Explanation of the additional modules used in BSTEM-Dynamic which are not “typical” of BSTEM and the role these modules have in determining the final results

Submitted by Dr. Andrew Simon
Cardno, Oxford, Mississippi
March 17, 2017

Background

At the request of Gomez and Sullivan Engineers and in response to a question posed by the Massachusetts Department of Environmental Protection, Cardno has been asked to provide a summary of the modules or sub-models within BSTEM-Dynamic that are not “typical”. We interpret this request as a reference to the enhancements made to BSTEM-Dynamic to provide a more robust model to evaluate the magnitude, distribution and causes of bank-erosion in the Turners Falls Impoundment of the Connecticut River.

As a way of review, the Bank-Stability and Toe Erosion Model (BSTEM) was originally developed at the National Sedimentation Laboratory (NSL) by Dr. Andrew Simon and his research team while employed by the U.S. Department of Agriculture, Agricultural Research Service (Simon et al., 1999; 2000). This work represents the first “dynamic version” of BSTEM where a flow series is used as hydraulic input. As with any research tool, modifications and improvements were made through the years, including the addition of a root-reinforcement sub-model to include the stabilizing effect of riparian vegetation on bank stability (Pollen and Simon, 2005). Additional enhancements were made to improve predictions of hydraulic erosion to account for the effective stress acting on grains and within the static model, the enhanced shear stress on the outside of meander bends. These model developments are summarized in Simon et al. 2011.

Enhancements to BSTEM-Dynamic for Study 3.1.2

To provide a state-of-the art modeling tool for research into bank erosion in the Turners Falls Reach, Cardno worked with our usual BSTEM partners, the NSL and the National Center for Computational Hydroscience Engineering (NCCHE) at the University of Mississippi to enhance BSTEM-Dynamic. Together the team provided the following four major enhancements to BSTEM-Dynamic:

1. Addition of 5 new riparian species representative of the Turners Falls reach to be used in calculations of additional cohesion provided by root reinforcement;
2. Improved accuracy for calculations of boundary shear stress by allowing for input of a unique energy-slope for each time step. Previously only stage could vary and energy slope was held constant.
3. Improved the effective stress algorithm from using a single value for Manning’s roughness coefficient “*n*” to vary by layer (up to 6 values; 5 *in situ* layers and the bank toe);
4. Development and application of a boat-wave sub model to determine the locations and magnitude of hydraulic erosion caused by boat-generated waves;

Role of Enhancements in Determining Final Results

To actually quantify the "role that these modules had on determining final results" one would need to conduct the modeling effort with and without the enhancements to determine differences. Overall though, we can confidently state that the addition of these sub-models and enhancements greatly improved the accuracy of the calculations that determine the magnitude of some of processes that control bank erosion. Thus, we can conclude that we produced more reliable results with these enhancements than we would have without them. Specifically, the enhancements resulted in more accurate and robust calculations of:

- Resistance of the bank materials to mass failure (enhancement #1);
- Boundary shear stress, one of the two major driving forces in hydraulic erosion of bank surfaces (enhancement #2 and #4);
- Excess shear stress, the major controlling factor in predicting particle-by-particle (hydraulic) erosion at the bank toe and for individual layers (enhancements #2, #3 and #4);
- Hydraulic-erosion rates, amounts and locations on the bank (enhancements #2, #3 and #4).
- Hydraulic shear stress due to boat-generated waves, which previous models could not calculate at all (enhancement #4);
- Bank (hydraulic) erosion due to boat-generated waves (enhancement #4).

References

Pollen, N., and Simon, A., 2005. Estimating the mechanical effects of riparian vegetation on streambank stability using a fiber bundle model, *Water Resources Research*., 41, doi:10.1029/2004WR003801.

Simon, A., Curini, A., Darby, S.E., and Langendoen, E.J., 1999, Streambank mechanics and the role of bank and near-bank processes in incised channels. Chapter 6., In S.E. Darby and A. Simon (Eds.), *Incised River Channels: Processes, Forms, Engineering and Management*, John Wiley and Sons, London, 123-152.

Simon, A., Curini, A., Darby, S.E., and Langendoen, E.J., 2000, Bank and near-bank processes in an incised channel. *Geomorphology*, 35: 193-217.

Simon, A., Pollen-Bankhead, N., and Thomas, R.E., 2011. Development and application of a deterministic bank stability and toe-erosion model for stream restoration. In. *Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses and Tools*. A. Simon, S.J. Bennett, and J.M. Castro (Eds.), Geophysical Monograph Series 194, 500 p. ISBN 978-0-87590-483-2, Washington, DC.