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Developing Oxidized Nitrogen Atmospheric Deposition Source Attribution from CMAQ for Air-Water Trading for Chesapeake Bay

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Chesapeake Bay
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There is strong interest in air-water trading so states can get water quality credit

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The Chesapeake Bay TMDL sets limits on the load that can be delivered from tributaries and the air to the Bay. The TMDL takes into account nitrogen deposition reductions from current national air rules (such as CAIR)

States may go beyond national CAA rules to meet local air quality standards

It is important to the costly, water-oriented TMDL process to take advantage of air emissions reductions that would occur in addition to national air rules

Because of the complex chemistry, transport and transformations, calculation of the incremental benefit needs an air quality model

We do not want to run the air quality model many times over (due to computational expense)

There is a special source attribution version of CMAQ (DDM-3D) that tracks the individual contribution of emissions by source or region, to the total deposition

Use CMAQ with DDM-3D Adapted for Deposition

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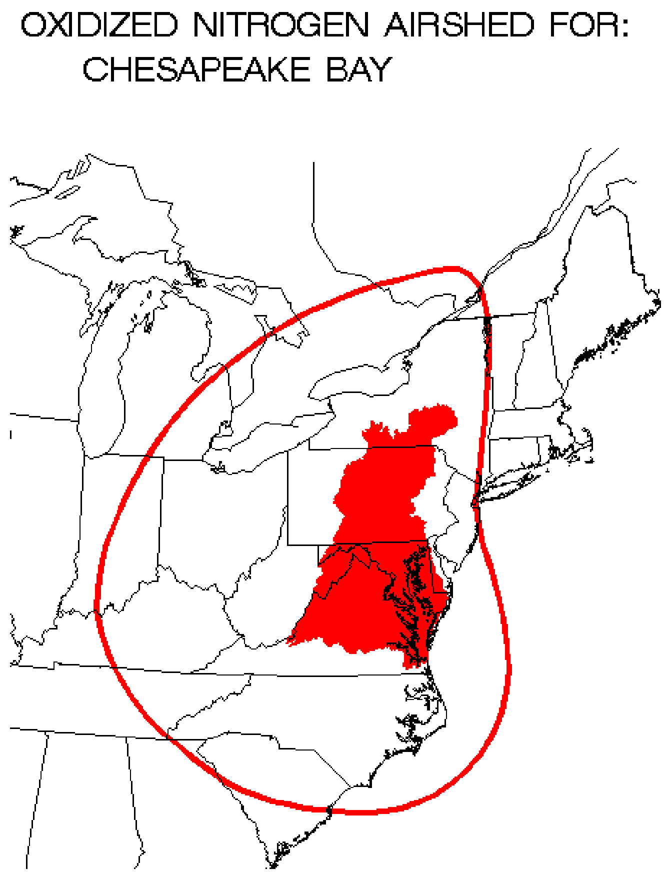
- DDM-3D calculates in the forward sense: how a specific source or sources impacts the domain
- DDM-3D for deposition estimates the fraction of the total deposition attributed to emissions from a particular source type or region
- We track NO_X emissions (oxidized nitrogen deposition) for a 2020 CAIR future
- We use the CMAQ DDM-3D version with 12km grids over the airshed domain
- We then create simplified state-level delta emissions–to-delta atmospheric deposition transfer coefficients by major source sectors within a state



The emissions from watershed states account for a little over half of the Ox-N deposition to the watershed

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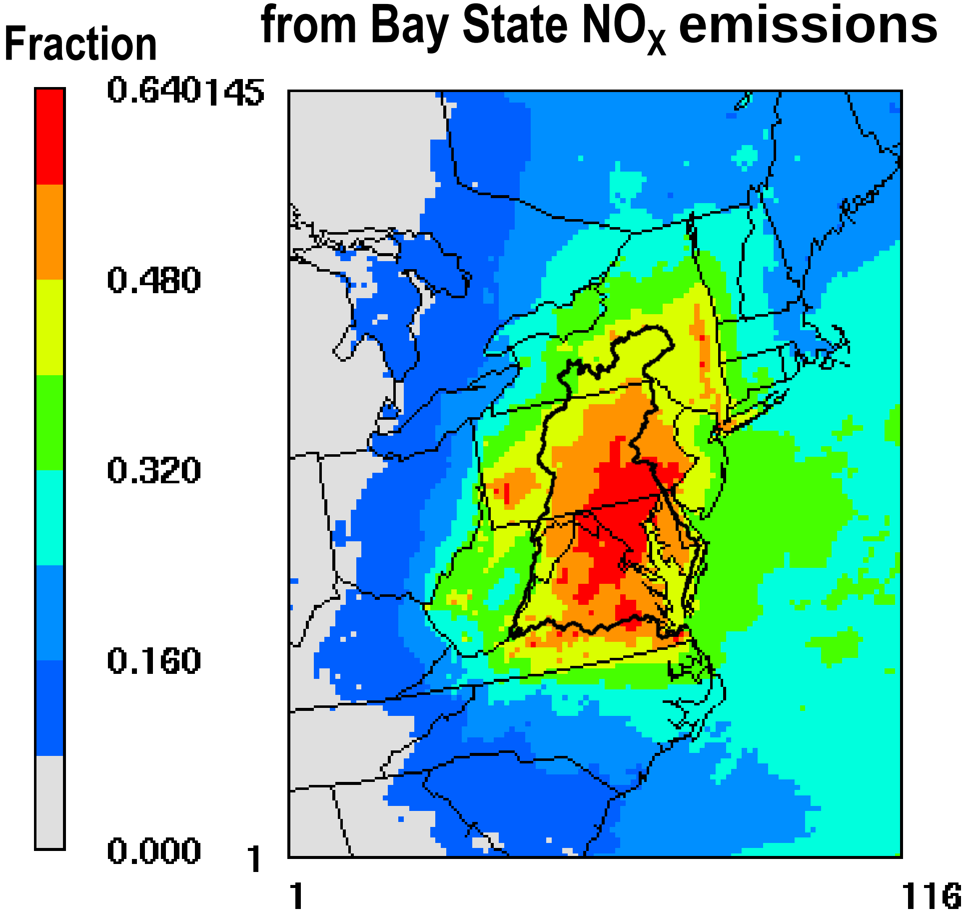
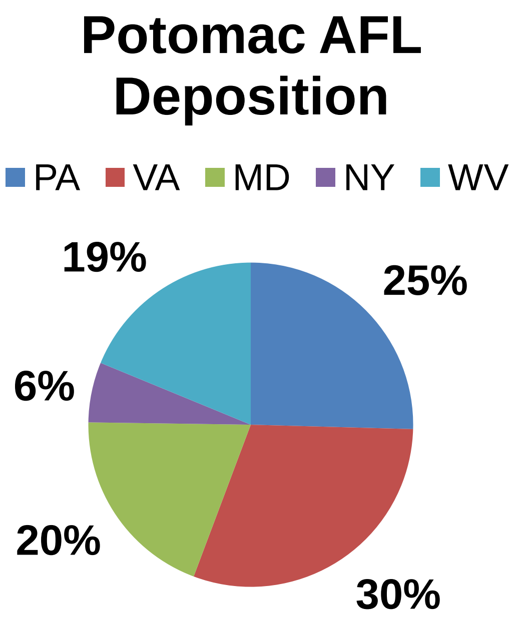
6 Bay States+DC
Fraction of Ox-N Deposition Derived from Bay State NO_X emissions



