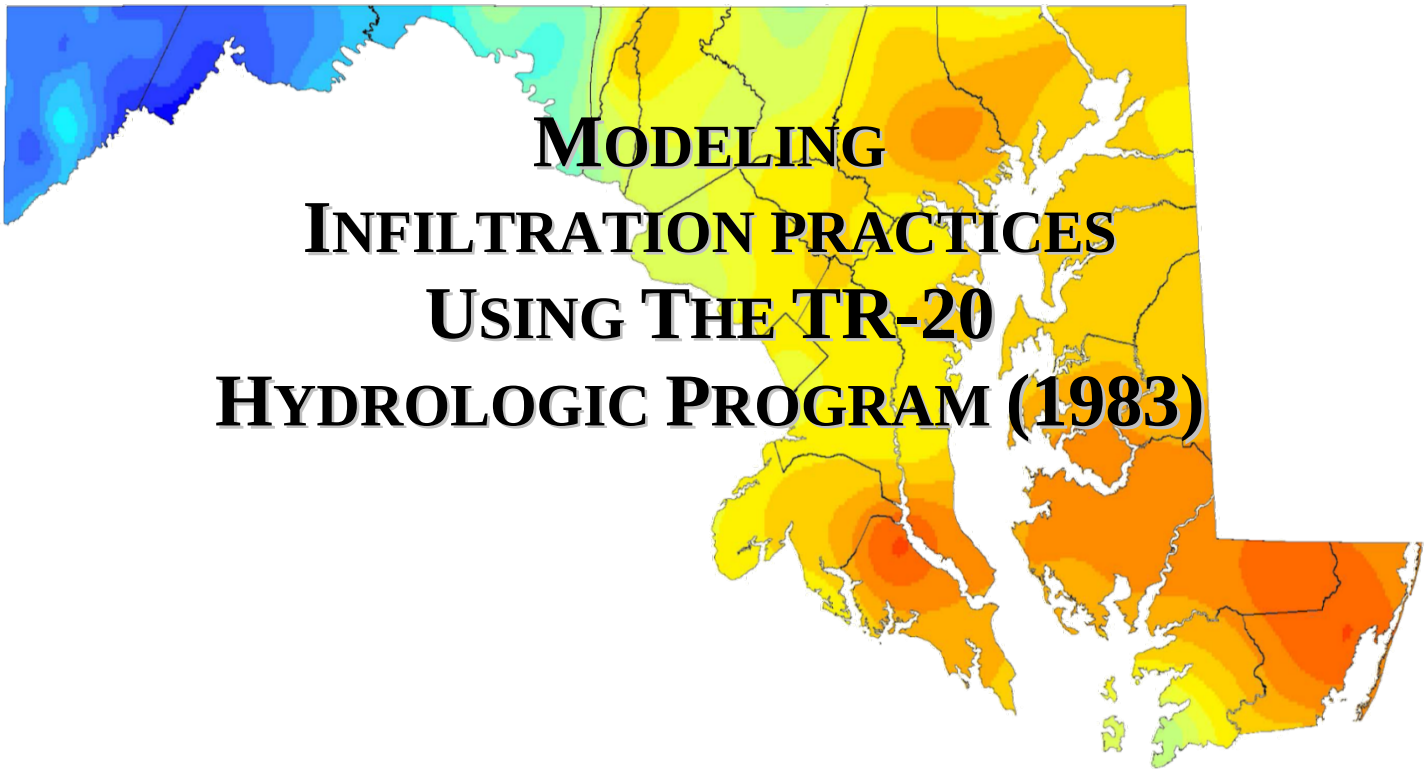


MODELING INFILTRATION PRACTICES USING THE TR-20 HYDROLOGIC PROGRAM (1983)

1800 Washington Boulevard, Baltimore, MD 21230-1718 | www.mde.maryland.gov
410-537-3000 | 800-633-6101 | TTY Users 800-735-2258
Larry Hogan, *Governor* | Boyd Rutherford, *Lt. Governor* | Ben Grumbles, *Secretary*

MODELLING INFILTRATION PRACTICES USING TR-20

If a hydrograph is to be developed, the SCS TR-20 Program can be used in conjunction with or in lieu of the methods presented in Chapter 4 of the Standards & Specifications for Infiltration Practices. There are three different methods that can be used with the TR-20 program for modelling infiltration systems. The TR-20 methods include: 1) the change in curve number method, 2) the truncated hydrograph method, or 3) the hydrograph routing method.

