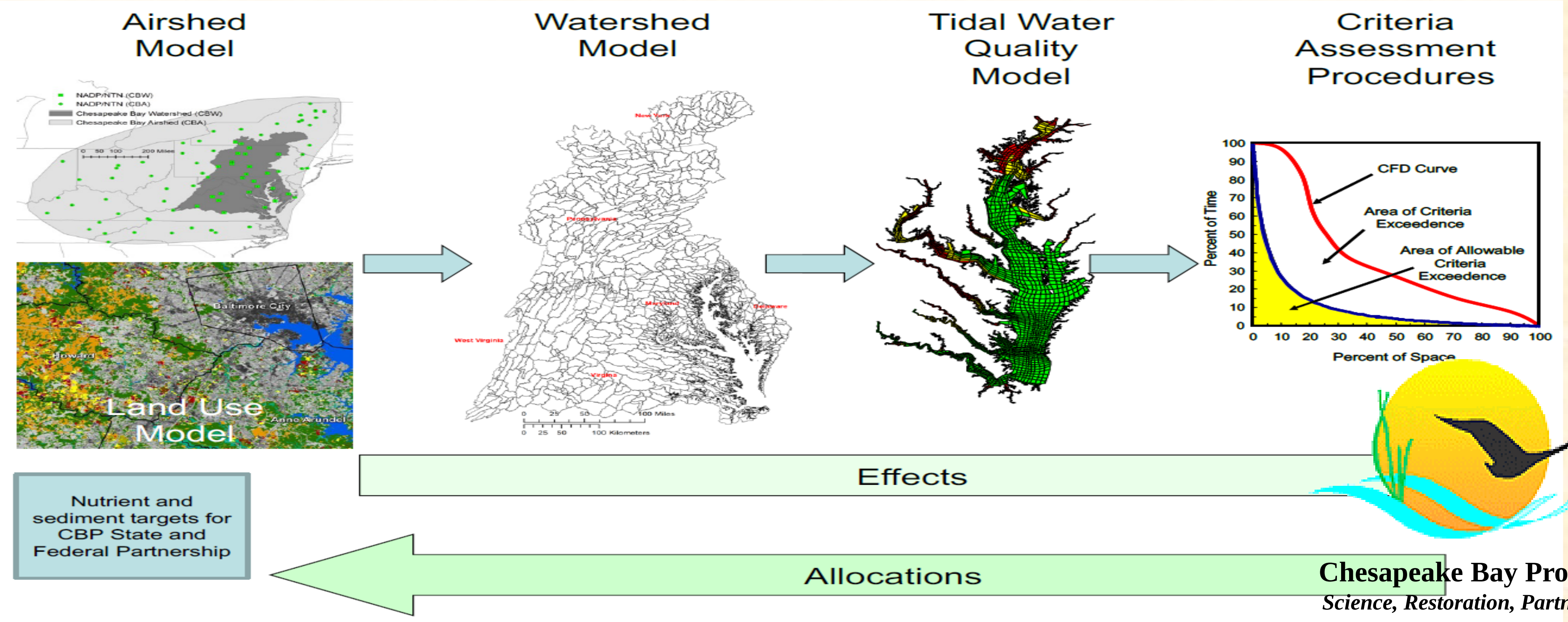
Meeting Context: Setting the Stage for Considerations of Climate Change in the Chesapeake Bay Program

Joint Climate Resiliency, Urban Stormwater, and Modeling Workgroup Meeting

April 4, 2024

Lew Linker (EPA-CBPO), Mark Bennett (USGS), and the CBP Modeling Team



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Setting the Stage: Considerations of CBP Climate Change in the STAC Climate Change 3.0 Workshop

- EC charge to the CBP to assess climate change and how that influences current CBP efforts.
- What the CBP learned from previous STAC 2.0 Climate Change Workshop.
- Modeling components and findings of the Phase 6 climate assessment and expectations of Phase 7.

The EC Directive on Climate Change

Chesapeake Executive Council

Directive No. 21-1 Collective Action for Climate Change

In the 2014 *Chesapeake Bay Watershed Agreement*, the Chesapeake Executive Council committed to *increase the resiliency of the watershed, including its living resources, habitats, public infrastructure and communities, to withstand adverse impacts from changing environmental and climate conditions*. In recognition of the growing body of science documenting the impacts of climate change and the urgent need for action, we must build upon previous commitments and hasten our efforts

"Directive No. 21-1 Collective Action for Climate Change commits the Chesapeake Bay Program to utilize their world-class scientific, modeling, monitoring and planning capabilities to prioritize the communities, working lands and habitats that are most vulnerable to the risks that a changing climate is bringing to the region..."

https://www.chesapeakebay.net/news/blog/the-chesapeake-bay-program-takes-action-on-climate-change

Specifically, for CBP Technical Workgroups of Modeling, Urban Stormwater, and Climate Resiliency

"Apply the best scientific, modeling, monitoring and planning capabilities of the Chesapeake Bay Program [to assess 2035 climate change conditions, and].

- Emphasize the continued need to update best management practice design standards to account for the impacts of climate change, using leading predictive models and tools, to ensure investments made today continue to yield benefits even as the climate changes.
- Determine capacity needed to monitor the impacts of climate change on our natural resources within the existing Chesapeake Bay Program partnership's science programs and evaluate the opportunity to fill those needs with ongoing climate change monitoring programs."
- [Also directs CBP in climate mitigation, and protection of vulnerable communities and habitats.]

https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/climatedirective_final.pdf

In the longer term (by 2025):

1. Create a more sophisticated evaluation framework that incorporates various sources of uncertainty:

   a. To model future climate beyond 2025, rely entirely on projections based on multiple General Circulation Models (GCMs) rather than extrapolation of past trends. This will allow for better incorporation of seasonal and spatial variability in climate projections.

   b. For projections of conditions beyond 2050, evaluate multiple Representative Concentration Pathways (RCPs; IPCC 5th Assessment) or Shared Socioeconomic Pathways (SSPs; IPCC 6th Assessment).

   c. Recognize and quantify multiple sources of uncertainty for use in modeling and decision making.

2. Continue development of climate-related watershed model capabilities with particular attention to BMP effectiveness.

3. Develop a new estuarine model with:

   a. An unstructured grid that extends onto the coastal shelf.

   b. Updated biogeochemistry, particularly appropriate for a future warmer climate.

   c. A simulation of wetting, drying, and waves.

Elements of Phase 6 CBP Climate Change Assessment

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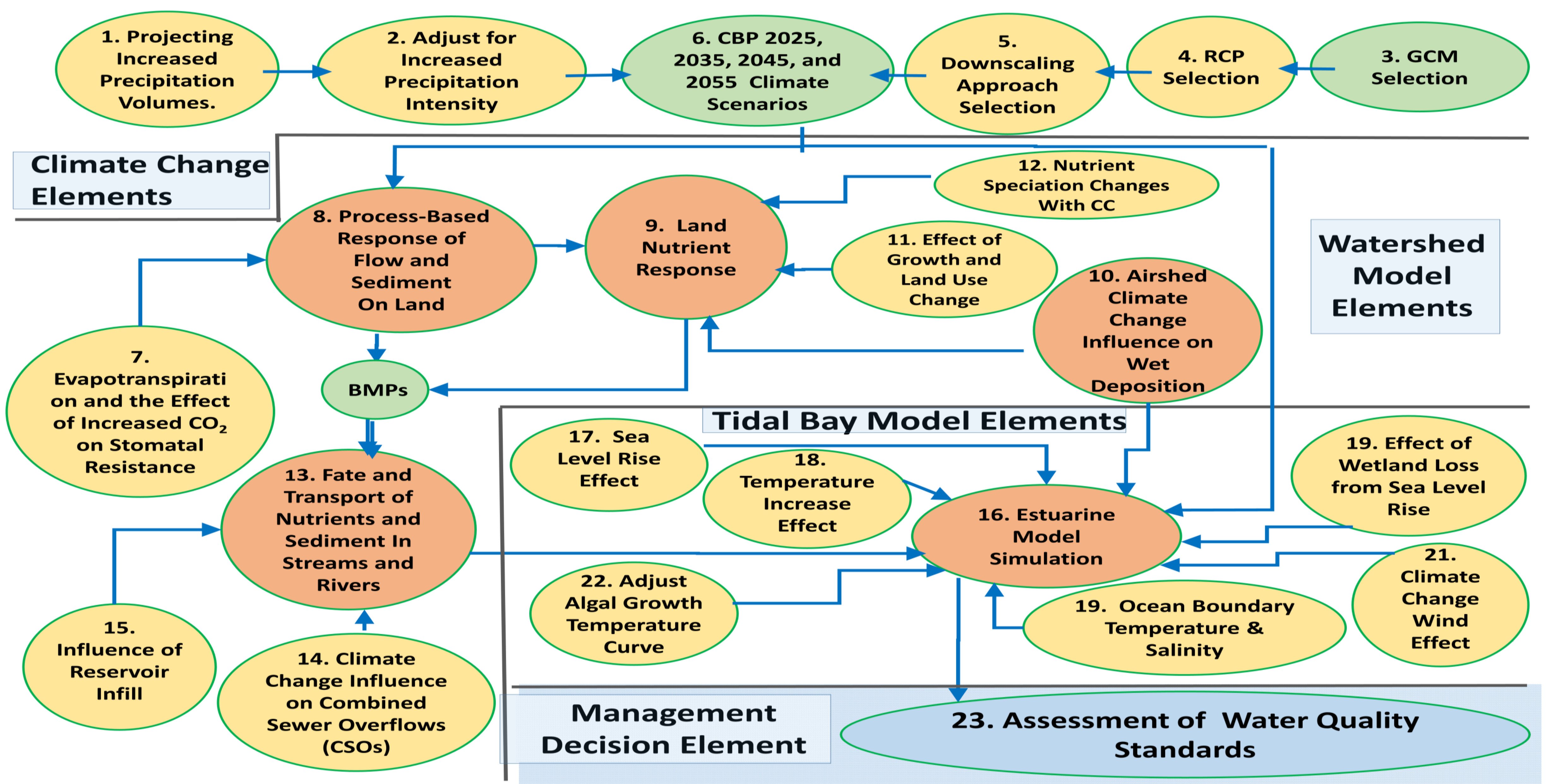

