How to model sediment and nutrient fluxes of floodplains and streambanks across the Chesapeake watershed

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U.S. Department of the Interior
U.S. Geological Survey

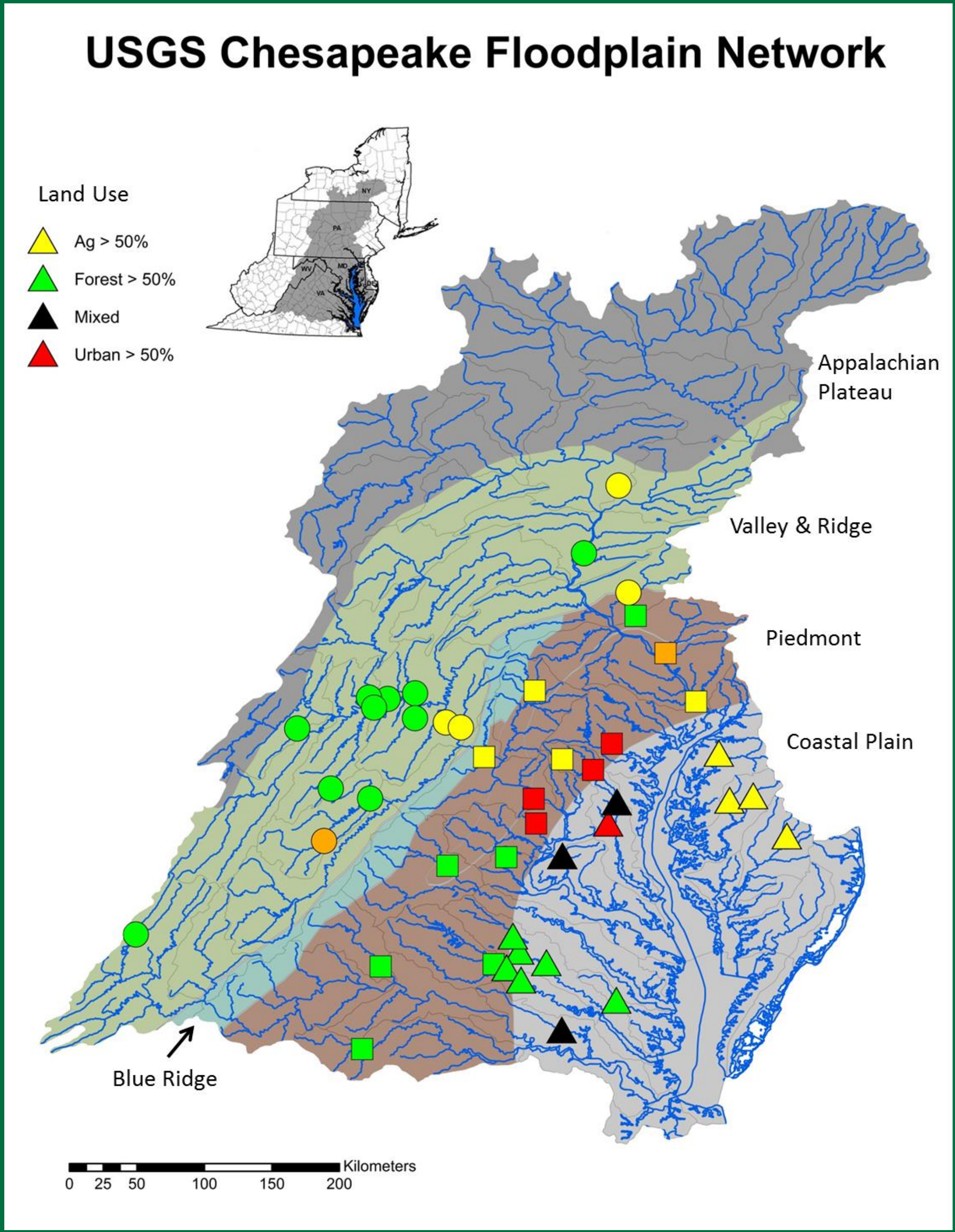
The USGS Chesapeake Floodplain Network: 42 full sites

Goal:
Measure and predict the sediment/N/P fluxes of bank erosion and floodplain deposition for entire Chesapeake watershed

Site selection:

- Chesapeake NTN load gages
- 'unmanaged' floodplain land use (forest/scrub/herbaceous; not ag/ pasture/developed)
- Unchannelized
- Landowner permission
- Range of watershed size and land-use

1. Measure
2. Predict
3. Scale



USGS GIS Toolkit Reach Geomorphology: LiDAR availability

~ 80% of Chesapeake watershed has available LiDAR

Coastal Plain analyzed by Spring 2016

Appalachian Plateau low quality

Remaining SW VA/WV planned September 2016

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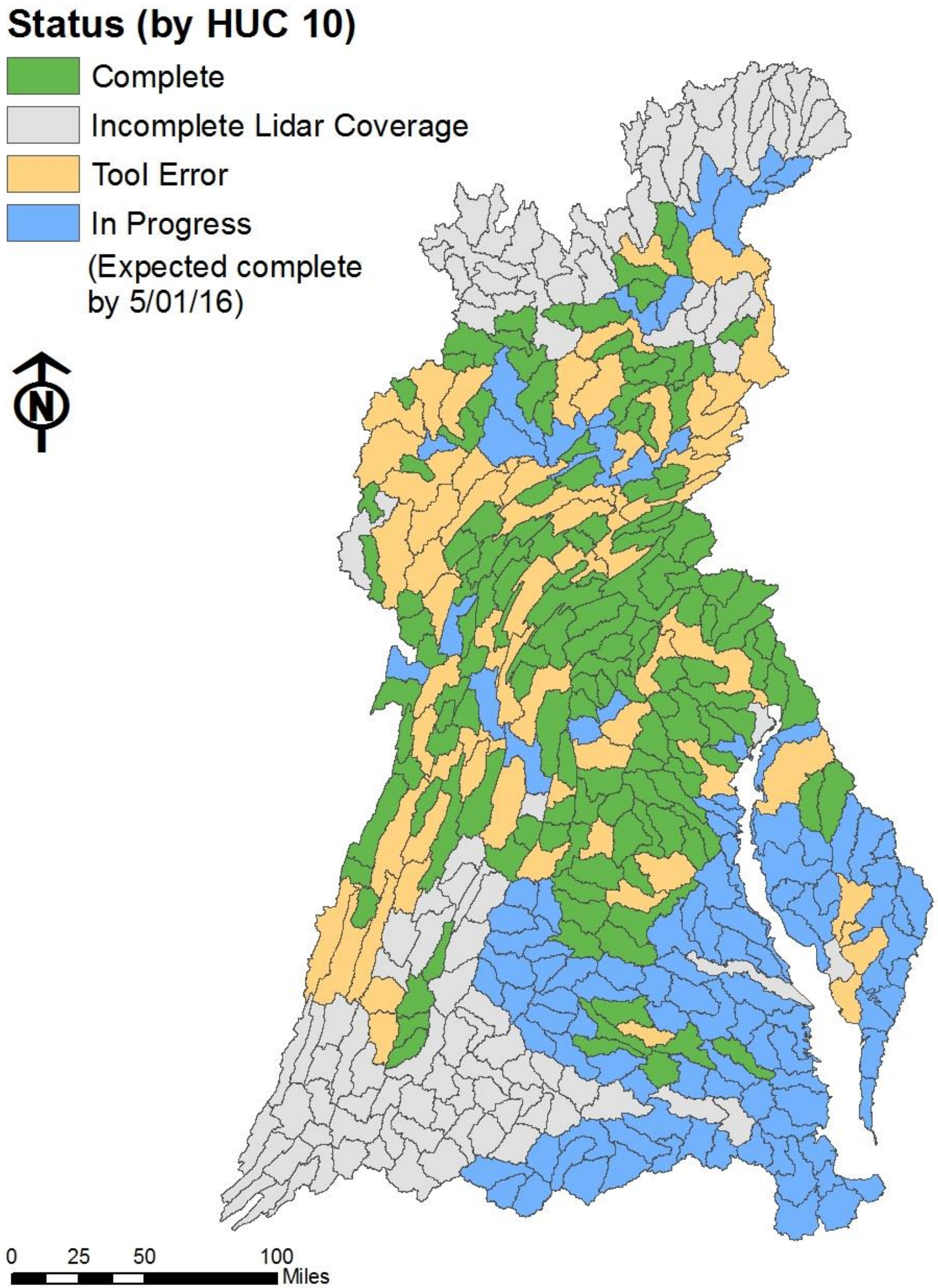
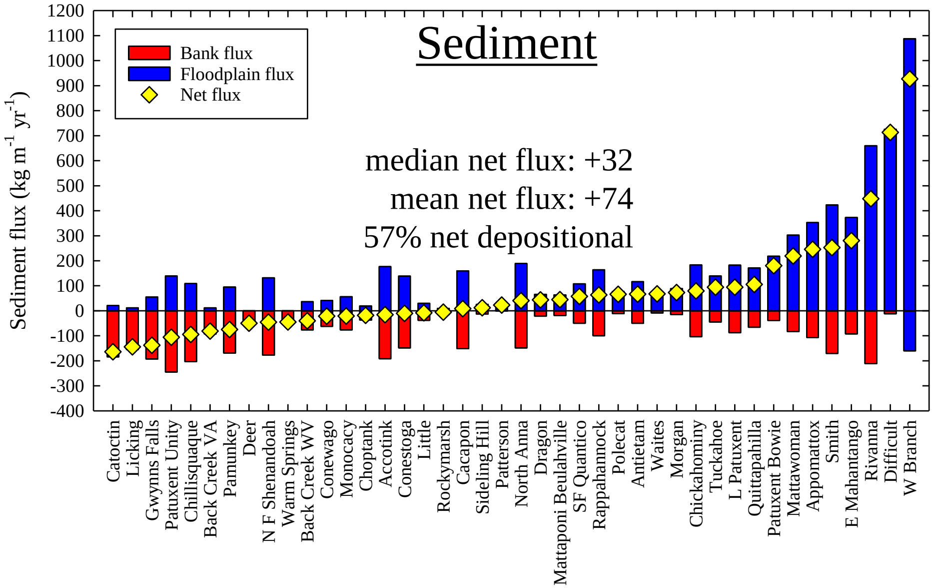
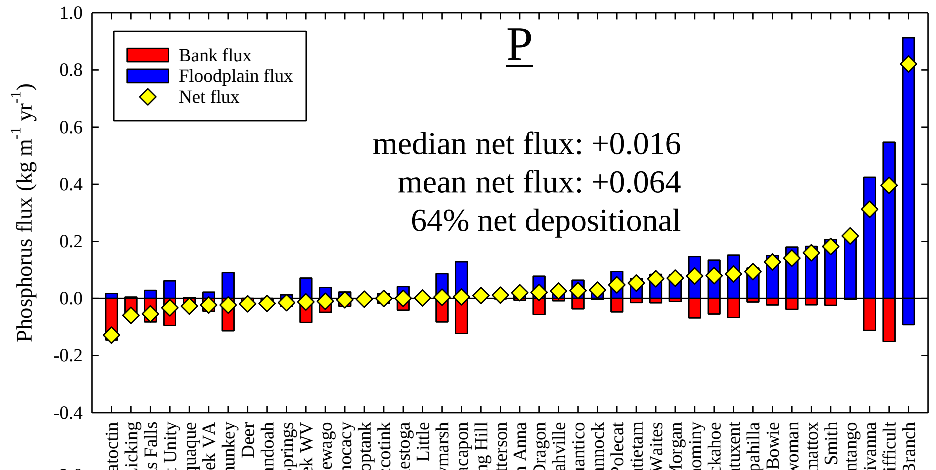
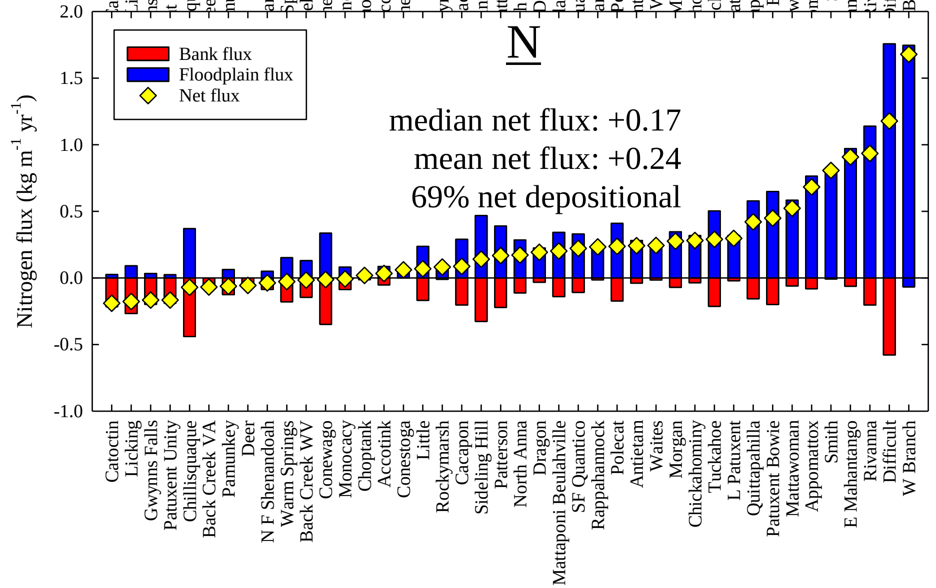


