February 8, 2006

Effects of Within-Day and Within-Week Peaking on Bank Erosion of the Roanoke River Downstream of the Roanoke Rapids Dam

Study Objectives and Methods

1. Determine water surface elevations over an 80-mi reach of the Roanoke River, downstream of the Roanoke Rapids Dam (RRD), as a function of the flow releases from the dam by using an unsteady hydrodynamic model.

    - HEC-RAS, a one-dimensional hydraulic model capable of performing steady and unsteady flow computations, will be used to model the entire reach for various flow release scenarios. This model has been developed by the U.S. Army Corps of Engineers.

    - FESWMS, a two-dimensional hydrodynamic model capable of performing computations for both steady and transient flow conditions, will be employed in 12 river reaches where more detailed information about flow velocity and shear stress is necessary, e.g. at locations where bank stability analyses will be carried out. Each of the river reaches will be about 20 channel widths long. An Acoustic Doppler Velocimeter (ADV) will be used to collect flow velocity data from the modeled reach that will be utilized for calibration and validation of the numerical model. Depth-sounding measurements will be used, where necessary, to augment available stream bathymetry data.

2. Carry out field and laboratory investigations to measure various geotechnical parameters describing the bank material (e.g. saturated hydraulic conductivity, friction angle, critical shear stress) at representative sites along the modeled reach.

    - *In situ* tests include the borehole shear test (BST) and matric suction measurements using a tensiometer. Both tests will be performed at the same depths. The BST test will provide information about the effective friction angle, total cohesion, and suction friction angle. These test will be carried at the 12 sites, where detailed river flow modeling will be performed.

    - A jet-test device developed by ARS will be used to determine the critical shear stress and the erodibility coefficient of the bank material at the same 12 sites.

- For 3 of the field sites, undisturbed soil samples will be extracted and carried to the geotechnical laboratory at Virginia Tech to perform triaxial tests and matric suction measurements. Shear strength, permeability, capillary pressures and grain size distribution will be determined from these tests.

3. Develop a method for calculating the boundary shear stress at the vicinity of the bank as a function of flow conditions and local channel geometry.

    - This will be based on the output generated by FESWMS.

4. Employ a two-dimensional hydrology model to determine the pore-water pressure created within the bank region under the conditions of a proposed river flow regime.

    - SEEP/W, a two-dimensional, transient seepage model, accounting for both unsaturated and saturated flow within the bank, will be used to obtain the pore water pressure changes occurring during a single flow event. The variation of stream water surface elevation with time obtained from FESWMS (or HEC-RAS) will be used as boundary condition. This model can take into consideration the effects of a rainfall event as well.

5. Determine the stability of the banks against mass wasting and grain by grain erosion by using suitable models. This requires information obtained from the previous components for a given flow release scenario. Identify locations most susceptible to erosion. Reproduce actual flow releases and compare calculated amounts of erosion with those measured via available erosion pins. Historical data of bank erosion could be used as well for examining the validity of the combined model (flow stage, pore-water pressure, bank stability).

    - For a given flow release from the dam, the fluvial erosion rate of the bank will be determined based on the excess shear stress (actual shear stress applied by the flow and calculated through FESWMS minus the critical shear stress obtained from the jet-test) formulation for cohesive materials and the Shields approach for non-cohesive ones. This procedure will identify possible changes in the bank geometry, especially at the vicinity of the bank toe. Then, a slope-stability analysis will be carried out by using the computer program SLOPE/W. Besides the geometry of the bank, pore pressure calculations obtained from SEEP/W and water level elevation of the stream flow are used as inputs to the slope-stability program. For each time step of the flow event, the program will provide the factor of safety (SF) for the surface failure with the minimum (SF) value.

6. Run the combined model (flow stage, pore-water pressure, bank stability) for various scenarios to develop correlation between hydrologic variables and bank erosion.

    - The procedure outlined in item 5 will be run at the 12selected sites for various flow release scenarios to identify the conditions that are more conducive to bank failure.

The ultimate goal of this study is to assess the effects of various within-day and within-week hydropower operation scenarios on bank stability and erosion along the 80-mile section of the Roanoke River downstream of the Roanoke Rapids dam. It is also expected that this study will identify locations most susceptible to erosion for a given flow release scenario. This study will provide a management/decision making tool that could be employed to determine the appropriate within-day and within-week reservoir releases that meet certain desirable objectives.

Panos Diplas and Marte Gutierrez, Civil and Environmental Engineering Dept., Virginia Tech