OPSC 2019

Odisha Public Service Commission

Assistant Engineer Examination

Civil Engineering

Engineering Hydrology

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY
Publications

Engineering Hydrology

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CHAPTER 01

Introduction

1.1 Hydrology

Hydrology means the science of water. Hydrology deals with the occurrence, circulation and distribution of water on the earth and atmosphere. *Hydrology may be defined as the science that deals with the charging and discharging of our water resource.* Practical application of hydrology is required in the design and operation of hydraulic structure, water supply, irrigation, hydro power generation, flood control, etc.

1.2 The Hydrologic Cycle

- Water occur on the earth and atmosphere in all three states (liquid, gas, solid). There is endless circulation of water between the earth and atmosphere. This circulation is called hydrologic cycle.
- Hydrologic cycle has no beginning or end and its many process occurs simultaneously.
- Water on earth exists in a space called hydrosphere and it has boundary 15 km up into atmosphere and 1 km down into lithosphere. Hydrologic cycle also moves within this boundary.
- Sun imparts energy for movement of this cycle.
- Sun and Coriolis force (due to this force, wind moves in different direction) play important role in completion of hydrologic cycle. Sun evaporates water and Coriolis force, by controlling wind circulate the water vapour, where precipitation occurs.

1.3 Components of Hydrologic Cycle

(i) Evaporation: When the water come into contact with heat radiation, it turns into vapour. It is called evaporation.

- In hydrologic cycle, evaporation mainly occur from ocean. Ocean evaporation contributes in large part and the real evaporation occur from land mass and raindrop evaporation.
- When rain drop comes to the earth surface, and come in contact with sunlight than they also get evaporated in air.

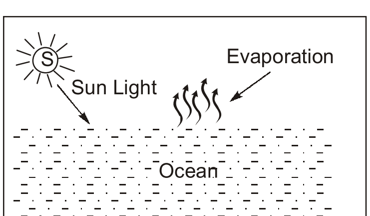

***Fig.** Evaporation from Ocean*

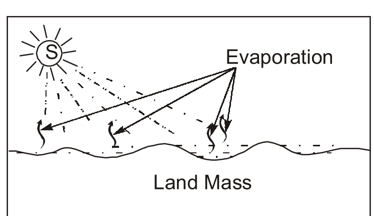

***Fig.** Evaporation from land mass*

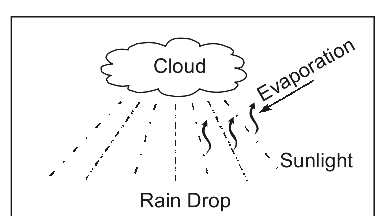

***Fig.** Rain drop evaporation*

(ii) **Precipitation:** As the evaporation continues, the amount of vapour in atmosphere goes on increasing, after reaching a certain amount, the vapour condense and come to earth's surface in solid or liquid form, this is called precipitation.

- As the air temperature decrease, its moisture holding capacity decreases.

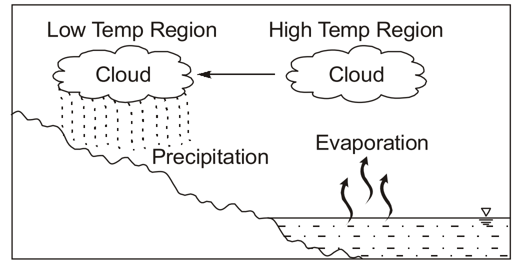

Fig. *Precipitation*

(iii) **Interception:** Some amount of precipitation is evaporated back to the atmosphere and another part of precipitation is intercepted by vegetation, structure etc. from where it may be either evaporated back to atmosphere or move down to ground surface.

- Amount of rainfall on the roof building is intercepted rainfall or simply interception.

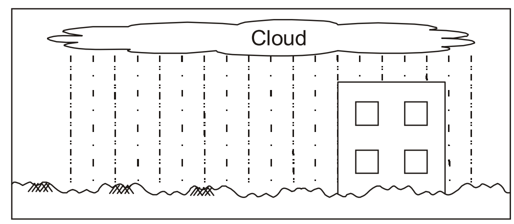

Fig. *Interception*

(iv) **Infiltration:** When the water come in to the earth surface. Some portion of it penetrate the ground and increase the moisture capacity of soil beneath the surface.

