#885

VOL. 118 NO. 9 SEP. 1992

ISSN 0733-9429
CODEN: JHEND8

Journal of Hydraulic Engineering

AMERICAN SOCIETY OF CIVIL ENGINEERS

HYDRAULICS DIVISION

The Kinematic Wave Controversy[a]

Discussion by David C. Goodrich,[2] Member, ASCE

Several statements made by the author require clarification. The first relates to the grid-dependent nature of the results of certain kinematic wave finite difference schemes. The author states, "Therefore it seems pointless to try to 'calibrate' a kinematic wave model by varying a physical parameter such as Manning's *n* in order to match calculated results and observed data." However, selecting a single correct value of Manning's *n* is only applicable in the case of routing non-sediment-laden flow in a region with fixed geometry and uniform, nonmobile surface characteristics such as a man-made, smooth concrete channel. In the case of hydrologic modeling, as soon as any geometric abstraction of the watershed is made to form model elements, be they kinematic or diffusion wave elements, Manning's *n* must be viewed in a statistical sense due to the mixed representation of overland and concentrated flow within an overload flow element (even in plot size elements of 30 m^2). In this case, Manning's *n* should be viewed as a parameter relating the statistical relationship between mean storage per unit area and discharge. Indeed, the author later points out that catchment topographic irregularities typically counteract the formation of kinematic shocks by adding diffusion. These same irregularities force a statistical interpretation of Manning's *n* or any other resistance-related parameter due to our inability to resolve all topographic detail in typical catchment modeling.

Given this perspective, if an objective, reproducible method to select an adequate number of time and space finite difference increments is employed, calibration for a suitable and statistically interpreted roughness value that replicates watershed behavior can proceed. Objective, reproducible criteria for selecting *dt* and *dx* values are presented by Woolhiser et al. (1990). Using these criteria, spatial increments of sufficient resolution are obtained so that a finite difference solution of the kinematic wave equation agrees with the diffusion wave solution for peak runoff rate and time to peak to within 1% for an example presented by the author in an earlier publication (Ponce 1986).

The author continues the first statement regarding adjustment of Manning's *n*: "This practice amounts to curve-fitting; at best it is good conceptual modeling, but it should not be interpreted as deterministic modeling." Given the required statistical interpretation of *n*, the definition of deterministic modeling becomes a question of semantics and scale. Dooge (1986) eloquently points out that all of our continuum-based hydraulic models break down at the molecular scale and states that this should serve as a warning in application of our preconceptions derived from hydraulics before applying them on the hydrologic scale.

The author concludes that the kinematic wave method should be limited primarily to watersheds less than 1 sq mi (2.5 km^2). This conclusion is made with little supporting evidence other than an earlier statement noting that this limit is somewhat arbitrary and it reflects "current hydrologic engineering practice."

The writer has obtained good modeling results on watersheds up to 2.5 sq mi (6.3 km^2) on the U.S. Department of Agriculture–Agricultural Research Service Walnut Gulch Experimental Watershed in southeastern Arizona using the kinematic wave method embodied in KINEROS (Woolhiser et al. 1990). This is a difficult modeling environment in which both infiltration and channel losses are significant and flow in dry ephemeral channels is the rule rather than the exception. In addition, high spatial gradients in rainfall over short distances are common. After a three-parameter calibration using 10 events covering a range of event sizes and initial conditions, prediction coefficients of efficiency (Nash and Sutcliffe 1970) of 0.70 and 0.25 for runoff volume and peak runoff rate, respectively, were obtained on a set of 20 independent validation events.

The fact that "the problem is more what to route than how to route" (Cordova and Rodriguez-Iturbe 1983) must also be kept in mind when assessing the nuances of routing algorithms. The errors associated with areal rainfall and excess runoff estimation are significantly greater, especially in a semiarid, convective storm environment (James and Burges 1982; Loague and Freeze 1985) than the errors introduced by kinematic modeling as long as the kinematic approach is appropriate according to current criteria and sufficient computational grid density is maintained.

Appendix. References

Cordova, J. R., and Rodriguez-Iturbe, I. (1983). "Geomorphologic estimation of extreme flow probabilities." *J. Hydrol.*, 65, 159–173.

Dooge, J. C. I. (1986). "Looking for hydrologic laws." *Water Resour. Res.*, 22(9), 46S–58S.

James, L. D., and Burges, S. J. (1982). "Selection, calibration and testing of hydrologic models." *Hydrologic modeling of small watersheds*. C. T. Haan, H. P. Johnson, and D. L. Brakensiek, eds., Soc. of Agric. Engrs., St. Joseph, Mich., 437–472.

Loague, K. M., and Freeze, R. A. (1985). "A comparison of rainfall and modeling techniques on small upland catchments." *Water Resour. Res.*, 21(2), 229–248.

Nash, J. E., and Sutcliffe, J. V. (1970) "River flow forecasting through conceptual models, I. A. discussion of principles." *J. Hydrol.*, 10, 282–290.

Woolhiser, D. A., Smith, R. E., and Goodrich, D. C. (1990). "KINEROS, a kinematic runoff and erosion model: Documentation and user manual." ARS-77, U.S. Dept. of Agric.–Agric. Res. Service, Nat. Tech. Information Service, Springfield, Va.

Discussion by Muthiah Perumal[3]

To resolve the kinematic wave controversy, the author has emphasized on the use of matched diffusivity method, which is also widely known as the Muskingum-Cunge (MC) method (Weinmann and Laurenson 1979), for solving the kinematic wave equation. A number of publications have appeared in literature and still continue to appear on the use of this method for solving runoff routing problems. Although the writer has no reservation about the usefulness of the end results of the MC method, he questions the means to arrive at these results, i.e., the necessity for employing the matched diffusivity concept for arriving at the Muskingum parameter relationships.

In this regard, the writer would like to recall the technique introduced by Apollov et al. (1964) but since largely neglected by the users of the

[a]April, 1991, Vol. 117, No. 4, by Victor M. Ponce (Paper 25673).

[2]Res. Hydr. Engr., Agric. Res. Service–U.S. Dept. of Agric., 2000 E. Allen Road, Tucson, AZ 85719.

[3]Reader, Dept. of Continuing Education, Univ. of Roorkee, Roorkee 247 667, India.