Early Look at Key Scenarios, Conowingo Infill, and 2025 and 2050 Climate Change Analysis

Modeling Workgroup Quarterly Review
December 14, 2016

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and the CBPO Modeling Team

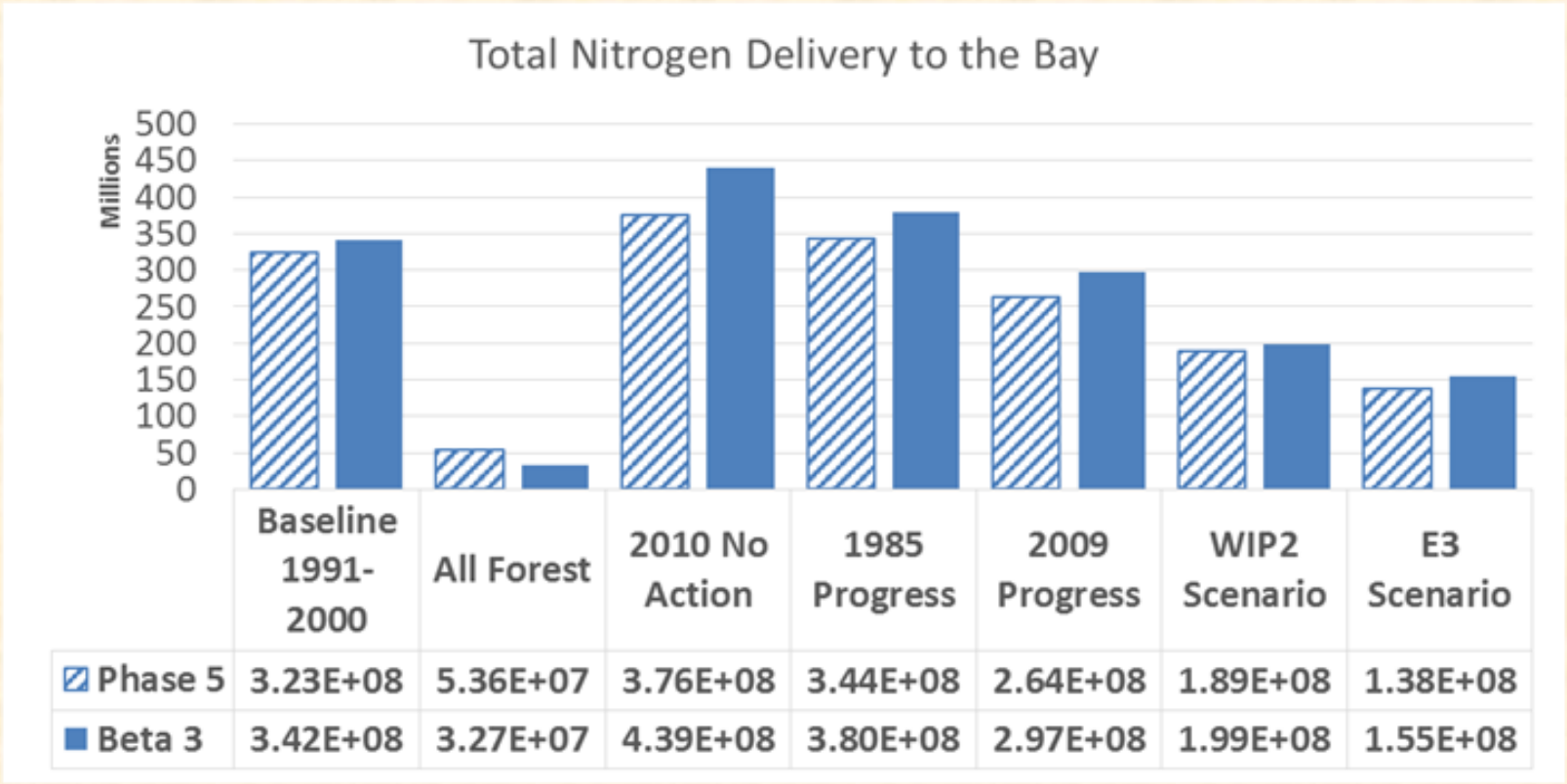
Chesapeake Bay Program
Science, Restoration, Partnership

Overview:

• Early review of key *Beta 3* scenarios of of No Action, 1985 Progress, 2009 Progress, WIP2 Level of Effort, E3, and All Forest.

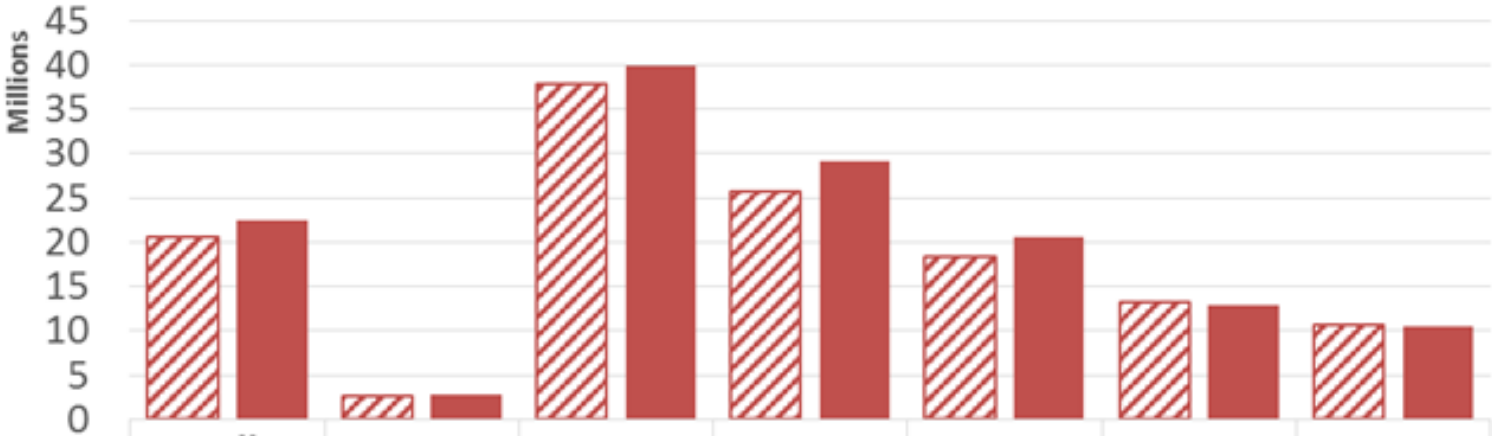
• Preliminary estimates of the influence of Conowingo infill on Chesapeake water quality based on an assessment of decreased net trapping under all flows.

• Preliminary estimates of 2025 & 2050 climate change influence on Chesapeake water quality.



