CALCULATION OF SUSPENDED SEDIMENT AT GAGING STATIONS

Jason W. Kean, Hydrologist, USGS, Boulder, CO, jwkean@usgs.gov; J.Dungan Smith, Hydrologist, USGS, Boulder, CO, jdsmith@usgs.gov

Abstract: Standard USGS procedure for gaging discharge in rivers is to measure stage and then to calculate discharge from an empirically generated rating curve. Measuring stage is relatively easy using a pressure gage and is not particularly expensive. To generate an empirical rating curve, however, requires making discharge measurements at a wide range of stages and then fitting a monotonic curve to the stage-discharge data field. Although this approach has been used for over a century, attesting to its accuracy and robustness, procurement of the data necessary to generate an accurate empirical rating curve can be time consuming and expensive. By developing procedures that account for the fluid mechanical effects of all of the physical and biological roughness elements on the entire potentially wetted perimeter of a geomorphically stable reach of a stream or river, the resistance to flow can be explicitly determined as a function of stage, making possible a completely predictive model for the flow in that reach at all stages. Using such a fully predictive model (namely, one with no empirically adjusted coefficients) a "theoretical rating curve" can be constructed. We have developed such a model and tested the rating curves produced by it against the empirical rating curves at seven gaging stations [two in Kansas (Kean and Smith, 2005), three in Colorado, and two in Montana]. In all cases, the variance of the discharge measurements around our "theoretical rating curves" is comparable to or less than that around the empirical rating curves generated from the same data.

In addition to providing a less labor intensive and potentially more accurate means of calculating discharge at a gaging station, our model provides all of the fluid-mechanical parameters required to do bed material (bedload and suspended-load) transport calculations for the measurement reach. This paper describes how calculations of suspended sediment in a gravel bedded stream can be incorporated into the theoretical rating curve model. The approach is applied to a reach downstream of USGS gage station 06071300, Little Prickly Pear Creek at Wolf Creek, MT (Figure 1). Monitoring streamflow and suspended sediment concentrations on Little Prickly Pear Creek is particularly important for ecological reasons, because it is a major spawning tributary for migratory rainbow and brown trout from the Missouri River. Discharge measurements at the station are used to test the theoretical discharge rating curve calculated by our model. Daily values of suspended sediment concentrations recorded by the USGS from 1962-1967 are used to develop an empirical relation between the concentration of suspended sediment near the bed and the rate of bed-load transport. This relation permits the calculation of accurate suspended sediment concentration fields using one or more point measurements of the sediment concentration as a function of grain size. The point sample is used to quantify the wash load and the amount of bed material of each sand size available for transport in suspension. The latter depends on the amount of fine sediment contributed from the hillslopes during previous heavy rainfall events and on the flow history of the stream. The combined flow and sediment transport model is then used to 1) reconstruct the flow and sediment transport fields for a high flow in Little Prickly Pear Creek, and 2) demonstrate the effect that density stratification can have on the velocity and sediment concentration fields for flows with moderate to high concentrations of sand.