

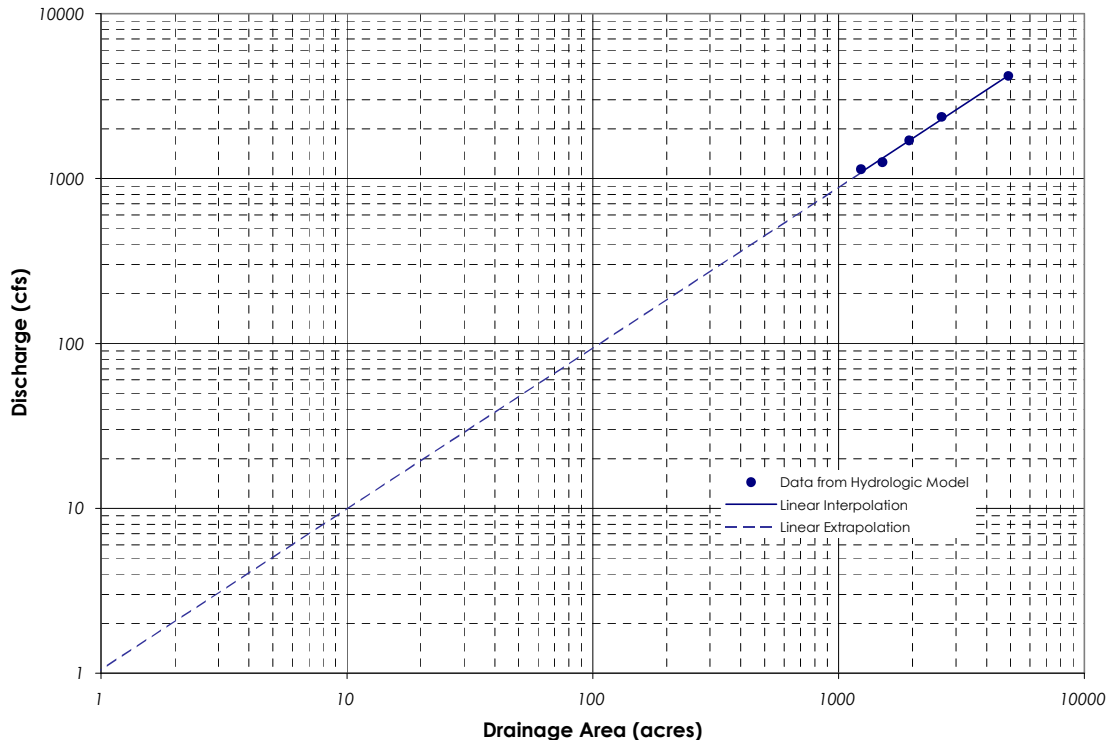
Recommendation for: Determining Discharges in Upstream Reaches of Subareas (Revised 01/24/2003; updated 06/18/2009)

Goal: To define discharges along a stream in reaches which are located within the upstream-most subarea of a watershed.

Recommended Procedure: It is recommended that the following steps be adopted as the method for developing discharges within the upstream-most subarea.

1. **Gather Discharge vs. Drainage Area Data from HEC-HMS:** From the HEC-HMS model for the watershed system, collect discharge and drainage area data for various points along the main stem or tributary stream to which the subarea in question drains.
2. **Plot Data:** Plot the discharge vs. drainage area pairs on a sheet of log-log paper.
3. **Determine Trend:** Plot a straight-line approximation through the paired data. Extrapolate linearly to define an approximate relationship for smaller areas (see Figure 1).

