CE6PE01(A)	WATER RESOURCE ENGINEERING II	PE – I	3-1-0	3 Credits

Prerequisites: Water Resources Engineering I

Detailed Syllabus:

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2.	Canal design and layouts , types of canal Canal alignment – Canal design – Kennedy's Silt theory method, Laceyes regime theory. RangaRaju and Misri Method. Basak Method, Tractive shear approach Jayout of canals. Conveyance losses.	10
3.	Diversion head Works, Layout of diversion head works, Components of head works, Bligh's and lane's theories, Khosla theory, Design of weir& Barrage	8
4.	Canal Regulation Works: Different types of regulation works, Types and Design of falls. Types and design of regulators, Cross regulator, head regulator, canal escapes, canal modulus etc.	8
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MODULE-01

Irrigation- Irrigation may be defined as the science of artificial application of water to the land, in accordance with the crop requirements through out the crop period for full fleged requirement of the crops.

Advantage & Disadvantage of irrigation.

Advantage of irrigation.

Direct Advantage –

1. Increase in food production.
2. Protection against drought
3. Revenue generation.
4. Mixed cropping.

Indirect Advantage.

1. Power generation.
2. Transportation.
3. Ground water table.
4. Employment.

Disadvantage of irrigation.

→ Abundant supply of irrigation water tempts the cultivators to use more water than required Excess water supplied to field would percolate into the soil. hence due to constant percolation ground water table would be raised and will lead to water logging.

→ The ground water can get polluted due to seepage of the nitrates into the ground water (Applied to the soil as fertilizers.

Note:- If irrigation water is used judiciously with proper scientific consideration then there won't be ill effects of irrigation.

Type of irrigation.

- Surface irrigation
  - Flow irrigation
    - Perennial irrigation.
      - → Direct irrigation.
      - → Storage irrigation.
    - Flood irrigation
  - Lift irrigation.
- Subsurface irrigation.
  - Natural sub-surface irrigation
  - Artificial sub-surface irrigation.

Method of irrigation.

① Free flooding.

② Border flooding.

③ check flooding.

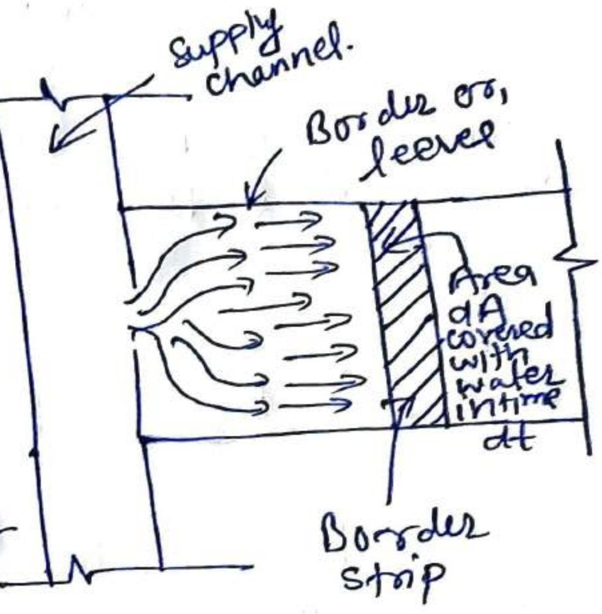
④ Basin flooding

⑤ Furrow method or, furrow irrigation.

⑥ spinkler irrigation method.

⑦ Drip irrigation method.

Relationship to obtain the maximum area irrigated with a supply ditch.



Volume of water supply in time dt,

$$Q \cdot dt = y \cdot dA + f \cdot A \cdot dt$$

$$\therefore dt = \frac{y \cdot dA}{Q - fA}$$

considering y, f and Q as a constant and integrating the above equation,

$$\int dt = \int \frac{y \cdot dA}{Q - fA}$$

$$\therefore t = \frac{-y}{f} \cdot \ln(Q - fA) + C$$

At, $t = 0, A = 0$

$$\Rightarrow 0 = \frac{-y}{f} \ln(Q) + C$$

$$\therefore C = y/f \ln Q.$$

$$\therefore t = \frac{-y}{f} \ln(Q - fA) + \frac{y}{f} \ln Q$$

$$t = \frac{y}{f} \ln\left(\frac{Q}{Q - fA}\right)$$

$$\therefore t = 2.303\, y/f \log_{10}\left(\frac{Q}{Q - fA}\right)$$

The above equation can be futher written as,

$$\frac{tf}{2.3y} = \log_{10}\left(\frac{Q}{Q-fA}\right)$$

Let, $\frac{tf}{2.3y} = x$

$$\therefore x = \log_{10}\left(\frac{Q}{Q-fA}\right)$$

$$\therefore \frac{Q}{Q-fA} = 10^{x}$$

$$\Rightarrow Q \times 10^{x} - 10^{x} \cdot fA = Q$$

$$\Rightarrow Q(10^{x}-1) = fA \cdot 10^{x}$$

~~$\therefore A = fA \cdot 10^{x}$~~

$$\therefore A = \frac{Q(10^{x}-1)}{f \cdot 10^{x}}$$

The maximum value of $\frac{10^{x}-1}{10^{x}} = 1$

$$\boxed{\therefore A_{max} = Q/f}$$

This equation enables us to determine the maximum area that can be irrigated with a supply ditch of discharge Q and soil having infiltration capacity f.

Where, Q = Discharge through the supply ditch.

A = Area of land strip to be irrigated.

y = Depth of water flowing over the border strip.

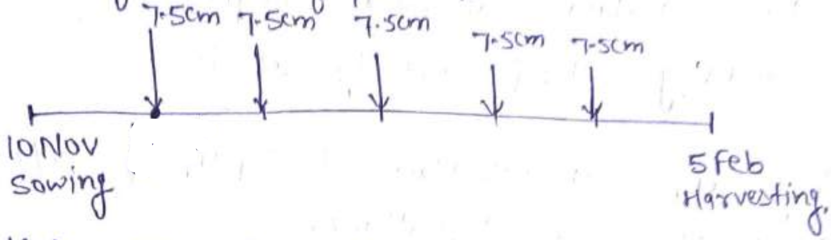
f = Rate of infiltration of soil.

t = time required to cover the given area A.

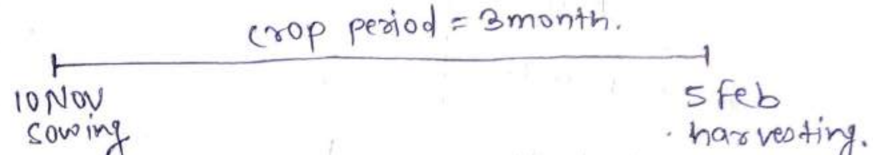
WATER REQUIRMENT OF CROP

→ Every crop required a certain quantity of water after a fixed interval throughout its period of growth.

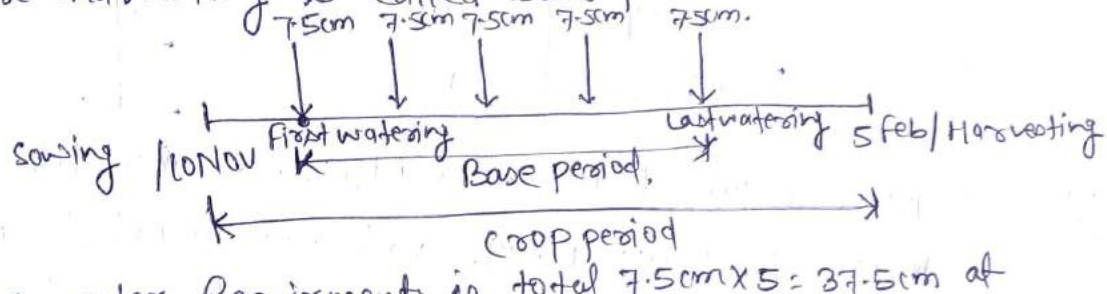
→ Hence water requirment of crop signifies the total quantity and the way in which a crop requires water throughout its growth of period.



