Legacy Sediment Removal and the Big Spring Run Restoration Project

Cost-Effective Aquatic Ecosystem Restoration

Pennsylvania
Department of Environmental Protection

Pennsylvania Legacy Sediment Workgroup

Jeffrey Hartranft

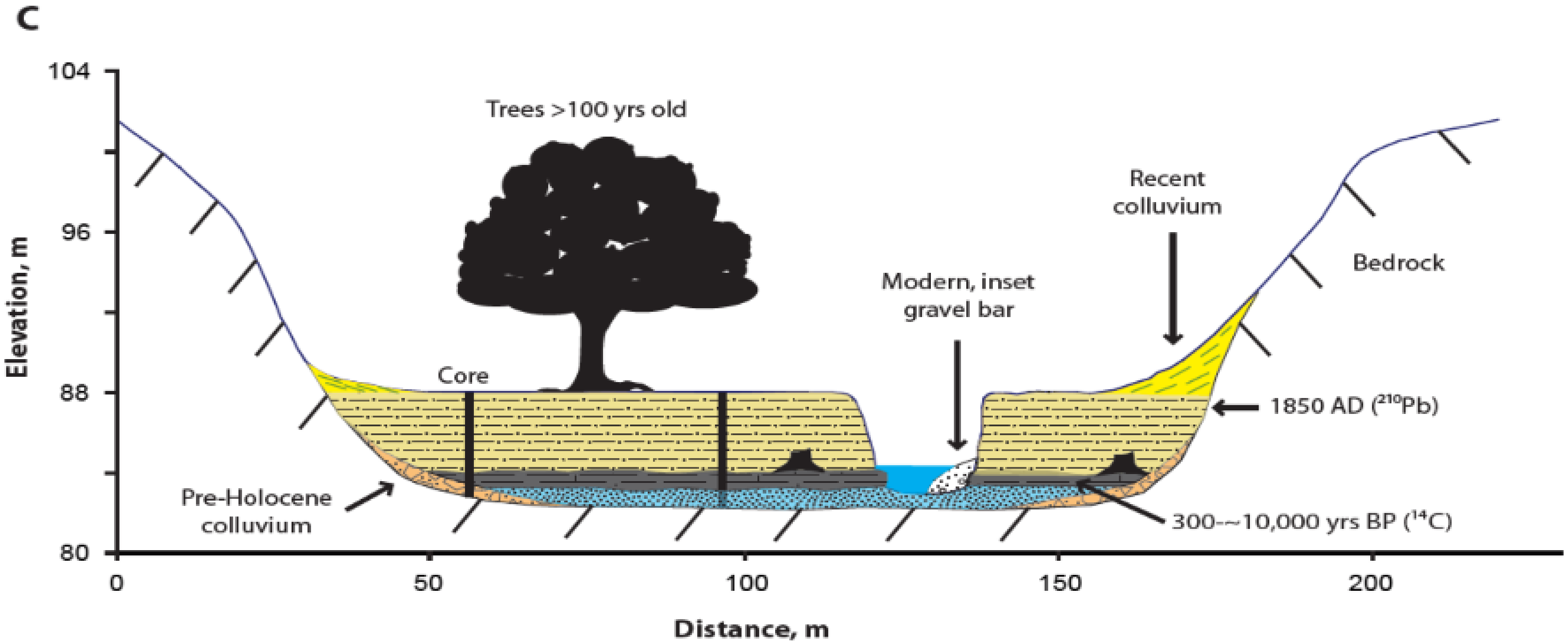
Bureau of Waterways Engineering and Wetlands

Division of Wetlands Encroachment and Training

jhartranft@pa.gov; 717-772-5320

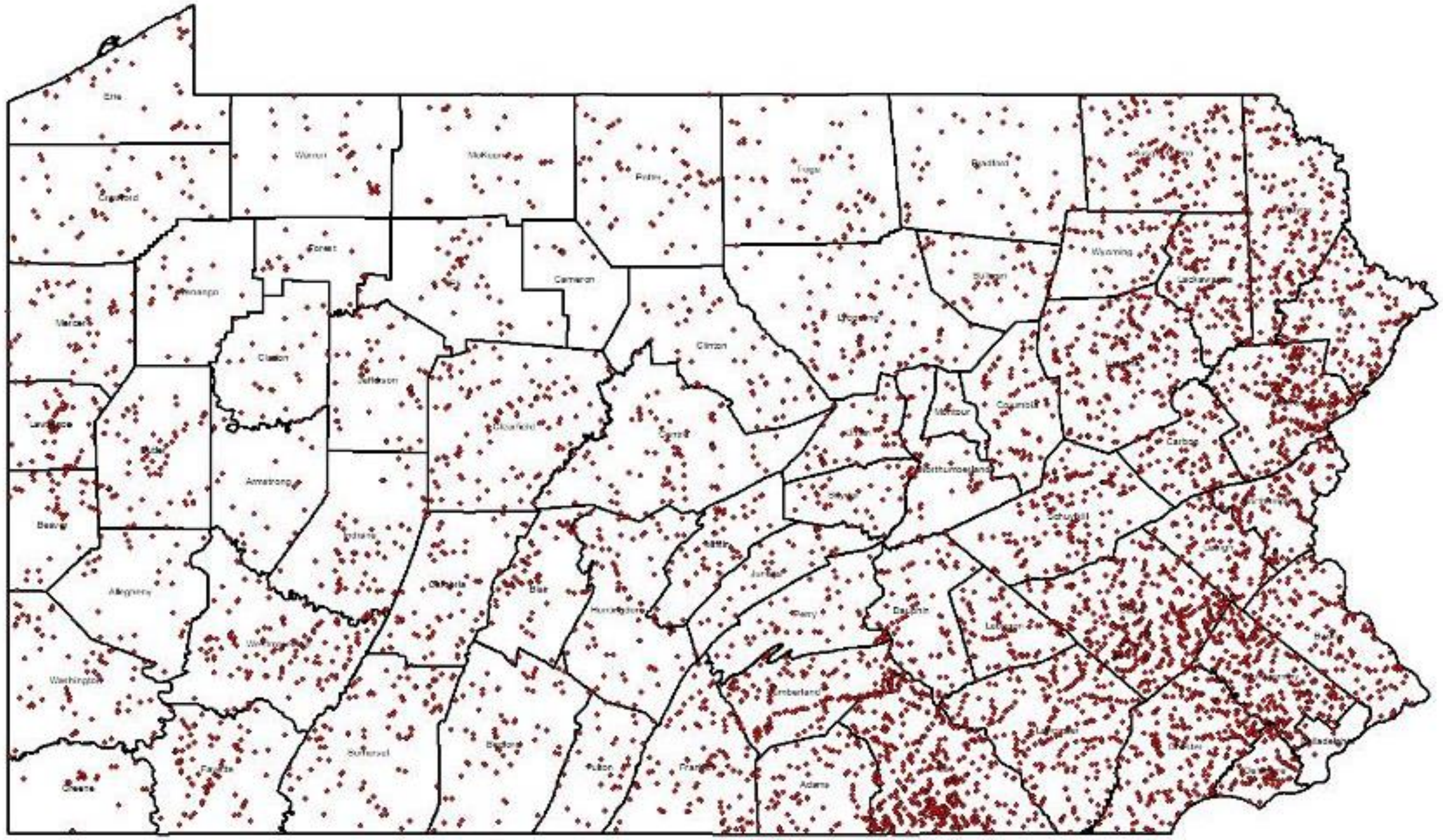
Presentation Outline

- Ecological restoration principles applied to legacy sediment impairments
- Big Spring Run test case and monitoring
- Geomorphology/physical results
- Water quality/chemical results
- Living resources/biological results
- Cost-effectiveness analysis



Walter and Merritts, 2008

Known Breached Dams In Pennsylvania



Source: PA Dam Inventory 1913-2023

Principles for the Ecological Restoration of Aquatic Resources (EPA841-F-00-003)

US Environmental Protection Agency Washington, DC. 2000.

- Intended for use by a wide variety of organizations and people
- Specific to aquatic ecosystem restoration projects
- Focused on scientific and technical issues

http://www.epa.gov/owow/wetlands/restore/

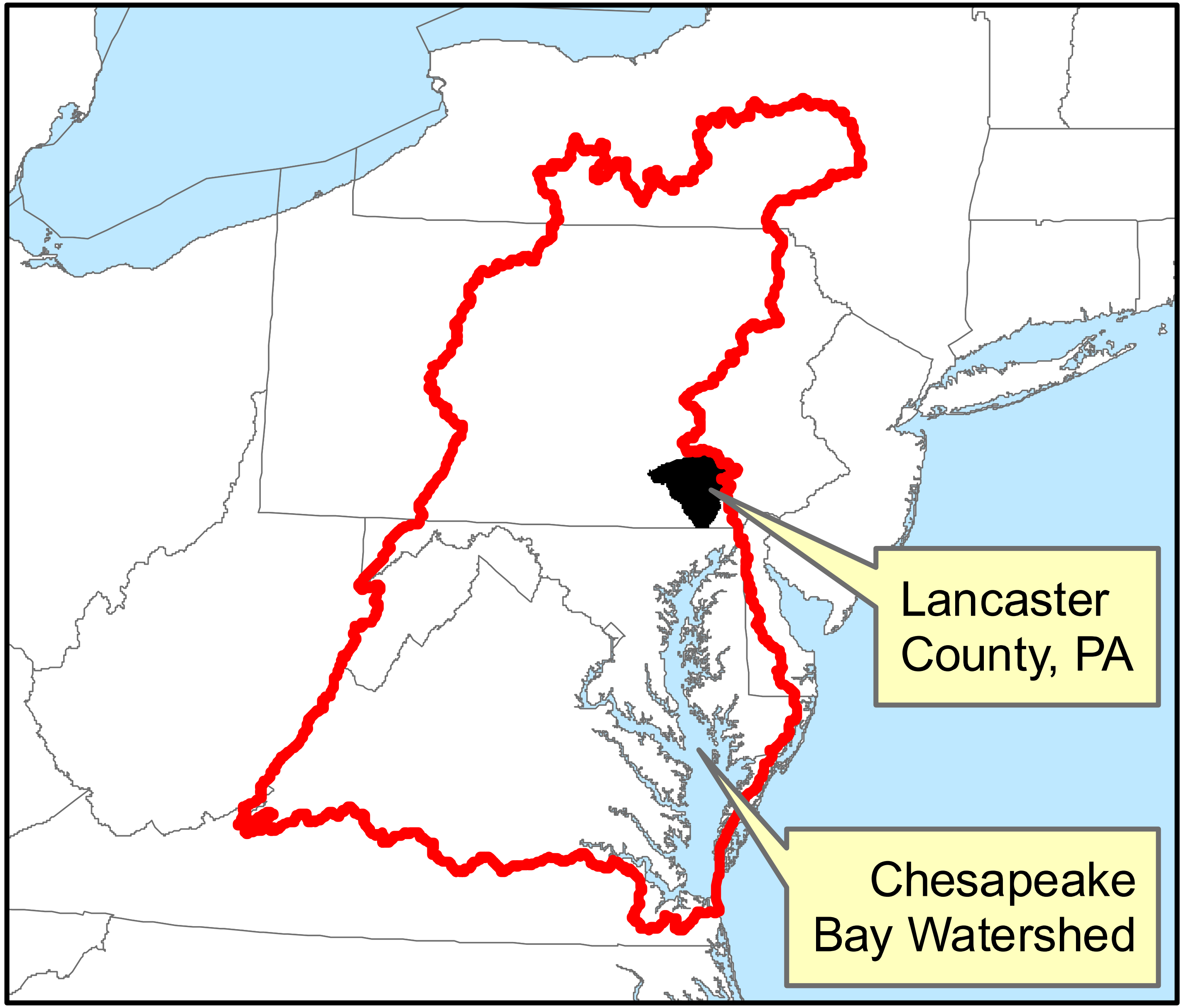
Involve multi-disciplinary skills and insights

- Restoration can be a complex undertaking that integrates a wide range of disciplines
- Universities, government agencies, and private organizations may be able to provide useful information and expertise
- Complex projects require effective leadership to bring viewpoints, disciplines and styles together as a functional team

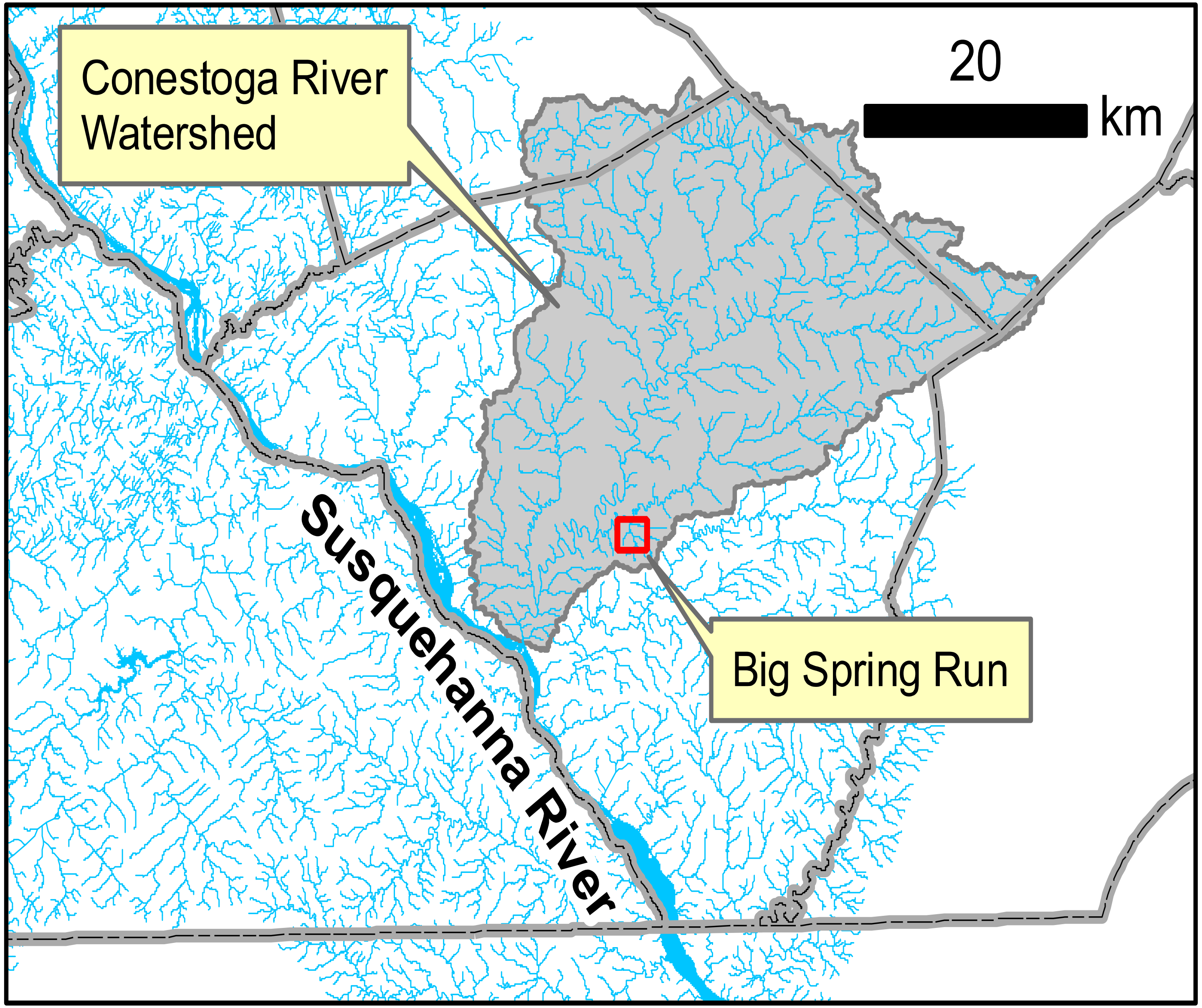
Principles for the Ecological Restoration of Aquatic Resources (EPA841-F-00-003)

Big Spring Run Legacy Sediment Removal and Aquatic Ecosystem Restoration Project

- A multidisciplinary team planned, designed, constructed and monitored this restoration project beginning in 2008 through present
- Team members included a wide range of scientific and technical disciplines
- Project sponsors included governments, academic institutions, non-profits, landowners and other private entities