Figure 1: Drainage Area vs. Discharge Extrapolation



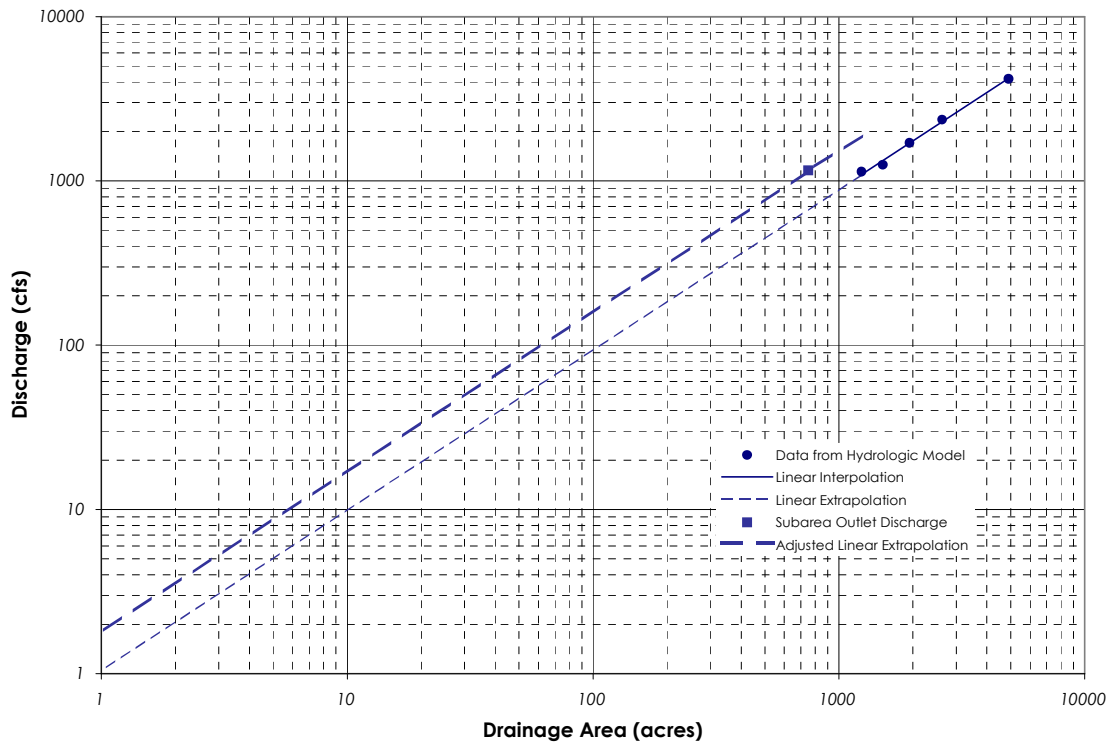
4. **Read Discharge:** From the extrapolated line, read the discharge which corresponds to the drainage area at the point in question.

For tributaries with only one subarea along which several discharges must be calculated, a similar approach is recommended.

1. **Gather Discharge vs. Drainage Area Data from HEC-HMS:** From the HEC-HMS model for the watershed system, collect discharge and drainage area data from one or more surrounding tributaries.
2. **Plot Data:** Plot the discharge vs. drainage area pairs on a sheet of log-log paper.

3. **Determine Trend:** Plot a straight-line approximation through the paired data. Extrapolate linearly to define an approximate relationship for smaller areas (see Figure 2).

Figure 2: Drainage Area vs. Discharge Extrapolation for Single Subarea Tributary



4. **Adjust Extrapolated Line:** Adjust the extrapolated line upward or downward so that it passes through the subarea outlet discharge of the subarea in question.
5. **Read Discharge:** From the adjusted extrapolated line, read the discharge which corresponds to the drainage area at the point in question.

Assumptions: This method assumes that a straight-line extrapolation is reasonable for defining the relationship between drainage area and discharge. The relationships defined in Figures 1 and 2 assume similar effects of development, slopes, and channel definition at various points along the stream and in the watershed.

Testing Procedure: None. This method has been used on Letter of Map Revision submittals to FEMA by Dodson & Associates in the past and has been approved.

Test Results: None.

Final Notes: None.

Committee Resolution: The committee agreed that this was a reasonable procedure.

