Report as of FY2008 for 2008TN53B: "A Survey of Bank Erosion in Beaver Creek, Knox County, Tennessee: Correlations of Channel Stability with Force and Resistance Variables"

Publications

- Dissertations:
    - Keaney,Bart,2009,Stream Channel Stability and Channel Evolution in a Rapidly Urbanizing, Ridge-and-Valley Watershed, Beaver Creek,Knox County, Tennessee,"MS Dissertation", Department of Civil and Environmental Engineering, College of Engineering, the University of Tennessee, Knoxville, TN.,pp. 119.
- Conference Proceedings:
    - Keaney,Bart, Qiang,He, and John,Schwartz,2009, Effects of Watershed Urbanization on Stream Channel Stability in Knox County,Tennessee, "in" Proceeding of the Nineteenth Tennessee Water Resources Symposium, Tennesse Section of the American Water Resources Association, Nashville, TN. pp 2A-26.

Report Follows

(6) Problem and Research Objectives:

The State of Tennessee contains many waterbodies that have been identified on the 303(d) list as impaired or threatened, by which they do not meet designated beneficial uses including biological integrity [40 CFR Part 130; TCA §69-3-101 and TDEC Rules Chapter 1200-4]. By far, the majority of streams listed are impacted by excessive sedimentation in channels causing physical habitat degradation, which reduces biological integrity. The Tennessee Department of Environment and Conservation (TDEC) is required by statutes to produce total daily maximum loads (TMDLs) for 303(d) listed streams impacted by siltation and habitat alteration. TDEC has produced sediment TMDLs for the Beaver Creek watershed, Knox County (Lower Clinch HUC). Field observations and output from a completed AnnAGNPS model suggest that bank erosion is a significant contributor.

The nature of this research is to investigate impacts from urbanization on watershed-scale patterns of channel instability. In addition, the proposed research studies how variables associated with force and resistance play into the development of a predictive model for bank erosion potential. The scope of the project is to intensively survey Beaver Creek and major tributaries for bank erosion problems by conducting RGAs. The number of RGAs conducted will be between 50 and 100.

The objectives for this research are:

(a) Evaluate AnnAGNPS model output with respect to identifying locations with bank erosion problems, and

(b) Develop a predictive model for bank erosion potential based on variables associated with channel force and resistance.

(7) Methodology and Accomplishments to Date:

The research being reported here, sponsored in part by the TNWRRC with FY08 and FY09 funding, is to evaluate the AnnAGNPS model output for Beaver Creek, which identified areas with potentially high bank erosion. The field survey carried out in this project using the Rapid Geomorphic Assessment (RGA) technique in Beaver Creek provides the BCTF on prioritization of proposed bank stability projects.

Methodology:

The field survey of bank erosion in the Beaver Creek watershed was performed with three key metrics for each site. These were a Channel Stability Index, water surface slope, and a Modified Wolman Pebble Count. If the bed material at the site was composed entirely of bedrock or of sand or smaller particles, a pebble count was not performed. The latitude and longitude for each site were recorded with a Global Positioning System receiver accurate to 5 meters.

I. Channel Stability Index

The Channel Stability Index is obtained with the Rapid Geomorphic Assessment (RGA) technique developed by Andrew Simon, of the National Sedimentation Laboratory in Oxford, MS, as a tool to allow a quick evaluation of reach-scale stream bank stability to be made in the field. RGA sites were selected using a detailed map of all streams, swales and water conveyances in the Beaver Creek Watershed that was provided by the Knox County Stormwater Department. Channelization was inferred by visual estimation of sinuosity. An effort was made to ensure that sites were somewhat evenly spaced along the length of the stream, to provide data for sites ranging from the headwaters to mouth. Field visits were made to determine whether access to the stream was available and whether there existed a baseflow adequate to perform an RGA.

The Rapid Geomorphic Assessment ranked stream channel stability on a scale from 0 to 36, as measured by a series of 9 quantitative and semi-qualitative metrics. The scores assigned to each metric were summed to obtain the total RGA score. This total score is also termed the "Channel Stability Index". The nine metrics are:

1. Primary bed material. A score between 0 and 4 was given based on the stability of the bed material. 0 was given to bedrock, 1 to boulder/cobble, 2 to gravel, 3 to sand and 4 to silt/clay.
2. Bed/bank protection. A score of 1 was given if no bed or bank protection was present. Two points were given if one bank was protected and 3 points if both banks were. Thus, if a reach had an unprotected bed and two banks protected, the score would be 4. If the bed was protected, the score would be 3.