Method 1 - Change in Curve Number Method

The change in curve number method is used by reducing the after development curve number to reflect the runoff volume stored by the infiltration practices. The runoff volume stored by the infiltration practices will be the total increased runoff volume as defined by Equation 4-4 in the Standards and Specifications for Infiltration Practices, or a volume based on the size of the infiltration practices. The revised after development curve number (CN*) is determined by the following equation:

$$CN^* = \frac{200}{(P+2Q+2) - \sqrt{5PQ+4Q^2}}$$

where P is the design rainfall depth in inches, and Q is the after development runoff depth minus the runoff depth stored by the infiltration practices (ΔQ) in inches. The after-development hydrograph computed by the TR-20 program with the revised curve number is the downstream hydrograph that accounts for infiltration storage.

The revised curve number method is most applicable for cases where several infiltration practices are distributed evenly over a drainage area. For example, the method is best applied to residential land uses where each lot may have an infiltration practice. The level of peak discharge reduction is

achieved by distributing the runoff storage volume over the entire watershed area and is reflected by adjusting the curve number. This method is analogous to the TR-55 design methods described in the Standards and Specifications for Infiltration Practices but allows for hydrograph development using TR-20.

Method 2 - Truncated Hydrograph Method

The truncated hydrograph method may be used to determine the volume of infiltration storage needed to achieve an allowable peak discharge rate. The before and after development hydrographs are computed by the TR-20 program. The time (t_2) at which the allowable discharge occurs on the recession limb of the after development hydrograph, as shown in Figure 1, is determined from the TR-20 computer printout. In most cases, the allowable discharge to be released downstream of infiltration practices is the before development peak discharge. The volume of runoff under the after development hydrograph to the left of the allowable discharge is to be stored by the infiltration practice.

The volume of runoff to be stored to achieve the peak discharge control can be determined by dividing the time (t_2) at which the allowable discharge occurs by 300, which is the maximum number of hydrograph ordinates generated. This value is entered into the TR-20 program on the compute card as the computing time increment. The TR-20 program will compute the volume under the after development hydrograph to the left of the allowable discharge which is the infiltration storage needed to control the peak discharge. The remaining storm volume to the right of the allowable discharge that will be released downstream of the infiltration practice is truncated off from the hydrograph. The truncated portion of the outflow hydrograph may be routed downstream by entering the ordinates on the TR-20 read hydrograph data table (READHD).

The computed infiltration storage volume is adjusted by subtracting out the exfiltration volume that occurs during the filling time period of the

