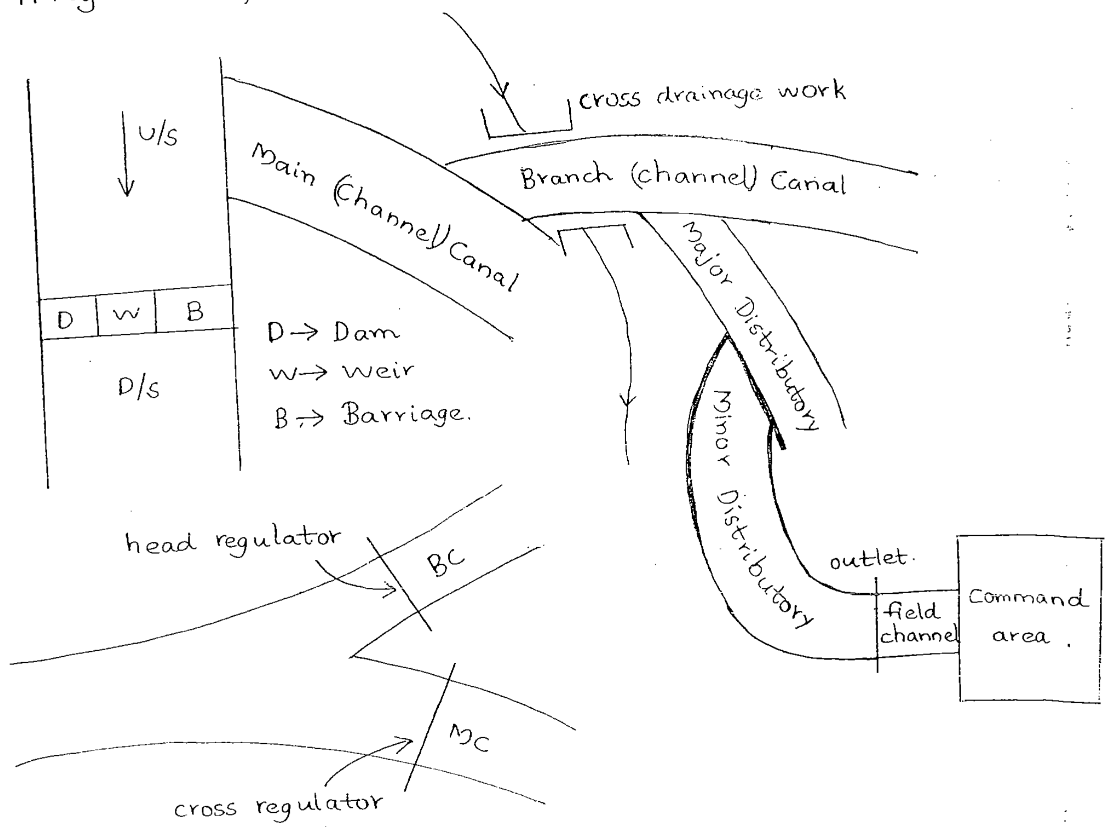
IRRIGATION

Science which deals with artificial supply of water to the crops.

→ Irrigation System :



A regulator controls the flow of water into the canal (weir-like structure)

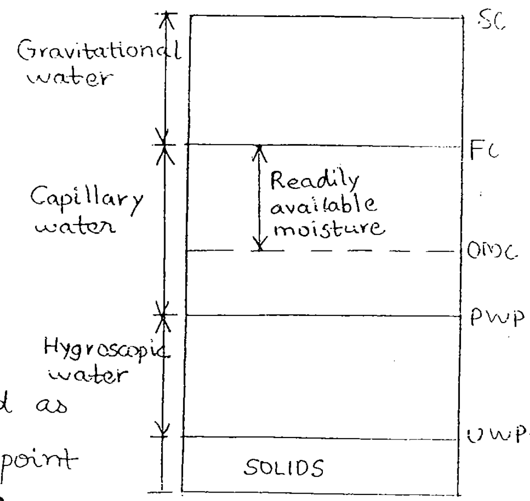
Irrigation system comprises of hydraulic structures like dam, weir, barriage, canal system, cross drainage works (like aquaduct), regulators, canal falls and canal escapes (Surplus escape & Silt escape)

* Hygroscopic water

Thin layer of water surrounding the soil grains which the roots of plants cannot absorb.

