# COMPUTATION OF FLOOD DISCHARGE WITH & WITHOUT DETENTION BASIN

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## Abstract

*Computation of peak flood in an urban catchment is necessary for the planning and design of storm water drainage system. Peak flood to be adopted for the design depends on the frequency of occurrence or return period which in turn is decided by cost and funds available for development. Urbanization increases peak discharge that adversely affects downstream floodplains. People want urban development without rise in flood peak in post development period. Storage of excess floodwater in detention basins is helpful in reduction of flood peak. Such basins in the catchment areas are helpful in conservation of flood water and help in artificial recharge of ground water and consequent rise in water table.*

*Different methodologies of flood estimation and their limitations will be discussed in the paper which will also include flood routing by use of detention basins.*

## 1.0 INTRODUCTION

Urban storm water drainage in India is becoming increasingly important over years due to rising population in the cities. Most of the metropolitan cities like Delhi, Kolkata, Mumbai, Chennai etc. are facing acute problem of communication due to water-logging during rainy seasons when life comes to a standstill. Generally, the cities are built by the side of rivers which are in spate during monsoon. Urbanisation leads to higher run-off as most of the open spaces are being covered and the existing water bodies are being filled in to meet the increasing need for human habitations, roads, industries etc. Majority of the people, migrating to cities and encroaching on flood plains for their livelihood, are poor and most affected by the floods. Safe disposal of storm water without causing water-logging and flooding should be given priority in any urban development program.

Urbanization of rural areas and development of smart cities, conceived recently by the Govt. of India, will result in rise in flood peak that will adversely affect downstream floodplains. Many local government are enacting ordinances which require that the post- development flood peaks do not exceed pre-development peaks i.e. zero excess runoff for defined storm frequency. The detention basin is the most widely used measure to control peak flood. Size of the basin can be adjusted to generate outflow peak flood discharge same as the pre-development flood peak. People curse God when floods damage localities in the pre-development stage. Same people will

ask for compensation from project authorities when flood damage occurs in post-development period. Rise in flood level causes congestion of flow and sometimes backflow into the storm sewers due to rise in flood level and consequent submergence. To ensure free fall of the storm sewer, it is important to ensure that the submergence do not exceed a critical value **(Mazumder and Joshi,1981a; Mazumder & Debroy,1998)** .

This paper deals with different methods of estimation of peak flood from an urban catchment with and without any detention basin which reduces peak flood.

## ESTIMATION OF PEAK FLOOD WITHOUT DETENTION BASIN

Peak inflow flood from an urban/semi urban catchment without any detention basin can be determined by a number of methods, namely, empirical formulae, rational formula, SCS-method, unit hydrograph method etc. Peak flood/HFL data are not available in many catchments, especially for small streams in remote and inaccessible areas. However, rainfall data collected by Indian Meteorological Department (IMD) are usually available for years. Depending on the size of catchment areas, a number of reliable methods of flood estimation based on observed rainfall data are briefly discussed underneath.

### 2.1 Use of Empirical Formula For Flood Estimation
One of the most popular empirical formula which is used in various part of India for the estimation of flood peak, is the Dickens Formula. This formula gives direct relation between flood peak (Q)and the drainage area(A) as follows:

$$Q = C \ A^{3/4} \tag{1}$$

Where, Q = Peak Flood discharge in Cumec
        A = Catchment Area in $Km^2$
        C = Dickens constant with values varying between 6 to 30 as mentioned underneath.
        North – Indian Plain- C=6
        North – Indian Hilly Regions - C varies from11 to14
        Central India - C varies from 14 to 28
        Coastal Andhra and Orissa- C varies from 22 to 28
Such empirical formula should be avoided as it is independent of rainfall.

### 2.2 Rational Formula
The rational formula for estimating peak flood is based on the concept that the critical rainfall intensity continues indefinitely and uniformly all over the catchment. The runoff at the outlet of a catchment will increase until the time of concentration $T_C$, when the whole catchment starts contributing flows to the outlet. The peak runoff is given by the following expression:

$$Q= 0.028 \ f \ P \ A \ I_c \tag{1}$$

where,
Q = peak flood in cumec
A = Catchment area in hectares

$I_c$ = Critical intensity of rainfall in cm/hr for the selected frequency and duration equal to the time of concentration, $t_c$ given by the relation

