The Interwoven Roles of Geologic Setting, Human Disturbance, and Time in Shaping the Geomorphic Characteristics of Midwestern Streams

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OSM Mid-Continent Region NSD Workshop
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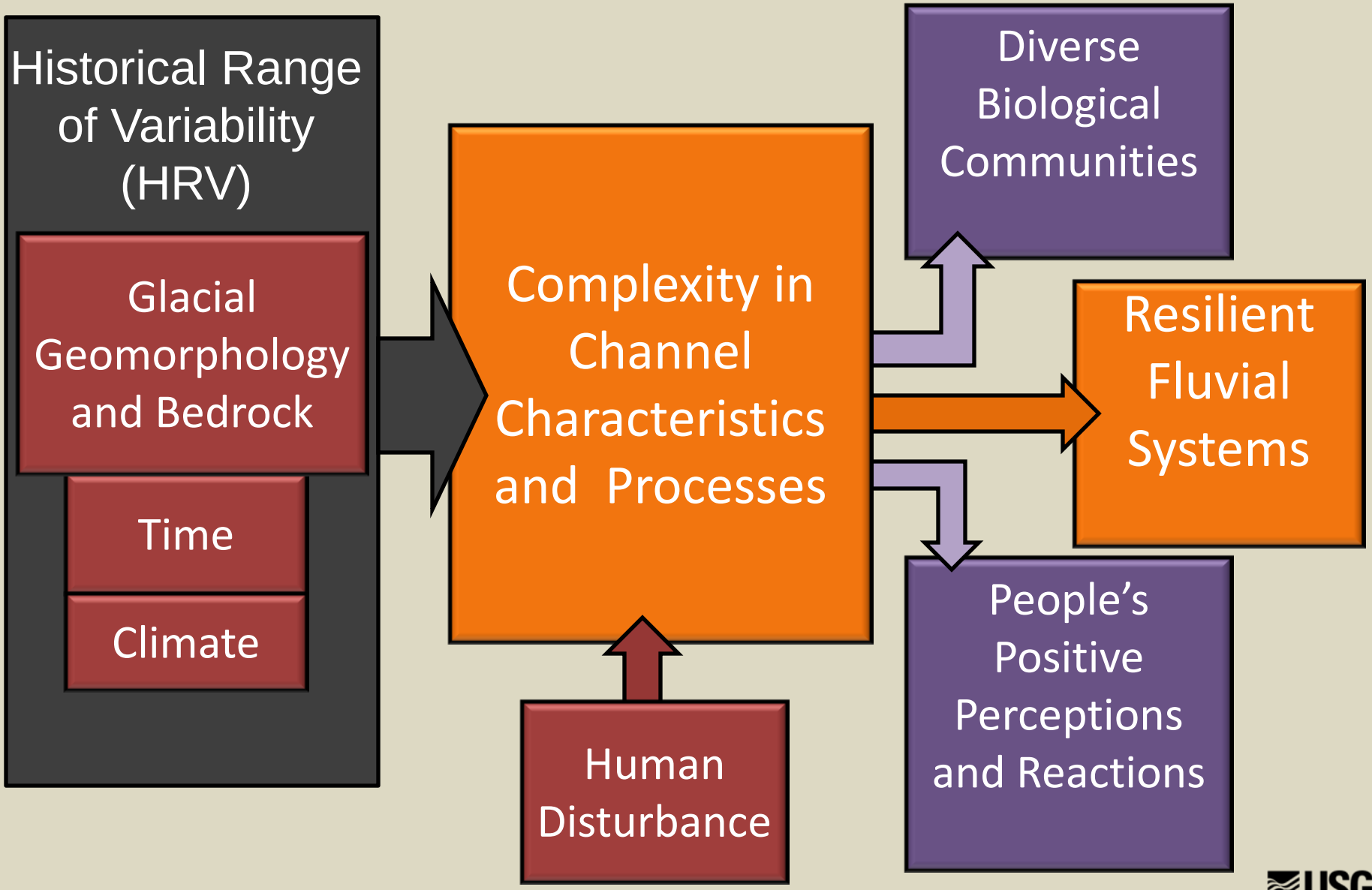
Midwestern Streams



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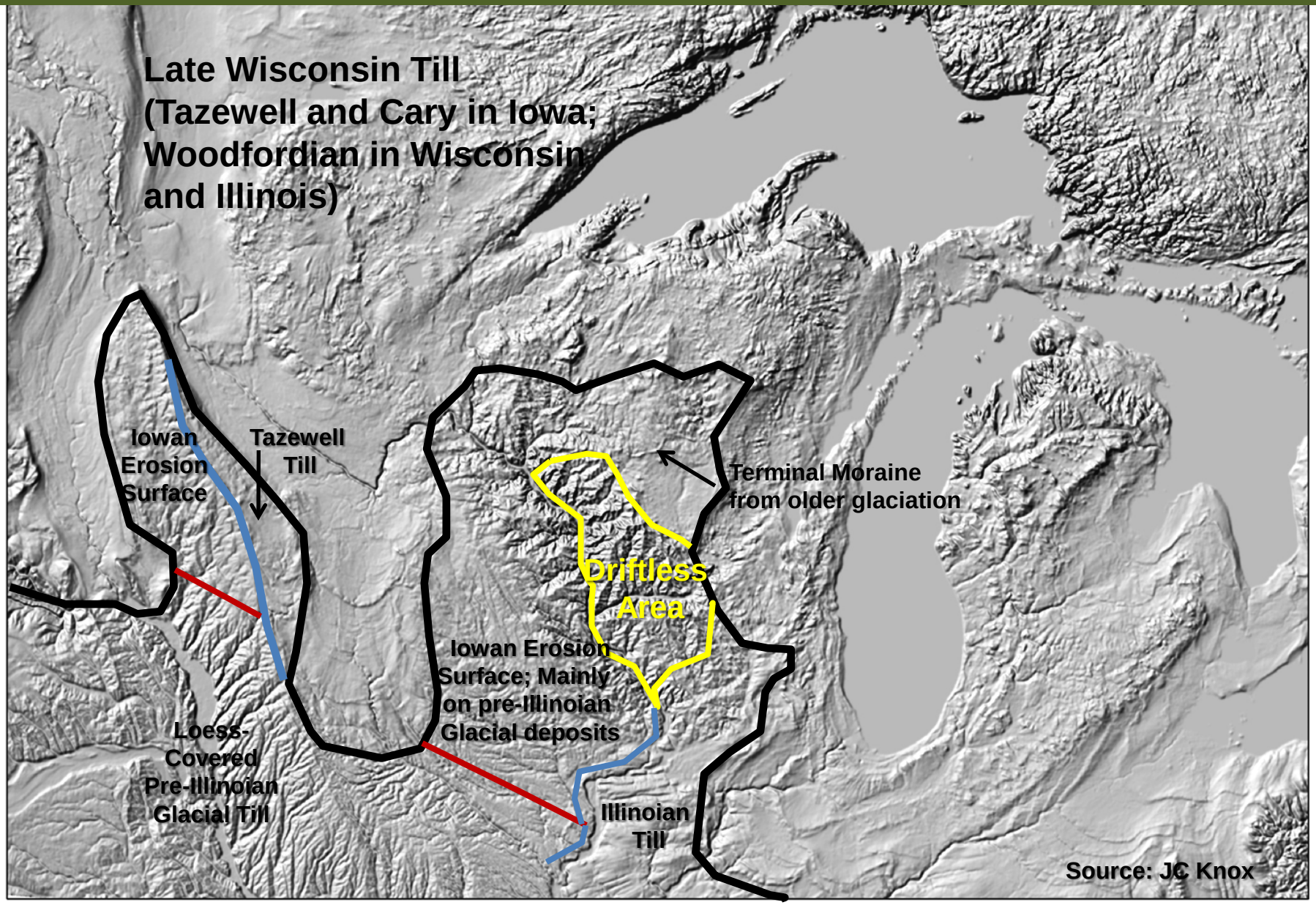
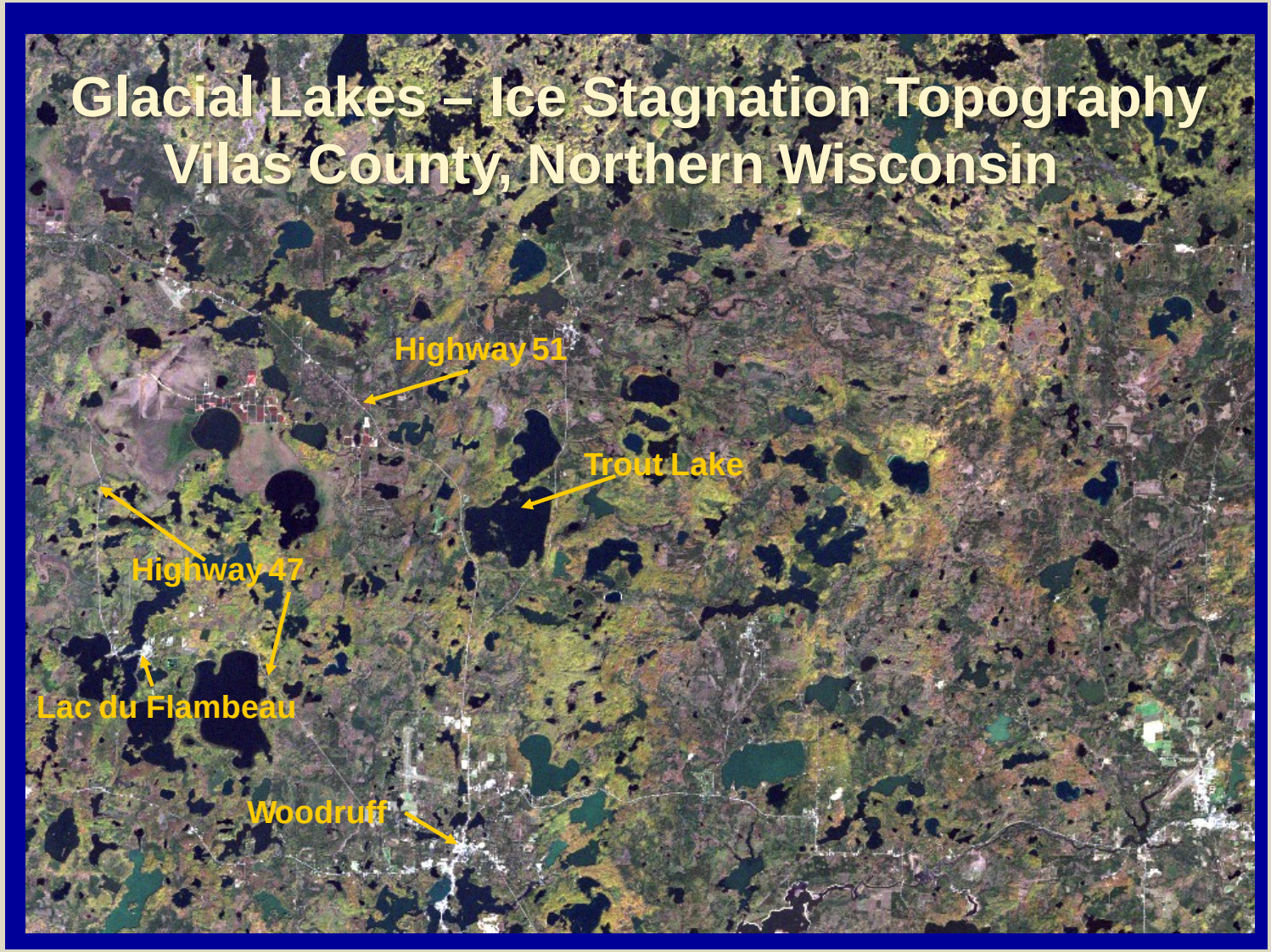
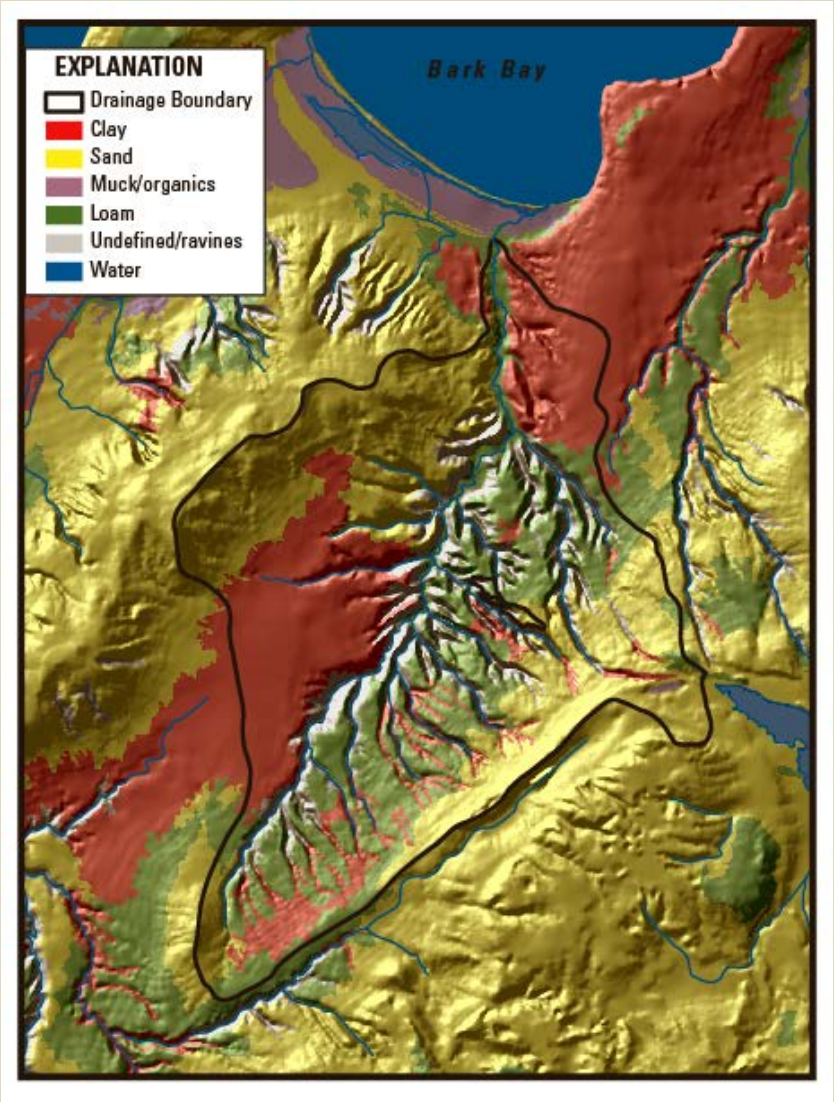
Glacial landforms



