



Urban Hydrology

An Online Continuing Education Course for Engineers

Course Number: C-3029

Credit: 3 Hours / 3 PDH / 3 CPD

Urban Hydrology

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URBAN HYDROLOGIC PROCEDURES

This course provides an overview of hydrologic methods and procedures commonly used in urban highway drainage design. The presentation here is intended to provide the reader with an introduction to the methods and procedures, their data requirements, and their limitations. Most of these procedures can be applied using commonly available computer programs.

Rainfall (Precipitation)

Rainfall, along with watershed characteristics, determines the flood flows upon which storm drainage design is based. The following sections describe three representations of rainfall which can be used to derive flood flows: constant rainfall intensity, dynamic rainfall, and synthetic rainfall events.

Constant Rainfall Intensity

Although rainfall intensity varies during precipitation events, many of the procedures used to derive peak flow are based on an assumed constant rainfall intensity. Intensity is defined as the rate of rainfall and is typically given in units of millimeters per hour (inches per hour).

Intensity-Duration-Frequency curves (IDF curves) have been developed for many jurisdictions throughout the United States through frequency analysis of rainfall events for thousands of rainfall gages. The IDF curve provides a summary of a site's rainfall characteristics by relating storm duration and exceedance probability (frequency) to rainfall intensity (assumed constant over the duration). Figure 1 illustrates an example IDF curve. To interpret an IDF curve, find the rainfall duration along the X-axis, go vertically up the graph until reaching the proper return period, then go horizontally to the left and read the intensity off of

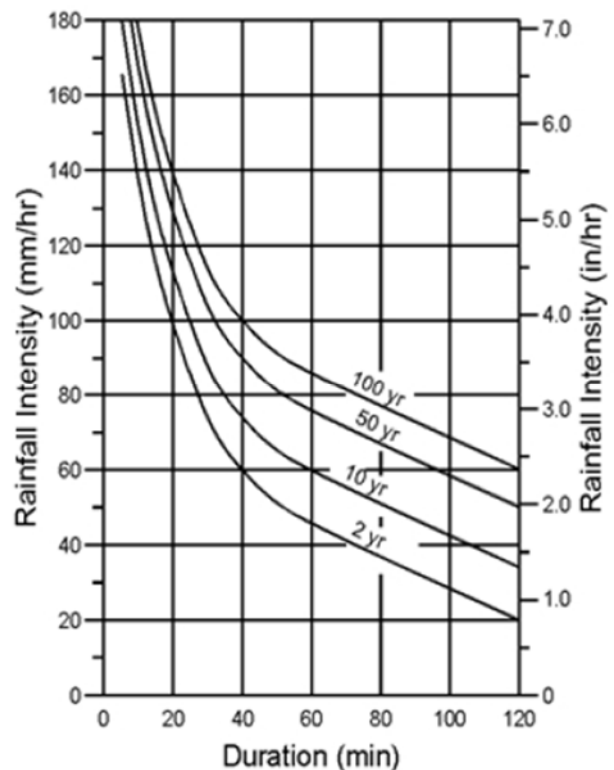


Figure 1. Example IDF curve.

the Y-axis. Regional IDF curves are available in most highway agency drainage manuals. If the IDF curves are not available, the designer needs to develop them on a project by project basis.

Dynamic Rainfall (Hyetograph)

In any given storm, the instantaneous intensity is the slope of the mass rainfall curve at a particular time. The mass rainfall curve is simply the cumulative precipitation which has fallen up to a specific time. For hydrologic analysis, it is desirable to divide the storm into convenient time increments and to determine the average intensity over each of the selected periods. These results are then plotted as rainfall hyetographs, an example of which is presented in figure 2. Hyetographs provide greater precision than a constant rainfall intensity by specifying the precipitation variability over time, and are used in conjunction with hydrographic (rather than peak flow) methods. Hyetographs allow for simulation of actual rainfall events which can provide valuable information on the relative flood risks of different events and, perhaps, calibration of hydrographic models. Hyetographs of actual storms are often available from the National Climatic Data Center, which is part of the National Oceanic and Atmospheric Administration (NOAA).

