Simulation of Tidal Wetland Water Quality Influence in the Chesapeake Bay

Marsh Resilience Summit

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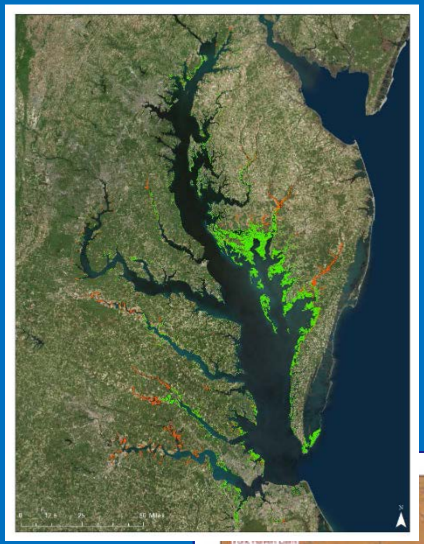
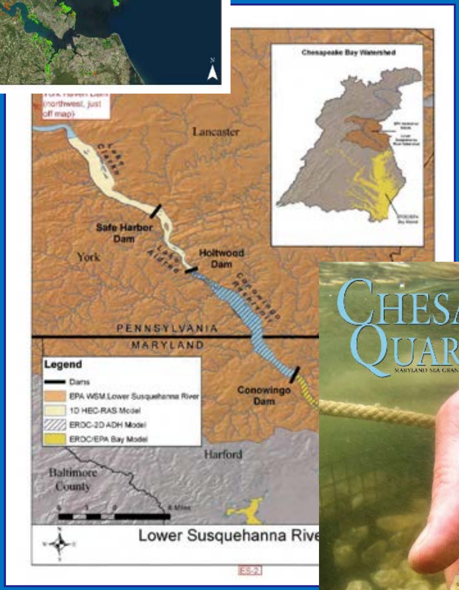
Chesapeake Bay Program
Science, Restoration, Partnership

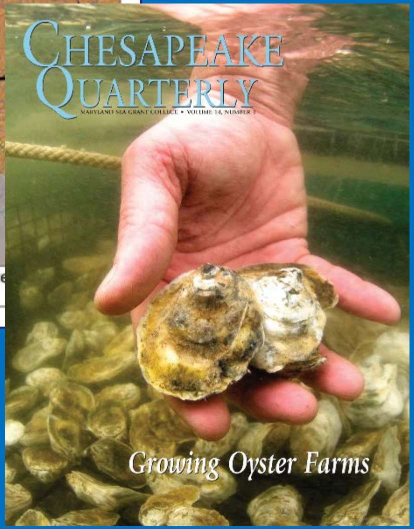
The 2017 Bay Model Objectives

- Develop a blueprint for Chesapeake restoration Watershed Implementation Plans (WIPs) for Chesapeake restoration from 2020 to 2025 .
- Assess water quality impacts of future growth.
- Assess water quality impacts of Conowingo infill.
- Assess influence of risk of future climate change on water quality.
- 2017 Bay Model has a simplified tidal marsh module that includes representation of tidal wetland particle burial (organic and inorganic), respiration, and denitrification allowing an estimate of the current influence of tidal wetlands on water quality and the impacts of conversion of tidal wetlands to open water through future sea level rise.

The 2017 Model

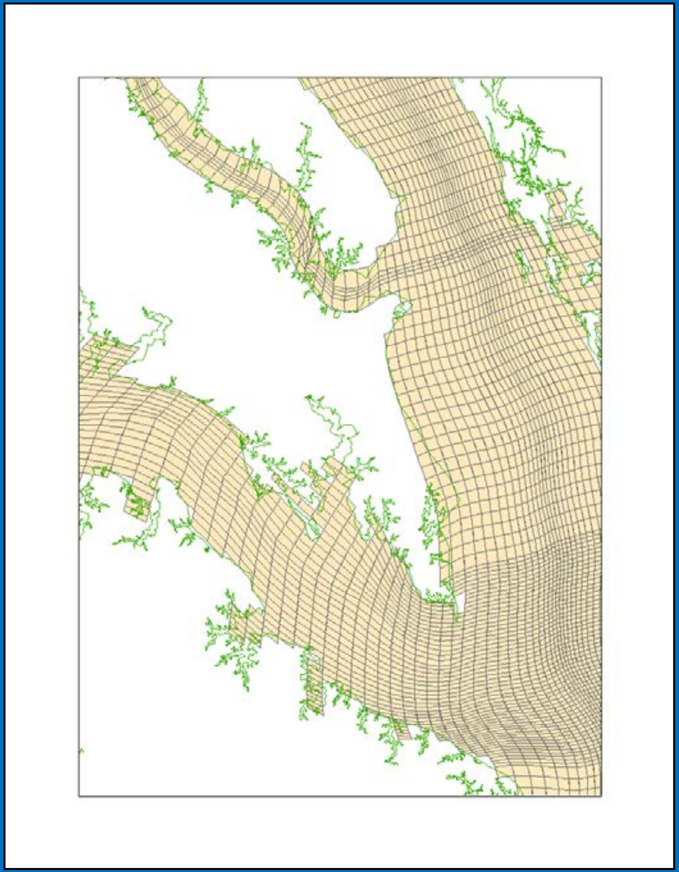






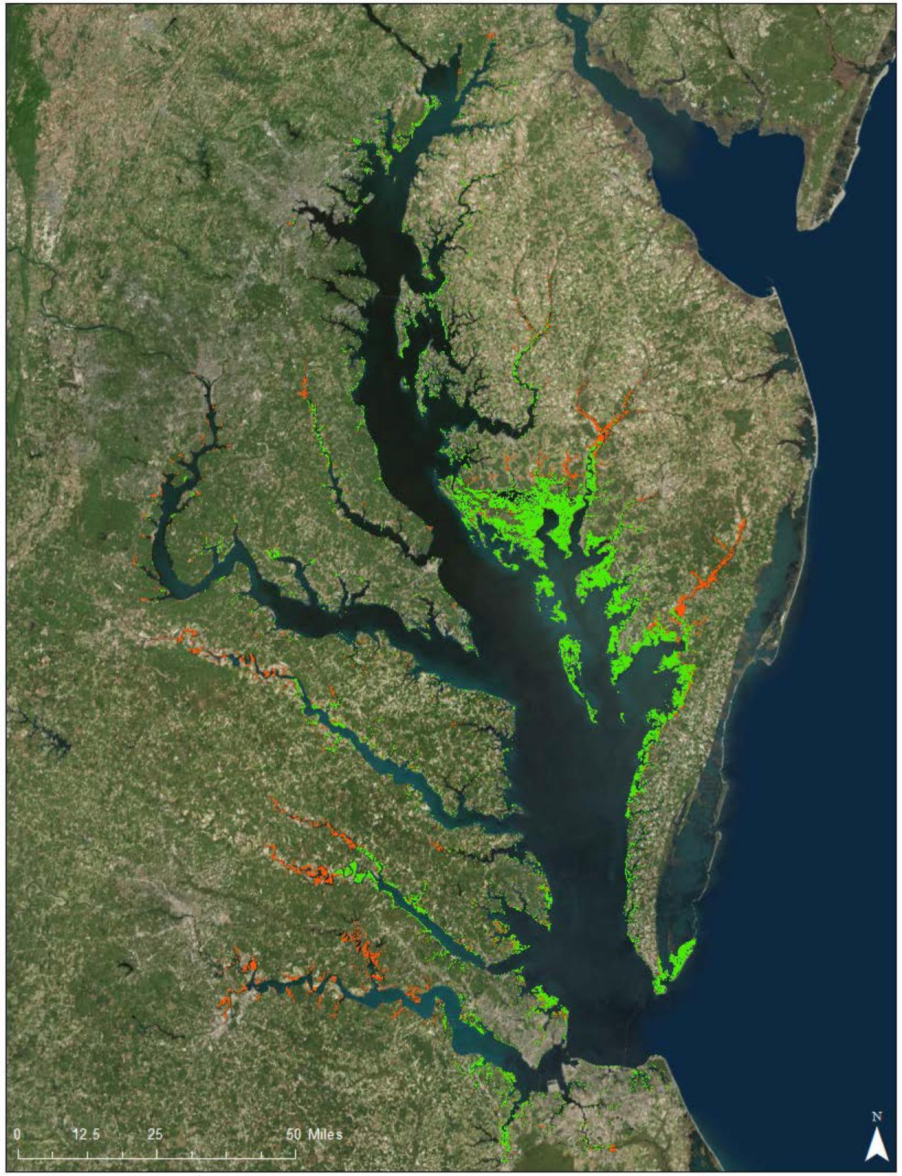
- The same grid and formulations as the fifth generation 2010 Bay Model.
- Phase 6 Watershed Model as inputs.
- Emphasis on novel nutrient sources and sinks, shallow water processes.
- Used in 2017 Midpoint Assessment of progress towards the 2010 TMDL goal.

