Channel erosion and floodplain deposition processes in the Minnesota River Basin, USA

Christian Lenhart, John Nieber, Jason Ulrich and Bruce Wilson
Department of Bioproducts and Biosystems Engineering
Research projects

- *Ravine, Bluff and Streambank (RBS)*  
  Erosion study of Minnesota River Basin  
  (Nieber and Mulla) MPCA (complete)

- *Streambank loading and floodplain sedimentation study* - MN Corn Growers  
  (ongoing through 2011)

- *Differential response of MN watersheds to climate change* - USGS & MN Water Resources Center (complete)
Minnesota River largest sediment loader to upper Mississippi R.
Sediment sources today

Channel erosion

Field erosion

Channels now largest source of sediment at MN river mouth (shown at left) 66 – 75%

Engstrom et al. 2009
Glacial River Warren carved wide valley 10,000 years b.p.

Present-day Minnesota River is underfit to wide valley

Map adapted from Richard W. Ojakangas and Charles L. Matsch's *Minnesota's Geology*. University of Minnesota Press, Minneapolis, 1982
Hydrologic alteration

- Increased streamflow in MN River
- Low flow to 90th percentile most changed

Quantifying channel erosion in the Minnesota River Basin

RBS study
- Bank erosion with monitoring
- Historic aerial photos
- Measured bank properties – particle size, cohesive & shear strength
- Modeling with CONCEPTS
Channel change: slope and sinuosity

- Changes to length and sinuosity since 1938

- Loss of 10-15% of length on MN River from channelization, cutoffs

- Impact on sediment transport modeled
MN River— alluvial; 
Low strength

Tributaries— highly variable but similar; glacial till more resistant
Main stem MN River highest
Steep drop zone to MN Valley highest tribs
sediment delivery ratio?
60% fine sediment

Bank erosion rates

Minnesota River Main stem
Tributaries
Channel widening

- Minnesota River and Elm Creek width increased by 50-75%
- Increased lateral erosion (up to 10 ft/yr on Minnesota River)
- 0-5 ft/yr on tribs
Sediment loading (gross)

- Streambank load from lower MN River (Mankato-St. Paul)
  - 350,000 t/year via BANCS model
  - 500,000---1,000,000 tons/year using modified BANCS model
  - Based on aerial photo change, 250,000-500,000 tons per year

- MN River annual suspended load is 100,000s tons to 1.5 million tons/year
Net changes to sediment transport capacity

- Changes since 1938
  - - sinuosity
  - + slope
  - - floodplain connectivity

- Net change is increase in bankfull shear stress (red – orange colors)
Floodplain deposition

- MN valley a large sink for sediment
- 0.3-0.5 m mean post-European deposit depth on lower MN river
- Rate decreases away from channel boundary
Post-European deposition of sediment.

SEDIMENT NOT EVENLY DEPOSITED

LEVEE DEPOSITS HAVE HIGHEST RATES
Hydrologic change
• More flow, esp. mean flow to small flood

Geomorphic alteration
• Channelization
• Widening response
• Alterations cause less connected floodplain

Channels now largest source of sediment in
Streambanks are a major sed source
Management options challenging; object of ongoing research - McKnight and MN Dept. of Agriculture grants
Acknowledgements

Funding:
- Minnesota Pollution Control Agency
- MN Corn Growers Association
- Water Resources Center, USGS

Data Collection:
- Brad Hansen, Geoff Kramer, Mike Talbot, Nick Moore, David Zumr, Britta Suppes