CE 3354 Surface Water Hydrology
Design Rainfall

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Original 19 August 2008

1 Introduction

Design rainfall in this chapter refers to estimates, usually probabilistic, of point rainfall depths or intensities. A design rainfall hyetograph extends the concept to the temporal behavior (time distribution) of such rainfall. Design rainfall is based on observations, but is distinct in that its goal is the estimation of future behavior rather than explanation of past behavior.

The average rainfall intensity[1], Equation 1, is the ratio of total rainfall depth, P for a storm and the length, D (or duration) of that storm.

$$\bar{I} = \frac{P}{D} \tag{1}$$

The remainder of this chapter presents different tools to make such estimates – these tools range from very location specific, to global generalizations. In cases where the analyst is actually working in the geographic region covered by the tool, then tool can be applied directly with some confidence[2].

2 Global Maximum Observations

Global maximum observations are point rainfalls observed for different time intervals tabulated from various sources (Barcelo and others, 1997; Jennings, 1950; Paulhus, 1965; Smith,and others, 2001). Figure 1 is plot of these various depths and durations. The reader is reminded that these markers represent point rainfalls from many different locations on the Earth that were actually recorded. Observing future events exceeding these values is certainly possible, but relatively unlikely — thus these values represent a reasonable "rule-of-thumb" upper bound for most engineering hydrology[3].

A global envelope curve (Paulhus,1965), Equation 2, that relates depth, P, in inches, and duration, D, in hours, also appears in many hydrology contexts and provides a useful upper boundary for

[1] Or typically just "intensity"
[2] The reader is cautioned that they should use the tools from original sources; the authors have taken pains to be sure the material is correctly transcribed, but there is no guarantee against a transcription error.
[3] These are observations, thus not technically estimation of future behavior, but because these represent the largest values observed to date they do constitute a reasonable starting point for such estimates

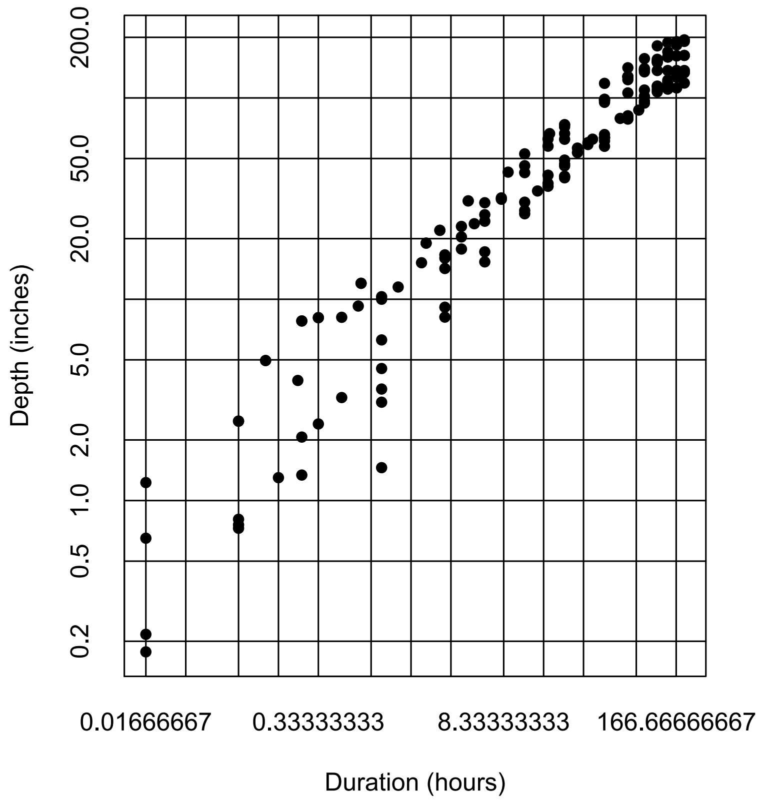

Figure 1: Global maximum observed point rainfall depths for different storm durations.

rainfall depth and average intensity estimates.

$$P = 16.6D^{0.475} \tag{2}$$

If the depths are subsequently divided by the corresponding duration, this ratio is an average intensity for that duration — the rainfall intensity. Dimensionally intensity is a rainfall velocity (depth/time), that when multiplied by an area produces a volumetric input rate. Figure 2 is plot of the intensities and durations for the global observed maxima.

