STREAMBANK EROSION: DEVELOPING RECESSION RATES BASED ON CONDITION CLASS AND FLOW STAGE CHARACTERISTICS

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ABSTRACT: In 2007 the Natural Resources Conservation Service National Water Quality and Quantity Technology Development Team began a collaborative six year streambank pin-based and bank profile recession rate study with Cheney Lake Watershed, Inc., Inc. The Cheney Lake Watershed is a designated Conservation Effects and Assessment Project (CEAP) Special Emphasis Watershed. The initial purpose was to determine the contribution of fine sediments from the 989 square mile watershed to the highly valued Cheney Lake Reservoir which provides water for the City of Wichita and to evaluate the downstream impacts of the current CRP, EQIP, WRP, and WHIP implementations. For the same time period, the USGS established suspended sediment load sampling (USGS depth integrated sampling procedures) at five gauge sites. Approximately one hundred erosion pins were strategically placed at ten streambank erosion sites to characterize five streambank erosion condition classes commonly represented within 782 square miles upstream from the USGS gauges. The five most probable erosion categories represent a significant presence or absence of characteristics such as roots, root mass, root depth relative to floodplain, bank angle, livestock impacts on streambanks, tension cracks, bank material, bankfull, bank height ratio, and other considerations to formulate BEHI (Bank Erodibility Hazard Index). The rate of lateral streambank recession was correlated to hydrologic runoff factors of flow duration above the inner-berm, assuming at least a bankfull event. This FISC paper is collaborative with, "The Dynamic Nature of Small Watersheds: Estimating the Inner Berm Geomorphic Channel Feature based on the Hydrologic Relationship of Channel Forming Events". In 2007 and 2008 the banks where comprehensively inventoried for condition, length of condition class, and bank height. Cheney Lake Watershed Inc. input and attributed over 186 miles of streambank conditions. The initial results show a significant pattern of recession rates relative to flow duration above inner berm flow. The findings will provide a reliable estimate of the portion of streambank suspended load contribution to the USGS sampler located on the North Fork of the Ninnescah Mainstem at the Whiteside Bridge. The data and analysis, along with the flow duration and intensity, will provide a considerably more robust result from the CEAP AnnAGNPS model because the streambank contributions to suspended sediment load will be proportionally accounted for as a reliable percentage of the total load. Just as significant is the utility of this information for ubiquitous, coarse, unconsolidated, high sand fraction soils, commonly found throughout the Midwestern U.S. Field staff in Midwest areas (Great Plains and Central Lowland physiographic provinces) with similar soil characteristics and predominantly thunderstorm-driven hydrology will have a field tool to reliably predict streambank erosion relative to their condition assessment and runoff conditions.

INTRODUCTION

There are many river models integrating sedimentology, hydrology, streambank conditions, soil stratigraphy and other physical input parameters to predict the streambank erosion associated with both average annual and high stage flow events (event-based). Streambank erosion rate by event-based flow stage is the more difficult proposition. It requires considerably more rigor in fieldwork and analysis to determine. It is often thought that more commonly used models are both validated and calibrated by a monitoring and assessment protocol. But the fact is, very few are both calibrated and validated by region or area to assure the erosion rates we receive are robust. Stakeholders, land operators, and planners ask the questions: How do I know the data you have gathered and the predictions you make are good or reasonable? What are the assumptions? Have you accounted for all of the physical and biological variables that affect streambank erosion in our watershed? These are good questions.

Paucity of field data is a major roadblock to river work. To approach any of these matters quantitatively one must have some data measured in the field. The value of river parameters can be estimated, but with no assurance of verity. Unfortunately, too many professionals approach such problems with the supposition that [the] computer can do all. In river work, computer modeling is an insidious procedure in which an air of surety hides questionable assumptions. A computer gives numerical answers, but the bases on which the computation rests are hidden (Leopold, 2001).

