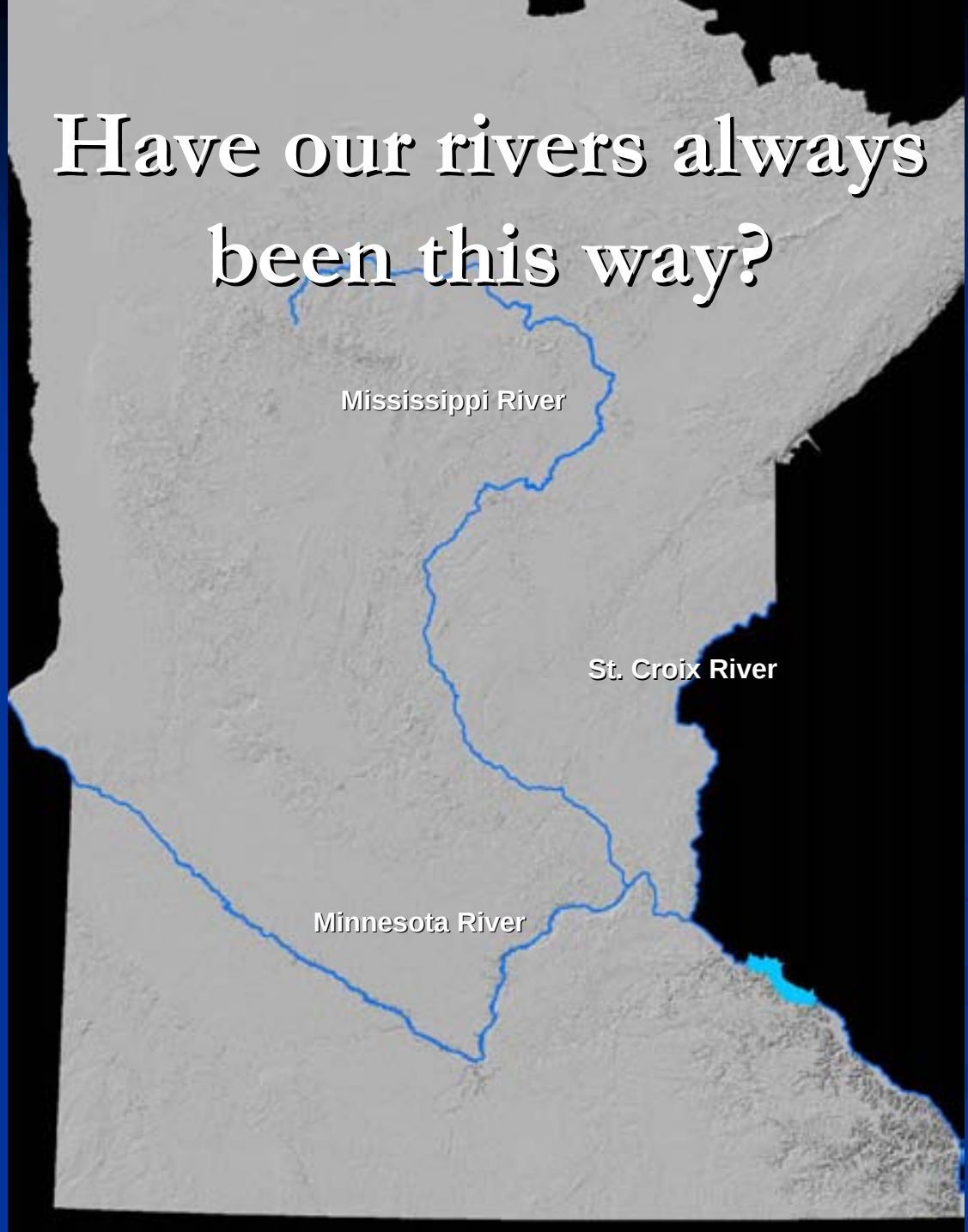
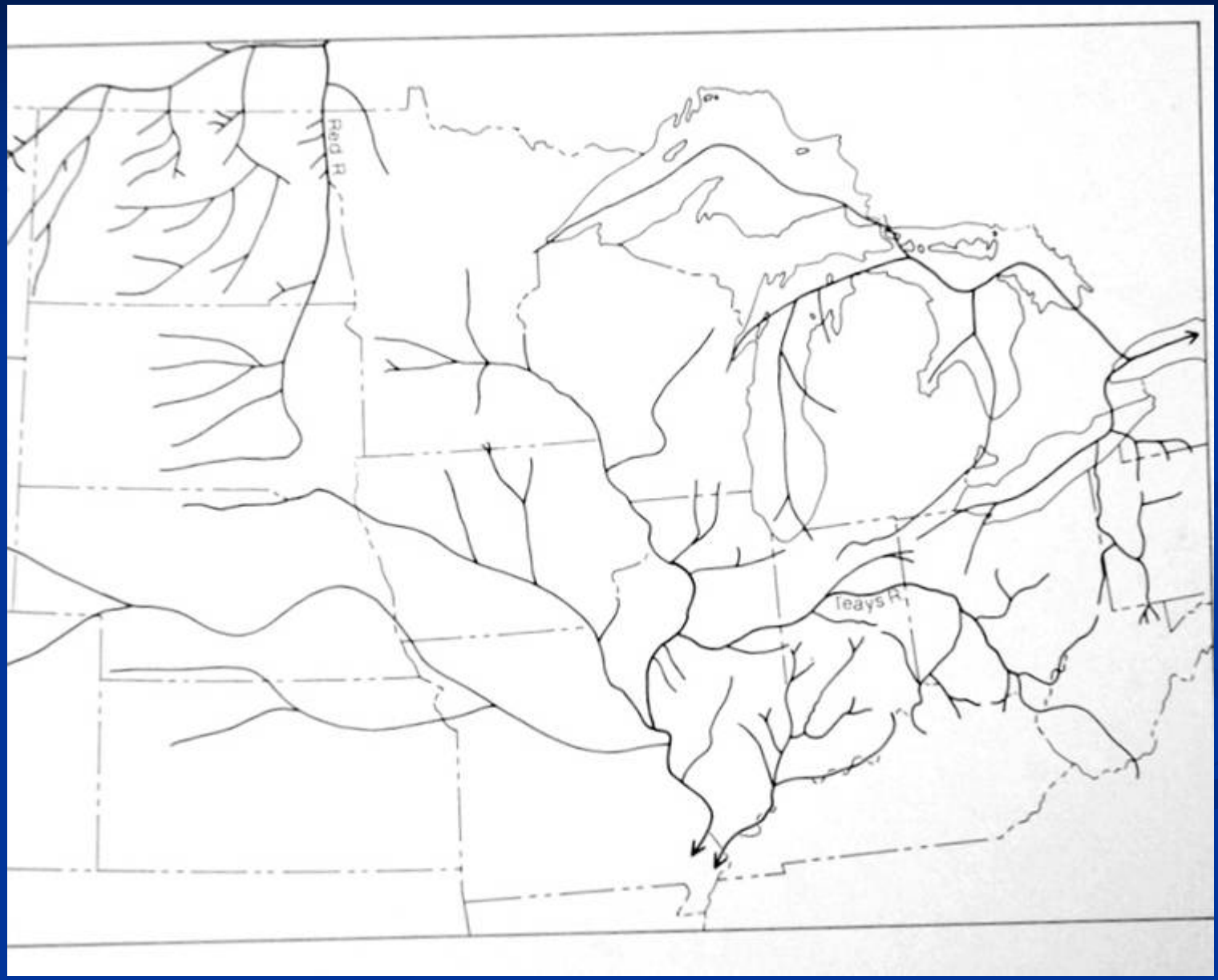
Minnesota Rivers—How They Work

Carrie E. Jennings, PhD
Minnesota Geological Survey
University of Minnesota

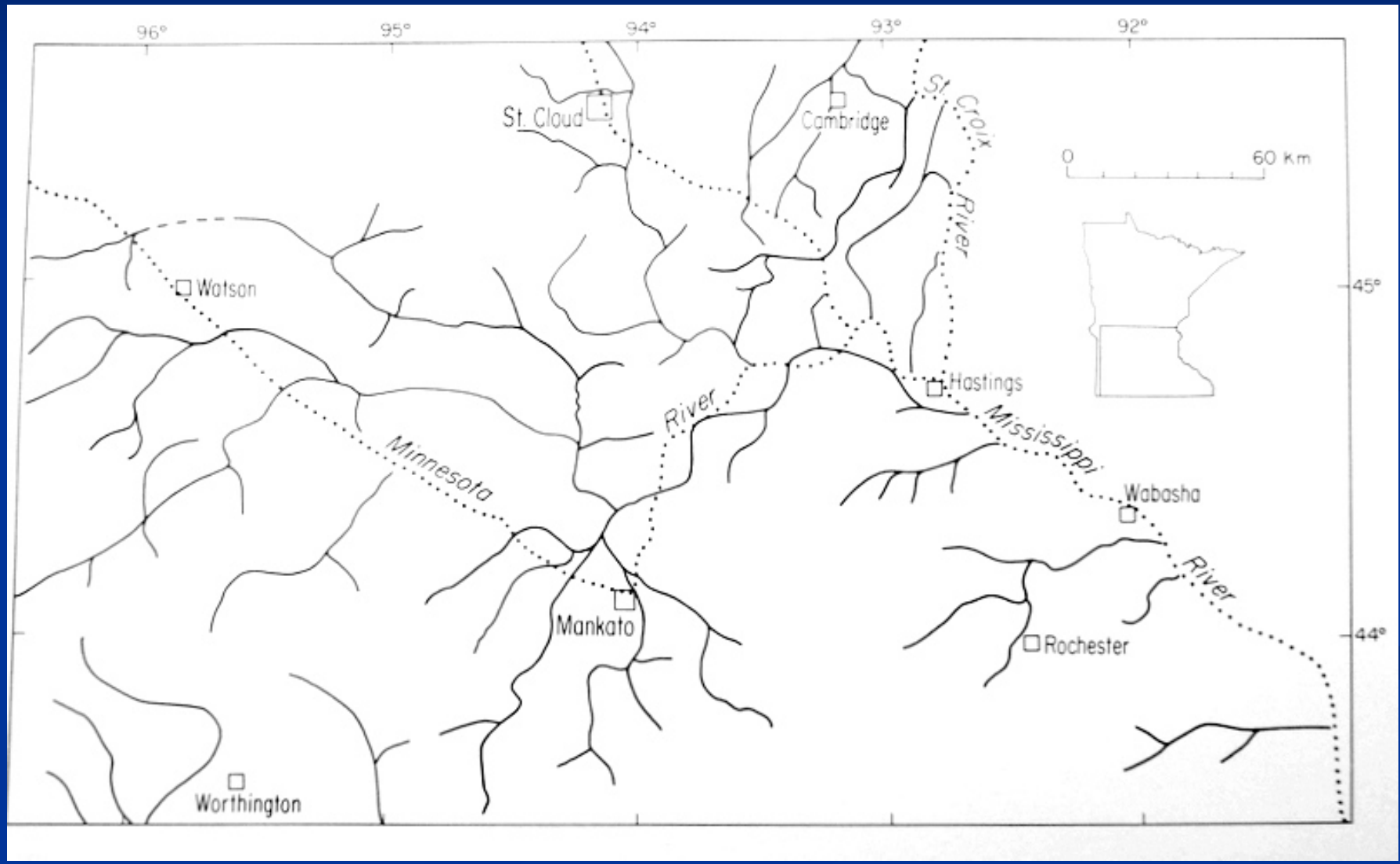
Have our rivers always been this way?