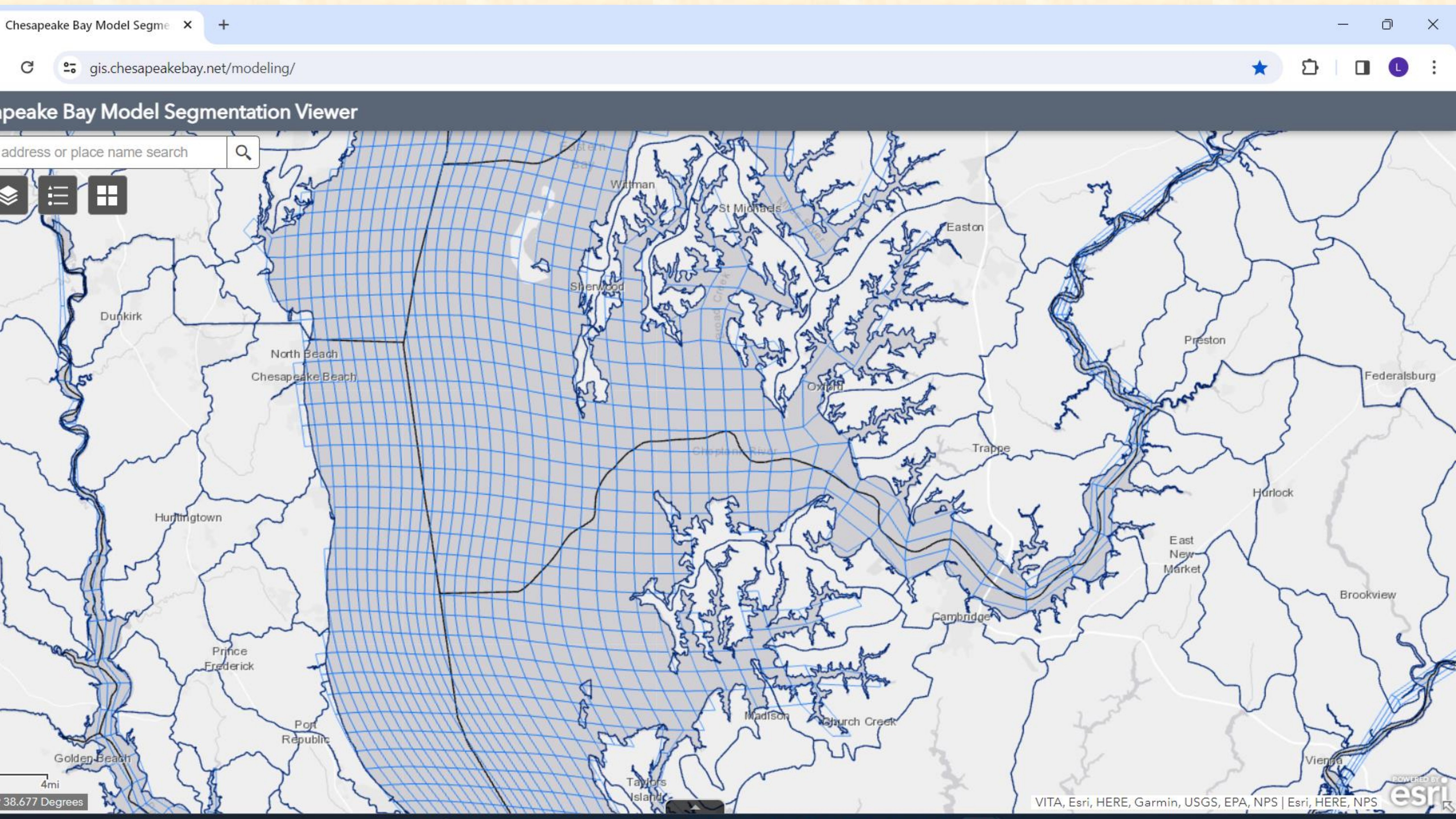
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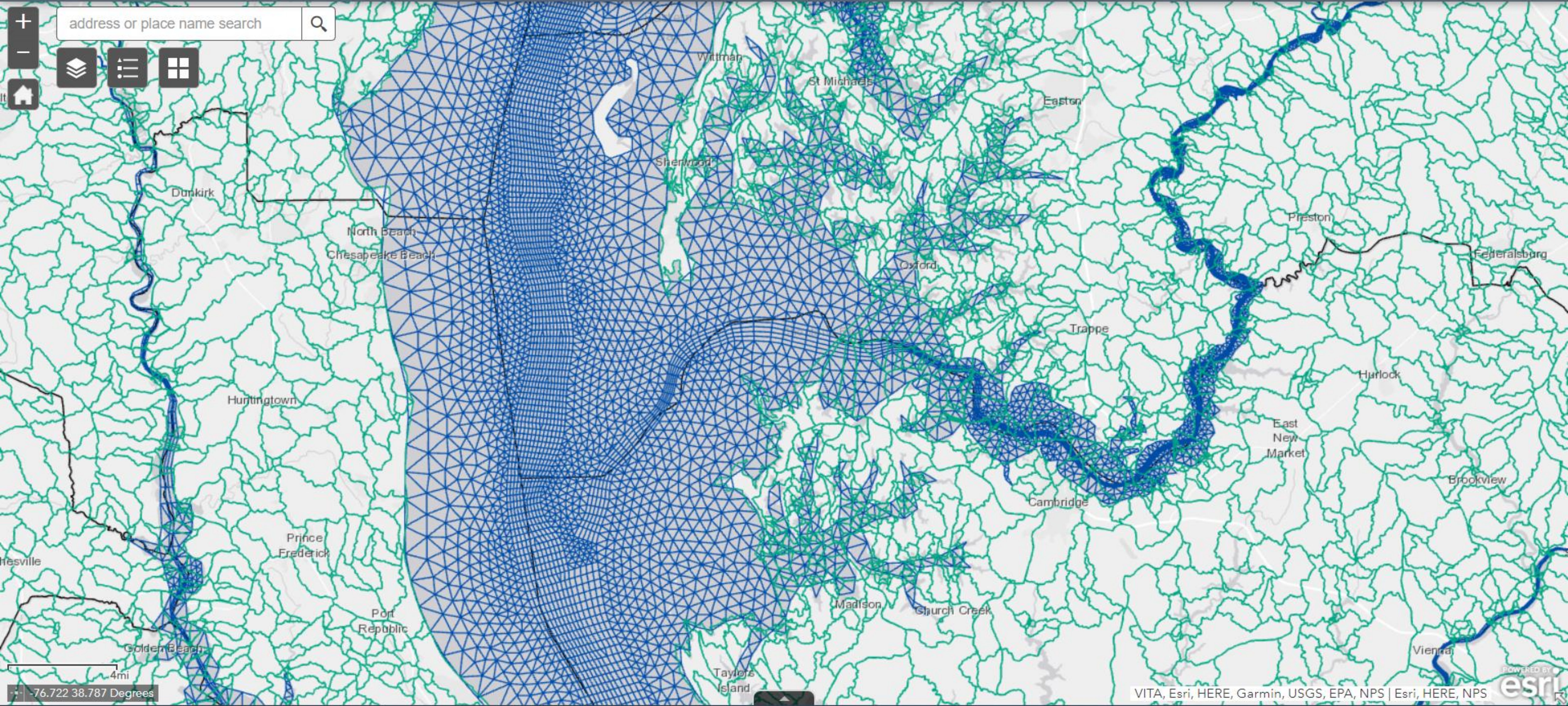

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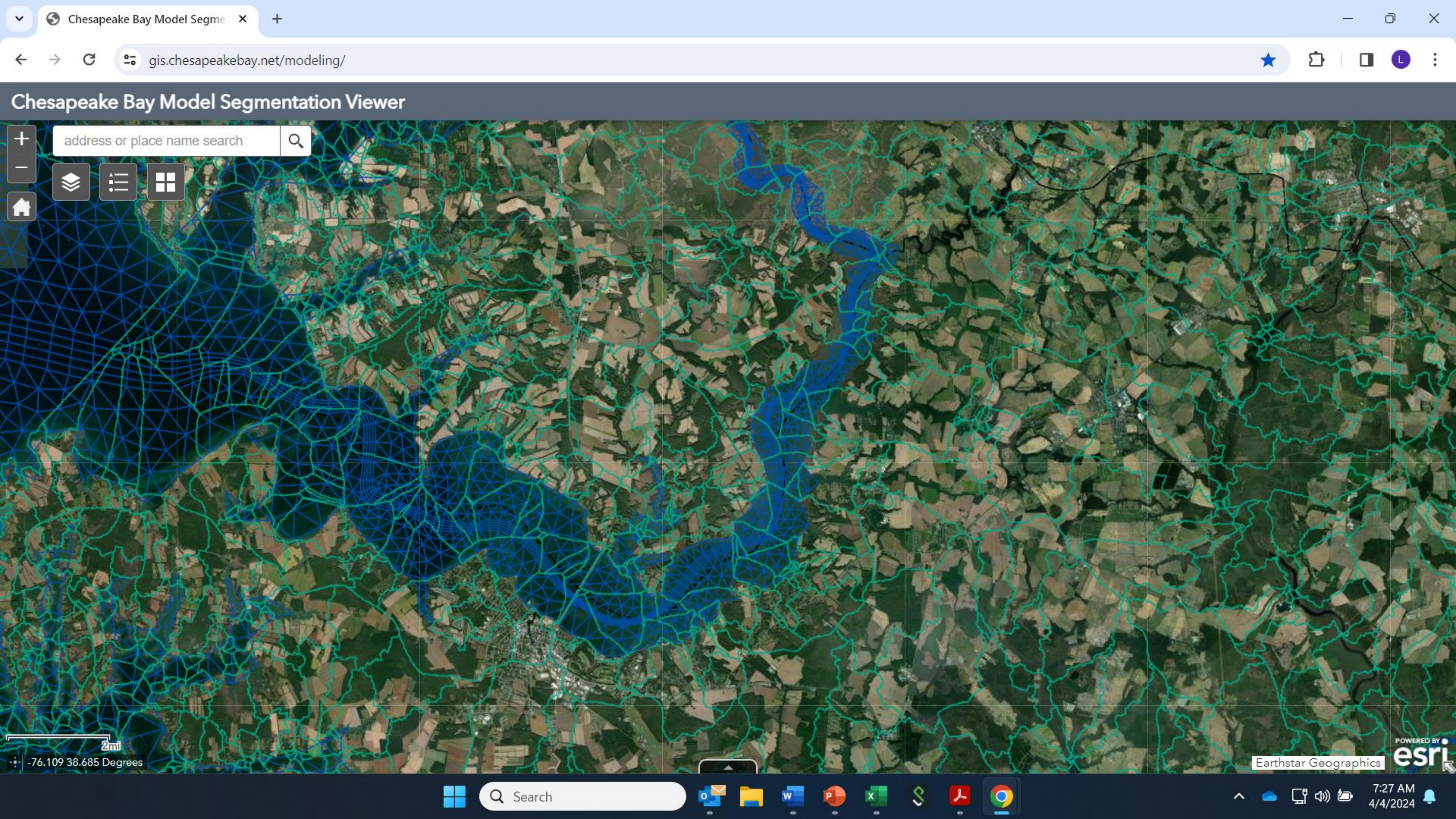
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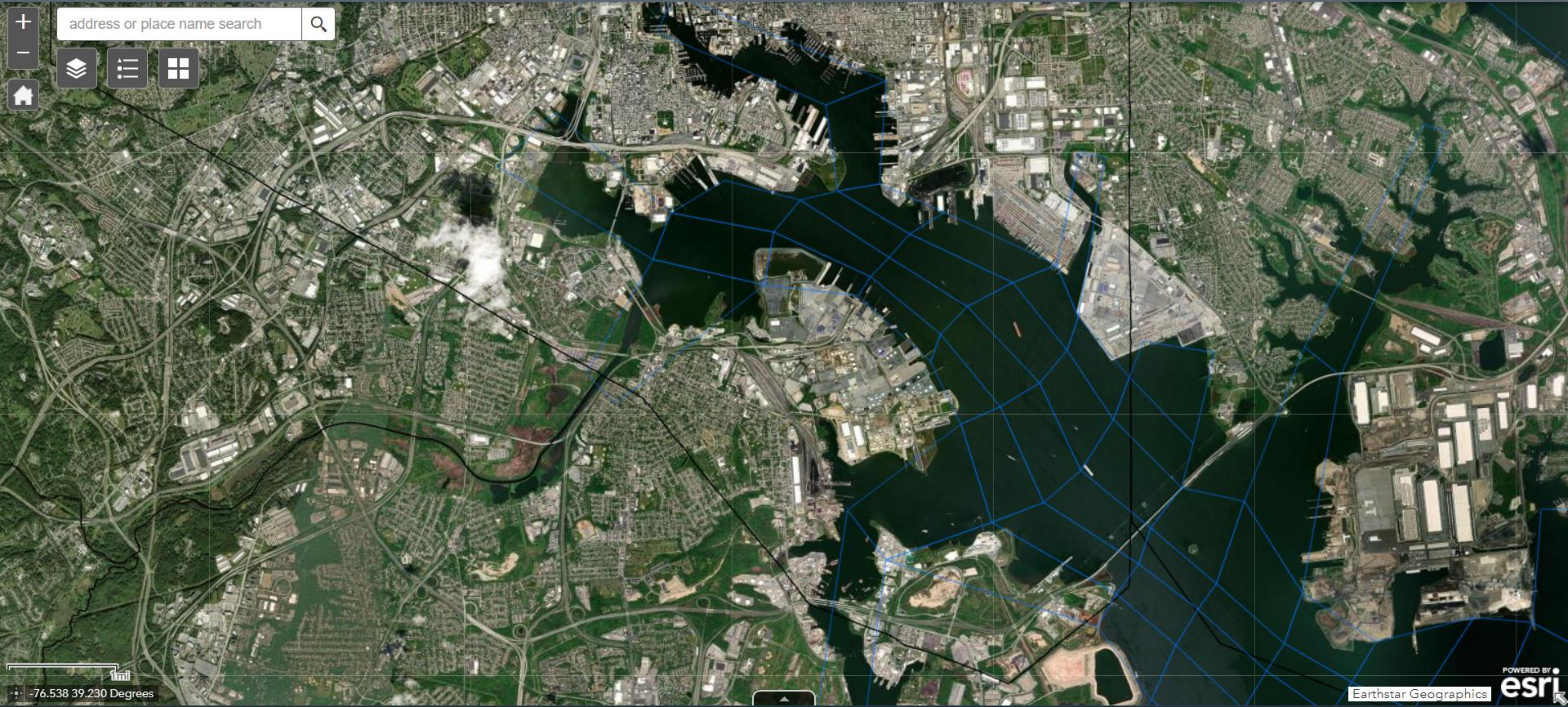

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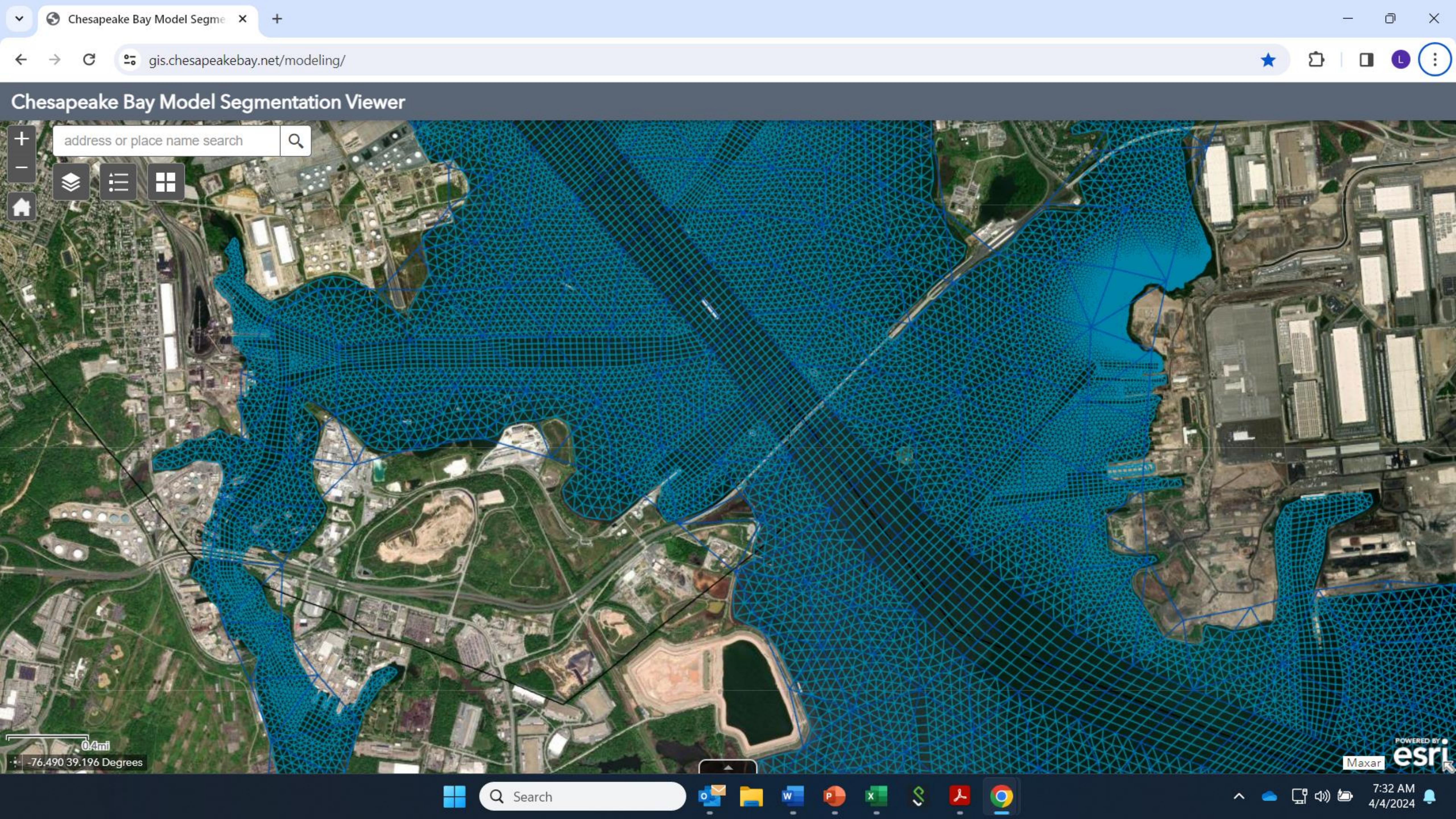
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Overview of Bay Designated Uses

