



## 5. PLANNING AND DESIGN OF SURFACE DRAINS

### 5.1 Introduction

The principal source of water stagnating on the fields and in low-lying areas in the monsoon is rainfall confined mostly to the four months from June to September. Major rivers and rivulets overflow their banks adding to the local drainage congestion. Drainage congestion caused due to natural factors or due to improper planning, affects agricultural production. In flat areas disposal of storm run-off through natural drainage takes considerable time due to adverse topographical features. In some cases such as in flat bowl shaped basins, natural outfalls do not exist. Even when the natural drainage has an outlet to a river, the area is not drained as long as the river continues to be in floods thus denying drainage by gravity. The resulting drainage congestion or accumulation of water on land affects crops, as most crops cannot withstand submergence beyond a particular depth for long duration. Problems of drainage are also created on account of inadequate waterways structures like bridges and culverts. Railway lines and roads constructed across natural drainage lines obstruct free flow of drains.

Drains are provided with the objective of quickly relieving excess water from agricultural areas, urban areas and other land areas and disposing off surplus water. Proper disposal of surplus rainwater is essential to avoid its percolation down to the water table and consequent water logging problems. Drains are also constructed for leaching agricultural lands to prevent salt accumulation. It is imperative to plan and design surface water drains appropriately so as to dispose of surplus rain water within minimum time.

### 5.2 Existing Design Criteria for Drains

There is wide variation in design criteria due to factors such as topography, intensity and pattern of rainfall, soil characteristics and nature of crops, intensity of development etc. Some states adopted the empirical formula like Dicken's, Ryve's or Boston Society formula and in some states the practice have been evolved after taking into consideration the type of crop, tolerance, submersion and duration, intensity of rainfall and optimum time of disposal while in some other States no scientific basis or rational approach has been adopted.

In NCR also the constituent States have adopted different methods for the design of drainage channels. In the design of surface drainage network, the following are the basic elements:

- i) **Design storm rainfall:** Duration and frequency of rainfall for which the protection should normally be provided to the agriculture in rural area and to the people in urban area.
- ii) **Tolerance period:** Time of submersion to avoid significant damage.
- iii) **Run off factor:** Applicable for design storm rainfall of selected duration and frequency.
- iv) **Design of drainage:** Design of a channel that is capable of draining out the computed run off within the tolerance period. The design provides the details of cross section, slope, and type of surface.



### 5.2.1 Existing Design Criteria for Drains in Uttar Pradesh

The Technical Advisory Committee (TAC) of UP State constituted in 1978 recommended the following design criteria:

- i) Three-day rainfall storm with 15 years return period worked out from long-term data should be taken as the design storm rainfall for the drains.
- ii) Runoff should be taken as 15% for Western Zone of UP and 30% for the Eastern zone. Entire area of UP sub-region of NCR lies in Western Zone.
- iii) The allowable period of submergence should be taken as 7 days for areas where the principal crops grown are paddy and sugarcane and 3 days where the crops are Maize, Jowar and Bajra etc.
- iv) Waterway of masonry works should be provided for 1.5 times the design discharge of the drains, and foundations be designed for 30% extra discharge over waterway design discharge.

The TAC suggested that further detailed investigations should be carried out in the field and if necessary the recommendations be modified suitably. It had also been recommended that the maximum allowable periods of submergence for the various crops be verified from the Agriculture Department.

The 3-day maximum rainfall of 15 years return period and the runoff factors recommended by the TAC for the districts of UP sub-region of NCR are given in Table 5.1.

**Table 5.1 Design Criteria for UP sub region**

Sl. No.	District	3 day maximum rain fall of 15 yrs. Return period (mm)	Drainage Factors in Cumec/sq. km. with submergence of	
			7 days	3 days
1.	Ghaziabad (30% runoff)	430.96	0.21	0.49
2.	Meerut (15% runoff)	254.06	0.06	0.15
3.	Bulandshahr (15% runoff)	307.61	0.08	0.18

Source: Technical Advisory Committee, UP, 1978

### 5.2.2 Design Criteria for Drains in Haryana

The existing system of drainage in the Haryana state was designed on the basis of an empirical Boston Society formula:

$$Q = C A^{1/2}, \text{ where}$$

Q = Discharge in cusecs

A = Catchment area in square miles

C = Coefficient to account for catchment characteristics and its value for Haryana area was taken as 200.



