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Sediment response of stream restoration practices, Turtle Creek, Union County, Pennsylvania

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USGS Turtle Creek products

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Sediment response to stream restoration in an agricultural watershed

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ABSTRACT

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Despite widespread implementation of stream restoration there is limited research of its effectiveness in impaired agricultural settings. To quantify the effects of stream restoration on sediment loss, we investigated erosion and deposition along 9 stream reach sites (1 restored, 4 unrestored, and 1 channelized) in Turtle Creek, Pennsylvania, United States – a representative agricultural subbasin of the Chesapeake Bay. These stream restoration projects had the goal of reducing sediment load primarily by installing log structure and repairing streambanks in order to stabilize streambanks and reconnect floodplains. Floodplain and streambank sediment fluxes were quantified over a 5-year period through repeated measurement of clay pale and pine and measurement of sediment bulk density. Unrestored aerial imagery was collected at 2 of the sites, then processed using structure from motion (SfM) to create high-resolution digital elevation models. Terrain analysis enabled three-dimensional understanding of the geometry of the specific field flux measurement locations to the larger stream reach. Restored sites on average had deposition on streambanks compared to streambank erosion along unrestored sites, and approximately two times greater floodplain deposition than unrestored sites. Overall, restored streams had an average seven fold increase in the net balance (sum of streambank and floodplain) of sediment flux, a 0.12 kg/m²/yr increase in retention, compared to unrestored streams. The measured larger measured particle size distribution (D₅₀) in restored streams also suggests additional improvements to instream habitat quality. Terrain analysis confirmed that the field-based measurements were representative of the larger reach. These results indicate that stream restoration in agricultural watersheds using low-engineered designs can reduce sediment loading and improve stream habitat and health goals.

1. Introduction

Sediment is one of the leading causes of ecological use impairments for several streams and rivers in the United States (U.S. Environmental Protection Agency, 2000; Woliver and Martens, 2000; Thompson et al., 2010; Nier et al., 2016). Stream restoration projects, which aim to improve stream health, have been implemented in agricultural watersheds, but there is limited research of its effectiveness in impaired agricultural settings. To quantify the effects of stream restoration on sediment loss, we investigated erosion and deposition along 9 stream reach sites (1 restored, 4 unrestored, and 1 channelized) in Turtle Creek, Pennsylvania, United States – a representative agricultural subbasin of the Chesapeake Bay. These stream restoration projects had the goal of reducing sediment load primarily by installing log structure and repairing streambanks in order to stabilize streambanks and reconnect floodplains. Floodplain and streambank sediment fluxes were quantified over a 5-year period through repeated measurement of clay pale and pine and measurement of sediment bulk density. Unrestored aerial imagery was collected at 2 of the sites, then processed using structure from motion (SfM) to create high-resolution digital elevation models. Terrain analysis enabled three-dimensional understanding of the geometry of the specific field flux measurement locations to the larger stream reach. Restored sites on average had deposition on streambanks compared to streambank erosion along unrestored sites, and approximately two times greater floodplain deposition than unrestored sites. Overall, restored streams had an average seven fold increase in the net balance (sum of streambank and floodplain) of sediment flux, a 0.12 kg/m²/yr increase in retention, compared to unrestored streams. The measured larger measured particle size distribution (D₅₀) in restored streams also suggests additional improvements to instream habitat quality. Terrain analysis confirmed that the field-based measurements were representative of the larger reach. These results indicate that stream restoration in agricultural watersheds using low-engineered designs can reduce sediment loading and improve stream habitat and health goals.

restoration), impervious surfaces, construction, and agriculture (Brakebill et al., 2010), and streambank erosion has also been shown to be a significant source of suspended sediment in streams (Gellin et al., 2009; Woliver and Martens, 2000; Thompson et al., 2010; Nier et al., 2016).

Web summary

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Frequently Asked Questions

CHESAPEAKE BAY ACTIVITIES SCIENCE

Evaluating the Effects of Stream-Restoration Practices in an Impaired Agricultural System

COMPLETED
Chesapeake Bay Activities July 26, 2026

Overview Publications

Stream-restoration practices are widely used throughout the Chesapeake Bay watershed to improve stream health and function, but research into their effectiveness is limited in agricultural settings. A study in Turtle Creek, Pennsylvania, suggests that stream-restoration practices can significantly reduce streambank erosion and enhance floodplain deposition, changes that can reduce in-stream sediment loads and improve habitat for fish and other stream biota.

Study Area

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Data release

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Datasets associated with sediment response study of Turtle Creek, Union County, Pennsylvania

Dates
Publication Date: 2026-06-24
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End Date: 2023

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Clune, J.W., DeWitt, J.D., Noe, G.B., Cortes, V., Cashman, M., Bell, J.M., Doody, T.R., and Weaver, M., 2026. Sediment associated with stream restoration study of Turtle Creek in Union County, Pennsylvania. U.S. Geological Survey data release. <https://doi.org/10.5066/9350002>

Summary
This web page links the datasets associated with a sediment response study of land management practices in agricultural areas. The study was conducted at seven sites along Turtle Creek in Union County, Pennsylvania. Datasets developed for the study include soil survey data collected at 100 m scale, soil type high-resolution (1:50,000) maps, and stream restoration project data collected by corrected aerial imagery (2020) and aerial photography (2010, 2012, and 2013).

Child Items (2)
Comparison of geomorphic measurements for Turtle Creek in Union County, Pennsylvania
Data Transferable Information and Data provided from USGS projects at sites in Turtle Creek, Union County, Pennsylvania

Contacts
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USGS Data Steward: Victor S. Cortes
Point of Contact: Gregory B. Noe
Originator: Catherine Brinkmann, Thomas R. Doody, Matthew J. Cashman, Mark A. Rostad, Victor S. Cortes, Joseph M. Bell, Jessica D. DeWitt, John W. Clune
Metadata Contact: Victor S. Cortes, Oregon B. Noe, Jessica D. DeWitt, John W. Clune
USGS Data Release: 10.5066/9350002
Publication: U.S. Geological Survey - Research
Distribution: U.S. Geological Survey - Research

Attached Files

<https://www.usgs.gov/centers/chesapeake-bay-activities/science/evaluating-effects-stream-restoration-practices-impaired>

I0.5066/PI3QH3XC

<https://doi.org/10.1016/j.ecoleng.2026.108082>

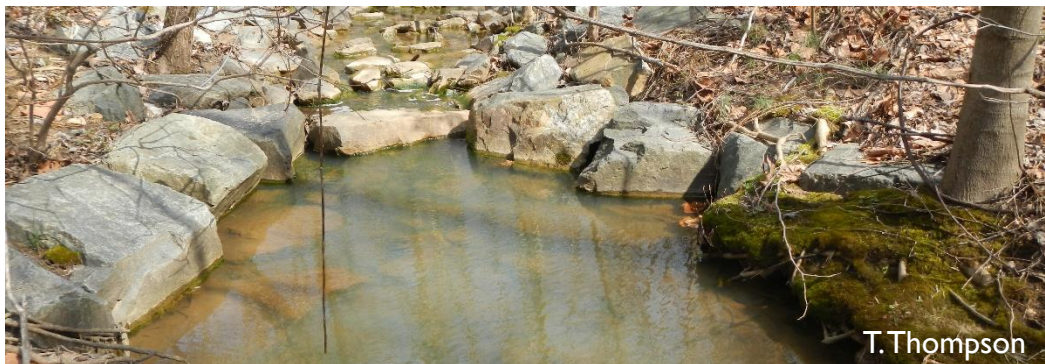
Stream restoration in the Chesapeake watershed

Streams are restored for many motivations and goals throughout the Chesapeake Bay watershed often, but not always, for TMDL crediting

Jurisdictions throughout the Chesapeake Bay watershed have implemented approximately 266 miles of stream restoration by 2010, with an additional 84 miles planned as reported in the Phase 3 WIPs

Stream restoration approaches vary across differing goals, land use setting, regulatory agencies, and contractors:

e.g. Natural Channel Design vs. Legacy Sediment Removal vs. Floodplain Reconnection vs. Regenerative Stream Conveyance vs. Beaver Dam Analogues vs.



