

Minnesota Rivers— How They Work



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Have our rivers always been this way?

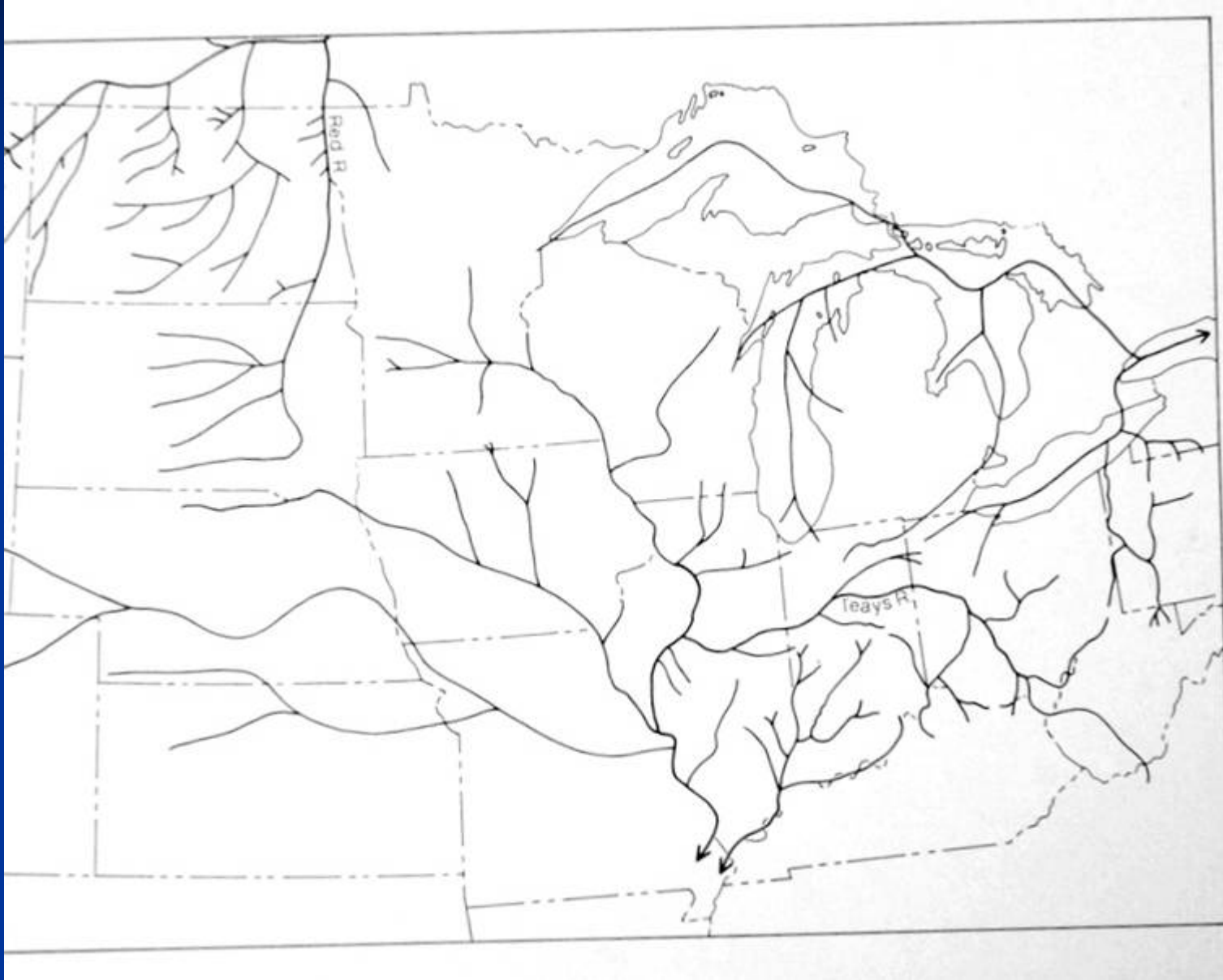
Mississippi River

St. Croix River

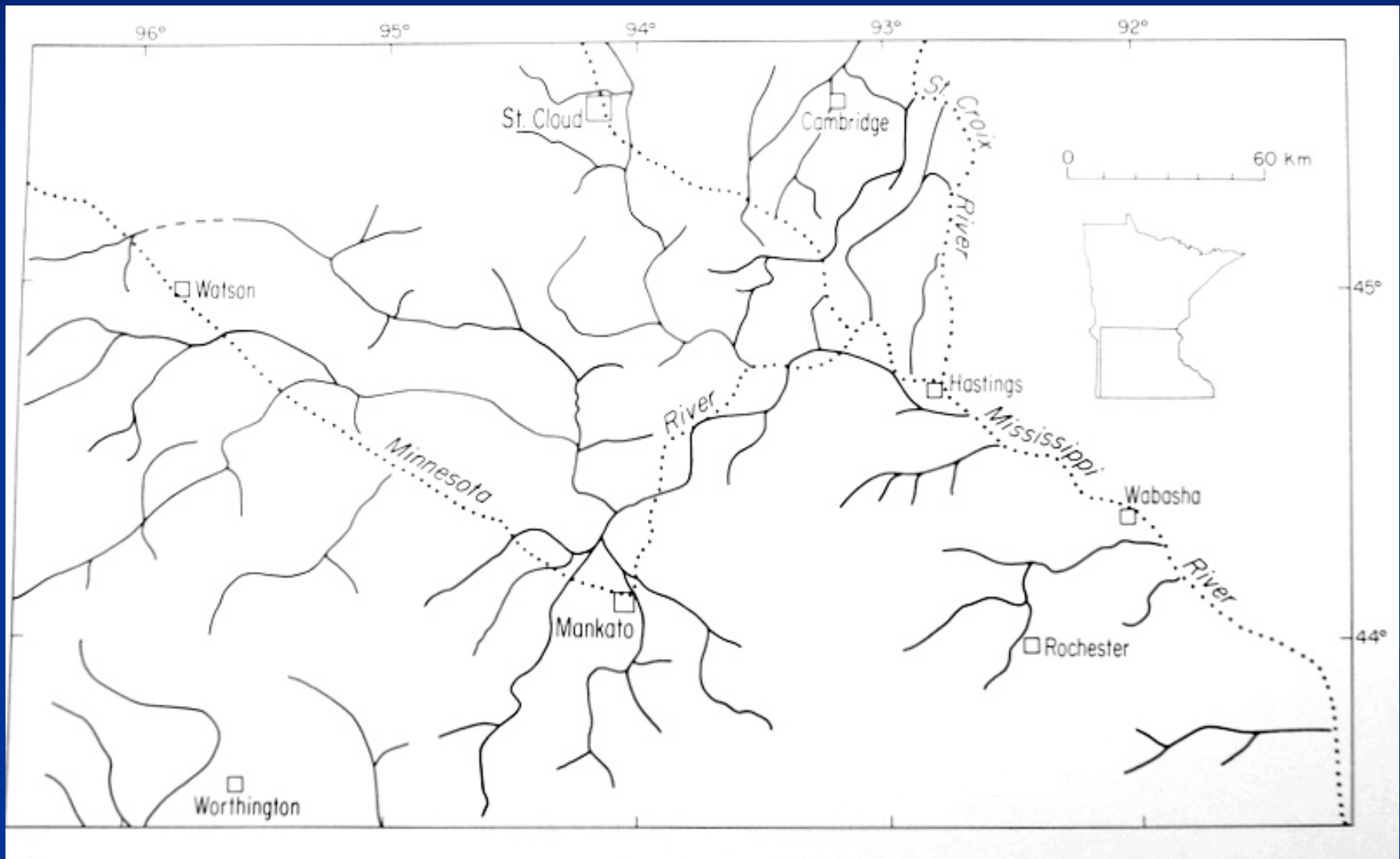
Minnesota River



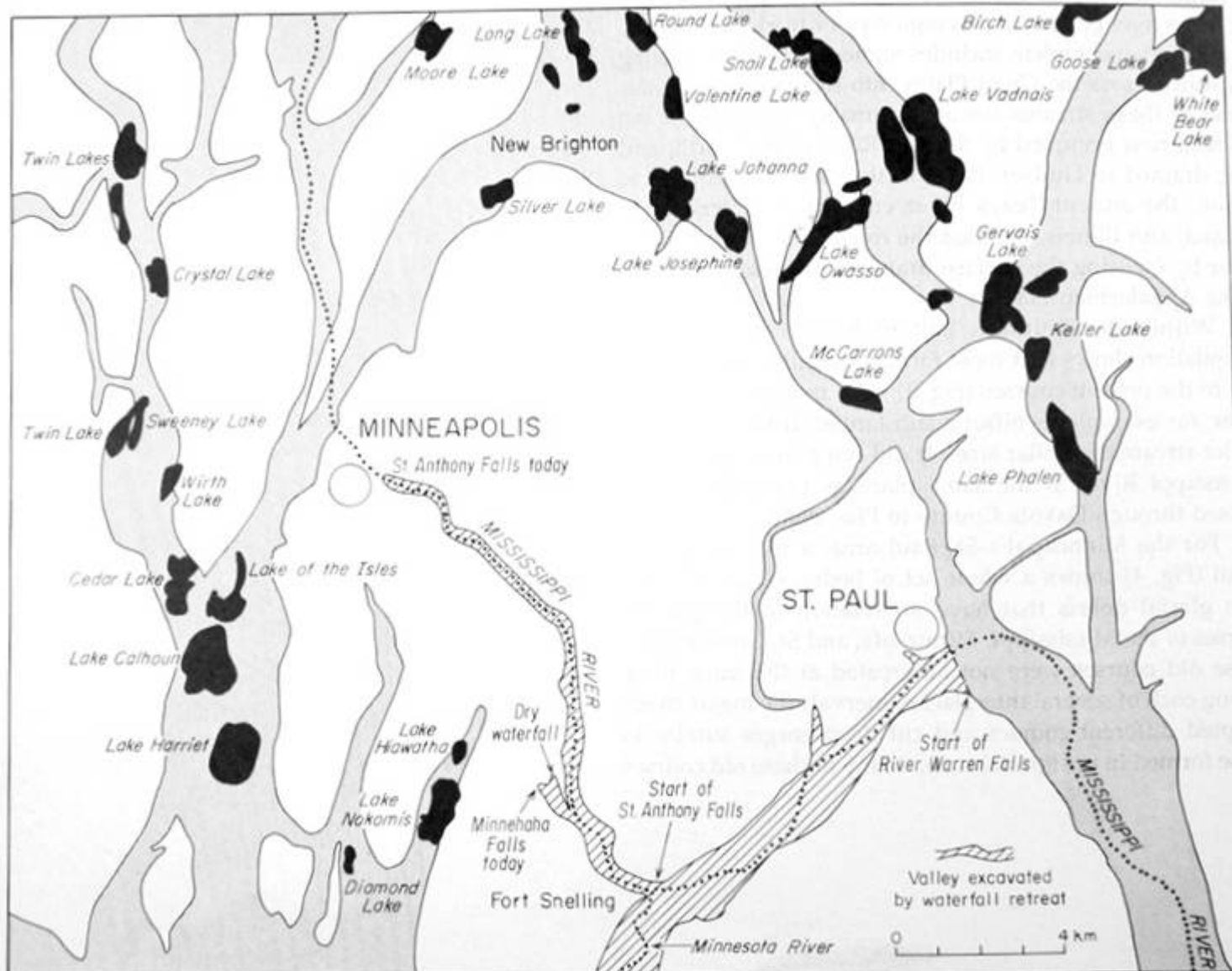
Yesterday's rivers = buried valleys



Metro area buried valleys

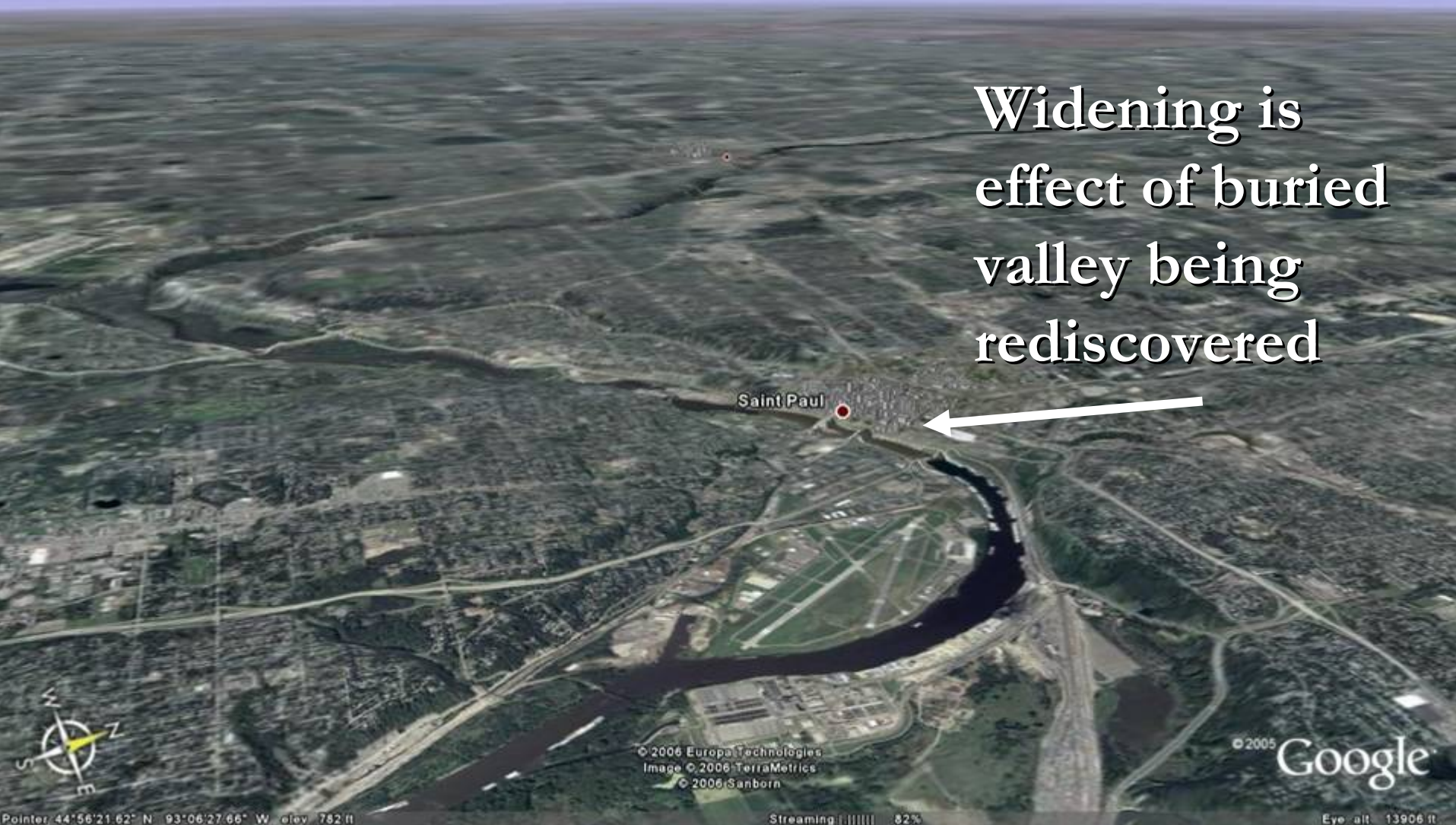


Chains of lakes mark buried valleys



Effect of buried valley on modern Mississippi

Widening is
effect of buried
valley being
rediscovered



Saint Paul

© 2006 Europa Technologies
Image © 2006 TerraMetrics
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Streaming 82%

Eye alt: 13906 ft

What controls the
current river
location and
configuration?

