# Climate Change Assessment Procedures

## Water Quality Goal Implementation Team

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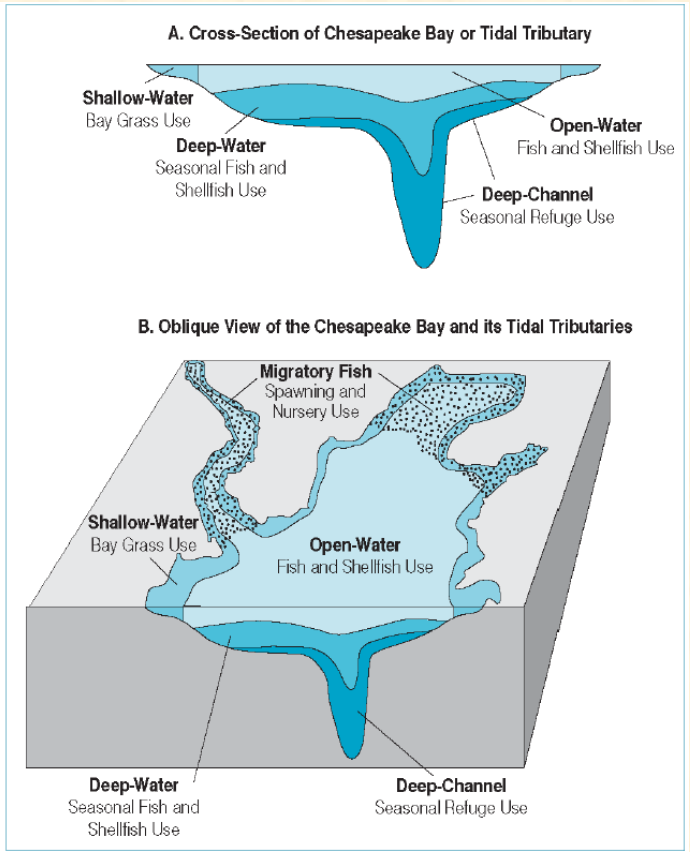
**Chesapeake Bay Program**
***Science, Restoration, Partnership***

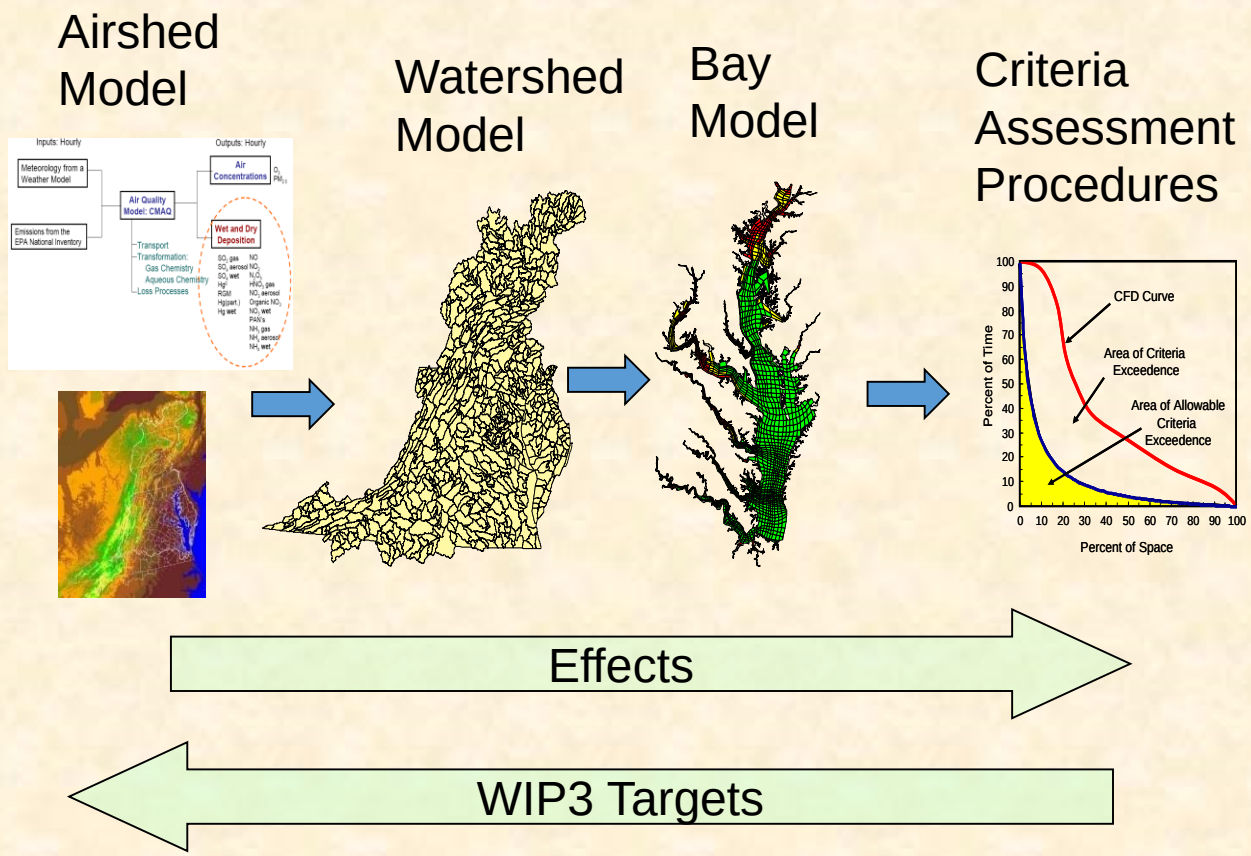
# Proposed Climate Change Assessment Procedures