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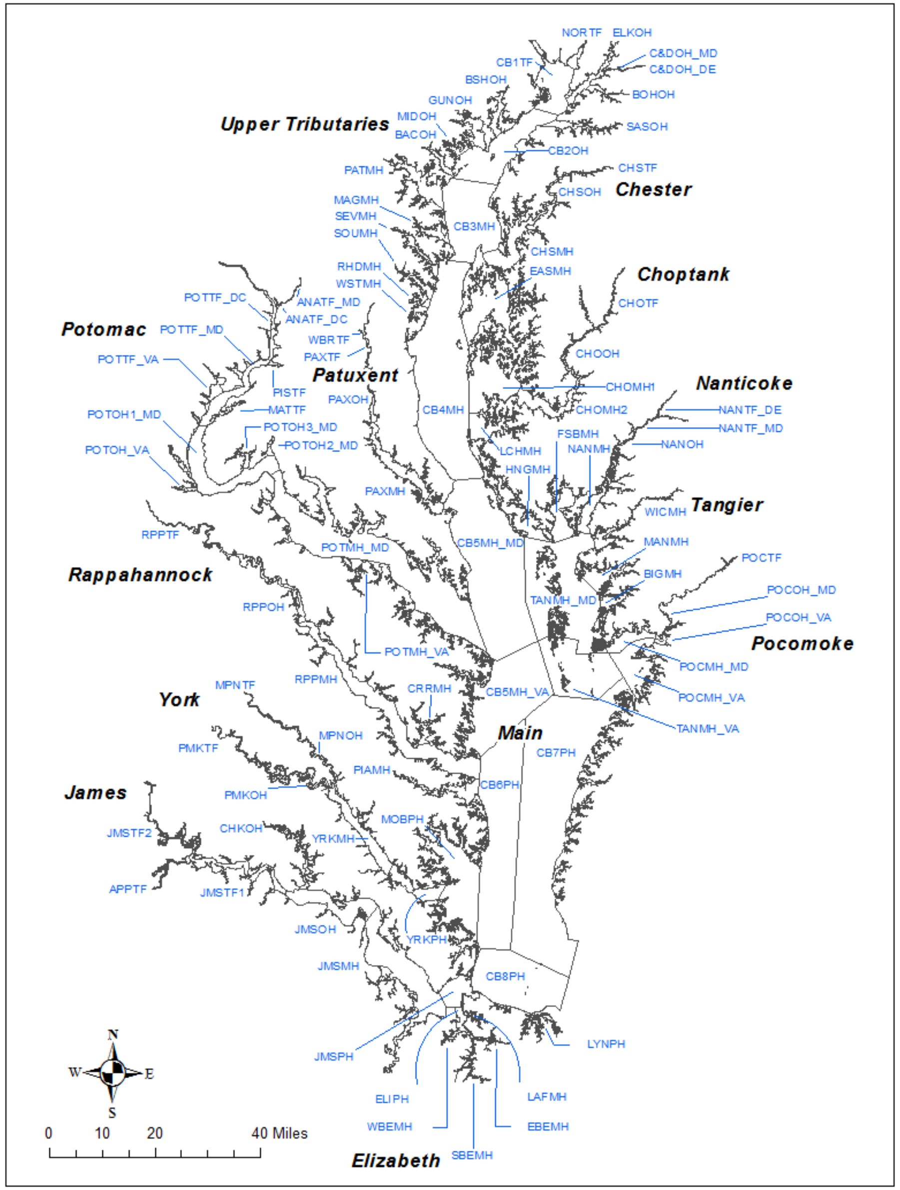

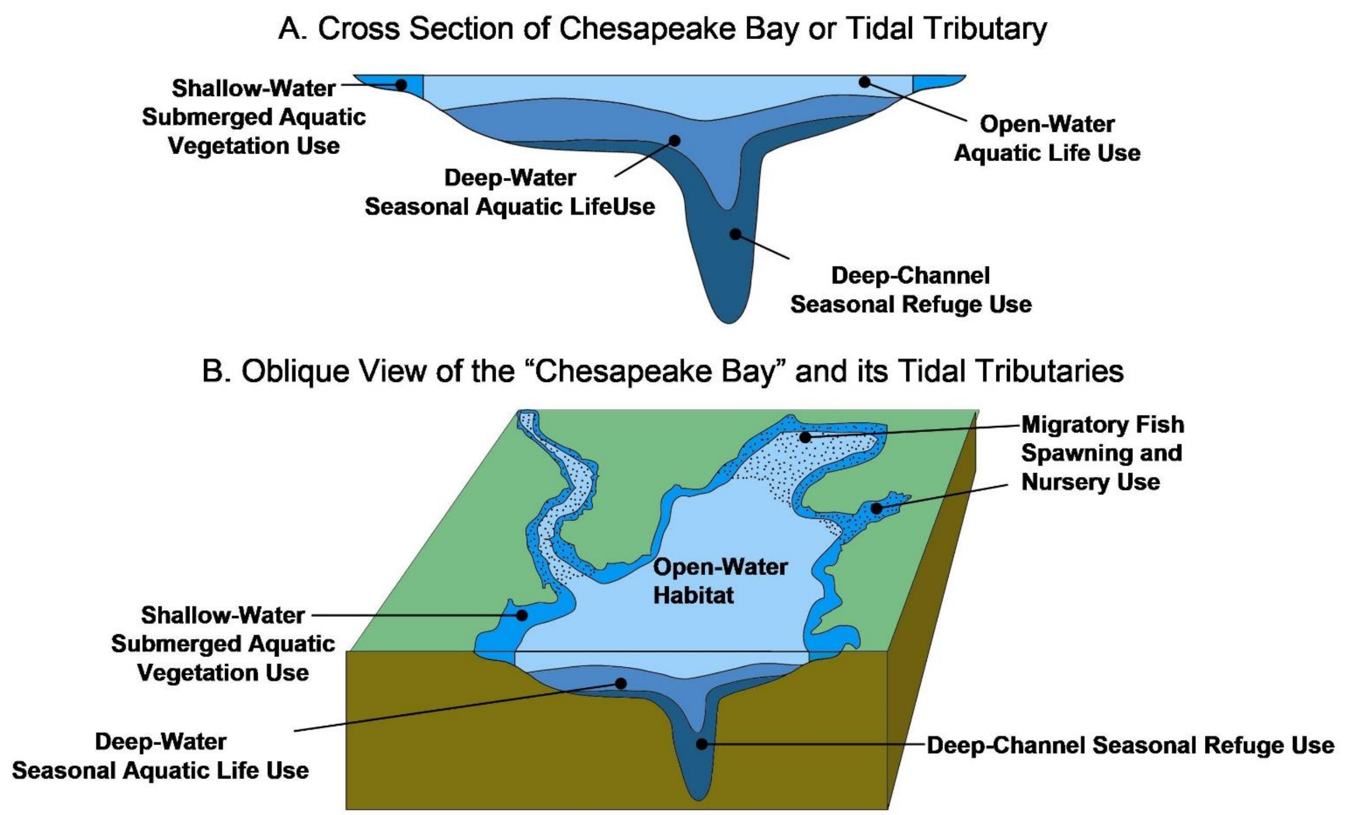

Agenda – Day 1

10:15 Management Motivation for Phase 7 Models for 2035 Climate Assessment

10:40 Were We've Been And Where We're Going: CBP Phase 6 and Current Phase 7 Watershed Models

11:25 Were We've Been And Where We're Going: CBP Phase 6 and Current Phase 7 Estuarine Models

1:00 Climate Management Application of the Phase 7 Models

1:15 Overview and Recommendations from Prior STAC Workshops

1:45 CHAMP Climate Change Findings

3:15 Breakouts

Agenda – Day 2

9:00 Ecosystem, Living Resources, and Shallow Water Management: Forty years from now what does the Bay look like? Processes and Pathways to Climate-Informed Marine Resource Decisions.

10:45 Climate Science – What is the CBP Ignoring That It Should Not.

11:20 Climate and Phenology: Seasonal Effects on the Watershed

1:00 Climate and Phenology: Seasonal Effects on the Tidal Bay

2:00 Breakouts

Agenda – Day 3

8:45 Breakouts, Report Outs, and Writing Draft

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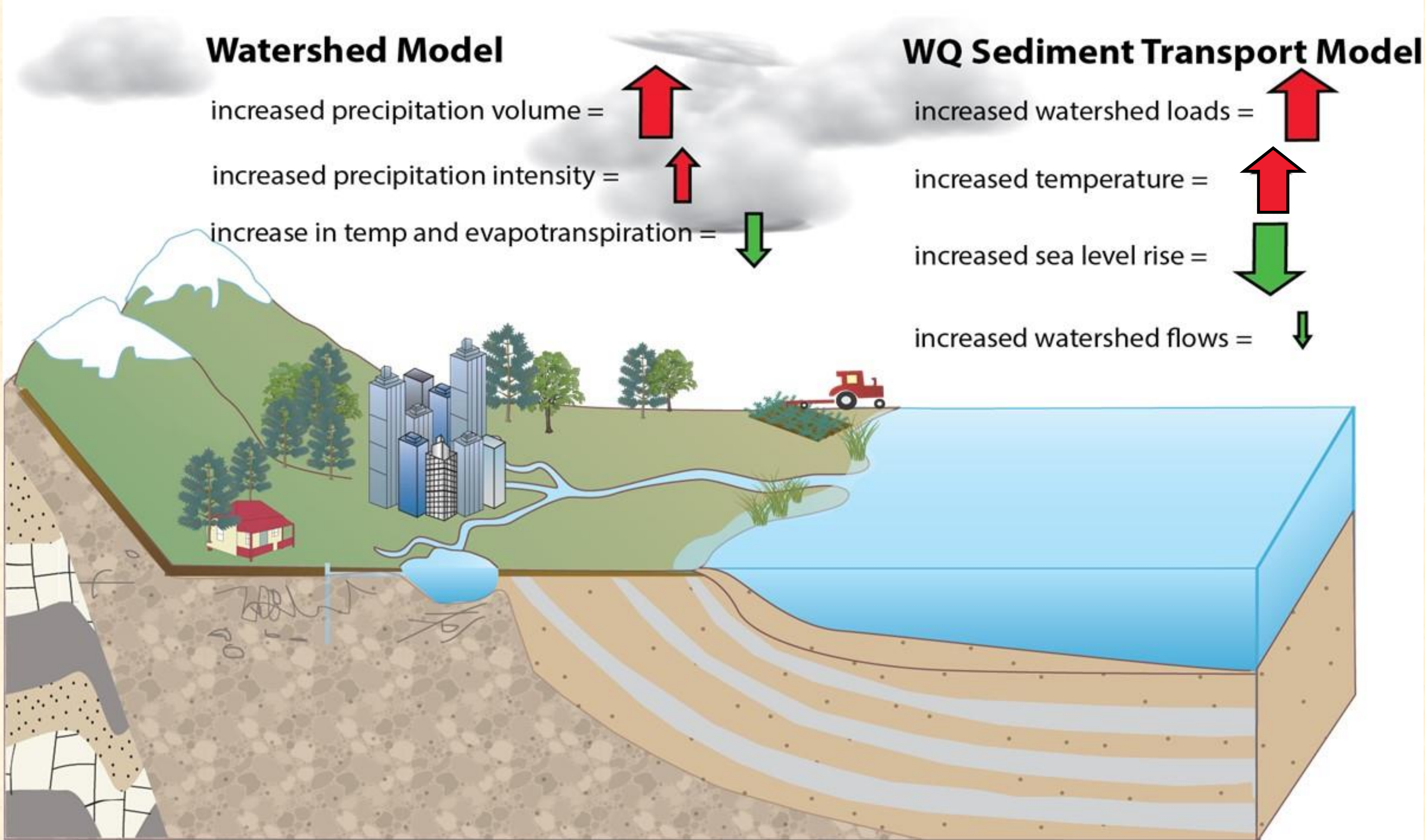
Components of Climate Change Effect on Tidal Hypoxia



Approaches, Methods, and Findings from the Watershed

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An ensemble of GCM projections from BCSD CMIP5[1] was used to estimate 1995-2025 temperature change.