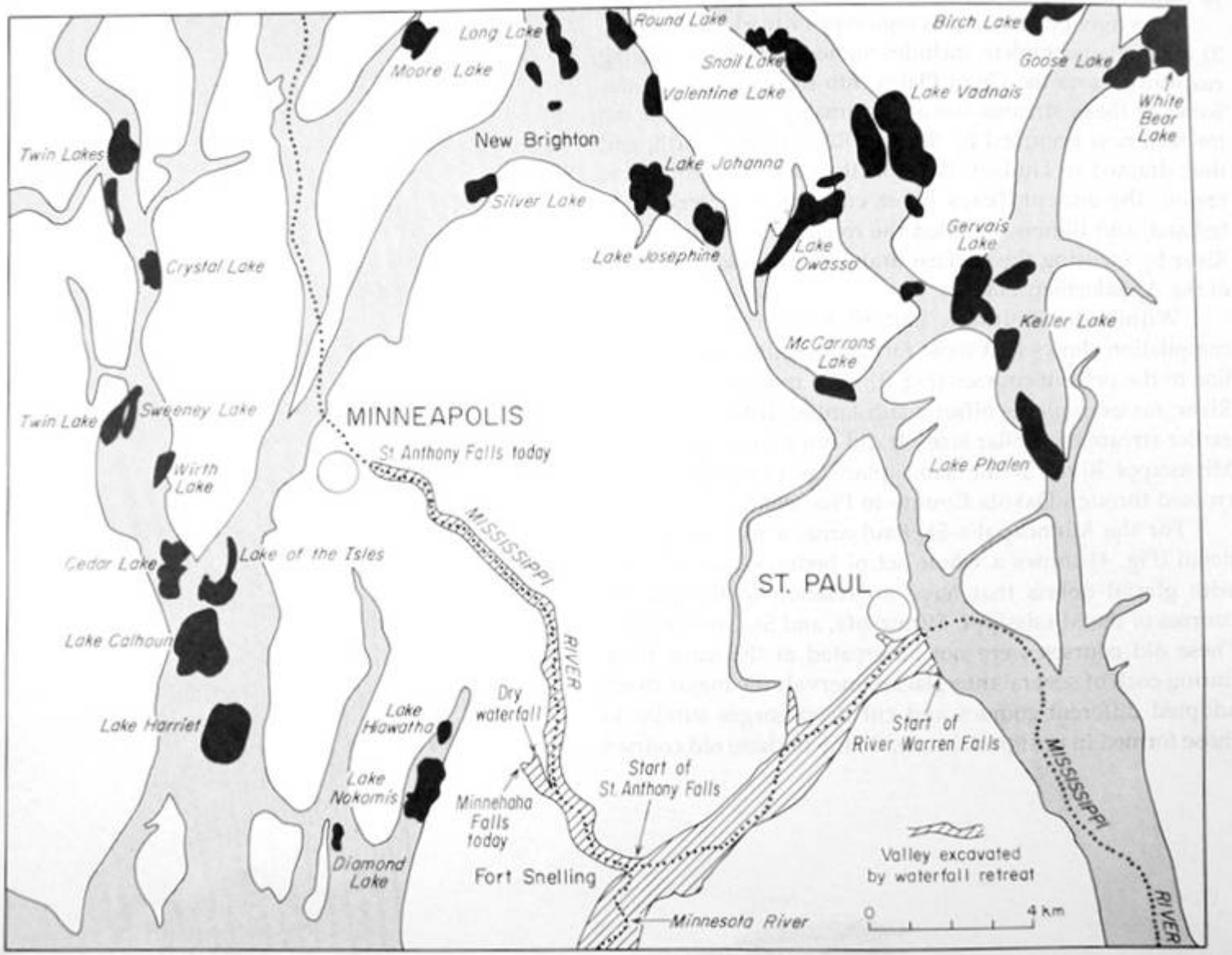
Yesterday's rivers = buried valleys



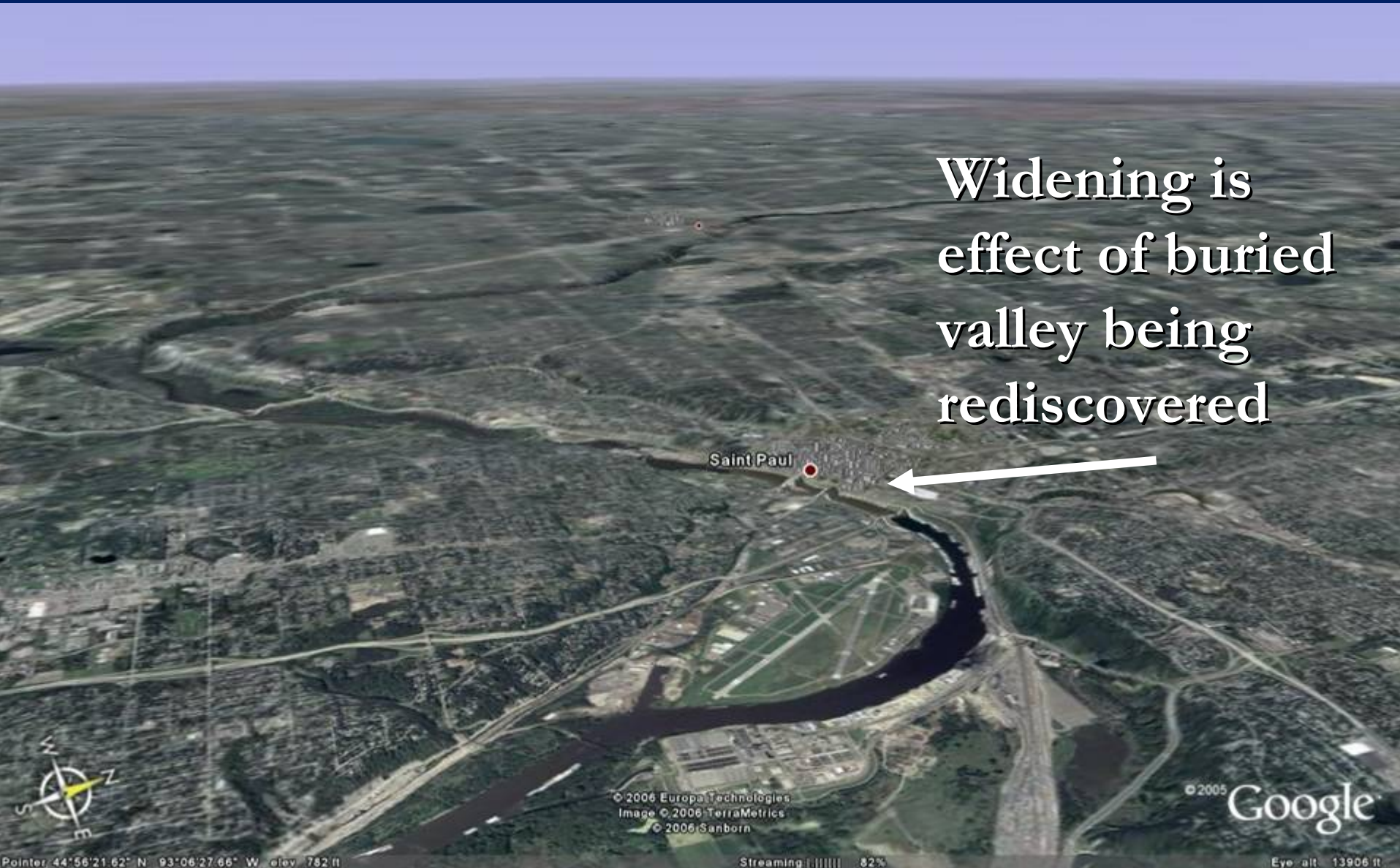
Metro area buried valleys



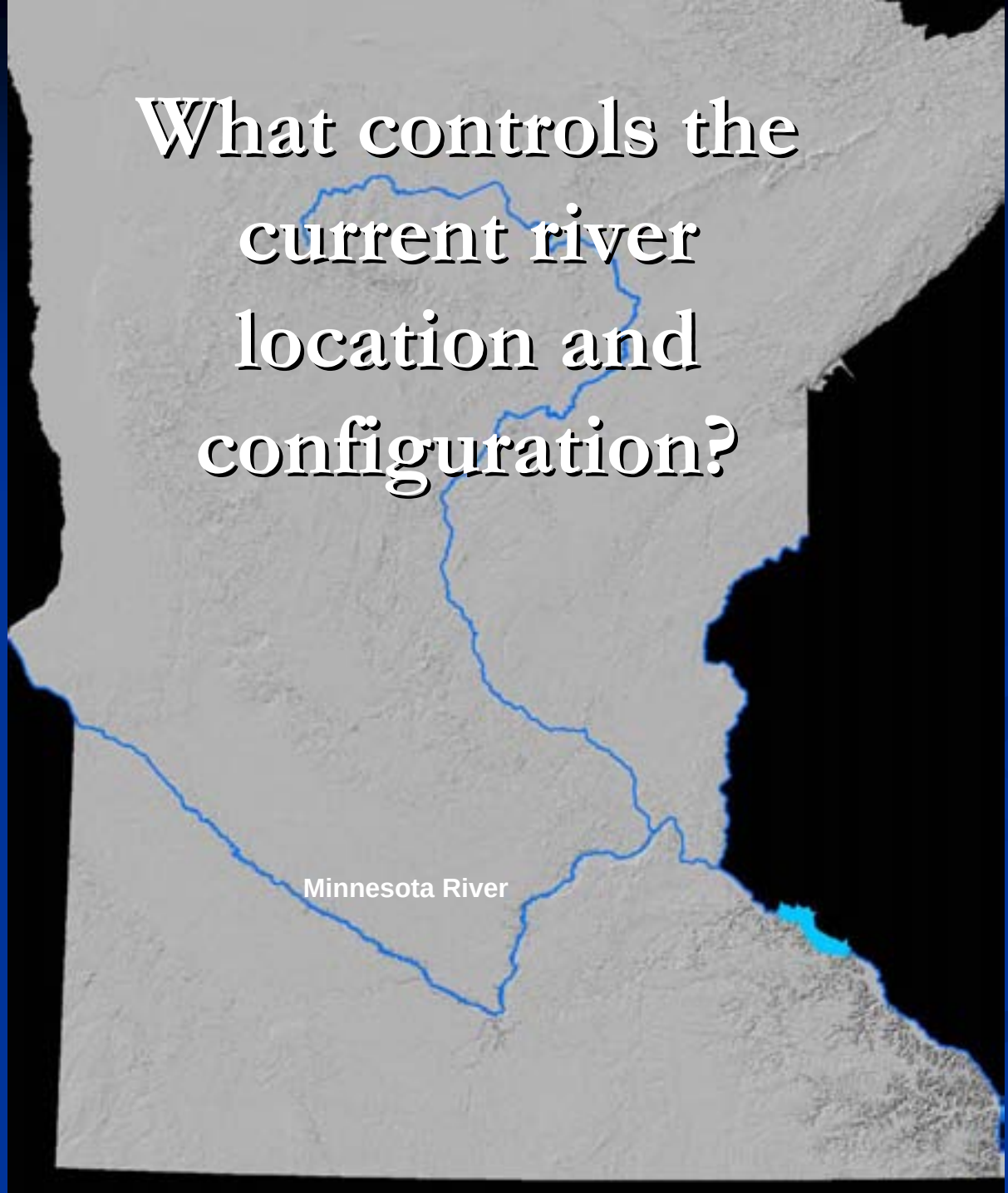
Chains of lakes mark buried valleys



Effect of buried valley on modern Mississippi



What controls the current river location and configuration?



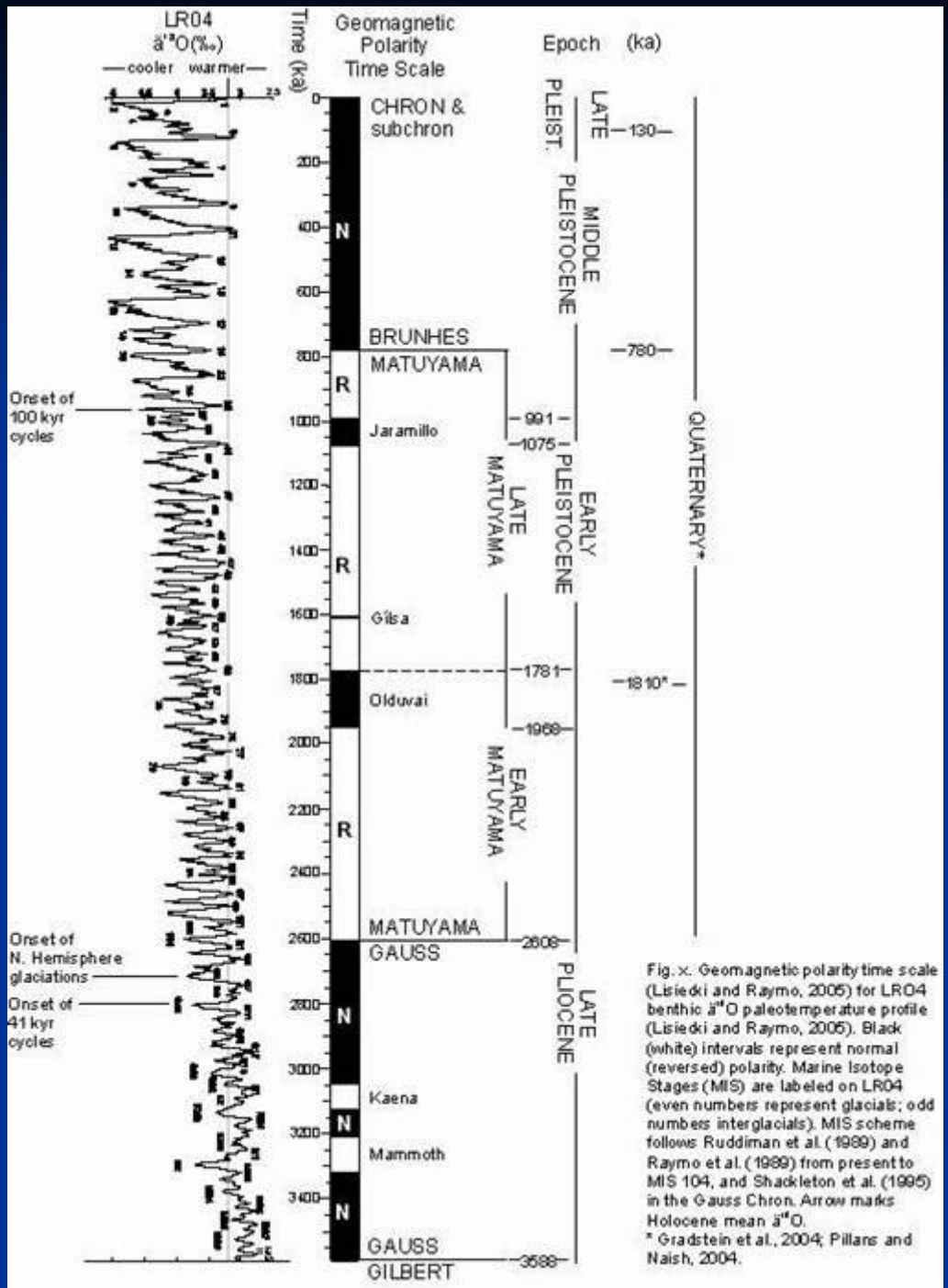
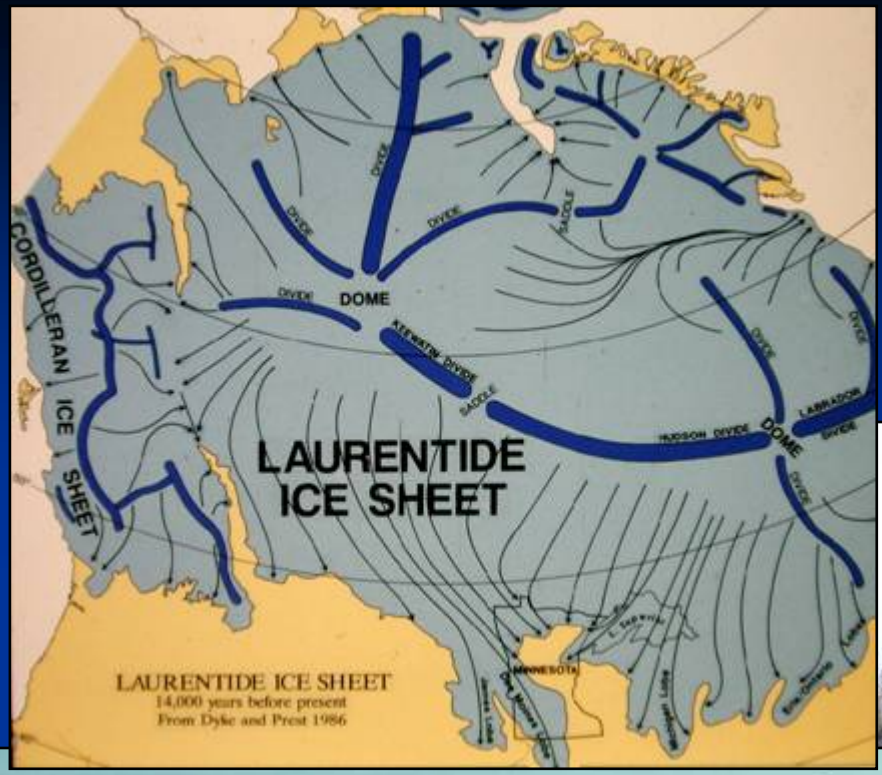


Fig. x. Geomagnetic polarity time scale (Lisiecki and Raymo, 2005) for LR04 benthic $\delta^{18}O$ paleotemperature profile (Lisiecki and Raymo, 2005). Black (white) intervals represent normal (reversed) polarity. Marine Isotope Stages (MIS) are labeled on LR04 (even numbers represent glacials; odd numbers interglacials). MIS scheme follows Ruddiman et al. (1989) and Raymo et al. (1989) from present to MIS 104, and Shackleton et al. (1995) in the Gauss Chron. Arrow marks Holocene mean $\delta^{18}O$.
* Gradstein et al., 2004; Pillans and Naish, 2004.

With each glaciation, we get a new hand

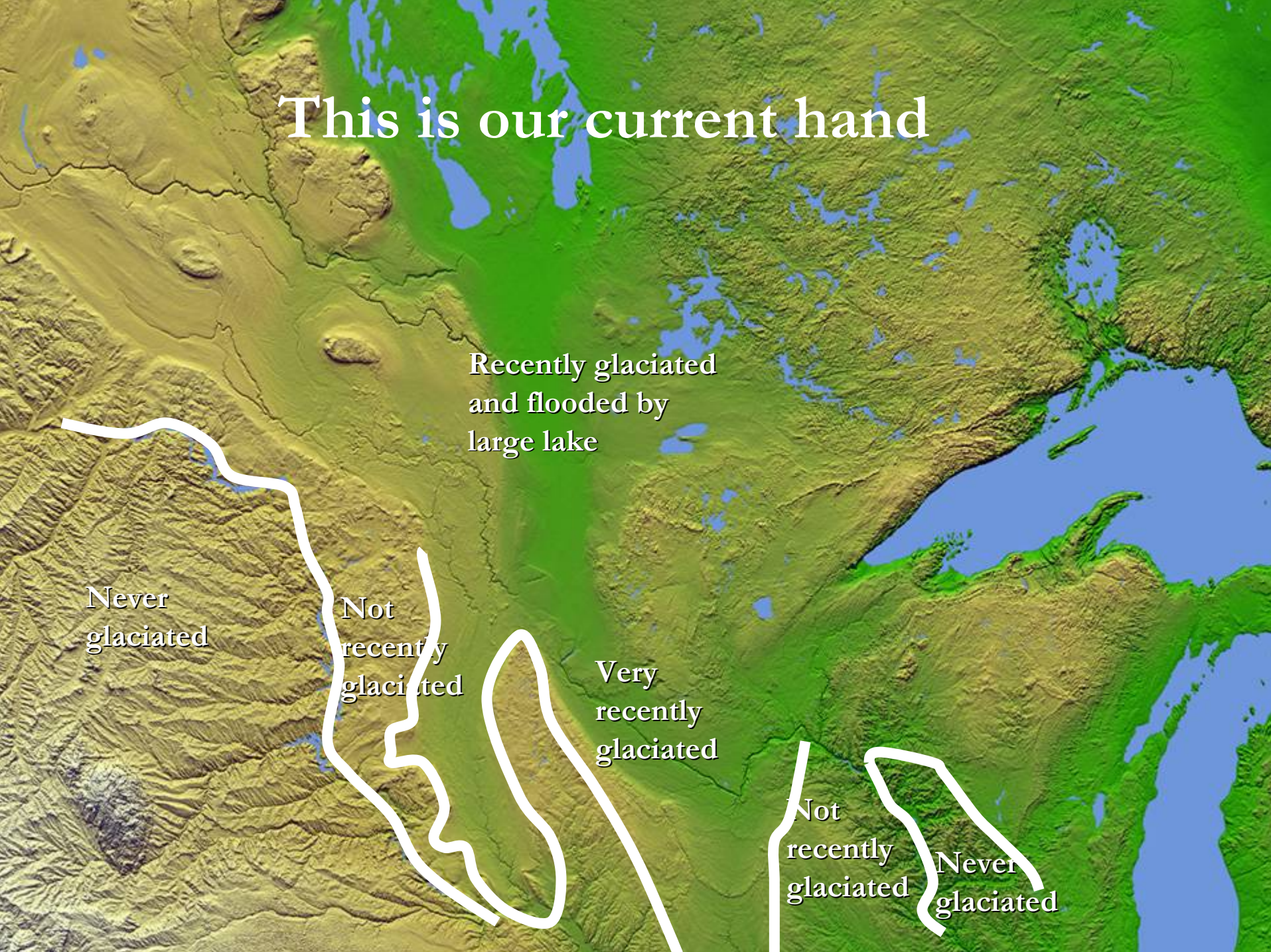
Rivers are filled in,
forced to new locations
and must start the game again.



Ice margin 14,000 years ago

Margin of
analog fo

NorthShore 2004


This is our current hand
Recently glaciated and flooded by large lake
Never glaciated
Not recently glaciated
Very recently glaciated
Not recently glaciated
Never glaciated