USGS Chesapeake Floodplain Network:
Dendrogeomorphic results all 3 PP







Mean ages of trees:

floodplain = 48 yr

bank = 17 yr root exposed

Approaches for predicting the whole Chesapeake watershed

Valley & Ridge, Piedmont, and Coastal Plain

- OPTION #1 Average: all 3 PP
- OPTION #2 Average: each PP
- OPTION #3 Regression: Watershed+Reach predictors
- OPTION #4 Regression: Watershed only predictors (where GIS Toolkit unavailable)

Appalachian Plateau and Blue Ridge

- OPTION #1 Average: PP of CFN

- OPTION #3 Regression: Watershed+Reach predictors
- OPTION #4 Regression: Watershed only predictors (where GIS Toolkit unavailable)

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USGS Chesapeake Floodplain Network:
Dendrogeomorphic fluxes of all 3 PP

		Flux (kg/m/yr)		One-sample t-test different than zero?
		Mean	95% CI	*P*
Sediment	Net Balance:	74.3	9.1 to 139.6	<0.027
	Floodplain:	167.6	100.1 to 235.1	<0.001
	Bank:	-93.3	-114.8 to -71.8	<0.001
Nitrogen	Net Balance:	.240	.118 to .361	<0.001
	Floodplain:	.377	. 250 to .505	<0.001
	Bank:	-.138	-.176 to -.010	<0.001
Phosphorus	Net Balance:	.064	.015 to .112	<0.011
	Floodplain:	.110	.057 to .162	<0.001
	Bank:	-.046	-.059 to -.033	<0.001

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USGS Chesapeake Floodplain Network:
Comparing fluxes of all 3 PP

Kruskal-Wallis tests comparing Valley & Ridge, Piedmont, and Coastal Plain

		P
Sediment	Net Balance:	0.194
	Floodplain:	0.262
	Bank:	0.190
Nitrogen	Net Balance:	0.016
	Floodplain:	0.115
	Bank:	0.138
Phosphorus	Net Balance:	0.046
	Floodplain:	0.055
	Bank:	0.249

		P
Sediment <1 mm	Net Balance:	0.128
	Floodplain:	0.194
	Bank:	0.187
Mineral sediment	Net Balance:	0.126
	Floodplain:	0.166
	Bank:	0.191
Organic sediment	Net Balance:	0.028
	Floodplain:	0.096
	Bank:	0.117
Carbonate sediment	Net Balance:	0.499
	Floodplain:	0.813
	Bank:	0.076
Carbon	Net Balance:	0.013
	Floodplain:	0.067
	Bank:	0.069

Root age since exposure also differed (P=0.008):

Valley & Ridge:	26 yr
Piedmont:	12 yr
Coastal Plain	12 yr

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Coastal Plain > Piedmont = Valley & Ridge

USGS Chesapeake Floodplain Network:
Comparing fluxes of all 3 PP

Net balance:

		Flux (kg/m/yr)
Carbon	Valley & Ridge:	1.27
	Piedmont:	3.19
	Coastal Plain:	6.34
Nitrogen	Valley & Ridge:	.129
	Piedmont:	.192
	Coastal Plain:	.438
Phosphorus	Valley & Ridge:	.0275
	Piedmont:	.0458
	Coastal Plain:	.1306

Coastal Plain > Piedmont = Valley & Ridge

Regressions: Predictors of flux

Geomorphology, hydrology, land use, sediment, nutrients, …

Wall-to-wall		Patchy availability
Watershed characteristics	+	Reach geomorphology
Topography		Floodplain
Geology		Bank
Climate		Channel
Hydrology		
Land use		
Soils		
Nutrient application		
River load		
Geomorphology		

USGS

Catchment + reach predictors of flux

Gages2

Area
Elevation median
Dimensionless elevation - relief ratio
Slope

Precipitation
Base Flow Index
Horton overland flow %
Topographic wetness index
Subsurface flow contact time index
Soil permeability
Soil R-factor rainfall/runoff

Soil K-factor erodibility upper horizon
Dam density 2009
Dam storage 2009

Nitrogen fertilizer+manure application
Phosphorus fertilizer+manure application

NAWQA

% Developed 1974
% Developed 2012
% Production 1974
% Production 2012
ΔDeveloped 2012-1974

Loads

SPARROW sed load
SPARROW P load
SPARROW N load
SPARROW sed yield
SPARROW P yield
SPARROW N yield

USGS NTN

Q50
Q90
Q99
Q50 yield
Q90 yield
Q99 yield
Q50 'watershed power'
Q90 'watershed power'
Q99 'watershed power'

NLCD urban 2011
NLCD forest 2011
NLCD ag 2011
NLCD impervious 2006/2011

Reach Geomorphology (USGS GIS Toolkit)

Floodplain width
Channel width
Bank height
Bank angle (mean, max, min)
Bankfull
Slope
Various ratios and products

Physiographic Province

Valley & Ridge = 1
Piedmont = 1
Coastal Plain = 1

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Fluxes are predictable: Watershed + Reach GIS-derived predictors

Stepwise multiple regressions (*P*-to-enter=0.10):

Sediment: net balance

n=31, R^2=0.61, P<0.001

FP_width:Bnk_height	β= +
FP_width:Ch_width	β= –
K factor erodibility uppersoil	β= +
Soil permeability avg	β= +
Elevation-Relief Ratio	β= –

Nitrogen: net balance

n=31, R^2=0.70, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
K factor erodibility uppersoil	β= +
Sed_load_SPARROW	β= +
Soil permeability avg	β= +
Base Flow Index avg	β= –

Phosphorus: net balance

n=31, R^2=0.70, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
K factor erodibility uppersoil	β= +
Sed_load_SPARROW	β= +
PP: Piedmont	β= –
Q50	β= –

Sediment: floodplain flux

n=33, R^2=0.70, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
Bank_avg_angle	β= –
Bank_ht	β= –
FP_range_elev	β= +
PP: Coastal Plain	β= +
Power_watershed_Q50	β= +

Nitrogen: floodplain flux

n=33, R^2=0.68, P<0.001

ΔDeveloped 2012-1974	β= +
K factor erodibility uppersoil	β= +
Soil permeability avg	β= +
Bank_avg_angle	β= –
Horton Overland Flow %	β= –
PPT_avg	β= +

Phosphorus: floodplain flux

n=33, R^2=0.93, P<0.001

ΔDeveloped 2012-1974	β= +
P_yield_SPARROW	β= +
N_appl_rate	β= –
NLCD_Ag_2011	β= +
Horton Overland Flow %	β= –
Bank_max_angle	β= –
Q50_yield	β= +
Dam_density	β= +
Bnk_height:FP_width	β= +
Dam_storage	β= +
P_appl_rate	β= –
NLCD_Urb_2011	β= +
K factor erodibility uppersoil	β= +

Sediment: bank flux

n=31, R^2=0.37, P=0.005

Bank_max_angle	β= +
PPT_avg	β= –
Over_ratio	β= +

Nitrogen: bank flux

n=31, R^2=0.27, P=0.004

Land-use Production 1974	β= –

Phosphorus: bank flux

n=31, R^2=0.55, P=0.002

Land-use Production 1974	β= –
NLCD_Ag_2011	β= +
Elevation-Relief Ratio	β= +
PP: Valley & Ridge	β= +
Dam_density	β= +

Fluxes are predictable: Watershed GIS-derived predictors

Stepwise multiple regressions (*P*-to-enter=0.10):

Sediment: net balance

n=31, R^2=0.55, P<0.001

- ΔDeveloped 2012-1974 β= +
- Horton Overland Flow % β= –
- Sed_load_SPARROW β= +
- K factor erodibility uppersoil β= +

Nitrogen: net balance

n=31, R^2=0.70, P<0.001

- ΔDeveloped 2012-1974 β= +
- Horton Overland Flow % β= –
- K factor erodibility uppersoil β= +
- Sed_load_SPARROW β= +
- Soil permeability avg β= +
- Base Flow Index avg β= –

Phosphorus: net balance

n=31, R^2=0.70, P<0.001

- ΔDeveloped 2012-1974 β= +
- Horton Overland Flow % β= –
- K factor erodibility uppersoil β= +
- Sed_load_SPARROW β= +
- PP: Piedmont β= –
- Q50 β= –

Sediment: floodplain flux

n=33, R^2=0.46, P<0.001

- ΔDeveloped 2012-1974 β= +
- Horton Overland Flow % β= –
- K factor erodibility uppersoil β= +

Nitrogen: floodplain flux

n=33, R^2=0.41, P<0.001

- ΔDeveloped 2012-1974 β= +
- PP: Coastal Plain β=+

Phosphorus: floodplain flux

n=33, R^2=0.87, P<0.001

- ΔDeveloped 2012-1974 β= +
- P_yield_SPARROW β= +
- N_appl_rate β= –
- NLCD_Ag_2011 β= +
- Horton Overland Flow % β= –
- Q50 β= +
- Land-use Production 2012 β= –
- Dam storage β= +
- Subsurface Flow Contact T β= –
- Q90 β= –

Sediment: bank flux

n=31, R^2=0.12, P=0.062

- Horton Overland Flow % β= –

Nitrogen: bank flux

n=31, R^2=0.27, P=0.004

- Land-use Production 1974 β= –

Phosphorus: bank flux

n=31, R^2=0.55, P=0.002

- Land-use Production 1974 β= –
- NLCD_Ag_2011 β= +
- Elevation-Relief Ratio β= +
- PP: Valley & Ridge β= +
- Dam_density β= +

Fluxes are predictable: Watershed + Reach GIS-derived predictors

Stepwise multiple regressions (*P*-to-enter=0.10, R^2 change > 0.05):

Sediment: net balance

n=31, R^2=0.61, P<0.001

FP_width:Bnk_height	β= +
FP_width:Ch_width	β= –
K factor erodibility uppersoil	β= +
Soil permeability avg	β= +
Elevation-Relief Ratio	β= –

Nitrogen: net balance

n=31, R^2=0.70, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
K factor erodibility uppersoil	β= +
Sed_load_SPARROW	β= +
Soil permeability avg	β= +
Base Flow Index avg	β= –

Phosphorus: net balance

n=31, R^2=0.70, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
K factor erodibility uppersoil	β= +
Sed_load_SPARROW	β= +
PP: Piedmont	β= –
Q50	β= –

Sediment: floodplain flux

n=33, R^2=0.61, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
Bank_avg_angle	β= –
Bank_ht	β= –
FP_range_elev	β= +

Nitrogen: floodplain flux

n=33, R^2=0.55, P<0.001

ΔDeveloped 2012-1974	β= +
K factor erodibility uppersoil	β= +
Soil permeability avg	β= +
Bank_avg_angle	β= –

Phosphorus: floodplain flux

n=33, R^2=0.79, P<0.001

ΔDeveloped 2012-1974	β= +
P_yield_SPARROW	β= +
N_appl_rate	β= –
NLCD_Ag_2011	β= +
Horton Overland Flow %	β= –
Bank_max_angle	β= –

Sediment: bank flux

n=31, R^2=0.37, P=0.005

Bank_max_angle	β= +
PPT_avg	β= –
Over_ratio	β= +

Nitrogen: bank flux

n=31, R^2=0.27, P=0.004

Land-use Production 1974	β= –

Phosphorus: bank flux

n=31, R^2=0.55, P=0.002

Land-use Production 1974	β= –
NLCD_Ag_2011	β= +
Elevation-Relief Ratio	β= +
PP: Valley & Ridge	β= +
Dam_density	β= +

