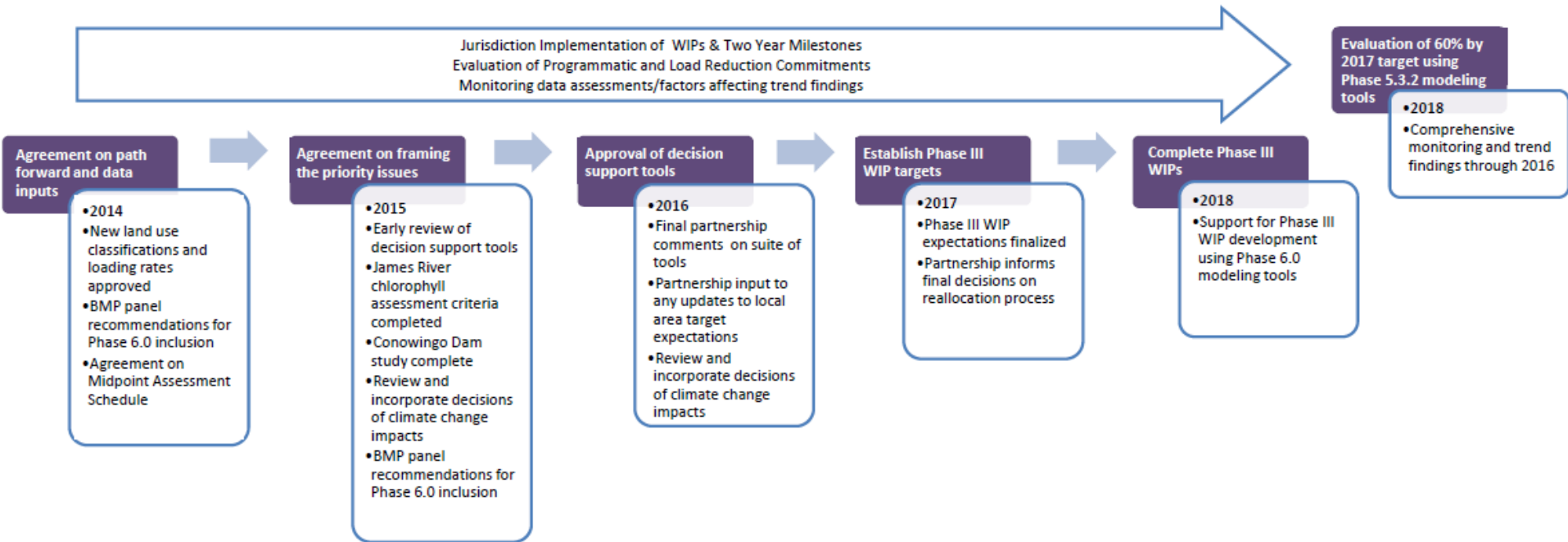


Scenario Builder and Watershed Model Progress toward the 2017 Mid Point Assessment of the TMDL

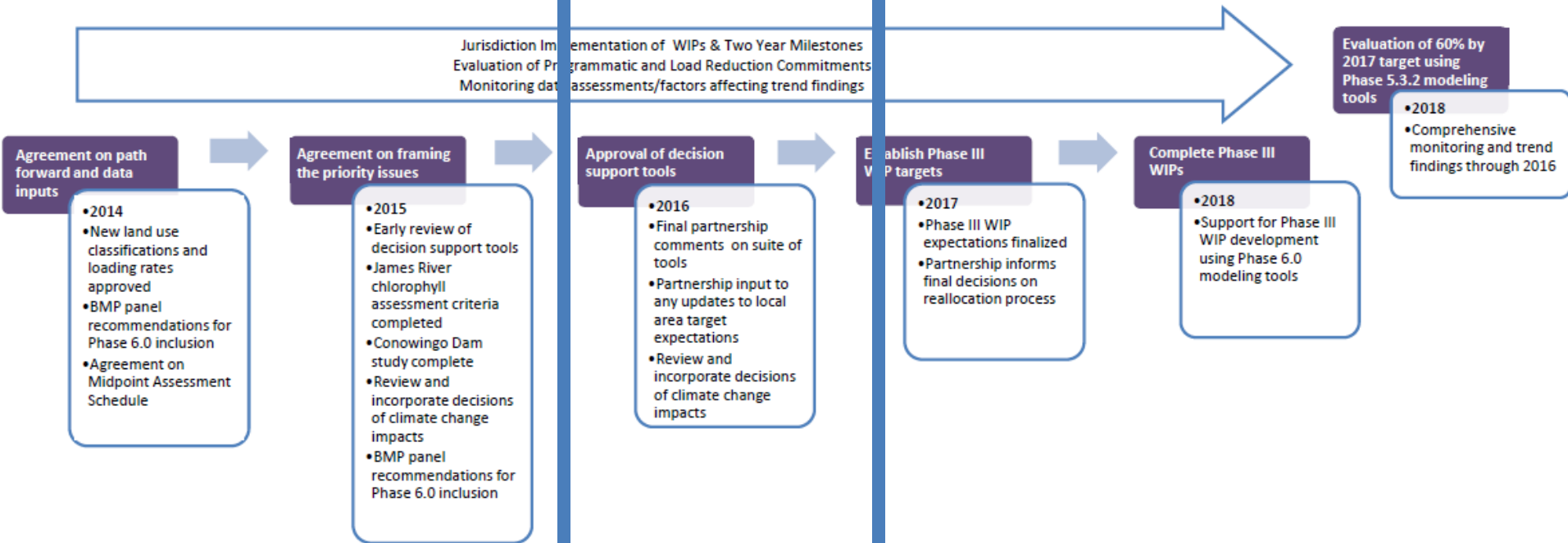
Gary Shenk STAC 12/10/2014



Midpoint Assessment Timeline



Midpoint Assessment Timeline

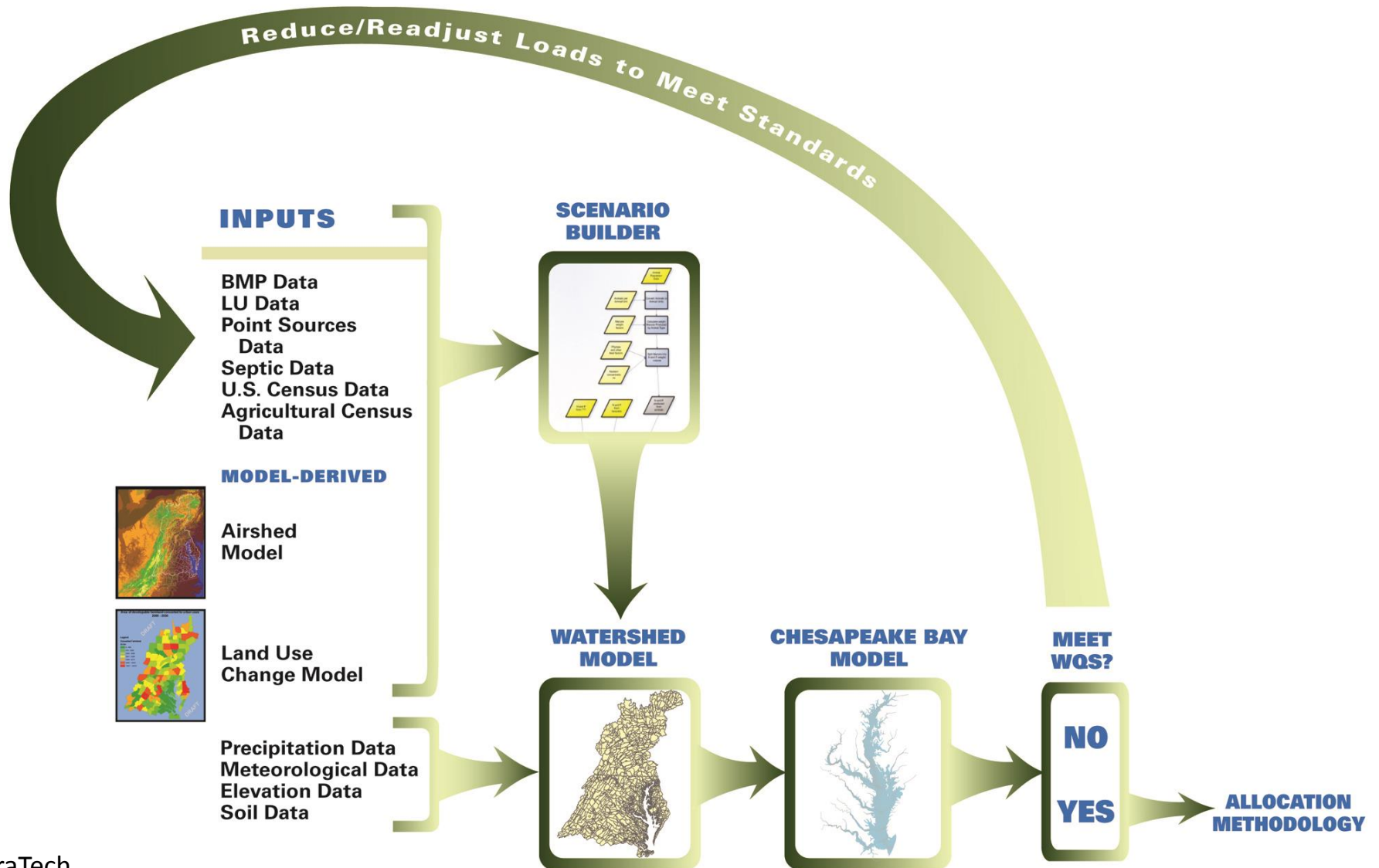


**CREATE
The Models**

**REVIEW
The Models**

**USE
The Models**

Partnership Models



CBP Modeling Tools

Interaction
Tools



CAST



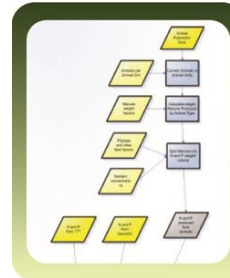
Decision
Models/
Databases



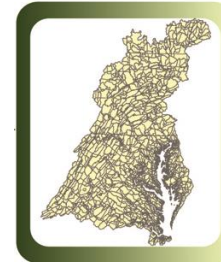
Land Use
Change Model



SCENARIO
BUILDER



WATERSHED
MODEL



Bay
WQSTM

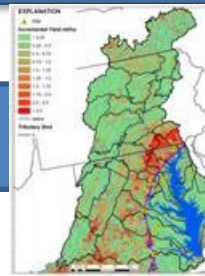


Related
Tools

APLE



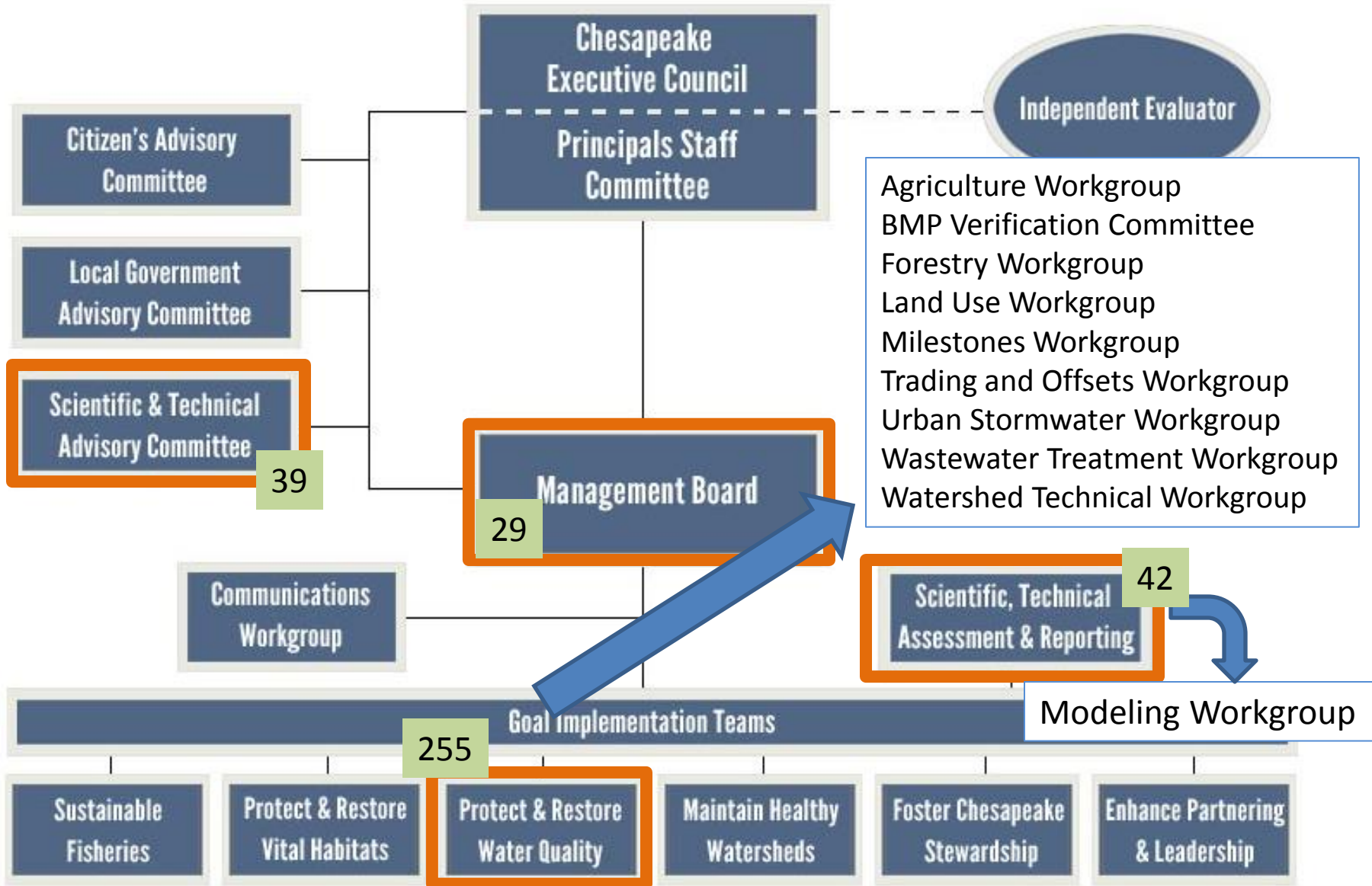
sparrow



SWAT Soil & Water
Assessment Tool

Model related Membership as of 7/2013 – 365 individuals

Chesapeake Bay Program Partnership



Water Quality Goal Implementation...

www.chesapeakebay.net/groups/group/water_quality_goal_implementation_team

1 Coastal Sciences, Rutgers University

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Home About the Bay Program How We Organized Water Quality Goal Implementation Team Text Size: A A

Water Quality Goal Implementation Team (GIT 3)
Scope and Purpose

The charge of the Water Quality Goal Implementation Team (WQGIT) is to evaluate, focus, and accelerate the implementation of practices, policies, programs that will restore water quality in the Chesapeake Bay and its tributaries to conditions that support living resources and protect human health. The Team reports to the Management Board and Principals' Staff Committee. Functions include:

- Provide a forum for discussion, exchange of information, and evaluation among federal, state, and local agencies, river basin commissions, industry groups, universities, and other interested parties on water quality goals, data, modeling, authorities, and restoration efforts.
- Evaluate and promote strategies to reduce nutrient, sediment, and chemical contaminant loads from municipal, industrial and onsite wastewater, agricultural lands and animal operations; urban and suburban stormwater; forested lands; tidal and in-stream sediment, and air emissions.
- Promote consistent, uniform and transparent processes to model, track, report, and verify water quality restoration efforts.
- Identify, define, quantify, and incorporate pollutant reduction and conservation practices into the Chesapeake Bay Program decision support system.
- Provide technical expertise and leadership to support the development, implementation, and tracking of the Chesapeake Bay TMDL, Watershed Implementation Plans, and two-year milestones that support long-term Bay restoration goals.

Members Meetings Workgroups & Task Groups Projects & Resources Publications

Partnership produced workplans for model development coming out of 2012 WQGIT

Midpoint Assessment

Guiding Principles working draft 11.26.12 (96.89 KB)

MPA Master Schedule 9-12-13 (144.33 KB)

EPA and ModelingWG MPA priority workplan -- schedule (75.68 KB)

MPA lower priority workplan - 60percent by 2017 (105.55 KB)

MPA lower priority workplan - Phase III expectations (101.54 KB)

MPA lower priority workplan - TMDL modification (25.67 KB)

AgWG MPA priority work plan - establishment and update of BMP definitions and efficiencies

AgWG MPA priority work plan -- model data processing (51.51 KB)

AgWG MPA priority work plan -- modeling baseline-input data and assumptions (10.15 KB)

FWG combined MPA workplans (147.55 KB)

LUWG MPA priority workplan - Improve spatial, temporal, and categorical representation of land

LUWG lower priority workplan - Representation of federal land boundaries (12.02 KB)

ModelingWG MPA priority workplan--revisit WSM calibration methods (168.59 KB)

ModelingWG MPA priority workplan--revise modeling system structure (74.09 KB)

Modeling workgroup workplans (26.64 KB)

STAR MPA priority workplan -- Conowingo reserivior and greater representation of reseriviors

STAR - assess and explain water-quality trends update jan 22 (150.06 KB)

TOWG MPA lower priority workplan - bay tas 2-7-13 (13.33 KB)

TOWG MPA lower priority workplan - delivery factors 2-7-13 docx (12.05 KB)

TOWG MPA lower priority workplan - offset demand 2-7-13 (11.82 KB)

TOWG MPA lower priority workplan - tms 2-7-13 (12.76 KB)

USWG MPA high priority workplan - Improve modeling accuracy of land use characteristics, (83.18 KB)

WTWG MPA workplan--algal turf scrubber expert panel (91.08 KB)

STAC Guidance

2005



Chesapeake Bay Watershed Model Phase V Review

February 20, 2008

Lawrence Band¹, Theo Dillaha², Christopher Duffy³,
Kenneth Reckhow⁴, Claire Welty⁵

Review of the Chesapeake Bay Watershed Modeling Effort

By

Lawrence Band¹, Kenneth Campbell², Russell Kinerson³,
Kenneth Reckhow⁴, and Claire Welty⁵

STAC Guidance

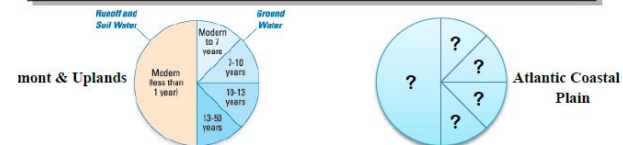
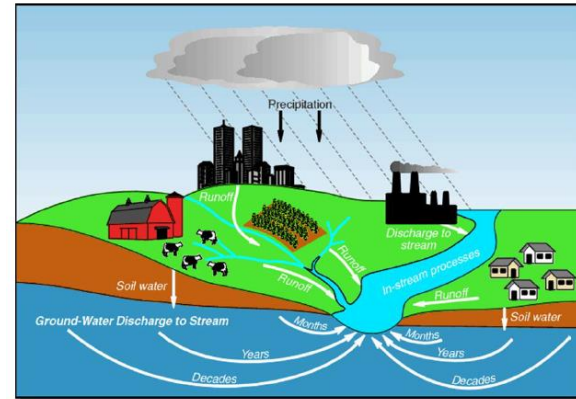
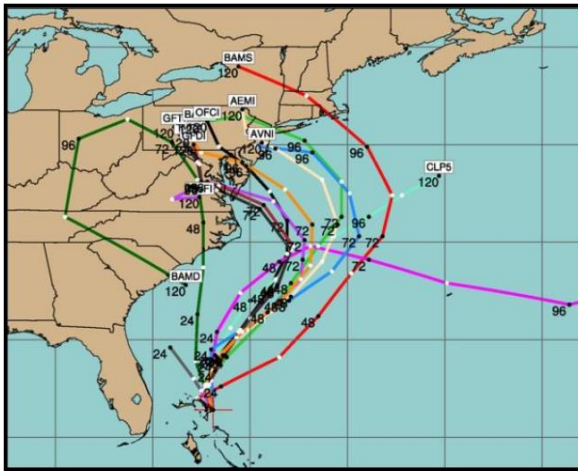
The Role of Natural Landscape Features in the Fate and Transport of Nutrients and Sediment



A Review of Agricultural P-dynamics in the Chesapeake Bay Watershed Model



Multiple Models for Management in the Chesapeake Bay



Incorporating Lag-Times Into The Chesapeake Bay Program



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About the Bay Program

Home > About the Bay Program > How We're Organized > Water Quality Goal Implementation Team > Scenario Builder and Watershed Model Plan for the MPA Text Size: A A A

Who We Are

How We Work

How We're Organized

Chesapeake Executive Council

Principals' Staff Committee

Management Board

Citizens Advisory Committee

Local Government Advisory Committee

Scientific and Technical Advisory Committee

Communications Workgroup

Scientific and Technical Analysis and Reporting

Scenario Builder and Watershed Model Plan for the MPA

In preparation for the 2017 Mid-Point Assessment, the CBP Partnership has expressed priorities for the Phase 6 watershed model development which are detailed in documents under the 'Projects and Resources' tab on the Water Quality GIT page. Initial priorities were set in the October 2012 water quality GIT meeting. These priorities have been updated and refined by recommendations from subsequent workshops and CBP meetings. The MPA master schedule lists these priorities in a table format. Additional documents on the web page are specific work plans to accomplish these tasks.

