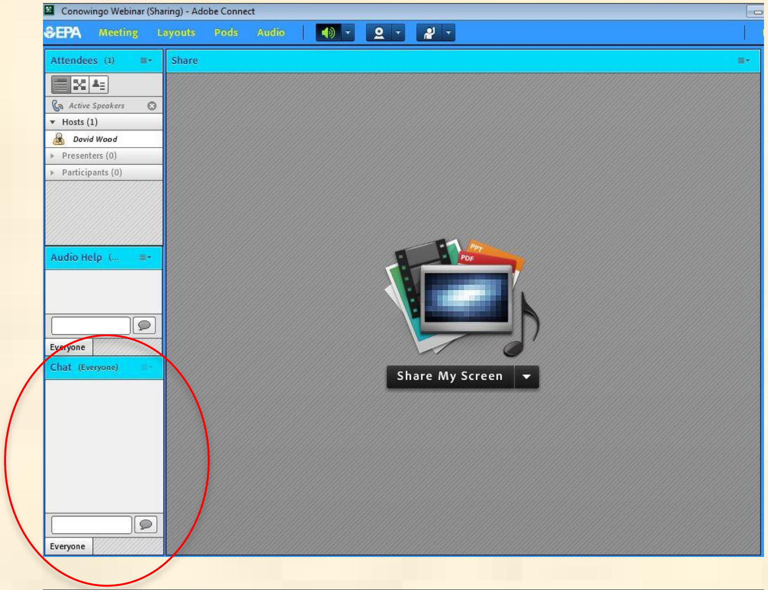
Overview of the Integrated Air Watershed and Bay Models, the Midpoint Assessment Decisions the Models Were Designed to Address, and the Decision Framework of Standards, Models, and Planning Target Methodology

Phase 6 Model Review Webinar Series
May 9, 2017

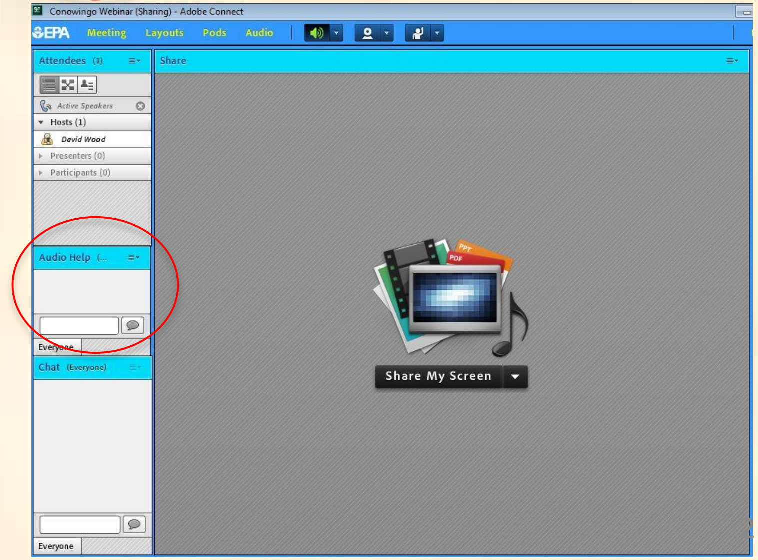
Chesapeake Bay Program
Science, Restoration, Partnership

Welcome to the Phase 6 Model Review Webinar

- To Ask a Question
  - Submit your question in the chat box, located in the bottom left of the screen, at any time during the webinar. We will answer as many as possible during a Q&A session following the presentation.



- For A/V Help
  - For audio or visual questions, please use the “Audio Help” box in the center-left of the screen.



Welcome to the Phase 6 Model Review Webinar

- We ARE Recording this Session
  - The recording and related resources will be available on the Chesapeake Bay Program's calendar page for today's webinar.
  - http://www.chesapeakebay.net/calendar/event/25114/

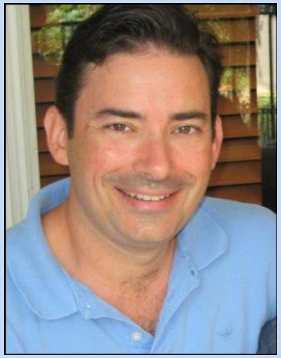
Goals for Today's Webinar

- Increasing understanding of the key features of the Phase 6 watershed, airshed, and estuary models and how the new model improvements provide information to CBP decision makers for the 2017 Midpoint Assessment decisions on the Phase 3 WIPS, Conowingo infill, and climate change.

- Understanding of how the 'dynamic equilibrium' of Conowingo infill was simulated by the Phase 6 watershed and estuary models and how the dynamic equilibrium simulation will be applied in the calibration and scenarios.

- Understanding how of the simulation of climate change with the watershed, airshed, and estuary models is represented and the estimated influence of changing temperature, precipitation, and sea level rise on water quality.

Today's Speakers

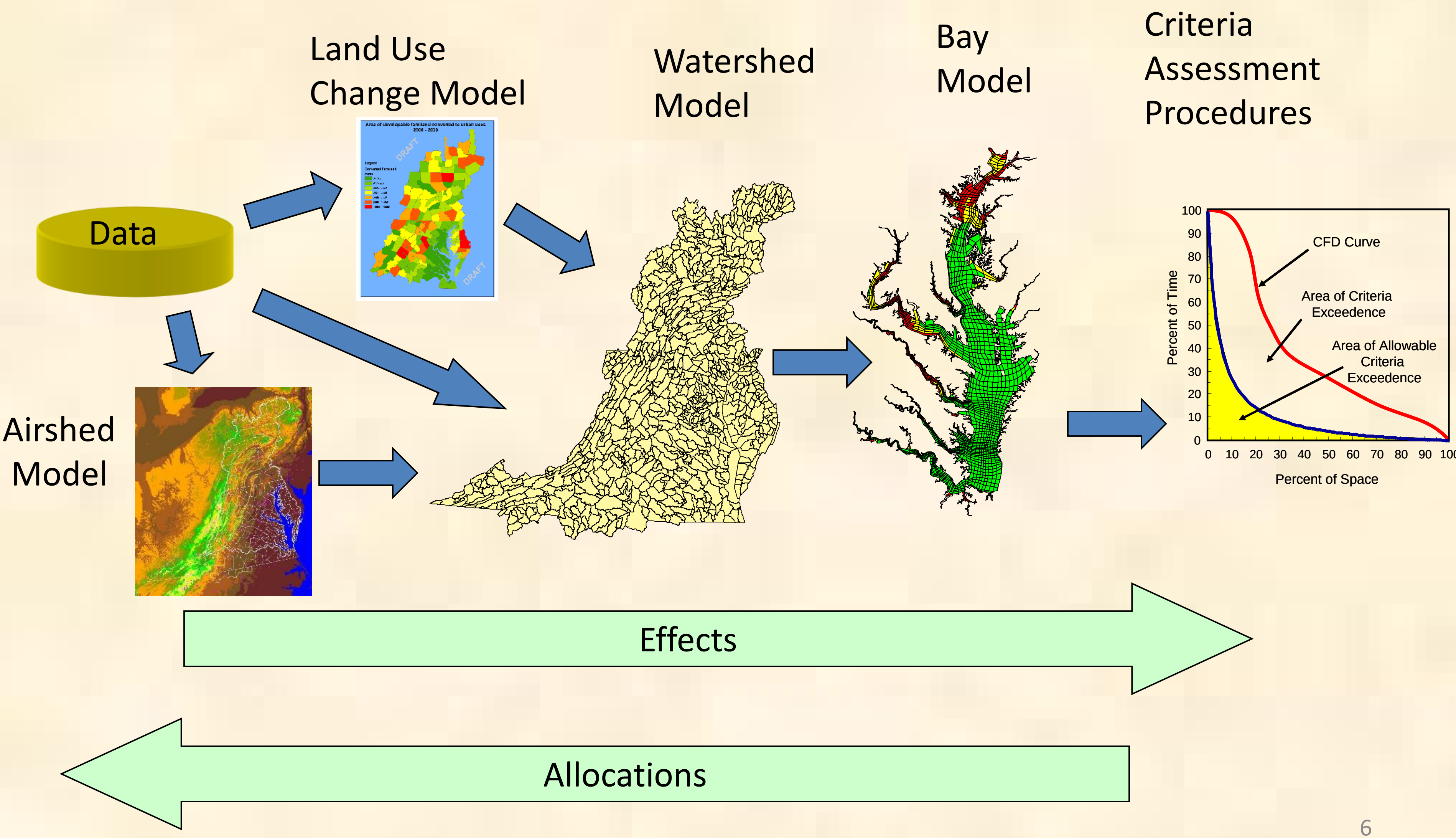


Gary Shenk
U.S. Geological Survey Hydrologist and Lead Phase 6 Watershed Model Practitioner

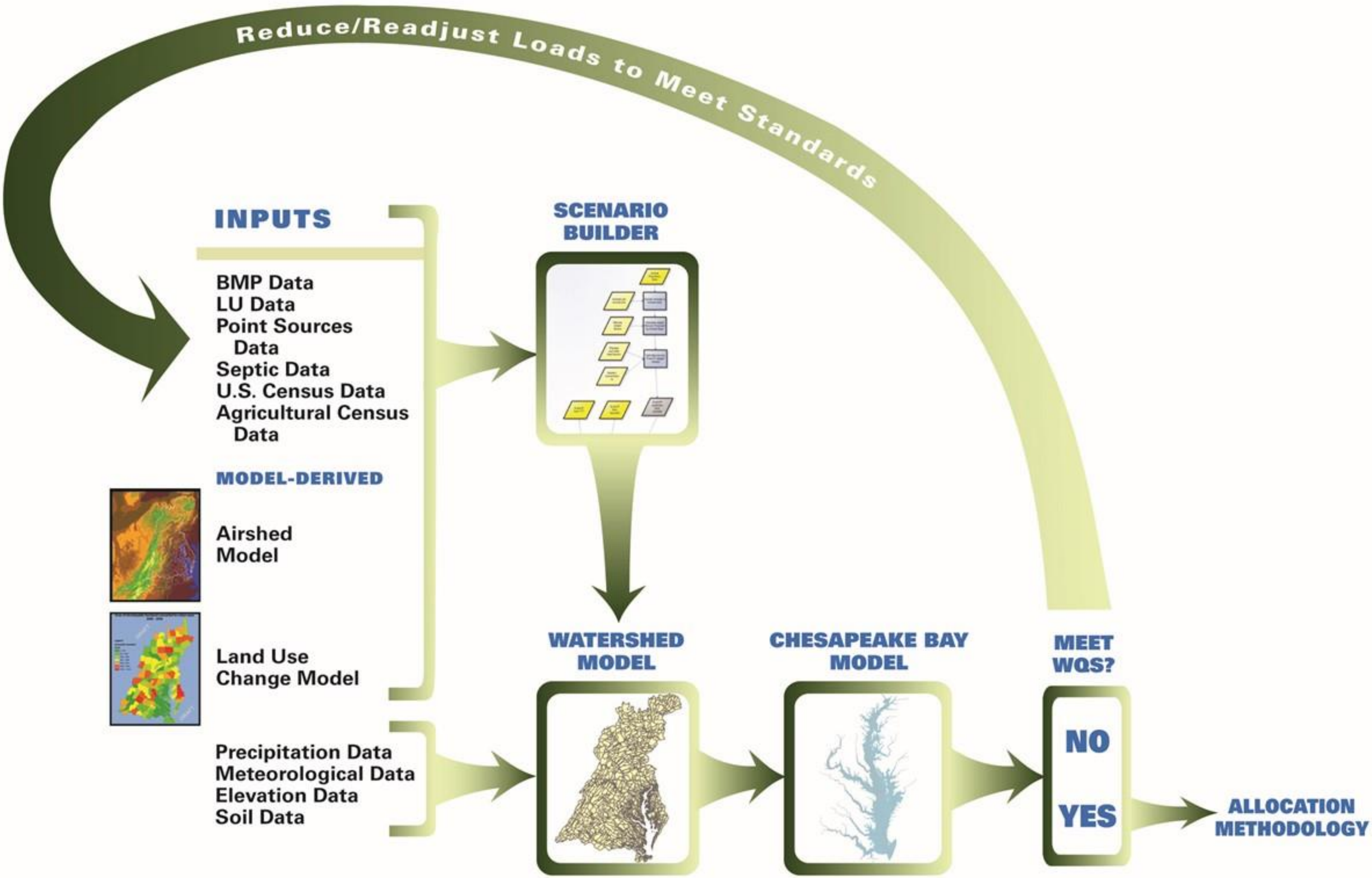
Lew Linker
U.S. Environmental Protection Agency
CBP Modeling Workgroup Coordinator

Kyle Hinson
Chesapeake Research Consortium
Modeling Workgroup Staff

Decision Support System



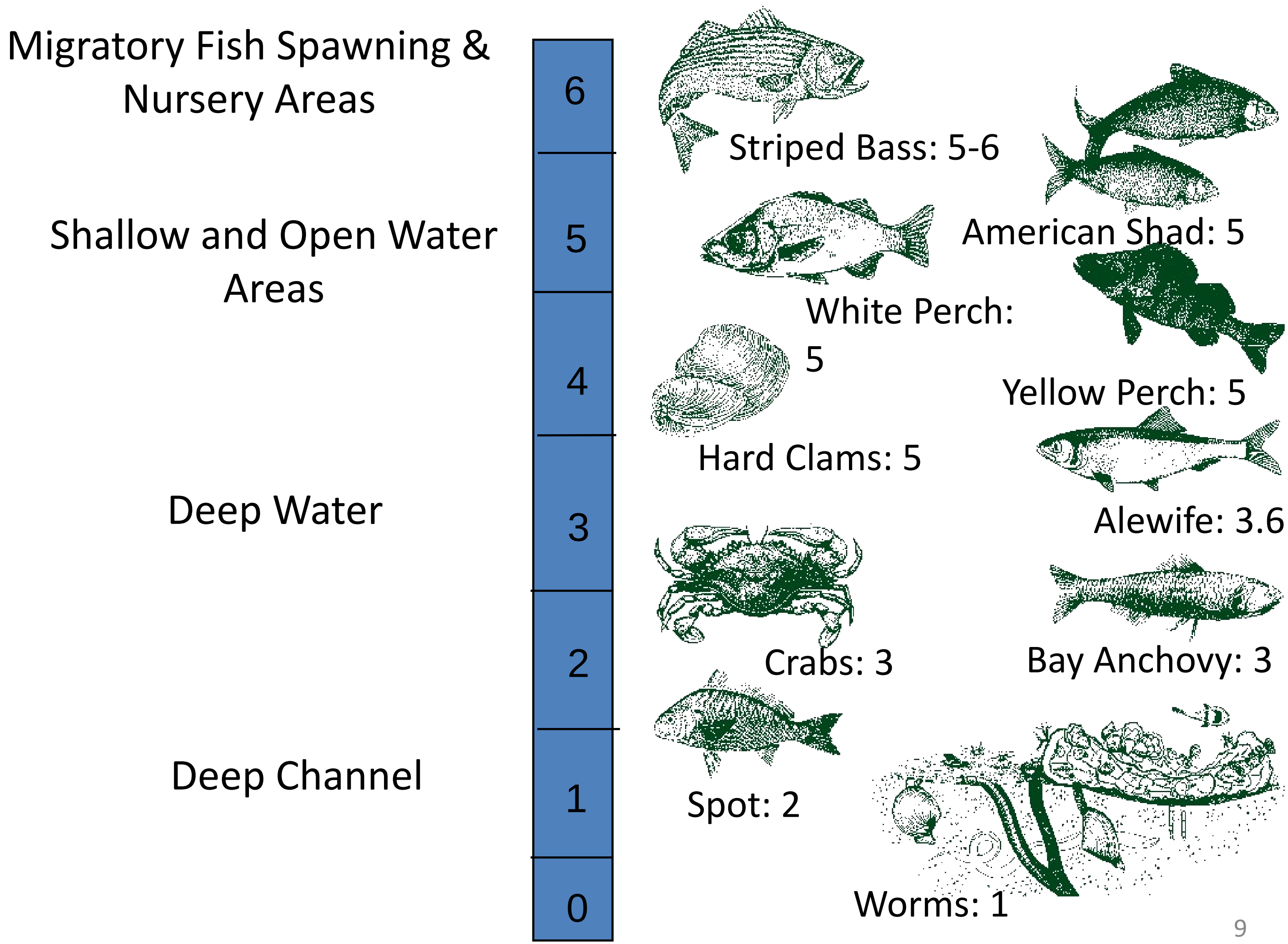
Chesapeake Bay Partnership Models



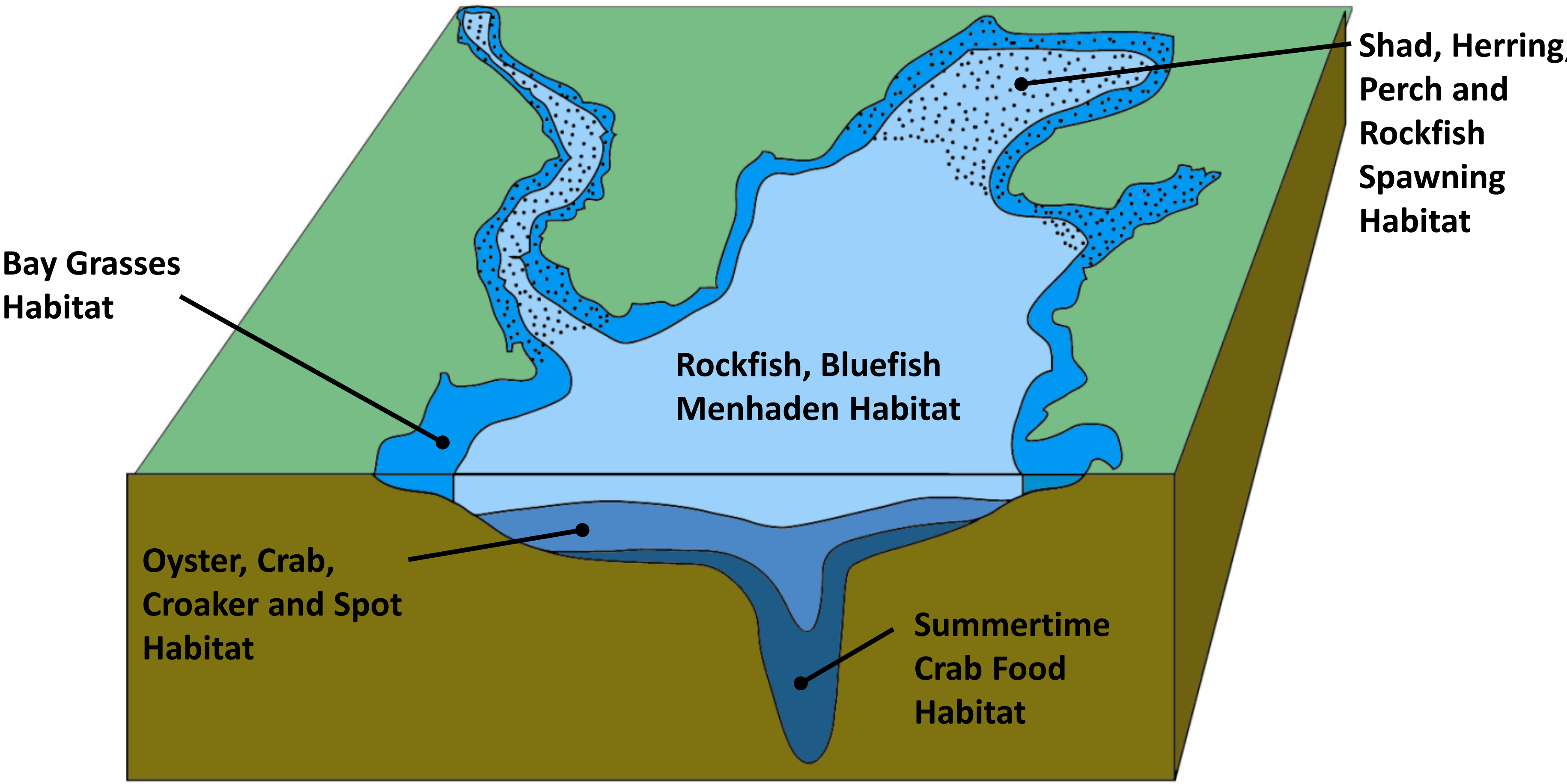
How will we do the State-basin targets for WIP3 and what improvements have we made in the Phase 6 Model to provide a better assessment of watershed implementation?

Bay Dissolved Oxygen Criteria

Minimum Amount of Oxygen (mg/L) Needed to Survive by Species



Local "Zoning" for Bay and Tidal River Fish, Crab and Grasses Habitats



Redefined 'swimmable/fishable' in terms the public could relate to

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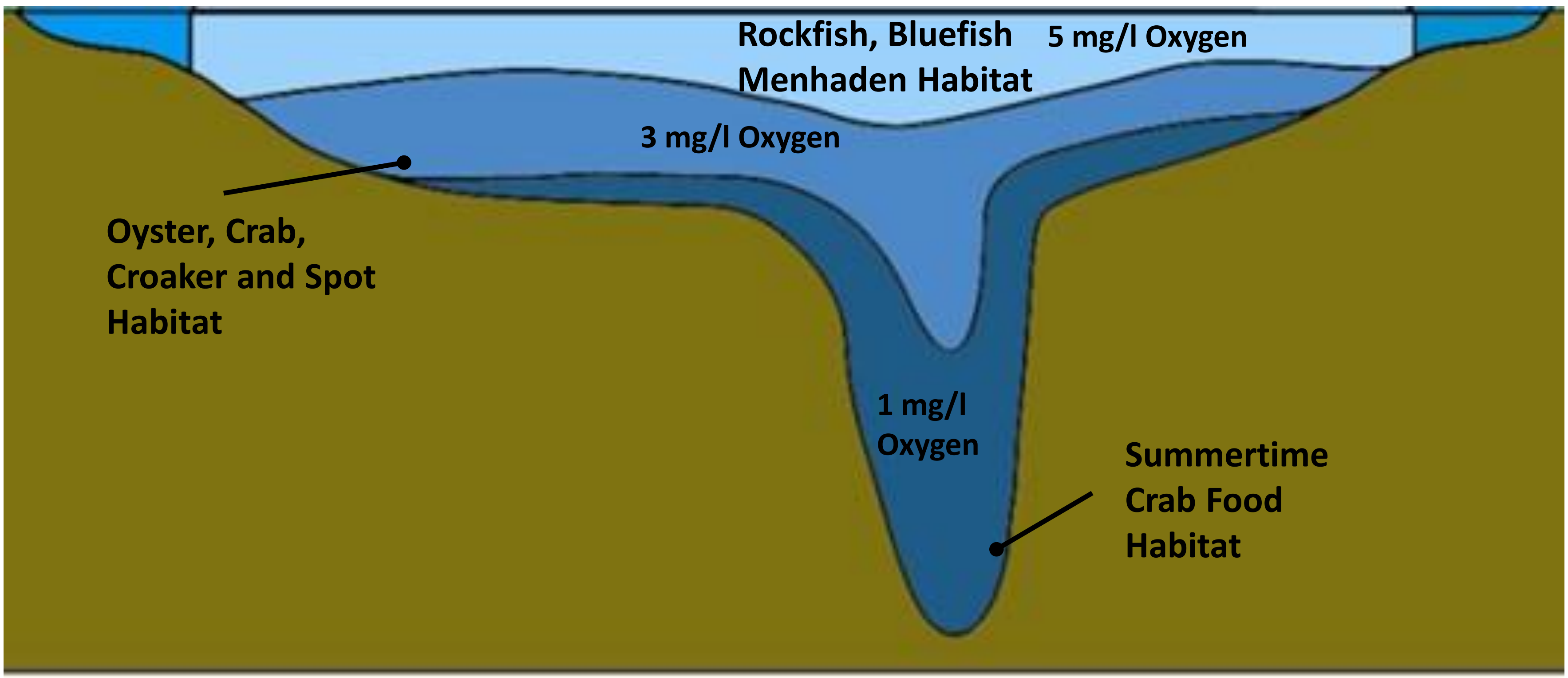

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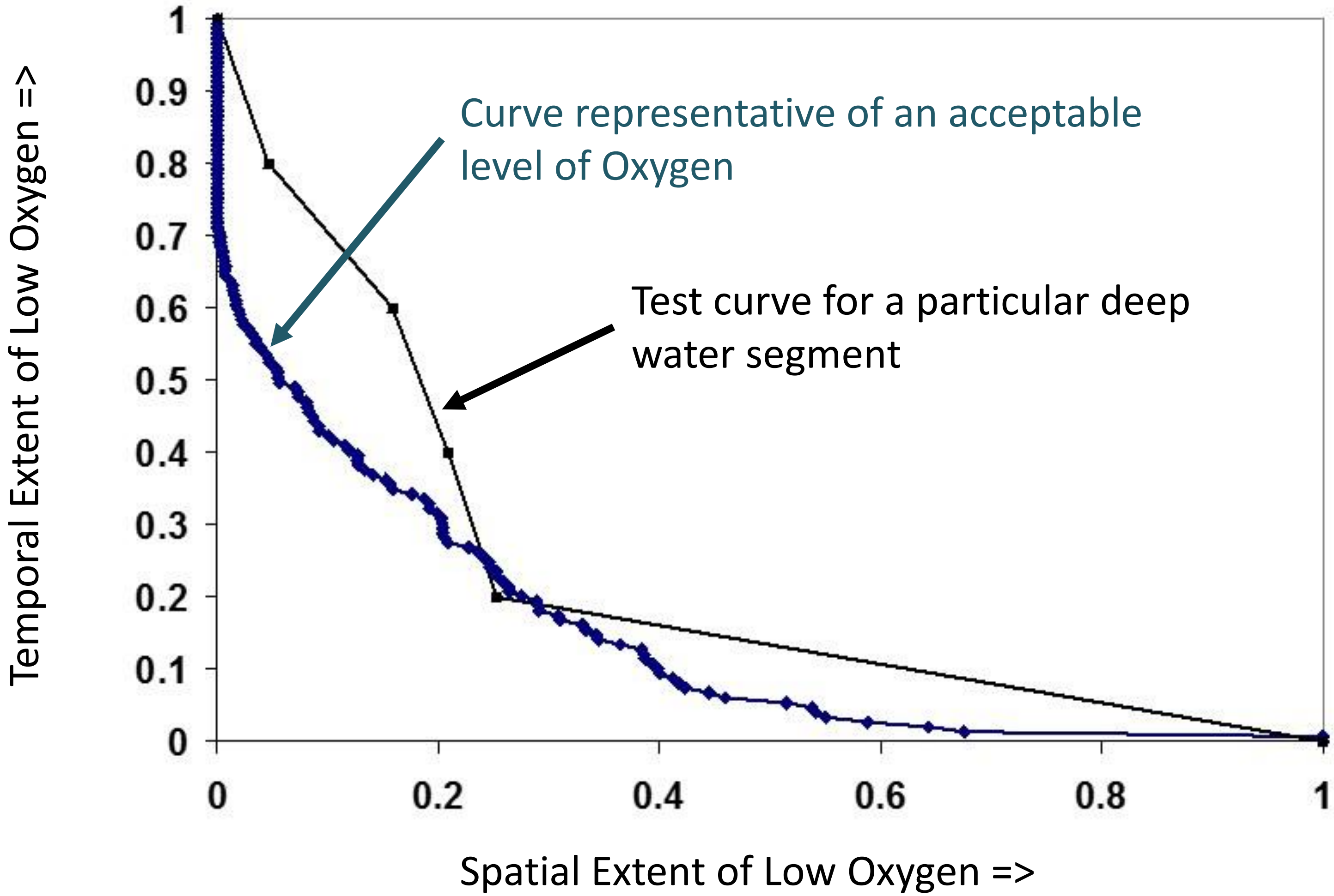
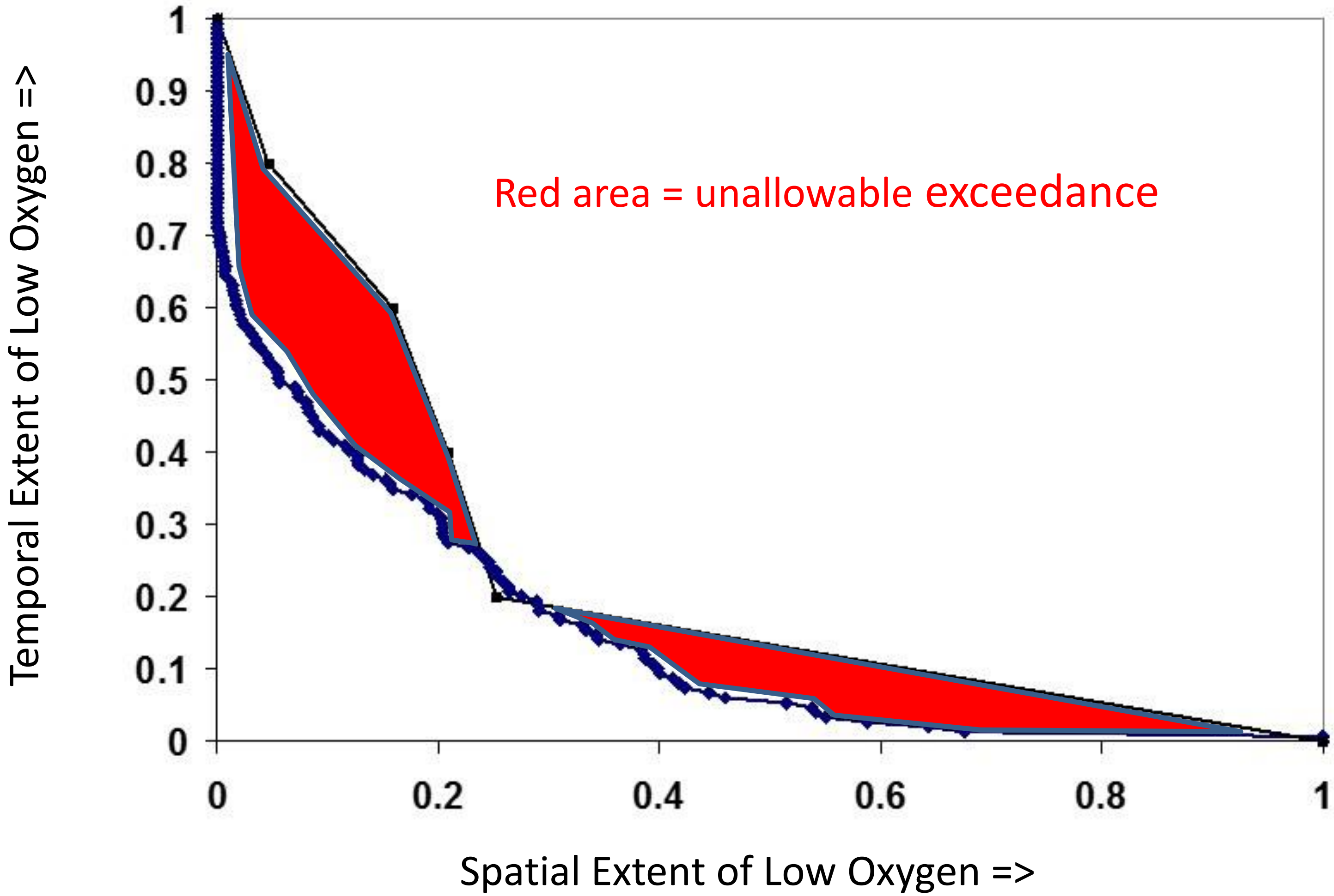
An Assessment of Dissolved Oxygen Criteria



An Assessment of Dissolved Oxygen Criteria



‘Stoplight’ Table

Deep Water Attainment			
Cbseg	Base	Draft Allocation	E3
CB3MH	2.5%	0.1%	0.0%
CB4MH	23.3%	3.8%	1.5%
CB5MH	5.3%	0.0%	0.0%
CB6PH	0.6%	0.0%	0.0%
CB7PH	0.4%	0.0%	0.0%
CHSMH	5.5%	0.0%	0.0%
EASMH	3.3%	0.0%	0.0%
Calculated January 2009			

Critical Period 1993-1995

- Stoplight tables are calculated over a 3-year period
- Regulations require that ‘critical conditions’ be determined where variable environmental factors make attainment more difficult
  - Often interpreted as a ‘once in 10 years’ event
- 1993–1995 selected for stream flows with a 10-year return.
  - 1996-1998 was more extreme
- Choice of the critical period affects the overall effort required to meet the TMDL

Hydrologic Averaging Period 1991-2000

- Loads from the watershed model are based on the weather during the hydrologic averaging period
- Wetter periods would show more load from nonpoint source
- Dryer periods would show more load from point source
- Any 10-year period is representative, 1991-2000 chosen as
  - slightly more representative
  - Includes the critical period

- Choice of hydrologic averaging period affects point/nonpoint balance.

