ARBA MINCH UNIVERSITY
Water Technology Institute
Faculty of Meteorology and Hydrology

Course Name:-Irrigated Lands Hydrology

Course Code:- MHH1403

CHAPTER FIVE

IRRIGATION DISTRIBUTION NETWORK

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Hydrology

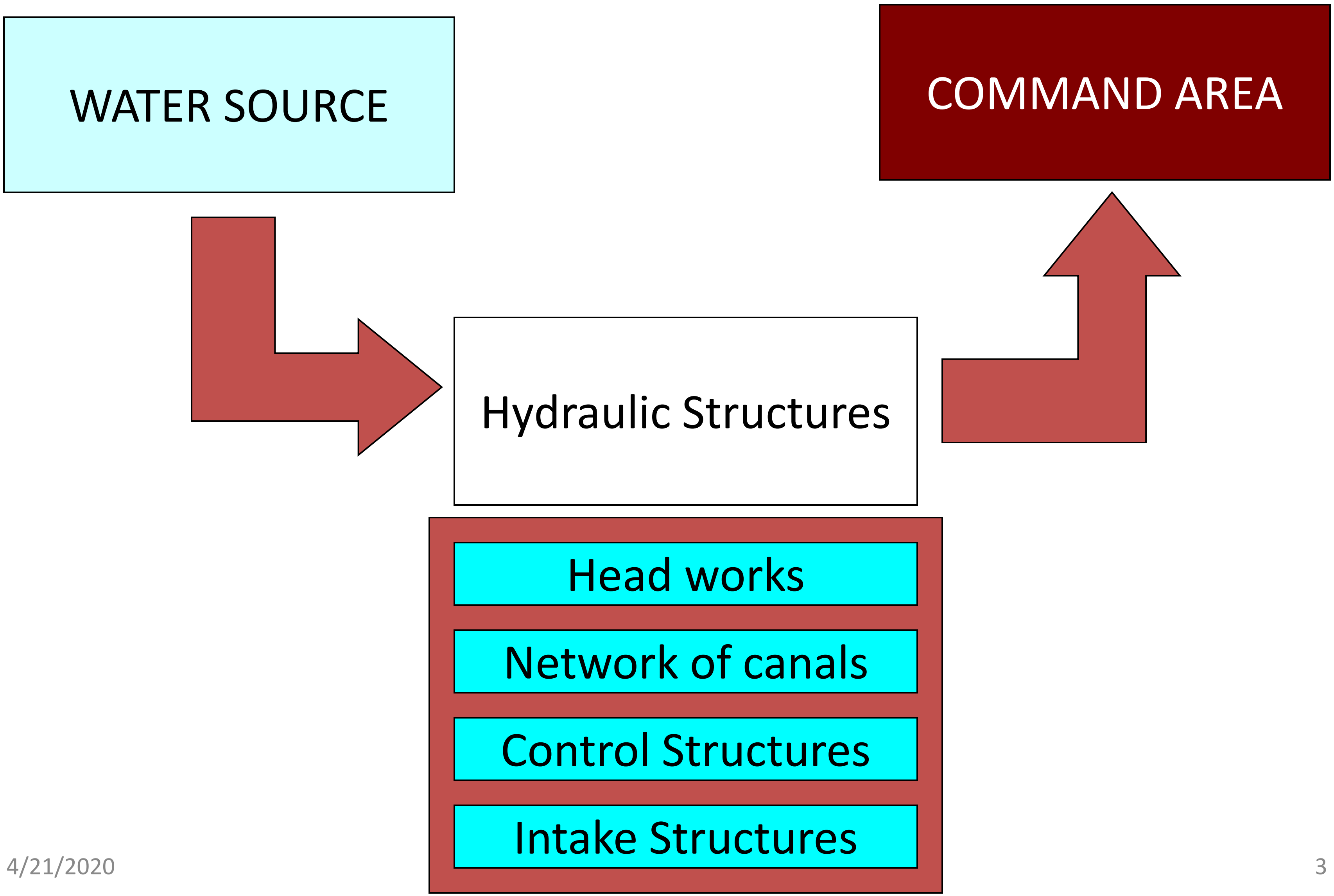
INTRODUCTION

- Irrigation networks are man made facilities for water conveyance, distribution and application.

- Includes Irrigation and drainage networks

- The network includes diversion headwork, conveyance system, distribution system and structures.

Irrigation Distribution Network



A typical tertiary off-take structure

Definition

- Irrigation distribution network:-network of irrigation canals including the diversion structures
- Diversion structures - Weir and Barrage are common regulatory structures in irrigation constructed across a river at the canal entrance or at the take-off point.