Out of necessity, phase 6 development is occurring along multiple parallel paths. These must eventually meet in a draft phase 6 watershed model and scenario builder that will be ready for full partnership review beginning January 1 2016. These parallel paths encompass all of the CBP priorities.

This document summarizes the priorities and identifies lead researchers for each effort. The descriptions here are brief with links to more detailed workplans.

Efforts

Below are the efforts related to the Scenario Builder and Watershed Model Plan for the Mid-Point Assessment

- **BMP effectiveness**
- **BMP Implementation Accounting**
- **Fertilizer and Manure Applications**
- **Land Use Types and Acreage**
- **Land Use Loading Rates**
- **Climate Change**



Who We Are

How We Work

How We're Organized

Sensitivities to inputs

The major structural change to phase 6 is the incorporation of multiple model estimates for sensitivity to nutrient inputs. Rather than relying on a single model estimate of load response to changes in inputs of atmospheric deposition, fertilizer, and manure, the phase 6 model will use evidence from multiple sources, including HSPF and other mechanistic models, sparrow and other statistical methods, and literature.

Chesapeake Bay Program Oversight:

Modeling Workgroup

Lead(s):

Lee Currey
(410) 537-3913
1800 Washington Boulevard
Suite 540
Baltimore, Maryland 21230
lcurrey@mde.state.md.us

Chesapeake Bay Program Contact(s):

Guido Yactayo, *Watershed Data Modeling Specialist*
(410) 295-1317
410 Severn Avenue
Suite 112
Annapolis, Maryland 21403
gyactayo@chesapeakebay.net

Documents:

- Pqual sensitivity draft 062614

Decisions:

Progress:

Nitrogen:

Nitrogen sensitivities have been compiled through three provisional sensitivities from this work

Phosphorus

Phosphorus sensitivities have a storage component that sensitivities to inputs.

Midpoint Assessment Priorities:

- Revise Modeling Structure: MWG

Component Efforts:

SS:

Document

Presentations:

- APLE Phosphorus Model - Alisha Mulkey 7/22/14
- STAC Review of CBP Watershed Model Phosphorus processes
- Recommendations for PQUAL Sensitivity to inputs - Guido Yactayo
- Recommendations for PQUAL Sensitivity - Guido Yactayo 4/1/14
- Surface Water Quality is Improving due to Declining Atmospheric Deposition
- APLE Phosphorus Model - Alisha Mulkey 1/8/14
- Investigating Watershed Models Sensitivity of Nutrients in the Chesapeake Bay
- Simulation of Forest using remote sensing data - Angelica Gutierrez
- Phase 6 Sensitivity - Gary Shenk 12/11/13
- AGCHEM Sensitivity Analysis - Richard Tian 7/23/13

Next Steps:

More work needs to be done with phosphorus relating export change

Expected Completion Date:

October 01, 2015

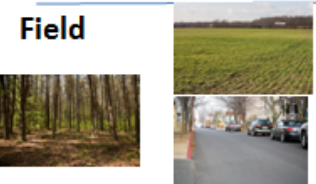



Major Topics – WQGIT AGWG

- Scenario Builder Development and Code Versioning
- Land use Categories
- Fertilizer and Manure Applications
- BMP implementation accounting
- [BMP effectiveness](#)

Major Topics – Modeling WG

- Watershed Model Development and Code Versioning
- Calibration Methodology
- Land use Loading Rates (with WQGIT and WGs)
- Sensitivities to inputs
- Fine Scale Processes (with LUWG)
- Lag Time
- Atmospheric Data
- Conowingo and other Reservoirs
- Climate Change

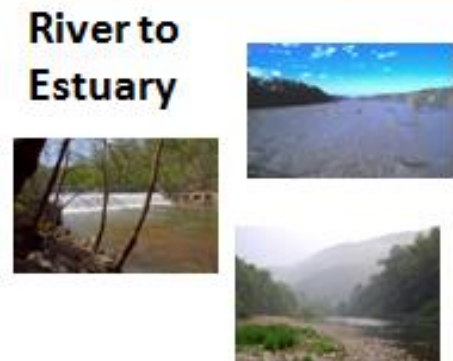
Scale in the Chesapeake Bay Program Watershed Model

Landscape	Phase 5		Phase 6		Sparrow	Other Data Sources
	Nutrients	Sediment	Nutrients	Sediment		
Field 		AG and Forest: Used RUSLE2 to estimate EOF sediment targets Urban: Used Langland and Cronin To estimate pervious vs impervious loading	<i>Can we estimate EOF loads directly based on available information?</i>	<i>Should we update the sediment EOF estimates?</i>	Sources (fertilizer, manure, atdep, urban area) multiplied by global coefficients	Literature Reviews from TetraTech Sources in Phase 5 documentation Sensitivity documentation CEAP APLE
Land to stream 	Field-level, hillslope, and small stream processes are all combined in the Edge-of-Stream nutrient estimates No EOF is simulated EOS estimates are a combination of regional factors and field-scale process simulation calibrated to average export rates	Hillslope and small stream processes are combined in a sediment delivery ratio that is based on the average distance between each major land use type and a major river, adjusted for the coastal plain.	<i>Can we estimate watershed delivery based on landscape parameters?</i>		Land to Water factors such as soil parameters and slopes	ICPRB/USGS Sparrow Land Data team Connected Impervious Land Data team Urban Tree Canopy
Stream to River 	Informed by inputs and calibration		<i>Can we estimate small stream effects?</i>		Explicitly simulated to NHD+ level	ICPRB/USGS Sparrow Land Data team Urban Stream Corridor Land Data team Riparian Forest Land Data team Riverine Wetlands Center for Watershed Protection CBP Grant
River to Estuary 	Directly Simulated in HSPF for river averaging at least 100 cfs Calibrated to WQ data		Directly Simulate in HSPF for river averaging at least 100 cfs Calibrate to WQ data		Explicitly simulated	Calibrate to sparrow DFS or loads?

Phase 5

Nutrients

Sediment



Field-level, hillslope, and small stream processes are all combined in the Edge-of-Stream nutrient estimates

EOS estimates are a combination of regional factors and field-scale process simulation calibrated to average export rates

Edge of field is explicitly simulated

Sediment delivery ratio based on the average distance between each major land use type and a major river.

Directly Simulated in HSPF for river averaging at least 100 cfs

Calibrated to WQ data

Phase 6

Nutrients

Sediment



Can we estimate EOF loads directly based on available information?

Should we update the sediment EOF estimates?

Can we estimate watershed delivery based on landscape parameters?

Can we estimate small stream effects?

Directly Simulated in HSPF for river averaging at least 100 cfs

Calibrated to WQ data

Sources of Information

Field

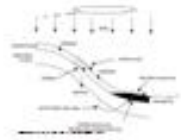


Sensitivity documentation
CEAP
APLE
Sparrow
Phase 5

Literature Reviews from TetraTech

Literature sources in Phase 5 documentation

Land to stream



Sparrow Land to Water factors

Land Data team Connected Impervious

Stream to River



Land Data team Riparian Forest

Land Data team Urban Tree Canopy

Land Data team Riverine Wetlands

Land Data team Urban Stream Corridor

Sparrow simulated to NHD+ level

Center for Watershed Protection CBP Grant

River to Estuary



Longer calibration period



Possible Re-configuration

Phase 5

- CAST

Matches
Pretty well

- SB

Accounting Tool

- WSM

Load WQM

Discovery

Phase 6

- CAST

Accounting Tool

- SB

Matches
precisely

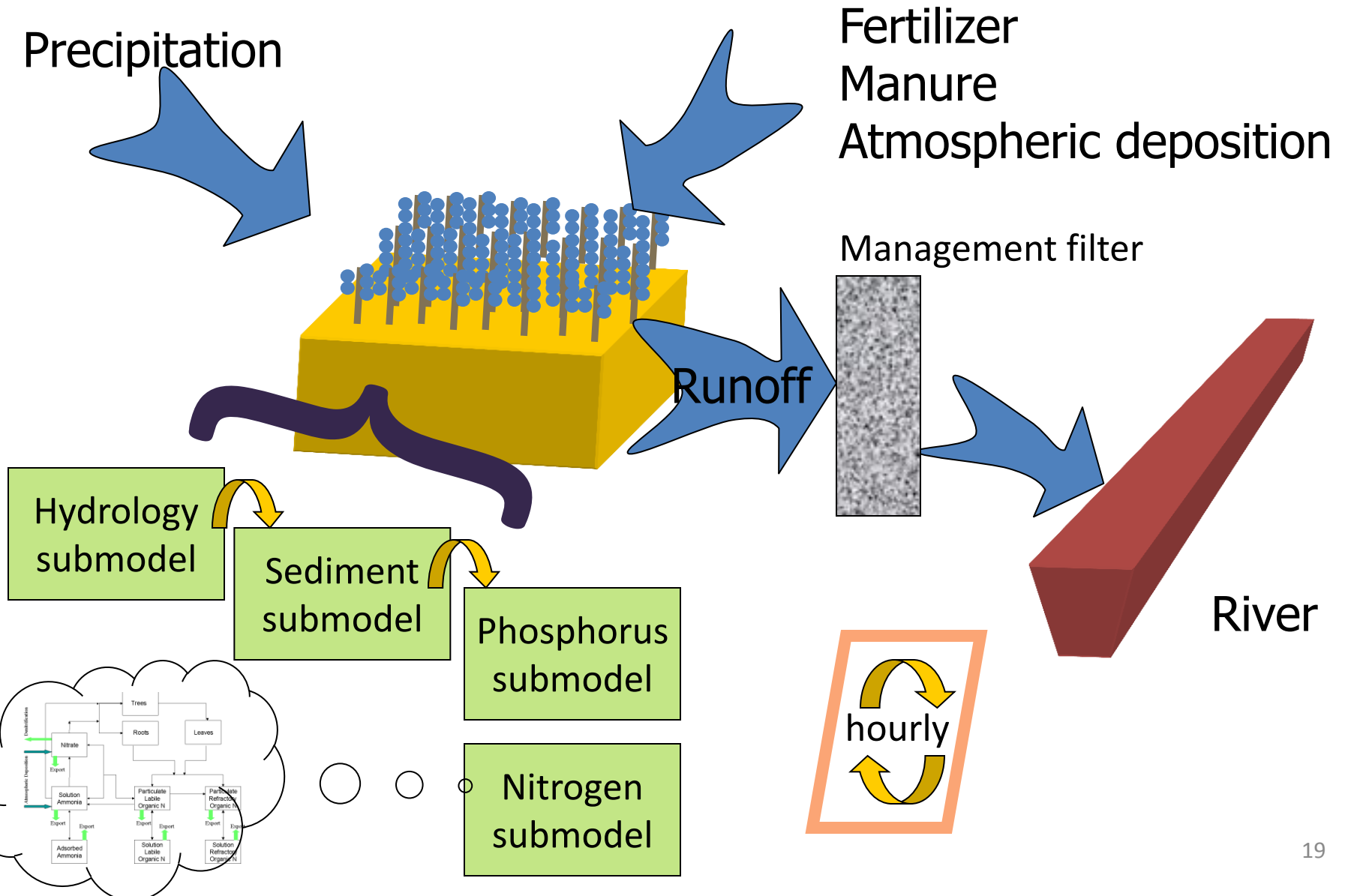
- WSM

Load WQM

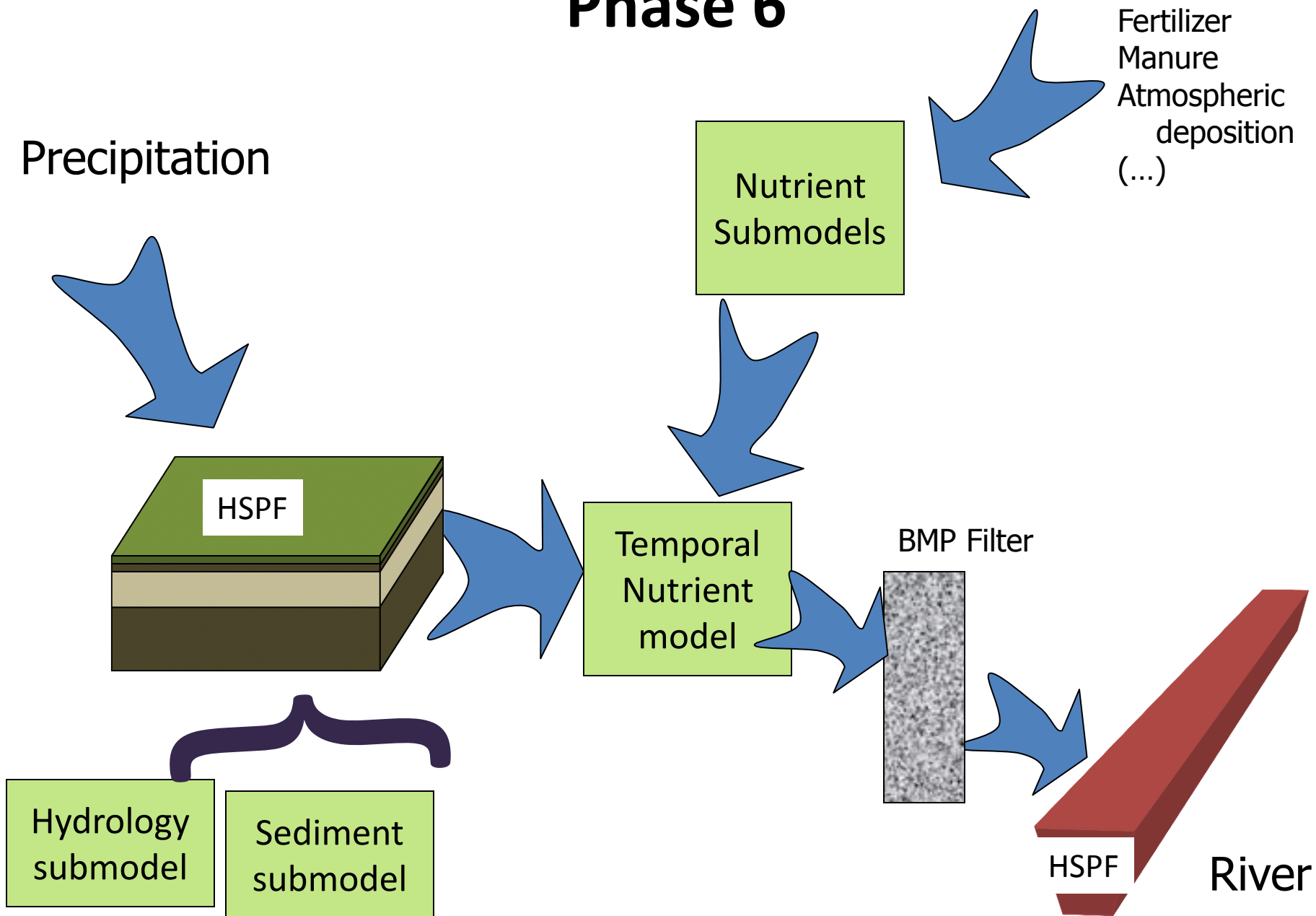
- SPARROW, PIMH, CEAP,
WSM, Others

Discovery

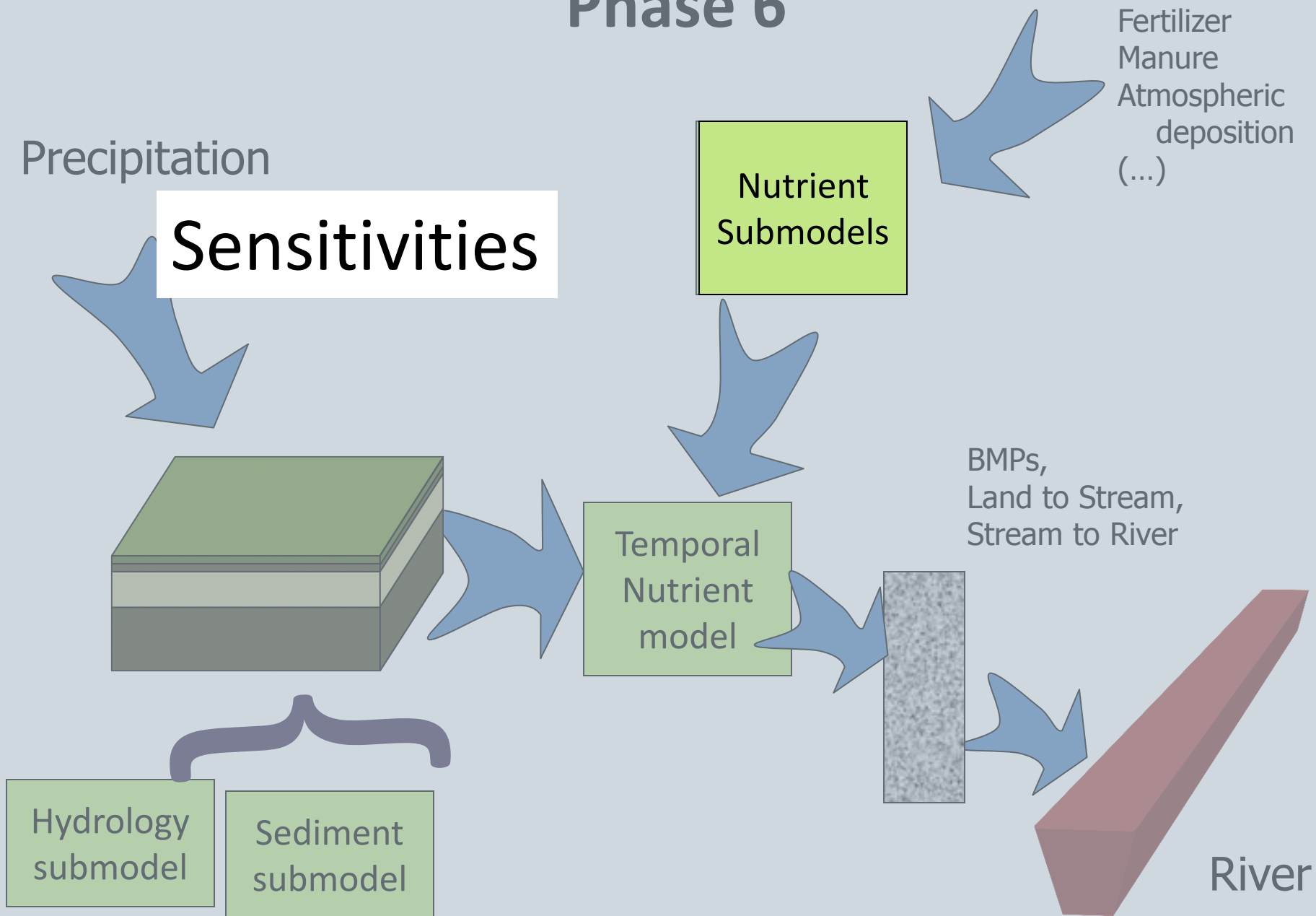
How the Phase 5 Model Works



Phase 6



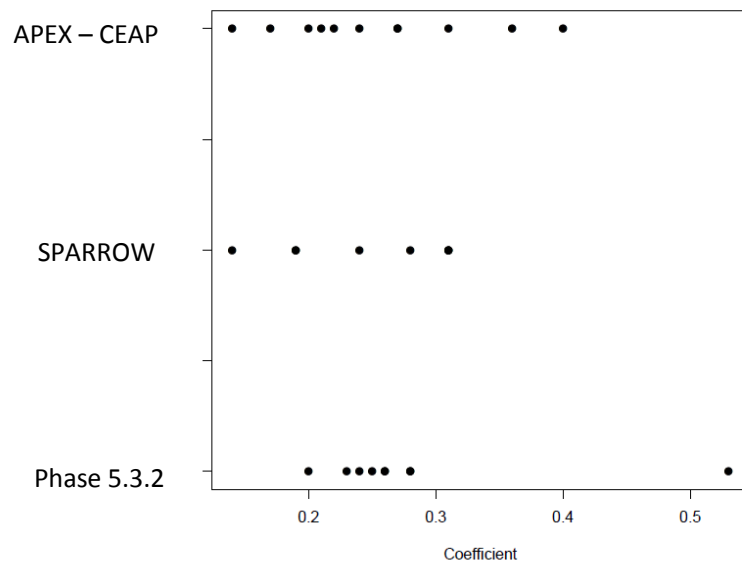
Phase 6



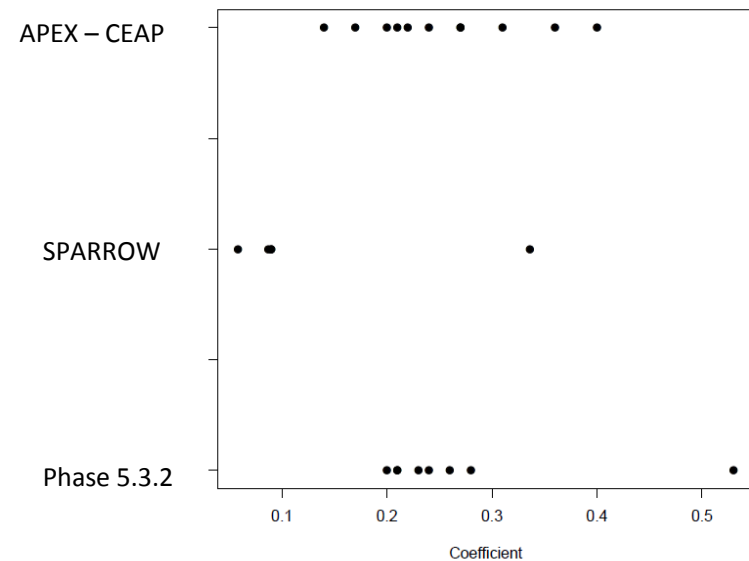
Sensitivities to total nitrogen inputs

- Following STAC recommendations of using multiple models, APEX, SPARROW, and P532-AGCHEM models were included in this analysis.
- The models sensitivities represent the relationship between nutrient predicted yields and input loads for cropland.

