Erosional or depositional streams?

Measurement and modeling of watershed material budgets in the Chesapeake

Greg Noe[1], Krissy Hopkins[1], Peter Claggett[1], Ed Schenk[2], Marina Metes[1], Labeeb Ahmed[3], Tom Doody[1], Cliff Hupp[1]

[1] USGS, [2] City of Flagstaff, [3] Attain LLC

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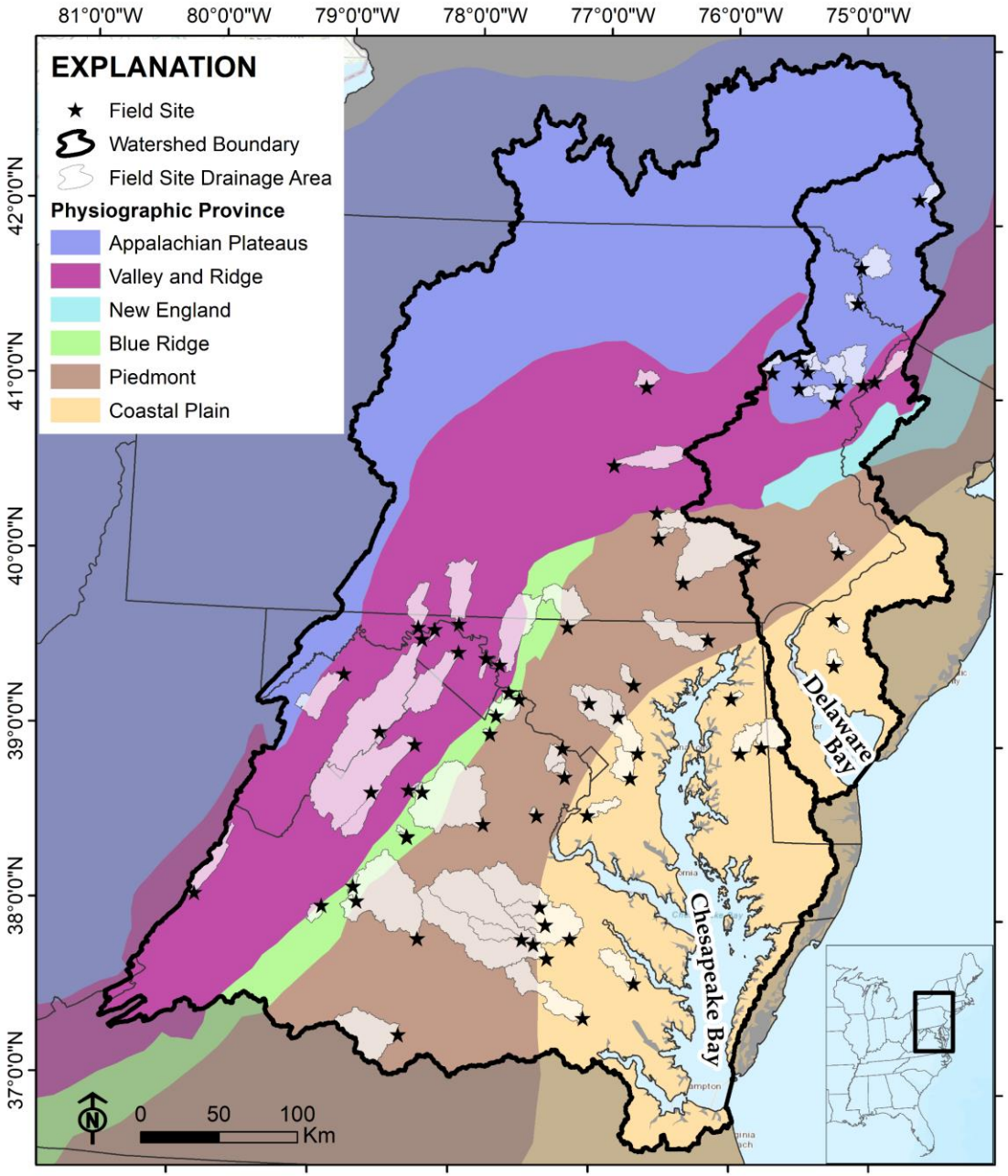
USGS Chesapeake and Delaware Floodplain Network: network design

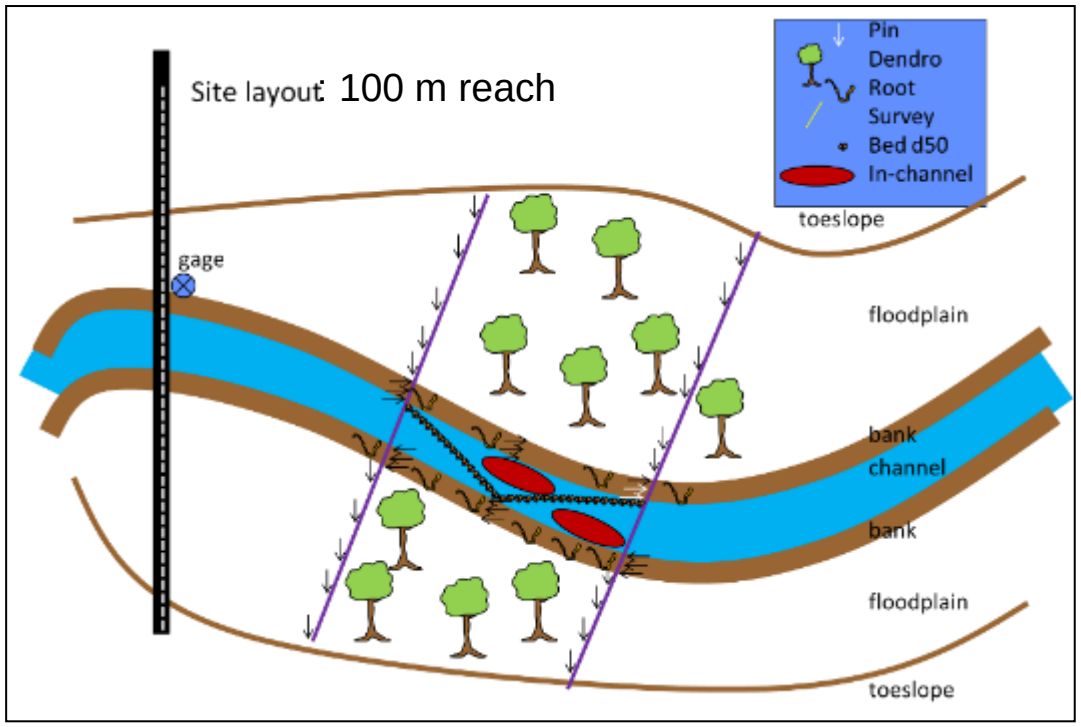
Long-term streambank and floodplain characteristics and sediment and associated nutrient loss/gain were measured at 68 reaches across U.S. Mid-Atlantic

