Big Spring Run Restoration Project Background & Monitoring Results

Pennsylvania

Department of Environmental Protection

Pennsylvania Legacy Sediment Workgroup

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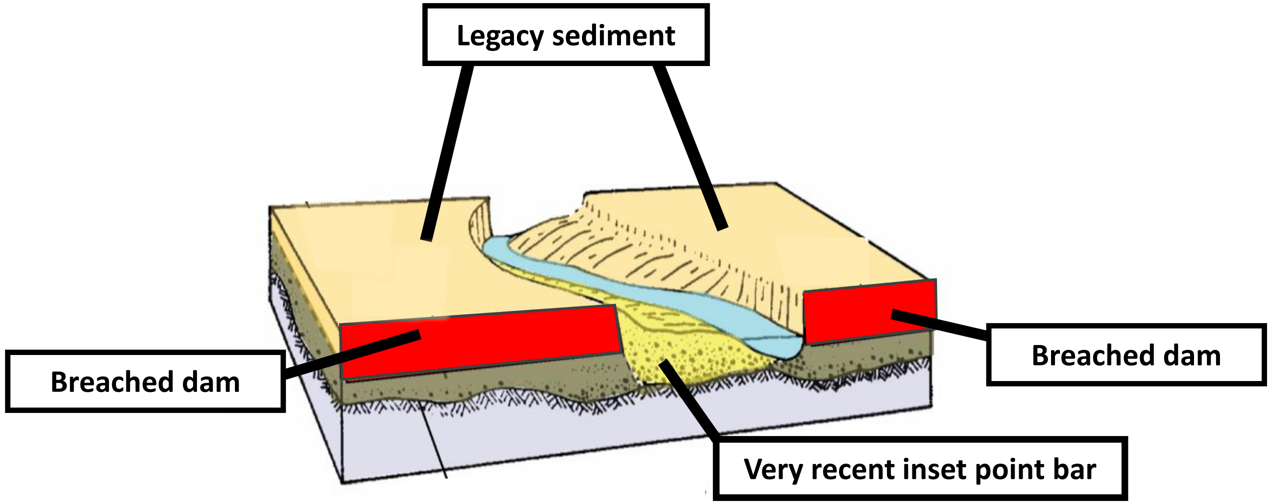
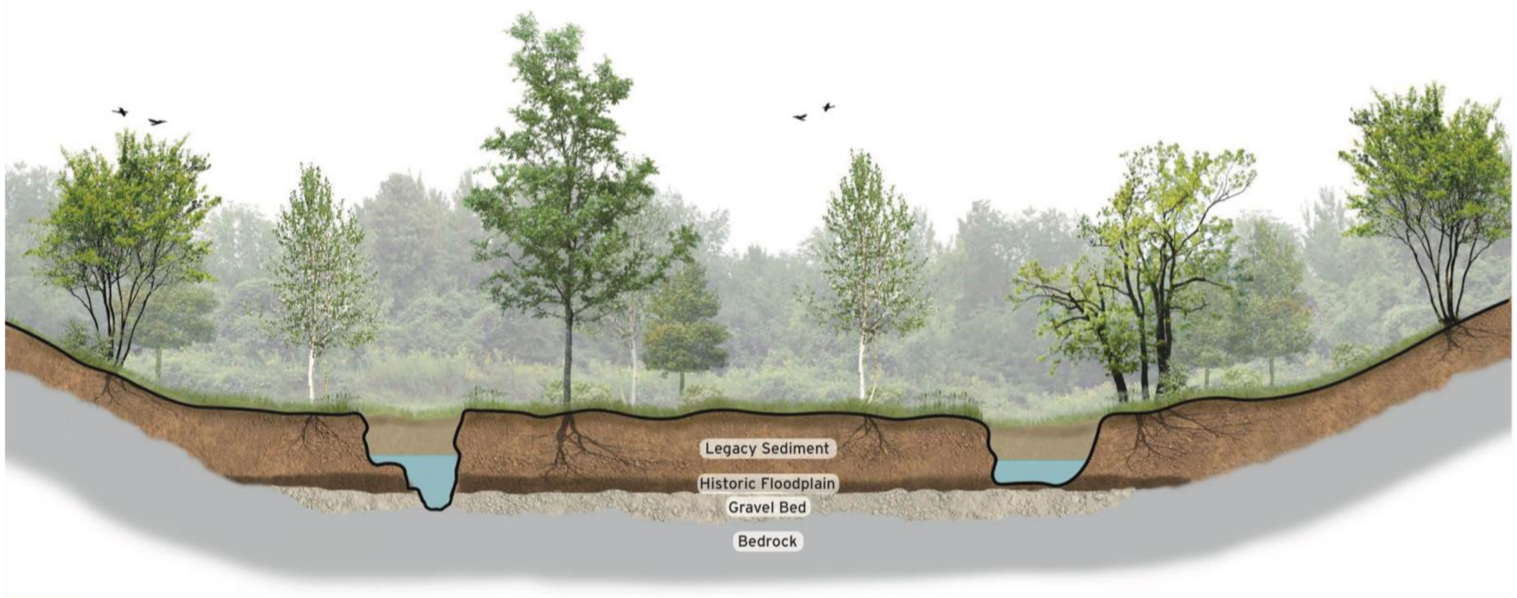
Presentation Outline

- 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



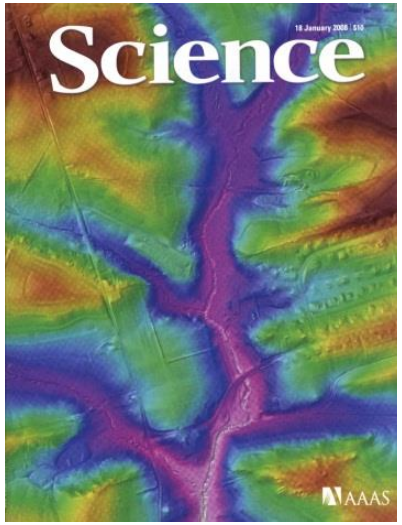
Modified from Jacobson and Coleman, 1986 after Walter and Merritts, 2008

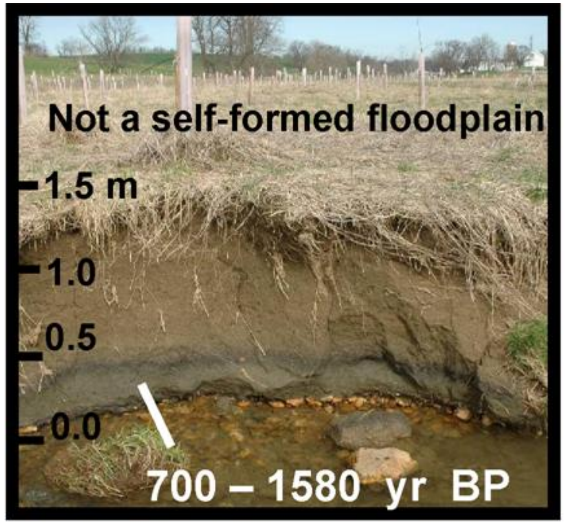


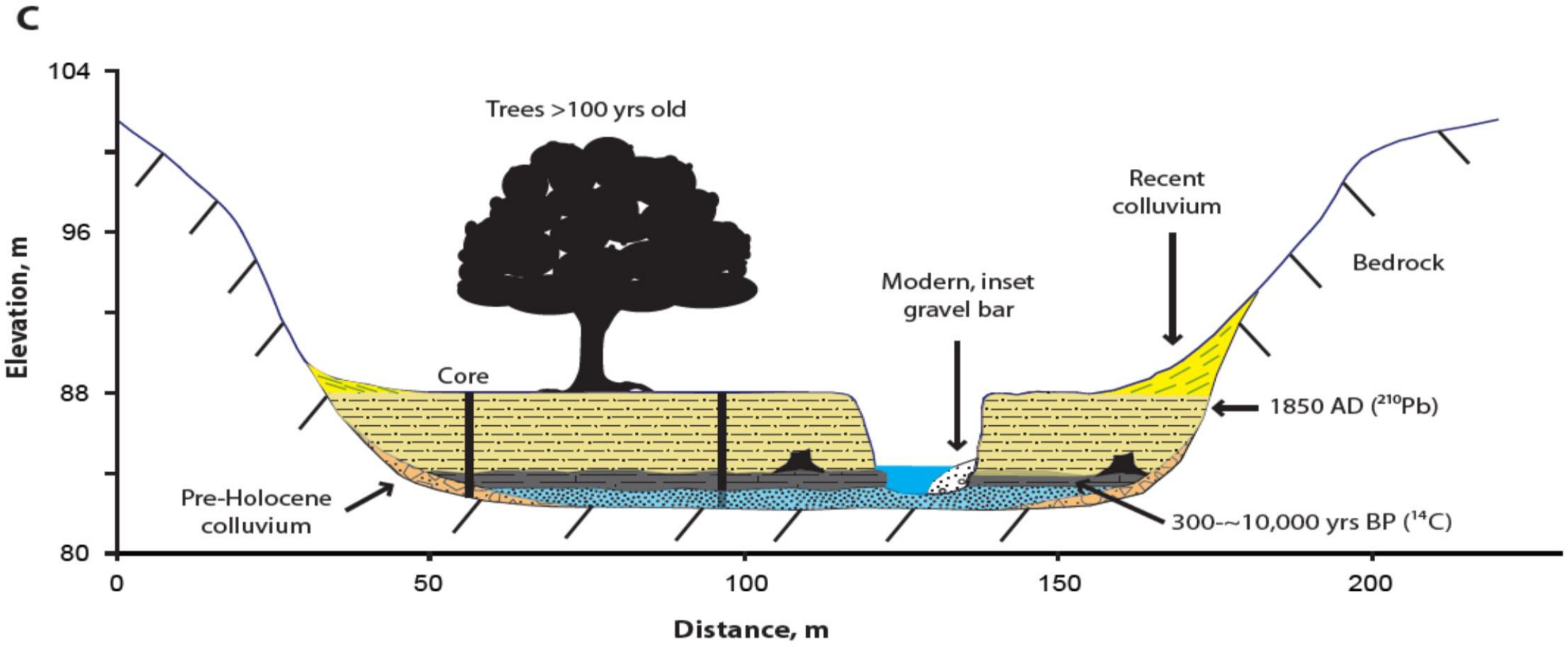
Land studies

Existing Conditions

Typical Stream and Floodplain Section View







Walter and Merritts, 2008

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)

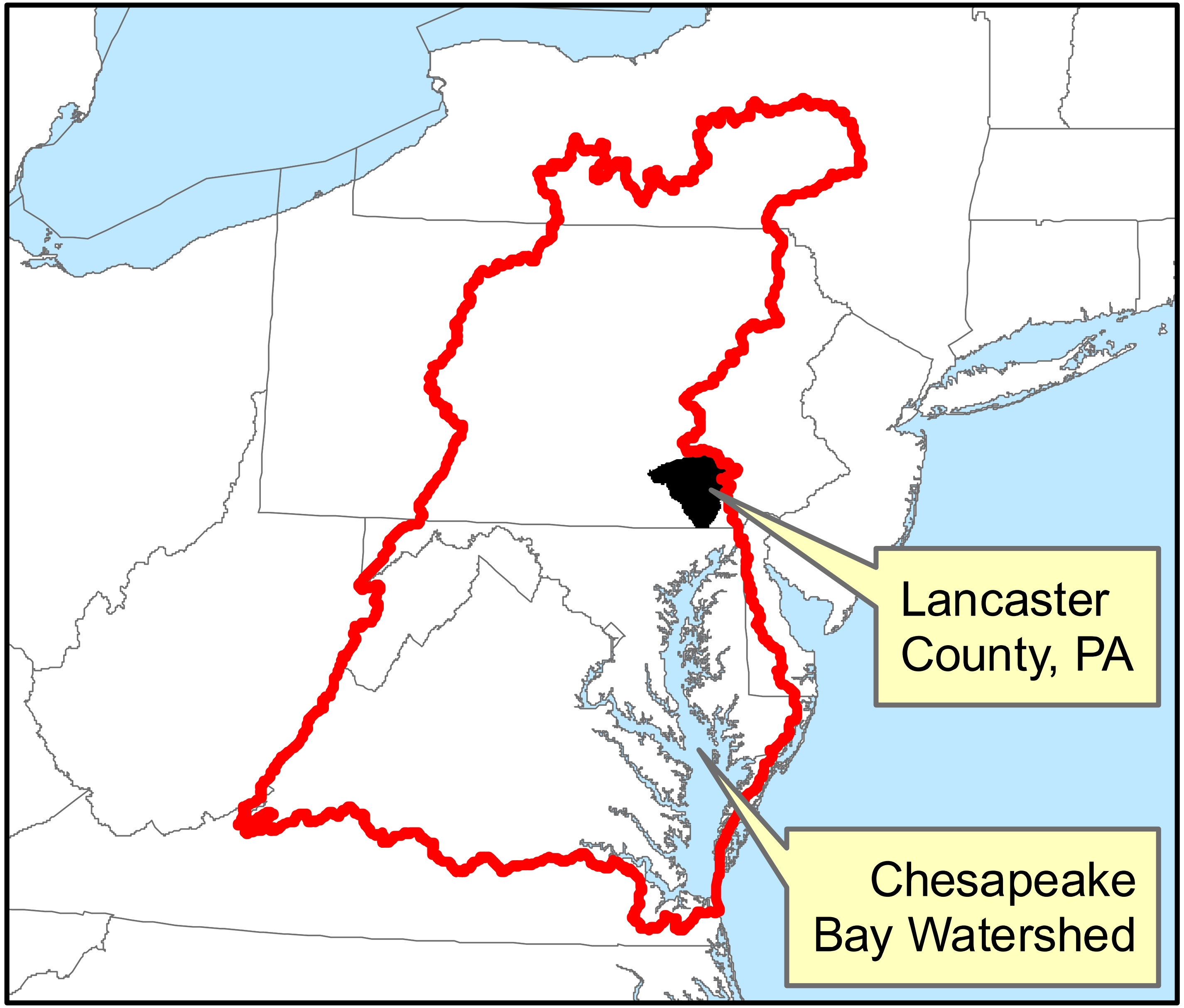
Big Spring Run Legacy Sediment Removal and Aquatic Ecosystem Restoration Project

- A multidisciplinary team planned, designed, constructed and monitored this restoration project beginning in 2008 through 2019
- Team members included a wide range of scientific and technical disciplines
- Project sponsors included governments, academic institutions, non-profits, landowners and other private entities

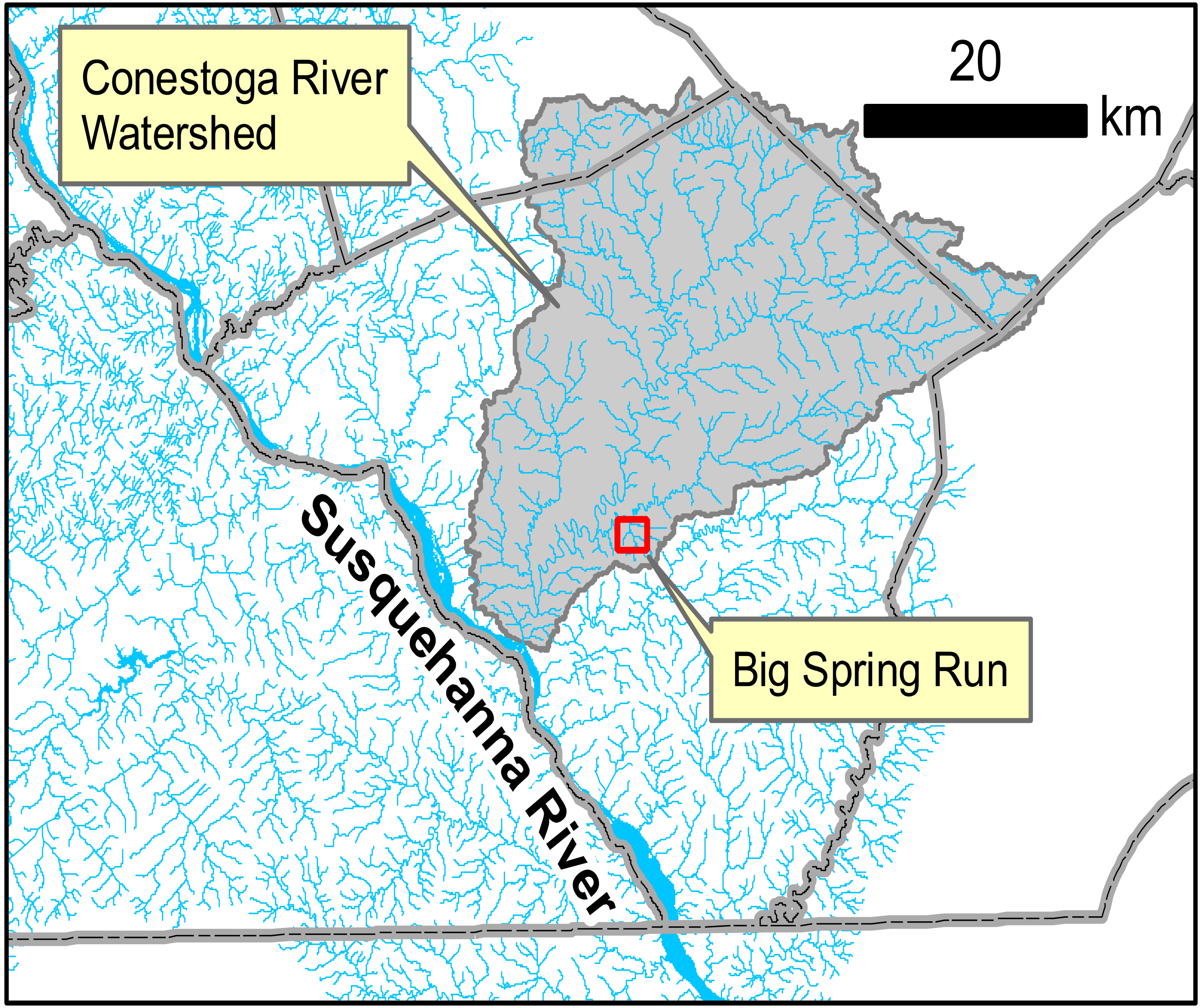
Monitor

- Before, during, and after project monitoring is used to evaluate goal and objective achievement
- Continuous at Big Spring Run from 2008 through 2019
- 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)

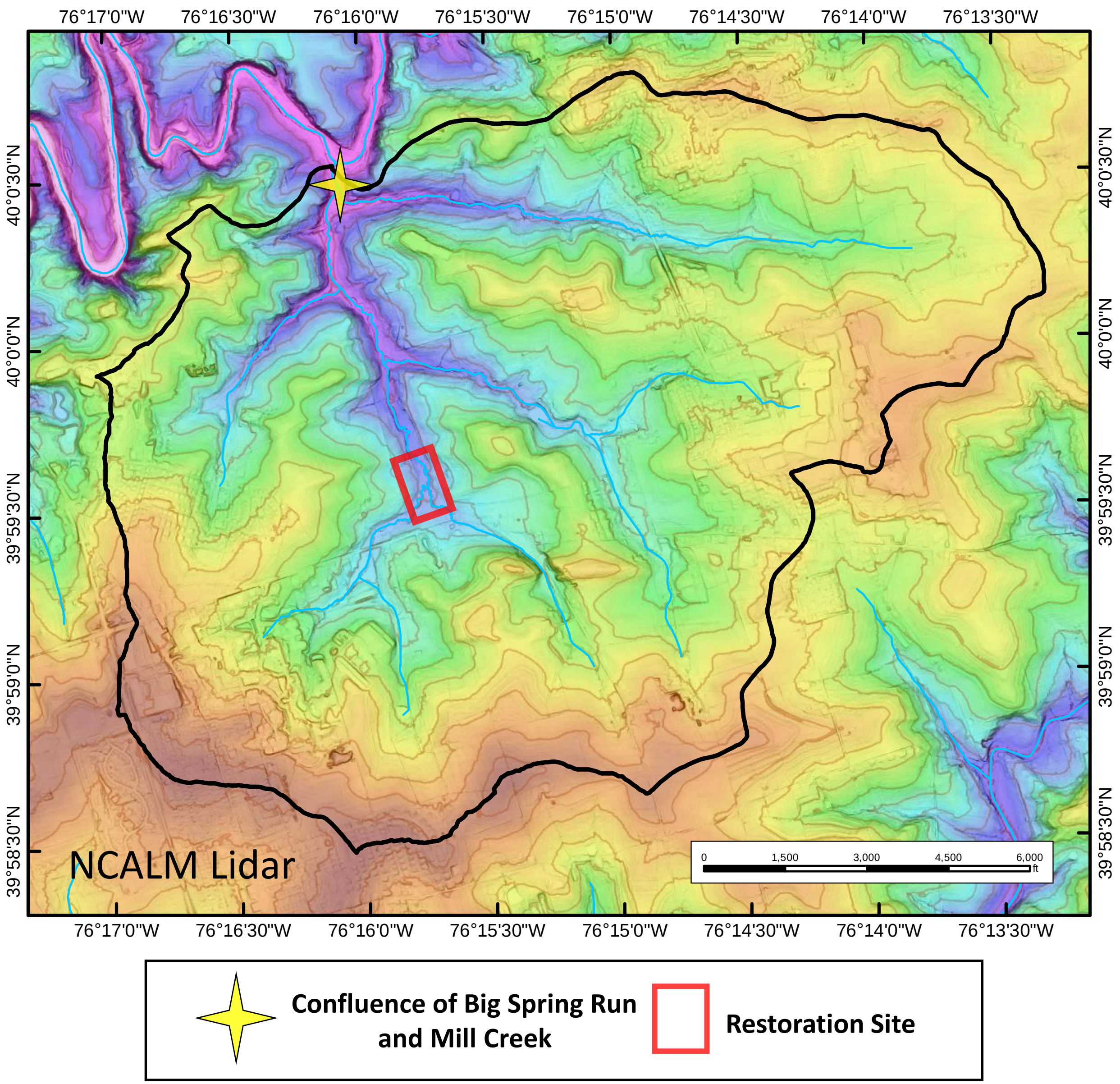


Courtesy Franklin & Marshall College



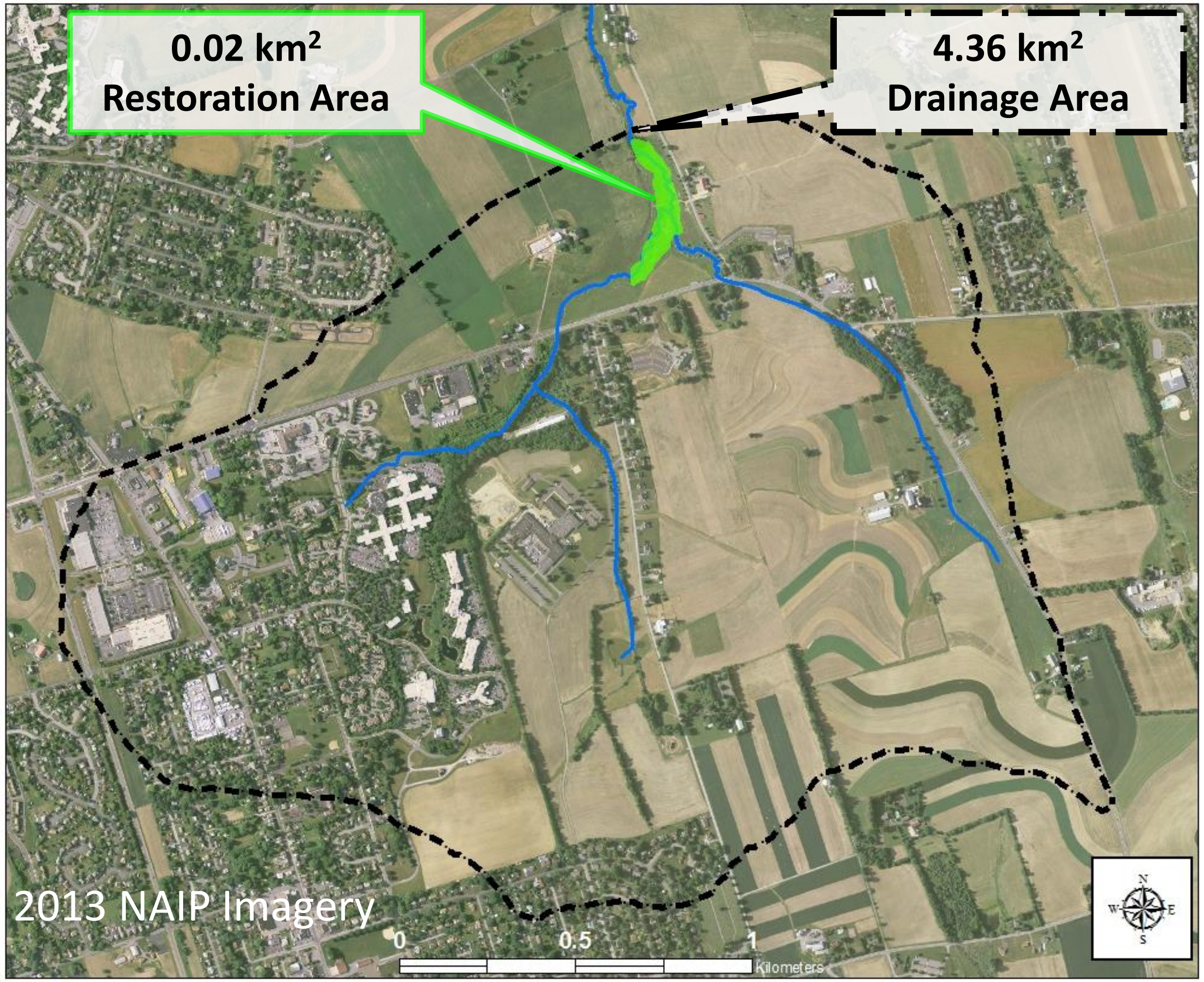
Courtesy Franklin & Marshall College

Big Spring Run Watershed Hillshade Elevations



Walter, et al., 2013 PADEP Report

Watershed and Restoration Area



The ratio of restoration area to drainage area < 0.5%

Address ongoing causes of degradation.