→ Types of Water

1. Gravitational water
2. Capillary water (available water).
3. Hygroscopic water



The moisture content expressed as percentage at ultimate wilting point is called 'Hygroscopic Coefficient'

* Hygroscopic Water

It consists of two parts:

(i) Amount of moisture absorbed from atmosphere by the soil grains.

(ii) Thin film of moisture sticking to the soil grain which cannot be extracted by the plant.

* Capillary water.

The amount of moisture stored in capillary pores which can be extracted by the plant, is called capillary water of available water

Saturation Capacity :– a state where all the voids are filled with moisture

Field capacity :– amount of moisture retained in the soil against pull of gravity.

Water stored in capillary pore against gravity pull in the root zone – field capacity

Water stored in the pore spaces of soil grains – saturation capacity

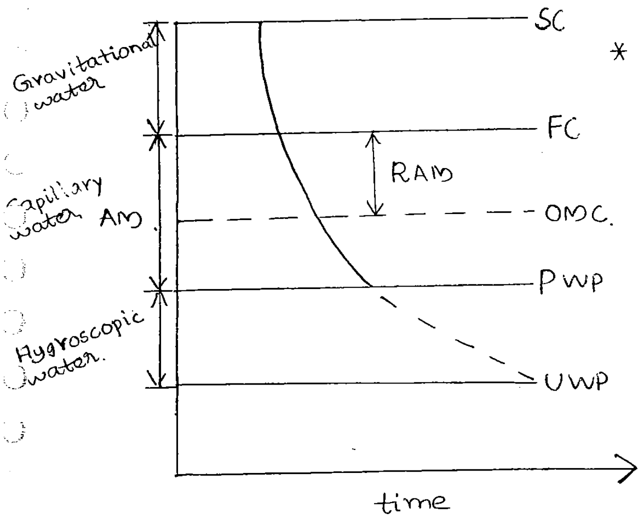
ET = Evaporation + Transpiration.

CU = Consumptive Use = E + T + ΔW
↳ for metabolic activity

* Temporary Witting Point – Plants can make use of water available in the soil.

* Permanent Witting Point – Plant recovers only with application of water.

* Ultimate Witting Point – even with application of water, plant cannot recover. ie, plant is dead.



* Available moisture (y):

AM, y = FC – PWP.

* Readily available moisture = 75 – 80% AM.

NOTE:

- Yield is less if irrigation is carried out below OMC
- Yield is more if irrigation is carried out above OMC
- Duty of irrigation engineer is to supply water when moisture content reaches OMC

* Gravitational water (or) Unavailable water = SC – FC

* Hygroscopic water

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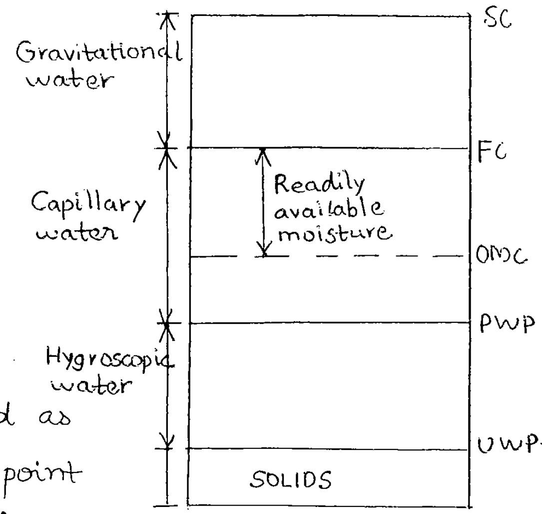

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Saturation Capacity :— a state where all the voids are filled with moisture

Field capacity :— amount of moisture retained in the soil against pull of gravity.

* Field Capacity, $F_C = \dfrac{\text{wt. of moisture retained in unit area of soil}}{\text{wt. of soil in unit area.}}$

Let $d \rightarrow$ depth of soil.

$\gamma_w \rightarrow$ unit weight of water

$\gamma_d \rightarrow$ unit weight of dry soil.

$A \rightarrow$ area.

$$F_C = \frac{\gamma_w * A * \text{depth of water}}{\gamma_d * A * d}.$$

$\therefore$ Depth of water at $F_C = \dfrac{\gamma_d}{\gamma_w} * d * F_C$.

$$= S * d * F_C.$$

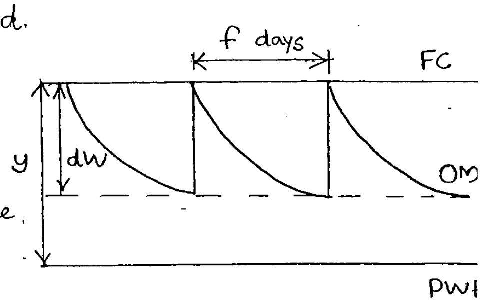
Similarly, depth of water at PWP $= S * d * PWP$.

