Minnesota River Turbidity TMDL Fingerprinting Sediment Sources

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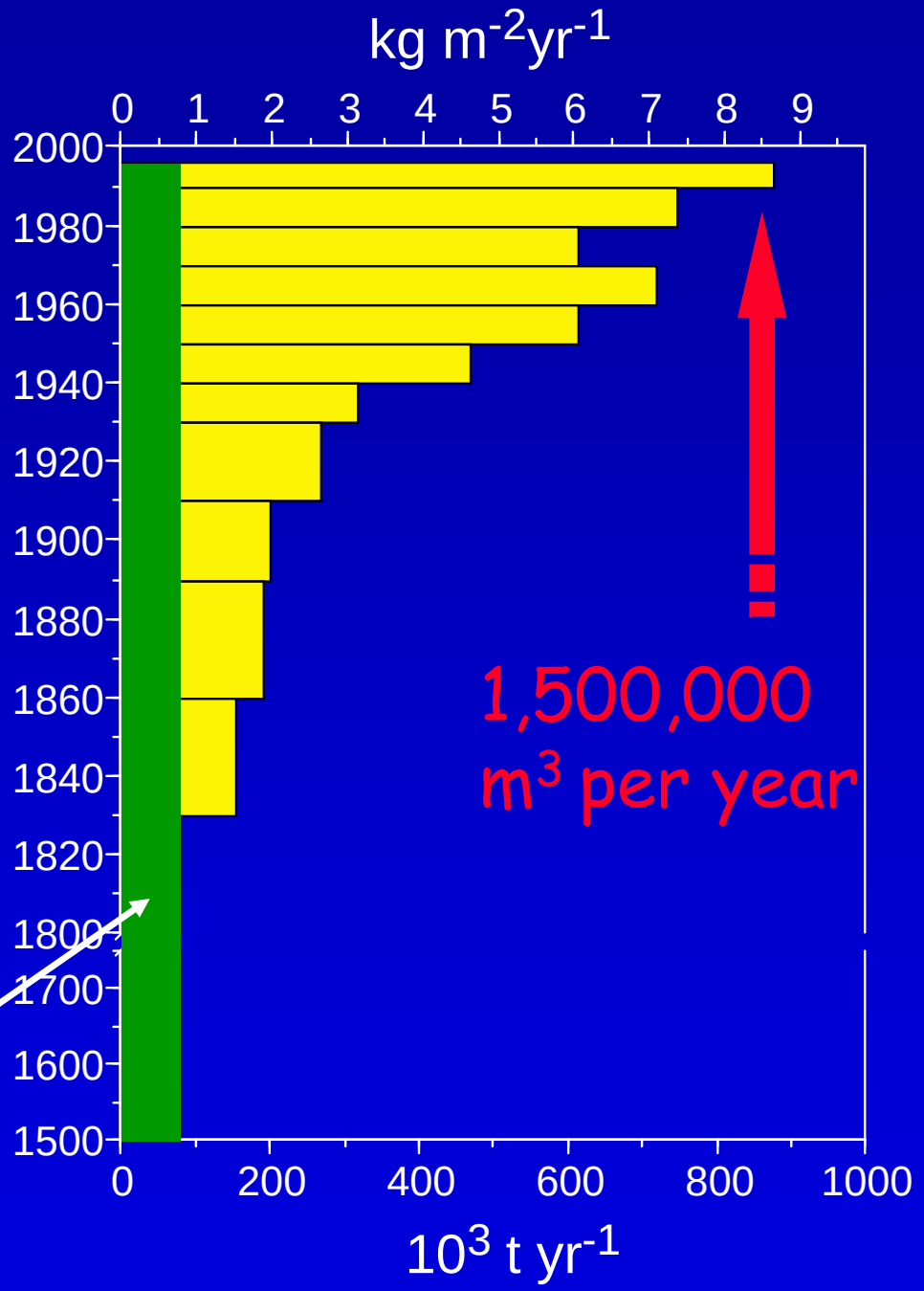
What's the problem?

1. Turbidity impairment of water quality
2. Accelerated infilling of Lake Pepin

What do we what to know?

