TUTORIAL-2

EXCESS RAINFALL AND DIRECT RUNOFF COMPUTATION

Problem

The rainfall-runoff data for a storm in a catchment Br. No. 807/1 are given in Table T 2.1. Theissen Weights for eight recording raingauge stations located in and around the catchment are given in Table T 2.2. The catchment area is 823.62 sq. Km. Calculate :

(a) average hourly rainfall using Theissen polygon method

(b) the direct surface runoff hydrograph after separating the baseflow from the discharge hydrograph using straight line separation technique

(c) the volume of the direct surface runoff hydrograph in mm

(d) the uniform loss rate (ϕ-index)

(e) the excess rainfall hyetograph

The discharge at recession point is 60 m^3/s. illustrates the Theissen polygons drawn around the locations of eight raingauge stations in the catchment.

Solution :

(a) Computation of average hourly rainfall using Theissen polygon method :

The average hourly rainfall values using Theissen polygon method are computed by taking the weighted mean of observed values at different stations. Mathematically,

$$AVP_i = \sum_{j=1}^{NS} W_j \, P_{i,j}, \quad \text{where } i=1, 2 \ldots\ldots\ldots\ldots \text{Nrain} \ldots\ldots\ldots\ldots \text{(T 2.1)}$$

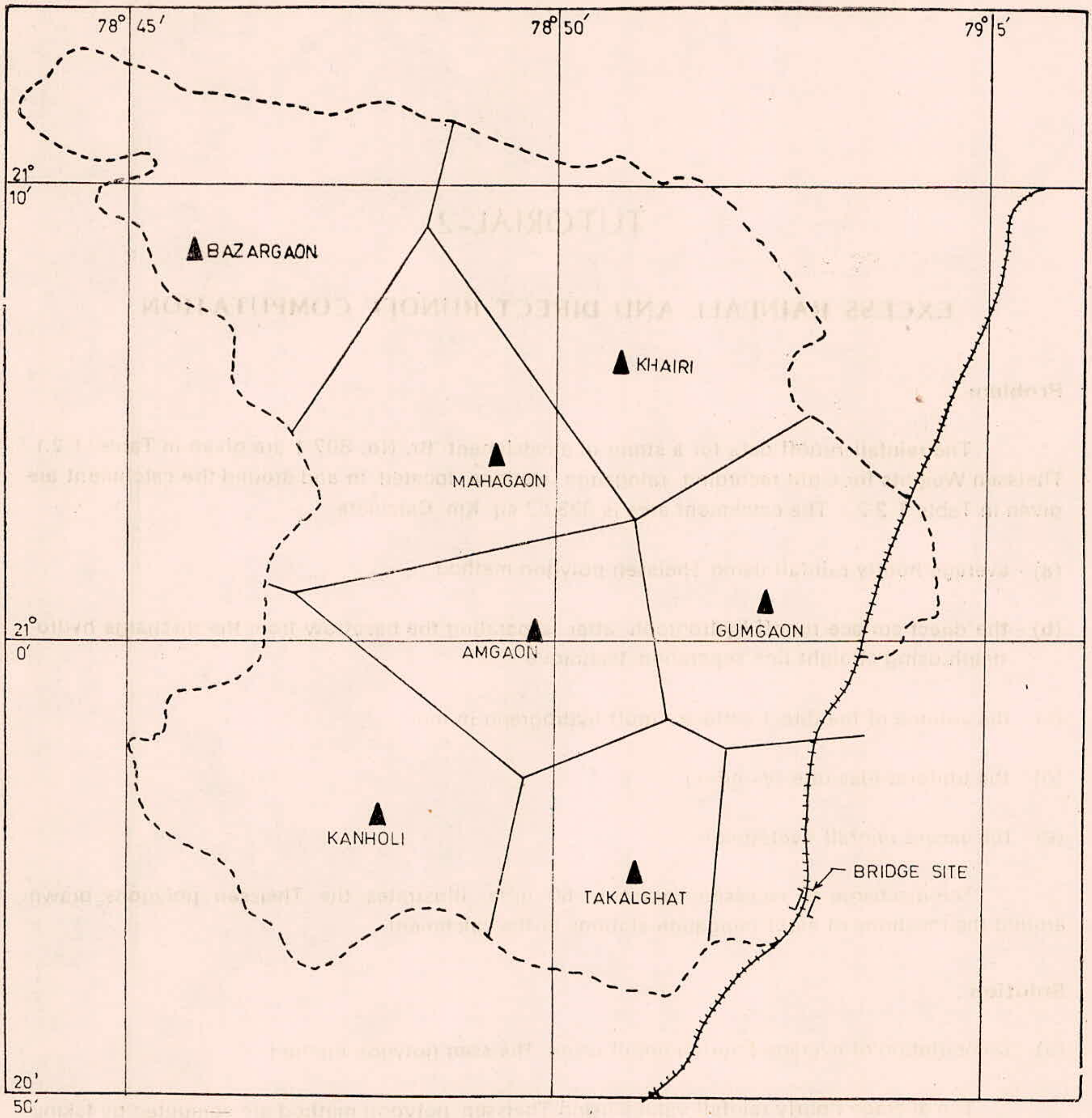
here AVP_i is the average rainfall at ith time interval,