Cont…

- The Purpose is:
  - To obstruct and divert the river flow into the canal
  - To raise the water level in the river locally at the canal take-off point and helps in maintaining gravity flow
  - Thus, reduces excessive cutting of the canal in the head ditch.
  - To reduce the fluctuation in the water level of the river
  - To enable diversion of silt-free water into the canal system

Small weir

Small barrage

Cont..

Weir

- ✓Most of the ponding of water is by a raised crest
- ✓Has a small shutter or none
- ✓The afflux during high flood is high
- ✓Less control of river flow at times of flood
- ✓Not possible to construct road way
- ✓Relatively expensive

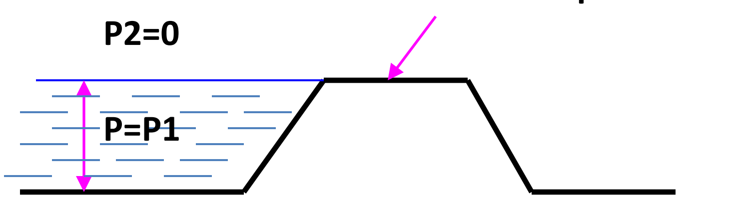
Cont…

Barrage (shuttered weir)

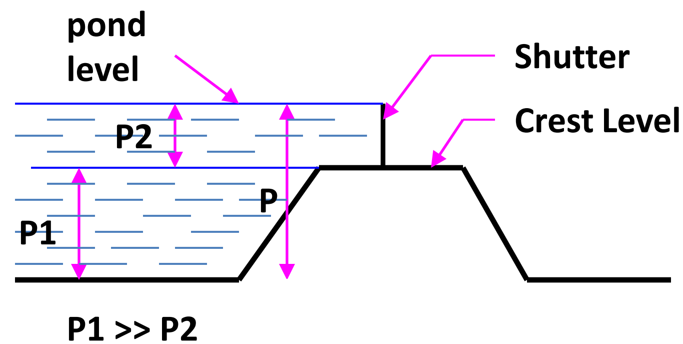
- ✓ Most of the ponding is by gates
- ✓ Has a small crest or none
- ✓ The afflux during high flood is nil or minimum
- ✓ A better control of river flow by manipulating gates
- ✓ A road way can be constructed
- ✓ Relatively expensive
- ✓ Cheaper to construct

Barrage

Weir and Barrage:

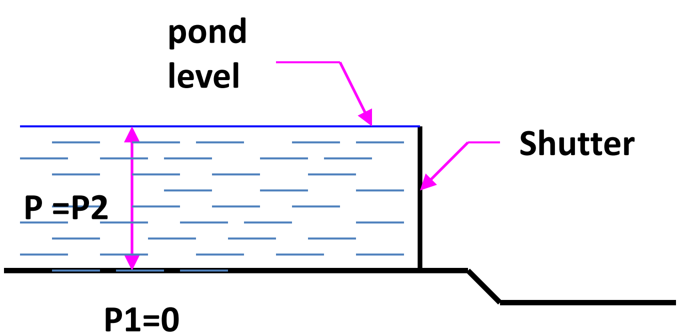


a) Without shutter

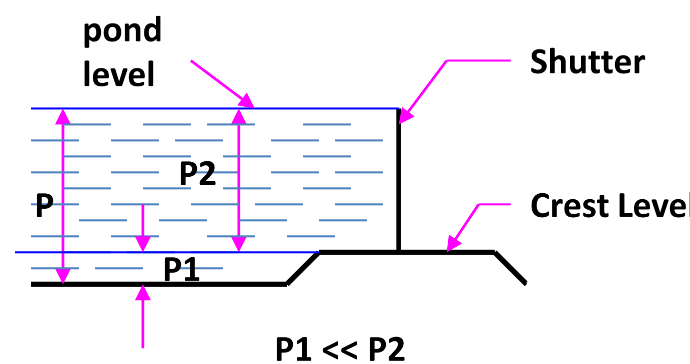


b) With shutter

Weir



a) Without crest



b) With crest

Barrage

Key: P = total ponding ; P1= Ponding by crest; P2= Ponding by shutter

Advantages and disadvantages of weirs and barrages

Weir:-

Advantage

- Low initial cost

Disadvantage

- High afflux (increase in water level) during floods;
- Siltation or sedimentation problem due to relatively high crest;
- Lack of effective control during floods.