The 2010 Grid Applied to 2017 Bay Model



- 12,000 surface cells, 57,000 total cells.
- Simulation period of 1985 to 2013.
- Includes tidal wetland simulation module:
  - Particle burial (organic and inorganic)
  - Respiration
  - Denitrification
  - Water quality impacts of conversion of tidal wetlands to open water through future sea level rise.

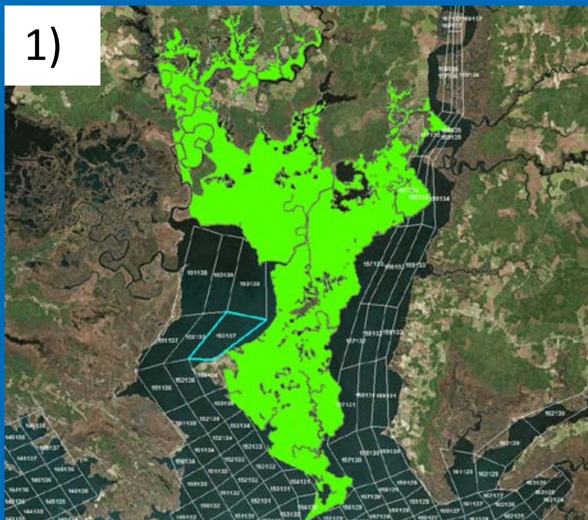
Chesapeake Bay Tidal Wetlands

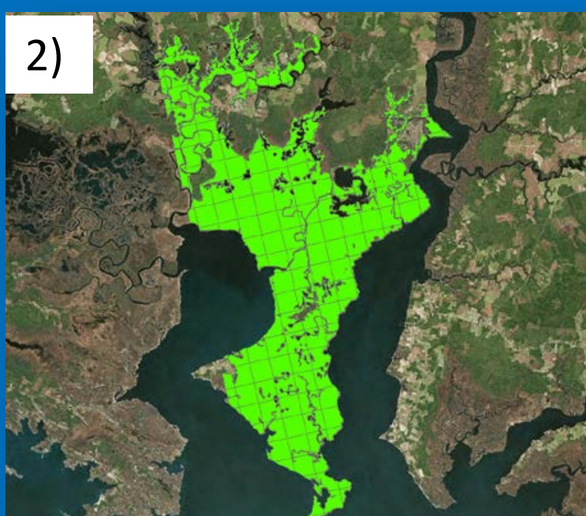


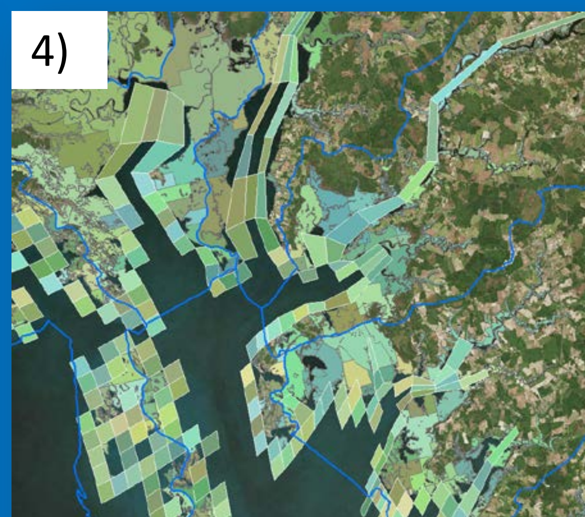
Source: Carl Cerco, U.S. CoE ERDC

- The extentfromNational Wetlands Inventory is determined largely from vegetation perceived via aerial photography.
- 190,000hectaresofestuarine (green) and tidal fresh (red) wetlands.
- A tidal wetlands module is now fully operational in the WQSTM. The loss of wetland function due to sea level rise and inundation will be accounted for explicitly in the assessment of the future risk of climate change on Chesapeake living resource based water quality standards.

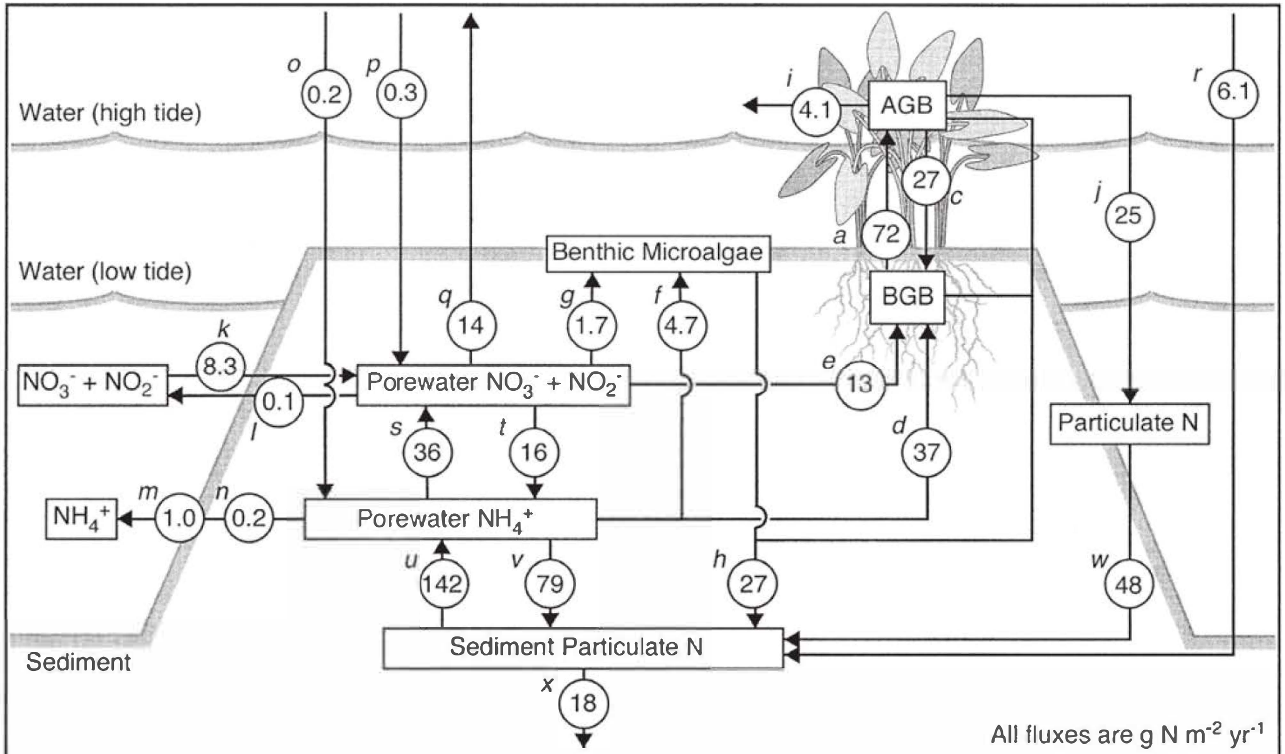
Assign Wetlands Areas to Model Cells







1. Wetlands polygon.
2. Divide polygon into "fishnet."
3. Overlay 10-digit HUC boundaries.
4. Assign wetlands areas to model cells based on proximity and local watershed boundaries.
5. Thank you, Scott Bourne, ERDC.



(a) total macrophyte N demand
(b) spring translocation (not shown)
(c) fall translocation
(d) "new" NH_4^+-N for macrophytes
(e) "new" NO_3^--N for macrophytes
(f) microalgal NH_4^+-N uptake
(g) microalgal NO_3^--N uptake
(h) reincorporation of autotroph N
(i) macrophyte leaching
(j) export of autotroph N
(k) diffusive NO_3^- uptake
(l) advective NO_3^- release
(m) diffusive NH_4^+ release
(n) advective NH_4^+ release
(o) atmospheric NH_4^+ deposition
(p) atmospheric NO_3^- deposition
(q) denitrification
(r) N_2 fixation
(s) nitrification
(t) dissimil. NO_3^- reduction to NH_4^+
(u) gross mineralization
(v) microbial immobilization
(w) sediment deposition
(x) sediment burial

Fig. 3. Nitrogen mass balance for Sweet Hall marsh. All fluxes are in g N m^{-2} yr^{-1} and are based on measured rates, literature values, or calculated by difference (assuming steady state) as detailed in the text. Standard deviations for each flux are omitted for visual clarity but can be found in Table 1 and in the text. AGB = aboveground macrophyte biomass; BGB = belowground macrophyte biomass.

Estuaries Vol. 28, No. 6, p. 909–922 December 2005

Nitrogen Cycling and Ecosystem Exchanges in a Virginia Tidal Freshwater Marsh

Scott C. Neubauer[1,2]*, Iris C. Anderson[1], and Betty B. Neikirk[1]

Wetlands Module

- Not a complete wetlands biogeochemical model but a generalized, simplified module that includes tidal wetland:
  - Particle burial (organic and inorganic)
  - Respiration
  - Denitrification
  - Water quality impacts of conversion of tidal wetlands to open water through future sea level rise

Particle Settling

$$V \cdot \frac{dC}{dt} = Transport\ + Kinetics\ - WSw \cdot C \cdot Aw$$

V = volume of WQM cell adjacent to wetlands
C = concentration
WSw = wetland settling velocity
Aw = area of wetland adjacent to WQM cell

This applies to all particles, organic and inorganic. Present settling rates 0.05 m/d for most particles, 0.005 m/d for phytoplankton.

