STORM WATER DRAINAGE OF DELHI

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1.0 GENERAL DRAINAGE PATTERN

The geographical area of Union Territory of Delhi is 1483 sq.km. A map of National Capital Region showing the general drainage pattern of Delhi is placed in Fig. 1 & 2.

From storm water drainage point of view, which are received from Haryana, U.P. and Rajasthan. Delhi can be broadly divided into six drainage basins, ultimately discharging into the Yamuna:

i. Najafgarh Drain (Rajasthan and Haryana) and urban and rural areas of Delhi.

ii. Barapullah Nallah

iii. Wild life sanctuary area discharging through Haryana Territory

iv. Drainage of Shahdara area

v. Bawana Drain Basin

vi. Other drains directly outfalling into river Yamuna on right bank.

2.0 BRIEF DESCRIPTION OF DRAINAGE AREAS

i. Najafgarh Drain

The Najafgarh Drain receives waters from Sahibi areas directly draining into the drain and other areas draining from Haryana.

Capacity of Najafgarh Drain

Capacity of Najafgarh Drain is 227 cumec from Dhansa to Kakraula and 283 cumec from Kakraula to G.T. Road.

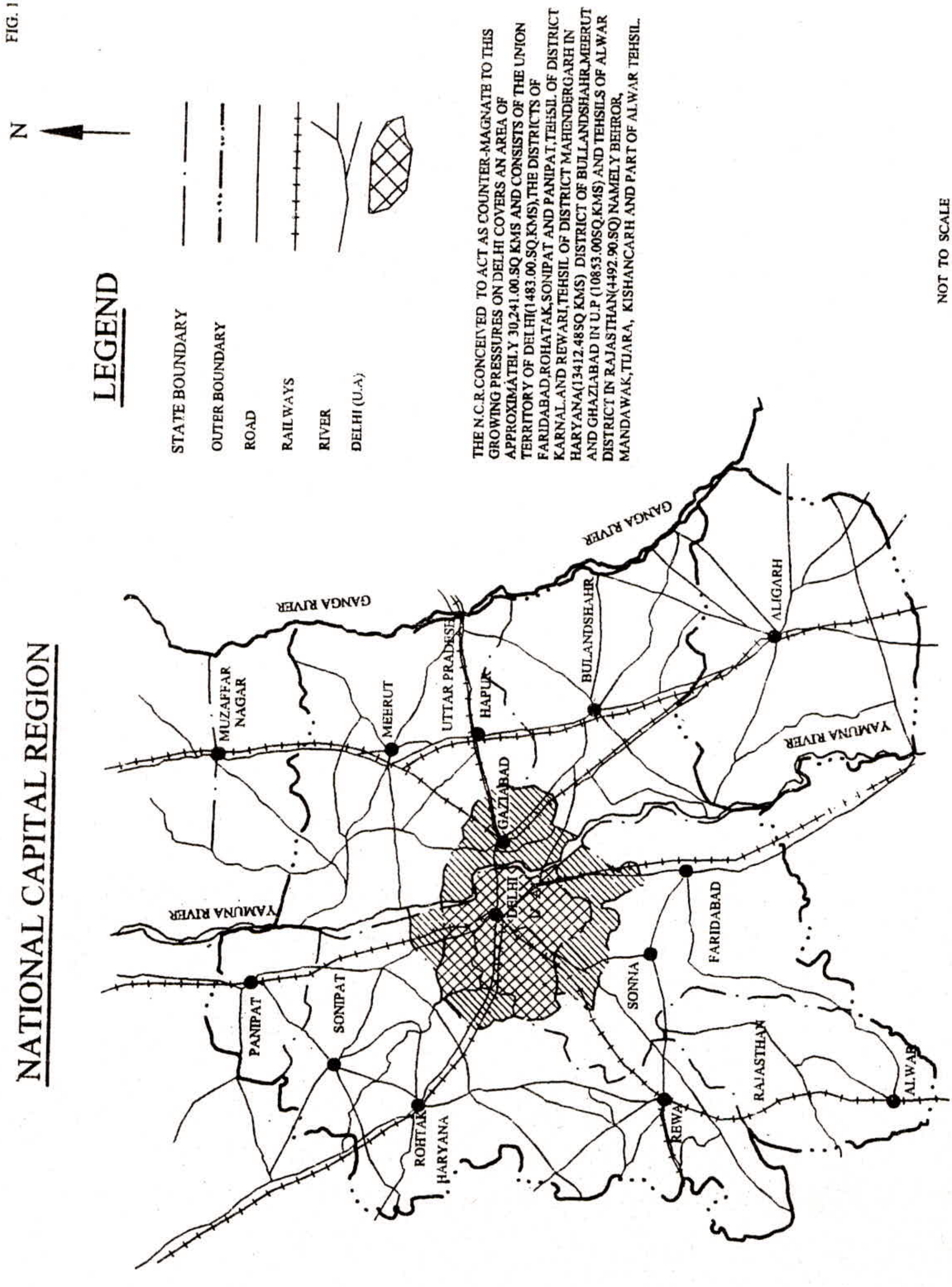


Fig. 1 : National Capital Region

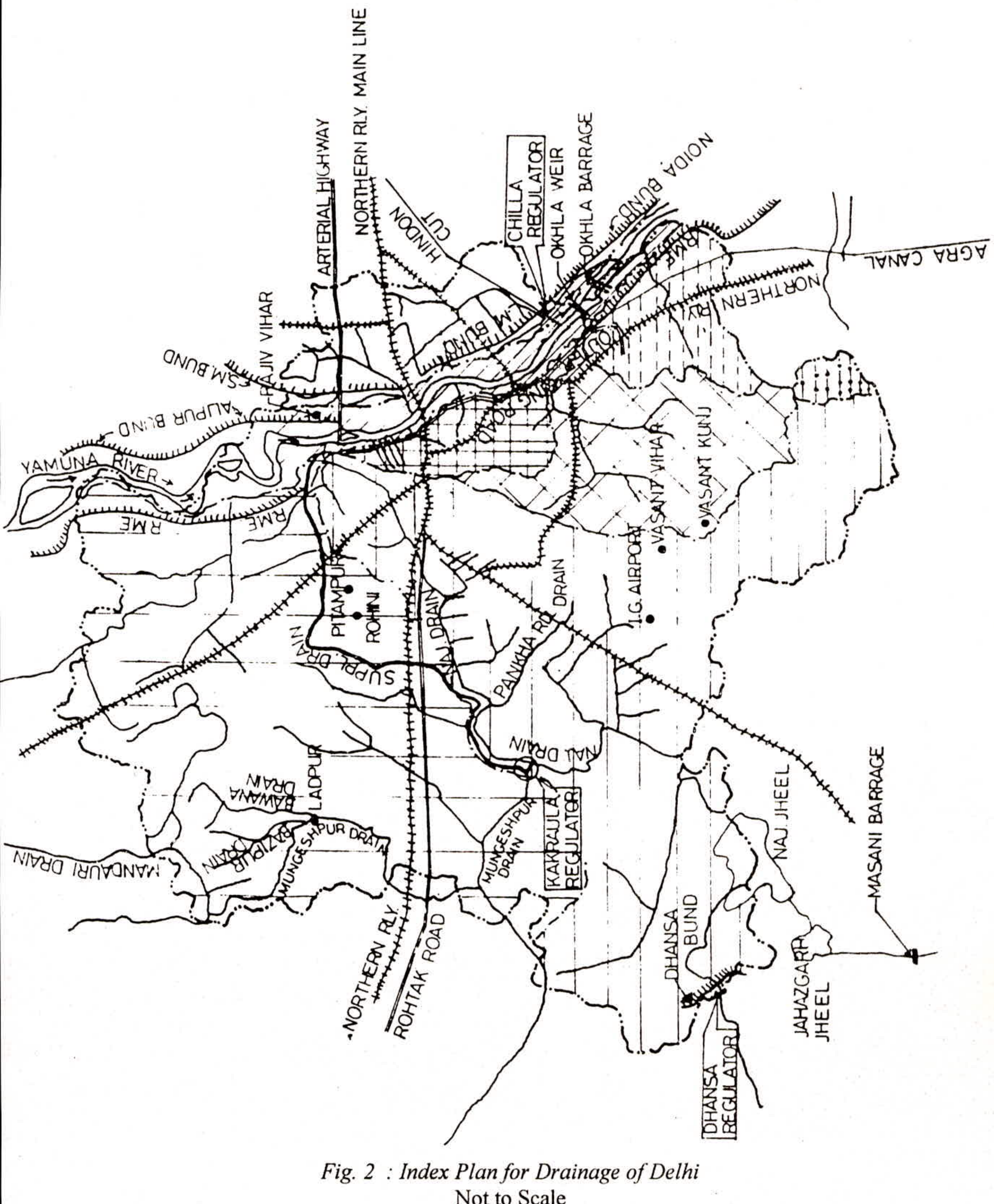