Leopold was not condemning models. His message was simple. Put field measured data into models based on real world morphometry and measures. Question the assumptions. Refine them when necessary and validate your model. Each time you consider re-calibration of a model or empirical-based tool, you must revalidate. This process will keep us out of the error margins which are often on order-of-magnitude away from real world data-based observations.

Exhibit A

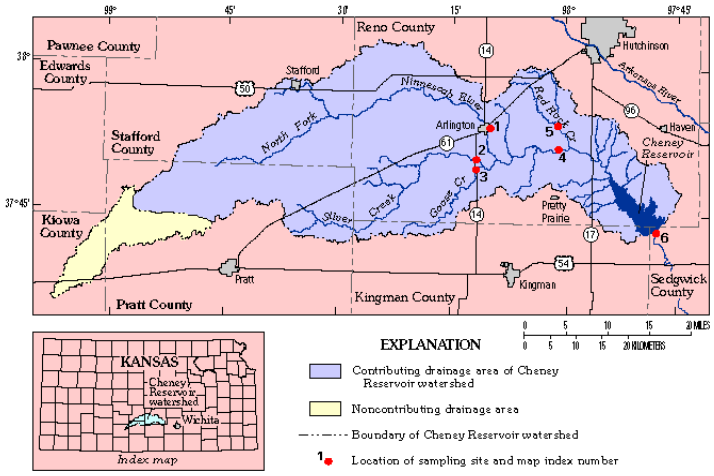


Figure 1. Location of Cheney Reservoir watershed in south-central Kansas and sampling sites used in this study.

The Cheney Lake Watershed is a designated Conservation Effects and Assessment Project (CEAP) Special Emphasis watershed (Exhibit A). This report provides an analysis of the

suspended load contribution from the banks of the contributing drainages within the 989 square miles of the Cheney Lake Watershed CEAP Project.

In 2007, an interdisciplinary team comprised of NRCS-Water Quality and Quantity Technology Development Team, Cheney Lake Watershed, Inc. with the Reno Conservation District, and the USGS completed an initial analysis report: Cheney Lake Watershed Streambank Erosion Analysis-CEAP Watershed (Southerland et al, 2007). Initial findings of streambank erosion contributions to suspended load were determined but it was based on a qualitative tool referred to as the Ventura Workshop Erosion and Sediment Yield Tool developed by Steffen, Lyle J., 1983. The estimated recession rate by condition class was developed in California. The recession rates were based on California studies over time and not calibrated nor validated for the Cheney Lake Watershed. This methodology was only used as an initial estimate of streambank erosion yield from the Cheney Lake Watershed. Three of four technical recommendations put forth in this report were adapted by the Cheney Lake Watershed, Inc. These findings led to the seven-year streambank erosion study resulting in both calibration and validation of streambank erosion rates by condition class.

The purpose of the special emphasis watershed study in the Cheney Lake Watershed is to evaluate the downstream impacts of conservation practices implemented through current USDA programs. The Annualized Agricultural Non-Pont Source Model (AnnAGNPS) will be calibrated and validated for a south central Kansas HUC eight watershed. Changes in offsite water quality will be described. Future watershed conservation practice implementations will also be evaluated to measure their offsite downstream impacts.

In order to appropriately calibrate the total loads in the AGNPS model it was essential to have a robust estimate of streambank erosion contributions to the suspended sediment load samplers. The streambank erosion study includes a surface runoff area of 782 square miles. Five USGS depth integrated sampling sites were established in 1996. Suspended load gauge data from several years were compiled to compute the average annual suspended load rate. This streambank and assessment field study will determine the annual rate and fraction of suspended load coming from streambanks contributed to the five United State Geological Survey (USGS) gauges.

