Q) Explain how a D-hour UH is converted into a 2D-hour UH by applying the method of superposition.

Answer:

The method of superposition is a fundamental principle in linear systems analysis, and it's applicable in Unit Hydrograph (UH) theory because the rainfall-runoff process is assumed to be linear and time-invariant.[1] To convert a D-hour Unit Hydrograph (D-hr UH) into a 2D-hour Unit Hydrograph (2D-hr UH) using superposition, we conceptually consider a rainfall event of 1 unit depth occurring uniformly over the catchment for a duration of 2D hours. This 2D-hour rainfall can be thought of as two successive D-hour rainfall events, each producing a D-hr UH.

Here's the step-by-step process:

1. **Obtain the ordinates of the D-hour Unit Hydrograph.** Let's denote the ordinates of the D-hr UH at time t as U(t). This hydrograph represents the direct runoff from 1 unit depth of effective rainfall occurring in D hours.

2. **Lag the D-hour Unit Hydrograph by D hours.** Since the 2D-hour rainfall can be considered as two consecutive D-hour rainfall events, the runoff from the second D-hour rainfall will be delayed by D hours compared to the first. To represent this, we shift the entire D-hr UH along the time axis by D hours. Let's denote the ordinates of this lagged D-hr UH as $U(t-D)$. Note that for $t \le D$, $U(t-D)=0$.

3. Superpose (add) the ordinates of the original D-hour UH and the lagged D-hour UH at each corresponding time step. The resulting hydrograph represents the direct runoff from a rainfall of 1 unit depth occurring in the first D hours plus the direct runoff from another 1 unit depth occurring in the subsequent D hours (lagged by D hours). Therefore, the ordinates of this combined hydrograph, let's call it DRH2D(t), are given by:
   $DRH2D(t)=U(t)+U(t-D)$

4. **Recognize the rainfall depth.** The resulting DRH2D(t) is the direct runoff hydrograph resulting from a total effective rainfall of 1 unit + 1 unit = 2 units occurring over a duration of 2D hours (1 unit in the first D hours and 1 unit in the next D hours).

5. Apply the principle of proportionality. To obtain the 2D-hour Unit Hydrograph, which by definition is the direct runoff from 1 unit depth of effective rainfall occurring in 2D hours, we need to scale down the ordinates of DRH2D(t) by the

Q) Compare Kennedy's and Lacey's silt theories.

Answer:

Kennedy's and Lacey's silt theories are both significant contributions to the design of stable irrigation channels in alluvial soils. They aimed to establish relationships between channel dimensions, discharge, and silt characteristics to prevent silting and scouring. However, they differ in their fundamental assumptions and the parameters they considered.

Aspect	Kennedy's Theory	Lacey's Theory
Developed by	R.G. Kennedy (1895)	G. Lacey (1930)
Based on	Observations of Upper Bari Doab Canal System in India	Observations from a wide range of Indian canals
Basic Assumption	A canal is stable (non-silting, non-scouring) if the velocity is "critical" and maintained by bed resistance alone.	A canal is stable when the silt brought in is carried away by the flow (regime conditions).
Key Parameter	**Critical velocity (V_0)**	**Regime velocity (V)**
Velocity Equation	V0=CDnV_0 = C D^n where C and n depend on silt grade (C ≈ 0.55, n ≈ 0.64)	V=kR2/3S1/3V = k R^{2/3} S^{1/3} where k = 10.8 for Lacey's regime canals
Silt Factor	Not used explicitly	Introduced as **f**, a function of silt size

Drip Irrigation

Drip irrigation is a method of applying water directly to the **root zone** of plants in a slow, controlled manner through a network of **valves, pipes, tubing, and emitters**. It is also referred to as **trickle irrigation**.

Water is delivered **drop by drop** at or near the roots, significantly **reducing evaporation and runoff** compared to conventional irrigation methods. It is especially efficient in **water-scarce regions**.

```
 Main Pipe
  __________
 |     |
 |     |
 |     |
↓     ↓
|     |
•     • <-- Emitters
|     |
🌱     🌱  <-- Plants
```

- A **main pipe** supplies water to several **lateral pipes**.
- **Emitters** are placed along the lateral pipes to drip water near the roots.
- Water reaches plants slowly and directly, conserving water.

Advantages over Conventional Methods

1. **Water Efficiency**
   Water is applied directly to the root zone, minimizing evaporation and deep percolation losses.
2. **Reduced Weed Growth**
   Only targeted areas are watered, limiting weed growth between plants.
3. **Prevents Soil Erosion**
   The low-pressure system prevents displacement of soil, unlike flood irrigation.
4. **Better Fertilizer Use (Fertigation)**
   Fertilizers can be applied through the system, ensuring nutrients reach roots efficiently.