1. Use the same CBP assessment tools that were applied in the 2010 allocation.
2. Partition the influence of climate change into separate elements of watershed flows and loads, storm intensity, increased estuarine temperatures, sea level rise, and ecosystem influences including loss of tidal wetland attenuation with sea level rise, as well as other ecosystem influences.
3. Frame initial future climate change scenarios based on estimated 2025 (potential TMDL application) 2050 conditions (future condition scoping scenario application) and other conditions as directed.
4. Develop an uncertainty estimate of the climate change assessment.

# Proposed Climate Change Assessment Procedures

1. Use the same CBP assessment tools that were applied in the 2010 allocation.

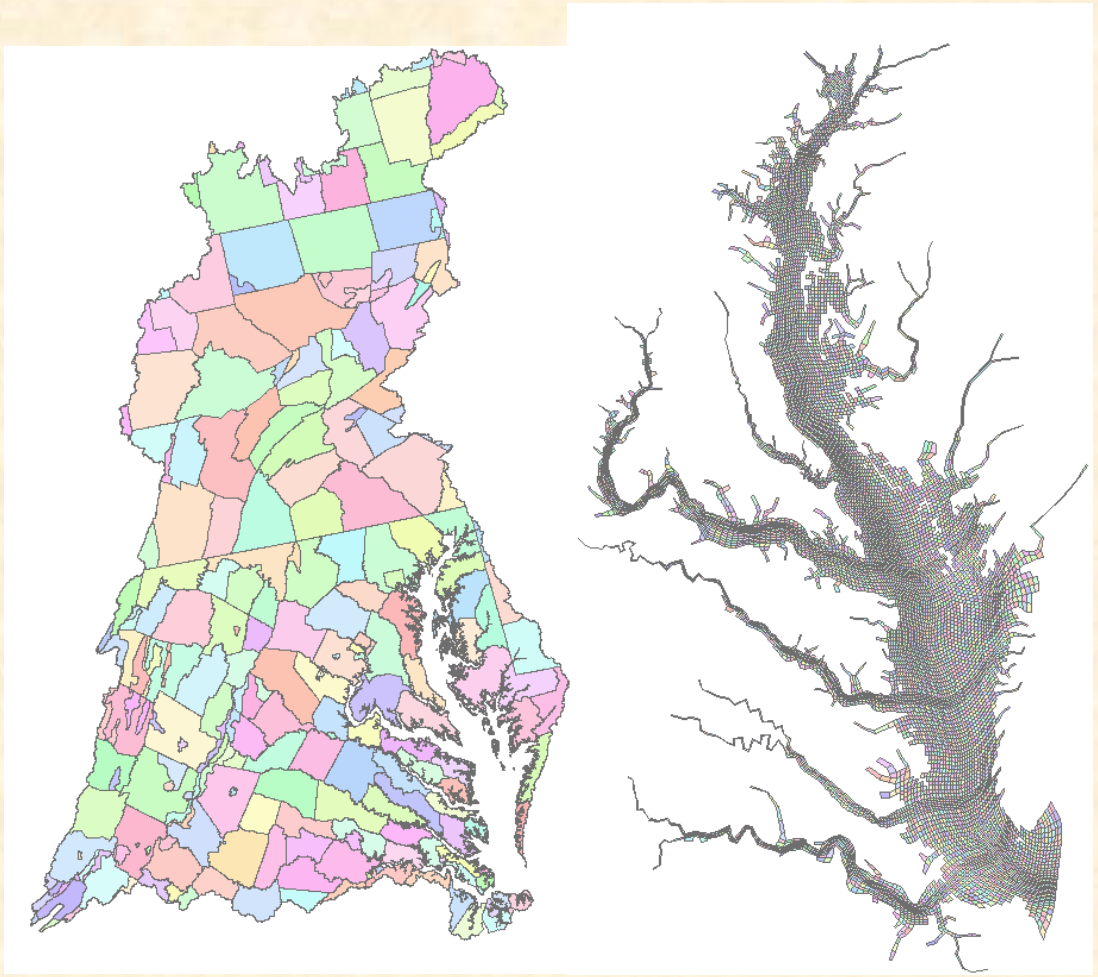


