Module - 5

Canals and Reservoirs

Canals

Canal :-

A Canal is an artificial channel, constructed on the ground to carry a water from reservoir (or) dams to the field (cropfield). Generally it is trapezoidal in shape.

If the full supply level (FSL) of a canal is below the natural Ground surface, an open cut (or) Excavation is necessary to construct a canal.

If the full supply level (FSL) of a canal is above the natural (or) Existing Ground surface, filling of Earthen banks on both sides is necessary to construct a canal.

Classification of canals

Irrigation Canals can be classified in different ways.

① Classification Based on lining :-

ⓐ lined canal

ⓑ unlined Canal

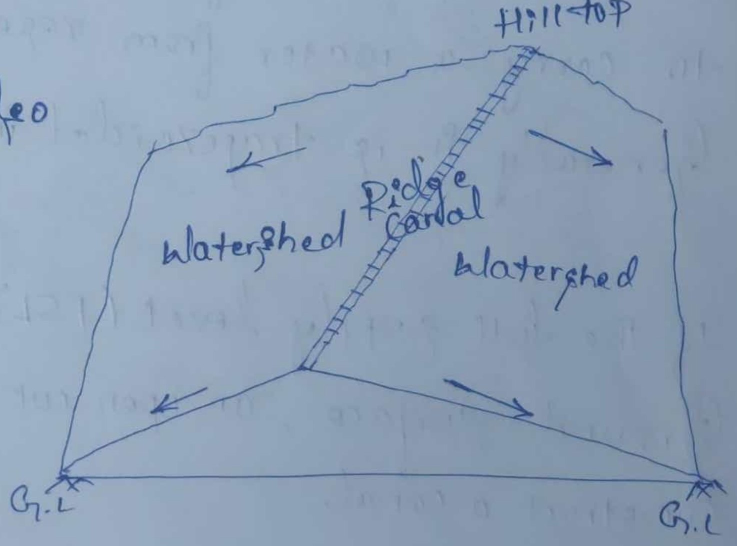
ⓐ **lined Canal** :- A lining is made up of brick masonry (or) stone masonry (or) RCC (or) Cement Concrete. it is an impermeable layer provided to bed and sides of canal to reduce seepage loss. It is also called Earthen type Canal.

(b) Unlined Canal :- This type of canal made up of natural soil. It means impervious layer (or) concrete layer is not provided. In this canal, velocity of flow kept low such that bed and sides of canal are not scoured.

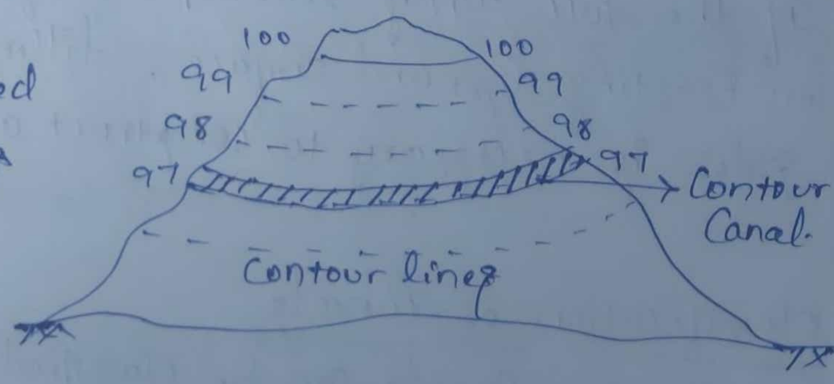
(2) Classification based on Alignment :-

(a) Ridge canal (b) Contour canal (c) side slope canal.

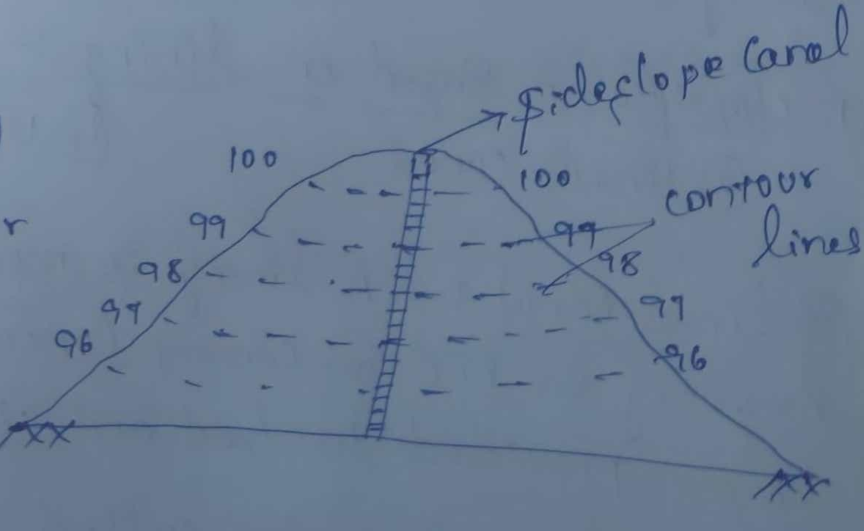
(a) Ridge Canal :- Ridge canal is also as Watershed canal. If canal is constructed along the Ridge line is called Ridge canal.