Sensitivity to fertilizer TN inputs



Sensitivity to manure TN inputs



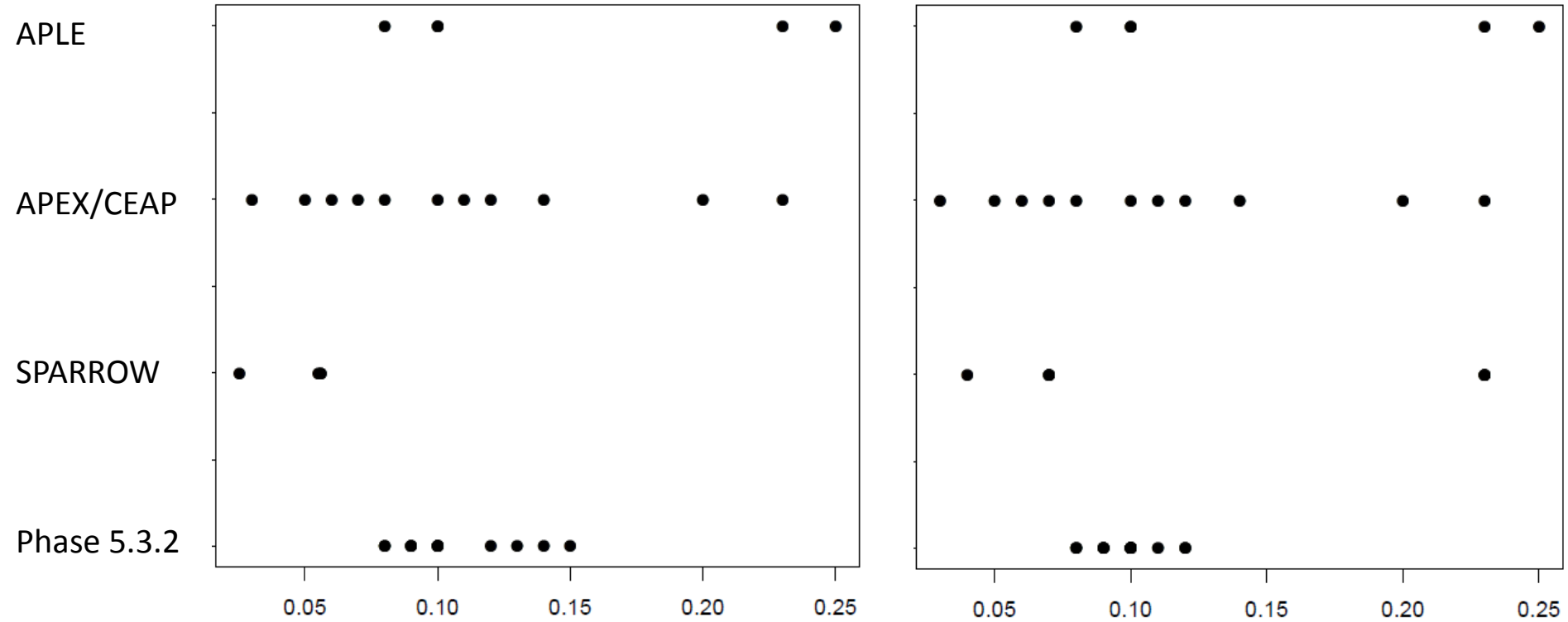
Recommended Nitrogen Application Sensitivity Implementation

- Use P5.3.2 Sensitivities
 - Spatially averaged
 - Broken out by nutrient species
- Rationale:
 - Answers the correct question
 - Has the species breakout
 - Supported by other models
- Implemented in phase 6.
- Possible approval by Modeling Workgroup in January 2015

Nutrient Submodels - Phosphorus

Manure

Fertilizer

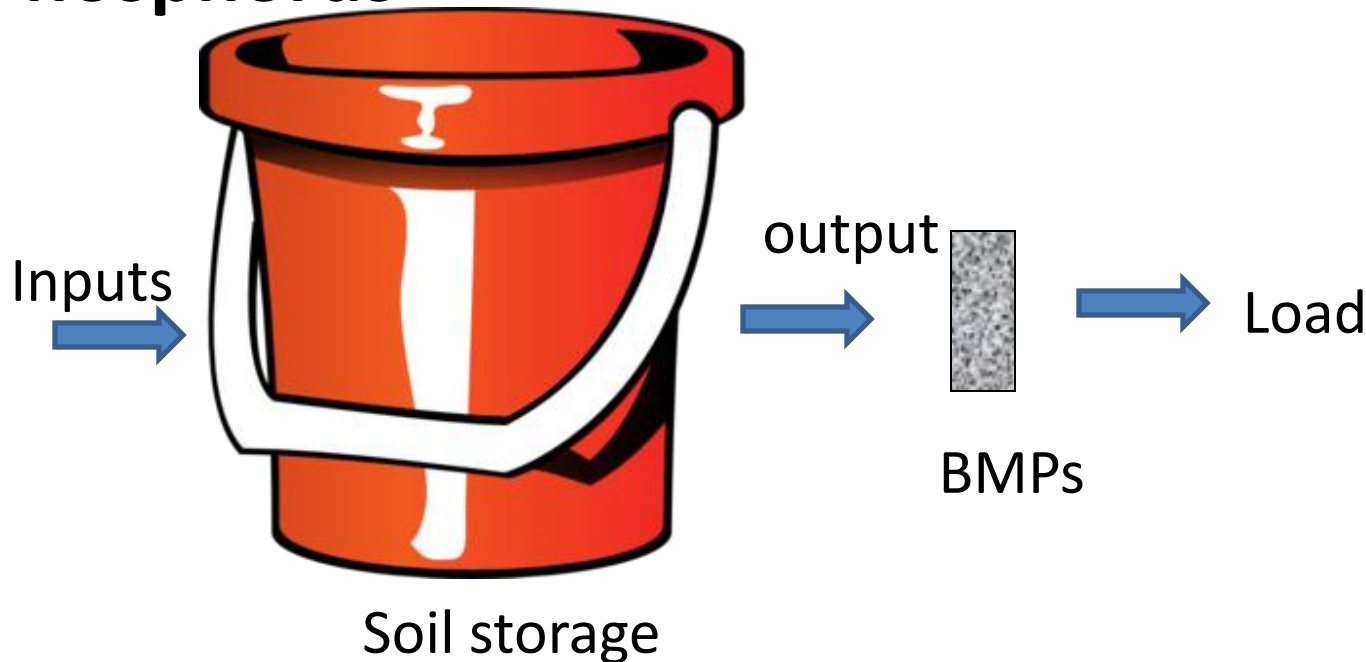


Change in pounds exported per change in pounds applied

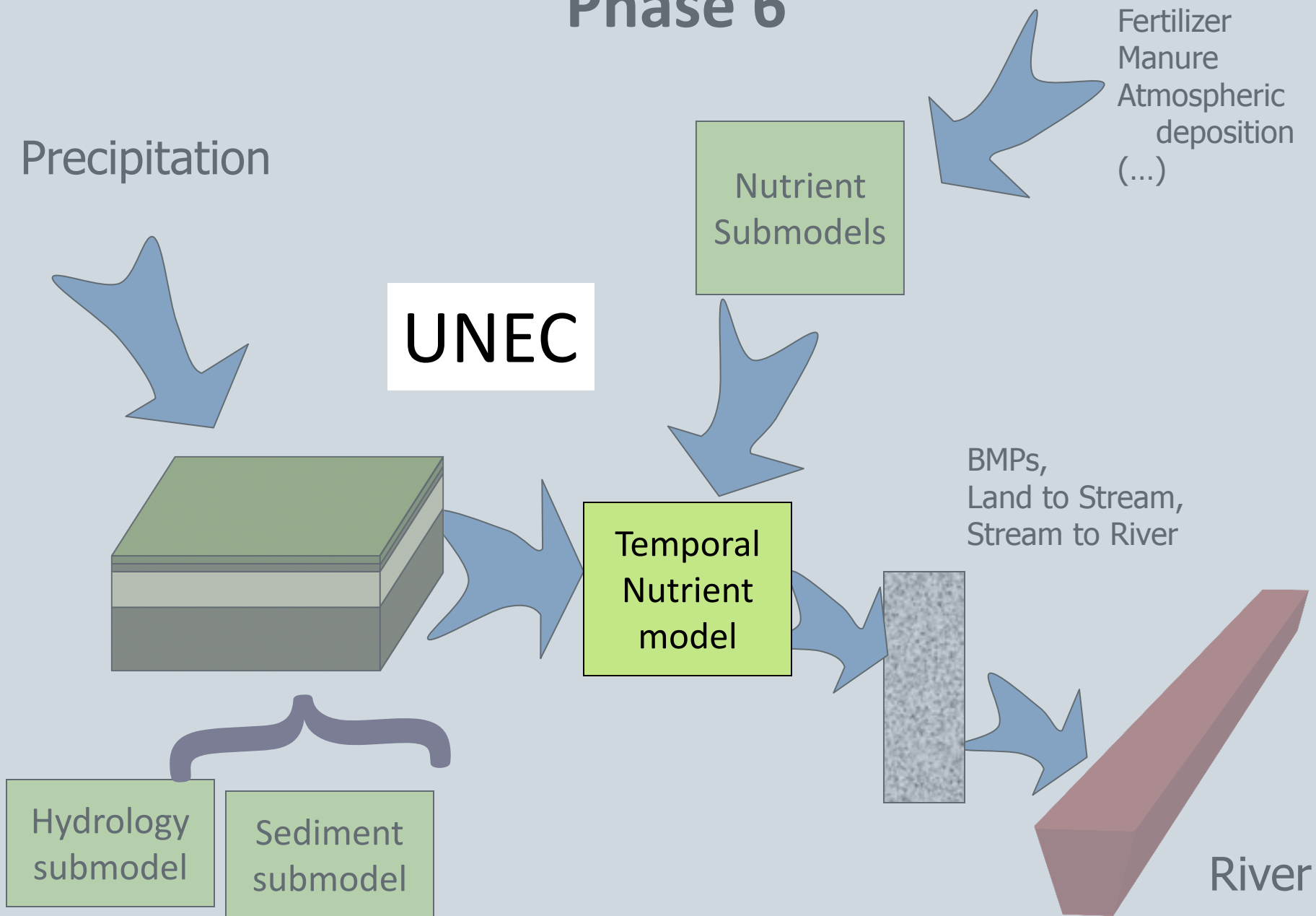
STAC Phosphorus Report

- Gather Soil Data
- Adjust Simulation – Investigating APLE

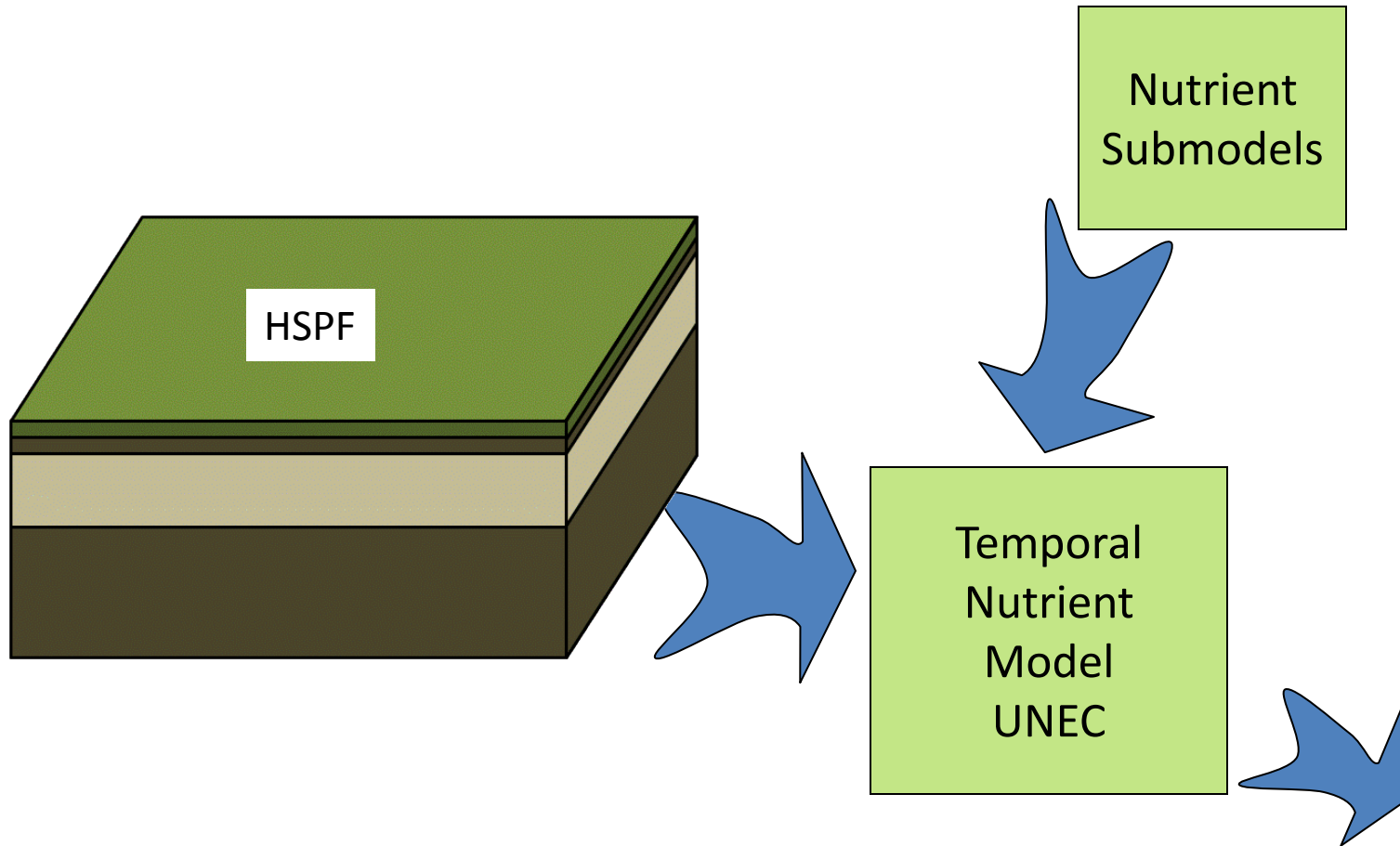
Phosphorus



Phase 6

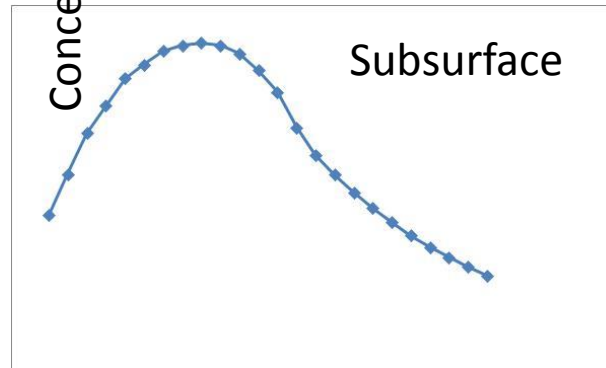
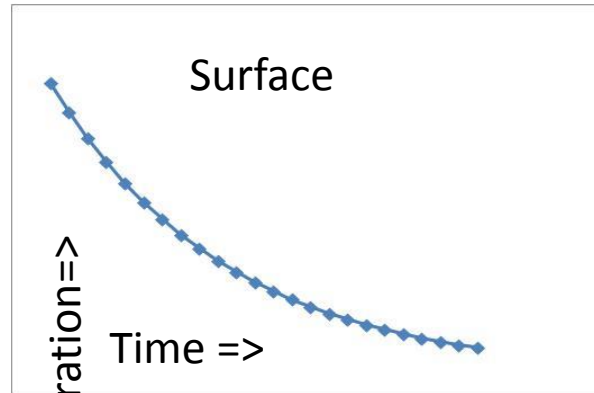
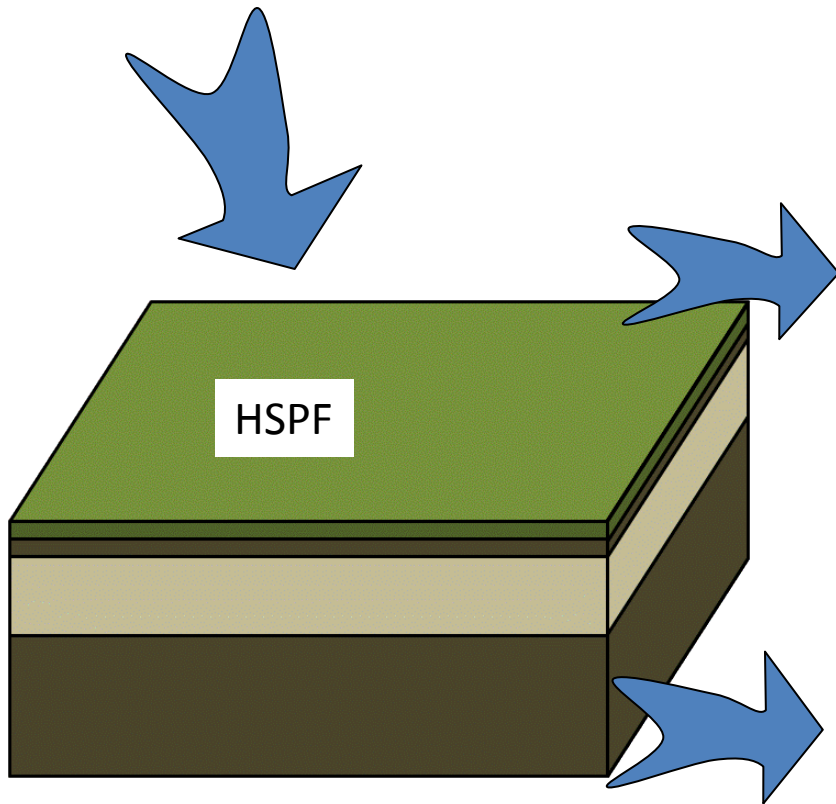


