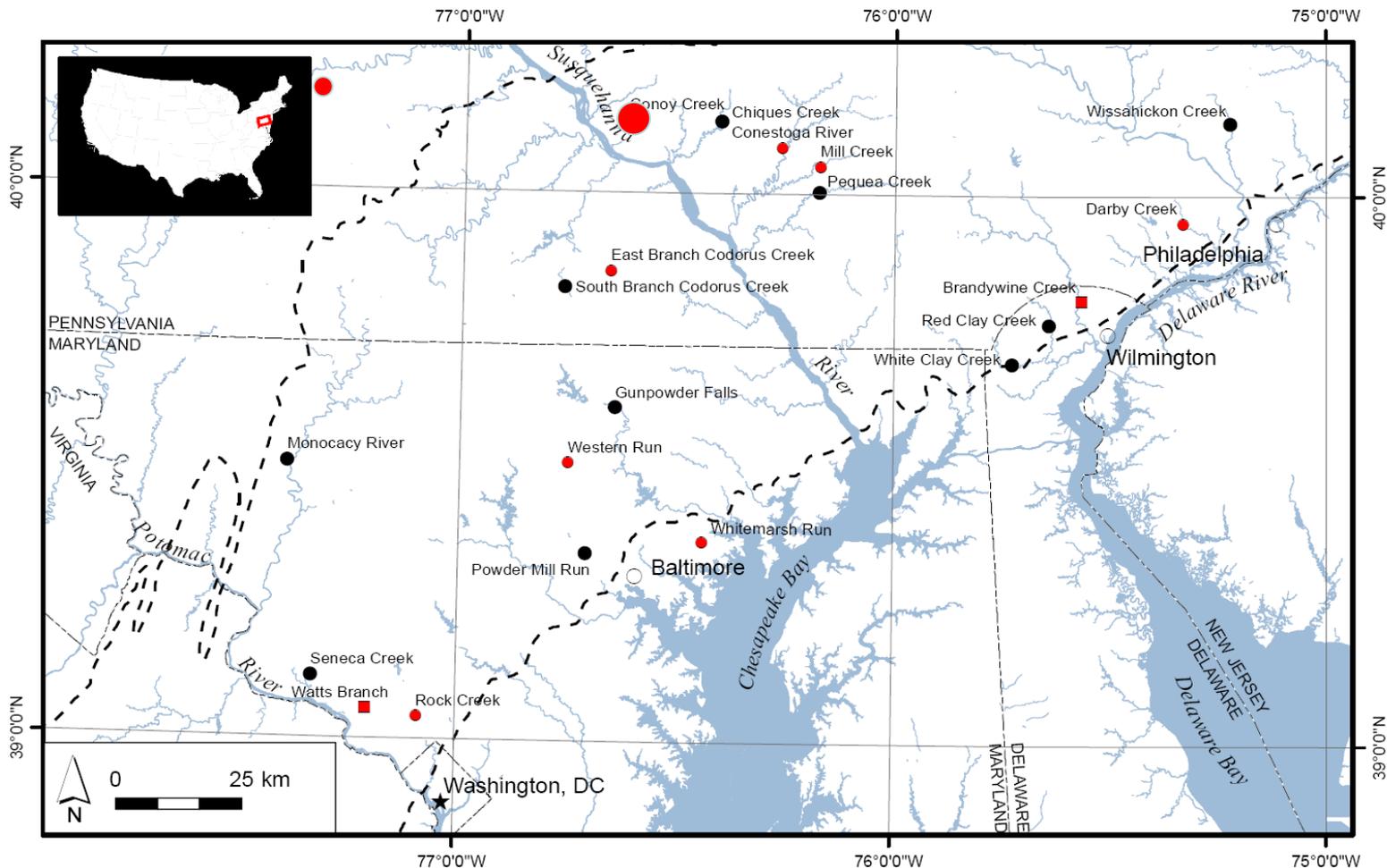


# The Rise and Fall of Mid-Atlantic Streams: Buried Soils and the History of Valley Bottom Sedimentation and Erosion

Dorothy Merritts, Robert Walter, and Mike Rahnis (F&M College)



Study Region includes 21 Mid-Atlantic Watersheds  
(Sites depicted in red have radiocarbon age control)

# Acknowledgements

## Funding:

Franklin and Marshall College, PA Department of Environmental Protection, PA Chesapeake Bay Commission, EPA, and NSF

## Professional Collaborators:

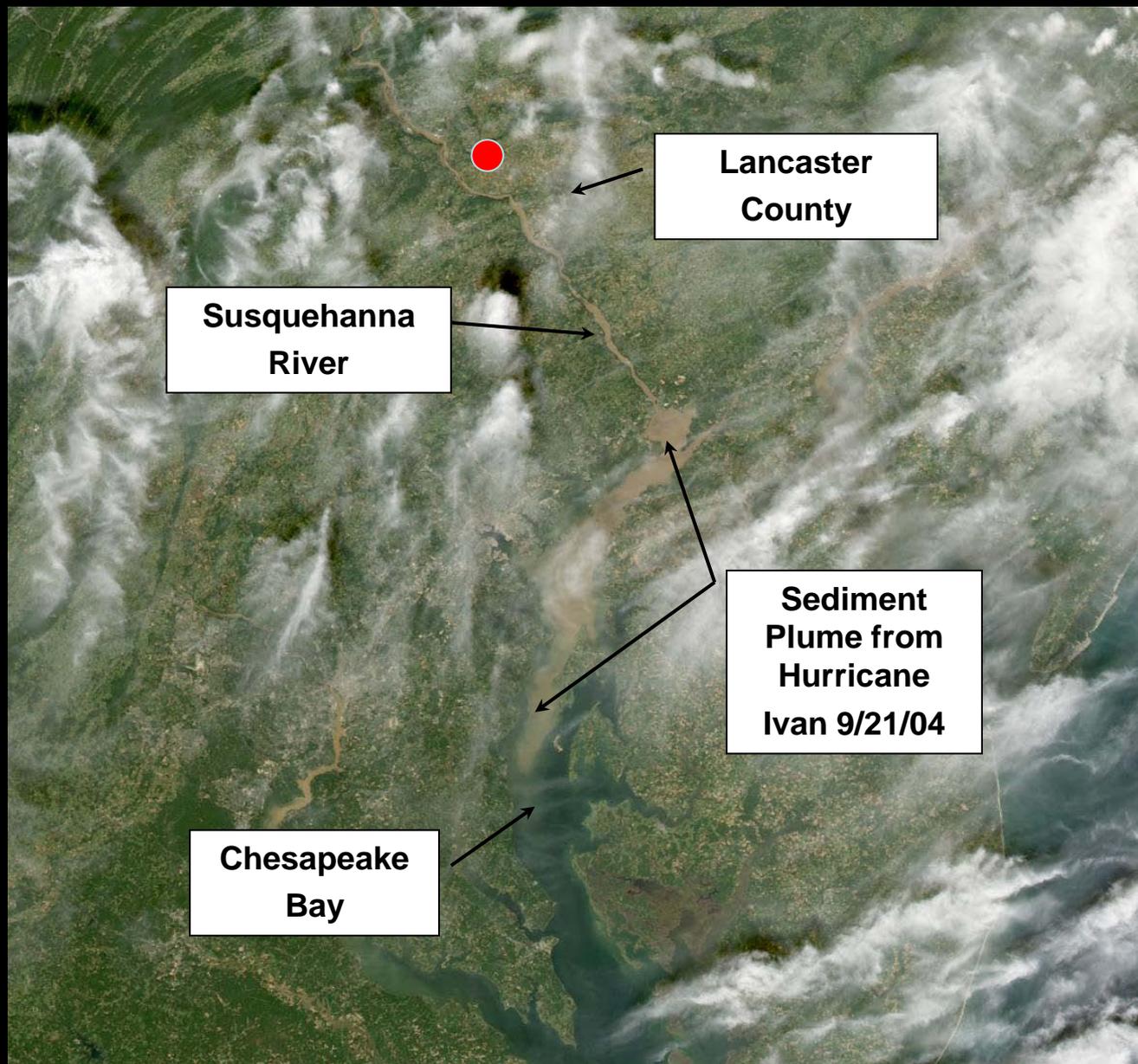
Jeff Hartranft (PA DEP), Bill Hilgartner (The Johns Hopkins University), Karen Mertzman (F&M), Rob Sternberg (F&M), Milan Pavich, Allen Gellis, and Mike Langland (*USGS*), Scott Cox (PA DEP), Ward Oberholtzer and Drew Altland (Landstudies, Inc.), Andy Stubblefield (Humboldt State), Jerry Ritchie (USDA), Noel Potter (Dickinson College), Art Parola (Univ. Louisville), Paul Mayer (EPA), Mark Gutshall (*LandStudies*), Lee Irwin and Jim Morris (ARRC, Inc.), and the PA Legacy Sediment Workgroup

## Student Collaborators:

Lauren Manion '04, Graham Boardman '05, Christina Arlt '05, Caitlin Lippincott '05, Sauleh Siddiqui '07, Yoanna Voynova '06, Andrey Voynov '05, Adam Ross '07, Mark Voli '08, Chris Scheid '08, Julie Weitzmann '08, Zain Rehman '09, Zach Stein '08, Erik Ohlson '10, Franklin Dekker '10, and Colette Buchanan '08, Stacey Sosenko '09, Liz Cranmer '09, Matt Jenschke '09, Wanlin Deng '12, Katie Datin '12, Laura Kratz '11, Andrea Shilling, '10, Yupu Zhao, '10, Derek Matuszewski, '10, Austin Reed, '10, Erik Olsen '11, Conor Neal, '12, Aakash Ahamad, '12, Peter Ripberger, '12, Elvis Andino, '12, Joe Galella, '11

# Soils and Sediment in the Chesapeake Bay Watershed

The conundrum of causality in environmental problems



**What are possible sources (and causes)  
of sediment in the Bay?**

**What are possible sources (and causes) of sediment in the Bay?**



**Fields, farms, soil erosion from uplands? In the 1930s? In 2010?**

# What are possible sources (and causes) of sediment in the Bay?



**Soil erosion from cows trampling banks?  
How do cows cause deep incision into fine-grained sediment?  
How did the sediment get in the valley bottom?**

## What are possible sources (and causes) of sediment in the Bay?

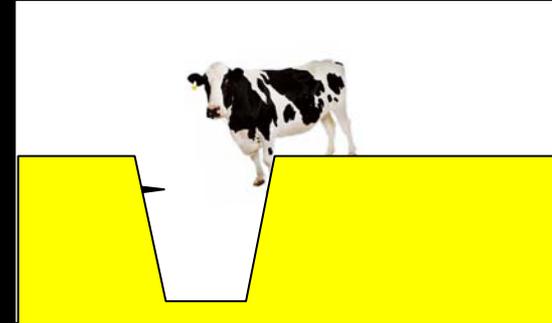
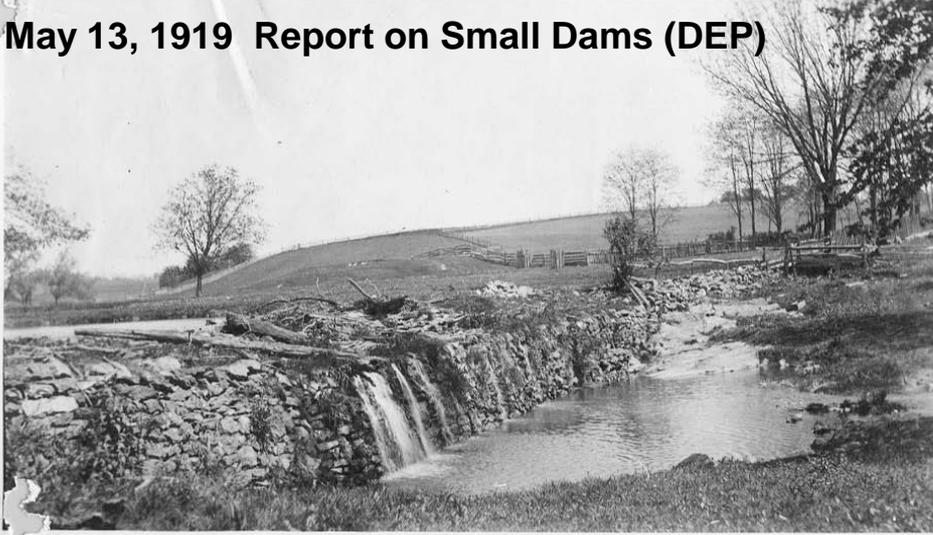


**Storm water runoff, rilling, and gullyng.**  
**What is the storm water cutting into? How much of this impact is due to water and how much to changes in base level (grade)?**

# What are possible sources (and causes) of sediment in the Bay?

Bender's Mill Dam—"dry masonry, overflow...watertight"

May 13, 1919 Report on Small Dams (DEP)



## A new source: Millponds

Historic sediment stored along valley bottoms (with help from breached dams, incised/straightened streams, and changes in grade).

