



Floodplain/streambank modulation of river loads of sediment and nutrients, from reaches to watersheds to regions

Greg Noe, Krissy Hopkins, Peter Claggett, Ed Schenk, Labeeb Ahmed, Marina Metes, Tom Doody, Cliff Hupp, Iara Lacher, Tom Akre, and Craig Fergus



Funding from: USGS Chesapeake Bay Studies, USGS Water Mission Area, Penn Foundation, and Smithsonian Institution

USGS Chesapeake and Delaware Floodplain Network: network design

Long-term streambank and floodplain characteristics and sediment and associated nutrient loss/gain were measured at 68 reaches across U.S. Mid-Atlantic

These sites are representative of regional variability in watershed drainage area, geology, topography, soils, hydrology, and land use

Site selection:

- Mixture of USGS NTN load gages and ungaged reaches
- 'Unmanaged' floodplain land use (with woody vegetation)
- Unchannelized
- Landowner permission

EXPLANATION

Field Site



Contributing drainage area



Physiographic Province

Appalachian Plateau

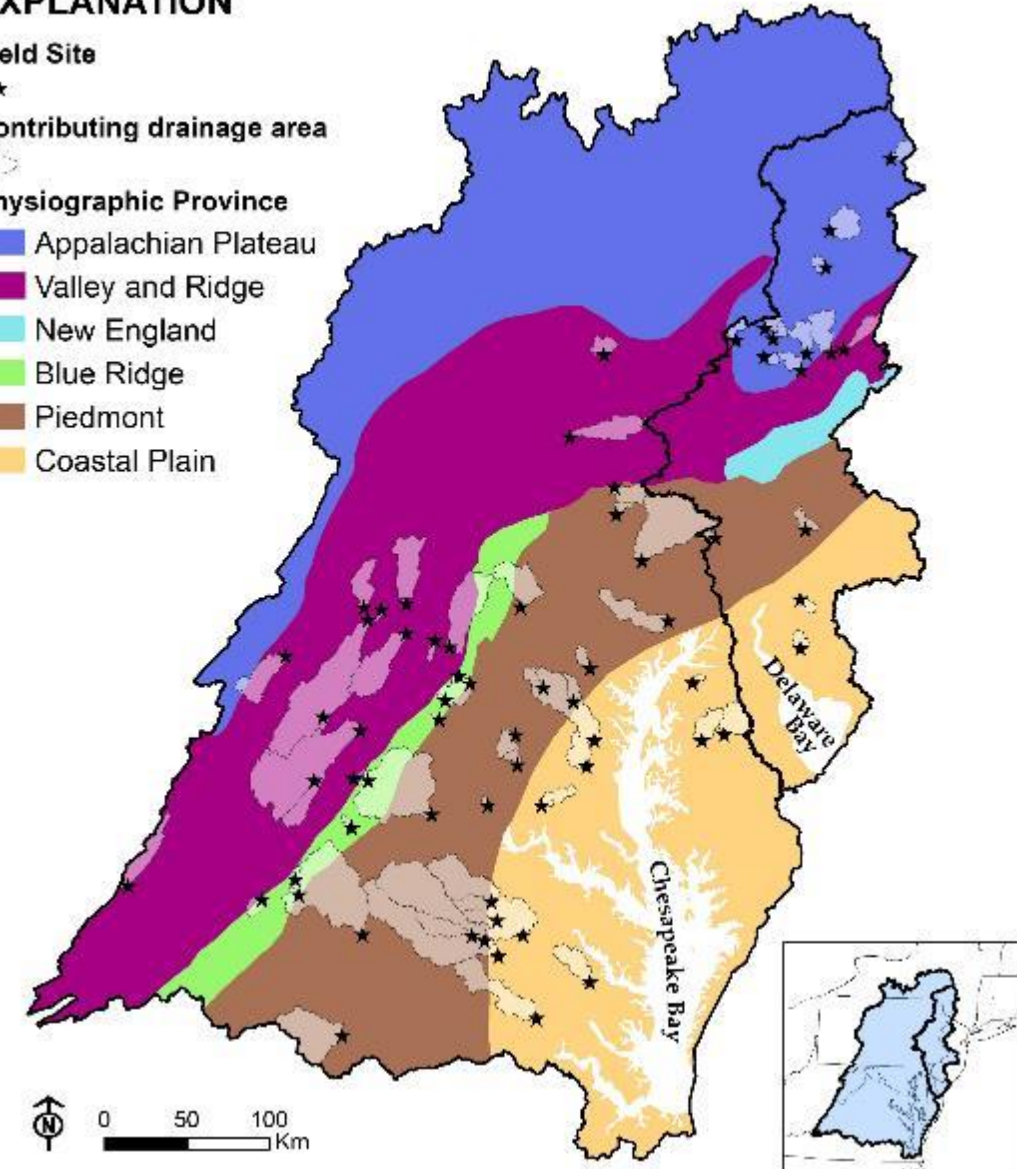
Valley and Ridge

New England

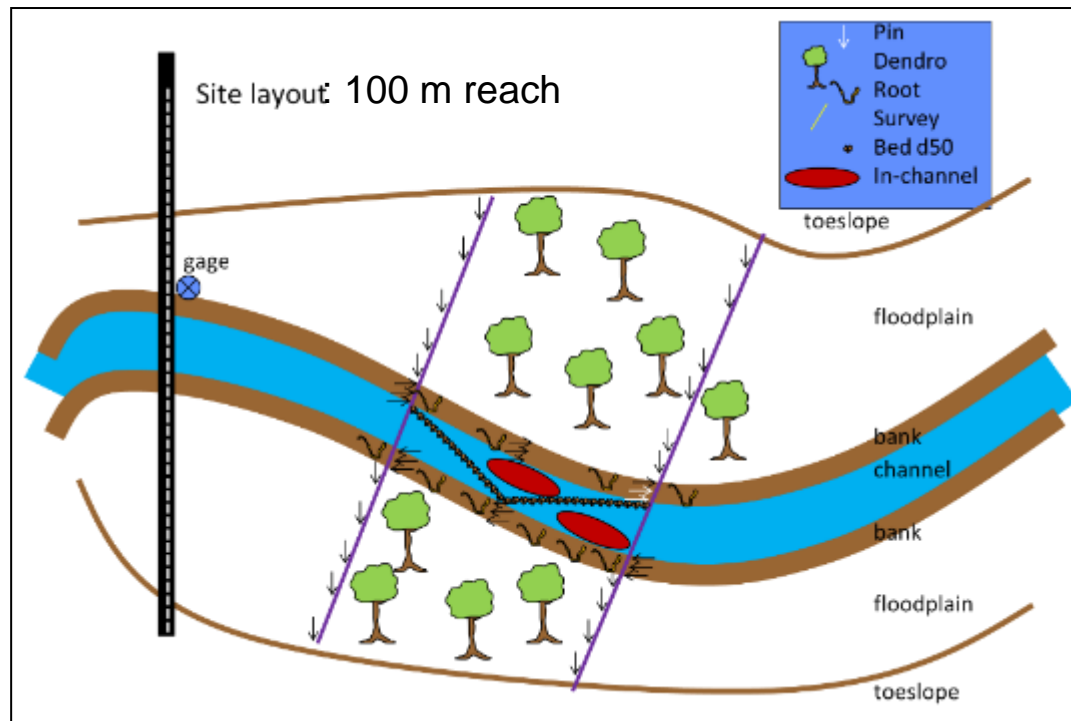
Blue Ridge

Piedmont

Coastal Plain



USGS Chesapeake and Delaware Floodplain Network: measurements at 68 reaches



Stream valley x-section surveying:
136 x-sections

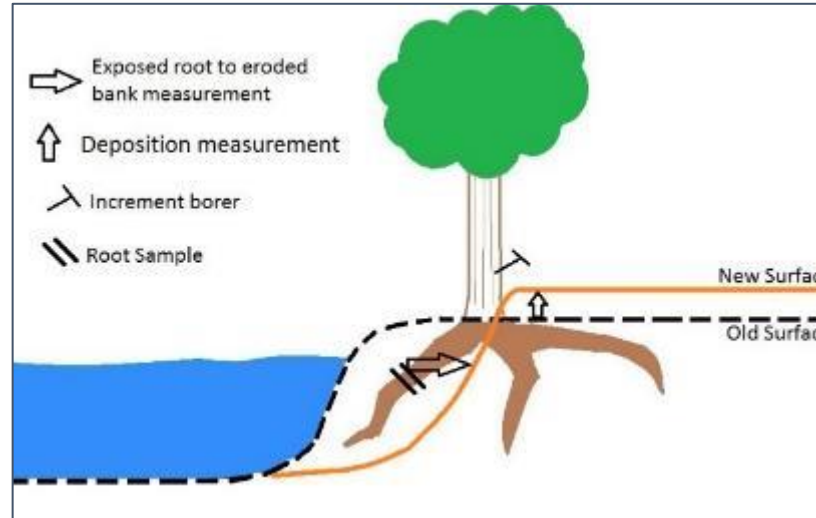
Floodplain tree coring:
667 floodplain tree cores

Bank root:
457 bank root samples

**Floodplain sed coring
(5 cm deep):**
376 floodplain samples

**Bank sed coring
(5 cm deep):**
541 bank samples

Dendrogeomorphic fluxes



Root analysis to determine years since exposure



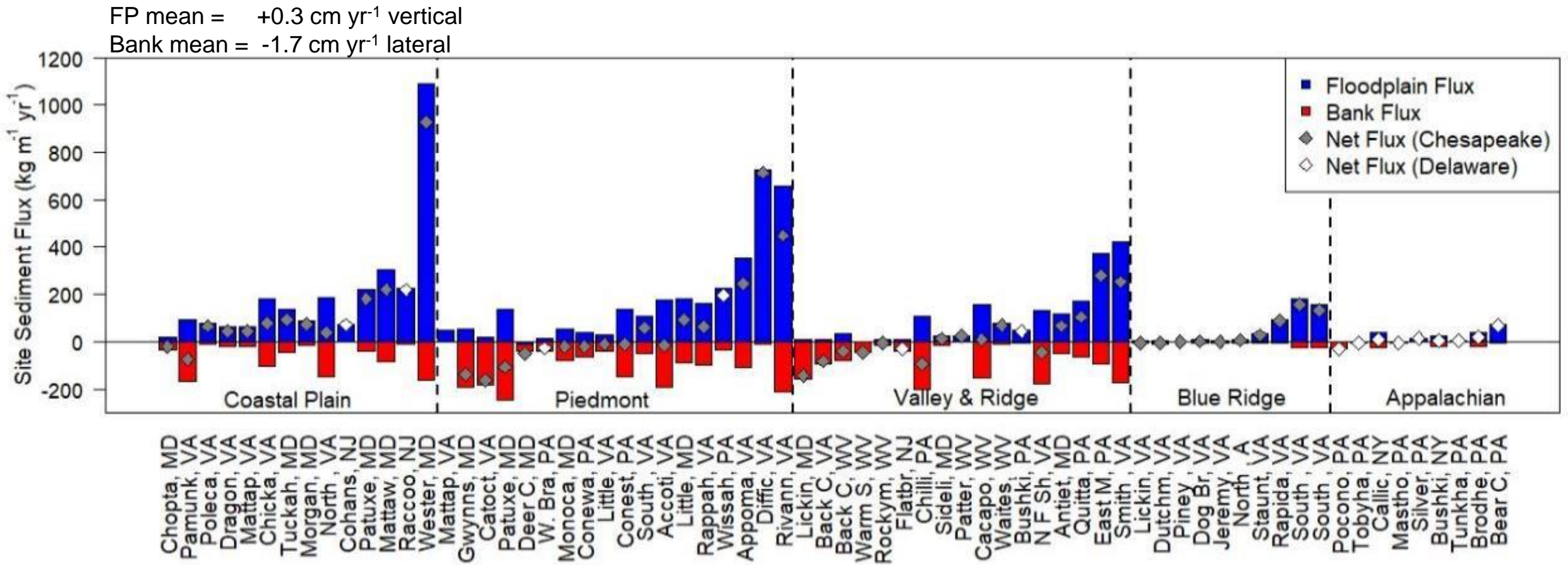
Geomorphic measurements:

Active (~2 yr) floodplain width
Bank height
Channel width
Lateral and vertical change (cm/yr)
% eroding bank
Adjusted lateral erosion (cm/yr)

Sediment characteristics:

Bulk density (g/cm³)
Bulk density <2 mm (g/cm³)
Bulk density <1 mm (g/cm³)
% organic
% mineral
% carbonate
Total OC (%)
Total N (%)
Total P (%)
Total Ca (mg/g)
Total Na (mg/g)
Total Mg (mg/g)
Total K (mg/g)
Total Al (mg/g)
Total Fe (mg/g)
Total Ti (mg/g)
Particle size: mean (um)
Particle size: d50 (um)
Particle size: %<63 um

USGS Chesapeake and Delaware Floodplain Network: long-term bank and floodplain fluxes



Mean ages of trees:
floodplain = 51 yr,
bank = 17 yr exposed

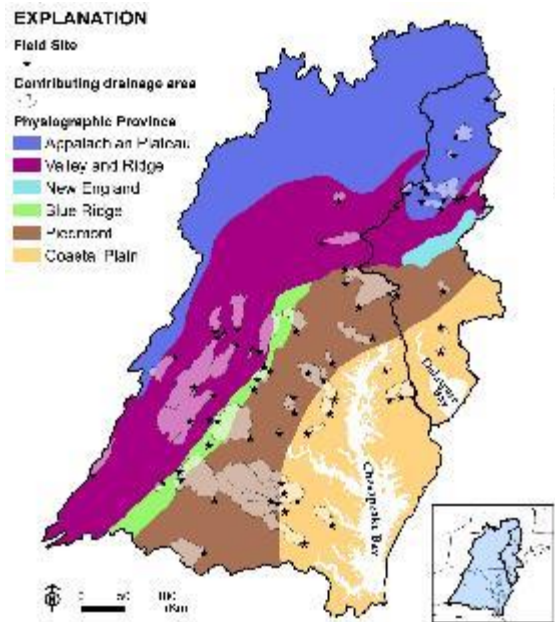
Bank flux =
lateral change rate * bulk density *
bank height * 2 * %eroding

Floodplain flux =
vertical change rate * bulk density *
total floodplain width

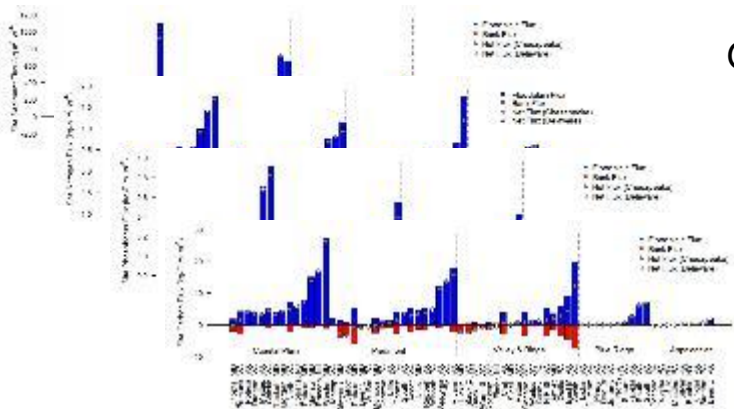
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USGS Chesapeake and Delaware Floodplain Network: approach

Measure



Analyze



Model (Random Forest)

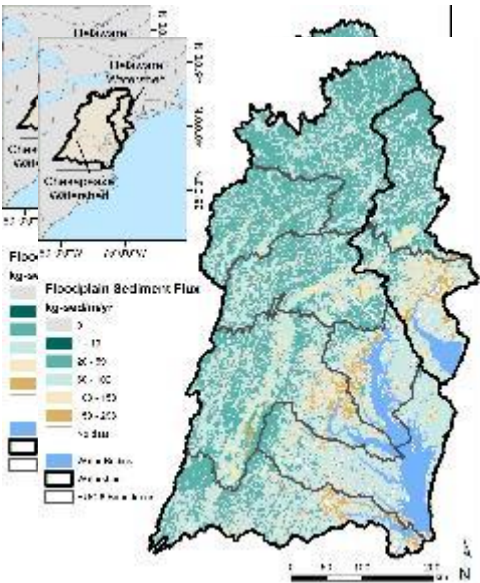
GIS reach-scale geomorphometry ("shape")
Floodplain width, bank height,
channel width, ...

Random Forests regressions

GIS upstream watershed attributes
Land use, hydrology, soils, topography

GIS upstream watershed attributes
FUTURE Land use, hydrology, soils, topography

Predict (99,664 NHDPlusV2 reaches)



Random Forest regressions' predictor variables tested

FACET Geomorphometry (Hopkins et al. 2020):

STREAM SLOPE (%)
STREAM SINUOSITY
BANK HEIGHT (m)
CHANNEL WIDTH (m)
FLOODPLAIN WIDTH (m)
BANK ANGLE (deg)
CHANNEL WIDTH / BANK HEIGHT
CHANNEL WIDTH / FLOODPLAIN WIDTH
FLOODPLAIN WIDTH / BANK HEIGHT

+

Watershed Attributes (Wieczorek et al. 2018):

BASIN_AREA	drainage area (km ²)
TWI	topographic wetness index (ln m)
KFACT	erodibility factor
NO200AVE	soil < 74 µm (%)
OLSON_S	rock sulfur content (%)
OLSON_FE	rock iron content (%)
BFI	base flow index (%)
WB5100_ANN	1951-2000 average annual runoff (mm)
IEOF	Horton overland flow (%)
NDAMS2013	# of dams
NLCD2011_21	developed open space (%)
NLCD2011_22+23+24	developed low+med+high intensity (%)
NLCD2011_31	barren land (%)
NLCD2011_41+42+43+52	forest + shrub/scrub (%)
NLCD2011_71+81	grassland + pasture/hay (%)
NLCD2011_82	cultivated crops (%)
NLCD2011_90+95	woody + herbaceous wetland (%)

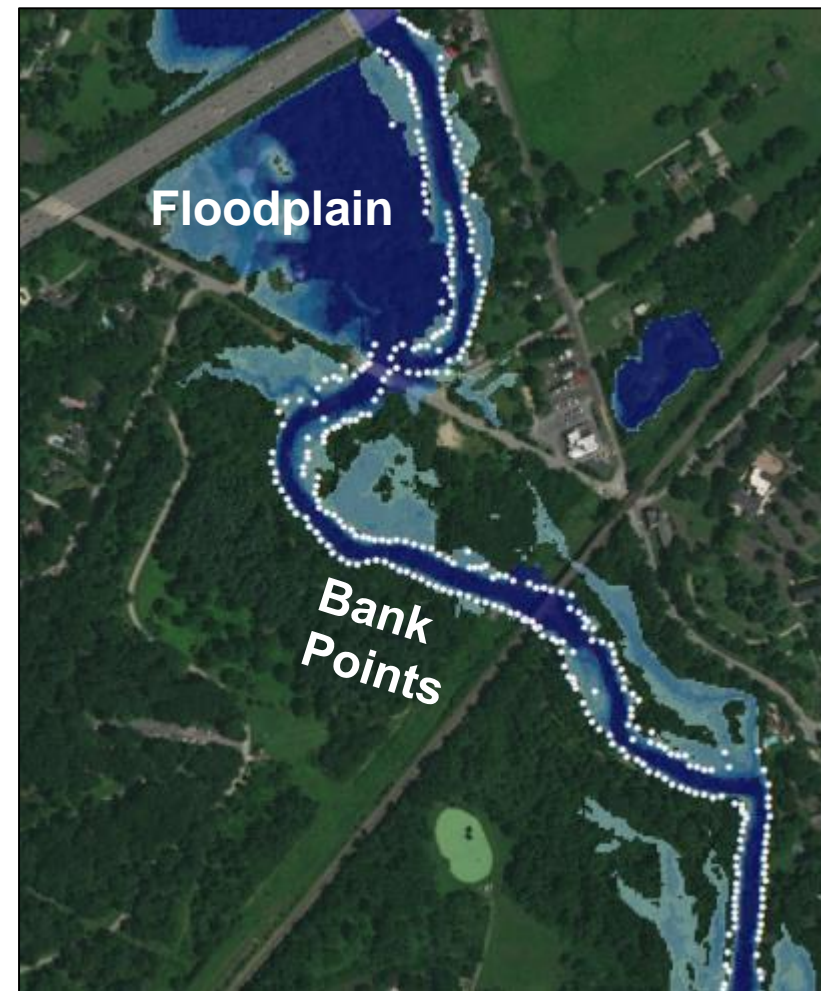
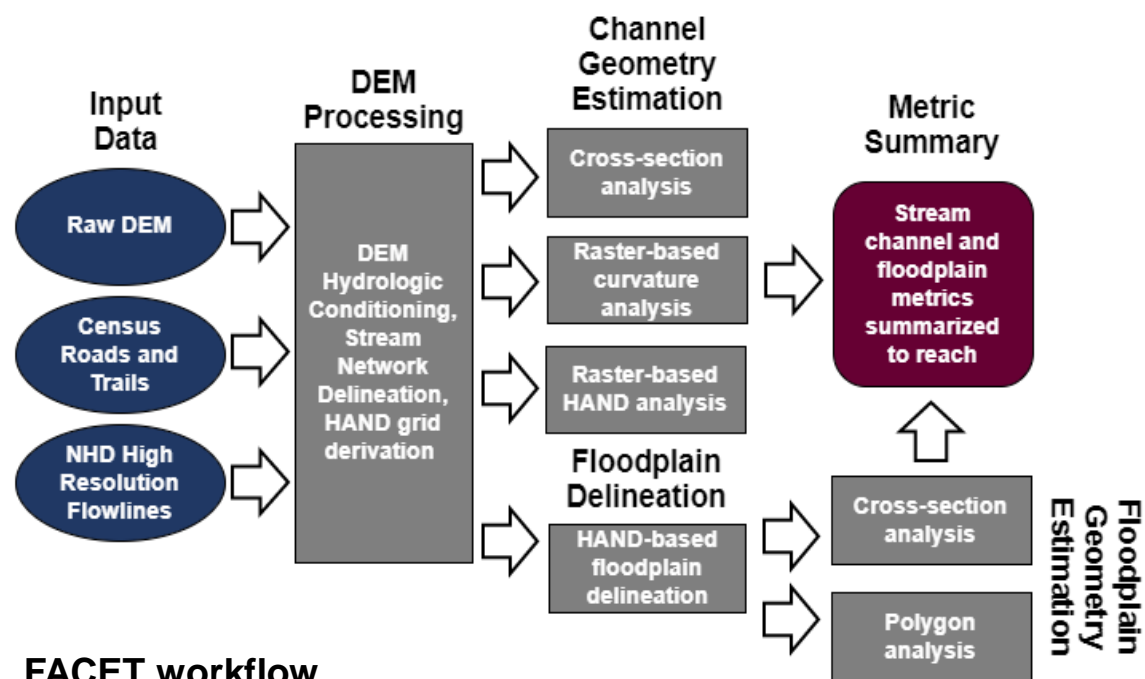
→ Choose best model for each prediction metric:

1) Watershed attributes; or 2) Geomorphometry + Watershed attributes (if available)

What is FACET?