The principle goal of this work was to provide measured data regarding the streambank erosion contributions of sediment for the AnnAGNPS model used in the CEAP project. A broader benefit of this work is the development of streambank recession rates for regions of the country that have similar hydrophysiographic and streambank conditions. The development of the Streambank Erodibility Visual Assessment Tool (SEVAT) calibrated to field measured bank is based on erosion pins and cross-sections by condition class. As a result of this assessment and analysis, these regions will have the opportunity to use real world recession rates on non-cohesive soils ubiquitous to the Midwestern United States.

METHODS AND ANALYSIS

In 2007 Cheney Lake Watershed, Inc., Reno County Conservation District and the USDA-NRCS-Water Quality and Quantity Technology Development Team (W2Q) became partners and

established 10 streambank erosion measurement sites with 30 annually measured bank profiles and 96 erosion pins. Bank erosion pin stations, concrete benchmarks with cross-sections, measured bank profiles, toe pins, bank erosion assessment worksheets, and photo references at ten sites were established. These ten sites varied in bank stability and erosion condition classes ranging from slight to severe (Photos 1 and 2).

Photos 1 and 2: Measuring Streambank Profile and Erosion Pins on Severe Erodibility Condition

Concurrently, both the Bank Erodibility Hazard Index (BEHI) described in Dave Rosgen's Watershed Assessment of River Stability and Sediment Supply (WARSSS) (Rosgen, D.L. 2006) and a more simplified, "Streambank Erosion Visual Assessment Tool" (SEVAT) characterizing condition class, were implemented to provide a comparison between a tool well recognized and often implemented with the SEVAT scores. The objective is to develop SEVAT score sheets which is a combination of verbal description of erosion characteristics combined with extensive photo documentation at an erosion pin station site. The SEVAT tool will be a simpler tool for field offices to use on non-cohesive, coarse textured soil of the Midwest U.S. The SEVAT score sheet is still currently under development by the USDA-WNTSC and the Cheney Lake Watershed, Inc. and targeted for evaluation in 2015. SEVAT scores will be tied to erosion pin recession rates by condition class.

Within each major stream course, streambank conditions were delineated into five categories of streambank erosion rates: negligible (non-contributor), slight, moderate, high, or severe. Within all of the identified stream courses that were evaluated, the estimated height and length of eroded streambanks were assigned according to the height and length of eroded dimensions relative to the channel size and hydraulic geometry characteristics interpreted from ARCGIS. Areas rated negligible were culled from the contributing eroding banks. The five major stream courses are:

1. North Fork Ninnescah (Arlington) above USGS gauge #07144601
2. Silver Creek above USGS gauge #07144660
3. Goose Creek above USGS gauge #07144680
4. Ninnescah – Main-stem above USGS gauge #07144780
5. Red Rock Creek above USGS gauge #07144730

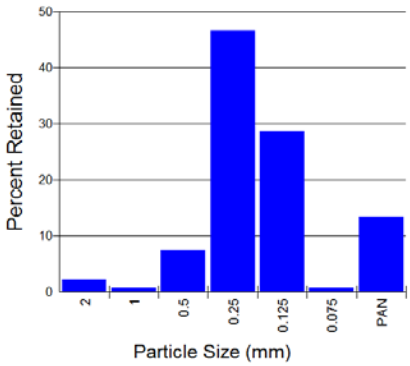
The data represent a combination of field morphometry, field reconnaissance, photo analysis, GIS measuring tools, wet and dry sieving of both bed and bank materials (Photo 3).