W_j is the Theissen Weight for jth station.

$P_{i,j}$ is the recorded rainfall at the jth station for the ith time interval.

NS is the no. of recording stations.

Nrain is the maximum number of rainfall values observed at any station.



STATION	AREA (in^2)	WEIGHTAGE
BAZARGAON	3.1	0.1559
KHAIRI	3.4	0.1710
MAHAGAON	2.7	0.1358
AMGAON	2.10	0.1056
GUMGAON	2.6	0.1308
KANHOLI	3.38	0.1700
TAKALGHAT	1.80	0.0905
BRIDGE SITE	0.80	0.0404

THIESSION POLYGON

SCALE : 1″ = 4 MILES

Fig. T 2.1 Catchment Area Plan Bridge No 807/1 Sub Zone (3f)

Table T 2.1 Rainfall-Runoff Data For The Storm of Dated 16.9.1973

Time	Recorded Rainfall at Different Stations (mm)								Observed discharge
Hrs.	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	m^3/s
1	0	0	0.20	0	7.20	0	0	0	35
2	0	0	17.20	0	2.40	0	0	0	35
3	0	13.20	12.60	15.20	1.20	32.0	0	3.60	35
4	0	33.40	3.40	10.40	3.60	19.20	7.80	6.00	35
5	39.0	3.60	2.80	5.60	10.40	7.80	1.60	16.40	85
6	3.20	2.20	0	0	1.00	3.40	2 20	3.20	150
7	0.60	0.40	0	0	3.40	0	3.40	3.00	410
8	0	0.40	0	0	20.00	0	0	1,80	455
9	0	0.00	0	0	0.00	0	0	3.52	380
10									260
11									260
12									200
13									175
14									165
15									135
16									105
17									85
18									75
19									70
20									70
21									70
22									60
23									60
24									60

Table T 2.2 Name of Raingauge Stations and Their Theissen Weights

Station No.	Name	Weights
1	Bridge site	0 0404
2	Takal Ghat	0.0905
3	Gum Gaon	0.1308
4	Am Gaon	0.1056
5	Kanholi	0.1700
6	Mahagaon	0.1358
7	Khairi	0.1710
8	Bazargaon	0 1559

$$\sum_{J=1}^{NS} W_j = 1 \qquad \text{......(T 2.2)}$$

The average hourly rainfall values computed using the Eq. (T 2.1) for the storm are :

Time (hrs)	1	2	3	4	5	6	7	8	9	Average Rainfall
(mm)	1.25	2.66	9.56	10.05	8.52	1.84	1.69	3.72	0.55	

(b) Computation of the direct surface runoff hydrograph using straight line technique for base flow separation :

The computational steps are :

(i) Plot the recession limb of the discharge hydrograph on semi log graph paper taking time on arithmatic scale and discharge values on log scale.