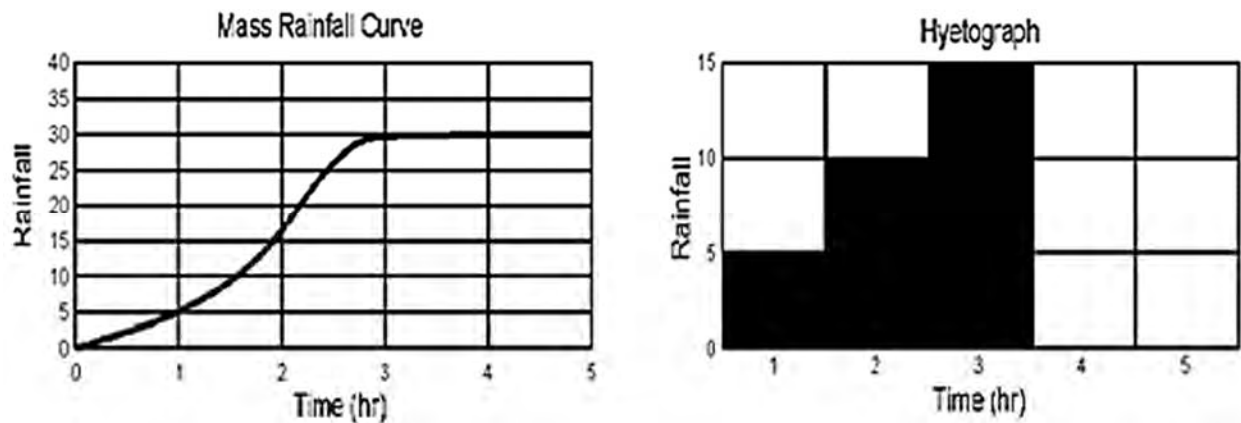


Figure 2. Example mass rainfall curve and corresponding hyetography.

Synthetic Rainfall Events

Drainage design is usually based on synthetic rather than actual rainfall events. The SCS 24-hour rainfall distributions are the most widely used synthetic hyetographs. These rainfall distributions were developed by the U.S. Department of Agriculture, Soil Conservation Service (SCS) which is now known as the Natural Resources Conservation Service (NRCS). The SCS 24-hour distributions incorporate the intensity-duration relationship for the design return period. This approach is based on the assumption that the maximum rainfall for any duration within the 24-hour duration should have the same return period. For example, a 10-year, 24-hour design storm would contain the 10-year rainfall

depths for all durations up to 24 hours as derived from IDF curves. SCS developed four synthetic 24-hour rainfall distributions as shown in figure 3; approximate geographic boundaries for each storm distribution are shown in figure 4.