Fig. 2 : Index Plan for Drainage of Delhi
Not to Scale

Capacity of Supplementary Drain

Kakraula to Keshopur Treatment Plant	142 cumec
Keshopur treatment Plant to G.T. Road	283 cumec
G.T. Road to outfall	425 cumec

Master Plan of Delhi 2001 A.D. envisages urbanisable limits of Delhi as 628 sq.km. to 688 sq.km. Drainage capacity so far planned/created is not adequate and therefore needs to be augmented.

ii. Barapullah Nallah

Its catchment area is now highly urbanised. Its existing capacity is designed for 2 yr. - 1 hr. intensity of rainfall. Total urban and rural catchment of this system is 139 sq.km. Due to urbanisation, the coeff. of runoff of 0.15 is considered inadequate.

iii. Wildlife Sanctuary Area discharging through Haryana Territory

South-eastern part of Delhi, comprising mostly the Asola wild life sanctuary area drains into Haryana. The drainage outfalls into river Yamuna through Batkal lake and Buriya Nallah.

iv. Drainage of Shahdara Area

Entire area of Shahdara comprising 8,100 ha is below HFL of the Yamuna. The area partly falls in U.P. and partly in Delhi. The natural drainage from Ghaziabad and Loni district slopes towards Delhi which is in the south.

