Chesapeake Climate Change Assessment Using A Suite of Atmospheric, Land Use, Watershed, and Estuarine Models

CBP Management Board

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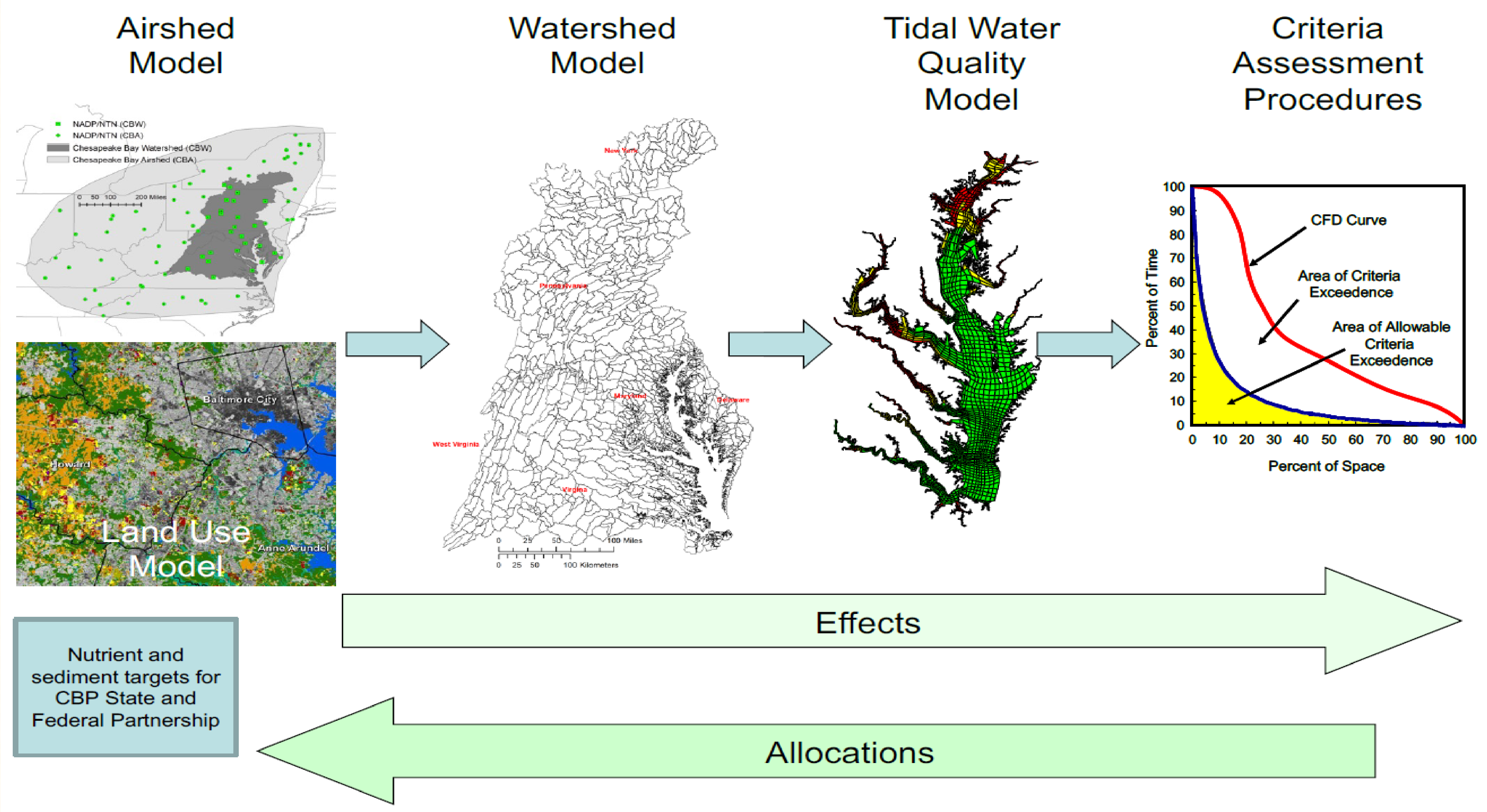
Science, Restoration, Partnership

Raison d'être

"Never make significant societal decisions that have large scale or long-term consequences without running simulations of the future course of events to ensure that we're doing the right thing."

Iain M. Banks ***The Hydrogen Sonata***

The CBP Climate Change Assessment



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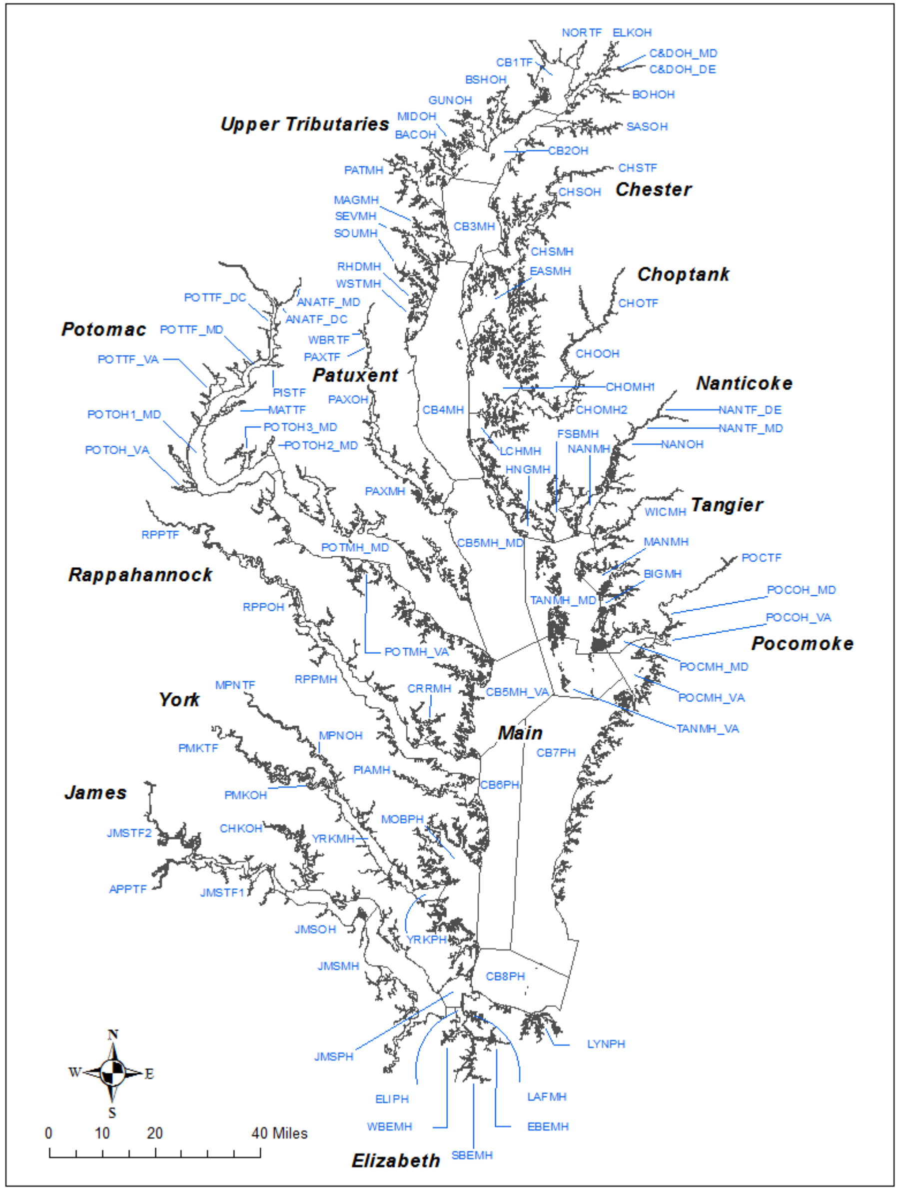
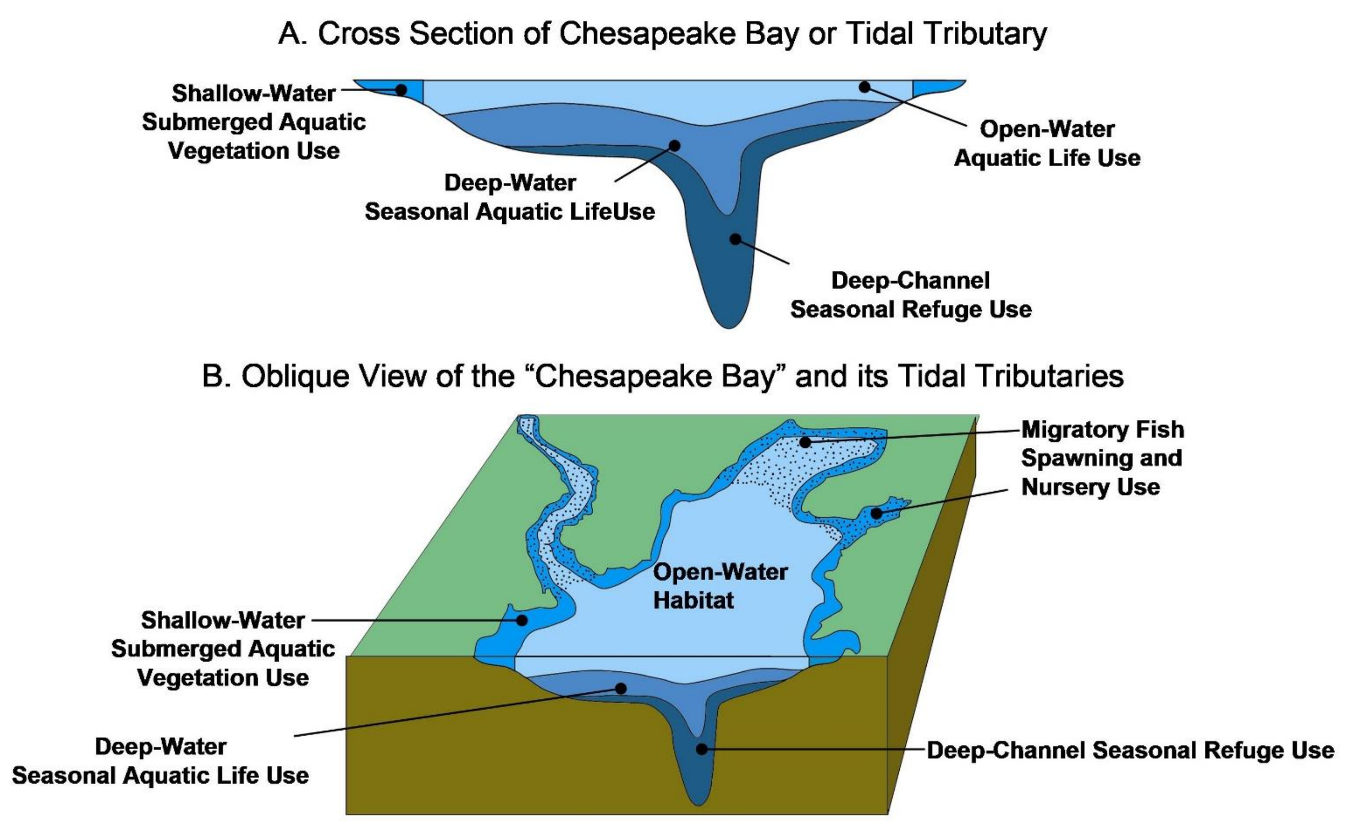
Overview of Bay Designated Uses





