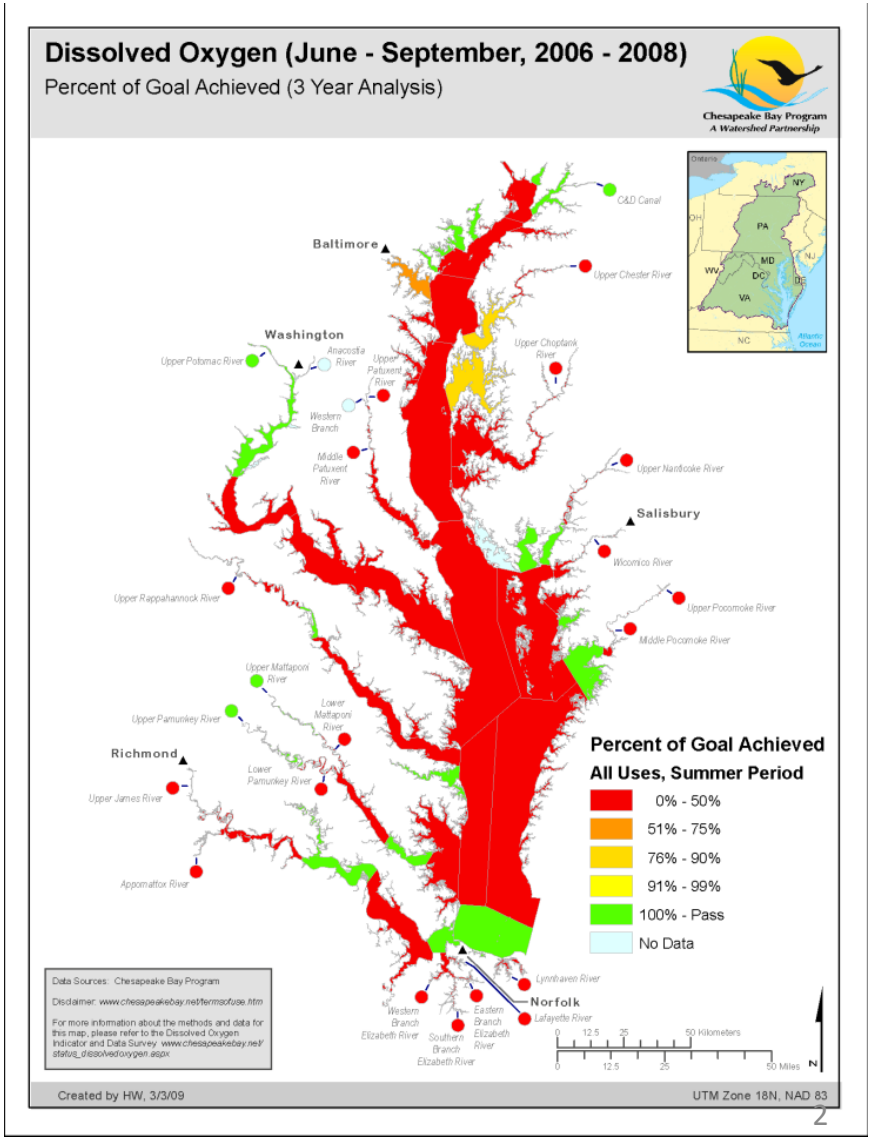
Sediment Simulation in The CBP Watershed Model

Gary Shenk – USGS - Chesapeake Bay Program

4/25/17

Chesapeake Bay TMDL

- Necessitated by failure to meet water quality standards for Dissolved Oxygen, Clarity, and Chlorophyll
- Sets limits on Nitrogen, Phosphorus, and Sediment
- Nitrogen and Phosphorus are the drivers



TMDL Timeline

- 1999 – Lawsuit by American Canoe Association and American Littoral Society
- 2010 – TMDL put in place
- 2017 MidPoint Assessment
  - 60% of the management practices implemented
  - Improved models
  - Mid-Course Correction?
- 2025 TMDL Goal Date
  - 100% of the management practices implemented
  - New Models?

Partnership Feedback on Modeling for the 2017 model

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

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

Keep it Simple!!

Include Everything!!!





Time Averaged Phase 6 Model Structure

Edge of Field

*

Land Use Acres

*

BMPs

*

Land to Water

*

Stream Delivery

*

River Delivery

Direct Loads

Phase 6

Keep It Simple

Include Everything

Edge of Field

*

Land Use Acres

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Land to Water

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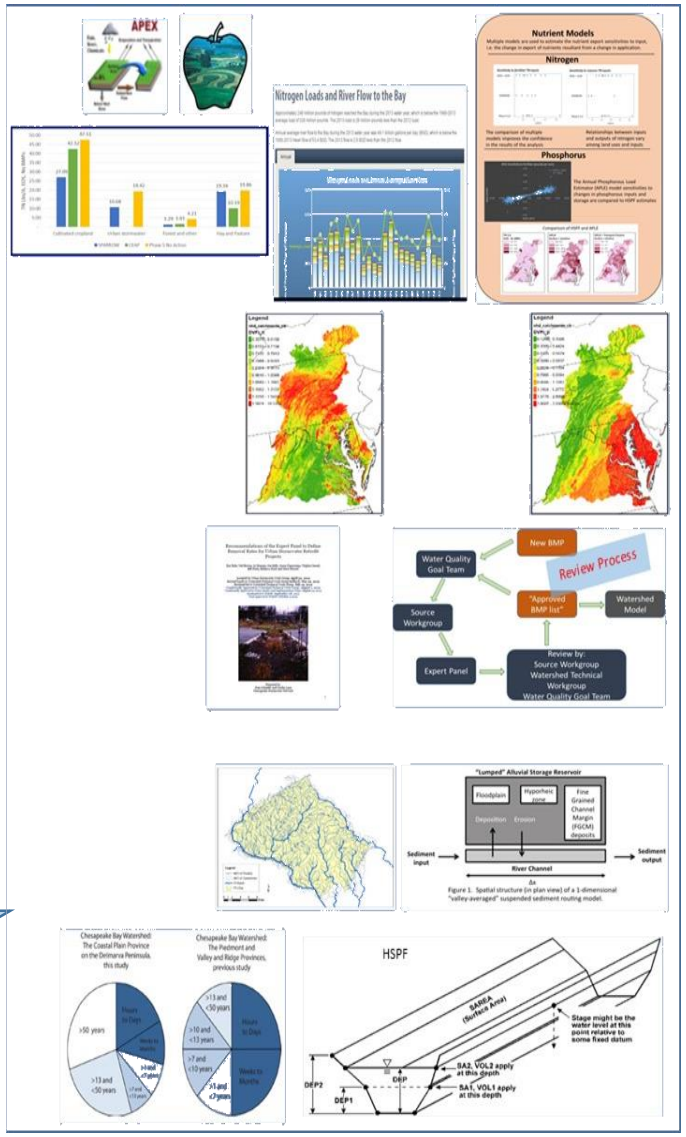
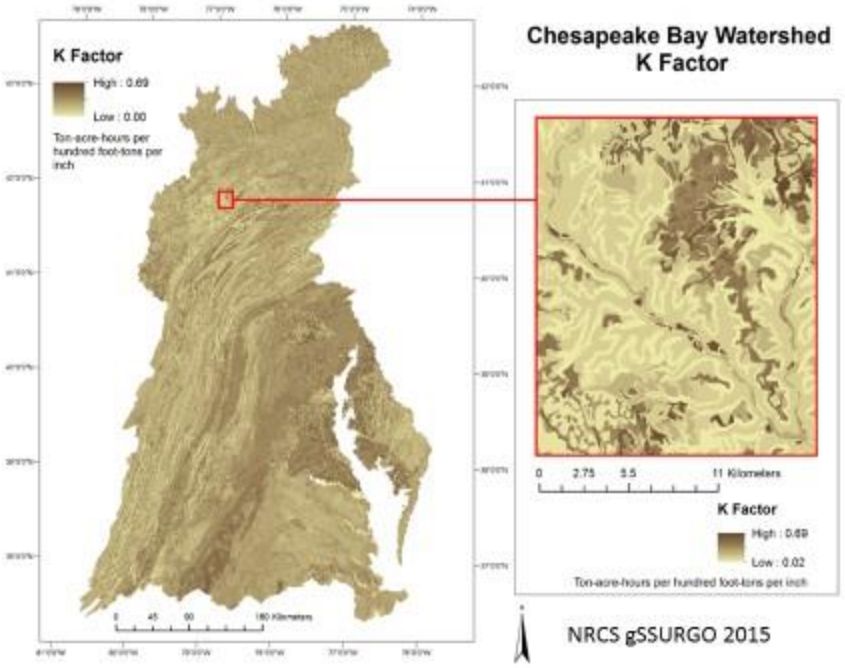
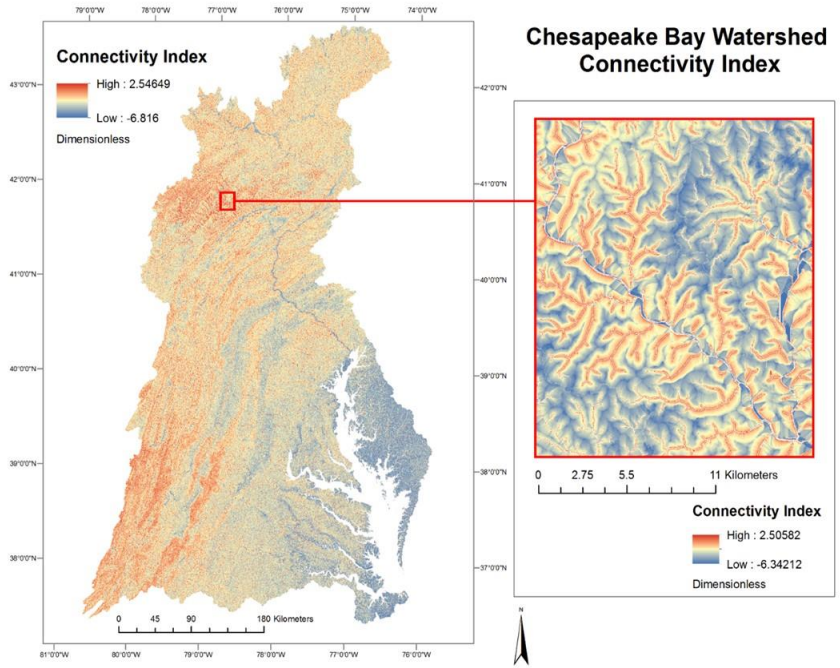
Direct Loads



Sediment Budget


K Factor
High : 0.69
Low : 0.00
Ton-acre-hours per hundred foot-tons per inch
0 45 90 180 Kilometers
Chesapeake Bay Watershed
K Factor
0 2.75 5.5 11 Kilometers
K Factor
High : 0.69
Low : 0.02
Ton-acre-hours per hundred foot-tons per inch
NRCS gSSURGO 2015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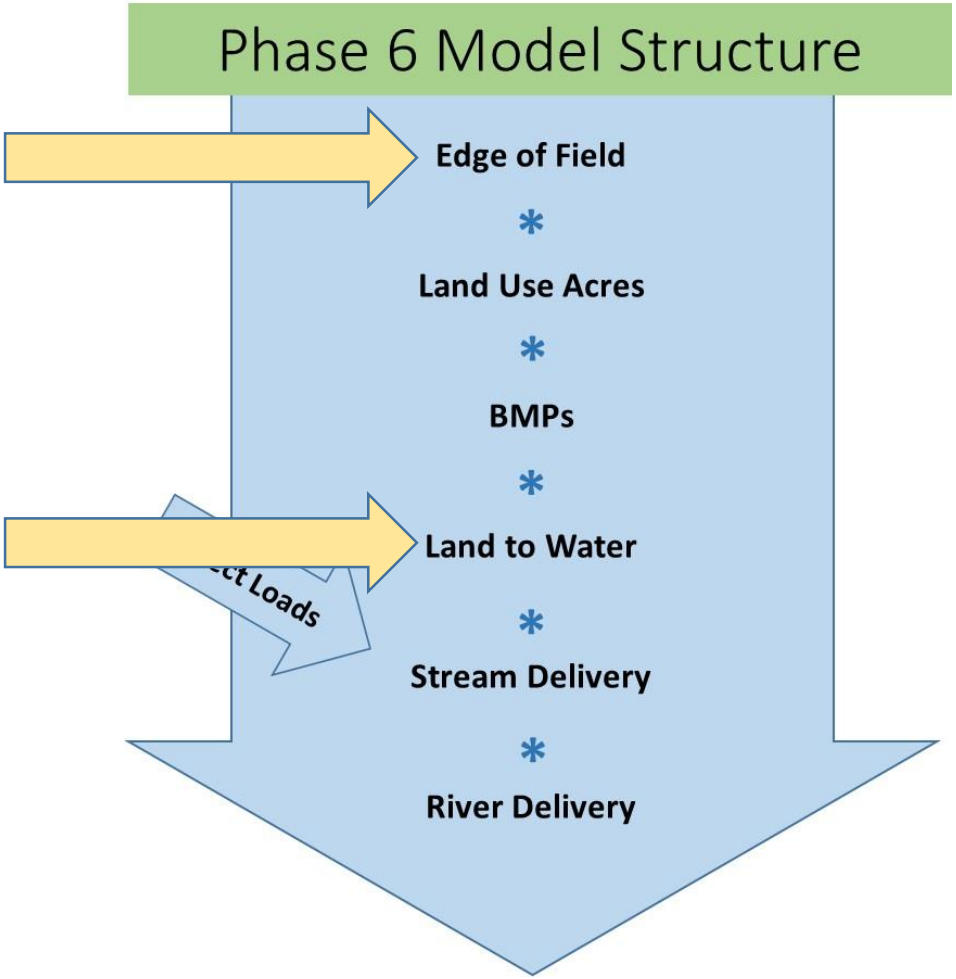
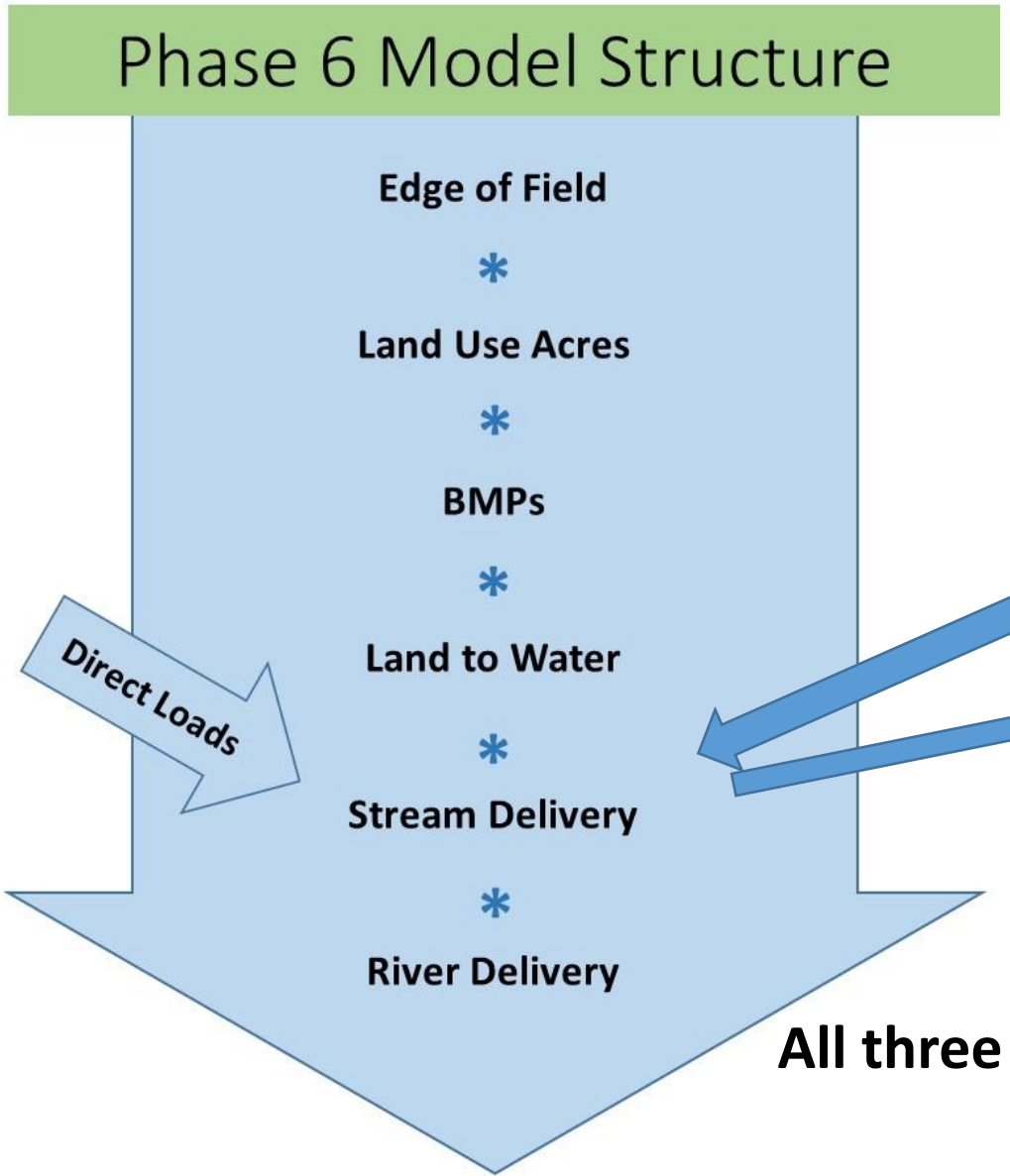

Phase 6 Model Structure
Edge of Field
*
Land Use Acres
*
BMPs
*
Land to Water
*
Stream Delivery
*
River Delivery

Stream Sediment Effects – 2 methods

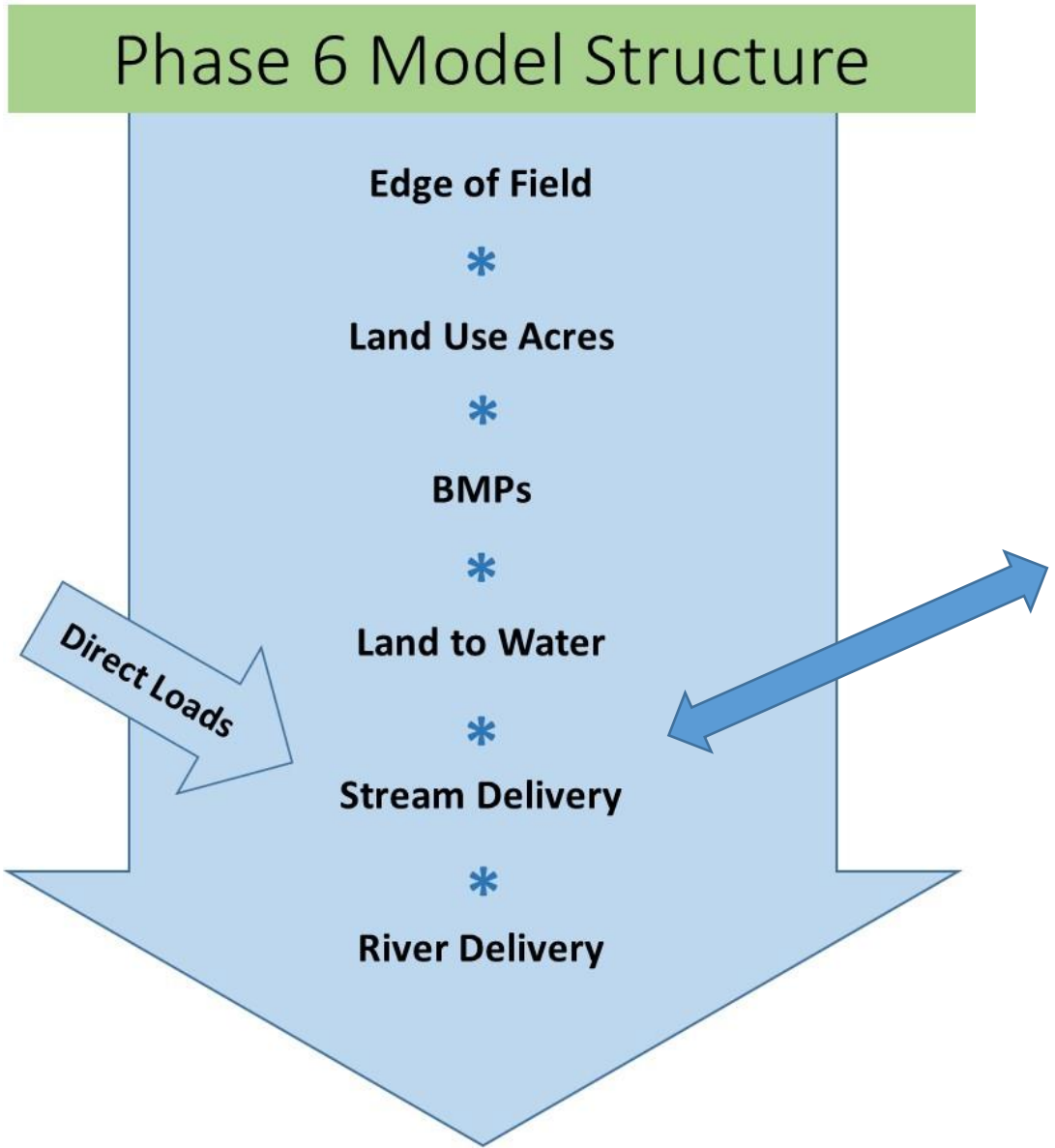


Absolute Load change
2 load sources
Streambank (+)
Floodplain (-)

Simple Factor
Based on Reservoirs

All three can exist in the same segment

Stream Restoration BMP



Reduction in Streambank loading source.