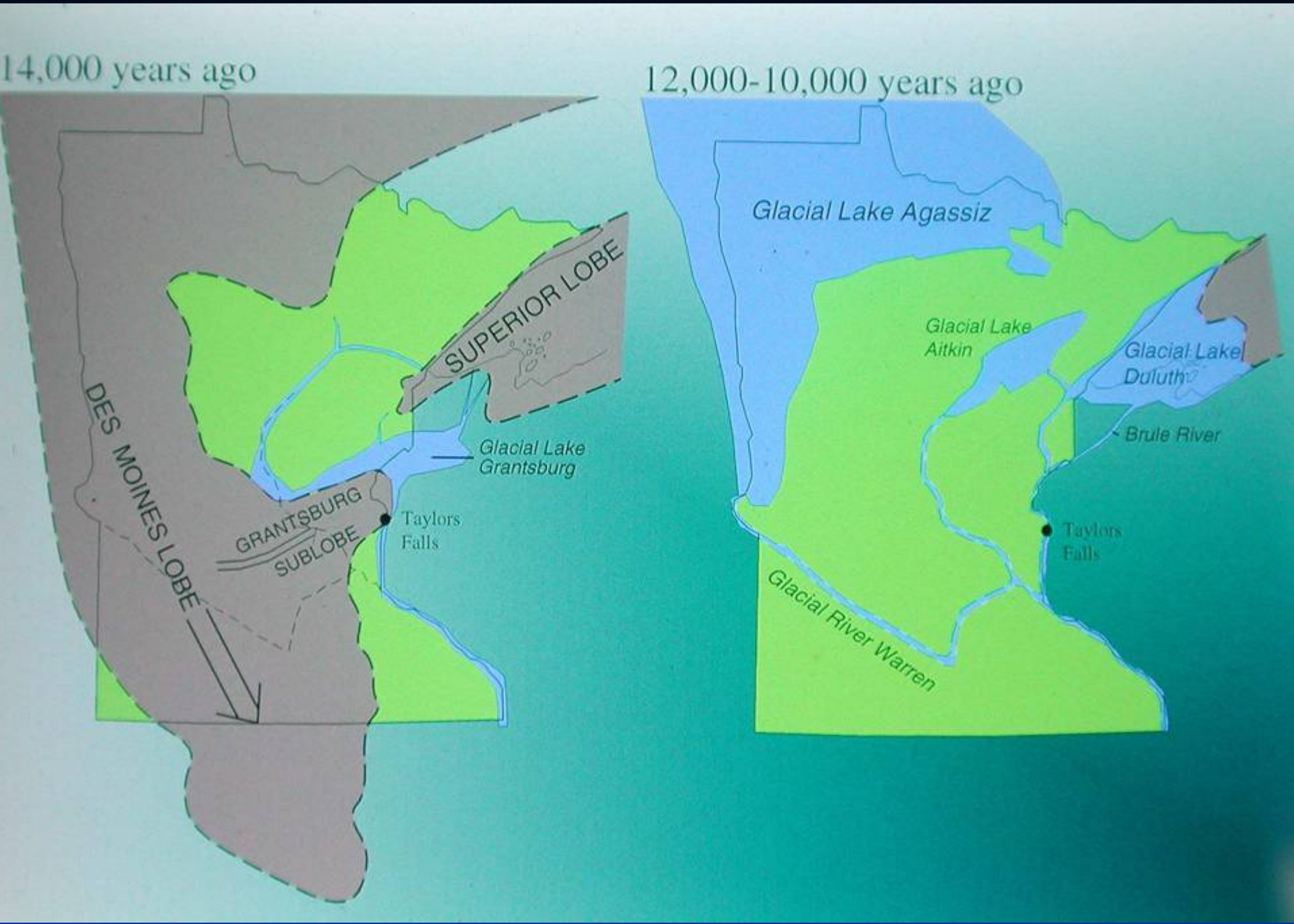
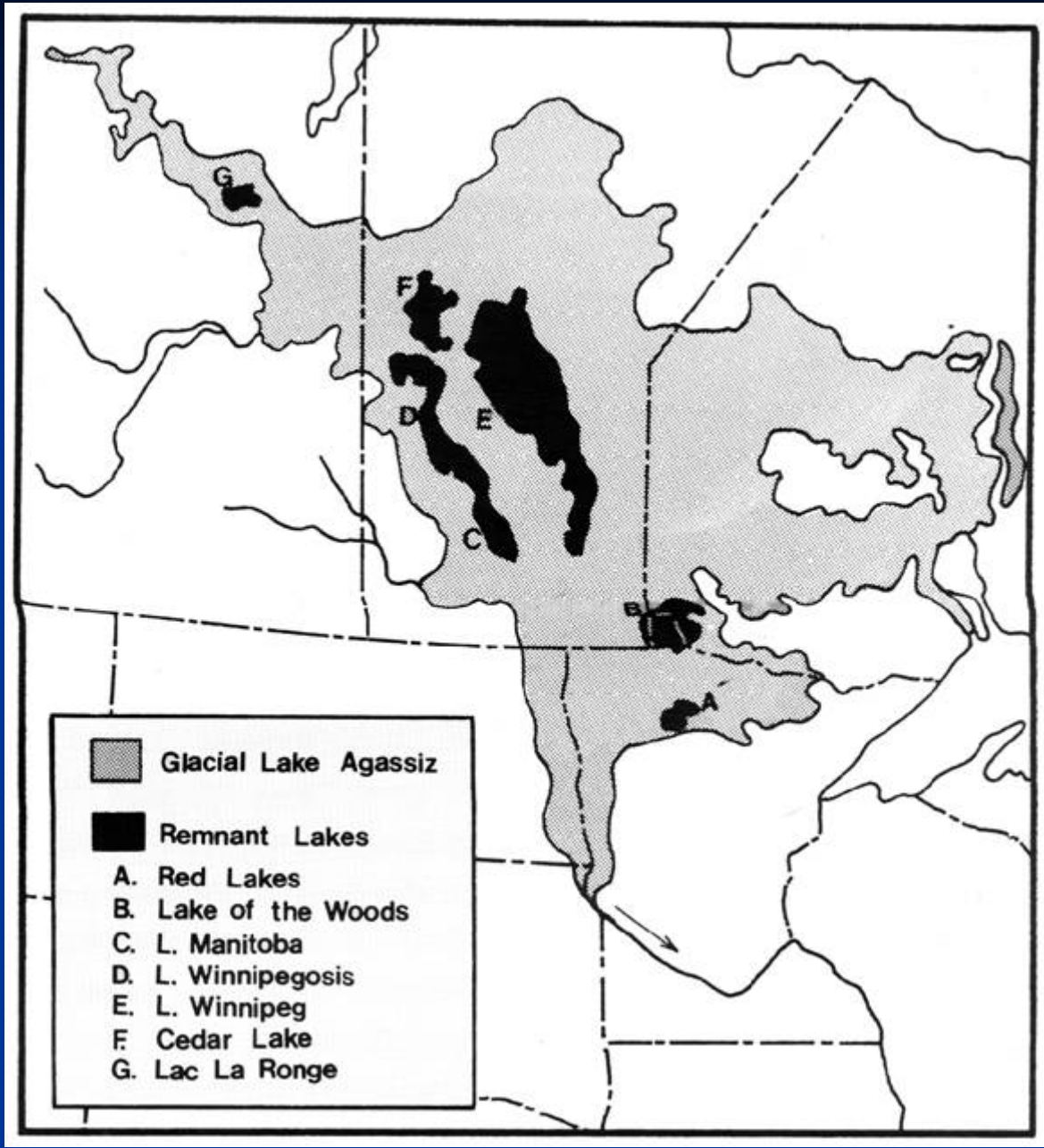


Illustration from Jim Miller, MGS



Lake Agassiz

The lake that started us on our present course.

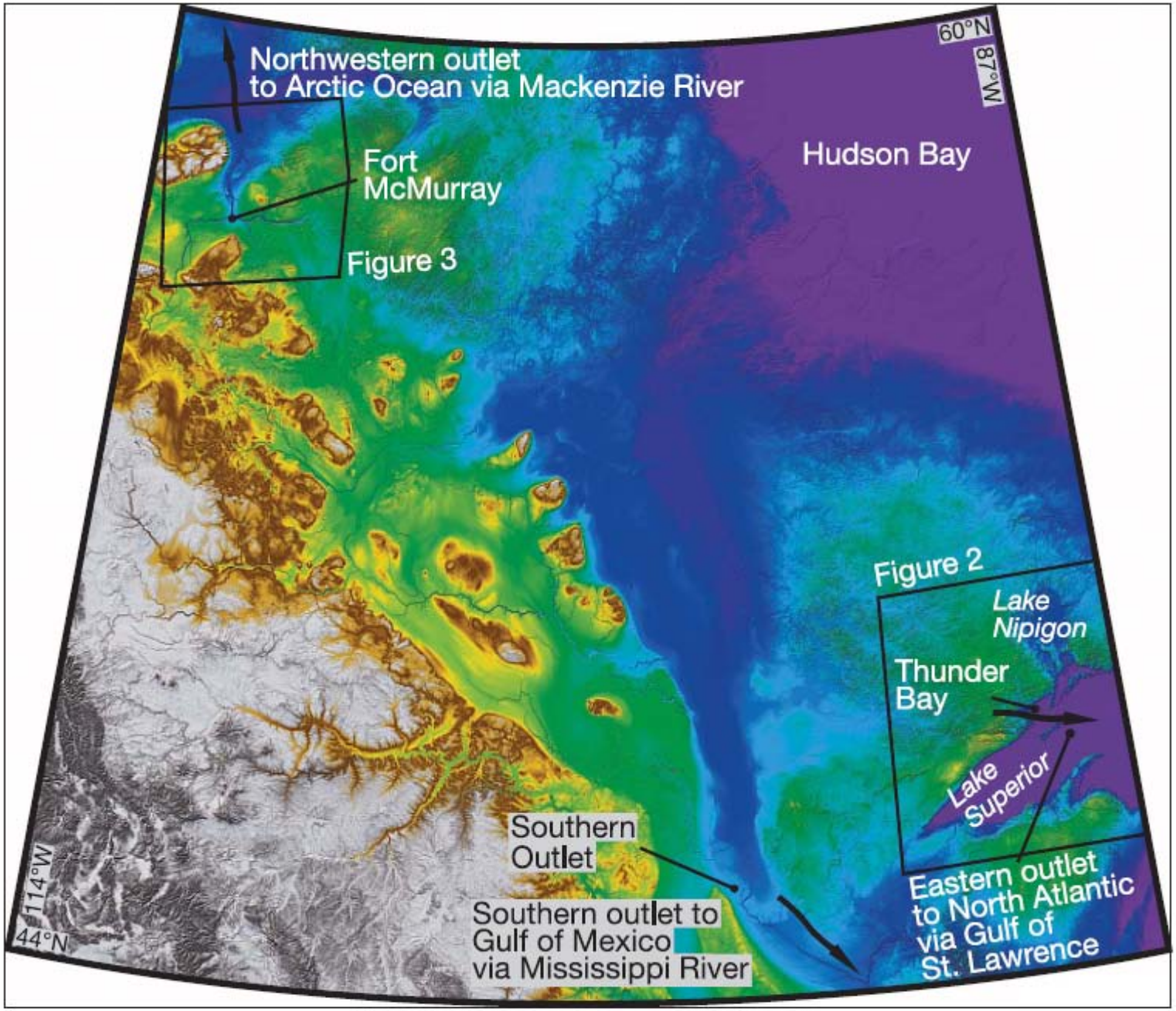
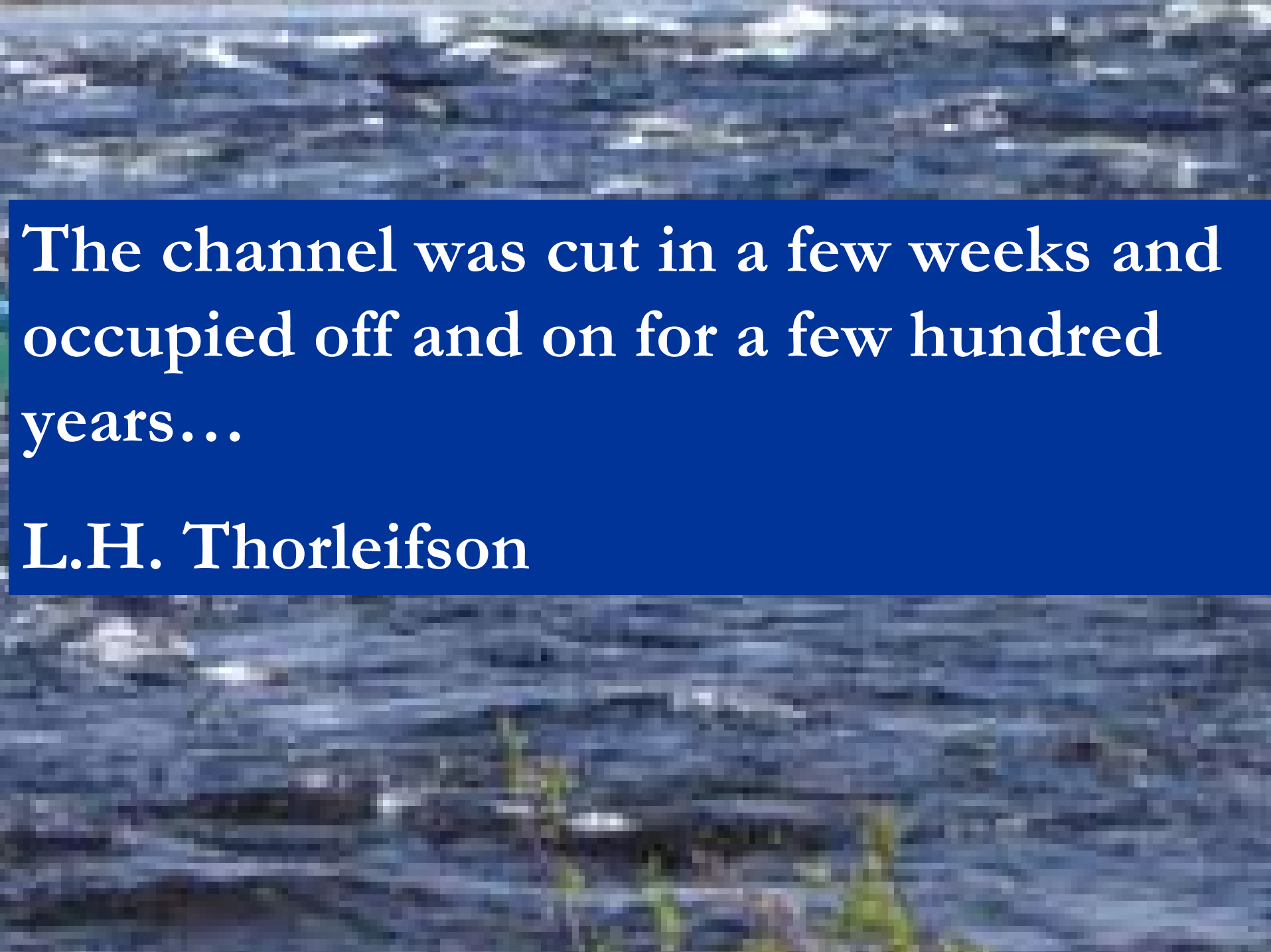


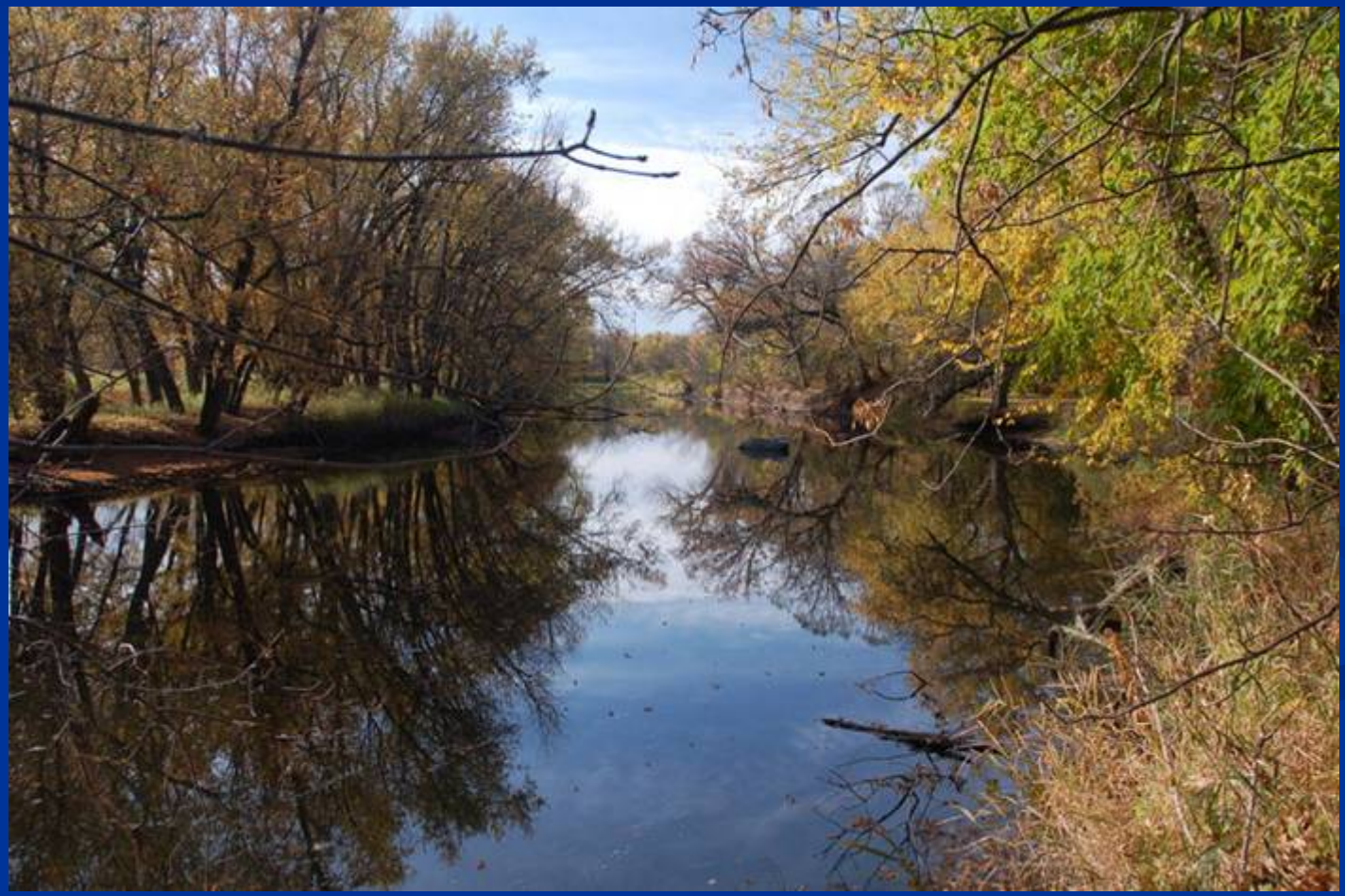
Fig. 1. Digital elevation model of central North America showing the southern, eastern, and northwestern outlets of Lake Agassiz.

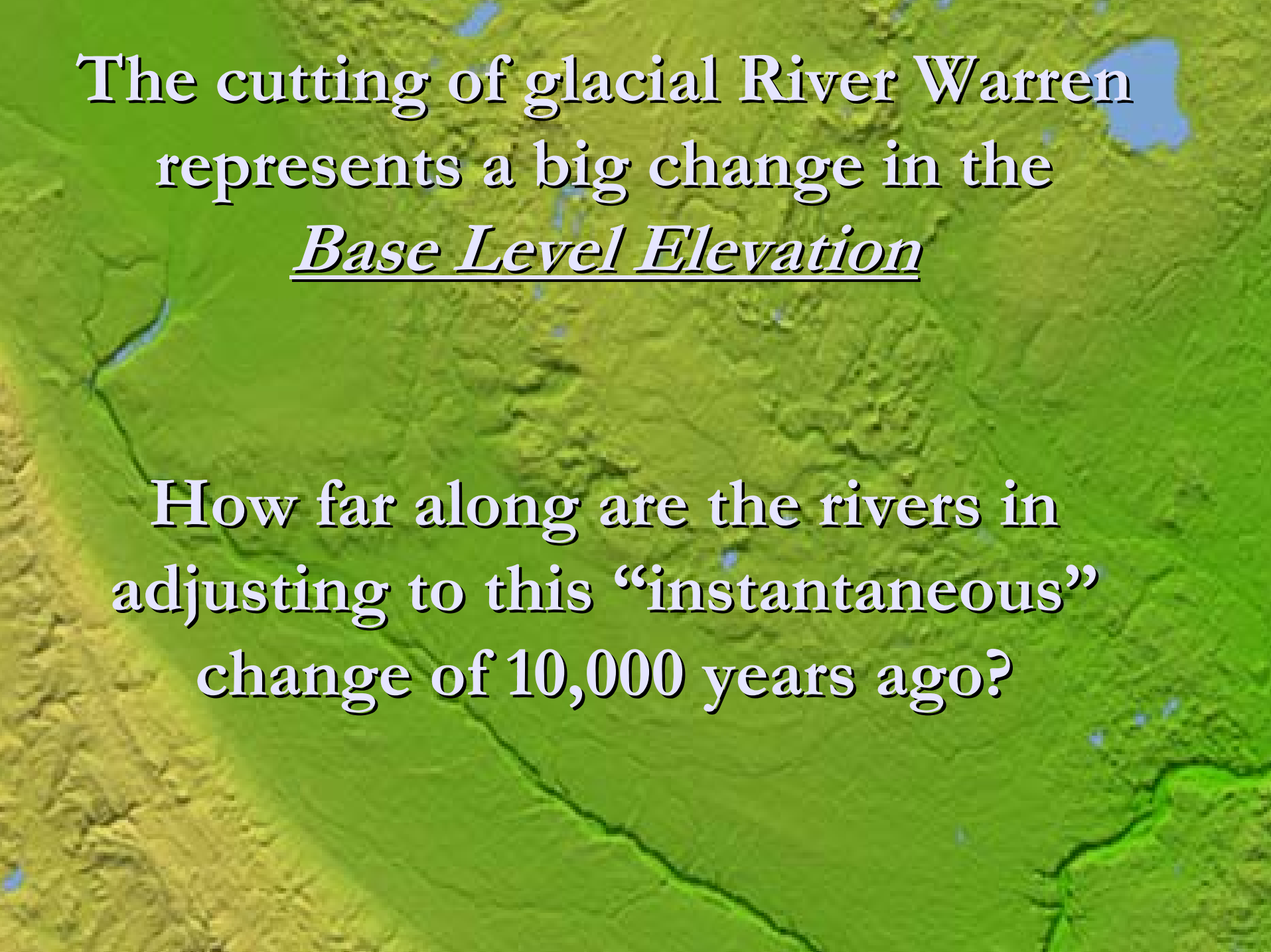
Lowell et al., 2005


The channel was cut in a few weeks and occupied off and on for a few hundred years…
L.H. Thorleifson