Guidelines for Allocations

- Areas that contribute the most to the problem must do the most to resolve the problem.
- All tracked and reported reductions in nutrient loads are credited toward achieving final assigned loads.
- Allocated N and P loads must result in attainment of water quality standards

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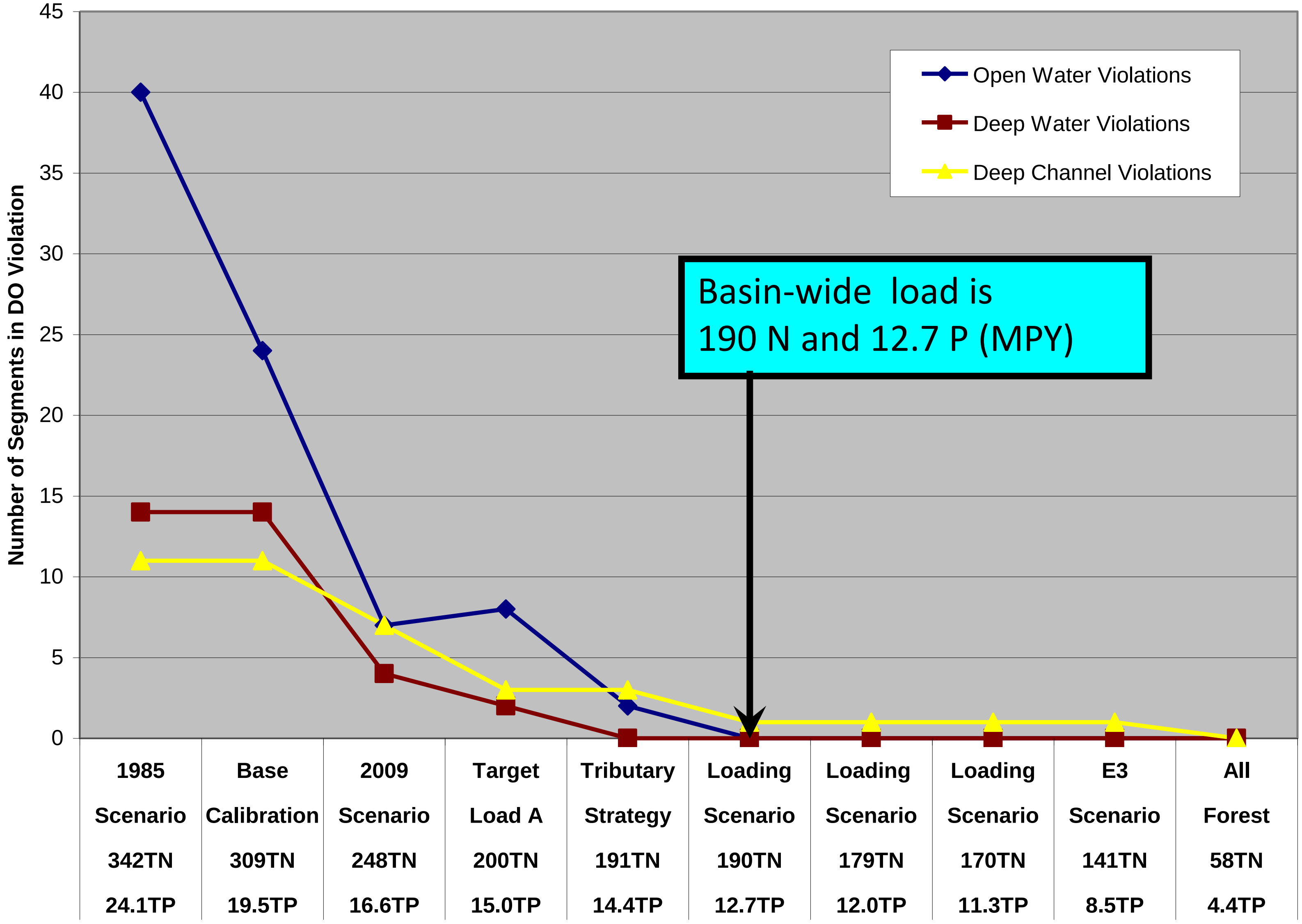
Dissolved Oxygen Criteria Attainment



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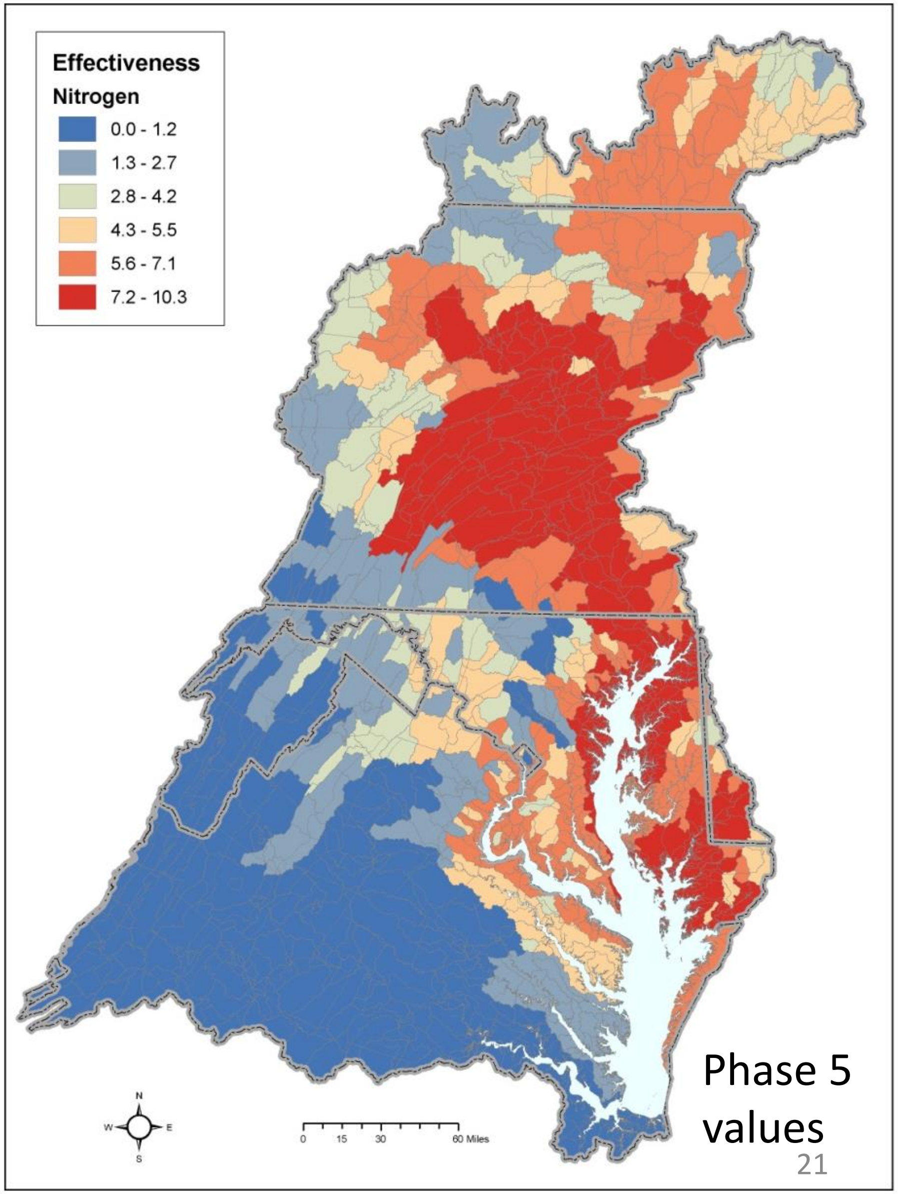
Determining Who Contributes the Most

Key factors:

Distance from Tidal water
- Riverine transport

Position along mainstem bay
- Estuarine circulation

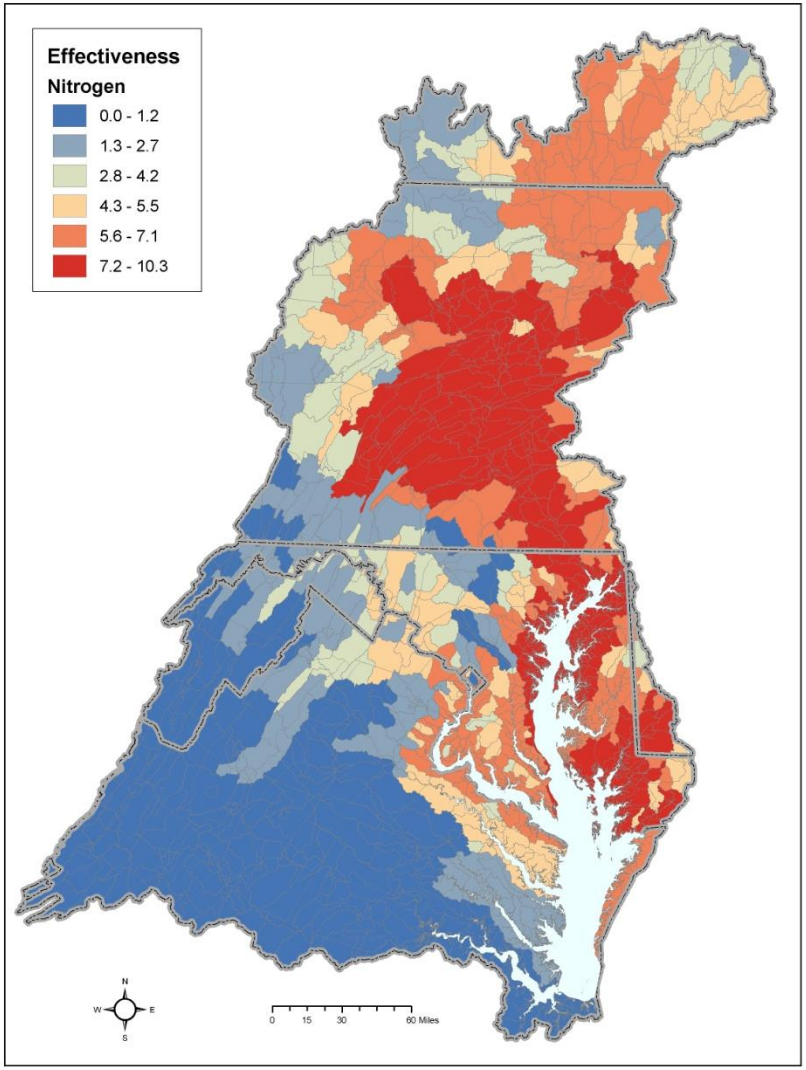
Existence of riverine estuary

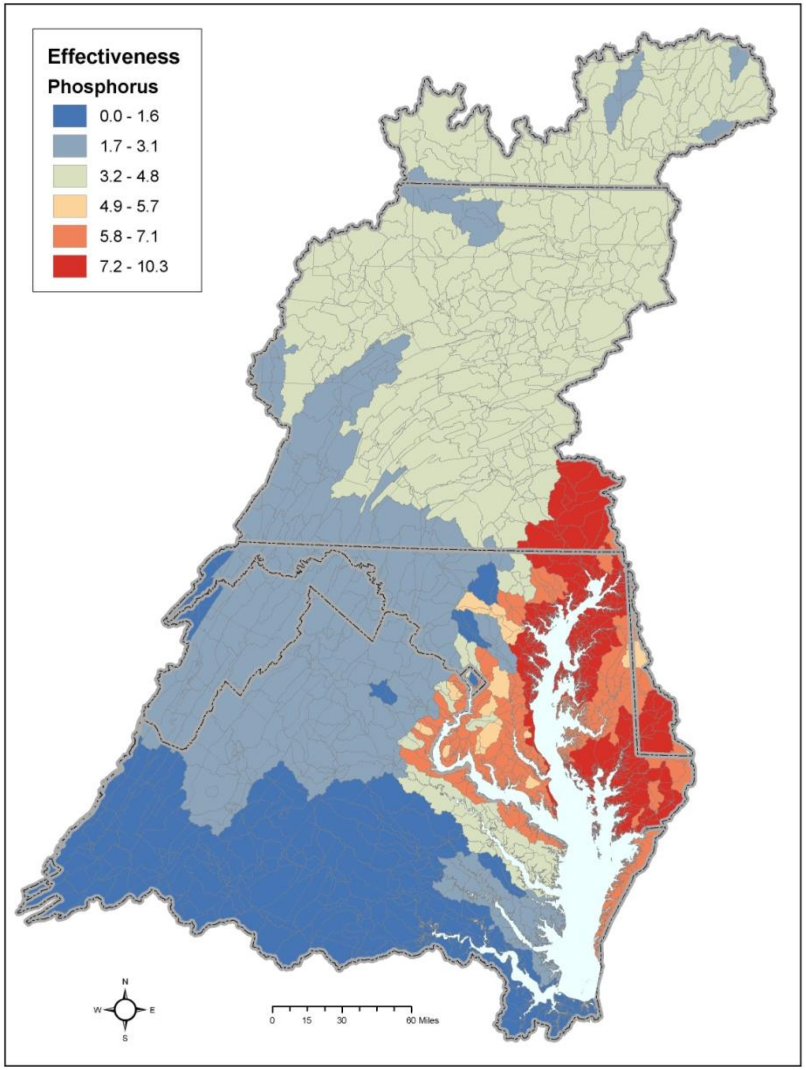


Phase 5 values

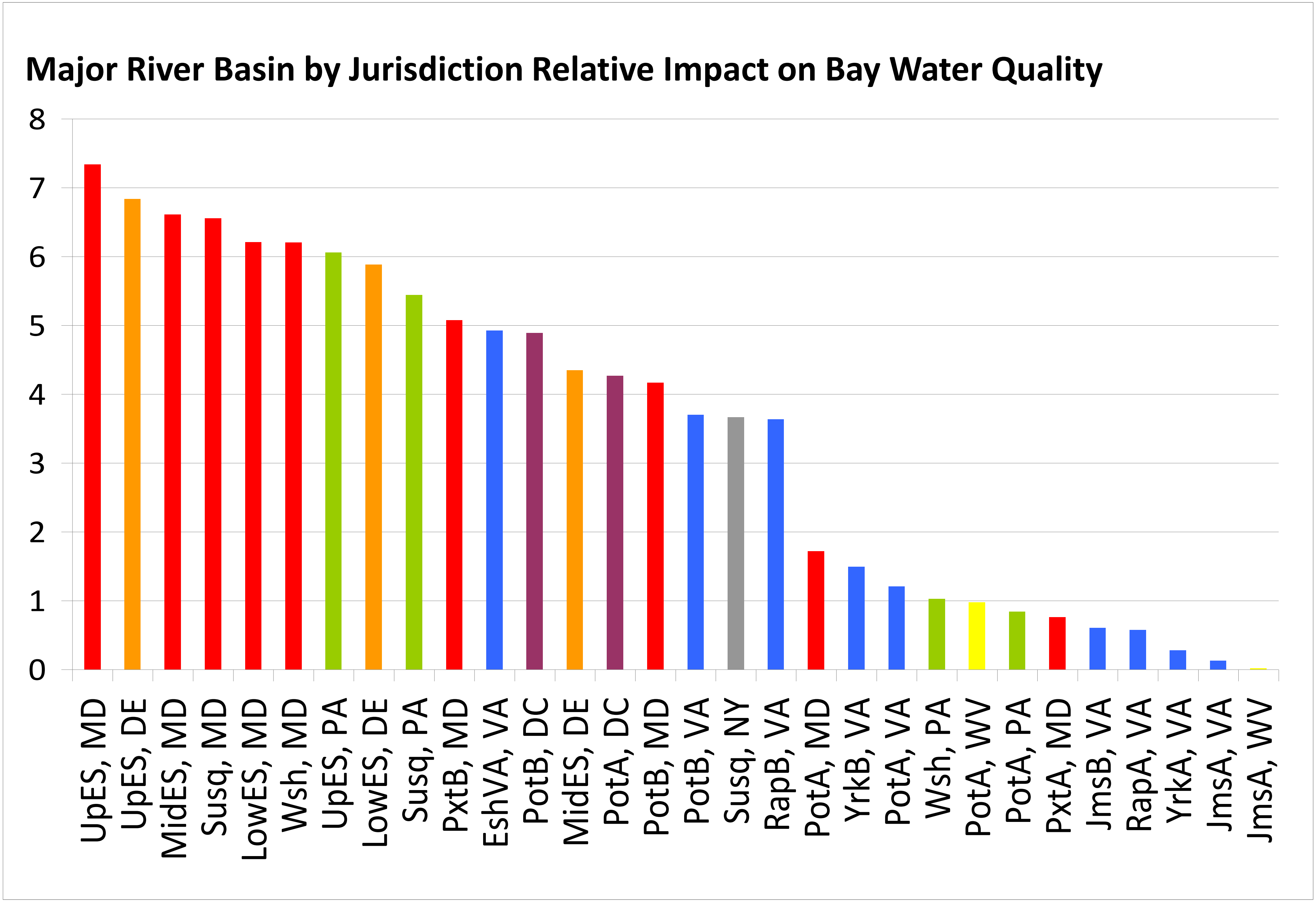
Riverine delivery:
  Pound delivered per pound produced
Estuarine delivery
  Oxygen reduced per pound delivered
Overall Effectiveness
  Oxygen reduced per pound produced

Relative Effect of a Pound of Pollution on Bay Water Quality





Phase 5 values



Major River Basin by Jurisdiction Relative Impact on Bay Water Quality
8
7
6
5
4
3
2
1
0
UpES, MD
UpES, DE
MidES, MD
Susq, MD
LowES, MD
Wsh, MD
UpES, PA
LowES, DE
Susq, PA
PxtB, MD
EshVA, VA
PotB, DC
MidES, DE
PotA, DC
PotB, MD
PotB, VA
Susq, NY
RapB, VA
PotA, MD
YrkB, VA
PotA, VA
Wsh, PA
PotA, WV
PotA, PA
PxtA, MD
JmsB, VA
RapA, VA
YrkA, VA
JmsA, VA
JmsA, WV

Guidelines for Allocations

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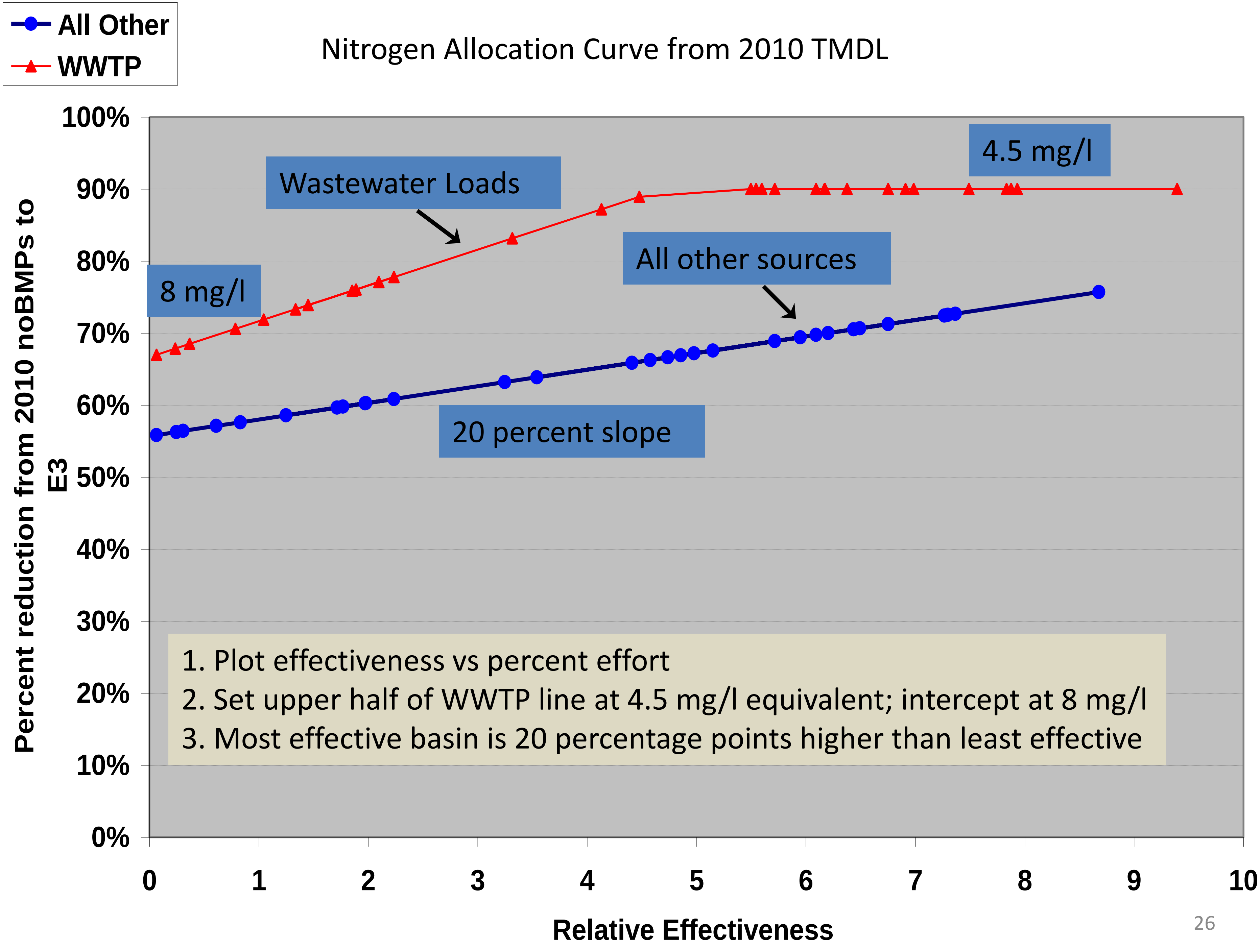
- All tracked and reported reductions in nutrient loads are credited toward achieving final assigned loads.

- Allocated N and P loads must result in attainment of water quality standards

Accounting for Previous Reductions

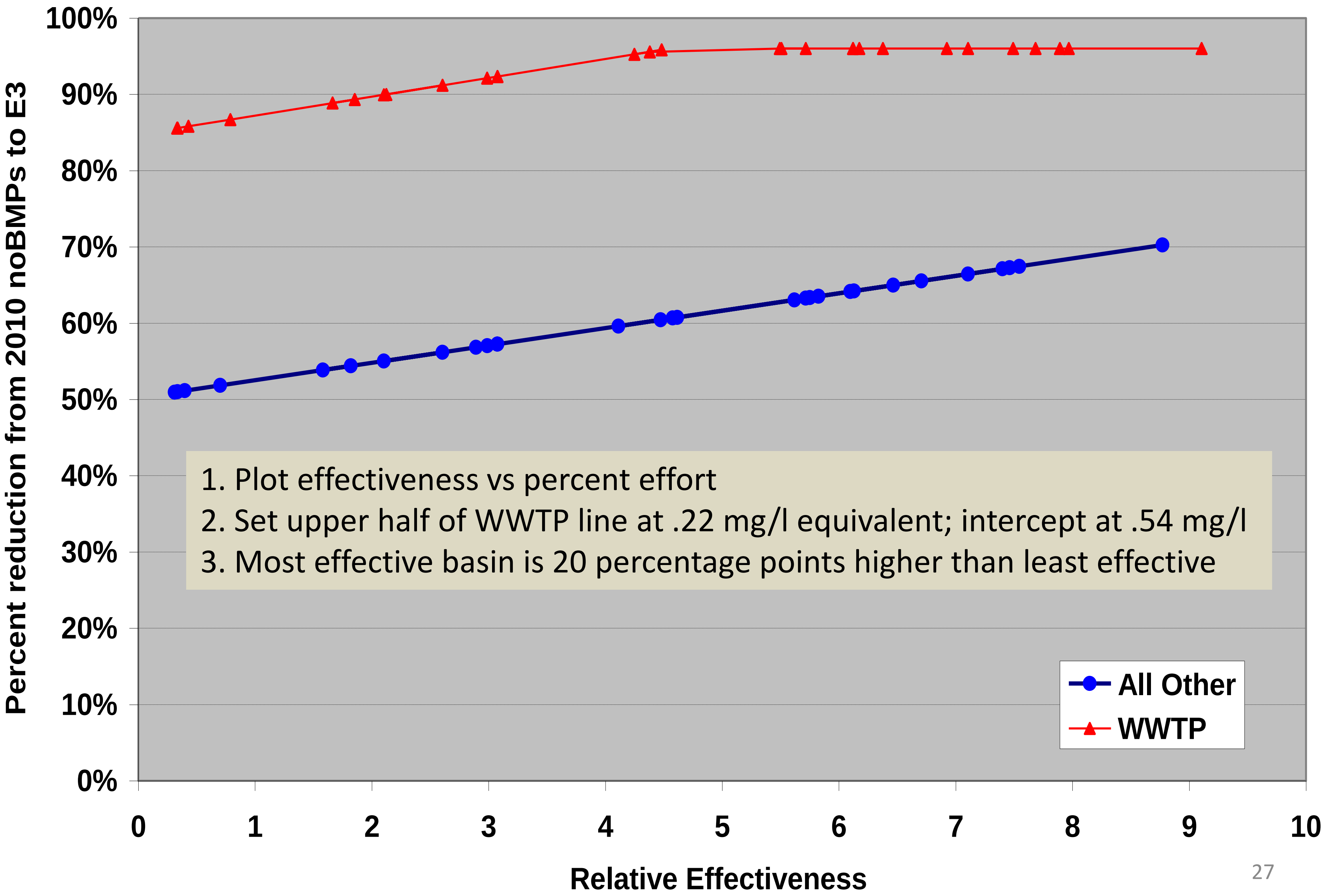
- An allocation method that requires all states to make a similar effort from here on out would disadvantage states that have already done more.

- Require a percentage of the way between:
  – No Action: no BMPs, low level of WWTP
  – Everyone, Everything, Everywhere (E3)

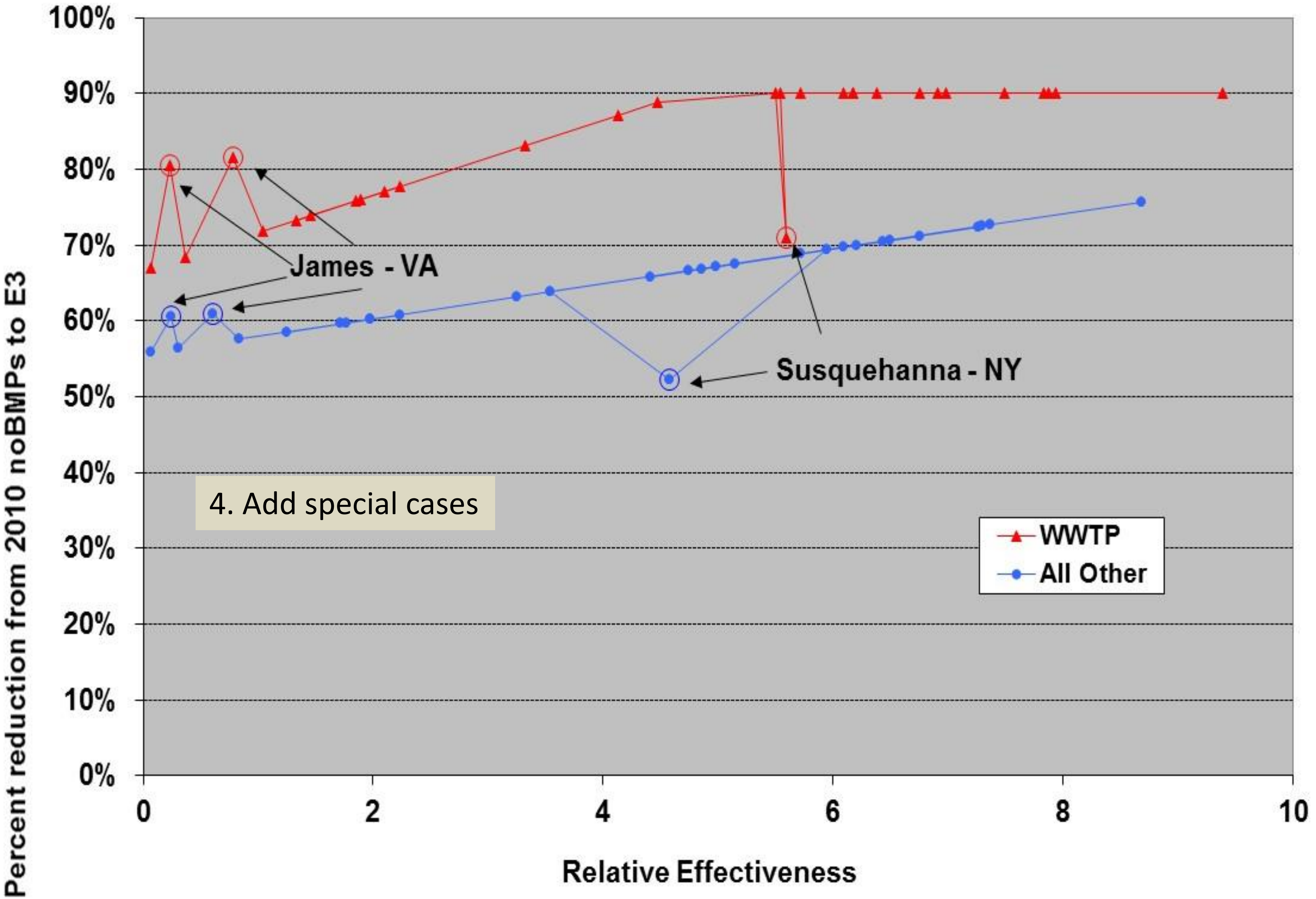


All Other
WWTP
Nitrogen Allocation Curve from 2010 TMDL
Wastewater Loads
4.5 mg/l
8 mg/l
All other sources
20 percent slope
1. Plot effectiveness vs percent effort
2. Set upper half of WWTP line at 4.5 mg/l equivalent; intercept at 8 mg/l
3. Most effective basin is 20 percentage points higher than least effective
Percent reduction from 2010 noBMPs to E3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
Relative Effectiveness