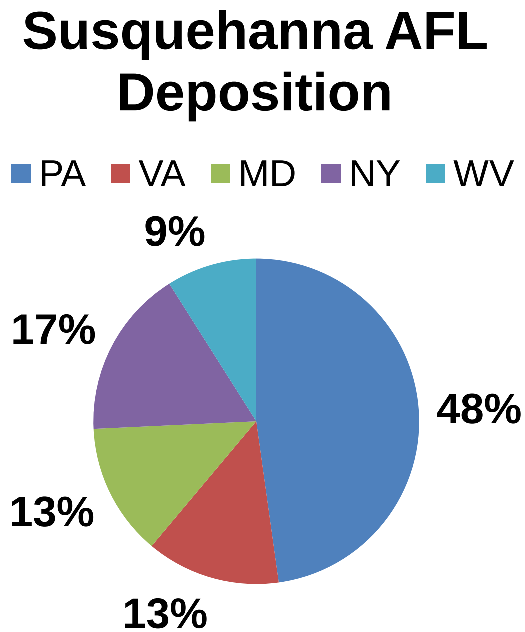
2020 State Attribution to Chesapeake Bay Watershed (12km)	
State	%
New York	5.5
Pennsylvania	16.3
Maryland	8.7
Virginia	15.0
Delaware	1.1
West Virginia	5.2
D.C.	0.5
6 States+DC Combined	52.5

State Contribution (2020 CAIR)

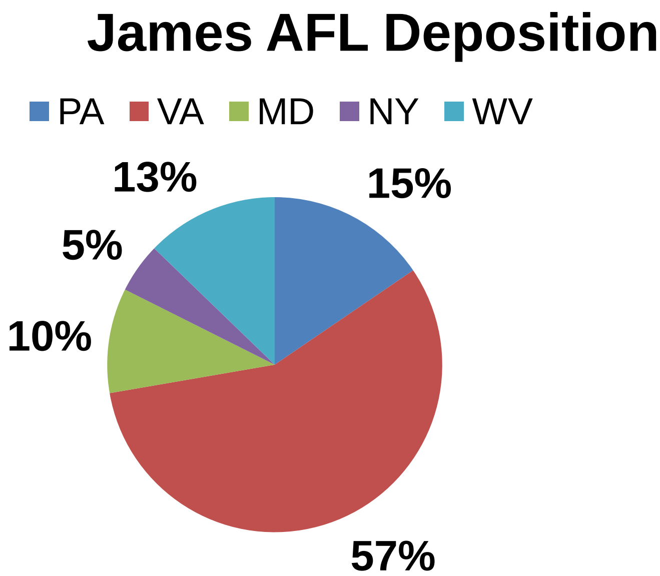
Fraction of kg-N deposition to a tributary watershed contributed by state, normalized to 5-State total