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

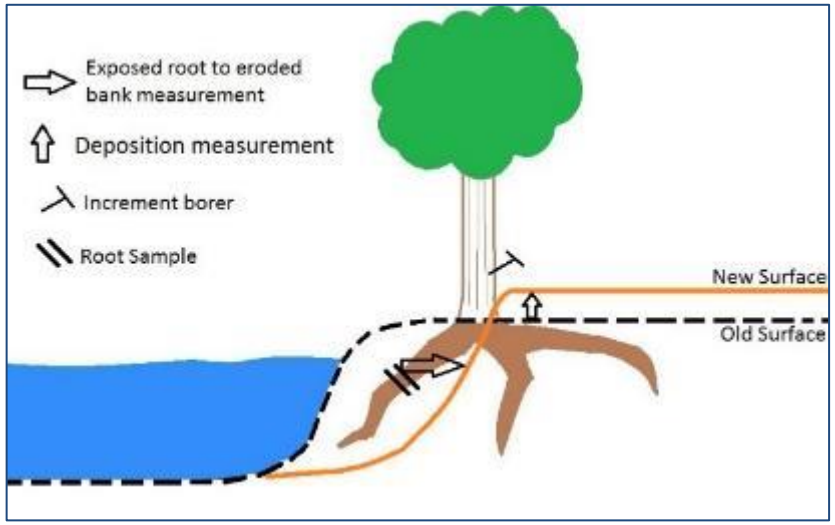
Site selection:
- Mixture of USGS NTN load gages and ungaged reaches
- 'Unmanaged' floodplain land use (with woody vegetation)
- Unchannelized
- Landowner permission



USGS Chesapeake and Delaware Floodplain Network: measurements at 68 reaches



Dendrogeomorphic fluxes



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

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)

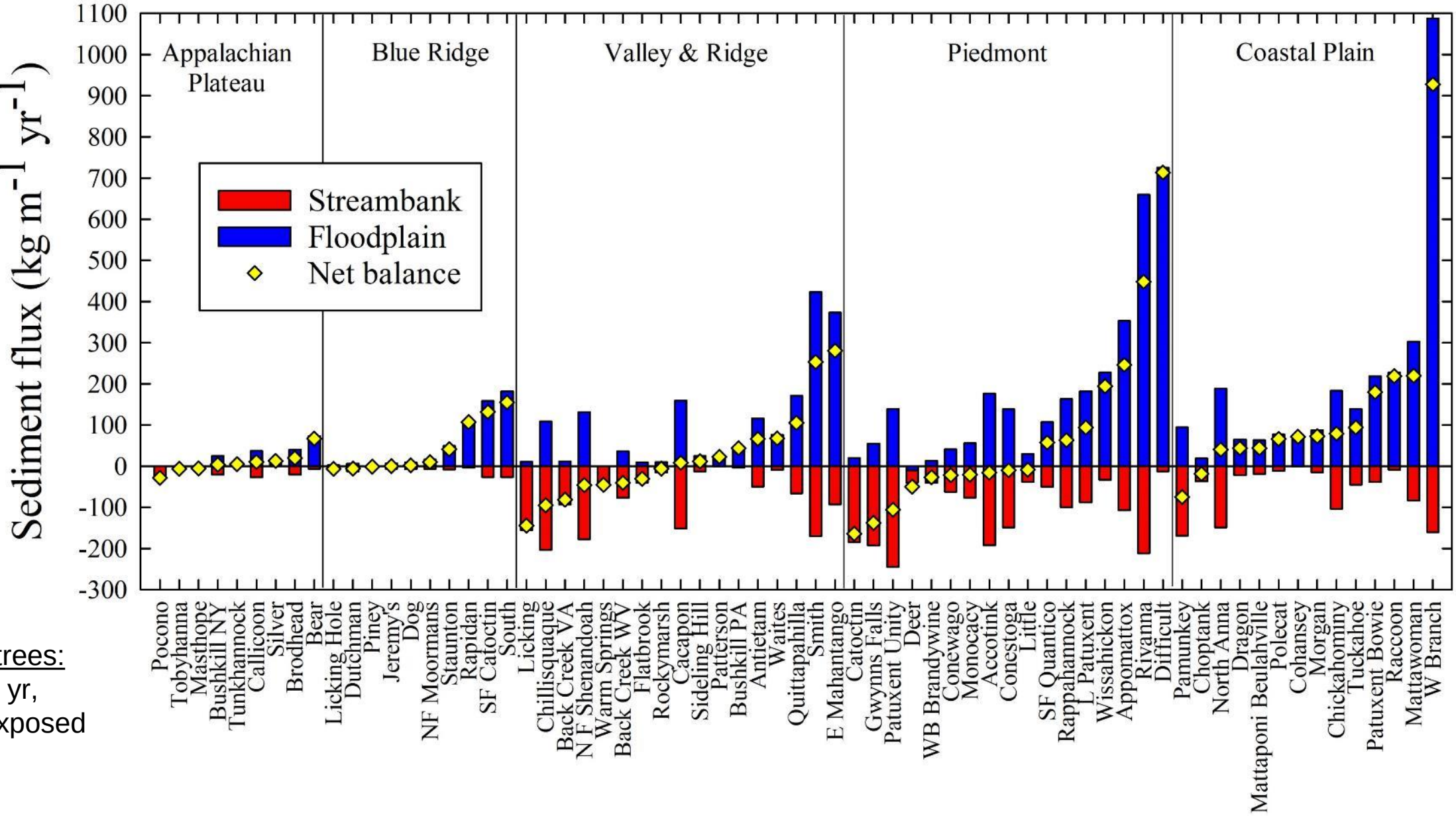
Sediment characteristics:

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

Noe et al. 2020a, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX.

