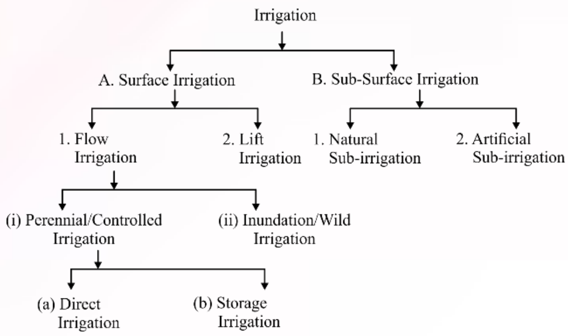
Irrigation Engineering

Classification of irrigation



Water distribution technique

Free/wild or ordinary flooding	Used over rolling land where borders, checks, basins and furrows are not feasible. • Water application efficiency is low and most suitable for close growing crops.
Border Flooding	Applied where land is divided into no. of long parallel strips separated by low levees.
Check flooding	Entire field is divided into number of leveled plots surrounded by levees.
Basin flooding	It is the special types of check flooding specially adopted for garden and orchard.
Furrow irrigation	For row crops deep furrow is widely used. • In furrow irrigation less evaporation occurs.
Contour method	Used for mountainous or land with very steep slope.
Sprinkler irrigation	It is the artificial rain in which optimum quantity of water is used.
Drip/trickle irrigation	Water is directly supplied to the root zone of plants.

Concentration of salt

Classification	Electrical conductivity (µMho/cm)
Low saline water, C_1	100-250
Medium saline water, C_2	250-750
High saline water, C_3	750-2250
Very high saline water, C_4	> 2250

Proportion of sodium ion concentration

$$S.A.R. = \frac{[Na^+]}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Classification of water on the basis of SAR-

Type of water	SAR value
Low sodium water, S_1	0-10
Medium saline water, S_2	10-18
High sodium water, S_3	18-26
Very high sodium water, S_4	> 26

Classification of saline and Alkaline soil-

Soil classification	E.C. (µMho /cm)	E.S.P.	pH Value
Saline soil or white alkali	> 4000	<15	≤ 8.5
Alkaline soil or non saline alkali/sodic soil/black alkali	< 4000	>15	8.5-10
Saline alkali soil	>4000	>15	<8.5

Soil Water

Capillary water	It is available water that held in soil against the gravity force
Hygroscopic water	It is not available for the plant and can't be easily removed from soil particle
Gravitational water	This water is not held by soil.

Important formula

Field capacity

It is the maximum amount of moisture held by a soil against gravity.

$$F.C. = \frac{\text{Weight of water stored in soil of unit area}}{\text{Weight of same soil of unit area}}$$

$$F.C. = \frac{\gamma_w . d_w}{\gamma . d}$$

Where,

d_w = Depth of water stored in root zone

γ_d = Dry unit weight of soil

Available moisture depth to plant

$$\frac{\gamma_w . d}{\gamma_w}[F.C. - P.W.P.]$$

$$\text{Available moisture for plant} = F.C. - \phi$$

ϕ = Permanent wilting point (P.W.P)

Readily available moisture depth to plant

$$d_w' = \frac{\gamma_d . d}{\gamma_w}[F.C. - P.W.P]$$

$$d_w' = \frac{\gamma_d . d}{\gamma_w}[F.C. - m_o]$$

$$d_w' = S.d(F.C. - m_o$$

m_o = Readily available moisture content

Irrigation requirements of crop

1. Consumptive Irrigation requirement

$$CIR = C_u - R_e$$

2. Net Irrigation requirement

$$N.I.R. = C.I.R. + L_e$$

$$= C_u - R. + L_e$$

3. Field Irrigation requirement

$$F.I.R. = \frac{N.I.R}{\eta_a}$$

4. Gross Irrigation requirement

$$G.I.R. = \frac{F.I.R}{\eta_c} = \frac{N.I.R}{\eta_a \cdot \eta_c}$$

Where,

C_u = Total consumptive use

R_e = Effective rainfall

L_e = Leaching requirement

Note–

$$GIR > FIR > NIR > CIR$$

Canal System and Irrigation Efficiency

(i) Water Conveyance Efficiency

$$\eta_c = \frac{W_f}{Wr} \times 100$$

Where,

W_f = Water delivered to the field.