Geologically young landscapes
Disconnected stream networks



Diversity of soils, topography, and groundwater contributions



Bark River Basin, Cornucopia, WI

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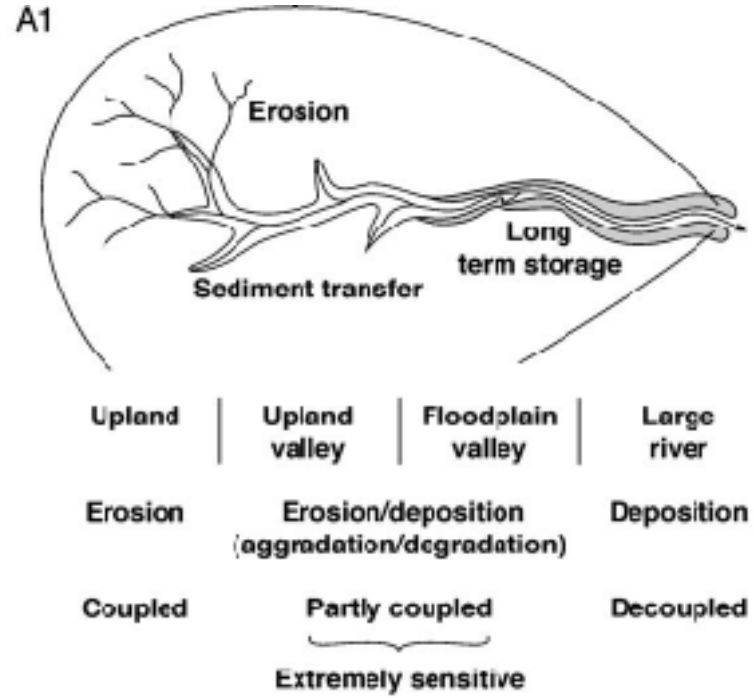
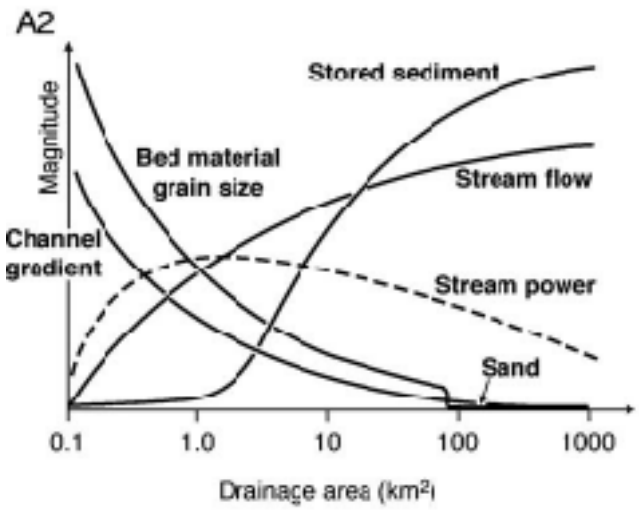
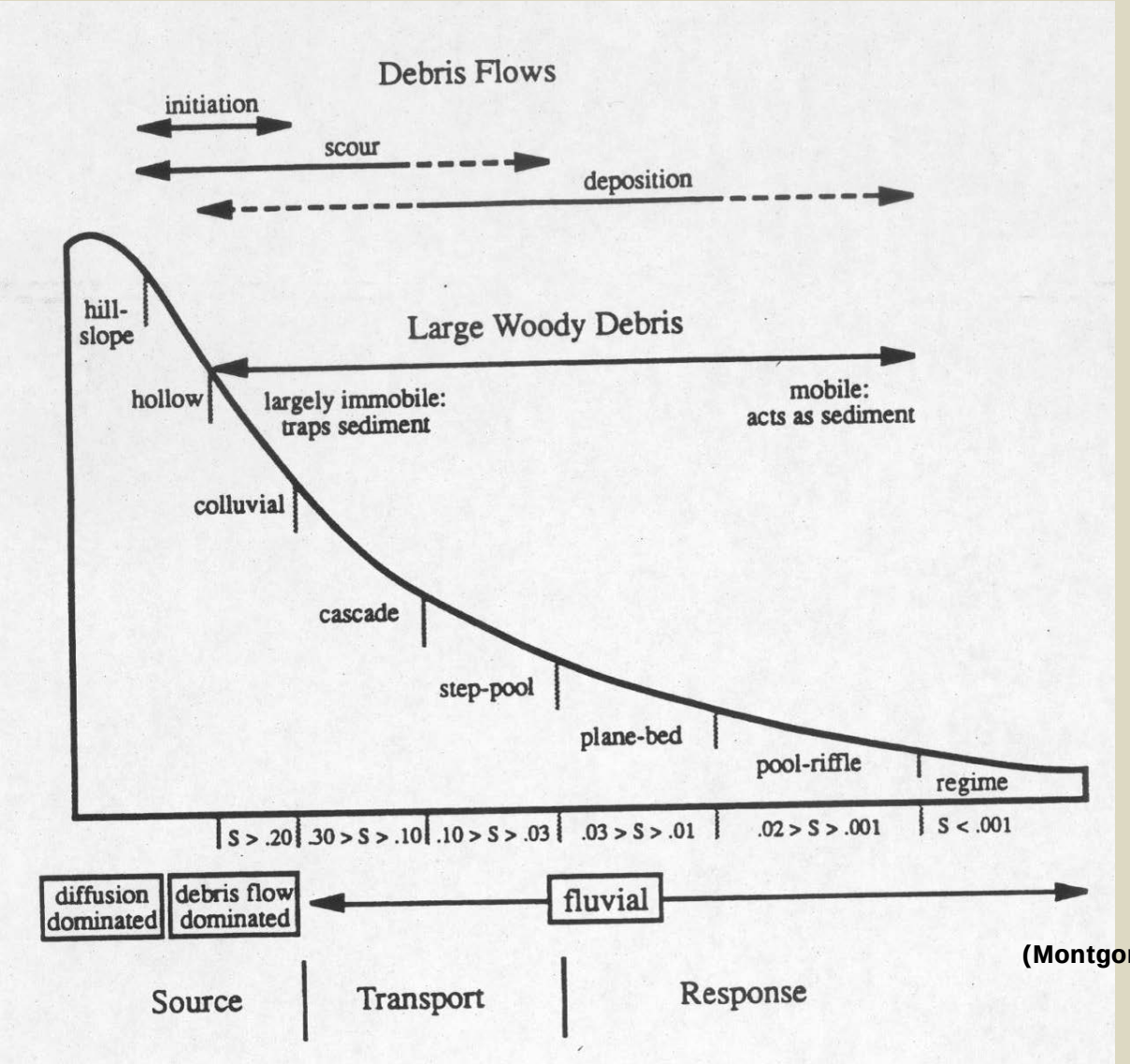
Drainage Network Position, Longitudinal Profile, and Influence on Geomorphic Processes





[GREGORY, 2006] A1 shows a view of the drainage basin developed from Schumm (1977) and related to sediment transfer (Church, 2002) that displays patterns of variation on A2.

Possible channel types along a long profile from headwaters to mouth



(Montgomery and Buffington, 1993)

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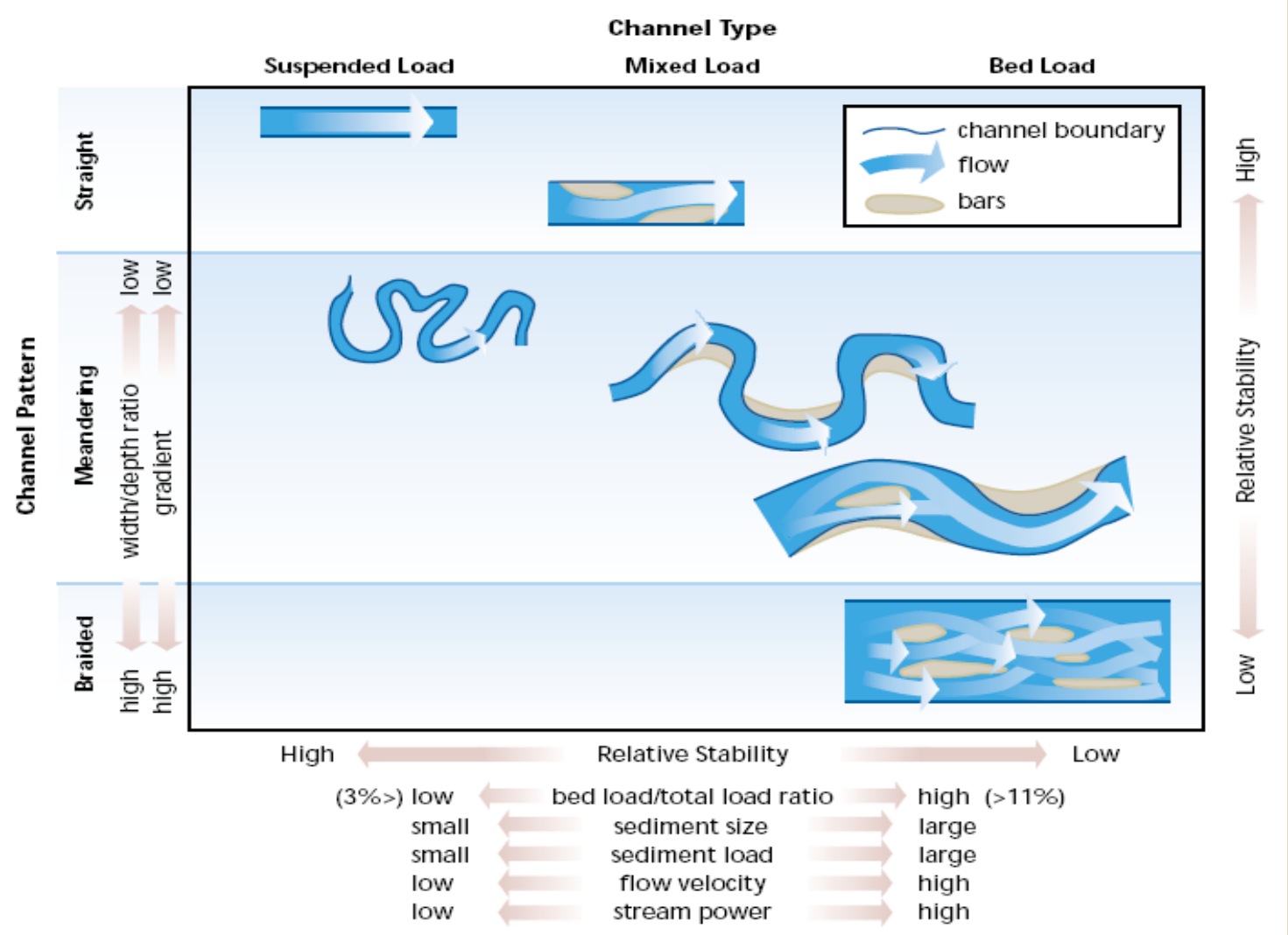
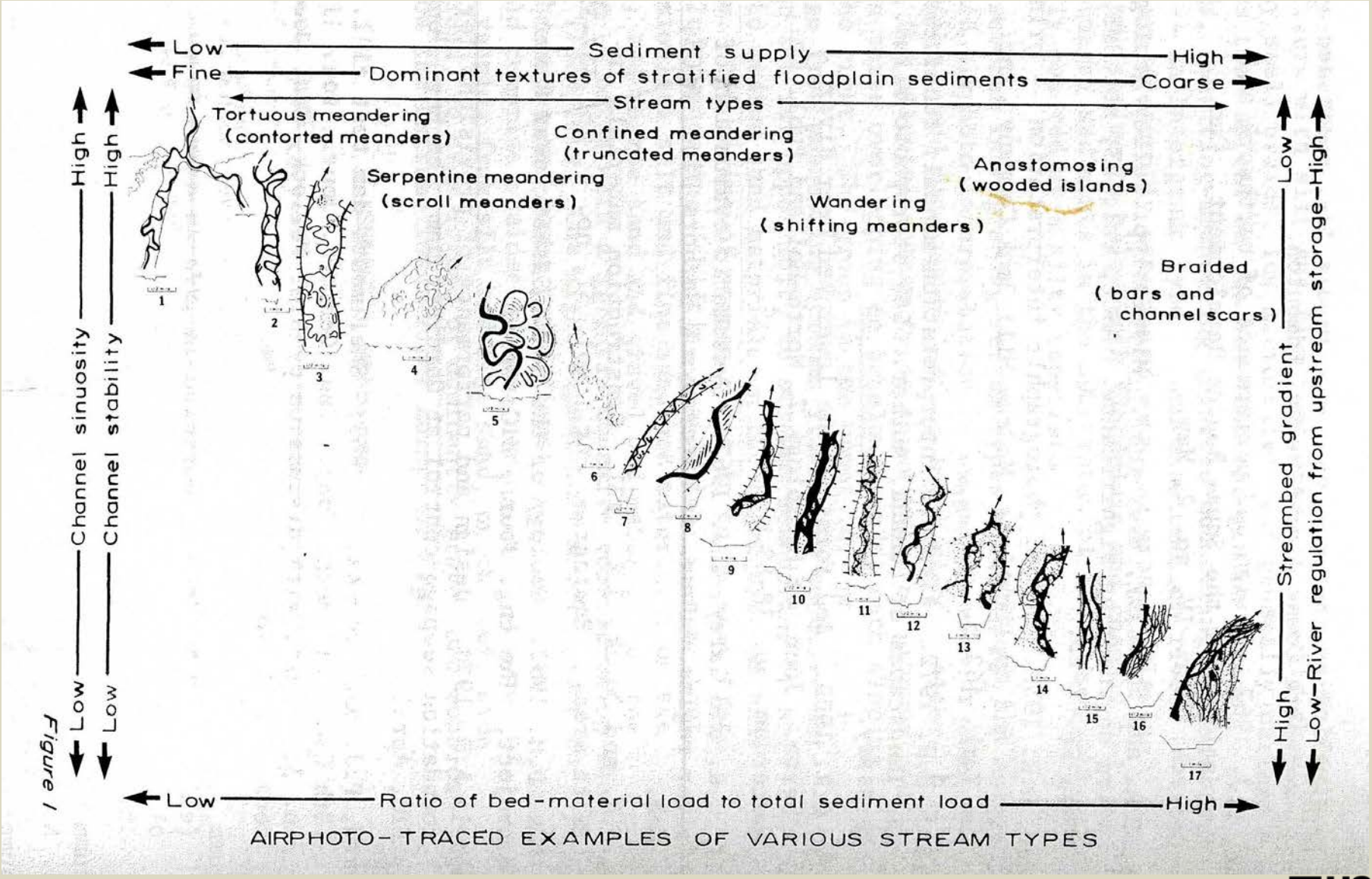
Schumm's (1977) Channel Types