Respiration

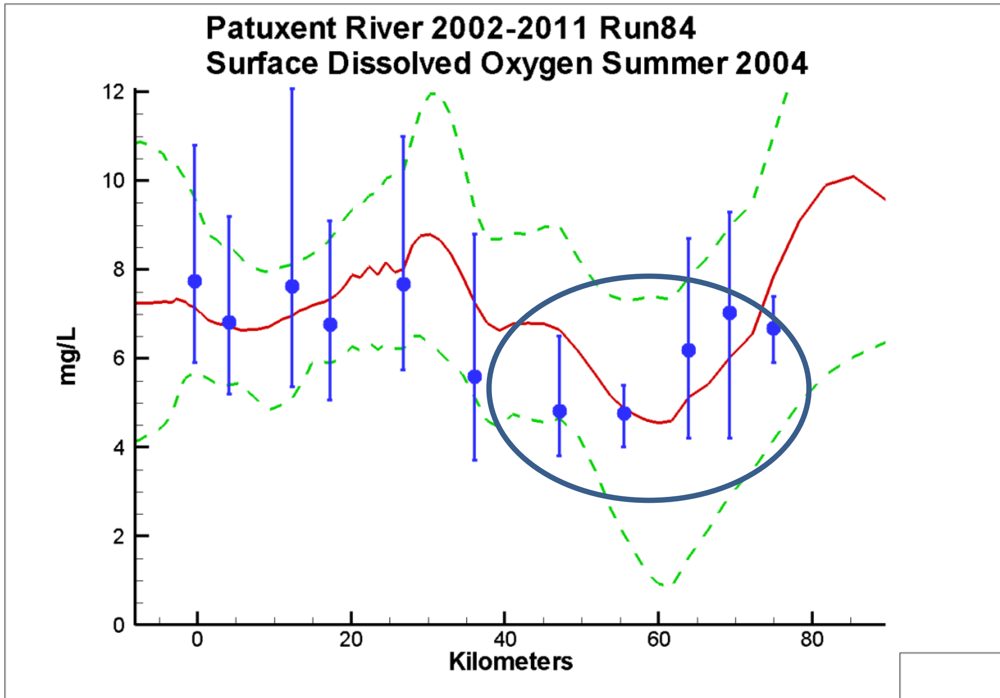
$$V \cdot \frac{dC}{dt} = Transport\ + Kinetics\ - f(DO) \cdot f(T) \cdot WOC \cdot Aw$$

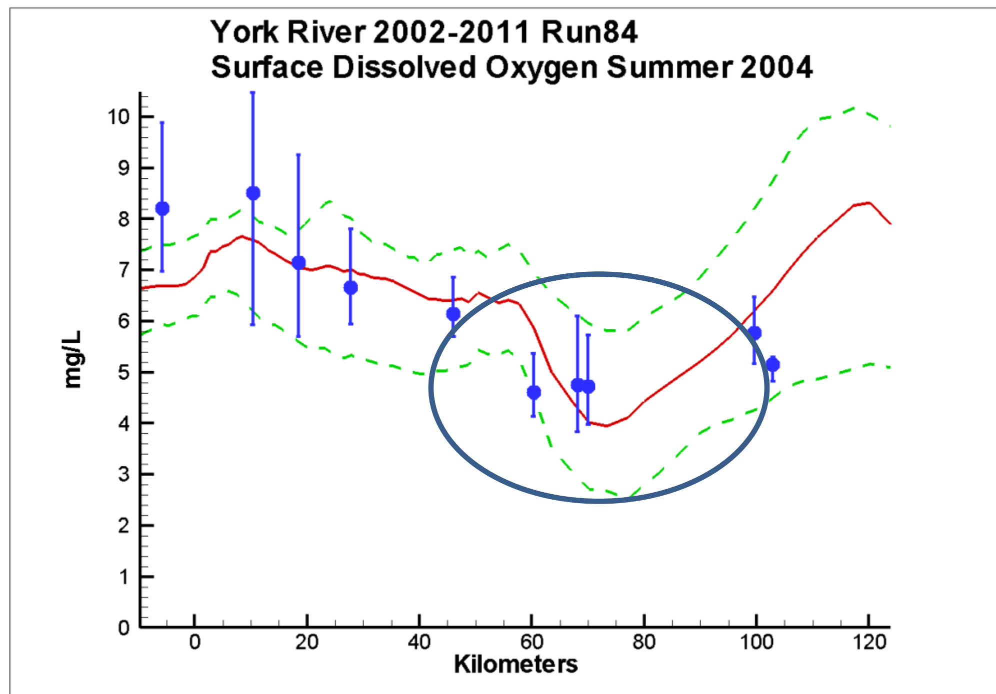
V = volume of WQM cell adjacent to wetlands
C = concentration
f(DO) = limiting factor = DO/(Kh+DO)
f(T) = temperature effect
WOC = wetland oxygen consumption
Aw = area of wetland adjacent to WQM cell

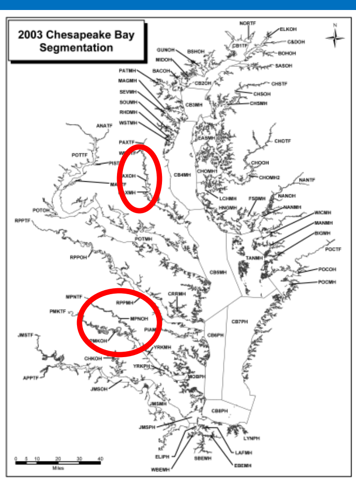
At present, WOC = 0.5 g DO/sq m/d at 20C. WOC doubles for a 10C temperature increase. Kh = 1.0 g DO/m3.

Previous calibration had WOC = 1 g DO/sq m/d and no limiting factor. Wetland areas from TMDL model.

Wetlands DO Effects







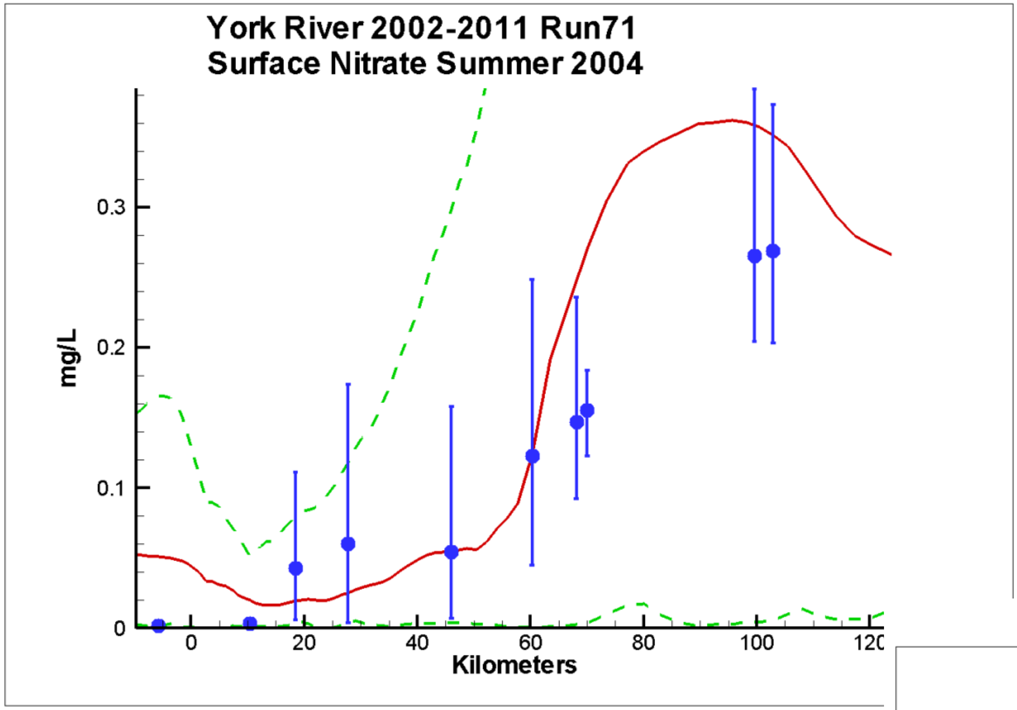
Denitrification

$$V \cdot \frac{dC}{dt} = Transport\ + Kinetics\ - MTC \cdot f(T) \cdot C \cdot Aw$$

V = volume of WQM cell adjacent to wetlands
C = nitrate concentration
MTC = mass-transfer coefficient
f(T) = temperature effect
Aw = area of wetland adjacent to WQM cell