Photo 3: Wet and Dry Sieving at Multiple Locations

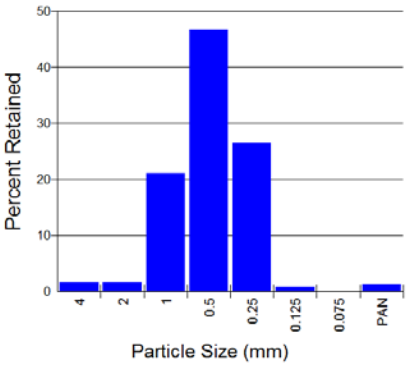
Bed and Streambank Particle Analysis

In the fall of 2007 and 2012, streambed and bank sieve analyses were completed in the North Fork of the Ninnescah, Photo 3. In 2007, sieve analyses were completed on two sites, one near the town of Arlington on the North Fork of the Ninnescah and one at Site NFN1 on the North Fork of the Ninnescah. The sieve analysis at Site NFN1 is located just upstream of the USGS Depth Integrated Sampling site at the Whiteside Bridge. The bed and bank wet sieve analyses were completed twice at Site NFN1 to compare, contrast and analyze particle size distribution and texture percentages over the six year study period. The two analyses yielded similar results (Figures 1 and 2).

Figures 1 and 2: Particle size distribution on streambanks located upstream of streambed



Streambank



Streambed

The dominant soil association throughout all of the streambank study sites in the catchment is the Kanza-Ninnescah, a coarse, predominately sandy, non-cohesive soil that is highly prone to erosion. The data show that nearly all the 0.125mm to 0.25mm and finer materials in the streambanks were mobile once delivered to the water column and moving as suspended load along the streambed. A portion of the 0.25mm to 0.5 sized load is moving as suspended and some of this fraction settles out. The data indicates that the coarser 0.5mm to 1.0 mm sized particles are more present in the streambed post hydrograph recession limb and is not a suspended load component. When sieving of the coarse non-cohesive soils was complete the percent of streambank material parsed to be consistently mobile at a wide range of flows averages 43 to 50 percent. A conservative value of 45 percent was chosen based on the indication that 0.5mm to 1.0mm fraction remaining in the bed indicating that the larger-sized range of the material size .025 to .050mm typically remains as a bedload component. The results of the particle size analysis are consistent for both sampling periods. Particle sizes finer than 0.075mm, primarily silts and clays, are nearly one hundred percent transported to the Cheney Lake Reservoir.

RESULTS

The six year study involved the meticulous field measurements and data generation for ten streambank erosion sites in five streambank condition classes. Annual longitudinal profiles and annual cross sections were developed at each site. A total twenty-eight streambank profile and pin erosion sites along with 28 toe pins and 24 concreted benchmarks were established on ten sites.

Table 1: Streambank Erosion Study Site and Condition Class

Site Name	Condition Class: SEVAT	BEHI SCORE	Sub-watershed (Catchment)	Catchment Size
GC1	Slight	24	Goose Creek	27,935 ac (43.6m^2)
NFN3	Slight	30	NF Ninnescah	331,210 ac (517.5m^2)
SC1	Slight	27	Silver Creek	156,535 ac (244.6m^2)
NFN4	Moderate	32	NF Ninnescah	160,301 ac (250.5m^2)
GC2	Moderate	30	Goose Creek	27,935 ac (43.6m^2)
NFN6	High	36	NF Ninnescah	122,120 ac (190.8m^2)
SC2	High-Severe*	42	Silver Creek	67,758 ac (105.9m^2)
NFN1	Severe	40	NF Ninnescah	356,189 ac (556.5m^2)
NFN5	Severe	46	NF Ninnescah	150,835 ac (235.7m^2)
NFN2	Severe	49	NF Ninnescah	335,549 ac (524.3m^2)

*Condition Class Change during period of study.

The erosion on one severe site was so extreme between 2007 and 2010 that eight-foot pins set in the bank were washed out. However, the team established a cross-section tied to a concreted benchmark. The measure of toe pins and cross-sections and longitudinal profiles also provided data regarding validation of vertical bed stability (incision or aggradation). Table 1 describes Condition class of SEVAT compared to BEHI scores. The results of the SEVAT and BEHI scores show a consistent categorical pattern.

