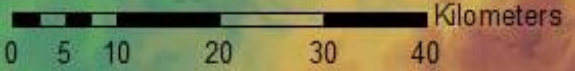
Role of geomorphic and recent history on near-channel erosion

Karen Gran
UMD Geological Sciences
Near-channel Sediment Source Management Forum
Mankato, MN
January 4, 2012

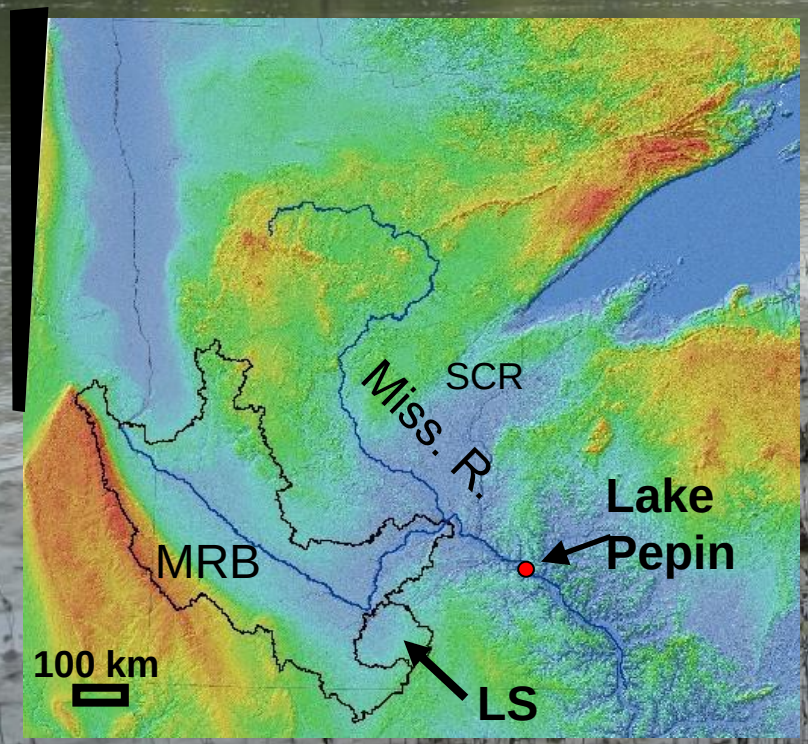
Funding provided by MPCA and NSF



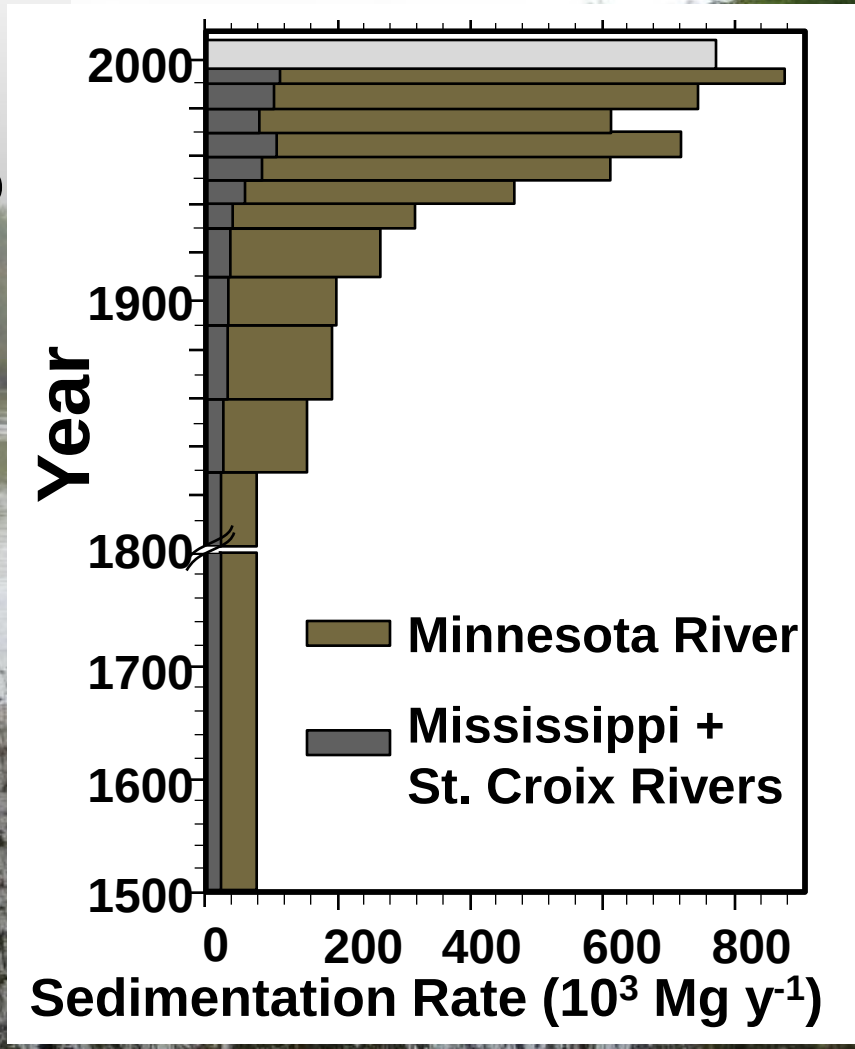

Le Sueur River

Minnesota River contributes ~85-90% of sediment to Lake Pepin
(Kelley and Nater, 2000)

Le Sueur River contributes ~25-30% of sediment to Minnesota River
(MPCA et al., 2007)



Lake Pepin

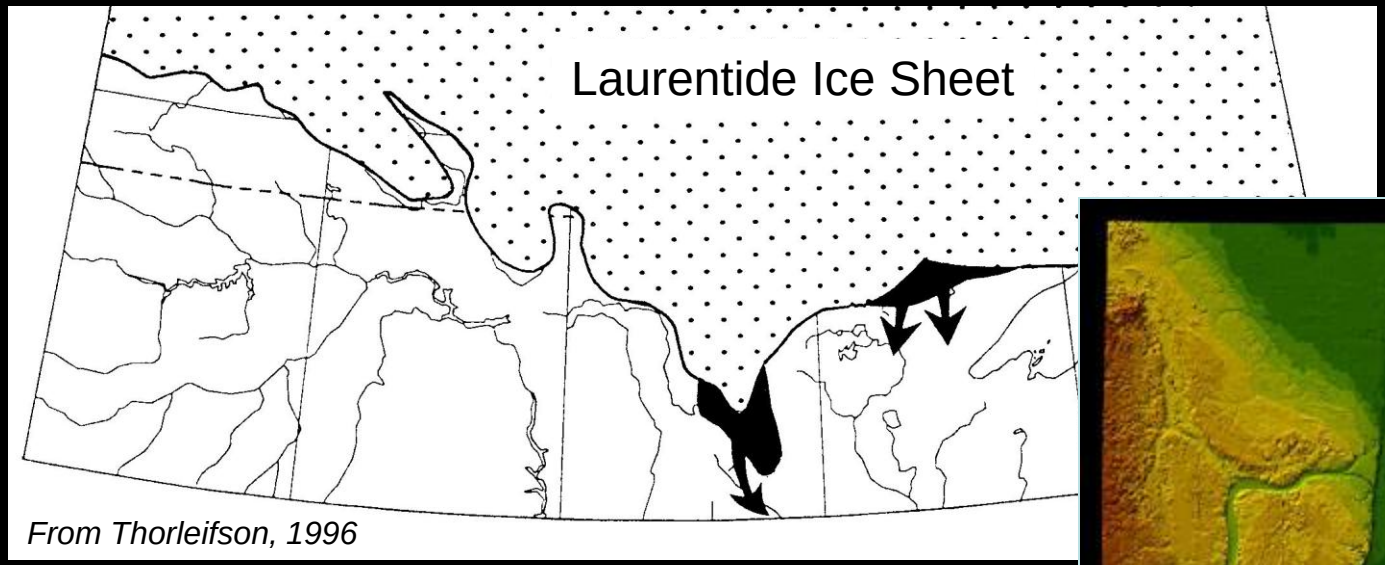


From Engstrom et al. Kelley & Nater

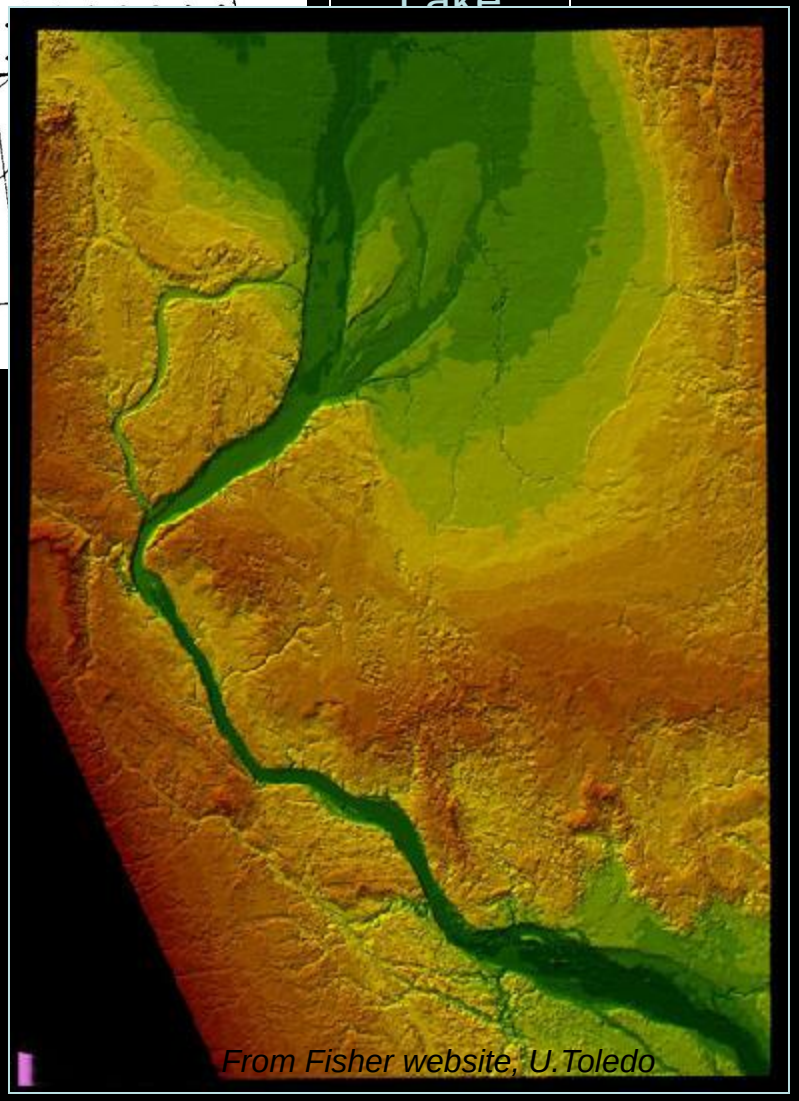
Big questions

- What is the role of geomorphic history on modern sediment loading?
  - How has the valley evolved through time?
  - What is the natural (pre-settlement) sediment load?
- Where is sediment derived in the modern system?
  - How much is natural and how much is anthropogenic?
- **What can we do to reduce sediment loads?**

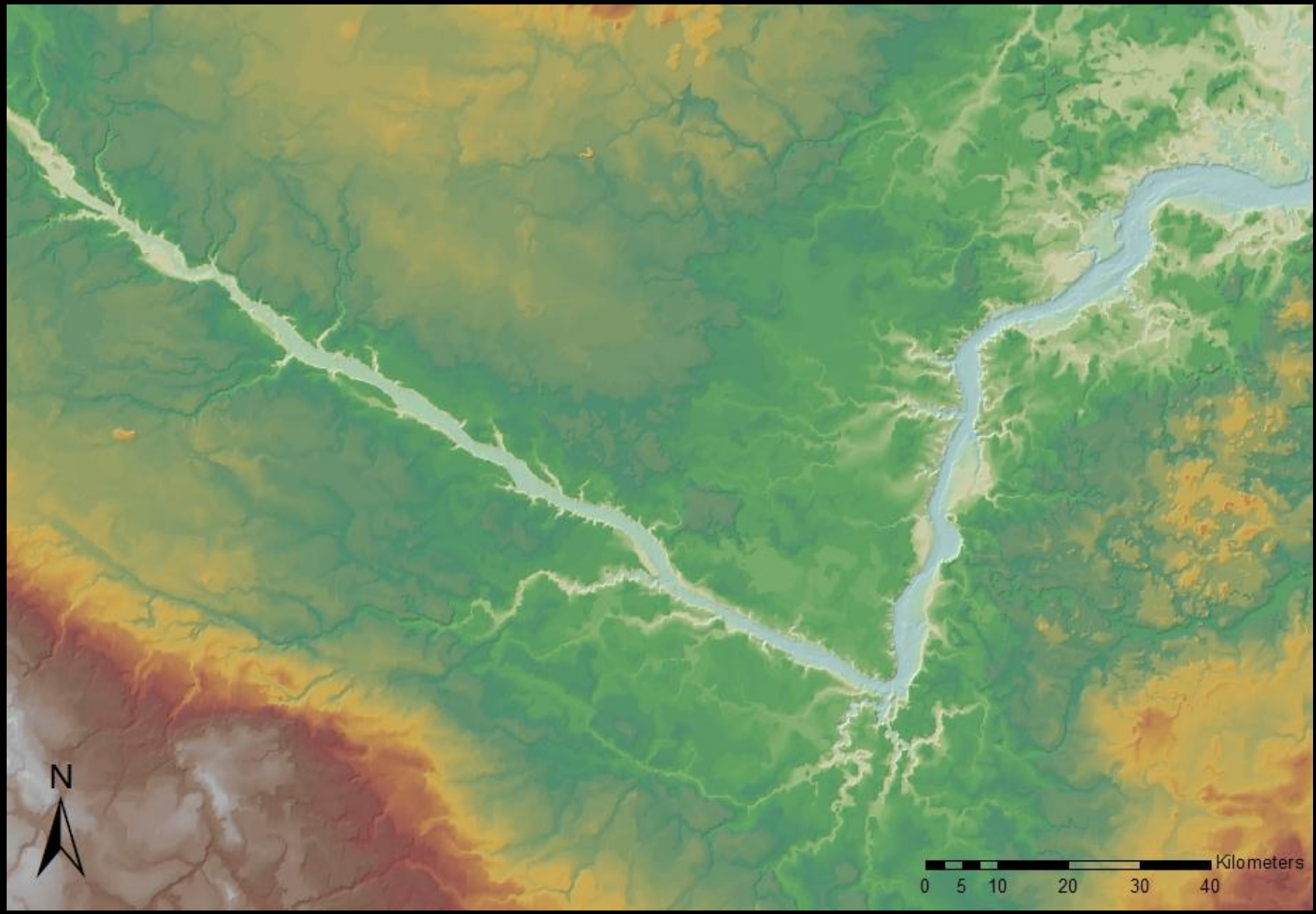
Glacial Lake Agassiz, 11,500 rc yr BP (13,400 cal yr BP)