(b) Contour Canal :- This type of canal is constructed parallel to the contour lines is called contour canal.



(c) Side slope Canal :- If the canal is constructed perpendicular to the contour lines is called side slope canal.



(3) classification based on discharge :-

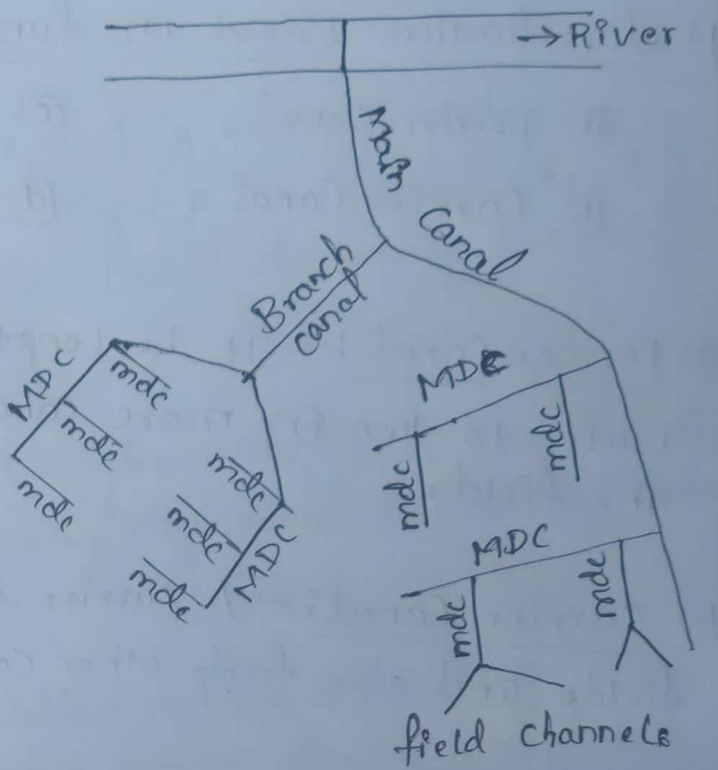
ⓐ Main Canal.

ⓑ Branch Canal.

ⓒ Major Distributory canal. (MDC)

ⓓ Minor Distributory Canal. (mdc)

ⓔ Field channel.



(a) Main canal :-

Main Canal is the principal canal. It directly takes off from a river. or reservoir. It has large Capacity and water supplied to Branch canals and also to distributaries.

(b) Branch canal :-

It takes off from either side of a main canal. It has discharge capacity of 5 cumec. These canals are used to supply a water to ~~disp~~ major distributory canals (MDC).

(c) Major Distributory Canal (MDC) :- It takes off from Branch canal or Main Canal. It has discharge Capacity of 0.25 to 5 cumec These canals are used to supply a water to minor distributory canal (mdc).

(d) Minor Distributory Canal (mdc) :- It takes off from Branch or Major distributory Canal. It has discharge Capacity less than 0.25 cumec. These canals supply a water to field channels.

(e) field channel :- These are constructed by cultivators/farmers. It takeoff from major (or) minor distributory (or) Branch canal also. It supplies a water to crop fields. 4

(4) classification Based on function :-

ⓐ Feeder canal
ⓑ Carrier Canal
ⓒ Navigation Canal.
ⓓ Power Canal.

(a) Feeder Canal :- It is constructed for the purpose of supplying water to two (or) more canals only, but not directly irrigating the fields.

(b) Carrier Canal :- A carrier canal carries a water for irrigating fields and also feeds other canals for their needs.

ⓒ Navigation Canals :- A canal is constructed for inland navigation is called Navigation canal.

ⓓ power canal :- A canal is constructed for Hydro-Electric power Generation purpose.

(5) classification Based on financial output :-

ⓐ productive Canal ⓑ protective Canal.

ⓐ productive Canal :- It is fully developed to earn Enough revenue for its running & maintainance. It is Essential that cost of its initial investment is recovered within 16yrs of construction.

ⓑ Protective canal :- It is constructed during drought to provide relief and Employement to the people. The revenue from such a Canal may not be sufficient for its maintenance.

⑥ Based on classification of nature of supply :-

ⓐ Permanent canal → (i) Perennial Canal. → (ii) Non-perennial canal.

ⓑ Inundation Canal.