Phosphorus Allocation Curve from 2010 TMDL

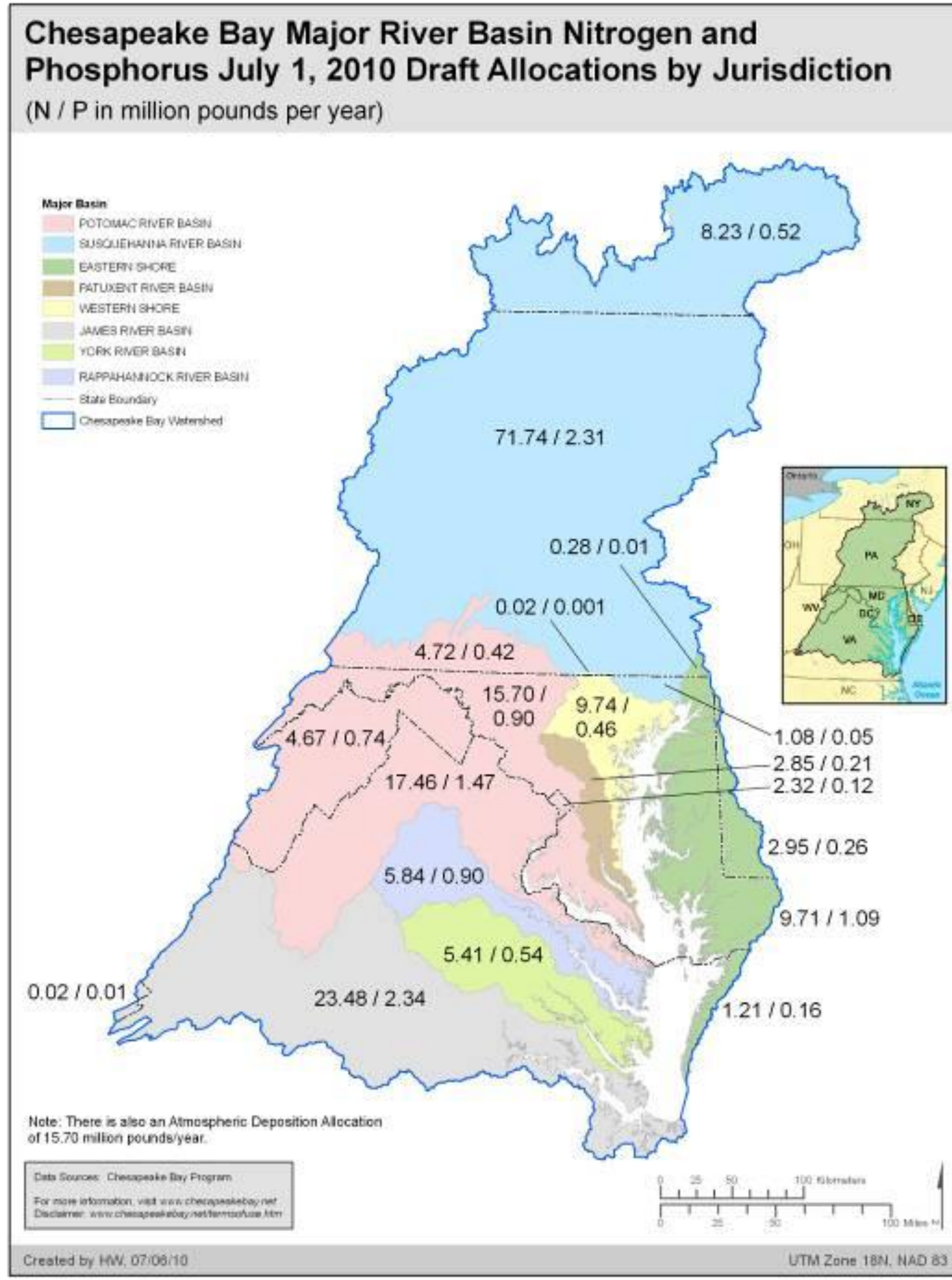


Nitrogen Allocation Curve from 2010 TMDL



State/basin allocations (N/P (MPY))

Phase I WIPs developed to meet these numbers

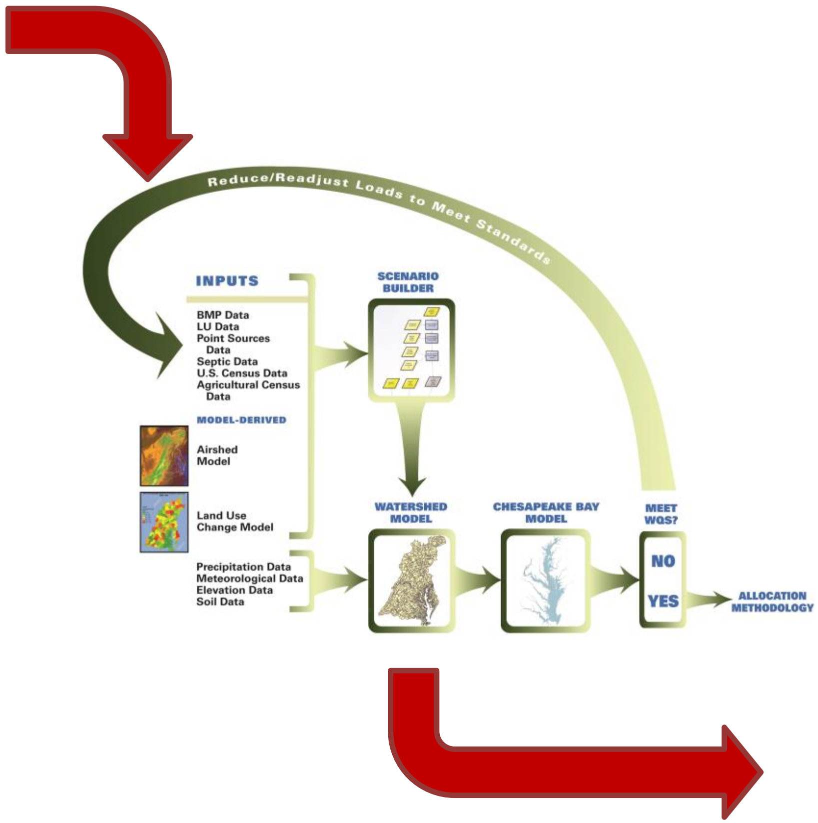


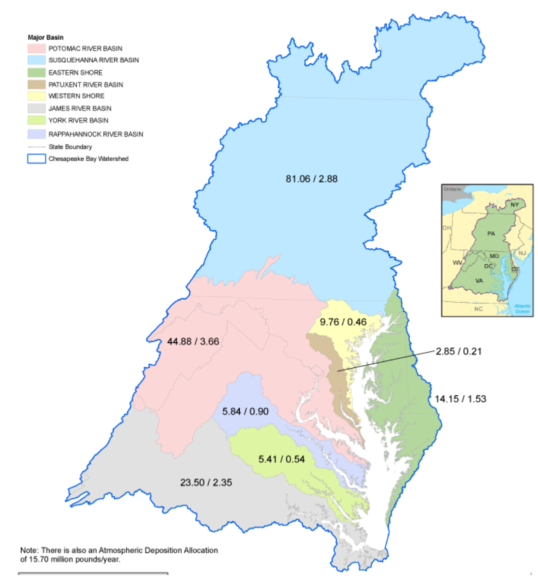
Phase II WIPs - 2011

- 2010 TMDL based on Phase 5.3 watershed model
- Partnership requested changes to Phase 5.3 during 2010
  - Land use
  - Nutrient Management
- Phase I WIPs (plus small adjustments to meet WQS) were run on the Phase 5.3.2 watershed model to generate **planning targets**
  - Consistent with the 2010 TMDL
  - Numbers were different but represented the same level of effort
- Phase II WIPs were developed to meet the planning targets.

Phase III WIPs and Planning Targets

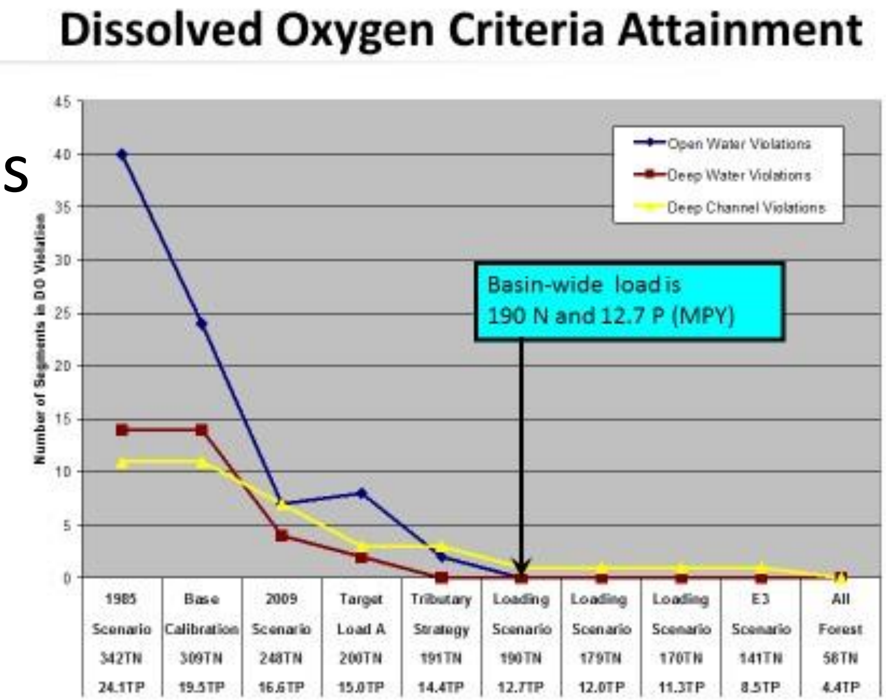
Target Method





Changes

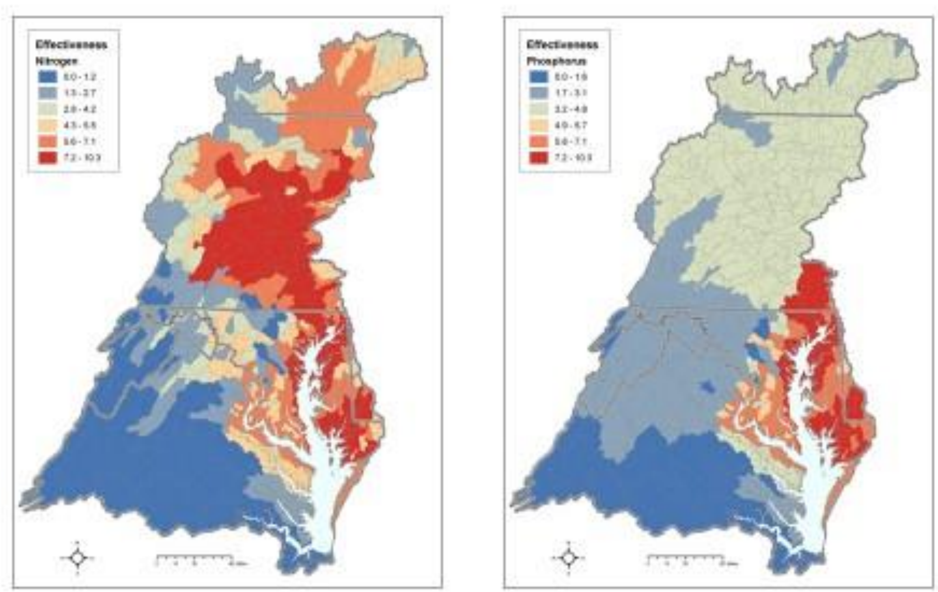
- New Watershed Model Loads
  - New calibration based on improved model
  - Change in seasonality
- New Estuarine Model
  - Biogeochemical changes
  - Wetland and shoreline



Changes

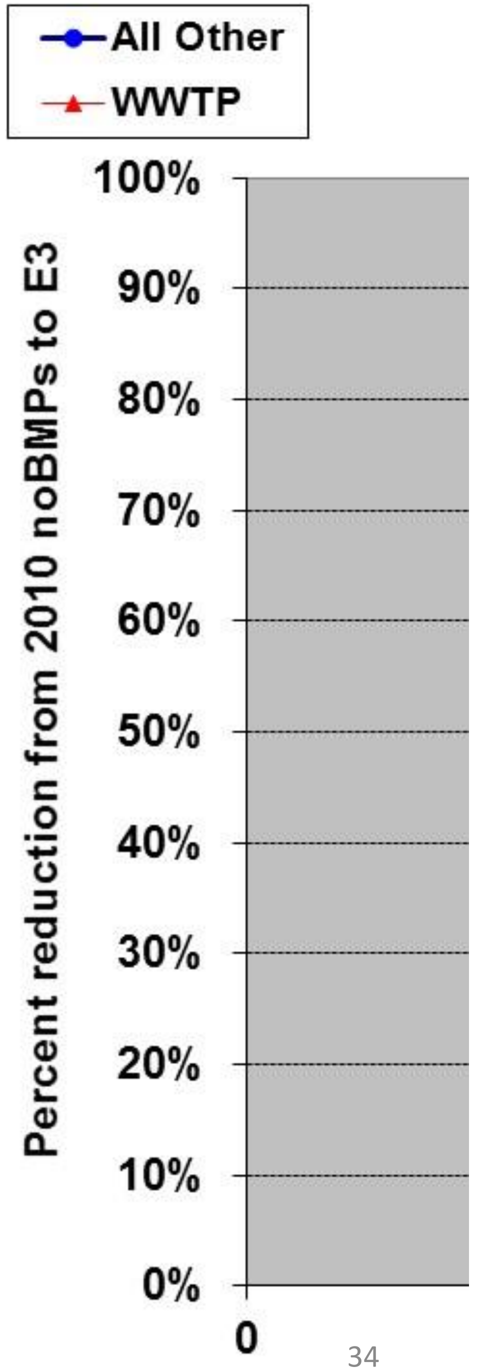
- New Watershed Model
  - Change in delivery factors
- New Estuarine Model
  - Biogeochemical changes

Relative Effect of a Pound of Pollution on Bay Water Quality



Changes

- New Watershed Model
  - Definition of No Action and E3
  - Effectiveness of BMPs
  - Loading rate of land uses



Default Target Method

- Plot effectiveness vs percent effort
- Use 2010 as the base year
- Set upper half of WWTP line at 4.5 mg/l equivalent; intercept at 8 mg/l
- Most effective basin is 20 percentage points higher than least effective for ‘all other’ line
- Special cases
- Hydro Period
- Critical Period

- Conowingo
- Climate Change

Reminder:

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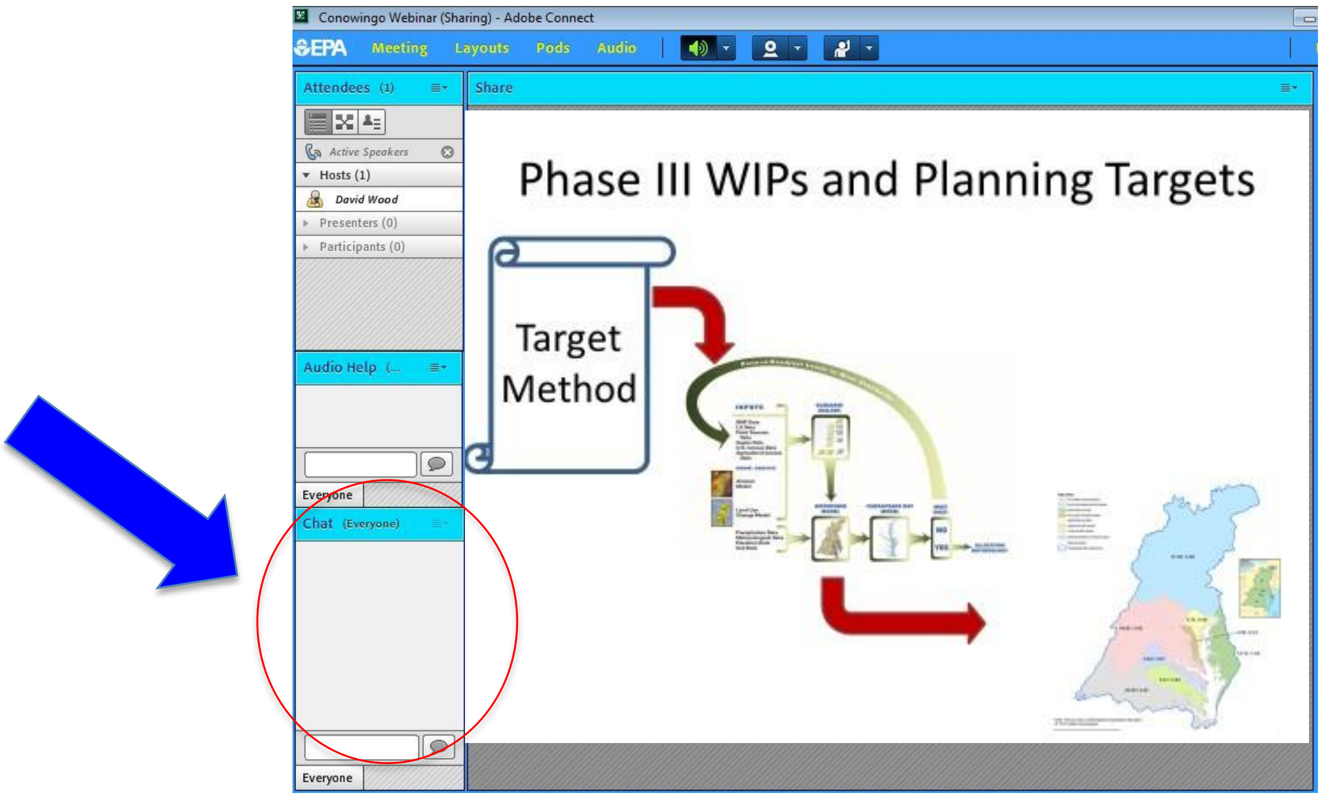
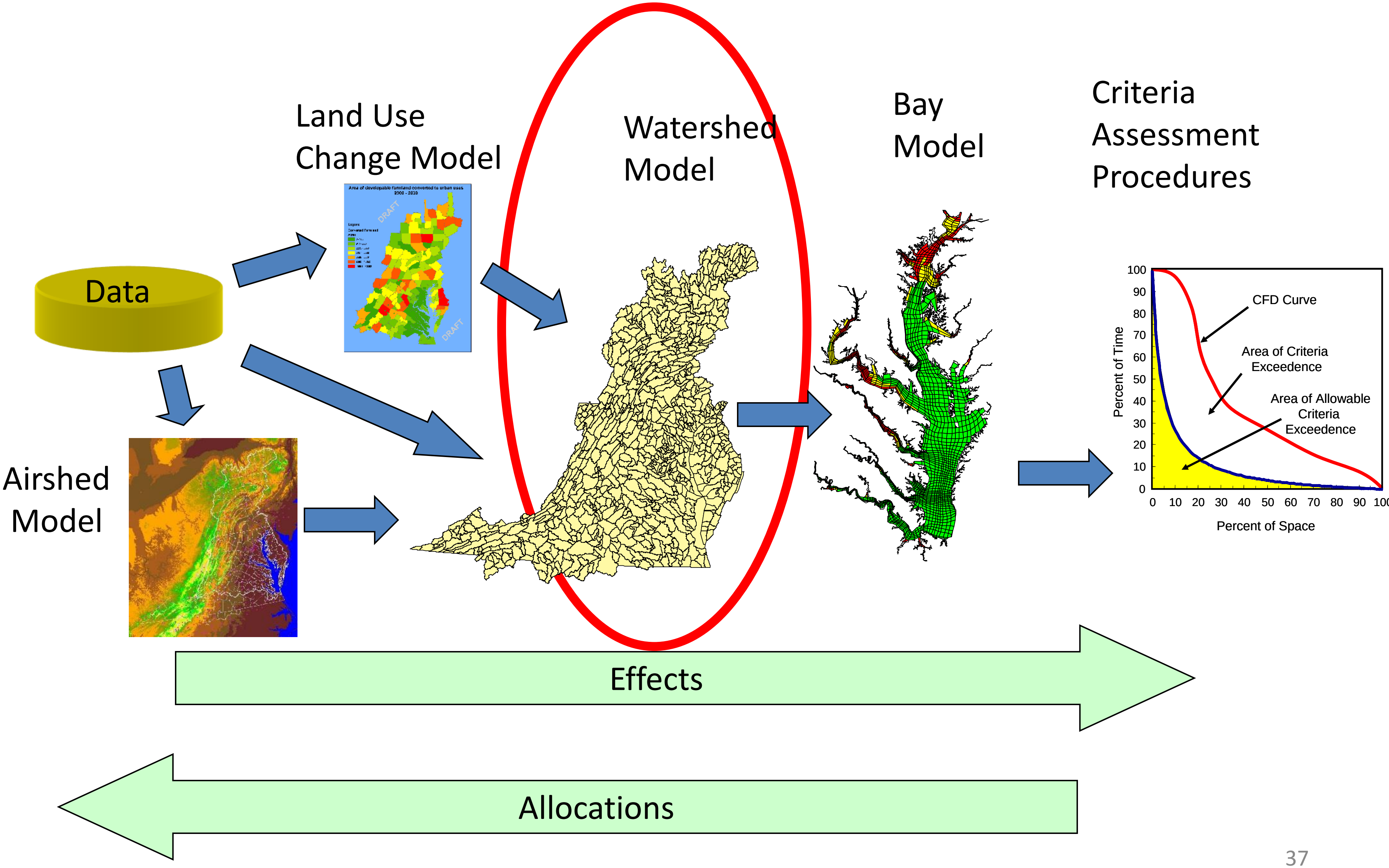


Chesapeake Bay Partnership Models



Partnership Feedback on Modeling

- **Water Quality Managers**
  - Need more **transparent and easier** to understand decision-support tools to enable successful engagement of local partners

- **Scientific and Technical Advisory Committee**
  - Multiple Models
  - Phosphorus
  - Complex Reservoir Dynamics
  - Fine-scale processes

Keep it Simple!!

Include Everything!!!

Main Prediction of the Watershed Model for decision support

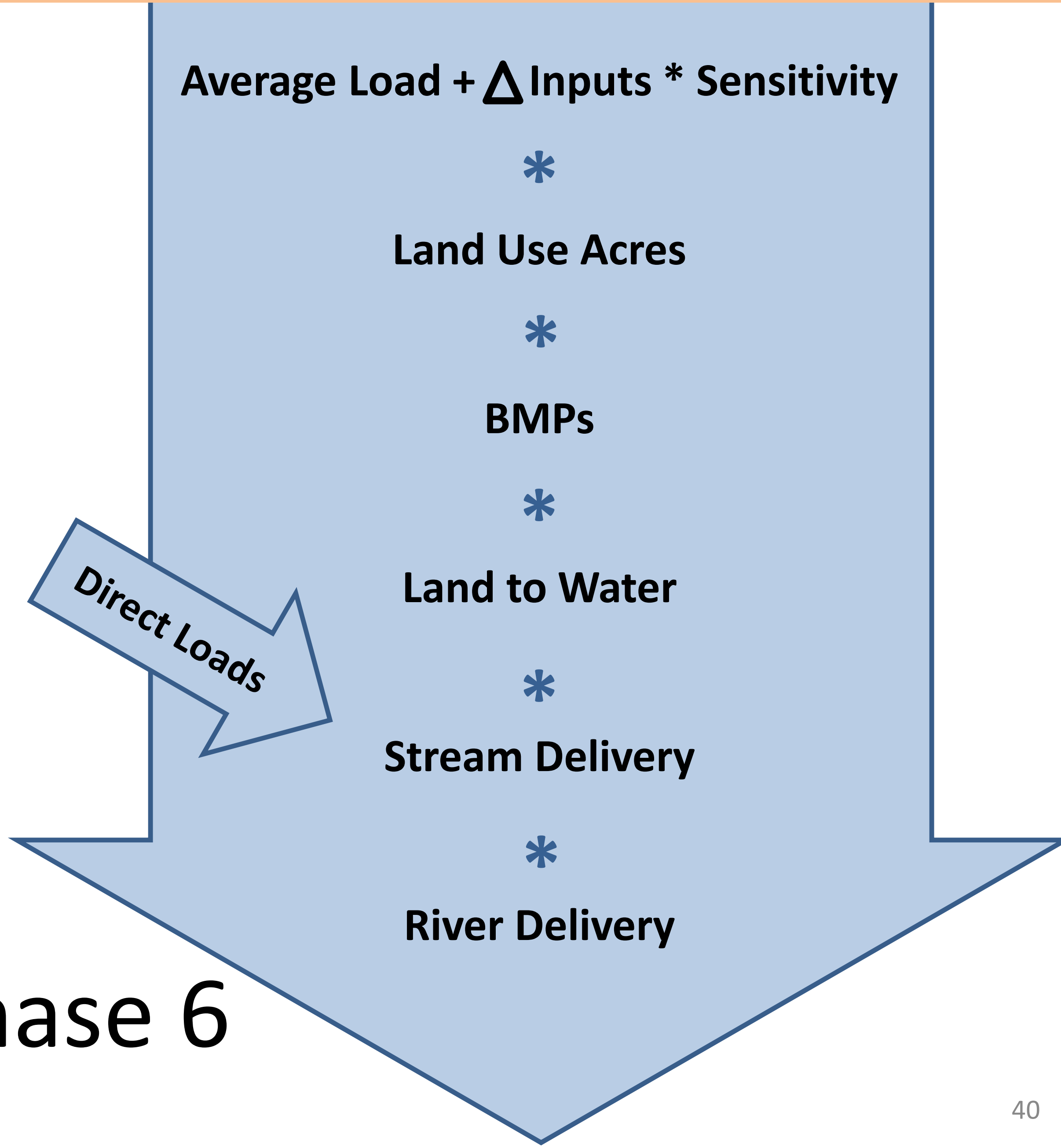
- Change in Anthropogenic Load
  - BMPs
  - WWTP
  - Land use Change
  - Response to Change in inputs

- How to keep it simple and include everything?

Phase 6 Model Structure







Phase 6

Keep It Simple

Average Load + Δ Inputs * Sensitivity

*

Land Use Acres

*

BMPs

*

Land to Water

*

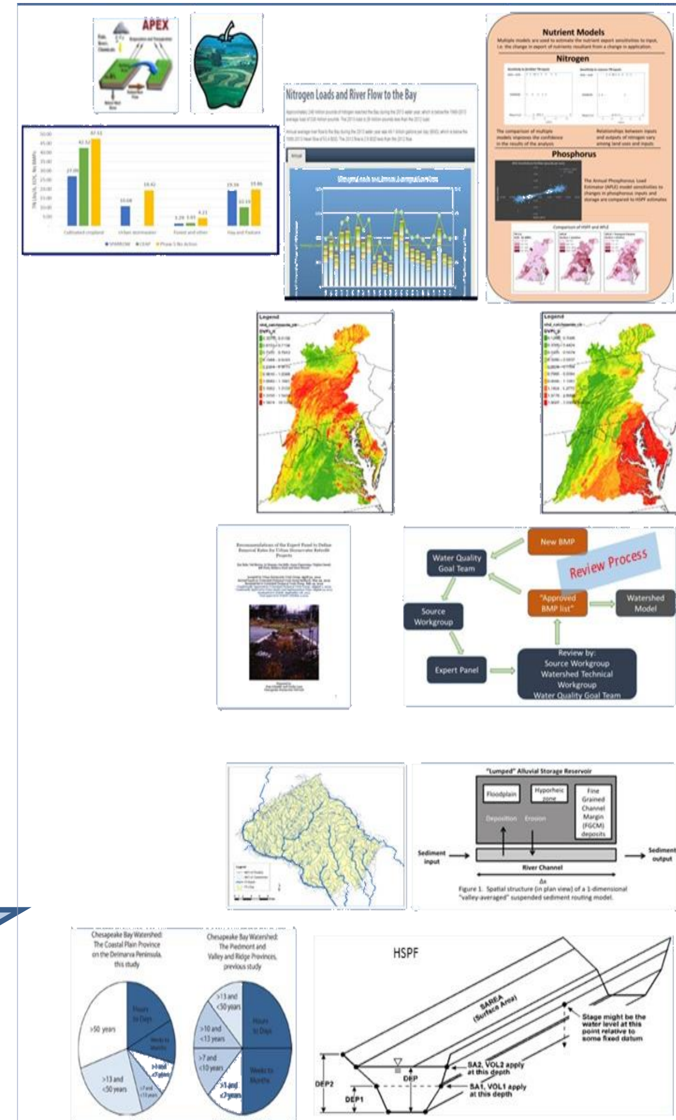
Stream Delivery

*

River Delivery

Direct Loads

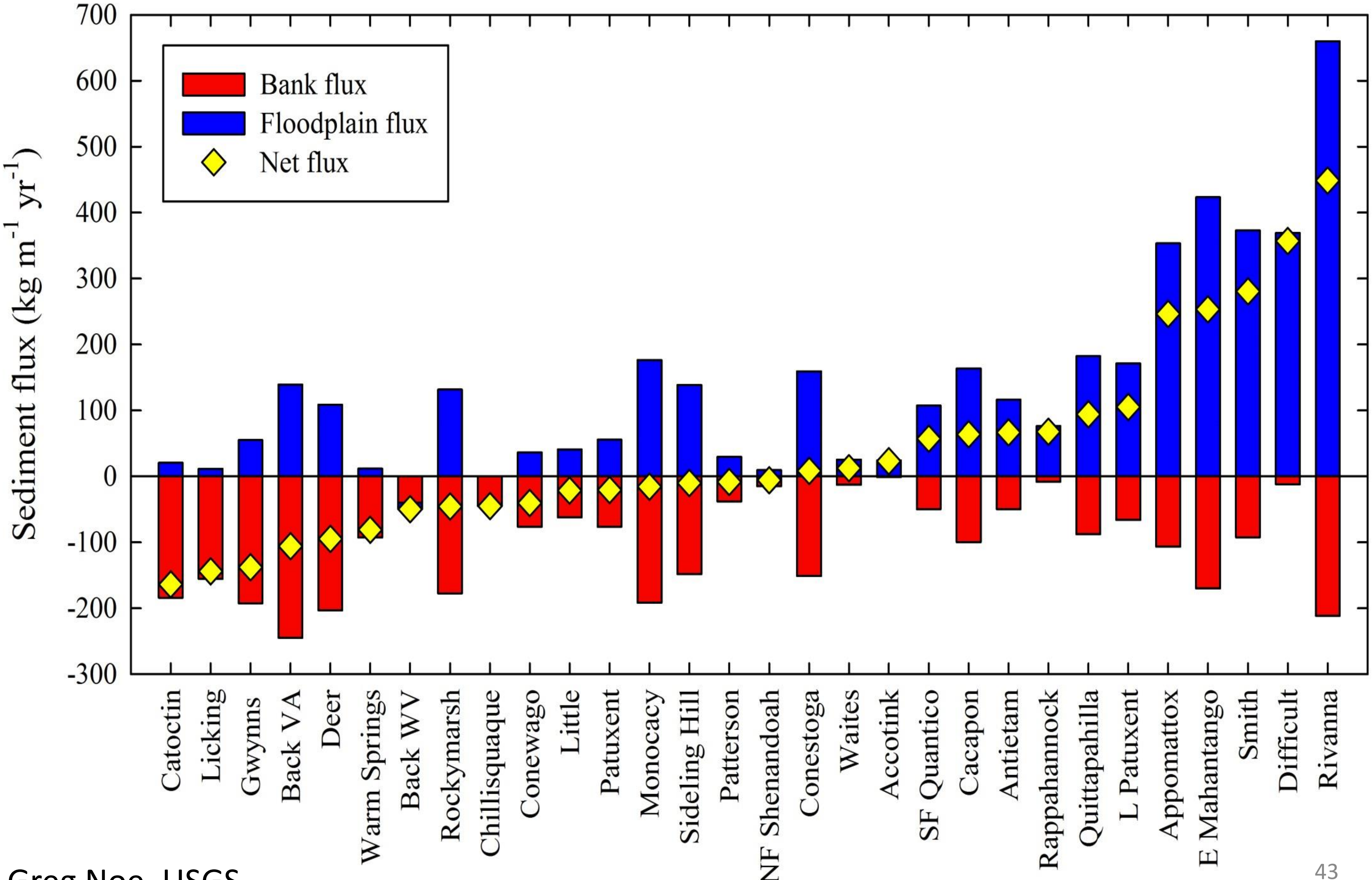
Include Everything



Use of Multiple Models
for Nitrogen Export Rate

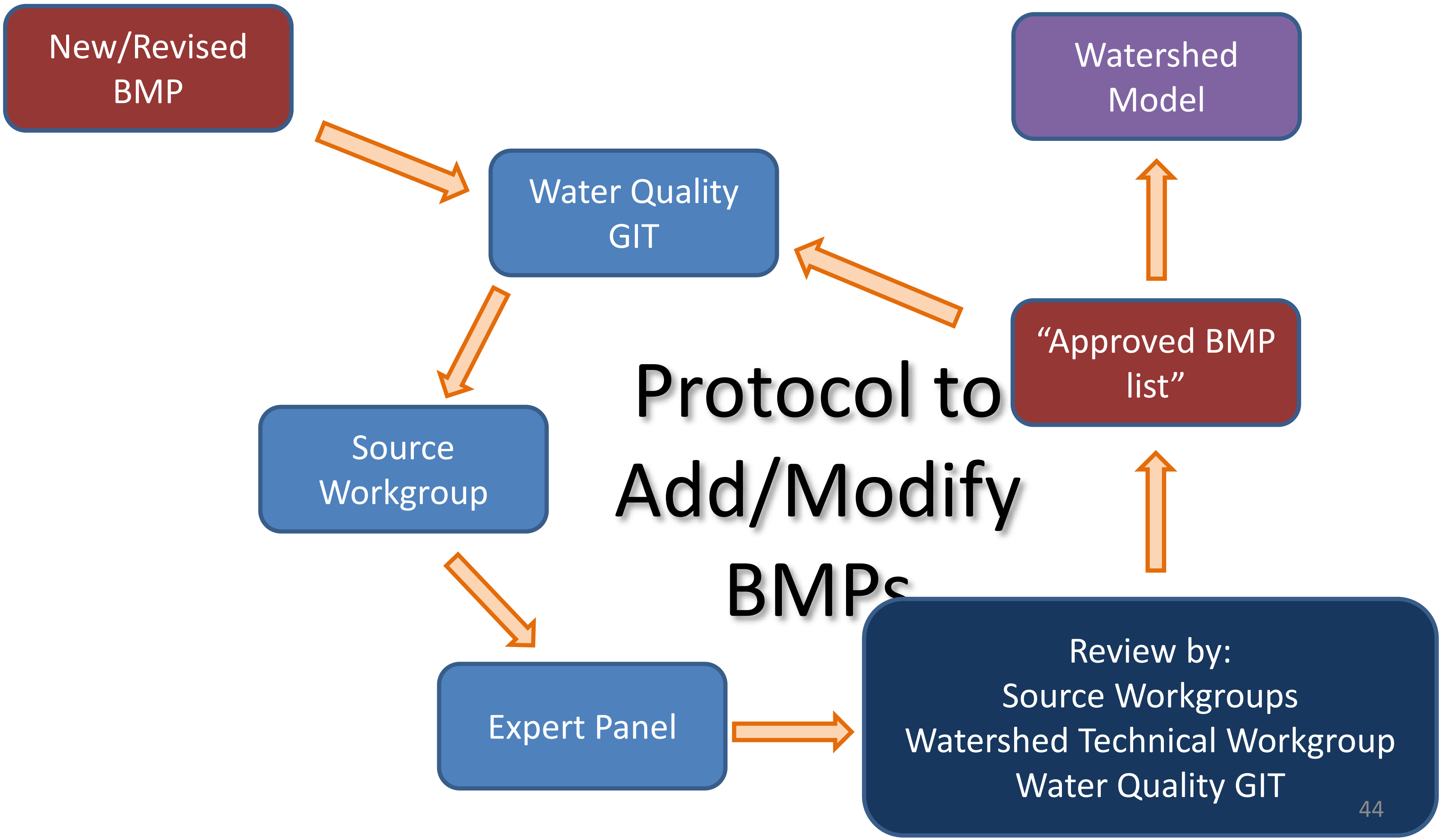
Sector	Crop	Pasture/ Hay	Developed	Natural
CBP Phase 5 model	47.5	19.9	19.4	4.2
USDA-CEAP Model	42.5	10.2	Not used	1.6
USGS- SPARROW Model	22.9	10.2	8.9	0.4
Average Ratio to Crop Rate	1.00	0.37	0.40	0.05

