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"UNIFICATION OF PARSHALL FLUME DATA"

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1/ Published in the Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, Vol. 87, No. IR4, December, 1961, Paper No. 13.

2/ Agricultural Engineer, Northern Plains Branch Soil and Water Conservation Research Division, Agricultural Research Service and Colorado Agricultural Experiment Station; and Graduate Assistant, Civil Engineering Department, Colorado State University, Fort Collins, Colorado.

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The paper by Mr. Davis represents a contribution to the understanding of the operation of the Parshall Measuring Flume. The dimensionless approach in the development of the unified equation is unique and the excellent agreement with existing data for all sizes of Parshall flumes is gratifying. However, it should be pointed out that equation 16 is a semi-empirical equation since experimental data has been used to determine the constants.

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The general form of the equation results from use of the energy and continuity equations between points 1 and 2. The general form of equation (1) and the specific form of equation (9) also results from the energy and continuity relationships. Equation (9) in its broadest sense also requires either the assumption that

$$y_1 = 3/2\, y_2 \tag{41}$$

in the derivation or the actual relationship between y_1 and y_2. As Mr. Davis has pointed out critical depth occurs in the contraction section upstream from the throat section. This makes it difficult to determine the location and magnitude of critical depth.

Using the energy relationship, the development of equation (9) will show that the exponent of y_1 should be 1.5. From Table 1 the values of n are always different than 1.5 which means that K_p is a function of depth y_1 for a given size of flume. For the 6-inch flume,

$$Q = 4.12\ b\ y_1^{1.58} = K_p\ g^{1/2}\ b\ y_1^{1.50} \tag{42}$$

so that

$$K_p = 0.728\, y_1^{0.08}\,. \tag{43}$$

Figure 2 is actually the relationship between K_p and y_1 for different sizes of flumes. In other words , an equation similar to eq. 43 exists for each size of flume. K_p is also a function of the throat width b as shown by the displacement of each curve in figure 2.

An examination of Table 1 and figure 2 raised a question as to the validity of the original calibration data. Since the sidewall angle θ as well as the drop-down angle ϕ are constant for all sizes of flumes, one would expect a definite trend in the values of K_c and n for the different flumes because of geometric similarity. This should be definitely true for the "foot" flumes and should apply also for the "inch" ones despite the slight difference in geometrical relationships. A family of curves possibly increasing in slope with increased throat width would be expected. Since equation 16 has been developed for flumes with constant contraction and drop-down angles it should not be applied to those with different angles. Experimental verification is needed to determine the effect of changing the sidewall angle. With equation 16, the allowable change of dimensions from that of the standard ones are throat width b and gage location X_1 only.

Actually the close fit of eq. 16 to the published data for the Parshall flume is not surprising in view of the relatively small spread in values of K_e and n as shown in Table 1. An equation of the form

$$Q = 4\, b\, y_1^{1.55} \tag{44}$$

can be used for flumes up to 8 feet with deviation only slightly greater than those given in eq. 16. The importance of equation 16 lies in the inclusion of the variable distances X and y in the discharge formula. With this relationship, the point of measuring upstream head can be changed from the standard one and a new rating table determined. It is hardly foreseeable that intermediate sizes of Parshall flumes, other than those now in published literature, are needed. There is a probable need for flumes in excess of the largest size (50 feet) which is presently available.

Equation 16 applies only to the free flow condition with the flow passing through critical depth within the flume. A rigorous equation for flow under submerged conditions does not presently exist.

Instead, empirical relationships using plots are utilized to determine the flow under these conditions. Special care should be used in installing the flumes so that the free flow condition exists for most of the flows. The elevation of the flume above the bottom of the channel must be set so that there is a submergence of less than 50 percent for the "inch" flumes and 60 percent for the "foot" flumes. The increase in elevation of the crest will raise the water surface upstream and restrict the use of Parshall flumes in channels with very flat slopes.

Tests at Colorado State University by the Agricultural Research Service have shown that trapezoidal measuring flumes are at times superior in operation to the Venturi or Parshall type flumes. Advantages which were noted include:

1) Trapezoidal flumes operate under higher degrees of submergence than will the rectangular flume without corrections being necessary to the standard rating.

2) The trapezoidal shape fits the common canal section more closely than does the rectangular flume. For the lined section this simplifies the transition design and construction.

3) A large range of flows can be measured with a relatively small change in depth thus minimizing the amount of freeboard needed on the canal.