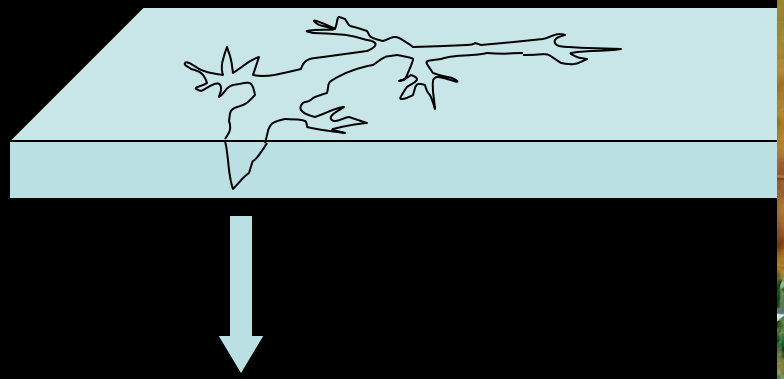


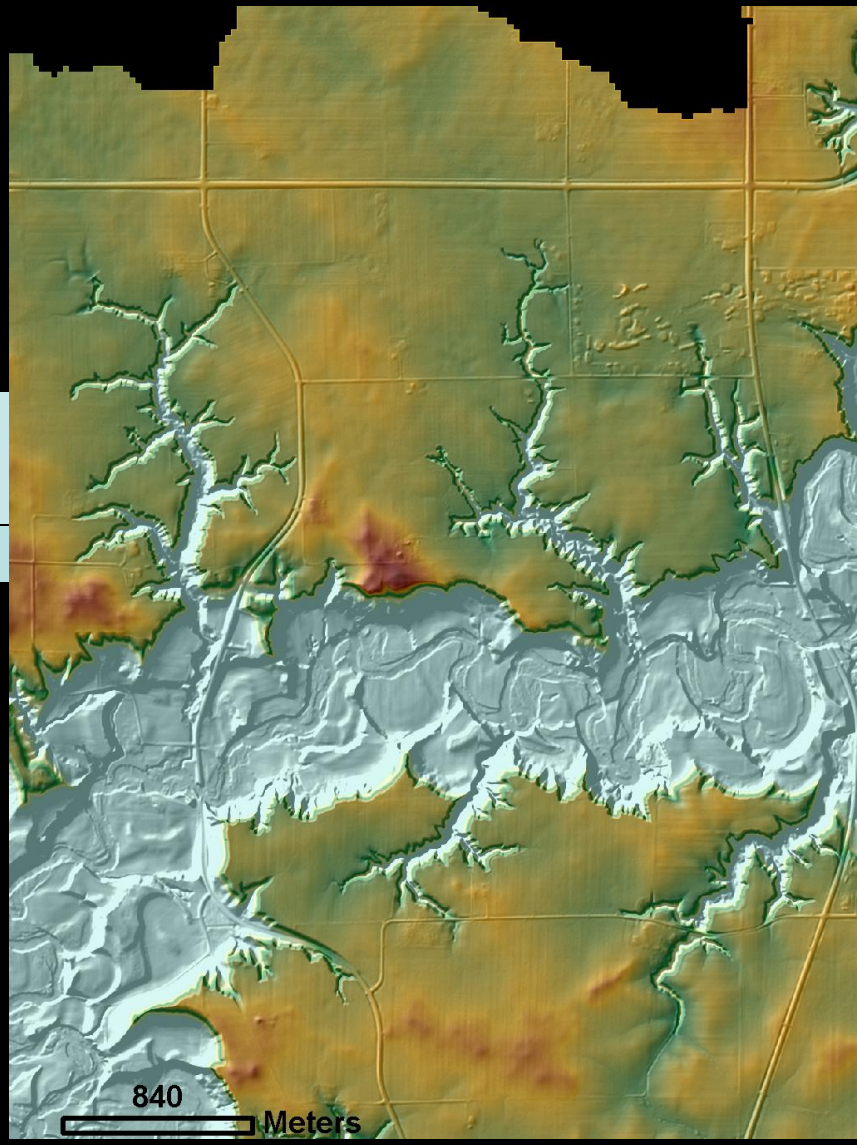
From Thorleifson, 1996

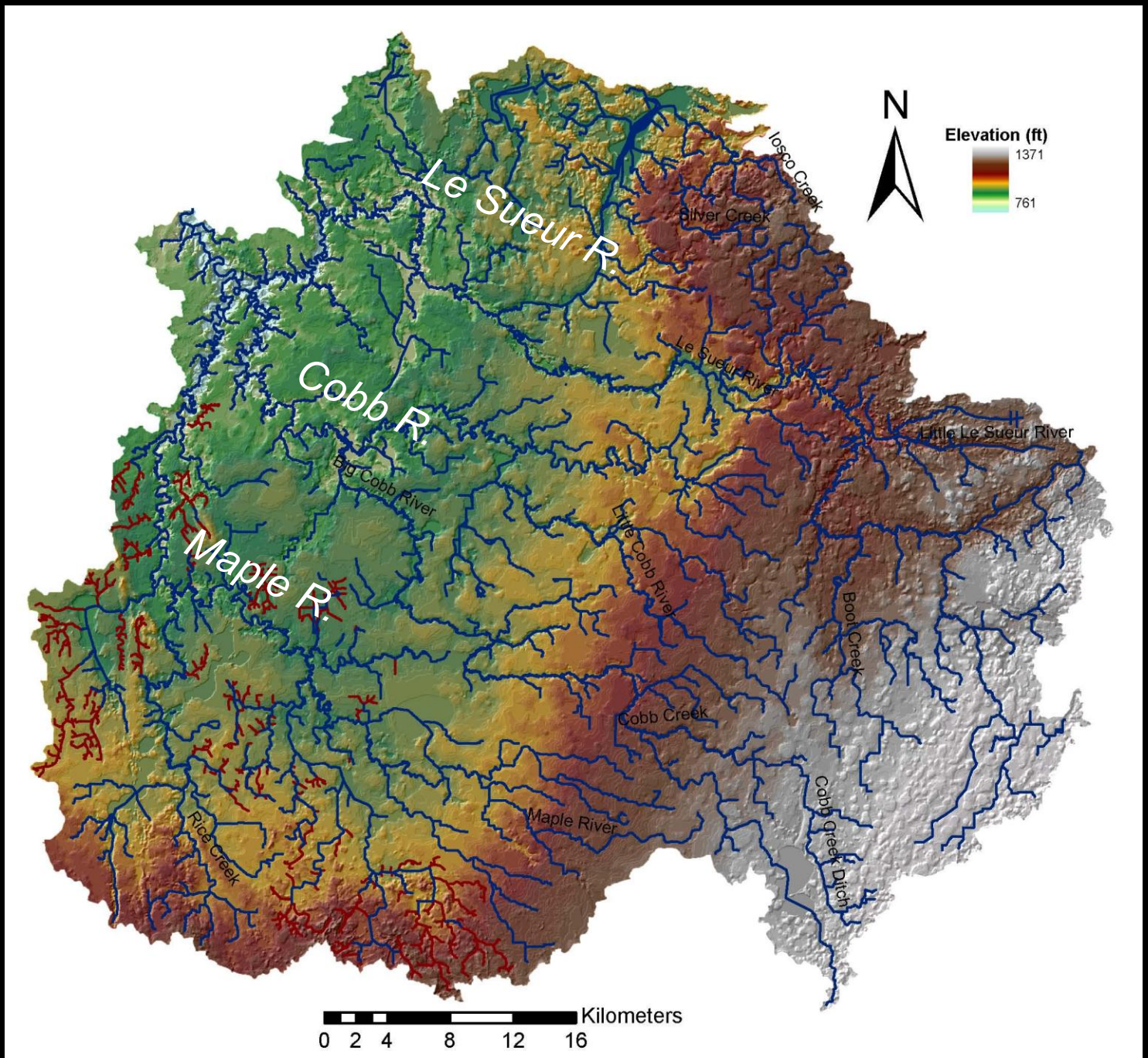


From Fisher website, U.Toledo

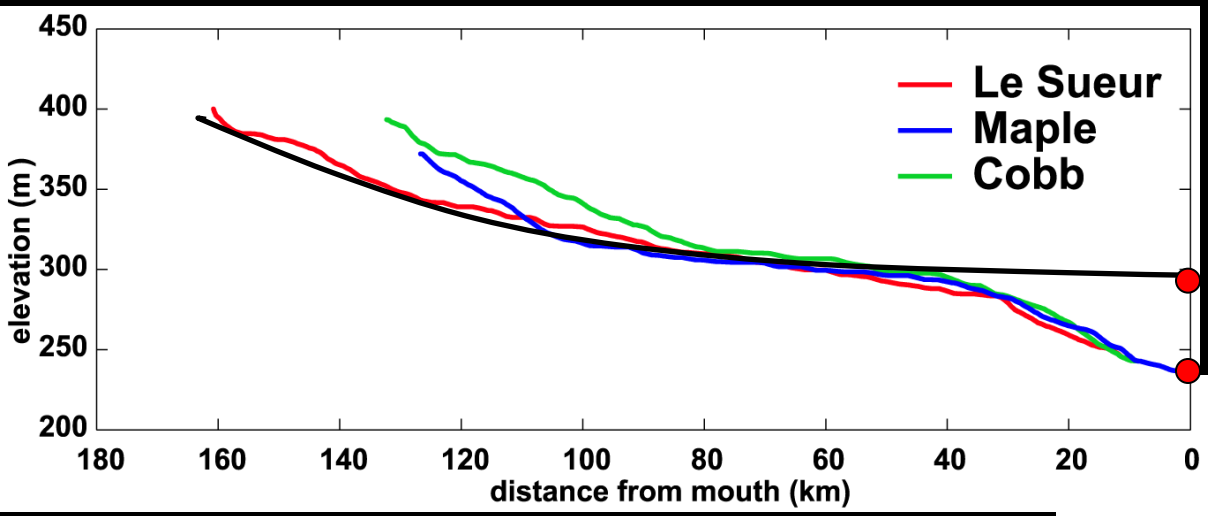

N
0 5 10 20 30 40
Kilometers

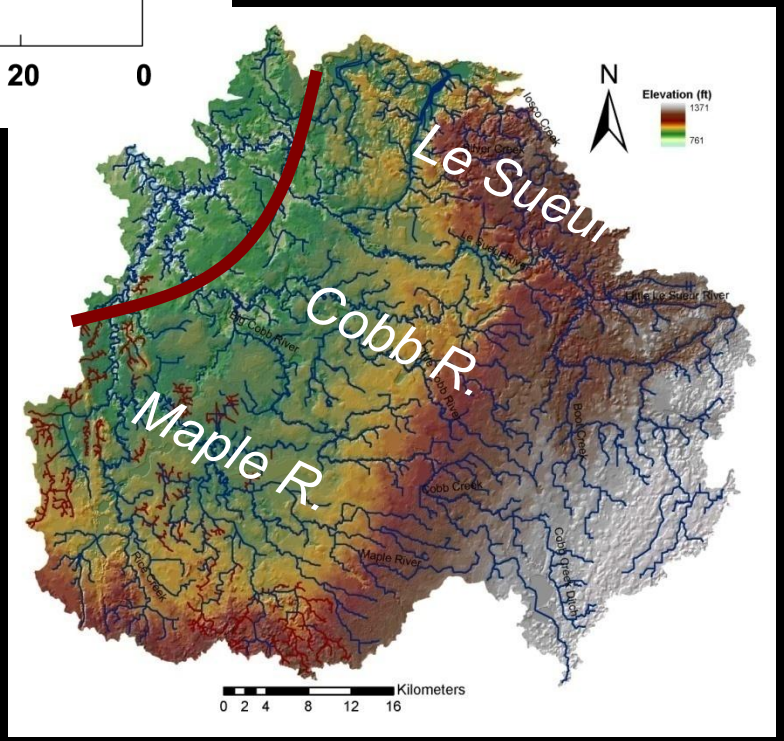



840
Meters


N
Elevation (ft)
1371
761
Le Sueur R.
Cobb R.
Maple R.
Iosco Creek
Silver Creek
Le Sueur River
Little Le Sueur River
Big Cobb River
Little Cobb River
Boot Creek
Cobb Creek
Cobb Creek Ditch
Maple River
Rice Creek
Kilometers
0 2 4 8 12 16

