RAMA UNIVERSITY

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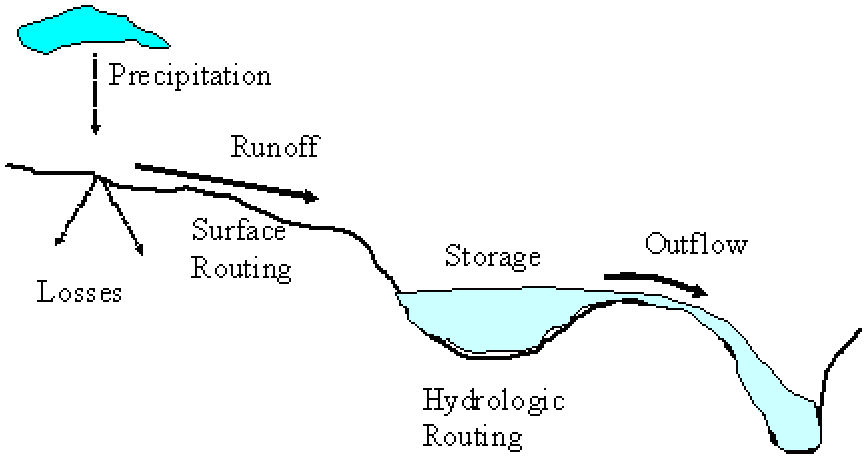
FACULTY OF ENGINEERING & TECHNOLOGY

TOPIC : HYDROLOGY (L-2)

Hydrology encompasses the occurrence, distribution, movement, and properties of the waters of the earth. It involves the interaction of water with the physical and biological environment.

Hydrologic System is a system of interrelated components, including the processes of precipitation, evaporation, transpiration, infiltration, groundwater flow, streamflow, etc., in addition to those structures and devices that are used to manage the system. Hydrologic system is subject to different kind of weather pattern and spatial complexity, and is dynamic and random in nature.

Surface Hydrology



Hydrologic Evaluations are required to determine the characteristics of the hydrologic system including the evaluation of the magnitude of various events and the frequency of certain magnitudes.

Engineering hydrology is a Apractising art@ concerned with the analysis of hydrologic systems and hydrologic evaluations related to planning and design objectives. One of the major problems in engineering hydrology is the lack of measurement at the location of interest.

Approaches to Engineering Hydrology:

- **Statistical analysis of historic records**

  Based on the analysis of past records of the system, the future behaviour of the system is estimated statistically. This approach assumes that land use, climate, vegetation, soil conditions, and other factors must all be static.

- **Extension of records**

  For short records, theoretical models which are based on physical or statistical laws can be used to extend the existing data record.

➢ Transferring of records

If records are short or inadequate at a location of interest, previous records from a similar catchment may be used to predict the system behaviour. It is important that the system performance be related to a set of easily-measured characteristics.

➢ Hydrological Modelling

If records are short or inadequate at a location of interest, a mathematical model is used to simulate the hydrologic processes directly. The mathematical model transforms the inputs such as rainfall to output such as runoff or stream flow. This transformation may involve simple conceptual models to complex physically based models.

❖ Hydrologic Budget

- Hydrologist usually define regions of analysis using the concept of watershed. A watershed is the land area that contributes surface runoff to any point of interest. The hydrologic system components interact with each other and the processes involved are enormous and complex. Nevertheless, important watershed processes should be identified so that the hydrologic system can be analyzed adequately. Inputs to the hydrologic system are rainfall and/or a regional groundwater flow system while outputs are groundwater outflow from the region, receiving channel and stream flows,

- and evapotranspiration to the atmosphere. Hydrologic processes are a function of the characteristics of the study area such as climate, topography, geology, soil cover, vegetation, land use and human activity. Although watershed processes are complex, it may be represented in a simplified way. For instance, evapotranspiration is usually assumed egligible when floods are being simulated but must be included in studies of long-term reservoir operation. If all the important inputs and outputs of a hydrologic system can be identified, a water budget analysis can be conducted which would give an estimate of the magnitude of hydrologic components. Hydrologic budget is usually applied to a well defined region. Watersheds are the easiest to deal with since they sharply define surface water boundaries. In order to apply the hydrologic budget equation, we need to define a control volume or a region which is fixed in space and completely surrounded by a control surface through which matter can freely pass. By identifying all inputs and outputs through the control surface, a change of water inside the control volume can be computed using the following conservation equations:

$$I - Q = \Delta S$$

whereas I is the amount entering the region in a specified time period delta t,

Q is the amount leaving,

ΔS is the amount of change within the system.

$$i - q = \frac{dS}{dt}$$

whereas i and q are the instantaneous input and output rates.

Although the concept of hydrologic budget is simple, the identification and quantification of inputs and outputs may be very complex.

