CHAPTER ONE : INTRODUCTION

WHAT IS THE HYDROLOGY ?

The Hydrology means the science of water. It is the science that deals with the occurrence, circulation and distribution of water of the earth and earth's atmosphere. As a branch of earth science, it is concerned with the water in streams and lakes, rainfall and snowfall, snow and ice on the land, and water occurring below the earth's surface in the pores of the soil and rocks. In a general sense, hydrology is a very broad subject of an inter-disciplinary nature depending upon allied sciences, such as meteorology, geology, statistics, chemistry, physics and fluid mechanics.

Hydrology is basically an applied science. To emphasize the degree of applicability, the subject is sometimes classified as:

1. **Scientific hydrology**—the study which is concerned chiefly with academic aspects.
2. **Engineering or Applied hydrology**—a study concerned with engineering application (design and operation of engineering projects for the control and use of water). In a general sense the engineering hydrology deals with estimation of water resources, study of precipitation, runoff, evapotranspiration & their interaction ,and study of problems such as floods & droughts, and strategies to combat them.

SCOPE OF HYDROLOGY

This hydrology course is an elementary treatment of engineering hydrology with descriptions that aid in a qualitative appreciation and techniques which enable a civil engineer to perform a quantitative evaluation of the hydrologic processes that are:

(i) the maximum probable flood that may occur at a given site and its frequency; this is required for the safe design of drains and culverts, dams and reservoirs, channels and other flood control structures.
(ii) the water yield from a basin—its occurrence, quantity and frequency, etc; this is necessary for the design of dams, municipal water supply, water power, river navigation, etc.
(iii) the ground water development for which a knowledge of the hydrogeology of the area, i.e., of the formation soil, recharge facilities like streams and reservoirs, rainfall pattern, climate, cropping pattern, etc. are required.
(iv) the maximum intensity of storm and its frequency for the design of a drainage project in the area.

HYDROLOGIC CYCLE

Water occurs on the earth in all its three states, viz. liquid, solid and gaseous, and in various degrees of motion. Evaporation of water from water bodies such as oceans and lakes, formation and movement of clouds, rain and snowfall, streamflow and groundwater movement are some examples of the dynamic aspects of water. The various aspects of water related to the earth can be explained in terms of a cycle known as the hydrologic cycle. Figure 1.1 is a schematic representation of the hydrologic cycle. The water vapor moves upwards and forms clouds. While much of the clouds condense and fall back to the oceans as rain, a part of the clouds is driven to the land areas by winds. There they condense and precipitate onto the land mass as rain, snow, hail, sleet, etc.