Prepared by: David Wood, Tom Schueler, and Bill Stack

“In general, stream restorations have led to minimal improvement to stream aquatic biota, effective ‘stabilization’ of channel form over time, moderate improvements to water quality, and short-term negative impacts to riparian vegetation.”

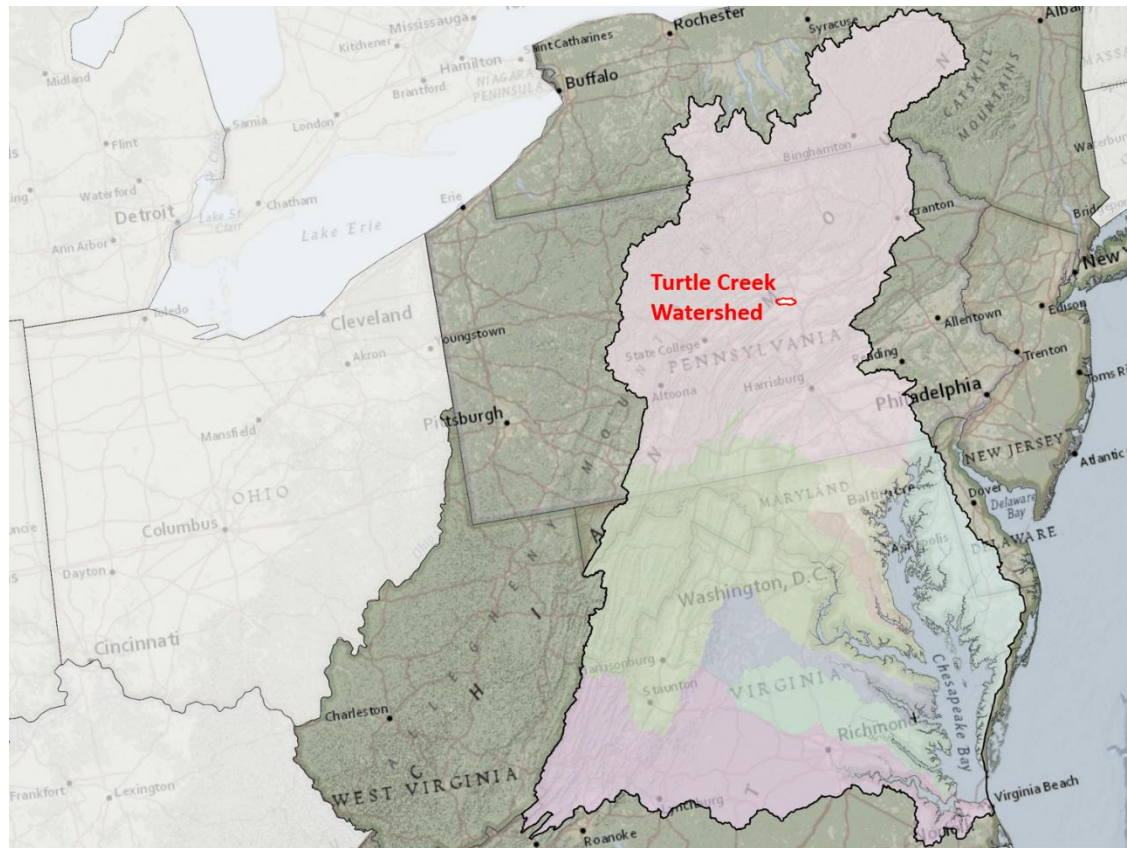
Turtle Creek

Valley and Ridge
Tributary of West Branch of Susquehanna R.
Union County, PA

24 stream miles
9 miles listed as impaired

13 mi² drainage area
47% agriculture
46% forest

(PA DEP 2013)



Turtle Creek: stream impairment

Causal Chain (STAC 2024)

Stream degradation →

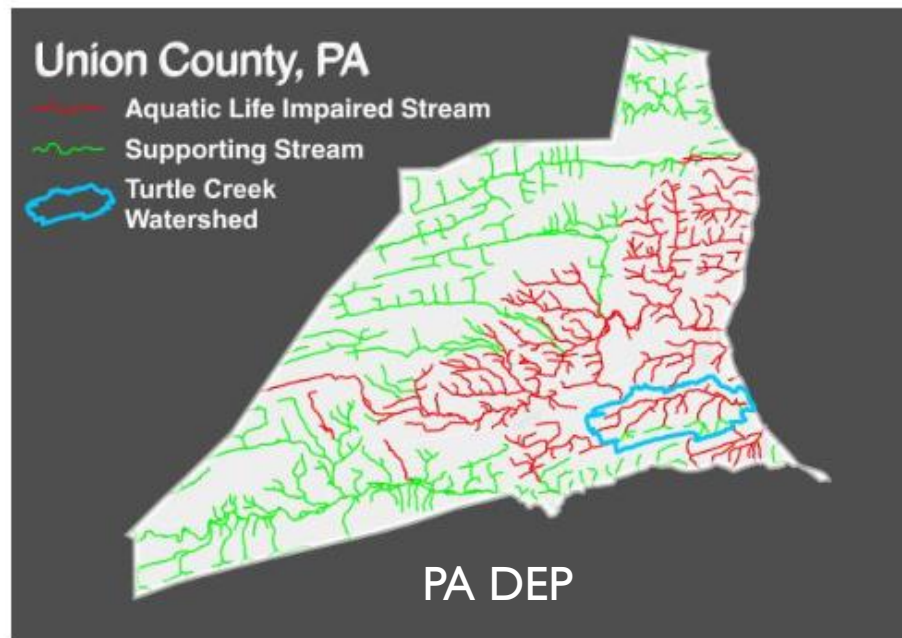
Regulatory/policy drivers →

Goals →

Design approaches/practices →

Monitoring →

Outcomes



Turtle Creek: before restoration



Turtle Creek Watershed TMDL Union County, Pennsylvania

Prepared by:



January 2013

“A Total Maximum Daily Load (TMDL) for sediment was developed to address impairments noted in Pennsylvania’s 2004 Section 303(d) and Integrated Lists. The impairments were documented during biological surveys of the **aquatic life** present in the watershed (10/17/2001). **Excessive siltation** resulting from agricultural activities and small residential runoff has been identified as the cause of these impairments in the basin.”

Turtle Creek restoration: 4+ miles of less intensive, less expensive, holistic restoration

Many log vanes and moundsills and shaved banks, plus stream crossings and fencing, and riparian tree planting