	Baseline 1991-2000	All Forest	2010 No Action	1985 Progress	2009 Progress	WIP2 Scenario	E3 Scenario
Phase 5	3.23E+08	5.36E+07	3.76E+08	3.44E+08	2.64E+08	1.89E+08	1.38E+08
Beta 3	3.42E+08	3.27E+07	4.39E+08	3.80E+08	2.97E+08	1.99E+08	1.55E+08

Total Phosphorus Delivery to the Bay



	Baseline 1991-2000	All Forest	2010 No Action	1985 Progress	2009 Progress	WIP2 Scenario	E3 Scenario
Phase 5	2.06E+07	2.59E+06	3.79E+07	2.57E+07	1.83E+07	1.32E+07	1.06E+07
Beta 3	2.25E+07	2.83E+06	3.99E+07	2.91E+07	2.05E+07	1.29E+07	1.04E+07

Phase 6 Beta 3		Base 349TN 20.8TP 10.9TSS	All Forest 32.7TN 2.83TP	No Action 439TN 39.9TP	1985 Progress 380TN 29.1TP	2009 Progress 297TN 20.5TP	WIP2 199TN 12.9TP	E3 155 TN 10.4TP
		1993-1995	1993-1995	1993-1995	1993-1995	1993-1995	1993-1995	1993-1995
Cbseg	State	Deep Channel	Deep Channel	Deep Channel	Deep Channel	Deep Channel	Deep Channel	Deep Channel
CB3MH	MD	16.0%	0.0%	27.7%	22.0%	13.0%	0.2%	0.0%
CB4MH	MD	46.0%	0.0%	59.5%	53.5%	42.2%	11.9%	0.8%
CB5MH	MD/VA	14.2%	0.0%	24.9%	20.3%	11.9%	0.0%	0.0%
CHSMH	MD	37.4%	0.0%	54.1%	41.5%	33.5%	8.7%	0.0%
POTMH	MD/VA	20.2%	0.0%	30.0%	25.8%	15.8%	0.0%	0.0%
POMMH	MD	20.4%	0.0%	30.2%	25.9%	15.9%	0.0%	0.0%
RPPMH	VA	19.0%	0.0%	34.4%	27.6%	15.0%	0.0%	0.0%
EASMH	MD	25.4%	0.0%	46.6%	35.2%	23.3%	7.1%	0.1%
MD5MH	MD	21.7%	0.0%	32.7%	27.0%	19.4%	0.0%	0.0%
VA5MH	VA	4.5%	0.0%	14.3%	11.6%	2.2%	0.0%	0.0%
PATMH	MD	24.8%	0.0%	59.9%	43.1%	7.0%	0.0%	0.0%

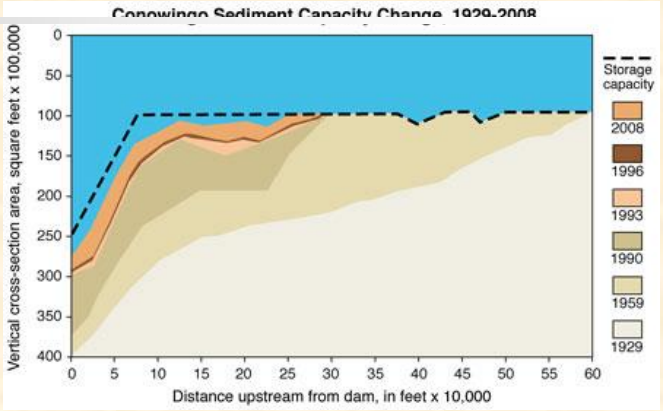
Phase 5.3.2		Base 323TN 20.6TP	All Forest 53.6TN 2.6TP	No Action 376TN 37.9TP	1985 Progress 344TN 25.7P	2009 Progress 264TN 18.3TP	WIP2 189TN 13.2TP	E3 138TN 10.6TP
		1993-1995	1993-1995	1993-1995	1993-1995	1993-1995	1993-1995	1993-1995
Cbseg	State	Deep Channel	Deep Channel	Deep Channel	Deep Channel	Deep Channel	Deep Channel	Deep Channel
CB3MH	MD	16.0%	0.0%	22.0%	19.2%	7.3%	0.2%	0.0%
CB4MH	MD	46.0%	0.0%	52.8%	49.1%	26.4%	2.9%	0.0%
CB5MH	MD/VA	14.2%	0.0%	20.0%	16.7%	0.6%	0.0%	0.0%
CHSMH	MD	37.4%	0.0%	41.5%	37.4%	35.6%	16.6%	2.3%
POTMH	MD/VA	20.2%	0.0%	27.4%	22.7%	0.0%	0.0%	0.0%
POMMH	MD	20.4%	0.0%	27.6%	22.8%	0.0%	0.0%	0.0%
RPPMH	VA	19.0%	0.0%	28.1%	25.1%	0.0%	0.0%	0.0%
EASMH	MD	25.4%	0.0%	35.6%	27.5%	14.0%	1.6%	0.0%
MD5MH	MD	21.7%	0.0%	27.2%	23.8%	3.9%	0.0%	0.0%
VA5MH	VA	4.5%	0.0%	10.7%	7.4%	0.0%	0.0%	0.0%
PATMH	MD	24.8%	0.0%	49.1%	38.2%	11.5%	0.0%	0.0%

Phase 6 Beta 3		Base 349TN 20.8TP 10.9TSS	All Forest 32.7TN 2.83TP	No Action 439TN 39.9TP	1985 Progress 380TN 29.1TP	2009 Progress 297TN 20.5TP	WIP2 199TN 12.9TP	E3 155TN 10.4TP
Cbseg	State	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water
CB3MH	MD	2.1%	0.0%	8.3%	3.4%	1.3%	0.1%	0.0%
CB4MH	MD	21.0%	0.0%	34.3%	27.2%	17.3%	7.3%	2.8%
CB5MH	MD/VA	4.2%	0.0%	8.0%	5.8%	3.5%	1.4%	0.0%
CB6PH	VA	0.0%	0.0%	1.2%	0.6%	0.0%	0.0%	0.0%
CB7PH	VA	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
CHSMH	MD	25.7%	0.0%	42.4%	34.4%	24.8%	3.3%	0.0%
EASMH	MD	5.9%	0.0%	45.1%	34.5%	3.0%	0.5%	0.3%
PAXMH	MD	6.3%	0.0%	26.4%	15.5%	5.4%	0.0%	0.0%
POTMH	MD/VA	4.1%	0.0%	10.5%	6.5%	3.4%	0.2%	0.0%
POMMH	MD	4.1%	0.0%	10.6%	6.6%	3.4%	0.2%	0.0%
RPPMH	VA	5.9%	0.0%	15.7%	11.0%	4.8%	0.0%	0.0%
SBEMH	VA	0.0%	0.0%	24.5%	8.4%	0.0%	0.0%	0.0%
YRKPH	VA	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
MD5MH	MD	8.5%	0.0%	14.5%	10.9%	7.5%	3.2%	0.4%
VA5MH	VA	0.5%	0.0%	1.4%	1.0%	0.3%	0.0%	0.0%
PATMH	MD	12.4%	0.0%	38.3%	22.0%	3.6%	0.0%	0.0%
MAGMH	MD	51.0%	0.0%	57.1%	57.1%	43.2%	7.9%	1.9%
SOUMH	MD	18.6%	0.0%	29.2%	29.7%	16.9%	2.7%	3.0%
SEVMH	MD	6.1%	0.0%	32.4%	17.5%	6.1%	0.0%	0.0%