Minnesota River

A topographic map of the Minnesota River basin, showing the river's course from its headwaters in the north to its mouth at Lake Superior in the east. The river is highlighted in blue. The map is set against a dark blue background with a wavy pattern on the right side.

With each
glaciation,
we get a new
hand

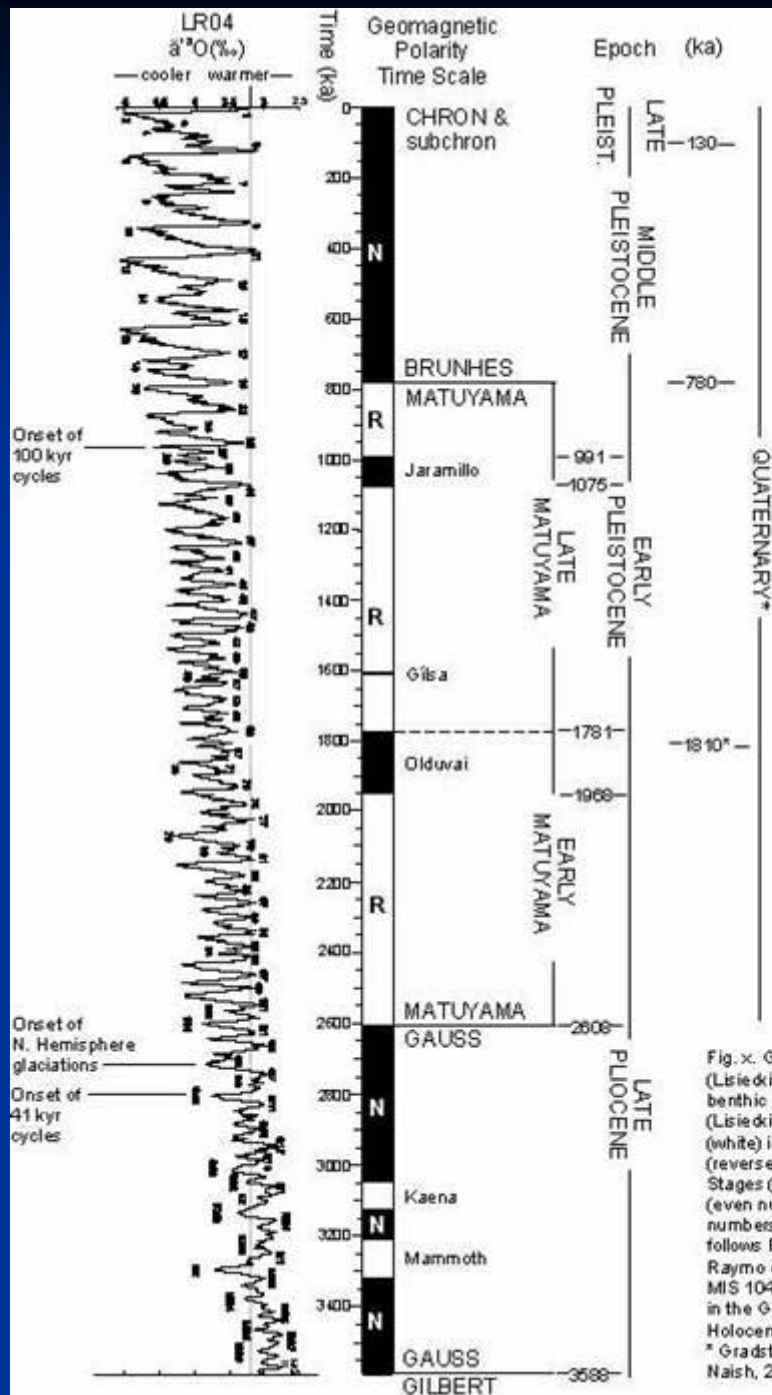
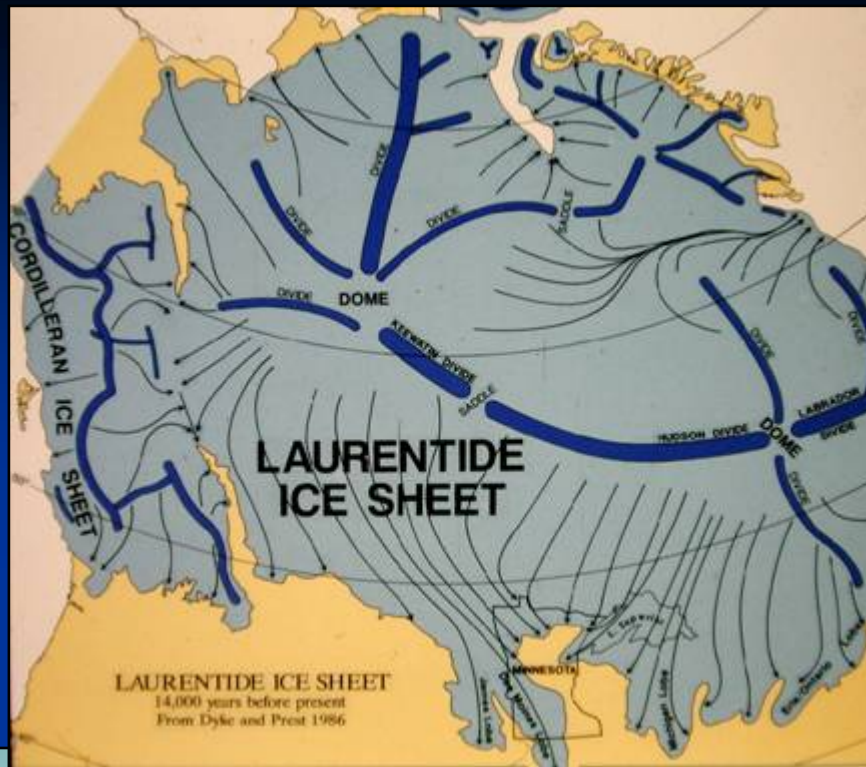


Fig. x. Geomagnetic polarity time scale (Lisiecki and Raymo, 2005) for LR04 benthic $\delta^{18}O$ paleotemperature profile (Lisiecki and Raymo, 2005). Black (white) intervals represent normal (reversed) polarity. Marine Isotope Stages (MIS) are labeled on LR04 (even numbers represent glacial; odd numbers interglacial). 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; Pillars and Naish, 2004.



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



NorthShore 2004



*Margin of
analog for*





This is our current hand

The image is a topographic map of North America, color-coded to show glacial history. The colors range from brown (highest elevation, never glaciated) to green (lower elevation, recently glaciated). White outlines delineate specific regions. The Great Lakes region is labeled 'Recently glaciated and flooded by large lake'. The western US is labeled 'Never glaciated'. The central US is labeled 'Not recently glaciated'. The eastern US is labeled 'Very recently glaciated'. The southern US is labeled 'Not recently glaciated' and 'Never glaciated'.

Recently glaciated
and flooded by
large lake

Never
glaciated

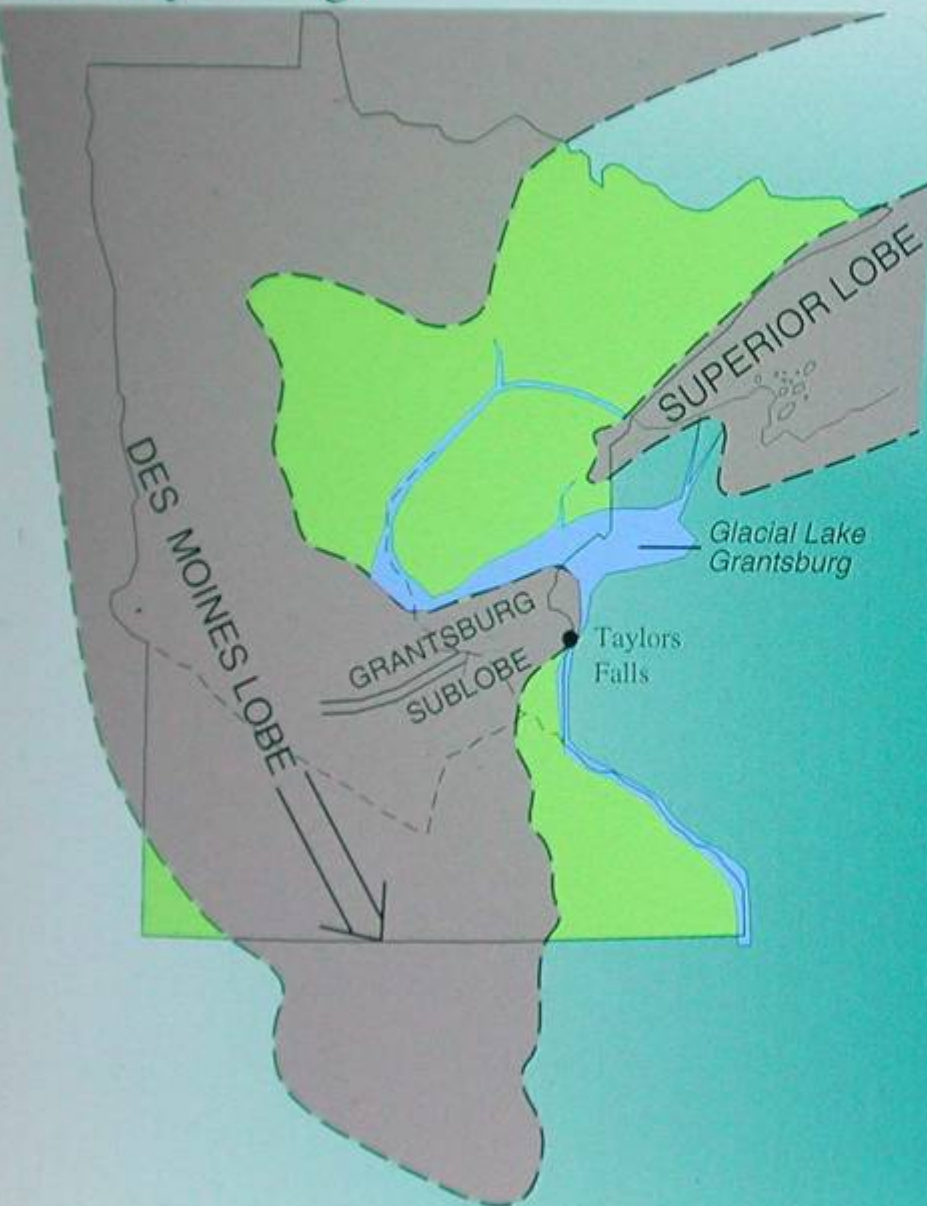
Not
recently
glaciated

Very
recently
glaciated

Not
recently
glaciated

Never
glaciated

14,000 years ago

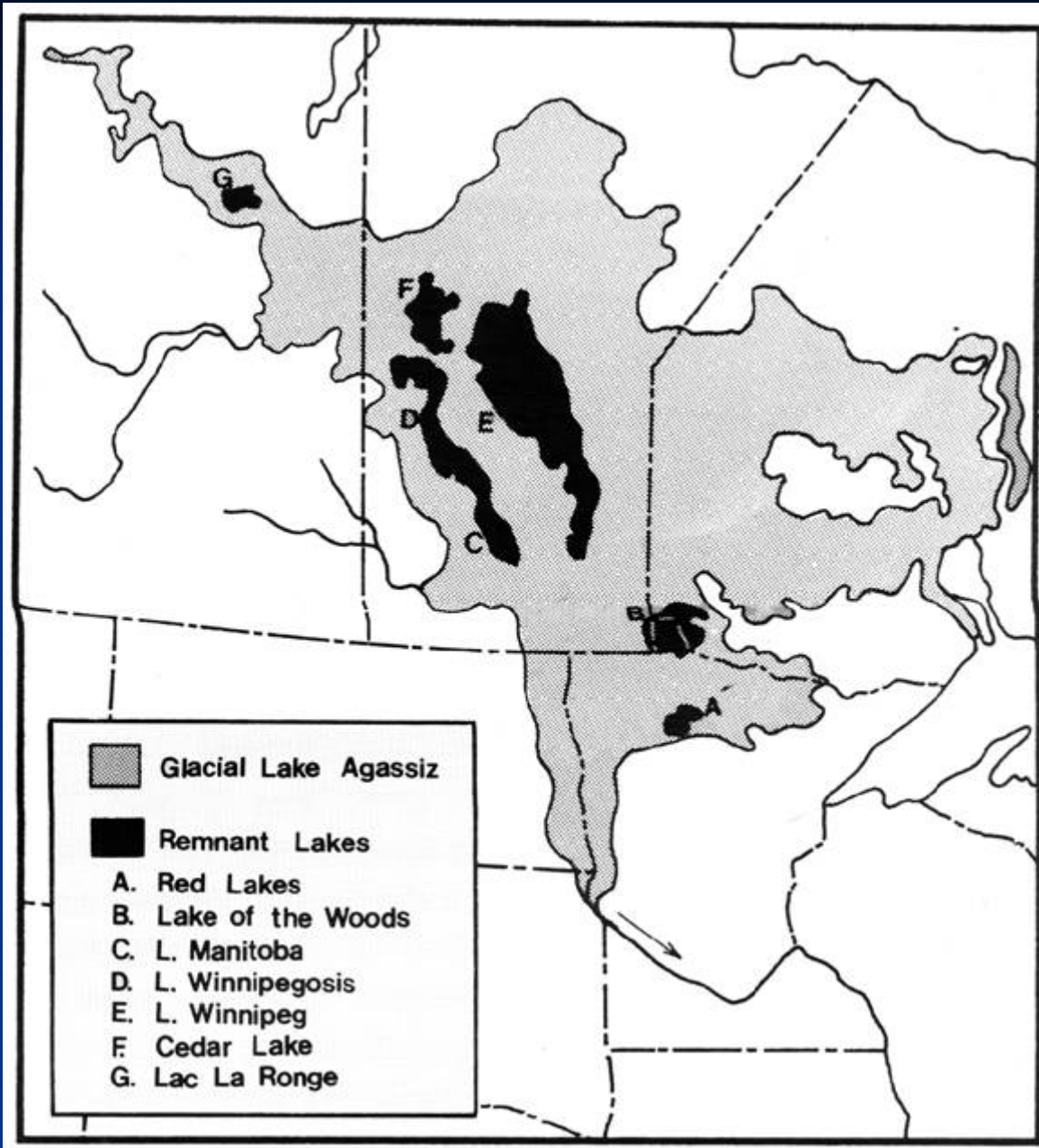


12,000-10,000 years ago



Lake Agassiz

The lake
that started
us on our
present
course.