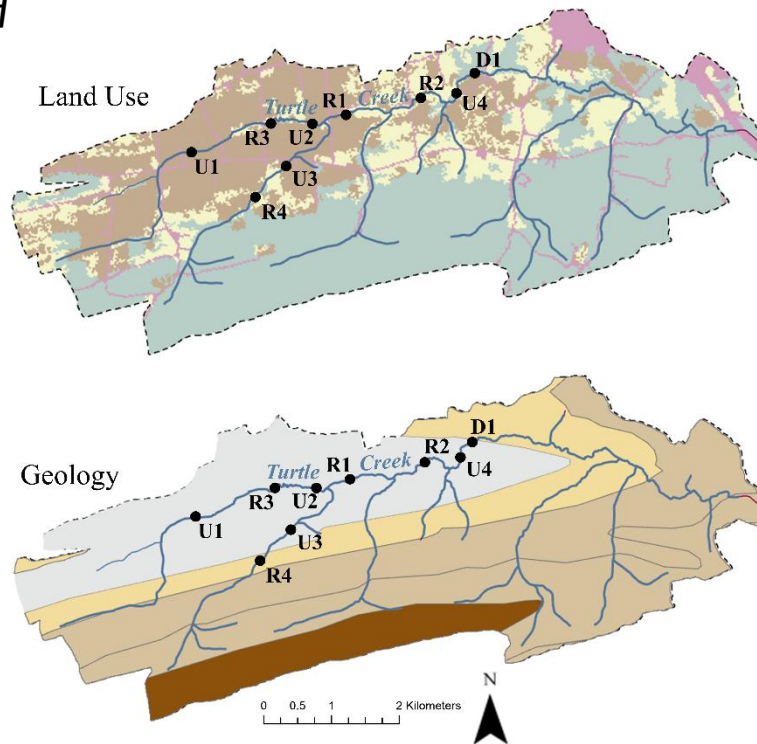
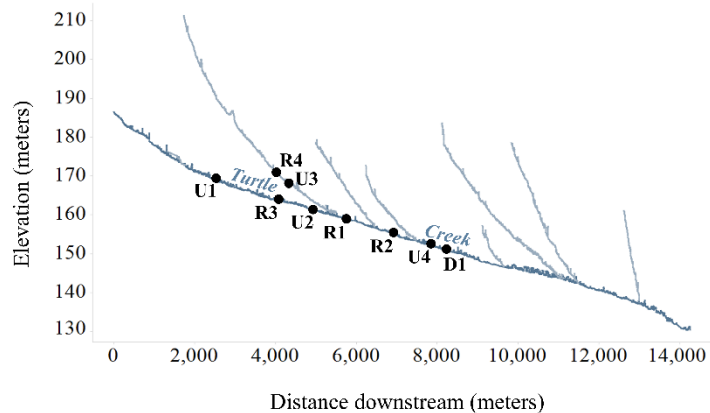


Restored and Unrestored stream locations



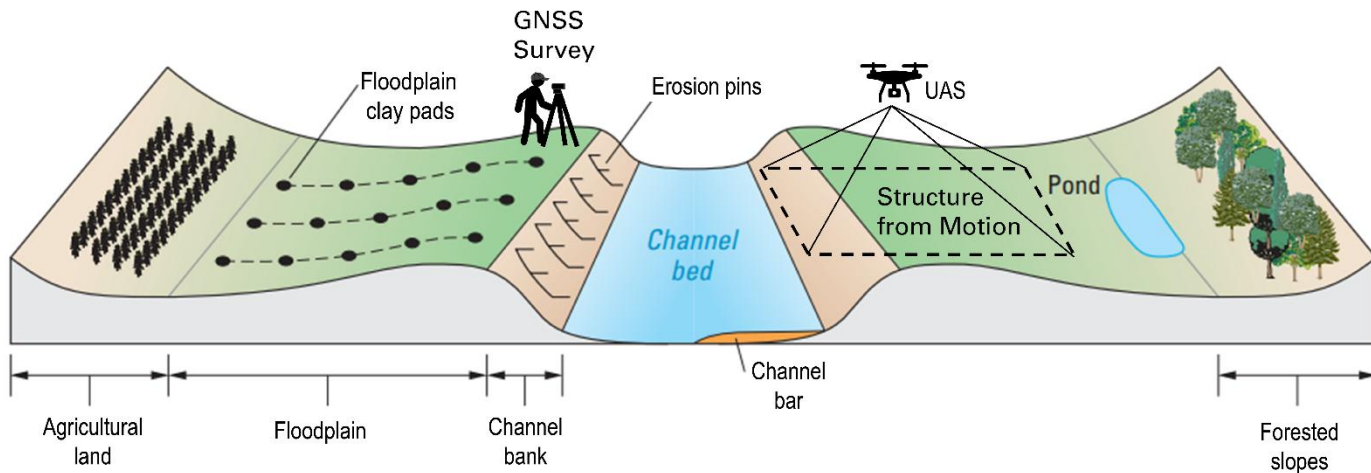
Locations of measured stream reaches

4 Restored and 4 Unrestored reaches
One Downstream reference Unrestored



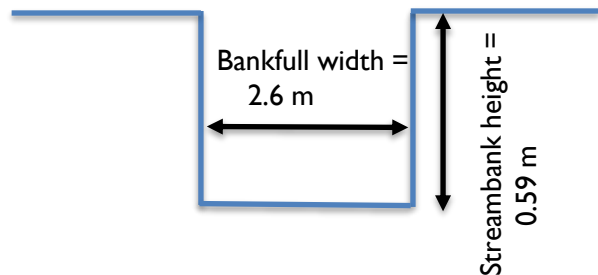
Measurements of geomorphic change in each stream reach

Restored and unrestored reaches measured for 3 yrs after restorations: 5 x-sections per site.



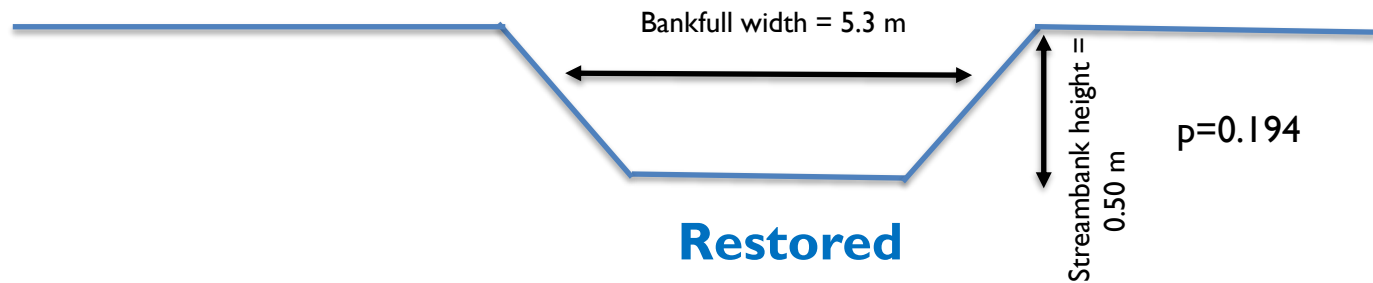
Restoration effects on channel shape

Unrestored



→ Stream channel widened 2X

$p=0.059$



$p=0.194$

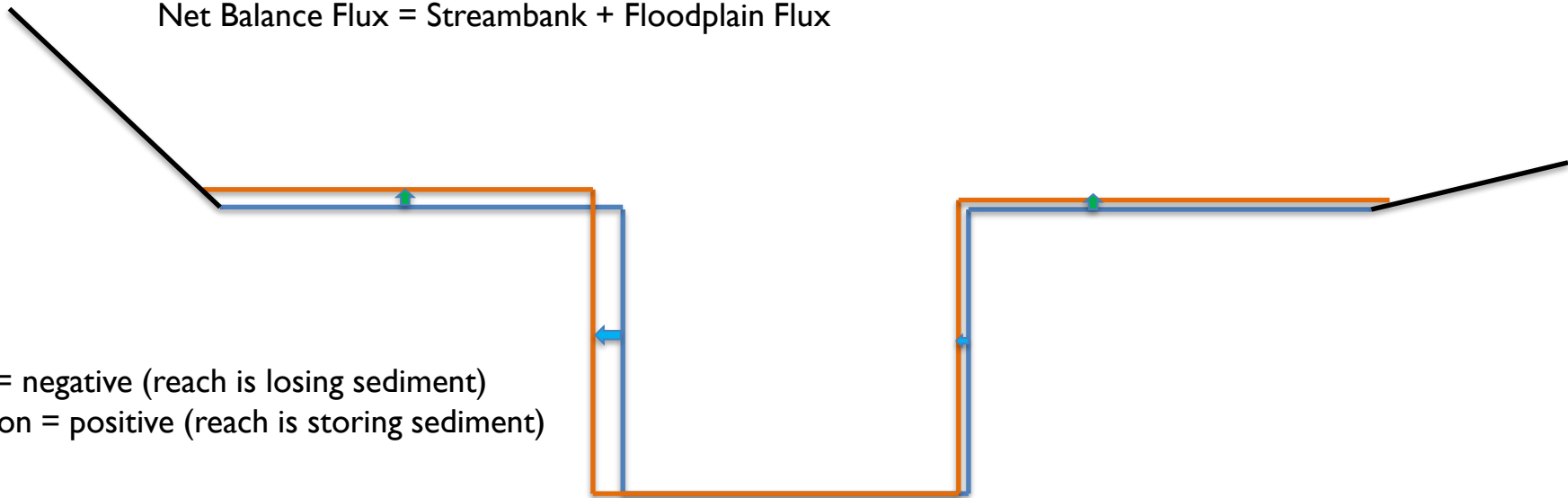
Calculation of sediment fluxes

Streambank Flux = lateral change rate (m/yr) * height (m) * bulk density (g/cm³) = kg/m/yr