$$t_c = F/T[(T+1)/(t_c+1)] \tag{2}$$

P = Coefficient of run-off for the given catchment. Since the run-off coefficents are different for different types of surfaces (e.g. concrete roof top, metalled roads, lawns etc.), equation (1) can be written as

$$Q = \sum Q_n = 0.028 f\, I_c \sum (P_n A_n) \dots n = 1.2.3 \dots \tag{3}$$

where,
$Q_n$ i.e. $Q_1$, $Q_2$, $Q_3$…. Etc. are the peak discharges from different areas $A_n$ i.e. $A_1$, $A_2$, $A_3$…etc. having different run-off coefficients $P_n$ i.e. $P_1$, $P_2$, $P_3$…respectively.
f = Spread factor for converting point rainfall into areal mean rainfall.
F = total rainfall in cm in a duration of T hours depending on storm duration and design return period
tc= Time of concentration in hours

Further details of computation of peak flood by Rational method may be found in **IRC: SP:42(2014).**
Rational formula should not be applied in catchments of area more than 500 hectares i.e. 5 sq. km.

## 2.3 SCS Method (Run Off Curve Number Method)

The SCS (Soil Conservation Services) method or Runoff Curve Number(CN) method of estimating direct runoff from storm rainfall is developed by U.S Soil Conservation Services. Relation between rainfall, runoff, initial abstraction and potential maximum retention can be expressed as;

$$Q = (P-I_a)^2 / [(P-I_a) + S] \tag{4}$$

Where,
Q = storm runoff in mm
P = storm rainfall in mm
Ia = initial abstraction in mm = 0.2S
S = potential maximum retention in mm =(25,400/CN) − 254
CN= Curve number applicable for the given surface and antecedent soil moisture condition
Further details of computation of peak flood by SCS method by use of SCS curve numbers are available in **IRC: SP:42(2014)**

## 2.4 Synthetic Unit Hydrograph Method
Unit hydrograph can be prepared synthetically **(Subramanya, 2013, CWC Flood Estimation Reports)** by using physiographic data like area of catchments, length of stream, longitudinal bed slope, soil and cover conditions etc. Daily rainfall corresponding to design flood return period is found from iso-hyetal curves for the catchment. Hourly distribution of rainfall and rainfall excess-values corresponding to design storm are found. By using the unit hydrograph and rainfall excesses, flood hydrograph is prepared and the peak flood is determined. Details of computing peak flood by using synthetic unit hydrograph are available in "Flood Estimation Reports"

prepared jointly by CWC, RDSO,IMD &MORTH, Govt. of India and published by Hydrology Directorate,Central Water Commission (CWC), for 26 hydro-meteorologically similar sub-zones in India. Unlike other methods, unit hydrograph is useful for generating flood hydrograph for a given storm of required frequency/return period. Such flood hydrographs give the volume of flood flow (area under flood hydrograph gives the flood volume) which is needed for design of detention storage capacity discussed under clause-3.1 below. Unit hydrograph method of flood estimation is applicable for catchment area varying from 30 to 3,000 sq. km.

## 2.5 Use of Manning's Equation
When stream cross-section is available, Manning's equation can be used to determine mean flow velocity (V) from the equation

$$V = (1/n) \, R^{2/3} \, S^{1/2} \tag{5}$$

and flood discharge (Q) corresponding to measured high flood level (HFL)

$$`Q = A.V \tag{6}$$

where,

V is mean velocity of flow in m/s, n is Manning's roughness coefficient, R is hydraulic mean depth in m given by R= A/P and S is the energy slope, A is area of cross section normal to flow in $m^2$ and Q is flow in $m^3$/s. Manning's n-values can be obtained from standard textbook of hydraulics **(Chow,1970 ; French,1986).**

Assuming different stages (water levels), Q-values corresponding to the different stages can be found from Manning's equation for the given stream section. Stage-discharge curve can be obtained by plotting discharges against corresponding stages/water levels. Peak flood can be obtained from the stage – discharge curve corresponding to measured HFL during flood.