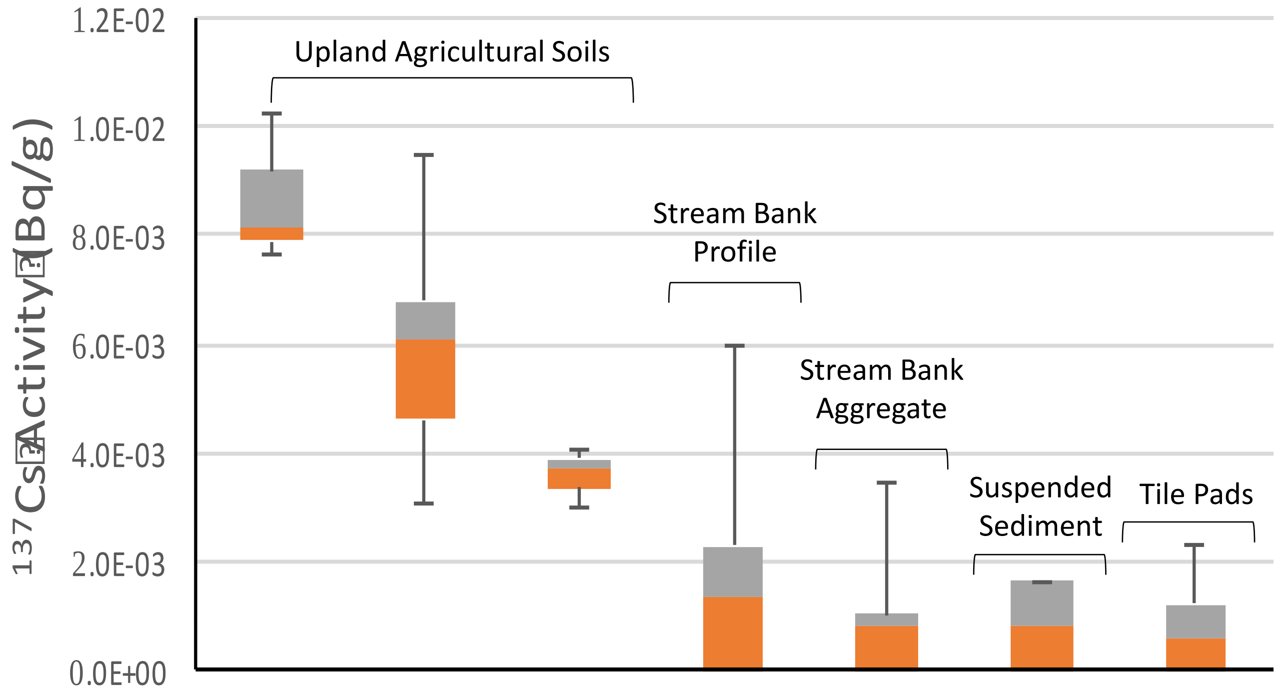
- Restoration efforts are likely to fail if the sources of degradation persist.
- Understanding an ecosystem's evolutionary trajectory is relevant to correctly diagnosing the problem, as well as to developing restoration approaches that are sustainable.

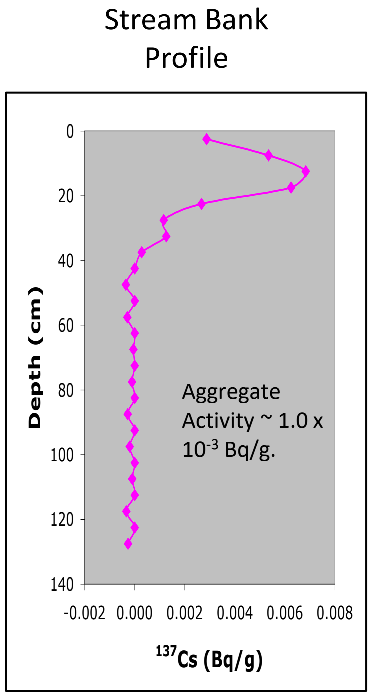
"… understanding the legacy sediment problem is the first step in proposing a fix."

Bay Journal, March, 2007. Alliance for the Chesapeake Bay.

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

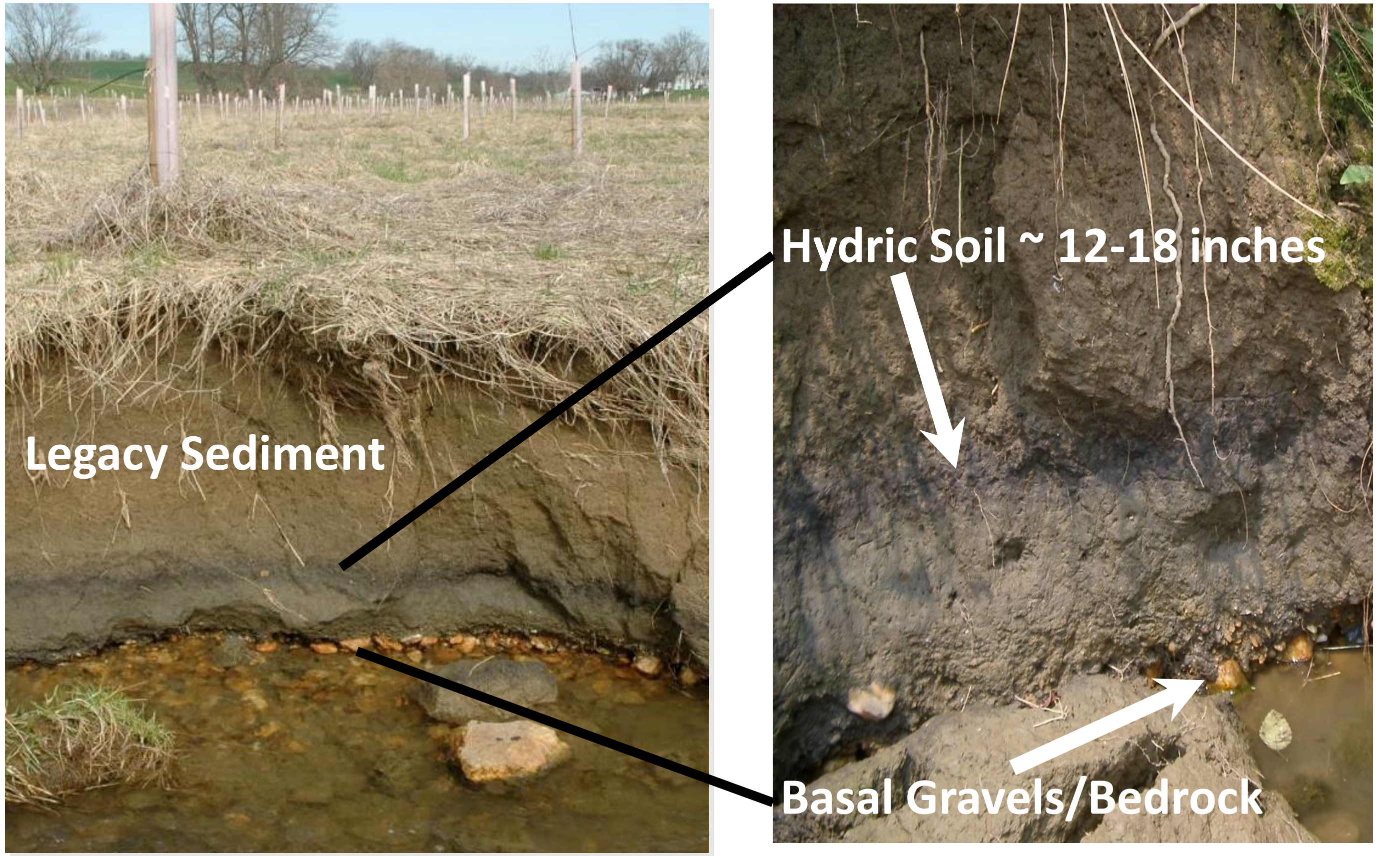
Walter et. al., 2017; Bai 2017 (Franklin & Marshall College Thesis)

Utilize a reference condition

- **Identifying natural reference conditions 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)

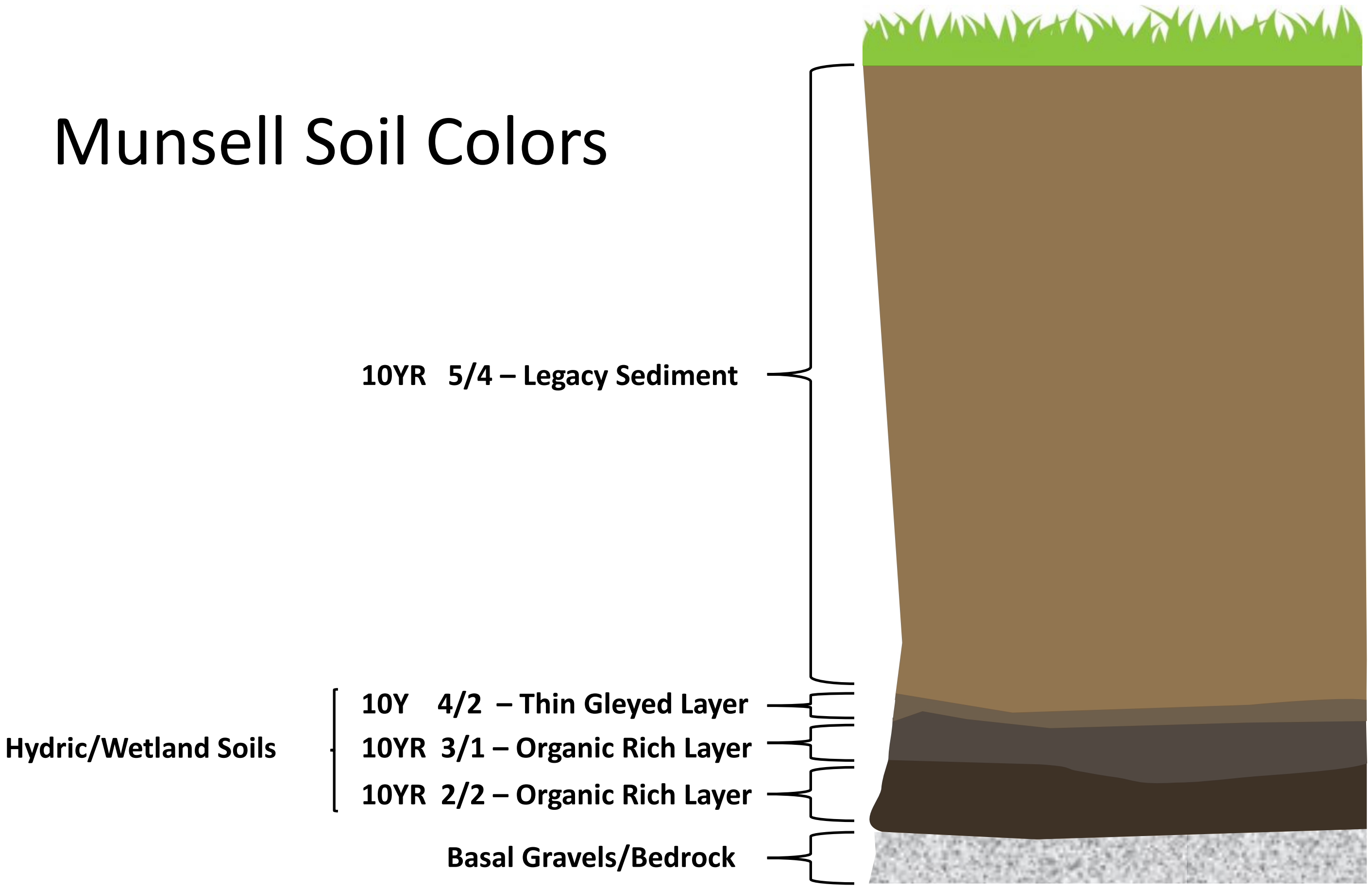
Big Spring Run In-situ Reference Condition



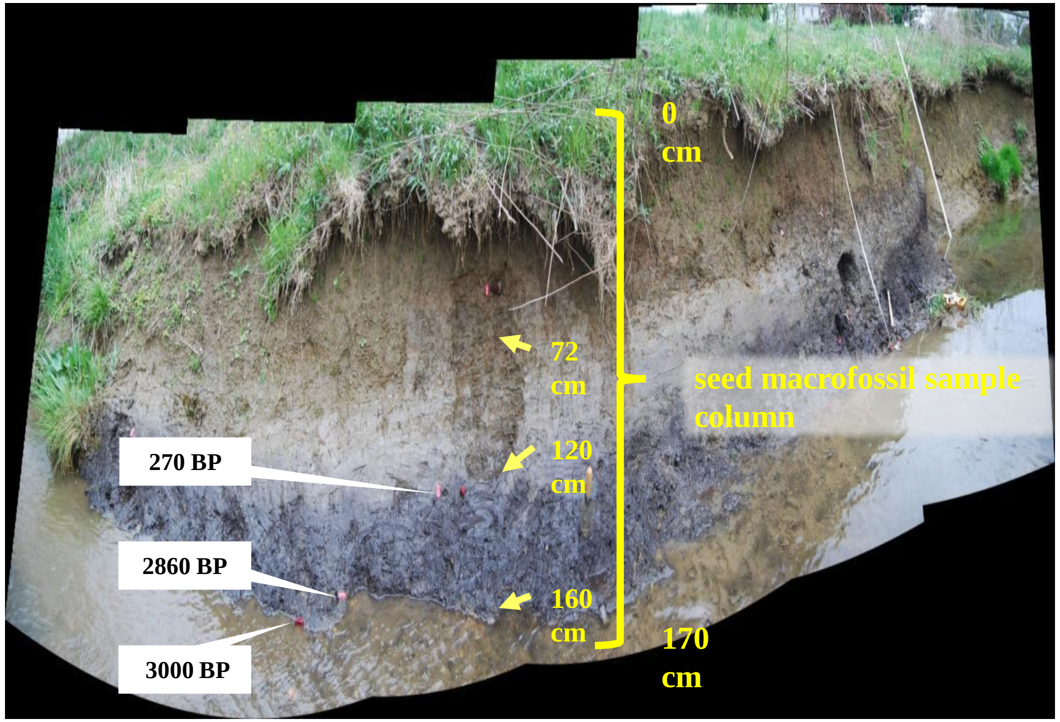
Photos Courtesy Franklin & Marshall College

Typical Legacy Sediment and Eroding Streambank Stratigraphy - West Branch Little Conestoga River

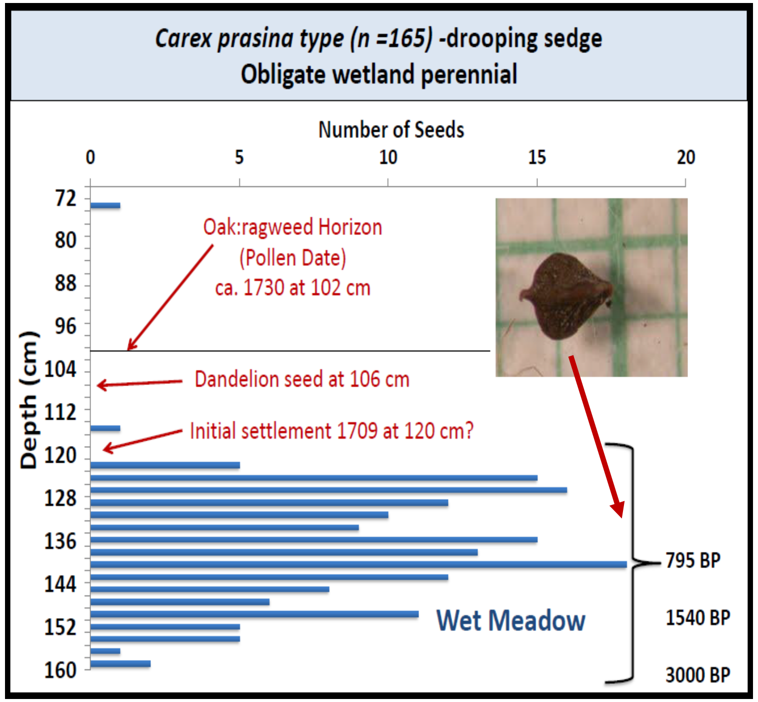
Munsell Soil Colors



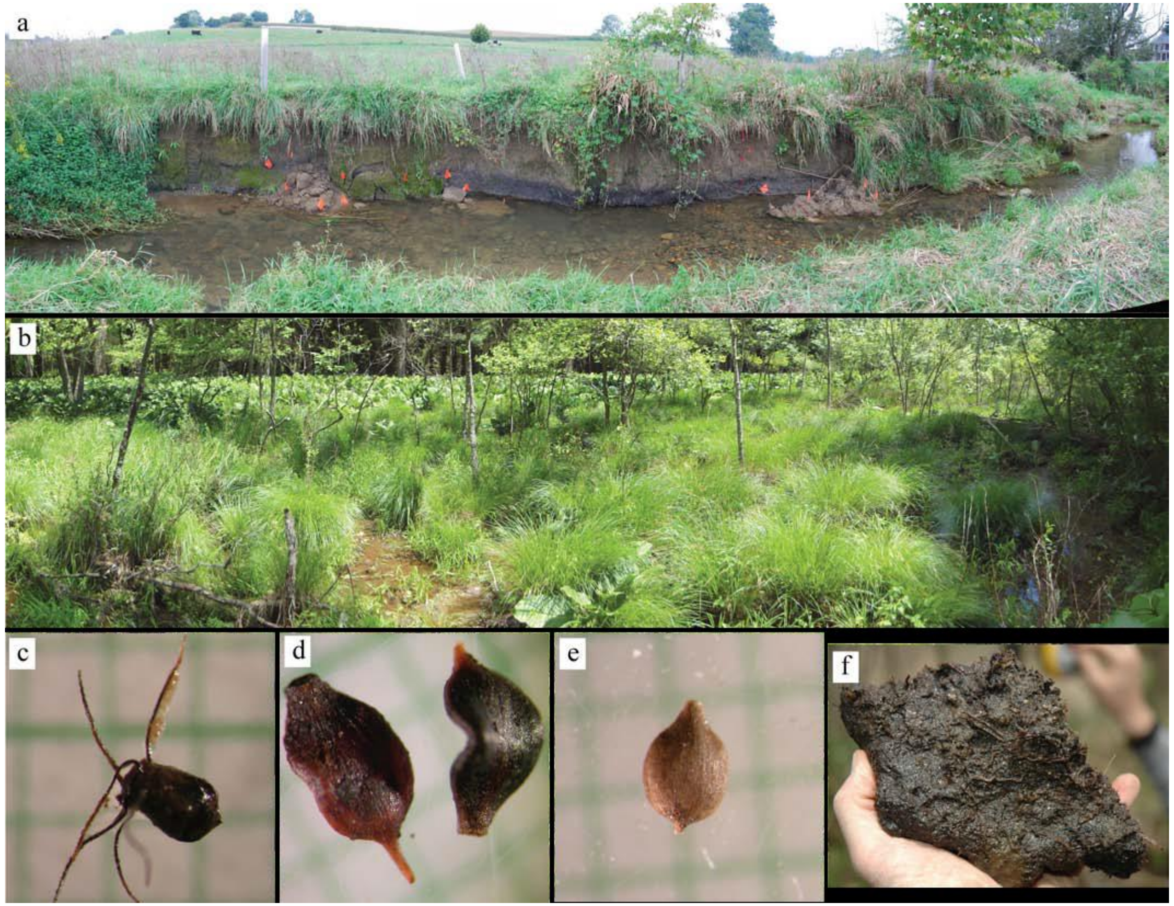
Big Spring Run Carbon-14 Dates and Vascular Plant Seed Macrofossil Analysis



