Assessing Future Risk of Climate Change on Chesapeake Bay Water Quality Standards

CHAMP Meeting

November 13, 2018

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Next Steps Directed by the PSC: Understanding the Science and Refining the Model Estimates

2018

- STAC Workshop to examine current results, assess lessons-learned and recommend next steps.
- Climate Resiliency Workgroup will incorporate actions in its 2018-2020 workplan to develop a better understanding of BMP responses, including new or other emerging BMPs, to climate change conditions.

2019

- Following the direction of the PSC, the Modeling and Climate Resiliency Workgroups, working with other key Chesapeake Bay Program groups, will develop and implement a complete and fully operational climate change modeling and assessment system in 2019.

2020

- In 2020, the CBP partners will complete a technical review and process for approval of the new refined climate change modeling and assessment system as well as the scientific and technical findings from its management applications.

2021

- In 2021, the policy implications for including targets adjusted for the influence of climate change into the 2022-2023 milestones will be considered by the Partnership.
- By the close of 2021, the refined findings on climate change will be implemented into the jurisdictions' 2022-2023 milestones.

Policy: Watershed Implementation Plan (WIP) Guidance to Address Impacts of Climate Change on Water Quality Goals

A Programmatic "Qualitative" (and Optional Quantitative) Policy Approach to Optimize Phase III WIP Development and Adaptively Manage Implementation Practices to Address Future Climate Risk

The Partnership will consider new information on the performance of management practices…no later than 2022. Management practices may include all wastewater treatment programs and practices in addition to non-point source best management practices (BMPs) on agricultural lands, developed lands, and open spaces.

Jurisdictions will assess this information and their support programs and adjust their Phase III Watershed Implementation Plans (WIPs) through the two-year milestone process to better mitigate anticipated increases in nitrogen, phosphorus, or sediment due to climate change.

Jurisdictions will provide a narrative that describes their programmatic commitments to address the impacts of climate change on water quality goals in their Phase III WIPs.

(Developed by the Climate Resiliency Workgroup and Water Quality Goal Implementation Team)

CBP Policy:

"The Chesapeake Bay Program (CBP) relayed its *preliminary* modeling results of climate change in 2025 to the jurisdictions at the March 2018 Principals Staff Committee (PSC) meeting. The jurisdictions will document these preliminary numeric targets in their respective Phase III WIPs and will include a narrative strategy, outlining their programmatic and/or numeric commitments to address projected impacts…"

Climate Change Loads: Nitrogen

Jurisdiction	1985 Baseline	2013 Progress	Climate Change	Phase III Planning Target
NY	18.71	15.44	0.400 (3.8%)	11.59
PA	122.41	99.28	4.135 (5.7%)	73.18
MD	83.56	55.89	2.194 (4.8%)	45.30
WV	8.73	8.06	0.236 (3.7%)	8.35
DC	6.48	1.75	0.006 (0.3%)	2.43
DE	6.97	6.59	0.397 (8.5%)	4.59
VA	84.29	61.53	1.722 (3.1%)	55.82
Basinwide	331.15	248.54	9.09 (4.6%)	201.25

*Units: millions of pounds

Climate Change Loads: Phosphorus

Jurisdiction	1985 Baseline	2013 Progress	Climate Change	Phase III Planning Target
NY	1.198	0.710	0.014 (2.9%)	0.606
PA	6.282	3.749	0.141 (4.7%)	3.073
MD	7.495	3.942	0.114 (3.2%)	3.604
WV	0.902	0.617	0.019 (3.9%)	0.456
DC	0.090	0.062	0.001 (0.8%)	0.130
DE	0.225	0.116	0.006 (5.1%)	0.120
VA	14.244	6.751	0.193 (3.0%)	6.186
Basinwide	30.44	15.95	0.489 (3.4%)	14.173

*Units: millions of pounds

The 2019 CBP Climate Change Assessment

- The CBP is developing the tools to quantify the effects of climate change on Chesapeake water quality standards through changes in watershed flows and loads, storm intensity, estuarine temperatures, sea level rise, and ecosystem influences including loss of tidal wetland attenuation with sea level rise.
- Current efforts are to frame initial future climate change scenarios based on estimated 2025 (short term), 2035 (moderate term), and 2045/2055 conditions (long term) by the close of 2019.

Big things and little things…

We focus on the big things for the 2025 estimate (and any potential management implications)

- Precipitation volume increases
- Precipitation intensity increases
- Temperature increases and increased evapotranspiration in the watershed
- Sea level rise increases and increased gravitational circulation
- Temperature increases in the tidal water column

Big things and little things……

And we acknowledge and quantify the small things in the 2025 assessment:

- Increases in [CO_2] and stomatal resistance
- Wind speed
- Wind direction
- Relative humidity
- Changes in salinity at ocean boundary
- Sea level rise and tidal wetland loss
- Atmospheric deposition of nitrogen

Approaches and Methods for the 2025 Climate Change Assessment

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For the 2025 Climate Change Estimate:

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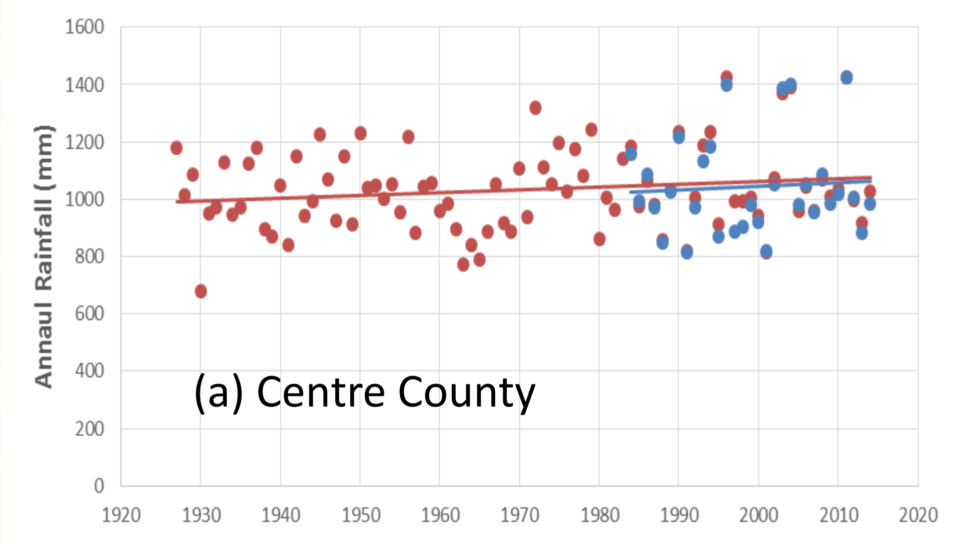
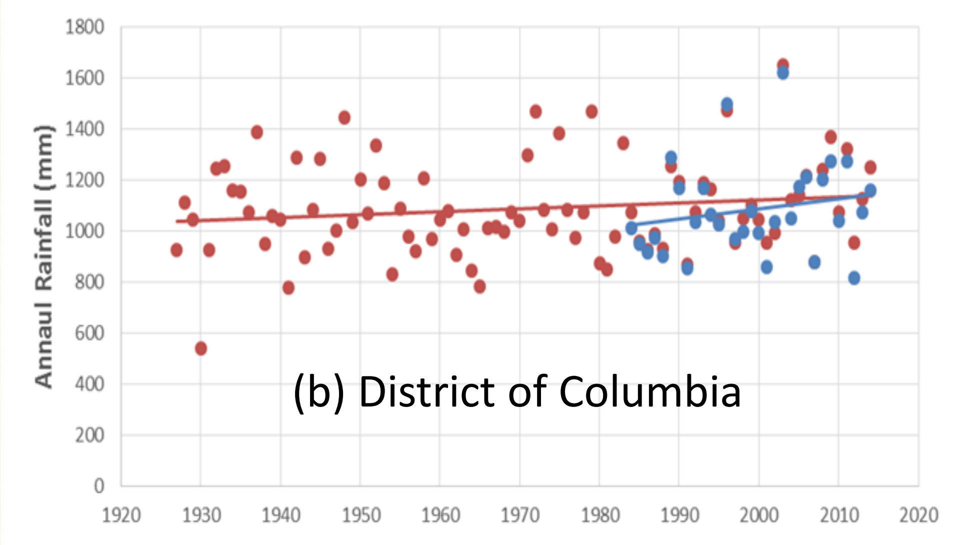
The trends in annual precipitation on a county level were developed through the application of PRISM data and analysis provided and recommended by Jason Lynch, EPA, and Karen Rice, USGS. The annual PRISM dataset for the years 1927 to 2014 (88 years) were used in for the regression trend analysis. For 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

Assessment of Influence of 2025 Climate Change in the Watershed

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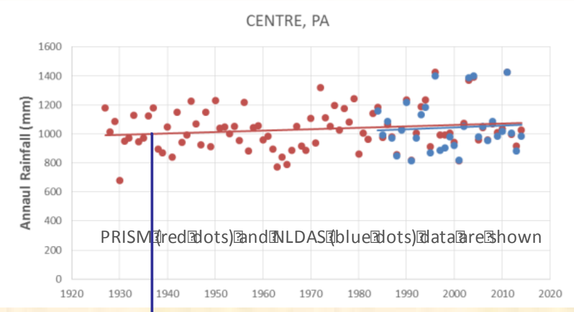