Rivers respond to two main forcing factors:

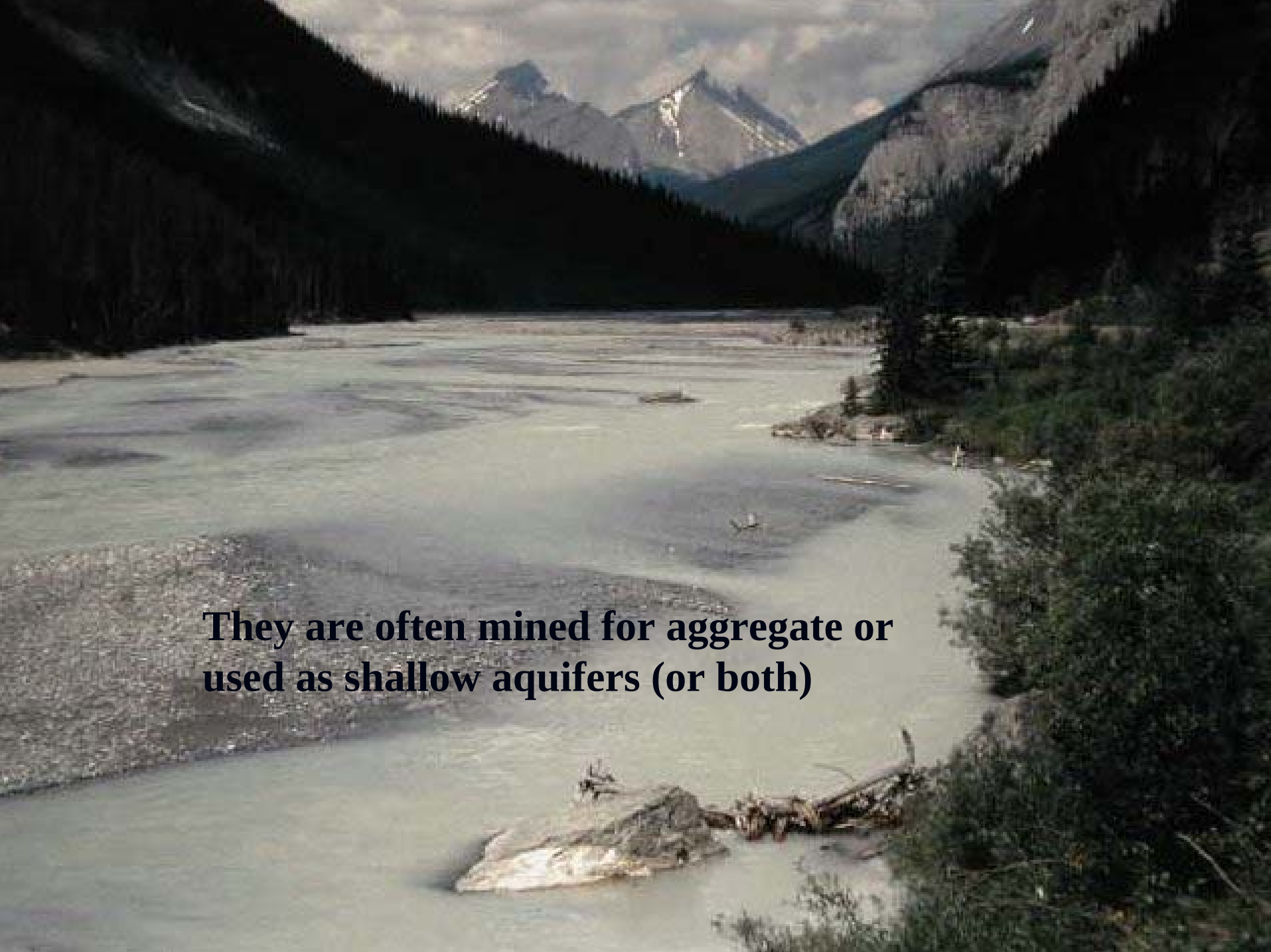
1. Change in water volume
2. Change in base level elevation

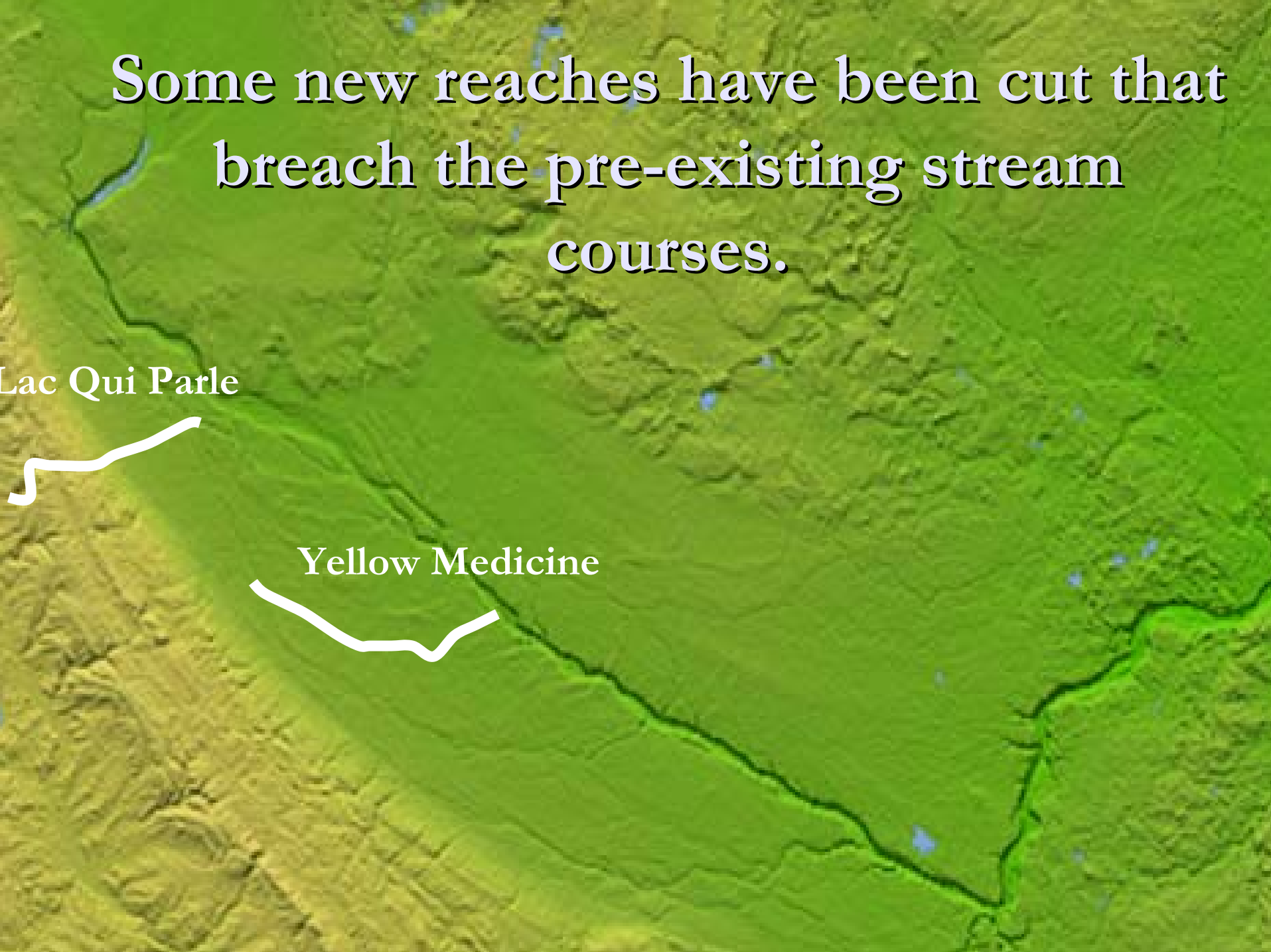



The cutting of glacial River Warren represents a big change in the *Base Level Elevation*
How far along are the rivers in adjusting to this "instantaneous" change of 10,000 years ago?

Don't be confused by pre-established, ice-marginal stream courses that are being reused.

They were confined by ice, have a low gradient, and are gravelly.


They are often mined for aggregate or
used as shallow aquifers (or both)

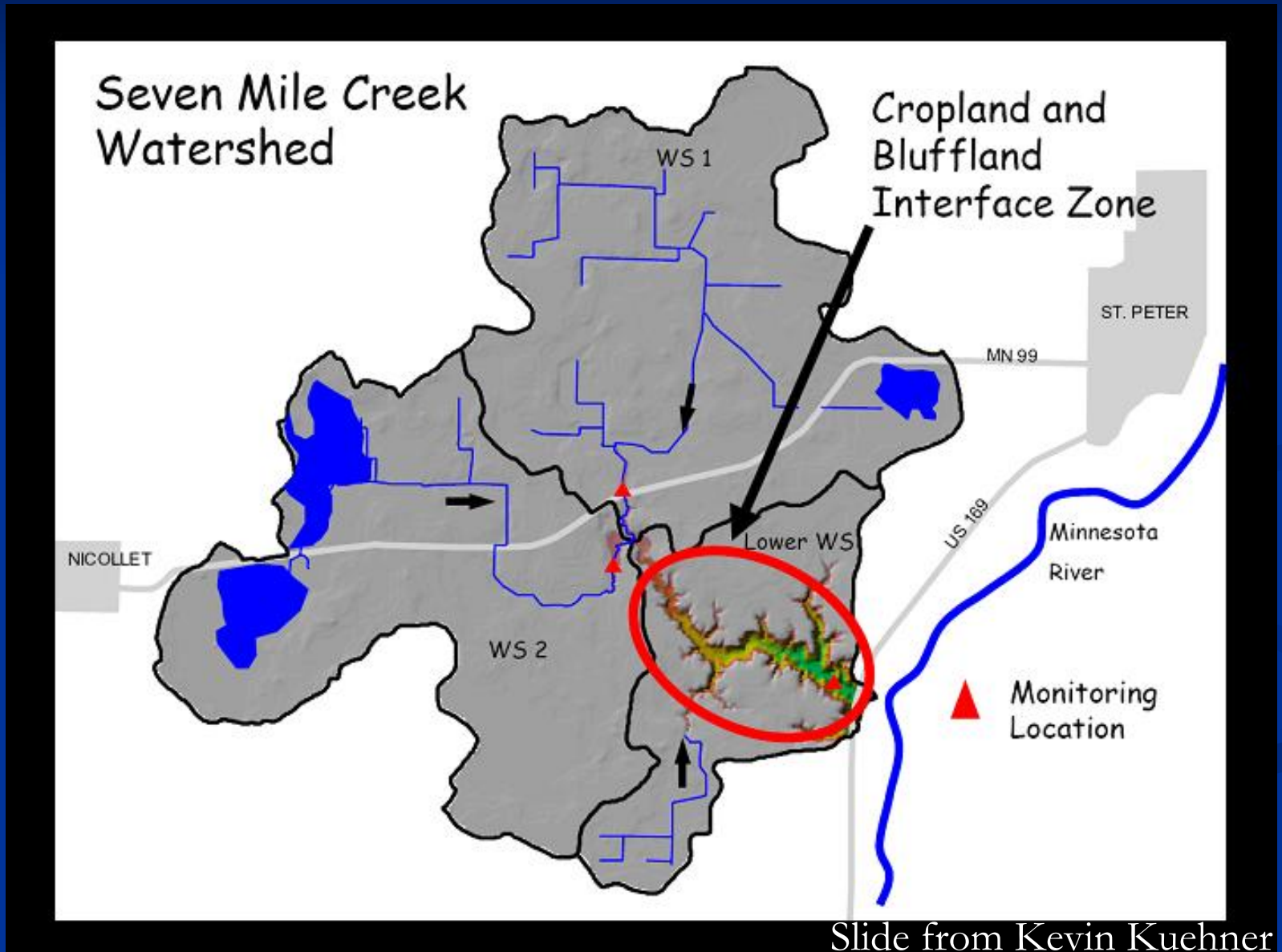

Some new reaches have been cut that breach the pre-existing stream courses.
Lac Qui Parle
Yellow Medicine

Yellow Medicine and Beaver Creek

Less than 10 miles of these new rivers are adjusted to River Warren base-level lowering.

Seven Mile Creek adjusted in lower 5 miles

(Hwy 99 crossing)



Slide from Kevin Kuehner

Simulation of river evolution

- http://talc.geo.umn.edu/people/grads/hasba002/num_sims/numerical_simulations.htm

Streams in incised reaches can still meander and adjust their gradients

Meander bends can also intersect the old valley wall locally

But keep your eye on the many, first-order streams as they eat their way into the landscape

- Incision will progress upstream
- Dendritic complexity will increase with time.
- Nick points will move as kinematic waves up into system.

River Warren in the metro and additional base level change

St. Anthony Falls = nick point on Mississippi (the tributary)