Mollard, 1973 – classification for Canadian streams based on glacial geomorphic setting from air photo interpretation



Defining Stream types based on geomorphic setting – Duluth, MN

(Fitzpatrick et al., 2005)

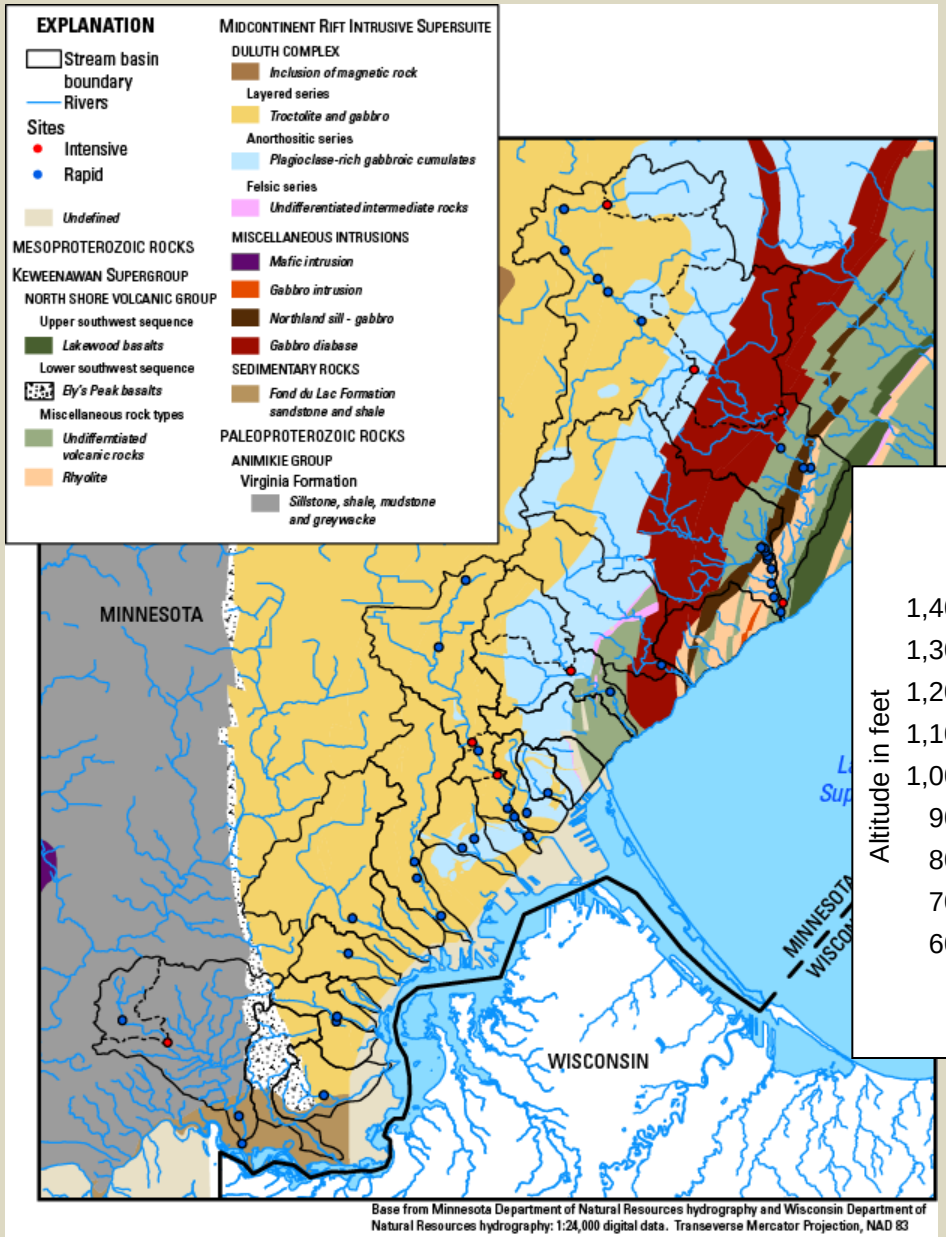
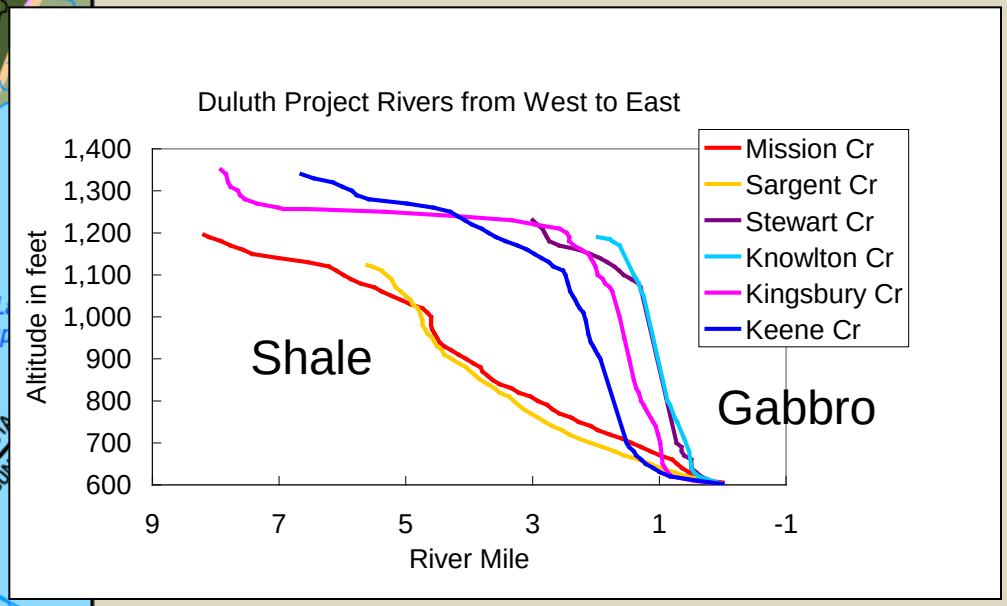


Figure 4. Bedrock geology of the Duluth, Minn. area (from Miller and others, 2002).



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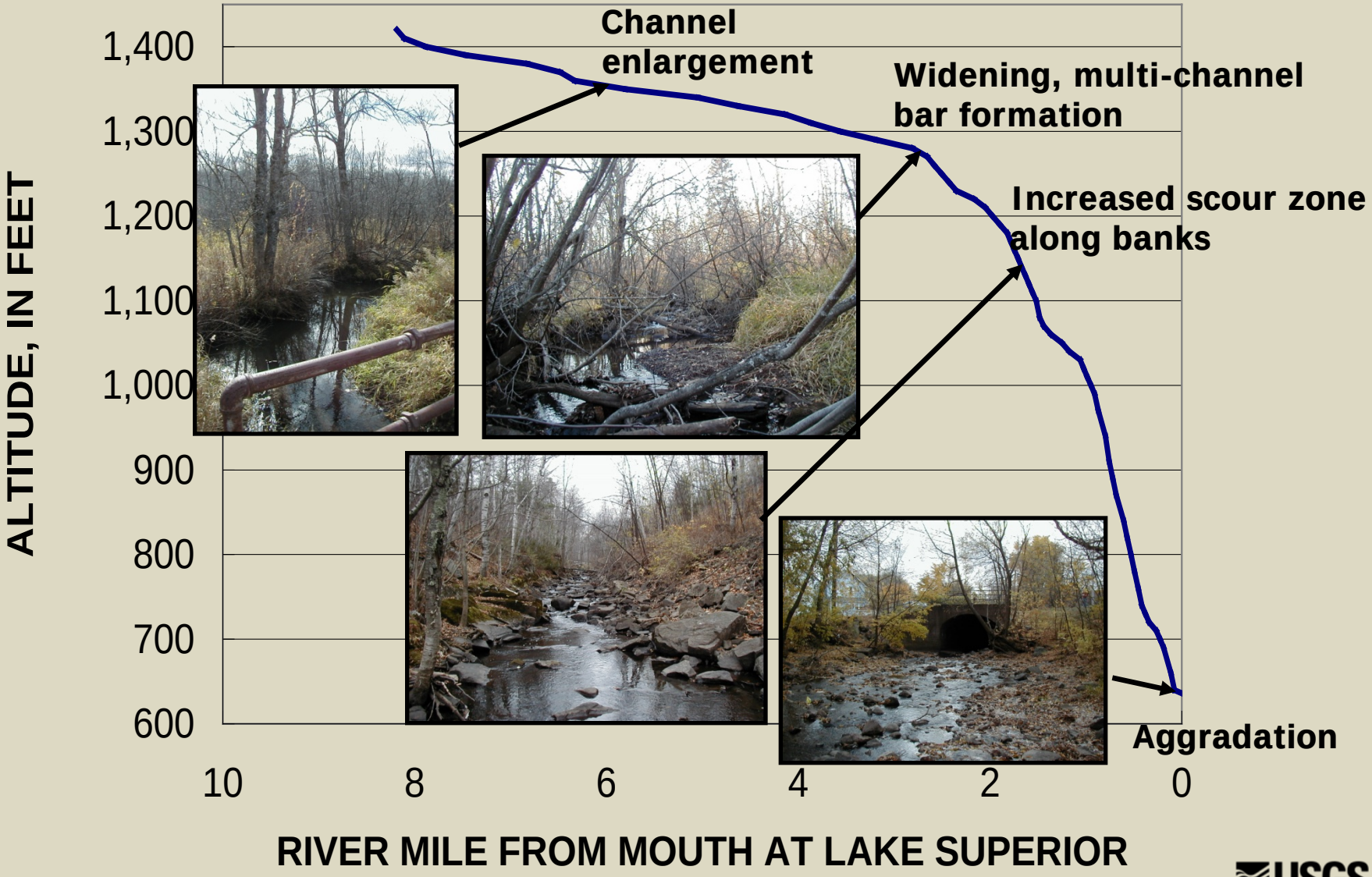
Drainage network position and local geology drive geomorphic response and adjustment to urbanization – Miller Creek, Duluth, Minn. (Fitzpatrick et al. 2005)



