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Using Mechanistic Understanding of Streambank Processes and a Deterministic Bank-Stability Model to Design and Evaluate a Reach-Scale Restoration Project

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Sediment is one of the leading contributors to water-quality impairment in the United States and streambank erosion has been found to be the dominant source of sediment in many disturbed watersheds. Goodwin Creek is a typical incised channel in northeastern Mississippi, USA (4.7 m-deep) that yields about an order of magnitude more suspended sediment than stable, “reference” streams in the region. Periodic channel surveys with dating of woody vegetation in an actively eroding meander disclosed a migration rate of 0.5 m/y. Because of continued land loss by mass failure of the streambanks, a restoration project was designed to stabilize the banks. Bank retreat occurs by interactions between hydraulic forces acting at the bed and bank toe and gravitational forces acting on in situ bank material. In fact, bank-toe protection which inhibits steepening of the bank, has been found to be one of the most effective means of stabilizing the upper part of the bank. To provide a stable alternative, analysis of the restored configuration needed to mechanistically address both hydraulic erosion and geotechnical stability. This was accomplished using the Bank-Stability and Toe-Erosion Model (BSTEM).

The proposed design was limited to 1:1 bank slopes due to the proximity of a road and included longitudinal stone-toe protection and bendway weirs to counter basal erosion by hydraulic shear. Worst-case conditions under the proposed design were simulated by modeling (1) typical, annual high flows (3 m-deep) to evaluate the amount of bank-toe erosion that would occur, and (2) geotechnical stability where groundwater levels were high and flow had receded to low-flow conditions in the channel (drawdown case). Stone size was selected based on a 1-D hydraulic analysis such that the stone would not be mobilized at peak flows where average boundary shear stresses can reach 60 – 80 N/m2. Calculations were made for a 3 m-deep flow at slopes between 0.002 and 0.003, resulting in recommended stone sizes of 42 and 63 cm, respectively.

Simulation of existing bank-stability conditions supported observations over the past 10 years where under low-flow conditions and a relatively deep near-bank groundwater table, banks were stable, but become unstable with higher levels of saturation. Keeping the geotechnical properties of the banks constant, the simulations were repeated with the designed 1:1 geometry. Much like the results for the existing geometry, the designed slope would be stable at low-flow conditions, but unstable for the drawdown case. In an attempt to increase the stability under drawdown conditions, simulations were conducted to include root reinforcement provided by common riparian species. This was attempted initially using Salix nigra because this is one of the most commonly used woody-riparian species in restoration work. Results, however, still showerd that the bank would be unstable. Simulations were repeated with Platanus occidentalis, which has been shown along with Betula nigra to provide the greatest amount of root reinforcement. In this case, stability was simulated. The design was, therefore, implemented and constructed in a week.

Over the period March 2007 to January 2010, there was no hydraulic erosion at the bank toe and no mass failures of the upper part of the bank. The most significant change in the channel was up to 0.5m of scour along some parts of the streambed. This was expected because of (1) the re-direction of flows into the center of the channel, and (2) the temporary fining of the streambed in some places due to construction activities (from 80% to 13% gravel). Post-construction storm events flushed much of the sand-sized material out of the cross section and

by November 2007 the streambed was again composed of about 80% gravel.