Phase 5.3.2		Base 323TN 20.6TP	All Forest 53.6TN 2.6TP	No Action 376TN 37.9TP	1985 Progress 344TN 25.7P	2009 Progress 264TN 18.3TP	WIP2 189TN 13.2TP	E3 138TN 10.6TP
Cbseg	State	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water	1993-1995 Deep Water
CB3MH	MD	2.1%	0.0%	3.4%	2.3%	0.7%	0.1%	0.0%
CB4MH	MD	21.0%	0.0%	27.0%	23.0%	11.2%	5.4%	0.9%
CB5MH	MD/VA	4.2%	0.0%	5.9%	4.9%	1.8%	0.4%	0.0%
CB6PH	VA	0.0%	0.0%	0.8%	0.3%	0.0%	0.0%	0.0%
CB7PH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHSMH	MD	25.7%	0.0%	35.8%	31.1%	12.6%	2.9%	0.0%
EASMH	MD	5.9%	0.0%	31.1%	13.9%	2.0%	0.8%	0.0%
PAXMH	MD	6.3%	0.0%	21.5%	11.6%	0.6%	0.0%	0.0%
POTMH	MD/VA	4.1%	0.0%	9.0%	5.1%	0.4%	0.0%	0.0%
POMMH	MD	4.1%	0.0%	9.1%	5.1%	0.4%	0.0%	0.0%
RPPMH	VA	5.9%	0.0%	11.3%	8.3%	0.1%	0.0%	0.0%
SBEMH	VA	0.0%	0.0%	5.0%	3.4%	0.0%	0.0%	0.0%
YRKPH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MD5MH	MD	8.5%	0.0%	11.3%	9.5%	4.1%	1.3%	0.0%
VA5MH	VA	0.5%	0.0%	0.8%	0.7%	0.0%	0.0%	0.0%
PATMH	MD	12.4%	0.0%	31.9%	19.0%	3.6%	0.0%	0.0%
MAGMH	MD	51.0%	0.0%	57.1%	51.0%	51.0%	9.5%	7.1%
SOUMH	MD	18.6%	0.0%	35.5%	22.8%	0.0%	0.0%	0.0%
SEVMH	MD	6.1%	0.0%	30.2%	6.1%	0.7%	0.0%	0.0%

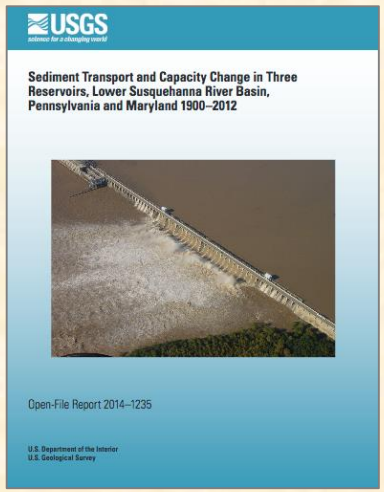
Brief Review of Conowingo Infill

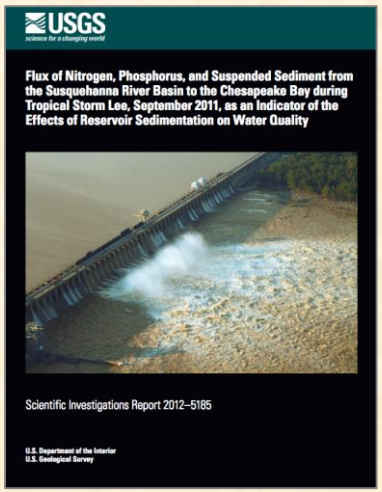
- Conowingo is nearing dynamic equilibrium, which has reduced its ability to trap sediment and nutrients.

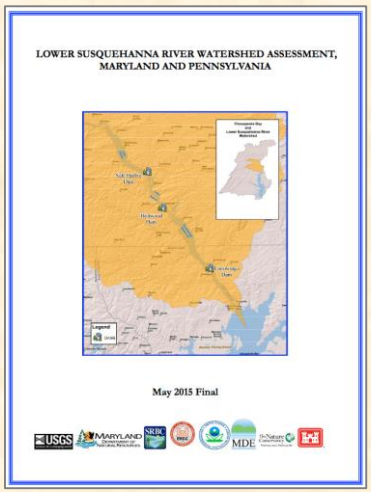


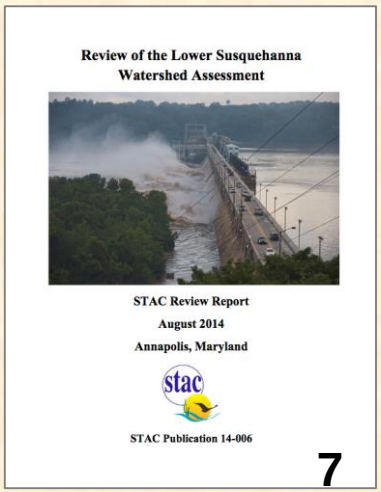
Source: Graph, Michael Langland, U.S. Geological Survey

- Several research articles have documented it, and they provide an analysis of changes in transport, which are incorporated in this analysis.

