Legacy Sediment in NC Piedmont Headwater Streams: Implications for Water Quality Improvements

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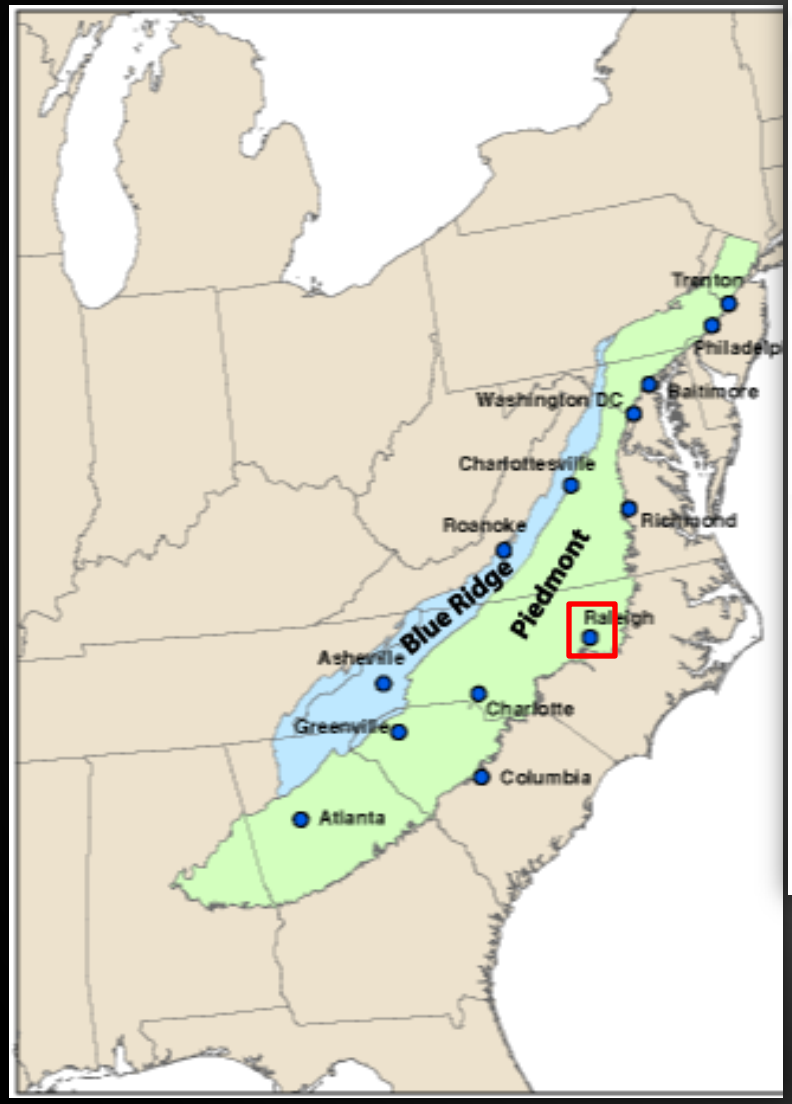
Piedmont Physiographic Province and Historic Upland Soil Erosion Rates



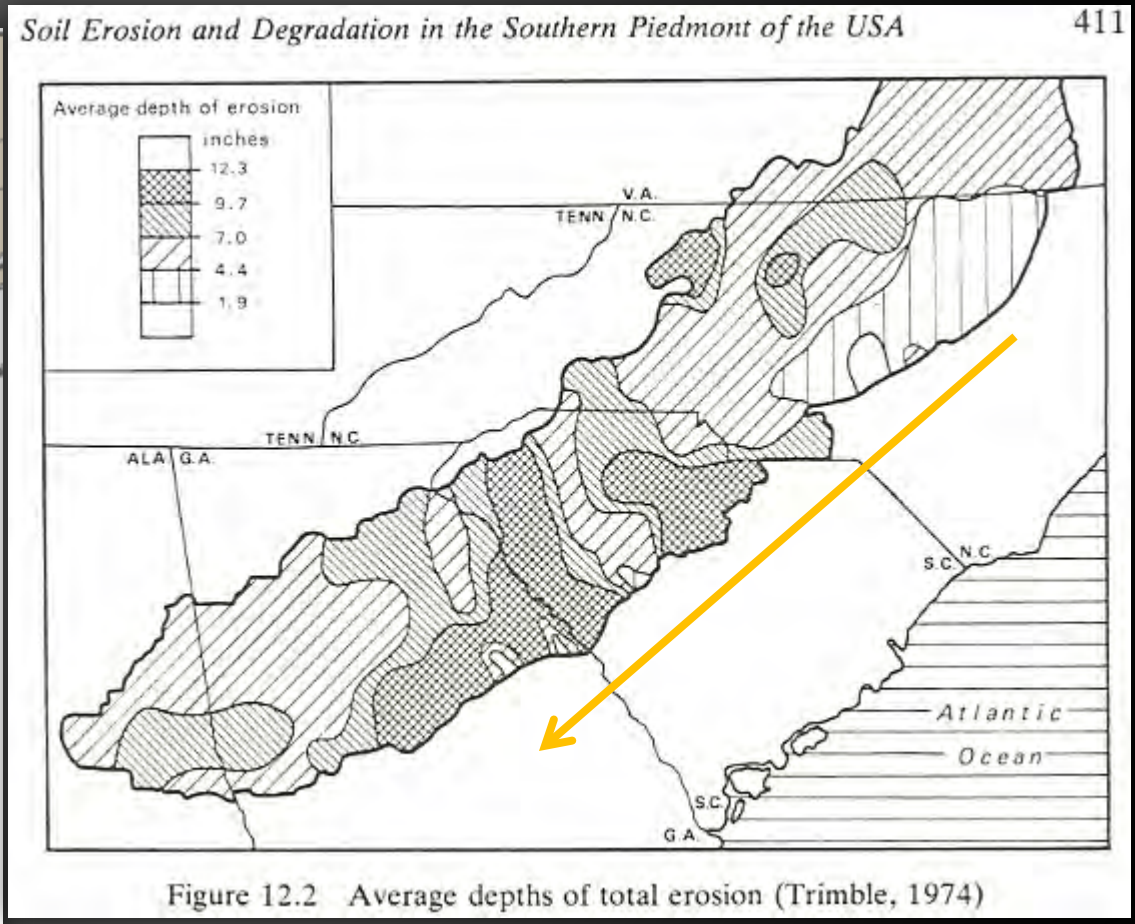


Figure 12.2 Average depths of total erosion (Trimble, 1974)

Historic spatially-averaged rates of upland soil erosion increased from the NE to SW along the axis of the Piedmont Physio. Province

Case in Point: Providence Canyon

Georgia's "Little Grand Canyon" 1 of 7 "natural" wonders of GA

Photo: Robert Walters

Massive hillside gullies up to 50 m deep were formed in the 1800's due to poor farming practices, clay-rich soils, and the recurrence of heavy rains.

Most of the eroded sediment is still stored along receiving valley bottoms (e.g., Jackson et al., 2005)

Basic Research Question:

What are (or were) the characteristics of streams in the Piedmont of North Carolina prior to eradication of beavers, extensive forest clearing, agricultural soil loss & mill dam construction and how might we get back to geomorphically functional valley-bottom ecosystems?