Depth of available moisture or Water holding capacity }	$y = S * d * (F_C - PWP)$.

Depth of moisture at OMC, RAM	$= S * d * (F_C - OMC)$

→ Frequency (or) Irrigation Period.

$$f = \frac{dw}{CU} \text{ days.}$$



$dw \rightarrow$ readily available moisture.

$CU \rightarrow$ consumptive use.

Say $dw = 10$ cm & $CU = 1$ cm/day.

$$f = \frac{10}{1} = \underline{\underline{10 \text{ days}}}$$

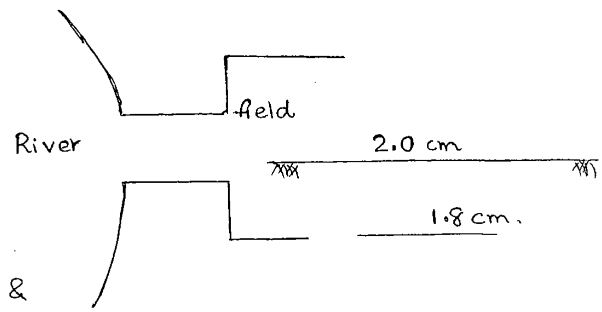
⊙ If $f = 10$ days, it means that once in 10 days irrigation is to be carried out (or) irrigation water is supplied once in 10 days.

→ Application Efficiency (η_a)

$$\eta_a = \frac{\text{Quantity of water stored in root zone}}{\text{Quantity of water delivered to the field.}}$$

$$\eta_a = \frac{1.8}{2} \times 100$$

$$= 90\%$$



∴ Loss = 10 % ; due to Tail water run off loss & ~~Deep~~ Deep Percolation loss.

→ Conveyance Efficiency (η_c)

$$\eta_c = \frac{\text{Qty of water delivered to the field}}{\text{Qty of water delivered to canal system.}}$$

$$= \frac{2}{3} \times 100 = 67\%$$

Loss = 33% ; Conveyance loss

8th Oct, Saturday → Water use Efficiency (η_w)

$$\eta_w = \frac{\text{Qty of water beneficially used}}{\text{Qty of water delivered to field.}}$$

Quantity of water beneficially used = water used by crop + water used for leaching

→ Water Storage Efficiency (η_s)

$$\eta_s = \frac{\text{Qty of water stored in root zone}}{\text{Qty of water required to bring moisture content to field capacity}}$$

Leaching is the supply of additional water to wash away the salts in a saline prone area

→ Water Distribution Efficiency (η_d)

$$\eta_d = \left(1 - \frac{d}{D}\right) * 100$$

D → average depth of penetrations (water) in the soil.

d → average of absolute values of deviations from the mean.

Say the $\eta_d = 90\%$, means that 90% area has received uniform depth of moisture in the root zone. The remaining 10% may receive excess water or less water called as 'over irrigation' or 'under irrigation'

→ Consumptive Irrigation Requirement (CIR)

CIR = Consumptive use + Effective rainfall.

* Net irrigation requirement, NIR = CIR + water require for leaching.

* Field irrigation requirement, $FIR = \frac{NIR}{\eta_a}$

* Gross irrigation requirement, $GIR = \frac{FIR}{\eta_c}$

A loamy soil has FC = 25%, PWP = 10%, γ_d of soil = 1.5 g/c if root zone depth = 0.75 m, what is storage capacity of soil. Irrigation water is applied when moisture content = 14%. If $\eta_a = 75\%$, determine the water depth required.

Water holding capacity, $y = S * d * (Fc - PWP)$.

$= \frac{1.5}{1} * 0.75 * (0.25 - 0.1)$.

$= 0.168$ m

$\therefore$ Readily available moisture, $d_w = S * d * (Fc - OMC)$.

$= 1.5 * 0.75 * (0.25 - 0.14)$.