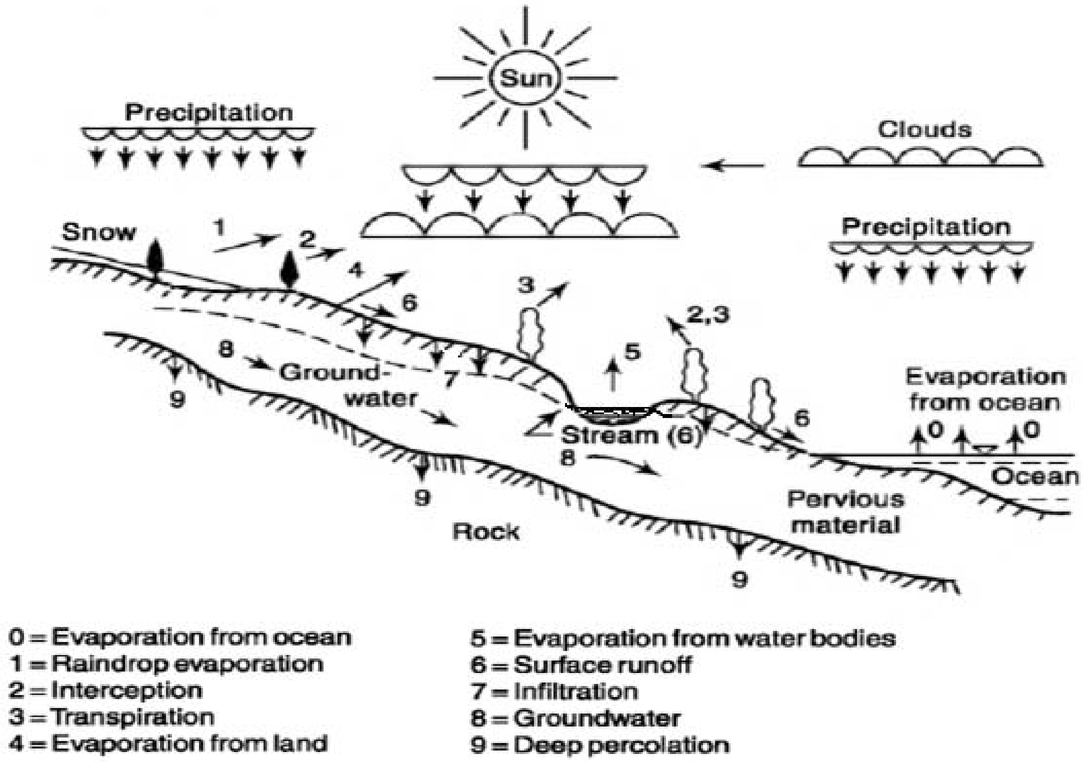

Fig. 1.1 The Hydrologic Cycle

A part of the precipitation may *evaporate* back to the atmosphere even while falling. Another part may be intercepted by vegetation, structures and other such surface modifications from which it may be either evaporated back to atmosphere or move down to the ground surface.

A portion of the water that reaches the ground enters the earth's surface through *infiltration*, enhance the moisture content of the soil and reach the groundwater body. Vegetation sends a portion of the water from under the ground surface back to the atmosphere through the process of *transpiration*. The precipitation reaching the ground surface after meeting the needs of infiltration and evaporation moves down the natural slope over the surface and through a network of gullies, streams and rivers to reach the ocean. The groundwater may come to the surface through springs and other outlets after spending a considerably longer time than the surface flow. The portion of the precipitation which by a variety of paths above and below the surface of the earth reaches the stream channel is called *runoff*. Once it enters a stream channel, runoff becomes *stream flow*.

The sequence of events as above is a simplistic picture of a very complex cycle that has been taking place since the formation of the earth. It is seen that the hydrologic cycle is a very vast and complicated cycle in which there are a large number of paths of varying time scales. Further, it is a continuous recirculating cycle in the sense that there is neither a beginning nor an end or a pause. Each path of the hydrologic cycle involves one or more of the following aspects:

(**i**) transportation of water, (**ii**) temporary storage (**iii**) change of state.

For example, (**a**) the process of rainfall has the change of state and transportation and (**b**) the groundwater path has storage and transportation aspects.

The main components of the hydrologic cycle can be broadly classified as transportation (flow) components and storage components.

Hydrologic Systems

The ***hydrologic system*** was defined as a structure or a volume in space, surrounded by a boundary, that accepts water and other inputs, operates on them internally, and produces them as outputs. The structure (for surface or subsurface flow) or volume in space (for atmospheric moisture flow) is the totality of the flow paths through which the water may pass as throughput from the point it enters the system to the point it leaves. The boundary is a continuous surface defined in three dimensions enclosing the volume or structure. A *working medium* enters the system as input, interacts with the structure and other media, and leaves as output. Physical, chemical, and biological processes operate on the working media within the system; the most common working media involved in hydrologic analysis are water, air, and heat energy.

Global Hydrologic Cycle

The ***global hydrologic cycle*** can be represented as a system containing three subsystems: the atmospheric water system, die surface water system, and the subsurface water system, as shown in Figure 1.2. Another example is the storm-rainfall-runoff process on a watershed, which can be represented as a hydrologic system. The input is rainfall distributed in time and space over the watershed, and the output is streamflow at the watershed outlet. The boundary is defined by the watershed divide and extends vertically upward and downward to horizontal planes.