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Data unavailable
GCM Used
Selection updated

Updated Ensemble members		
ACCESS1-0	FGOALS-g2	IPSL-CM5A-LR
BCC-CSM1-1	FIO-ESM	IPSL-CM5A-MR
BCC-CSM1-1-M	GFDL-CM3	IPSL-CM5B-LR
BNU-ESM	GFDL-ESM2G	MIROC-ESM
CanESM2	GFDL-ESM2M	MIROC-ESM-CHEM
CCSM4	GISS-E2-H-CC	MIROC5
CESM1-BGC	GISS-E2-R	MPI-ESM-LR
CESM1-CAM5	GISS-E2-R-CC	**MPI-ESM-MR**
CMCC-CM	HadGEM2-AO	MRI-CGCM3
CNRM-CM5	HadGEM2-CC	NorESM1-M
CSIRO-MK3-6-0	HadGEM2-ES	
EC-EARTH	INMCM4	

31 member ensemble

[1] BCSD – Bias Correction Spatial Disaggregation;
[1] CMIP5 – Coupled Model Intercomparison Project 5

Source: Kyle Hinson, VIMS

Reclamation, 2013. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 47pp.

For the 2025 Climate Change Estimate:

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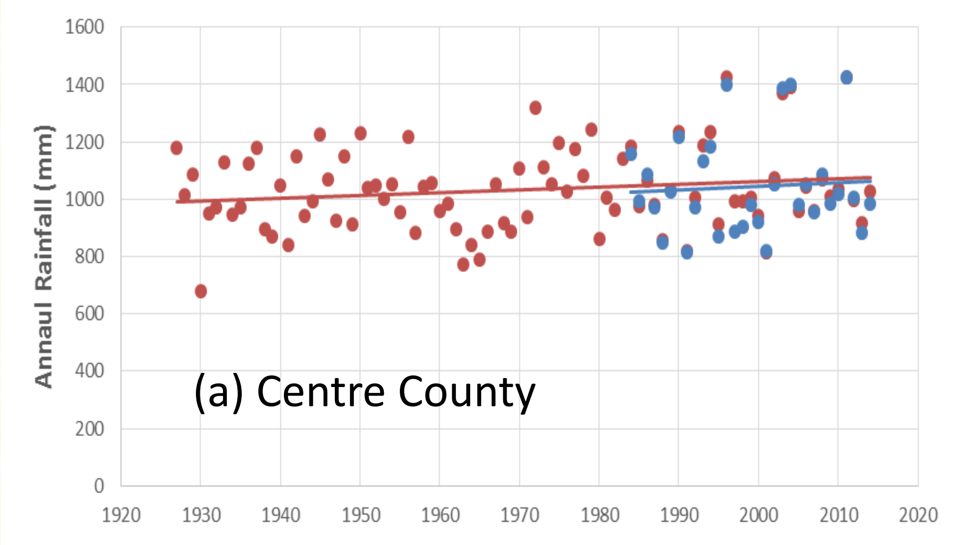
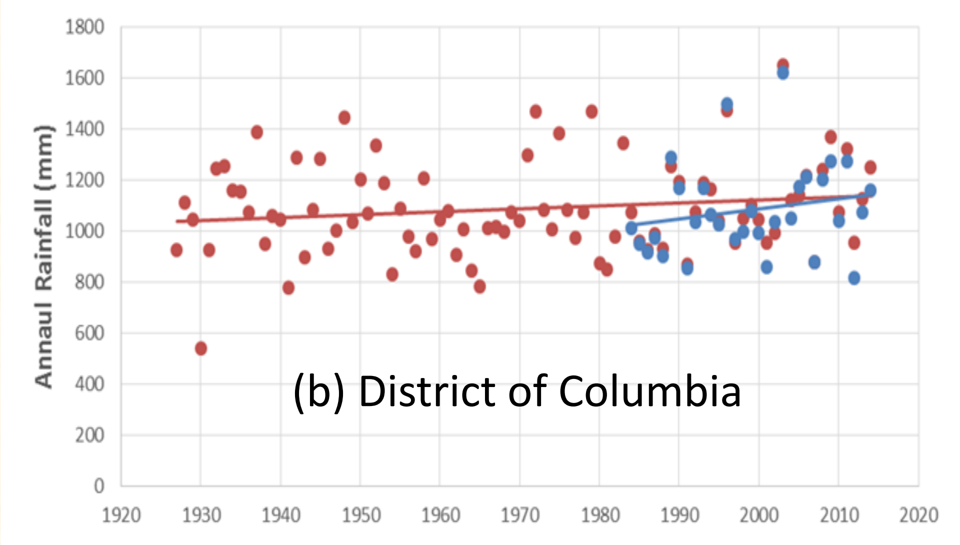
The trends in annual precipitation on a county level were developed through the application of PRISM data and analysis provided and recommended by Jason Lynch, EPA, and Karen Rice, USGS. The annual PRISM dataset for the years 1927 to 2014 (88 years) were used in for the regression trend analysis. For the analysis PRISM data were first spatially aggregated for each Phase 6 land segments. The Phase 6 land segments typically represent a county. For each land segment a simple linear trend was fitted to the annual rainfall dataset.





Annual rainfall volumes for the 88-year period linear regression lines are shown in red for the two land segments (counties) – (a) Centre County in Pennsylvania and (b) District of Columbia. The values for the slope of the regression lines, and the corresponding 30-year projections in the rainfall volume (1995 to 2025) are also shown.

Source: Section 12 of Phase 6 Documentation

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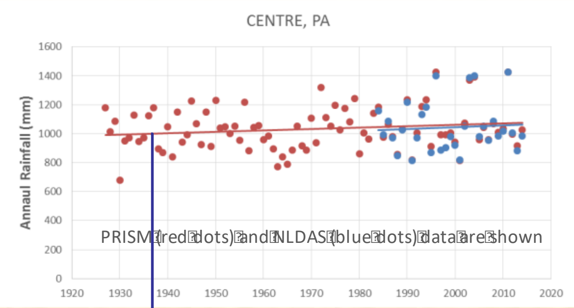
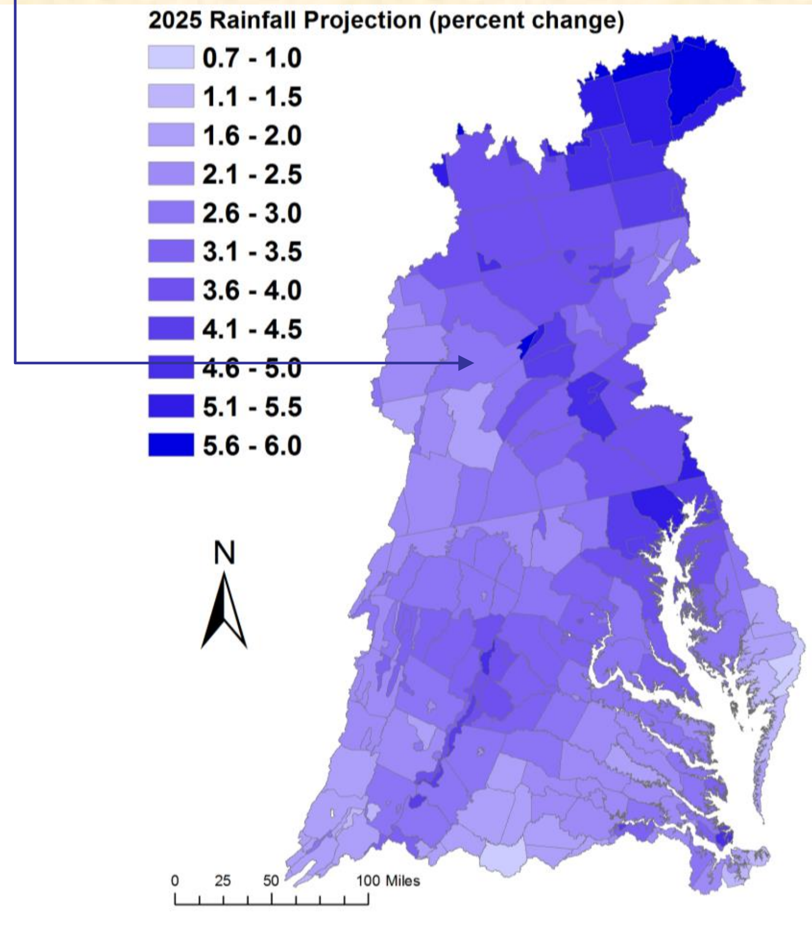
Assessment of Influence of 2025 Climate Change in the Watershed





Projections of rainfall increase using trend in 88-years of annual PRISM[1] data

Change in Rainfall Volume 2021-2030 vs. 1991-2000

Major Basins	PRISM Trend
Youghiogheny River	2.1%
Patuxent River Basin	3.3%
Western Shore	4.1%
Rappahannock River Basin	3.2%
York River Basin	2.6%
Eastern Shore	2.5%
James River Basin	2.2%
Potomac River Basin	2.8%
Susquehanna River Basin	3.7%
Chesapeake Bay Watershed	**3.1%**

[1] Parameter-elevation Relationships on Independent Slopes Model

1940-2014 streamflow trends based on observations

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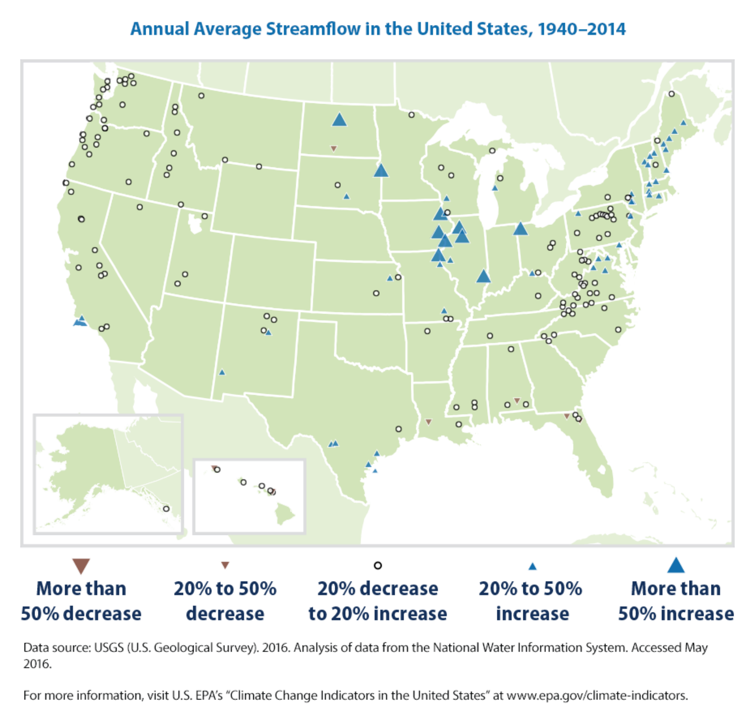
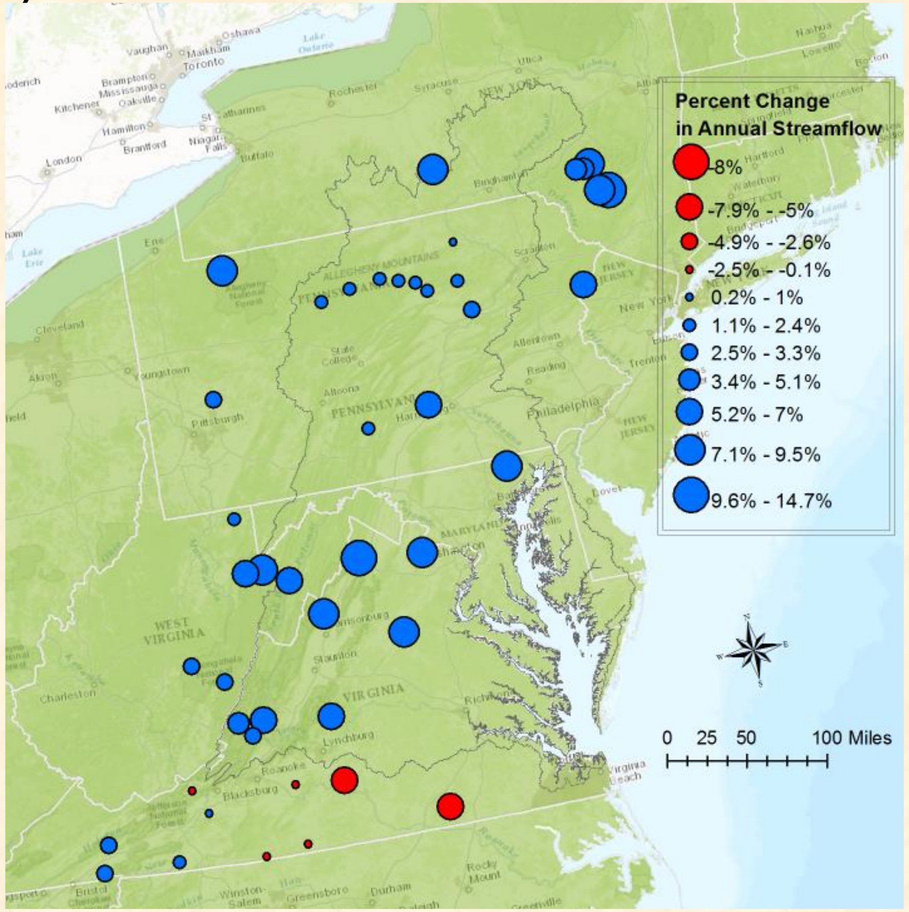
The study analyzed USGS GAGES-II data for a subset of Hydro-Climatic Data Network 2009 (HCDN-2009).