Start of River Warren Falls

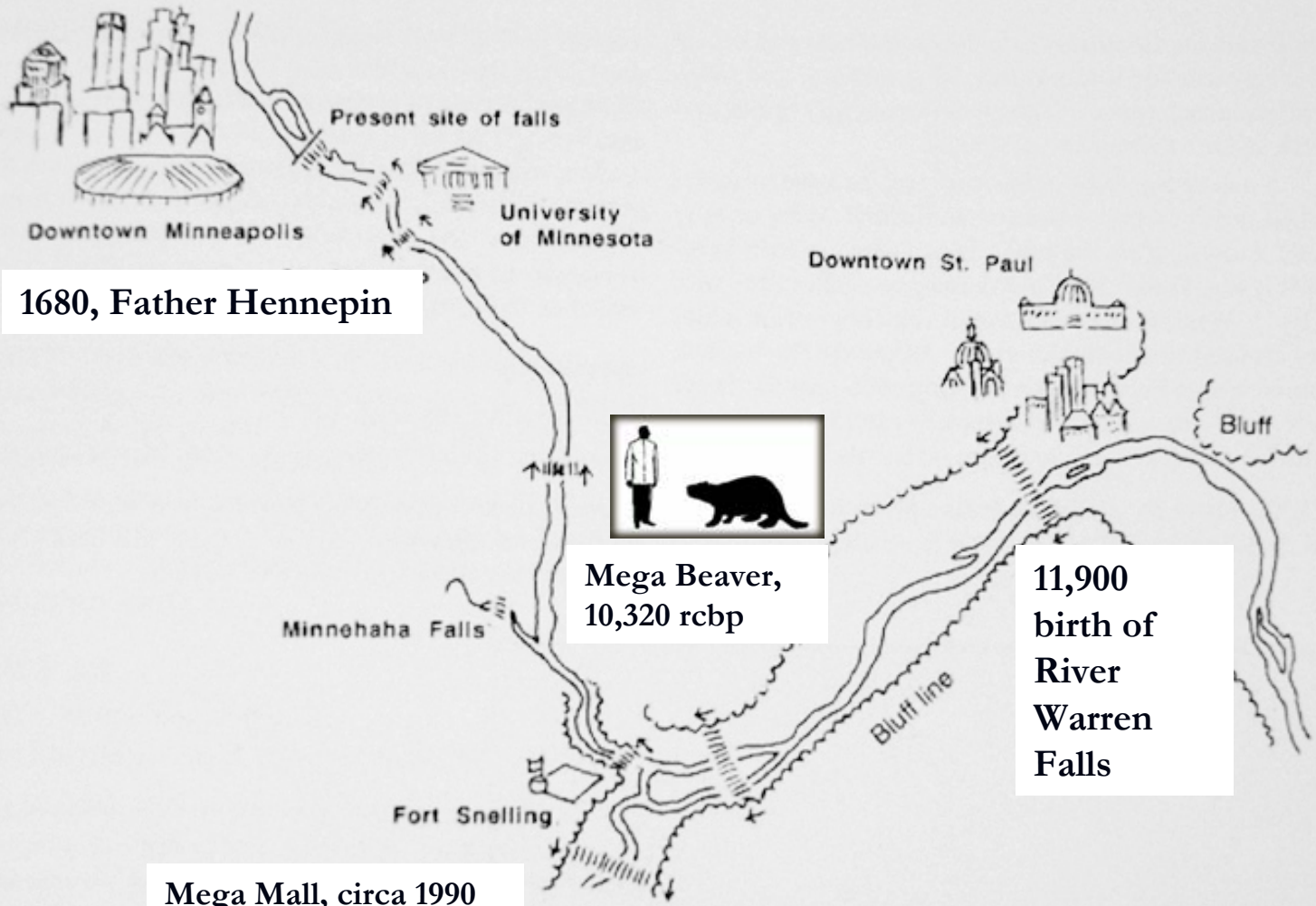
Start of St. Anthony Falls

Imagine a waterfall spanning the Mississippi in downtown St. Paul

Bridge approximates former height of falls

Evidence of retreat of falls

Retreat rate of River Warren Falls



1680, Father Hennepin

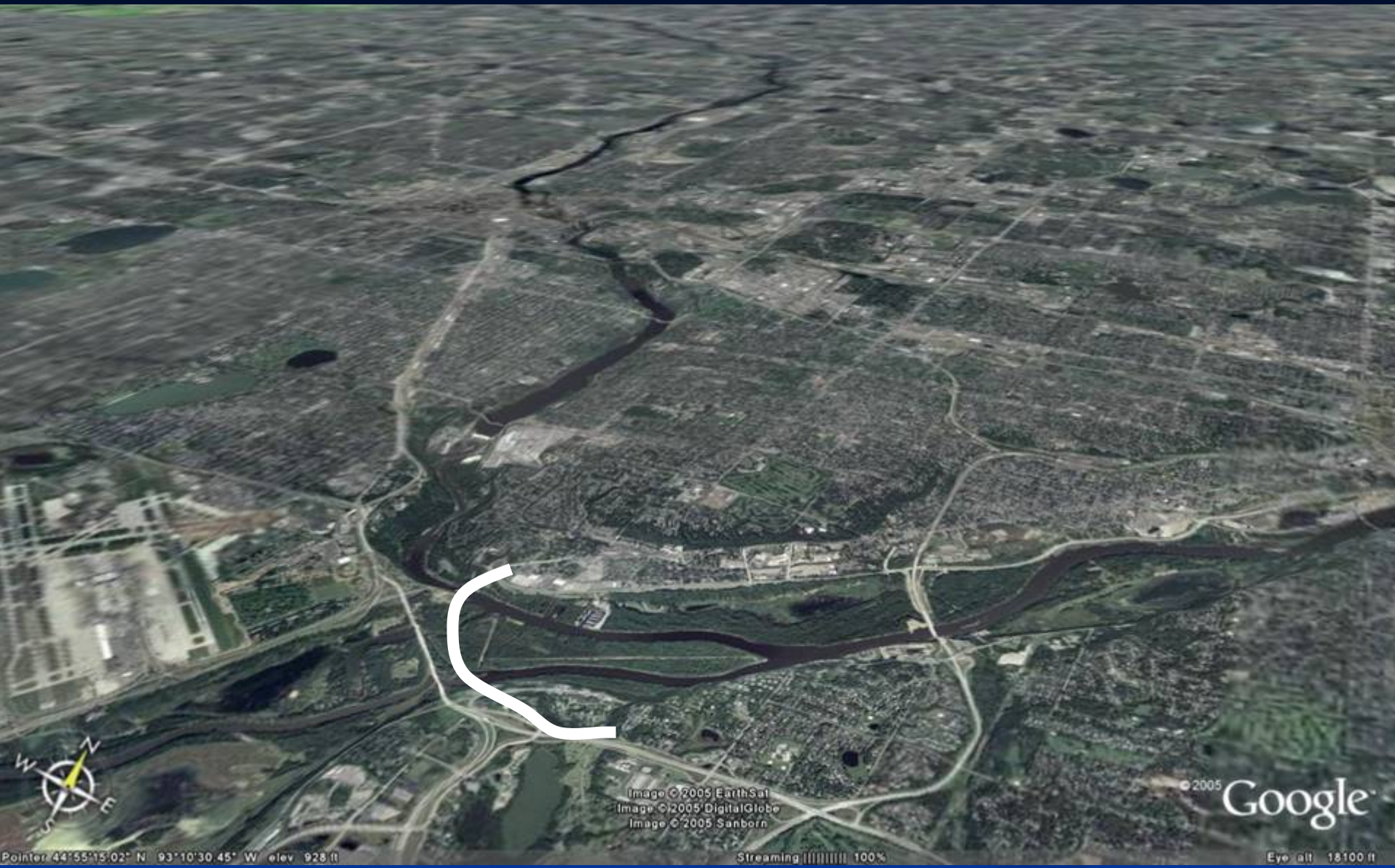
Mega Beaver, 10,320 rcbp

11,900 birth of River Warren Falls

Mega Mall, circa 1990

Figure 1.4. Illustration showing the retreat of glacial River Warren (Institute for Minnesota Archaeology, 1999).

Based on the work of Winchell, 1888

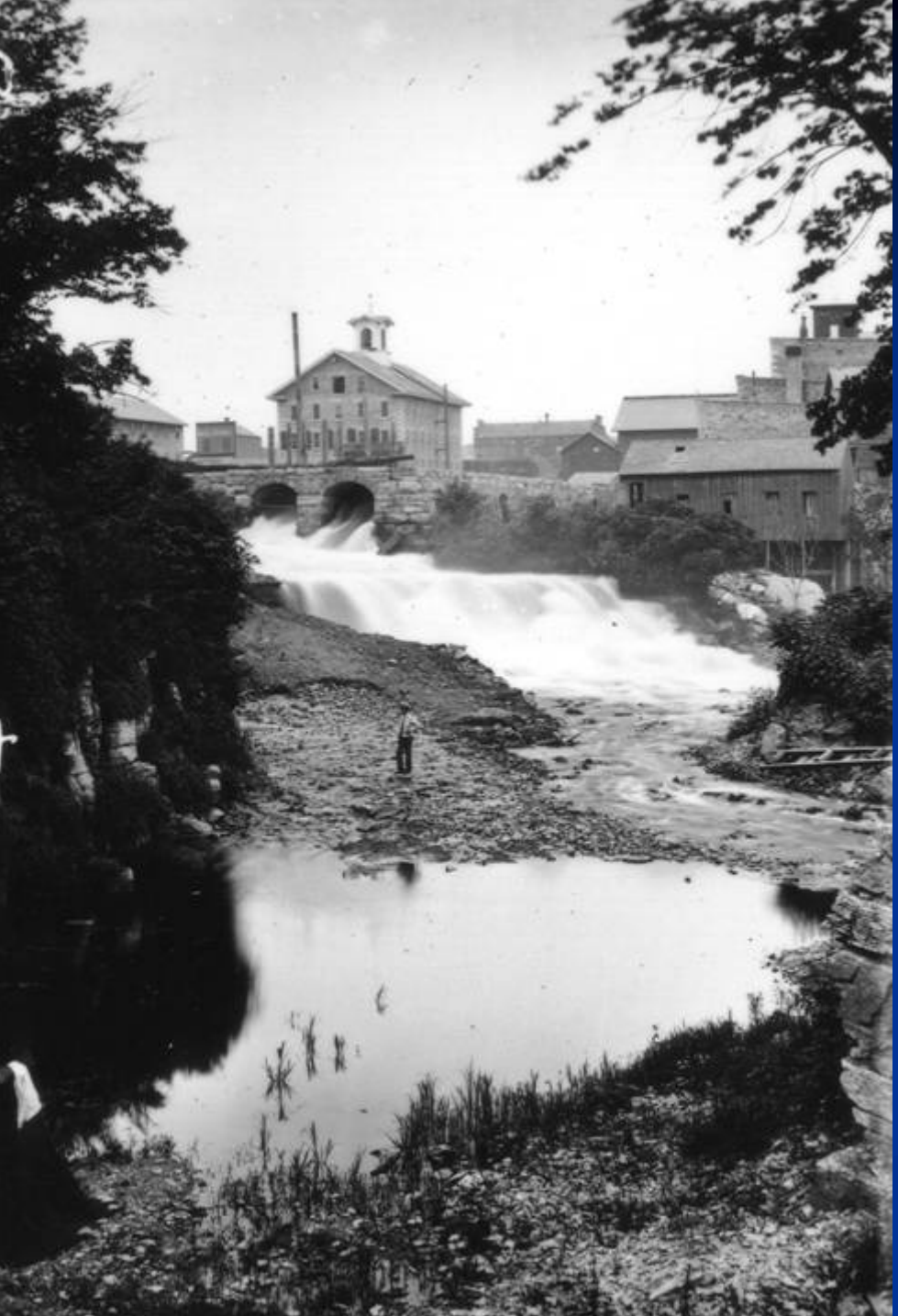


Location of horseshoe falls in River Warren

St. Anthony Falls

Painting of the falls in 1842 by an Alexander Loemans, a rare image of the natural waterfall known to the Dakota

Saint Anthony Falls, 1865.
Spirit Island on the left.



1880's during the height of lumbering operations.

Logs in river affected retreat rate by battering the falls.

Saint Anthony Falls today

Historic retreat rates

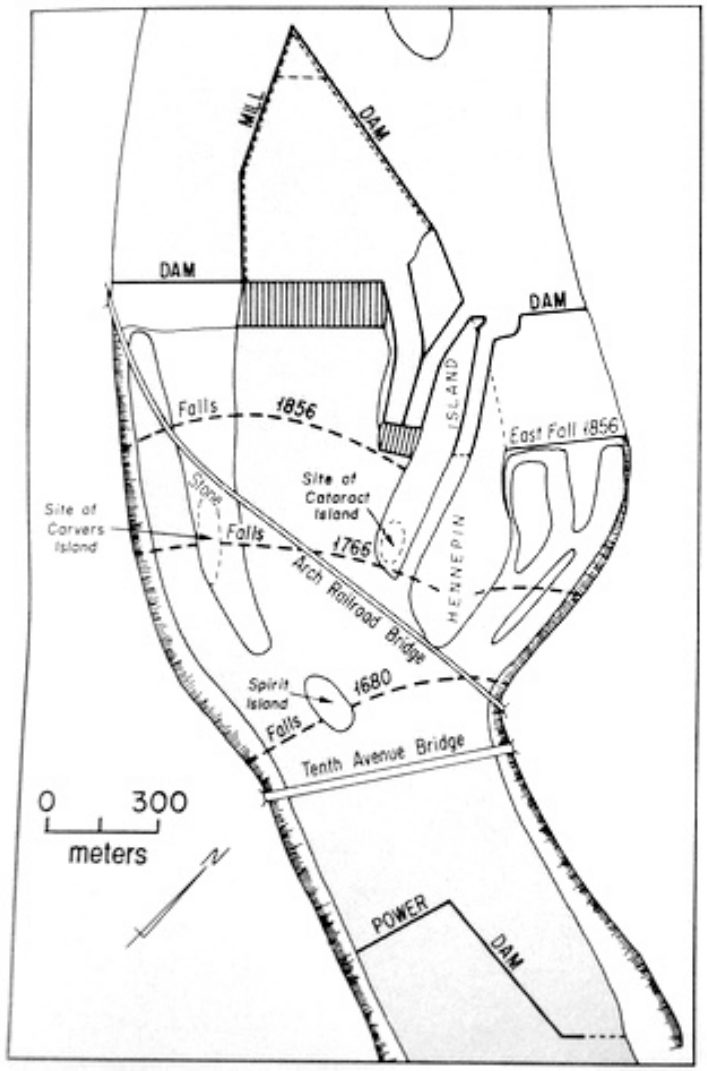


FIGURE 15.

Positions of St. Anthony Falls as sketched in 1680 and later. Newton Horace Winchell extrapolated the rate of retreat to estimate the length of postglacial time From Winchell and Upham (1888); redrawn from Sardeson (1916).

St. Anthony Falls Retreat

- Varied with thickness of cap rock
- Accelerated during logging
- Would have extinguished itself if not for the Corps (out of cap rock)

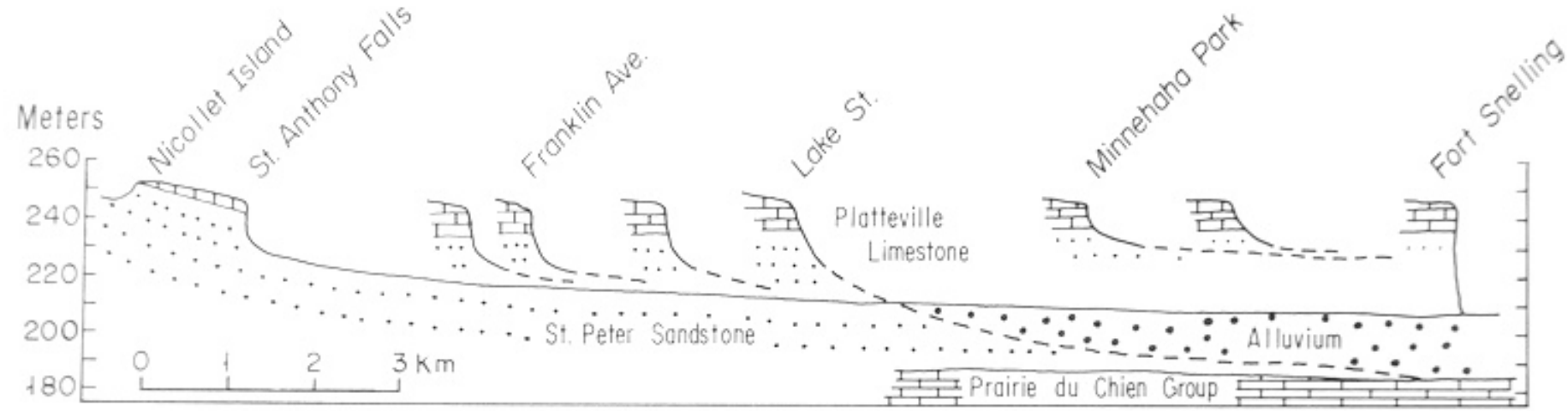
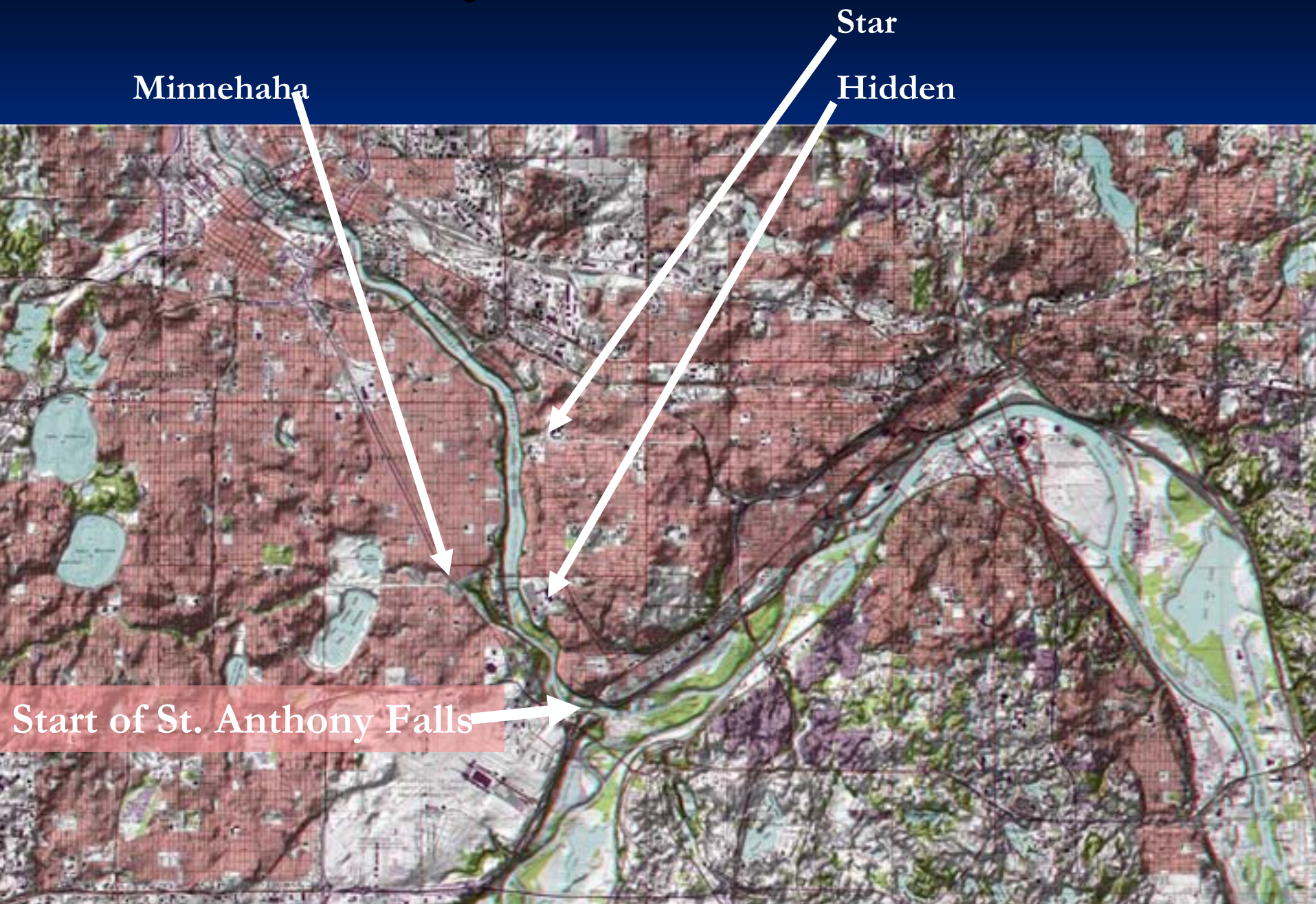


FIGURE 14.

