Restoration Question #9 under the Stability theme.

Improving the Success of Stream Restoration Practices

TESS WYNN THOMPSON, ASSOCIATE PROFESSOR, BIOLOGICAL SYSTEMS ENGINEERING

ERIC SMITH, PROFESSOR, STATISTICS

STUDENTS: REX GAMBLE, CORAL HENDRIXS, BILLY PARASZCZUK, BEN SMITH, U. SAMUEL WITHERS

Biological Systems Engineering

VIRGINIA TECH

Thanks to...

Anne Arundel County
Baltimore County
Frederick County
Harford County
Howard County

Bill Buettner
Ken Choi
Heather Cobb
Ryan Cole
Michele Dobson
Jeremy Joiner
Christine Lowe
Heather McGee
Kerry McMahon
Erik Michelsen

This research focused on 3 questions:

1. Linking stream restoration success with watershed and design characteristics
2. Design, project, and watershed factors that affect structure success
3. Comparison of 1-D and 2-D HEC-RAS modeling for stream restoration design

Study 2:

Design, project, and watershed factors that affect structure success

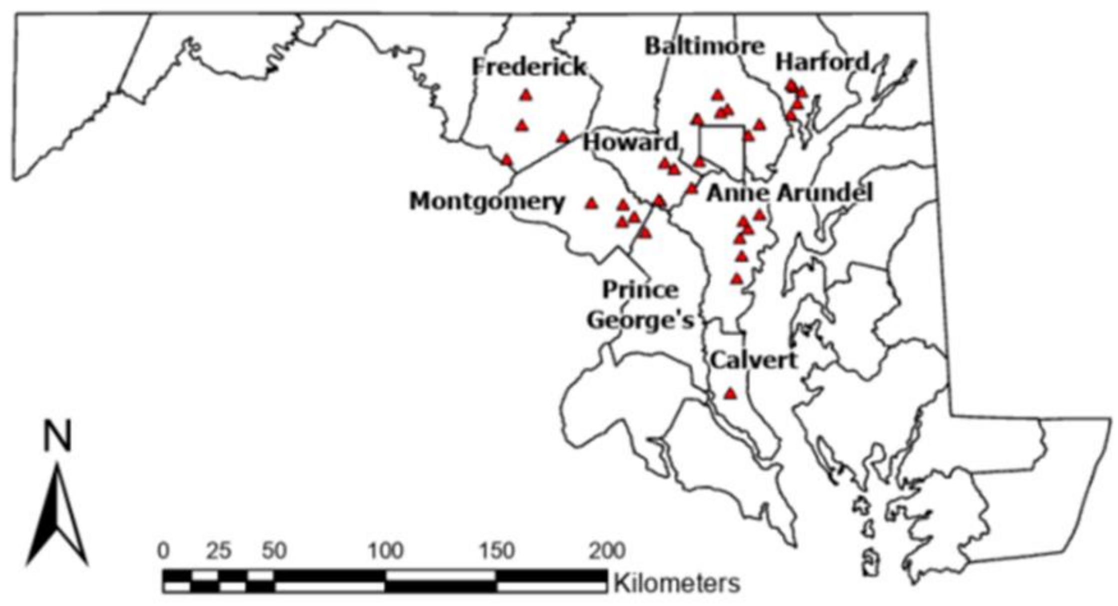
TESS WYNN THOMPSON, BIOLOGICAL SYSTEMS ENGINEERING

ERIC SMITH, STATISTICS

BENJAMIN SMITH, STANTEC, FORMER GRADUATE STUDENT

The goal of Study 2 is to evaluate existing instream structures with the aim of informing structure design and siting

1. Structures were evaluated in the field
   - 38 Projects
   - 536 Structures
2. Watershed, project, and design characteristics correlated to structure assessment



What is structure success?

Attribute	1	2	3	4
Structure				
% remaining	0-25%	25-50%	50-75%	75-100%
material movement	significant	moderate	slight	none
Sediment				
unintended bank erosion or bed scour	significant	moderate	slight	none
unintended aggradation	significant	moderate	slight	none
Function				
serving intended purpose	no	partially	yes	

Structures were grouped by function and material

- Bank protection (n = 147)
- Full span vanes (n = 105)
- Partial span vanes (n = 68)
- Constructed riffles (n = 102)
- RSC weirs (n = 57)
- Step-pools (n = 31)

- Rock (n = 282)
- Log (n = 36)
- Combination

Design explanatory variables depended on structure family and were scaled by channel size.

http://clipart-library.com/

Statistical *Correlation*

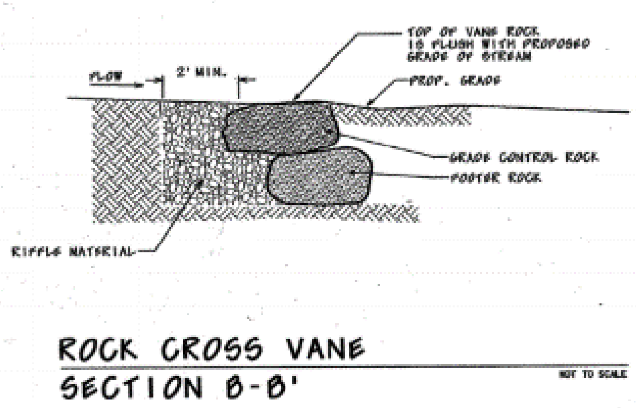
Parameters which indicate:

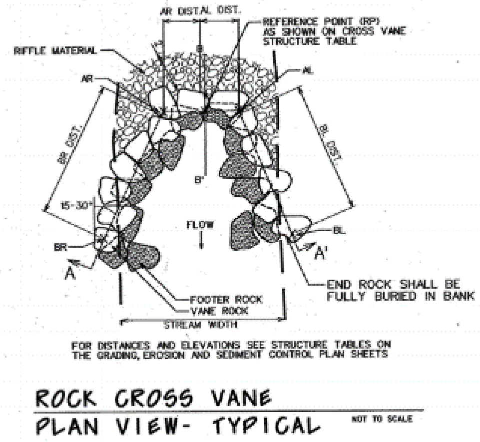
- Flow energy
- Erosion resistance
- Design approach

Correlation determined using simple and multiple linear regression and linear mixed-effects models

Structure-scale data was collected using multiple data sources.

Design Drawings

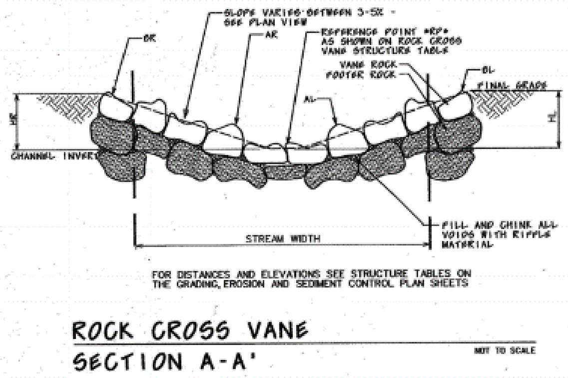




ROCK CROSS VANE STRUCTURE TABLE

RP STATION	RP ELEVATION	AL DISTANCE	AR DISTANCE	BL DISTANCE	BR DISTANCE	HL HEIGHT	HR HEIGHT
12+10	467.5	3.3'	3.3'	26.0'	13.0'	1.3'	1.3'
14+37	462.6	3.3'	3.3'	28.0'	32.0'	1.3'	1.3'
14+90	462.0	3.3'	3.3'	31.0'	16.0'	1.3'	1.3'