Load = 6.1 x 10^6 kg-N
= 53% of total load



Load = 15.2 x 10^6 kg-N
= 49% of total load



Load = 3.9 x 10^6 kg-N
= 49% of total load

AFL = Above the Fall Line

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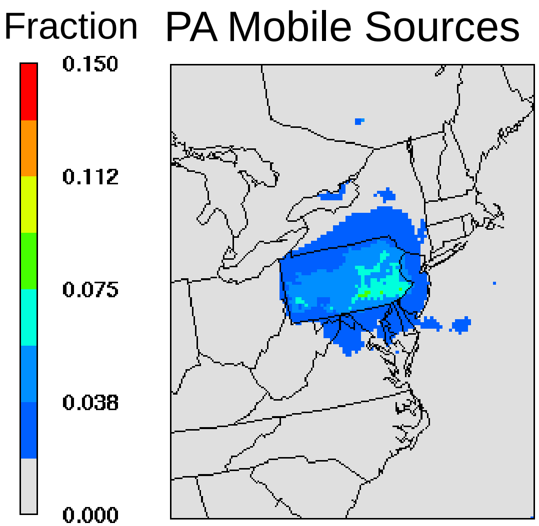
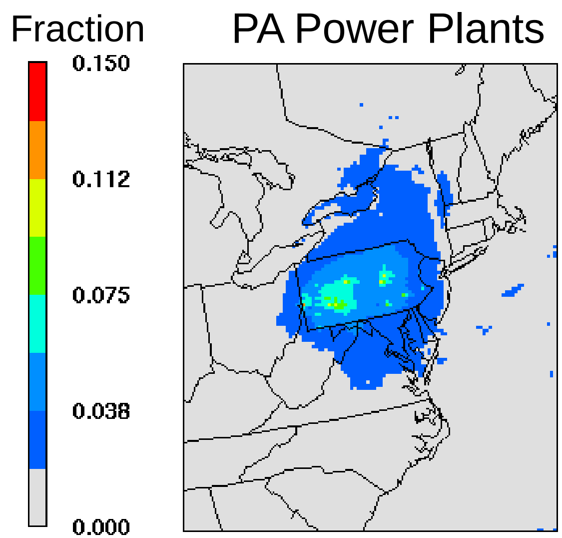
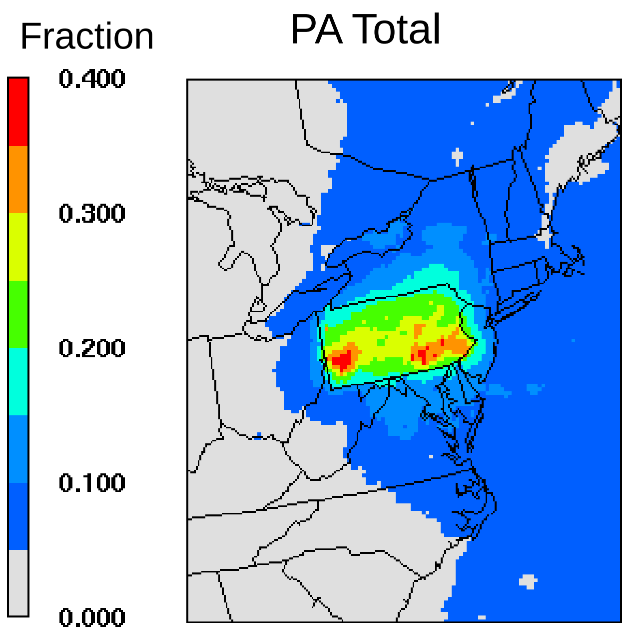
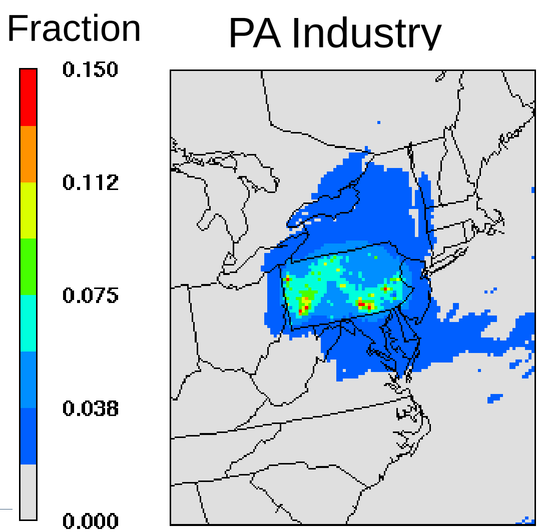
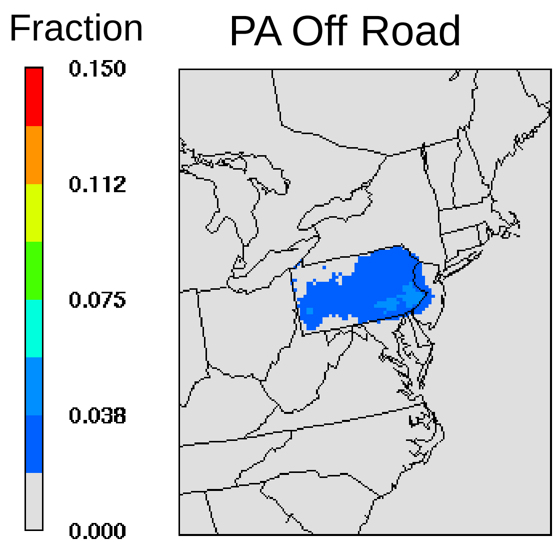
The states are interested in the fraction of Ox-N deposition by key emission sectors (since rules typically are by sector) for 2020 CAIR conditions











The states are interested in the fraction of Ox-N deposition by key emission sectors (since rules typically are by sector) for 2020 CAIR conditions

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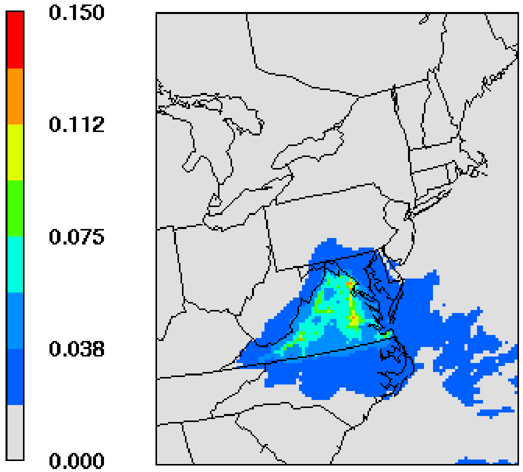
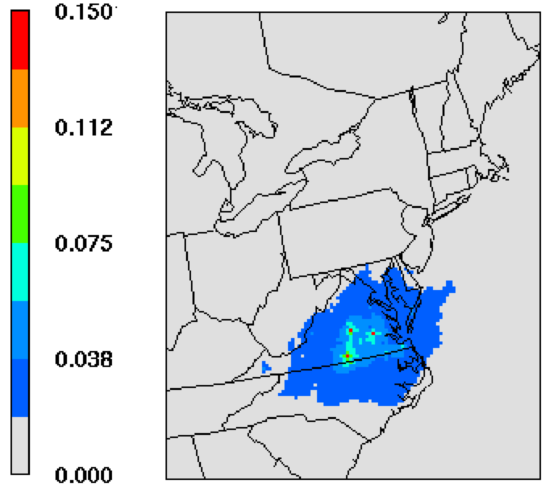
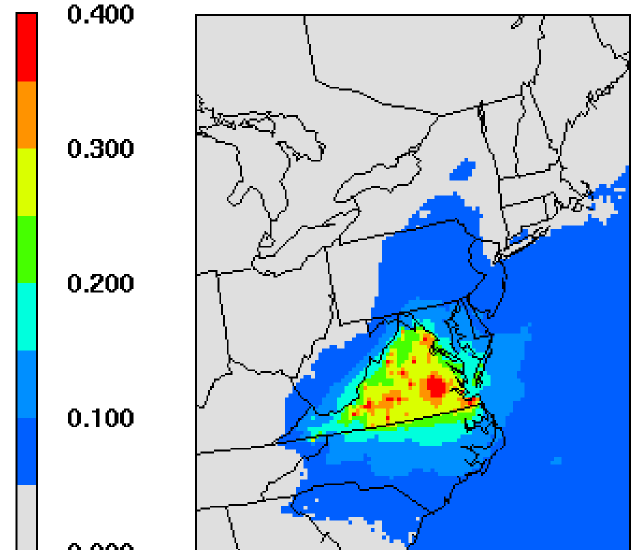
Fraction VA Mobile Sources



