Tutorial 2 - Exercise 2: Computation of Storm Runoff and Design of Storm Sewer

Design a system of storm sewers for the area shown in Figure 1 based on the Rational Formula for the estimation of peak runoff.

Basic Data and Assumptions

Imperviousness - Built up and paved area	0.7
Imperviousness – Open space, lawns, etc,	0.2
Inlet time -Built up and paved area (tb)	8 Minutes
Inlet time - Open space, lawns (t1)	15 Minute
Minimum velocity in sewer	0.8 mps
Minimum depth of cover above crown	0.5 m

Rainfall intensity = consider once in 5 year storm as the area is central and high priced. (Use Table 3 for the record of rainfall intensity and frequency of rainfall).

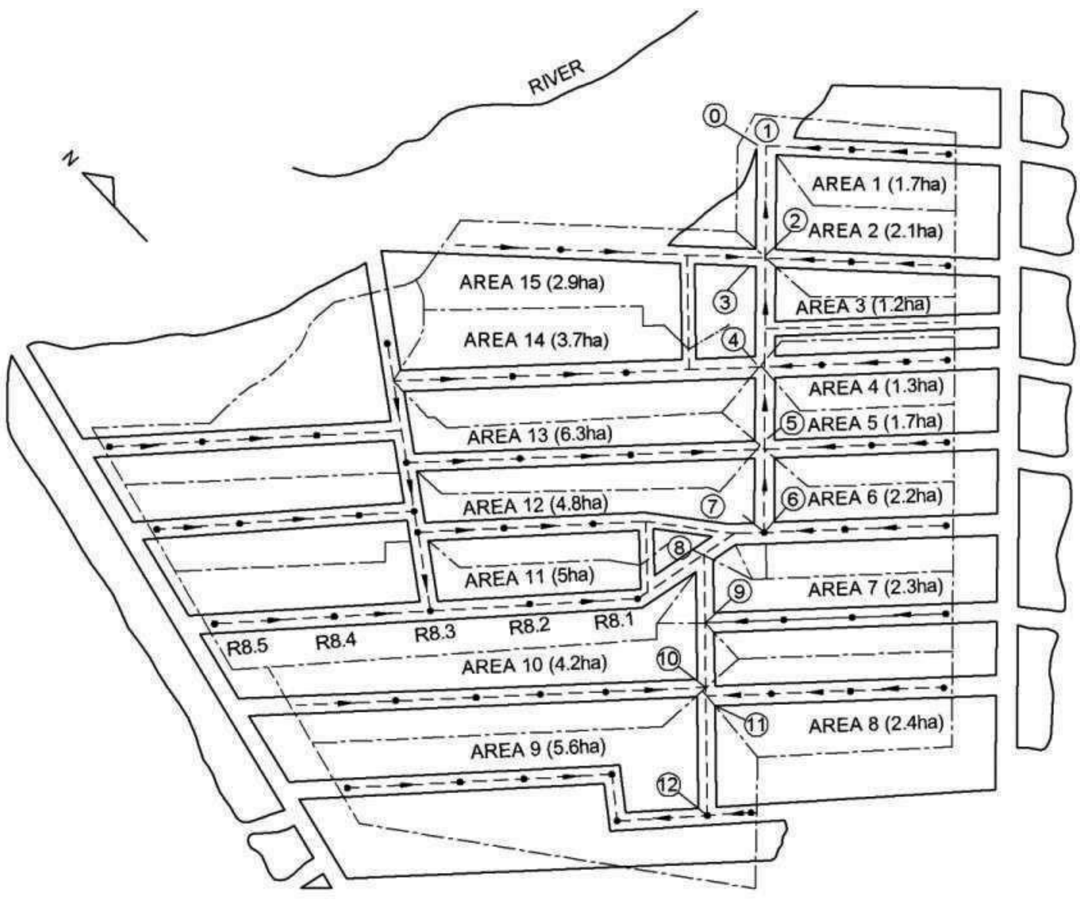

Figure 1

Procedure:

1. Quantity of storm water runoff is calculated using the Rational Formula i.e Q=10CiA; where, Q: Runoff in m^3/h; C: Coefficient of runoff; i: Intensity of rainfall in mm/h; and A: Area of drainage district in hectares.

2. Storm water runoff is determined in the following manner.

   Residential areas

- Peripheral areas – twice a year
- Central and comparatively high-priced areas - once a year to once in 5 years
- Commercial and high-priced areas – once in 5 years to once in 10 years

   From the rainfall records for the last 25 years given in Table 1, the storm occurring once in 5 years, i.e. 5 times in 25 years, the time-intensity values for this frequency are obtained by interpolation and can be tabulated as per Table 2.