(a) Crop period(B) – The time lapse from the instant of its sowing to the instant of its harvesting of crop is termed as crop period.



(b) Base period (B) – The time b/w the 1st watering of a crop at the time of its sowing to its last watering before harvesting is called Base period.



Here water Requirment is total 7.5cm × 5 = 37.5cm at Regular interval of 2-3 month.

→ crop period is slightly more than Base period but for all pratical purposes it is taken same.

→ It is also termed as growth period.

(c) Delta of crops (Δ) –

Every crop required a certain amount of water after a certain fixed interval of time, throughout its growth period.

→ The depth of water required every time generally varies between 5-10cm depending upon type of soil, type of crop & type of climate.

→ The water is required at an interval (termed as frequency) 6-15 days.

→ Hence the total quantity can be expressed in terms of depth (or, volume) of water required by the crop for its full growth (maturity) is termed as ~~delt~~ delta.

Avg. approximate value of depth of different crop in india - - are as follows.

crop	Delta on field (cm)
*sugarcane	120
* Rice	120
fruits	60
vegetables	45
* Wheat	40
Barley	30
Peas.	15

(Q.) If Rice required 11.5cm depth of ~~s~~ water at an avg. interval of about 11 days and crop period for Rice is 121 days whereas if wheat required 7cm of water after every 25 days and the base period of wheat is 150 days. Find the ratio of Δ of Rice to wheat.

(d) Duty of crop (D)

It is defined as the number of hectare of land area irrigated for given crop for its full growth by supply of 1 m^3/sec of water continuously during the entire base period of the crop.

Volume of water applied to the crop during Base period of B days at rate $1\ m^3/sec = V$

$$V = 1 \times B \times 24 \times 60 \times 60 = 86400B\ m^3.$$

Assuming All type of losses to be zero.

$$V_{applied} = V_{stored}.$$

$86400B$ = Area to be irrigated × Depth of water required for full growth of crop (Δ)

$$\text{Duty (D)} = \frac{\text{Area to be irrigated in hectare}}{1 \text{ cumec } (1\ m^3/sec)}$$

∴ Area to be irrigated = D hectare.

$= D \times 10^4\ m^2$

$$86400B = D \times 10^4 \times \Delta$$

$$D = \frac{86400B}{10^4 \times \Delta} = \frac{8.64B}{\Delta}$$

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

where, D → hectare/cumec

Δ → in m

B → in days.

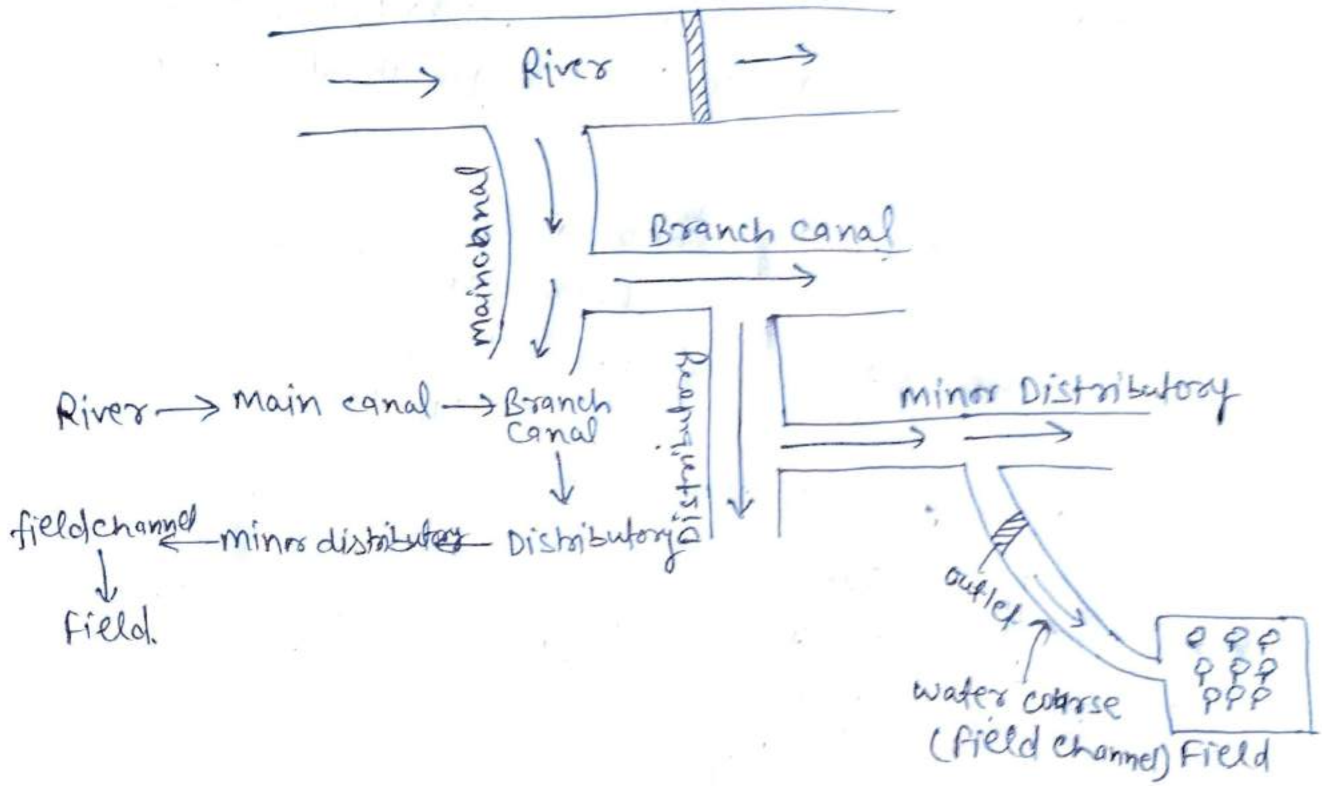
Avg. Approx value of Duty for Indian crops.

Crop.	Duty (hect/cumec)
sugarcane	730
Rice	775
wheat	1800
Fodder	2000

(Q.) Find the Δ for a crop when its duty 1728 hectare/cumec on the field the base period of the crop is 115 days

Ans. 57.5cm.

Duty at various places.



→ During this passage of water from one point to another point in irrigation system loss of water due to evaporation & percolation take place, termed as Transmission / Transit / conveyance losses.

→ As we move ahead in irrigation system from head to main canal to the head of field. Length of flow of water in these channels reduce, which in turn reduced the transmission losses.

→ Hence the availability of water for irrigation increases there by for some Δ, more area can be irrigated. hence duty increases.

Note- ⓐ Duty of water, therefore varies from one place to another place and increases as we move downstream from head of the main canal towards the head of branch or water course.

The duty at head of water course or, outlet of of minor is termed as outlet discharge factor.

ⓑ The outlet point is the point where the responsibilities of irrigation department finishes and it becomes the responsibility of individual farmer to carry the water to his field beyond this point.

ⓒ In case of flow/Direct irrigation, duty is always expressed as Area/Discharge (or, hectare/cumec). It is termed as flow duty or, duty. but in case water is Stored (Stored irrigation) duty is expressed in terms of area per unit volume of water available in reservoir for irrigation (ex- hectare/ M-m³). this type of duty is termed as quantity duty or, storage duty.

