Watershed Routing (Hydrograph Determination)

A. Introduction

Watershed routing is utilized when the watershed contains multiple subbasins and it is desired to add the flows from each subbasin together to determine the combined flow rate at critical locations along the conveyance system. This method follows the flow through the basin and results in the development of an inflow hydrograph. The resulting hydrograph plots the flow rate against the time of the storm event. The most common location where an inflow hydrograph is required is at a stormwater detention basin. (See Section 2G-1 for detention basin design). Two methods for watershed routing are provided in this chapter: Modified Rational Method for Basin Routing and the Tabular Hydrograph TR-55 Method.

B. Modified Rational Method for Basin Routing

1. **Method Description:** The Modified Rational Method can estimate peak flows at critical points in basins with numerous subbasins. The Modified Rational Method can give a triangular and trapezoidal hydrograph for determining storage volumes. To assist the engineer in the calculations, there are numerous computer programs available, such as MODRAT, which is a Modified Rational Method program developed by the Los Angeles County Department of Public Works.

   The basis of the Modified Rational Method (and any hydrograph) is that the area under the hydrograph equals the volume of runoff. For the Modified Rational Method hydrograph, it is assumed that runoff begins at the start of the storm and increases linearly to the peak value (equal to the T_c). The peak runoff is sustained until the event duration has elapsed, and then decreases linearly to zero. For real-world conditions, this is highly unlikely.

   When using the Modified Rational Method, it is recommended that a coefficient be used in order to account for the antecedent moisture conditions of storms with a 25 year, or greater, recurrence interval. This attempts to predict a more realistic runoff volume for major storms. The equation to account for this increased volume is:

$$Q = (C_a)(C)(i)(A)$$ **Equation 2B-5.01**

Table 2B-5.01: Recommended Antecedent Precipitation Factors for the Rational Method

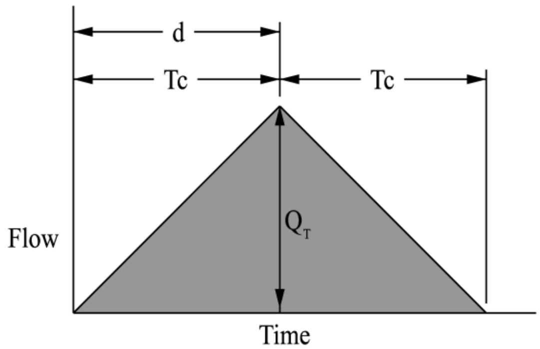
Recurrence Interval (years)	C_a
2 to 10	1.0
25	1.1
50	1.2
100	1.25

Note: The product of C x C_a cannot exceed 1.0.

The time of concentration (T_c), which is the time of travel from the most remote point (in time of flow), determines the largest peak discharge. Therefore, there are two possible approximate hydrographs that can be used for runoff and storage requirements.

If the rainfall duration is equal to the T_c, the approximate hydrograph is a triangle.

Figure 2B-5.01: Modified Rational Method Hydrograph

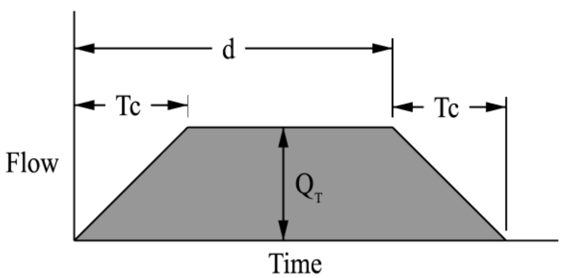


d = Duration of Storm
Q_T = Peak flow rate (=CiA)
T_c = Time of concentration

In this example, the storm duration equals the T_c resulting in a triangular shaped hydrograph.

If the rainfall duration is greater than the T_c, the approximate hydrograph is a trapezoid.

Figure 2B-5.02: Modified Rational Method Hydrograph



d = Duration of Storm
Q_T = Peak flow rate (=CiA)
T_c = Time of concentration

In this example, the storm duration exceeds the T_c resulting in a trapezoidal shaped hydrograph.