Single-thread meandering channels.... Or .... Beaver-controlled wetland-meadow complexes

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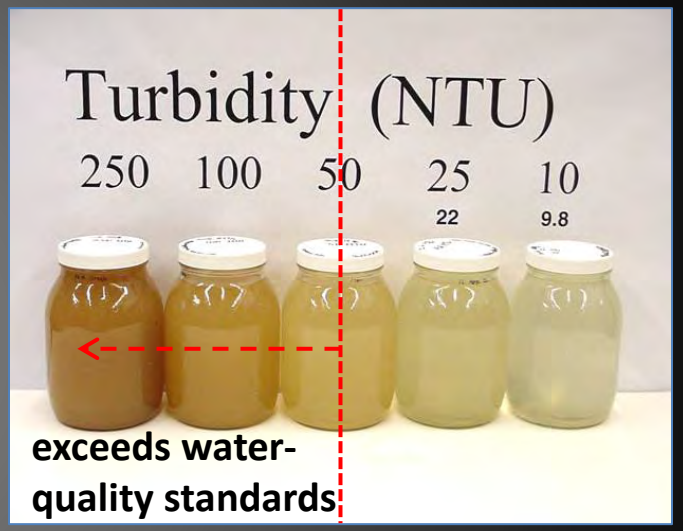
Observation 1:

NC Piedmont Streams have high suspended sediment concentrations following precipitation events.

Richland Creek, Umstead State Park, Raleigh, NC



What are the sources of the suspended sediment?

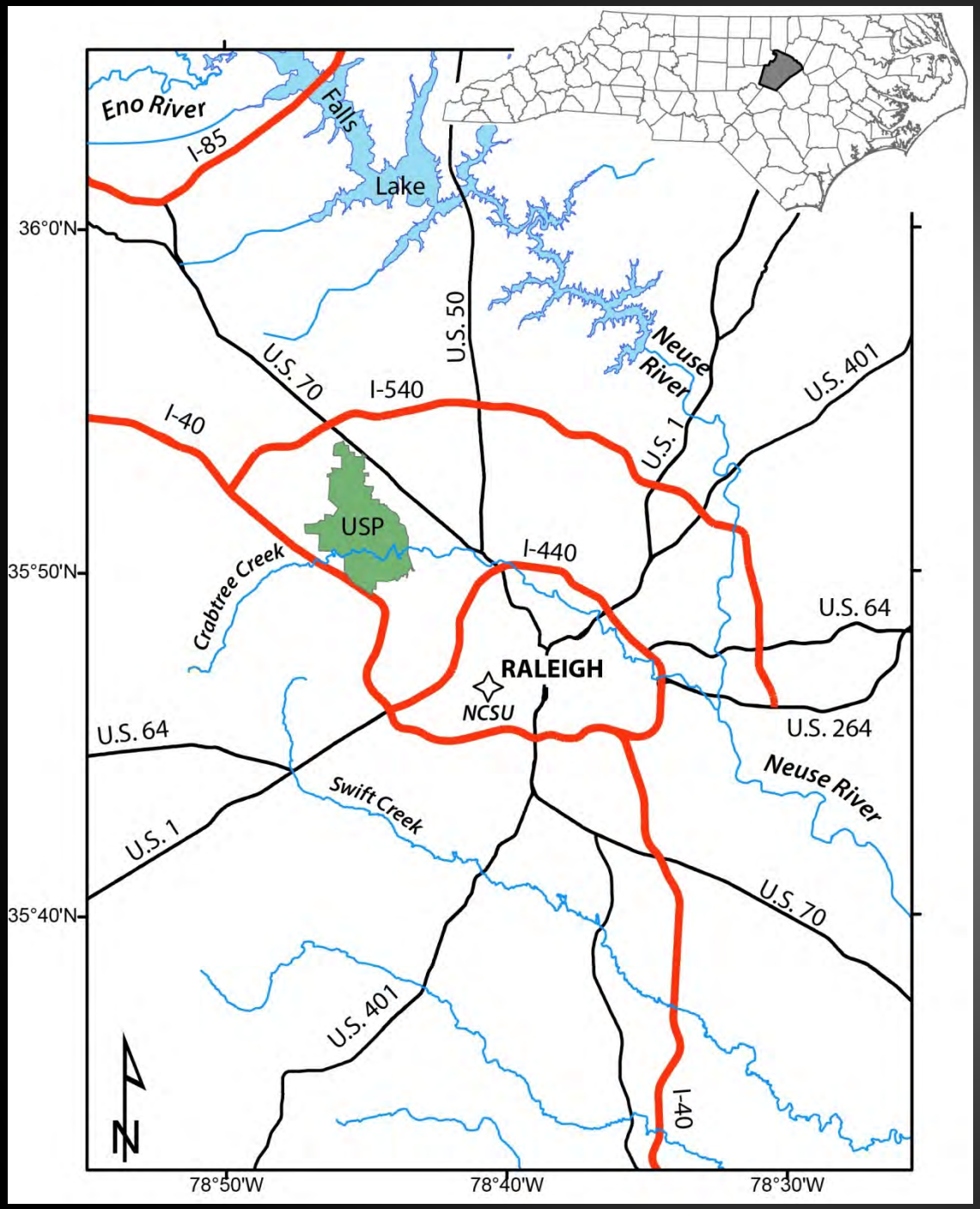
In urban to suburban areas, poor water quality is often blamed upon development

Observation 2:

Many NC Piedmont streams have tall banks of fine-grained, highly-erodible sediments

Richland Creek, Umstead State Park, Raleigh, NC

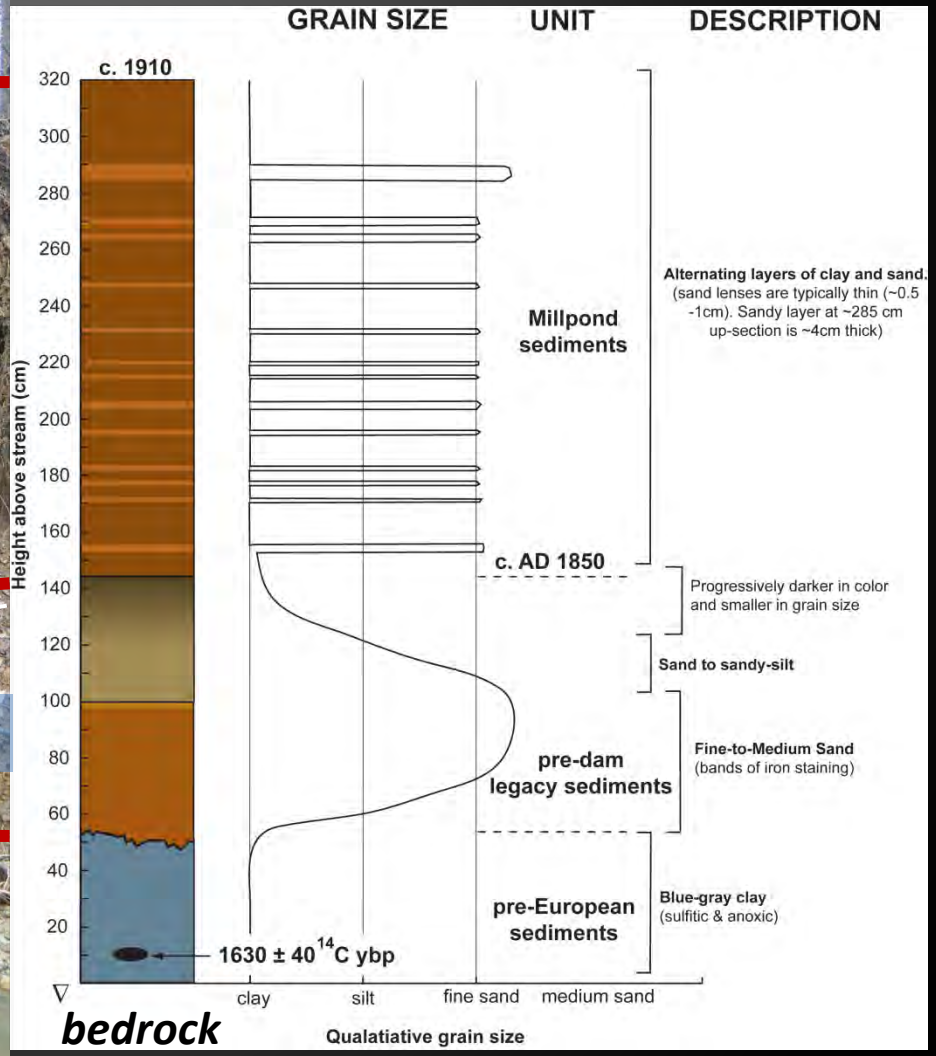
- Are these deposits “natural” or anthropogenic?
- How old are they?
- Is their erosion contributing to modern water quality impairment?



