How Changes in Nitrogen Loading to the Neuse River Estuary have Affected Algal Biomass

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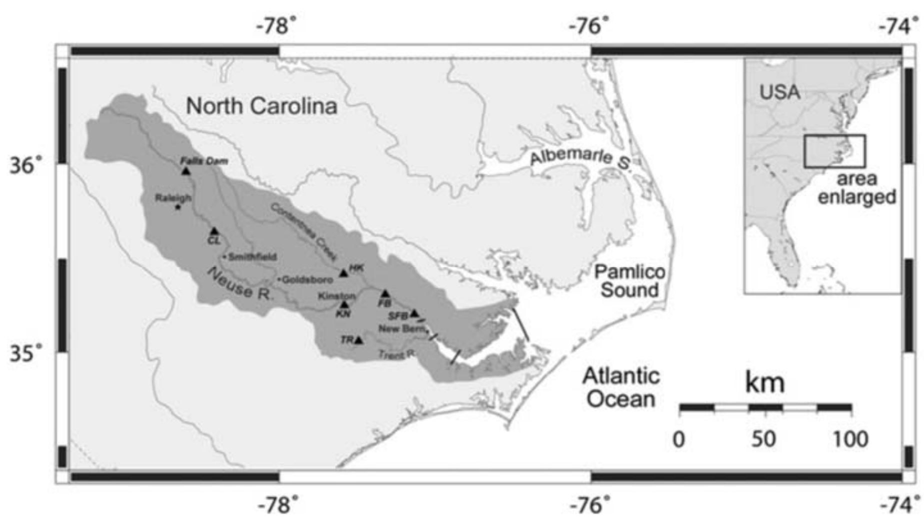
March 16, 2017
James Bowen – Civil & Environmental Engr. Dept.

The Neuse River Estuary, North Carolina



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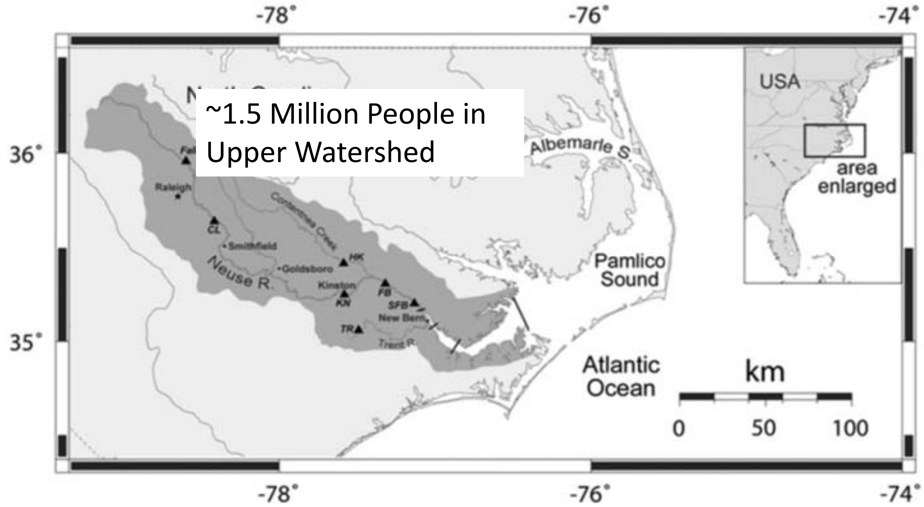
The Neuse River Estuary, North Carolina



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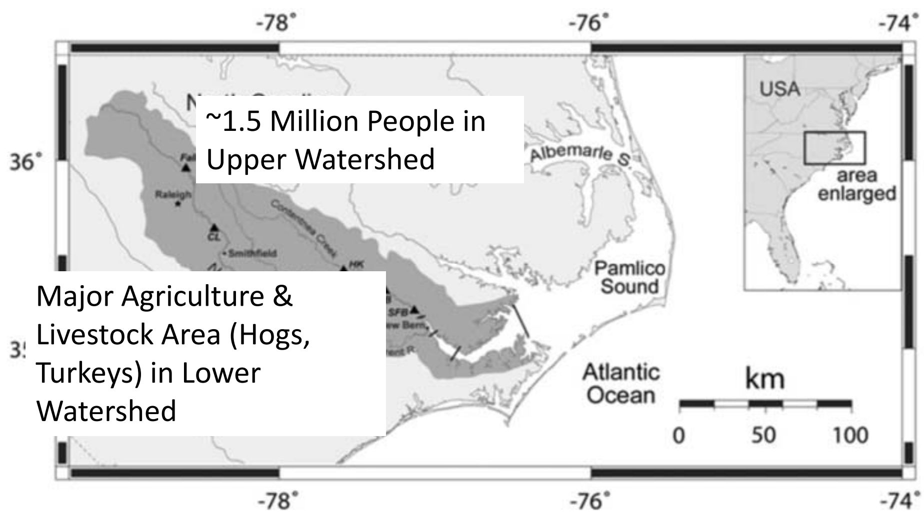
The Neuse River Estuary, North Carolina



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Neuse River Estuary (NRE) water quality problems are not new

1. Algal Blooms – regular Chl-a water quality criteria (>40 ug/L) exceedences since the 1980's
2. More frequent blooms in lower estuary in the 2000's
3. Multiple major fish kills in late 90's
4. Intermittent, but widespread bottom water anoxia during Spring, Summer, early Fall

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Water Quality Modeling of Neuse River Estuary also not a new story


REPORT NO. 325-D

NEUSE RIVER ESTUARY MODELING AND MONITORING PROJECT STAGE 1: PREDICTIONS AND UNCERTAINTY ANALYSIS OF RESPONSE TO NUTRIENT LOADING USING A MECHANISTIC EUTROPHICATION MODEL

by
James D. Bowen and Jeffrey Hieronymus

University of North Carolina at Charlotte
Charlotte, NC

October 2000

Water Resources Research Institute
of The University of North Carolina

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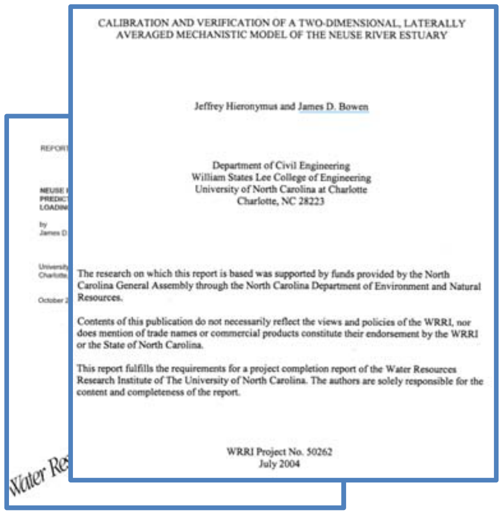
Water Quality Modeling of Neuse River Estuary also not a new story


CALIBRATION AND VERIFICATION OF A TWO-DIMENSIONAL, LATERALLY AVERAGED MECHANISTIC MODEL OF THE NEUSE RIVER ESTUARY

Jeffrey Hieronymus and James D. Bowen

Department of Civil Engineering
William States Lee College of Engineering
University of North Carolina at Charlotte
Charlotte, NC 28223

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This report fulfills the requirements for a project completion report of the Water Resources Research Institute of The University of North Carolina. The authors are solely responsible for the content and completeness of the report.

WRRI Project No. 50262
July 2004

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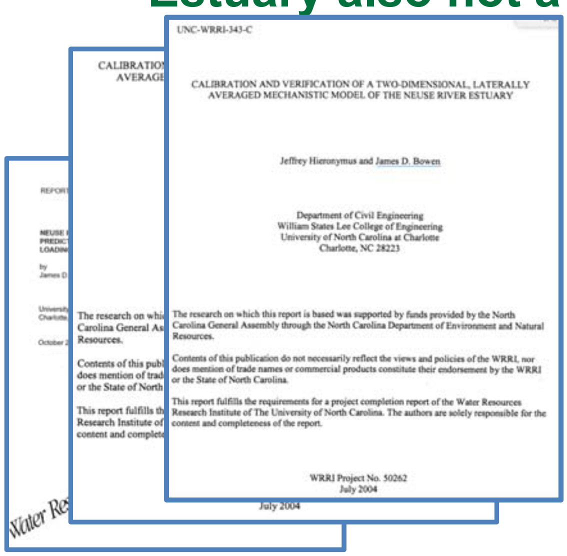
Water Quality Modeling of Neuse River Estuary also not a new story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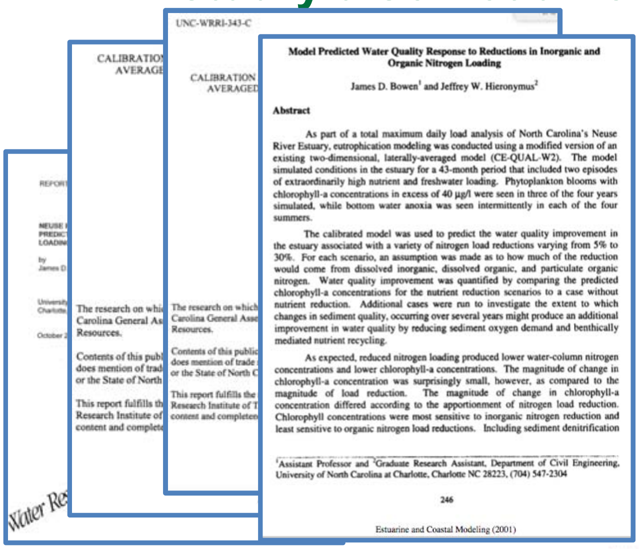