(a) Permanent Canal :- A permanent canal is one which draws water from permanent source of supply. A permanent canal may also perennial (or) Non-perennial canal depending source of supply.

Perennial canals provide water throughout the year. but inundation canal receives the water during high flood, So ~~...~~ Inundation canal is also called as flood canal.

(b) Inundation Canal :- It is also called as flood canal. It takes -off from large rivers, and receives a water during high flood. without constructing any barrages.

(7) Based on classification of soils :-

ⓐ Alluvial Canal ⓑ Non- Alluvial Canal.

ⓐ Alluvial Canal :- A canal is constructed in alluvial soils is called alluvial canal. A Alluvial canals are found in Indo-gangetic plains.

ⓑ Non-alluvial Canal :- A canal is constructed in hard soils (or) disintegrated rocks is called Non-alluvial Canal. A Non-alluvial canals are found in Central and south india.

→ Alignment of Canals :-

For aligning a irrigation Canal, following points must be - - considered.

* An irrigation canal should be aligned in such a way that Max area is irrigated with least length of canal.
* An irrigation Canal should be aligned in such a way that sharp curves must be avoided
* A canal should be aligned in such a way that cross drainage works should be avoided, such that cost is reduced.
* A canal should be aligned such that heavy cutting (or) heavy filling are avoided.
* A Canal should be aligned such that idle length of the Canal is minimum.
* A canal should be aligned such that villages, roads, places of worship are avoided.
* A canal shouldn't be aligned in rocky and cracked strata.
* A Canal should be made to run as a contour canal, when it is not possible to construct ridge Canal, in hilly areas.

Definition of important terms:-

① Gross Command Area (GCA) :- The whole Enclosed b/w an imaginary boundary line which can be included an irrigation project for supplying water to agricultural land by the network of command is known as Gross Command Area

Gross Command Area includes Cultivated area & uncultivated area.

(a) Uncultivated Area :- The Area where agriculture can't be done and crops can't be grown, due to lack of irrigation system is known as uncultivated area

eg:- The Marshy land, lakes, ponds, forest are considered as uncultivated Area

(b) Cultivated Area :- The Area where agriculture can be done satisfactorily is known as Cultivated Area

② Culturable Command Area (CCA) :- The total area within an irrigation project. where the cultivation can be done & crops can be grown is known as Culturable Command Area

Culturable Command Area includes
(i) Culturable Cultivated Area
(ii) Culturable uncultivated Area

(i) Culturable Cultivated Area :- It is the area within CCA where the cultivation has been actually done.

(ii) Culturable Uncultivated Area :- It is the area within CCA where the cultivation is possible But it is not being cultivated due to some reasons.

③ Intensity of Irrigation (IOI) :- The total culturable command area mayn't be cultivated @ the same time in a year due to various reasons. some area may remain vacant every year. so the intensity of irrigation may be it is the ratio of cultivated area for a particular crop to the total culturable command area.

i.e Intensity of Irrigation = $\frac{\text{Cultivated area (for particular crop)}}{\text{Total culturable Command Area}}$

It is expressed in % of CCA

for eg:- If total CCA is 1000 Hectares where wheat is cultivated in 250 Hectares then intensity of irrigation for wheat

$$IOI)_{wheat} = \frac{250}{1000} = 25\%$$

so the area to be irrigated = CCA × IOI

= 1000 × 25

= 250 Hectares

④ Crop Ratio :- It is defined as ratio of the areas of two main crop seasons.

for Eg:- If the area under Kharif crop is 2500 Hectares

" Rabi crop is 5000 Hectares

The crop ratio of Kharif to rabi is 1 : 2 (9)

The crop ratio should be so selected that the discharge of canal for supplying water to Kharif & rabi may be nearly equal.

(5) Cash crops :- The crops which are cultivated by farmers to sell in market and to meet their current financial requirement is known as cash crops.

Eg:- vegetable, fruits, & tobacco etc

(6) Crop rotation :- The process of changing the type of crop for the cultivation on the same land is known as crop rotation. It is found that if the same crop is cultivated on the same land every year, the fertility of the land gets reduced & yield of crops also gradually reduces. This is because of the ~~reason~~ reason that necessary salts require for the growth of particular crop get exhausted. It is found by a experiment that if the principle of crop rotation is practice the fertility of soil can be restored. A few crop rotation possible are

(a) rice : gram : wheat

(b) wheat : millets : grams

(7) Crop period :- The crop period is defined as the total period from the time of sown to the time of harvesting ~~that~~ means ~~it is~~ the ~~period~~ in ~~which~~ ~~crops remains in~~ ~~the~~

(3) Time factor:- The ratio of no of days the canal as actually kept open to the no of days the canal was designed to remain open during the Base period is known as Time factor.

for Eg:- A canal was designed to kept open for 15days but it was practically open for 10days for supplying water to the culturable area.