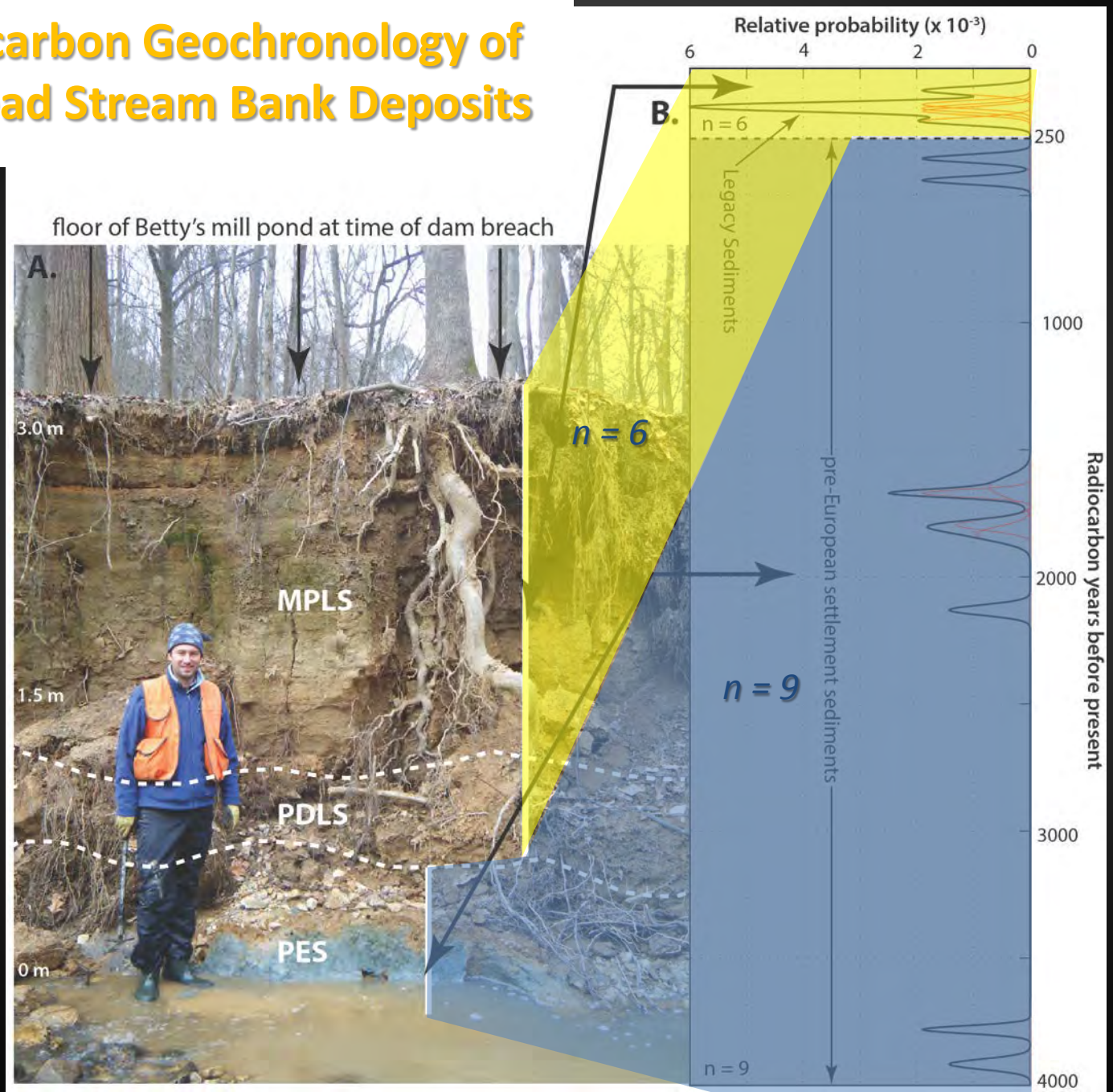
Study locations:

Greater Raleigh Metro Area, Wake County

Typical NC Piedmont Stream Bank Stratigraphy - W.B. Umstead State Park, Raleigh, NC