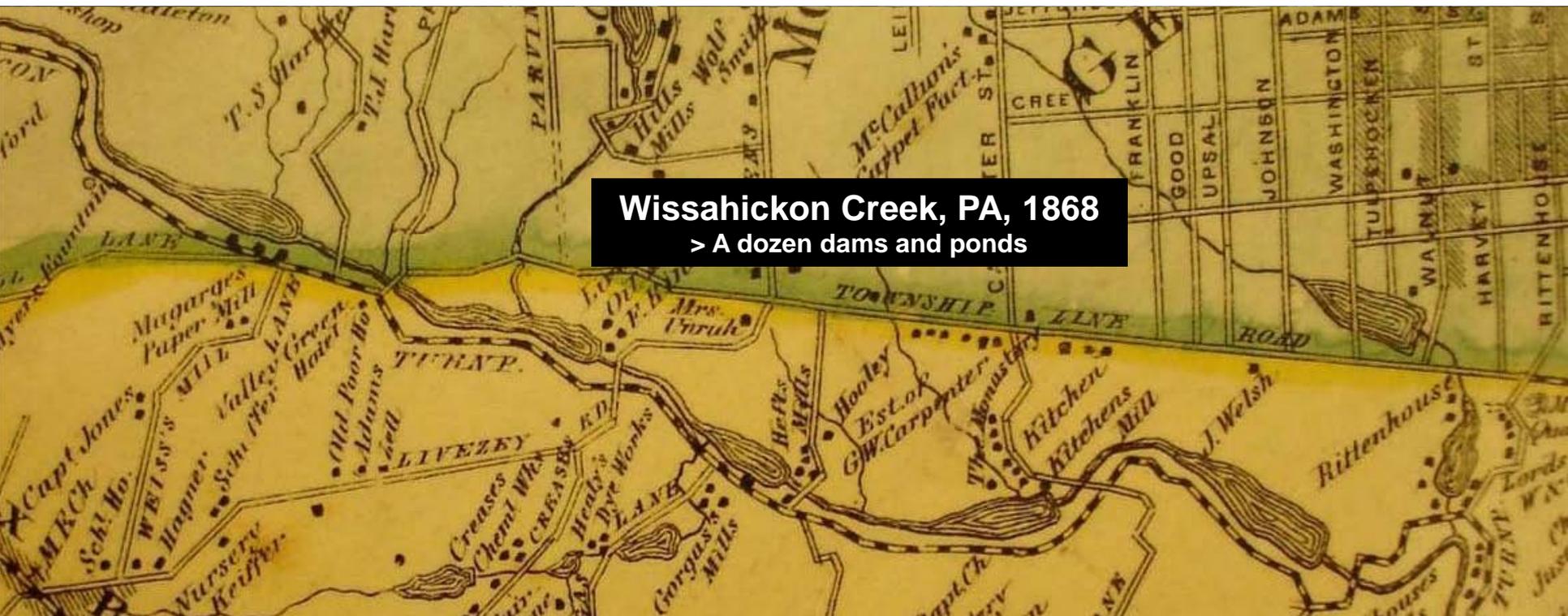


150 m upstream of breach; seeds 7200 yrs BP at base

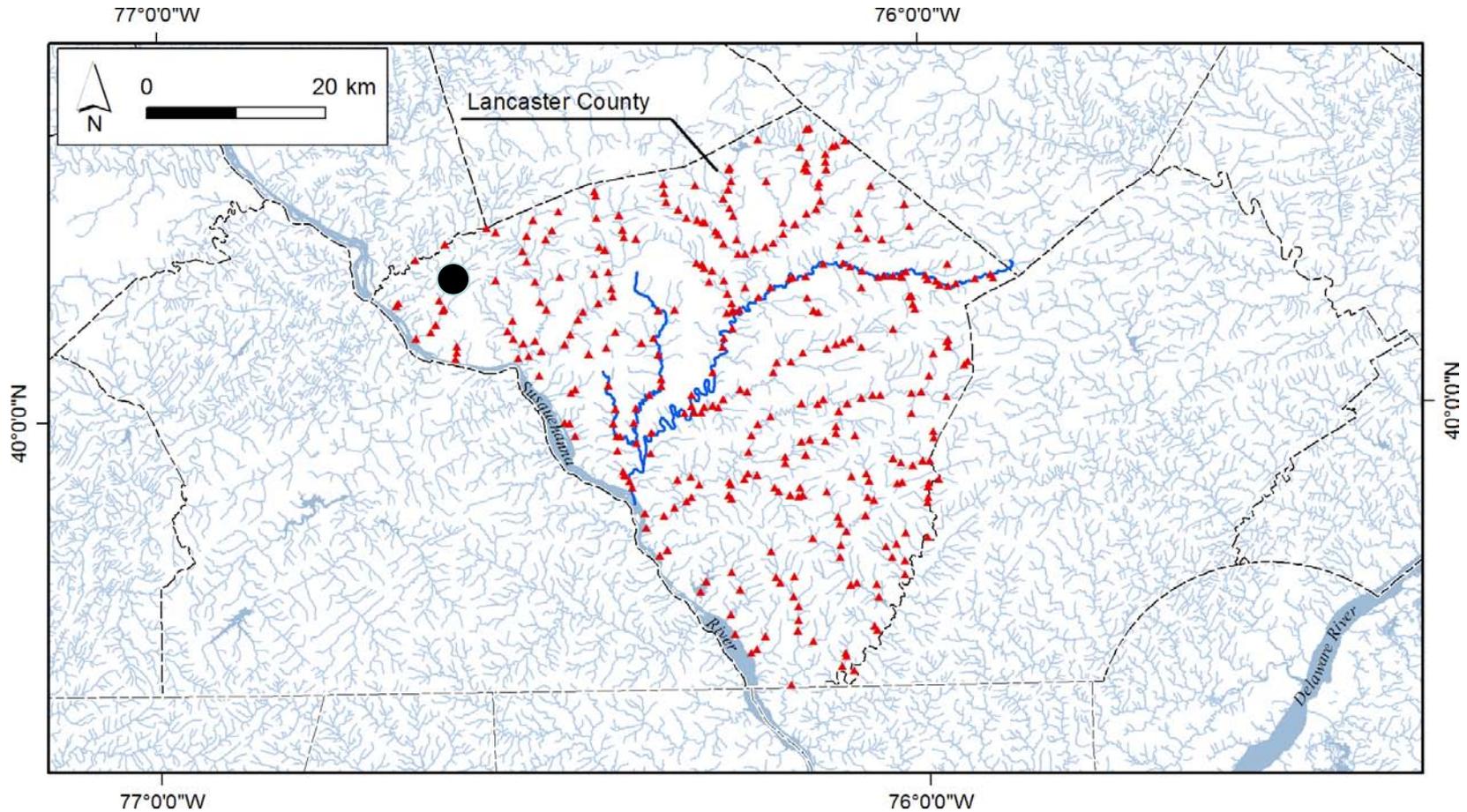
# CLINTON, NEW JERSEY—THE RED MILL (1810)



A photogenic symbol of early America's rural industry..... originally a woolen mill. .... used at different times to process grains, plaster, talc and graphite, to generate electricity and pump water for the town.



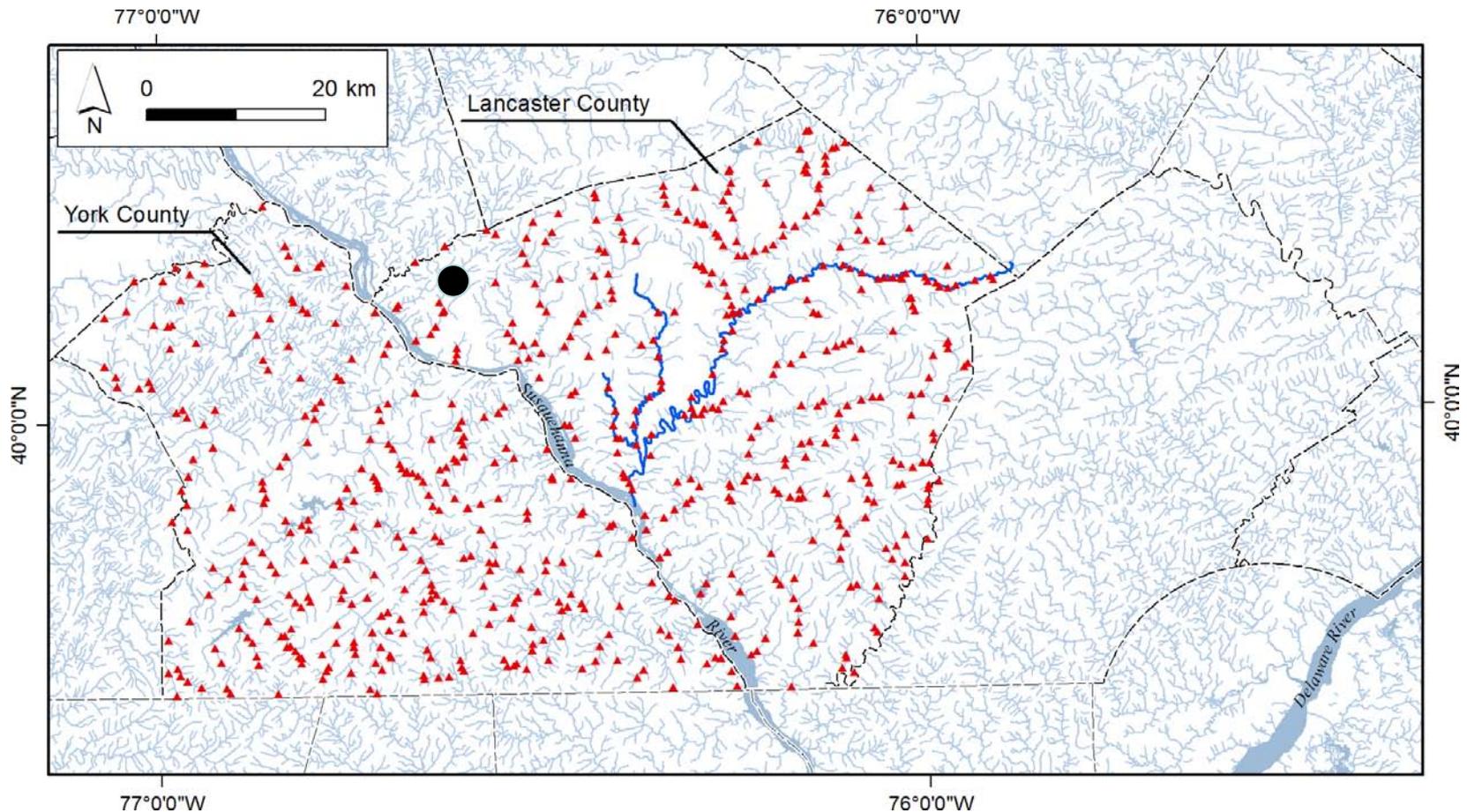
***“There is no neighborhood in any part of the United States without a water gristmill.”***  
**Thomas Jefferson, 1786**