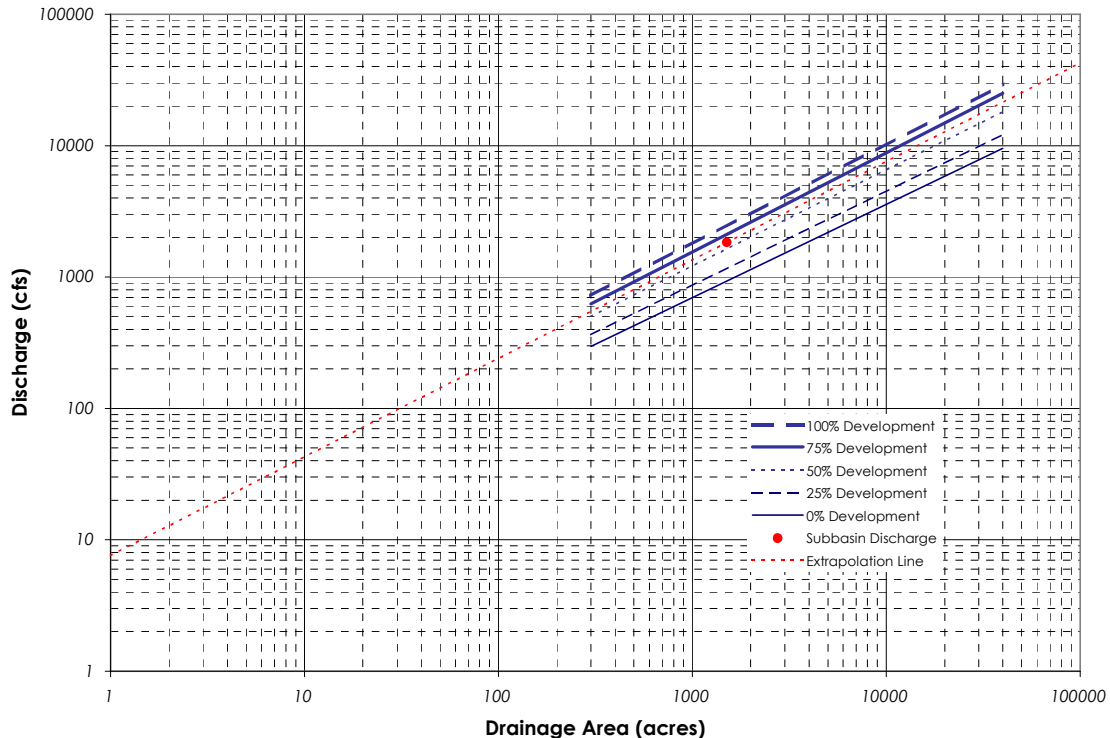
Additional Discussion: This additional discussion is included as an alternative method for determining discharges for single subarea tributaries, based on problems in some areas related to collecting discharge and drainage area data from one or more surrounding tributaries which do not provide a linear relationship for extrapolation.

As an alternative, the following method is suggested:

1. **Gather Discharge, Channel Slope, and Drainage Area Data for the Subarea in Question:** From hydrologic data and the HEC-HMS model for the subbasin, collect discharge, channel slope, and drainage area information.

2. **Select Appropriate Channel Conveyance Curve:** Based on the channel slope, choose a Full Channel Conveyance graph with a similar channel slope. Two curves may be chosen if interpolation is necessary.
3. **Plot Discharge vs. Drainage Area:** Ignoring the percent development in the subarea, plot the discharge vs. drainage area pair. Plot a straight-line approximation through this data point which roughly parallels the given curves on the graph. Extrapolate linearly to define an approximate relationship for smaller areas (see Figure 3).

Figure 3: Alternate Drainage Area vs. Discharge Extrapolation for Single Subarea Tributary



4. **Read Discharge:** From the adjusted extrapolated line, read the discharge which corresponds to the drainage area at the point in question.

Additional Analysis and Final Discussion: The purpose of this additional analysis and final discussion is to provide you with some background information and a few comments related to a review of current upper subarea discharge development used in the TSARP study. From floodplain mapping information, it appears that the current method for developing flows within a single subarea (from TSARP Issue Paper #15) produces higher than expected flows and a “ballooning” effect of the floodplain in several headwater subareas across the county. To determine the reasonableness of the current method, several other methods were analyzed to determine the watershed responses under these other methods. They were then compared to the flows from current HEC-RAS and HEC-HMS models.

The first step was to analyze these methods at the outlet point of the subarea and compare them with the HMS 1% flows. The following methods were reviewed in this step.

- *Site Runoff Curves*—This is simply an extrapolation of the site runoff curves contained in the current criteria manual.
- *Rational Formula*—This is the rational formula in the form $Q=C_pCiA$.
- *TR-55*—This is the method contained in Technical Release No. 55 (“Urban Hydrology for Small Watersheds”) developed by the NRCS. Times of Concentration were derived using the Kirpich Formula.
- *USGS*—These are the regional regression equations developed in WRIR 96-4307 for Region 11 of Texas (Houston Metro Area and east to the Sabine River), and as adjusted for urbanization in WSP 2207 using 3-

parameter equations. WRIR 96-4307 is a USGS paper sponsored by TxDOT. A total of 66 gages from Region 11 were used in development of the regression equations; 34 were in the Clear/Cedar/San Jacinto watersheds, and 22 were in Harris County.