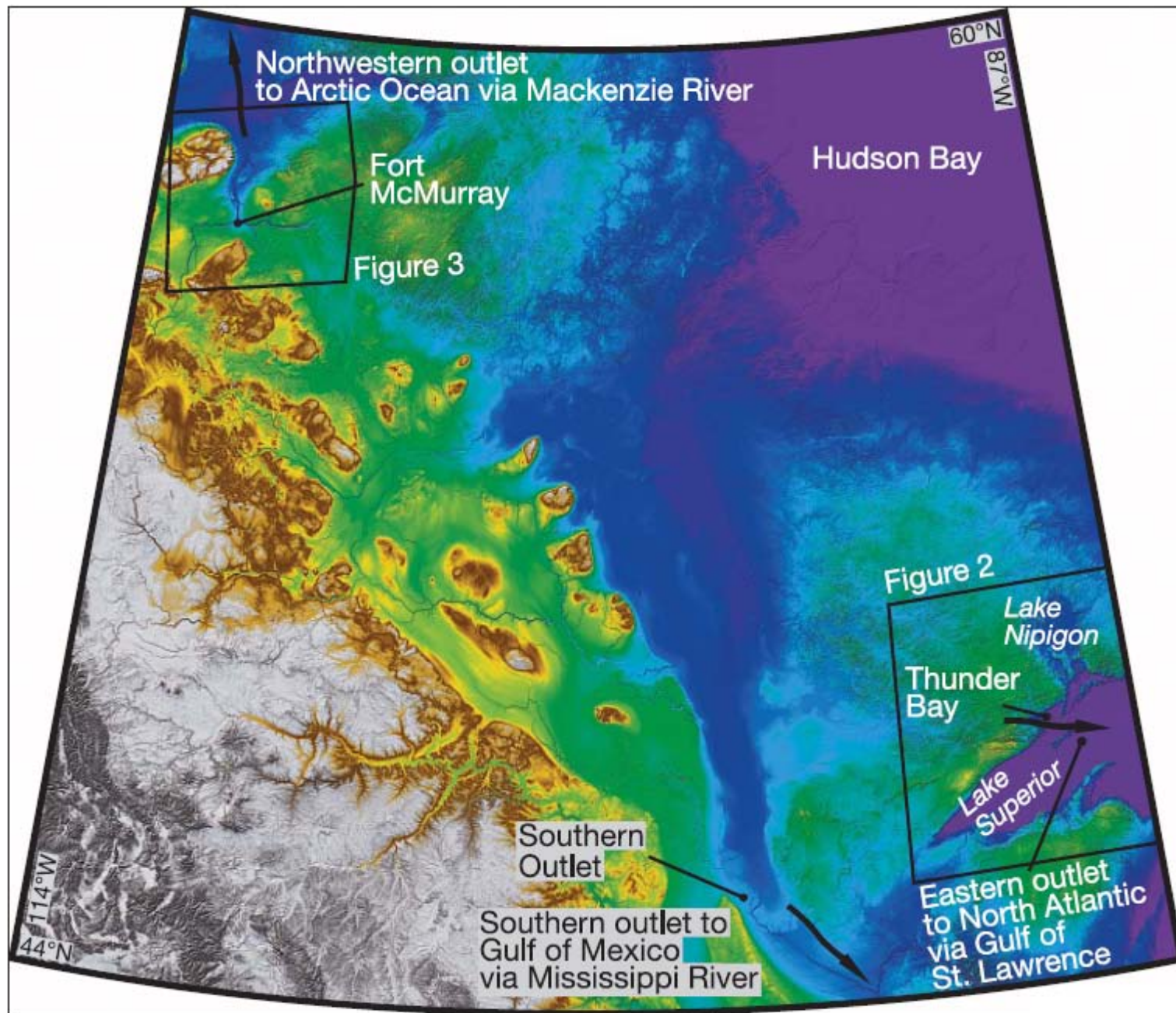


Fig. 1. Digital elevation model of central North America showing the southern, eastern, and north-western outlets of Lake Agassiz.

Lowell et al., 2005

The background of the slide is a photograph of a body of water, possibly a lake or a wide river, with a blue overlay box covering the middle section. The water is dark blue with some lighter patches, and there are some green plants visible in the foreground at the bottom.

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



A topographic map of a mountainous region, likely the Sierra Nevada, showing various peaks, ridges, and valleys. The map is color-coded by elevation, with green representing lower elevations and brown/yellow representing higher elevations. Several river systems are visible, including the Sacramento River and the Feather River. The text is overlaid on the map.

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.



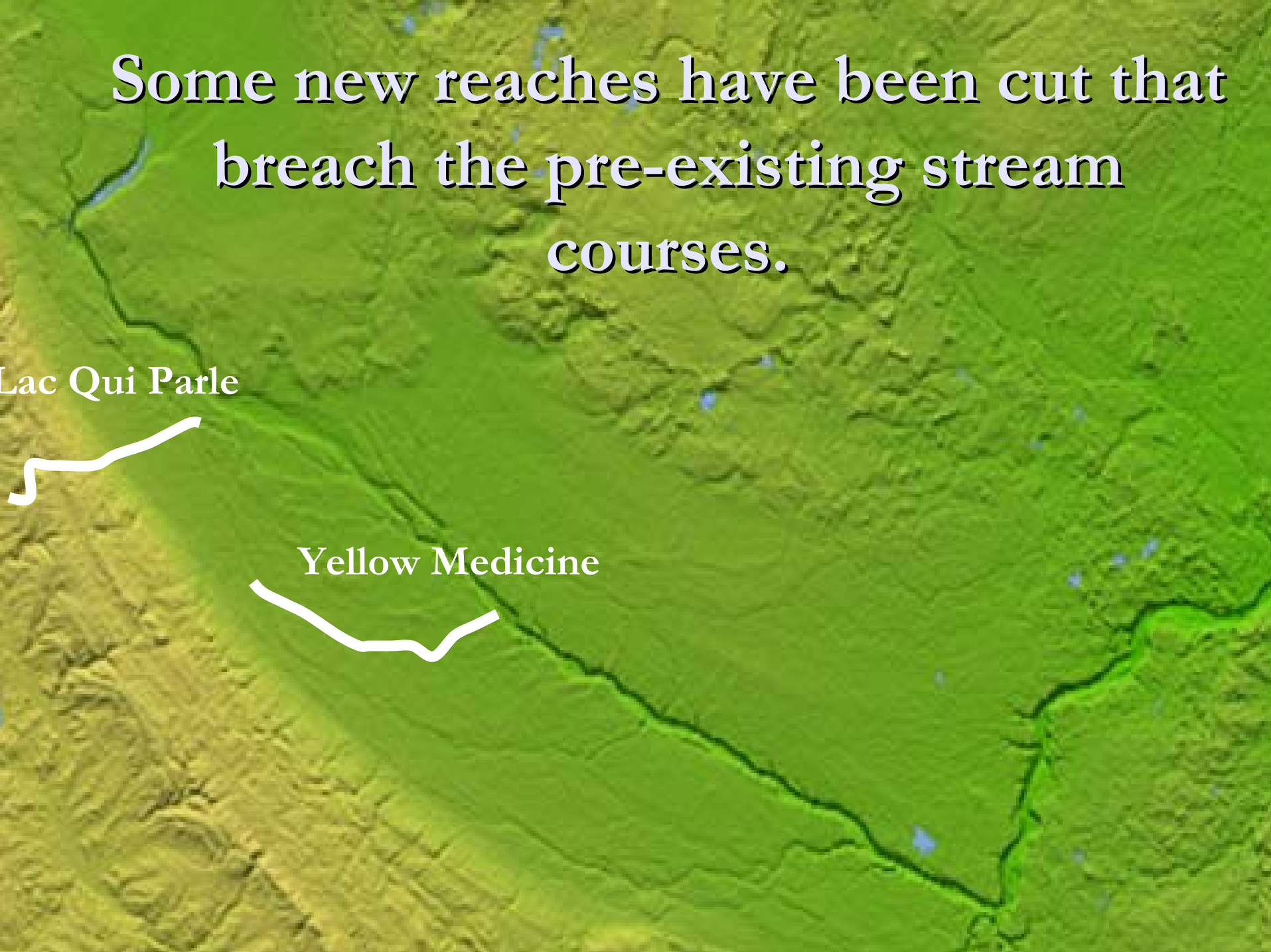


**They are often mined for aggregate or
used as shallow aquifers (or both)**

Some new reaches have been cut that
breach the pre-existing stream
courses.