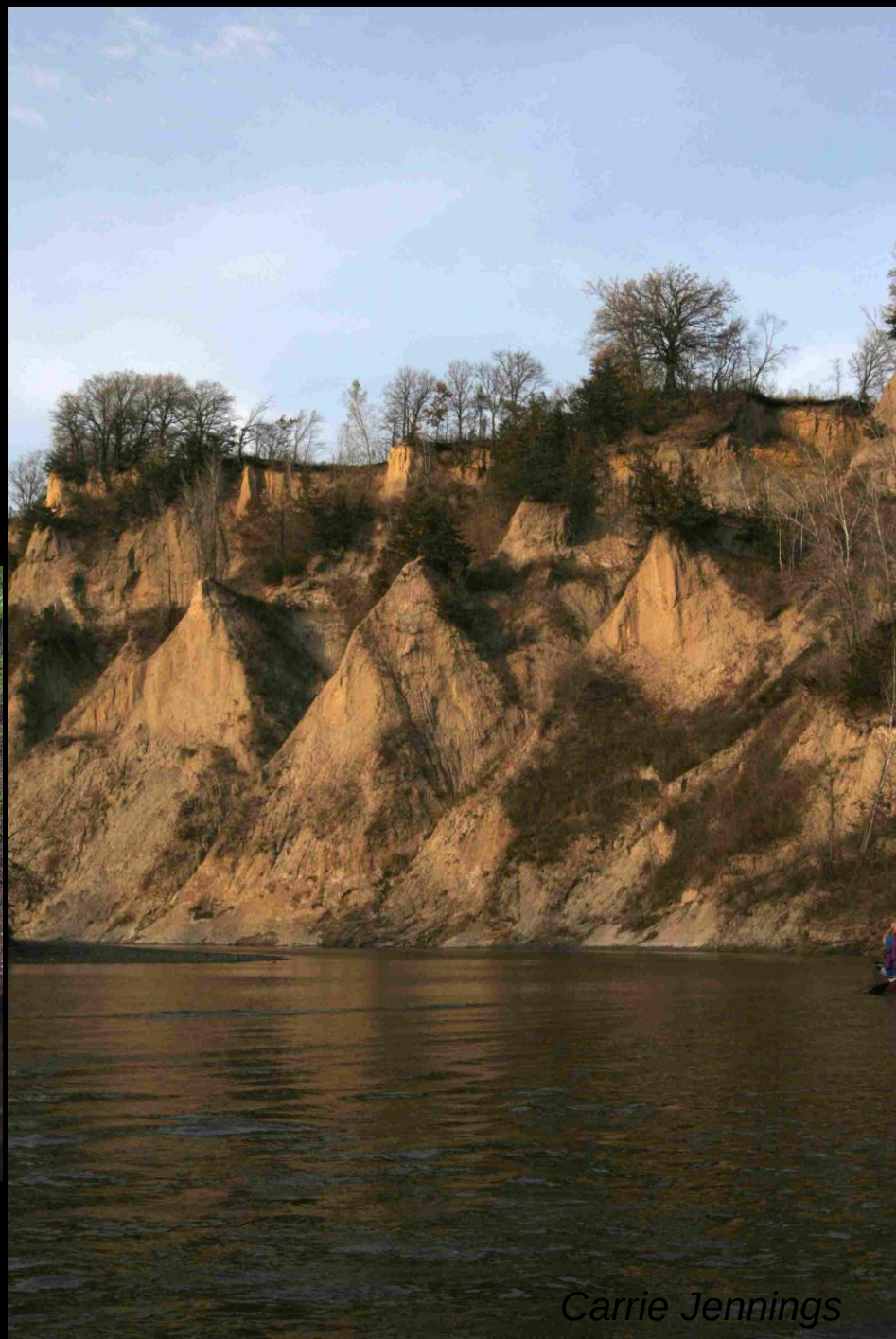
River Longitudinal Profiles



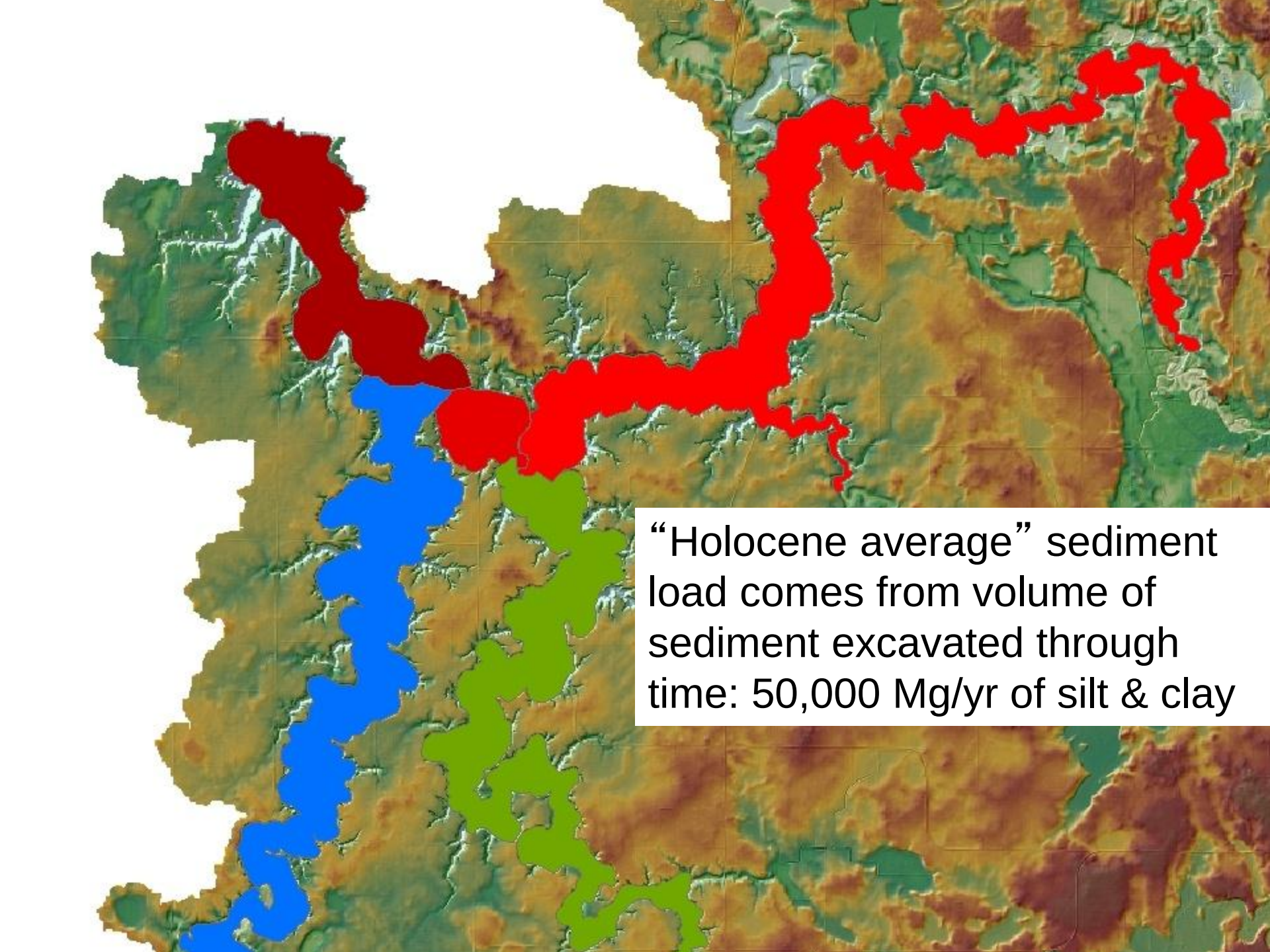


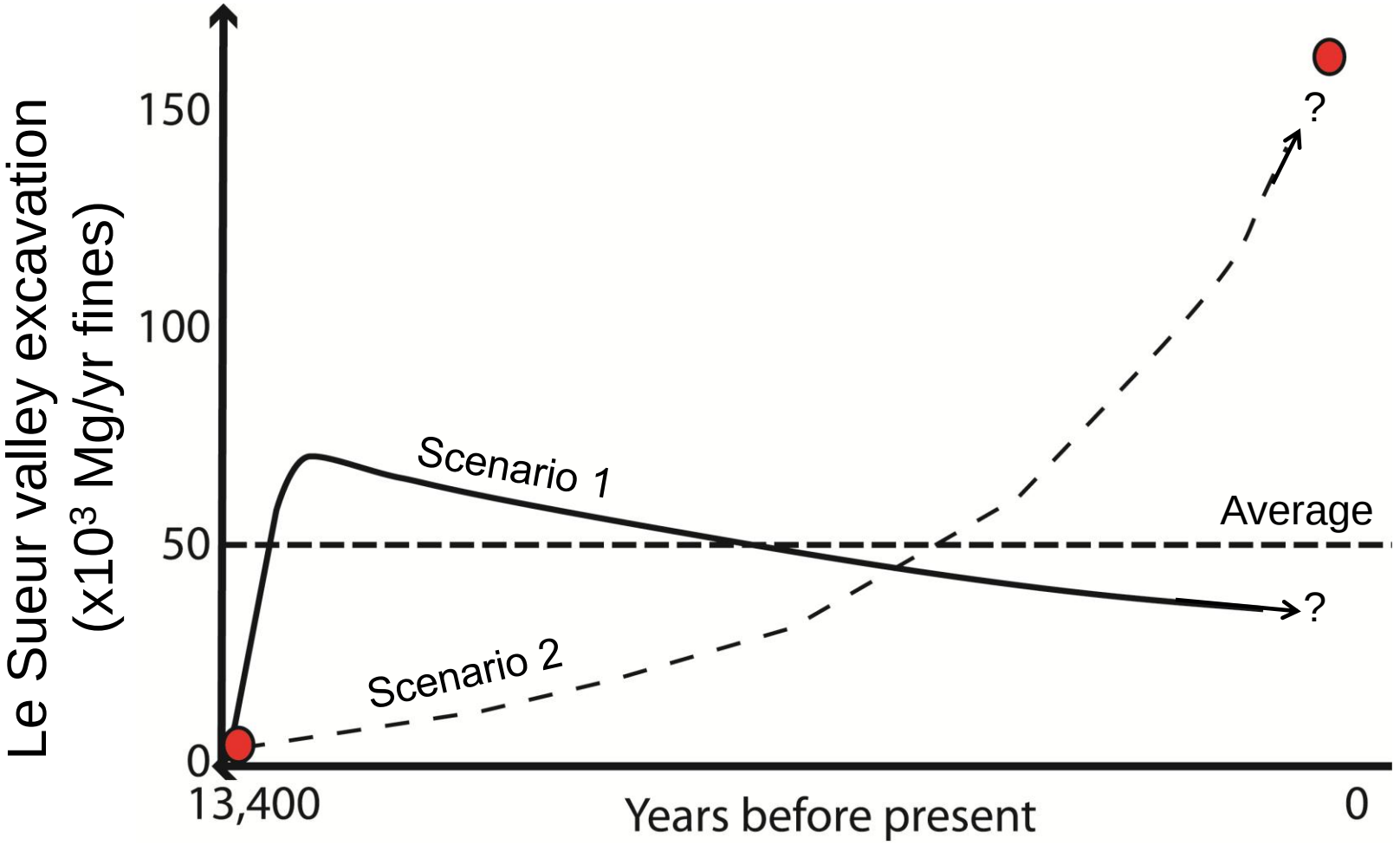
Above the knick zone

Below the knick zone



Carrie Jennings


“Holocene average” sediment load comes from volume of sediment excavated through time: 50,000 Mg/yr of silt & clay


Le Sueur valley excavation
(x10³ Mg/yr fines)
150
100
50
0
13,400
Years before present
0
Scenario 1
Scenario 2
Average
?
?

