Mar 22nd, 2:00 PM

Session 2B

Kentucky Water Resources Research Institute, University of Kentucky

OUTER SCALING METHOD FOR VELOCITY PROFILE COLLAPSE IN GRAVEL-BED RIVERS

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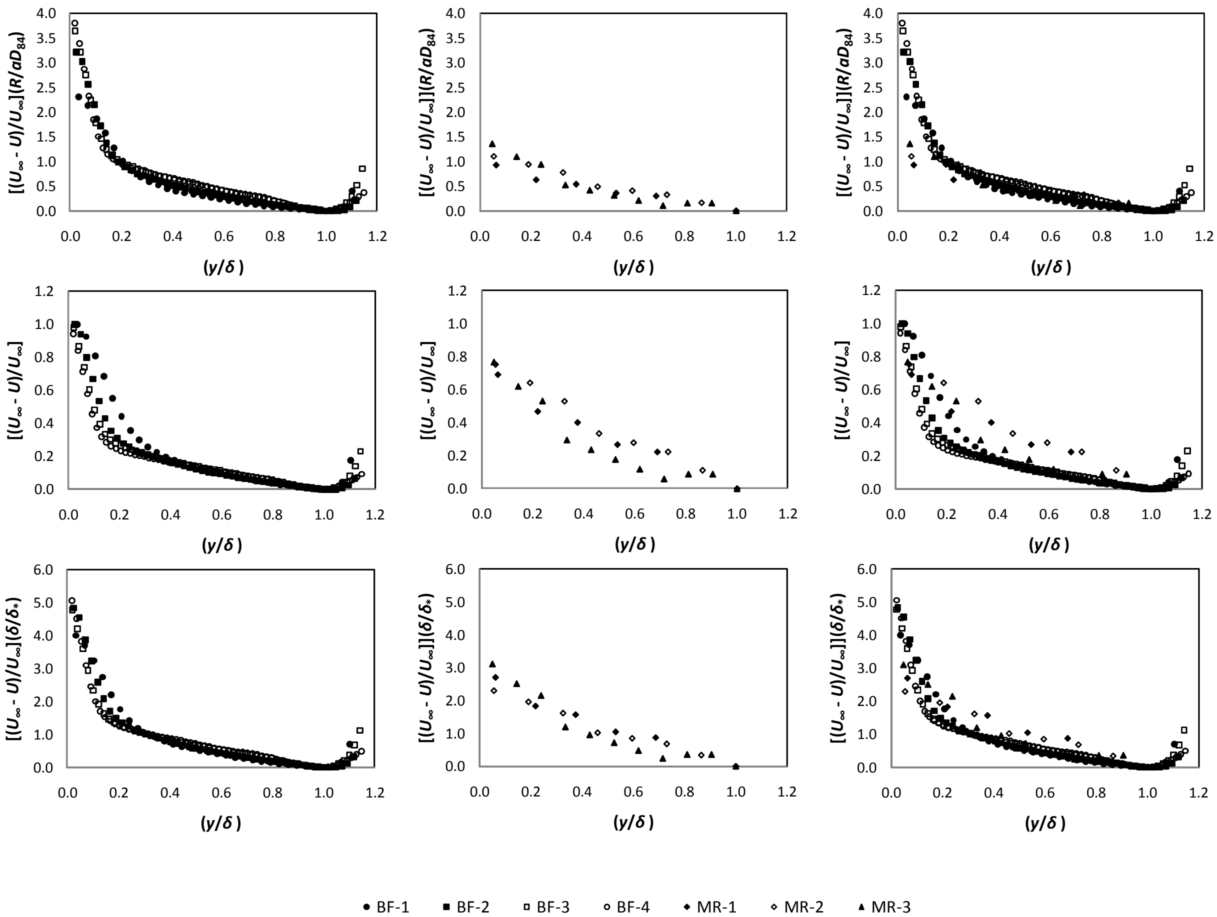
This paper provides a similarity analysis of the time-average velocity distribution in a hydraulically rough open channel flow over a gravel bed. The analysis is based on equilibrium turbulent boundary layer theory derived using the asymptotic invariance principle. The scaling parameter (R/aD_{84}) is included to account for the dominant upstream conditions, including vortex shedding responsible for boundary layer growth. Outer scaling based on the similarity theory shows agreement with velocity measurements from the laboratory and field, having Reynolds numbers on the order of 10^4 and 10^6, respectively.