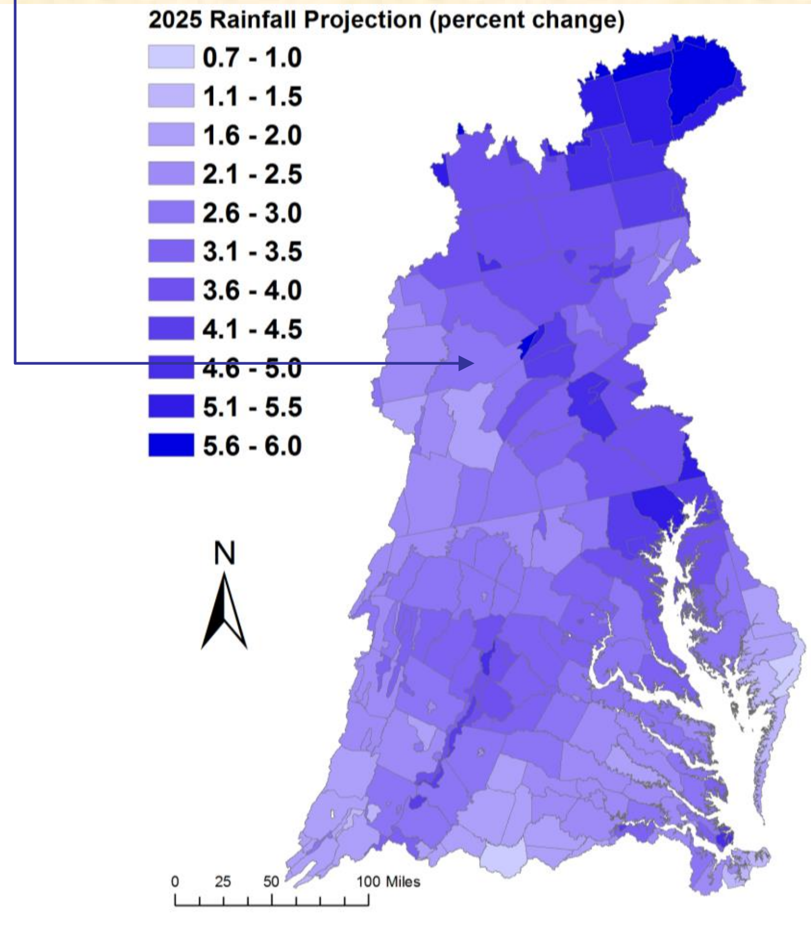

Projections of rainfall increase using trend in 88-years of annual PRISM[1] data

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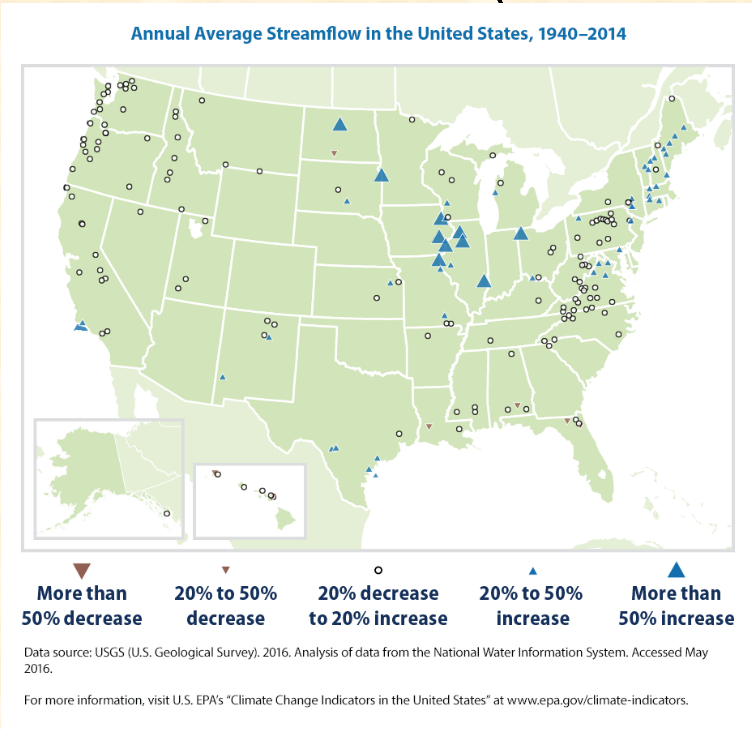
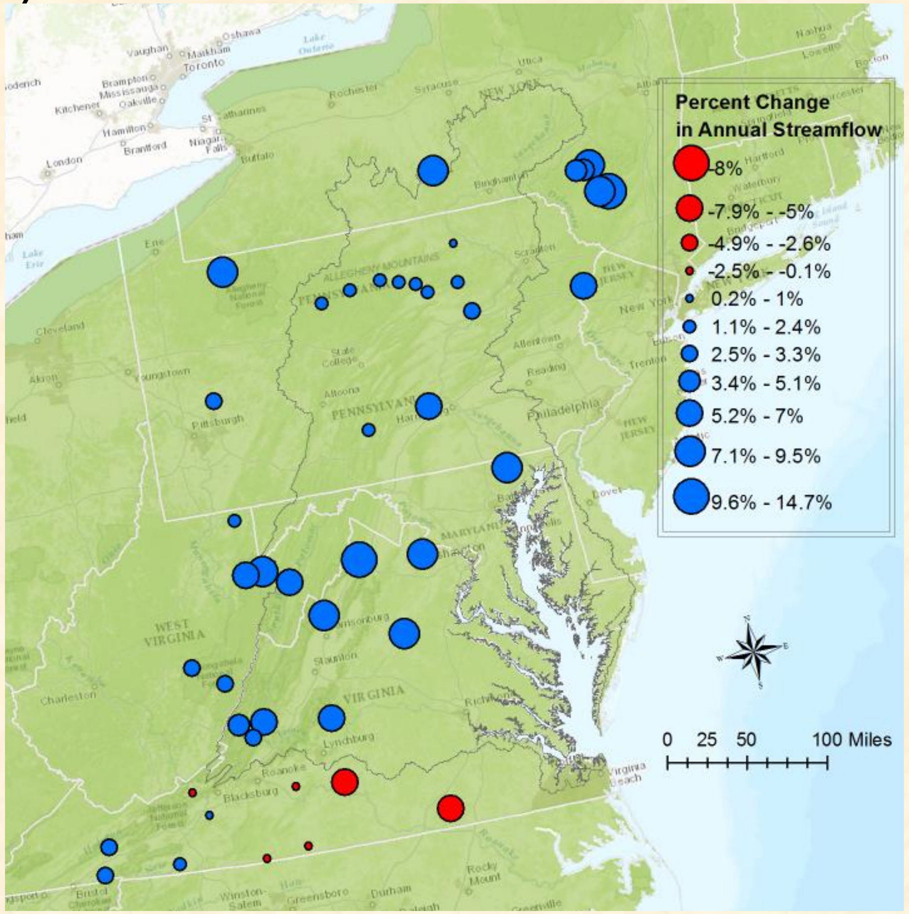
The study analyzed USGS GAGES-II data for a subset of Hydro-Climatic Data Network 2009 (HCDN-2009).





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.

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

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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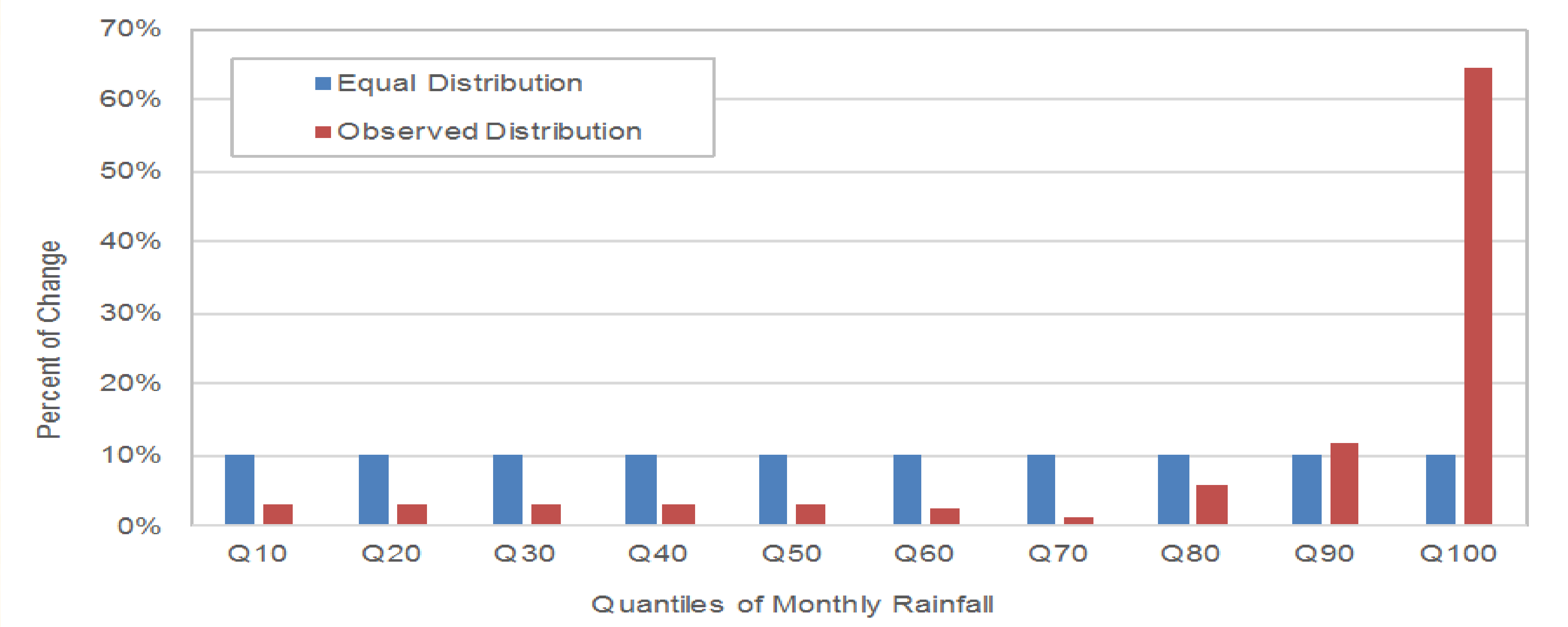
Trends in Observed Rainfall Intensity



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

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.