Record of incision is recorded in terraces throughout lower basin

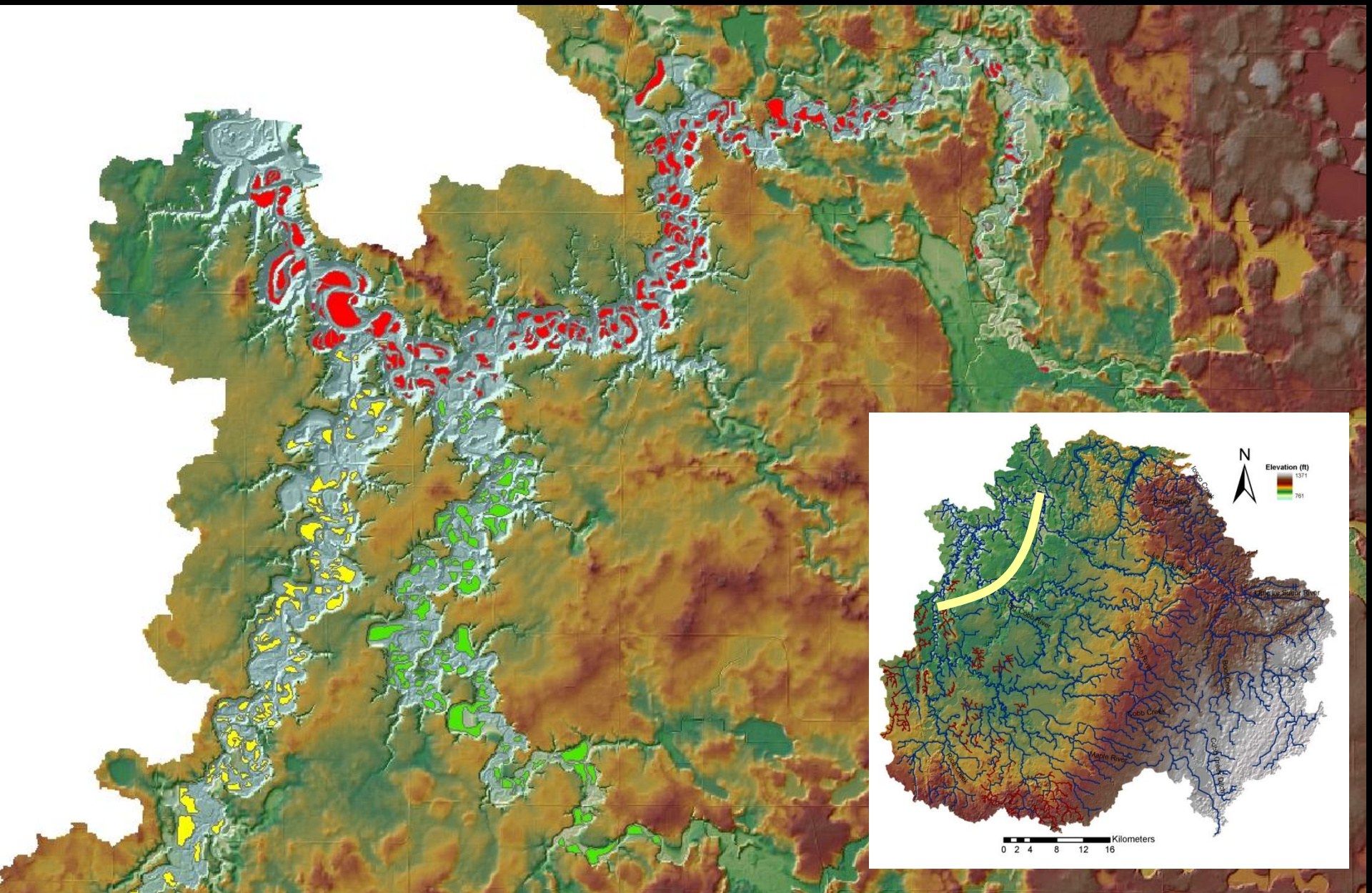
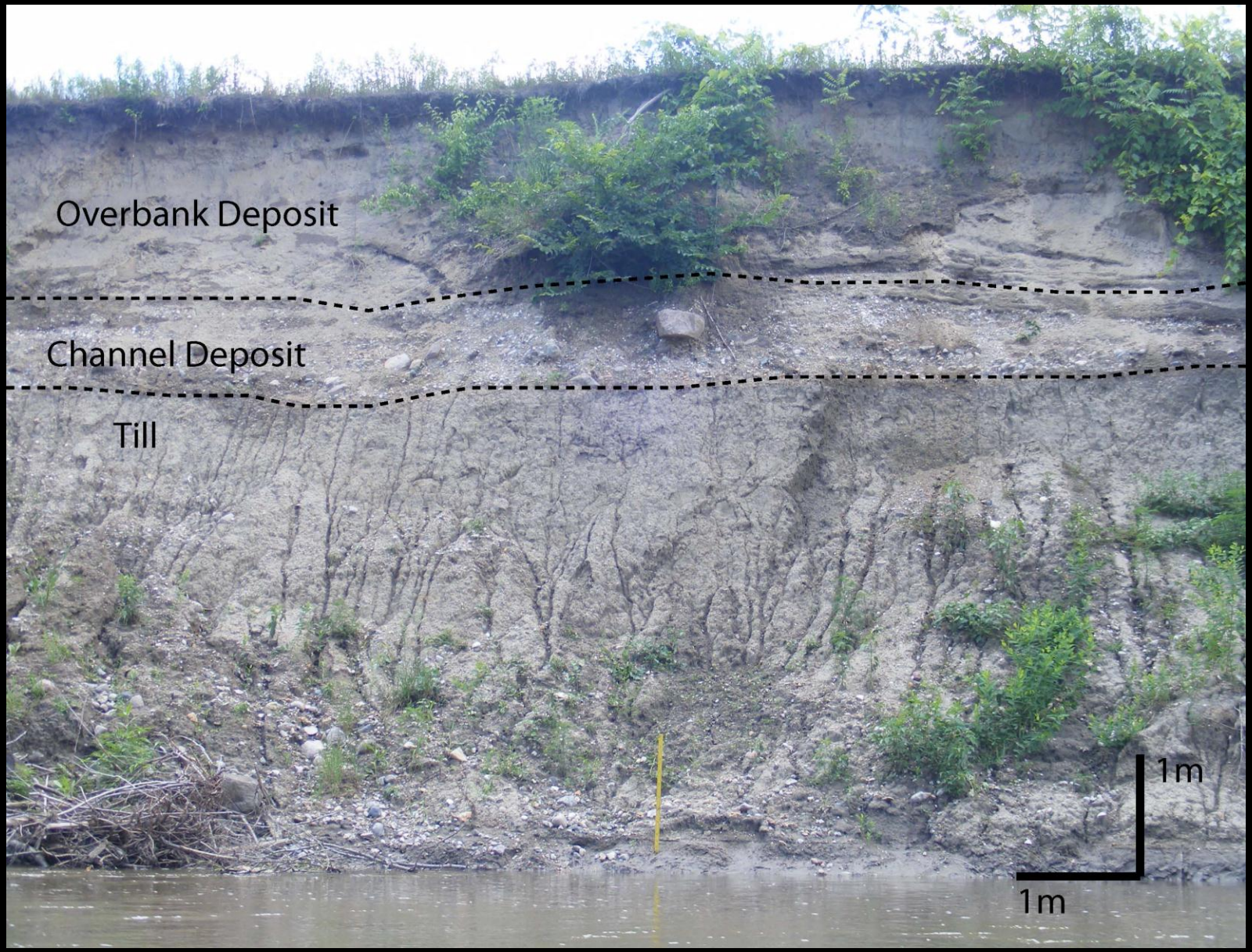
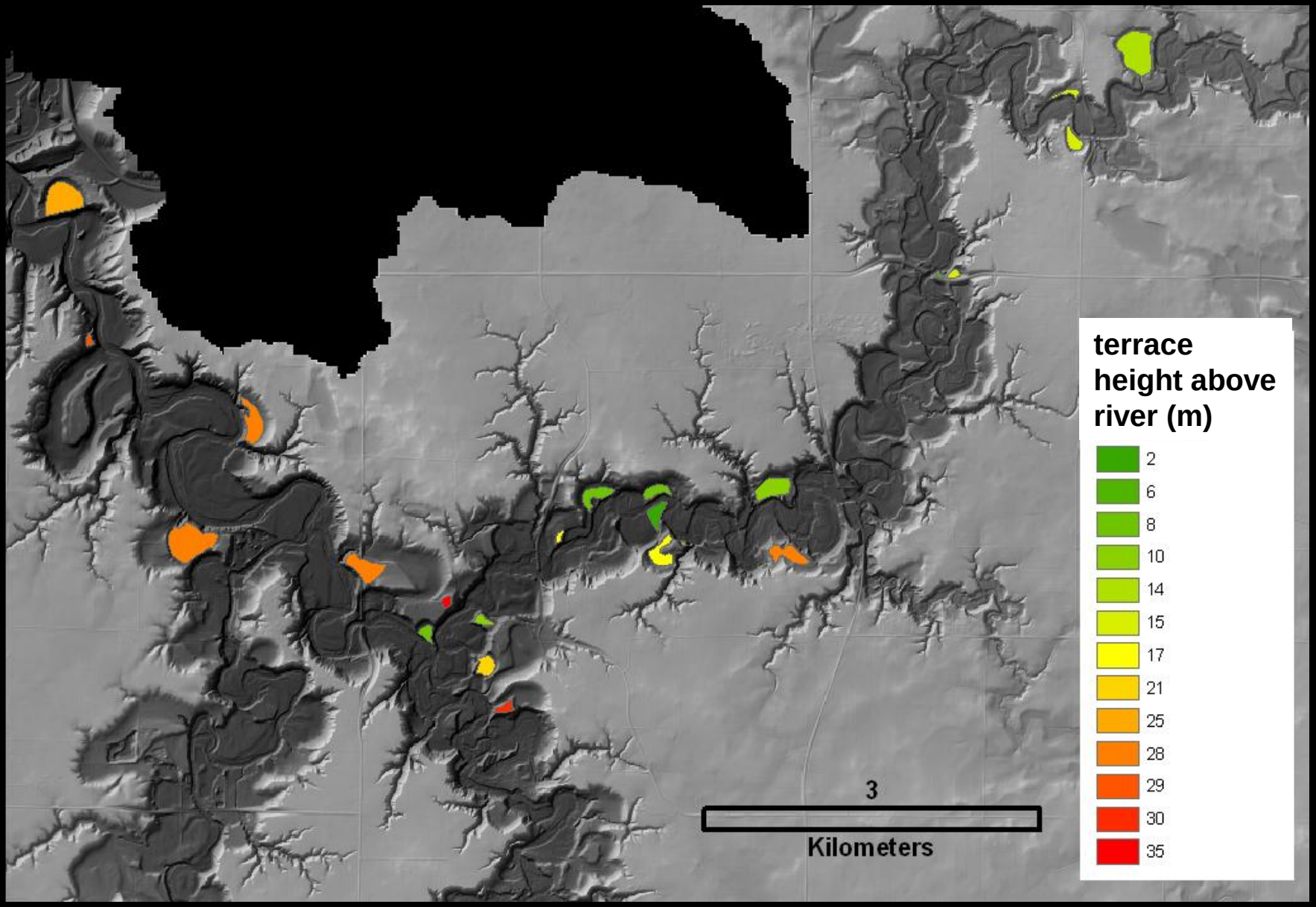



Photo by C. Jennings
Terrace sediment
Native material (till)