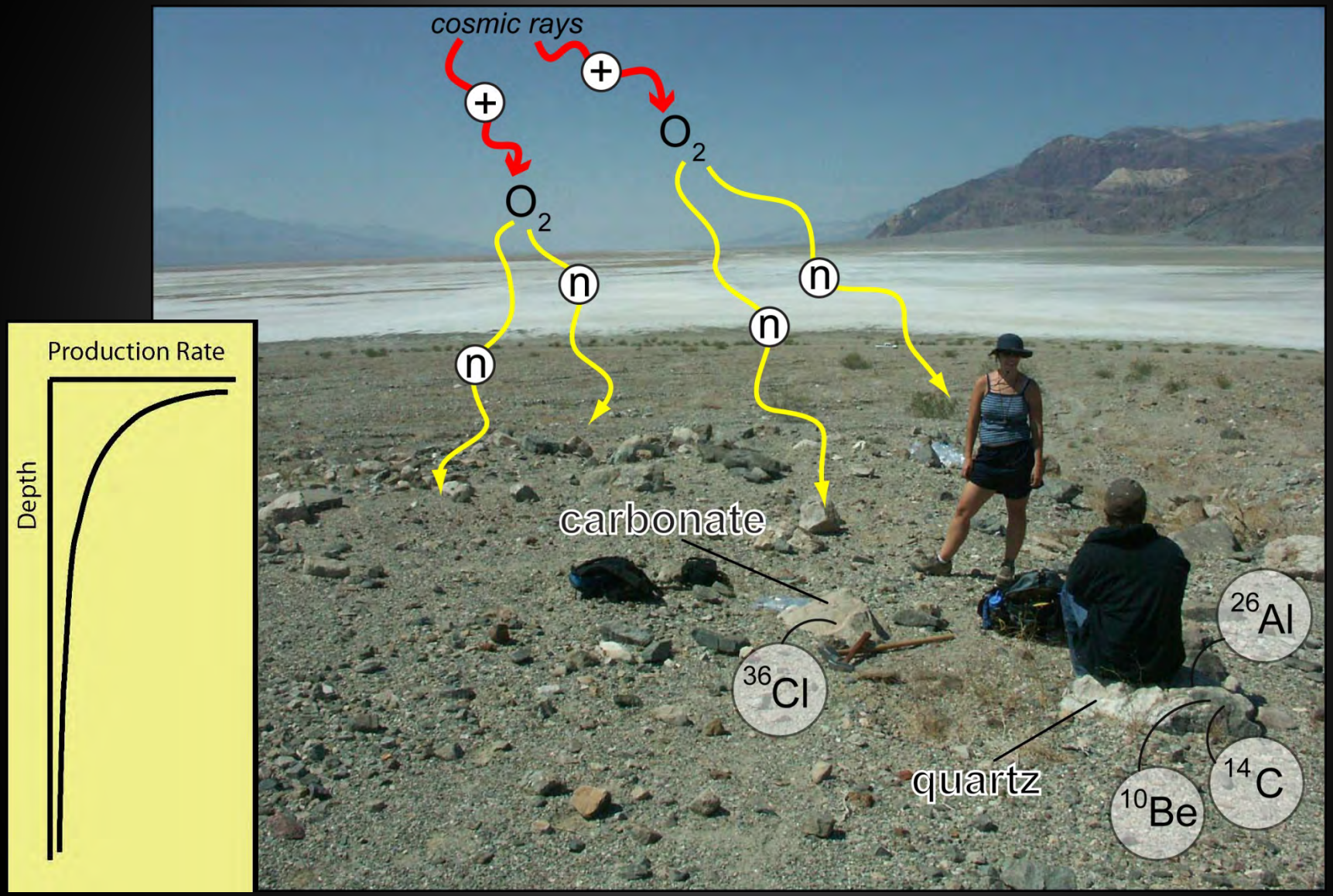


Radiocarbon Geochronology of Umstead Stream Bank Deposits



How do historic and modern rates of upland soil erosion and basin sediment yields compare to "geologic" rates derived the in-situ production of terrestrial cosmogenic ^{10}Be as measured in modern stream sands along the southern Piedmont?

Terrestrial Cosmogenic Nuclide Geochronology

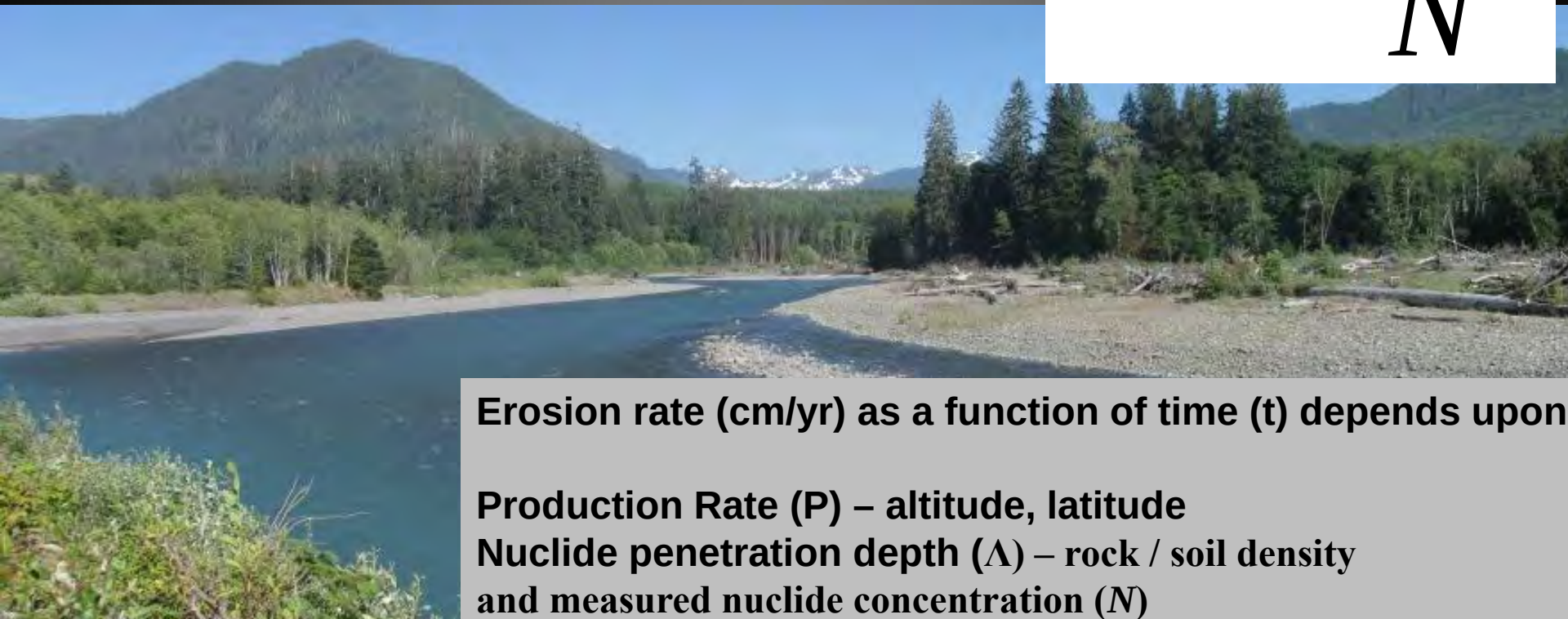


Using ^{10}Be to estimate basin-average erosion rates

Brown et al., 2005; Granger et al. 1996; Gosse & Phillips, 2001

Let nature do the averaging…

$$\varepsilon_{(t)} = \frac{P\Lambda}{N}$$



Erosion rate (cm/yr) as a function of time (t) depends upon

Production Rate (P) – altitude, latitude
Nuclide penetration depth (Λ) – rock / soil density
and measured nuclide concentration (N)

