Development of Bacterial TMDL of Nassawadox and DO TMDLs of Little Mosquito and Assawoman along Virginia's Eastern Shore

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DEQ Virginia Department of Environmental Quality

VIMS William & Mary Virginia Institute of Marine Science 1940-2015 75 Years

Why We Are Here

1. To review water quality conditions and pollutant sources for these creeks
2. To present model results for Total Maximum Daily Load (TMDL) development
3. To discuss allocation
4. To gather comments and encourage public participation

What is a TMDL ?
Total Maximum Daily Load

A TMDL is the amount of a particular pollutant that a stream can receive and still meet Water Quality Standards
AKA "Pollution Diet"

TMDL = Sum of WLA + Sum of LA + MOS

Where:

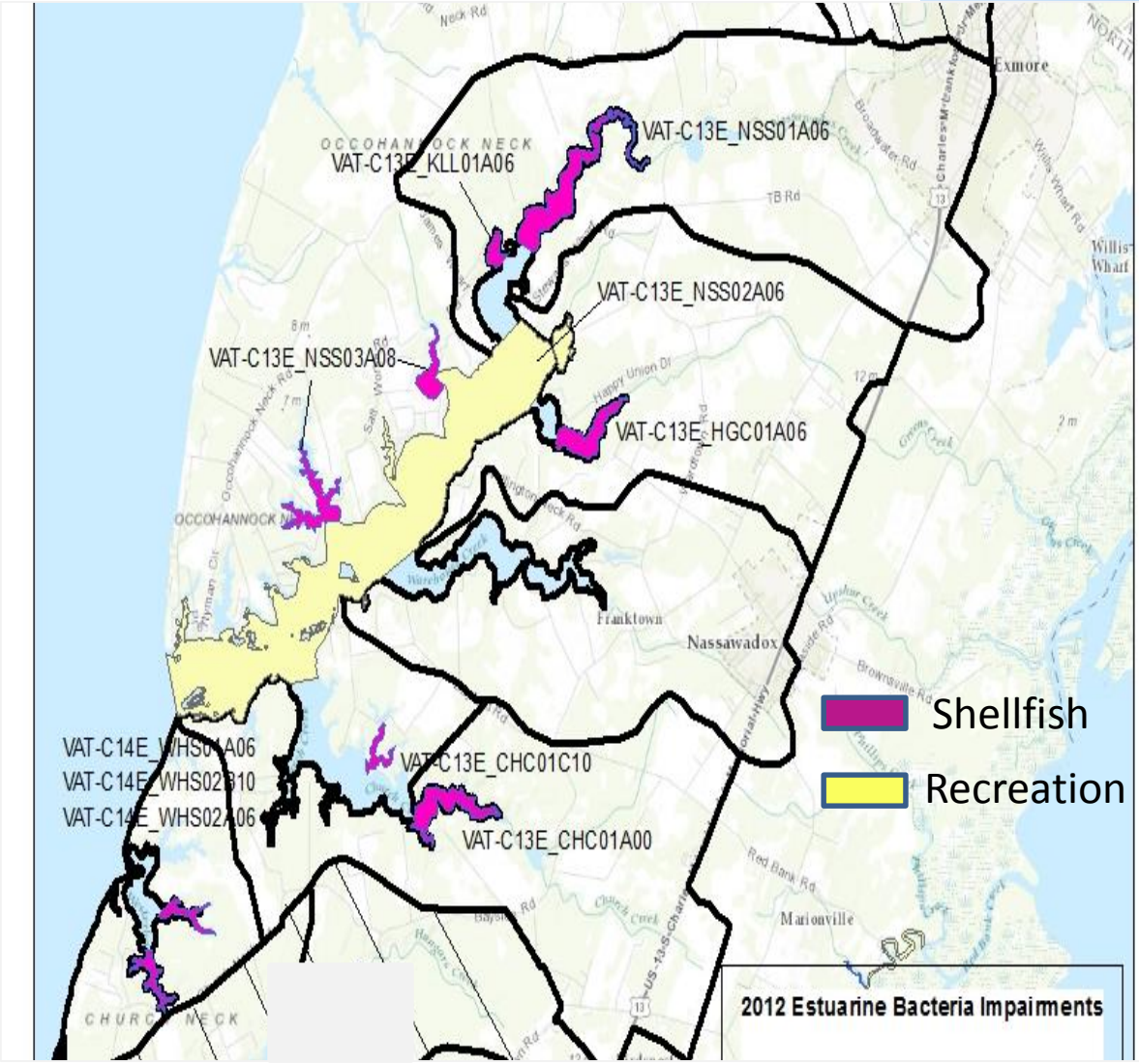
TMDL = Total Maximum Daily Load
WLA = Waste Load Allocation (point sources)
LA = Load Allocation (nonpoint sources)
MOS = Margin of Safety

Current Load = current loads discharged to the water body, which will be determined during this study

Reduction % = (current load –TMDL)/ current load x 100%

Nassawadox Creek and Westerhouse Creek

Impaired Waters of Nassawadox and Westerhouse Creeks



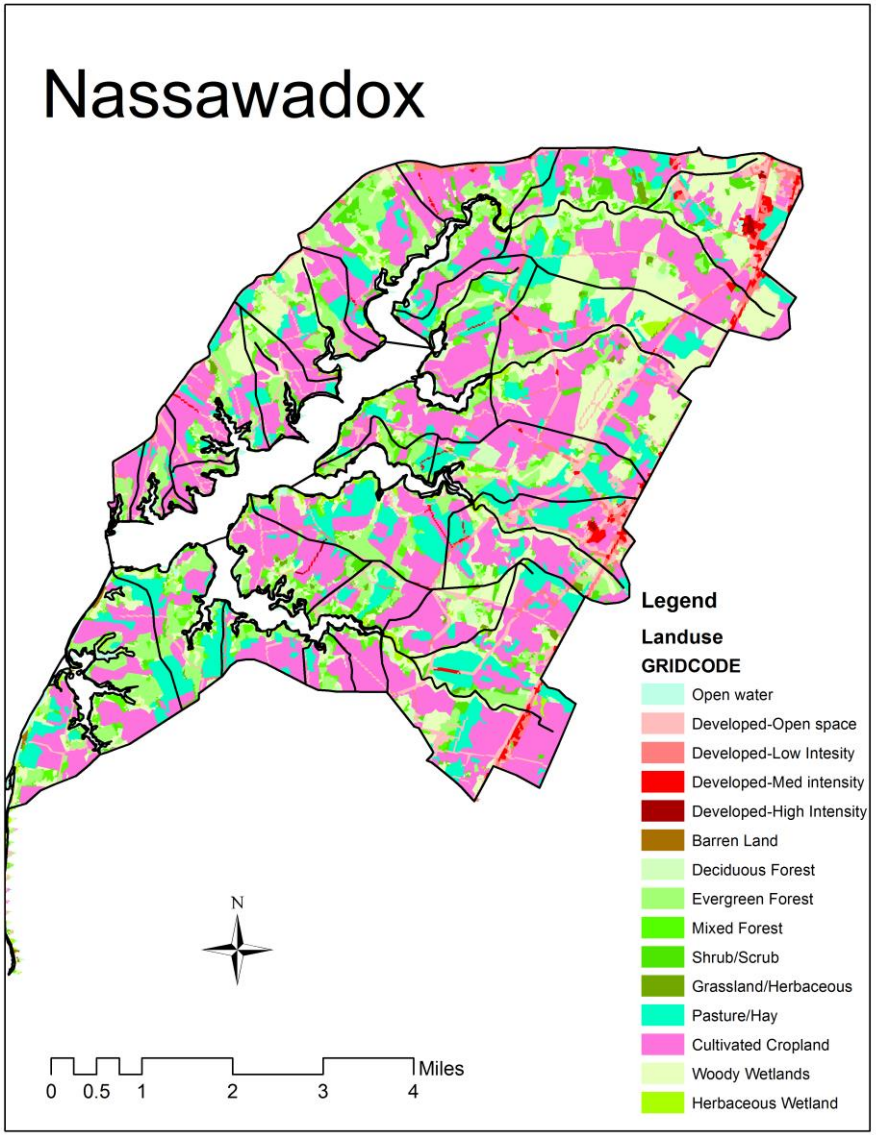
Impaired Waters of Nassawadox and Westerhouse Creeks

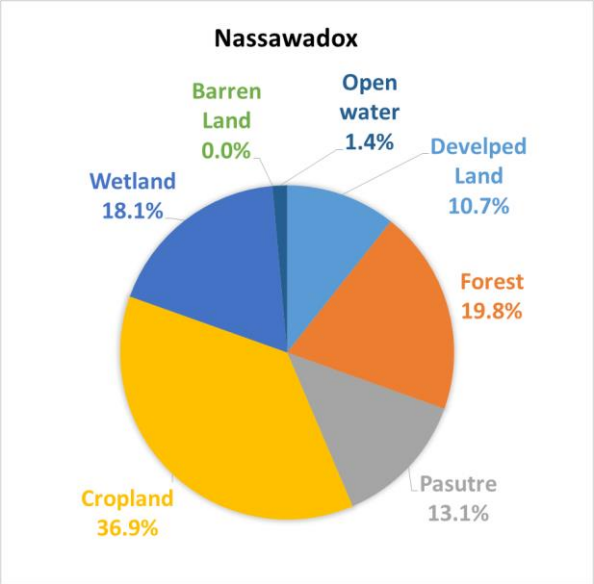
- 9 segments are impaired for shellfish consumption designated use (fecal coliform)
- 1 segment is impaired for the recreation designated use (enterococcus)

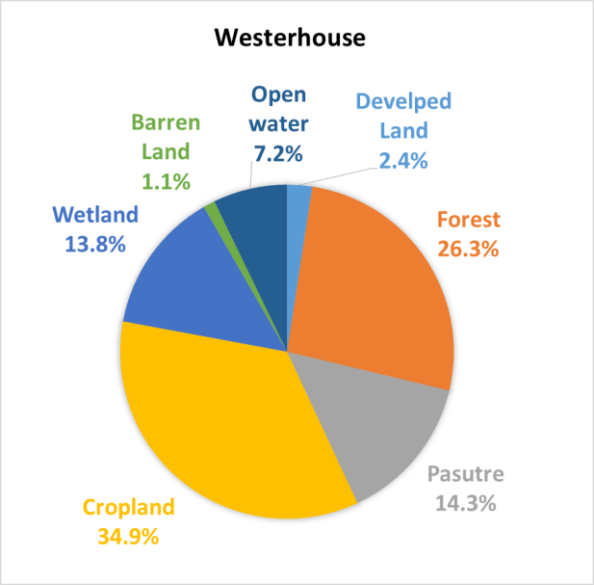
Water Quality Criteria

Water Type	Use	Name	Criteria
Class II (tidal water) Class III (freshwater)	Shellfish	Fecal coliform	Geomean 14 counts/100ml 90th percentile: 49 counts/100ml using MPN or 31 counts/100ml using mTEC method
	Recreation	E. Coli (freshwater)	Geomean 126 counts/100ml Single Sample Max. 235 counts/100ml
		Enterococci (salt water)	Geomean 35 counts/100ml Single Sample Max. 104 counts/100ml

Nassawadox and Westerhouse Creeks

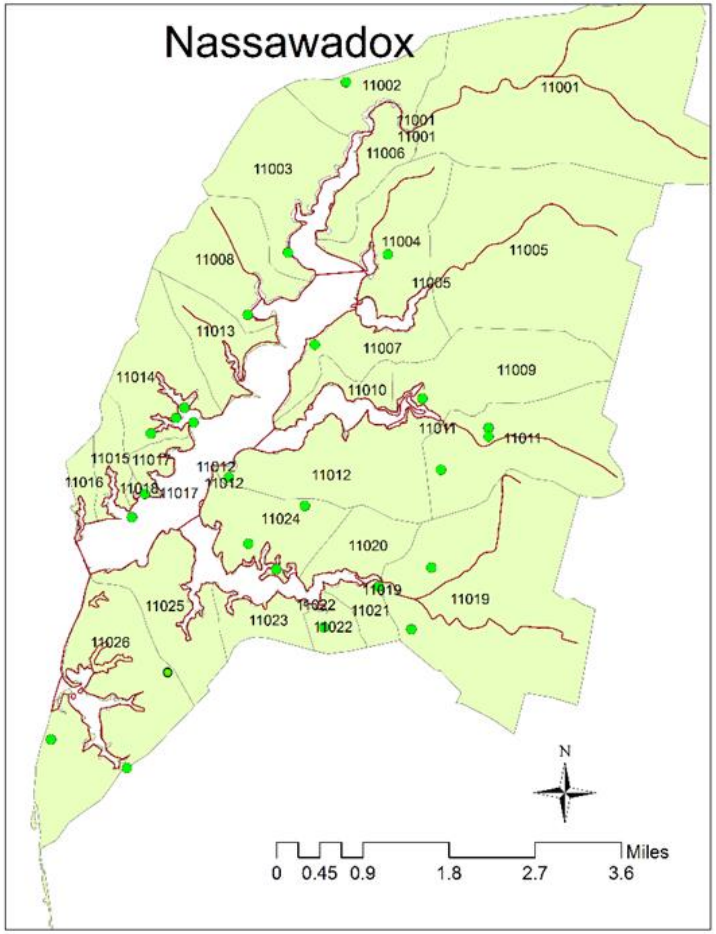




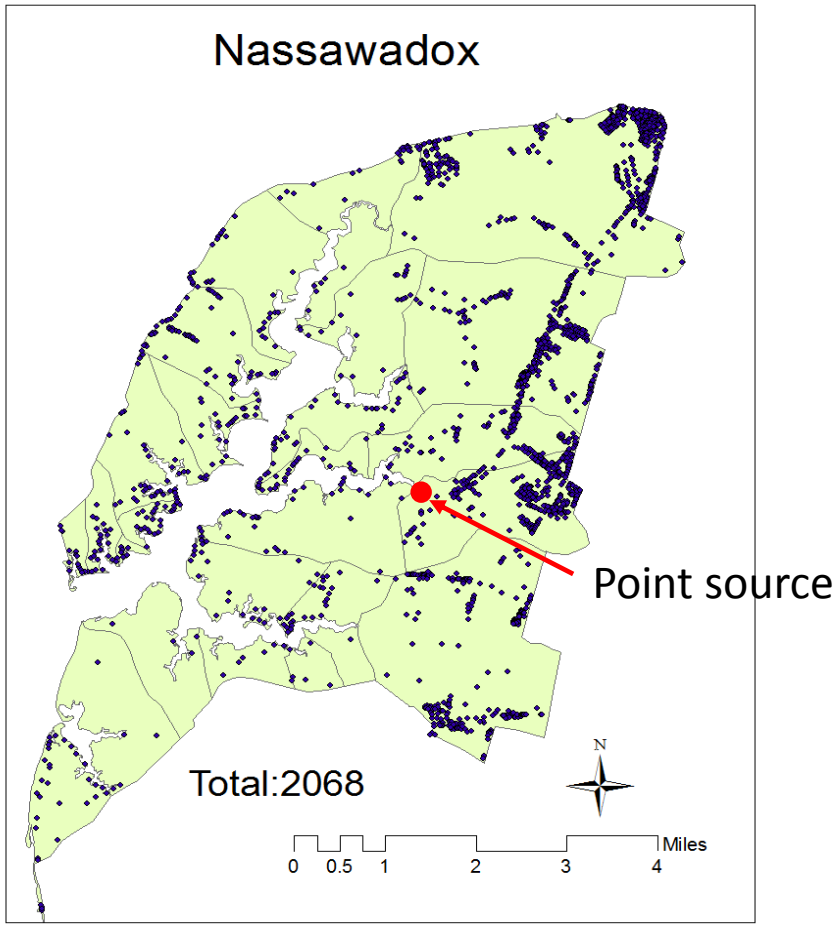


Summary of Source Assessment for Nassawadox and Westerhouse Creeks

Potential sources of Livestock Distribution

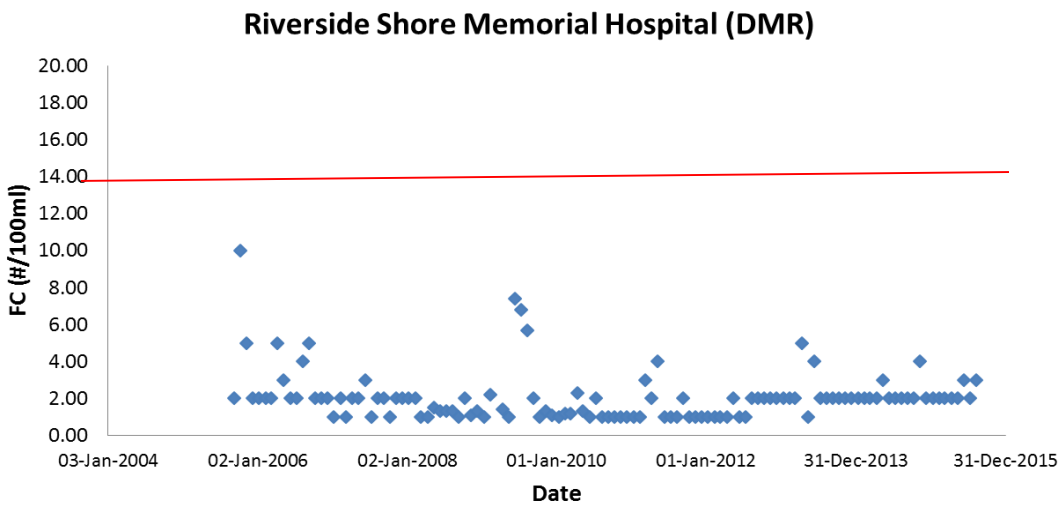


Septic Distribution



Point Sources

Permit	Facility name	Permit type	Receiving stream	Design Flow (MGD)	Bacteria limits	Estimated allowable loading (counts/day)*
VA0027537	Riverside Shore Memorial Hospital	Sewage Treatment Plant Individual VPDES	Unnamed tributary to Warehouse Creek	0.1	FC: 200 cfu/100mL E.coli: 126 cfu/100mL	7.57×10^{7} (FC) 4.77×10^{7}(E.coli)
VAR051805	Butch's Car & Parts Inc	Industrial Stormwater General Permit	Nassawadox Creek	NA	NA	NA