## 3.0 DESIGN FLOOD DISCHARGE

Design flood is the peak flood discharge for which the storm sewer is to be designed to safely dispose the flood water without causing water logging and other problems. Cost is one of the prime concern. Too high a peak will require large size conduits/channels requiring high investment, although it will ensure instant clearance of flood water. Apart from cost, such large size conduits/channels will run partially full with low velocity  when flow of lower magnitude will occur during low flow season or during floods lower than design peak flood in other years. This will result in in silting and accumulation of debris thereby increasing annual maintenance cost. Fig.1, for example, illustrates the design flood for a typical culvert. It is seen that the total cost comprising of capital cost and cost of damage is the lowest for a peak flood of 25 year return period and hence the design flood of the culvert is taken as the peak with 25 year return period .The following range of design period is commonly used in storm sewer design. **(ASCE-1992, HEC:22-2013)**

  (i)  2 to15 years for sewers in residential areas, most commonly 10 years
  (ii)  10 to 50 years for sewers in commercial and high-value areas

(iii)     25 years for drainage culverts
(iv)     50 years for flood- protection works
(v)      5 years for District Roads
(vi)     10 years for district roads at valley points

Guidelines for Urban Drainage **(IRC:SP:50-2013)** prescribes rational formula for determination of design flood discharge based on design rainfall intensity. Current practice being followed in some of the metropolitan cities in India is given below:
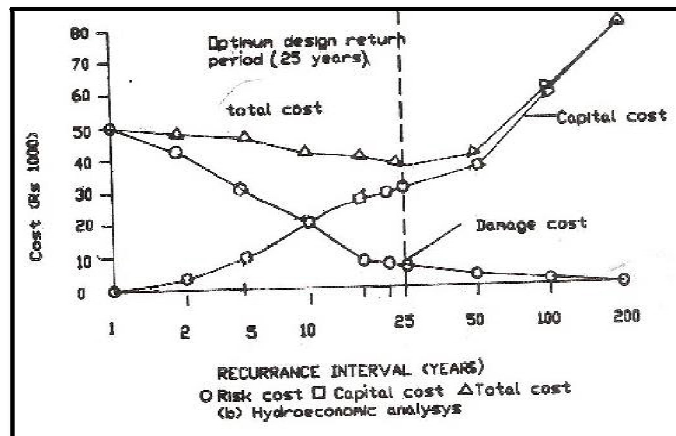


**Fig.1 Illustrating the Determination of Design Flood for a Road Culvert**

**Delhi:**(i) Internal Drains- 1cusec/acre, (ii) Intercepting Drains-0.75 cusec/acre and
(iii) Main Drains-0.5 cusec/Acre
**Mumbai:** Critical intensity of rainfall- 50 mm/hour (Frequency of storms:2times a year)
**Chennai:** Critical intensity of rainfall-25mm/hour(corresponding to a duration of 1 hour with 1.25 year return period

## 4.0 DETETION BASIN

The detention basin is most widely used to control peak flood. Ponds/lakes within the flow path act as detention basin. Apart from reduction in  flood peak, such detention basins/ponds are useful in trapping pollutants, debris and sediments before the sewer water is discharged into the adjoining river/stream/nalla .They can be used for fish culture and as recreation spot with proper aesthetical planning. Detention basin helps in artificial recharge of ground water due to increased depth of water and wide perimeter.

### 4.1Flood Routing in Detention Basin

Denoting $Q_{in}$  as inflow rate, $Q_{out}$ as outflow rate and S as storage, The basic principle of flood routing in a detention basin can be expressed as

$\Delta S = S_2 - S_1 = [1/2(Q_{in}1+Q_{in}2) - 1/2(Q_{out}1+Q_{out}2)]\Delta t$ (7a)

In differential form, eq. (7a) may be expresse as

$dS/dt = dQ_{in}/dt - dQ_{out}/dt$ (7b)

where,

$S_1$ and $S_2$ are the storage volumes in the basin before and after a time interval $\Delta t$, $\Delta S$ is the storage in time interval $\Delta t$, $Q_{in}1$ and $Q_{in}2$ are the inflow rates in to the basin, $Q_{out}1$ and $Q_{out}2$ are the outflow rates from the basin before and after the time interval $\Delta t$. Inflow rates can be found from inflow hydrograph (without detention basin) as discussed under sections 2 & 3. Outflow rates are governed by the head (H) at control point at the outlet. For weir type control at the outlet, outflow rate $Q_{out}$ can be expresses as

$Q_{out} = C_d.L_{eff}.H^{3/2}$ (8)