All Dates +/- 40



Adapted 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

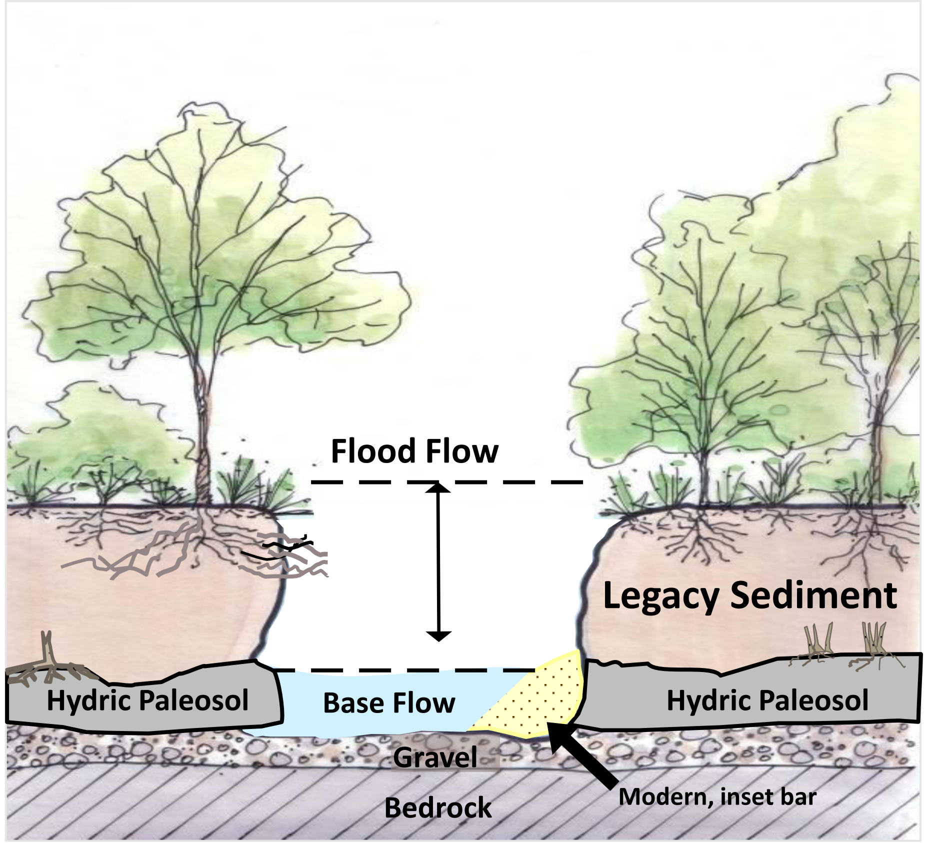
Restore natural function

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

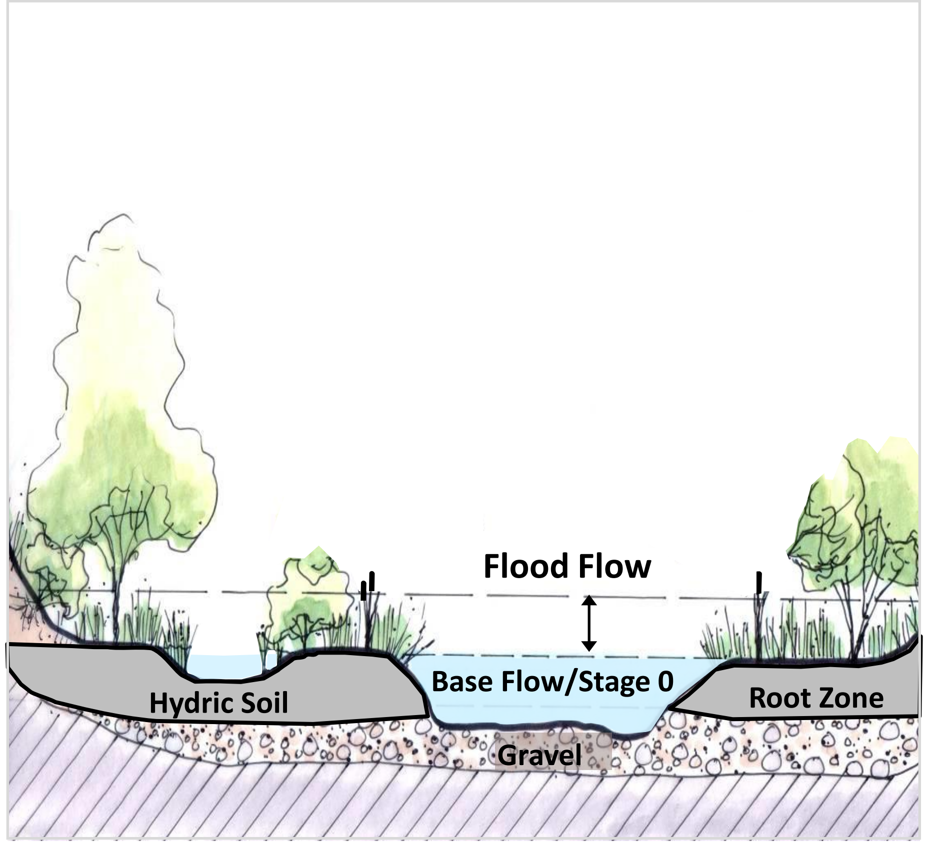
Principles for the Ecological Restoration of Aquatic Resources (EPA841-F-00-003)

Legacy Sediment Removal and Aquatic Ecosystem Restoration Best Management Practice

Typical Existing Conditions

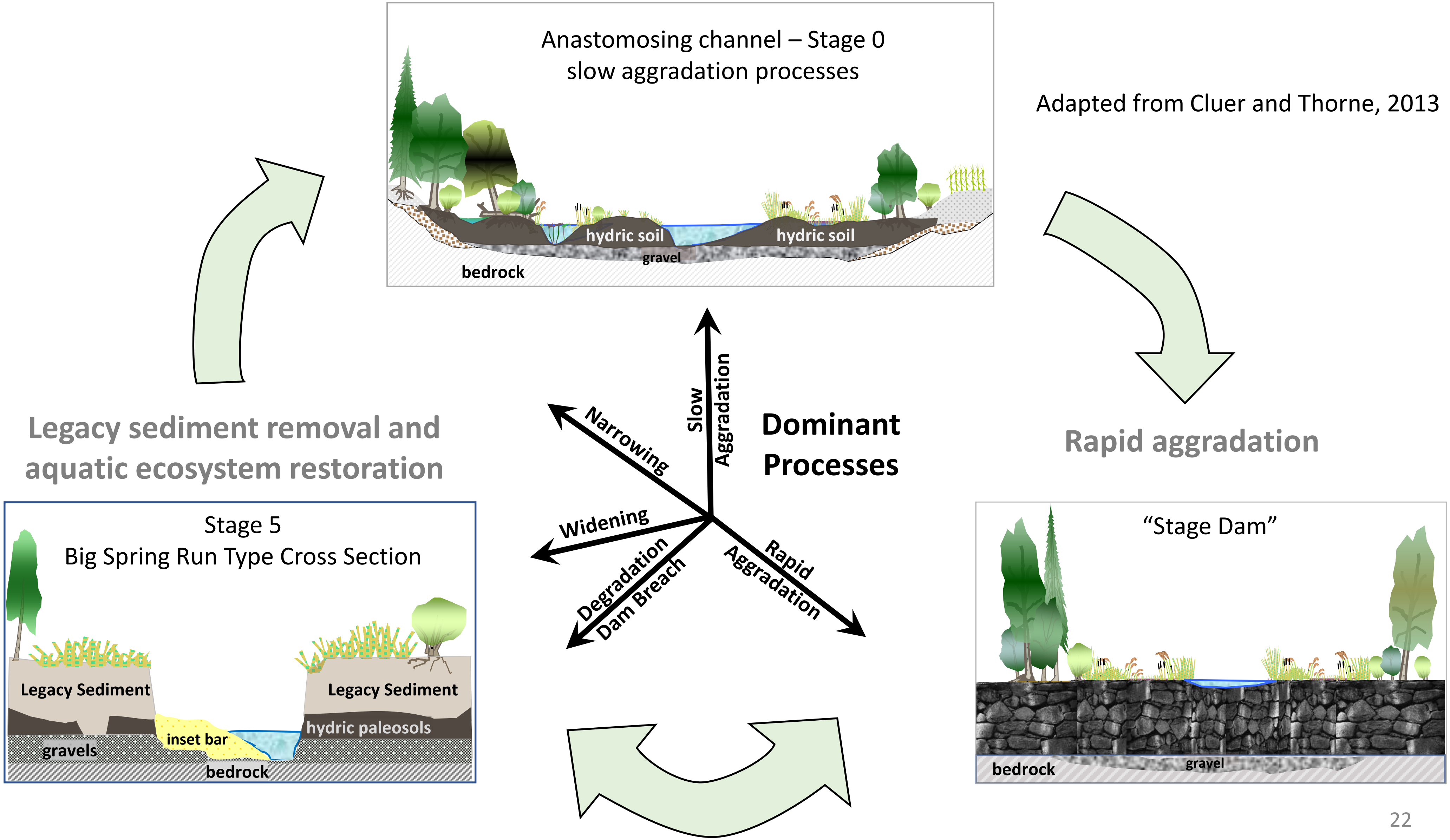


Proposed Restoration

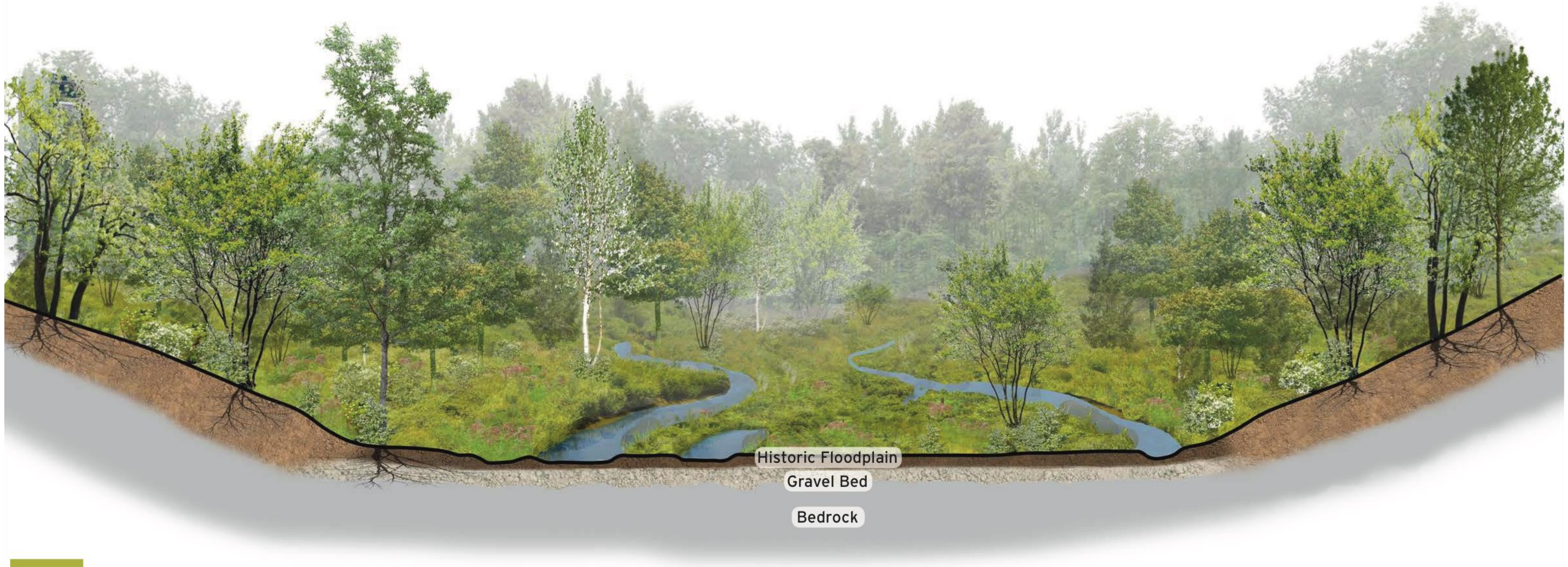


Conceptual Design Adapted from LandStudies, Inc.