Phase 6



UNEC - Nitrogen

Each Loading Event



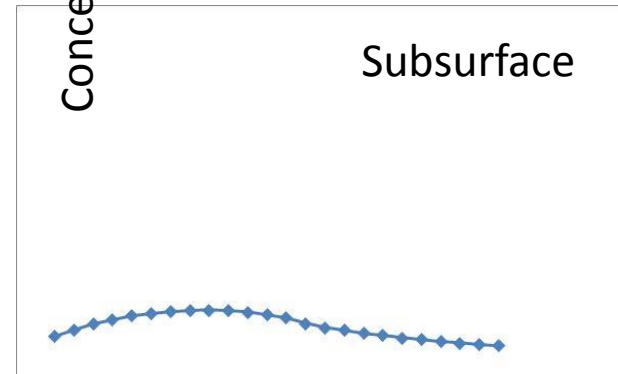
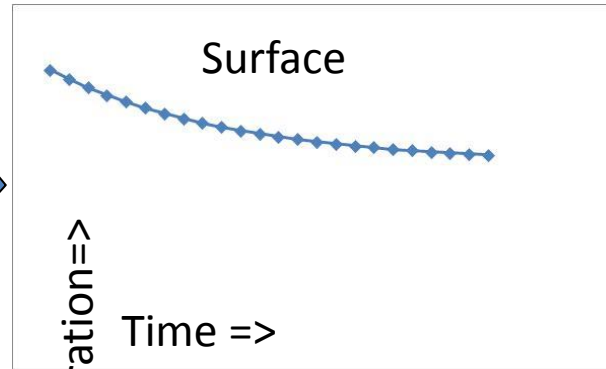
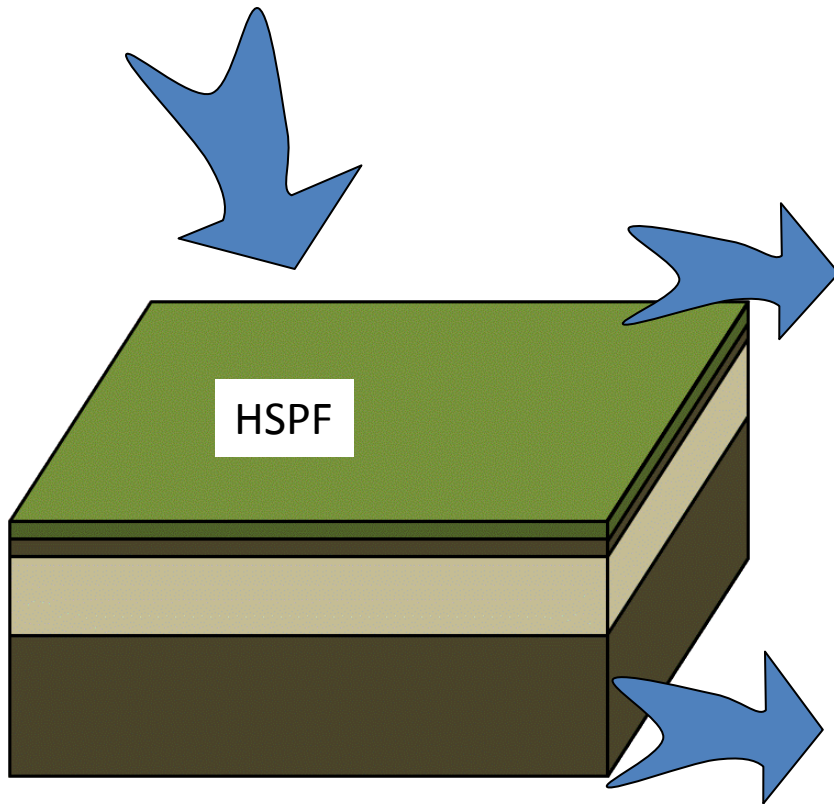
Sum=

