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DISCUSSION

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A PROPOSED WATERSHED RETENTION FUNCTION[a]

Discussion by Roger E. Smith

ROGER E. SMITH,[2] A. M. ASCE.—The author is to be commended for recognizing the need for a watershed model that will include recovery of retention capacity between rainfall events. He also treats the important problem of the distribution of retention capacity within a watershed. In his discussion of microscale versus macroscale concepts, he proposes that infiltration theory is invalid where infiltration properties vary over an area. No doubt, areal variation in properties makes the total watershed response different from point response, but this is the justification for distributed models as opposed to lumped models and does not negate the validity of infiltration theory.

Eq. 1 is a type of linear storage model for soils. An infiltrating soil does not act in this manner except that it is asymptotic to a final infiltration rate (10,11). Whether this assumption is applicable to a watershed with a certain distribution of properties is open to question.

The author, however, proposes Eq. 4, which is not a linear differential equation. In differential form, this equation may be integrated to produce an expression in r and t:

$$(r - r_c)^{a+bc}\,(c - r)^{-\left(a+br_c\right)}\,(a + br)^{-b\left(c-r_c\right)} = K_b e^{-(K_r D)\,t} \qquad (5)$$

in which $D = (a + bc)(a + br_c)(c - r_c)$; $D >> 0$; $K_b = e^{\left(C_i D\right)}$; C_i = constant of integration; $K_r = (R_t - r_c)/(R_t + r_c)(R_t + r_u - r_c)$; and $c = R_t + r_u$. This implicit exponential equation confirms that for $R_t < r_c$, K_r is negative, and $r \to r_u + R_t$. For $R_t > r_c$, K_r is positive, and $r \to r_c$. Also note the constraint that if $b < 0$, $\left|\frac{a}{b}\right| > c$ (a is assumed > 0).

It is of interest to study the results of this function in describing watershed response. The author encouraged suggested modifications; thus, the writer would like to suggest some weaknesses in the formulation of Eq. 3. First, there is a restrictive upper limit to the rate of reduction of the retention rate, noticeable and unrealistic when R_t and r_t are both high. This is demonstrated in the author's curve I (Figs. 2-5) at $t > 15$ hours. It would seem that curve IV, Fig. 4, is more realistic in this region. Second, there are rational and theoretical objections to limiting reduction in r_t to cases where $R_t > r_c$. A rainfall $0 < R_t \leq r_c$ with high r_t (dry initial conditions) will, in fact, lower the retention capacity, although runoff will not occur as long as $R_t \leq r_c$. The author's model would predict a continuing increase in r_t under these conditions. Finally, there is no physical reason for a parameter r_u; rainfall on an

[a] March, 1971, by Willard M. Snyder (Proc. Paper 7979).

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initially dry soil shows an initially unlimited retention rate for a short time.

Perhaps these objections would be overcome to some extent by

$$\text{Let } k = a\left[\frac{R_t\left(\frac{r_t}{r_c}\right)^b - r_c}{r_c}\right]\left[\frac{r_c + CR_t}{r_t + CR_t}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Note that there is no parameter r_u. Term a is a scaling parameter, and b and C are the remaining parameters to be evaluated. For $R_t = 0$, $k = -a\, r_c/r_t$. When $0 < R_t < r_c$, r_t will always decrease somewhat if r_t is sufficiently large, but r_t cannot decrease to r_c if $R_t < r_c$. For $R_t < r_c$, rate of decay is increased by higher R_t and by higher r_t.

It is wished that the author would have included the rainfall and runoff patterns used to produce Table 1. The writer feels that the parameters obtained for Plot 8 on 6/26/40 are not at all unreasonable. The interrelations of a and b are demonstrated in Eq. 5; the required restraint on these parameters has been mentioned. A positive value for b simply implies that rate of decay of r_t is highest at higher r_t (as is proposed in Eq. 6). As previously discussed, a limiting parameter r_u is unnecessary, so there should be no reason to discredit high values of r_u for this event under the formulation of Eq. 3. The utility of optimization on which the parameter values are based is dependent on length of record. It appears that the events may not exceed one day of record, a very limited sample of R_t and a very limited study of recovery of r_t. Much longer records would be needed to obtain useful values of the parameters and to test whether a given formulation is acceptable.

If the author is proposing this model as appropriate for areas of mixed infiltration characteristics, one would like to see a test on such areas, including partially impervious watersheds, rather than plot runoff data comparisons more related to the microscale.

Appendix.—References.

10. Philip, J. R., "The Theory of Infiltration: 4. Sorptivity and Algebraic Infiltration Equations," *Soil Science*, Vol. 84, No. 3, Sept., 1957, pp. 257 264.

11. Smith, R. E., and Woolhiser, D. A., "Mathematical Simulation of Infiltrating Watersheds," *Hydrology Paper No. 47*, Colorado State University, Jan., 1971, 44 pp.