Big Spring Run Research Results

Pennsylvania Department of Environmental Protection
Welcome to the Webcast

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◦ Fill out our evaluations – our funders need to hear it!
Upcoming Webcasts

December 3 – Stormwater Roots Part “2”: Big Trees, Small Spaces

December 10 – Outfall and Gully Stabilization Practices

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Poll Question #1

Tell us a little about yourselves...who are you representing today?

- Local government
- Private sector
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- Academia
- Other...*tell us in the chat box*
Poll Question #2

How many people are watching with you today?

- Just me!
- 2
- 3-5
- 6-10
- 10+
Today’s Speaker:

Jeffrey Hartranft
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Big Spring Run Restoration Project
Background & Monitoring Results

Pennsylvania
Department of Environmental Protection

Pennsylvania Legacy Sediment Workgroup

Jeffrey Hartranft
Bureau of Waterways Engineering and Wetlands
Division of Wetlands Encroachment and Training
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• 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
• 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/
• 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
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
Big Spring Run Watershed Hillshade Elevations

Confluence of Big Spring Run and Mill Creek

Restoration Site

NCALM Lidar

Walter, et al., 2013  PADEP Report
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._
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)
• 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.
Big Spring Run In-situ Reference Condition

Hydric Soil ~ 12-18 inches

Legacy Sediment

Basal Gravels/Bedrock

Photos Courtesy Franklin & Marshall College
Typical Legacy Sediment and Eroding Streambank Stratigraphy - West Branch Little Conestoga River

Munsell Soil Colors

- Basal Gravels/Bedrock
  - 10YR 5/4 – Legacy Sediment
- Hydric/Wetland Soils
  - 10YR 3/1 – Organic Rich Layer
  - 10YR 2/2 – Organic Rich Layer
  - 10YR 4/2 – Thin Gleyed Layer
Big Spring Run Carbon-14 Dates and Vascular Plant Seed Macrofossil Analysis

All Dates +/- 40

Adapted from Hilgartner et. al. 2012
• Natural valley morphology
• Address legacy sediment storage and erosion
• Ecosystem physical characteristics are essential to both form and process restoration

• 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

Legacy Sediment Removal and Aquatic Ecosystem Restoration Best Management Practice

Proposed Restoration

Conceptual Design Adapted from LandStudies, Inc.
Cyclical stream evolution model and restoration linked to habitat and ecosystem functions and services

Adapted from Cluer and Thorne, 2013
Artist rendition of restored conditions
Big Spring Run Geomorphic Results

Typical Existing Conditions

9/13/2011

Restoration

07/27/2012
Big Spring Run As-Built - Hillshade Elevations

- Legacy Sediment Excavation Limits
- Legacy Sediment Temporary Stockpiles
- 4.7 Acre Restoration Area

Courtesy Franklin & Marshall College
Pre-Restoration Flow Model

Abandoned Oxbows

Shear Stress (psf)

2.0
1.5
1.0
0.5
0.0

October 15, 2014

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

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

construction limits
High : 359.62 feet
Low : 305.39 feet
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

Pre-restoration legacy sediment surface
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

Approximate area of view next terrestrial laser survey image
Post-restoration terrestrial laser survey
April 11, 2014
• 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

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.
USGS Sample Sites

- Stream gage locations
- Flow direction
Surface Water Pre- and post- restoration suspended sediment concentrations (SSC) in Big Spring Run
Discrete and continuous methods for computing SSC loads in Big Spring Run
Annual suspended sediment load for 2008 through 2015 water years

![Graph showing annual suspended sediment load for 2008 through 2015 water years. The graph displays two periods: Pre-restoration and Post-restoration. The graph indicates a significant reduction of 71% in suspended sediment load post-restoration.]
Pre- and post- restoration unfiltered total phosphorous concentrations in Big Spring Run

![Box plot showing pre- and post-restoration unfiltered total phosphorous concentrations in Big Spring Run. The p-value is less than 0.0036.](image)

**EXPLANATION**
- **30** 30: Number of values
- **0** 0: Far outlier that is more than 2 times the 75th percentile
- **0** 0: Far outlier that is more than 1.5 times the interquartile range or largest value, whichever is smaller
- **35** 73: Outlier that is 1-2 times greater than the 75th percentile
- **0** 0: Outlier that is 1-2 times less than 25th percentile
- **0** 0: Far outlier that is at least 2 times lower than the 25th percentile

Data censored at 0.02 ug/L
Pre- and post-restoration SSC at USGS site 015765195 (WY2009-15) and at two sites from Galeone and others (2006)
References


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

Kenneth J. Forshay¹, Julie Weitzman², Jessica Wilhelm³, Paul Mayer⁴, Ann Keeley¹, Dorothy Merritts⁵, and Robert Walter⁵

(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.
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

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

Nitzschia palea s.l.
Nitzschia cf. gessneri

Navicula gregaria
Navicula reichardtiana

Common diatoms from Big Spring Run

• 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.
Restored habitat where green frog egg mass was found.

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

Lithobates clamitans (Green frog) tadpole

Green frog egg mass
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.

“SRBC Water Tour 2017” excerpts

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

Courtesy Susquehanna River Basin Commission, 2017
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 m² plots at 5 m intervals repeated along transects.
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.
• 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
Flemming, et. al. 2019 Journal of Soil and Water Conservation
Flemming, et. al. 2019 Journal of Soil and Water Conservation
Annual cost and total restoration acreage required to achieve 5% of Chesapeake Bay total maximum daily load (TMDL) sediment goal for Pennsylvania agriculture ($17 \times 10^6$ lb abatement annually).

Legend
- Area
- Cost
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
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Questions?

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Evaluation

Please take a moment to fill out our very short survey and let us know what you thought of today’s webcast. We (and our funders!) love to hear it...

https://www.surveymonkey.com/r/BSR_research