(ii) Locate the recession point on the above plot. (The point on the graph at which the straight line changes the slope is known as the recession point).

(iii) Draw straight line from the rising point of the hydrograph to the recession point on the hydrograph for base flow separation.

(iv) Subtract the base flow ordinates from the corresponding discharge hydrograph ordinates for the estimation of direct surface runoff hydrograph ordinates.

Table T 2.3 given below shows the above computations. Here the base flow ordinates, given in column (3) are subtracted from the discharge hydrograph ordinates, given in column (2). The resulting hydrograph ordinates known as direct surface runoff hydrograph ordinates are given in column (4). Fig. T 2.2 illustrates the separation of base flow from the discharge hydrograph.

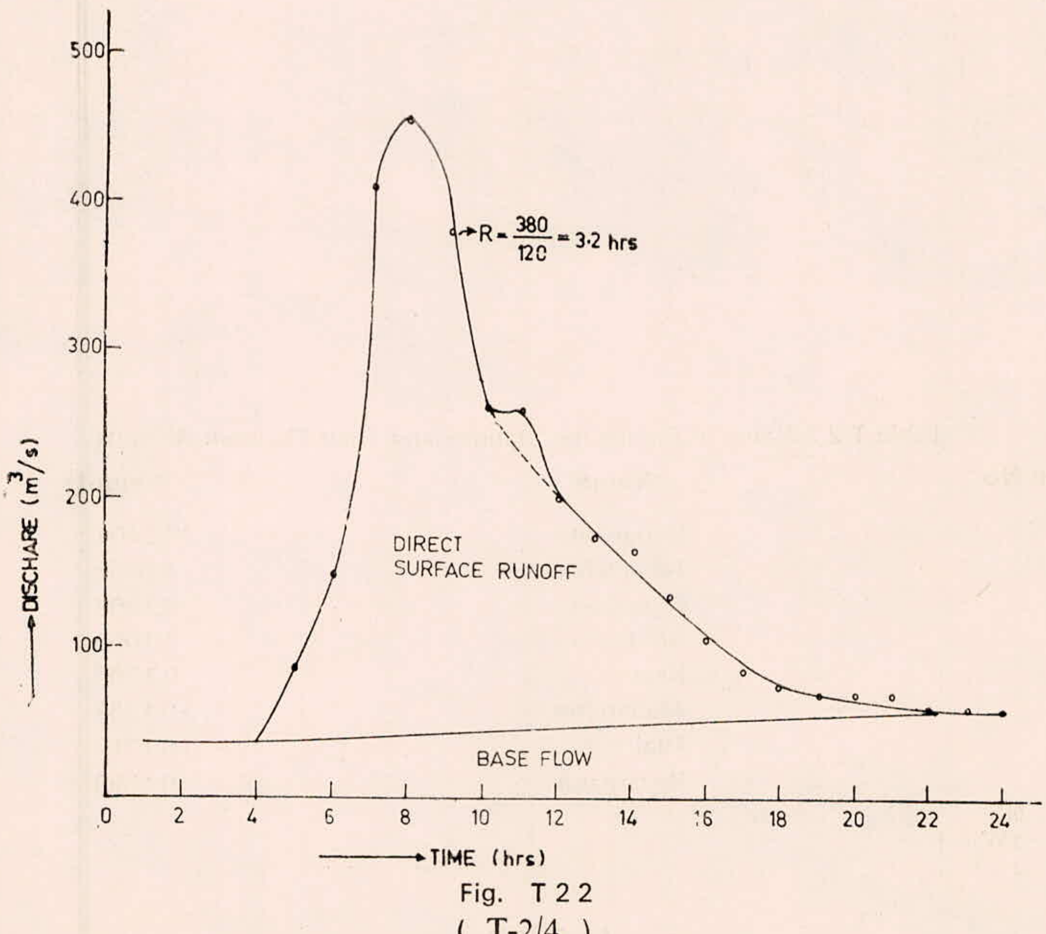


Fig. T 2 2

Table T 2.3 Estimation of Direct Surface Runoff

Time (hrs)	Discharge Hydrograph (m/s^3)	Base flow (m^3/S)	Direct surface runoff (m^3/S)
(1)	(2)	(3)	(4)=(2)−(3)
1	85	35	0
2	35	35	0
3	35	35	0
4	35	35	0
5	85	37.63	47.37
6	150	38.95	111.05
7	410	40.26	369.74
8	455	41.58	413.42
9	380	42.89	337.11
10	260	44.21	215.79
11	260	45.53	214.47
12	200	46.84	153.16
13	175	48.16	126 84
14	165	49.47	115.53
15	135	50.79	84.21
16	105	52.11	52.89
17	85	53.42	51.58
18	75	54.74	20.26
19	70	56.05	13.95
20	70	57.37	12.63
21	70	58.68	11.32
22	60	60	0
23	60	60	0
24	60	60	0

(c) Computation of the volume of the direct surface runoff hydrograph in mm

The computational steps are :

(i) Compute $DSRO_{vol}$ (the direct surface runoff volume in Cumec-hour) as :

$$DSRO_{ol} = \triangle t \sum_{i=1}^{n} DSRO_i \qquad \text{......(T 2.3)}$$

For the above problem, $\triangle t=1$ hour, $n=17$