Overbank Deposit
Channel Deposit
Till
1m
1m

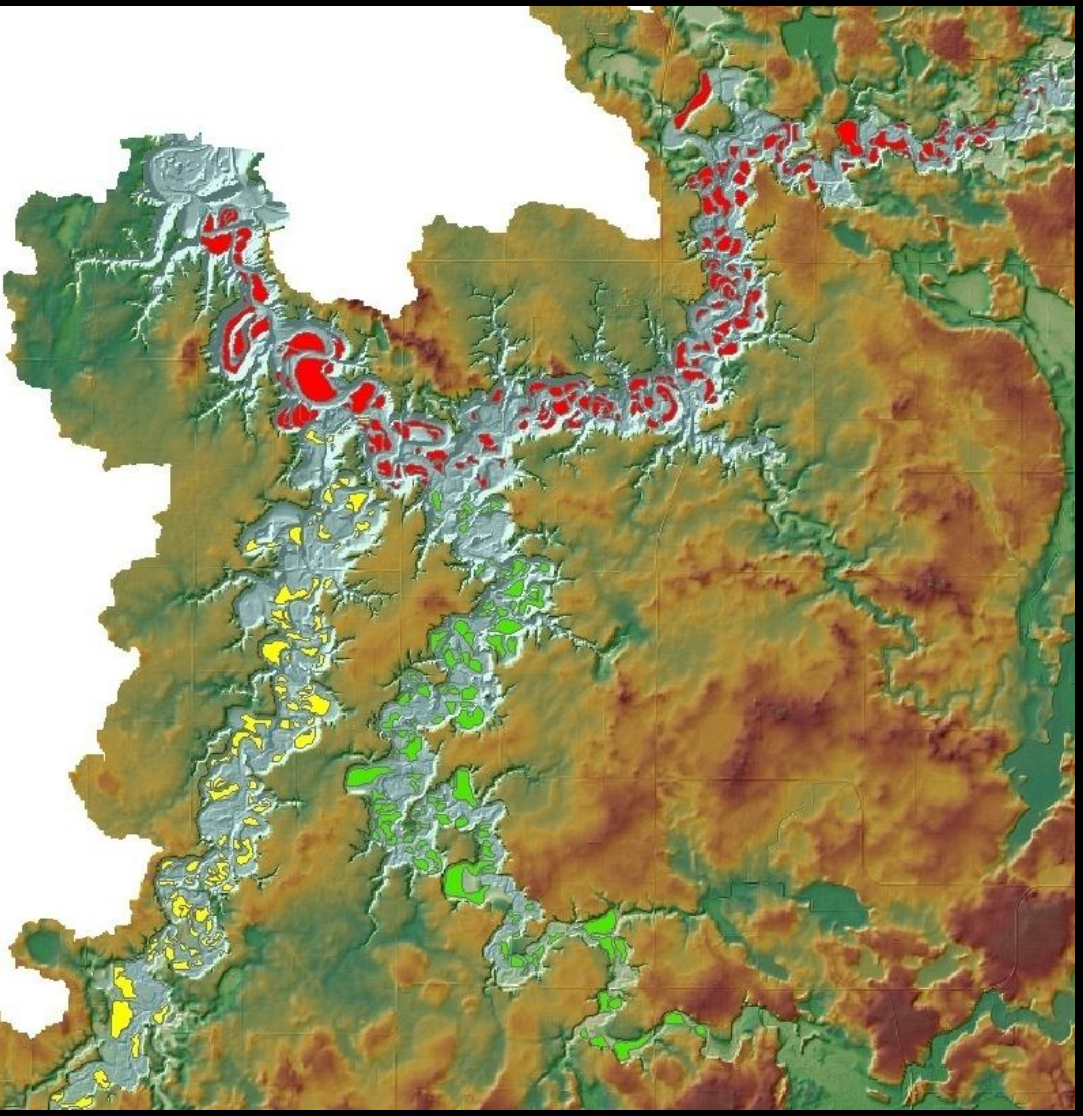
A. Johnson

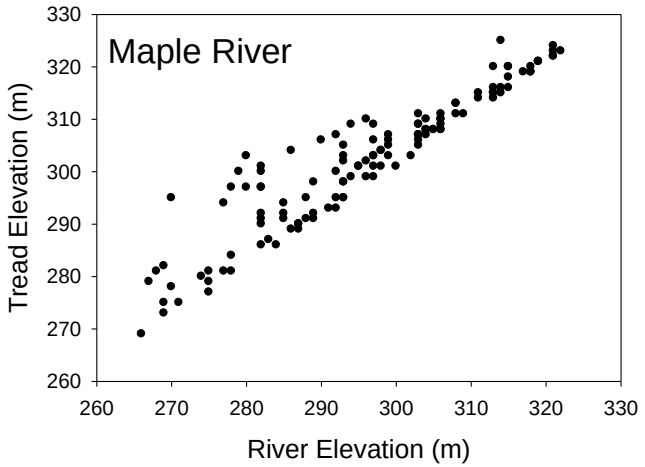
Constraining Holocene incision history

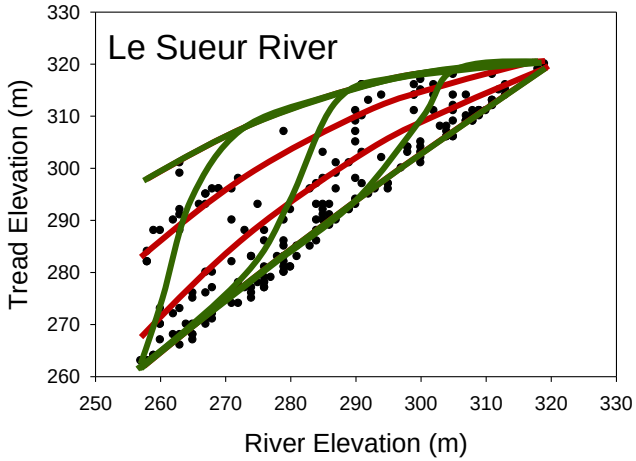


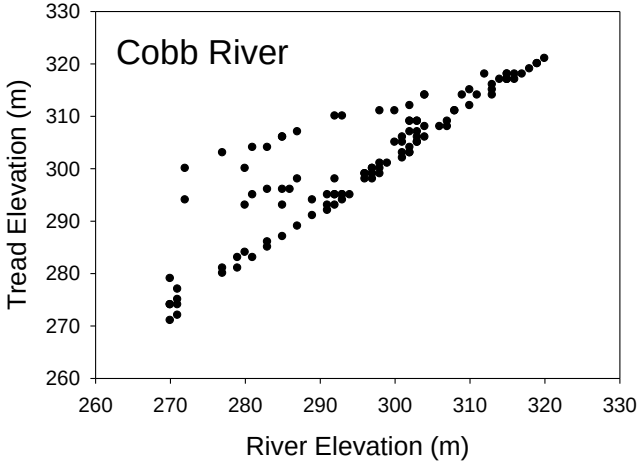
Fluvial Terraces

The Record of Incision





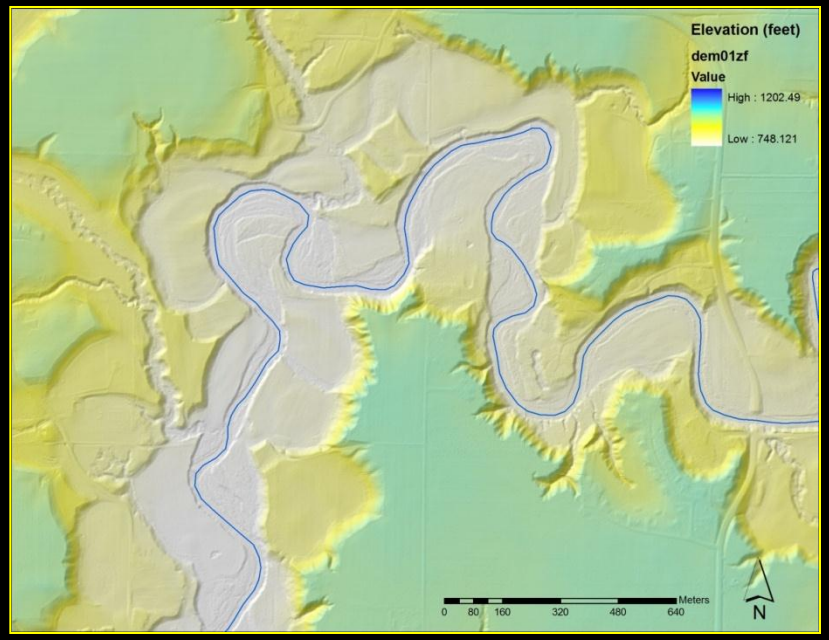


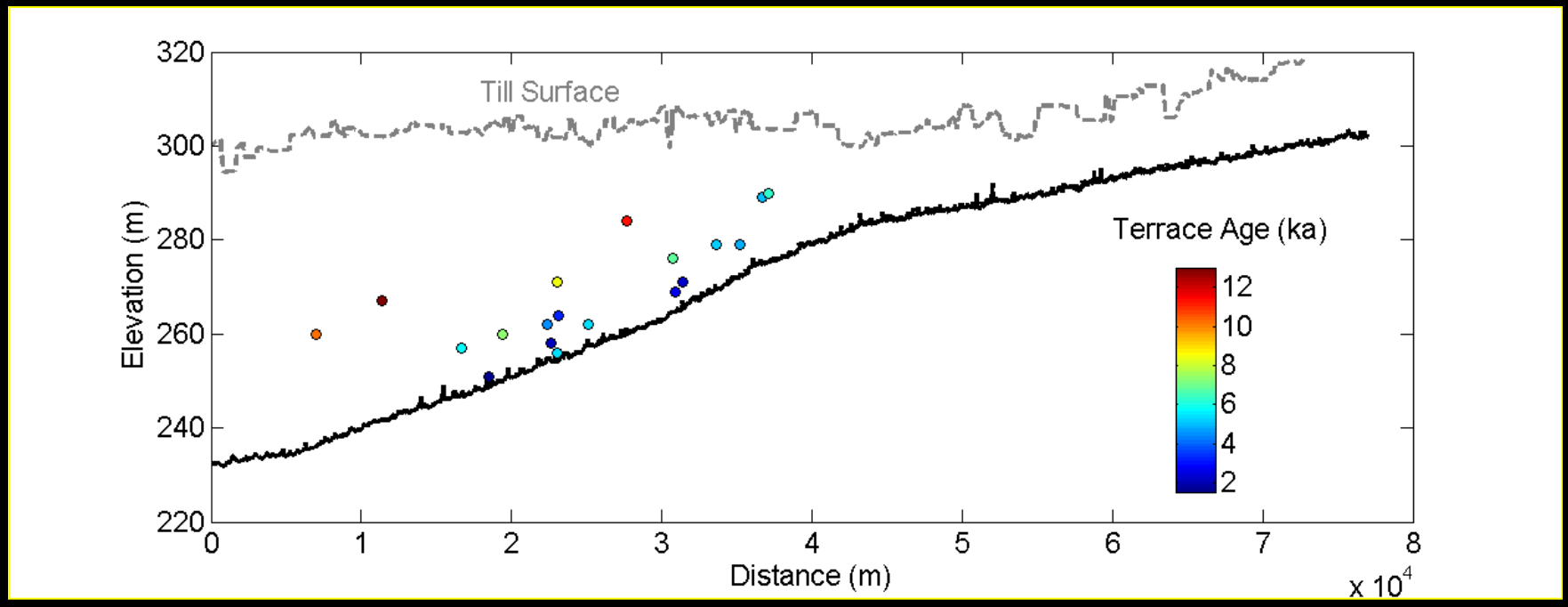


Pre-settlement conditions

Constraints on Holocene Incision History of the Le Sueur

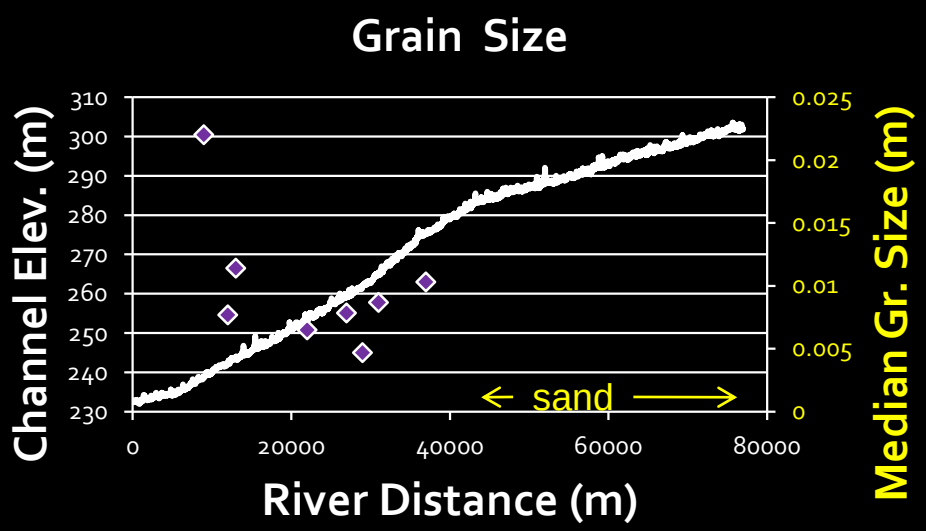
- 22 OSL & ^{14}C dates on strath terraces
- 60-70 m incision at 13,400 cal yr ago)
- Hydraulic geometry (width, depth) from modern channel





Finnegan et al., 2010

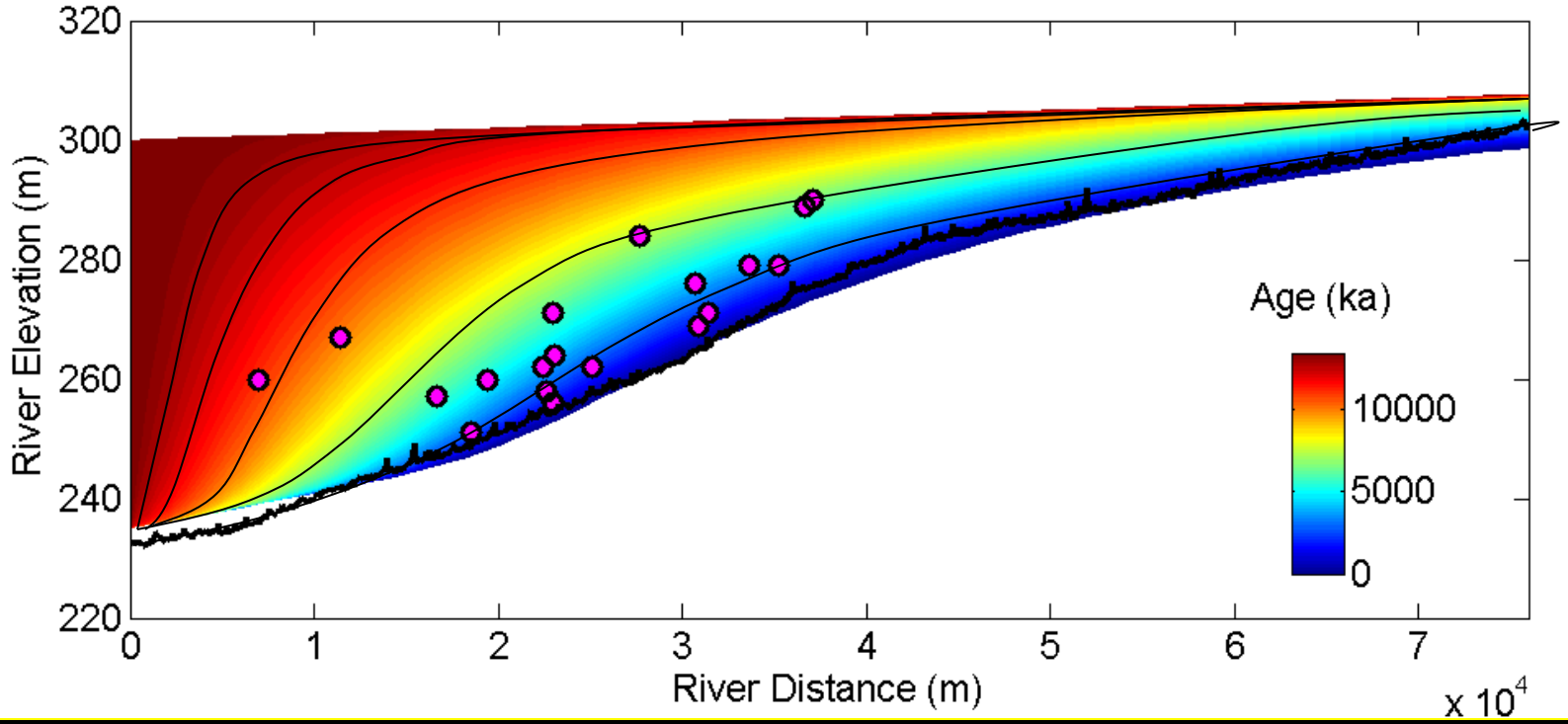

Tills are source of coarse material


Grain Size
Channel Elev. (m)
310
300
290
280
270
260
250
240
230
0
20000
40000
60000
80000
River Distance (m)
← sand →
0.025
0.02
0.015
0.01
0.005
0
Median Gr. Size (m)