Fluxes are predictable: Watershed GIS-derived predictors

Stepwise multiple regressions (*P*-to-enter=0.10, R^2 change > 0.05):

Sediment: net balance

n=31, R^2=0.55, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
Sed_load_SPARROW	β= +
K factor erodibility uppersoil	β= +

Nitrogen: net balance

n=31, R^2=0.66, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
K factor erodibility uppersoil	β= +
Sed_load_SPARROW	β= +
Soil permeability avg	β= +

Phosphorus: net balance

n=31, R^2=0.66, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
K factor erodibility uppersoil	β= +
Sed_load_SPARROW	β= +
PP: Piedmont	β= –

Sediment: floodplain flux

n=33, R^2=0.46, P<0.001

ΔDeveloped 2012-1974	β= +
Horton Overland Flow %	β= –
K factor erodibility uppersoil	β= +

Nitrogen: floodplain flux

n=33, R^2=0.41, P<0.001

ΔDeveloped 2012-1974	β= +
PP: Coastal Plain	β=+

Phosphorus: floodplain flux

n=33, R^2=0.69, P<0.001

ΔDeveloped 2012-1974	β= +
P_yield_SPARROW	β= +
N_appl_rate	β= –
NLCD_Ag_2011	β= +
Horton Overland Flow %	β= –

Sediment: bank flux

n=31, R^2=0.12, P=0.062

Horton Overland Flow %	β= –

Nitrogen: bank flux

n=31, R^2=0.27, P=0.004

Land-use Production 1974	β= –

Phosphorus: bank flux

n=31, R^2=0.55, P=0.002

Land-use Production 1974	β= –
NLCD_Ag_2011	β= +
Elevation-Relief Ratio	β= +
PP: Valley & Ridge	β= +
Dam_density	β= +

Approaches for predicting the whole Chesapeake watershed

Valley & Ridge, Piedmont, and Coastal Plain

- OPTION #1 — Average: all 3 PP (for sediment, and all floodplain and bank fluxes)
- OPTION #2 — Average: each PP (for N and P net balance fluxes)
- OPTION #3 — Regression: Watershed+Reach predictors
- OPTION #4 — Regression: Watershed only predictors (where GIS Toolkit unavailable)

Appalachian Plateau and Blue Ridge

- OPTION #1 — Average: Valley & Ridge and Piedmont
- OPTION #3 — Regression: Watershed+Reach predictors
- OPTION #4 — Regression: Watershed only predictors (where GIS Toolkit unavailable)

Other issues:

- Intensive land-use on floodplain (e.g. urban, row crop)
- Channelized/leveed rivers
- Headwaters

USGS

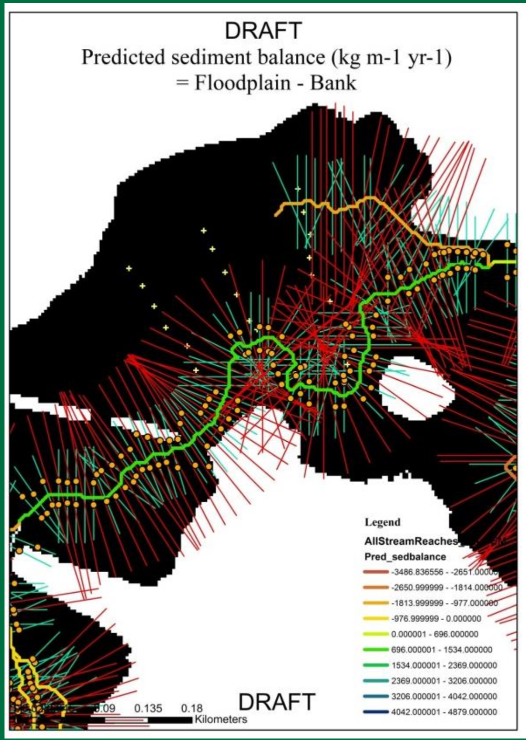
Predicting fluxes: Difficult Run pilot

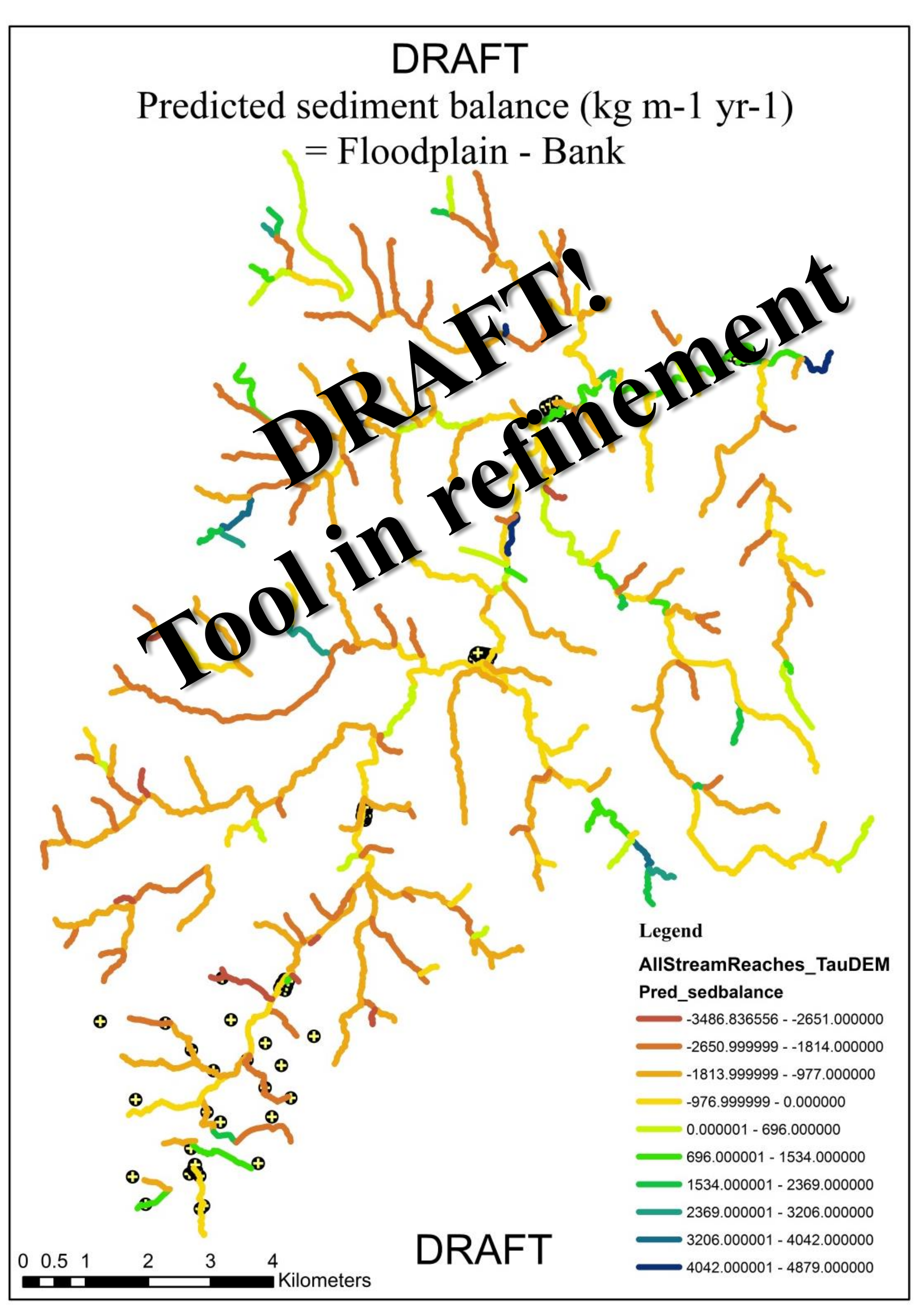
<u>Regression</u>

Mainstem X-section

net sediment balance predicted (R^2=0.57, P=0.007) by:

- Channel width
- Floodplain elevation range





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Dendrogeomorphic method

Flux calculations:

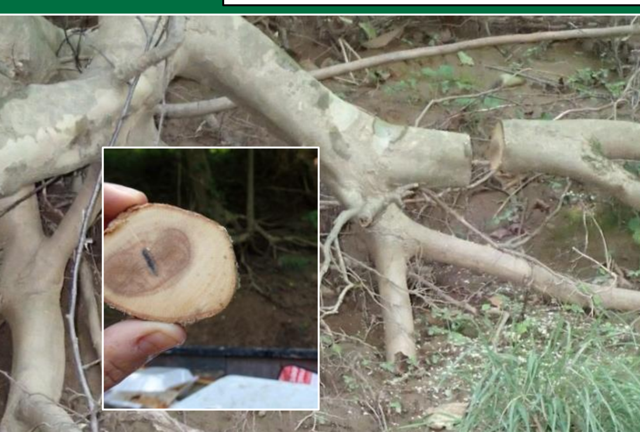
$g\ m^{-1}\ yr^{-1}$

Floodplain: vertical change rate * bulk density * total floodplain width

(m yr^{-1}) (g cm^{-3}) (m)

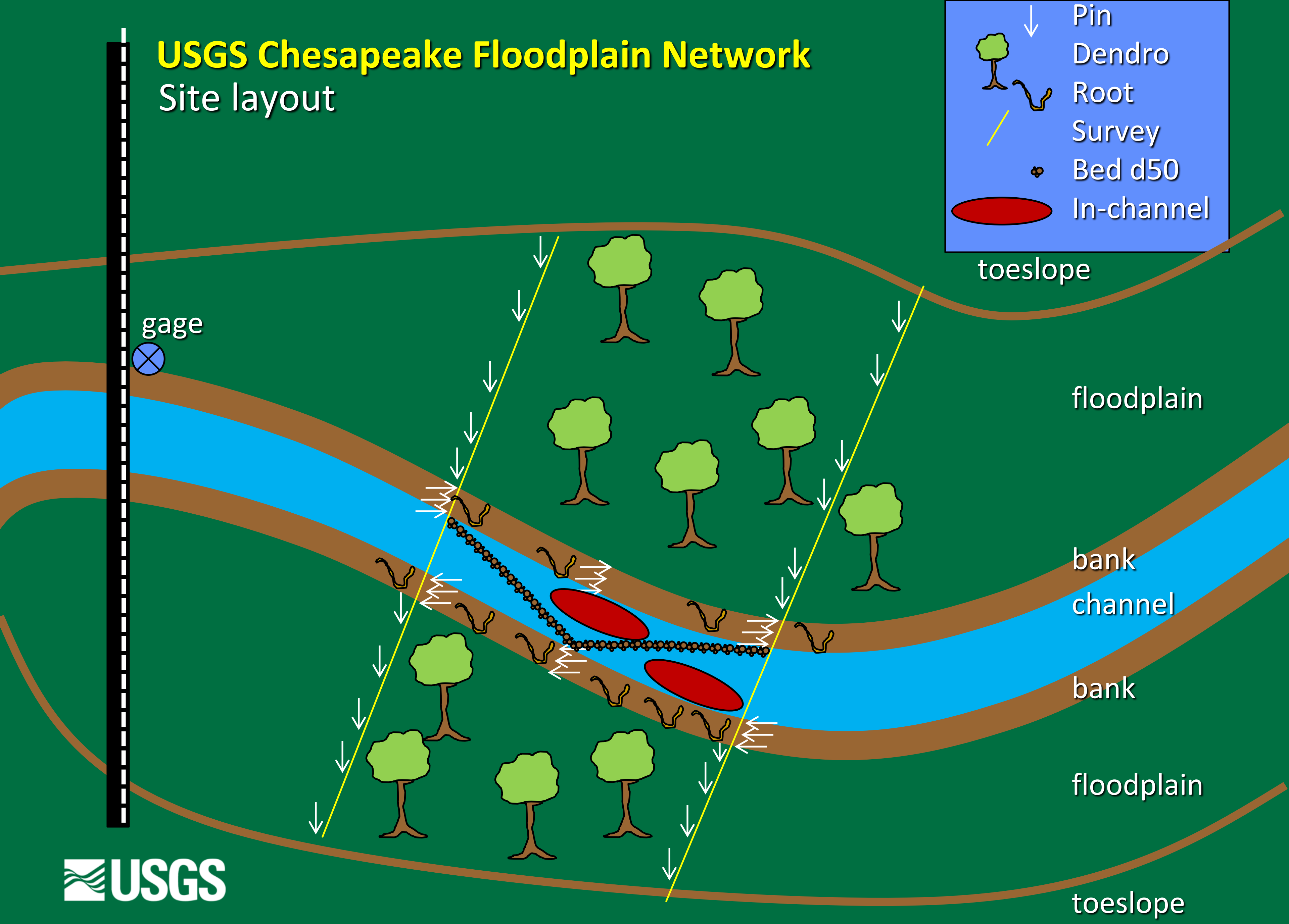
Bank: lateral change rate * bulk density * bank height * 2 * correction