W_r = Water delivered from the reservoir

(ii) Water Application Efficiency

(Maximum for sub surface irrigation)

$$\eta_a = \frac{W_s}{W_f} \times 100$$

Where W, Water stored in the root zone

(iii) Water Use Efficiency

$$\eta_u = \frac{W_u}{Wf}$$

Where, W Water use consumptively

(iv) Water Storage Efficiency

$$\eta_s = \frac{W_s'}{Wf}$$

Where,

$W_{s'}$ = Actual water stored in the root zone.

W_η = Water needed to store to bring the water content up to field capacity.

(v) Water Distribution Efficiency

$$\eta_d = \left(1 - \frac{y}{d}\right) \times 100$$

where,

y = Avg. of the absolute values of deviation from the mean

$$= \frac{|d_1 - d| + |d_2 - d| + |d_3 - d| + ...}{n}$$

d = Average depth during irrigation

$$= \frac{d_1 + d_2 + d_3 + ...}{n}$$

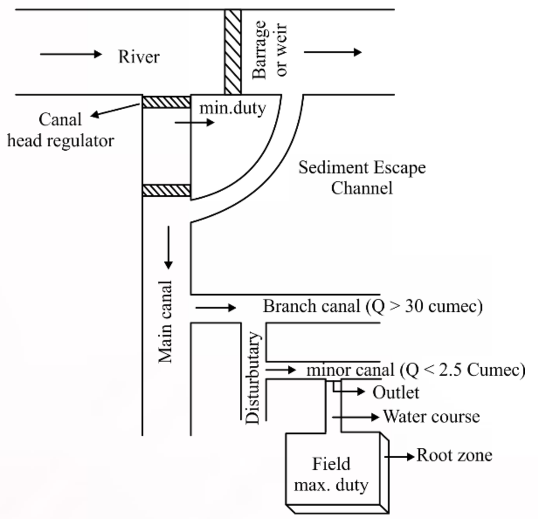
(vi) Consumptive Use Efficiency

$$\eta_{cu} = \frac{W_{cu}}{W_d} \times 100$$

Where,

W_{cu} = Water used by plant consumptively.

W_d = Net amount of water depleted from root zone



Frequency of irrigation

$$\frac{\text{Available or readily available moisture depth}}{\text{Consumptive use}} = \frac{d_w'}{C_u}$$

Water depth required in the field,

$$\frac{\text{Net irrigation requirement}}{\text{Water application efficiency}} = \frac{NIR}{\eta_a}$$

Duration of Indian crop season-

Kharif June - September (Mansoon crops)

Rabi October March

Zaid April - June

Note-

- **Cash crop-** Cotton (8 month), Coffee, Tea, Sugarcane, Spices.
- **Perennial crop - (Time taken 1 year)-** Sugarcane

Important terminology

Field capacity	Maximum amount of moisture which can be held by soil against gravity. • Soil is not saturated but still a very wet condition
Permanent wilting point (PWP)	It is the state of soil when plants fail to extract sufficient water for their requirements.
Saturation capacity	Water required to fill all the pore spaces between soil particles by replacing all air held in pore spaces.
Temporary wilting point	Water content at which the plant wilts at day time, but recovers during night or when water is added to soil.
Crop period	The total time period that elapse from the instant of its showing to the instant of its harvesting.
Base period (B)	Time between the first watering of a crop from the time of its sowing to its last watering before harvesting. **Note-** Base period < crop period
Paleo Irrigation	• It is the watering done prior to the sowing of a crop. • It is done to prepare the land for sowing and to add enough moisture to the soil.
Kore watering	• It is the first watering after the plants have grown a few centimeter high. • • Kore watering required max. discharge in limited time.

Kore depth	Depth of water applied during kore watering.
Outlet factor	It is the duty of canal water at the outlet.
Crop Ratio	$= \frac{\text{Irrigated area of Rabi season}}{\text{Irrigated area of Kharif seasons}}$
Duty (D)	It represents the irrigating capacity of a unit water.
Delta (Δ)	It is total depth of water required for a crop during the entire period of the crop's.

Time factor

It is the ratio of number of days the canal has actually run to the number of days or irrigation period.