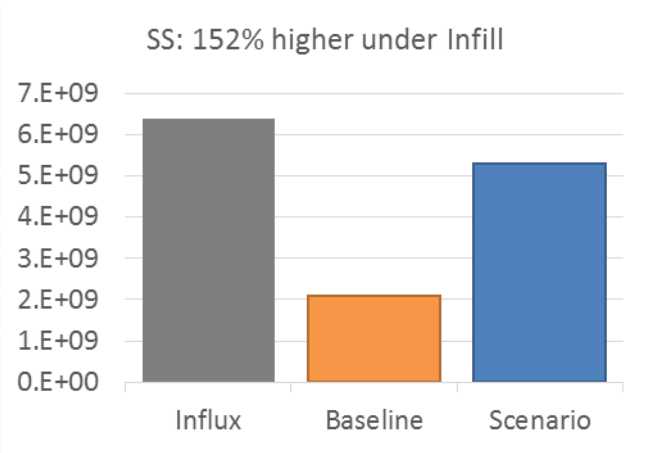


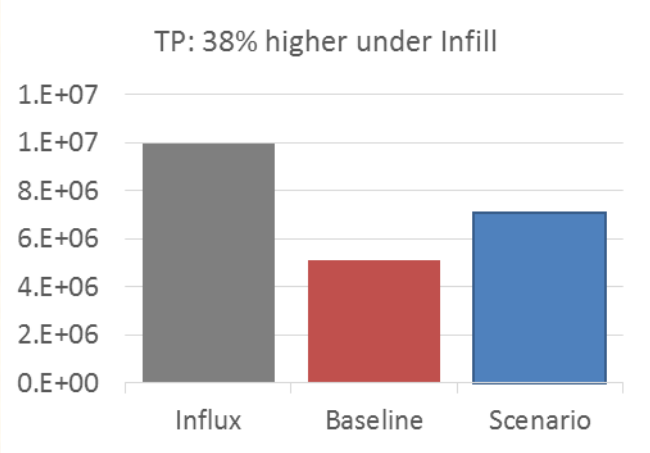




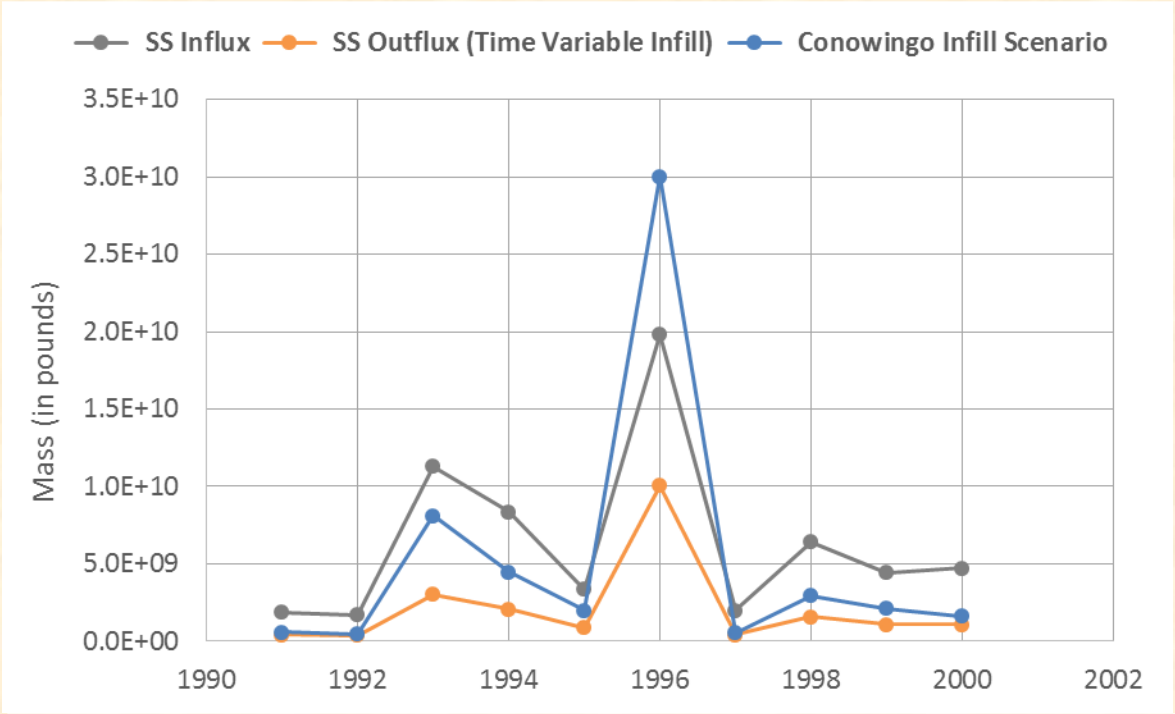


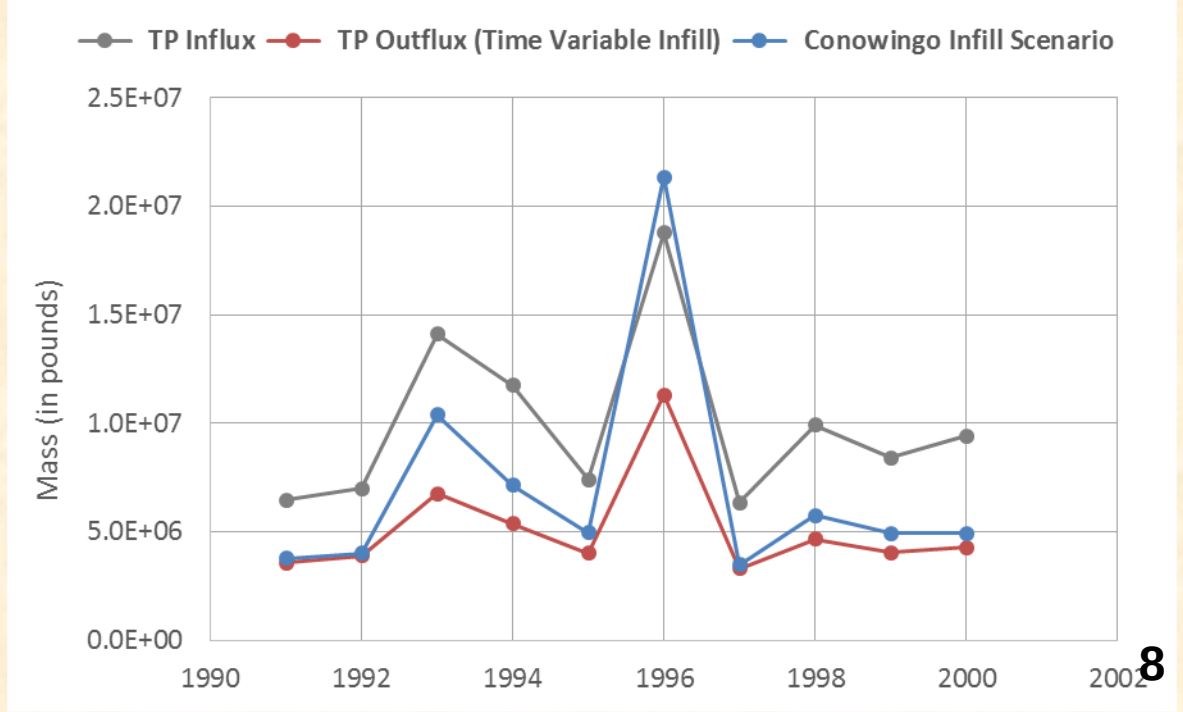
Conowingo Infill Scenario





less net deposition over the 10 years period as compared to





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%**

Beta 3 Estimated Deep Water Nonattainment Under Conowingo Infill Conditions:

CB Segment	State	Conowingo Base Case 1993_1995 Deep Water	Conowingo Infill Scenario 1993_1995 Deep Water	Increase in Nonattainment With Infill Deep Water
CB3MH	MD	2.1%	2.3%	0%
CB4MH	MD	21.0%	22.5%	2%
CB5MH	MD/VA	4.2%	4.5%	0%
CB6PH	VA	0.0%	0.1%	0%
CB7PH	VA	0.0%	0.0%	0%
CHSMH	MD	25.7%	28.8%	3%
EASMH	MD	5.9%	12.8%	7%
PAXMH	MD	6.3%	8.5%	2%
POTMH	MD/VA	4.1%	4.5%	0%
POMMH	MD	4.1%	4.5%	0%
RPPMH	VA	5.9%	6.5%	1%
SBEMH	VA	0.0%	0.1%	0%
YRKPH	VA	0.0%	0.0%	0%
MD5MH	MD	8.5%	9.0%	0%
VA5MH	VA	0.5%	0.6%	0%
PATMH	MD	12.4%	13.8%	1%
MAGMH	MD	51.0%	51.0%	0%
SOUMH	MD	18.6%	22.6%	4%
SEVMH	MD	6.1%	6.4%	0%

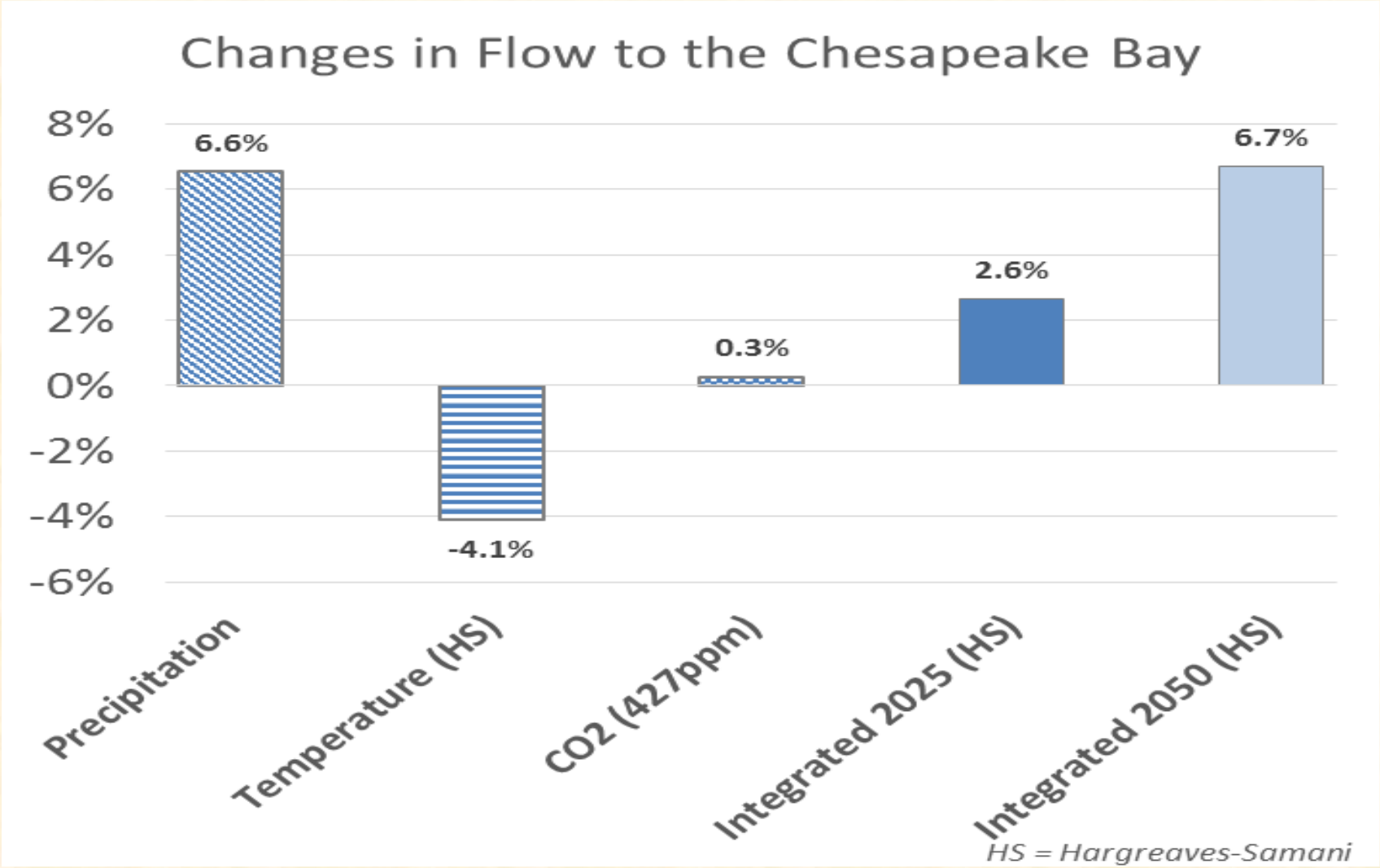
JEQ Estimated Deep Channel Nonattainment under Conowingo Infill Conditions