If the global curve is expressed as an average intensity using Equation 1, the result is a hyperbolic equation (with a 0 offset). This relationship is expressed in Equation 3.

$$\bar{I}_{GMax} = \frac{16.6}{(D+0.0)^{0.525}} \tag{3}$$

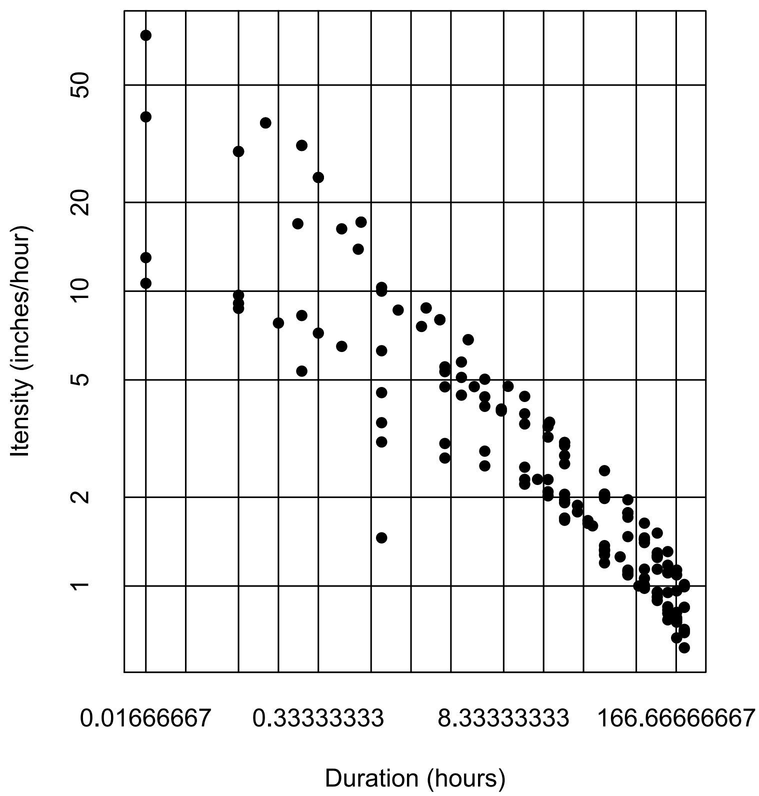

Figure 2: Global maximum observed point rainfall depths for different storm durations.

3 National Weather Service TP-40 and HY 35

The U.S. Weather Bureau (now called the National Weather Service (NWS)) analyzed observations from hundreds of point gages (rain gages) in the United States in the late 1950's. The analysis determined the largest precipitation depth at each gage for a given time interval (duration) for each year of record. These results were then "fit" to a distributional model (a Gumbel Extreme Value distribution) and low probability event magnitudes were estimated for each gage. These estimates comprise a spatial database that was then used to produce contour maps of expected rainfall depth for a given duration for a given probability level. This set of maps was published at Technical Paper 40 (TP-40) (Hershfield, 1961).

Hershfield (1961) also provided interpolation diagrams for estimating precipitation for durations and probabilities not explicitly mapped. Figure 3 is an example of one such map from the report.