Then, Time factor $= \frac{10}{15}$

$= 1 : 1.5$

(4) capacity factor:- Generally the canal is designed for Maximum discharge but actually it is not require that the canal runs to the Maximum capacity all the time of base period. so the ratio of the actual discharge to the Max discharge (Design discharge) is known as capacity factor.

i.e capacity factor $= \frac{\text{Actual Discharge}}{\text{Maximum Discharge}}$

for Eg:- A canal is designed for Max discharge of 50 cumec But they actually discharge $40 m^3/sec$ then the capacity factor is,

Capacity factor $= \frac{40}{50} = 0.8$

(10) <u>No of Watering</u> :- The total depth of water required by a crop is supplied @ a time but it is supplied over Base period depending upon the requirement. The initial watering which is done on the land to provide moisture to the soil just before sowing the crop is known as <u>paleo</u>. The 1st water is done when the crop as grown to about 3cm this watering is known Kor watering & period is known as Kor period.

(11) <u>Cumec day</u> :- The quantity of water flowing continously for one day @ the rate of 1 cumec is known as cumec day

$$1 \text{ cumec day} = 1\ m^3/sec \times 24 \times 60 \times 60\ sec$$
$$= 24 \times 60 \times 60\ m^3$$
$$= 8.64\ \text{Hec-m}$$

<u>Design of Canals</u> :- (Unlined canals)

1. Kennedy's Method.
2. Lacey's Method.

1. <u>Kennedy's Method</u> :-

Kennedy design a Earthen canal (or) unlined canal Based on critical velocity concept.

Kennedy selected a No of sites in upper doab canal, punjab Carryout investigations about depth & velocity of channel. with non-silting and Non-scouring & they assume flowing of water velocity.

Kennedy's investigation revealed the following:

1. The silt present in river water is kept in suspension due to eddies.
2. A sufficient velocity of flow is required to generate these eddies keeps the silt (or) sediment in suspension. thereby avoiding silting up of the channel.

This velocity is also called as critical velocity (V_c), & He established a reln b/w critical velocity (V_c) & depth of water (d) as,

$$V_o = 0.55 \times (d)^{0.64}$$

then, critical velocity,

$$\Longrightarrow \boxed{V_c = 0.55 \times (m) \times (d)^{0.64}}$$

where, m = Critical Velocity Ratio

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

V_a = actual velocity, calculated by using Kutter's Equation,

$$\Longrightarrow V_a = \left[\frac{23 + \frac{1}{N} + \frac{0.00155}{S}}{1 + \left(23 + \frac{0.00155}{S}\right) + \frac{N}{\sqrt{R}}} \right] \times \sqrt{RS}.$$

where, N = Manning's rugosity Co-efficient.

R = Hydraulic Radius = $\frac{\text{Area}}{\text{Perimeter}}$ $(R = A/P)$

S = Longitudinal slope of the channel bed.

Design procedure

Step 1 :- Assume a trial depth, d

Step 2 :- Calculate the critical velocity (V_c)

$$V_c = 0.55 \times m \times (d)^{0.64}$$

Step 3 :- Calculate the area of section

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

Step 4 :- Calculate the Bed width, B using reln

$$A = Bd + nd^2$$

where, n = side slope (i.e side slopes 1 : 0.5) V : H

Step 5 :- Calculate the wetted perimeter, using

$$P = B + 2d\sqrt{1+n^2}$$

finally calculate hydraulic Radius, $R = A/P$

Step 6 :- Calculate actual velocity (V_a) using Kutter's eqn

$$V_a = \left[\frac{23 + \frac{1}{N} + \frac{0.00155}{S}}{1 + \left(23 + \frac{0.00155}{S}\right) \frac{N}{\sqrt{R}}} \right] \times \sqrt{RS}$$

Step 7 :- If the values of actual velocity & critical velocity then the assumed depth (d) is correct, otherwise procedure is repeated.

Drawbacks of Kennedy's theory :-

1. It ignores the importance of bed width & depth ratio.
2. This theory needs Kutter's Equation for actual velocity calculation.
3. This theory aims at the design of avg regime channel.
4. This theory has not given an Equation for the slope.
5. This theory procedure is by trial & Error only.

Problems

1. Design an irrigation canal section to carry 50 cumecs of water at a slope of 0.25 m per km, given that $N = 0.0225$ and $m = 1.0$ with usual ~~notations~~. notations.