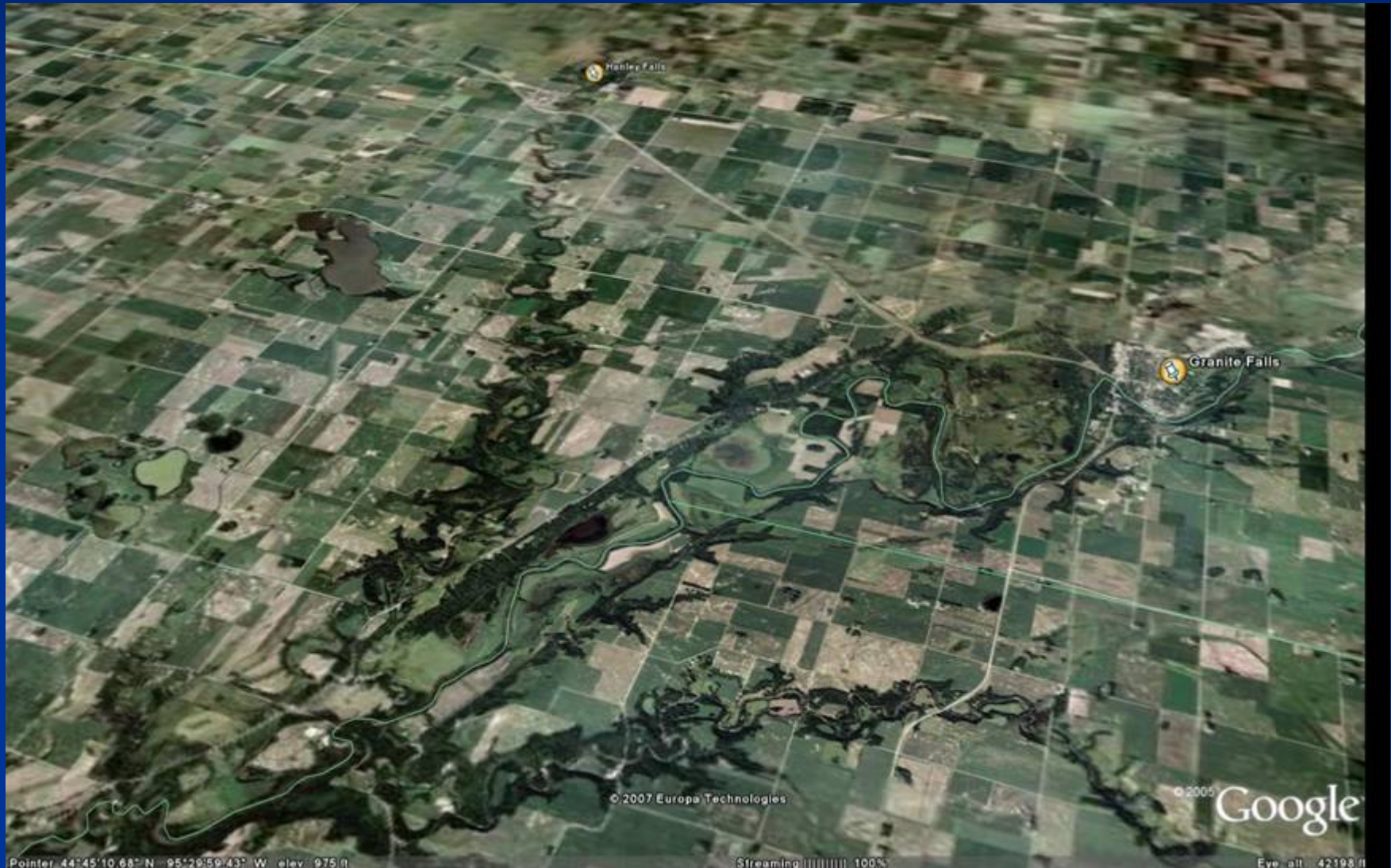
Lac Qui Parle

Yellow Medicine

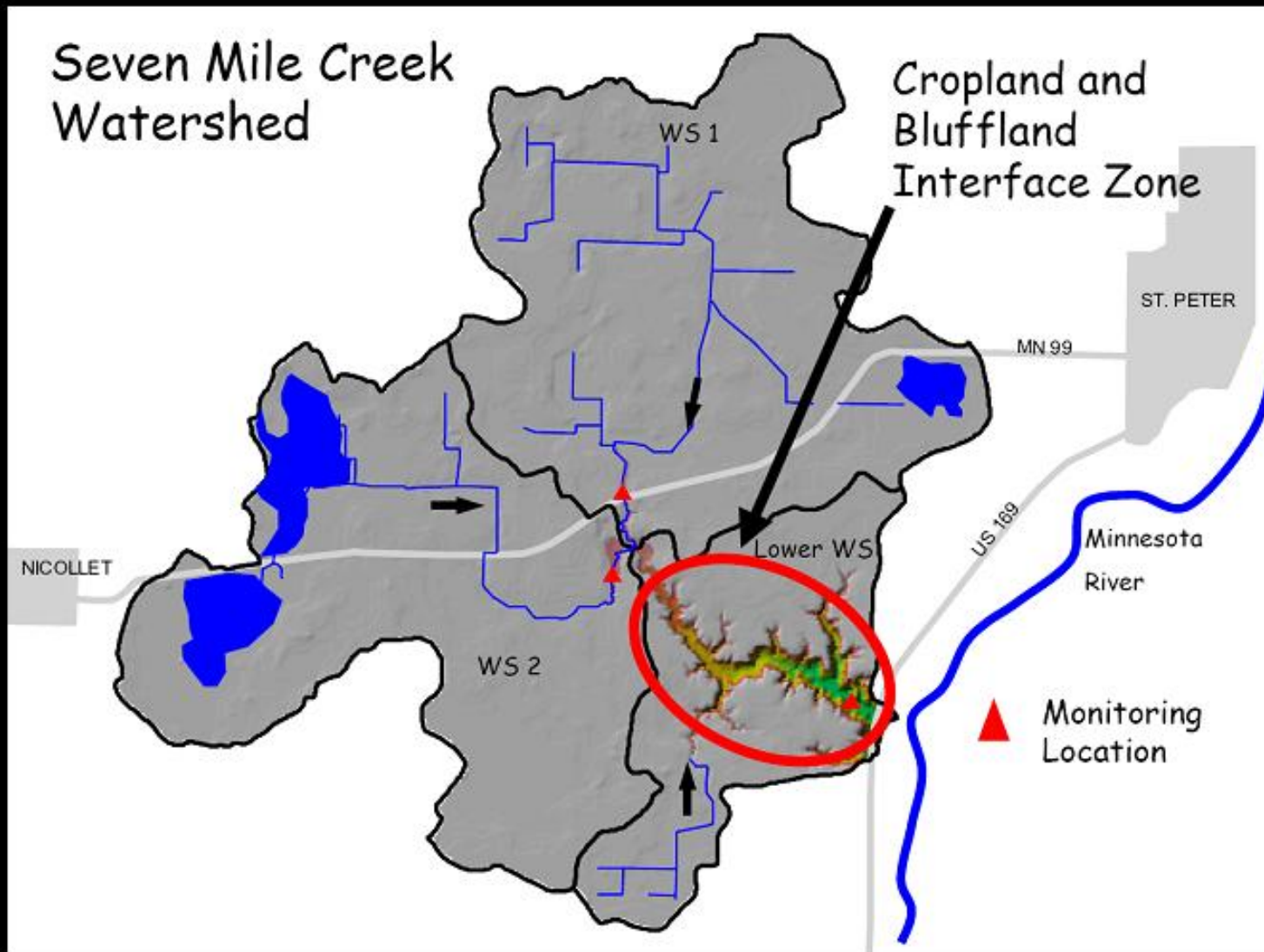


Yellow Medicine and Beaver Creek

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



© 2006 Europa Technologies

Image © 2006 DigitalGlobe

© 2005 Google

Pointer 44°05'32.07" N 94°00'55.23" W elev 823 ft

Streaming 100%

Eye alt 4484 ft

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

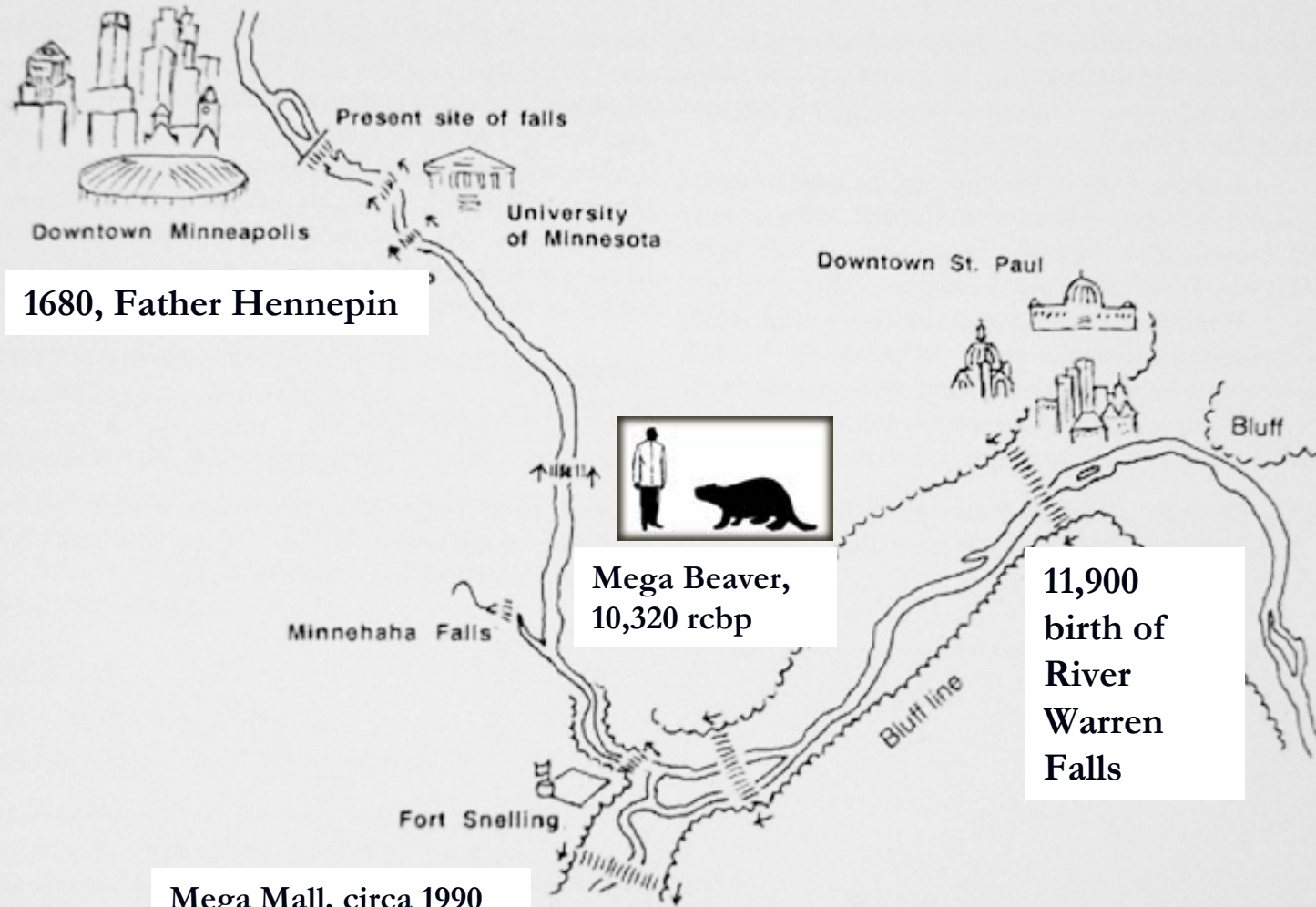
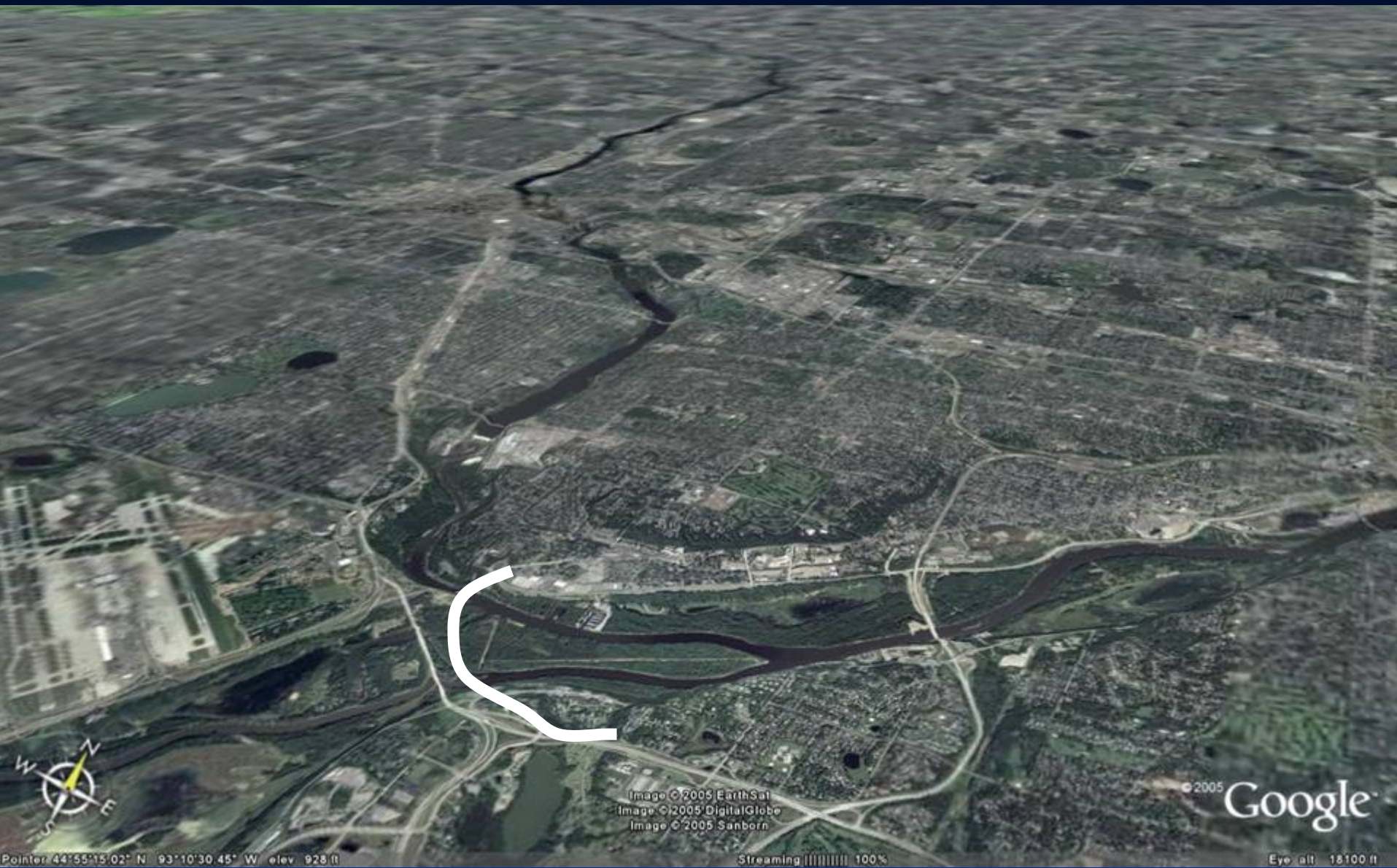


Figure 1.4. Illustration showing the retreat of glacial River Warren (Institute for Minnesota Archaeology, 1999).

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



(Not going anywhere according to the Corps of Engineers)

Historic retreat rates

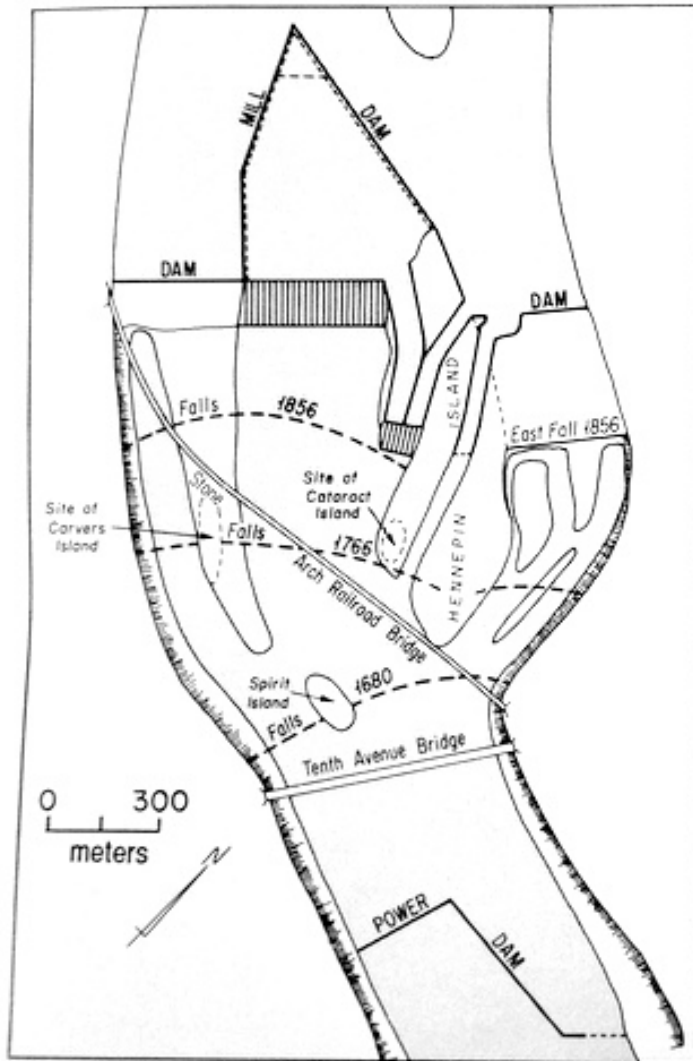


FIGURE 15.