Cont…

Barrage:

Advantage

- Effective control of flow is possible;
- Afflux and thus flooding is small during floods;
- Silt inflow into the off-taking canal can be effectively controlled.

Disadvantage

- It has a disadvantage that its initial cost is high.

Conveyance Structures

- In irrigation, water is transported from the source to the command area by either in
  - Open canals:- common in surface irrigation system
  - Pipes:- common in pressurized system

Open canals

- Has free surface
- Hydraulics of flow difficult

Pipes

- No free surface
- Hydraulic analysis of flow relatively simple

Conveyance and distribution systems

- ❖ Two types of water conveyance and distribution systems:
  - – Gravity system
  - – Pressurized system
- ✓ A combination of these two can also be used.

Cont…

I. **Gravity irrigation systems** consist of canals and canal structures for regulating the flow.

✓ Water is

- Conveyed
- Distributed and
- Applied to the field by gravity

Cont…

II. **In pressurized irrigation systems,** water is conveyed and distributed either on the whole or part of the system by closed conduit (pipelines) under pressure.

- In several irrigation systems around the world, a combination of **gravity** and **pressurized** conveyance and distribution system can be used.
- Water might be conveyed in some part of the system by gravity and a pump can be used to pump it to the higher elevation.

A combination of gravity and pressurized conveyance system (Metahara Sugar factory)

Cont…

- **Field application of water** to the crops can also be done under pressure with pressurized system such as **sprinkler and drip systems** or a combination of surface and pressurized systems.
- The selection depends on a number of factors such as **topography, soil type, water quality, water availability, affordability** etc.

Classification based on discharge and its relative importance irrigation net work canals:

1-Main canal(M.C): Carrier water direct irrigation from the source .

- ✓ its not used for direct irrigation but carry water only.

2-Branch canals(B.C):the canals branches from M.C ,feeder the distributaries canal.

- ✓ It s also don’t carry out any direct irrigation.