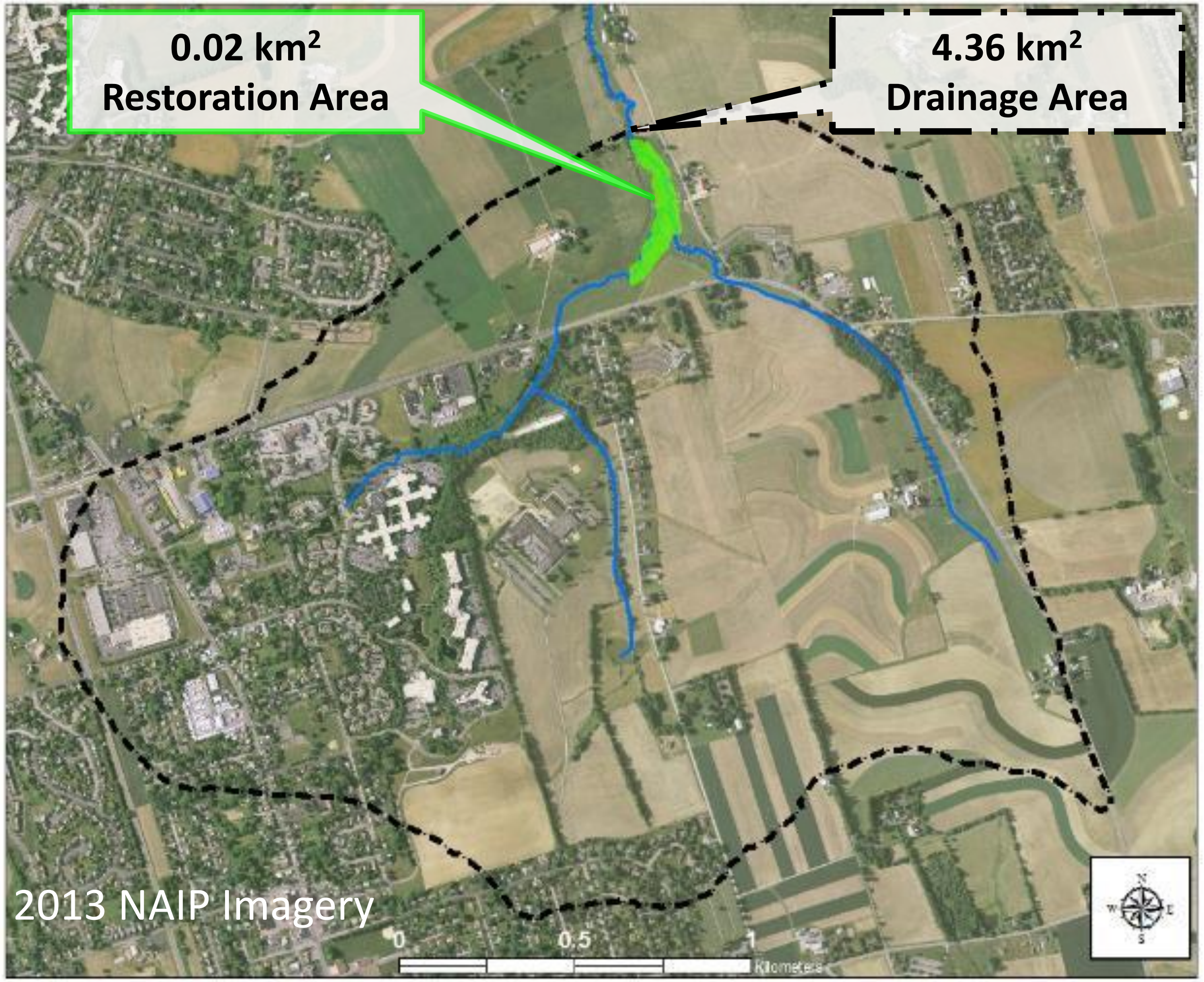


Courtesy Franklin & Marshall College



Courtesy Franklin & Marshall College

Watershed and Restoration Area



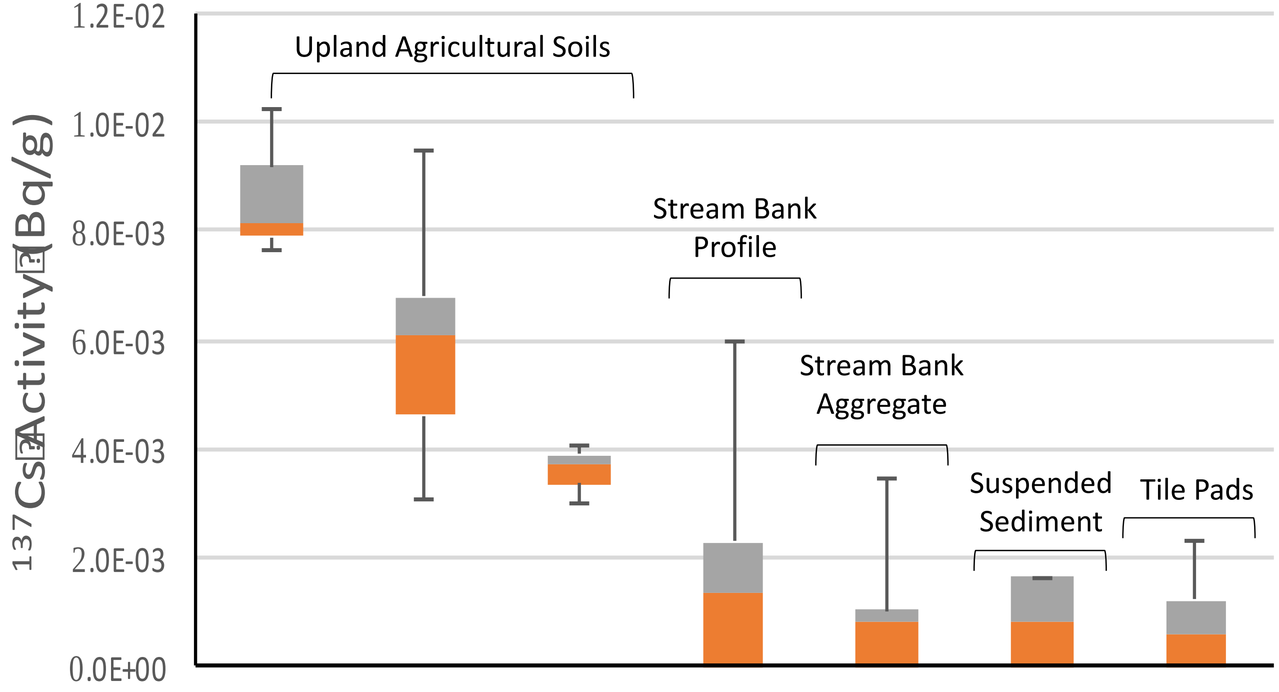
The ratio of restoration area to drainage area < 0.5%

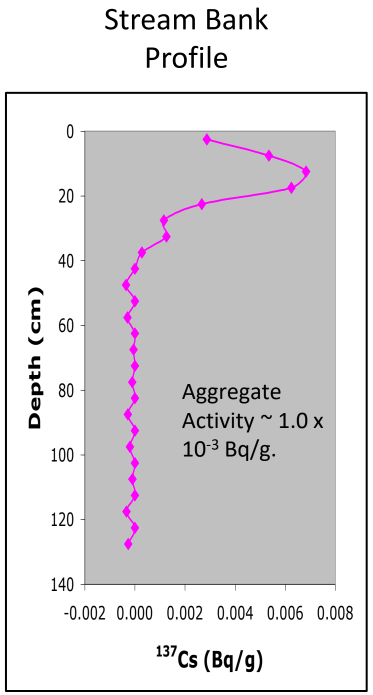
Monitor

- Before, during, and after project monitoring is used to evaluate goal and objective achievement
- Continuous at Big Spring Run from 2008 through present
- Data gathered may be useful for model development and predicting results when scaling up in size
    1. **developing and defining a new BMP**
    2. **estimating nutrient reductions**
    3. **cost-effectiveness analysis**

Principles for the Ecological Restoration of Aquatic Resources (EPA841-F-00-003)

Pre-restoration sediment source identification by landscape position using ^{137}Cs activity in Big Spring Run





Conclusion:

^{137}Cs radiotopic isotopes from pre-restoration suspended sediment and tile pad deposition are consistent with a sediment source entirely from stream bank erosion

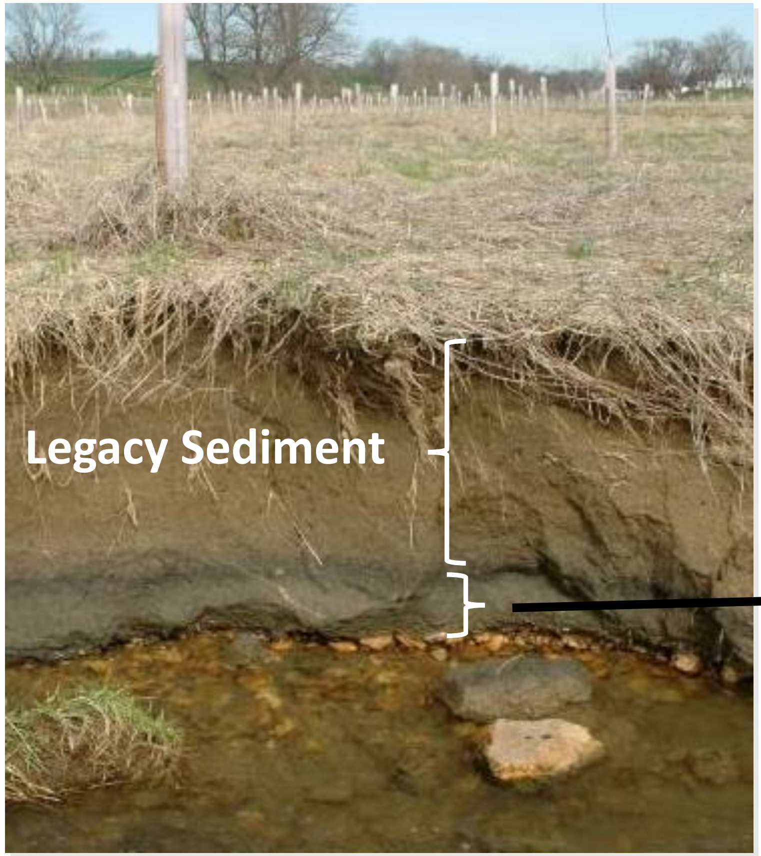
Walter et. al., 2017; Bai 2017 (Franklin & Marshall College Thesis)

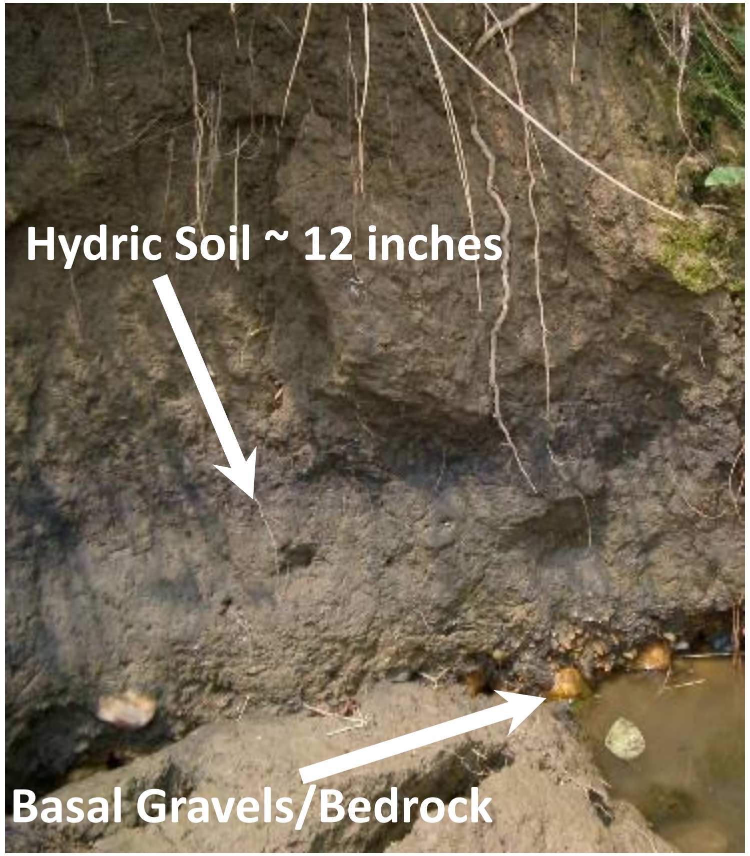
Utilize a reference (analogs)

- **Identifying natural reference characteristics are essential to ensure project success.**
- Channels incised through legacy sediment, are not natural analogs in the mid-Atlantic Region (Walter and Merritts, 2008).
- **Use historic information on altered sites.**

Principles for the Ecological Restoration of Aquatic Resources (EPA841-F-00-003)

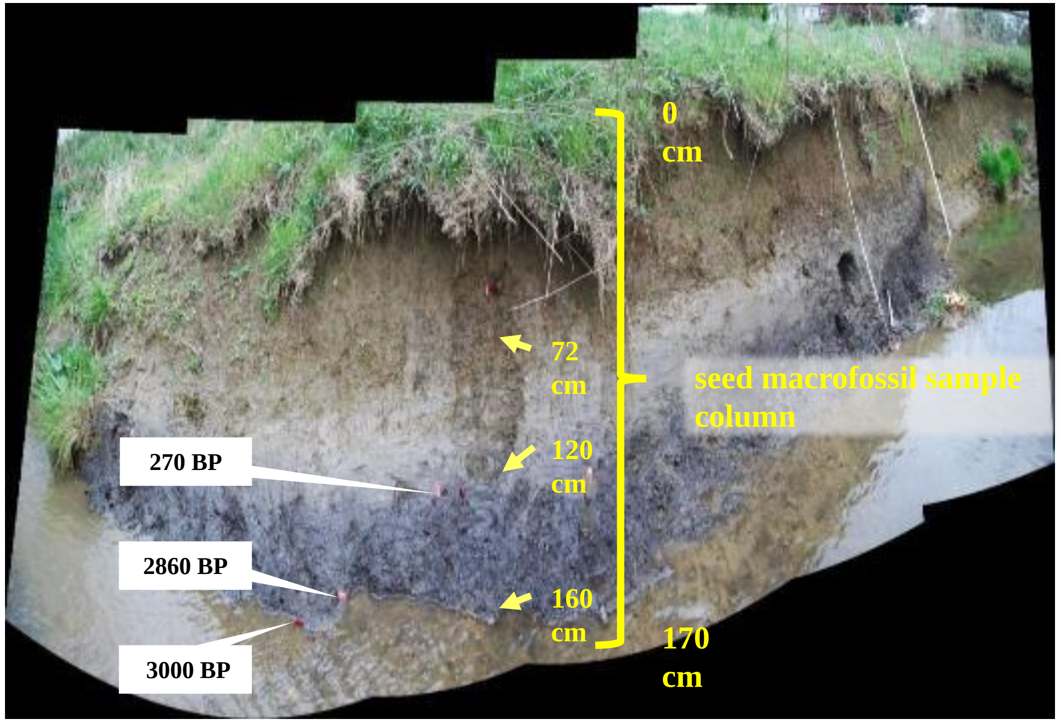
Big Spring Run In-situ Reference Characteristics



