Briefing on Latest Results of 2025 Climate Change Forecast Analysis
&
Considerations for Phase III WIPs

Water Quality GIT

May 8, 2017

Purpose of Today's Presentation

- **Present latest climate change assessment findings**
  - **WORK IN PROGRESS!!** Need to run the analysis on the final Phase 6 Watershed and WQSTM models as well as additional climate scenarios to bound range of possible future conditions.
- **Discuss planned approach for identifying and implementing resilient BMPs**
- **Present revised language for combining policy options 5-7**
  - Addressing climate change qualitatively in the Phase III WIPs

PSC Decision-Making Timeline

- **December 13, 2016**: Agreement on 1) climate change assessment procedures, 2) guiding principles, and 3) the range of options for how and when to factor climate change considerations into the jurisdictions' Phase III WIPs
- **Late October 2017**: How and when to incorporate climate change considerations into the Phase III WIPs
- **March 2018**: Final Phase III WIP planning targets fully reflecting Partnership decisions regarding how and when to incorporate climate change considerations

PSC Approved
Climate Change Assessment Procedures

- Partition the influence of climate change into separate elements:

Watershed (WSM)

- Increased Precipitation
- Increased temperature
- Increased evapotranspiration
- Storm intensity
- **Modeling Results: Influence on watershed flows and loads**

Estuary (WQSTM)

- Increased watershed loads
- Increased estuarine temperatures
- Increased sea level rise
- Loss of tidal wetlands
- **Modeling Results: Influence on water quality standards**

- Run climate change scenarios based on estimated 2025 and 2050 conditions
- Run a range of scenarios to bound the range of uncertainty

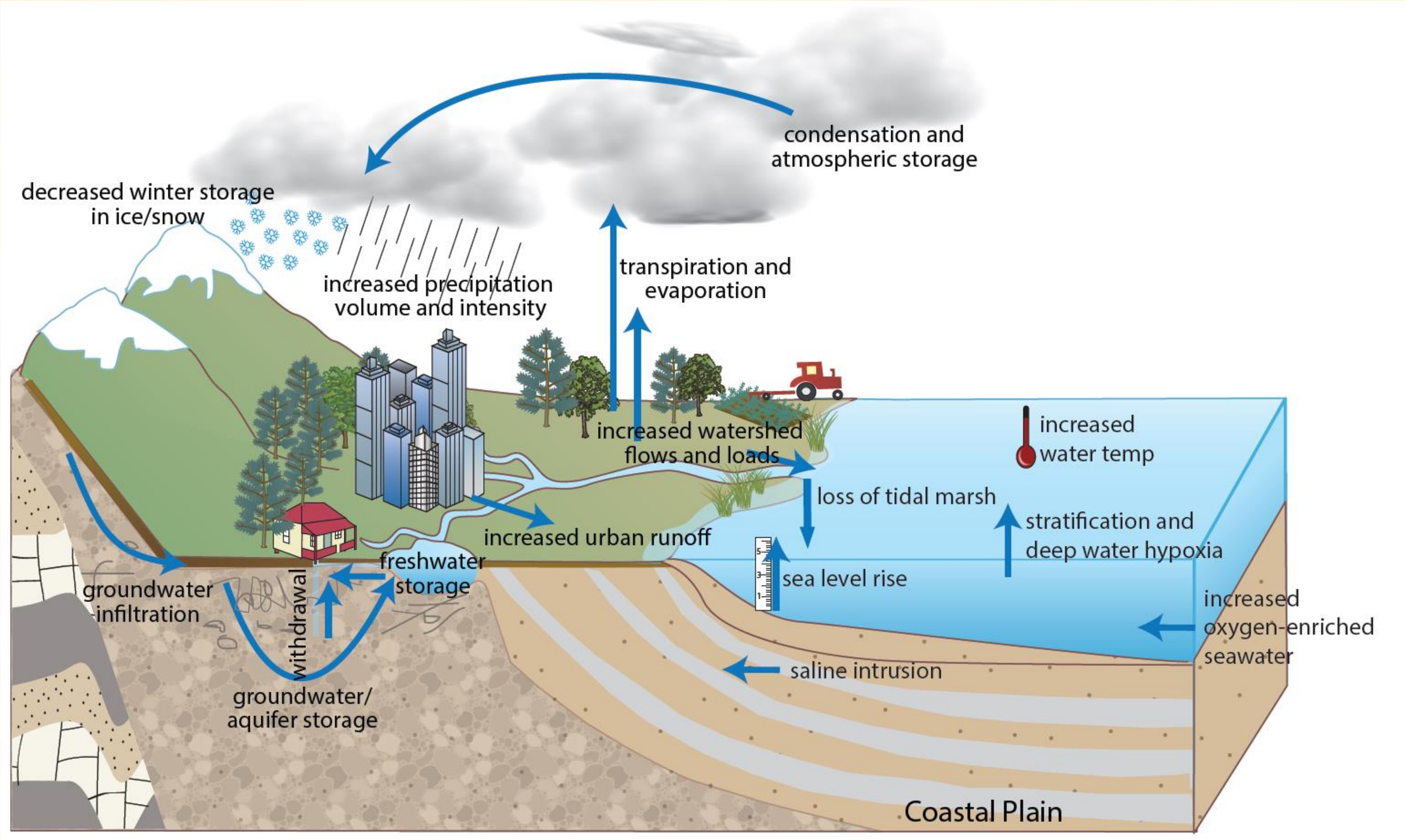
Preliminary Estimates of Climate Change Influence On Chesapeake Water Quality Attainment

