Project Summary

Texas Department of Transportation

0-5822: Subdivision of Watersheds for Modeling

Background

The Texas Department of Transportation (TxDOT) is responsible for design of new roadway systems and maintenance of existing roadways and highways in the state of Texas. A component of this responsibility is the design of new and replacement drainage structures. These structures range in size from bar-ditch culverts to major bridge crossings and in complexity from single, small-diameter culverts to drainage networks comprising many inlets that operate in conjunction with surface and sub-surface drainageways.

Drainage design for some systems is done in-house and some is contracted with outside engineers (consultants). TxDOT experience has been that there is a tendency for analysts to subdivide watersheds excessively, that is, to break up the watershed into small (sometimes tiny) sub-components. The sub-watersheds are used for development of design discharge for hydraulic structures. No guidelines exist for when a watershed should be subdivided, or for how to accomplish watershed subdivision in a reasonable and logical manner. Furthermore, no guidance is available to promote understanding of what might be gained by watershed subdivision and what might be lost.

It is a commonly held belief among engineers that subdivision of a watershed into small (or smaller) sub-watersheds improves the accuracy of predicted runoff events. That is, many engineers believe they are improving the accuracy of their design estimates by subdividing the watershed. As a result, the project objectives were 1) to review the professional literature for guidance on when watershed subdivision is appropriate (improves hydrologic estimates), 2) develop guidance for watershed subdivision, and 3) review whether use of distributed models is appropriate for TxDOT applications.

What the Researchers Did

The first objective was to conduct a review of the professional literature. Only a few publications directly addressed the topic. Hrodmadka (1986) developed an application manual for hydrologic design for San Bernadino County. Hrodmadka states: *Arbitrary subdivision of the watershed into subareas should generally be avoided. It must be remembered that an increase in watershed subdivision does not necessarily increase the modelling [sic] "accuracy" but rather transfers the model's reliability from the calibrated unit hydrograph and lag relationships [sic] to the unknown reliability of the several flow routing submodels used to link together the several subareas.* The remaining papers and reports reviewed for the project provided insight that arbitrary subdivision did not increase the accuracy of hydrologic estimates. However, a number of researchers reported that when calibrating hydrologic models, increasing the number of parameters in the hydrologic model caused problems identifying appropriate values of those parameters from a relatively limited rainfall-response signal. That is, determining parameter estimates became increasingly challenging as the number of parameters increased.

Research Performed by:

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A suite of tools was used to conduct the modeling phase of the study. `ArcGIS`, `ArcHydro`, `HEC-GeoHMS`, and `HEC-HMS` were the basic tools used to develop the hydrologic models. An equal-area approach, an ad-hoc approach, and a distributed modeling approach were used to develop hydrologic models for a handful of study watersheds. Watersheds were modeled as a single unit (not subdivided) or subdivided. Subdivisions numbering 2, 3, 5, 7, 9, 10, 15, and 30 were created (depending on the modeling approach). Multiple events were used in each model and each subdivision scheme. The hydrologic models were operated and estimates of runoff volume, peak discharge, and time to peak discharge were extracted from model results. These estimates were compared with observed values.

What They Found

- The conclusion of other researchers presented in the professional literature is that, in general, subdivision of watersheds for modeling results in no more than modest improvements in prediction of peak discharge. Improvements generally disappear when the number of subdivisions reaches a relatively small number, something between five and seven sub-watersheds.
- Watershed subdivision multiplies the number of model parameters to be estimated. Discriminating parameter values between sub-watersheds is difficult to justify from a technical perspective.
- When using the runoff curve number method as the rainfall-runoff model, little change in runoff volume resulted from watershed subdivision.
- Watershed subdivision introduces the requirement for hydrograph routing. The routing sub-process introduces additional parameters requiring estimates. If these values are not correctly estimated, then error is introduced into peak discharge and time to peak estimates.
- Little or no change in errors between model-predicted and observed runoff hydrographs was observed as a function of watershed subdivision.
- The dependence of computed hydrographs on internal routing became more apparent as the number of subdivisions increased.
- Application of distributed modeling, as implemented in `HEC-HMS`, was difficult and time-consuming. It is unclear what technical advantage is gained by application of this modeling approach, given the level of effort required to develop the models.

What This Means

- There appears to be little justification for arbitrary subdivision of a watershed to promote increased accuracy in prediction of runoff volume, peak discharge, and time to peak discharge using commonly applied tools. Subdivision increases the number of parameters to be estimated and introduces hydrograph routing to move internally-generated hydrographs toward the main watershed outlet.
- Unless flow rates (design quantities) are needed at locations internal to the main watershed, there is no technical reason to subdivide the watershed into smaller components.
- Fully-distributed hydrologic modeling, as implemented in `HEC-HMS`, is technically difficult and time consuming. Use of this technology is not recommended at this time.

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