- *Statistical Correlation*—This is a statistical analysis developed by Dodson & Associates based on an examination of hundreds of subareas across the county. This method divided subareas into those with less than 20% imperviousness and those with greater than 20% imperviousness.
- *NSS*—This is the National Stream Statistics program developed by the USGS and using the Houston urban regression equations developed by Liscum, et al, in 1980.
- *FIS Avg. Q vs. A*—This is a statistical analysis based the drainage areas and 1% flows listed in the Flood Insurance Study for Harris County.

A total of 19 upper subareas were analyzed with these methods for the evaluation. Three of these subareas do not necessarily have “ballooned” floodplains, but were included as part of the overall analysis.

Based on the analyses, the TR-55 and Site Runoff Curve methods produced extraordinarily high flows when compared with HMS. The NSS method produced extraordinarily low flows. The Statistical Correlation method produced good results, but it lumped all subareas into either greater or less than 20% impervious cover (i.e., it did not account for variable imperviousness above or below 20%) and had a significant discontinuity at the 20% threshold. The FIS Avg. Q vs. A method produced excellent results, but since it was a list of average flows and drainage areas, it did not allow for changes in development. This left the Rational Formula and the USGS regional equations. When the comparison was limited to those flows less than 2000 cfs (which is the range generally expected for upper subarea discharges), the USGS method produced better results. A secondary consideration is that the Rational Formula is generally not considered reasonable for areas greater than 200 acres. Figure 4 shows the comparison of each method tested, while Figure 5 compares only the Rational Formula and the USGS regional equations to HMS 1% flows at the outlet of the subarea (for flows less than 2000 cfs).