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



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

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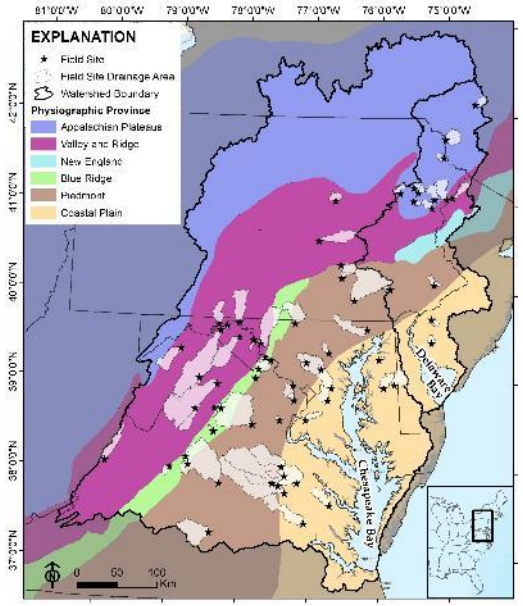
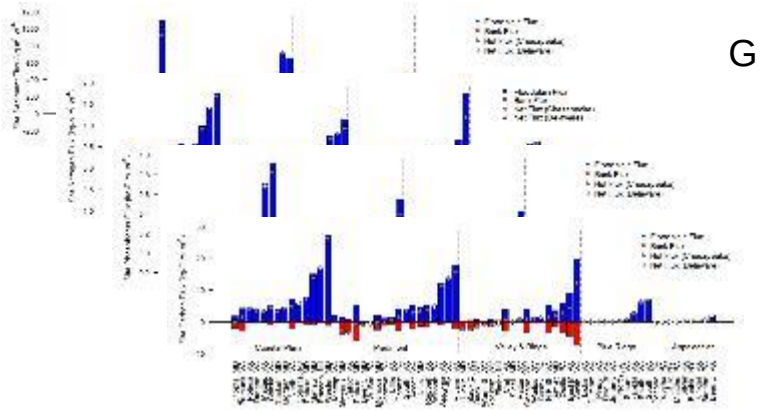
Noe et al. 2020a, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX.

USGS Chesapeake and Delaware Floodplain Network: approach

Measure



Analyze



Model
(Random Forest)

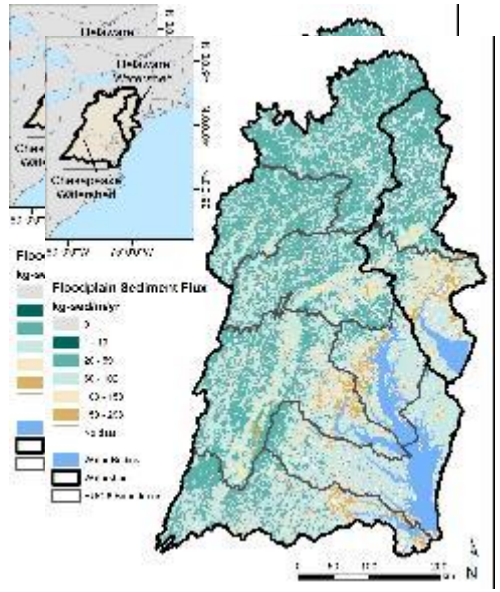
GIS reach-scale geomorphometry (“shape”)
Floodplain width, bank height,
channel width, …

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)



Predictions:

- Floodplain sediment flux
- Floodplain fine sediment flux
- Floodplain sediment-N flux
- Floodplain sediment-P flux
- Floodplain sediment-C flux
- Floodplain change m^2
- Streambank sediment flux
- Streambank fine sediment flux
- Streambank sediment-N flux
- Streambank sediment-P flux
- Streambank sediment-C flux
- Streambank lateral erosion rate
- Streambank change m^2
- Streambed d50
- Streambed fine sediment cover
- Streambed fine+sand cover

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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 (%)

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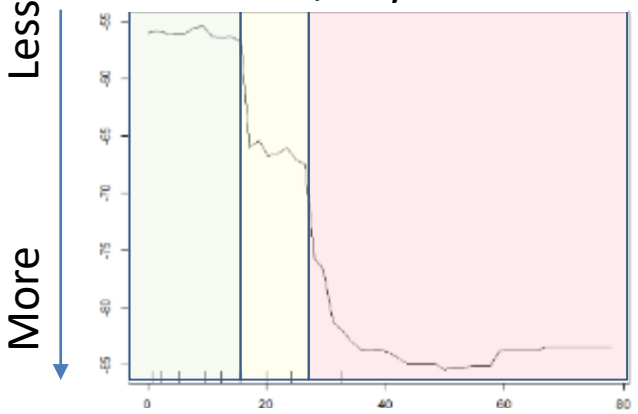
→ Choose best model for each prediction metric:
1) Watershed attributes; or 2) Geomorphometry + Watershed attributes (if available)