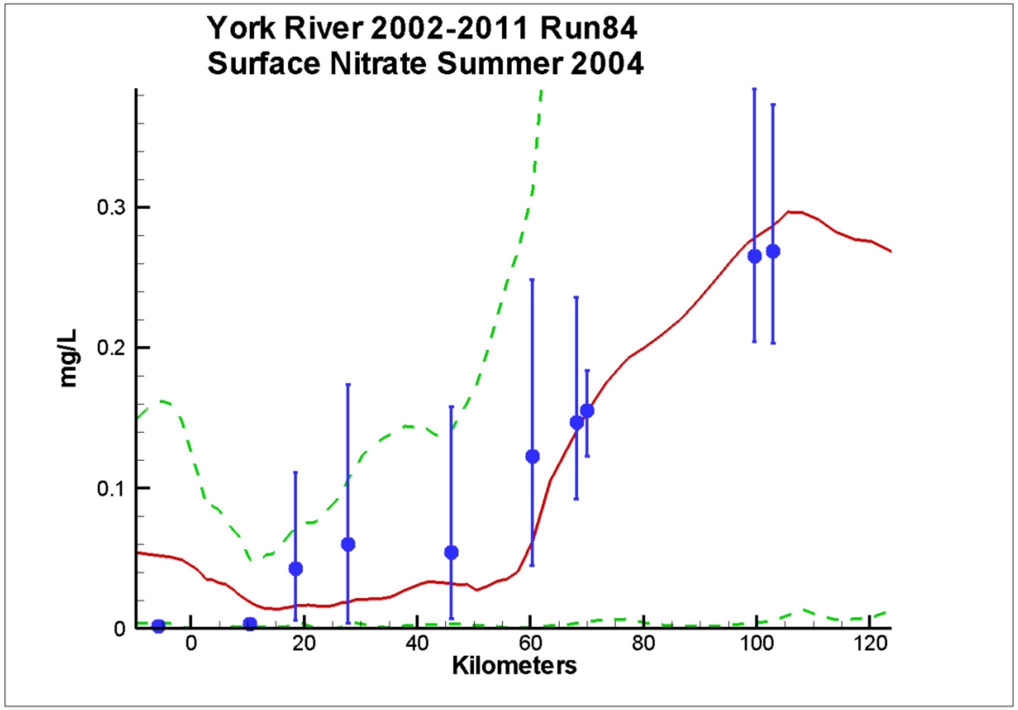
At present, the mass-transfer coefficient is 0.05 m/d.
Denitrification doubles for a 10C temperature increase.