**~400 mill dams in 19<sup>th</sup> C. Atlases of Lancaster County**

**▲ Location of mill dams**

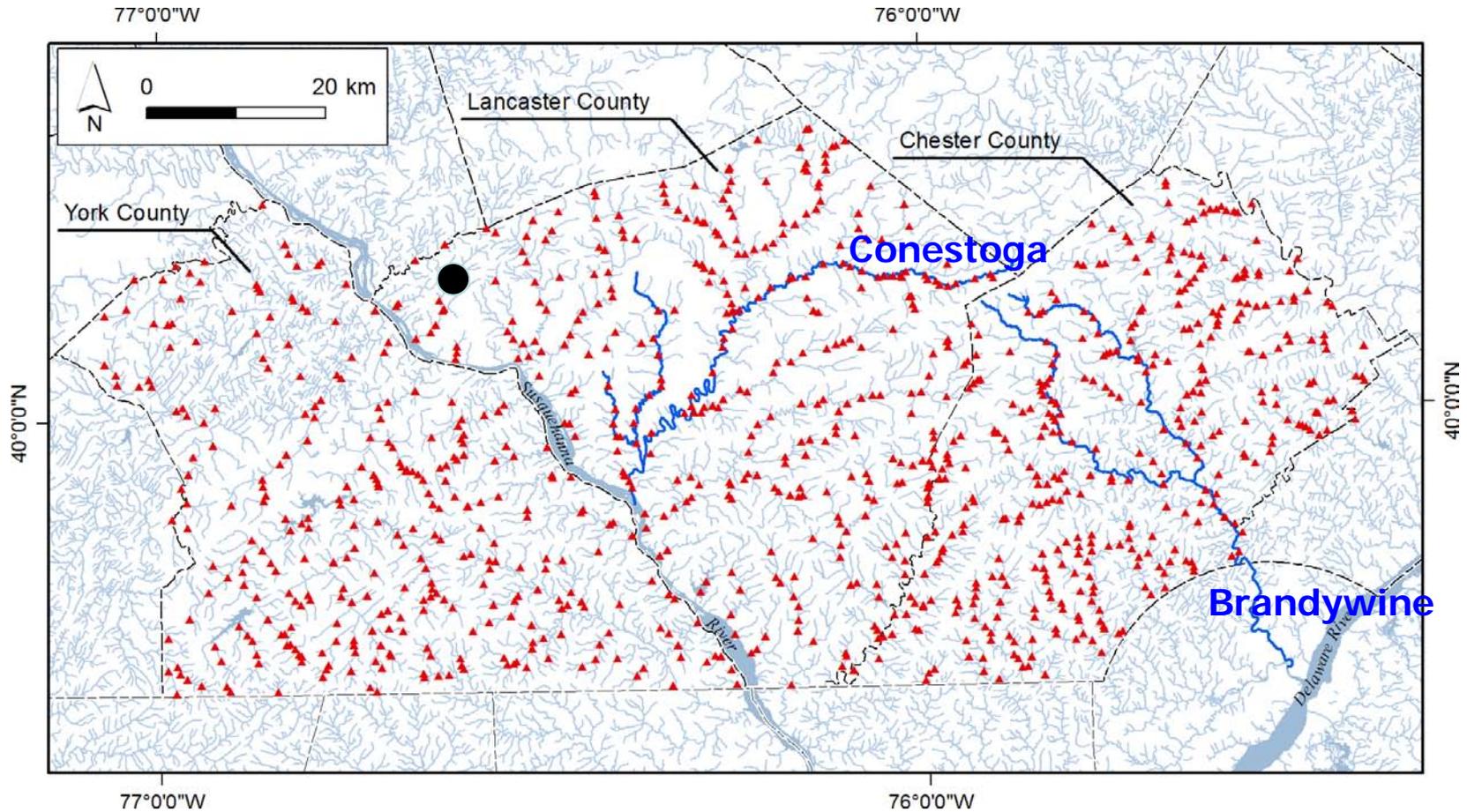
***“There is no neighborhood in any part of the United States without a water gristmill.”***  
**Thomas Jefferson, 1786**