# With Model Climate Inputs Consistent with STAC Workshop and Climate Resiliency Workgroup Guidance

- Precipitation Volume
  - 2025: +3.1% (long term trends)
  - 2050: +7.3% (RCP* 4.5)
- Temperature: RCP 4.5
  - 2025: +1.05 $^{o}$C
  - 2050: +2.08 $^{o}$C
- CO2 Concentration: Meinhausen, Malte, et al, (2011)
  - 2025: 427 ppm
  - 2050: 487 ppm

*RCP 4.5 is a specific Representative Concentration Pathway scenario as defined by the Intergovernmental Panel on Climate Change

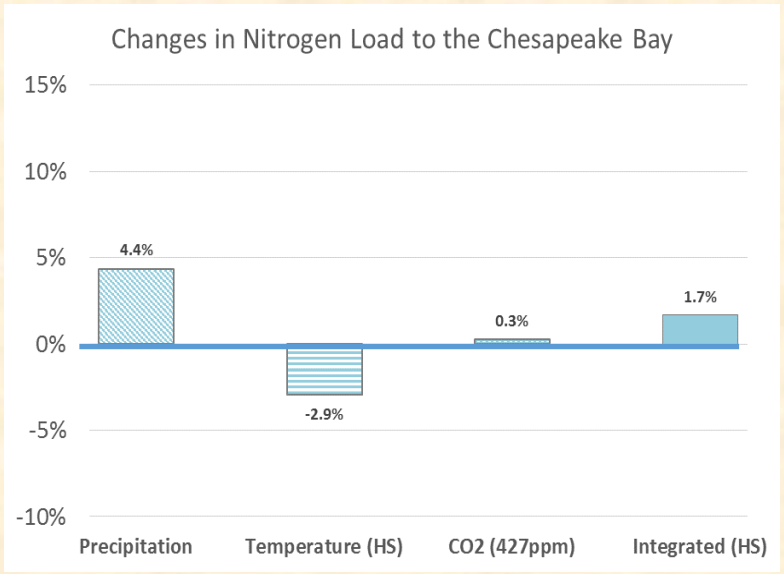


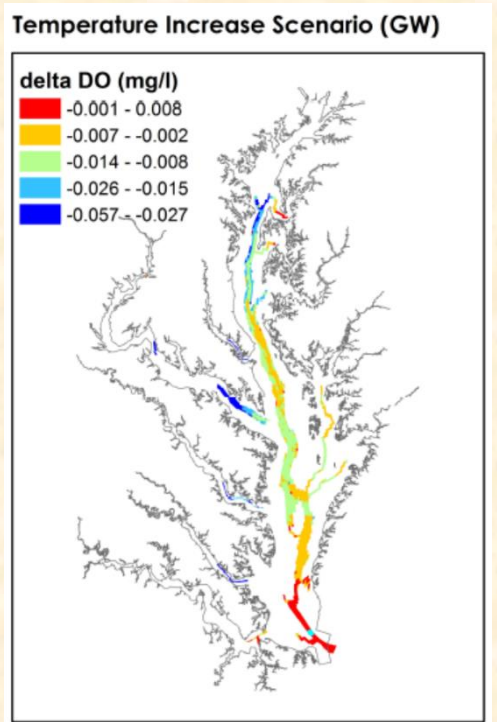
- Sea Level Rise: CRWG**
  - 2025: +0.3 m
  - 2050: +0.5 m
- Temperature: RCP 4.5
  - 2025: +0.95 $^{o}$C
  - 2050: +1.86 $^{o}$C

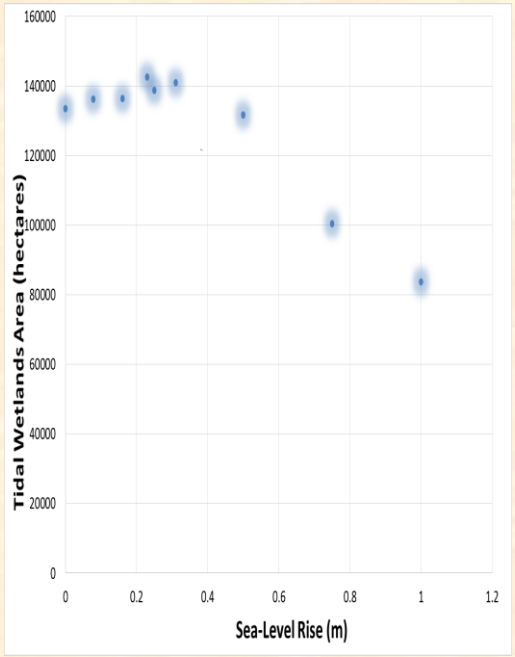
**Based upon guidance provided by the Climate Resiliency Workgroup