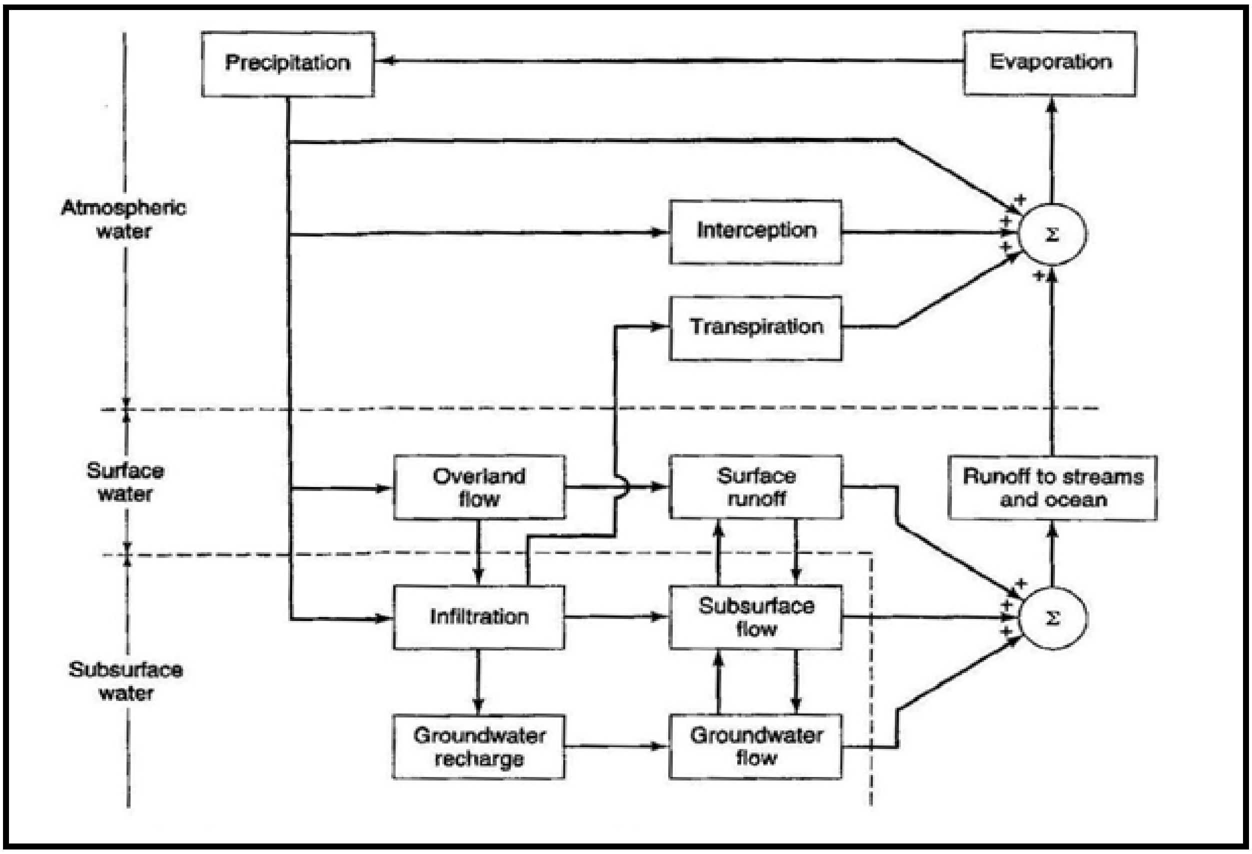

Figure 1.2 Block-diagram representation of the global hydrologic system.

Water Budget Equation

The quantities of water going through various individual paths of the hydrological cycle can be described by the continuity principle known as *water budget equation* or *hydrologic equation*. For a given problem area, say a catchment, in an interval of time Δt, the continuity equation for water in its various phases is written as ;

Mass inflow - Mass outflow = Change in mass storage

If the density of the inflow, outflow and storage volumes are the same

$$\forall_i - \forall_o = \Delta S \qquad (1.1)$$

Where; $\forall_i$ = the inflow volume of water into the specified area during the time period, $\forall_o$ = the outflow volume of water from the specified area during the time period, and ΔS = the change in the storage of the water volume over and under the given area during the given period. In applying this continuity equation [Eq. (1.1)] to the paths of the hydrologic cycle involving change of state, the volumes considered are the equivalent volumes of water at a reference temperature.

