Knickpoint Migration in Western Iowa Streams

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• Loess is a wind blown silt deposit often formed near large rivers.

• Loess is a very erosive streambed material.

• Thicker loess deposits = ↑ potential erosion.

• MRV loess deposits reach great enough depth (> 5 m) to cause widespread stream channel downcutting and erosion.
Excavating a large ditch using steam power, circa 1910.
Highly erodible loess soils
+ Stream straightening and land use changes
= Higher water velocities
= Channel downcutting
= Increased channel erosion
  Higher sediment loads
  Altered flow regimes
  Lost fish habitat
  No pool-riffle sequences
  Lost lateral connectivity w/ floodplain
  Decreased biodiversity
Examples of Knickpoints in Western Iowa
Consequences of knickpoint passage

Approx. old channel cross section

Old streambed elevation
1,200+ Grade Control Structures in Western Iowa
Purpose

• Field measurement of migration rate of a knickpoint and compare this rate to rates of knickpoint migration in other studies

• Results of this field study:
  – better understanding of principal factors causing knickpoint propagation
  – give a range for migration rates of other knickpoints around western Iowa
  – estimate needed response time to control propagation of other knickpoints
Mud Creek DA – 97.5 km²
Rural agricultural landscape
Channel 4-5 m deep
Baseflow - knickpoint - 5 m wide and average flow depth 10 cm

Knickpoint DA – 85.5 km²
Weir and bridge upstream
In knickzone
Potholes

3.5 - 4 m

0.5 m

Potholes

Potholes
Erosion Rate vs. Critical Shear Strength

- Erosion jet test experiments conducted to estimate mechanical shear strength of bank and knickpoint soils
- Three distinct ranges of critical shear strength separated by an order of magnitude:
  - bank soil weakest
  - subsurface of knickpoint bed moderate strength
  - knickpoint surface strongest
- 2006 knickpoint
  - 0.7 m drop from knickpoint lip to scour hole base
  - Another 0.6 m drop in elevation underwater 6 m downstream
- 2007 knickpoint
  - retreated 1.8 m
  - scour hole had expanded in width and depth
- Linear channels upstream from the knickpoint lip
  - Possibly caused by passage of past knickpoints leaving a scar on channel bed
• 2008 knickpoint
  – Finger-like projection extended upstream, funneling majority of water going over knickpoint

• 2008 knickpoint
  – Retreated 3.6 m between February 11 and March 3, 2009 along path of finger-like projection
  – Deep narrow channel bypassed knickpoint ledge sediment on either side and scour hole created US
  – Only baseflow during this period
Fluvial Erosion or Other Cause?

- Knickpoint retreat by fluvial erosion can occur when:
  - $\tau_0 \geq \tau_m$ (400 Pa minimum)
  - Average bed shear stress approximately by: $\tau_0 = \gamma S y$
    - $\gamma = 9810 \text{ N/m}^3$, $S = 0.05 \text{ m/m}$, $y = 0.815 \text{ m}$
  - Flow depth only exceeded 0.815 m five times during study
    - once in October 2007 and four times in June 2008
    - But surveys showed knickpoint migrated outside these events also
- Elevation of knickpoint does not decrease or incline over time but areas of focused flow do appear to erode faster
- Discrepancy between available hydraulic shear stress and shear strength and erodibility of knickpoint indicate fluvial erosion not responsible for some or all of observed knickpoint migration
- However bed shear stress alone could easily erode knickpoints formed in the bank material
Local longtime resident – channel in 1950’s less incised, larger drop in KP elevation, and KP “there one summer and gone the next” (indicating migration rates > 1,000 m/yr). Stream likely eroding through weaker bank material at that time. Past authors also likely observed KP eroding through bank material.
• Between April and August 2010 knickpoint retreated 30.5 m
  – No significant snowmelt or rain events
  – Another example of little change in driving stresses (flow) but had rapid retreat

• Look closer at stratigraphy
  – Boreholes into streambed
  – Stratigraphic diagram shown later extrapolates stratigraphy using these boreholes, deep boreholes on banks, and photographs
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<th>Cumulative Time (yr)</th>
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Cumulative Headward Knickpoint Retreat with Time
Erosional Topography

- Caused by presence and propagation of multiple knickpoints in series
  - Current streambed and knickpoint surface is scar of passage of past knickpoints
- Rapid knickpoint migration – little channel bed scour – become exposed ledges through which future knickpoints migrate
- Slow knickpoint migration – high channel bed scour and deep, large scour holes – remain pools between future knickpoints
Other Factors in Knickpoint Migration

- Abrasive scour of krotovina potholes may be areas of weakness through which knickpoint advances
- Areas of unfocused flow exposed to weathering may become more erodible and probable area of focused flow in future
- Pipe-flow during ice-over conditions and plucking
• Ice froze to knickpoint bed surface during extended cold spell
• Large snow melt event
  • Temperatures warmed more than 40°F in one day
• Several large blocks of sediment plucked and moved due to buoyancy of ice
• Segregation ice observed on detached block
• Block likely plucked along similar segregation ice layer
Conclusions

• Knickpoint migrated a total of 48 m, at rate of 7.4 m/yr
• No correlation between knickpoint retreat and increased flow
• Discrepancy between available hydraulic shear stress and shear strength and erodibility of knickpoint
• 30.5 m of retreat occurred in a four-month period when knickpoint finally eroded through a resistant ledge and into weaker layer below and stopped when highly erodible layers again dipped below the a critical depth threshold
• Higher knickpoint migration rates observed locally in past
  1. Eroded through weaker stream bank material
  2. Lower mechanical shear strength allowed fluvial erosion
  3. Steeper stream gradient in past – higher erosion rates
Conclusions

• Presence and propagation of multiple knickpoints in series cause erosional topography
  – Current knickpoint is bed scar of past knickpoints
• Other factors in knickpoint erosion
  – Not direct causes of knickpoint retreat
  – Abrasive scour of krotovina potholes may be areas of weakness through which knickpoint advances
  – Areas of unfocused flow exposed to weathering may become more erodible and probable area of focused flow in future
  – Formation of ice over knickpoint
    • Pipe-like flow under the ice – fluvial erosion of surface
    • Plucking and removal of large sediment blocks
Research Partners and Future Paper

- Hungry Canyons Alliance
- IIHR–Hydroscience and Engineering Department at the University of Iowa
- Iowa Department of Transportation Highway Research Board
- USDA-NRCS
- Iowa Department of Natural Resources

Paper in preparation –
Earth Surface Processes and Landforms in 2014 or 2015

Thank You

Any Questions?