Initial Applications of the Draft Phase 6 Watershed Model – Climate Change

CHAMP – Aug 2017

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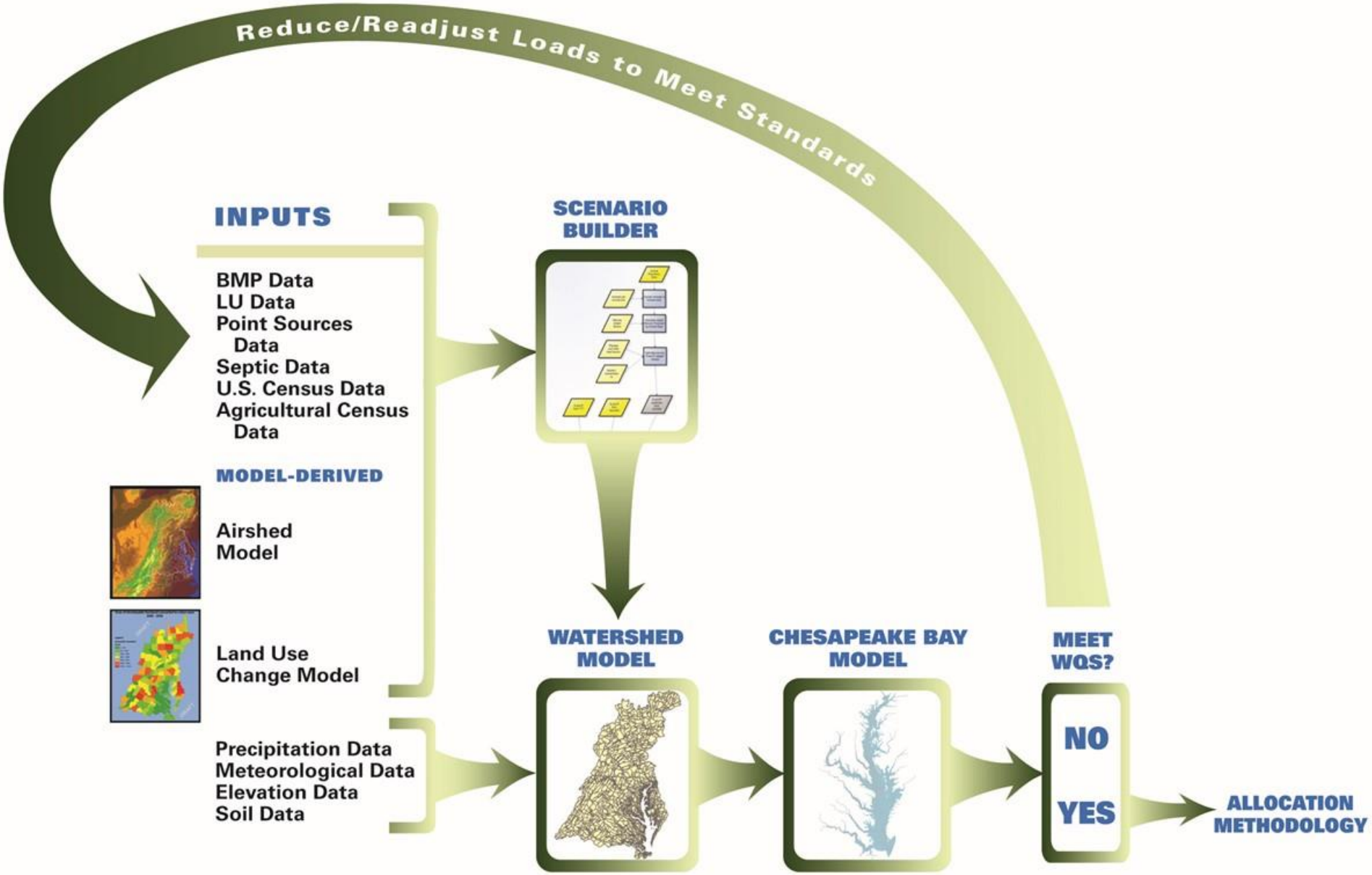
Chesapeake Bay Partnership Models