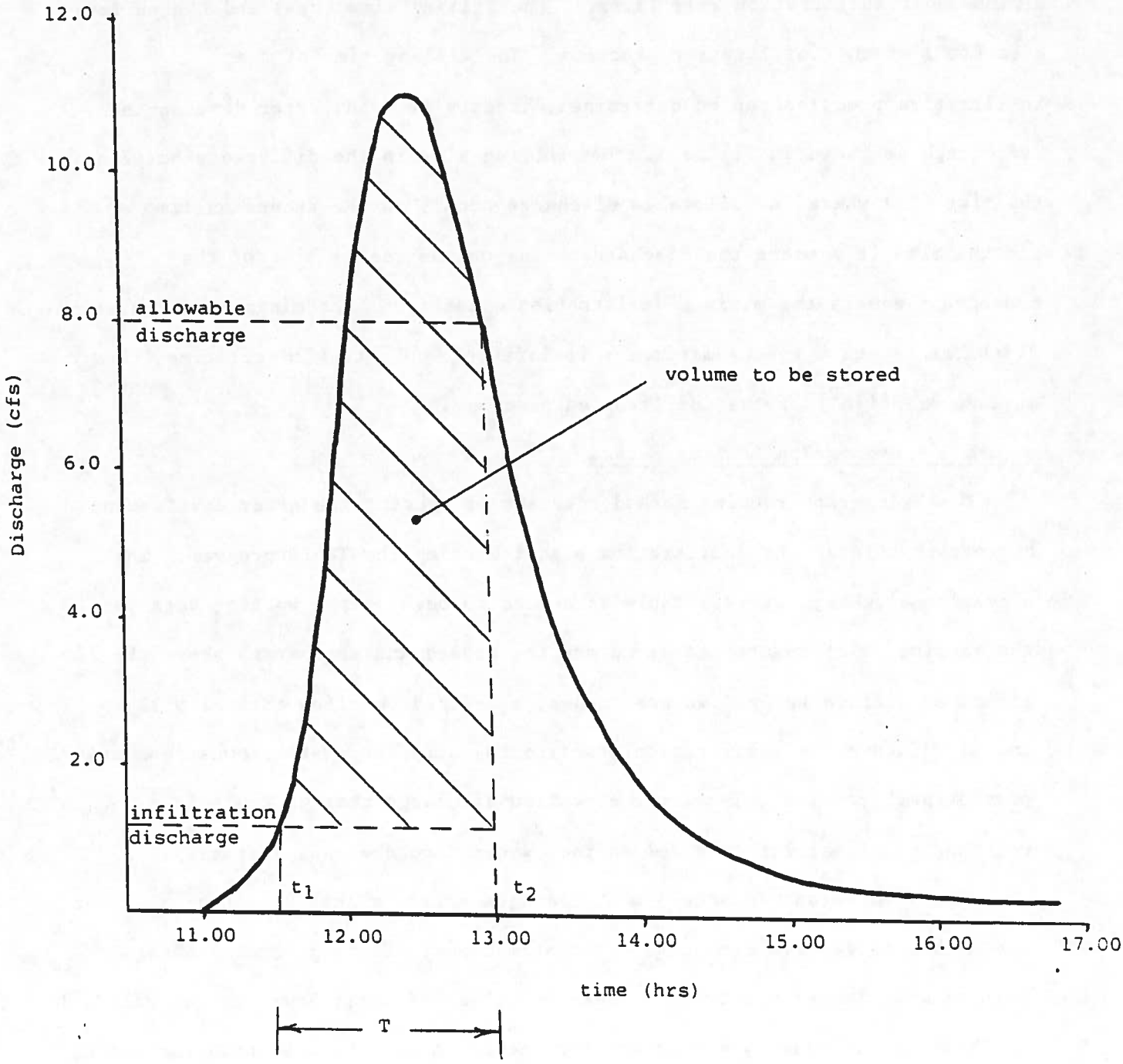


FIGURE 1 - TRUNCATED HYDROGRAPH METHOD

infiltration practice. The exfiltration volume is simply the product of the minimum soil infiltration rate (ft/hr), the filling time (hrs) and the surface area (ft^2) of the infiltration practice. The filling time of the infiltration practice can be determined directly from the after development hydrograph as shown in Figure 1. The filling time is the difference between the time (t_2) where the allowable discharge occurs on the recession limb and the time (t_1) where the discharge value on the rising limb of the hydrograph equals the minimum infiltration discharge. The minimum infiltration discharge is equal to the minimum soil infiltration rate (ft/sec) times the surface area (ft^2) of the infiltration practice.

Method 3 - Hydrograph Routing Method

The hydrograph routing method consists of routing the after development hydrograph through the infiltration practice using the TR-20 program. The elevation-discharge-storage table is needed to develop the working data for the routing of stormwater as it enters the ground and surcharges above the ground as surface water. In most cases, a defined overflow channel will be installed above the infiltration practice to carry stormwater downstream and prevent soil erosion. Thus, the elevation-discharge-storage table is a combination of exfiltration and surface water discharge and storage.

It is important to adhere with the data criteria that is established for the method of reservoir routing. The elevations, discharges, and storage volumes must increase between successive values of data; however, the values do not have to increase by a constant increment. Also, the main time increment, discharge, and storage must satisfy the following inequality:

$$\frac{\Delta O}{2} < \frac{\Delta S}{t}$$

where ΔO is the incremental outflow in cfs between two successive values, ΔS is the incremental storage volume in cfs-hours, and Δt is the main time increment in hours. If the above criteria is not satisfied, the discharge values will oscillate on the descending limb of the hydrograph, which may include some negative discharges. Adjustments to either the outflow rates or storage volumes are usually needed to rectify the oscillations, not the main time increment.

The TR-20 program will route the after development hydrograph through the infiltration practice and the overflow channel, and print out the outflow hydrograph. The exfiltration flow is added to the surface water hydrograph as the TR-20 program cannot adequately separate the exfiltration and surface water hydrographs and still account for the routing. Because the exfiltration flow rate is very small compared to the surface water flow rate, there is little loss in accuracy in the outflow hydrograph. The exfiltration flow routing accounts for the volume of water stored and exfiltrated out of the infiltration practice.

Summary

Three methods have been presented showing how to model infiltration practices using the TR-20 program. The three methods are the change in curve number method, the truncated hydrograph method, and the hydrograph routing method.

The change in curve number method will develop a single reduced downstream hydrograph based on the total volume of runoff stored by the infiltration practices. The method is most applicable for cases where infiltration practices are distributed evenly over an entire drainage area. It is the most practical method for scattered infiltration practices as the other methods require a hydrograph at each and every infiltration practice, which can be extremely time consuming and cumbersome.