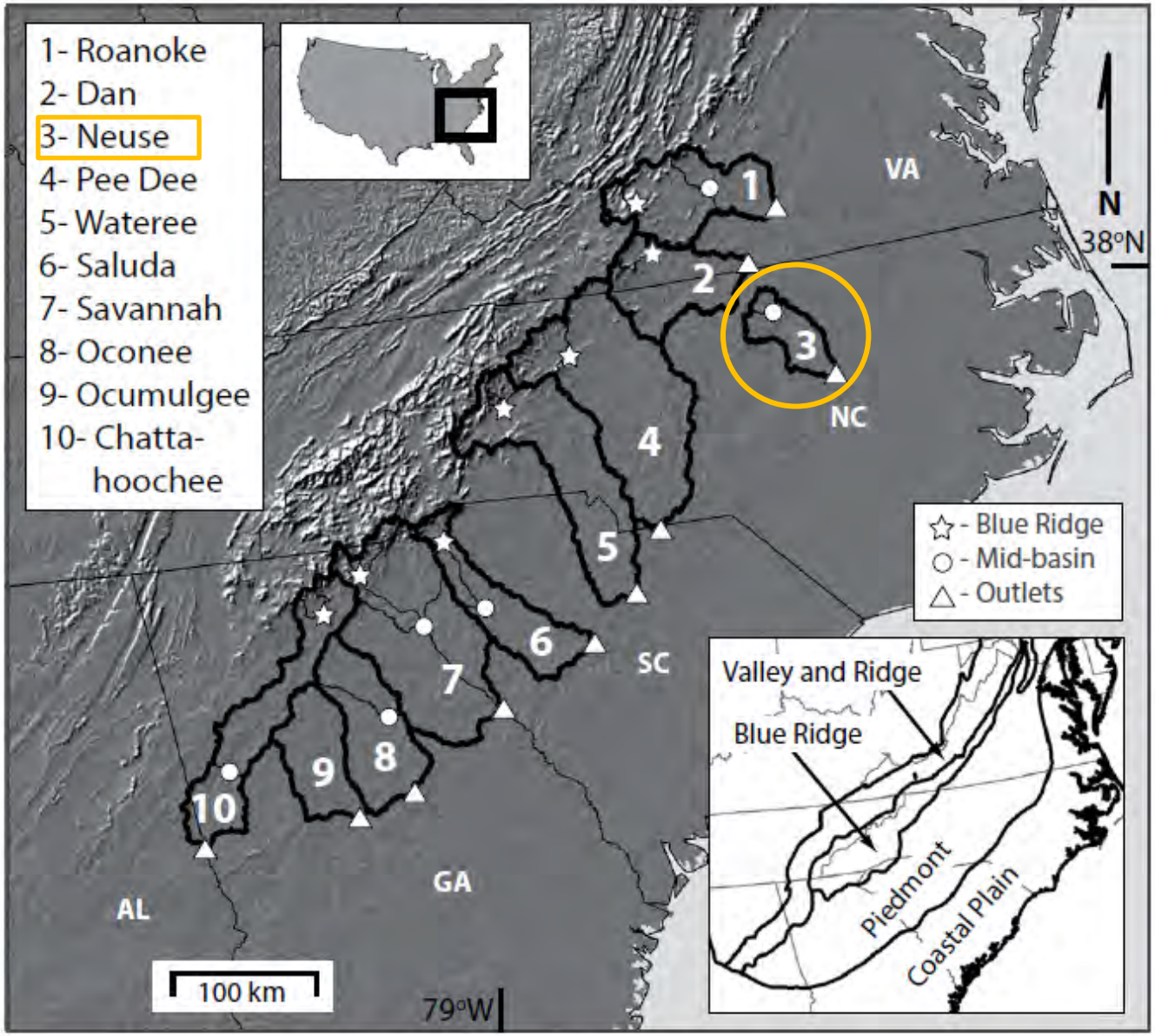
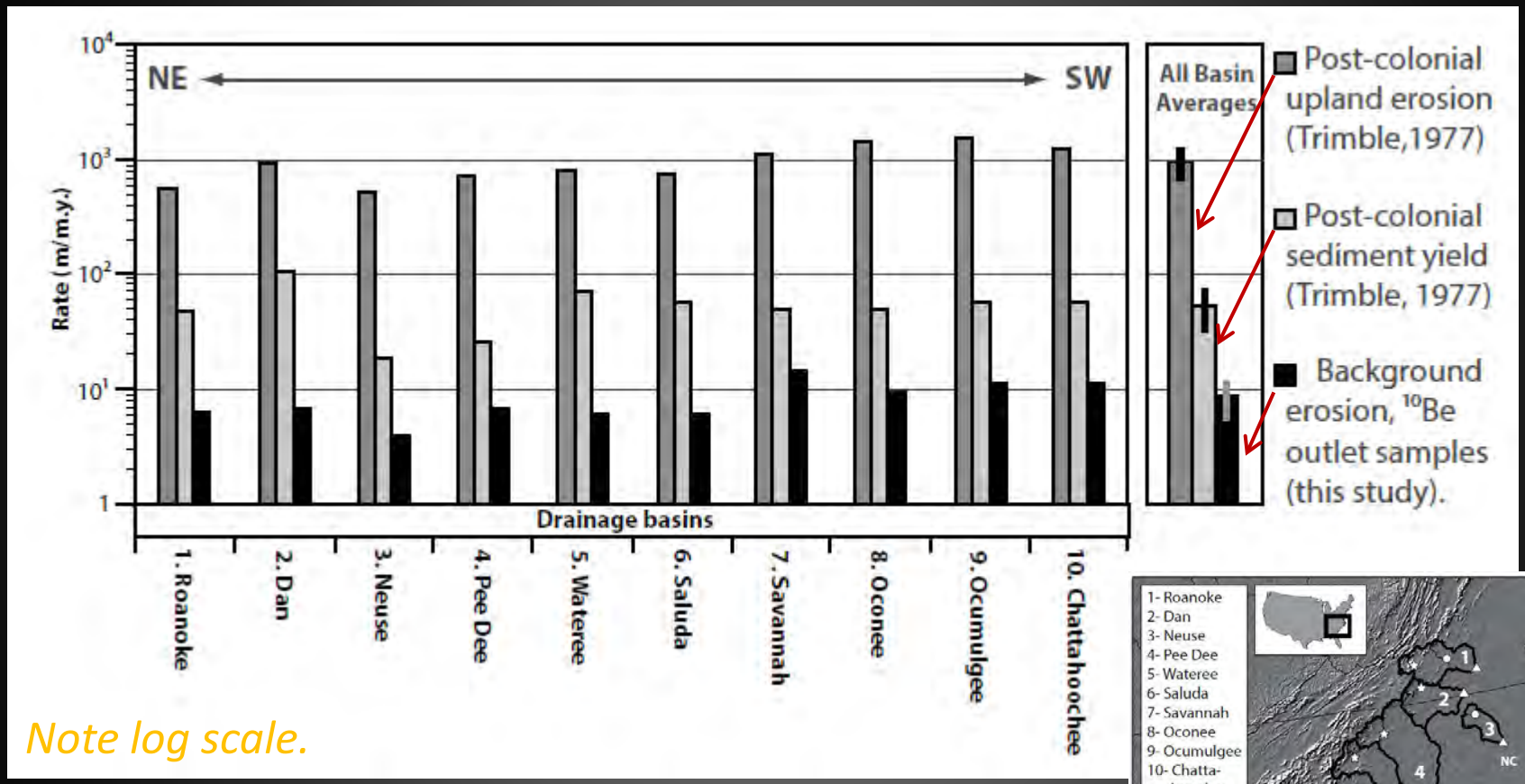


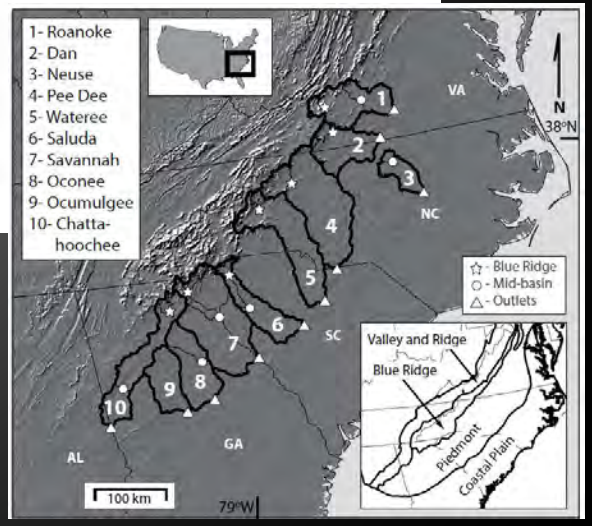
Figure 1. Map of southern Appalachian Piedmont along southeastern passive margin of North America. River basins 1–10 are those of Trimble (1977). Blue Ridge (star), mid-basin (circle), and outlet (triangle) denote locations of in situ ^{10}Be sample sites within each catchment. Insets show location of map and physiographic provinces mentioned in text. Modified from Trimble (1977, his figure 1). VA—Virginia; NC—North Carolina; SC—South Carolina; GA—Georgia; AL—Alabama.

Southern Piedmont study basins of Reusser et al. (2015)

Summary by Reusser et al. (2015) of erosion rates for large-scale catchments of the Appalachian Piedmont.



Note log scale.



- Background (geologic) erosion rate = ~ 8 m/my
- Peak disturbance erosion rate = ~ 950 m/my
- Sediment yield 5-10x pre-settlement norms, yet rivers transported only ~6% of eroded soils

What volumes of legacy sediment storage in headwater Piedmont valley bottoms are we talking about?