Nitrate in York River

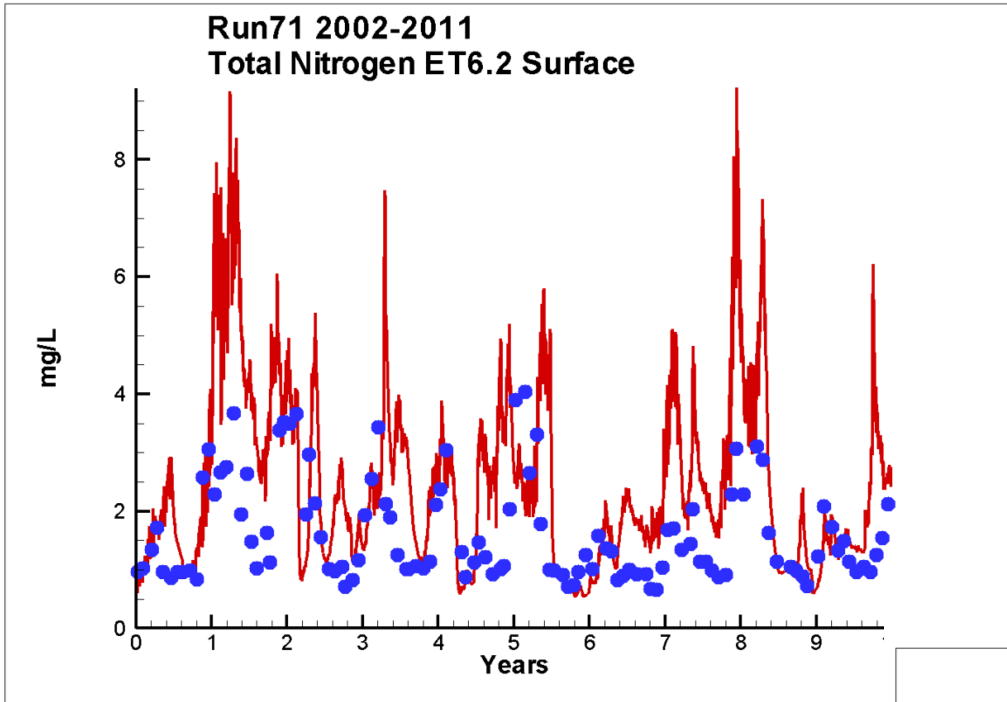


No Wetlands

With Wetlands

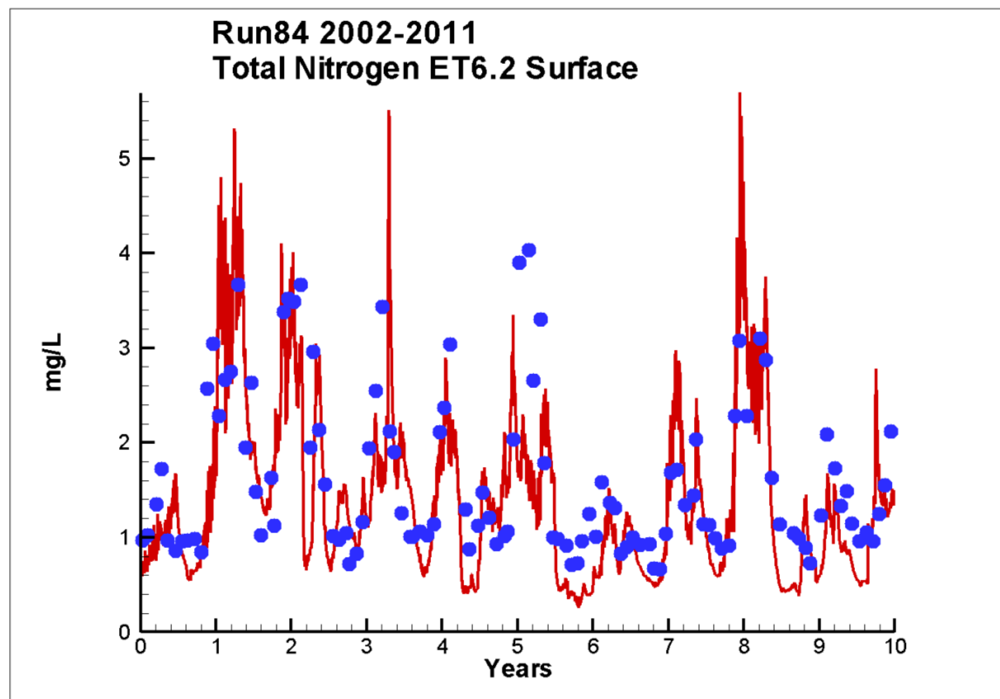


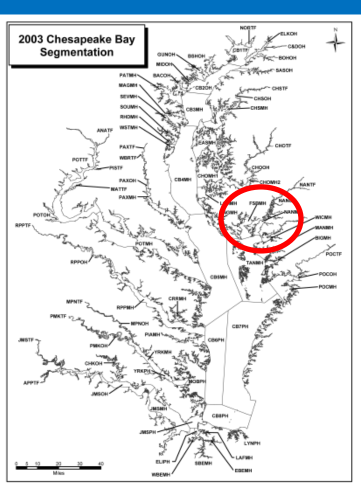
Total Nitrogen in Nanticoke River

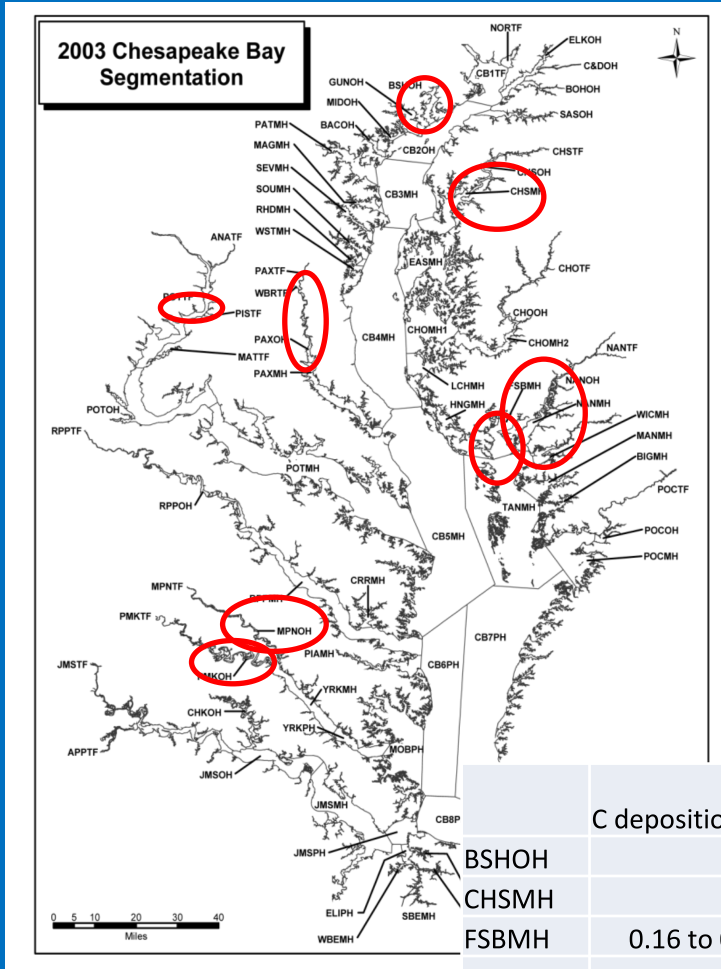


No Wetlands

With Wetlands

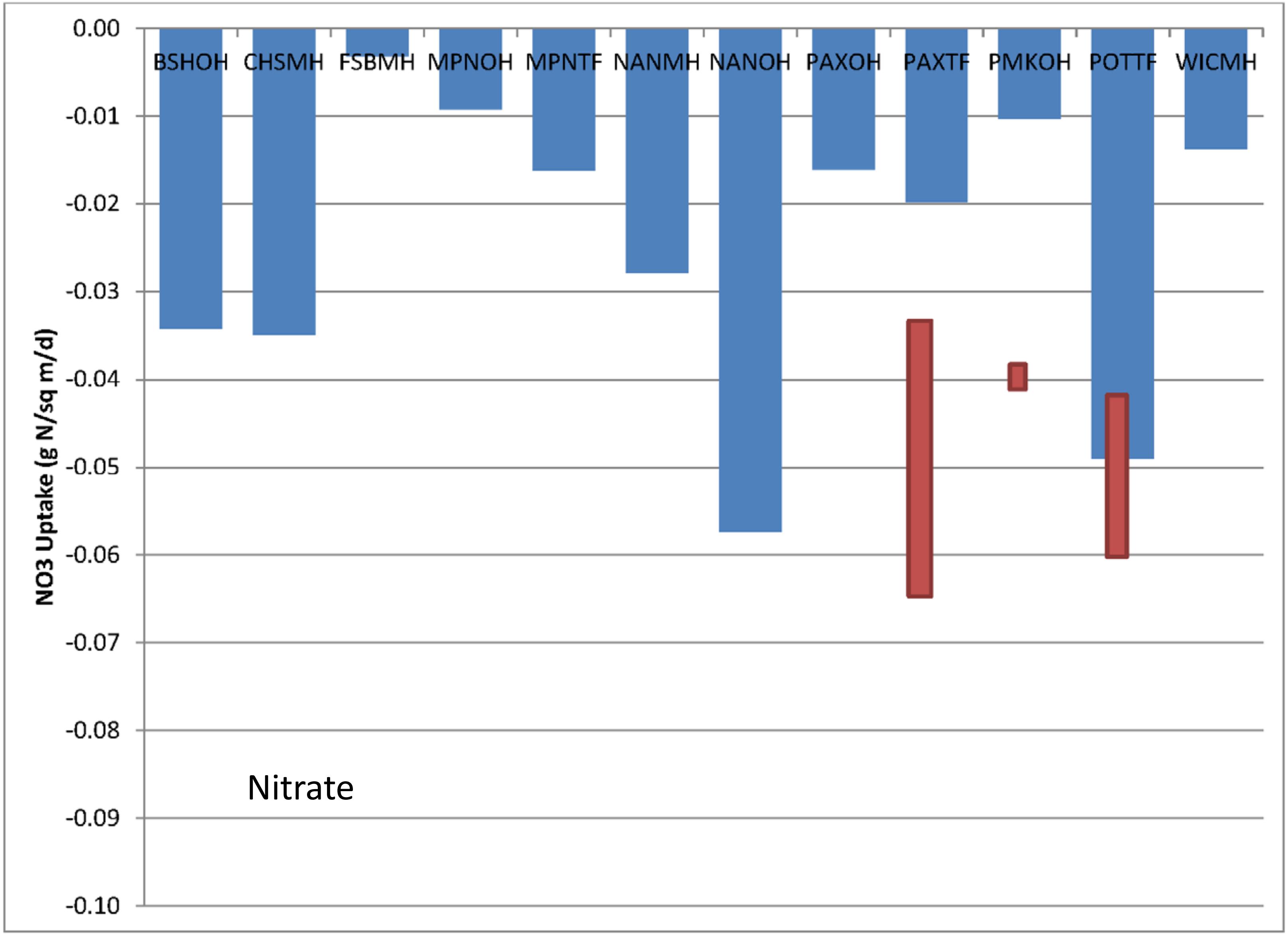




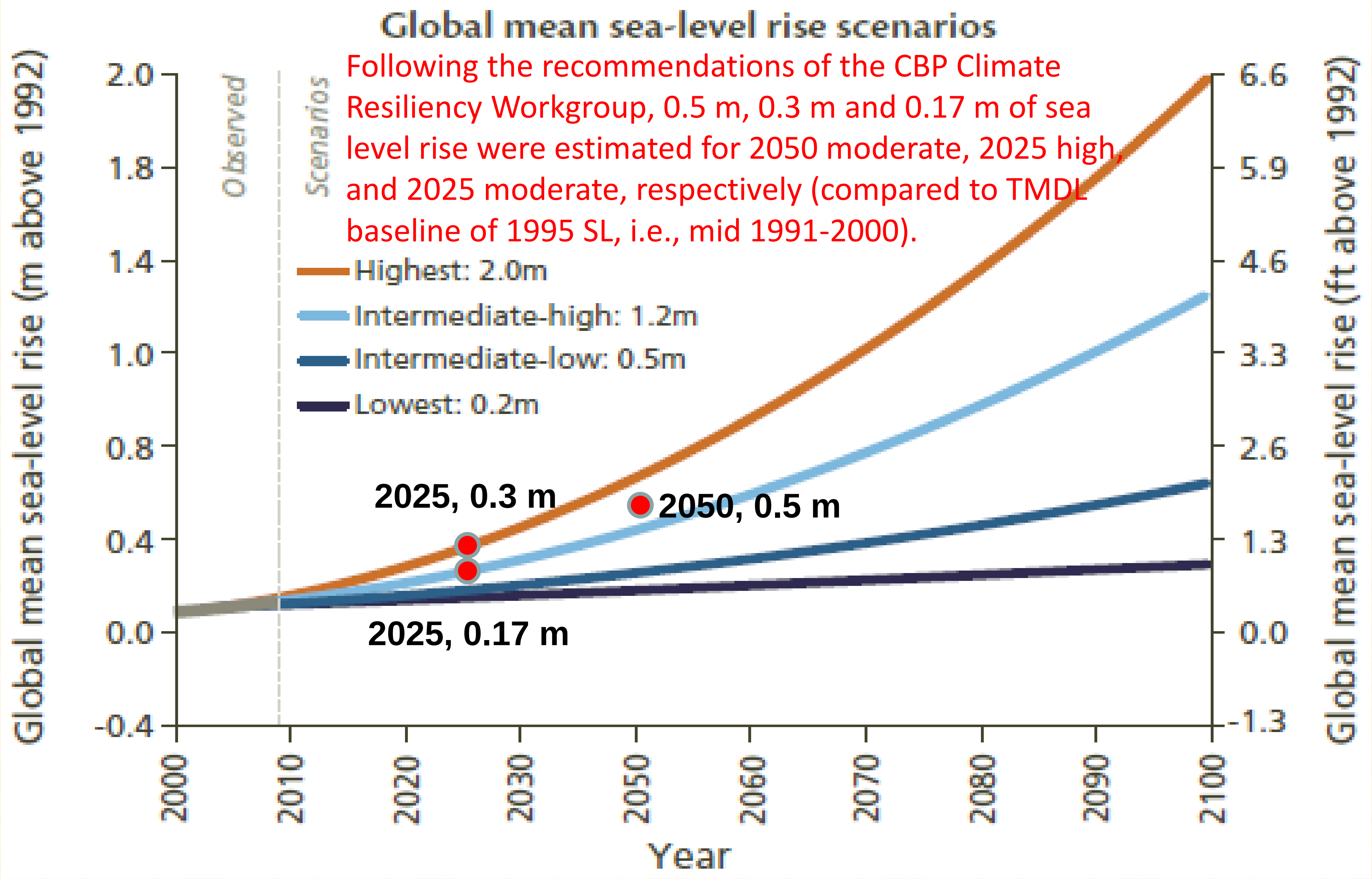


Hot Spots for Calibration

	C deposition	N deposition	P deposition	denitrification	solids deposition	respiration
BSHOH		0.008 to 0.032	0.001 to 0.006			
CHSMH		0.02 to 0.064	0.01 to 0.019		3.6	
FSBMH	0.16 to 0.33				0.3	
MPNOH	0.24 to 2.77	0.019 to 0.238	0.004 to 0.085		1.43 to 42.0	
MPNTF						
NANMH	0.033 to 0.126				1.61 to 8.12	
NANOH	0.033 to 0.126				1.61 to 8.12	
PAXOH		0.008	0.002		5.75	
PAXTF		0.033 to 0.064	0.01	0.108 to 0.197	5.75	
PMKOH	0.61	0.05		0.04		1.12 to 2.77
POTTF	1.44			0.043 to 0.06	5.88	
WICMH	0.033 to 0.126	0.037	2.74x10^-5 to 0.004		1.61 to 8.12	
CHOMH		0.053 to 0.074	4.9x10^-4 to 0.005			
WQGIT			0.0016	0.026		