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



Artist rendition of restored conditions



Land Studies

Historical / Restored Conditions

Typical Stream and Floodplain Section View

October 2011

October 2011

Courtesy Franklin & Marshall College

Big Spring Run Geomorphic Results

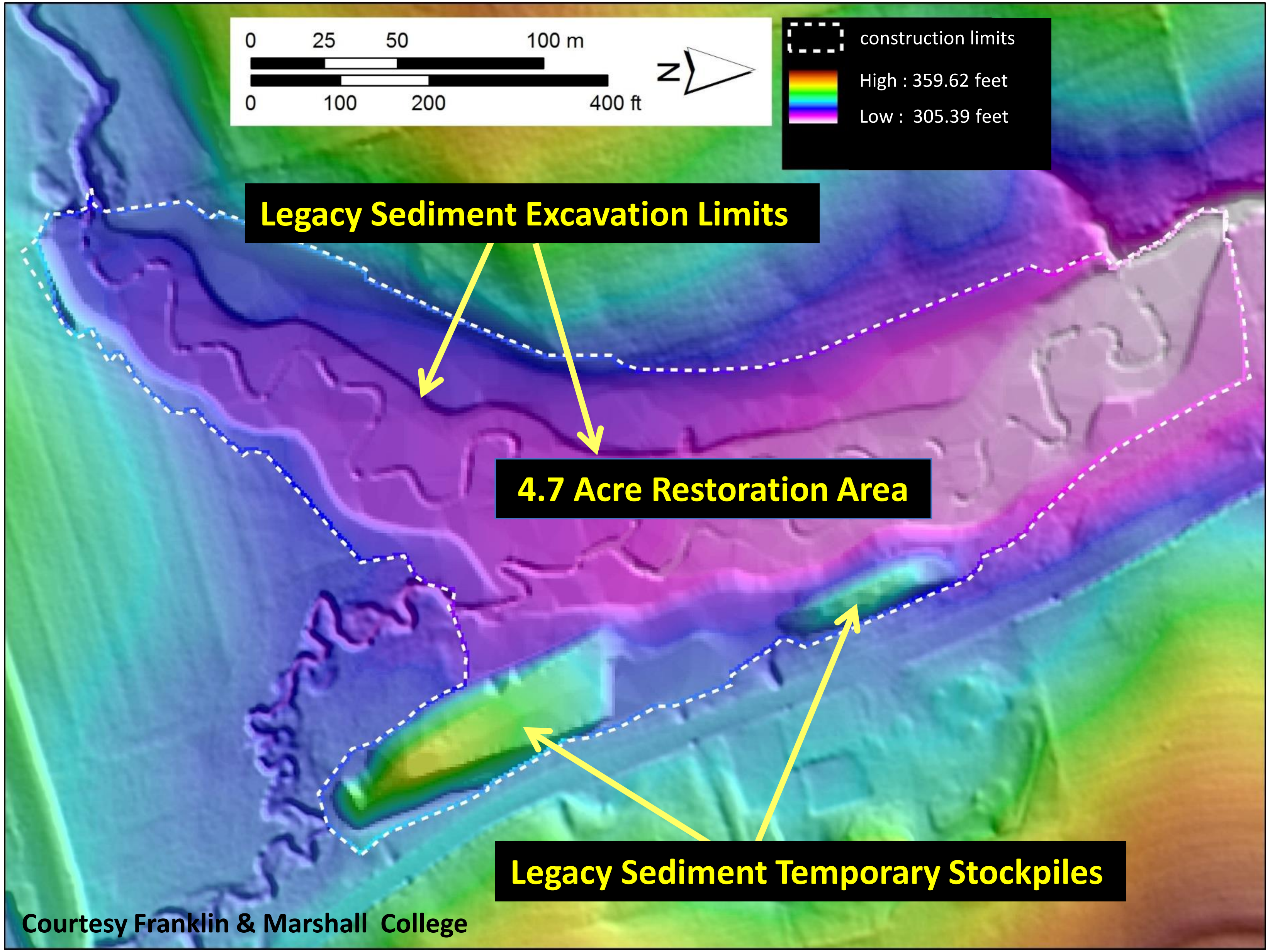
Typical Existing Conditions

Restoration

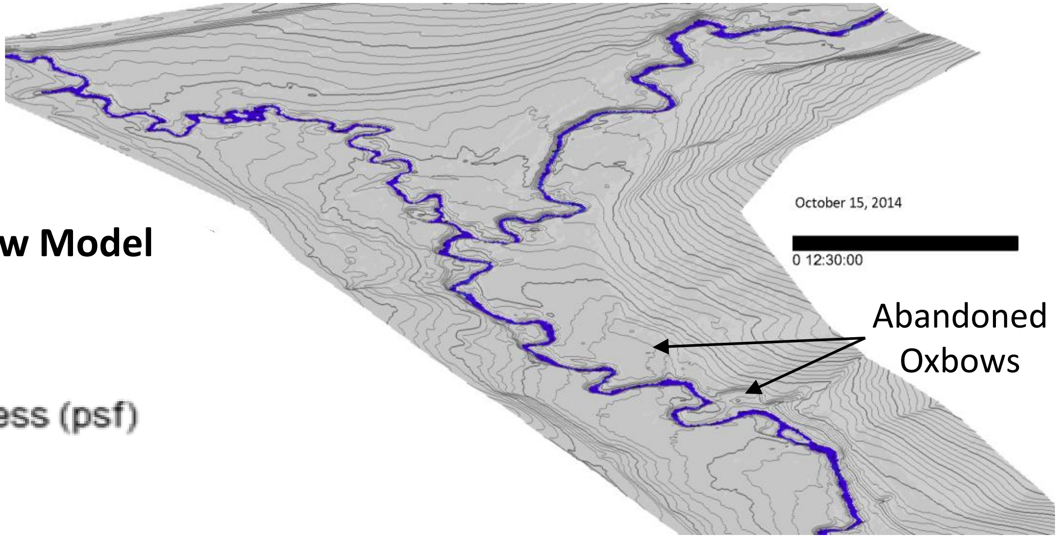
9/13/2011

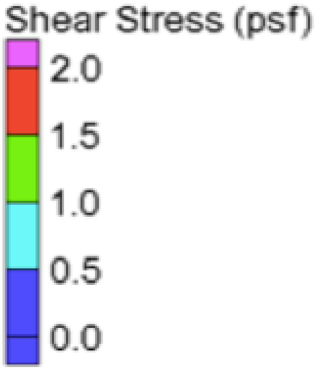
07/27/2012

Big Spring Run As-Built - Hillshade Elevations

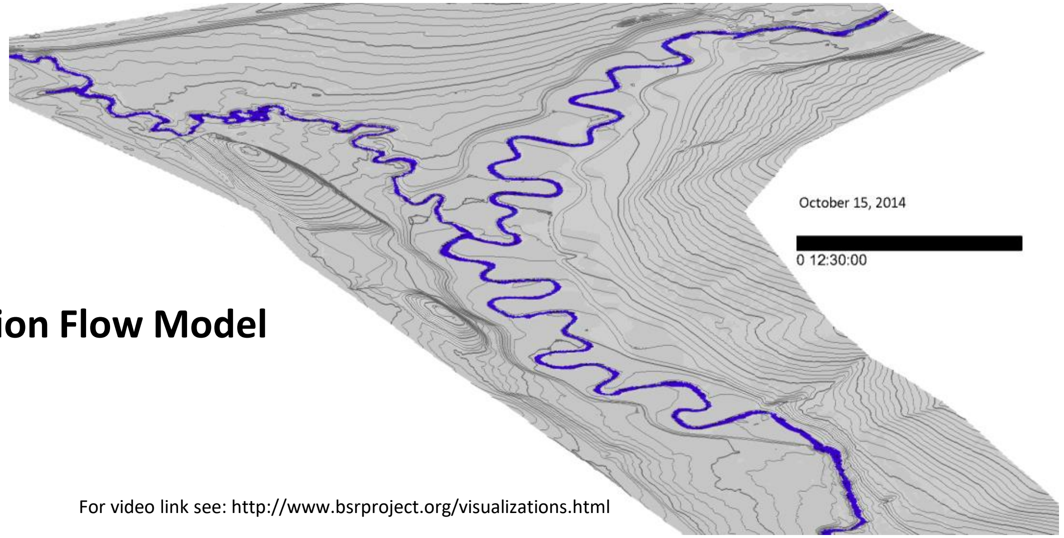


Pre-Restoration Flow Model





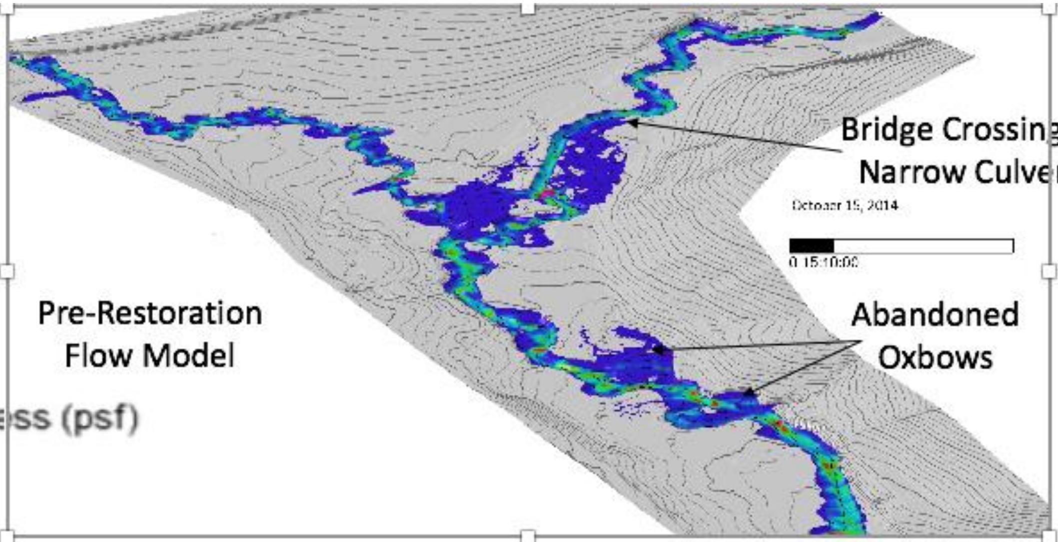
Post-Restoration Flow Model

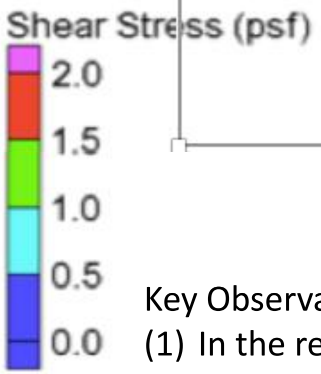


For video link see: http://www.bsrproject.org/visualizations.html

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

Instantaneous storm flow conditions

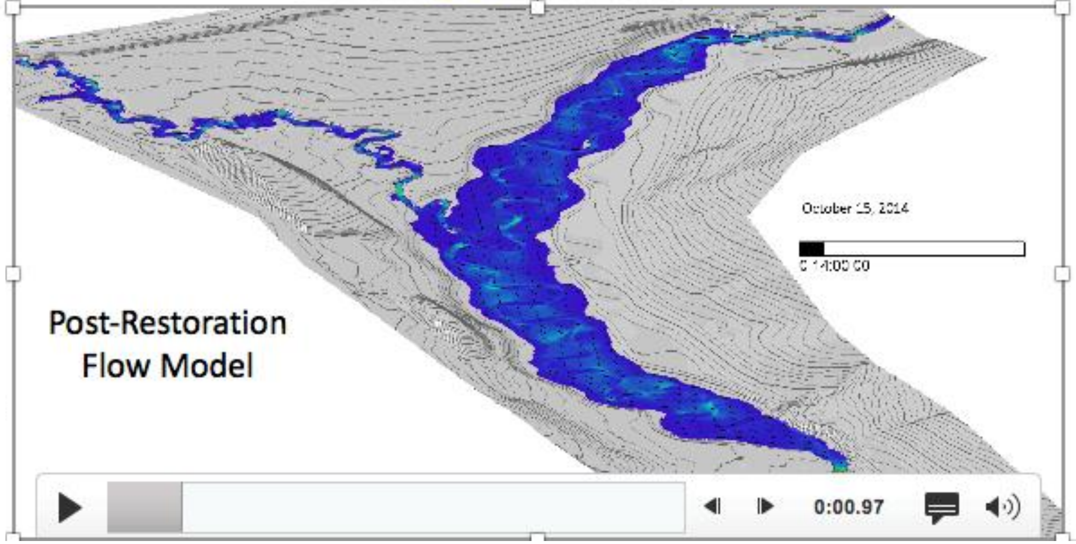




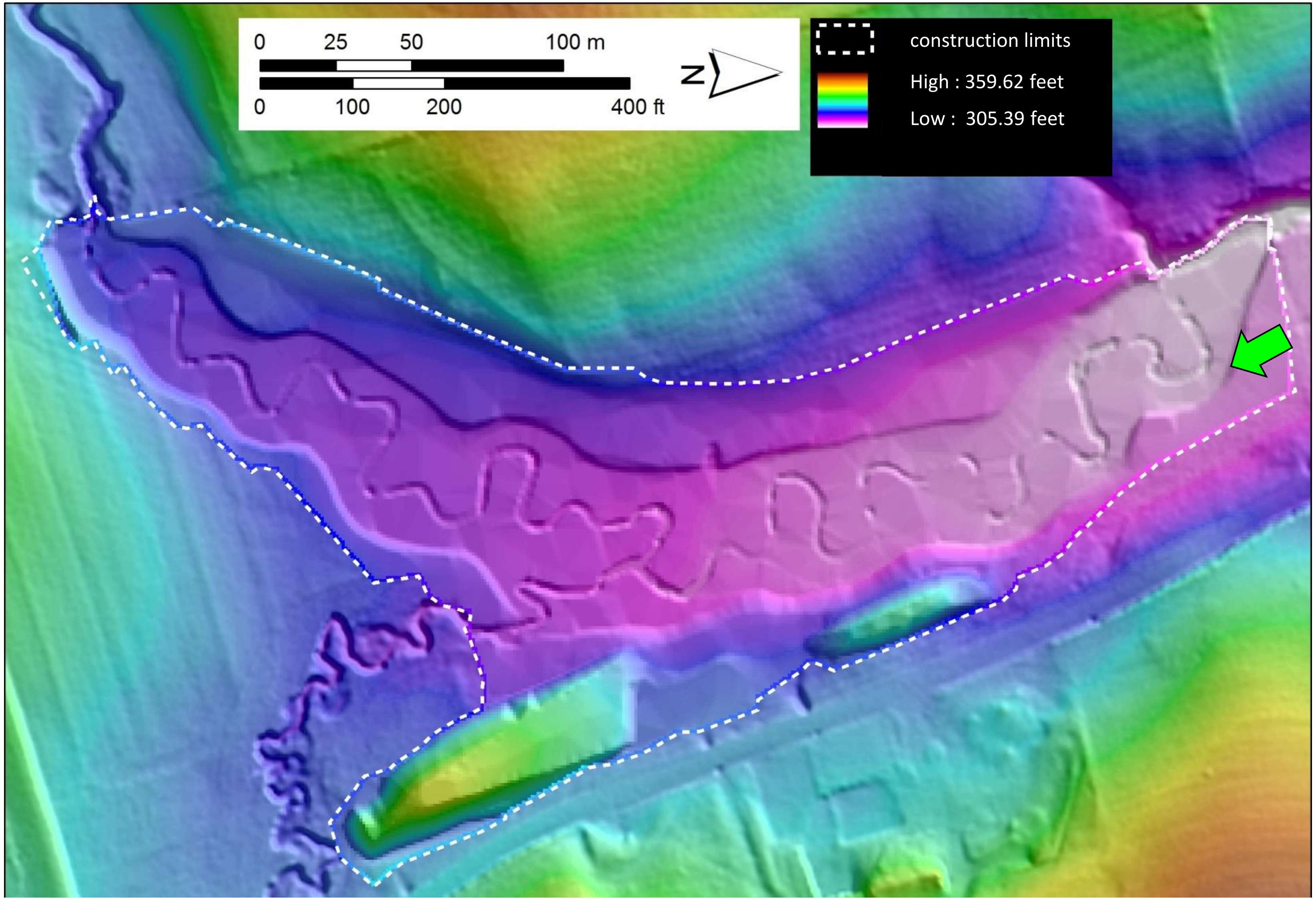
RiverineSystems
LandStudies

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

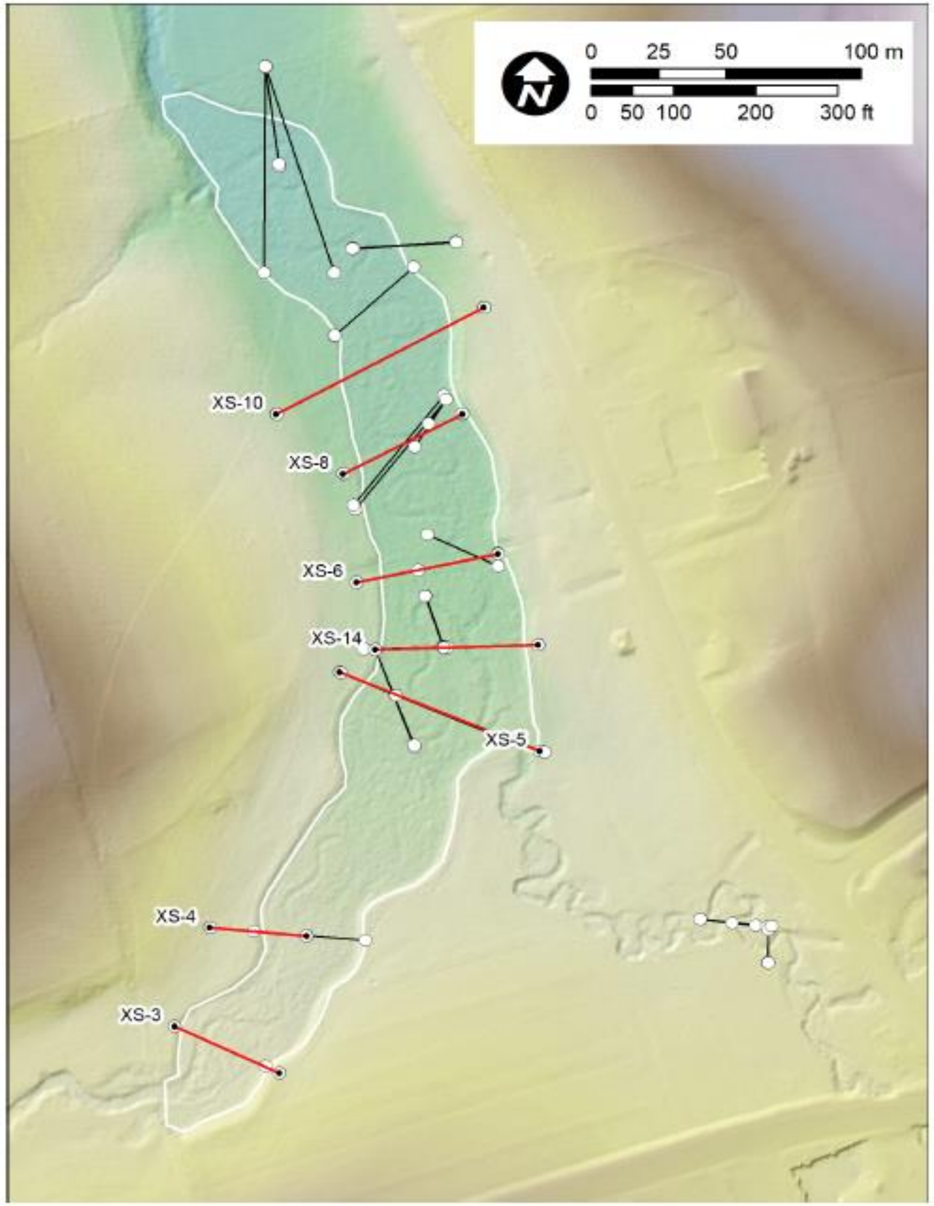
Big Spring Run post-restoration storm

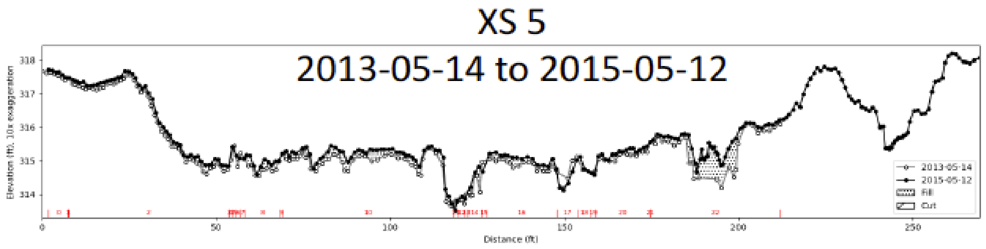
September 18, 2012 @ 8:30 PM

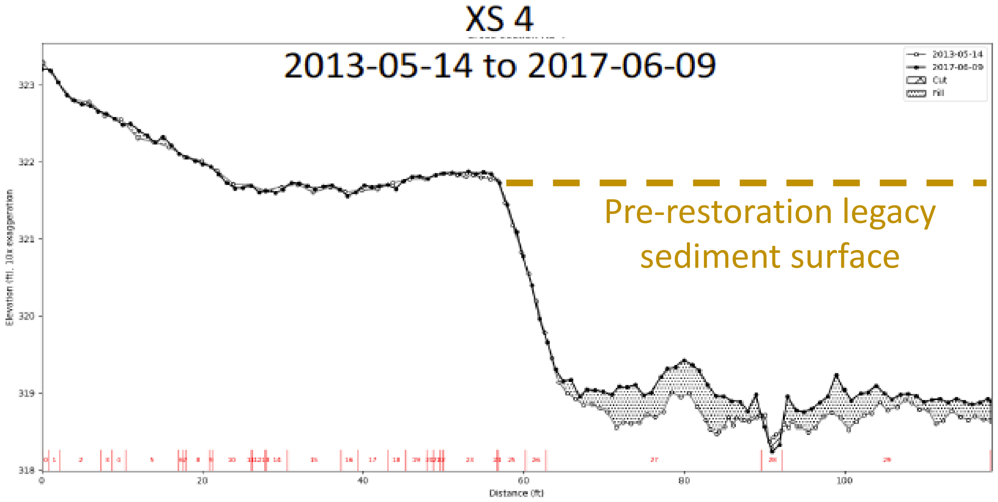
Big Spring Run post-restoration storm

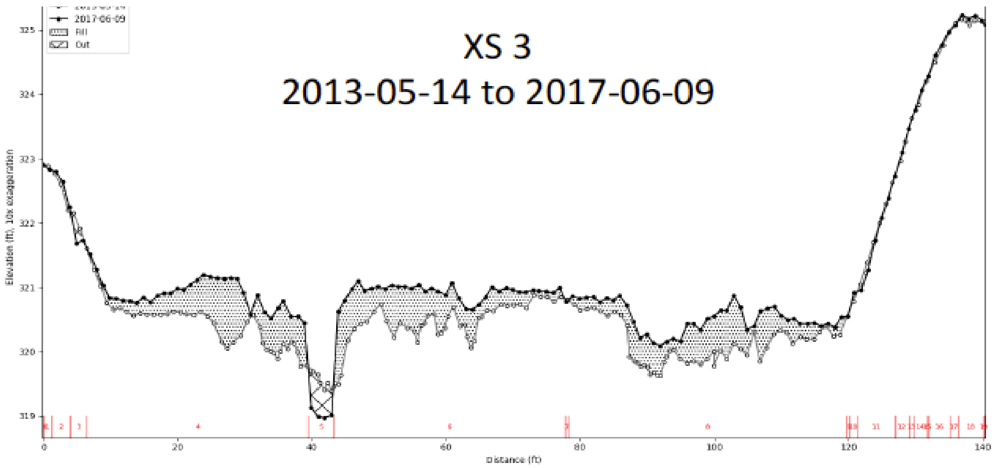
September 19, 2012 @ 10:00 AM

Post-restoration repeat cross section surveys, 2013-2017

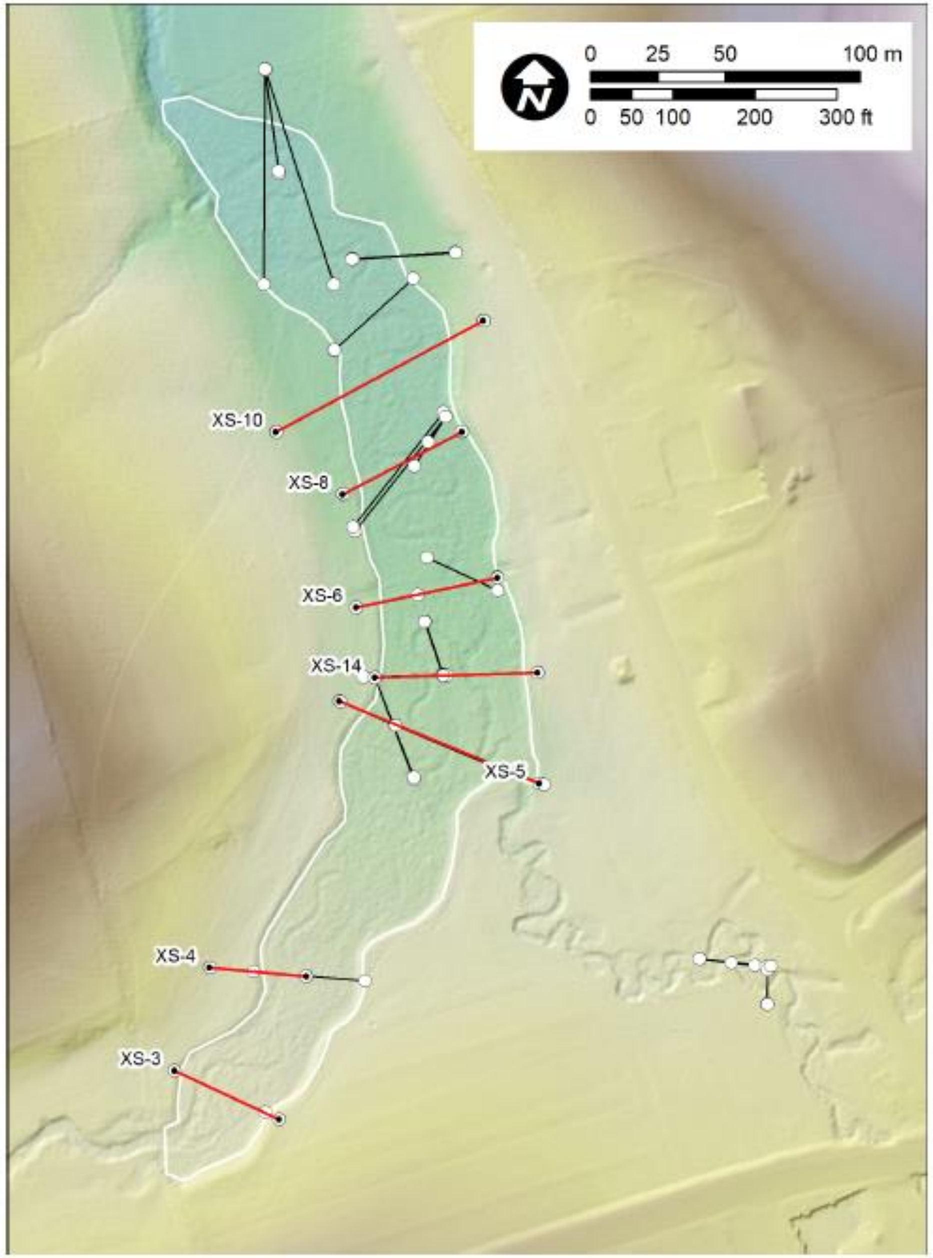


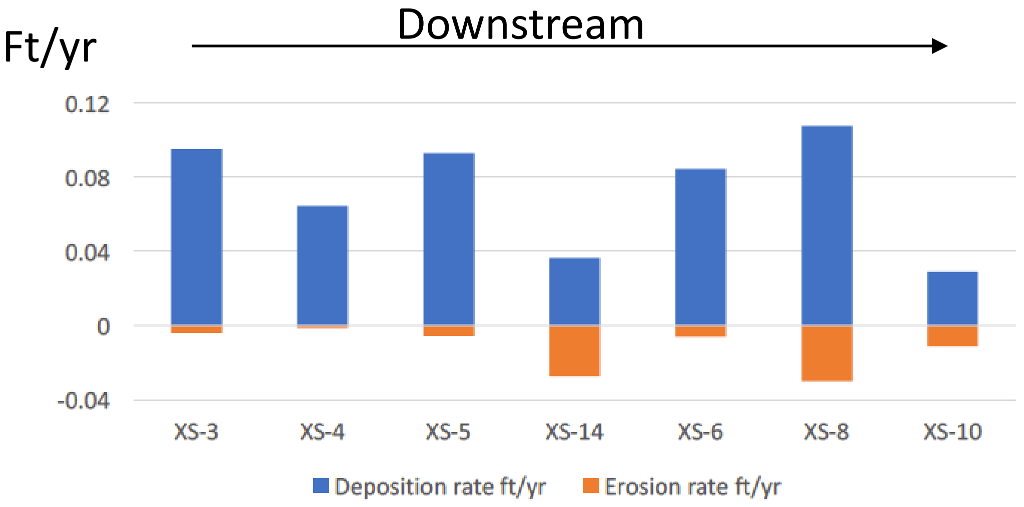


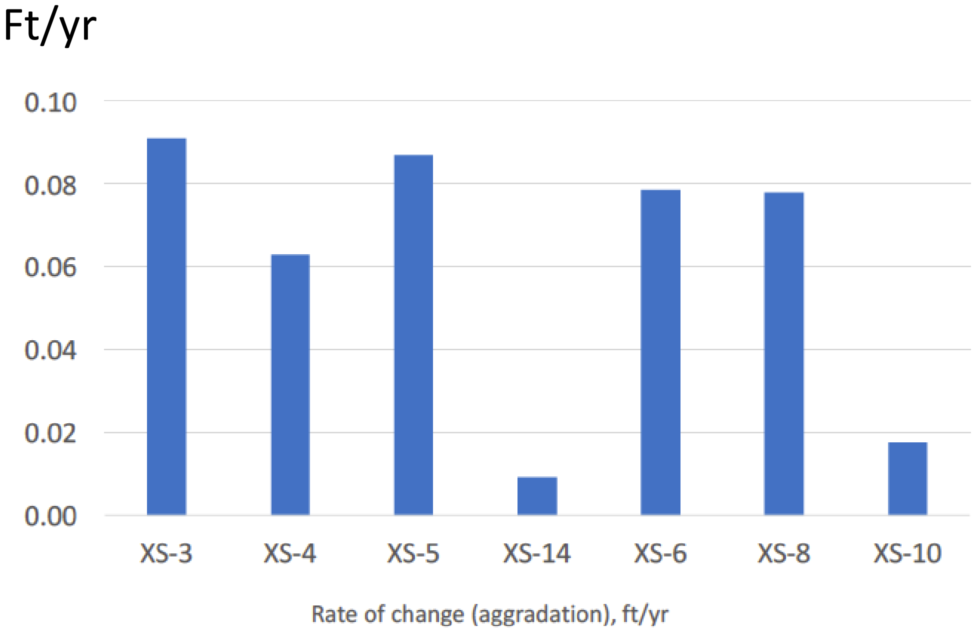




Post-restoration repeat cross section survey locations

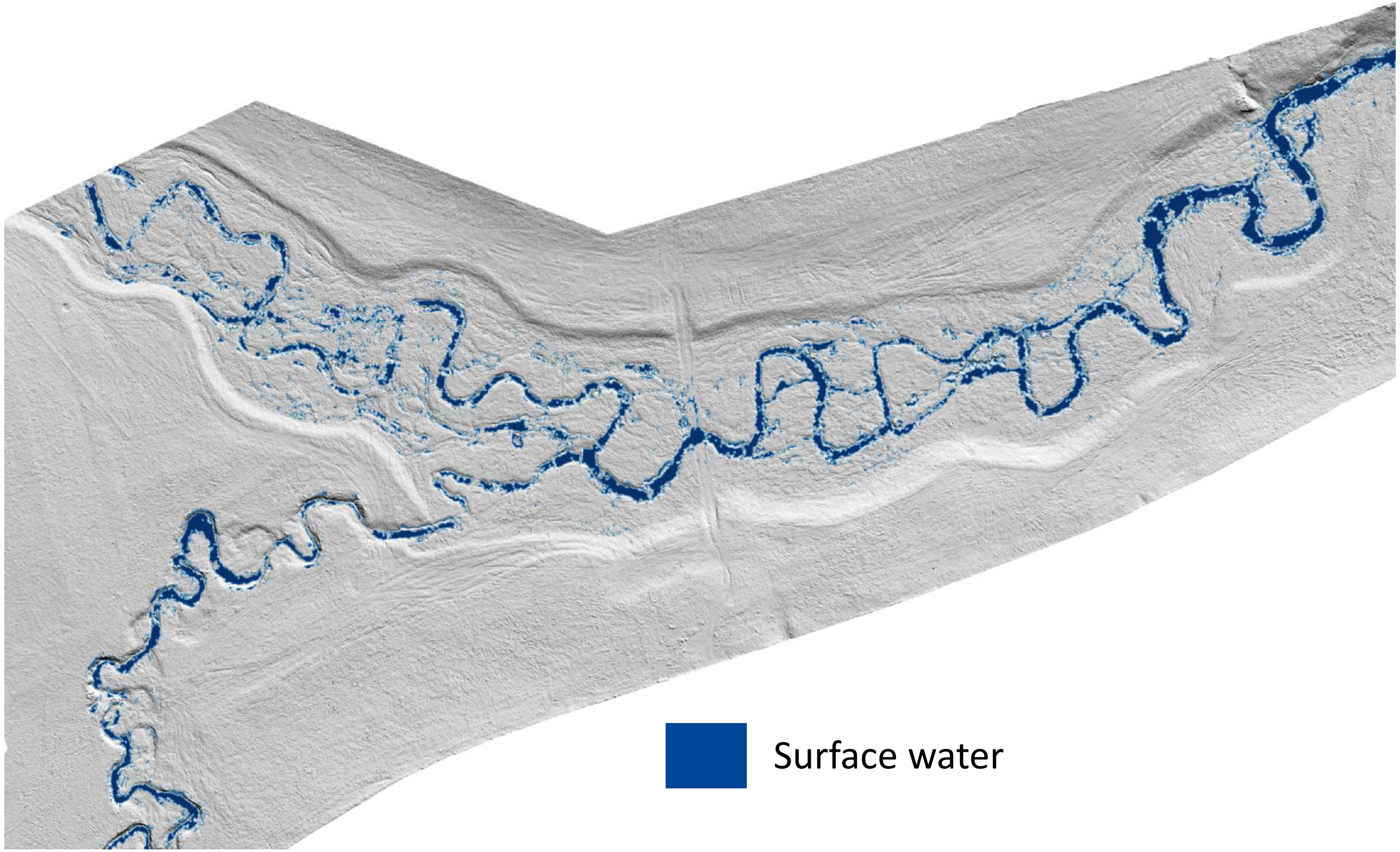






Deposition (blue), erosion (orange), and net change (aggradation) for seven cross sections surveyed at least twice between 2012-13 and 2015-17.