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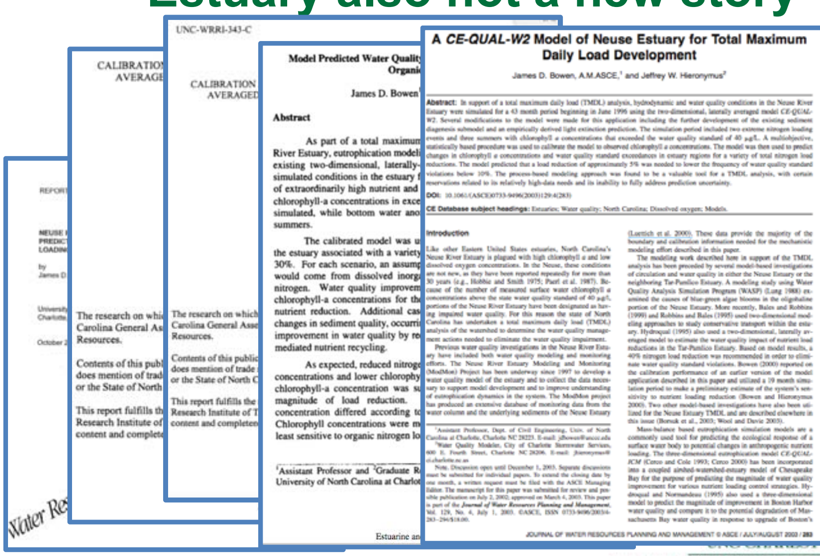

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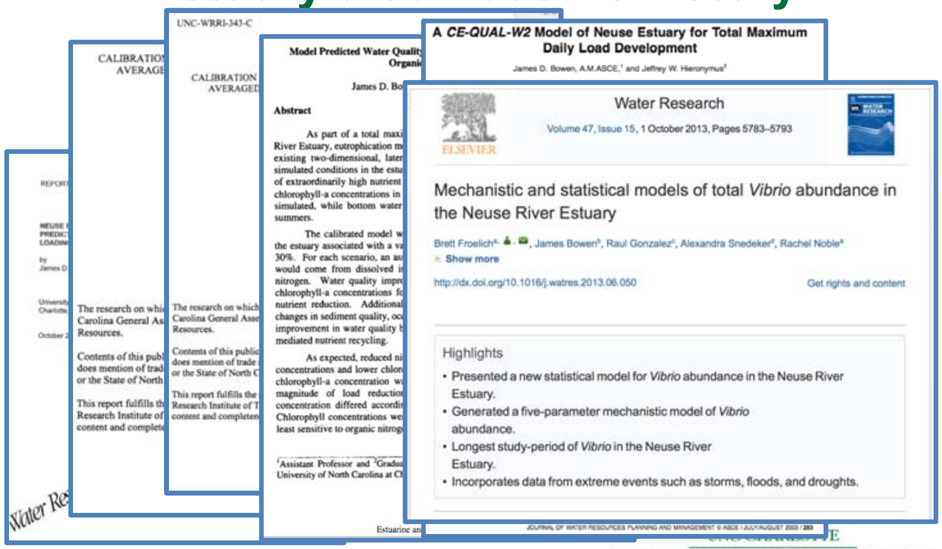
Water Quality Modeling of Neuse River Estuary also not a new story



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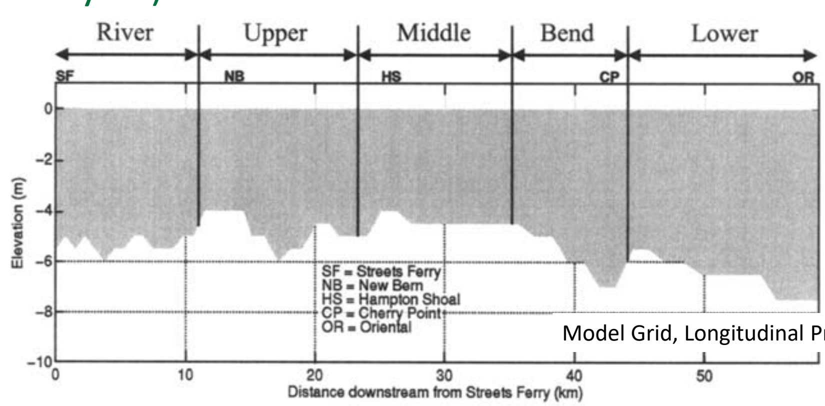
Neuse Estuary Eutrophication Model (NEEM)

- Two- dimensional laterally averaged model
- Application of CE-QUAL-W2 (61 segments, 20 layers)



Model Grid, Longitudinal Profile

Original W2 grid

62 segments, 18 layers　　2 branches, 11 tributaries

CE-QUAL-W2 Water Quality State Variables

Physical Properties

1. Temperature 2. Salinity
3. Suspended Solids

Phytoplankton

4. Diatoms & Dinoflagg's
5. Chloros & Cryptos
6. Blue-Green Algae

Organic Matter

7. LPOM 8. RDOM
9. RPOM 10. Part Silica
11. LDOM

Nutrients

12. NH_3
13. NO_2+ NO_3
14. Dissolved Silica
15. Ortho Phosphate

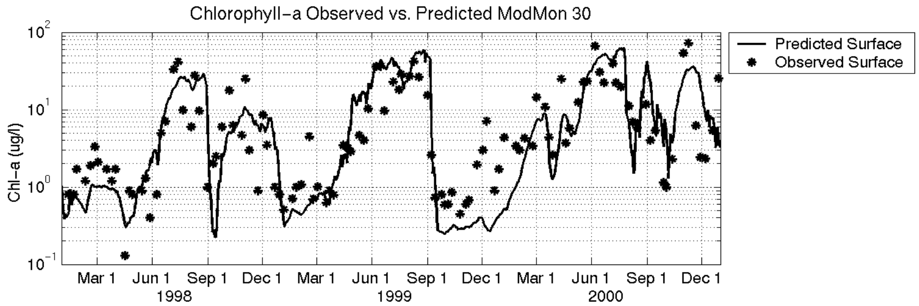
Oxidants/Reductants

17. Dissolved Oxygen

Sediment Organic Matter

18. Labile SOM
19. Refr. SOM

Old NEEM vs. New NEEM: Chlorophyll predictions, mid-estuary 1998- 2000



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NEEM Development: Added a Sediment Diagenesis Submodel

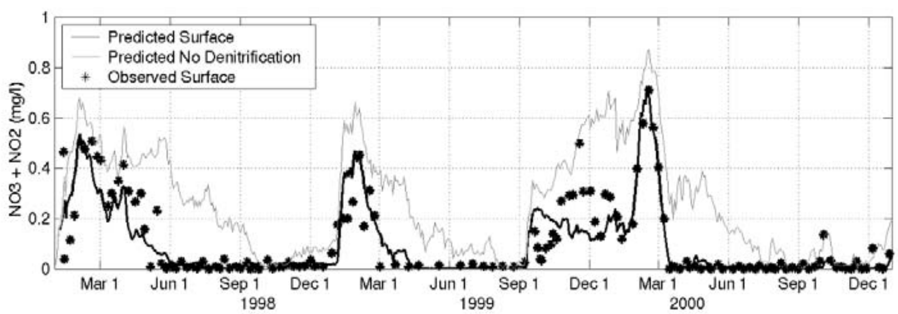

Figure 9. Predicted (bold line), predicted with denitrification turned off (gray line), and observed (symbols) nitrite + nitrate in the near-surface waters at MODMON station 120 from January 1998 to December 2000.

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NEEM Development: Added a light model too

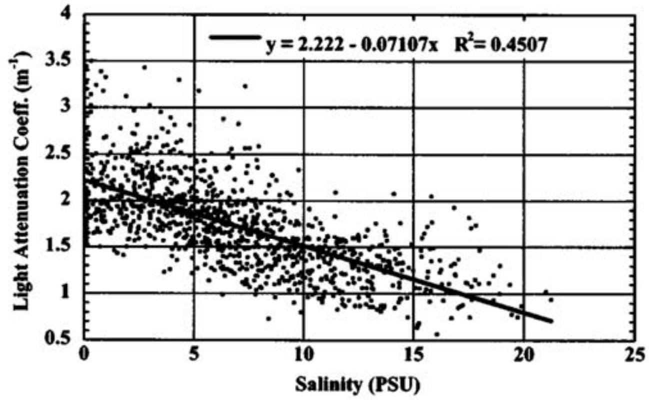

Fig. 4. Measured light attenuation coefficients versus observed salinities in Neuse River Estuary

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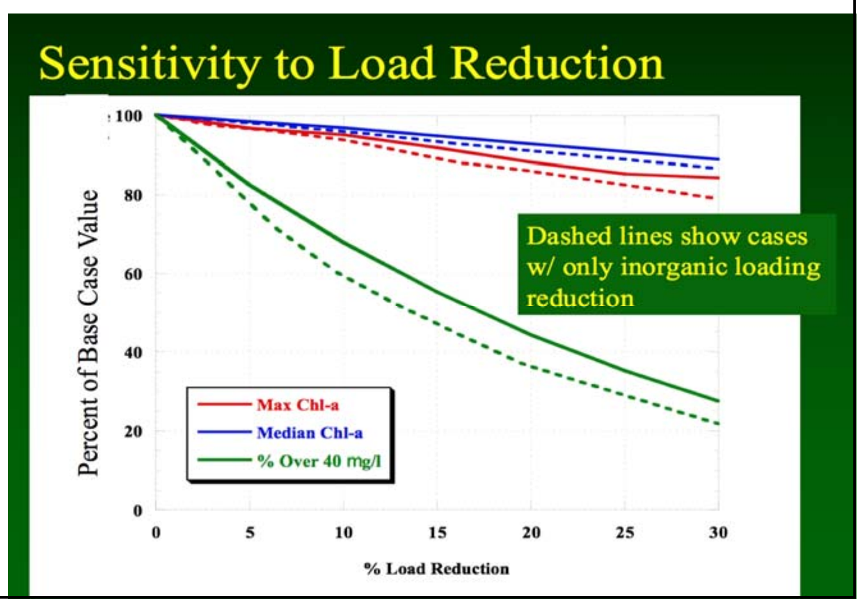
TMDL Basis - Nitrogen Load Reductions Scenarios