- To compare estimated Base (calibration 1991-2000) and WIP2 scenarios under 1995 climate conditions to Base and WIP2 scenarios under 2025 climate conditions of sea level, watershed flows, temperature, and watershed loads.
- Investigate why decreased hypoxia is estimated under 2025 temperature, precipitation, and sea level despite higher estimated watershed loads.
- Using the Base Scenario, examine the influence separate elements of estimated 2025 conditions have on Bay hypoxia:
  - changes in sea level (SL)
  - watershed flows (Q)
  - temperature (T)
  - all combined SL, T, and Q
  - all combined SL, T, and Q along with increased 2025 watershed loads.

Preliminary Estimates of Climate Change Influence On Chesapeake Water Quality Attainment *(continued)*

- Increases in sea level rise and watershed flow both increase estuarine gravitational circulation which in turn decreases estimated hypoxia in the Chesapeake under estimated 2025 conditions of sea level and watershed flows.
- On one hand, increased 2025 temperatures ameliorates the estimated increased precipitation in the watershed through evapotranspiration, but also increases stratification and hypoxia in the tidal Bay.
- This is a work in progress using the Beta 3 Watershed Model and the Beta 4 WQSTM to provide the best estimate available today of 2025 conditions compared to the 1995 TMDL conditions. We need to run the analysis on the final Watershed and WQSTM models.

Climate Influence on the CB Watershed



Source: CBP Modified UMCES/ IAN graphic (2011)