Photo of Richland Creek (near Wake Forest, NC):
Example of legacy sediment aggradation in the absence of historic mill dams

Example: Richland Creek – 3rd Order tributary to the Neuse River in northern Wake County

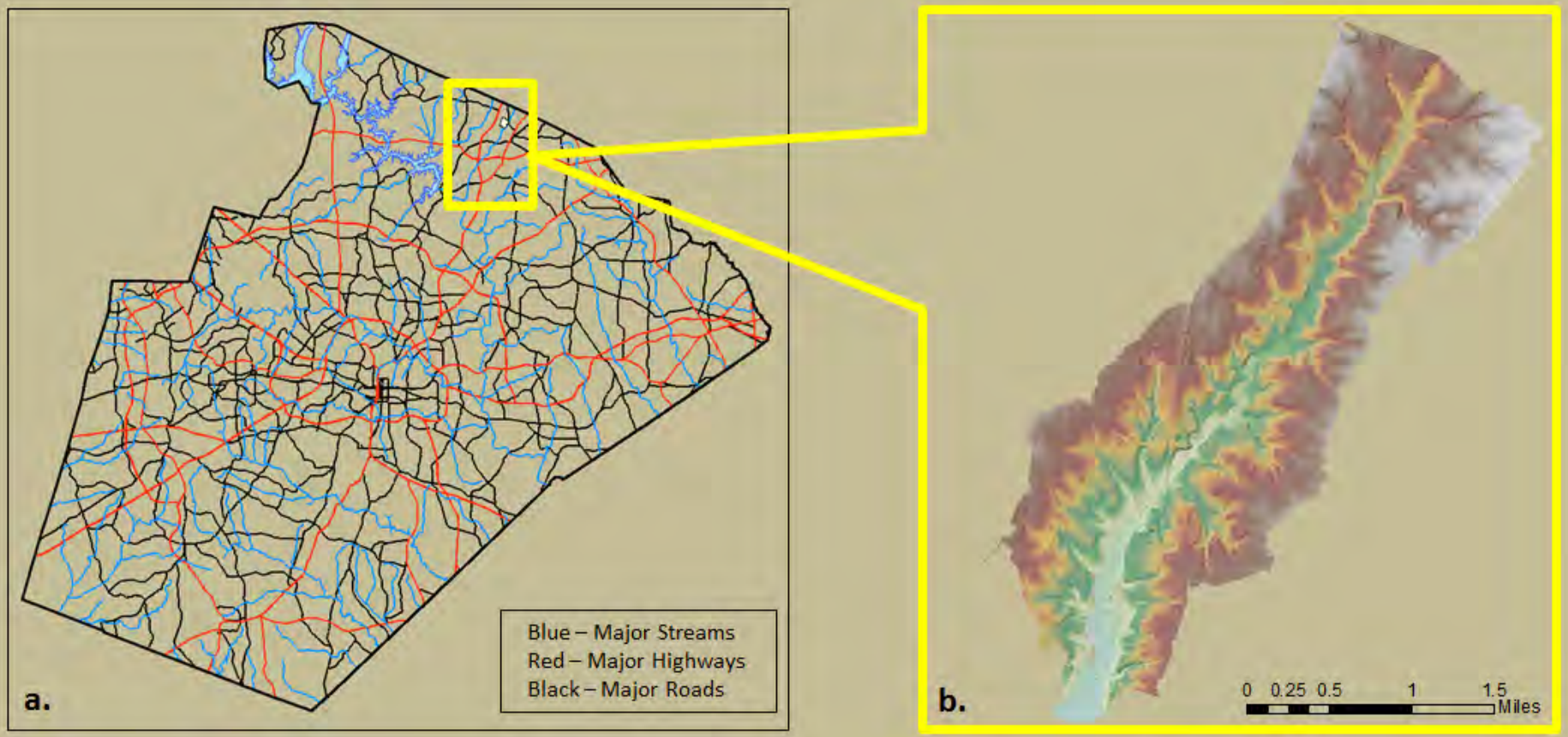


Figure 1: *a.*) Wake County, NC. *b.*) Richland Creek study area

Calculating volumes

B.) DEM total volume of legacy sediment remaining

Richland Creek valley bottom

Flood Plain Vol.

Vol. removed by creek

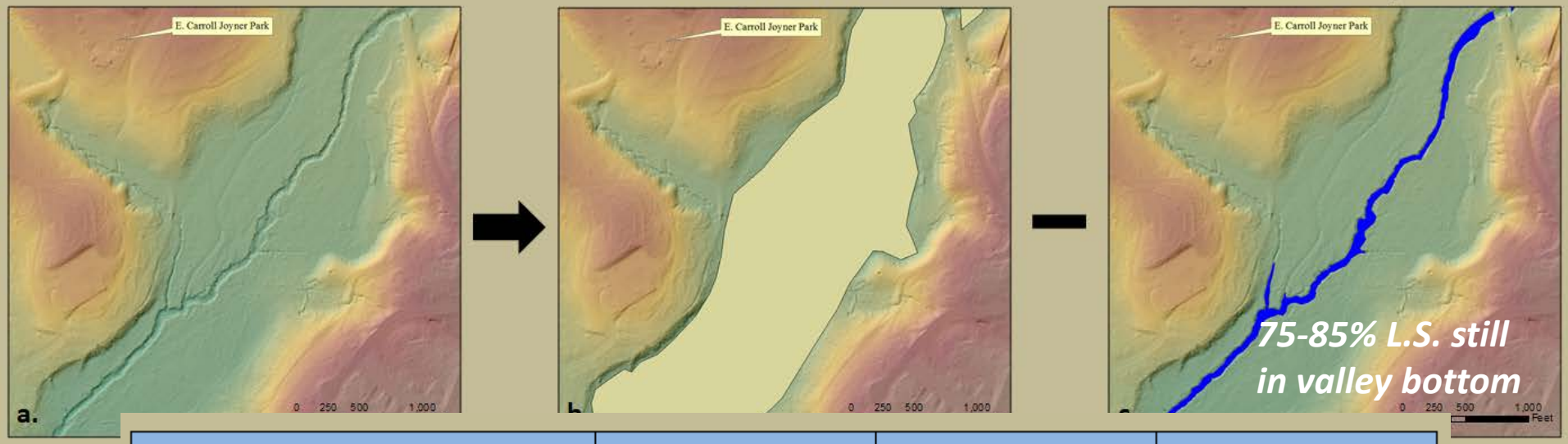


Figure 4 ...) Polygon generat...

Sediment Depth	.5 m	.75 m	1 m
Flood Plain Vol. (m^3)	786,624	1,179,935	1,573,247
Vol. removed by creek (m^3)	180,141	180,141	180,141
Vol. of Legacy Sediment Remaining (m^3)	606,483	999,795	1,393,106

Table 1: Calculations estimating total legacy sediment remaining within the Richland Creek floodplain

Putting this into perspective…
A standard 8m long, 3-axel dump truck holds 7.5 m^3 of earth materials