Figure 4: Evaluation of Upper Subarea Methods vs. HEC-HMS

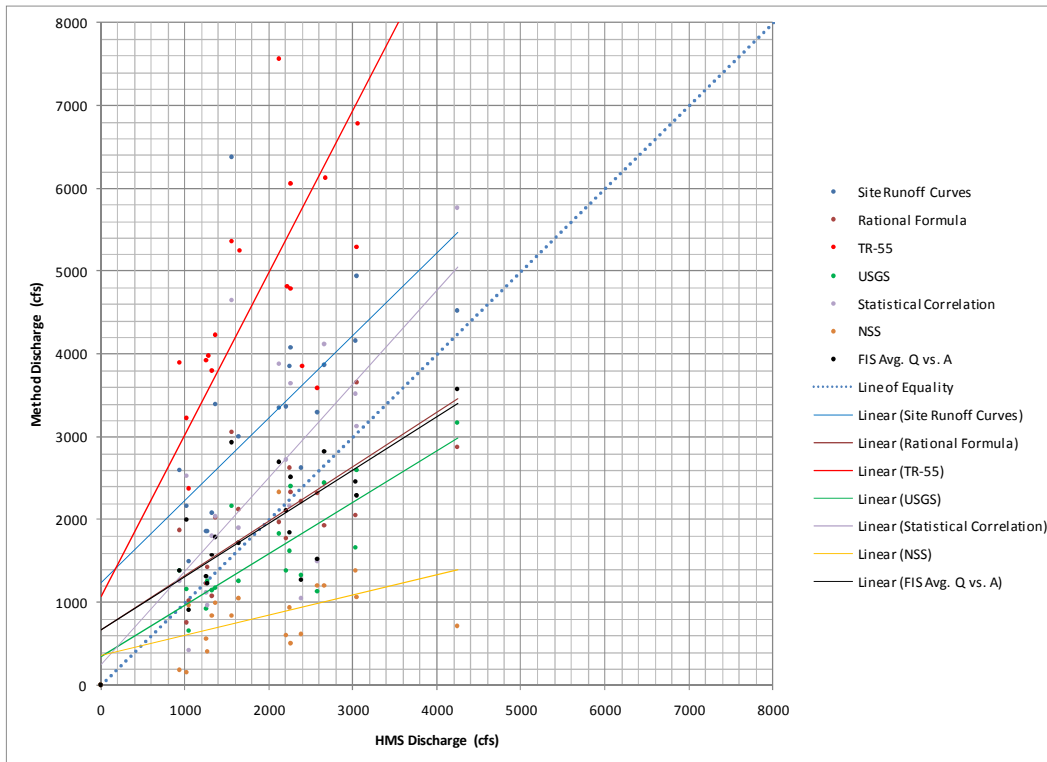
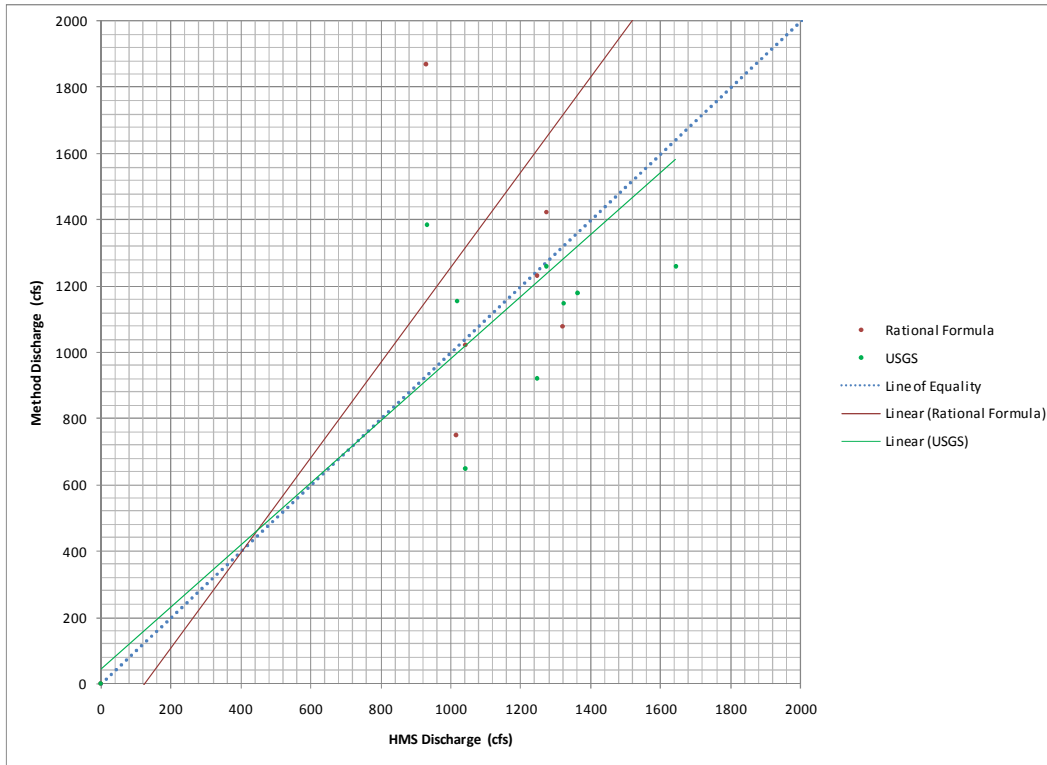
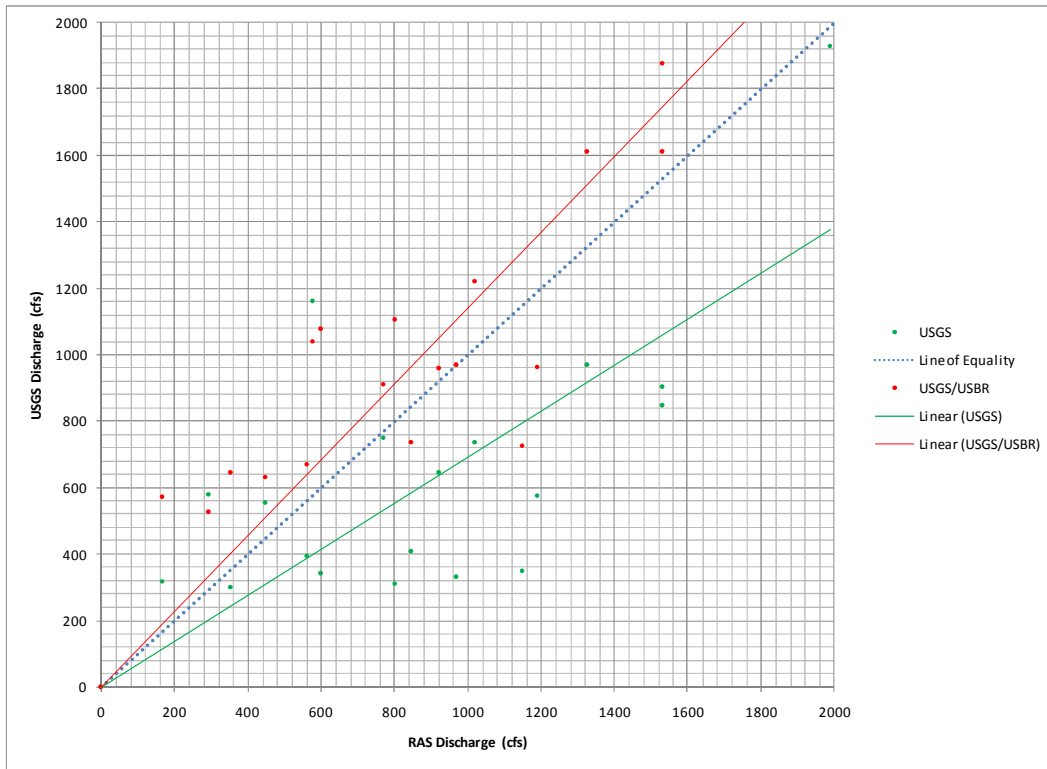