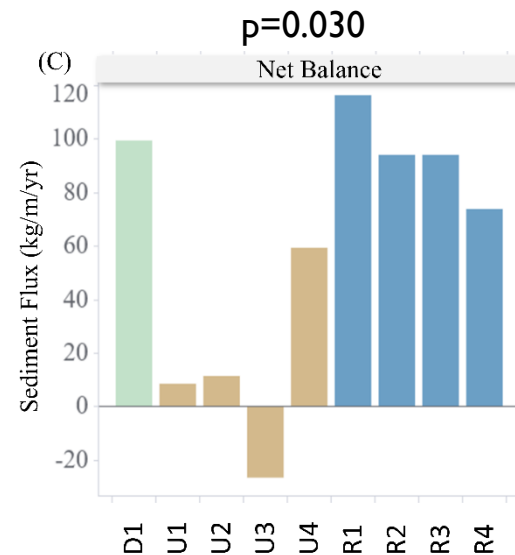
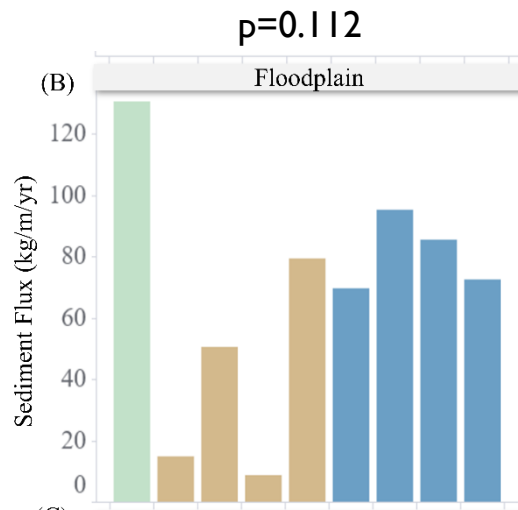
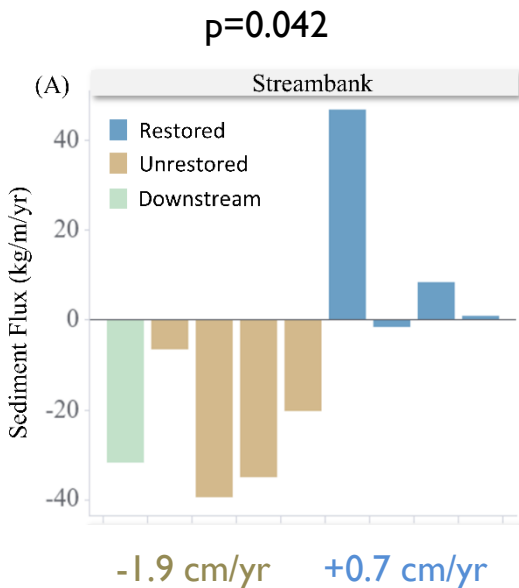
Floodplain Flux = vertical change rate (m/yr) * width (m) * bulk density (g/cm³) = kg/m/yr

Net Balance Flux = Streambank + Floodplain Flux

Erosion = negative (reach is losing sediment)
Deposition = positive (reach is storing sediment)

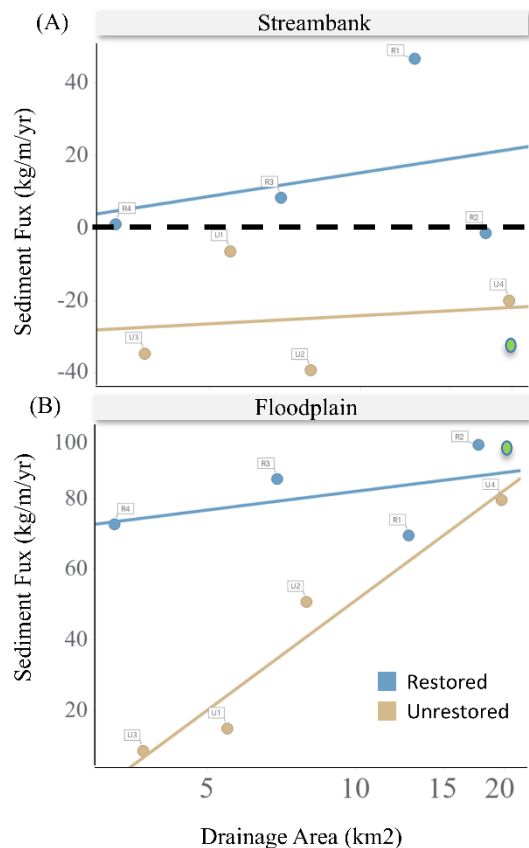


Restoration effects on sediment fluxes



→ Streambank erosion changed from erosional to depositional
→ Net Balance changed from slightly to greatly depositional

Restoration effects on sediment fluxes



Restoration $p=0.070$
Drainage area $p=0.630$
Interaction $p=0.820$

Restoration $p=0.006$
Drainage area $p=0.020$
Interaction $p=0.040$

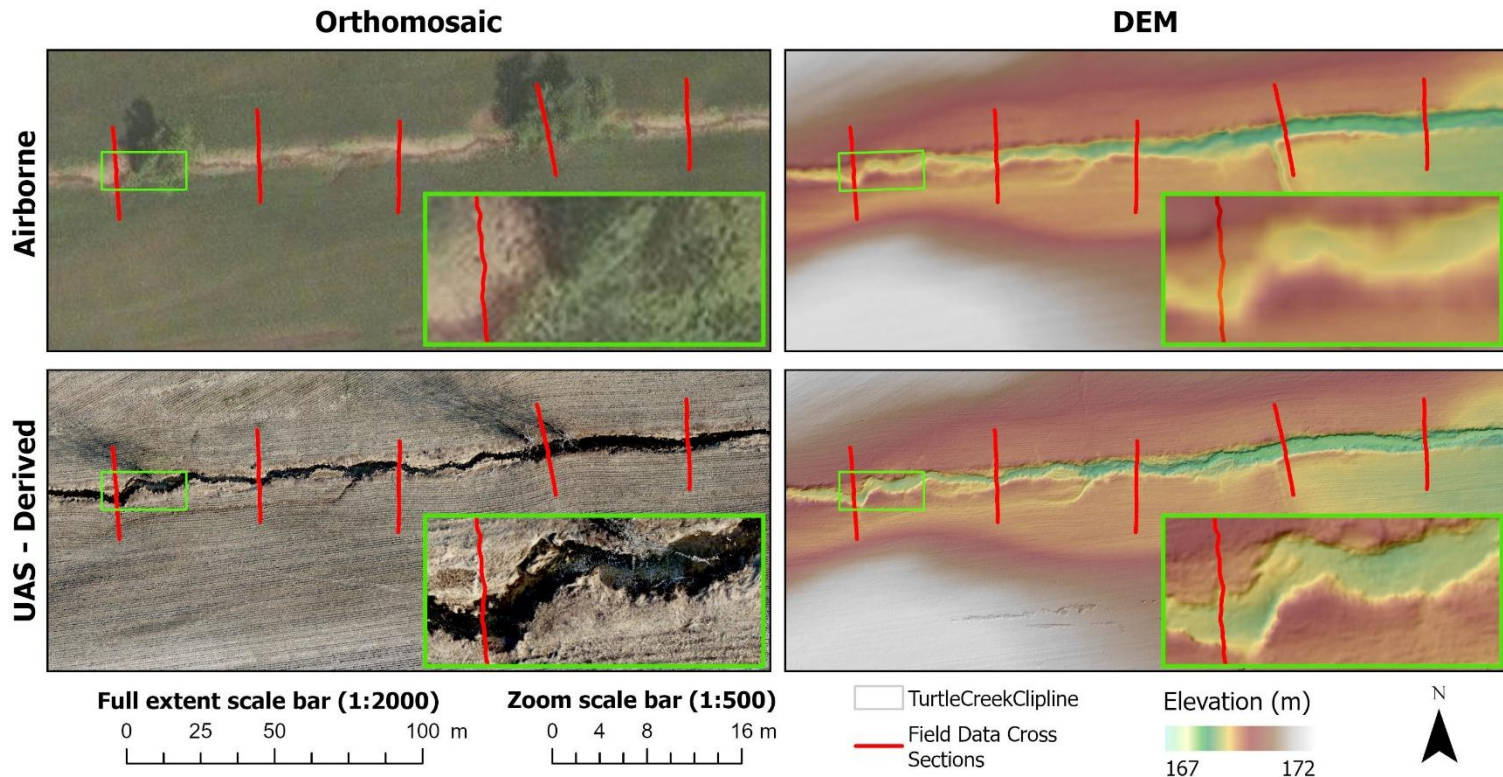
→ **Floodplain deposition
increased 7X at
headwaters**