	Delhi	**U.P.**	**Total**
Rural	5439 Ha.	1715 Ha.	7154 Ha.
Urban	2360 Ha.	5328 Ha.	7688 Ha.

The Reddy Committee had recommended providing internal drainage for Shahdara area with an independent outfall into the river below Okhla weir. The drainage has since been constructed and the outfall taken below New Okhla weir.

v. Bawana Drain Basin

The area with CA of 223 sq.km. is bound by Right Marginal Embankment in the East, Drain No. 8 on the North, Delhi Tail Distributary on the West and supplementary drain on the South. The area is mainly drained by supplementary drain.

vi Other drains directly outfalling into Yamuna

There are 17 other drains directly outfalling into the river Yamuna.

Some important ones are:

- Magazine Road drain
- Mutcalf House Drain
- Maharani Bagh drain
- Delhi Gate drain
- Kalkaji drain
- Tughlakabad drain
- Delhi Gate drain

3.0 RECOMMENDATIONS OF PAST COMMITTEES FOR DRAINAGE OF DELHI

i. Reddy Committee, 1959 :

Drainage system be remodelled for intensity of rainfall likely to occur once in two years (42 mm) for one hour duration.

Drainage of rural areas of Delhi be so designed as to restrict flooding to a maximum period of 3 days with return period of 5 years. Maximum 3-day precipitation likely to occur once in 5 years is 208mm (8.2") which causes run-off of 10 cusec/ sq.mile of C.A., considering run-off factor 15%.

$$Q = \frac{8.2}{12 \times 2 \times 3} X .640 \ X \ \frac{15}{100} = 10.8 \text{ say } 10 \text{ cusec /sq.mile}$$

The Committee recommended adopting appropriate higher run-off factor for hilly areas.

ii. Moti Ram Committee, 1965 :

This Committee was set up after floods of 1964 in the Sahibi to examine Sahibi - Najafgarh drainage system. It was assessed that according to the Master Plan - 1961, total area draining into Najafgarh drain within the limits to be urbanised is 66.91 sq.miles (17,340 ha.). The discharge requirement of Najafgarh drain were assessed at 21,400 cusec (605.9 cumecs). However, considering limitations of widening of Najafgarh drain, the design discharge recommended was 10,000 cusec (283.12 cumecs).

iii. J.P. Jain Committee, 1968

The Committee set up after flood of 1967, recommended preparation of Master Plan for drainage. The Committee also suggested construction of supplementary drain with capacity of 113 to 127.5 cumec (4,000 to 4,500 cusec) to serve urbanisation envisaged in Master Plan 1961.

iv. Tripathi Committee :

The Committee discussed drainage requirements of Najafgarh drain below Kakraula.

v. Master Plan of Drainage, 1976

Irrigation and Flood Control Dept. proposed a Master Plan for Storm Water Drainage of Delhi in 1976 which was considered by Technical Committee of experts. The Committee approved the plan in General and decided to utilise the same as an Outline Plan.

The Master Plan was based on the following:

Urban Areas

Time of Concentration	1/2 hour
Storm Intensity (Corresponding to 2 year return period)	63.5 m/hr (2.5")
Average run-off factor	0.6
Average runoff	1.5 in/hr (1.5 cusec/acre)

Flooding of streets for an hour or so was allowed and drains designed for 1 cumec/acre. The following intensity of rainfall was indicated for 1 hour duration.

Return Period	Intensity of Rainfall	
2 yr.	43.7 mm/hr	(1.32 in/hr)
5 yr.	58.2 mm/hr	(2.29 in/hr)
10 yr.	69.3 mm/hr	(2.73 in/hr)
25 yr.	83.8 mm/hr	(3.30 in/hr)

vi. High Level Committee on Floods

Some important recommendations of the High Level Committee on Floods (1993) are:

- Three day rainfall (208 mm or 8.2") for 5-year frequency to be drained in three days.
- Area dispersal factor appropriate to topography of the area may be assumed in computing runoff.

- Urban drainage which was being designed for 2 year frequency rainfall of one hour duration may be designed for 1 in 5 year frequency for internal drains and 1 in 10 year frequency for main drains and appropriate time of concentration be considered.

- Value of C to be adopted as per IS : 8835-1978

4.0 DESIGN CRITERIA RECOMMENDED FOR ADOPTION

Rural Drains

Three day rainfall of 5 year frequency be drained in three days.