Multiple Models Used as Basis for TMDL

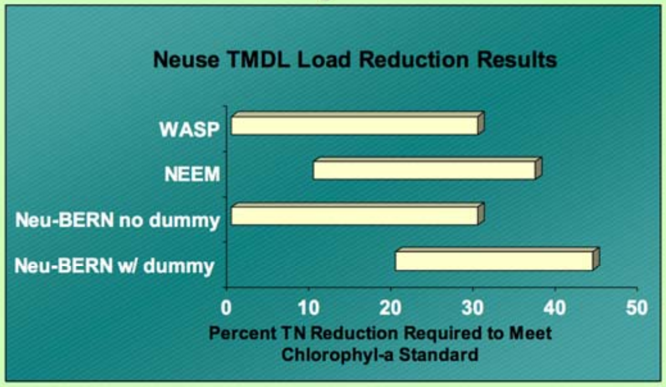


Figure 6. Summary of model results used to recommend a 30% reduction in Nitrogen Loading from the 1995 baseline loading.

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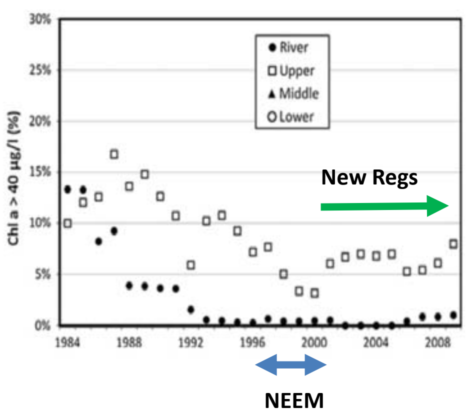
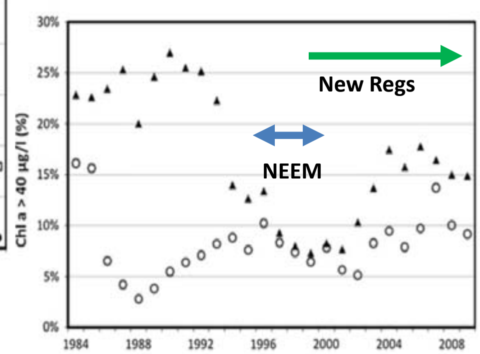
NRE Water Quality Conditions Improved – For a While





Figures from Lebo et al., 2012, Environmental Management

Fig. 9 Cumulative frequency of Chl*a* greater than 40 µg/l standard by 5-year assessment period and zone along NR Estuary. Values are plotted in year 5 of each period

NRE Trends – Changes in Form & Location of N Loading

Upper Neuse Watershed (Neuse R. @ Clayton)

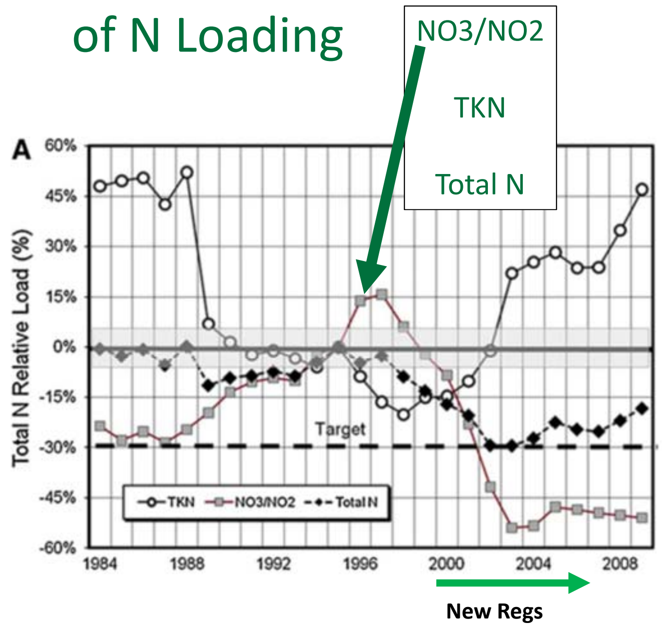


Figure from Lebo et al., 2012, Environmental Management

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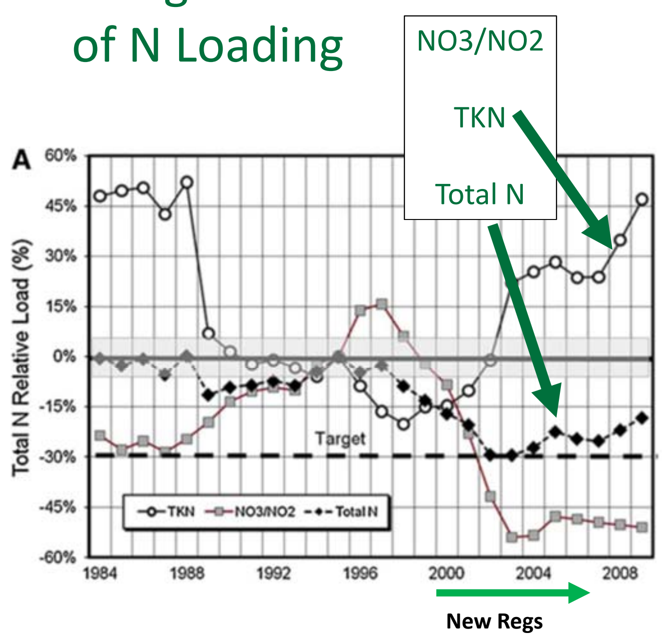

Figure from Lebo et al., 2012, Environmental Management

Nutrient Load Reductions Not Fully Met and Varies by N Form & Location

Estuary Branch (Trent River)

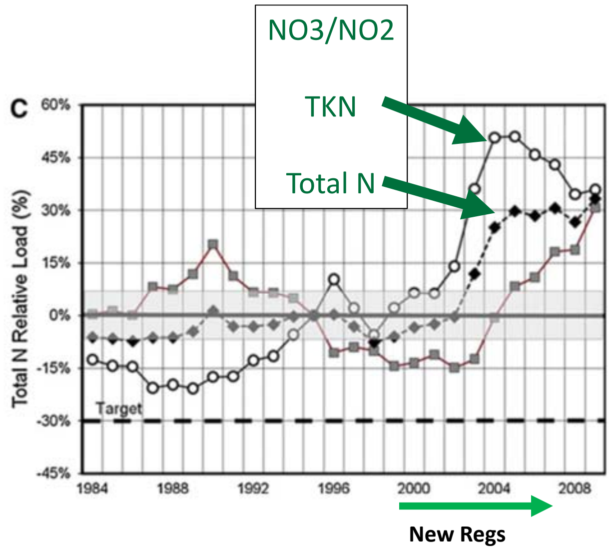

Figure from Lebo et al., 2012, Environmental Management

Now Working on an Updated Neuse Estuary Eutrophication Model

- Additional Branches and Lower Estuary Segments
- Model Period: June 1997 – May 2009 (13 yrs!)
- Two Key Questions
  1. How Well Does Updated Model Simulate Water Quality Dynamics?
  2. What are the Consequences of Recent Changes in Nitrogen Load Quantity and Quality?