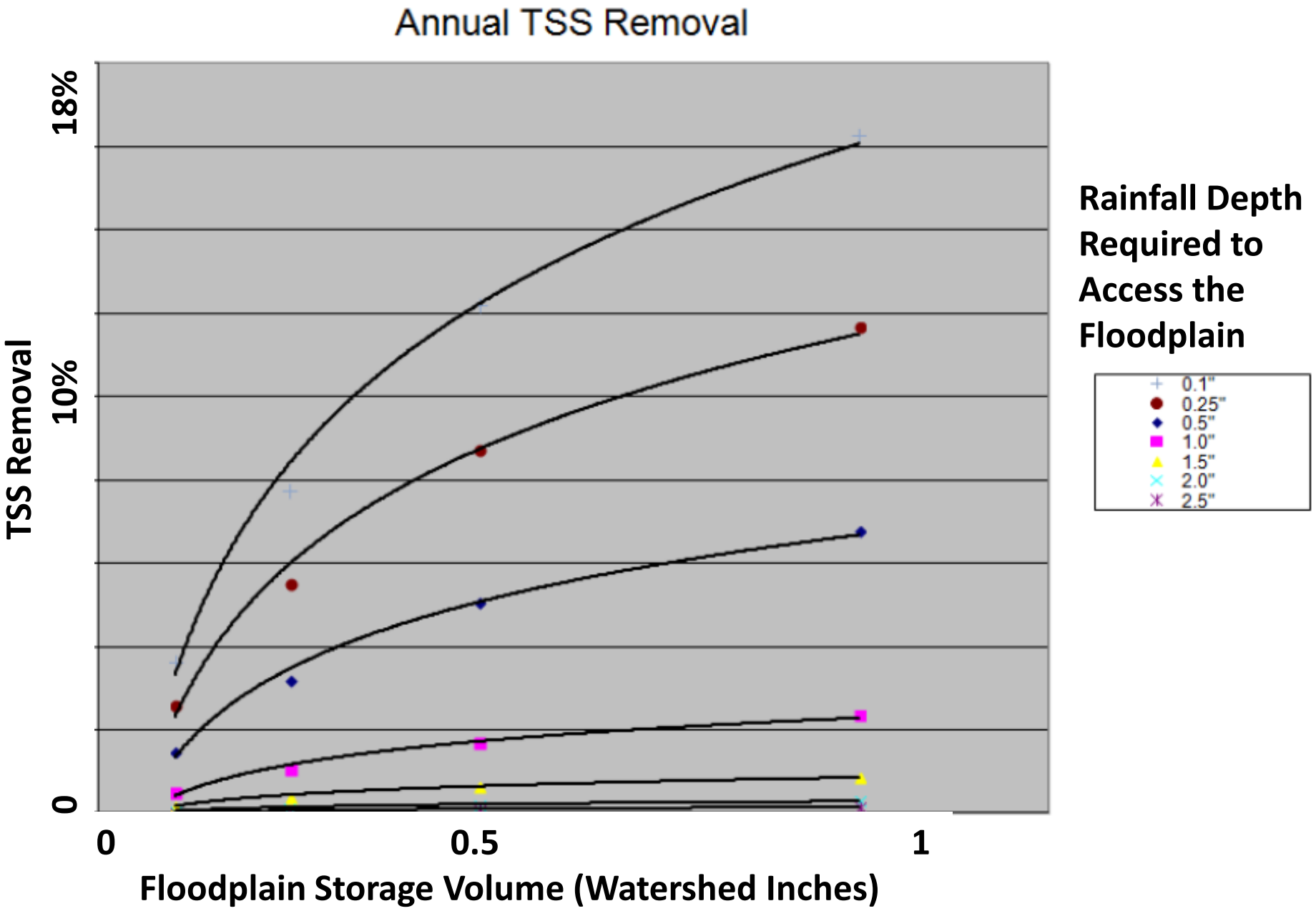
Stream Restoration Credit

- Protocol 1: Prevented Sediment
- Protocol 2: Nutrient Processing
- Protocol 3: Floodplain Reconnection
- Protocol 4: Dry Channel RSC

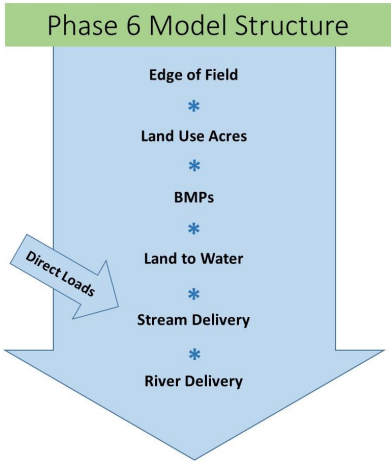
--------- or ----------

- Default pounds per linear foot

  (0.075 TN, 0.068 TP, 248 TSS)



Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects – Berg, et al 2013



STAC Review

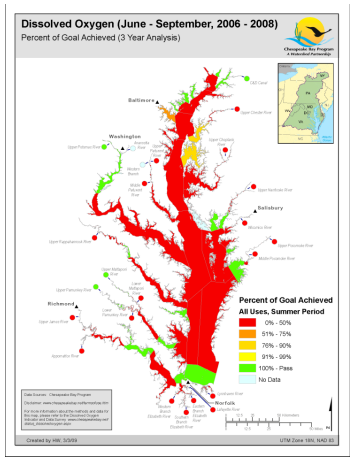
- It has been said that democracy is the worst form of Government except for all those other forms that have been tried from time to time
  - Winston Churchill 11/11/47

- new model structures should be created that account for the variety of potential sediment sources in the watershed and the wide distribution of timescales for sediment delivery. A coordinated modeling and field research program will be needed to support such an effort

Sediment Effect on Nutrient Models







Average Load + Δ Inputs * Sensitivity

*

Land Use Acres

*

BMPs

*

Land to Water

*

Stream Delivery

*

River Delivery

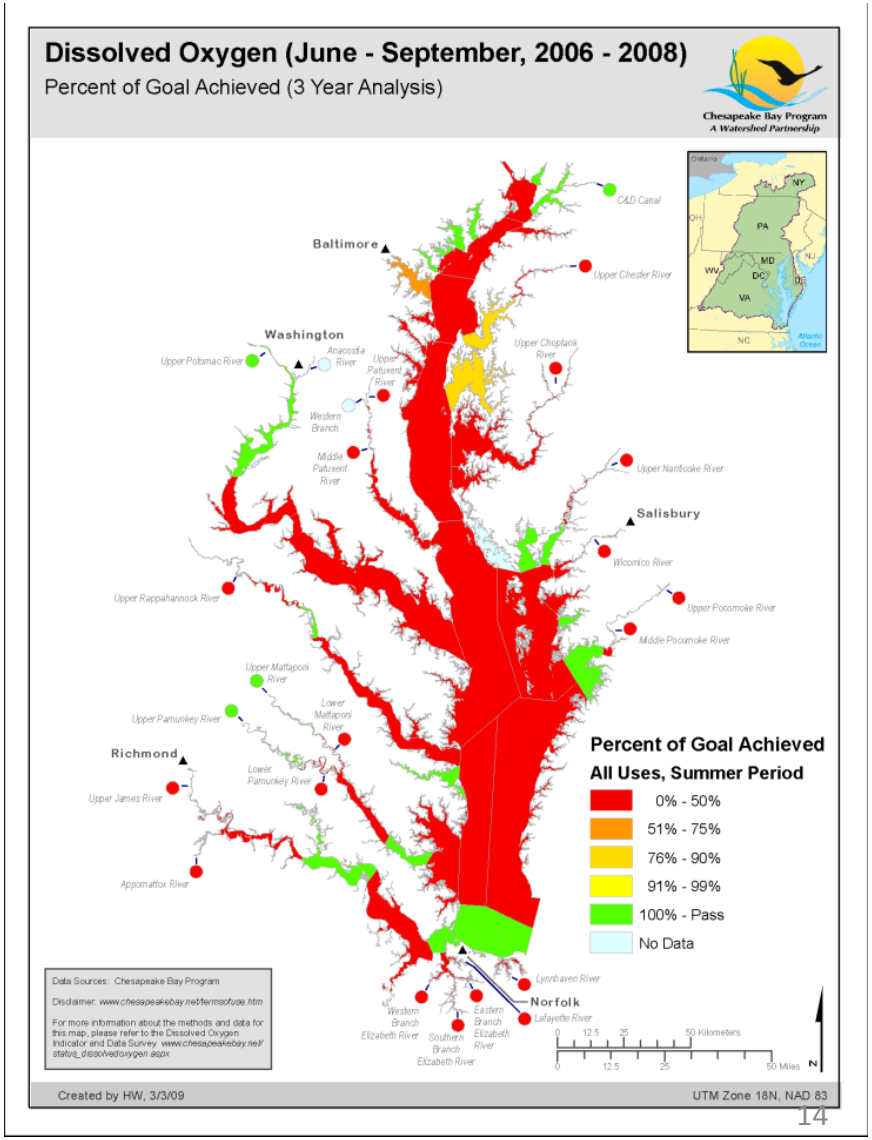
Direct Loads

Phase 6

Sediment Effect on the Bay

Coarse sediments needed for wetlands

Fine sediments block light for aquatic vegetation



Chesapeake Assessment Scenario Tool

HOME ABOUT CONTACT US

CAST PLANNING TOOLS

Logging in to CAST allows users to rapidly develop scenarios for reducing nitrogen, phosphorus and sediment with varying best management practices to streamline environmental planning. Costs are provided so users may select the most cost-effective practices to reduce pollutant loads.

Log In To Get Started

Email

Password

Forgot Password

Log In | Register | BayFast Log In

ADDITIONAL RESOURCES

Resources most frequently requested by planners are below. These include links to data and information associated with water quality monitoring and modeling.

TRANSITION TO PHASE 6

Get answers to your questions about the transition to the new Chesapeake Bay Partnership's Phase 6 Modeling tools.

Phase 6 FAQs

SOURCE DATA

While we prepare for the release of the Phase 6 modeling tools, this DRAFT information is being made available now.

View Source Data

BMPS, MODELS & GEOGRAPHY

View additional information on BMPs, CBP Partnership Models, Shapefiles and Geographical Information

Learn More

Partnership Feedback on Modeling

- **Water Quality Goal Implementation Team**
  - 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

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Steady State Phase 6 Model Structure

Edge of Field

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Land Use Acres

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Direct Loads

Phase 6

Keep It Simple

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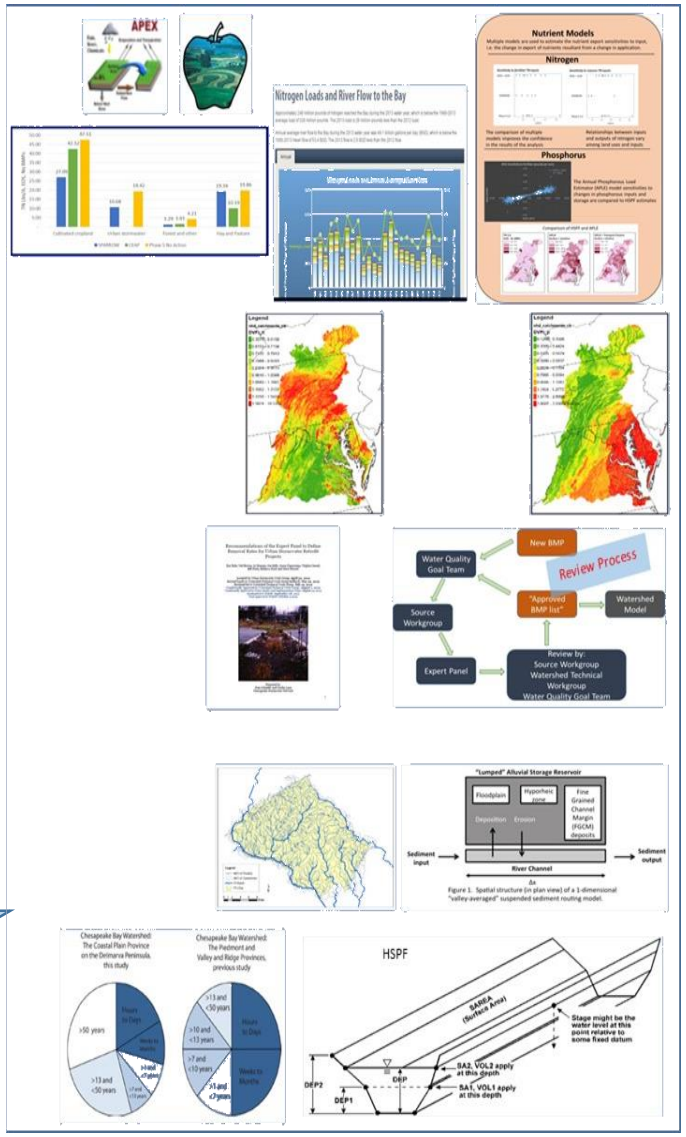
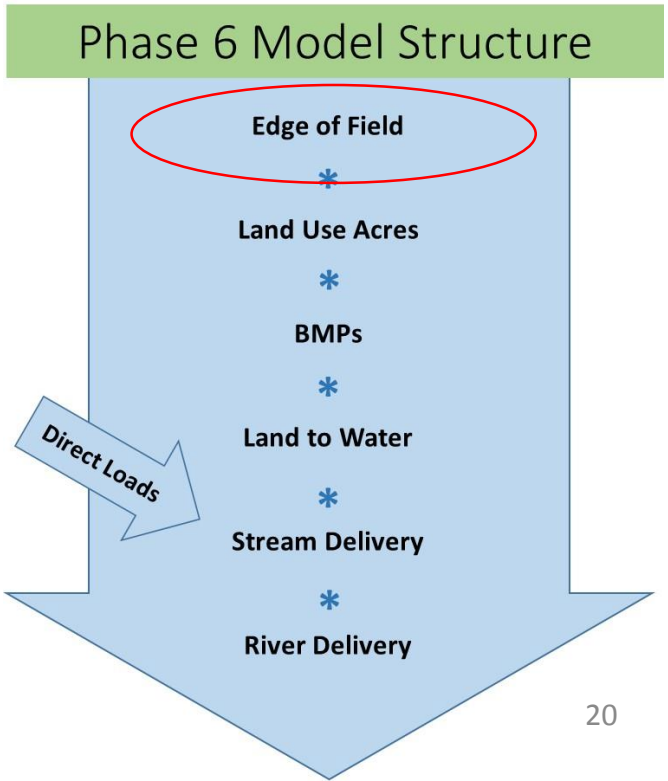


RUSLE = Edge-of-Field Loads

- Evaluated at the 10m Pixel Level
- Summarized to LRseg and land use
  - Forest
  - Open Space
  - Crop
  - Pasture
  - Turfgrass
  - Tree Canopy over Turfgrass