Factors for converting point rainfall values to Areal Average Value

The point rainfall values of any station are generally higher than areal values. For example, 5 year, 10 year etc. frequency point rainfall values may be higher than corresponding values over a larger area. US Weather Bureau based on field studies has found a relation between point rainfall of a specified duration and the average rainfall over areas upto 1000 sq.km. Such relationships should be developed for Delhi for use in studies. Pending development of such relationships, following area-wise correction factors may be applied based on drainage area:

Drainage Area (ha)	Correction Factor
Upto 50	1.000
Upto 100	0.999
Upto 200	0.998
Upto 1000	0.997
Upto 2000	0.994
Upto 3000	0.936
Upto 10000	0.871

Design Frequency

Drains may generally be designed to carry 3-day rainfall of 5 years frequency/ 208 mm (8.2"). The data base for computing 3-day storm should be as large as possible.

Studies carried out indicate that designs of drains based on 5 years frequency give optimum benefits. However, in specific cases requiring higher degree of protection, frequency of 10-15 years can also be adopted if justified on economic considerations.

Period of Disposal

Period of disposal of excess rainfall may be entirely dependent on the tolerance of individual crops. Following periods of disposal may generally be considered:

a.	High yielding paddy	3 days
b.	Maize, Bajra etc.	3 days
c.	Sugarcane & Bananas	7 days
d.	Cotton	3 days
e.	Vegetables	1 day (24 hour rainfall may be drained in 24 to 40 hours)

Runoff from 3-day duration rainfall of 5 year frequency shall be disposed off in 3-days for all crops other than maize, vegetables and fruit crops.

Runoff from 1-day duration storm of 5 year frequency shall be disposed off in 24 to 40 hours for maize, cotton, vegetables and fruit crops.

The above periods of disposal may be valid for drainage areas upto about 5 sq.km. For larger drainage areas, disposal period for main drains may be suitably increased depending upon type of crop, terrain and drainage area. Following periods of disposal are indicative, considering basin lag.

Drainage Area	Disposal Period
Upto 5 sq.km	3 days
Upto 5 to 25 sq.km.	3-6 days
Upto 25 to 50 sq.km.	6 days
Upto 50 to 100 sq.km.	6-10 days
Upto 100 to 500 sq.km.	10 days

However, disposal period may also be obtained by considering likely travel time from source to point of consideration and decided as suitable for the area, taking into account the interception, if any, due to existence of field bunds, etc.

Discharge from large catchment areas

It is more appropriate to consider maximum flood discharge from contributing catchment area upto point of consideration.

Dominant flood level for drains outfalling into rivers

a. attained and not exceeded for more than 3 days at a time,

b. attained and not exceeded 75% of the time over a period of not less than 10 years.

Whenever a drain is outfalling into a river, the FSL should be slightly higher than dominant flood level.

Runoff Coefficient

Runoff Coefficient to be adopted depends upon the type of soil, crops, general topographical conditions like land slope, etc. For plain areas, run-off may be around 15% to 20%. For hilly and semi-hilly areas, it may be higher and can be decided after analysing rainfall - runoff of other catchments in the area; till then a value of 50% to 70% may judiciously be adopted.

Until precise data are available, following runoff coefficients for different soils are recommended for plain areas as per IS:8835-1978.

a.	loam lightly cultivated or covered	0.40
b.	loam largely cultivated and shrubs with gardens, lawns, macadamized roads	0.30
c.	Sandy soils, light growth	0.20
d.	Parks, lawns, cultivated area, gardens	0.05 - 0.20
e.	Plateaus lightly covered	0.70
f.	Clayey soils, stiff and bare clayey soils, lightly covered	0.55

Often there are different types of crops grown over large areas. In such cases, field and link drains may be designed for runoff on the basis of crops grown in a particular area. For outfall drain, a composite discharge may be worked out depending upon the extent of area under each major crop.

Drainage Structures

Cross-drainage structures are always designed for a higher discharge than that of the drains because the damage caused to the structures in the event of flows resulting from rainfall higher than the designed rainfall can be costly. Also, any remodelling of the structures will be costly and time consuming apart from dislocation of the facilities like roads, railways, irrigation canals, etc.

Design Discharge

As per IS:8835-1978, cross drainage structures should be designed for discharge resulting from 3-day rainfall of 50 years frequency, time of disposal remaining the same depending upon type of crop.

Rational Formula

For estimating design discharge of small catchment (upto 50 sq.km.) cross-drainage structures, the most widely used method is `Rational formula' described below gives peak rate of run off from a storm.

Q	=	CIA/3.6, where
Q	=	peak discharge in cumec
C	=	coefficient of runoff depending upon catchment characteristics
I	=	intensity of rainfall corresponding to time of concentration (mm/hr)
A	=	area of catchment in sq.km.