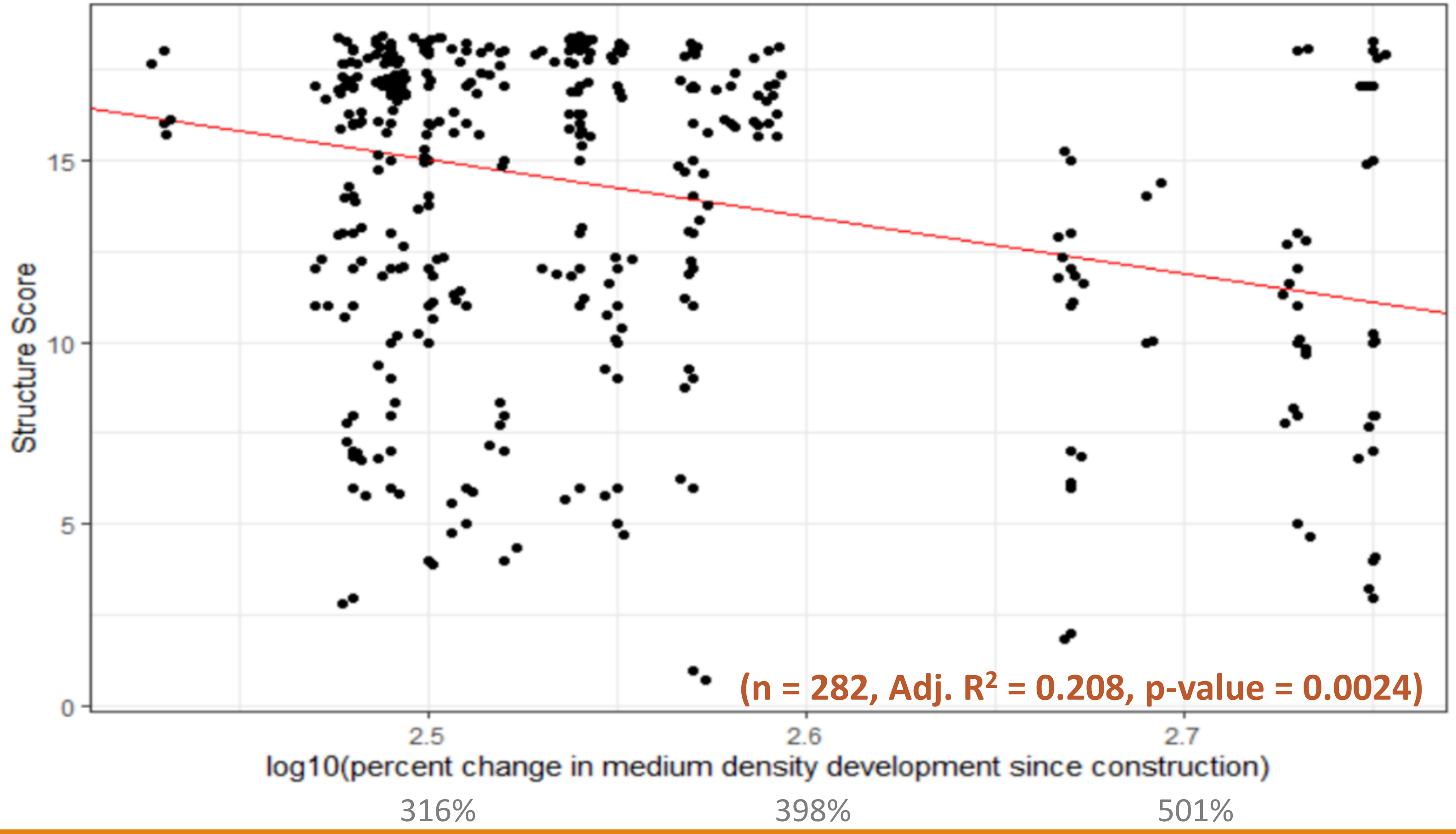
Structure Table



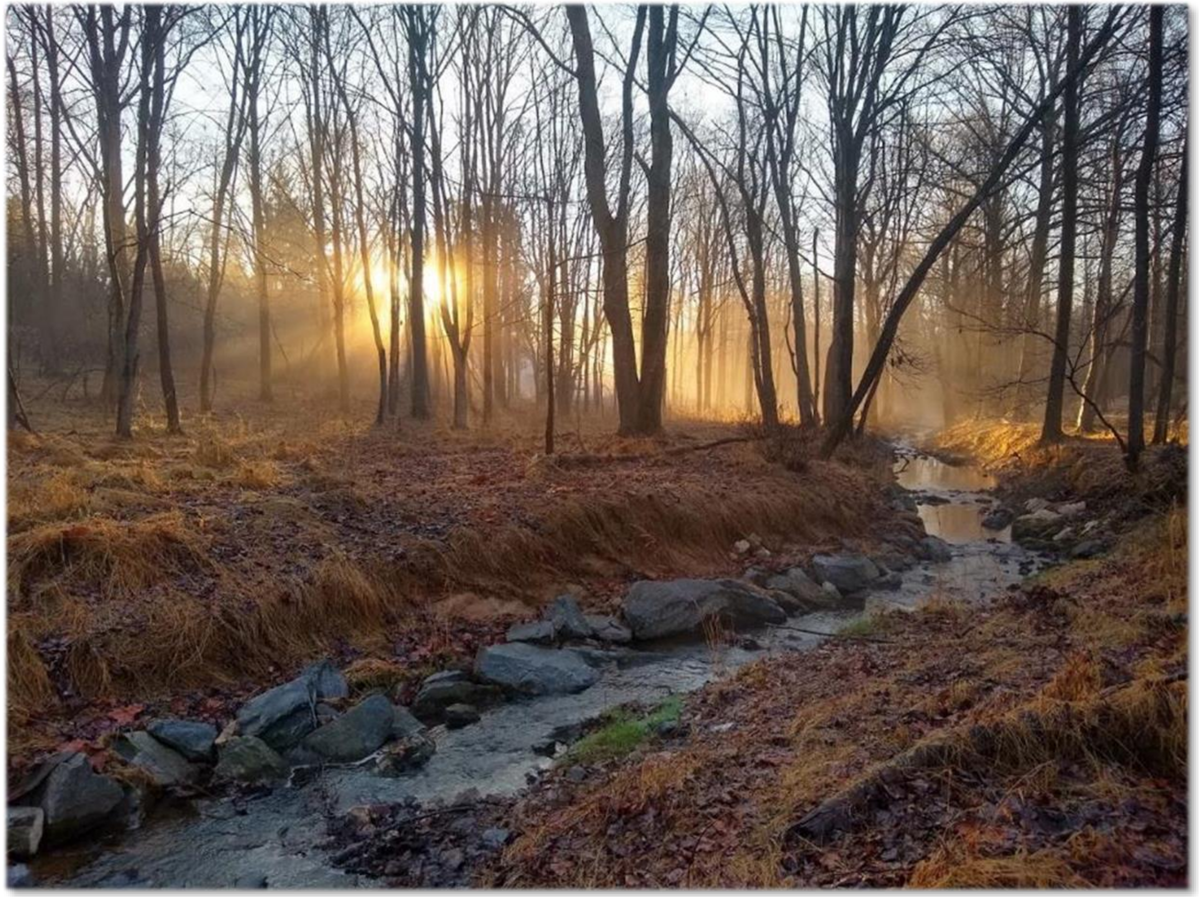
Main results…

1. Watershed factors
2. Project factors
3. Structure factors

Increased urbanization post-construction is negatively correlated with structure performance

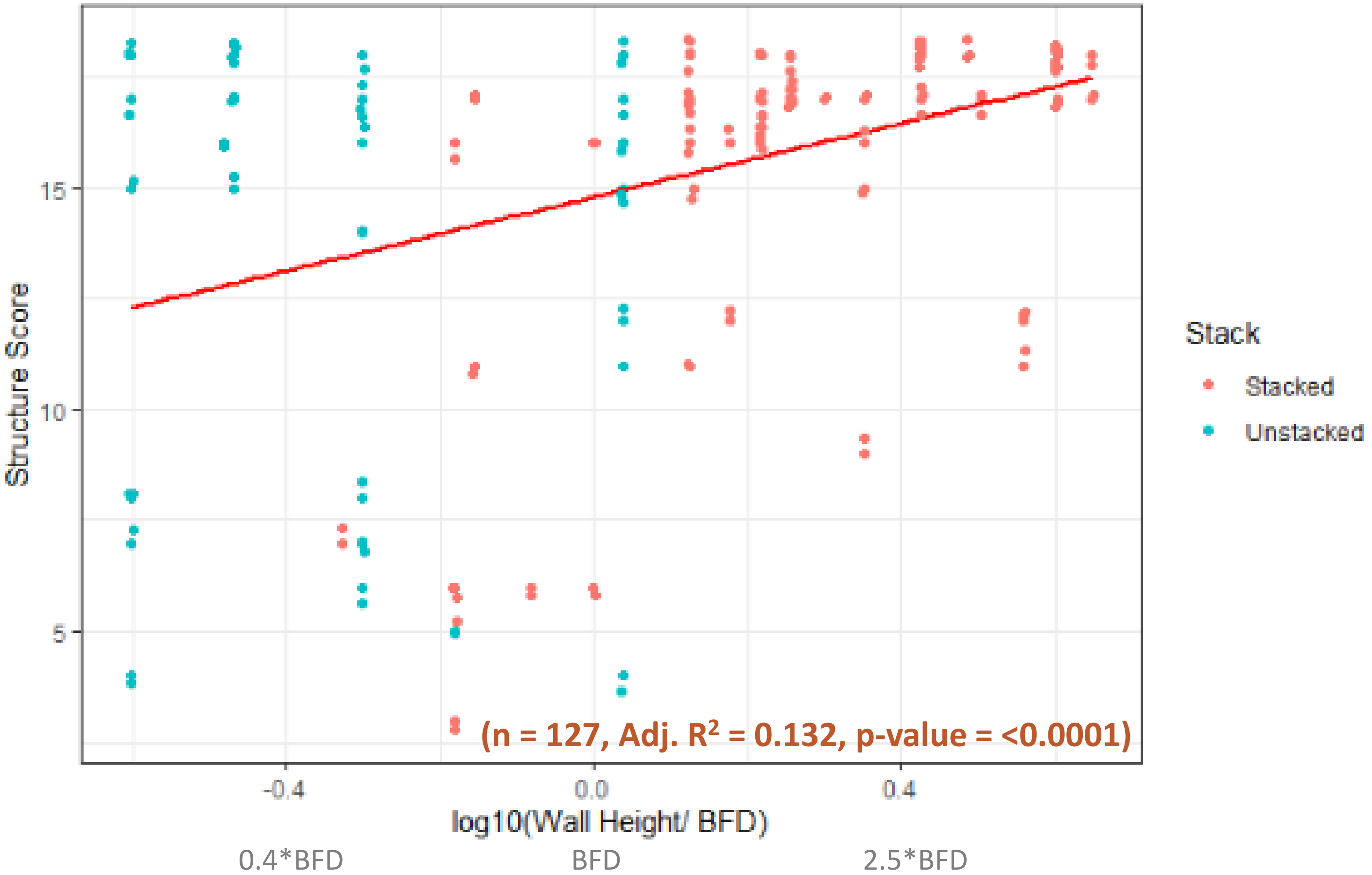


Structure performance is strongly influenced by the individual project.

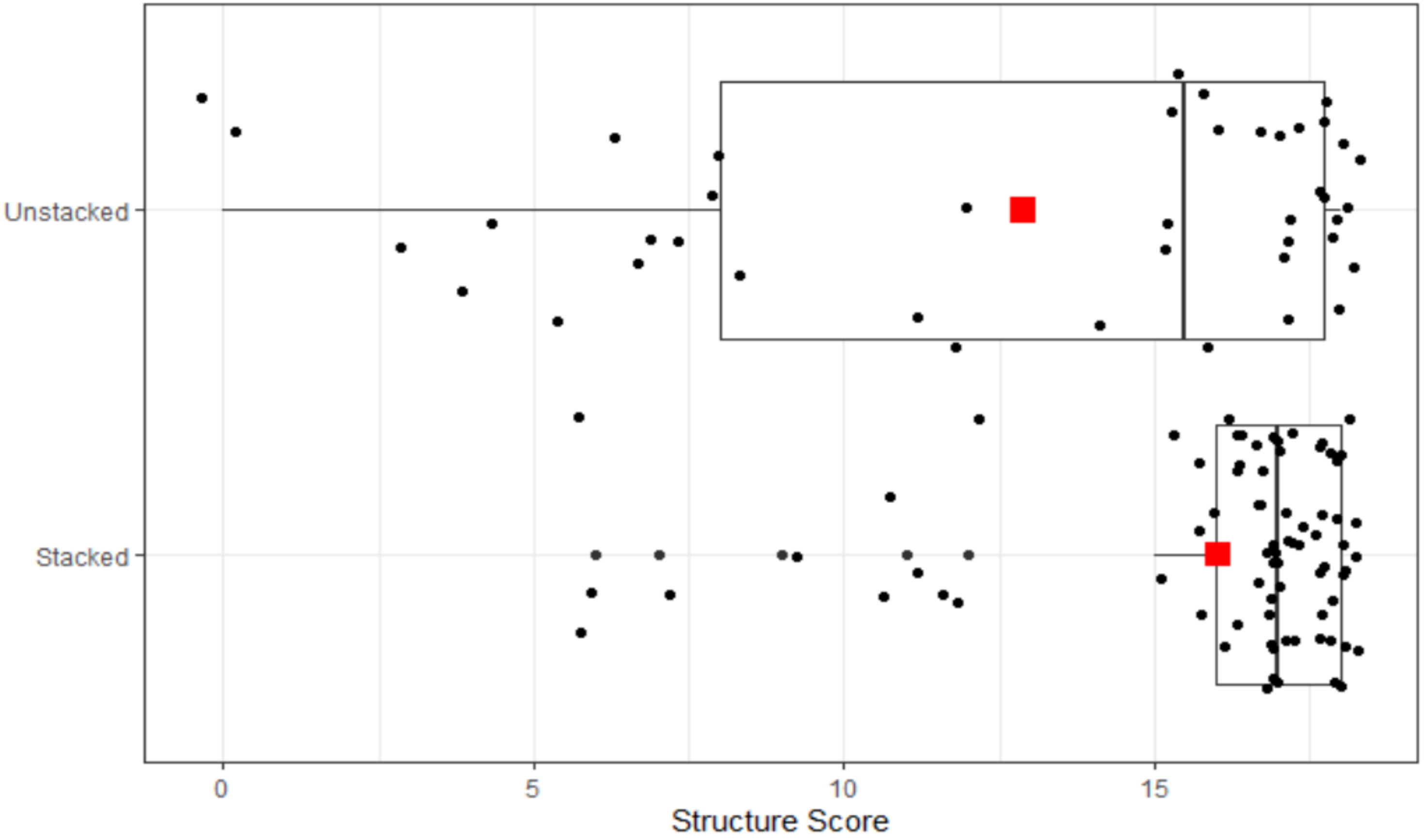


- Design quality
- Construction quality
- Vegetation
- Maintenance

Rock bank protection performance was positively correlated to wall height.