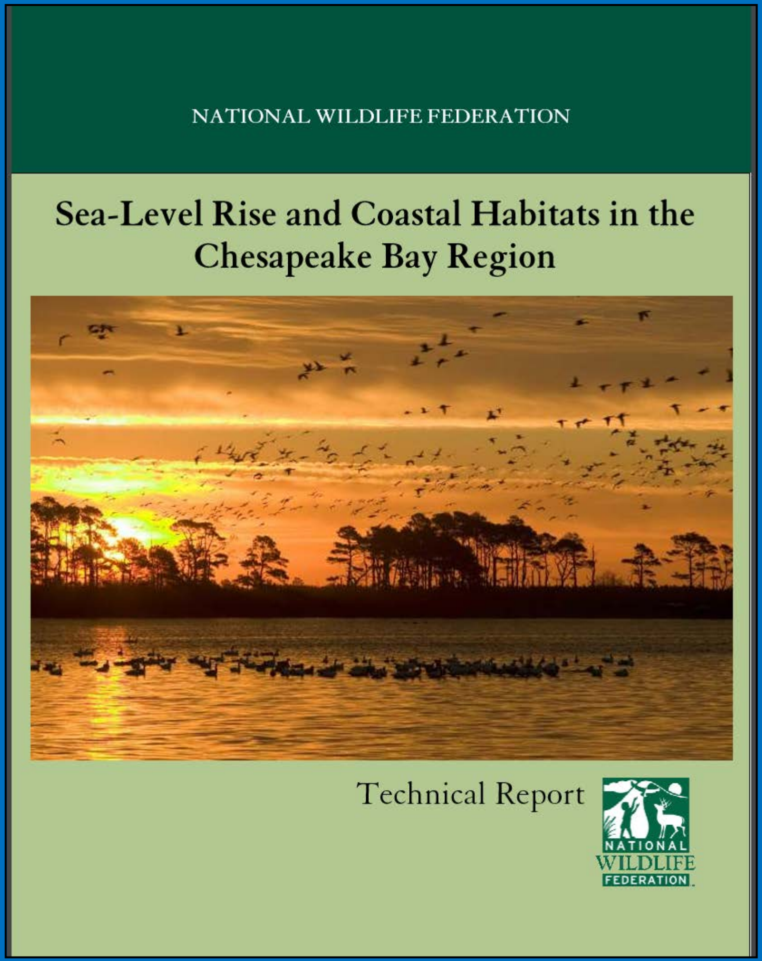


0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
NO3 Uptake (g N/sq m/d)
BSHOH
CHSMH
FSBMH
MPNOH
MPNTF
NANMH
NANOH
PAXOH
PAXTF
PMKOH
POTTF
WICMH
Nitrate



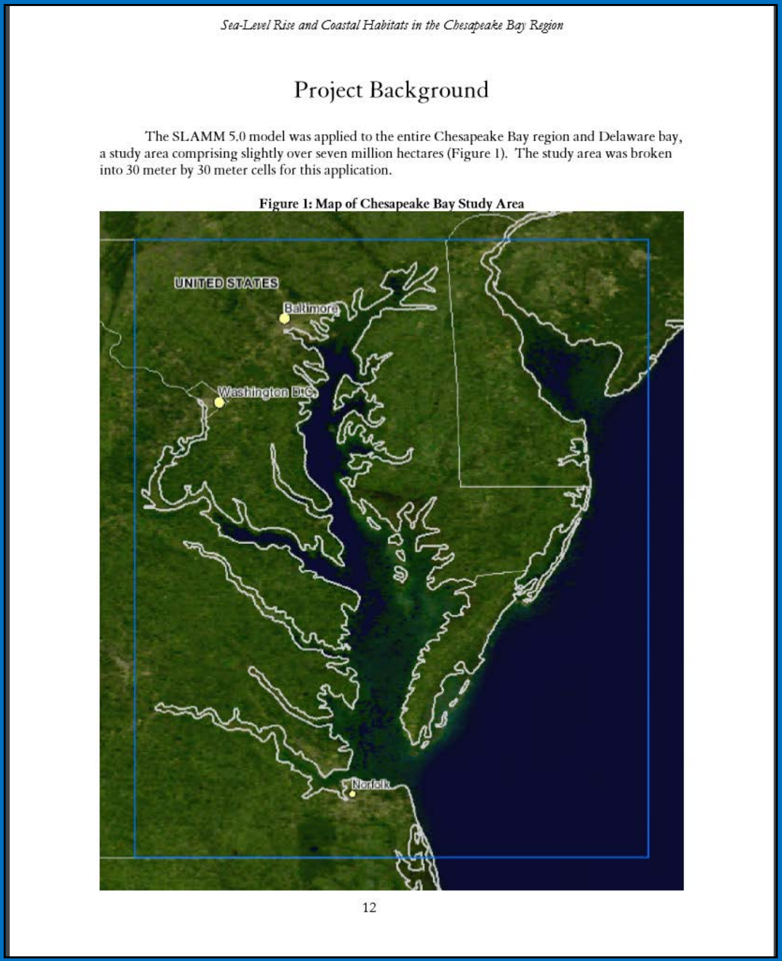
From Parris, A. et al. (2012). *Global Sea Level Rise Scenarios for the United States National Climate Assessment. NOAA Technical Report OAR CPO-1. National Oceanic and Atmospheric Administration, Silver Spring, Maryland.*

Sea-Level Rise and Tidal Wetlands



- Our estimates of effect of sea-level rise on tidal wetlands come from the Sea-Level Affecting Marshes Model (SLAMM).
- Study conducted for the national Wildlife Federation by Glick et al. (2008).
- SLAMM scenarios:
  - IPCC B1: 0.31 m sea-level rise, broken into four increments.
  - 1 Meter: 1 m sea-level rise, broken into four increments.

Sea-Level Rise and Tidal Wetlands


Sea-Level Rise and Coastal Habitats in the Chesapeake Bay Region

Project Background

The SLAMM 5.0 model was applied to the entire Chesapeake Bay region and Delaware bay, a study area comprising slightly over seven million hectares (Figure 1). The study area was broken into 30 meter by 30 meter cells for this application.

Figure 1: Map of Chesapeake Bay Study Area

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- The study included Delaware Bay and Atlantic coastal regions.
- The Chesapeake Bay portion was extracted from the complete model output and provided to us by Lora Harris of University of Maryland.
- Four Wetlands Categories:
  - Brackish Marsh
  - Salt Marsh
  - Transitional Marsh
  - Tidal Freshwater Marsh