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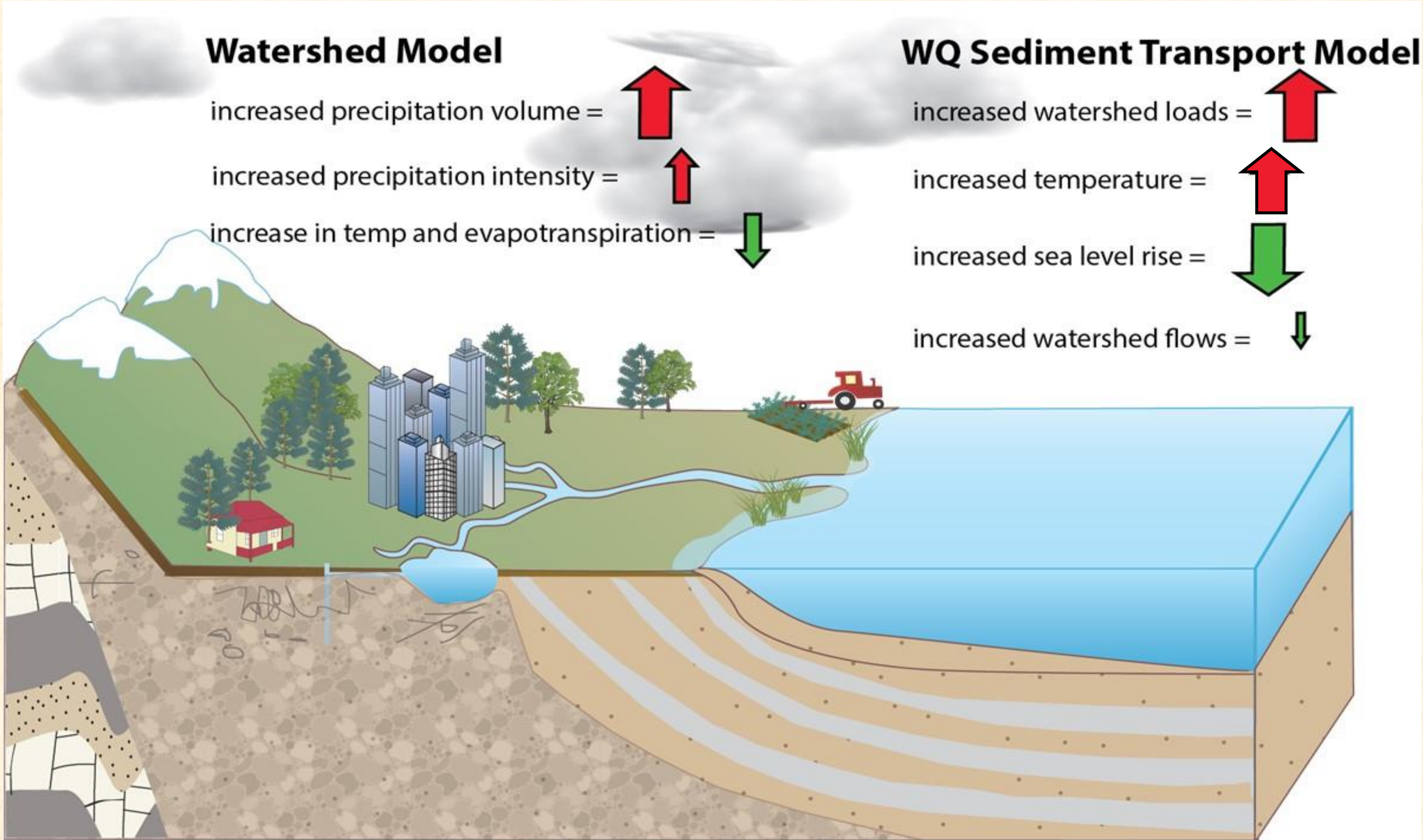
Components of Climate Change Effect on Tidal Hypoxia



Elements of Chesapeake Water Quality Climate Risk Assessment

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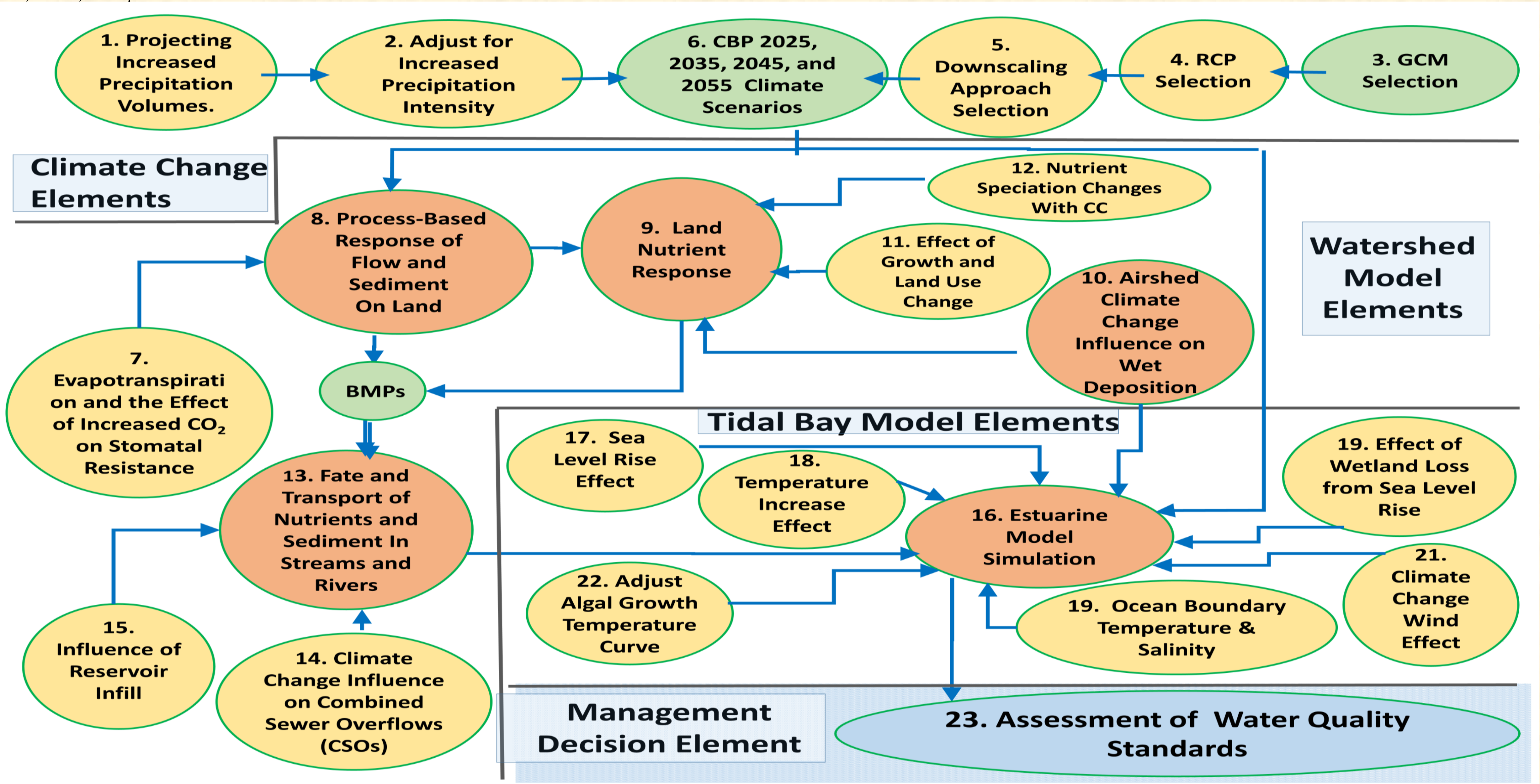

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Big Things & Little Things: Climate Change & Water Quality

Big things:

Higher precipitation volume, flows, and N, P, S loads.

Temperature

Sea Level Rise

Little things: **(Less than 3 percent change of total nitrogen load when comparing the 2055 climate change load estimates to the 1995 base conditions load.)**

Higher precipitation intensity.

Influence of temperature increases on phytoplankton biomass

Tidal wetland loss (then about midcentury it's a big thing)

Wind effects

CSOs

Greater wet deposition of atmospheric deposition of nitrogen

Increased CO_2 and stomatal resistance

Nutrient speciation changes

Elements of 2025 Climate Change (1995-2025)

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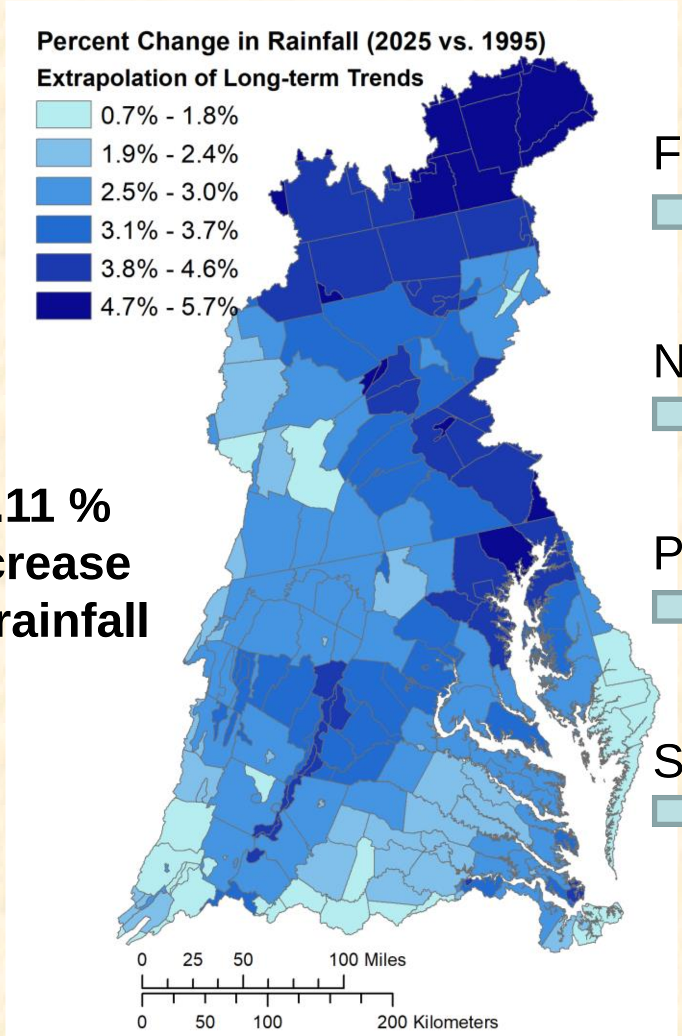
+3.11 % Increase in rainfall