Given

$Q = 50$ cumec

$= 50\ m^3/sec$

$S = 0.25$ m per 1 km

$= 0.25/1000 = 1/4000$

$N = 0.225$, $m = 1.0$

(a) Assume trial depth, $d = 3.35m$

(b) calculate Critical velocity,

$$V_c = 0.55 \times (m) \times (d)^{0.64}$$

$$= 0.55 \times (1) \times (3.35)^{0.64}$$

$$= 1.192\ m/sec$$

w.k.T

(c) Discharge reln from continuity eqn,

$$Q = A \times V$$

$$A = \frac{Q}{V_c} = \frac{50}{1.192} = 41.935\ m^2$$

(d) calculate Hydraulic Radius.

$$R = A/P$$

for trapezoidal section, Area, (A)

$$A = Bd + nd^2$$

$$A - nd^2 = Bd$$

$(\div d$ on both side)

$$\boxed{(A/d - n \times d) = B}$$

$$\text{So, } B = \left(\frac{41.935}{3.35} - 0.5 \times 3.35\right) = 10.84\ m$$

wetted perimeter (P)

$$P = B + 2d\sqrt{1+n^2}$$

$$= 10.84 + (2 \times 3.35)\sqrt{1+(0.5)^2}$$

$$= 18.334\ m$$

So, Hydraulic Radius, $R = A/P$

$$R = \frac{41.935}{18.334} = \underline{\underline{2.29\ m}}$$

(e) calculate actual velocity using Kutter's Eqn

$$Va = \left(\frac{23 + \frac{1}{N} + \frac{0.00155}{S}}{1 + \left(23 + \frac{0.00155}{S}\right) + \frac{N}{\sqrt{R}}}\right) \times \sqrt{R \times S}$$

$$= \left(\frac{23 + \frac{1}{0.0225} + \frac{0.00155}{1/4000}}{1 + \left(23 + \frac{0.00155}{1/4000}\right) + \frac{0.0225}{\sqrt{2.29}}}\right) \times \sqrt{2.29 \times (1/4000)}$$

$$Va = 1.227\ m/sec$$

(f) compare V_a & V_c values

V_a) 1.192 m/sec $<$ V_c) 1.227 m/sec

Above Values are not exactly same so we can make 2nd trial by increasing a depth ($d = 3.55m$)

(a) trial depth, $d = 3.55m$

(b) critical velocity, $V_c = 0.55 \times m \times (d)^{0.64}$

$= 0.55 \times (1) \times (3.55)^{0.64}$

$= 1.237$ m/sec

(c) actual velocity, $V_a = \left(\dfrac{23 + \frac{1}{N} + \frac{0.00155}{S}}{1 + \left(23 + \frac{0.00155}{S} + \frac{N}{\sqrt{R}}\right)} \right) \times \sqrt{R \times S} \rightarrow (a)$

W.K.T, $R = \dfrac{A}{P}$

$Q = A \times V$

$A = \dfrac{Q}{V_c}$

$= \dfrac{50}{1.237}$

$= 40.42\ m^2$

$P = B + 2d\sqrt{1+n^2}$

But, $B = \left(A/d - nd\right)$

$= \left(\dfrac{40.42}{3.55} - 0.225 \times 3.55\right)$

$B = 10.587$ m

Now,

$P = 10.587 + 2 \times 3.55\sqrt{1 + 0.5^2}$

assume ($n = 0.5$)

$\boxed{P = 18.525m}$

Now, $R = \dfrac{A}{P} = \dfrac{40.42}{18.42} = 2.19m$

actual velocity, $V_a = \left(\dfrac{23 + 1/0.0225 + \dfrac{0.00155}{1/4000}}{1 + \left(23 + \dfrac{0.00155}{1/4000}\right) \dfrac{0.0225}{\sqrt{2.19}}} \right) \times \sqrt{2.19 \times (1/4000)}$

online
(check class Notes)

$= 1.22\ m/sec$

(17)

$\left[V_a) 1.220\ m/sec \quad \simeq \quad V_c) 1.227\ m/sec \right]$

Design of canals (unlined canals) by Lacey's Method :-

Lacey's Theory :-

Regime channel :- According to lacey a regime channel is a stable channel transporting a regime silt charge. A channel is said to be in regime if it flows in incoherent unlimited alluvial of the same character as that transported and the silt grade and silt charge are all constant.

Incoherent alluvium :- It is loosely composed granular soil which can be scoured with the same ease with which it is deposited.

Regime silt charge :- It is the minimum transported load consistent with fully active bed.

Regime silt grade :- This indicates the range b/w the small & Big particles. It is not be taken as the avg mean diameter of a particle.

Regime conditions :- An irrigation channel is said to be in regime when the following conditions are satisfied.

(1) The channel is flowing in unlimited incoherent alluvium of the same character as that transported. (18)

(2) Silt grade and silt charge is constant.

(3) Discharge is constant.

Initial Regime :- It is the state of the channel that has formed its section only and not yet secured the longitudinal slope.

Final Regime :- It is the state when the channel is protected on the bed and sides with protecting material. so that neither the cross-section changes nor its longitudinal slope.