For storage volume determination using the Modified Rational Method, see Section 2G-1.

2. **Limitations:** It should be noted that the Modified Rational Method does have limitations. Because this method assumes a constant intensity storm event, and does not recognize soil conditions, the method does not produce a true hydrograph, only an approximation.

   Because of this limitation, the Modified Rational method should be limited to drainage basins of 5 acres or less with no off-site pass-through.

C. Tabular Hydrograph Method

The TR-55 Tabular Hydrograph Method is used for computing discharges from rural and urban areas, using the time of concentration (T_c) and travel time (T_t) from a subarea as inputs. The SCS TR-55 methodology can determine peak flows from areas of up to 2,000 acres, provide a hydrograph for times of concentration between 0.1 to 2 hours, and estimate the required storage for a specified outflow.

This method can develop composite flood hydrographs at any point in a watershed by dividing the watershed into homogeneous subareas. In this manner, the method can estimate runoff from non-homogeneous watersheds; a common occurrence in developed urban areas. The method is especially applicable for estimating the effects of land use change in a portion of a watershed.

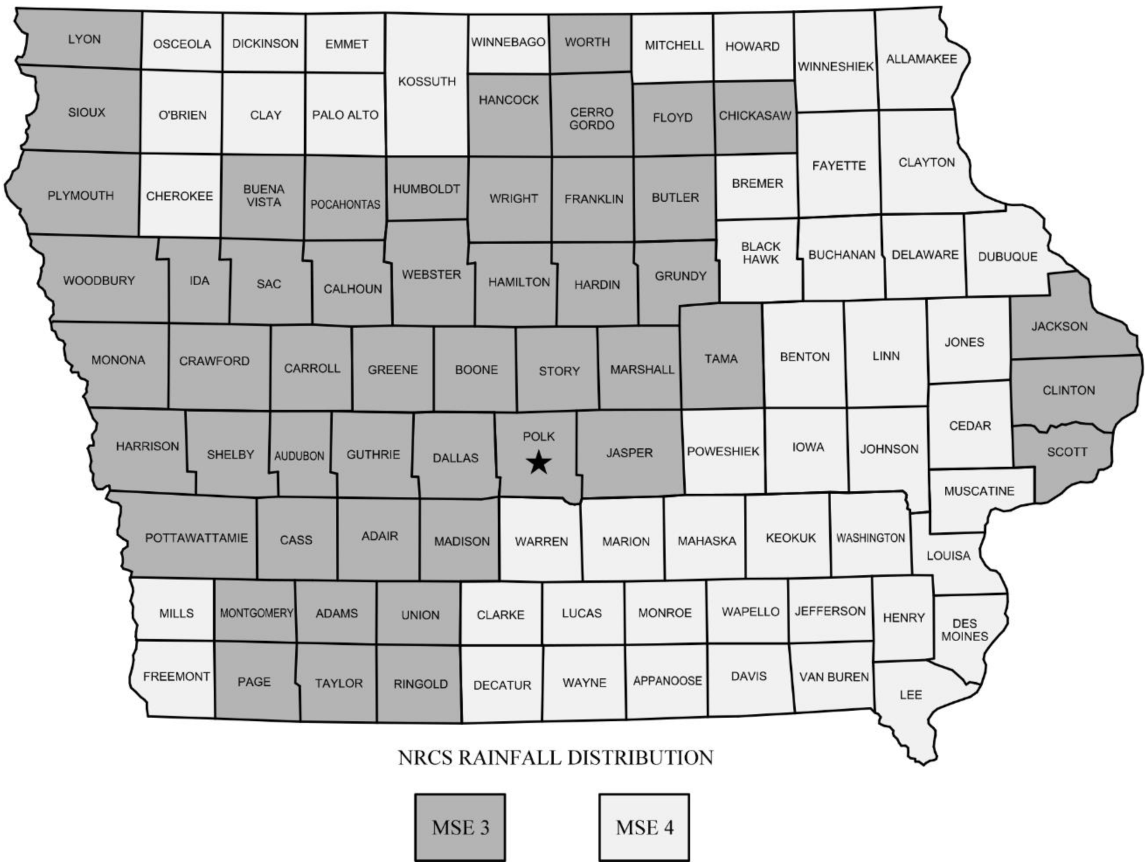
1. **Method Description:** The Tabular Hydrograph method is based on a series of unit discharge hydrographs developed by the SCS. The tabular data was developed by computing hydrographs for one-square mile of drainage area for selected T_c's and routing them through stream reaches with a range of T_t's. The resulting values, expressed in cubic feet per second per square mile of watershed per inch of runoff, are summarized in ten tables provided in the SCS TR-55 manual.