Phase 6 Watershed Model

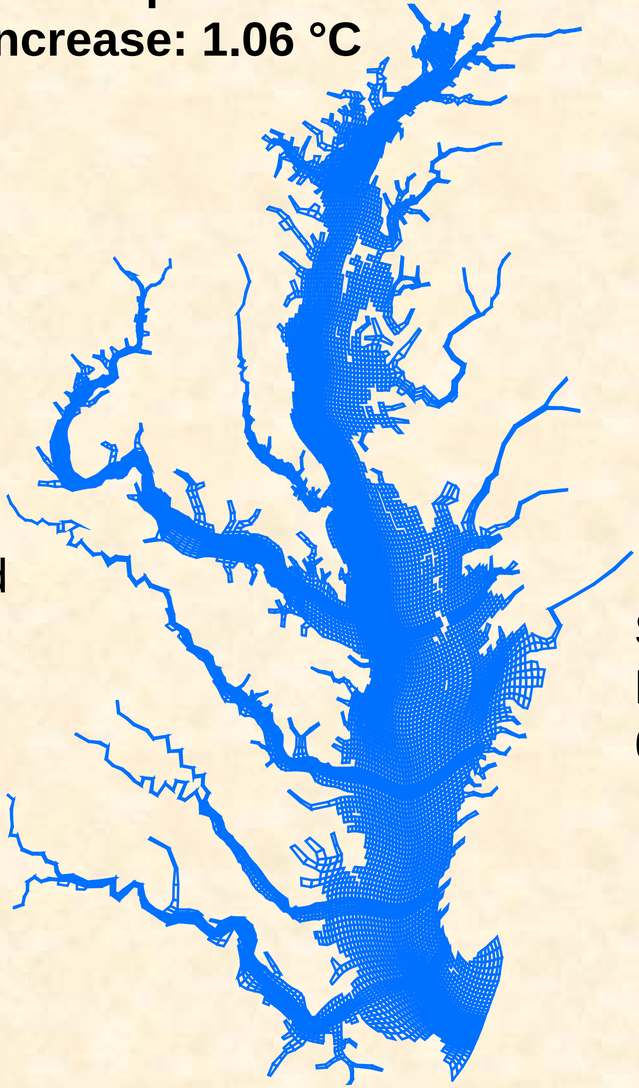
Flow
2.4% Increase

Nitrogen Load
2.6% Increase

Phosphorus Load
4.5% Increase

Sediment Load
3.8% Increase

Air-temperature increase: 1.06 °C



Model: CH3D-ICM
400m-1km Resolution

Sea Level Rise: 0.22m

Open boundary:
Temperature: +0.95 °C;
Salinity: +0.18 psu
(Thomas et al., 2017)

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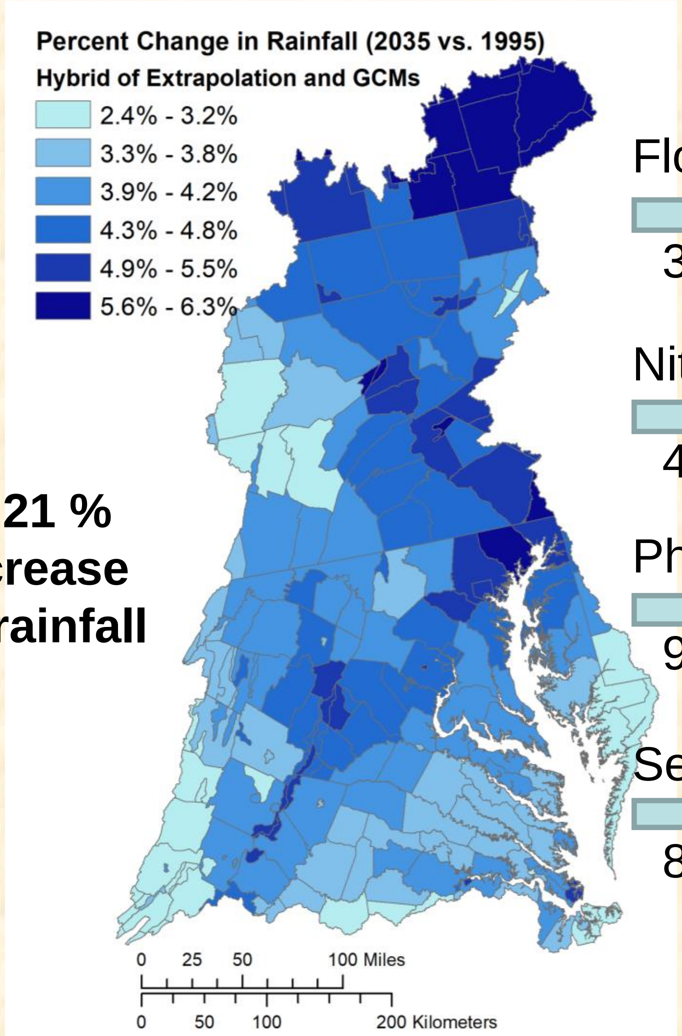
Elements of 2035 Climate Change (1995-2035)