Nutrient
Submodels

Unit Nutrient Export Curve

UNEC - Phosphorus

Each Loading Event

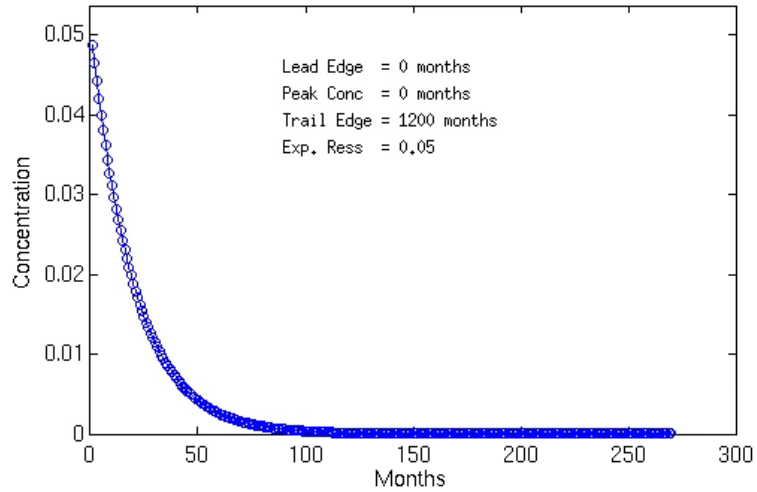


Sum=

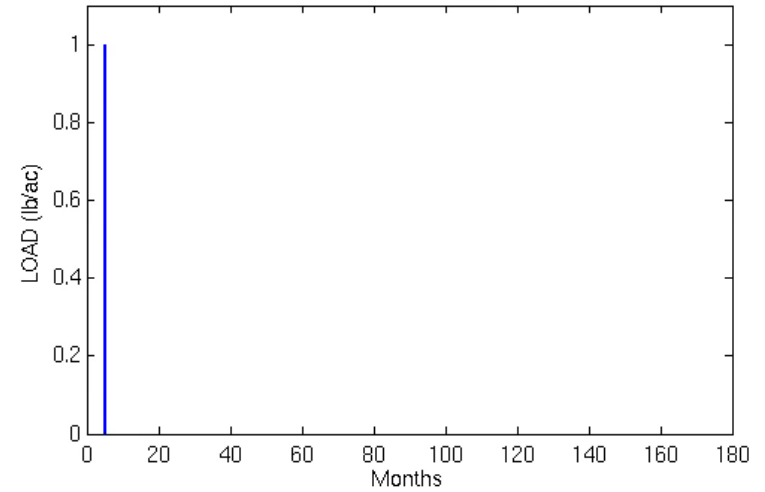
Nutrient
Submodels

Dirac-delta / Pulse input

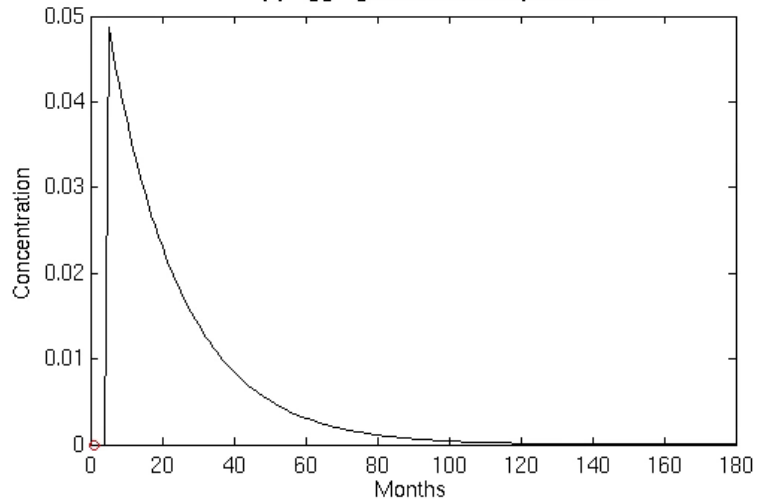
(1) Unit Nutrient Export Curve



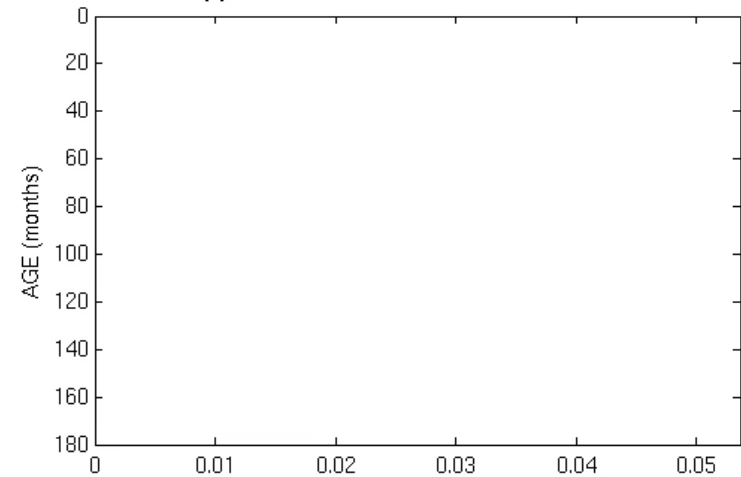
(2) Nutrient Input



(3) Aggregate Nutrient Export

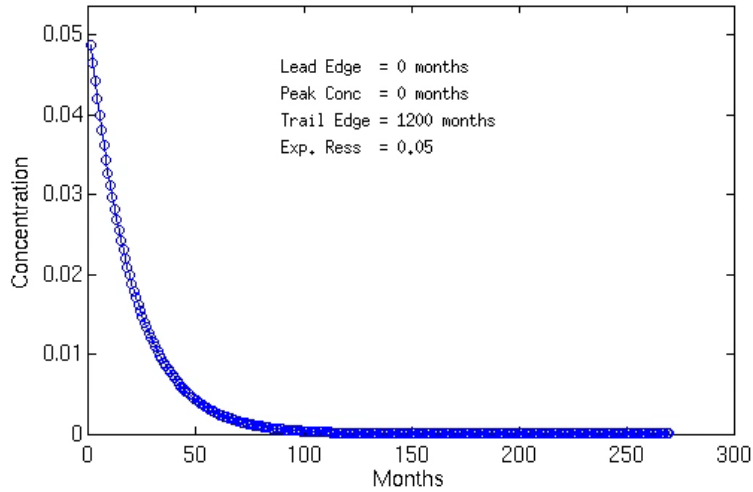


(4) Transit Time Distribution, $t = 1$ months

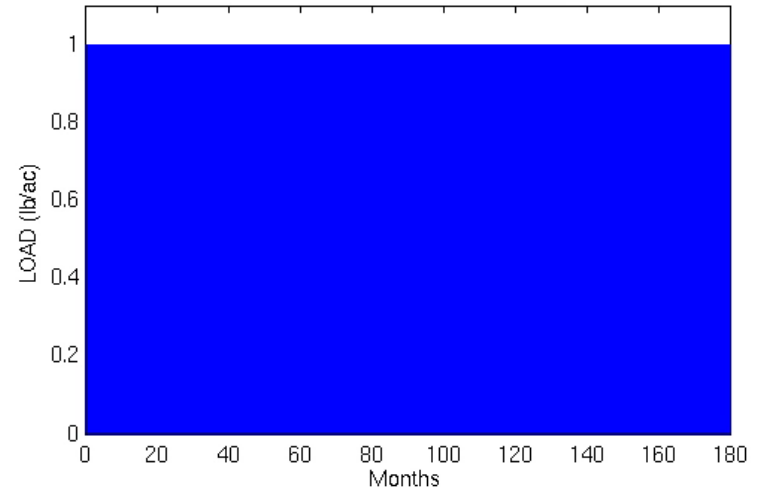


Continuous inputs

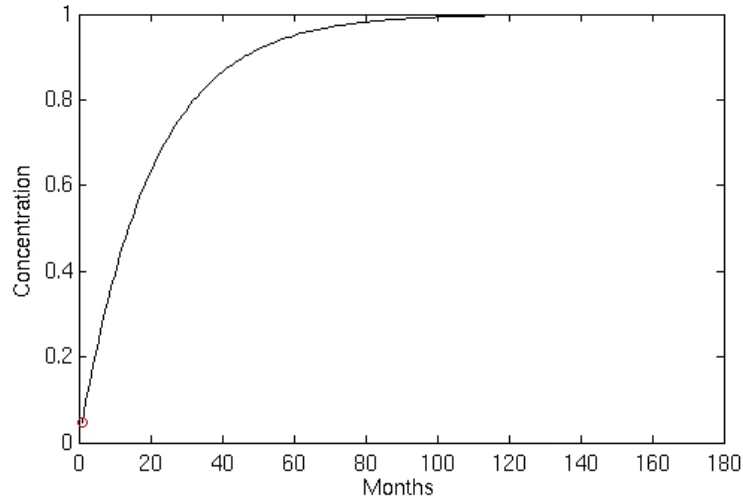
(1) Unit Nutrient Export Curve



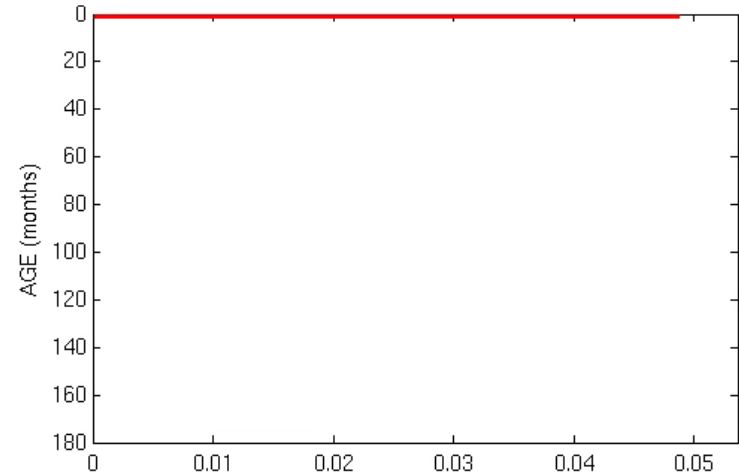
(2) Nutrient Input



(3) Aggregate Nutrient Export

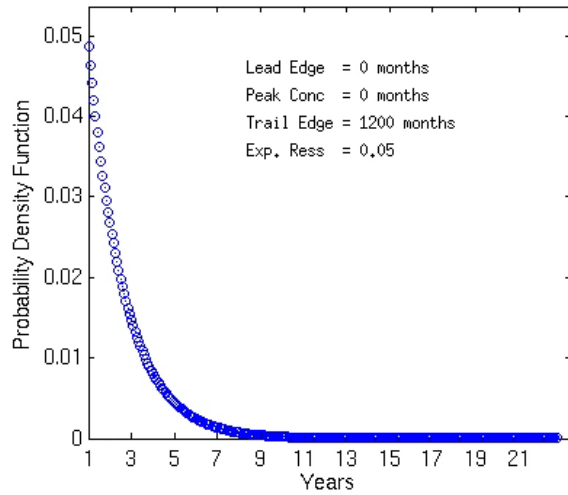


(4) Transit Time Distribution, $t = 1$ months

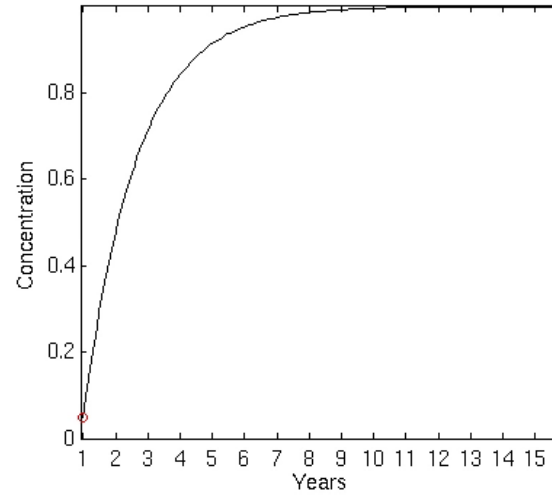


Continuous inputs – variable flow

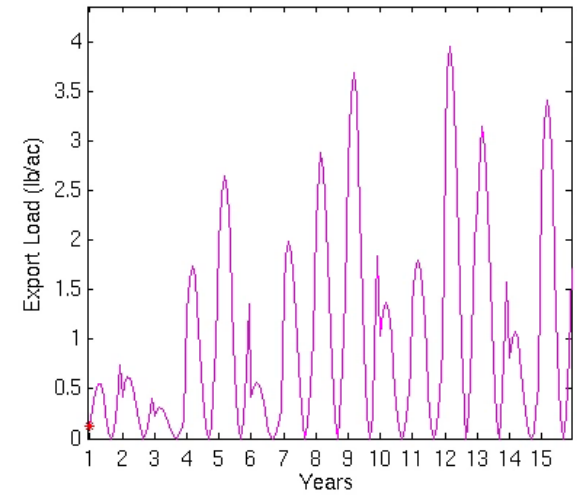
(1) Unit Nutrient Export Curve



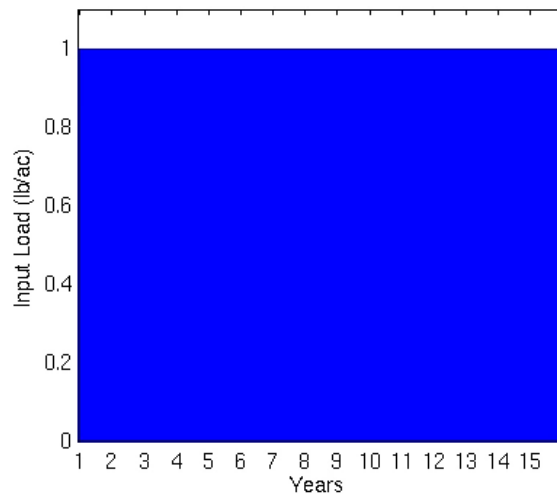
(3) Aggregate Nutrient Export



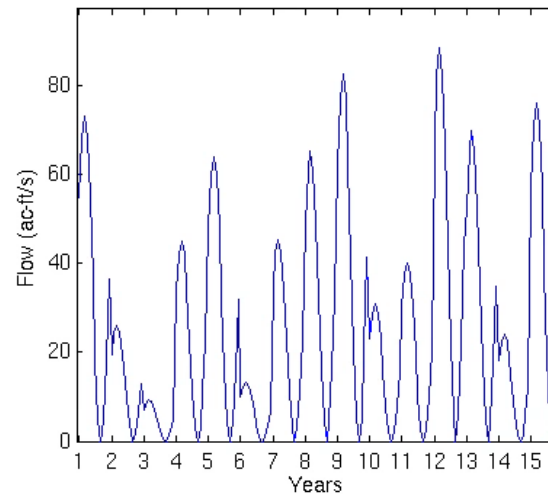
(5) Nutrient Export



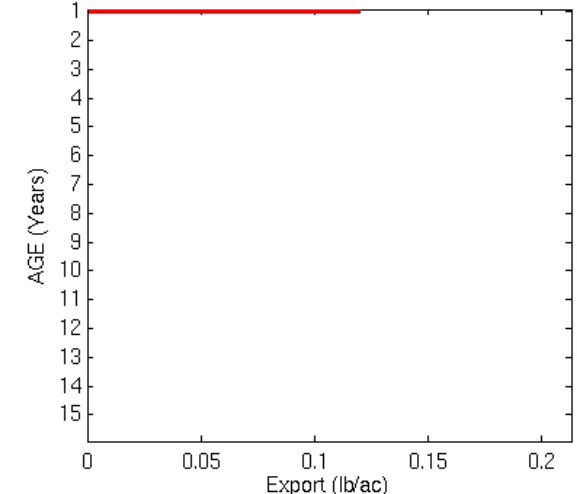
(2) Nutrient Application



(4) Flow



(6) Transit Time Distribution, $t = 1$ months



Watershed Model Calibration

Watershed model

Updated
Land loading
targets
EOF

Calibration Points

Mid-Scale
Processes

Land
Sediment

Land
Phosphorus

Land
Nitrogen

Land to
Stream

Stream to
River

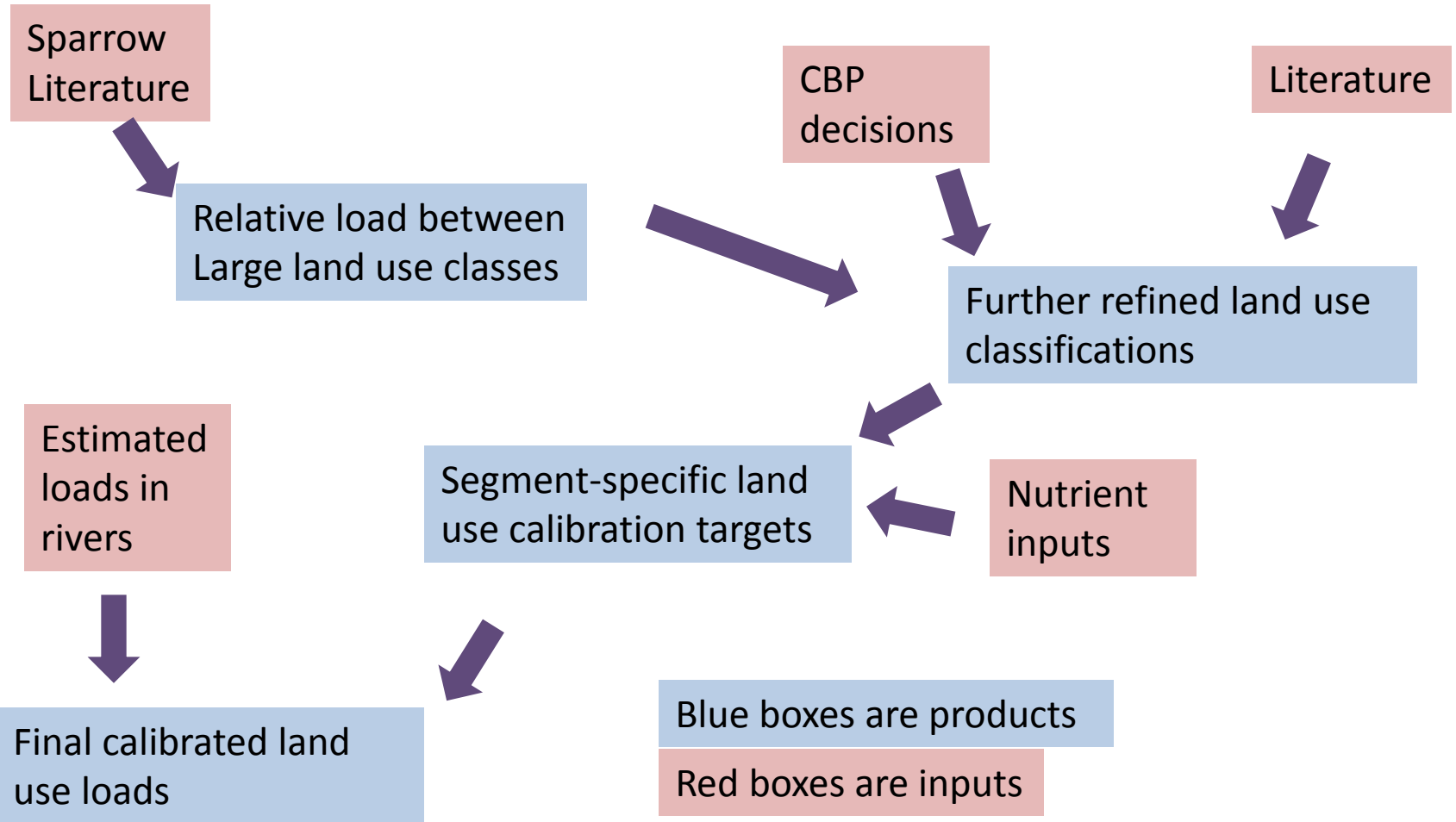
River to
Estuary

Calibration
Stations as
P5.3.2 plus
new stations

Delivery

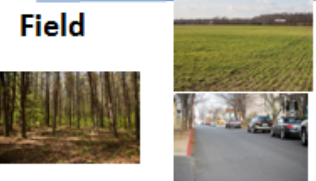



In **Sensitivities** Out

Land Use Load Decisions – Phase 6

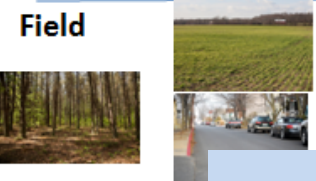
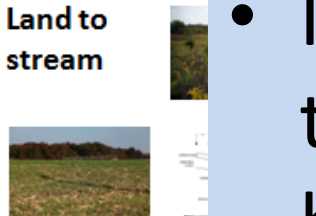




←----- Modeling workgroup -----> ←----- other CBP groups ----->

Scale in the Chesapeake Bay Program Watershed Model

Landscape	Phase 5		Phase 6		Sparrow	Other Data Sources
	Nutrients	Sediment	Nutrients	Sediment		
Field 		<p>AG and Forest: Used RUSLE2 to estimate EOF sediment targets</p> <p>Urban: Used Langland and Cronin To estimate pervious vs impervious loading</p>	Canal		<ul style="list-style-type: none"> Phase 5 had calibrated regional Factors to account for differences in small watershed and small stream delivery Necessary to meet water quality measurements Presented difficulties in communication 	
Land to stream 	<p>Field-level, hillslope, and small stream processes are all combined in the Edge-of-Stream nutrient estimates</p> <p>No EOF is simulated</p> <p>EOS estimates are a combination of regional factors and field-scale process simulation calibrated to average export rates</p> <p>Informed by inputs and calibration</p>	<p>Hillslope and small stream processes are combined in a sediment delivery ratio that is based on the average distance between each major land use type and a major river, adjusted for the coastal plain.</p>				
Stream to River 						
River to Estuary 		<p>Directly Simulated in HSPF for river averaging at least 100 cfs</p> <p>Calibrated to WQ data</p>				

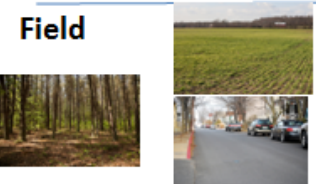



Scale in the Chesapeake Bay Program Watershed Model

Landscape	Phase 5		Phase 6		Sparrow	Other Data Sources
	Nutrients	Sediment	Nutrients	Sediment		
Field 		AG and Forest: Used RUSLE2 to estimate EOF sediment targets Urban: Used Langland and Cronin To estimate pervious vs	<i>Can we estimate EOF loads directly based on available information?</i>	<i>Should we update the sediment EOF estimates?</i>	Sources (fertilizer, manure, atdep, urban area) multiplied by global coefficients	Literature Reviews from TetraTech Sources in Phase 5 documentation Sensitivity documentation CEAP APLE
Land to stream 				Impervious area	Land to Water factors such as soil parameters and slopes	ICPRB/USGS Sparrow Land Data team Connected Impervious Land Data team Urban Tree Canopy
Stream to River 					Explicitly simulated to NHD+ level	ICPRB/USGS Sparrow Land Data team Urban Stream Corridor Land Data team Riparian Forest Land Data team Riverine Wetlands Center for Watershed Protection CBP Grant
River to Estuary 		Directly Simulated in HSPF for river averaging at least 100 cfs Calibrated to WQ data	Directly Simulate in HSPF for river averaging at least 100 cfs Calibrate to WQ data		Explicitly simulated	Calibrate to sparrow DFS or loads?

• If we can describe the function of hillslopes and small streams



Scale in the Chesapeake Bay Program Watershed Model

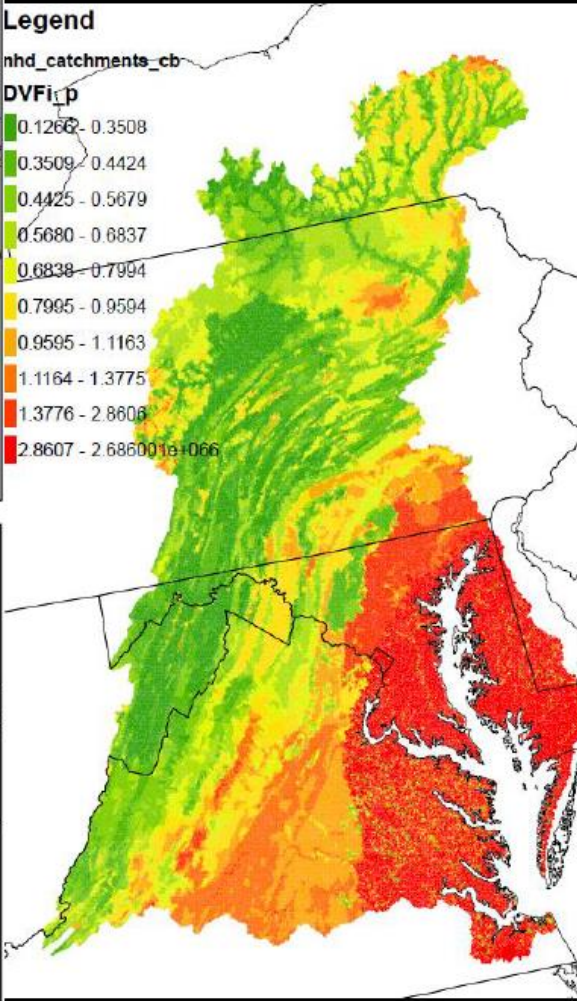
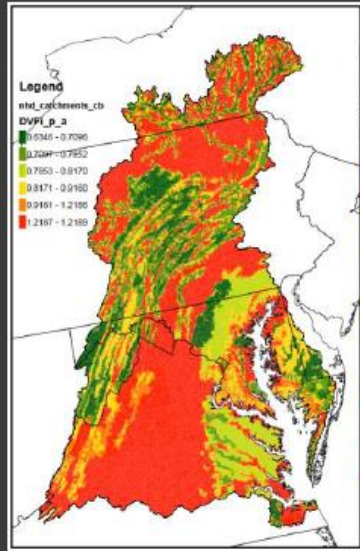
Landscape	Phase 5		Phase 6		Sparrow	Other Data Sources
	Nutrients	Sediment	Nutrients	Sediment		
Field 		AG and Forest: Used RUSLE2 to estimate EOF sediment targets Urban: Used Langland and Cronin To estimate pervious vs impervious loading	<i>Can we estimate EOF loads directly based on available information?</i>	<i>Should we update the sediment EOF estimates?</i>	Sources (fertilizer, manure, atdep, urban area) multiplied by global coefficients	Literature Reviews from TetraTech Sources in Phase 5 documentation Sensitivity documentation CEAP API F
Land to stream 	Field-level, hillslope, and small stream processes are all combined in the Edge-of-Stream nutrient estimates No EOF is simulated EOS estimates are a combination of regional factors and field-scale process simulation calibrated to average export rates Informed by inputs and calibration	Hillslope and small stream processes are combined in a sediment delivery ratio that is based on the average distance between each major land use type and a major river, adjusted for the coastal plain.	<i>Can we estimate watershed delivery based on landscape parameters?</i>			
Stream to River 			<i>Can we estimate small stream effects?</i>			CBP Grant
River to Estuary 	Directly Simulated in HSPF for river averaging at least 100 cfs Calibrated to WQ data		Directly Simulate in HSPF for river averaging at least 100 cfs Calibrate to WQ data		Explicitly simulated	Calibrate to sparrow DFS or loads?

... we can put them into phase 6

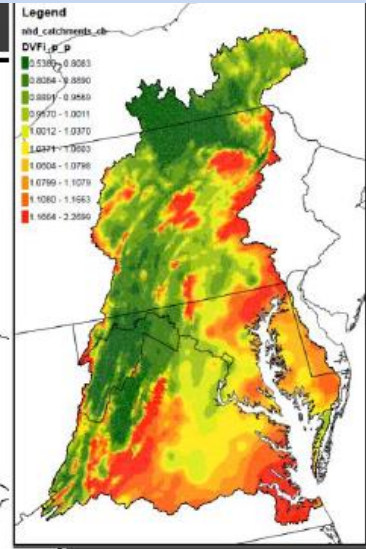


Sparrow estimates of phosphorus processes from land to water

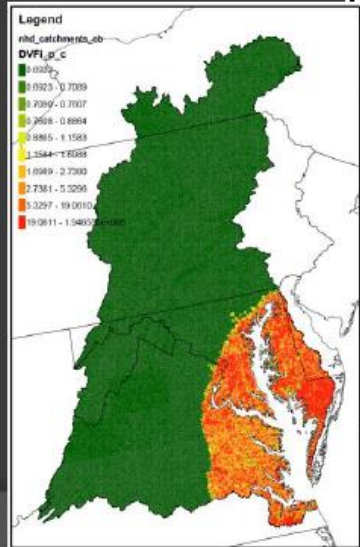
Type A Soils (-)



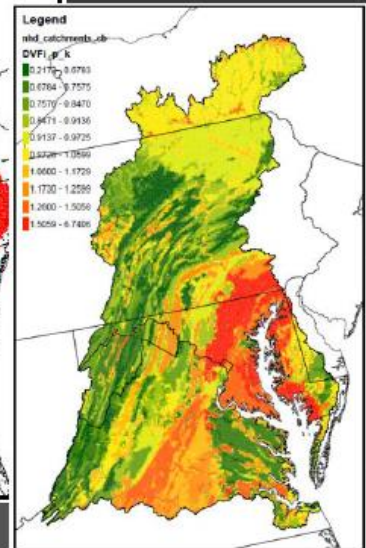
Precip (+)



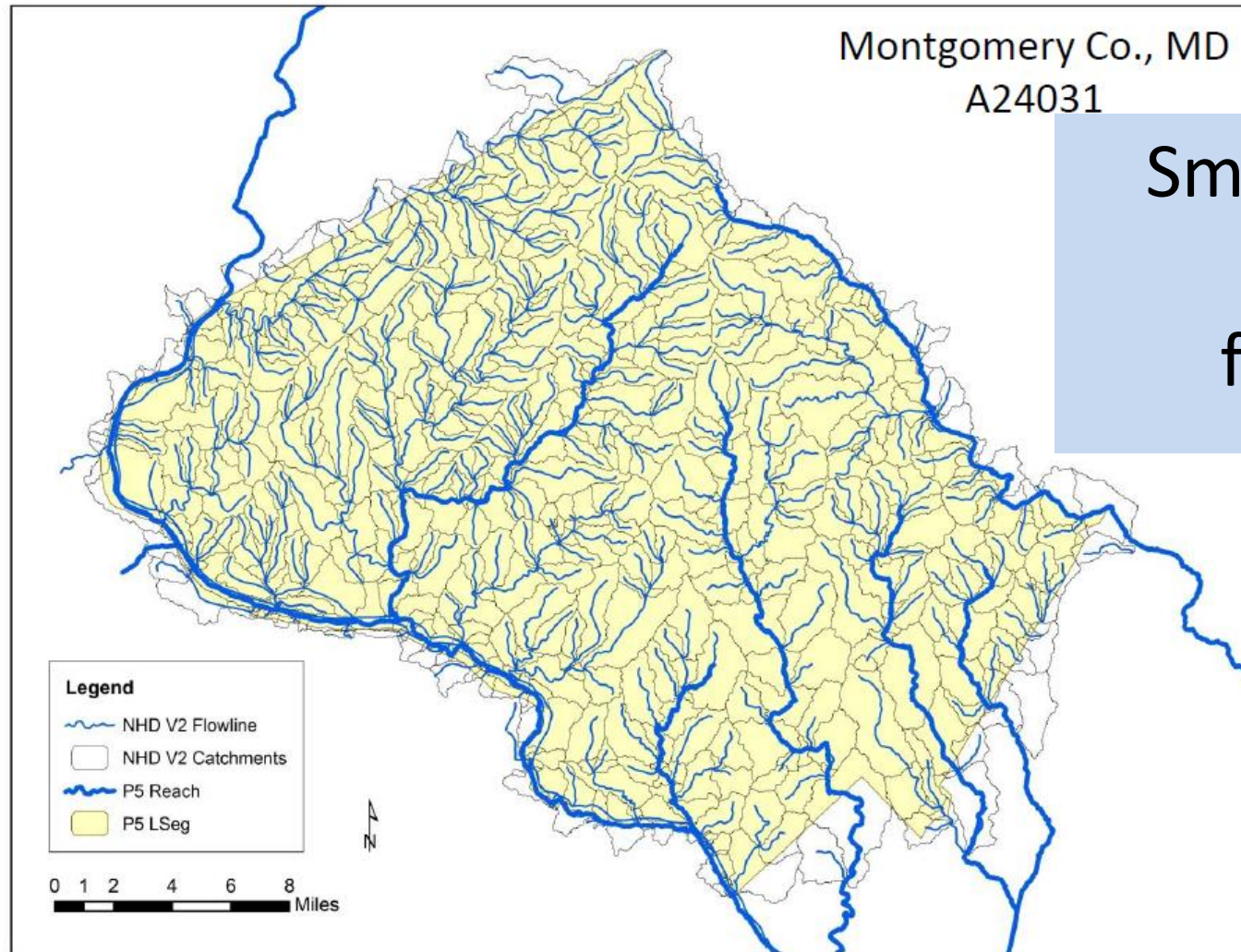
Coastal Plain (+)



Soil K-factor (+)