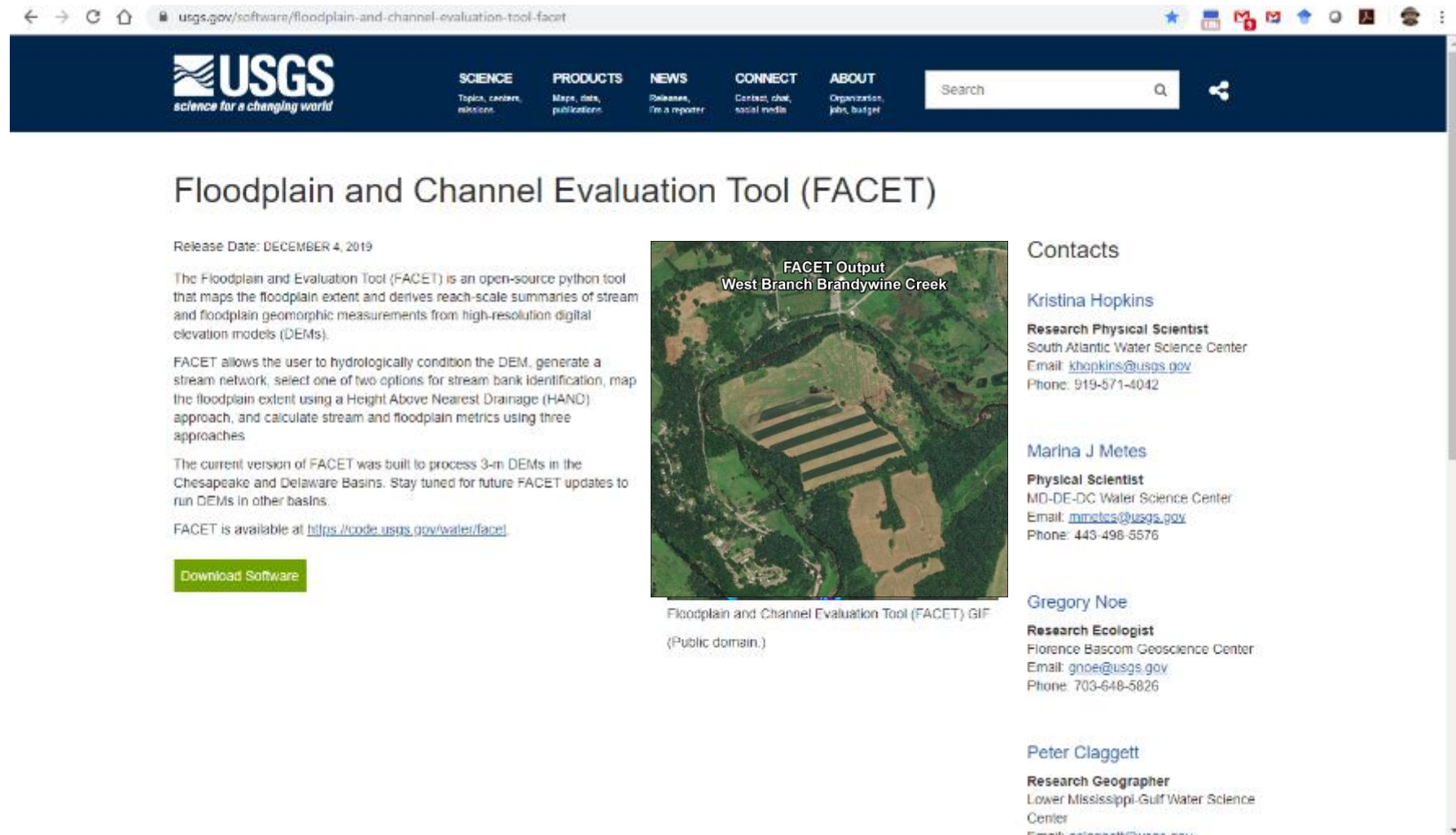
Automated fine-scale geomorphometry

- Open source Python tool
- Hydrologic conditioning of DEM
- Delineates floodplain & stream network
- Calculating channel and floodplain metrics
- **Code available at code.usgs.gov/water/facet**



Example FACET output for Wissahickon Creek at Fort Washington, PA

Floodplain and Channel Evaluation Toolkit (FACET): software



The screenshot shows the USGS website for the Floodplain and Channel Evaluation Tool (FACET). The page features a dark blue header with the USGS logo and navigation links for Science, Products, News, Connect, and About. A search bar is also present. The main content area is titled "Floodplain and Channel Evaluation Tool (FACET)" and includes a release date of December 4, 2019. The text describes FACET as an open-source Python tool for mapping floodplains and calculating metrics. A central image shows a satellite map of West Branch Brandywine Creek with a yellow floodplain overlay. To the right, contact information for Kristina Hopkins, Marina J Metes, Gregory Noe, and Peter Claggett is provided. A green "Download Software" button is located at the bottom left of the main text area.

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Floodplain and Channel Evaluation Tool (FACET)

Release Date: DECEMBER 4, 2019

The Floodplain and Evaluation Tool (FACET) is an open-source python tool that maps the floodplain extent and derives reach-scale summaries of stream and floodplain geomorphic measurements from high-resolution digital elevation models (DEMs).

FACET allows the user to hydrologically condition the DEM, generate a stream network, select one of two options for stream bank identification, map the floodplain extent using a Height Above Nearest Drainage (HAND) approach, and calculate stream and floodplain metrics using three approaches.

The current version of FACET was built to process 3-m DEMs in the Chesapeake and Delaware Basins. Stay tuned for future FACET updates to run DEMs in other basins.

FACET is available at <https://code.usgs.gov/water/facet>

[Download Software](#)

FACET Output
West Branch Brandywine Creek

Floodplain and Channel Evaluation Tool (FACET) GIF
(Public domain.)

Contacts

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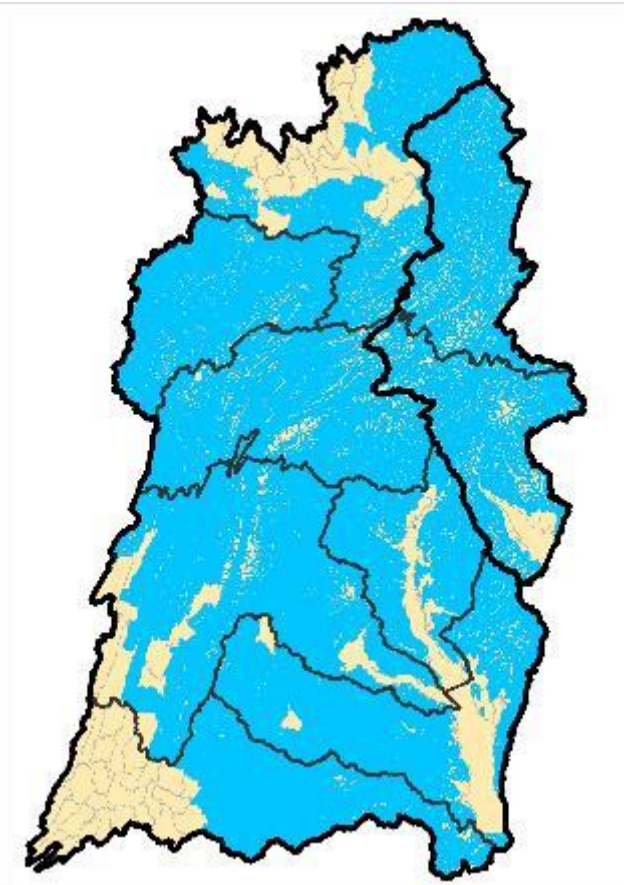
Peter Claggett
Research Geographer
Lower Mississippi-Gulf Water Science Center
Email: pclaggett@usgs.gov
Phone: 601-768-2000

<https://www.usgs.gov/software/floodplain-and-channel-evaluation-tool-facet>

Lamont, S., L. Ahmed, M.J. Metes, P. Claggett, K.G. Hopkins, and G.B. Noe. 2019. Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: <https://doi.org/10.5066/P9PI94Z1>.

Floodplain and Channel Evaluation Toolkit (FACET): output

Geomorphometry for Streams and Floodplains in the Chesapeake and Delaware Watersheds

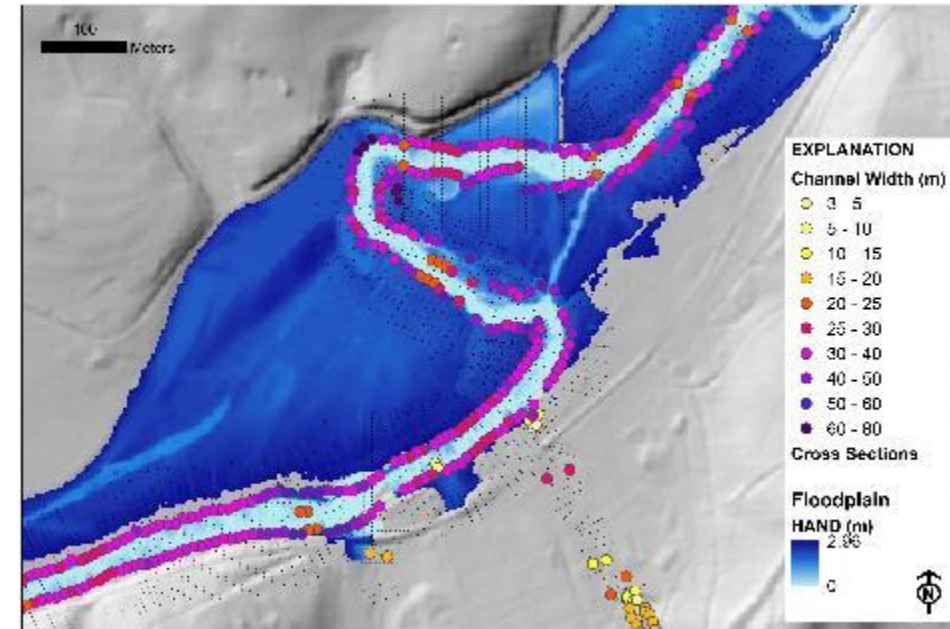


Extent of stream layer output

Every watershed with LIDAR

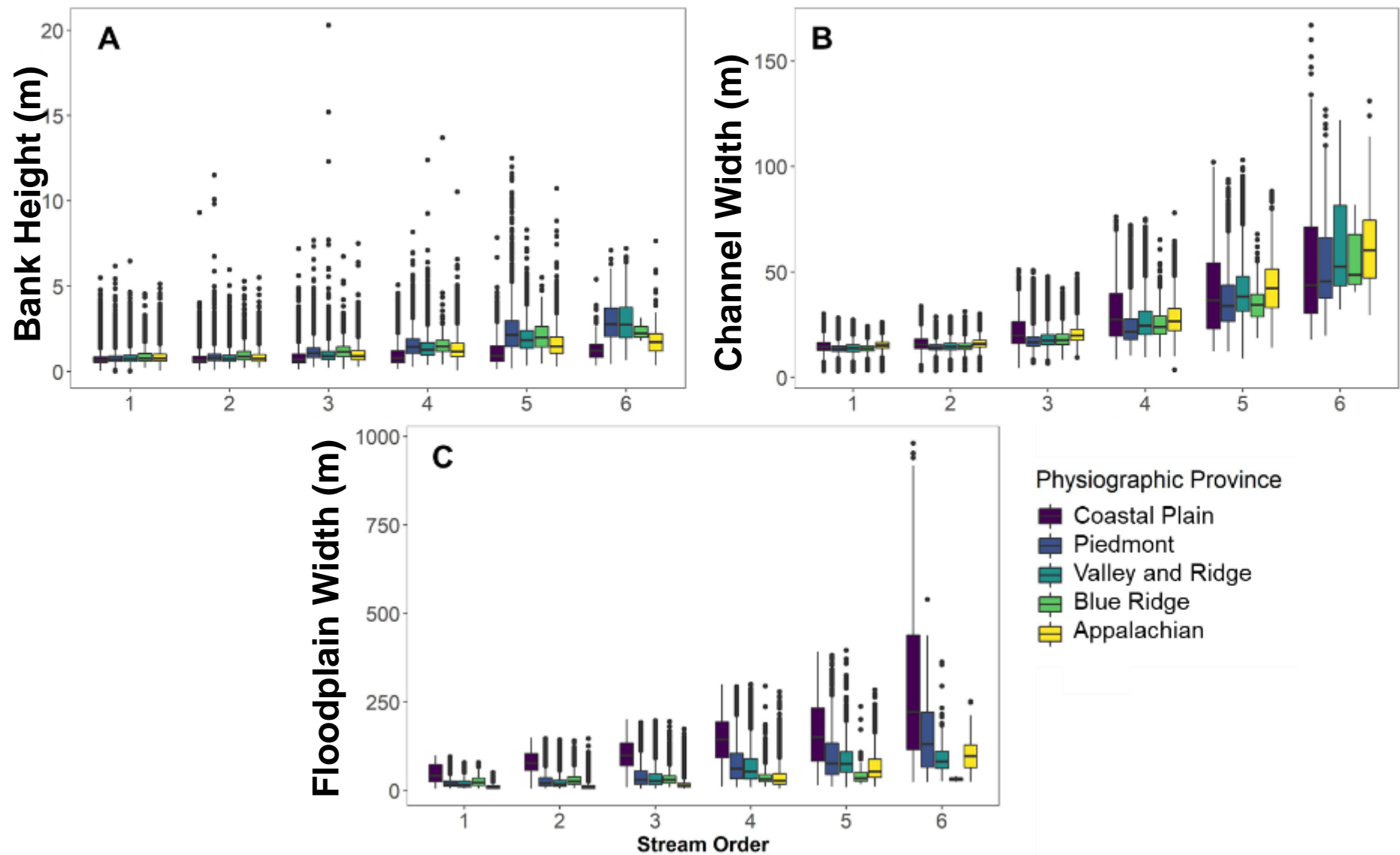
GIS: shapefiles and rasters of the stream network, cross sections, streambank point locations, floodplain extent, height above nearest drainage (HAND)