Design procedure :-

(1) calculate silt factor.

$$F = 1.76\sqrt{m}$$, where m = mean particle size in mm.

(1) calculate the avg velocity from the Eqn

$$V = \left[\frac{Qf^2}{140}\right]^{1/6}$$

(2) Calculate area of c/s of the channel from the continuity Eqn.

$$Q = A \times V$$

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

(3) calculate the wetted perimeters of the channel from the Eqn.

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

(4) Knowing (A) & perimeter (P), assume side slopes & calculate the bed width (B) & depth (d)

Area, $A = Bd + nd^2$

perimeter, $P = B + 2d$ (where n = side slope)

(5) Calculate the hydraulic Radius,

$$R = \frac{A}{P}$$

(6) Also calculate the hydraulic Radius 'R' using rel

$$R = \frac{5}{2}\frac{V^2}{f}$$

the values R calculated from step (6) & (7), should be same.

(7) Calculate bed slopes 'S' from the eqn

$$S = \left\{ \frac{f^{5/3}}{3340\, Q^{1/6}} \right\}$$

From the above procedure it is very clear that Lacey's Method doesnot involve any trial and Error procedure as in the case of Kennedy's theory.

Drawbacks of lacey's theory:-

1. The characteristics of a regime channel aren't precisely defined
2. Silt charge & silt grade aren't properly defined by Lacey.
3. Lacey's Equations don't include silt charge.
4. Lacey's theory doesn't consider the concentration of silt.
5. The values of 'f' obtained from Various Eqns of Lacey are often divergent.

problems

1. Design a irrigation channel section for the following data discharge = 50 cumecs, silt diameter = 0.323 mm, side slopes 1:1. Determine the longitudinal slope also.

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Soln:-

1. silt factor, $f = 1.76\sqrt{m}$

$= 1.76\sqrt{0.323}$

$= 1.0$

2. Velocity, $V = \left[\frac{Qf^2}{140}\right]^{1/6} = \left[\frac{50\times 1^2}{140}\right]^{1/6} = 0.842 \text{ m/sec}$

3. Area of c/s of channel, $A = \frac{Q}{V}$

$= \frac{50}{0.842}$

$= 59.36 \text{ m}^2$

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

$= 4.75\sqrt{50} = 33.588 \text{ m}$

5. Width, $B = ?$

W.K.T $A = Bd + nd^2$

$59.36 = Bd + (1)d^2 \quad (n = 1)$ side slope

$59.36 = Bd + d^2 \rightarrow (1)$

lly $P = B + 2d\sqrt{1+n^2}$

$33.588 = B + 2d\sqrt{1+1^2} \Rightarrow 33.588 = B + 2.828d$

$\boxed{B = 33.588 - 2.828d} \rightarrow (2)$

Substitute Eqn 2 in 1

$$59.36 = (33.588 - 2.828d)\,d + d^2$$

$$59.36 = 33.588d - 2.828d^2 + d^2$$

$$59.36 = 33.588d - 1.828d^2$$

$$1.828d^2 - 33.588d + 59.36 = 0 \qquad \left[y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \right]$$

$$d = \frac{33.588 \pm \sqrt{33.588^2 - (4 \times 1.828 \times 59.36)}}{2 \times 1.828}$$

$$d = \frac{33.588 \pm 26.344}{2 \times 1.828}$$

depth, $d = 1.98\,m$ (or) $d = 16.39\,m$

Select $d = \underline{1.98\,m}$

Now, Eqn 2 becomes

$$B = (33.588 - 2.828 \times 1.98)$$

$$= 27.99 \simeq \underline{28\,m}$$

6. Hydraulic Radius, $R = \frac{A}{P}$

$$= \frac{59.36}{33.588} = \underline{1.772\,m}$$

7. from the reln, $R = \frac{5}{2}\frac{v^2}{f}$

$$= \frac{5}{2} \times \frac{(0.842)^2}{1} = \underline{1.772\,m}$$

(8) longitudinal slope, $S = \left(\frac{f^{5/3}}{3340\, Q^{1/6}}\right)$

$$= \left(\frac{(1)^{5/3}}{3340\,(50)^{1/6}}\right)$$

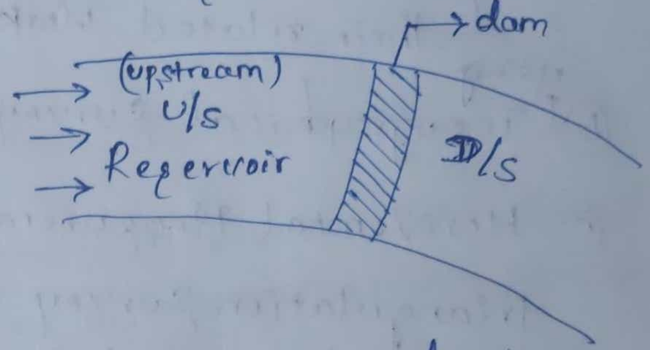
$$= \frac{1}{6410} = \underline{\underline{1.56 \times 10^{-4}}}$$