Air-temperature increase: 1.39 °C



+4.21 % Increase in rainfall

Phase 6 Watershed Model

Flow

3.7% Increase

Nitrogen Load

4.7% Increase

Phosphorus Load

9.9% Increase

Sediment Load

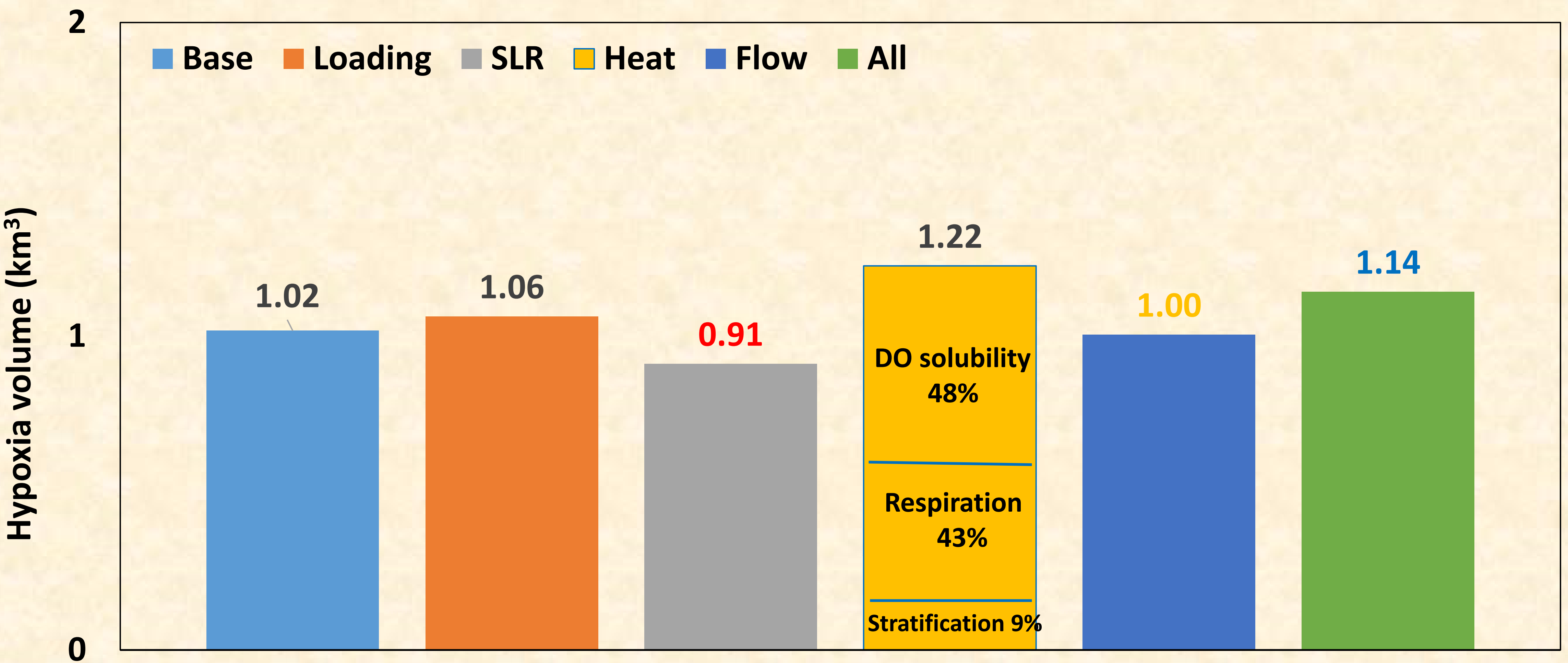
8.5% Increase

Model: CH3D-ICM
400m-1km Resolution

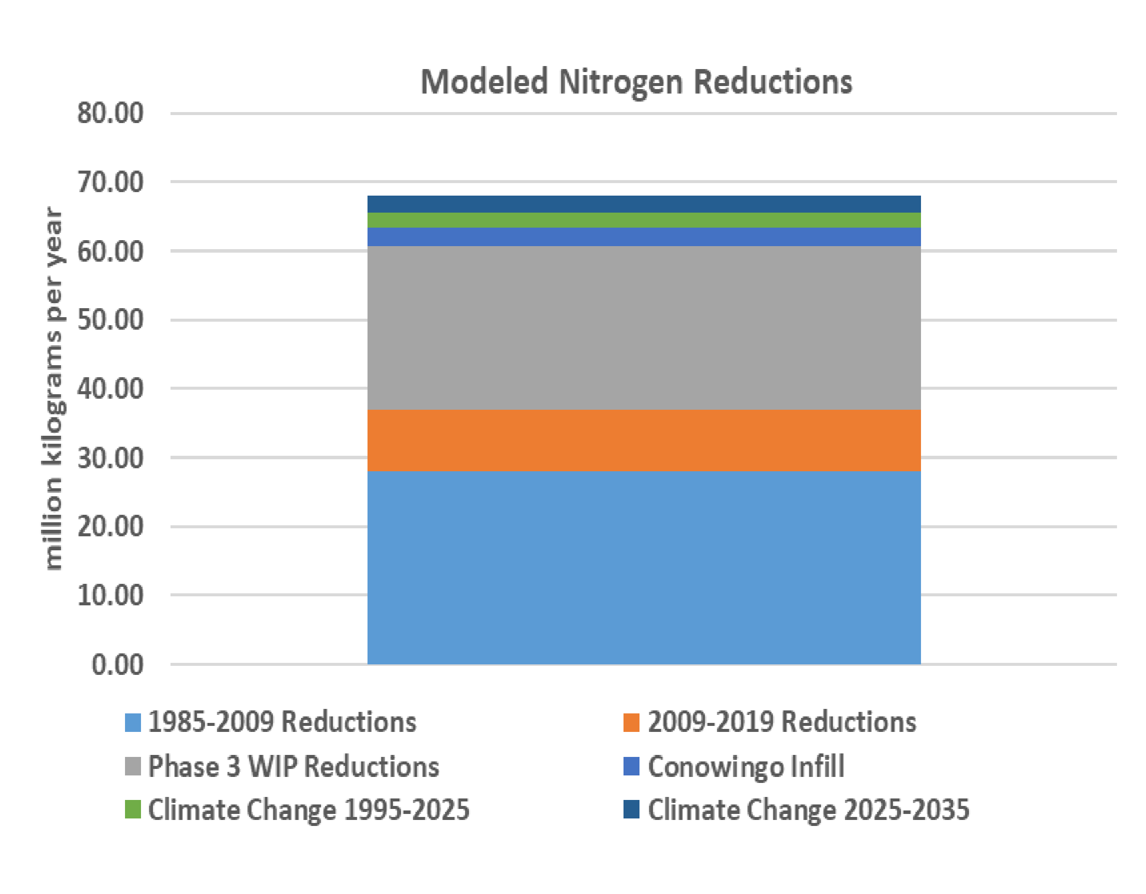
Sea Level Rise: 0.31m

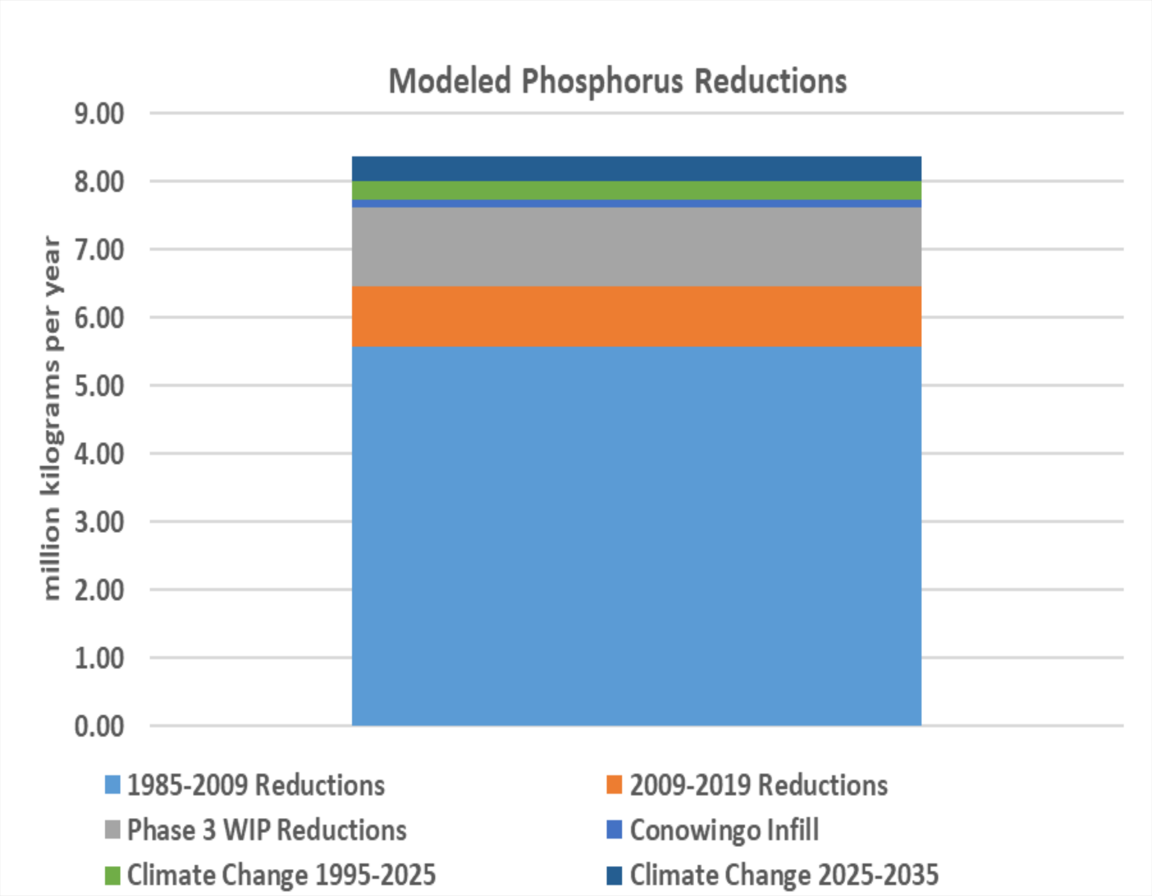
Open boundary:
Temperature: +1.32 °C;
Salinity: +0.25 psu
(Thomas et al., 2017)

Summer (Jun.-Sep.) Hypoxia Volume (<1 mg/l) 1991-2000 in the Whole Bay Under 2025 WIP3 Condition



Climate Target Loads in Perspective





Overall, the CBP found that a target load of 5 million pounds nitrogen and 0.6 million pounds phosphorus will be sufficient to offset 30 years of climate change in the Chesapeake Bay.

Model load reduction estimates from CAST-2019 (current version of the CBP watershed model)

The Importance to the CBP of Reducing Atmospheric Deposition of Nitrogen Through the National Clean Air Act

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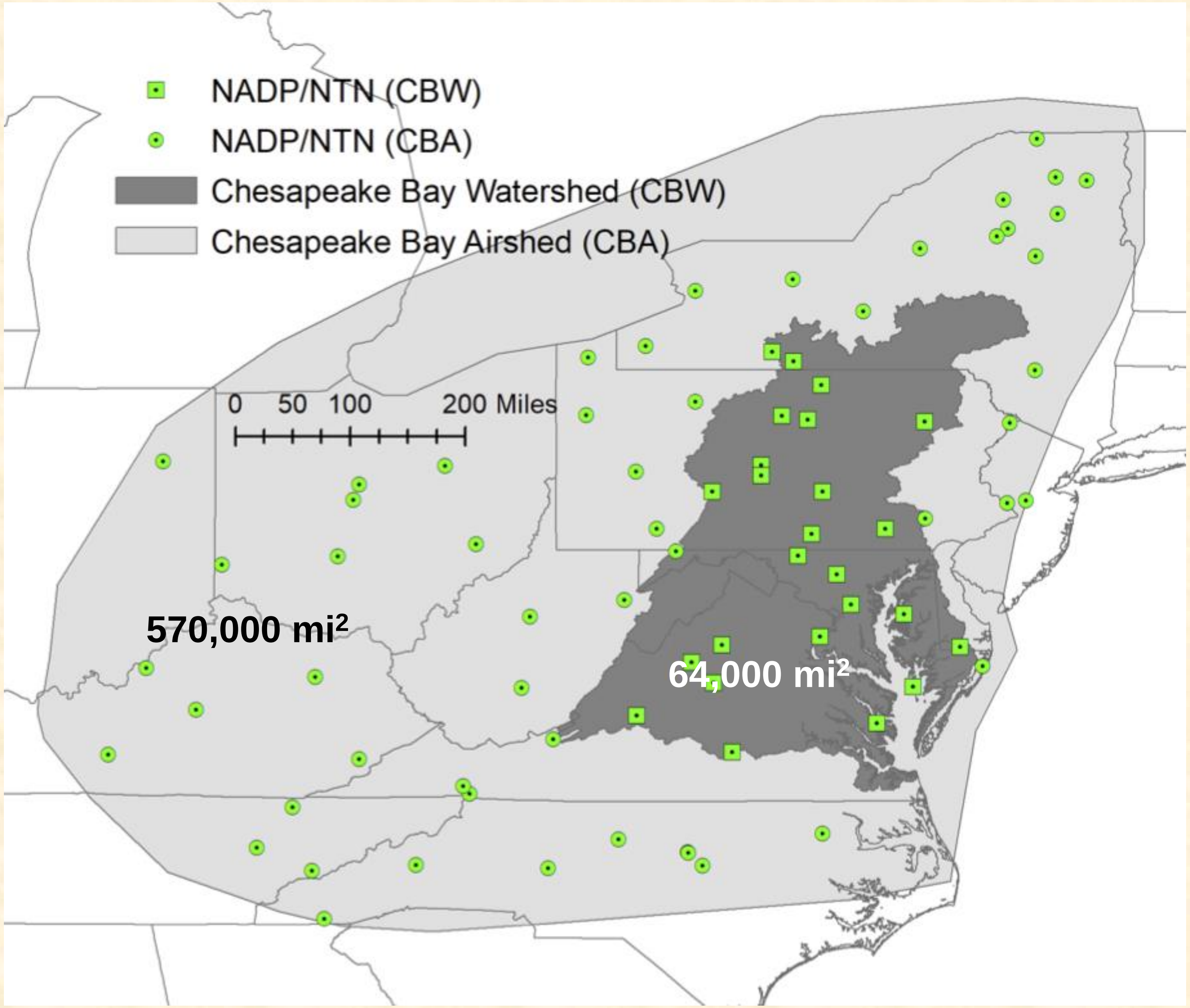
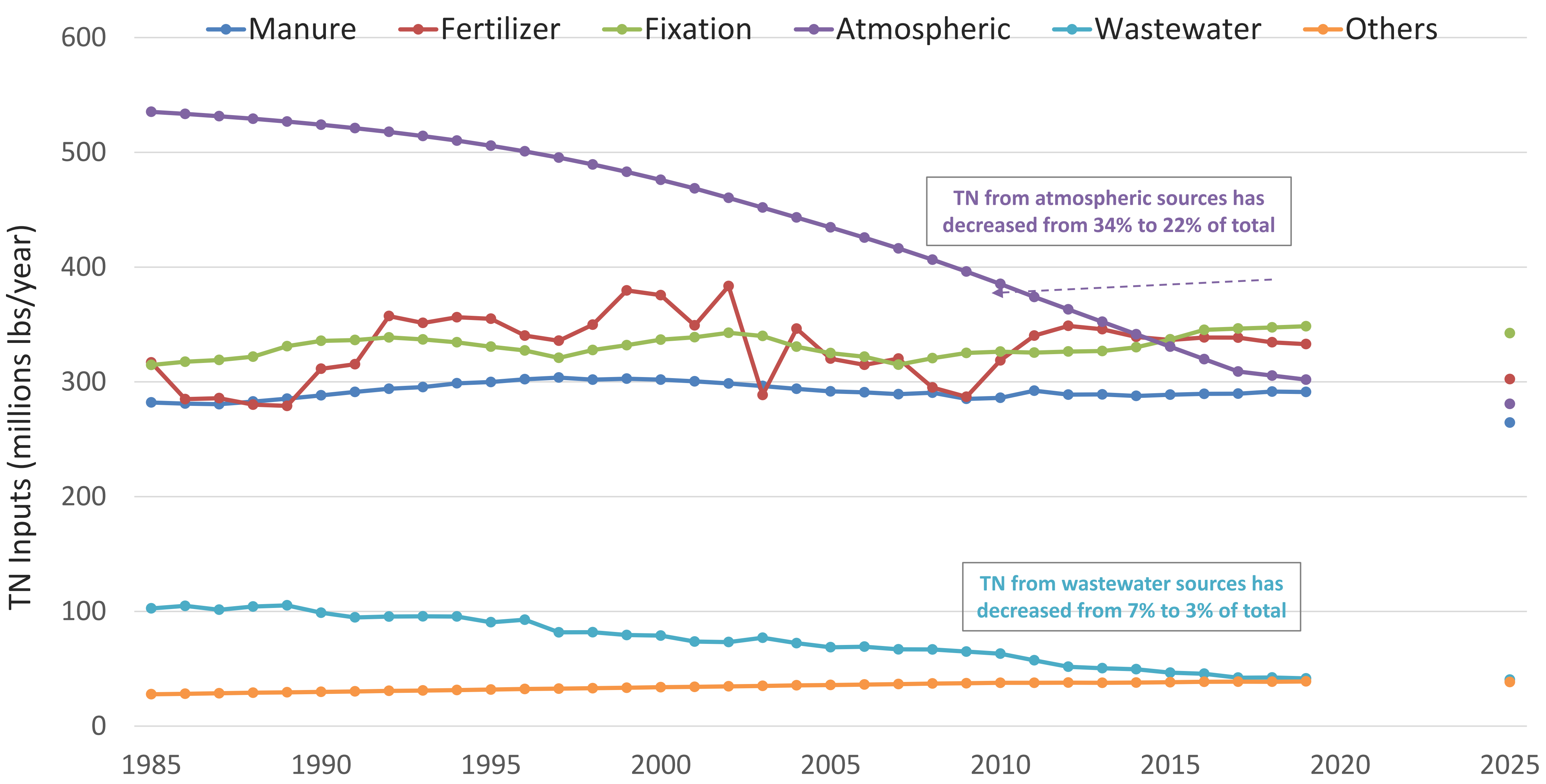
Chesapeake Airshed