Phase 6 Model Structure

Average Load + ΔInputs * Sensitivity

*

Land Use Acres

*

BMPs

*

Land to Water

*

Stream Delivery

*

River Delivery

Direct Loads

Phase 6

Keep It Simple

Include Everything

Average Load + ΔInputs * Sensitivity

*

Land Use Acres

*

BMPs

*

Land to Water

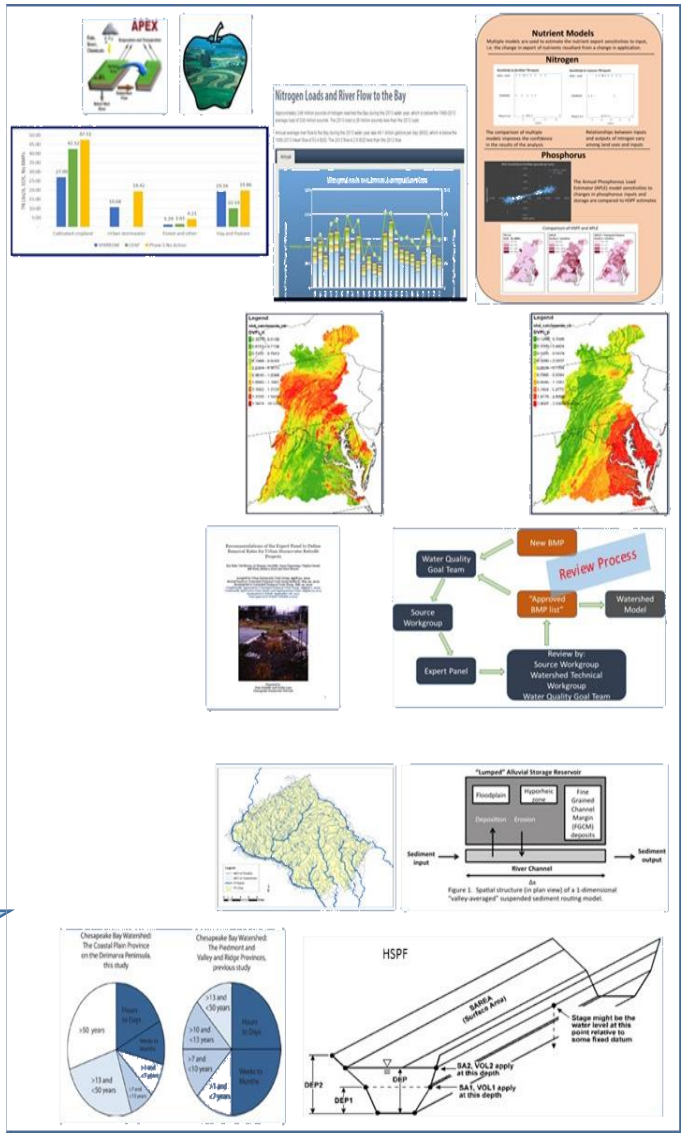
*

Stream Delivery

*

River Delivery

Direct Loads

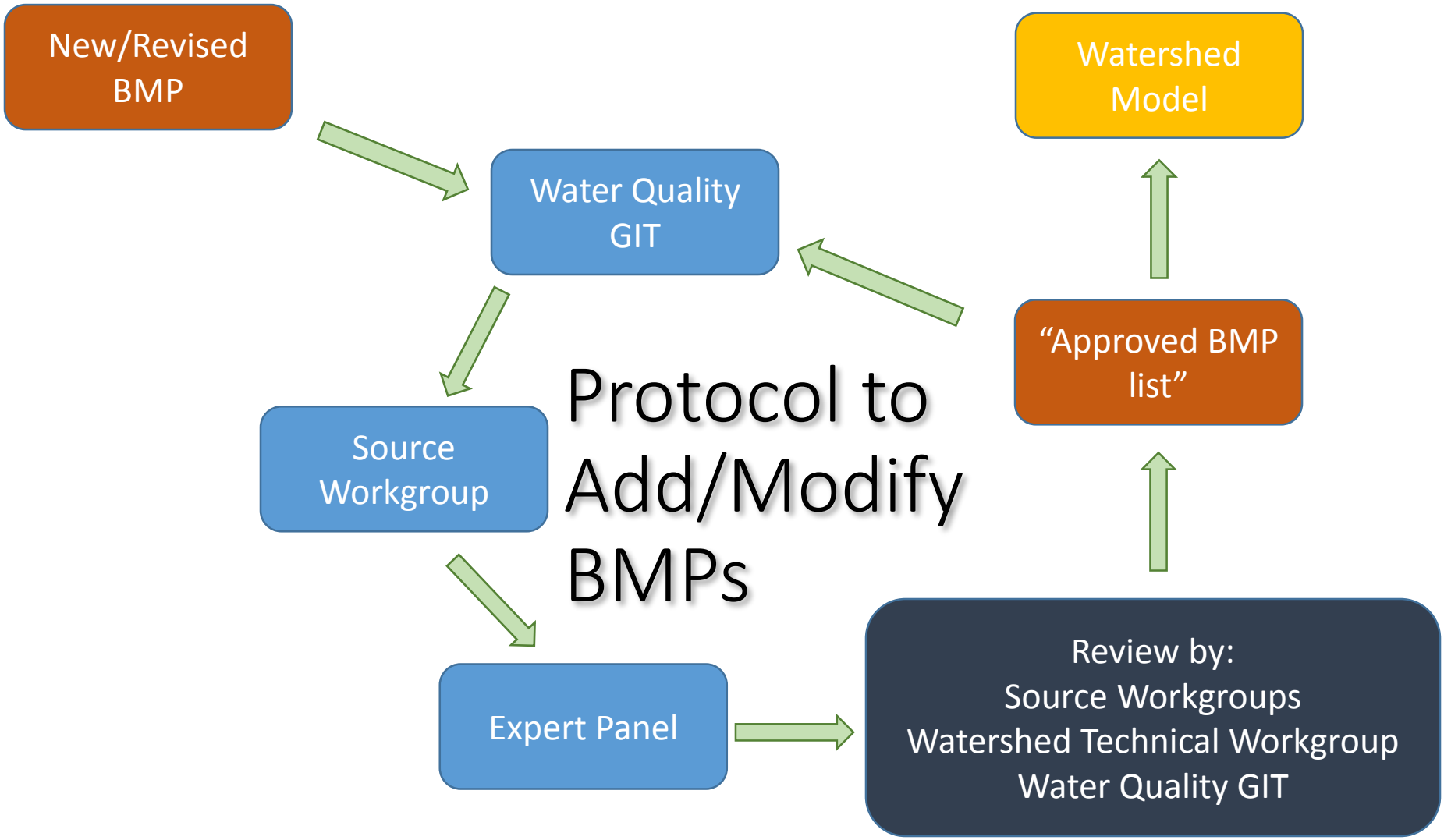


Use of Multiple Models
for Nitrogen Export Rate

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

Chesapeake Bay Program
A Watershed Partnership

Collaborative Stakeholder Processes



Keep It Simple

Include Everything

Average Load + ΔInputs * Sensitivity

*

Land Use Acres

*

BMPs

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Land to Water

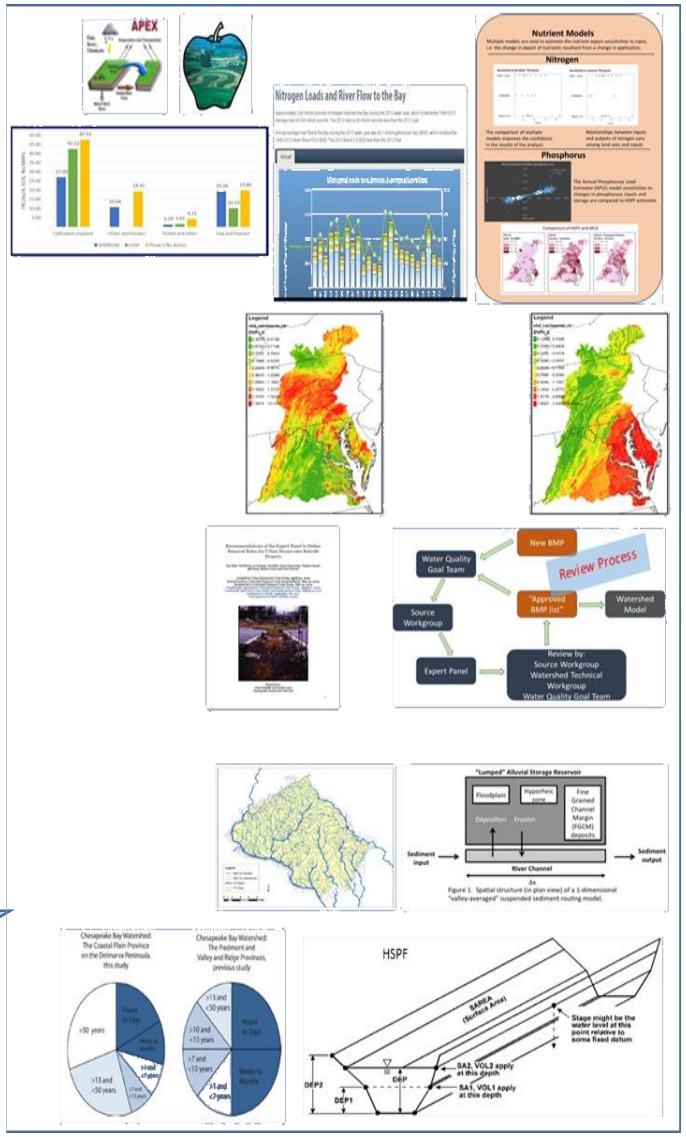
*

Stream Delivery

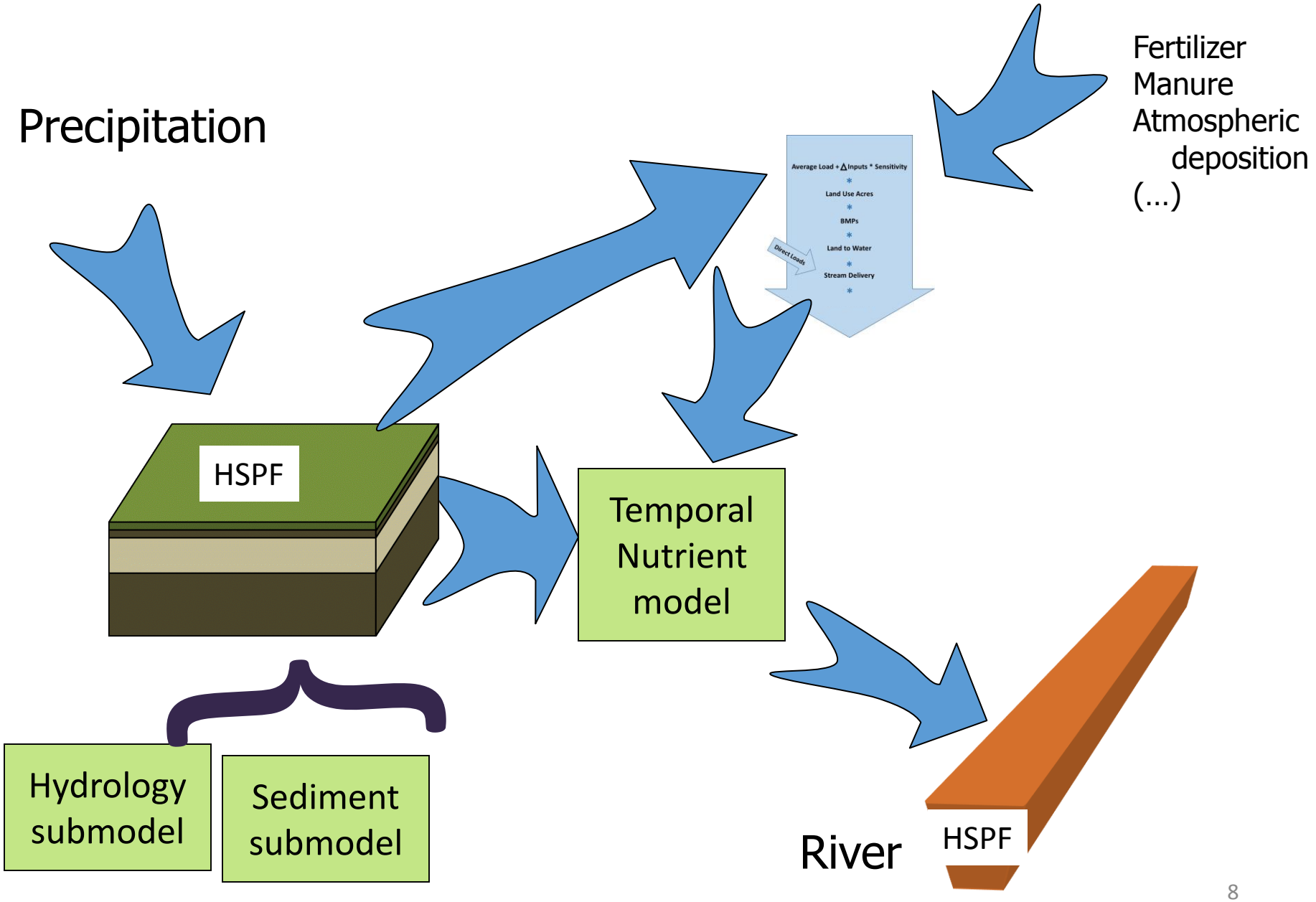
*

River Delivery

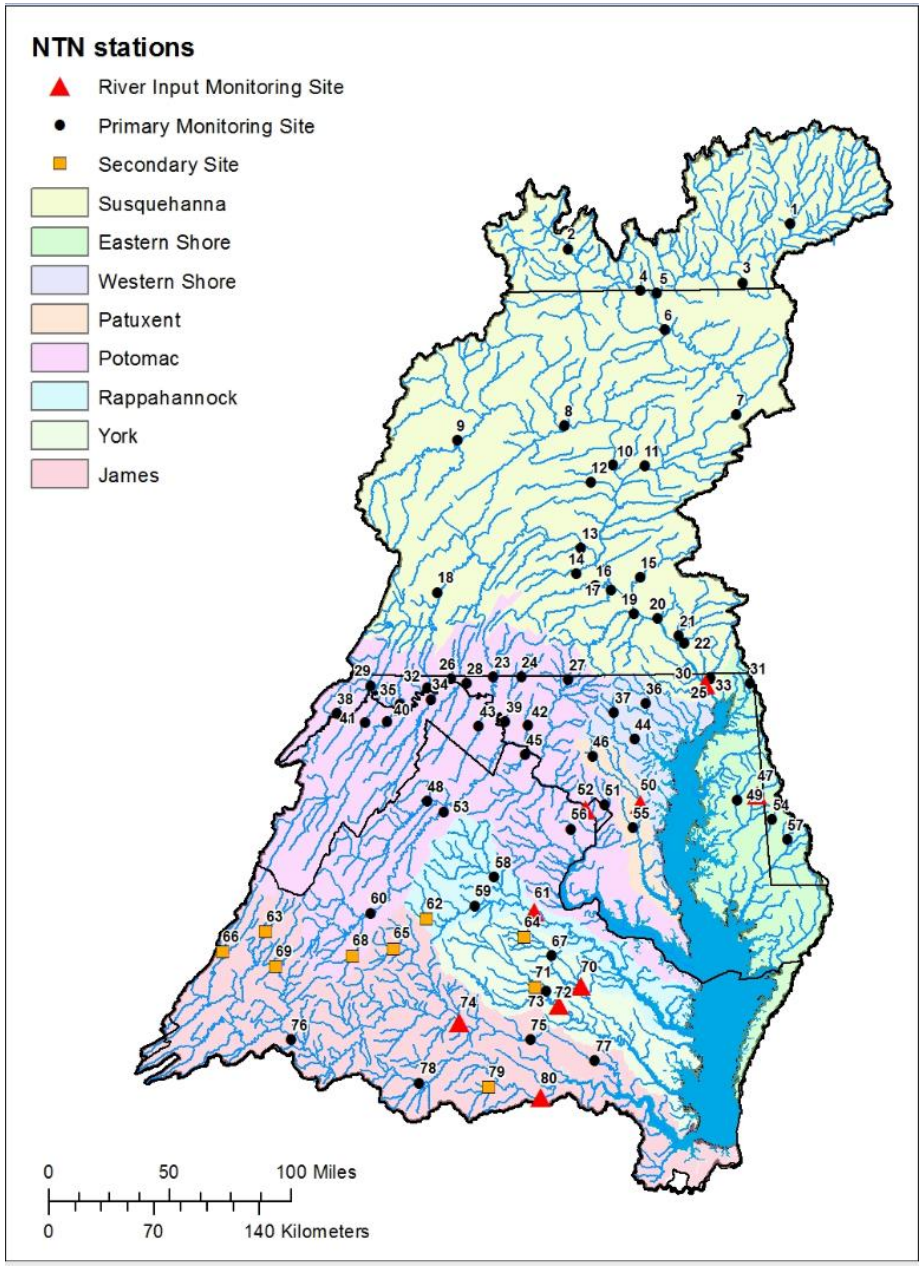
Direct Loads



Model to compare against Observations



Chesapeake Bay Nontidal Monitoring Network



- 1990s – begin widespread monitoring
- 2000s – create nontidal network
- Early 2010s – develop method to determine trends
- Mid-2010s – explain trends
  - BMPs
  - land use change
  - atmospheric deposition
  - lag times
  - natural factors