and $\sum_{i=1}^{n} DSRO_i$ is obtained by adding the direct surface runoff values given in column (4) of the Table T-2.3 which is equal to 2331.32 therefore,

$$DSRO_{vol} = 1 \times 233\ \ 1.32$$

$$= 2331.32 \text{ cumec-hour}$$

(ii) Compute $DSRO_{depth}$ in mm as :

$$DSRO_{depth} = \frac{DSRO_{vol} \times 3600 \times 10^3}{\text{Catchment area (km}^2) \times 10^6} \quad \text{......(T 2.4)}$$

For the given problem,

$$DSRO_{depth} = \frac{2331.32 \times 3600 \times 10^3}{823.62 \times 16^6}$$

$$= 10.19 \text{ mm}$$

(d) Computation of the uniform loss rate (ϕ-index) :

The computational steps are :

(i) Calculate the volume of the direct surface runoff hydrograph in mm. For the given problem it is already calculated as 10.19 mm.

(ii) Compute the total of the average hourly rainfall. This is equal to 39 84 mm for the given storm.

(iii) Compute the total infiltration loss as :

Total infiltration (mm) = P — R ......(T 2.5)

where P=Total rainfall (mm) contributing in the direct surface runoff
R=volume of the direct surface runoff hydrograph (mm)

Total infiltration (mm) = 39.84-10.19
= 29.65

(iv) Assume time of rainfall excess (t_e) equal to the total duration of the storm for the first trial i,e t_e=9 hours (For the given problem)

(v) Compute the first trial value of ϕ as :

$$= \frac{P-R}{t_e} \quad \text{......(T 2.6)}$$

$$= \frac{29.65}{9}$$

$$= 3.29 \text{ mm/hr.}$$

(vi) Compare the ϕ=3.29 mm/hr with the intensity of each individual block of rainfall. This value of ϕ makes the rainfalls of first hour, second hour, sixth hour, seventh hour and ninth hour ineffective as their intensities are less than 3.29 mm/hr. The value of the total rainfall contributing to the direct surface runoff and the time of rainfall excess (t_e) are therefore modified.

Modified value of total rainfall P=9.56+10.05+8.52+3.72=31.85 mm
and Modified value of t_e=4 hours.