Difference b/w Kennedy's and Lacey's Theory :-

Kennedy's Theory	Lacey's Theory
(1) There can be Many section for a given discharge.	(1) only one regime section is possible for given discharge & silt factor.
(2) Kennedy's Method introduce Critical Velocity Ratio (m).	(2) Lacey's Method introduce silt factor (f).
(3) Kennedy's didn't specify regime slope.	(3) lacey's specified regime slope for given discharge and silt factor.
(4) Kennedy considered channel section as trapezoidal.	(4) Lacey's considered channel to be semi elliptical.
(5) Kennedy channel section is wider & shallower.	(5) Lacey's channel section is tighter & deeper.
(6) Kennedy's theory applicable to irrigation channels only	(6) Lacey's Theory applicable to irrigation channels as well as rivers
(7) Kennedy's Theory ~~Required~~ depends on Kutter's Eqn	(7) Lacey's theory doesn't depend on Kutter's Equation.

Reservoirs

Defn:- It is a large water body which is constructed across a river to store a water on upstream side



∴ Reservoir & dam exist together.

(or)

A Barrier (dam) is construction across the river inorder to store the water. The pool of water in U/s called Reservoir

Necessity of Reservoir :-

1. Irrigation purpose.
2. Flood control.
3. Hydroelectric power generation
4. Domestic as well industrial water supply
5. Navigation.

Investigation for reservoir site :-

1. Geological investigation/survey
2. Hydrological investigation/survey
3. Engineering investigation/survey

1. Geological Investigation / Geological survey :-

Geological survey is conducted for following reasons.

a. Suitability of foundation for the dam.
b. Water tightness of the reservoir Basin.

(c) location of quarry sites for the construction material usage.

(2) <u>Engineering Investigation</u> | <u>Engineering Survey</u> :-

(a) It is conducted for the construction of dams, reservoirs, & their related works.

(b) Using Topographical survey, contour plan is prepared.

(c) Horizontal Measurement (length) is usually provided by triangulation survey and the v/e measurement (Height) is usually provided by levelling.

(3) Hydrological <u>Survey</u> | <u>Investigation</u> :-

(a) To study runoff co-efficient.

(b) To study storage capacity.

(c) To determine Maximum Discharge

⇒ <u>Selection</u> of <u>site</u> <u>for</u> a <u>reservoir</u>:-

A good site is selected for the construction of reservoir have following characteristics.

(1) Proposed reservoir site should be such that reservoir has a good foundation and cost of construction should be minimum.

(2) proposed reservoir site should be such that entire basin of reservoir is water tight.

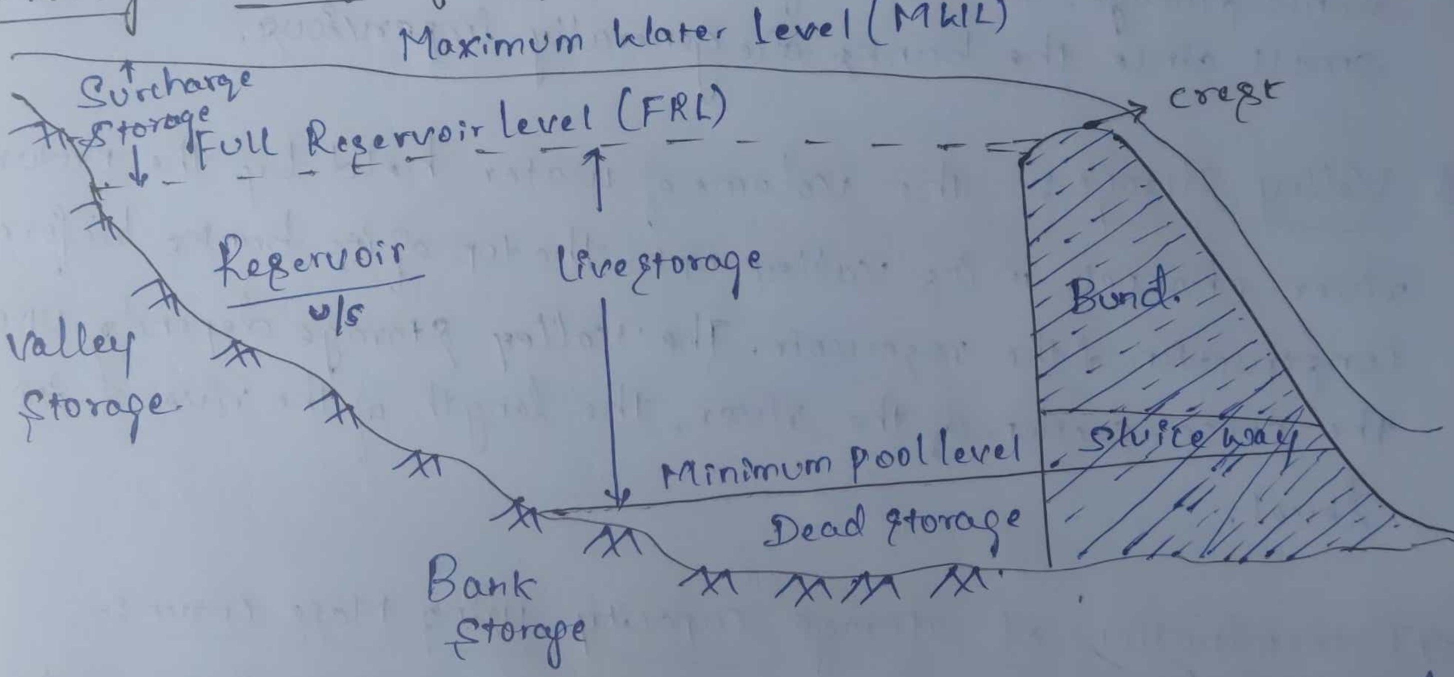
(3) proposed reservoir site should be such that reservoir has a good foundation & cost of construction should be minimum.