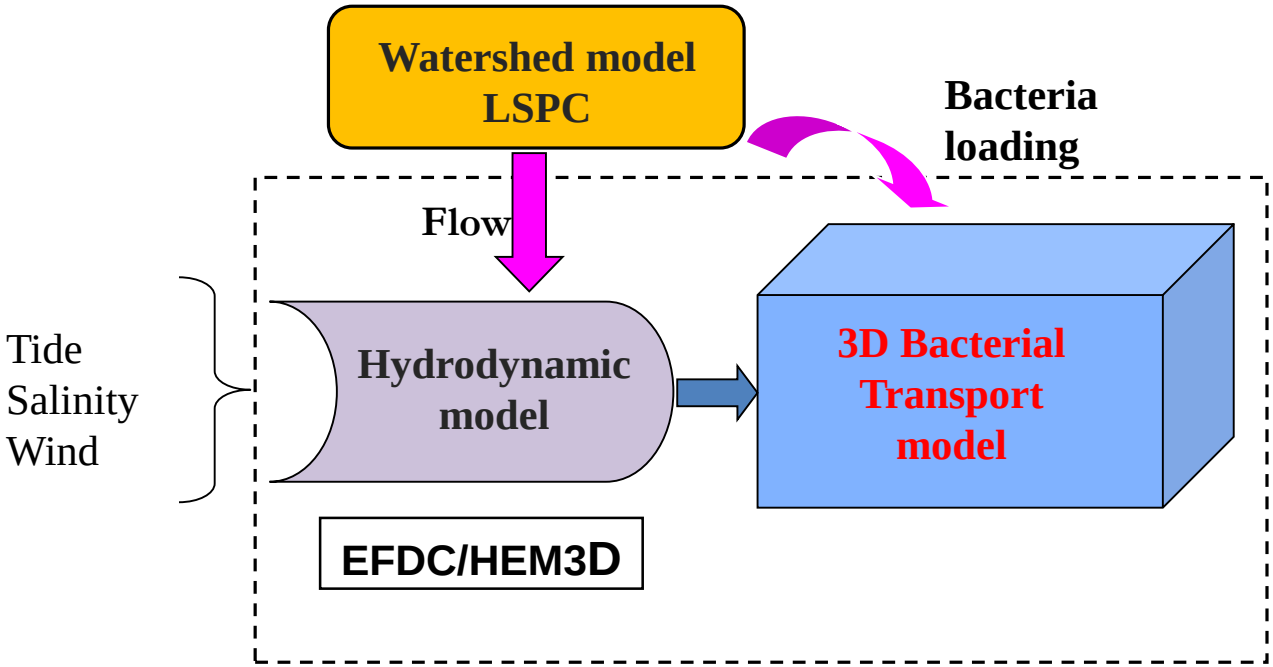
		Nassawadox Creek watershed	Westerhouse Creek watershed
Human	Population	4700	97
	Septic system	2026	42
	Dogs*	1183	25
	Cats* (unused)	1293	27
Livestock	Horse	46	0
	Cattle	65	0
	Fowl	129	12
	Chicken**	5509	0
	Geese	12	0
Wildlife	Deer	1940	150
	Raccoons	1321	102
	Muskrats	2864	236
	Geese	293	24
	Ducks	597	49
	Geese (seasonal peak)	527	44
	Ducks (seasonal peak)	1074	89

* Dogs = (36.5% of houses) × (1.6 dogs/house), Cats = (30.4% of houses) × (2.1 cats/house) (AVMA, 2012)
**no permitted manure application in this watershed and chickens do not contribute to the loading significantly in this watershed.

Bacteria Source Distributions

Waterbody Name	Source	Loads (counts per day)	Percent of Source
Nassawadox Creek	Human	6.23E+11	2.2%
	Pets	2.90E+12	10.3%
	Wildlife	1.72E+13	61.2%
	Livestock	7.38E+12	26.3%
	Total	2.81E+13	100.0%
Westerhouse Creek	Human	1.29E+10	0.87%
	Pets	6.02E+10	4.04%
	Wildlife	1.41E+12	94.98%
	Livestock	1.63E+09	0.11%
	Total	1.49E+12	100.00%

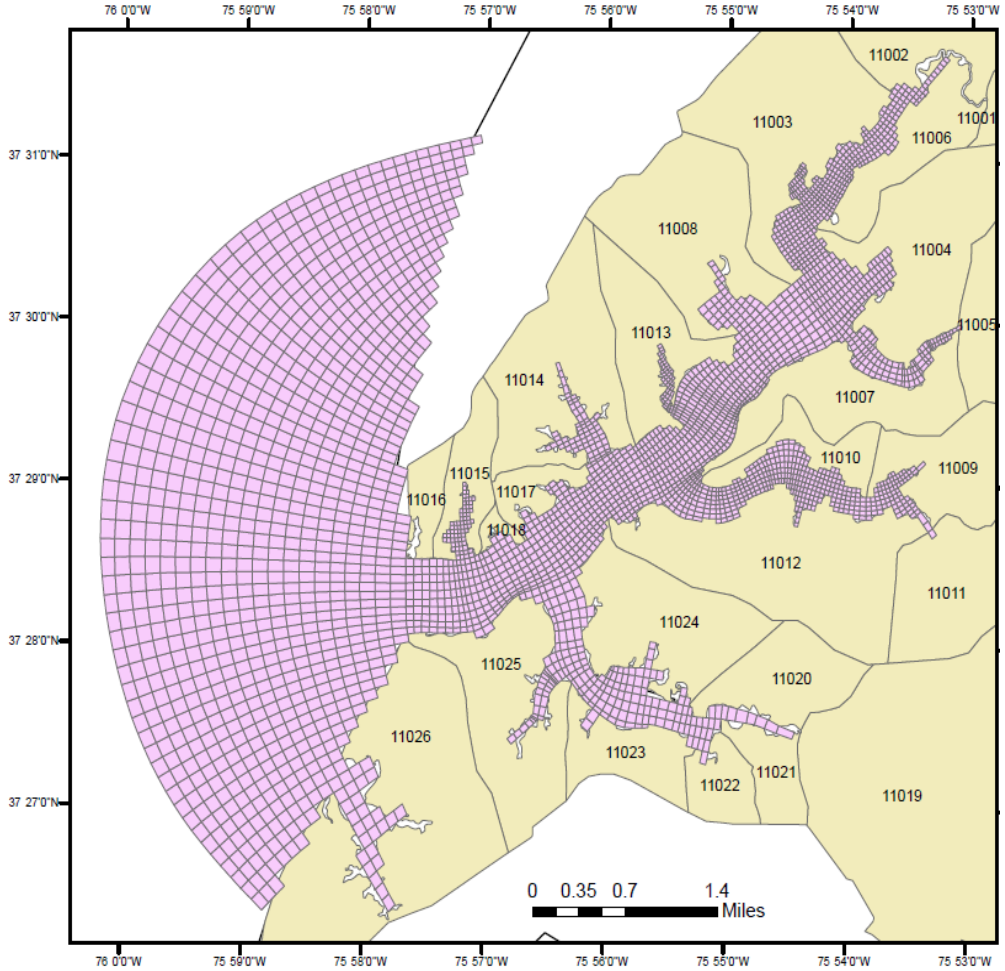
Modeling Approach

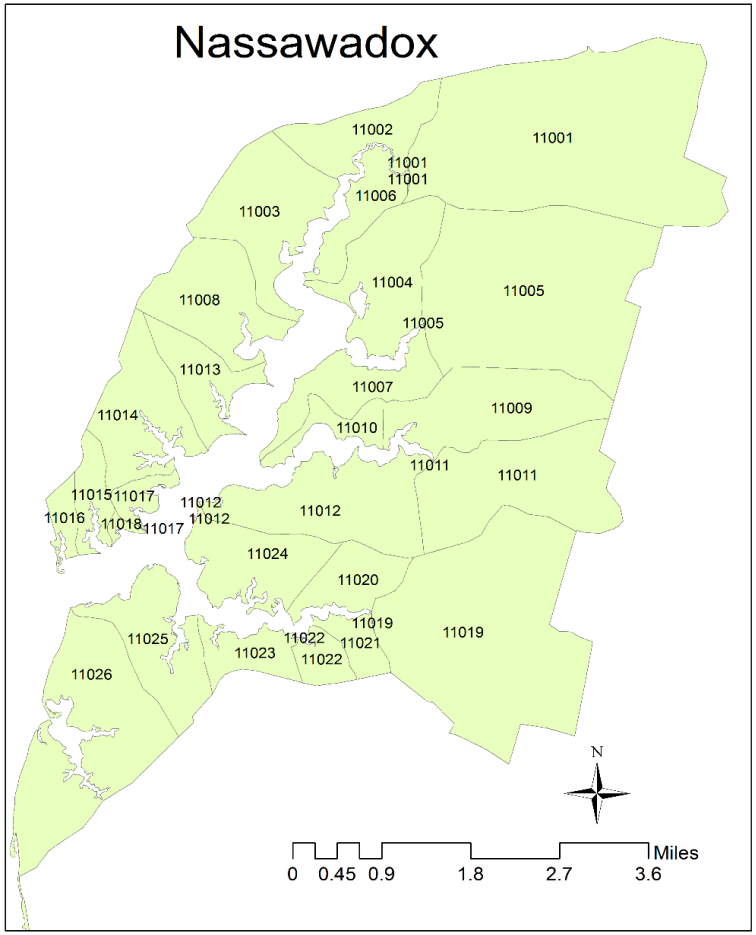


- Watershed model simulates fecal coliform loading
- Transport model simulates fecal coliform for assessing shellfish impaired segment
- Convert fecal coliform concentration to Enterococci to assess recreational use impairment

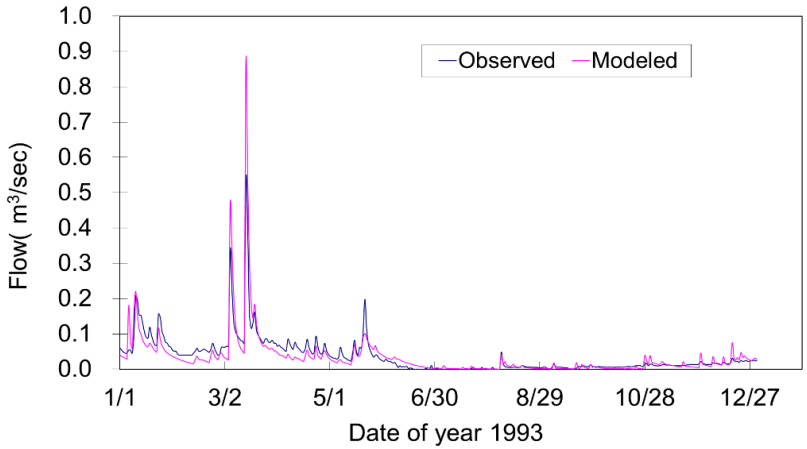
$$\log_2(Enterococci) = 1.2375 + 0.59984 \times \log_2(Fecal\ Coliform)$$