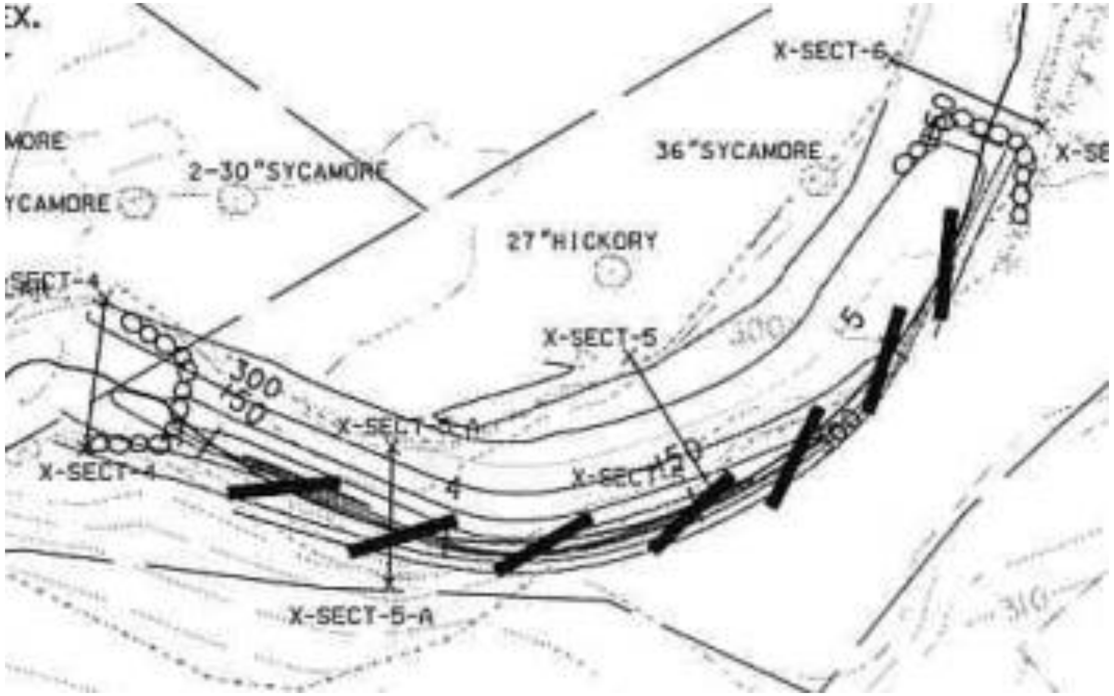
Stacked bank protection performed better than unstacked bank protection



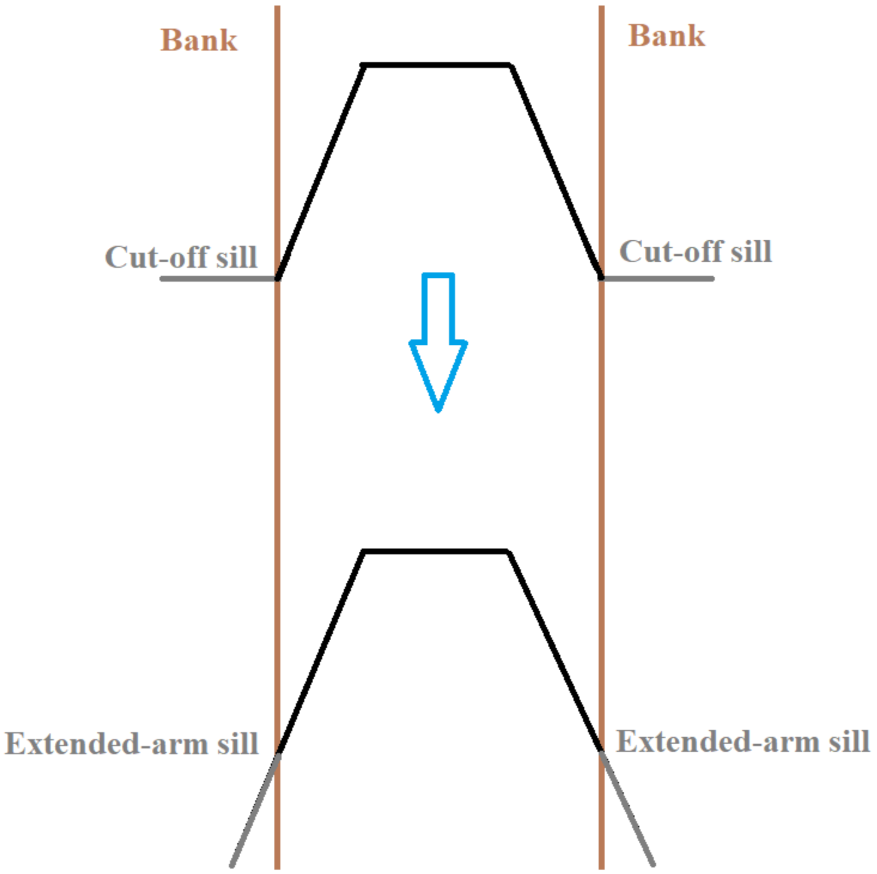
Log partial span vanes perform better when another structure is upstream.