Q) What is S-curve? How is it constructed? What are its uses?

Answer:

Definition:

An **S-curve**, also known as an **S-hydrograph**, is a hydrograph representing the direct runoff from a catchment due to a continuous effective rainfall occurring at a constant rate for an infinite period. For a unit hydrograph of D-hour duration, the S-curve is theoretically produced by a continuous effective rainfall of 1/D unit depth per hour. Its shape typically resembles a stretched "S," rising gradually to reach a constant equilibrium discharge.

Construction:

An S-curve is constructed using the principle of superposition applied to a Unit Hydrograph (UH) of a specific duration (D-hour UH). The steps involved are:

1. **Obtain the ordinates of the D-hour Unit Hydrograph.** This hydrograph represents the direct runoff resulting from 1 unit depth of effective rainfall occurring uniformly over the basin for a duration of D hours.

2. **Lag the D-hour Unit Hydrograph by D hours.** This means shifting the entire hydrograph along the time axis by D hours.

3. **Lag the D-hour Unit Hydrograph by 2D hours.** Shift the original UH by 2D hours.

4. **Continue lagging the D-hour Unit Hydrograph by successive intervals of D hours.** Repeat this process until the entire hydrograph's effect has been accounted for in the summation.

5. **Sum the ordinates of the original D-hour UH and all the lagged UHs at each time step.** The resulting values, when plotted against time, form the S-curve hydrograph.

   Mathematically, if $U(t)$ are the ordinates of the D-hour Unit Hydrograph at time t, the ordinates of the S-curve $S(t)$ can be calculated iteratively as:
   $S(t)=U(t)+S(t-D)$
   where $S(t-D)=0$ for $t \le D$.

Q) Define: Infiltration capacity and Infiltration rate. Explain briefly about the factors affecting infiltration.

Answer:

Infiltration Capacity:

Infiltration capacity (fp) is defined as the **maximum rate at which a given soil at a given time can absorb water**. It represents the upper limit of how much water can enter the soil surface under specific conditions. It is typically expressed in units of depth per unit time (e.g., mm/hour, cm/hour). When the rainfall intensity exceeds the infiltration capacity, the excess water will accumulate on the surface and become runoff.

Infiltration Rate:

Infiltration rate (f) is the **actual rate at which water enters the soil at a given time**. It is the velocity at which water moves into the soil profile. The infiltration rate is limited by either the infiltration capacity of the soil or the rate at which water is supplied at the surface (rainfall intensity or irrigation rate), whichever is smaller. Therefore, $f \leq fp$.

Factors Affecting Infiltration:

Several factors influence the infiltration capacity and rate of a soil. These can be broadly categorized as soil characteristics, surface conditions, and rainfall characteristics.

1. **Soil Characteristics:**

    - **Soil Texture:** The proportion of sand, silt, and clay significantly affects pore size and distribution. Sandy soils with large pores have higher infiltration rates than clayey soils with small, interconnected pores.
    - **Soil Structure:** The arrangement of soil particles into aggregates influences porosity and permeability. Well-aggregated soils have more macropores, leading to higher infiltration. Compaction reduces porosity and thus lowers infiltration.
    - **Organic Matter:** Organic matter improves soil structure, increases porosity, and enhances water retention, leading to higher infiltration rates. It also supports soil biota like earthworms, which create channels that facilitate water movement.
    - **Soil Moisture Content:** Initially dry soils have a higher infiltration capacity because there are more unfilled pores available to store water. As the soil becomes saturated, the infiltration rate decreases and eventually approaches a steady-state value.

5. **Increased Crop Yields**
   Plants receive uniform moisture, leading to healthier growth and better yield.

6. **Labor and Energy Saving**
   Requires lower energy and can be automated to reduce manual labor.

Design Emphasis	Emphasis on **velocity-depth** relationship for non-silting conditions	Emphasis on **regime dimensions** (area, velocity, slope) for stability
Cross-Section Shape	Not defined by theory, designer's choice	Semi-elliptical (or trapezoidal), as per regime equations
Bed Slope Equation	Not provided directly	S=f5/33340Q1/6S = \frac{f^{5/3}}{3340 Q^{1/6}}
Application Limitation	Empirical – suitable mainly for the canal system studied	More general – applicable to a wider range of alluvial canals
Flexibility in Design	Limited – fixed by critical velocity concept	More flexible – based on actual silt properties and discharge