- This water is called infiltrated water and this process is called infiltration.
- Through infiltration the water level of underground water bodies increases.
- Infiltration is important for underground water movement, by increasing in its volume.
- Infiltration will be more in a village in comparison to town, because the town have pacca road which is treated as impervious strata.
- Infiltration will be more in forest area in comparison to dessert land because the tree make the surface pervious and increase the infiltration.

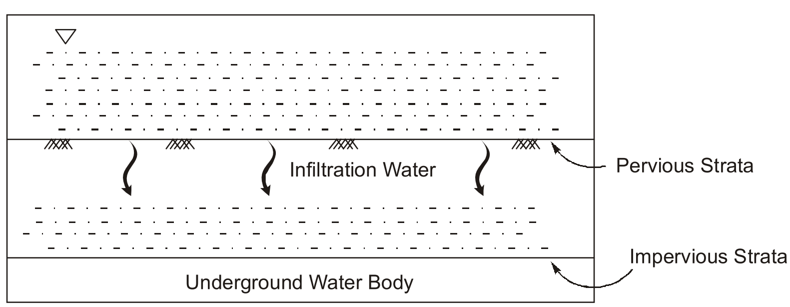

Fig. *Infiltration Beneath a Water Body*

(v) **Transpiration:** Vegetation use the ground water or soil moisture for their growth. This moisture again convert in evaporation through vegetation. This is called transpiration.

- Water extracted by plant's roots, transported upward through its stem and diffused into the atmosphere through tiny openings in the leaves is called transpiration water and process is called transpiration.

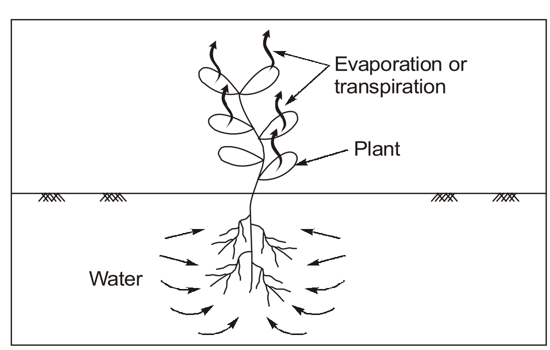

Fig. *Transpiration*

(vi) **Runoff:** The portion of precipitation which come on the surface and reach the stream channel by above and below the surface of earth is called runoff.

- The portion of precipitation that reach the stream after reaching on surface, only from above the surface is called surface runoff.
- The runoff reach in stream channel is called *stream flow*.
- Runoff means the draining or flowing off of precipitation from a catchment area through a surface channel.

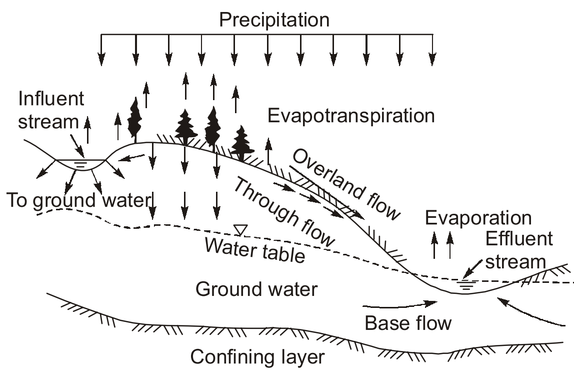

***Fig.** Different routes of runoff*

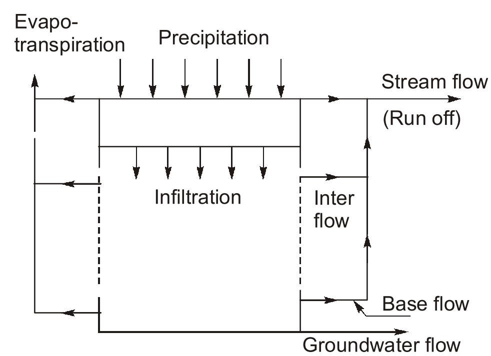

***Fig.** Transportation Components of the Hydrologic Cycle*

World Water Balance

- 96.5 percent of water on the earth's surface is in the ocean. Remaining 1.7 percent is in the polar ice, 1.7 percent in ground water and 0.1 percent in the surface and atmospheric water system.
- If we assume that the 100 parts of water come to the land area through precipitation then 61 parts of this precipitation goes to atmosphere through evaporation and 39 parts form runoff to the ocean.
- Average annual depth of precipitation over the world is 0.752 m, but 0.428 m depth of water gets evaporated. Only 0.342 m water is available for runoff.
- Average annual precipitation in India is 120 cm in a highly uneven portion.
- The per capita water availability for the Indian people is less in comparison to world's. As we have 4% of world's average annual water supply and 16% of world's population.