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)

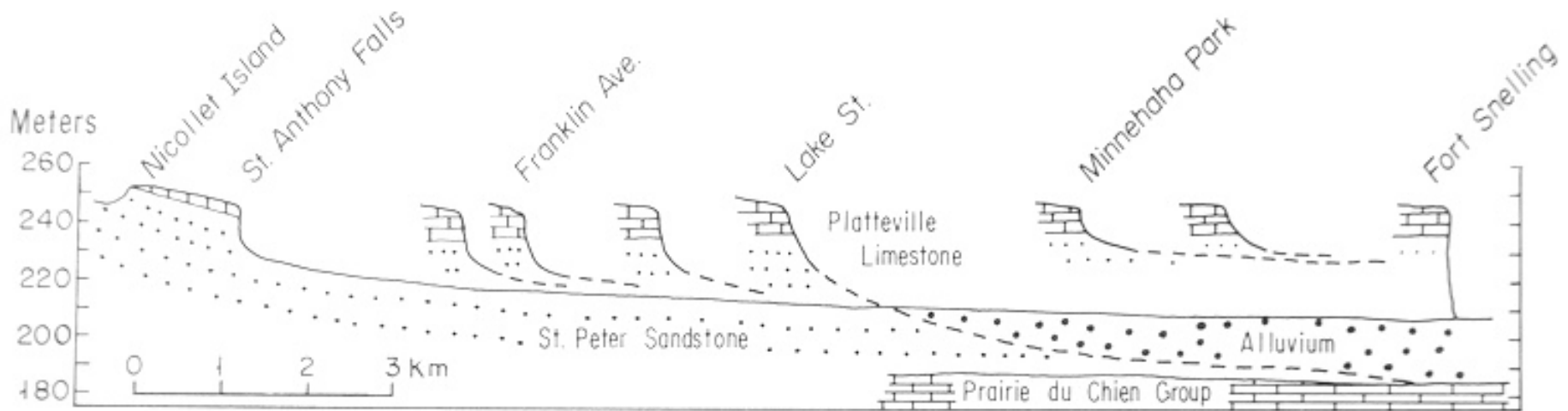


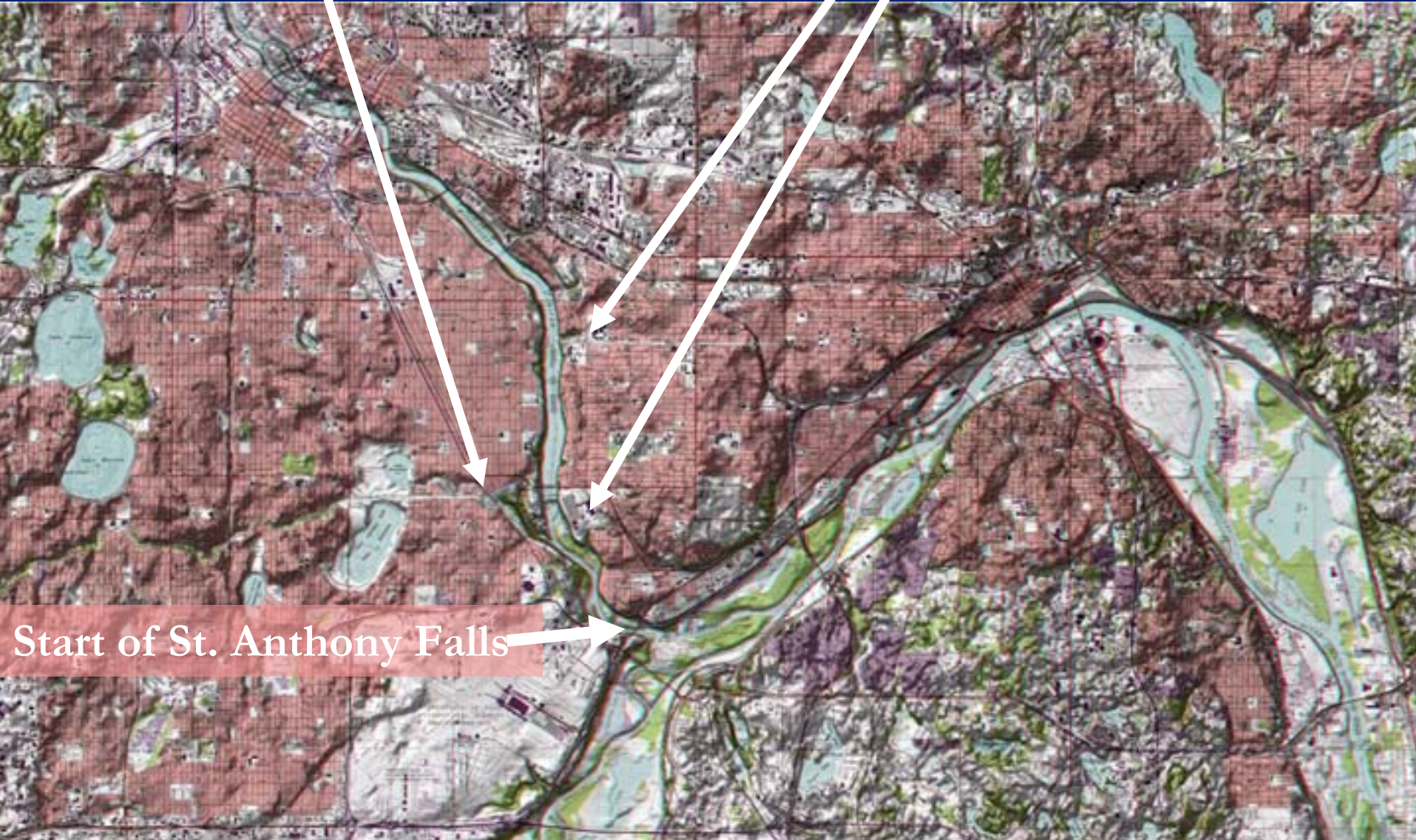
FIGURE 14.

Tributary Falls in the Metro

Minnehaha

Star

Hidden



Start of St. Anthony Falls

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.

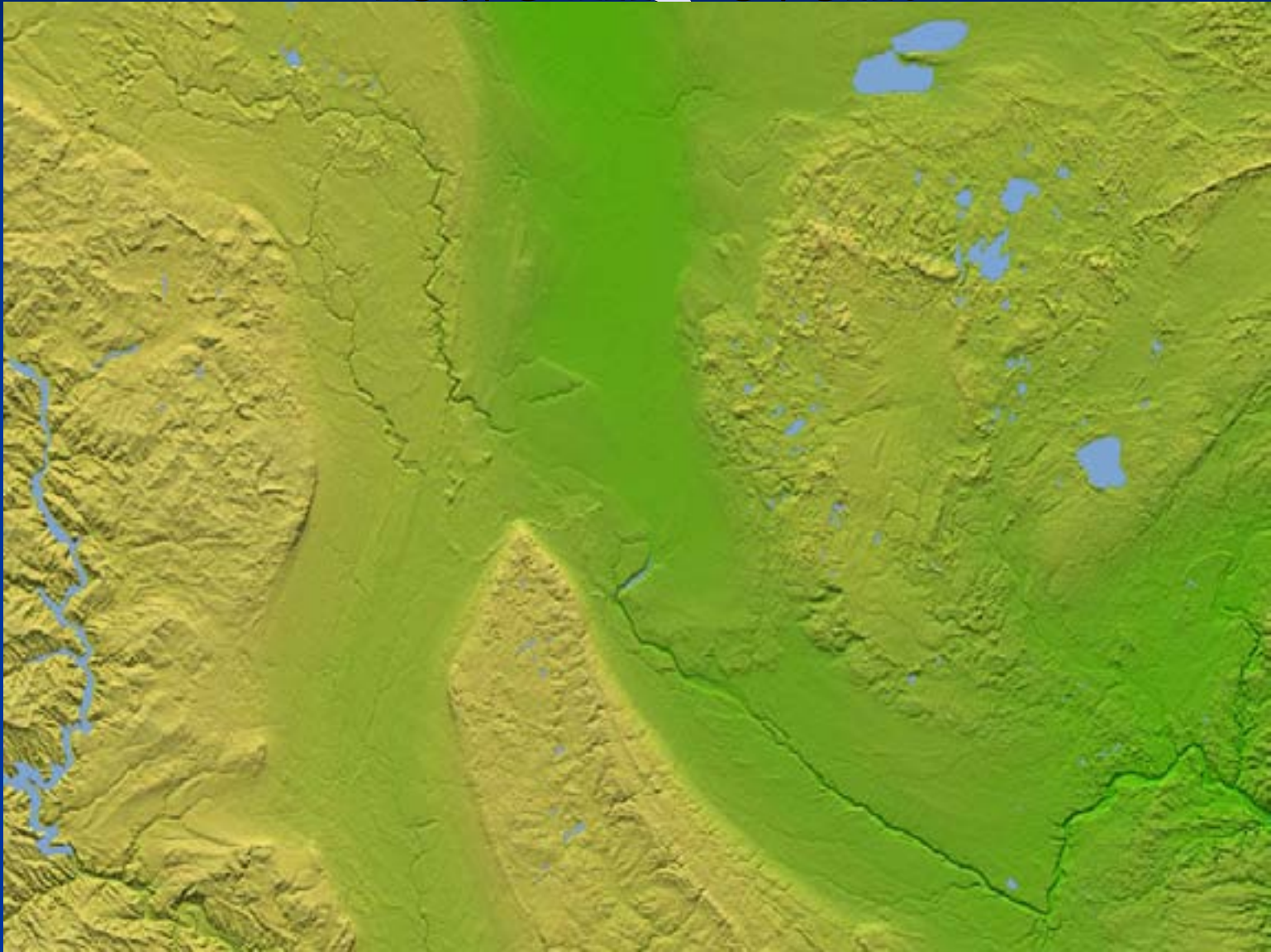
A waterfall (nick point) passed here
long ago.



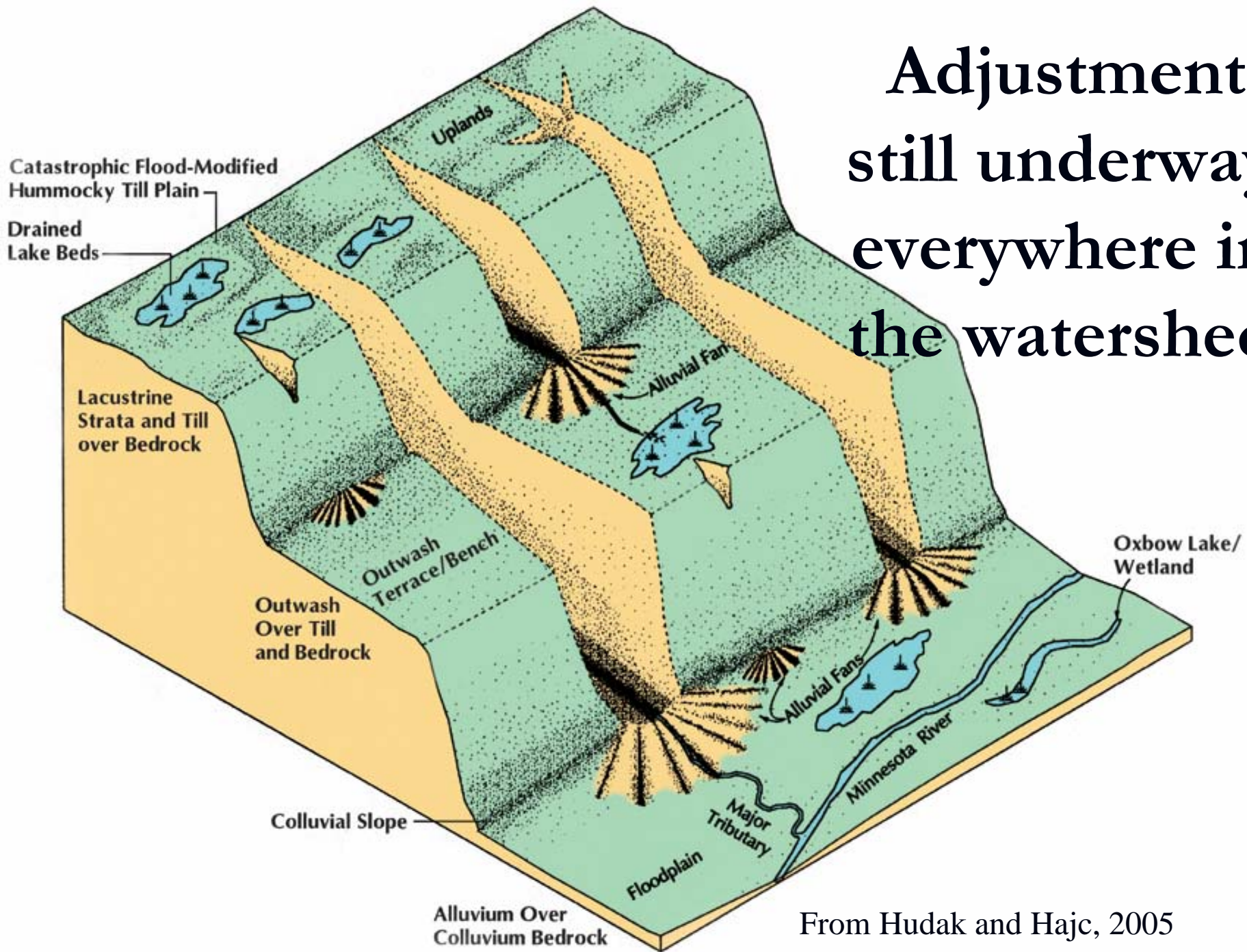
That is not the same as saying we are having no impact on these bluff faces with land-use changes.



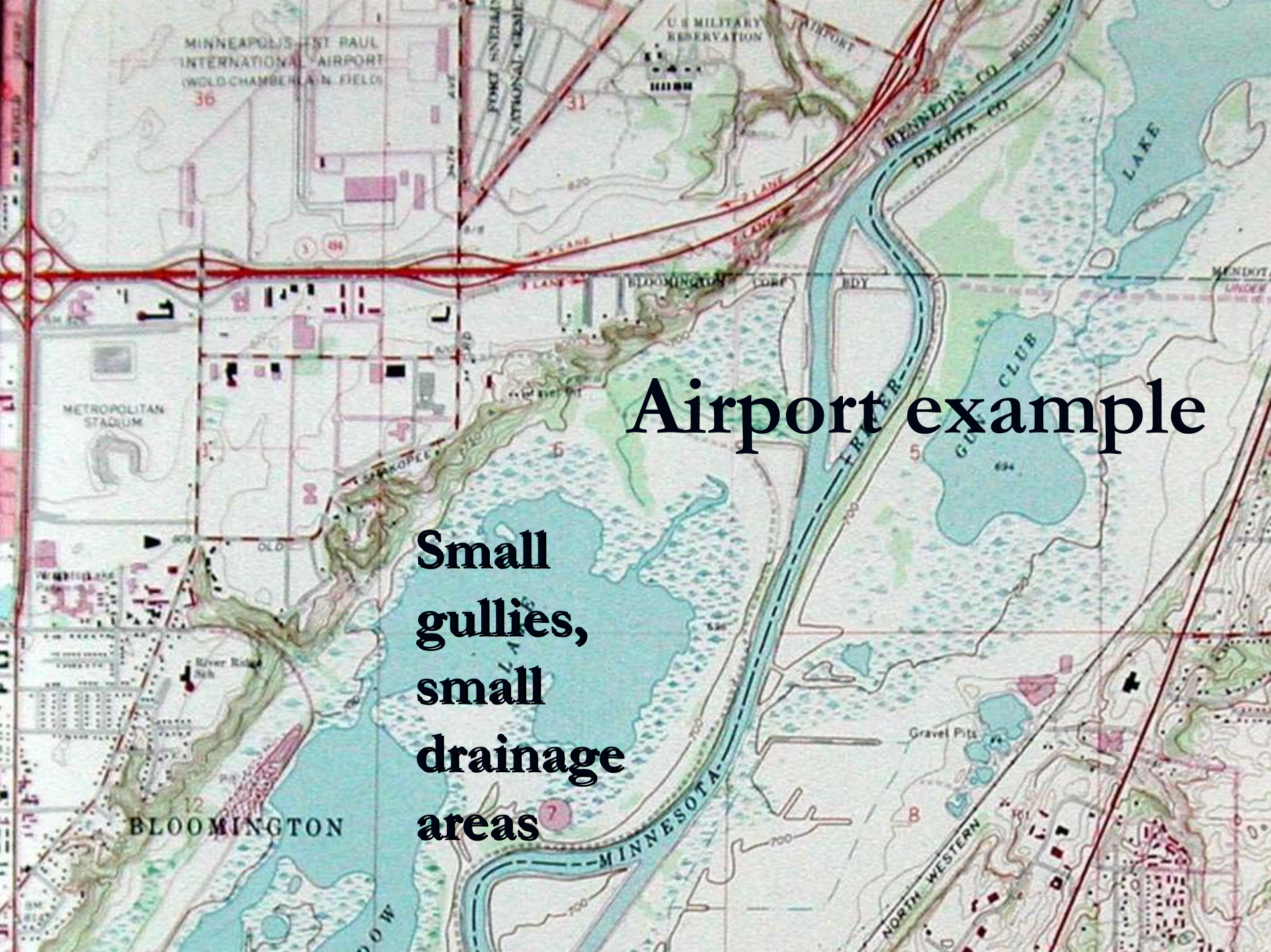
Recap: Initial incision = base level
lowering event