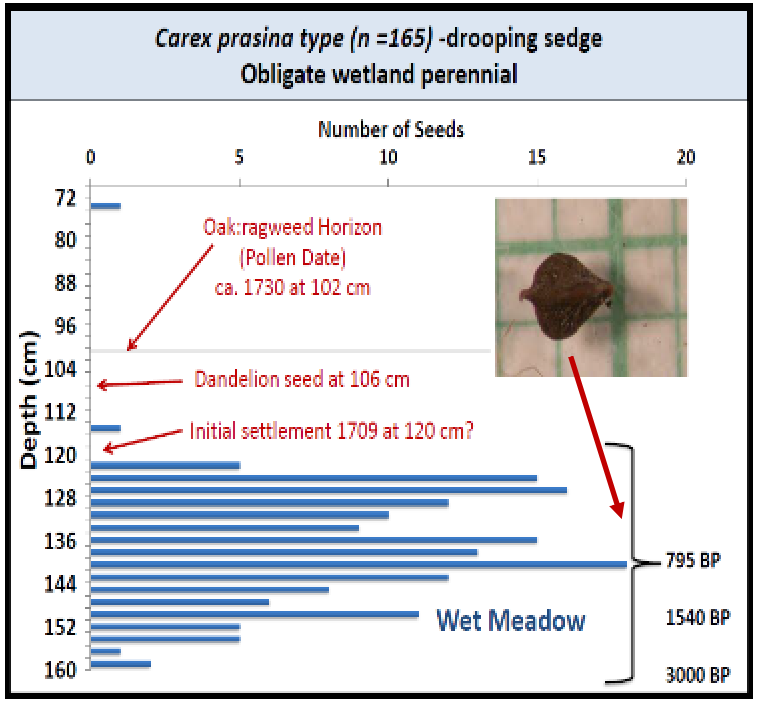


Photos Courtesy Franklin & Marshall College

Big Spring Run Carbon-14 Dates and Vascular Plant Seed Macrofossil Analysis

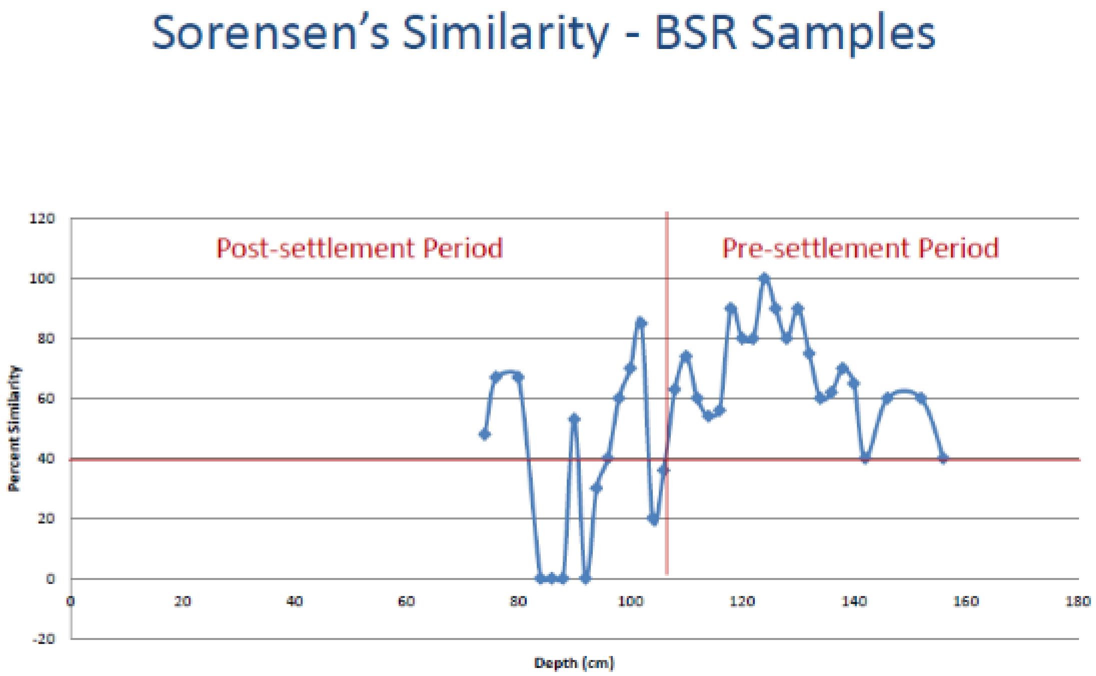


All Dates +/- 40



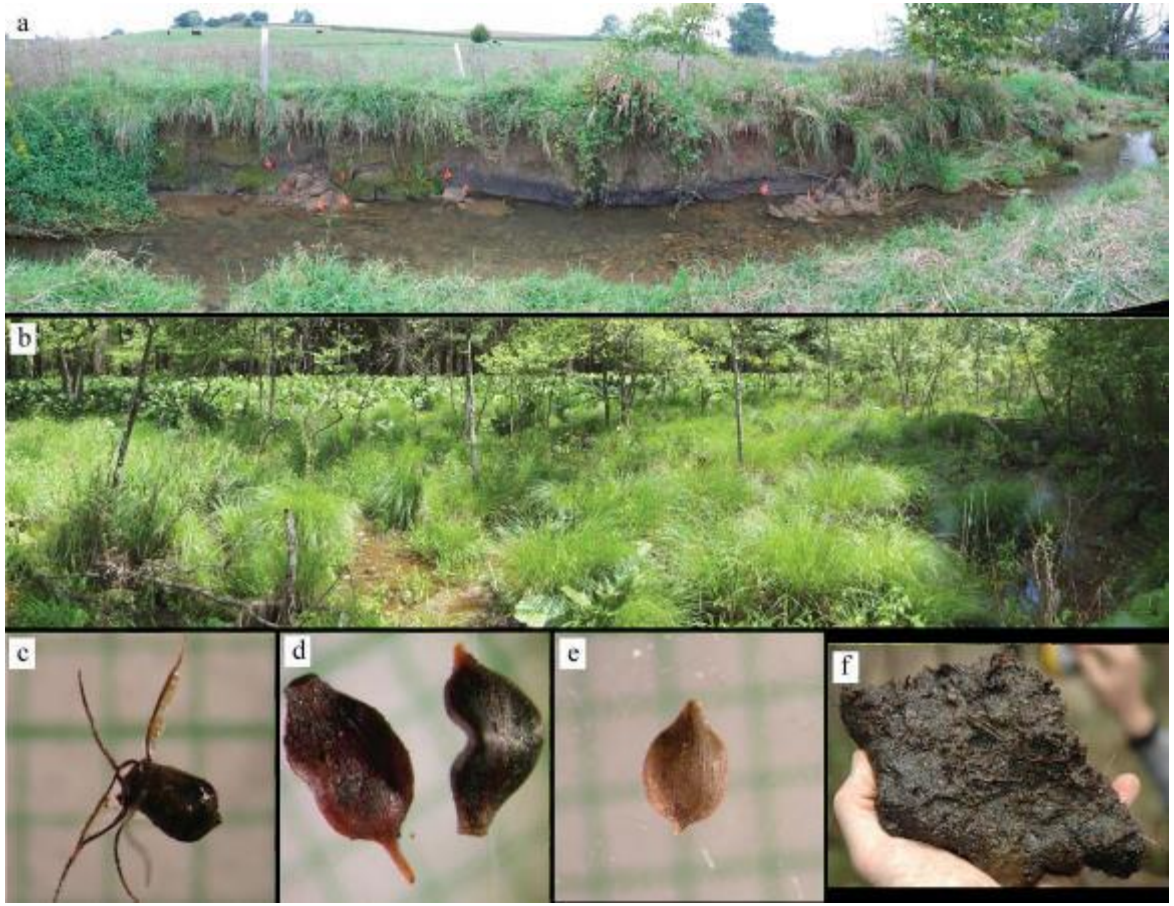
Adapted from Hilgartner et. al. 2012

Seed Macrofossil Analysis of Plant Community Stability Through Time at Big Spring Run, Lancaster County PA



Indicates long-term relative stability of a wetland plant community representative of a wet meadow and not a closed canopy forest

from Hilgartner, et al. 2012



from Merritts, et. al. 2012

Restore natural structure

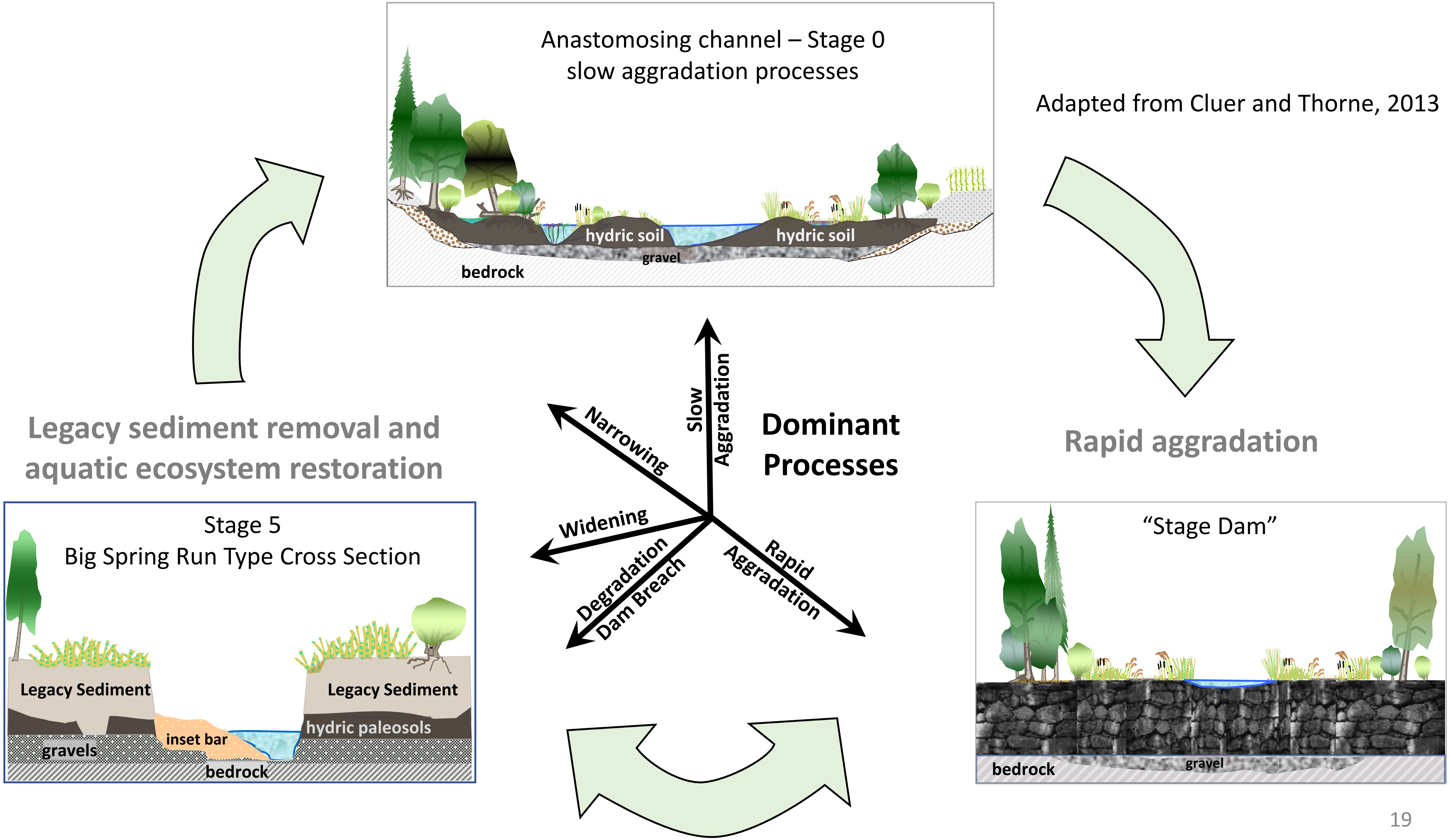
- **Natural valley morphology**
- Address legacy sediment storage and erosion
- Ecosystem physical characteristics are essential to both form and process restoration

Restore natural function

- Natural function and natural structure are closely linked to produce successful restoration processes.

Principles for the Ecological Restoration of Aquatic Resources (EPA841-F-00-003)

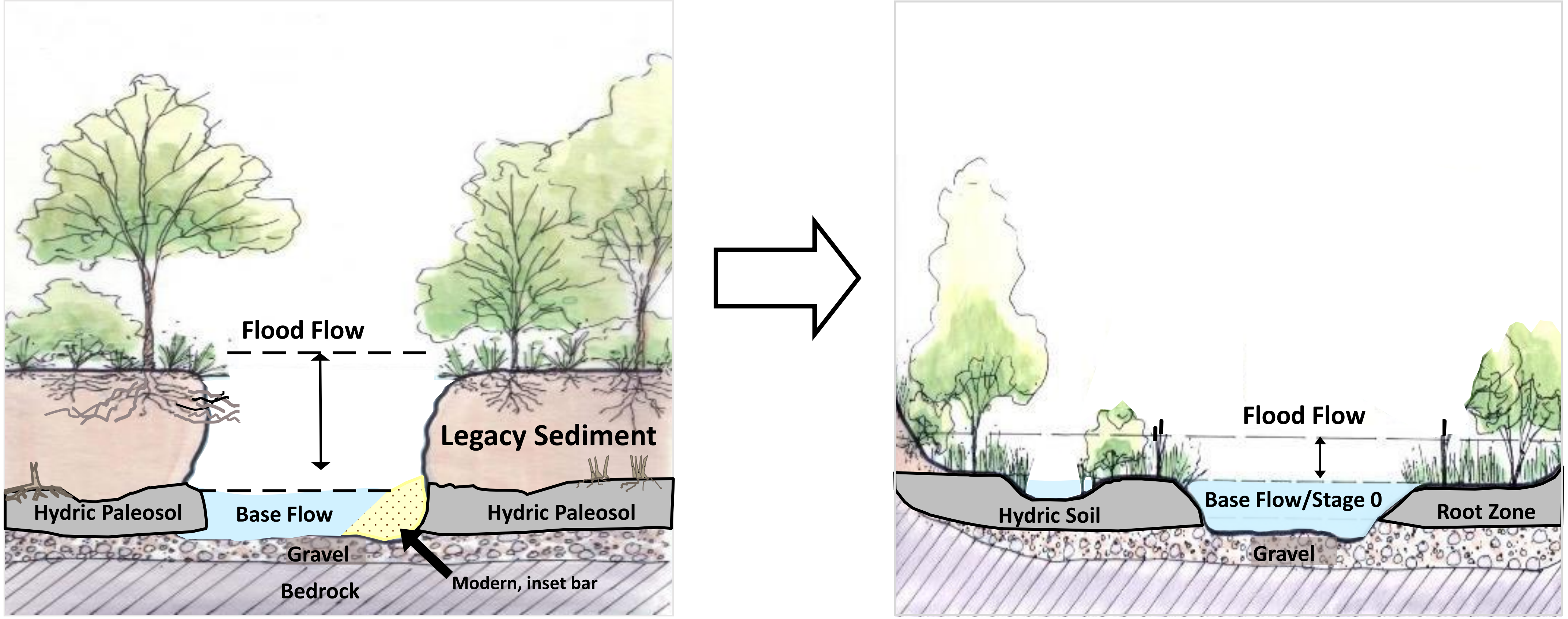
Cyclical stream evolution model and restoration linked to habitat and ecosystem functions and services



Legacy Sediment Removal and Aquatic Ecosystem Restoration Best Management Practice

Typical Existing Conditions

Proposed Restoration



Conceptual Design Adapted from LandStudies, Inc.

October 2011

October 2011

Courtesy Franklin & Marshall College

Big Spring Run Geomorphic Results

Typical Existing Conditions

9/13/2011

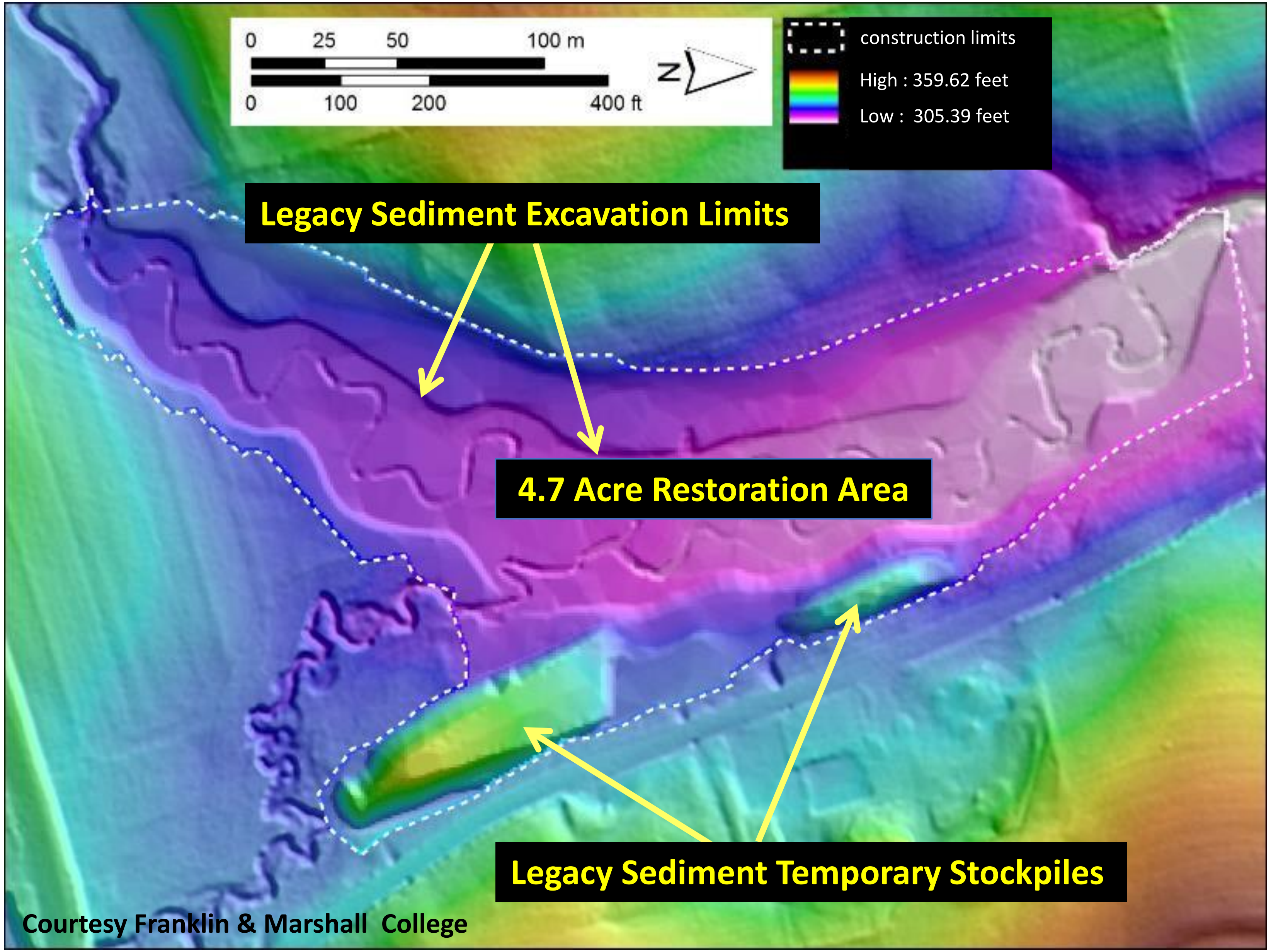
Restoration

07/27/2012

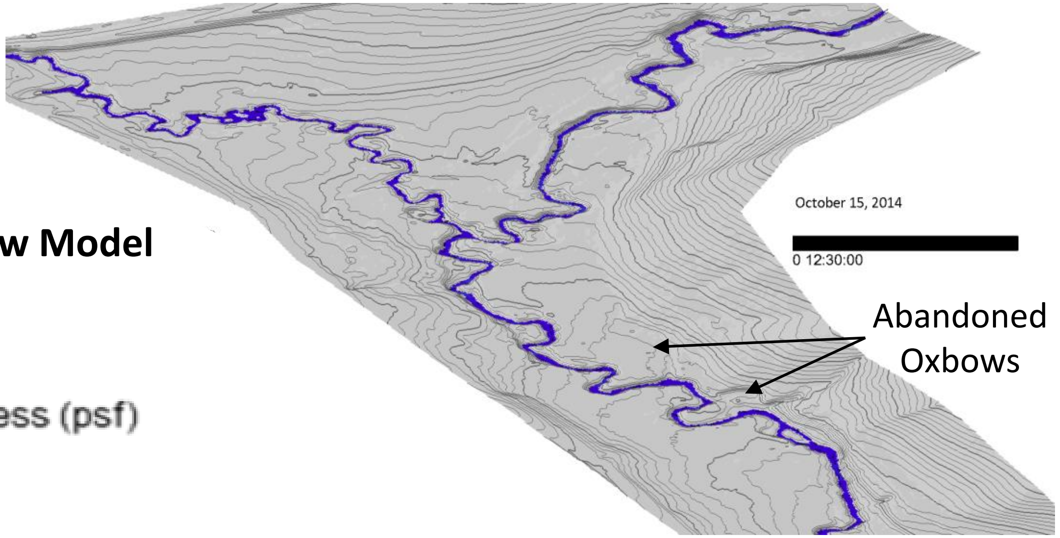
September 2011

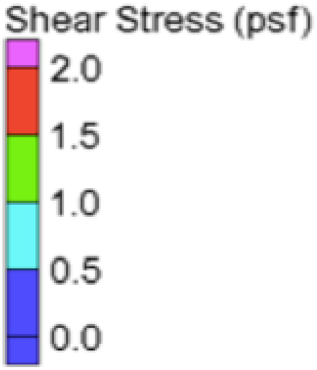
July 2014

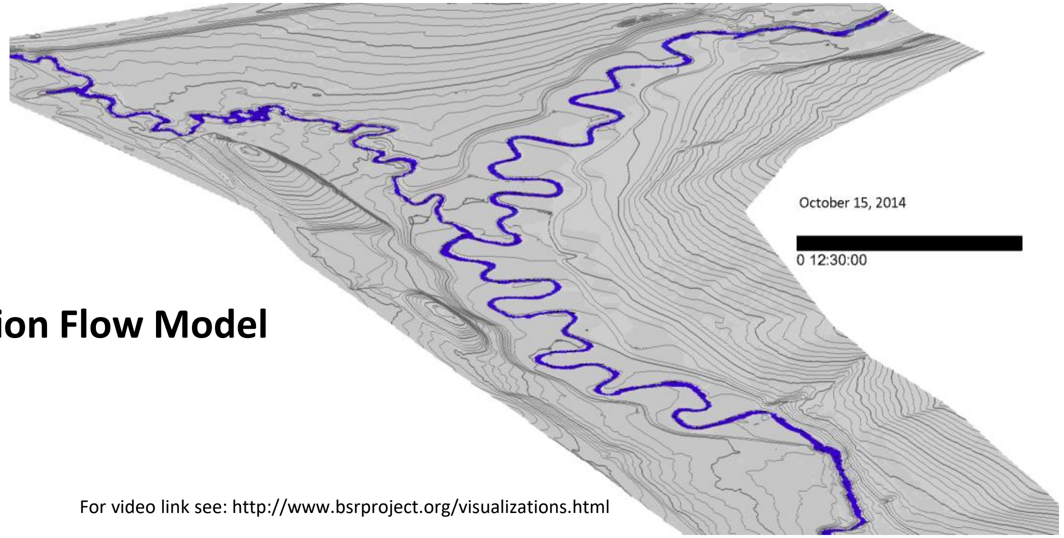
Big Spring Run As-Built - Hillshade Elevations