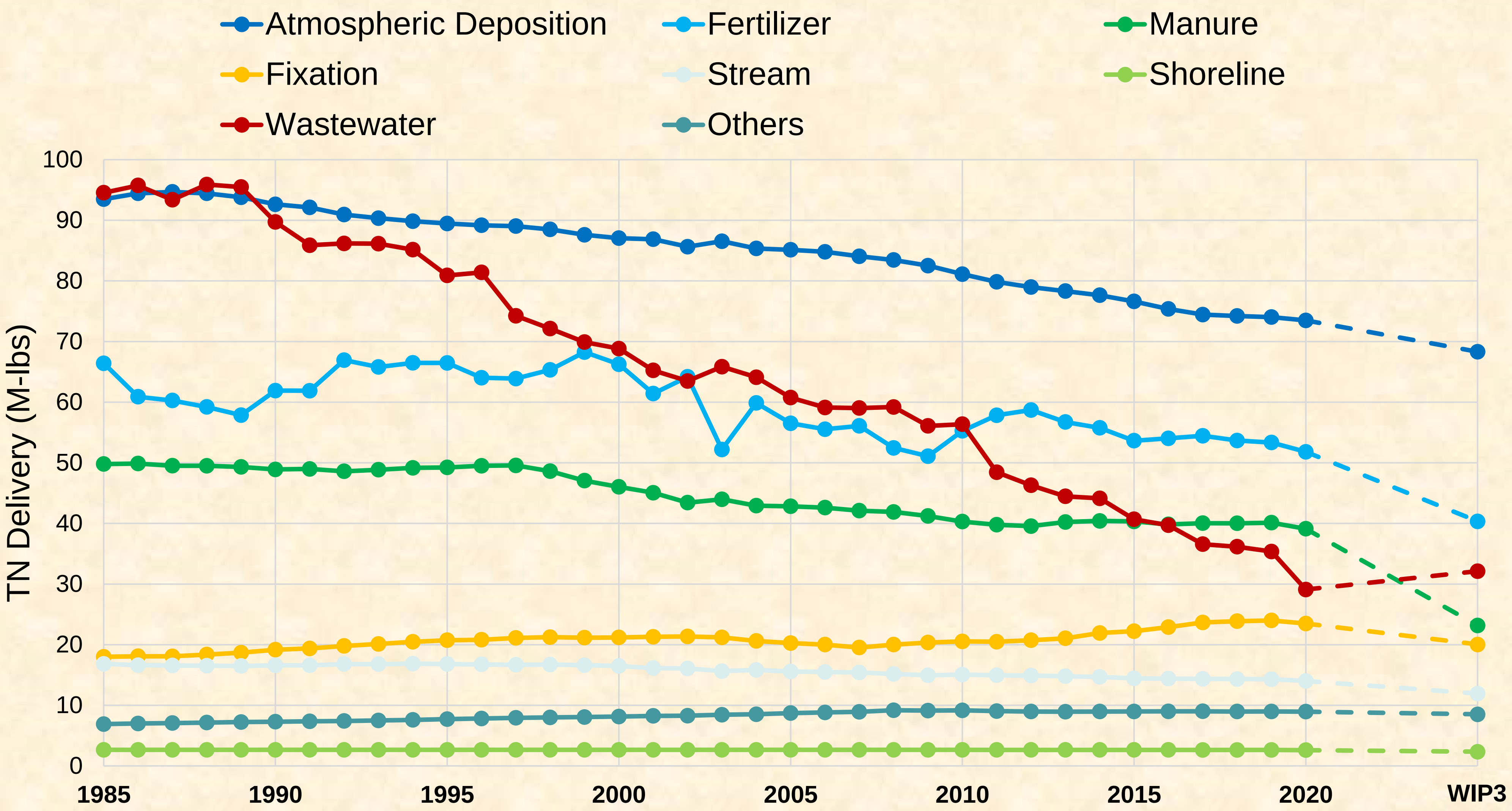
Phase 6 Estimates of Total Nitrogen (TN) Input to the Chesapeake Watershed