1. What is the source of the sediment?
2. How has that changed over time?

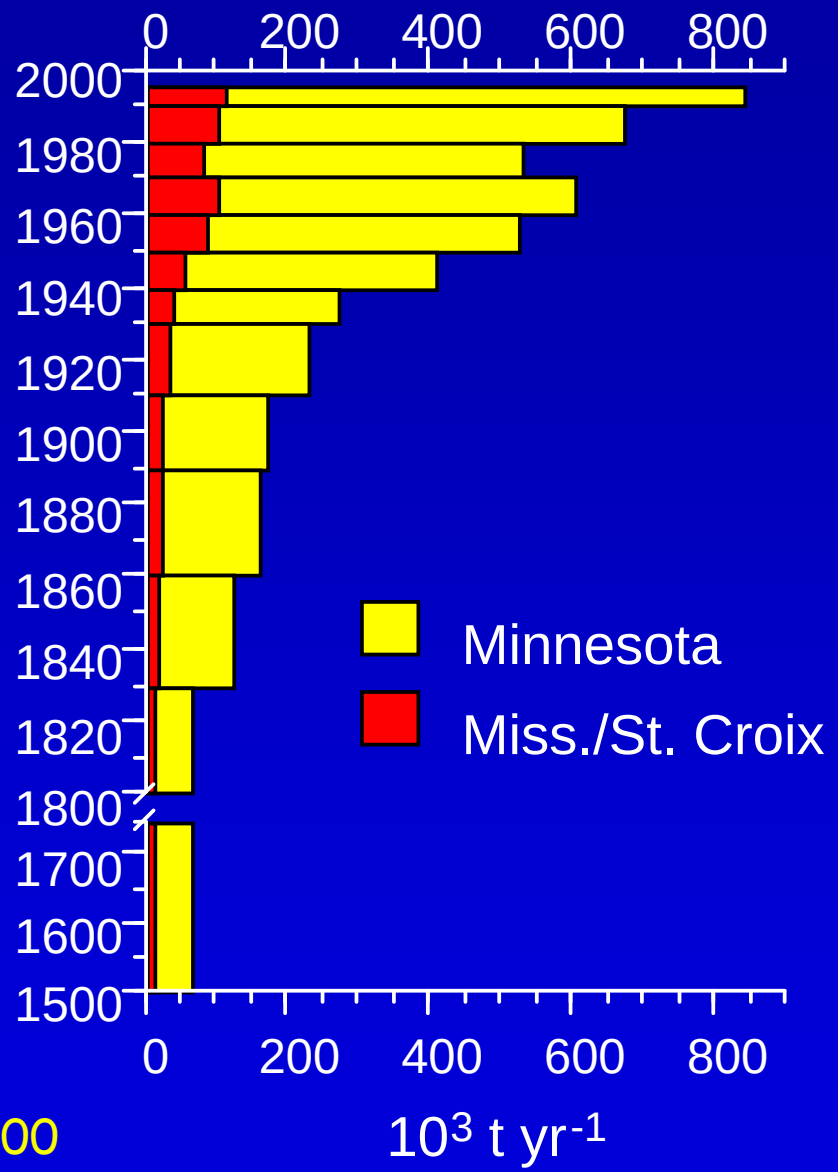
Lake Pepin Sedimentation



The Minnesota River is the primary source – both past and present

Pre-settlement = 81%

Present Day = 88%



Kelley & Nater 2000
J. Environ. Qual.

The Question

How much from upland field erosion?

vs.

How much from non-field sources?

(*banks, bluffs, ravines*)

(*upland fields*)

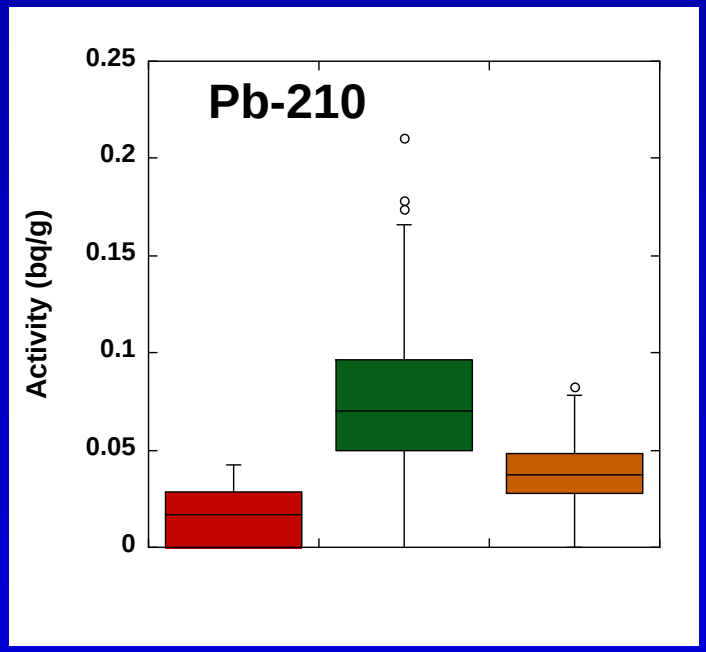
The Challenge

How to quantify…

…and believe the answer?