Tables: reach-scale summaries of bank height, channel width, floodplain width, and a suite of other metrics



Hopkins, K.G., Ahmed, L., Metes, M.J., Claggett, P.R., Lamont, S., and Noe, G.B, 2020, Geomorphometry for Streams and Floodplains in the Chesapeake and Delaware Watersheds: U.S. Geological Survey data release, <https://doi.org/10.5066/P9RQJPT1>.

1-D Cross-Section Output for ~270,000 stream reaches



FACET Data

ScienceBase.gov search for
“Geomorphometry Chesapeake”
OR

<https://doi.org/10.5066/P9RQJPT1>

Attached Files:
Use Reference Map to find HUC#



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Geomorphometry for Streams and Floodplains in the Chesapeake and Delaware Watersheds

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Dates
Publication Date : 2020-04-28

Citation
Hopkins, K.G., Ahmed, L., Metes, M.J., Claggett, P.R., Lamont, S., and Noe, G.B., 2020, Geomorphometry for Streams and Floodplains in the Chesapeake and Delaware Watersheds. U.S. Geological Survey data release, <https://doi.org/10.5066/P9RQJPT1>.

Summary
Geomorphometry for Streams and Floodplains in the Chesapeake and Delaware Watersheds was generated as part of the project Quantifying Floodplain Ecological Processes and Ecosystem Services in the Delaware River Watershed funded through the William Penn Foundation's Delaware Watershed Research fund. This dataset contains geomorphometry for streams and floodplains in the Chesapeake and Delaware River watersheds. Geomorphometry is a quantitative representation of landscape surface form (e.g., channel width and depth) obtained from digital elevation models (DEMs). The dataset contains geomorphometry derived from running 3-m DEMs through the Floodplain and Channel Evaluation Tool (FACET) version 0.1.0. FACET generates shapetables and rasters of the stream network, cross sections, streambank point locations, floodplain extent, height above nearest drainage (HAND), and reach-scale summaries of bank height, channel width, floodplain width, and a suite of other metrics outlined in the data dictionary. These data were generated to aid in modeling the amount of sediment and nutrients trapped on floodplains or eroded from streambanks in the Chesapeake and Delaware River watersheds.

Files are organized into folders by hydrologic unit code (HUC) for subbasins within the Chesapeake and Delaware watersheds. Each folder contains the following files within the main folder and a sub folder called "post processing."
XXXX folder, where XXXX is a 4-digit HUC.

... show more ...

Child Items (6)

- 0204
- 0205
- 0206
- 0207
- 0208
- Chesapeake and Delaware Basin Combined Files

Map »

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- Chesapeake and Delaware Floodplain Network
- USGS Chesapeake Bay
- USGS Data Release Products

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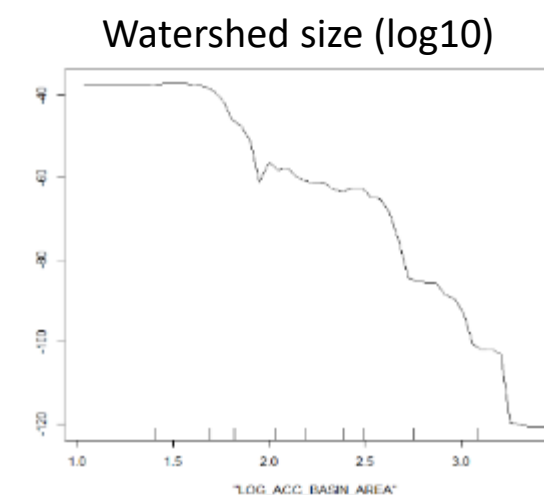
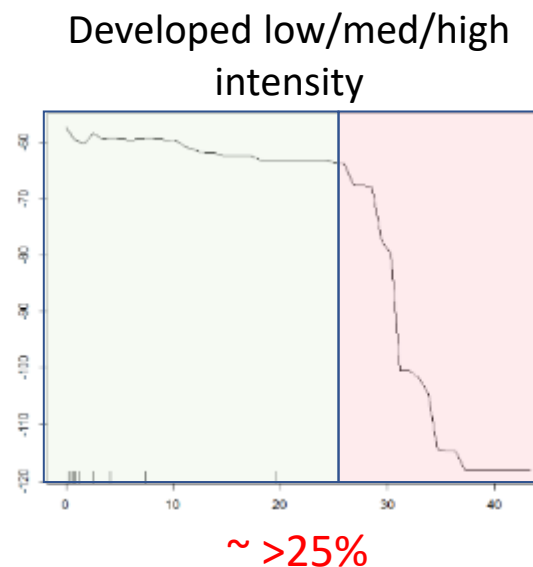
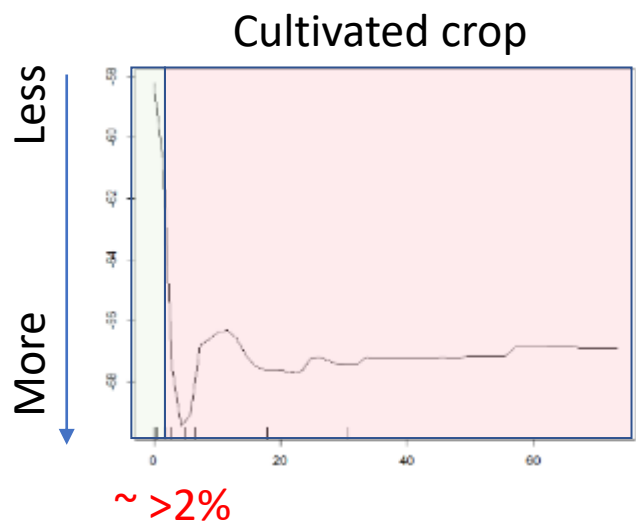
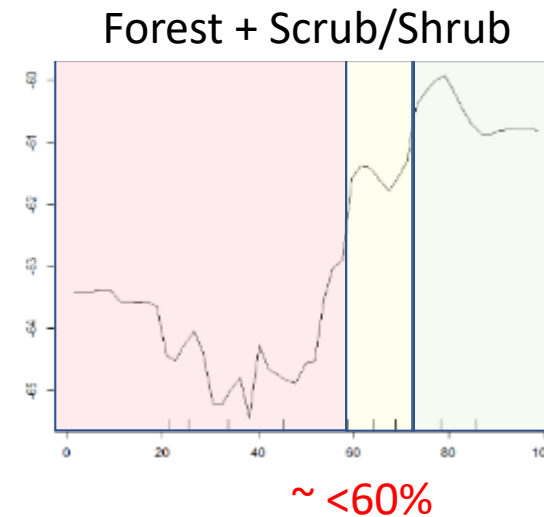
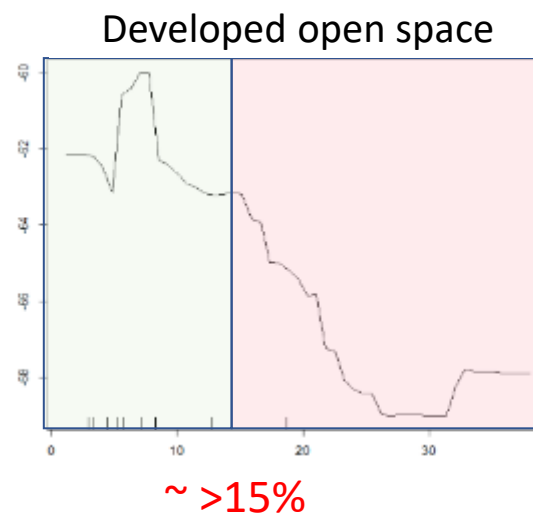
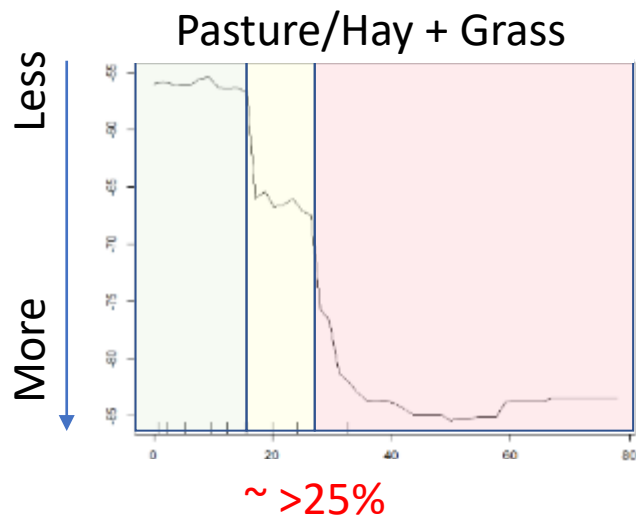
Tags

Theme : Floodplain, Geomorphology, Hydrography, Stream, geospatial, lidar, mapping, remote sensing, streambank

Place : Chesapeake Bay Watershed, Delaware River Basin

Modeled 2011 Land use effects on Streambank sediment flux (kg/m/yr)