Karen C. Rice, Douglas L. Moyer, and Aaron L. Mills, 2017. Riverine discharges to Chesapeake Bay: Analysis of long-term (1927 - 2014) records and implications for future flows in the Chesapeake Bay basin *JEM* 204 (2017) 246-254

USGS station ID	Precipitation		Discharge	
	Slope	p-value	Slope	p-value
04252500	0.0007	**0.0011**	0.0021	**<0.0001**
01512500	0.0008	**0.0007**	0.0016	**0.0028**
01503000	0.0007	**0.0022**	0.0013	**0.0181**
01531000	0.0006	**0.0219**	0.0018	**0.0030**
01531500	0.0007	**0.0044**	0.0016	**0.0029**
01532000	0.0006	**0.0374**	0.0015	**0.0330**
01534000	0.0005	**0.0497**	0.0015	**0.0120**
01550000	0.0005	**0.0493**	0.0019	**0.0015**
01543000	0.0004	0.1000	0.0018	**0.0058**
01545500	0.0004	0.0953	0.0017	**0.0026**
01536500	0.0006	**0.0078**	0.0016	**0.0027**
01551500	0.0005	0.0612	0.0017	**0.0017**
01439500	0.0005	0.0972	0.0007	0.1661
01541500	0.0003	0.2357	0.0017	**0.0017**
01540500	0.0006	**0.0111**	0.0016	**0.0023**
01541000	0.0004	0.0985	0.0016	**0.0021**
01567000	0.0004	0.1577	0.0011	**0.0250**
01570500	0.0005	**0.0260**	0.0013	**0.0088**
North-South Split				
01562000	0.0004	0.1693	0.0007	0.2082
01638500	0.0004	0.1150	0.0008	0.1026
01608500	0.0004	0.1725	0.0010	0.0833
01636500	0.0005	0.1245	0.0008	0.0624
01606500	0.0003	0.1958	0.0009	0.1108
01668000	0.0006	0.0794	0.0004	0.4727
02035000	0.0003	0.2653	−0.0001	0.8243
02019500	0.0002	0.4333	0.0003	0.4836
03488000	0.0003	0.2480	0.0006	0.2841

U.S. Environmental Protection Agency. 2016. Climate change indicators in the United States, 2016. Fourth edition. EPA 430-R-16-004. www.epa.gov/climate-indicators.

Annual average percent change were calculated using Sen slope (Helsel and Hirsch, 2002).

Lins, H.F. 2012. USGS Hydro-Climatic Data Network 2009 (HCDN-2009). U.S. Geological Survey Fact Sheet 2012-3047. https://pubs.usgs.gov/fs/2012/3047.
Helsel, D.R., and R.M. Hirsch. 2002. Statistical methods in water resources. Techniques of water resources investigations, Book 4. Chap. A3. U.S. Geological Survey. https://pubs.usgs.gov/twri/twri4a3.

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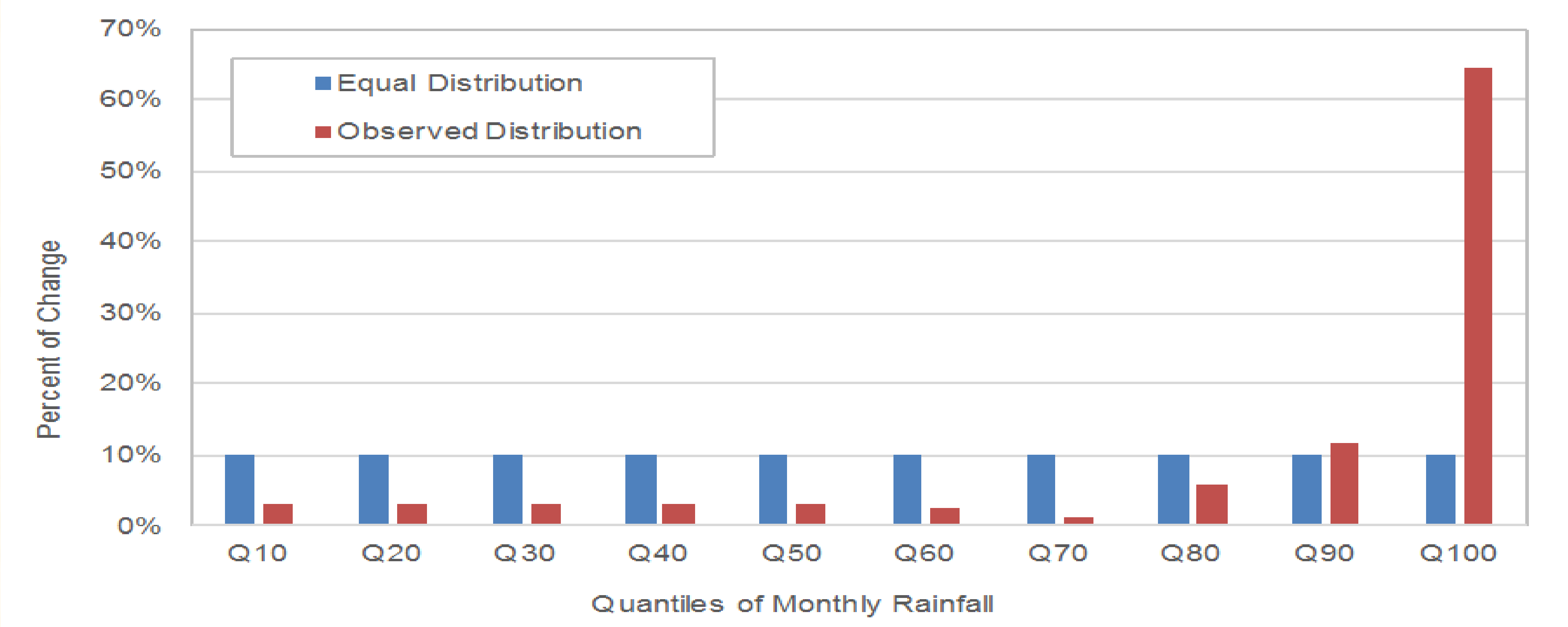
Trends in Observed Rainfall Intensity



Observed changes in rainfall intensity in the Chesapeake region over the last century. The equal allocation distribution (blue) is contrasted with the distribution obtained based on observed changes (red).

Source: Groisman et al. 2004

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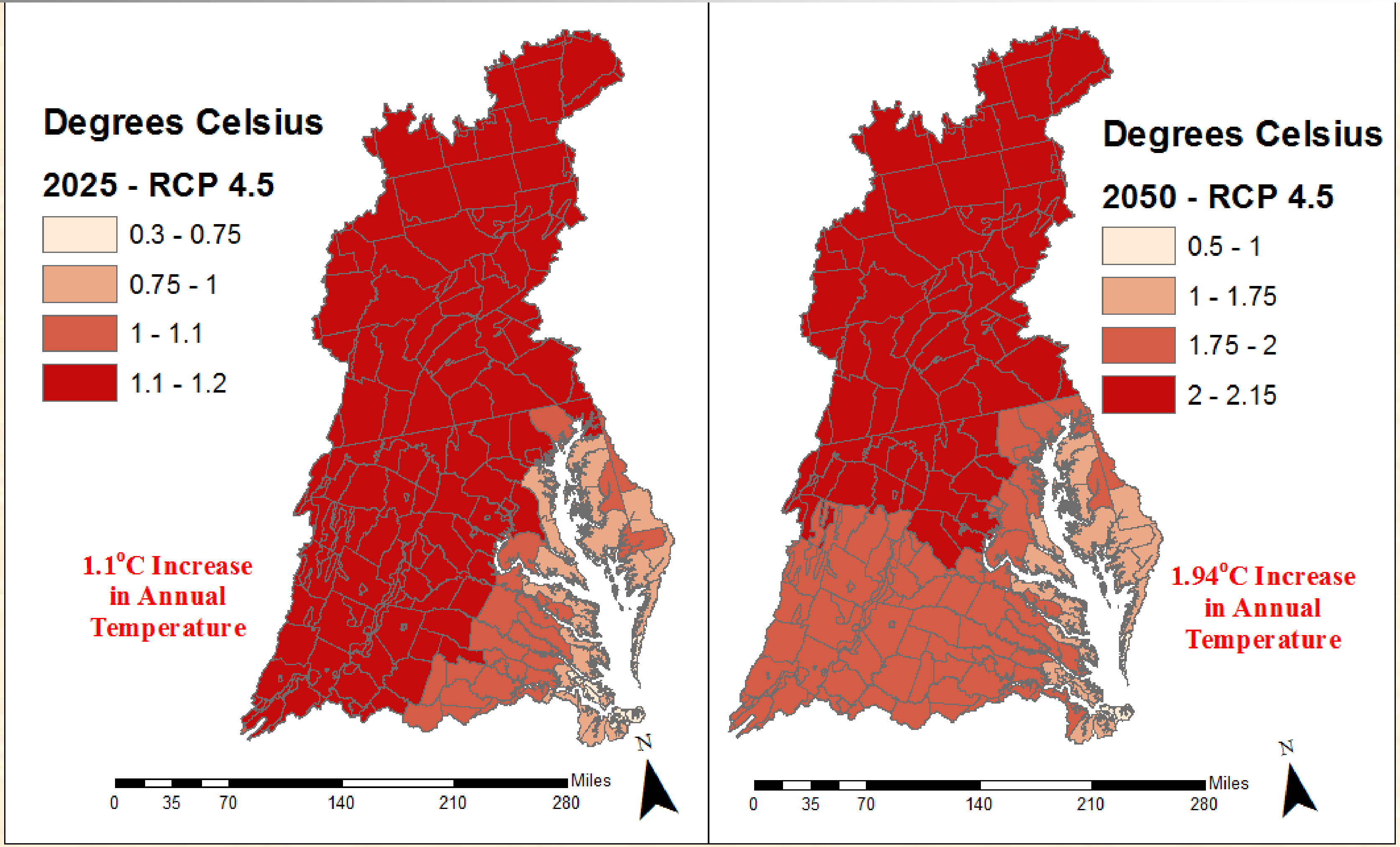
Chesapeake Bay Watershed Annual Change in Temperature



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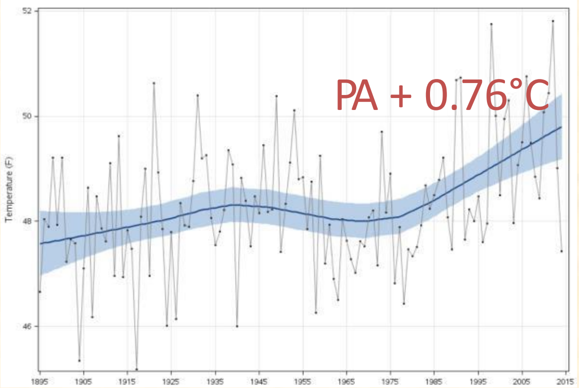
Temperature trends for the six CBP states

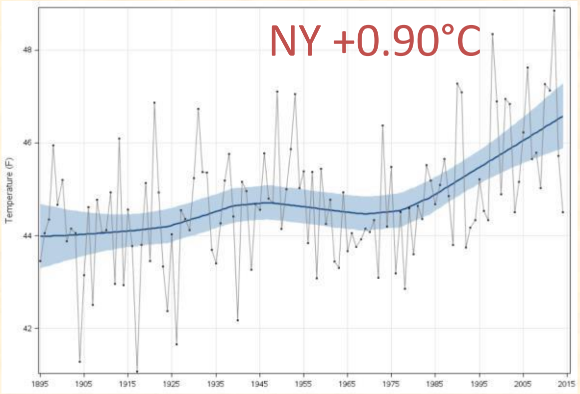
Annual temperature for 1895 to 2015 are shown.

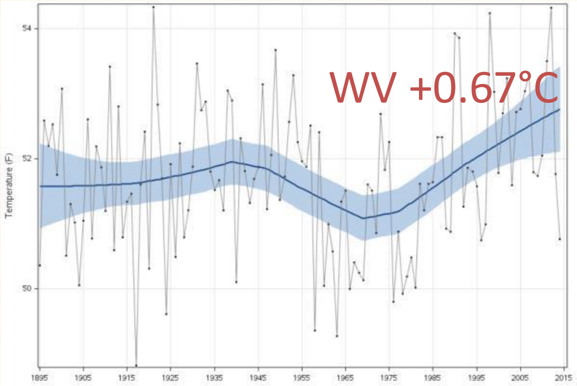
Annual Temperature

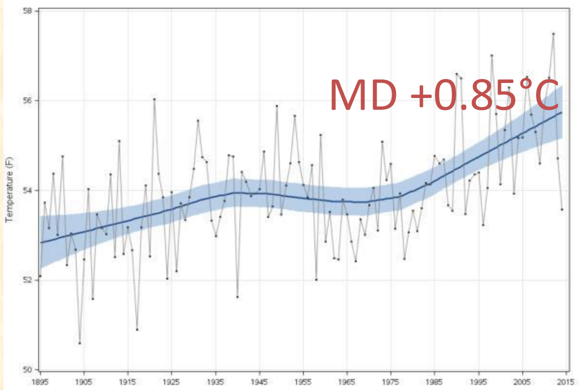
Trend Line

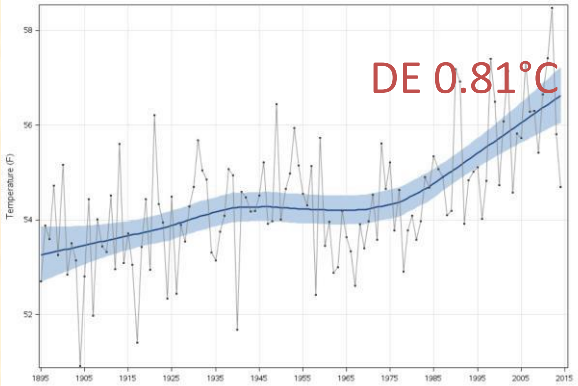
95% Confidence Limits



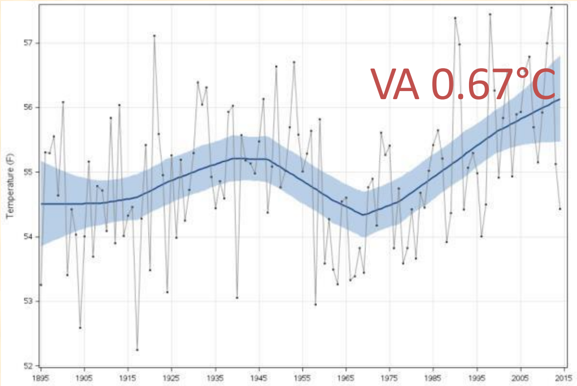








Approx. increases over the last 30 years based on the trend line are shown.