In working out the drain capacities, an ad-hoc reduction factor was applied depending upon catchment area as given below on the premise that relatively smaller sections gave better hydraulic performance than those designed for peak discharge.

**Table 5.2 Reduction factor for discharge in Haryana sub region**

Sl.No.	Catchment Area	Reduction Factor
i)	Upto 100 mile <sup>2</sup> (258.9 km <sup>2</sup> )	1/12
ii)	100 to 250 mile <sup>2</sup> (258.9-645 km <sup>2</sup> )	1/8
iii)	Above 250 mile <sup>2</sup> (645 km <sup>2</sup> )	1/4

The intensity of rainfall adopted is 25mm per hour and run off coefficient is 1/8 for designing of storm water drainage channels in Haryana urban area. Banks of carrier drains and cross drainage works are designed for peak hours.

### 5.2.3 Existing Design Criteria for Drains in Delhi

Recommendations of Reddy Committee 1959: Reddy Committee was constituted in 1959 to study the problems of flooding/drainage congestion and suggest remedial measures. Reddy Committee recommended the following criteria for Drainage system design for Delhi:

**Rural Area:** The drainage system for the rural areas of Delhi should be so designed as to restrict flooding to a maximum period of three days with return period of five years. The maximum three days precipitation likely to occur once in five years is 208 mm (8.2 inch), which works out to a run off of about 10 cusecs per sq mile (0.11 cumec/km<sup>2</sup>) of catchment area. The run off coefficient adopted is 0.15. For semi hilly rural drains the run off coefficient adopted is 0.30 leading to run off of about 0.22 cumec/km<sup>2</sup>. The Committee recommended remodelling to be carried out on this basis and suggested that run off factor for hilly area be suitably increased.

**Urban Area:** The drains in urban areas are to be designed for 1-hour rainfall depth of 43.7mm with a return period of 2 years. An areal distribution factor of 90% and run off coefficient of 35% has been adopted for arriving at the run off of 0.5 inches per hour or 0.5 cusec per acre i.e. 3.8 cumec/Km<sup>2</sup>.

### Master Plan for Drainage (1976)

In order to address the problems of flooding in Delhi, after the Reddy Committee, Moti Ram Committee (1965), S.P. Jain Committee (1968) & Tripathi Committee were constituted. Irrigation & Flood Control Department of NCT-Delhi prepared a Master Plan for Storm Water Drainage (SWD) for Delhi in June, 1976 which was considered by Technical Experts Committee (TEC). The TEC approved the Plan in general and decided that the Master Plan to be utilize-d as an Outline Plan. However, the drainage norms could not be finalized by TEC.



This Plan was based on following:

### Urban Areas

i) Time of Concentration	=	0.5 hr
ii) Storm Intensity (2 yr return period)	=	63.5 mm (2.5 inch/hr.)
iii) Average run off factor	=	0.6
iv) Average run off Q	=	2.5x0.6 =1.5 inch/hr (i.e. 1.5 cusec/acre) or =10.5 Cusecs/Km <sup>2</sup>

However, flooding of streets for an hour or so may be allowed and drains were designed for 1 cusec/acre.

The intensity of rainfall for one hour-storm duration for various return periods was indicated as under:

i) 2 Yrs return period	:	43.7 mm/hr. (1.72 inch/hr.)
ii) 5 Yrs return period	:	58.2 mm/hr. (2.29 inch/hr.)
iii) 10 Yrs return period	:	63.2 mm/hr. (2.73 inch/hr.)
iv) 25Yrs return period	:	83.8 mm/hr. (3.30 inch/hr.)

It was further stipulated in the above mentioned Report that whenever, Master Plan 2001 is prepared by DDA, Master Drainage Plan shall be re-considered and updated.

## 5.3 Planning and Design of Drainage System for Urban Area

The characteristics of urban areas are different from rural areas. Due to high concentration of population and economic activities in urban area the loss to life and property is much higher compare to rural area. This necessitates a different approach for design of storm water drains in urban areas. Various agencies have prepared Design Manuals for Drainage which have been discussed in subsequent paras.