…Fingerprinting Fundamentals

Constant Exposure to Atmosphere and Rain



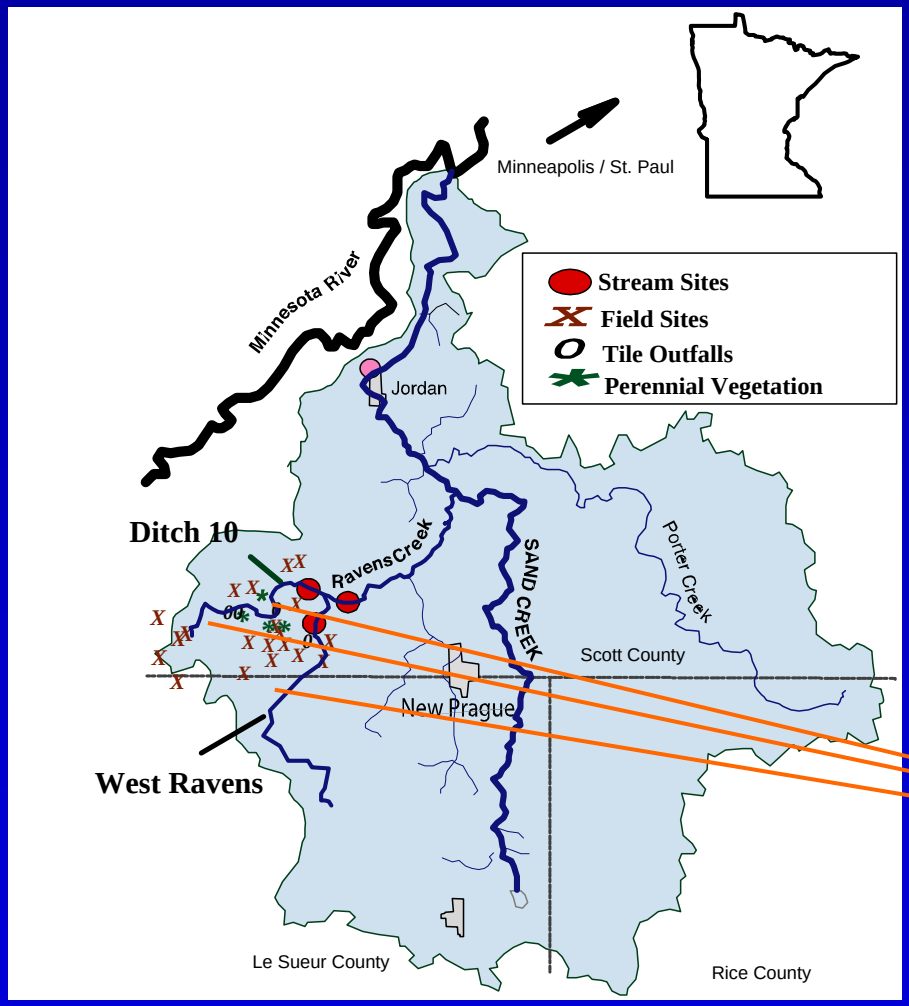
Cultivated Field

Bank (etc.) Sediment

Suspended Sediment

Minimal Exposure to Atmosp. and Rain

"Traditional" Fingerprinting Approach



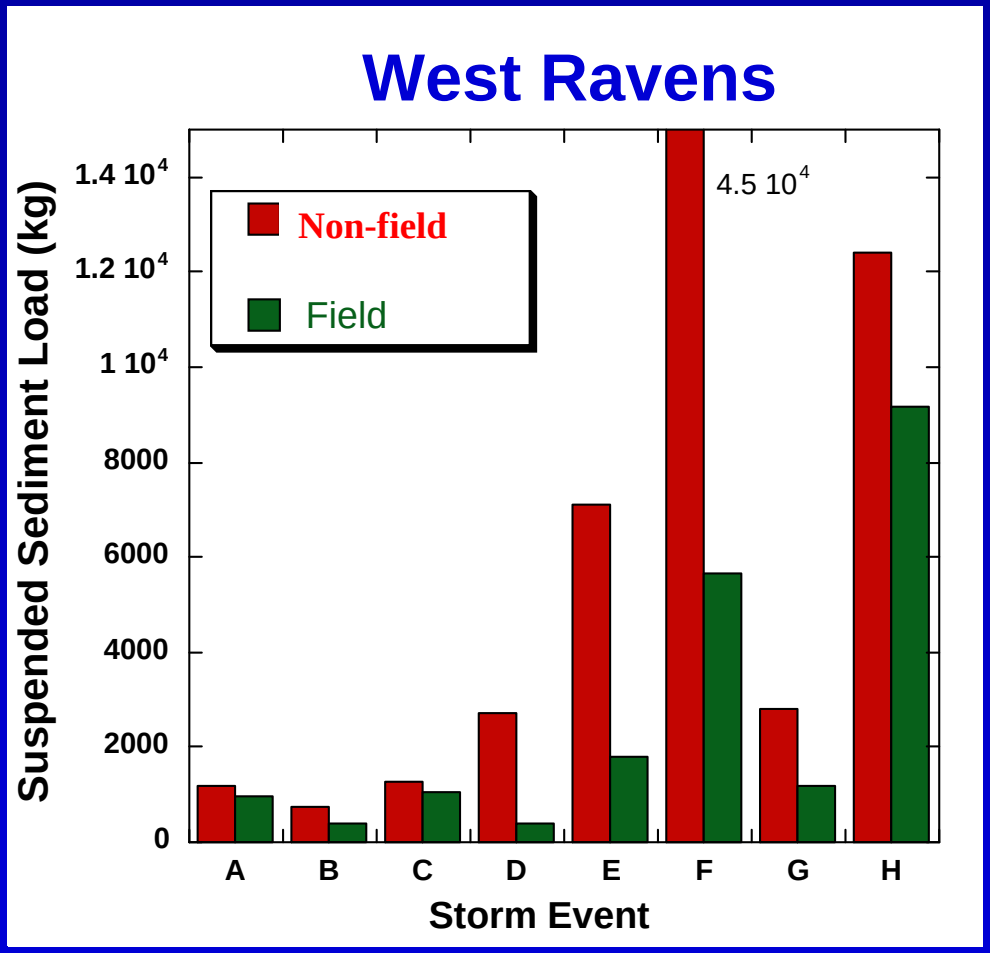
Sampled

- Fields, Streambanks, River TSS
- 700 total samples
- Utilized 15 tracers

Direct sampling of "mobilized" field sediment

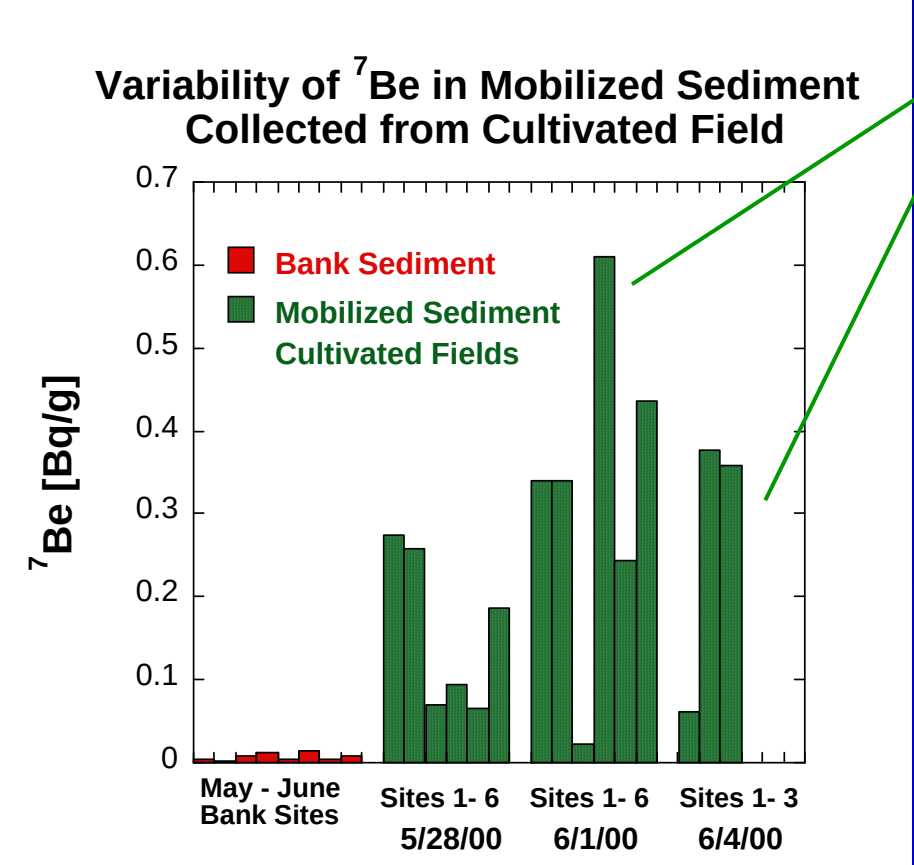
Ravens Creek (sub-watershed of Minnesota River)