The truncated hydrograph method is a direct method for determining the volume of water to be stored by the infiltration practice; no trial and error is required. The method will compute the required volume that is necessary to achieve any desired level of discharge control. The outflow hydrograph may be routed downstream by entering the discharge ordinates of the after development hydrograph on the TR-20 read hydrograph data table (READHD). The allowable discharge rate and the ordinates to the right of the allowable discharge rate are entered into the hydrograph data table.

The hydrograph routing method is perhaps the most accurate method to determine a hydrograph downstream of an infiltration practice. However, this method will require a trial and error process based on selecting the dimensions of an infiltration practice and routing the after development hydrograph through the practice to determine the level of discharge control provided. The time involved in the trial and error process can be considerably shortened if the truncated hydrograph method is used first to determine the volume of storage required by the infiltration practice. The outflow hydrograph can be stream routed downstream to any selected study point.

Case Study

A 25 acre wooded area is to be converted to 1/4 acre residential lots. The three TR-20 methods will be used to determine the volume of storage required to release the 2-year pre-development discharge rate, and develop the outflow hydrograph below an infiltration basin.

Hydrologic Data

D.A. = 25 acres = 0.0390 square miles
P (2-year storm) = 3.3 inches
CN_b = 66 : t_b = 0.75 hrs
CN_a = 75 : t_a = 0.37 hrs
q_{ub} = 375 csm/in (From TR-55 Figure 5-2)
q_{ua} = 590 csm/in

2-Year Peak Discharges (TR-20 Program)

q_a = 23.0 cfs
q_b = 8.0 cfs (goal)

Method 1 - Change in Curve Number Method

Step 1 - Compute the increased upland runoff depth for the 2-year storm.

$$Q = Q_a - \frac{q_{ub}}{q_{ua}} Q_b$$

$$Q = 1.16 - \frac{375}{590}(0.69) = 0.72 \text{ inches}$$

The infiltration basin is sized to store 0.72 inches (65,340 ft^3) of runoff.

Step 2 - Compute the adjusted curve number (CN*) associated with the revised after development runoff depth (Q).

$$Q = Q_a - \Delta Q$$

$$Q = 1.16 - 0.72 = 0.44 \text{ inches}$$

$$CN^* = \frac{200}{(P+2Q+2) - \sqrt{5PQ+4Q^2}}$$

$$CN^* = \frac{200}{(3.3+2(.44)+2) - \sqrt{5(3.3)(.44) + 4(.44)^2}}$$

$$CN^* = 59.78$$

Step 3 - Compute the revised peak discharge and outflow hydrograph from the TR-20 Program.

Input

D.A. = 0.0390 square miles
CN* = 59.78
t_c = 0.37 hrs
P = 3.3 inches

Output

q_a (with infiltration basin) = 6.1 cfs

See Figure 2 for the resultant outflow hydrograph.

Method 2 - Truncated Hydrograph Method

Step 1 - Find the time from Figure 3 where the 2-year pre-development peak discharge occurs on the recession limb of the 2-year post-development hydrograph.

8.0 cfs occurs at approximately hour 12.56.

Step 2 - Divide the pre-development discharge time (12.56 hrs.) by 300:

12.56/300 = 0.042

Step 3 - Compute the volume under the 2-year post-development hydrograph up to hour 12.56 by entering 0.042 on the TR-20 compute card as the computing time interval. The TR-20 program will print the hydrograph discharge ordinates up to hour 12.56 and compute the total runoff volume under the hydrograph up to the pre-development discharge ordinate; only the first 300 discharge ordinates are printed.

V_s = 0.534 inches (TR-20 printout)

$$V_s = \frac{0.534 \text{ in.} \times 25 \text{ ac.} \times 43560 \text{ ft}^2/\text{ac}}{12 \text{ in/ft}}$$

V_s = 48,461 ft^3

Step 4 - Select an infiltration basin that has a total volume of at least 48,461 ft^3.

Use a 100 ft. long by 75 ft. wide by 6.5 ft. deep basin.