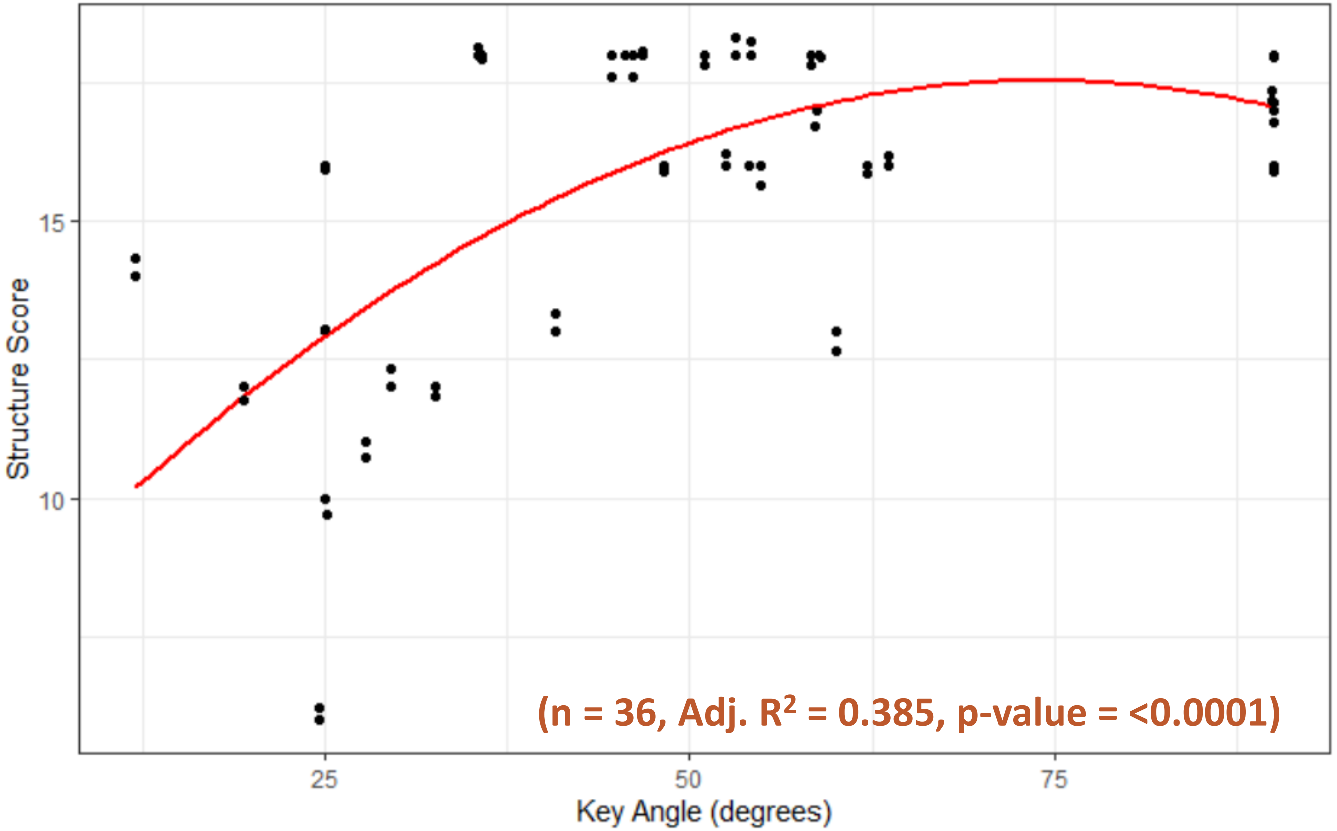
Log partial span vanes success

- ↑ with proximity to other structures
- n = 10, adj. r^2 = 0.443, p = 0.0214

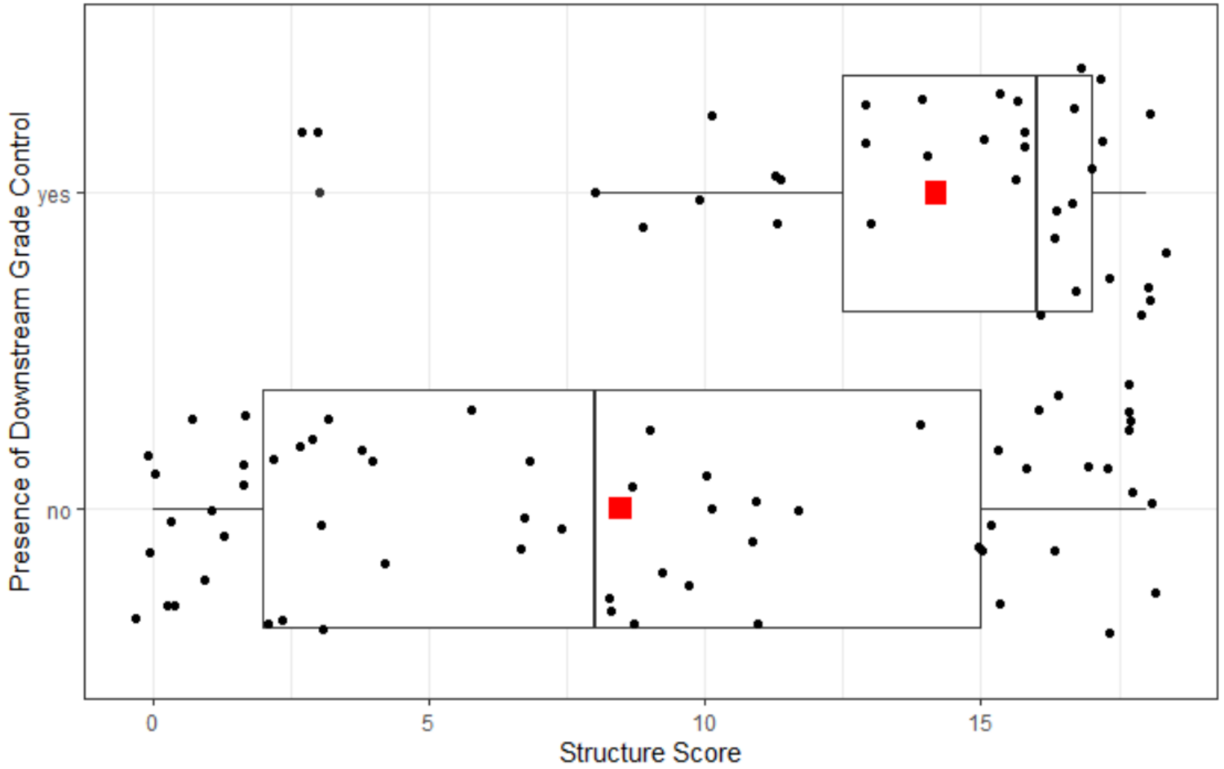


Full span vanes with angles of 35-90°between bank and sill performed better.

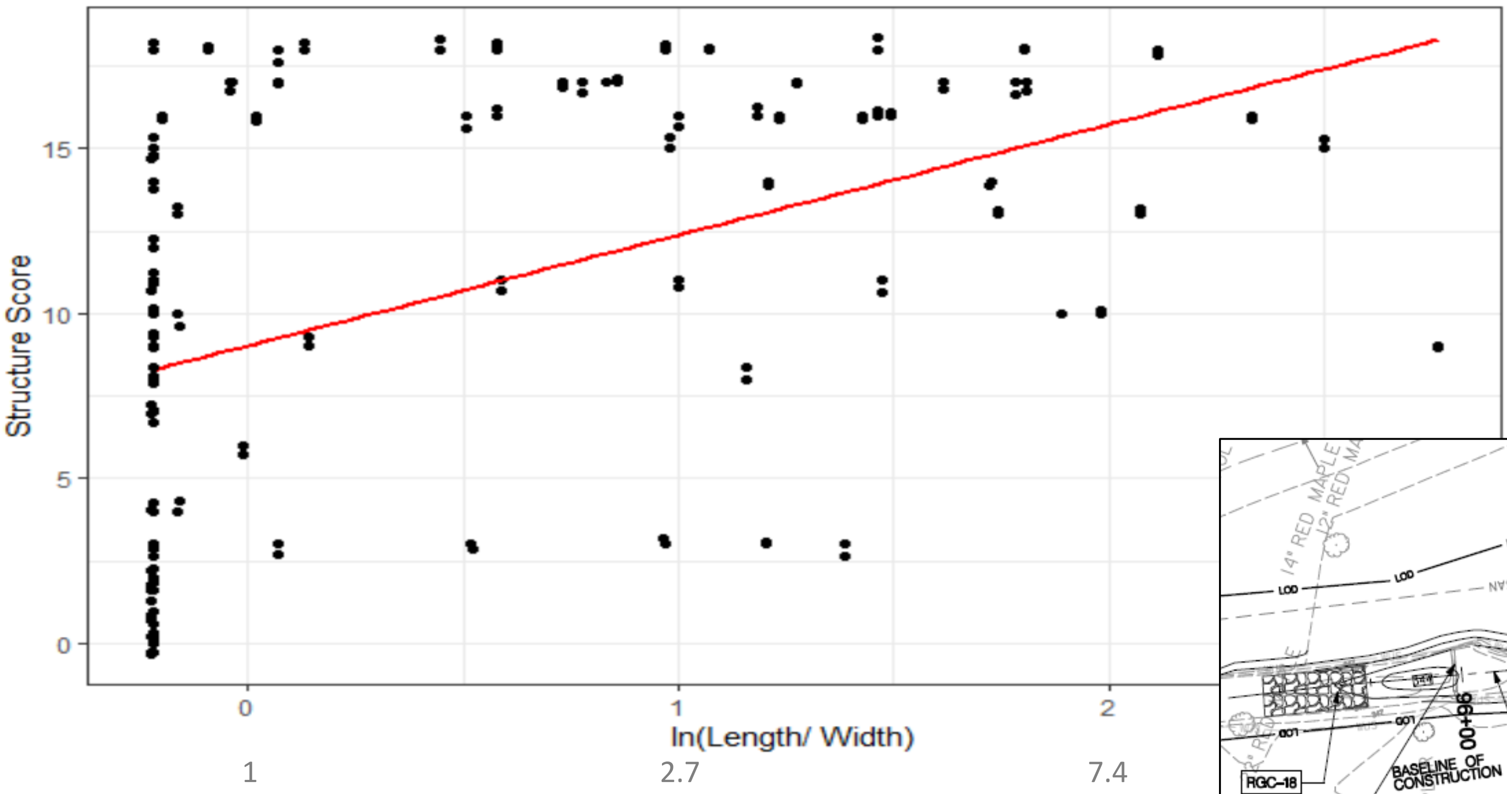


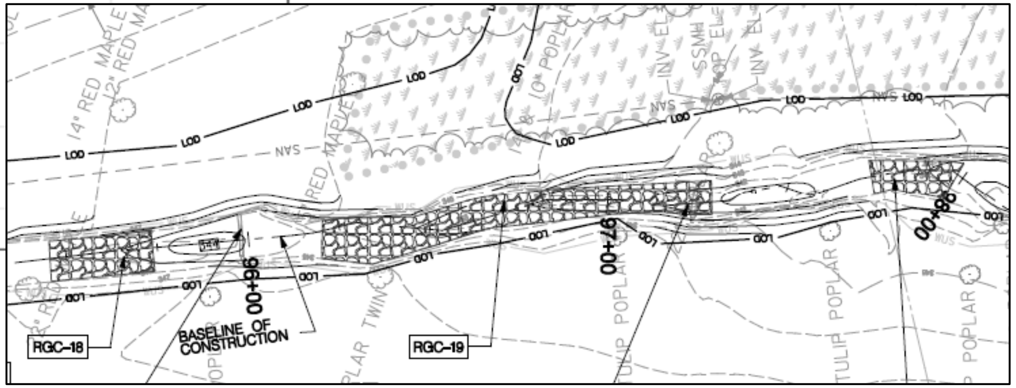


Constructed riffles with downstream grade control perform better.



Constructed riffle scores were positively correlated to the L:W and substrate depth.





(n = 75, Adj. R^2 = 0.228, p-value = <0.0001)

Study limitations

- Did not assess impact of structures on ecological function
- Structure assessment was visual
- Design variables were based on design and as-built drawings, not measured in the field
- Maintenance

Something to think about…

Clean Water Act Goal:

"restore and maintain the chemical, physical, and biological integrity of our nation's waters."

+

Streams are *highly dynamic ecosystems*.

=

Healthy streams move – use structures only when absolutely necessary.

Study 3:

Comparison of 1D and 2D HEC-RAS modeling for stream restoration design

Tess Wynn Thompson, Biological Systems Engineering

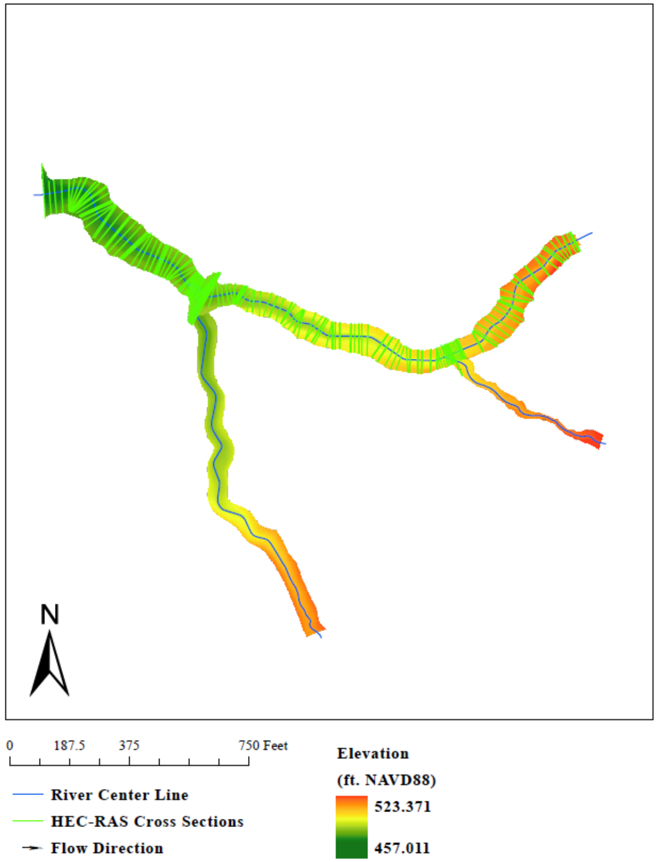
Rex Gamble, GZA, former graduate student

William Paraszczuk, RES, Former graduate student

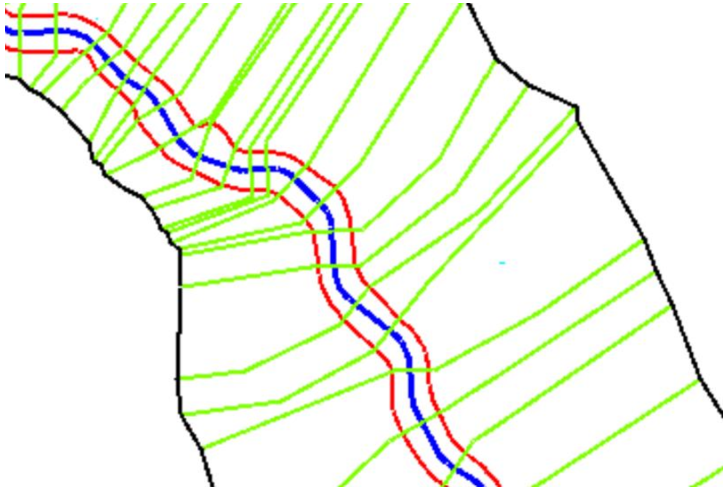
Six stream restoration projects modeled using HEC-RAS 5.07