Figure 5: Rational Formula and USGS Regional Equations vs. HEC-HMS



The second step was to pick points in each subarea considered in the first step and compare the discharges with the respective HEC-RAS flow files. The results indicated that using the USGS regional equations would produce smaller discharges than currently shown in the RAS models. As an additional check, comparison of HEC-RAS discharges was also made to the USGS/USBR formula. This formula takes the form $Q_2=Q_1 (A_2/A_1)^{0.5}$ to derive flows at intermediate points within a given subarea. This USGS/USBR formula generally produced discharges which were higher than the HEC-RAS flows. Figure 6 shows the comparison of the USGS regional equations and the USGS/USBR formula to the HEC-RAS 1% flows (the y-intercept in this figure was set to zero).

Figure 6: USGS Regional Equations and USGS/USBR Formula vs. HEC-RAS



Final Conclusions: It appears that any number of methods could be used to determine upper subarea discharges, but whether any method would produce superior discharges to those derived from the current method is speculative. Therefore, based on discussions with HCFCF and in order to maintain consistency, it was decided that there was no need to modify the method described earlier in this issue paper. Additionally, of the 164 upper subareas with defined floodplains in Harris County, only 25 indicated a clear “ballooning” of the floodplains (Exhibit 1; Table 1 identifies the 25 subareas along with the 19 which were tested in this evaluation). This accounts for 15.2% of the subareas in Harris County affected by this problem. Further, it is noted that some “ballooning” may be a result of structures (such as bridges) backing up water or due to topographic features such as low, flat overbanks. Therefore, no change from the current flow determination method for upper subareas is recommended.

Table 1: Upper Subareas with “Ballooned” Floodplains

Subbasin	Test Subarea	"Ballooned" Subarea
<i>C103</i>	X	X
<i>C106D</i>	X	X
<i>C118</i>	X	X
<i>D129A</i>		X
<i>D142A</i>	X	X
<i>E100J</i>		X
<i>E101A</i>	X	X
<i>E115A</i>		X
<i>E121A</i>	X	X
<i>E125A</i>		X
<i>E135A</i>		X
<i>J131</i>		X
<i>K120A</i>	X	X
<i>K131A1</i>	X	X
<i>K131B</i>		X
<i>K140A</i>	X	X
<i>K142A</i>	X	X
<i>K155A</i>		X
<i>O100A</i>		X
<i>O105A</i>	X	X
<i>P107A</i>	X	
<i>P1300202A</i>	X	X
<i>P138A</i>	X	X
<i>P145A</i>	X	
<i>R100A</i>	X	X
<i>U101E</i>	X	
<i>W141A</i>	X	X
<i>W167B</i>	X	X