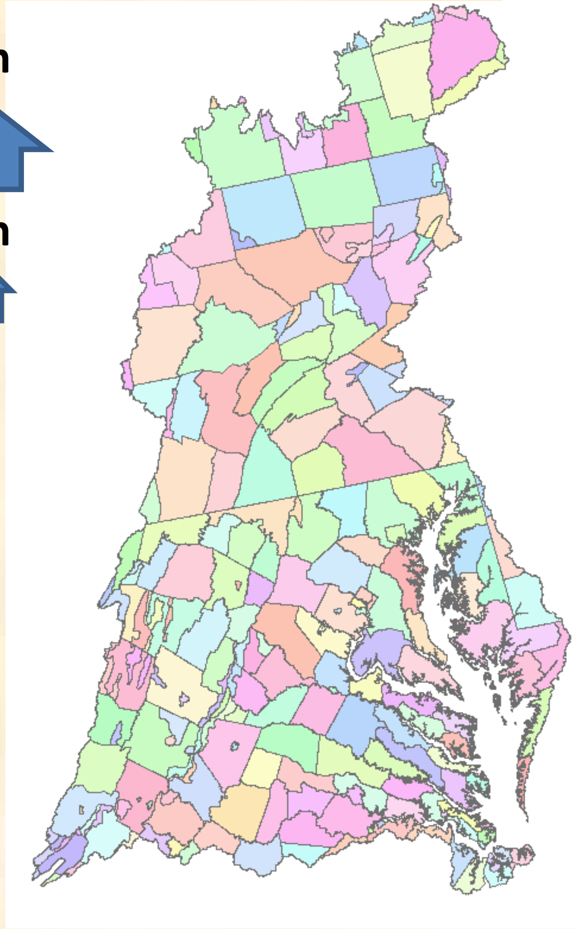
Keeping Score

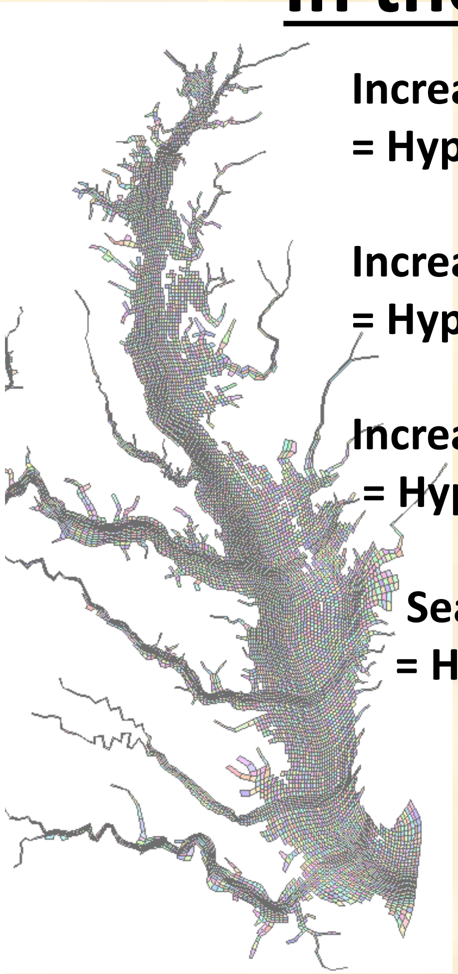
In the Watershed

Increased Precipitation Volume = Hypoxia

Increased Precipitation Intensity = Hypoxia

Increase in Temp and Evapotranspiration = Hypoxia





In the Estuary

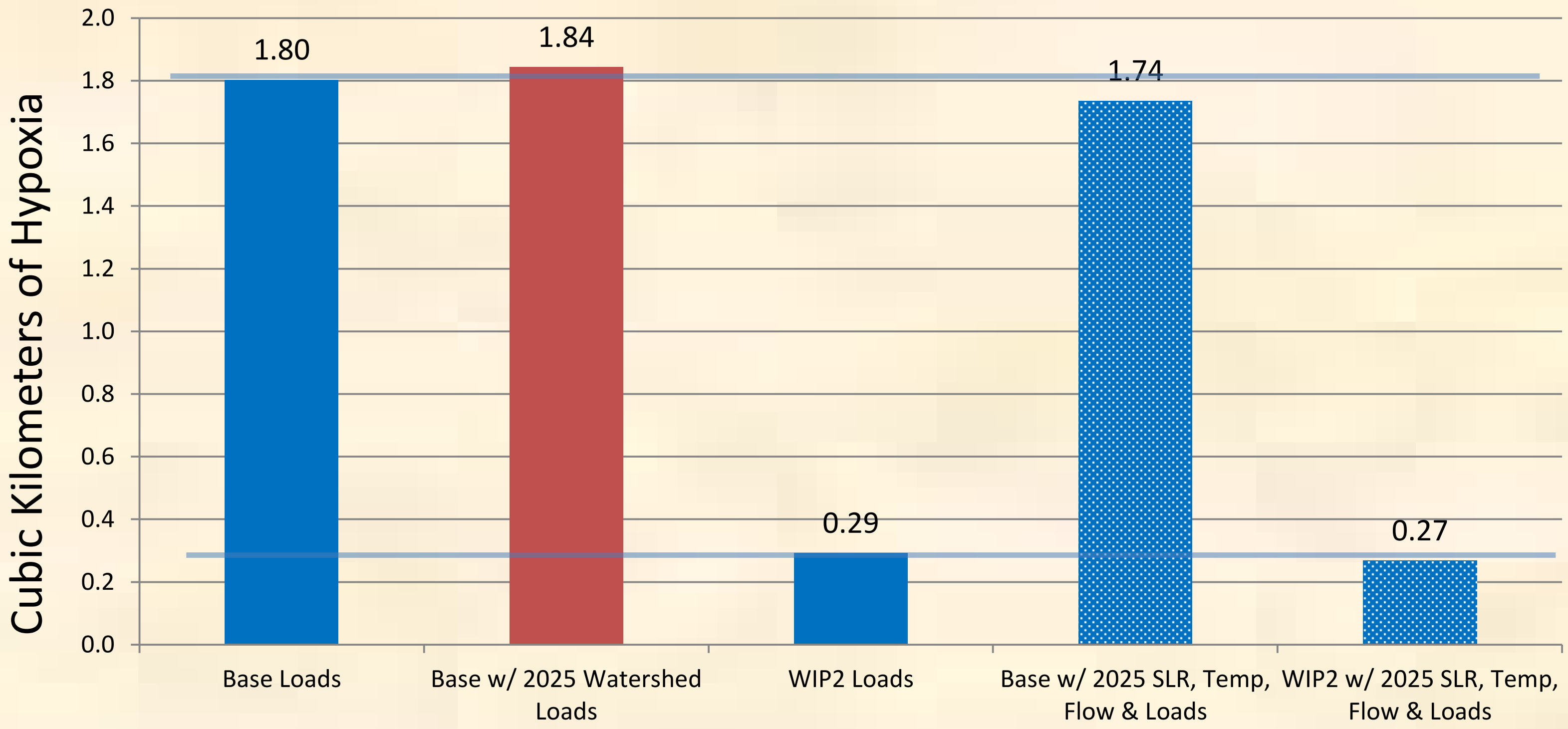
Increased WS Loads = Hypoxia

Increased WS Flows = Hypoxia

Increased Temperature = Hypoxia

Sea Level Rise = Hypoxia

Why does hypoxia decrease under estimated under 2025 temperature, precipitation, and sea level despite higher estimated watershed loads?