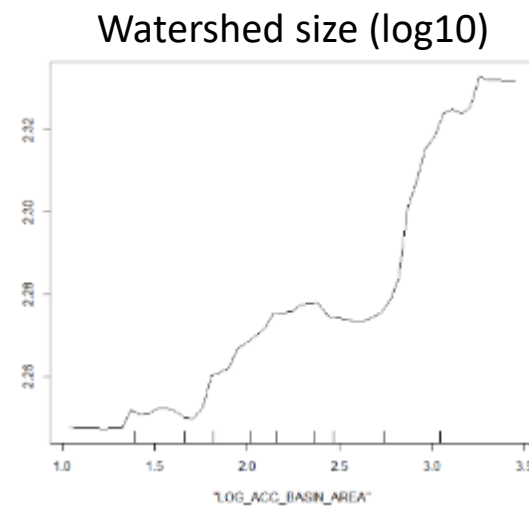
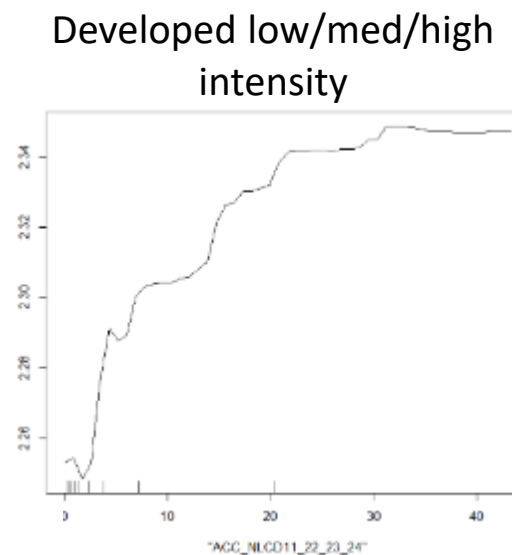
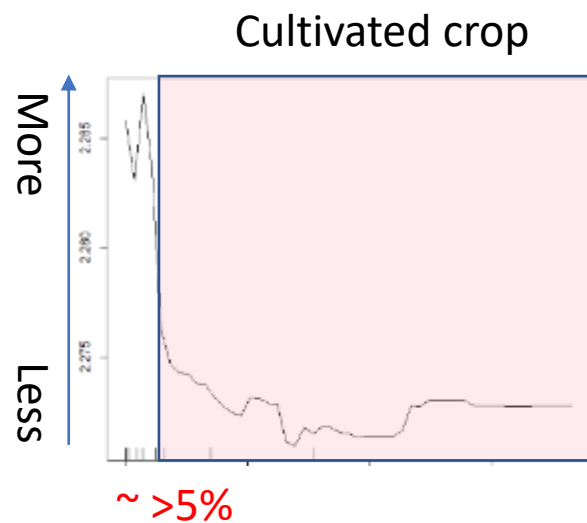
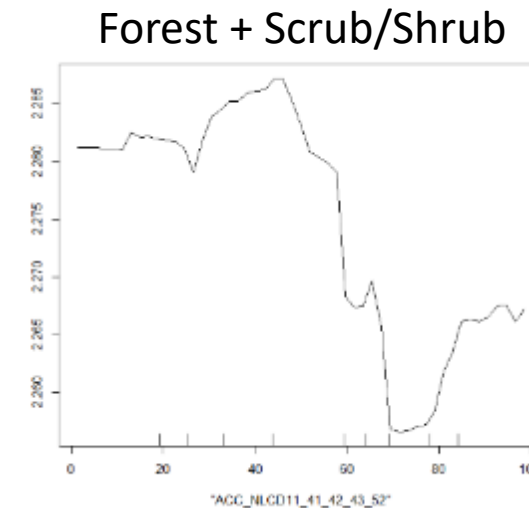
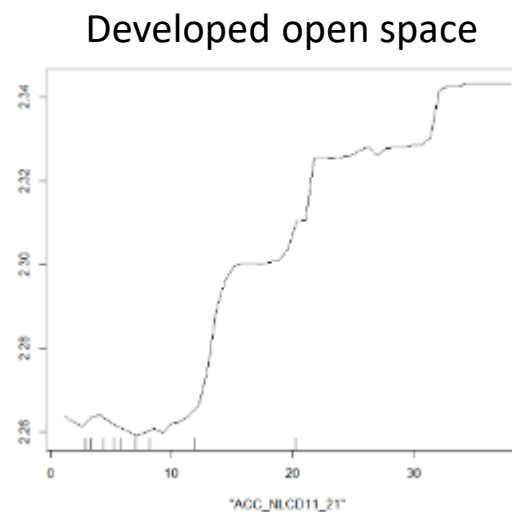
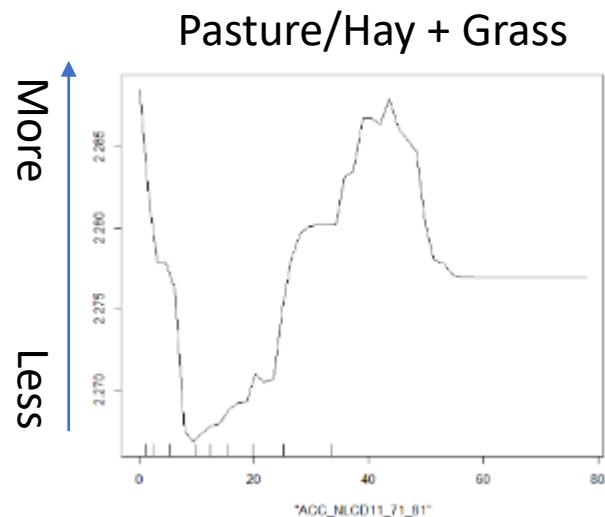
Streambank sediment erosion



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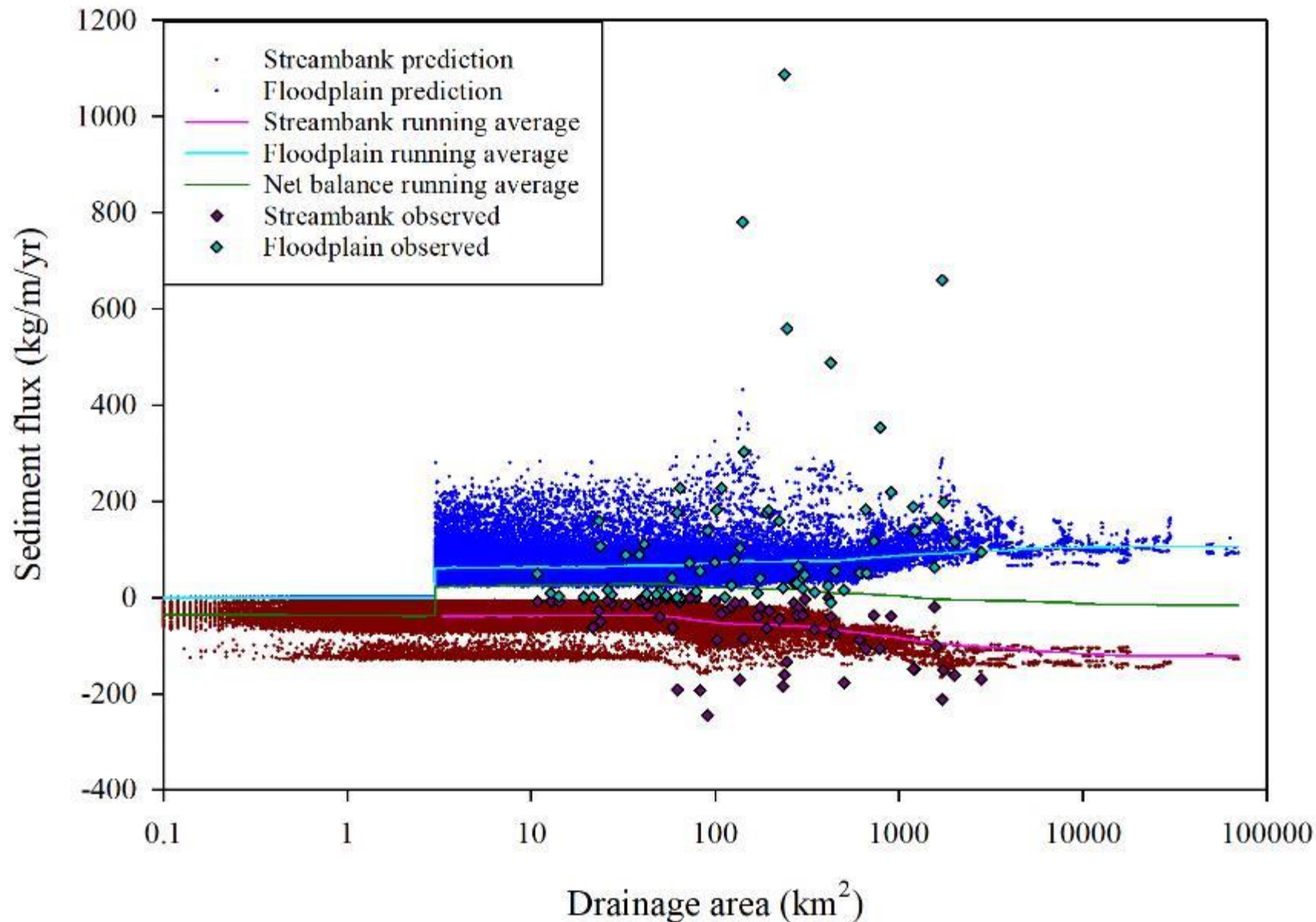
Modeled 2011 Land use effects on log10 Floodplain sediment flux (kg/m/yr)