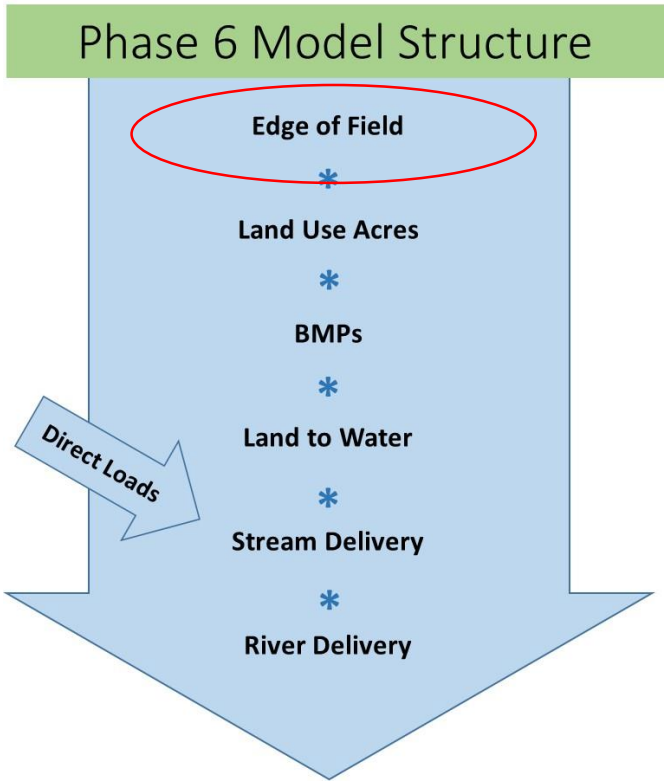


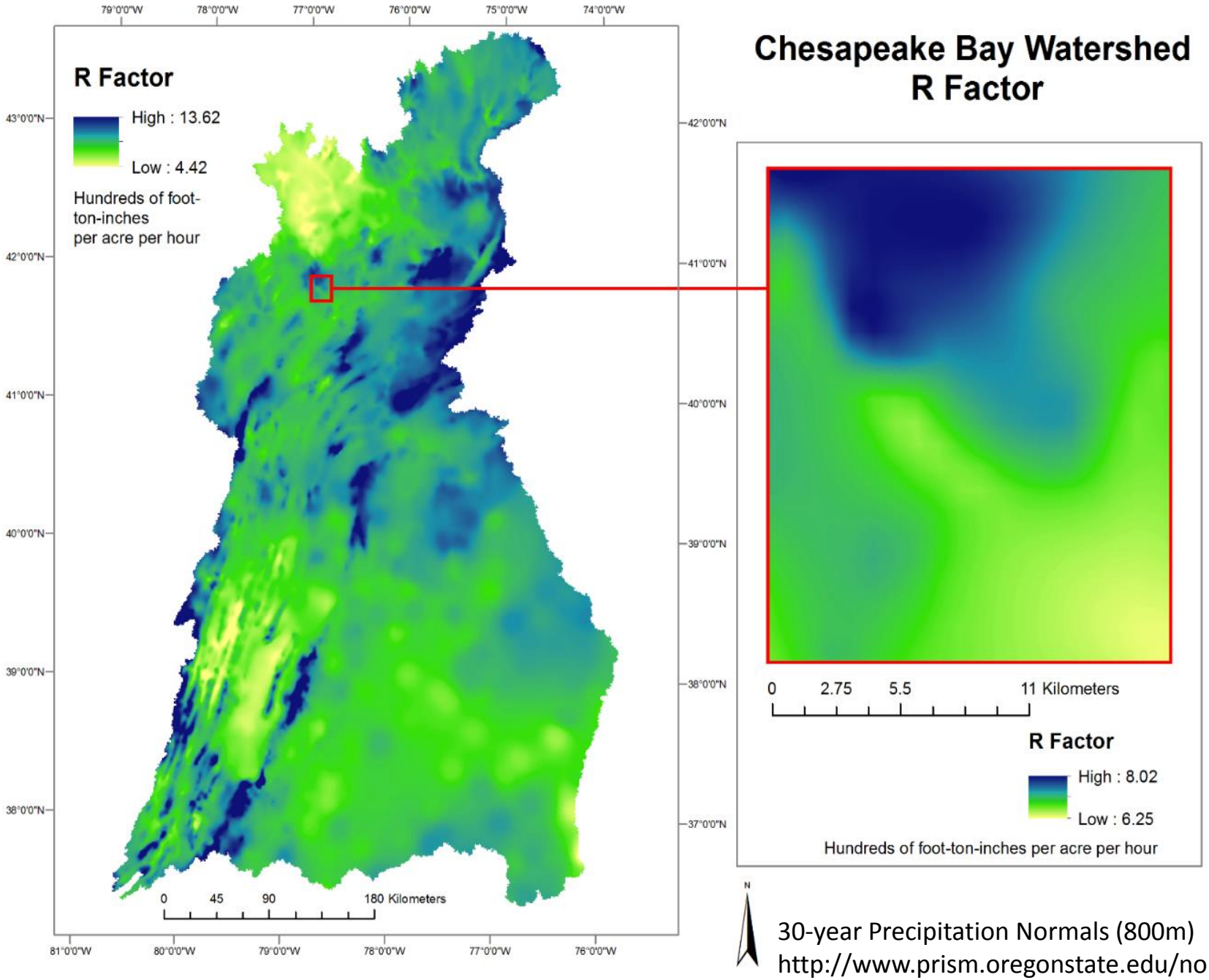
RUSLE => R * K * LS * C * P

- R = Runoff
- K = Erodibility
- LS = slope length

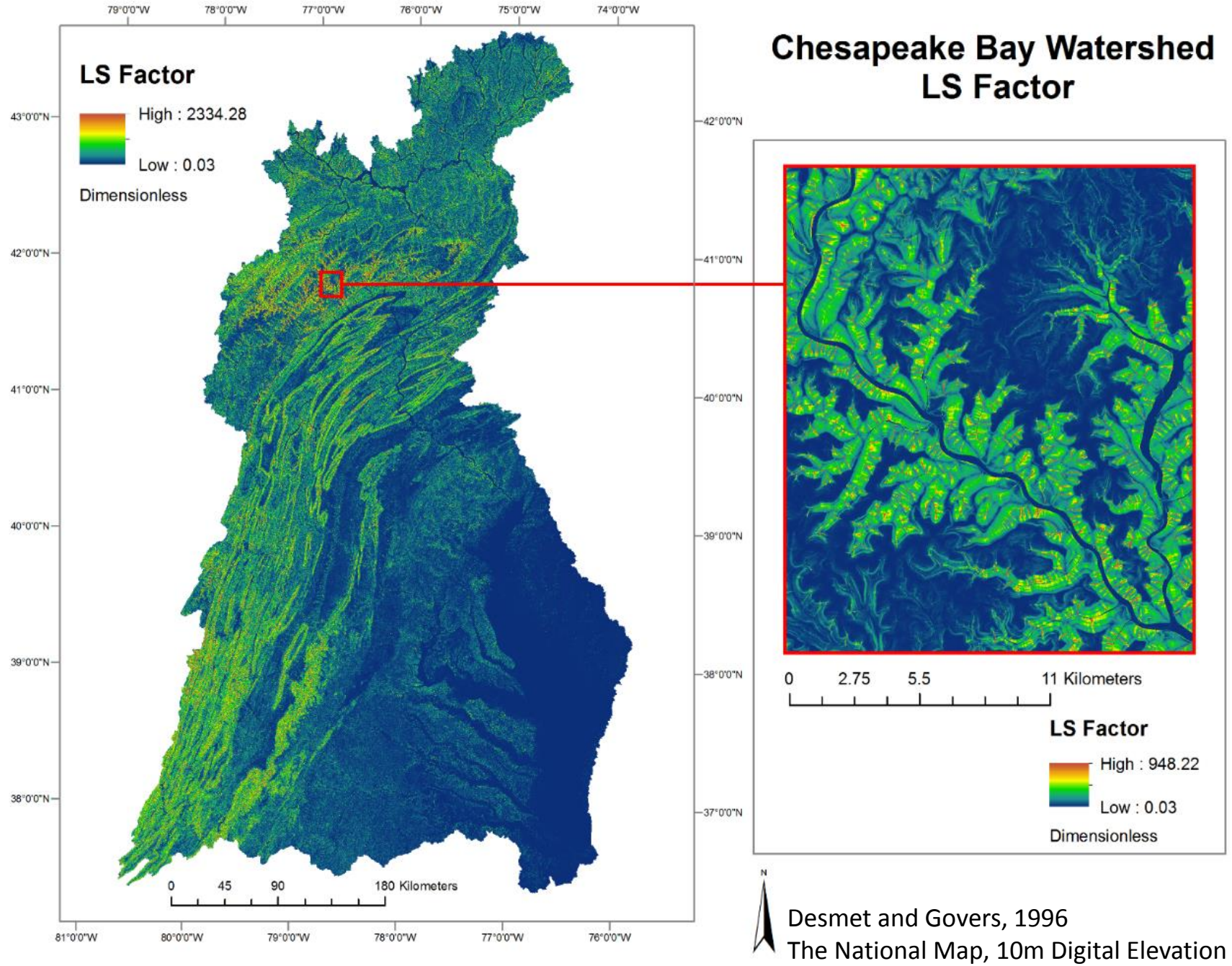
} Evaluated at 10 meter resolution

- C = Cover
  - By land use and Land-River segment
- P = Practice
  - = 1 since no action loads



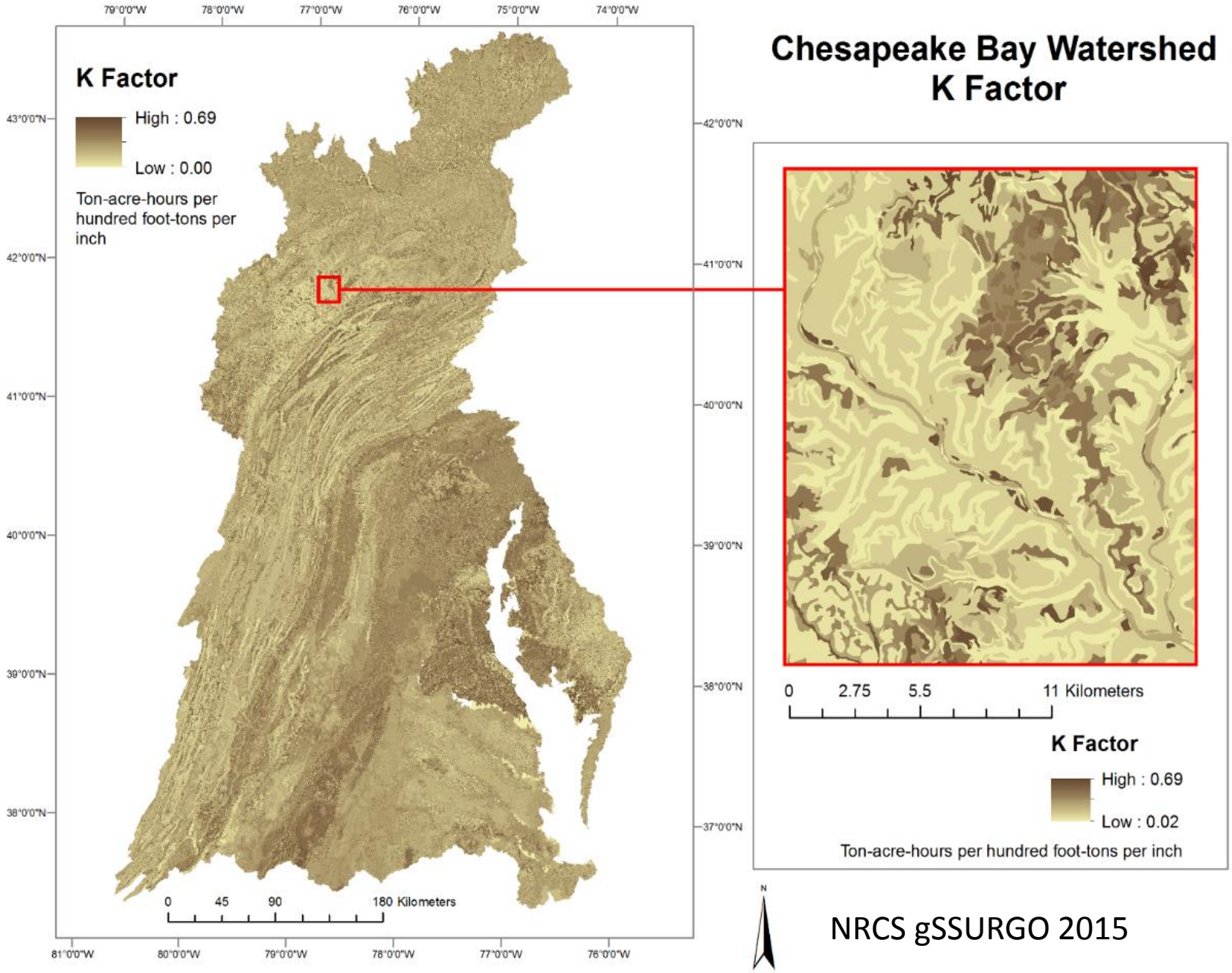


30-year Precipitation Normals (800m)
http://www.prism.oregonstate.edu/normals/



Desmet and Govers, 1996

The National Map, 10m Digital Elevation Model

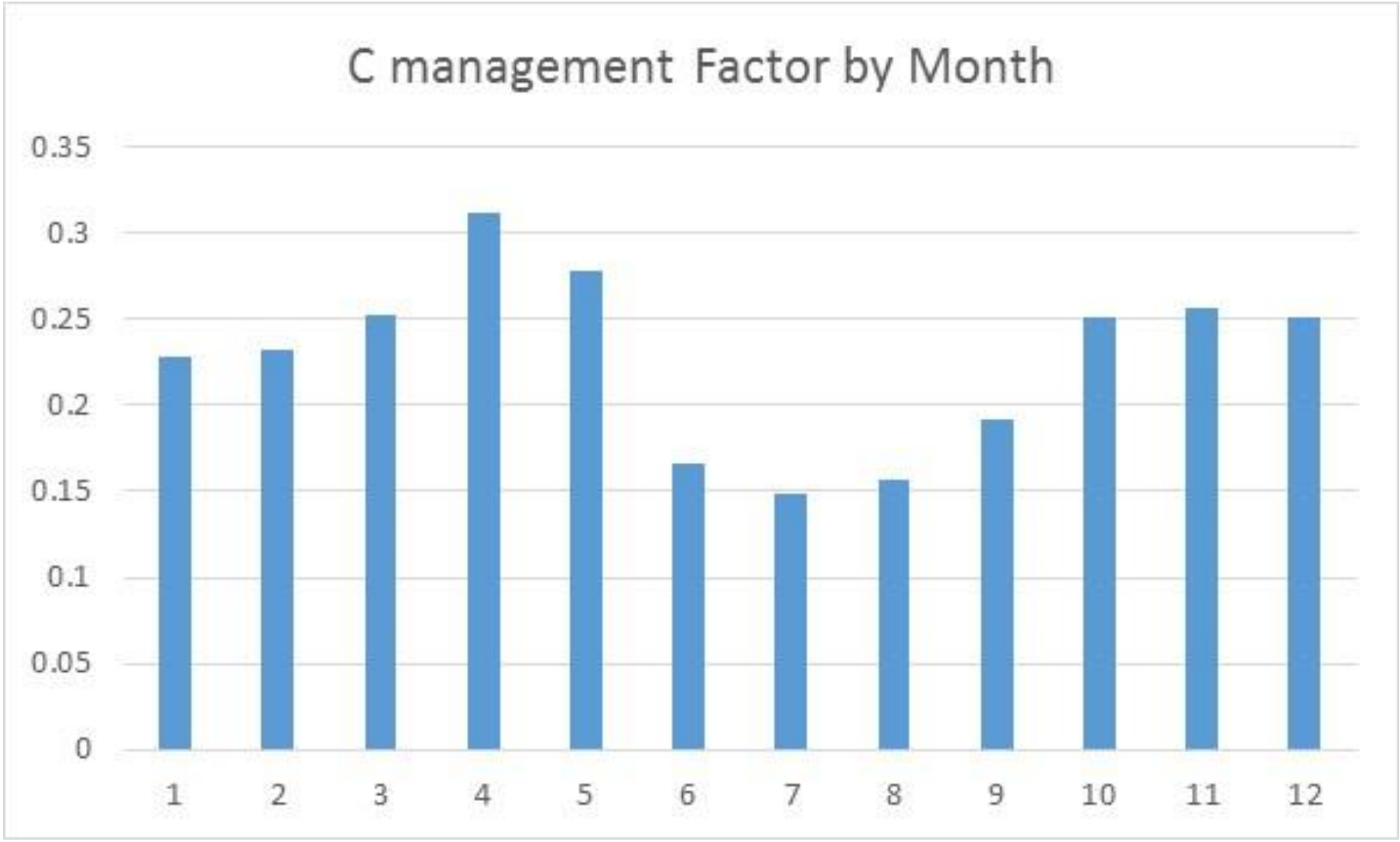

Chesapeake Bay Watershed
K Factor
K Factor
High : 0.69
Low : 0.00
Ton-acre-hours per hundred foot-tons per inch
79°0'0"W
78°0'0"W
77°0'0"W
76°0'0"W
75°0'0"W
74°0'0"W
43°0'0"N
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
37°0'0"N
81°0'0"W
80°0'0"W
0 45 90 180 Kilometers
0 2.75 5.5 11 Kilometers
K Factor
High : 0.69
Low : 0.02
Ton-acre-hours per hundred foot-tons per inch
N
NRCS gSSURGO 2015

C-Factor

- The C management Factor represents the effect of vegetative cover on erosion rates.
- Agricultural values were challenged during a STAC review and were revised using RUSLE2
- Literature values were used for non-agricultural lands.

Simple average

Agricultural C-management factor



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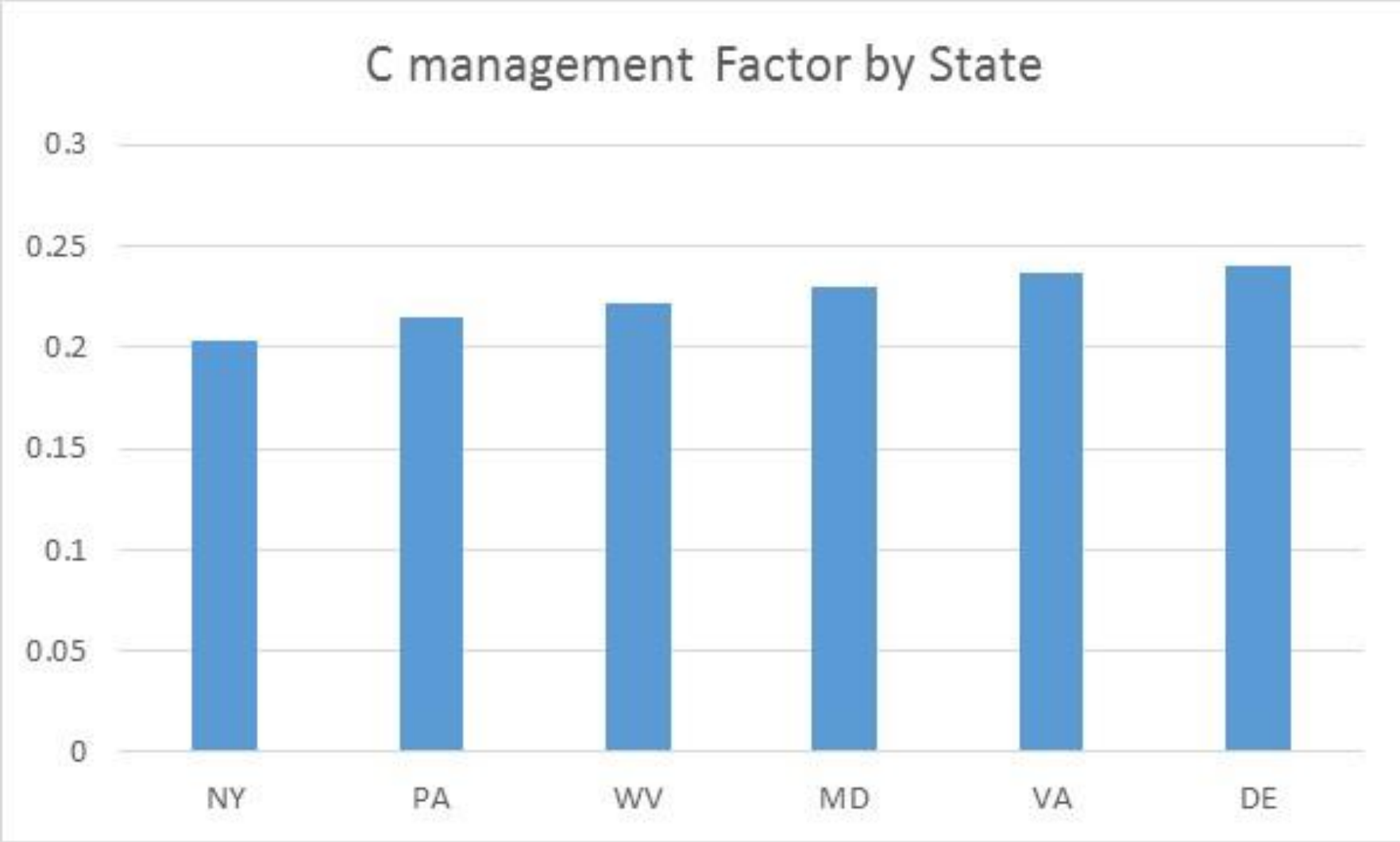

