IJCSN International Journal of Computer Science and Network, May 2014
ISSN (Online) : 2277-5420
www.IJCSN.org
Conference Proceeding – RDFCORDGE - 2014

Estimation of Maximum Discharge for Small Catchment Area

[1]Shabri Khant, [2]Mamta Gendre, [3]Rohit Kshatre, [4]Rohan Singh, [5]Dalam Singh, [6]Akash Pathak, [7]Dileshwar Ku. Sahu

[1-7]Department of Civil Engineering, MMCT, CSVTU, Bhilai (C.G.)

Abstract- A flood is a usually high state in a river, normally the level at which the river overflow its banks. The damages caused by floods in terms of loss of life, property and loss due to the disruption of economy activity are all too well known. Thousands of crores of rupees are spent every year in flood control and flood forecasting. In the design of practically all hydraulic structure the peak flow that can be expected with assigned frequency (say 1 in 100 years) is of primary importance to adequately proportion the structure to accommodate its effect. The design of bridge, culverts, waterways and spillway for dams and estimation of scour at a hydraulic structure are some example where in flood peak value is required. In project work, studied to estimate maximum discharge/flood or yield in small catchment area of less than 50 sq. km has been enumerated along with analysis and example.

Keywords - *Flood, Irrigation, Catchment area.*

1. Introduction

In developing country like India, river valley projects are of vital importance due to huge demand of irrigation, flood control and power. The efforts of the water resources engineers all along have been to control and smoothen the surging flood peaks which have hitherto been estimated largely on the basis of empiricism and local regional experience. In the past few decades, projects were designed adopting the design floods based on empirical formulae, due to lack of hydro-meteorological data. But now with the availability of correlated basic studies in the interfacial areas with the field data, it is possible to design the projects on sound rational basis. The design of any water regulating structure requires the adoption of a design flood flow. The risk involved for the kind if the property affected, economy and the type of the structure under consideration, will influence the designer judgment in the selection of the design flood magnitude.

The measurement of discharge in stream is very costly process requiring technical skill and the site of the project cannot be fixed in advance hence methods were developed to estimation discharge of the required site (outlet) of stream by means of Rainfall over catchment. It is easy to measure depth of rainfall on catchment and rainfall records for past years were available.

The methods used for maximum discharge/flood are:

1. Empirical
2. Rational method
3. Unit hydrograph
4. Gumbel's method

2. Literature Survey

For calculating the maximum flood of river/outlet at any site there are four methods which are as following below-

2.1 Empirical Formula

Empirical formulae are about the earliest to be used for estimating peak discharge. Many are purely empirical and some are based on theoretical considerations with liberal approximations, assumptions and over simplifications.

2.2 Unit Hydrograph Technique

A unit hydrograph is defined as the hydrograph of direct runoff resulting from one unit depth of rainfall excess occurring uniformly over the basin and at a uniform rate for a specified duration. This method is used for catchment area upto 5000 sq.km. (Between 50 sq.km to 5000 sq.km)

2.3 Analytical Method

This is based on statistical and probability analysis of available hydrological data of rainfall and runoff. This method is used for catchment area greater than 5000 sq.km rainfall is random variable hence Gumble's method is used.

2.4 Rational Method

This is based on record of single rain gauge station i.e. Point rainfall. This method is used for catchment area less than 50 sq.km.Rational method, a simple estimation technique introduced by Kuichling in 1889. Our Project is Estimation of maximum discharge for small catchment area by rational method, which is to be analyzed and discuss in detail.

3. Rational Method

Amongst various types of empirical relation, rational formula is the most rational method of calculating peak discharge for small catchment. The rational method for estimating maximum discharge/ flood is useful for design of structures where the catchment area is less than 50 sq.km. Such structures include mini tanks (dabari in villages), culverts on road, cross-drainage works on canals and storm water drains.