(vii) Compute second trial value of infiltration rate (ϕ) as :

$$= \frac{P-R}{t_e}$$

$$= \frac{31.85-10.19}{4}$$

5.42 mm/hr

(viii) Compare the ϕ=5.42 mm/kr with the intensity of each individual block of rainfall. This value of makes the rainfall of eight hour ineffective in addition to the five rainfall blocks mentioned at step (vi).

Therefore, the modified value of total rainfall

P=9.56+10.05+8.52

=28.13 mm

modified time of excess rainfall t_e=3 hrs.

(ix) Compute third trial value of infiltration rate (ϕ) as :

$$= \frac{P-R}{t_e}$$

$$= \frac{28.13-10\ 19}{3}$$

$$= 5.98 \text{ mm/hr}$$

(x) The value of ϕ=5.98 mm/hr is the required one as it gives the time of excess rainfall (t_e) equal to 3 hrs and the volume of DSRO (R) equal to 10.19 mm

Thus, the uniform loss rate computed for the given problem is 5.98 mm/hr.

(e) Computation of excess rainfall hyetograph :

The excess rainfall hyetograph is computed after accounting the losses from the average hourly rainfall values taking the uniform loss rate equal to 5.98 mm/hr. If the individual rainfall blocks (mm) are less then the uniform loss then it is assumed that the losses during those periods are the same as the volume of the individual rainfall blocks (mm). Table T 2.4 shows the computation of excess rainfall hyetograph. Here the average rainfall values are given in column (2) and the losses are in column (3). The excess rainfall ordinates obtained from subtracting the values of column (3) from column (2) are given in column (4). Fig. T 2.3 shows the uniform loss rate and excess rainfall hyetograph.

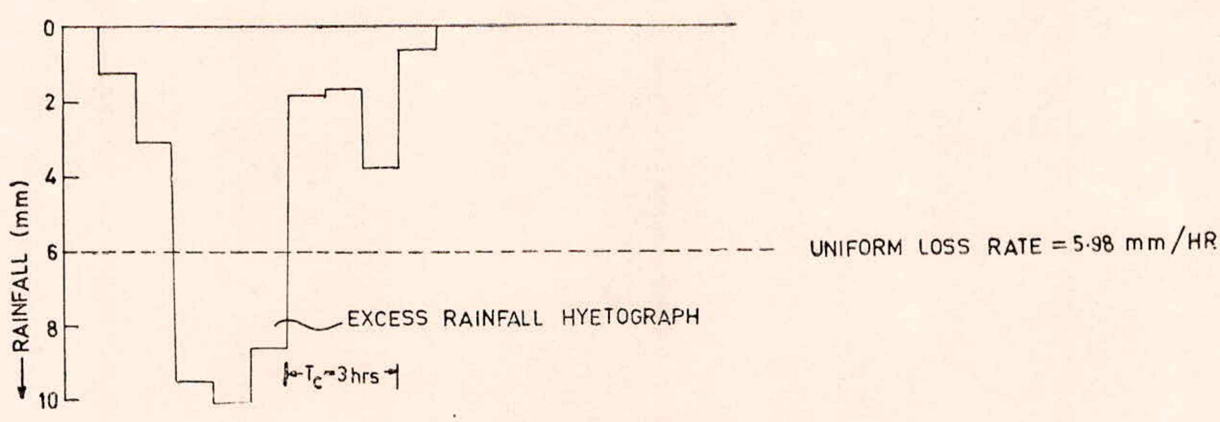


Fig. T 2.3

Table T-2.4 Computation of excess rainfall hyetograph

Time (hrs)	Average rainfall (mm)	Loss (mm)	Excess rainfall (mm)
(1)	(2)	(3)	(4) = (2) − (3)
1	1.25	1.25	0
2	2.66	2.66	0
3	9.56	5.98	3.58
4	10.05	5.98	4.07
5	8.52	5.98	2.54
6	1.84	1.84	0
7	1.69	1.69	0
8	3.72	3.72	0
9	0.55	0.55	0