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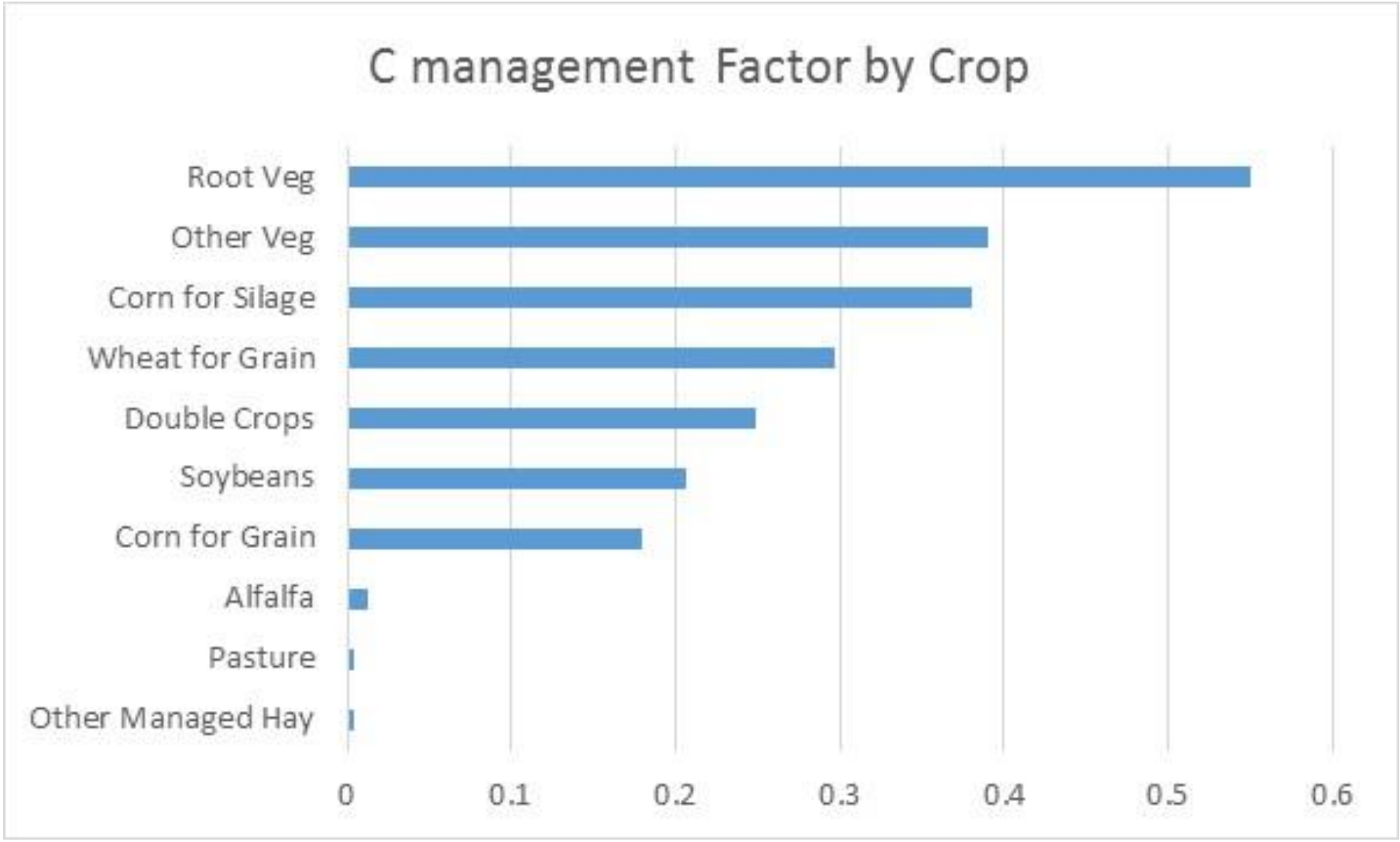
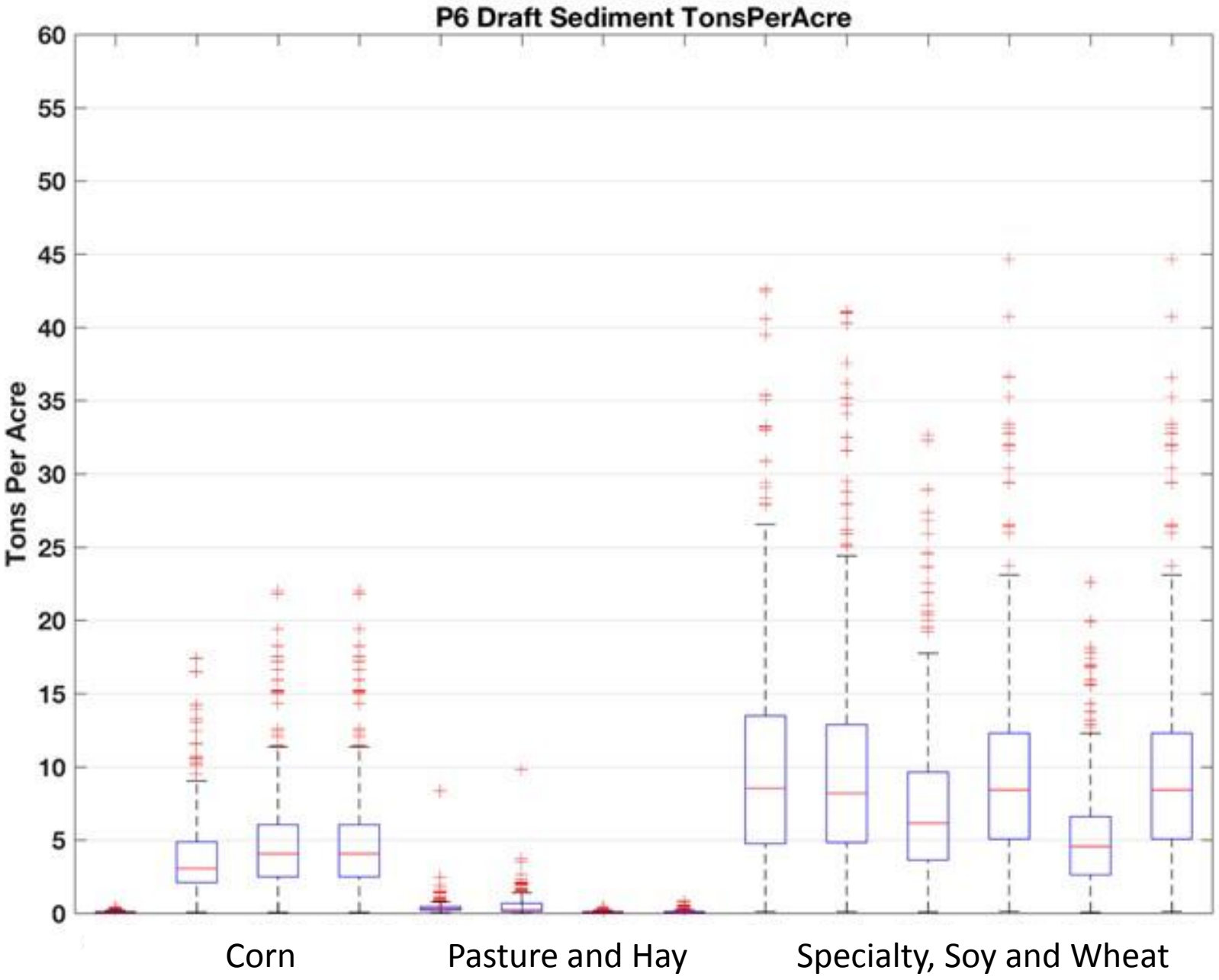
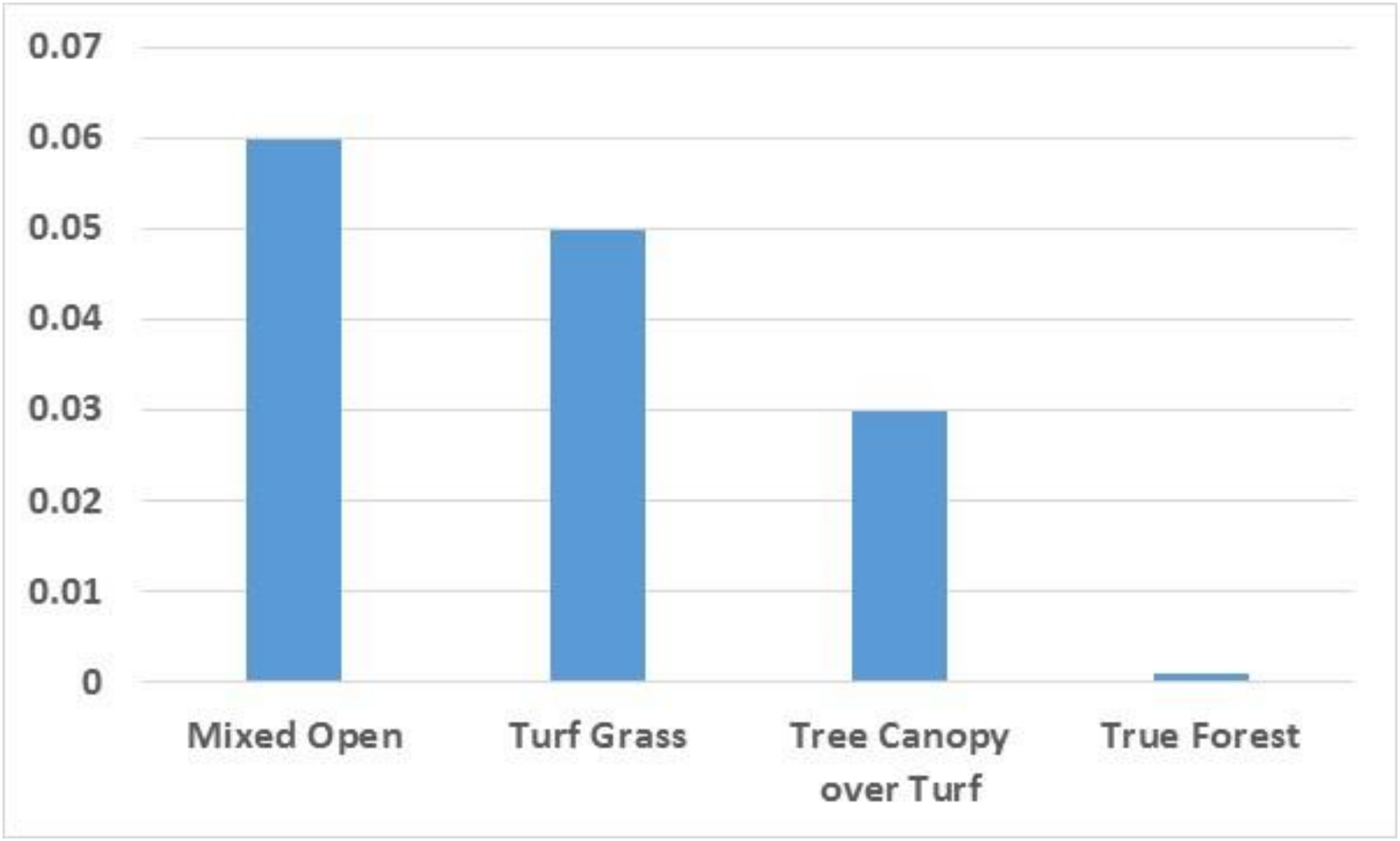



P6 Draft Sediment TonsPerAcre
Tons Per Acre
60
55
50
45
40
35
30
25
20
15
10
5
0
Corn
Pasture and Hay
Specialty, Soy and Wheat

Non-Agricultural C factors

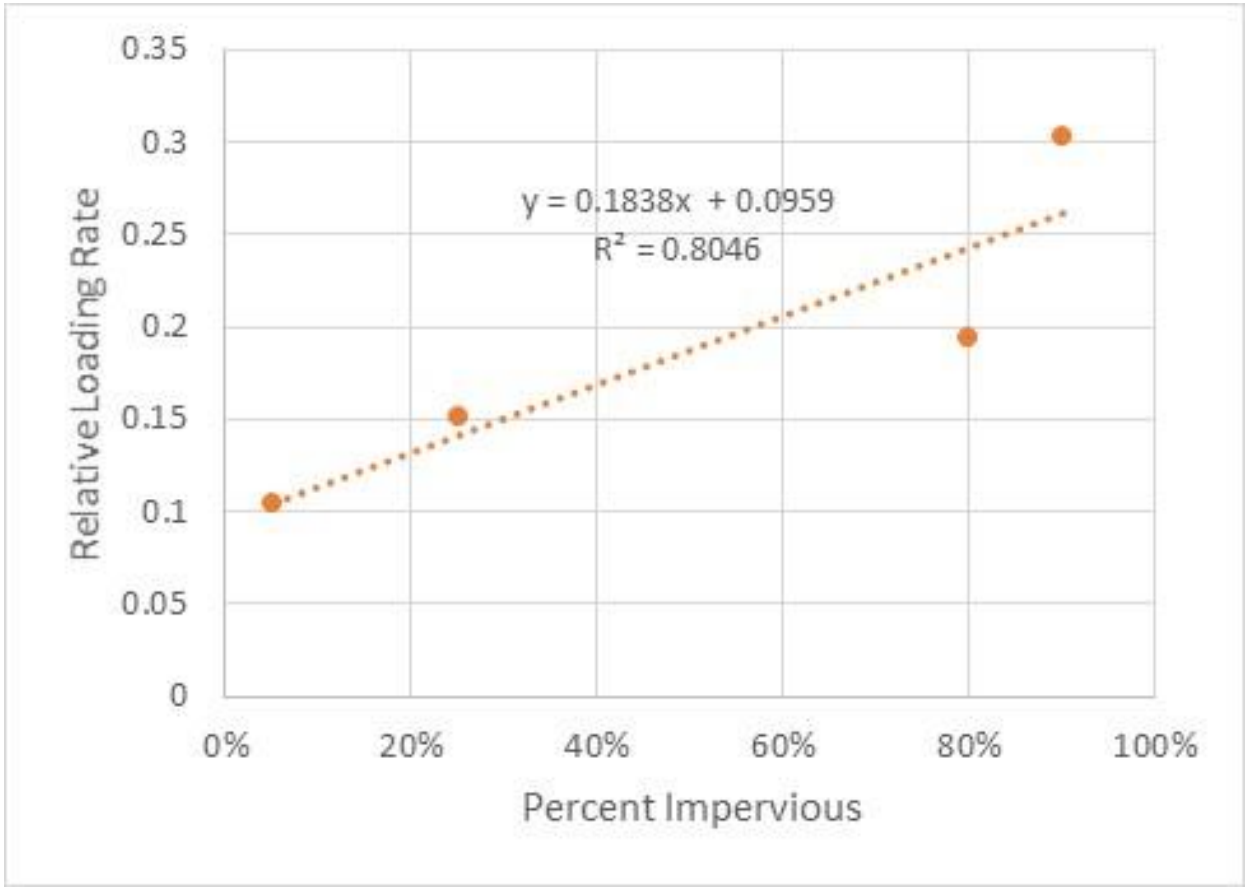


Construction

- Construction is set at 12 tons/acre/year as a global average by the Sediment and Erosion Control BMP Panel (Clark and others 2014).