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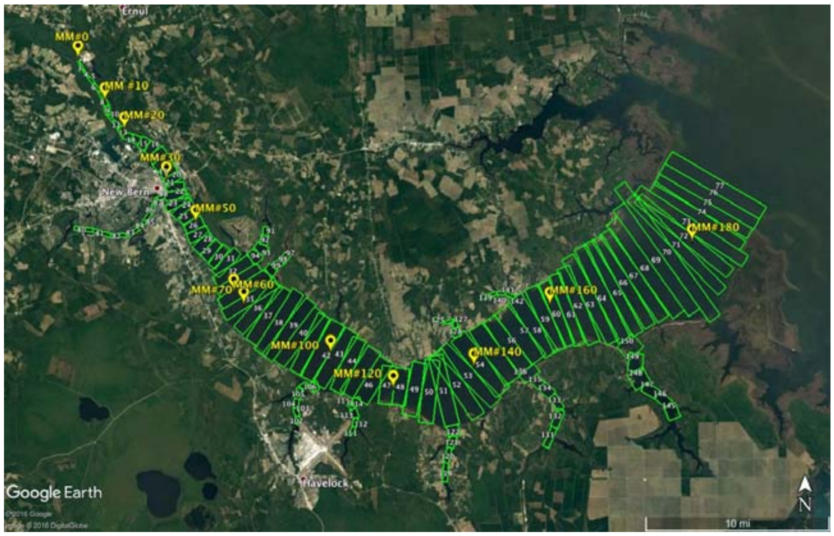
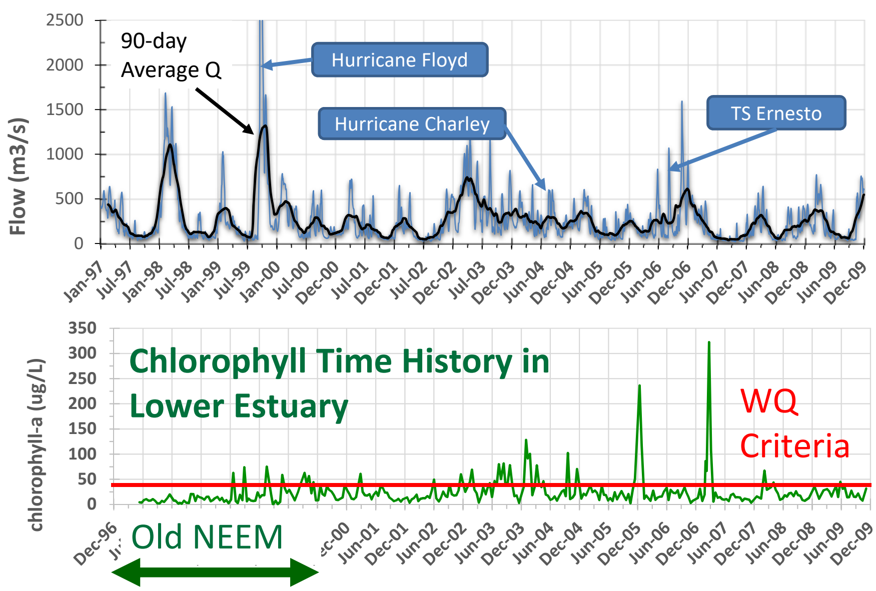
New W2 grid

129 segments, 18 layers 11 branches, 5 tributaries



Neuse Estuary Total Flow

11 branches + 5 tributaries



Neuse Estuary Total Flow

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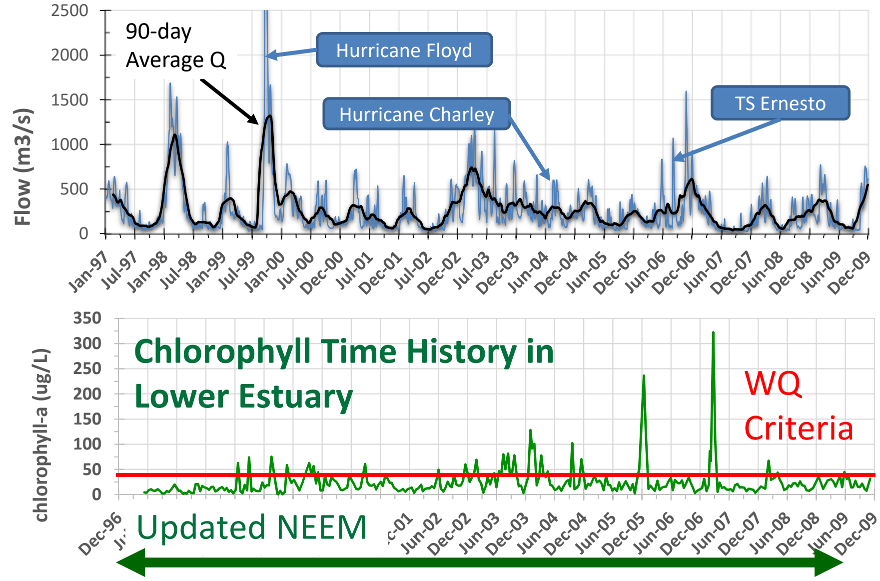
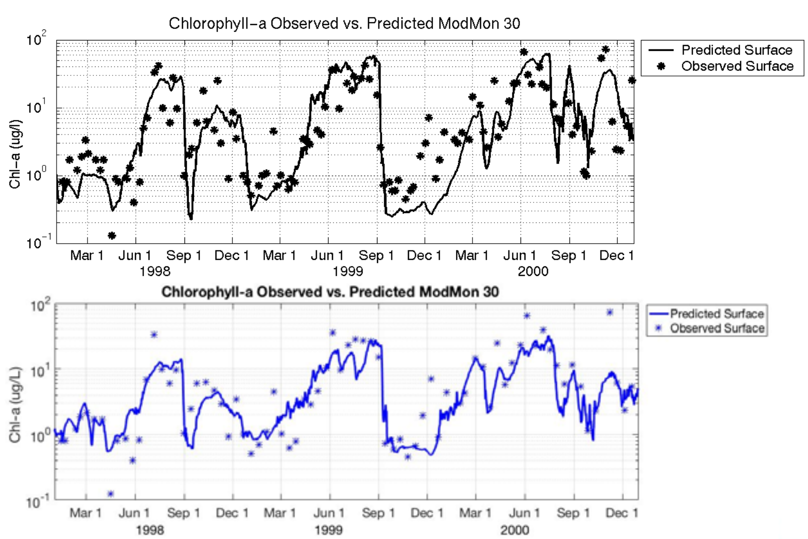


Old NEEM vs. New NEEM: Chlorophyll predictions, mid-estuary 1998- 2000



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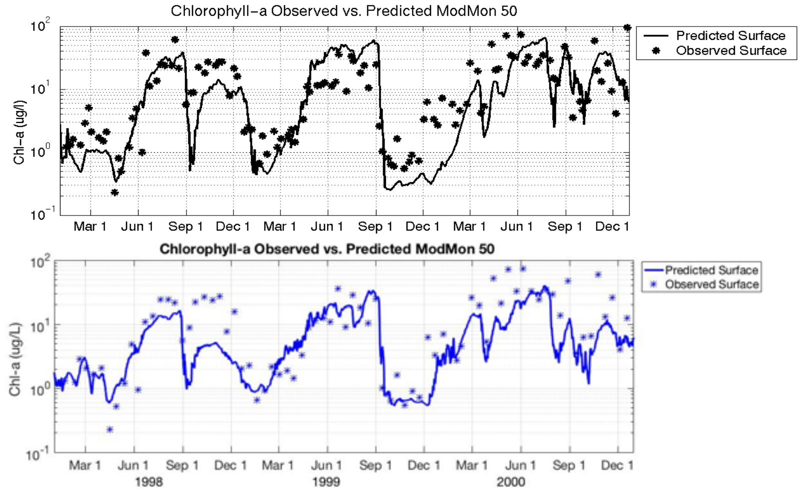

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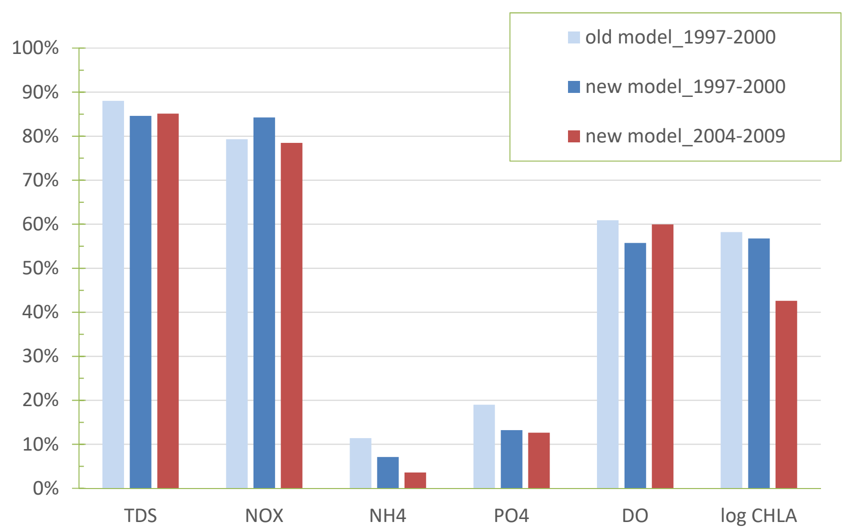
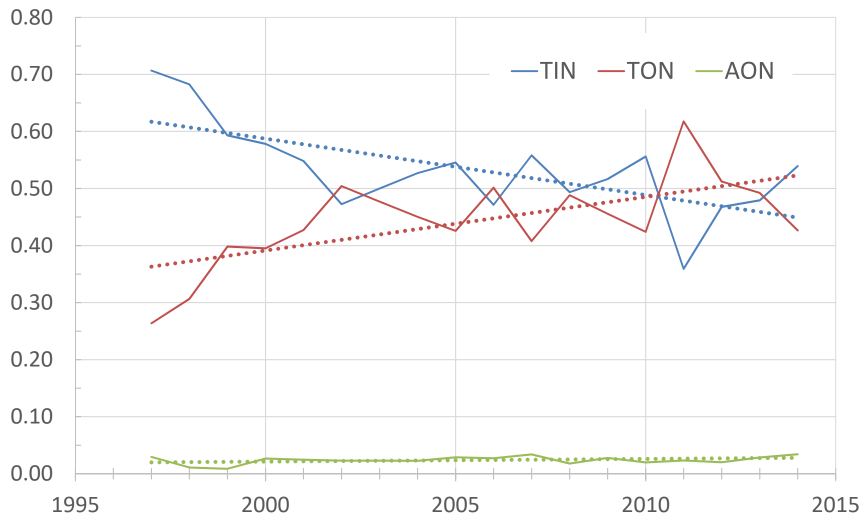
Correlation between predicted and observed values



Loading to Estuary: Fraction of flow-normalized N loading

(branches 1-11)