Here, $L_{eff}$ is the effective waterway of outlet (in case of weir type control, it is the weir length), $C_d$ is the coefficient of discharge which depends upon free fall weir or submerged weir condition **(Mazumder,1981b; Mazumder,2007)**. From eq.(7b), storage is maximum when $Q_{in}=Q_{out}$ and the pond level is the maximum. Storage capacity of a detention pond for routing of a given peak inflow flood (without detention basin) to a desired peak outflow flood (with detention basin) can be found in a tabular form by incremental time ($\Delta t$) step method **(USBR,1968; Mays,2012).** Fig.2 ilustrates the inflow ($Q_{in}$) and outflow ($Q_{out}$) hydrographs obtained by routing procedure as discussed above. Detention storage volume required $V_s$ ($=\sum\Delta S$) is indicated by the shaded area between inflow and outflow hydrographs as shown in Fig.2.Further details about design of detention storage is given in the textbook Ground and Surface Water Hydrology by **Mays (2012).**It may be noted from Fig.2 that the peak value of inflow flood (inflow hydrograph '$Q_{in}$' without basin) is substantially reduced to peak value of outflow flood (outflow hydrograph'$Q_{out}$'with basin) due to provision of detention basin.

## 5.0 CONCLUSION

Computation peak flood in an urban catchment with and without any detention storage is needed for finding the storm sewer capacity. Several methods available for determining peak flood discharge in a stream/nalla where the sewer outflow is discharged has been described. Detention storage within the catchment helps in reduction of flood peak and corresponding high flood level. Apart from reducing peak flood, such basins/ponds are useful for trapping pollutants, and sediments. They can be used for recreation, fish culture and artificial recharge of ground water. Flood routing procedure showing inflow and outflow hydrographs, required basin storage capacity and reduction in flood peak have been illustrated in Fig.2.
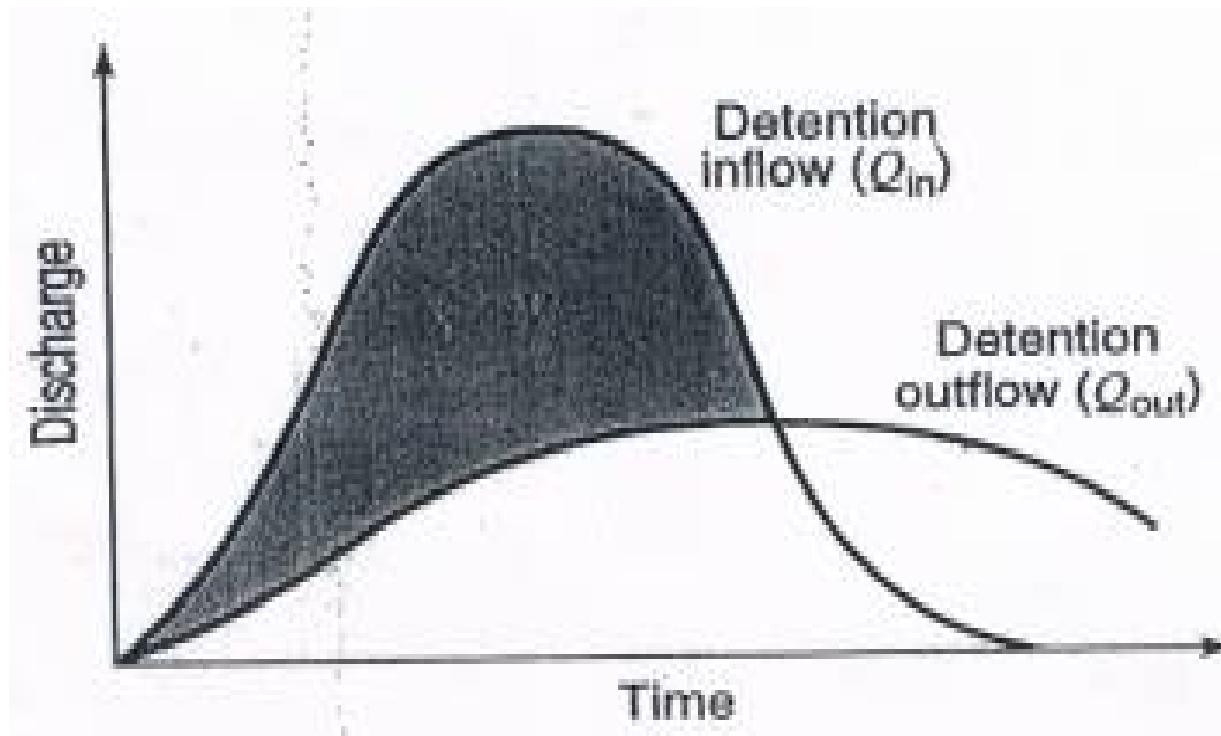
**Fig.2 Flood Routing by Detention Basin**

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