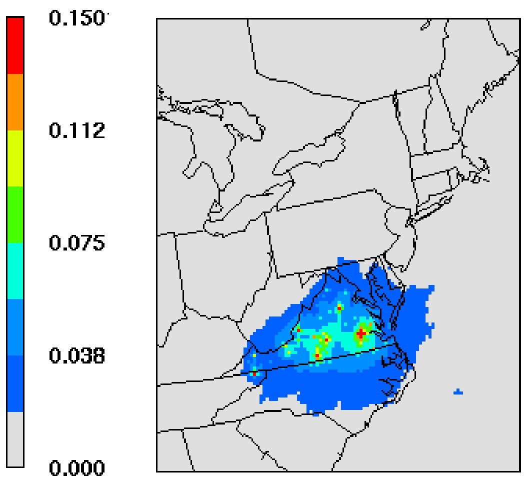
Fraction VA Power Plants



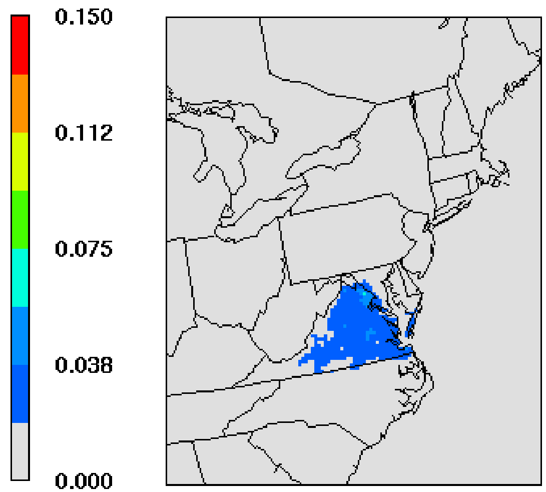
Fraction VA Total



Fraction VA Industry



Fraction VA Off Road



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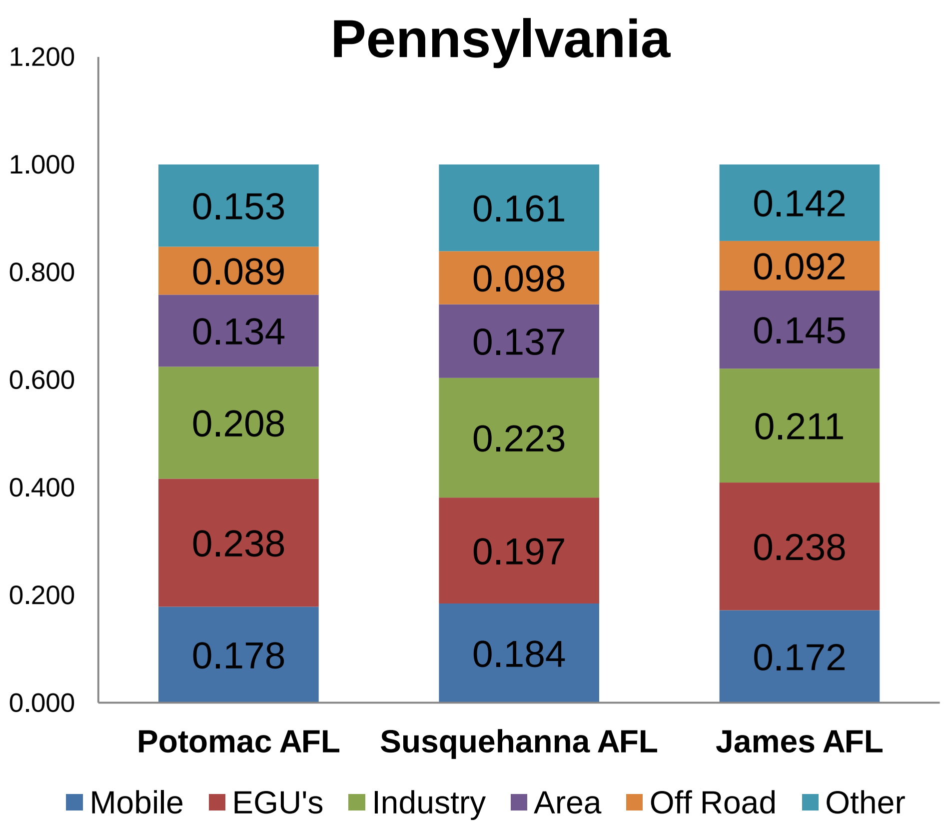
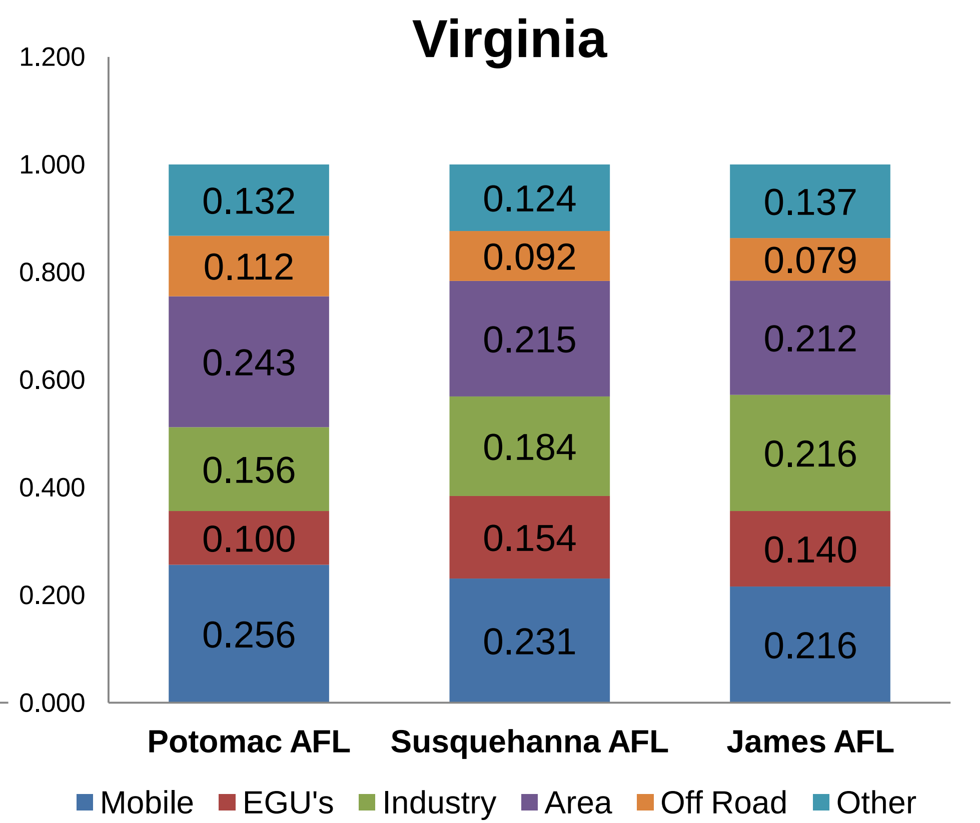
State Sector (2020 CAIR)