- The local load is a ratio of turfgrass

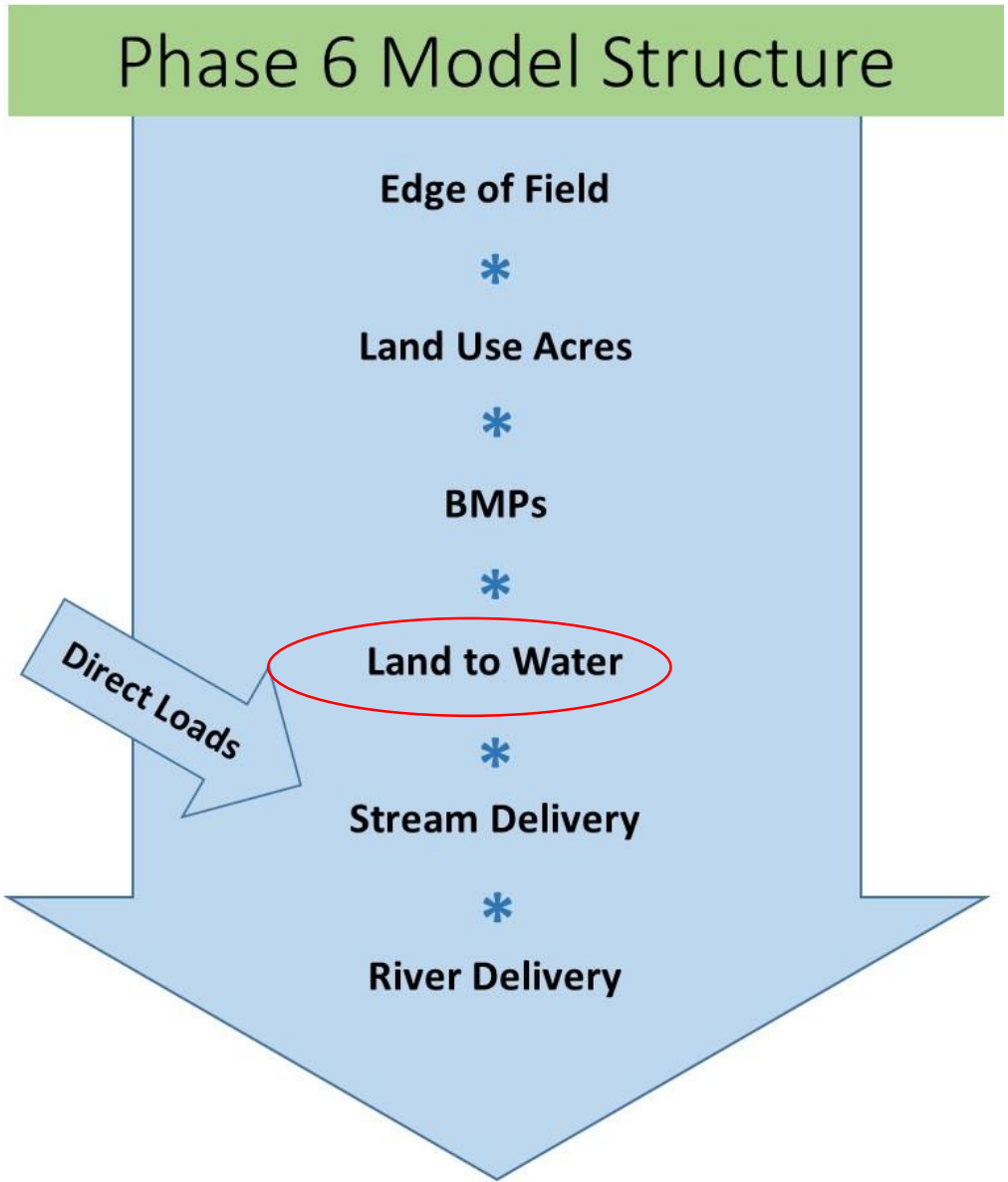
Impervious Load



Factor
1.0
3.0
3.0
3.0
1.0

- Impervious is 3x the sediment load **according to *outfall* data** in the NSQD

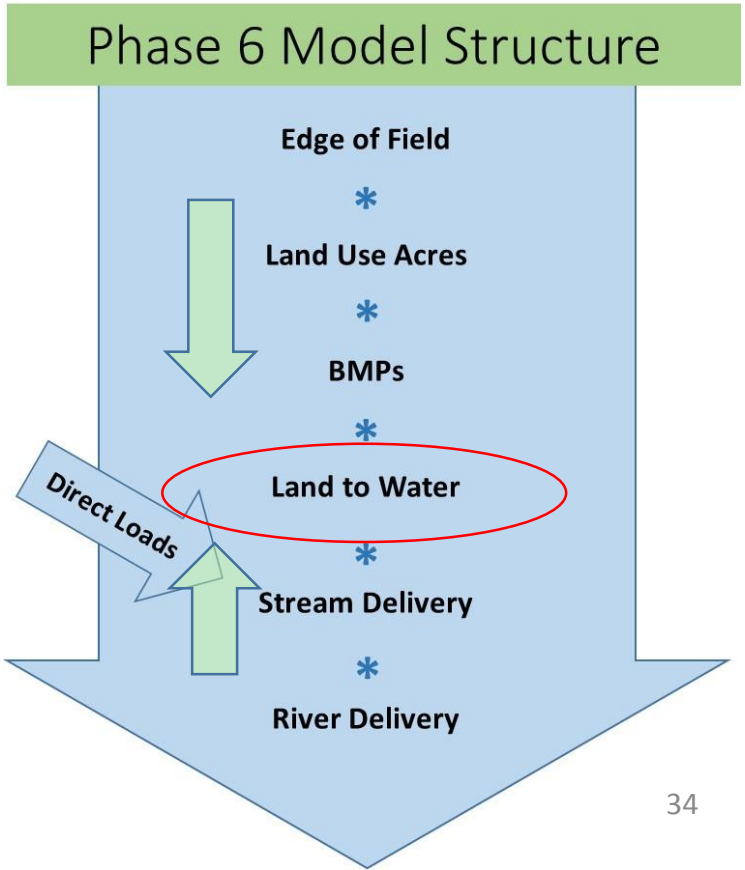
Sediment Delivery Ratio



Land to Water – calculate average

- [(EOF * acres * BMPs * L2W) + DL] * SD* RD = RIM Load

- L2W = 0.48



Sediment Delivery to Small Streams

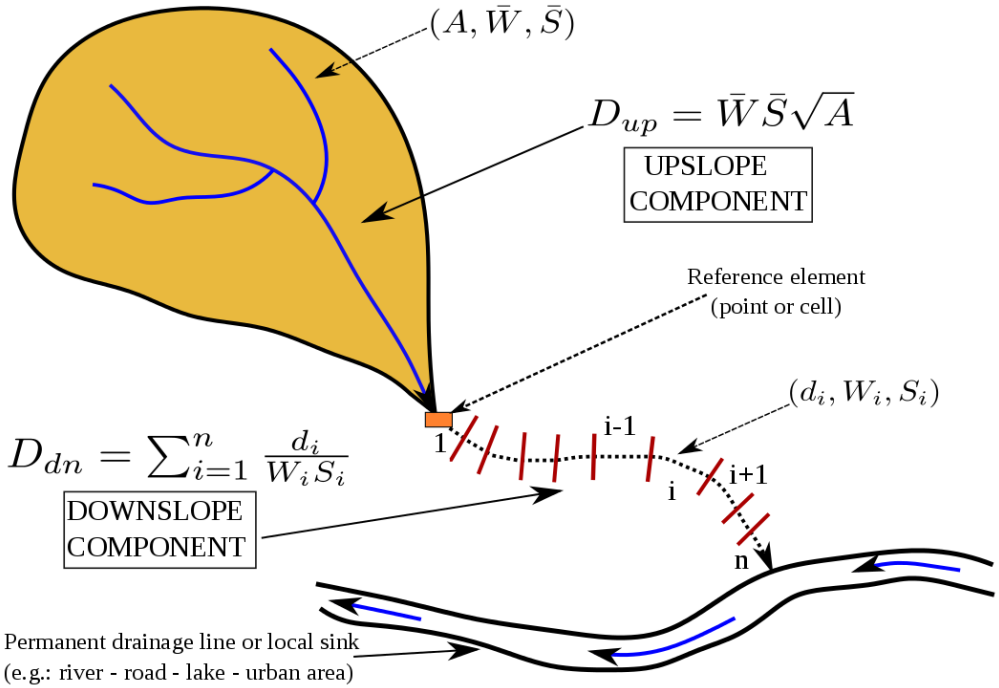
What is a small stream?

Synthetic stream network derived from 10m-DEM using a 60-acre minimum drainage area (meant to approximate 1:24,000 scale NHD network).

Phase 5.3.2 approach:

SDF = 0.417762 × Drainage Area $^{-0.134958}$ – 0.127097

Phase 6 approach:



Guidelines on the Sediment Connectivity

ArcGis 10.1 and 10.2 Toolbox

Release: 1.1

Marco Cavalli, Stefano Crema, Lorenzo Marchi

CNR-IRPI Padova (PP4)

June 2014

Sediment Delivery to Small Streams

$$IC = \log_{10}\left(\frac{D_{up}}{D_{dn}}\right)$$

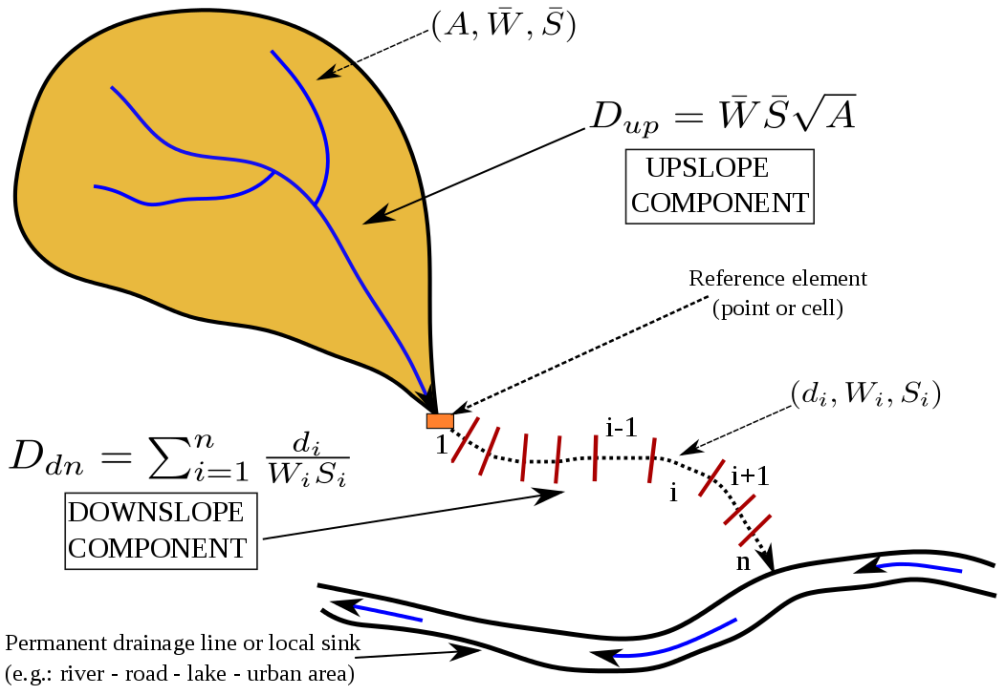
IC = Index of Connectivity

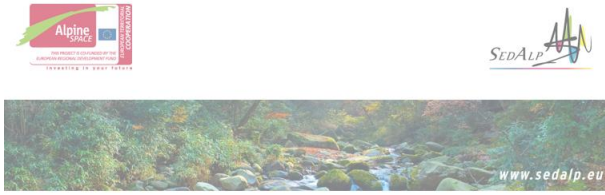
$$D_{dn} = \sum_i \frac{d_i}{W_i S_i}$$

Path length

Relative surface roughness

Slope gradient





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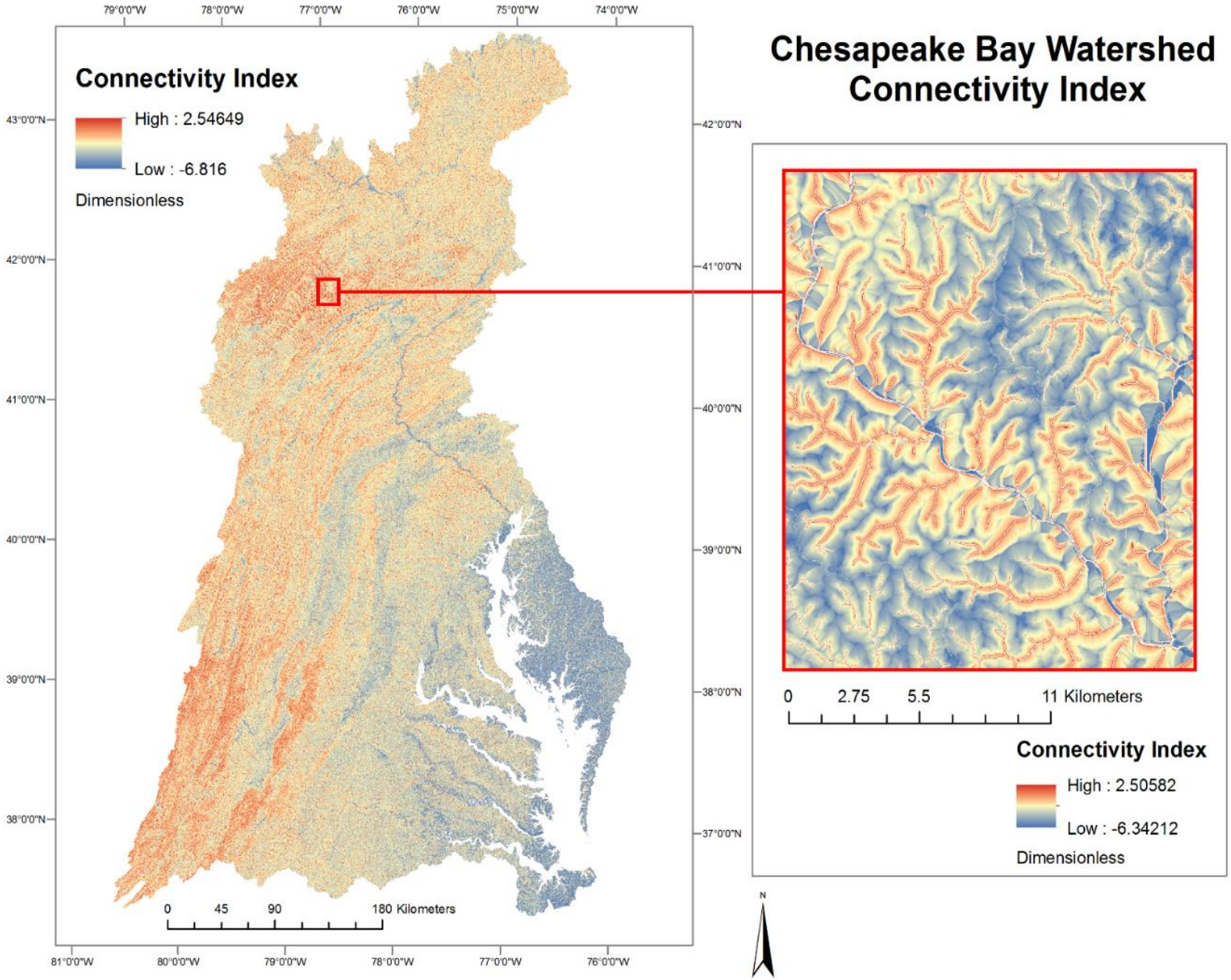
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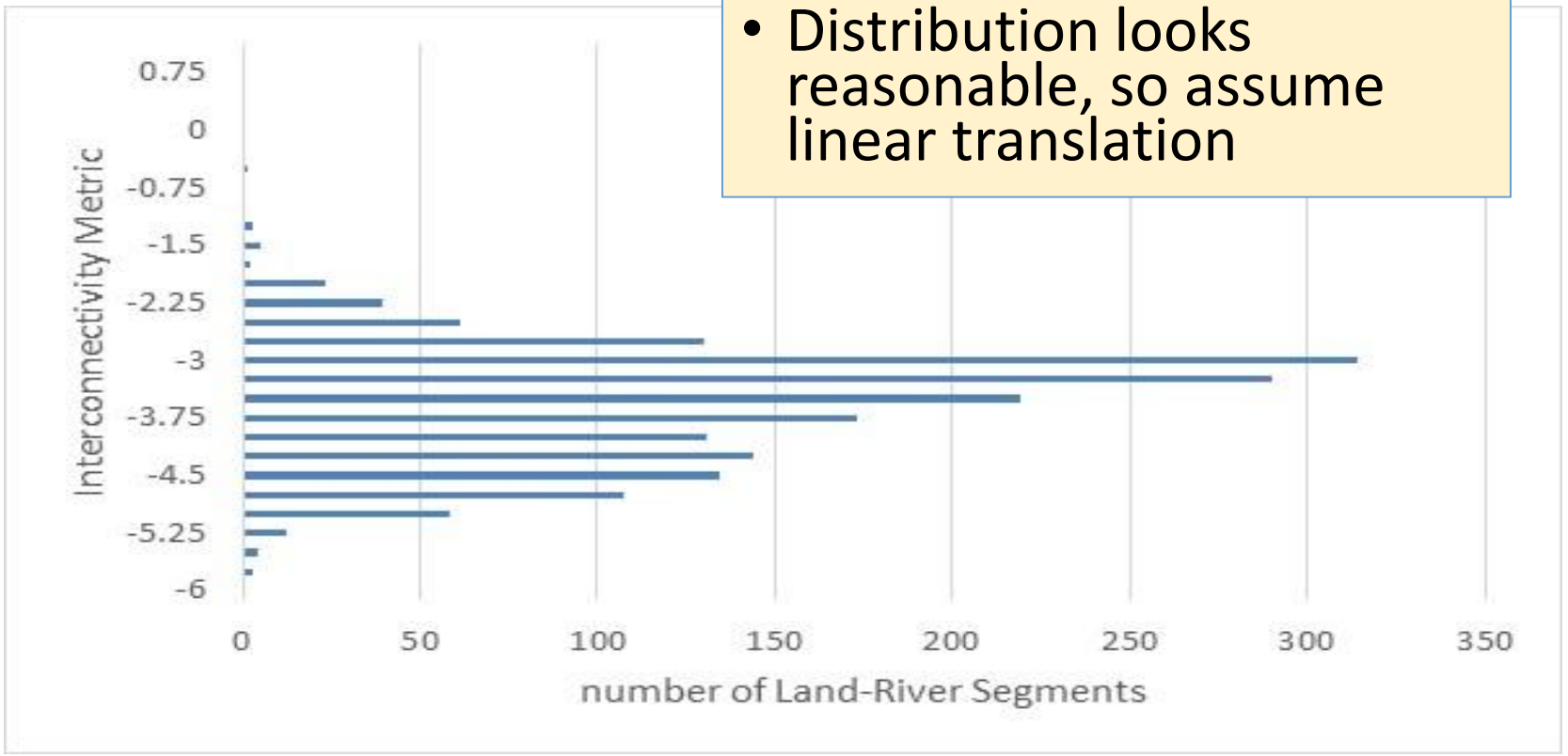
80°0'0"W
0 45 90 180 Kilometers
0 2.75 5.5 11 Kilometers
Connectivity Index
High : 2.50582
Low : -6.34212
Dimensionless
N

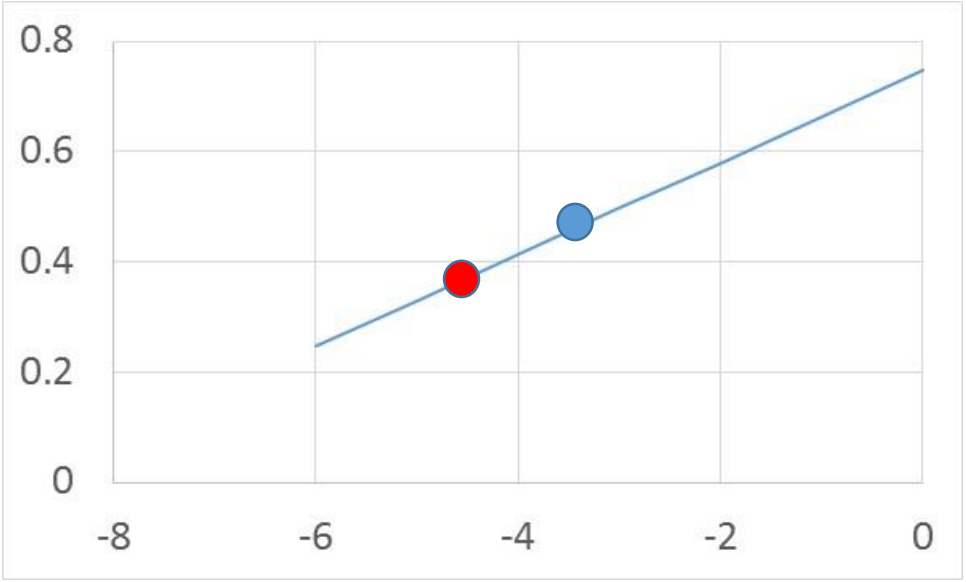
Sediment Delivery Ratio

- Need to convert to scale of 0 to 1 with an average of 0.48
- Distribution looks reasonable, so assume linear translation