Adjustments
still underway
everywhere in
the watershed



From Hudak and Hajc, 2005



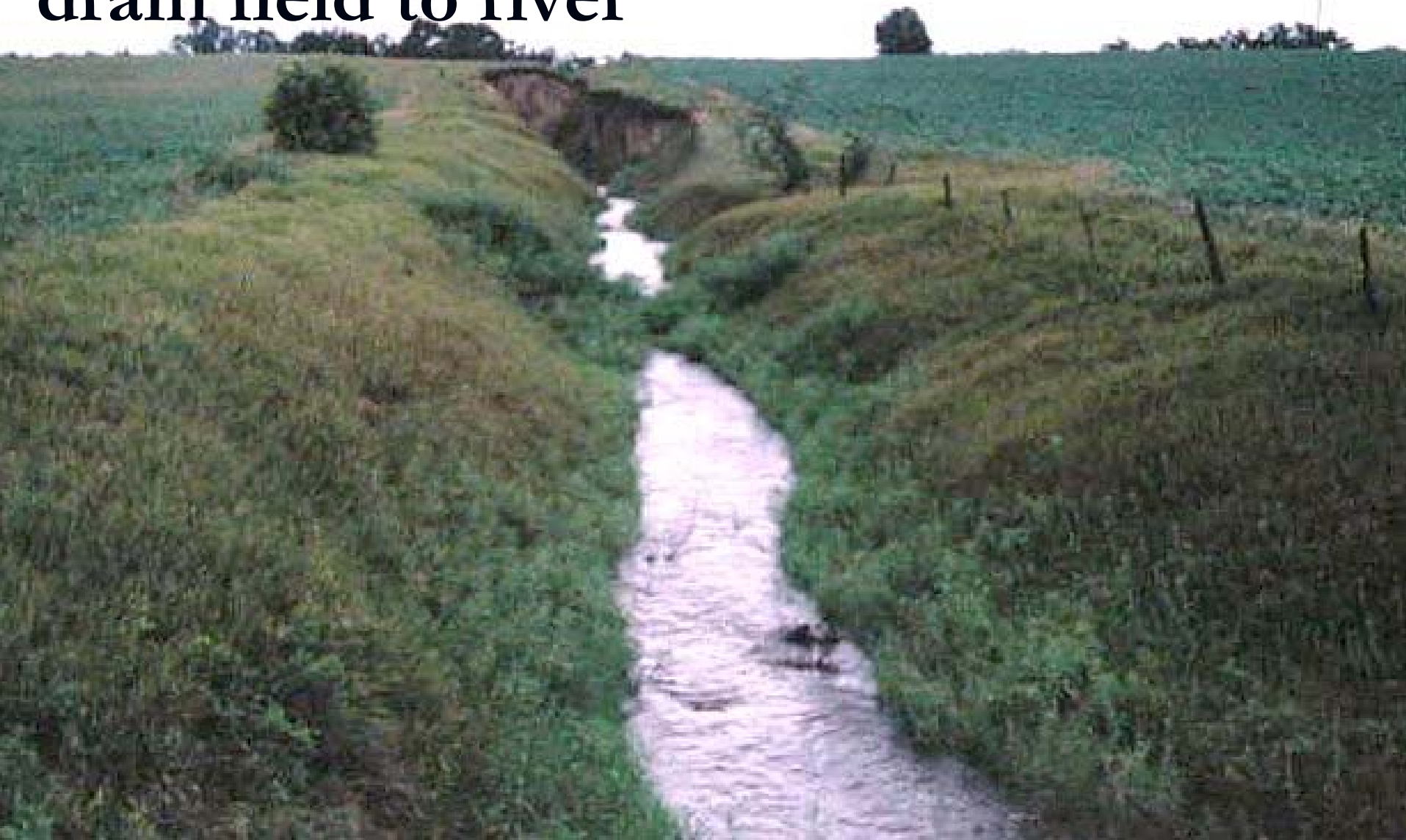
Airport example

**Small
gullies,
small
drainage
areas**

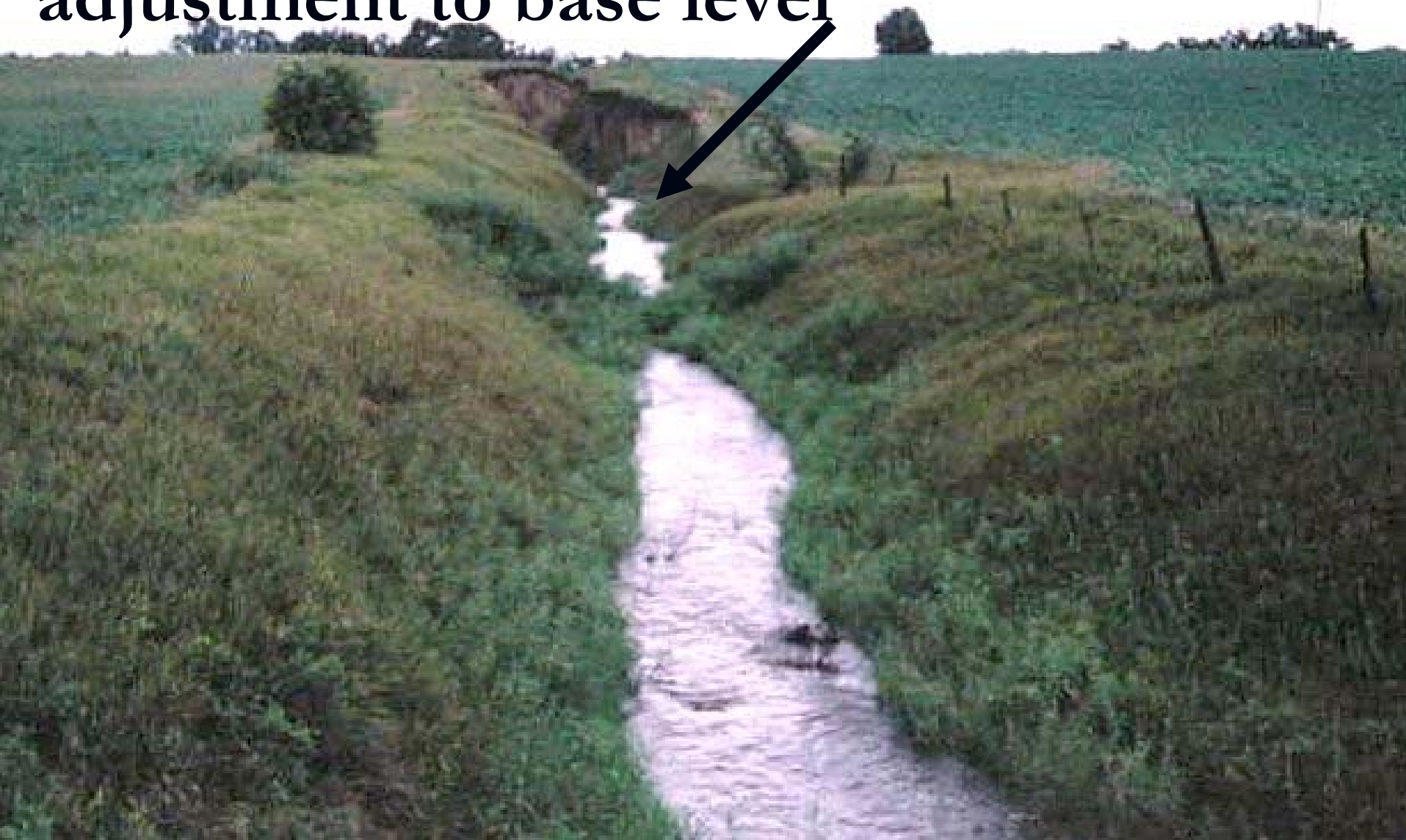
Airport modification required new retention pond.



Agricultural example—dig ditch to drain field to river



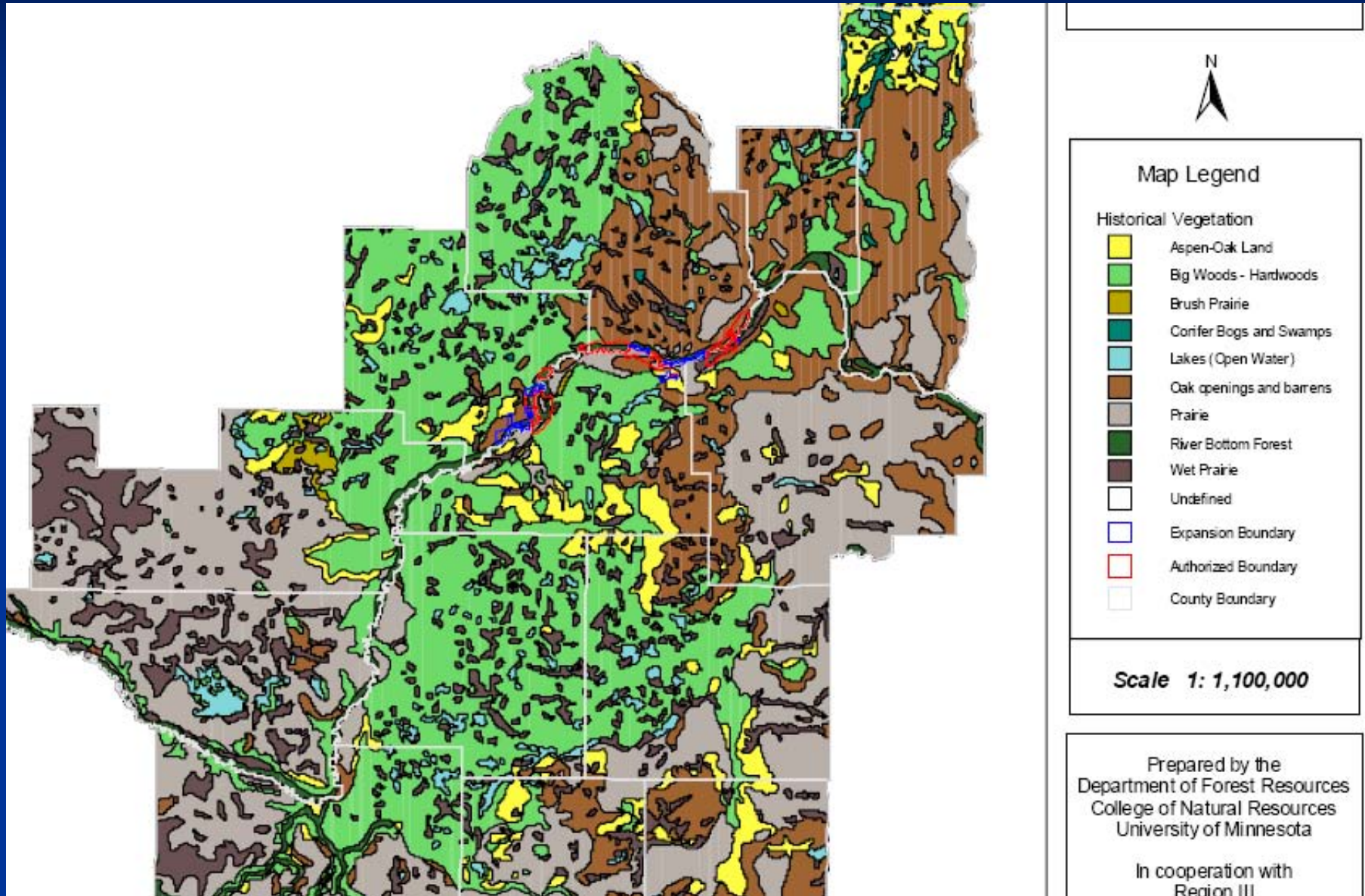
Agricultural example—changed rate of adjustment to base level



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?