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.

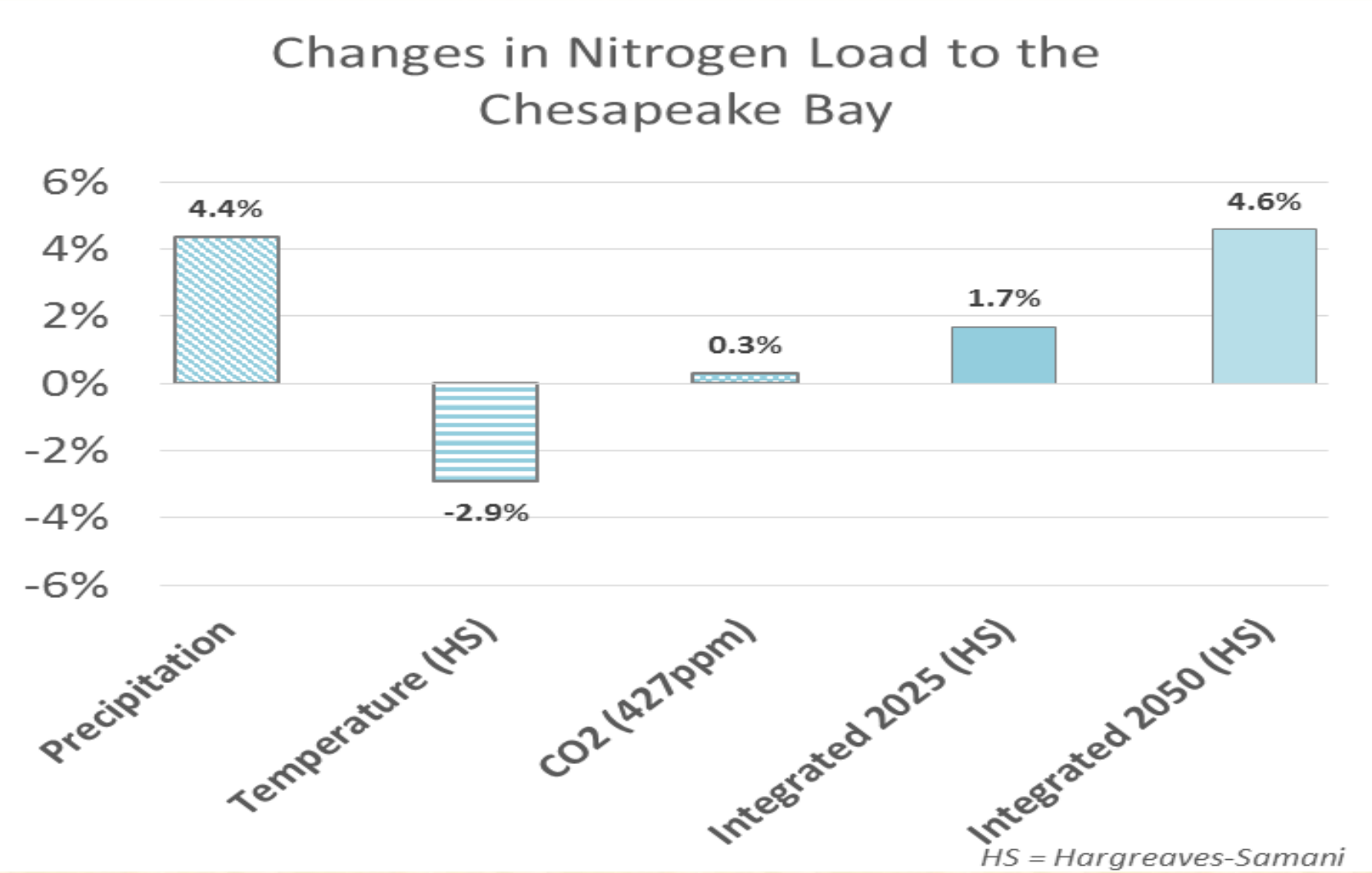
Scenario	1985 Scenario 160 TN 11.2 TP 5480 TSS	2010 Scenario 119 TN 8.8 TP 3790 TSS	TMDL WIP† Scenario 87 TN 6.8 TP 3030 TSS	All Forest Scenario 24 TN 1.2 TP 610 TSS	Increase of nonattainment under Conowingo scour conditions in January storm	Increase of nonattainment under January storm conditions compared with No Storm Scenario	Increase of nonattainment under June storm conditions compared with No Storm Scenario	Increase of nonattainment under Moderate High Flow conditions
CB segment	%							
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.