$= 0.124$ m.

$$\eta_a = \frac{\text{depth of water stored in root zone}}{\text{depth of water applied to field.}}$$

$$0.75 = \frac{0.124}{\text{depth applied.}}$$

$\Rightarrow$ Depth of water applied $= \frac{0.124}{0.75} = 0.165$ m

2 FC = 29% , PWP = 11% , d = 70 cm = 0.7 m.

Consumptive use, CU = 12 mm.

Water holding capacity; $y = \frac{1.3}{1} * 0.7 (0.29 - 0.11)$.

$= 0.1638$ m.

Readily available moisture, d_w $= 0.75 \times y$.

$= 0.123$ m.

$\therefore$ Irrigation period (or) frequency of irrigation, } $f = \frac{d_w}{C_u} = \frac{0.123}{12/1000}$

$= 10.25$ days

3. Area irrigated = 50 ha. ; t = 12 hours/day

$\eta_c = 85\%$; y = 20 cm/m depth.

Average root zone depth, $d = 1$ m.

$\eta_a = 80\%$

Readily available moisture, $d_w = 50\%\ y$.

Consumptive use $= 5$ mm.

$f = ?$ & $Q = ?$ (L/min).

$$d_w = 0.5 \times 20 = 10 \text{ cm/m.} \quad (\text{given } d = 1 \text{ m}).$$

$$f = \frac{d_w}{C_u} = \frac{10}{0.5} = \underline{\underline{20 \text{ days}}}$$

$$Q = \frac{\text{volume of water to be delivered}}{\text{Time of pumping}}$$

$$= \left(\frac{A * d_w}{t}\right) \times \frac{1}{\eta_a \times \eta_c}$$

$$= \frac{50 * 10^4 * 0.1}{0.85 \times 0.8 \times (20 \times \textcircled{12} \times 60)} = 5.106 \text{ m}^3/\text{min}$$

$$= \underline{\underline{5106}} \text{ L/min}$$

4 $A = 5000$ ha, $F_c = 25\%$, $PWP = 5\%$, $S = 1.4$, $d = 0.8$ m, $C_u = 1.68$ cm/day, $d_w = 75\%\ y$, $f = ?$, $Q = ?$; $\eta_a = 20\%$

$$y = S * d * (F_c - PWP).$$

$$= 1.4 * 0.8 * (0.25 - 0.05).$$

$$= \underline{\underline{0.224 \text{ m}}}.$$

$$d_w = 0.75 \times y = 0.75 \times 224 = 0.168 \text{ m}$$

$$f = \frac{d_w}{C_u} = \frac{0.168}{1.68/100} = \underline{\underline{10 \text{ days}}}$$

$$Q = \frac{\text{volume of water delivered}}{t} = \left(\frac{A * d_w}{\eta_a}\right) \times \frac{1}{\text{time}}$$

$$Q = \frac{5000 \times 10^4 \times 0.168}{0.2 \times (10 * 24 * 3600)} = \underline{\underline{48.61 \ m^3/s}}$$

Q. A discharge of 130 L/s was delivered from a canal and ~~hum~~ 100 L/s was delivered to the field. An area of 1.6 ha was irrigated in 8 hours. The run off loss in the field is 420 m^3. Determine conveyance efficiency and water application efficiency. Depth of root zone is 1.7 m and available moisture holding capacity of soil is 20 cm/m depth of root zone. Irrigation is started at a moisture extraction level of 50% of available moisture. Determine water storage efficiency.

Discharge into canal = 130 L/s.

Discharge delivered to field = 100 L/s.

$$\eta_c = \frac{100}{130} \times 100 = 76.92\%.$$

$$\eta_a = \frac{\text{vol. of water stored in root zone}}{\text{vol. of water delivered to field.}}$$

Volume of water stored = vol. applied − run off loss.

$$= 0.1 \times 8 \times 3600 - 4\overset{2}{8}0$$

$$= 2880 - 4\overset{2}{8}0 = 2460 \ m^3.$$

$$\eta_a = \frac{2460}{2880} \times 100 = \underline{\underline{85.4\%}}$$

Given,

$d = 1.7$ m, $y = 20$ cm/m depth.