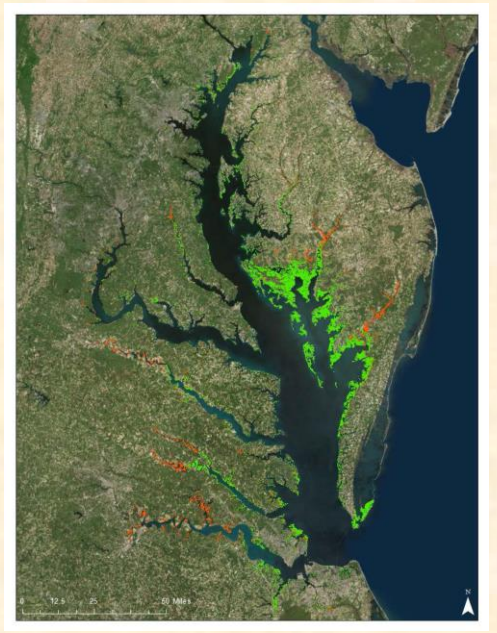
# Proposed Climate Change Assessment Procedures

2. Partition the influence of climate change into separate elements of watershed flows and loads, storm intensity, increased estuarine temperatures, sea level rise, and ecosystem influences including loss of tidal wetland attenuation with sea level rise, as well as other ecosystem influences.



# With the CBP Analysis Tools We're Examining….

**Increased Estuarine Temperature**

- Direct warming of tidal water
- Indirect warming from watershed inputs
- Indirect warming from ocean boundary inputs

**Sea Level Rise**

- Influence on hydrodynamics
- Influence on tidal wetland loss and associated loss of nutrient attenuation
- Increased organic loading from wetland erosion

**Watershed Hydrologic and Loading Changes**

- Changes in precipitation volume
- Changes in precipitation intensity
- Changes in land use

# With the CBP Analysis Tools We're Examining….

**Ecological Changes**

- Temperature ranges and optima (*Zostera*)
- Other ecological changes

**Changes in Airshed**

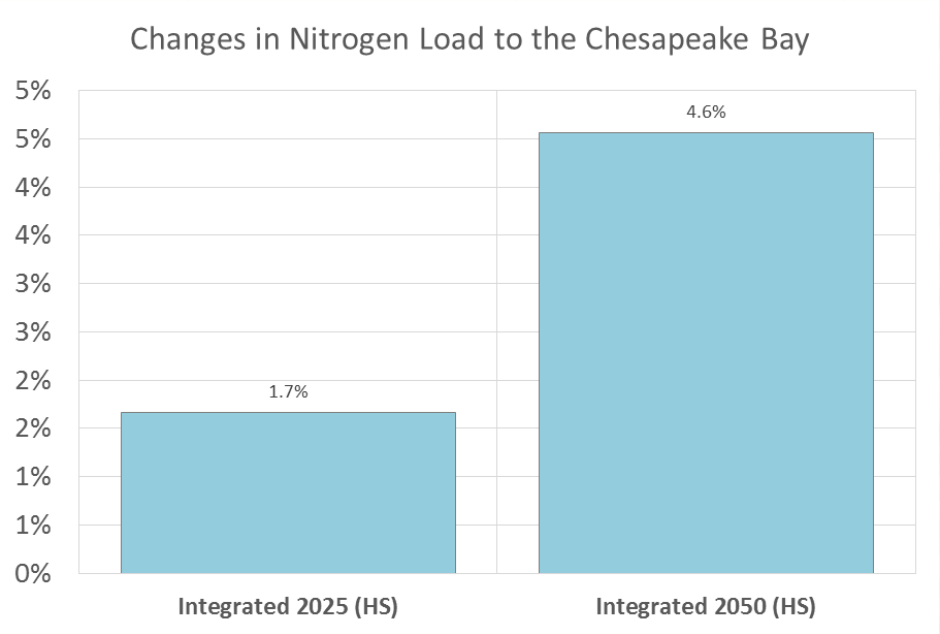
- Changes in precipitation volume
- Changes in precipitation intensity
- Changes ground level ozone with temperature increases