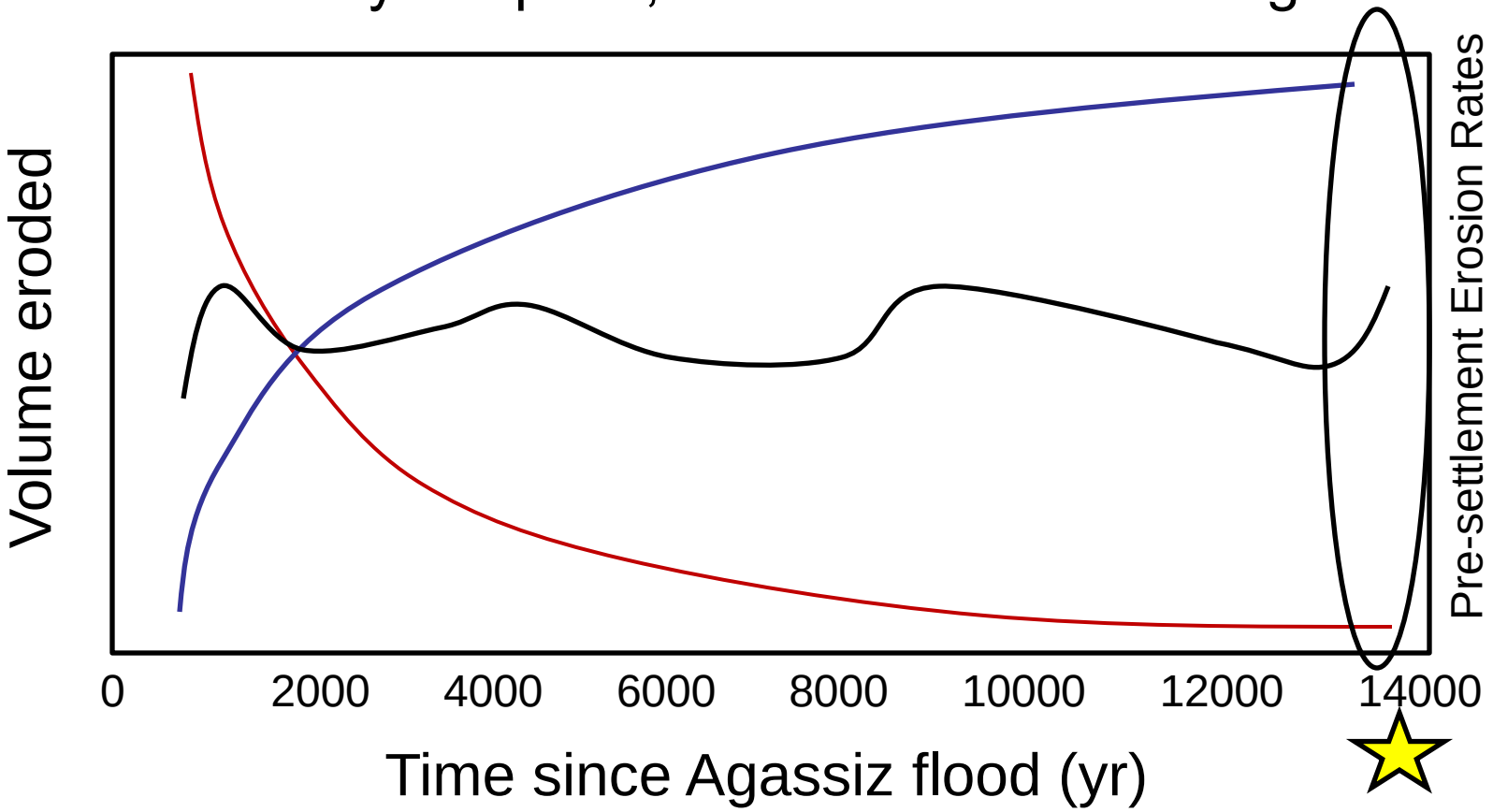

Coarse bars

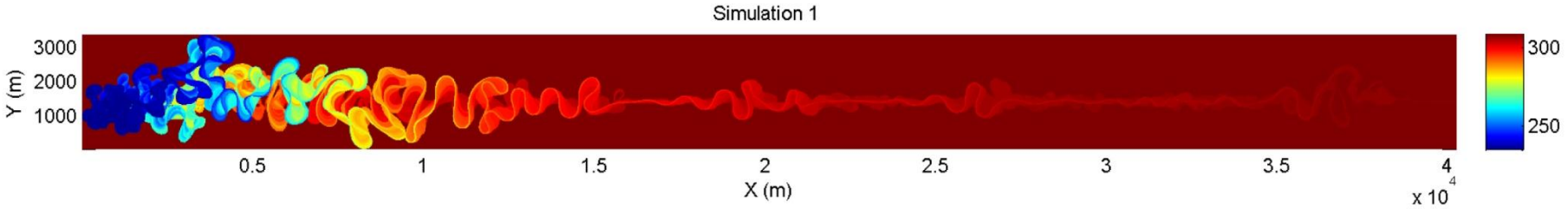
$$D_{50} = k_d(z_o - z)$$

Le Sueur is best modeled as a bedrock channel w/ downstream coarsening

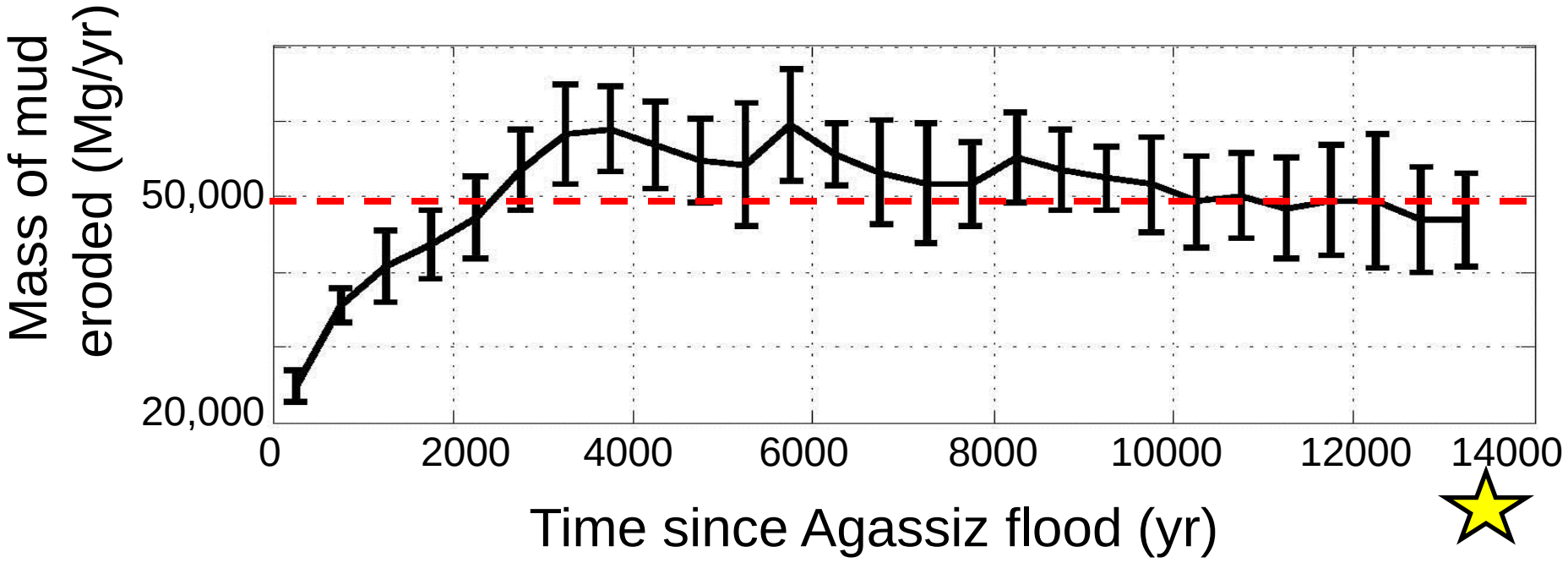


As the valley widens, channels access valley walls less frequently,
…but as the valley deepens, those walls become higher.



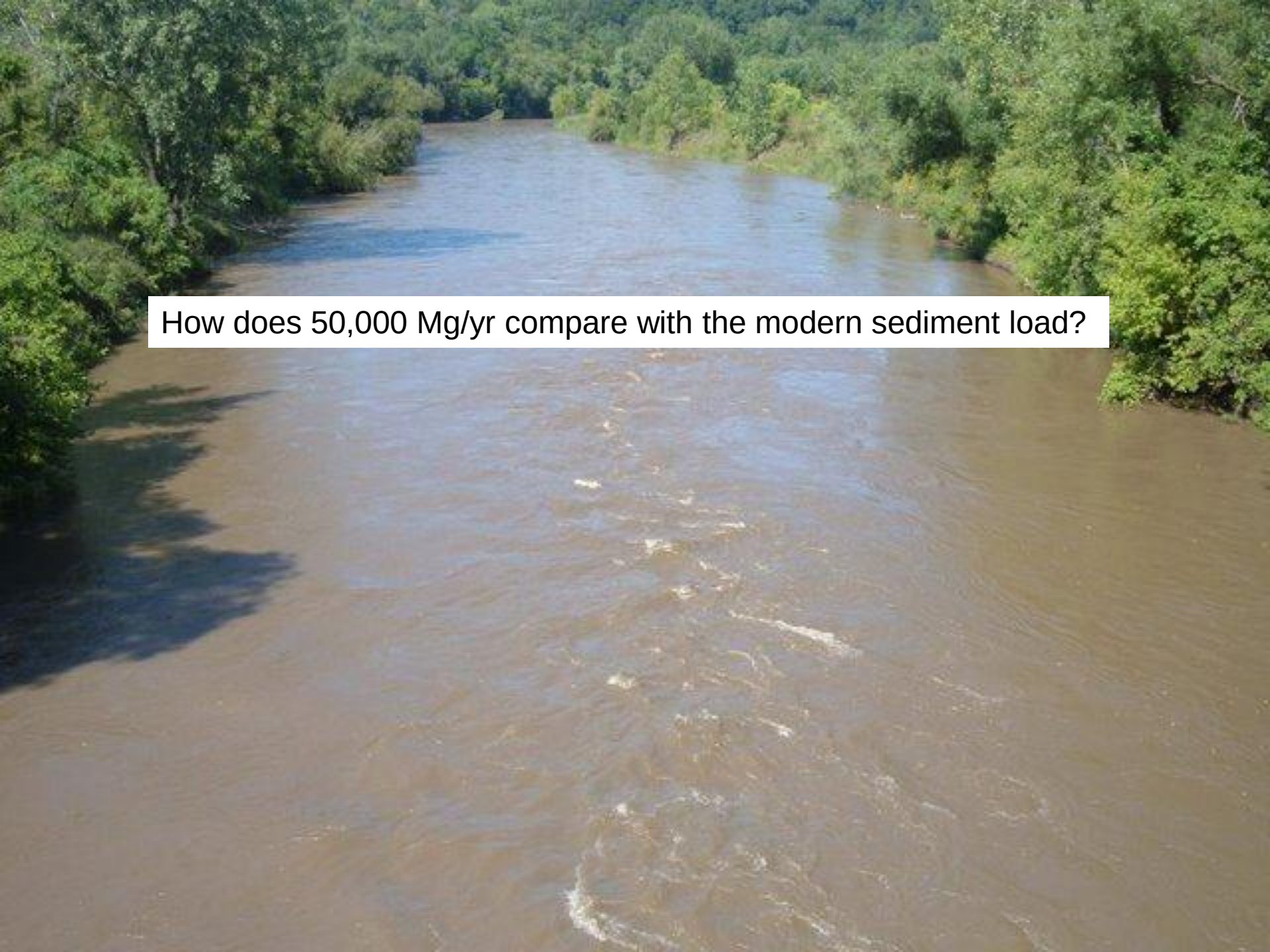


End result is that volumes of sediment eroded are rather steady.