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

Summary of post-restoration geomorphic monitoring

- Small, anastomosing channels were well established by April 2014 - 3 years after restoration.
- Terrestrial laser surveys confirmed that the wetland-floodplain surface remained stable from April 2014 through April 2016 and little change in ground elevation has occurred (i.e., erosion is minimal).
- Fine sediment (silt size) deposition is occurring within the restoration area over time, but it is localized, mostly along channel edges, and on the order a few centimeters.
- Springs that were daylighted when legacy sediment was removed became pools of water connecting small channels that were well established by April 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

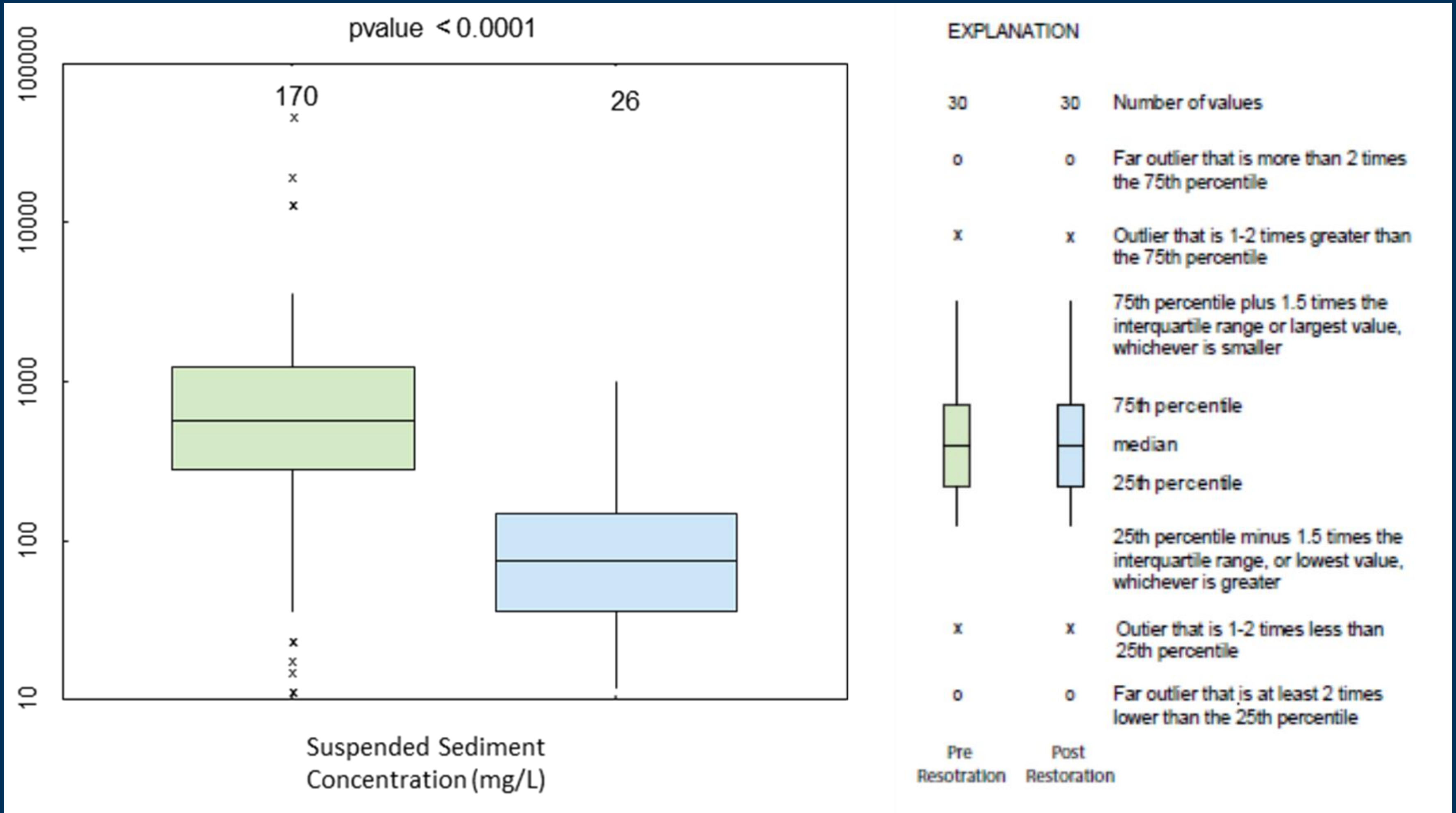
In cooperation with the Pennsylvania Department of Environmental Protection and in collaboration with Franklin and Marshall College and the U. S. Environmental Protection Agency

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

USGS Sample Sites

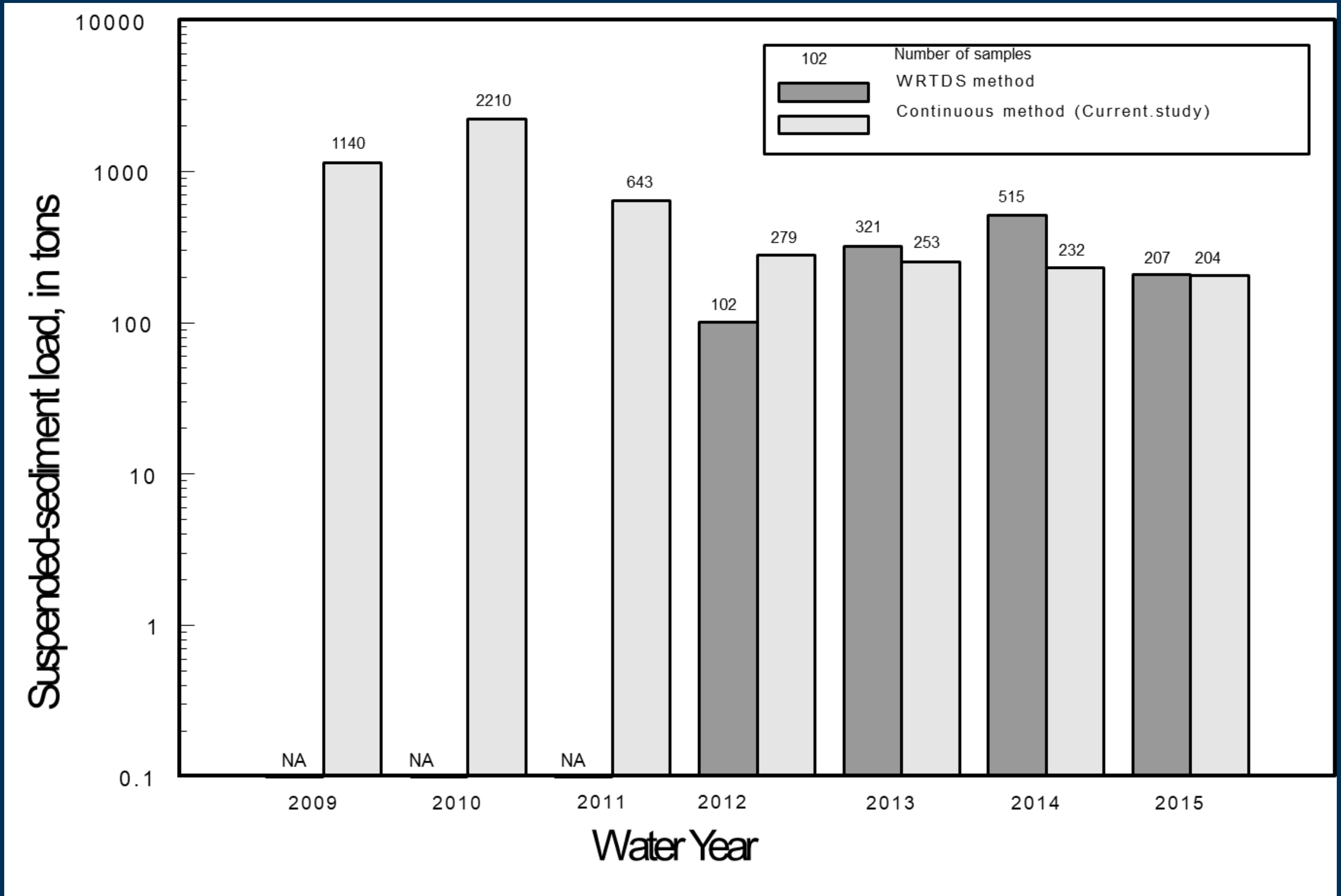
Stream gage locations   Flow direction

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



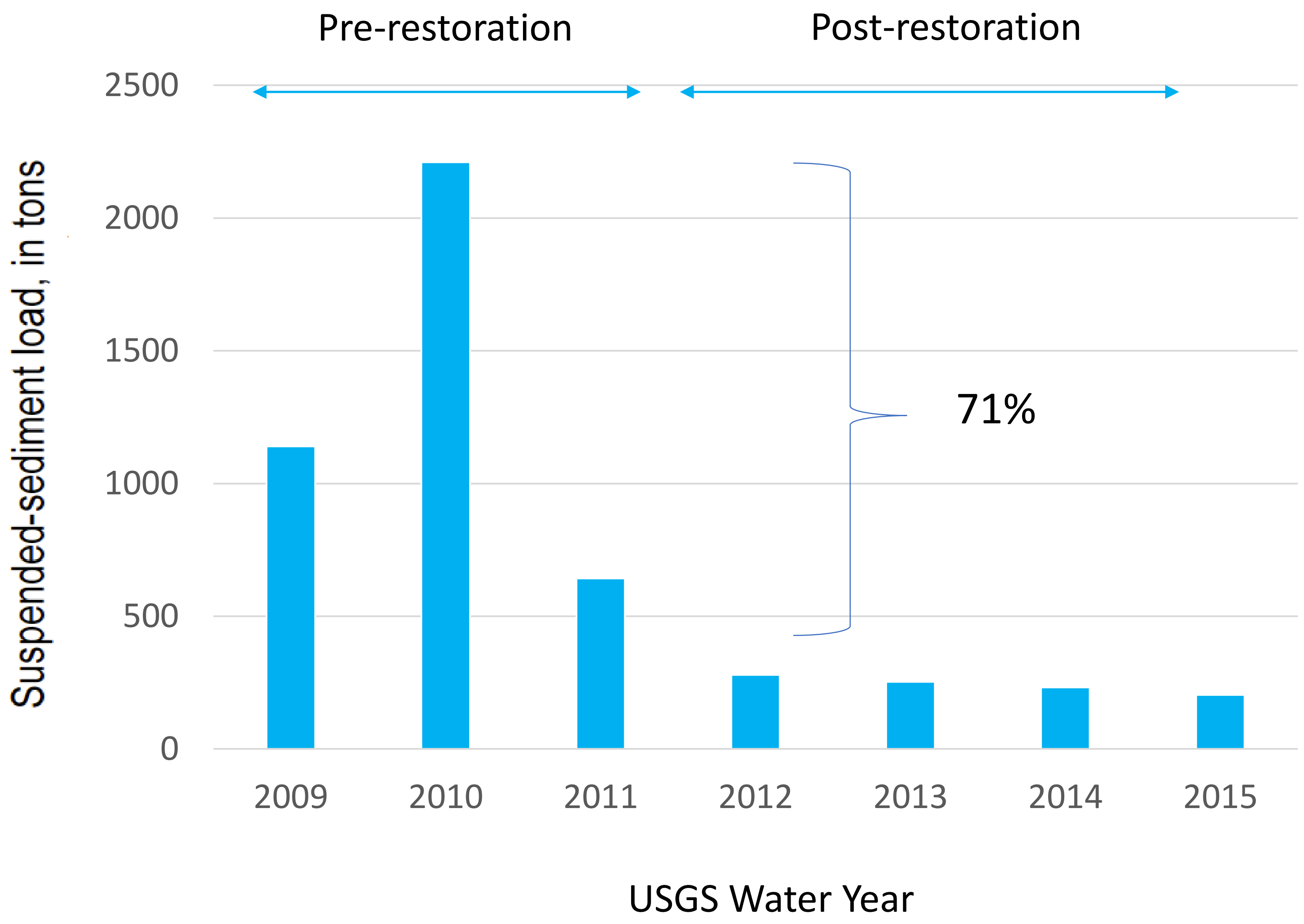
USGS

Discrete and continuous methods for computing SSC loads in Big Spring Run

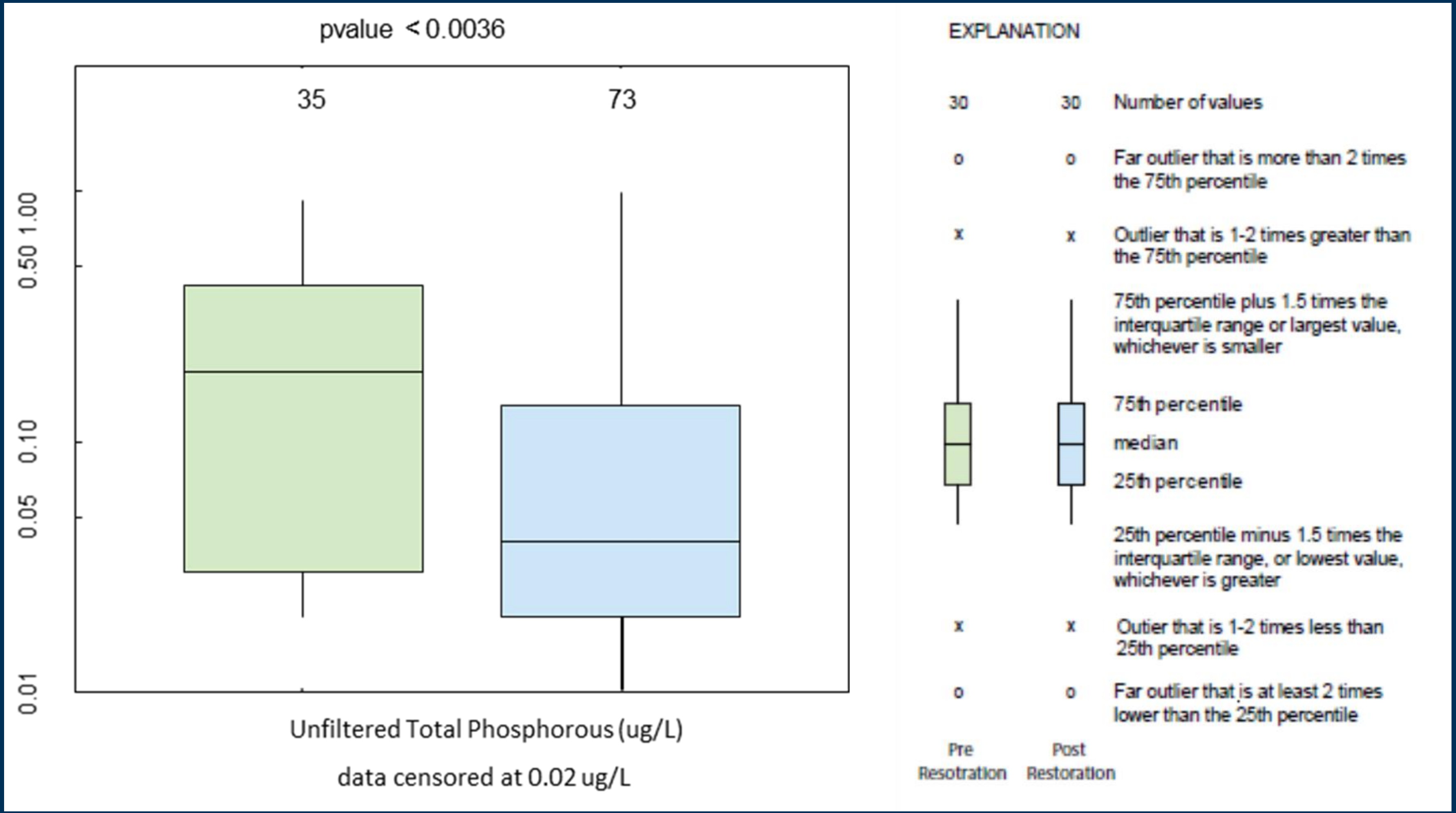


USGS

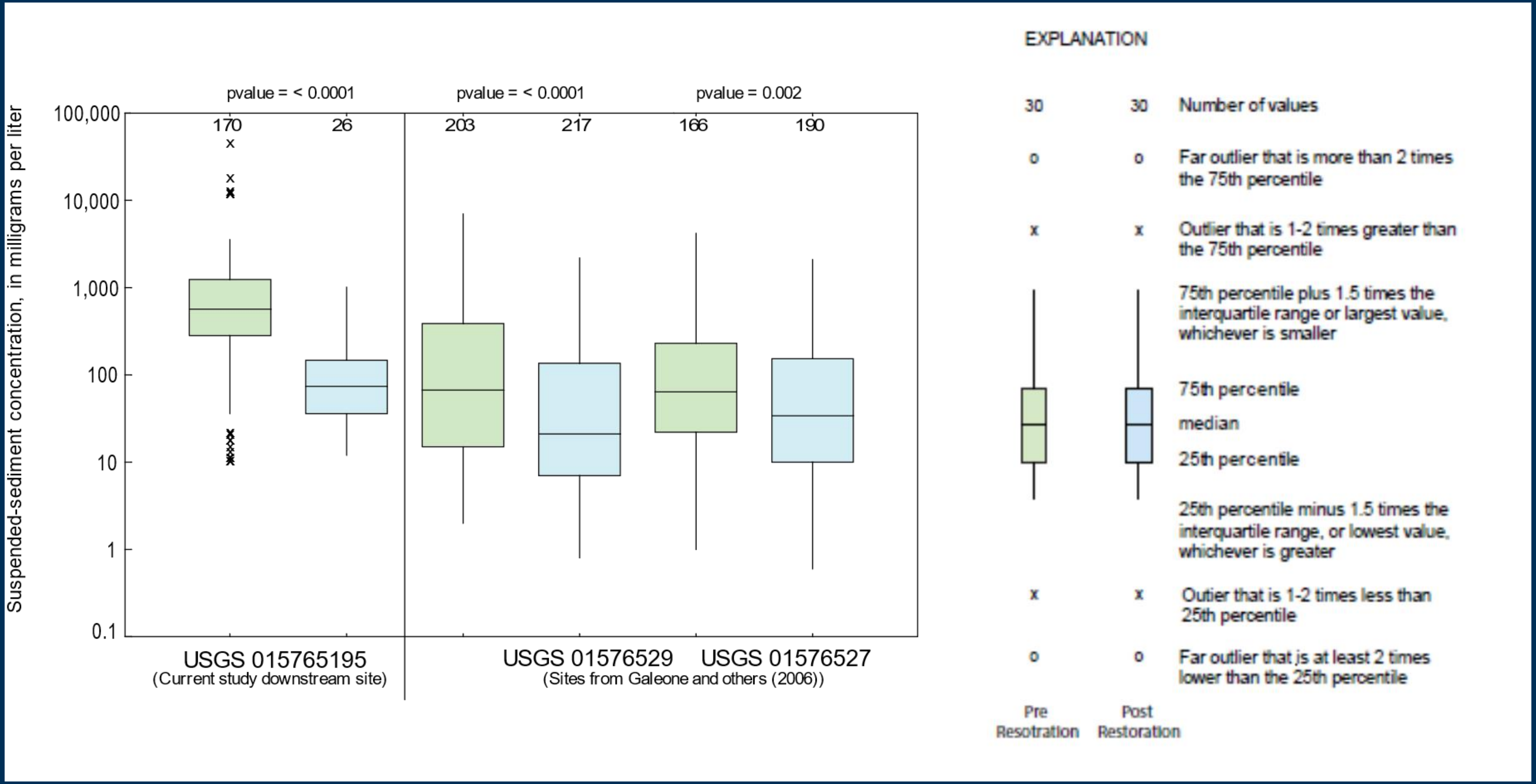
Annual suspended sediment load for 2008 through 2015 water years



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



Pre- and post-restoration SSC at USGS site 015765195 (WY2009-15) and at two sites from Galeone and others (2006)



USGS
science for a changing world

References

Langland, M.J., 2019, Data in support of study evaluating effects of legacy-sediment removal on nutrients and sediment in Big Spring Run, Lancaster County, Pennsylvania, 2009-15: U.S. Geological Survey data release, https://doi.org/10.5066/F7GH9G5K

Langland, M.J., Duris, J.W., Zimmerman, T.M., and Chaplin, J.J., *in press*, Effects of legacy-sediment removal and effects on nutrients and sediment in Big Spring Run, Lancaster County, Pennsylvania, 2009-15: U.S. Geological Survey Scientific Investigations Report

Summary of USGS surface water quality monitoring

- Median suspended sediment concentrations decreased from 556 mg/L to 74 mg/L representing an 87% reduction from pre- to post- restoration.
- The suspended sediment load decreased by 71% (600 tons per year) from pre- to post- restoration.
- Total phosphorus concentrations decreased from 0.19 mg/L to 0.04 mg/L representing a 79% reduction from pre- to post- restoration.
- Legacy sediment removal and aquatic ecosystem restoration was 10.5 times more effective in reducing suspended sediment than other agricultural best management practices that included a combination of streambank fencing and cattle crossings.