### 5.3.1 Design Manuals: National and International

The Central Public Health and Environmental Engineering Organization (CPHEEO), under the Ministry of Urban Development (MoUD), Govt. of India have published the “Manual on Sewerage” (1993). This manual has given extensive guidelines for sewer design, but has given only a small section for storm drainage design. However, even this was not being followed by many cities in the past. This Manual mentions a uniform design rainfall intensity of 12-20 mm/hour for all cities and does not take into account the spatial distribution of rainfall over India or within the cities. Systems designed with these values will cause flooding, whenever rainfall intensity values exceed 20 mm/hour. However, while taking up projects under JNNURM, rainfall data obtained from Self-Recording Rain Gauge stations is followed, which takes into account the rainfall pattern of the cities. The Ministry of Urban Development



(MoUD) has constituted an “Expert Committee for the preparation of Urban Storm Drainage Manual”. The comprehensive Urban Storm Drainage Design Manual is under preparation.

The Indian Roads Congress (IRC) brought out guidelines on urban drainage in 1999 (SP-501999, IRC). This provides guidance for drainage design for roads, but does not provide design information on rainfall intensities to be adopted for various cities. For example, it mentions that Mumbai drains are being designed for 50 mm/h and Chennai for 25 mm/h, but does not provide guidelines for future planning for other Indian cities. This will take into account current international practices, the locations specific factors and rainfall pattern of the cities and future needs.

Most countries have dedicated Codes and Manuals for storm water drainage design. USA has the “Urban Drainage Design Manual”, published by the Federal Highway Administration of the US Department of Transportation (2009, Revised in August, 2013 Third Edition). Moreover, each state/ country has brought out its own Manual and, in many cases, even individual cities have their own city-specific Manual. These are updated regularly, some of them are on an annual basis. European countries are now following a common code on “Drainage and Sewer System Outside Buildings”. In Australia, the “Australian Rainfall and Runoff Manual” (2008, 4th edition) is used in the various states of Australia, while the north-eastern state of Queensland, which experiences the monsoon type rainfall, has its own storm water drainage manual. The national meteorological agencies in most countries have developed Intensity- Duration-Frequency (IDF) curves from the rainfall records and provide these to the design engineers for carrying out urban drainage design.

For better urban flood management, many cities like Bangkok, Tokyo, Singapore, etc., have developed a real-time satellite-radar-rainfall based warning system with adequate number of radars and ARGs. Regular de silting of drains is also carried out on a time bound schedule in many important cities.

### 5.3.2 National Disaster Management Manual

Manual prepared by National Disaster Management Authority for National Disaster Management has dealt this issue in detail. The same has been discussed below:

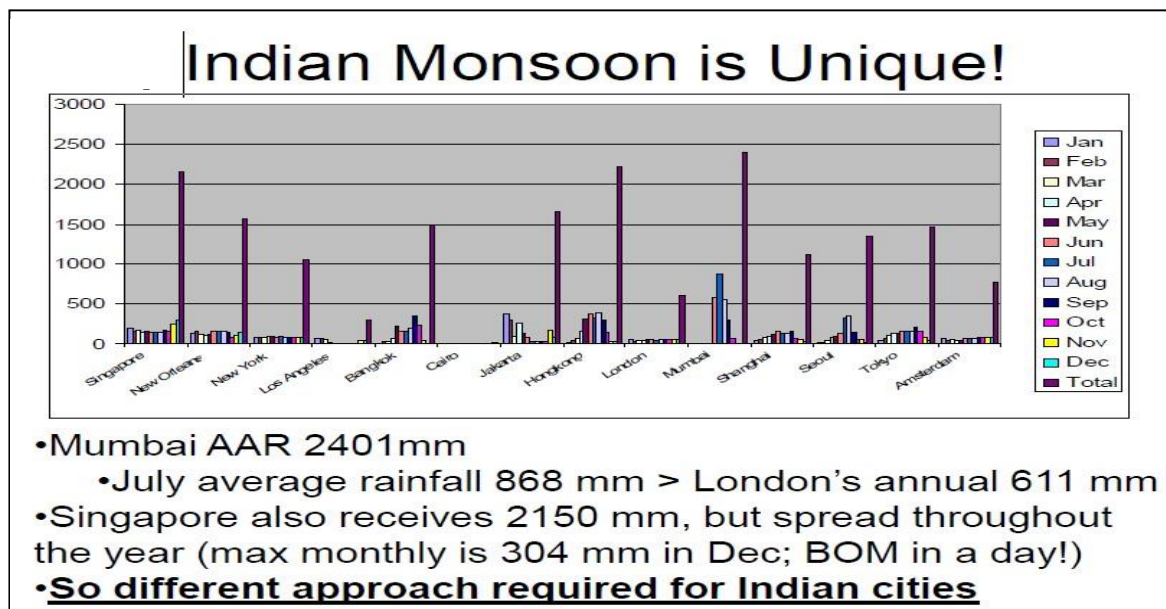
- i) **Catchment as basis for Design:** States and cities have political and administrative boundaries. However, rainfall and runoff processes are independent of these boundaries, and depend on the watershed delineation. The outline of the drainage divide must follow the actual watershed boundary rather than the administrative boundaries. Each urban area may consist of a number of watersheds. A watershed is the geographic region within which water drains into a stream, river, lake or sea. The watershed may be composed of several sub watersheds and catchments. The catchment is the area draining surface water to a particular location or outlet point. Catchment will be the basis for planning and designing the storm water drainage systems in all Urban Local Bodies (ULBs).
- ii) **Contour Data:** Accurate contours are necessary for determining the boundaries of a watershed/catchment and for computing directions of flow. Detailed contour maps at required