Phase 6 Model Structure

Average Load + Δ Inputs * Sensitivity

Climate Modeling

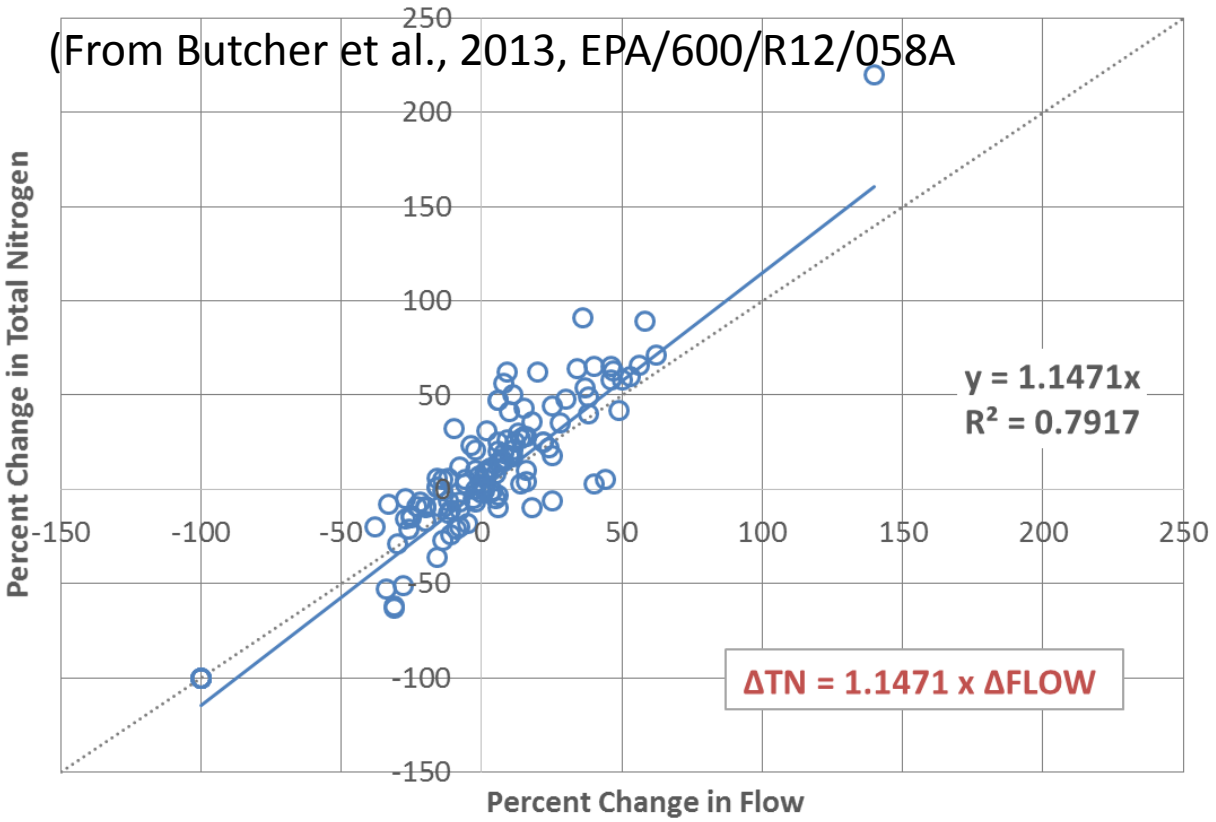




Phase 6 Model Structure

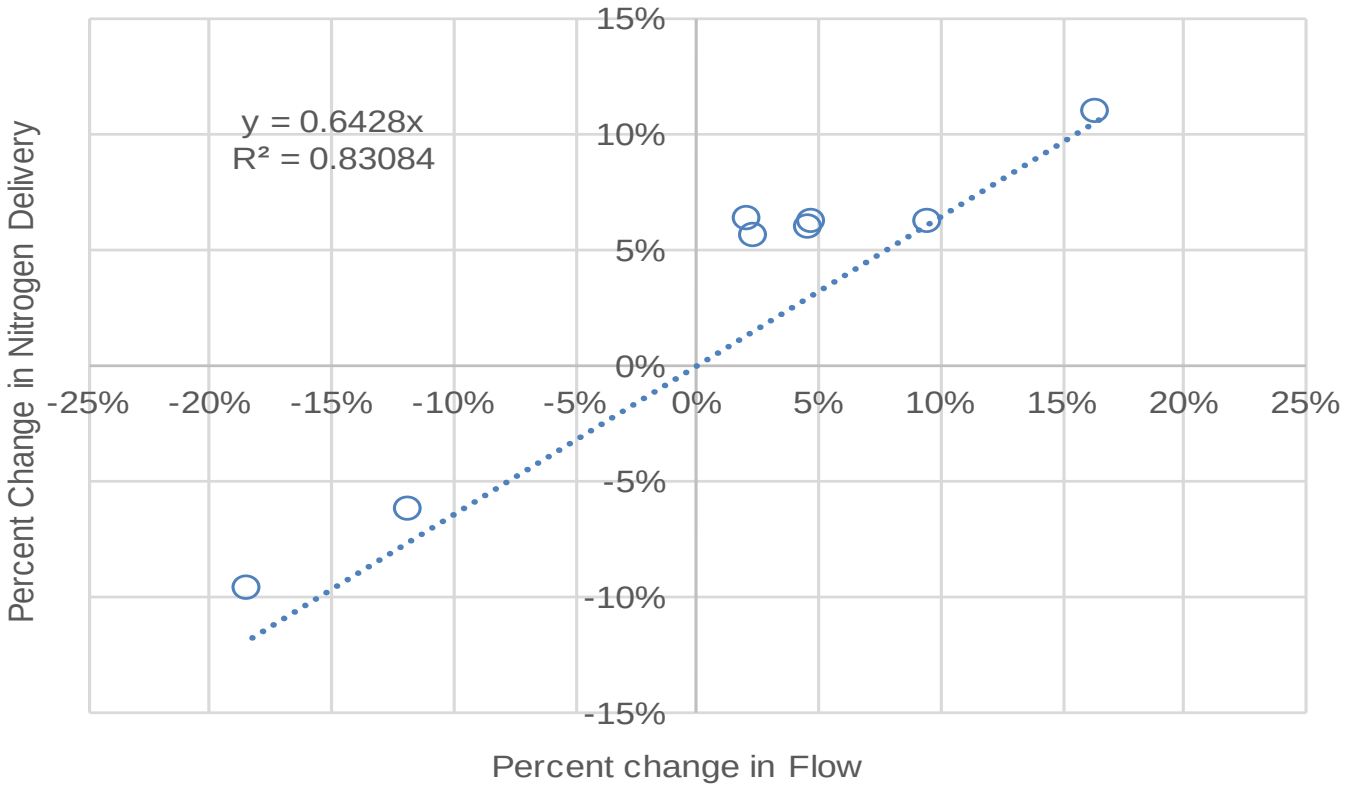
Average Load + ΔInputs * Sensitivity

(From Butcher et al., 2013, EPA/600/R12/058A



Phase 5.3.2

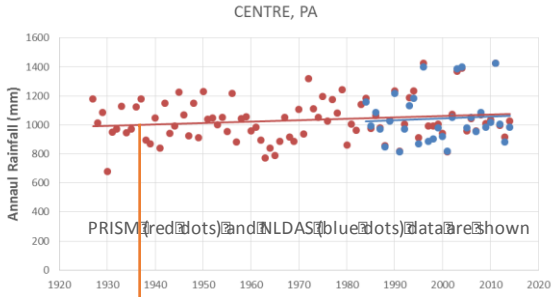
Year	Scenario	% Change in Flow	% Change in Nitrogen
2025	All Variables	2.5%	5.5%
	Rainfall Only	9.6%	6.1%
	Rainfall and Temperature	-11.7%	-6.4%
	Carbon Dioxide	4.7%	5.9%
2050	All Variables	2.3%	6.2%
	Rainfall Only	16.6%	10.9%
	Rainfall and Temperature	-18.3%	-9.7%
	Carbon Dioxide	4.9%	6.1%

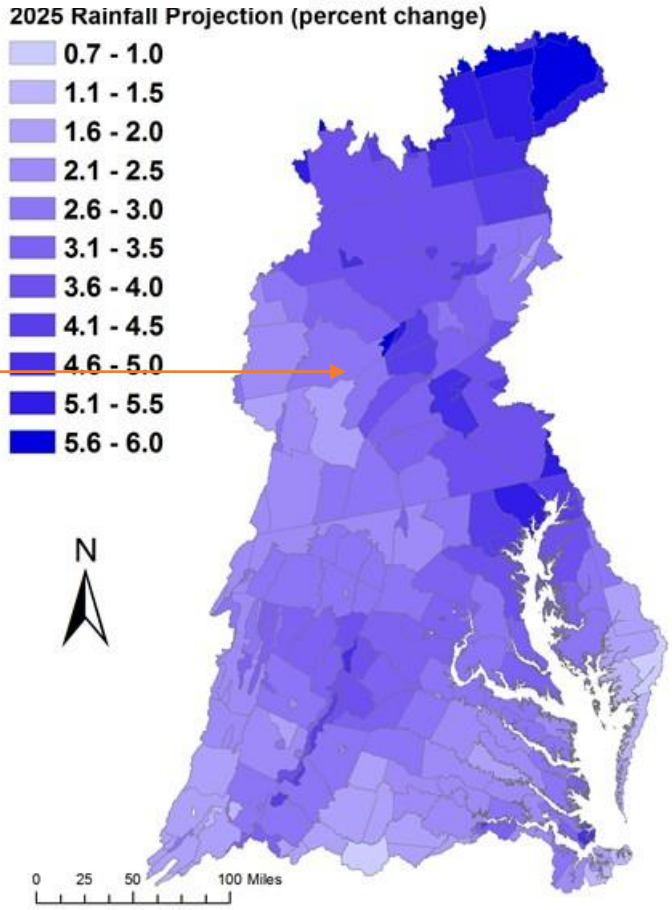


Climate Change Analysis

- The Draft Phase 6 watershed model was used to estimate the changes in the delivery of flow, nutrients and sediment with the 2025 projections of rainfall and temperature.
- For the 2025 rainfall projections, STAC has recommended the use of extrapolations of long-term historical trends. This is a 30-year extrapolation from 1995.
- For the changes in temperature an ensemble analysis of CMIP5 projections was recommended.