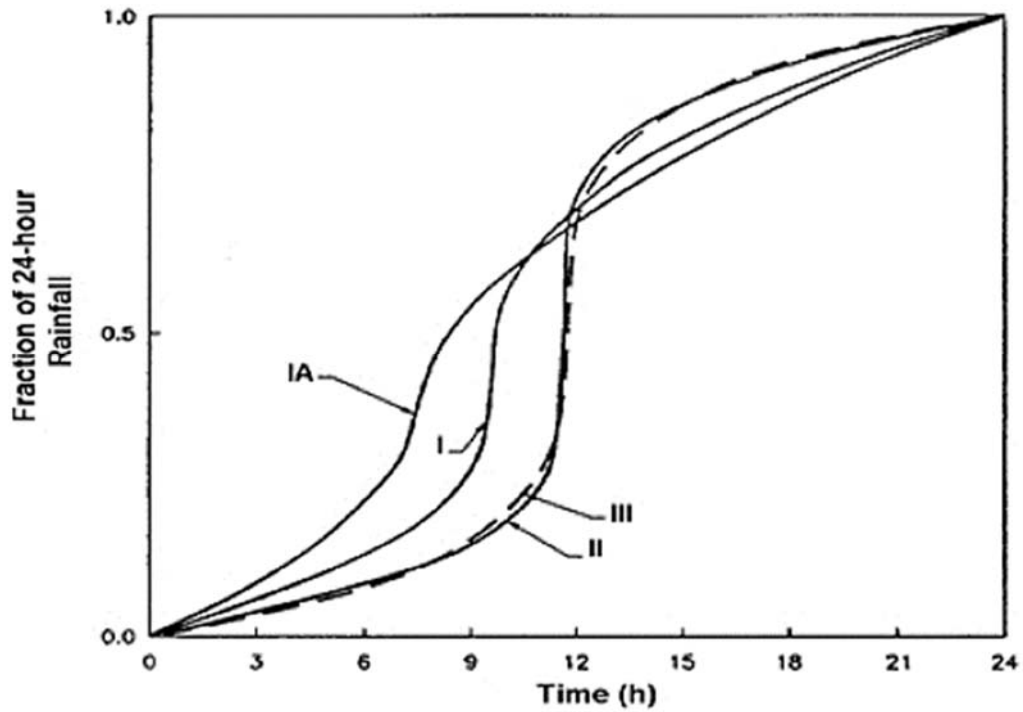


Figure 3. SCS 24-hr rainfall distribution.



Figure 4. Approximate geographic areas for SCS rainfall distributions.

Determination of Peak Flow Rates

Peak flows are generally adequate for design and analysis of conveyance systems such as storm drains or open channels. However, if the design or analysis must include flood routing (e.g., storage basins or complex conveyance networks), a flood hydrograph is required. This section discusses methods used to derive peak flows for both gauged and ungauged sites.

Stochastic Methods

Stochastic methods, or frequency analysis, can be used to evaluate peak flows where adequate gaged streamflow data exist. Frequency distributions are used in the analysis of hydrologic data and include the normal distribution, the log-normal distribution, the Gumbel extreme value distribution, and the log-Pearson Type III distribution. The log-Pearson Type III distribution is a three-parameter gamma distribution with a logarithmic transform of the independent variable. It is widely used for flood analysis because the data quite frequently fits the assumed population. It is this flexibility that led the U.S. Water Resources Council to recommend its use as the standard distribution for flood frequency studies by all U.S. Government agencies. Figure 5 presents an example of a log-Pearson Type III distribution frequency curve. Stochastic methods are not commonly used in urban drainage design due to the lack of adequate streamflow data.

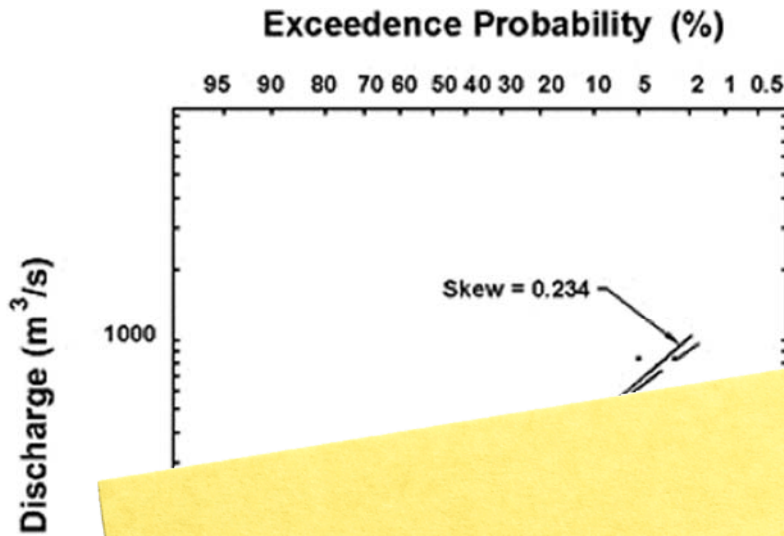


Figure 5.

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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Rational Method

One of the most common methods for estimating peak runoff areas is the Rational formula, given by:

$$Q = \frac{CIA}{K_u} \quad (1)$$

where:

- Q = Flow, m³/s (ft³/s)
- C = dimensionless runoff coefficient
- I = rainfall intensity, mm/hr (in/hr)
- A = drainage area, hectares, ha (acres)
- K_u = units conversion factor equal to 360 (1.0 in English Units)