United States Environmental Protection Agency

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

Monitored groundwater and surface water ~50 samples bimonthly Late 2008-2016

Annual sediment collection 35-40 per yer 2010-2016

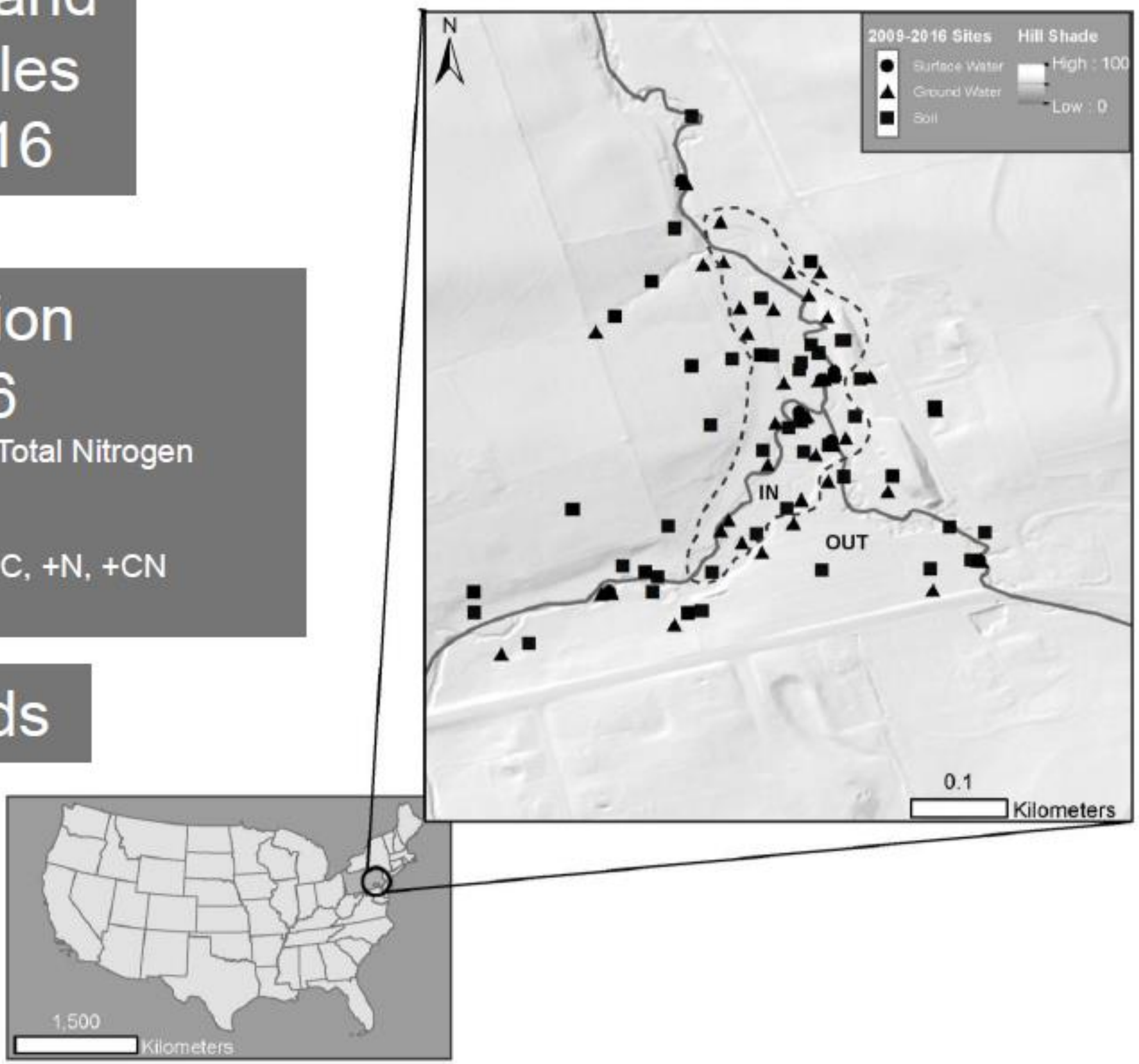
Measurements of Total Carbon, Organic Matter, Total Nitrogen

Process Measurements

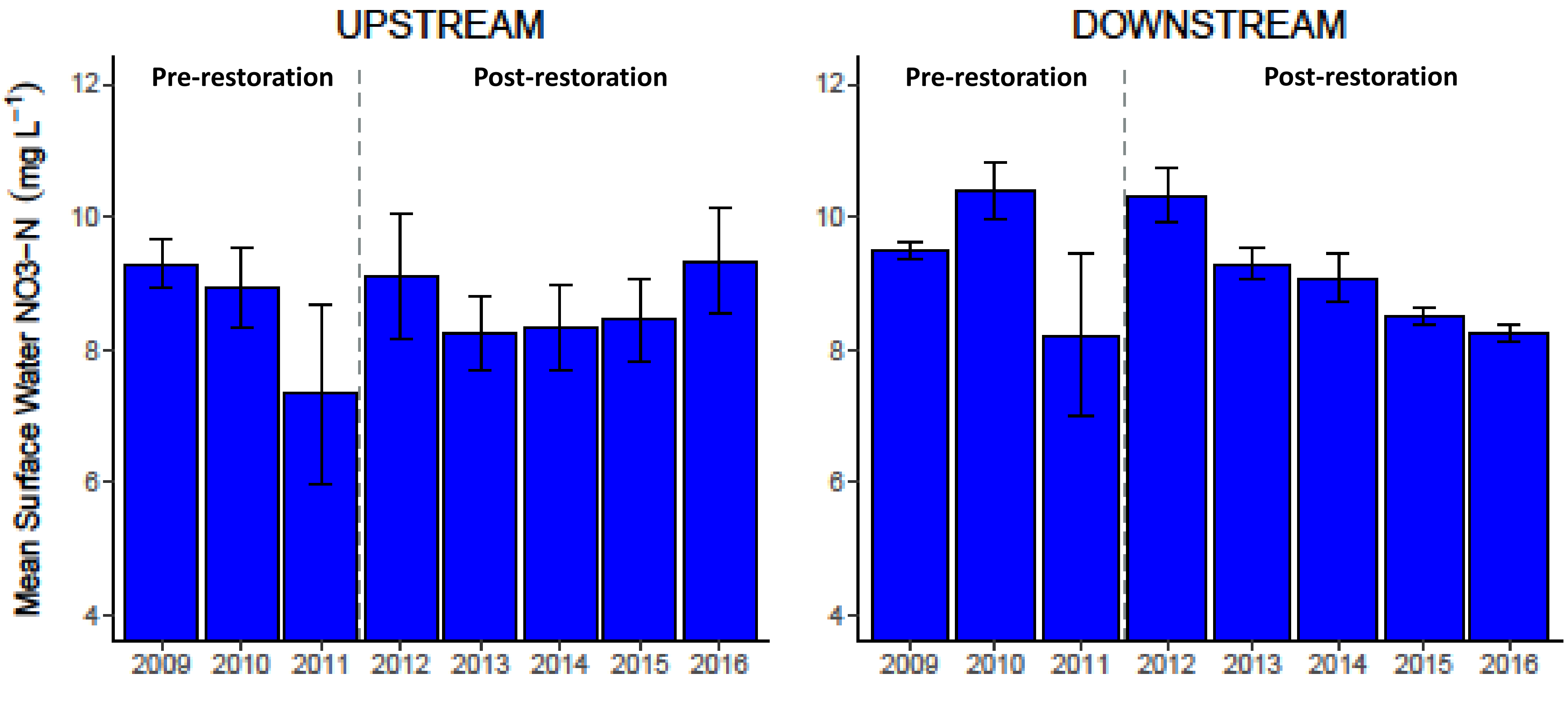
DEA in a Factorial design 4 treatments control, +C, +N, +CN

Nitrification

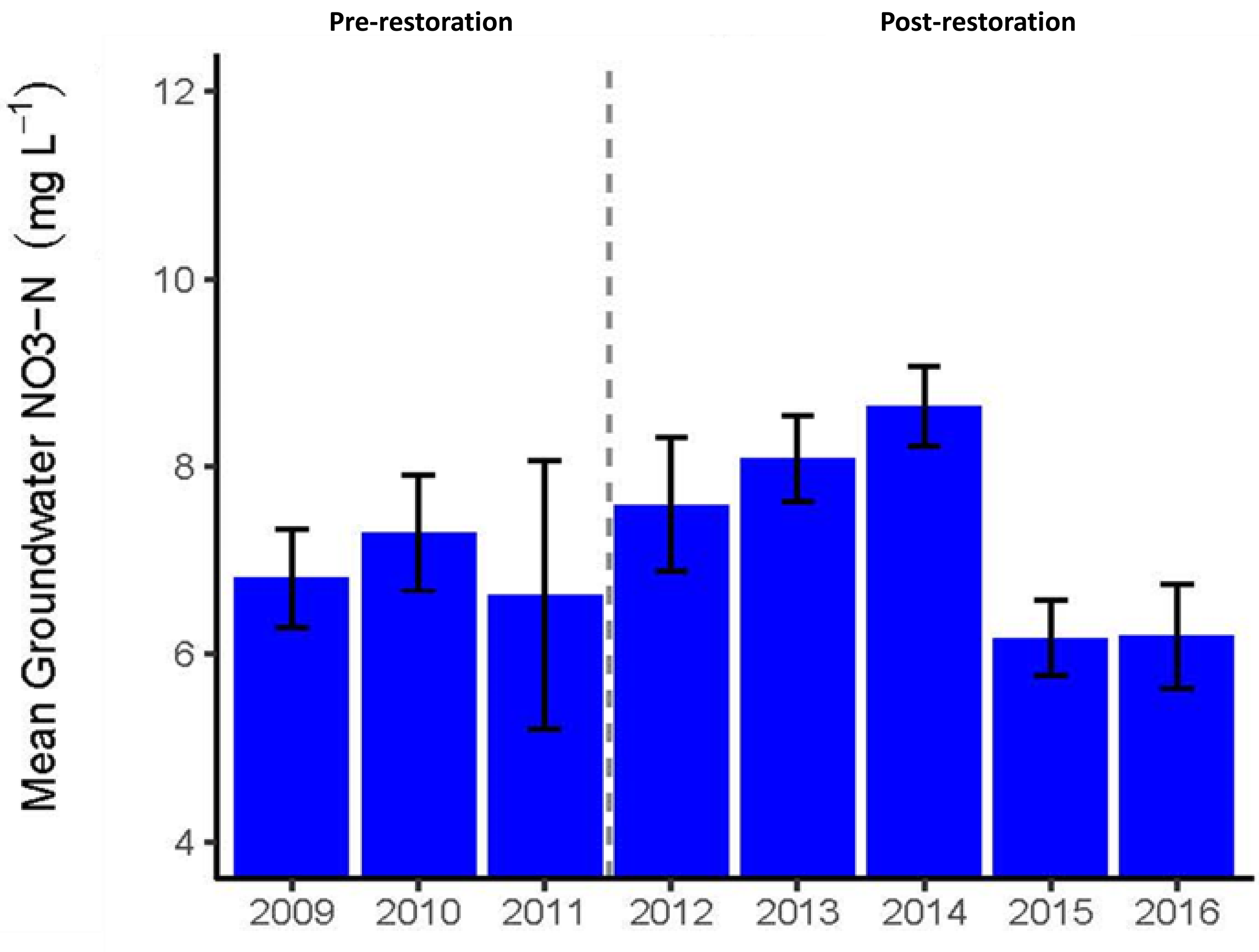
Estimated Nitrogen Loads



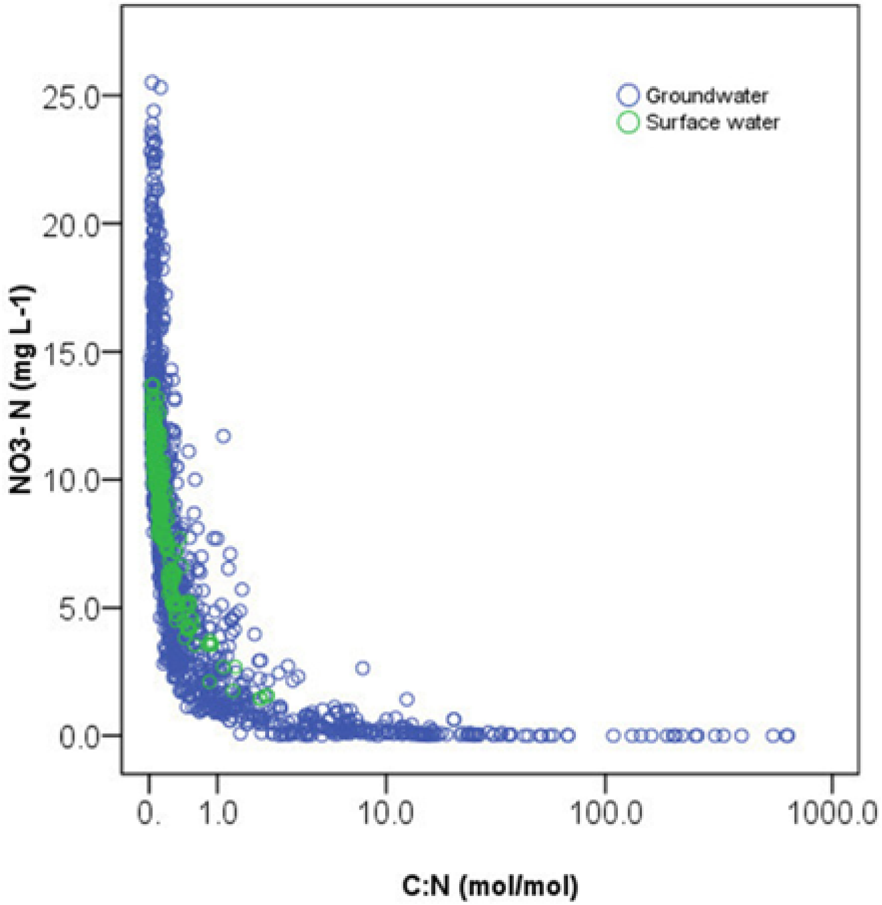
Surface water nitrate decreased gradually.

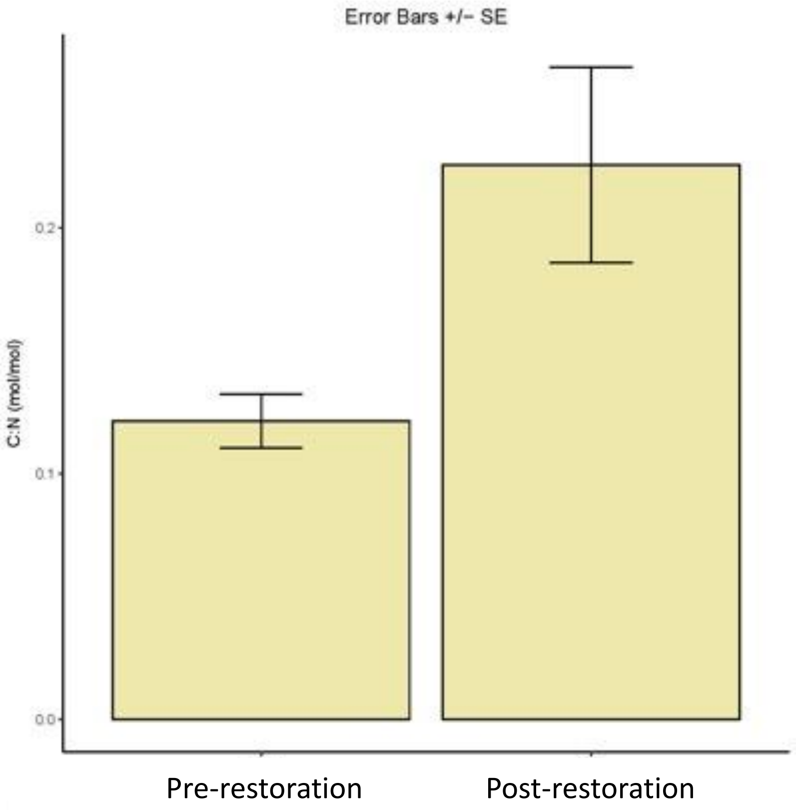


Groundwater nitrate decreased in the fourth year after restoration.

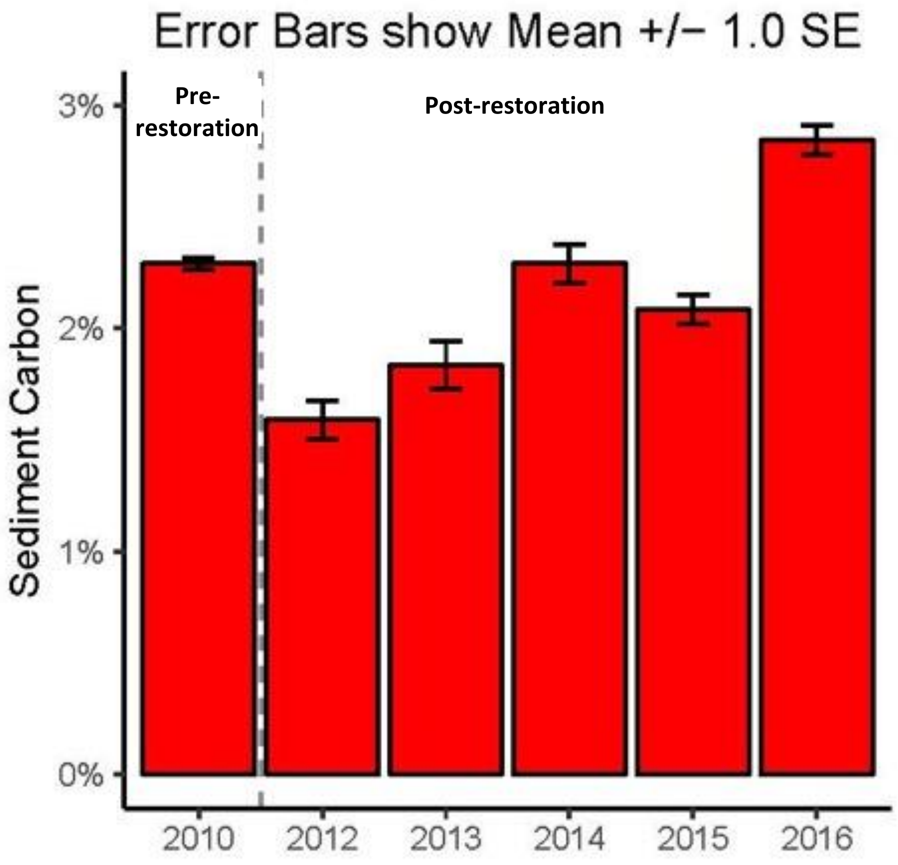


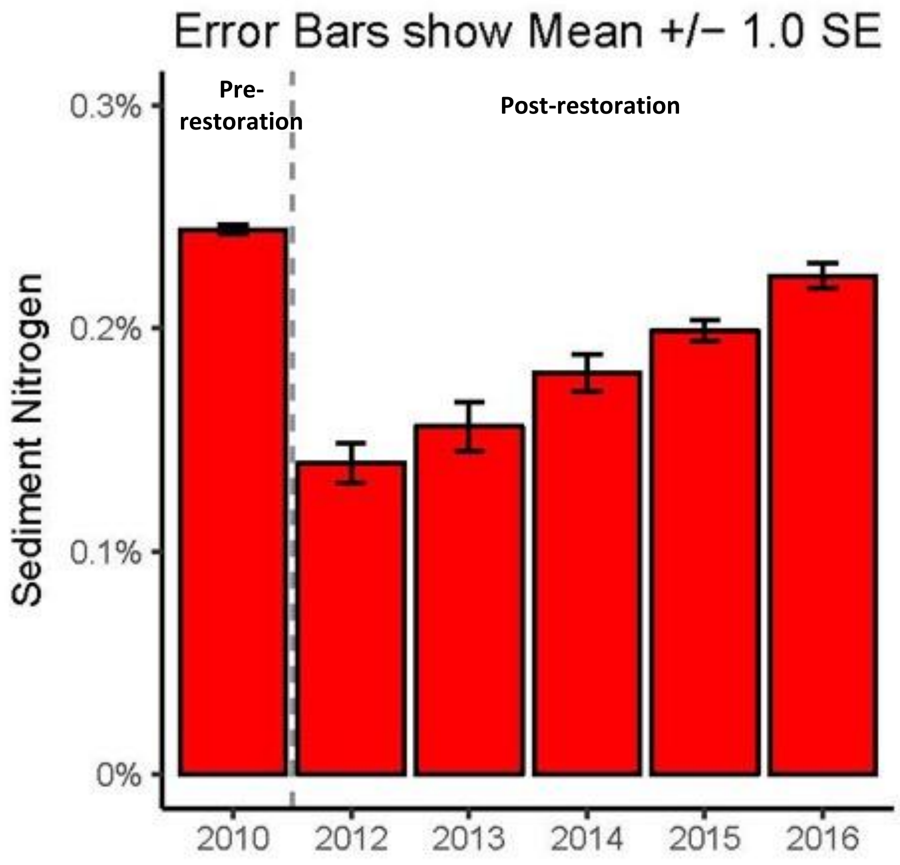
High C:N is an indicator of nitrate reduction and GW connectivity.





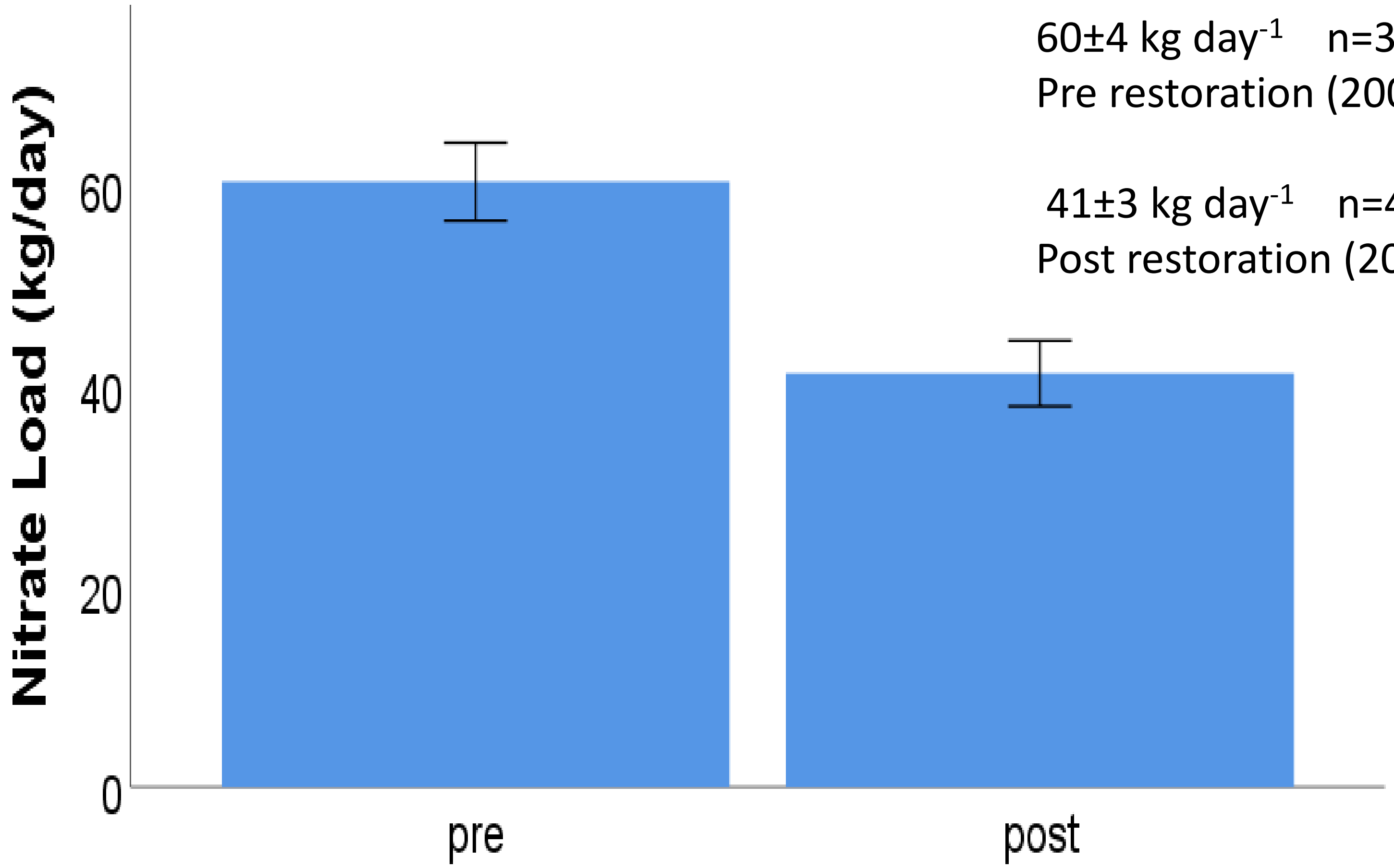
Sediment C and N recovered simultaneously.