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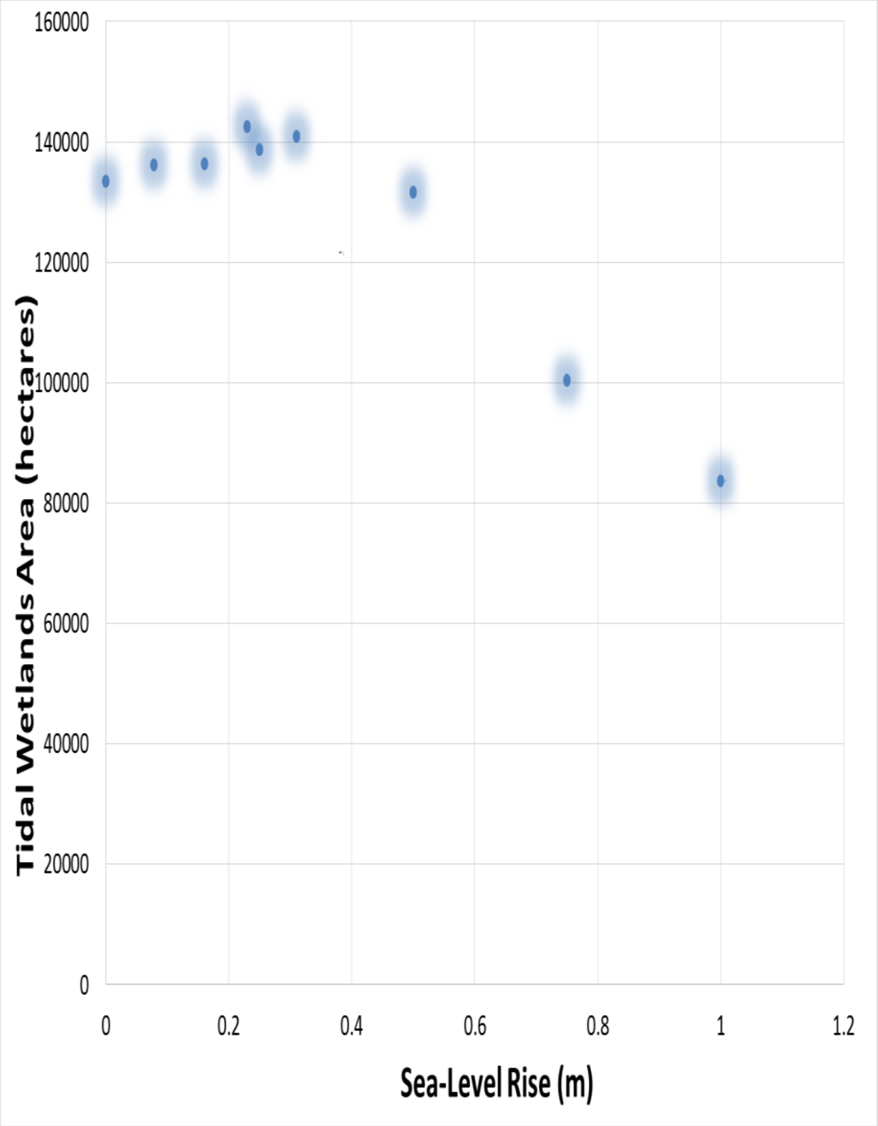
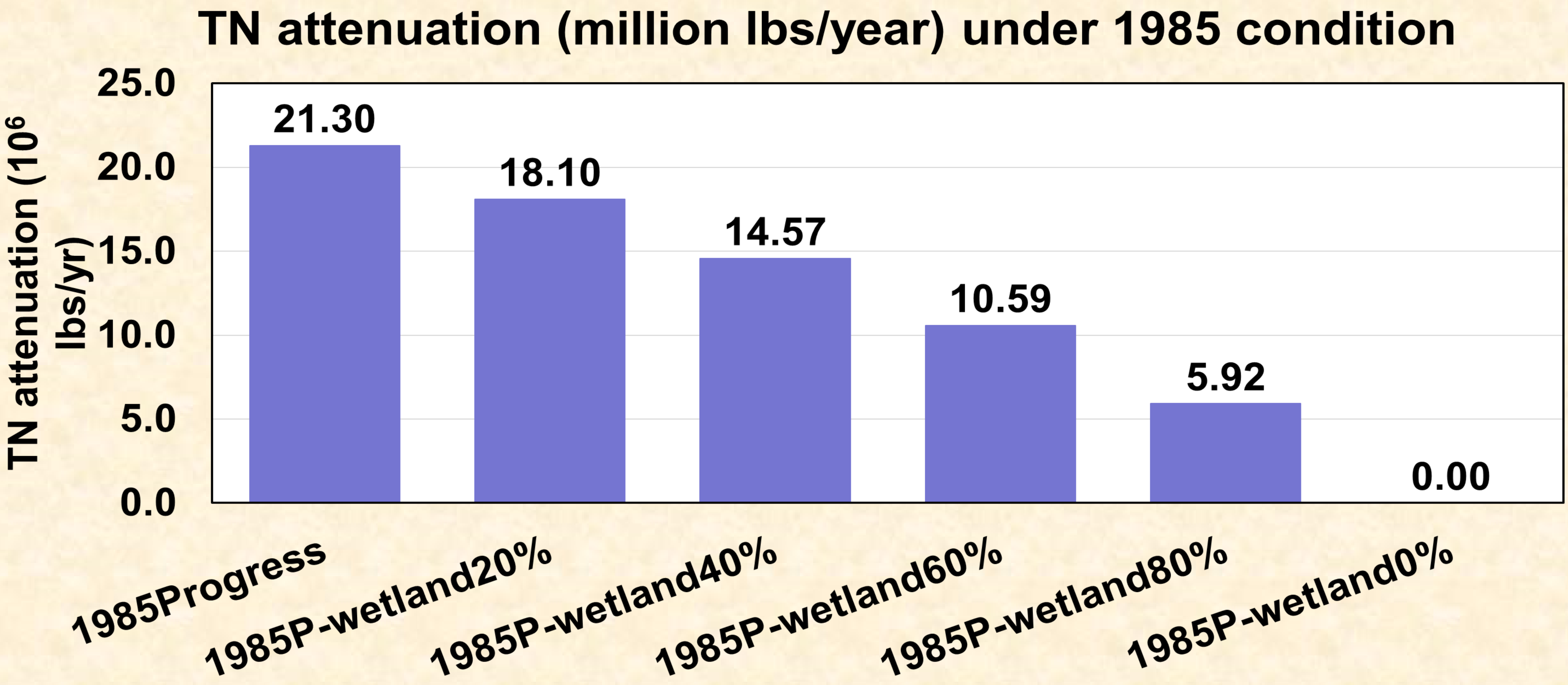
Influence of Estimated 2025 (0.3 m) and 2050 (0.5m) Sea Level Rise on Tidal Wetland Attenuation



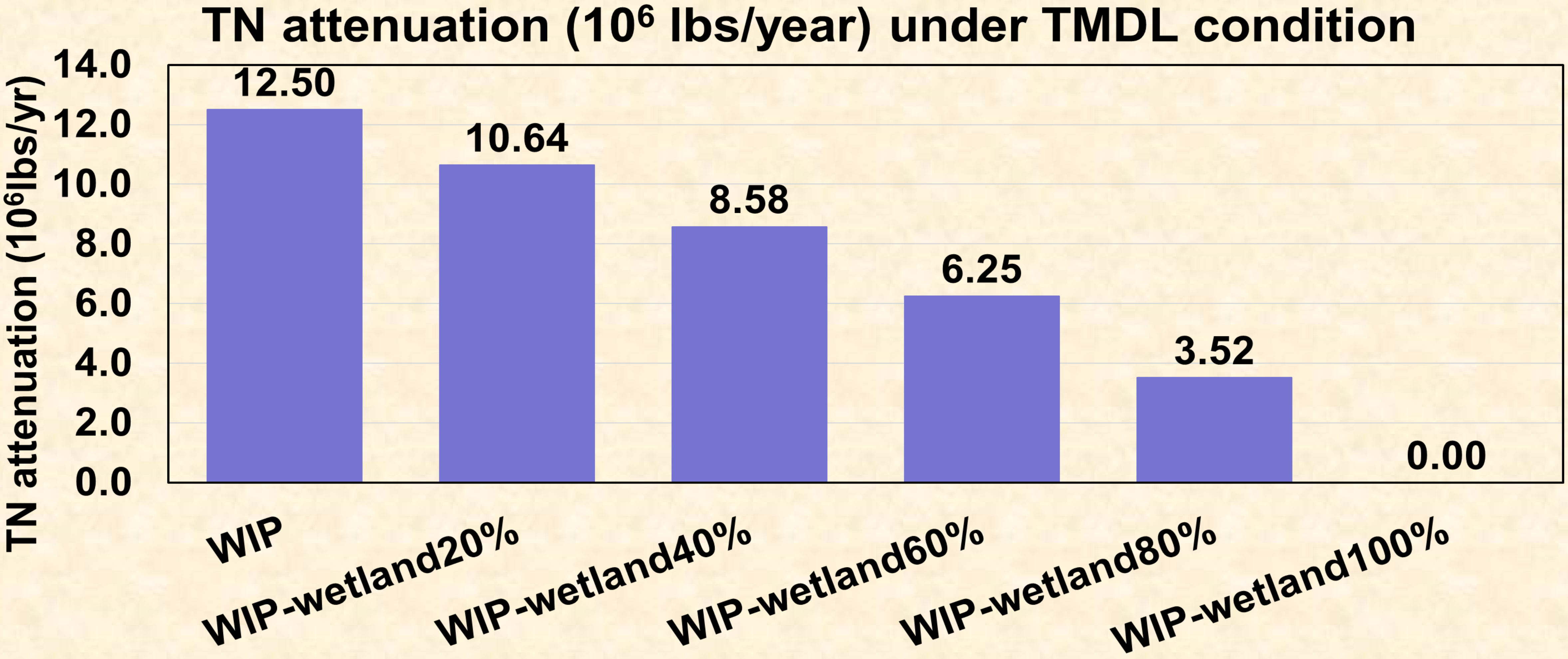
There is little change in estimated total tidal wetland area for 2025 (0.3 m) and 2050 (0.5 m) which equates to negligible changes in tidal wetland attenuation.