Rainfall projections using the trends in 88-years of annual PRISM[1] data





Change in Rainfall Volume 2021-2030 vs. 1991-2000

Major Basins	PRISM Trend
Youghiogheny River	2.1%
Patuxent River Basin	3.3%
Western Shore	4.1%
Rappahannock River Basin	3.2%
York River Basin	2.6%
Eastern Shore	2.5%
James River Basin	2.2%
Potomac River Basin	2.8%
Susquehanna River Basin	3.7%
Chesapeake Bay Watershed	**3.1%**

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[1] Parameter-elevation Relationships on Independent Slopes Model

An ensemble of GCM projections from BCSD CMIP5[1]

Data unavailable

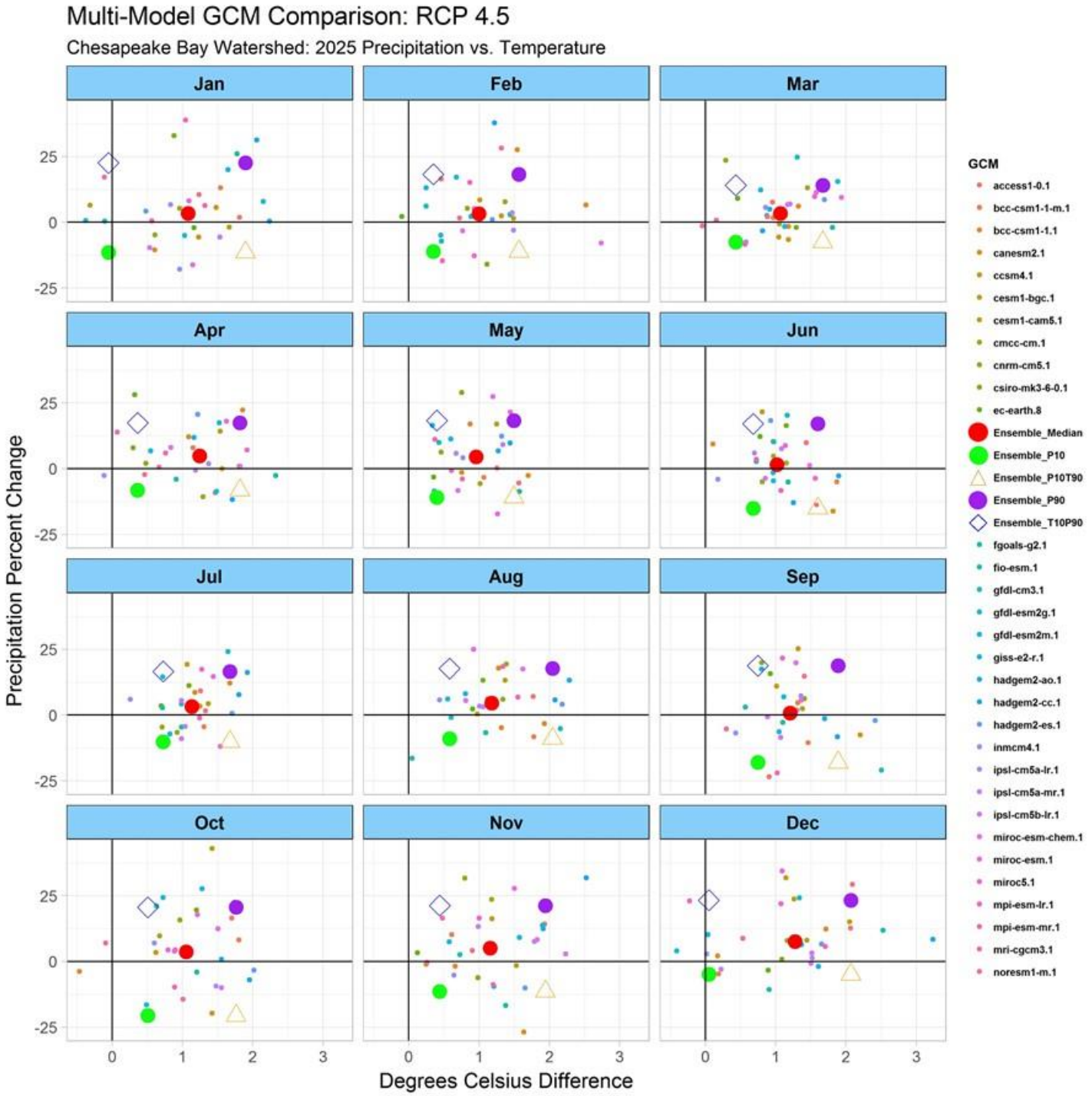
GCM Used

Updated Ensemble members		
ACCESS1-0	FGOALS-g2	IPSL-CM5A-LR
BCC-CSM1-1	FIO-ESM	IPSL-CM5A-MR
BCC-CSM1-1-M	GFDL-CM3	IPSL-CM5B-LR
BNU-ESM	GFDL-ESM2G	MIROC-ESM
CanESM2	GFDL-ESM2M	MIROC-ESM-CHEM
CCSM4	GISS-E2-H-CC	MIROC5
CESM1-BGC	GISS-E2-R	MPI-ESM-LR
CESM1-CAM5	GISS-E2-R-CC	**MPI-ESM-MR**
CMCC-CM	HadGEM2-AO	MRI-CGCM3
CNRM-CM5	HadGEM2-CC	NorESM1-M
CSIRO-MK3-6-0	HadGEM2-ES	
EC-EARTH	INMCM4	

31 member ensemble

Reclamation, 2013. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 47pp.

[1] BCSD – Bias Correction Spatial Disaggregation;
[1] CMIP5 – Coupled Model Intercomparison Project 5


Multi-Model GCM Comparison: RCP 4.5
Chesapeake Bay Watershed: 2025 Precipitation vs. Temperature
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Precipitation Percent Change
Degrees Celsius Difference
GCM
access1-0.1
bcc-csm1-1-m.1
bcc-csm1-1.1
canesm2.1
ccsm4.1
cesm1-bgc.1
cesm1-cam5.1
cmcc-cm.1
cnrm-cm5.1
csiro-mk3-6-0.1
ec-earth.8
Ensemble_Median
Ensemble_P10
Ensemble_P10T90
Ensemble_P90
Ensemble_T10P90
fgoals-g2.1
fio-esm.1
gfdl-cm3.1
gfdl-esm2g.1
gfdl-esm2m.1
giss-e2-r.1
hadgem2-ao.1
hadgem2-cc.1
hadgem2-es.1
inmcm4.1
ipsl-cm5a-lr.1
ipsl-cm5a-mr.1
ipsl-cm5b-lr.1
miroc-esm-chem.1
miroc-esm.1
miroc5.1
mpi-esm-lr.1
mpi-esm-mr.1
mri-cgcm3.1
noresm1-m.1

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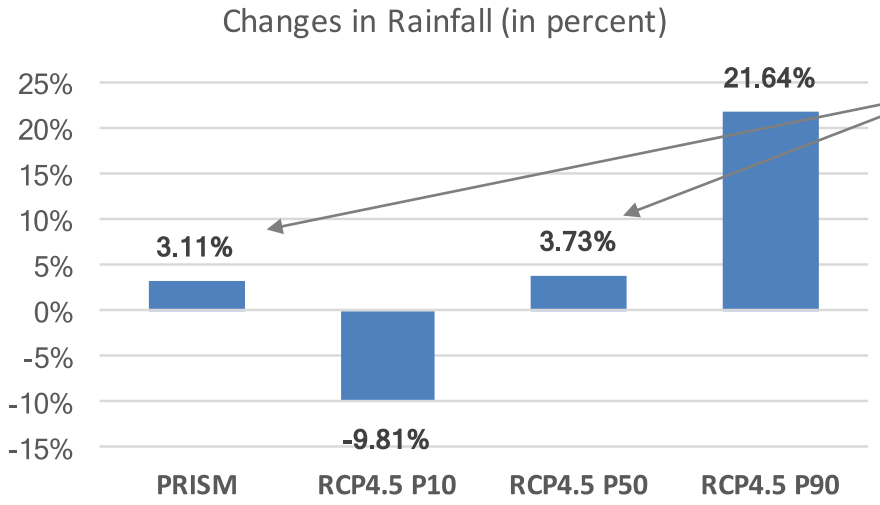
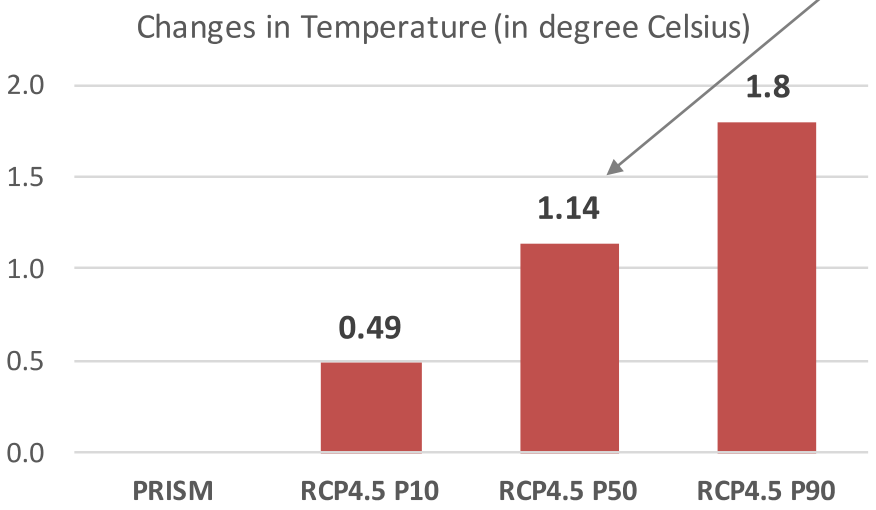
2025 climatic projections summary for Chesapeake Bay Watershed