(4) proposed reservoir site should be such that submerged area should be minimum and shouldn't affect the Ecology of the area, important places, Monuments, Roads, Railways, shouldn't submerge.

(5) proposed reservoir site should be free from soluble & objectionable salts, which may pollute the reservoir.

(6) Hydrological conditions of the river @ the reservoir should give high yield, Here Evaporation, transpiration & percolage losses should be minimum.

⇒ Storage Zones of Reservoir :-



(1) Live storage :- It is also called as useful storage. The amount of water available (or) stored b/w minimum pool level & Maximum water level

Minimum pool level is considered when minimum working head required for the efficient working of turbines.

② **Surcharge storage** :- The amount of water stored above the full reservoir level & below the Maximum water level ~~and~~

(or)

The volume of water stored b/w Maximum water level (MWL) & full reservoir level (FRL)

~~[illegible] of multipurpose reservoir,~~

③ **Dead storage** :- The amount of water held below the minimum pool level. This storage is not useful & hence cannot be used for any purpose.

④ **Bank storage** :- Water stored in the banks of river is known as bank storage. In most of the reservoirs the bank storage is small since the banks are generally impervious.

⑤ **Valley storage** :- The volume of water held by the natural river channel in its valley upto the top of its banks before the construction of the reservoir. The valley storage depends upon the cross-section of the river, the length of the river & its H_2O level.

⇒ **Determination of storage capacity using Mass curve** :-

Mass curve is a graphical representation of cumulative volume of water in the reservoir v/s cumulative time. It is continuously raising curve.

Mass Curve Method (or) Graphical Method :-

(1) prepare mass inflow curve for the flow hydrograph of site for a number of consecutive years including the most critical years (driest years) when discharge is low.

(2) prepare mass demand (outflow) Curve corresponding to the given rate of demand. If the rate of demand is constant, the mass demand curve is a straight line.

(3) Draw the lines AB and FG, such that they are parallel to the mass demand curve, and they are tangential to the peak points on crest @ A, F etc.

(4) Draw vertical intercepts CD, HJ b/w tangential line & mass inflow curve. These intercept indicates volume by which the inflow volumes fall short of demand. which is Explained below.

* Assume that the reservoir is full @ point 'A'. the inflow volume during the period AE is equal to ordinate 'DE' & the demand is equal to ordinate CE. Thus the storage required is equal to the volume intercepted by the intercept CD.

(5) Determine the largest of the v/e intercept determined in step (4). The largest v/e intercept represents the storage capacity required.

(a) The capacity of reservoir obtained in the net storage capacity which must be available to meet the demand. The gross capacity of the reservoir will be more than the net storage capacity. It is obtained by adding evaporation & seepage losses to the net storage capacity.

(b) The tangential lines AB, FG etc. when extended forward must interest the inflow curve. This is necessary for the reservoir to get filled again. If these lines don't intersect the mass curve, the reservoir wouldn't fill again. Many times very large reservoirs may not get refilled every year.

(c) the v/e distance such as FL, b/w two successive tangents represents the volume of water flowing over the spillway.

Economic Height of dam:-

① Cost of the dam per unit storage is minimum.

② It requires estimation of cost of construction for several heights of dam and also corresponding storage in the reservoir.

③ For each dam height, the reservoir storage is known.

④ draw the curve b/w dam height & their corresponding cost of construction. ⑤ Workout the construction cost per unit storage for all the dam heights & plot a curve.