Time factor =

$$\frac{\text{Actual operating period of distributary}}{\text{Crop period}}$$

Capacity factor-

It is the ratio of mean supply discharge to the full supply discharge.

$$C_v = \frac{\text{Mean discharge}}{\text{Design discharge}}$$

$$\text{G.C.A Culturable area + unculturable area}$$

$$\text{C.C.A = G.C.A. unculturable area}$$

G.C.A Gross commanded area

$$\text{Irrigated area = C.C.A} \times \text{Irrigation Intensity}$$

Relation b/w Duty and Delta

$$\Delta = \frac{8.64B}{D}\ \text{m} \quad \text{or} \quad \Delta = \frac{864B}{D}\ \text{cm}$$

B = base period in days

D = Duty in hectares/cumec

Kore depth

Crops	Kore Depth
Rice	19 cm
Wheat	13.5 cm
Sugarcane	16 cm

Crops	Delta	Duty ha/m^3/s
Rice	120 cm	775
Wheat/Rabi	40 cm	1800
Sugarcane	120 cm	730
Tabacco	75 cm	-

Important Irrigation Canal

Water shed or ridge canal	Designed along the watershed line and it can irrigate both side of canal under gravity flow. • It is economical and minimum cross drainage work required.
Contour/single bank canal	Irrigate only one side of canal and aligned parallel to the contours of the country.
Side slope canal	Aligned at right angle of the contours and runs parallel to natural drainage. • Cross drainage works are completely eliminated
Inundation canals	Directly taken from rivers to control the water level in river during flood
Feeder canal	Constructed to feed two or more other canals.

River training works

- **Aggrading River-** This is because of silting.
- **Degrading River-** This is because of scouring.

Meandering of River

Meandering of a river is due to erodibility of the bed and banks of stream.

$$\text{Meandring Ratio} = \frac{\text{Meander belt}}{\text{Meander length}} = \frac{M_B}{M_L}$$

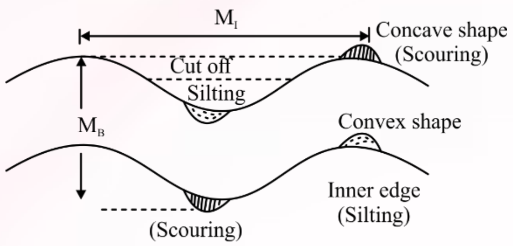
Meander Length $M_L = 65.8\sqrt{Q}_{dominant}$

Cut of Ratio $1.7 \leq \text{C.O.R.} \leq 3.0$

$$\text{C.O.R/Tortusity} = \frac{\text{Curved length of cut off}}{\text{Straight length of cut off}}$$

Dominant Discharge

$$Q_{dominant} = \frac{1}{2} \text{ or } \frac{2}{3} \text{ of } Q_{max} = \frac{9}{16} \cdot Q_{max}$$



Meandering River

River Training

Type of river training	Training for	Example
Low	Depth	Navigation
Medium	Velocity	Silt control
High	Discharge	Flood control

Ideal shape of canal

- For lined canal - Trapezoidal
- For unlined canal or Alluvial soil - Semicircular
- Best section of canal, when it is in - Partially cutting and filling

Regime channel

A channel is said to be in a stage of regime if there is neither silting nor scouring in the channel.

Design parameter of lacey's theory

1. Velocity, $V = \left(\frac{Qf^2}{140}\right)^{1/6}$ V = Velocity in (m/sec.)

   Q = Discharge in cumec (m³/sec)

   - Lacy's regime velocity equation, $V = 10.8R^{2/3}s^{1/3}$
   - Silt factor, $f = 1.76\sqrt{d_{mm}}$

2. Hydraulic mean depth, $R = \frac{5}{2}\left(\frac{V^2}{f}\right)$

3. Wetted perimeter, $P = 4.75\sqrt{Q}$

4. $\text{Lacey's regime scour depth} = 1.35\left(\frac{q^2}{f}\right)^{1/3}$

   (for any river)

   $\text{Lacey's regime scour depth} = 0.48\left(\frac{q}{f}\right)^{1/3}$

   (for alluvial river)

Note-

According to Lacey's theory, eddies generate from canal bed and side both or total wetted perimeter.

Kennedy's Theory

(i) Critical velocity, $v_0 = 0.55my^{0.64}$

Where, y = Trial depth

m = Critical velocity ratio

(ii) Area, $A = (B + ny)y$

Where, $A = \frac{Q}{v_0}$ Q = Discharge (m³/sec.)