The peak value of runoff is given by-

Q=AIR

Where,

A= Area of the catchment in sq.km.
I= Imperviousness factor (Runoff coefficient)
R= Intensity of rainfall in mm/hr

Now in the above formula the area usually measured from plan is in sq.km. or hectare-meter and rainfall depth is available in mm/hr.
Hence instead of converting above values to S.I system, they are substituted directly in the units in which they are measured and a dimensional constant 'k' is introduced

Q= KAIR cumec

Where,

K= Dimensional constant
A= Area of the catchment in sq.km.
I= Imperviousness factor (Runoff coefficient)
R= Intensity of rainfall in mm/hr
$K = 10^6 \times 10^3/60 \times 60$
$K = 1/3.6$
$Q = \frac{1}{3.6}$AIR cumec

For estimating the maximum discharge three parameters i.e. A, I and R are to be evaluated as follows:

4. Imperviousness Factor

The coefficient I represent the integrated effect of the catchment losses and hence depend upon the nature the surface, surface slope and rainfall intensity. The coefficient accounts for the water that percolates into exposed soil and other porous surface, that which is lost by evaporation and the water held in puddles and depression of both pervious and imperviousness surface.

Table No.2.1–
Typical Values of Imperviousness Factor [1] (Runoff Coefficient) I

Type of area	Value of I
A) Urban area	
(a.)Lawns	
(1.) Sandy soil, flat 2%	0.05-0.10
(2.) Sandy soil, average 2.7%	0.1-0.15
(3.) Sandy soil ,steep <7%	0.15-0.2
(4.) Heavy soil, flat	0.13-0.18
(5.) Heavy soil, average	0.18-0.22
(6.) Heavy soil, steep	0.25-0.35
(b.) Residential area	
(1.) Single house area	0.3-0.5
(2.) Multi-units attached	0.6-0.75
(3.) Suburban	0.65-0.4
(c.) Business area	0.5-0.95
(d) Industrial area	
(1.) Unimproved	0.1-0.3
(2.) Light area	0.5-0.8
(3.) Heavy area	0.6-0.9
(4.) Rail yard	0.2-0.4
(e) Streets	0.7-0.95
B) Agriculture area	
(a) Flat	
(1.)Light clay; cultivated	0.5
(2.)Light clay; woodland	0.4
(3.)Sandy loam; cultivated	0.7
(4.)Sandy loam; woodland	0.1
(b)Hilly	
(1.)Light clay; cultivated	0.7
(2.)Light clay; woodland	0.6
(3.)Sandy loam; cultivated	0.4
(4.)Sandy loam; woodland	0.3

5. Catchment Area

Area supplying water between ridge lines to the outlet is known as catchment area. In other words, we can say the area supplying water to the outlet is known as catchment area. Depending upon type of soil of the area, infiltration and runoff takes place. Infiltration is high in porous surface. For different surface there is a different imperviousness coefficient.

6. Time of Concentration

Time of concentration of a drainage basin may be defined as the time required by the water to reach the outlet from the most remote point of the drainage area. It is represented by T_c. There are numbers of empirical equations available for the estimation of the time of concentration. Two of these are described below.
US practice:

$T_c = C_{tL} (LL_{ca}/\sqrt{S})^n$

Where,

C_{tL} and n are Basin constants.
S is basin slope.
L is basin length along the water course from the basin.

L_{ca} is distance along the main water course from the gauging station to Point opposite the watershed centroid.
Kirpich equation:

$T_c = 0.01947\ L^{0.77}\ S^{-0.385}$

Where,

L is maximum length of travel of water.
S is slope of catchment.
T_c is in hours.

The time of concentration for a given storm water drain generally consist of two parts-

6.1 The Inlet Time or Overland Flow Time (T_i)

The time taken by the water to flow overland from the critical point upto the point where it enters the drain mouth.

6.2. Flow Time in Drain (T_f) [2]

The time taken by the water to flow in the drain channel from the mouth to the considered point. This may be obtained by dividing the length of drain by the flow velocity in the drain.

T_f =length of the drain/velocity in the drain

Total time of concentration at a given point in the drain, for working out the discharge at that point, can be easily obtained as-

$$T_c = T_i + T_f$$

To use rational formula 'T_c' value is very important for selection of duration of storm.
If duration of storm < T_c , the entire area will not contribute water to the outlet site of catchment area.
If duration of storm > T_c , average intensity will become less as rainfall intensity is not constant throughout storm.
So maximum discharge/flood the duration of storm should be equal to 'T_c' of catchment area.