Non-field vs. Field Loading During Storm Events



Two year mean % contribution from non-field erosion ~70%

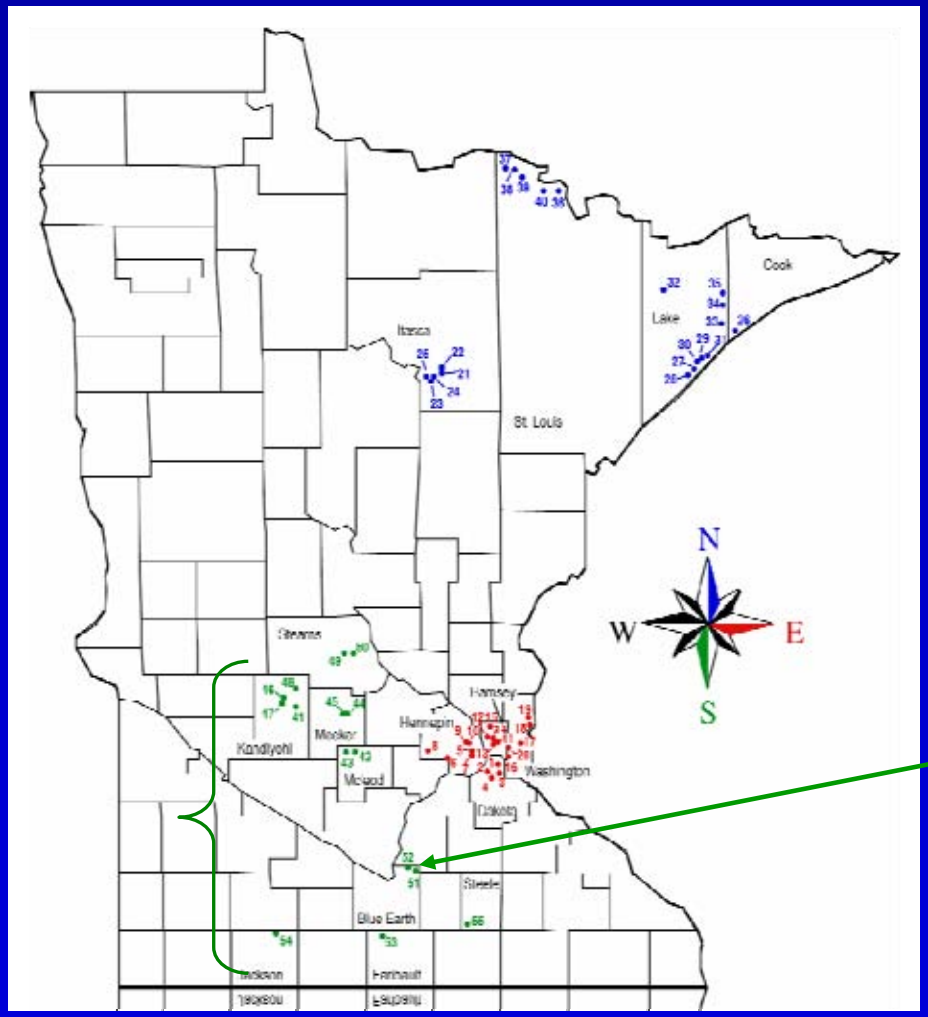
Accurately Characterizing Upland-source Fingerprint is Tricky



- High spatial and temporal variability
- Significant particle size correction
- Event based
- Expensive for whole basin…

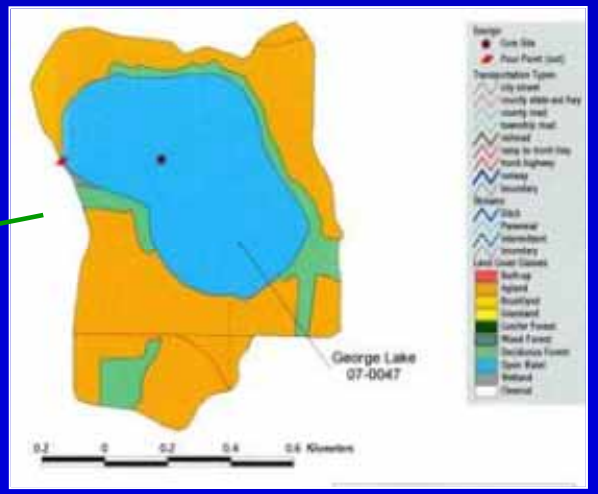
…won't work for Pepin-size watershed!