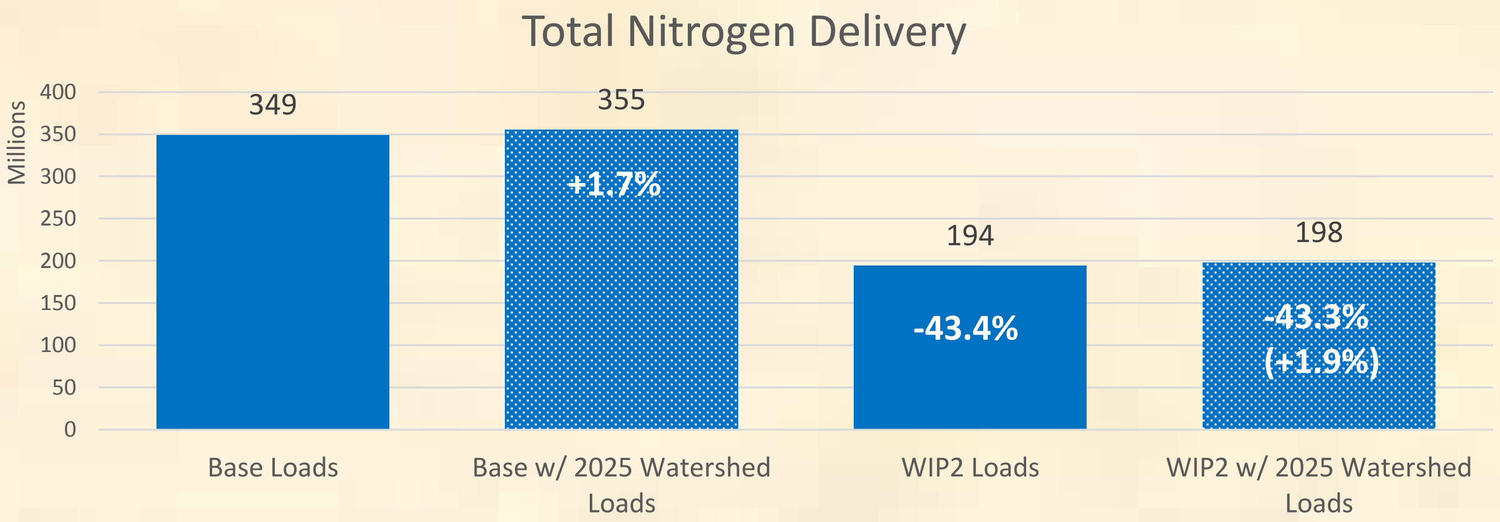


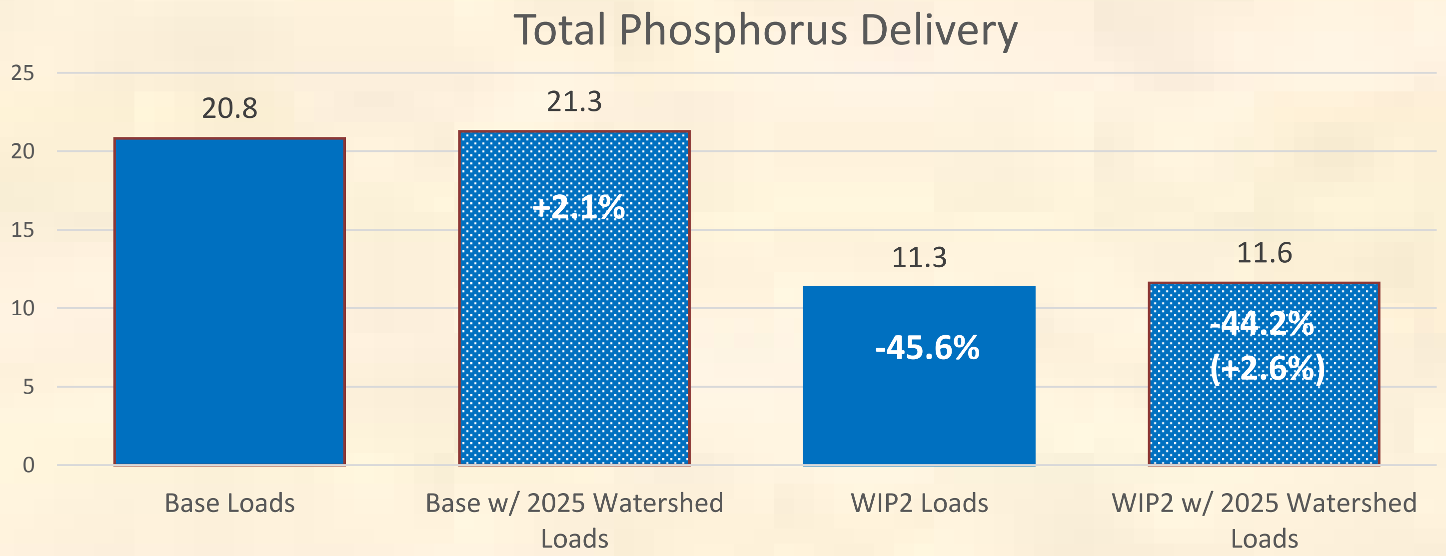
DO <1 mg/l annual average daily hypoxia from 1991 to 2000 over the summer hypoxic season of May through September.

solid blue = key scenario, solid red = sensitivity scenario, stippled blue = 2025 climate scenario

Watershed loads increase under estimated 2025 climate conditions compared to 1995 conditions.