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

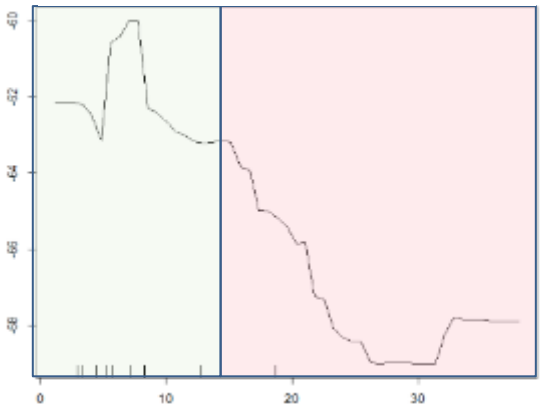
Streambank sediment erosion

Pasture/Hay + Grass



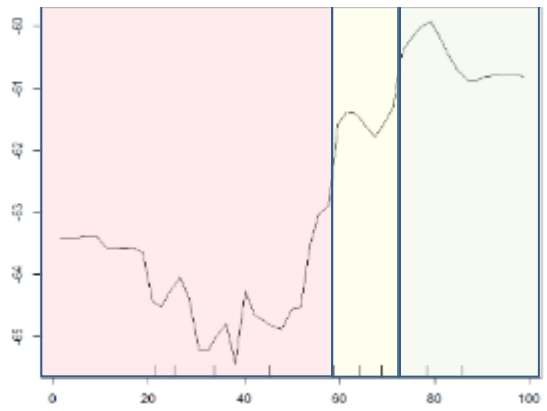
~ >25%

Developed open space



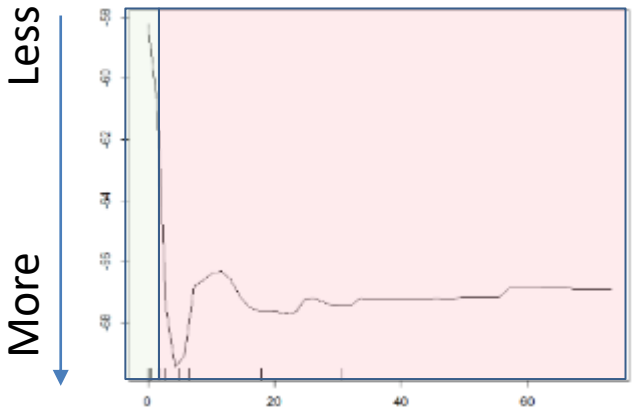
~ >15%

Forest + Scrub/Shrub



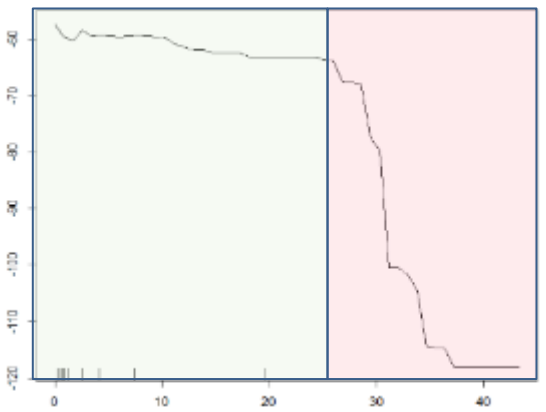
~ <60%

Cultivated crop



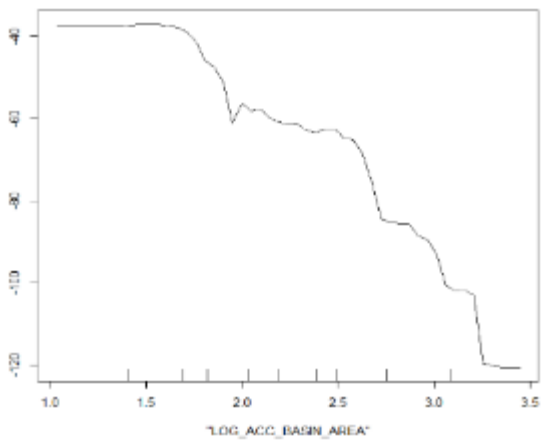
~ >2%

Developed low/med/high intensity



~ >25%

Watershed size (log10)



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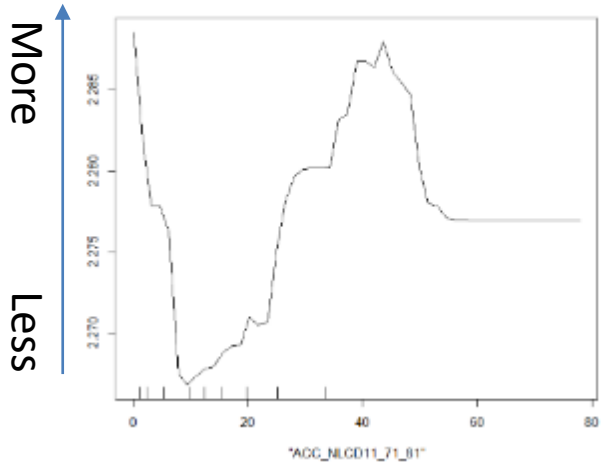
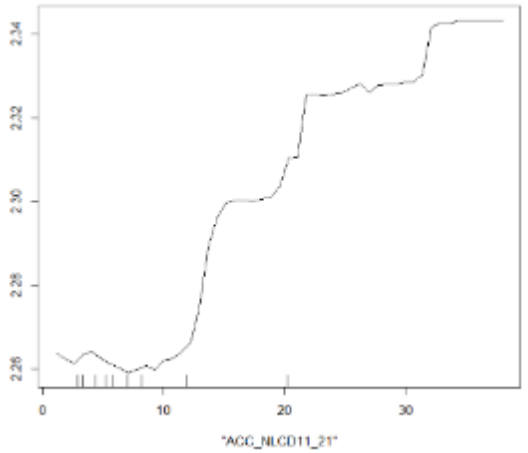
Modeled 2011 Land use effects on log10 Floodplain sediment flux (kg/m/yr)

Log10 Floodplain sediment deposition

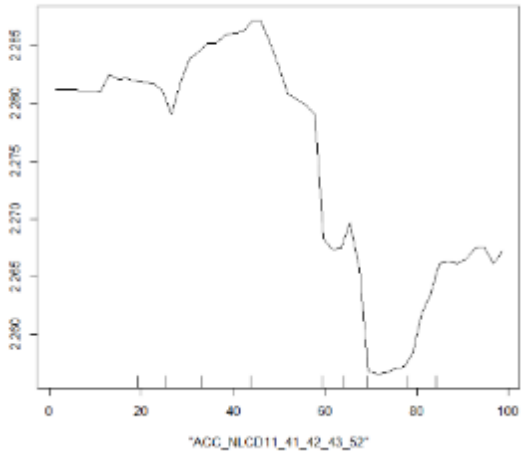
Pasture/Hay + Grass



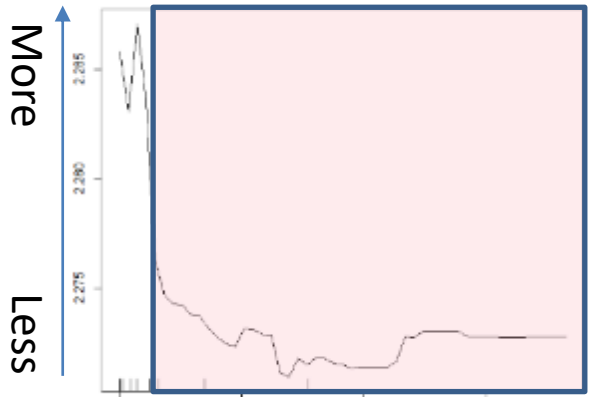
Developed open space



Forest + Scrub/Shrub

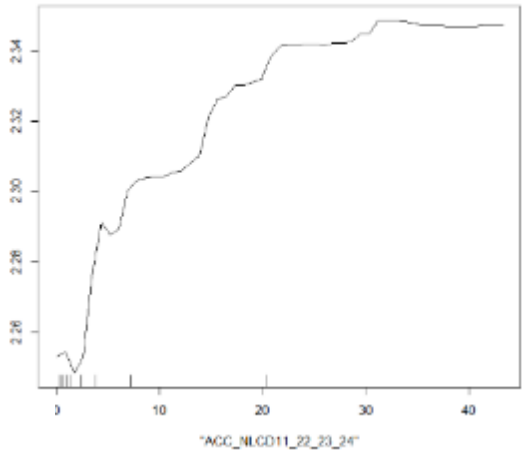


Cultivated crop

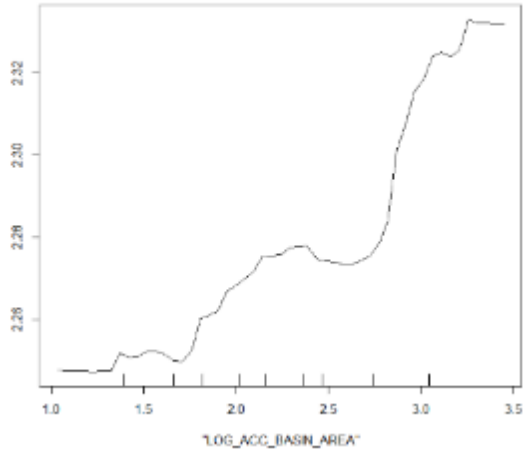


~ >5%

Developed low/med/high intensity



Watershed size (log10)



