Chapter 28: Measurement of Infiltration

Introduction

Infiltration refers to the process by which water on the ground surface enters the soil. It is a crucial aspect in hydrological studies as it governs groundwater recharge, surface runoff, and soil moisture content. Accurate measurement of infiltration is essential for designing irrigation systems, predicting flood hazards, assessing groundwater potential, and managing stormwater. This chapter delves into the various methods for measuring infiltration, factors affecting it, and how infiltration data is analyzed and applied in hydrological design and modelling.

28.1 Infiltration Process and Mechanisms

- **Infiltration Capacity**: The maximum rate at which soil can absorb rainfall or surface water.
- **Infiltration Rate**: Actual rate at which water enters the soil, usually in mm/hr or cm/hr.
- **Cumulative Infiltration**: Total volume or depth of water infiltrated over a period.

Infiltration starts at a higher rate and gradually decreases until it reaches a steady-state rate. This is due to saturation of soil pores, compaction, air entrapment, and temperature effects.

28.2 Factors Affecting Infiltration

1. **Soil Properties**:
    - **Texture**: Sandy soils infiltrate faster than clayey soils.
    - **Structure**: Granular and well-aggregated soils promote better infiltration.
    - **Porosity and Permeability**: High porosity and permeability increase infiltration rates.
2. **Vegetation Cover**:

- Roots and organic matter increase porosity.
- Interception by leaves delays water reaching the ground.

3. **Land Use and Land Cover**:
    - Urbanization reduces infiltration due to impervious surfaces.
    - Agricultural practices may compact soil, reducing infiltration.
4. **Moisture Content**:
    - Dry soil has higher infiltration capacity compared to already wet soil.
5. **Rainfall Characteristics**:
    - Intensity, duration, and frequency of rainfall influence infiltration.
    - High-intensity rainfall can exceed infiltration capacity, leading to runoff.
6. **Temperature**:
    - Affects water viscosity and soil permeability.
7. **Soil Surface Conditions**:
    - Crusting, sealing, and compaction reduce infiltration.

28.3 Methods of Measuring Infiltration

There are two major categories:

- **Field Methods**
- **Laboratory Methods**

We focus mainly on field methods, as they reflect natural infiltration more accurately.

28.3.1 Field Methods

A. Infiltrometer Method

An **infiltrometer** is a device used to measure the rate of water infiltration into soil. There are different types:

*i. **Double Ring Infiltrometer**:*

- Comprises two concentric rings (inner and outer).

- Water is poured into both rings simultaneously.
- Outer ring reduces lateral flow from the inner ring.
- Water level drop in the inner ring is measured over time.

Procedure:

1. Place the infiltrometer rings on the soil surface and drive them a few cm into the soil.
2. Fill both rings with water to a desired level.
3. Refill water to maintain the constant head.
4. Record water level drop in the inner ring at regular time intervals.

Advantages:

- Minimizes lateral spread.
- Suitable for laboratory-quality measurements in field conditions.

Disadvantages:

- Time-consuming.
- Requires careful handling and accurate measurement.

*ii. **Single Ring Infiltrometer**:*

- Simpler, but subject to lateral flow error.
- Used where double ring is not feasible.

*iii. **Tension Infiltrometer**:*

- Maintains a negative pressure head.
- Measures unsaturated infiltration.

B. Basin or Flooding Method

- A small area of land is encircled with bunds and flooded with water.
- Water level is maintained or replenished.
- Drop in water level is recorded with time.

Applications:

- Agricultural fields.
- Comparison of infiltration under different land covers.

C. Trench or Ponding Method

- A trench is dug and flooded.
- Used in forested or rough terrain areas.
- Helps assess infiltration over larger area than ring methods.

D. Artificial Rainfall Simulator

- Rainfall is simulated using sprinklers at a known intensity.
- Infiltration is calculated by subtracting runoff and evaporation from the total applied water.

Use:

- Research purposes.
- Evaluation of infiltration under controlled rainfall.

28.3.2 Laboratory Methods

Laboratory methods are seldom used for actual field predictions but useful for controlled experiments.

- **Permeameter Tests**: Soil columns are subjected to water flow to measure saturated/unsaturated hydraulic conductivity.
- **Soil Water Retention Curves**: To derive infiltration-related properties indirectly.

28.4 Infiltration Indices

Simplified values used in hydrological modeling:

1. **ϕ-index**:
    - Constant rate of infiltration above which the rainfall is considered excess.
    - Computed from rainfall-runoff data.
    - $\phi = \frac{P - R}{t}$
2. **W-index**:

   - Accounts for infiltration during storm duration.
   - More accurate than ϕ-index.
3. **Horton's Equation** (Empirical):

$$f(t)=f_c+(f_0-f_c)e^{-kt}$$

   Where:

   - $f(t)$ = infiltration rate at time t,
   - f_0 = initial infiltration rate,
   - f_c = final (steady) infiltration rate,
   - k = decay constant.

28.5 Analysis of Infiltration Data

- Plotting **infiltration rate vs time** curve.
- Determining **cumulative infiltration**.
- Fitting data to Horton's equation or other empirical formulas.
- Using infiltration indices for rainfall-runoff modeling.

28.6 Applications of Infiltration Data in Engineering

- **Irrigation Planning**: Determine irrigation frequency and depth.
- **Stormwater Management**: Design of infiltration trenches, soak pits, rain gardens.
- **Flood Prediction**: Estimating runoff potential during storm events.
- **Groundwater Recharge Estimation**: Assessing recharge zones and aquifer sustainability.
- **Soil Conservation**: Evaluate effectiveness of anti-erosion measures.

28.7 Limitations and Sources of Error

- Lateral flow error in single ring infiltrometers.
- Soil heterogeneity affects repeatability.
- Disturbance to soil while installing equipment.
- Evaporation losses during long tests.
- Human errors in observation and timing.