Flow parameters for the test conditions are listed in Table 1 and the similarity collapse for these data are shown in Figure 1. The outer scaling method using (R/aD_{84}) collapses these data across the water column and is an improvement over the two other outer scaling methods shown in Figure 1. The results are important for modeling the time-average velocity distribution under bankfull conditions in rivers with a gravel bed, which transport high fluid momentum responsible for driving environmental hydraulics phenomena.

Table 1. Flow parameters for the laboratory and field studies.

Test	D_{84}	U_∞	δ	R
	(mm)	(m s^{-1})	(m)	(m)
BF-1	5.6	0.62	0.034	0.035
BF-2	5.6	0.76	0.051	0.048
BF-3	5.6	0.83	0.060	0.056
BF-4	5.6	0.83	0.066	0.061
MR-1	190	2.25	0.64	0.64
MR-2	190	1.80	0.74	0.70
MR-3	190	1.70	1.05	0.85

Figure 1. Scaling using $U_\infty(aD_{84}/R)$ as well as outer scaling with U_∞ alone, and U_∞ (δ^*/δ) that includes laboratory data (left column), field data (center column), combined plots (right column).



WATER AVAILABILITY TOOL FOR ENVIRONMENTAL RESOURCES (WATER)

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To assist the State of Kentucky in the management of its water resources, the U.S. Geological Survey and the Kentucky Division of Water created the Water Availability Tool for Environmental Resources (WATER). WATER is a geospatially-referenced, deterministic hydrologic modeling tool recently developed and tested in the USGS Kentucky Water Science Center (Williamson and others, 2009). WATER is a flexible platform from which multiple extensions may be run; the first of these extensions is the TOPMODEL deterministic rainfall-runoff approach originally developed by Beven and Kirkby (1979). The TOPMODEL-based approach programmed into WATER uses historical climate data together with physiographic data that quantitatively describe watershed topography and soil-water storage to obtain a simulated record of daily streamflow within any user-defined watershed (surface catchment) area. The current version of the WATER application uses a custom map-based, point-and-click graphical user interface that provides for automated delineation of watershed (catchment) boundaries of any size, and is capable of simulating approximately 60 years of streamflow data (from 1948-2000 it uses climate data from Kentucky cooperative-weather stations and from 2000-2006 it uses available NEXRAD data). With these capabilities, WATER provides a variable field-scale hydrologic-modeling tool that generates streamflow hydrographs and other hydrologic analytical outputs such as flow duration curves for gaged or ungaged watersheds, and optimally functions in smaller, unregulated, upland watersheds where topographic gradients may be comparatively steep and precise channel-geometry data is not available or is unfeasible to collect.

NOTES

METHODS FOR ESTIMATING LOW-FLOW FREQUENCIES OF UNREGULATED STREAMS IN KENTUCKY

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Decisions related to waste-load allocations, discharge and withdrawal permits, water-supply planning, and in-stream flow requirements depend on estimates of low-flow frequencies. Low-flow frequencies are needed for effective management of Kentucky's water resources. Methods for estimating low-flow frequencies at ungaged stream sites are part of this need. The U. S. Geological Survey, in cooperation with the Kentucky Division of Water, made estimates of the unregulated streams in Kentucky for 7-day mean low flows for recurrence intervals of 5, 10, and 20 years ($7Q_2$, $7Q_{10}$, and $7Q_{20}$) and 30-day mean low flows for recurrence intervals of 2 and 5 years ($30Q_2$ and $30Q_5$) at 121 streamflow-gaging stations with data through the 2006 climate year and developed regional regression equations for estimating low-flow characteristics of unregulated streams in Kentucky. Data were screened to identify the periods of homogeneous, unregulated, natural flows by use of annual-low-flow time-series plots, trend tests, available information on permitted water discharges and withdrawals, and double-mass curves for comparing annual low flows at each gaging station to flows at a reference gaging station.