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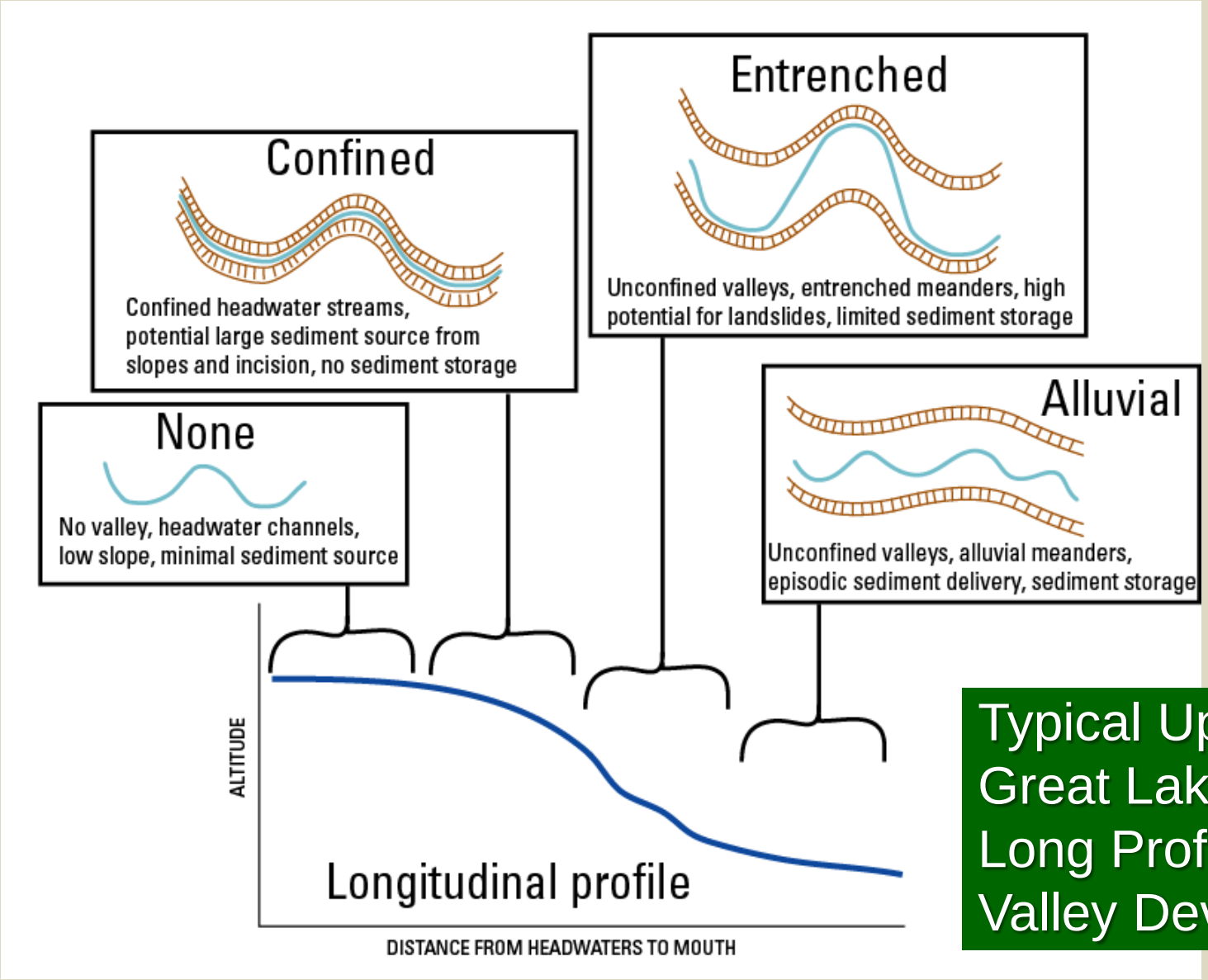

Typical Upper Great Lakes Long Profile and Valley Development

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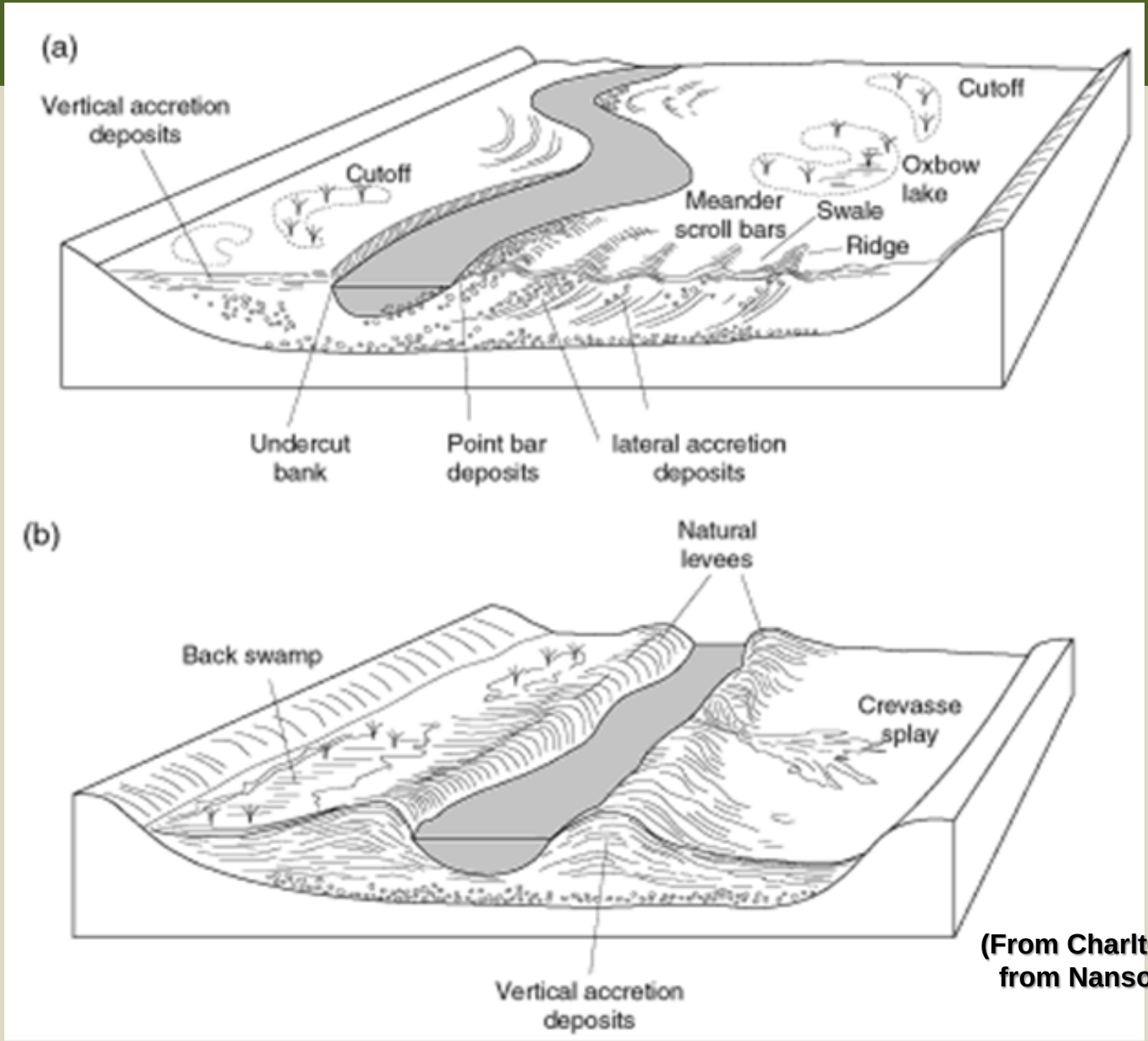
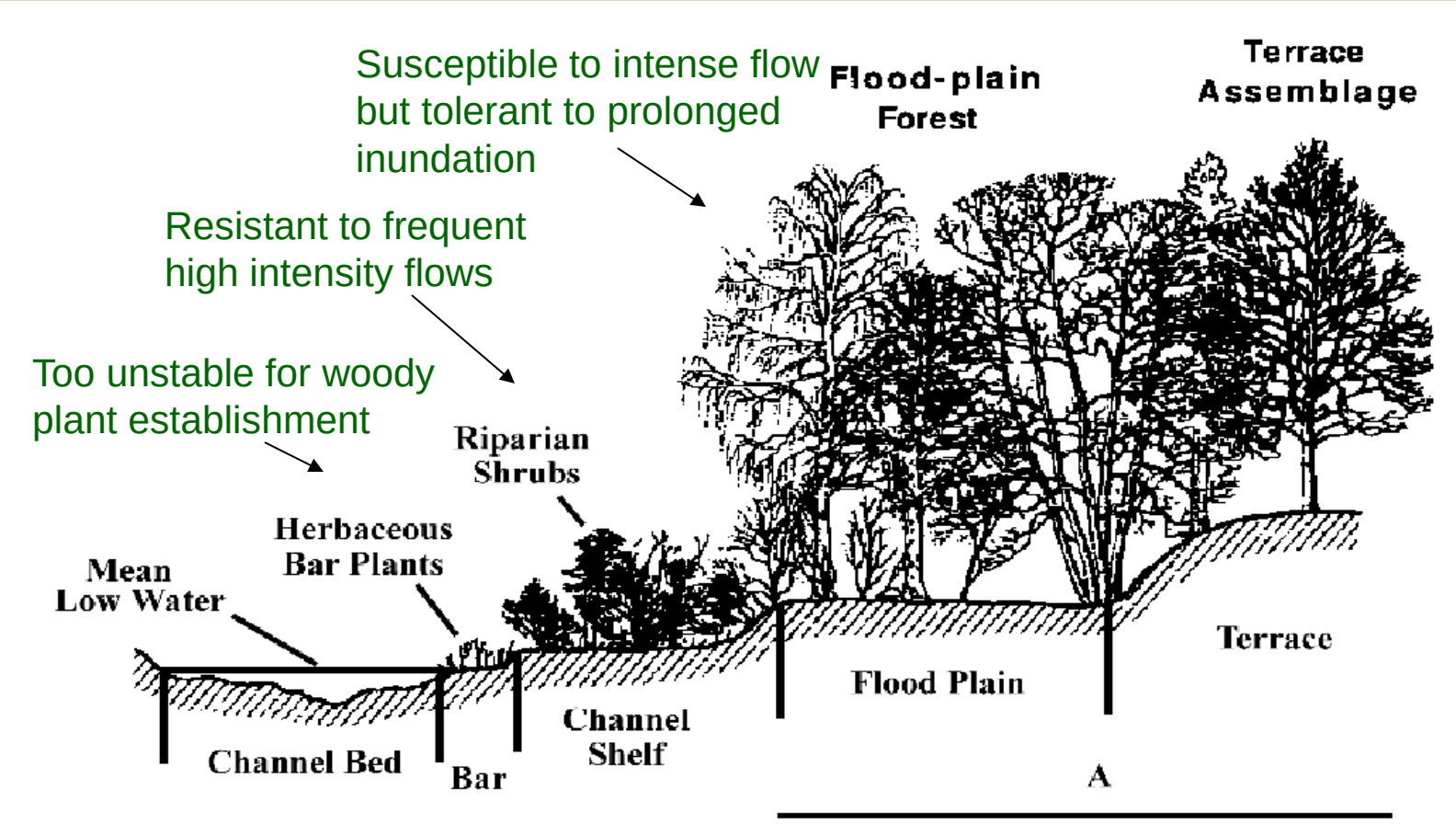
Channels and Floodplains = Fluvial Systems



(From Charlton, 2008 as adapted from Nanson and Croke, 1992)

Vegetation and Fluvial Landforms



(source: Cliff Hupp, USGS)

“The life of every river sings its own song, but in most the song is long since marred by the discords of misuse” Aldo Leopold, A Sand County Almanac