Uncrewed aerial systems (UAS; drones)



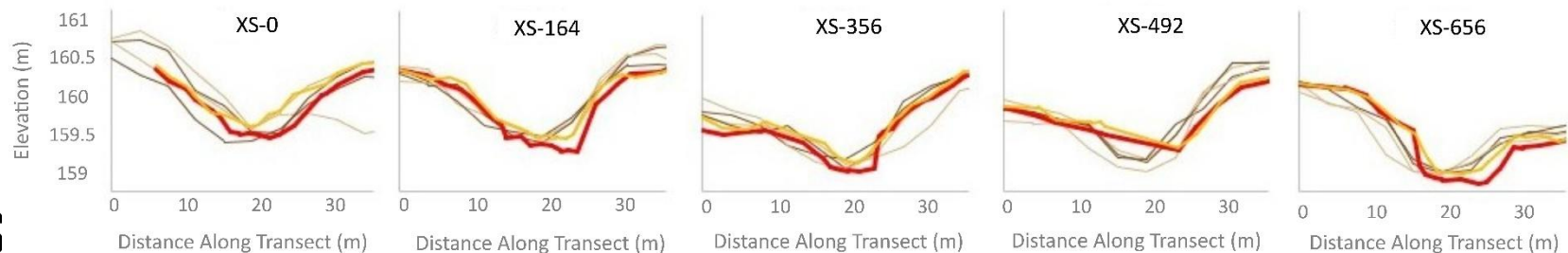
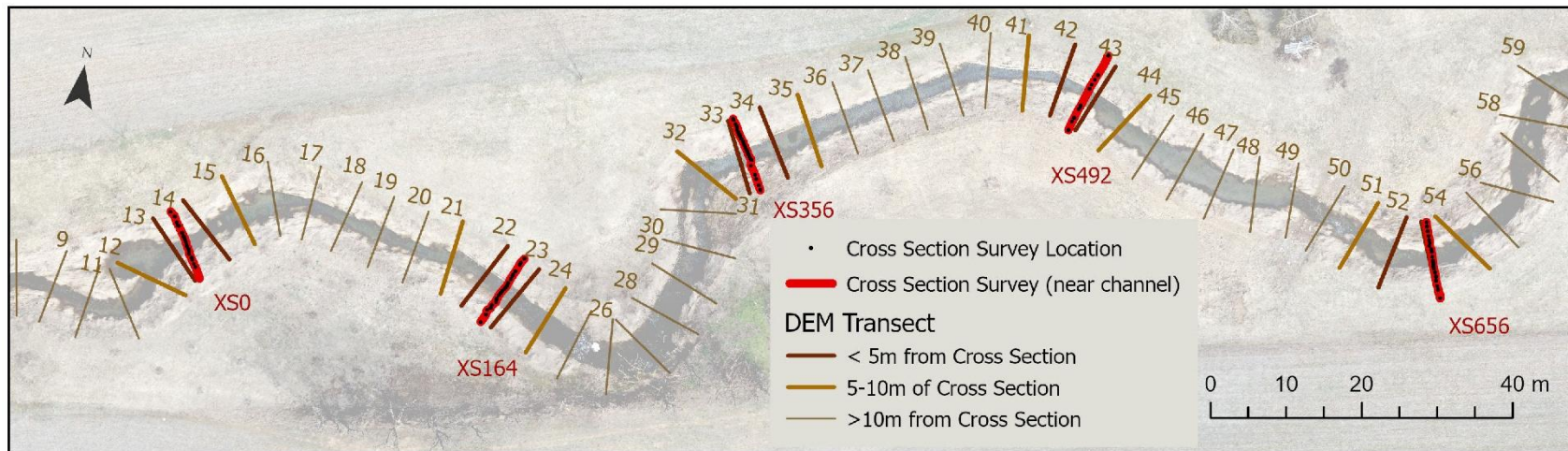
UAS can better identify stream instability

Drones produce much higher resolution imagery and topography than other remote sensing (e.g. plane lidar)



UAS measure geomorphic x-sections over larger reach

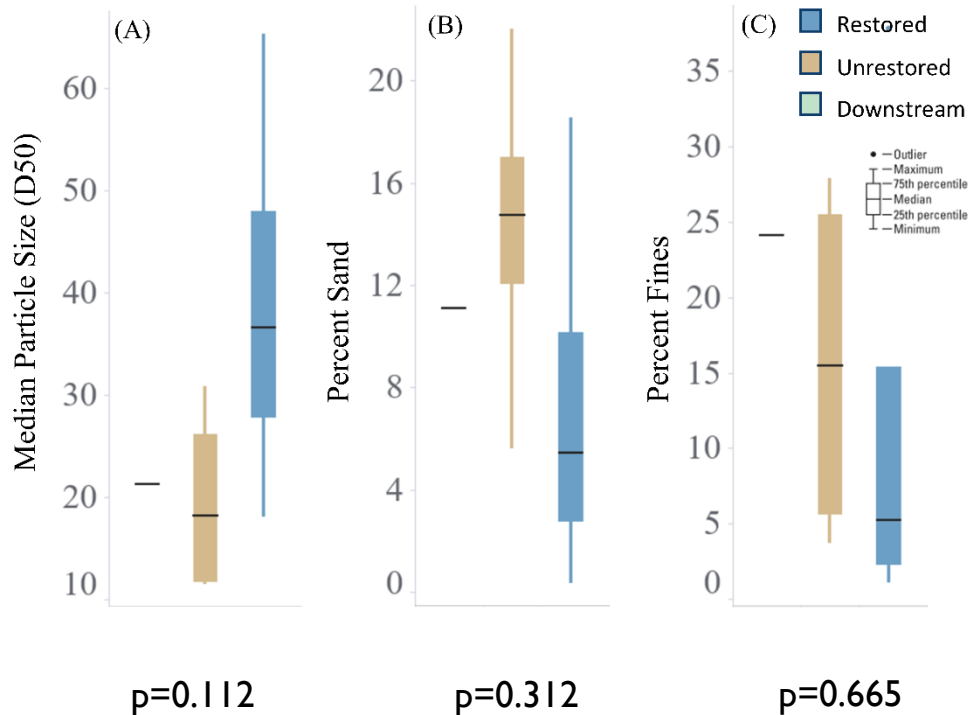
Terrain analysis confirmed that field-based measurements were representative of larger reaches