V_s = 100 x 75 x 6.5 = 48,750 ft^3 (OK)

FIGURE 2 - Change in Curve Number Method

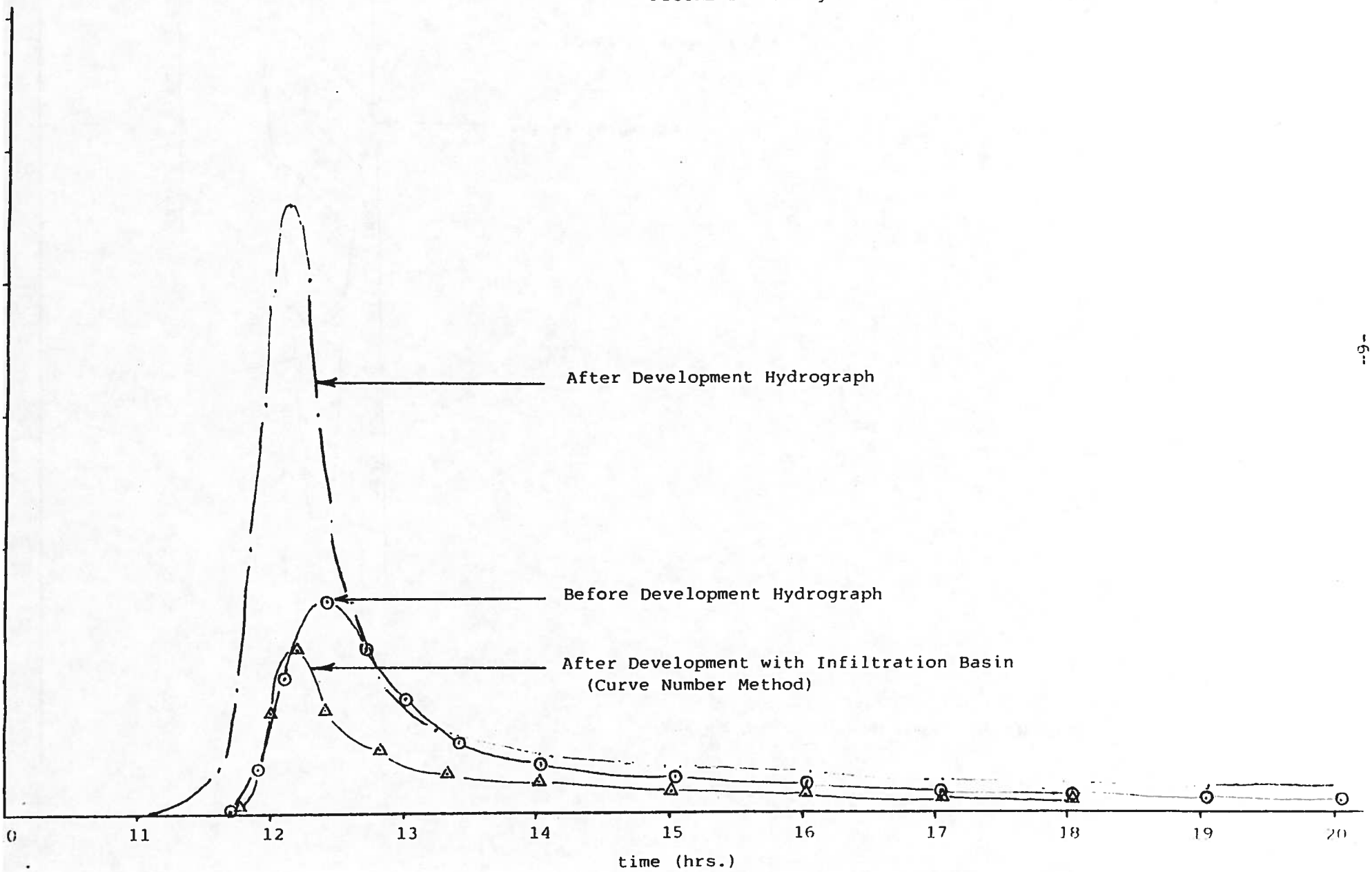
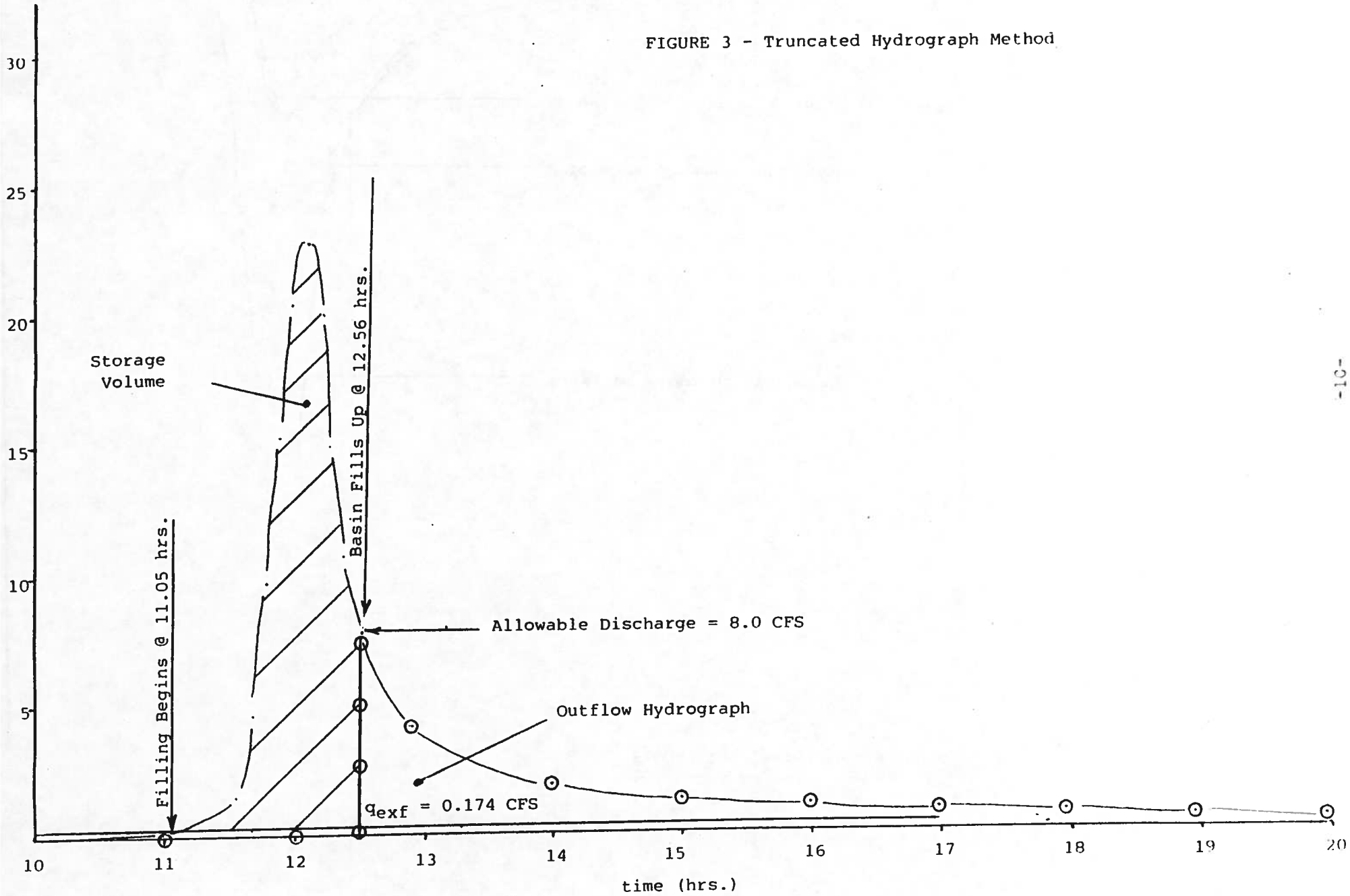