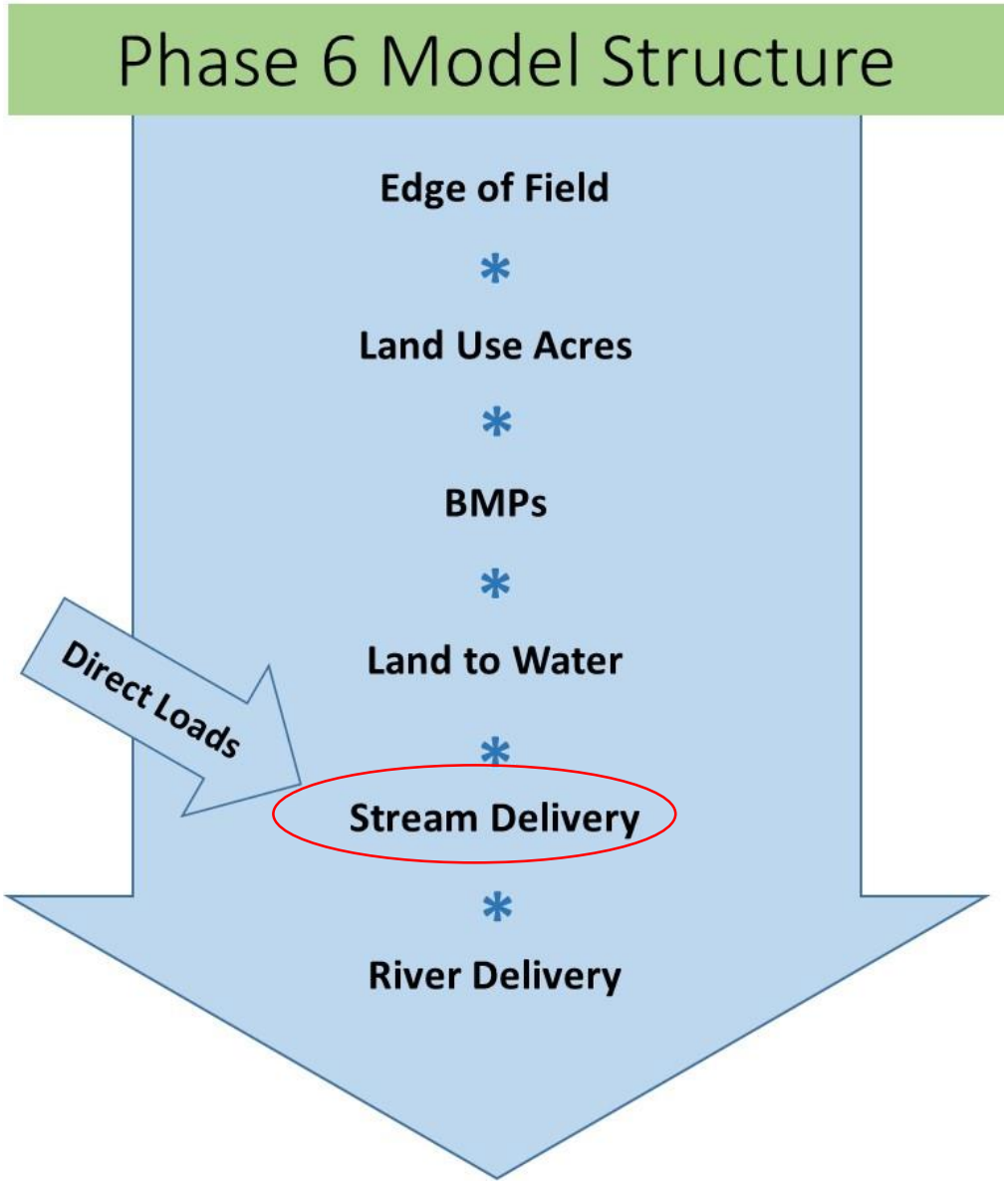
Interconnectivity Metric

- Center point at averages: (-3.2, 0.48)
- Second point at 1 Standard Deviation
  - SD of SDR from CEAP in the Upper Miss was 0.08 (8-digit HUC)
  - SD of P5.3.2 was 0.10
  - Choose 0.10
  - Establish second point at (-4.4, 0.38)

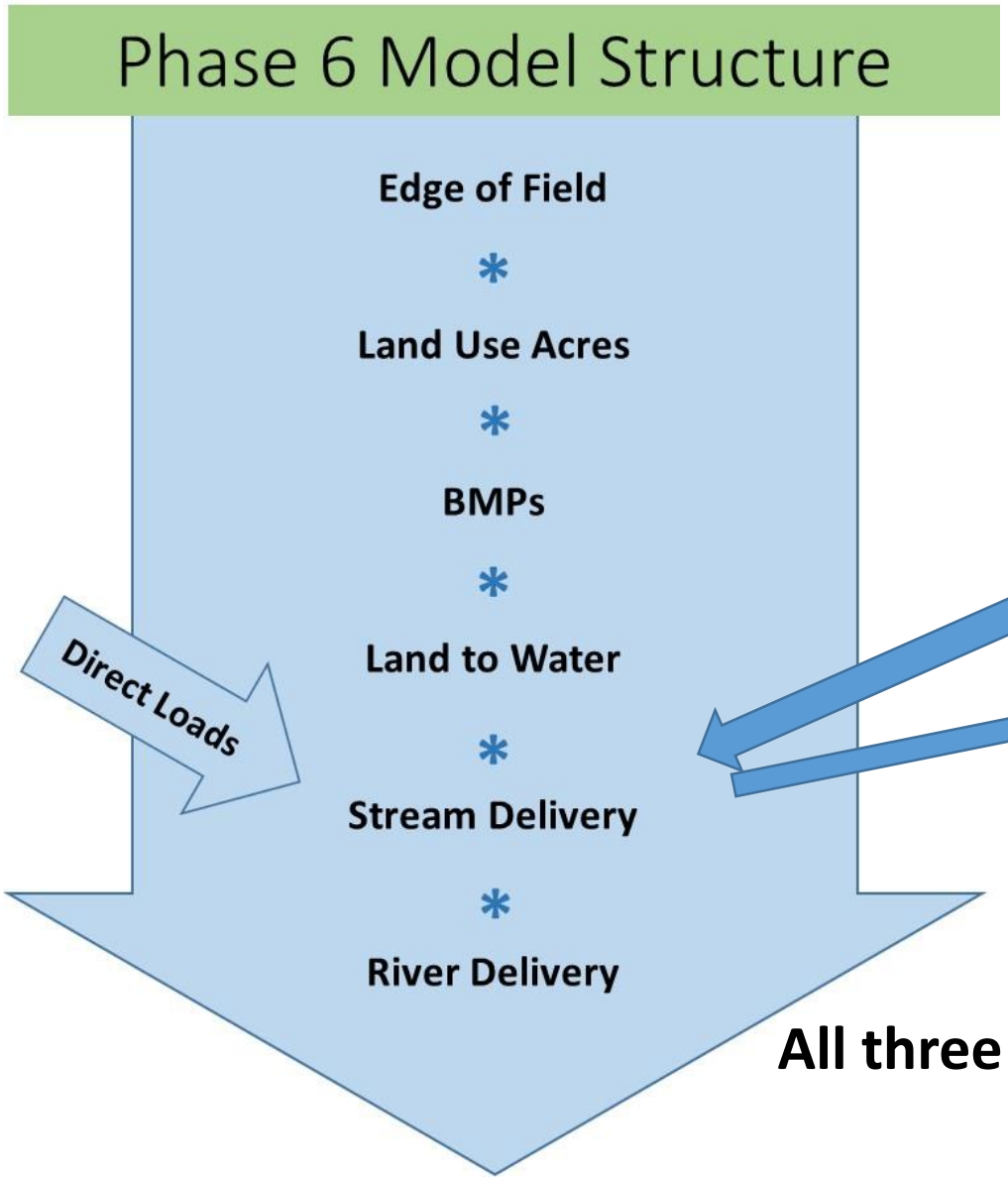


SDR = 0.083 * IC + .747

Stream Sediment Effects



Stream Sediment Effects – 2 methods



Absolute Load change
2 load sources
Streambank (+) STR
Floodplain (-) STF

Simple Factor - STR

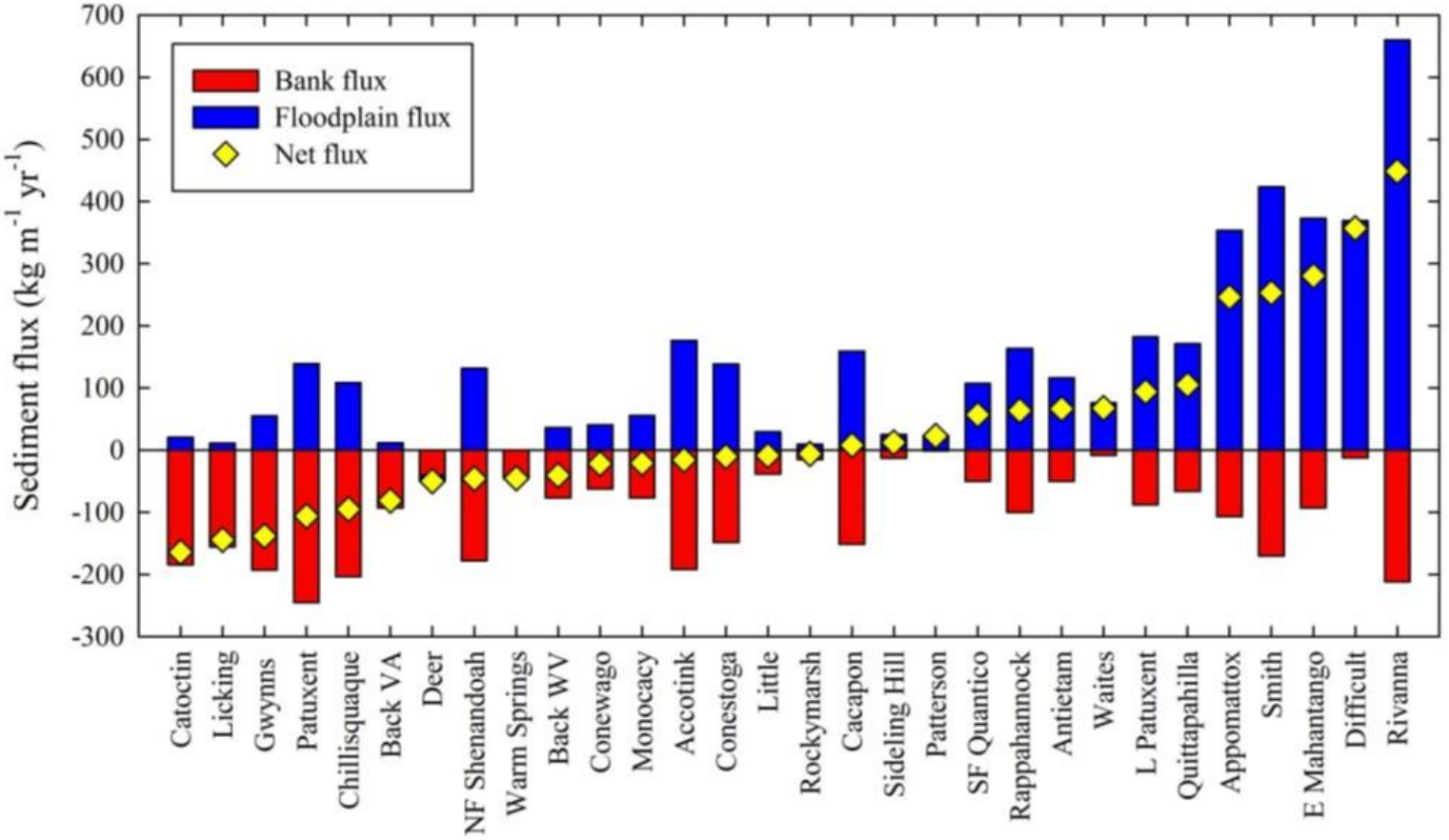
All three can exist in the same segment

Methods for Stream Estimation

- Chesapeake Floodplain Network
- Stream Source Ratio
- USGS Sparrow Regression Model

Chesapeake Floodplain Network – Ag and Natural

Greg Noe and others



- No net change
- Spatial variability generalized

Stream Delivery – Developed

- Center for Watershed Protection Work

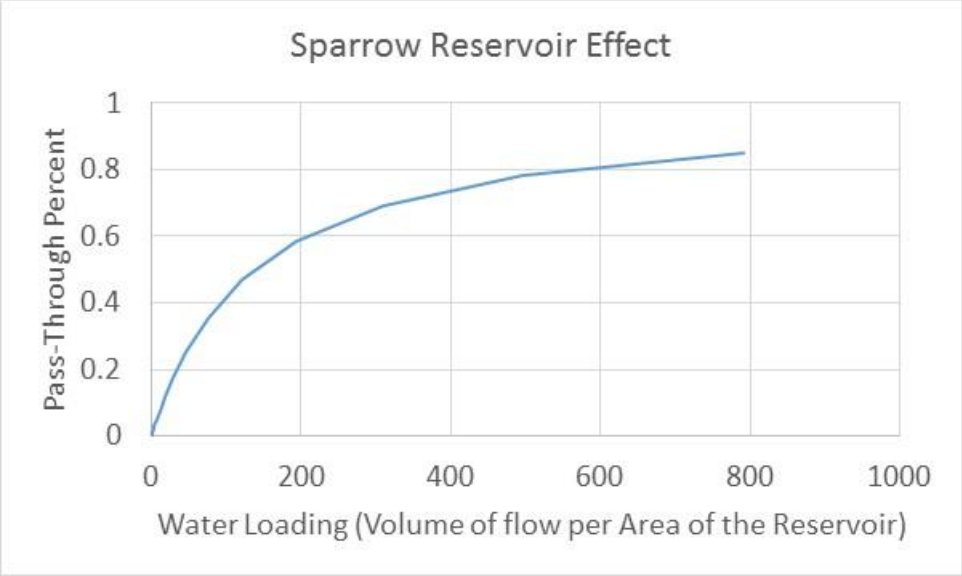
$$\text{Stream Source Ratio} = \frac{\text{Stream Load}}{\text{Total Watershed Load}}$$

SSR = 1.4085 * (fraction Impervious)
+ 0.5341 * (fraction CD soils)
- 0.2828

Averages about 0.5 for developed areas

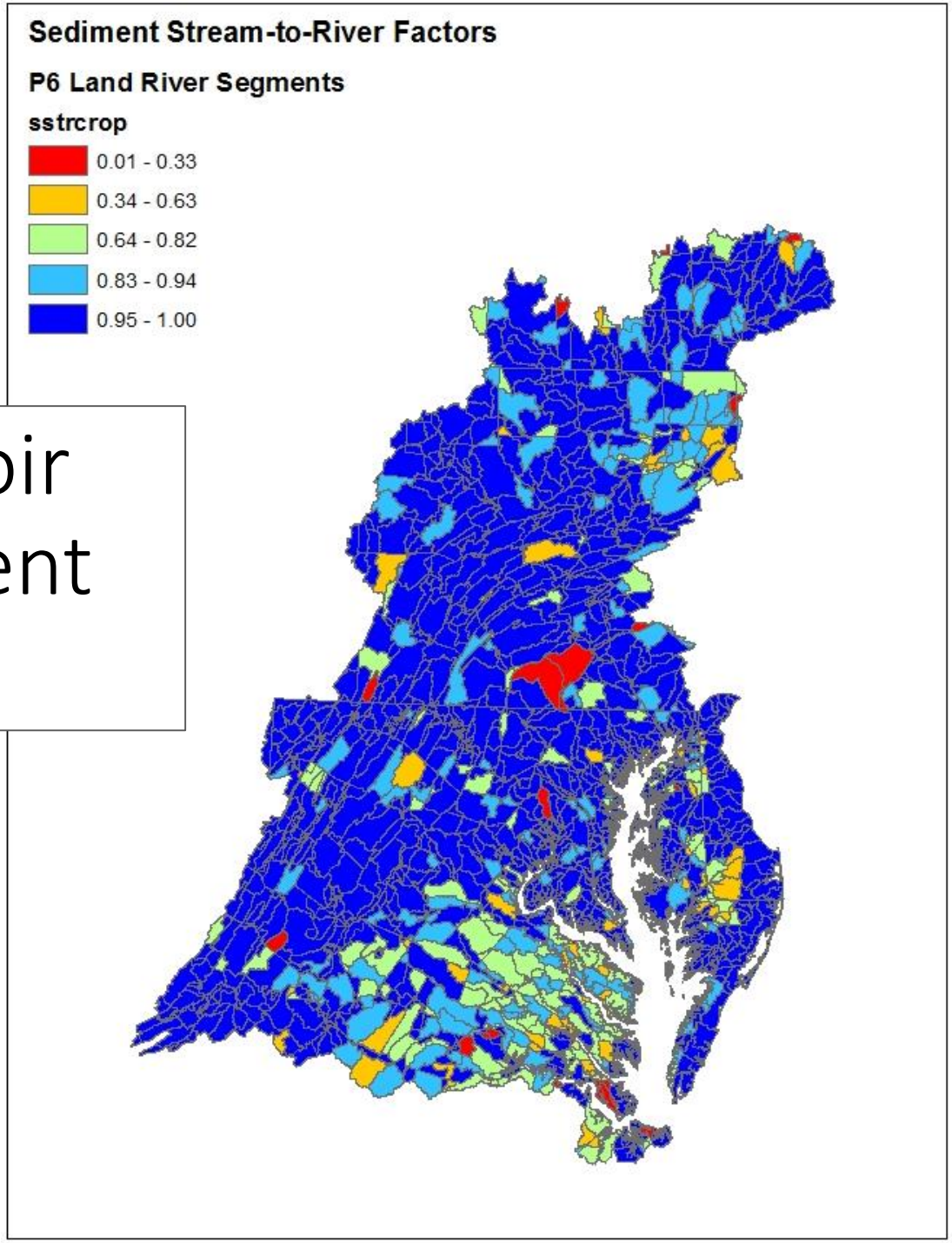
Sediment Sparrow

- Rivers are not a significant sediment sink except
  - Coastal Plain rivers larger than 120 cfs
  - Reservoirs



Brakebill, Ator, and Schwarz, 2010

Sparrow Reservoir Effect on Sediment from crop



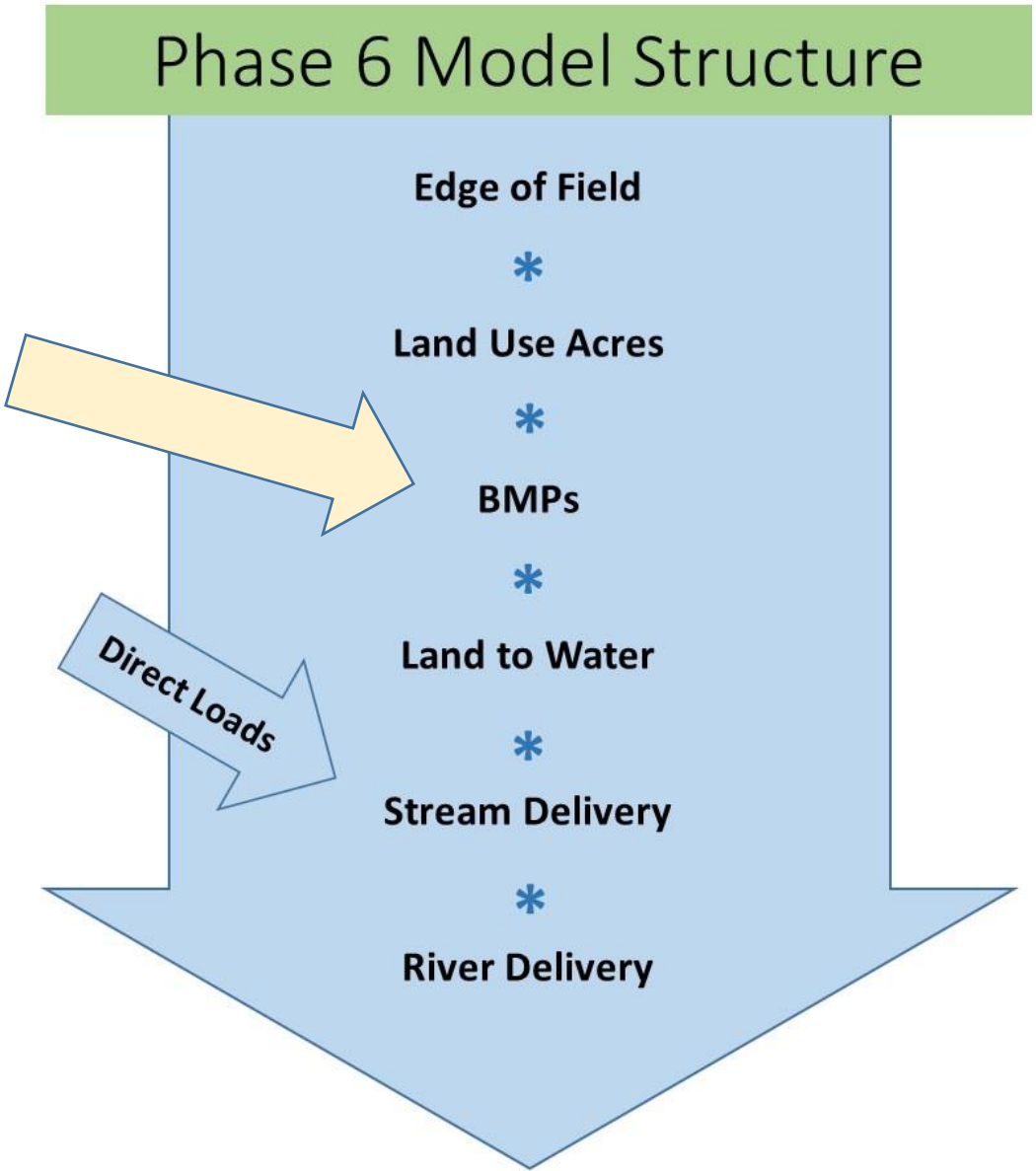
Stream Effects

- Streams in developed areas contribute roughly half of the sediment from those areas
- Streams in non-developed areas do not gain or lose sediment
- Reservoirs are sinks for sediment.