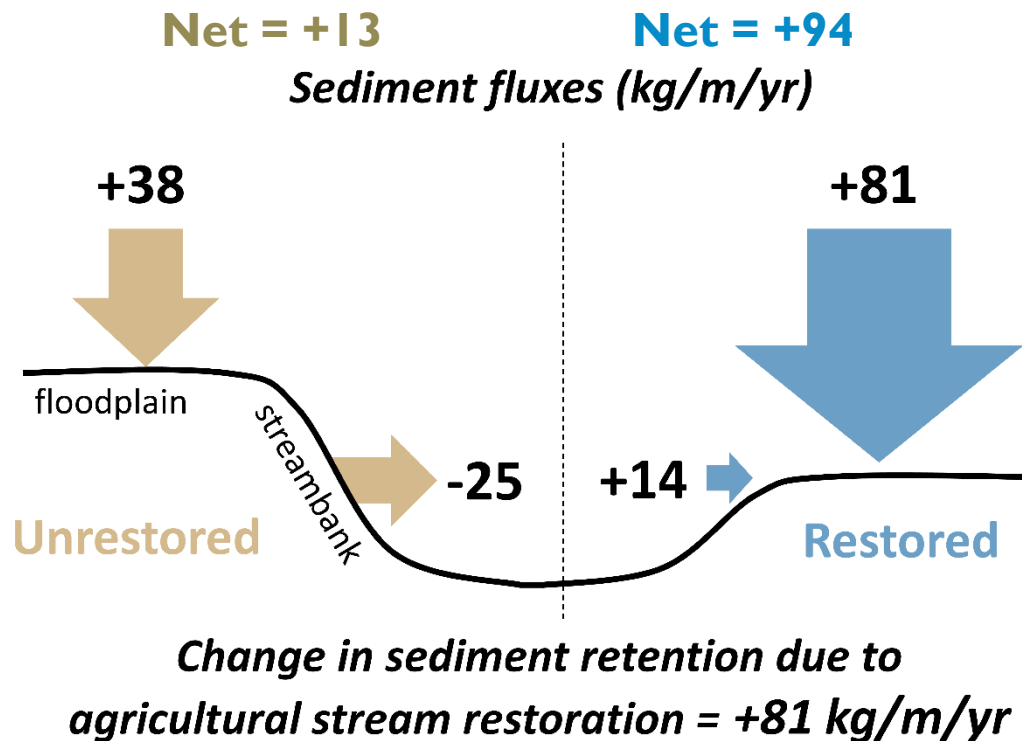
Restoration effects on sediment fluxes



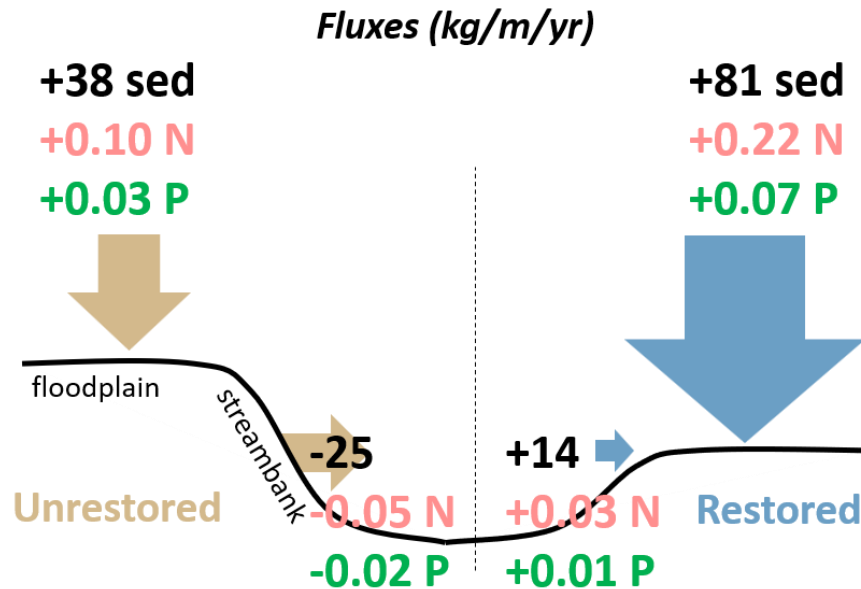
→ Streambed likely coarsened 2X



Summary of restoration effects on sediment fluxes



Summary of restoration effects on sediment fluxes: N and P



*Change in sediment retention due to
agricultural stream restoration = +81 sed kg/m/yr*

*+0.202 N
+0.061 P*

Turtle Creek restoration successes



NONPOINT SOURCE SUCCESS STORY

Pennsylvania

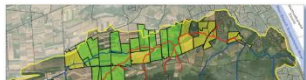
Partners Collaborate to Improve the Turtle Creek Stream Corridor

Waterbody Improved

In 2004, excess sediment from eroding streambanks, over-widened channels, livestock access, and lack of tree canopy caused the impairment of Pennsylvania's Turtle Creek. The Pennsylvania Department of Environmental Protection (PA DEP) added 8.79 miles of stream to the state's 2004 Clean Water Act (CWA) section 303(d) list of impaired waters. From 2012 through 2020, the Northcentral Stream Restoration Partnership (Partnership) worked with 14 landowners along 5.3 miles of Turtle Creek. Together, they implemented best management practices (BMPs) including streambank fencing, streambank stabilization, and riparian buffers. As a result of the Partnership and landowners' efforts, water quality and aquatic habitat have significantly improved.

Problem

Turtle Creek is a tributary to the West Branch Susquehanna River in central Pennsylvania's Union County (Figure 1). An 8.79-mile segment of Turtle Creek was listed as impaired for siltation in 2004. The creek flows from forested headwaters into an agricultural area.



Turtle Creek in context:

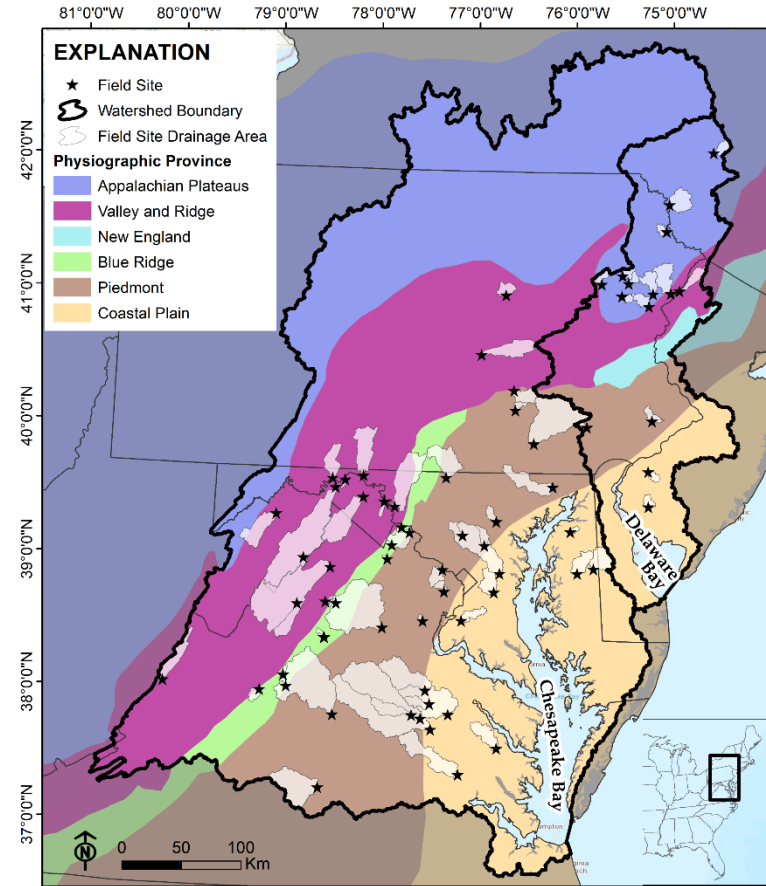
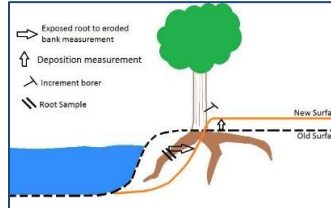
USGS Chesapeake & Delaware Floodplain Network (CDFN)