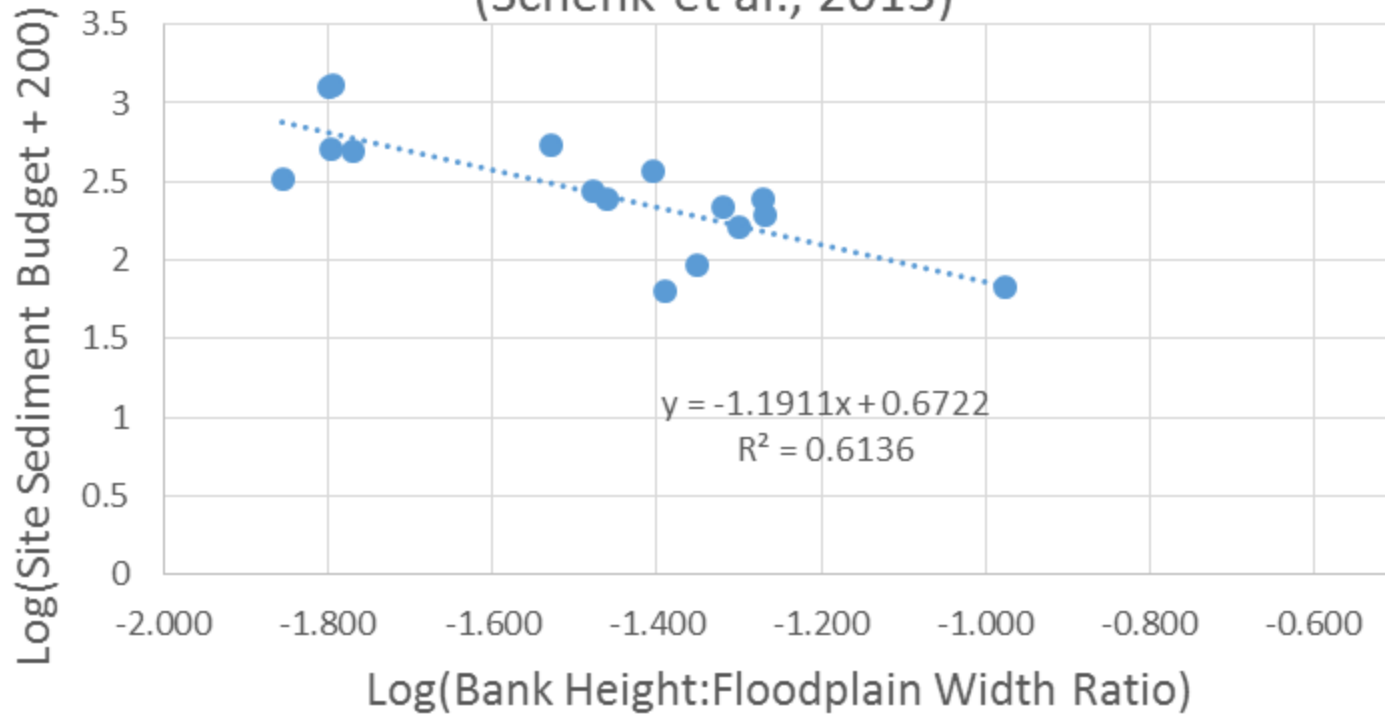


SPARROW Scale vs. P6 Scale



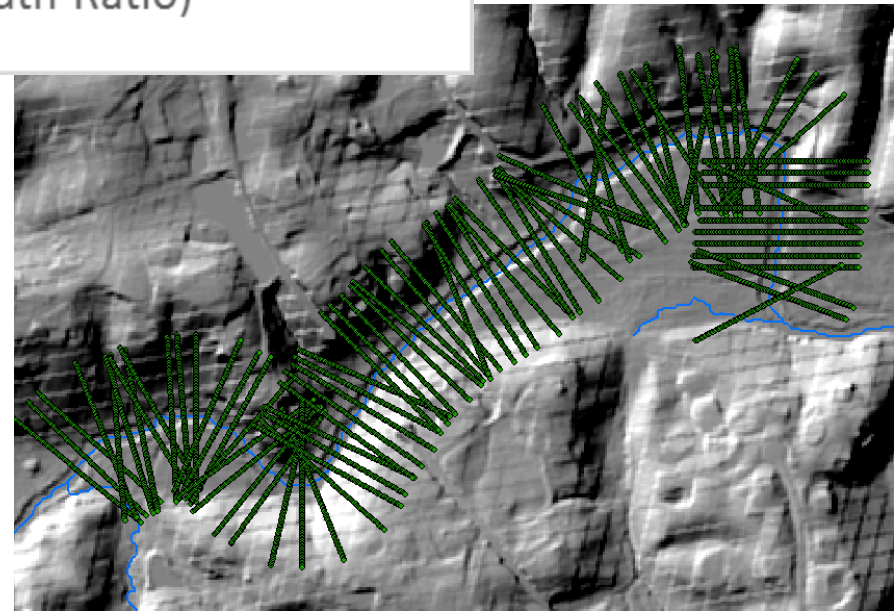
Small scale
stream
function

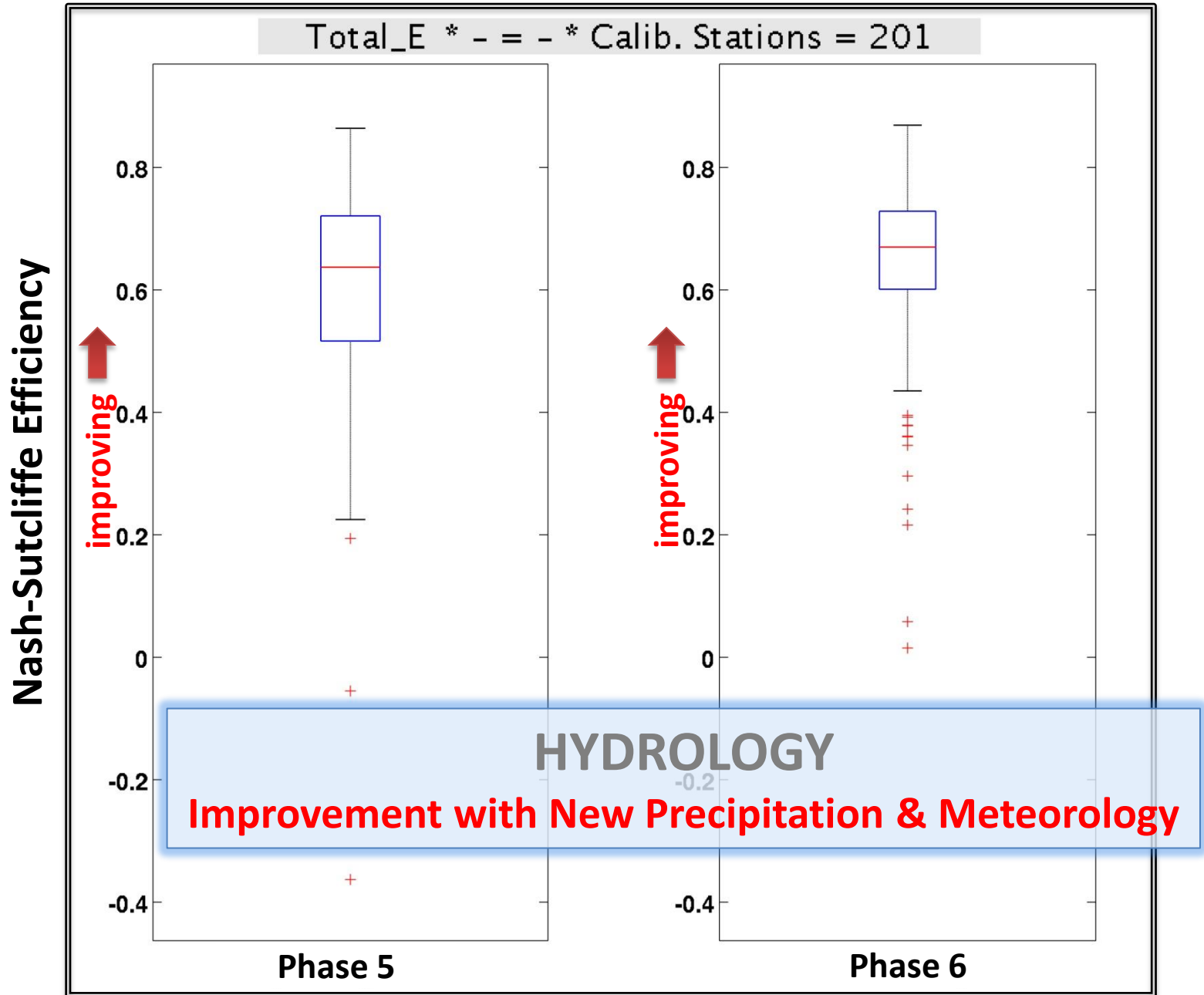
USGS Cross Section Sediment Budget (Schenk et al., 2013)



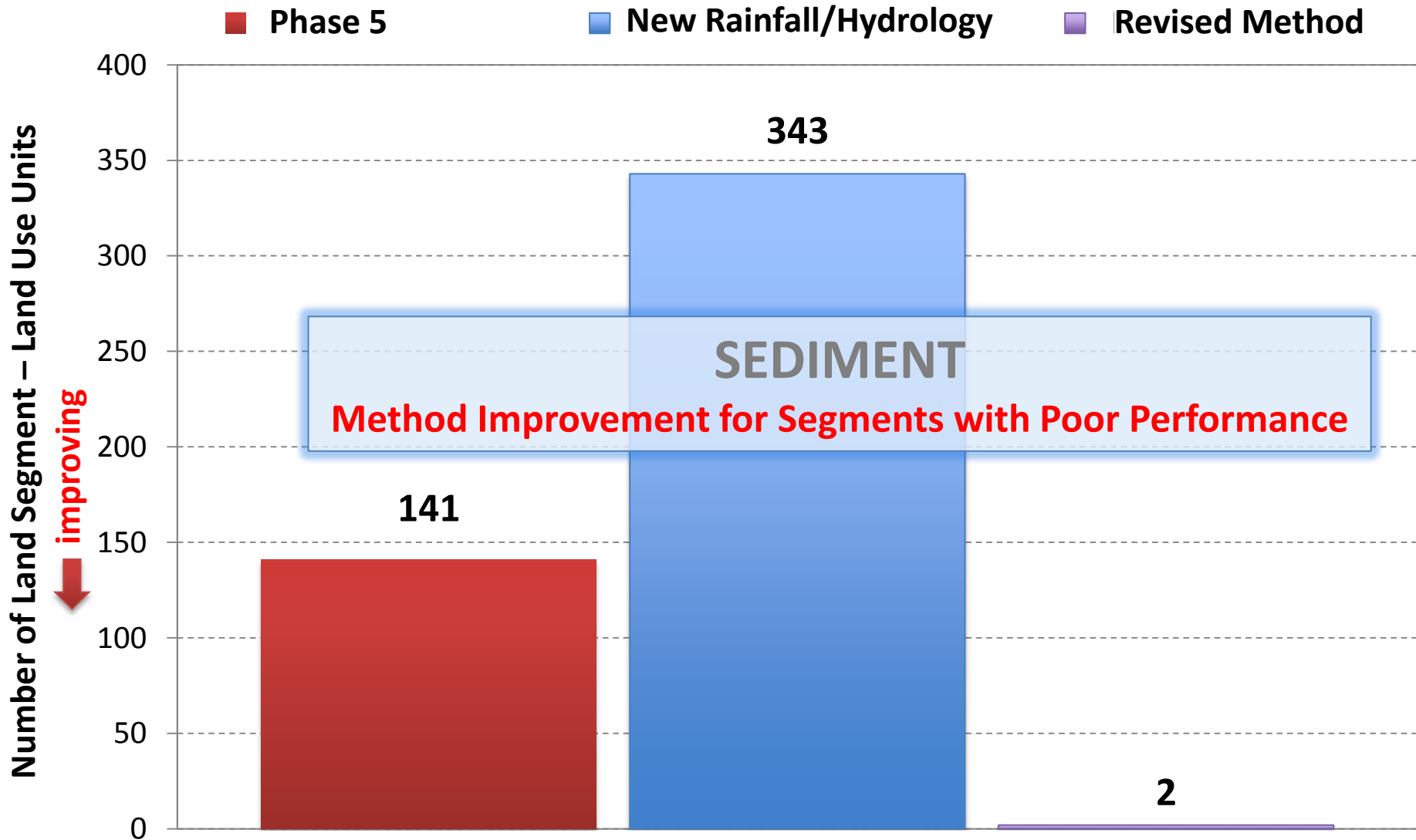
Also looking
at Buffers

Small scale
stream
function





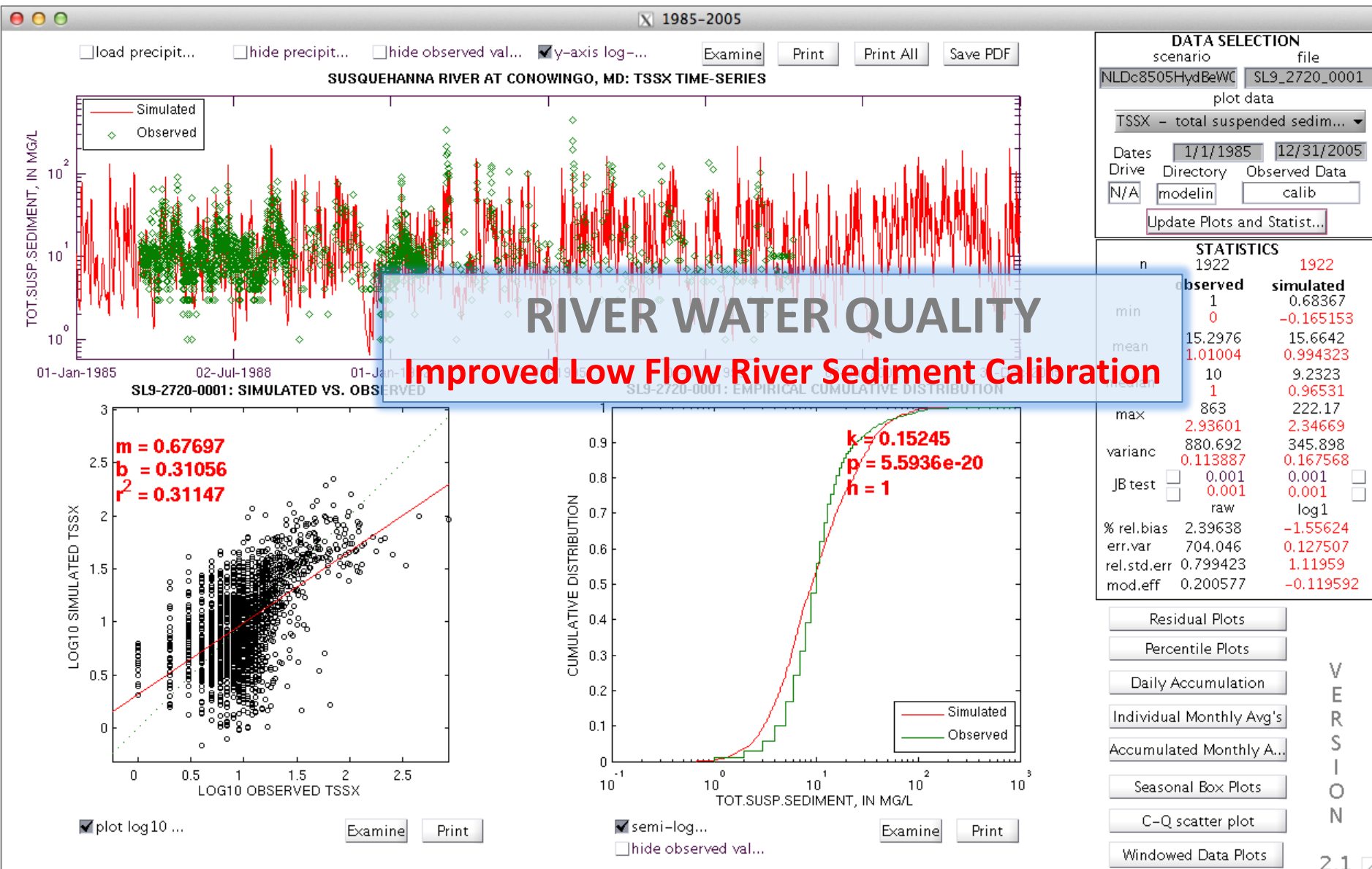
Improvement in Matching the a-priori *Targets**



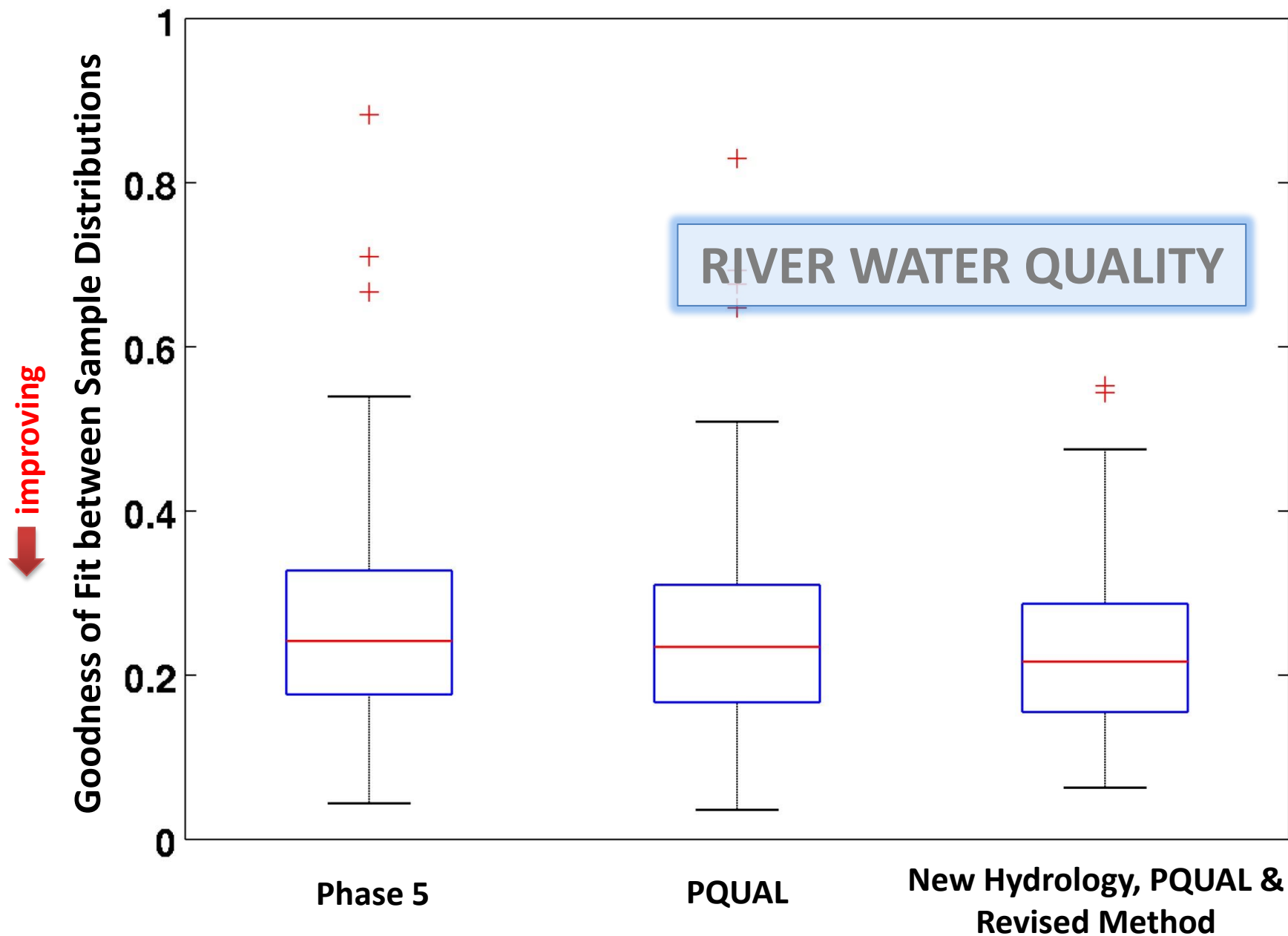
* Total Number of Land Segments (367) x Number of **Pervious** Land Uses (25) = 9175