Pre-Restoration Flow Model





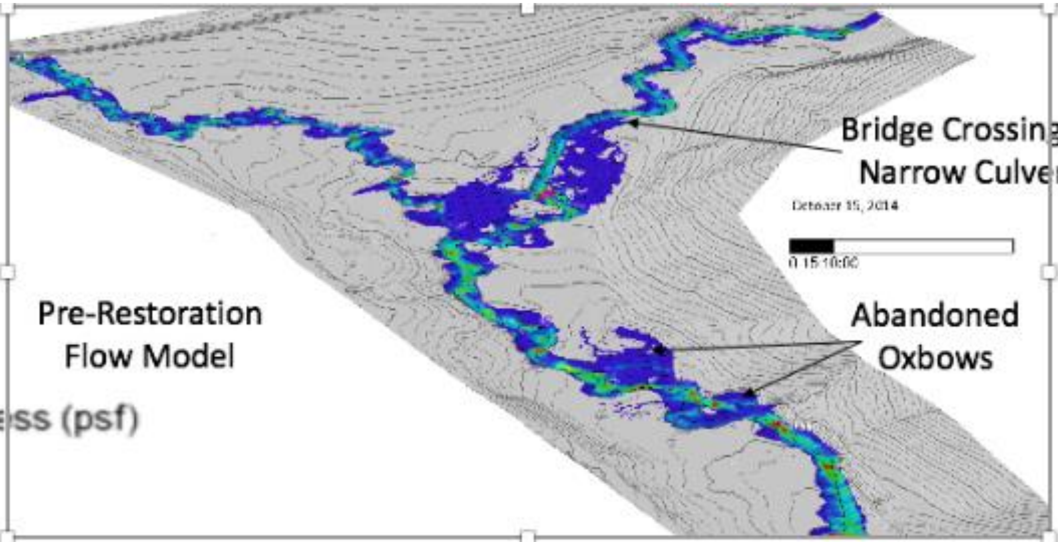


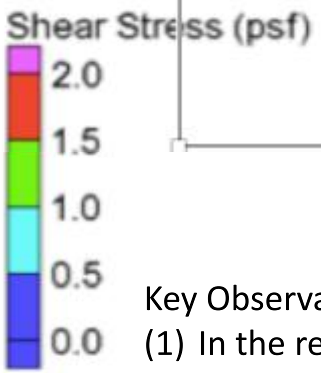
Post-Restoration Flow Model

For video link see: http://www.bsrproject.org/visualizations.html

Art Parola, Univ. Louisville
Dorothy Merritts, F&M

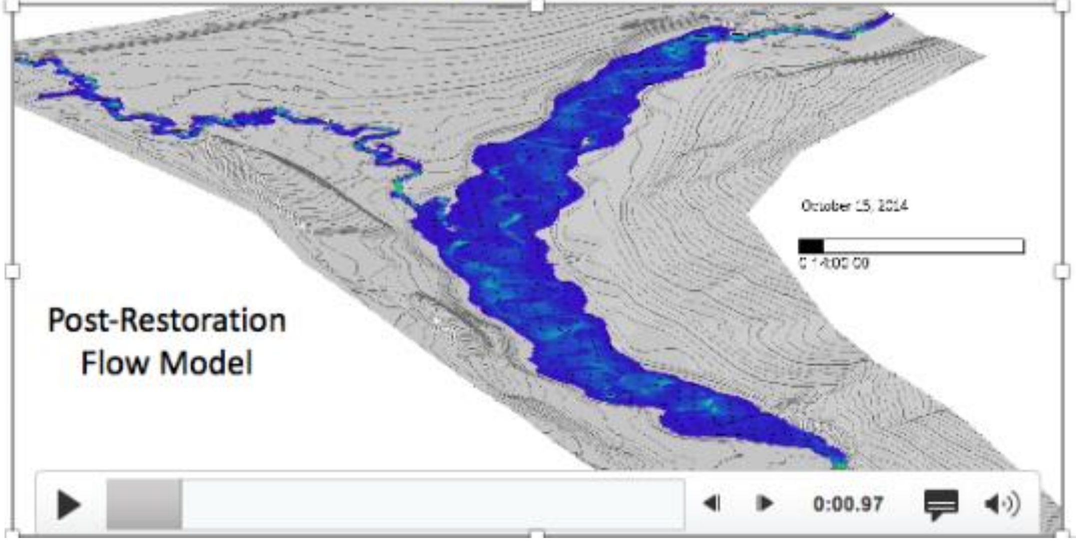
Instantaneous storm flow conditions



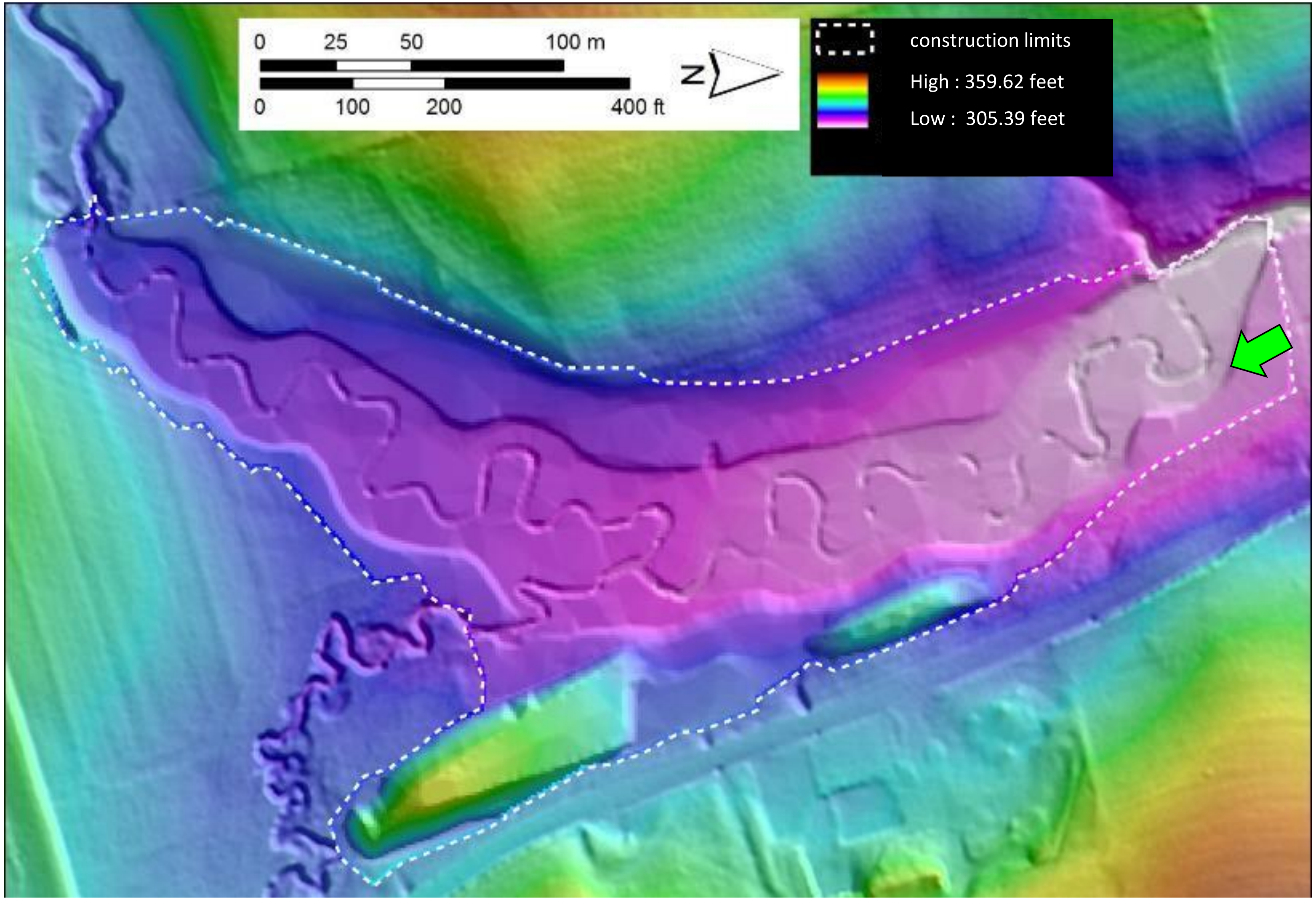


Art Parola, Univ. Louisville
Dorothy Merritts, F&M

Key Observations:
(1) In the restored condition floodwater goes over bank more frequently, at lower flow, and over a greater area.
(2) Shear stresses are much lower.



