MODULE 3

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3.1 RUN OFF

3.1.1 INTRODUCTION

When precipitation occurs on land, a part of it is intercepted by vegetation and some part of it is stored as depression storage. A part of precipitation infiltrates into the ground. The rate of infiltration depends on the nature of the soil, moisture content in soil, topography, etc. If the rate of precipitation is greater than the rate of infiltration, then the rainfall in excess of infiltration will start flowing over the ground surface and is also known as over land flow. When overland flow is occurring infiltration and evaporation may also occur. When over land flow reaches a well-defined stream it is known as surface run off. A portion of infiltrating water will satisfy soil-moisture deficiency. A portion may move in soil but very close to the surface. If this also reaches a well-defined stream it is known as inter flow or subsurface flow. Another portion of infiltration may percolate deeper into the soil to reach ground water table. Under favorable conditions some of the ground water may reach the streams and this portion is known as Base flow or ground water flow. A part of precipitation may occur directly on stream surface and this is known as channel Precipitation.

Hence, Total runoff = Surface run off + Inter flow + Base flow + Channel precipitation.

It is also evident that evaporation always occurs along with transpiration.

Hence, Precipitation = Run off + Evaporation

OR

Precipitation = (Surface run off + Inter flow + Base flow + Channel precipitation) + Evaporation

3.1.2 DEFINITIONS

1. Total Run off: This is the part of precipitation which appears in streams. It consists of Surface run off, Inter flow, Base flow, and Channel precipitation.

2. Surface run off (SRO): This is the part of overland flow which reaches the streams.

3. Direct run off (DRO): It consists of Surface run off, Inter flow, and Channel precipitation, but does not include Base flow. Since channel precipitation is small and inter flow is uncertain, it is usual to include these two run offs in surface run off. Hence there is no difference between direct run off and surface run off. Hence Total run off = Surface run off + Base flow Since the base flow occurs in the stream after a longer time compared to surface run off, it is necessary to separate the base flow and surface run off in preparing hydrographs.

4. Hydrograph: A hydrograph is a plot of the run off or discharge in a stream versus time. Hydrographs may be developed for isolated or complex storms using stream gauging data. The area under the hydrograph gives the total volume of runoff and each ordinate gives the discharge at the instant considered. It also indicates the peak discharge and the time base of the flood in the stream.

5. Rainfall excess: This is the portion of rainfall appearing in the stream as surface run off.

6. Effective rainfall: This is the portion of rainfall which appears in the stream as the sum of Surface run off, Inter flow, and Channel precipitation. Since channel precipitation is small and inter flow is uncertain, it is usual to include these two run offs in surface run off. Thus rainfall excess and effective rainfall may be considered to be the same.

Note: Surface run off = Precipitation – (interception + depression storage + evaporation + infiltration)

7. Channel storage: As runoff occurs in the stream, the water level will rise along the length of the stream. Thus a large volume of water is temporarily stored in the channel. This is known as channel storage. It reduces or moderates flood peaks. The channel storage therefore causes delay in the appearance of discharge at any section of the stream.

3.1.3 METHODS OF ESTIMATING RUN OFF FROM BASINS

The basin area contributing to the flow in a stream goes on increasing as we go down along a stream. Hence the section at which the flow is measured should be specified. The various methods for estimating run off from basins are

a. Empirical formulae and charts

b. By estimating losses (evaporation, transpiration, etc.)