Value of `C' depends upon soil infiltration capacity, shape and size of catchment, rainfall pattern, vegetation cover, surface storage, viz. lakes, marshes, antecedent precipitation condition, etc. Thus the run off coefficient represents the integrated effect of catchment losses.

The time of concentration t_c is obtained from the equation.

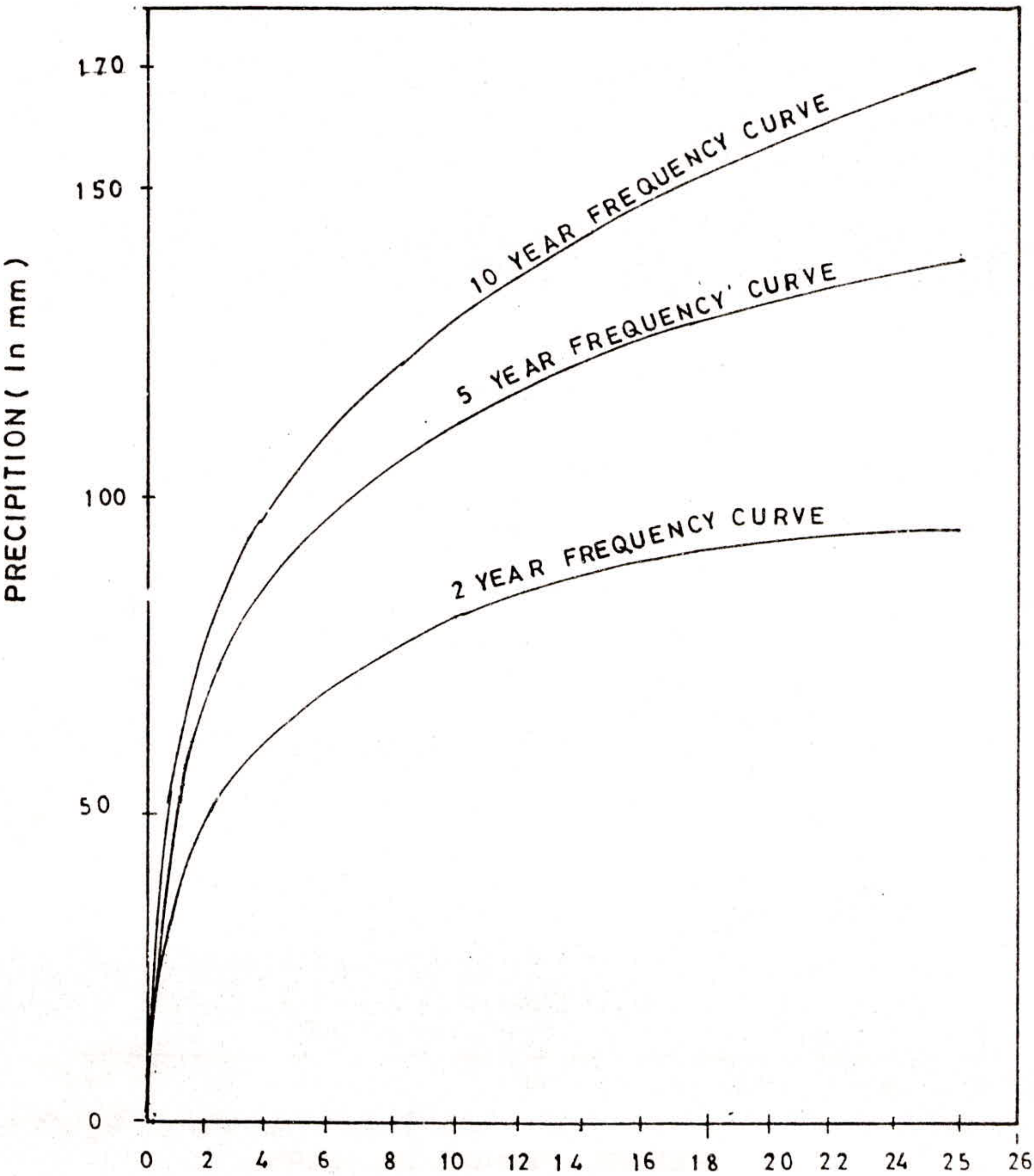
t_c	=	$C\,(LLc/S)^n$, where
L	=	the length of main stream in km
Lc	=	length in km along main stream from the outlet to a point opposite the centre of gravity of the catchment.
S	=	basin slope

C and n are basin constants.

Another equation known as Kirpich equation much in use for estimating t_c is

t_c	=	$[0.87\,L^3/H]^{0.385}$, where
t_c	=	time of concentration in hrs.
L	=	maximum length of travel of water in km
H	=	elevation difference between the remotest point on on the catchment and outlet in metres

Rainfall intensity - duration relationship for a given catchment can be used to obtain the rainfall intensity corresponding to duration t_c and desired return period. Depth duration curves are placed at Figures 3 & 4.



