SESSION L4-L5: THE UNIT HYDROGRAPH METHOD

OBJECTIVES

1. To calibrate the unit hydrographs of a rural and an urban catchment (L4)
2. To synthesise the flood hydrograph of a catchment for a given unit hydrograph and design storm (L4)
3. To transform a unit hydrograph of a time-base to another time-base using the S-curve. (L5)

TOOLS

IBM-compatible PC and the EXCEL program.

BACKGROUND

The unit hydrograph technique is a very simple method for synthesising the flood hydrographs of a catchment due to a given design storm. The method is based on the principle that, the *net effect* of all the overland and channel slopes and roughnesses in a catchment *on the rate of discharge,* of a *unit depth* of runoff from a catchment, can be represented by, *a single hydrograph,* called the unit hydrograph. The following are some basic points related to the method.

1. A catchment is considered as a “lumped control-volume” in the method.
2. The rainfall used in the method are *net rainfall*, that is they are the part of the total catchment rainfall that appears at the catchment outlet as direct runoff, after allowing for infiltration and other losses.
3. Each unit hydrograph is related to the *duration* of the net constant rainfall that produced the direct runoff used to calibrate it. Consequently, a short duration unit hydrograph is associated with a high intensity rainfall and vice versa for a longer duration unit hydrograph. This is because the volume of runoff is fixed at one unit, defined as one cm of water depth across the whole catchment area.
4. A set of net (effective) rainfall and direct (after baseflow removal) runoff records is required for the calibration of any unit hydrograph of a catchment.
5. The unit hydrograph of a catchment is assumed to be constant if there are no changes to the catchment characteristics. If major changes occur to the slopes and roughnesses of a catchment the hydrograph characteristics will change for the same rainfall input into the catchment.

The steps to calibrate a unit hydrograph for a catchment are as follows:

(a) Compute the direct runoff volume V from the direct runoff hydrograph.
(b) Compute the direct runoff depth D (=V/A) for the catchment with area, say A, in centimetre.
(c) Divide the ordinates of the direct runoff hydrograph by D to get the ordinates of the UH.

The steps to synthesise the flood hydrograph for a given unit hydrograph and design storm, are as follows:

(a) Compute the net rainfall by removing losses. Ensure that the time interval of the net rainfall is equal to the duration of the unit hydrograph.
(b) Compute the hydrographs associated with each value of the net rainfall.
(c) Sum the ordinates of the computed hydrographs occurring at the same time. Add the baseflow to the direct runoff hydrograph ordinates to get the total hydrograph.

PROCEDURE

(a) Calibration of the unit hydrographs for a rural and an urban catchment.

The following are the observed hydrographs at the outlet of a 95 km^2 catchment for two constant *net rainfall* events, of 30-minute duration, in the year 1960 and 1990. The catchment in 1960 was made up of mostly agricultural land. However, by 1990 most of the agricultural land has been replaced by housing and industrial developments. Calibrate the 30-minute unit hydrographs for the catchment for the rural and urban states by means of the EXCEL program. You may assume that the baseflow is constant throughout the duration of the rainfall and are equal to the discharge at time zero of the hydrographs.

<u>Observed hydrograph for the 30-minute net rainfall in 1960 (rural)</u>

Time (hr)	0	1	2	3	4	5	6	7
Flow (cu.m/s)	*6.7*	*10.2*	*51.9*	*73.6*	*104*	*147.4*	*186.6*	143.2
Time (hr)	8	9	10	11	12	13	14	15
Flow (cu.m/s)	*88.3*	*63*	*41.4*	*30.2*	*22.1*	*18.3*	*15.5*	*6.7*

<u>Observed hydrograph for the 30-ininute net rainfall in 1990 (urban)</u>

Time (hr)	0	0.5	1	1.5	2	2.5	3	3.5
Flow (cu.m/s)	0.5	*15.9*	*70.1*	*267.4*	*395.5*	*469.9*	*389.3*	*300*
Time (hr)	4	4.5	5	5.5	6	6.5	7	7.5
Flow (cu.m/s)	*210.3*	*160*	135.4	*98.9*	*89.3*	*73.9*	*66.3*	*49.5*
Time (hr)	8	8.5	9	9.5	10	10.5		
Flow (cu.m/s)	*38.6*	*28.2*	*18.8*	*8.7*	*4.7*	*0.5*		

(b) Flood hydrograph synthesis for a given unit hydrograph and design storm

Compute the *total flood hydrograph* for the following storm, for the urban catchment, using the 30-minute unit hydrograph of the catchment by means of the EXCEL program. You may assume that at the start of the storm the baseflow discharge is 0.6 cu.m/s and that it remains constant throughout the storm. Also, you may assume that there is no initial loss and that the constant infiltration loss throughout the storm is 20 mm/ hr.

Time (hr)	0-0.5	0.5-1	1-1.5	1.5-2	2-2.5
Depth (mm)	16	43	54	36	12

BATCH REPORT (L4)

1. Submit a copy of the following graphs:
   (a) the unit hydrographs for the rural and urban catchments.
   (b) the total flood hydrograph for the given design storm.
2. State the differences between the unit hydrographs of the urban compared to the rural catchment. Explain them in terms of their catchment characteristics.

3. Sketch the likely shapes of the 15 and 60-minute unit hydrographs of the urban catchment on the graph of the 30-minute urban unit hydrograph. Explain their differences.

Session L5

This session is intended as an extended exercise to complement the lectures on:

- unit-hydrograph,
- S-curve and transformation of unit hydrograph
- Synthesis of runoff hydrograph using combinations of various time-based Unit Hydrograph.

Procedure

1. Based on the 30-minute unit hydrograph of the urban catchment, establish the S-curve using the EXCEL spreadsheet. You may wish to add and staggered a series of the 30-minute UHs (1 per column, lagged by 30 minutes each) and sum them to the right. Notice the maximum number of UH columns that contribute to the sum at any one row. Also notice the ‘constant’ values at the tail end of the S-curve. Next, establish the algorithm for deriving the S-curve using S-curve addition.

2. From the S-curve, establish the 15-minute, 45-minute and 1-hour UHs. Notice the quantity of rainfall at each step and the way the scaling factor is determined.

3. Re-establish the S-curve using the 15-minute, 45-minute and 1-hr UHs. What is the main difference ?

4. How do you make use of the 15-minute and 45-minute UHs to derive a 1-hr UH without using the S-curve method ? Try it and compare with the 1-hr UH obtained.

5. The following is the net rainfall profile during a storm.

Time	0-15 min	15-60 min	60-90 min	90-150 min
Rainfall (mm)	5	45	15	5

6. Establish the runoff hydrograph :
   - Using 15-minute UH
   - A combination of appropriate UHs.

   Compare the 2 runoff hydrographs obtained.

No batch report required.