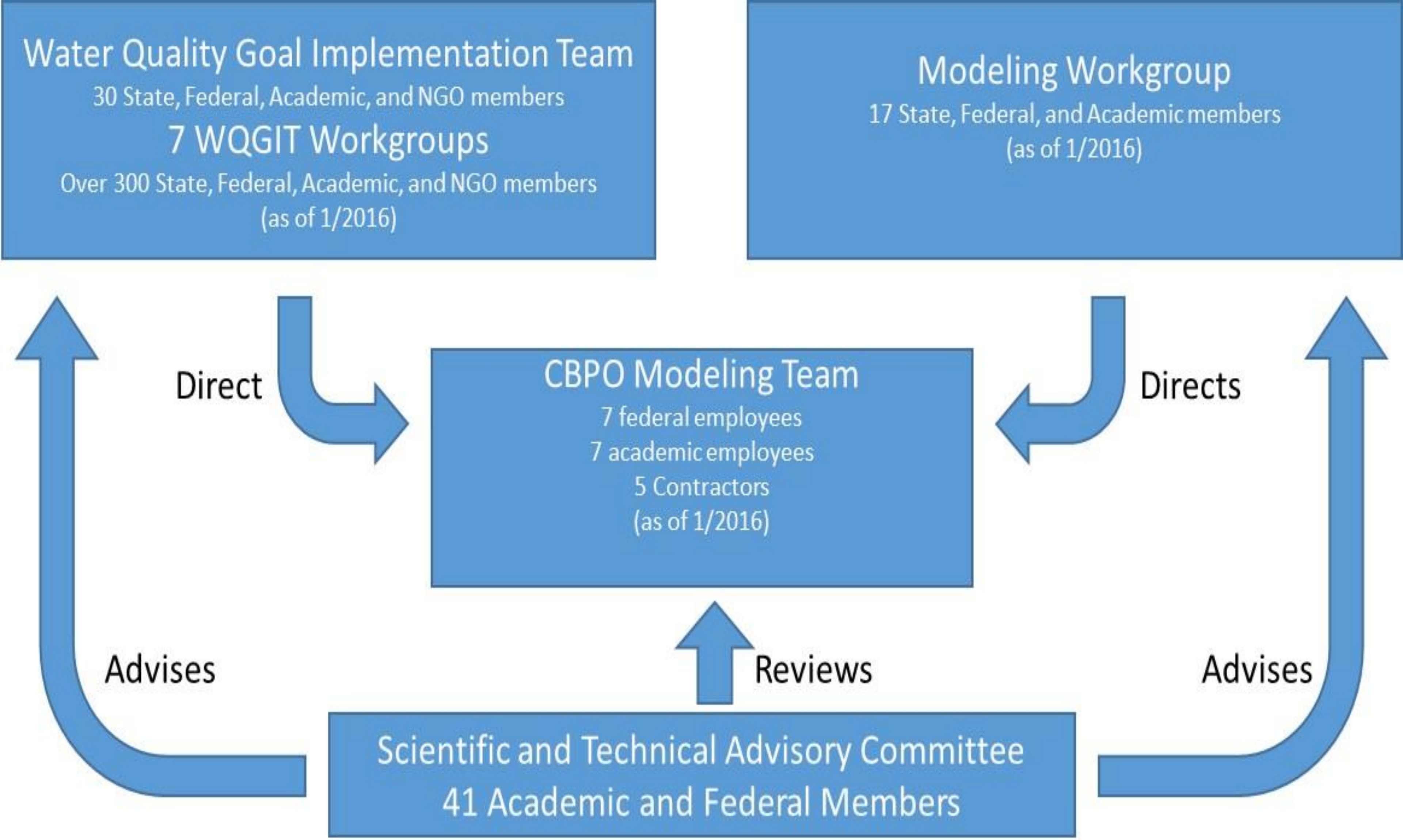
USGS Chesapeake Floodplain Network



Greg Noe, USGS

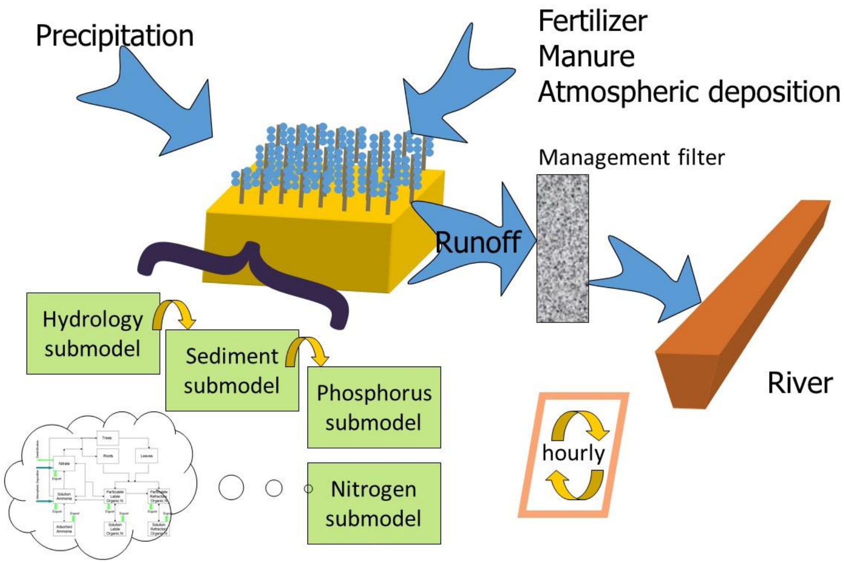
Collaborative Stakeholder Processes




Water Quality Goal Implementation Team
30 State, Federal, Academic, and NGO members
7 WQGIT Workgroups
Over 300 State, Federal, Academic, and NGO members
(as of 1/2016)
Modeling Workgroup
17 State, Federal, and Academic members
(as of 1/2016)
Direct
Directs
CBPO Modeling Team
7 federal employees
7 academic employees
5 Contractors
(as of 1/2016)
Advises
Reviews
Advises
Scientific and Technical Advisory Committee
41 Academic and Federal Members

Phase 5 CAST

Watershed Model



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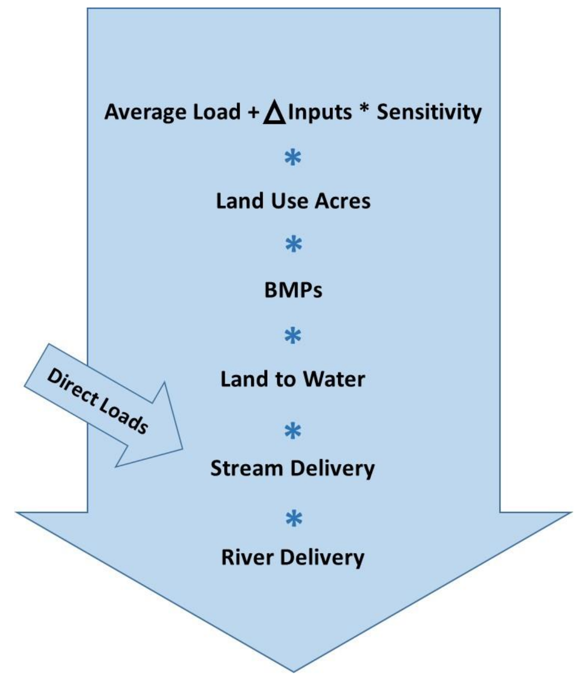
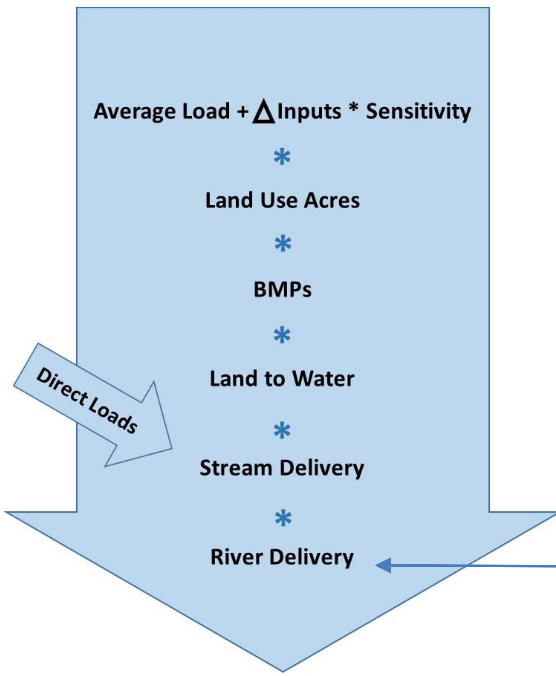
CAST

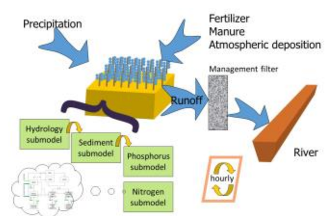


Phase 6 CAST

CAST = Watershed Model



Temporal Watershed Model



Phase 6 Model Documentation

Section 1: Overview

Section 2: Ave Load + Section 3: Inputs * Section 4: Sensitivity

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Section 5: Land Use

*

Section 6: BMPs

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Section 7: Land to Water

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Section 8: Direct Loads

Section 9: Stream Delivery

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Section 10: River Delivery

Section 11: Physical Setting

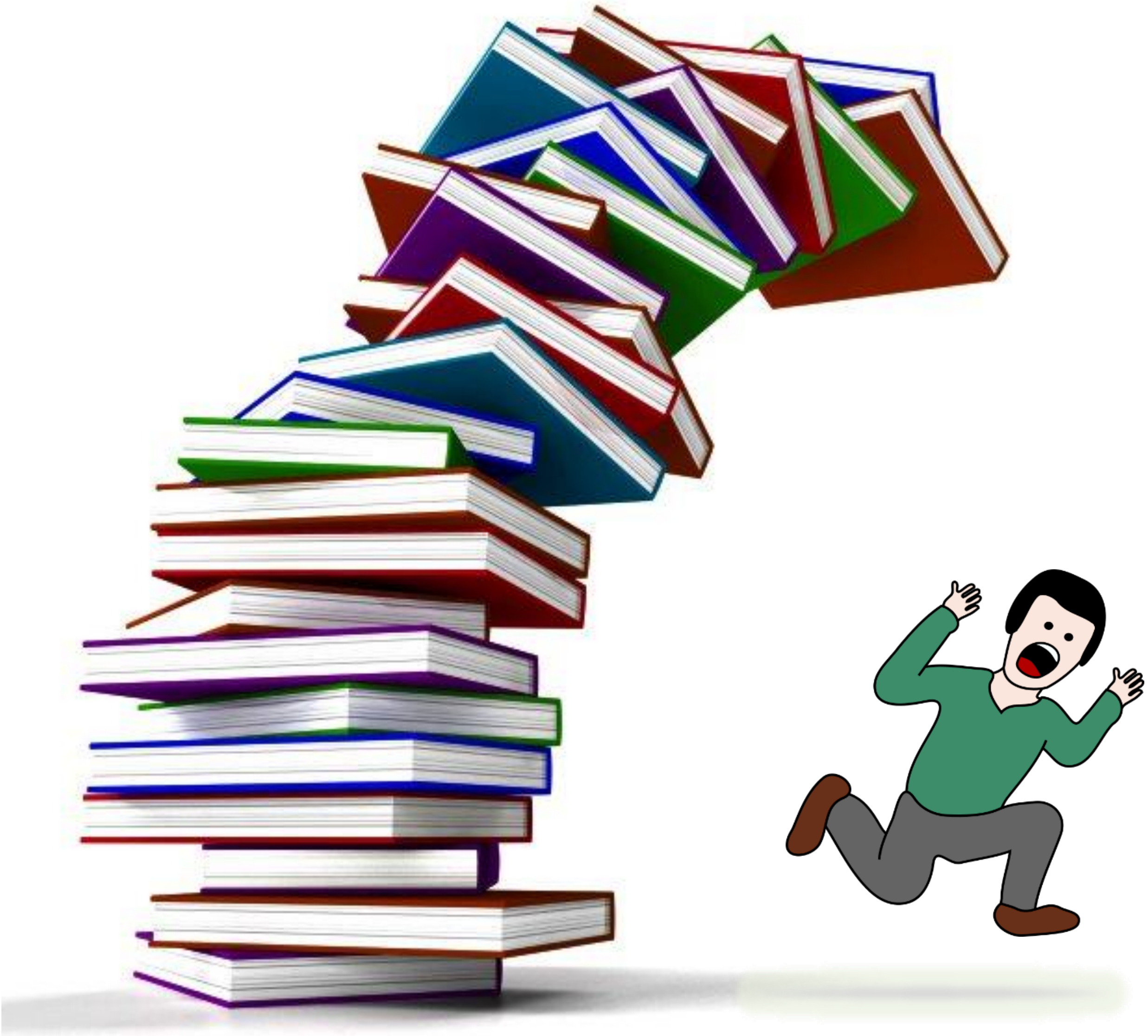
Section 12: Applications

Section 13: Reviews

Section 14: References

Total ~400 pages

Review Strategy



Review Strategy

- Read Chapter 1
- Target Chapters and Sections that are important to you

- Main Prediction of CAST for decision support: Change in Anthropogenic Load
  - BMPs
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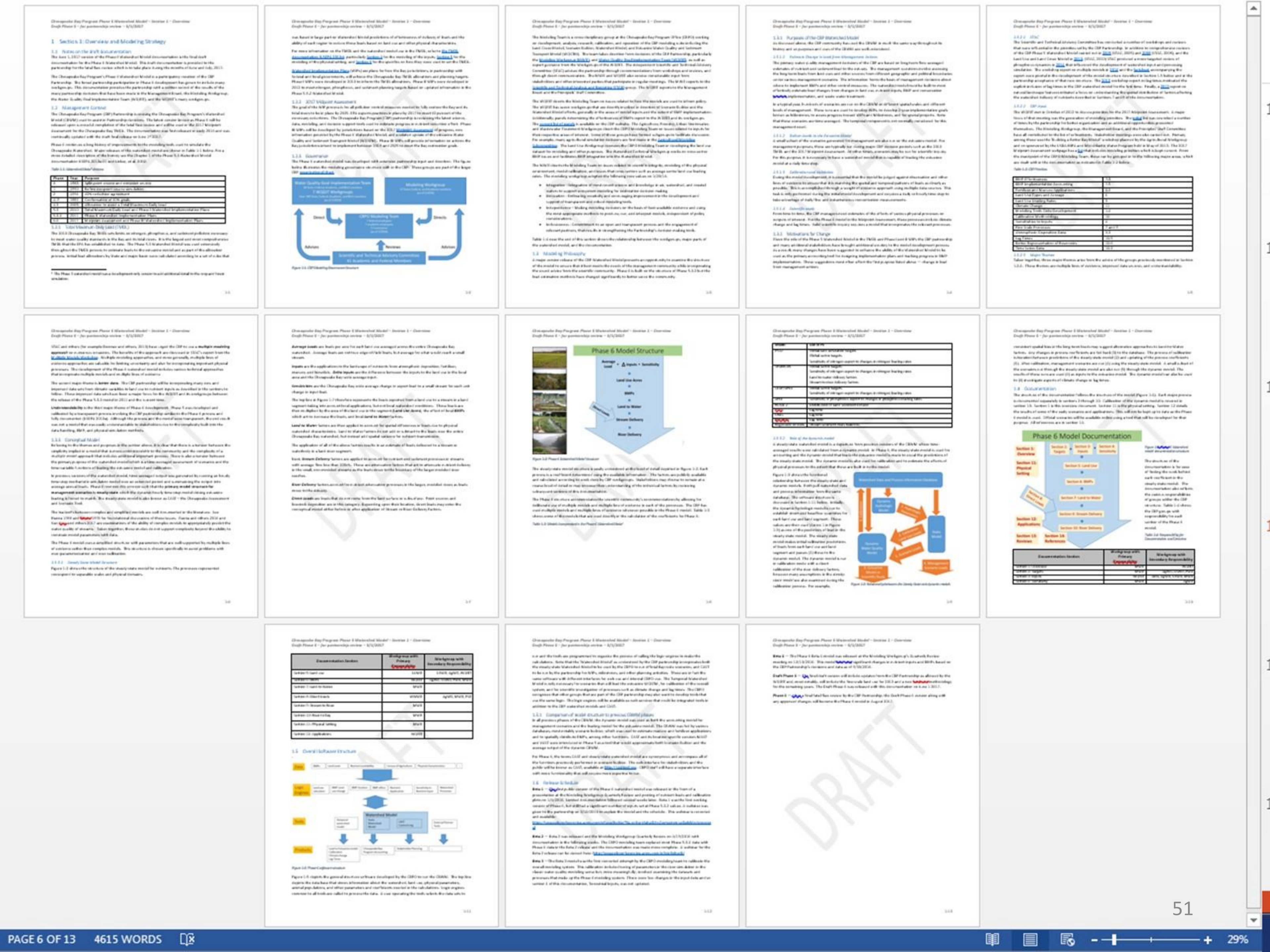
  - Response to Change in inputs


Phase 6 Model Structure
Phase 6 Model Documentation
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PAGE 6 OF 13
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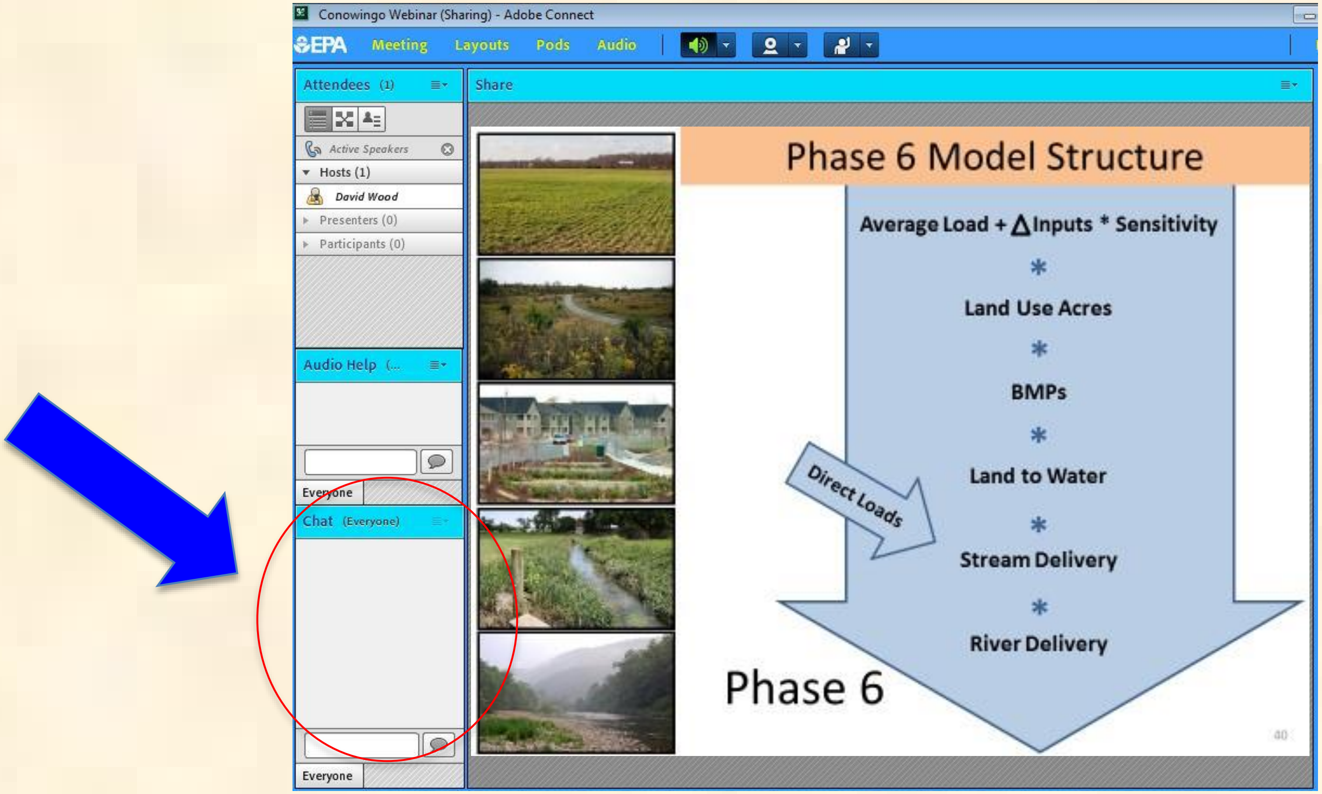
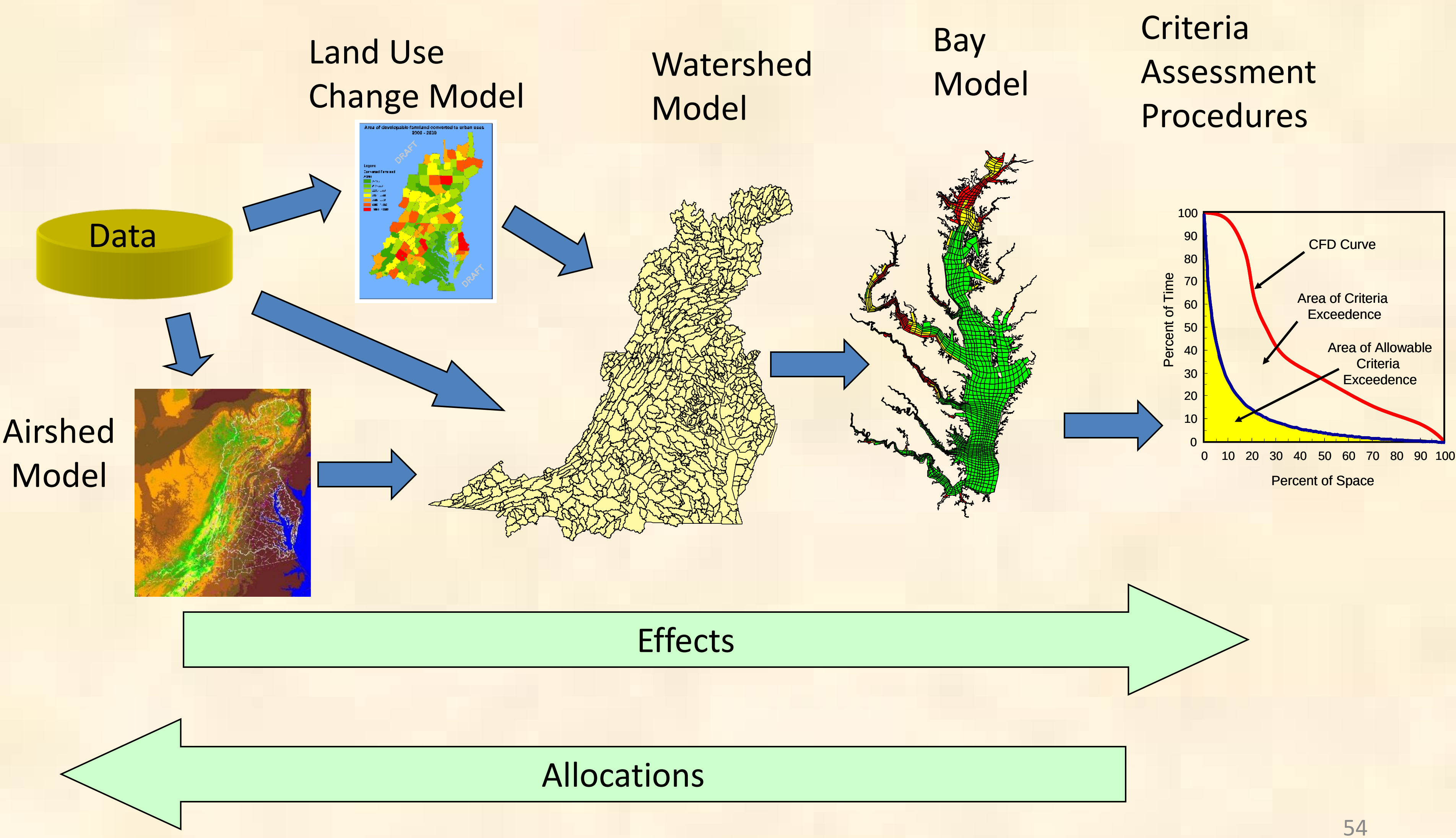
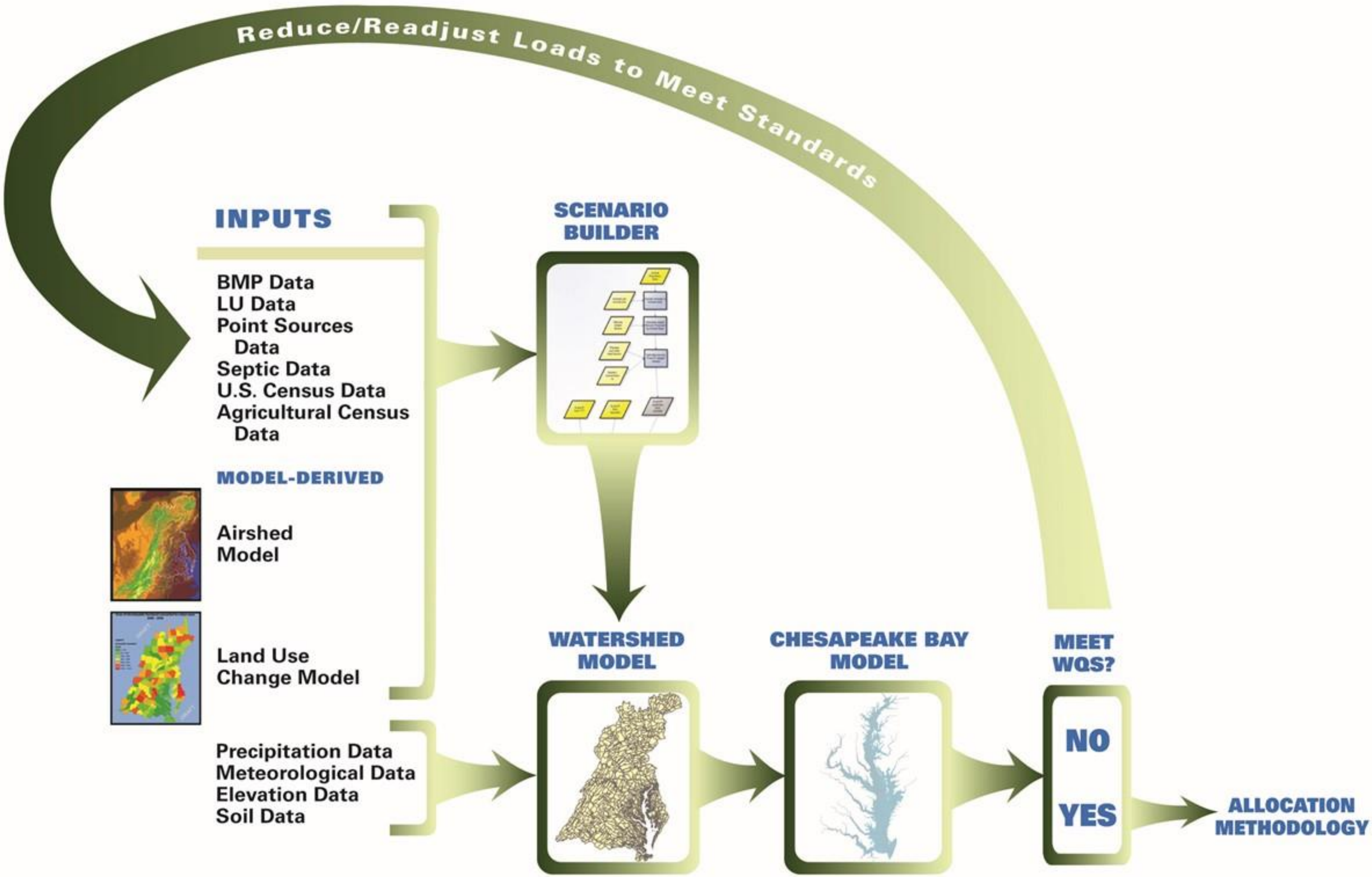


Decision Support System



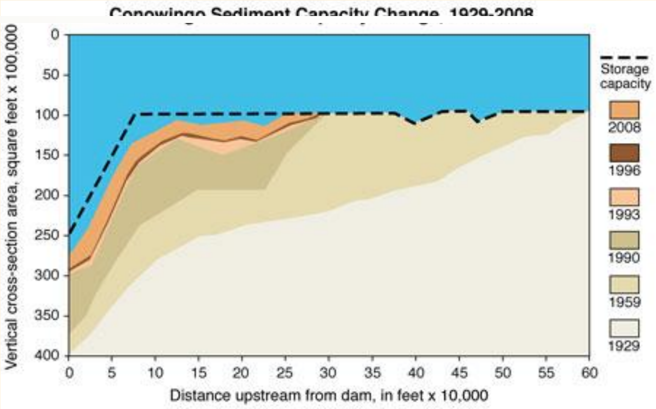
Chesapeake Bay Partnership Models



What has changed in the Phase 6 Watershed and WQSTM to better represent the ‘dynamic equilibrium’ of Conowingo infill?