While realizing that all the terms in a hydrological water budget may not be known to the same degree of accuracy, an expression for the water budget of a catchment for a time interval Δt is written as:

$P - R - G - E - T = \Delta S$ ....(1.2)

In this P = precipitation, R = surface runoff, G = net groundwater flow out of the catchment, E = evaporation, T = transpiration and ΔS = change in storage.

In terms of rainfall-runoff relationship, Eq. (1.2) can be represented as; R = P - L where L = Losses due to water not available to runoff due to infiltration, evaporation, transpiration and surface storage.

The details of various components of the water budget equation are discussed in subsequent lectures.

WORLD WATER BALANCE

The total quantity of water in the world is estimated to be about **1386** million cubic Kilometers (M km^3). About **96.5%** of this water is contained in the oceans as saline water. Some of the water on the land amounting to about **1%** of the total water is also saline. Thus only about **35.0** M km3 of fresh water is available. Out of this about **10.6** M km^3 is both liquid and fresh and the remaining **24.4** M km^3 is contained in frozen state as ice in the polar regions and on mountain tops and glaciers. An estimated distribution of water on the earth is given in Table 1.1.

Table 1.1 Estimated World Water Quantities (after UNESCO)

Item	Volume Percent (M km^3)	Percent total water	Percent fresh water
1. Oceans	1338	96.5	–
2.Groundwater: (a) fresh	10.53	0.76	30.1
(b) saline	12.87	0.93	–
3. Soil moisture	0.0165	0.0012	0 0.05
4. Polar ice	24.0235	1.7	68.6
5. Other ice and snow	0.3406	0.025	1.0
6. Lakes (a) fresh	0.3406	0.025	1.0
(b) saline	0.0854	0.006	–
7. Marshes	0.01147	0.0008	0.03
8. Rivers	0.00212	0.0002	0.006
9. Biological water	0.00112	0.0001	0.003
10.Atmospheric water	0.01290	0.001	0.04
Total**:** All kinds of water	1386	100%	2.5%

These estimates are only approximate and the results from different studies vary; the chief cause being the difficulty in obtaining adequate and reliable data on a global scale.

APPLICATION IN ENGINEERING

Hydrological science has both pure and applied aspects. Understanding the engineering hydrology science is essential for:

- Water resources development and management;
- Prevention and control of natural disasters;
- Control problems of tidal rivers and estuaries;
- Soil erosion and sediment transport and deposition;
- Mitigation of the negative impacts of climatic change;
- Water supply;
- Flood and drought control;
- Sustainable agriculture (foods for the growing population);and
- Environmental protection and management;

Traditional water management has focused on providing freshwater resources to the needs of humans, livestock, commercial enterprises, agriculture, mining, industry, and electric power.

Until 1950, pragmatic considerations dominated hydrology. Theoretical approaches in hydrology have been increasingly developed due to the development of digital computers since 1950. The focus now is on how best to optimize the use of existing surface-water projects and ground-water resources.

Challenge for the 21st century in hydrology will still be maintaining water quantity and quality against to the increasing stress on water resources by the increasing world population, contamination, human induced climate-hydrology change, and extreme events (flood and drought).

SOURCE S OF DATA

Depending upon the problem at hand, a hydrologist would require data relating to the various relevant phases of the hydrological cycle playing on the problem catchment.
The data normally required in the studies are:

- Weather records—temperature, humidity and wind velocity
- Precipitation data.
- Stream flow records.
- Evaporation and evapotranspiration data.
- Infiltration characteristics of the study area.
- Soils of the area.
- Land use and land cover.
- Groundwater characteristics.
- Physical and geological characteristics of the area.
- Water quality data.