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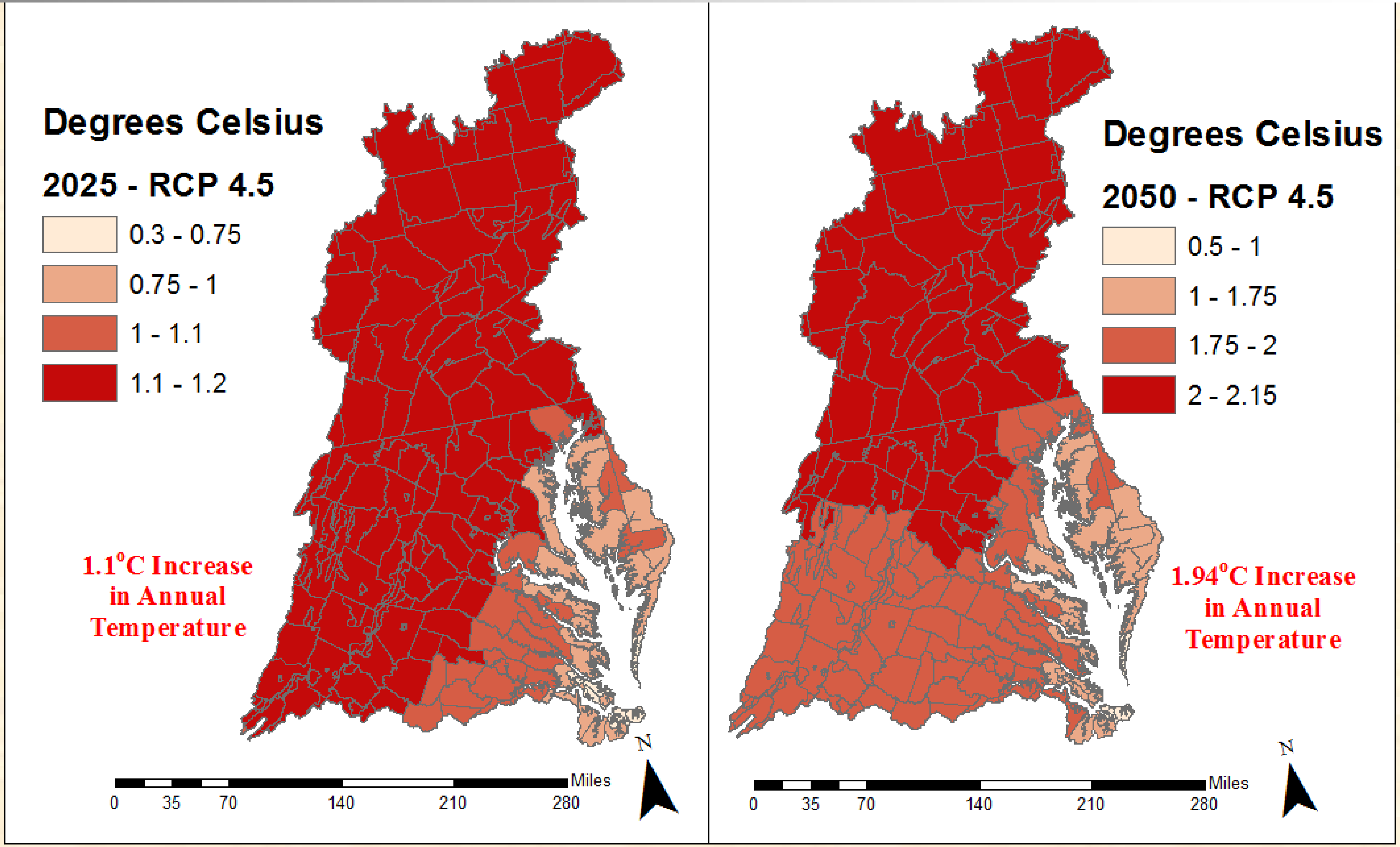
Chesapeake Bay Watershed Annual Change in Temperature



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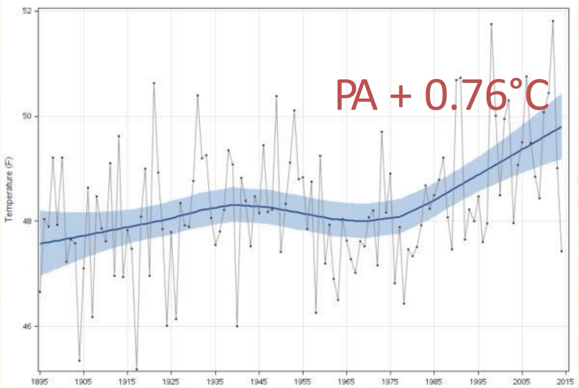
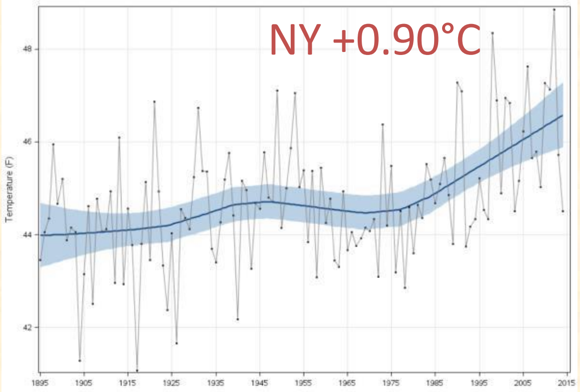
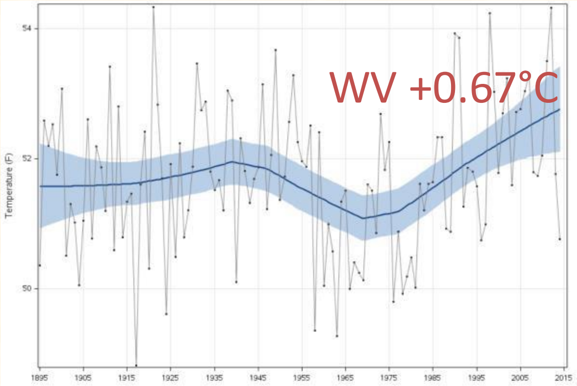
Temperature trends for the six CBP states