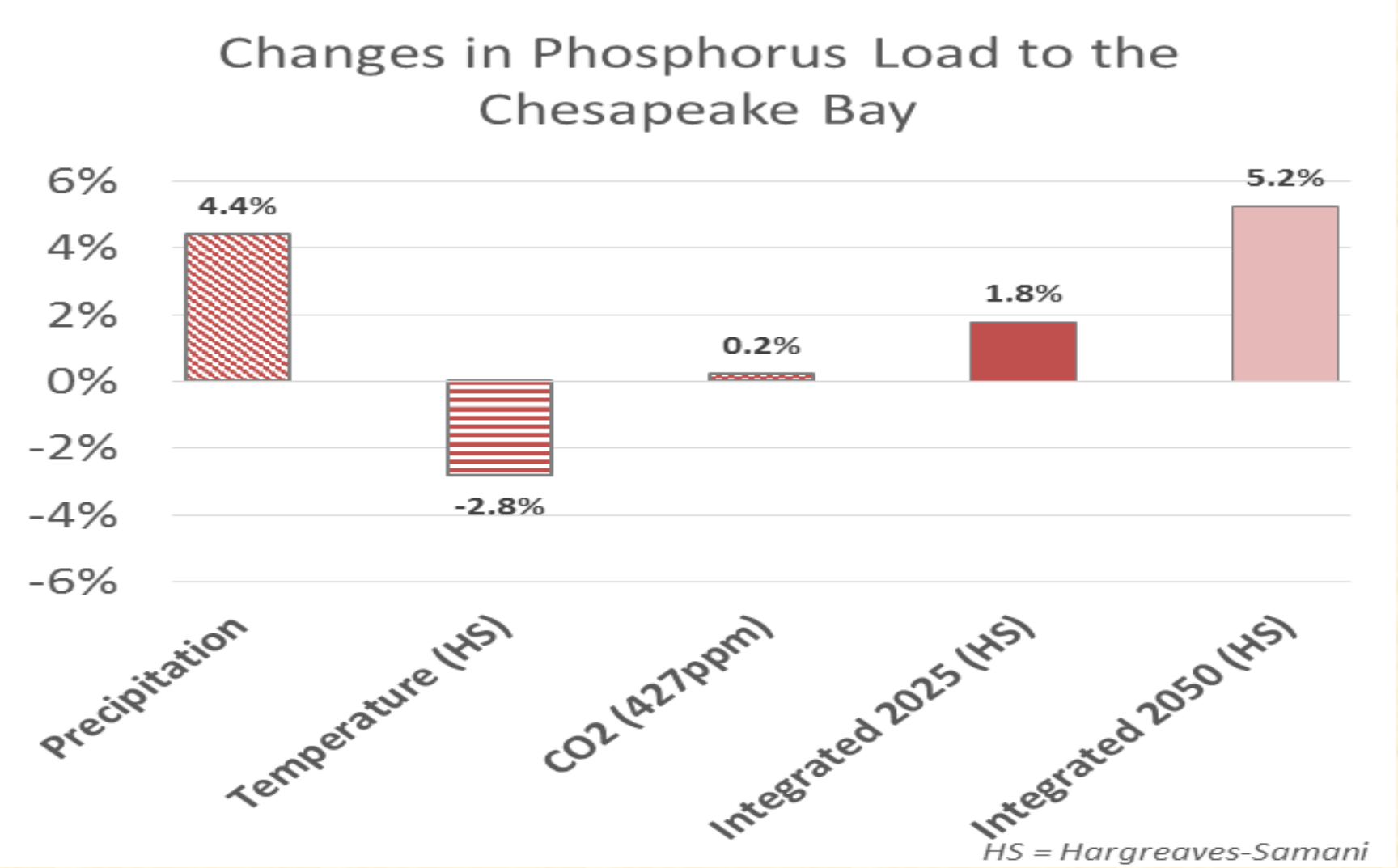
Climate Change 2025 Flow:



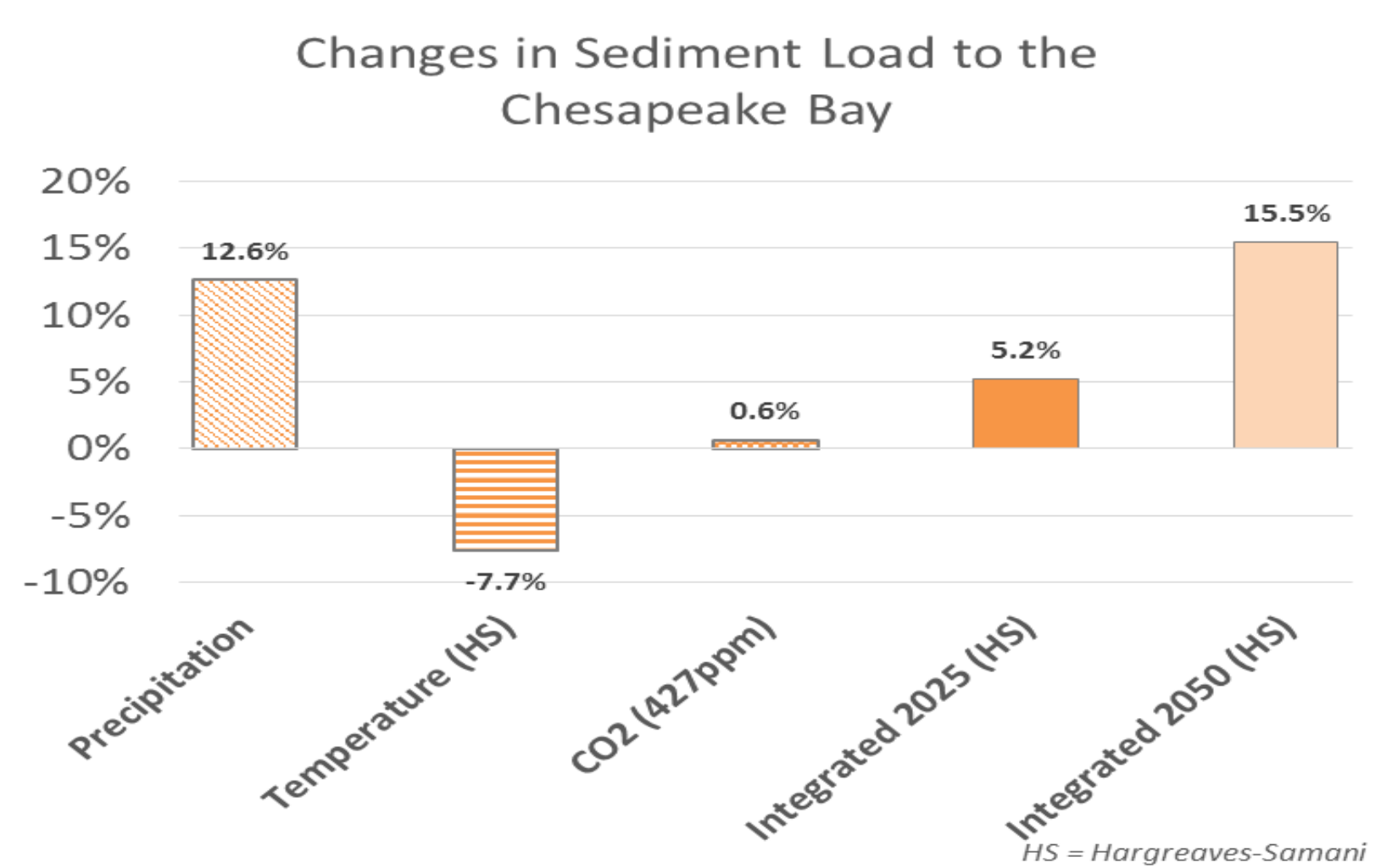
Climate Change 2025 Nitrogen:



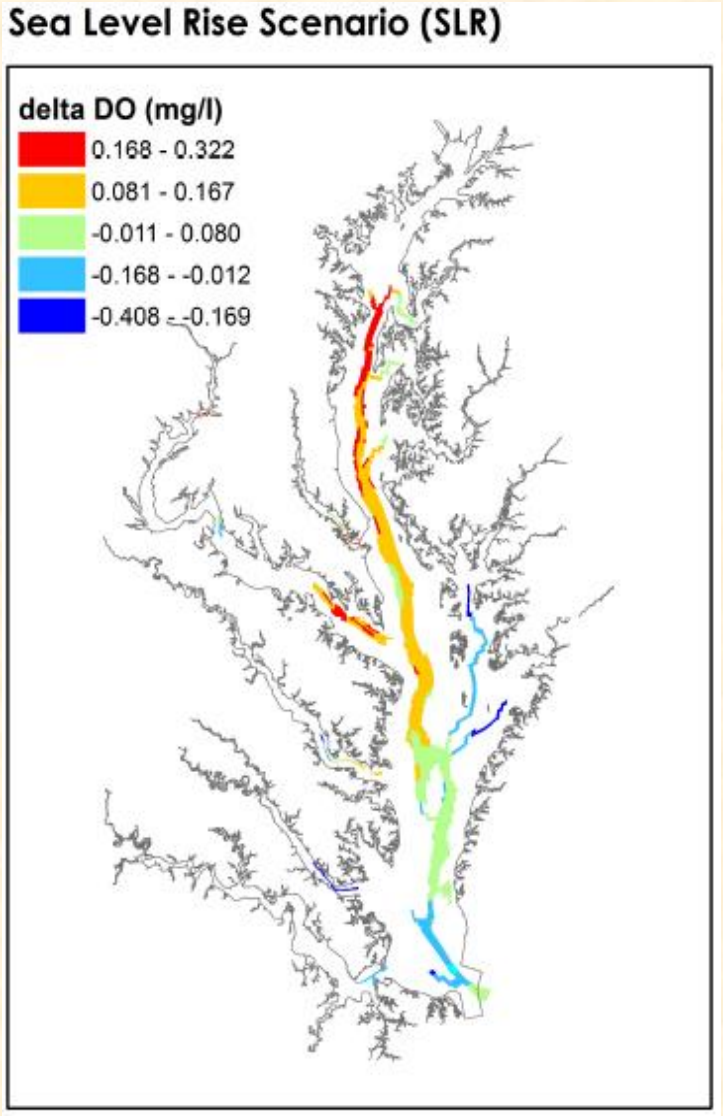
Climate Change 2025 Phosphorus:

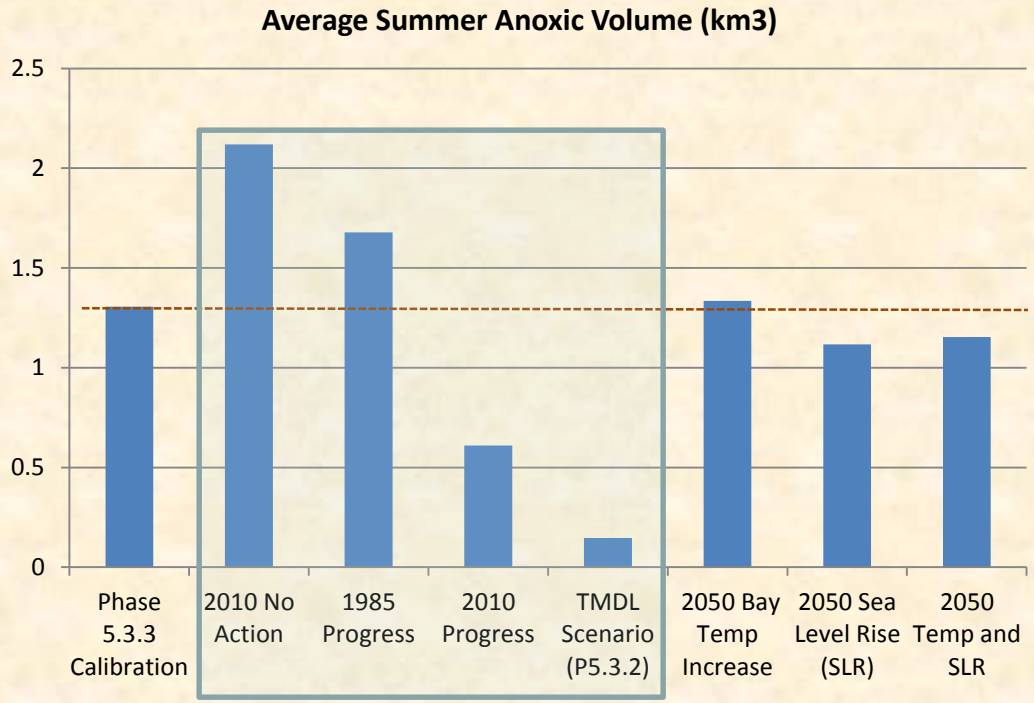


Climate Change 2025 Sediment:



Changes in Hydrodynamics due to Sea Level Rise





The influence of an 2050 estimated sea level rise on Chesapeake hypoxia is also relatively small.

The estimated delta in Chesapeake hypoxia due to 2050 estimated sea level rise ranges from 0.3 to -0.4 mg/l.

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

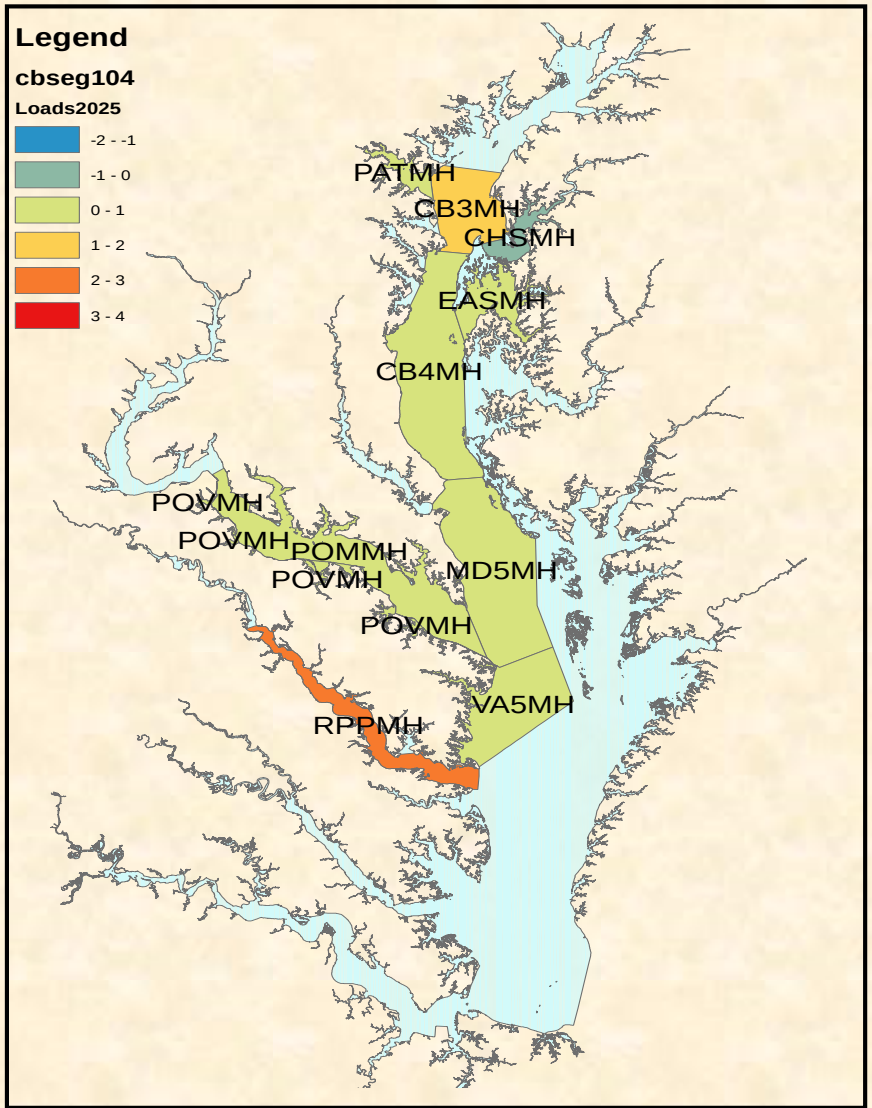
		Base Scenario 349TN 20.8TP 10.9TSS 1993-1995	2025 Climate Change Watershed Load 355TN 21.3TP 11.5TSS 1993-1995	2050 Climate Change Watershed Load 366TN 22.1TP 12.6TSS 1993-1995	2025 Watershed Load and Sea Level Rise (0.3m) 355TN 21.3TP 11.5TSS 1993-1995
CB Segment	State	Deep Channel	Deep Channel	Deep Channel	Deep Channel
CB3MH	MD	16.0%	17.1%	17.5%	17.0%
CB4MH	MD	46.0%	46.7%	48.0%	44.3%
CB5MH	MD/VA	14.2%	14.7%	15.7%	12.8%
CHSMH	MD	37.4%	37.4%	37.4%	37.2%
POTMH	MD/VA	20.2%	20.6%	21.7%	18.5%
POMMH	MD	20.4%	20.7%	21.8%	18.6%
RPPMH	VA	19.0%	21.7%	24.7%	22.4%
EASMH	MD	25.4%	25.9%	26.7%	24.8%
MD5MH	MD	21.7%	22.2%	23.2%	20.0%
VA5MH	VA	4.5%	4.9%	6.0%	3.4%
PATMH	MD	24.8%	25.5%	29.1%	28.7%