7. Rainfall Intensity

This parameter is very important as safety of structure depends on its correct evaluation. For this, data is to be collected from a single rain gauge station situated in this area. This is called point rainfall. The following data is to be collected:

1) Daily rainfall records for 15 to 20 years.
2) Selection of 4 to 5 storms giving maximum precipitation on the area in each year.
3) Mass rainfall curves of the above storms.

After collection of data, the following are to be prepared:

8. Intensity Duration Analysis

It can be generally observed that the most intense storms last for every short duration. As the duration of storm increases the maximum average intensity of the storm decreases. If the observed maximum rainfall intensity at a place for various durations is plotted against the respective durations, a graph known as Intensity-Duration graph is obtained. A simple method of finding the maximum intensity for a given duration in any storm is to use a transparent scale with two vertical lines drawn on it at a distance equal to the required duration and to measure the maximum vertical intercept of the rainfall mass curve when the transparent scale is slides across the mass curve
The maximum intensity varies inversely with the duration and generally an equation of the form

$$i=C/(t+a)^b$$

Where,
C, a, b are constant values,
T is generally expressed in minutes,
i may be expressed in mm/hr or cm/hr

9. Frequency Analysis

9.1 Recurrence Interval

Recurrence interval denotes the number of years in which a flood can be expected once. This is usually denoted by a symbol T_r.
Intensity duration frequency curve is prepared by analysis which shows probability of occurrence of a maximum rainfall of given duration in future.

i.e. once in 30 years
or once in 20 years
or once in 5 years

$$T_r = N/m$$

Where,
T_r = recurrence time
N = number of years
m = rank

9.2 Probability

The Probability of an event being equaled or exceeded in any one year is the probability of its occurrence. The probability (P) of occurrence of a flood having in a recurrence interval of T years in any year or the probability of exceedance is-

$$P=1/T_r \times 100\%$$

Where,
P = probability in % i.e. 1 in 100, 1 in 1000
T_r = recurrence time

The probability that it will not occur in a year is known as probability of non-exceedance (q) is given by-

$$q = 1-P$$

The probability of occurrence of an event expressed as a percent in known as frequency (f).

9.3 Design Period

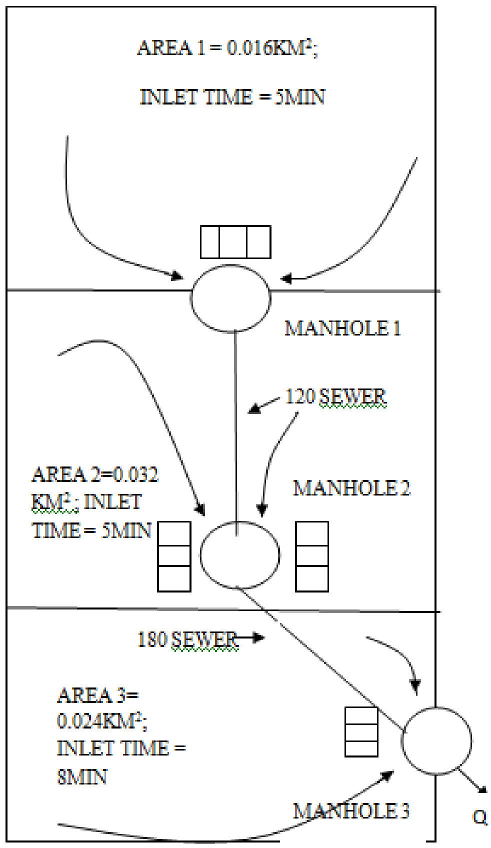
Decision of 'P' will depend on loss expected to life and property. For dams it may be 1 in million, for storm water drains it may be P=20% i.e. =5 years.