Post restoration nitrate loads are smaller than pre-restoration.

Load = [NO3] x Mean Daily Discharge

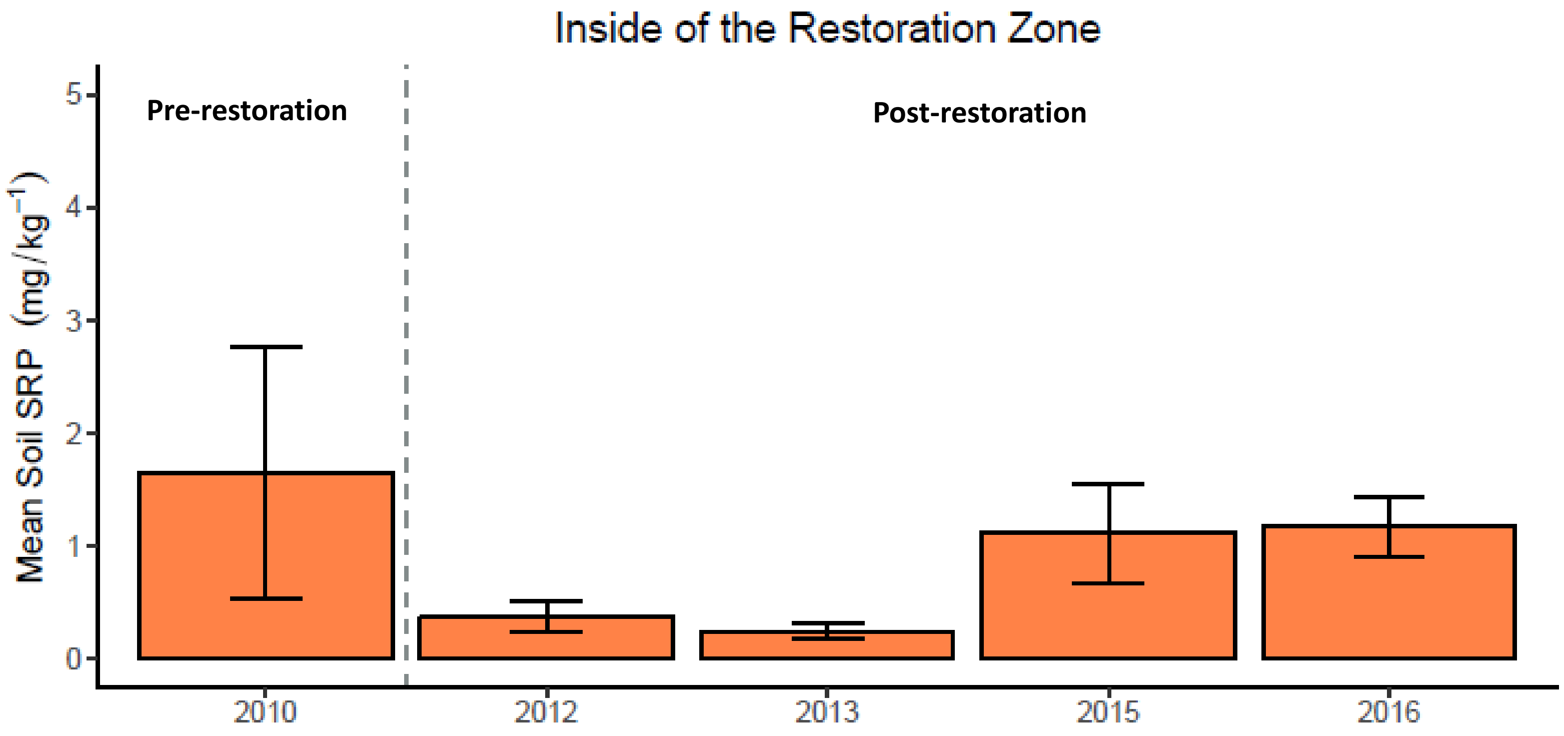


60±4 kg day^{-1} n=33
Pre restoration (2008-2011)

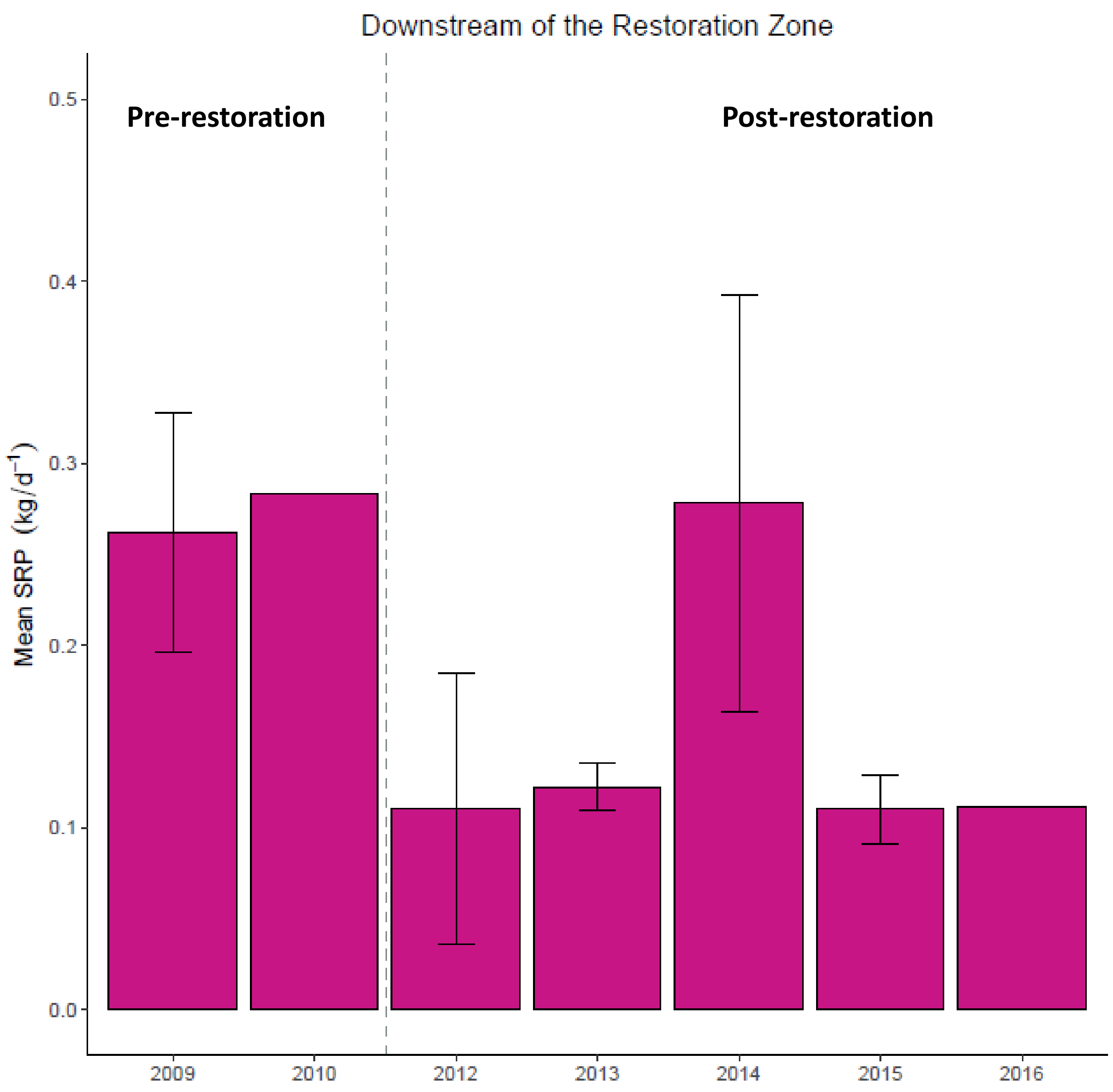
41±3 kg day^{-1} n=44
Post restoration (2012-2016)

$p<0.001$ df = 76

Soil extractable P is lower.



Downstream dissolved P is lower post restoration.



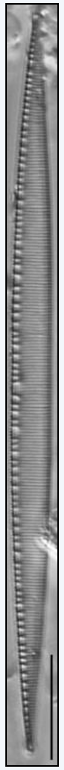
Summary of USEPA surface & ground water quality monitoring

- Nitrate retention primarily is driven by enhancement of organic carbon and resulting bio-geochemical processes at Big Spring Run
- The restoration improved nitrate retention, but it took several years for that trend to emerge in response to the maturation of the wetland complex
- Nitrogen and phosphorous fluxes are reduced when comparing the pre-restoration and post- restoration periods

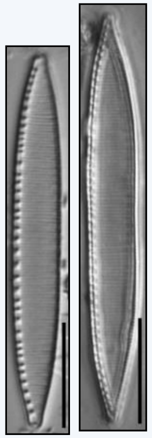
Big Spring Run biological and living resources monitoring results

August 2012

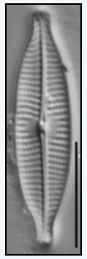
2011: pre-restoration



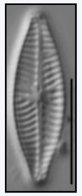
Nitzschia cf. gessneri



Nitzschia palea s.l.



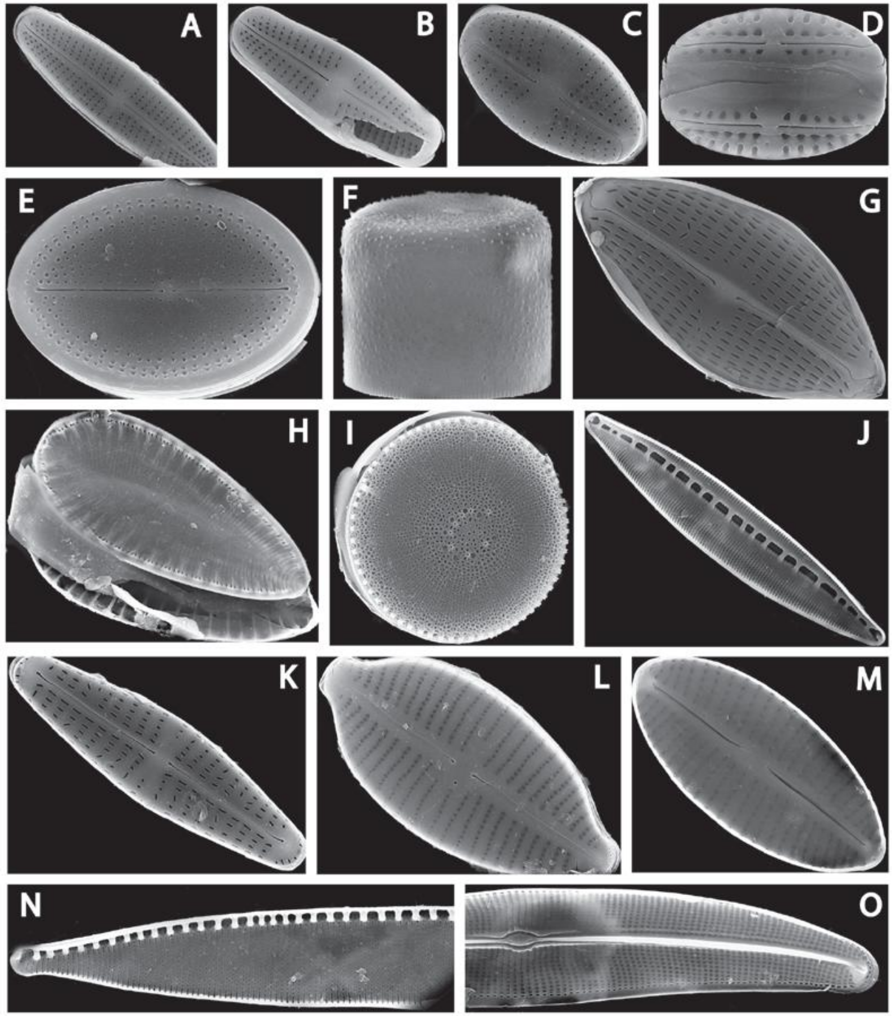
Navicula gregaria



Navicula reichardtiana

Diatom assemblages similar to those found in 1948 in relatively "healthy" Lancaster County streams.

Potapova, et al, 2016



Common diatoms from Big Spring Run

Potapova, et al, 2016

- Before the 1700s, Big Spring Run was inhabited by diverse diatom communities that are known to prefer slow-moving clean waters with abundant vegetation and wetlands.
- 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

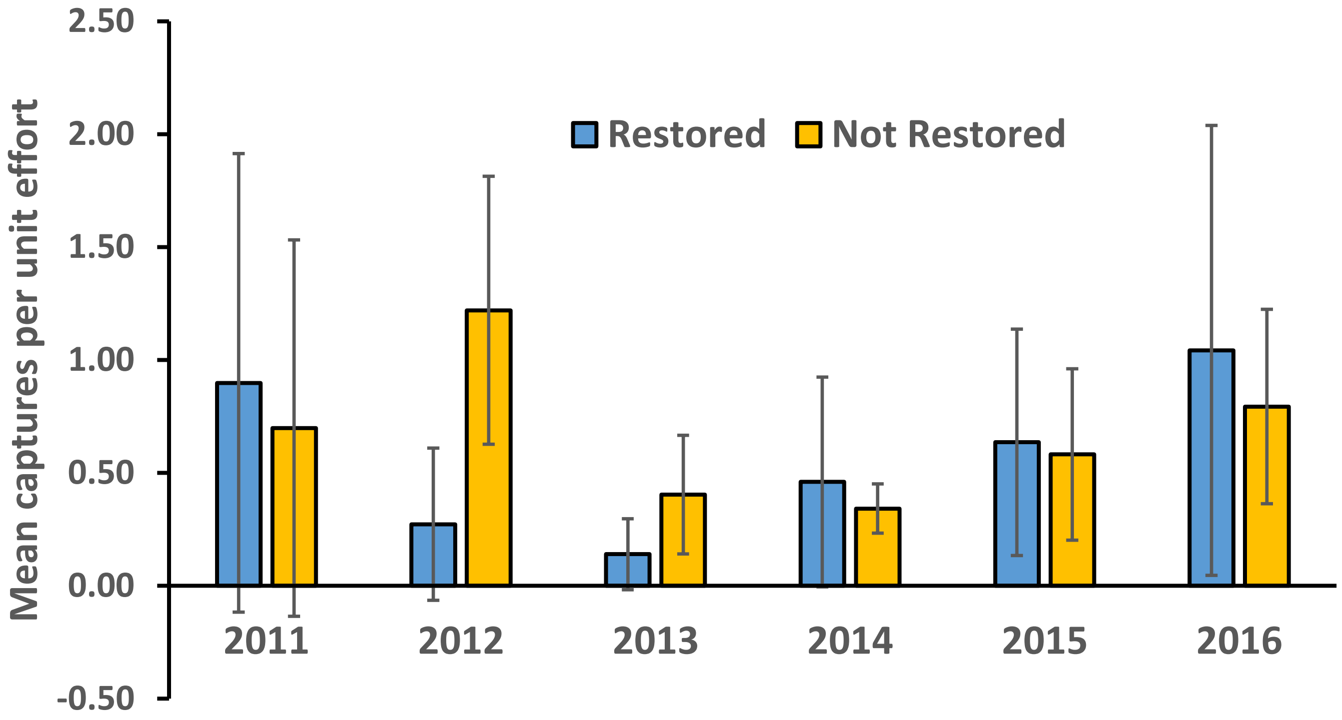


Figure 2. The mean number of captures per unit effort (± STD) of *Eurycea bislineata* for restored and not restored stream segments from 2011 to 2016. All of the data from 2011 are pre-restoration. The mean number of captures did not significantly vary by year or treatment.

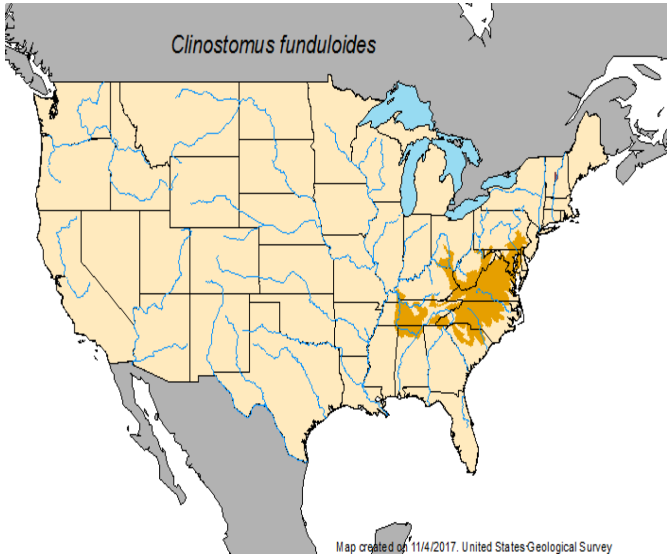
Bowne, D.R., and Conway, R. *In prep.* Amphibian Use of a Restored Wetland in an Agricultural Landscape. Department of Biology, Elizabethtown College, PA.

“SRBC Water Tour 2017” excerpts

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

Courtesy Susquehanna River Basin Commission, 2017

September 2015 Fish Survey

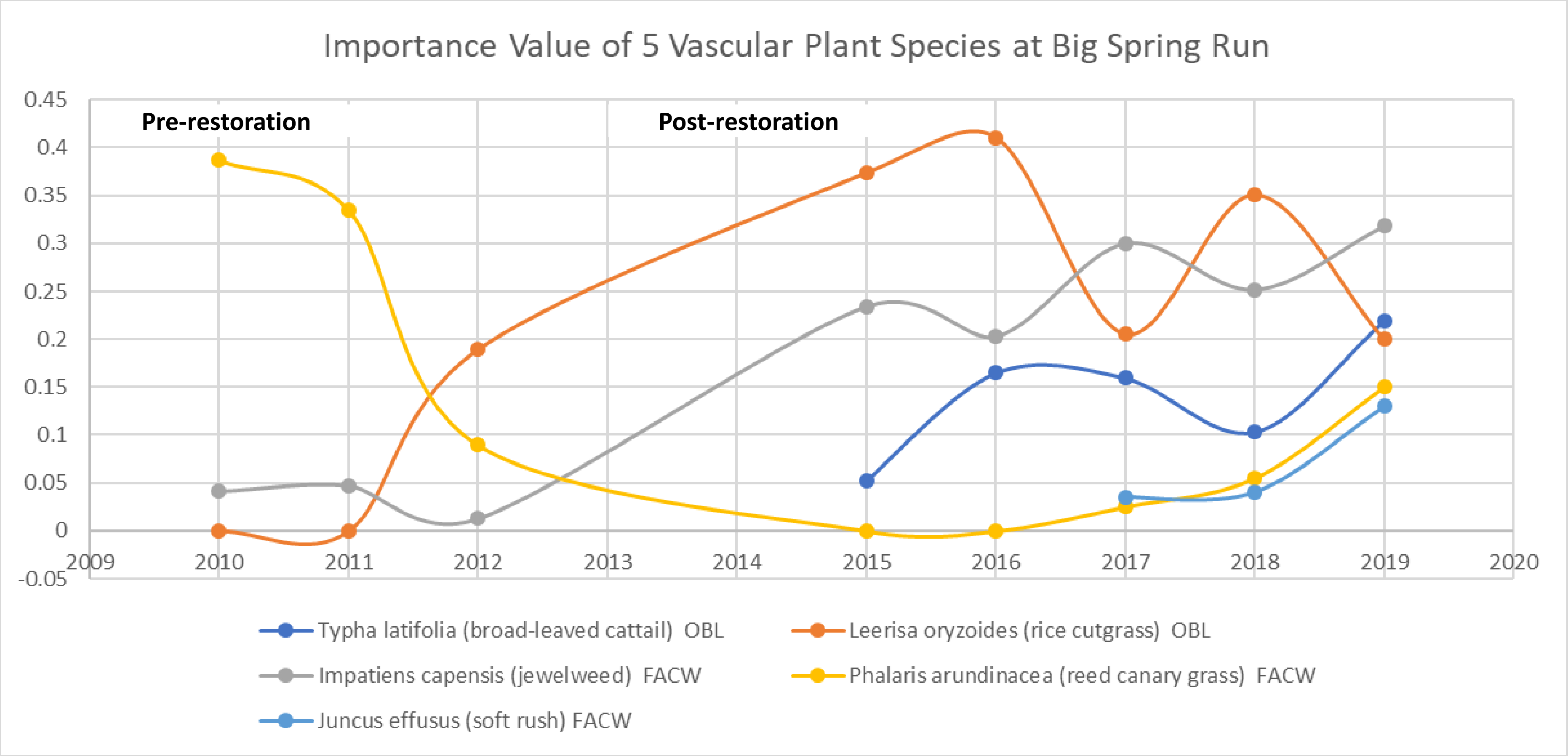


Native Range

rosyside dace (*Clinostomus funduloides*)

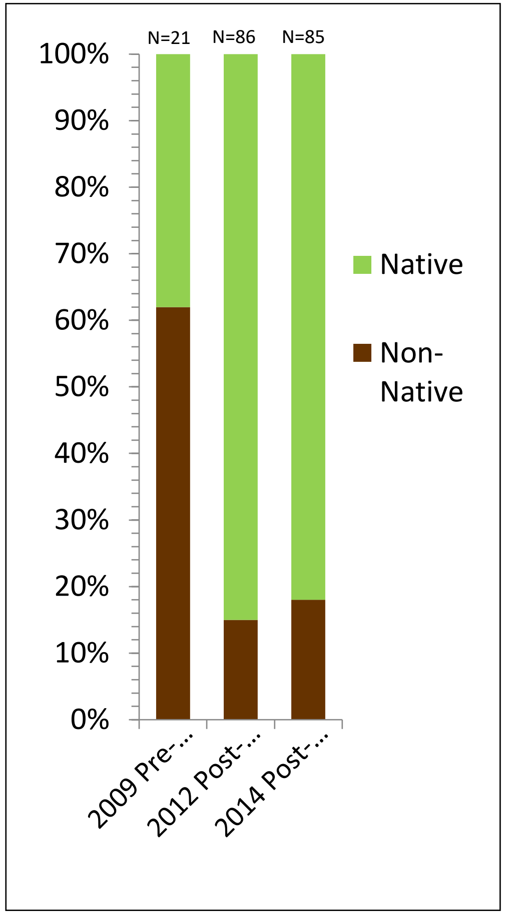
This species prefers headwater streams typical of cold water fishes and is an indication of improved water quality in the restored reach. It also prefers gravelly riffles for spawning and typically inhabits rocky streams.

