Final examination River Morphodynamics Kleinhans GEO3-4305 2009

This exam consists of three assignments. Be concise and sharp: extensive answers with some good remarks hidden in a flood of words will not earn you as many points as just good answers. Hint: if you do not know an answer, you could also provide two possible answers or directions or scenarios and work out both (or skip and go to the next question).

1. The Old Man's beard: long profiles of the Mississippi River

The long profile of the Lower Mississippi has been measured from width-averaged bed elevations (see abstract and relevant figure of the publication by Biedenharn et al. (2000) on the next page). Several meanders were cut off by man which shortened the river.

A. Explain *why* a meander cutoff increases the slope (=gradient) of the river, and *why* it increases the stream power, and *why and where* it increases the bed sediment transport.

B. Sketch the long profile (elevation against distance along the river) of the river before and after a cutoff based on figure 5 of Biedenharn et al. Explain *where* (in what km range) the cutoffs took place, and explain why you think so. The pre-cutoff data dates from just before the cutoffs. The cutoffs were mostly done from just before to just after World War II. The post-cutoff data dates from 1972-1992.

C. Carefully sketch the evolution of the long profile of the river (simplified as if in a 1D model) before cutoff, immediately after cutoff and two times after the cutoff. Explain why you draw it like this.

D. Explain what the effects were on flood water levels upstream of a cutoff, at a cutoff and downstream of a cutoff a decade or so after the cutoff was created.

E. Argue why the river managers and engineers wanted to cut off the bends: what were the problems they wanted to mitigate, and how did these problems come about?

2. SSTT: Silly sediment transport trouble

Two mediocre earth scientists, named Rollingstone and Sandeman, compare their sediment transport measurements and predictions done in two different rivers. Rollingstone measured and predicted sediment transport in a small gravel bed river, and Sandeman did similar work in a small sand bed river. They discuss a number of issues. Give your view on these and explain why.

A. Sandeman used dunetracking during a flood to measure sediment transport. He found that the measured transport rate was a factor of 10 less than predicted by Engelund-Hansen. Discuss the most likely cause(s) of the discrepancy.

B. Rollingstone measured the change in bed elevation at many points by measuring the bed elevation before and after a flood and now wants to use the Exner equation to calculate sediment transport. Discuss whether she can do this, and if so, how she could do it (use the Exner equation).

C. Both Rollingstone and Sandeman derived an empirical sediment transport predictor from their data. Rollingstone fitted a power function based on shear stress: $q_s=\alpha\tau^{8.42}$; and Sandeman fitted a power function based on unit stream power: $q_s=\beta\omega^{1.077}$ where α and β are empirical coefficients that can be ignored in this exercise. Rollingstone claims that Sandeman's relation must be wrong because sediment transport should depend on flow velocity to a power of 3-5. Sandeman claims that Rollingstone's relation must also be wrong because the power is far too high. Are they right? Explain.

D. The gravel bed river is situated in the mountains, but has a meandering planform. Sandeman argues that mountain rivers should be braided because they are overloaded with sediment, so that this meandering river must have been affected by humans. Explain why a river would braid in general when it is overloaded with sediment, and explain whether Sandeman is necessarily correct or not.

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Recent morphological evolution of the Lower Mississippi River

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Abstract

This study documents slope and stream power changes in the Lower Mississippi River during the pre-cutoff (1880s–1930s), and post-cutoff (1943–1992) periods. The study reach extends from New Madrid, MO, to Natchez, MS, a distance of about 900 km. Analyses for six major reaches and 13 sub-reaches for the pre- and post-cutoff periods indicate that the river presently has a much larger slope and stream power than prior to the cutoffs. The largest increases have occurred between Fulton, TN, and Lake Providence, LA, where slope and stream power increases range from about 27% to 36% and 20% to 38%, respectively. Increases in slope and stream power in reaches upstream and downstream have also occurred, but to a lesser degree. Previous investigations have shown that no coarsening of the bed material has occurred since 1932, and that the bed material may actually be somewhat finer overall. As the Lower Mississippi River is not a sediment-starved system, an increase in stream power with no change in D_{50} would be expected to be offset by an increase in the bed material load as the river adjusts towards equilibrium. Previous investigators have inferred a reduction in the sediment loads on the Mississippi River this century based on analyses of total measured suspended loads. However, these results should be viewed as primarily representing the changes in wash load and should not be taken to imply that bed material loads have also decreased. Therefore, the bed material loads in the study reach should be greater than in the pre-cutoff period. Excess stream power in the sub-reaches directly affected by cutoffs resulted in scour that increased downstream bed material load. These elevated sediment loads play a key role in driving morphological adjustments towards equilibrium in the post-cutoff channel. The stability status of the channel in the study reach currently ranges from dynamic equilibrium in the farthest upstream reaches through severe degradation to dynamic equilibrium in the middle reaches, and aggradation in the lowest reaches. These evolutionary trends cannot be explained by consideration of changes in slope and stream power alone. Changes in the incoming bed material load to each reach generated by upstream channel evolution must also be considered.

Keywords: slope; stream power; degradation; aggradation; dynamic equilibrium; cutoffs; Mississippi River