Long range (2100) conditions estimate tidal wetland changes to be on the order of a 40% loss in the Chesapeake which could reduce tidal wetland attenuation on the order of about 4 million pounds nitrogen and 0.3 million pounds phosphorus under estimated WIP Loads

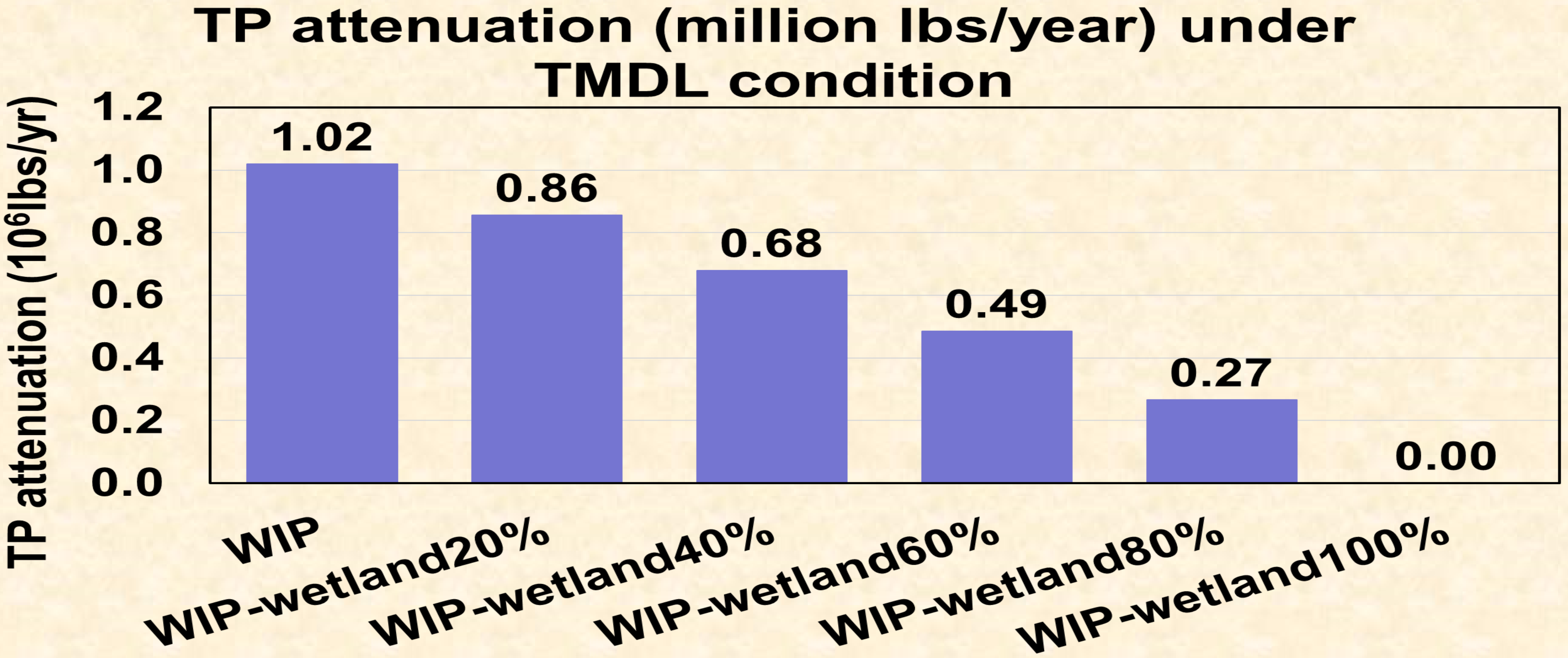
Source: Carl Cerco, CoE ERDC and Lara Harris, UMCES Sea Level Affecting Marshes Model (SLAMM) results.



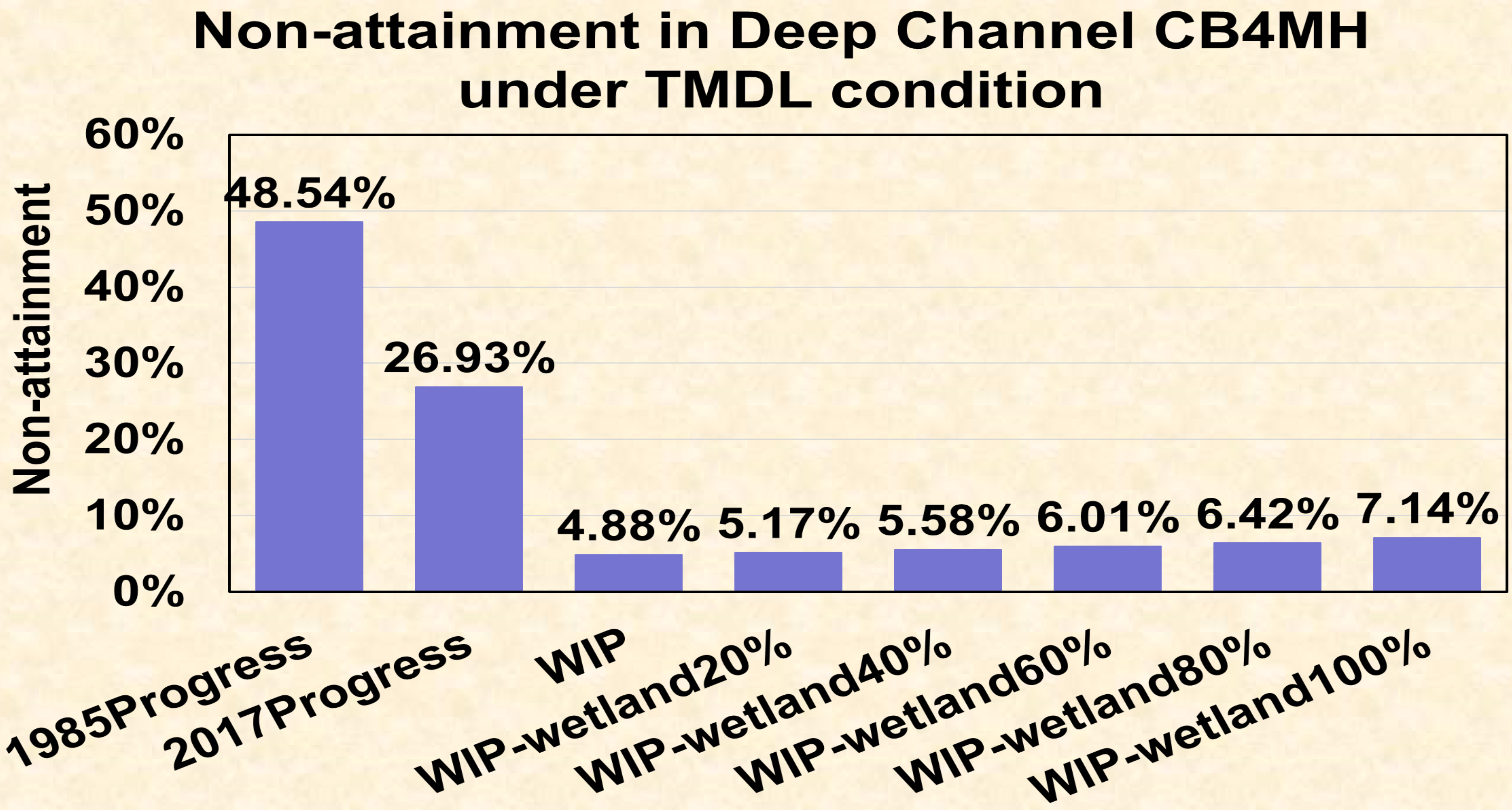
Tidal wetland nitrogen attenuation accounted for an estimated 21 million pound reduction of Chesapeake nitrogen loads under mid-1980s load conditions. This is a little less than the entire combined 2017 WIP3 nitrogen target loads from New York (11.3 million pounds), West Virginia (8.1 million pounds), and Delaware (4.5 million pounds).



With less loads to the Bay under estimated 2025 WIP loads attenuation from tidal wetland is about half that as under estimated 1985 loads.



Tidal wetland phosphorus attenuation accounted for an estimated 1 million pound reduction of Chesapeake nitrogen loads under WIP load conditions. This is a little less than the entire combined 2017 WIP3 target loads from New York (0.59 million pounds), West Virginia (0.43 million pounds), and Delaware (0.11 million pounds).


Non-attainment in Deep Channel CB4MH under TMDL condition
Non-attainment
60%
50%
40%
30%
20%
10%
0%
48.54%
26.93%
4.88%
5.17%
5.58%
6.01%
6.42%
7.14%
1985Progress
2017Progress
WIP
WIP-wetland20%
WIP-wetland40%
WIP-wetland60%
WIP-wetland80%
WIP-wetland100%

CBP Management Direction

For Climate Change (***PSC Decisions of December 2017)***

Understand the Science - Address the uncertainty [of the risk of future climate change] by documenting the current understanding of the science and identifying research gaps and needs:

- Develop an estimate of pollutant load changes (N, P, and S) due to climate change conditions [so that] starting with the 2022-2023 milestones, [the CBP will] determine how climate change will impact the BMPs included in the WIPs and address these vulnerabilities in the two-year milestones.
- <u>Develop a better understanding of the BMP responses, including new or other emerging BMPs, to climate change conditions.</u>
- In 2021, the Partnership will consider results of updated methods, techniques, and studies and revisit existing estimated loads due to climate change to determine if any updates to those load estimates are needed.
- Jurisdictions will be expected to account for additional nutrient and sediment pollutant loads due to 2025 climate change conditions in a Phase III WIP addendum and/or 2-year milestones beginning in 2022.
- **Consider co-benefits of management actions.**