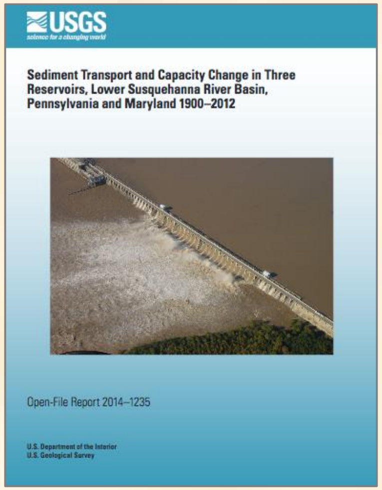
Brief Review of Conowingo Infill

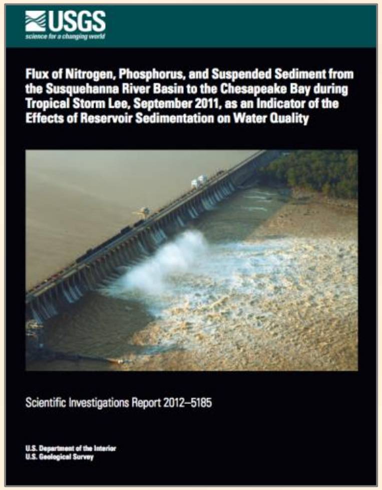
- Conowingo is nearing dynamic equilibrium, which has reduced its ability to trap sediment and nutrients.

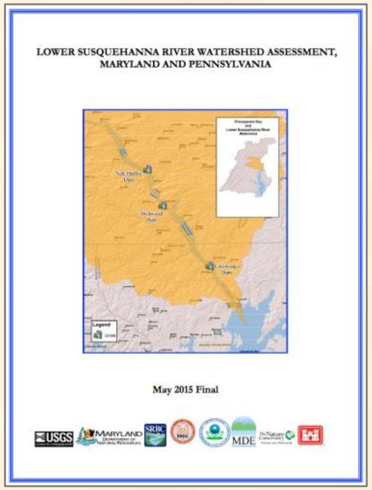


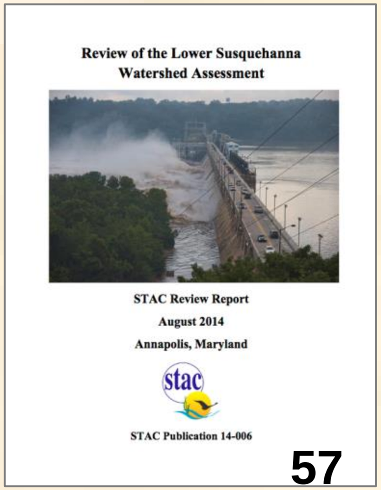
Source: Graph, Michael Langland, U.S. Geological Survey

- Since 2010 multiple research articles have provided an analysis of changes in transport, which are incorporated in this analysis.



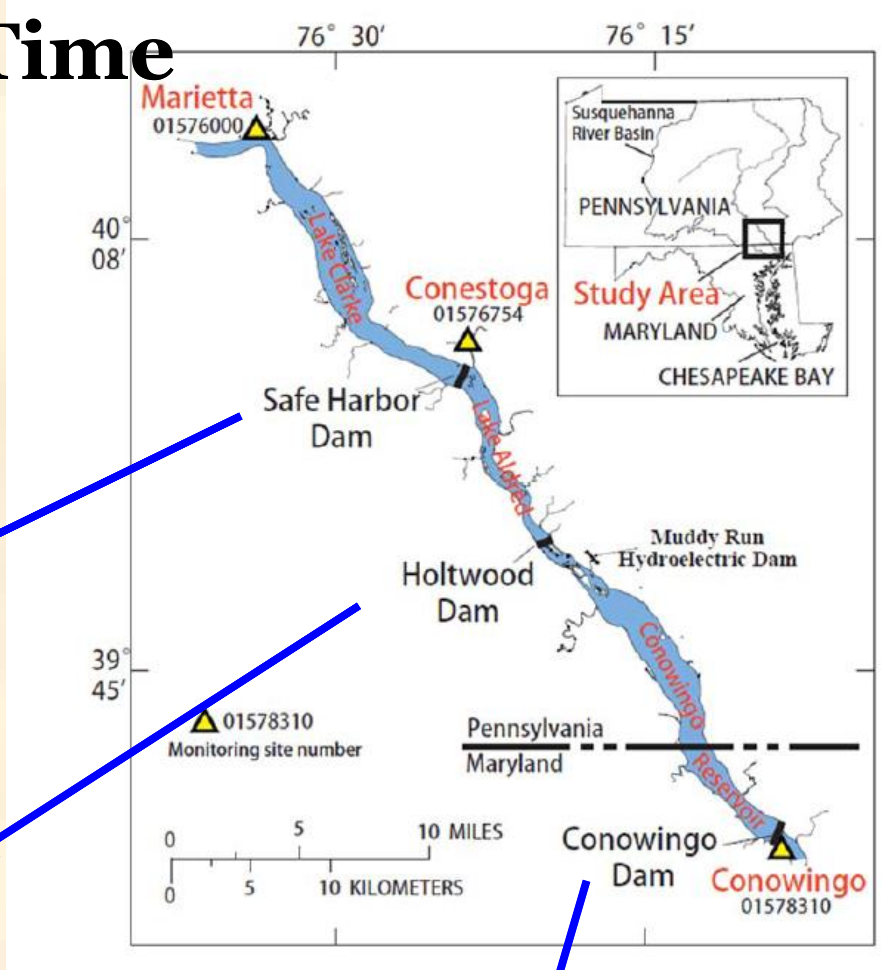


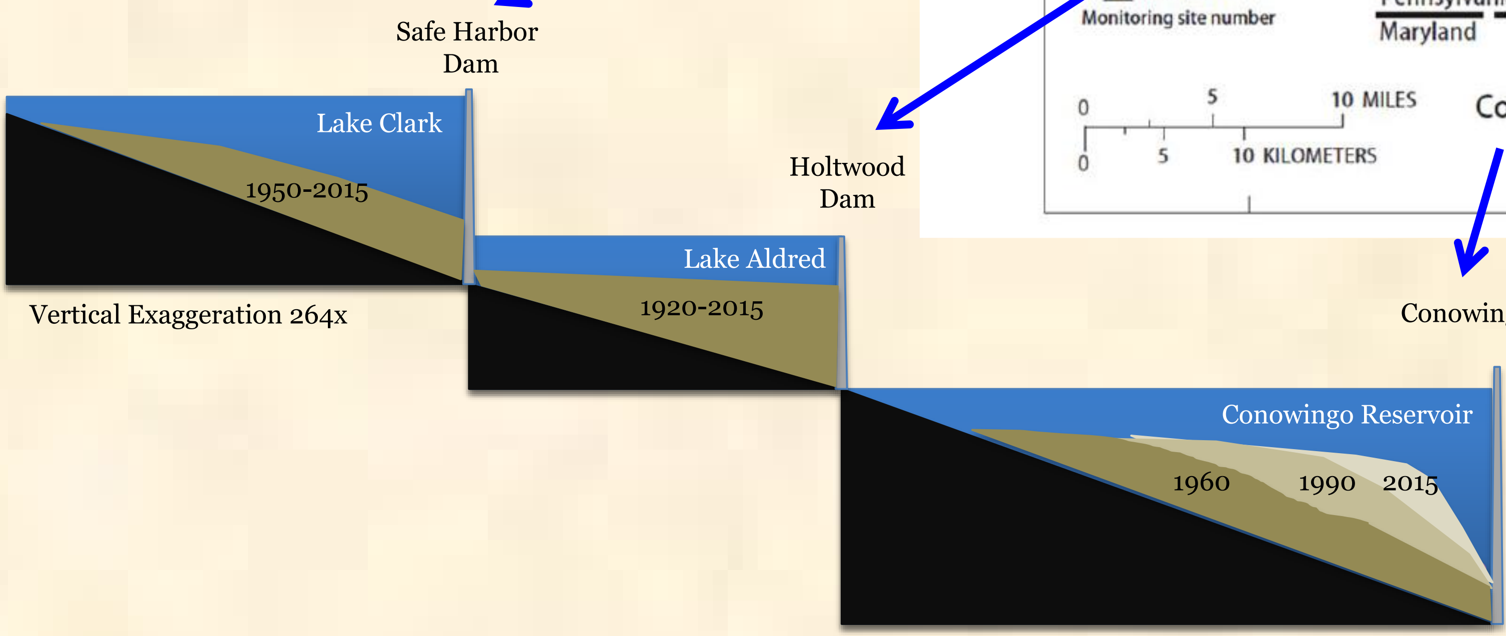




Reservoirs Filling Over Time

The System of Reservoirs has been filling over time, with the upper two reservoirs losing trapping capacity in the 1960s, and Conowingo Reservoir more recently

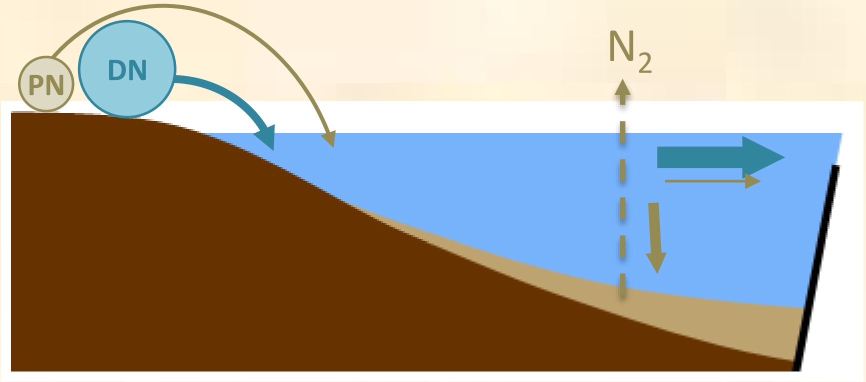




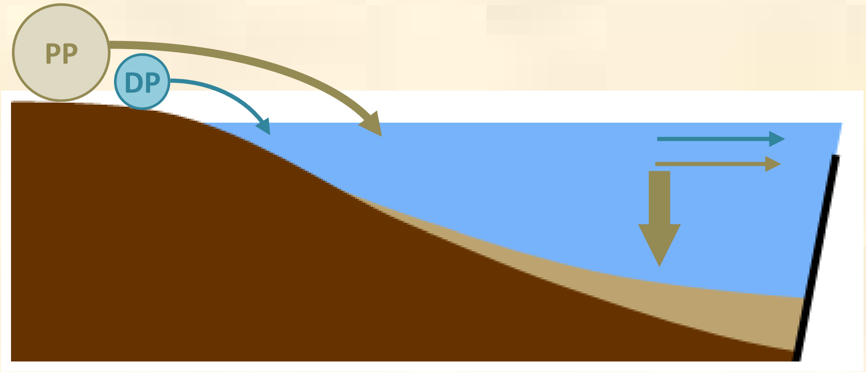
Source: Langland and Blomquist, USGS, personal communication

Differences in Trapping Effectiveness

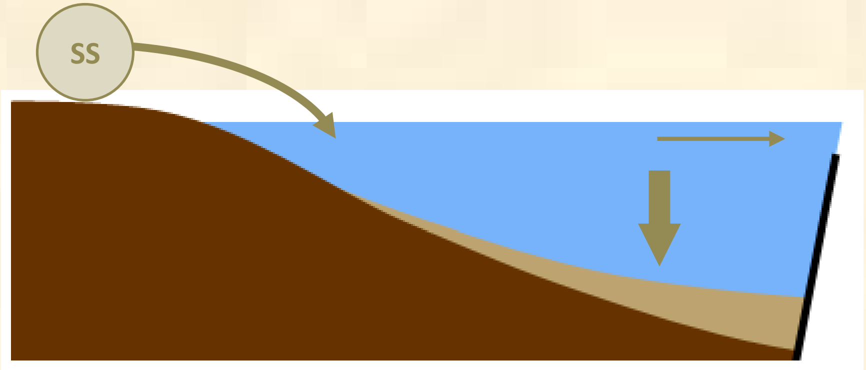
Nitrogen



Phosphorus



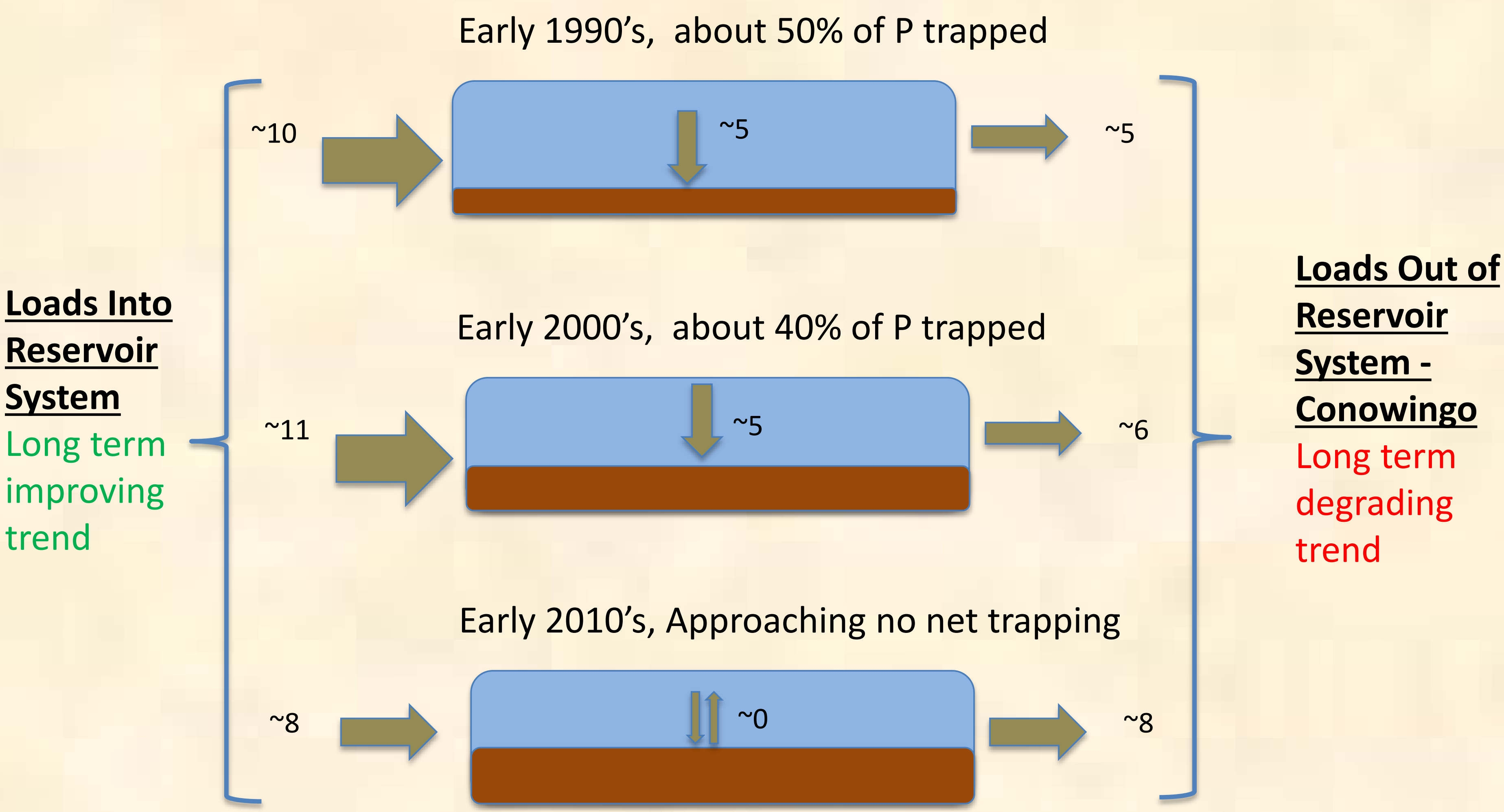
Sediment



Key:	
PN=	Particulate Nitrogen
DN=	Dissolved Nitrogen
PP=	Particulate Phosphorus
DP=	Dissolved Phosphorus
SS=	Suspended Sediment

Source: Currey, MDE, Personal Communication

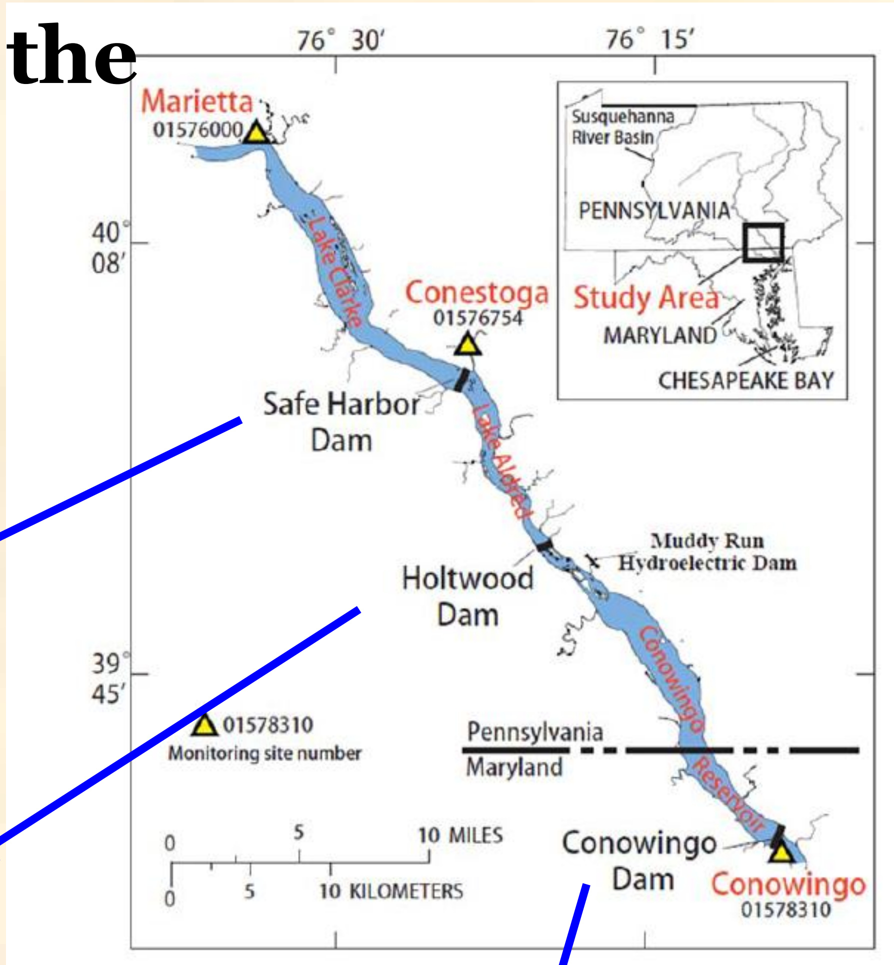
Phosphorus Loads Into, Trapped Within and Exiting the Reservoir System: 1990s-2010s

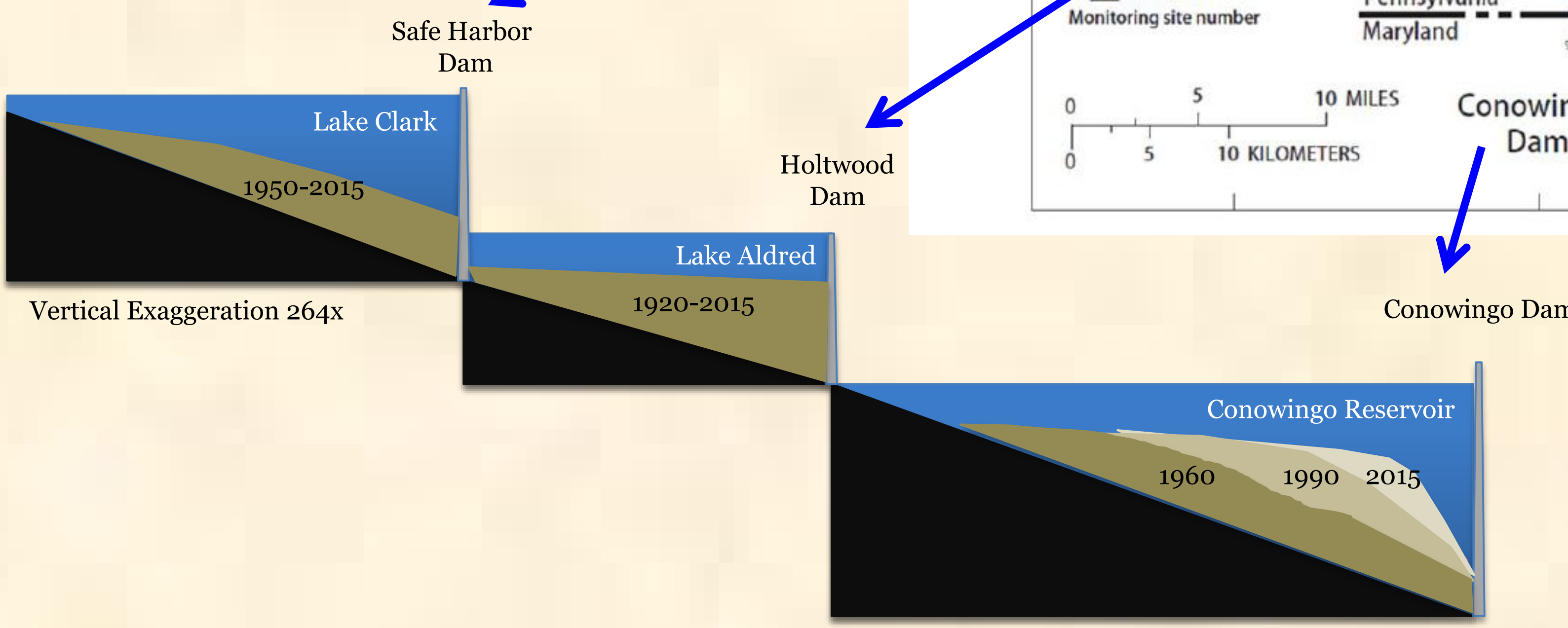


Source: Data from USGS (2016), http://cbrim.er.usgs.gov/loads_query.html
loads are approximate and in units of million lbs/year using estimates for 1992, 2002, and 2012

What has changed with the Phase 6 Model?

The upper two reservoirs behind Safe Harbor and Holtwood dams have been simulated with HEC-RAS giving the CBP, for the first time, detailed sediment load estimates over all flows

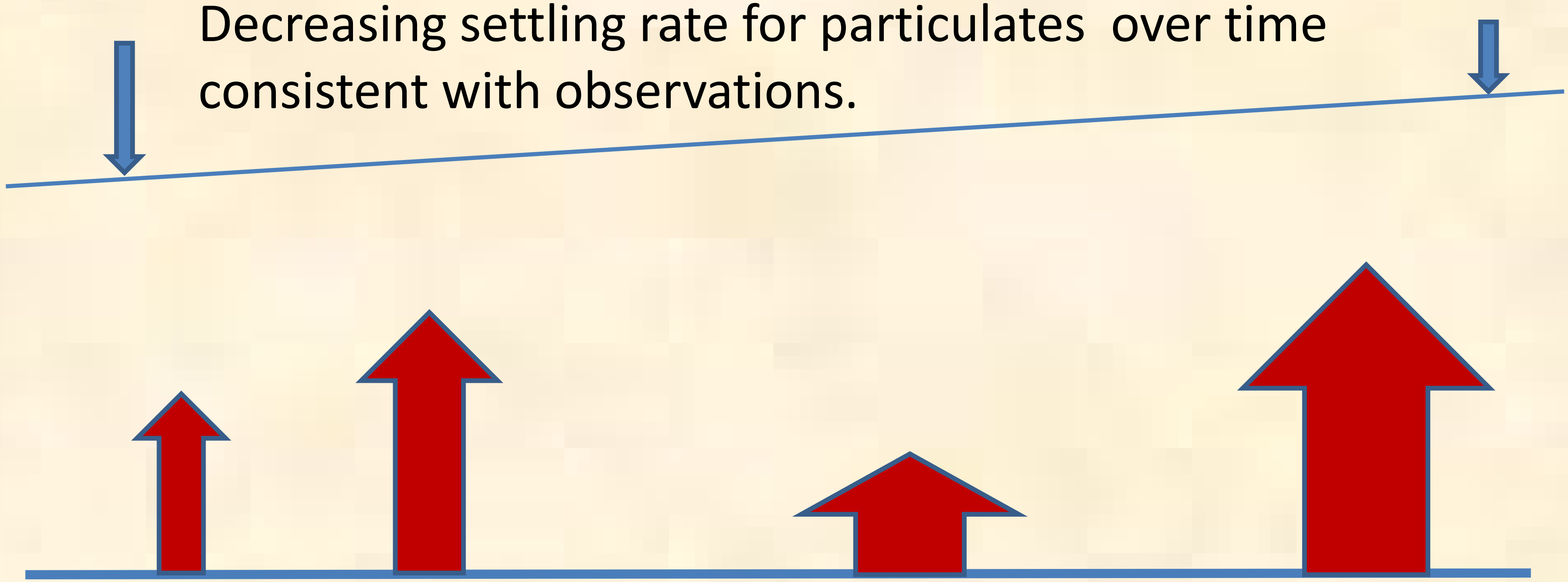




Source: Langland and Blomquist, USGS, personal communication

What has changed in the Phase 6 Model?

Decreasing settling rate for particulates over time consistent with observations.



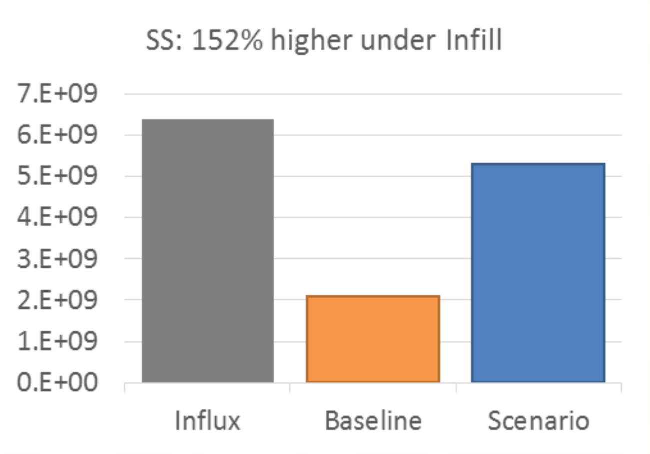
1985

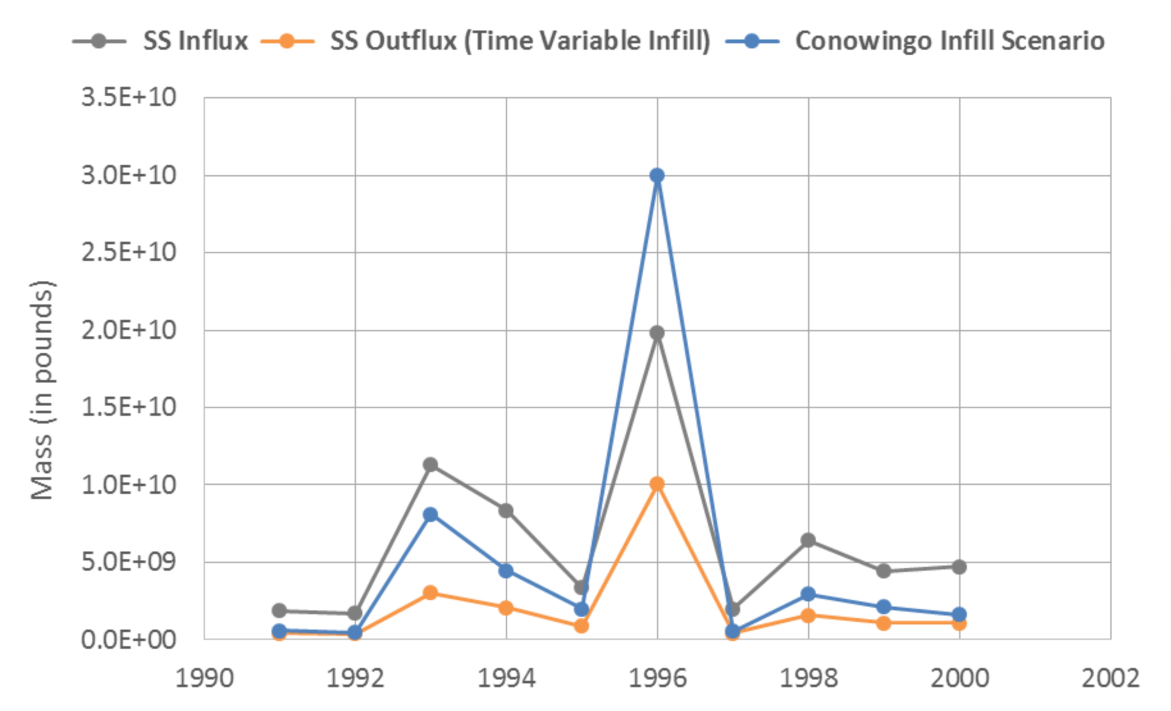
Phase 6 simulation period

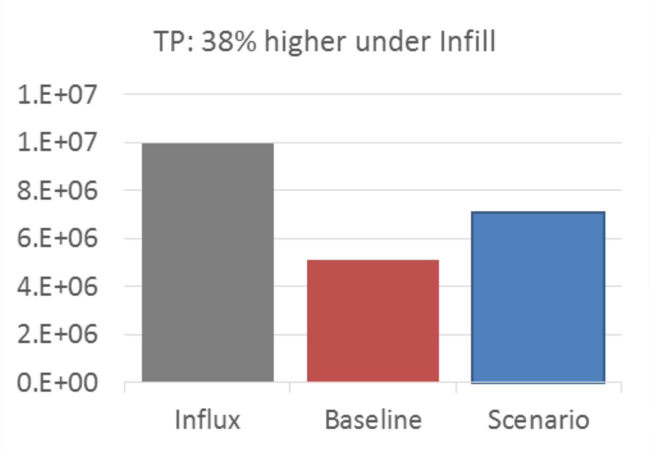
2013

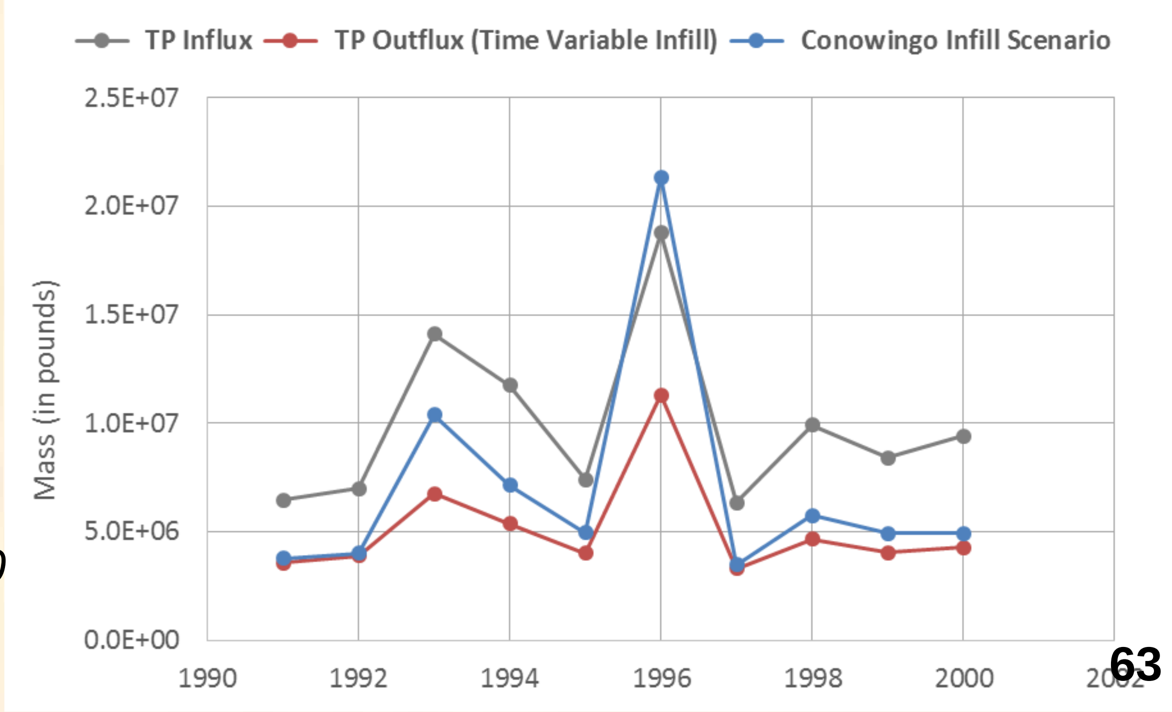
Decreased critical shear stress for high flow events allows for greater scour (visualized by increased arrow width) from Conowingo sediment bed, consistent with observations, during high follow periods.