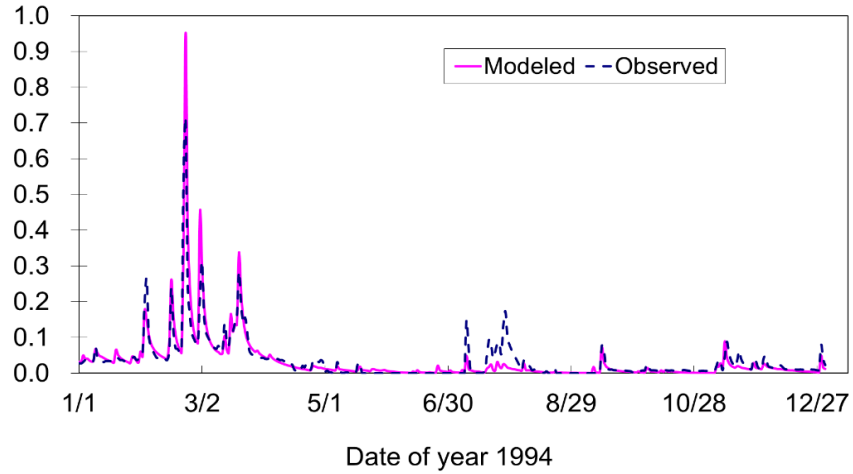
Model Grid and Watershed Delineation

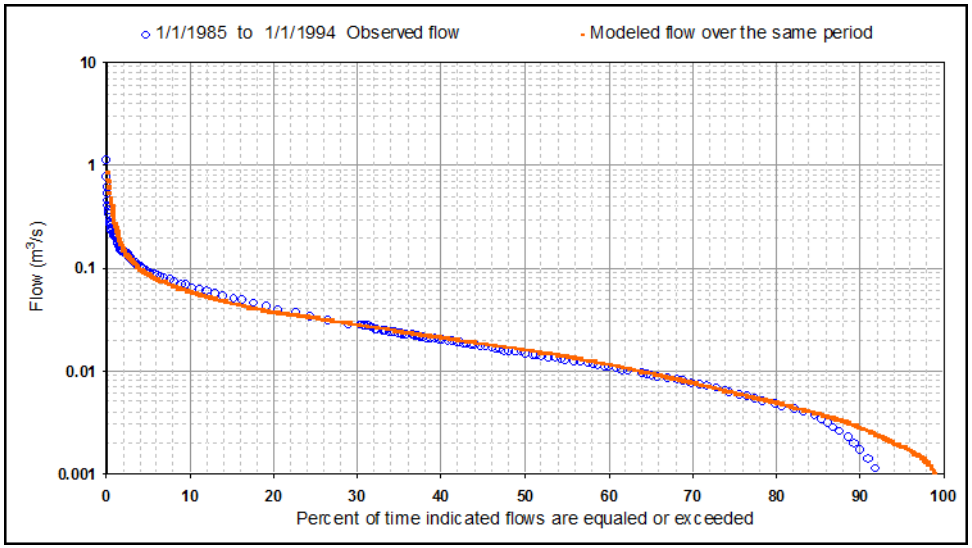




Model Simulation: Hydrology

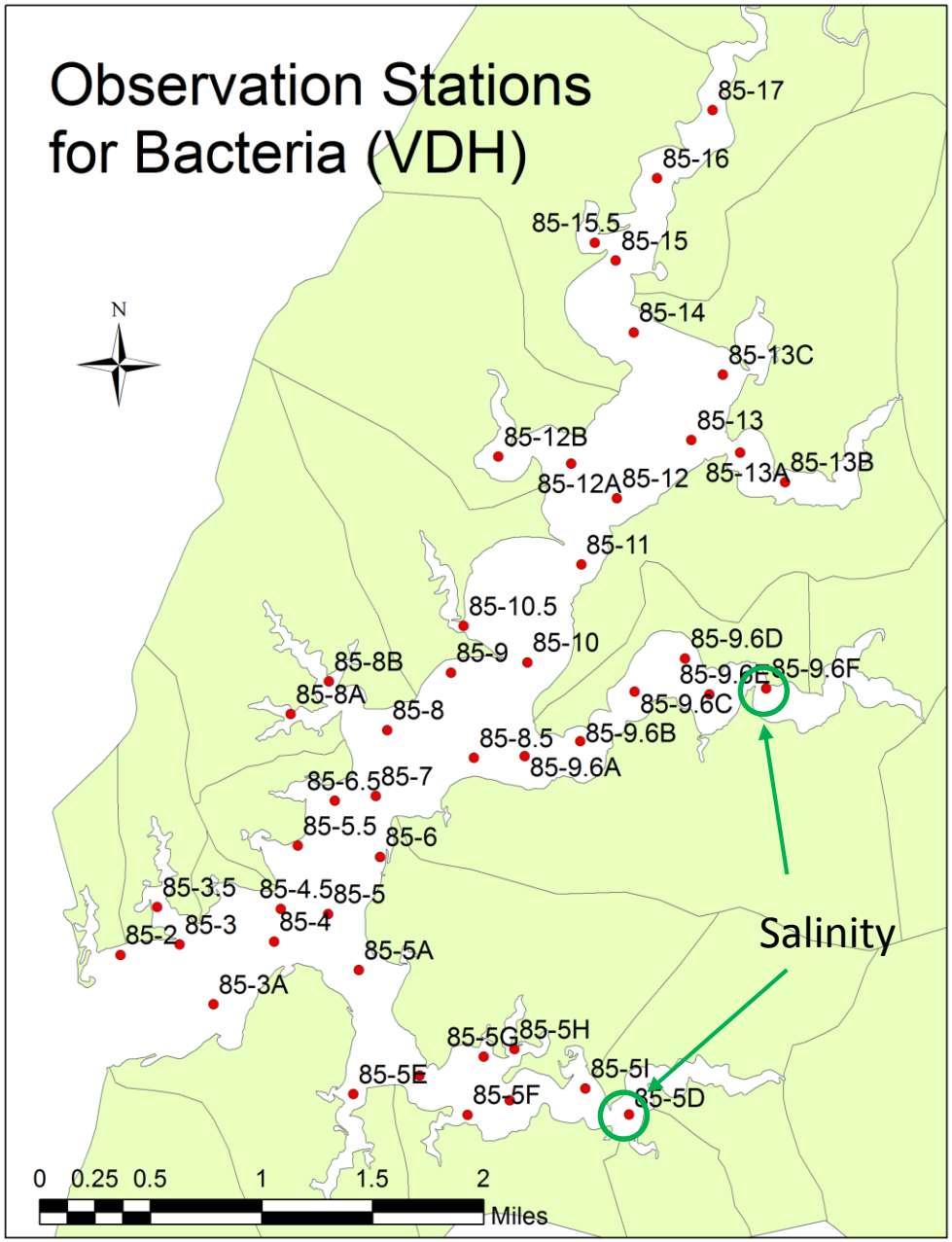




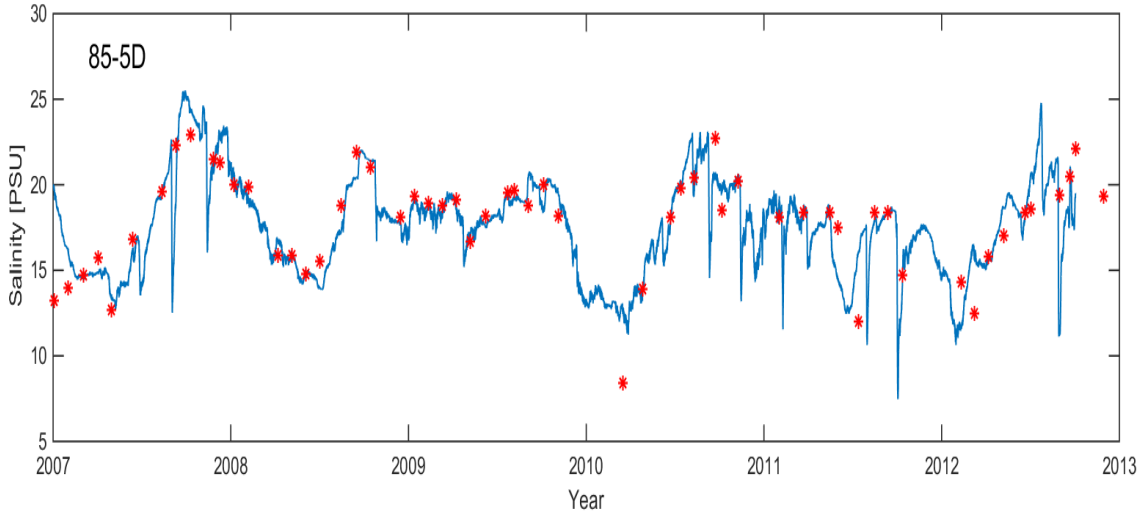


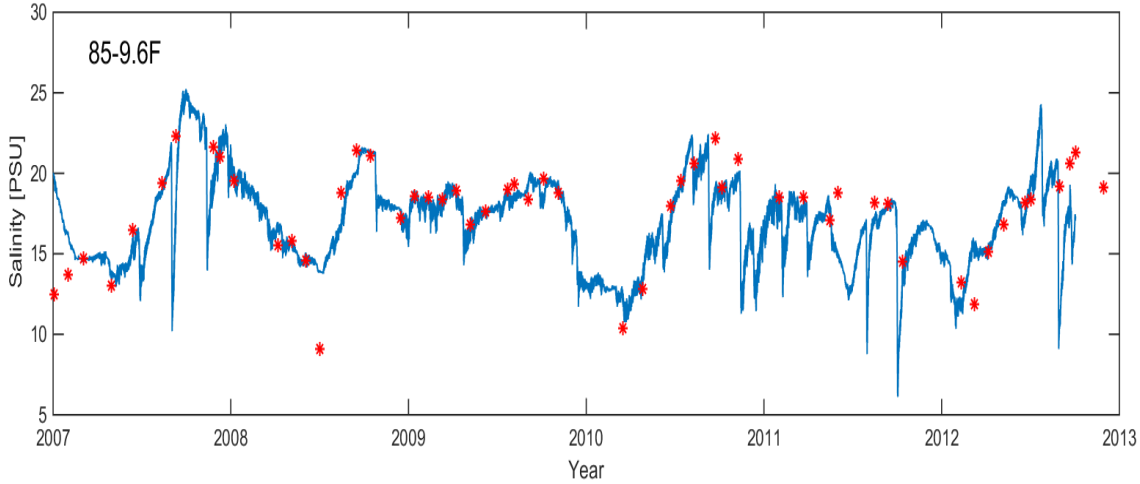
Observations for model calibration and impairment assessment

There are a total of 46 VDH stations in Nassawadox Creek.