resolution should be prepared for proper delineation of drainage catchments. Contour mapping of urban areas will be prepared at 0.2 to 0.5 m contour interval for detailed delineation of the watershed/catchment for planning drainage systems.

iii) **Rainfall Variations:** The conventional practice for designing of a drainage system is to choose an appropriate, statistically relevant design storm to establish the storm water flows to be conveyed, based on existing national and international practices. Design storms can be estimated from rainfall data records where available. Rainfall is the main driver of runoff processes.

**Box 5.1 Indian Monsoon is Unique**



The frequency and intensity of rainfall in India, not only shows a great variation but the intensity of rainfall also is generally much higher than in many other countries. There is wide variation of rainfall amongst the cities and, even within the city, rainfall shows large spatial and temporal variation; Due to the high variability of rainfall in space and time, rainfall measurements are required at high temporal and spatial resolution from dense Rain Gauge networks for the adequate design of new systems and/or renovation of existing drainage systems. Up to date Intensity Duration frequency (IDF) relationships need to be used to maintain design standards for new systems and retrofitting/replacement of old urban drainage systems.

iv) **Thunderstorm Rainfall Intensity:** Special consideration should be given to rainfall caused due to thunderstorms, which result in high intensity rainfall in short durations (e.g. 15 mm rainfall in 15 minutes i.e. 60 mm/h). Delhi and many other cities faced severe disruption due to flooding in 2009 and 2010, caused by thunderstorms embedded in monsoon systems which overwhelmed the drainage systems, designed for much lesser values of the rainfall intensity. By the very nature of formation, it is observed that severe thunderstorms result in rainfall intensities of the order of 50-70 mm/h which cause flash flooding. Hence, the frequency





of thunderstorms becomes an additional consideration for planning future urban drainage systems.

- a) IDF curves should be developed for each city, based on extraction of data from the raw data charts at 15 minutes resolution and from Automatic Weather Stations (AWS) at 5 minutes resolution, and
- b) IDF relationships will be adjusted taking into account climate change impacts and urban heat island effects. At the very least, a trend analysis of short duration rainfall intensities will be carried out and if an increasing trend in the recent years is shown, higher intensities than those provided by IDF relationships will be used for resizing existing systems and design of new systems, especially for critical infrastructure like airports, major roads and railway tracks.