Conowingo Infill Scenario









Less net deposition over the 10 year period as compared to baseline.

Beta 3 calibration

Beta 3 Estimated Deep Channel Nonattainment Under Conowingo Infill Conditions:

CS Segment	State	Conowingo Base Case 1993_1995 Deep Channel	Conowingo Infill Scenario 1993_1995 Deep Channel	Increase in Nonattainment With Infill Deep Channel
CB3MH	MD	16.0%	17.6%	**-2%**
CB4MH	MD	46.0%	47.7%	**-2%**
CB5MH	MD/VA	14.2%	15.9%	**-2%**
CHSMH	MD	37.4%	37.4%	**0%**
POTMH	MD/VA	20.2%	21.8%	**-2%**
POMMH	MD	20.4%	22.0%	**-2%**
RPPMH	VA	19.0%	24.2%	**-5%**
EASMH	MD	25.4%	27.2%	**-2%**
MD5MH	MD	21.7%	23.2%	**-2%**
VA5MH	VA	4.5%	6.2%	**-2%**
PATMH	MD	24.8%	26.2%	**-1%**

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JEQ Estimated Deep Channel Nonattainment under Conowingo Infill Conditions

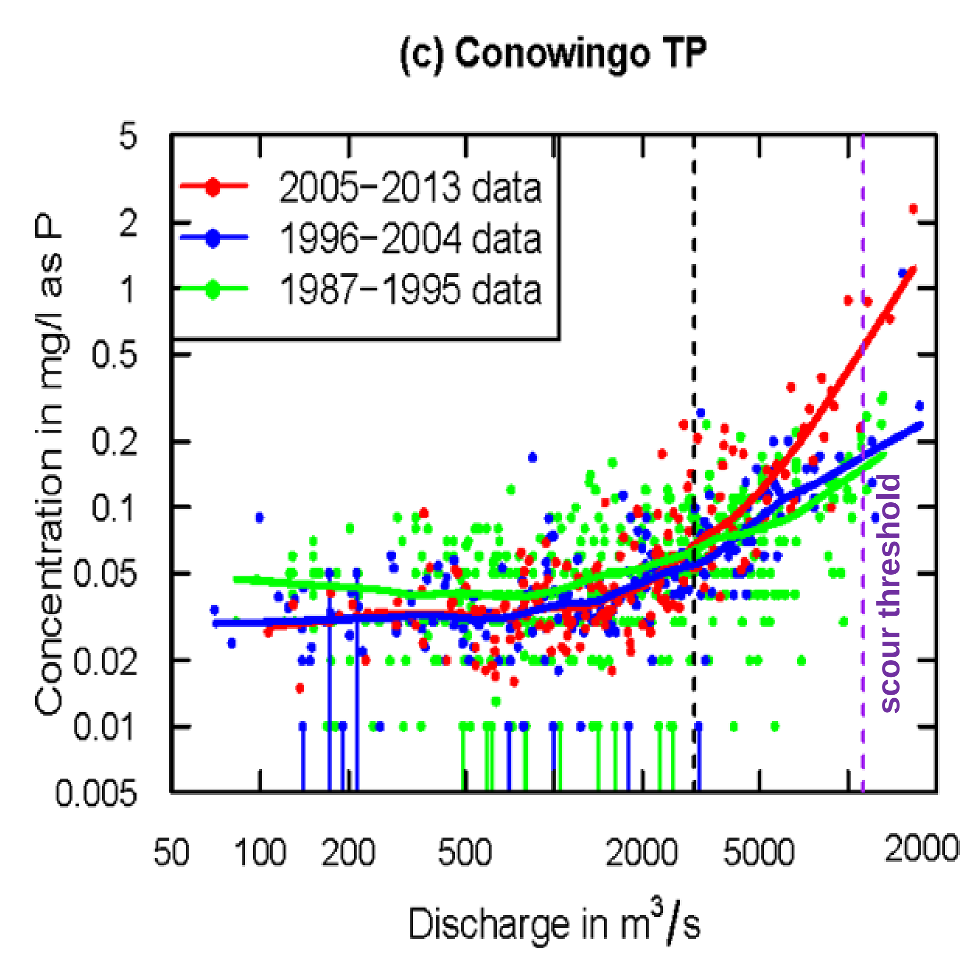
Table 1. Model-estimated level of time and space nonattainment of deep-channel dissolved oxygen (DO) in all Chesapeake Bay segments that have a deep-channel designated use. The first four scenarios (columns 2–5) are key milestone scenarios and are ordered from the highest to the lowest nutrient and sediment loads for the entire Chesapeake watershed. The nutrient and sediment scenario loads are under the scenario title and have units of millions of kilograms for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS). The last four columns (columns 6–9) are different Conowingo infill scenarios. Deep-channel variances of 2% are applied in the central mainstem (CB4MH) and Eastern Bay (EASMH) and 16% in the lower Chester River (CHSMH). (A variance is an allowable exceedance of an established water quality standard based on the best available data on achievable water quality conditions.) The estimated degree of nonattainment of the deep-channel DO water quality standard is shown in bold type for each deep-water segment of the Chesapeake. Once attainment is estimated to be achieved, the value is shown in italic type.

Scenario / CB segment	1985 Scenario 160 TN 11.2 TP 5480 TSS	2010 Scenario 119 TN 8.8 TP 3790 TSS	TMDL WIP† Scenario 87 TN 6.8 TP 3030 TSS	All Forest Scenario 24 TN 1.2 TP 610 TSS	Increase of nonattainment under Conowingo scour conditions in January storm	Increase of nonattainment under January storm conditions compared with No Storm Scenario	Increase of nonattainment under June storm conditions compared with No Storm Scenario	Increase of nonattainment under Moderate High Flow conditions
	%							
CB3MH	**17**	**5**	*0*	*0*	*0*	**1**	**1**	*0*
CB4MH	**49**	**23**	*1*	*0*	**1**	**1**	**4**	**2**
CB5MH	**17**	*0*	*0*	*0*	*0*	*0*	*0*	*0*
CHSMH	**39**	**28**	*15*	*0*	**1**	**2**	**8**	**1**
EASMH	**29**	**14**	*1*	*0*	**1**	**2**	**3**	**3**
PATMH	**42**	**18**	*0*	*0*	*0*	*0*	*0*	*0*
POTMH	**20**	*0*	*0*	*0*	*0*	*0*	*0*	*0*
RPPMH	**23**	*0*	*0*	*0*	*0*	*0*	*0*	*0*

† Total maximum daily load Watershed Implementation Plan.

What's changing in the Water Quality Sediment Transport Model (WQSTM)?

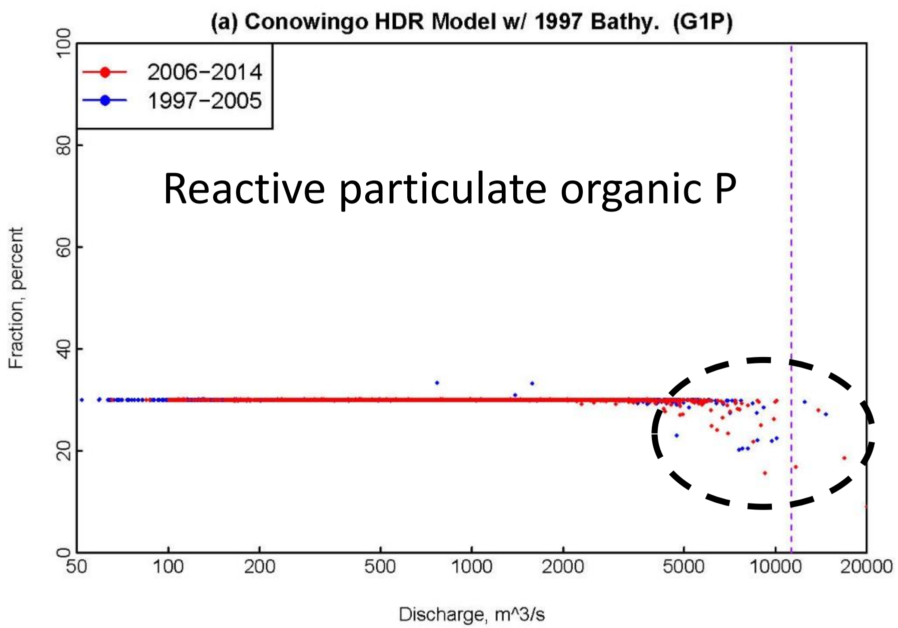
Consistent with research and observations, less reactive particulate organic material is scoured from Conowingo and transported to tidal water under extreme high flow events (when flow is greater than 400,000 cfs).

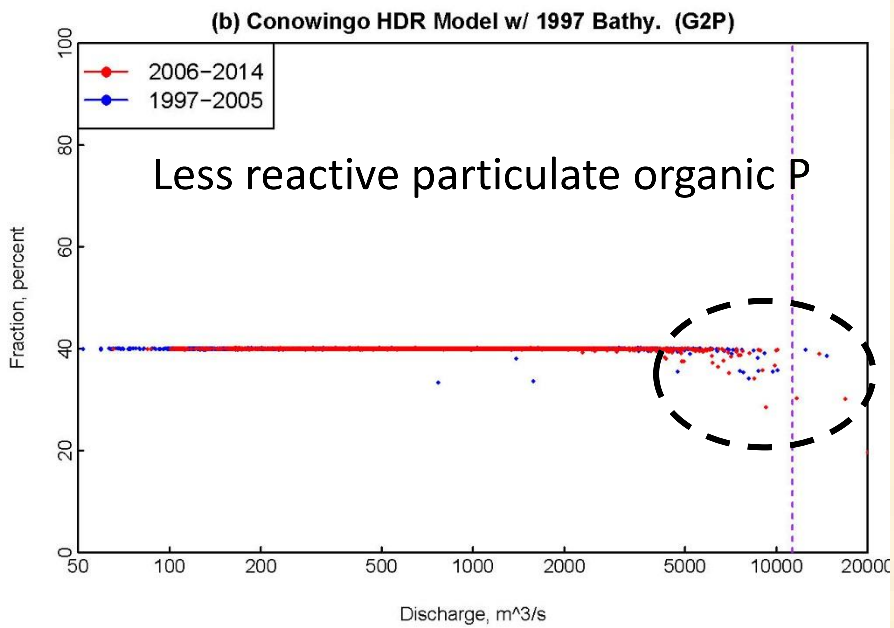


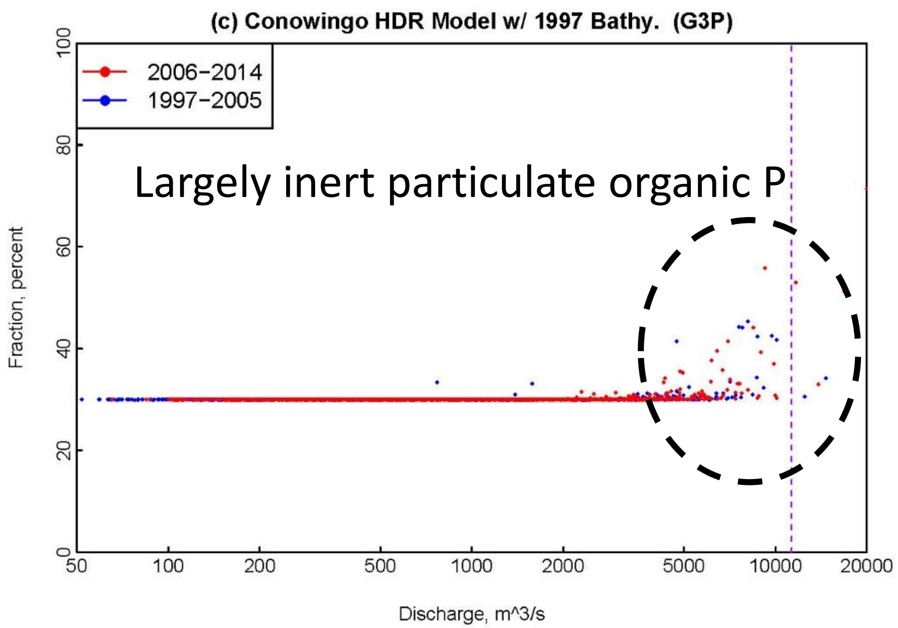
(fitted lines are **LOWESS curves**)

(Zhang, Hirsch, Ball, ES&T, 2016)

HDR Model: G1P/G2P/G3P (1997 Bathy.)



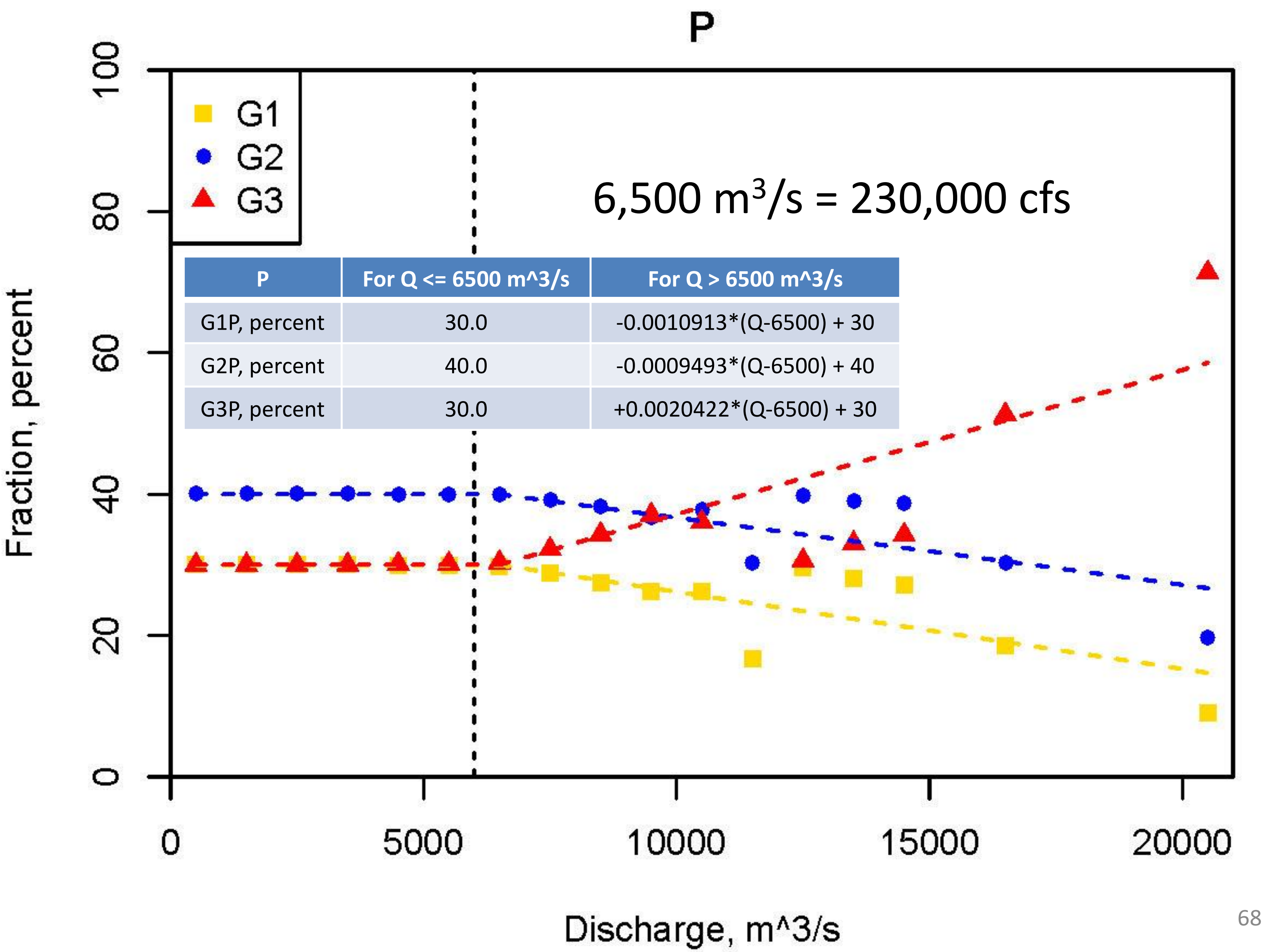




G1/G2 fractions decrease at high flows
G3 fraction increases at high flows

11,300 m^3/s = 400,000 cfs

G1, G2, and G3 Organic Phosphorus



P	For Q <= 6500 m^3/s	For Q > 6500 m^3/s
G1P, percent	30.0	-0.0010913*(Q-6500) + 30
G2P, percent	40.0	-0.0009493*(Q-6500) + 40
G3P, percent	30.0	+0.0020422*(Q-6500) + 30

Initial, Preliminary Conclusions on Conowingo Infill:

- The Phase 6 Models have the ability to represent all salient aspects of dynamic equilibrium in the Conowingo Reservoir including decreasing deposition and increased scour over time, consistent with observations.
- The research and monitoring of Conowingo infill since 2010 has provided key support to model changes and provided new and useful information on changing deposition and settling rates with increased infill and on the dynamics of G1, G2, and G3 in terms of flow and scour, i.e., a higher G3 fraction but lower G1 and G2 fractions at extreme flows.
- The current best estimates of the increase in net transport of phosphorus loads to the Chesapeake due to Conowingo infill is about 1.95 million pounds which results in an estimated 1-3% increase in nonattainment of the Deep Channel DO water quality standard

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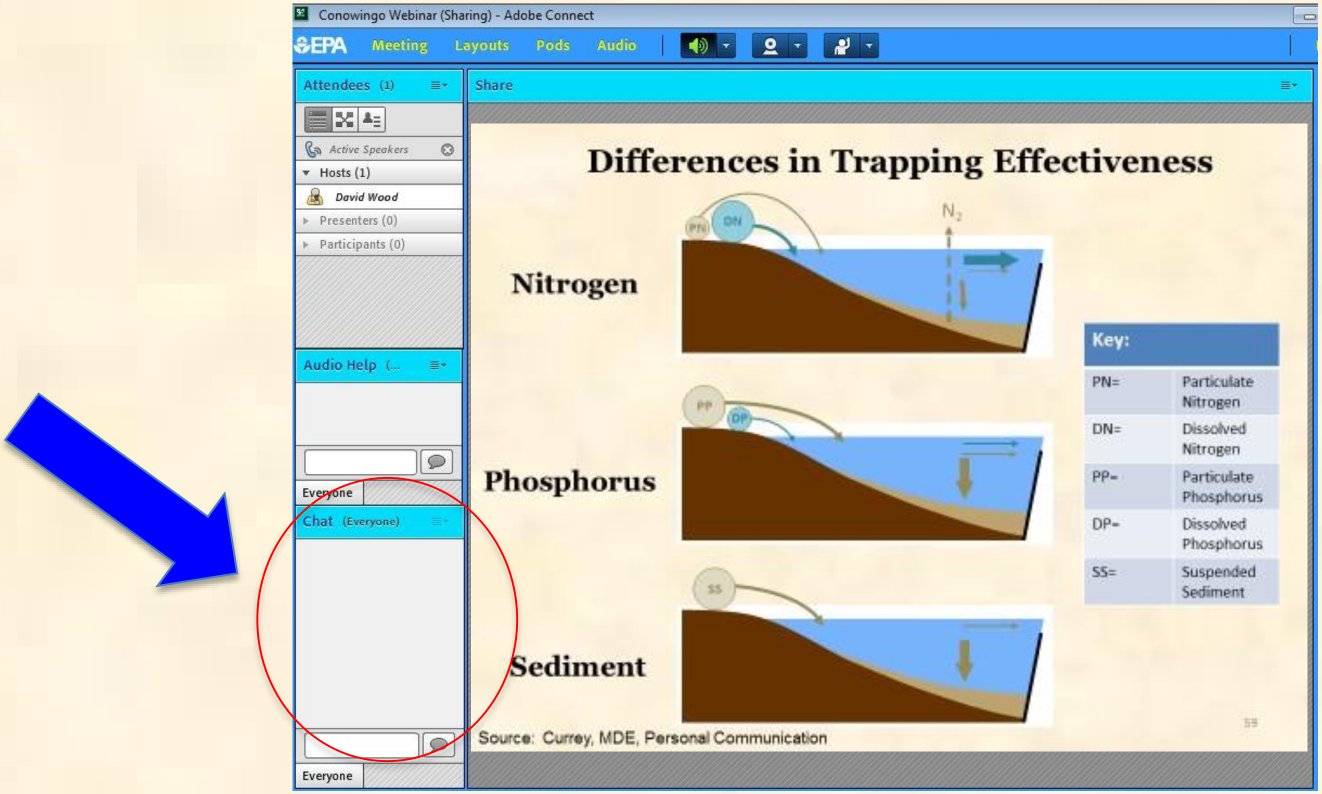
Reminder:

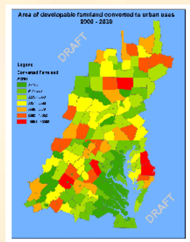
- To Ask a Question
  - Submit your question in the chat box, located in the bottom left of the screen.



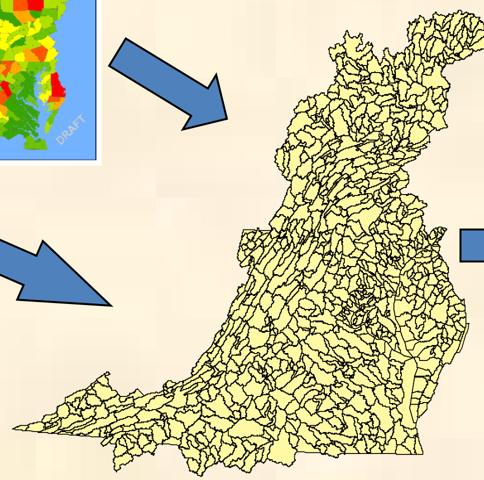
Decision Support System

Data

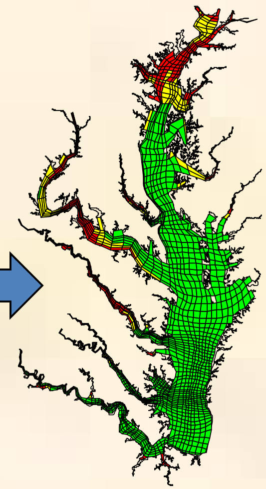
Land Use
Change Model



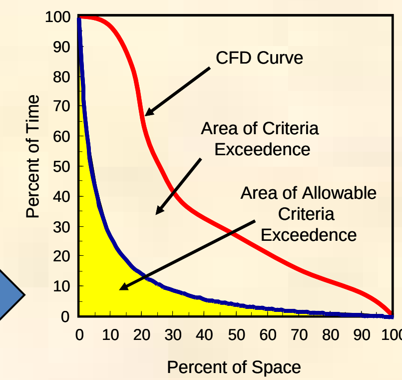
Watershed
Model



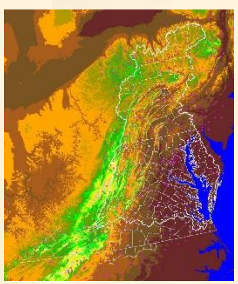
Bay
Model



Criteria
Assessment
Procedures



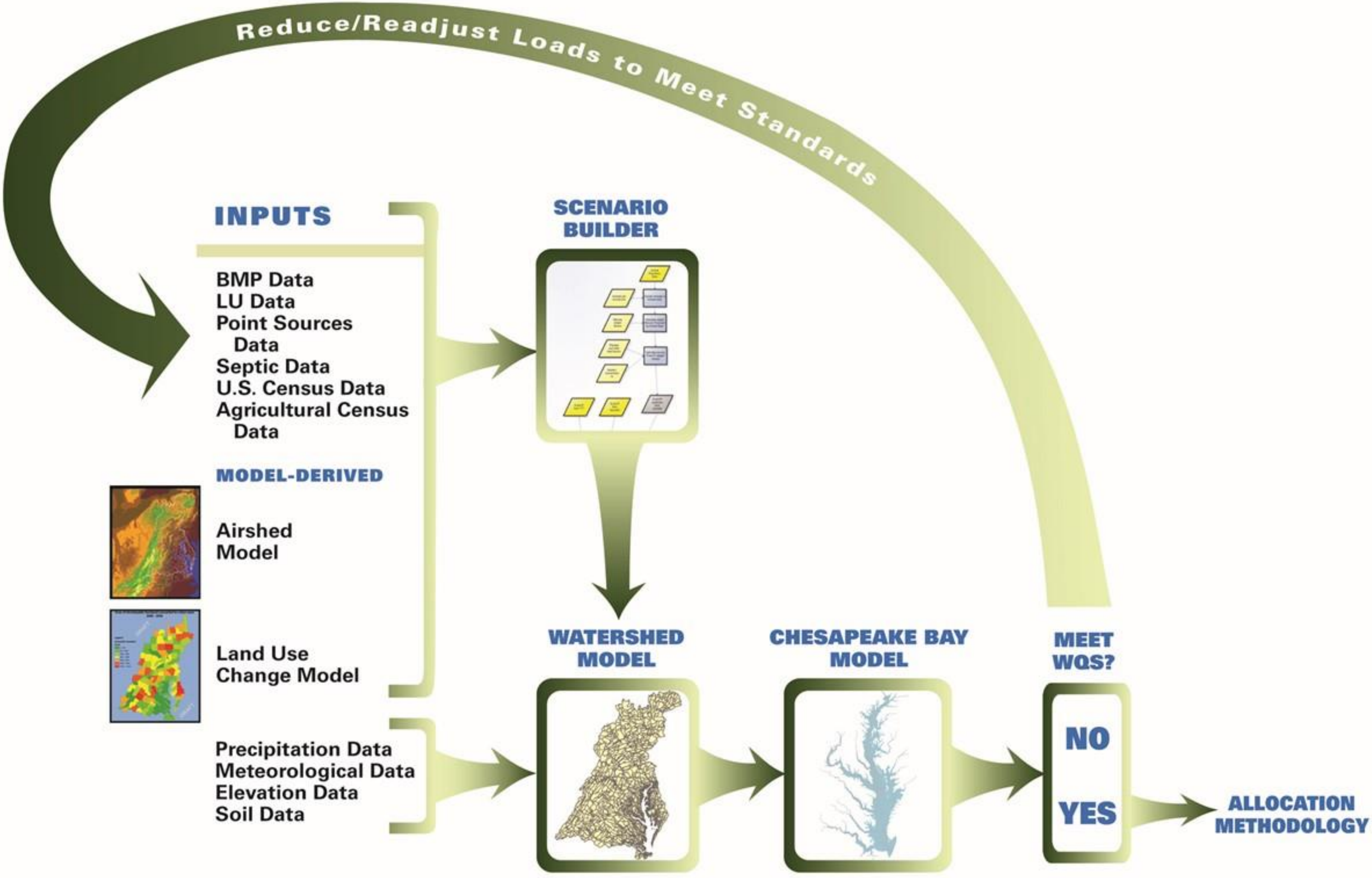
Airshed
Model



Effects

Allocations

Chesapeake Bay Partnership Models



What has changed in the Phase 6 Watershed, WQSTM and CMAQ airshed model to better assess the influence of climate change on Chesapeake Bay water quality standards?

Stationarity is Forever Assured

Under the 2010 decision rules stationarity is assured. But precipitation, temperature, and sea level have all been observed to have increased over the last century.

The 1991-2000 ten year average hydrology set the state-basin target loads and the 1993-95 critical period was used to examine the assimilation capacity of the Bay for nutrient loads. The full 1985 -2013 full simulation period is used for sensitivity scenarios and to better understand changes over time in the Chesapeake watershed and Bay.

Phase 6 simulation period

1985 1991 2000 2013

10 Year Average Hydrology

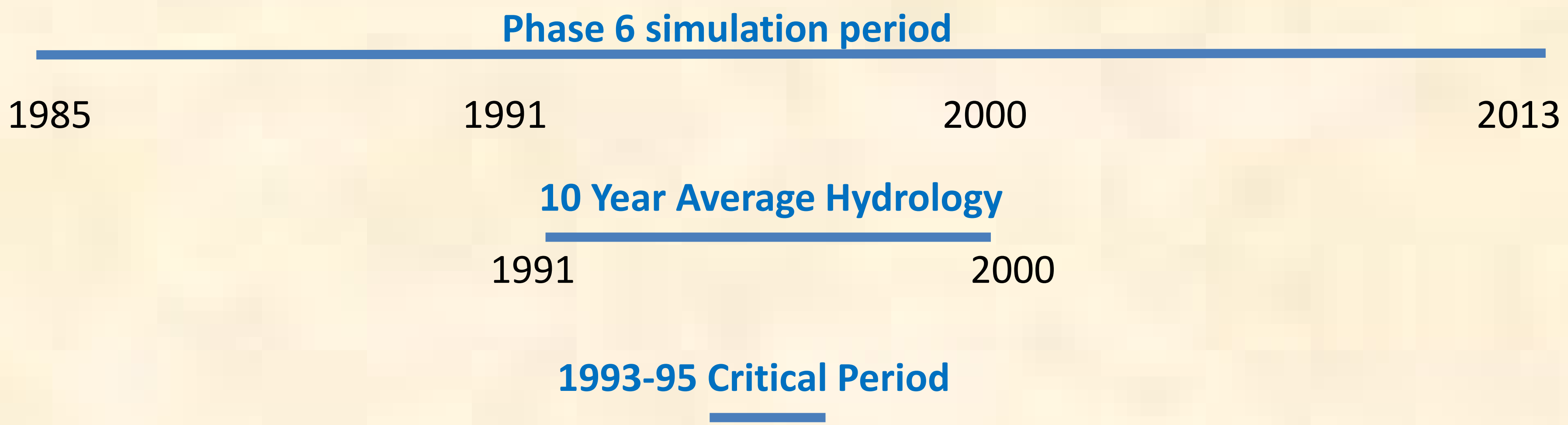
1991 2000

1993-95 Critical Period

1993-95

Stationarity is (Properly) Dead

To reestablish realistic precipitation, temperature, and sea level estimates for 2025, yet still preserve the standing 10 year average hydrology and critical period, the estimated delta, or difference, in the observed changes for 30 years, i.e., between 1995 and 2025 is applied to the precipitation, temperature, and sea level data time series.