Loading to Estuary: Fraction of flow-normalized N loading

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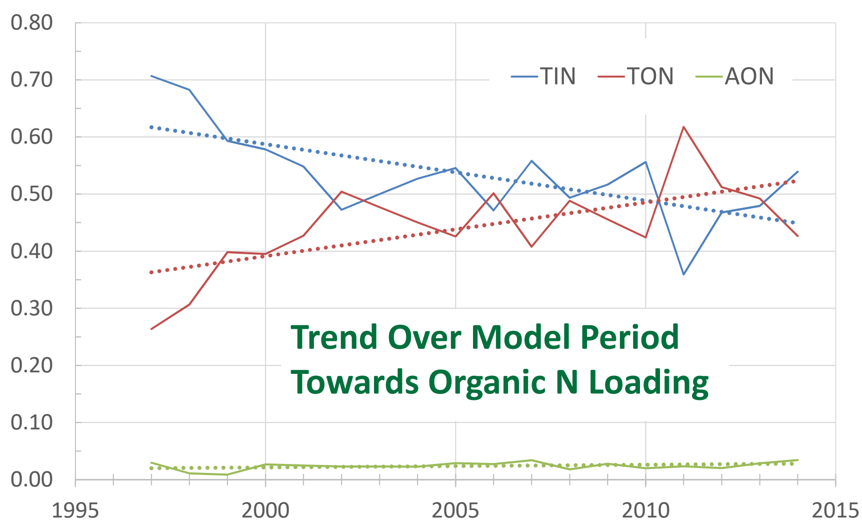
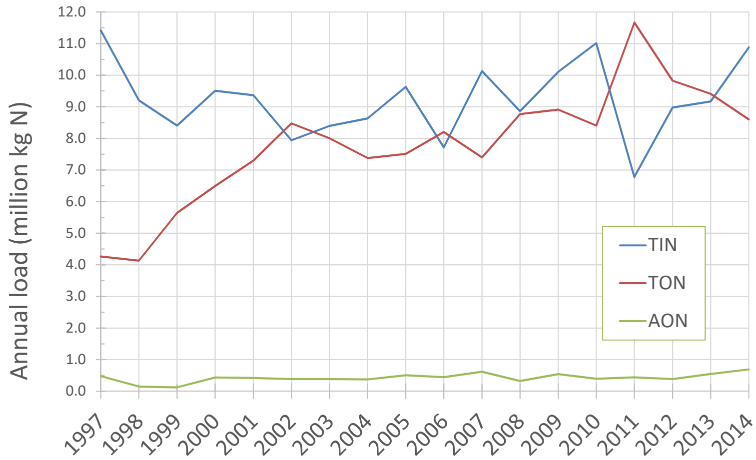


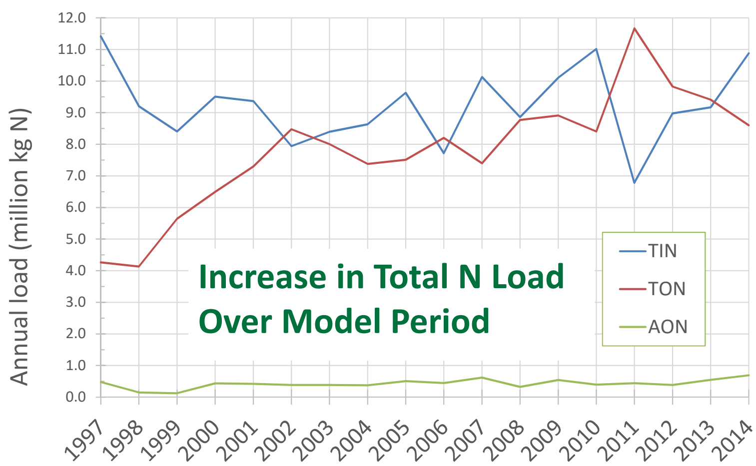
Loading to Estuary: Annual flow-normalized N load

(branches 1-11)



Loading to Estuary: Annual flow-normalized N load

(branches 1-11)



Latest Results

- Working to Update Sediment Model to Support Scenario Testing (i.e. system sensitivity to load reduction)
- Need to Examine Chlorophyll Frequency Distributions (model vs. predicted)
- Sensitivity to N load reduction much lower in 2004-2009 model runs
  - lack of sediment model?
  - shift to organic N load?
  - Change in spatial-temporal N loading pattern?

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Thank You

Questions?

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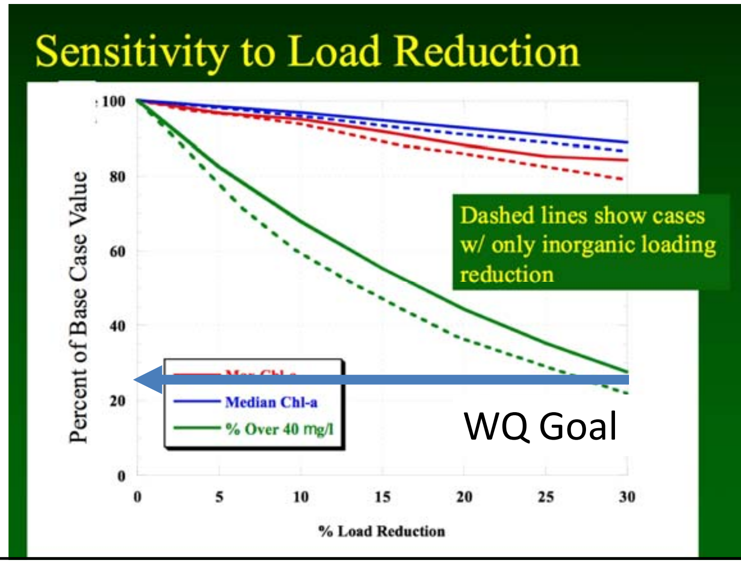
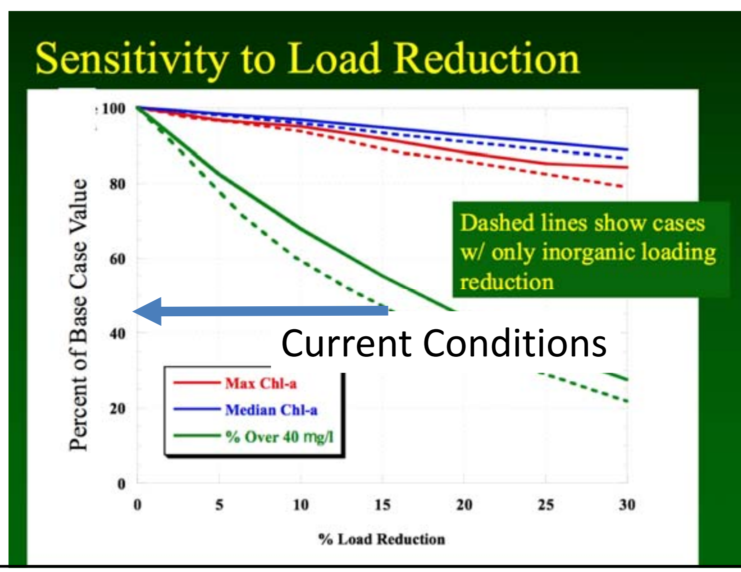
The Updated Neuse Estuary Eutrophication Model – What to Expect?

ECM 7 Slide



The Updated Neuse Estuary Eutrophication Model – What to Expect?

ECM 7 Slide



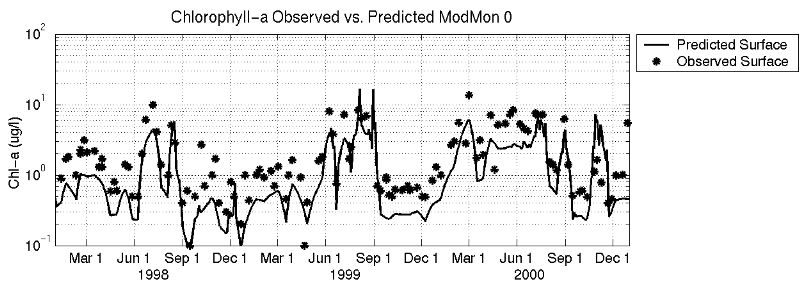
Summary & Future Work

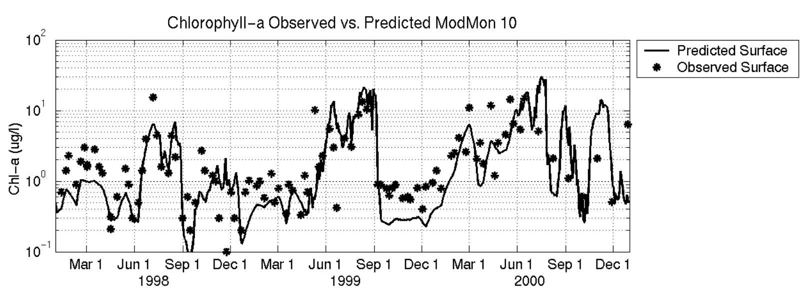
- Updated NRE Model Available by end of 2016
- Greatly expanded simulation time (1997 – 2009)
- Used to examine relative sensitivity to inorganic vs. organic N load
- Model may need additional development of sediment sub-model
- Expected use by NC environmental regulators