East Fork Cranberry River, Herbster, WI

Human Disturbance Disrupts the Balance of River Forces

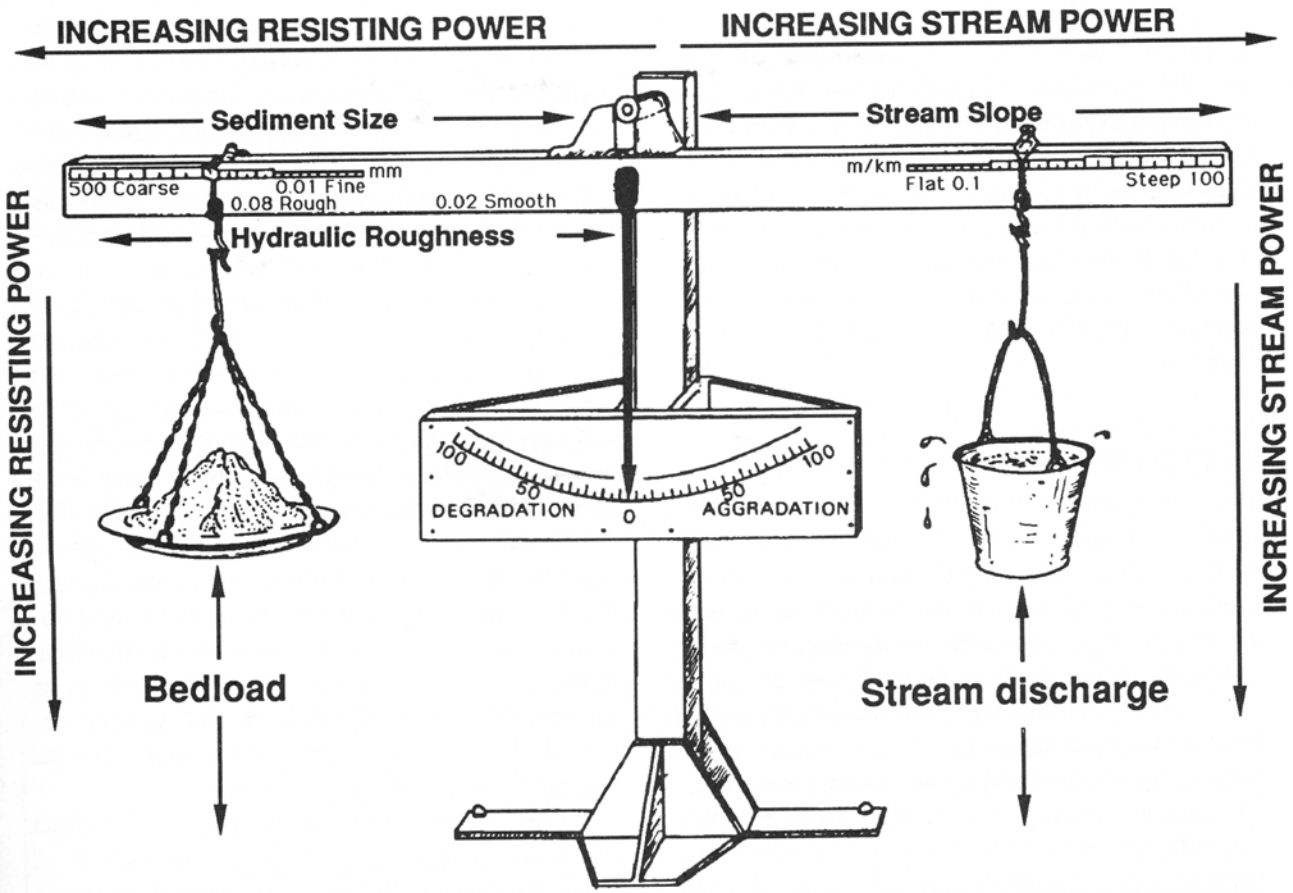
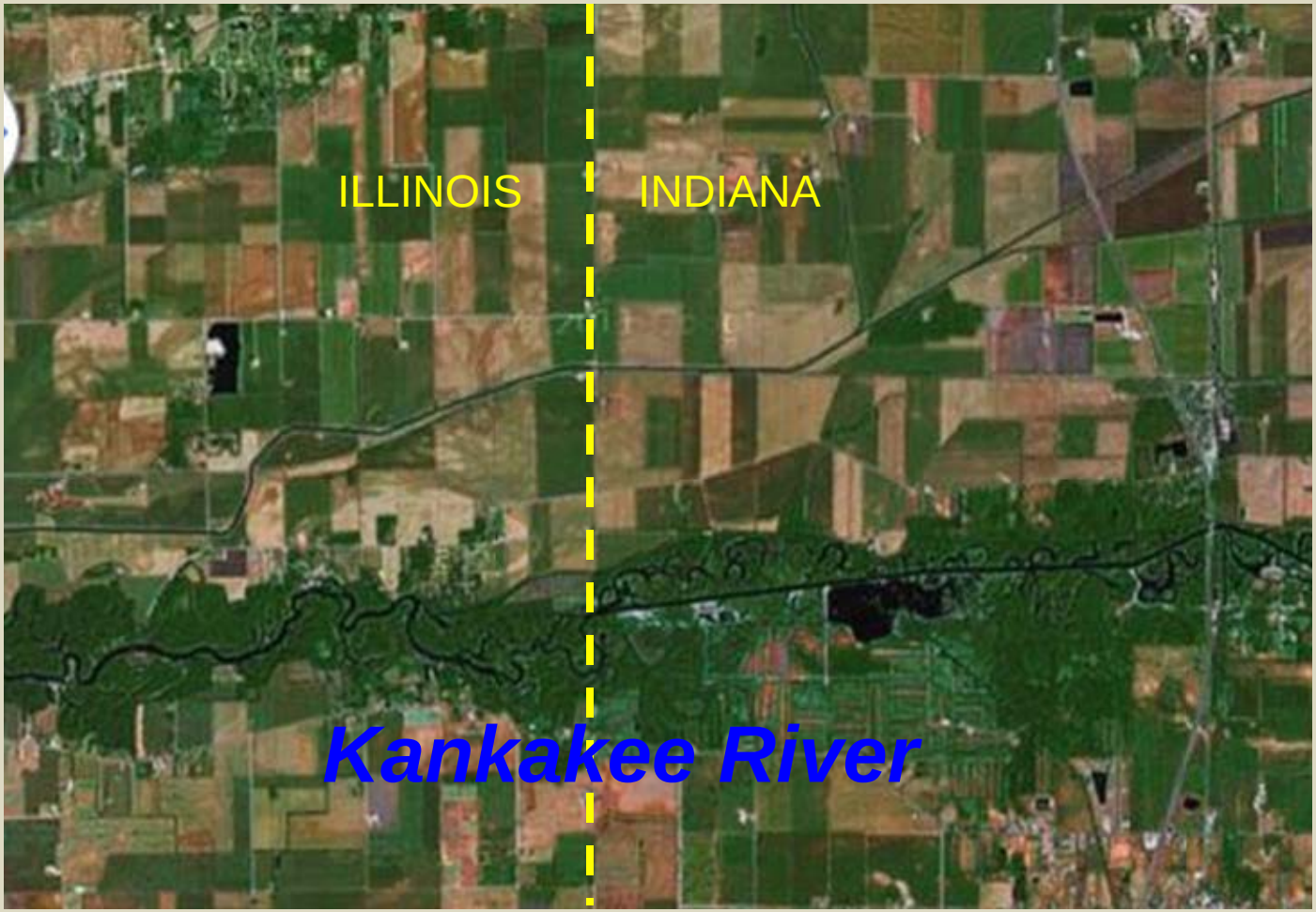


FIGURE 1.4 Schematic balance between modes of aggradation and degradation in streams; zero is the threshold of critical power. Increases or decreases of one or more of the important variables may cause the mode of stream operation to depart markedly from the threshold condition. (Originally from notes of E. W. Lane; modified from Chorley et al., 1984.)

(Bull, 1991, "Geomorphic response to climate change", p. 15; Lane 1955)

Agriculture – Ditching, tiling, draining, dredging….



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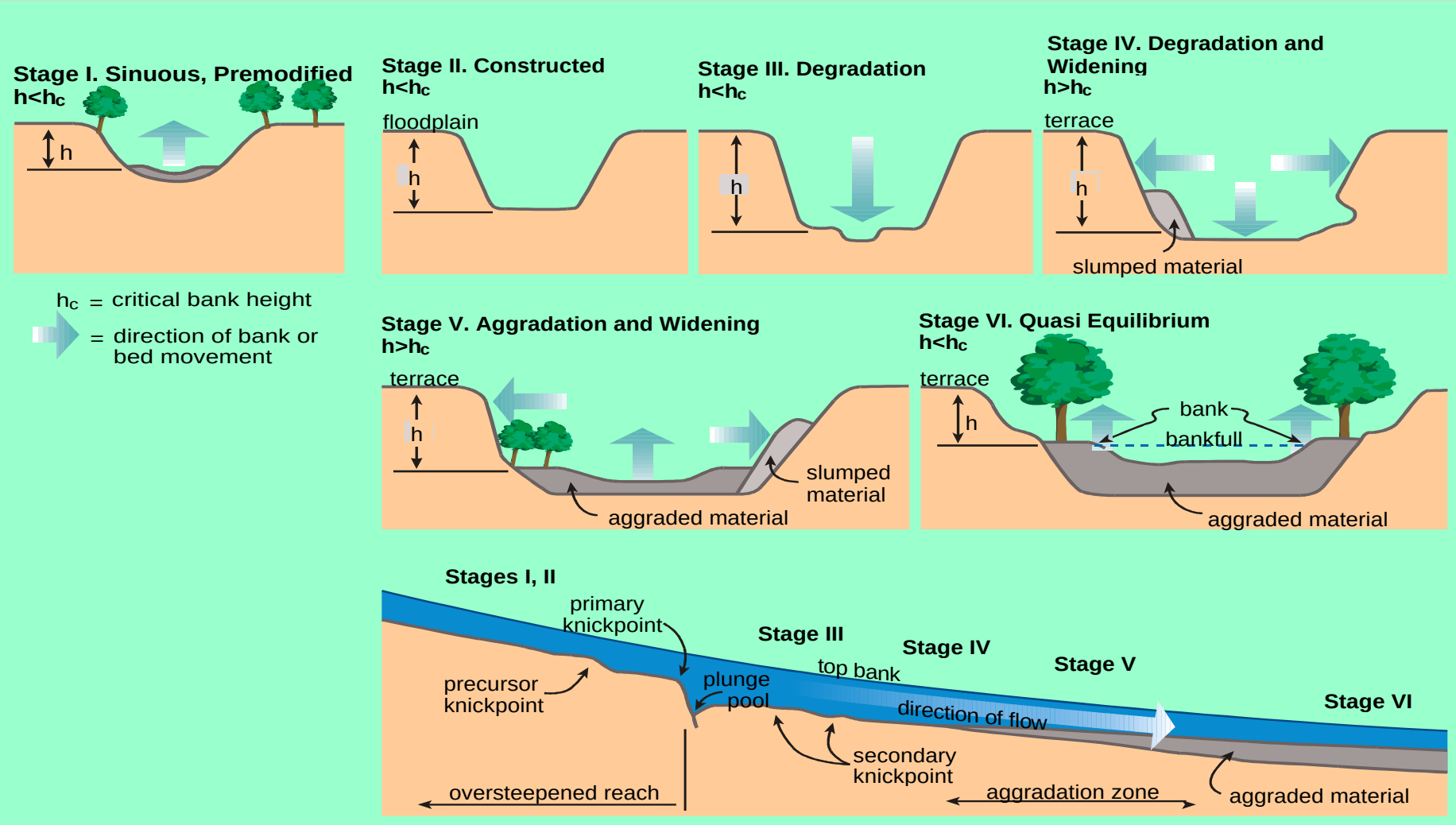
Channel Evolution Model (CEM) – Qualitatively Describes Time Dependent Channel Erosion Caused by Headward Incision

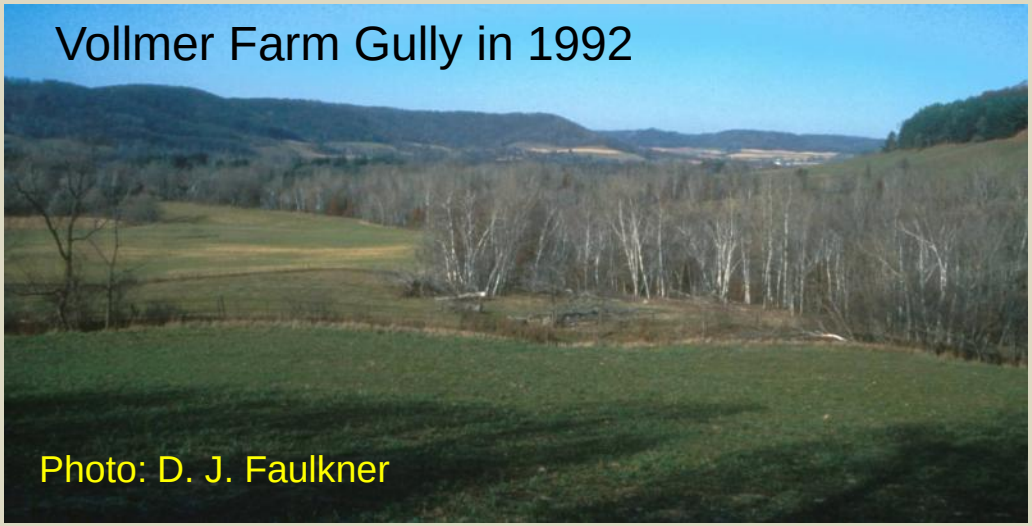


(Simon and Hupp, 1986; Simon, 1989)

USGS

Agriculture in SW Wisconsin Driftless Area 19-20th century gullies/sediment sources = 21st century tree-lined headwater channels

Pleasant Valley, site #27, 2009



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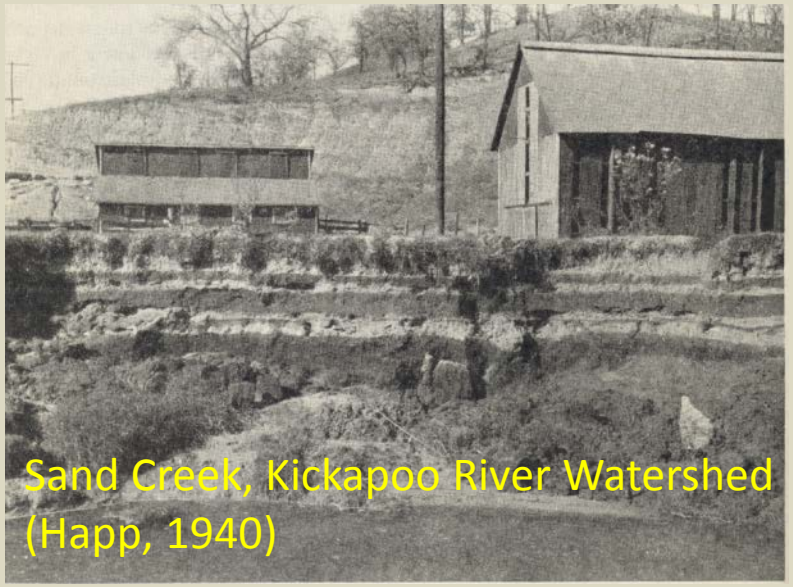
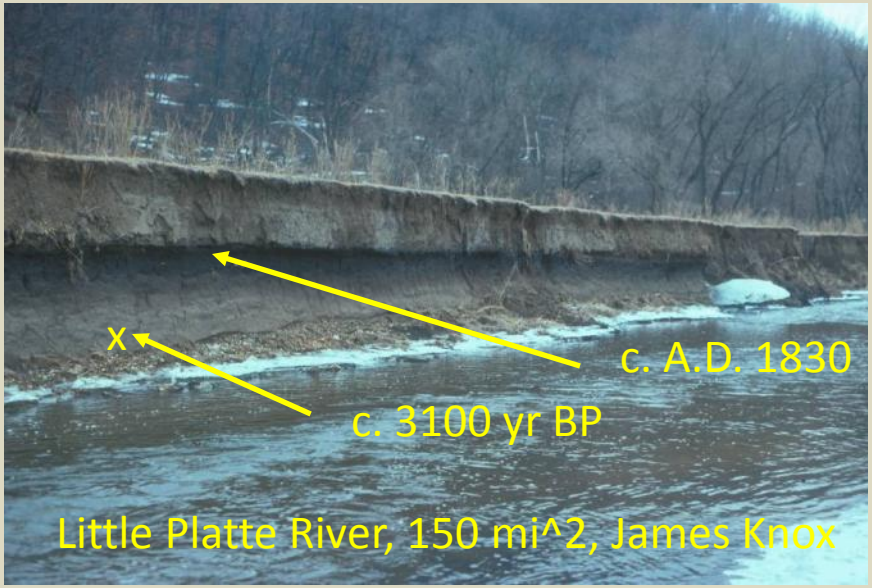
Agriculture in SW Wisconsin Driftless Area
19-20th century valley sedimentation = 21st bank erosion source of sediment