DURATION (IN HOUR)

Scale :- Hor. 1 : 2, Ver. 1 : 10

Fig. 3 Depth Duration Curves for Various Frequency Storms
Data of Lodhi Road Observatory, New Delhi

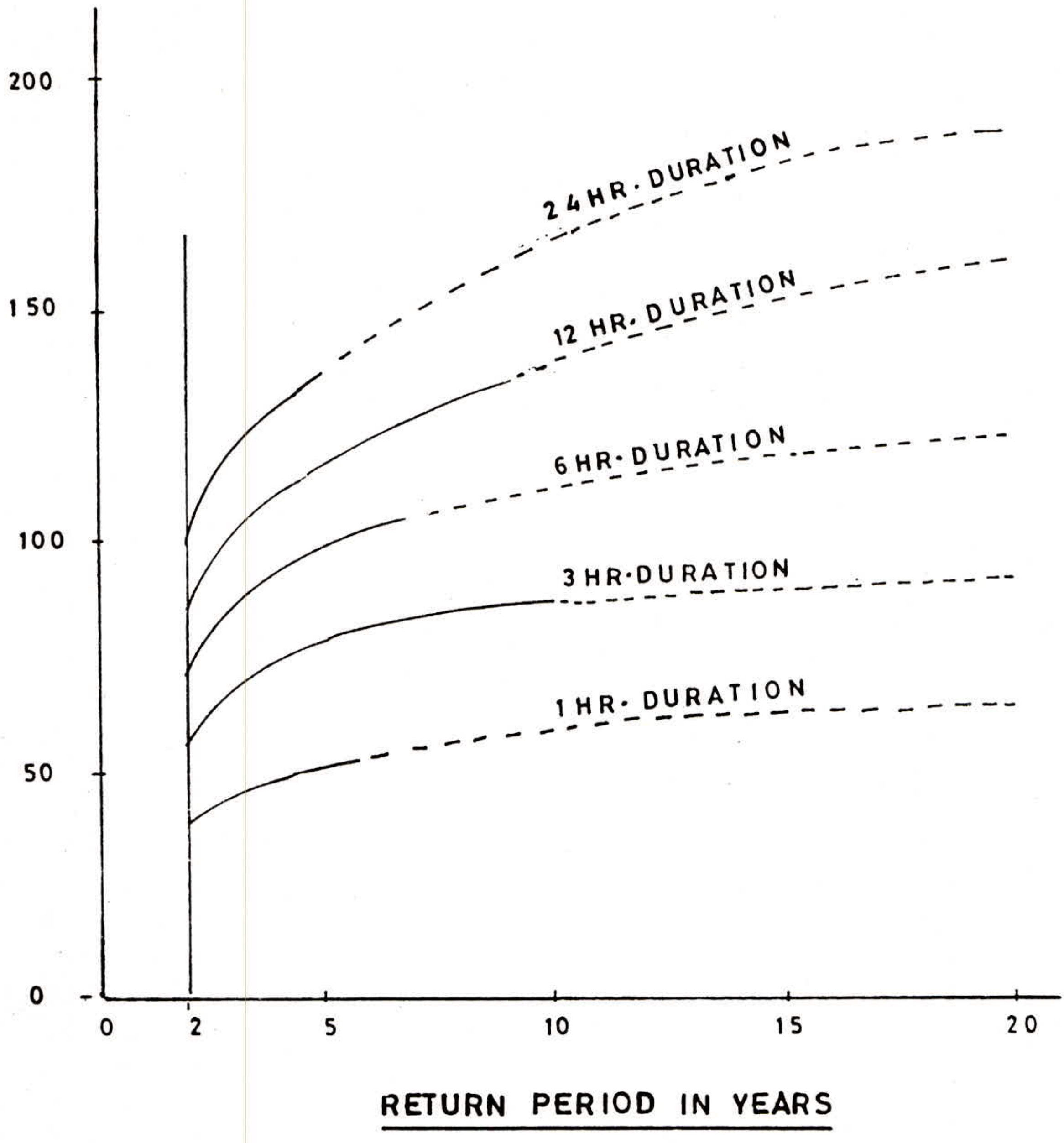


Fig. 4 Depth Duration Curves for Storm Periods of Return Periods
Data of Lodhi Road observatory, New Delhi

5.0 URBAN DRAINAGE

Typical Urban Drainage Problems

Urban Drainage problems are specific. Some of the major problems can be summarised as under:

Type of Problem	Example
Concentration of Population Concentration of Rainfall Property lying in flood prone areas	China
Critical combination of rainfall and abnormal rise in sea level as a result of storm surges during typhoon	Hongkong especially Adjoining New Areas
Rapid urbanisaton of river basins reducing water retaining and retarding functions of land, increased volume of flood flows	Japan
Habitations in flood prone areas	Japan
Overflowing of rivers like Mekong river	Lao People's Democratic Republic
Flash Floods	Vietiane Plain
Overtopping of River (Klang River)	Kaula Lumpur
Uncontrolled developments in flood plains and Reduction in Wetland Storage owing to rapid Urbanisation of metropolitan areas	Philippines
Disasters due to floods in major cities, rapid urbanisation, insufficient capacity of pumping stations and secondary drainage facilities	Republic of Korea
Overland flow and local drainage congestion combined with high river water levels (Chao Phraya river)	Bangkok

Classification of Flood Damages

(i) Tangible Damages

(ii) Intangible Damages

Tangible Damages : These are Direct and Indirect.