Logistic-regression equations were developed for estimating the probability of the annual 7- and 30-day low flows being zero. Weighted-least-squares regression equations were developed for estimating the magnitude of the nonzero $7Q_2$, $7Q_{10}$, $7Q_{20}$, $30Q_2$, and $30Q_5$ low flows. Three low-flow regions were defined and are used as location-indicator variables for estimating the nonzero 7-day low-flow frequencies.

In addition to the low-flow regions, the explanatory variables in the regression equations include the basin total drainage area and the mapped streamflow-variability index, which is determined from a revised statewide coverage of this characteristic. The percentage of the station low-flow frequencies correctly classified as zero or nonzero by use of the logistic-regression equations ranged from 87.5 to 93.8 percent. The average standard errors of prediction of the weighted-least-squares regression equations ranged from 108 to 226 percent. The regression equations are applicable only to stream sites with low flows unaffected by regulation from reservoirs and local diversions of flow and to drainage basins within specified ranges of basin characteristics. Caution is advised when applying the equations for basins with characteristics near the applicable limits and for basins with karst drainage features.

The estimating equations can be applied by (1) determining the basin characteristics required for the appropriate equation, (2) checking to ensure that the basin characteristics are within the range of values used to develop the equation, and (3) substituting the basin-characteristic values for the variables in the estimating equations. The user first determines the probability of the low-flow frequency having a value of zero by use of the logistic-regression equation, and if a nonzero value is likely, the low-flow frequency value is estimated by use of the weighted-least-squares regression equations as described in the example applications presented in this report.

INVESTIGATION OF THE SURFACE FINE GRAINED LAMINAE USING A WATERSHED SCALE SEDIMENT TRANSPORT MODEL

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Sediment transport at the watershed scale in the Bluegrass Region of Kentucky is dominated by surface fine grained laminae (SFGL), streambed, and streambank erosion; high in-stream sediment storage; and surface erosion processes. All these processes can be impacted by agricultural, urban, and suburban land-uses as well as hydrologic forcing. Understanding sediment transport processes at the watershed scale is a need for budgeting and controlling sediment pollution, and watershed modeling enables investigation of the cumulative effect of sediment processes and the parameters controlling these processes upon the entire sediment budget for a watershed.

An in-house conceptually based sediment transport model was created which models SFGL erosion, streambed erosion, streambank erosion, in-stream deposition, and in-stream storage at the watershed scale. The in-stream hydraulic and sediment transport model was set up with bathymetry measurements, bed sediment characteristics, and bank sediment characteristics for the South Elkhorn watershed located in Lexington Kentucky. This 61 km^2 watershed is partially urbanized, has gentle upland slopes, and is representative of semi developed watershed in the bluegrass region of Kentucky. The in-stream hydraulic and sediment transport model is driven by flow rate measurements at the outlet of the South Elkhorn watershed. The sediment model was then calibrated with sediment yield measurements at the outlet of the watershed. Outputs from the sediment transport model include total yield at the watershed outlet, the source fractions from surface fine grained lamina, streambed, and streambank sources; deposition; and biological generation within the streambed. Using this configuration, a sediment budget, organic matter budget, stream bed storage pattern, and flow and sediment yield frequency analysis for the South Elkhorn watershed were predicted.

The SFGL shows a control on sediment transport in the watershed. The streambed is in quasi-equilibrium for the model runs. Small and moderate events are dominated by a net erosion from the streambed as the SFGL is downcut. Large events cause a deposition of sediment to the SFGL which is reflective of the transport limited condition of the lowland system. Results provide very good agreement with sediment yield analysis. A sediment budget is performed and it is seen that most sediment that comes into the stretch of stream is deposited to the SFGL, spends time there as intermittent sediment storage, and then erodes out of the watershed in a later event. The importance of the SFGL on protecting sediments deeper in the bed is seen as the bed has a low contribution to the sediment load in a cumulative sense. It is estimated that organic carbon generated in the SFGL makes up approximately 30% of the carbon loading for the watershed.