Net balance: Floodplain flux – Bank flux



USGS Chesapeake Floodplain Network

Site layout



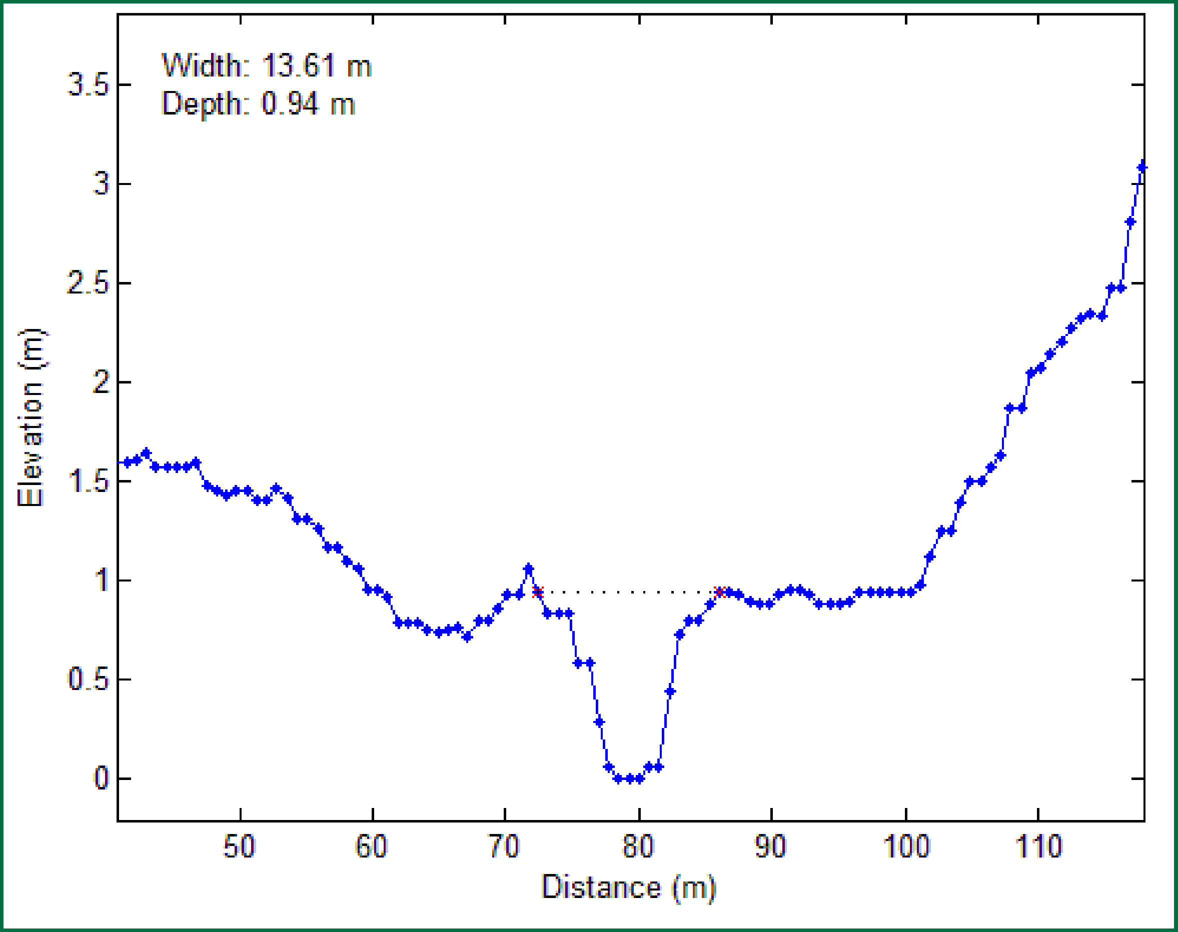
USGS Chesapeake Floodplain Network

Goal:

Measure and predict the sediment/N/P balance of streams and rivers (sink or source of floodplain and banks) in entire Chesapeake watershed

Chesapeake Geomorphic GIS toolkit:
Channel x-section analysis

Bank locations based on slope breaks



Fluvial Geomorphic Characteristics

- Bank height
- Bank angle

- Channel width
- Channel profile slope

- Floodplain width
- Floodplain elevation range
- Floodplain elevation StDev

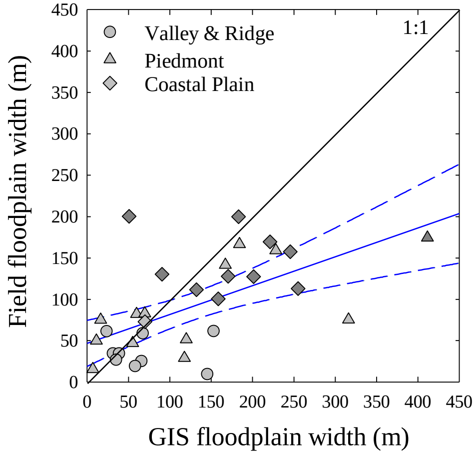
- Valley width

- Drainage area

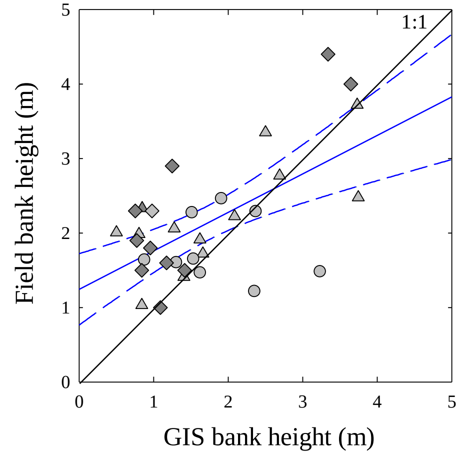
Measured vs. GIS geomorphology: evaluating Toolkit performance

Cross section -scale

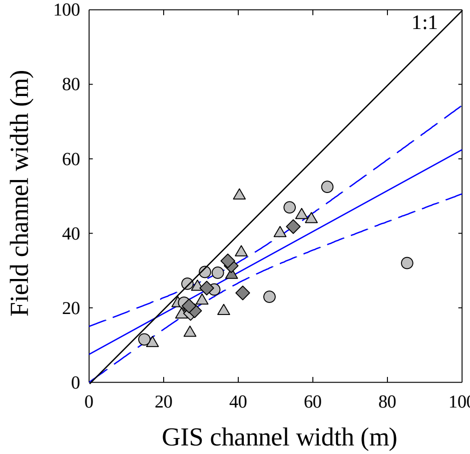
Floodplain Width (outlier removed)
b[0] 46.7
b[1] 0.349
r^2 □0.34



Bank Height (outlier removed)
b[0] 1.25
b[1] 0.517
r^2 □0.37

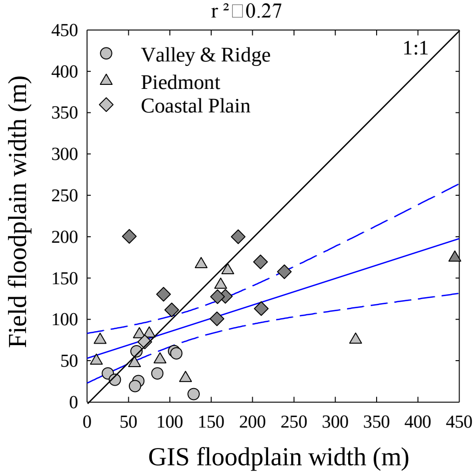


Channel Width (2 outliers removed)
b[0] 7.47
b[1] 0.5507
r^2 □0.56

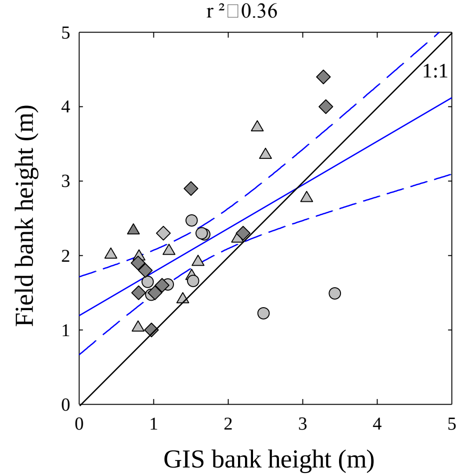


Reach-scale

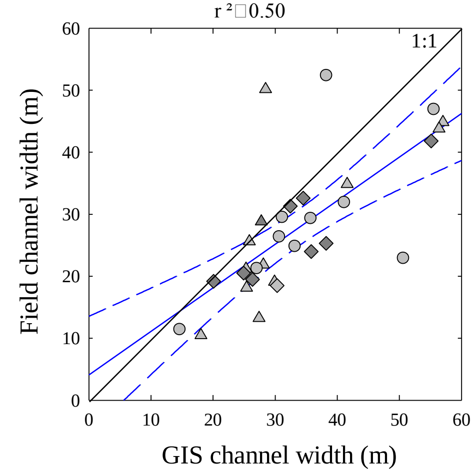
Floodplain Width (outlier removed)
b[0] 53.1
b[1] 0.322
r^2 □0.27



Bank Height (outlier removed)
b[0] 1.19
b[1] 0.586
r^2 □0.36



Channel Width (2 outliers removed)
b[0] 4.09
b[1] 0.703
r^2 □0.50



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Understanding and scaling transport processes thru watersheds