3. Degree of incision. A score of 0 to 4 was awarded based on the ratio of the bank height (from the toe to the top bank) to the depth of flow at the deepest part of the reach. 0-10% incision was scored 4, 11-25% incision was scored 3, 26-50% incision was scored 2, 51-75% incision was scored 1 and 76-100% incision was scored 4.
4. Degree of constriction. A score of 0 to 4 was awarded based on the ratio of channel width at the head of the reach to the width at the bottom of the reach. 0-10% incision was scored 0, 11-25% constriction was scored 1, 26-50% constriction was scored 2, 51-75% constriction was scored 3 and 76-100% constriction was scored 4.
5. Stream Bank Erosion. Each bank was considered separately. If no erosion was present, it was scored 0. If fluvial erosion was the dominant process, it was scored 1. If mass wasting was the dominant process, it was scored 2.
6. Stream bank instability. If mass wasting was present, whether or not it was the dominant process, the percentage of each bank in the reach on which it appeared was assessed. 0-10% failing was scored 0, 11-25% failing was scored 0.5, 26-50% failing was scored 1, 51-75% failing was scored 1.5 and 76-100% failing was scored 2. This assessment was performed separately for each bank.
7. Established riparian woody-vegetative cover. The percentage of each bank on which woody vegetation was present was considered separately. 0-10% covered was scored 2, 11-25% covered was scored 1.5, 26-50% covered was scored 1, 51-75% covered was scored 0.5 and 76-100% covered was scored 0.
8. Occurrence of bank accretion. The percentage of each bank upon which fluvial deposition was present was considered separately. 0-10% covered was scored 2, 11-25% covered was scored 1.5, 26-50% covered was scored 1, 51-75% covered was scored 0.5 and 76-100% covered was scored 0.
9. Stage of channel evolution. A score between 0 and 4 was awarded based on the stage of channel evolution. Stage 1 was scored 0, Stage 2 was scored 1, Stage 3 was scored 2, Stage 4 was scored 4, Stage 5 was scored 3 and Stage six was scored 1.5.

II. Water surface slope

Slope was measured with a Pentax AL-M4c Autolevel. Frequently, the reach of interest was less than or equal to 100 ft in length, so the slope was measured from points 50 ft upstream and 50 ft downstream of the level, in order to ease calculations. At certain downstream sites, longer reaches were surveyed, to account for the fact that a reach length of six to ten channel widths would be longer than 100 ft. In these instances, the measurements were corrected to provide a percent slope.

III. Modified Wolman Pebble Count

The pebble count procedure was modified from Wolman (1954). A fiberglass tape measure was stretched across a riffle to such a distance that 50 feet were covered (since most reaches would not accommodate a 50ft length of tape directly across the stream, several transects across the same riffle were often used.) Every 0.5 ft the operator lowered his finger straight down and selected the first object he touched. If it was a pebble between 2 mm and 125mm, its size was recorded. If it was a finer particle, it was categorized as clay, silt or sand, depending on feel. If it was larger, it was categorized as cobble, boulder or bedrock, based on visual estimation.

Spatial Analysis:

A digital elevation model of the Beaver Creek watershed area was obtained from the United States Geological Survey National Map Seamless Server. The hydrology toolset incorporated in ESRI's ArcMap 9.3 was used to delineate flow paths as a raster image based on flow accumulation. The latitude / longitude location of each geomorphic assessment site was then plotted onto this map as a point shapefile. The points representing the assessment sites were fitted to the flow accumulation raster so that upstream catchments could be developed. The degree of urbanization in each catchment was determined by overlaying the map with a layer containing the NLCD 2001 Land Cover Classification. "Urbanization" was defined as areas that were labeled 21: Developed, Open Space; 22: Developed, Low Intensity; 23: Developed, Medium Intensity and 24: Developed, High Intensity. The percentage of each catchment that was forested was determined by summing the total of 41: Deciduous Forest and 42: Evergreen Forest. Due to the difficulty of combining the NCLD 2001 Impervious Surfaces raster with the watershed rasters, the area of impervious surfaces was estimated using the "averaging-by-land-use" system used previously in Knox County in the Second Creek watershed and developed by Camp, Dresser & McKee, an environmental consulting firm (Castle, 1996).

Statistical Analysis:

The scores for each metric at each site, as well as the total Rapid Geomorphic Assessment score, the slope, the d50 of the pebble count, the percentage of developed land in the local upstream area and total upstream catchment, the percentage of each catchment that was forested and the percentage of each catchment that was covered by impervious surfaces were used as the input for multivariate statistical analysis using SAS's JMP 7.0.1. The dataset was input as 15 independent and semi-dependent variables and 1 dependent variable. The overall RGA score was taken to be the dependent variable in most analyses, although most of the metrics used to compute the RGA are also controlled, to varying extents, by the same processes as overall channel stability. In particular, the Stage of Channel Evolution, percent of bank failing, degree of incision, bed material and presence of bank accretion were the variables that should have most closely correlated with the overall stability score. Correlations between these variables would not convey information as useful as those between metrics that gave approximations of the processes that control stream channel morphology.