(a) Direct Damages

- Buildings
- Equipment
- Crops
- Livestock
- Public facilities
  - Road
  - Port/Harbour
  - Rail/Road
  - Telecommunication

(b) Indirect Damages

- Disruption of Business
- Disruption of Production
- Other business activities
  - Retail distribution, office business
  - Recreational business
  - Tourism
- Disruption of Communications
  - Roads
  - Other traffic
- Public Services
  - Sewerage & Sewage Treatment
  - Gas
  - Telecommunication

- Additional costs
    - Flood Fighting
    - First Aid
    - Evacuation
    - Rehabilitation
    - Essential supplies
    - Police
    - Public Health

Intangible Damages

- Death
- Sickness
- Stress
- Anxiety
- Environmental Quality
- Loss of near ones

Drainage Criteria

Internal Drainage of Urban Areas - Internal drainage of Urban Areas is not designed for peak flow of rare occurrences 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 may cause some inconvenience, it may have to be accepted once in a while considering economy in drainage costs, efficient functioning of drainage system, possible silting of the drainage due to very low velocity during normal/low flood discharges etc.

Following is the gist of suggestions given in various sources/committees.

(i) Ref. Publication - Design of Sewers

	Residential Areas	Flooding Permitted
a.	Peripheral Areas	Twice a week
b.	Central and comparatively high priced areas	Once a year.
c.	Commercial and high priced areas	Once in two years.

(ii) Reddy Committee (1959)

Drainage system to be remodelled for intensity of rainfall likely to occur once in two years (42 mm) for one hour duration.

(iii) Master Plan of Drainage (1976) : Irrigation & Flood Control Dept.

Urban Area

Time of concentration	=	1/2 hr for internal drains 1 hr for peripheral and main drains
Storm Intensity	=	63.5 mm/hr (corresponding to 2 year return period)
Average runoff factor	=	0.60
Average runoff = Q = 2.5x0.6	=	1.5 mm/hr (1.5 cusec/acre)

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

Intensity of Rainfall for 1 hr. duration

Return Period (Refer Figure 3 & 4)

2 yr.	43.7 mm/hr	(1.72 inch/hour)
5 yr.	58.2 mm/hr	(2.29 inch/hour)
10 yr.	69.3 mm/hr	(2.73 inch/hour)
20 yr.	83.8 mm/hr	(3.30 inch/hour)

(iv) Criteria recommended by High Level Committee on Floods (1993).

- Delhi is capital city of the country with heavy density of population.
- Design criteria for 2 year frequency - 1 hr. rainfall are not considered adequate as such frequent congestion would not be acceptable in Mega city of Delhi. It results in frequent disruption of already congested traffic on roads, power failures, failure of communication system, damage to roads and highly costly urban property.
- HLC recommended preparation of Manual for fixing design of urban/mega cities by CWC.

- Pending above, any new proposal be formulated for frequency rainfall of 1 in 5 years for internal as well as peripheral drains and 1 in 10 years for main drains. Appropriate time of concentration may be considered while selecting storm duration.
- Closed conduits may be designed to obtain maximum flow at 0.8 to 0.85 of total depth.

Design of Major Structures

The design of large areas should be based on detailed hydrologic study as per Recommended procedures for estimation of design flood for major structures considering storm (CWC) pattern, appropriate frequency storm, time of concentration, nature and extent of development, man-made interventions etc.

6.0 CRITERIA FOR PROTECTION FROM FLOODING IN THE RIVER YAMUNA

Delhi is located along the river Yamuna whose both banks are well-raised to protect the city from flooding.

UNDP has prepared Manual and Guidelines to assist the Agencies of the Economic and social Commission for Asia and the Pacific (ESCAP) region in fixing the criteria to reduce the social and economic impact of flood and reduce the losses resulting from flooding.

For reasons of simplicity, expediency and administrative ease, many authorities adopt a uniform flood risk such as the 1-in-100 year flood (1 per cent flood). In other cases, flood authorities have adopted the highest recorded or historical flood as the appropriate standard. Another alternative is to base each case on its merits where the selected standard for each particular area is determined by balancing social, economic and environmental considerations against the consequences of flooding so as to minimize potential flood losses.

Because of financial constraints and present community aspirations, many developing countries may opt for a lower flood standard in the short term and increase this standard in the future as additional resources become available.