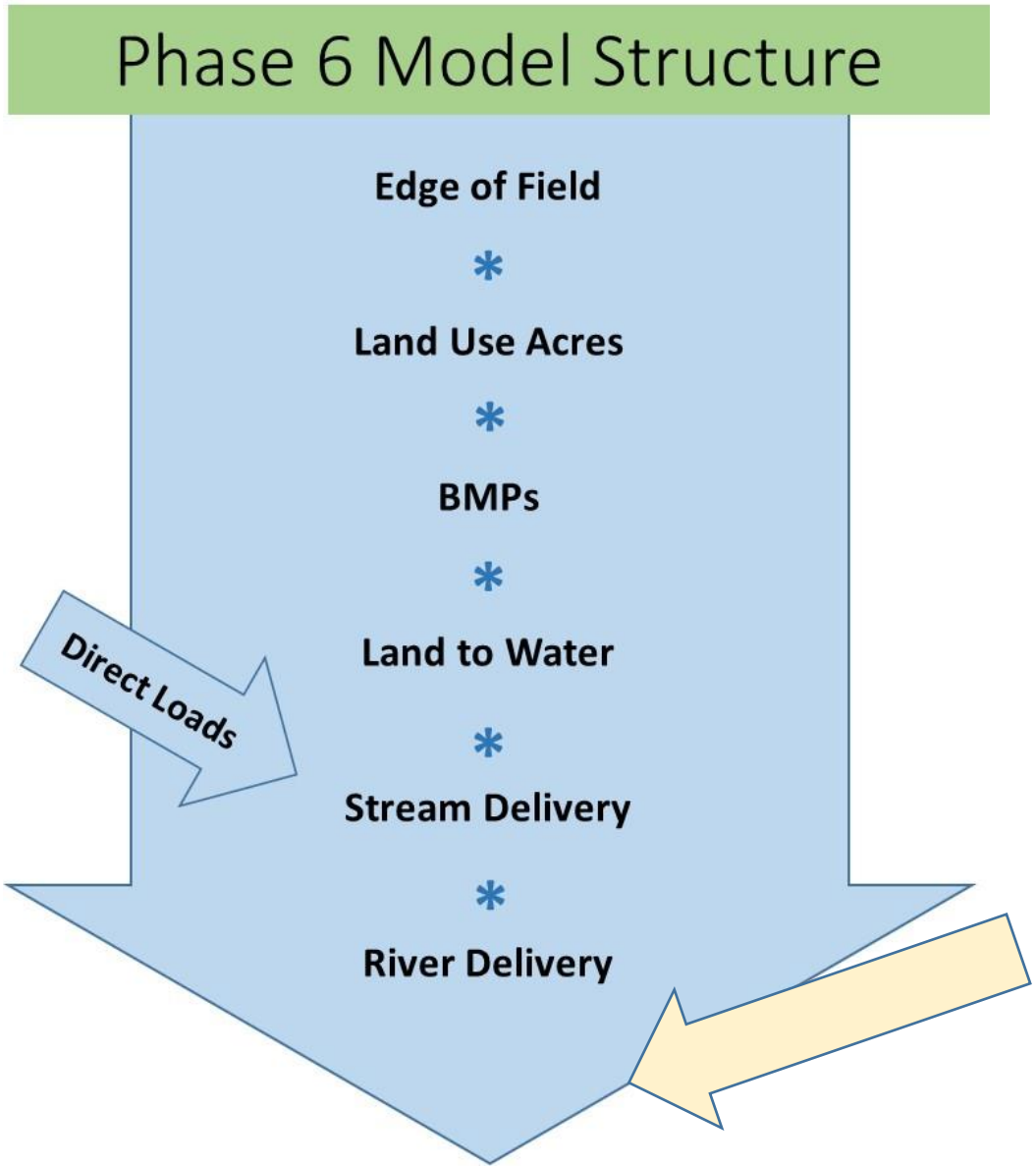
Stream Effects

- Streams in developed areas contribute roughly half of the sediment from those areas
  - STB loads in developed areas
- Streams in non-developed areas do not gain or lose sediment on average
  - Test STB and STF predictions from Chesapeake Floodplain Network
- Reservoirs are sinks for sediment.
  - Apply sparrow factors.

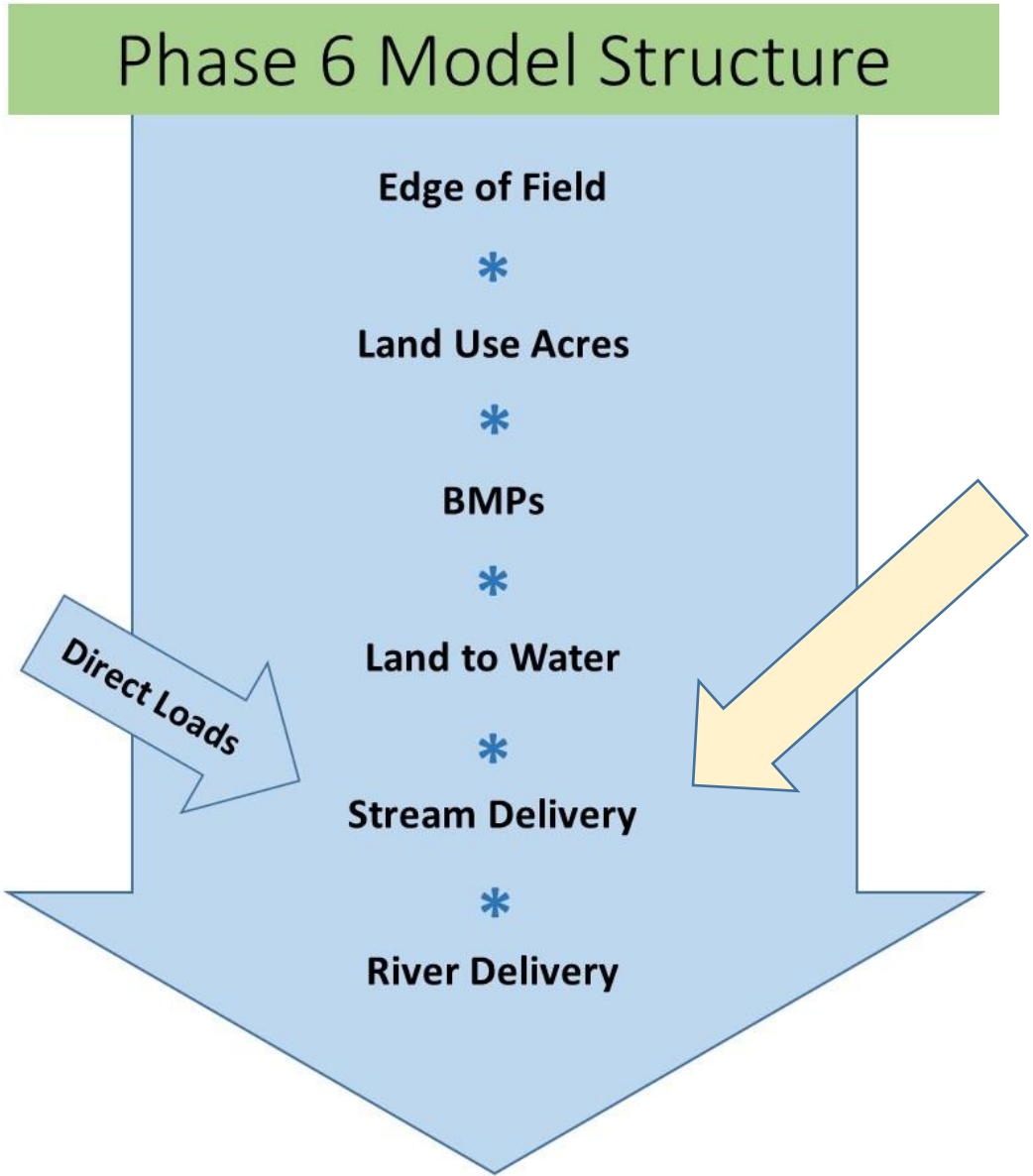
Most Sediment BMPs



Tidal Shoreline Restoration BMP



Stream Restoration BMP

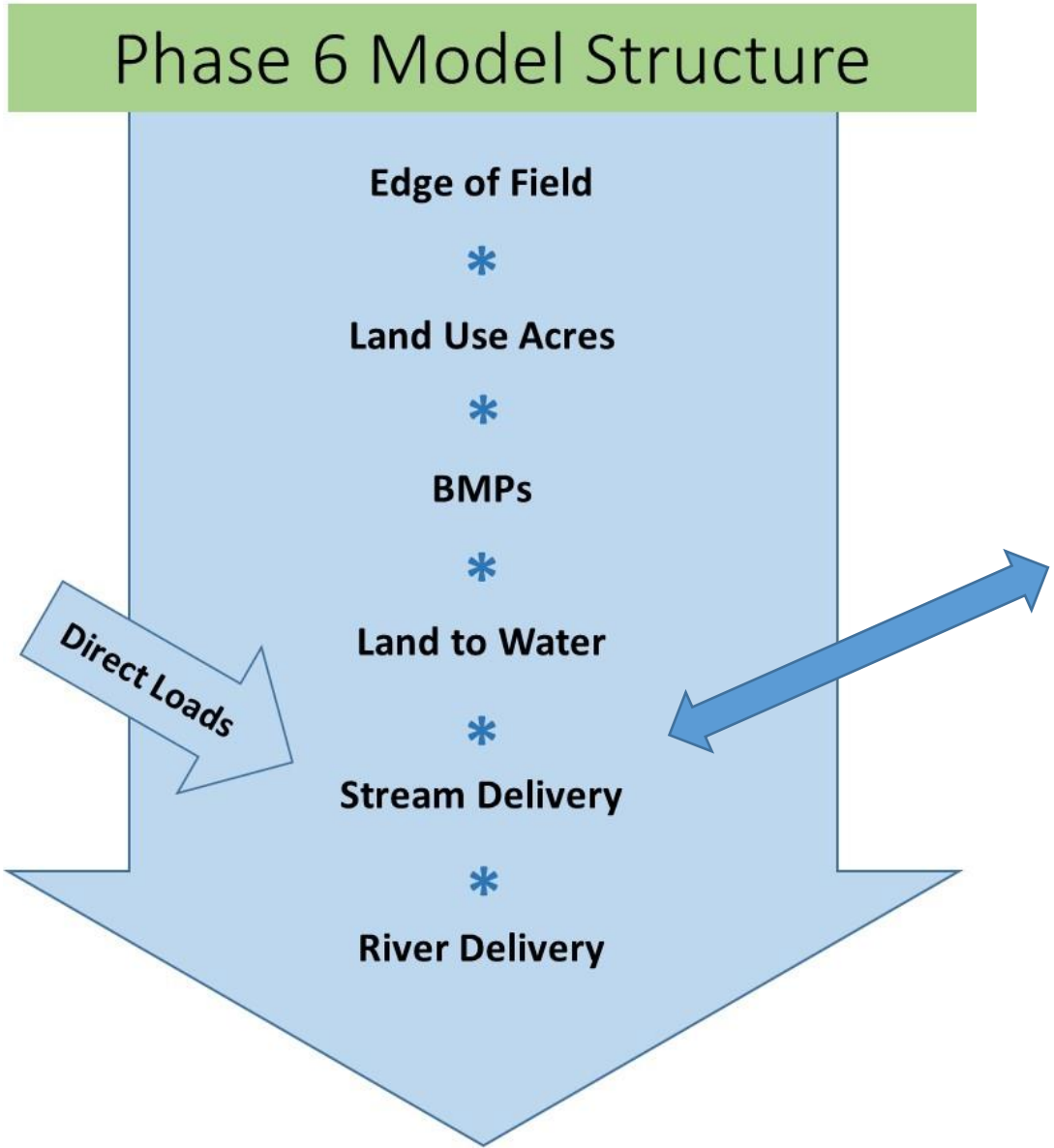


Guidance from the Stream Restoration BMP panel

The WTWG approved this BMP for use only along first, second and third order streams.

The panel recommended accounting for [small stream] sediment attenuation just as the Watershed Model does