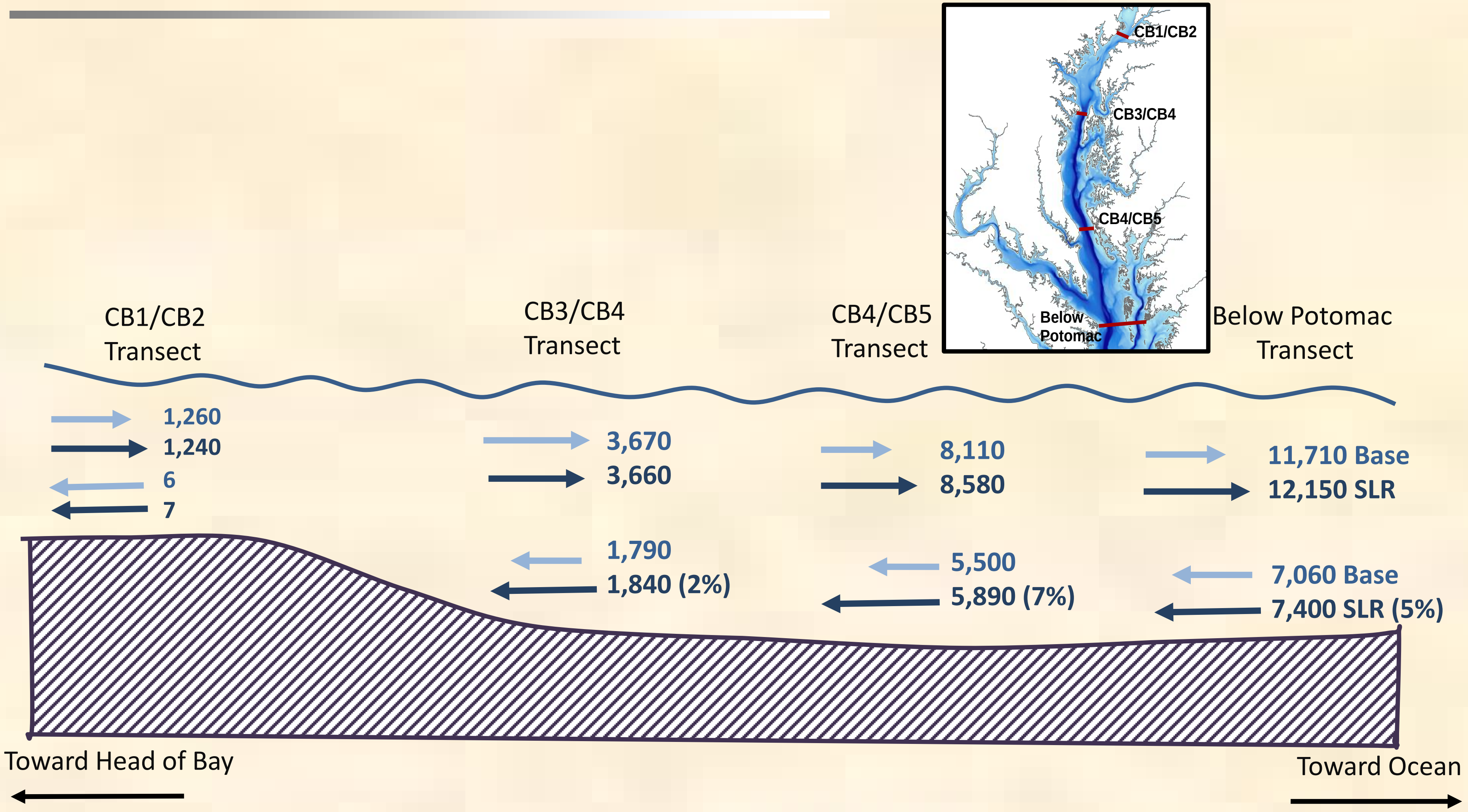
Percent change from Base Loads except for (% change in WIP loads under 2025 conditions).





Gopal Bhatt, December 2016 Quarterly Review

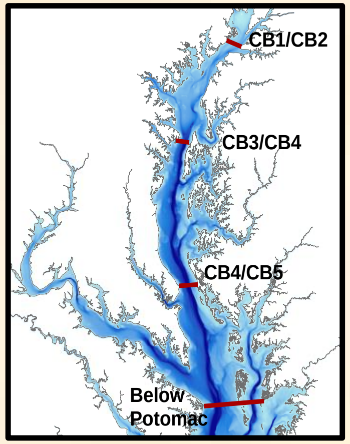
Cross-transect water mass fluxes (m^3/s) : Base Case versus Sea Level Rise Scenario