CAST 2019



Phase 6 Estimates of <u>Total Nitrogen (TN) Delivery</u> to the Chesapeake Bay

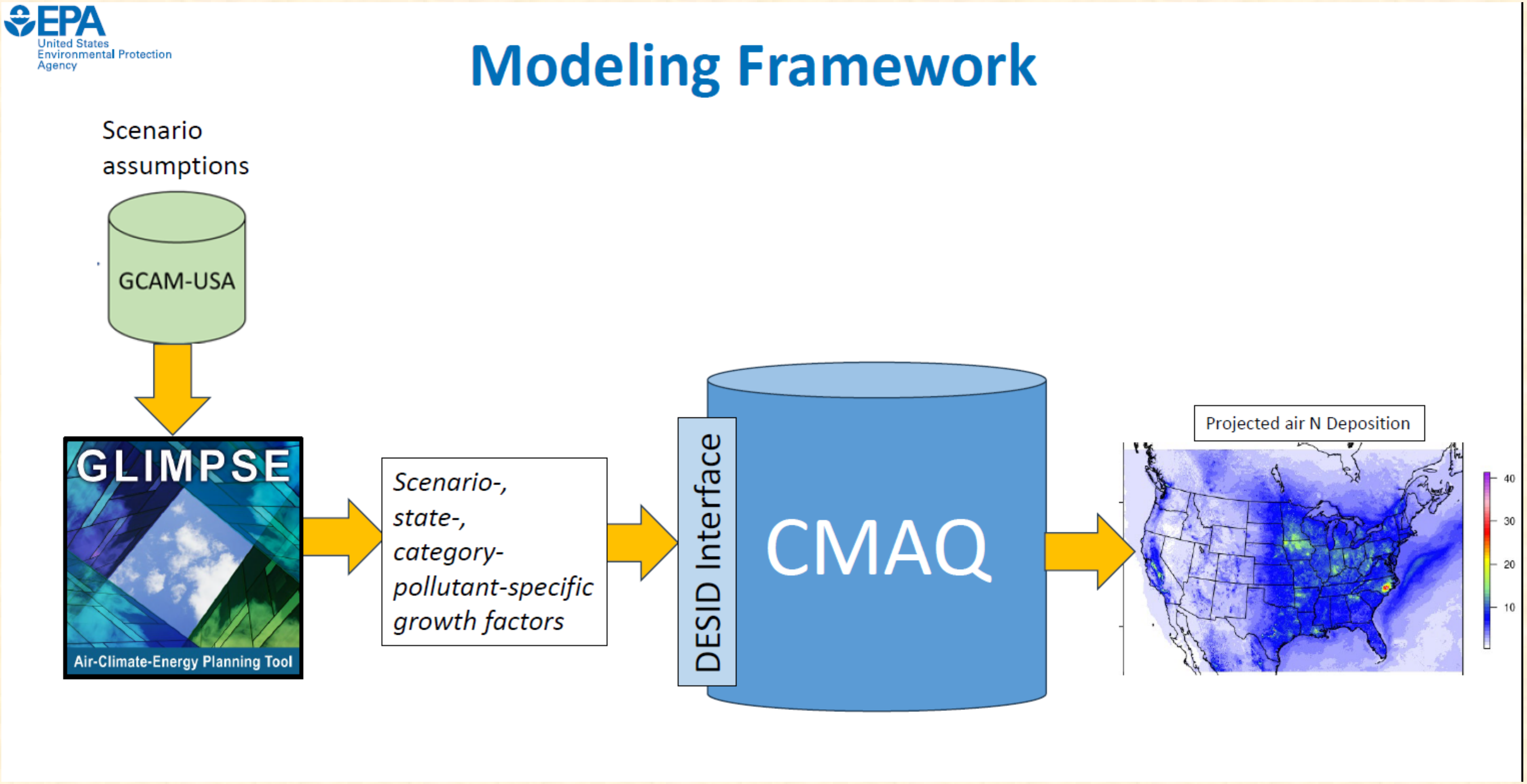
CAST 2019



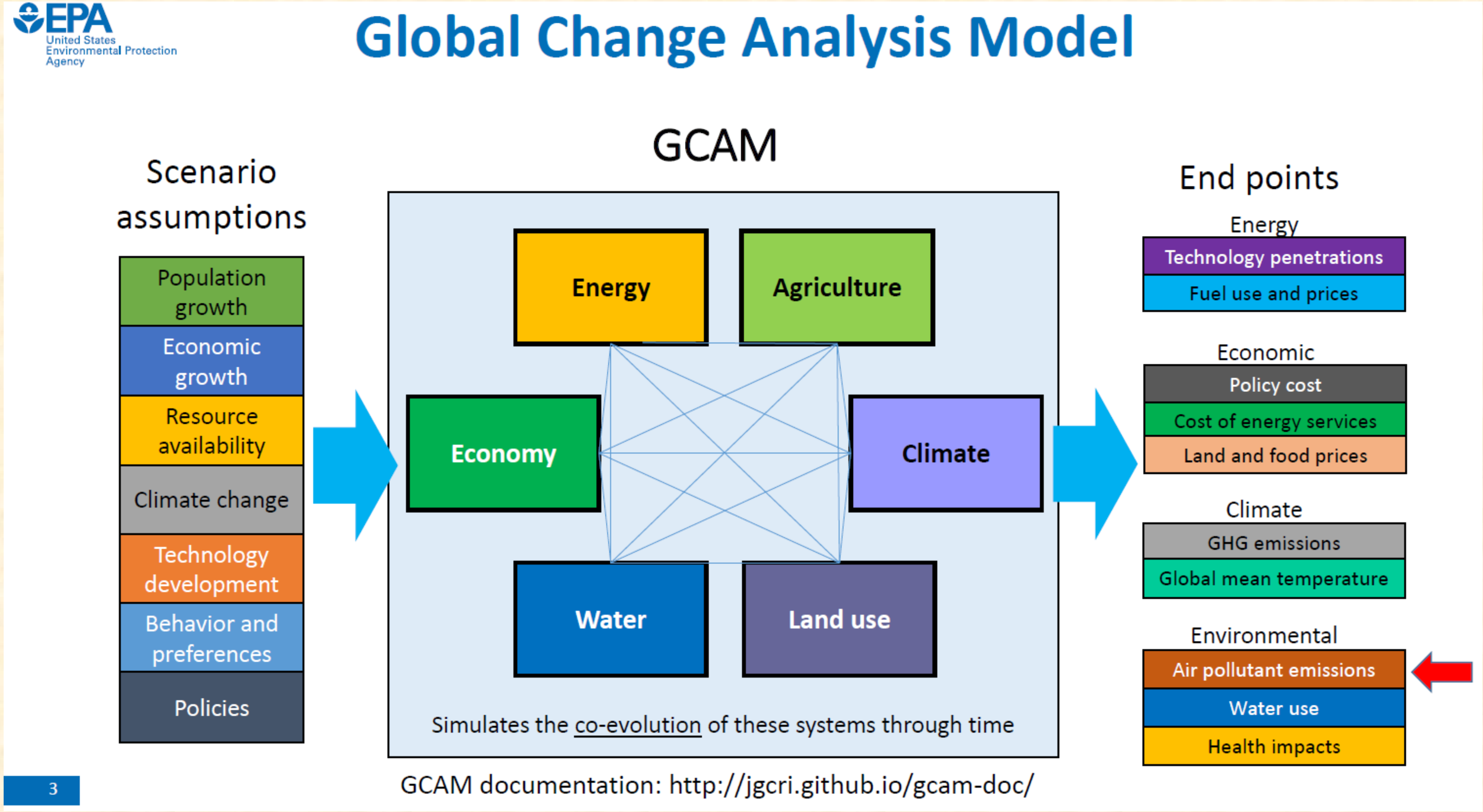
Others include Septic, Biosolids, Rapid Infiltration Basin, and Urban Spray Irrigation.

Estimated decreasing TN delivery is due a combination of changes in inputs, BMPs, and management actions.

Phase 6 Estimates of Total Nitrogen (TN) Input to the Chesapeake Watershed



Phase 6 Estimates of Total Nitrogen (TN) Input to the Chesapeake Watershed



CBP Airshed Model Scenario Design

IRA-LM: A “current condition” scenario that includes:

- Limited GHG mitigation and no additional air pollutant control requirements and Inflation Reduction Act (IRA).

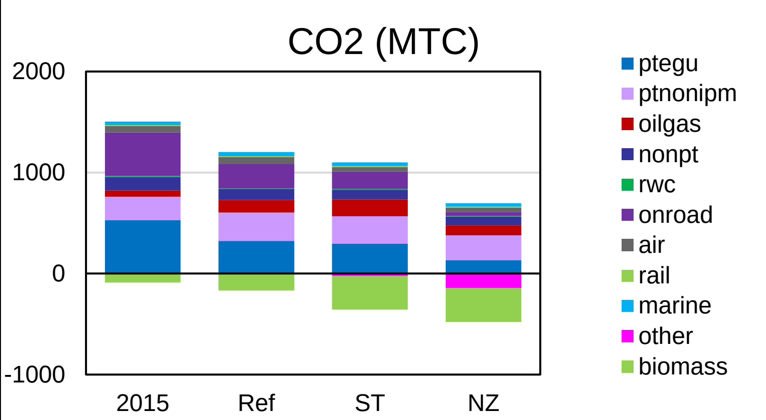
State Targets: A mitigation scenario that includes IRA-LM plus:

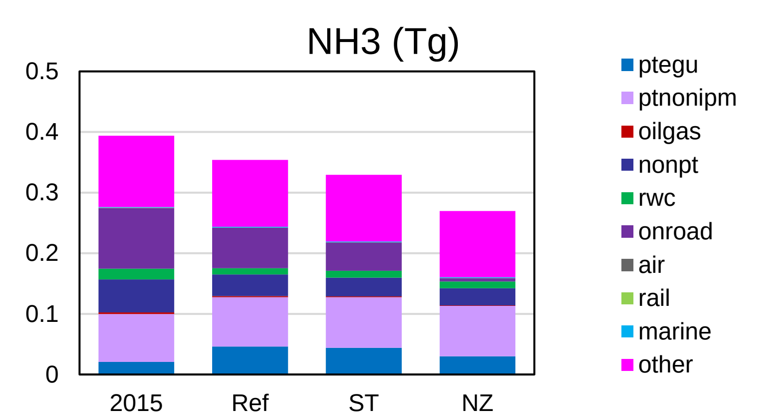
- State GHG reduction goals, implemented as regional CO_2 targets.
- New CA light-duty electrification targets adopted by Section 177 states.
- Medium- and Heavy-Duty Electrification MOU adopted by signatory states.

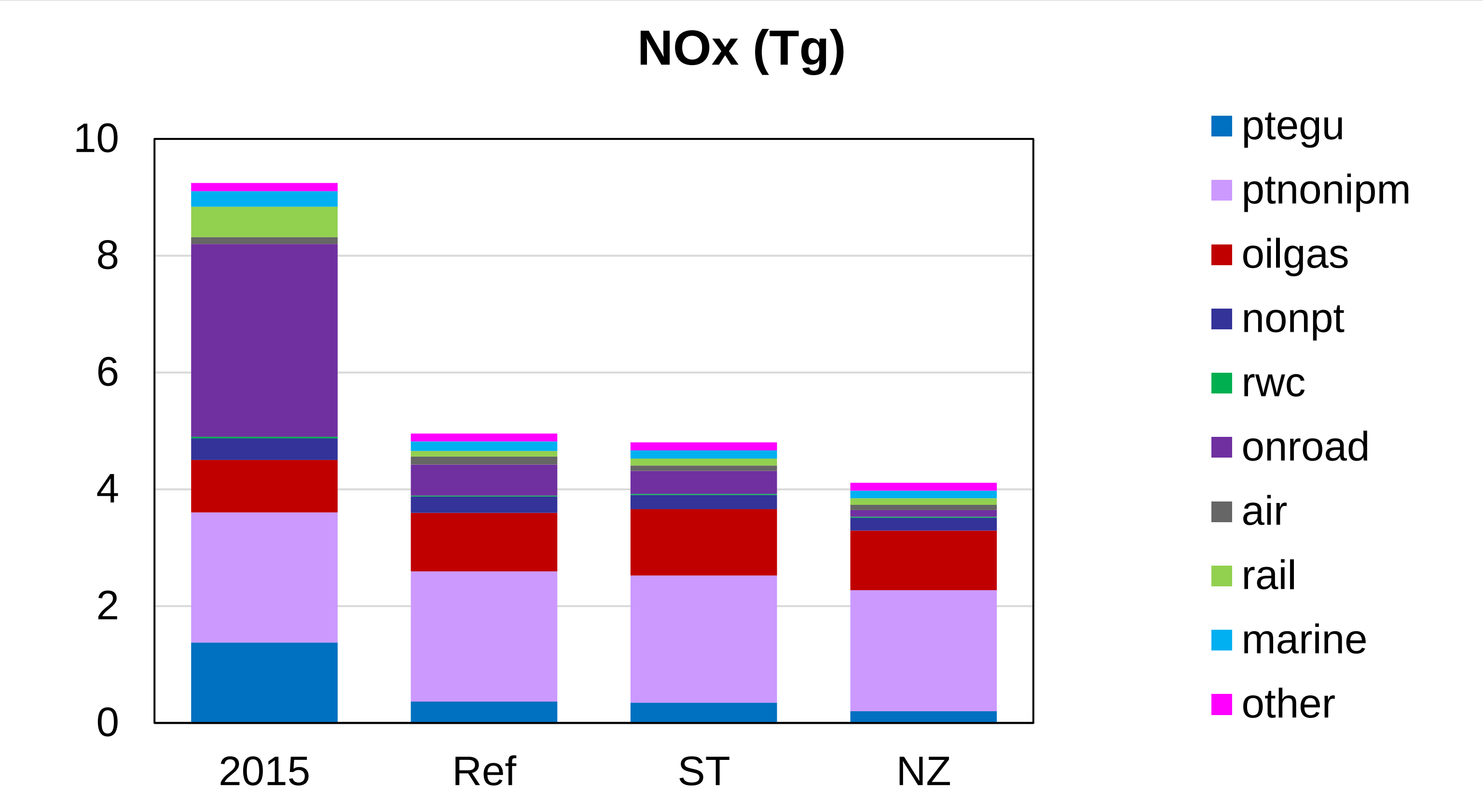
NetZeroZEV: A mitigation scenario that includes IRA-LM, State Targets plus:

- A national, economy-wide declining CO_2 cap reaches Net-Zero by 2050.
- Transportation electrification targets in *StateTargets* adopted nationally.

National CO2 and NOx GCAM Projections







CO2 emissions relative to *Reference* in same year

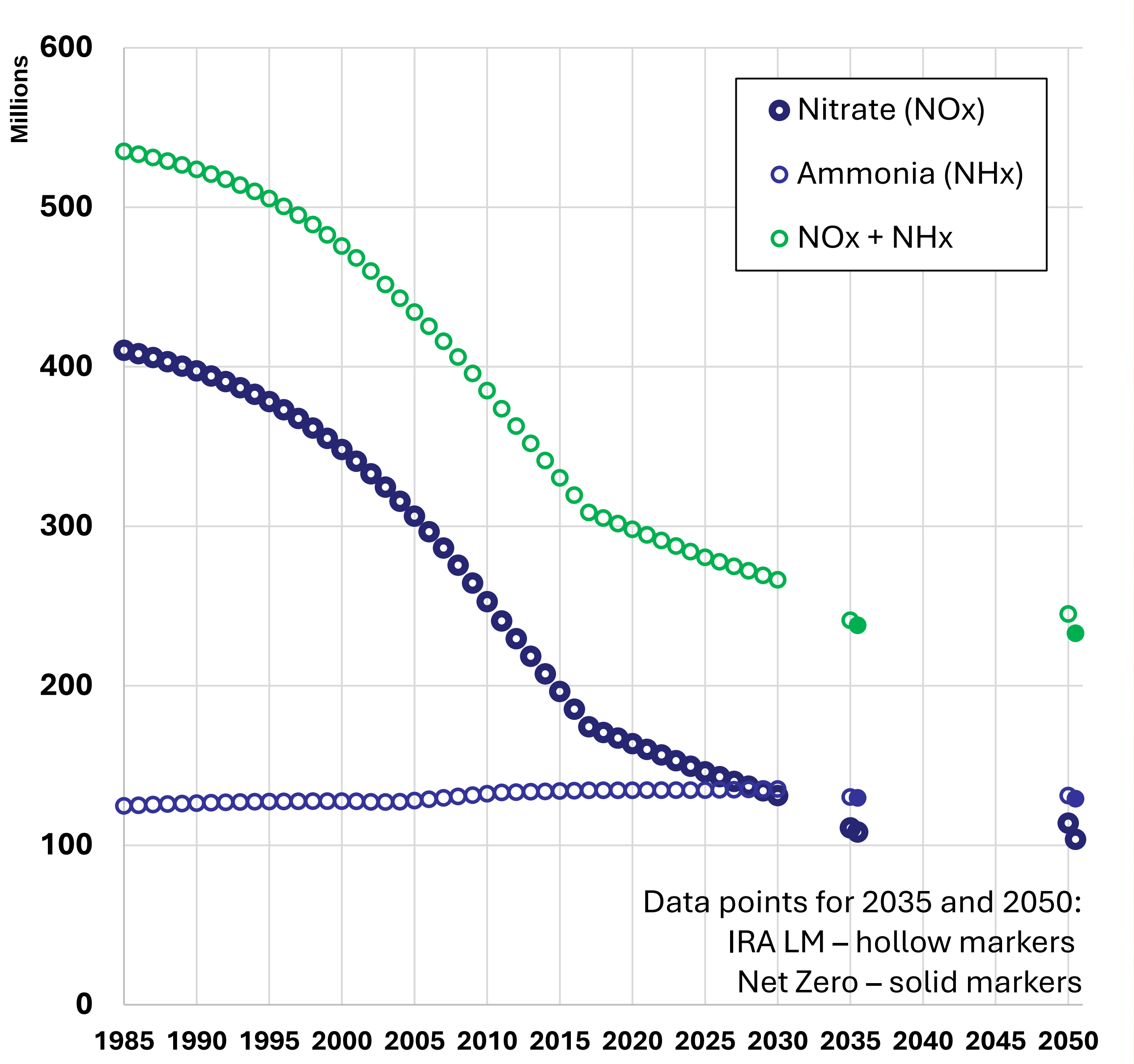
	2023	2026	2028	2032	2050
StateTargets	-1.2%	-2.9%	-4.5%	-8.4%	-28%
NetZeroZEV	-1.9%	-5.6%	-11%	-22%	-79%