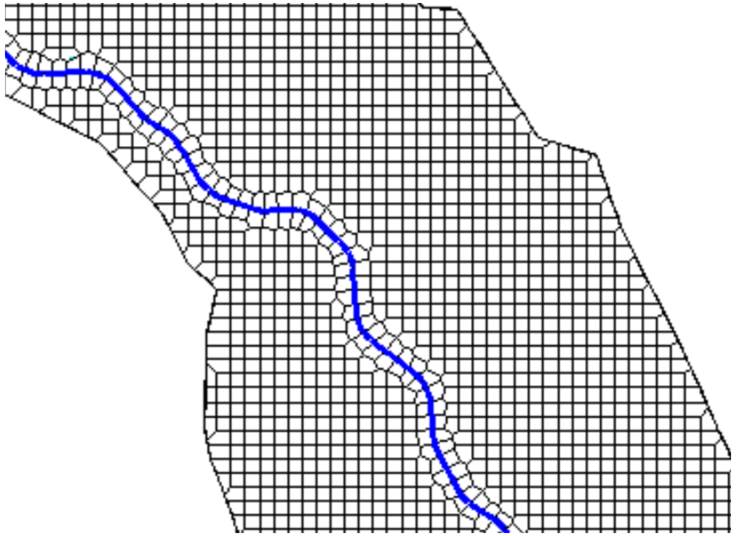
- Range of watershed sizes, types of structures
- Models for each project
  - Original FEMA model (2 projects only)
  - Steady, 1D HEC-RAS, with structures
  - Unsteady, 2D HEC-RAS with full momentum eqn.
- Modeled 100-yr discharge – worst-case scenario

Models were not calibrated, so differences between models are more important than absolute values of velocity and shear stress



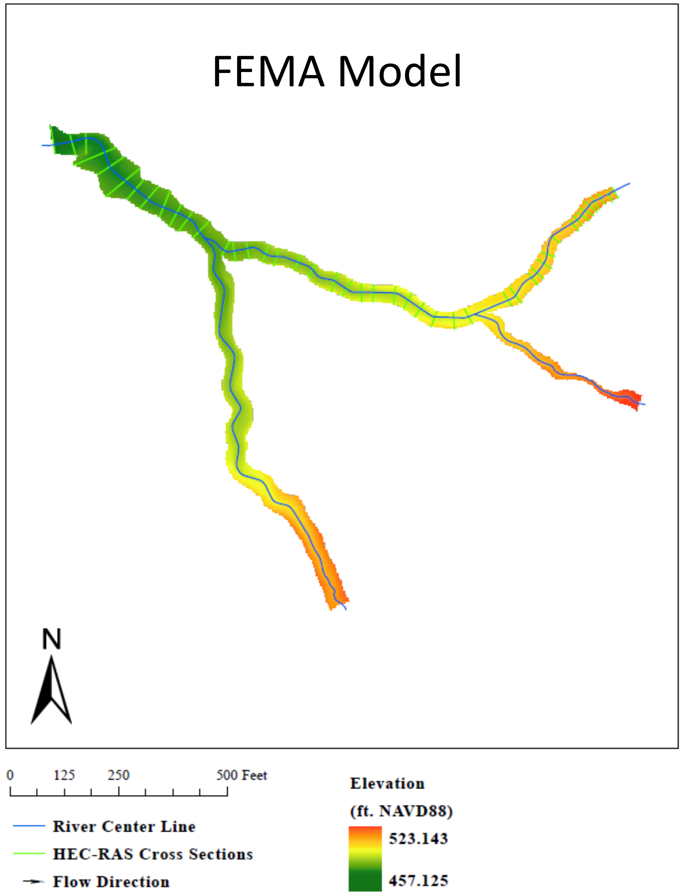
1D models view streams as a main channel and two floodplains

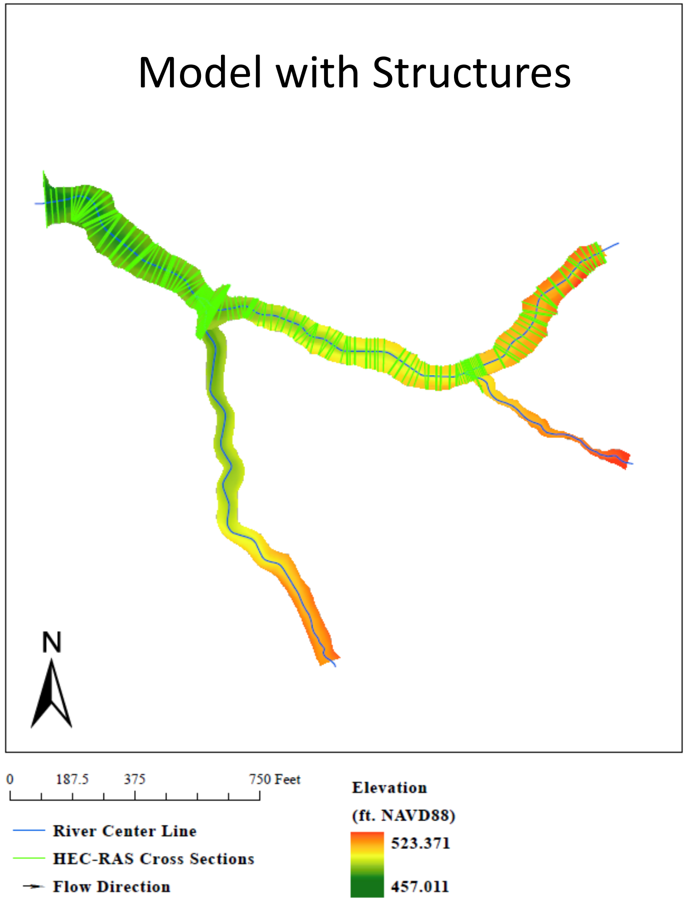




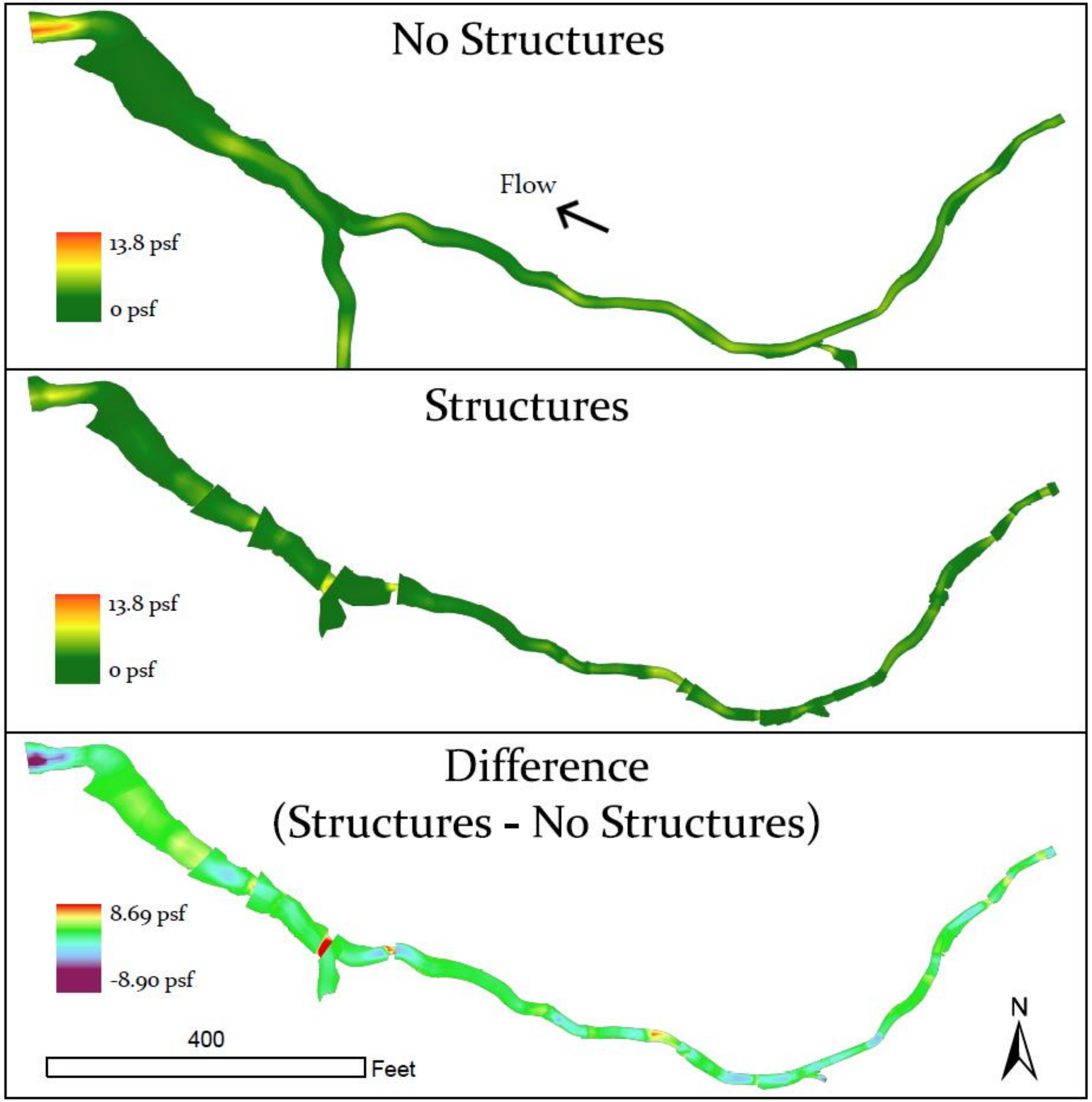
2D models view streams like a sidewalk made with pavers