Total water holding capacity in 1.7 m = $20 \times 1.7 = 34$ cm.

$$d_w = 0.5 \times y = \underline{\underline{17 \text{ cm}}}$$

∴ Volume of water required to bring moisture content to field capacity = Area × d_w

$= 1.6 \times 10^4 \times 0.17 = \underline{2720 \text{ m}^3}$

⇒ water storage efficiency, $\eta_s = \frac{2460}{2720} \times 100 = \underline{\underline{90.4\%}}$

Q. The depths of penetration along the lengths of an irrigation field at 130m apart are observed as follows:
2m, 1.9 m, 1.8 m, 1.6 m, 1.5 m. Compute distribution efficiency.

$$D = \frac{2+1.9+1.8+1.6+1.5}{5} = \underline{\underline{1.76 \text{ m}}}$$

Deviations from mean:

$2-1.76 = 0.24$ $\quad 1.8-1.76 = 0.04$ $\quad |1.5-1.76| = 0.26$

$1.9-1.76 = 0.14$ $\quad |1.6-1.76| = 0.16.$

$$d = \frac{0.24+0.14+0.04+0.16+0.26}{5} = 0.168 \text{ m}$$

$$\Rightarrow \eta_d = \left(1 - \frac{d}{D}\right) \times 100 = \left(1 - \frac{0.168}{1.76}\right) \times 100$$

$$= \underline{\underline{90.45\%}}$$

∴ 90.45% of command area receives equal depth of moisture in the root zone.

19th Oct,
SUNDAY

* Crop Period:

Time elapsed b/w sowing and harvesting.

* Base Period:

Time elapsed b/w 1st watering and last watering before harvesting.

Crop Period > Base period.

* Duty of water:

It establishes a relation b/w Q & area.

It is defined as the area of land in hectares which can be irrigated for growing any crop if $1\ m^3/s$ is continuously supplied throughout the base period.

$$\therefore \boxed{\text{Duty} = \frac{\text{Area}}{\text{Discharge}}}$$

If duty = 1000 ha/cumecs, it means that 1000 ha can be cultivated if $1\ m^3/s$ is supplied continuously for the entire base period B.

– Variation of Duty along the Canal System:

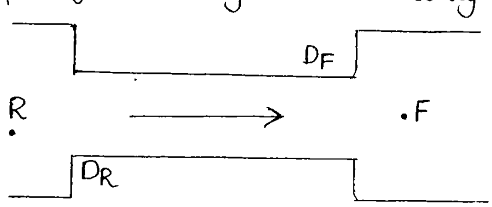
$$\boxed{D_F = \frac{D_R}{\eta_c}}$$

$D_F \rightarrow$ duty on the field.

$D_R \dashrightarrow$ duty at the head of the canal.

$\eta_c \rightarrow$ conveyance effeciency.

Unless specified, duty means duty on the field.



* Delta (Δ) :

The depth of flow applied during entire base perioa

$$\Delta = \frac{8.64\ B}{D}$$

$\Delta \rightarrow$ depth of flow (in m)

$B \rightarrow$ base period. (in days)

$D \rightarrow$ duty (in. ha/cumecs).

- Volumetric Units:

1. m^3

2. ~~ha-cumec~~ or cumec day

It is the total volume of water supplied at the rate of $1\ m^3/s$ in a day.

$$1 \text{ cumec day} = \frac{1\ m^3}{s} \times 24 \times 3600$$

$$1 \text{ cumec day} = 8.64 \text{ ha-m}$$

3. TMC

1 TMC = Thousand Million Cusecs.

$1 \text{ cusec} = 1\ ft^3/s$

$1 \text{ cumec} = 1\ m^3/s$

To represent inflows and outflows from a reservoir, generally TMC is used.

→ Paleo irrigation :

Watering done for land preparation, ie, first watering is called as Paleo irrigation.

→ Kor watering :

Watering done or irrigation carried out when the plants are at a younger stage, ie, the height of the plant is few cm. The demang for water during this period is more.

- Kor Period

The period of Kor watering is Kor period, which is around 2-3 weeks.

- Kor Depth

The total depth applied during Kor period is called as Kor depth.

→ Gross Command Area (GCA)

The total area under a canal system

* Culturable Command Area (CCA)

CCA = GCA − uncultivated area.

Uncultivated area includes :-

a) Habitants

b) Paved areas.

* Culturable Cultivated Area.

Culturable Cultivated Area = CCA − Culturable Uncultivated Area.

= % CCA

* Culturable Uncultivated Area.

(i) Water logging

(ii) Fallow land – land which is left idle for a few crop seasons to allow replenishment of nutrients.

(iii) Lack of Resources.

* Intensity of Irrigation.