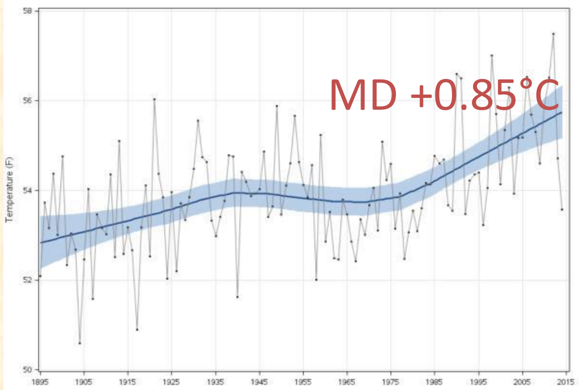
Annual temperature for 1895 to 2015 are shown.

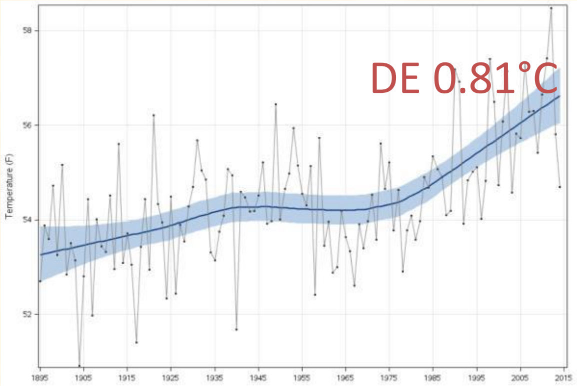
Annual Temperature
Trend Line
95% Confidence Limits

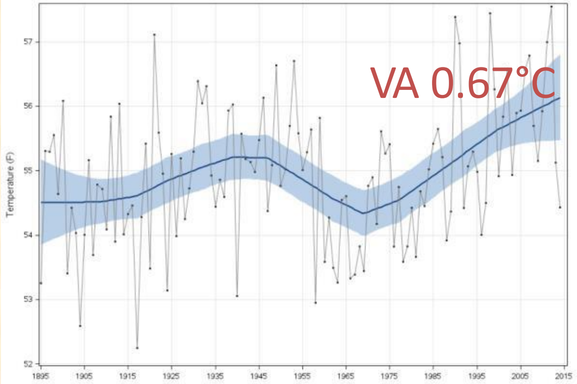










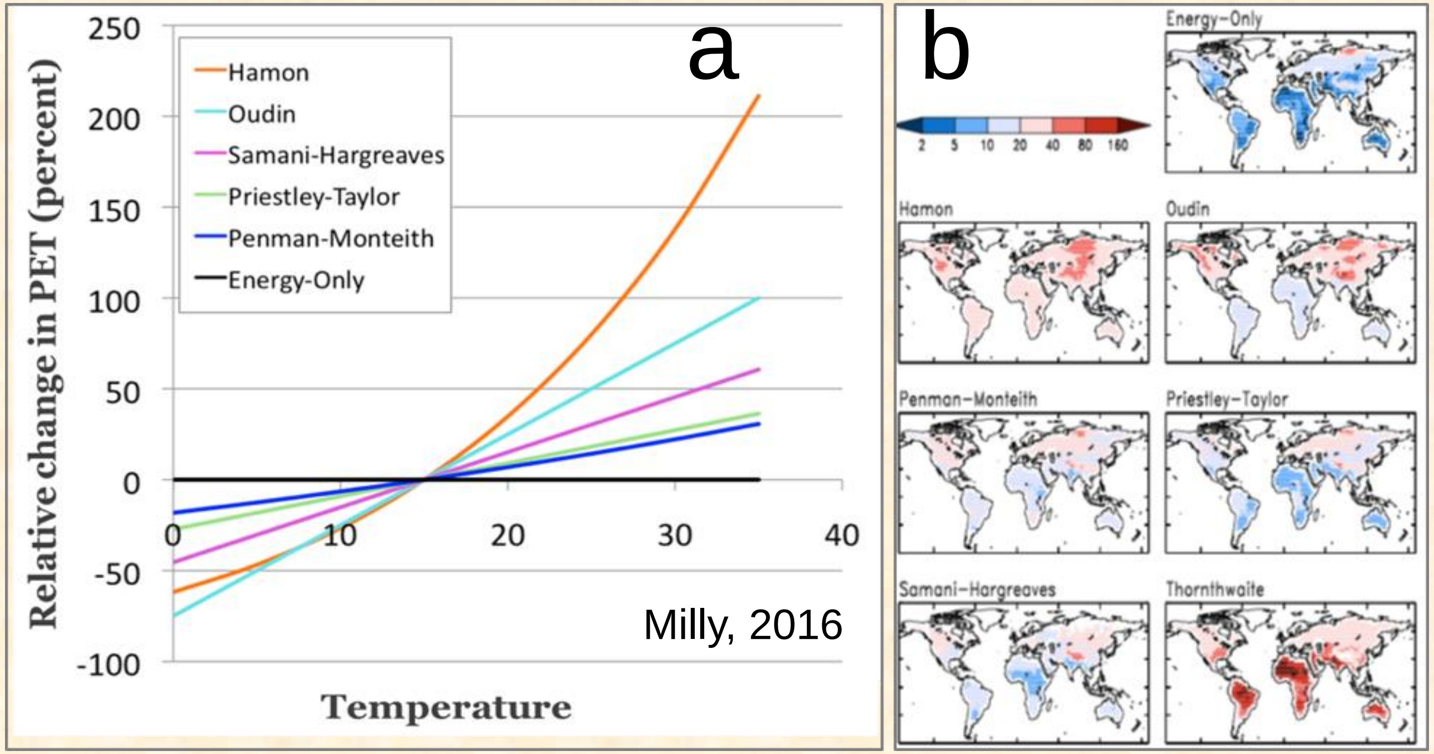


Approx. increases over the last 30 years based on the trend line are shown.