Factors Affecting Duty.

① Type of crop- A crop requiring more ~~more~~ water will have less coverage of area for some quantity of water being supplied as computed to the crop requiring less water. hence duty will be less for a crop which needs more water and vise-versa.

② Type of soil- If the permeability of soil under irrigation is high water loss due to percolation will be more and hence duty will be less and vise-versa.

③ usefull Rainfall – If some of the cases if useful rainfall is more, hence certain demand of water crop is fulfilled by it, there by more Irrigation water is available which Provides higher duty.

④ Climate and season –
As duty includes the water loss in evaporation and Percolation.
These losses will varies in different climatic condition, different season and different days of particular seasons.
Hence more is the loss due to higher temp.(evaporation loss) lesser is the Duty.

⑤ Efficiency of irrigation –
If higher is the efficiency of irrigation lesser is the loss of water, more is the availability of water for irrigation that results in higher duty.

Significance of Duty.

→ If area of the field is to be irrigated is known and duty of water various crops is also known then rate at which need to be supply can be calculated.

$$Q = \frac{Area}{Duty}$$

→ If Discharged Required by the crop is known & duty of water for various crops is also known the area of field can be calculated

Area = Q × Duty.
where A = hectare
Duty = hectare/cumec
Q = cumec.

Crop Ratio / Area Ratio / Kharif - Rabi Ratio

The Ratio of proposed area of kharif season to that of Rabi season to be irrigated is called kharif-Rabi ratio.

Paleo irrigation.

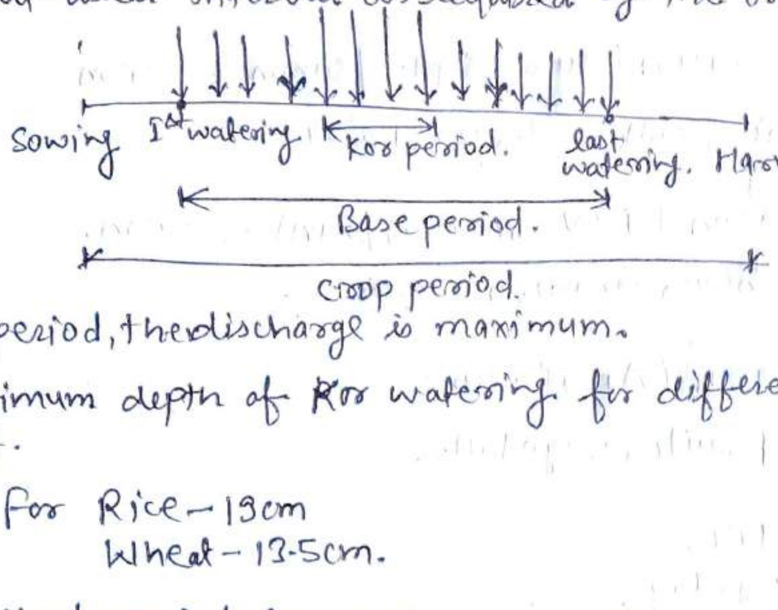
In Initial stages before the crop is sown the field is very dry which is generally found at the time of sowing of Rabi (Due to / as of sepetember month soil is may be too dry to be sown easily).

In such case soil is moistured with water so as to help in the sowing of the crop it is known as paleo irrigation.

Kor watering.

The first watering which is given to a crop, when the crop is few cm high is called kor watering.

It is usually maximum single watering followed by other watering at usual interval as required by the crops.



→ In kor period, the discharge is maximum.

→ The optimum depth of Kor watering for different crop are different.

eg. For Rice – 19cm
Wheat – 13.5cm.

→ The limited period for which kor watering it is done it is known as kor period.

If the kor watering is not recieved by the plant at desired time period the plant suffers significant loss.

For Rice – 2-4 weeks.
Wheat – 3-8 weeks.

Methods for Improving the duty of water.

① Alkaline soil should be properly leached.
② use of improved method of irrigation.
③ Land to be used must be levelled as far as possible.
④ Field should be properly ploughed before application of water.
⑤ Adoption of Rotation of crops.
⑥ The source of irrigation water must be selected within the prescribed limit.
⑦ Highly efficient method of ~~applicatation~~ application of water must be adopted (Drip irrigation, sprinkler irrigation).
⑧ By lining of canal.
⑨ Free flooding must be avoided.

Agricultural or cropping season in India.

① Kharif season (June – sept) / summer season
Rice, cotton, Jowar, Bajra.

② Rabi season (Nov – march) / winter season.
wheat, Gram, oil seeds.

③ Zaid season (April – June)
fruits, vegetables.

④ PERENNIAL
B ≥ 300 days.
Sugar cane.

When crop required water for its cropseason and also for sometimes in the begining of the next crop season provision has to be made. For this additional water / overlap it is known as overlap Allowable.

Cash crops.

A crop which has to be encashed in the market for processing ~~as~~ it cannot be consumed directly by the cultivator is termed as cash crops.

eg. Tea, cotton, Jute, sugarcane --- etc

~~All the non foo~~

Crop Rotation.

When the same crop is grown again & again over the period of time in same time, the fertility of land gets reduced as soil becomes deficient ~~typ~~ in specific type of Nutrients or, have accumulate excess of different type of Nutrients.

In order to enhance the fertility of soil and to make the soil regain its original structure it is necessary to either allow the land to lie idle/Fallow or, grow some other type of crop which complement the ~~priv~~ previous crop.

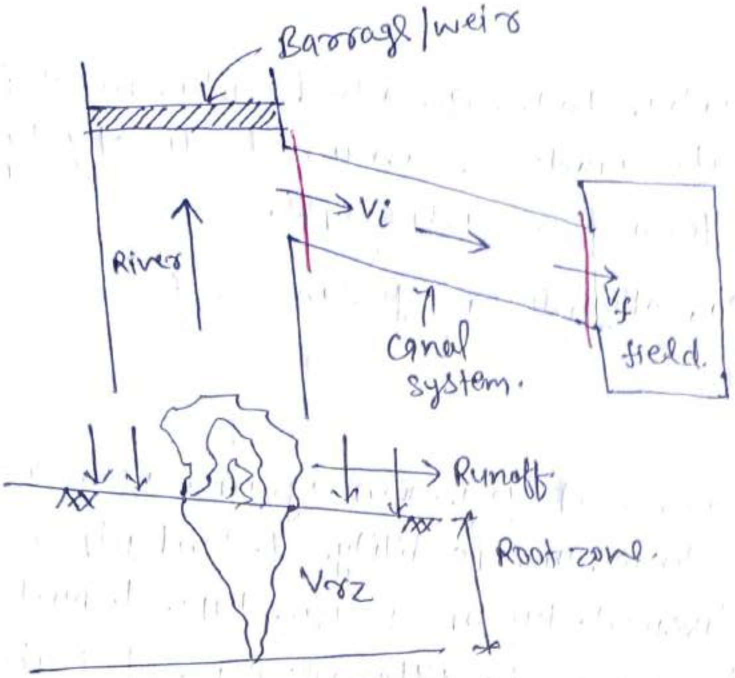
This method of growing different crops in Rotation one after the another in some field is termed as crop rotation.

Irrigation Efficiency.

Efficiency of any system depends on output & input of Parameter (water in our case) Involved.

Here it is the ratio of output water to the input water. This difference of output & Input water is termed as losses. Hence higher are the losses of water lesser is the efficiency.

$$\boxed{\eta \propto \frac{1}{\text{losses of water}}}$$



① Efficiency of water conveyance.