Big Spring Run As-Built



Flood Photo Location and Orientation

Big Spring Run post-restoration storm

September 18, 2012 @ 3:30 PM

Big Spring Run post-restoration storm

September 18, 2012 @ 4:00 PM

Big Spring Run post-restoration storm

September 18, 2012 @ 4:30 PM

Big Spring Run post-restoration storm

September 18, 2012 @ 4:35 PM

Big Spring Run post-restoration storm

September 18, 2012 @ 4:45 PM

Big Spring Run post-restoration storm

September 18, 2012 @ 5:00 PM

Big Spring Run post-restoration storm

September 18, 2012 @ 7:15 PM

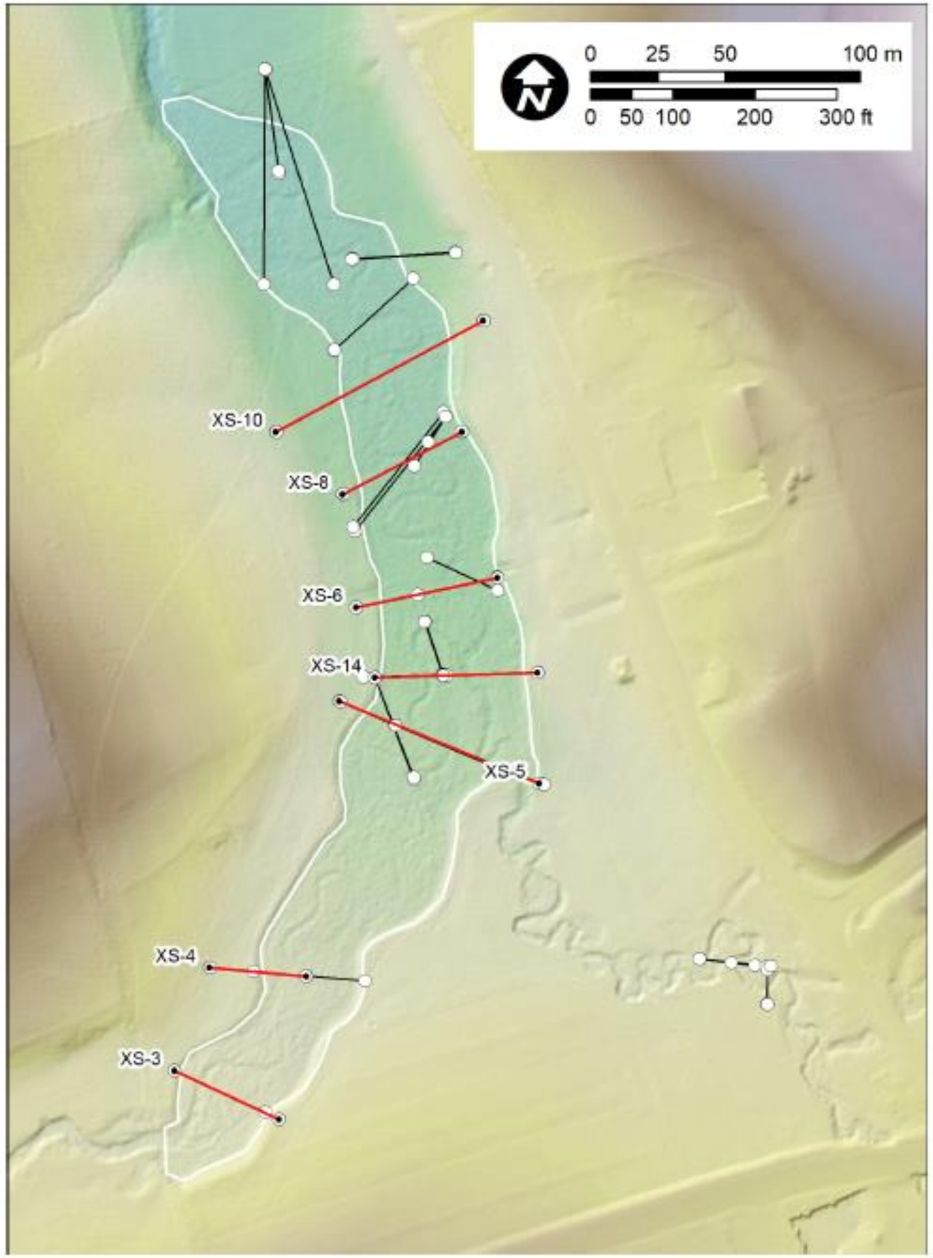
Big Spring Run post-restoration storm

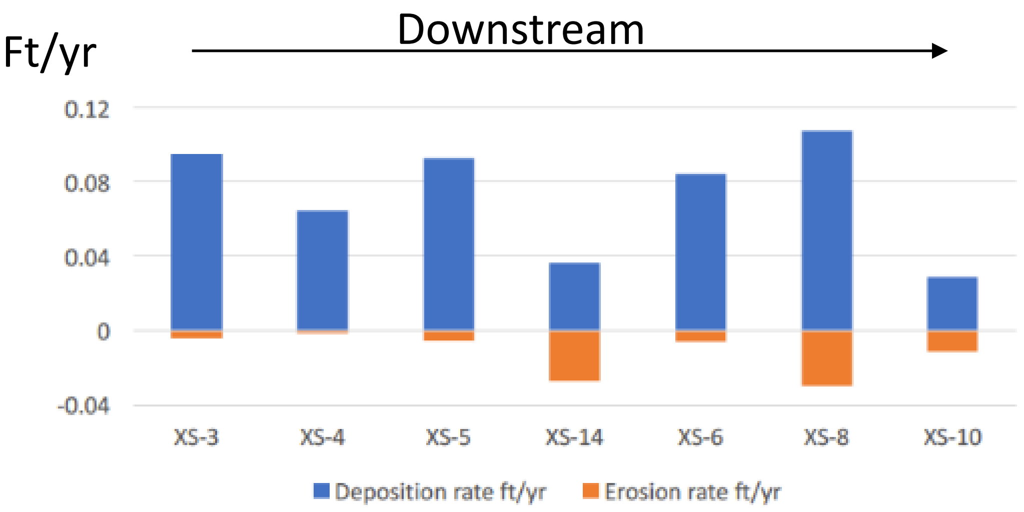
September 18, 2012 @ 8:30 PM

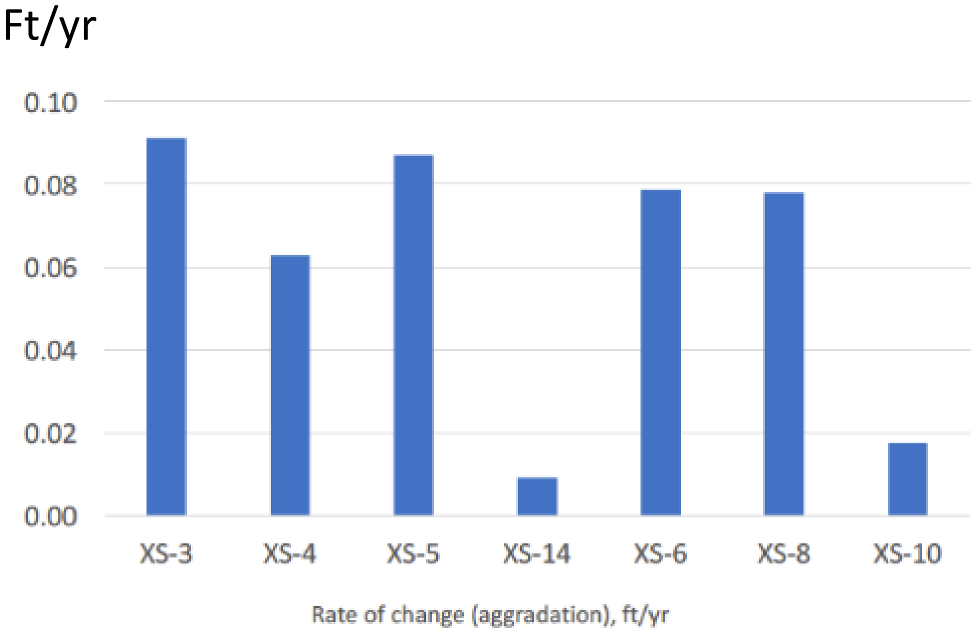
Big Spring Run post-restoration storm

September 19, 2012 @ 10:00 AM

Post-restoration repeat cross section survey locations

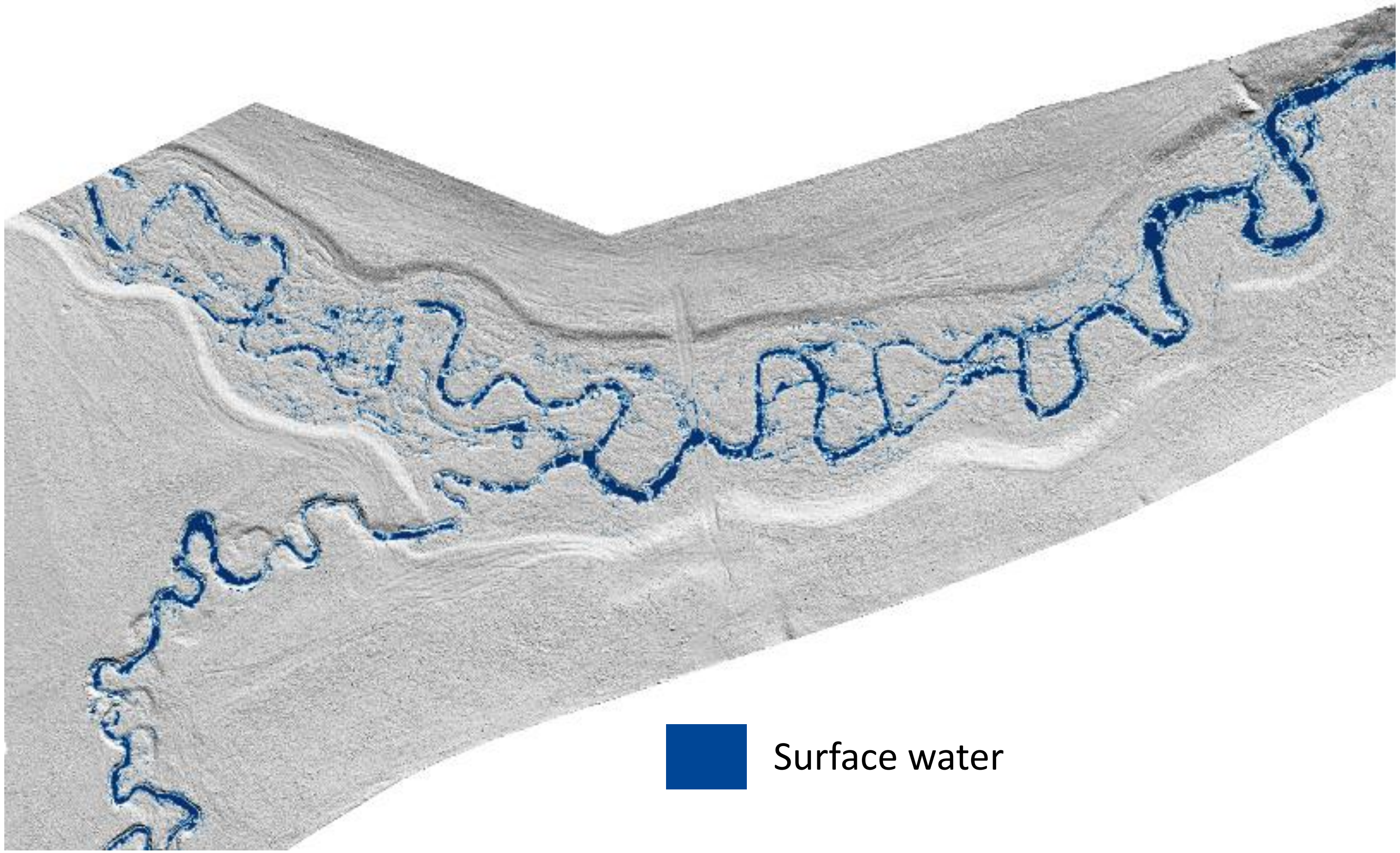






Deposition (blue), erosion (orange), and net change (aggradation) for seven cross sections surveyed at least twice between 2012-13 and 2015-17.

Post-restoration terrestrial laser survey April 11, 2014



Post-restoration UAV (drone) image of anastomosing channel form
April 22, 2018

Post-restoration terrestrial laser survey

April 11, 2014

Effects of legacy-sediment removal on nutrients and sediment in Big Spring Run, Lancaster County, Pennsylvania, 2009-15

U.S. Geological Survey

Pennsylvania Water Science Center

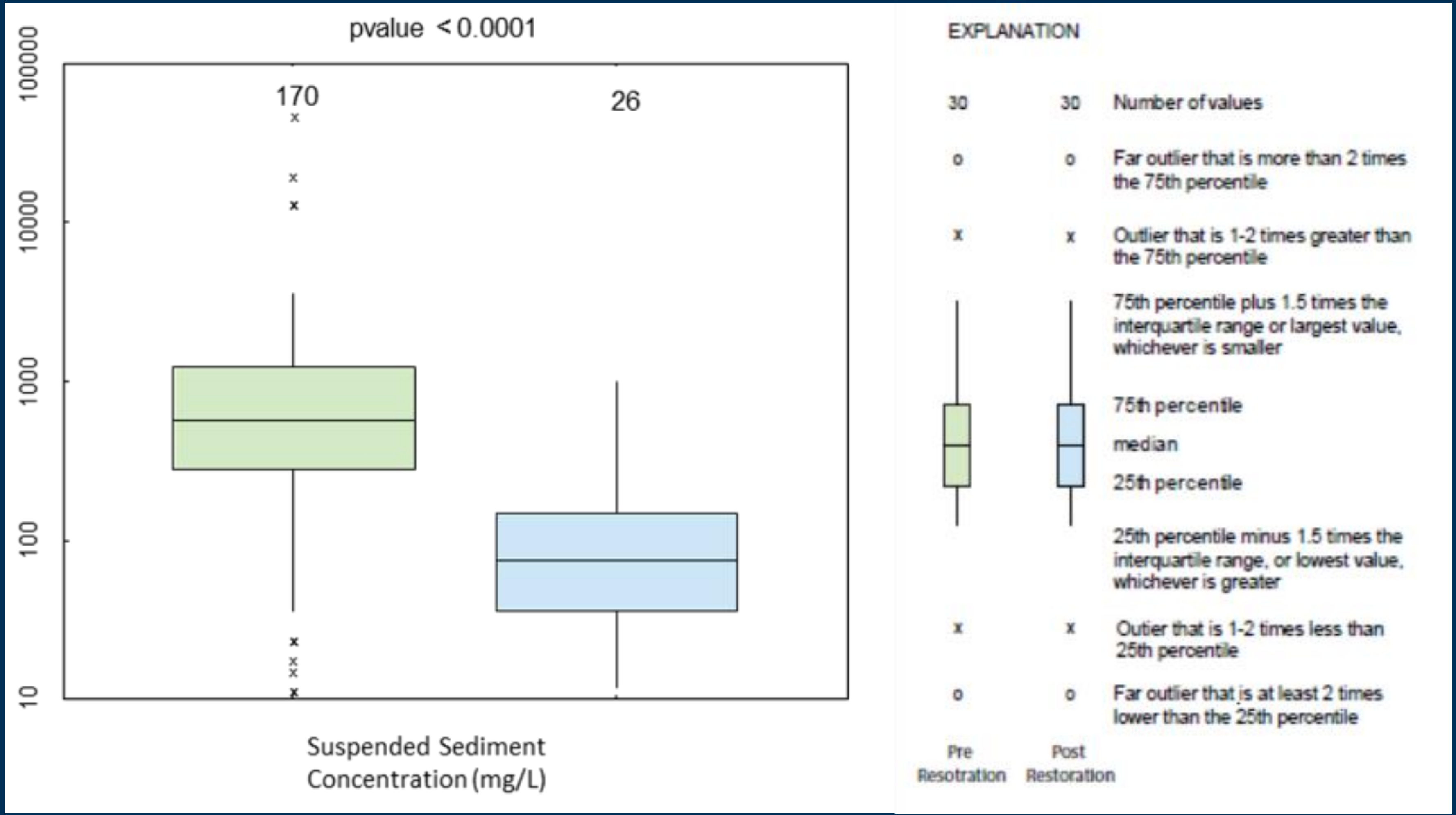
In cooperation with the Pennsylvania Department of Environmental Protection and in collaboration with Franklin and Marshall College and the U. S. Environmental Protection Agency

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

USGS Sample Sites

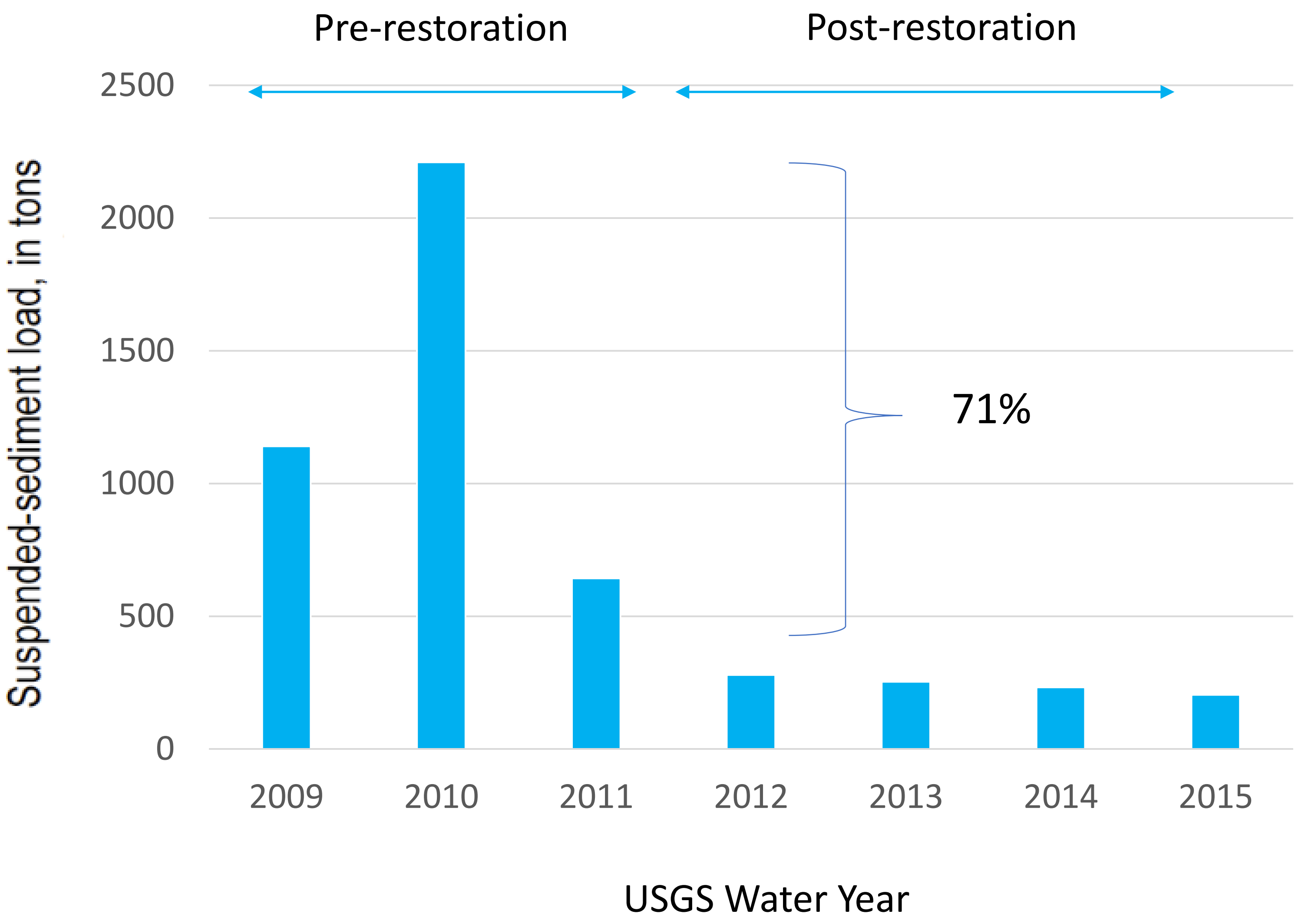
Stream gage locations Flow direction

Surface Water Pre- and post- restoration suspended sediment concentrations (SSC) in Big Spring Run

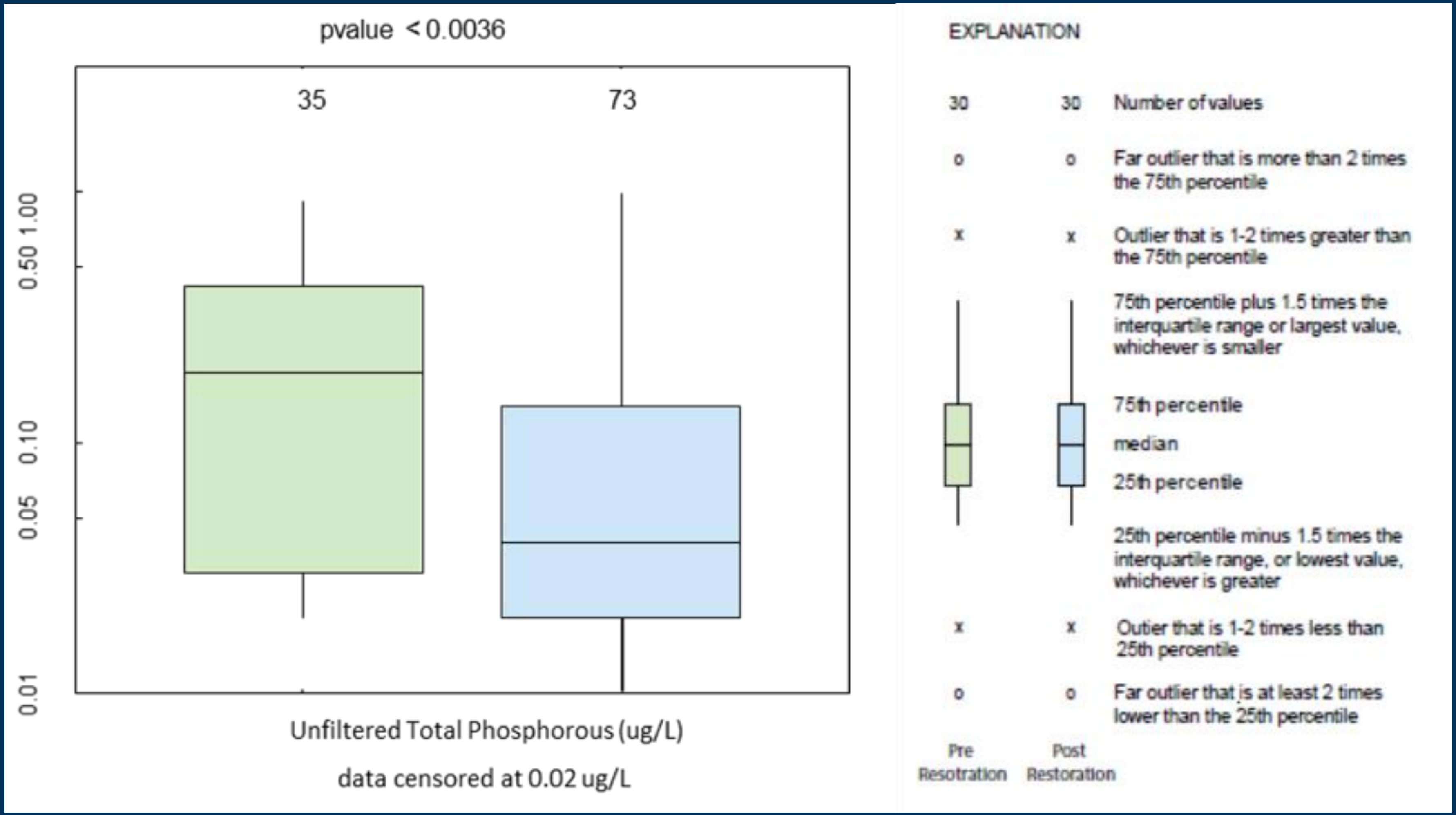


USGS

Annual suspended sediment load for 2008 through 2015 water years



Pre- and post- restoration unfiltered total phosphorous concentrations in Big Spring Run



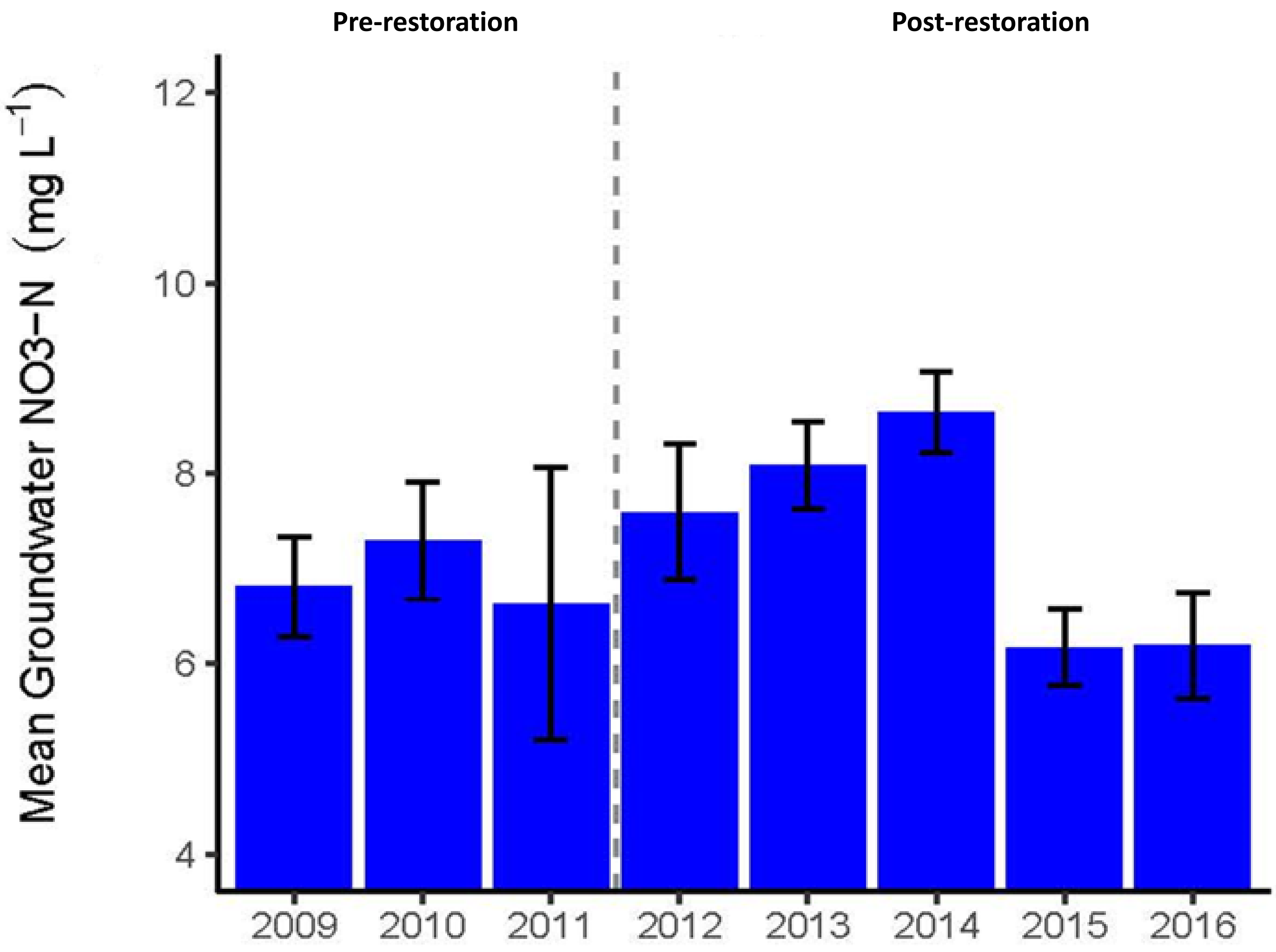
Restoring stream-floodplain connection with legacy sediment removal increases denitrification and nitrate retention, Big Spring Run, PA USA.