Alluvial sediment exchange

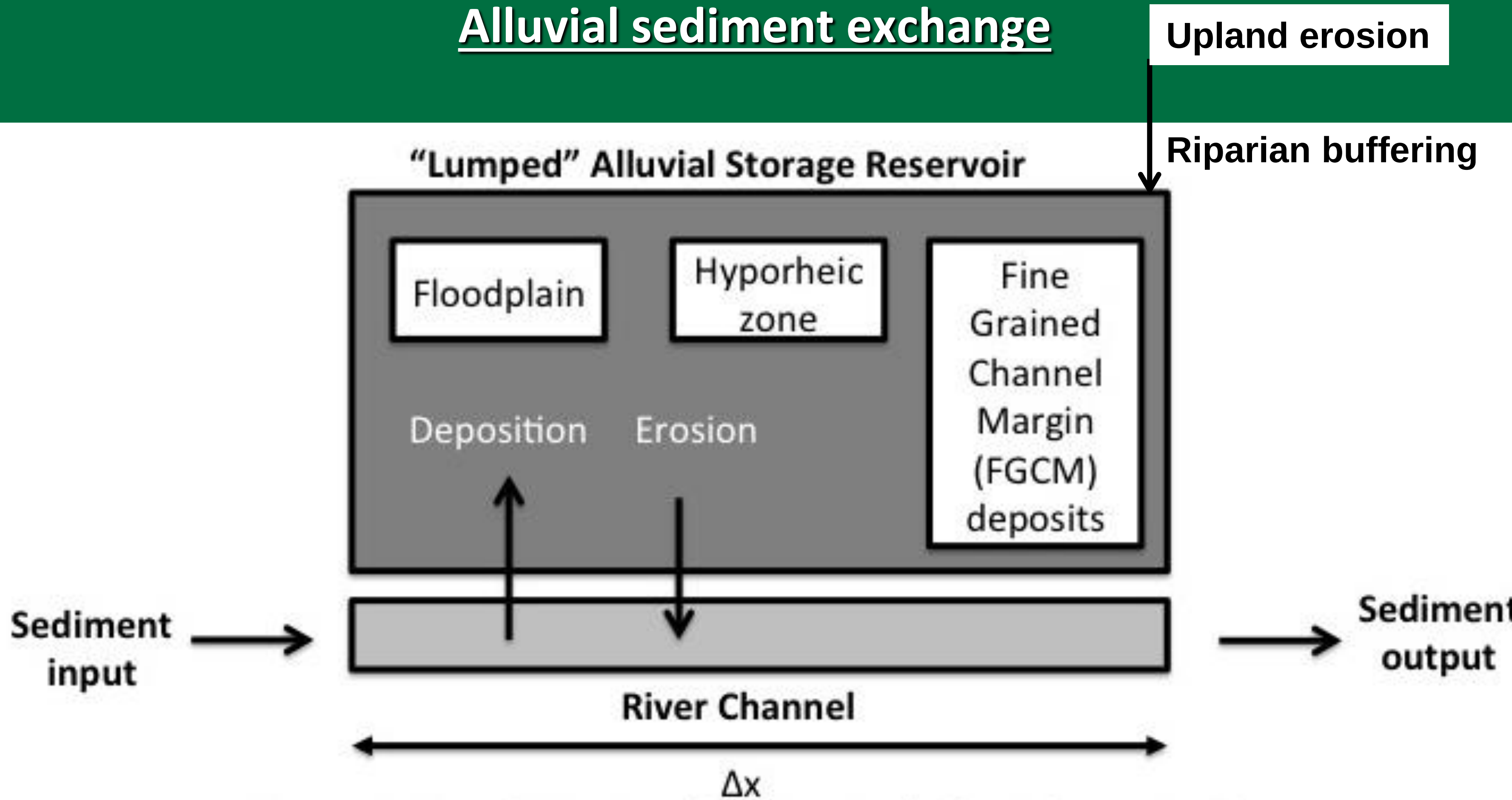


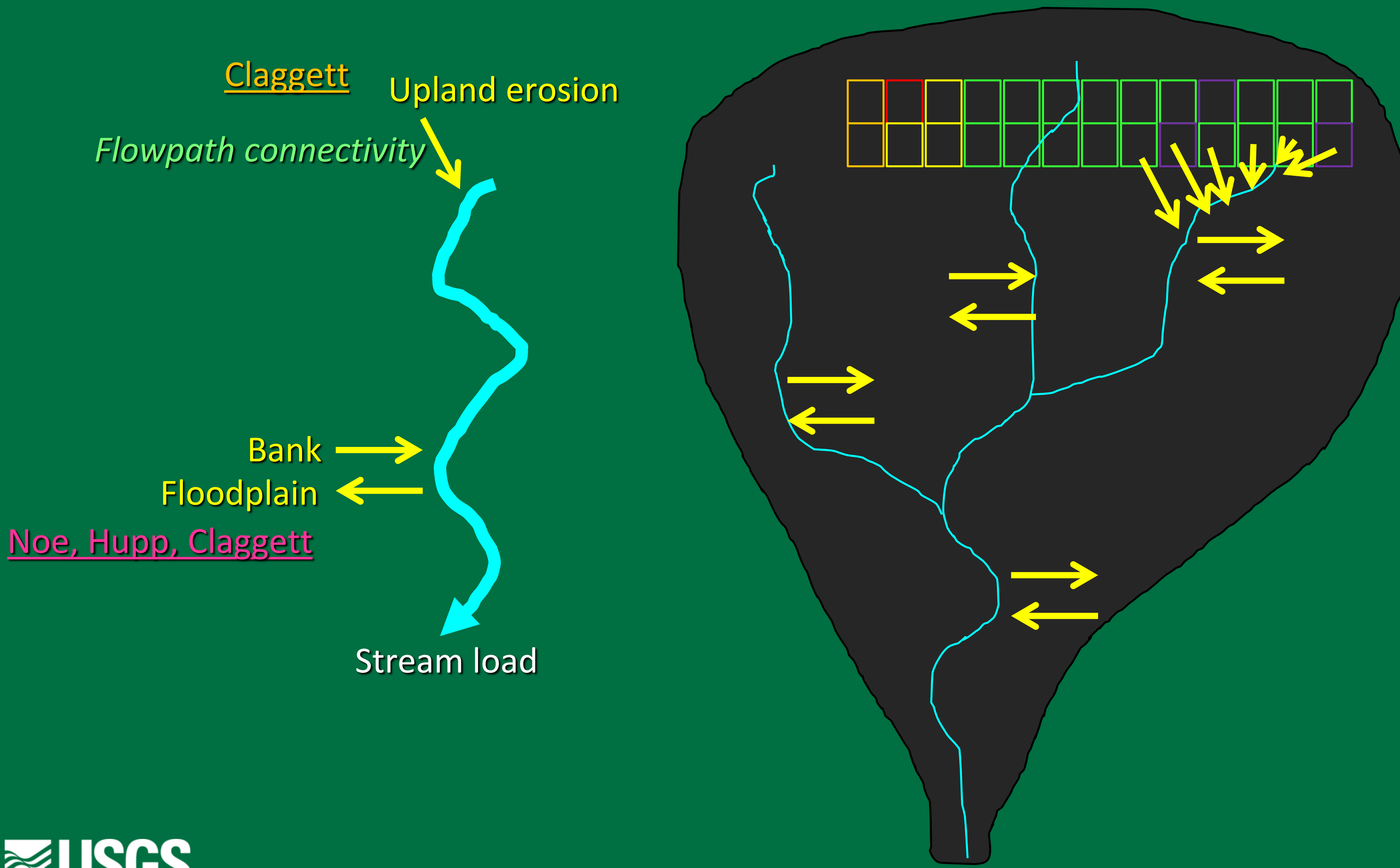
Figure 1. Spatial structure (in plan view) of a 1-dimensional "valley-averaged" suspended sediment routing model.

Modified from Benthem and Skalak

USGS

79% of P load and 28% of N load to Chesapeake Bay is particulate (Noe and Hupp 2009, from Langland et al. 2006)

Big picture of approach for sediment modeling



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Any and every reach: alluvial geometry, upland flux, bank flux, floodplain flux

USGS Chesapeake Floodplain Network

- We can measure and model if streams and rivers are sinks for sediment and associated particulate N and P over long time scales

- The Chesapeake watershed is mostly in 'equilibrium' for sediment fluvial exchange; but some floodplains are strongly depositional

- Fluxes of sediment and nutrients were similar in Valley & Ridge and Piedmont physiographic provinces (and sediment in Coastal Plain), indicating limited control of regional geology over alluvial sediment exchange.

- Measured rates of floodplain depositional flux of N and P were typical of the Mid-Atlantic and Southeastern U.S.

- Regional floodplain, bank, and net fluxes of sediment and nutrients were predictable using a combination of reach geomorphology and watershed characteristics (all of which could be estimated in GIS).

- Floodplains are hotspots in the landscape for sediment and nutrient sinks and sources, influencing river loads to the Chesapeake Bay.

- Chesapeake GIS toolkit and database should be valuable tool for additional research on transport processes and stream condition and health.

USGS

We can measure and predict the important role of floodplain/bank sediment exchange in Chesapeake watersheds

USGS

Morgan Creek, MD

Model Summary[g]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.416[a]	.173	.144	205.45703	.173	6.055	1	29	.020	
2	.531[b]	.282	.230	194.83627	.109	4.248	1	28	.049	
3	.616[c]	.379	.310	184.46894	.097	4.236	1	27	.049	
4	.736[d]	.542	.471	161.51628	.163	9.219	1	26	.005	
5	.781[e]	.610	.532	151.97766	.068	4.366	1	25	.047	
6	.809[f]	.654	.568	146.01814	.044	3.082	1	24	.092	2.327

a. Predictors: (Constant), FPdivBNK

b. Predictors: (Constant), FPdivBNK, FPdivCH

c. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP

d. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP, PERMAVE

e. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP, PERMAVE, RRMEDIAN_30M

f. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP, PERMAVE, RRMEDIAN_30M, BFAREA

g. Dependent Variable: Site_balance_Sed_Kgmyr

ANOVA[g]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	255613.6	1	255613.594	6.055	.020[a]
	Residual	1224165	29	42212.590		
	Total	1479779	30			
2	Regression	416865.8	2	208432.921	5.491	.010[b]
	Residual	1062913	28	37961.174		
	Total	1479779	30			
3	Regression	561001.3	3	187000.449	5.495	.004[c]
	Residual	918777.4	27	34028.791		
	Total	1479779	30			
4	Regression	801503.4	4	200375.861	7.681	.000[d]
	Residual	678275.3	26	26087.510		
	Total	1479779	30			
5	Regression	902348.5	5	180469.694	7.813	.000[e]
	Residual	577430.2	25	23097.209		
	Total	1479779	30			
6	Regression	968067.6	6	161344.594	7.567	.000[f]
	Residual	511711.1	24	21321.297		
	Total	1479779	30			

a. Predictors: (Constant), FPdivBNK

b. Predictors: (Constant), FPdivBNK, FPdivCH

c. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP

d. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP, PERMAVE

e. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP, PERMAVE, RRMEDIAN 30M

f. Predictors: (Constant), FPdivBNK, FPdivCH, KFACT_UP, PERMAVE, RRMEDIAN 30M, BFAREA

g. Dependent Variable: Site_balance_Sed_Kgmyr

Coefficients[a]

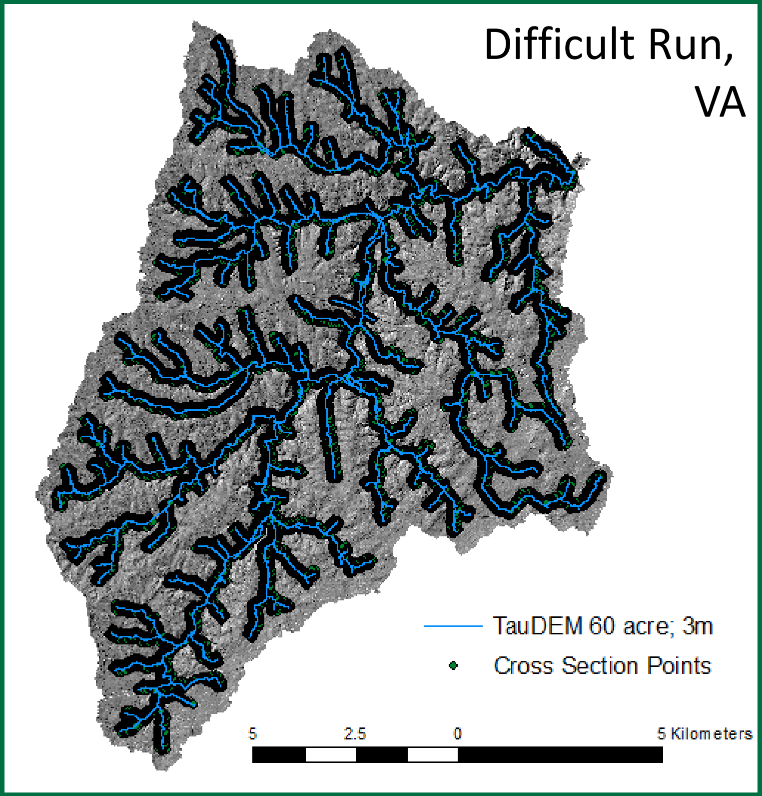
Model		Unstandardized Coefficients: B	Std. Error	Standardized Coefficients: Beta	t	Sig.	Collinearity Statistics: Tolerance	VIF
1	(Constant)	.296	48.062		.006	.995		
	FPdivBNK	.722	.293	.416	2.461	.020	1.000	1.000
2	(Constant)	46.899	50.878		.922	.365		
	FPdivBNK	2.121	.734	1.221	2.891	.007	.144	6.952
	FPdivCH	-47.258	22.930	-.870	-2.061	.049	.144	6.952
3	(Constant)	-355.588	201.409		-1.765	.089		
	FPdivBNK	2.173	.695	1.251	3.126	.004	.144	6.961
	FPdivCH	-53.097	21.894	-.978	-2.425	.022	.141	7.070
	KFACT_UP	1481.687	719.936	.322	2.058	.049	.937	1.067
4	(Constant)	-1145.718	314.353		-3.645	.001		
	FPdivBNK	2.025	.611	1.166	3.317	.003	.143	7.005
	FPdivCH	-48.084	19.241	-.886	-2.499	.019	.140	7.123
	KFACT_UP	3230.318	853.829	.703	3.783	.001	.511	1.958
	PERMAVE	91.524	30.143	.559	3.036	.005	.521	1.919
5	(Constant)	-1559.690	356.008		-4.381	.000		
	FPdivBNK	2.074	.575	1.194	3.607	.001	.143	7.017
	FPdivCH	-39.065	18.612	-.719	-2.099	.046	.133	7.528
	KFACT_UP	4645.501	1050.790	1.011	4.421	.000	.299	3.349
	PERMAVE	143.698	37.788	.877	3.803	.001	.294	3.407
	RRMEDIAN_30M	-519.665	248.700	-.415	-2.090	.047	.396	2.527
6	(Constant)	-1607.339	343.123		-4.684	.000		
	FPdivBNK	1.882	.563	1.083	3.342	.003	.137	7.291
	FPdivCH	-33.144	18.197	-.610	-1.821	.081	.128	7.795
	KFACT_UP	5240.687	1064.984	1.140	4.921	.000	.268	3.726
	PERMAVE	165.801	38.427	1.012	4.315	.000	.262	3.816
	RRMEDIAN_30M	-830.959	297.548	-.664	-2.793	.010	.255	3.919
	BFAREA	-1.802	1.027	-.293	-1.756	.092	.518	1.929

