USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Project ID: 2002WA12G

Title: Collaborative Research: Hydraulic and Geomorphic Controls on the Evolution of Cluster Bedforms in Gravel-Bed Streams

Project Type: Research

Focus Categories: Sediments, Hydrology, Geomorphological Processes

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Abstract

This project is a collaborative effort among researchers in the Department of Civil Engineering at Washington State University, the Department of Geological Sciences at Central Washington University, and USGS collaborator Dr. Randal Dinehart, Sacramento, CA. The focus of the research is the hydraulic conditions associated with the evolution of sediment clusters that develop on gravel-bed streams. These bedforms, known as cluster microforms, have been only recently recognized as vital in controlling sediment transport and flow roughness in gravel bed streams. Understanding the processes under which these structures evolve is of fundamental importance in river engineering, restoration, and habitat management. Recent biological surveys have shown that the gravel clusters provide refuge for benthic populations in streams. Fine sediments are also trapped in the "wake" and "stoss" regions of the clusters, preventing suffocation of spawning beds. New theoretical methods will be developed in the course of this research to determine the flow conditions necessary for the formation and disintegration of sediment clusters by accounting for the turbulent nature of the flow and the frictional characteristics of the flow over the clusters.

The project entails both laboratory flume experiments and field studies, the results of which will be compared and integrated to exploit the advantages of each method. A major goal is to define the near bed turbulence structure to improve the understanding of the coupling between near-bed turbulence and sediment transport when clusters are present. In the laboratory a series of experiments will be conducted for unisized and non-unisized spheres to examine the cluster geometry, the flow ranges under which clusters form, remain stable, and disintegrate, and the interaction between near-bed hydraulic parameters and clusters bedforms. The reduced number of variables in the laboratory experiments will allow specific relations between the hydraulic parameters, sediment supply, and resulting particle clusters to be isolated

and quantified. Realization of this goal is made feasible for both the flume and field studies by the use of newly developed technology that allows simultaneous measurements of local sediment transport and adjacent near-bed flow at turbulence-resolving frequencies without disturbing the flow. In particular, recent advances in high-resolution cameras and acoustic sensors for measuring turbulence around clusters, combined with the development of hardware for image analysis and bed scanning, will allow for the detailed approach proposed here.

Field settings are naturally more complex and difficult to measure and observe, especially during the high-flow events when most of the channel-bed sediment transport occurs. However, field studies are critical for achieving a more complete understanding of the natural system, which is the ultimate goal of this research. Two field sites on gravel-bed streams will be selected for study in the Pacific Northwest region. The sediment clusters and stream geometry will be measured and mapped in detail before and after each high-flow event and instruments will be installed to continuously monitor flow velocity, water-surface stage, and bedload sediment transport. More detailed direct measurements of flow velocity and turbulence will be taken during high flow events using an existing USGS cableway across the river at one of the sites, the North Fork Toutle River in western Washington.

The controlled laboratory results will be calibrated with the field results and vice versa in an iterative process throughout the study. Through this interdisciplinary approach the relation between the laboratory and field results will be quantified in a manner that is directly applicable to modeling and predicting sediment transport in natural gravel-bed channels. One anticipated result is refined equations for channel-averaged bedload sediment transport that account for the varied entrainment conditions of sediments forming a cluster and the role of near-bed turbulence. As a final step, the utility of these findings will be assessed for specific applications toward river management, restoration and habitat evaluation. At present there is a great interest in utilizing hydraulic structures to enhance aquatic habitat by creating non-uniform flow fields, which in turn create scour holes and sediment cluster microforms desirable to aquatic species. Strategic placement of gravel and boulder structures have also been used in regulated channels to increase the diversity of aquatic micro-habitats and help mitigate the impacts of dams or other structures. The research proposed here will provide unique information about the optimal ranges or thresholds of flow and frictional characteristics to stabilize or mobilize cluster bedforms in these situations.