v) **Design Flow:** To protect residential, commercial, industrial and institutional buildings in urban areas, safe management and passage of water, resulting from frequent storm events (hydrologic design aspects) and adequate capacity (hydraulic design aspects) ~~must~~ be considered. In the context of urban drainage, the main objectives of hydrologic analysis and design are to estimate peak flow rates and/or flow hydrographs for the adequate sizing and design of conveyance and quantity control facilities. To estimate peak flow rates, knowledge of the rainfall intensity, its duration and frequency is required for preparing satisfactory urban drainage and storm water management projects. Due to limited data, statistics and probability concepts are used in hydrologic analysis. Current international practice involves frequency analysis of rainfall intensities, based on extreme value distributions with adjustments for climate change effects. Intensity-Duration-Frequency (IDF) curves are required to be developed for systematic analysis. However, the return period concept has an element of subjectivity. Increasing rainfall intensities induced by climate change, urban heat islands and other factors will possibly result in varying return periods for a given intensity of rainfall. The rainfall intensity to be used for design will also depend on the time of concentration. Higher the catchment area, higher will be the time of concentration and lower will be the design rainfall intensity, other factors remaining the same.

Peak flow rates can be estimated using the Rational Method. However, for computation of water level profiles in the drainage systems or channels/rivers, suitable software for flood routing should be used. The available public domain software are the HEC-HMS for hydrologic modelling of the watershed, HEC-RAS for river modelling, both developed by the US Army Corps of Engineers and SWMM (Storm water Management Model) for sewer/drainage design, developed by the US Environmental Protection Agency. These software's are available on web.

vi) **Runoff Coefficient for Long Term Planning:** Keeping in view the projected rate of urbanization, it is imperative to consider a 50-year planning horizon. Due to development that is bound to take place during this period, it will be difficult to upgrade the underground drains once they are laid. Therefore, it is recommended that all future drainage plans for urban areas should be carried out, taking these factors into consideration. All future storm water drainage systems will be designed taking into consideration a runoff coefficient of up to  $C = 0.95$  for



estimating peak discharge using the rational method, taking into consideration the approved land use pattern of the city.

### **5.3.3 Drainage Design as per Manual on Sewerage and Sewage Treatment CPHEEO, Ministry of Urban Development (1993).**

#### **Estimation of Storm Runoff:**

Storm runoff is that portion of the precipitation, which drains over the ground surface. Estimation of such runoff reaching the storm sewers therefore is dependent on intensity and duration of precipitation, characteristics of the catchment area and the time required for such flow to reach the sewer is runoff time. The storm water flow for this purpose may be determined by using the rational method, hydrograph method, rainfall-runoff correlation studies, digital computer models, inlet method or empirical formulae.

The empirical formulae that are available for estimating the storm water runoff can be used only when comparable conditions to those for which the equations were derived initially can be assured.

A rational approach, therefore, demands a study of the existing precipitation data of the area concerned to permit a suitable forecast. Storm sewers are not designed for the peak flow of rare occurrence such as once in 10 years or more but it is necessary to provide sufficient capacity to avoid too frequent flooding of the drainage area. There may be some flooding when the precipitation exceeds the design value, which has to be permitted. The frequency of such permissible flooding may vary from place to place, depending on the importance of the area. Though such flooding causes inconvenience, it may have to be accepted once in a while considering the economy effected in storm drainage costs.

The maximum runoff, which has to be carried in a sewer section should be computed for a condition when the entire basin draining at that point becomes contributory to the flow and the time needed for this is known as the time of concentration ( $t_c$ ) with reference to the concerned section. Thus estimating the flow to be carried in the storm sewer, the intensity of rainfall that lasts for the period of time of concentration ~~is the one~~ to be considered contributing to the flow of storm water in the sewer. The Rational Method is more commonly used for designing drainage.

#### **i) Rational Method**

##### **Runoff - Rainfall Intensity Relationship**

The entire precipitation over the drainage district does not reach the sewer. The characteristics of the drainage district, such as, imperviousness, topography including depressions and water pockets, shape of the drainage basin and duration of the precipitation determine the fraction of the total precipitation, which will reach the sewer. This fraction known as the coefficient of runoff needs to be determined for each drainage district. The runoff reaching the sewer is given by the expression,





$$Q = 10 C I A$$

Where

'Q' is the runoff in m<sup>3</sup>/hr;

'C' is the coefficient of runoff;

'I' is the intensity of rainfall in mm/hr and

'A' is the area of drainage district in hectares.

## ii) Storm Frequency

The frequency of storm for which the sewers are to be designed depends on the importance of the area to be drained. Commercial and industrial areas have to be subjected to less frequent flooding. The suggested frequency of flooding in the different areas is at Table 5.3.