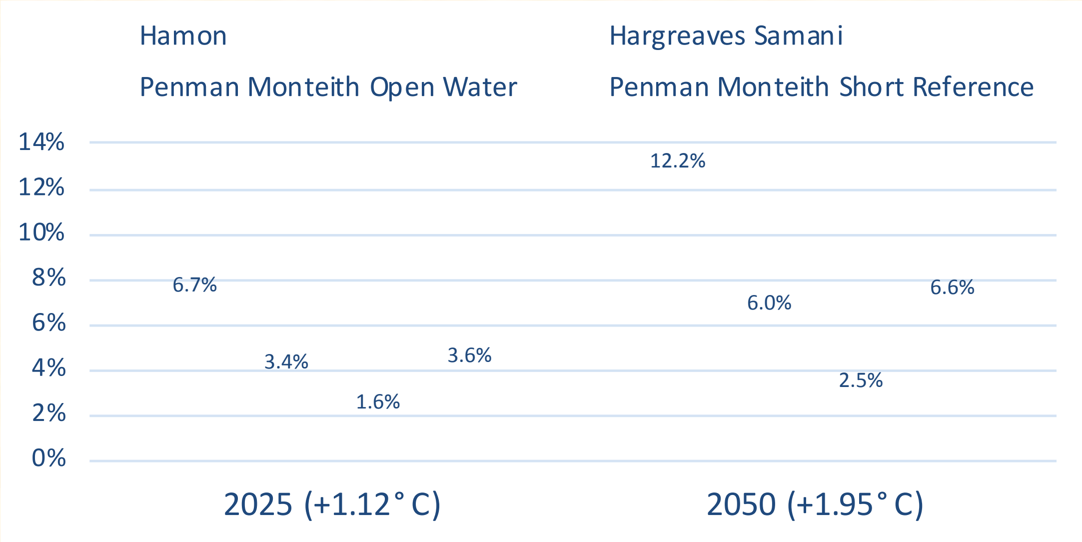
NOAA National Climatic Data Center

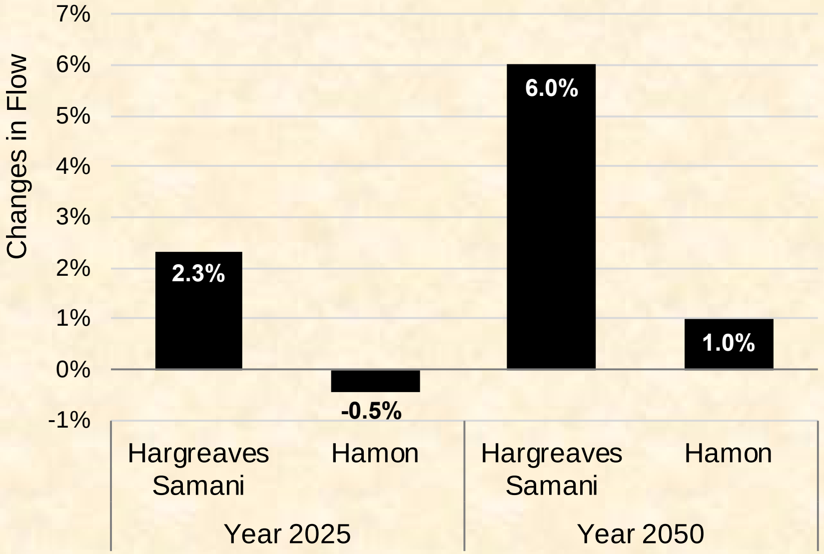
https://www.ncdc.noaa.gov/temp-and-precip/state-temps/

Estimated potential evapotranspiration



(a) Relative change in estimated change in potential evapotranspiration due to change in temperature is shown from different methods. It shows temperature alone can introduce considerable differences in estimation of potential evapotranspiration with the selection of method. (b) Estimate of percent changes in potential evapotranspiration





