Atmospheric Phase of Hydrologic Cycle

Atmospheric phase of hydrologic cycle starts with the formation of clouds after vaporization from water bodies and ends after the occurrence of precipitation.

Land Phase of Hydrologic Cycle

After occurrence of precipitation, water comes in contact with the earth surface and hydrologic cycle enters the land phase. Part of precipitation is infiltrated and a part of it, depending upon circumstances, is intercepted by trees and vegetation. If there are depressions in the surface upon which precipitation falls, a part of precipitation will be stored in the depressions in the form of depression storage. All of these parts are liable to vaporization. Rainwater stands on the surface of earth where it falls, after various losses, depending upon the rate of rainfall. When the depth of standing water becomes sufficient it starts flowing over the ground surface in the form of surface runoff. During the travel of surface runoff towards streams, again a part of water is infiltrated and a part of it is evaporated. A part of infiltrated water moves laterally through the upper soil layers above the groundwater level, in the form of interflow which soon joins the stream flow. The remaining portion of infiltrated water percolates to deeper layers of the ground and is stored as groundwater. Sometimes this ground water joins the stream flow through spring or seepage process. The stream flow is then called the total runoff. The total runoff from the streams goes back to the oceans subjected to vaporization throughout its travel. The depression storage is either evaporated or infiltrated into the ground and similar is the case of interception. The ground water also may go to oceans after a long time.

Hydrologic Equation

The hydrologic equation states that for a given time interval, difference of inflow to and outflow from a system is equal to change of storage of the system. In its differential form it states that rate of volume inflow minus the rate of volume outflow is equal to the rate of change of storage. Mathematically

$$I - O = \Delta S / \Delta t \quad \text{- - - - - - - - - - - - - - - -} \quad 1.1$$

Where,

I = Rate of volume inflow (volume/time), measured in m^3/sec, ft^3/sec, etc.

O = Rate of volume outflow (volume/time) measured in m^3/sec, ft^3/sec, etc.

$\Delta S / \Delta t$ = Rate of change of storage ('S' represents storage and 't' represents Time, hence this is also Volume / time)

The above equation is a hydrologic or storage equation which only approximates some hydrologic processes.

It is used in many different ways. If, for example, assuming inflow changes linearly from 'I_1' to 'I_2' in time 'Δt', the outflow changes linearly from 'O_1' to 'O_2' and storage changes from 'S_1' to 'S_2' in this time, the equation can be written as:

$$(I_1 + I_2) / 2 - (O_1 + O_2) / 2 = (S_2 - S_1) / \Delta t \quad \text{- - - - -} \quad 1.2$$

If we fix time 'Δt' and talk about total inflow in certain time 'Δt', total outflow and total change in storage in that time, the hydrologic equation can be written as:

Volume inflow - Volume outflow = Total change in storage.

If further, we fix the area of the system (for example, we talk of a catchment) and assume inflow as precipitation 'p', the outflow as the losses 'L' and runoff 'R' then the equation can be written as:

$$P - L - R = D \quad \text{- -} \quad 1.3$$

Where 'D' is the depression storage.

This concept is further applied to estimate the water budget of a catchment.

Components of Inflow

There are two components of inflow, viz.

a. precipitation over the catchment and reservoir, and
b. surface or groundwater flow from other catchment areas.

Components of Outflow

Three components of outflow are:

a. surface evaporation
b. groundwater seepage, and
c. direct runoff i.e. water taken for irrigation or to spill ways for producing power

Example 1.1

Flow of River Chenab at Marala Barrage varied linearly from 34 cumec (m^3/sec) to 283 cumec in 10-hours during a flood. The flow variation at Khanki Barrage, downstream of Marala was observed to be from 28 to 255 cumec during the above mentioned time. Assuming no lateral flow in or out of the reach, find out the rate of change of storage of the river reach between Marala and Khanki. What is total change in storage of the reach in this period?

Solution

$I_1 = 34$ cumec $\qquad I_2 = 283$ cumec

$O_1 = 28$ cumec $\qquad O_2 = 255$ cumec

$I = (I_1 + I_2) / 2 = (34 + 283) / 2 = 158.5$ cumec

$O = (O_1 + O_2) / 2 = (28 + 255) / 2 = 141.5$ cumec

$\Delta S / \Delta t = ?$

According to hydrologic equation

$(I_1 + I_2) /2 - (O_1 + O_2) / 2 = \Delta S / \Delta t$

$158.5 - 141.5 = \Delta S / \Delta t = 17$ cumec

$\Delta t = 10$ hours $= 10 \times 60 \times 60 = 3.6 \times 10^4$ sec

Total change in storage $= \Delta S = (\Delta S / \Delta t) \times \Delta t$

$= 17 \times 36{,}000 = 6.12 \times 10^5\ m^3$