Kenneth J. Forshay[1], Julie Weitzman[2], Jessica Wilhelm[3], Paul Mayer[4], Ann Keeley[1], Dorothy Merritts[5], and Robert Walter[5]

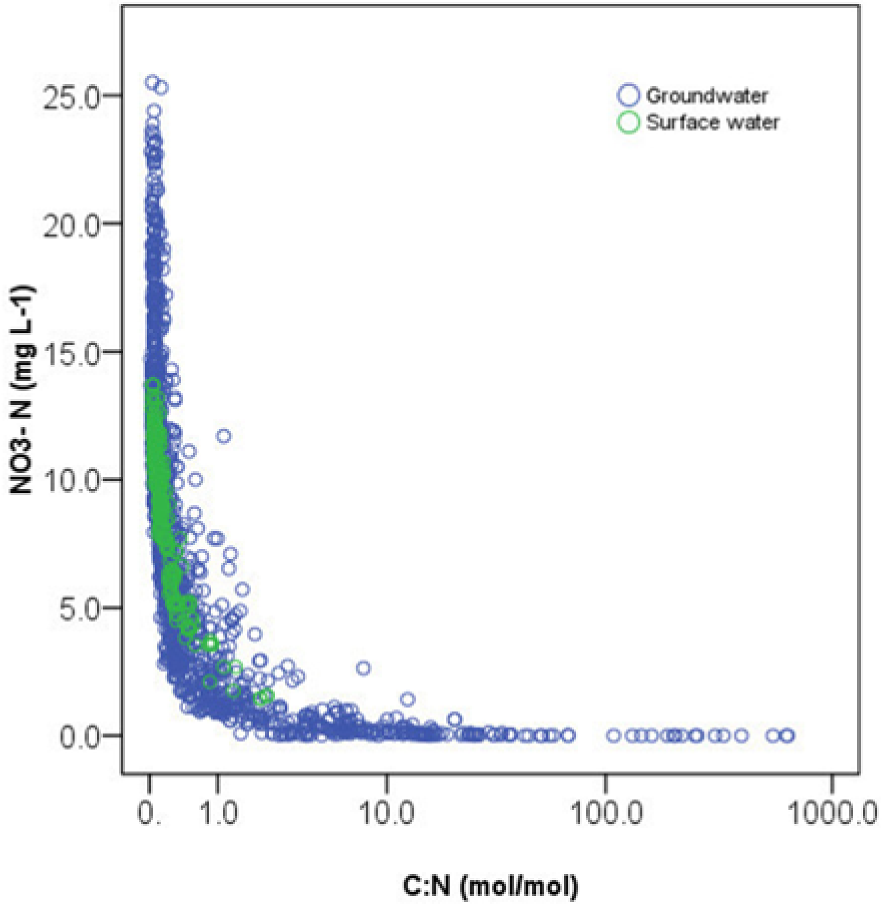
(1)Office of Research and Development, United States Environmental Protection Agency, Ada, OK, (2)Carrey Institute, (3)Oak Ridge Affiliated Universities(4) Office of Research and Development United states Environmental Protection Agency, Corvallis, OR, (5) Franklin and Marshall College

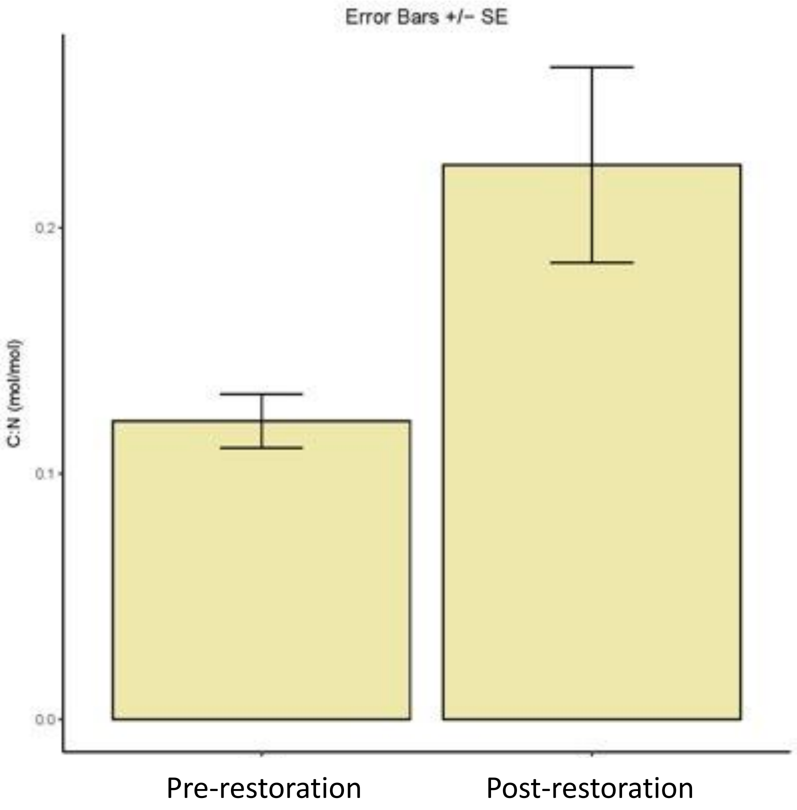
This presentation contains research done by EPA staff and does not necessarily reflect EPA policy

Groundwater nitrate decreased in the fourth year after restoration.

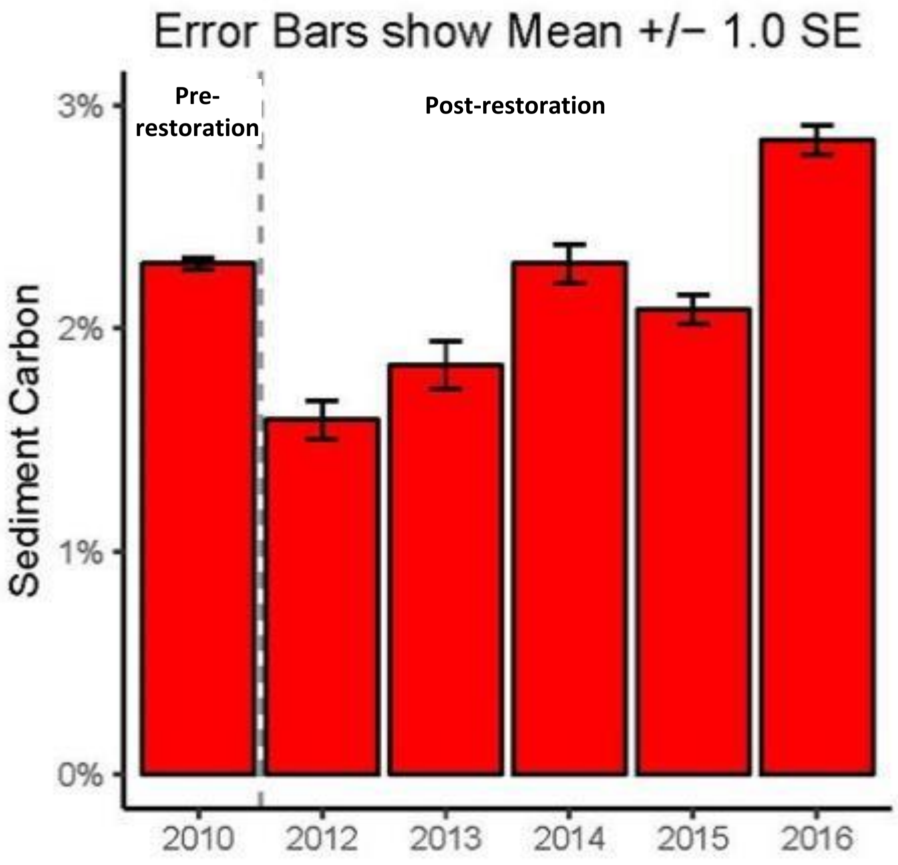


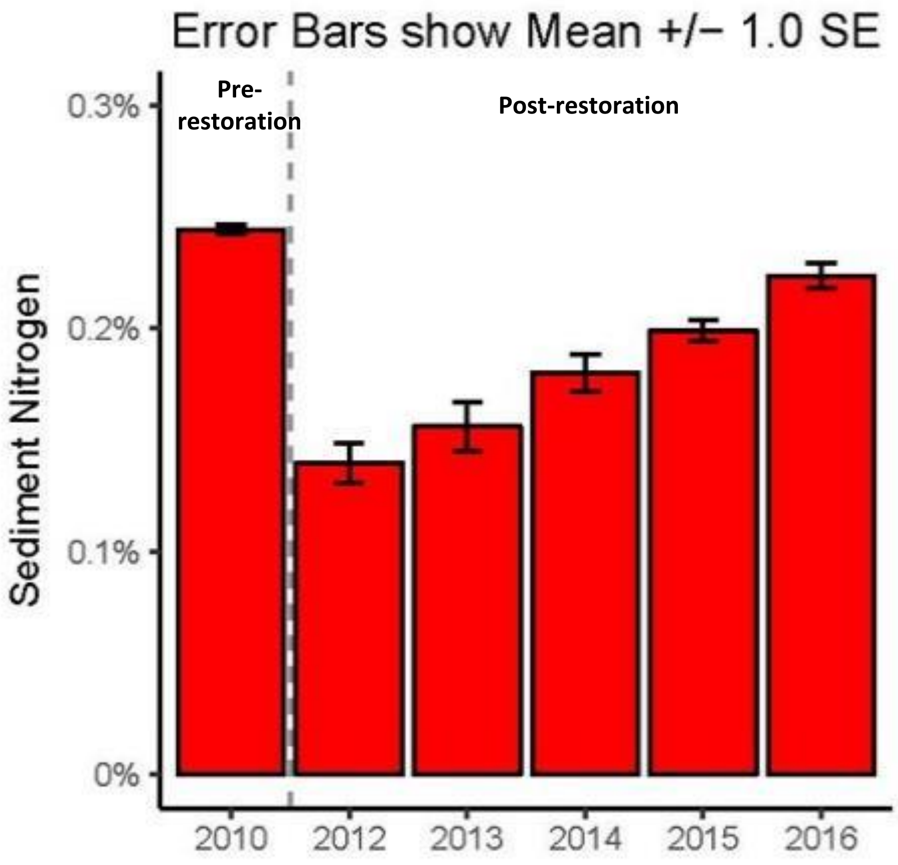
High C:N is an indicator of nitrate reduction and GW connectivity.





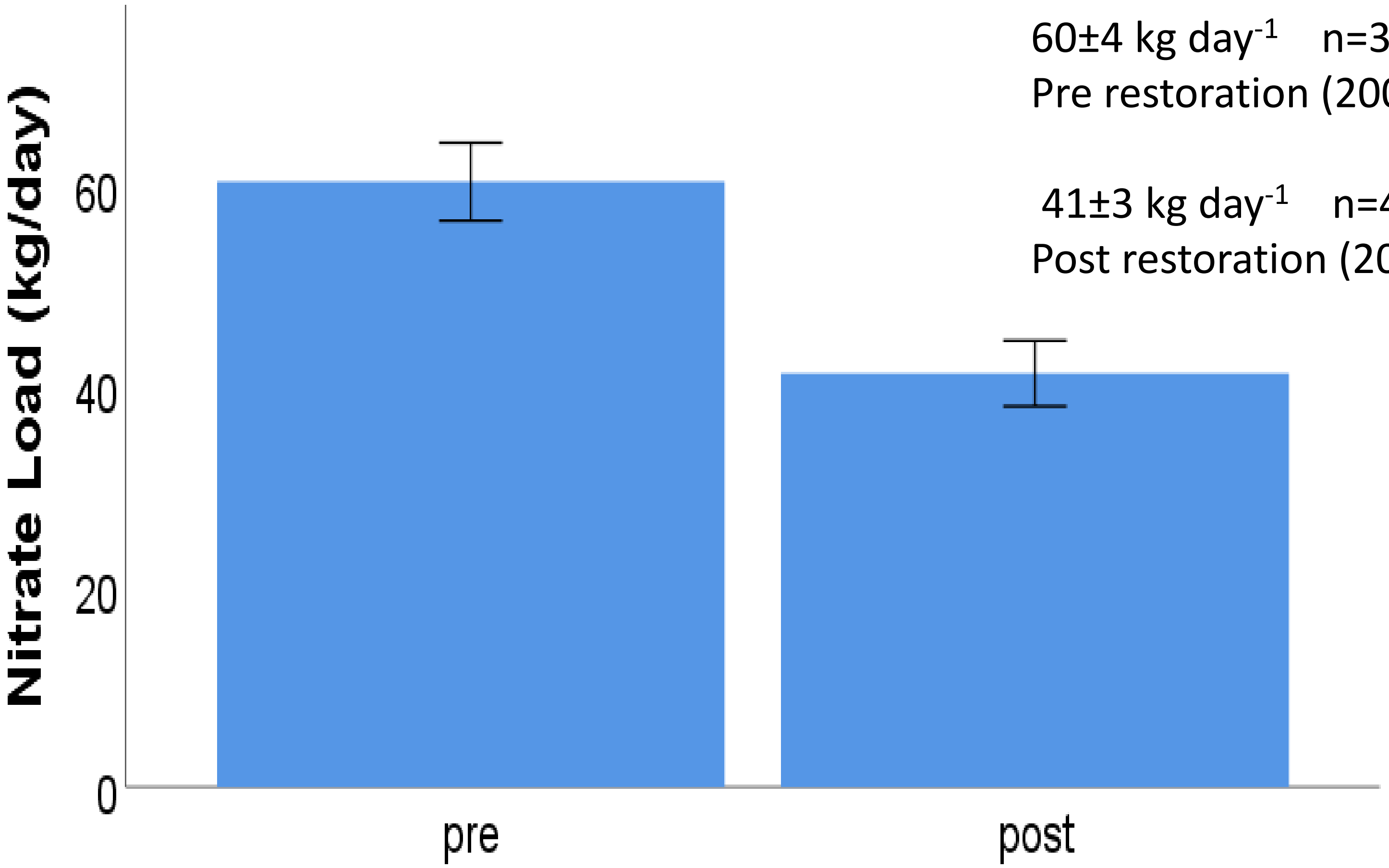
Sediment C and N recovered simultaneously.





Post restoration nitrate loads are smaller than pre-restoration.

Load = [NO3] x Mean Daily Discharge



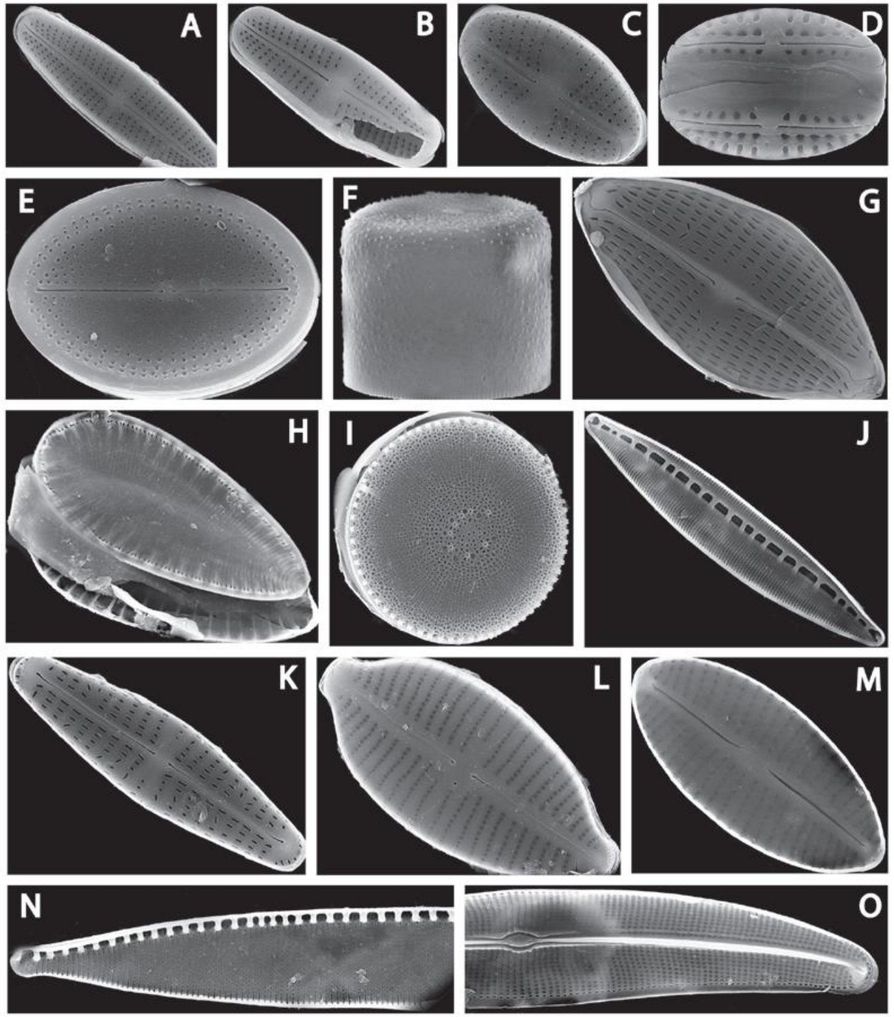
60±4 kg day^{-1} n=33
Pre restoration (2008-2011)

41±3 kg day^{-1} n=44
Post restoration (2012-2016)

$p<0.001$ df = 76

Big Spring Run biological and living resources monitoring results

August 2012



Common diatoms from Big Spring Run

Potapova, et al, 2016

Diatom diversity increased after restoration based on mean species richness in the restored reach. The increase in species richness may be attributed to enhanced habitat complexity that provides a greater diversity of substrates and flow conditions.

