Chapter 45: Canal Systems

Introduction

A canal system is an artificial waterway constructed to convey water from rivers, reservoirs, or other water sources for purposes such as irrigation, water supply, navigation, or hydroelectric power generation. In India, canal irrigation plays a crucial role in agricultural productivity, especially in arid and semi-arid regions. Designing and managing a canal system requires a deep understanding of hydraulics, soil mechanics, hydrology, and structural engineering. This chapter explores the types of canal systems, their alignment, various canal losses, methods for estimating design discharge, and the design principles for both rigid boundary and alluvial channels.

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1. Canal Systems

1.1 Classification of Canals

Canals can be classified based on various criteria:

a) Based on the Source of Water:

- **Perennial Canals**: Draw water from perennial rivers or reservoirs and supply water throughout the year.
- **Non-perennial Canals**: Operate only during the rainy season, drawing water from seasonal rivers.

b) Based on the Function:

- **Irrigation Canals**: Used for agricultural irrigation.
- **Navigation Canals**: Designed for transport of goods and passengers.
- **Power Canals**: Convey water to generate hydroelectric power.
- **Feeder Canals**: Supply water to other canals or reservoirs.

c) Based on Lining:

- **Unlined Canals**: Constructed by excavating earth, prone to seepage losses.
- **Lined Canals**: Have a protective lining (e.g., concrete, brick) to prevent seepage.

d) Based on Command:

- **Main Canal**: The primary canal carrying water from the source.
- **Branch Canal**: Branches off the main canal.
- **Distributary**: Smaller canals distributing water to field channels.
- **Minor and Field Channels**: Convey water directly to the agricultural fields.

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2. Alignment of Canals

2.1 Principles of Canal Alignment

Proper alignment is critical for efficient operation and minimal losses. Factors influencing alignment:

- **Topography**: Canals should follow natural contours to minimize earthwork.
- **Soil Conditions**: Avoid water-logged or highly permeable soils.
- **Cross-drainage Works**: Minimize the number and size of CD works like aqueducts and siphons.
- **Command Area**: The alignment must ensure irrigation coverage for the maximum possible area.
- **Economy**: Optimum use of materials and labor with the least construction cost.

2.2 Types of Canal Alignment

- **Contour Canal**: Aligned along the contour line; best for undulating terrain.
- **Ridge Canal**: Runs along the watershed; supplies water to both sides.
- **Side Slope Canal**: Constructed along the slope of a valley or hill.
- **Valley Canal**: Aligned through the valley, often requiring CD works.

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3. Canal Losses

Losses in canals reduce the effective availability of water at the outlet points. These losses include:

3.1 Types of Canal Losses

*a) **Seepage Losses**:*

- Water seeps through the bed and banks.
- Higher in unlined canals and sandy soils.
- Lining and soil compaction reduce seepage.

b) ***Evaporation Losses****:*

- Water evaporates from the surface due to heat and wind.
- Proportional to surface area, temperature, and exposure.

c) ***Absorption Losses****:*

- Initial filling of pores in dry soil during the first run.
- Prominent during the initial stages of canal operation.

d) ***Transpiration Losses****:*

- Caused by vegetation (especially aquatic weeds) around the canal.

e) ***Operational Losses****:*

- Water lost during regulation, overflow, and improper management.

3.2 Estimation of Losses

Empirical formulas are used to estimate seepage losses. Examples:

- **Kostiakov's Formula**: $Q = K \cdot L \cdot (B + D)$ where: Q = Seepage loss (cumecs/km) L = Length of canal (km) B = Bed width (m) D = Depth (m) K = Coefficient depending on soil type

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4. Estimation of Design Discharge

The design discharge refers to the maximum flow rate a canal is designed to carry under normal working conditions.

4.1 Methods of Estimating Discharge

a) ***Duty-Delta Relationship****:*

- **Delta (Δ)**: Depth of water required for a crop in meters.

- **Duty (D)**: Area irrigated per unit discharge (hectares/cumec).

$$D = \frac{8.64 \times 10^6}{\Delta \cdot B}$$

  where B is base period in days.

b) ***Crop Water Requirement Method****:*

- Based on water requirement (WR) for different crops.
- Total discharge = Total water requirement / Time available.

*c) **Command Area Approach**:*

- Based on Gross Command Area (GCA), Culturable Command Area (CCA), and intensity of irrigation.

$$Q = \frac{A \cdot \text{Delta}}{D}$$

where A = Area to be irrigated.

*d) **Empirical Formulas and Field Data**:*

- Historical data from similar projects help refine discharge values.

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5. Design of Channels

Designing canal channels involves determining their cross-sectional dimensions, slope, and roughness to carry the desired discharge safely and economically.

5.1 Rigid Boundary Channels

These are channels where the boundary material (like concrete or masonry) does not deform due to flow.

*a) **Assumptions**:*

- No change in channel geometry.
- No sediment transport.
- Use of Manning's or Chezy's formula.

*b) **Manning's Formula**:*

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Where:

- V = Velocity (m/s)
- R = Hydraulic radius = A/P
- S = Slope of the energy grade line
- n = Manning's roughness coefficient

*c) **Design Steps**:*

1. Fix discharge and permissible velocity.
2. Choose side slopes and bed slope.
3. Use Manning's formula to compute dimensions.

4. Check for economic section (minimum wetted perimeter).

*d) **Typical Shapes**:*

- Trapezoidal
- Rectangular (in lined canals)

5.2 Alluvial Channels

These channels are excavated in alluvial soil and carry sediment-laden water. Their shape may change over time due to sediment deposition and erosion.

*a) **Challenges**:*

- Channel bed and bank may erode or deposit sediment.
- Stability depends on balancing tractive force and resisting force.

*b) **Kennedy's Theory**:*

Focuses on non-silting and non-scouring velocities for stable canals.

- **Critical velocity (Vc)**:

$$V_c = C \cdot D^{0.64}$$

  Where:

  - D = Depth of flow (m)
  - C = Coefficient based on silt grade

- **Critical Velocity Ratio (CVR)**:

$$m = \frac{V}{V_c}$$

*c) **Lacey's Theory**:*

Used for stable channel design with silt-laden flow.

Key formulas:

- **Velocity (V)**:

$$V = \sqrt{\frac{Q f}{140}}$$

- **Area (A)**:

$$A = \frac{Q}{V}$$

- **Wetted Perimeter (P)**:

$$P = 4.75\sqrt{Q}$$

- **Slope (S)**:

$$S = ¿¿$$

Where:

- f = Silt factor
- Q = Discharge

*d) **Design Procedure**:*

1. Estimate discharge and silt factor.
2. Use Lacey’s formulae to determine dimensions.
3. Adjust for local conditions (e.g., sediment load, bed material).
4. Verify flow is stable (no scouring or silting).