Table 1: Duration Versus Intensity of Storms

Duration in Minutes	**Intensity Mm/hr**	**30**	**35**	**40**	**45**	**50**	**60**	**75**	**100**	**125**
		No. of storms of stated intensity or more for a period of 26 years								
5						100	40	18	10	2
10				90	72	41	25	10	5	1
15			82	75	45	20	12	5	1	
20		83	62	51	31	10	9	4	2	
30		73	40	22	10	8	4	2		
40		34	16	8	4	2	1			
50		14	8	4	3	1				
60		8	4	2	1					
90		4	2							

Table 2: Intensity Versus Duration Data for a Storm of Given Frequency

Intensity, i mm/h	30	35	40	45	50	60
Duration, t minute	…	…	…	…	…	…

The generalised formula adopted for intensity and duration is

$$i = {}^{a}/_{t^n}$$

Where, i: Intensity of rainfall in mm/h; t: Duration in minutes; and a and *n* are constants. Values of a and n are to be estimated using regression analysis for above mentioned equation and data.

3. Using the regression equation i = (a / t^n), i.e. after substituting the values of a and n for different values of i for various values of t can be calculated and tabulated as follows:

Table 3: Intensity-duration Curve for Once in 5 years Storm

	5	10	15	20	25	30	35	40	45	60	80	100	120
$i = a/t^n$													

4. Calculation of Runoff Coefficient:

Table 4: Percentage of Imperviousness of Areas

S No	Type of Area	Percentage of Imperviousness
1	Commercial and Industrial Area	70-90
2	Residential Area - High Density - Low Density	 61-75 35-60
3	Parks and undeveloped areas	10-20

When several different surface types or land use comprise the drainage area, a composite or weighted average value of the imperviousness runoff coefficient can be computed, such as:

$$I = [(A_1 I_1) + (A_2 I_2) + \ldots\ldots + (A_n I_n)]/[(A_1 + A_2 + \ldots\ldots + A_n)] \qquad (1)$$

Where, I is Weighted average imperviousness of the total drainage basin; A1, A2, …., An are Sub drainage areas; and I1, I2, …., In are Imperviousness of the respective sub-areas.

Imperviousness of the respective sub-areas:

Residential areas

- Peripheral areas – twice a year
- Central and comparatively high-priced areas - once a year to once in 5 years
- Commercial and high-priced areas – once in 5 years to once in 10 years

5. Another graph (Figure 2) of runoff-coefficient C vs. duration time t is plotted as per values of duration of storms of interest as per Table 3.

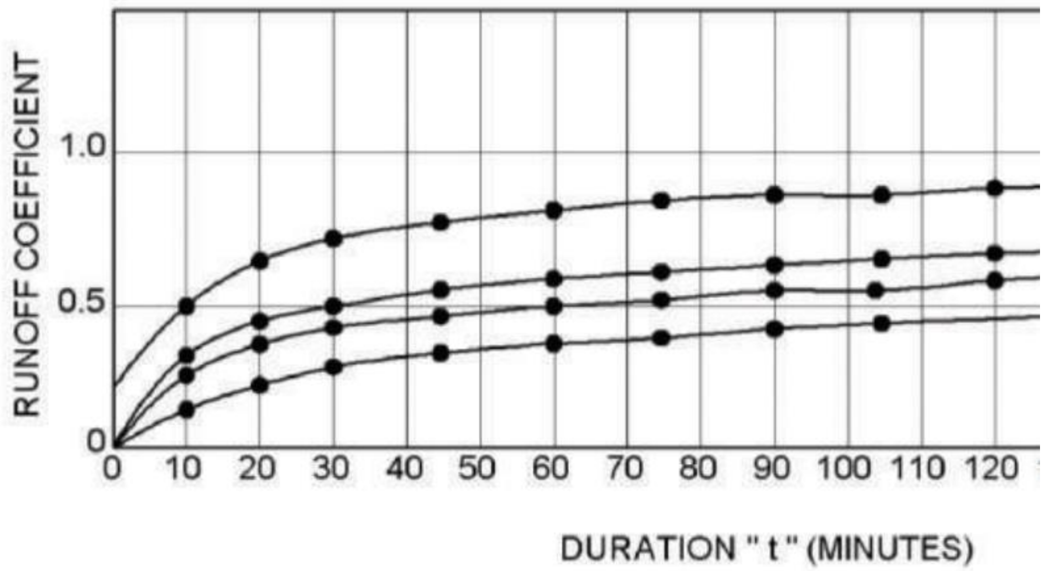

Figure 2 After horner area rectangle

6. The value of 10 C i gives the rate of runoff in m3/h per hectare of the tributary area.
7. Another graph (Figure 2 A3.1-5) of runoff-coefficient C vs. duration time t is plotted as per values of duration of storms of interest as per Table 3.