Larger floods than the Standard Flood will occur and the completion of flood loss prevention measures or zoning of an area does not imply that flood damages will be eliminated forever. It is however important to add that it **can not be assumed that lands outside the limit of the standard flood or land protected up to that level will be free of flood damages.** These could experience flooding in case of higher frequency flood.

An indication of the range of flood standards adopted by selected countries throughout the world is presented in Table below. The main source of information contained in the table was a review carried out by the International Commission on Irrigation and Drainage.

In Japan, the approach is to increase the level of flood protection in stages until protection for ultimate stage of urbanisation is achieved. A flood standard of 1 in 200 years (0.5 percent flood) is adopted for design of flood protection measures on important rivers which is reduced to 1 in 100 years and 1 in 50 years for less important areas and even 1 in 10 years for lesser important areas.

Table : Typical World Flood Standard - Design Flood Return Period (years)

Country/Area	Commercial	Industrial	Residential	Rural	Agricultural	General
Australia	50-100	50-100	50-100		5-50	
Brunei Darussalam (3)	10		5			
Bulgaria	100-500			30-100	5-10	
China (2)	200			100		
Colombia						30
Czechoslovakia	100	50			7-10	
Hong Kong	50-200	50-200	50-200	10-200	2-5	
Hungary						60
India (2)	50				25	
Indonesia						5-20
Japan	10-200	10-200	10-200	10-200	10-200	
Malaysia (3)	5-100	5-100	5-100	5-100	5-30	
Philippines (2)	100			50-70		
Poland	1,000	500		100	20-100	
Singapore (3)	5	5	5			
Turkey	100-500	100-500				
Thailand	25-100	25-100	25-100	25-100	50-200	
UK	10-100	10-100	10-100		10-100	
USA	25-100	25-100	25-100		5-25	
USSR	1,000	100	50		10	
Venezuela						
Vietnam						
Thailand (Bangkok)	1 in 40 years					
Other countries	1 in 100 years					

In Hong Kong,

a) Flood protection bunds for villages — 1 in 200 years

b) Village Drainage — 1 in 10 years

c) Main Catchment Drainage Channel — 1 in 50 years

d) Urban drainage in developed areas — 1 in 50 years

e) Urban drainage trunk systems — 1 in 200 years

f) Intensively used agricultural land — 2 - 5 years

For protection of Seoul, flood frequency of 1 in 200 years is adopted Bangkok has adjusted 1 in 40 years flood standard.

Selection of return period in various urban cities is not so far based on economic consideration.

In view of above and vast development in Delhi, the flood embankments may be designed for atleast 100 year frequency.

7.0 SPECIFIC PROBLEMS OF STORM WATER DRAINAGE OF DELHI

Delhi experiences flooding/drainage due to any or all of the following situations:

(a) **Heavy rains in the catchment of River Yamuna :** Heavy rains in the catchment of river Yamuna raise flood levels in the Yamuna. The discharges are released at Tejewala which take 2-3 days to reach Delhi. The city of Delhi is protected by a series of flood embankments on both banks. When the river stage is high, a number of regulators/sluices outfalling into the Yamuna have to be temperarily closed to prevent river waters entering city areas. This however results in drainage congestions during heavy down pours in the city and pumping arrangements are made at many places along both the banks of the river.

(b) **Heavy rains in the rural/urban areas of Delhi :** Heavy rains in the rural/urban areas of Delhi can cause temporary flooding/drainage congestion in some low lying areas of Delhi. The problem is however not very serious in case there is no flooding in the river Yamuna and no heavy releases from Sahibi at Dhansa/Masani. However, there can be substantial drainage congestion if the river Yamuna is simultaneously in spate.

(c) The problem of drainage can assume serious proportions when there is heavy contribution from Sahibi coupled with heavy storm in Delhi and simultaneous flood situation in the Yamuna.

Fortunately such a synchronisation has not occurred during last 40 years or so. Perhaps such a situation can not be ruled out but drainage can not be economic and efficient if designed for such a rare occurrence. It may be adequate to protect Delhi for following situation:

(i) All embankments of river Yamuna/inflowing drainage from drains in embankments may be safe against at least a 100 year frequency flood.

(ii) The release from Sahibi through Dhansa bund need to be regulated considering carrying capacity of drains in Delhi at any particular point of time.

(iii) Internal urban drainage be safe against 1 in 5 years for internal drains and 1 in 10 years for main drainage considering appropriate time of concentration.

(iv) Strict vigil and relief & rehabilitation measures should be in place for situation in excess of above norms to minimise loss of life and property.

8.0 CONCLUSION

Since there is no set guidelines for urban areas especially heavily developed mega cities like Delhi an attempt has been made to give detailed account of storm water drainage criteria, the criteria followed in other countries especially in respect of river embankments so that a serious review is possible and guidelines developed. This background paper is aimed to stimulate discussions and arrive at consistent and reasonable norms for adoption in future planning. In view of the nature of topic of the paper, information has been freely taken from available sources.