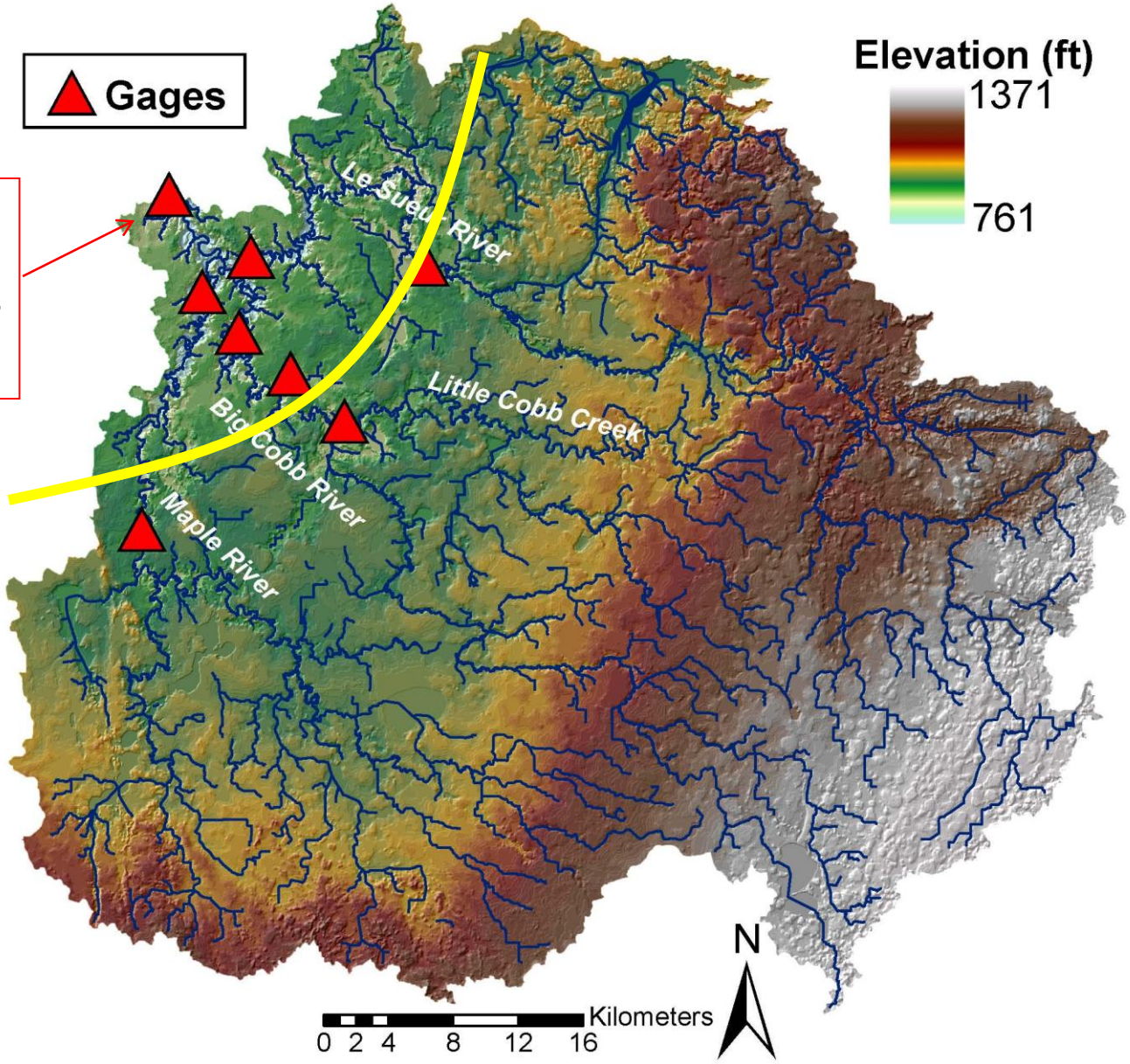


Take-home messages:

1. Valley excavation rates are not changing through time.
2. Variability is high, but quantifiable.
3. We can use this mass removed through valley excavation as a pre-settlement load.

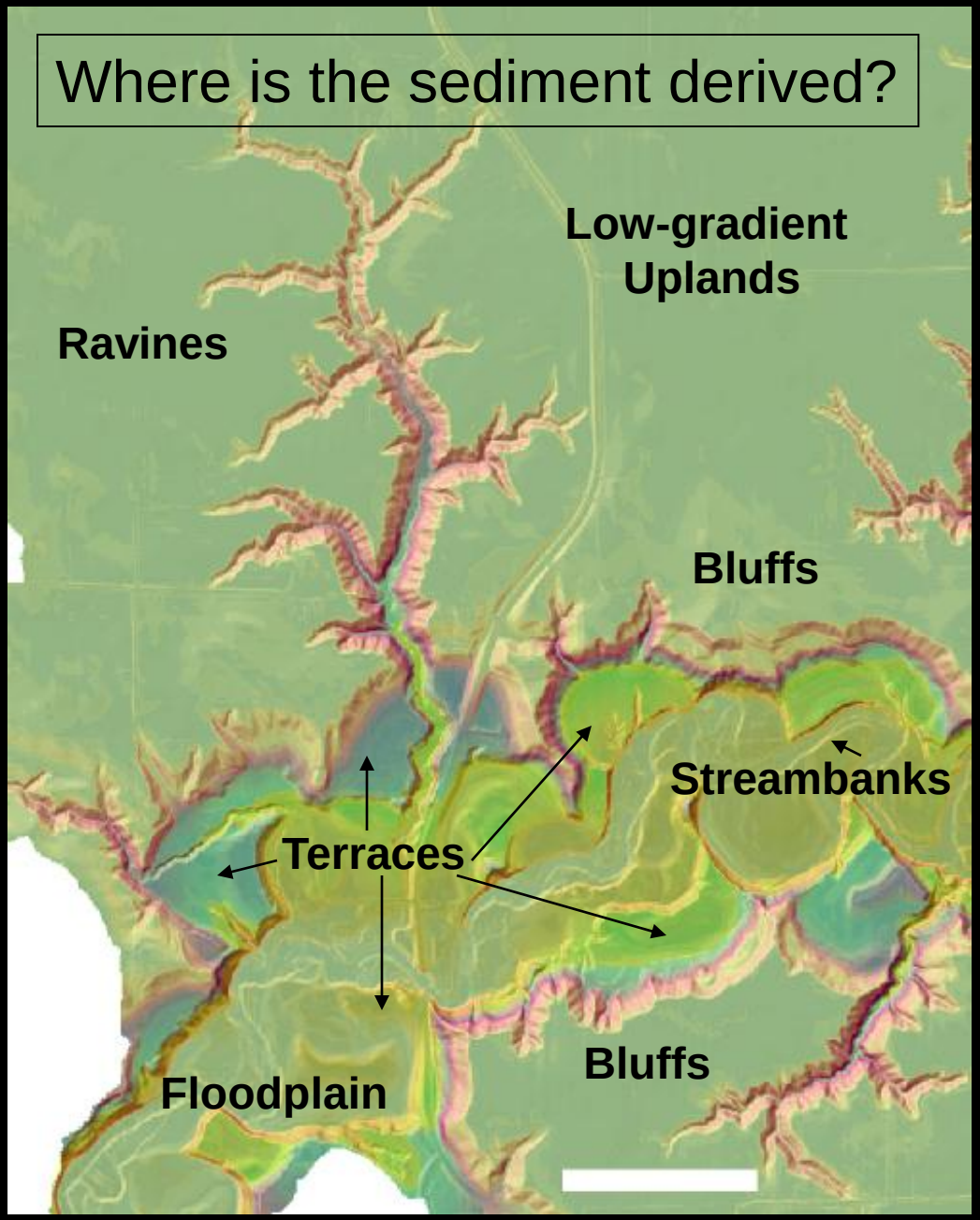

How does 50,000 Mg/yr compare with the modern sediment load?

Gage Locations in Le Sueur River watershed



Red Jacket:
2000-2010:
225,000 Mg/yr
TSS

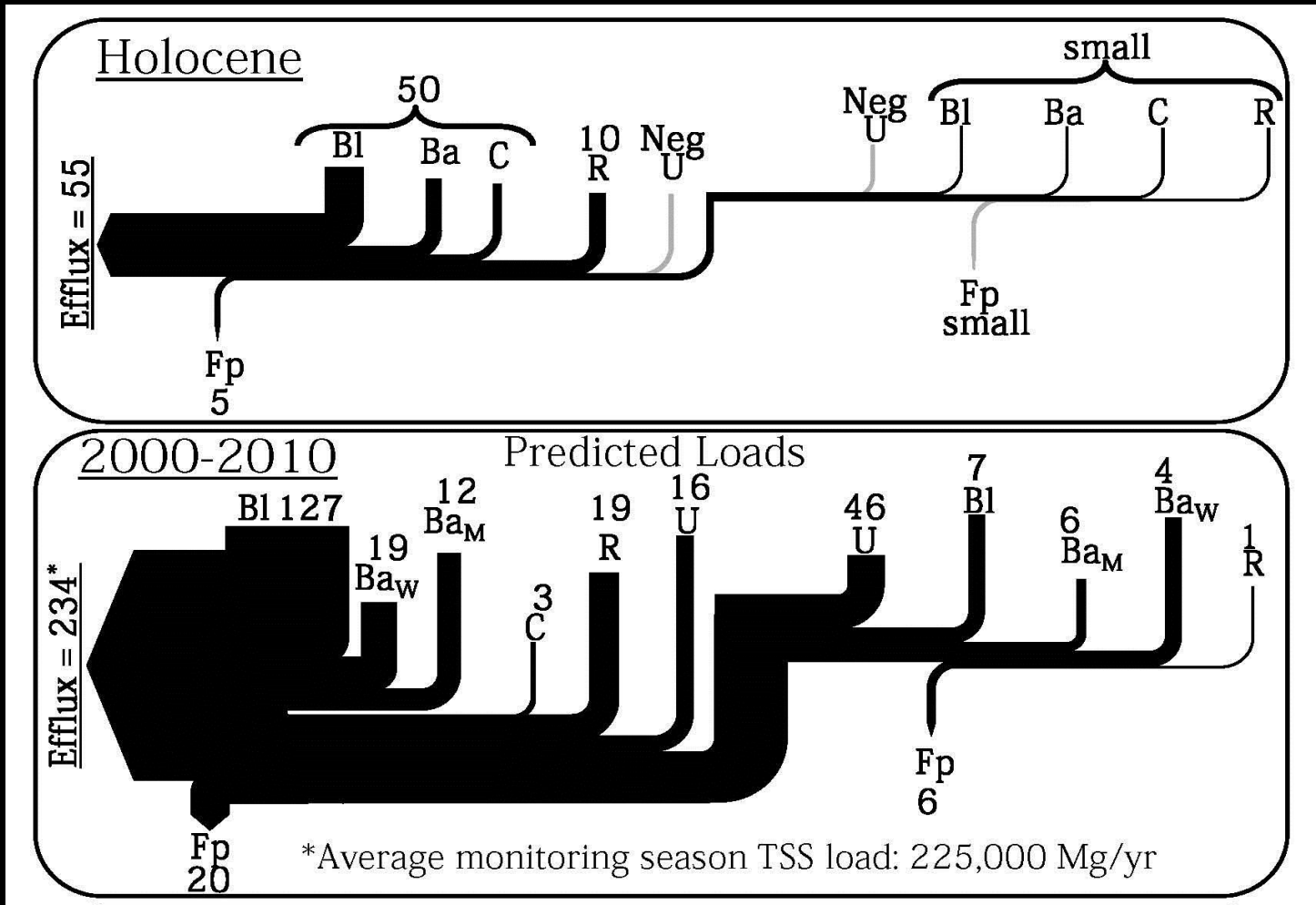
Where is the sediment derived?



How has the sediment budget changed through time?

Sources

U: Uplands
F_p: Floodplain
Bl: Bluffs
Ba: Banks
C: Channel incision
R: Ravines



Constraints

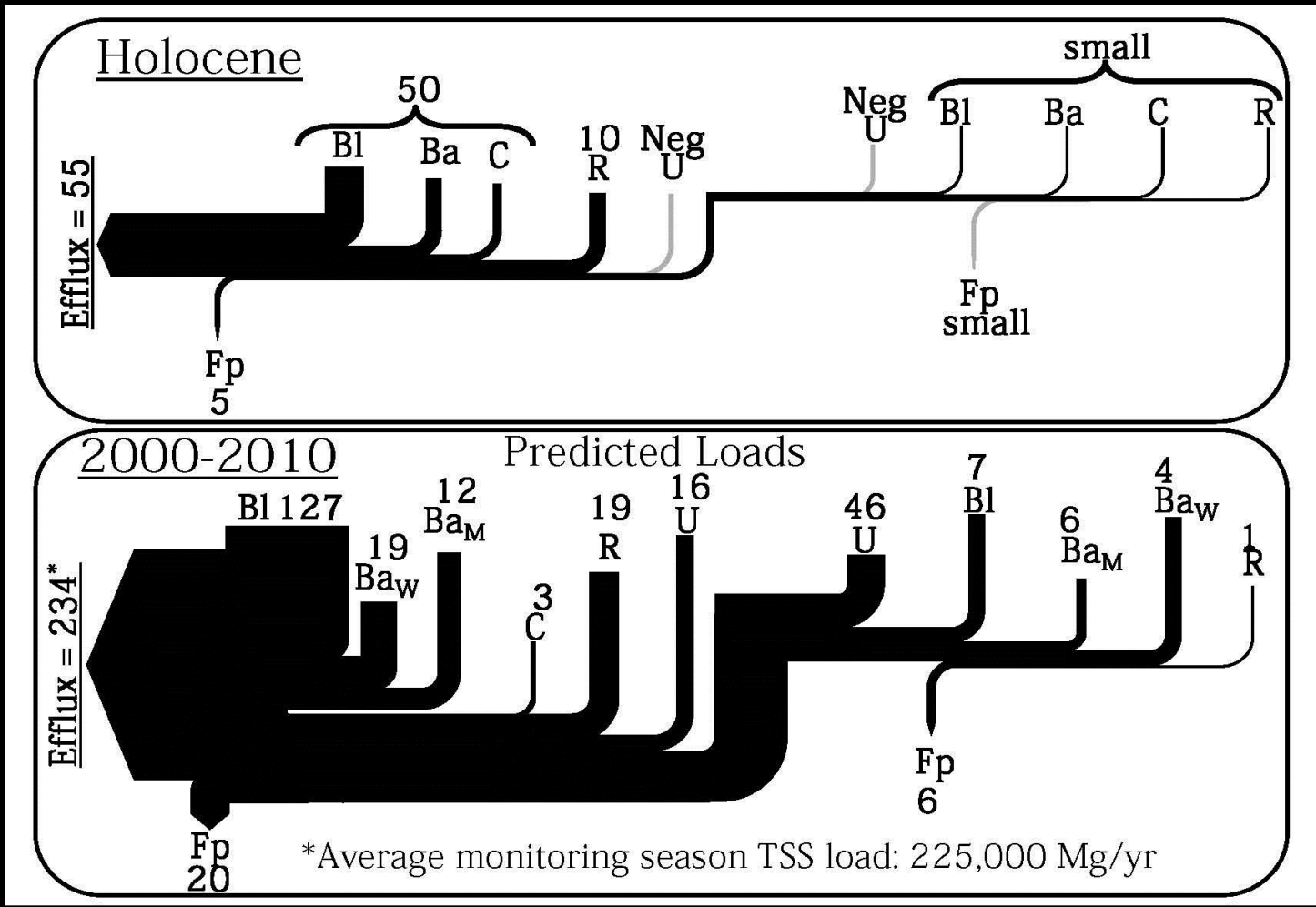
1. Gaging data
2. Geochemical tracers
3. Aerial lidar analysis
4. Terrestrial lidar scans
5. Air photo analysis
6. Numerical modeling
7. Field surveys
8. Optically Stimulated Luminescence and ^{14}C dating

How has the sediment budget changed through time?