About two decades after TP-40 was published a follow-up publication was prepared by the National

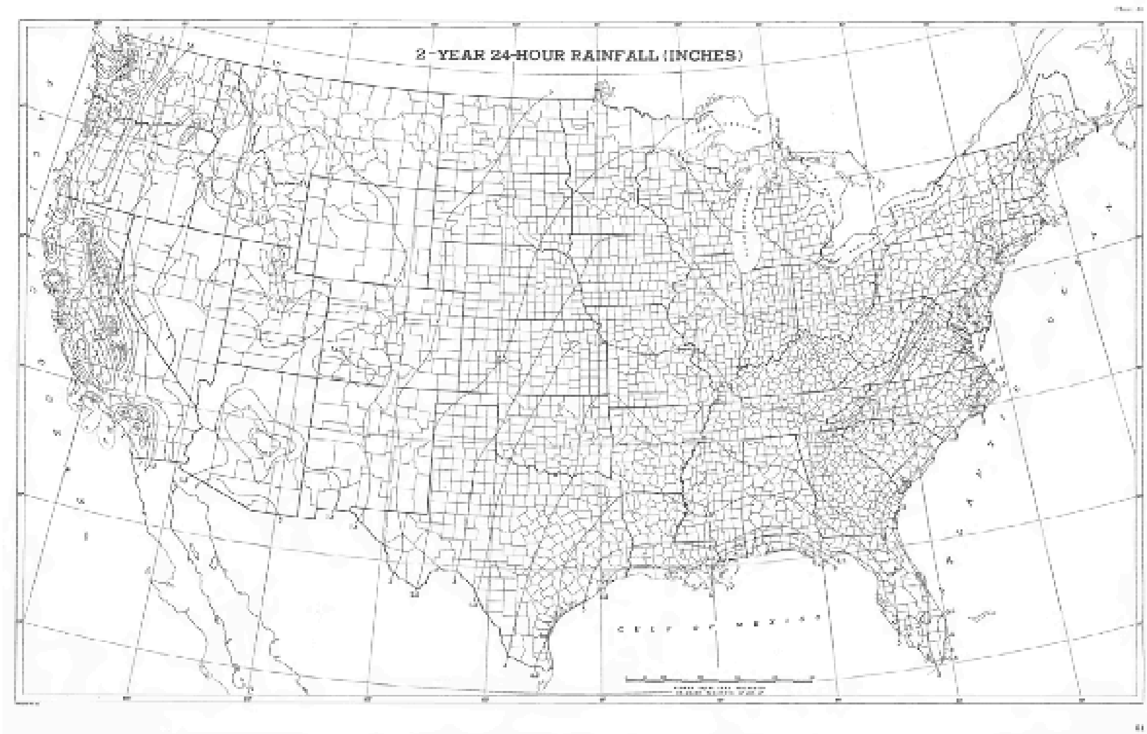

Figure 3: Selected map from TP-40. The map depicts the United States with contour lines of estimated rainfall depth (isoheyets) for the specified probability and duration. Several such maps are in the report, along with methodology and interpolation procedures to infer values not mapped.

Weather Service (NWS) that performed a similar analysis for the eastern portion of the United States. This publication used similar methodology, but focused on shorter durations that TP-40 (5- , 15-, and 60-minute durations were mapped). This report, HY-35 (Frederick et al., 1977) supplements TP-40 for these shorter durations for the specified geographic coverage. Figure 3 is an example of one such map from the report.

4 Texas Department of Transportation - EBDLKUP Tool

A design intensity equation, Equation 4, that relates duration and intensity appears in many hydrology contexts (TxDOT, 2002; Hann and others, 1994) and is commonly used to constructed intensities for specified quantiles. In this section, the equation in use by the Texas Department of Transportation is shown.

The value $\bar{I}_{ARI\%}$ represents the specified percentile intensity at a given duration. The value, b, is a constant that represents the zero-time duration intensity (it is essentially an intercept term in the equation as t_c approaches zero. The time shift, d, is a value that determines where (in time)