Relative fraction of kg-N contributed to tributary watershed deposition by state emission sectors: Normalized to 1.0





AFL = Above the Fall Line

Divide Ox-N deposition by NO_X emissions to create a deposition transfer function by state and sector = kg-N deposition / ton-N emissions

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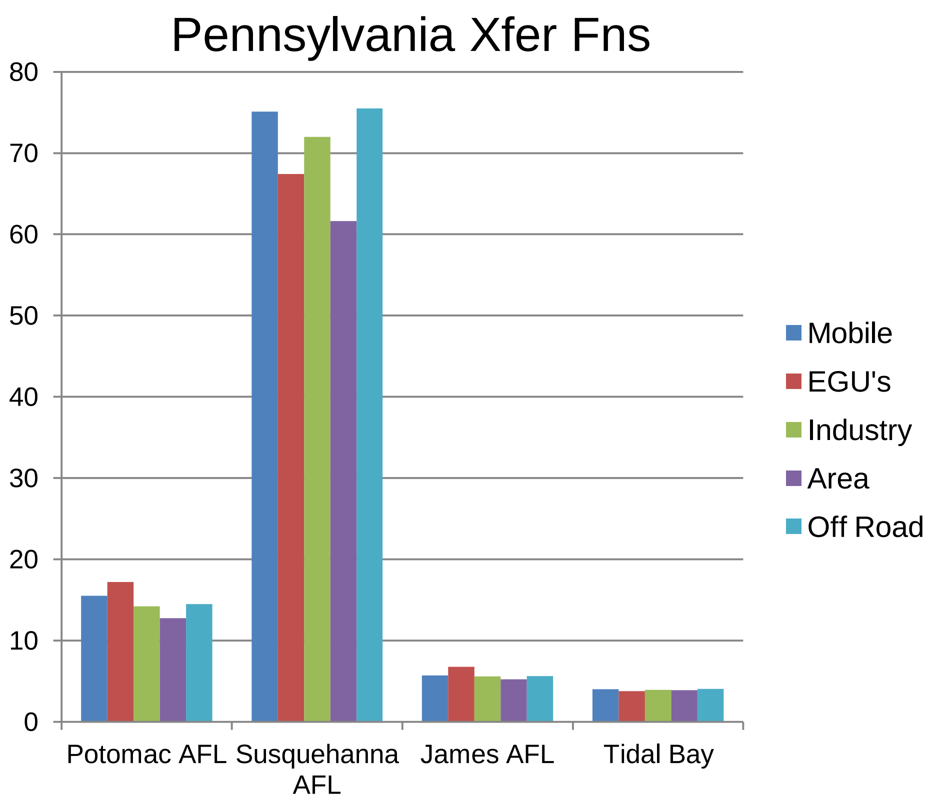