8. The value of 10 C i gives the rate of runoff in m3/h per hectare of the tributary area.

DESIGN OF STORM SEWER SYSTEM

Table A3.1-2 gives the various components of the storm sewer system design. Column 1-4 identify the location of drain, street and manholes.

Columns 5-6 record the increment in tributary area with the given imperviousness factors. Column 7 gives the tributary area increment with equivalent 100 percent imperviousness factor. Column 8 records the total area served by each drain.

Column 9 records the time of concentration at each upper end of line (drain).

The time of concentration is found by taking the weighted average of the two areas. i.e.,

$$t_c = \frac{A_1 t_b + A_2 t_1}{A_1 + A_2}$$

Where,

A_1: Built up area.

A_2 : Area of lawns

Column 10 records the time of flow in each drain. For example, the time of flow in line 1 is calculated to be 70 / (60 x1.0) = 1.17 min.

Column 11 is the total time of concentration for each drain.

Column 12 is the value of runoff as 10 C i read from the Figure A3.1-6 for the corresponding time of concentration.

Column 13 gives the total runoff from each tributary area.

Column 14 gives the runoff in lps from each tributary area.

Columns 15-18 record the chosen size, required grade resulting capacity, velocity of flow for each drain or line. These designs of storm sewers are computed from the Manning's chart for each required flow and maintaining a minimum velocity.

Columns 19-23 identify the profile of the drain.

Column 19 is taken form the plan.

Column 20 = Col.19 xCol.16

Column 21 the required drop in manholes is obtained directly from the recommended values in section 3.17.1.

Column 22 gives invert elevation at the upper end with minimum cover of 0.6m at starting manhole.

Table 5

Line Number	Location of drain			Tributary area (hectares) increment				tc Time of Concentration			Runoff m^3/hr		Flow Q	Design						Profile		
	Street	Manhole Froml	Manhole To	0.7 Imp Factor	0.2 Imp Factor	Eq 100% Imp Factor	Total Area	Time of Inlet to Upper End	Time of Flow in Drain	Total	Per Hectare (10 Ci)	Total	Lps	Dia in mm	Slope m/1000	Capacity Lps	Velocity Mps	Length - m	Fall - m	Drop in Man hole	Invert Elevation Upper end	Invert Elevation Lower end
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	South st	5	4											200	10.0	32	1.0	70		0.000		
2		4	3											250	6.65	50	1.0	125		0.025		
3	North south St.2	R32	R 3.1											250	6.65	50	1.0	70		0.000		
4		R31	3											350	4.55	98	1.0	70		0.050		
5	South St.	3	2											450	3.14	160	1.0	125		0.066		
6	North south St.3	R2.2	R 2.1											200	10.0	32	10	70		0.000		
7		R21	2											300	5.55	70.	1.0	70		0.050		
8	South St.	R2	1											600	2.22	280	1.0	160		0.200		
9	North south St.4	R12	R1.1											250	10.0	60	1.25	70		0.000		
10		R11	1											350	5.0	100	1.1	70		0.050		
11	South St.	1	Pump house											700	1.67	400	10	25		0.234		

Table 5: Runoff Coefficients for Times of Concentration

Duration, t, minutes	10	20	30	45	60	75	90	100	120	135	150	180
Weighted Average Coefficient												
A. Sector concentrating in stated time												
a. Impervious	0.525	0.588	0.642	0.700	0.740	0.771	0.795	0.813	0.828	0.840	0.850	0.865
b. 60% Impervious	0.365	0.427	0.477	0.531	0.569	0.598	0.622	0.641	0.656	0.670	0.682	0.701
c. 40% Impervious	0.285	0.346	0.395	0.446	0.482	0.512	0.535	0.554	0.571	0.585	0.597	0.618
d. Pervious	0.125	0.185	0.230	0.277	0.312	0.330	0.362	0.382	0.399	0.414	0.429	0.454
B. Rectangle (length= 4 x width) concentrating in stated time												
a. Impervious	0.550	0.648	0.711	0.768	0.808	0.837	0.856	0.869	0.879	0.887	0.892	0.903
b. 50% Impervious	0.350	0.442	0.499	0.551	0.590	0.618	0.639	0.657	0.671	0.683	0.694	0.713
c. 30% Impervious	0.269	0.360	0.414	0.464	0.502	0.530	0.552	0.572	0.588	0.601	0.614	0.636
d. Pervious	0.149	0.236	0.287	0.334	0.371	0.398	0.422	0.445	0.463	0.479	0.495	0.522

Source: CPHEEO, 1993