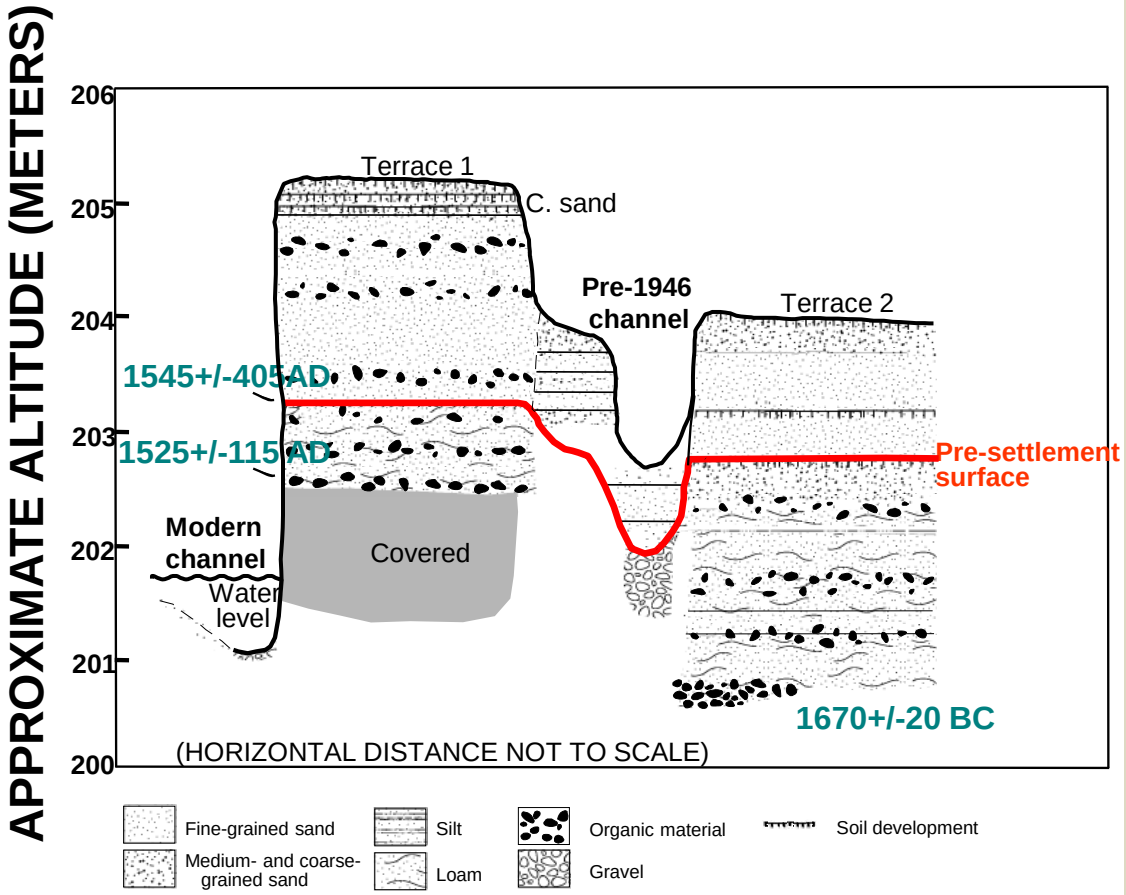




Loss of floodplain micro-topography

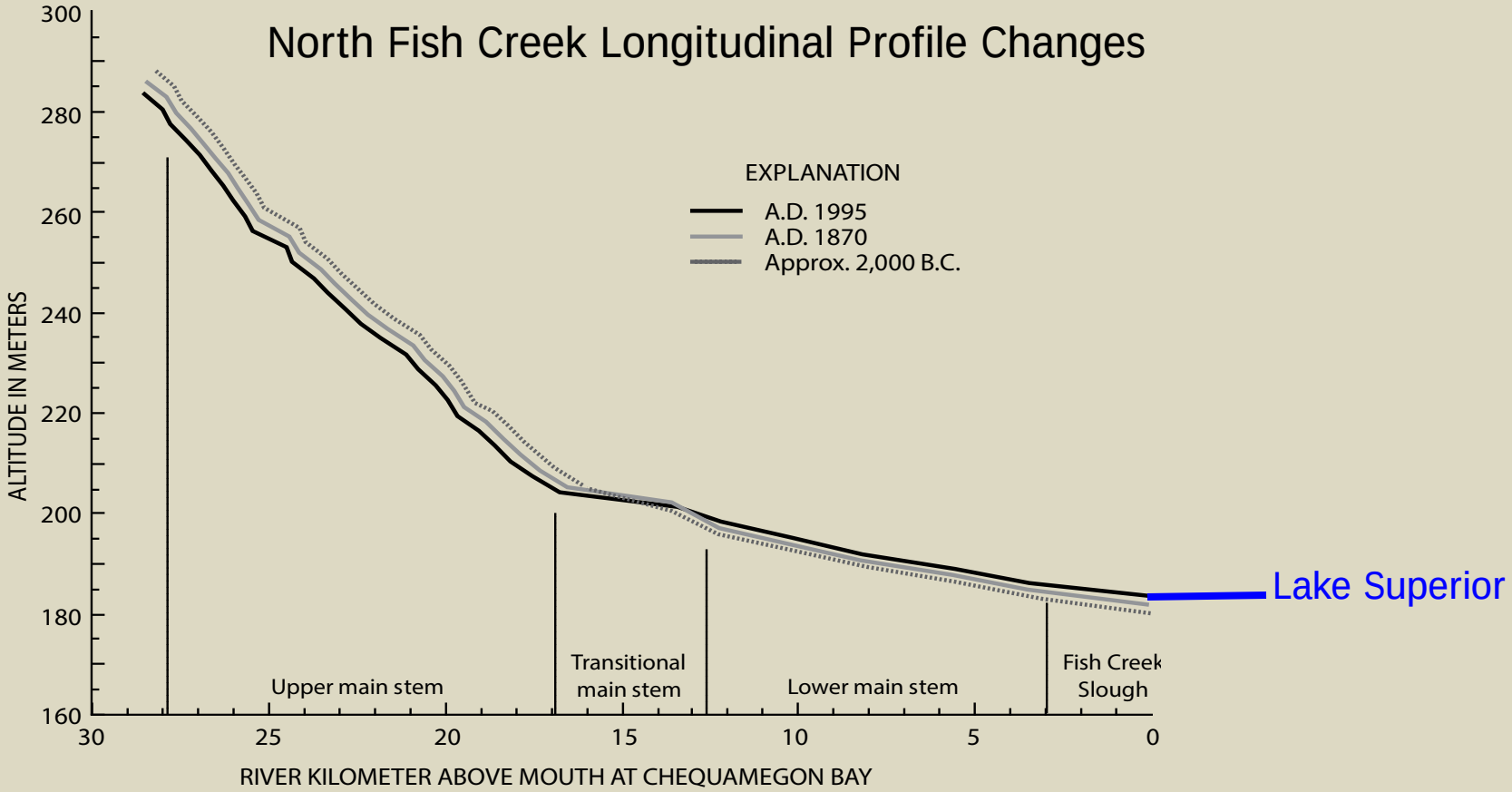
Photo: J. C. Knox

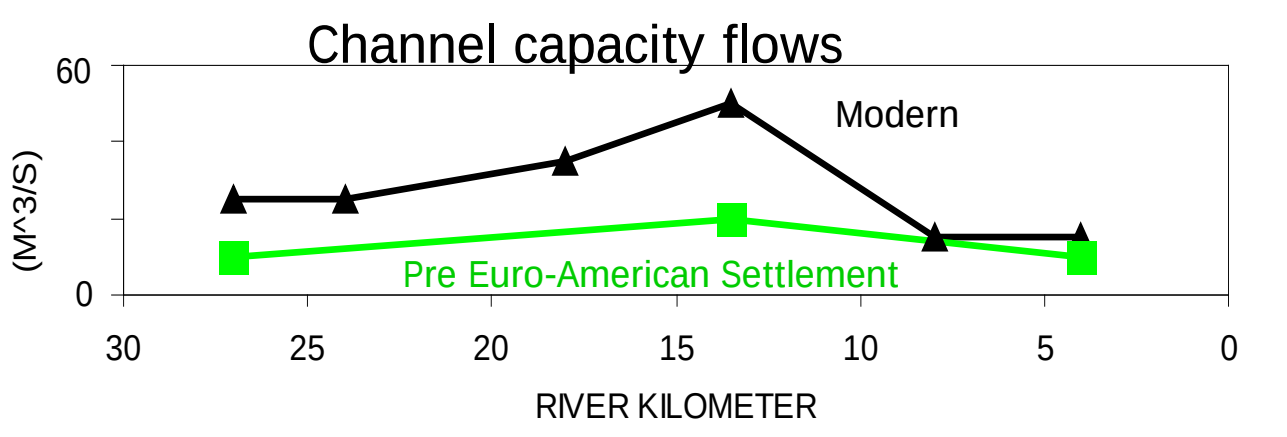
Logging in Northern Lakes and Forest North Fish Creek Middle Main Stem



Stratigraphic diagram of historical overbank sedimentation

USGS





Fitzpatrick et al. 1999

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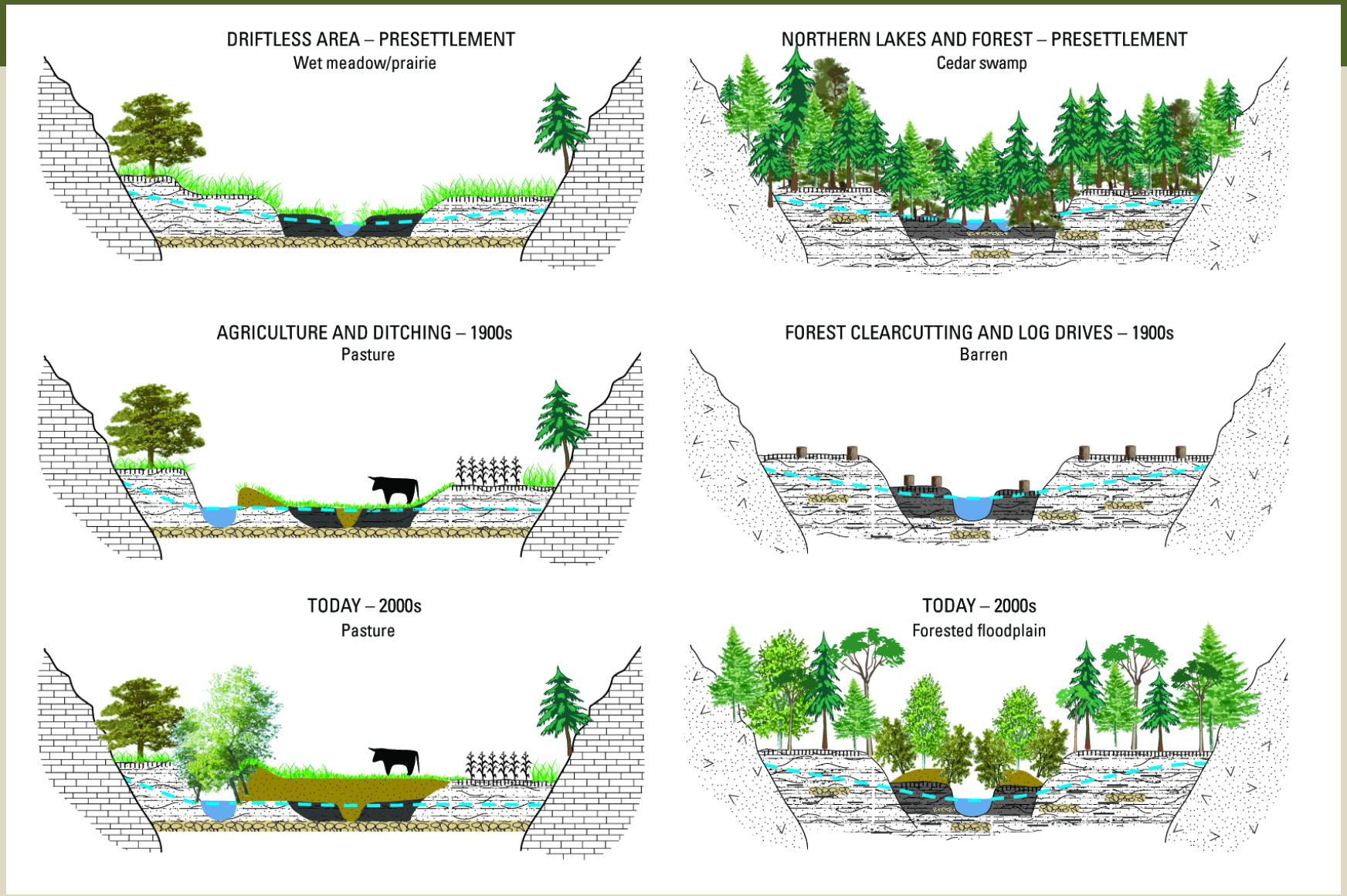
Evolution of Midwest lowland streams