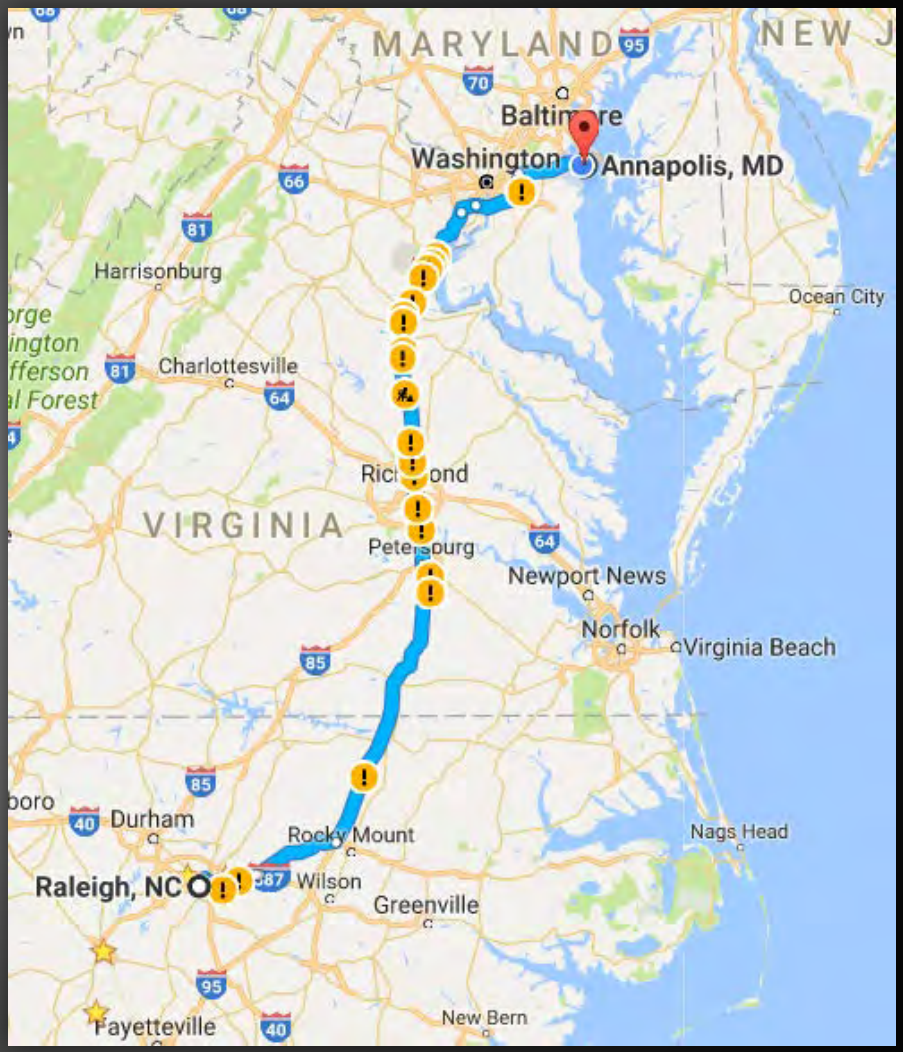
Photo source: http://www.lapinetrucks.com/processprodlinesearch.asp?strListedProdLines=DUM

It would require ~<u>130,000</u> dump trucks loads to contain the volume of Legacy Sediment still stored in the valley bottom of Richland Creek, a typical low-order Piedmont tributary stream

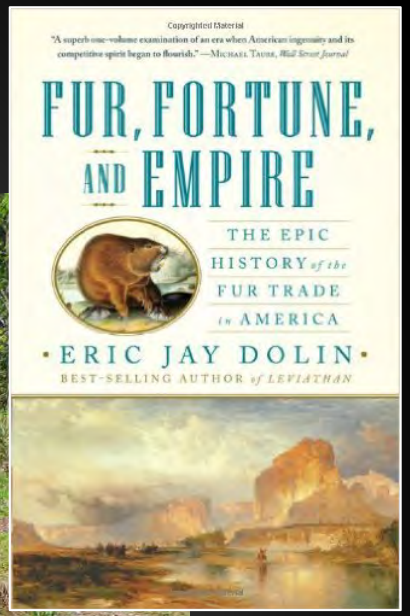
Putting this into perspective…

130,000
Dump Trucks
=

1,000 km long dump-truck traffic jam that would extend from Raleigh to Annapolis (502 km) and back again



One approach to mitigating our legacy sediment problem...



Perhaps by tacit or overt encouragement of beaver impoundments to restore low-order (1-4) valley-bottom wetland meadow complexes that increase longitudinal channel complexity, decrease peak flows, & reconnect shallow groundwater to the floodplain

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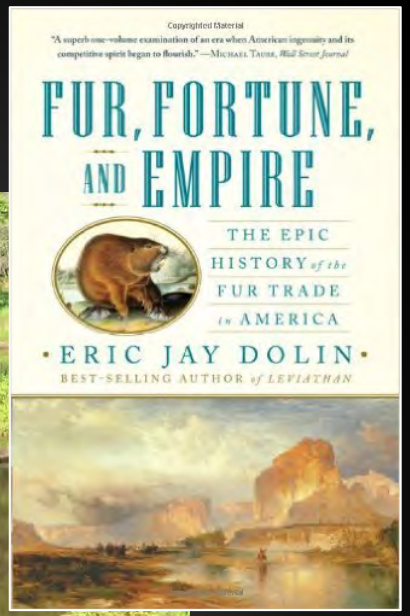

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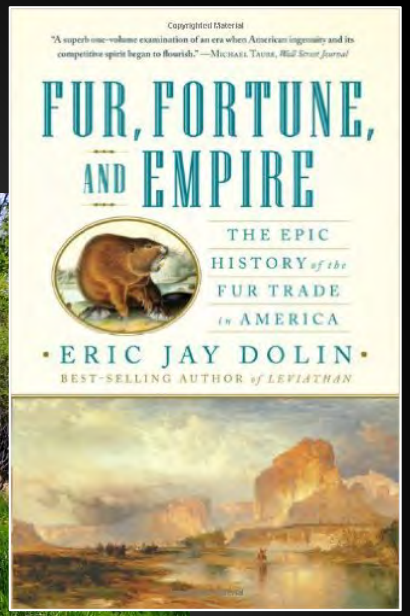

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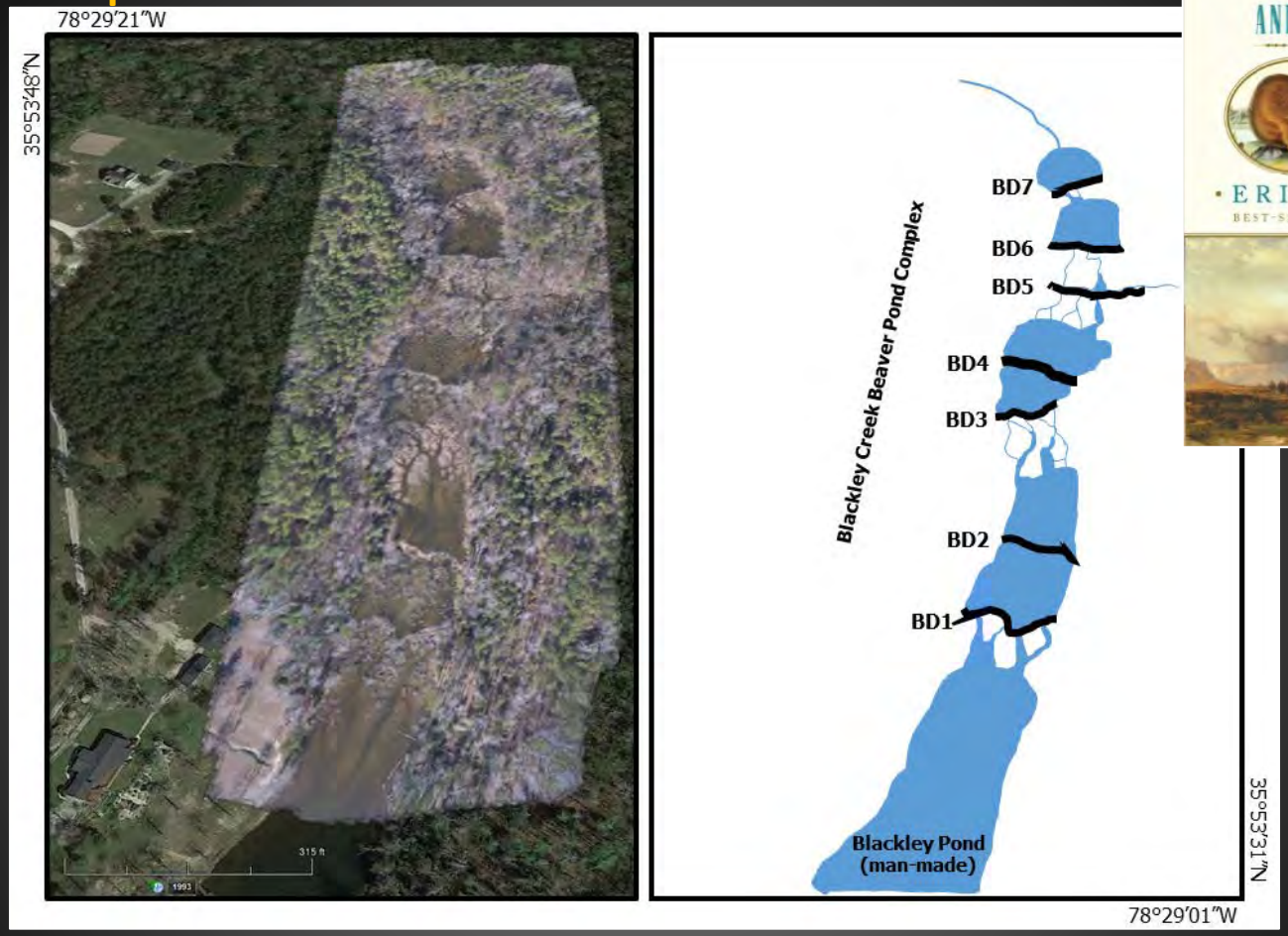