Table 2. Streambank Erosion Rates: Pin, Bank Profile, and Cross Sections

Site Name	Rating SEVAT	BEHI Rating*	Average Annual Recession Rate Ft 5 years	Period of collection Water Cycle Years	Above inner berm flow erosion rate Q_{ib} **	Stream
GC1	Slight	30	0.125	6		Goose
NFN3	Slight	24	0.223	6	.0011ft/hr cycle 3	NFN
SC1	Upper Slight	27	0.224	5		Silver
GC2	Moderate	30	0.50	6		Goose
NFN4	Moderate	32	0.91	6		NFN
SC2	High	42	1.1	6		Silver
NFN6	High	36	1.23	6		NFN
NFN5	Severe	46	2.1	5***		NFN
NFN1	Severe	40	3.02	5***	.045ft/hr cycle 2	NFN
NFN2	Severe	49	3.75	5***	.076ft/hr cycle 2	NFN

*not taking into account near bank stress ratings and two years of BEHI Ratings

**One runoff water cycle, year 2 based on 192 hours above Q_{ib}

*** Water Cycle 6 to be included.

Table 2 is a summary of the five to six year field data. The average annual recession rates of the Kanza-Ninnescah Soil Association ranged from 0.125ft/yr to 3.75ft/yr. These values are higher than the original estimates based on the Ventura Workshop Erosion and Sediment Yield Tool.

Discharges above inner berm flow at two sites located in the proximity of the principle USGS gage near the outlet of the study were analyzed by Thom Garday and W. Barry Southerland. The recession rates averaged between 0.0011ft/hr (for a condition class rating of slight) to 0.076 ft/hr (for a condition class rating of severe).

CONCLUSION

The Cheney Lake Watershed Conservation Effects and Assessment Project has come a long way since the first year of collecting field data and early model runs. Field-based streambank erosion data has been gathered, assessed, and used to provide input to the AnnAGNPS Model. Providing realistic and considerably more robust estimates of streambank erosion based on field-measured data will substantially improve the AGNPS CEAP model. In 2015 the final study will be concluded and report will be completed. Streambank contributions from suspended load estimates from the 2007 Cheney Lake Watershed Streambank Erosion Analysis-CEAP Watershed Technical Report range from 13 to 40 percent of the total suspended load, relative to the five originally gaged catchments. The overall percent of suspended load from the 2007 study was estimated at 13 percent. The preliminary estimates from measured data indicate that the suspended load contribution from banks is between 20 and 25 percent. A more in-depth analysis based on field data and the use of GIS will be used to determine amounts and percent contribution from streambanks will be completed in 2015.

Streambank erosion is highly variable throughout the USA due to integrative processes and variability of streambank material, geomorphic stream type, stratigraphy, change in runoff conditions, and past and present perturbations. This effort of CEAP modeling deserved realistic

input of streambank erosion based on field data, as its hydrophysiographic and streambank conditions are ubiquitous in the Great Plains of Central United States.

Streambank erosion pins and bank profiles were established to calibrate lateral recession rates on the several streambank types with typical conditions. The cost and personnel time committed to establish pins is minimal and the data are highly useful for future planning efforts and calibration of lateral recession rates. These data can be used to developed regional streambank erosion curves that would be characteristic of Midwestern areas and states similar to Kansas to assist NRCS planning efforts in the future. The Cheney Lake Watershed is large and diverse enough to establish an excellent database for streambank erosion and stability.

The appropriate parsing of suspended sediment load contribution from streambank contribution to total load was essential for a robust model. In 2014, after six years of field date collection, the annual recession rates based on condition class has been refined. Ten years would be more desirable and potentially within the prevue of the Cheney Lake Watershed, Inc.

There has been a tendency to use streambank erosion data throughout other regions of the country where the variability in recession rates are substantially different, given similar runoff conditions. Now is the time to begin this effort. There has never been a better time to commit to field collection of this valuable data as our reservoirs continue to fill at accelerated rates and suspended sediment loads from streambanks continue to be a significant source.

I would like to express my appreciation to the Cheney Lake Watershed, Inc. and the Reno Conservation District for supporting this critical data collection and analyses for the past seven years.

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