**Table 5.3 Frequency of Storm**

Type of Areas	Frequency
a) Residential areas	
i) Peripheral areas	Twice a year
ii) Central and Comparatively high priced areas	Once a year
b) Commercial and high Priced areas	Once in 2 years

## iii) Intensity of Precipitation

The intensity of rainfall decreases with duration. Analysis of the observed data on intensity duration of rainfall of past records over a period of years in the area is necessary to arrive at a fair estimate of intensity-duration for given frequencies. The longer the record available, the more dependable is the forecast. In Indian conditions, intensity of rainfall adopted in design is usually in the range of 12mm/hr to 20mm/hr.

The rainfall data from automatic rain gauges should be analyzed to develop duration-intensity curve for design frequency and from it relationship may be expressed by a suitable mathematical formula, several forms of which are available. The following two equations are commonly used:

$$(i) \quad I = a / (t.n)$$

$$(ii) \quad I = a / (t + b), \text{ where,}$$

I = intensity of rainfall (mm/hr)

t = duration of storm (minutes) and

a, b and n are constants

The available data on I and t are plotted and the values of the intensity (I) can then be determined for any given time of concentration, (tc).

## iv) Time of Concentration

It is the time required for the rain water to flow over the ground surface from the extreme point of the drainage basin and reach the point under consideration. Time of concentration (tc) is



equal to inlet time (t) plus the time of flow in the sewer (t). The inlet time is dependent on the distance of the farthest point in the drainage basin to the inlet manhole, the shape, characteristics and topography of the basin and may generally vary from 5 to 30 minutes. In highly developed sections, the inlet time may be as low as 3 minutes. The length of the sewer and the velocity of flow in the sewer determine the time of flow. It is to be computed for each length of sewer to be designed.

**v) Runoff Coefficient**

The portion of rainfall, which finds its way to the sewer, is dependent on the imperviousness and the shape of tributary area apart from the duration of storm.

**a) Imperviousness**

The percent imperviousness of the drainage area can be obtained from the records of a particular district. In the absence of such data, the following may serve as a guide.

**Table 5.4 Imperviousness of the drainage area**

Type of area	Imperviousness %
Commercial and Industrial area	70 to 90
Residential area:	
i) High density	60 to 70
ii) Low density	35 to 60
Parks & undeveloped areas	10 to 20

The weighted average imperviousness (I) of drainage basin for the flow concentrating at a point may be estimated as

$$\frac{A_1I_1 + A_2I_2 + \dots}{A_1 + A_2 + \dots}$$

$$A_1 + A_2 + \dots$$

where,

A<sub>1</sub>, A<sub>2</sub> = drainage areas tributary to the section under consideration

I<sub>1</sub>, I<sub>2</sub> = imperviousness of the respective areas and

I = weighted average imperviousness of the total drainage basin.

**b) Catchment Area**

The drainage areas should be indicated clearly on the map and measured for each length of storm sewer. The boundaries of each catchment are dependent on topography, land use nature of development and shape of the drainage basins. The incremental area may be indicated separately on the compilation sheet and the total area computed.

**c) Duration of storm**

Continuously long light rain saturates the soil and produces higher coefficient than that due to heavy but intermittent rain in the same area because of the lesser saturation in the latter case.



Runoff from an area is significantly influenced by the saturation of the surface nearest the point of concentration, rather than the flow from the distant area. The runoff coefficient of a larger area has to be adjusted by dividing the area into zones of concentration and by suitably decreasing the coefficient with the distance of the zones.

**d) Computation of Runoff Coefficient**

The weighted average runoff coefficient for rectangular areas, of length four times the width as well as for sector shaped areas with varying percentages of impervious surface for different times of concentration are given in **Table 5.5**. Although these are applicable to particular shapes of areas, they also apply in a general way to the areas which are usually encountered in practice. Errors due to difference in shape of drainage are within the limits of accuracy of the rational method and of the assumptions on which it is based.