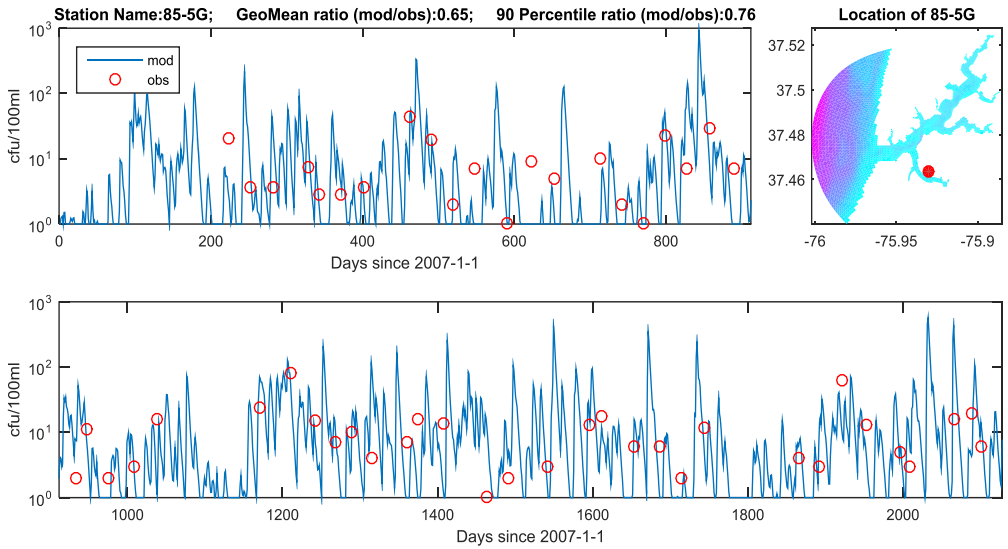


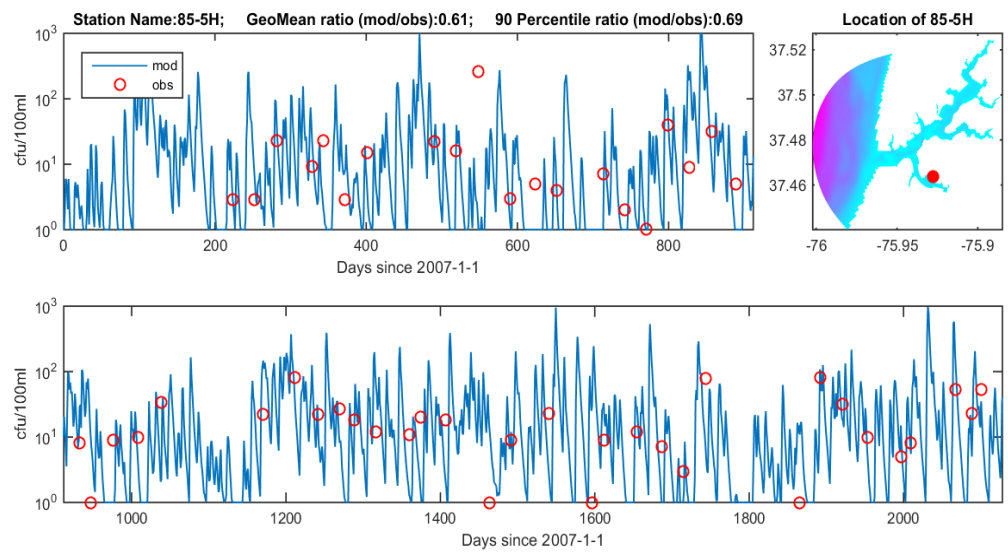
Model Simulation: Salinity



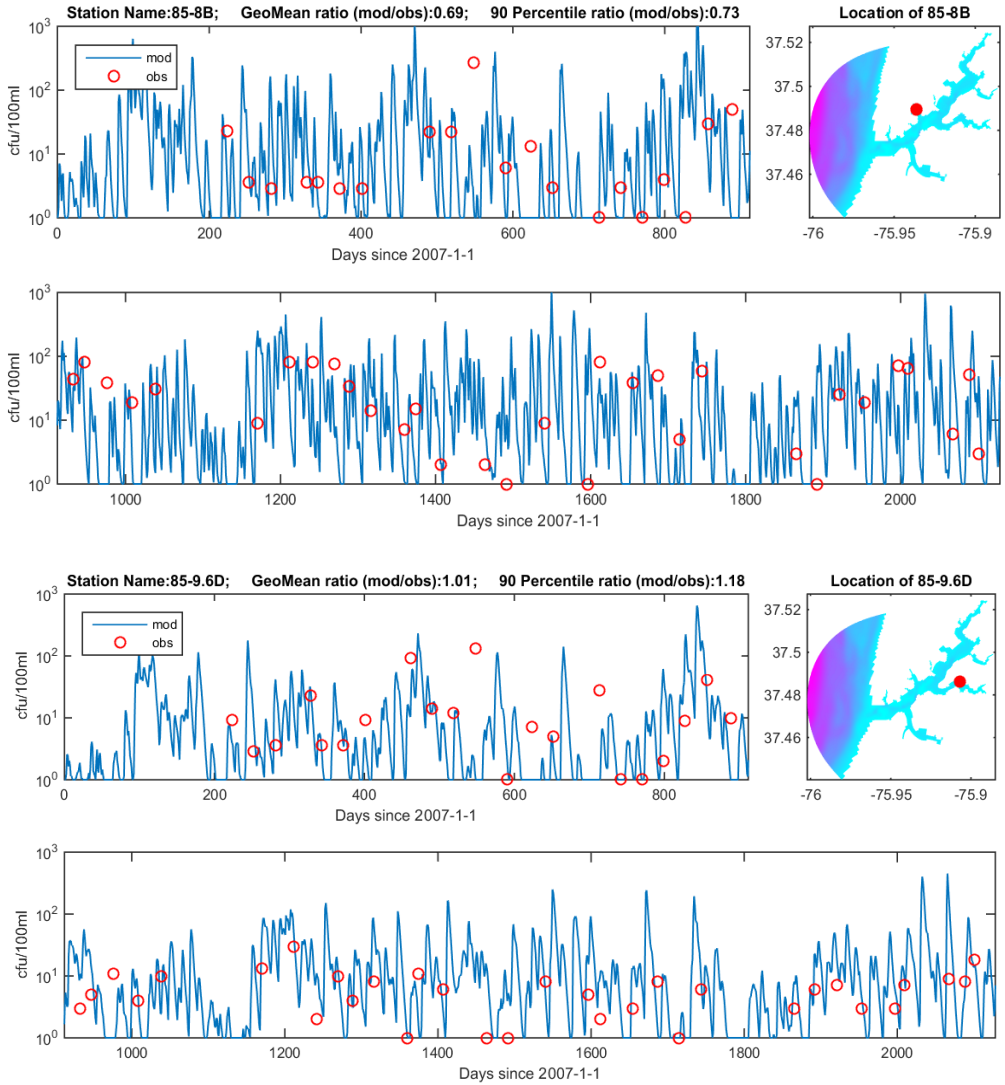


Model Simulation: Bacteria

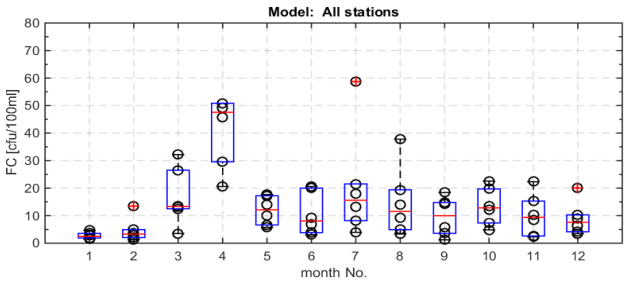


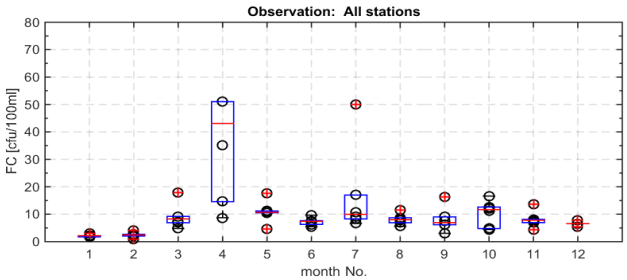


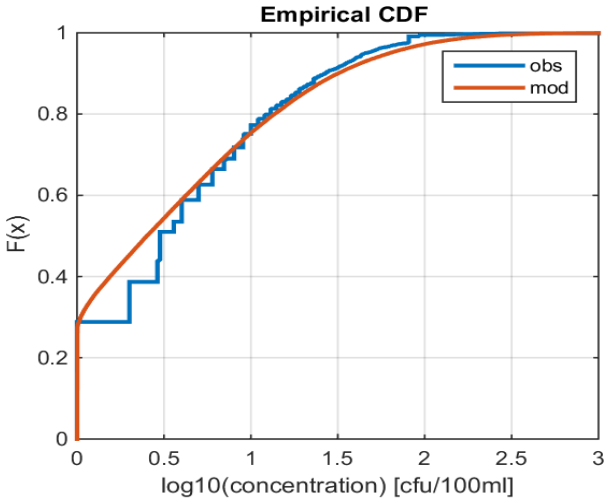
Model Simulation: Bacteria

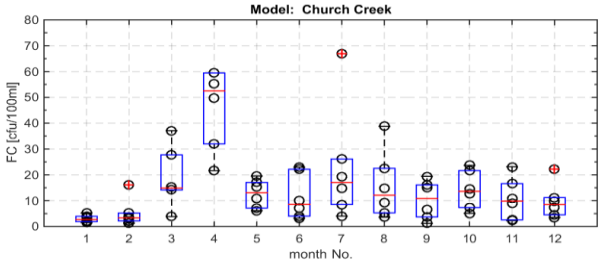


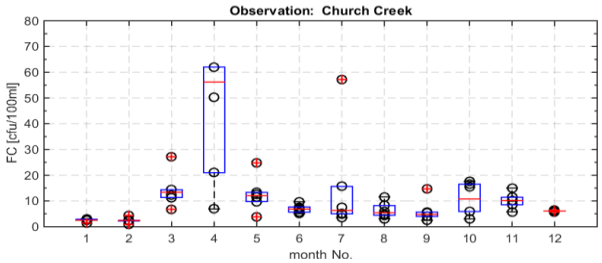
Model Simulation: Seasonal Bacteria

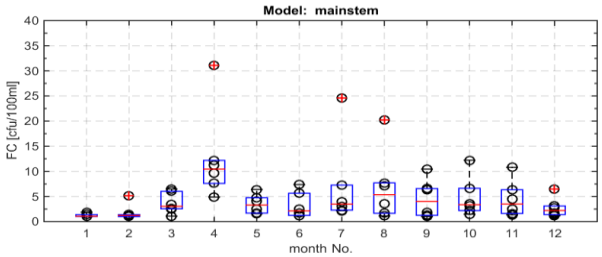


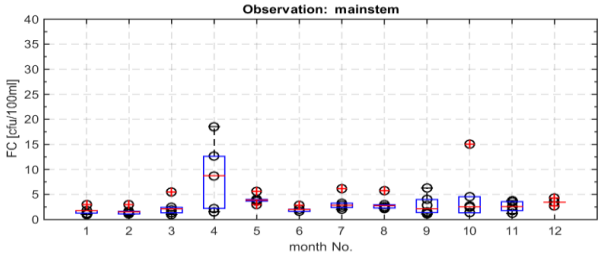






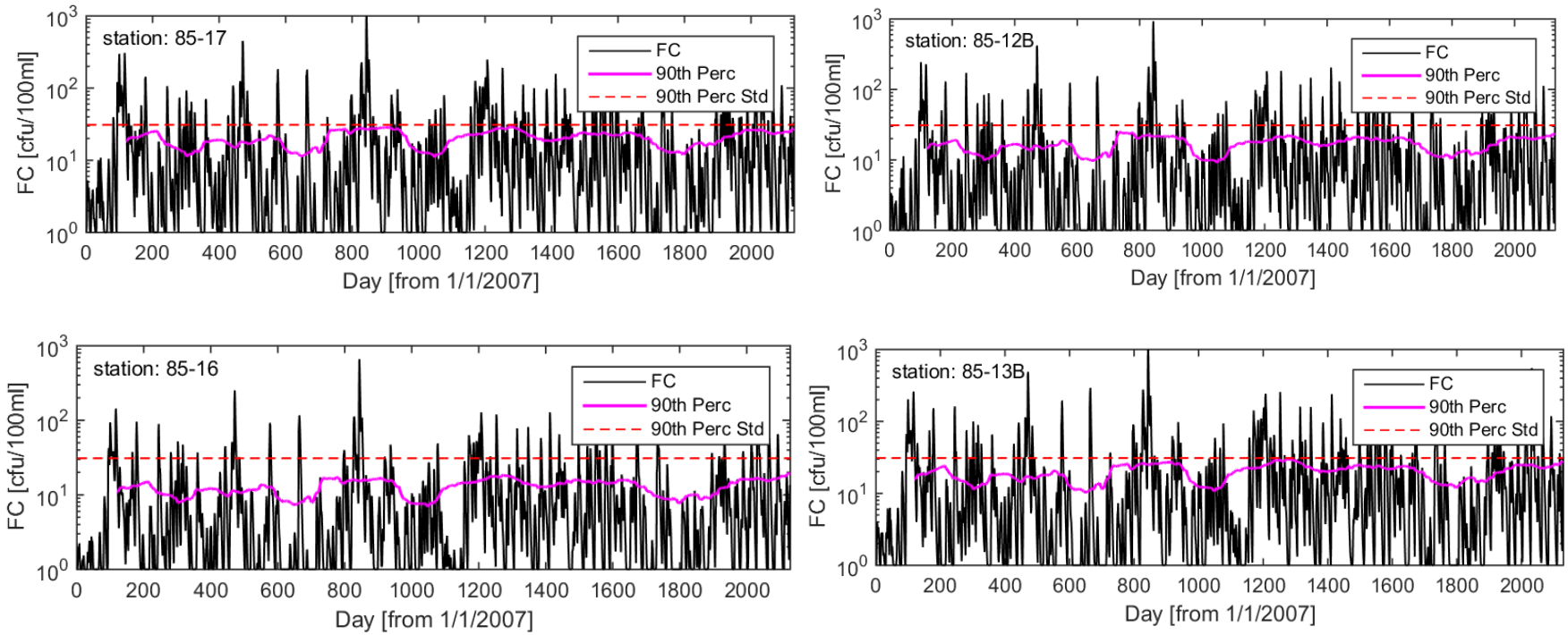






TMDL Development

- Reduce loading to meet WQS standards <u>geo-mean</u> (14 cfu/100mL) and <u>90th percentile</u> (31 cfu/100mL)



TMDLs

Daily Maximum Loading

Impairment	WLA	LA	MOS	TMDL
Nassawadox	**1.72E+10**	1.70E+12	Implicit	1.72E+12
VA0027537*	*7.57E+07*			
Future load (1%)	*1.72E+10*			
Westerhouse Creek	**5.95E+08****	5.89E+10	Implicit	5.95E+10
Future load (1%)				

Annual Maximum Loading

Impairment	WLA	LA	MOS	TMDL
Nassawadox	***3.04E+12***	2.98E+14	Implicit	3.01E+14
*VA0027537**	*2.77E+10*			
Future load (1%)	*3.01E+12*			
Westerhouse Creek	***1.15E+11*****	1.13E+13	Implicit	1.15E+13
Future load (1%)				

Summary of Current and Allowable Load

	Pollutant	Criterion	Current Load	Allowable Load	Required
		(CFU/100mL)	(counts/Year)	(counts/Year)	Reduction (%)
Nassawadox Creek-Upper	Fecal coliform	90th percentile	8.78E+13	3.69E+13	58.0%
Kelly Cove	Fecal coliform	90th percentile	3.29E+13	1.38E+13	58.0%
Holly Grove Cove	Fecal coliform	90th percentile	7.31E+13	4.75E+13	35.0%
Nassawadox Creek-Middle	Fecal coliform	90th percentile	5.65E+13	4.57E+13	19.1%
Church Creek-Upper	Fecal coliform	90th percentile	5.38E+13	4.09E+13	24.0%
Church Creek-Middle	Fecal coliform	90th percentile	1.85E+13	1.85E+13	0.0%
Nassawadox Creek (all)	Fecal coliform	90th percentile	4.70E+14	3.01E+14	36.0%
Westerhouse Creek	Fecal coliform	90th percentile	2.16E+13	1.15E+13	46.9%

Allocation

- The TMDL seeks to eliminate 100% of the human-derived fecal component regardless of the allowable load determined through the LA process.
- If the attainment cannot be achieved, the source from wildlife is reduced.
- The point source in the Warehouse Creek watershed (VA0027537) contributes minimal bacteria. The highest concentration measured (<10 cfu/100mL) from this source is below the shellfish geometric mean standard of 14 cfu/100mL.

Allocation

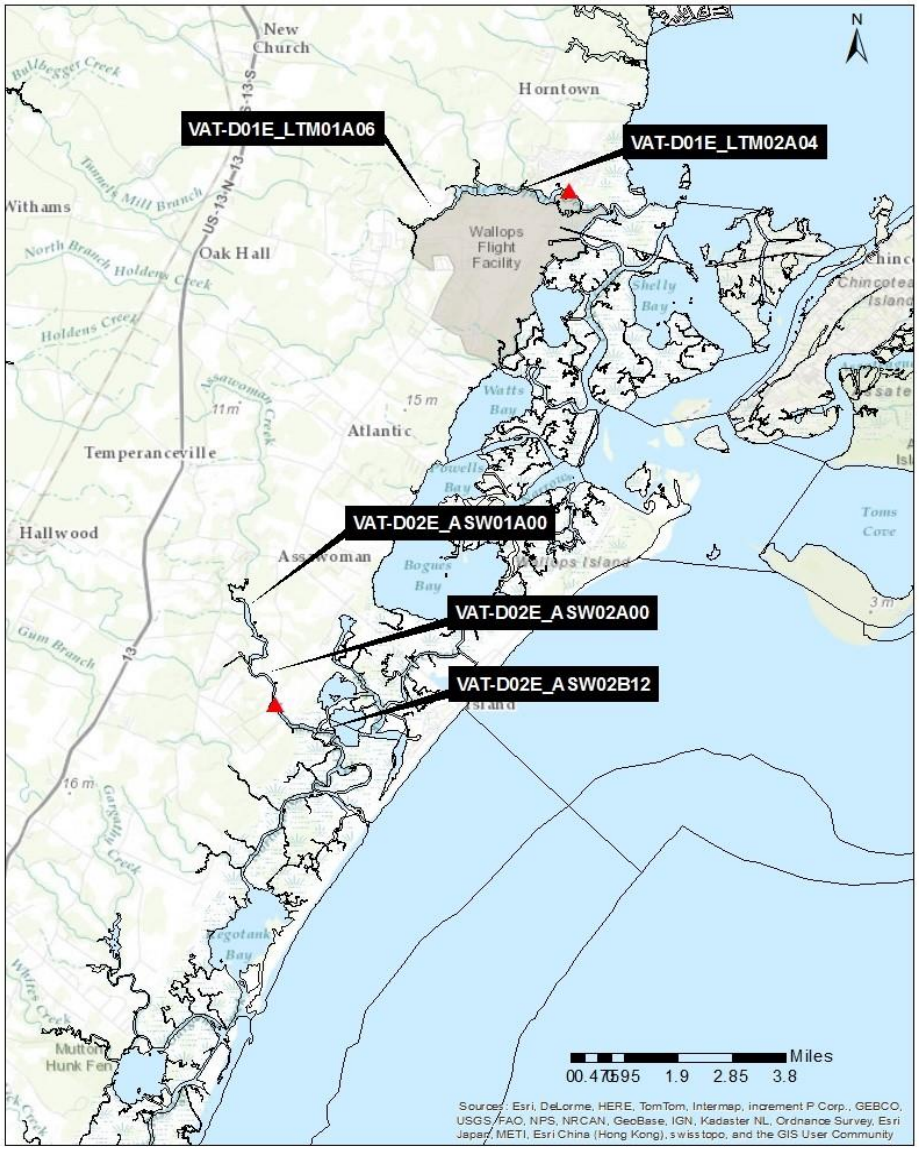
Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek	Human	5.94E+10	0	100.0%
	Pets	2.77E+11	0	100.0%
	Wildlife	1.64E+12	1.643E+12	0.0%
	Livestock	7.05E+11	7.41E+10	89.5%
	Total	2.68E+12	1.72E+12	36.0%
Westerhouse Creek	**Source**	**Current Load (counts/day)**	**Allocation (counts/day)**	**Reduction Needed**
	Human	9.71E+08	0	100.0%
	Pets	4.53E+09	0	100.0%
	Wildlife	1.06E+11	5.95E+10	44.1%
	Livestock	1.23E+08	0	100.0%
	Total	1.12E+11	5.95E+10	46.9%

For meeting Recreational Use as the First Step for Implementation

Waterbody Name	Source	Current Load (counts/day)	Allocation (counts/day)	Reduction Needed
Nassawadox Creek	Human	2.85E+10	0	100.0%
	Pets	1.33E+11	0	100.0%
	Wildlife	7.88E+11	7.881E+11	0.0%
	Livestock	3.38E+11	1.32E+11	60.9%
	Total	1.29E+12	9.20E+11	28.5%

Assawoman and Little Mosquito Creeks

Impaired Waters of Little Mosquito and Assawoman

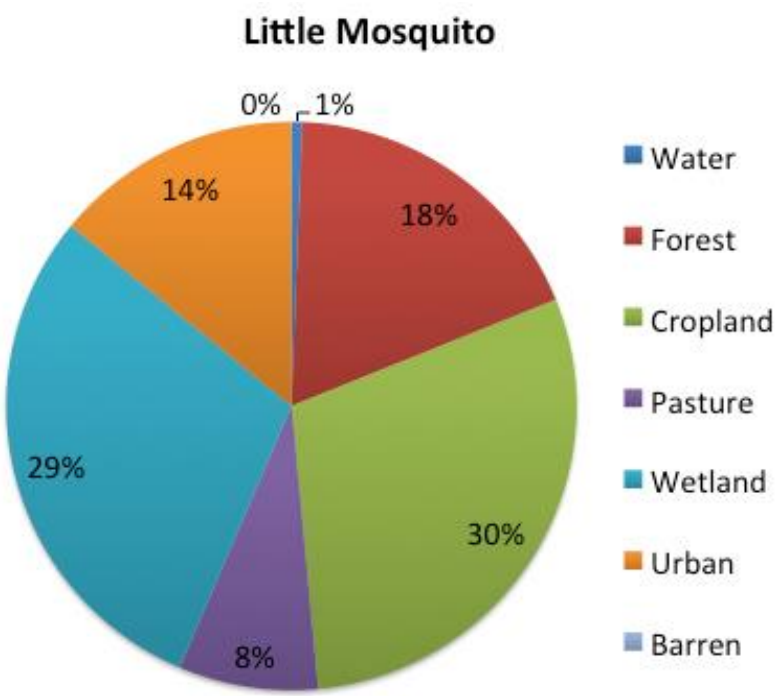


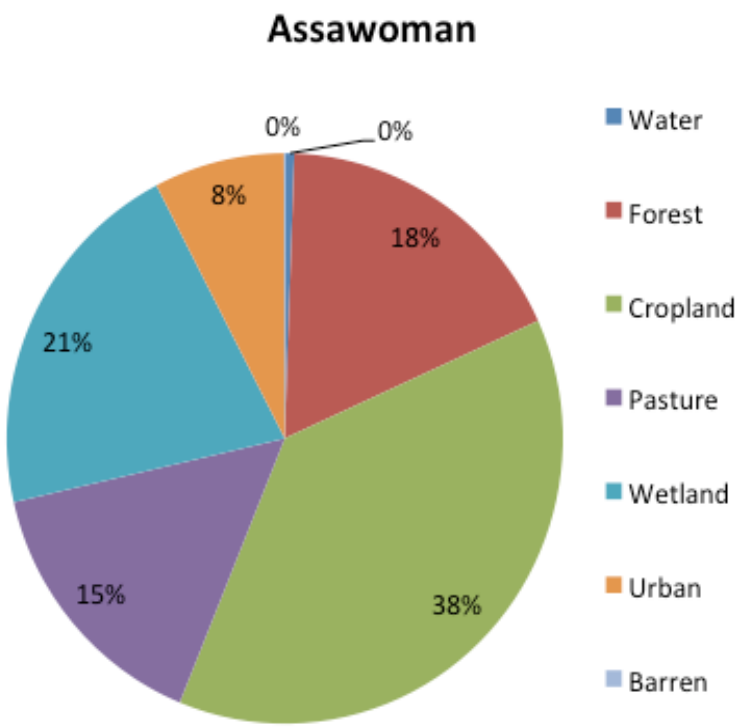
Impaired Waters of Little Mosquito and Assawoman

- 5 segments are impaired for aquatic life designated use due to violations of Virginia's Dissolved Oxygen (DO) criteria.
- Water Quality Standards (9VAC25-260-50)

  The numerical criteria for DO for Class II waters is a minimum of 4.0 mg/L and a daily average of 5.0 mg/L.

Land Use Distributions of Little Mosquito and Assawoman Creeks





Summary of Nitrogen Sources

		Assawoman Creek	Little Mosquito Creek
Human	Population	1073	3753*
	Septic system	477	1005 625**
	Dogs	279	587*
Livestock	Horses	30	12
	Cattle	100	0
	Goats	4	5
	Chickens	1,620,900	51,204
	Geese	0	0
Wildlife	Deer	695	982
	Raccoons	474	669
	Muskrats	2618	2978
	Geese	242	264
	Ducks	493	539
	Geese (peak season)	435	476
	Ducks (peak season)	887	970

*Population includes Trail's End Campground, which assume 25% of total 2500 lots.