What's changed in the Phase 6 Model?

- The ability to separately or combined, examine the influence of estimated 2025 conditions have on Bay hypoxia:
  - Changes in precipitation volume
  - Increased precipitation intensity
  - Changes in watershed flows (Q)
  - Increased temperature (T)
  - Changes in evapotranspiration
  - Increased watershed loads
  - Changes in sea level (SL)
  - Tidal wetland attenuation of nutrients and sediment
- 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.

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.
- 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.

Model Climate Inputs Were Developed with STAC Workshop and Climate Resiliency Workgroup Guidance

Precipitation Volume

- 2025: +3.1% (long term trends)
- 2050: +6.2% (RCP* 4.5)

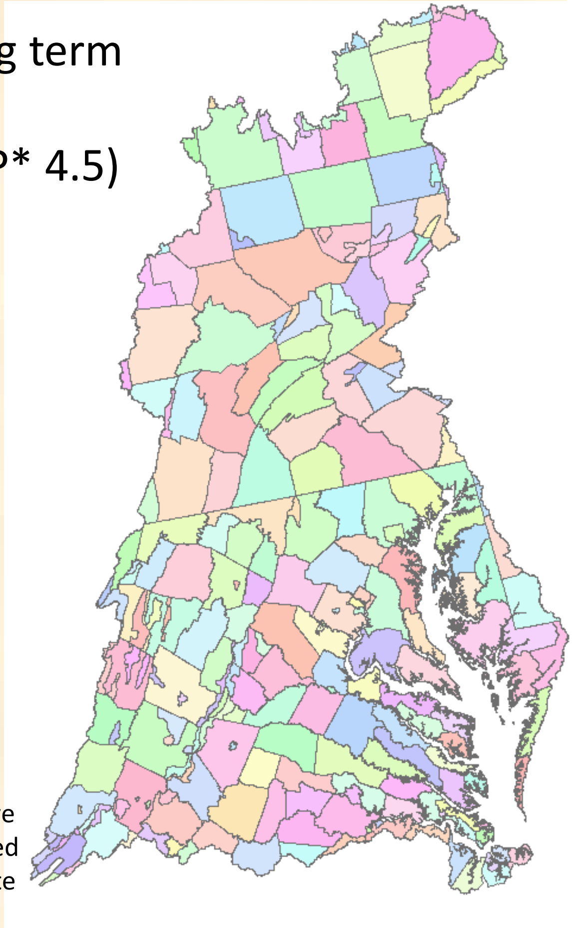
Temperature: RCP 4.5

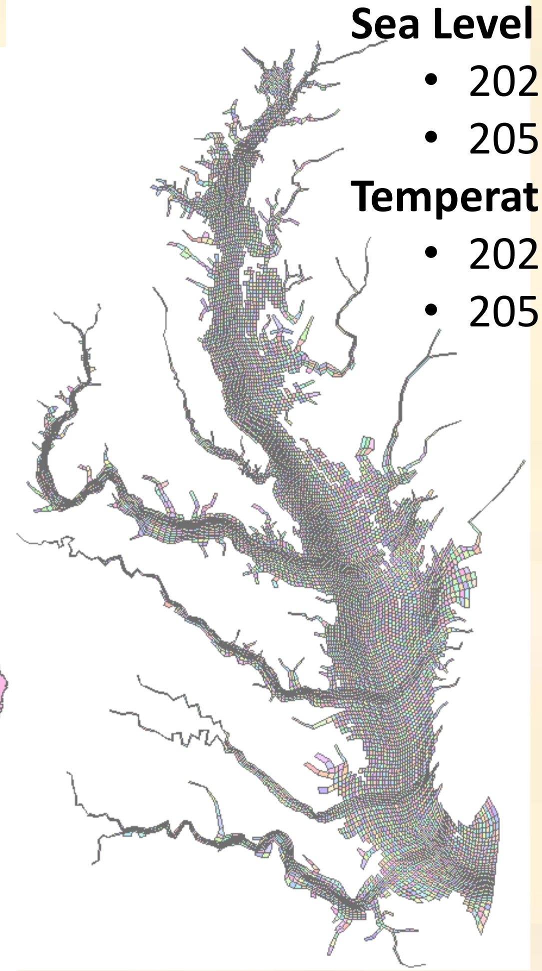
- 2025: +1.1 ^oC
- 2050: +1.94 ^oC

CO_2 Concentration:

Meinhausen et al., 2011

- 2025: 427 ppm
- 2050: 487 ppm





Sea Level Rise: CRWG**

- 2025: +0.3 m
- 2050: +0.5 m

Temperature: RCP 4.5

- 2025: +0.95 ^oC
- 2050: +1.86 ^oC

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

**Based upon guidance provided by the Climate Resiliency Workgroup

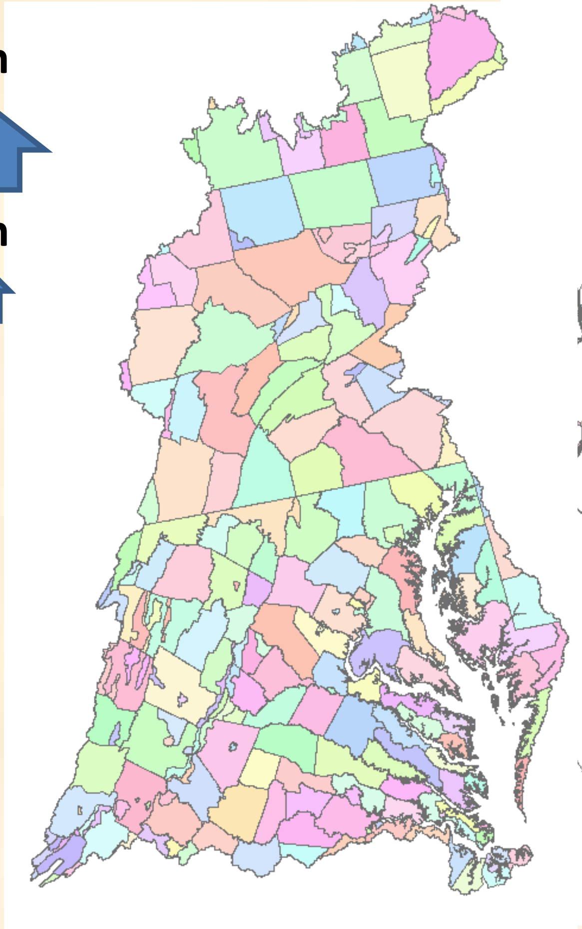
Keeping Score

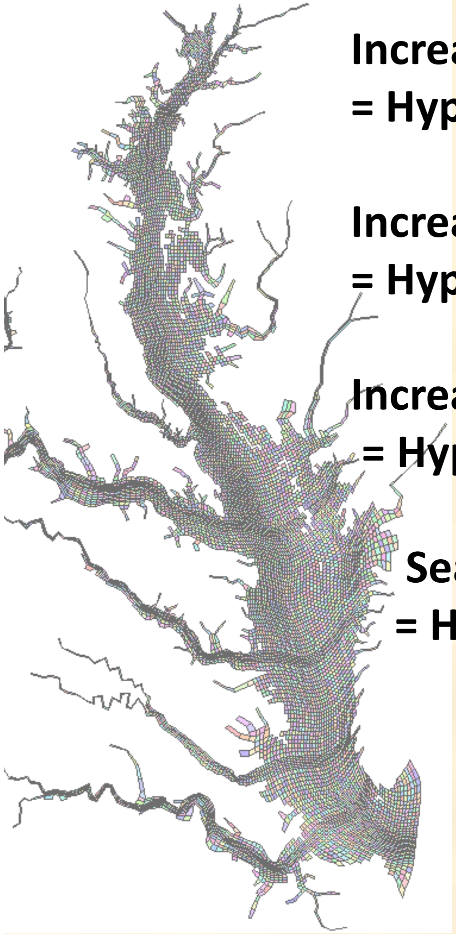
In the Watershed

Increased Precipitation Volume = Hypoxia ↑

Increased Precipitation Intensity = Hypoxia ↑

Increase in Temp and Evapotranspiration = Hypoxia ↓





In the Estuary

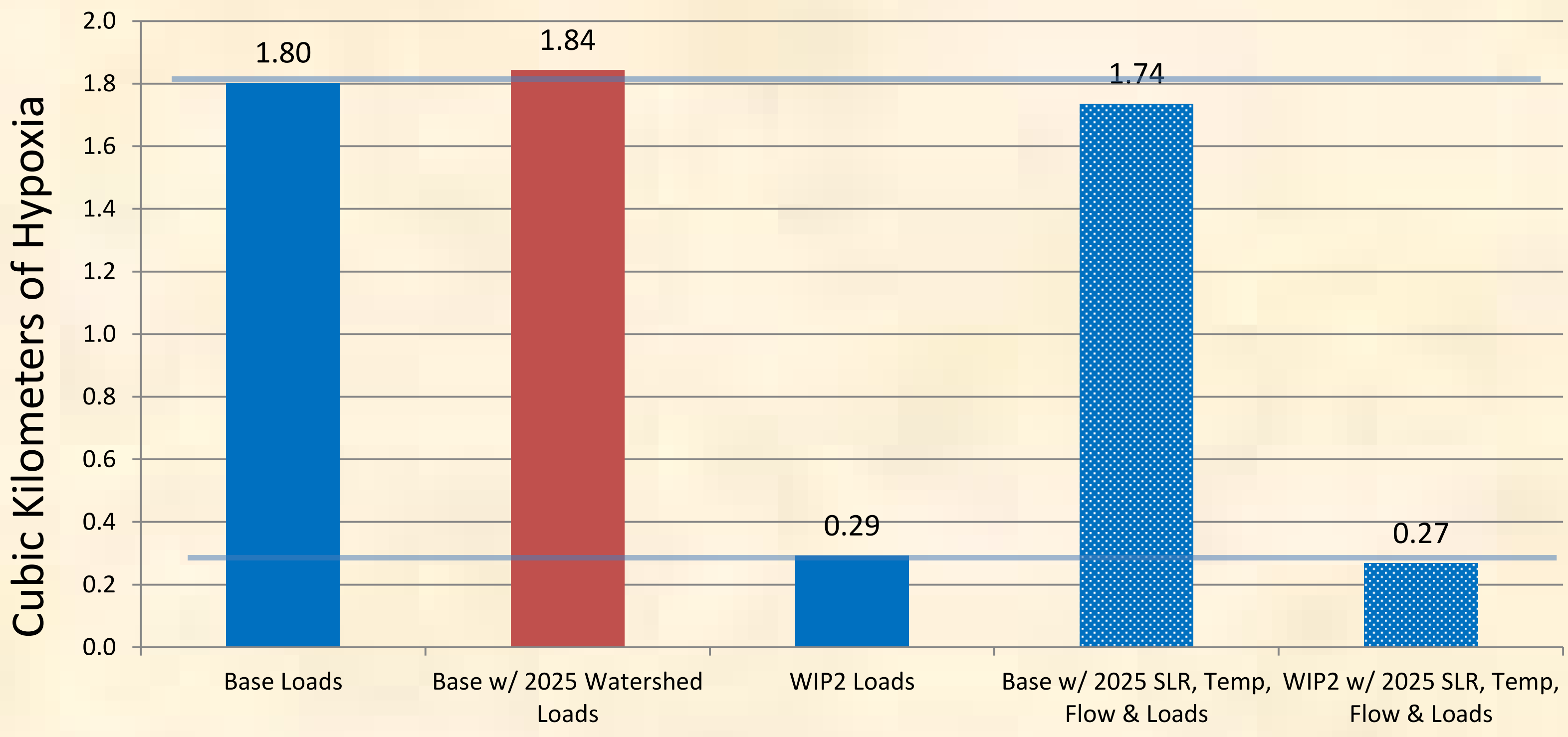
Increased WS Loads = Hypoxia ↑

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?

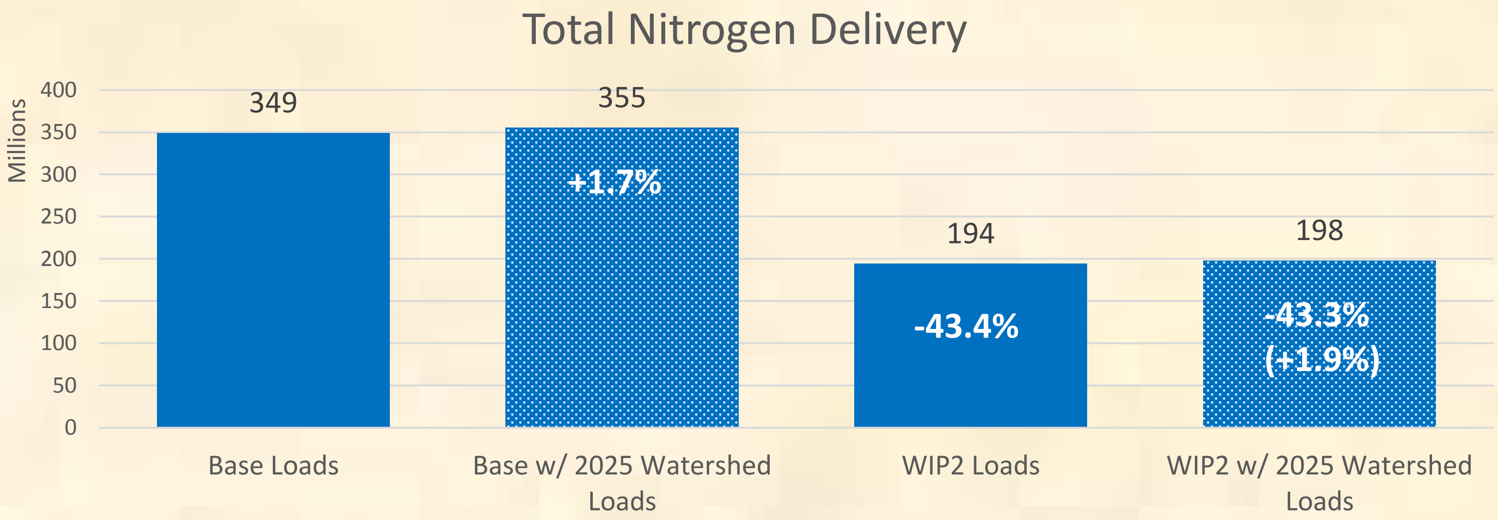


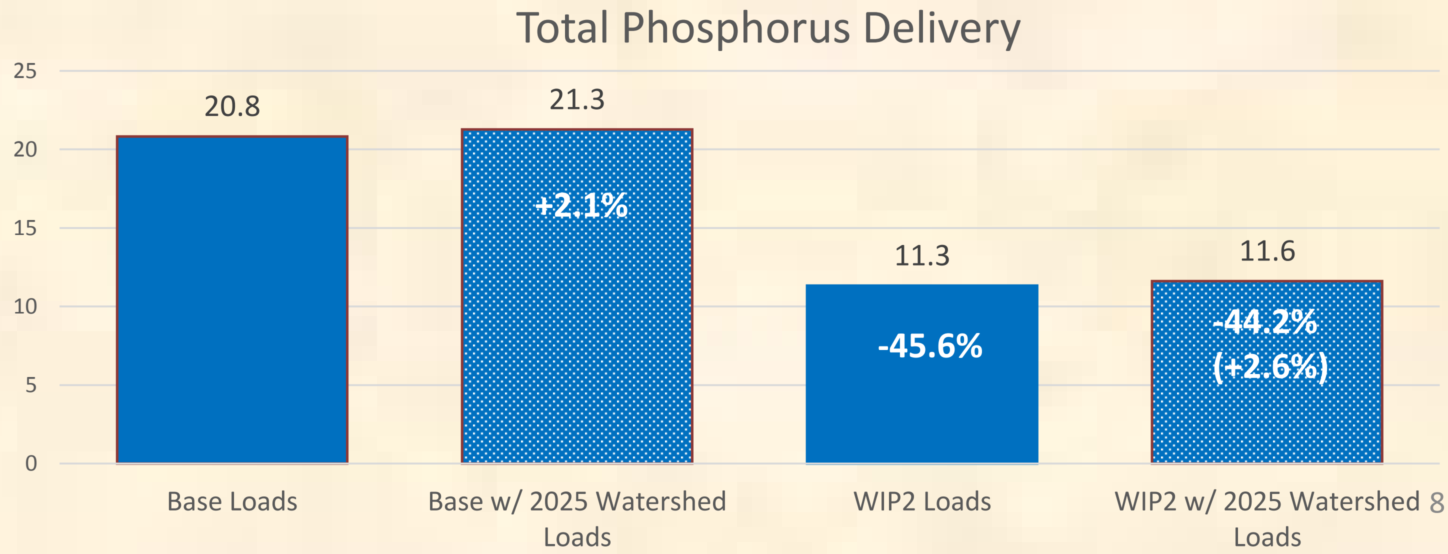
DO <1 mg/l annual average daily hypoxia from 1991 to 2000 over the summer hypoxic season of May through September.

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

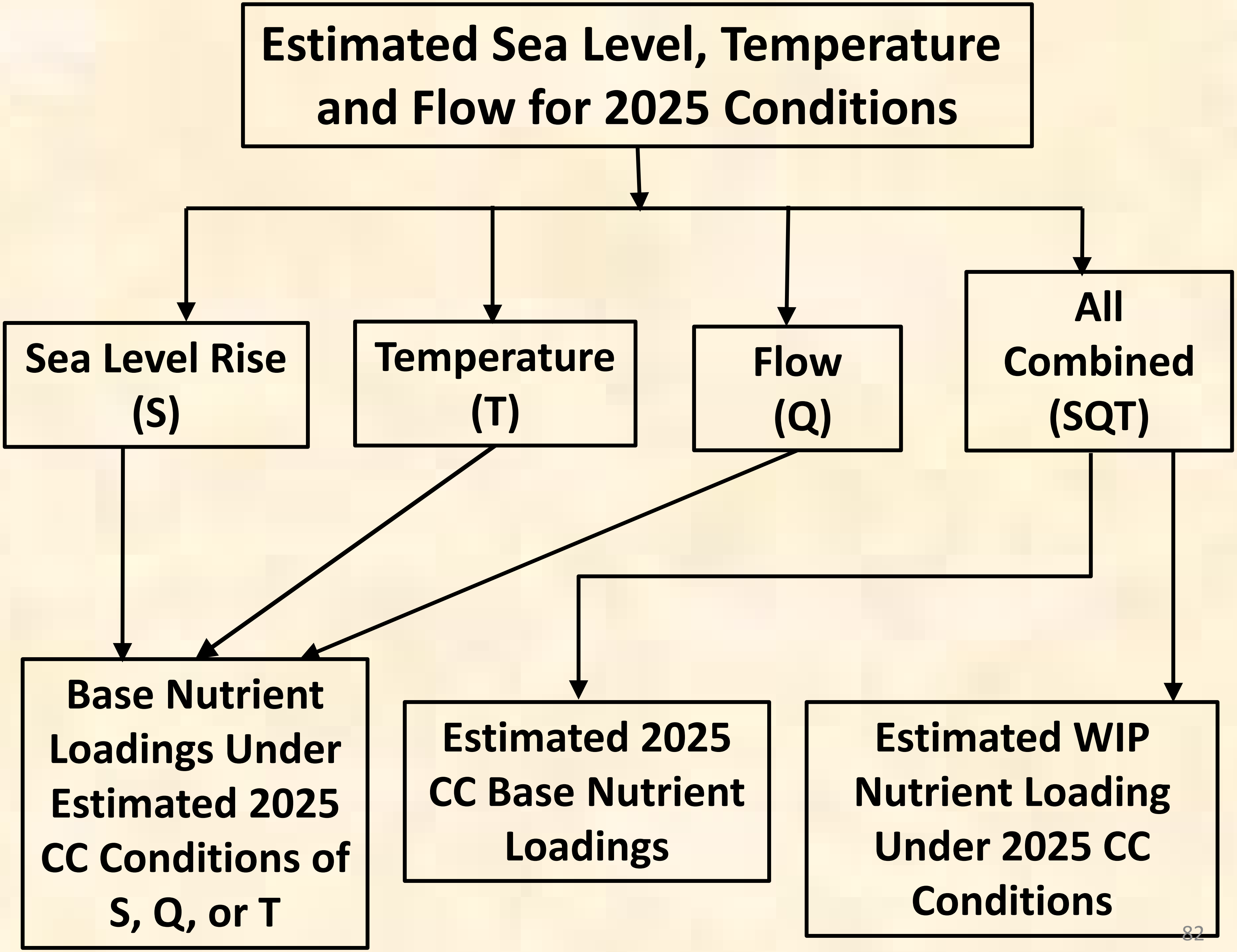
Watershed loads increase under estimated 2025 climate conditions compared to 1995 conditions.

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

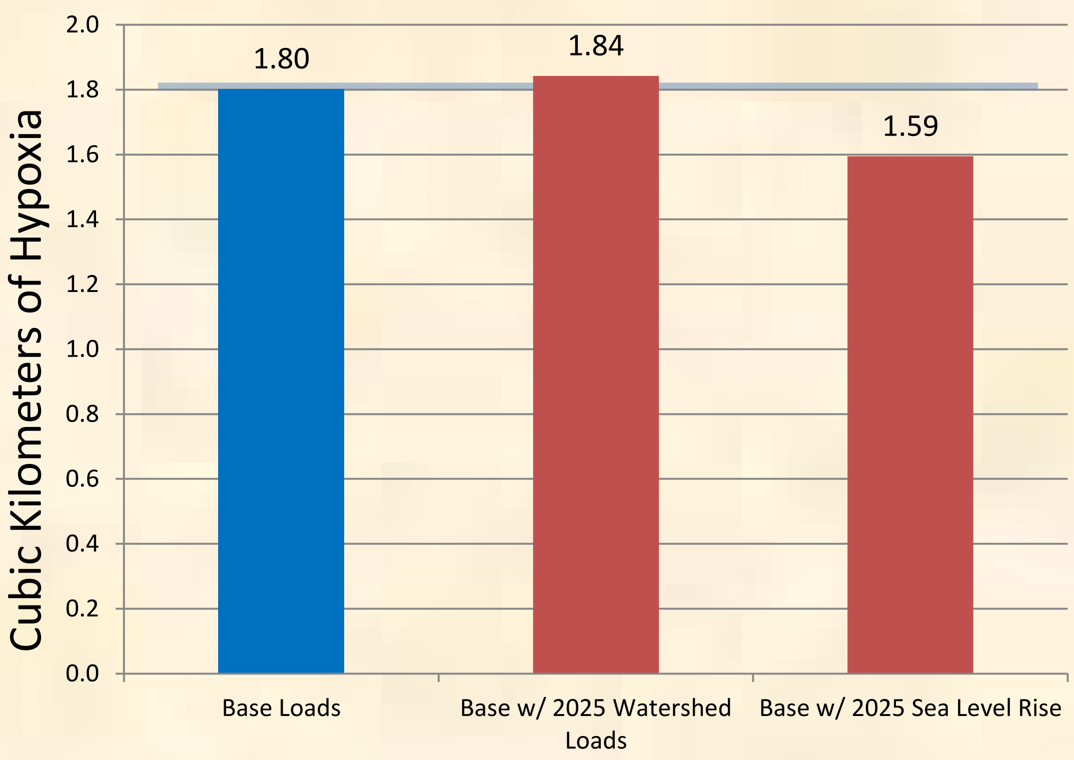




Gopal Bhatt, December 2016 Quarterly Review


Estimated Sea Level, Temperature and Flow for 2025 Conditions
Sea Level Rise (S)
Temperature (T)
Flow (Q)
All Combined (SQT)
Base Nutrient Loadings Under Estimated 2025 CC Conditions of S, Q, or T
Estimated 2025 CC Base Nutrient Loadings
Estimated WIP Nutrient Loading Under 2025 CC Conditions

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

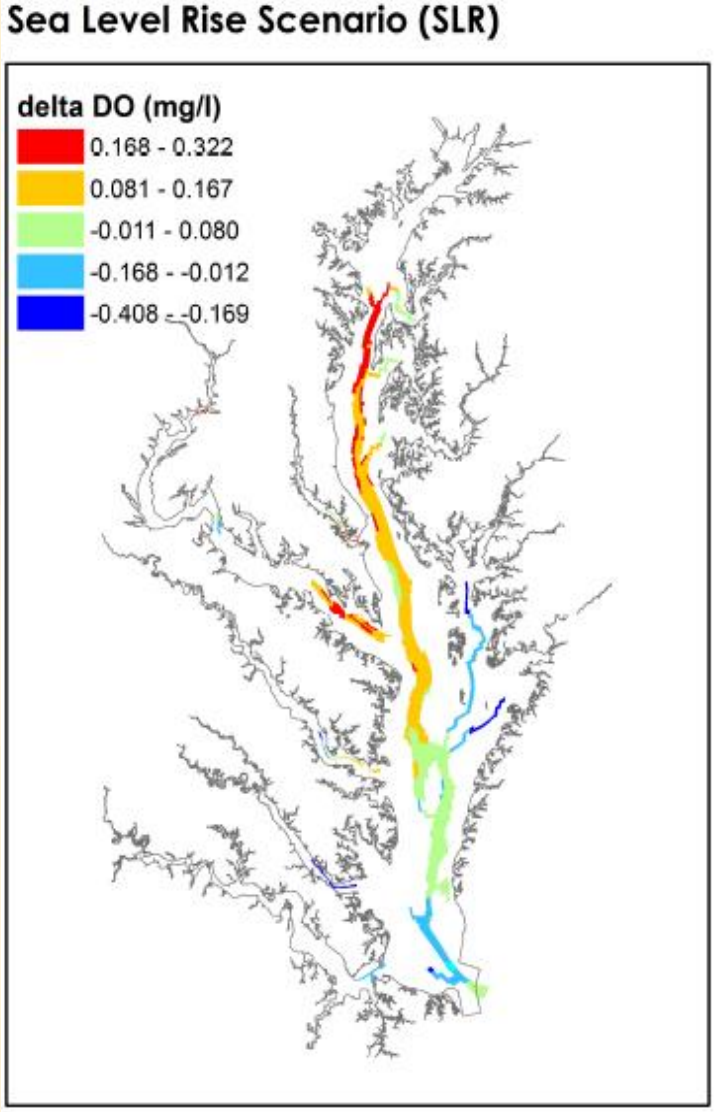


Sea level rise increases bottom water dissolved oxygen because of increased estuarine circulation, increased ventilation of Bay deep waters by oxygenated ocean waters, and in some areas decreased stratification.

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

Influence of Estimated 2050 Sea Level Rise (0.5 m) on Bottom DO



The influence of an 2050 estimated sea level rise on Chesapeake hypoxia is significant.

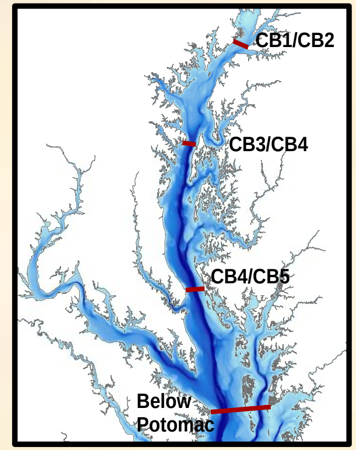
The estimated change from the base (1991 to 2000) condition in Chesapeake hypoxia due to 2050 estimated sea level rise conditions ranges from 0.3 mg/l to -0.4 mg/l.

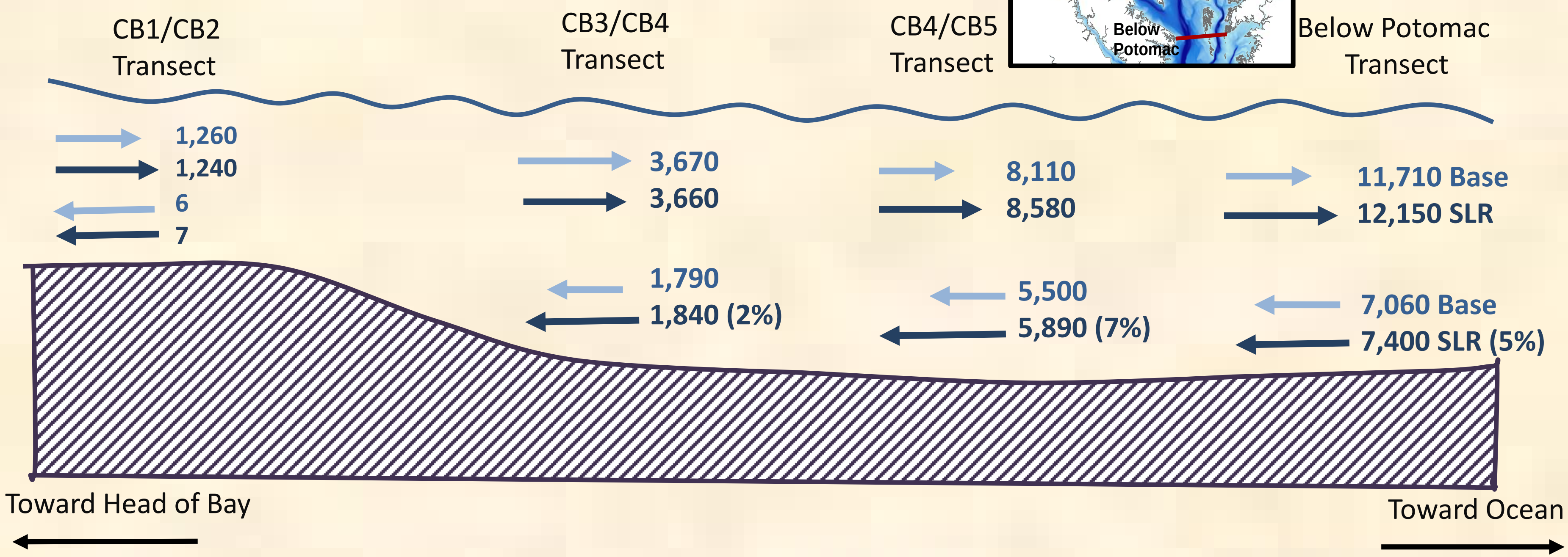
Hypoxia decreases in the mid-Bay are due to increased ventilation of deep Chesapeake waters by well oxygenated ocean waters and also because of changes in vertical stratification.

By extension, estimated 2025 (0.3 m) sea level rise increases will also have slight influence on water quality standard achievement.