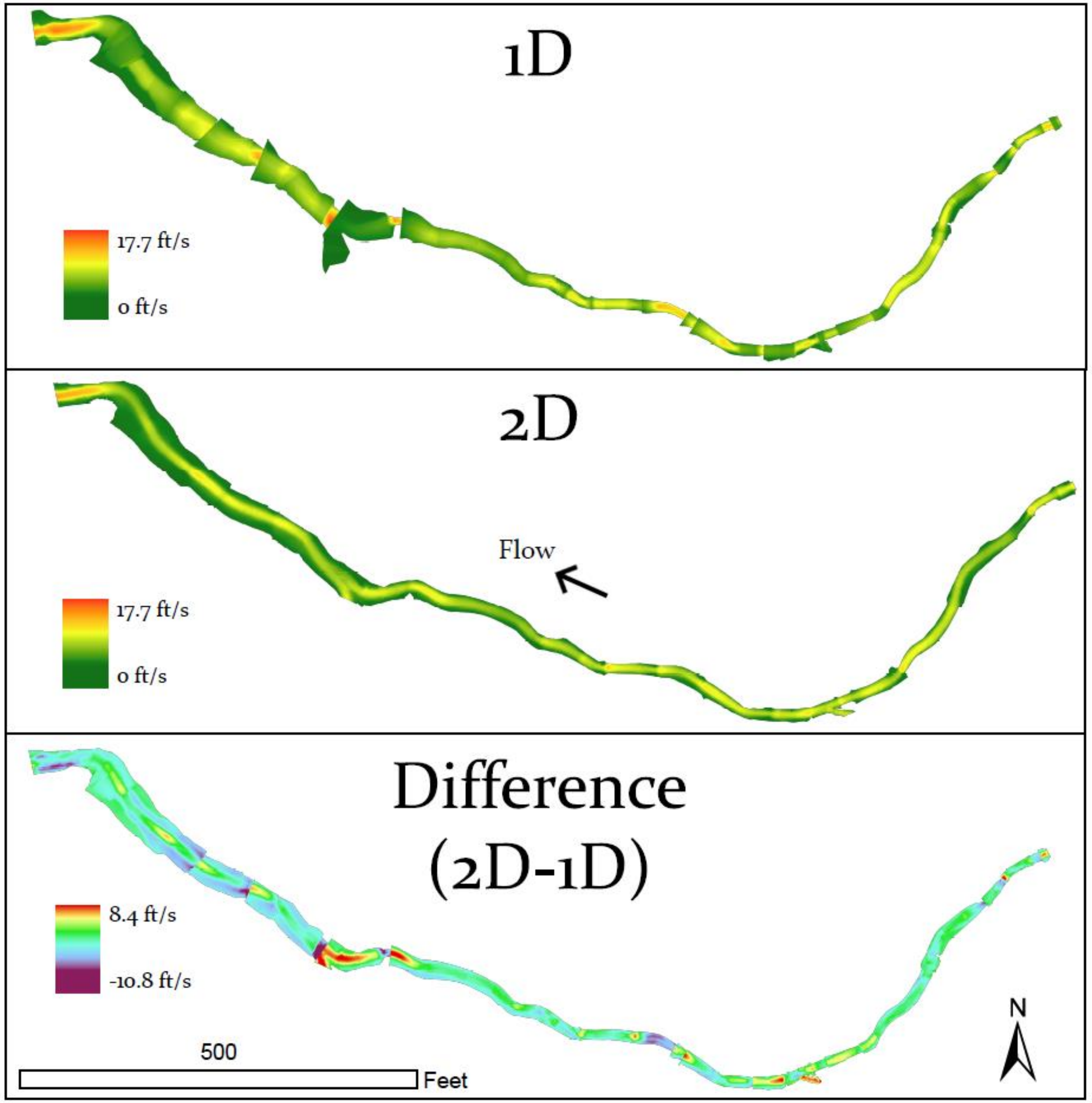
Incorporating structures into HEC-RAS required adding more cross-sections



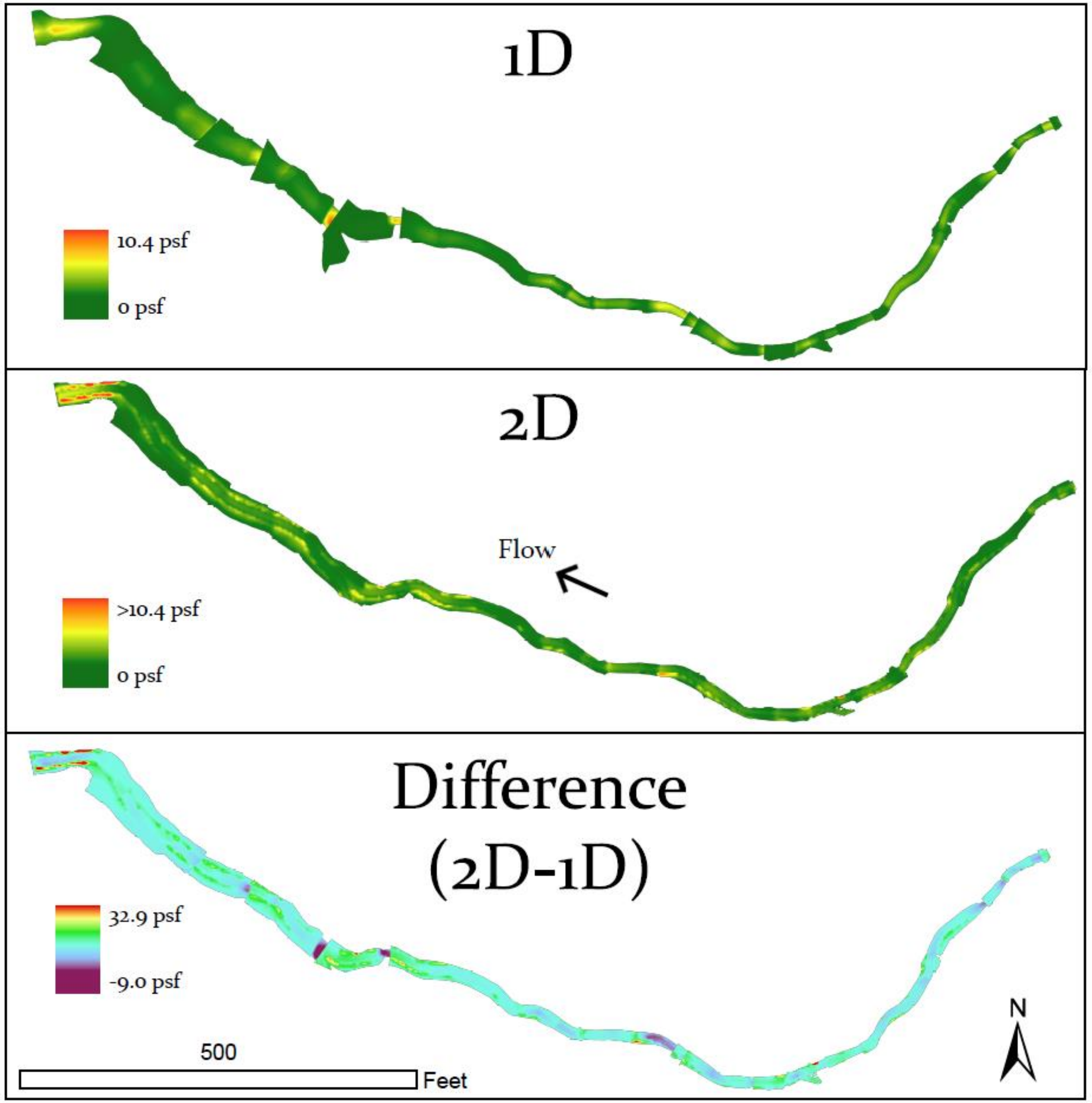


Decreased shear stress in pools and increased shear stress downstream of steps are not captured when structures are not explicitly included in HEC-RAS 1D models.



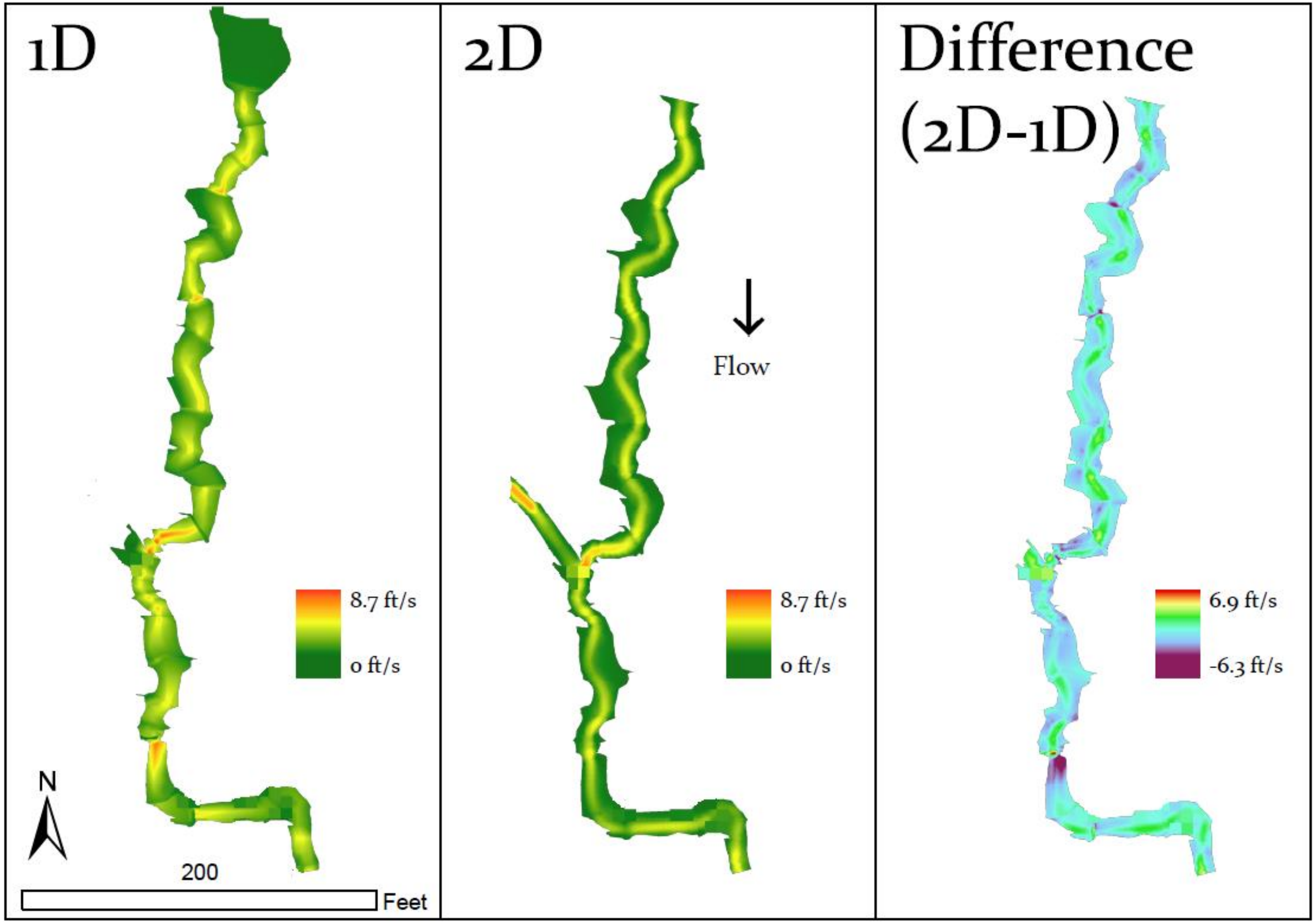


The 2D model better represented higher velocity in the center of the channel.