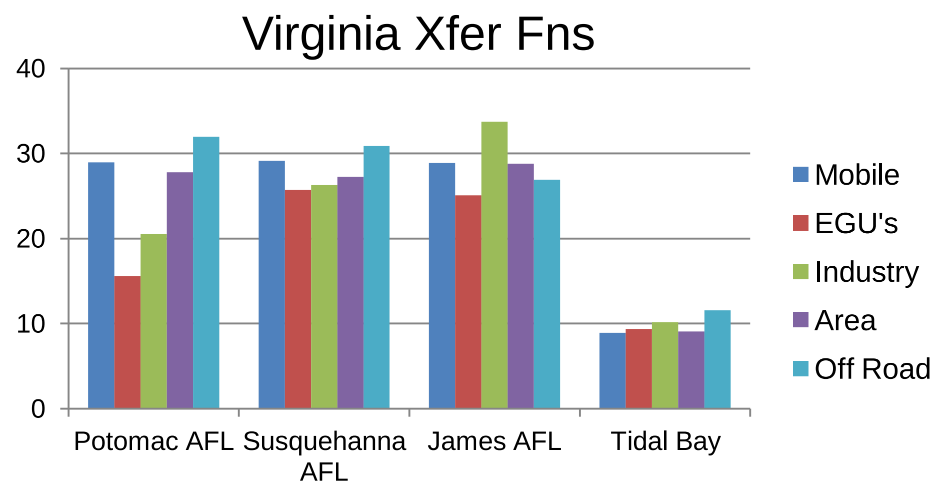

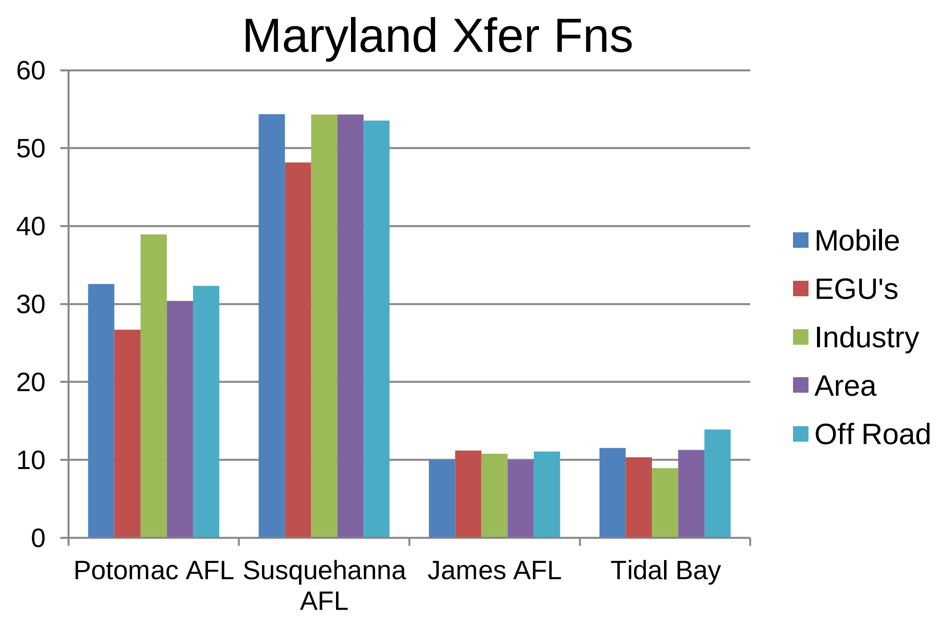

0-10 on Y scale approximately the same height for each graph

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The deposition transfer function for the tributary can then be multiplied by a load transfer function from the watershed model to estimate a final tributary-based load to the Bay

Ox-N Deposition Transfer Function
Pennsylvania

PA	Potomac AFL	SusquehannaAFL	James AFL	Tidal Bay		State-Sector Emissions
Sector	Xfer Fn*	Xfer Fn*	Xfer Fn*	Xfer Fn*		tons-N
Mobile	15.52	75.09	5.68	4.01		17,742.0
EGU's	17.18	67.42	6.75	3.76		21,183.9
Industry	14.19	72.00	5.56	3.93		22,552.1
Area	12.76	61.62	5.22	3.87		16,170.5
Off Road	14.48	75.51	5.62	4.04		9,373.2
*Xfer Fn = kg-N deposition/ton-N emissions						

For Perspective: What impact would Pennsylvania Diesel Rule NO_X emission reductions have?

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Estimated reduction: 736 tons NO_X = 224.1 tons-N (0.3045 conversion)

Impact of PA State-wide Diesel Rule NO_X Emission Reduction					
	PA Mobile Xfer Fn	ΔKg-N Deposition (x 224.1)	% Trib. Deposition	Δkg-N load Delivered* (x0.1107)	Δlb-N load Delivered (x 2.2)
Potomac AFL	15.52	3,478	0.030%	385	847
Susquehanna AFL	75.09	16,828	0.054%	1,863	4,098
James AFL	5.68	1,273	0.016%	141	310
Tidal Bay	4.01	899	0.022%	899	1,978

*Average tributary load transfer coefficient from the watershed model; no attenuation to Tidal Bay

