PROJECT SUMMARY REPORT

LAMAR UNIVERSITY

Research Project Summary Report 0-4696-S
Project 0-4696

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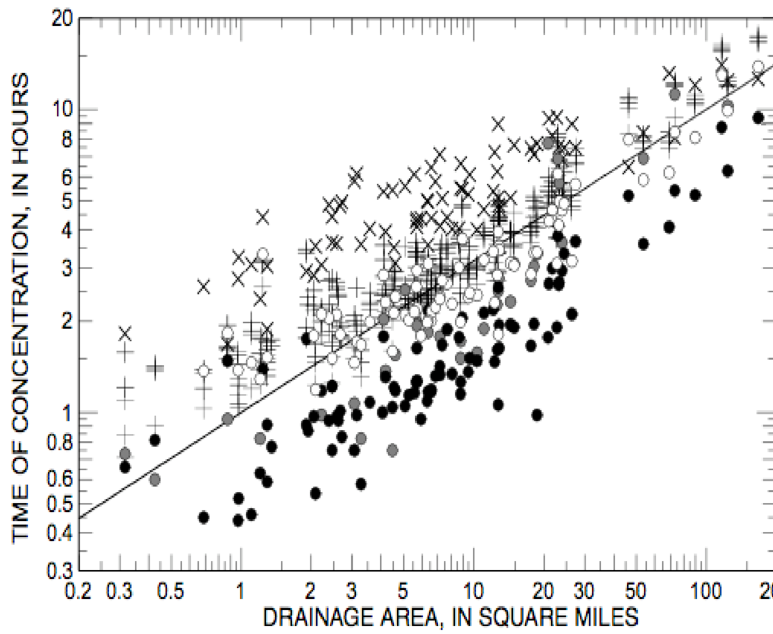
Timing Parameters for Texas Watersheds

Performing hydrologic and hydraulic designs and analyses for highway drainage projects is an important component of TxDOT roadway-design operations. Highways have to be drained, streams crossed, and drainage ditches designed. Likewise, the design of storm water management structures relies on the hydrologic and hydraulic analyses. TxDOT currently uses three main methods for developing design peak discharges: the rational method, the unit hydrograph method, and regional regression equations. The first two methods require an estimate of the time response of the watershed as part of the procedure; time characterization of a watershed is not a component of the regional regression equations.

Whereas a number of candidate timing parameters could be chosen, engineers commonly use time of concentration to characterize the time response of a watershed. The time of concentration is defined as *the length of time required for a parcel of runoff to travel from the most hydraulically distant part of a watershed to its outlet.* A parallel definition is *the time required for a watershed to become fully contributing*. Both of these definitions are present in almost every hydrology textbook. Because of the ubiquity of the time of concentration concept,



EXPLANATION

- LINE DEPICTING SQUARE ROOT OF DRAINAGE AREA
- × SIMAS AND HAWKINS METHOD PLUS 30 MINUTES FOR OVERLAND FLOW
- ○ NRCS TRAVEL-TIME METHOD IMPLEMENTED BY LAMAR UNIVERSITY RESEARCHERS
- ● (gray) NRCS TRAVEL-TIME METHOD IMPLEMENTED BY TEXAS TECH UNIVERSITY RESEARCHERS
- ● NRCS TRAVEL-TIME METHOD IMPLEMENTED BY USGS RESEARCHERS
- + ESTIMATES FROM ALL OTHER APPROACHES CONSIDERED

Figure 1. Relation between drainage area and time of concentration for selected Texas watersheds with emphasis on NRCS travel-time method and on the Simas-Hawkins method.

TxDOT requested an investigation of methods for estimating time of concentration.

Historically, TxDOT designers used Natural Resources Conservation Service (NRCS) procedures for estimating time of concentration. The NRCS method also is called the "travel-time method" and uses an assumption of uniform flow to determine an average flow velocity for three flow regimes: overland or sheet flow, shallow-concentrated flow, and channel flow. The commensurate length over which each component occurs is divided by the average velocity for each component to estimate the travel time, for each component. The three resulting travel times are then added to estimate the time of concentration for the watershed.