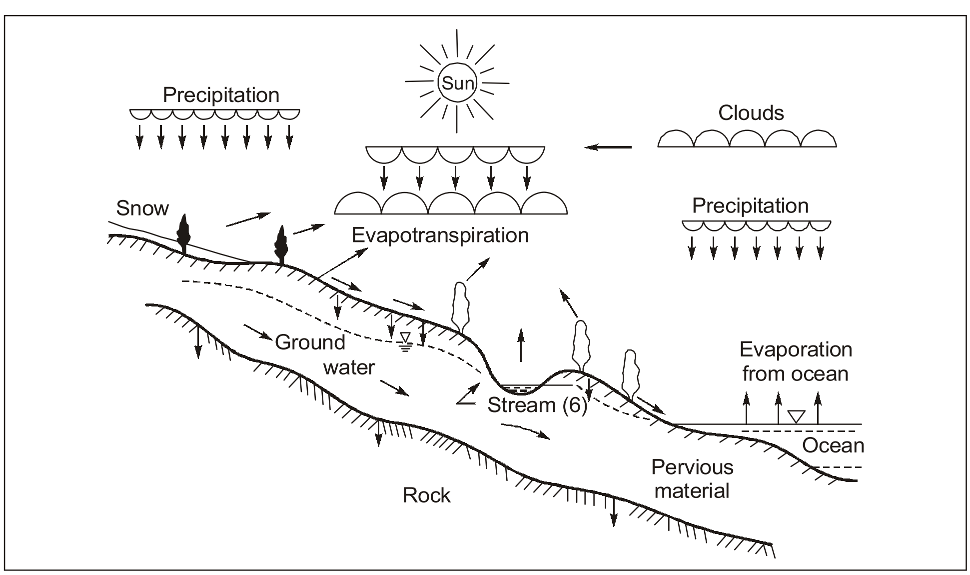

***Fig.** The global hydrologic cycle represented as a system*

- Due to unevenness in precipitation at different place of world, a large quantity of available river runoff is wasted as they join the ocean. We use water around 20% of available water.
- The Amazon river carries about 17% of total flow of world.
- Per capita average annual runoff of India is about 1700 m^3.
- The percentage of total quantity of **fresh water** in the world is only 0.3% available in liquid form.
- Most of the water that evaporate from the ocean gets back to the ocean in the form of precipitation. About 9% more water evaporates from the ocean than what falls back on them as precipitation.

1.4 Catchment Area

- The area of land from which the runoff comes into a stream is called the catchment area of that stream.
- It is also called as *drainage basin* or *drainage area* or *water shed*.
- The area of land draining into a stream or water course at a given location is known as catchment area.
- A catchment area is separated from its neighbouring areas by a ridge called *divide* or *watershed*.
- The catchment area of tributary river *A* is α and $(\alpha + \beta)$ is the catchment area of river B.
- If the catchment has no outlet point than it is called a *closed catchment*. In closed catchment water converges to a single point inside the basin known as *sink*, which may be a permanent lake, or a point where surface water is lost underground.

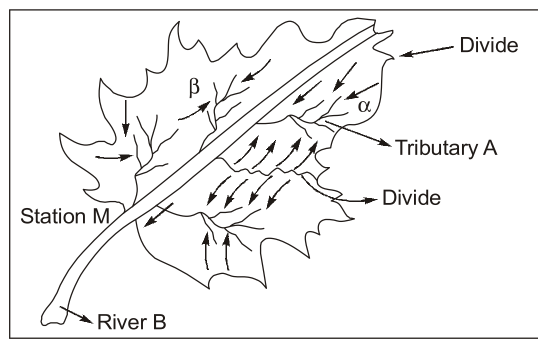

Fig. *Schematic Sketch of Catchment of River B at station M*

Leakage of Catchment:

- We measure the runoff at the outlet of catchment area, sometimes, it happens that runoff from nearby catchment also come so due to this the error will come in result. This generally occur due to subsurface water. Thus, the catchment leakage is said to occur.
- Catchment leakage also occur when the topographic divide are not coincident with the ground water divide.