Water surface slope was expected to be a controlling factor for incision, bank accretion, and bed particle size, so these factors were analyzed independently. The presence of vegetation on stream banks was expected to have a strong influence on bank stability, and the RGA allows for each bank to be assessed separately, so the scores for overall stream bank woody vegetation and percentage of stream banks failing, as well as the scores for the left and right banks for both those metrics were analyzed.

Accomplishments:

In total, full assessment were conducted in 57 sites in Beaver Creek watershed with Rapid Geomorphic Assessment (RGA) as well as the slope measurement and pebble count. In addition, there were 34 sites at which only the RGA was conducted.

- Five sites in the Plumb Creek watershed were assessed completely, with one site rated as unstable.
- Four sites in the Meadow Creek watershed were fully assessed, with two sites rated as unstable.
- Eight sites in the Grassy Creek watershed were evaluated fully, with 6 sites rated as unstable
- Eight sites were fully assessed in the Knob Fork watershed, with three sites rated as unstable
- Five sites were fully assessed along Hines Branch, with 1 site rated as unstable
- Fifteen sites were evaluated in the headwaters area, covering several small streams including North Fork, Mill Branch, Willow Fork, Lammie Branch, Kerns Branch, Cox Creek and a stretch of Beaver Creek. Fives sites were rated as unstable.
- Eleven sites were evaluated on the main stem of Beaver Creek downstream of the headwaters area, with 6 sites rated as unstable.

(8) Principal Findings and Significance:

Many rivers and streams in our nation have been identified on the 303(d) list as impaired or threatened as a result of siltation and habitat alteration, and commonly occurring in urbanizing watersheds. Urbanization creates more impervious surfaces that alter the hydrologic regime causing increased storm flow peaks and duration that can lead to excessive stream bank erosion in some locations. Beaver Creek in Knox County, Tennessee has been identified on the state 303(d) list and a sediment TMDL has been proposed by the Tennessee Department of Environment and Conservation (TDEC). In addition, state 319 funds have been awarded to the Beaver Creek Task Force (BCTF) to address the siltation problems. A sediment model for the Beaver Creek watershed completed by the University of Tennessee in 2005, in which the model found bank erosion to significantly contribute to stream sediment loads. However, the model output was never evaluated with a field study to confirm its findings. This study surveyed the extent of bank erosion in the Beaver Creek watershed to evaluate the extent of bank erosion problem. The Rapid Geomorphic Assessment (RGA) developed by the USDA National Sedimentation Laboratory was used to quantify channel stability and bank erosion potential.

RGA analysis found no clear spatial relationship between a study site's position along the stream reach and its stage of channel evolution in this study. Nor was there a clear correlation between the degree of watershed development and channel stability. Previous studies have shown that the presence of vegetative growth on and near stream banks can be one of the dominant controls of bank stability, but this was not the case in this study. Another expected relationship that was not apparent in the data was an influence of slope on channel incision. Notably, none of the stream channels in the sub-watersheds in the Beaver Creek watershed showed discernable patterns in the stages of channel evolution observed along their courses of flow. The main stem of Beaver Creek did appear to show a pattern of adjustment. The results from this study suggest that the Rapid Geomorphic Assessment is simply not suited to measuring system-wide stream channel stability on the watershed scale under a condition of rapid urbanization. That said, it remains a valuable tool for comparing channel stability at reach-scale sites within a watershed.

Of the 57 sites surveyed for bank stability, 24 were classified as unstable. The study results will provide the BCTF with useful information on prioritization of proposed bank stability projects.

Educational opportunities from the research included support and training of a graduate student, who has graduated with a Master's thesis.

Publications and Presentations Resulting from this Research:

F. B. Keaney, J.S. Schwartz, and Q. He, "Effects of Watershed Urbanization on Stream Channel Stability in Knox County, Tennessee," Proceedings of the 19th Tennessee Water Resources Symposium, Burns, TN, 2009: pp 2A-26.

Platform presentation at the 19th Tennessee Water Resources Symposium, April 15-19, 2009, Montgomery Bell State Park, TN: F. B. Keaney, J.S. Schwartz, and Q. He, "Effects of Watershed Urbanization on Stream Channel Stability in Knox County, Tennessee."