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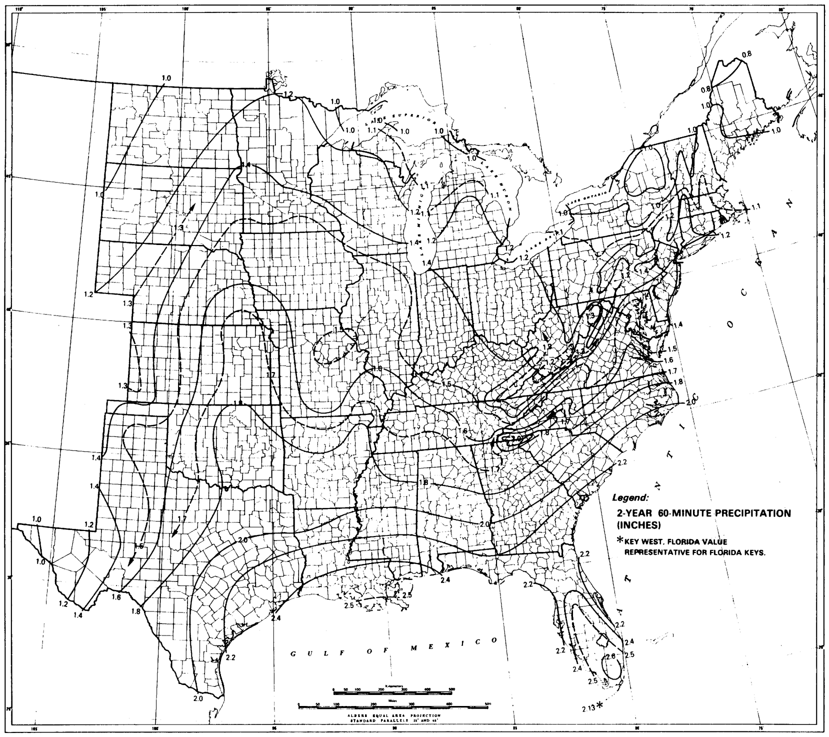

Figure 4.--2-year 60-min precipitation (inches)--adjusted to partial duration series.

Figure 4: Selected map from HY-35. The map depicts the eastern United States with contour lines of estimated rainfall depth (isoheyets) for the specified probability and duration. Several such maps are in the report, along with methodology and interpolation procedures to infer values not mapped.

the inverse time intensity relationship begins to curve downward[4] The exponent, e, determines how rapidly the downward curve occurs. The numerical values are usually determined from a tabulation (TxDOT 2002) or from local depth-duration-frequency data.

$$\bar{I}_{ARI\%} = \frac{b}{(t_c + d)^e} \tag{4}$$

A similar equation appears in (Haan et al., 1994)

Figure 5 is an image of a spreadsheet tool to access the tabular data required in the equation. Attached to the worksheet are tabulations of e,b, and d. The numerical values of these coefficients were determined using the methods described in TP-40 and HY-35 and were produced for each county in Texas. The reader is cautioned that the coefficients contain unit-conversion components, thus the analyst must use care not to mix dimensional units when using this particular tool.

[4]Negative concordance – as duration increases, intensity decreases.

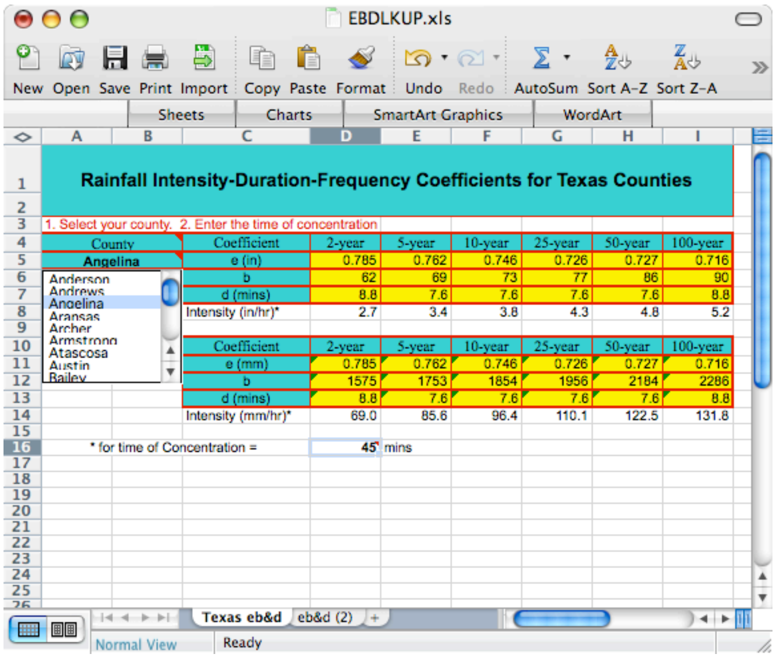

Figure 5: EBDLKUP spreadsheet interface. The worksheet is a rapid tool to access tabular values of e,b, and d.