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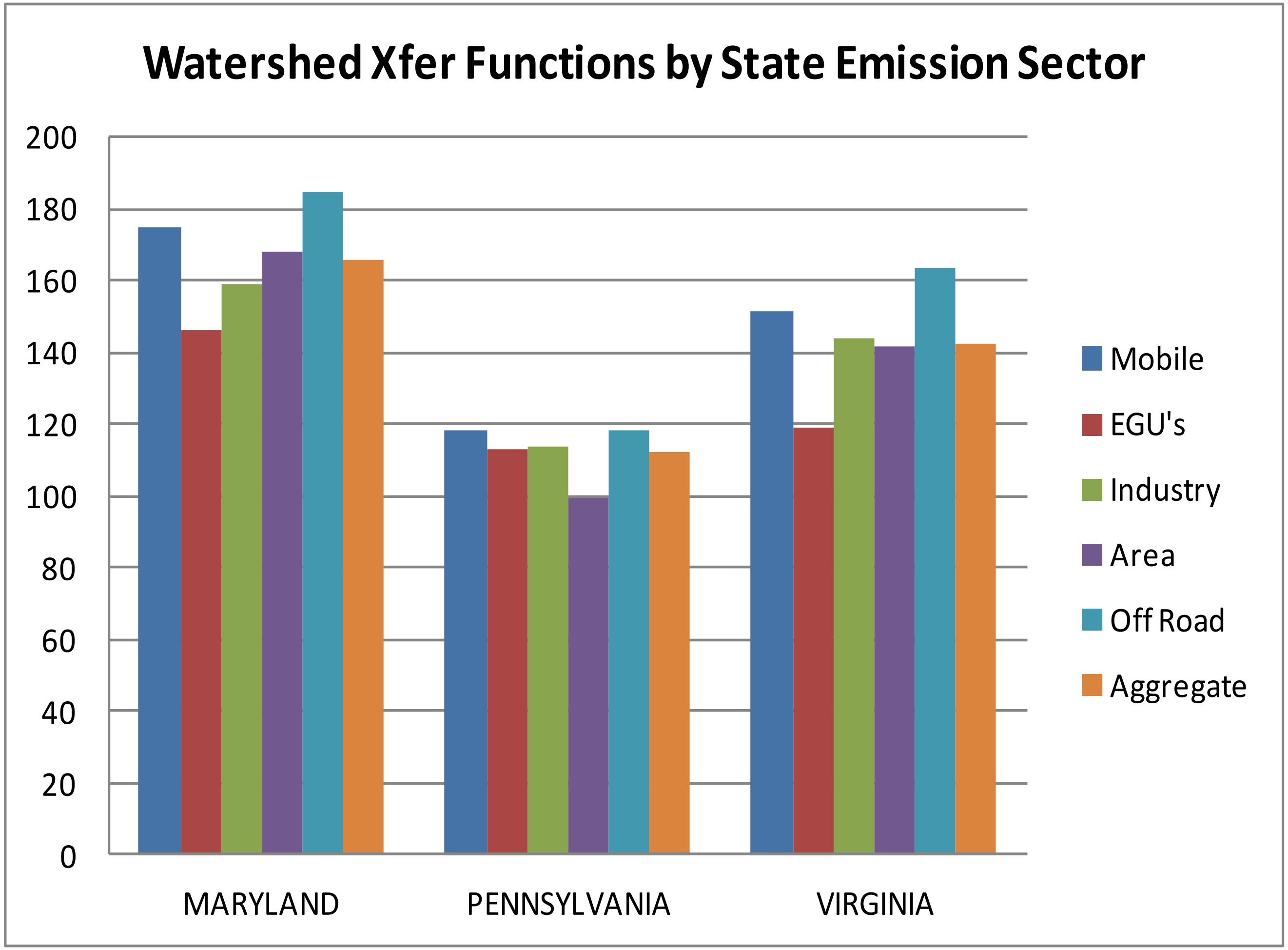
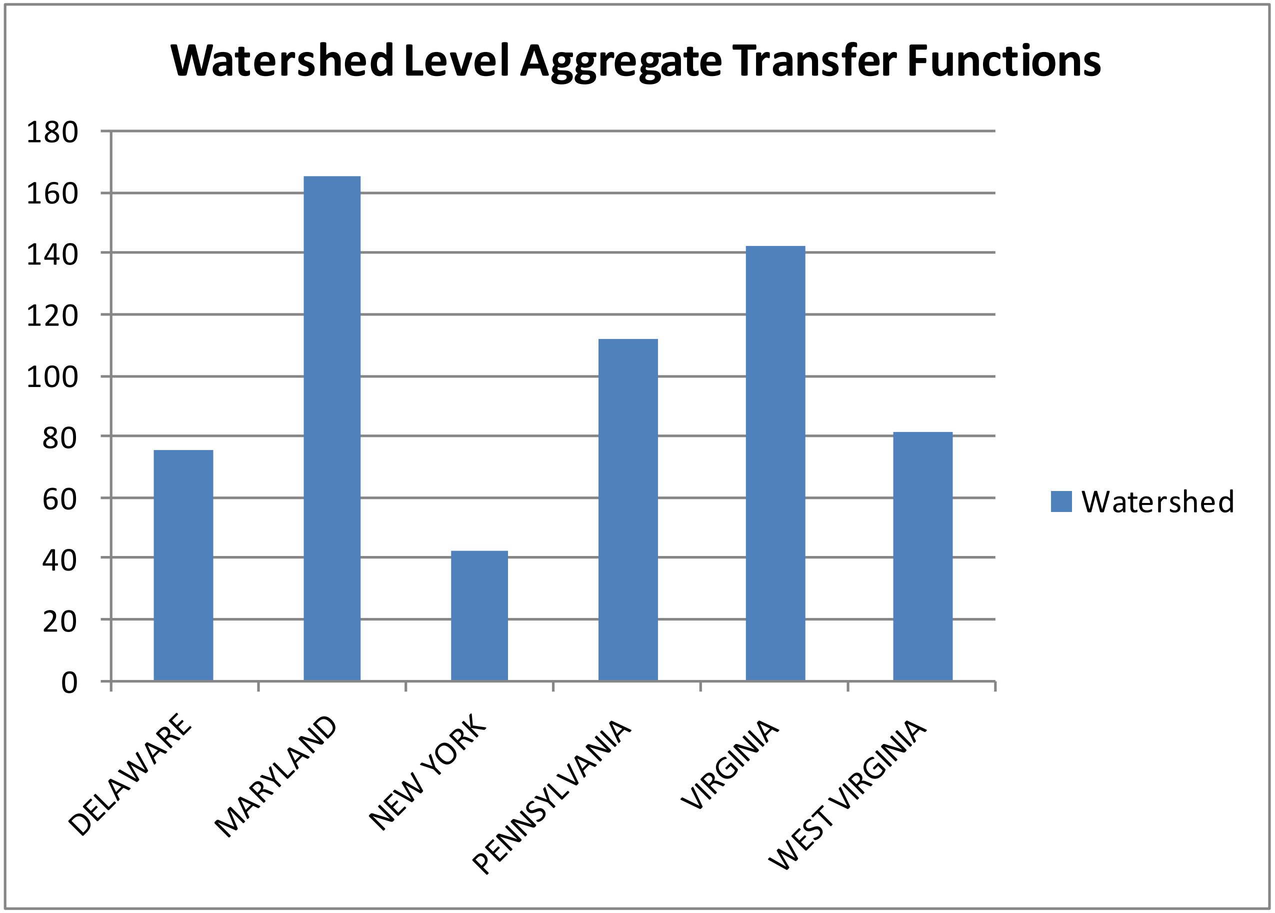
New Direction