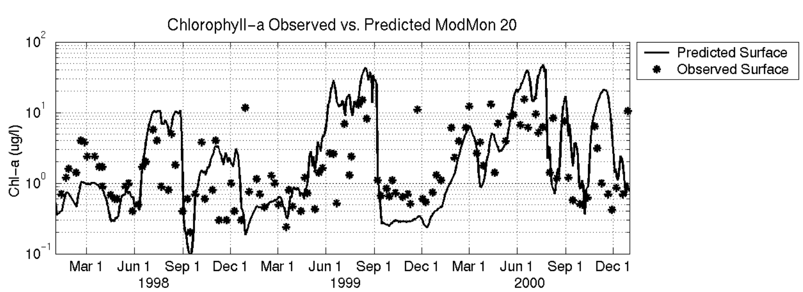
Thank You

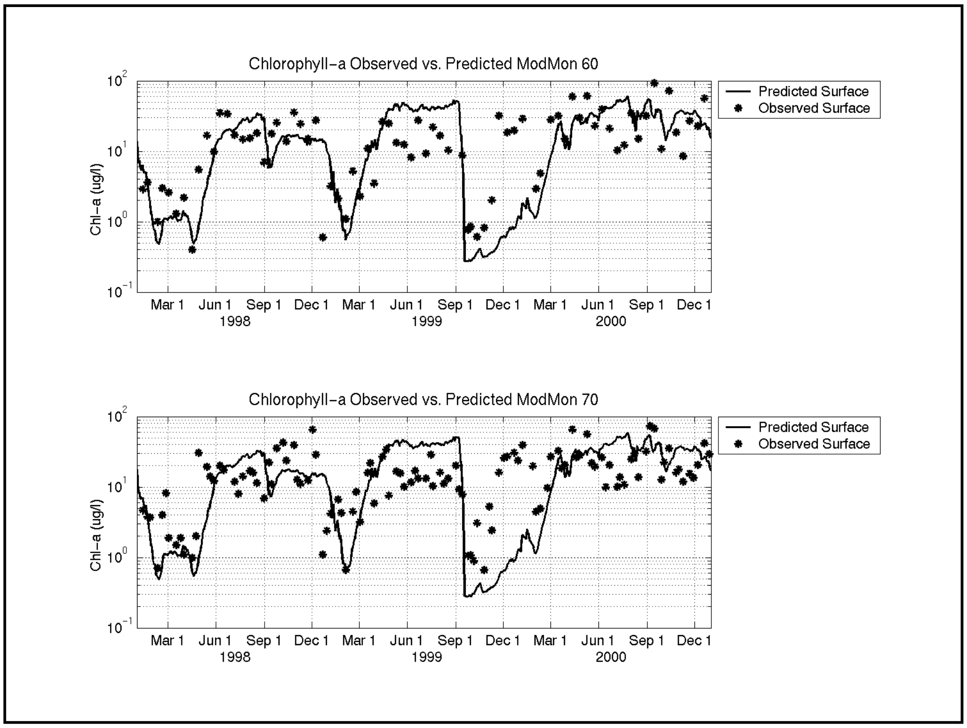
Questions?

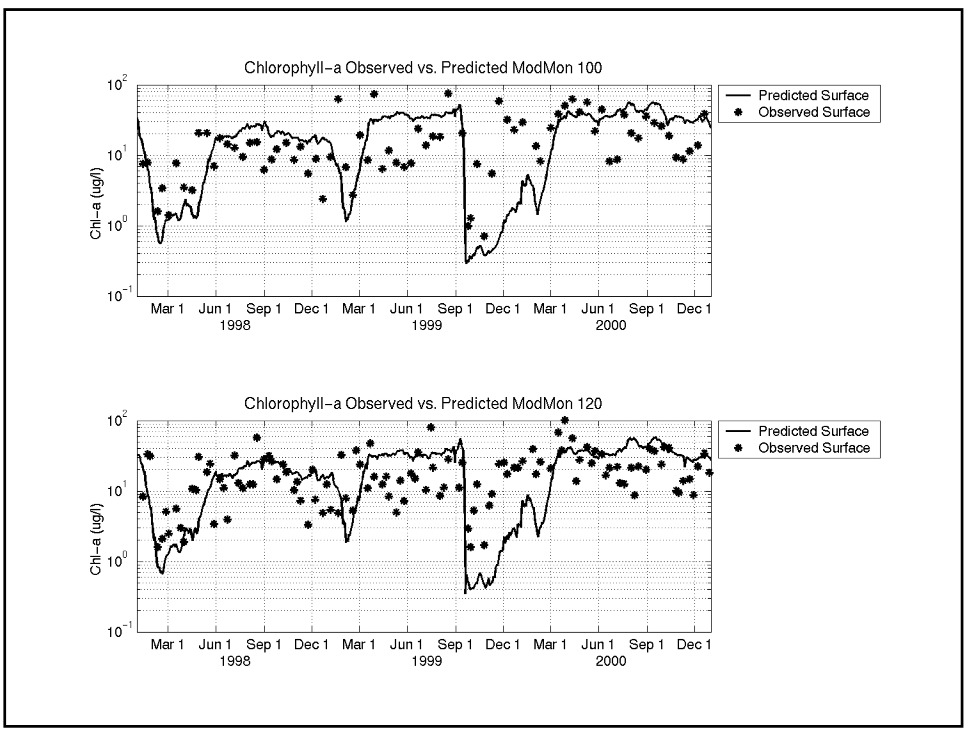
Chlorophyll-a

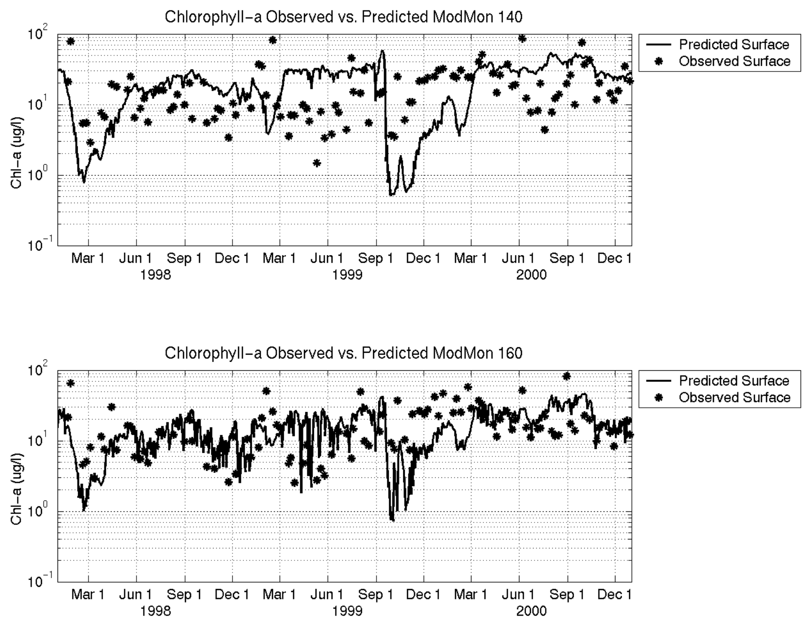







Chlorophyll−a Observed vs. Predicted ModMon 60
Predicted Surface
Observed Surface
Chl−a (ug/l)
Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1
1998 1999 2000
Chlorophyll−a Observed vs. Predicted ModMon 70
Predicted Surface
Observed Surface
Chl−a (ug/l)
Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1
1998 1999 2000


Chlorophyll−a Observed vs. Predicted ModMon 100
Predicted Surface
Observed Surface
Chl−a (ug/l)
Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1
1998 1999 2000
Chlorophyll−a Observed vs. Predicted ModMon 120
Predicted Surface
Observed Surface
Chl−a (ug/l)
Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1 Mar 1 Jun 1 Sep 1 Dec 1
1998 1999 2000

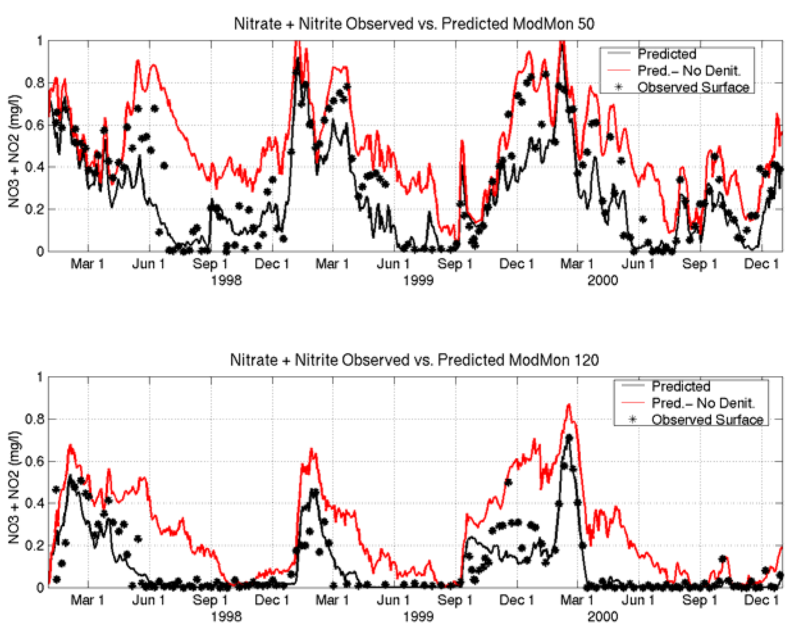


Fit Statistics Summary, '98-'99 Simulations, Entire Estuary

	6/97 - 12/99							
		Predictions vs. Observations - All Stations						
Constituent	# obs	ME	%	MAE	%	RMSE	%	R^2
Salinity (PSU or g/l)	13564	-1.04	-17%	1.46	24%	2.2082	37%	88.0%
Phosphate (mg/l)	1628	0.01	19%	0.02	48%	0.0319	78%	19.0%
Ammonia (mg/l)	1975	-0.01	-13%	0.04	69%	0.0697	122%	11.4%
Nitrate+Nitrite (mg/l)	1807	-0.03	-9%	0.09	29%	0.1405	46%	79.3%
DO (mg/l)	14127	0.12	2%	1.19	16%	1.7629	24%	60.9%