Hydrologic budget equations can be developed for the surface system, subsurface system, and the combined system. The difficulty in solving these equations for practical problems lies mainly in the inability to measure or estimate properly the various hydrologic equation terms. Precipitation is measured by rain or snow gauges. Surface flows can be measured by weirs, flumes, velocity meters and depth gauges. Soil moisture can be measured using neutron probes and gravimetric methods. Infiltration can be determined locally by infiltrometers. The extent and rate of movement of groundwater are usually exceedingly difficult to determine and adequate data on quantities of groundwater are not always available. The determination of quantities of water evaporated and transpired is also extremely difficult.

One of the fundamental tools used in defining hydrologic response has been a water balance analysis. This type of analysis has historically been used to obtain an understanding of the overall hydrologic response of an area or watershed. While not generally being overly detailed, the analysis gives a basic understanding of the rainfall-runoff relationship over a long term planning period (e.g., seasonal or yearly). The outcome of such an analysis allows for the general breakdown of the components and their percentages which go into defining runoff from a site, surface and subsurface.

typical water balance analysis will compare meteorological input data to a measured (or transferred) set of flow data within the receiving stream. The analysis of the stream flow over time allows for this data to be broken down into surface runoff and ground water or baseflow components. The flow data along with typical estimates of evapotranspiration losses and the input meteorological information allows for breakdown of each component and a determination of infiltration, baseflow and the surface flow components of individual site water balance.

A water balance (or hydrologic budget) analysis gives information which can be useful from a series of planning or analytical perspectives. At a watershed level of planning, a watershed manager can determine on an annual or seasonal basis the general volumes and percentages of precipitation which is being runoff directly into the surface streams and the percentage of stream flow which can be attributed to base flow and ground water. This information can assist in determining the potential sensitivities of the watershed to alteration features which may affect these functions (e.g., land use change, climate change).

From a watershed management perspective, a water balance analysis is useful in establishing some of the broad level issues which may exist within the watershed and assisting in setting direction for further detailed assessments or policy development.

The relative percentage of surface runoff to rainfall input is useful in establishing the volumetric parameters required to effectively calibrate and verify the more detailed hydrologic modeling. The information developed regarding the base flow characteristics of the watercourses and the percentage of meteorological input which feeds this hydrologic component can be used be used in defining fisheries and geomorphologic directions for watershed level of study.

Rainfall

Most of us are aware of the saying AGarbage in, garbage out@. In engineering hydrology, the input to the hydrologic cycle is precipitation. Hydrologic analysis cannot be performed with confidence until we believe the input precipitation is adequately measured in both the spatial and temporal dimensions. Nevertheless, accurate measurement of precipitation does not mean extensive gauging stations and endless amount of resource. By designing a suitable gauing network, the precipitation of a region of interest may be estimated reasonably.

Precipitation is derived from atmosphere water, its form and quantity is influenced by climatic factors such as wind, temperature, and atmospheric pressure. There are different forms of moisture falling from the atmosphere to earth: drizzle, rain, glaze, sleet, snow, snow pellets, and hail.

Precipitation is produced primarily when the water vapour in the atmosphere becomes saturated, condenses and increases in weight such that solid or liquid water can no longer be supported by up-drafts and other air currents and fall to the earth surface.

The following three conditions are required in order to produce precipitation:

1. A continuous supply of water vapour through evaporation and transpiration processes and the air movement to transport the water vapour to the location of rainfall.
2. Nucleating particles such as dust, salt, pollen, and various atmospheric ions for condensation must be present.
3. A cooling mechanism sufficient to cause condensation and growth of water droplets or ice crystals from water vapour.

A number of rain gauges are commonly used for measuring rainfall. They are:

- **Non-recording storage gauge**

  This gauge can only record periodic volume of rainfall such as daily rainfall. It cannot be used to indicate the time distribution of rainfall.

- **Recording weighing gauge**

  It operates by continuously recording the weight of the accumulated rainfall. Data are either recorded on tape or transmitted to remote data gathering station.

- **Recording tipping bucket gauge (See the following figure)**

  It senses each consecutive rainfall accumulation when it reaches a prescribed amount usually 0.01 in or 1 mm of rain. A small calibrated bucket is located below the rainfall entry port of the gauge. When it fills to the 0.01 in or 1 mm increment it tips over, bring a second bucket into position. These two small buckets are placed on a swivel and the buckets tip back and forth as they fill. Each time a bucket spills it produces an indication on a strip chart or other recording form. A record of rainfall depth versus time is produced.

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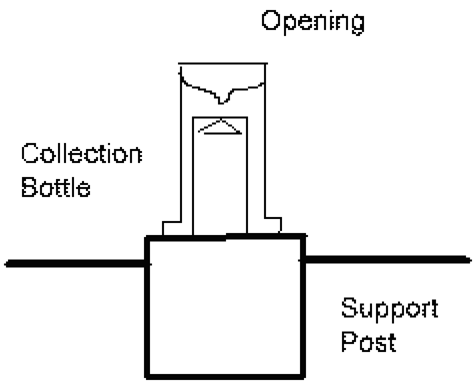