Intensity of irrigation = % of CCA proposed to be irrigated annually

* Capacity Factor (CF)

$$CF = \frac{\text{mean discharge}}{\text{max. discharge}}$$

* Time Factor (TF)

$$TF = \frac{\text{No. of days canal has run}}{\text{No. of days canal is supposed to run}}$$

Also

$$TF = \frac{\text{Actual discharge}}{\text{Design discharge}}$$

$$\therefore \boxed{\text{Design discharge of canal} = \frac{\text{Mean discharge}}{CF * TF}}$$

→ Kharif Season (monsoon season).

April to September (6 months).

Crops during this period are called Kharif crops.

Eg: Paddy, Maize.

→ Rabi Crops (winter Crops).

October to March (6 months).

Crops grown during this period are called Rabi crops.

Eg: Wheat.

* Perennial Crops. – crop grown throughout the year.

Eg: Sugar cane.

* 8 month crops

May to Dec / January.

Eg: Cotton.

* Hot weather crops

February – June.

* Dry Crops. – no irrigation required.

* Wet crops – irrigation needed.

$\Delta = D_F = 800$ ha/cumecs.

$\eta_c = 80\%$ (given loss is 20%)

$D_F = \frac{D_R}{\eta_c} \Rightarrow D_R = 800 \times 0.8 = \underline{\underline{640}}$ ha/cumecs

For rice:

$B = 140$ days

$\Delta_R = 1.34$ m.

$D_R = 8.64 \frac{B}{\Delta}$.

$= 8.64 \times \frac{140}{1.34}$

$= 902.686$ ha/cumecs

For wheat:

$B = 120$ days

$\Delta_w = 0.52$ m

$D_w = 8.64 \times \frac{120}{0.52}$

$= 1993.846$ ha/cumecs.

Area irrigated under rice, AR = 1200 ha.

$$D_R = \frac{A_R}{Q}.$$

$$\therefore \; Q = \frac{1200}{902.686} = 1.33 \; m^3/s$$

Area irrigated under wheat $= Q \times D_w$.

$$= 1.33 \times 1993.846$$

$$= 2650.55 \text{ ha}$$

8 Volume of tank $= 10 \, Mm^3 = 10 \times 10^6 \, m^3$.

Loss = 10%

Available storage $= 90\% \; 10 \, Mm^3 = 9 \, Mm^3$.

B_w = 120 days

$\Delta = 0.4$ m

Volume = Area * Δ.

$9 \times 10^6 \, m^3$ = Area * 0.4.

$$\therefore \; A = 2250 \times 10^4 \, m^2 = 2250 \text{ ha}$$

9. B = 15 days

Δ = 60 cm = 0.6 m.

Useful rain = 8 cm.

D_F = ? & D_R = ?

$$D_F = 8.64 \times \frac{B}{\Delta} = \frac{8.64 \times 15}{(0.6-0.08)} = 246 \text{ ha/cumecs}.$$

$$D_R = D_F \times \eta_c$$

$$= 249 \times 0.75 = 186.92 \text{ ha/cumecs}$$

10.

Crop	Base period	Duty (D_F)	Intensity of irrigation	Area
Wheat	120	1800	20	8000
Sugar Cane	360	1700	20	8000
Cotton	180	1400	10	4000
Rice	120	800	15	6000
Vegetables.	120	700	15	6000

CCA = 40,000 ha.

$\Delta = 8.64 \frac{B}{D} \Rightarrow$ $\Delta_{wheat} = 0.576$ $\quad \Delta_{sugar} = 1.83$

$\Delta_{cotton} = 1.11$ $\quad \Delta_{rice} = 1.296$

$\Delta_{vegetables} = 1.48$

$\Rightarrow$ Volume $= 8000 \times 0.576 + 8000 \times 1.83 + 4000 \times 1.11 + 6000 \times 1.296 + 6000 \times 1.48$

$= 40344$ ha-m.

$\therefore$ Reservoir capacity $= \frac{40354}{0.8 \times 0.9} = \underline{\underline{56047.22}}$ ha-m

11. $\eta_p = \frac{o/p}{i/p}$

Output of pump, $o/p = \frac{\gamma Q H}{75}$ hp.

$D = \frac{A}{Q}.$

$\therefore \; Q = \frac{2.5}{860} = \frac{2.907}{1000}$ cumecs

$o/p = \frac{\overset{1000}{\cancel{9810}} \times 2.907 \times 10^{-3} \times (107.5 - 100)}{75} = \overset{0.29}{\cancel{2.85}}$ hp

$i/p = \frac{o/p}{\eta_p} = \frac{\overset{0.29}{\cancel{2.85}}}{0.5} = \underline{\underline{\overset{0.57}{\cancel{5.7}}}}$ hp

1 kw = 1.34 hp.