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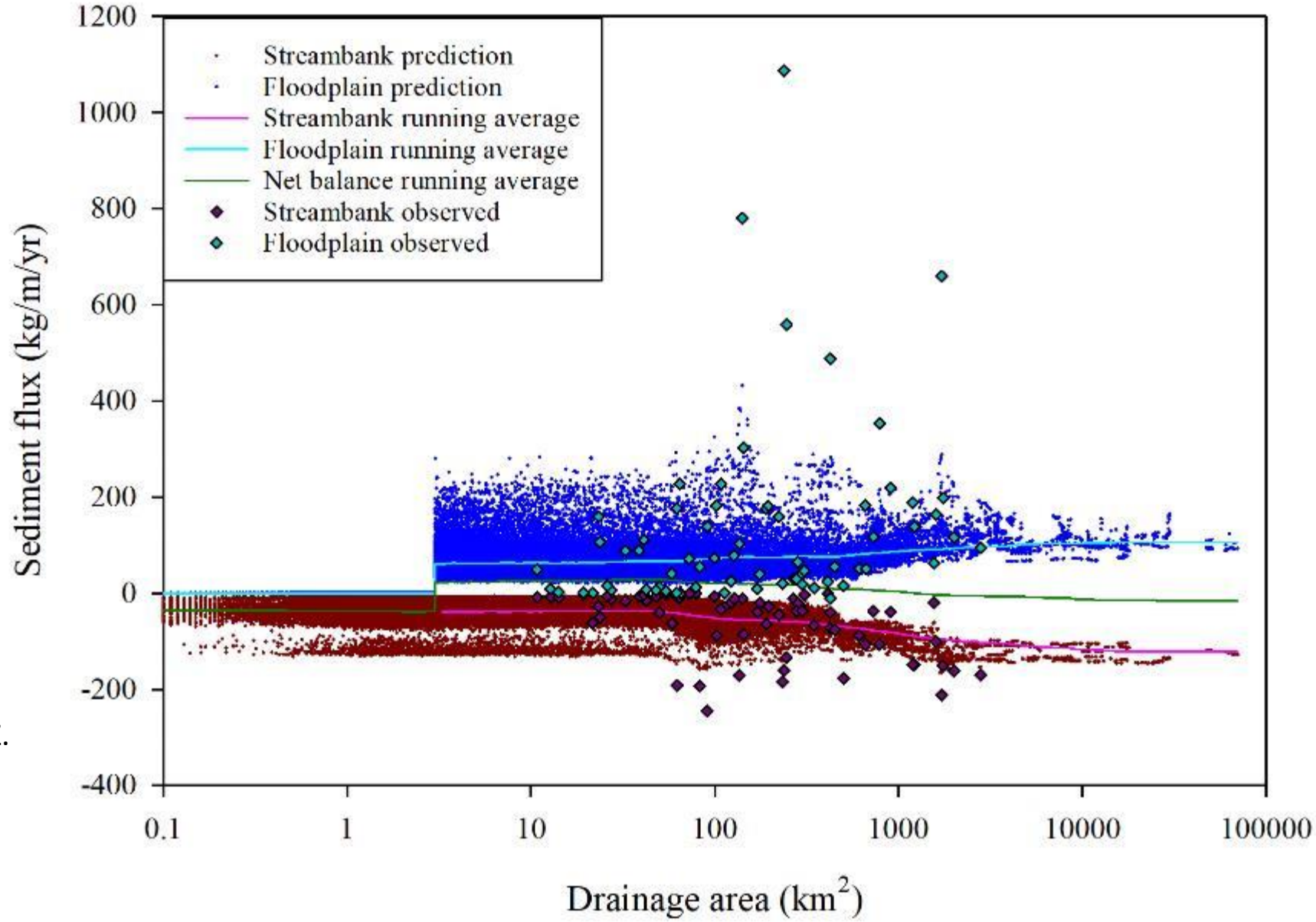
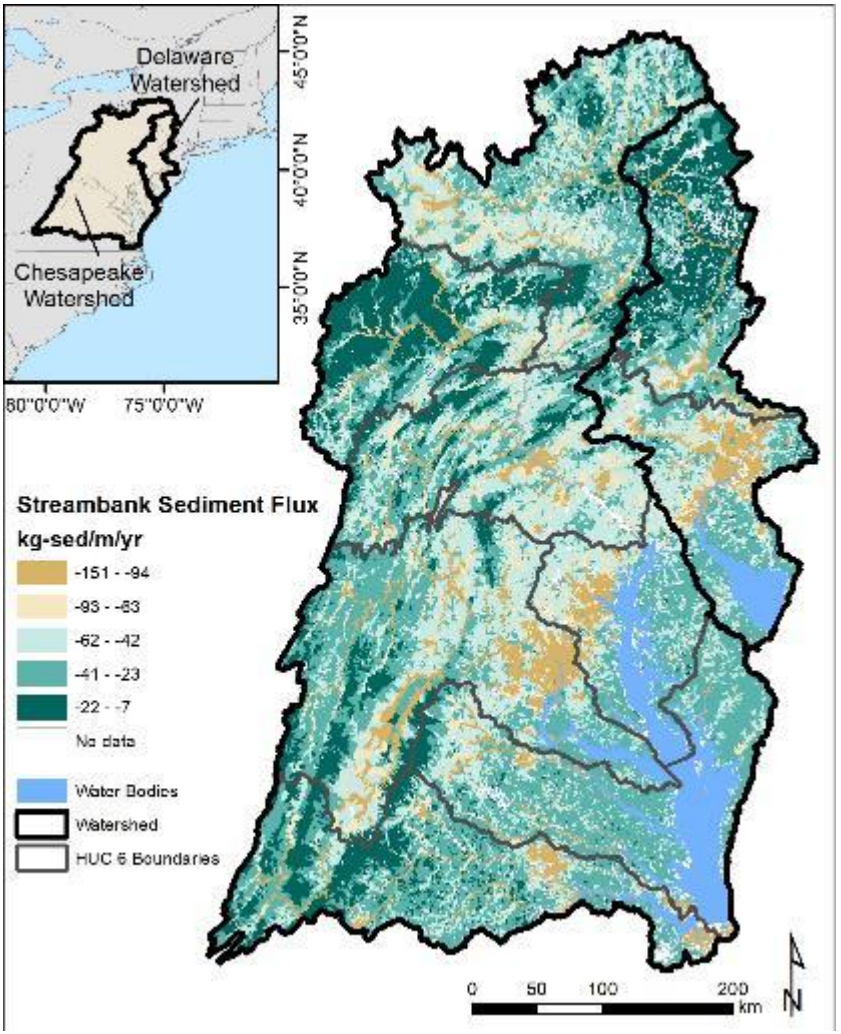
Predictions for each of the 74,133 nontidal streams in the mid-Atlantic

