Streambanks: Sediment and Phosphorus Contributions to an Impaired Water Body in Eastern Nebraska

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Abstract

Streambank erosion contributes to sediment and phosphorus loading of water bodies. Few studies have been done in eastern Nebraska to evaluate the extent of that contribution to impaired water bodies, such as in Wagon Train Lake. The pollutant reduction target has not been met even after implementation of BMPs throughout most of the Wagon Train Watershed of 4,000 hectares. The objectives of this research are 1) to quantify sediment and phosphorus loads from streambanks, 2) to examine dominant mechanism(s) of streambank erosion, and 3) to determine site-specific factors controlling bank erosion in the watershed. Data of the stream reach network were generated using GIS-interface of the AnnAGNPS Model and divided by size of drainage which resulted in four strata. From each of the four strata, four stream reaches were selected for detailed streambank observation. Erosion pins were installed in grids with minimum disturbance to the bank. Site-specific factors such as bank angle, vegetation cover, bank height, and other factors were assessed. Results indicate that streambank erosion contributes 2,619 Mg/yr of the estimated 7,205 Mg yr^{-1} entering Wagon Train Lake. Current erosion pin data suggest that falling soil crumbs from subaerial processes, often thought of as a preparatory agent, cause a significant portion of the erosion in the Wagon Train Watershed.

Figure 1: Location of Wagon Train Lake in Nebraska

Objectives

The objectives of this research are:

1) To quantify sediment and phosphorus loads contributed from streambanks in Wagon Train Watershed.
2) To examine dominant mechanism(s) of streambank erosion and their contribution; that is fluvial erosion, subaerial processes (wet/dry and freeze/thaw), and mass failure.
3) To determine site-specific factors controlling bank erosion in the watershed.

Figure 2: Installation of grid using laser level and rod. Pictured here is Daniel Ginting

Methodology

Reach Selection

- 122 reaches were defined and characterized by the AnnAGNPS (Annualized Agricultural Nonpoint Pollution) Model using a GIS-interface.
- The 122 stream reaches were stratified by drainage area (See Figure 3). From each of the four strata, four stream reaches were selected by SAS based upon probability proportional to reach length. In all, sixteen reaches were selected for the study.

Erosion Estimation

- The manual erosion pin method was chosen due to the nature of the study. This erosion pin method is ideal for small ephemeral/intermittent streams.
- A silicon-bronze welding rod (3 mm diameter, 30 cm long) was utilized as erosion pins which were inserted into the banks with 3 cm exposed (Figure 6) so that measurements with a Vernier caliper could be made from this point of reference.
- A grid of pins consist of three to nine columns with 50 cm horizontal spacing and two to thirteen rows with vertical spacing set at 20 cm to achieve adequate spatial coverage at each bank. The amount of pins ranged from 36 to 66 pins per site (Figure 2).
- An annualized bank sediment yield calculation and data analysis were performed with SAS.

Other Methodology:

- Soil from streambanks were sampled by the use of a 10-cm diameter cylindrical device. Bulk density, organic matter, texture, total phosphorus, and Bray-P1 were analyzed for all 63 samples.
- USGS-style stream flow gauges were installed at the sixteen sites.
- Moisture and temperature sensors were installed at four sites to record wet/dry and freeze/thaw cycles.

Figure 3: ArcView map of 4,000 hectare watershed. Strata by drainage area

Orange: Strata 1 <100 hectares

Yellow: Strata 2 100-500 hectares

Purple: Strata 3 500-1500 hectares

Blue: Strata 4 >1500 hectares

Results & Discussion

Important methods/concepts for estimating streambank erosion:

- Concept of statistics; pick representative reaches by randomization to avoid human bias in site selection.
- Use a grid of pins that attempts to capture the inherent variation of streambank erosion, which includes multiple cross sections (Figure 4) to differentiate channel movement versus channel widening.
- The surface area of banks used (Figure 4) to calculate erosion rates, instead of using bank heights, which provides the best estimate of erosion rates.

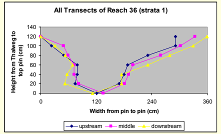

Figure 4: Cross section view of stream with three transects. Points represent pins. Lines represent surface area of bed and bank

Figure 5: Positive pin reading of 7 cm. Heat-shrink sleeving (blue) is 3 cm

Figure 6: Pin reading of 0 cm (no change)

Figure 7: Negative pin reading of -1.5 cm. If pin was buried, then reported as –99.