- We clearly need to look at more than one sector at a time to achieve sufficient loading reductions
- We most likely need to look at more than one state
- It makes sense to work at the watershed level rather than the tributary level
- We would like to see how much each state is contributing to the deposition to the watershed area in other states as well as to itself
- So it makes sense to orient the analysis towards emitting states and the watershed area of receiving states

Transfer Functions at the Watershed Level by Sector are Similar



Transfer Functions at the Watershed Level by State Show Differences



The Aggregate State Transfer Functions at the Watershed Level can be Parsed to the Watershed Area within each State

State Level Transfer Coefficients to State Watershed Area						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N
Delaware	5.40	2.31	0.44	0.87	1.10	0.44
Maryland	19.46	57.16	5.30	14.33	20.95	10.60
New York	5.31	7.25	11.50	10.47	4.76	4.73
Pennsylvania	23.86	49.09	16.37	62.28	24.79	28.11
Virginia	19.55	43.34	7.84	20.59	85.05	27.70
W. Virginia	1.88	6.04	1.03	3.73	5.50	9.88
WaterSHED Aggregate	75.46	165.19	42.49	112.27	142.15	81.47

An Example of State NO_X Emission Changes Summed Across All Sectors For All of the Bay States

State Level NO_X Emission Changes						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Sector ↓	tons-NOx	tons-NOx	tons-NOx	tons-NOx	tons-NOx	tons-NOx
Area	-1,215	-10,939	-27,856	-3,126	-29,606	17,204
Off Road	-393	-1,796	-7,340	-5,860	6,307	-4,269
Mobile	1,727	2,877	14,302	30,005	-4,073	1,454
EGU's	-5,175	-7,228	-19,499	-13,471	-17,783	-10,979
Industry	-1,602	3,498	-5,045	-19,499	-13,541	-25,508
TOTAL	-6,659	-13,588	-45,438	-11,950	-58,696	-22,098

Example estimates from Mary Jane Rutkowski

Converting the NO_X Emission Changes to tons-N

State Level Tons-N Emission Changes						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Sector ↓	tons-N	tons-N	tons-N	tons-N	tons-N	tons-N
Area	370.0	3,330.5	8,481.1	951.7	9,013.8	-5,238.1
Off Road	119.8	546.9	2,234.7	1,784.2	-1,920.2	1,299.8
Mobile	-525.7	-875.8	-4,354.5	-9,135.3	1,239.9	-442.7
EGU's	1,575.6	2,200.5	5,936.7	4,101.2	5,414.3	3,342.7
Industry	487.8	-1,065.1	1,535.9	5,936.6	4,122.7	7,766.2
TOTAL	2,027.4	4,137.0	13,834.0	3,638.4	17,870.5	6,728.0

Example estimates from Mary Jane Rutkowski

Multiplying by the Transfer Function to Calculate the kg-N Deposition Change

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Change in Deposition to Watershed Area due to Change in State Emissions						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep
Delaware	10,954.8	9,558.1	6,151.2	3,168.1	19,585.5	2,958.6
Maryland	39,448.9	236,461.2	73,355.2	52,154.9	374,431.1	71,301.5
New York	10,758.6	30,002.0	159,071.5	38,107.4	85,011.4	31,854.3
Pennsylvania	48,376.8	203,076.9	226,518.9	226,603.5	442,931.1	189,151.6
Virginia	39,634.0	179,294.9	108,407.1	74,910.2	1,519,893.5	186,370.6
W. Virginia	3,810.8	24,973.5	14,262.6	13,557.5	98,375.9	66,490.3
WaterSHED Deposition	152,984.0	683,366.6	587,766.5	408,501.5	2,540,228.5	548,126.9

Multiplying by the Attenuation Factor (0.1107) to Calculate the kg-N Delivered Load Change

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Change in Load Delivered to Bay due to Change in Watershed Deposition						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N	kg-N	kg-N	kg-N	kg-N	kg-N
Delaware	1,212.7	1,058.1	680.9	350.7	2,168.1	327.5
Maryland	4,367.0	26,176.3	8,120.4	5,773.5	41,449.5	7,893.1
New York	1,191.0	3,321.2	17,609.2	4,218.5	9,410.8	3,526.3
Pennsylvania	5,355.3	22,480.6	25,075.6	25,085.0	49,032.5	20,939.1
Virginia	4,387.5	19,847.9	12,000.7	8,292.6	168,252.2	20,631.2
W. Virginia	421.9	2,764.6	1,578.9	1,500.8	10,890.2	7,360.5
Total Load Change (kg-N)	16,935.3	75,648.7	65,065.8	45,221.1	281,203.3	60,677.7

Converting the kg-N to lbs-N Delivered Load Change

Change in Load Delivered to Bay due to Change in Watershed Deposition						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	lb-N	lb-N	lb-N	lb-N	lb-N	lb-N
Delaware	2,667.9	2,327.8	1,498.1	771.6	4,769.8	720.5
Maryland	9,607.4	57,587.8	17,864.9	12,701.8	91,189.0	17,364.8
New York	2,620.2	7,306.7	38,740.3	9,280.7	20,703.7	7,757.8
Pennsylvania	11,781.7	49,457.4	55,166.4	55,187.0	107,871.4	46,066.0
Virginia	9,652.5	43,665.5	26,401.5	18,243.6	370,154.9	45,388.7
W. Virginia	928.1	6,082.0	3,473.5	3,301.8	23,958.5	16,193.0
Total Load Change (lb-N)	37,257.7	166,427.1	143,144.7	99,486.5	618,647.2	133,490.8

Total Load Reduction to Bay = 1,198,454 lbs

Summary

- Now seeing a potential for significant load reductions
  - Makes sense to work at the watershed level
  - Makes sense to use total state-level NO_X emission reductions
  - Makes sense to combine NO_X emission reductions across states
    - See if the states can combine or share efforts on this
- States seem to like knowing what they are doing to the watershed deposition in other states
- States seem to like knowing what other state emissions are doing to deposition in their state
- Working at the state level may be a viable approach that is worth pursuing

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Thanks

Questions?