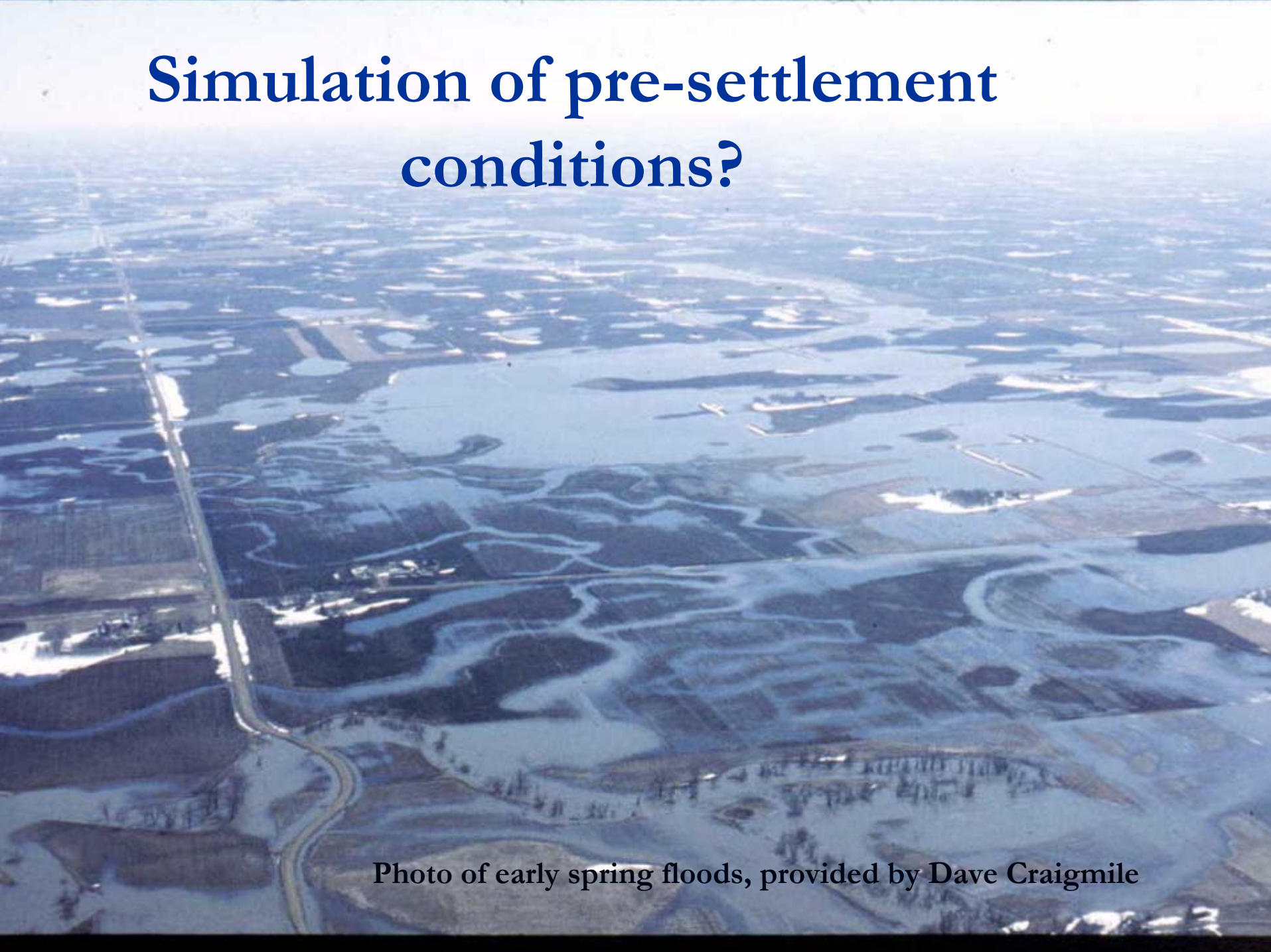
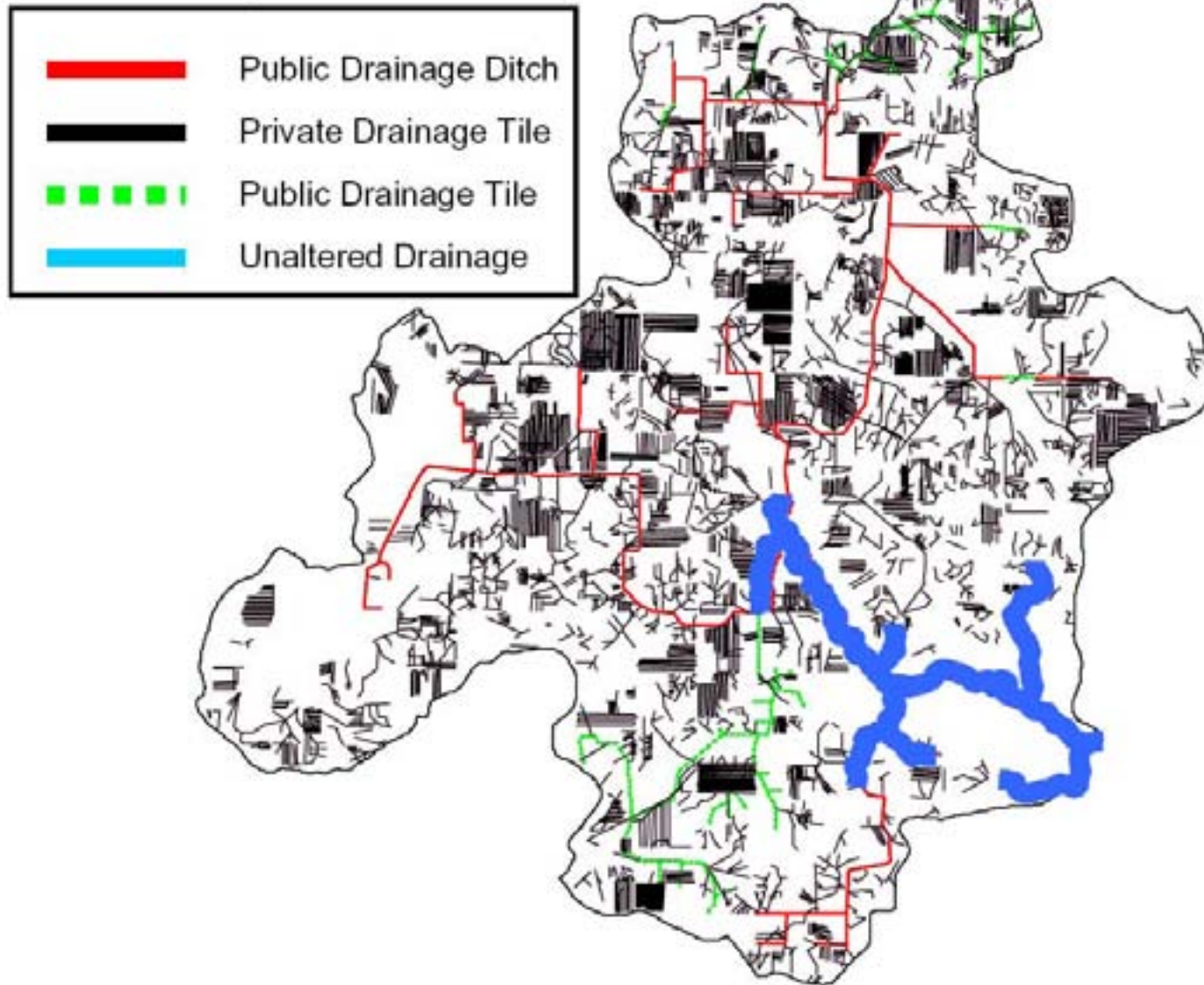


Photo of early spring floods, provided by Dave Craigmile

The Engineered System



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

Catastrophic Flood-Modified
Hummocky Till Plain

Drained
Lake Beds

Lacustrine
Strata and Till
over Bedrock

Outwash
Over Till
and Bedrock

Colluvial Slope

Alluvium Over
Colluvium Bedrock

Uplands

Outwash
Terrace/Bench

Alluvial Fan

Alluvial Fans

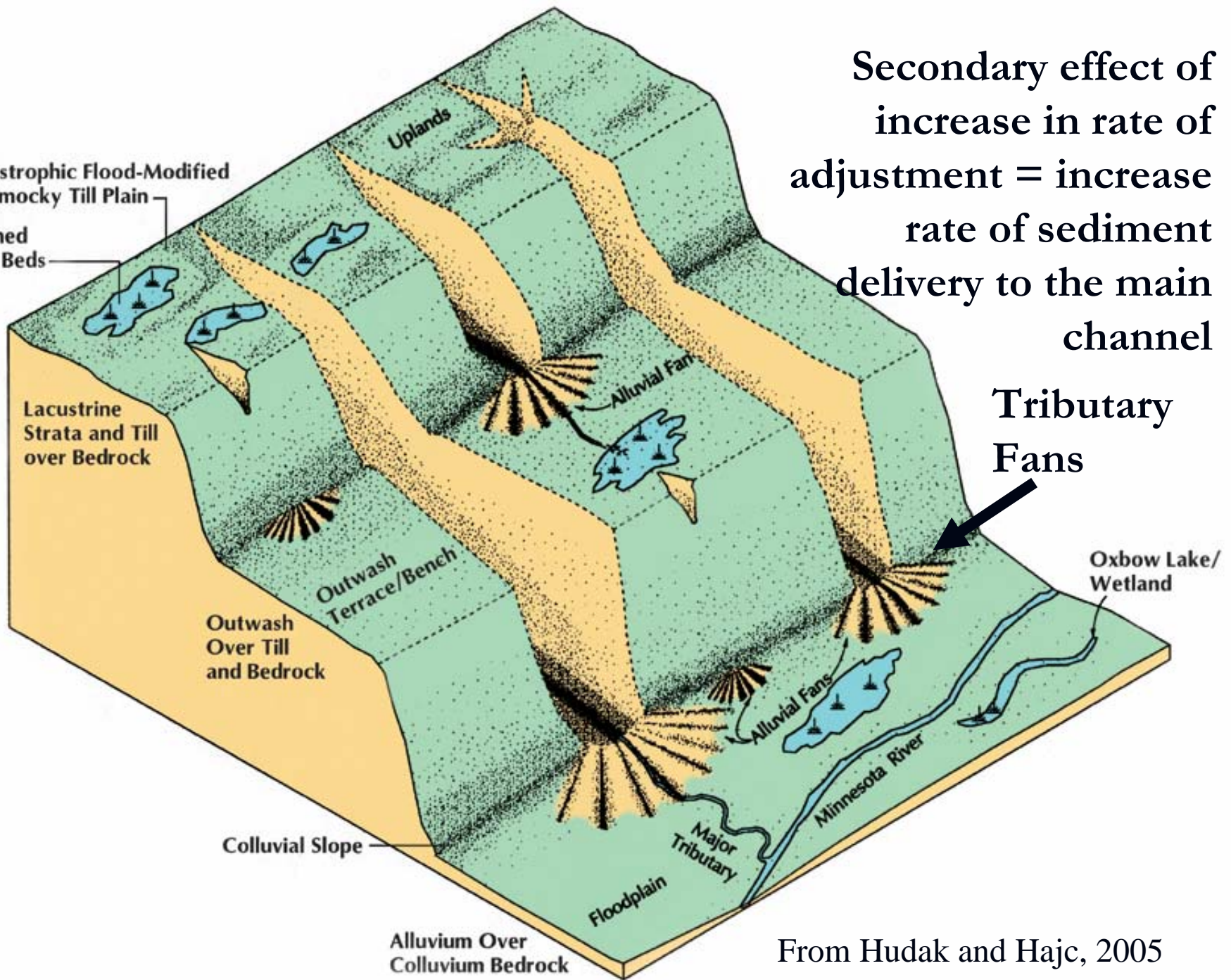
Major
Tributary

Minnesota River

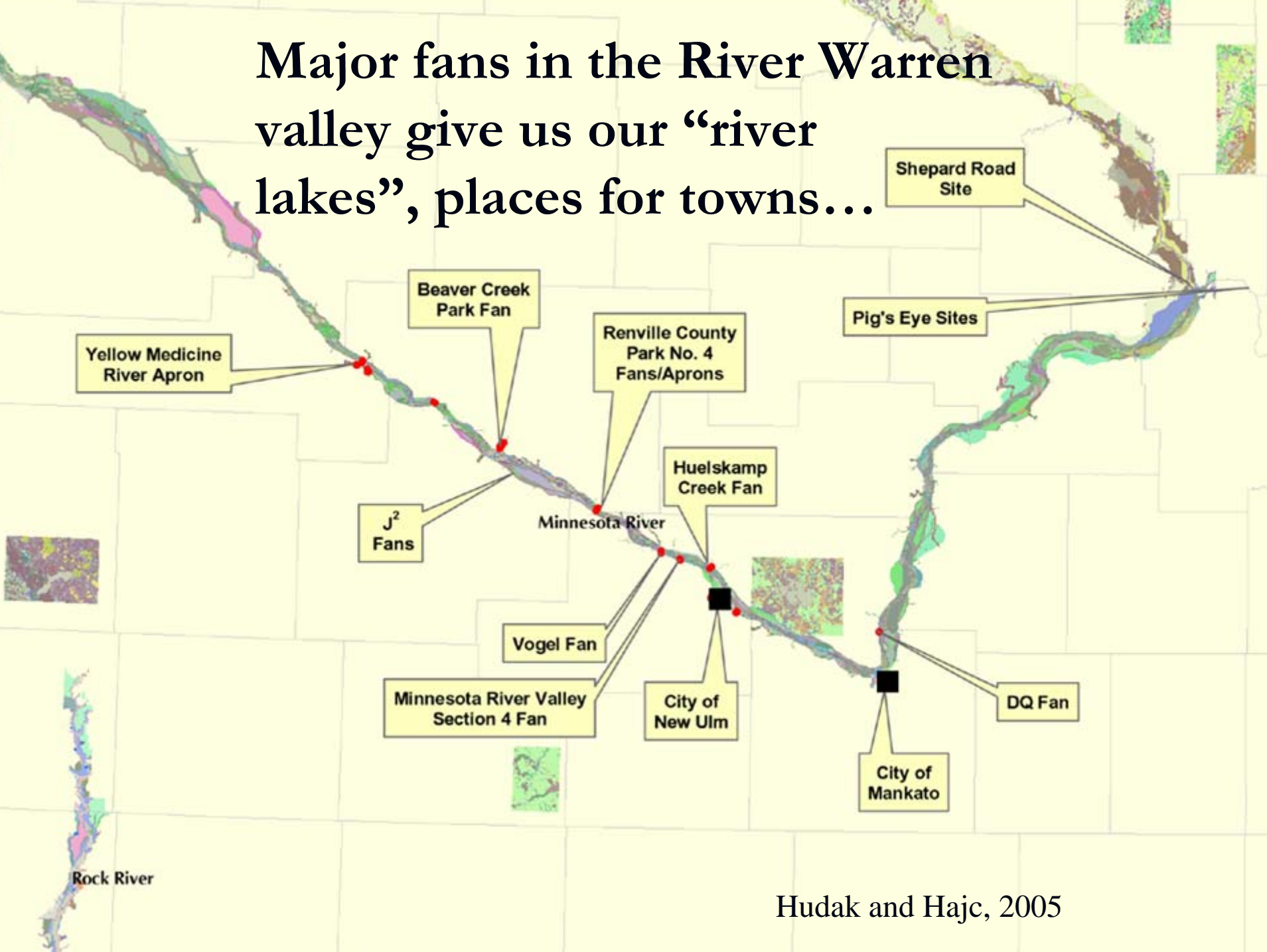
Floodplain

Oxbow Lake/
Wetland




From Hudak and Hajc, 2005



Major fans in the River Warren valley give us our “river lakes”, places for towns...