FIGURE 3 - Truncated Hydrograph Method



Step 5 - Compute the volume of exfiltration out the bottom of the basin based on a soil infiltration rate of 1.0 in/hr.

a. Convert the soil infiltration rate to a discharge rate by multiplying the soil infiltration rate in ft/sec by the bottom area in ft^2.

$$f = 1.0 \text{ in/hr} \times \frac{1 \text{ ft.}}{12 \text{ in.}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} = 2.31 \times 10^{-5} \text{ ft/sec}$$

$$q \text{ (exfiltration)} = f \times A = 2.31 \times 10^{-5} \times (75 \times 100)$$
$$= 0.174 \text{ cfs}$$

b. Determine the basin filling time from Figure 3 by subtracting the time at which the exfiltration discharge is exceeded (11.05 hrs) from the time at which the basin completely fills (12.56 hrs):

$$T = 12.56 - 11.05 = 1.51 \text{ hrs.}$$

c. Compute the exfiltration volume:

$$V \text{ (exfiltration)} = fAT$$
$$= 1.0 \text{ in/hr} \times \frac{1 \text{ ft.}}{12 \text{ in.}} \times (75\text{ft} \times 100\text{ft}) \times 1.51 \text{ hrs.}$$
$$= 944 \text{ ft}^3$$

Step 6 - Compute the adjusted volume required by the infiltration basin.