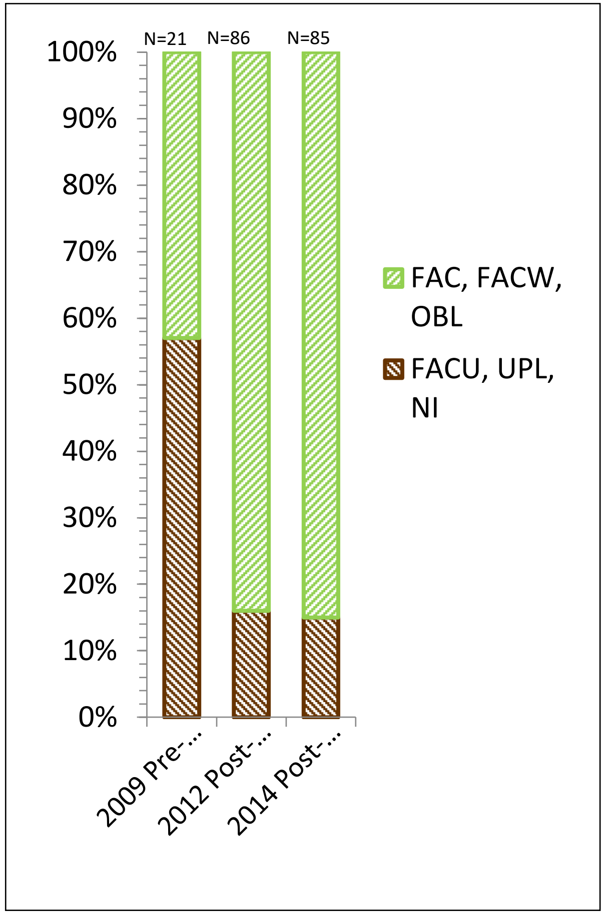
Vascular plant surveys of 1 m^2 plots at 5 m intervals repeated along transects

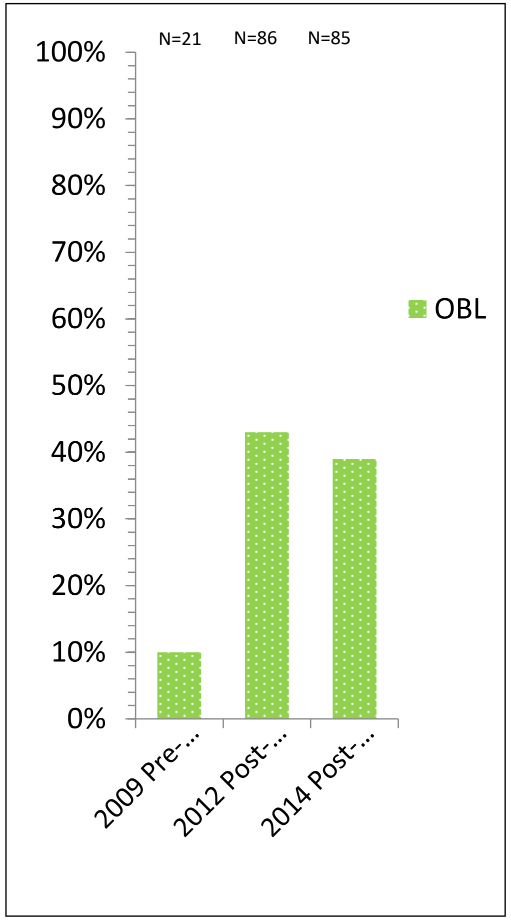


Courtesy William Hilgartner

Vascular plant species richness and wetland indicator status





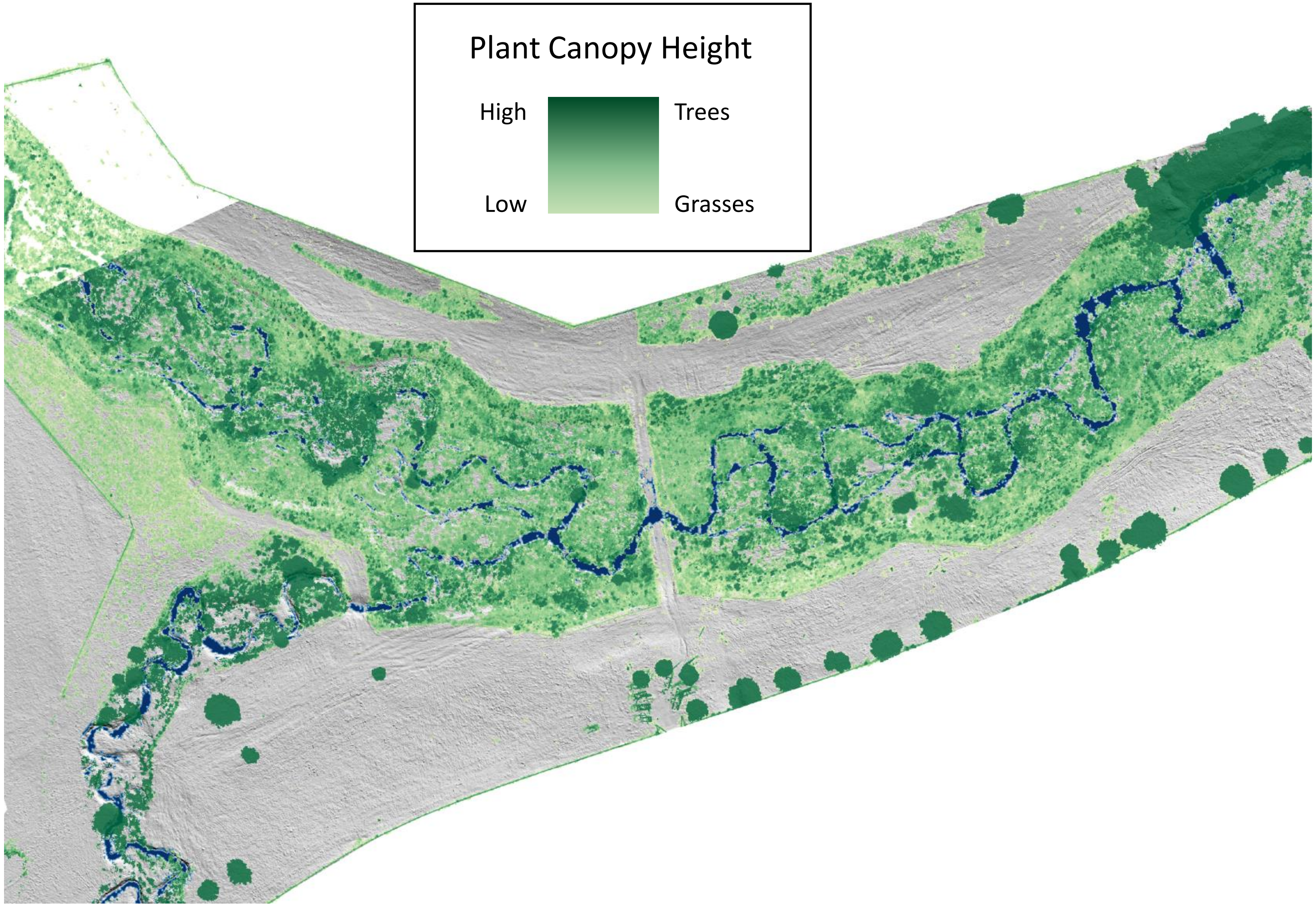


Notable post-restoration vascular plant colonizers

Juncus torreyi
Torrey's rush
PA State Threatened
Facultative

Carex amphibola
narrowleaf sedge
Facultative

Post-restoration terrestrial laser survey June 6, 2015



Summary of biological and living resources monitoring

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

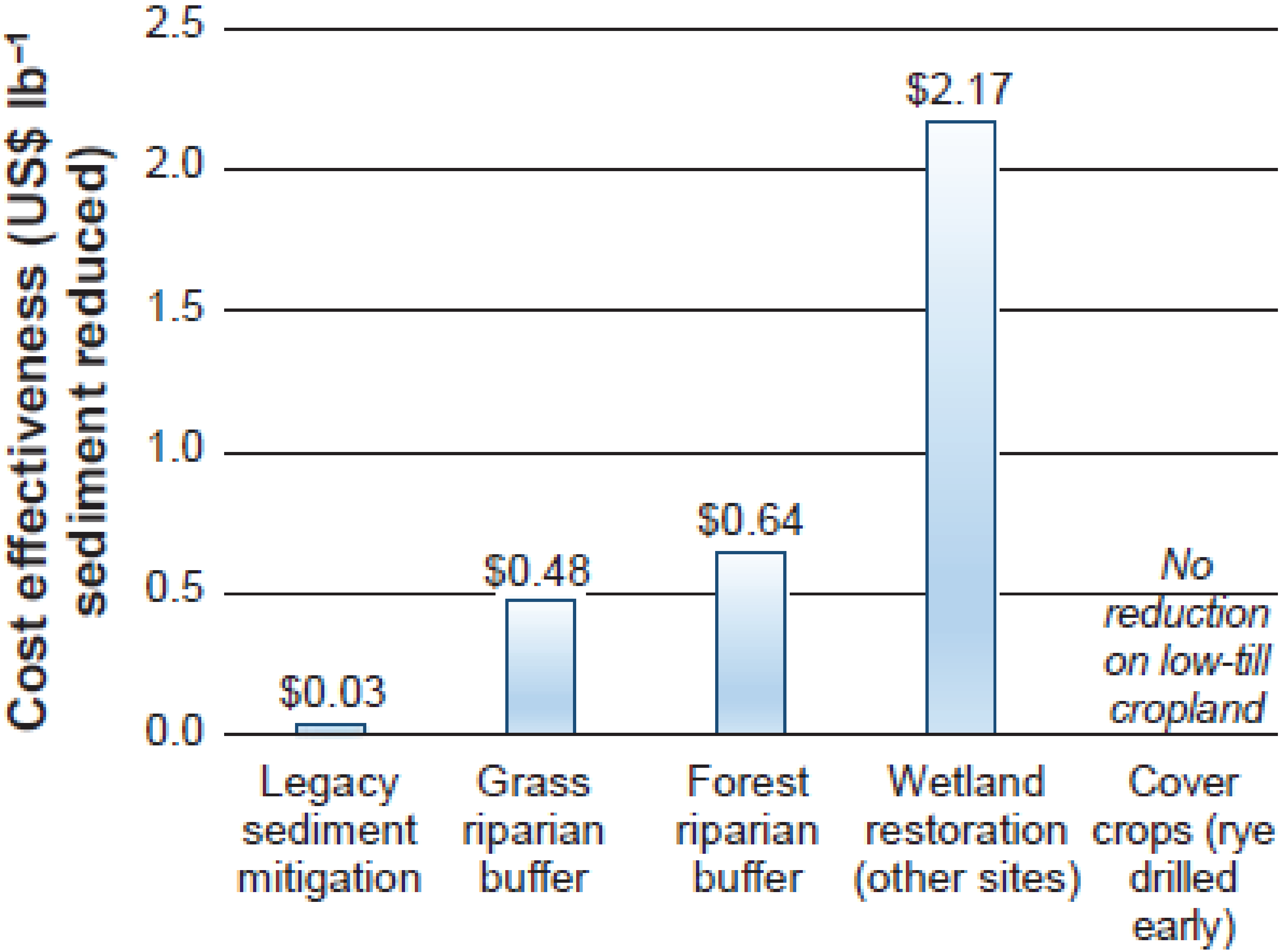
- Diatom nutrient metrics indicated that post-restoration assemblages had fewer diatoms associated with high nutrients and more of those indicative of low nutrients.

- Northern two-lined salamanders (E. bislineata) captures have consistently increased in the restoration area while its captures in adjacent unrestored areas have fluctuated.

- While green frog (L. clamitans) is a nationally common frog species, it was found residing and breeding in the restored areas after restoration but was previously absent.

Summary of biological and living resources monitoring (cont.)

- A major vascular plant community shift occurred from a dry upland pasture to a wet meadow plant community type
- Increasing importance of vascular plant hydrophytes after restoration provides diverse 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



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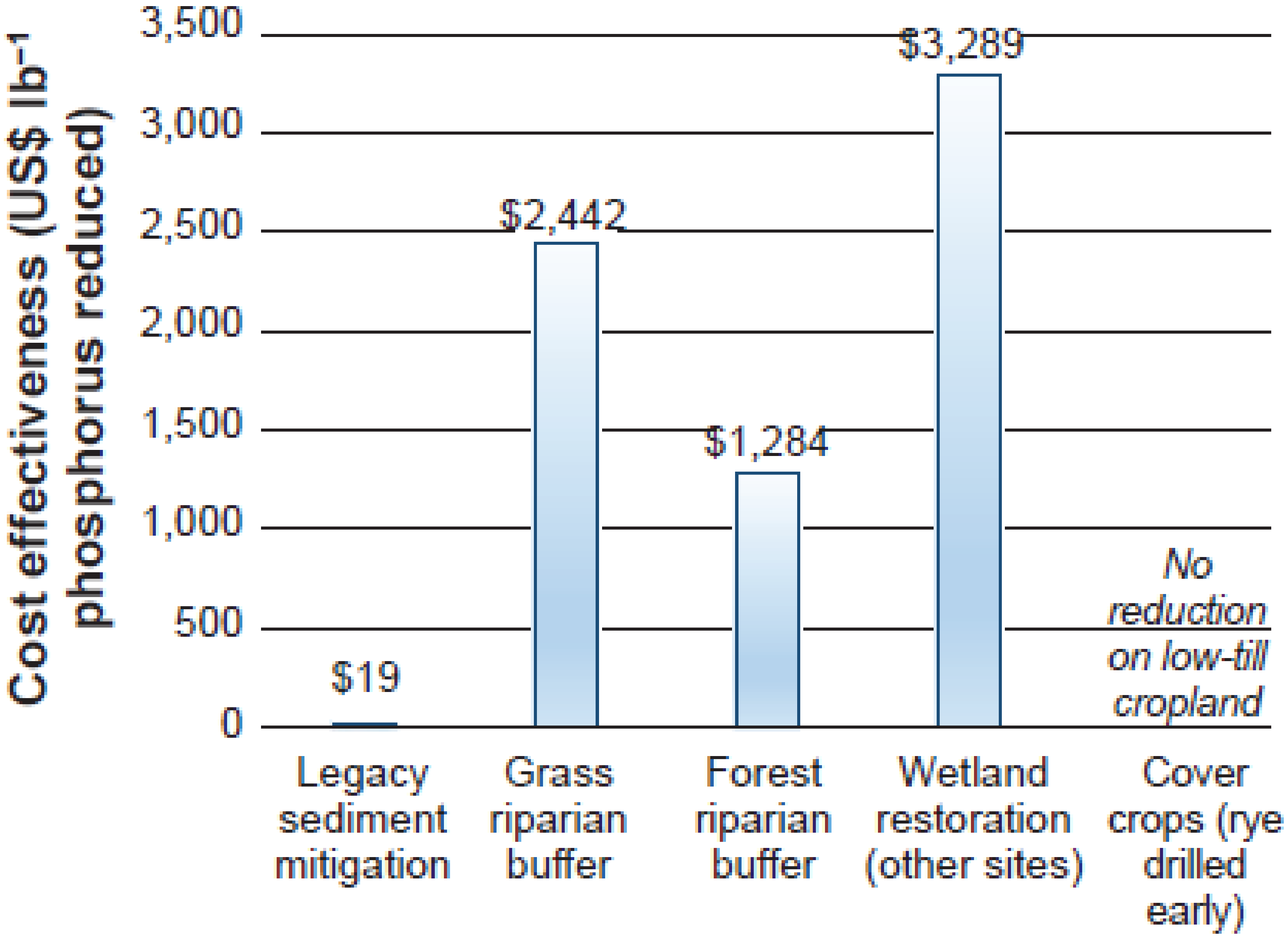

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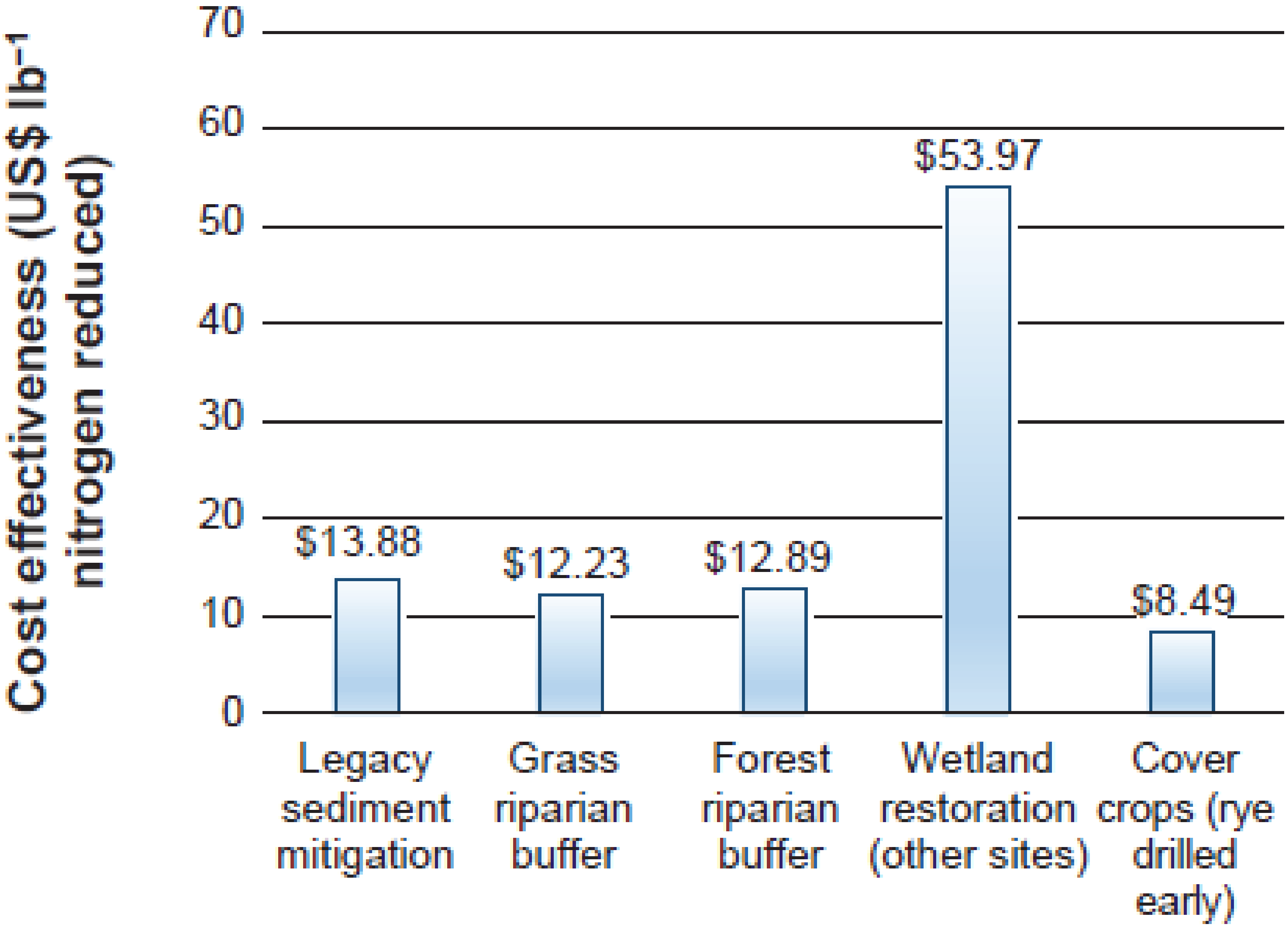

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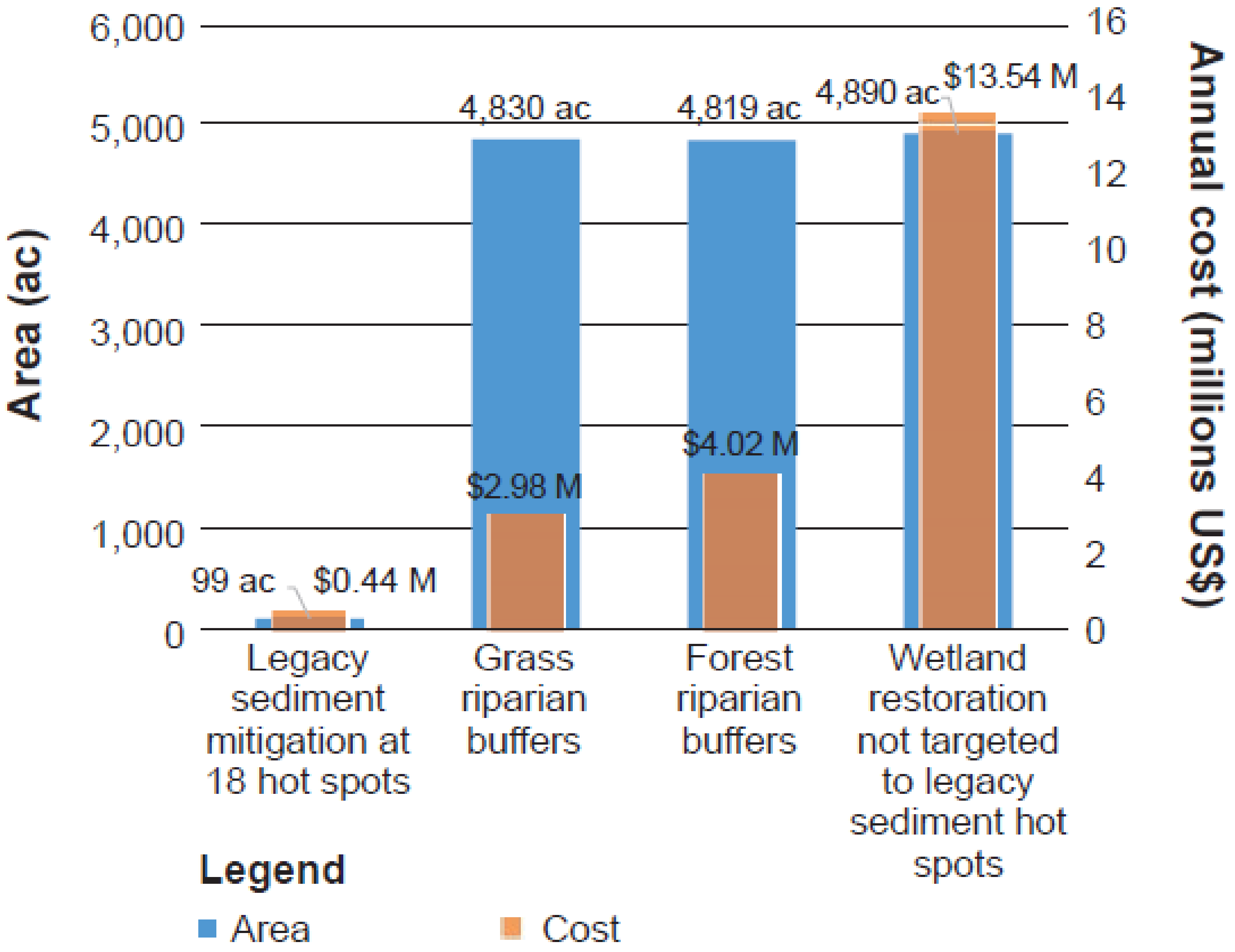
Annual cost and total restoration acreage required to achieve 5% of Chesapeake Bay total maximum daily load (TMDL) sediment goal for Pennsylvania agriculture (17×10^6 lb abatement annually).



Flemming, et. al. 2019 Journal of Soil and Water Conservation

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Questions ?

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