** Septic for Trail's End Campground is estimated based on seasonal 25% of occupancy.

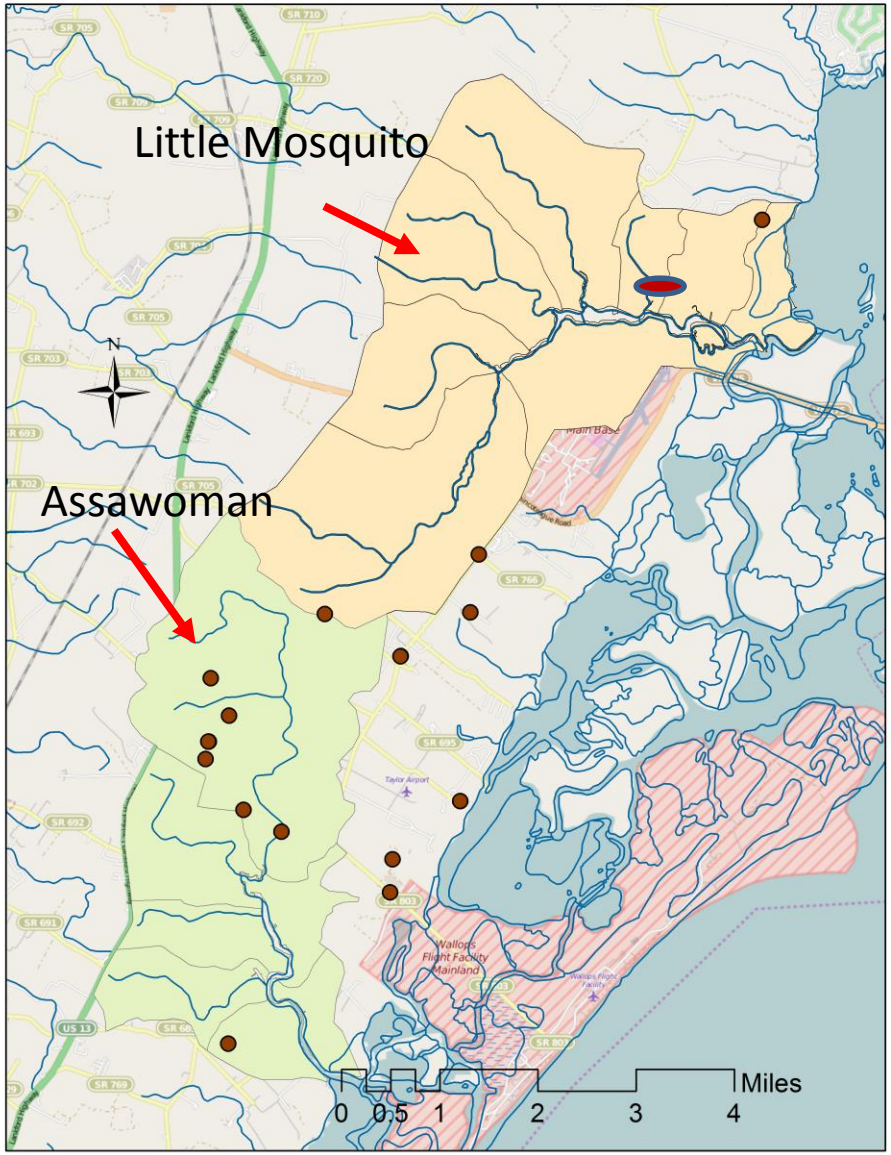
DSS Shoreline Survey Data

- Use shoreline survey data and local inputs to identify the potential causes of problems

	Assawoman	Little Mosquito
Chickens	657,000*	98,000*
Goats	4	5
Cattle	100	
Horses	30	12

•See poultry permit for additional #s

Note that chicken farming causes no problems if manure is stored appropriately



Septic Failing and Loading Estimation

1. # Failing septic tank = # septic tanks * failure rate (5% is used based on local VDH and Hungars-Mattawoman IP)
2. Nutrient concentration and flow used for the estimation of loading (USEPA TMDL tool)
   - Total nitrogen 60.0 mg/L
   - Total phosphorus 23.5 mg/L
   - Organics (BOD) 290.0 mg/L
   - Flow of 70 gallons/person/day

Nutrient Application and Inputs

- N-fertilizer applied to cropland is ~ 125 lbs/acre/year (Chesapeake Bay Program)
- Lawn fertilizer is 44 lbs/acre/year (44-132) (Rosen et al., http://www.extension.umn.edu/garden/yard-garden/lawns/fertilizing-lawns/, EPA)
- N:P=7:3
- Chicken manure application rate is 1-2 tons/acre/year (Bay estimation for county)?
  - Total area with permitted land-applied manure is about 1355.6 ac and 425 ac, respectively, for Assawoman and Little Mosquito Creeks.
    - Based on the recent NMP manure Spreading Summary since 2011 only 2 farms had poultry litter application: 4 tons over 50 acres.
- Atmospheric deposition TN=11.5 lbs/ac/year and TP=0.2 lbs/ac/year.

Livestock Estimation

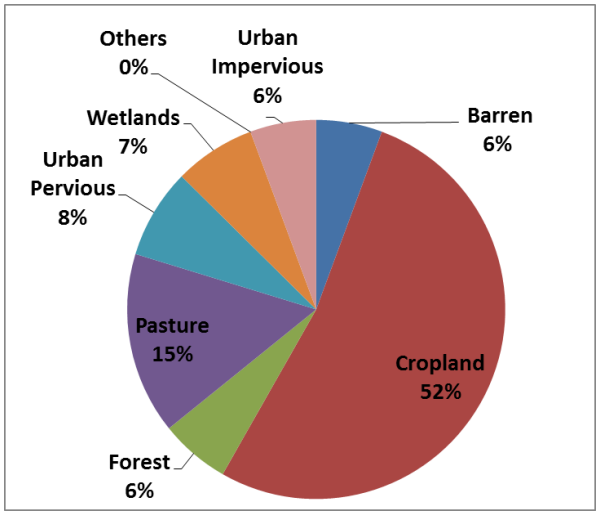
- USDA only reports county total livestock
- Estimation
  - Use county data and agriculture landuse data
  - Use shoreline survey data
  - Use CAFO and AFO database (with permits)
    - 2 permitted poultry farms in Little Mosquito watershed
    - 9 permitted poultry farms in Assawoman watershed
  - Local inputs

Source Estimation

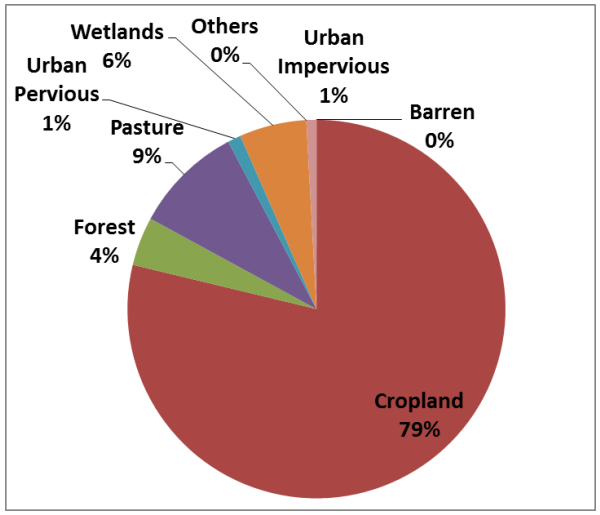
Sources	N (lbs/ac/year)	Percent	P (lbs/ac/year)	Percent
Wildlife	5.4	2.3%	1.35	3.2%
Lawn	25.1	10.7%	5	11.9%
Manure	26	11.1%	8.8	20.9%
Livestock	40	17.1%	7.3	17.3%
Septic	1.4	0.6%	0.6	1.4%
Fertilizer	125	53.3%	18.9	44.8%
Atm. Deposition	11.5	4.9%	0.2	0.5%
Sum	234.4	100.0%	42.15	100.0%

Percent of Nutrient Input (Assawoman)

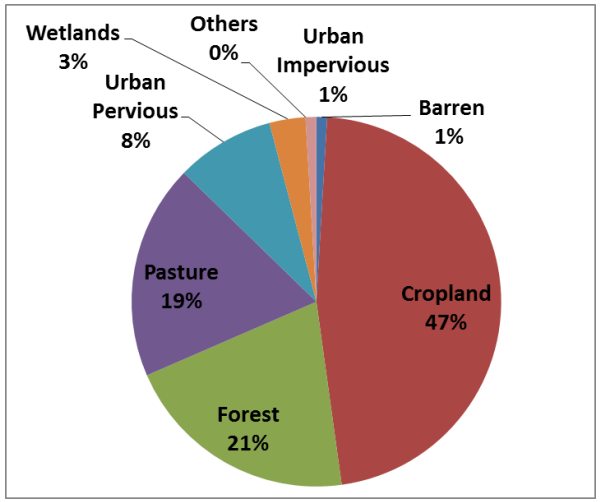
N (Lbs/ac/year)



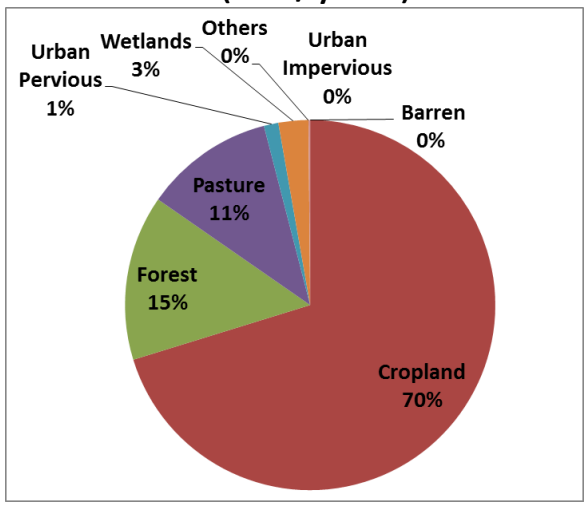
N (Lbs/year)



P (Lbs/ac/year)

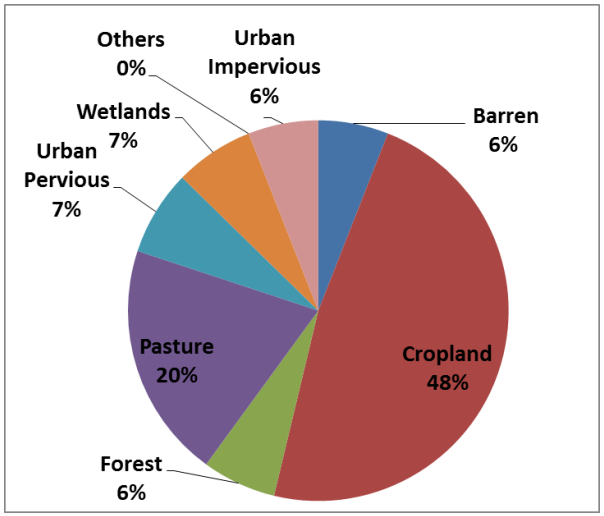


P (Lbs/year)

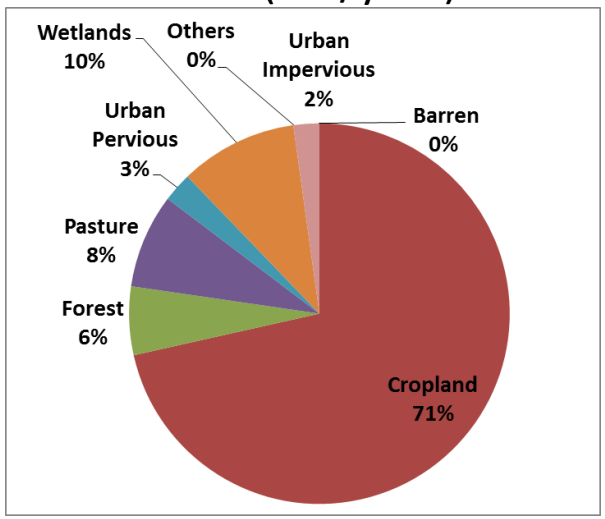


Percent of Nutrient Input (Little Mosquito)

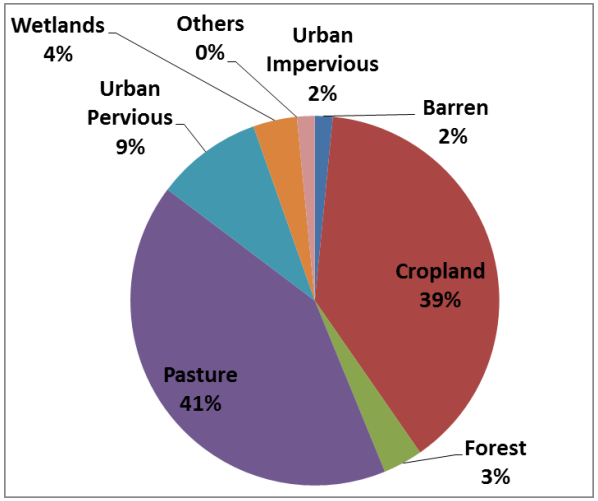
N (Lbs/ac/year)



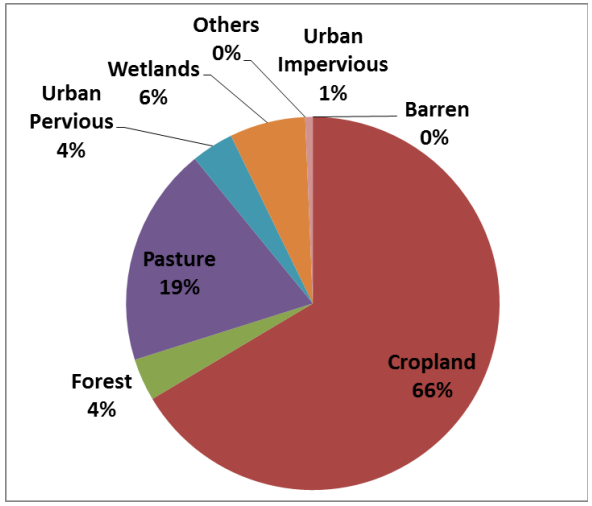
N (Lbs/year)



P (Lbs/ac/year)



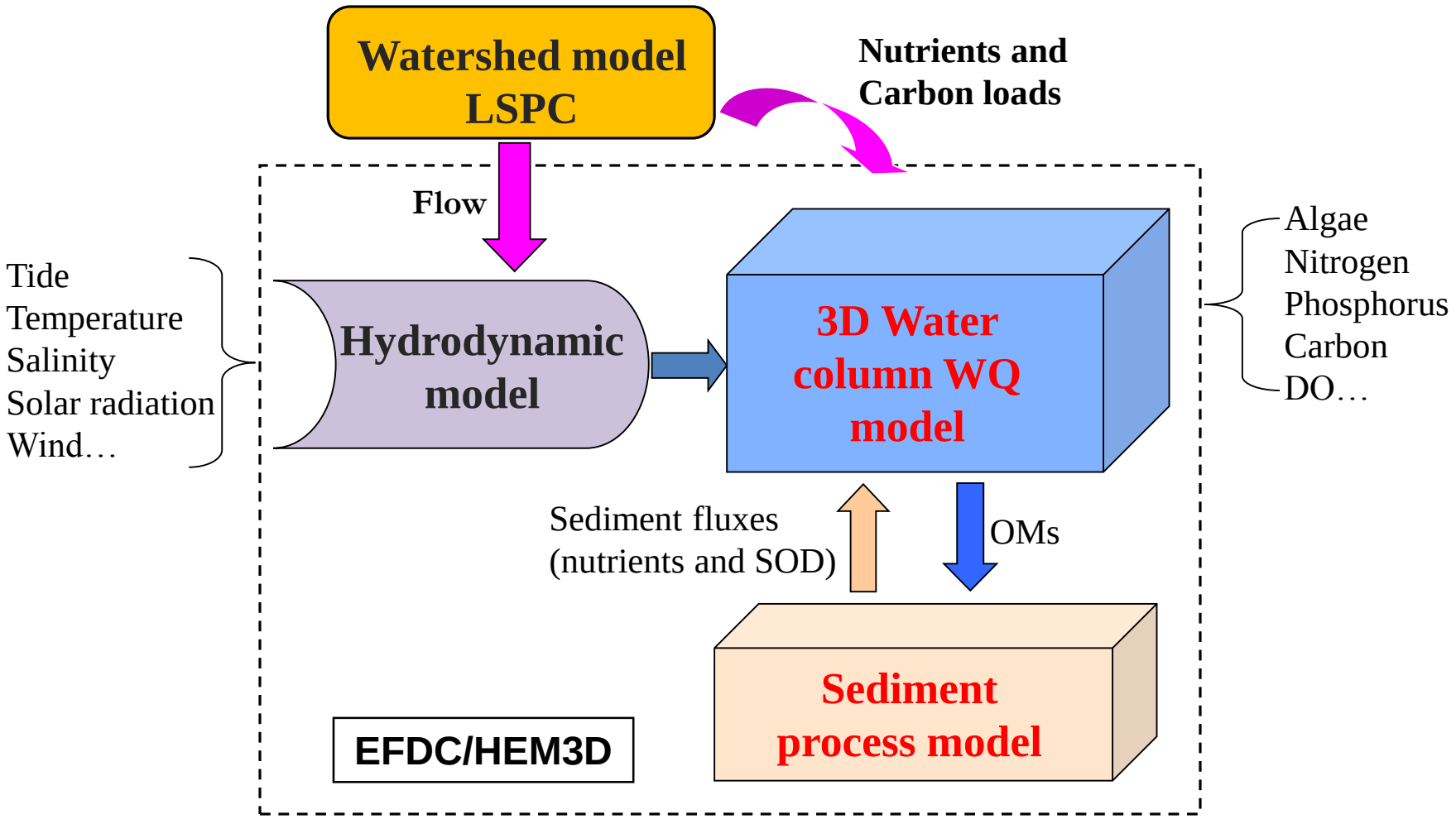
P (Lbs/year)



