Report as of FY2006 for 2006KY63B: "Experimental Study of the Impact of Upland Sediment Supply upon Cohesive Streambank Erosion"

Publications

- Conference Proceedings:
  - Belcher, Brian and Jimmy Fox, 2007, Experimental Study of the Impact of Upland Sediment Supply upon Cohesive Streambank Erosion Part 1: Fluid Turbulence, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 7-8.

Report Follows

Problem and Research Objectives

This project was initially formulated to study the impact of upland sediment supply upon cohesive streambank erosion. Due to the complexities of understanding the impacts of fluid turbulence on erosion, the focus was shifted to study the structure of turbulence in gravel-bed rivers. Thus the fluid characteristics were focused upon for this work, with studies of sediment characteristics planned for future research. It is well recognized by the scientific and engineering communities that turbulent structure impacts scour-deposition, contaminant mixing, solute fluxes at river boundaries and aquatic habitats. However, the cyclical nature of turbulent structure (form) and the source-sink energy transfer attributed to turbulent bursting phenomena (function) remain poorly understood, particularly in gravel-bed rivers, where high gradients and high turbulent intensity make measurements of instantaneous turbulent processes difficult. To overcome those problems and study turbulence over gravel beds, we developed a scientific method that utilizes advanced velocity instrumentation with high spatial and temporal resolution and accepted visualization filtering methods (i.e. turbulence decomposition), advanced statistics, and theoretical analysis of turbulence length and frequency scales. We used this method in a fixed gravel-bed flume in order to isolate potential parameters impacting turbulent structure within a controlled setting.

Methodology

Experiments were performed in two different 12-m-long open-channel flumes with fixed roughness elements placed on the bed. Spatial data was collected with particle image velocimetry (PIV) and this data was decomposed using turbulence filtering techniques to visualize eddy structure. Time-series data were collected at a point using acoustic Doppler velocimetry (ADV) and decomposed using a temporal equivalent decomposition method to visualize the impact of eddy structure upon velocity time-series data. The decomposition methods provided plots of large- and small-scale coherent structures in the turbulent field. These plots were statistically analyzed for length scales and topological description of eddies; as well as the turbulent bursting phenomena such as sweeps, ejections, inward interactions and outward interactions. Results were further analyzed to provide a comprehensive conceptual model of turbulence for the range of conditions tested.

Principal Findings and Significance

Our specific findings are (1) particle image velocimetry coupled with turbulence filtering methods are excellent tools to visualize and measure characteristics of the dominant scales of turbulent structures in rough-bed channels; (2) spatial and temporal fluctuations of important turbulent processes are related to the birth, growth and destruction of the characteristic eddies, which are projected along larger scale patterns that spatially encompass $>6.5H$ in the streamwise direction, where H is the flow depth; and, (3) existing structural models may be extended to rough-bed flows in open channels.