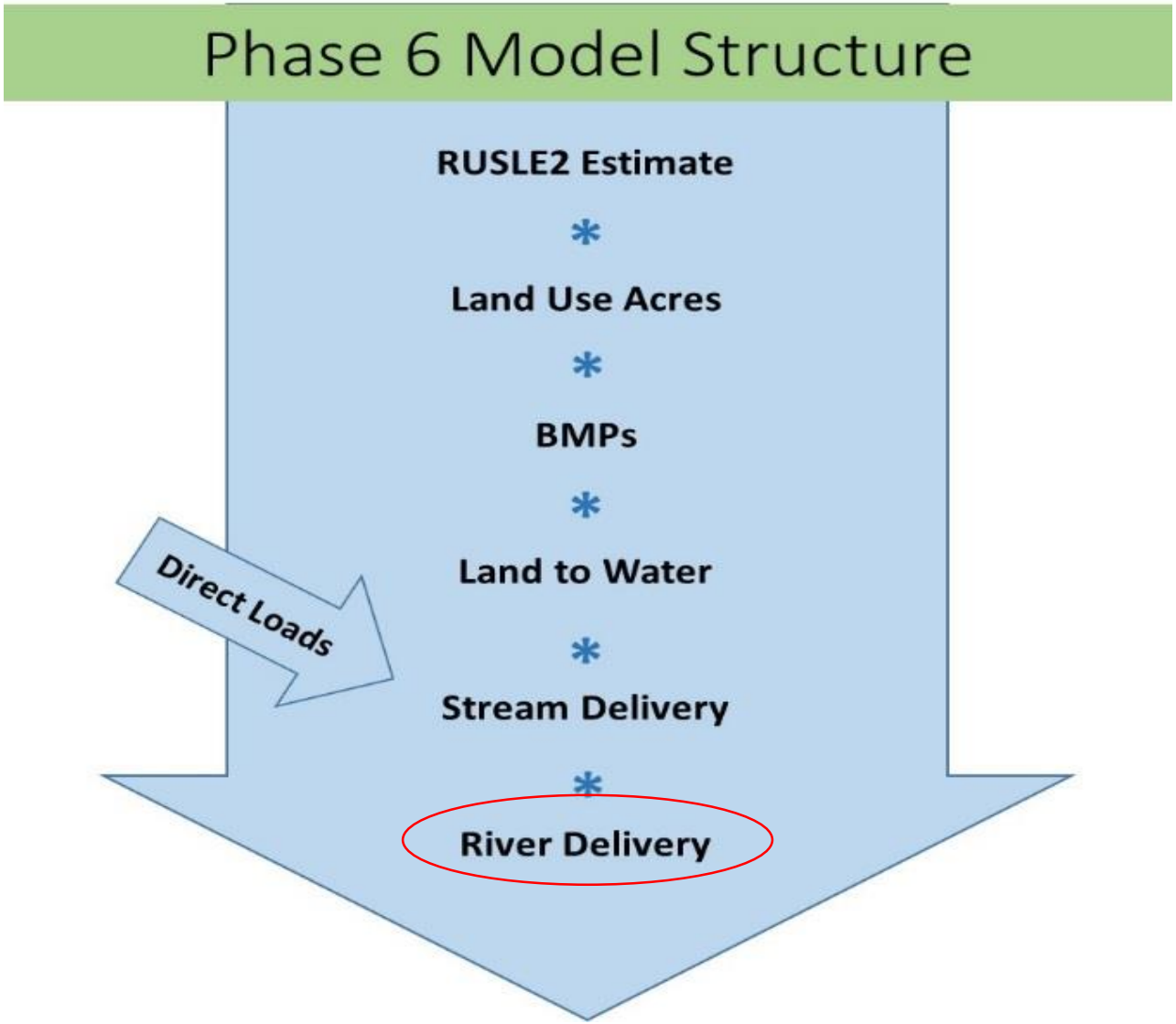
Stream Restoration BMP



Reduction in Streambank (STR) loading source. Can become negative

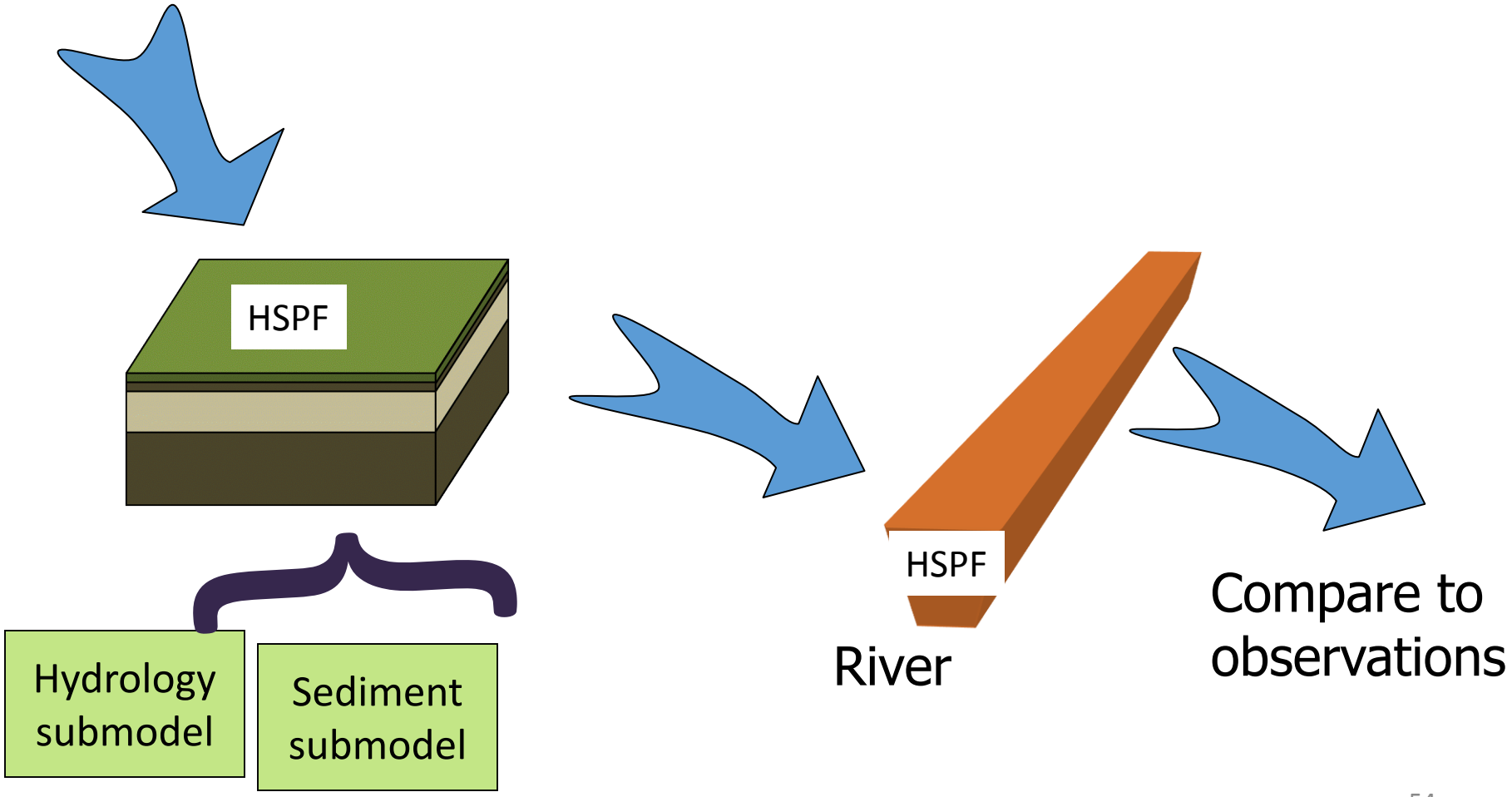
Multiplied by stream to river factor

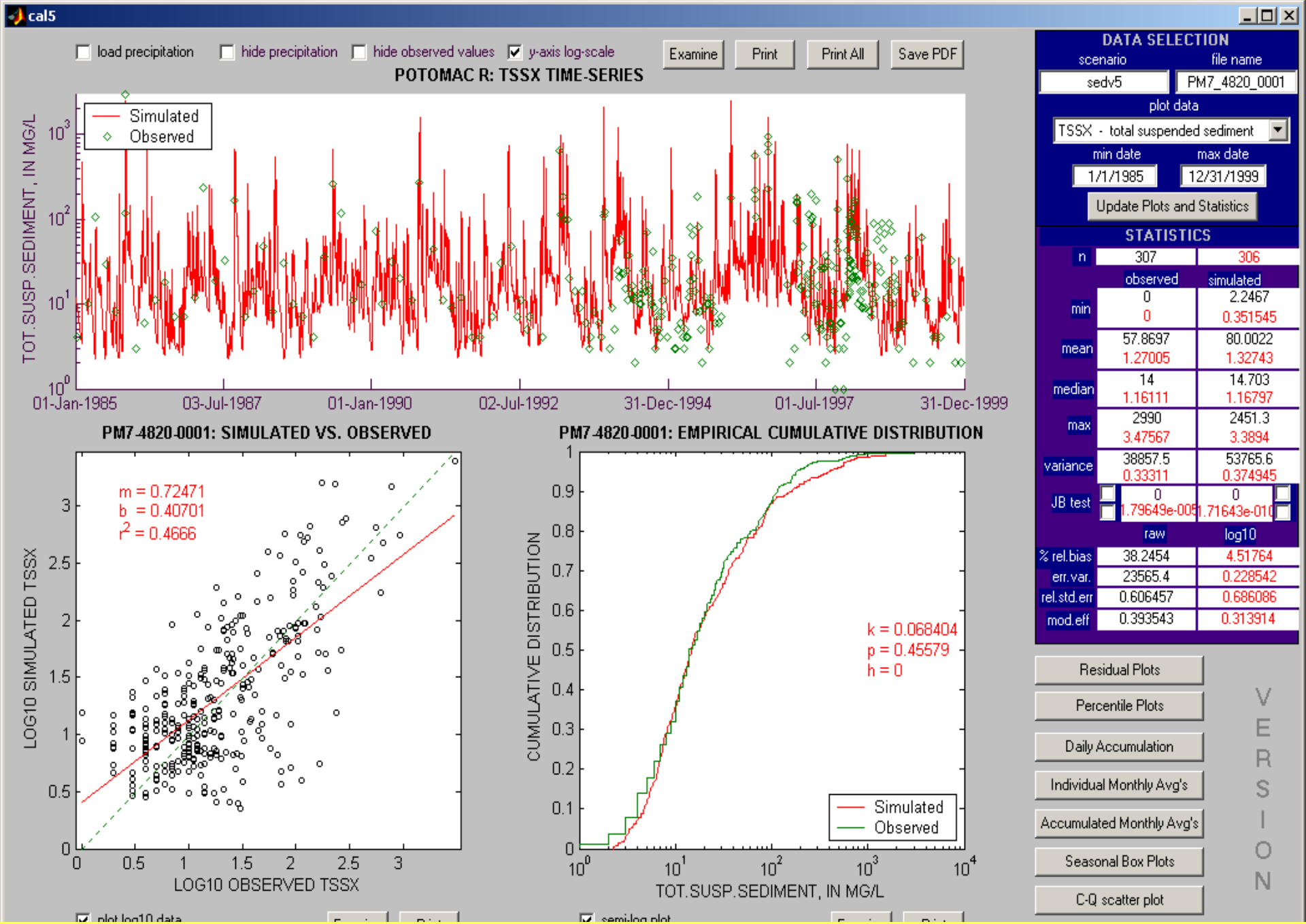
Sediment Delivery Ratio



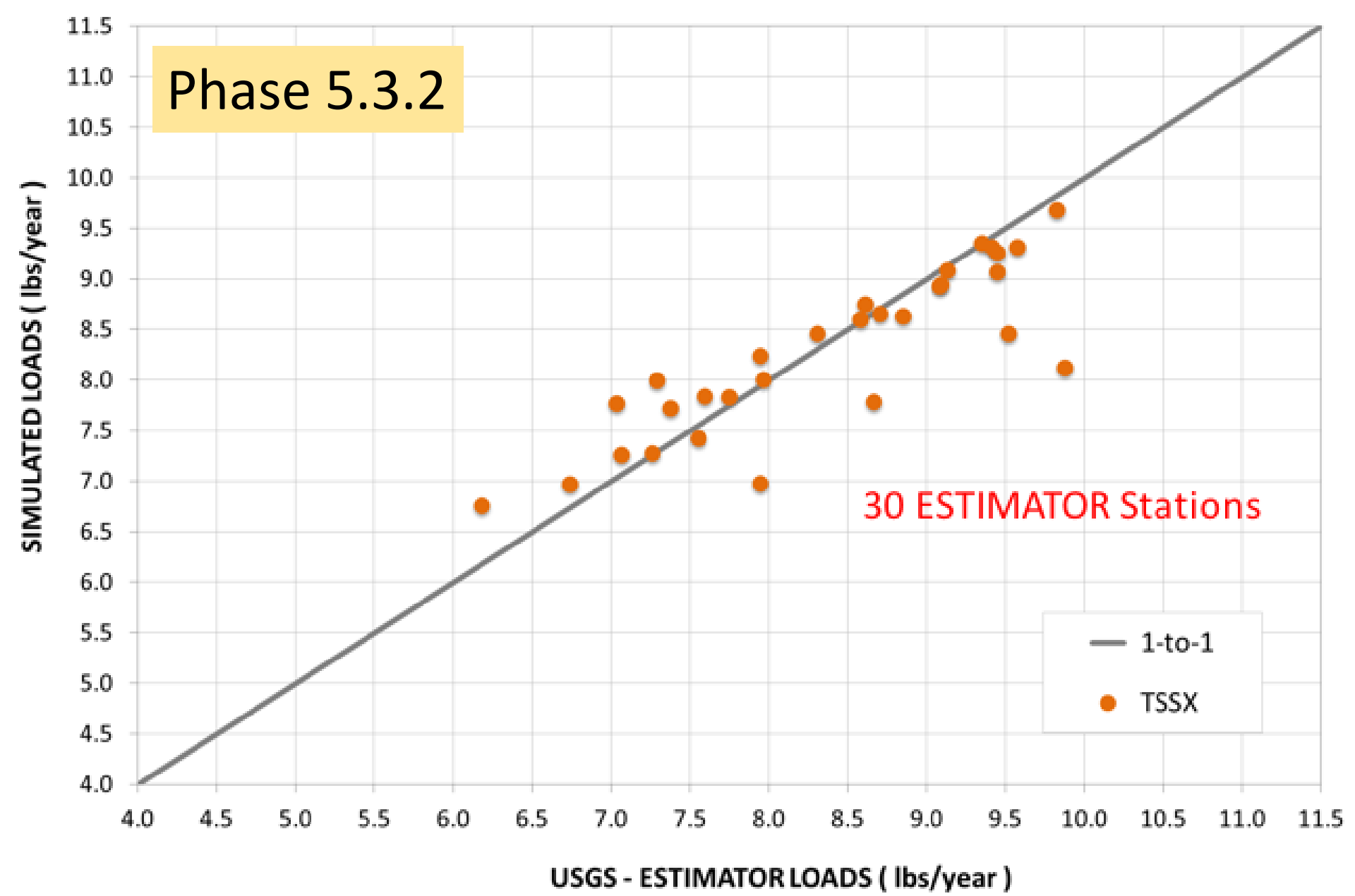
River Delivery Calibrated in the HSPF model

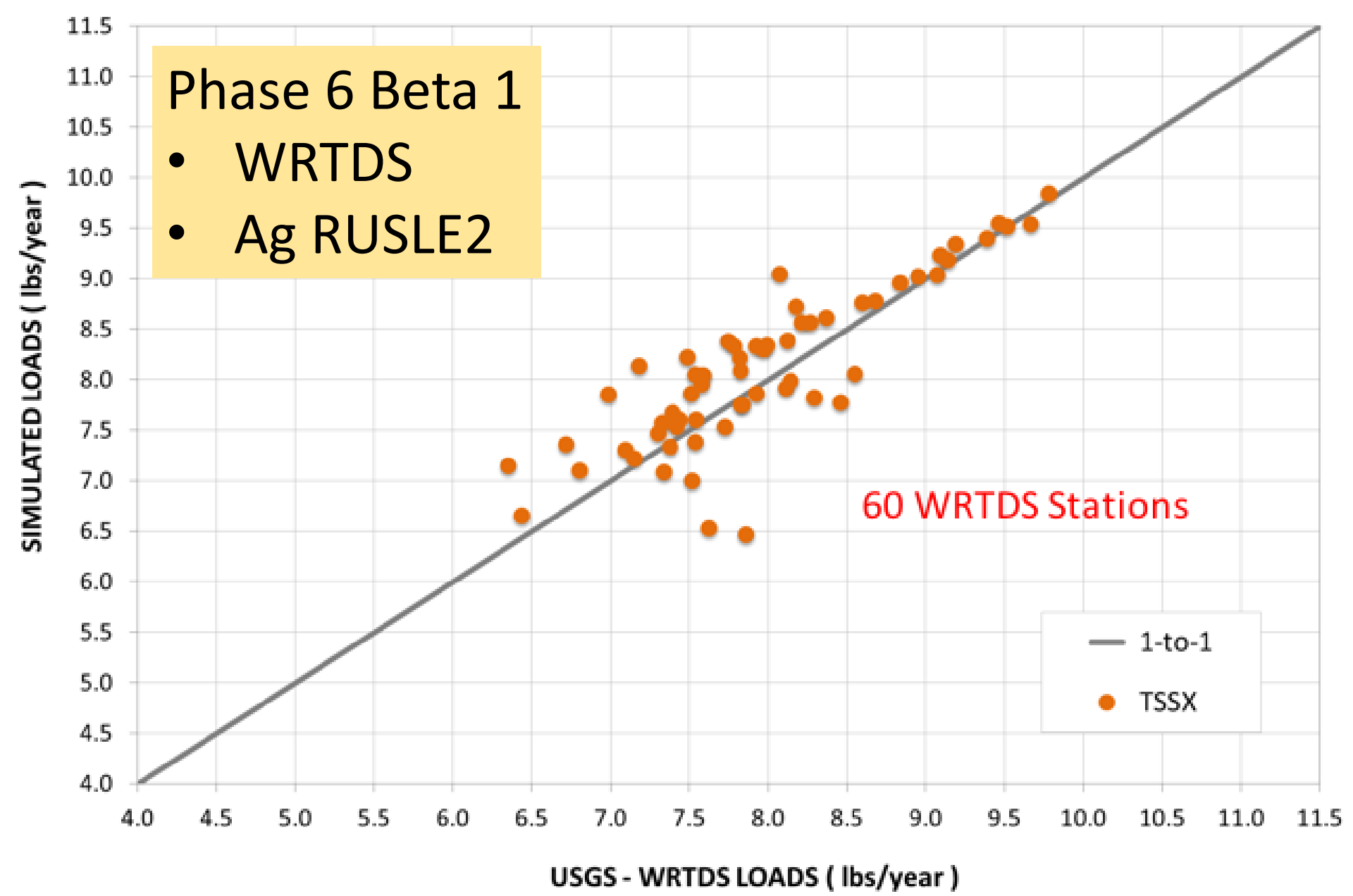
Precipitation

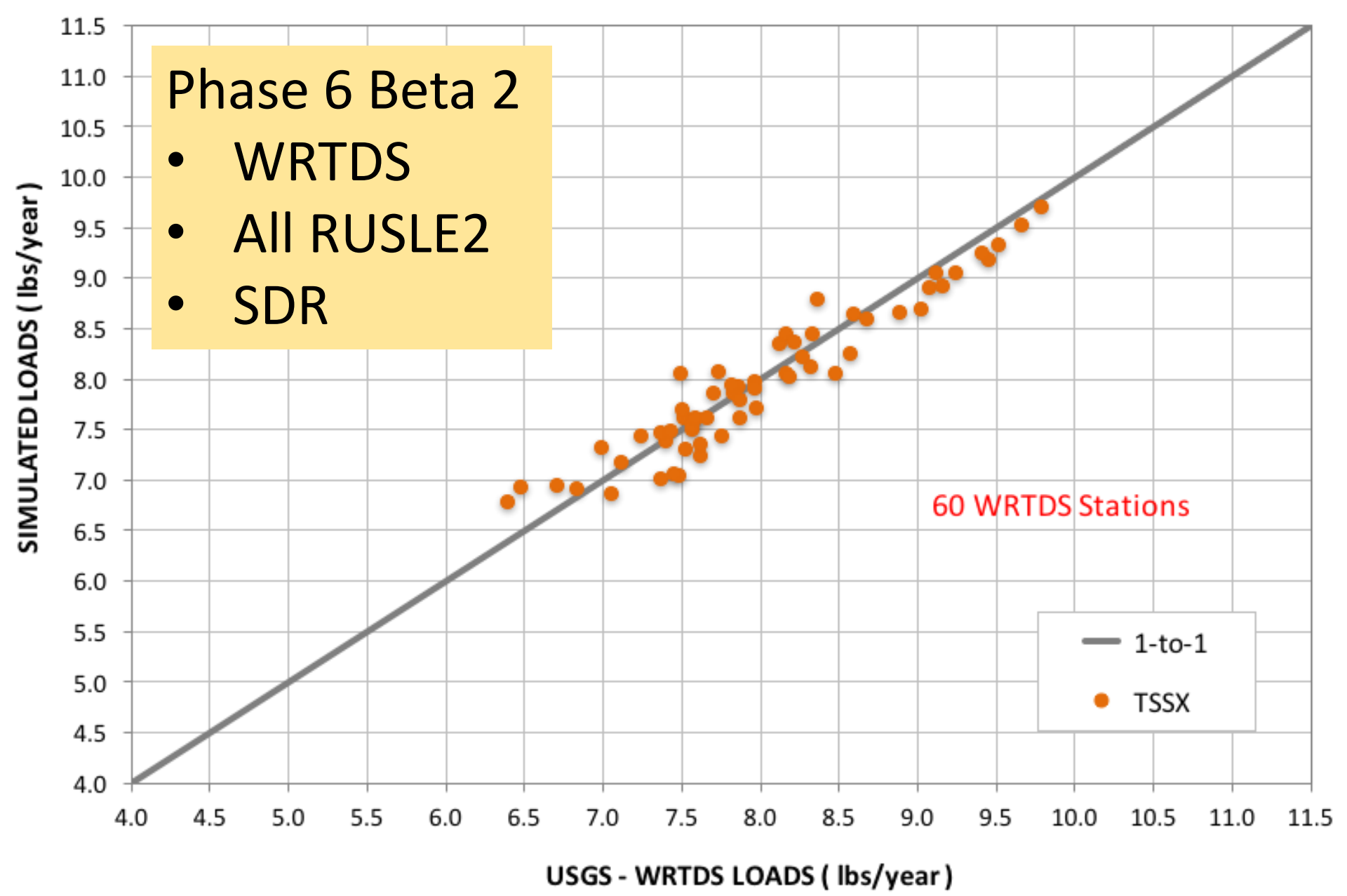




Potomac Fall Line


Phase 5.3.2
SIMULATED LOADS (lbs/year)
USGS - ESTIMATOR LOADS (lbs/year)
30 ESTIMATOR Stations
1-to-1
TSSX
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5


Phase 6 Beta 1
• WRTDS
• Ag RUSLE2
60 WRTDS Stations
1-to-1
TSSX
SIMULATED LOADS (lbs/year)
USGS - WRTDS LOADS (lbs/year)
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5


Phase 6 Beta 2
• WRTDS
• All RUSLE2
• SDR
60 WRTDS Stations
1-to-1
TSSX
SIMULATED LOADS (lbs/year)
USGS - WRTDS LOADS (lbs/year)
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5





Questions?

Edge of Field

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Land Use Acres

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BMPs

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Land to Water

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Stream Delivery

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River Delivery

Direct Loads

Phase 6