THE ROLE OF STREAMBANK EROSION CONTRIBUTIONS TO SEDIMENT LOADS IN TOWN CREEK WATERSHED IN MISSISSIPPI

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1 Why did we do the research?

The Town Creek watershed (TCW) (A=1,769 km²) is located in the northeastern part of MS within Ecoregion 65 (Fig. 1).

Principal channel and 4 other tributaries were listed by the Mississippi Department of Environmental Quality (MDEQ) in the MS 2010 Section 303(d) List of impaired water bodies.

Fig. 1. Town Creek Watershed - TCW Location

Sediment yield (950,000 Mg yr^{-1}) from TCW greatly attributes to the estimated 570,000 Mg yr^{-1} of deposition in Aberdeen pool, where annual dredging between 1985 and 2006 averaged 280,000 Mg yr^{-1}.

Proposed Total Maximum Daily Load (TMDL) for TCW recommended that streams located near cultivated lands, road crossings and construction activities should be considered a priority for streambank and riparian buffer zone restoration and sediment reduction Best Management Practices (BMPs).

To develop remedial measures and future BMPs within TCW for reducing water quality impairment and dredging costs, it is necessary to identify the sediment sources and loads currently transported within the watershed.

Fig. 2. Town Creek Watershed reconnaissance

2 What was the hypothesis?

Streambank erosion is an important mechanism driving sediment supply into the streams and an important portion of the sediment budget for TCW.

Research was focused on the identification, assessment, evaluation and prediction of streambank erosion processes within TCW.

Fig. 3. Streambank erosion processes at Town Creek Watershed - TCW

What were we searching for?

The overall goal of this research was to identify erosion mechanisms, the potential effects of streambank erosion processes, and to quantify and model the magnitude and rates of these processes within TCW.

3 How did we carry out the research?

The research used a combination of methods

- Field reconnaissance and detailed data collection
- Laboratory analysis
- Computational channel modeling

Four substudies were undertaken to address the research goal and objectives

Analysis of suspended sediment transport rates

Biweekly grab sampling (24 stations)

3 Automatic sampling stations (daily)

Laboratory analysis (SSC)

Suspended sediment transport rating relations ($Q_s=aQ^b$)

Grab sampling stations
1. Yonaba Ck at Rd 9
2. Town Ck at Natchez Trace
3. Town Ck at Main St. Tupelo, MS
4. Mud Ck at Main St. Tupelo, MS
5. Town Ck at Eason Blvd Tupelo, MS
6. Town Ck at Brewer Rd
7. Town Ck at Hwy 278 near Nettleton, MS
8. Town Ck at USGS Station near Nettleton, MS

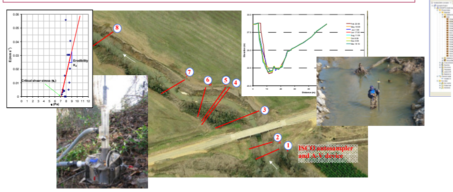
Streambank erosion monitoring

8 cross sections along a 270 m incised channel reach of the Yonaba Creek in the northern headwaters.

8 pin erosion plots (24 columns 1 m apart * 4 rows) along middle 20 km on Town Creek (stable channels).

Jet testing (streambank soil resistance to erosion)

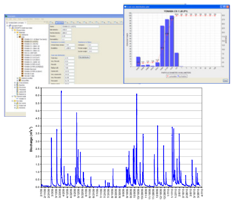
Soil streambank sampling and laboratory analysis



Computational modeling (CONCEPTS model)

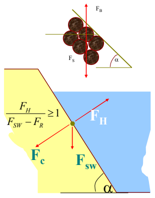
Model setup, calibration and validation from data collected during streambank erosion monitoring

Sensitivity Analysis



Streambank erosion approach development

Analytical approach based on the conceptual model of particle entrainment by flow.



4 What did the research show?

Analysis of suspended sediment transport rates

Mean Q_S of 1,100,000 Mg yr^{-1}.

Agricultural incised channels along northern headwaters (upper 400 km²) contributing up to 65% of total Q_s (Fig. 4).

Q_s reduction along middle 600 km² caused by sediment retention structures and differences in channel morphology and landuse.

Sediment rating parameters suggested transition between streambed (Stage III) and streambank erosion (Stage IV) as major mechanism driving Q_s supply (Fig. 6).

Streambank erosion monitoring

Critical shear stress and erodibility of streambank material ranged from 0.14 to 11.84 Pa and from 0.76 to 35.8 cm³ N^{-1} s^{-1} (moderate to highly erodible material).

Streambed change and rates of streambank erosion vary seasonally.

Streambank erosion most commonly due to gravitational failures and subsequent clean out of the failed streambank material deposited on the base of the streambank.

Widening and strembank erosion rates on agricultural incised channels with limited riparian vegetation up to 3 m and 28.5 Mg per m^{-1} of streambank (Table 1), respectively.