(Fitzpatrick and Hansis, in prep)

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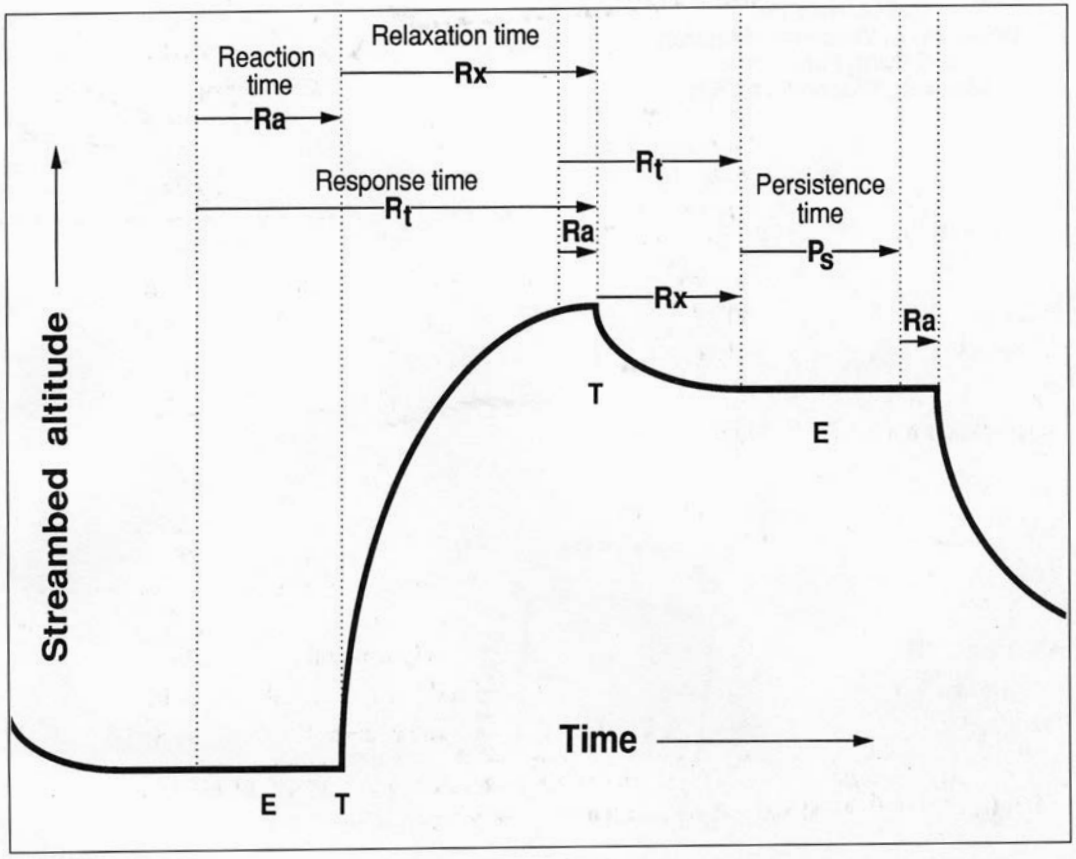
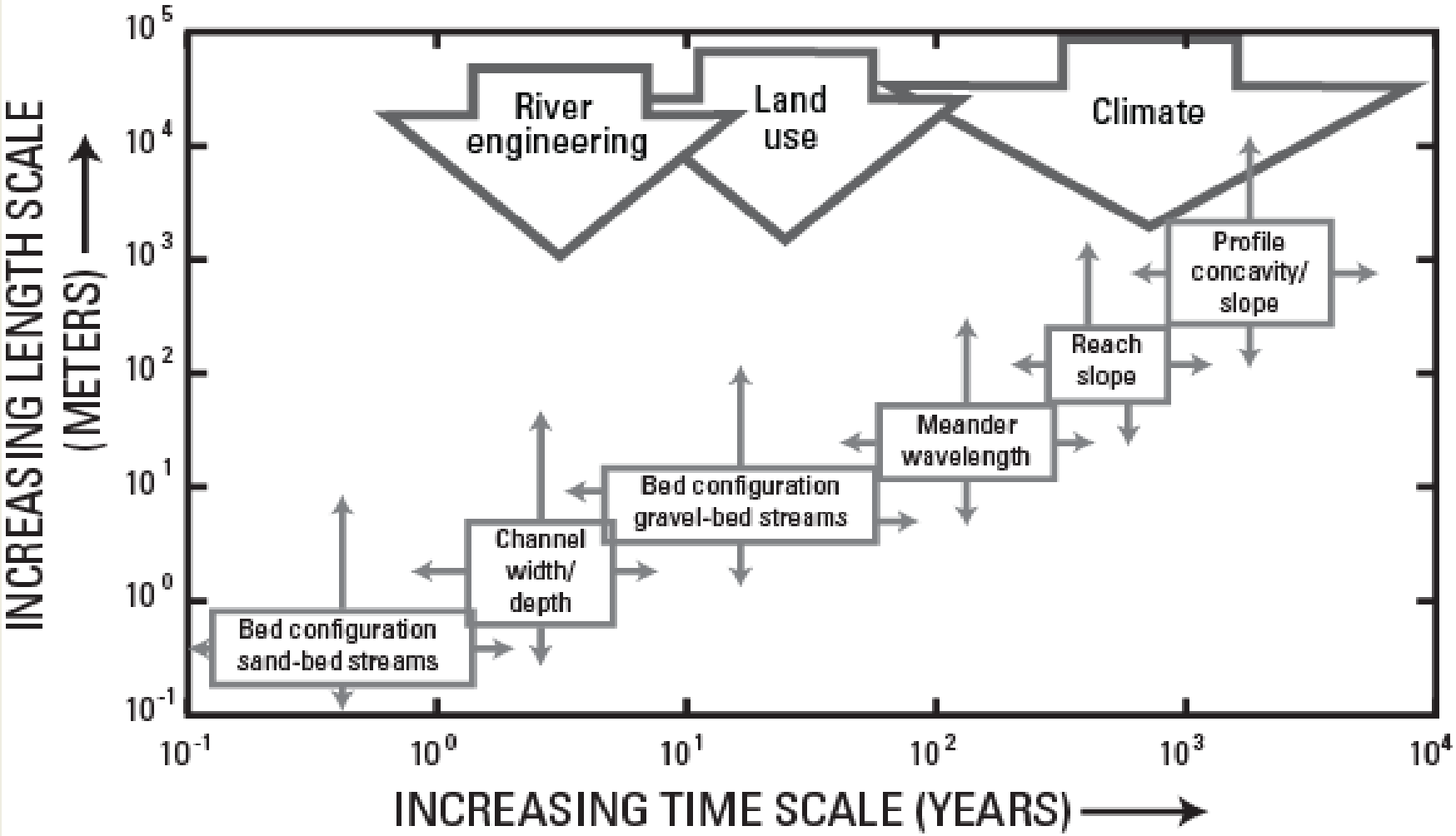
Geomorphic Responses and Time

(Bull, 1991, “Geomorphic response to climate change”)

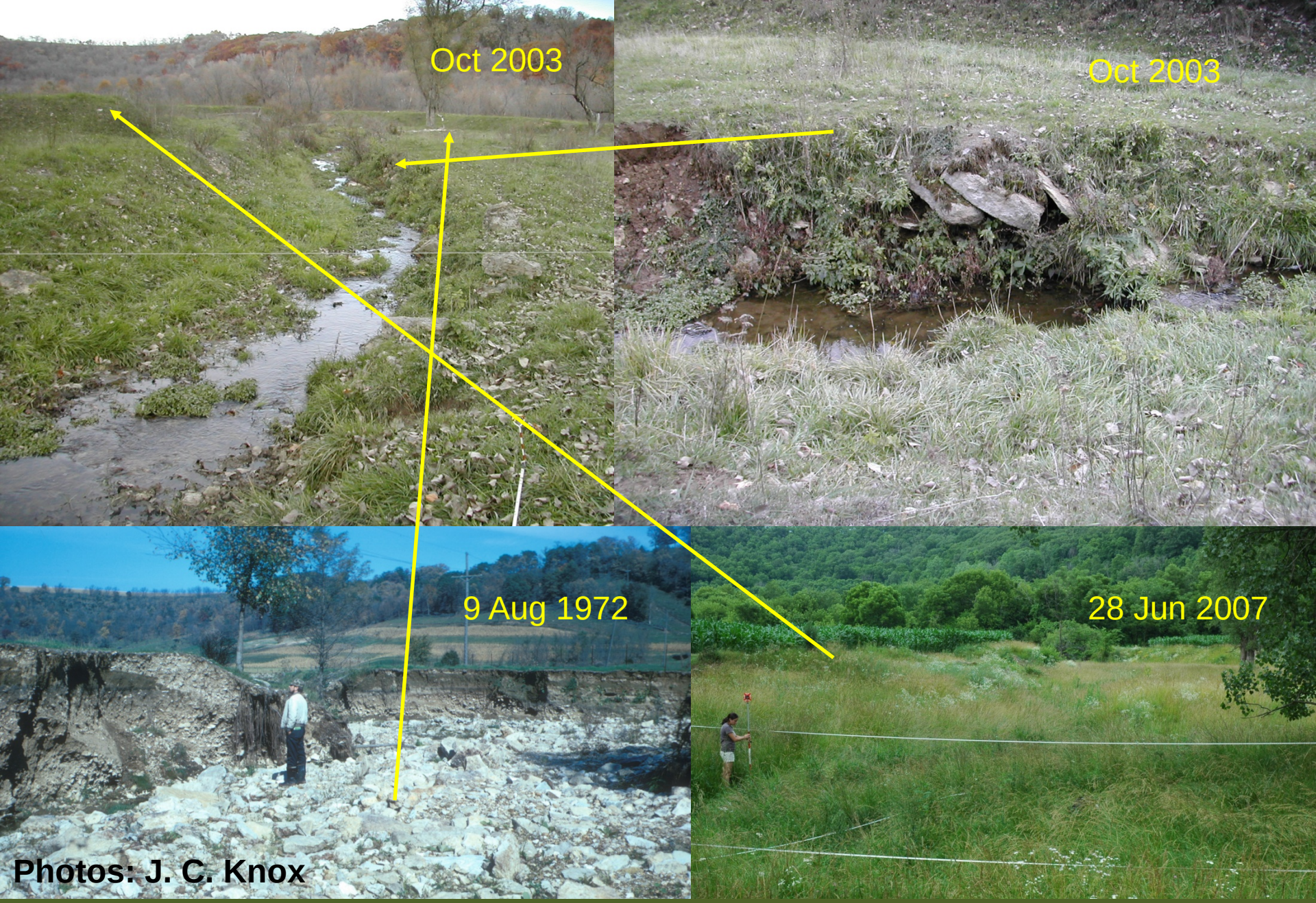


Changes in streambed altitude caused by aggradation and degradation are used as a reference plot to show the components of response time. R_t, response time, is the sum of the reaction time, Ra, and relaxation time, Rx. P_s is the time of persistence of new equilibrium conditions, and T and E are threshold and equilibrium conditions, respectively.



The importance of spatial and temporal scale in determining potential geomorphic responses (modified from Newson and Sear 1993).

(Fitzpatrick and Peppler, 2007)



Geomorphic Response to Extreme Events

Irrigation and Biofuel Production

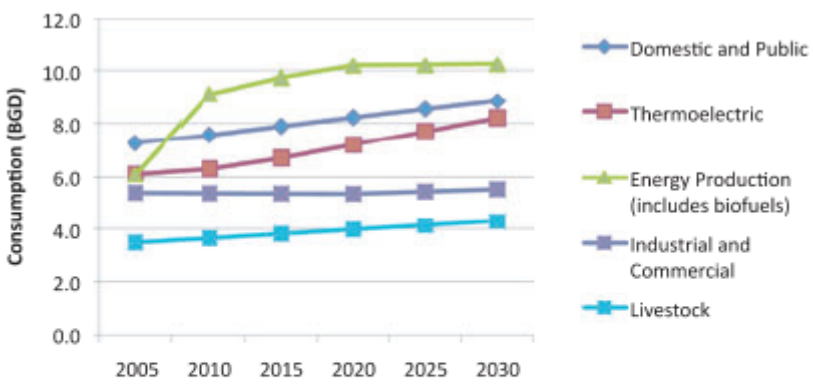


FIGURE 1. Projected Water-Consumption Estimates for the Energy Production and Nonenergy Production Sectors (Except Irrigation). Note that over the projection period, water consumption increases faster for energy production than for other sectors.