Diatom nutrient metrics indicated that post-restoration assemblages had fewer diatoms associated with high nutrients and more of those indicative of low nutrients.

It is unrealistic to expect the biota to revert to its pre-1700s condition given the existing water quality, but increased diversity and higher proportion of oligotraphenic species is a benefit and positive ecosystem recovery trajectory.

Eurycea bislineata (Northern two-lined) and *Pseudotriton ruber* (Northern red) larvae

Lithobates clamitans (Green frog) tadpole

Green frog egg mass

Restored habitat where green frog egg mass was found.

Courtesy D. Bowne Elizabethtown College

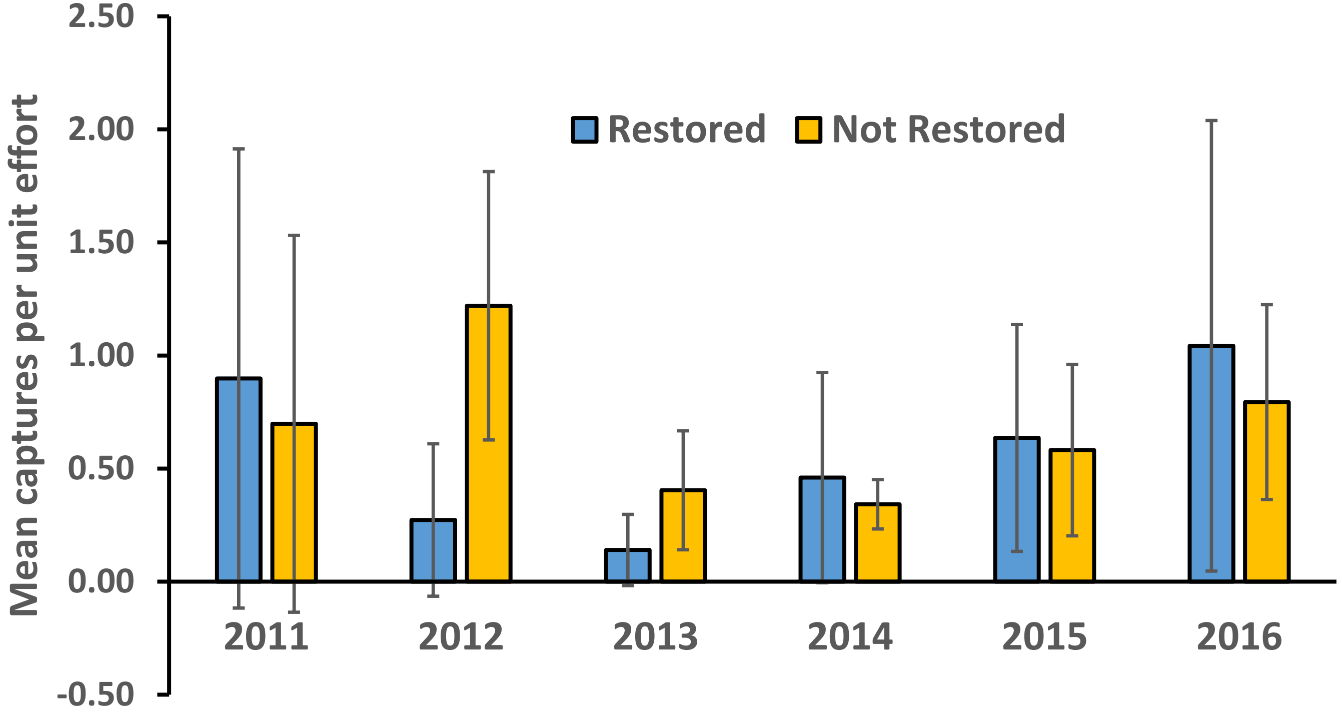


Figure 2. The mean number of captures per unit effort (± STD) of *Eurycea bislineata* for restored and not restored stream segments from 2011 to 2016. All of the data from 2011 are pre-restoration. The mean number of captures did not significantly vary by year or treatment.

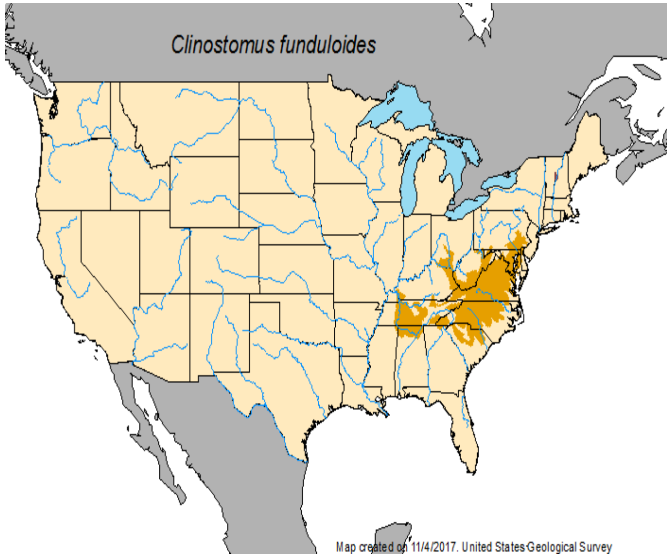
Bowne, D.R., and Conway, R. *In prep.* Amphibian Use of a Restored Wetland in an Agricultural Landscape. Department of Biology, Elizabethtown College, PA.

“SRBC Water Tour 2017” excerpts

https://www.youtube.com/watch?v=nnxhs3aTTJs

Courtesy Susquehanna River Basin Commission, 2017

September 2015 Fish Survey

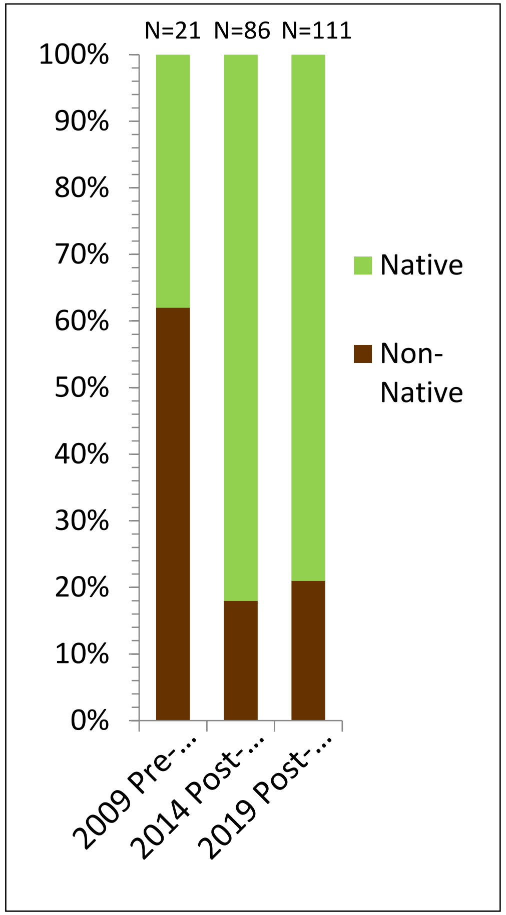


Native Range

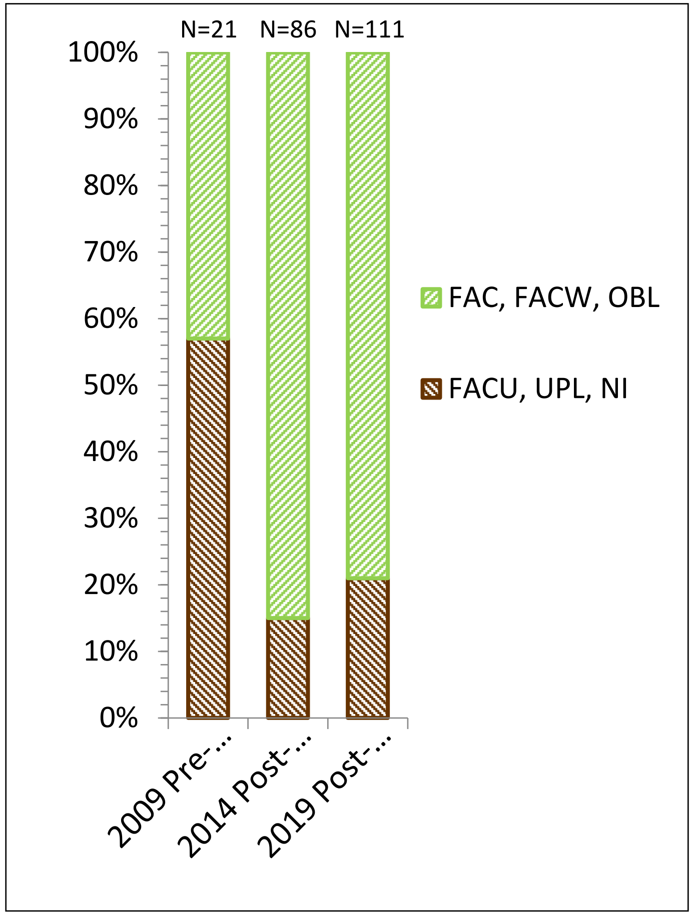
rosyside dace (*Clinostomus funduloides*)

This species prefers headwater streams typical of cold water fishes and is an indication of improved water quality in the restored reach. It also prefers gravelly riffles for spawning and typically inhabits rocky streams.

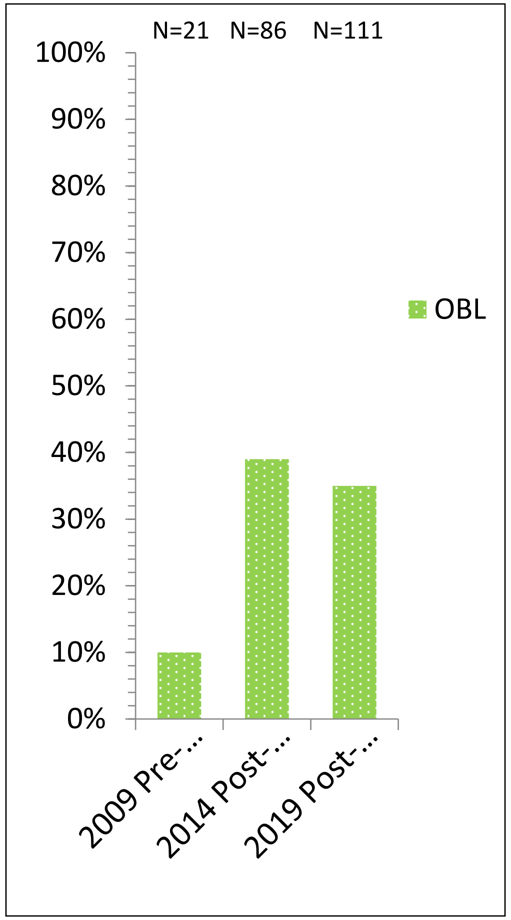
Vascular plant species richness and wetland indicator status