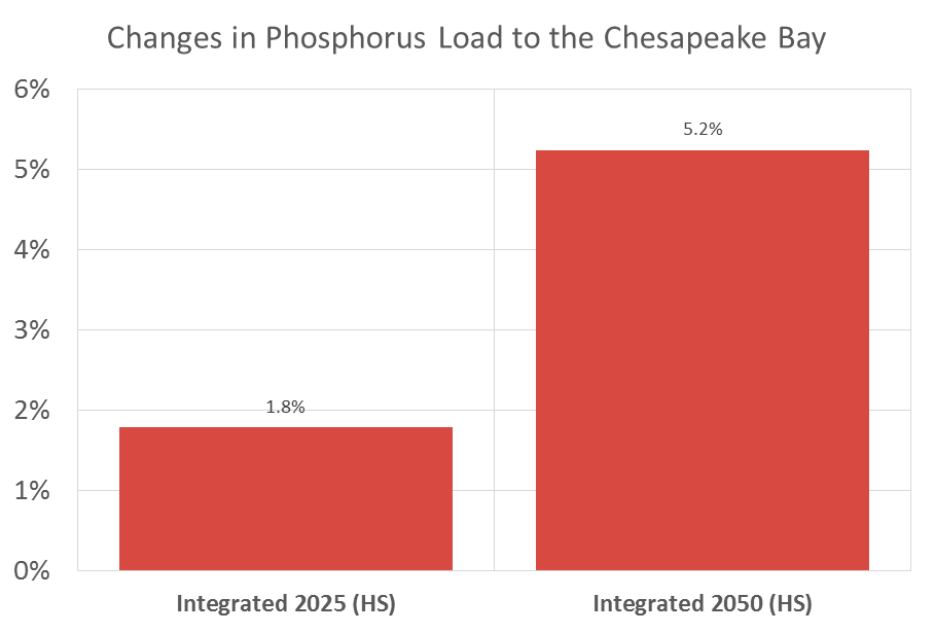
**Additional Inputs To the CBP TMDL Climate Change Decision:**

- Historical studies of climate change
- GCM models downscaled for the Chesapeake watershed
- Intercomparison of other coastal systems
- Other relevant climate change research, monitoring, and observations.

# Proposed Climate Change Assessment Procedures

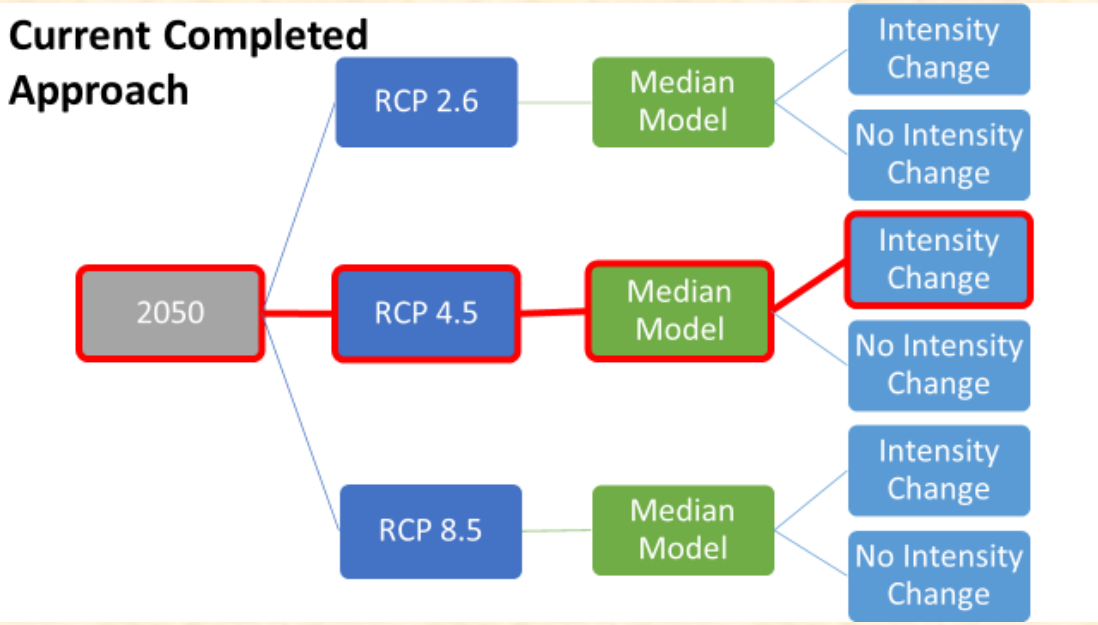
3. Frame initial future climate change scenarios based on estimated 2025 (potential TMDL application) 2050 conditions (future condition scoping scenario application) and other conditions as directed.