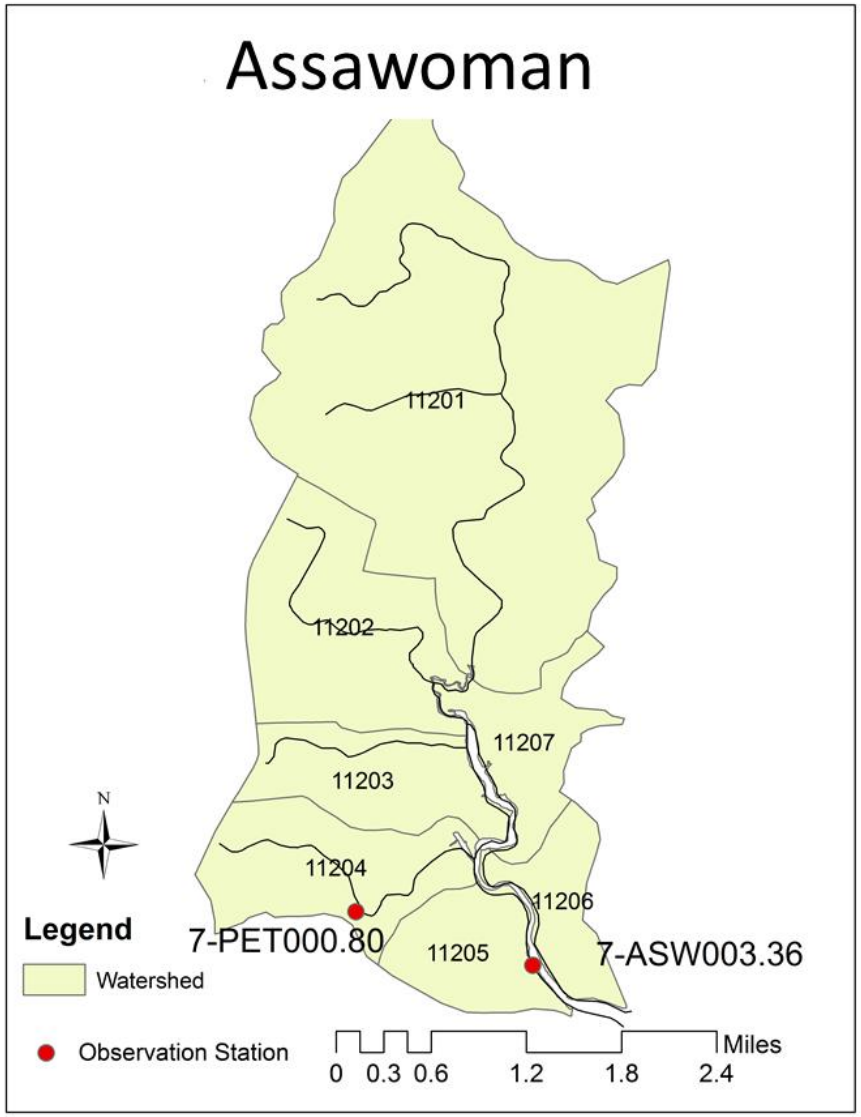
Point Sources

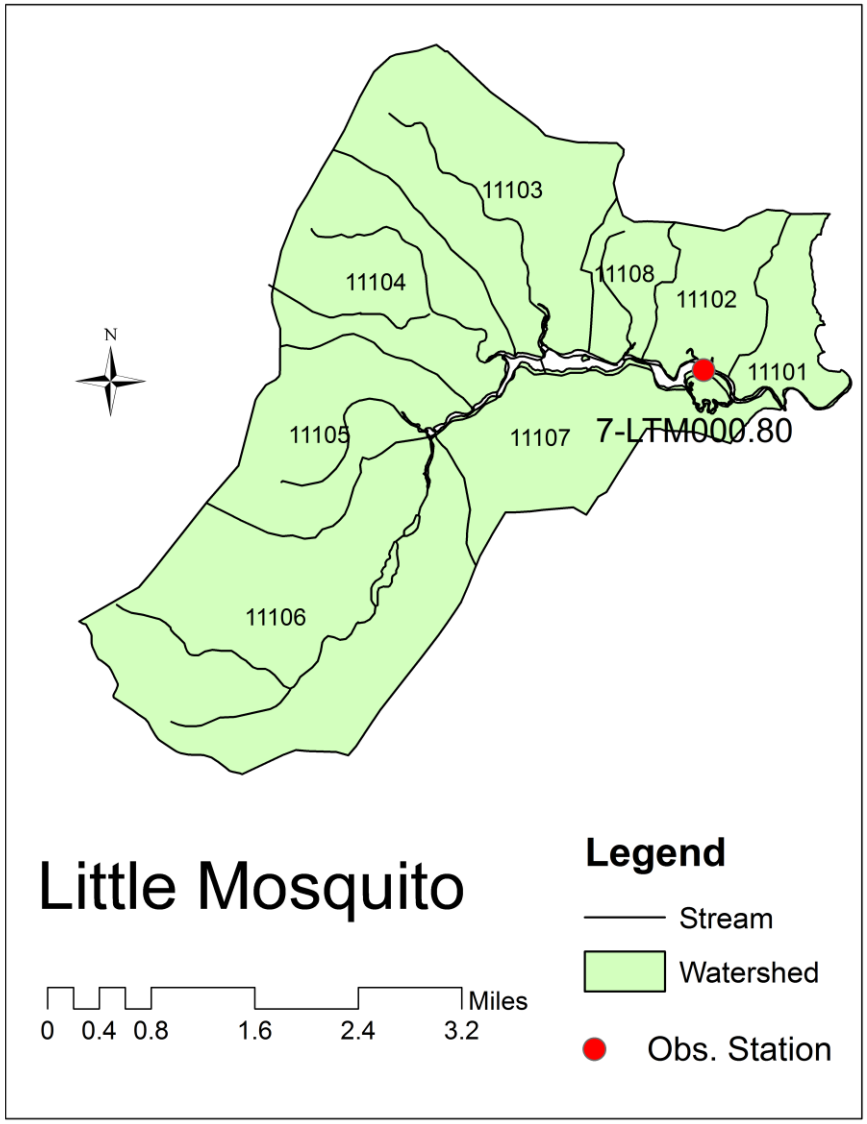
Permit	Facility Name			Monthly average (mg/L)		
			Flow	CBOD5	TKN	NH3-N
VA0024457	U.S. NASA-Wallops Flight Facility	Little Mosquito	NL	10	3	
VA0091529	Accomack County Leachate Treatment Facility	Assawoman	NL	10		4.9
VAR051367	Accomack County Northern Landfill	Assawoman	NL	37		4.9

Modeling Approach for Dissolved Oxygen



Observation Stations (DEQ)

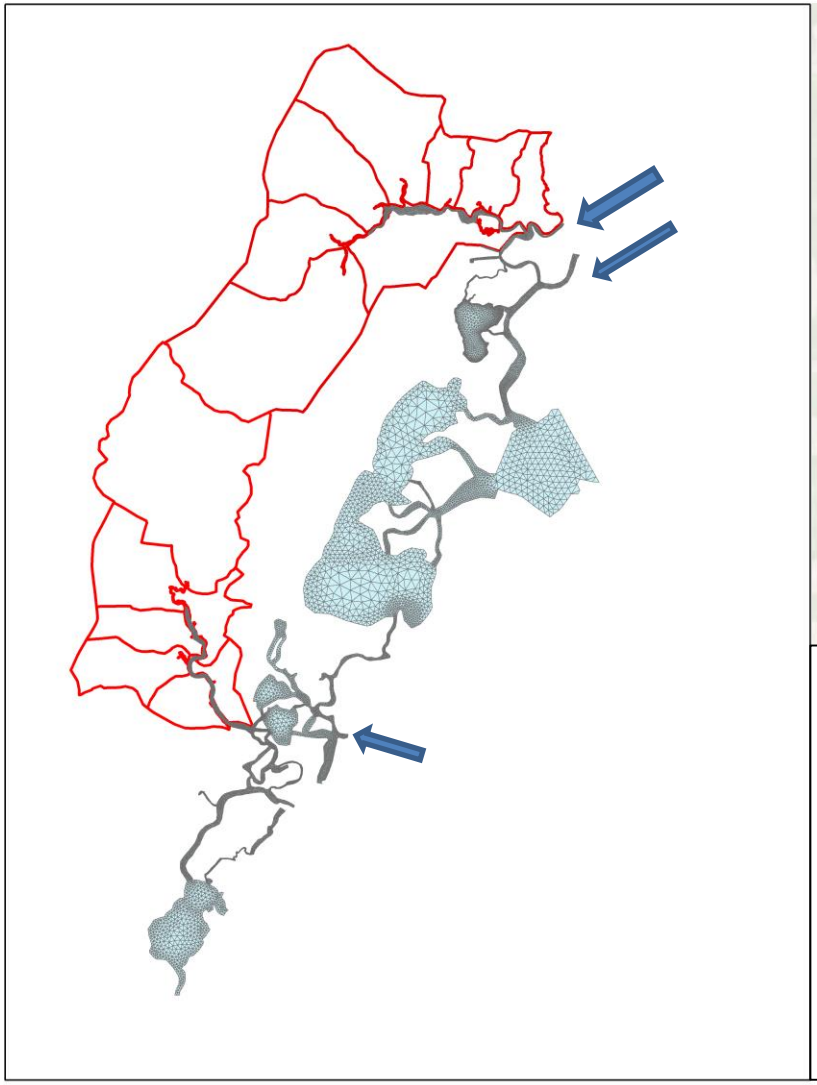


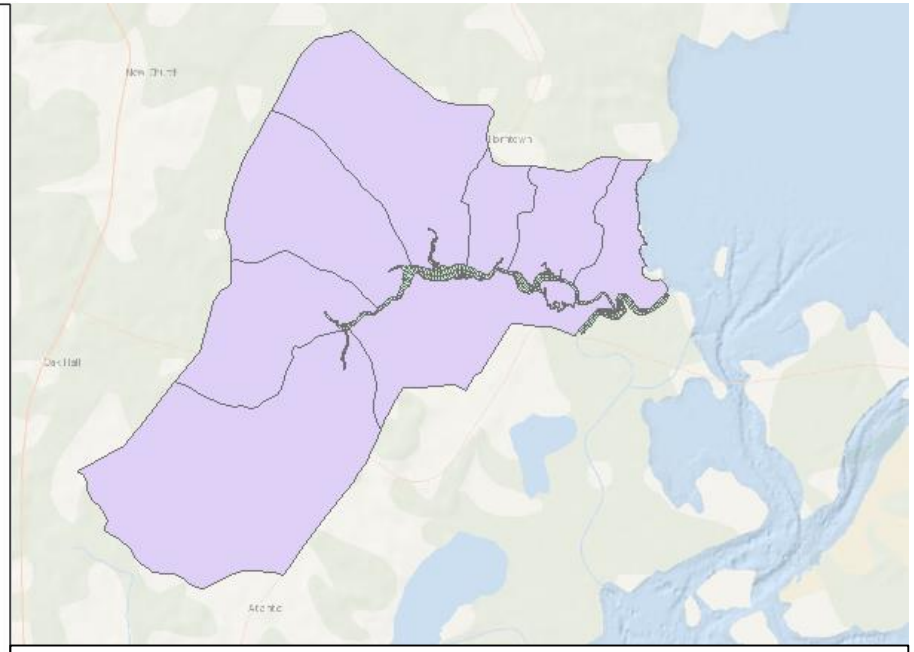


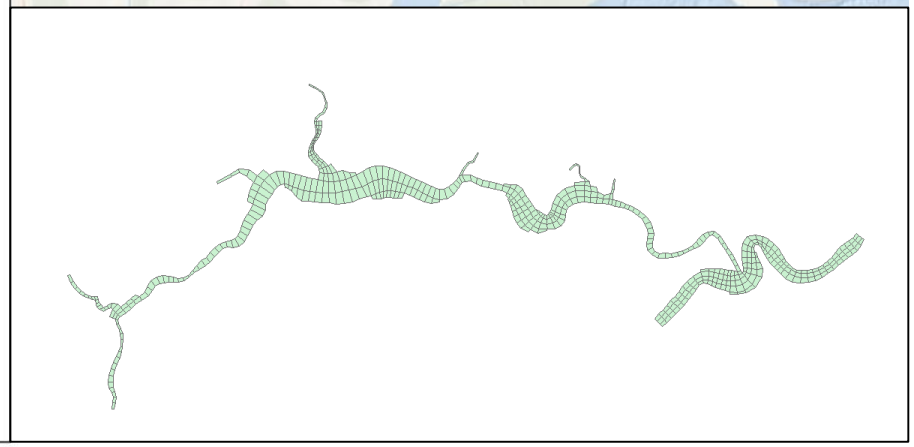
Model Simulation

- Watershed Segmentation
  - Simulation flow, loading using Loading Simulation Program C^{++} (LSPC)
- Receiving water
  - Simulate pollutant transport using Environmental Fluid Dynamic Computer Code (HEM3D/EFDC)
  - Boundary condition of tide is provided by VIMS large domain model (SELFE model)