Measure long-term rates of streambank erosion using
dendrogeomorphology

68 sites over Chesapeake and Delaware watersheds diversity

Noe et al. 2022 | *ERL*

Predictions of change, flux, and load (kg/yr) per
NHDPlusV2 1:100K stream reach



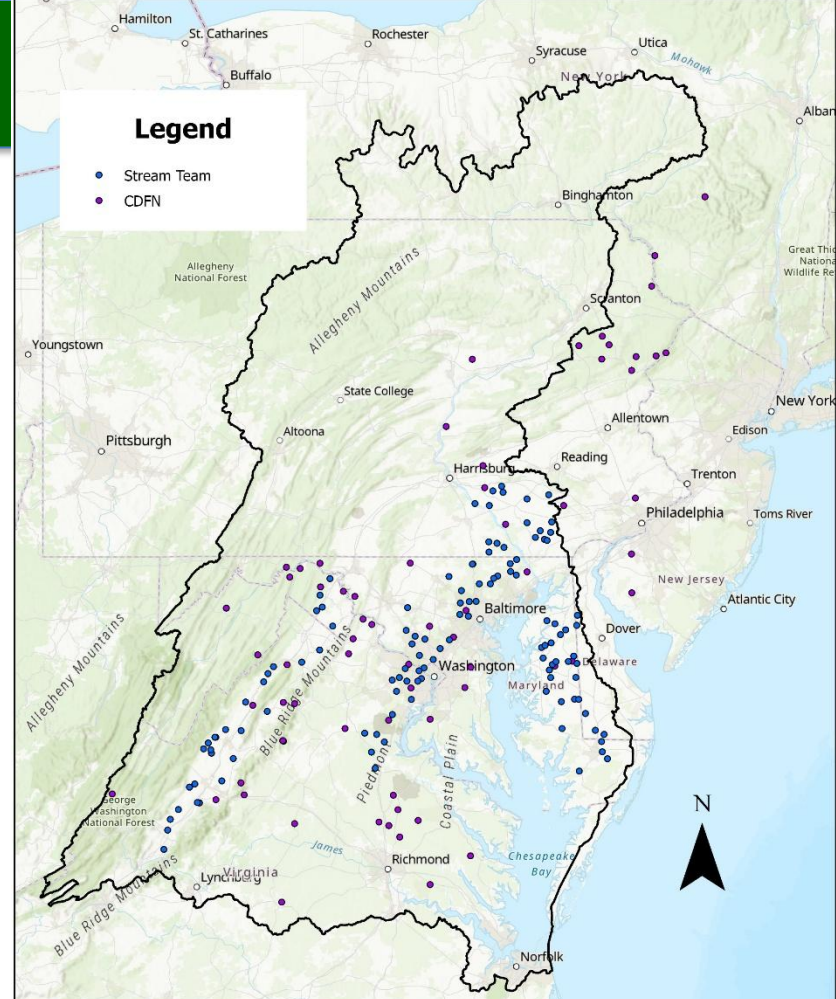
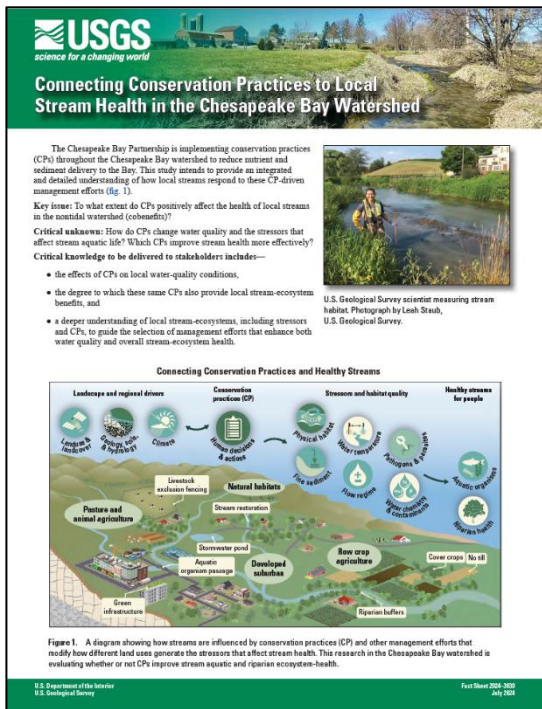
Turtle Creek in context:

USGS + VT Stream Team

5 to 52 km² drainage areas

Streambank erosion only, not floodplain deposition

Just dendrogeomorphology and surveying, no sediment characteristics



<https://www.sciencebase.gov/catalog/item/62fea68ed34e3a4442876167>

<https://doi.org/10.3133/fs20243030>

Summary of restoration effects on sediment fluxes: N and P

CDFN net:

+69 sed
+0.22 N
+0.06 P

Net = +13

Net = +94

Fluxes (kg/m/yr)

CDFN floodplain:

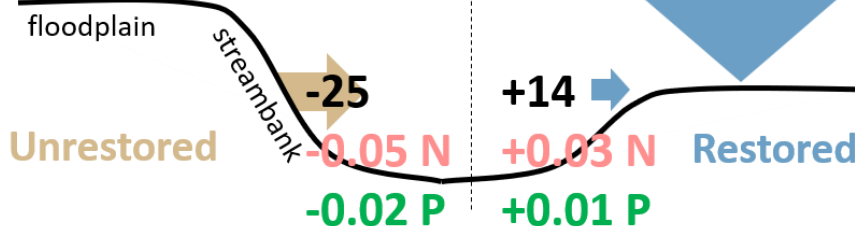
+130 sed
+0.31 N
+0.09 P

+38 sed
+0.10 N
+0.03 P

+81 sed
+0.22 N
+0.07 P

CDFN streambank:

-62 sed
-0.09 N
-0.03 P



Change in sediment retention due to
agricultural stream restoration = +81 sed kg/m/yr