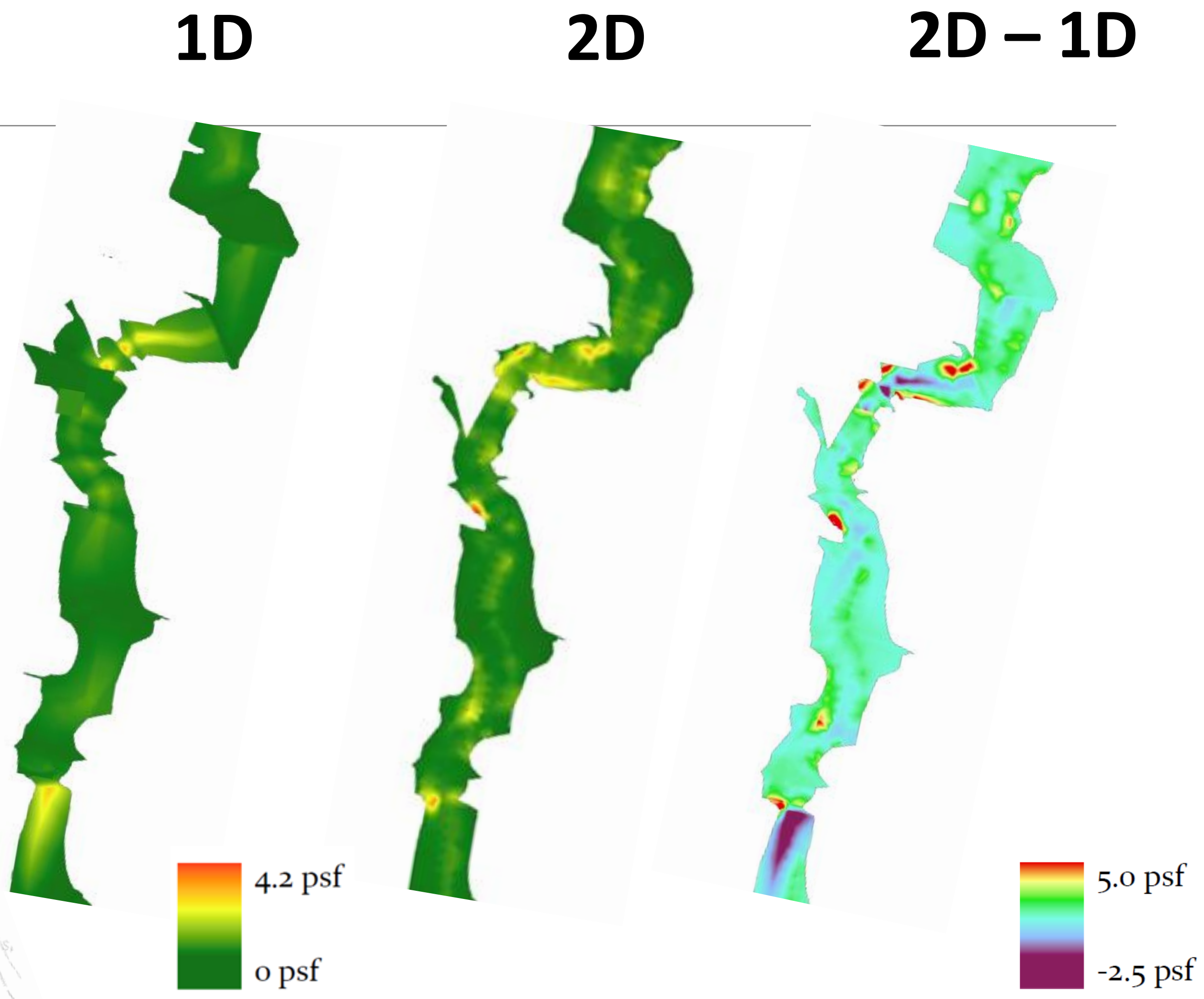
The 2D model better represented higher shear stress at the channel-floodplain interface.

Taking a closer look…

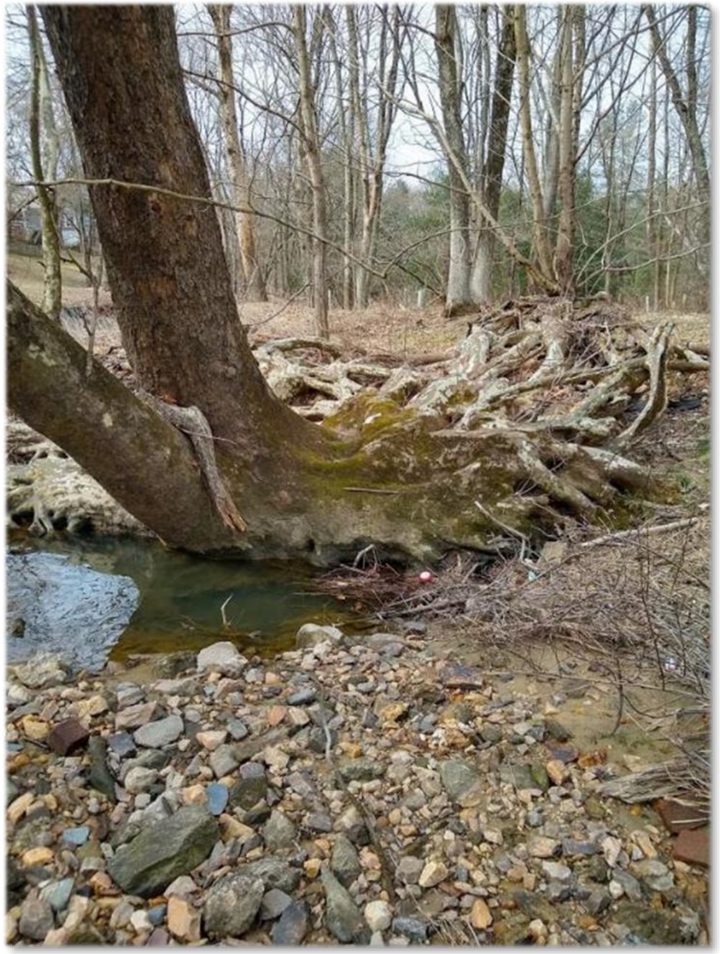


TRIBUTARY 5
BASELINE OF CONSTRUCTION
PERPETUAL EASEMENT FOR STREAM STABILIZATION

Max shear stress in psf



Questions?

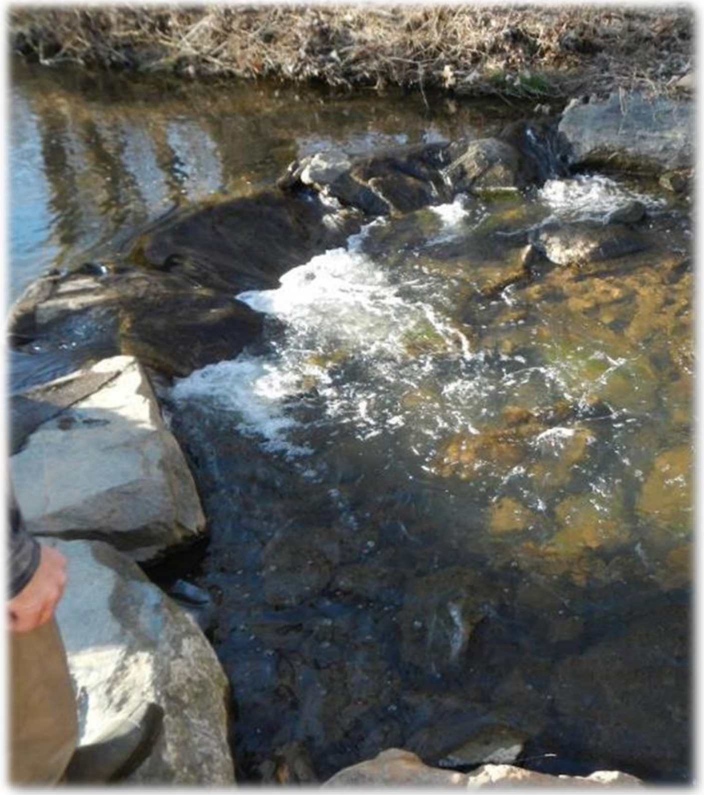


Study 2 research take-aways…

- Design in urban/urbanizing watersheds is challenging
- Avoid reliance on structures when possible
- Structure performance is dependent on the project as much as the design of individual structures
- Imbricated rock walls are more durable than stone toe
- Vane-type structures should be keyed into the bank at angles of 35-90°
- Constructed riffles with higher L:W, downstream support, and deeper substrate depth last longer

Observation: Rock structures are frequently used to hold streams in a specific form and to force habitat features.

Study 3 research take-aways…

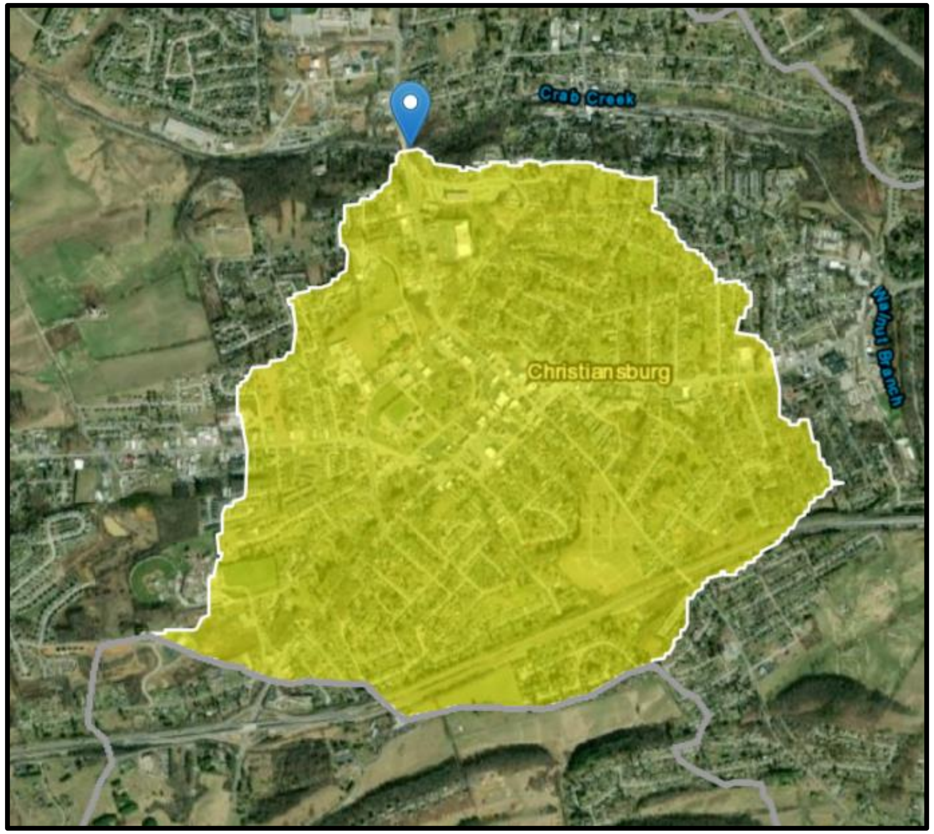


- 1D models
  - Representing structures requires the addition of a large number of cross sections
  - Localized areas of high/low velocity and shear stress are not captured unless structures are explicitly included in models
  - The structures produce a jagged flood extent as a result of rapidly changing cross sections through cross vanes and step pools
- 2D models
  - Best represent areas of localized increases in velocity and shear stress
  - Level of effort has decreased significantly with ability of HEC-RAS to use digital terrain models

Watershed-scale explanatory variables relate to flow energy and erosion resistance.