5 Jurisdictional IDF curves

In some jurisdictions the intensity-duration-frequency curves are prepared by the regulatory authority. Generally engineers can use the prepared curves as-is, or in special circumstances will generate their own using actual data and/or published sources.

Figure 6 is an example of such a set of curves for Houston, Texas. The figure was adapted from Figure 9.1. City of Houston Design Manual.

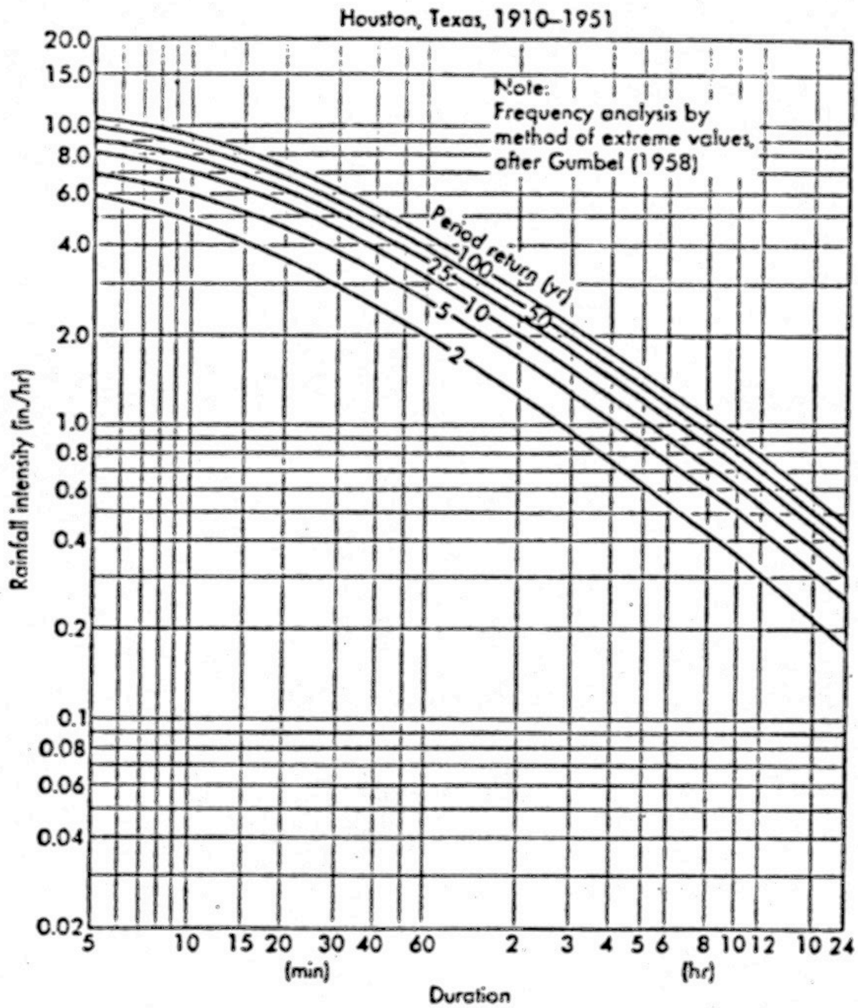

Figure 6: Houston, Texas Intensity-Duration-Frequency curves.

References

Frederick, R. H., V. A. Meyers, and E. P. Auciello (1977). Five to 60-minute precipitation frequency for the eastern and central united states. Technical Memorandum HYDRO-35, National Weather Service.

Haan, C., B. Barfield, and J. Hayes (1994). *Design Hydrology and Sedimentology for Small Catchments.* Academic Press.

Hershfield, D. M. (1961). Rainfall frequency atlas of the united states for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. Technical Paper 40, U.S. Weather Bureau.