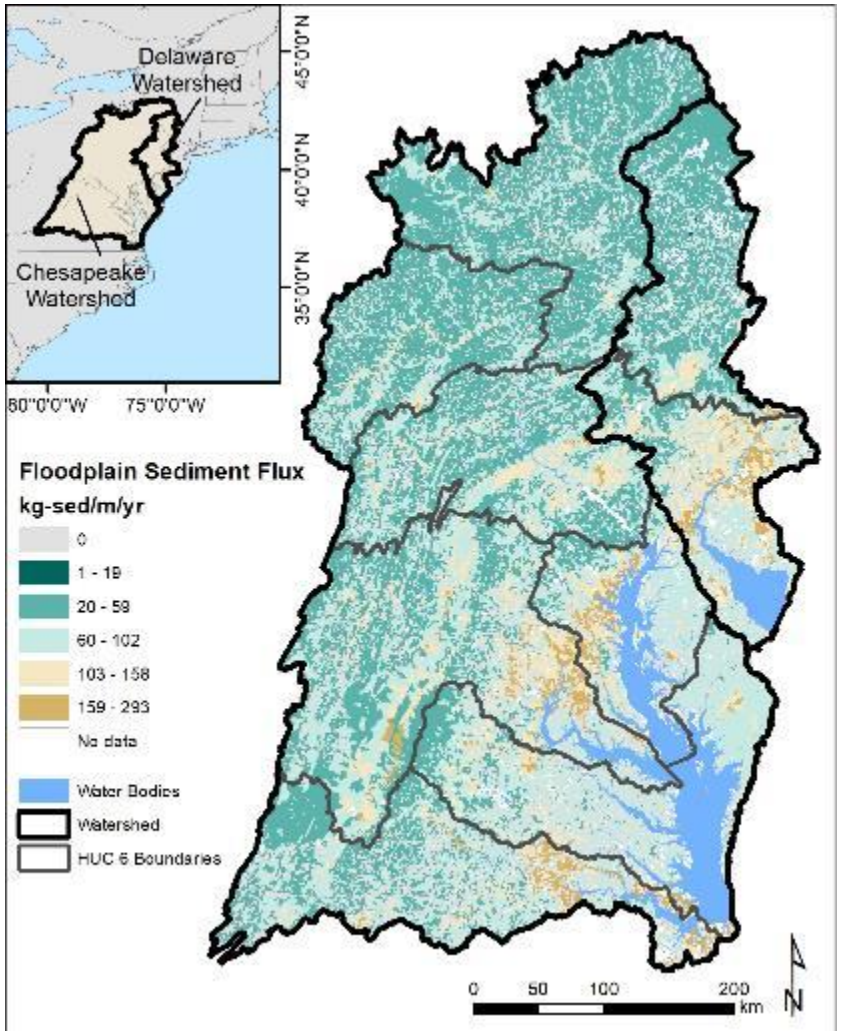


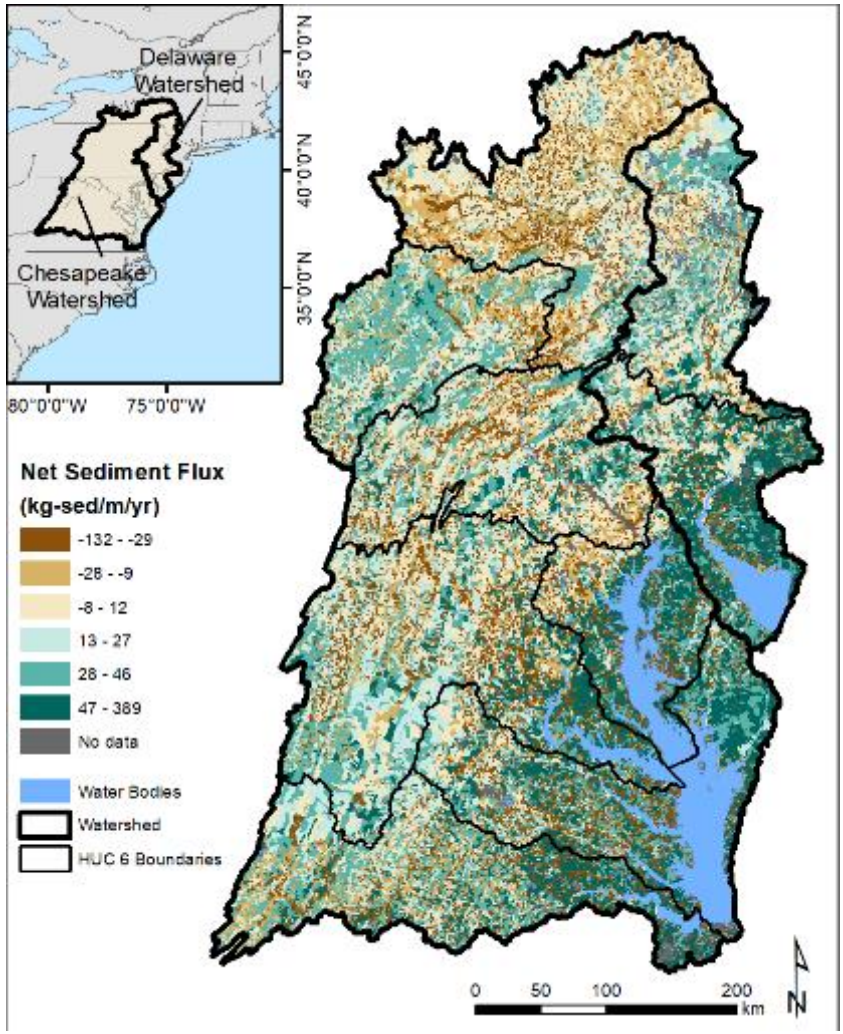
Noe et al. 2020b,
U.S. Geological Survey data release,
https://doi.org/10.5066/P93OUWYZ.