NOAA National Climatic Data Center

https://www.ncdc.noaa.gov/temp-and-precip/state-temps/

Elements of 2025 Climate Change (1995-2025)

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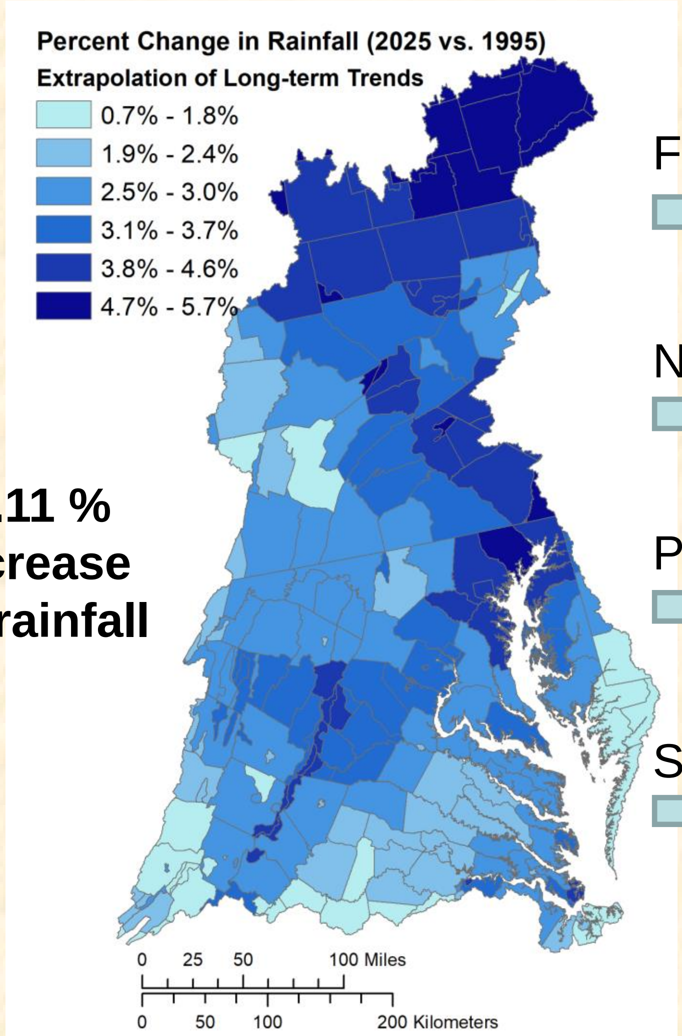
+3.11 % Increase in rainfall



Phase 6 Watershed Model

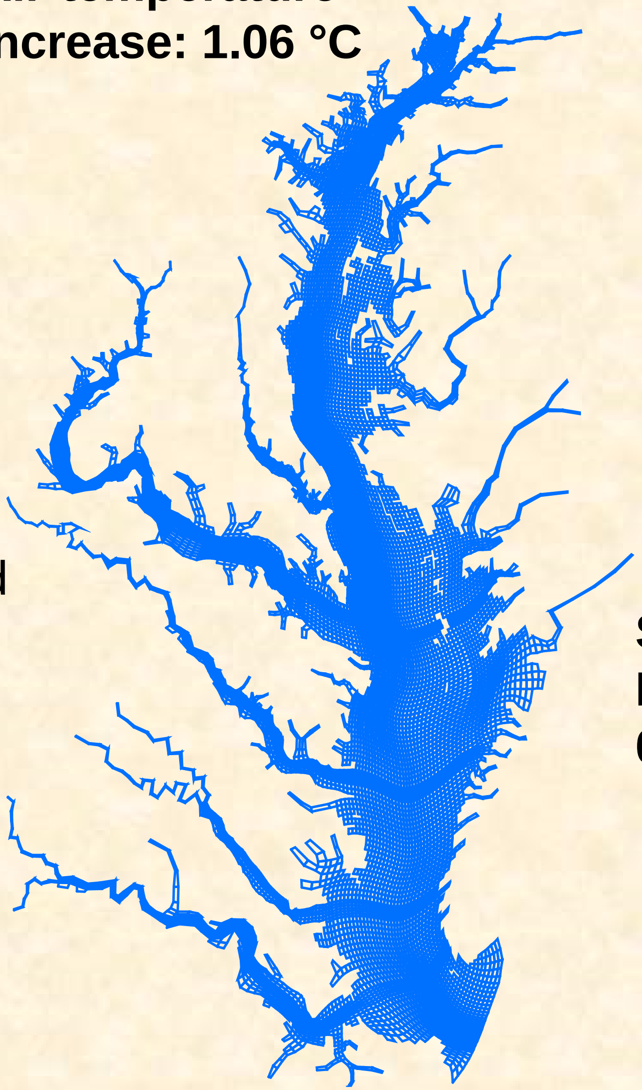
Flow
2.4% Increase

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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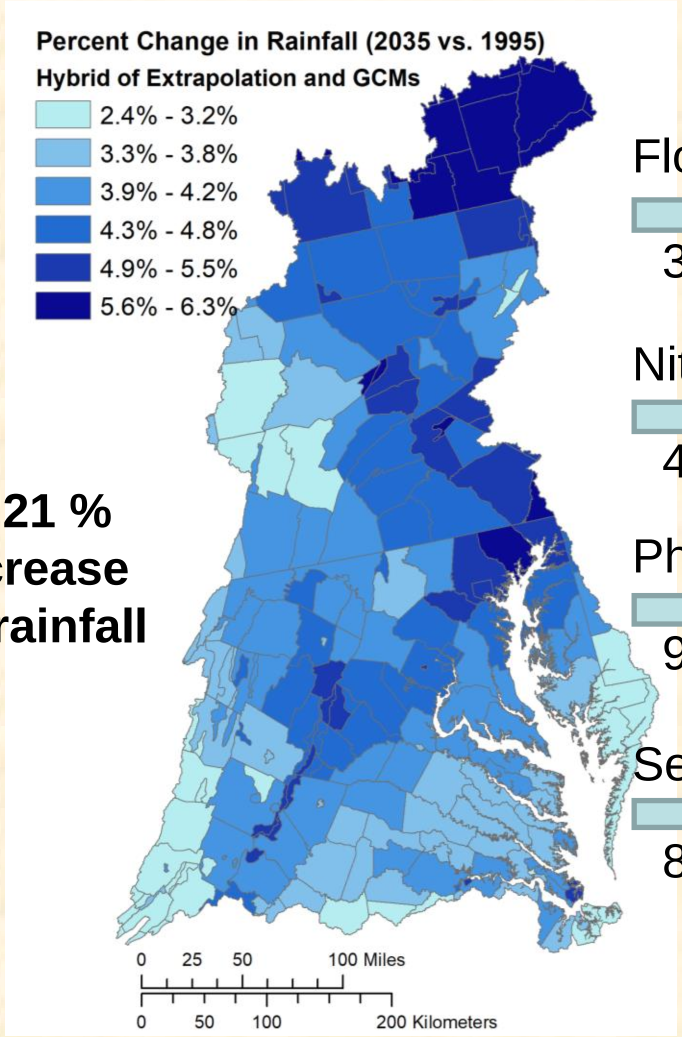
Elements of 2035 Climate Change (1995-2035)



Phase 6 Watershed Model

+4.21 % Increase in rainfall

Flow
3.7% Increase

Nitrogen Load
4.7% Increase

Phosphorus Load
9.9% Increase

Sediment Load
8.5% Increase

Air-temperature increase: 1.39 °C

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)

Estimates of Climate Only and Climate and Land Use

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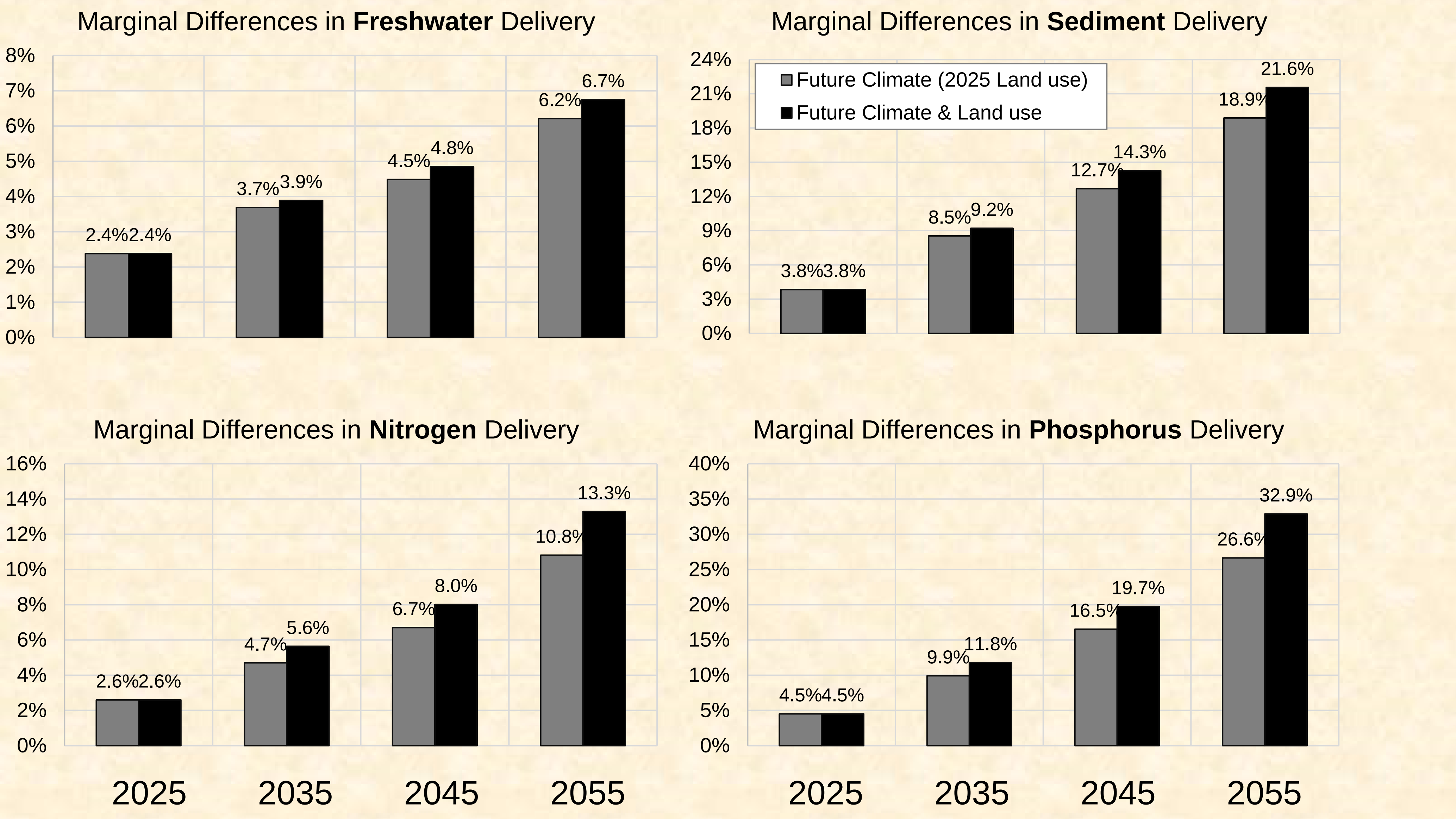

Grey bar = climate only   Black bar = Climate and Land Use

Approaches, Methods, and Findings from the Tidal Bay

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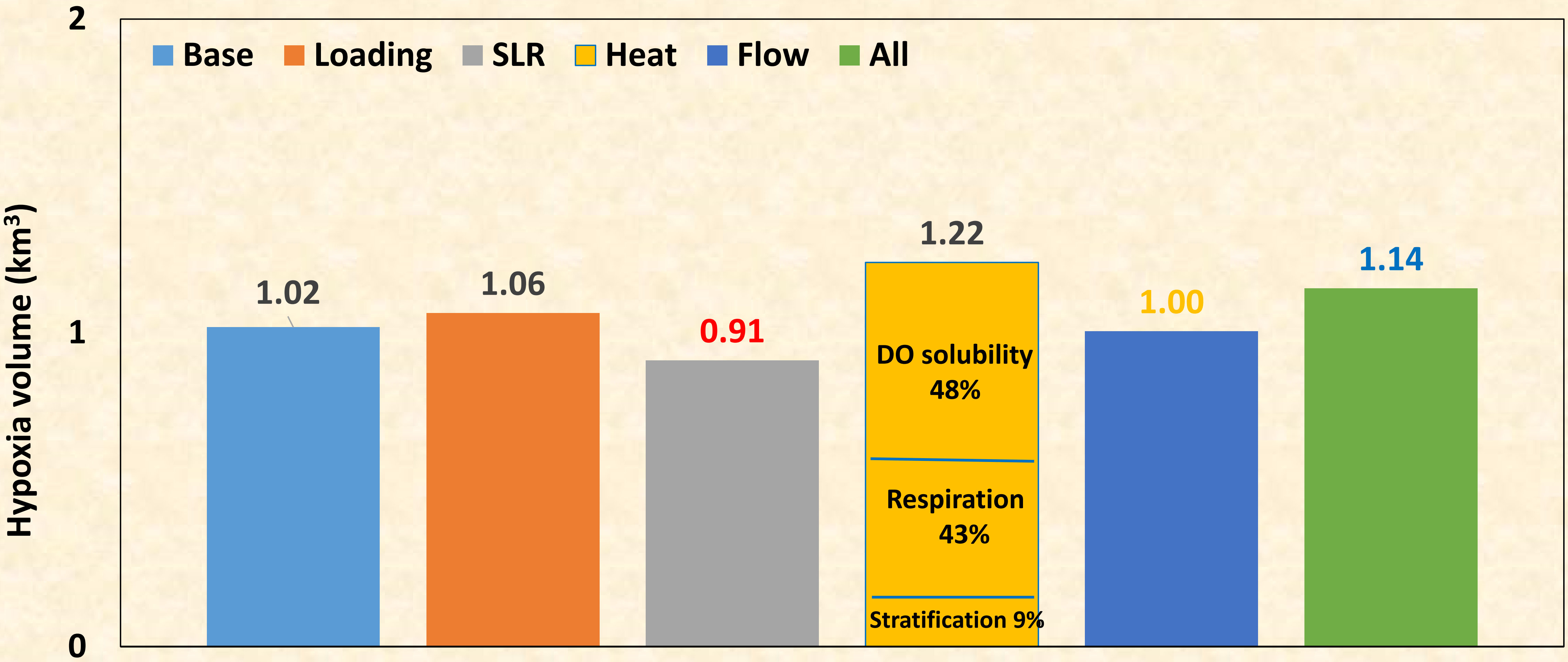
Summer (Jun.-Sep.) Hypoxia Volume (<1 mg/l) 1991-2000 in the Whole Bay Under 2025 WIP3 Condition