What We Did…

Many methods for estimating time of concentration are presented in the professional literature. The researchers reviewed the literature and then prepared a list of candidate procedures for examination. Candidates from this list were then applied to a database of 92 selected Texas watersheds for which concurrent rainfall and runoff measurements are available. These watersheds have been subjected to intense study over the last five years as part of an overall review of TxDOT hydrologic practices. The range of main channel slope for the selected 92 Texas watersheds is from 0.002 to 0.02 (dimensionless). The range of drainage area for the selected 92 Texas watersheds was from 0.26 mi^2 to 166 mi^2. The intent of the project reported herein was to compare the results of time of concentration estimates from a wide variety of methods, choose a method or methods for recommendation to TxDOT, and then validate those methods using observations from the study watersheds.

The methods studied included Kirpich, Kerby, NRCS travel time, Kinematic Wave Formula, Haktanir and Sezen, and Simas-Hawkins methods. Comparison of all methods is expounded in the 0-4696-2.

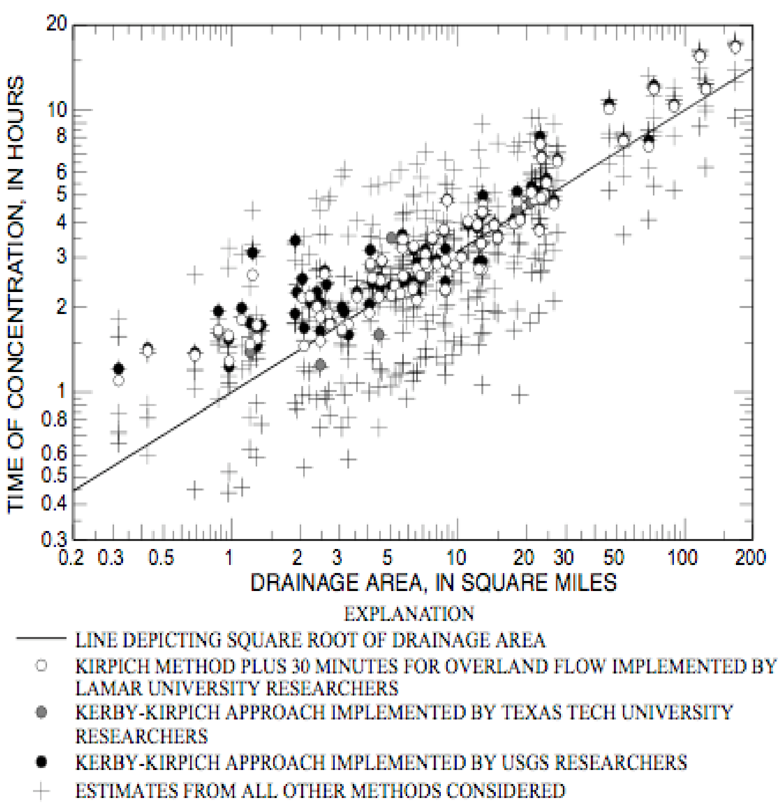


Figure 2. Relation between drainage area and time of concentration for selected Texas watersheds with emphasis on Kirpich-based methods.

What We Found…

Results of estimating time of concentration using the NRCS travel-time method are emphasized in Figure 1. The NRCS travel-time approach produces estimates that are consistently less than the time of concentration estimates of other methods. This outcome was true regardless of which research team applied the method and how the basic inputs for the method were determined. The observation that the NRCS method produces estimates of time of concentration that are less than those produces by other methods is important because if the time of concentration is reduced, then the estimate of peak discharge will be increased. The practical implication of this finding is that overdesign of the drainage structure may occur if time of concentration is estimated using the NRCS travel-time method.

Results of the Simas-Hawkins method also are emphasized in Figure 1. Estimates of time of concentration using the Simas-Hawkins method generally exceeded those produced using other methods. In this case, peak discharges computed using the Simas-Hawkins time of concentration would be less than those computed using other methods for estimating time of concentration and underdesign of drainage structures might result, another undesirable situation.