Chl-a, by Station & Region, '98 - '00

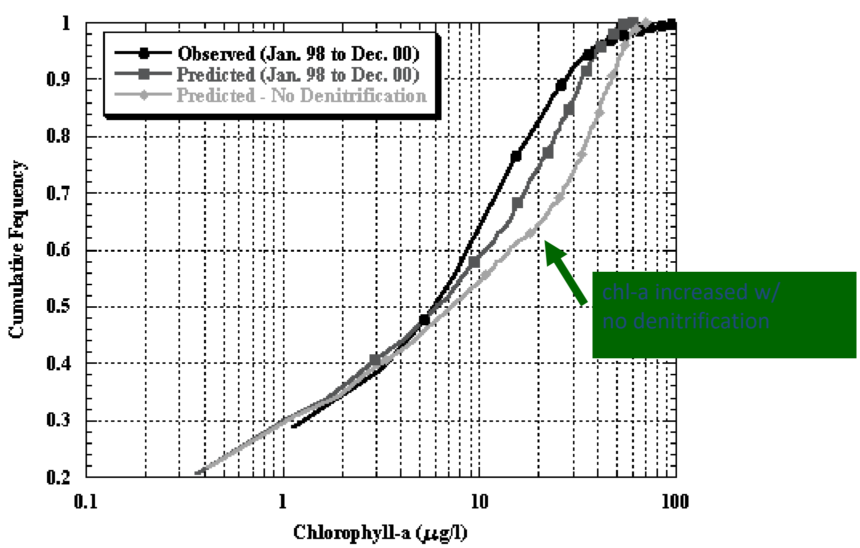
Section	Station	1/98 - 12/00			
			Log10(Chla ug/l)		
		# obs	ME	RMSE	R^2
River	0	192	-0.5931	0.9616	62.2%
	10	162	-0.2065	1.047	43.0%
	20	193	0.1932	1.3144	33.0%
Upper	30	195	-0.0648	1.0821	60.8%
	50	195	-0.2769	1.0963	61.1%
Middle	60	154	-0.218	1.1779	48.2%
	70	194	-0.1701	1.2153	41.1%
Bend	100	154	-0.0865	1.1501	32.8%
	120	193	-0.1733	1.0895	24.7%
Lower	140	175	-0.0751	1.1467	6.9%
	160	171	-0.2093	0.9777	17.5%
River		548	-0.1978	1.1231	41.6%
Upper		390	-0.1709	1.0892	61.0%
Middle		348	-0.1913	1.1989	44.4%
Bend		347	-0.1348	1.1168	28.8%
Lower		346	-0.1414	[illegible]	11.3%
Total		1980	-0.1708	1.1195	58.2%



Sediment Denitrification Causes Negative Feedback w/ Chl-a

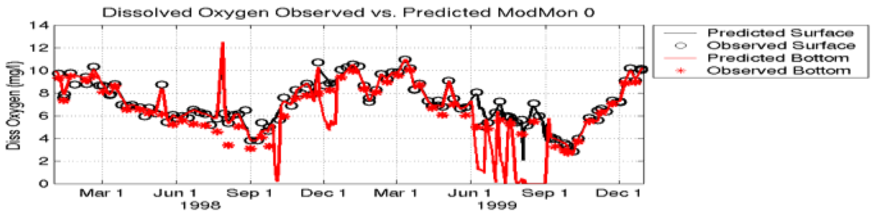
Lower nutrient loading
↓
reduced organic matter (OM) loading to sediment
↓
reduced sediment OM concentrations
↓
reduced denitrification
↓
higher water column nitrates
↓
higher chlorophylls