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Bottom DO Change: 1995 to 2025

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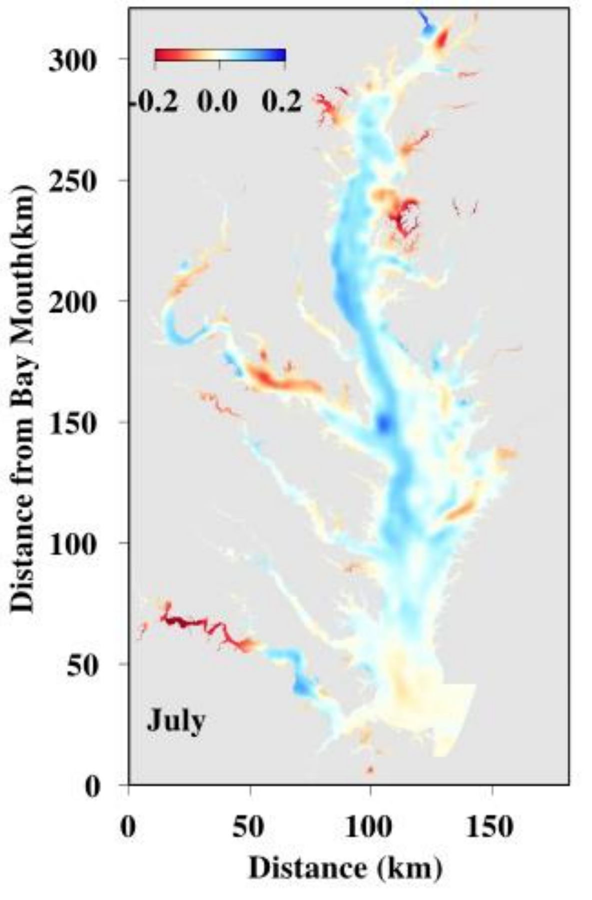
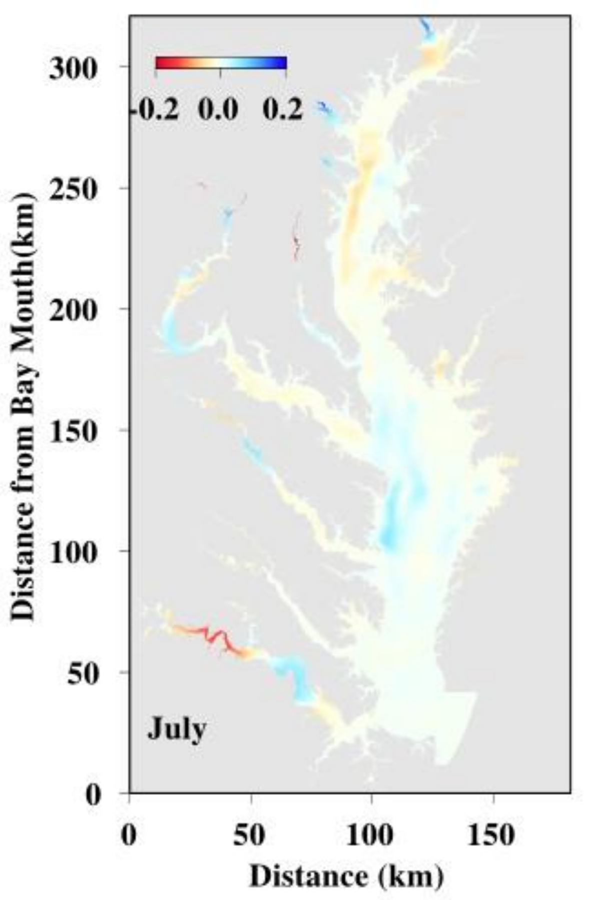
Keeping all other factors constant, sea level rise and increased watershed flow reduce hypoxia in the Bay, but the predominant influence are the negative impacts of increased water column temperature.

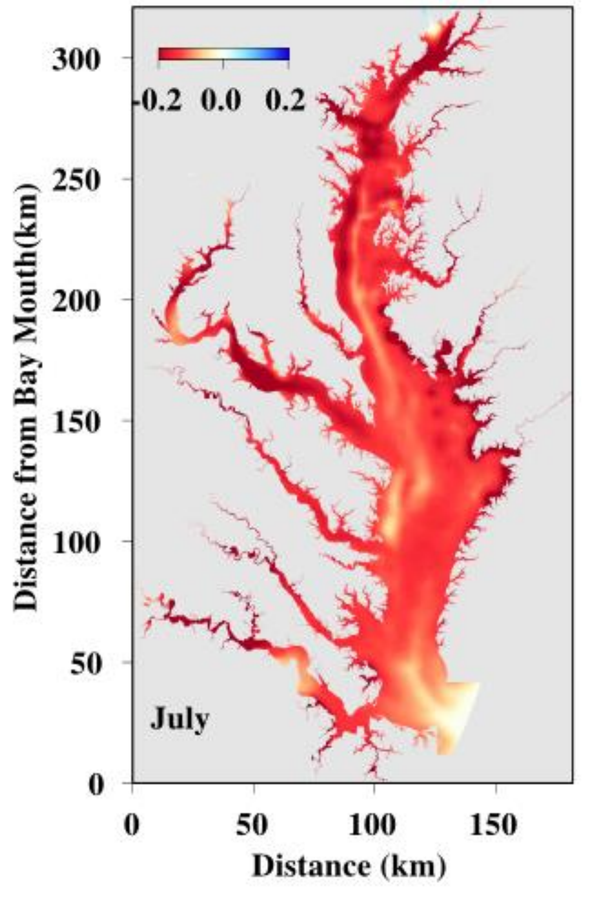
Sea Level Rise



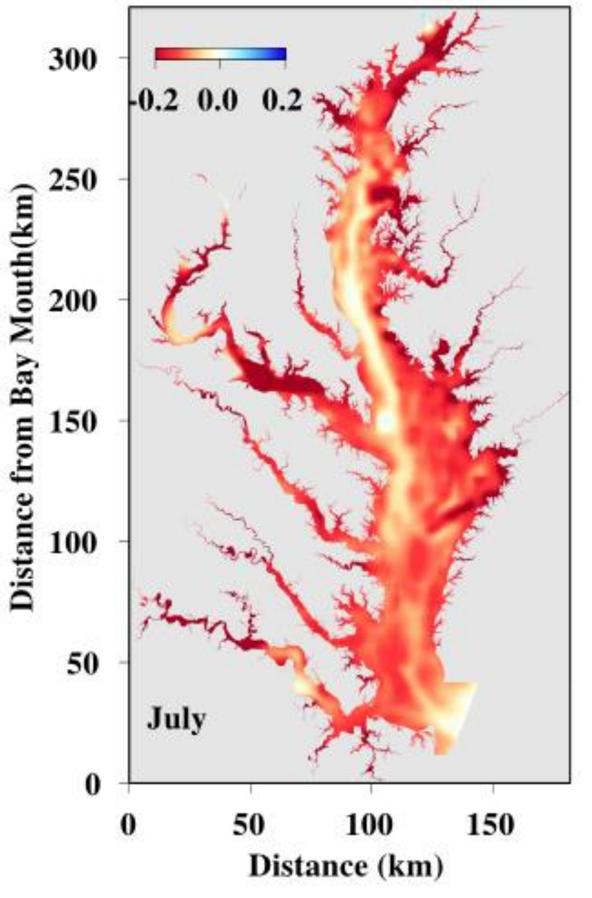
Watershed Flow



Increased Temp.