Tributary Falls in the Metro



1840 painting of Minnehaha Falls

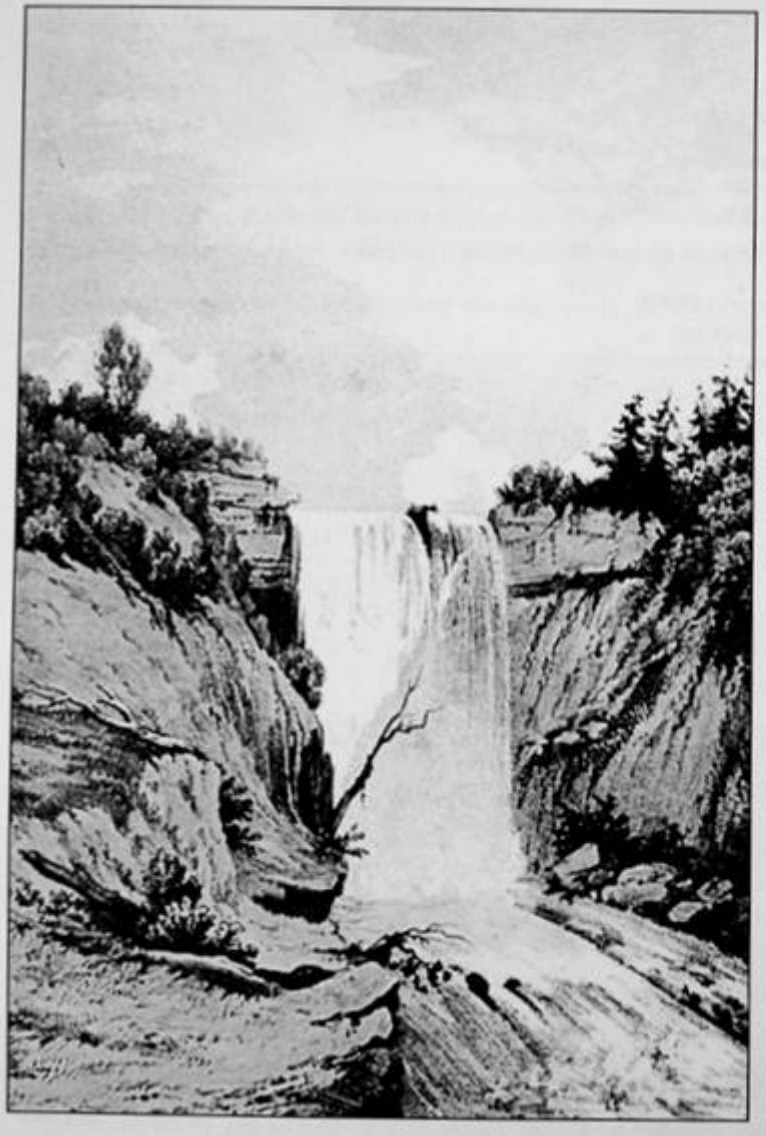


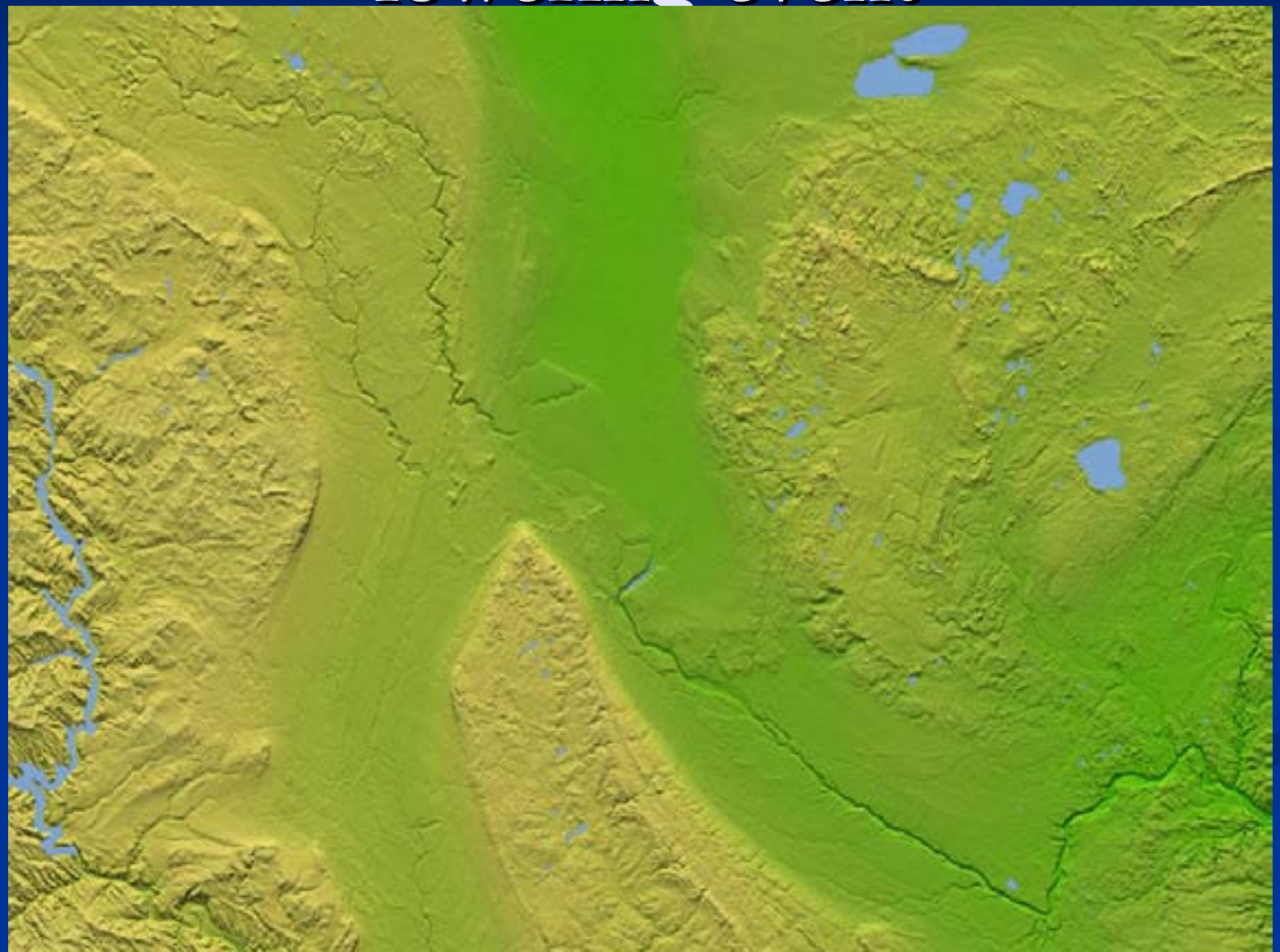
Figure 1.6. Minnehaha Falls as painted by Henry Lewis circa 1840 (Institute for Minnesota Archaeology, 1999).

These bluffs of glacial sediment were created in the same way as the bedrock bluffs, at the same general time.

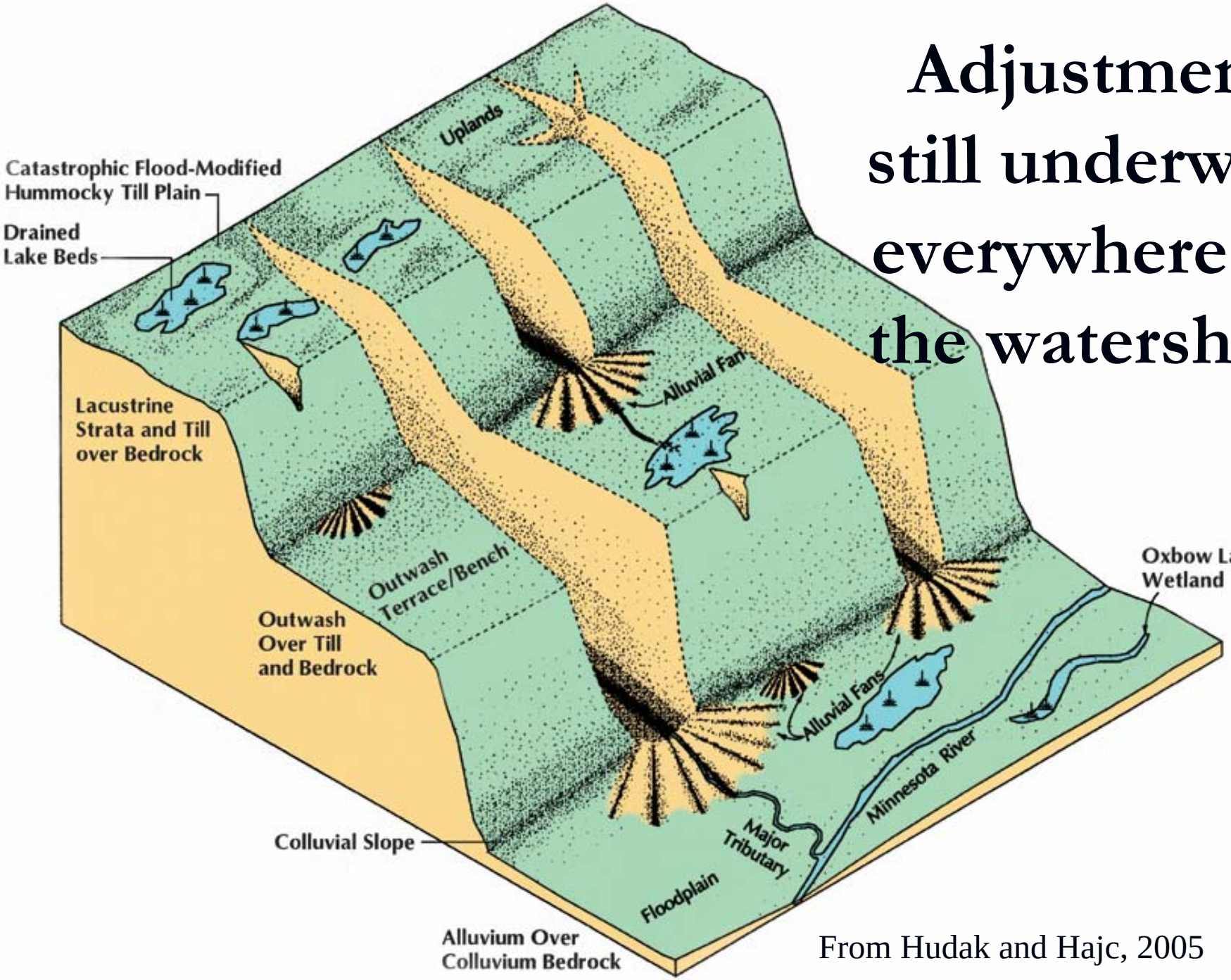
A waterfall (nick point) passed here long ago.

That is not the same as saying we are having no impact on these bluff faces with land-use changes.

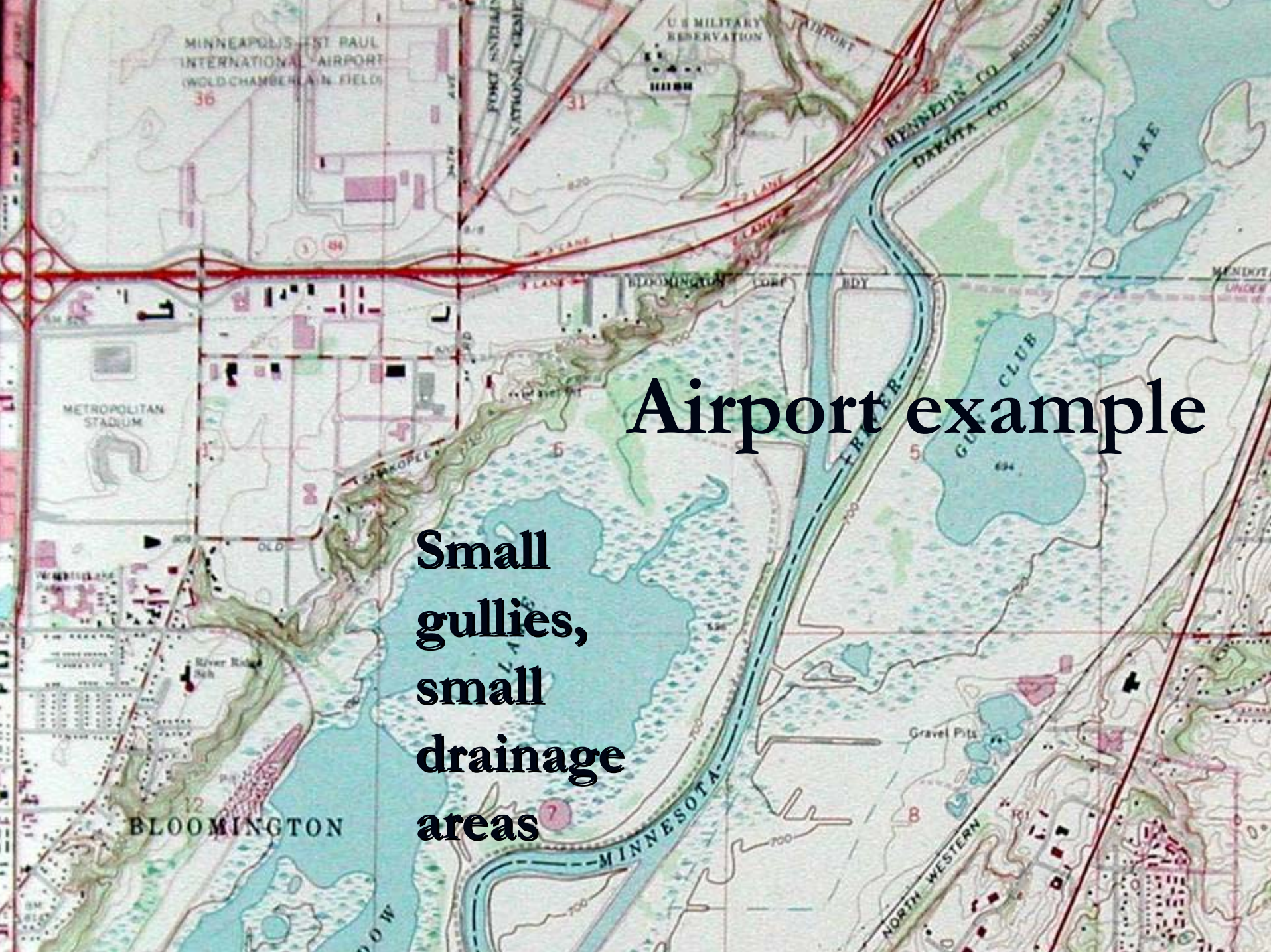
Recap: Initial incision = base level lowering event



Adjustments still underway everywhere in the watershed

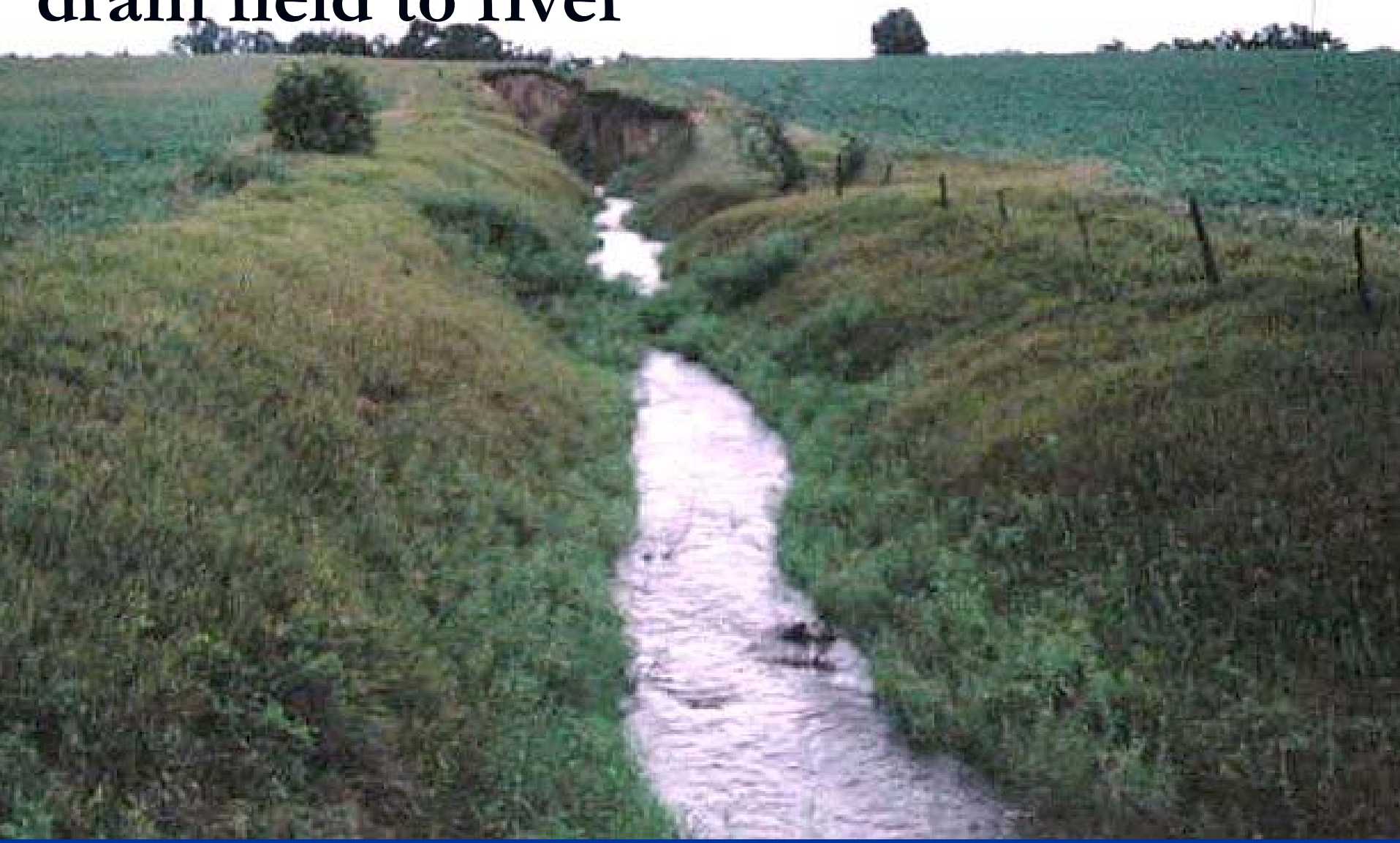


From Hudak and Hajc, 2005

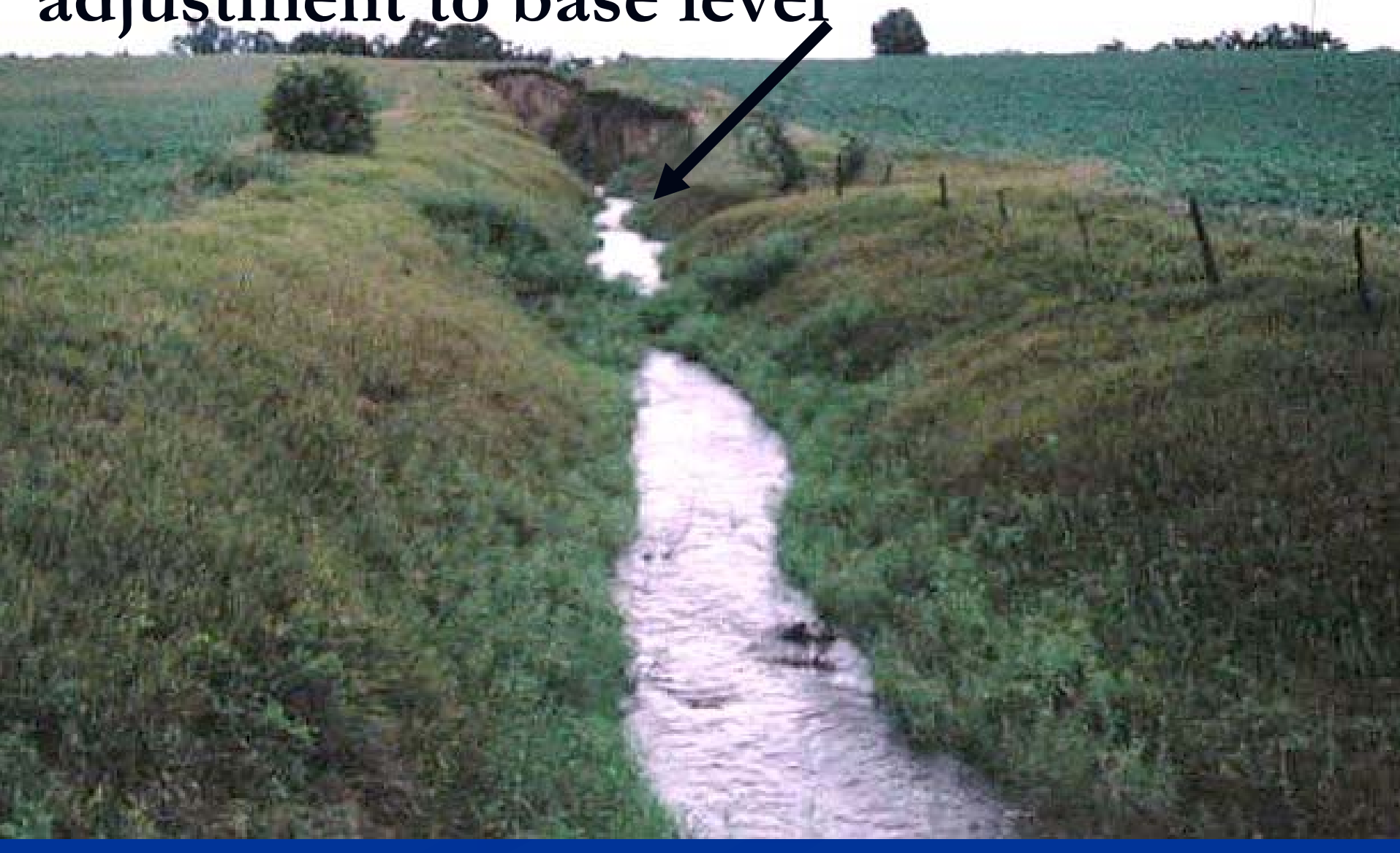

MINNEAPOLIS-ST PAUL
INTERNATIONAL AIRPORT
(WOLD-CHAMBERLAIN FIELD)
U.S MILITARY RESERVATION
HENNEPIN CO
DAKOTA CO
LAKE
METROPOLITAN STADIUM
BLOOMINGTON
MINNESOTA
RIVER
Gravel Pits
NORTH WESTERN
Airport example
Small gullies, small drainage areas

Airport modification required new retention pond.

