methods for Future Flow Estimation for ungaged middle and lower tributary locations

- The WARMF, Basin Proration and USGS Streamflow Regionalization Methods do a good job of predicting flow, usually within about +/-10% of the mean daily flow.
- The Basin Proration and USGS methods methods tend not to overpredict flow, particularly large flows, which could lead to higher estimates of nutrient loading than is actually occurring. Both methods tend to overpredict the lowest flows.
- Updating and calibrating the WARMF model for all tributaries and years of interest would be a significant investment for the UNRBA.
- Basin Proration method is the most cost effective approach.

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Next Steps

Action Items

- Identify a database review team and meeting date
- Review statistical methods for predicting WQ and determining monitoring frequency
- Combine findings into a range of proposed monitoring programs and describe the associated cost and data quality associated with each
- Meet with UNRBA to select preferred combination of water quality monitoring locations and frequency, as well as locations for installation of new USGS flow gage