c. By infiltration

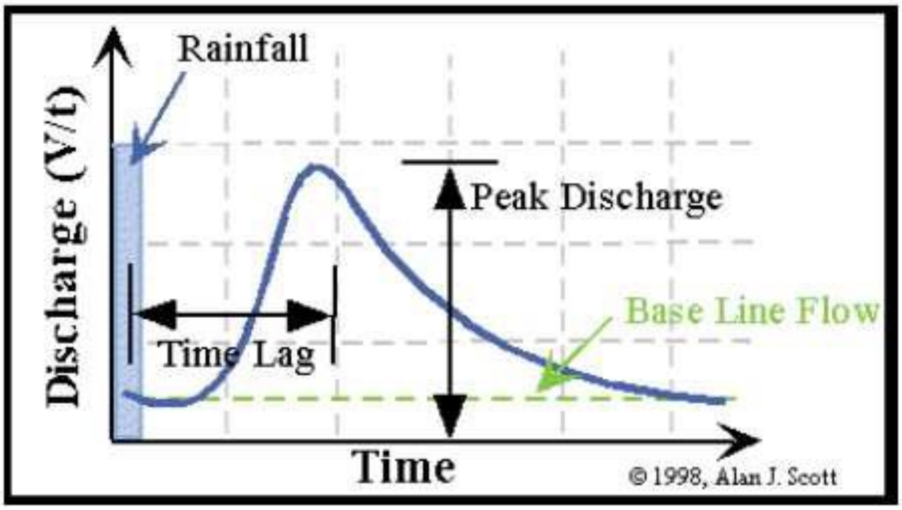
d. Unit Hydrograph method

e. Synthetic Unit Hydrograph method (Synder‘s method)

It is difficult to obtain even a fairly approximate estimate of run off because the various processes such as overland flow, base flow, infiltration, evaporation, etc are highly irregular and complex. Thus none of the above methods can be considered as accurate. However the Unit Hydrograph method is easier and is considered as the best among the methods mentioned.

3.2 HYDROGRAPH

A Hydrograph is a graph showing the variation of discharge versus time.



At the beginning there is only base flow (i.e., the ground water contribution to the stream) gradually deflecting in a conical form. After the storm commences, the initial losses like interception and infiltration are met and then the surface flow begins. They hydrograph gradually rises and reaches its peak value after a time tp (log time or basin log) measured from the centroid of the hydrograph of the net rain. Thereafter it declines and there is a change of slope at the inflection point i.e., there has been inflow of the rain up to this point and after this there is gradual withdrawal of catchment storage. There after the GDT declines and the hydrograph again goes on depleting in the exponential form called the ground water depletion curve or the recession curve.

3.2.1 HYDROGRAPH WITH MULTIPLE PEAKS

Basic definitions (Hydrograph features):

a) Rising limb: It is the curve or line joining the starting point ‘A’ of the raising curve and the point of reflection. The shape of the raising line is influenced by the rainfall characteristics.

b) Peak or Crest: It represents the highest point/position of the hydrograph. Its duration also depends on the intensity and duration of the rainfall.

c) Falling limb or depletion curve: It is the descending portion or the hydrograph. The shape of the falling limb it mainly a function of the physical features of the channel alone and is independent of storm characteristics (it depends on basin characters).

d) Time to peak (tp): It is the time to peak from the starting point of hydrograph

e) Lag time: The time interval from the centre of mass of rainfall to the centre of mass hydrograph is the lag-time.

f) It is the total duration or time elapsed between the starting and ending of the hydrograph.

3.2.2 FACTORS AFFECTING THE SHAPE OF THE FLOOD HYDROGRAPH

a) Climatic factors

b) Physical factors

- Climatic factors include

1) Storm characteristics, intensity, duration, magnitude and movement of storm

2) Initial loss due to interception etc.

3) Evapotranspiration

- Physical factors include

1) Basic characteristics, shape, size, slope, nature of the valley, elevation, drainage density

2) Infiltration characteristics, land use and cover, soil type, geological conditions etc.

3) Channel characteristics, cross section, roughness and storage capacity

(For a given duration, the peak and volume of surface runoff are essentially proportional to the rainfall intensity. Duration of rainfall of given intensity directly effects the volume of runoff. If the storm moves in the downstream direction flow will be quicker at the basin. Smaller catchments yield a more rapid and intense flood per unit area. Vegetation and forests increase infiltration and also the storage capacity of the soils; vegetal cover reduces the peak flow.

