



Project Summary

Texas Department of Transportation

0-6070: Use of the Rational and Modified Rational Methods for TxDOT Hydraulic Design

Background

The Texas Department of Transportation (TxDOT) is responsible for drainage of roadways and conveyance of cross-highway streamflow on the Texas highway system. A component of the design, construction, and maintenance of this transportation system requires estimates of peak discharge, for selected risk (probability) criteria, that are used to size drainage works. Two of several techniques available to the engineer are the rational and modified rational method. These methods, whereas considered mature, remain in common use by TxDOT and the broader water-resources community.

The purpose of research project 0-6070 was to examine the origin, use, and applicability of the rational and modified rational methods. The specific objectives of the project were to 1) evaluate the appropriateness of using the rational and modified rational methods for small watershed design, 2) evaluate tabulated values of the runoff coefficient, and 3) construct guidelines for TxDOT analysts for selection of appropriate parameter values for Texas watershed conditions.

What the Researchers Did

The researchers compiled a table of runoff coefficients from the engineering literature with the intent to: 1) determine the original source of various values, and 2) devise if possible a reduced tabulation for practical application. The researchers then analyzed thousands of storms from a rainfall-runoff database assembled for a group of Texas-specific hydrologic studies to determine “back-computed” runoff coefficients. The back-computed runoff coefficients were compared to “literature-derived” runoff coefficients for the various runoff-generating conditions.

The researchers examined the characteristic time (historically the time of concentration) required for application of the rational method to specify the rainfall intensity (through the storm duration). The specification of characteristic time is vital to the application of the method, and the importance of the characteristic time became apparent during the “back-computed” analysis effort. The researchers also examined, again by analysis of thousands of storms on hundreds of watersheds, the importance of the size limit typically imposed on the watershed drainage area for application of the rational method.

Research Performed by:

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What They Found

The runoff coefficient is the constant of proportionality in both volumetric and rate conceptualizations. Typically, the runoff coefficient is a volumetric proportionality in the modified rational method, and rate proportionality in the conventional (peak only) rational method. The coefficients are often reported with probability adjustments to account for different rainfall recurrence intervals; a non-linear, confounding (and cross-correlated) adjustment.

Based on estimations derived through the “back-computed” analysis, literature-derived values of the runoff coefficient are, on average, too large by a factor of about two when used in the modified rational method. Therefore, the modified rational method will tend to overestimate total runoff volumes when used with literature-derived (tabulated) values of the runoff coefficient.

Based on analysis of observed rainfall-runoff data, the limitation on watershed drainage area for application of the rational method was unidentifiable. That is, the limitation of 200 acres for application of the rational method appears to be artificial. However, the critical assumption for application of the rational method is that the steady-state assumption (of the storm rainfall) applies for watersheds with drainage areas that exceed the current threshold.

An implicit assumption in most hydrologic methods is that the rainfall and runoff have the same non-exceedance probability (or risk). However, there is little evidence that this assumption has adequately been articulated in the literature. Furthermore, the appearance of probability in both the coefficient and the intensity component of the method was deemed confounding, so the researchers devised a proposed unified rational method for Texas (URAT) that eliminates probability adjusted runoff coefficients (and land-use based coefficients entirely), and forces probability equivalence. The URAT for Texas collapses selected watershed characteristics and probability into the specification of critical storm duration and consequent rainfall intensity.

What This Means

The drainage area limit for application of the rational method could be extended from the commonly accepted value of 200 acres. As a practical matter, there is no need to change the upper limit of applicability as recognized by TxDOT but the researchers stress that 200 acres is a “fuzzy limit.” Beyond a one-square mile size, the researchers strongly suggest other methods such as the unit hydrograph.

The URAT for Texas, by forcing probability equivalence between runoff and rainfall, provides the first tuned version of the rational method for the intensity-duration frequency and flood-flow frequency equations in Texas. URAT is depicted by county and eliminates the tabulated runoff coefficients entirely. The runoff coefficient is an area-weighted coefficient based on the proportion of functional impervious cover to pervious cover on a contributing area.

The modified rational method is anticipated to considerably overestimate runoff volumes; using the URAT to parameterize a modified rational method may not reduce the magnitude of the overestimation.

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