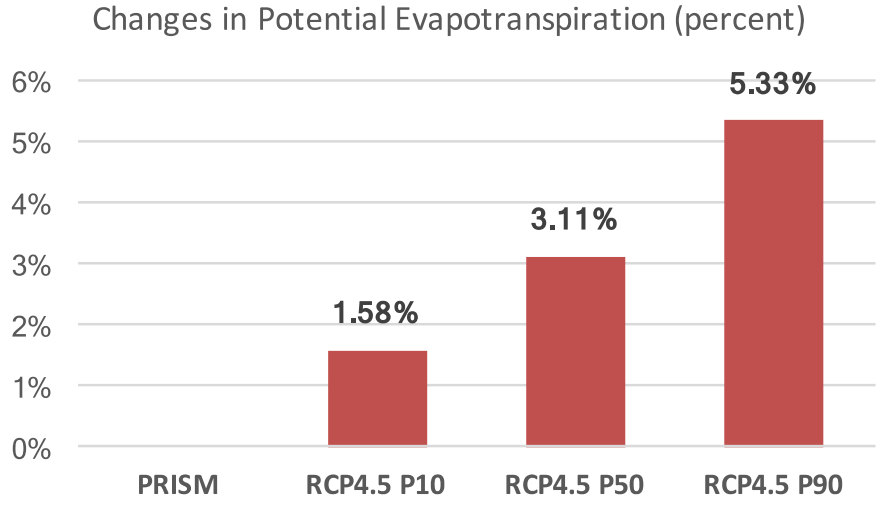


The central tendency of the projections for the changes in rainfall volume based on the 31 member ensemble median, P50, matches well with the extrapolation of PRISM's 88-year trends.

The rainfall uncertainty bounds (P10 and P90) of the ensemble members show wide range.

The central tendency of the temperature increase is potentially bit higher.





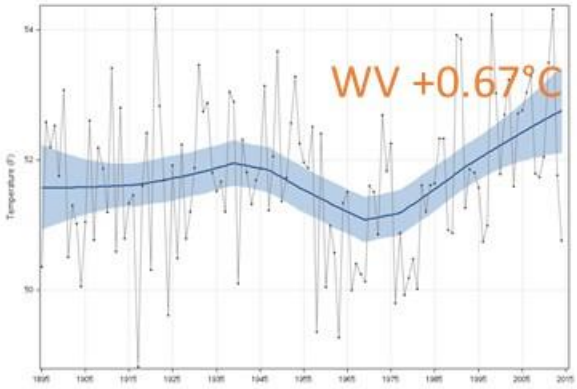
Temperature trends for the six states

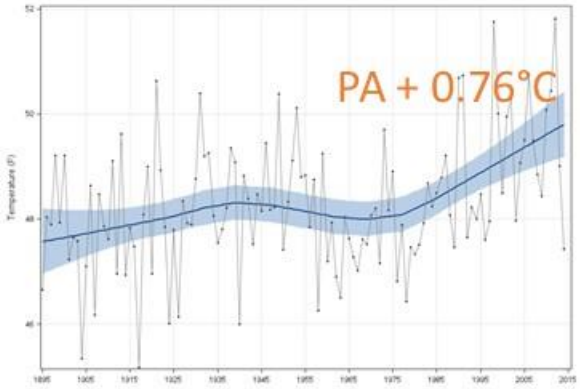
Annual temperature for 1895 to 2015 are shown.

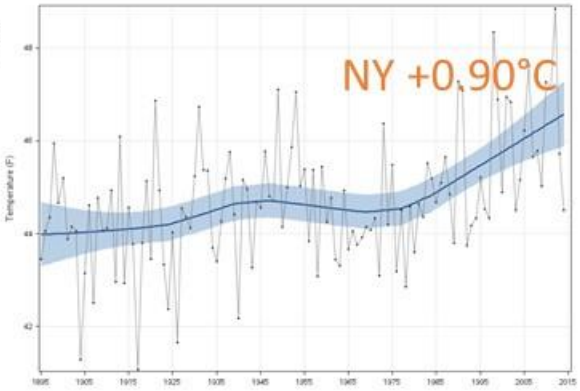
Annual Temperature

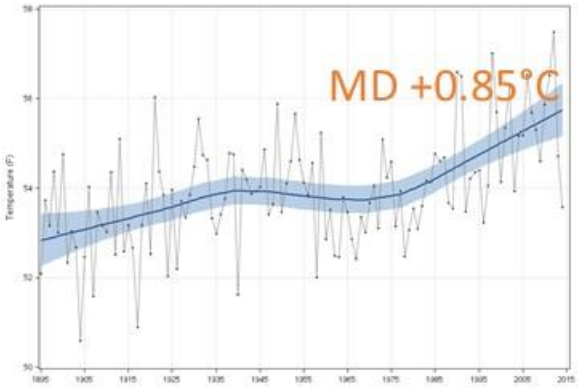
Trend Line

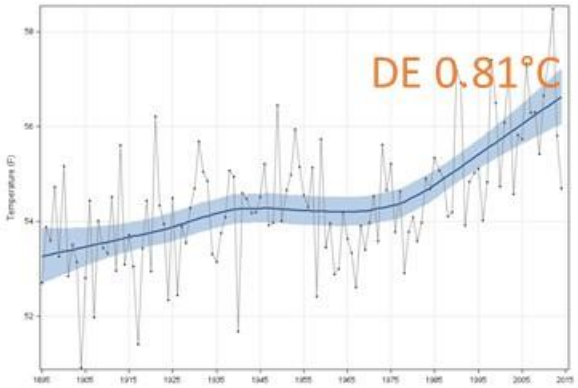
95% Confidence Limits

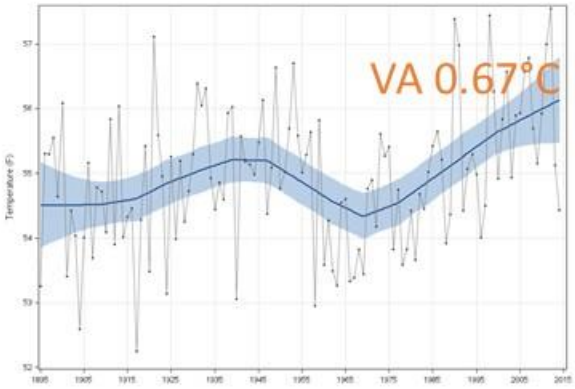










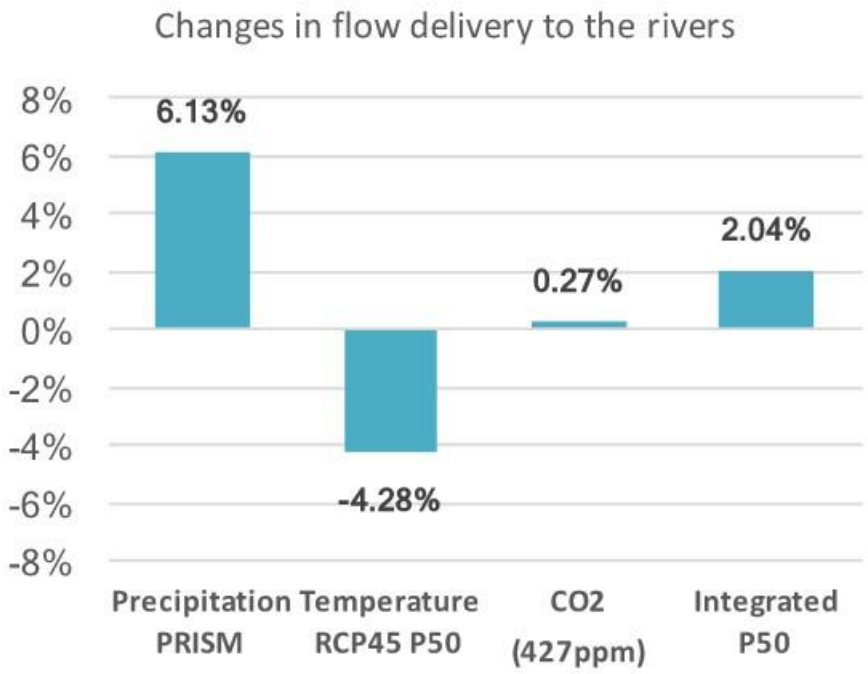


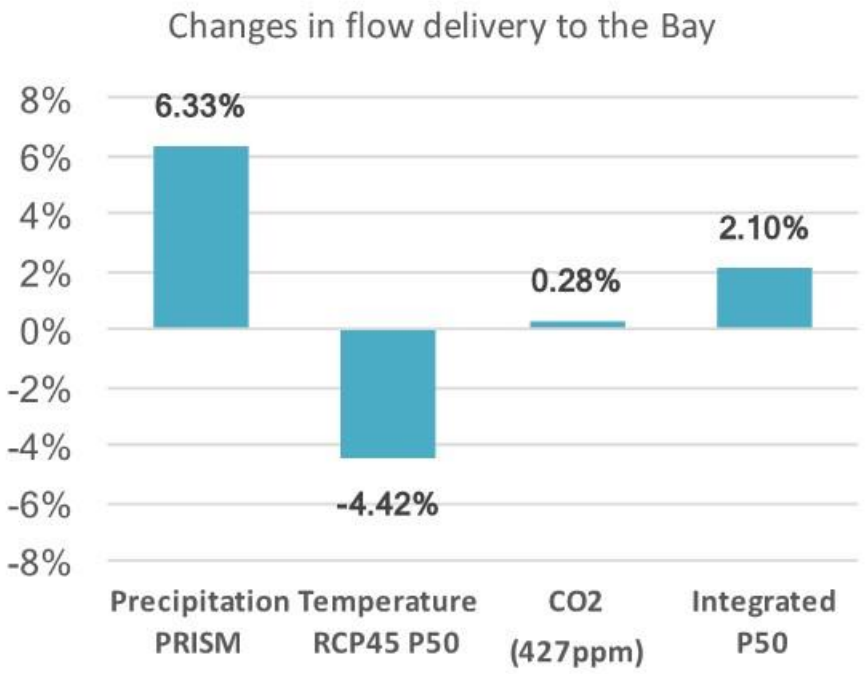
Approx. increases over the last 30 years based on the trend line are shown.