$$V_s^* = V_s - V \text{ (exfiltration)}$$

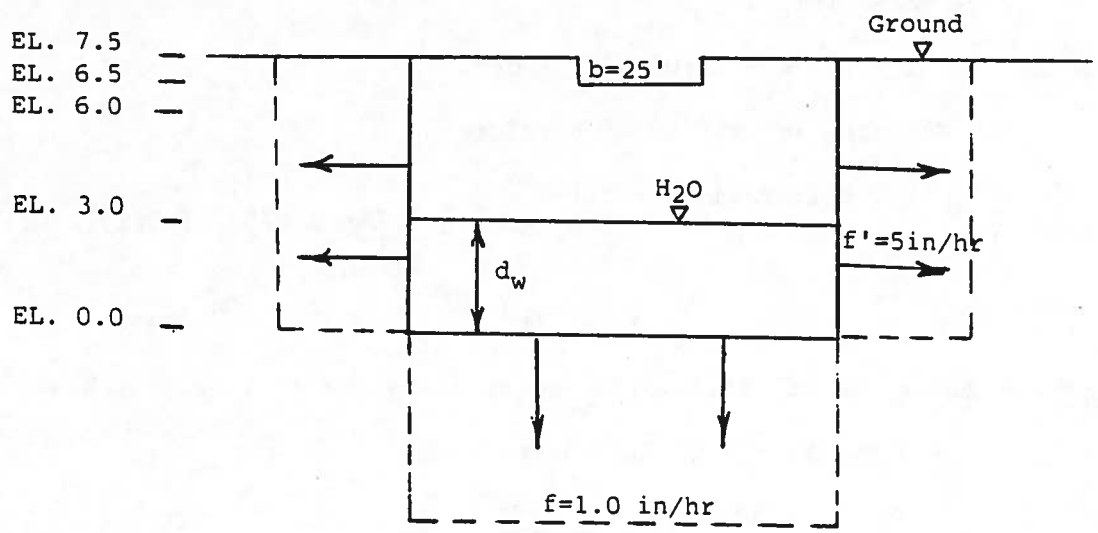
$$V_s^* = 48750 - 944 = \underline{47{,}806 \text{ ft}^3}$$

The peak discharge is 8.0 cfs and the resultant outflow hydrograph is shown in Figure 3. The resultant outflow hydrograph does not include any storage that may be provided in the outflow channel.

Method 3 - Hydrograph Routing Method

Step 1 - Develop the structure rating data for the TR-20 Program based on a 100 ft. by 75 ft. by 6.5 ft. infiltration basin, and a 25 ft. wide by 1 ft. deep outflow channel.

Assume a constant infiltration rate of 1.0 in/hr out the bottom of the basin and a triangular infiltration rate distribution out the sides of the basin. To simplify the infiltration rate out the sides, use an equivalent rectangular distribution with an average infiltration rate of 0.5 in/hr.



A_B = bottom area = 75 x 100 = 7500 ft.^{2}

A_S = side area = 2 d_w (75 + 100) = 350 d_w

Exfiltration Discharge (q_{exf})

$$q_{exf} = fA_B + f'A_s$$

$$= f(in/hr)A_B(ft^2)+f'(in/hr)A_s(ft^2) \times \frac{1\ ft}{12\ in} \times \frac{1\ hr}{3600\ sec}$$

$$= \frac{fA_B}{43200} + \frac{f'A_s}{43200} \quad (cfs)$$

$$= 0.174f + 0.008f'd_w$$

EL. (ft)	f (in/hr)	f' (in/hr)	q_{exf} (cfs)	Storage (acre-ft)
0.0	1.0	0.5	0.0	0.0
1.5	1.0	0.5	0.180	0.258
3.0	1.0	0.5	0.186	0.516
6.0	1.0	0.5	0.198	1.033
6.5	1.0	0.5	0.200	1.110

Surface Discharge (Q)

The Mannings Equation is used for simplicity to develop the outflow channel rating data.

$$Q = \frac{1.49\ AR^{2/3}S^{1/2}}{n}$$

$A = 25 \times d$
$R = A/P = 25d/25 + 2d$
$S = 0.01$ ft/ft
$n = 0.03$

$$Q = 4.97\ AR^{2/3}$$

The volume of storage provided behind the outflow channel is assumed to be ponded over the surface area of the infiltration basin. The routing would not work without any storage provided in the outflow channel.

EL (ft)	Q (cfs)	Storage (acre-ft)
6.5	0	0.0
7.0	38.1	0.090
7.5	118.0	0.170

Step 2 - Combine the subsurface and surface rating data. Include the volume of storage provided in the infiltration basin and behind the outflow channel.

Elevation (ft)	Discharge (cfs)	Storage (ac-ft)
0.0	0.0	0.0
1.5	0.180	0.258
3.0	0.186	0.516
6.5	0.200	1.110
7.0	38.1	1.200
7.5	118.0	1.280

Step 3 - Compute the peak discharge and outflow hydrograph from the TR-20 program.