Agricultural example—dig ditch to drain field to river

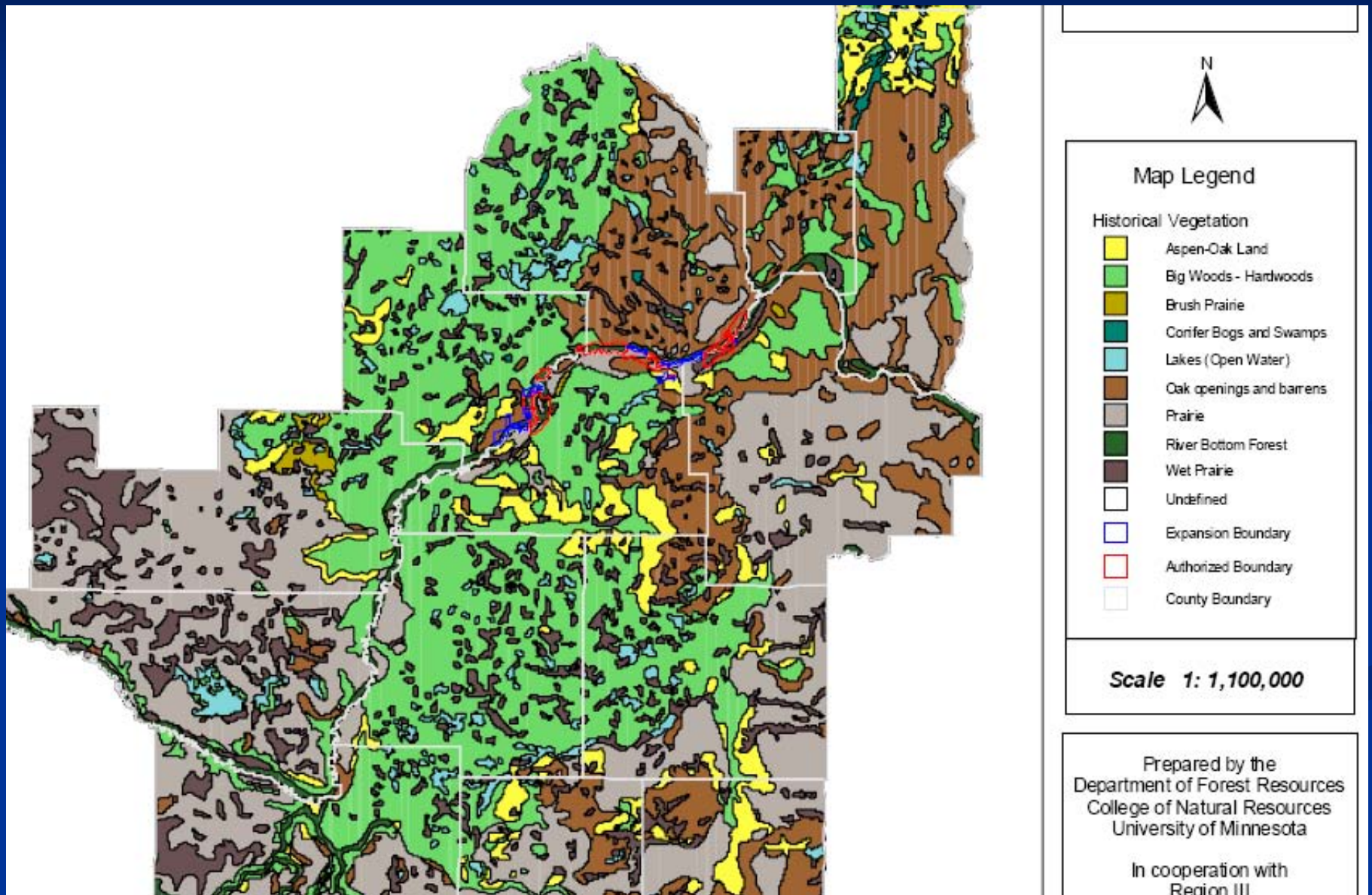


Agricultural example—changed rate of adjustment to base level



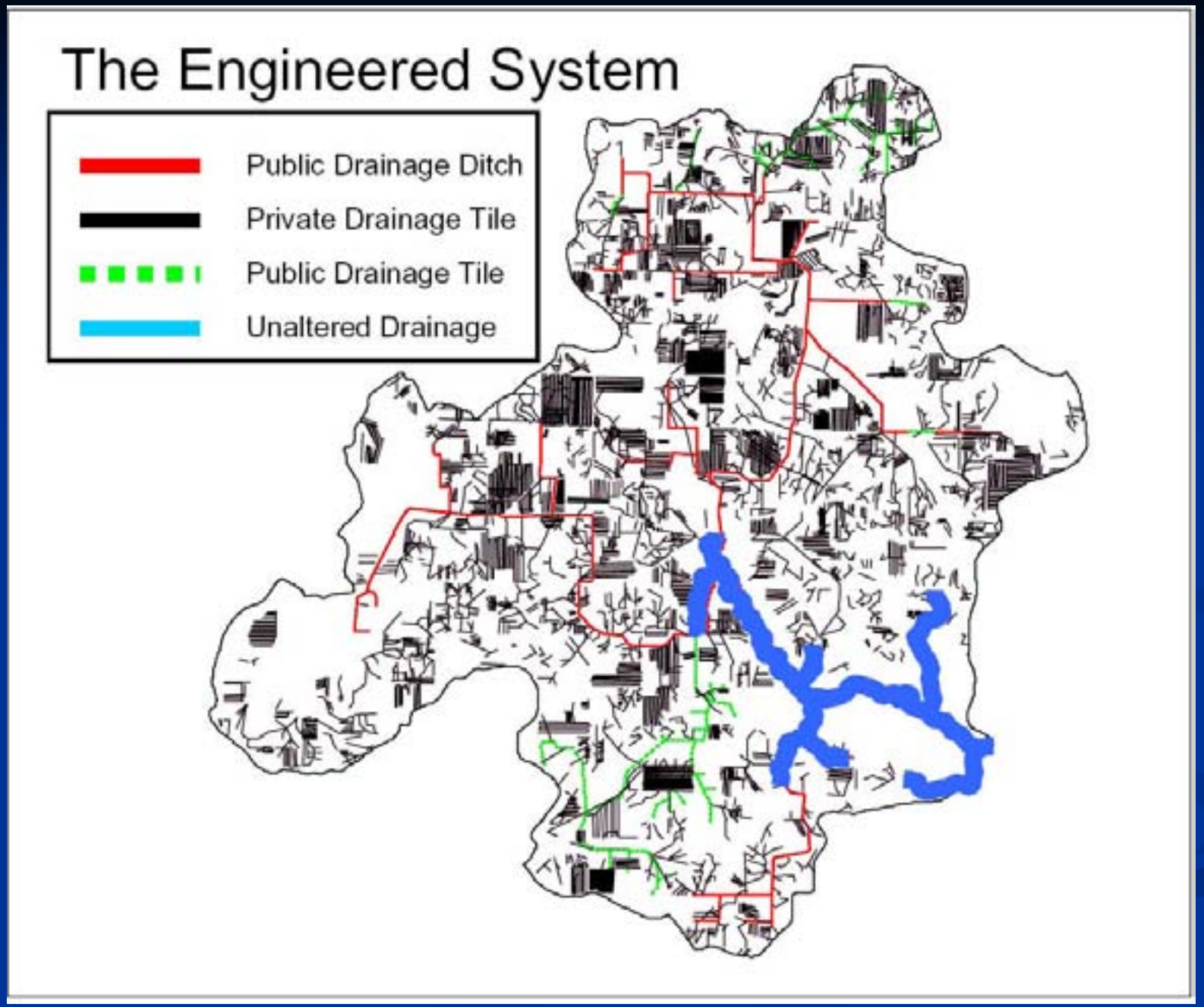
Rate of adjustment dependent on available water to do the work

Changing the volume of water available to do the work on a watershed scale



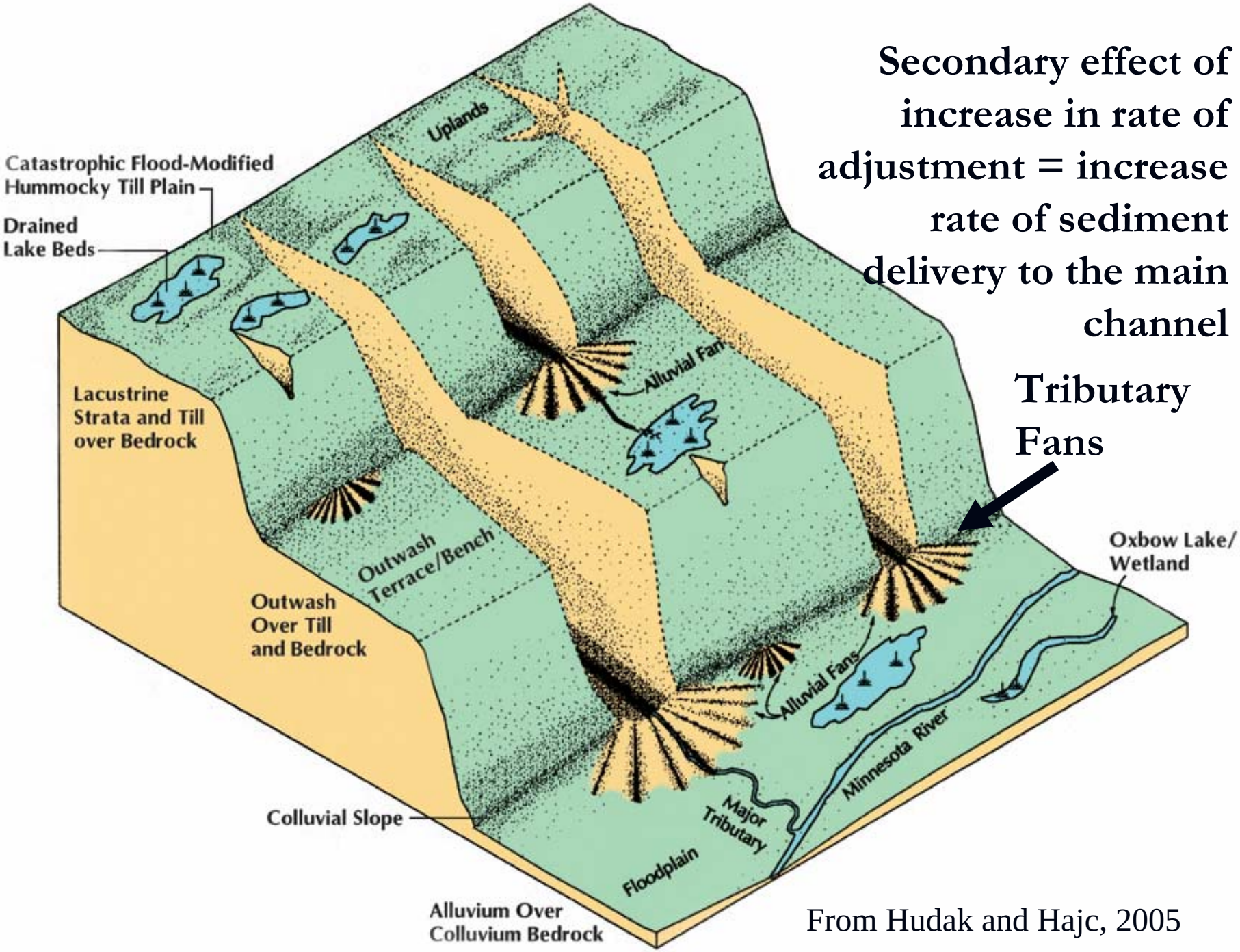
Simulation of pre-settlement conditions?

Photo of early spring floods, provided by Dave Craigmile



Slide courtesy of Kevin Kuehner


Blue Earth County,
slide from MPCA

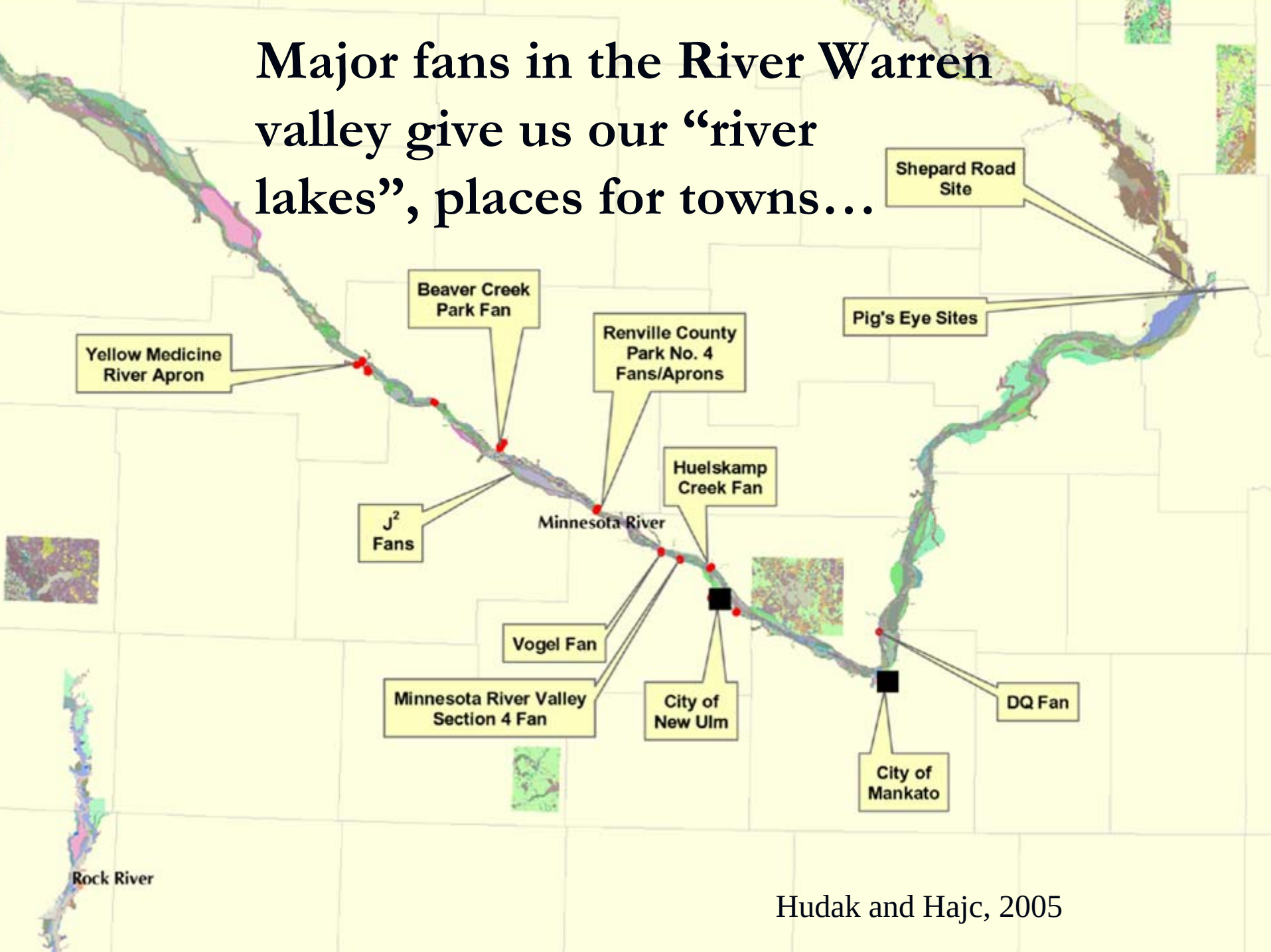


Secondary effect of increase in rate of adjustment = increase rate of sediment delivery to the main channel