NOAA National Climatic Data Center

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

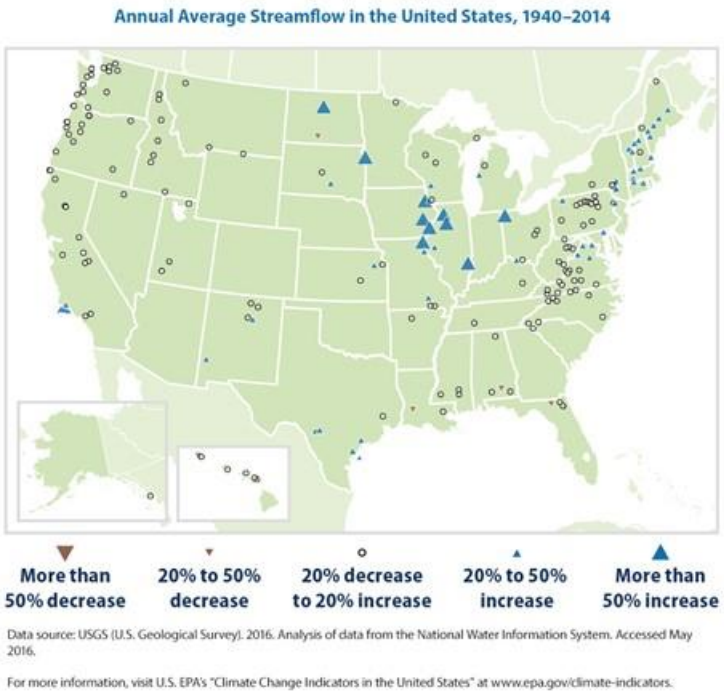
Model results: *flow to rivers and the Bay*



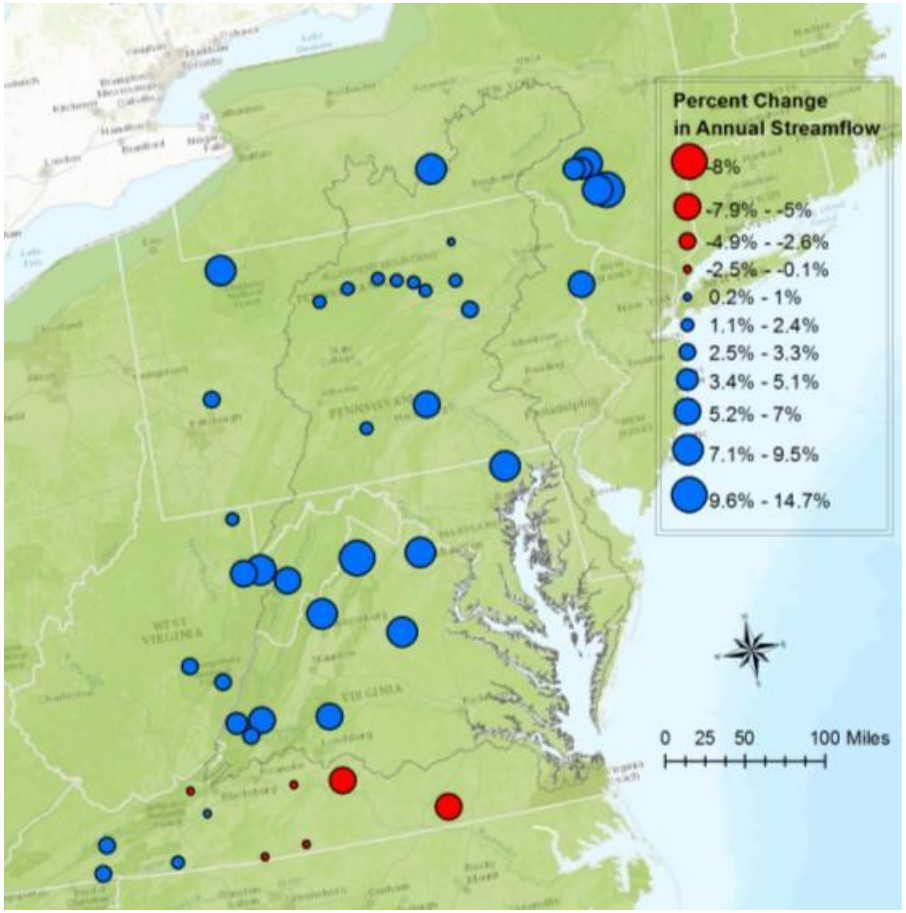


1940-2014 streamflow trends based on observations

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



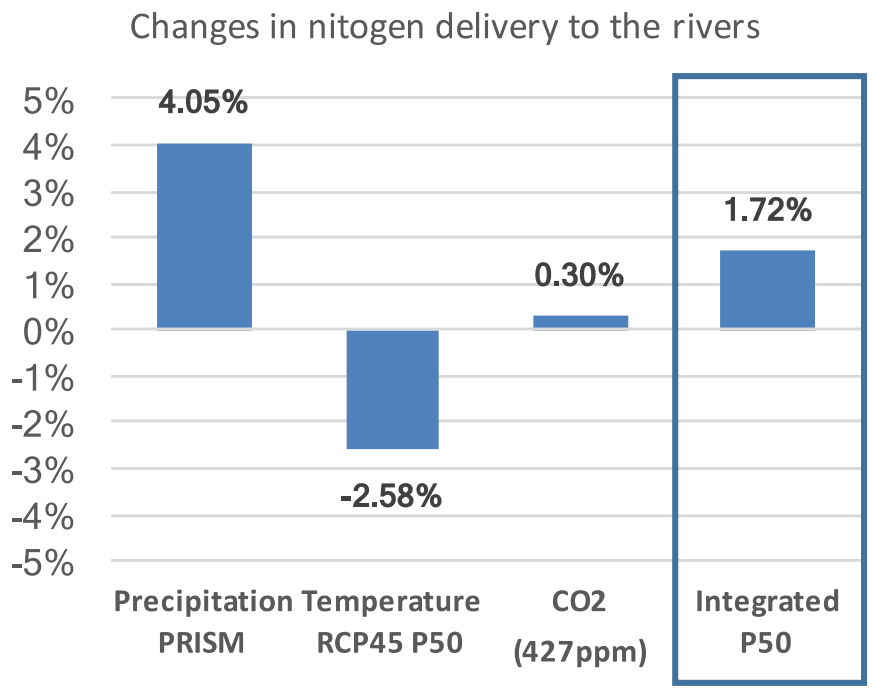
U.S. Environmental Protection Agency. 2016. Climate change indicators in the United States, 2016. Fourth edition. EPA 430-R-16-004. www.epa.gov/climate-indicators.

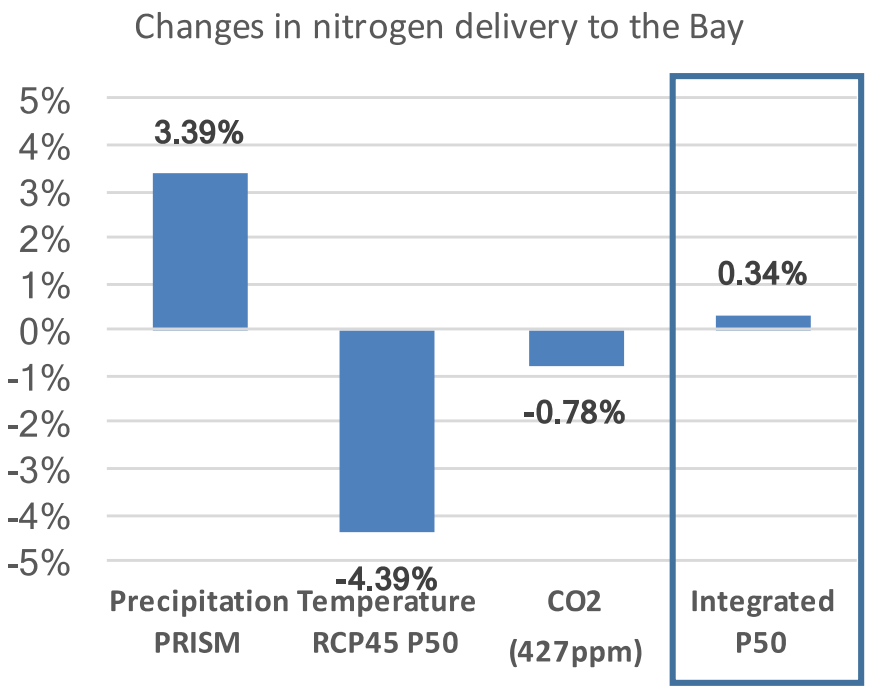


Annual average percent change were calculated using Sen slope (Helsel and Hirsch, 2002).