Lakes as reference systems for upland fingerprint



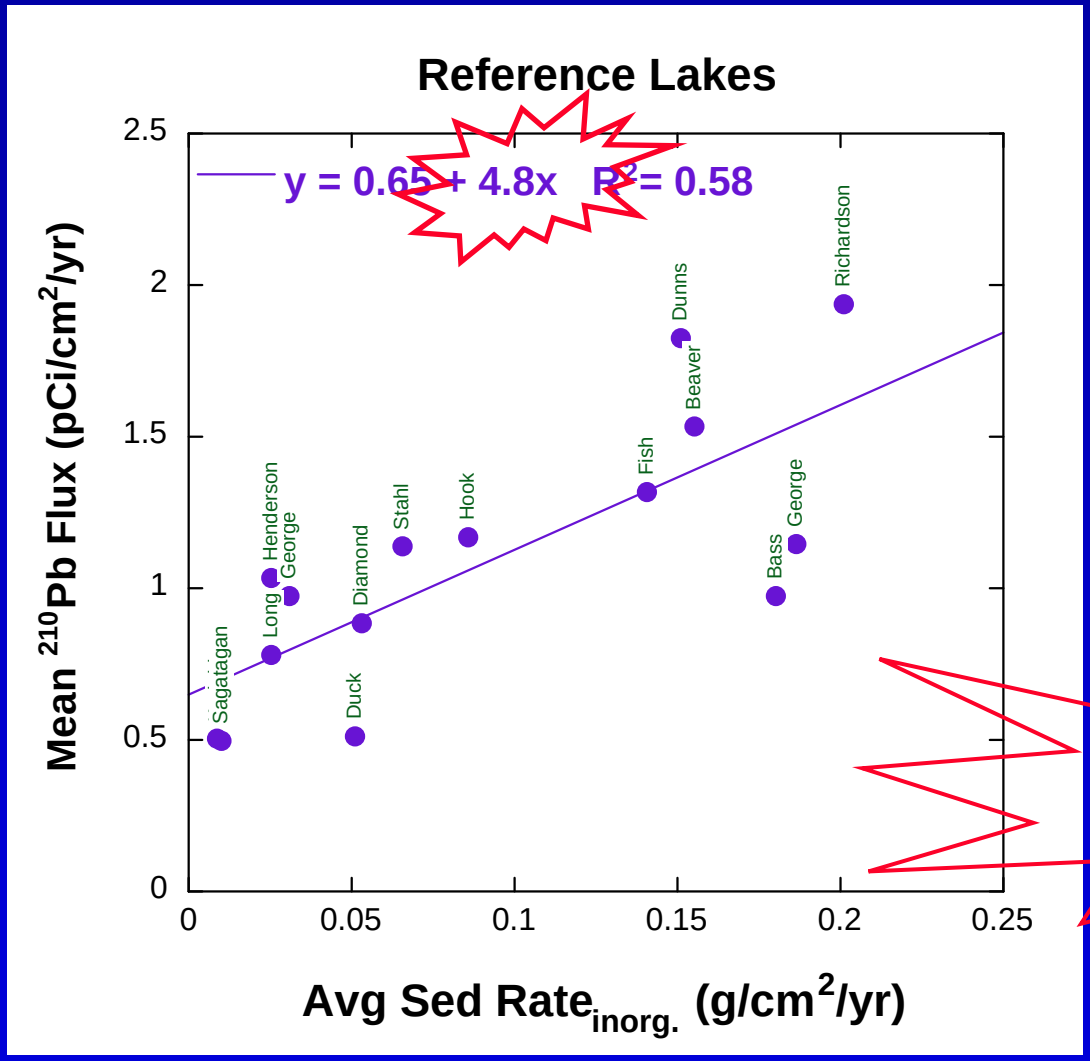
Seepage-type lakes with small watersheds

- No incoming rivers
- Time integrated
- Upland source integrated (sheet + rill + gully)



George Lake, Blue Earth Co.

Lakes as reference systems for upland fingerprint



Use large number of lakes to derive isotopic fingerprint

Slope = concentration on incoming particles

= integrated upland fingerprint

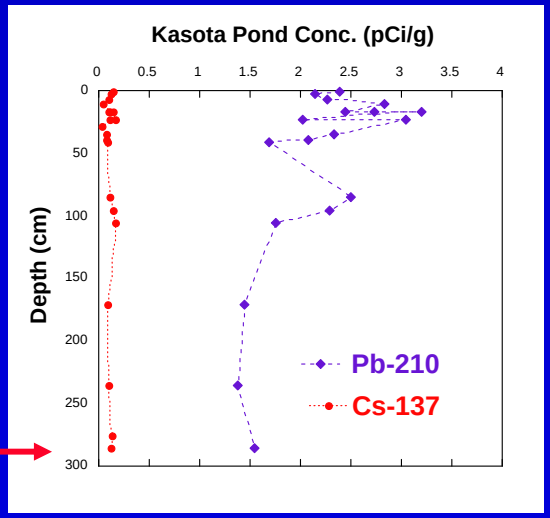
Riverine Depositional (Integrator) Sites

Sites like Kasota Pond:

- collect and store suspended sediment
- integrate upstream erosion processes

Excess ^{210}Pb = 1.4 pCi/g

Very high sed rate



… other integrator sites: Reservoirs

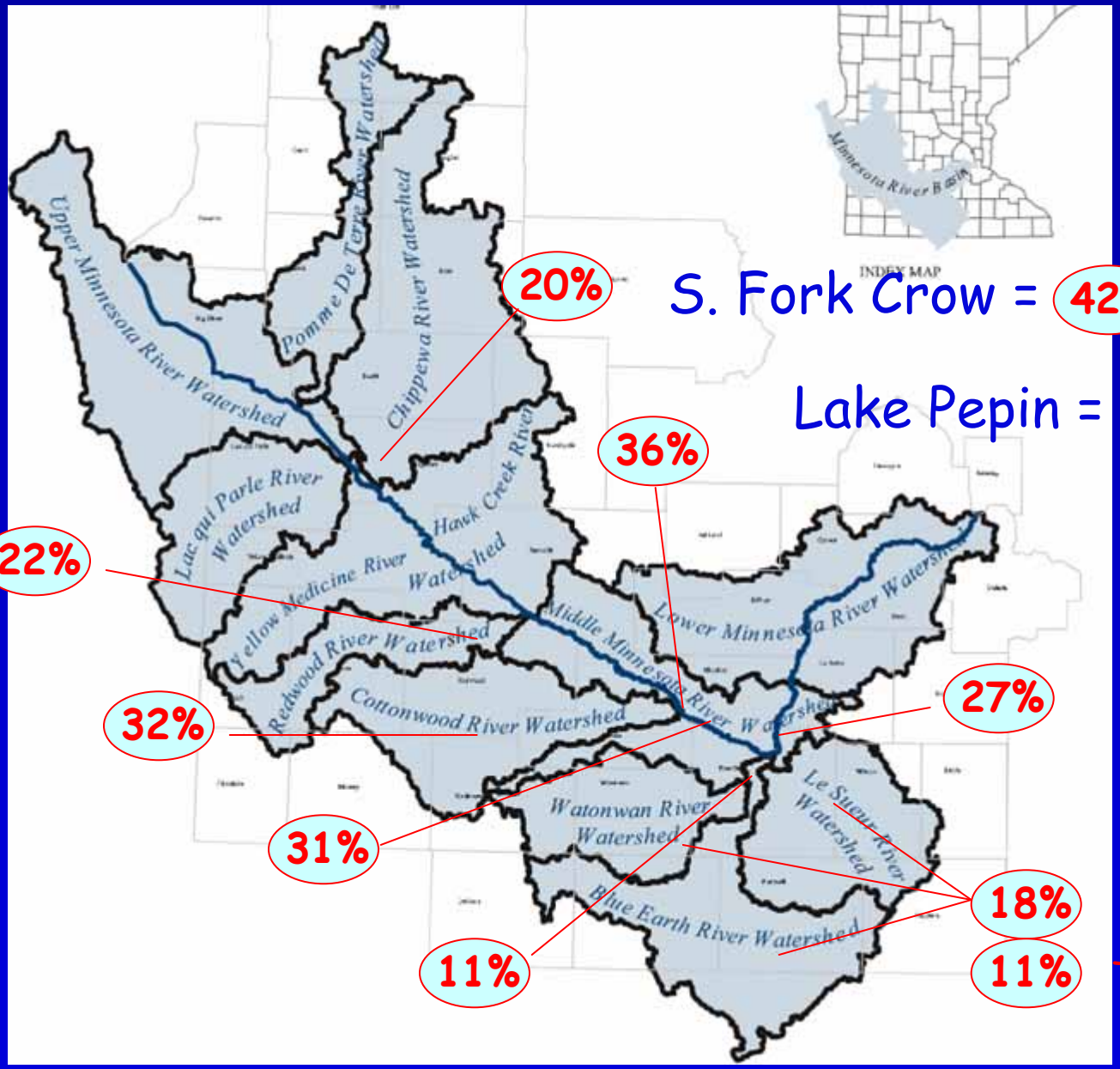
e.g. Redwood Reservoir: 100-yr record

… or backwater sites of temporary riverine storage (Hawk Creek)