**~800 mill dams in 19<sup>th</sup> C. Atlases of York and Lancaster Counties**

**▲ Location of mill dams**

<http://edisk.fandm.edu/michael.rahnis/ex-census.html>

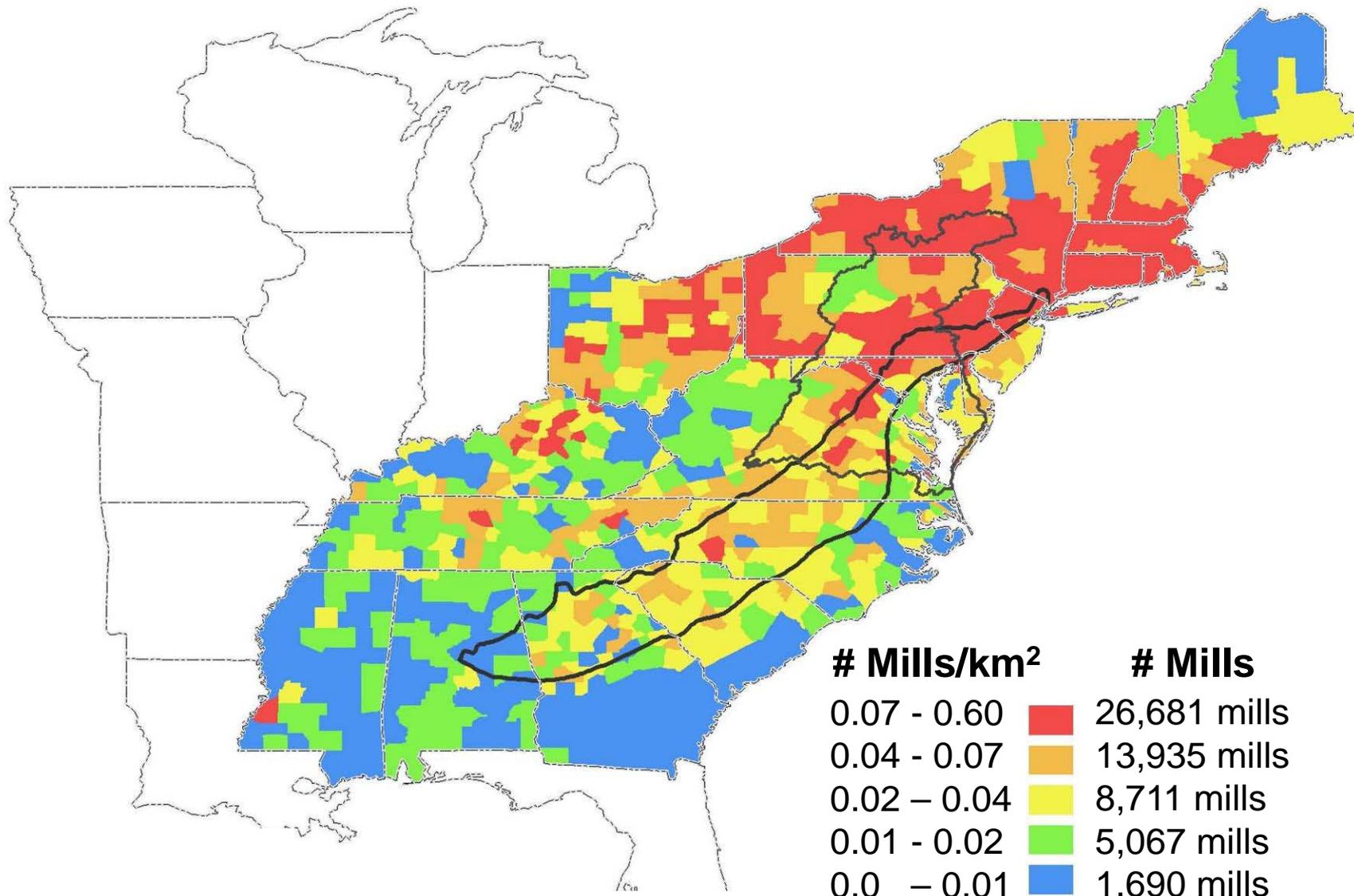


**Over 1,000 mill dams in 19<sup>th</sup> C. Atlases of York, Lancaster & Chester Counties**

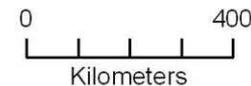
▲ Location of mill dams

**“There is no neighborhood in any part of the United States without a water gristmill.”**

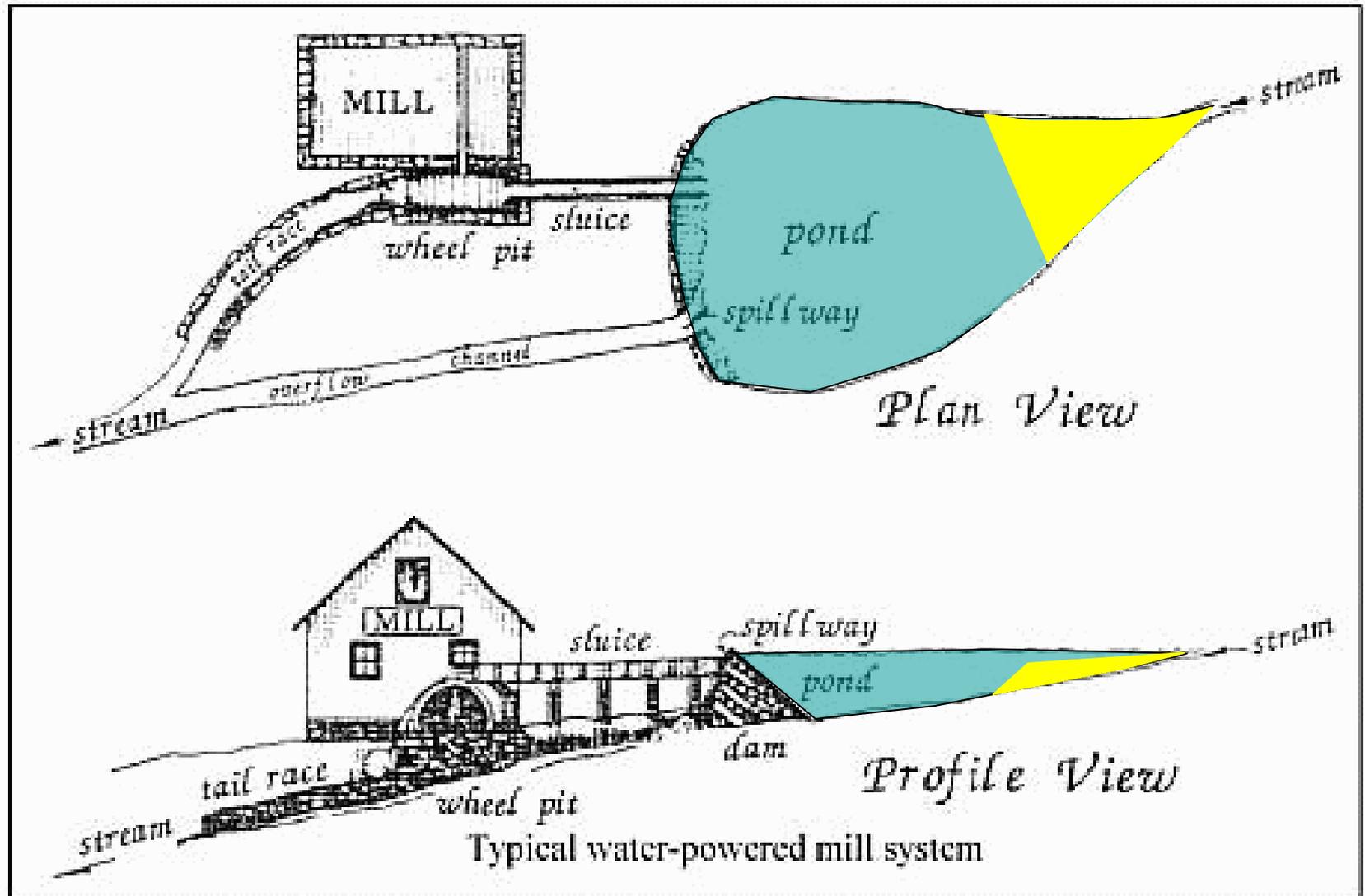
**Thomas Jefferson, 1786**



**Mill Density from 1840 US Census**  
**~65,000 Water-powered Mills**

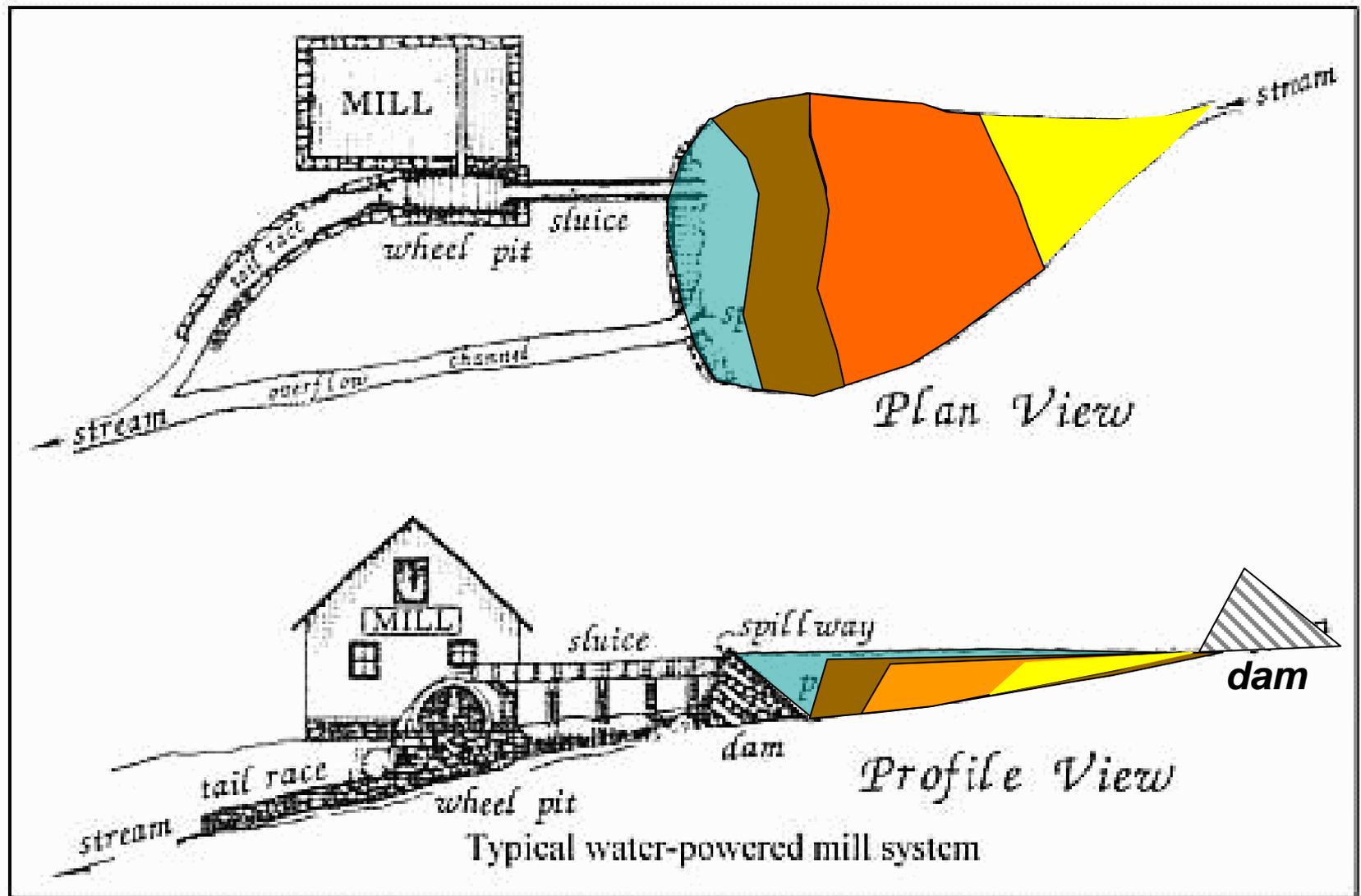


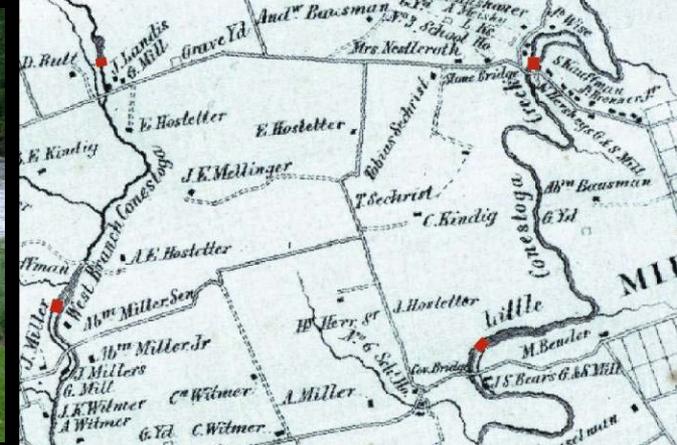
# Impact of Water-Powered Mill Dams on Sediment Storage in Valleys



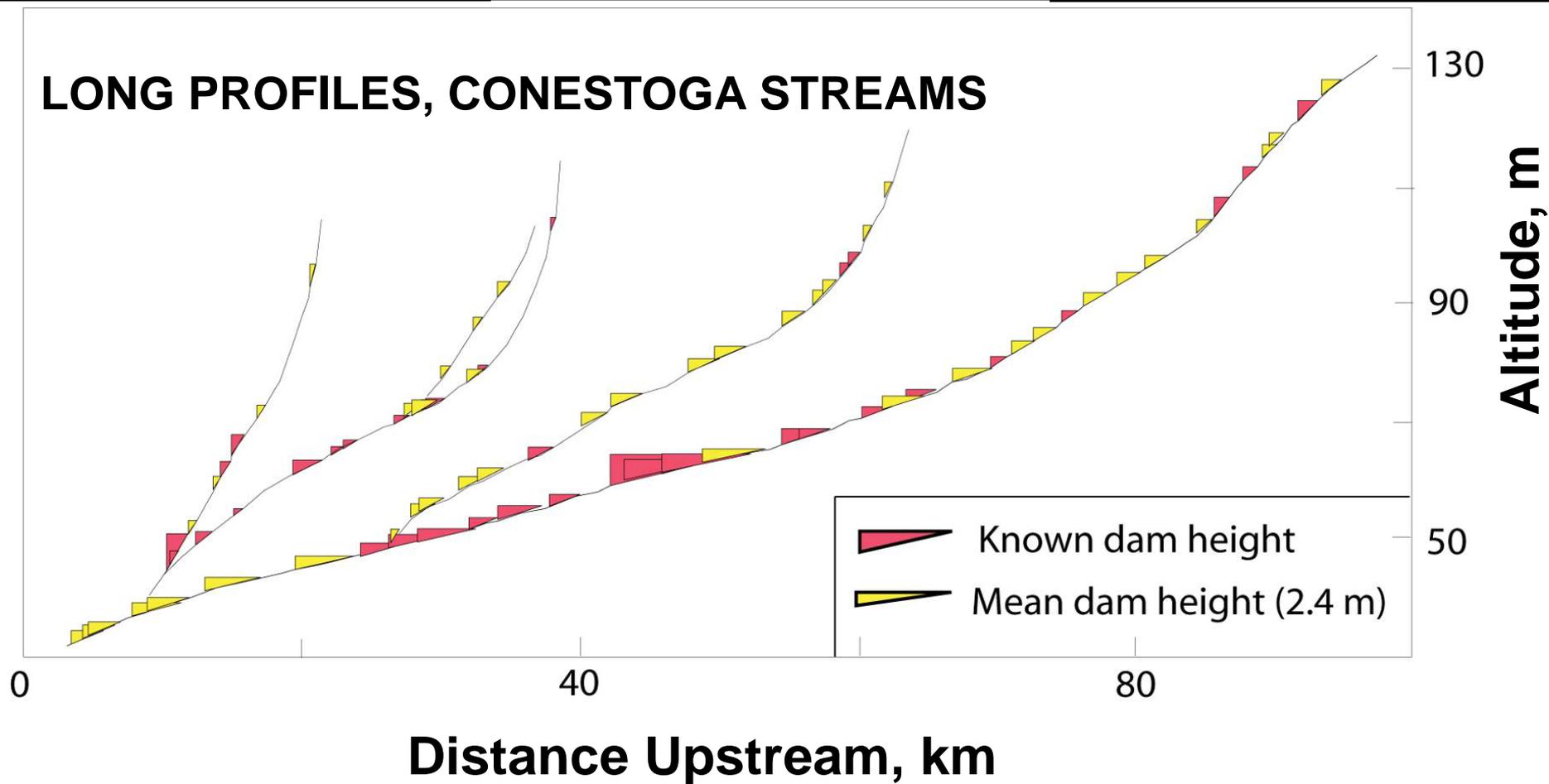
From: Mills on the Tsatsawassa: Techniques for Documenting Early 19th Century Water-Power Industry in Rural New York, by Philip L. Lord