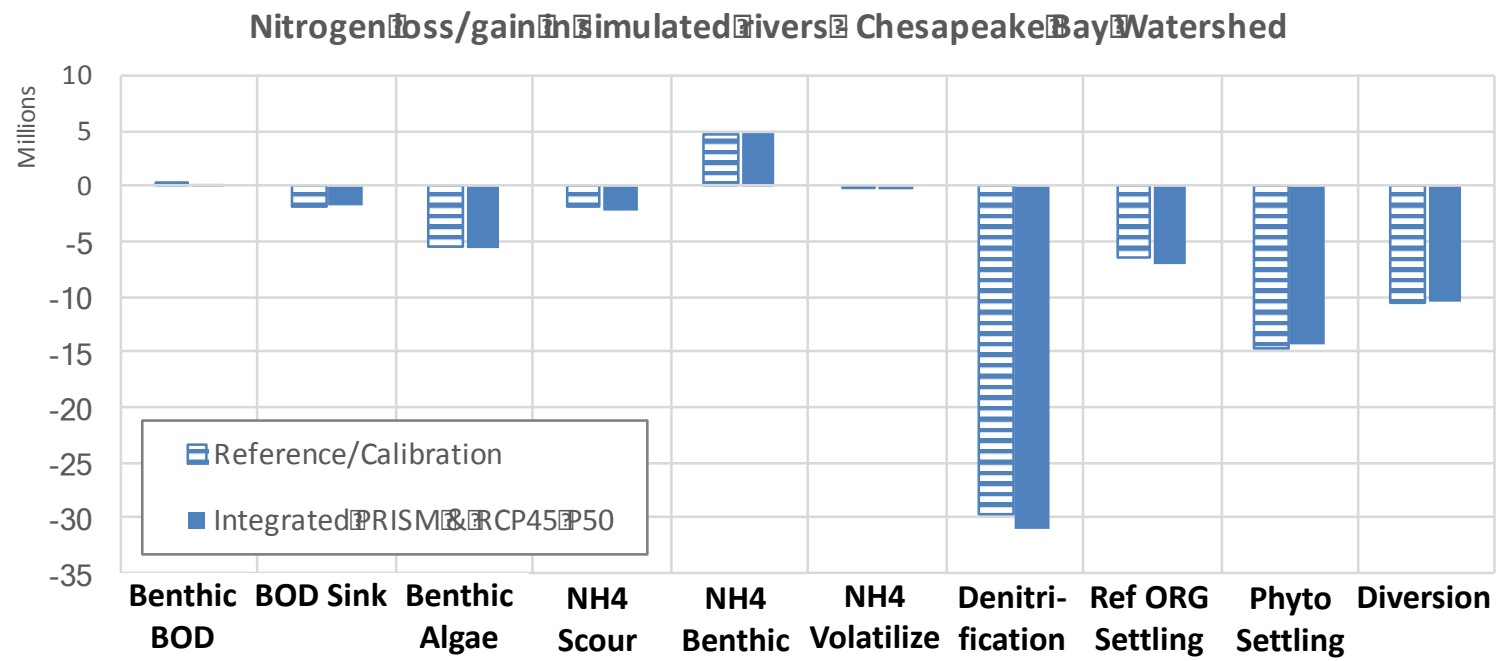
Lins, H.F. 2012. USGS Hydro-Climatic Data Network 2009 (HCDN-2009). U.S. Geological Survey Fact Sheet 2012-3047. https://pubs.usgs.gov/fs/2012/3047.
Helsel, D.R., and R.M. Hirsch. 2002. Statistical methods in water resources. Techniques of water resources investigations, Book 4. Chap. A3. U.S. Geological Survey. https://pubs.usgs.gov/twri/twri4a3.

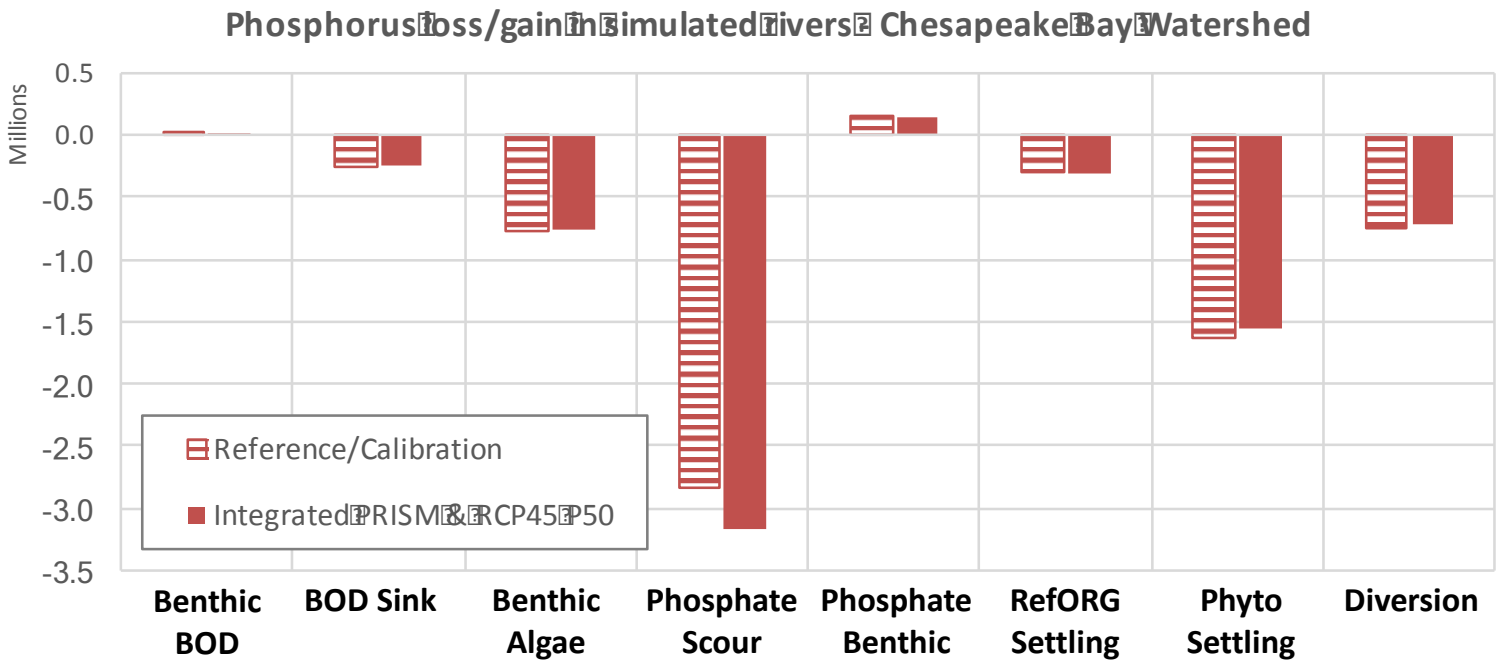
Model results: *nitrogen to rivers and the Bay*



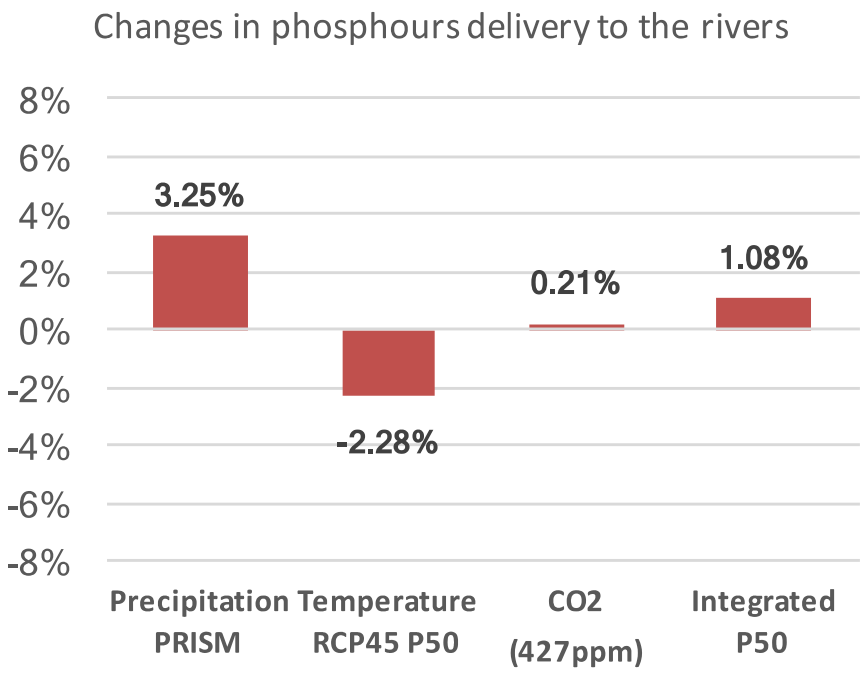


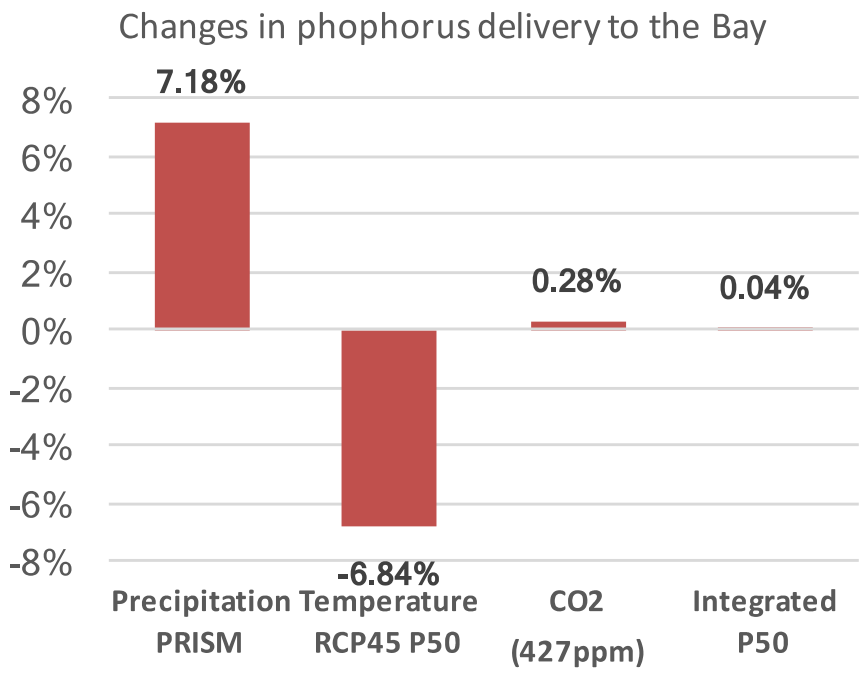
Jessica Rigelman – CAST for the application of Phase 6 sensitivities