NOx emissions relative to *Reference* in same year

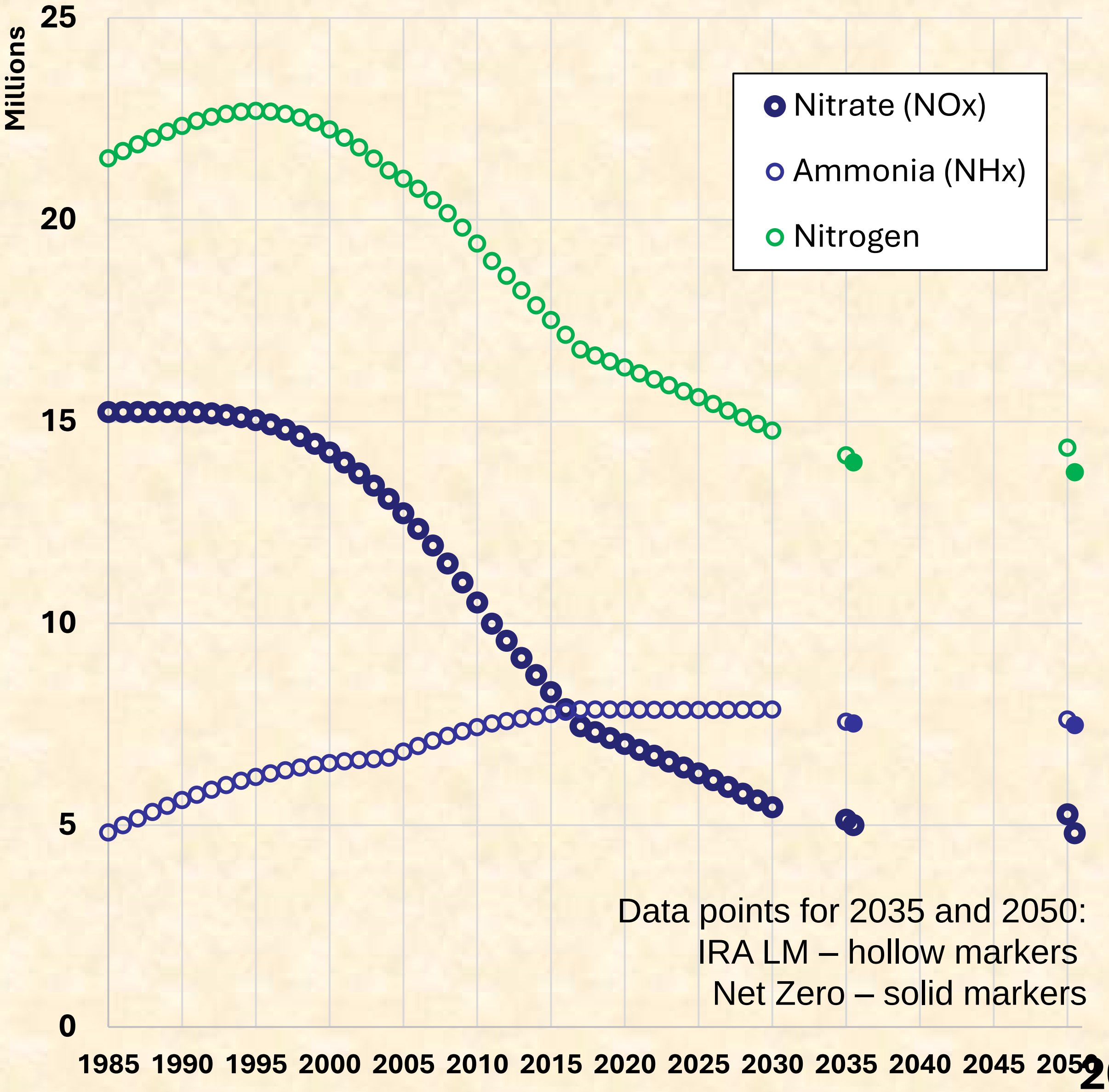
	2023	2026	2028	2032	2050
StateTargets	-1.2%	-2.0%	-1.8%	-2.2%	-7.0%
NetZeroZEV	-0.9%	-2.7%	-5.3%	-10%	-21%

Estimated Trends in Atmospheric N Deposition With Decarbonization

N-Deposition to the Watershed



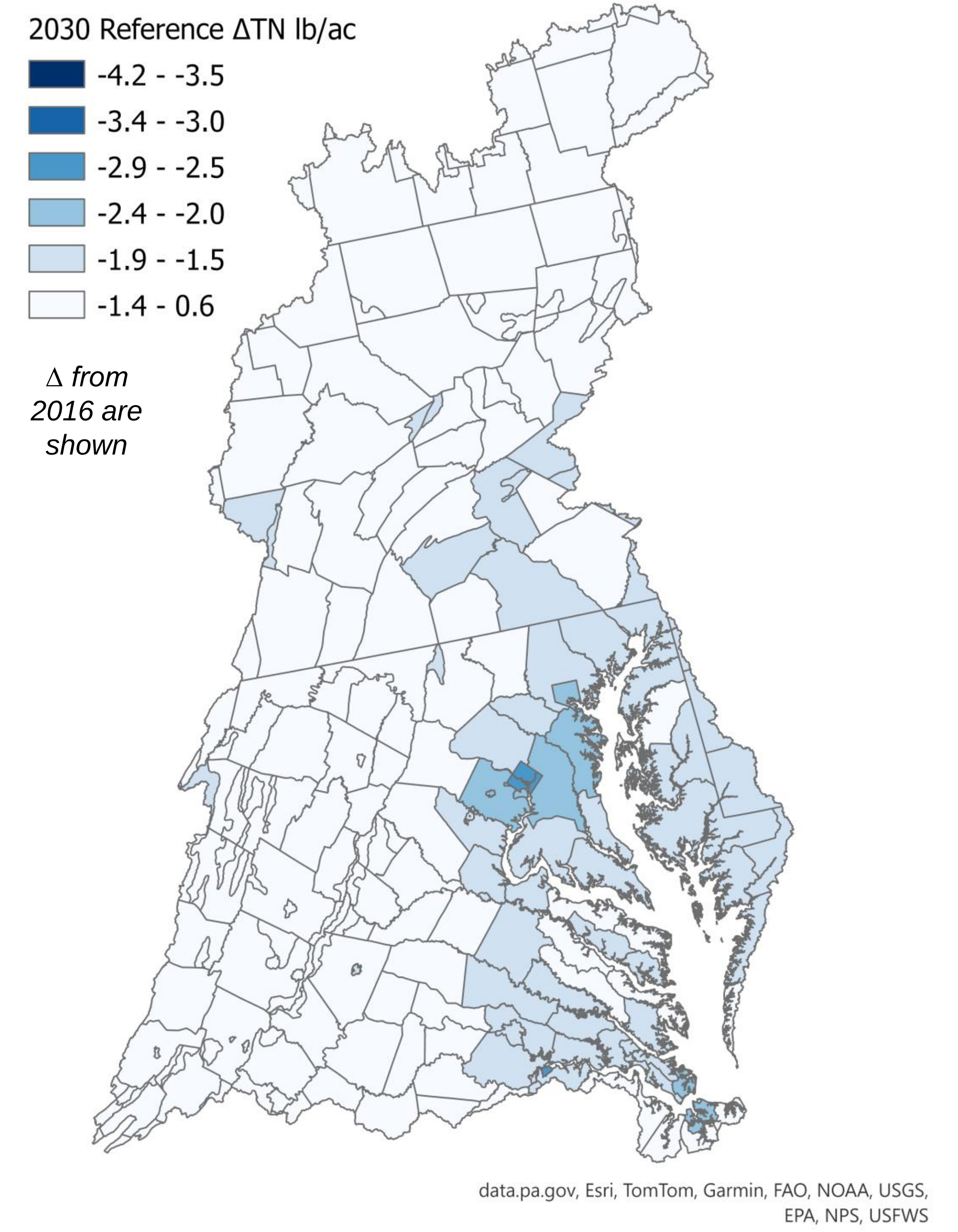
N-Deposition to the Tidal Bay



Phase 6 Estimated 2030 N Deposition Loads Relative to 2016

The Phase 6 2030 N deposition loads were used in the CBP 2017 Midpoint Assessment allocation.