It is the ratio of water delivered into the field from the ~~outlet~~ outlet point to the water entering into the main channel at its starting point.

$$\eta_c = \frac{V_f}{V_i} \times 100$$

This efficiency takes into accounts conveyance losses.

② Efficiency of water applications.

It is the Ratio of quantity of water stored into the root zone of the crops to the quantity of water actually directed into the field.

$$\eta_a = \frac{V_{rz}}{V_f} \times 100$$

V_{rz} – Quantity of water stored in root zone.

The efficiency represents Runoff losses.

③ Efficiency of water storage.

It is the ratio of water stored in the root zone during irrigation to the water required in the root zone prior to the irrigation to reach at field capacity.

$$\eta_s = \frac{V_{rz}}{V_{frz}}$$

V_{rrz} = Quantity of water required in the root zone before irrigation.

It represents the extent of chocking of voids in root zone.

④ Efficieny of water use.

It is defined as the ratio of water beneficially use by the crop for its growth (including leaching water requirment) to the quantity of water delivered.

$$\eta_u = \frac{V_u}{V_f} \times 100$$

Vu — Volume of water beneficially used for crop growth.

⑤ Efficieny of water distribution / uniform coefficient.

The efficieny represents the extent to which the water has distributed / penetrated to a uniform depth throughout the field.

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

D = Mean depth of water stored during irrigation.

d = Average absolute value of deviation of depth of storage from mean.

Evapotranspiration / consumptive use (cu)

Consumptive use may be defined as amount of water used in the evapotranspiration from an area under vegetation plus the water used by the plant in their metabolic process for building up of new tissues.

Since quantity of water required by the plant for its metabolic activity is very less it is negleted and consumptive use (cu) is taken equal to evapotranspiration (ET).

Evapotranspiration is the total amout of water used by the plant in transpiration of the plant and evaporation from adjustant soil or any other water body.

→ The value of evapotranspiration / consumptive use may be different for different crops or, it may be different for some crop at different time and place.

→ The transpiration is defined as the process in which water leaves a living plant during photosynthesis through it's leaves to enter the atmosphere for its growth by the process of photosynthesis.

→ Since transpiration occurs during day light hours its 95% Extent is observed during photosynthesis.

→ On the other hand evaporation is continous throughout the day and night.

→ Transpiration losses not only depends on available sunlight but also depend upon the available moisture.

→ Different plant will have different amount of water and hence their water consuming property will be different thereby in order to standardise and it is reported in terms of Transpiration Ratio (T.R).

Transpiration Ratio (T.R) – Transpiration Ratio defined as mass of water transpired by plant to the mass of dry matter produced after its full growth.

$$T.R = \frac{\text{Total mass of water transpired by plant}}{\text{Mass of dry matter produced.}}$$

Transpiration Ratio, Wheat 300-600 (Avg - 450)
Rice - 600-800 (Avg - 700).

Transpiration in lab is generally measured using Phytometer. This is most widely used method when consist of a closed and watertight tank containg sufficient soil to nurish the plant.

Water is applied to it artificially over the growth Period of the plant and transpiration is measured as follow.

$$\boxed{T = M_1 + M - M_2.}$$

T = Transpiration.
M_1 = Initial mass of instrument.
M = Total mass of water added during its full growth.
M_2 = Final mass of the Instrument.

The result obtained from this method does not match with those of actual as exact field condition cannot stimulated. Moreover screened shelter are observed to give 10%. Lower Result.

Note :- When sufficient moisture freely available to completely meet the needs of plant for evaporation & transpiration is termed as potential Evapotranspiration.
However the actual amount of water use for this Purpose is termed as Actual evapotranspiration.

PET depend upon - climate factors.
AET depend upon - Type of soil & crop.

→ AET in field can be measured using device is termed as Lysimeter.

Effective Rainfall / usefull Rainfall (Re)

A portion of Rain falling over a croped area during growing period of the crop is utilised by the crop to fulfill its evapotranspiration requirement.

Thereby it reduces irrigation requirement of the crop. The portion of Rainfall that is effectively used for the growth of crop is termed as useful Rainfall (Re).

The value can be calculated by substracting from total Rainfall -

(a) Evaporation.
(b) Deep percolation.
(c) Runoff.

usefull Rainfall can be found empirically as follows.

(i) $Re = (0.8R - 25)$ mm, if $R > 75$ mm/month.
(ii) $Re = (0.6R - 10)$ mm. if $R < 75$ mm/month.

R = total Rainfall in mm/month.

if $R = 75$mm.
$Re = 0.8 \times 75 - 25 = 35$mm.
$Re = 0.6 \times 75 - 10 = 35$mm.

Consumptive Irrigation Requirement (CIR)

That portion of consumptive use which has to be satisfied through irrigation is called as CIR.

$$\boxed{CIR = Cu - Re}$$

Net irrigation Requirment (NIR)

That portion of Consumptive use which has to be satisfied by irrigation along with leaching requirement is termed as NIR.

NIR = CIR + leaching Requirement.

$$\boxed{NIR = Cu - Re + LR}$$

Field irrigation Requirement (FIR).

In addition to NIR field irrigation Requirement takes into account surface, runoff losses.

$$\boxed{FIR = NIR + \text{Run off losses}}$$

$$\eta_a = \frac{NIR}{FIR} \times 100.$$

Gross irrigation Requirement (GIR).

In addition to FIR, GIR also takes into account, conveyance or transit losses.

$$\boxed{GIR = FIR + \text{Transit losses}}$$

$$\eta_c = \frac{FIR}{GIR} \times 100.$$

Indirect Method to find consumptive use (Cu).

Consumptive use can also be find by empirically by following method.

1. Blaney - criddle equation.
2. Hargreaves class A pan equation.

1) Blaney criddle equation.

It state that monthly consumptive use is given by

$$\boxed{C_u = \frac{KP}{40}\left[1.8t + 32\right]}$$

Cu — Monthly consumptive use in cm.

K — crop factor which is found empirically & depends ~~de~~ upon condition of Particular area.

t — Mean monthly temp(°C)

If t is in °F then Cu is given by

$$\boxed{C_u = \frac{KPt}{40}}$$

P = monthly % of annual day light hours that occurs during that period.

Note :- The value of K for different crops of Indian sub-continent is not available hence it is not suitable to used here.

2) HARGREAVES CLASS 'A' PAN EVAPORATION.

In this method ET/Cu is related to pan evaporation by a constant termed as Consumptive use coefficient (K).

Evapotranspiration (ET/Cu) = K x Pan evaporation.

$$K = \frac{ET}{Ep}$$

Consumptive use coefficient (K) is different for different crops used and is diff. for same crop. at diff. place. It depends upon crop growth, location, type of soil, stage of growth of particular crop.

The value of this constant is available for diff. crop in Indian sub-continent, hence this method steadily used here.

Here pan evaporation Ep. can be experimentally determined by directly measuring the quantity of water evaporated from the standard class A Pan.

This pan is 1.2m in diameter and 25cm deep and its bottom is raised by 15cm above the ground level.

The depth of water in it is kept in the range of 5-7.5 cm below the depth.

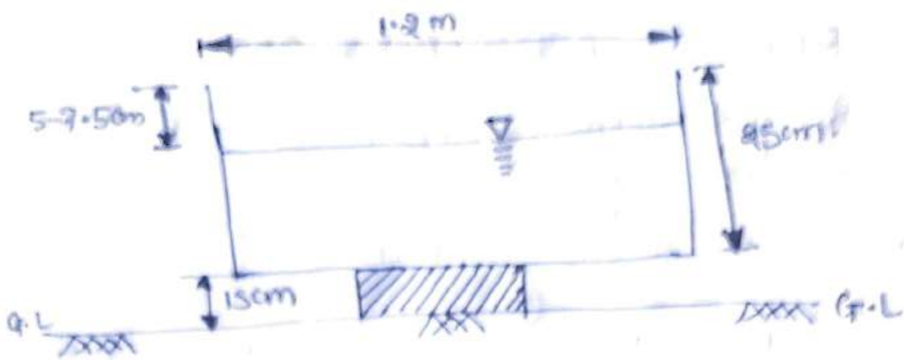


Fig. standard class A pan.