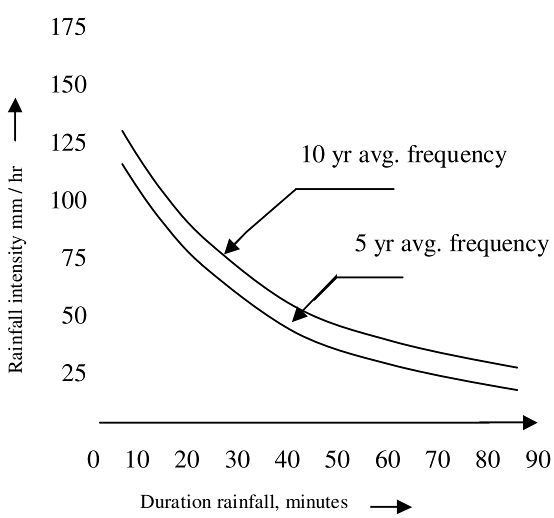
10. Conclusion

If the site construction is situated on a stream then- the first step is to mark the area of catchment on plan. After this demarcate the area for different soil type. Fix value of impervious coefficient (I); determine T_c of the area to get required duration of rainfall. Then, rainfall intensity is calculated. So finally flood discharge is computed. culverts, bridge, flood reservoir, spillways are constructed near dam and sewer, man-made reservoir are constructed in the city.

APPENDIX

PROBLEM ON STORM WATER [2]:





Imperviousness factor for the entire area = 0.30
Velocity of flow in sewer flowing full=0.75m/sec.
5 year average frequency curve is used.

Solution-

Flow time (T_{f1}) in sewer from manhole 1 to manhole 2

$=\frac{120\text{m}}{0.75\text{m/sec}}$

$= 120\times\frac{4}{3}$ sec

$=\frac{120\times4}{3\times60}$ min

= 2.7 min.

Flow time (T_{f2}) in sewer from manhole 2 to manhole 3

$=\frac{180\text{m}}{0.75\text{m/sec}}$

$= 180\times\frac{4}{3}$ sec

$=\frac{128\times4}{3\times60}$ min

= 4 min.

Time of concentration for area 1 (to contribute wholly at manhole3)

$T_{i1} + T_{f1} + T_{f2} = (5+2.7+4)$ min.
= 11.7 min.

Time of concentration for area 2 (to contribute wholly at manhole3)

$T_{i2} + T_{f2} = (5+4)$ min.
= 9 min.

Time of concentration for area 3 (to contribute wholly at manhole3)

$T_{i3} = 8$ min.

That means that after 11.7 min., all the three areas 1, 2 and 3 will start contributing fully at manhole 3. The time of concentration for the entire catchment (area 1 + area 2 + area 3) will, thus be equal to 11.7 min.

Since 5 years frequency is to be considered in designing the sewer, let us workout the rainfall intensity for such a rain having a frequency of 5 years and a duration of 11.7 min. such an intensity is read out from the given intensity duration curve, using the 5 year frequency curve, as 115mm/hr.

Q=KAIR

Where,

$A= A_1+A_2+A_3$
$= (0.016+0.032+0.024)$ sq.km.
A= 0.072 sq.km.
R= 115mm/hr
I= 0.30
$Q=\frac{1}{3.6}\times0.072\times 0.30\times 115$
$Q= 0.69\ m^3/\text{sec}.$

11. Acknowledgement

We are indebated to Dr. Shamita Chakraborty, Director of this institute for giving us an opportunity to show how we work as a team. We show heartfelt gratitude to Mrs. Shubha Vaghmarey Head of department of civil engineering for her constant encouragement, patience guidance and inspirational discussions throughout the course of our work especially in our tough time. It gives us immense pleasure to express the deepest sense of gratitude and sincere thanks to guide Prof. S.V.Dandekar, Department of Civil Engineering, M.M. College of Technology, Raipur(C.G.) for his revered guidance throughout our dissertation work, which made this task a pleasant job. It was real pleasure to work under his guidance.

References

[1] Dr.B.C.Punmia, “irrigation and water power engineering”, ed.-16.
[2] Santosh Kumar Garg, “sewage disposal and air pollution engineering”, vol.2, ed.-Jan 2009.
[3] K.Subramanya, “engineering hydrology”ed.-3.
[4] Jaya Rami Reddy, “hydrology”, ed.-2008.
[5] H.M.Raghunath, “hydrology principle, analysis and design”, ed.-2