**Table 5.5 Runoff Coefficient**

Duration, time, minutes	10	20	30	45	60	75	90	100	120	135	150	160
<b>Weighted Average coefficient</b>												
<b>1) Sector concentrating in stated time</b>												
(a) Impervious	.525	.588	.642	.700	.740	.771	.795	.813	.828	.840	.850	.865
(b) 60% impervious	.365	.427	.477	.531	.569	.598	.622	.641	.656	.670	.682	.701
(c) 40% imperious	.285	.346	.395	.446	.482	.512	.532	.554	.571	.585	.597	.618
(d) Pervious	.125	.185	.230	.277	.312	.330	.362	.382	.399	.414	.429	.454
<b>2) Rectangle (Length = 4 x width) concentrating in stated time</b>												
(a) Impervious	.550	.648	.711	.768	.808	.837	.856	.869	.879	.887	.892	.903
(b) 50% Impervious	.350	.442	.499	.551	.590	.618	.639	.657	.671	.683	.694	.713
(c) 30% Impervious	.269	.360	.414	.464	.502	.530	.552	.572	.558	.601	.614	.636
(d) Impervious	.149	.236	.287	.334	.371	.398	.422	.445	.463	.479	.495	.522

**Hydraulic Models**

The purpose of the hydraulic analysis is to evaluate the adequacy of the existing storm drainage system (major drains only) and to determine design options for inadequately sized channels. Channels and storm drains are simulated using the flow data generated in the hydrology model. Storm drains are simulated using Manning’s equation as below:

$$V = (R^{2/3} \times S^{1/2})/n, \text{ where,}$$

V = Velocity (m/s); n = Friction Factor;  
R = Hydraulic Radius (m); and S = Channel Slope (m/m)

Friction factor (n) is given below:

- Cement Concrete with Good finish = 0.013
- Concrete channel, wood toweled = 0.015
- Earth channel, ordinary condition = 0.025



Earth channel, poor condition = 0.035  
 Earth channel, partially obstructed with debris or weeds = 0.050

### Limitations of Rational Method

Although Rational Method is widely used for designing drainage system it has certain limitations, which are as under:

#### Assumptions

- i) Peak flow occurs when the entire watershed is contributing to the flow
- ii) Rainfall intensity is the same over the entire drainage area
- iii) Rainfall intensity is uniform over a time duration equal to the time of concentration
- iv) Frequency of the computed peak flow is the same as that of the rainfall intensity, i.e., the 10-year rainfall intensity is assumed to produce the 10-year peak flow
- v) Coefficient of runoff is the same for all storms of all recurrence probabilities

#### Limitations:

- i) Best suited for estimation of design peak runoff
  - Inlet design
  - Storm drainage system design
  - Area limitation < 200 acres (80 hectares)
- ii) Area of drainage needs to be assessed accurately
- iii) Has no capability to calculate detention or reservoir routing flows

### 5.3.4 Intensity Duration Frequency Curve for Delhi

Rainfall data of Delhi for the period 1984 to 2006 (23 years) have been used to develop the Intensity Duration Frequency (IDF) Curve for Delhi. Data on number of occurrence of rain of particular duration and intensity as given in Table 5.6 has been used to develop the IDF Curve for Delhi.