USGS

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







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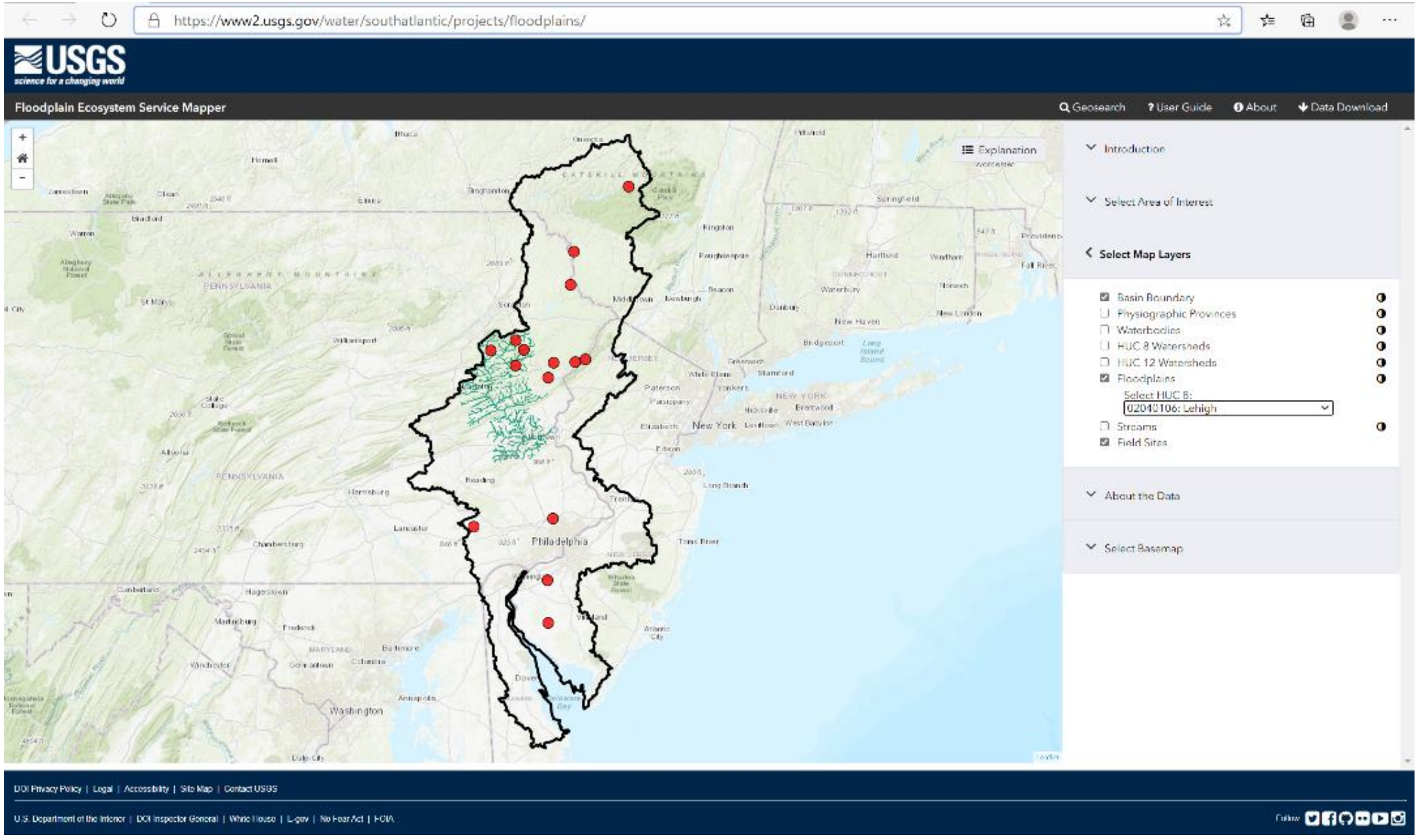
Web viewer for each of the nontidal streams in the mid-Atlantic

https://www2.usgs.gov/water/southatlantic/projects/floodplains/



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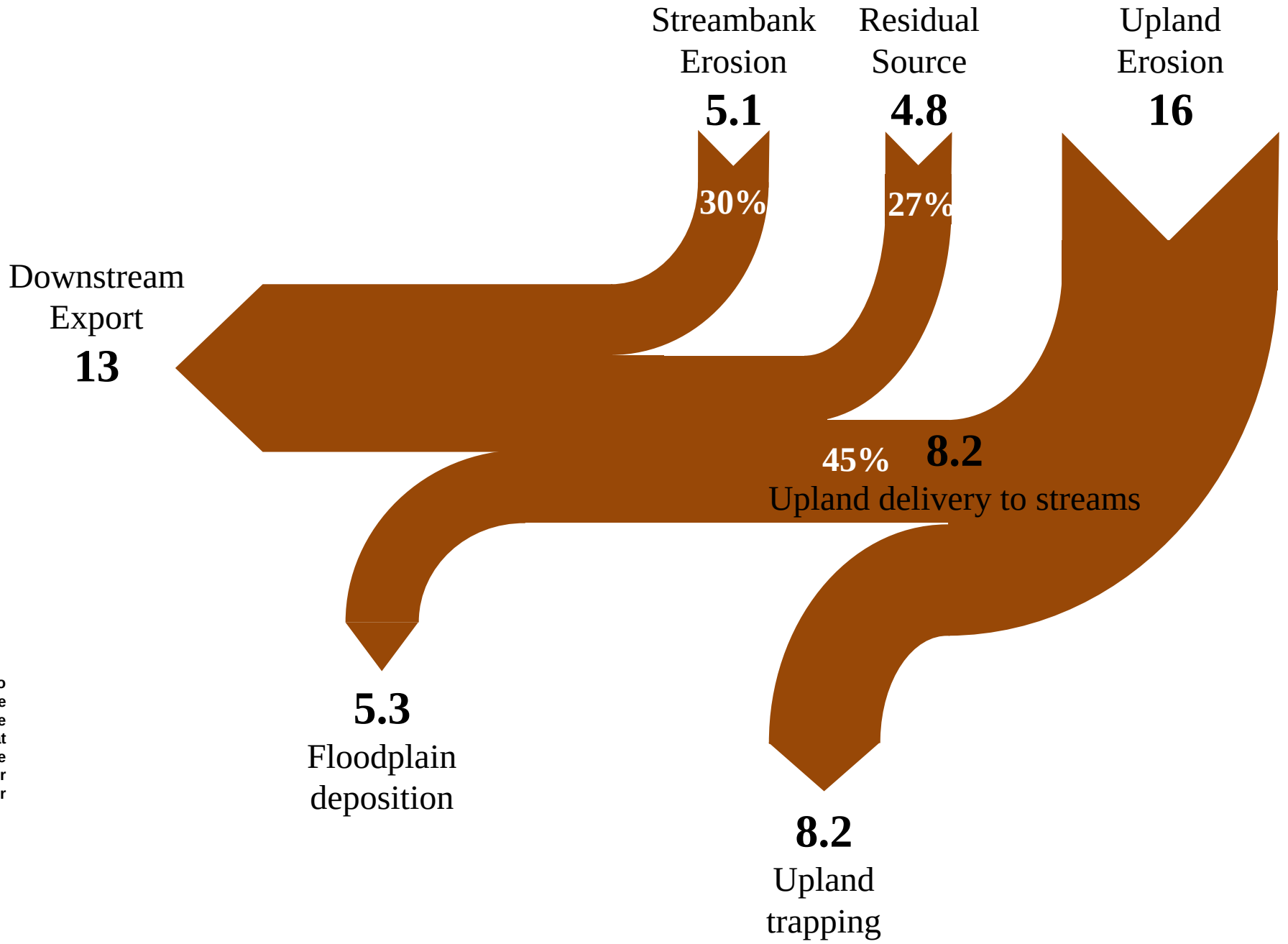
Sediment loads summed for all Chesapeake watershed 64,294 nontidal NHDPlusV2 reaches