V&R + Piedmont fluxes are predictable (and available in GIS)

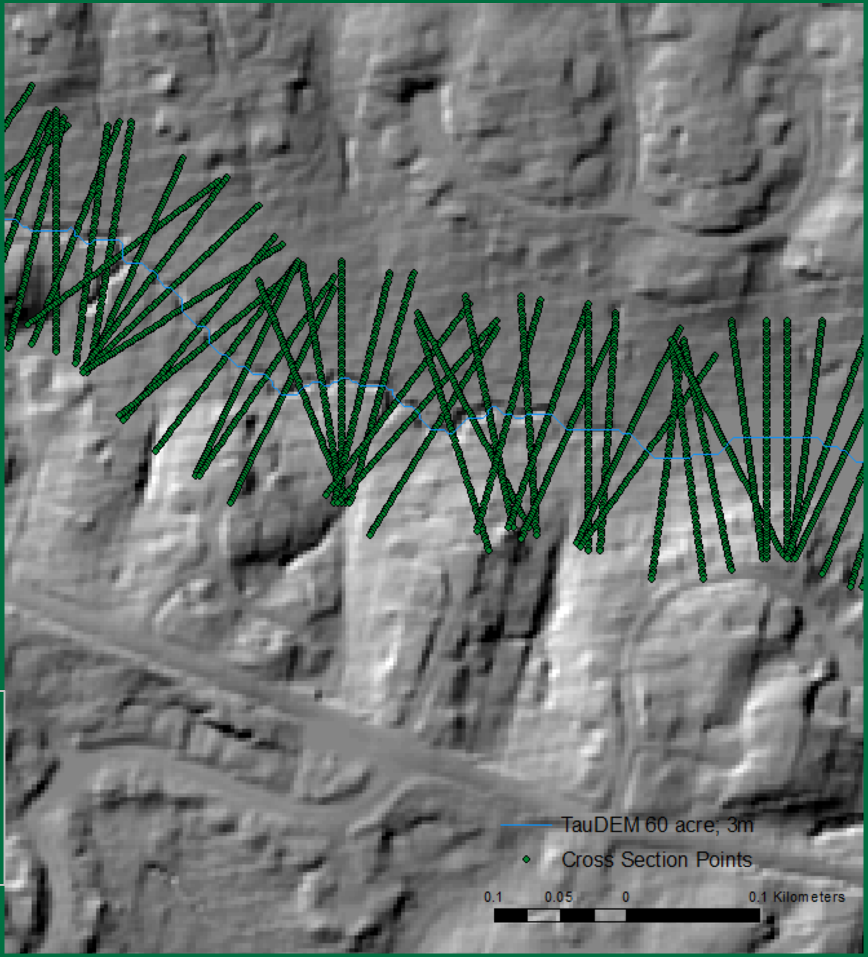
Stepwise multiple regressions:

Set of predictors	Statistics		Fluxes		
			Net sediment balance	Floodplain sediment flux	Bank sediment flux
Geomorphology only	**P-to-enter <0.05**	R^2	0.15	0.54	0.35
		Predictors	1. Bank Height	1. Channel width ÷ Floodplain width 2. Bank height	1. Floodplain width
	P-to-enter <0.10	R^2	0.15	0.54	0.41
		Predictors	1. Bank Height	1. Channel width ÷ Floodplain width 2. Bank height	1. Floodplain width 2. Channel width
Watershed only	**P-to-enter <0.05**	R^2	0.23	0.20	0.00
		Predictors	1. Dam #	1. Dam #	None
	P-to-enter <0.10	R^2	0.23	0.20	0.22
		Predictors	1. Dam #	1. Dam #	1. Stream power index (Q50) 2. Forest land-use 2011
Geomorphology + Watershed	**P-to-enter <0.05**	R^2	0.23	0.72	0.57
		Predictors	1. Dam #	1. Channel width ÷ Floodplain width 2. Bank height 3. Physiographic province 4. Production land-use 2012	1. Floodplain width 2. Elevation-Relief Ratio 3. Channel width ÷ Floodplain width
	P-to-enter <0.10	**R^2**	**0.53**	**0.76**	**0.77**
		Predictors	1. Dam # 2. Channel width ÷ Floodplain width 3. Floodplain width ÷ Bank height 4. Elevation-Relief Ratio	1. Channel width ÷ Floodplain width 2. Bank height 3. Physiographic province 4. Production land-use 2012 5. K factor	1. Floodplain width 2. Channel width ÷ Floodplain width 3. P application 4. Impervious 2006/2011 5. R factor 6. Dam storage

Chesapeake Geomorphic GIS toolkit:
Analyzing (LIDAR) DEMs to estimate geometry of alluvial system



Can vary:
- Linear fit length, spacing, width, point spacing
- Width limited to catchment boundary



USGS

Chesapeake Geomorphic GIS toolkit:

Fluvial Geomorphic Characteristics:

- Bank height
- Bank angle

- Channel width
- Channel profile slope

- Floodplain width
- Floodplain elevation range
- Floodplain elevation StDev

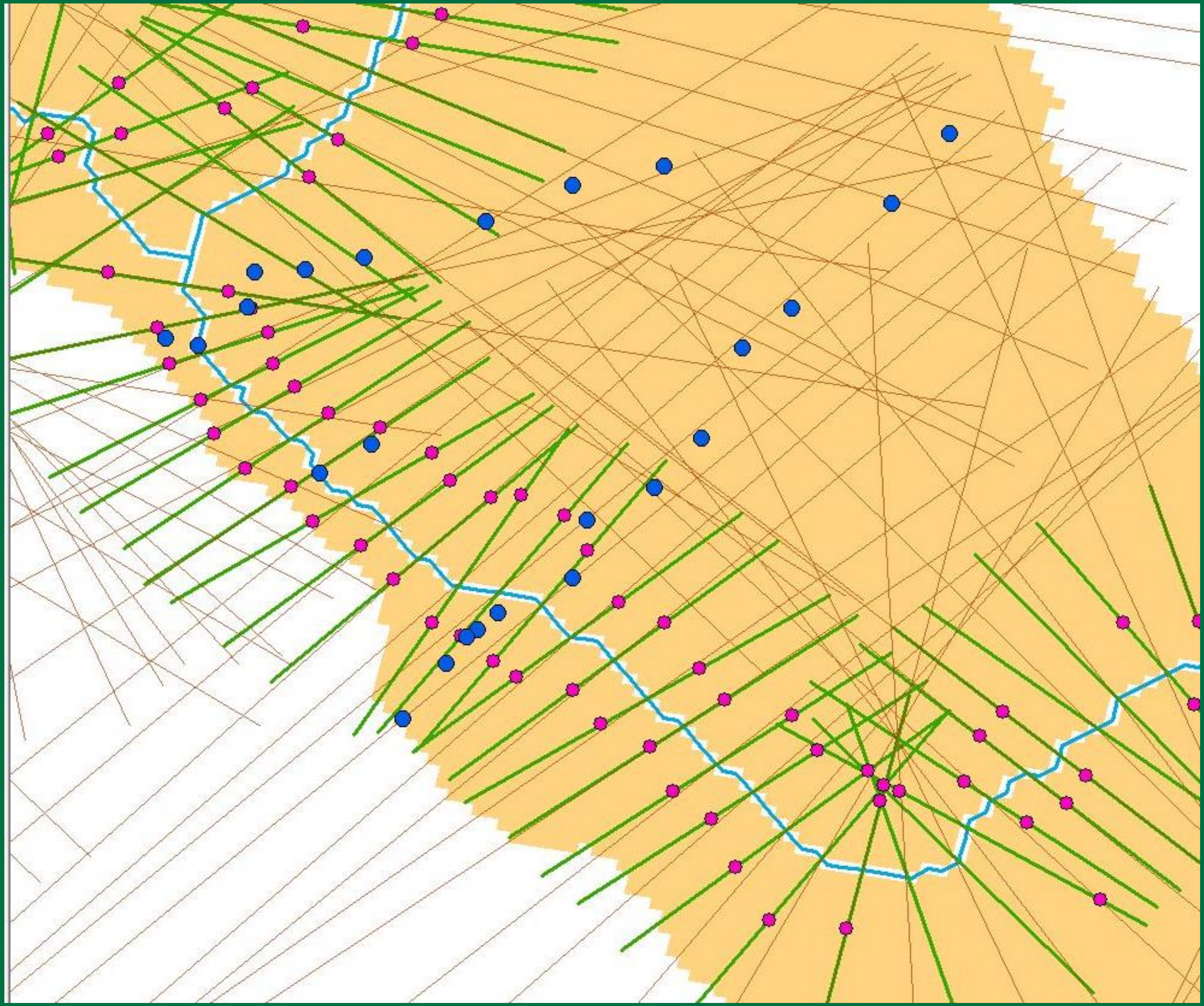
- Valley width

- Drainage area

USGS

Chesapeake Geomorphic GIS toolkit:
Field vs. GIS validation

Patuxent River near Unity MD



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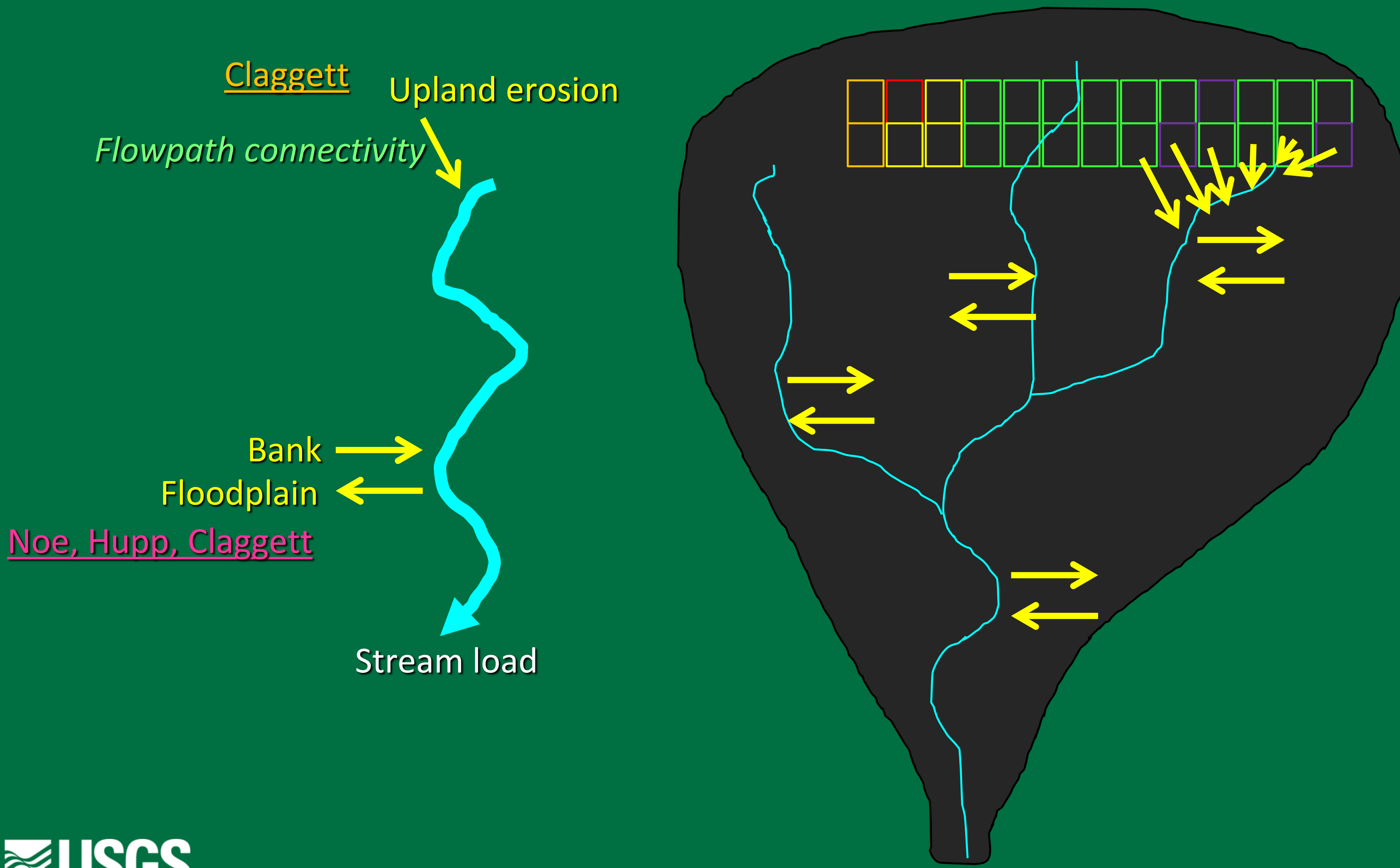
Big picture of approach for sediment modeling



