Technical Memorandum: Development of Subdivision Approach for TxDOT Project 0–5822 Subdivision of Watersheds for Modeling

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Background

The purpose of this document is to present approach and results from work on Texas Department of Transportation (TxDOT) Project 0–5822 *Subdivision of Watersheds for Modeling* associated with Task 2, *Development of Subdivision Approach.*

Work done on Task 1, *Literature Review* was documented in a technical memorandum dated 31 August 2007. In that memorandum, six methods were defined for subdividing a watershed. They are:

1. An iso-temporal approach, where each subwatershed is selected to have about the same characteristic response time (that is, t_c). This particular approach may have great value in concurrent flooding (concurrent arrival times of flood waves). A challenge of this conceptualization is that lumped systems will necessarily be replaced by routed systems and any gain in certainty by using smaller sub-basins may be more than offset

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by increased uncertainty caused by routing. Despite this important criticism, the researchers still feel this is an line of investigation that needs consideration. At some scale of high subdivision, the entire runoff process that is currently explained using unit hydrographs becomes entirely replaced by hydraulic elements; interestingly the hydrographs "look" like convolved unit hydrographs so the accepted connection between the physical processes in a distributed hydraulic model and the lumped hydrologic model are well manifest in this sense.

2. An iso-characteristic approach, where each sub-basin has about the same physical characteristic (area,length, etc.). Drainage area ratios would fall into this approach. The characteristics may be subtle — one paper presented at the 2006 American Geophysical Union used contiguous areas of similar slope to define watershed subareas (McGuire, 2006). Although watershed subdivision was not the focus of the particular paper, nevertheless the idea appeared sound. The San Bernardino manual seems to imply a range of area ratios that are acceptable for preserving sufficient model believability, again a spatial characteristic based concept.

3. A scoring approach. Scoring is similar to the above concepts, except a set of characteristics is assigned a score; similar scores that are geographically connected are selected as watersheds. The scoring approach could admit descriptors not easily quantified numerically. For example the use of binary variables in 0–4193 and 0–4696 to account for the effect of developed/undeveloped and rocky/non-rocky are arguably scoring approaches.

4. A gage-defined approach where the locations of existing gages are used to subdivide a watershed — not necessarily a modeling tool, but a good comparative tool. An extension would be to locate good gage locations based on measuring requirements and use these locations to divide a watershed.

5. Stream-order/bifurcation approach. Watersheds are subdivided based on branches in the dendritic drainage network. Several papers at 2006 American Geophysical Union used this approach to divide research watersheds for water quality and nutrient transport studies.

6. The ad hoc approach is a research-only approach where basins would be defined at random, perhaps preserving some minimum measure. These random subareas would then be used to simulate runoff and these results compared to observations on the same watershed. Patterns that best agree with observations would be saved and analyzed to determine what physical features are common to "good" subdivisions (i.e. iso-temporal, iso-characteristic, etc.)

As a result of the literature review and subsequent discussions between the research team and TxDOT personnel, a number of observations resulted. They are:

1. Watershed subdivision that results in drainage-area ratios exceeded 1:100 will not be effective because the contribution of the smaller watershed(s) is lost in the hydrograph of the larger watershed.

2. Much of the perceived advantage of heavily subdividing watersheds (by whatever approach chosen by the analyst) results in large numbers of parameters to be estimated. As a result, significant uncertainty is associated with those parameter values and in practice the parameters are often lumped using single values or ranges, obviating the purpose for subdividing[1].

Development of Subdivision Approach

Current thought is to develop subdivisions of each study watershed into 3, 5, and 9 sub-basins using two mechanics. First is equal drainage area. That is, the study watershed is subdivided into *n* sub-basins of approximately equal drainage area using an ad-hoc approach. The analyst chooses sub-basin outlet location at "appropriate" points and then constructs a watershed model from the assemblage of sub-basins. Second is equal watershed timing parameter. In this case, time of concentration is used and the analyst selects *n* sub-basins using time of concentration as a filtering factor. A combination of **?** and **?** will be used to estimate time of concentration[2].

As described in the March 2008 semi-annual report, Task 3 *Assessment of Watershed Subdivision* is in progress. Both University of Houston (UH) and Texas Tech University (TTU) researchers are in the process of sub-dividing a set of 13 study watersheds.

UH researchers have implemented a subdivision assessment using an iso-characteristic approach based on watershed (and subbasin) areas. The subdivision is done manually from paper maps[3]. A watershed is subdivided into 3, 5, and 7 subbasins of approximately equal area – hence the iso-characteristic is area. Models are then constructed using HEC-HMS for these different configurations and simulated hydrographs are compared to observed hydrographs. These models are not calibrated to mimic the approach that would be used on an ungaged watershed. Timing parameters are computed using the methods reported in **?**. Loss is computed from the composite CN method as reported in TR-55.

[1] The watershed-modeling literature contains many papers discussing parameter identifiability when calibrating watershed models. The consensus of the research community is that the least number of parameters required to represent a watershed is the best approach.

[2] **?** describe the particulars of TxDOT applications of watershed timing parameters.

[3] The maps need not be paper, they could be electronic. The subdivision process is manual in that the analyst determines sub-basin outlines from topographic information.

The principal findings are that there is no pattern of subdivision that outperforms another (i.e. sometimes a lumped model works best, sometimes 7 sub-basins, etc.). Without calibration to actual events, peak discharges were difficult to exactly match, although the time of peak was reasonable. Calibration, which would not be possible on an ungaged basin, improved model results but could not be used across storms. The researchers conclude from this particular study that subdivision is useful if internal discharges are needed, or if physical structure demands it [a reservoir within the watershed]; otherwise to subdivide to improve simulation accuracy does not justify the additional modeling effort and data preparation required.

TTU researchers are implementing a distributed modeling approach (Task 6 *Assessment of Distributing Modeling*) using a the subdivision equal-area and equal time response mechanics. HEC-HMS (**?**) is the modeling tool[4]. The modClark and gridded NRCS curve number methods are the modeling technologies being studied by TTU researchers.

A significant issue was encountered when it was learned that there is no general tool for producing gridded precipitation data required by the distributed modeling approach implemented in HEC-HMS. U.S. Geological Survey researchers developed an approach to assign rainfall measured at point gages to a distributed grid. Much effort was expended by USGS researchers developing and implementing a precipitation-gridding scheme to support TTU research work.

Work continues on Task 3.

[4] Although other distributed models are in current use in the profession, HEC-HMS represents a commonly used modeling tool and has distributed modeling capability.