Prototype Phase 6 – TSSX : : 1985 – 2005

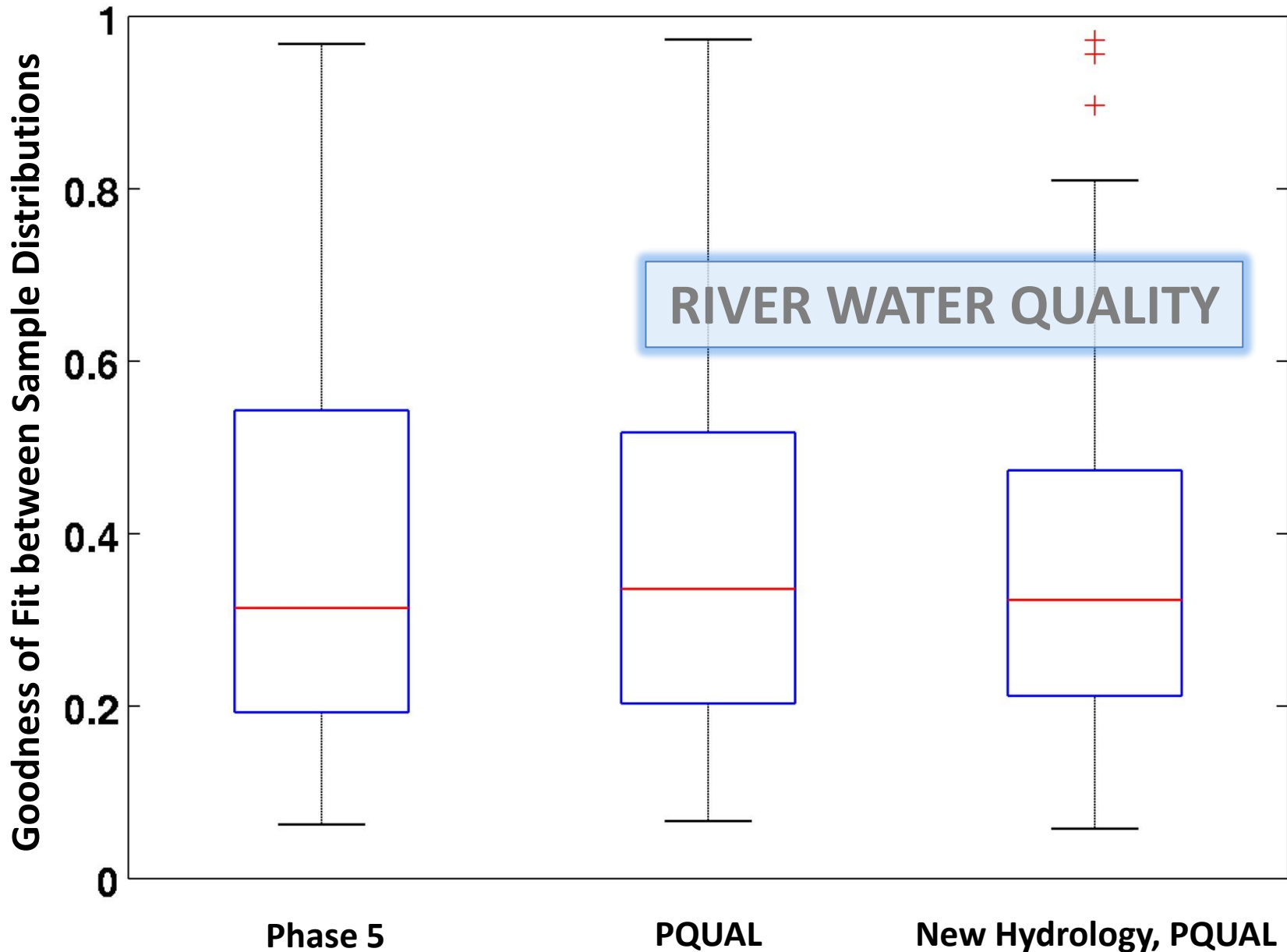
Susquehanna River near Conowingo, MD



Total Suspended Sediment (TSSX) at 193 Monitoring Stations

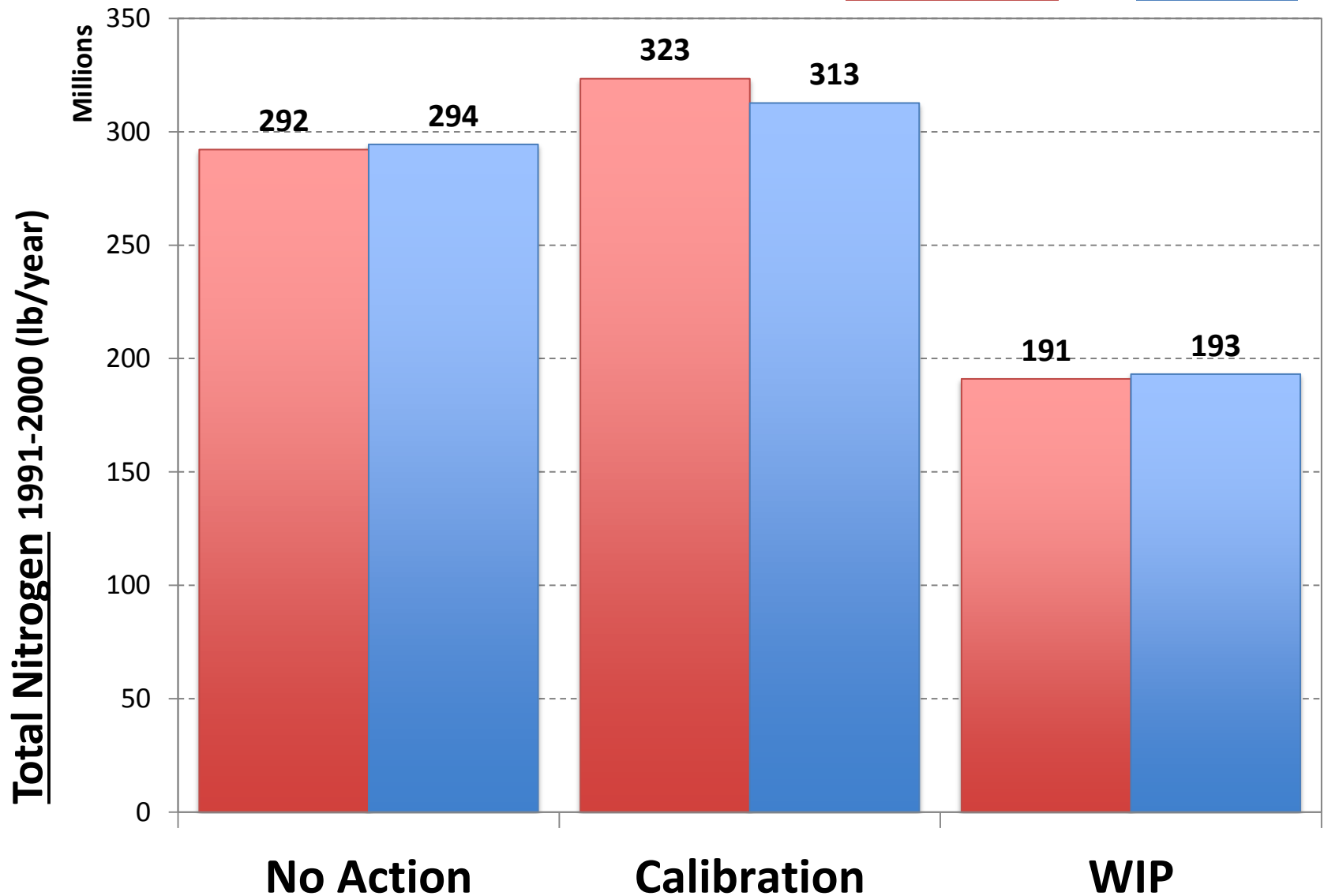


Total Nitrogen (TOTN) at 149 Monitoring Stations



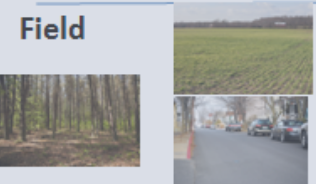
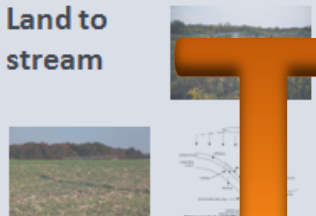
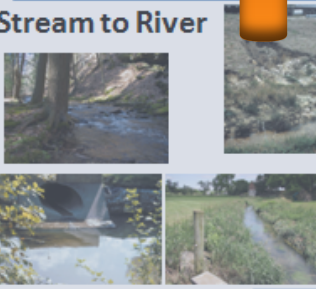
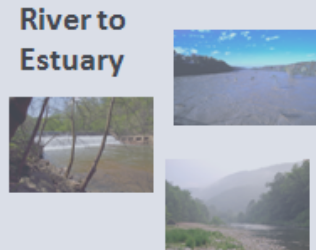
Provisionally Operational Phase 6 Watershed Model

Phase 532 vs. Phase 6*



* using draft nutrient export sensitivities

Scale in the Chesapeake Bay Program Watershed Model

Landscape	Phase 5		Phase 6		Sparrow	Other Data Sources
	Nutrients	Sediment	Nutrients	Sediment		
Field 		AG and Forest: Used RUSLE2 to estimate EOF sediment targets Urban: Used Langland and Cronin To estimate pervious vs impervious loading	<i>Can we estimate EOF loads directly based on available information?</i>	<i>Should we update the sediment EOF estimates?</i>	Sources (fertilizer, manure, atdep, urban area) multiplied by global coefficients	Literature Reviews from TetraTech Sources in Phase 5 documentation Sensitivity documentation CEAP APLE
Land to stream 	Field, hillslope, and stream processes are all considered in the Edge-of-Stream process simulation. No E... simulate... EOS... rates are... Informed by inputs and calibration	Hillslope and small stream... are... delivery ratio... based on the... dis... which... and use... and... river...	<i>Can we estimate watershed delivery based on landscape parameters?</i>		Land... water factors... soil parameters... slopes	ICPRB/USGS Sparrow Land Data team Connected Imperviousness Land Data team Urban Tree Canopy
Stream to River 			<i>Can we estimate small stream effects?</i>		Explicitly simulated to NHD+ level	ICPRB/USGS Sparrow Land Data team Urban Stream Corridor Land Data team Riparian Forest Land Data team Riverine Wetlands Center for Watershed Protection CBP Grant
River to Estuary 	Directly Simulated in HSPF for river averaging at least 100 cfs Calibrated to WQ data		Directly Simulate in HSPF for river averaging at least 100 cfs Calibrate to WQ data		Explicitly simulated	Calibrate to sparrow DFS or loads?

Thank You

BayFAST

2 farm example Location

Help

Save Reset Cancel



User Process

Draw an outline around parcel

Define for the parcel

- Land use and acres in each
- Population on septics and number of septic systems

Create scenario

- Select facility for scenario (scenario is for only one facility at a time)
- Select baseline BMPs

Create additional scenarios as needed for load comparisons

Apply BMPs

to each land use for each land-river segment

Output

Edge of stream and delivered pounds for each land use for a facility.
Provided on the webpage as well as in a file for download in tabular form.

Estuarine Model

2017 Chesapeake Bay Estuarine Model

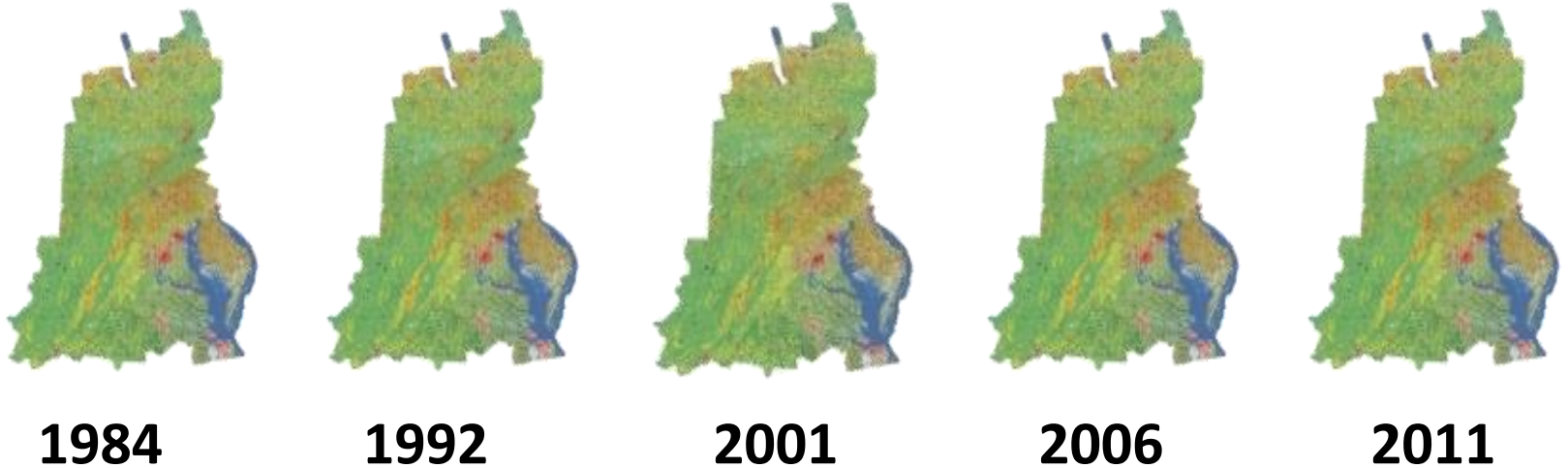
- Improved sediment biogeochemistry with scour, resuspension, fate and transport of organic material
- Finer computational grid in shallow water
- Full explicit simulation of oyster and menhaden and other major filter feeder and deposit feeder groups
- Full sediment transport simulation with resuspension of sediment
- Extension of simulation period into recent time
- Refined chlorophyll simulation and assessment particularly in the James and DC waters

2017 Chesapeake Bay Estuarine Model

- Estuarine wetland simulation (maybe)
- Explicit simulation of adjacent coastal ocean (maybe)
- Fine temporal scale light field for diurnal DO in small embayments (maybe)
- Representation of maintenance dredging and other marine activities that resuspend sediment (maybe)

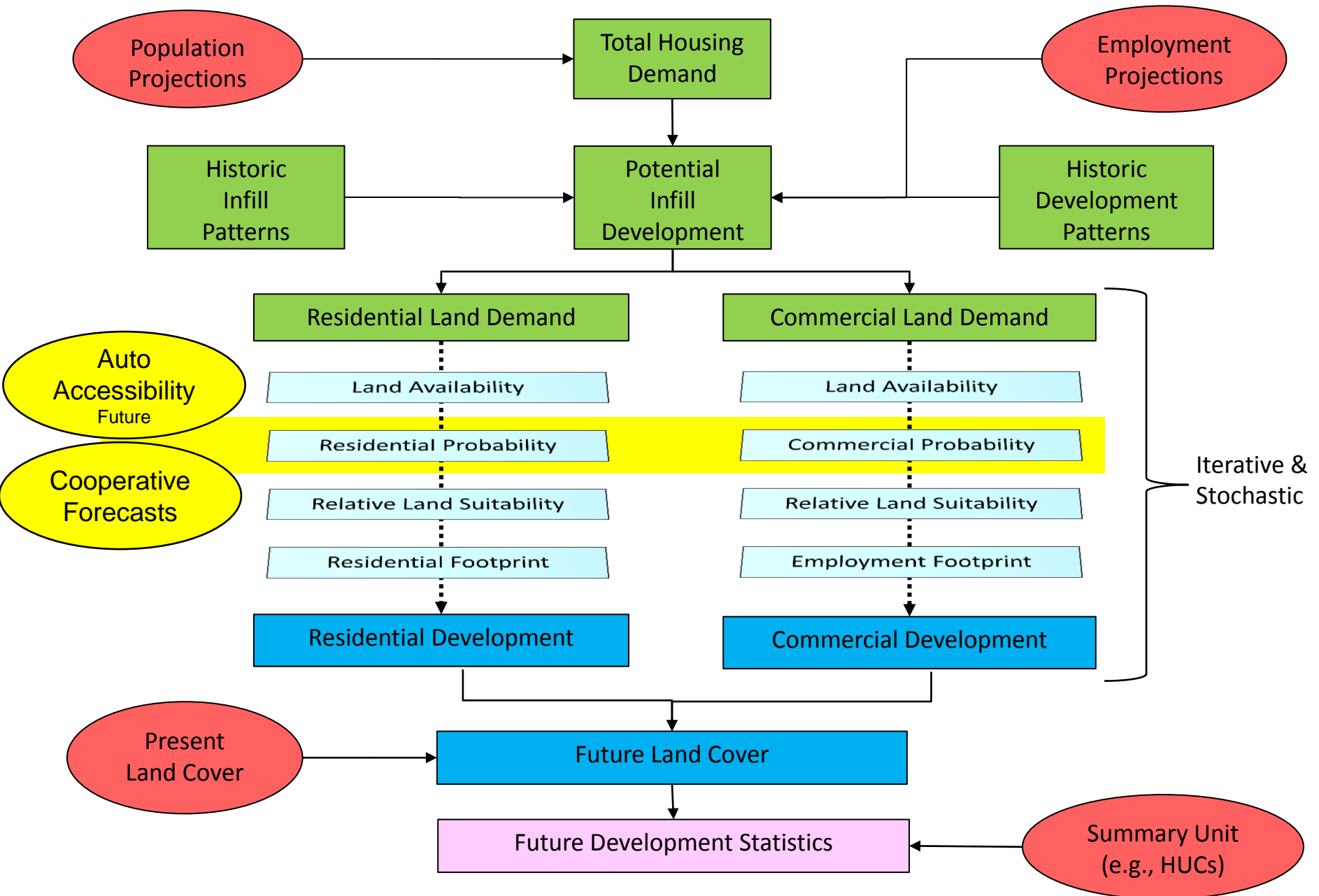
Land Use Change Model

Chesapeake Bay Land Cover Data Series

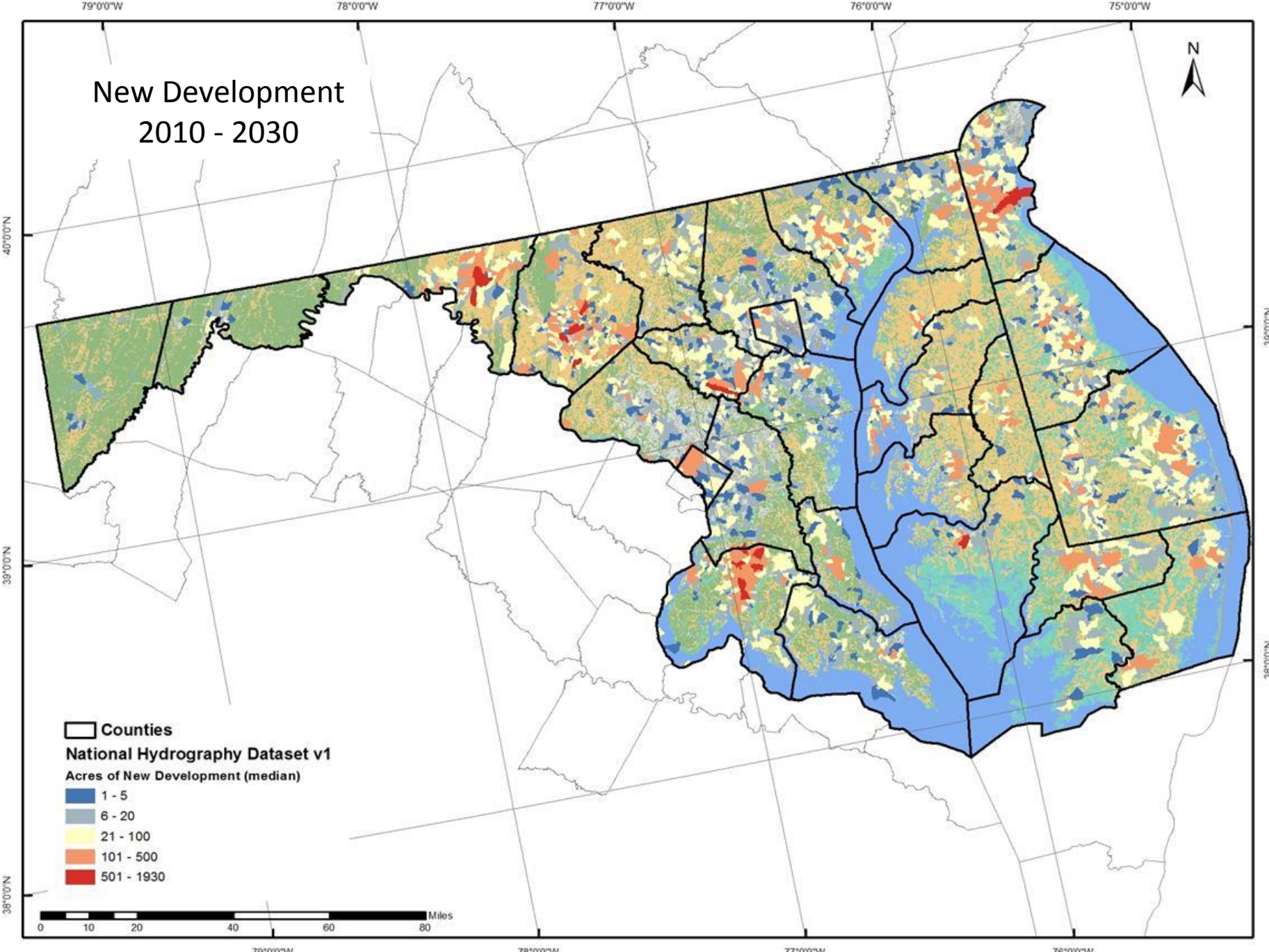


Irani, F. M., & Claggett, P. (2010). Chesapeake Bay Watershed Land Cover Data Series. *US Geological Survey Data Series*, 505.