Now 4-5 times more sediment coming out of the Le Sueur River

All sources have increased.

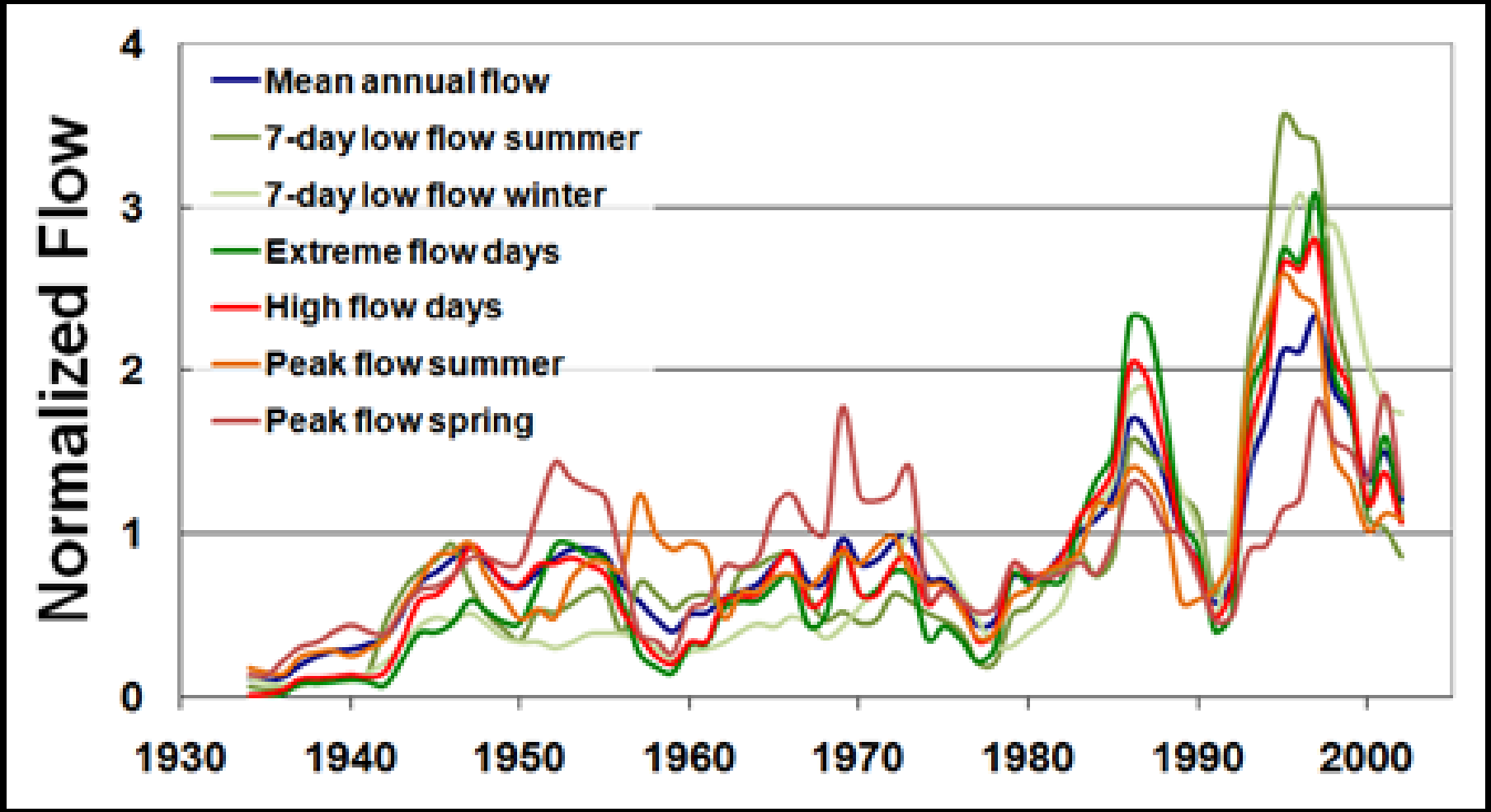
Consistent with changes in land use and hydrology.



Anthropogenic Disturbance

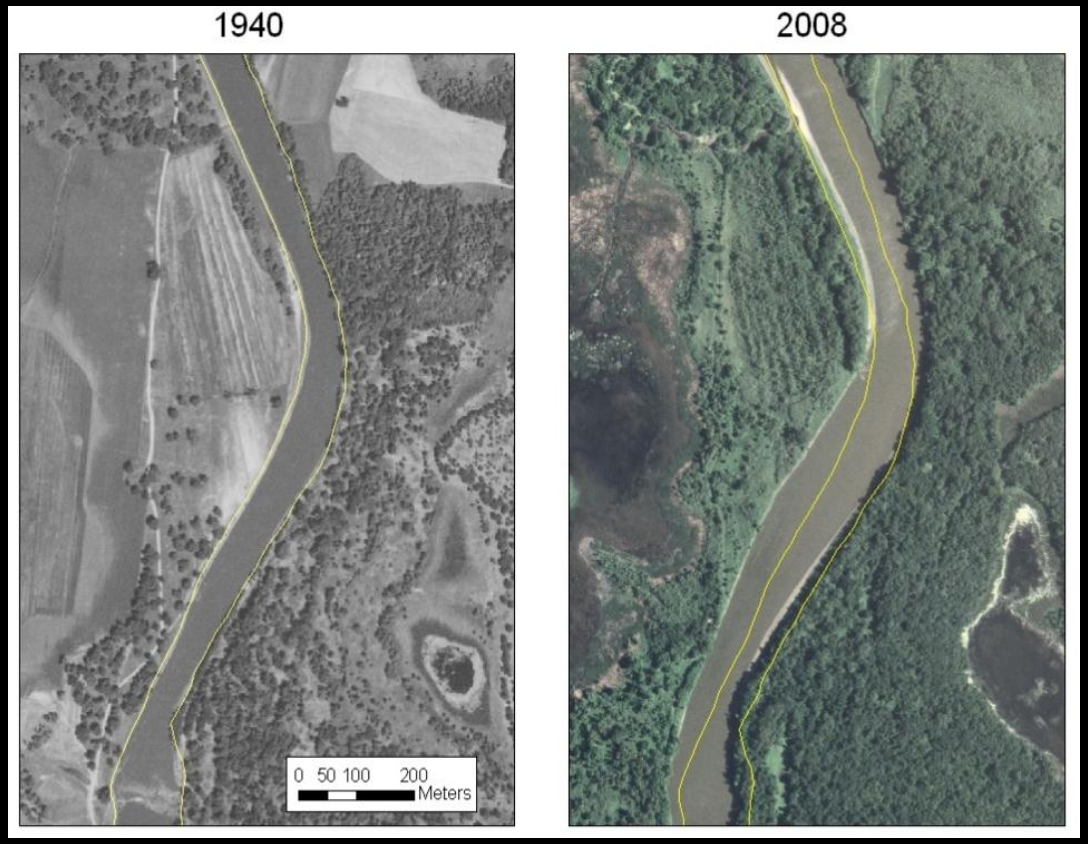
precisiongps

Minnesota River Hydrology Trends



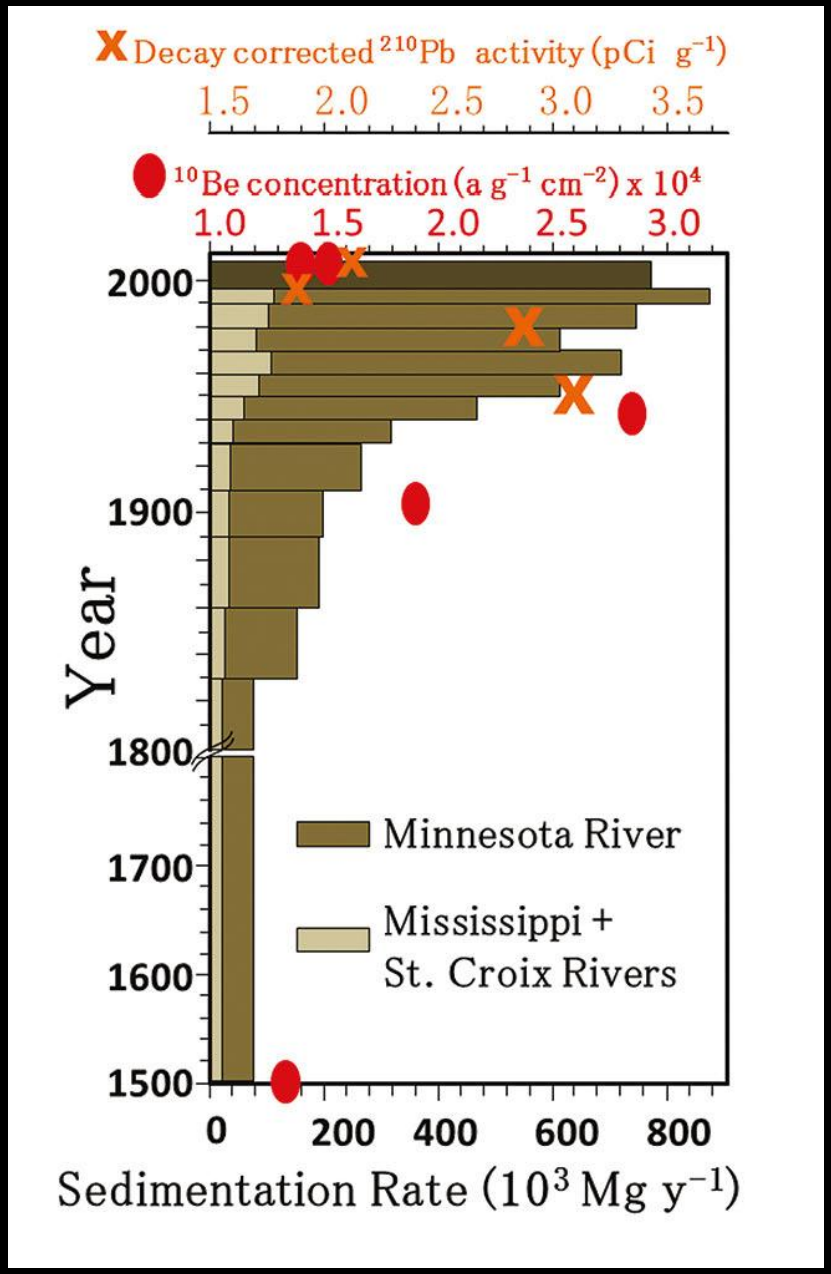
Novotny and Stefan (2007)
Dadaser-Celik and Stefan (2009)

Channel Widening



Minnesota R. only	0.49%
All reaches excluding Minnesota R.	0.18%
Reaches > 25 m wide only	0.39%
All Data	0.29%

Annual rate of widening



Belmont et al. (2011)

Two important shifts in sediment sources:

1. Late 1800s/ Early 1900s from near-channel to upland
2. Post-1950s from upland back to near-channel

Summary

- MN River tribs are young incising systems, geomorphically-primed for high sediment loads
- Excavation history can be used to determine pre-settlement erosion rates
- Pre-settlement “TSS” loads from valley excavation are ~ 50,000 Mg/yr, much lower than modern TSS loads of 225,000 Mg/yr
- Sediment sources in the last 50-60 years are shifting…

Acknowledgements:

Funding from:

Minnesota Pollution Control Agency
National Center for Earth-surface Dynamics (NSF)

S. Day, C. Jennings – U Minnesota, MN Geological Survey
P. Belmont – Utah State University
P. Wilcock – Johns Hopkins University
J.W. Lauer – Seattle University
A. Melesse, F. Khalif, L. Azmera, A. Thomas -Florida International University
G. Parker & E. Viparelli –U. Illinois
T. Rittenour – Utah State University Luminesence Lab
C. Wittkop – Minnesota State U.
MN Supercomputing Institute

& many others…