Three-dimensional Model Grid

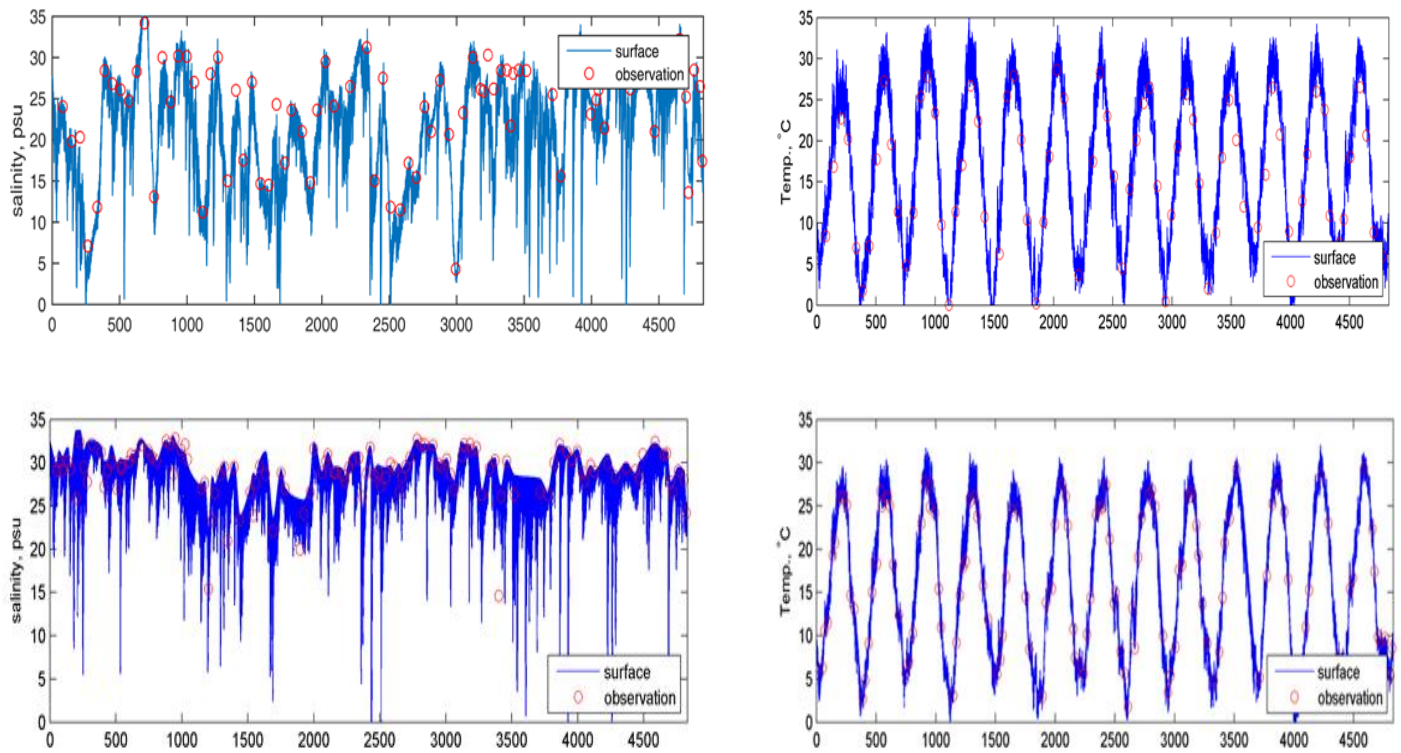




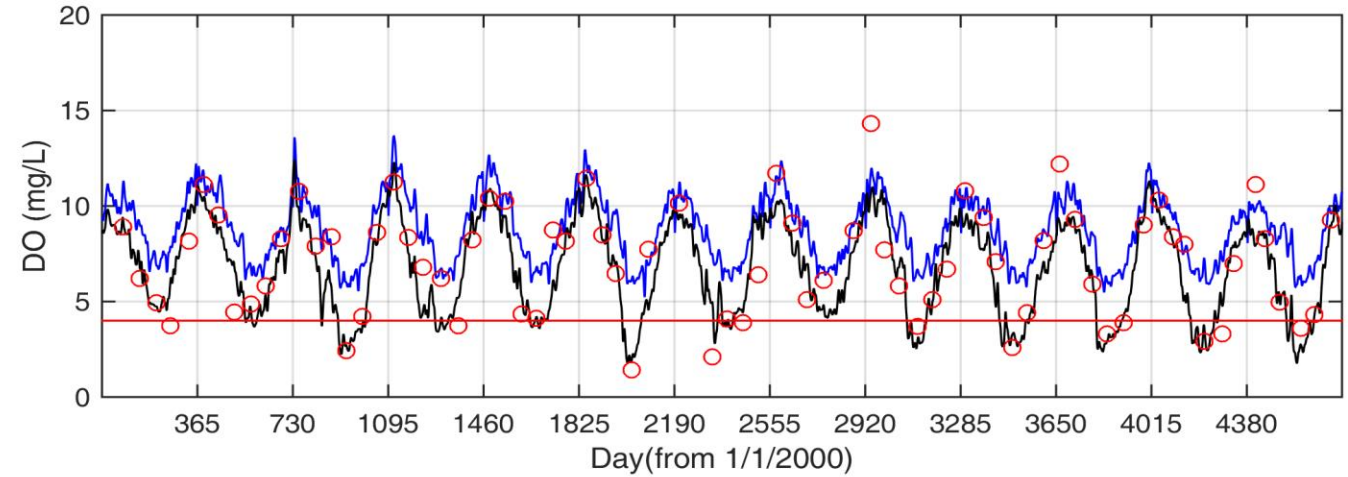


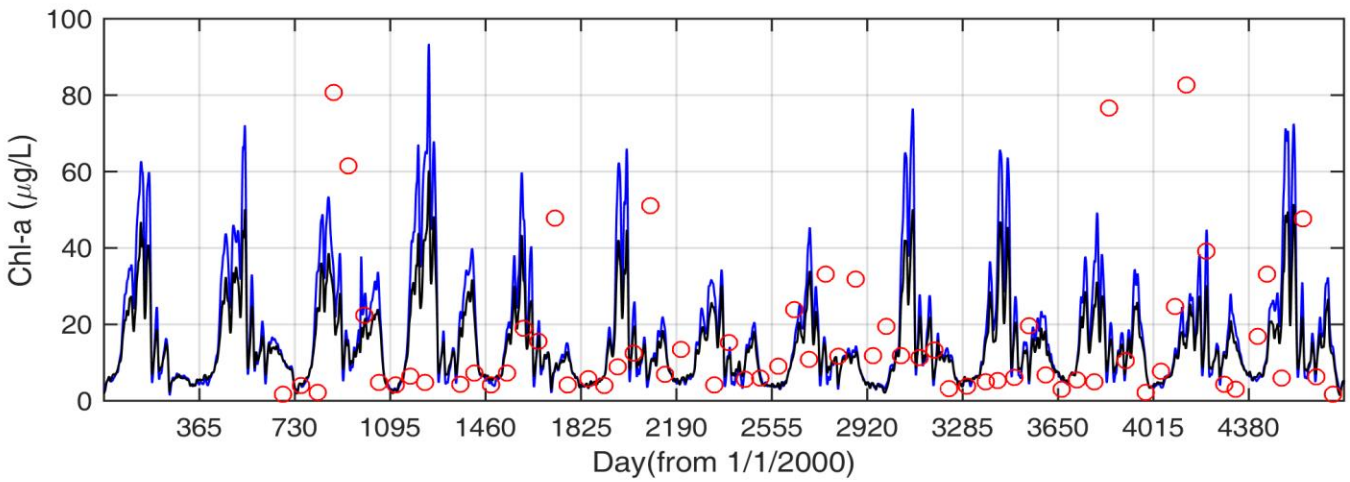
Hydrodynamic Calibration

- Watershed model uses same parameters calibrated for USGS Gage 01484800 at Guy Creek.
- Transport model is calibrated for salinity and temperature

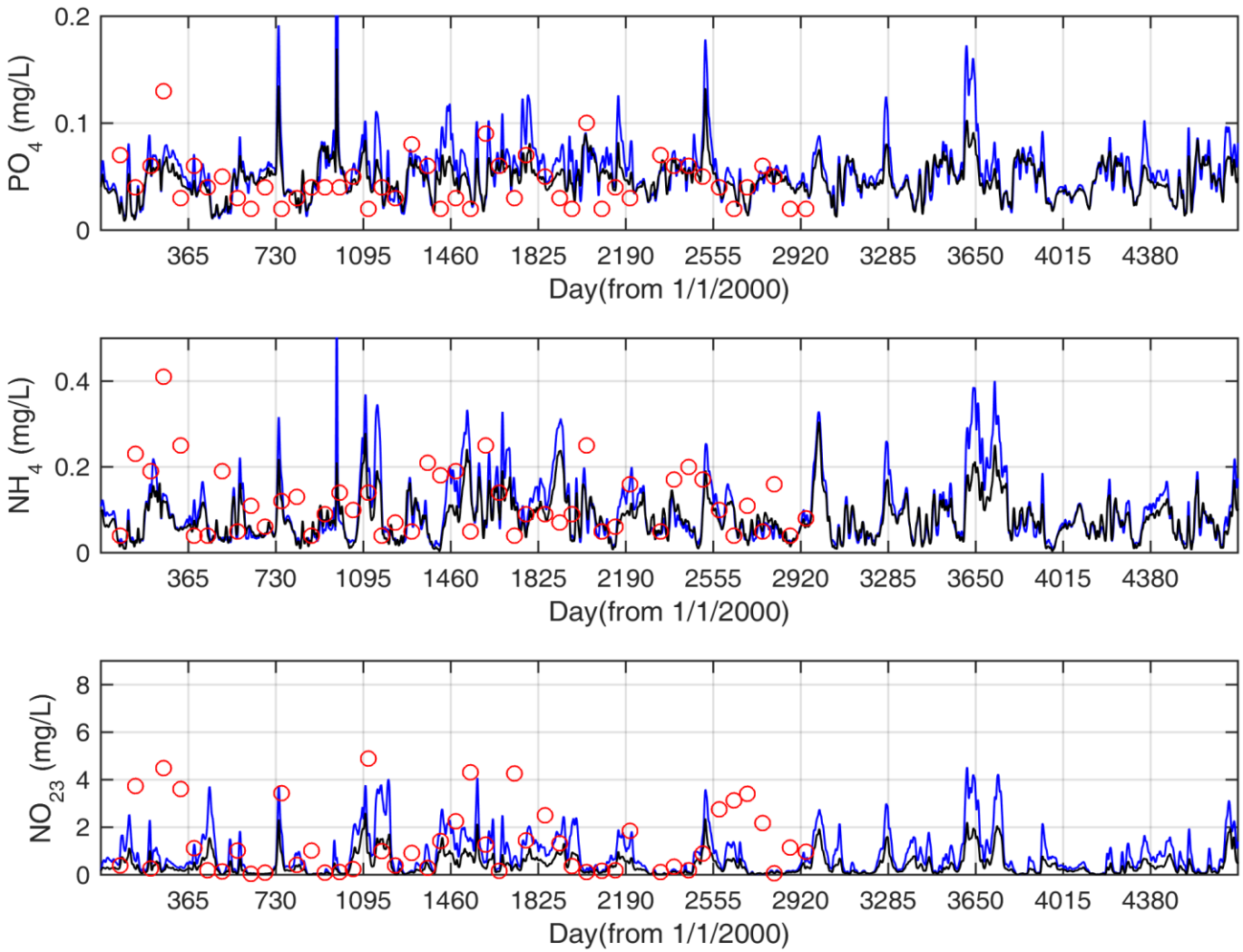


Station 7-ASW003.36 in Assawoman Creek

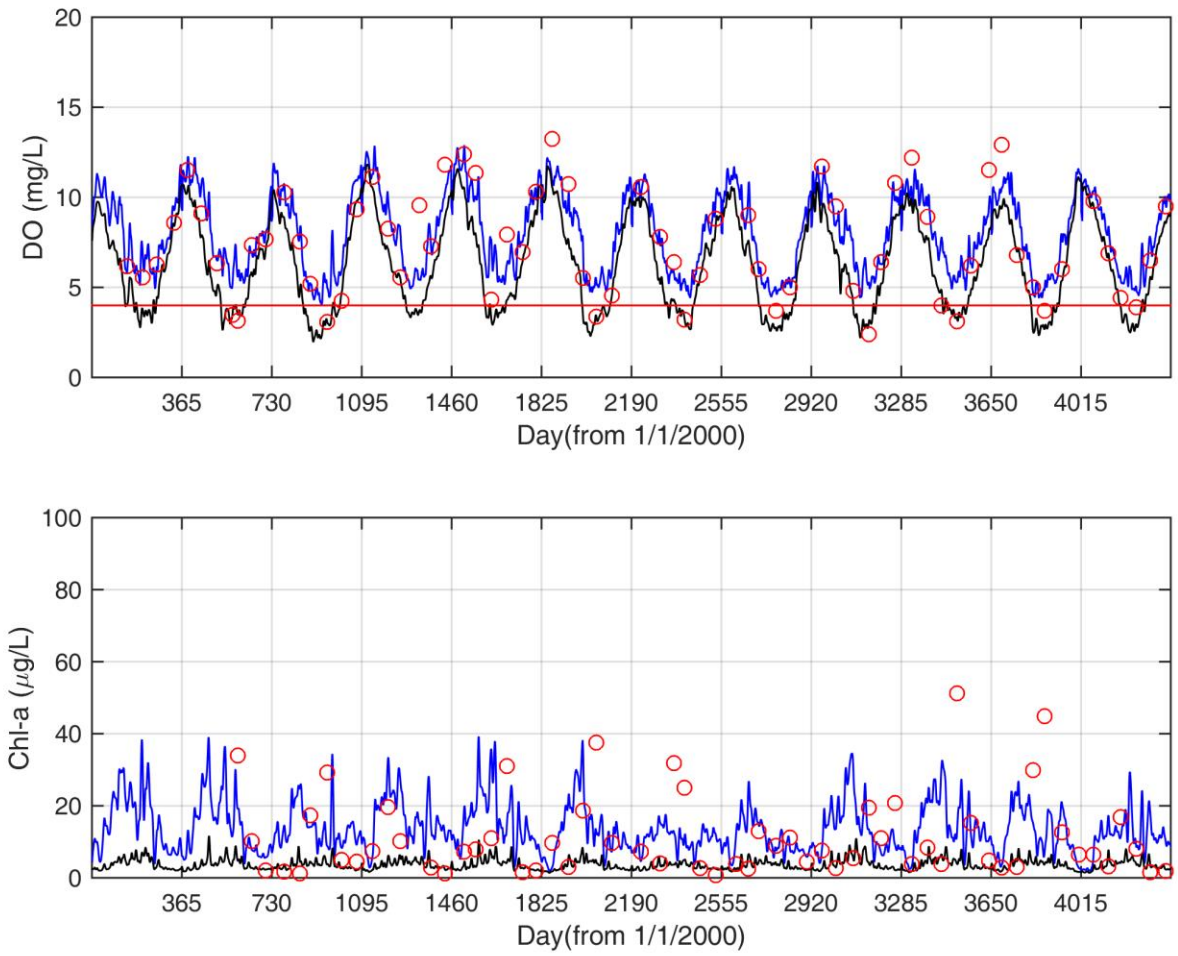




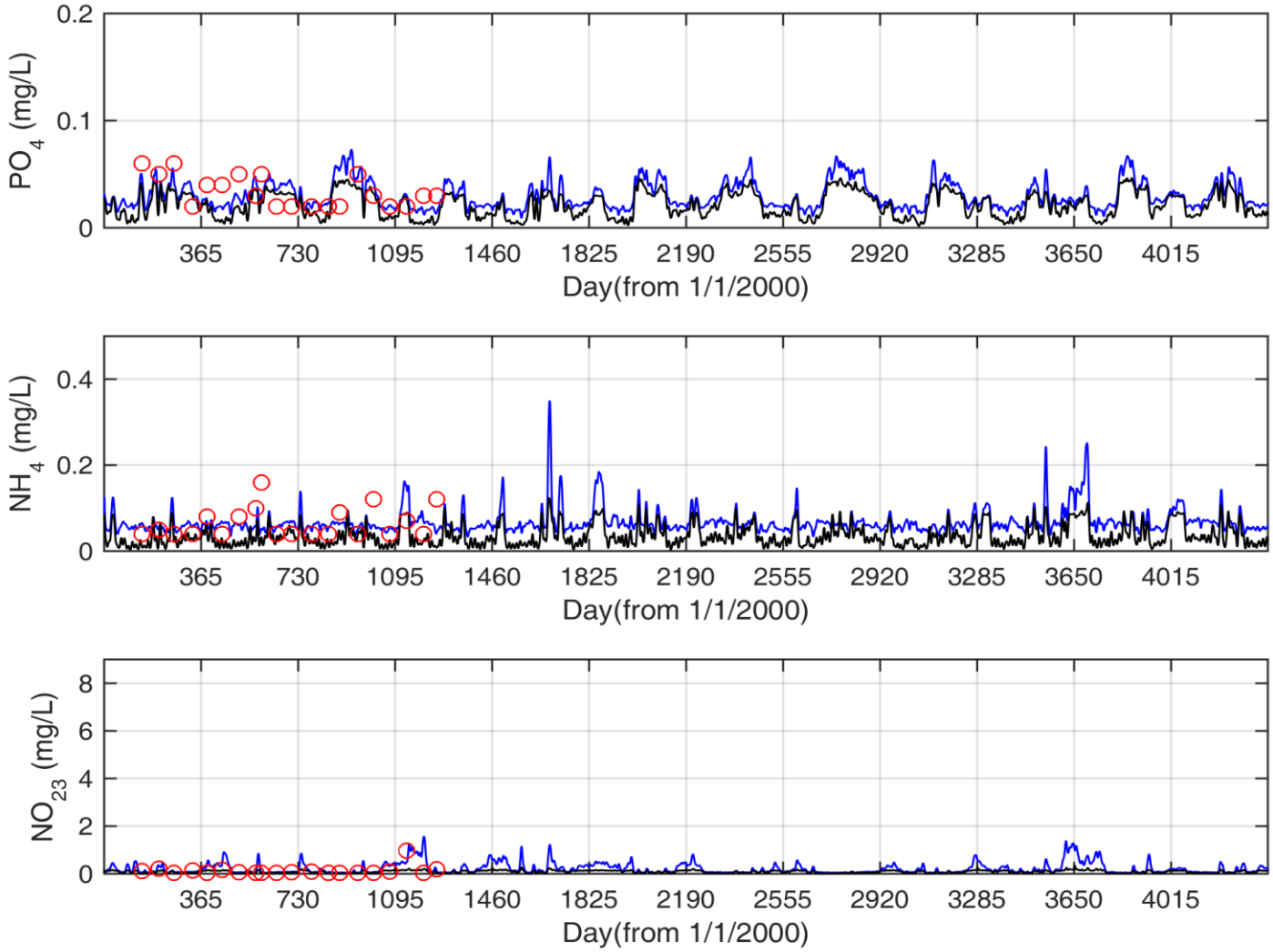
Station 7-ASW003.36 in Assawoman Creek



Station 7-LTM000.80 in Little Mosquito Creek

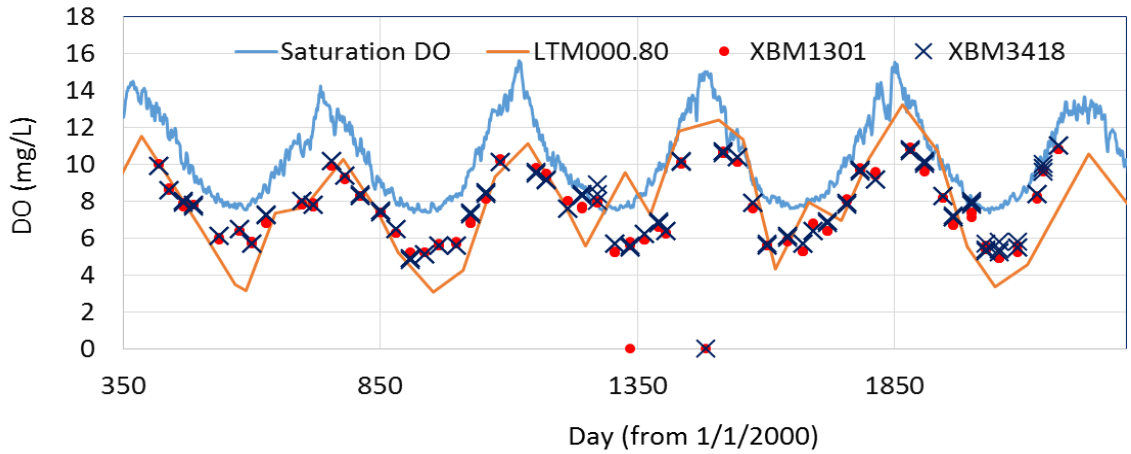


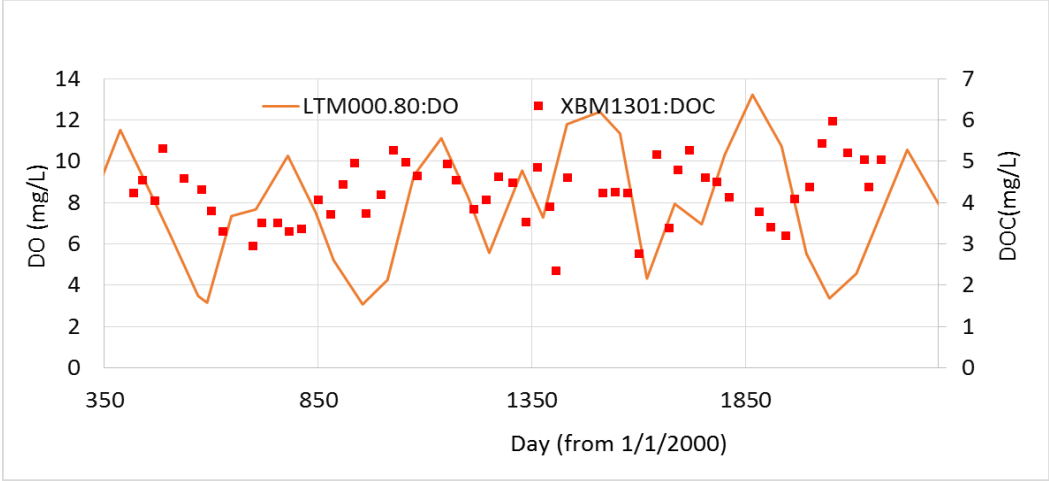
Station 7-LTM000.80 in Little Mosquito Creek