Effect of no denitrification on chl-a

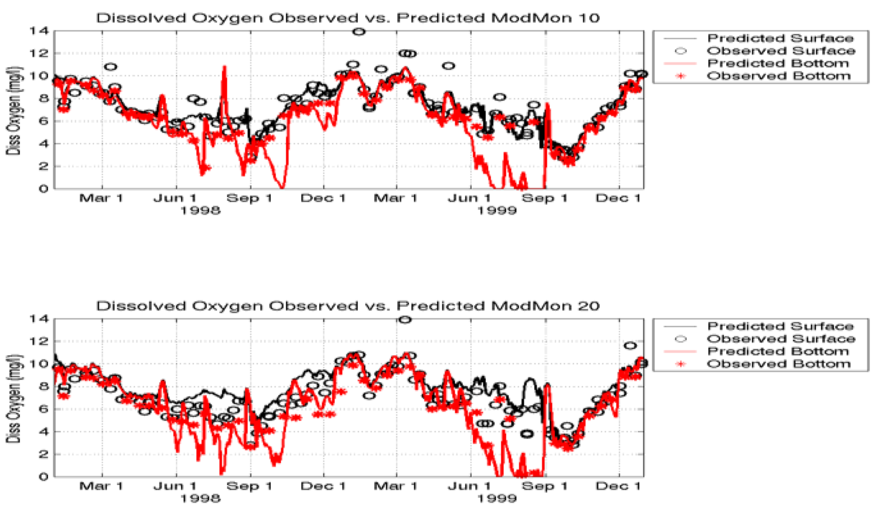


Dissolved Oxygen

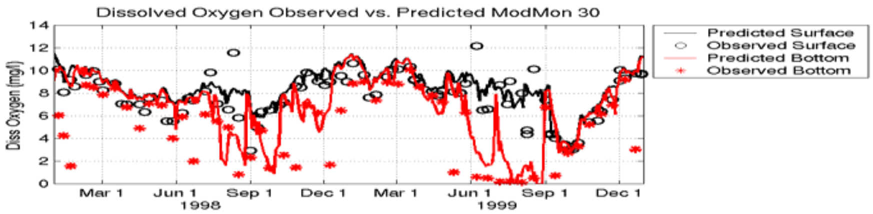
River

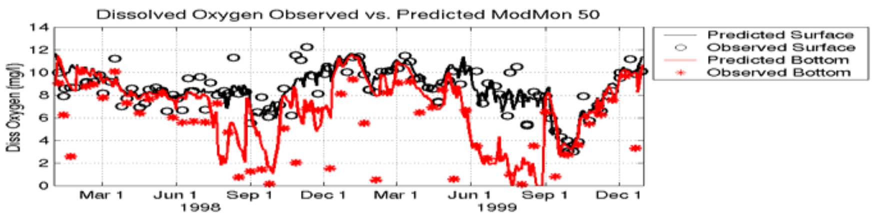


River

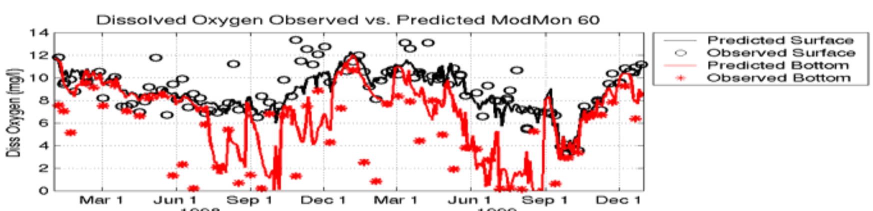


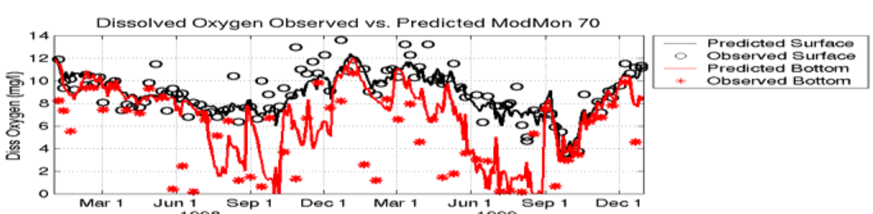
Upper Estuary



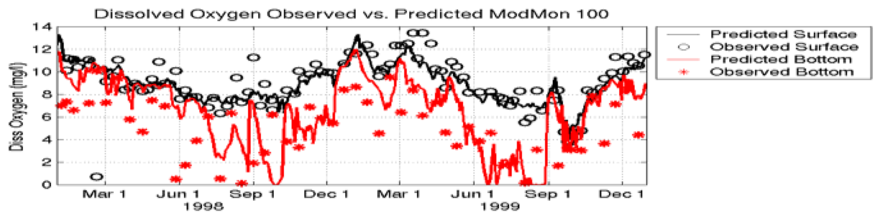


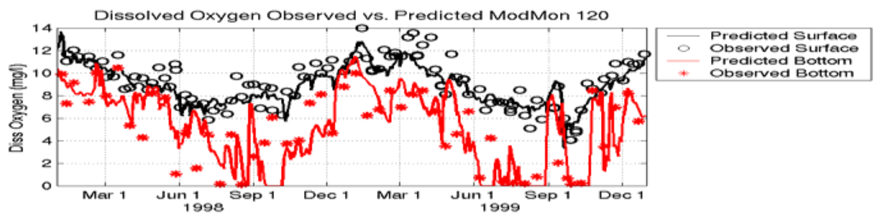
Middle Estuary



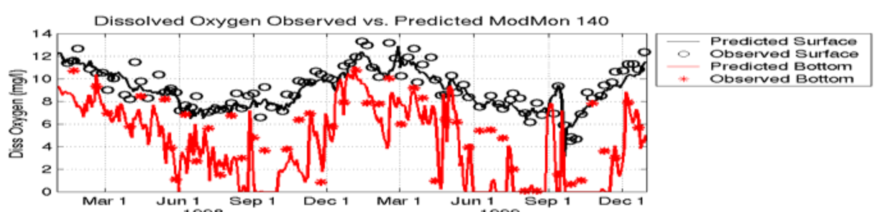


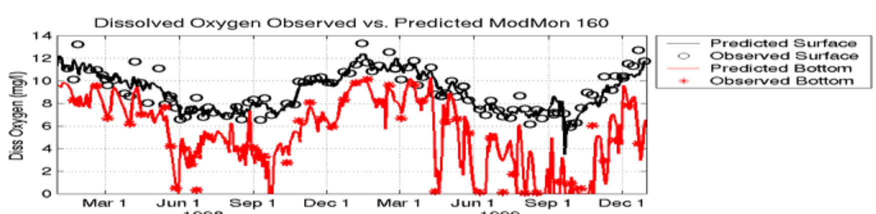
Bend of Estuary





Lower Estuary

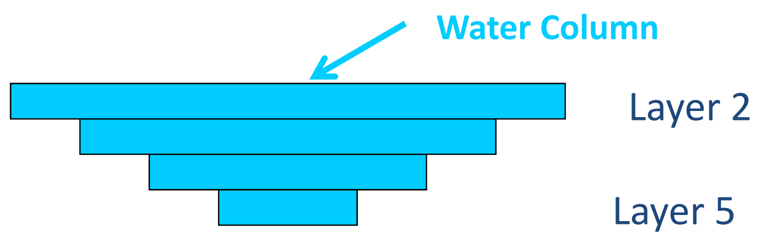




Each Segment divided into Layers

6 - 18 layers vertically (top 3 = 1 m, bottom 15 = 0.5 m)

Layers may have varying widths

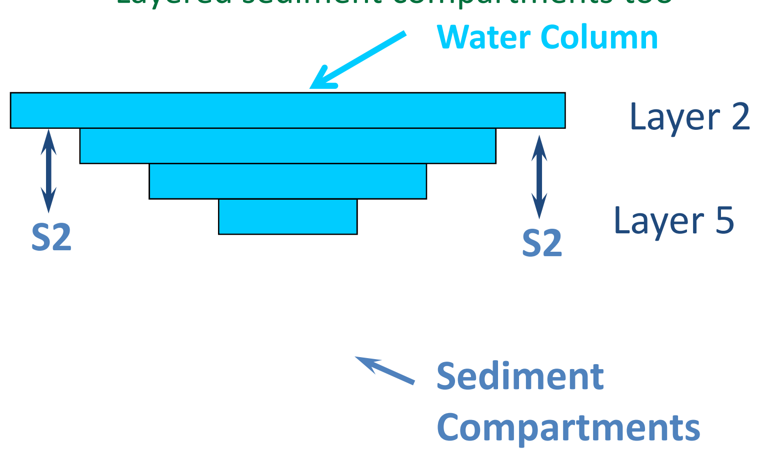


Each Segment divided into Layers

6 - 18 layers vertically (top 3 = 1 m, bottom 15 = .5 m)

Layers may have varying widths

Layered sediment compartments too

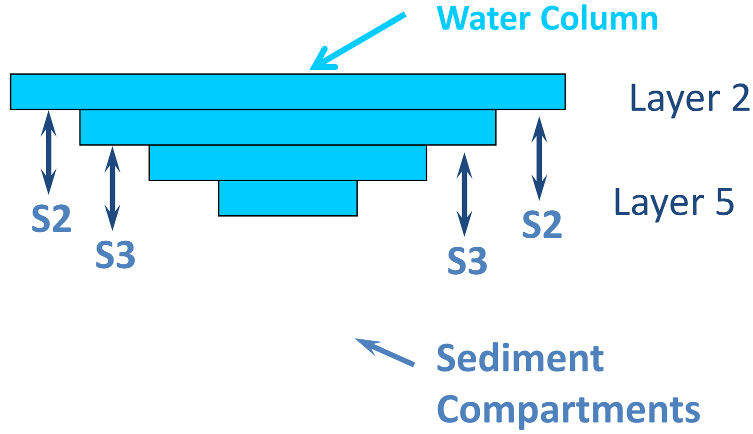


Each Segment divided into Layers

6 - 18 layers vertically (top 3 = 1 m, bottom 15 = .5 m)

Layers may have varying widths

Layered sediment compartments too



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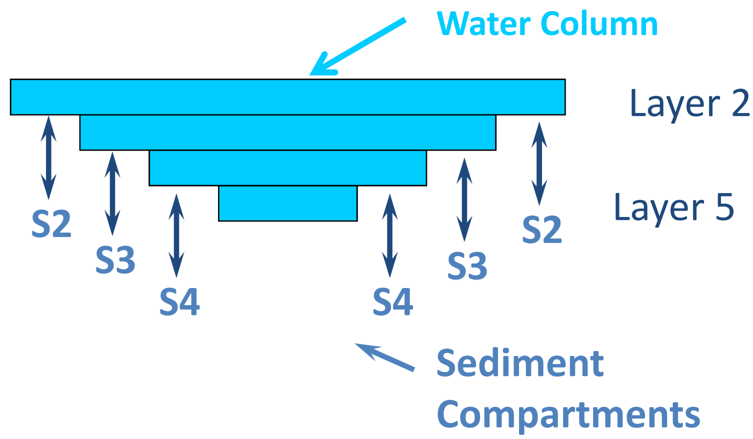

Each Segment divided into Layers

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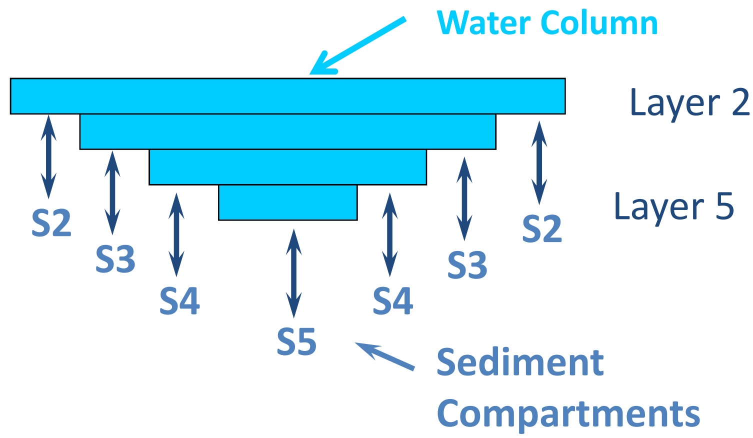
Layered sediment compartments too



NRE Trends – Changes in Form & Location of N Loading

Upper Neuse Watershed (Neuse R. @ Clayton)

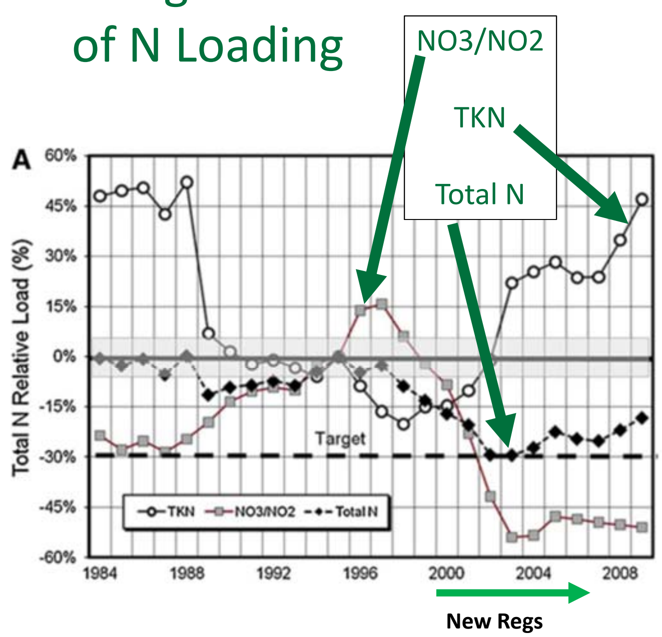


Figure from Lebo et al., 2012, Environmental Management

Nutrient Load Reductions Not Fully Met and Varies by N Form & Location

Lower Neuse Watershed (Contentnea Creek)

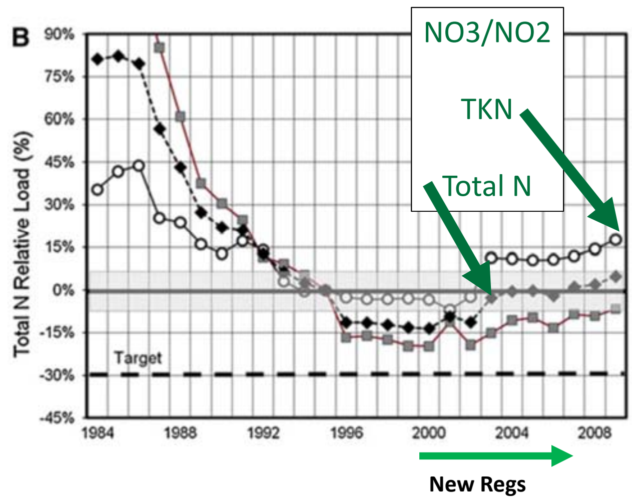


Figure from Lebo et al., 2012, Environmental Management