These value are on basic of obtaining precise Ep.

MODULE-02

CANAL IRRIGATION SYSTEM.

The entire Distribution system from the head of main canal to the agricultural field is divided into following.

i) Primary Distribution system
(main canal & Branch canal)

ii) secondary distribution system.
(Distributory and minor)

iii) Territiary Distribution system.
(water course and field channels)

The above integral management of conveying and distributing water is called warabande system.

wara + bande
turn   fixed

By following this wara bande system the turn of different farmers are fixed so that daily water is not supplied to a single farmers.

Classification of canals.

i) Alluvials and Non Alluvials Canals.

The canals when excavated through alluvial soil are called Alluvial canals.

canal in such area use the water from direct irrigation instead of storage irrigation as river in Alluvial soil have tendency to change its water course.

Note- The soil which are formed by contineous deposition of solids from running water through an area is termed as Alluvial soil.

Hard foundation | strata are generally not available in this case or, in this kind of soil.

Canal excavated through non-alluvial soil (ex-formed due to integration of Rocks in mountaineous region) are formed as non-alluvial canals.

These canal are part of storage irrigation as rivers in non-alluvial soil hardly changes their water course. Hard foundation are generally available in this case.

(ii) On the basis of Alignment of the canal.

ⓐ Watershed canal / Ridge canal.

→ The canal which is aligned along ~~the~~ any watershed or, ridge line is called watershed canal or, Ridge canal.

→ The natural limit of command area of such irrigation channel would be on either side of the canal.

→ Aligning a canal (main or, branch) along the ridge line ensures gravity irrigation on both sides of the canal.

→ Since drainage always flows away from ridge no drainage can cross a canal hence there is no requirment of cross drainage work for these canals.

→ If the watershed passing through villages or, town the canal may have to leave the watershed or, Ridge line for some distance.

→ The depression in the Ridge line may also required construction of ducts or, syphons to maintain canal full supply level.

(b) contour canal.

The water shad canal cannot be provided in case of hilly areas since the conditions in hilly are vastly different compared to plain where river flows in vally hence it is not, possible to align the canal along the ridge line.

In such condition contour canals are provided which are align at the contour except for giving the required longitudinal slope to the canal.

A contour canal can irrigate only one side because area of the other side is on higher level.

As the drainage flow is always at right angle to the contour such canals also meet drainage in between hence these canals also require cross drainage work.

since slope of River is much steeper than the canal bed slope the canal surrounds more and more area between itself and the river.

(c) side slope canal.

A canal which is aligned at right angle to the contour i.e. along the side slope is termed as side slope canal.

since natural drainage also flows at right angle contour it never meets this canal hence no cross-drainage is required in this case.

Time factor:

The case of water logging, salinity etc, canal are not allowed to operate all the days during any crop season.

The Ratio of actual operating time of a channel to the crop period is called Time factor.

Capacity factor:

The capacity factor for a canal is the Ratio of the mean supply discharge in a canal during a period to its designed full capacity discharge.

$$C_V = \frac{\text{Mean discharge.}}{\text{Design Discharge.}}$$

Since canal have to run almost to their full design capacity during kharif season C_V is approx. 0.9 to 0.95.

However since water requirment reduce in Rabi season, C_V reduces to about 0.6 – 0.7.

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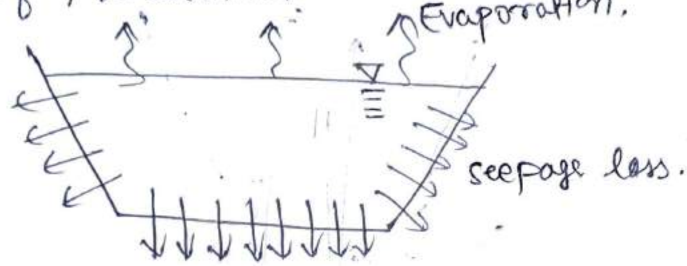
Since canal have to run almost to their full design capacity during kharif season CV is approx. 0.9 to 0.95.

However since water requirement reduce in Rabi season CV reduces to about 0.6 – 0.7.

LOSSES OF WATERS IN CANALS.

During the flow of water from main canal to outlet at the head of water course, water is lost either by evaporation from the surface or, by seepage through peripheries of the channel.



These losses may extend up to order of 20–25% of water diverted into the main canal.

1) Evaporation loss.

→ The water lost by evaporation is generally very small as compared to water lost by seepage.

→ It is in order of 2-3% of total losses.

→ It depends upon temperature, wind velocity & Humidity at a particular location.

→ Evaporation lose comes out be comparitively more in summer.

ii) seepage loss.

These losses are further of 2 types.

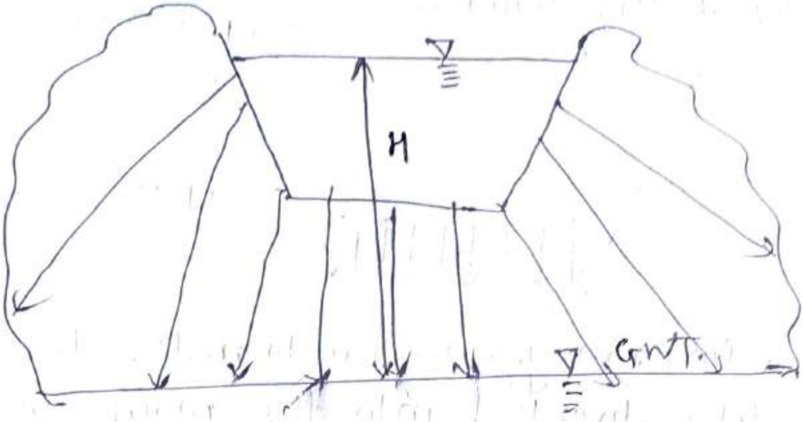
(a) Percolation (b) Absorption.

- (a) Percolation.

→ In percolation there exist a zone of contineous saturation from canal to the water table and a direct flow established.

Almost all the water lost from the canal to joins the Ground water table (GWT).

The loss of water depends upon the difference of the top of water surface level of the canal and the level of the water table.



Percolation.

Absorption.

In absorption all saturated zone exist round the canal section and is surrounded by a zone of decreasing saturation.

Above water table their also exist zone of capillary saturation.

In this case rate of flow depends upon the head of water in canal and ~~capal~~ capillarity head.

Factors Affecting seepage losses.

(1) Type of seepage.

If percolation, losses are more.

If Absorption, losses are less.

② Type of soil.

If soil is permeable losses will be more (as loss would be due to percolation).

If soil is porous losses will be less. (as loss would be due to absorption.)

③ condition of canal.

If canal is new it is unsilted and all the voids of soil are open hence seepage losses are ~~observed~~ observed be more the old silted canal whose voids are closed.

④ Amount of silt carried by canal.

The more the silt, more the choking of the voids lesser are the losses.

⑤ velocity of water in canal.

More the velocity of water lesser is the time available for seepage hence lesser are the losses.

⑥ section of canal.

More the wetted perimeter more are the seepage losses.

Note- The Channel losses can be computed empirically as follows.

$$\Delta Q = \frac{1}{200}(B+y)^{2/3}$$

ΔQ = Channel losses in cumec per km length of channel.