Log10 Floodplain sediment deposition



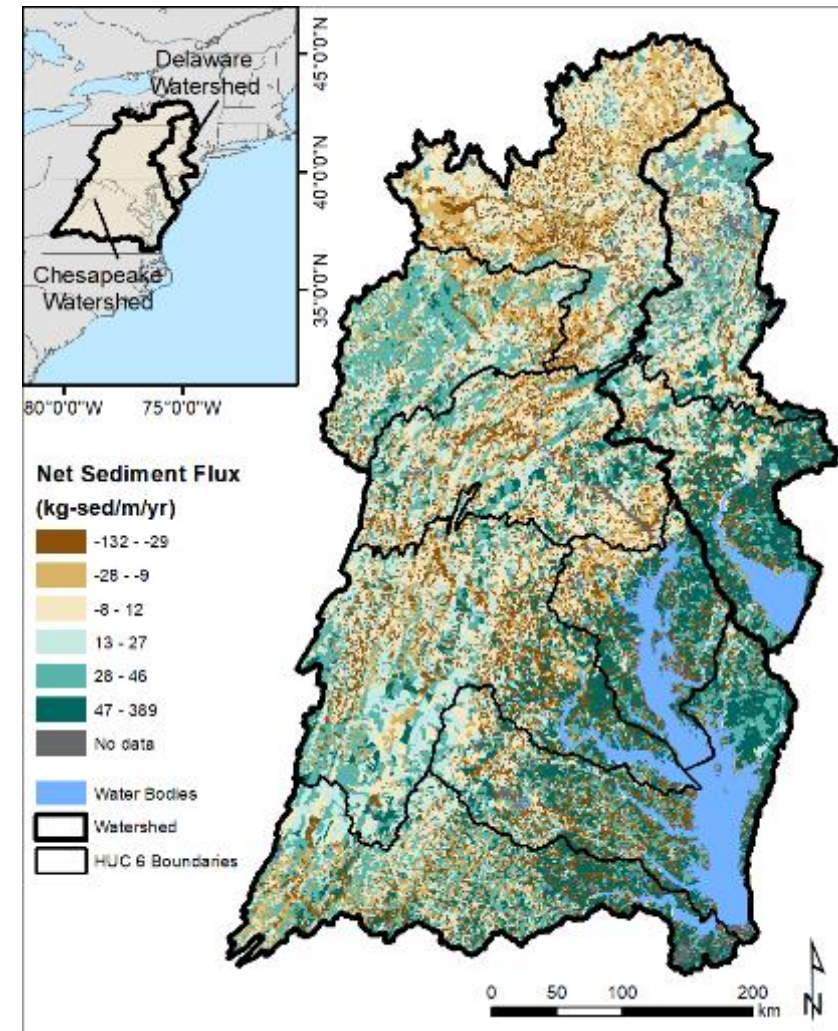
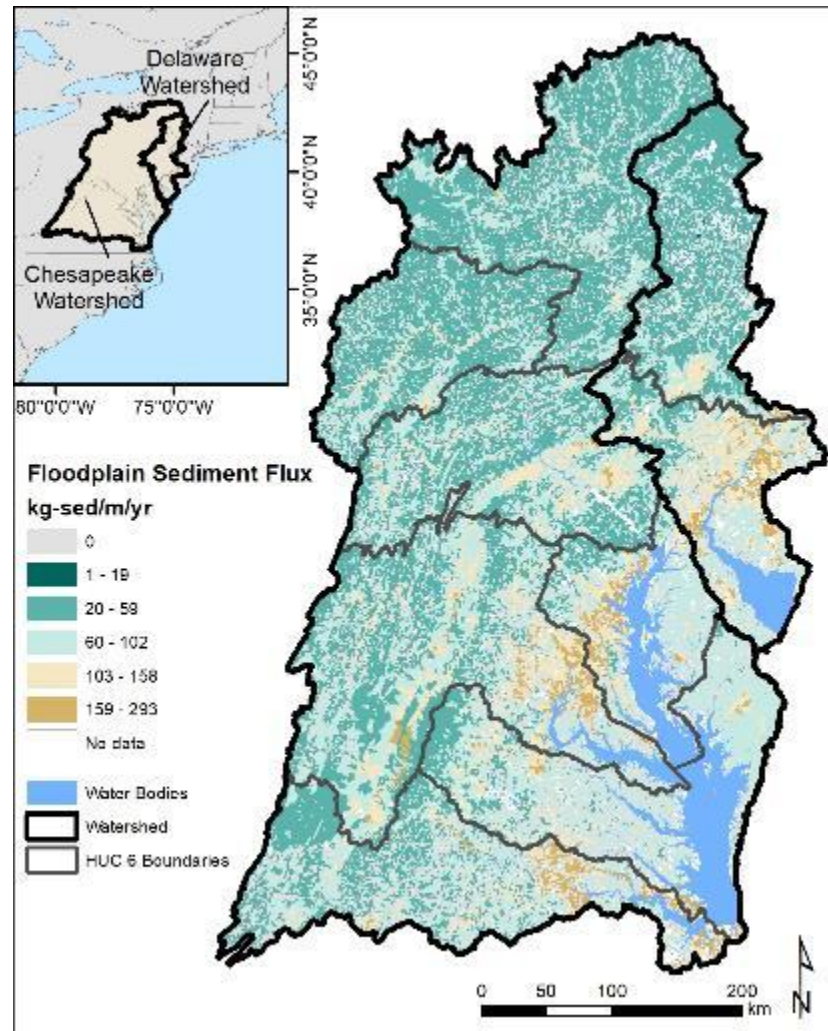
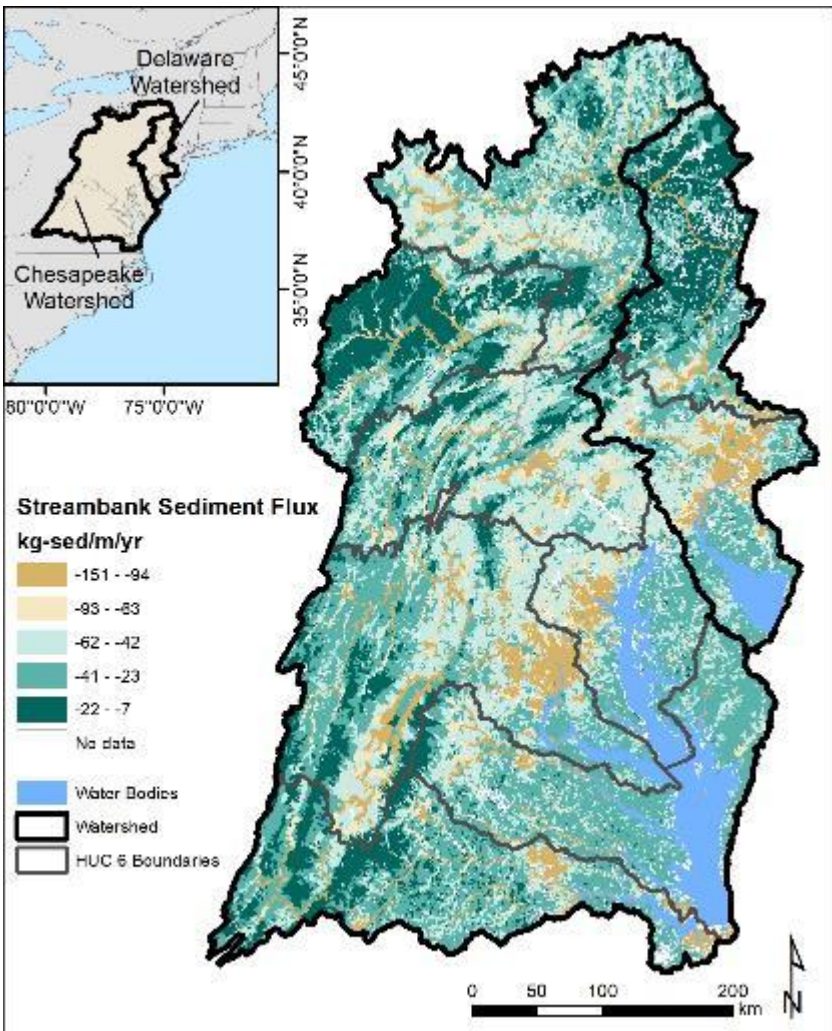
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Predictions for each of the 74,133 nontidal streams in the mid-Atlantic



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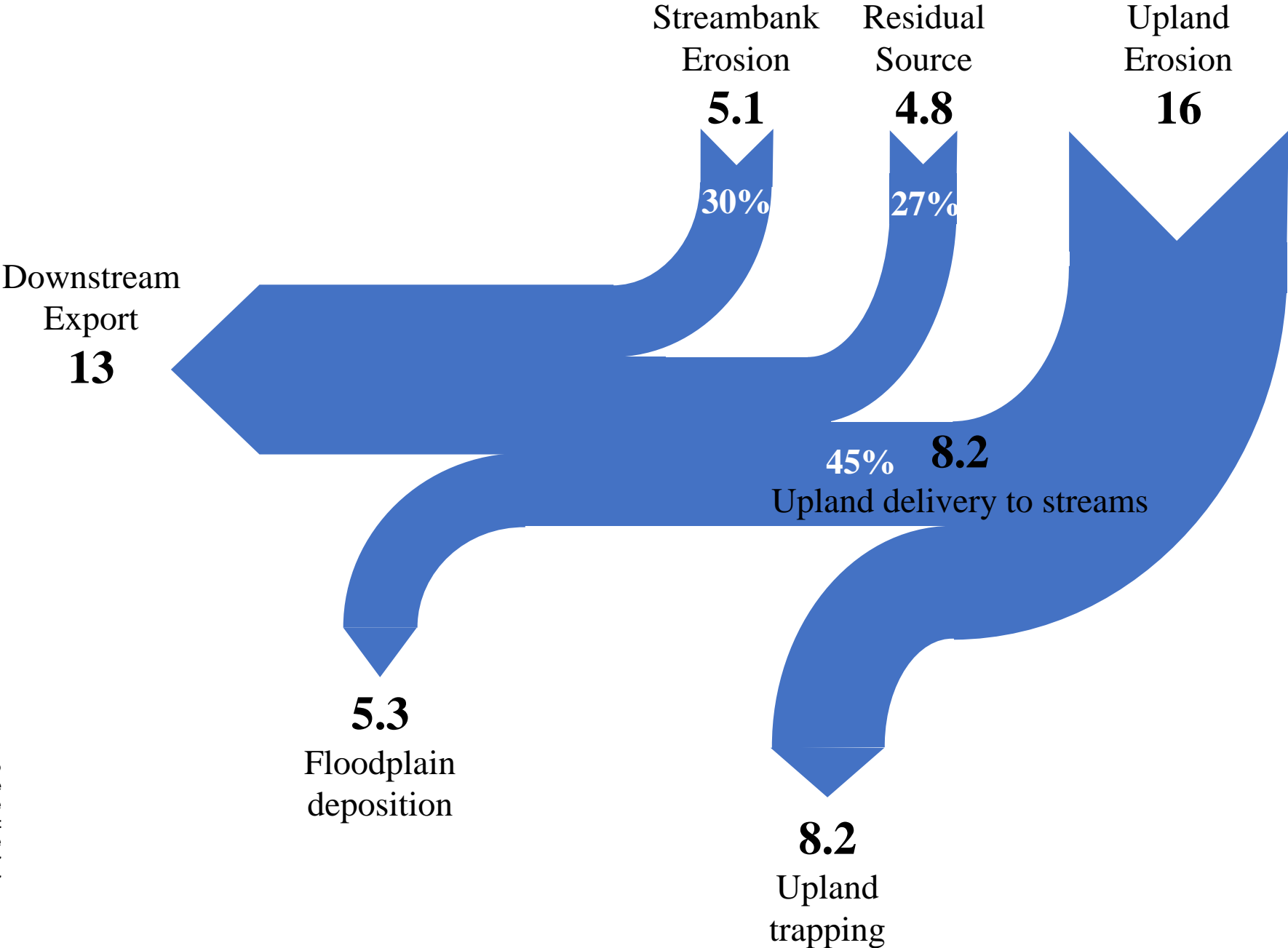
Predictions for each of the nontidal streams in the mid-Atlantic



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Censored loads summed for all Chesapeake watershed 64,294 nontidal NHDPlusV2 reaches

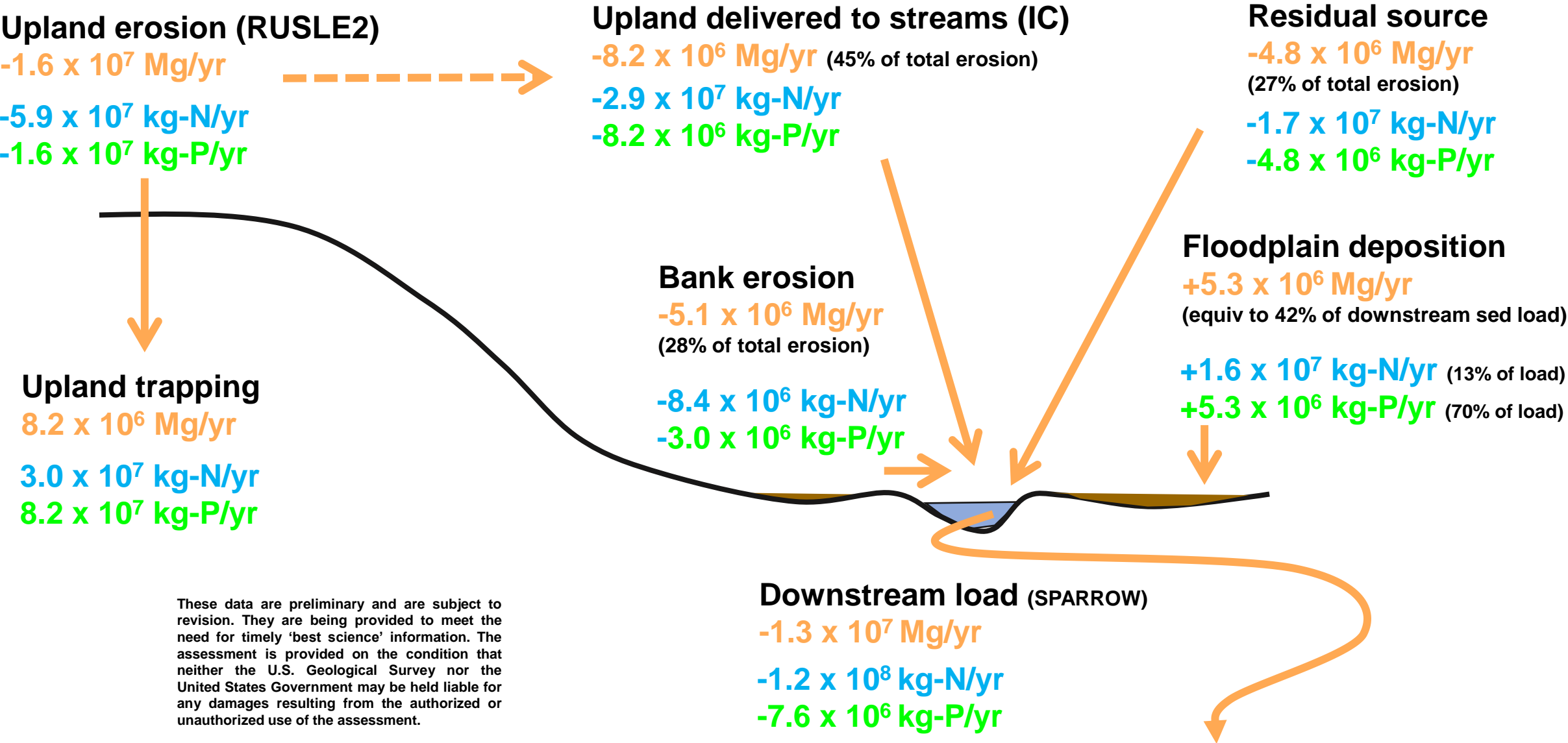
Sediment load
Tg/yr




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Censored loads summed for all Chesapeake watershed 64,294 nontidal NHDPlusV2 reaches