# Impact of Water-Powered Mill Dams on Sediment Storage in Valleys

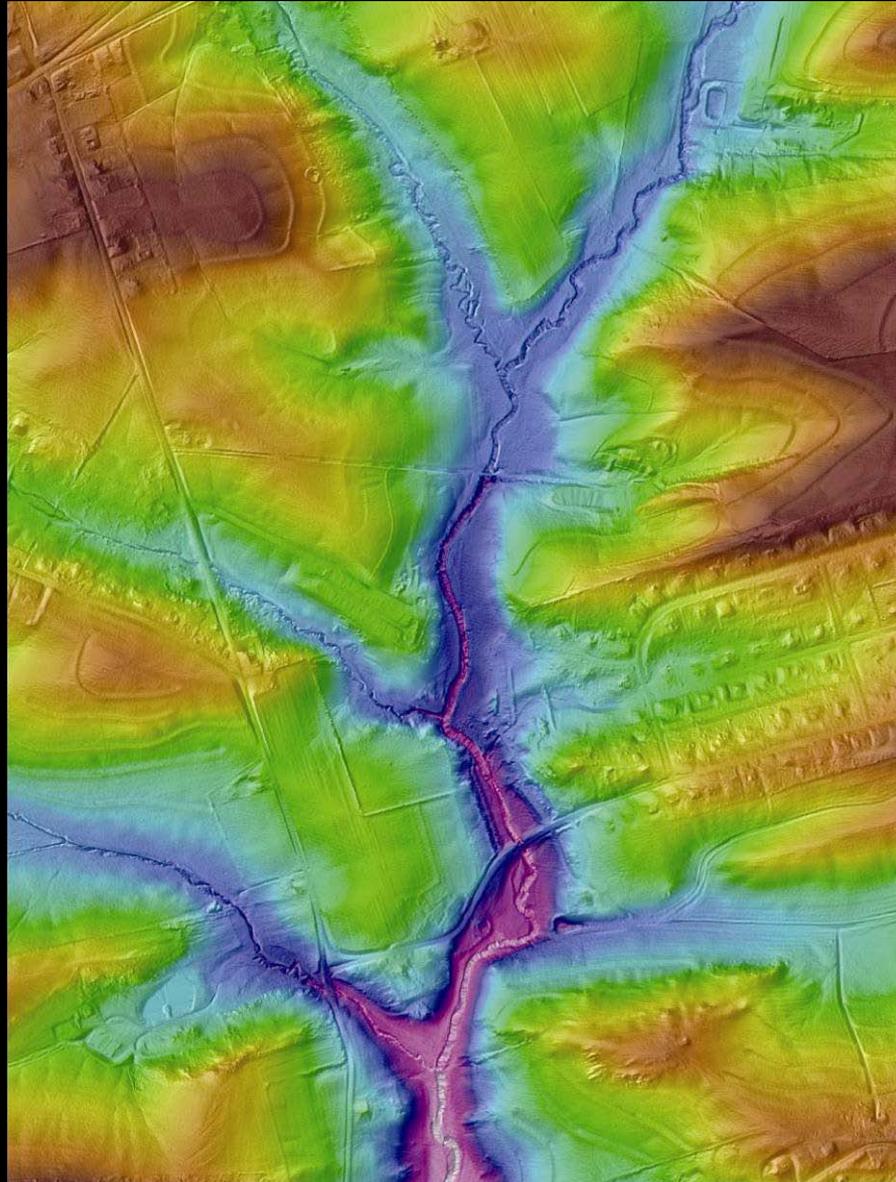




## LONG PROFILES, CONESTOGA STREAMS



Science Cover, January 18, 2008

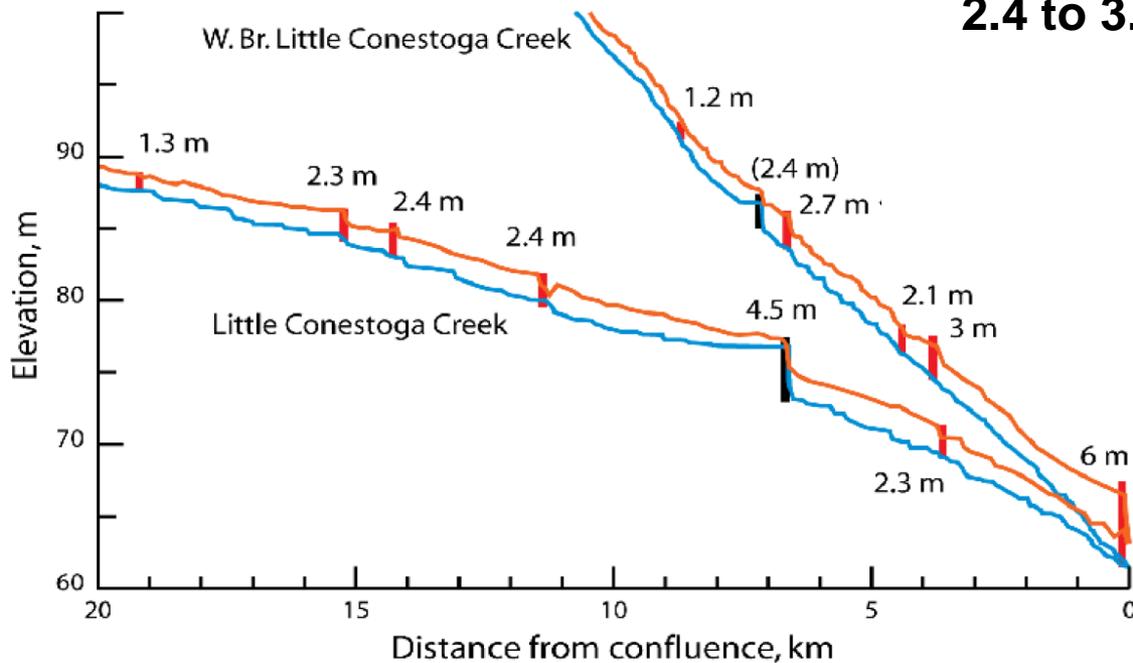


Walter and Merritts, 2008

**LIDAR, ~15 cm vertical resolution, 25 cm horizontal**

# Sediment storage in valleys

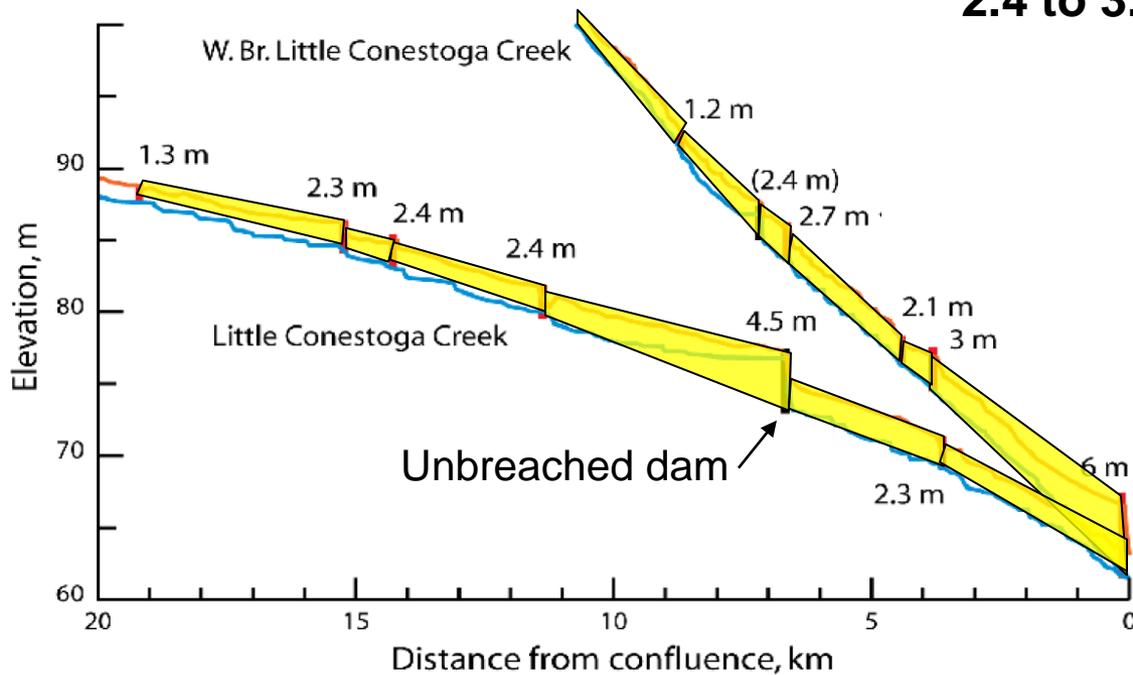
**Average dam height 2.4 to 3 m;  
Average mill pond length  
2.4 to 3.3 km**



**Lidar analysis (15 cm vertical resolution)**

# Sediment storage in valleys

Average dam height 2.4 to 3 m;  
Average mill pond length  
2.4 to 3.3 km



Lidar analysis (15 cm vertical resolution)



**Unbreached dam:  
Pickering Creek  
Mill Dam (~3 m),  
Chester County, PA**



Historic sediment,  
unbreached dam



# Breached Earthen Dam: Panther Branch, MD



Historic sediment, Breached dam

Crest of 19<sup>th</sup> c. earthen dam

*Fine-grained mill pond sediment wedge*

*flow* →

What happens once a mill dam breaches?  
Flume experiments provide experimental analogs.

Flume experiments and video footage from  
Dr. Allesandro Cantelli, University of Minnesota  
[http://www.nced.umn.edu/Stream\\_Restoration\\_Toolbox.html](http://www.nced.umn.edu/Stream_Restoration_Toolbox.html)

# Flume Studies: Base level matters for dam removal and breaching



Resembles a Typical Piedmont Stream

**Exp. 9**

***Processo di erosione***

**Vista da valle**

**St. Anthony Falls  
Laboratory  
University of Minnesota**

**Resembles a Typical Piedmont Stream**

## Base level drops with dam removal and breaching



**Big Spring Run: Typical Piedmont Stream**

**What was the landscape before  
milldams, ponds, and muds?**

# Mill Pond Reservoir Sediment Stack



**Denlinger's Mill, W. Br. Little Conestoga, PA**

# Denlinger's Mill Stream Bank

# Geochronology

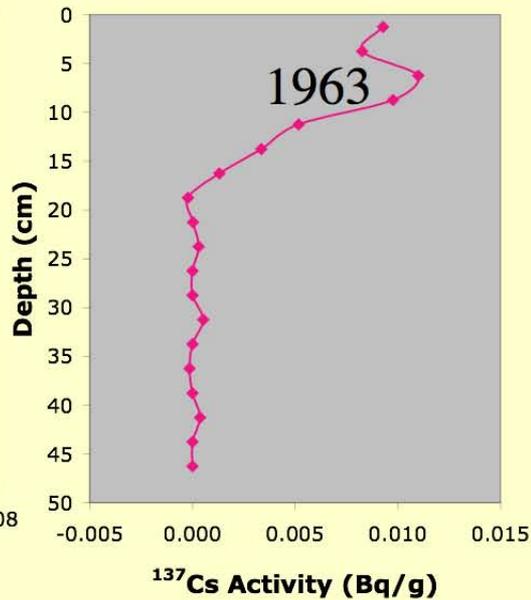
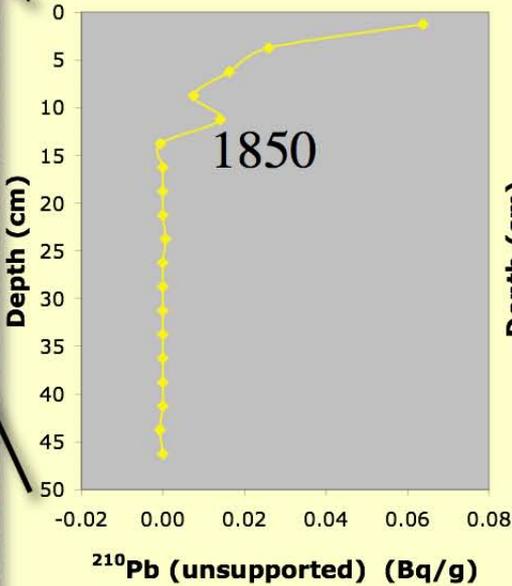


$^{210}\text{Pb}$

$^{137}\text{Cs}$

Denlinger's Mill

Denlinger's Mill



✦ AMS Dates

# Reconstructing Past Landscapes and Ecosystems from Buried Soils



Going deeper and farther back in time.....to buried Holocene soils and Pleistocene deposits.....early Colonial and native American artifacts

# Holocene peat core, wetland seeds



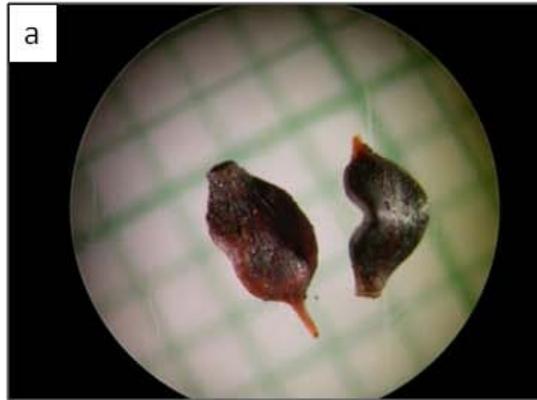
## Alder sp. (OBL) [Alder]



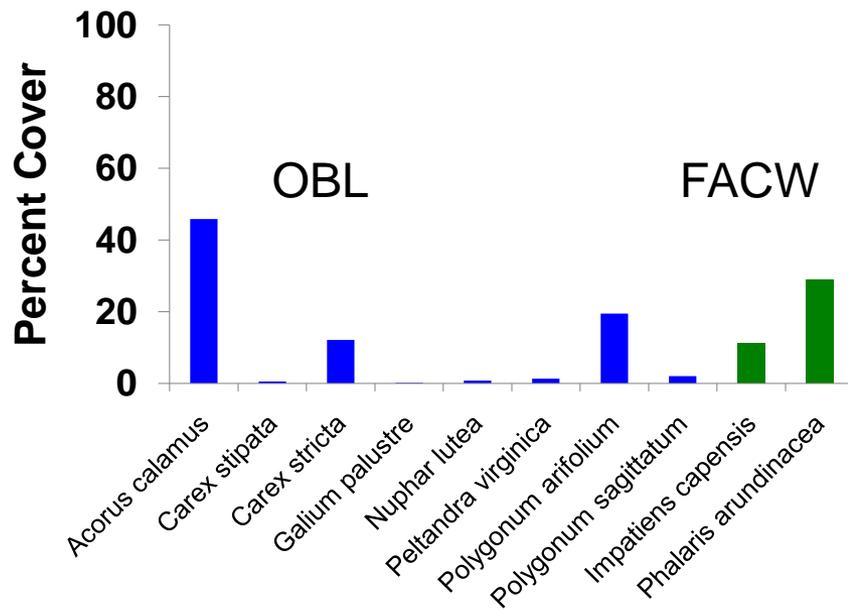
mm scale

## Carex sp (OBL) [sedge]





a) *Carex crinita* (fringed sedge), b) *Carex stipata* (awlfruit sedge), c) *Carex stricta* (tussock sedge), and d) *Eleocharis ovata* (ovate spikerush), all of which are obligate wetland species in this region. Grid markings are mm spacing.