B = width of channel (m) [Bed measure]

y = depth of flow (m)

Design of canals.

The area bounded by Indo-gangetic plain used to be in form of depressions with water flowing over it.

With the passage of time it was filled with loosely carried silt particle there by forming Alluvial soil.

Almost all the rivers in Northern India flows through such soil hence carries certain amount of sediments.

Since Artificial canal have to ~~tendency~~ carry water from these rivers have the tendency of get silted and scoured.

Hence designing of such canal is to be done which neither silts nor scours these type of canal / channels are known as stable / Regime channel.

Regime channels.

A channel is said to be in a state of Regime if the flow is such that silting and scouring is not take place.

Such a state cannot be attained practically in natural channel. ex- Rivers, but can be attained in artificial channel if designed properly.

Principle of designing such a channel is that whatever silt has entered the channel at its head is kept in suspension only so that it does not settle and the velocity of the water should be such it does not carry out scouring of the channel. (Bed & slopes).

Designing of the channel can be done by any of following methods.

1. Kennedy's theory.
2. Lacay's theory.

KENNEDY'S THEORY.

On the basis of observation he concluded that the silt supporting power in a channel cross-section mainly depends upon generation of eddies obserbed of the channel, ~~the~~ rising to the surface.

These eddies are generated due to the friction of the flowing water with horizontal. (distribution of which is non-uniform across the section).

The vertical component of these eddies try to kept the sediments in suspension while the weight of sediment tries to being it down.

So, if the velocity is sufficient to generate the eddies so as to keep these solids in suspension, silting will be avoided.

The velocity at which this state occur is termed as critical velocity.

According to kennedy this velocity is given by,

$$\boxed{V_0 = C_1 y^{C_2}}$$

$C_1, C_2 \rightarrow$ constant, depends on type of silt.

Acc to kennedy,

$C_1 = 0.55,\ C_2 = 0.65$

Note.

Since the above expression is valid only for upper bari Doab region, in order to make this theory applicable to other region also Kennedy's theory introduced a constant termed as critical velocity ratio (CVR), denoted by m, which depends upon silt grade and type of silt.

Now, critical velocity is given by

$$V_0 = 0.55\, m y^{0.64}$$

For, coarse sand, m = 1-1.2

fine sand, m = 1-0.7

Type of silt	m.
Silt of indus (River)	0.7
Light sandy silt	1.0
coarse sand silt	1.1
Sandy, Lomy silt	1.2
Hard soil	1.3

Design steps in Kennedy theory.

Step 1. From the given value of discharge by assuming a suitable trial depth compute the critical velocity of flow.

$$V_0 = m c_1 y^{c_2}$$

Q (m³/sec)	0-20	20-40	40-80	80-100	>100
Trial depth (y)	1.0	2.0	2.5	3.0	3.5

Step2. Calculate c/s area of canal.

$$A = \frac{Q}{V_0}$$

Step3. By assuming a trapeziodal section and side slope of $\frac{1}{2}H:1V$. calculate the dimensions of the canal.

Step4. calculate Hydraulic radius.

$$R = A/P$$

Step5. calculate Actual mean velocity of flow by using chezy's equation.

$$V = C\sqrt{RS}$$, C = chezy's constant.

$$C = \frac{\frac{1}{N} + \left[23 + \frac{0.00155}{S}\right]}{1 + \left[23 + \frac{0.00155}{S}\right] \times \frac{N}{\sqrt{R}}}$$ → kutter's equation

N = manning's constant

S = canal Bed slope.

Step6. If the above velocity is same as critical velocity then the design is correct or, else the above steps are repeated by assuming other trial depth.

Note :- If Bed slope S is not given then it can be assumed between $\frac{1}{3500}$ to $\frac{1}{5000}$.

of Roughness constant is not given it can be assumed as,

Type of surfaces.	mannings / kutter's Rugosity coeff.
Poorly maintained earthen channel	0.025 – 0.030
Good earthen channel	0.022 – 0.025
concrete lined channel	0.015 – 0.018

Note:- In this method, there is lot of calculation is involved in kennedy's theory. A graphical solution was proposed by Garret.

Limitions of kennedy's theory.

→ kennedy's observe that eddies current are developed by from the canal bed, wheare as in actual they are also develops from side..

→ He did not proposed any mathematical equation to calculate canal bed slope.

→ He did not proposed any equation to calculate mean velocity of flow instead used chezy's equation, therefor all the limitition of chezy's thery are also included in this theory.

→ He did not proposed any relation to calculate critical velocity ratio and randomly related with silt grade. (Type of silt and size of silt).

LACEY'S THEORY.

It was stated by kennedy that a channel is said to be in state of Regime if there is neither silting nor scouring in the channel.

Opposite to this Lacey's proposed that even a channel showing no silting & no scouring may actually not be in regime hence the differentiated between following regime condition.

① True regime
② Initial regime
③ Final regime.

① True Regime

A channel is said to be in regime if there is neither silting nor scouring.

For this condition to be satisfied the silt entering into channel must remain in suspension and carried through the channel.

There can be only one channel section and one bed slope at which a channel carrying a given discharge and a particular quantum and type of silt, would be in regime.

following condition for the True regime.

① Discharge is constant.
② Flow is uniform.
③ silt charge is constant (constant amount of silt)
④ silt grade is constant (The type and size of silt is always same)

If the above condition satisfy then channel said to be True regime, But in pratice all these condition can never be satisfied.

so Artificial channel can never be in true regime. They can either be in initial regime or, final regime.

② Initial regime.

→ It is the first stage of regime attained by a channel after it is in service.

→ Bed slope of the channel is increased due to deposition of silt on the bed of the channel to develope an increased flow velocity. Hence the given discharge is allowed to be through the cannel.

→ with increase in the bed slope, the depth may also vary but the width of the channel does not change because the side of channel are usually cohesive and hence they resist erosion.

Therefore keeping the discharge, silt grade, silt charge, and width fixed and only be varying bed slope and depth, the channel attains stability. This condition is known as initial regime.

③ Final regime.

→ It is the ultimate state of regime attained by a channel when in addition to bed slope and depth, the width of the channel is also adjusted as per requirement.

→ In this condition, the resistance of the sides of the channel is ultimately over come due to contineous action of water.

→ So, the channel adjust its width, depth and bed slope in order to obtain a stable channel. This condition is known as final regime.

Lining of canal.

By lining the canal signifies that the earth surface of the channel is lined with a stable lining surface such as concrete, tiles, asphalt, Bricks etc.

Depending upon the type of lining adopted the seepage losses can be reduced upto 2-3% of their original values.

Apart from reduction in seepage losses, it also offers other advantage as follows —

(i) seepage losses — Depending upon type of lining used a particular extent of seepage control is achieved.

Type of lining.	Initial Rate of seepage cumec/ million sqm of Area	Final Rate of seepage cumec/ million sq. km of Area.
unlined channels	7·5	3·5
cement mortar	0·17	0·009
cement mortar with Brick Ballast.	0·13	0·007
cement lime concrete.	0·4	0·13

(ii) Prevention of water logging — uncontrolled seepage often raises the water table level surrounding the fields upto or, near the ground level there by causing water logging, lining of canal since it prevents seepage avoids it.

(iii) Increase in Discharge capacity.

The capacity of canal depends on Roughness of the channel. ($Q \alpha \frac{1}{N}$)

By lining the canal Roughness is reduced that in turn increases the discharge carrying capacity of the canal.