(iii) Perimeter, $P = B + 2y\sqrt{n^2 + 1}$

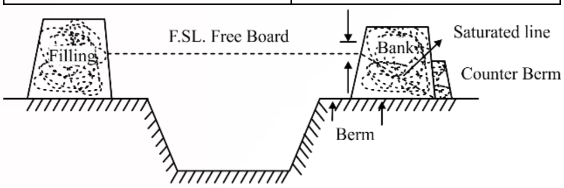
(iv) Hydraulic mean depth $R = \frac{A}{P}$

(v) Actual velocity, $v = C\sqrt{R \times s}$

Different between Lacy's and Kennedy's theory-

Kennedy's theory	Lacey's theory
Silt is kept in suspension due to eddies from bottom	Silt is kept in suspension due to both from bottom and side.
Design is tedious and based on trial and error procedure.	Simple and based on direct procedure.
Not given any equation for bed slope.	Given for bed slope.
Applicable for irrigation channel only.	Both for channel and rivers

Considered channel section is trapezoidal.	Semi-elliptical section
There can be many section for the given discharge.	Only one regime section for given discharge and silt factor.
Used critical velocity ratio (m) to account for silt that is depends upon silt charge and perimeter.	Established silt factor that is depends upon avg. size of particle.
Recommended the use of kutter's equation.	Gave is own flow equation.



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Canal Head Work Terminology

Canal head regulator	Provided at the head of the off taking canal (99-110°).
Divide wall	Constructed at right angle to the axis of weir/barrage for creating still pond.
Under sluiced/ scouring sluice	Provided on the same side as the off taking canal.
Fish Ladder	Fish ladders are the Baffle walls that provides smooth flow of water by dissipating flow energy due to which fishes moves freely and safely in the river.
Silt excluders & Silt ejector	It is used for silt prevention work.

Note -

- Most suitable location of canal head works is trough stage of the river.
- It is constructed normal to the river flow.

River training work includes-

- Flood protection
- Guiding the flow
- Efficient navigation
- Sediment control

Safety against piping or undermining-

Safe creep length, $\boxed{L = C.H_L}$

C = Bligh's coefficient of creep

To prevent piping failure, $\boxed{\frac{H}{L} \le \frac{1}{C}}$

Safety against uplift pressure-

Floor thickness, $\boxed{t \ge \frac{h}{G-1}}$

Where, h = Ordinate of the H.G.L. above the top of floor.

$$\boxed{t = 1.33\left(\frac{h}{G-1}\right)}$$

As per Lane's theory-

To prevent piping failure-

$\frac{H}{L_l} \le \frac{1}{C_1}$ Where, C_1 = Lane's creep coefficient

To precent up life failure-

$t \le \frac{h}{G-1}$ t = Floor thickness

Cross drainage work and its Suitability

Cross drainage work	Suitable for	Remark
Aqueduct	• HFL of drain is sufficiently below the bottom of the canal • Drainage water flows	FSL > CBL > HFL FSL-Full supply level CBL-Canal bed level
Syphon aqueduct	• HFL of drain is higher than canal bed • Water passes through aqueduct barrels under syphonic action	FSL > HFL > CBL HFL-High flood level
Super passage	• FSL of canal is sufficiently below the bottom of the drain trough • Canal water flows freely under gravity	HFL > DBL > FSL DBL-Drainage Bed level
Canal Syphon or syphon	• FSL of canal is sufficiently above the bed level of drainage trough • Canal flows under syphonic action under the trough	HFL>FSL> DBL
Level crossing	Generally provided when a large canal and huge drainage (such as a stream or river) approach each other practically at the same level	

Types of aquifer-

Confined/ artesian aquifers	It is one that is confined on its upper and lower surfaces by impervious rocks formation or aquiclude.
Unconfined or non-artesian aquifers	It is the topmost water bearing strata with no confined impermeable overburden (aquiclude) laying over it.
Perched aquifer	It is in the shape of inverted lens or cup.
Aquitard Ex.- Silty clay	It is a layer through which only seepage is possible.
Aquiclude Ex.- Clay	An aquiclude is a solid impermeable layer under laying or overlaying an aquifer
Aquifuge Ex.- Compact rock	There is neither porous nor permeable formation and no inter connected openings hence it can't transmit water.
Specific capacity	Wells yield per unit draw down is known as specific capacity.
Cone of depression	If the aquifer is homogeneous and isotropic and water table is assumes a conical shape, called cone of depression.