1 hp = 0.746 kW. (British hp).

= 0.736 kw (Metric hp).

$o/p = \gamma QH = 9.81 \times \frac{2.5}{860} \times 7.5$

$= 0.214$ kw

$i/p = \frac{o/p}{\eta_p} = \frac{0.214}{0.5} = 0.427$ kw $= \underline{\underline{0.5736}}$ hp

12.

Crop	B(days)	A(in ha)	Duty	$Q = \frac{A}{D}$.
Rice	120	4000	1500	2.667
wheat	120	3500	2000	1.75
Sugar Cane	310	3000.	1200	2.5

Discharge required during Kharif season $= Q_{Rice} + Q_{S.C}$

$= \underline{\underline{5.167}}$ cumecs

Discharge required during Rabi season $= 1.75 + 2.5$

$= \underline{\underline{4.25}}$ cumecs

∴ Discharge = greater of above two values.

$= \underline{\underline{5.167}}$ cumecs

Design discharge $= \frac{5.17}{\eta_c \times TF} = \frac{5.17}{0.8 \times 0.75} = \underline{\underline{8.611}}$ cumecs

Q The main canal taking of from a storage reservoir irrigates the following crops. Necessary data is given as follows.

Crop	Crop Period	A	D.
Sugar Cane	280	360	640
Overlap in SC in hot weather	100	70	640
Jowar (rabi)	120	4860	1700
Bajri (monsoon)	120	6480	2860
Vegetables (hot weather).	120	360	700.

7.125

Find the discharge required at the head of the main canal taking $\frac{6}{10}$ as time factor and 0.8 as capacity factor for the main canal.

→ Crop Ratio

$$\text{Crop ratio} = \frac{\text{Area under Rabi}}{\text{Area under Kharif}}$$

Q Wheat crop requires 55cm of water during 120 days of base period. The total rainfall during this period is 100 mm.

Assume irrigation efficiency as 60%.. The area is hectares of land which can be irrigated with a canal flow of 0.01 m^3/s is —— ?

$\Delta = 55$ cm , Total rainfall = 10 cm.

$B = 120d$, $\eta = 60\%$

Net $\Delta = 55-10 = 45$ cm $= 0.45$ m.

Duty on field, $D_F = \frac{8.64 B}{\Delta} = \frac{8.64 \times 120}{0.45} = \underline{\underline{2304}}$ ha/cumec

$$D_F = \frac{D_R}{\eta_c}$$

Duty on canal, $D_R = D_F \times \eta_c = 2304 \times 0.6$

$= 1382.4$ ha/cumecs.

1 cumecs irrigates $= 1382.4$ ha.

0.01 cumec irrigates $= 1382.4 \times 0.01$

$= \underline{\underline{13.824}}$ ha

Q 10 m^3/s of water is delivered to a 32 ha field for 4 hours Soil after irrigation showed that 0.3 m of water had been stored in root zone. Application efficiency is a) 96%
b) 66.67% c) 48% d) 24%.

$$\eta_a = \frac{\text{vol. stored in root zone}}{\text{vol. of water applied.}}$$

$$= \frac{32 \times 10^4 \times 0.3}{10 \times 4 \times 3600} = 0.666 \times 10 = \underline{\underline{66.67\%}}$$

Q. In an irrigation project, in a certain year, 70% and 46% of CCA in Kharif and Rabi remained without water and the rest of the area got irrigation water. The intensity of irrigation in that period for the project wa —— ?

Area which received water during Kharif season

$= 100 - 70 = 30\%$

Area which received water during Rabi season.

$= 100 - 46 = 54\%$.

∴ Intensity for that year $= 54 + 30 = 84\%$

Q. The CCA for a distributed channel is 20,000 ha. Wheat is grown in the entire area and intensity of irrigation is 50%. The Korr period is 30 days, korr depth = 120 mm. The outlet discharge for the distributory is ——

Area under wheat = 10,000 ha.

$$D = \frac{8.64 \times 30}{0.12} = 2160 \text{ ha/cumecs.}$$

$$\text{Outlet discharge} = \frac{A}{D} = \frac{10000}{2160} = \underline{\underline{4.63 \text{ cumecs}}}$$