… or direct sampling of suspended sediment

Relative Field Contribution to Riverine Sediment

Average of Cs and Pb methods



S. Fork Crow = 42%

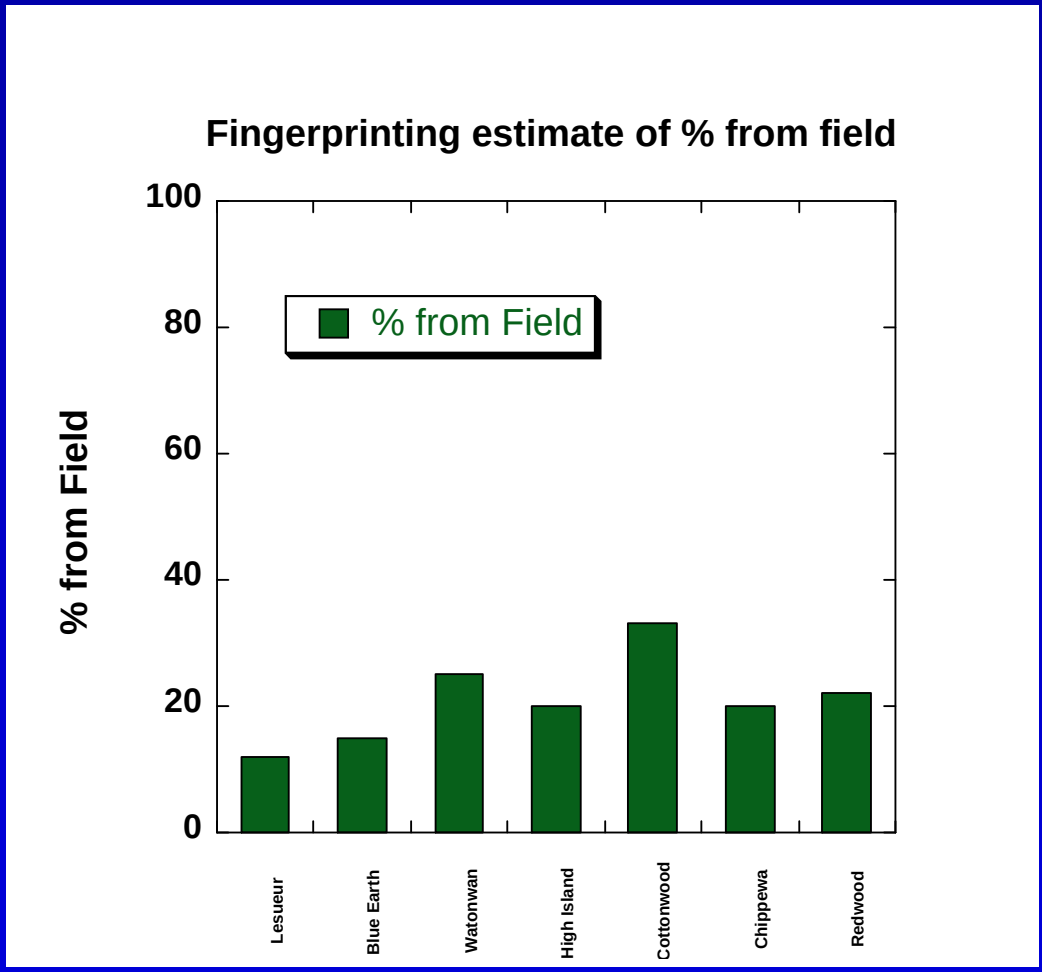
Lake Pepin = 22%

TSS-Snowmelt

Relative Field Contribution by Watershed

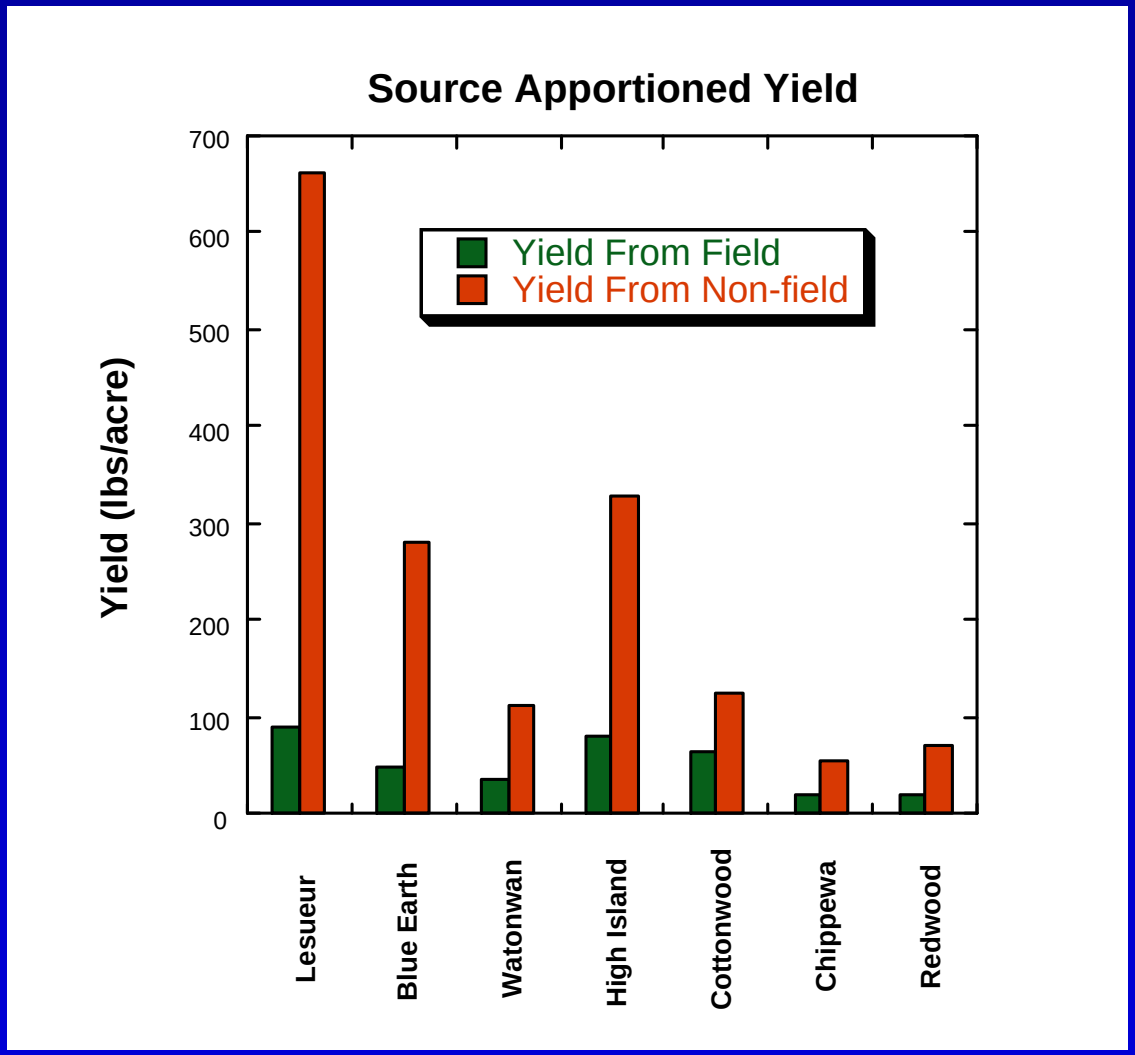
Watersheds are very different, but field contribution always relatively small

This doesn't seem right…?



Sediment Yields by watershed

Some basins have fewer ravines, bluffs, thus % from field should be greater.



Differences in non-field loading drive overall sediment yield variance…
i.e. field yield roughly constant throughout MN River watershed