Input

Elevation-discharge-storage data from Step 2.
D.A. = 0.0390 square miles
CN = 75
t_c = 0.37 hrs
P = 3.3 inches

Output

q_a (with infiltration basin) = 8.3 cfs

See Figure 4 for the resultant outflow hydrograph.

Summary

	Method	Discharge (cfs)	Volume of Storage (ft^3)
1.	Change in CN	6.1	65,340
2.	Truncated Hydrograph	8.0	47,806
3.	Hydrograph Routing	8.3	48,750

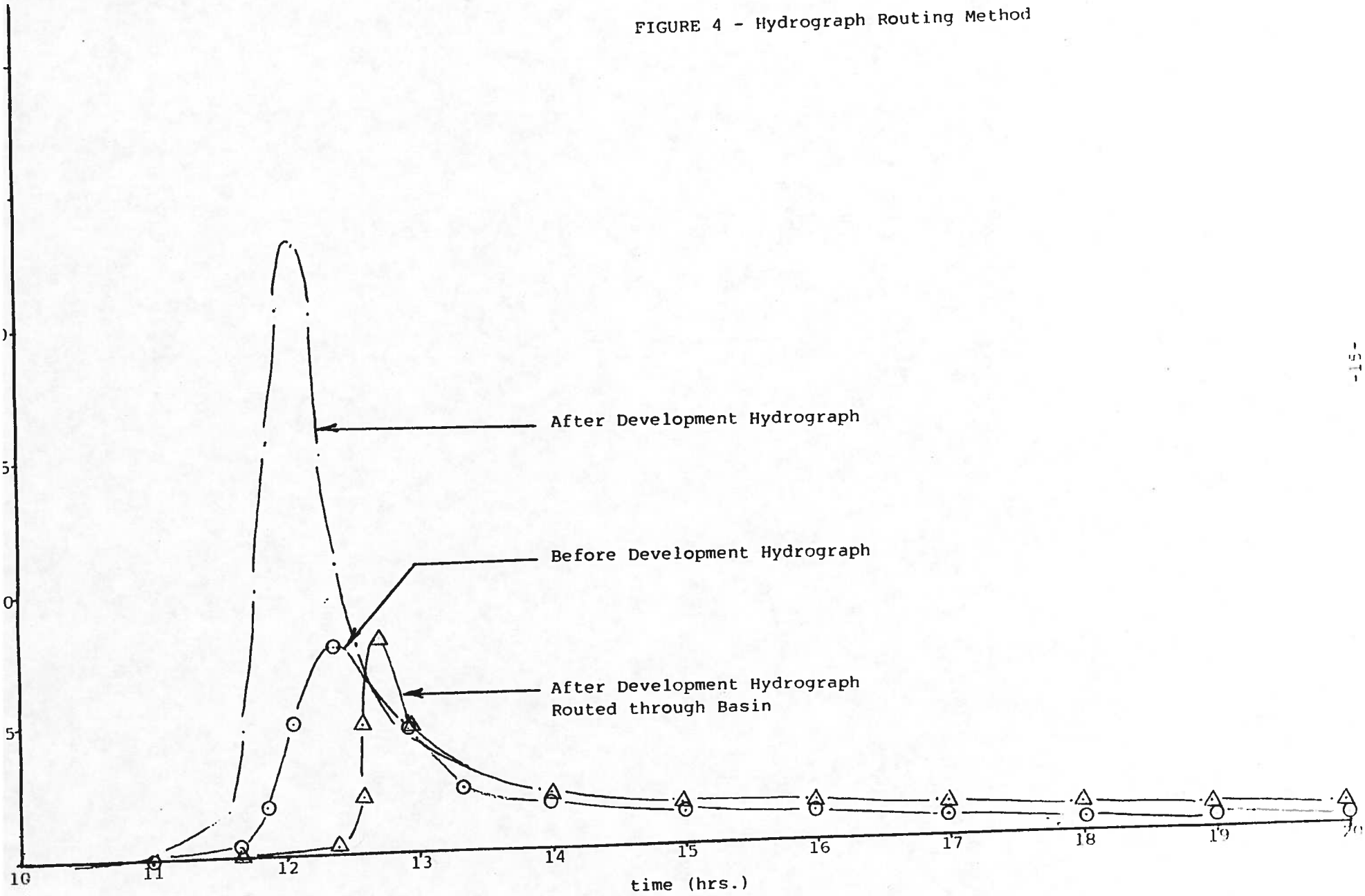



FIGURE 4 - Hydrograph Routing Method