Budget: sediment, N, P



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Floodplain Ecosystem Service Mapper

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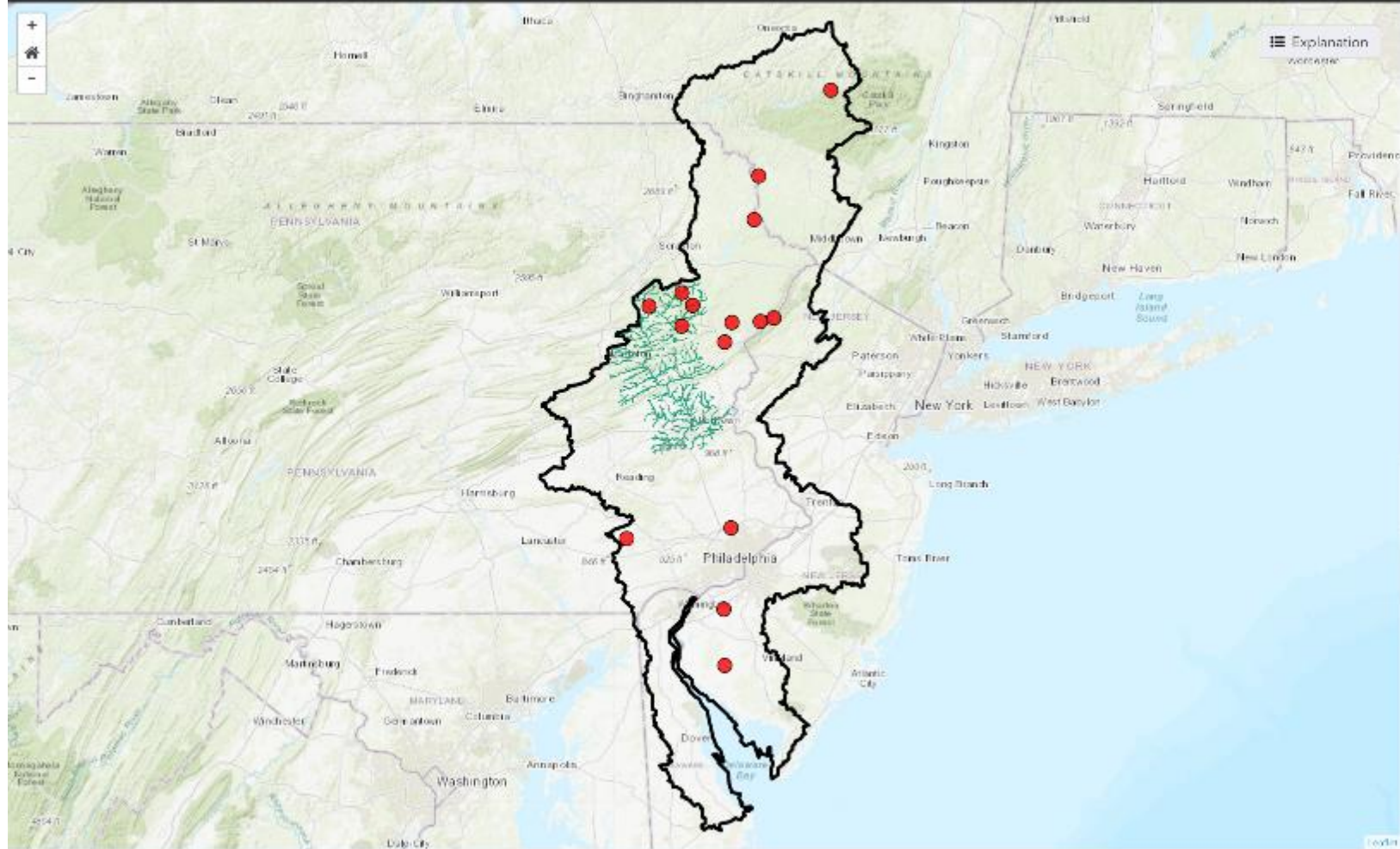
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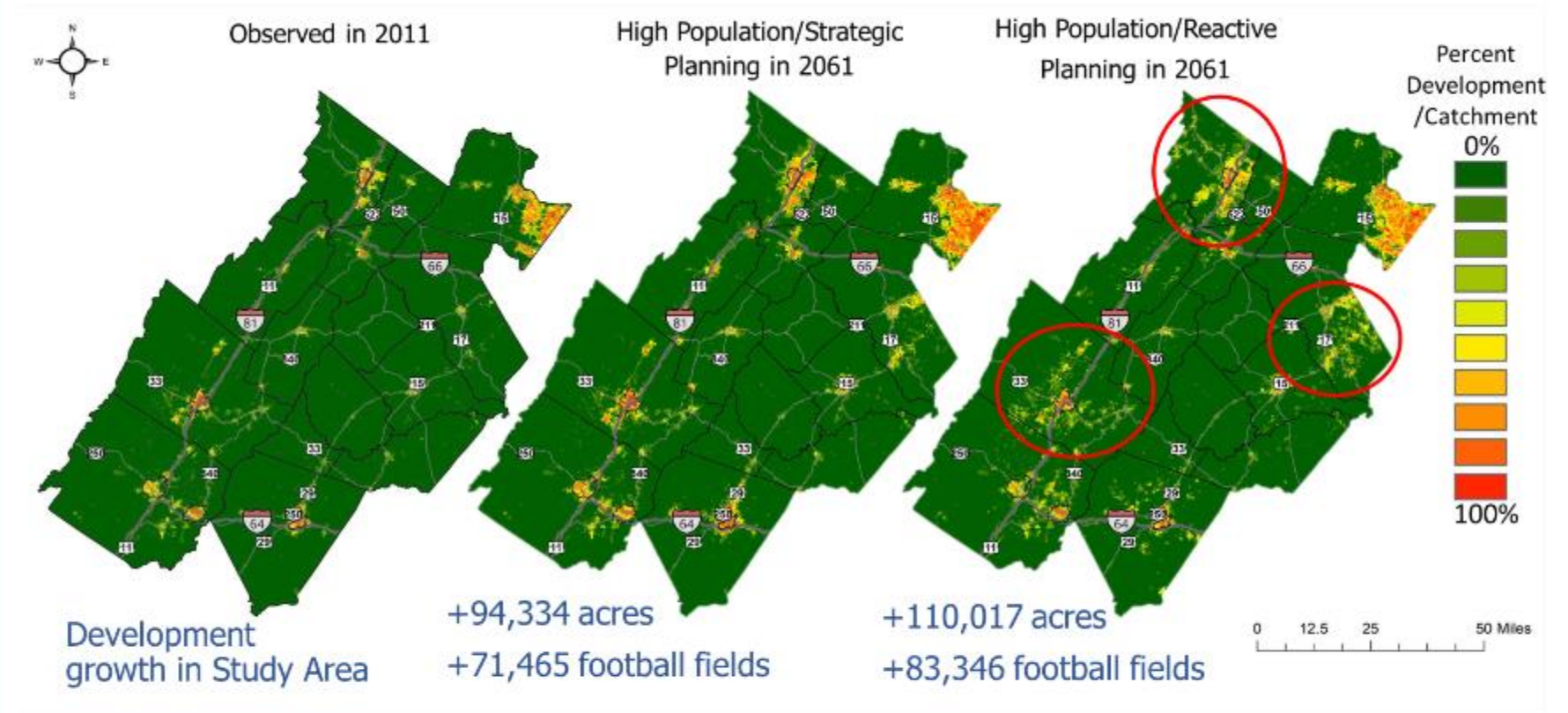
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Future land use scenarios: 2061 development strategies

Scenario Landscapes



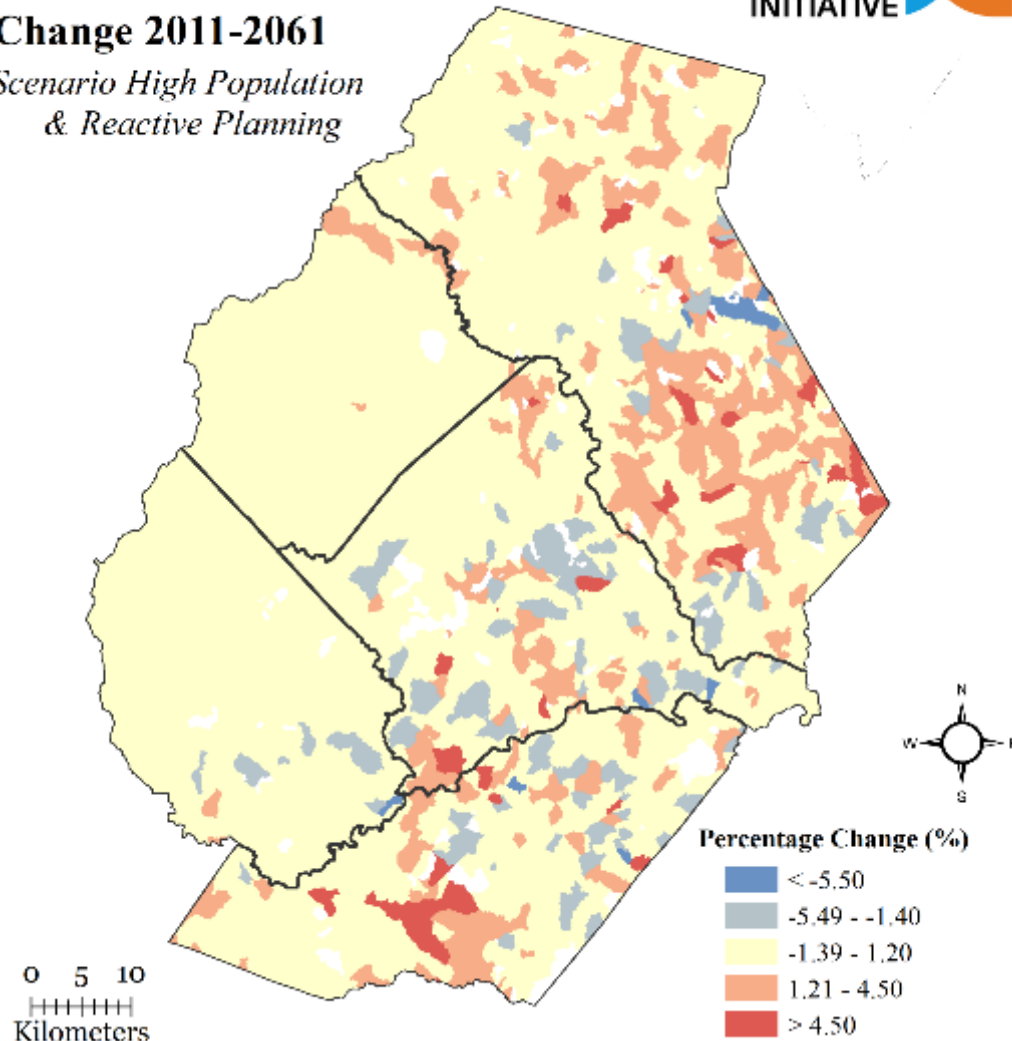
Change in Development in Stream Catchments