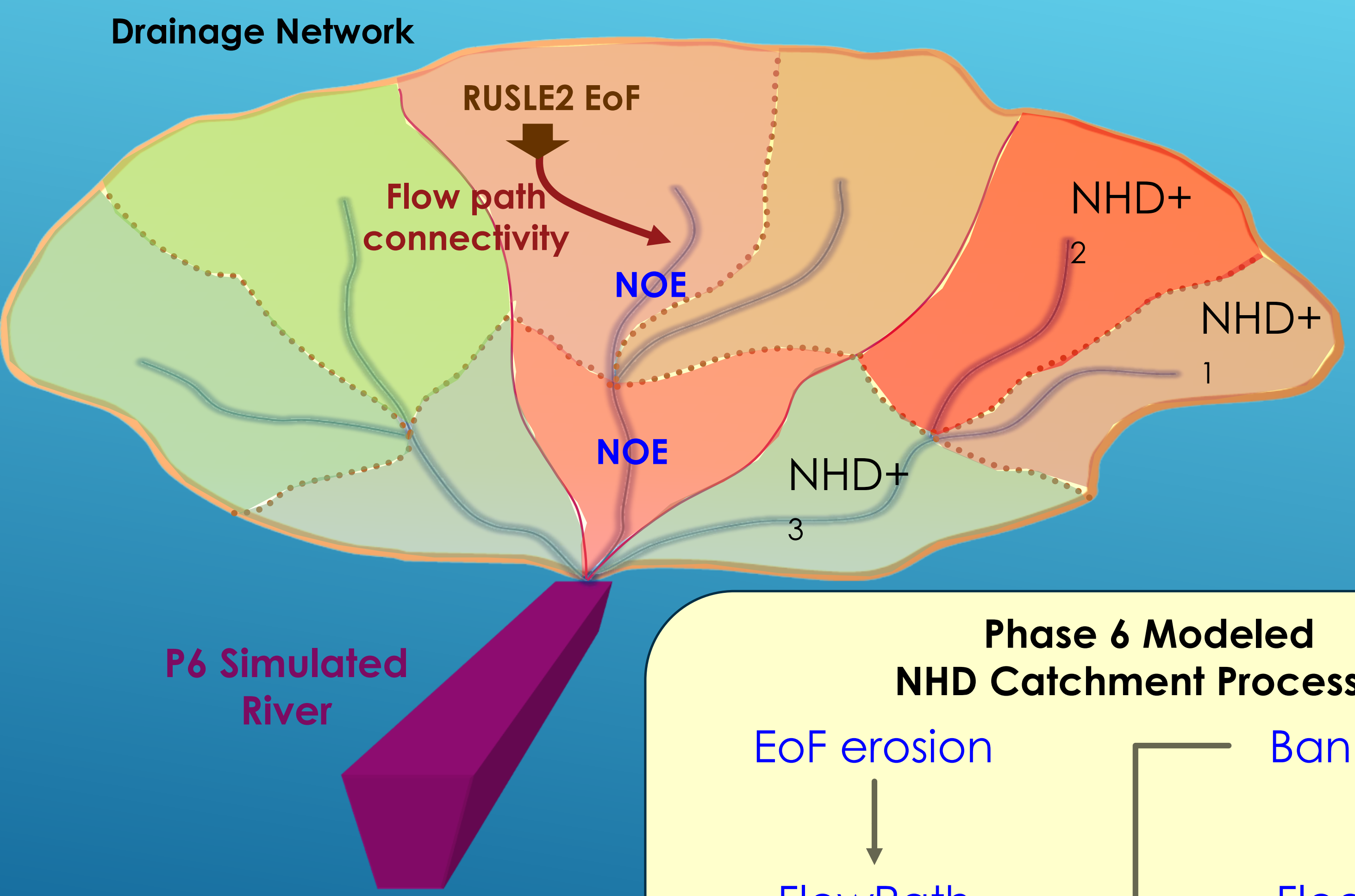
Any and every reach: alluvial geometry, upland flux, bank flux, floodplain flux

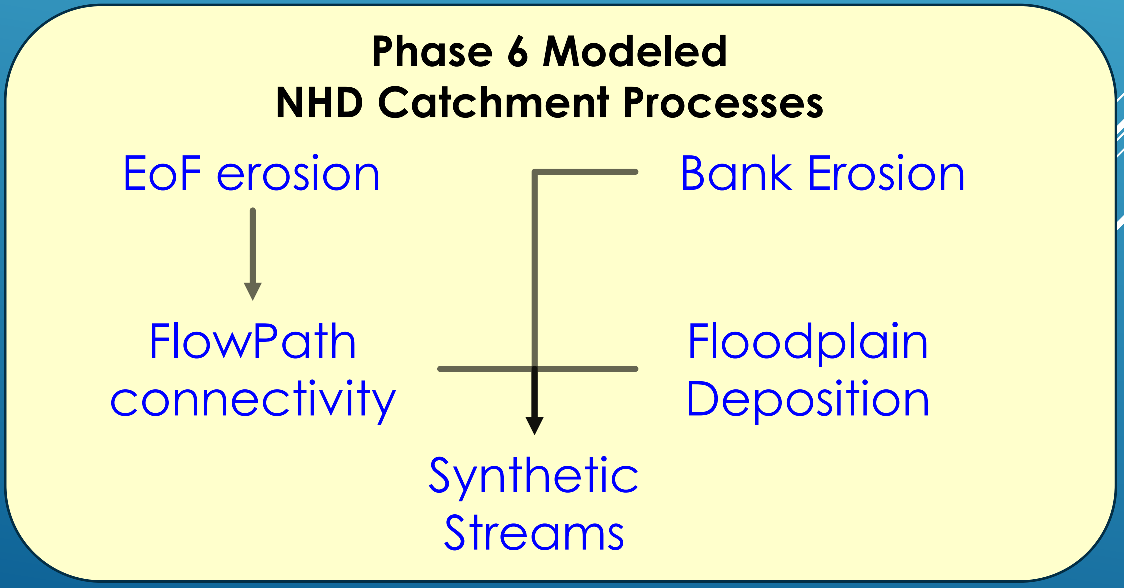
USGS Chesapeake Floodplain Network

What's next:	Completed:
1. Validate GIS geomorphology (VR & PIED) using field geomorphology.	Nov 2015
2. Calculation of Coastal Plain long-term fluxes.	Dec 2015
3. Regress VR & PIED fluxes using GIS geomorphology.	Dec 2015
4. GIS geomorphology database ready (VR & PIED)	Jan 2016
5. GIS geomorphology database complete (~90%; CP and Shenandoah added).	Apr 2016
6. Regress VR & PIED & CP fluxes using GIS geomorphology + watershed characteristics.	Apr 2016
7. Extrapolate bank and floodplain sediment fluxes to all of VR & PIED & CP 1. Summed by NHD+ catchment 2. Maps by reach of fluxes	May 2016
8. Add SW VA and WV LiDAR gap (100% of watershed complete)	Jan 2017
9. Measure contemporary fluxes 3-yr post installation and repeat.	2019