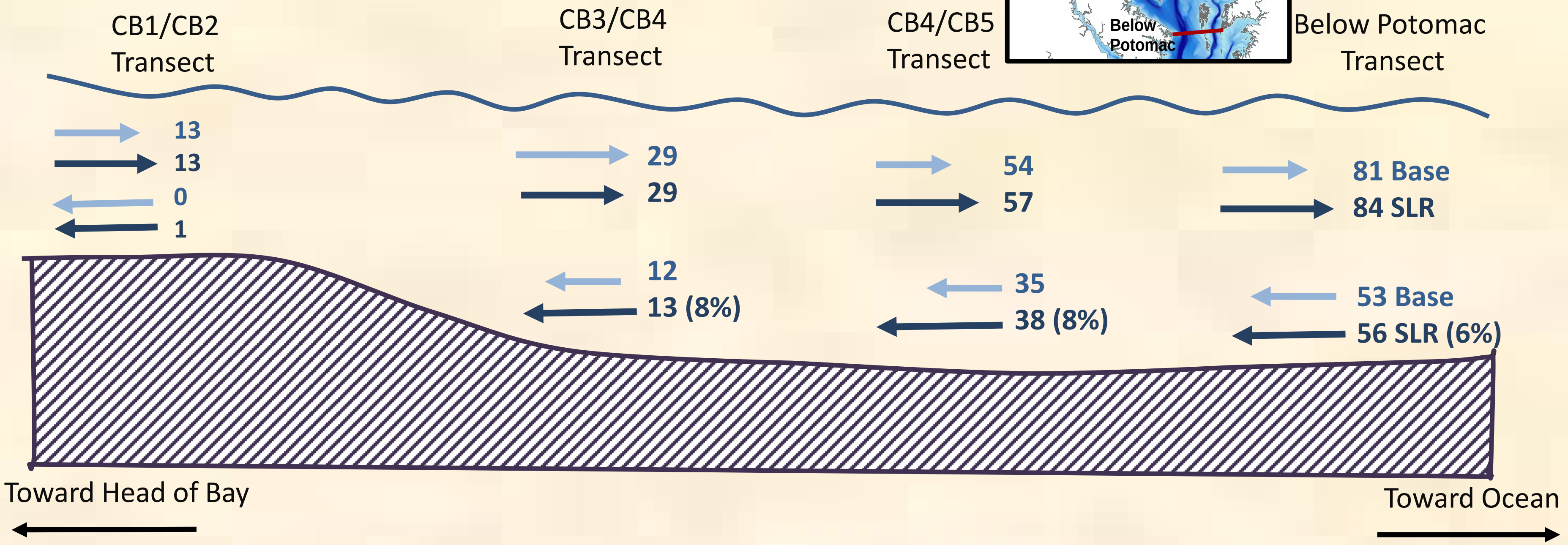


Base = Beta 4 Calibration. SLR = 0.3m Sea Level Rise Scenario representing relative Chesapeake sea level rise from 1995 to 2025. Units in mean cubic meters per second (m^3/s) for 1991 to 2000 hydrodynamics.

Cross-transect DO fluxes (kg/s): Base Case versus Sea Level Rise (SLR) Scenario

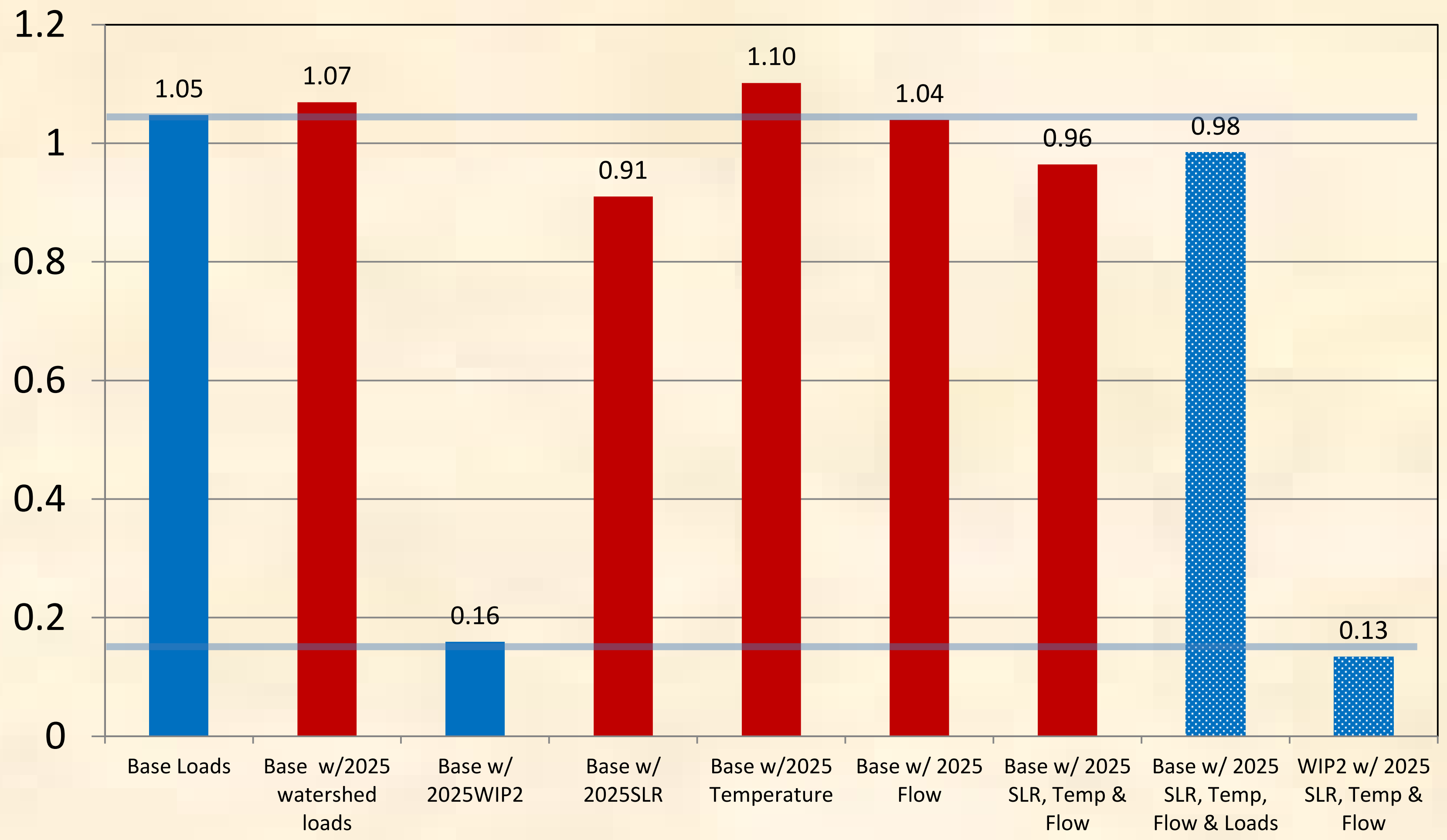
To put into context, 3.2 kg/sec of O_2 delivered to bottom waters at the edge of the deep water channel (Below Potomac Transect) is equivalent to delivering the volume of air in a box larger than 1 kilometer long, 1 kilometer wide, and 1 kilometer tall each day.