Chesapeake Bay Land Change Model v3a



New Development 2010 - 2030



79°00'W

78°00'W

77°00'W

76°00'W

75°00'W

Variability in Forecast 2010 - 2030



40°00'N

39°00'N

39°00'N

38°00'N

38°00'N

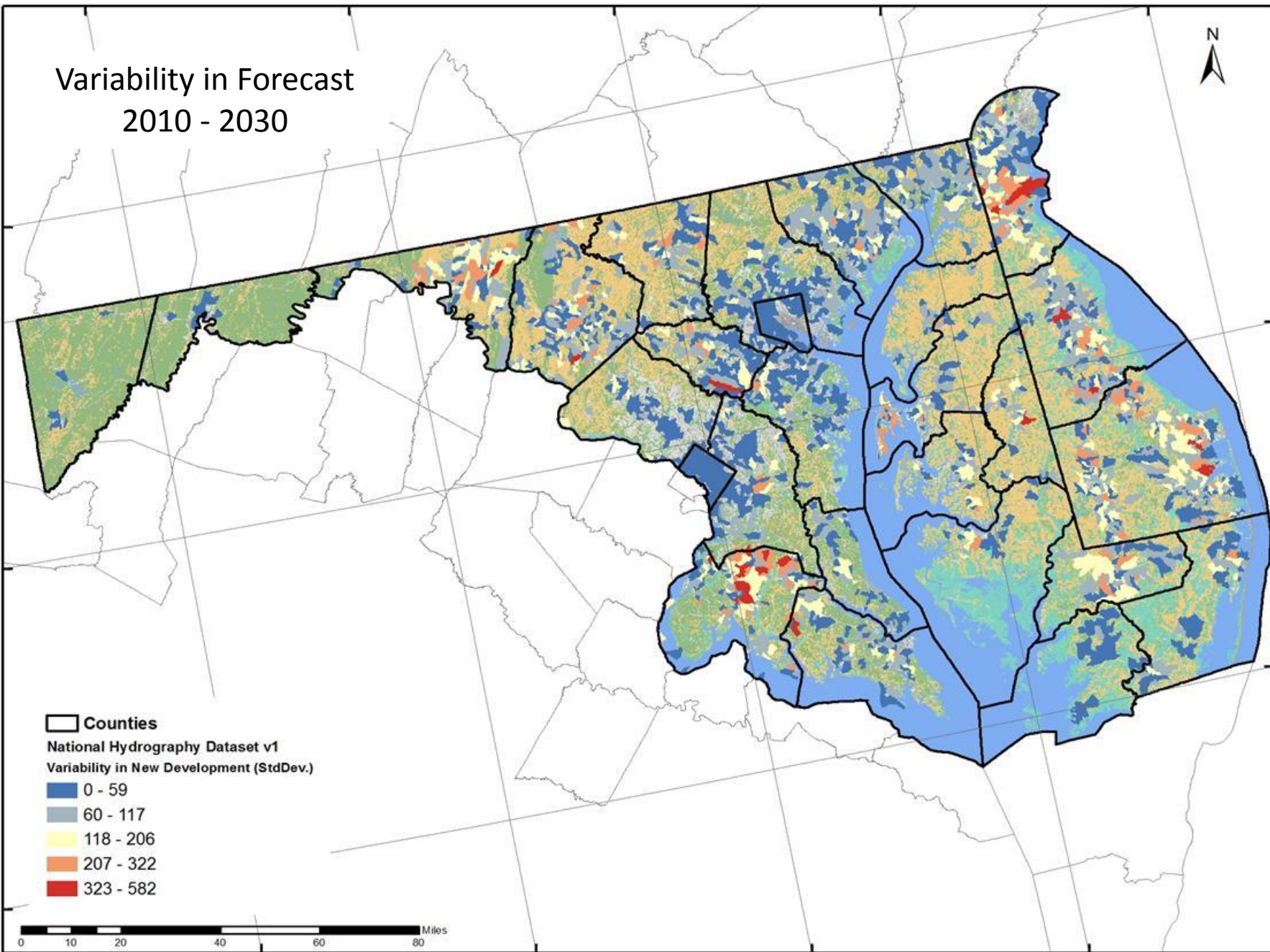
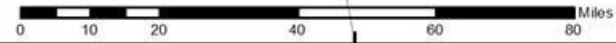
79°00'W

78°00'W

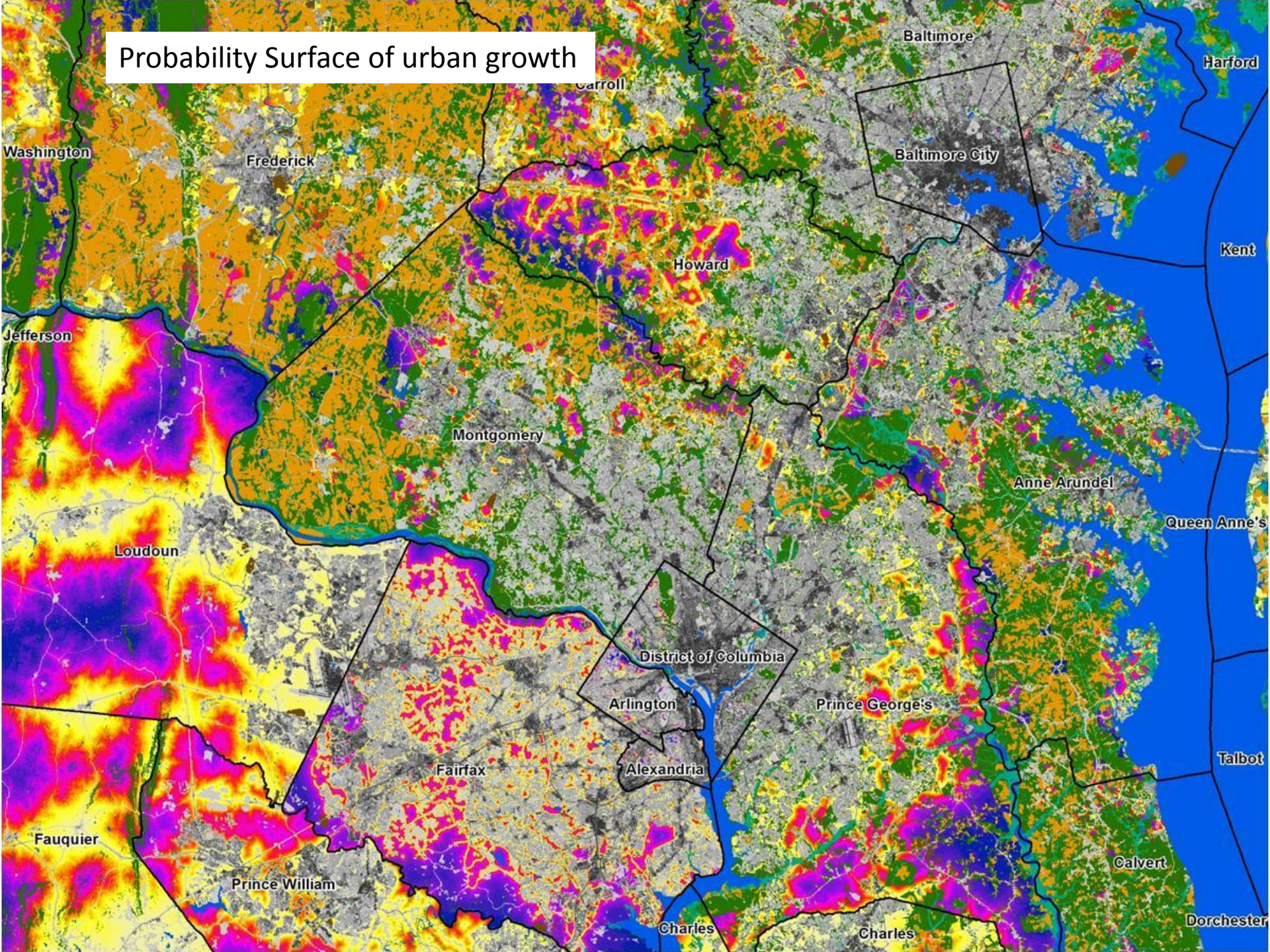
77°00'W

76°00'W

- Counties
- National Hydrography Dataset v1
- Variability in New Development (StdDev.)
- 0 - 59
- 60 - 117
- 118 - 206
- 207 - 322
- 323 - 582

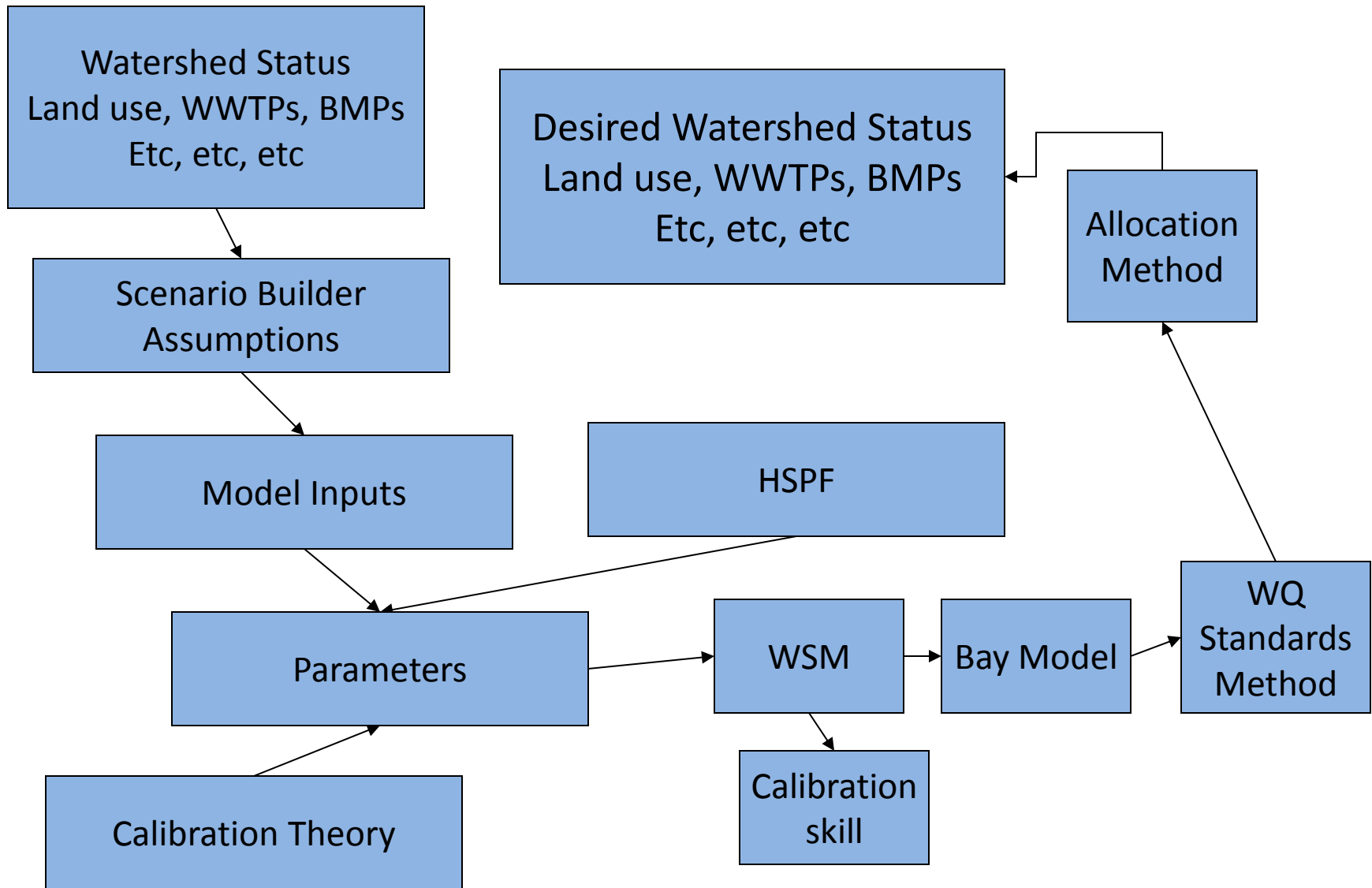


Probability Surface of urban growth

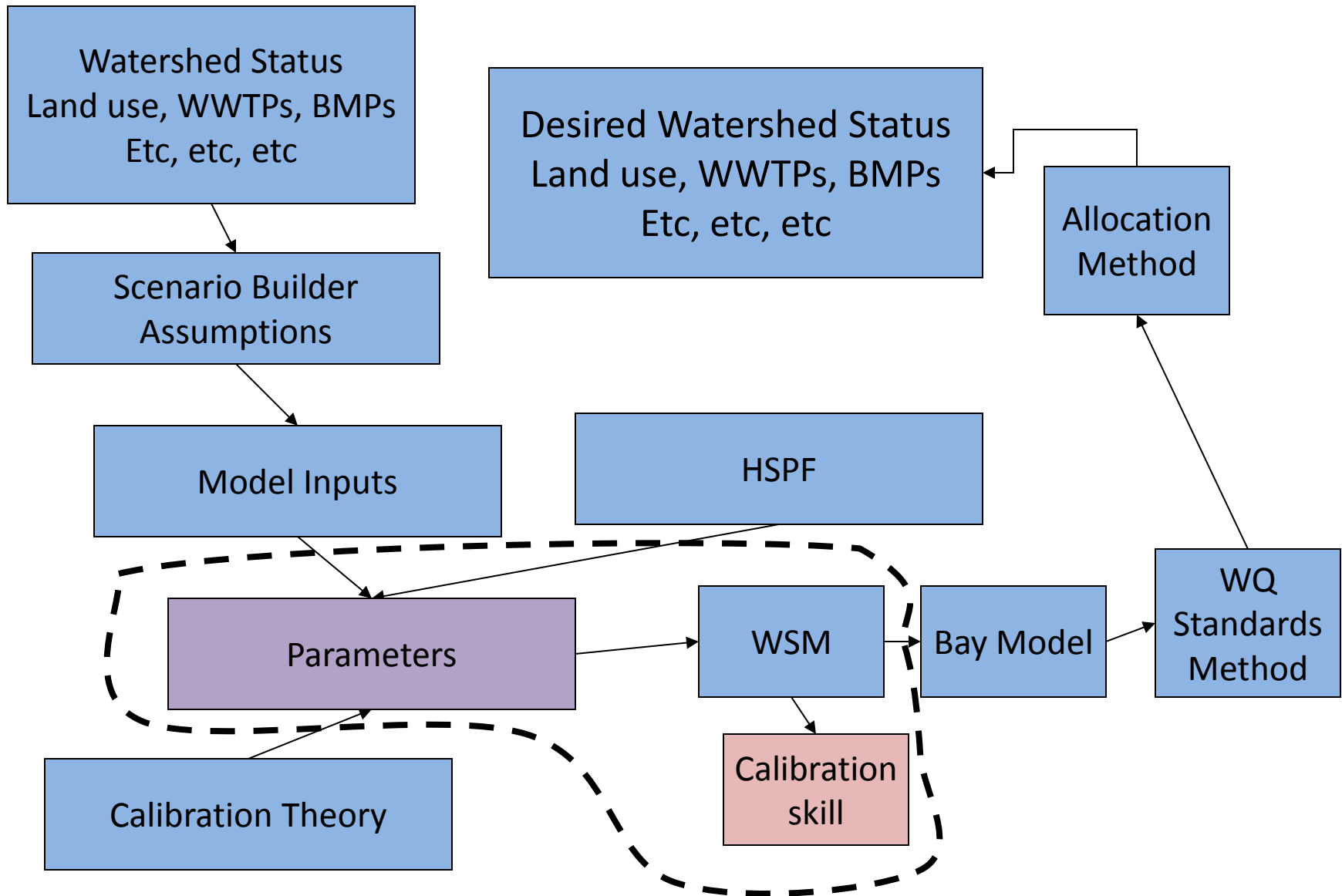


Uncertainty

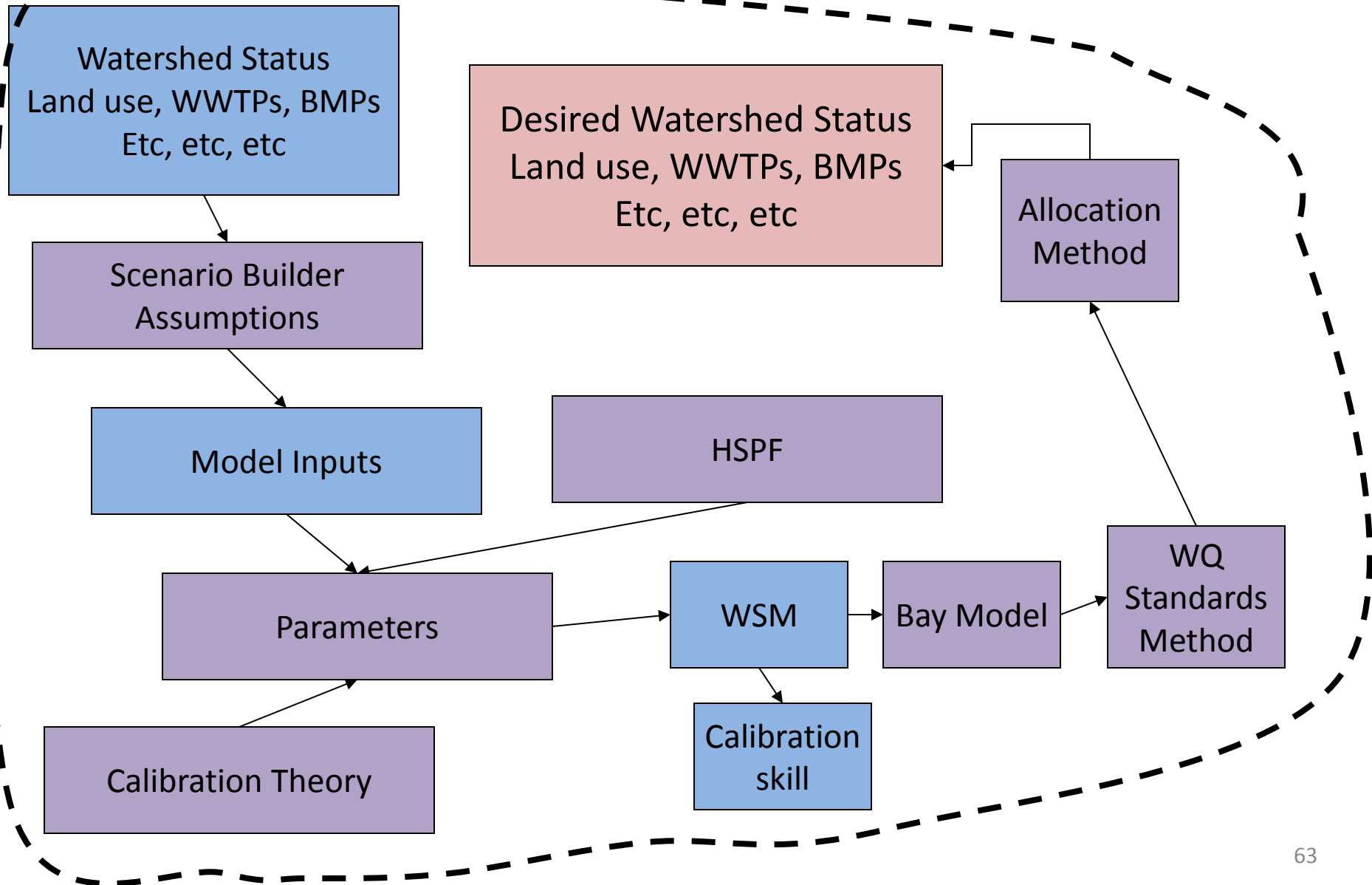
Decision Algorithm



Traditional Uncertainty Analysis



Decision Algorithm

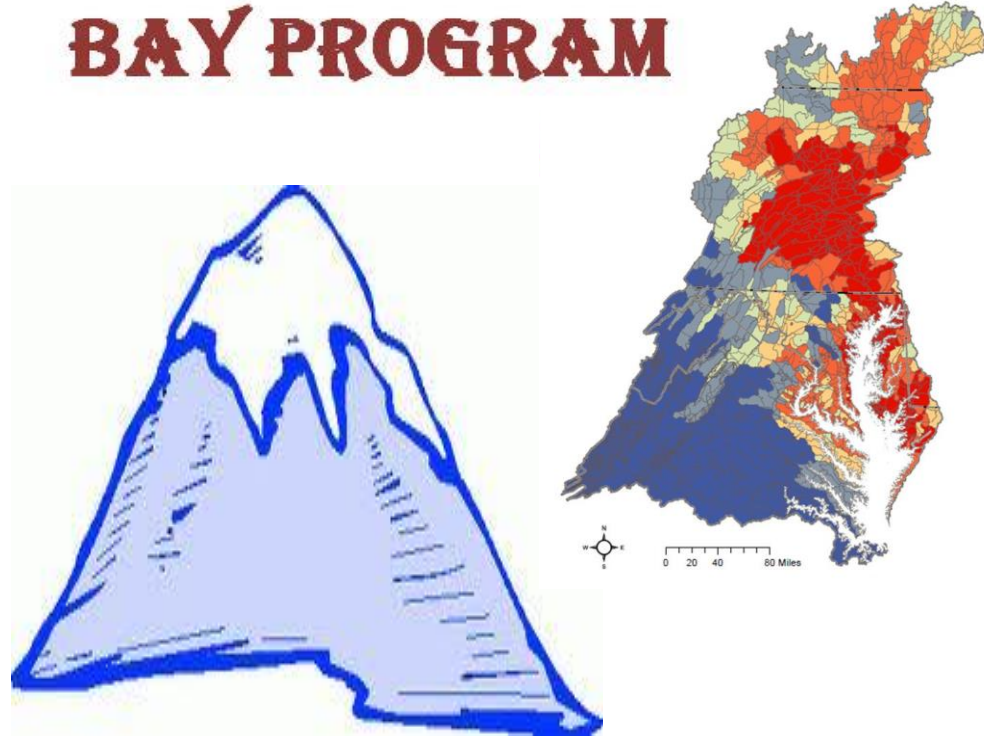


Modeling Change

The old CBP view of modeling



CHESAPEAKE BAY PROGRAM



Other models



The New CBP view of modeling