In conclusion, while Kennedy's theory was a foundational step in understanding stable channel design, Lacey's theory offered a more advanced and comprehensive approach by introducing the regime concept, a quantitative silt factor, and direct equations for key channel parameters like bed slope. Lacey's theory is generally considered an improvement over Kennedy's for designing stable alluvial channels.

total rainfall depth that produced it (which is 2 units). Therefore, the ordinates of the 2D-hour Unit Hydrograph, U2D(t), are obtained by:
$U2D(t)= DRH2D(t) / 2 = U(t)+U(t-D) / 2$

In summary, to convert a D-hour UH to a 2D-hour UH using superposition:

1. Take the ordinates of the D-hour UH.
2. Lag these ordinates by D hours.
3. Add the ordinates of the original and the lagged D-hour UH at each time step.
4. Divide the resulting ordinates by 2.

This process effectively simulates the response to a 2D-hour rainfall by combining the responses of two consecutive D-hour rainfalls and then scaling down to represent the runoff from a unit depth of rainfall over the 2D-hour duration.

- **Soil Depth and Presence of Layers:** The depth of permeable soil and the presence of less permeable layers (like clay pans or compacted layers) can restrict the downward movement of infiltrated water, affecting the overall infiltration rate at the surface over time.
- **Swelling and Shrinkage of Clay:** Some clay soils shrink and develop cracks when dry, leading to initially high infiltration rates.However, these cracks swell and close when the soil gets wet, significantly reducing infiltration.

2. **Surface Conditions:**

   - **Vegetation Cover:** Vegetation intercepts rainfall, reducing its direct impact on the soil surface and preventing the breakdown of soil structure. Roots create pathways for water to enter the soil, and surface litter protects the soil from crusting, thus enhancing infiltration.
   - **Land Use and Management:** Practices like tillage can initially increase infiltration by loosening the soil, but excessive tillage can lead to compaction in the long run. Urbanization and impervious surfaces drastically reduce infiltration.
   - **Surface Crusting and Sealing:** The impact of raindrops on bare soil can disperse soil particles, which then clog surface pores, forming a crust that significantly reduces infiltration.
   - **Surface Detention:** Depressions and irregularities on the soil surface can temporarily store water, allowing more time for infiltration.

3. **Rainfall Characteristics:**

   - **Rainfall Intensity:** If the rainfall intensity is less than the infiltration capacity, the infiltration rate will be equal to the rainfall intensity. However, if the rainfall intensity exceeds the infiltration capacity, the infiltration rate will be limited by the soil's ability to absorb water.
   - **Rainfall Duration:** Infiltration capacity generally decreases with time during a rainfall event as the soil surface layers become saturated.
   - **Raindrop Size and Velocity:** Larger and faster-falling raindrops have more energy to cause surface sealing, thus reducing infiltration.

Understanding these factors is crucial for various hydrological applications, including runoff estimation, groundwater recharge assessment, irrigation management, and erosion control.

6. The S-curve will initially rise and eventually reach an equilibrium discharge (Qs). This equilibrium discharge occurs when the runoff from all the preceding rainfall increments is contributing to the flow at the outlet. The theoretical equilibrium discharge can be calculated as:
   Qs=2.778×A×(1/D) / 1
   where A is the catchment area in km^2 and 1/D is the rainfall intensity in cm/hr.

Uses:

The S-curve hydrograph is a valuable tool in hydrology, primarily used for:

1. **Deriving Unit Hydrographs of Different Durations:** The most significant application of the S-curve is to derive a Unit Hydrograph of a different duration (D′-hour UH) from a known D-hour UH. This is achieved by:
   - Lagging the S-curve by the desired new duration D′ hours.
   - Subtracting the ordinates of the lagged S-curve from the ordinates of the original S-curve. This difference hydrograph represents the runoff from a rainfall excess of 1/D cm/hr occurring for a duration of D′ hours.
   - Multiplying the ordinates of the difference hydrograph by D/D′ to obtain the D′-hour Unit Hydrograph (representing 1 cm of effective rainfall over D′ hours).
2. **Developing Instantaneous Unit Hydrographs (IUH):** By considering a very small duration ($D' \to 0$), the S-curve can be used conceptually to derive an Instantaneous Unit Hydrograph, which is the response of a catchment to a unit volume of instantaneous rainfall.

3. **Analyzing Catchment Response:** The shape of the S-curve provides insights into the time response characteristics of a catchment. A steeper rising limb indicates a faster response, while a gentler slope suggests a more delayed response.

In summary, the S-curve is a theoretical construct derived from the unit hydrograph that serves as a fundamental tool for manipulating the duration of unit hydrographs and understanding the rainfall-runoff relationship of a catchment.