Base = Beta 4 Calibration. SLR = 0.3m Sea Level Rise Scenario representing relative Chesapeake sea level rise from 1995 to 2025. Units in mean kg DO per second (m^3/s) for 1991 to 2000 hydrodynamics.

Hypoxic volume (DO <1 mg/l) in CB4MH (Model estimate in summer 1991-2000)



DO <1 mg/l annual average daily hypoxia from 1991 to 2000 over the summer hypoxic season of May through September.

solid blue = key scenario, solid red = sensitivity scenario, stippled blue = 2025 climate scenario

So what does this mean?

- Overall influence of estimated 2025 conditions is likely to have a small influence on water quality standard achievement, but impacts will vary across the watershed.
- Although more mixing may offset watershed load increases by 2025, need to focus on **local impacts**




Policy considerations to deal with "uncertainty"

Modeling

- Focus on 2025 for Midpoint Assessment; but use 2050 as a scoping scenario
- Use historic trends to forecast precipitation to 2025
- Bound range of possible future conditions (low, medium, high emission scenarios for SLR and Temp) – **STILL TO COME**!!!

BMP Performance

- **Assess vulnerability** of BMP's to projected impacts over intended design life
- **Incorporate** resilient **siting and design principles**
- **Monitor performance** over-time and adjust implementation, as necessary
- **Research changes in BMP efficiencies** in response to extreme events or changing conditions.

Climate Change & the TMDL
Mid-Point Assessment: 3 Major Components

Assessment Procedures

(PSC Approved)

- Assess how climate change may affect current water quality standards (i.e., nutrient and sediment source loads over time and attainment)
    - Watershed Model
    - WQ Sediment Transport Model

Guiding Principles

(PSC Approved)

- WIP Development
- WIP Implementation

Policy Options

(PSC Consideration)

- Quantitative (Option #2)
- Qualitative (Options #5,6,7)

Resilient BMPs: Good Risk Management

- "Risk management is critical in any restoration project. Risks include those associated with climate patterns, such as more intense storms, as well as those associated with land use change, site selection, and design. Addressing these risks in conjunction with ongoing restoration efforts will prepare communities for greater variability and may result in cost savings and reduced risk. (MD DNR 2013)"

Resilient BMPs: Capitalize on Co-Benefits

EXISTING PRACTICES PROVIDE A VALUE ADDED BENEFIT FOR REDUCING CLIMATE RISK

Management Practice	Nutrient Benefit	Climate Resilience Benefit				
		Temperature Reduction	Storm Buffer	Drought Buffer	Sea Level Rise Buffer	Wildlife Corridor
Wastewater Treatment Plant	●			●		
Stream Restoration	●	◖	◖			●
Forest Buffer	●	●	●			●
Wetlands	●		●	●	●	●
Infiltration	●		●	●		
Shoreline Erosion Control	●		●		●	
Vegetated Open Channel	●		●			

* Practices designated with a ◖ potentially buffer against climate impacts and could be enhanced through modifications suggested in this document.

Source: MD DNR (2013)

Resilient BMPs: Reduce Vulnerability

Resilient BMPs: Account for Uncertainty

Resilient BMPs: Siting & Design Guidance

Design Storm Events

Changes in rainfall volumes have a significant impact on infrastructure.

Design storms are the selected events that engineers use to design drainage infrastructure, bridges, culverts, etc.

Input from DC Water, DDOT and DDOE's Stormwater Management Division informed the selection of events that are used as standards for stormwater, wastewater, and transportation infrastructure.

The chart shows how rainfall volumes are projected to increase across the relevant design storm events, especially for the more extreme (100 and 200 year) events.