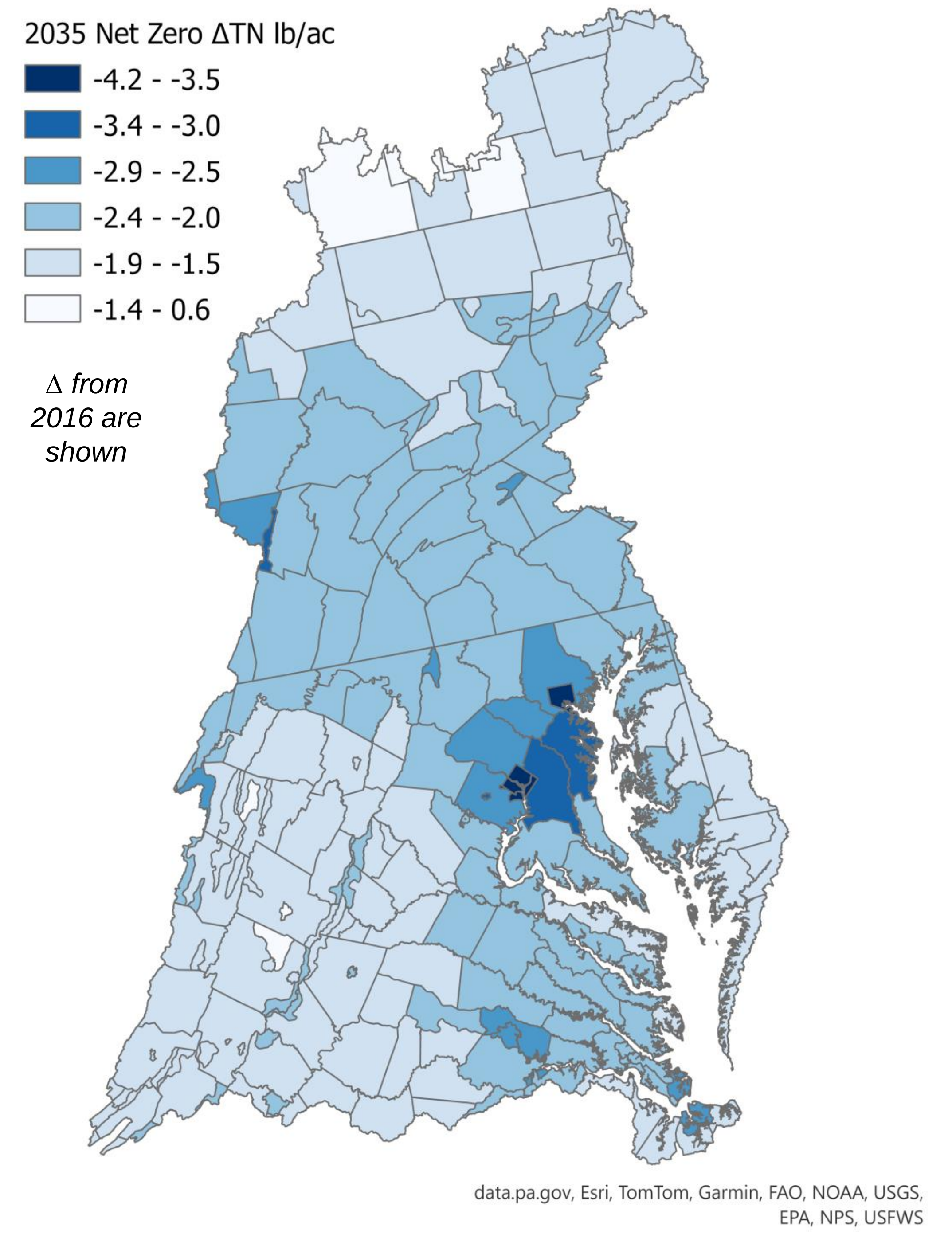
Nitrogen deposition reductions by the Inflation Reduction Act (IRA), state targets, and CO2 mitigation were not considered in the Phase 6 2030 N Deposition Scenario.



Phase 6 Estimated 2035 Net Zero N Deposition Loads Relative to 2016

<u>NetZeroZEV</u>: A mitigation scenario that includes IRA-LM and State Targets plus:

- A national, economy-wide declining CO_2 cap reaches Net-Zero by 2050.
- Transportation electrification targets in *State Targets* adopted nationally.



Phase 6 Estimated 2050 Net Zero N Deposition Loads Relative to 2016

NetZeroZEV: A mitigation scenario that includes IRA-LM and State Targets plus:

- A national, economy-wide declining CO_2 cap reaches Net-Zero by 2050.
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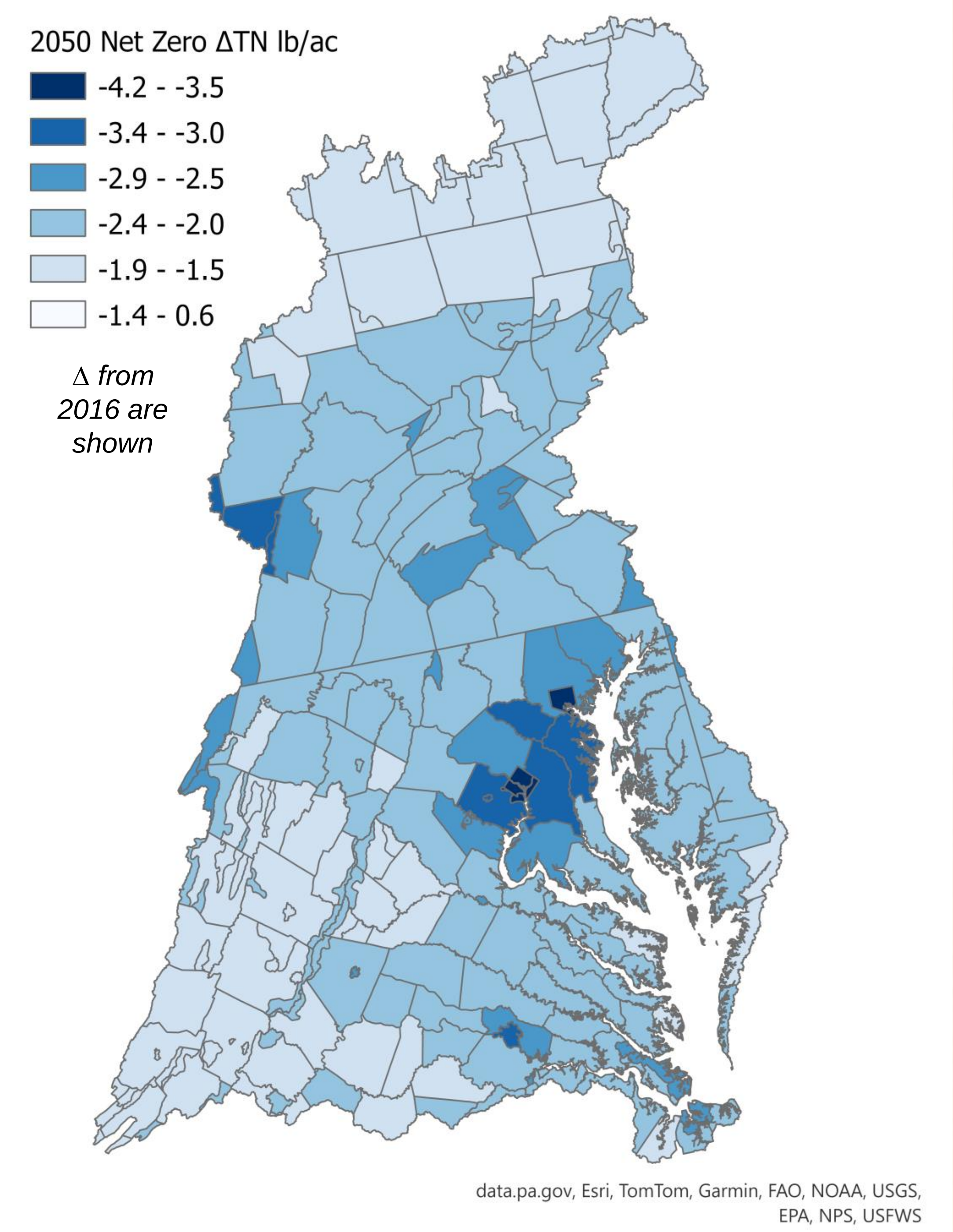

Atmospheric Deposition <u>Inputs</u> to the Chesapeake Watershed and Bay

Atmospheric Deposition	2016 Air	2030 Air	2035 IRA LM	2035 Net Zero	2050 IRA LM	2050 Net Zero
Chesapeake Bay Watershed	319.80	266.70	241.39	238.28	245.25	233.26
Direct to Chesapeake Bay	17.15	14.77	14.16	13.99	14.35	13.75
Total Input	**336.95**	**281.47**	**255.55**	**252.27**	**259.60**	**247.00**

Δ Atmospheric Deposition	2016 Air	2030 Air	2035 IRA LM	2035 Net Zero	2050 IRA LM	2050 Net Zero
Chesapeake Bay Watershed		0	-25.31	-28.42	-21.44	-33.44
Direct to Chesapeake Bay		0	-0.61	-0.78	-0.42	-1.03
Total Input		**0**	**-25.92**	**-29.20**	**-21.87**	**-34.46**

Change in Delivery of TN to the Bay Compared to the 2030 Reference

Δ Atmospheric Deposition	2016 Air	2030 Air	2035 IRA LM	2035 Net Zero	2050 IRA LM	2050 Net Zero
Chesapeake Bay Watershed		0	-25.31	-28.42	-21.44	-33.44
Direct to Chesapeake Bay		**0**	**-0.61**	**-0.78**	**-0.42**	**-1.03**
Total Input		0	-25.92	-29.20	-21.87	-34.46
States (*wrt* 2030 Air)						
DC		0	-0.003	-0.004	-0.003	-0.006
DE		0	-0.007	-0.011	-0.002	-0.015
MD		0	-0.252	-0.301	-0.195	-0.379
NY		0	-0.071	-0.081	-0.058	-0.093
PA		0	-0.660	-0.741	-0.547	-0.850
VA		0	-0.328	-0.370	-0.282	-0.444
WV		0	-0.069	-0.074	-0.062	-0.087
Total		**0**	**-1.390**	**-1.581**	**-1.149**	**-1.875**
		0	**-2.003**	**-2.365**	**-1.572**	**-2.901**

Conclusions:

Estimated nutrient load reductions needed to address climate change for the three-decade period from 1995 to 2025 are 2.3 million and 0.3 million kg for nitrogen and phosphorus per annum, respectively. Load reductions to address climate change between 2026 and 2035 are currently estimated to be 2.4 and 0.4 million kg per annum for nitrogen and phosphorus.

The CBP climate change analysis looked at 22 different influences on Chesapeake water quality standards, principally on the living resource-based oxygen concentration criteria in the deep waters of the Chesapeake.

In the Chesapeake watershed, the major influences are greater precipitation volumes and to a lesser extent intensities, which increase flows and consequently nitrogen, phosphorus, and sediment loads. On the other hand, increased evapotranspiration from higher watershed temperatures reduces and ameliorates higher future flows and loads.

Conclusions *(continued)*:

In the Chesapeake tidal waters, the estimated key impacts on water quality standards were higher water temperatures, which decrease DO saturation rates and increase stratification, and deep-water respiration causing an amplification of hypoxia in the Chesapeake. However, sea level rise and freshwater inflows (in the absence of their associated higher nutrient loads) from the watershed are estimated to increase estuarine circulation and ameliorate somewhat the estimated increase in hypoxia.

Decarbonization of the U.S. economy has the potential to reduce atmospheric deposition of nitrogen to the Chesapeake watershed, tidal waters, and coastal ocean providing benefits to Chesapeake water quality going forward.

Next steps: Run the loads on the Phase 6 Bay Model, develop the work on the Phase 7 Models, and examine the influence of reduced nitrogen deposition to the coastal ocean.