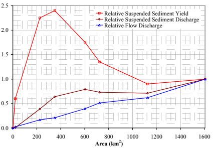


Fig. 4. Spatial variation of flow, suspended sediment load and yield along TCW

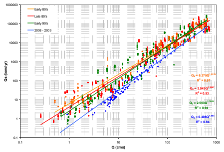


Fig. 5. Relations between suspended sediment load (Q_s) and instantaneous flow (Q) for different time periods at the outlet of TCW

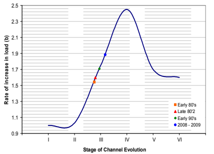


Fig. 6. Changes in time of channel evolution stage determined from changes in sediment rating parameters

Table 1. Results from streambank erosion monitoring along a 270 m reach on the Yonaba Creek

Distance (m)	Mean Streambank Material Bulk Density (Mg m^{-3})		Streambank Erosion per m of stream (Mg m^{-1} stream)		Segment Streambank Erosion (Mg)	
	Left	Right	Left	Right	Left	Right
0	1.38	1.48	-0.33	-0.40	-1.66	-2.00
20	1.45	1.45	0.15	0.64	10.15	44.66
90	1.44	1.53	16.32	0.57	489.46	16.98
135	1.53	1.59	1.04	0.60	31.21	18.13
140	1.53	1.57	20.17	-0.88	302.48	-13.19
165	1.38	1.48	**28.47**	-4.82	996.43	-168.87
210	1.11	1.11	0.27	-0.11	13.32	-5.55
270	1.11	1.11	-0.39	-0.44	-13.60	-15.54
		Total			**1,827.79**	**125.38**

Negative values represent deposition on streambank

Table 2. Comparison of simulated and monitored streambank erosion rates along a 270 m on the Yonaba Creek

Distance (m)	Simulated		Observed	
	Streambank Erosion (Mg)	Contribution (%)	Net Streambank Erosion (Mg)	Contribution (%)
0	0.0	0.0	-3.7	-0.2
20	0.0	0.0	54.8	3.2
90	892.2	44.5	506.4	29.3
135	49.4	2.5	49.3	2.8
140	56.8	2.8	289.3	16.7
165	996.3	49.7	827.6	47.8
210	0.0	0.0	7.8	0.5
270	5.2	0.3	-0.8	-0.1
Total	**1999.9**		**1,730.7**	

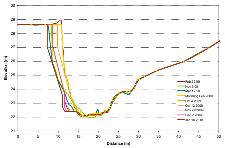


Fig. 7. Comparison between simulated and observed changes on a section along the Yonaba Creek between July 2009 and March 2010

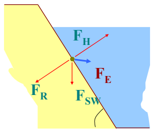


Fig. 8. Forces acting on a soil particle on a streambank

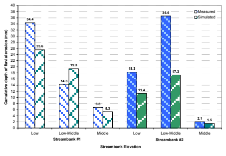


Fig. 9. Comparison of simulated and monitored streambank erosion rates along a 270 m on the Yonaba Creek

Computational modeling (CONCEPTS model)

Model simulation yielded streamflow and streambank degradation predictions (time and magnitude) comparable to those observed (Table 2 and Fig. 7).

CONCEPTS predicted streambank erosion over a 13.5 months period was 115% of the observed net streambank erosion.

Streambank soil friction angle was the most sensitive parameter accounting for streambank erosion retreat by planar failure.

Fluvial erosion approach development

Streambank soil erodibility (k_d) was the most sensitive parameter accounting for erosion retreat.

Spatial and temporal changes on magnitude of τ_c and k_d need to be considered to explain possible differences between simulated and measured depths of erosion (Fig. 9).

Continuous simulation adequately predicted occurrence in time of the observed events.

$$E = \frac{F_E * k_d}{\frac{\pi}{4} * D_{50}^2}$$

E: streambank erosion rate; **F_E:** net force infered by the streamflow on streambank surface; **k_d:** streambank soil erodibility; **D_{50}:** representative soil particle size; **C_L:** coefficient of lift force for a uniform particle size; **τ_{sb}:** shear stress acting on the streambank; **τ_c:** streambank soil critical shear stress; **$c_{\tau c}$:** critical shear stress coefficient; **α:** streambank slope; **θ:** channel bed slope; **γ_s** and **γ_w:** soil and water specific weight

$$E=\left\{\left[\left(0.5*C_L^{'}*\tau_{sb}-c_{\tau_c}*\tau_c\right)\right]-\left[\frac{2}{3}D_{50}*\left(\gamma_s-\gamma_w\right)*\left(\cos^2\alpha-\sin^2\theta\right)^{0.5}\right]\right\}*k_d$$

5 What can be concluded from the research and what the research contributes?

Research identified representative streambank erosion processes and channel changes within the entire watershed.

By using basic methodologies combining actual and historic flow and suspended sediment concentration records, temporal and spatial changes in sediment supply and temporal changes of stages of channel evolution were determined for TCW.

Rates of sediment contribution by streambank erosion processes, and the definitive identification of these processes as the driving mechanism of sediment supply within the Town Creek watershed were assessed and determined.

The conceptual model of sediment particle entrainment on the streambank by flow was validated after developing an analytical approach for estimating streambank erosion rates and depths.

Further research needs to consider the effects on the streambank erosion rates induced by seasonal changes on vegetation cover and the occurrence of subaerial processes increasing soil susceptibility to erosion (τ_c and k_d) and increasing streambank instability.

Research contributes to enhance the understanding of interconnections between landscape and watersheds, which will finally affect the marine ecosystem in the Gulf of Mexico.

A streambank stability design along the 270-m modeled reach is currently in progress involving field assessment and modeling techniques.

Acknowledgments

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