Design Storm	Baseline 1981-2000	2020s	2050s	2080s
1-yr 24 hr. storm (in)	1.6	1.7 (1.5 - 1.8)	1.7 (1.5 - 1.8)	2 (±<1)
2-yr 24 hr. storm (in)	3.2	3.4 (3.2 - 3.7)	3.7 (3.5 - 3.9)	4 (4 - 5)
15-yr 24 hr. storm (in)	5.5	6.8 (6.0 - 7.3)	7.1 (6.7 - 7.6)	8 (4 - 9)
25-yr 24 hr. storm (in)	6.3	7.9 (6.8 - 8.6)	8 (7.5 - 8.8)	10 (8 - 12)
100-yr 24 hr. storm (in)	8.1	10.5 (8.9 - 12.4)	10.3 (9.0 - 11.9)	14 (10 - 16)
200-yr 24 hr. storm (in)	9	12 (10.1 - 14.7)	11.7 (9.8 - 13.6)	16 (11 - 19)
2-yr 6 hr. storm (in)	2.3	2.4 (±<0.1)	2.6 (2.6 - 2.7	3 (±<1)
15-yr 6 hr. storm (in)	3.6	4.6 (4.3 - 4.8)	4.7 (4.6 - 4.8)	5 (4 - 6)
100-yr 6 hr. storm (in)	5.1	6.7 (6.5 - 6.8)	6.5 (6.4 - 6.7)	9 (7 - 10)
200-yr 6 hr. storm (in)	5.6	7.5 (7.2 - 7.7)	7.2 (±<0.1)	10 (8 - 11)
80th Percentile storm (in)	0.8	0.9 (0.1)	0.9 (0.1)	0.95 (0.1-0.15)
90th Percentile storm (in)	1.14	1.24 (0.1)	1.24 – 1.34 (0.1-0.2)	1.24 – 1.39 (0.1-0.25)
95th Percentile storm (in)	1.5	1.6 – 1.65 (0.1-0.15)	1.6 – 1.75 (0.1-0.25)	1.75 – 1.85 (0.15-0.35)

Source: DDOE (2016)

STAC Workshop (Fall 2017): Monitoring and Assessing Impacts of Changes in Weather Patterns and Extreme Events on BMP Siting and Design

- What are the general principles of BMP siting and design to reduce the vulnerability of urban, agriculture, and coastal BMP's to future impacts of sea level rise, coastal storms, increased temperature, and extreme events?
- How flexible or adaptable are BMPs to anticipated changes in weather patterns and extreme events and what types of adjustments (e.g., retrofits) in BMP design to maintain structural integrity?
- What suite of BMPs are most robust (e.g., mitigate the anticipated increased nitrogen, phosphorus, and sediment loads) to anticipated changes in weather patterns and extreme events?
- What are the remaining gaps and highest priority needs (i.e., research, monitoring measures, programmatic efforts) to address in order to better inform and improve BMP development and implementation?

Resilient BMP’s: A call for candidate projects

- Identify a project(s) within each jurisdiction to showcase resilient BMP practices.
- Criteria:
  - Completed or planned projects
  - Coastal and inland practices
  - Address one or more approved Guiding Principles
    - ✓ Capitalize on “Co-Benefits”
    - ✓ Align with existing climate resiliency plans and strategies
    - ✓ Account for and integrate planning and consideration of existing stressors
    - ✓ Manage for risk and plan for uncertainty
    - ✓ Reduce vulnerability
    - ✓ Build in flexibility and adaptability

CRWG Recommended Policy Option:

Optimize Phase III WIP Development and Adaptively Manage BMP Implementation

- During the development of Phase III WIPs, jurisdictions will **prioritize BMPs that are more resilient** to future climate impacts over the intended design life of the proposed practices.
- During each two-year milestone development period, jurisdictions will **consider new information on the performance of BMPs and the programs that support them**, including the contribution of seasonal, inter-annual climate variability and weather extremes.
- Jurisdictions will **assess this information and adjust plans to implement their Phase III WIPs to better mitigate anticipated increases** in nitrogen, phosphorus or sediment due to climate change.
- Jurisdictions would **provide a narrative consistent with the Guiding Principles** that describes their programmatic commitments to address climate change in their Phase III WIPs.

PSC Decision-Making Timeline

- **December 13, 2016**: Agreement on 1) climate change assessment procedures, 2) guiding principles, and 3) the range of options for how and when to factor climate change considerations into the jurisdictions' Phase III WIPs
- **Late October 2017**: How and when to incorporate climate change considerations into the Phase III WIPs
- **March 2018**: Final Phase III WIP planning targets fully reflecting Partnership decisions regarding how and when to incorporate climate change considerations

Lew Linker
CBP Modeling Coordinator
U.S. EPA Chesapeake Bay Program
410-267-5741
linker.lewis@epa.gov

Mark Bennett
Co-Chair, Climate Resiliency Workgroup
U.S.G.S
804-261-2643
mrbennet@usgs.gov

Zoë Johnson
Coordinator, Climate Resiliency Workgroup
NOAA Chesapeake Bay Office
410-267-5656
zoe.johnson@noaa.gov

Chesapeake Bay Program
Science. Restoration. Partnership.

www.chesapeakebay.net