Analysis of Climate Change in the Tidal Bay

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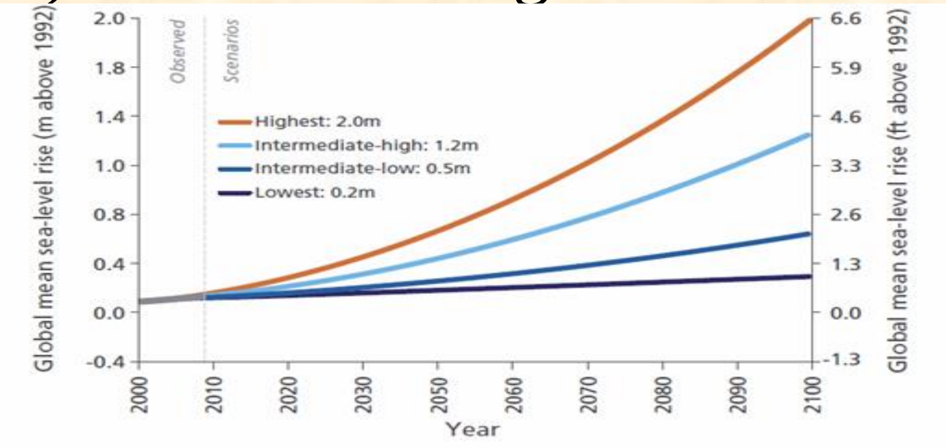
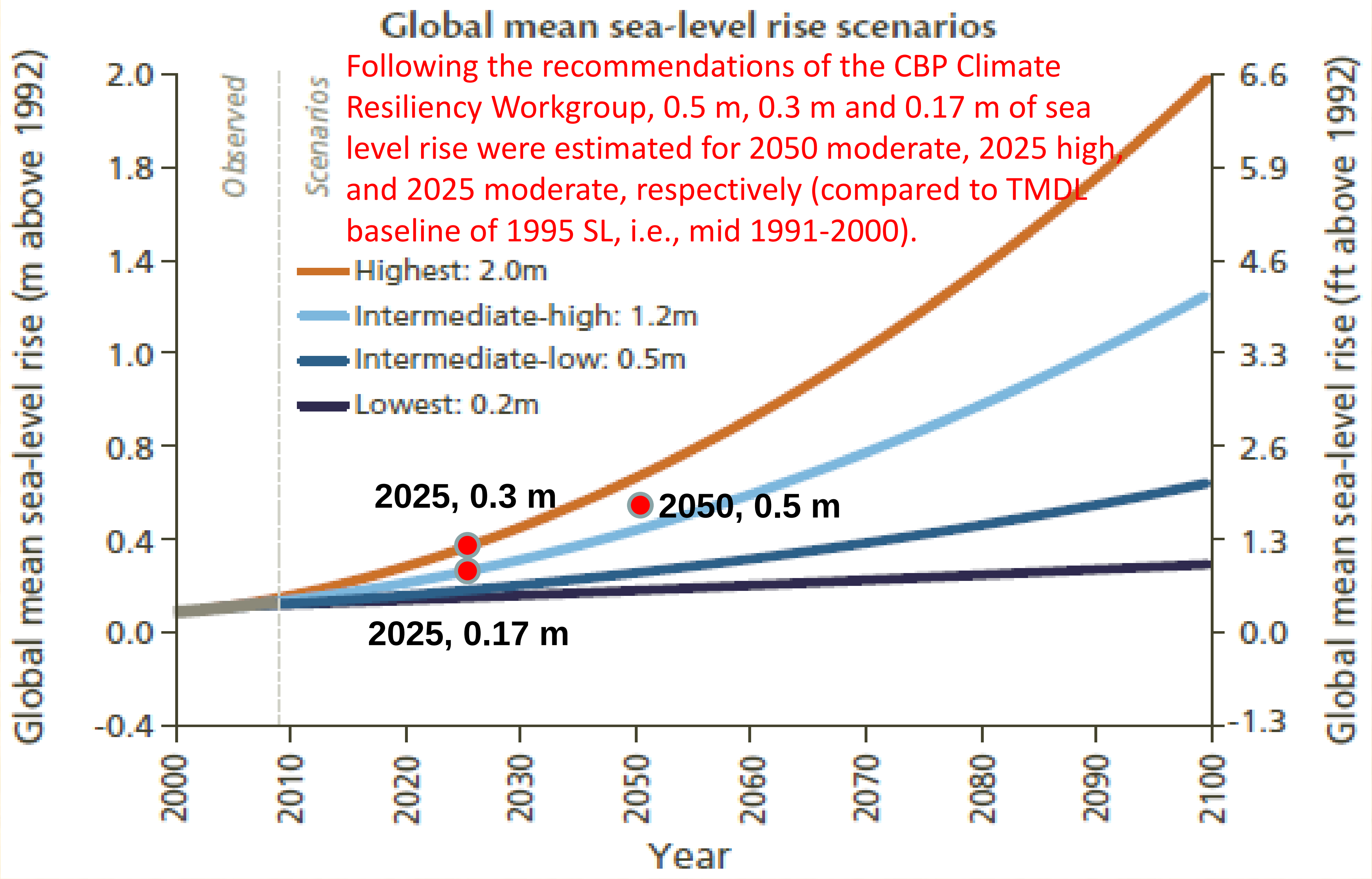
Estimates of the influence of sea level rise, increased temperature of tidal waters, and tidal wetland loss were incorporated into the Water Quality and Sediment Transport Model (WQSTM) of the tidal Bay (Cerco and Noel 2017). Guidance for increasing levels of regional sea level rise based upon global tide gauge rates and regional land subsidence rates came from the Climate Resiliency Workgroup CRWG). Specifically, the CRWG recommended that sea level rise projections for 2025 be based on long term observations at Sewells Point, VA (0.17 m) and that a range be used for 2050 (0.3 - 0.8 m) be applied in the WQSTM. The approximate median of the 2050 range (0.5 m) was used for initial simulations.





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.*

Analysis of Climate Change in the Tidal Bay

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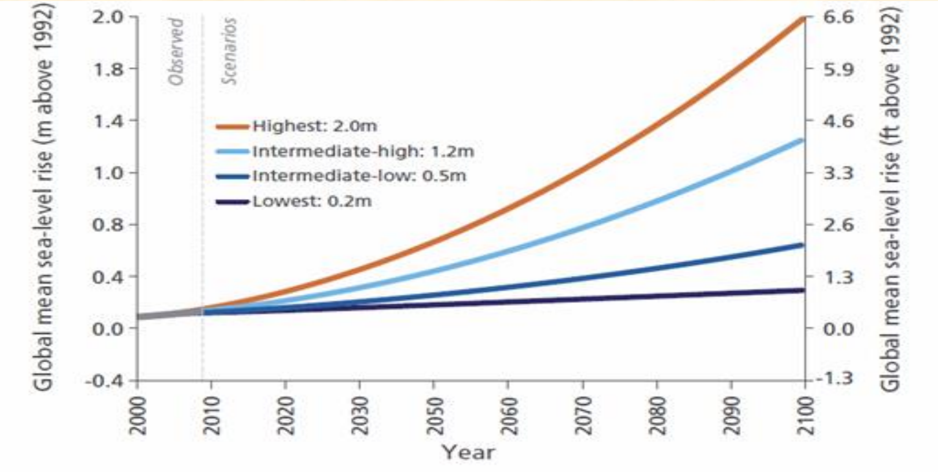
Overall, higher temperatures and loads from the watershed increases hypoxia in the tidal Bay.

However, increases in sea level rise, salinity increases at the Bay mouth, and increased watershed flows all increase estuarine gravitational circulation which in turn decreases estimated hypoxia in the Chesapeake under estimated 2025 and 2050 conditions of sea level rise and watershed flows.



Hypoxic volume (DO <1 mg/l) in All Bay (June-Sept. 1991-2000)