When the remaining equations were compared, time of concentration estimates varied over a substantial range but were contained within the envelope defined by the NRCS and Simas-Hawkins methods. However, in general, the results were similar, as shown in Figure 2. A distinguishing characteristic of the Kirpich-Kerby is its simplicity and ease of applicability. The Kirpich-Kerby method also produces results that are reasonable when compared with results of the other approaches.

Other methods for estimating time of concentration can be applied to improve the analyst's confidence in results obtained from the Kirpich-Kerby method. The researchers suggest that multiple approaches for estimating time of concentration be standard operating procedure.

The NRCS hydrograph method assumes that the lag time is six-tenths the time of concentration. For the database of 92 Texas watersheds, the researchers extracted the lag time from the representative unit hydrographs for these watersheds and compared six-tenths of that lag time with the Kirpich-Kerby estimate of time of concentration. The Kirpich-Kerby time of concentration with comparable to six-tenths of the lag time of unit hydrographs from the study database, as shown in Figure 3, and the researchers conclude that estimates of time of concentration produced by Kirpich-Kerby are consistent with standard unit hydrograph practice.

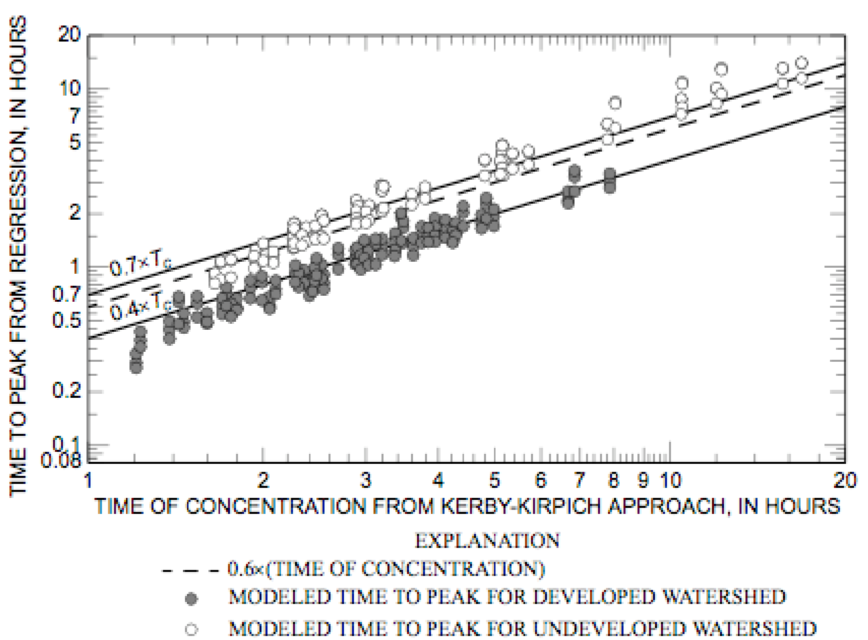


Figure 3. Relation between time of concentration and time to peak for hydrographs from selected Texas watersheds.

The Researchers Recommend...

1. The NRCS travel-time method produces results that are substantially less than time of concentration estimates produced by the other methods evaluated as part of the research reported herein. The NRCS travel-time is also time-intensive to apply, and different analysts can arrive at widely differing results. Therefore, the researchers recommend that TxDOT hydraulic designers abandon the NRCS travel-time method.

2. The Kirpich-Kerby method produces estimates of time of concentration that agree with other methods studied in the project. The Kirpich-Kerby method is straightforward to apply and requires input parameters easily obtained from site maps and simple estimates of site conditions.

3. The Kirpich-Kerby method should be used for estimating time of concentration for watersheds in Texas.

4. The range of slopes for the selected 92 Texas watersheds was from 0.002 to 0.02 (dimensionless). The recommendations in this report for estimating time of concentration may not applicable for watersheds with slopes outside this range. It is the opinion of the researchers that extra care should be taken when watershed slope is less than 0.002 and that application of the findings reported herein is not recommended for such slopes.

For More Details...

The research is documented in the following:

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