Type of lining	N
cast in situ concrete lining.	0.01–0.018
cement plastered Masonary.	0.012–0.015
PCC Tiles.	0.018-0.020
Brick lining.	0.018-0.020
~~Bto~~ Boulder lining	0.020–0.025

(IV) Increase in command Area.

A lined canal can be designed to carry same at reduced area, there by it increases culturable command Area.

(V) Elimination of flood.

An unlined canal founded on weaker foundation have alway to tendency to fail and causing the flooding of nearby field.

Lining of these canals avoids it flooding.

(vi) Maintance cost is reduced.

Lining of canal reduce the maintence cost incured for.–

(a) periodic removal of silt from bed & sides of canal.

(b) minor Repairs (cracks, cuts ... etc)

(c) Removal of weeds and water plant.

Financial Justification of lining

Mathematical expenditure on lining is justified if the resultant annual benefit exceeds annual costs – i.e. Benefit cost Ratio is more than 1.

financial Justification of lining canal can be computed as follows

(i) Annual Benefits.

Irrigation water is sold to the cultivator that generates revenue.

Let Rate of irrigation water be 'R_1' Rs. per cumec.

If x cumec of water saved by lining then additional revenue generated would be 'xR_1' Rs.

Let 'R_2' Rs. be the maintance cost of the unlined canal.

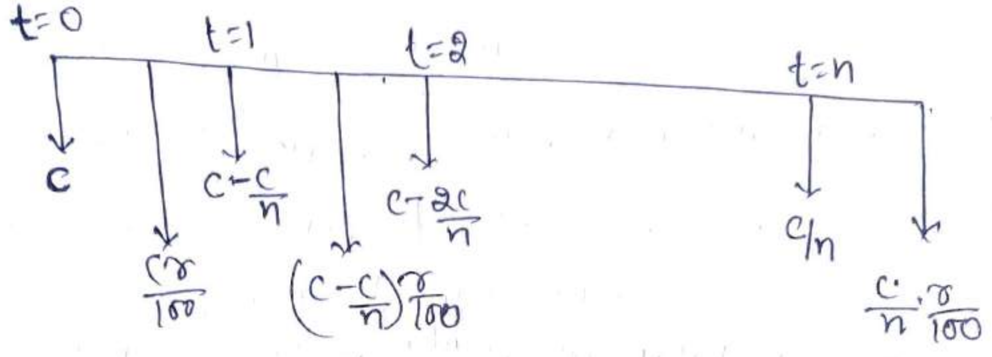
on lining maintence cost is saved by y%.

$$\text{Total Annual Benfit} = xR_1 + yR_2$$

(ii) Annual cost.

If the capital expenditure on lining be 'C' Rs. and lining has life 'n' years, then annual depriciation cost would be C/n Rs./year.

If r% be the rate of simple interest, then interest lost on an Average per year would be.



Average Annual Interest lost $= \dfrac{\frac{Cr}{100} + \frac{C}{n}\cdot\frac{r}{100}}{2}$

$= \frac{Cr}{100}(1+1/n) \times \frac{1}{2}$

Since n is comparitively large $1+\frac{1}{n} \simeq 1$

∴ Hence Average Annual interest cost $= \frac{Cr}{2\times 100}$

Total Annual cost $= \frac{C}{n} + \frac{Cr}{2\times 100}$

$$\text{Benefit cost Ratio} = \frac{xR_1 + yR_2}{\frac{C}{n} + \frac{Cr}{2\times 100}}$$

Note – There are certain benefits of lining of canal which cannot be represented in terms of monetary value i.e. Reduced risk of breaching, Reduced break out of water borne disease ... etc.

Assumptions.

1. make the calculation for 1 km/length of canal and find the cost and the benefit for 1 year.
2. Interest Rate is taken between 5-8%.
3. Percentage saving in maintenance cost is approximately 40%.
4. Life of canal after lining is 40–60 year.
5. Seepage loss from unlined canal is 30 – 35% and from that of lined canal it may be 1-2%.

Design of lined Channels.

Irrigation canal should be aligned and laid out so that the velocity of flow is uniform under all condition and so that the water reaches the irrigated Area at an elevation sufficient to ensure even distribution of water.

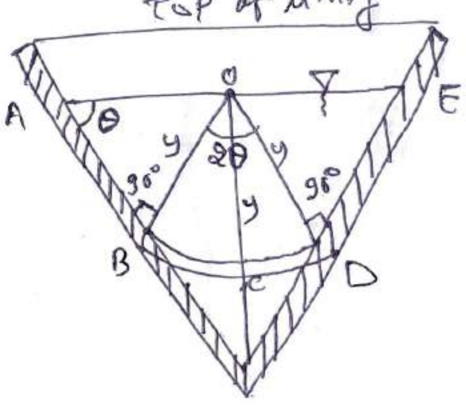
Generally 2 Type of channel sections are adopted.

i) Triangular channel (for low discharge) < 55 cumec

ii) Trapeziodal channel (for high discharge) > 55 cumec.

1) Triangular channel (Q < 55 cumec).

In order to increase the discharge carrying capacity ($Q \propto R$) hydraulic mean depth of flow is increased by reducing the perimeter for given area, that is achieved by rounding of the channel bottom & corners.



$\tan\theta = y/AB$

$AB = \frac{y}{\tan\theta} = y\cot\theta$

Area of flow A = Area of ABCDEO

$= \text{Area of AOB} + \text{Area of BCDO} + \text{Area of ODE}$

$= \frac{1}{2} y \cot\theta \times y + \frac{\pi y^2}{2\pi} \times 2\theta + \frac{1}{2} \times y \cot\theta \times y$

$= y^2 \cot\theta + y^2\theta$

$A = y^2(\theta + \cot\theta).$

Perimeter of flow = length of ABCDE
= AB length + length BCD + length of DE
$= y\cot\theta + \frac{2\pi y}{2\pi} \times 2\theta + y\cot\theta$

$$\boxed{P = 2y\cot\theta + 2y\theta}$$

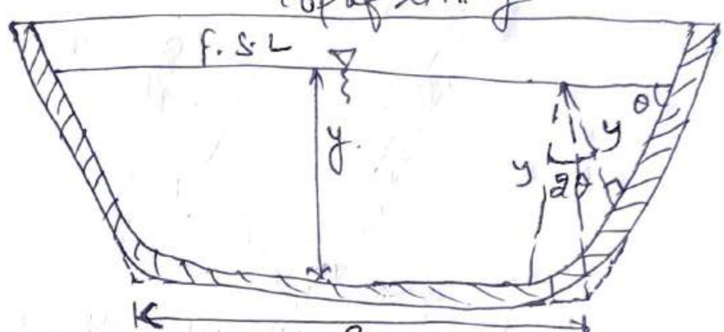
Hydraulic mean depth of flow $R = A/P$.

$$R = \frac{y^2(\theta + \cot\theta)}{2y(\cot\theta + \theta)}$$

$$\boxed{R = y/2}$$

Where, y = Radius.

2) Trapezoidal section.



$A = B \times y + 2y^2\theta + 2y^2\cot\theta \times 1/2$

$A = y[B + y\cot\theta + y\theta]$

$P = 2y\cot\theta + \frac{2\pi y}{2\pi} \times \theta \times 2 + B$

$= 2y\cot\theta + 2y\theta + B$

$$\boxed{R = A/P = \frac{y(B + y\cot\theta + y\theta)}{B + 2y\theta + 2y\cot\theta}}$$

In order to limit the scouring of the material used for lining maximum velocity is limited in channel as per the type of material of lining.

Type of lining	permissible velocity (m/sec).
cement concrete lining	2-2.5
Burnt clay/ Tile lining	1.8
Boulder lining	1.5

In order to prevent the overflow from channel during excess flow additional space is being provided (free board) at the top which depends upon discharge to be carried by the channel.