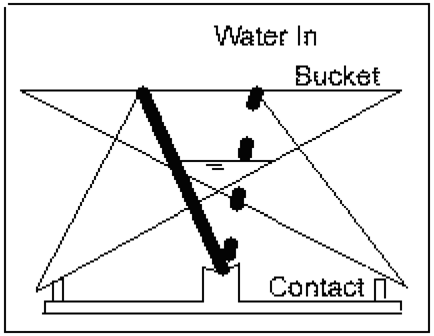

➢ Radar

It is used to estimate rainfall intensity because it can detect any type of raindrops in the atmosphere. The reflection of the raindrops is determined by electromagnetic energy of the radar pulse, called echo. The brightness of the echo is a measure of the rainfall intensity. The strength of reflected radar pulses is a function of the number and size of the raindrops. As a result, it can detect light, medium, intense and very intense rainfall. Because of interference such as building and trees, it should be used together with rain gauges to provide estimate for areas not covered by rain gauges. The Meteorological Services of Canada (MSC) operates 14 weather radars across Canada.

➢ Satellite

The principal value of remote sensing is its ability to provide regional coverage and point measurement. Additionally, satellite communications can be digitized and transfered to computer for analysis and presentations. MSC also has real time access to digital imagery from both geostationary and polar orbiting satellites launched by agencies in the U.S.

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In Canada, the MSC publishes precipitation data. Other sources include private companies, municipal networks and other government agencies.

The minimum precipitation-gauge densities recommended by the World Meteorological Organization (1974) for various climatic situations are shown in the following table. In Canada, the target density is about 25 km separation between standard precipitation gauges and there are about 200 recording rain gauges. The national network provides large-scale and long-term records of precipitation and other meteorological information, which may be used for the planning and design of water resources structures on a regional scale. In Ontario, there are currently about 50 recording rain gauges in operation.

Table: Minimum precipitation-gauge densities recommended by World Meteorological Organization for various climatic situations (1974)

Geographic Region	km^2/gauge	gauge/km^2
Small mountainous islands with irregular precipitation	25	0.04
Temperate, Mediterranean, and Tropical Mountainous Regions	100-250	0.004-0.01
Flat areas in Temperate, Mediterranean, and Tropical Regions	600-900	0.0011-0.0017
Arid and Polar Regions	1500-10,000	0.0001-0.00067

For mountainous setting, a higher density of gauging stations is usually required to monitor the patterns of precipitation and irregularities based on topography.

The number of rain gauges required for watershed monitoring depends on the nature of rainfall, topography, and the level of analysis (e.g., flooding, water balance). Typically, lower density of rain gauges is required to get representative measurements for long periods or larger areas. For individual rainfall event measurement, the rain gauge density may be very high (e.g., 5 km^2/gauge). Measurement of daily rainfall over an area typically requires much lower rain gauge density (e.g., 18 km^2/gauge).

The approximate lengths of records necessary to achieve stable frequency distributions are:

1. Mountains - 50 years
2. Plains - 40 years
3. Coastal - 30 years

When we have collected rainfall data from multiple gauges, the average depths for the whole area can be estimated by a number of techniques:

(1) Arithmetic Average Method;

(2) Thiessen Method;

(3) Isohyetal method.

Arithmetic Average Method

This method uses the sum of all precipitation values and divides by the total number of gauges used. Although this is the simplest method, it is also the least accurate. It may be satisfactory if gauges are uniformly distributed and the topography is flat.

Thiessen Method

In this method, all the gauge locations are plotted on the map at an appropriate scale. Next, straight lines are drawn to connect gauges without crossing any other lines. Each connecting line is then bisected and a perpendicular is drawn through the connecting line. Each gauge is near the centre of a polygon whose size varies according to the spacing of the gauges. The area of each polygon is then measured and the percentage of the total area for each polygon is then computed. Finally, the average rainfall over the basin (P_{avg}) is computed as

$$P_{avg} = \sum_{i=1}^{n} \left(\left[\frac{A_i}{\sum A_i} \right] * P_i \right)$$

where A_i is the area of each polygon and P_i is the rainfall data at the centre of each polygon, and n is the total number of polygons. This method is not suitable for mountainous areas because of orographic influences.

Isohyetal Method

In this method, the rainfall values are used to develop a contour plot. The average precipitation is calculated between isohyets (or contour lines) by taking the mid-value between two successive contours. The area between each successive isohyets is found by either measuring with a planimeter or counting grid squares. The average rainfall over the basin (P_{avg}) is computed as

$$P_{avg} = \left(\frac{\sum_{i=1}^{n} A_i * P_i}{\sum A_i} \right)$$

where A_i is the area of each polygon and P_i is the rainfall data at the centre of each polygon, and n is the total number of polygons. This method is perhaps the most accurate approach for estimating average rainfall.

Meteorological data can be described by both average observation and extreme events such as floods and droughts. In order to transform the large meteorological database into some useful value for planning and design purposes, hydrologists apply statistical techniques to record data.

The statistical problems in hydrology are usually associated with the frequencies with a set of observations. The frequencies of extreme rainfall events are termed as return period, that is, the average interval of time between events which equal or exceed the magnitude of the event of interest.

Thank You