Native vs Non-Native

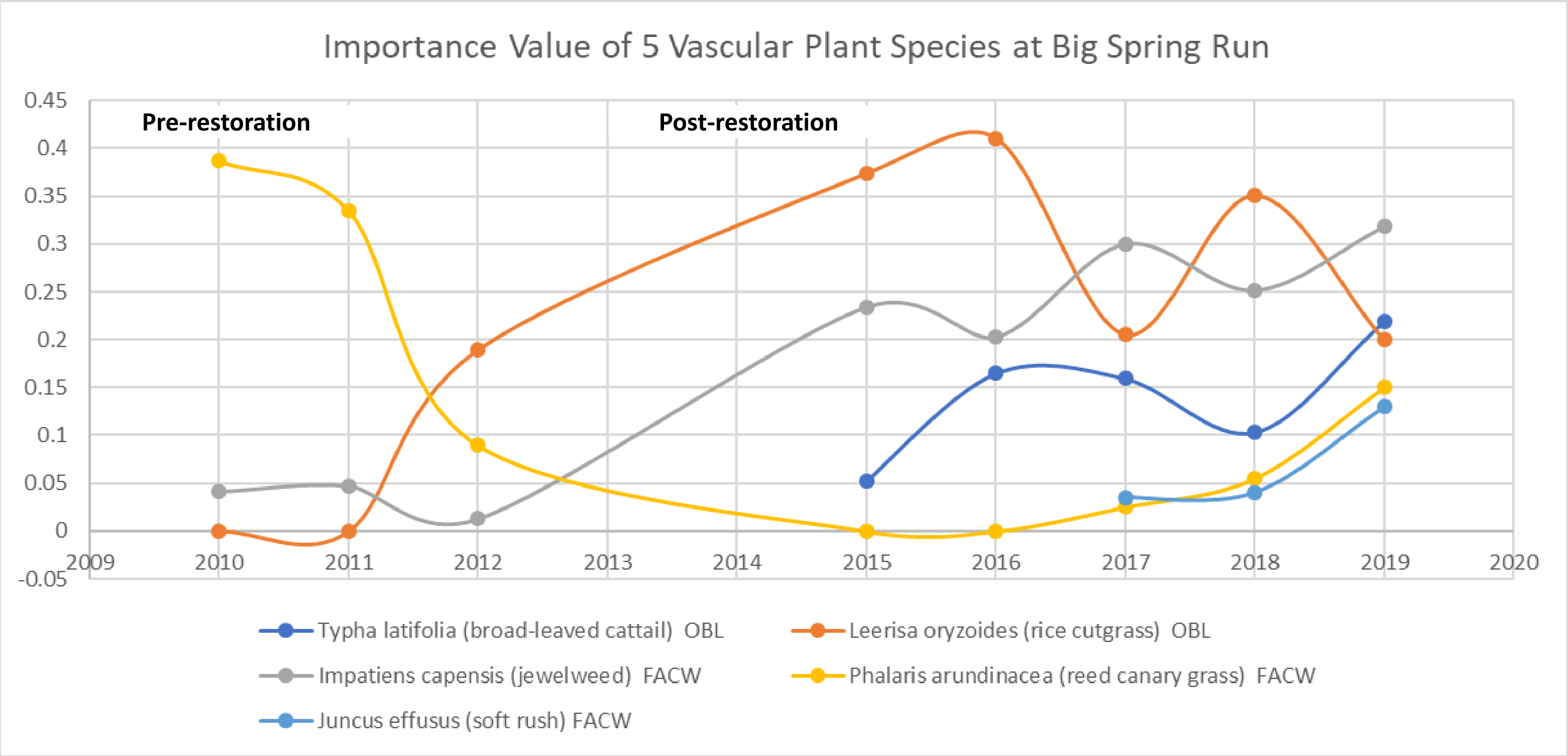


Wetland Indicator Status



Obligate Wetland Species

Vascular plant surveys of 1 m^2 plots at 5 m intervals repeated along transects



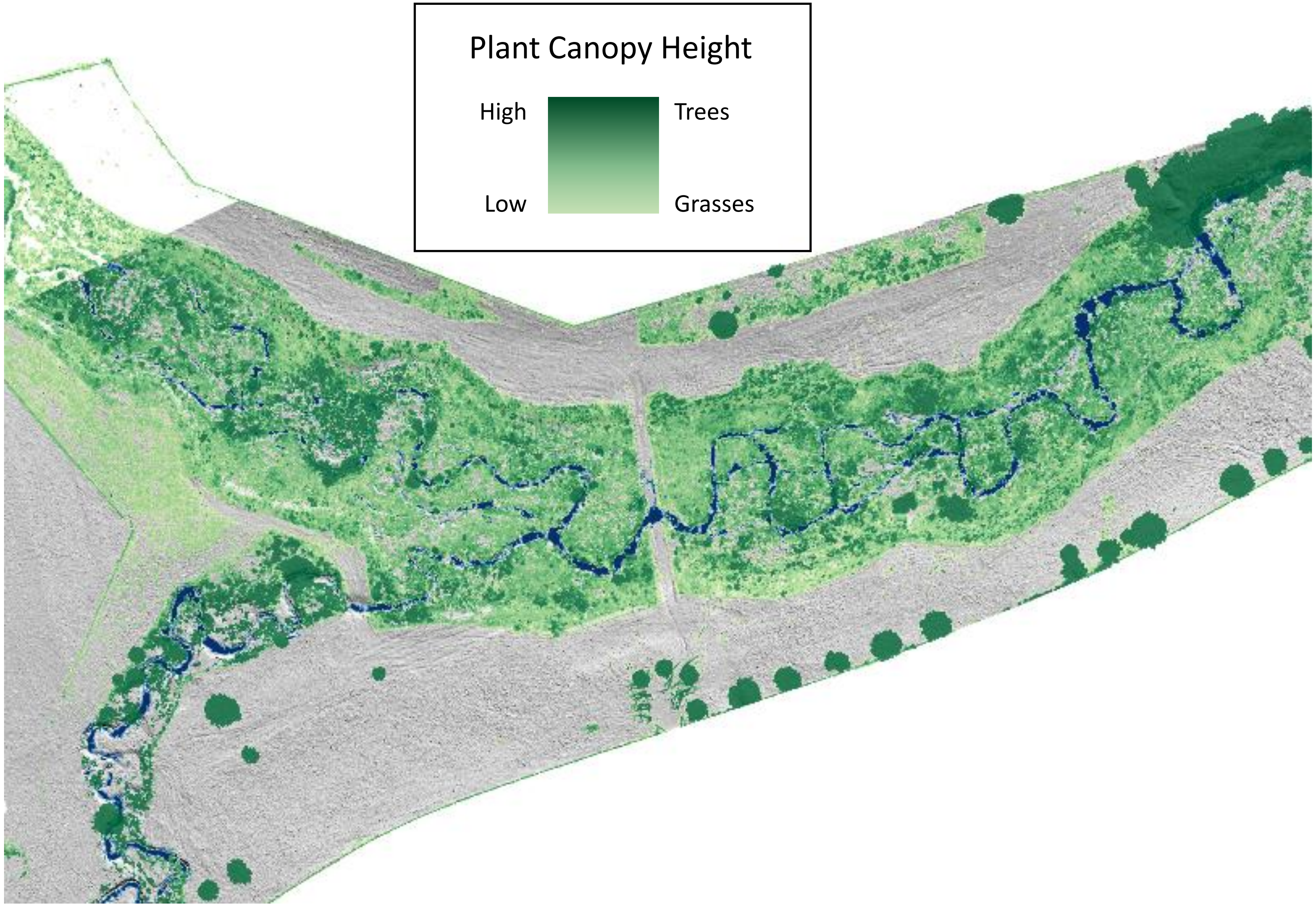
Courtesy William Hilgartner

Notable post-restoration vascular plant colonizers

Juncus torreyi
Torrey's rush
PA State Threatened
Facultative

Carex amphibola
narrowleaf sedge
Facultative

Post-restoration terrestrial laser survey June 6, 2015



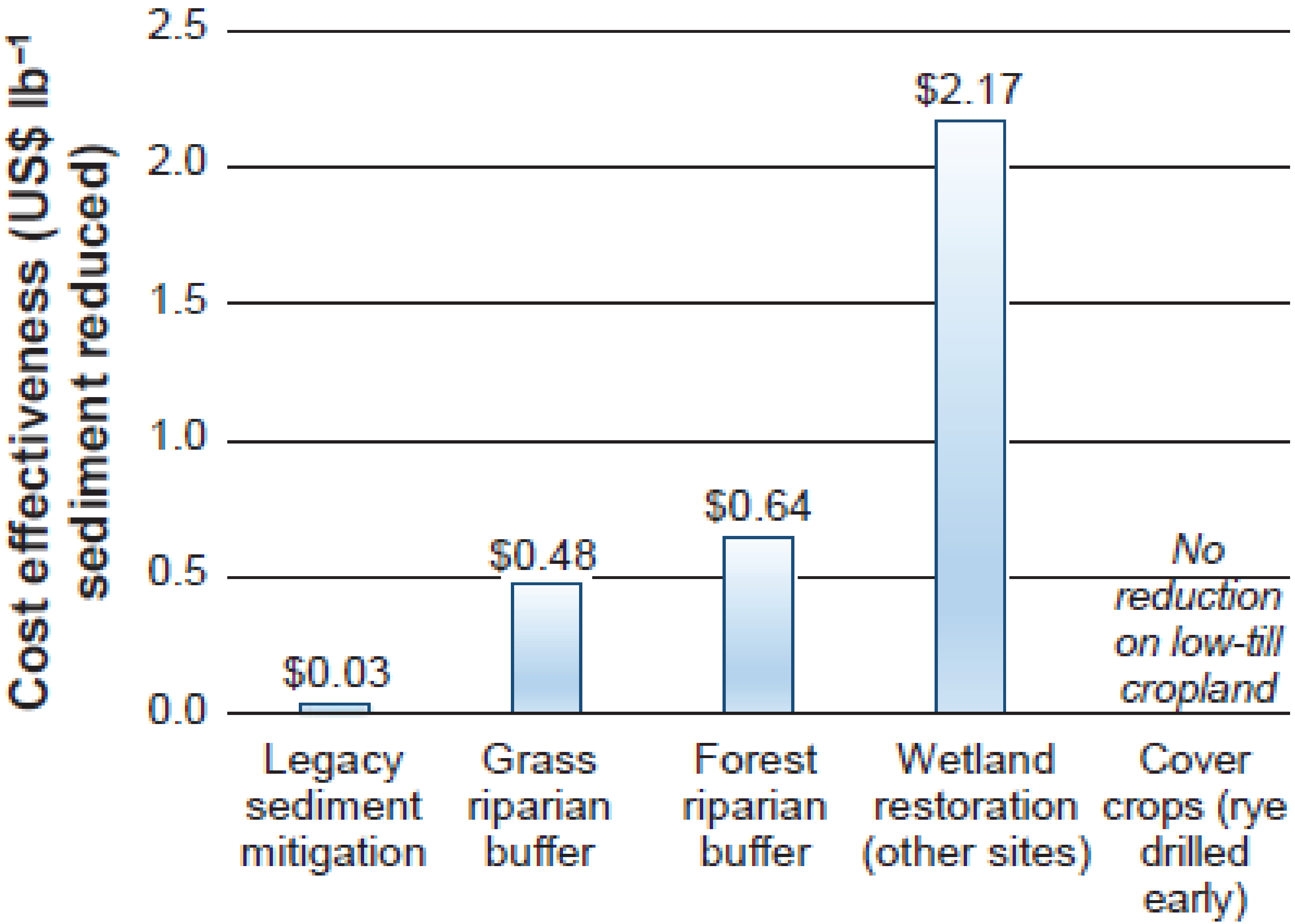
Summary of plant community response

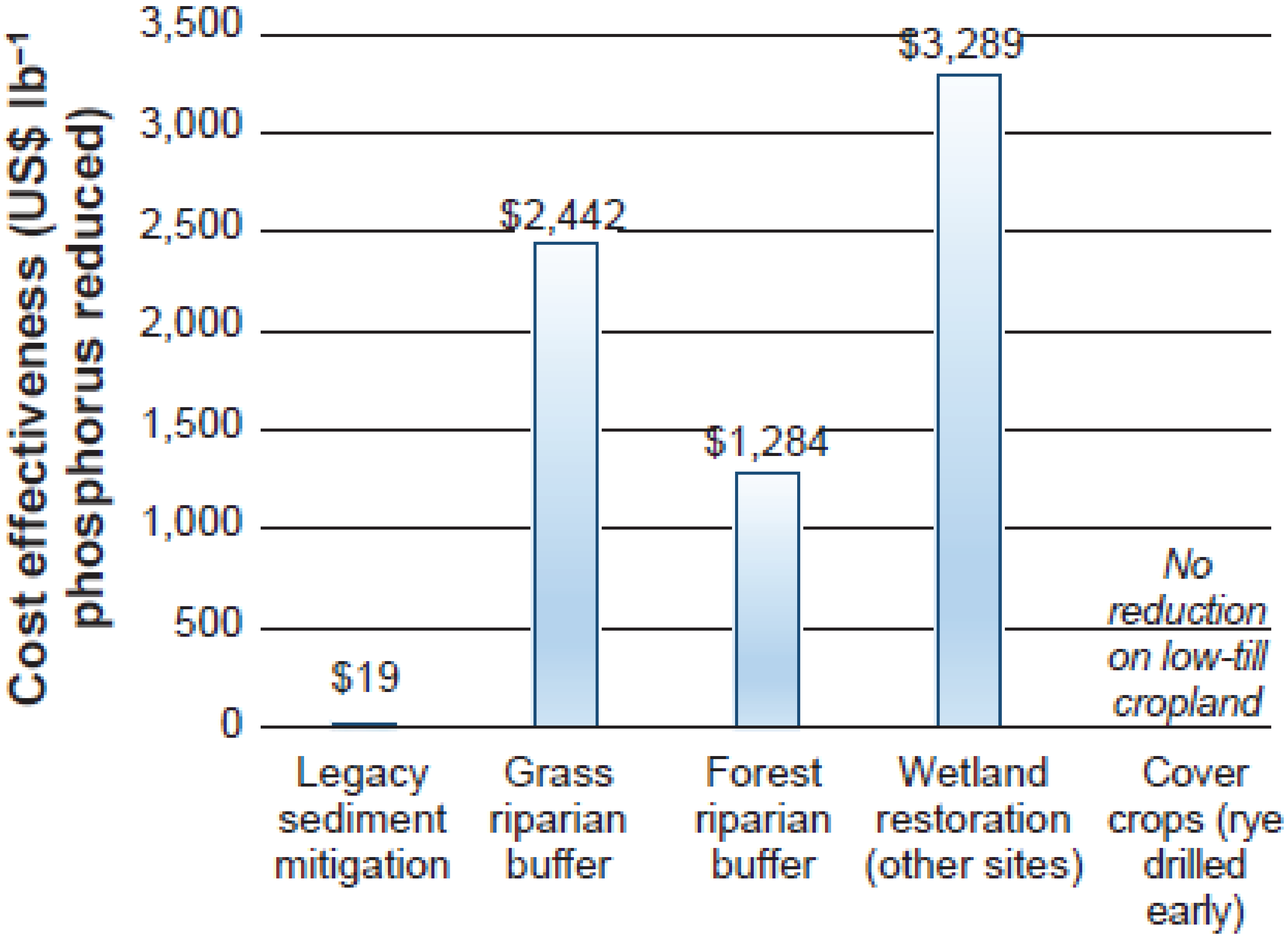
- A major vascular plant community shift occurred from a dry upland pasture to a wet meadow plant community type
- Increasing importance of hydrophytes after restoration provides wetland habitat that is comparable to the reference condition
- Vascular plant hydrophytes have colonized the restoration area, including the PA Threatened Torrey's sedge (Juncus torreyi)
- The presence of threatened and endangered species indicates Exceptional value wetlands in accordance with 25 PA Code § 105.17 Wetlands have been restored

Legacy sediment erosion hot spots: A cost-effective approach for targeting water quality improvements

Patrick M. Fleming, Dorothy J. Merritts and Robert C. Walter

Journal of Soil and Water Conservation July 2019, 74 (4) 67A-73A; DOI: https://doi.org/10.2489/jswc.74.4.67A





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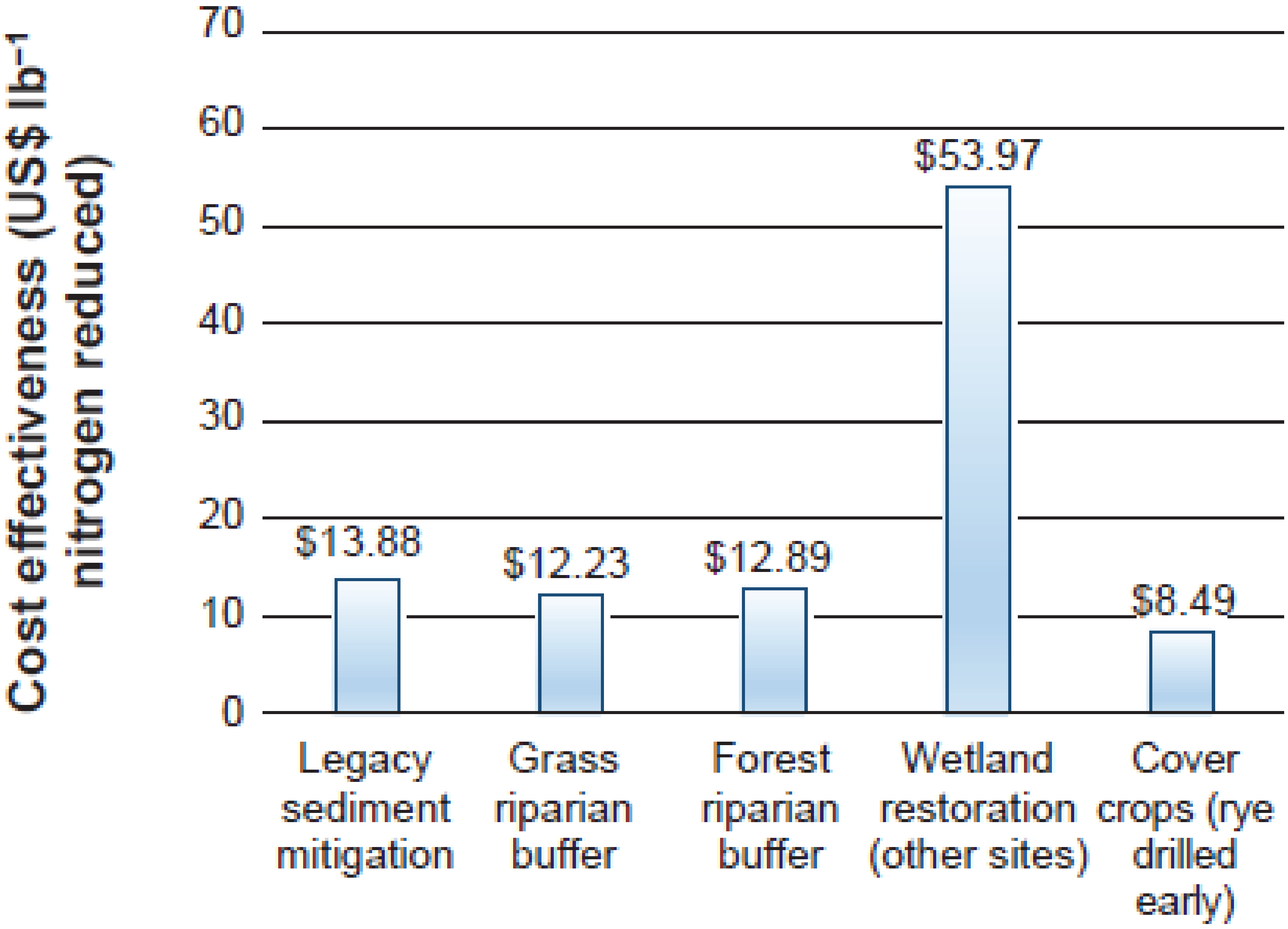

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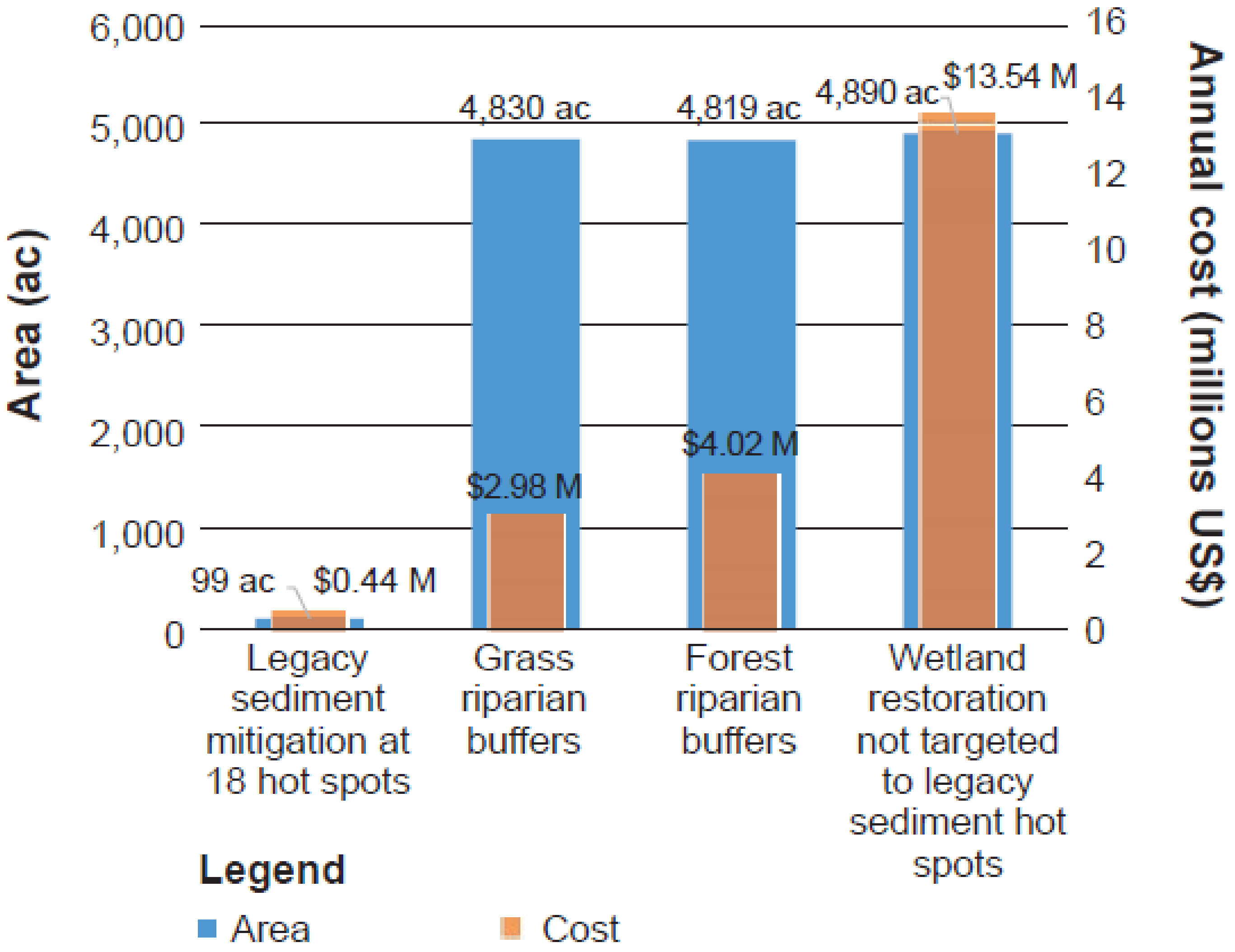
Annual cost and total restoration acreage required to achieve 5% of Chesapeake Bay total maximum daily load (TMDL) sediment goal for Pennsylvania agriculture (17×10^6 lb abatement annually).



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Presentation Contributors

Dr. Dorothy Merritts, Franklin and Marshall College

Dr. Robert Walter, Franklin and Marshall College

Michael Rahnis, Franklin and Marshall College

U.S. Geological Survey; Michael Langland, Joe Duris, Tammy Zimmerman and Jeff Chaplin

U.S. Environmental Protection Agency; Kenneth Forshay, Julie Weitzman, Jessica Wilhelm, Paul Mayer, Ann Keeley

LandStudies Incorporated, Lititz PA

Dr. Art Parola, University of Louisville

Dr. David Bowne, Elizabethtown College

Dr. Marina Potapova, Drexel University

Dr. Patrick Flemming, Water Science Institute & Franklin and Marshall College

Susquehanna River Basin Commission, Jamie Shallenberger

Joseph Sweeney, Water Science Institute

Questions ?

Contact Information

Jeffrey Hartranft

Bureau of Waterways Engineering and Wetlands

Division of Wetlands Encroachment and Training

jhartranft@pa.gov

717-772-5320