-  Turbidity Impairments
-  Excess Nutrients
-  Lake Pepin Drainage Basin

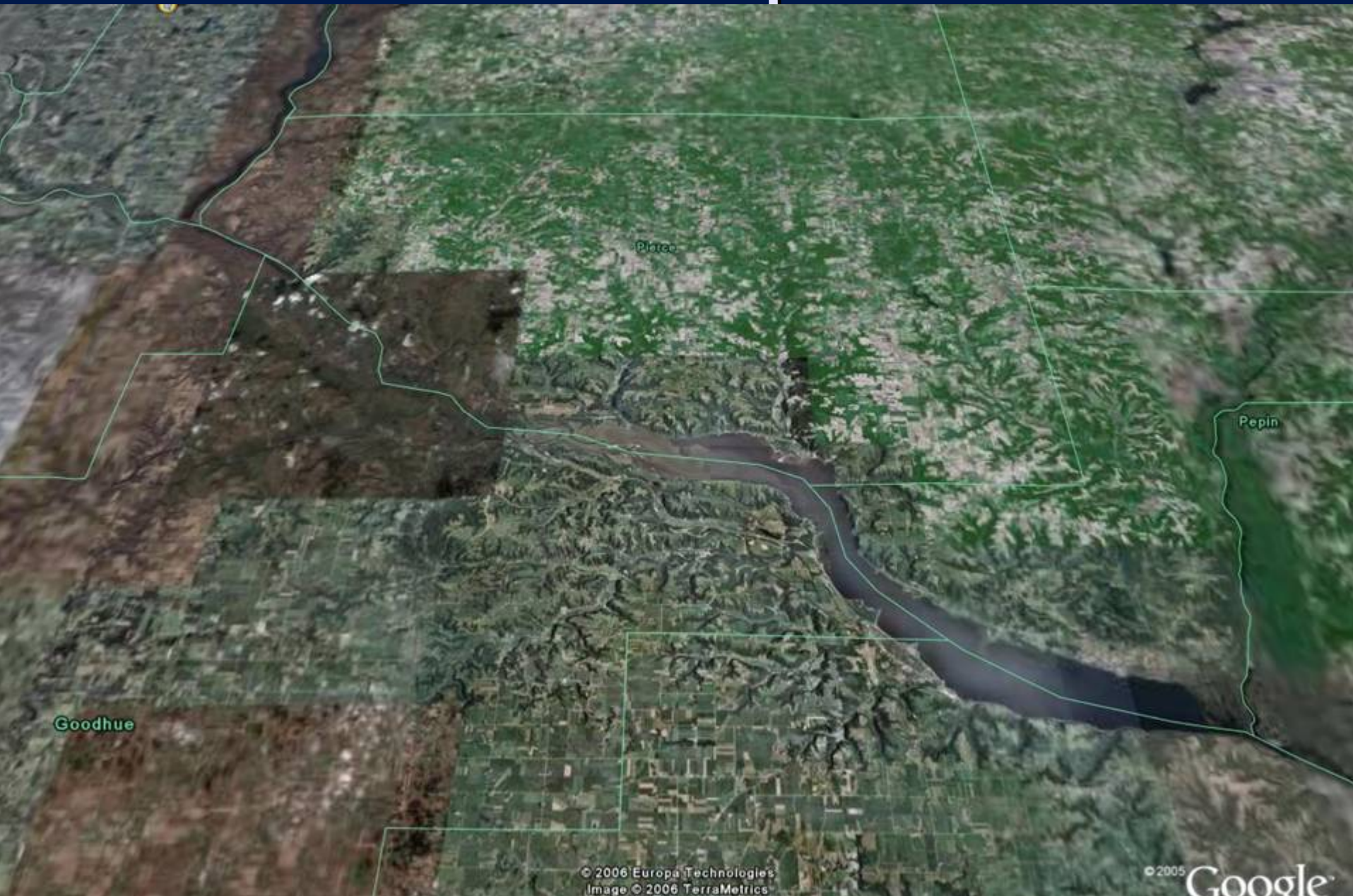
0 3 6 12 18 24 Miles



Minnesota Pollution
Control Agency

A tributary fan gave us Lake Pepin

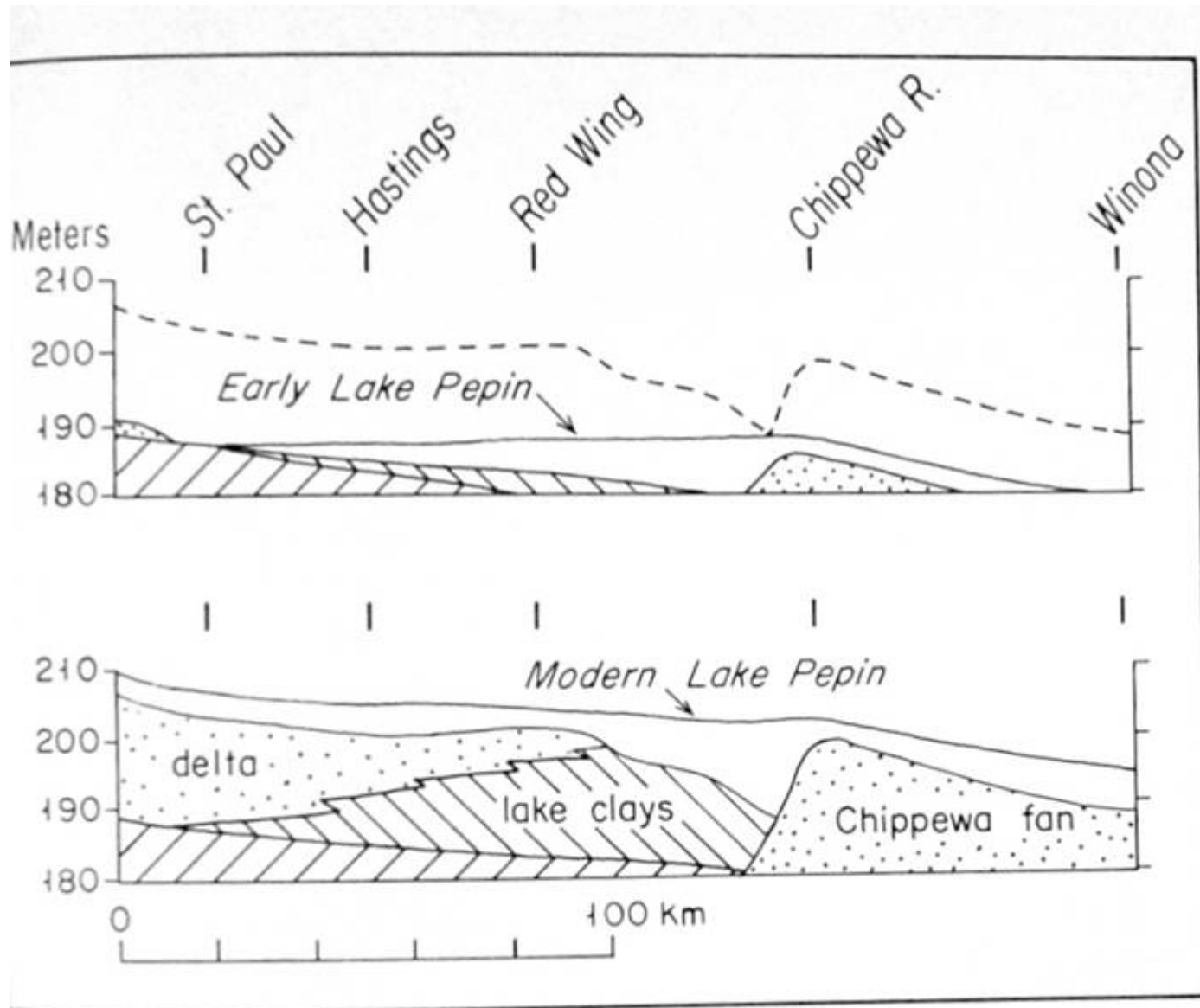
Lake Pepin



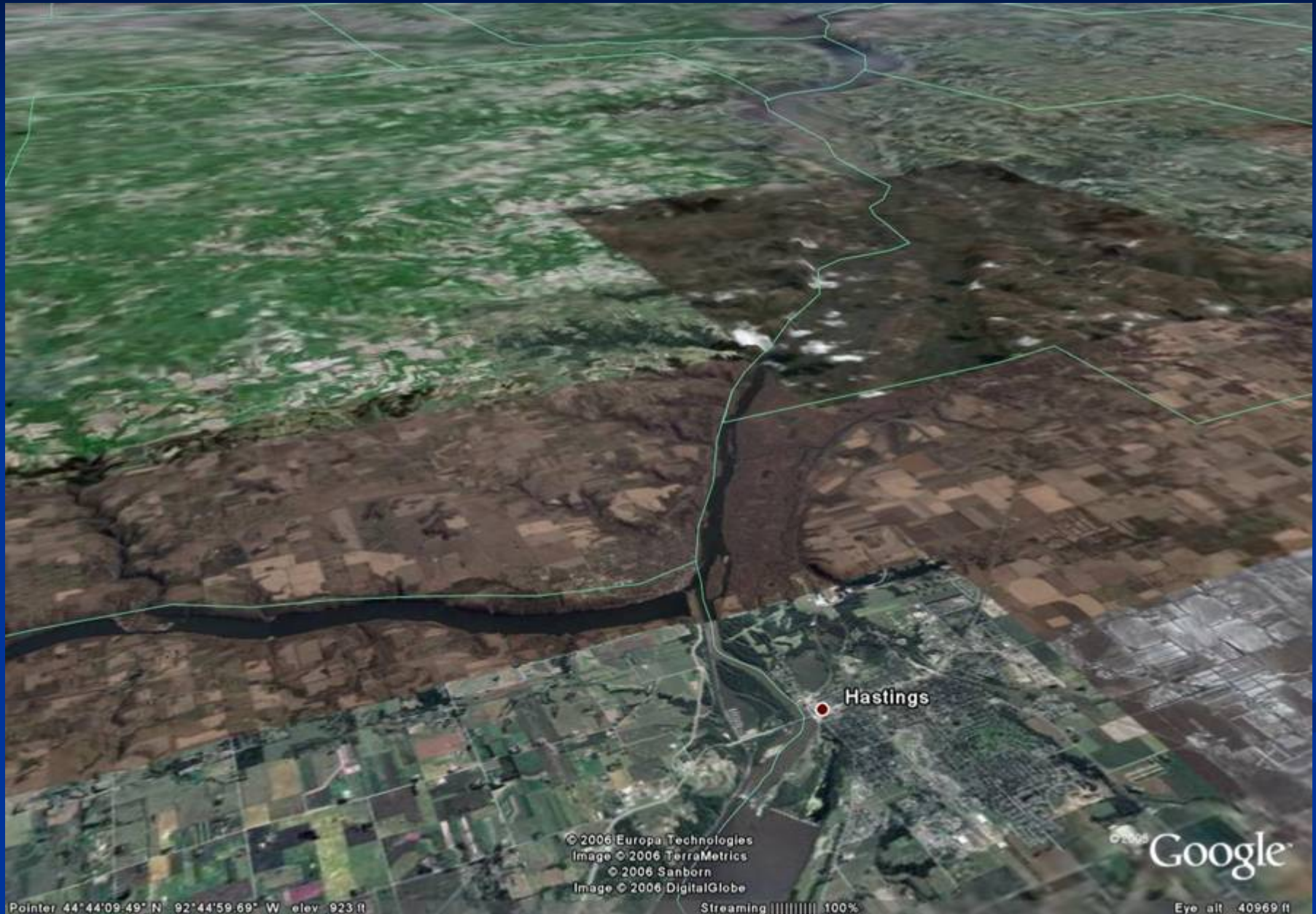
Chippewa Delta



Lake Pepin Delta migration



Pepin delta across St. Croix mouth (SE)



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



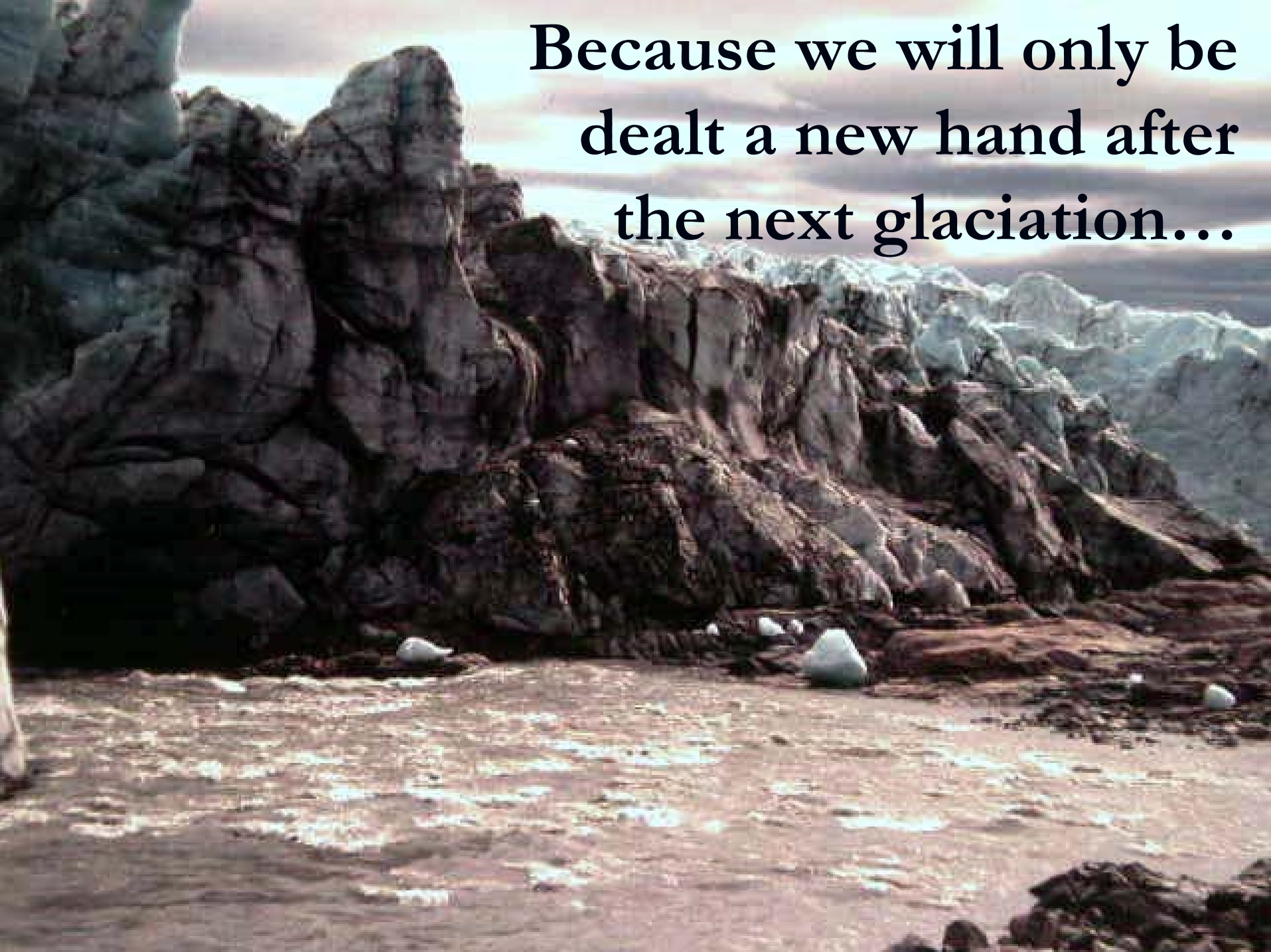
These rivers
...and the
course they
are on...
represent
the cards
we've been
dealt.



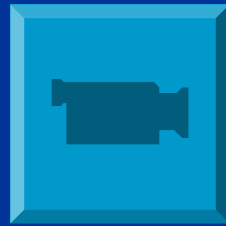


We need to
understand the
rules of the
game and the
consequences
of how we play
this hand.

**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?

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