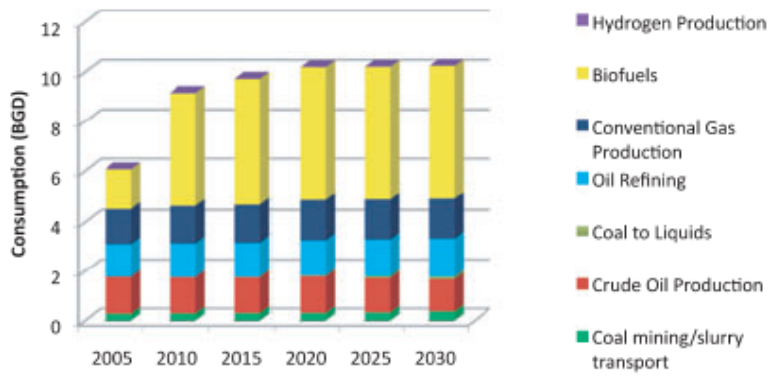


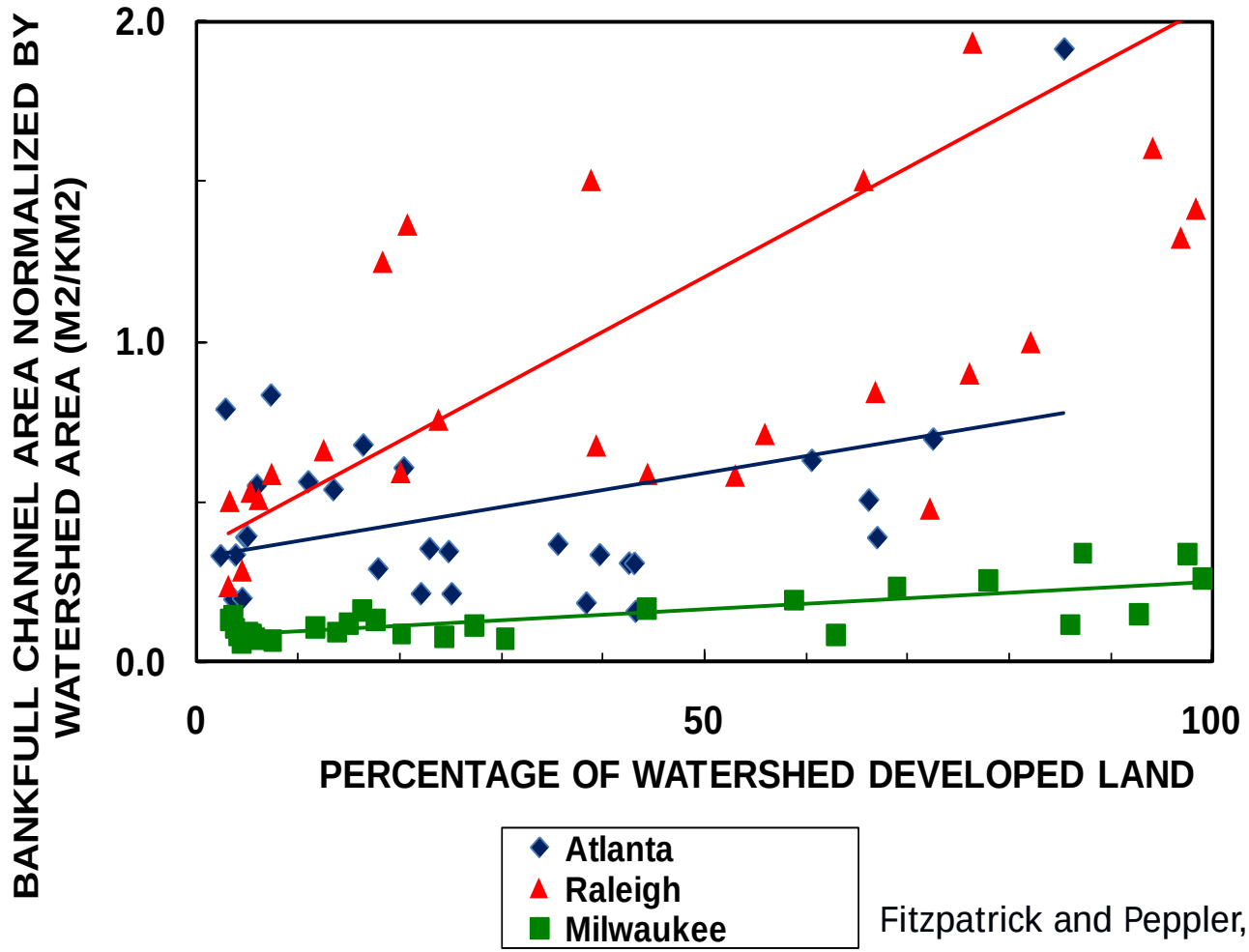
FIGURE 2. Projected Water Consumption for Energy Production Sectors, 2005-2030. Note that biofuels production is projected to consume about half of the water consumed by all energy-production sectors over most of the projection period.

Elcock, D. 2010. Future U.S. Water Consumption: The Role of Energy Production. *Journal of the American Water Resources Association* (JAWRA) 46(3):447-460

USGS

Channel size increases with increasing urbanization

Confounding factors: water diversions and storage, historical channel alterations, dams, difficulty in identifying bankfull elevation



Fitzpatrick and Peppler, 2010

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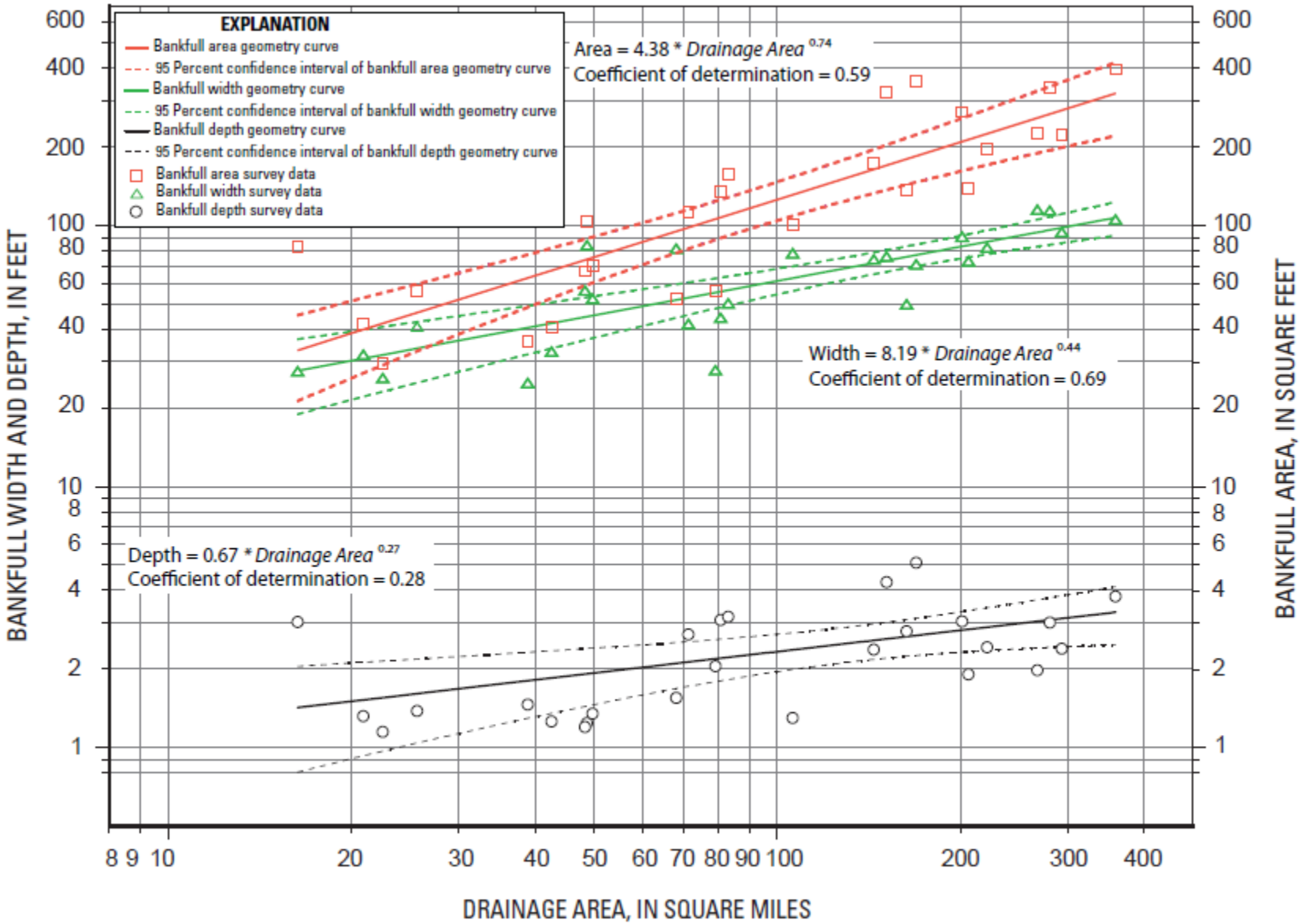
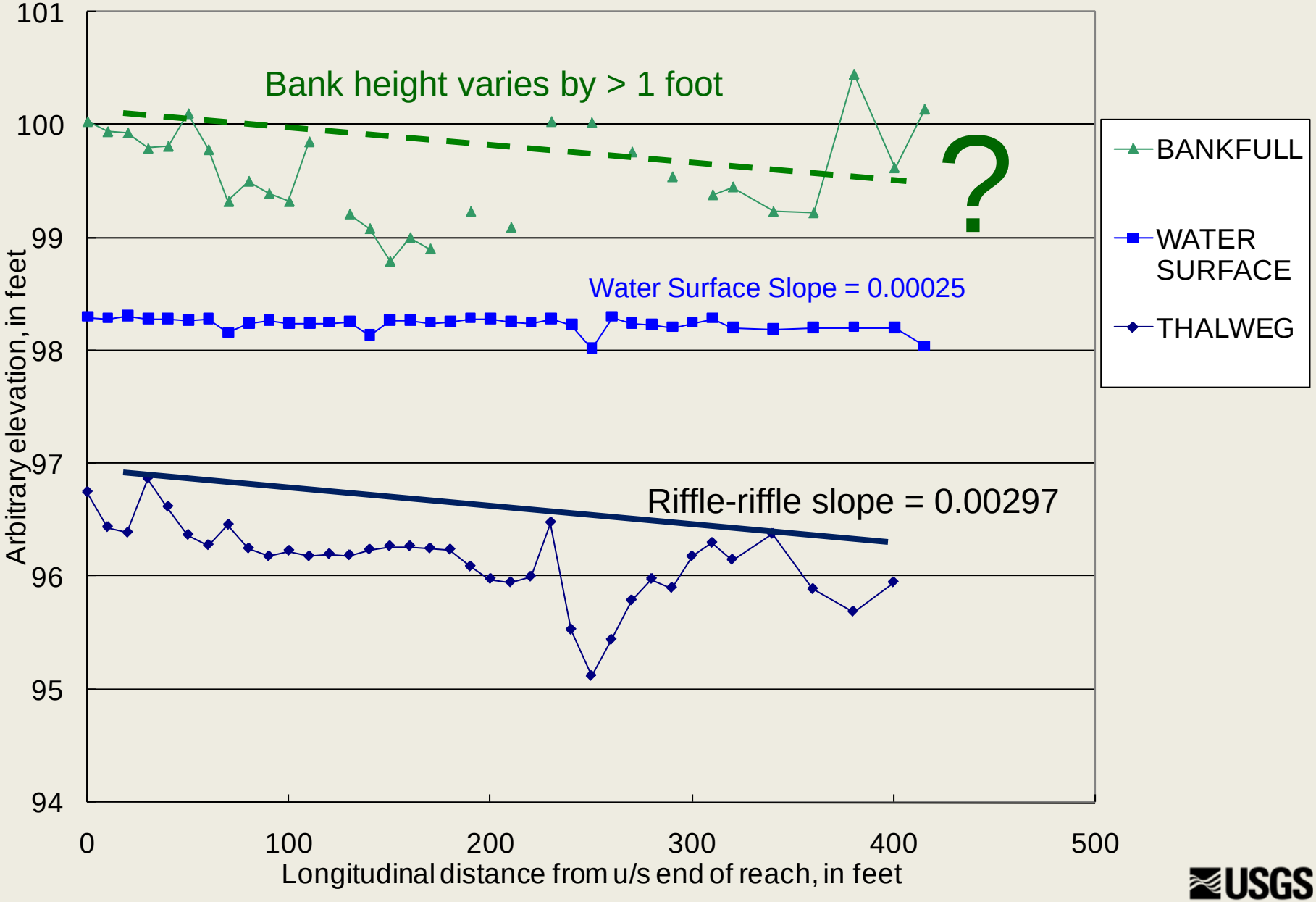


Figure 10. Regional bankfull width, depth, and area curves for the Southern Lower Michigan Ecoregion. (Rachol and Boley-Morse, 2009)

Middle Branch Escanaba River, October 2009 longitudinal profile



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Base-flow channels?

- Once common across the Midwest?
- Direct connection between stream and floodplain
- Rich habitat for multiple types and ages of organisms
- Promote sediment and organic matter deposition
- Transform nutrients into biomass
- Sequester carbon

Mecan River, Wisconsin April 2011

Howards Branch Ann Arundel County; Berg, Biohabitats; Inc.; Keith Underwood & Assoc.

USGS

Concluding Thoughts about Midwestern Streams

- Glacial landforms give diverse stream geomorphic settings
- Human disturbance has altered and limited the diversity of natural stream geomorphic settings, especially in wetlands
- Knowing the history of human alterations and stream responses helps to determine appropriate management and rehabilitation strategies
- Widespread usage of channel design based on 1.5-yr bankfull hydraulic geometry limits geomorphic diversity especially in wetland settings