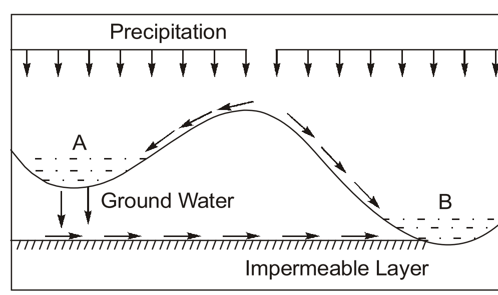

Fig. *Leakage of Catchment*

1.5 Water Budget Equation

The quantity of water going through various individual paths of the hydrological cycle in a given system can be described by the continuity principle known as *Water Budget Equation* or *Hydrologic Equations*. The *Conservation of Mass* is the most useful physical principle in hydrologic analysis and is required in almost all applied problem.

For a given catchment area in an interval of time Δt, the continuity equation for water is

Mass of water inflow – Mass of water outflow = Change in mass of water storage

If the density of water in inflow, outflow and storage water are same, then

Vol. of inflow water – Vol. of outflow water = Change in storage vol. of water

$$V_i - V_o = \Delta S$$

For solving the problem of water budget equation we should be clear in mind, what factor recharges the water discharged in the water body.

(i) Water Budget Equation for a Catchment

For a particular time Δt,

$$P - R - G - E - T = \Delta S$$

(ii) Water Budget Equation for Water Bodies

$$I + P - G - E - O = \Delta S$$

(iii) Water Budget Equation for Surface Flow

$$P + I + I_G - O - E - T - I_n = \Delta S$$

(iv) Water Budget Equation for Underground Flow

$$I_G + I_n - O_G - O_S - T = \Delta S$$

Where, P = Precipitation; R = Surface runoff; G = Net ground water flow out of the catchment

E = Evaporation; T = Transpiration; ΔS = Change in storage = $S_s + S_{sm} + S_g$

S_s = Surface water storage; S_{sm} = Water in storage as soil moisture

S_g = water in storage as groundwater; I = Inflow; O = Outflow

I_G = Ground water come to the surface; I_n = Infiltration

O_G = Ground water outflow; O_S = Ground water come to the surface

Water budget equation in terms of rainfall runoff relationship can be represented as

$$R = P - L$$

R = Runoff, P = Precipitation and L = Losses (infiltration, evaporation, transpiration and surface storage)

- For large catchment area, ground water inflow and outflow are almost equal.
- In general, after a long period the storage in catchment be same as prior.

Example 1.1 A small catchment of area 150 Ha received a rainfall of 10.5 cm in 90 minutes due to a storm. At the outlet of the catchment, the stream draining the catchment was dry before the storm and experienced a runoff lasting for 10 hours with an average discharge of 1.5 m^3/s. The stream was again dry after the runoff event. (a) What is the amount of water which was not available to runoff due to combined effect of infiltration, evaporation and transpiration? What is the ratio of runoff to precipitation?

Solution: The water budget equation for the catchment in a time Δt is

$$R = P - L$$

Where, L = losses = water not available to runoff due to infiltration (causing addition to soil moisture and groundwater storage), evaporation, transpiration and surface storage.

In the present case Δt = duration of the runoff = 10 hours.

Note that the rainfall occurred in the first 90 minutes and the rest 8.5 hours the precipitation was zero.

(a) P = Inflow due to precipitation in 10 hours

$= 150 \times 10^4 \times (10.5/100) = 157{,}500 \text{ m}^3$

R = Runoff volume = outflow volume at the catchment outlet in 10 hours

$= 1.5 \times 10 \times 60 \times 60 = 54{,}000 \text{ m}^3$

Hence losses $L = 157{,}500 - 54{,}000 = 103{,}500 \text{ m}^3$

(b) Runoff/rainfall = 54,000/157500 = 0.343