USGS

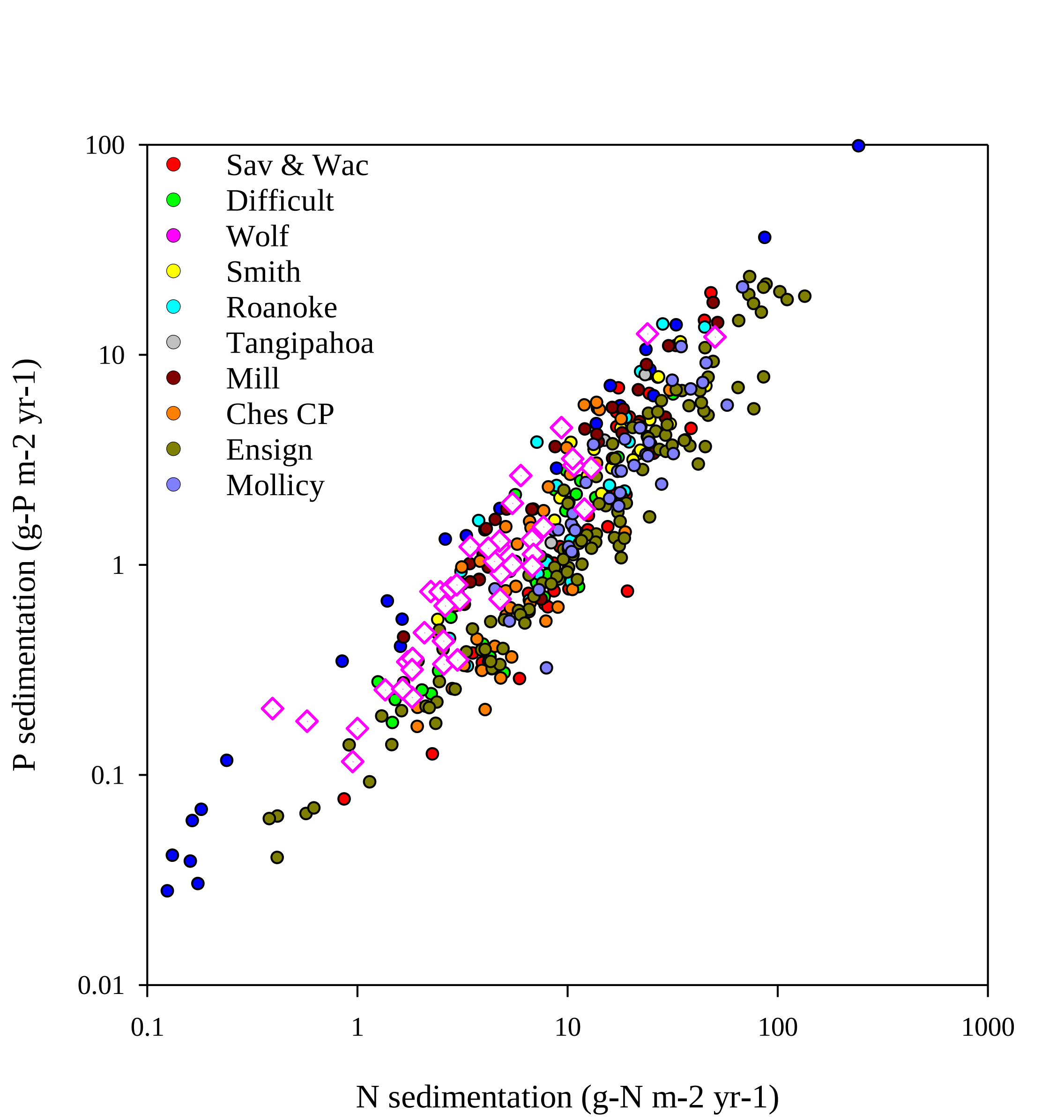
Sediment Delivery to Simulated Rivers





USGS Chesapeake Floodplain Network vs. other studies

Floodplain flux rates are typical



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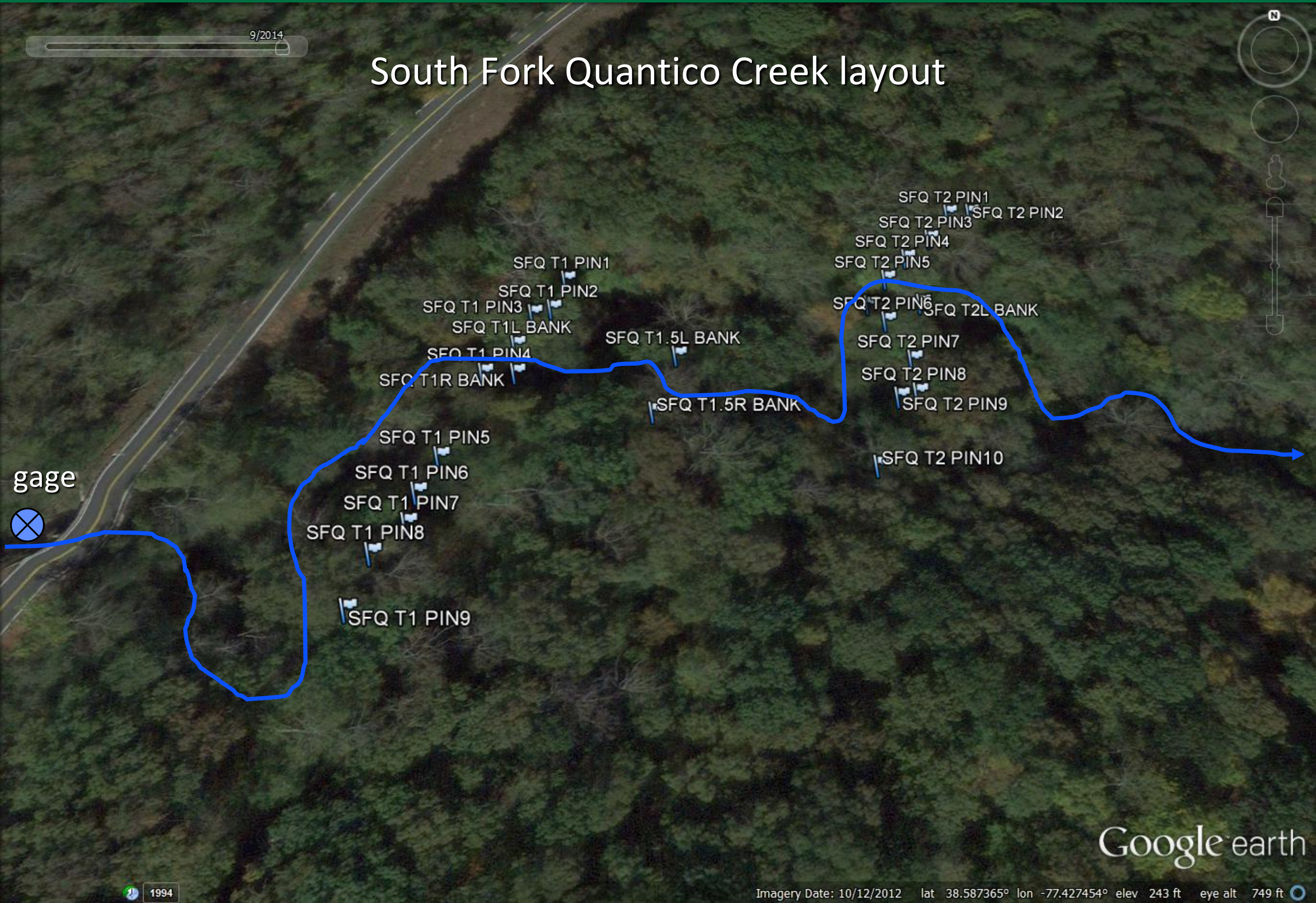
USGS Chesapeake Floodplain Network: example site



USGS Chesapeake Floodplain Network

Measurements:

<u>Sediment budget terms</u> (45 sites)
Contemporary (pin) floodplain and bank flux
Long-term (dendro) floodplain and bank flux
In-channel sediment storage volumes

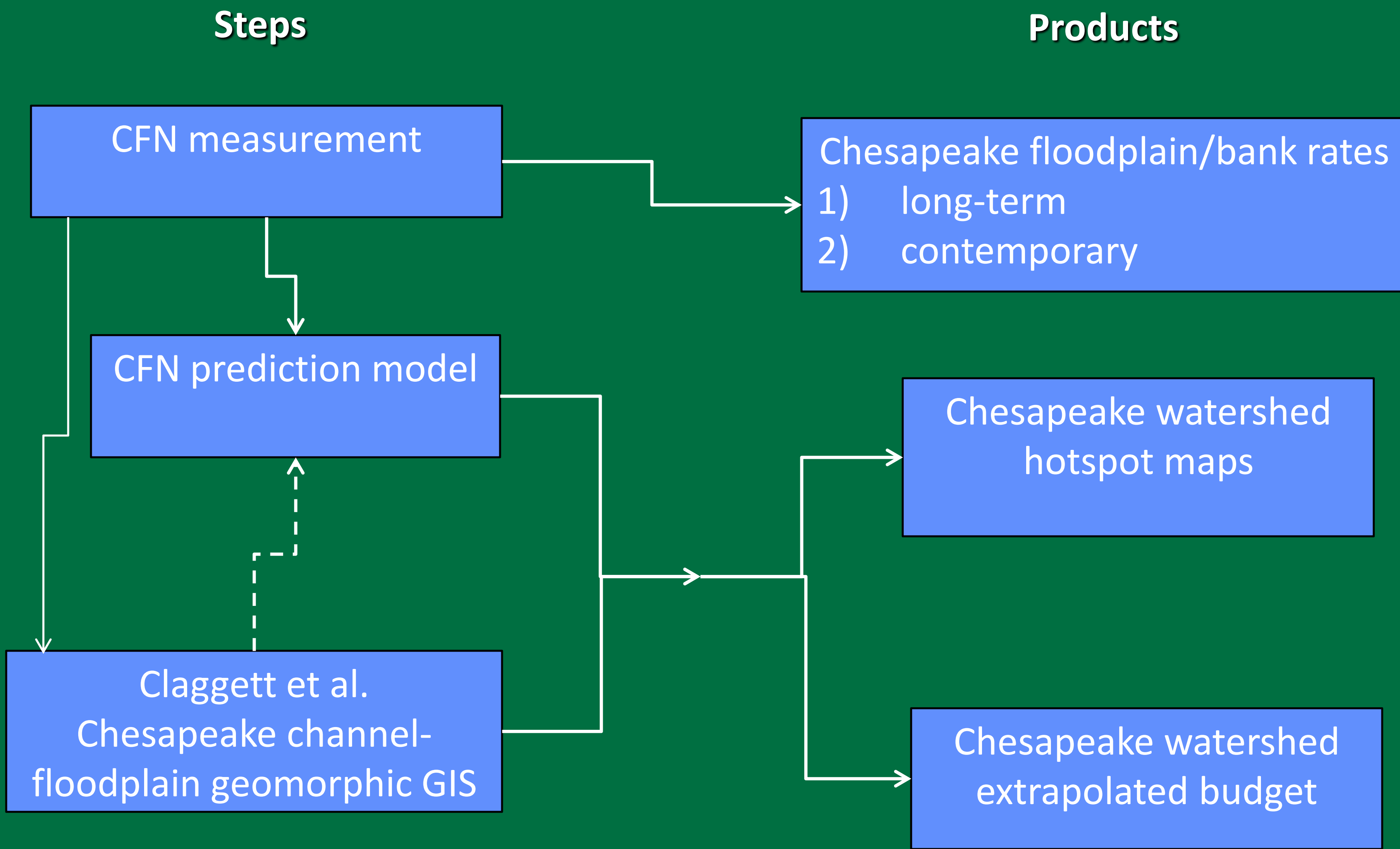
<u>Geomorphic measurements</u> (45 sites)
X-section survey (channel, banks, floodplain)
Longitudinal survey (tie to gage, reach slope)
Channel bed particle size

<u>Biogeochemistry</u> (45 sites)
Soil/sediment TN, TP, TOC, LOI, particle size
Soil/sediment biogeochemical processes

<u>Age Distributions</u> (6 sites)
In-channel (bomb radiocarbon, Be-7, Pb-210)
Floodplain (Be-7, Pb-210, OSL, radiocarbon)

USGS

Scaling to the whole Chesapeake watershed: measuring and predicting bank and floodplain rates



Dynamic exchange of sediment + nutrients = hotspot

Gross floodplain trapping factor (Schenk et al. 2013):

	Avg.
Sed:	72
P:	40
N:	12

Kg m^{-2} yr^{-1} of floodplain
SPARROW yield estimates

Average hectare of floodplain traps 72X the sediment load generated by hectare of watershed

Indicator of importance to watershed loads

USGS

The importance of floodplains to WQ in the Chesapeake watershed

Measurement of functions

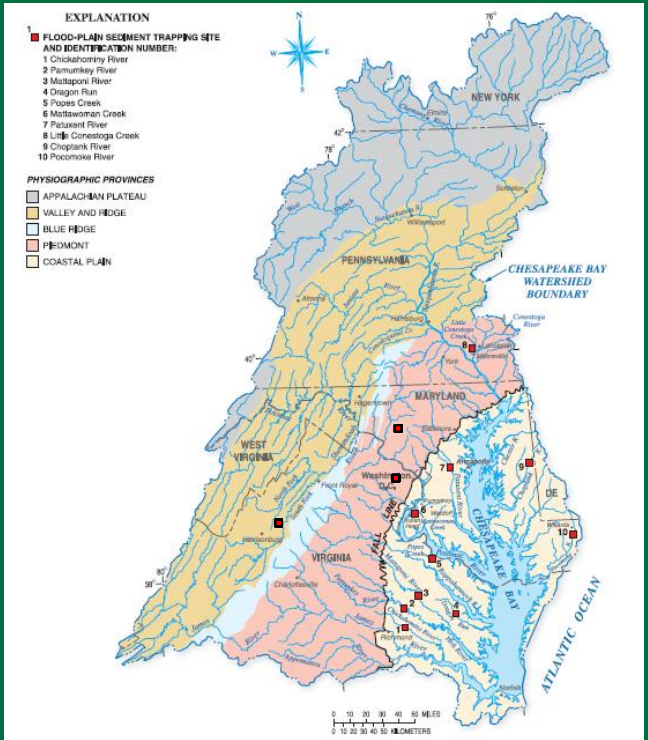
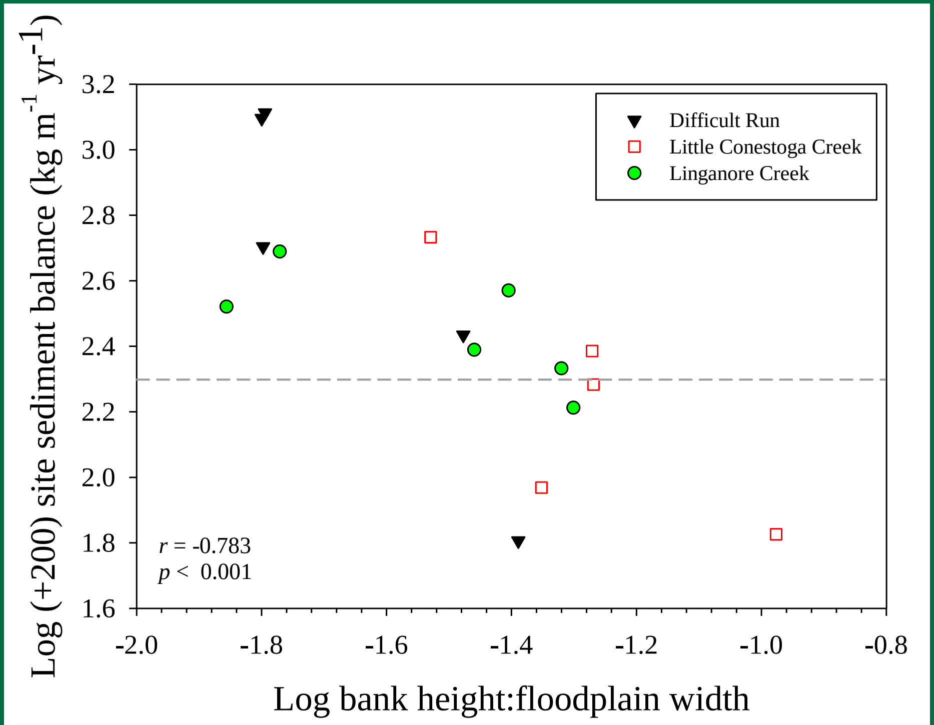


Figure 2. Location of flood-plain sediment trapping sites in the Chesapeake Bay Watershed. [Dates of measurements range from 1996 through 2006 (modified from Bachman and others, 1998).]

Ross et al. 2004
Noe and Hupp 2005
Noe and Hupp 2007
Gellis et al. 2008
Hogan and Walbridge 2009
Noe and Hupp 2009
Schenk and Hupp 2009
Kroes and Hupp 2010
Hupp et al. 2013
Schenk et al. 2013
Noe et al. 2013a
Noe et al. 2013b
Gellis et al. 2015

USGS

Predictability of functions



Schenk et al. 2013, *ESP&L*

Gellis et al. 2015, SIR

Only 3 Piedmont watersheds!

→ Not expected to be general, but shows promise of approach:

Easy geomorphic metrics may be predictive