Flow energy

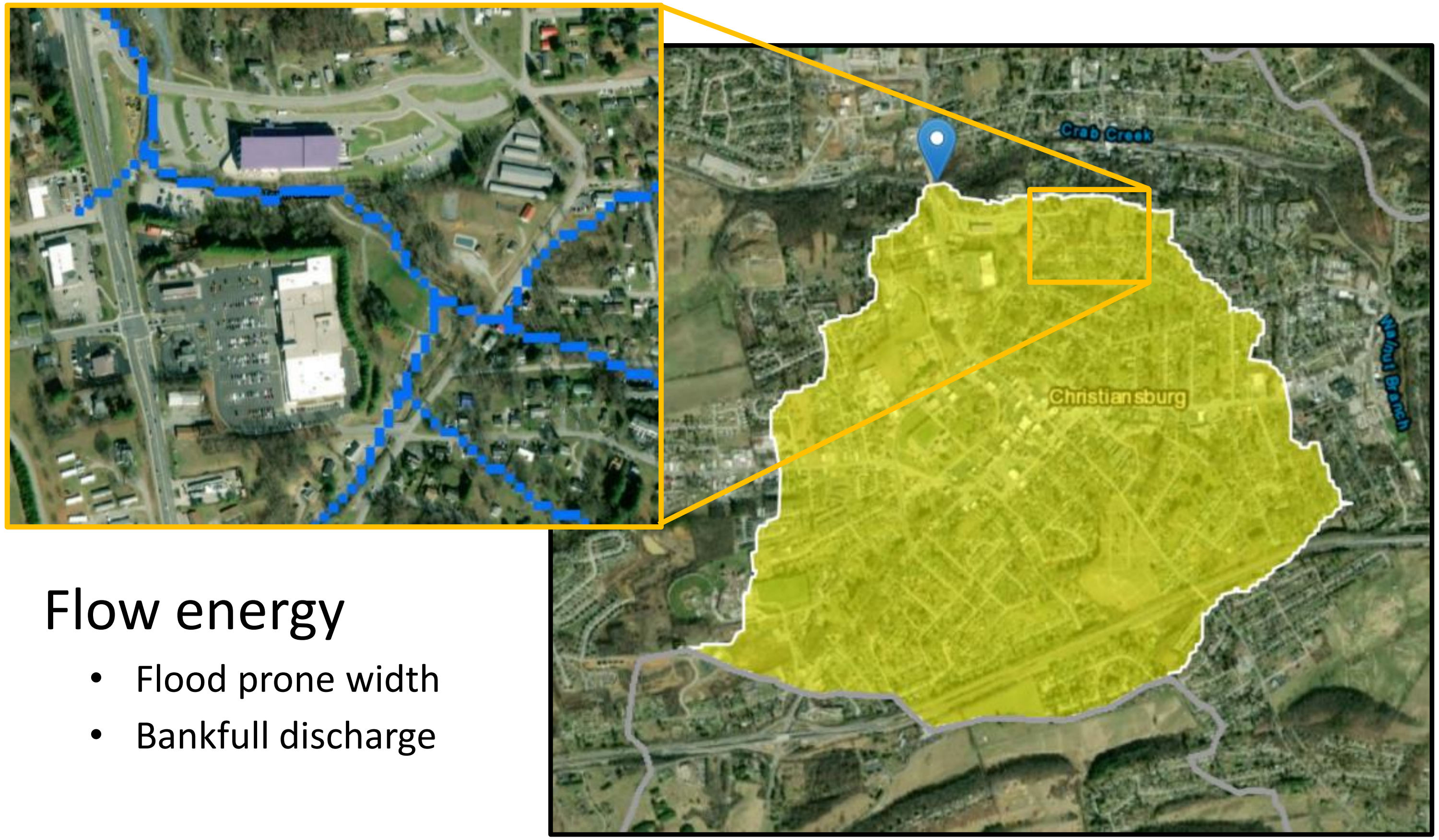
- Watershed area
- Stormwater BMP density
- Channel slope
- Land use
- Change in land use



Erosion resistance

- Watershed soil erodibility
- Streambank soil erodibility

Project-scale explanatory variables relate to flow energy, erosion resistance, and design approach.



Flow energy

- Flood prone width
- Bankfull discharge

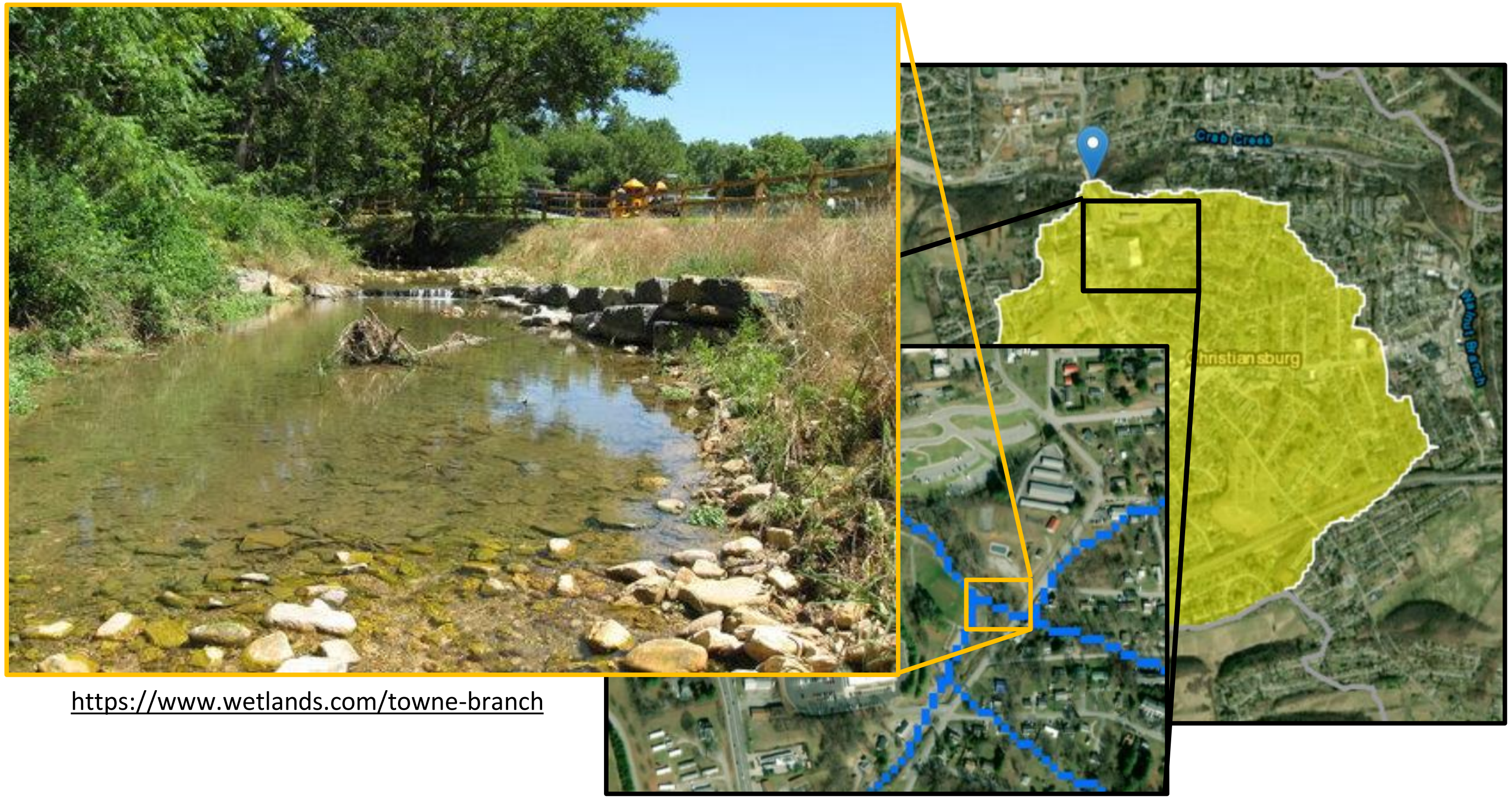
Design approach

- Structure density
- Channel slope/sinuosity
- Width:Depth

Erosion resistance

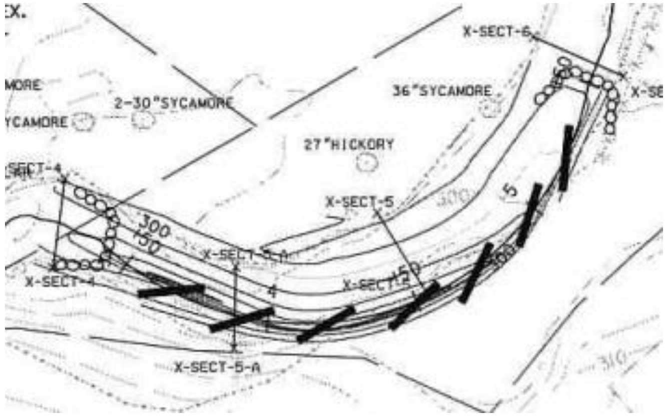
- Project bank erodibility
- Riffle D_{50}
- Upstream and downstream grade control

Structure-scale explanatory variables related to the design and placement of structures.



https://www.wetlands.com/towne-branch

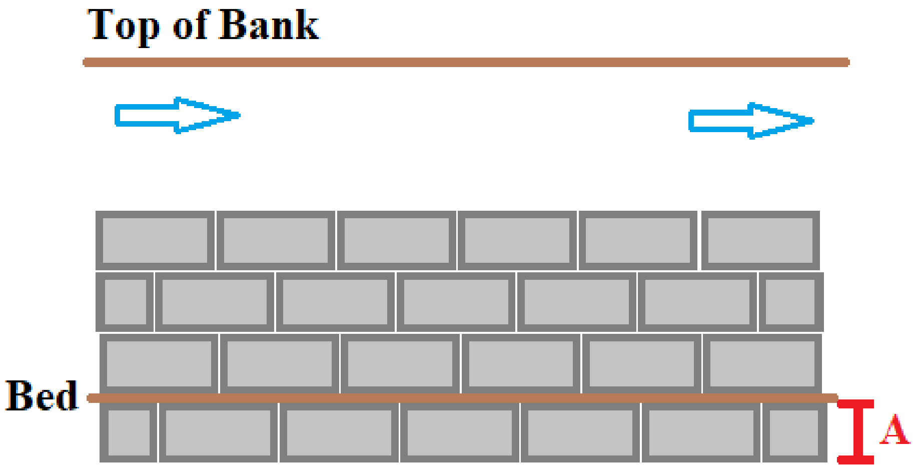
Certain structure-scale predictors relate to properties common to all structures.



Proximity to other structures

Location in channel

- Planform location
- Bankfull width
- Bankfull depth



Design

- Material type and size
- Footer depth (A)