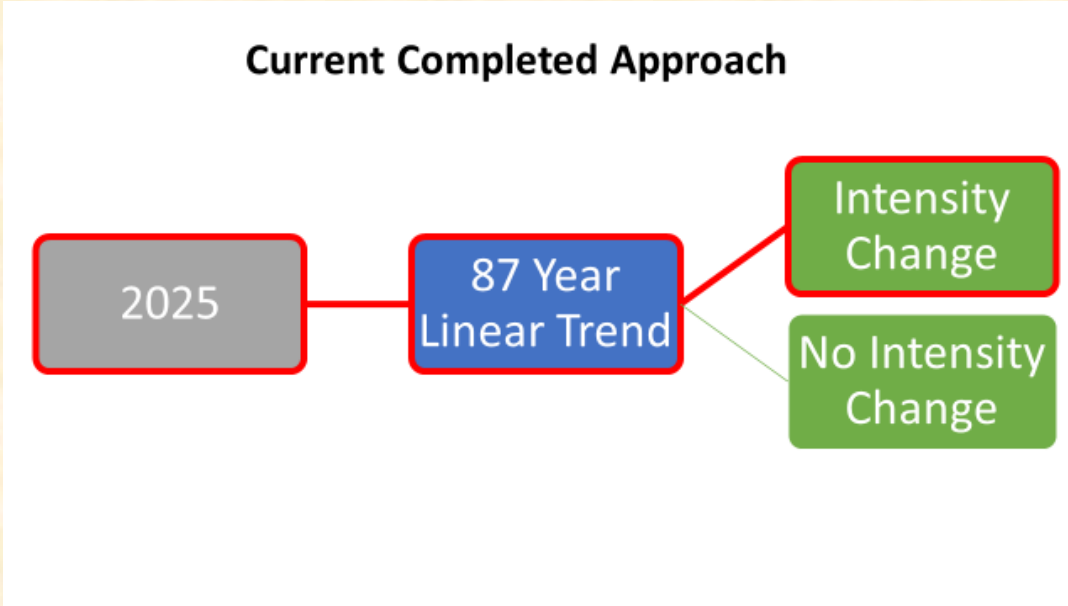


# Proposed Climate Change Assessment Procedures

4. Develop an uncertainty estimate of the climate change assessment.



| Year | Variable | Input | Parameter | Sensitivity | Used for Uncertainty |
|---|---|---|---|---|---|
| 2025 | $CO_2$ | 427 ppm | Stomatal resistance | very low | no |
| | Potential Evapotranspiration | Hamon Method | PET with high temperature response | high | yes |
| | | Hargreaves Method | PET with moderate temperature response | high | yes |
| | Temperature | RCP 2.6 | Monthly median of 32 member ensemble of climate change models | low in tidal water; moderate as influence on PET | yes |
| | | RCP 4.5 | Monthly median of 32 member ensemble of climate change models | low in tidal water; moderate as influence on PET | yes |
| | | RCP 8.5 | Monthly median of 32 member ensemble of climate change models | low in tidal water; moderate as influence on PET | yes |
| | Precipitation | Historical | With Observed Intensity | moderate | yes |
| | | Historical | Without Intensity | moderate | yes |
| | Sea Level Rise | 0.2 m | Bay Hydro Model | low | no |
| | | 0.3 m | Bay Hydro Model | low | no |
| | | 0.4 m | Bay Hydro Model | low | no |

Key:

Recommended approach

Useful to examine range of uncertainty

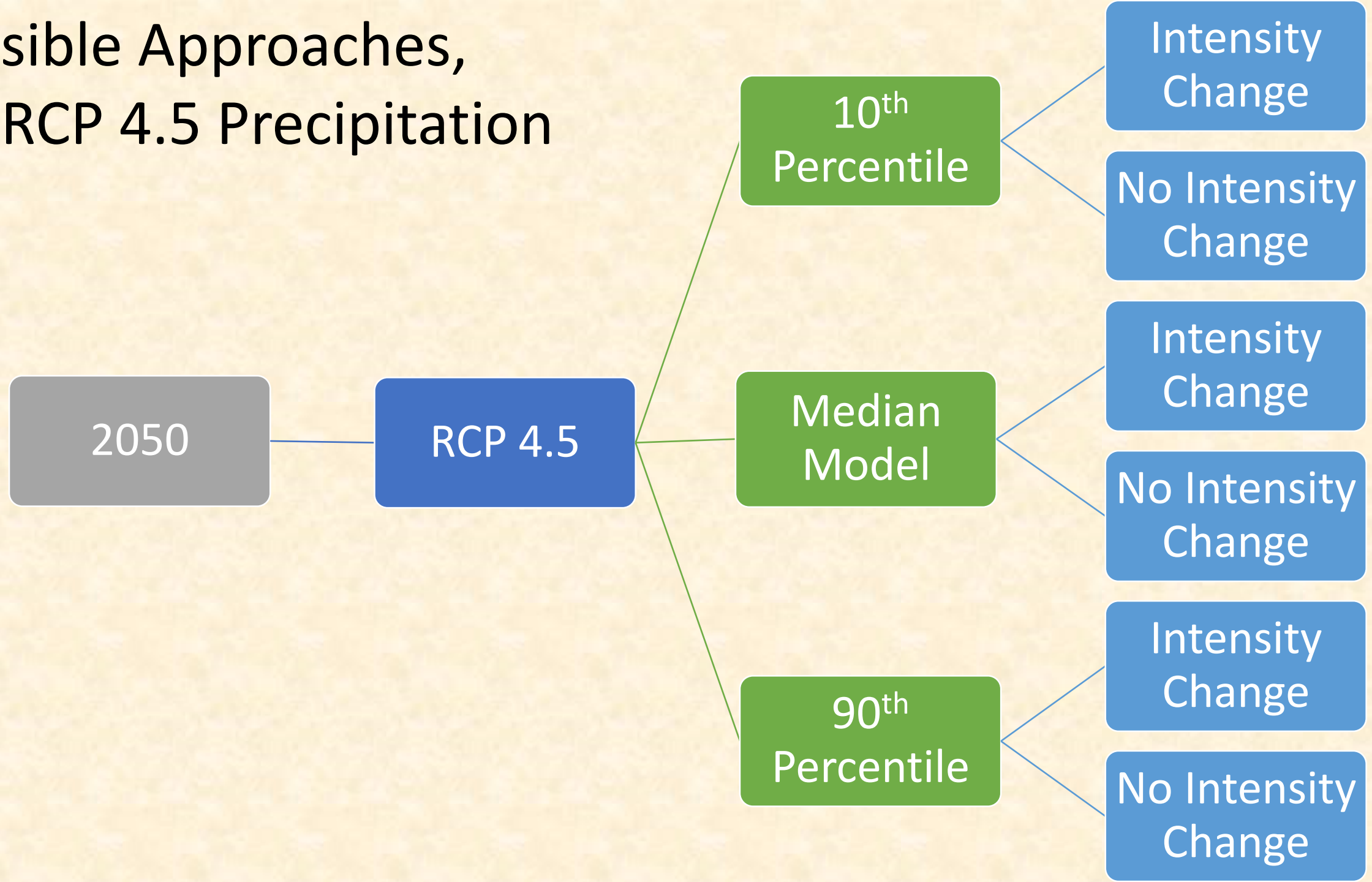
Full uncertainty approach

| Year | Variable | Input | Parameter | Sensitivity | Used for Uncertainty |
|---|---|---|---|---|---|
| 2050 | $CO_2$ | 487 ppm | Stomatal resistance | very low | no |
| | Potential Evapotranspiration | Hamon Method | PET with high temperature response | high | yes |
| | | Hargreaves Method | PET with moderate temperature response | high | yes |
| | Temperature | RCP 2.6 | Monthly median of 32 member ensemble of climate change models | low in tidal water; moderate as influence on PET | yes |
| | | RCP 4.5 | Monthly median of 32 member ensemble of climate change models | low in tidal water; moderate as influence on PET | yes |
| | | RCP 8.5 | Monthly median of 32 member ensemble of climate change models | low in tidal water; moderate as influence on PET | yes |
| | Precipitation | RCP 2.6* | 10 percentile of precip w/ observed intensity | moderate | yes |
| | | | 10 percentile of precip w/o observed intensity | moderate | yes |
| | | | median precip w/ observed intensity | moderate | yes |
| | | | median precip w/ observed intensity | moderate | yes |
| | | | 90 percentile of precip w/ observed intensity | moderate | yes |
| | | | 90 percentile of precip w/o observed intensity | moderate | yes |
| | | RCP 4.5* | With Observed Intensity | moderate | yes |
| | | | Without Intensity | moderate | yes |
| | | RCP 8.5* | With Observed Intensity | moderate | yes (w/90 percentile) |
| | | | Without Intensity | moderate | yes |
| | Sea Level Rise | 0.3 m | Bay Hydro Model | low | no |
| | | 0.5 m | Bay Hydro Model | low | no |
| | | 0.8 m | Bay Hydro Model | low | no |