CB Segment	State	Base Scenario 349TN 20.8TP 10.9TSS 1993-1995 Deep Water	2025 Climate Change Watershed Load 355TN 21.3TP 11.5TSS 1993-1995 Deep Water	2050 Climate Change Watershed Load 366TN 22.1TP 12.6TSS 1993-1995 Deep Water	2025 Watershed Load and Sea Level Rise (0.3m) 355TN 21.3TP 11.5TSS 1993-1995 Deep Water
CB3MH	MD	2.1%	2.2%	2.3%	2.0%
CB4MH	MD	21.0%	21.4%	22.4%	19.6%
CB5MH	MD/VA	4.2%	4.3%	4.6%	3.6%
CB6PH	VA	0.0%	0.0%	0.1%	0.0%
CB7PH	VA	0.0%	0.0%	0.0%	0.0%
CHSMH	MD	25.7%	25.7%	29.7%	25.7%
EASMH	MD	5.9%	7.2%	12.6%	5.4%
PAXMH	MD	6.3%	6.8%	8.4%	6.8%
POTMH	MD/VA	4.1%	4.2%	4.5%	4.0%
POMMH	MD	4.1%	4.3%	4.5%	4.0%
RPPMH	VA	5.9%	6.2%	6.8%	6.1%
SBEMH	VA	0.0%	0.2%	2.5%	2.0%
YRKPH	VA	0.0%	0.0%	0.0%	0.0%
MD5MH	MD	8.5%	8.7%	9.1%	8.0%
VA5MH	VA	0.5%	0.5%	0.6%	0.1%
PATMH	MD	12.4%	12.4%	13.8%	14.4%
MAGMH	MD	51.0%	51.0%	51.0%	51.0%
SOUMH	MD	18.6%	18.6%	18.9%	18.6%
SEVMH	MD	6.1%	6.1%	6.1%	6.1%

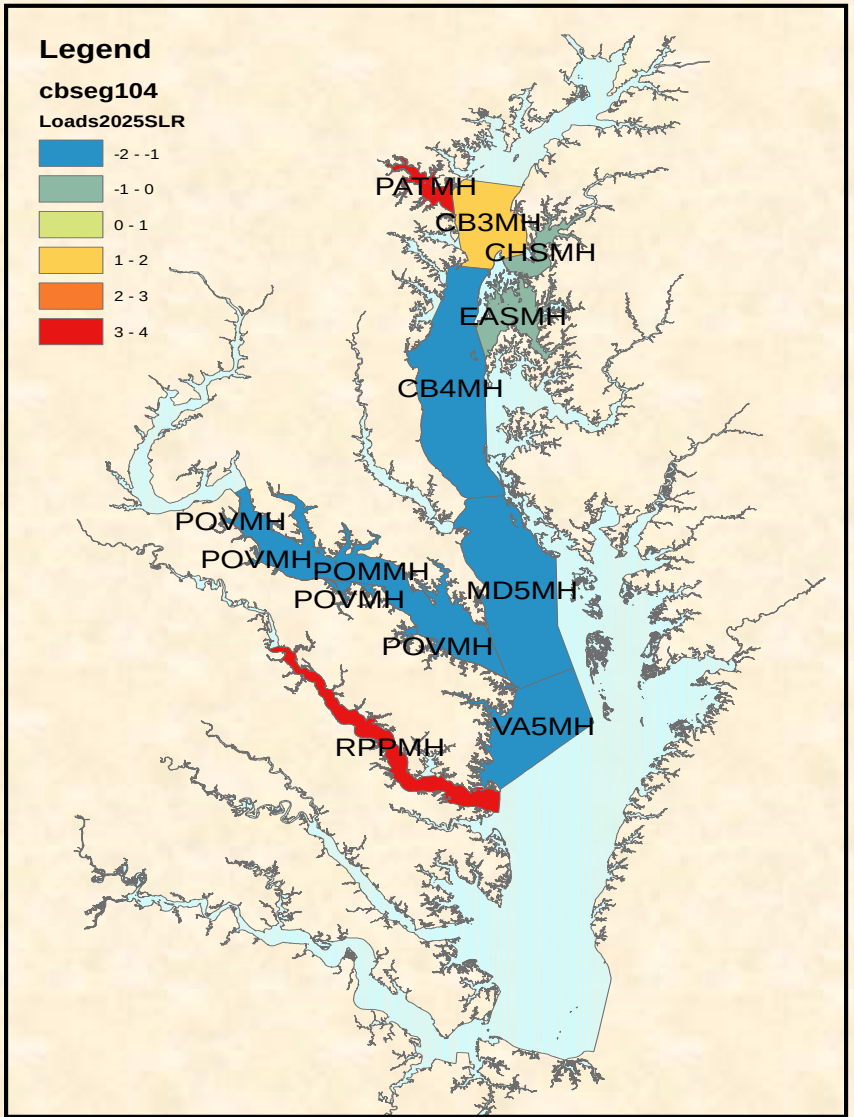
Estimated 2025 Changes in Deep Channel Nonattainment

With estimated 2025 watershed loads, which increased by 2% for both nitrogen and phosphorus, DO attainment degraded by <1% in the lower and middle portion of the mainstem, but by 1-2% in CB3 in the upper Bay and by 2-3% in Rappahannock. With estimated 2025 load and sea level rise (0.3m) combined, DO attainment improved by 1-2% in the low and middle portion of the mainstem, but degraded by 1-2% in CB3 in the upper Bay and by 3-4% in the Patuxent and Rappahannock mesohaline regions.

2025 nutrient load only



2025 nutrient load and 0.3 m sea level rise



Initial, Preliminary Conclusions:

- The Beta 3 version of the 2017 CBP Models has findings consistent with the 2010 CBP Models.
- The current best estimates of the increase in net transport of phosphorus loads to the Chesapeake is about 1.95 million pounds which results in an estimated 1-3% increase in nonattainment of the Deep Channel DO water quality standard.
- The current best estimate of the increase in nitrogen and phosphorus loads to the Chesapeake due to estimated 2025 climate induced changes to hydrology is 2% watershed wide for both nutrients. The detrimental influence of increased nutrient loads will be somewhat offset in 2025 by sea level rise and a Bay more open to the ocean.

Next Steps:

- Apply improved *Beta* 4 estimates of Conowingo infill and climate change in January 2017.
- Complete 2017 Midpoint Assessment analysis system in April 2017 for final review and application by Bay Program partners.