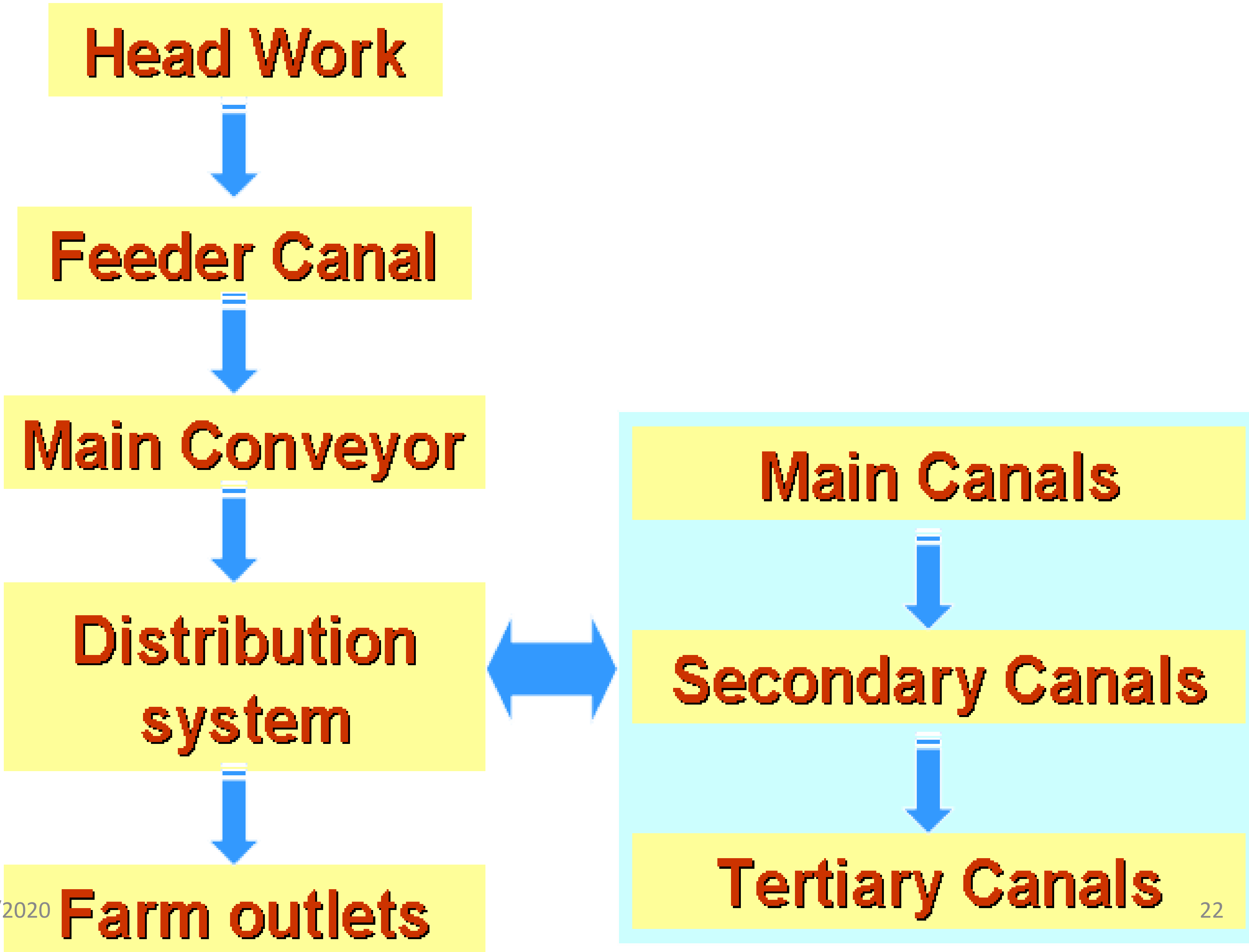
Cont…

3-distributary canals(D.C): Smaller channels ,which take off from the branch canals and distribute their supply through outlets into water courses are called distributaries.

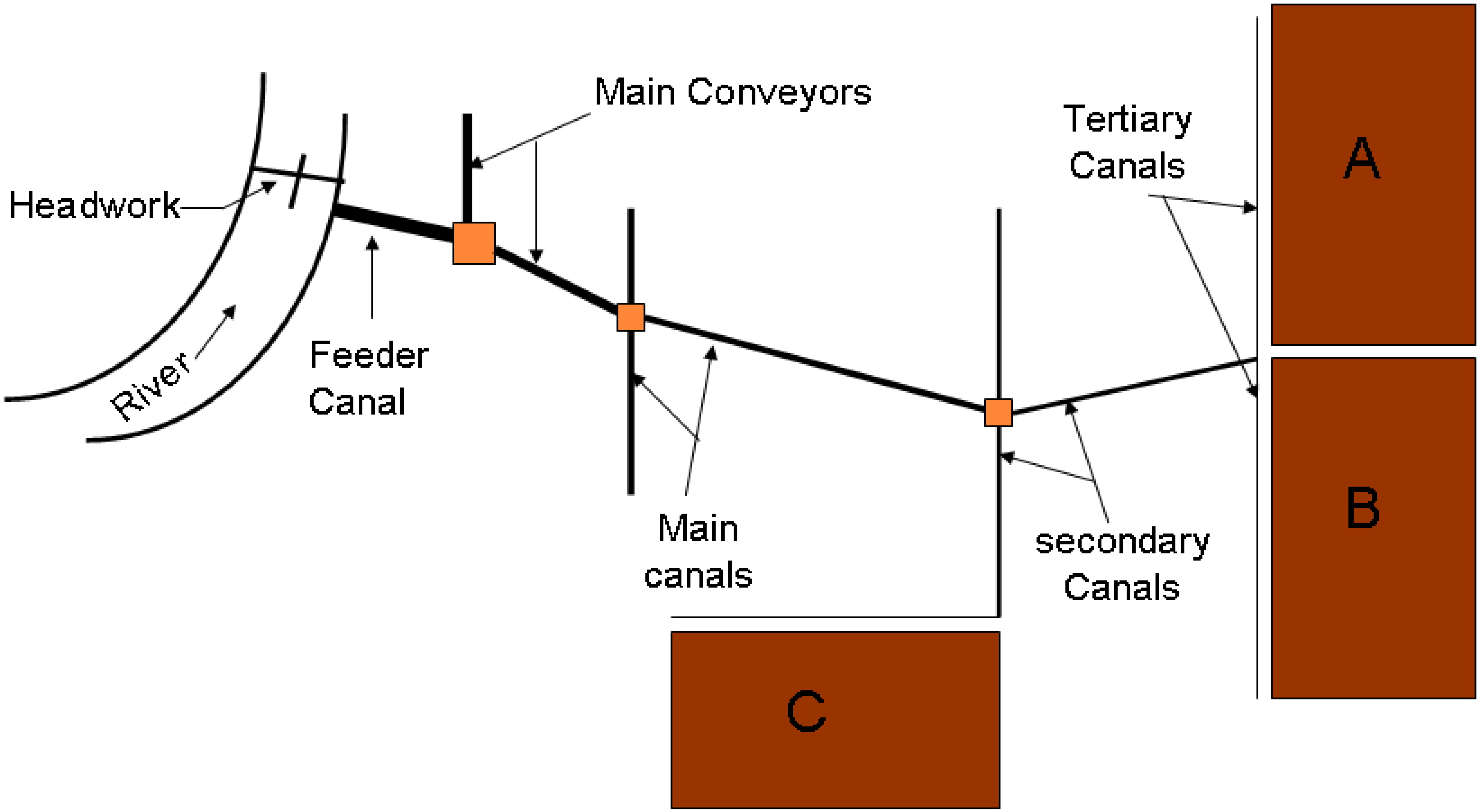
4- water courses(W.C): The canals which feeds the water to the farm units.