Source: CERF Conference 2015

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

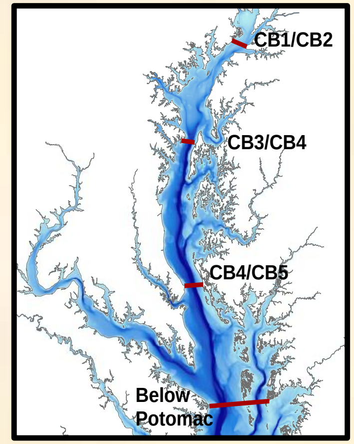


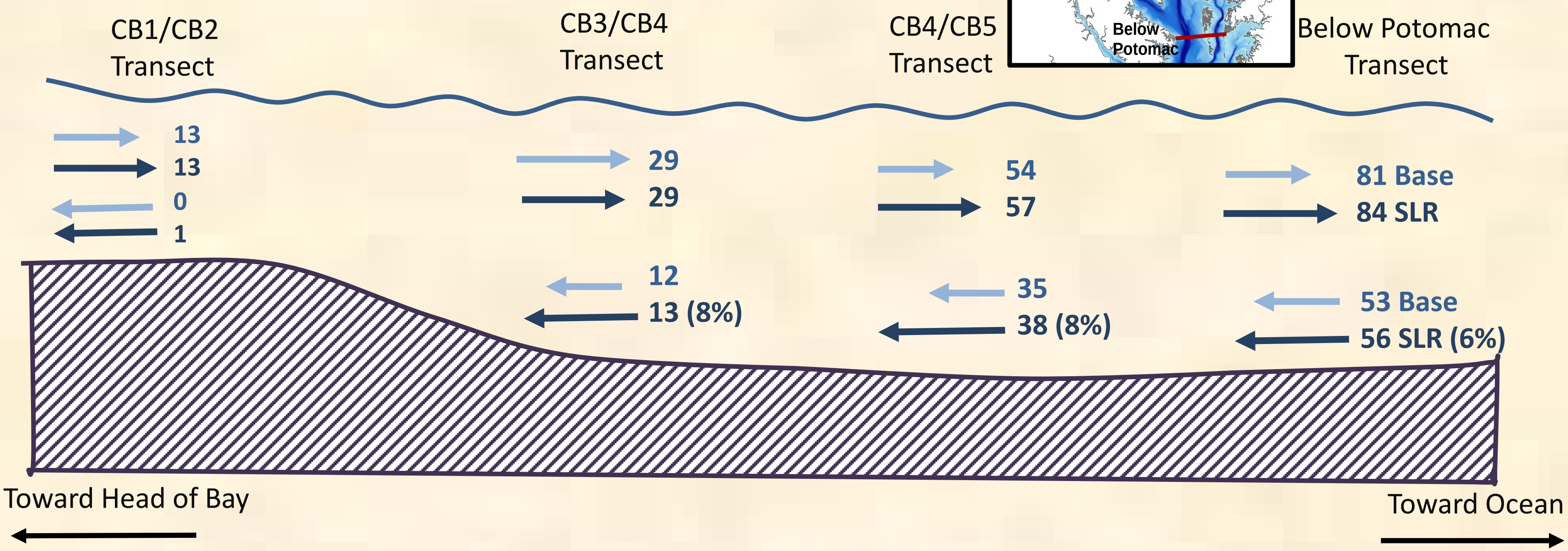


Base = Beta 4 Calibration. SLR = 0.3m Sea Level Rise Scenario representing relative Chesapeake sea level rise from 1995 to 2025. Units in mean cubic meters per second (m^3/s) for 1991 to 2000 hydrodynamics.

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.

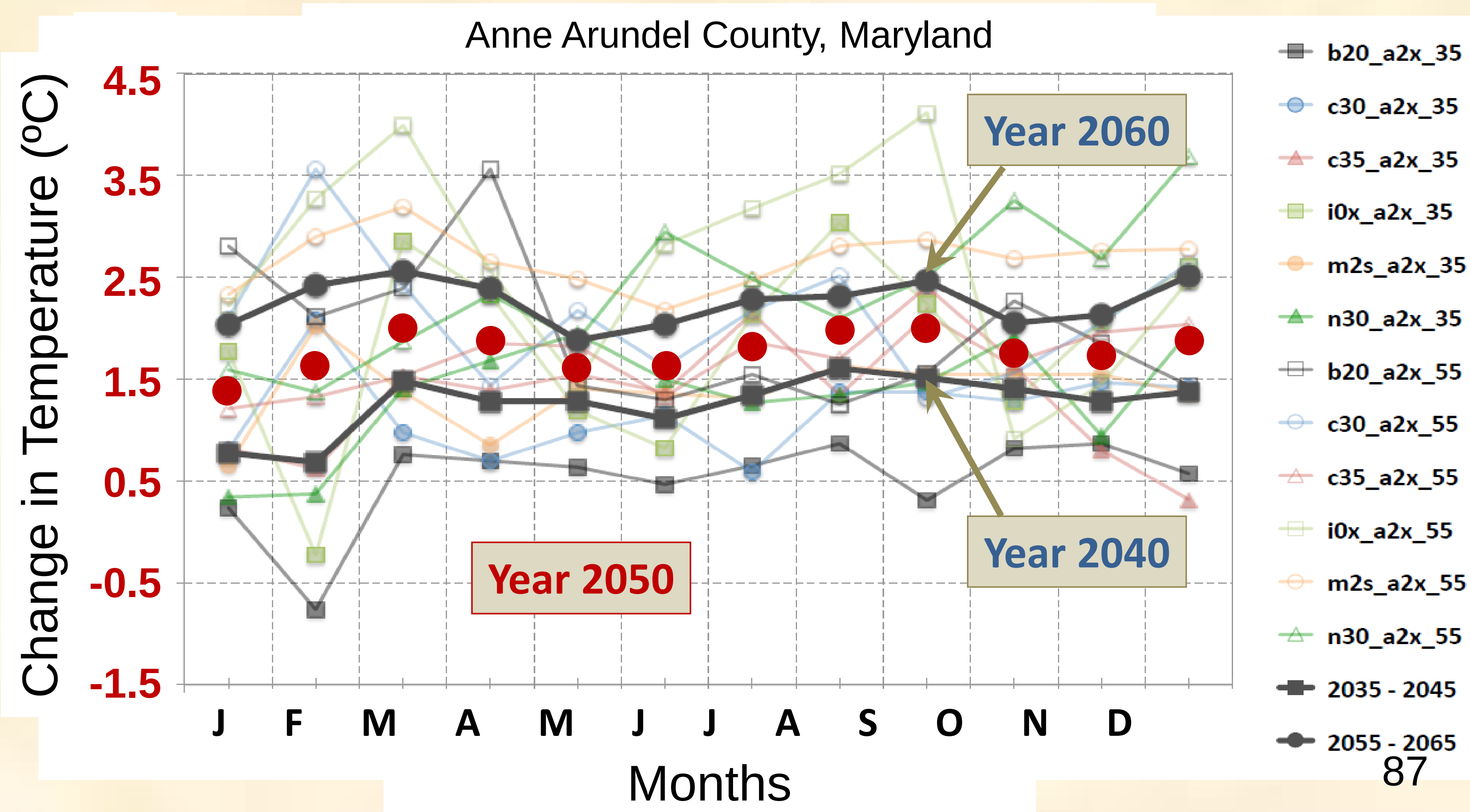




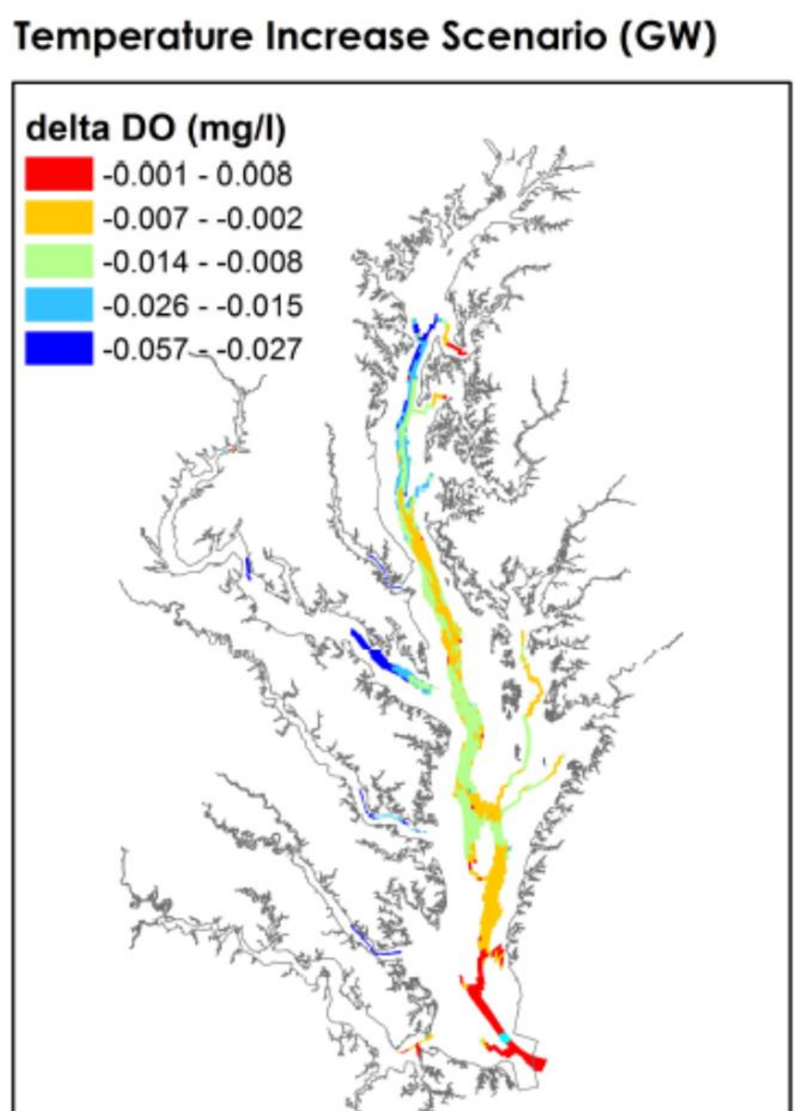
Base = Beta 4 Calibration. SLR = 0.3m Sea Level Rise Scenario representing relative Chesapeake sea level rise from 1995 to 2025. Units in mean kg DO per second (m^3/s) for 1991 to 2000 hydrodynamics.

2050 Temperature Increase Scenario

Projections of downscaled ***mean monthly change in temperature*** were obtained from multiple global climate models. Estimated overall increase in watershed-wide annual average temperature was 1.75˚C.



Estimated 2050 Temperature Increases on Bottom DO



Source: CERF Conference 2015

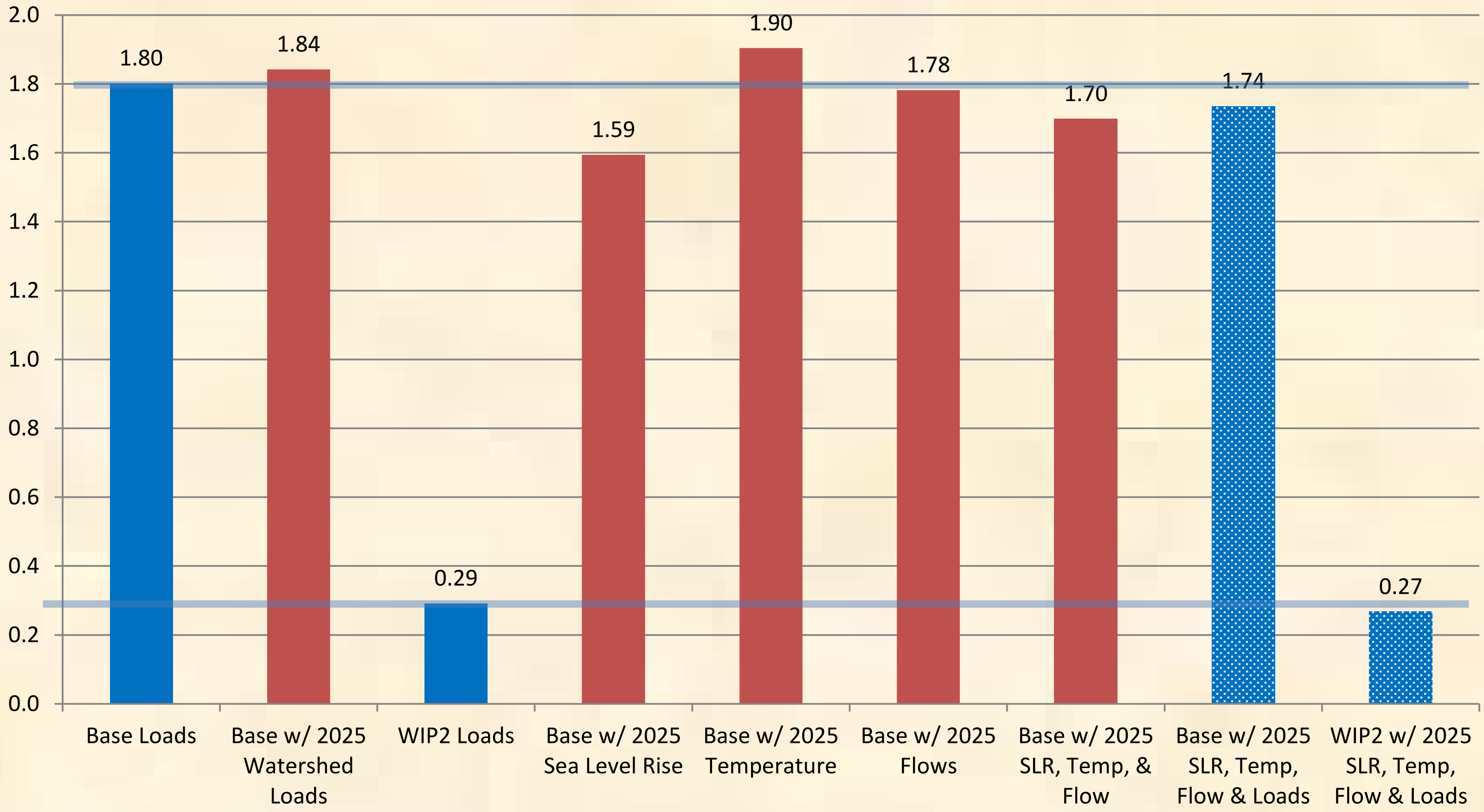
The influence of an 2050 estimated temperature increase on Chesapeake hypoxia is small.

But we can measure in infinitesimal with our models. The estimated increase in Chesapeake hypoxia due to 2050 estimated temperature increases ranges from 0.008 to - 0.06 mg/l.

Hypoxia increases are due to the increase in vertical stratification due to the increased thermocline, reduced oxygen saturation levels, and increased respiration.

Estimated 2025 temperature increases will also have slight influence on water quality standard achievement.

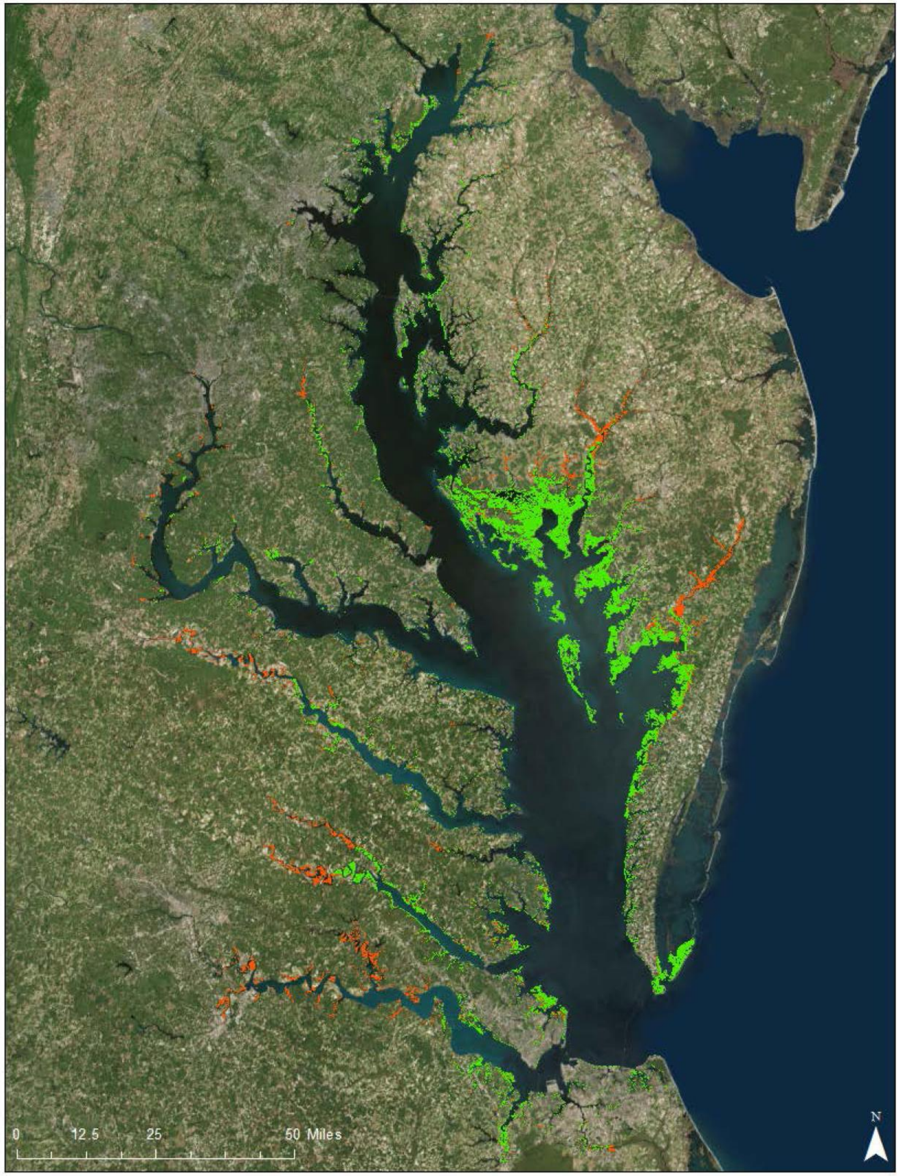
Hypoxic volume (DO <1 mg/l) in Chesapeake Mainstem (Model estimate in summer 1991-2000)



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

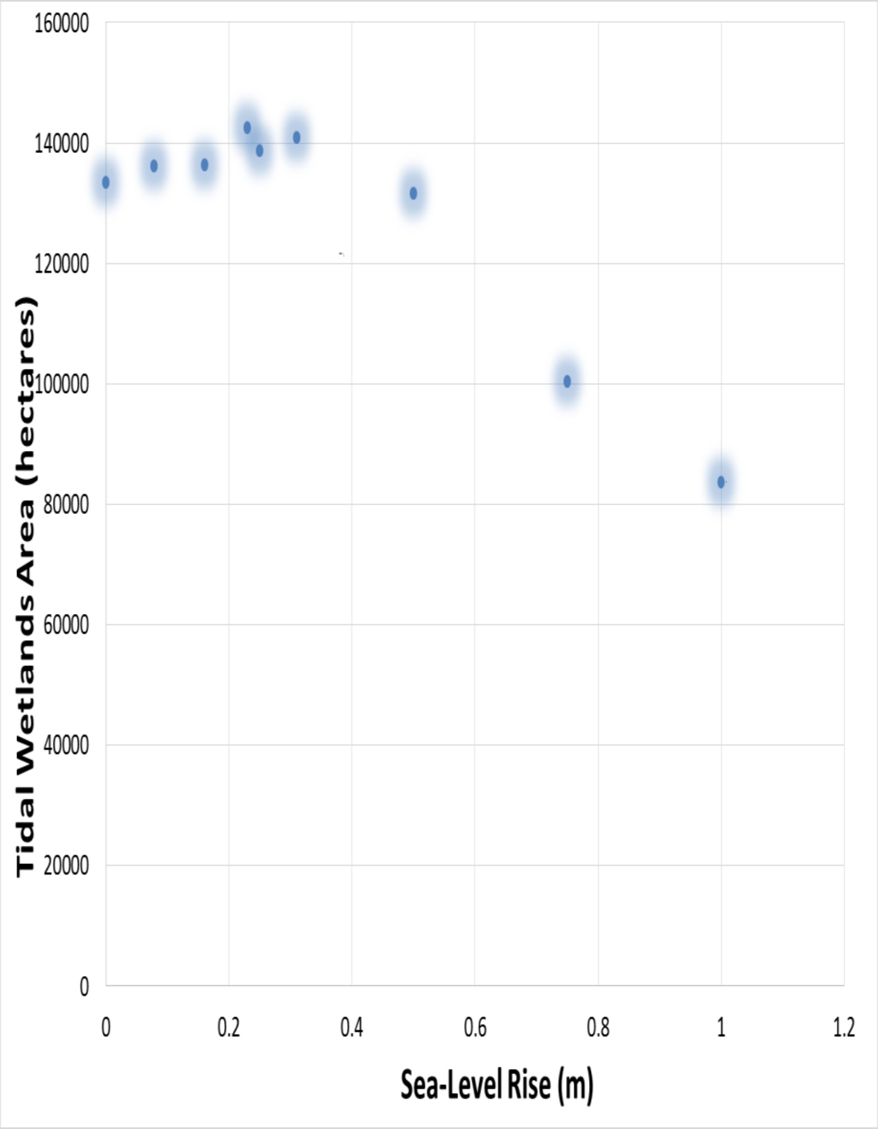
Chesapeake Bay Tidal Wetlands



Source: Carl Cerco, U.S. CoE ERDC

- The extent from National Wetlands Inventory is determined largely from vegetation perceived via aerial photography.
- 190,000 hectares of estuarine (green) and tidal fresh (red) wetlands.
- A tidal wetlands module is now fully operational in the WQSTM. The module incorporates functions of sediment and particulate nutrient removal and burial, denitrification, and respiration. The loss of wetland function due to sea level rise and inundation will be accounted for explicitly.

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 10 million pounds nitrogen and 0.6 million pounds phosphorus.

Source: Carl Cerco, U.S. CoE ERDC

Conclusions

- This is a work in progress using the Beta 3 Watershed Model and the Beta 4 WQSTM to provide the best estimate available today. Need to run the analysis on the final Watershed and WQSTM models.
- 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.
- Influence of 2025 sea level rise is estimated to be a small but positive influence on Chesapeake hypoxia.
- Likewise, the influence of greater watershed flows (not loads) increases estuarine circulation, albeit with an increase in stratification, and overall is estimated to have a very slight positive influence on hypoxia.

Conclusions *(continued)*

- Influence of estimated 2025 temperature on Chesapeake water quality standards (WQS) has a negative influence on Chesapeake hypoxia.
- Estimated influence of changes in tidal wetland attenuation is small in 2025 and 2050 because of little change in overall tidal wetland area, but accompanied by wetland type changes. However, tidal wetland losses are 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.

Conclusions *(continued)*

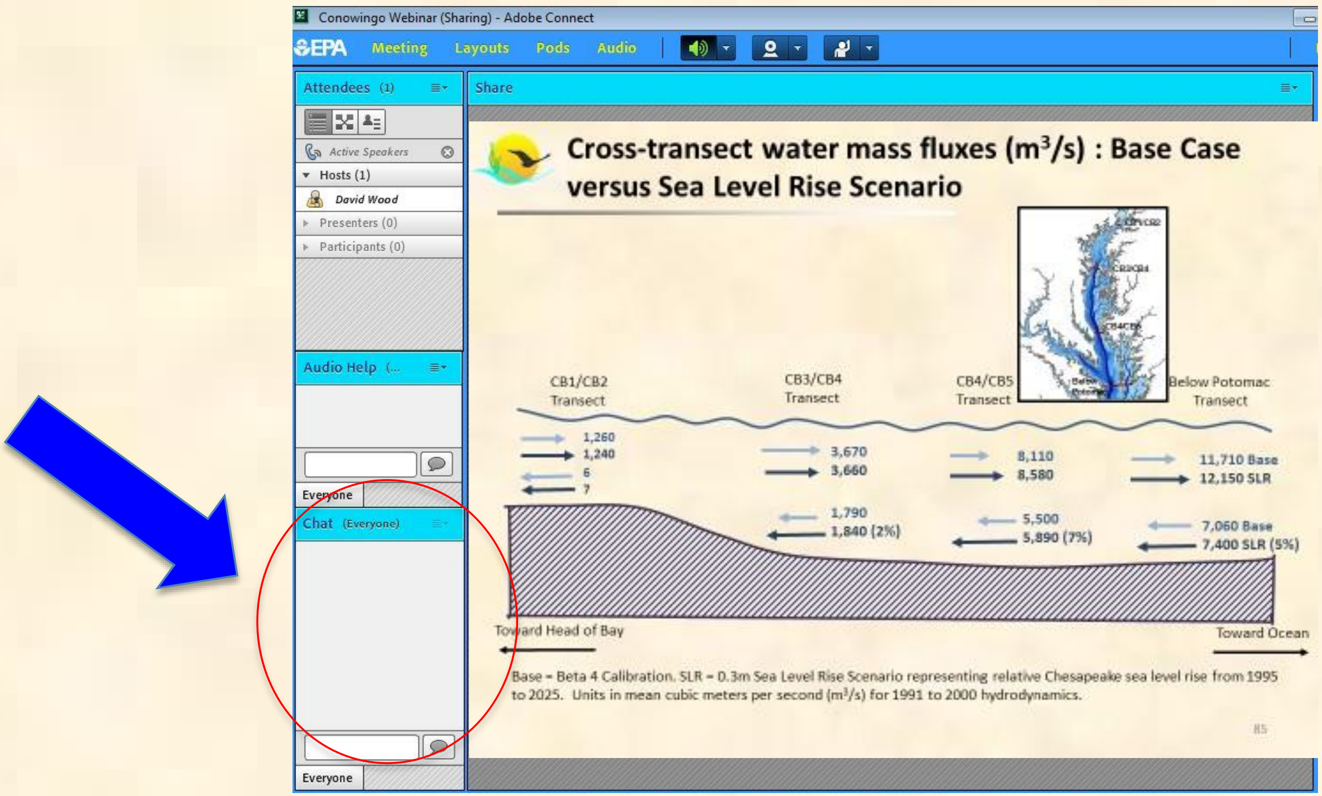
- Future work is oriented toward developing a range of climate change estimates to reflect different assumptions of rainfall intensity for 2025 estimates and different future estimated greenhouse gas concentrations (Representative Concentration Pathways (RCPs)) for 2050.

Further Notes on Phase 6 Model Changes

- The 2017 Community Multiscale Air Quality Model (CMAQ) has an improved bidirectional flux of ammonia for the first time and has demonstrable improvements in calibration over the 2010 version of CMAQ used previously.
- The WQSTM has full representation of shoreline nutrient loads, improved simulation of particulate organic reactivity throughout, representation of attenuation by tidal wetland of nutrient and sediment loads in the estuary and representation of the water quality influences of oyster aquaculture and sanctuaries.
- Independent peer reviews of the Phase 6 watershed and Bay models are underway. (The nationally applied CMAQ Model has a separate peer review process.)

Reminder:

- To Ask a Question
  - Submit your question in the chat box, located in the bottom left of the screen.



Questions and Answers Session

Kyle Hinson
Chesapeake Research Consortium
Modeling Workgroup Staff

Questions and Answers Session

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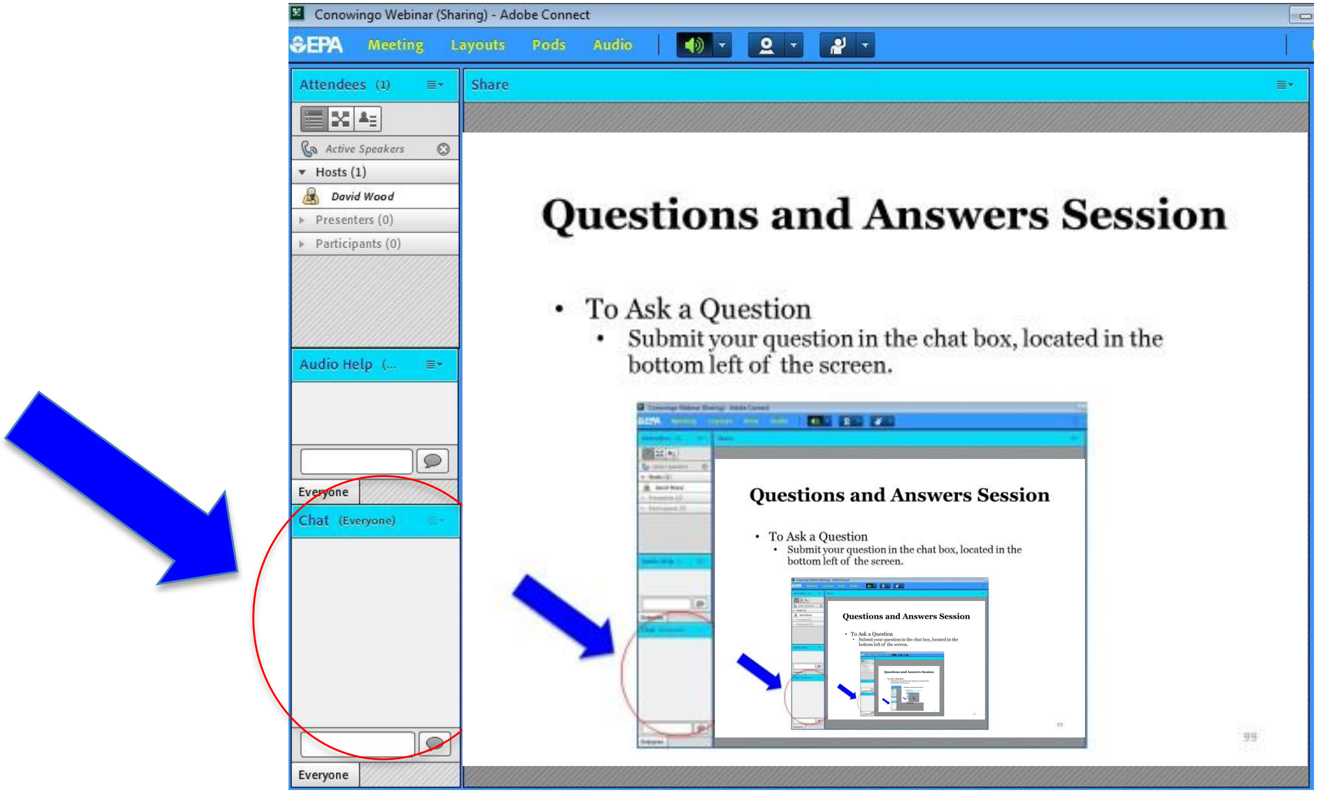

Access to Overview of the Integrated Air Watershed and Bay Models Webinar Recording

A recording of this webinar along with the presentation will be posted to the following page on the Chesapeake Bay Program Partnership's website:

Phase 6 Model Overview Webinar Calendar Page:
http://www.chesapeakebay.net/calendar/event/25114/

This webinar is one in a series of webinars:

Phase 6 Chesapeake Bay Model Poultry Data
May 24, 2017 1:00 – 3:00 pm
Adobe Connect: https://epawebconferencing.acms.com/mpawebinars
Webinar Calendar Page:
http://www.chesapeakebay.net/calendar/event/25117/
Webinar Lead: Matt Johnston
A webinar on the Phase 6 Chesapeake Bay Model, with an emphasis on poultry data.

Phase 6 Inputs Webinar
May 25, 2017 1:00 – 3:00 pm
Adobe Connect: https://epawebconferencing.acms.com/mpawebinars/
Webinar Calendar Page:
http://www.chesapeakebay.net/calendar/event/25087/
Webinar Lead: Matt Johnson
An informational webinar reviewing the inputs to the Phase 6 Chesapeake Bay Program suite of modeling tools.

Series of Phase 6 Review webinars *(continued)*:

Phase 6 Loads Webinar
June 1, 2017 1:00 – 3:00 pm
Adobe Connect: https://epawebconferencing.acms.com/mpawebinars
Webinar Calendar Page: http://www.chesapeakebay.net/calendar/event/25115/
Webinar Lead: Gary Shenk
The nutrient loading rates, how the rates are calculated and how the loading rates are modified due to sensitivities, and sediment.

Phase 6 Physical Transport Webinar
June 20, 2017 1:00 – 3:00 pm
Adobe Connect: https://epawebconferencing.acms.com/mpawebinars
Webinar Calendar Page: http://www.chesapeakebay.net/calendar/event/25116/
Webinar Leads: Gary Shenk and Gopal Bhatt
This webinar will review in detail the processes of riverine and small stream transport as well as the attenuation of nutrient and sediment loads.