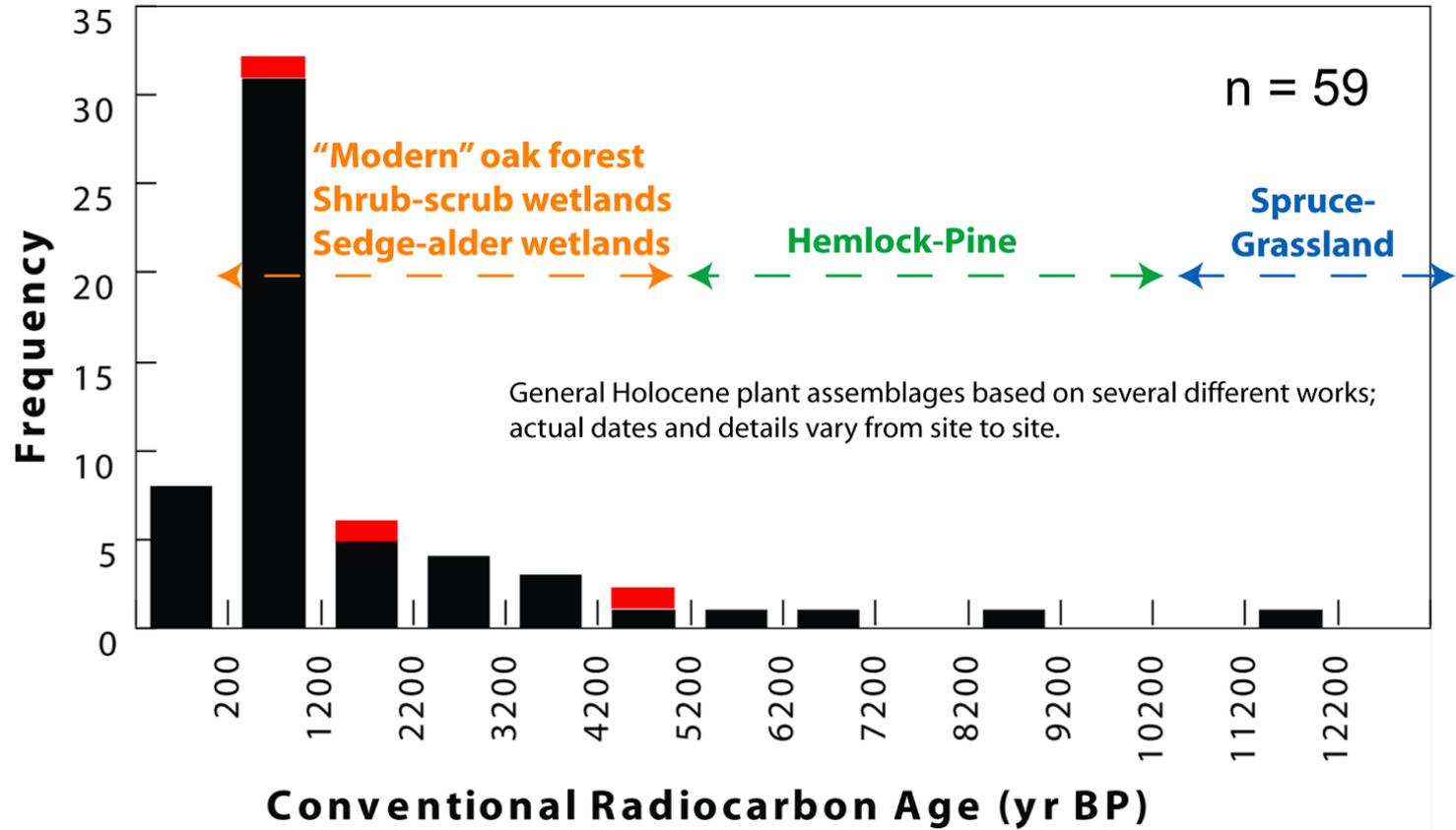


# Modern Analog for Pre-settlement Valley Bottom Wetlands



Jones Falls, MD

# Time Matters: Climate and Vegetation Change in the Holocene are Documented in Pre-Settlement Fluvial-Wetlands



# Western Run, MD

A



# Big Spring Run, PA

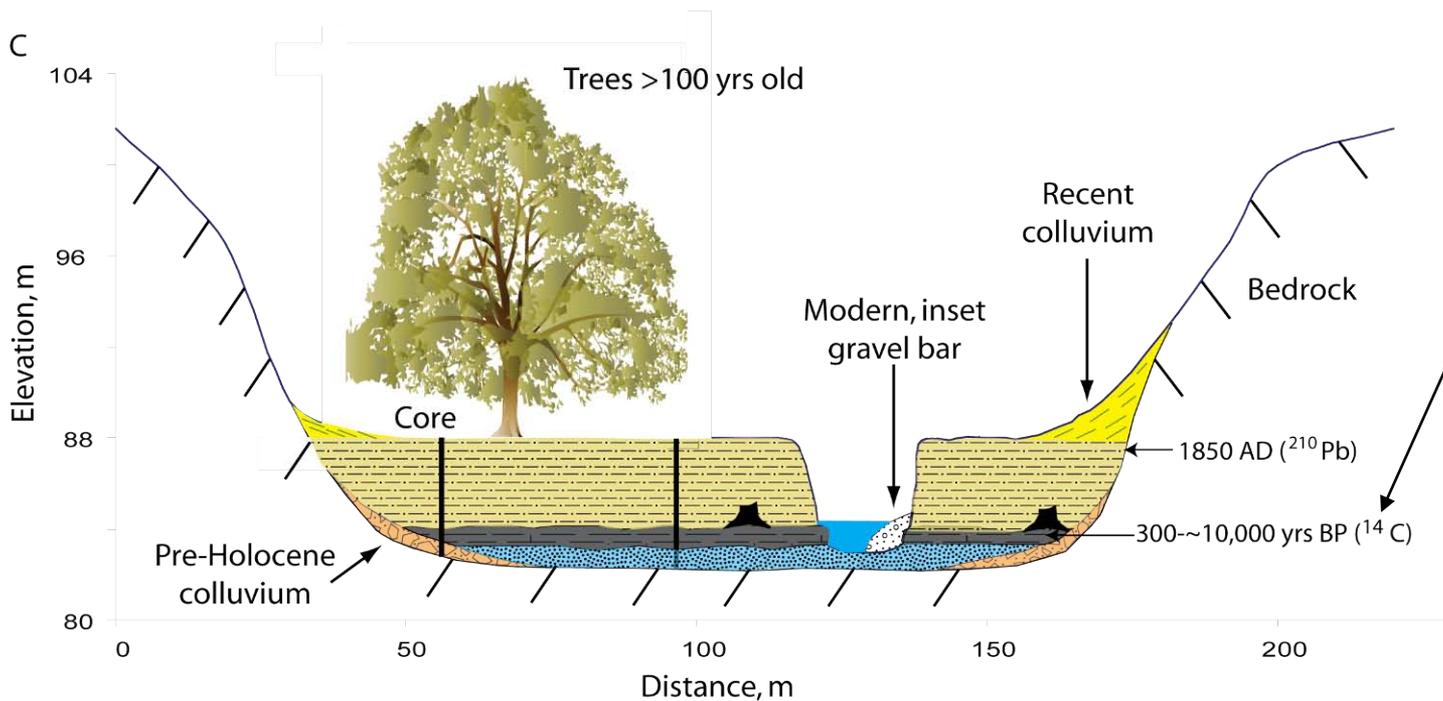
B



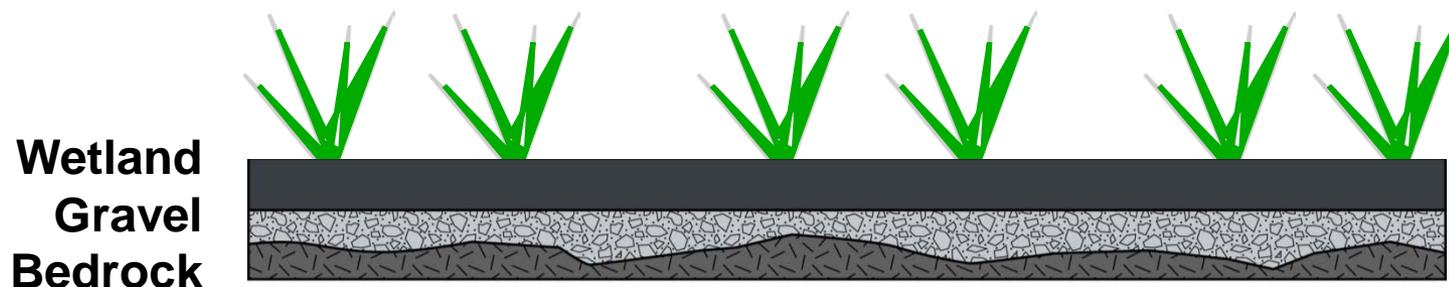
Legacy Sediments

Buried Holocene Wetland

C

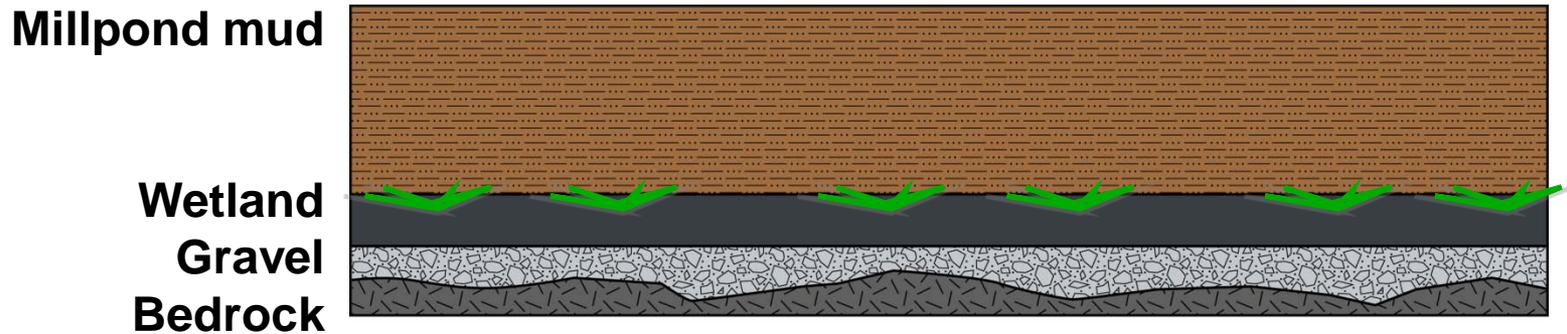


# Holocene (pre-settlement) wetlands on Pleistocene gravel

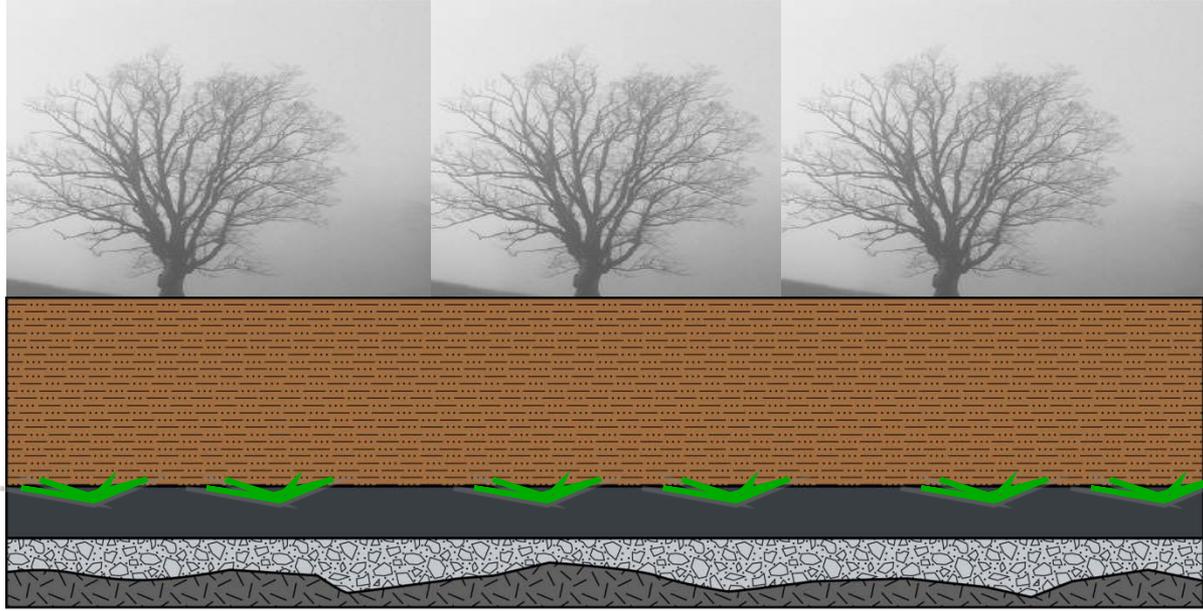


**Wetlands from valley wall to valley wall,  
and no evidence of buried single-thread stream channels**

# Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel



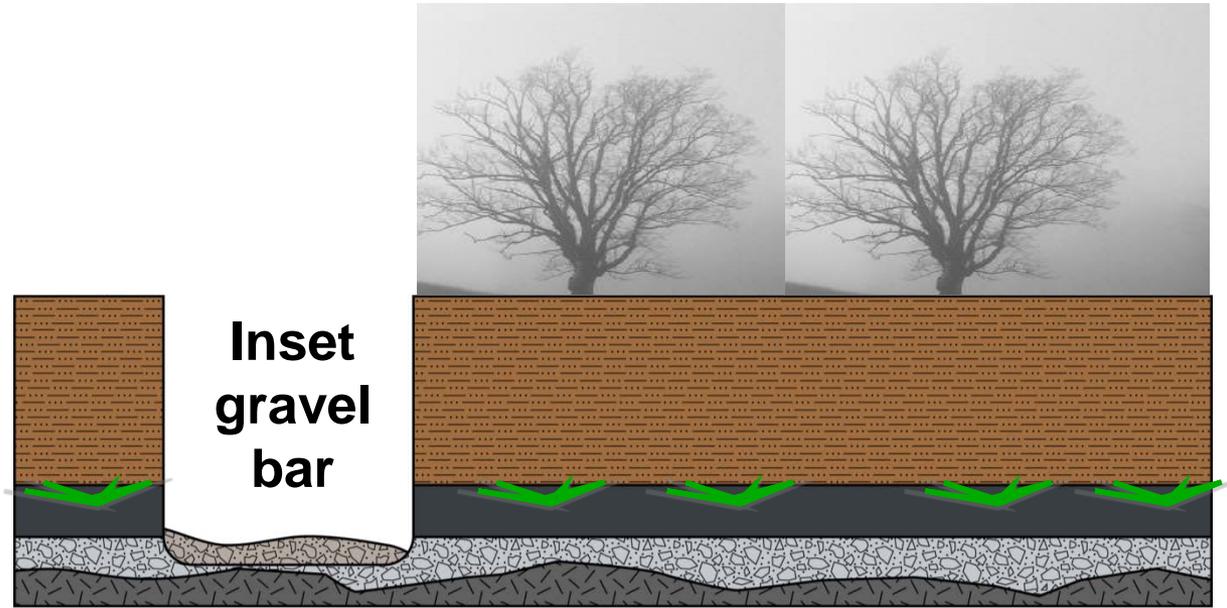
# Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel



**Millpond mud**

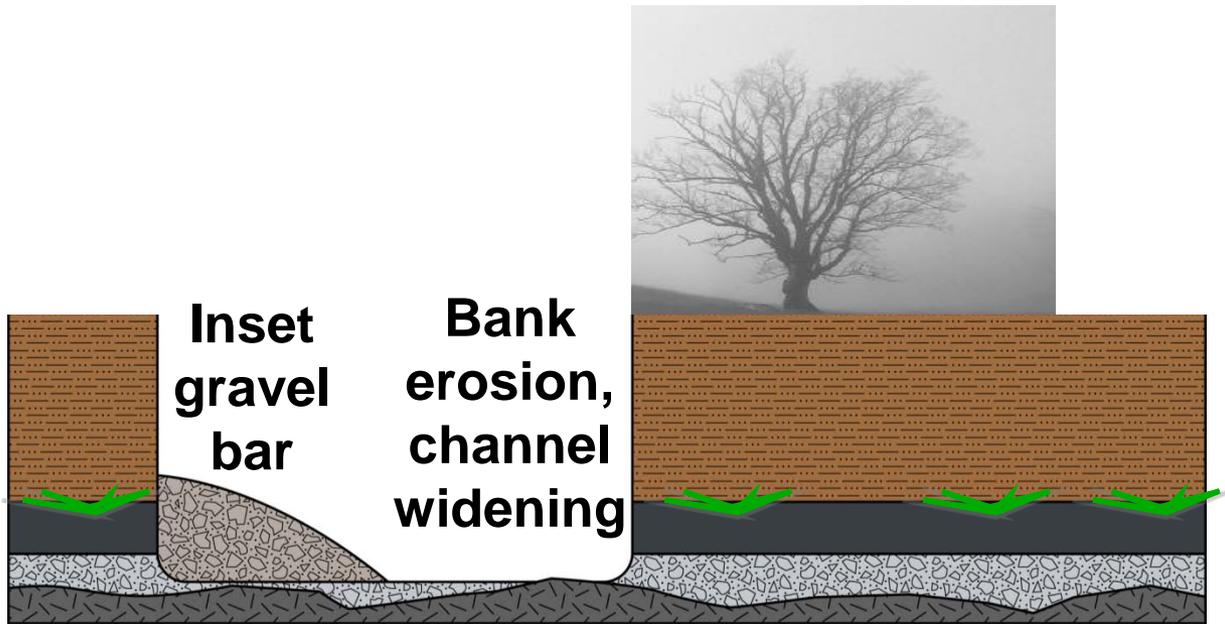
**Wetland  
Gravel  
Bedrock**

# Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel



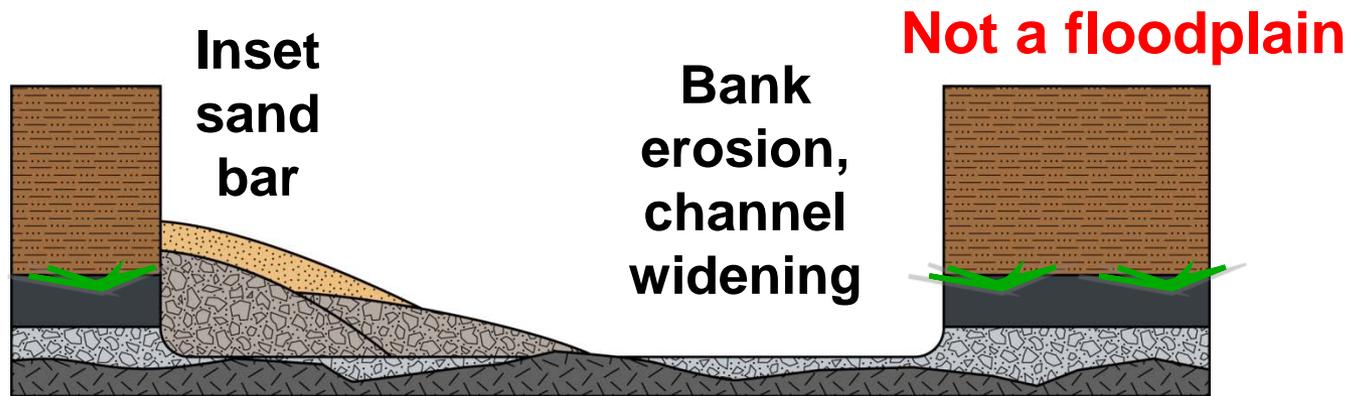
Modern inset  
sand/gravel bars

**DAM BREACH**



**With time, width increases and depth decreases for a given runoff event, thus shear stress decreases.**

# Post-settlement millpond mud on Holocene wetlands on Pleistocene gravel



With time, width increases and depth decreases for a given runoff event, thus shear stress decreases.

# Anthropocene Streams



**Pleistocene gravel, Holocene wetlands and grasslands (?),  
and historic millpond mud**





**Conoy Creek, Elizabethtown  
Masonic Villages Stream  
Restoration**

**Susquehanna broadspear  
beneath mill pond sediment**

**~4000 yrs old**







# Conoy Creek Before Restoration

03-12-2008



05-15-2008



# After Restoration

5-10-2010



5-10-2010



**THE END**

What can be done about erosion and sediment in the Chesapeake Bay?



Seneca Creek, MD  
(Eastern USA Piedmont)



New Fork River, Pinedale Wyoming,  
with gravel bar

# River Flood Plains: Some Observations On Their Formation

By M. GORDON WOLMAN and LUNA B. LEOPOLD

PHYSIOGRAPHIC AND HYDRAULIC STUDIES OF RIVERS

---

GEOLOGICAL SURVEY PROFESSIONAL PAPER 282-C

## Wolman and Leopold, 1957:

- Overbank deposition (flooding) results in fine-grained sediment across a self-formed floodplain; bar migration results in gravel deposition on the bed.
- Eastern and western streams were assumed to form by the same processes.
- Similarity in form was associated with similarity in process.