Three ways to determine the erosion rate from the pin readings:

- Convert all negative pin readings to a value of zero. Assume the sediment covering the pin will be removed back to the reference point at some time in the future.
- Use only measurable or exposed pins (negative 3 cm or greater) to calculate an erosion rate, while all non-measurable, fully buried pins are removed from the data set.
- Convert all non-measurable pins to a value of negative 3 cm (converted from –99).

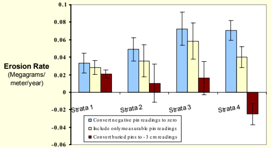

Figure 8: Erosion rate comparison

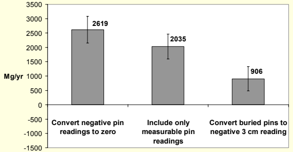

Figure 9: Streambank sediment yield in Wagon Train Watershed.

Negative Pin Readings:

- Utilization of negative pin readings can change the relationship between erosion rate and strata (Figure 8).
- Negative pin readings dramatically affects the overall estimated streambank sediment yield (Figures 9). Subaerial processes are normally assumed to be a preparatory agent for fluvial erosion. Due to low stream flows, more sediment tends to accumulate on the bottom (toe) of the bank from subaerial processes. Without substantial stream flow to transport this sediment downstream, negative pin readings tend to increase (Figure 7).

Limitations and assumptions in estimating bank sediment yield:

- It is assumed that a majority of the sediment/phosphorus loss will enter the lake from bank erosion on a long enough time-scale.
- No fingerprinting or tracer studies have been done in this watershed.
- Streambank soil texture is predominately silty clay loam. The fraction < 63 microns was not analyzed separately from the bulk soil (Figure 12).
- It is assumed wet/dry and freeze/thaw cycles do not significantly affect pin position as supported by observations from this study and current literature.
- The erosion rates (Figure 8) were determined based upon the four replications in each strata (Figure 3). It is a reasonable assumption that the mean erosion rate determined for a strata (drainage area) is the best estimate of the actual erosion rate compared to using a single erosion rate for the entire watershed yielded prior. Additional soil samples are being analyzed to determine source/sink relationship.
- Erosion rates were extrapolated across the total length of streams in each strata and summed to determine total streambank sediment yield (Figure 8, 9, 10, 11)

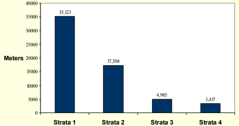

Figure 10: Total length of streams generated from AnnAGNPS

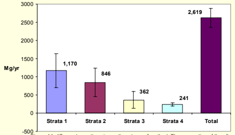

Figure 11: "Convert negative pin readings to zero" method. The summation of all the strata yield the total.

Sediment and phosphorus load:

- There is a significant 20 ppm difference between phosphorus concentration on the outside versus inside of a stream bend. It is likely that recently deposited sediment is higher in phosphorus than was the alluvial material deposited prior. Additional soil samples are being analyzed to determine source/sink relationship.
- The annual total sediment delivered to the lake is 7,205 Mg/yr as measured by D. Ginting, et.al.(2004)
- Estimates of total phosphorus (TP) attributed to streambanks were 1420 kg, 1093 kg, and 474 kg using streambank sediment yields and TP (Figure 9 & 12).
- It was estimated by D. Ginting, et.al.(2004) that 4,573 kg of TP is delivered to the lake from all nonpoint sources (measured TP in collected runoff).

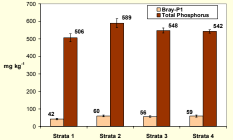

Figure 12: Soil test results for bulk soil.

Conclusions

- Streambank erosion contributes 12-36% of the sediment and 10-31% of the total phosphorus from the watershed entering the lake.
- Sediment contributions are lower due to insignificant stream flow levels, thus fluvial erosion and mass failure were less significant.
- The concentration of phosphorus is high in the streambanks throughout the watershed.
- Subaerial processes (wet/dry and freeze/thaw) were the dominant mechanism of erosion in this temporal sample.
- The duration of the study needs to be increased to capture temporal variability.
- Best Management Practices (BMPs) should include more nonpoint sources such as streambanks in Wagon Train Watershed.
- Suggest that subaerial processes account for most of the upper bank erosion in headwater regions in eastern Nebraska.

Additional Information: There is virtually no irrigation or subsurface drainage other than from terraces outlets. All streams are ephemeral or intermittent as seen in Figure 2. Only several rainfall events have caused significant streamflow since this study started in November of 2005. At most sites, bankfull depth=bank height, thus the entrenchment ratio is low.