Other factors Influencing DO

- Outside boundary condition (DO and OC)
- Ground water

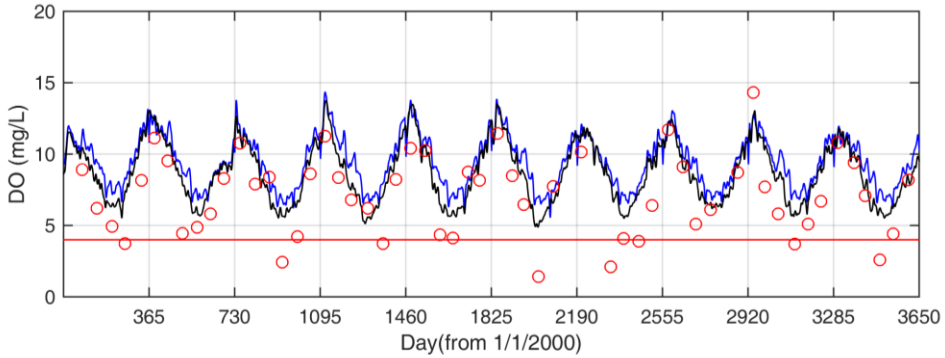




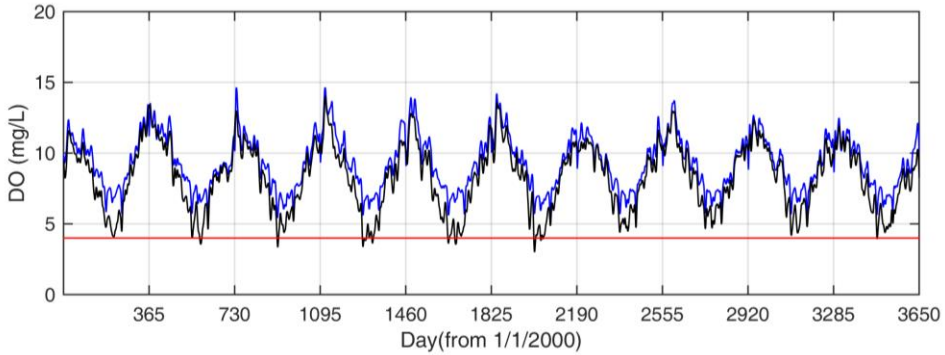
Influence of Boundary Condition

- If open boundary condition is forced by saturation DO and typical organic carbon condition, low DO will occur at middle and upstream of the Creek
- Same DO behavior occurred in Little Mosquito Creek

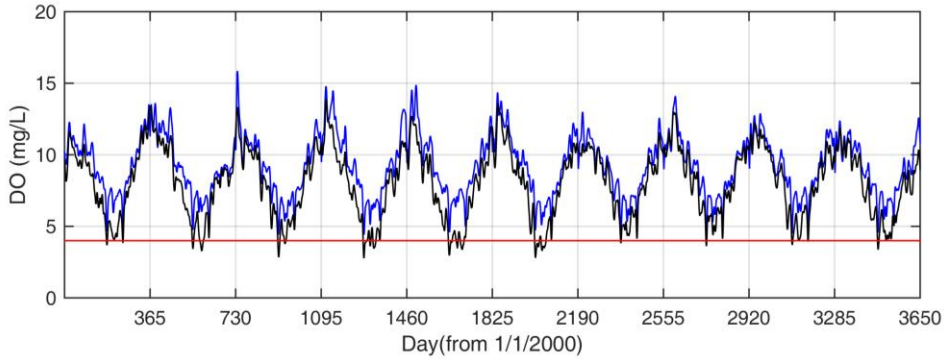
Assawoman Creek



Downstream



Middle

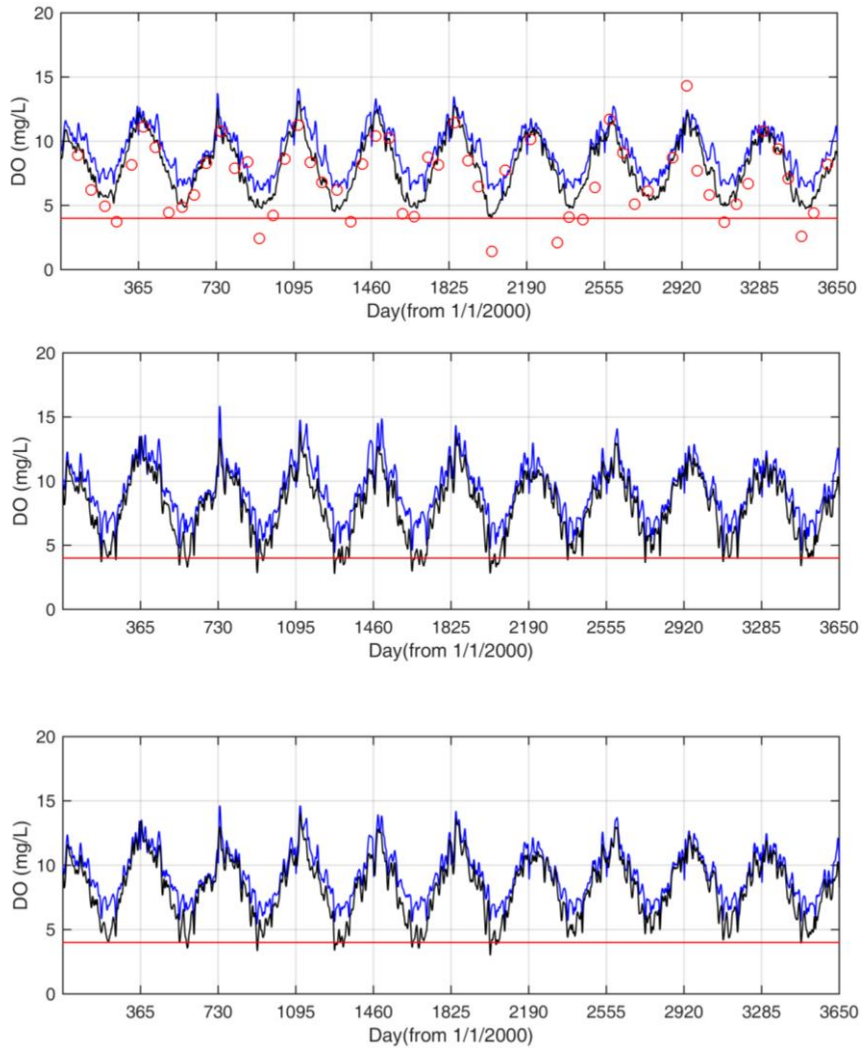


Upper

Without Ground Water

- Without ground water nutrients, low DO occurs in the midstream and upstream for both Assawoman and Little Mosquito Creeks

Assawoman Creek



Downstream

Middle

Upper

TMDL and Load Allocation

- Although both creeks are influenced by outside conditions, the middle and upstream sections of both creeks are not affected by the outside. Therefore, the reduction is determined based on the DO conditions in the middle and upstream of the section.
- Reduction strategy: remove human impact (failing septic system, urban runoff (lawn, pets etc.), manure, and fertilizer.
- Model simulations show WQS can be achieved by reducing nitrogen. It is assumed the organic carbon will be reduced in proportion to nitrogen.
- Model sensitivity runs show that, by reducing failing septic system, urban runoff, and manure (no large amount has been used), DO conditions would not be improved sufficiently to meet WQS.
- Because ground water input nitrogen accounts for about 50% of total nutrient inputs, the WQS cannot be achieved unless almost 100% of the surface runoff is removed.
- When surface nutrient runoff is reduced, the ground water condition will be improved. Two allocations are presented.

TMDLs

Total Maximum Daily Load (lbs/day) of Nutrient

Impairment	WLA	LA	MOS	TMDL
Assawoman	4.4	291.4	15.6	311.4
VA0091529	1.3			
Future load (1%)	3.1			
Little Mosquito	12.2	433.8	23.5	469.4
VA0024457	7.5			
Future load (1%)	4.7			

Total Maximum Daily Load (lbs/year) of Nutrient

Impairment	WLA	LA	MOS	TMDL
Assawoman	1,003.7	48689.1	2,615.4	52,308.2
VA0091529	480.6			
Future load (1%)	523.1			
Little Mosquito	3538.9	72584.2	4006.5	80129.6
VA0024457	2737.6			
Future load (1%)	801.3			

Allocation I for Assawoman Creek

Land use Name	Current condition (Lbs/Year)	Percent	Allocation (Lbs/Year)	Percent reduction
Barren	6.1	0.0%	6.1	0.0%
Cropland	33,248.1	31.8%	4,987.2	85.0%
Forest	1,736.8	1.7%	1,736.8	0.0%
Pasture	3,891.1	3.7%	583.7	85.0%
Urban Pervious	468.1	0.4%	70.2	85.0%
Wetlands	2,396.5	2.3%	2,396.5	0.0%
Urban Impervious	358.6	0.3%	53.8	85.0%
Sum of surface runoff	42,105.3	40.2%	9,834.3	76.6%
Ground	62,511.2	59.8%	42,474.0	32.1%
Total	104,616.5	100.0%	52,308.2	50.0%

Allocation I for Little Mosquito

Land use Name	Current condition (Lbs/Year)	Percent	Allocation (Lbs/Year)	Percent reduction
Barren	2.8	0.0%	2.8	0.0%
Cropland	47,733.2	35.7%	7,160.0	85.0%
Forest	3,884.0	2.9%	3,884.0	0.0%
Pasture	5,348.1	4.0%	802.2	85.0%
Urban Pervious	1,661.4	1.2%	249.2	85.0%
Wetlands	6,680.6	5.0%	6,680.6	0.0%
Urban Impervious	1,464.6	1.1%	219.7	85.0%
Sum of surface runoff	66,774.7	50.0%	18,998.5	71.5%
Ground	66,774.7	50.0%	61,131.1	8.5%
Total	133,549.3	100.0%	80,129.6	40.0%

Allocation II for Assawoman Creek

Land use Name	Current condition (Lbs/Year)	Percent	Allocation (Lbs/Year)	Percent reduction
Barren	6.1	0.0%	6.1	0.0%
Cropland	33,248.1	31.8%	14,165.2	57.4%
Forest	1,736.8	1.7%	1,736.8	0.0%
Pasture	3,891.1	3.7%	2,334.7	40.0%
Urban Pervious	468.1	0.4%	234.0	50.0%
Wetlands	2,396.5	2.3%	2,396.5	0.0%
Urban Impervious	358.6	0.3%	179.3	50.0%
Sum of surface runoff	42,105.3	40.2%	21,052.6	50.0%
Ground	62,511.2	59.8%	31,255.6	50.0%
Total	104,616.5	100.0%	52,308.2	50.0%

Allocation II for Little Mosquito

Land use Name	Current condition (Lbs/Year)	Percent	Allocation (Lbs/Year)	Percent reduction
Barren	2.8	0.0%	2.8	0.0%
Cropland	47,733.2	35.7%	26,253.3	45.0%
Forest	3,884.0	2.9%	3,884.0	0.0%
Pasture	5,348.1	4.0%	4,352.2	18.6%
Urban Pervious	1,661.4	1.2%	830.7	50.0%
Wetlands	6,680.6	5.0%	6,680.6	0.0%
Urban Impervious	1,464.6	1.1%	732.3	50.0%
Sum of surface runoff	66,774.7	50.0%	42,735.8	36.0%
Ground	66,774.7	50.0%	37,393.8	44.0%
Total	133,549.3	100.0%	80,129.6	40.0%

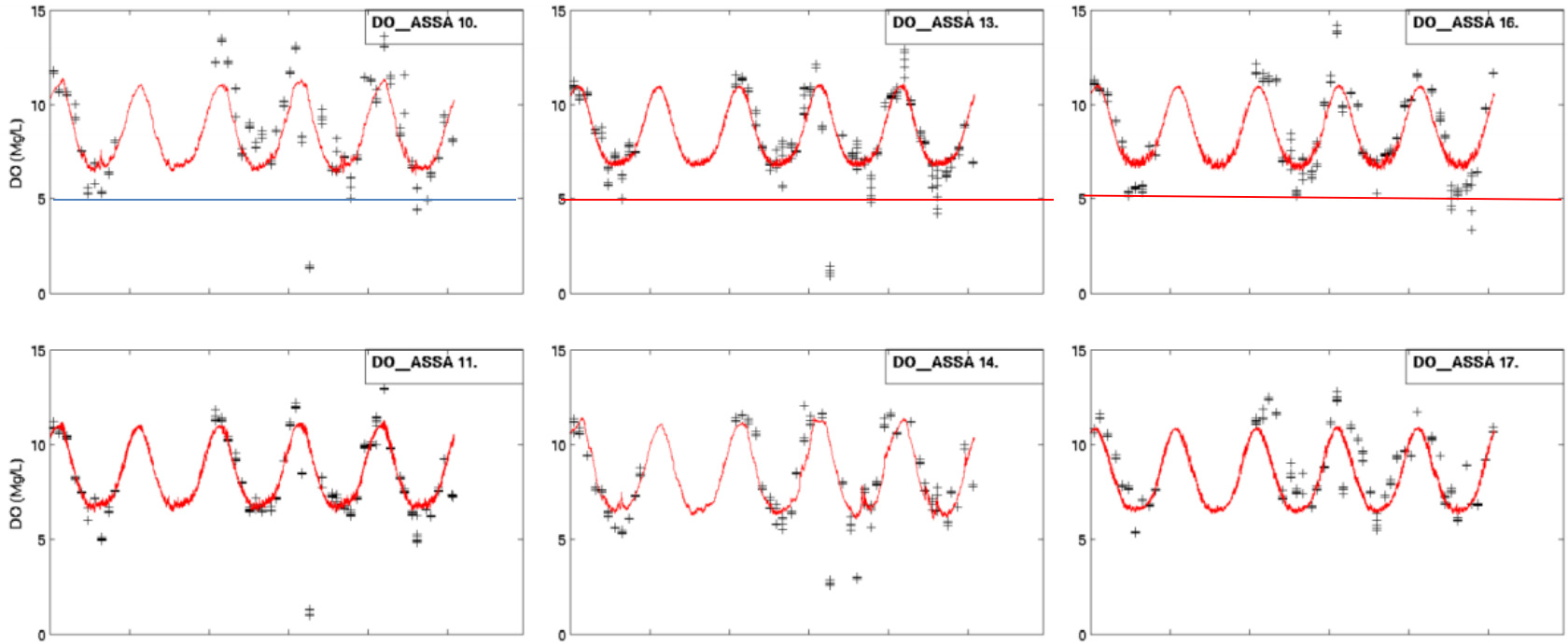
Questions and Comments

JR_WQ_regression_20160208.m

Thanks!

Comment Period March. 10th – Apr. 10th

Comments send to:
Anne Schlegel (Anne.Schlegel@deq.virginia.gov)
Office of Water Quality Programs
Virginia Department of Environmental Quality
P. O. Box 1105 Richmond, VA 23218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