   Chapter 5 of TR-55 provides a detailed description for manual calculation with the tabular hydrograph method, in addition to the tables necessary to complete the calculation. The input data required to develop a flood hydrograph by the SCS TR-55 method includes:
   - 24 hour rainfall, in
   - Appropriate rainfall distribution, (MSE Types 1-6) (Iowa is Type 3 and 4)
   - Curve Number (Refer to Section 2B-4)
   - Time of Concentration, T_c, hr.
   - Travel Time, T_t, hr.
   - Drainage Area, sq. mi.

   Using the Weather Bureau's TP-40 (1961) data, SCS developed four 24 hour synthetic storm distributions (Type I, IA, II, and III) associated with broad climatic regions across the United States. The Type II rainfall distribution applied to a vast majority of the continental United States (including Iowa), even though typical storm events can vary widely between regions. With the release of NOAA's Atlas 14 database (2013), more than 50 years of new rainfall data became available. NRCS's analysis of this data led to the development of new synthetic rainfall distributions, including distributions specifically intended for Midwest and Southeast (MSE) regions. These MSE distributions reflect regional variation, consider recent changes in weather patterns, and prevent the over/under estimation of peak discharges. The new MSE distributions also better account for shorter rainfall durations within the 24 hour rainfall distribution (e.g. 24 hour, 2 hour, 10 minute, 5 minute, etc.) (Merkel and Moody, 2015).

   Six MSE distributions were developed for regions in the Midwest and Southeast. Most of Iowa falls within two of the MSE distributions: MSE3 and MSE4. Several outlier areas of the state fall into the MSE2 and MSE5 regions; however, the areas are small enough that the Iowa NRCS has assigned all counties in the state to either the MSE3 or MSE4 distribution. The following figure identifies which distribution is applied within each county.

Figure 2B-5.03: NRCS MSE Rainfall Distributions



The 24 hour rainfall amount, rainfall distribution, and the runoff curve number are used in Equations 2B-4.06 and 2B-4.07 to determine the runoff depth in each subarea. The product of the runoff depth times drainage is multiplied times each tabular hydrograph value to determine the final hydrograph ordinate for a particular subarea. Subarea hydrographs are then added to determine the final hydrograph at a particular point in the watershed.

Calculating runoff hydrographs manually utilizing the tabular method is time consuming, tedious, and rarely done. This calculation is typically completed utilizing user-created spreadsheets, WinTR-55, or other software that utilizes the TR-55 methodology. The NRCS has incorporated the MSE storm distributions into WinTR-55.

2. **Limitation:** The tabular method is used to determine peak flows and hydrographs within a watershed. However, the accuracy of the Tabular Method decreases as the complexity of the watershed increases. The Tabular Method should not be used if any of the following conditions exist:
   - The drainage area of the watershed is greater than 2,000 acres.
   - T_t is greater than 3 hours (largest T_t in tabular hydrograph data)
   - T_c is greater than 2 hours (largest T_c in tabular hydrograph data)
   - Drainage areas of individual subareas differ by a factor of 5 or more

   If any of the above situations exist, NRCS TR-20, or another applicable methodology should be utilized.

D. References

NRCS. *NOAA Atlas 14 Rainfall for Midwest and Southeast States.* Merkel and Moody. 2015

U.S. Department of Agriculture. *Urban Hydrology for Small Watersheds.* Technical Release No. 55. 1975.

U.S. Department of Transportation. *Urban Drainage Design Manual*. Hydraulic Engineering Circular, No. 22. Third Ed. 2009.