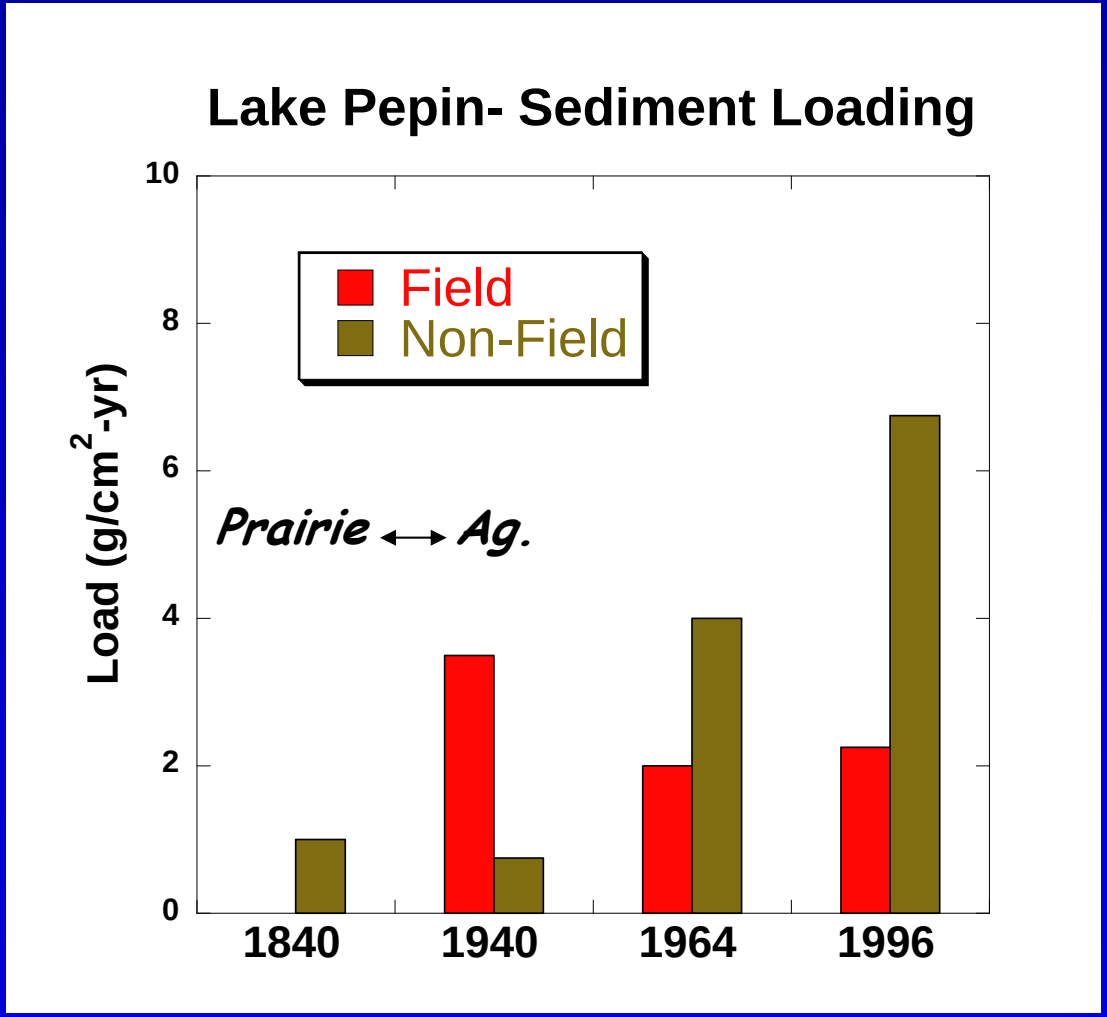
Source of Sediment to Pepin …

	Field	Non-field
1996	25%	75%
1964	33%	67%
1940	83%	17%
Pre~1860	0%	100%

Why change over time???

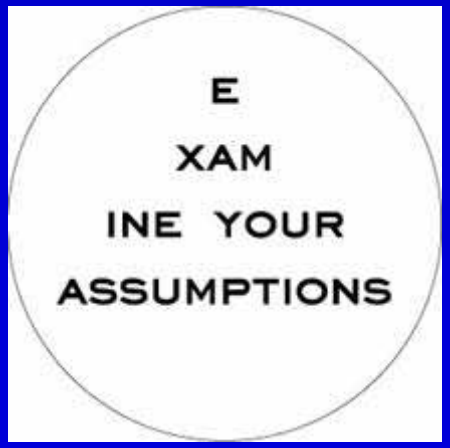
… if you express as loading, some sources not really changing

- Field constant (or decreasing)
- Non-field constant until c. 1940
- Non-field accelerating since 1940



Fingerprinting… important assumptions

1. Average Particle Residence time in river is small <~5 years
2. Direct Atmospheric Contribution of ^{210}Pb to river surface is minimal
3. Value from reference lakes is correct and representative



1. Average Particle Residence time in river is small <~5 years

Considerations:

- only concerned with very fine particles (2-10 μm)
  low storage potential
- results similar throughout lower basin & Pepin;
  if res-time long this wouldn't be true…
  … Pepin would show greater non-field than tribs
- if we are wrong -- Pepin has more field than estimated

2. Direct Atmospheric Contribution of ^{210}Pb to river surface is minimal

Considerations:

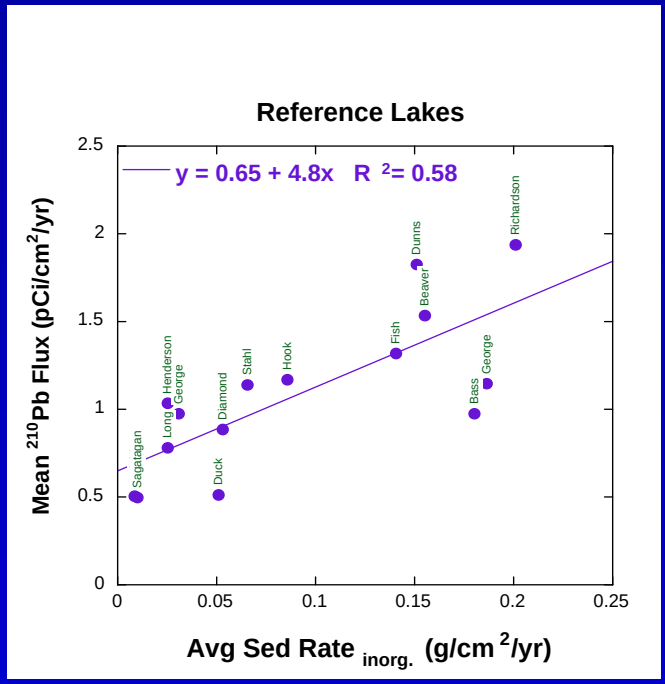
- results similar throughout lower basin & Pepin;
  if atmospheric contribution was large…
  … Pepin would show greater field than tribs
- if we are wrong -- Pepin is even more non-field than presently estimated

Will address using $^{210}Pb/^{137}Cs$ ratios on TSS in upper and lower River

3. Value from reference lakes is correct and representative

Considerations:

- Effect of sediment focusing on sedimentation rates?
- Regional differences?
- If we are wrong -- reference fingerprint could be too large or too small



- Add 15 more reference lakes, examine difference among lakes
- Compare/Validate to direct sampling of field soils

Conclusions

- ✓ Sedimentation in Lake Pepin has increased 10X since pre-settlement times
- ✓ The Minnesota River is the primary source of the sediment
- ✓ Apx. 70% of the sediment currently entering the Minnesota R. and L. Pepin is from non-field erosion
- ✓ Differences in non-field loading among tribs drive overall sediment yield variance …i.e. field yield roughly constant throughout MN River watershed
- ✓ The portion due to non-field erosion has increased substantially in the last 60 years