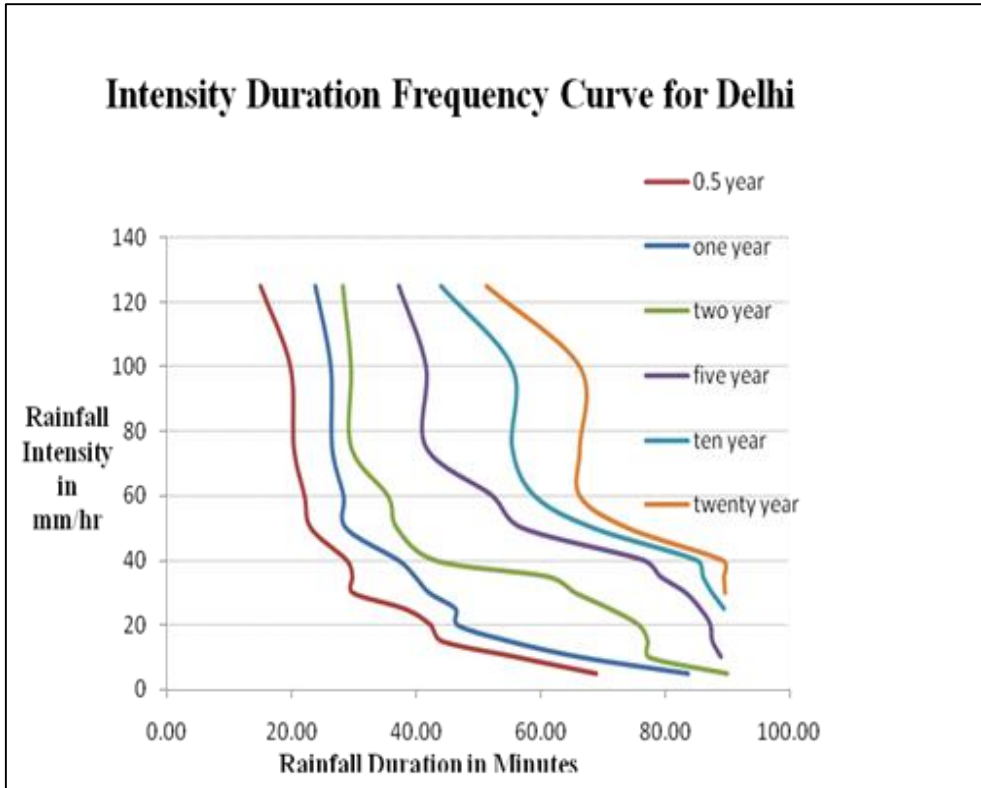
**Table 5.6 Rain fall data of Delhi (1984 to 2006) indicating number of occurrences of rain of given intensity & duration**

Time (in min)	Rain fall intensity (in mm/ Hr)												
	5	10	15	20	25	30	35	40	50	60	75	100	125
15	346	346	344	319	265	229	177	162	79	72	66	63	46
30	256	252	206	151	73	44	44	37	18	17	10	10	7
45	128	95	37	24	24	18	12	8	7	7	3	3	2
60	58	31	16	15	13	13	12	8	4	2	2	2	0
75	38	13	13	12	11	9	6	5	1	0	0	0	0
90	12	4	3	3	2	1	1	1	0	0	0	0	0



From above Table for different frequency find duration for different intensities as given in Appendix 5.1. The duration and intensity can be expressed by equation for each frequency. The plot of above is an Intensity Duration Frequency curve. Such curve should be developed for each city. The IDF Curve developed given in the above for Delhi is given below:

**Figure 5-2 Intensity duration curve for Delhi**



### 5.3.5 Refinement in Runoff Estimations

“Urban Drainage Design Manual”, published by the Federal Highway Administration of the US department of transportation (2013, 3rd Edition) stipulates three representations of rainfall which can be used to derive flood flows: constant rainfall intensity, dynamic rainfall, and synthetic rainfall events. Constant Rainfall Intensity method follows Intensity-Duration Frequency curves.

#### Dynamic Rainfall (Hyetograph)

In any given storm, the instantaneous intensity is the slope of the mass rainfall curve at a particular time. The mass rainfall curve is simply the cumulative precipitation, which has fallen up to a specific time. For hydrologic analysis, it is desirable to divide the storm into convenient time increments and to determine the average intensity over each of the selected periods. These results are then plotted as rainfall hyetographs. Hyetographs provide greater precision than constant rainfall intensity by specifying the precipitation variability over time, and are used in conjunction with hydrographic (rather than peak flow) methods. Hyetographs allow for simulation of actual rainfall events, which can provide valuable information on the relative flood risks of different events and, perhaps, calibration of hydrographic models.



## **Synthetic Rainfall Events**

Drainage design is usually based on synthetic rather than actual rainfall events. The Soil Conservation Service (SCS) 24-hour rainfall distributions are the most widely used synthetic hyetographs. These rainfall distributions were developed by the U.S. Department of Agriculture, Soil Conservation Service (SCS) (13) which is now known as the Natural Resources Conservation Service (NRCS). The SCS 24-hour distributions incorporate the intensity-duration relationship for the design return period. This approach is based on the assumption that the maximum rainfall for any duration within the 24-hour duration should have the same return period. For example, a 10-year, 24-hour design storm would contain the 10-year rainfall depths for all durations up to 24 hour as derived from IDF curves.