MODULE 2: CANALS AND RESERVOIRS

Canals

Types of Canals

Canals are artificial waterways constructed to carry water from rivers, reservoirs, or other sources to agricultural fields for irrigation or to urban areas for domestic and industrial use. Based on the source of water and purpose, canals are classified as:

- **Permanent Canals:** These are constructed from perennial rivers or reservoirs and have a continuous water supply throughout the year. They are generally lined and properly engineered.
- **Inundation Canals:** These are drawn directly from rivers without any storage or control structures. Water is supplied during flood seasons only.
- **Irrigation Canals:** Built primarily for agricultural irrigation, they provide water to command areas.
- **Navigation Canals:** Designed to facilitate transportation, they maintain minimum water levels suitable for boat and ship movement.
- **Power Canals:** Constructed to carry water to hydroelectric power stations.
- **Combined Canals:** Serve multiple purposes such as irrigation, navigation, and power generation simultaneously.

Alignment of Canals

The alignment of a canal refers to its position and path on the ground between the source and the command area. Proper canal alignment ensures minimal construction cost, efficient water delivery, and low maintenance. Types of alignments are:

- **Contour Canal:** Aligned along the contour lines, suitable for undulating terrains, and requires little excavation.
- **Ridge Canal:** Runs along the ridgeline separating two drainage basins. It facilitates irrigation on both sides of the canal.
- **Side-Slope Canal:** Built along the side slopes of hills and is used where the ridge or contour alignment is not feasible.

Important considerations for canal alignment include avoiding marshy areas, rocky terrains, landslide-prone zones, and minimizing the number of crossings over natural drains.

Command Area Concepts

Gross Command Area (GCA)

Gross Command Area refers to the total area that can be irrigated from a canal system without considering any land losses due to roads, villages, forests, or uncultivable patches.

Cultural Command Area (CCA)

Cultural Command Area is the portion of the Gross Command Area which is actually cultivable and fit for growing crops. It excludes uncultivable and wasteland portions from the GCA.

Intensity of Irrigation

Intensity of irrigation is the percentage of CCA proposed to be irrigated in a year. It is usually different for rabi (winter) and kharif (monsoon) seasons. It is expressed as:

$$\text{Intensity of Irrigation (\%)} = \left(\frac{\text{Area irrigated in a season}}{\text{CCA}}\right) \times 100$$

Time Factor

Time factor refers to the proportion of total available time that the canal is actually supplying water for irrigation. It accounts for resting periods and maintenance closures.

Crop Factor

Crop factor is a ratio that expresses the amount of water required by a crop relative to the reference crop (usually grass). It helps in estimating the water needs for different crops under varying climatic conditions.

Canal Construction

Unlined and Lined Canals

- **Unlined Canals:** Canals excavated in natural earth without any lining. They are cheaper to construct but suffer from water losses due to seepage and higher maintenance problems like silting and erosion.
- **Lined Canals:** These canals are provided with a lining (brick, concrete, stone, or synthetic materials) to prevent seepage, reduce water losses, minimise erosion, and enhance flow efficiency. Lining increases construction cost but greatly improves water conservation and operational efficiency.

Standard Sections

A standard section of a canal is designed to balance cutting and filling, maintain structural stability, and ensure efficient water flow. Typical canal cross-sections include:

- A trapezoidal shape with specific side slopes depending on soil stability.
- Provision of freeboard (extra height above the water level) to prevent overflow.
- Bed slope and velocity carefully designed to avoid silting and scouring.

Design of Canals

Lacey's Method

Lacey's theory provides guidelines for designing stable alluvial canals (canals in loose soil) based on observations of natural rivers. Important formulas of Lacey's regime theory include:

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- **Regime Velocity (V):**

$$V = 0.48(fR)^{0.5}$$

where f is the silt factor and R is the hydraulic mean radius.

- **Regime Channel Width (W):**

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

where Q is the discharge in cumecs.

- **Regime Slope (S):**

$$S = \frac{(Q^2 f^{5/3})}{140}$$

Lacey's method assumes that a canal achieves a state of "regime" when the flow is steady, and the channel neither silts up nor scours.

Kennedy's Method

Kennedy developed a method for designing irrigation canals based on the concept of critical velocity, which is the velocity that prevents silting and scouring in a canal.
Key aspects of Kennedy's theory:

- **Critical Velocity (Vc):**

$$Vc = CmD^{0.64}$$

where C is a constant (about 0.55 for Indian conditions), m is the critical velocity ratio, and D is the hydraulic depth.

- **Critical Velocity Ratio (m):** It is the ratio of actual velocity to critical velocity and is used to modify the design based on local silt conditions.

Kennedy's design is empirical and heavily relies on past experiences and observations.

Reservoirs

Definition of Reservoir

A reservoir is an artificial lake used for storing water for various purposes such as irrigation, drinking water supply, industrial use, flood control, hydropower generation, and recreational activities. Reservoirs are created by constructing dams across rivers or valleys.

Investigation for Reservoir Site

Selection of a suitable site for a reservoir involves a thorough investigation of various factors:

- **Topography:** A narrow valley with steep sides is preferred to minimize dam length and maximise storage.
- **Geology:** The foundation must be strong and impermeable to prevent seepage and ensure dam stability.
- **Water Availability:** Adequate and dependable river flow is required to fill the reservoir.

- **Climate:** Rainfall and evaporation rates must be analysed to assess water retention.
- **Socio-economic Factors:** Minimising displacement of people, environmental impacts, and cost considerations are crucial.

Field investigations like soil tests, geological surveys, and hydrological studies are conducted before finalising the site.

Storage Zones in Reservoirs

The total storage in a reservoir is divided into several zones:

- **Dead Storage:** Volume below the outlet level that cannot be used for regular operations; allows sediment accumulation.
- **Live Storage:** Usable storage between the dead storage level and the spillway crest; available for intended purposes.
- **Flood Storage:** Space provided above live storage to temporarily store floodwater and prevent downstream flooding.

Proper zoning ensures optimal reservoir management and operational flexibility.

Determination of Storage Capacity Using Mass Curves

A **mass curve** is a plot of cumulative inflow against time. It is a useful graphical method to determine reservoir storage capacity.

Procedure:

- Plot cumulative inflow over time.
- Superimpose a demand line (representing cumulative usage).
- The maximum vertical distance between the inflow curve and the demand line gives the required storage capacity.

Mass curve analysis helps in reservoir sizing and planning for seasonal variations in inflow and demand.

Economical Height of Dam

The economical height of a dam is the height at which the combined cost of the dam and the associated benefits (like water supply, irrigation, hydropower) is optimised.
Factors considered in determining the economical height include:

- Cost of construction per unit height.
- Incremental benefits (additional water storage, power generation).
- Safety factors against floods and earthquakes.
- Environmental and social impacts.

Economic analysis involves plotting the cost-benefit curves and identifying the point of maximum net benefit, corresponding to the optimal dam height.