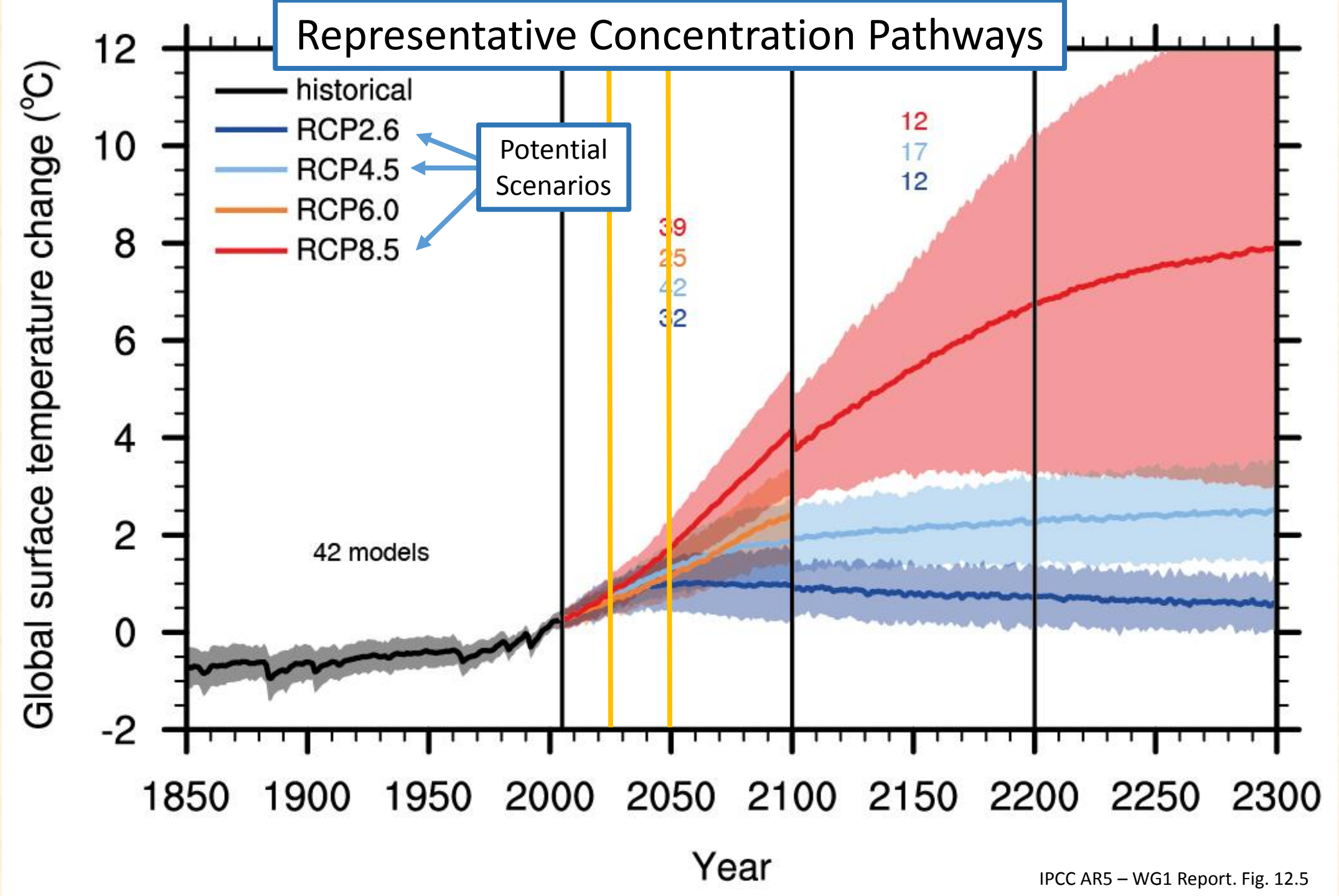
Key: Recommended approach Useful to examine range of uncertainty Full uncertainty approach

* Each 2.6, 4.5, and 8.5 RCP scenario for 2050 is generated from a 32 member ensemble of climate change models with assessments of the 10 percentile precipitation, median precipitation, and 90 percentile precipitation.

# Possible Approaches,
# Ex: RCP 4.5 Precipitation



# Representative Concentration Pathways




IPCC AR5 – WG1 Report. Fig. 12.5

# Take away Messages Redux:

- The CBP Modeling Workgroup is factoring into the Chesapeake Bay assessment tools the latest research on climate change with guidance from the STAC and the Climate Resiliency Workgroup.
- The CBP Models are under development, with the current (*Beta* 3) version to be replace by *Beta* 4 in December 2016 (*Beta* 4) and a final version in March 2017. The results presented today will be refined going forward.
- Influence of estimated 2050 temperature on Chesapeake water quality standards (WQS) is slight.
- Influence of 2050 sea level rise is estimated to be small and variable with both positive and negative impacts on deep channel DO.

# Take away Messages Redux:

- Estimated influence of changes in tidal wetland attenuation is small in 2025 and 2050 because of little change in overall tidal wetland area, but wetland type changes and tidal wetland loss is estimated to increase beyond 2050.
- The  range of the influence of estimated watershed loads in future climate change conditions using observed (87 year) increase of precipitation volume (Karen Rice) and precipitation intensity (Karl and Knight) depends on the evapotranspiration method chosen.
- The estimated 2025 and 2050 range of  nutrient (nitrogen & phosphorus) are 0% to 2% and 0% to 5%, respectively.
- Scientific peer reviews of the representation of climate change by the CBP models will be conducted by the CBP Scientific and Technical Advisory Committee (STAC).