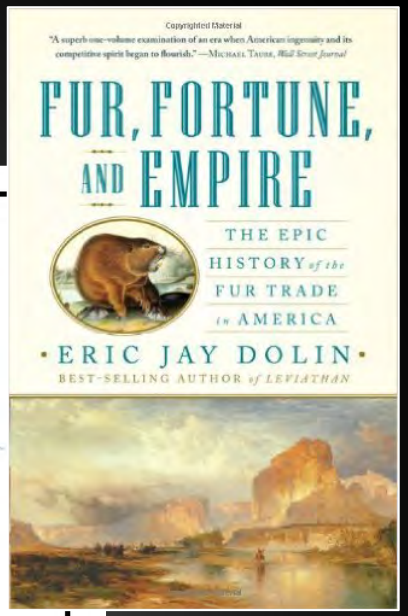

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Beaver dam analog Structures (BDAs)

Recent BDA installation along incised channel at Historical Yates Mill County Park, Raleigh. A beaver now maintains this dam.

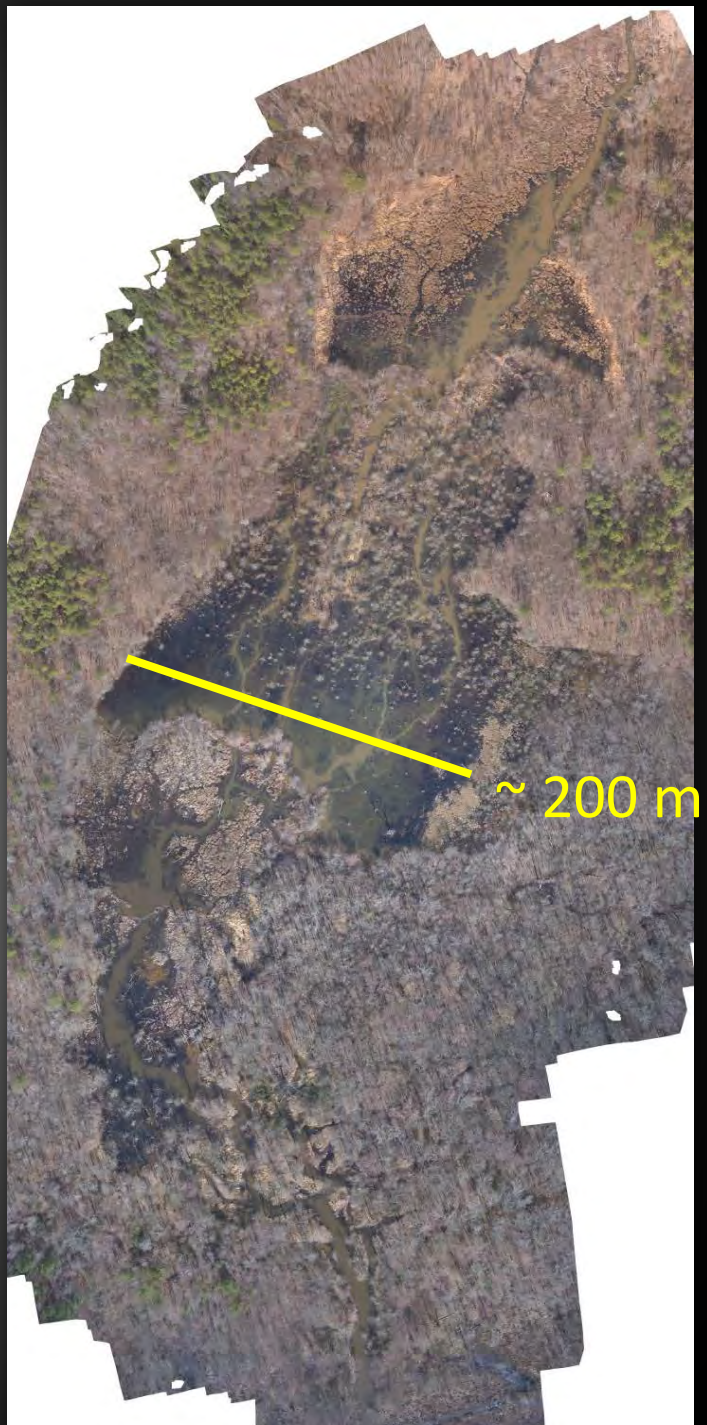
Beaver dam analog Structures (BDAs)

Example of a beaver dam analog (BDA) in action in the John Day River basin of Oregon (Pollock et al., 2015; Bouwes et al., 2016). The photograph is annotated with some of the expected channel responses to BDA installation.

Finishing remarks: Where removal of legacy sediment is impractical (e.g. due to total volume, land ownership status, etc.) one option that requires more study and consideration is the facilitation of beaver dam-pond complexes .

Single-thread channel flowing through former beaver-pond meadow complex: Yates Mill County Park, Wake County, NC

Conversion of a former single-thread channel system into a forested wetland – beaver meadow complex near Creedmoor, NC



Conclusions

- Post-Colonial forest clearing and agricultural practices led to rapid erosion of upland soils, almost 100x the long-term background rate of soil production and erosion.

- Yet Piedmont streams only exported ~ 6% of the eroded upland material
  - (Trimble, 1977; Phillips, 1992, 1993; Reusser et al. 2015)

- Eroded sediments still remains as legacy sediment stored at the base of hillslopes and along valley bottoms. Locally, milldams trapped large volumes of these sediments.

Conclusions

- The present-day erosion of this legacy sediment is contributing significantly to non-point source total suspended solids loads and persistent stream water quality problems.

- At current sediment export rates, the remobilization of legacy sediment will remain a water quality problem for centuries to millennia (e.g. Jackson et al., 2005).

- Natural and/or artificial beaver-dam structures should be studied to evaluate their effectiveness at reducing nutrient and sediment loading to regional waterways

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