Tributary Fans

From Hudak and Hajc, 2005

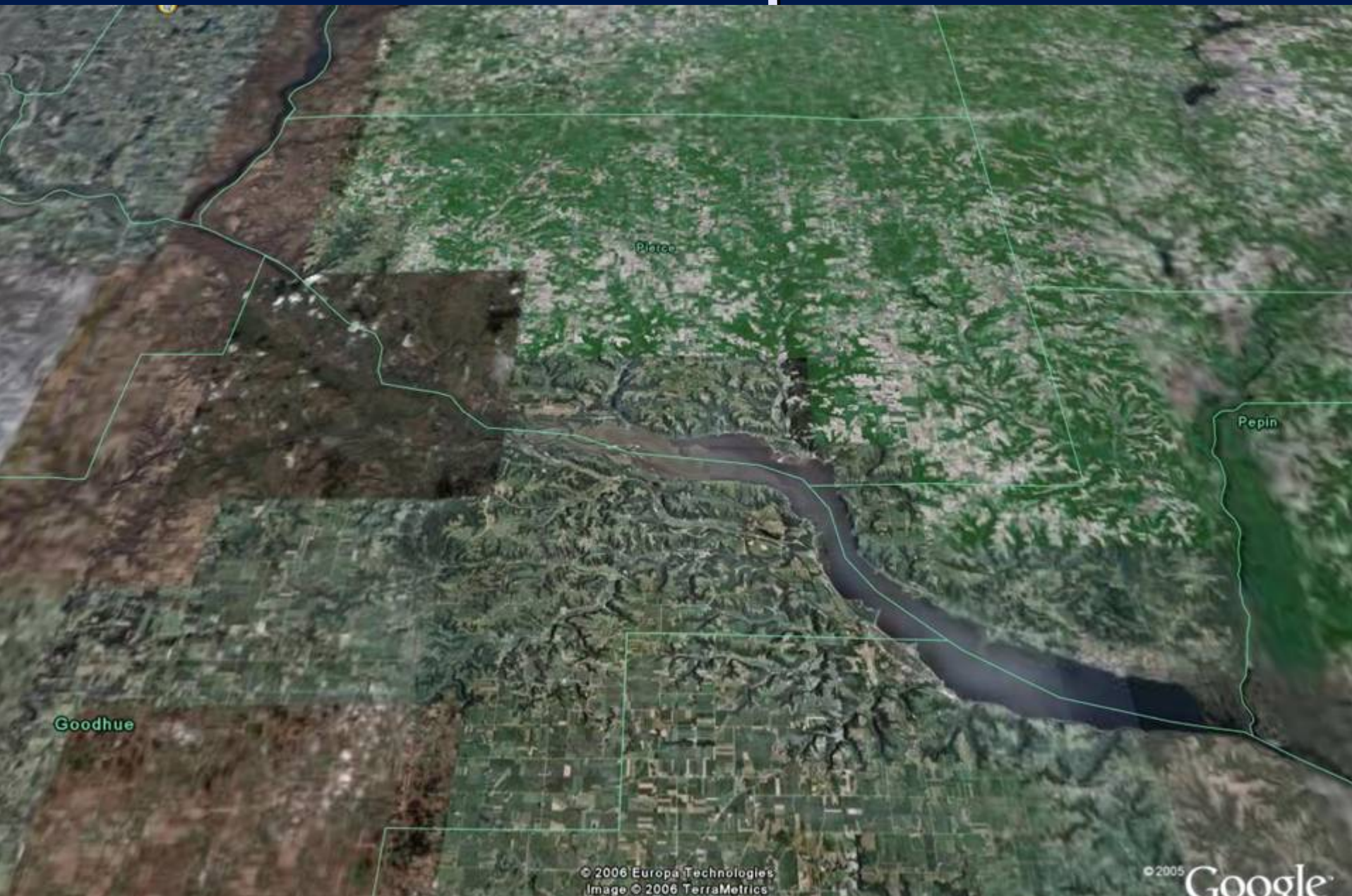
Major fans in the River Warren valley give us our "river lakes", places for towns…



Hudak and Hajc, 2005

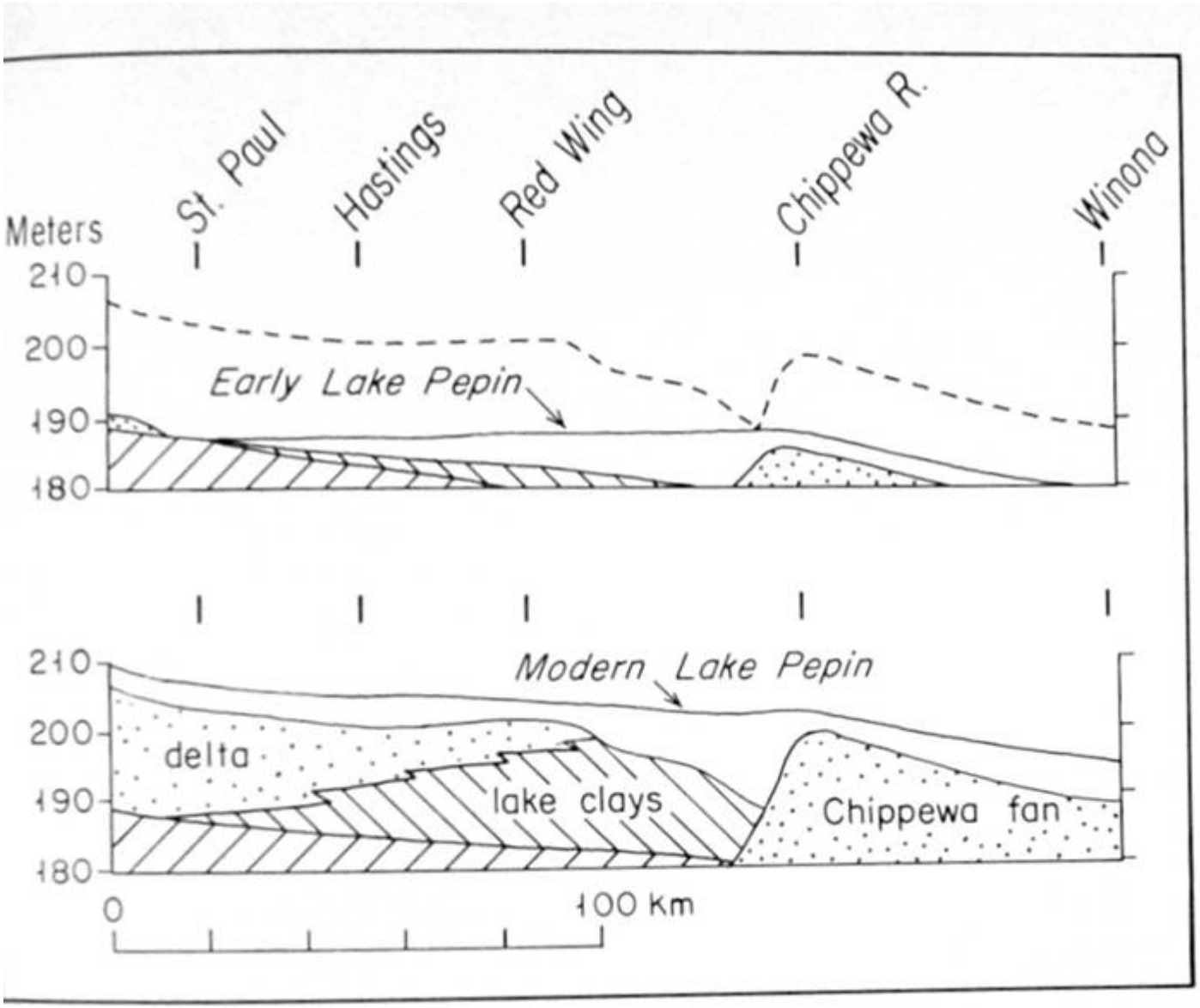
A tributary fan gave us Lake Pepin

Lake Pepin

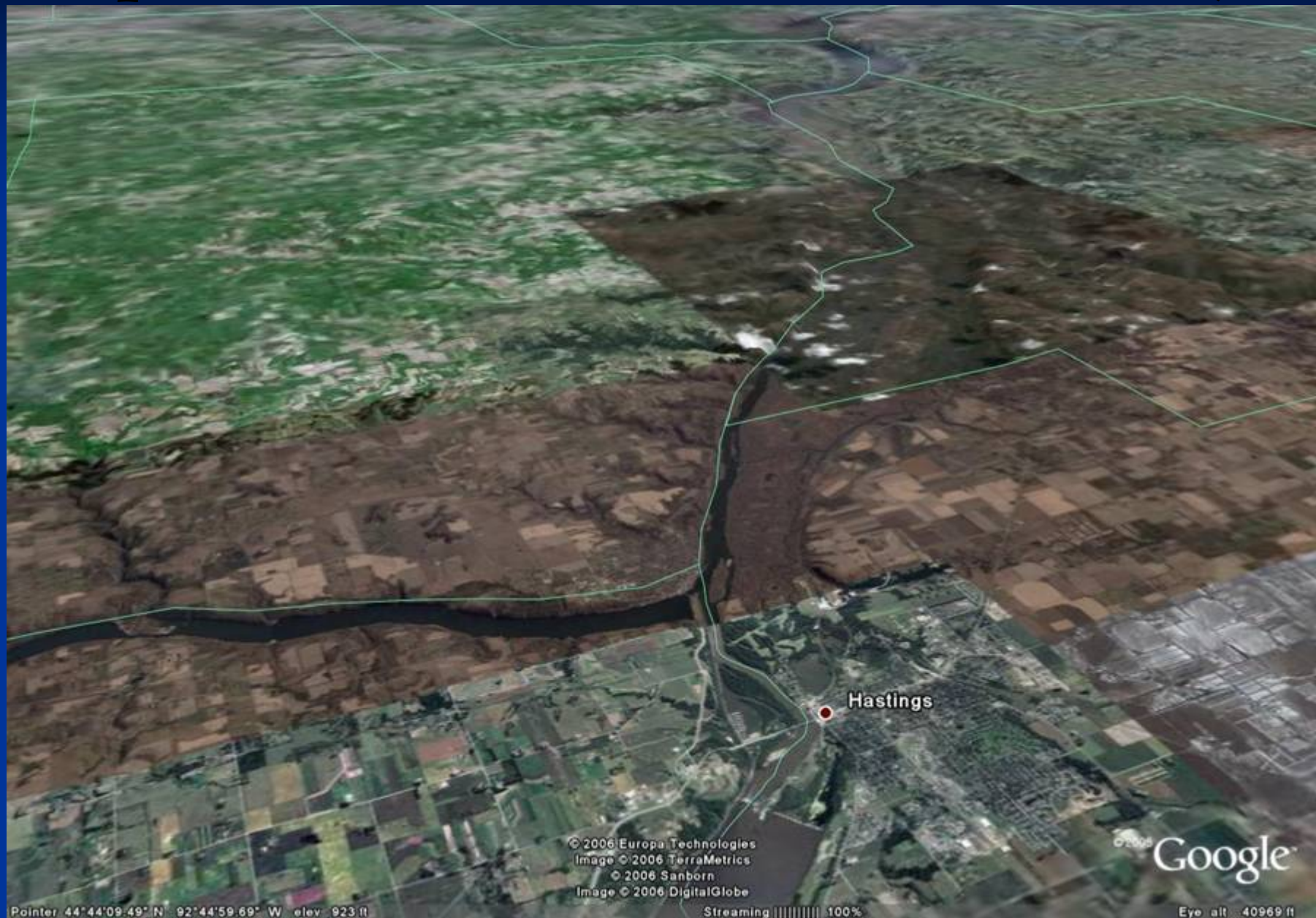

Pepin
Goodhue
© 2006 Europa Technologies
Image © 2006 TerraMetrics
©2005 Google

Chippewa Delta

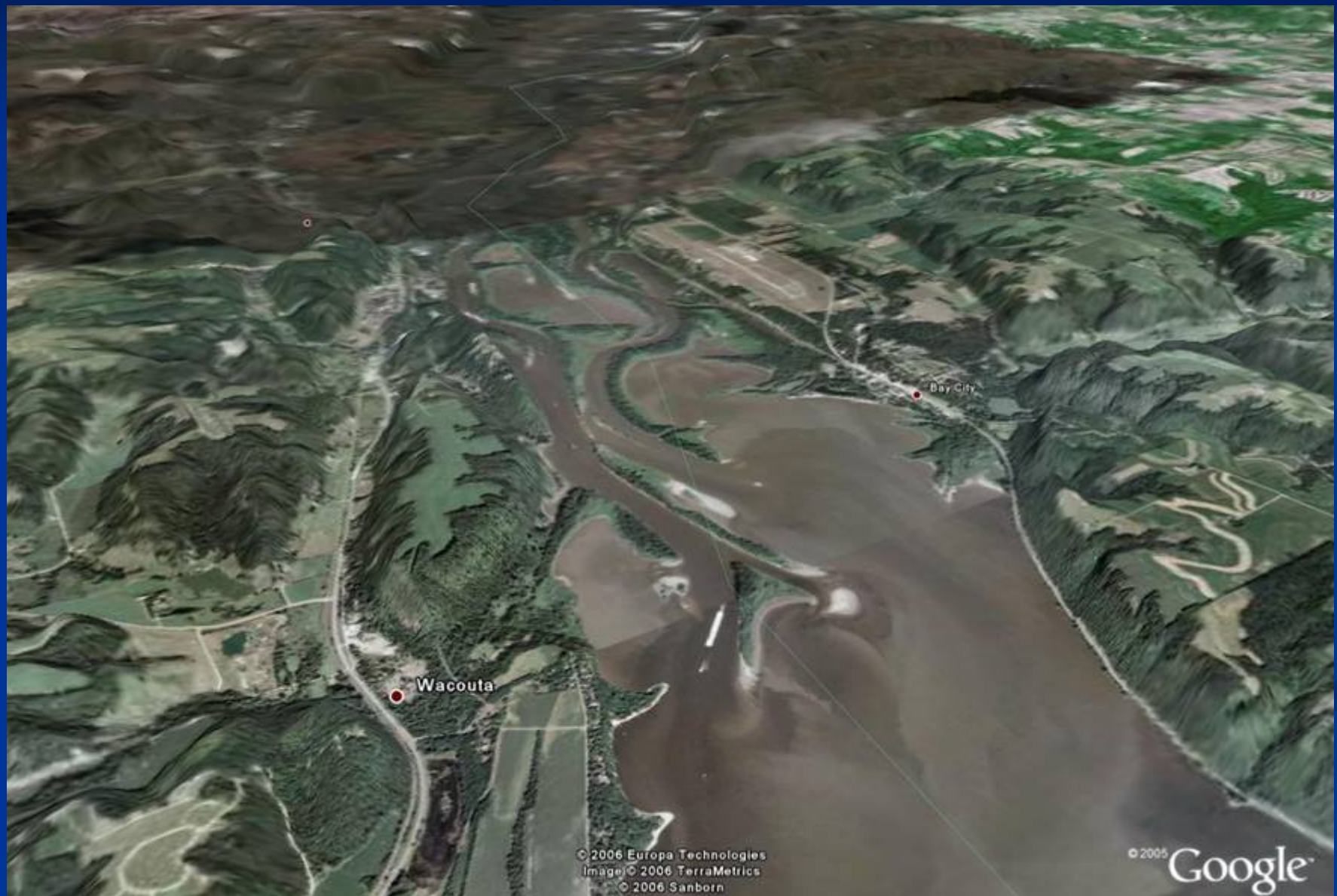
Lake Pepin Delta migration



Pepin delta across St. Croix mouth (SE)

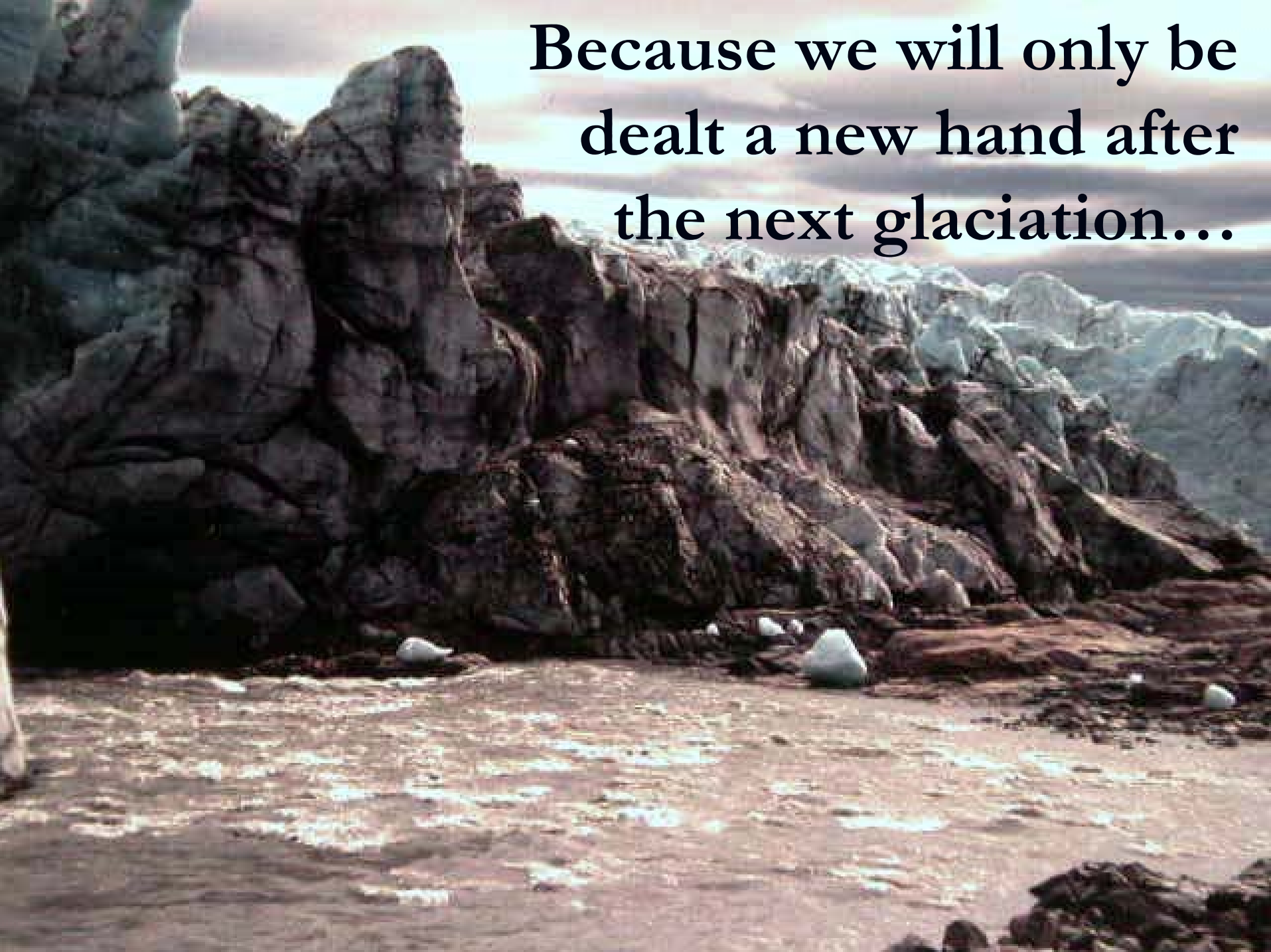


Pepin Delta at Red Wing – still advancing but at what rate?

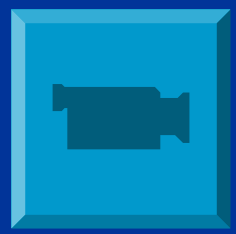


These rivers …and the course they are on… represent the cards we've been dealt.

We need to understand the rules of the game and the consequences of how we play this hand.


Because we will only be dealt a new hand after the next glaciation…

Now is not a good time to be counting on the next glaciation to solve your problems



Questions?

Minnesota Rivers—How They Work

Carrie E. Jennings, PhD
Minnesota Geological Survey
University of Minnesota