Type of canal.	Discharge (m^3/sec)	FB(m).
Main and Branch	Q > 10	0.75
Branch	5 < Q < 10	0.6
Distributories	1 < Q < 5	0.5
Minors	Q < 1	0.3
water course	Q < 0.06	0.1-0.15

Type of lining.

Various type of canal lining which are commenly used are as follows.

① Hard surface lining.

ⓐ ~~concre~~ cement conrete lining.

ⓑ Shortcrete.

ⓒ Tile of cement concrete.

ⓓ Brick

ⓔ Asphaltic

ⓕ Boulders.

② Earthy type lining.

④ compaction earth.

⑤ soil cement.

ⓐ cement concrete lining.

→ It offers longer life.

→ less permeable.

→ More Resistant to erosion.

→ It permitts fast construction.

→ Maintenance cost is less.

→ High initial cost.

→ High tendency of development of cracks.

→ It requires skilled supervision.

ⓑ shortcrete.

→ It is suitable to be used in smaller jobs.

→ It is also used for repair works.

→ It is very helpful in case canal has irregular c/s.

ⓒ Brick lining / cement concrete tiles.

→ It does not required any skilled supervision.

→ No. expansion joints required.

→ Even if section is not of regular geometry.

→ large no. of labour is required.

(d) Asphalt.

→ It is high flexible.
→ It does not decreases Roughness coefficient.
→ It also permits growth of weed.

(e) Boulder lining.

→ It is also termed as dry stone lining / stone pitching.
→ The biggest advantage of such lining is it is pervious lining allowing free flow of water from through it hence has no concerned regarding uplift Pressure.
→ It is generally provided to impart stability to the channel.

(f) Compaction Earth.

When cost is limited locally available soil compacted to wet of omc can also be used as lining.

(g) Soil cement.

When more strength & less permeability is required soil can also be cement slurry mixed with soil can also be used as lining material.

Properties Required in lining.

→ Impermeability.
→ Hydraulic efficiency.
→ Economic
→ Resistant to Erosion.
→ Structural Stability.
→ Durability.

SEDIMENT TRANSPORT MECHANISM.

→ When water flows in channel it is carries out scouring of the surface due to which these particle are swept down stream by the moving water. It is termed as sediment transport.

→ The sediment in canal is a burden to carried by the flowing water and is therefore termed as sediment load.

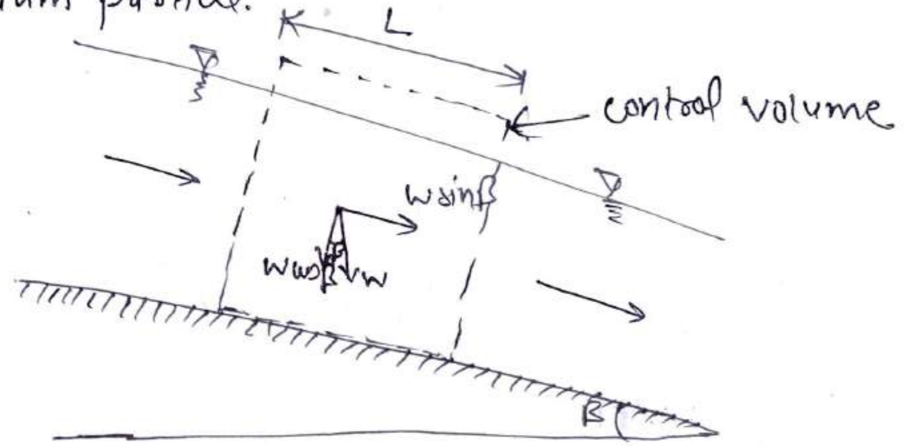
→ The sediment may move in water either as load or, suspended load.

→ Assumption in Mechanism of sediment transport as per shield theory.

ⓐ soil is incoherent.

ⓑ sediment load is uniform.

ⓒ The basic mechanism of sediment transport is the weight of water enerting a shear force / Drag force / tractive force on the medium particle.



shear force acting on soil particle $= w\sin\beta$

when β is small $\beta \simeq \sin\beta \simeq \tan\beta$

$\therefore \; f = w\tan\beta$

$\tan\beta =$ slope of channel Bed $= S$

$f = wS = \forall_w \cdot \gamma_w \cdot S$

$f = A \cdot L \cdot \gamma_w \cdot S$

$\text{Shear stress} = \frac{f}{\text{Area}} = \frac{AL \cdot \gamma_w \cdot S}{PL} = R \cdot \gamma_w \cdot S$

$\boxed{\therefore \; \tau = R \cdot \gamma_w \cdot S}$

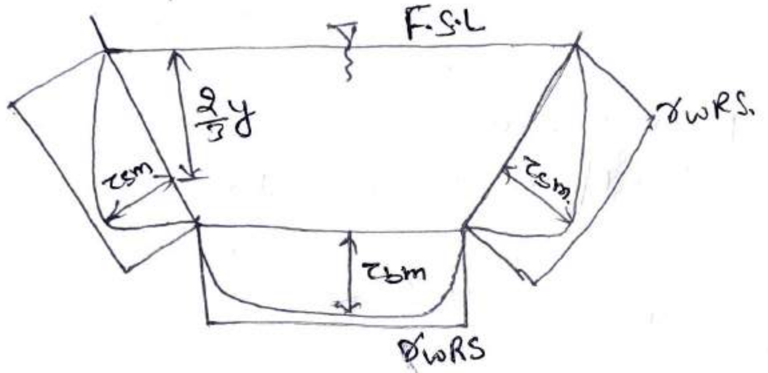
→ The above expression represents avg. shear/friction/Tractive.

→ The maximum stress induced by any flow occurs at the Point of greatest depth or, at the centre of any channel. (horizontal bed)

$$\boxed{\tau_{max} = \gamma_w \cdot y \cdot S}$$

y = Greatest water depth in channel.

Actual shear stress Distribution in the channel is observed as.—



$\tau_{sm} = 0.75 \gamma_w RS$

$\tau_{bm} = 0.97 \gamma_w RS$

To prevent scouring canal bed soil particles.

(Shear stress)$_{\text{canal bed soil particles}}$ ≤ (Shear strength)$_{\text{canal bed soil particles}}$.

$$0.97 \gamma_w RS \leq 0.056 \gamma_w d (G-1)$$

$$0.97 RS \leq 0.056 d (G-1)$$

Assume,

$G = 2.65$

$$0.97 RS \leq 0.056 d (2.65 - 1)$$

$$d \geq 10.49 RS$$

$$\boxed{d \geq 11 RS}$$

To prevent scouring of side slope.

(shear stress)$_{\text{canal side slope Particle}}$ ≤ (shear strength)$_{\text{canal side slope Particl}}$

$$0.75\gamma_w RS \leq 0.056\gamma_w d(G-1)\cdot\sqrt{1-\frac{\sin^2\theta}{\sin^2\phi}}$$

ϕ – Angle of internal friction of soil particles.

θ – Side slope.

Assume, $G = 2.65$.

$$0.75\gamma_w RS \leq 0.0924\gamma_w d\sqrt{1-\frac{\sin^2\theta}{\sin^2\phi}}$$

$$\boxed{0.75RS \leq \frac{d}{11}\sqrt{1-\frac{\sin^2\theta}{\sin^2\phi}}}$$

Note – For Rigid sections i.e lined canals and non-alluvial canal ~~mean~~ manning's constant can also be computed empirically using strickler's equations.

$$\boxed{n = \frac{d^{1/6}}{24}}$$ d(m) = Avg. size of Particles.