3.2.3 UNIT HYDROGRAPH

A unit hydrograph is defined as the hydrograph of direct runoff resulting from one cm depth excess rainfall occurring uniformly over the basin and at a uniform rate for a specified duration.

Assumptions:

1. The effective rainfall is uniformly distributed within the specified period of time or within its duration
2. The time or base duration of the hydrograph of direct runoff due to an effective rainfall of unit duration shall be constant.
3. The effective rainfall is uniformly distributed throughout the area of drainage basin.
4. The direct runoff of common base line are proportional to the total amount of direct runoff.
5. The hydrograph of runoff due to a given period of rainfall for a drainage area shows all the combined physical characteristics.

Limitations of Unit hydrograph theory:

1. Unit hydrograph is based on the assumption that effective rainfall is uniform over the entire basin. However it is seldom true particularly in the case of large base. As such unit hydrograph theory is limited to the basins of size nor exceeding 6000 km2 . Thus large basins should be subdivided & unit hydrograph should be separately developed for each basin.

2. This theory is not applicable when approachable quantity of precipitation occurs in the form of snow.

Derivation:

1. Few unit periods of intense rainfall duration corresponding to an isolated storm uniformly distributed over the area are collected from the past rainfall records.

2. From the collected past records of the drainage for the forms prepare the storm hydrograph for some days after and before the rainfall of that unit duration.

3. Draw the line reporting the ground water flow and direct runoff by any of the standard base flow separation procedures.

4. From the ordinate of the total runoff hydrograph deduct the corresponding ordinates of base flow to obtain the ordinates of direct runoff.

5. Divide the volume of direct runoff by the area of the drainage basin to obtain the net precipitation depth(x) over the basin.

6. Divide each of the ordinates of direct runoff by net precipitation depth to obtain the ordinates of the unit hydrograph. i.e., ordinate of unit hydrograph (UHG) = Ordinate of direct runoff

(FHG)/Depth of net precipitation(x) i.e, UHG=FHG/x

7. Plot the ordinates of the unit hydrograph against time since the beginning of direct runoff, which is the unit hydrograph for the basin for the duration of the storm.

3.2.4 HYDROGRAPH SEPARATION/BASE FLOW SEPARATION:

In figure: By simply drawing a line ‘AC’ tangential to both the limbs at their lower portion. This method is very simple but is approximate and can be used only for preliminary estimates.

2. Extending the recession curve existing prior to the occurrence of the storm upto the point ‘D’ directly under the peak of the hydrograph and then drawing a straight line DE. Where E is a point hydrograph ‘N’ days after the peak & N 9in days) is given by N= 0.8f

3 Where A is the area of drainage basin (km) & the size of the areas of the drainage basin as a

guide to the values of 'N' are given below: Area of drainage basin, km Time after peak N (days) Simply by drawing a straight line AE, from the point of rise to the point E on the hydrograph, 'N' days after the peak. By producing a point on the recession curve backwards up to a point 'F' directly below the inflection point and the joining a straight line AF.

3.3 IMPORTANT QUESTIONS

- Explain factors affecting Runoff?
- Explain relation between rainfall & runoff using regression analysis.
- With a neat sketch explain the fan and fern leaf catchment.
- List out various methods for estimation of design flood. Explain rational method of flood estimation.
- Explain typical single peaked hydrograph components with a neat sketch.
- Define unit hydrograph. List the assumptions made in deriving unit hydrograph and its limitations.
- Explain the procedure for drawing master depletion curve.
- Explain the procedure for deriving a unit hydrograph from an isolated storm.
- With a neat sketch explain S Hydrograph or summation hydrograph.

3.4 OUTCOMES

- Understand the concept of hydrograph and runoff

3.5 FURTHER READING

https://nptel.ac.in/courses/105101002/9

https://nptel.ac.in/courses/105101002/7