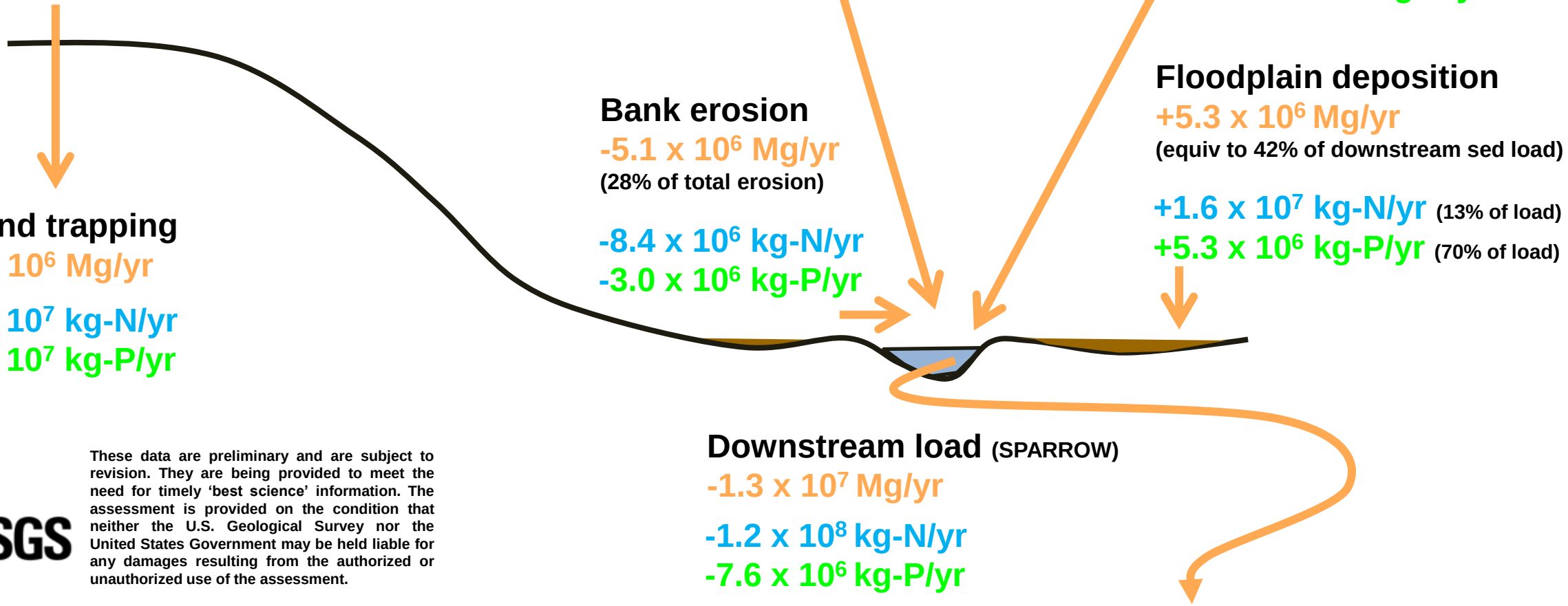
Sediment load
Tg/yr



USGS

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

Budget: sediment, N, P



Upland erosion (RUSLE2)
-1.6 x 10^7 Mg/yr

-5.9 x 10^7 kg-N/yr

-1.6 x 10^7 kg-P/yr

Upland delivered to streams (IC)
-8.2 x 10^6 Mg/yr (45% of total erosion)

-2.9 x 10^7 kg-N/yr

-8.2 x 10^6 kg-P/yr

Residual source
-4.8 x 10^6 Mg/yr

(27% of total erosion)

-1.7 x 10^7 kg-N/yr

-4.8 x 10^6 kg-P/yr

Floodplain deposition
+5.3 x 10^6 Mg/yr

(equiv to 42% of downstream sed load)

+1.6 x 10^7 kg-N/yr (13% of load)

+5.3 x 10^6 kg-P/yr (70% of load)

Bank erosion
-5.1 x 10^6 Mg/yr

(28% of total erosion)

-8.4 x 10^6 kg-N/yr

-3.0 x 10^6 kg-P/yr

Upland trapping
8.2 x 10^6 Mg/yr

3.0 x 10^7 kg-N/yr

8.2 x 10^7 kg-P/yr

Downstream load (SPARROW)
-1.3 x 10^7 Mg/yr

-1.2 x 10^8 kg-N/yr

-7.6 x 10^6 kg-P/yr

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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 predictions 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 8 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

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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	Floodplain sediment flux	Floodplain fine sediment flux	Floodplain sediment-C flux	Floodplain 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 sinuousity	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

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