Seneca Creek, MD (Eastern  
USA Piedmont)



New Fork River, Pinedale Wyoming,  
with gravel bar

# River Flood Plains: Some Observations On Their Formation

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 282-C

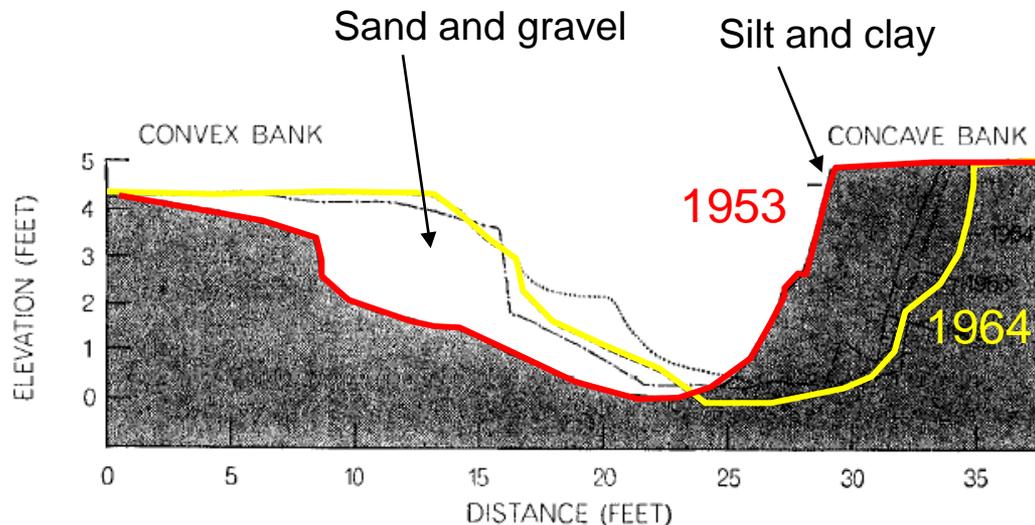
## Walter and Merritts, 2008:

- Banks along eastern streams are fine-grained (silt, clay, and fine sand), whereas beds are generally gravel, and the two have different origins and ages.
- Eastern and western streams did not form by the same processes.
- Most eastern stream banks are not self-formed floodplains. They are reservoir fill terraces.

# THE MODEL FOR WATTS BRANCH, MD—WOOTTONS MILL PARK

Conclusions from *Wolman and Leopold, 1957*:

Meandering streams and bank erosion are natural, long-term processes.  
Streams erode one bank and deposit bars on the other.



Lateral migration at “typical meander” from 1953 to 1964, Watts Branch, small tributary to Potomac River. *“The lateral migration of meanders by erosion of concave banks and deposition on convex banks over many years results in a river channel’s occupying every possible position between valley walls.”*



Floodplain of Watts Branch with point bar (Wolman and Leopold, 1957). Basis for classic conception of meandering streams was breached 19th c. mill pond.

## WATTS BRANCH, MD—WOOTTONS MILL PARK

**Restoration Rationale: Urbanization leads to incision, accelerated meander migration, and channel widening. Unfortunately, the problem was mis-diagnosed. The actual problem was a partially breached mill dam, and a 2-m stack of mill pond silt and clay.**



2005



2008

“During his 20-year tenure with the U.S. Geological Survey, Luna Leopold made a personal project of monitoring Watts Branch, a meandering stream near Rockville, Maryland.... **It flowed through a cow pasture then; now it is surrounded by suburban housing.**” (Brian Hayes)

# Watts Branch stream restoration 2 years later in 2007



**Natural Stream Channel Design:** “Morphologically defined as the ability of the stream to maintain, over time, its dimension, pattern, and profile in such a manner that it is neither aggrading nor degrading and is able to transport without adverse consequences the flows and detritus of its watershed”. (From Rosgen, Applied River Morphology, 1996)

**BEFORE, 2004**



**Banta Floodplain/Wetland  
Restoration, Lititz Creek**

*LandStudies, Inc.*



**AFTER, 2007**



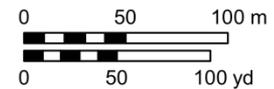
# BIG SPRING RUN, LANCASTER COUNTY, PA, WETLAND-FLOODPLAIN RESTORATION EXPERIMENT

Partners: USGS, PA DEP, US EPA, F&M COLLEGE, LANDSTUDIES, PEC

-  USGS Gage Stations
-  Seed Collection Sites
-  Bank Erosion Pin Sites
-  Stream Cross Sections



-  USGS Gage Stations
-  Bank Erosion Pin Sites
-  Seed Collection Sites
-  Stream Cross Sections



## IN CLOSING

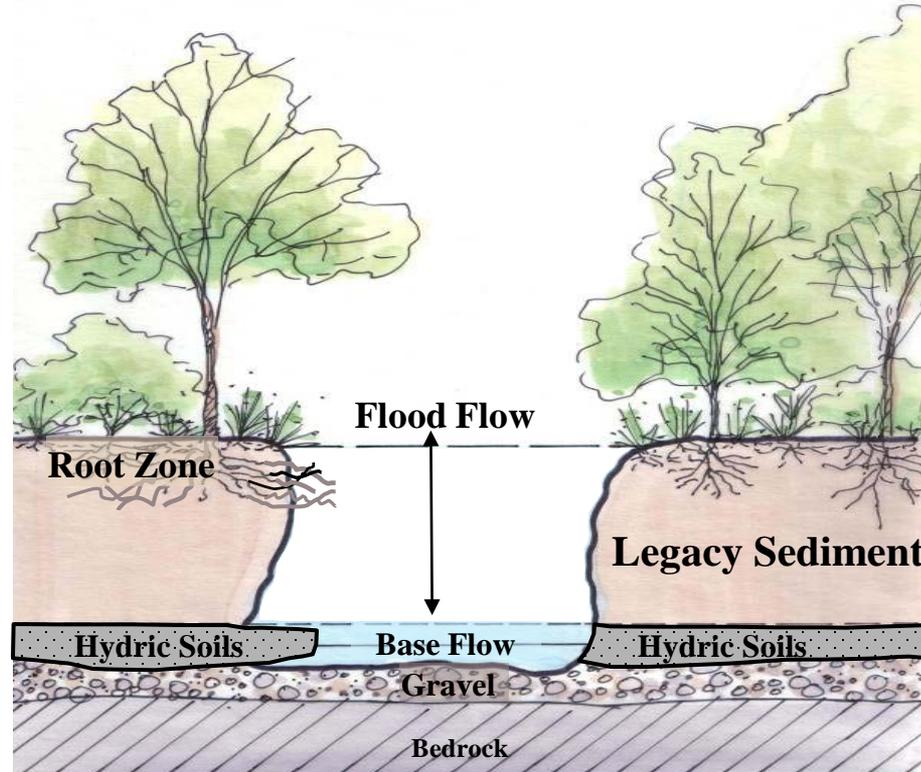
The value of building teams of collaborators that include students of different ages and levels of background and experience, and of merging scientific understanding with policy and engineering.

The importance of thinking outside the box and acknowledging the ways in which scientists develop and revise ideas.

The modern environmental challenge of figuring out how to restore streams and wetlands in landscapes that have been disturbed in multiple ways for centuries. Diagnosing the problem is difficult and we are saddled with misconceptions.

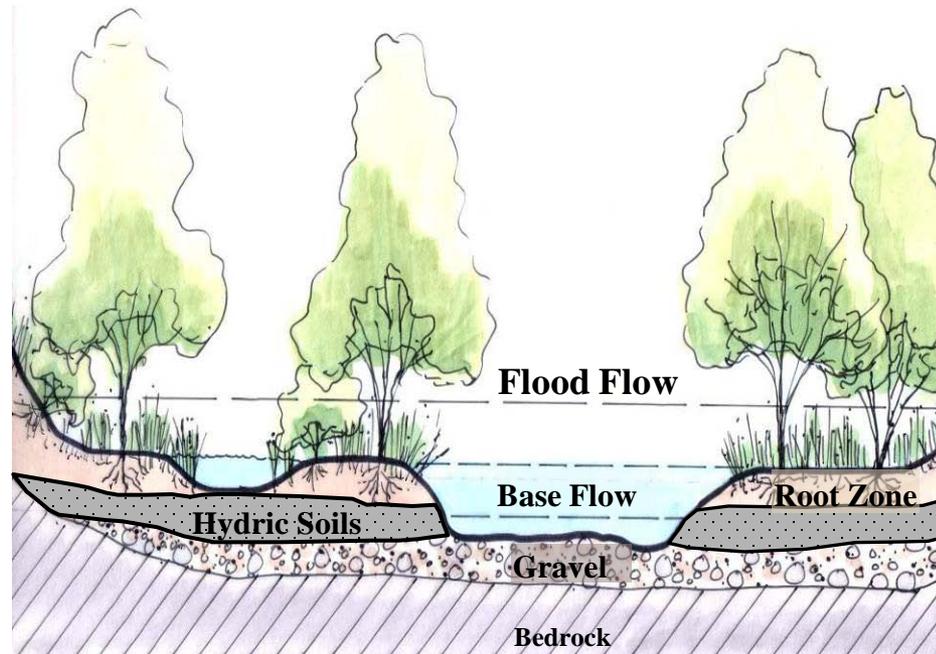


# Existing Condition



- **The existing condition formed rapidly as a result of widespread upland soil erosion and fine-grained sediment storage in valley bottoms of the Mid-Atlantic Region**
- **After dam breaching, streambank erosion of legacy sediment represents a significant sediment and nutrient source in some watersheds**
- **High quality, naturally formed, and indigenous aquatic resources are buried under legacy sediment and impaired in our modern environment**

# Natural Condition



- The natural condition formed under long-term geologic and climatic processes and represents truly indigenous aquatic resources in the Mid-Atlantic Region
- The indigenous aquatic resources are natural and stable ecosystems that function as nutrient and sediment sinks, sources of groundwater recharge and discharge (cool water springs and base-flow to streams), and zones of highly concentrated biota
- The natural condition represents the best future condition and restoration goal

# Floodplain and Riparian Wetland Restoration BMP

- The proposed BMP is an ecological restoration and management strategy.
- Restoration and management actions are proposed to re-establish natural stream, wetland, floodplain and riparian condition and function.
- Implementing the practice will target legacy sediment.
- Monitoring at future implementation sites (e.g., Big Spring Run) is necessary to quantify and document the BMP benefit.
- Understanding and recognizing the role that legacy sediment plays in modern environmental conditions and impairments will improve aquatic resource restoration strategies in the Mid-Atlantic Region.

... more information and definitions



[www.state.pa.us](http://www.state.pa.us)

**PA Keyword : Chesapeake Bay**

**Workgroup Products**

**Legacy Sediment Workgroup**

## Links to Our DEP Report and GSA Field Guide:

<http://edisk.fandm.edu/dorothy.merritts/report.html>

<http://edisk.fandm.edu/robert.walter/gsa-fieldguide.pdf>

# Base-Level Rise and Fall: Example of Dam Building and Dam Breaching

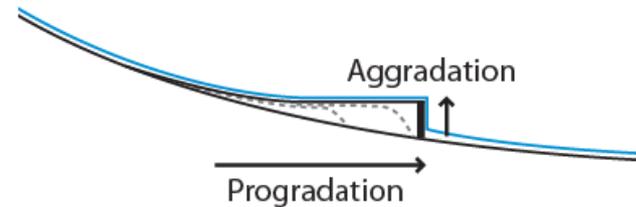


1919 photo

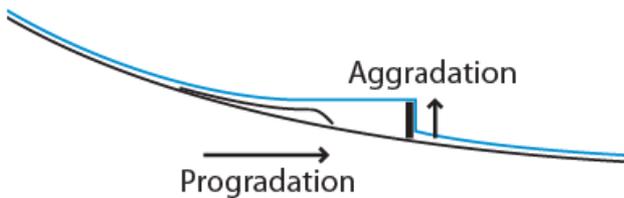
1. Graded stream profile



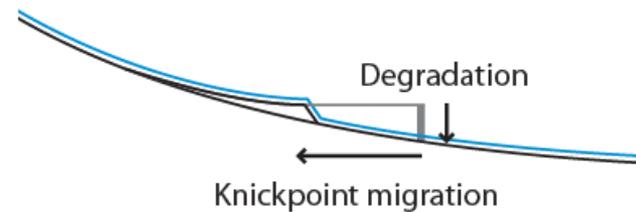
3. Reservoir filling



2. Base level rise / Dam building



4. Base level fall / Dam breaching



This dam is shown in the center of the lidar image in slide # 23; it breached circa 1960-1975.

# When floodplains are not floodplains and the past is key to the present



# Modern Analog for Pre-settlement Valley Bottom Wetlands



# Valley with Historic Pond Sediment on Buried Wetland and Incised Stream