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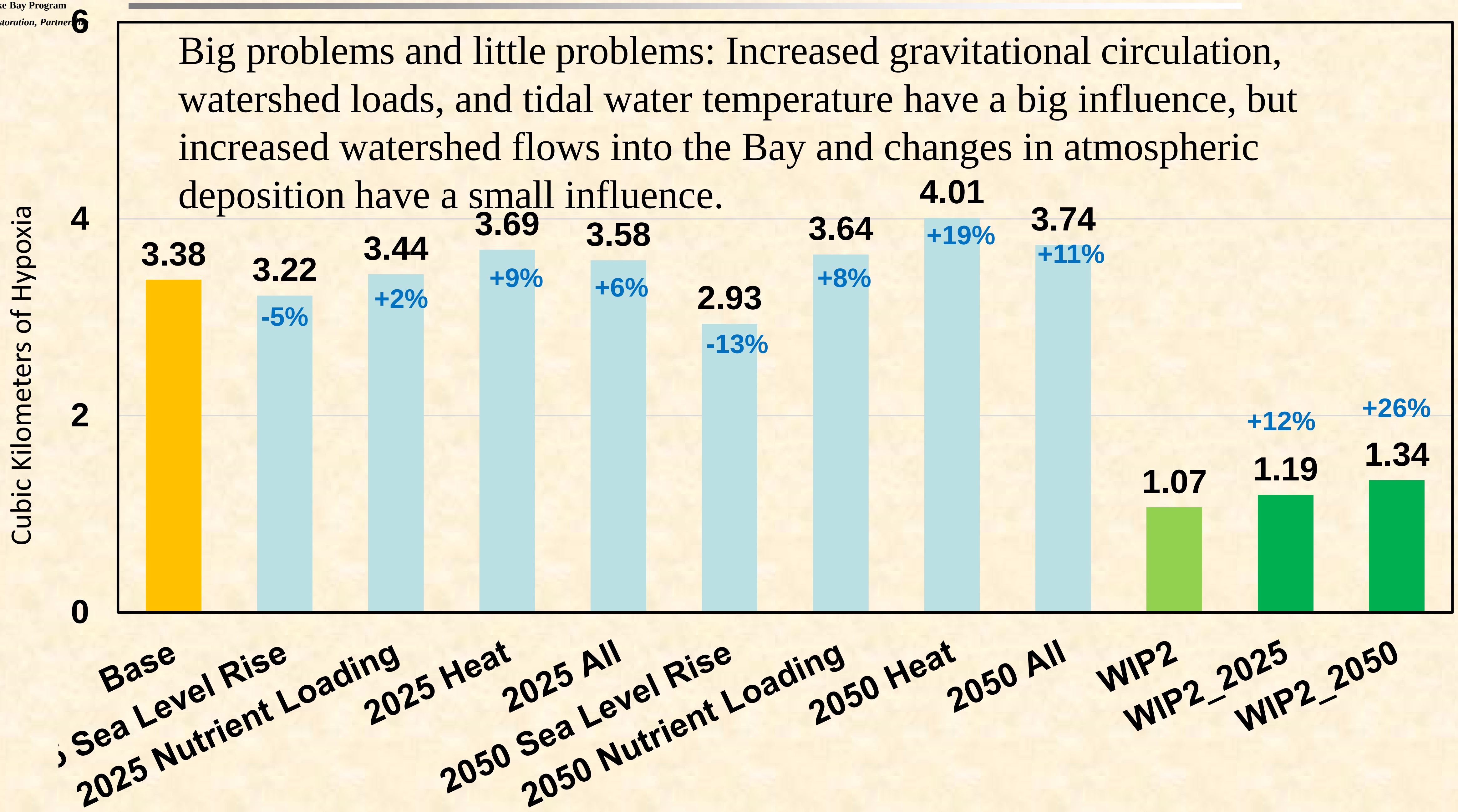

Bay Water Quality Responses to 2025 Climate Change Conditions

Changes in estimated 2025 dissolved oxygen criteria attainment for Deep Channel, Deep Water, and Open Water due to observed temperature and precipitation changes since 1991-2000 (years of average Bay hydrology).

Run 223 11/30/17 CAST Loads		WIP2	WIP2 + Cono Infill	WIP2 + Cono Infill + CC
		195TN	208TN	210TN
		13.7TP	15.4TP	15.3TP
		1993-1995	1993-1995	1993-1995
Cbseg	State	Deep Channel	Deep Channel	Deep Channel
CB3MH	MD		0%	0%
CB4MH	MD	6%	8%	10%
CB5MH	MD	0%	0%	0%
CB5MH	VA	0%	0%	0%
POTMH	MD	0%	0%	0%
RPPMH	VA	0%	0%	0%
ELIPH	VA	0%	0%	0%
CHSMH	MD	0%	0%	4%
EASMH	MD	6%	7%	8%

Deep Channel nonattainment increases by 2% in CB4MH

Run 223 11/30/17 CAST Loads		WIP2	WIP2 + Cono Infill	WIP2 + Cono Infill + CC
		195TN	208TN	210TN
		13.7TP	15.4TP	15.3TP
		1993-1995	1993-1995	1993-1995
Cbseg	State	Deep Water	Deep Water	Deep Water
CB4MH	MD	5%	6%	7%
CB5MH	MD	1%	1%	2%
CB5MH	VA	0%	0%	0%
CB6PH	VA	0%	0%	0%
CB7PH	VA	0%	0%	0%
PATMH	MD	1%	2%	3%
MAGMH	MD	1%	5%	5%
SOUMH	MD	3%	8%	7%
SEVMH	MD	0%	0%	0%
PAXMH	MD	0%	0%	0%
POTMH	MD	0%	0%	0%
RPPMH	VA	0%	0%	0%
YRKPH	VA	0%	0%	0%
ELIPH	VA	0%	0%	0%
CHSMH	MD	0%	0%	0%
EASMH	MD	0%	0%	0%

Deep Water nonattainment increases by 1% in CB5MH

Procedures for assessing Open Water attainment under climate change conditions are being developed.

On CBP Climate Change Assessment Collaboration:

STAC's peer reviews and workshops on the assessment of climate change in the Chesapeake watershed and Bay (DiPasquale 2014; Johnson et al. 2016; Pyke et al. 2008; Pyke et al. 2012; STAC 2011; Wainger 2016; Benham 2018) have made a substantial contribution as part of STAC's essential ongoing advice on the state of the science in this field, and particularly with respect to watershed and coastal water restoration in the Chesapeake region. There is need for the continued deeply collaborative work among CBP technical managers (technical direction: WQGIT, Climate Resiliency Workgroup, WSWG, Modeling Workgroup, etc.) and the CBP scientific community (STAC guidance) and other efforts (CHAMP collaboration) to effectively achieve CBP policy maker's goal for inclusion of climate change nutrient targets by 2022 to address risks to long term achievement of living resource based Chesapeake water quality standards.

Management Actions on CB Climate Change:

The Principal Staff Committee (PSC) in December 2017 directed the CBP, through the Modeling and Climate Resiliency Workgroups, to direct immediate efforts toward a more refined analysis of climate change influence on Chesapeake water quality, to be delivered as a complete and fully operational modeling system by the close of 2019.

PSC Decisions of December 2017

Understand the Science - Address the uncertainty 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.
- Develop a better understanding of the BMP responses, including new or other emerging BMPs, to climate change conditions.
- 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.
- <u>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</u>.