+0.202 N
+0.061 P

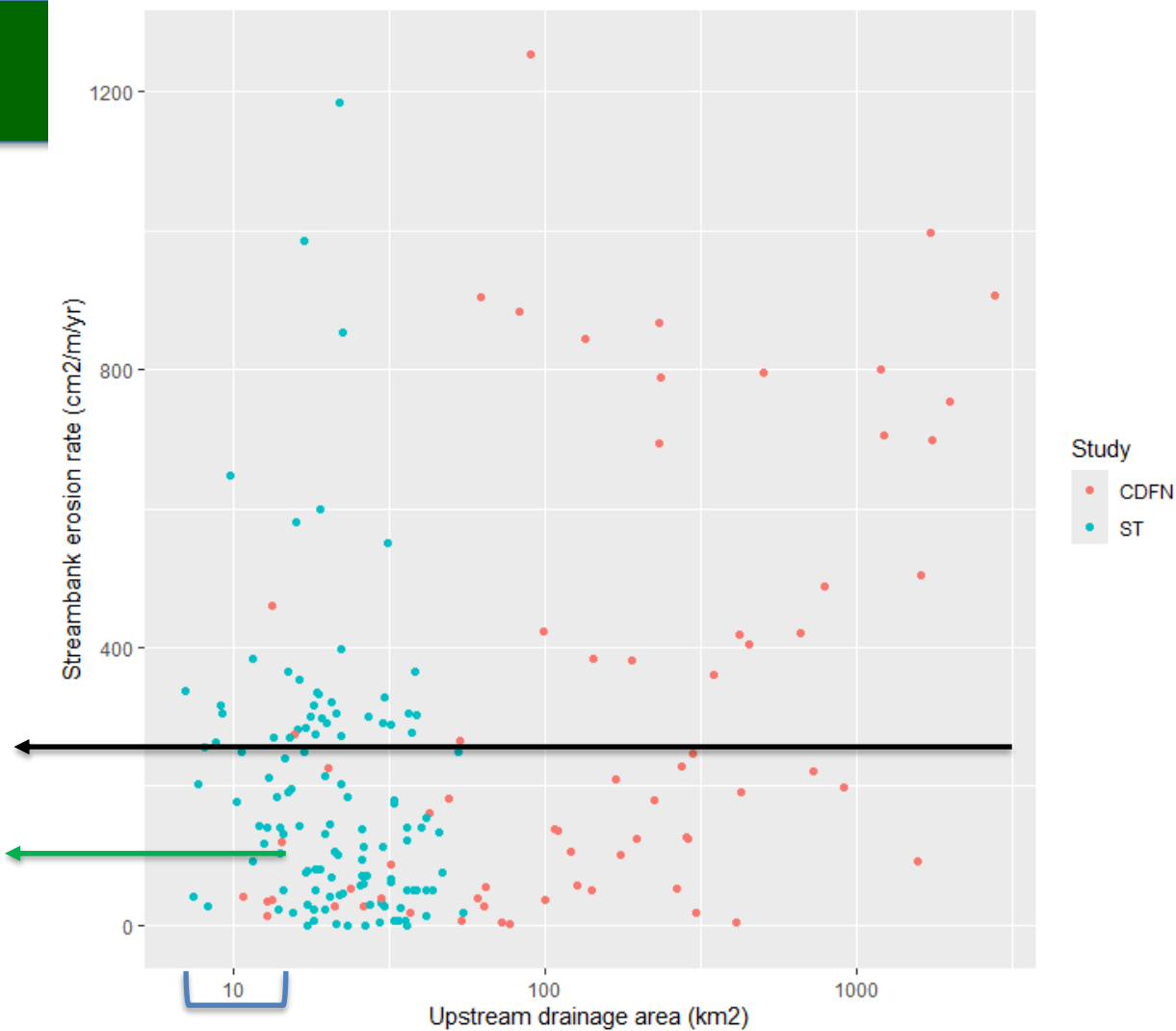
USGS CDFN + ST

Streambank Erosion Area Rate (cm^2/yr)

[lateral erosion rate * streambank height]

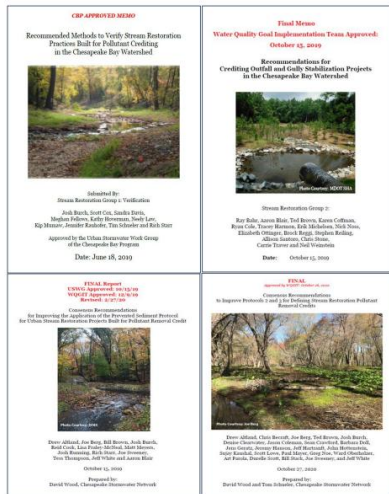
CDFN+ST:
Unrestored average
= -231

Turtle Creek:
Unrestored average
= -108



CBP crediting

A Unified Guide for Crediting Stream and Floodplain Restoration Projects in the Chesapeake Bay Watershed



August 18, 2021

Prepared by: David Wood, Tom Schueler, and Bill Stack

The original Chesapeake Bay Program TMDL crediting system assigned a default rate of 369 kg/m/yr (248 pounds/ft./yr). An expert panel concluded that stream restoration should be provided a TMDL credit calculated as a reduction in streambank erosion by 50%, or a 185 kg/m/yr (124 pounds/ft./yr) reduction due to restoration (prevented erosion; Berg et al., 2013);

The current protocol requires a site-specific calculation (Altland et al., 2019), and currently applies the urban stream restoration protocol to agricultural settings due to the insufficient number of agricultural stream studies

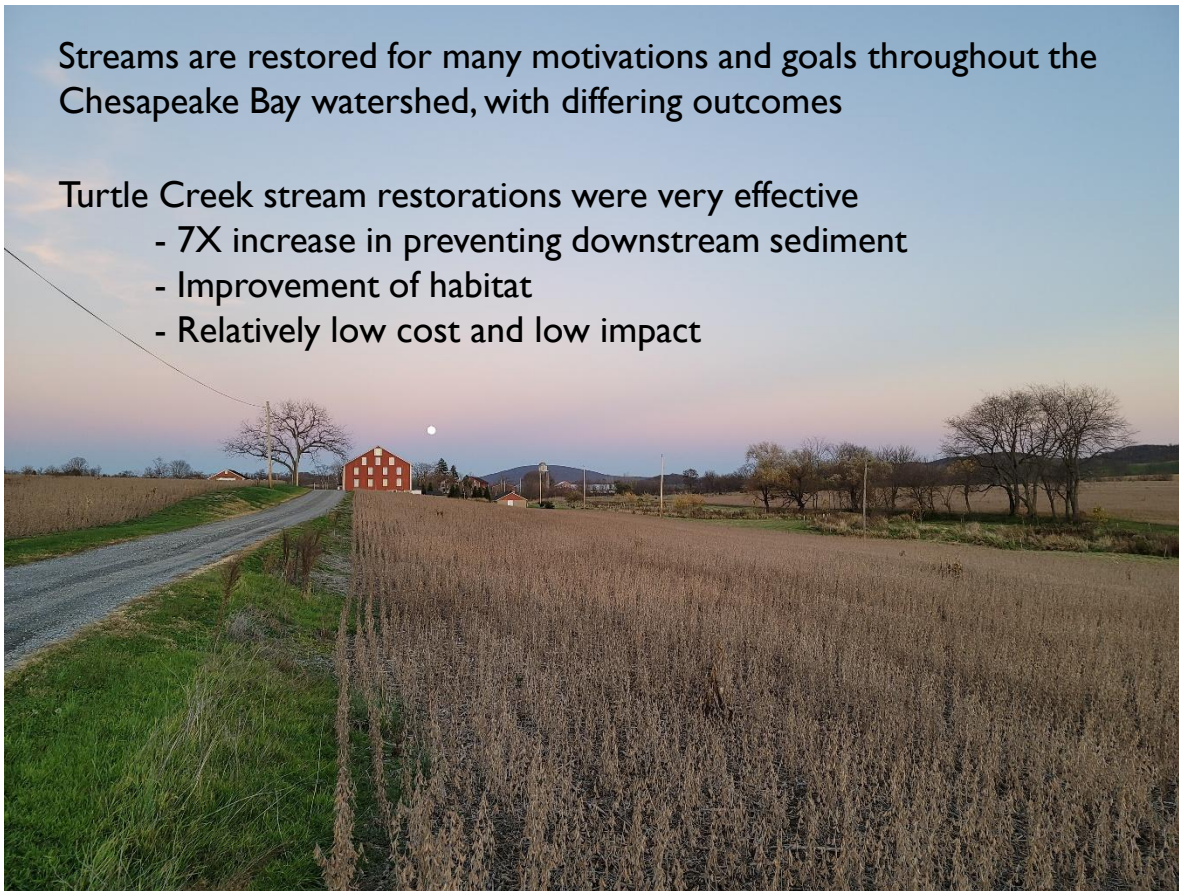
The measured to agricultural total net reduction in sediment net balance flux due stream restoration in Turtle Creek averaged +54.5 pounds/ft./yr (+81 kg/m/yr).

Conclusions

Streams are restored for many motivations and goals throughout the Chesapeake Bay watershed, with differing outcomes

Turtle Creek stream restorations were very effective

- 7X increase in preventing downstream sediment
- Improvement of habitat
- Relatively low cost and low impact



USGS CDFN + ST

	Turtle Creek: Unrestored average	CDFN+ST: Unrestored average
<i>Streambank Lateral Erosion Rate</i>	-1.9 cm/yr	-1.7 cm/yr
<i>Streambank Total Height</i>	0.59 m	1.24 m
<i>Streambank Lateral Area Erosion Rate</i>	-108 cm ² /yr	-231 cm ² /yr