All Factors



Climate Target Loads in Perspective

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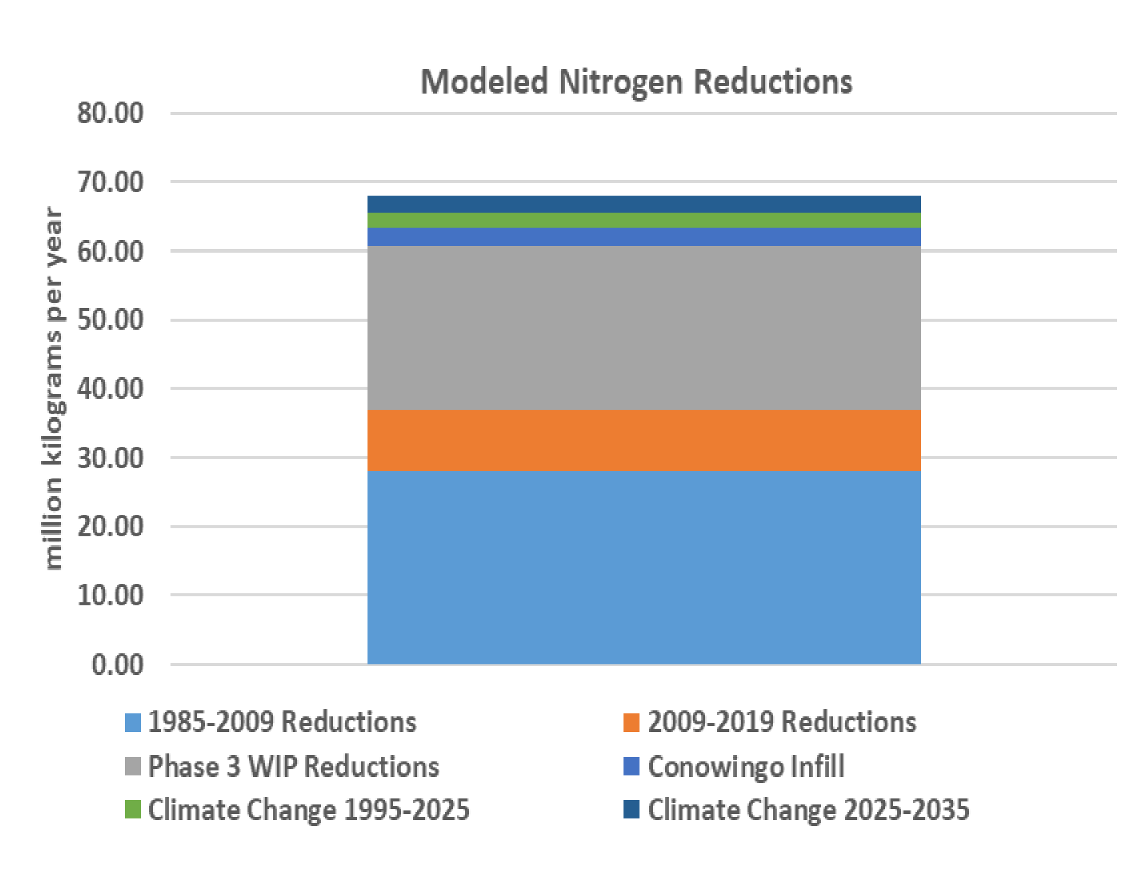
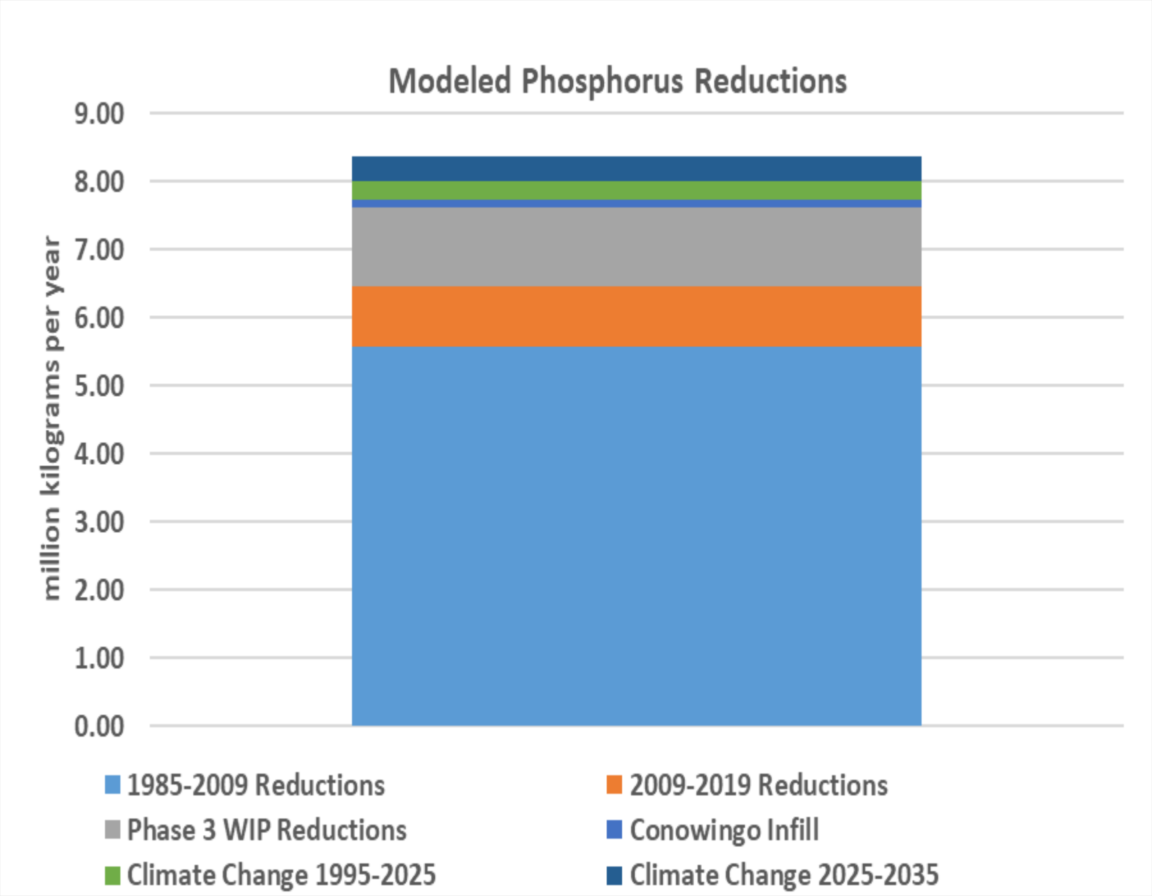
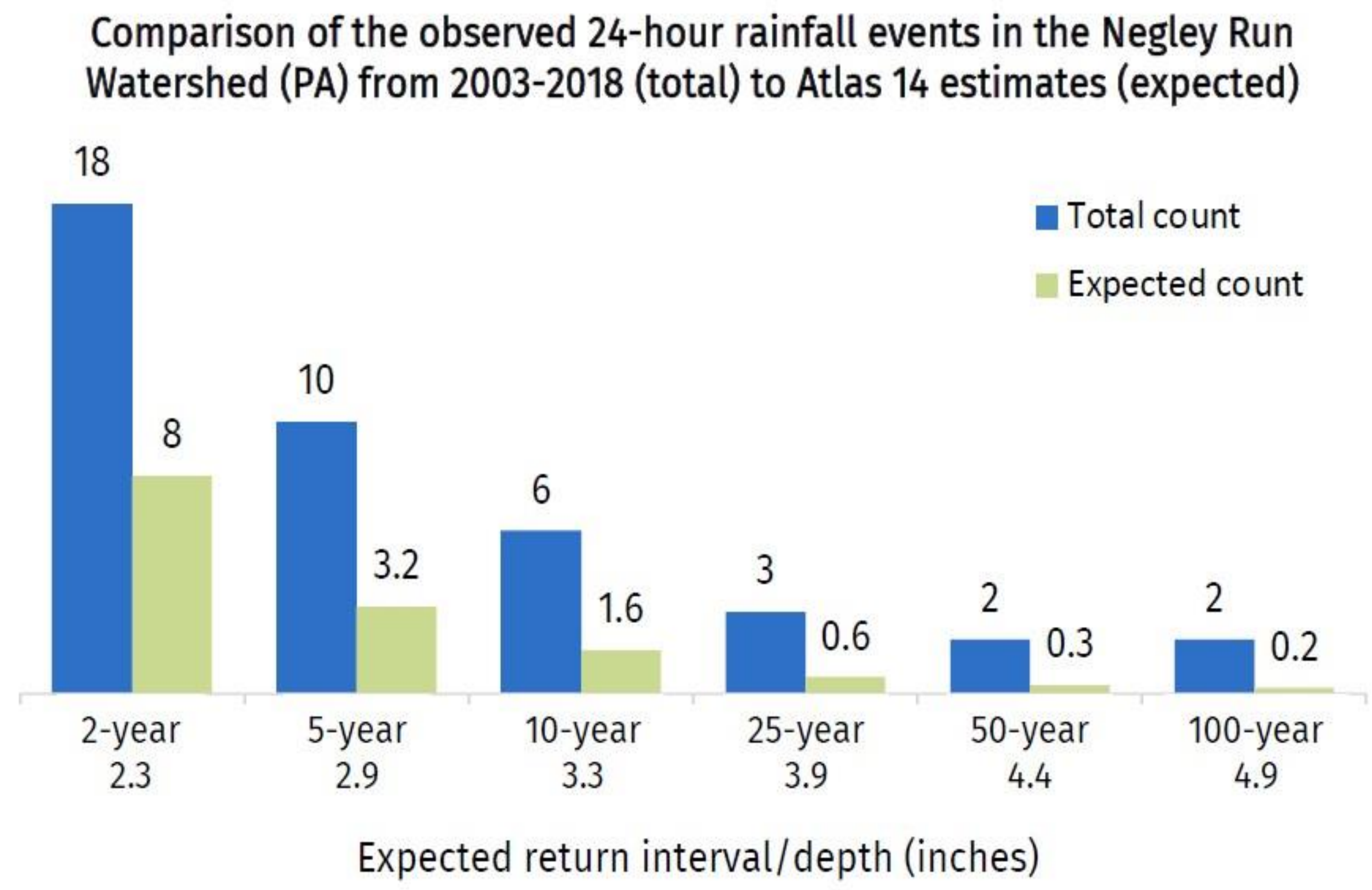




Overall, the CBP found that a target load of 5 million pounds nitrogen and 0.6 million pounds phosphorus will be sufficient to offset 30 years of climate change in the Chesapeake Bay.

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

ATLAS 14 vs OBSERVED

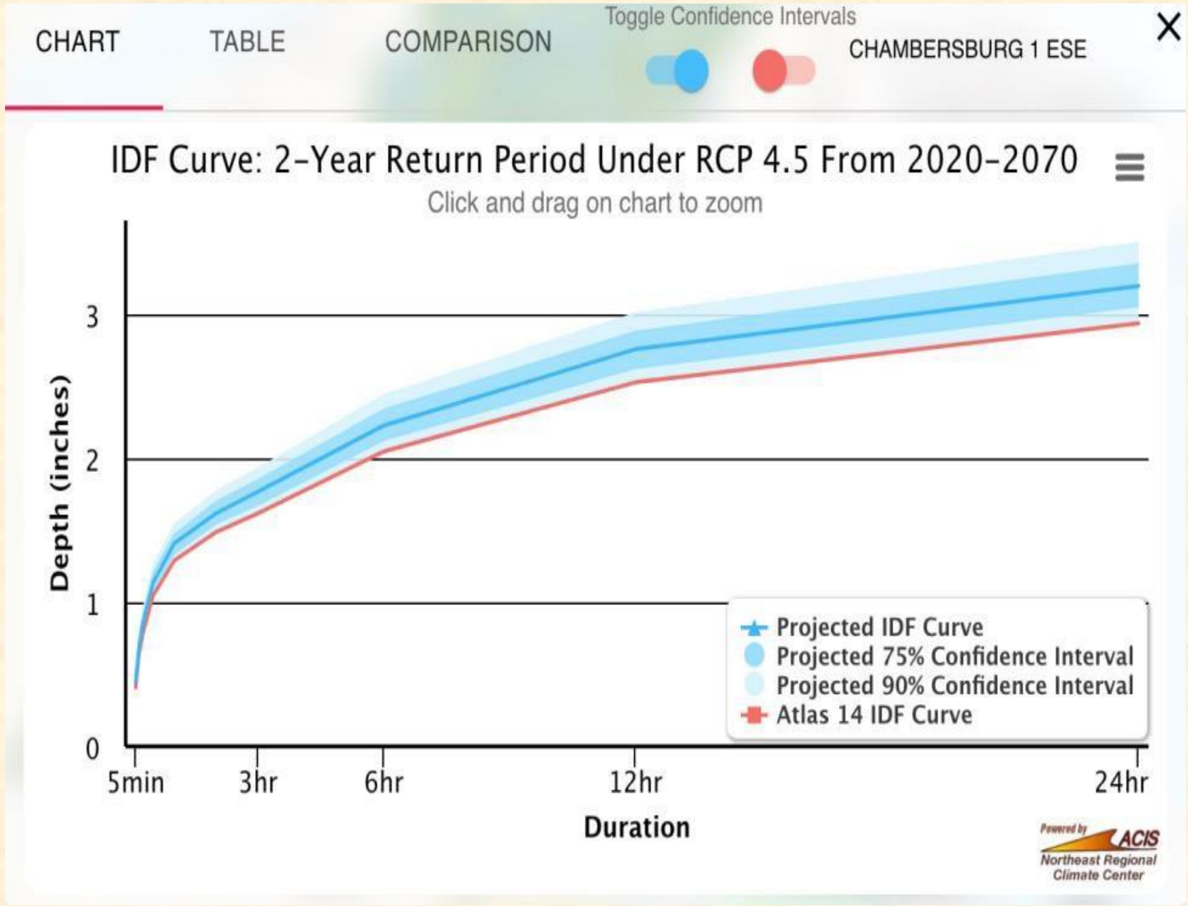


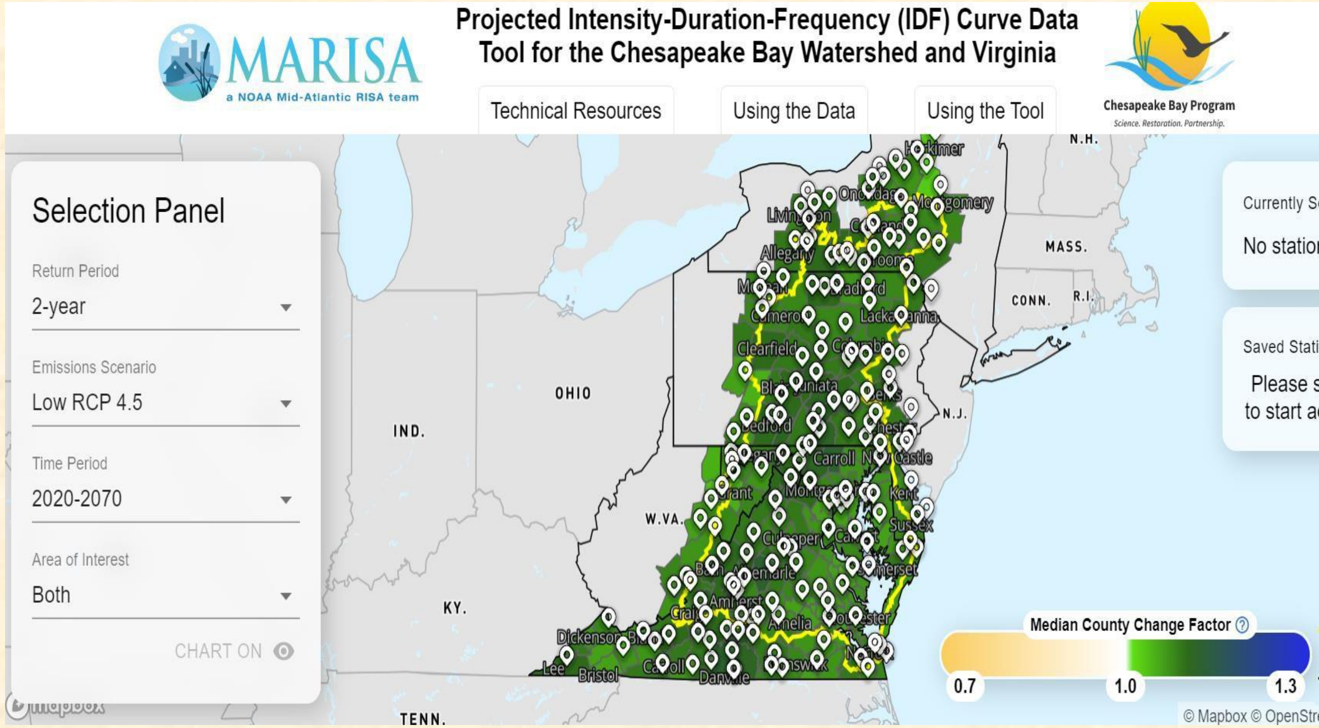
Fischbach et al. (2020) https://www.rand.org/pubs/research_reports/RRA564-1.html

CLIMATE CHANGE-INFORMED IDF CURVES

Data Tool: https://midatlantic-idf.rcc-acis.org/

Webinar: https://chesapeakestormwater.net/events/projected-chesapeake-idf-curves/





Source: RAND, Cornell U., and Carnage Mellon U.

Conclusions for Phase 6:

Climate change is a multigenerational challenge for the CBP and is a force multiplier for headwinds to the Chesapeake restoration.

However, the CBP is working on management practices that are effective counters to climate change such as:

- The design and accelerated adoption of stormwater management practices appropriately designed for increased rainfall volumes and intensities that are expected in the future for all counties in the Chesapeake watershed.
- Examination of the top tier agriculture and urban BMPs that are most vulnerable to future climate risk, with an emphasis on practices that could be adapted to become more resilient to future climate conditions of increased rainfall intensities and volumes.
- A quantification of the co-benefits of BMPs that mitigate future climate risk.
- Findings in JAWRA Featured Collection ***Influence of Climate Change on Chesapeake Bay Water Quality.***

The climate change risk to the Chesapeake TMDL can be effectively managed and the CBP is actively addressing the challenge.