Nitrogen loss/gain in simulated rivers of Chesapeake Bay Watershed
Millions
10
5
0
-5
-10
-15
-20
-25
-30
-35
Reference/Calibration
Integrated PRISM & RCP45 P50
Benthic BOD
BOD Sink
Benthic Algae
NH4 Scour
NH4 Benthic
NH4 Volatilize
Denitri-fication
Ref ORG Settling
Phyto Settling
Diversion


Phosphorus loss/gain in simulated rivers of Chesapeake Bay Watershed
Millions
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
Reference/Calibration
Integrated PRISM & RCP45 P50
Benthic BOD
BOD Sink
Benthic Algae
Phosphate Scour
Phosphate Benthic
RefORG Settling
Phyto Settling
Diversion

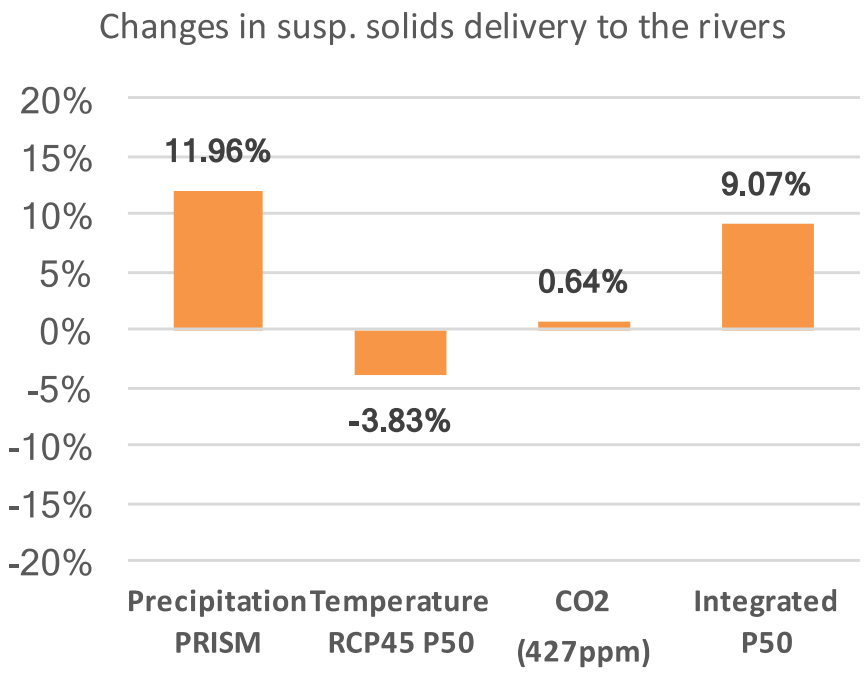
Model results: *phosphorus to rivers and the Bay*

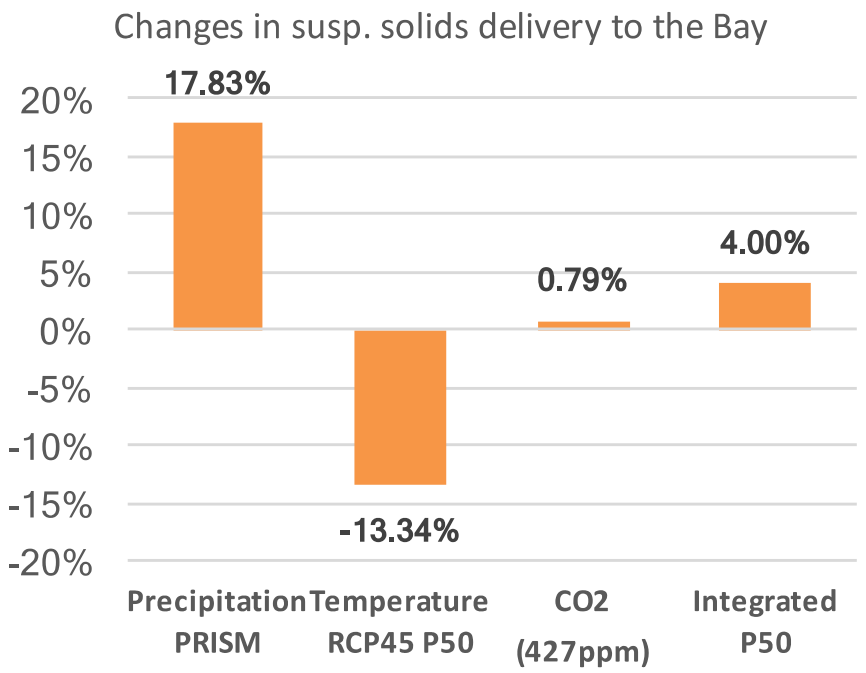




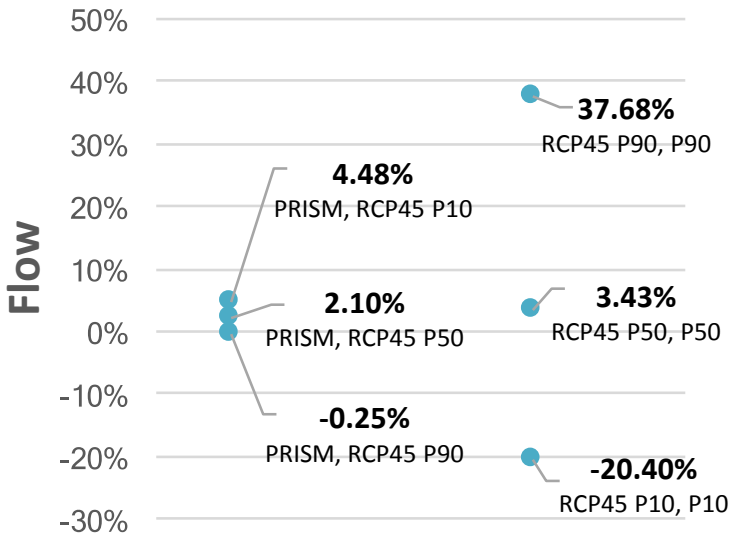
Jessica Rigelman – CAST for the application of Phase 6 sensitivities

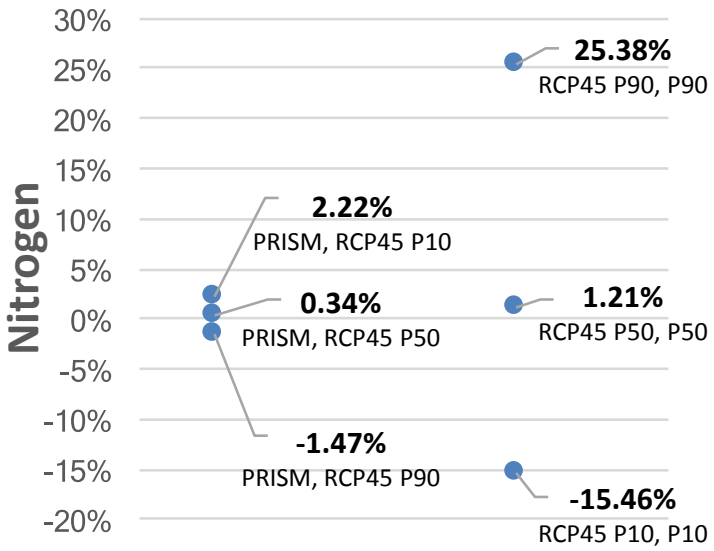
Model results: *suspended solids to rivers and the Bay*

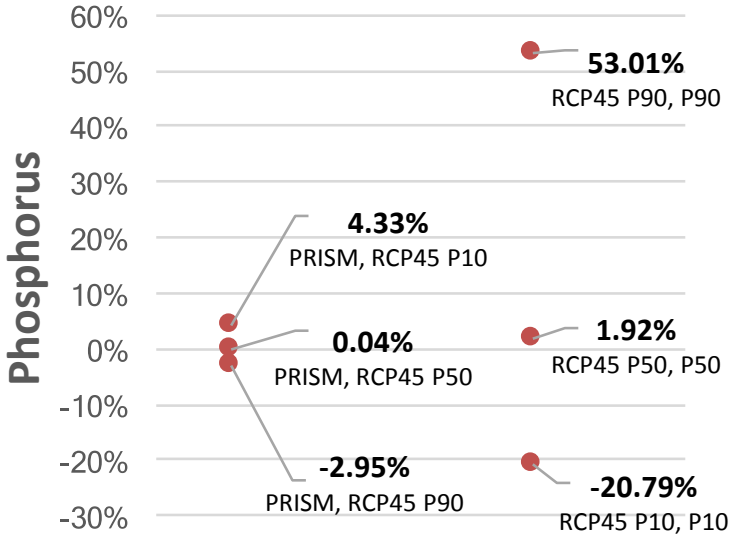


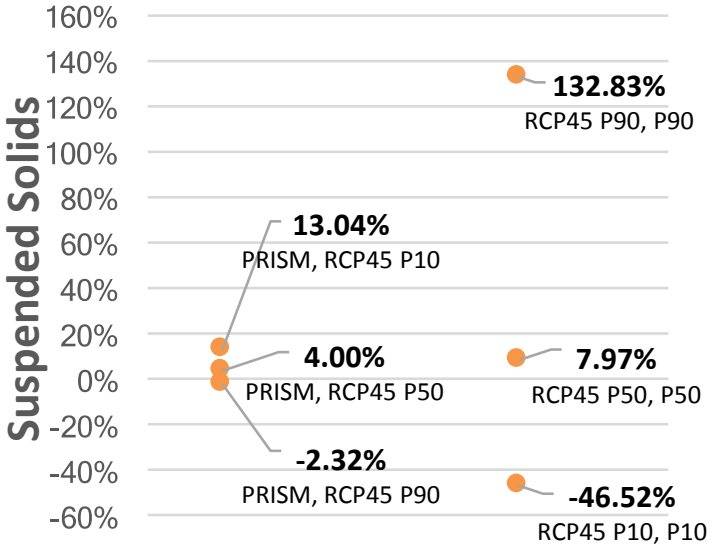


Uncertainty quantification









Summary and Conclusions

- The results shown were based on the Draft Phase 6 Watershed Model.
- Climate change simulations for 2025 were updated, as well as the uncertainty bounds were included in the assessment.
- Nutrient load increases under the estimated 2025 climate change conditions are negligible. Sediment loads are estimated to increase by about 4% under the same condition.