Future land use scenarios: 2061 change in streambed fines+sands cover

Stream Bed Structure Fines & Sands Change 2011-2061

*Scenario High Population
& Reactive Planning*

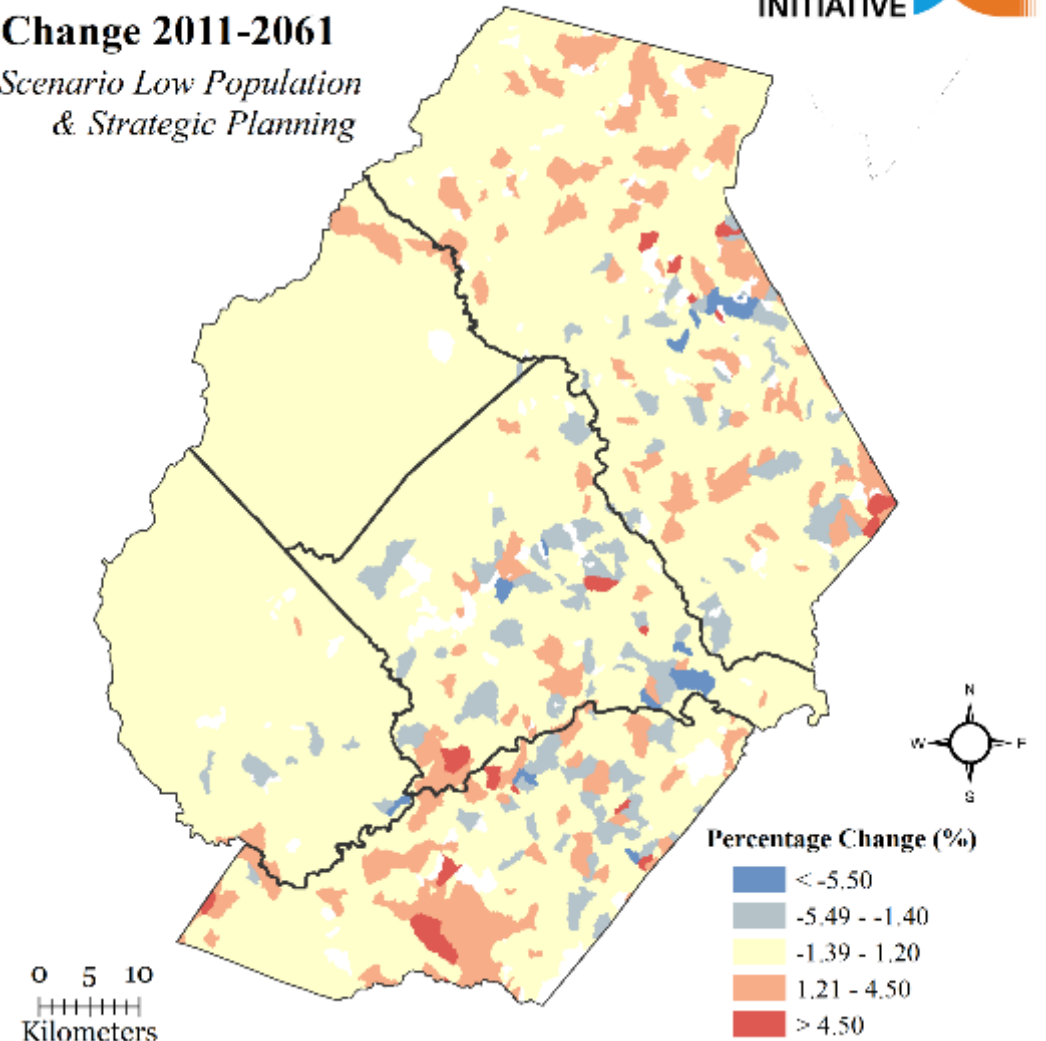
CHANGING
LANDSCAPES
INITIATIVE



Stream Bed Structure Fines & Sands Change 2011-2061

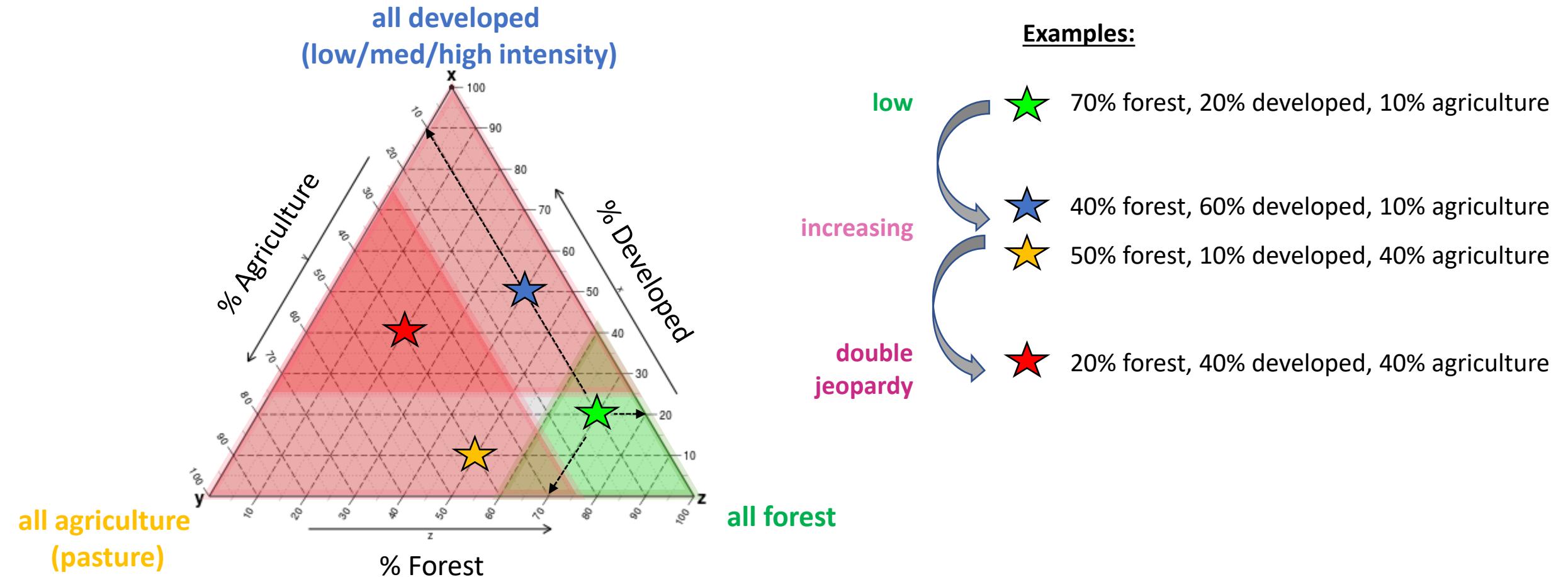
*Scenario Low Population
& Strategic Planning*

CHANGING
LANDSCAPES
INITIATIVE



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Thresholds of mixed land-use for worsening streambank sediment erosion



Growing capabilities are enabling new approaches for measuring and modeling fluvial geomorphic change and its influence on modulating watershed transport of pollutants, from reaches to regions

- In the scale of the U.S. Mid-Atlantic, floodplain deposition and streambank erosion have been in balance for past 20-50 yr
- Floodplain and streambank fluxes are very important components of reach + regional sediment + nutrient budgets
- Reach-scale floodplain and streambank attributes and flux data can help resource managers assess and plan for management actions to reduce downstream loading

Thanks to all (38 of us) who have helped over the past 7 years!!!



Jackie Batson, Adam Benthem, Norm Bourg, Carissa Chambers, Tom Doody, Mitchell Doyle, Kelly Floro, Kacey Garber, Jaimie Gillespie, Stephanie Gordon, Jiyan Hatami, Todd Knobbe, Alicia Korol, Mateusz Kowalski, Andrew Kunz, Sam Lamont, Mario Martin-Alciati, Christina Mirda, Jane Oswalt, Shannon Pace, Grant Palmer, Eleanor Rappolee, Emma Rieb, SCBI interns, Sydney Salley, Sam Schoenmann, Patty Sullivan, Sara Ulrich, Bobby Voeks, Gabe Westergren

Random Forest models

	Bank sediment flux	Bank fine sediment flux	Bank sediment- C flux	Bank sediment-N flux	Bank sediment- P flux	Bank lateral erosion rate	Bank area eroded	Floodplai n sediment flux	Floodplain fine sediment flux	Floodplai n sediment- C flux	Floodplai n sediment- N flux	Floodplain sediment- P flux	Floodplain area deposition	Streambed d50	Streambed %fines	Streambed %fines+sands
% Var explained	30.4	30.1	26.4	31.1	27.4	15.1	32.0	25.9	31.2	28.4	22.5	9.6	15.0	52.2	26.1	58.3
Term	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE	%IncMSE
Log drainage area (km2)	23.3	12.0	11.3	6.8	11.2	NIM	17.9	10.8	5.3	5.2	5.4	1.8	4.0	NIM	NIM	NIM
Erodibility factor	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	0.3	NIM	NIM	NIM
Soil < 74 µm (%)	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	4.2	NIM	NIM	-0.1	1.8	NIM	NIM	NIM
Base flow index (%)	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	3.1	NIM	NIM	2.4	2.9	NIM	NIM	NIM
Topographic wetness index	NIM	NIM	NIM	NIM	4.5	NIM	5.2	8.0	6.5	NIM	3.1	4.1	2.5	13.5	15.9	17.8
1951-2000 average annual runoff (mm)	6.6	7.2	9.7	5.2	5.6	NIM	6.6	7.9	7.4	6.0	5.5	2.4	2.6	NIM	4.6	NIM
Horton overland flow (%)	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	2.9	NIM	3.6	1.3	1.6	NIM	NIM	NIM
Rock sulfur content (%)	NIM	6.6	NIM	NIM	1.9	NIM	NIM	NIM	NIM	NIM	NIM	NIM	0.4	NIM	NIM	NIM
Rock iron content (%)	NIM	NIM	5.5	NIM	3.2	NIM	NIM	5.3	2.7	5.0	3.8	1.4	2.3	10.4	3.5	15.6
Number of dams	NIM	NIM	NIM	NIM	NIM	NIM	NIM	5.3	4.9	3.8	4.4	2.5	2.5	4.0	NIM	NIM
2011 NLCD developed open space (%)	1.8	4.0	4.1	7.2	2.0	2.2	1.6	8.3	5.0	6.2	4.2	6.2	3.5	0.4	2.1	2.6
2011 NLCD developed low+med+high intensi	10.5	9.3	7.9	6.7	5.6	10.6	7.6	12.2	7.9	4.4	5.0	5.2	5.9	3.1	1.9	0.1
2011 NLCD barren land (%)	4.6	1.0	4.2	4.0	0.7	3.8	3.5	3.5	0.7	2.3	3.3	2.7	3.2	3.1	3.6	5.7
2011 NLCD forest + shrub/scrub (%)	2.0	3.7	3.5	1.8	2.4	3.2	0.3	5.4	4.6	3.3	2.6	3.1	2.6	5.0	0.7	7.5
2011 NLCD grassland + pasture/hay (%)	7.5	8.2	7.1	8.5	3.0	7.3	8.2	3.3	1.9	-0.2	-0.1	-0.1	1.2	4.6	-0.7	7.3
2011 NLCD cultivated crops (%)	6.0	4.1	5.8	5.4	3.6	3.2	4.8	6.7	4.1	3.7	4.7	3.5	4.0	7.6	3.0	10.1
2011 NLCD woody + herbaceous wetland (%)	5.1	7.1	7.1	6.6	5.2	7.3	6.8	4.4	2.9	1.1	4.1	3.4	3.0	5.3	1.0	11.4
Stream slope (°)	NIM	NIM	NIM	4.9	NIM	10.3	NIM	NIM	6.4	4.4	3.7	1.8	1.8	NIM	NIM	NIM
Stream sinuosity	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	1.2	NIM	0.8	NIM	NIM	NIM
Streambank height (m) 7525mean_1D	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	0.0	NIM	NIM	NIM
Channel width (m) 7525mean_1D	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	0.3	NIM	NIM	NIM
Floodplain width (m) mean_1D	NIM	NIM	10.3	6.0	NIM	6.8	NIM	10.3	6.0	6.2	6.4	5.8	5.9	NIM	NIM	NIM
Bank angle mean (degrees) 7525mean_1D	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	2.7	3.0	2.4	NIM	NIM	NIM
Channel width / Streambank height	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	2.0	0.8	1.0	1.1	NIM	NIM	NIM
Channel width / Floodplain width	NIM	NIM	NIM	NIM	NIM	NIM	NIM	6.5	4.8	4.6	5.5	4.0	3.6	NIM	NIM	NIM
Floodplain width / Streambank height	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	5.0	4.8	3.9	1.7	9.3	NIM	NIM