5- farm channel(F.C): the channels which distributers water on the farm.

A complete canal system



Canal Irrigation System



A complete canal system

Design of open channels

- Open channels in irrigation conveyance system could be lined Canals or unlined canals

Unlined Canals

- Common type of irrigation Conveyance channels
- Excavated in natural material
- Cheapest, easiest type to construct
- Easily damaged by livestock, rodents and erosion
- Require continuous maintenance
- Design is difficult unless a uniform flow is assumed

Cont…

Lined Canals

- Common near the head works
- Made of impervious material
- Initial construction cost is high
- Not easily damaged and resistant to erosion
- Reduce the labour cost in maintenance
- Satisfactorily designed using uniform flow equations

Cont…

- Channel design… working out its longitudinal and cross-sections to suit the requirements.

- Design requirement… to take maximum required discharge safely which is called Full Supply Discharge (FSD).

- To calculate FSD, it is essential to proceed with discharge calculations from the tail of a canal system upwards up to the head.

Cont…

- In this calculation, proper allowances are to be made for various losses which may occur in transit.
- For determination of canal capacity, design flows are estimated using the peak gross irrigation requirement.

  – **For Example:** in a location with the Peak Gross Irrigation Requirement of the crop 7.69 mm/day.

Cont…

$$Duty = \left(\frac{7.69}{1000}\right) m/day \times \frac{1 day}{24 hrs} \times \frac{1 hr}{3600 s} \frac{10^4 m^2}{1 ha} \times \frac{1000 lit}{1 m^3}$$
$$= 0.89 lit/s/ha$$

- ✓ For a canal serving an area of 1000 ha, canal design flow:

Peak flow (Q) = 890 L/s or 0.89 m^3/s.

Cont…

- **For determination of canal capacity – Proper steps**
  - Calculate gross depth of application.
  - Calculate irrigation frequency and/or cycle.
  - Calculate system capacity by $Q = V/T$, where V = volume of water to be diverted and T = time of irrigation per day.
  - Volume is determined by $V = A \times D_{gross}$, where A = area to be irrigated per day and D = gross depth of application.
  - A is calculated by: $A = A_t/I_c$, where A_t = total irrigation area and I_c = irrigation cycle.

Cont…

$$Q_c = \frac{A_t \cdot d}{I_c \cdot T \cdot E_p}$$

Where,

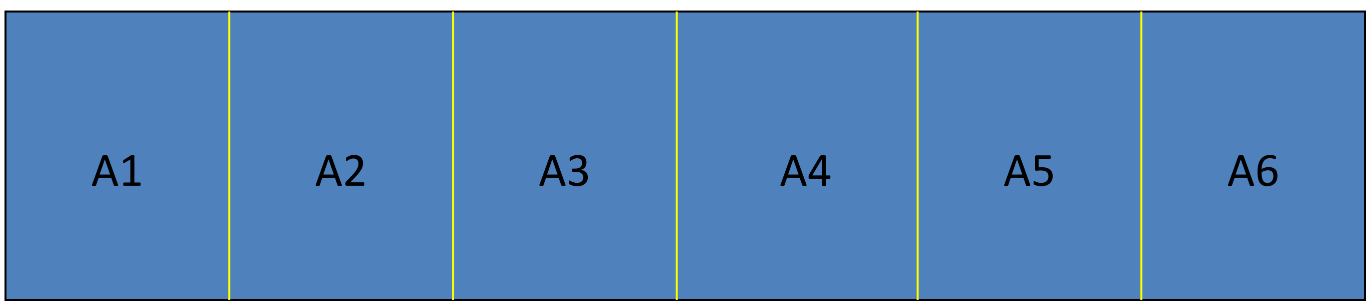
- d = net depth of irrigation
- Ep = project efficiency
- At =total area irrigated
- Ic = irrigation cycle
- T = working time per day

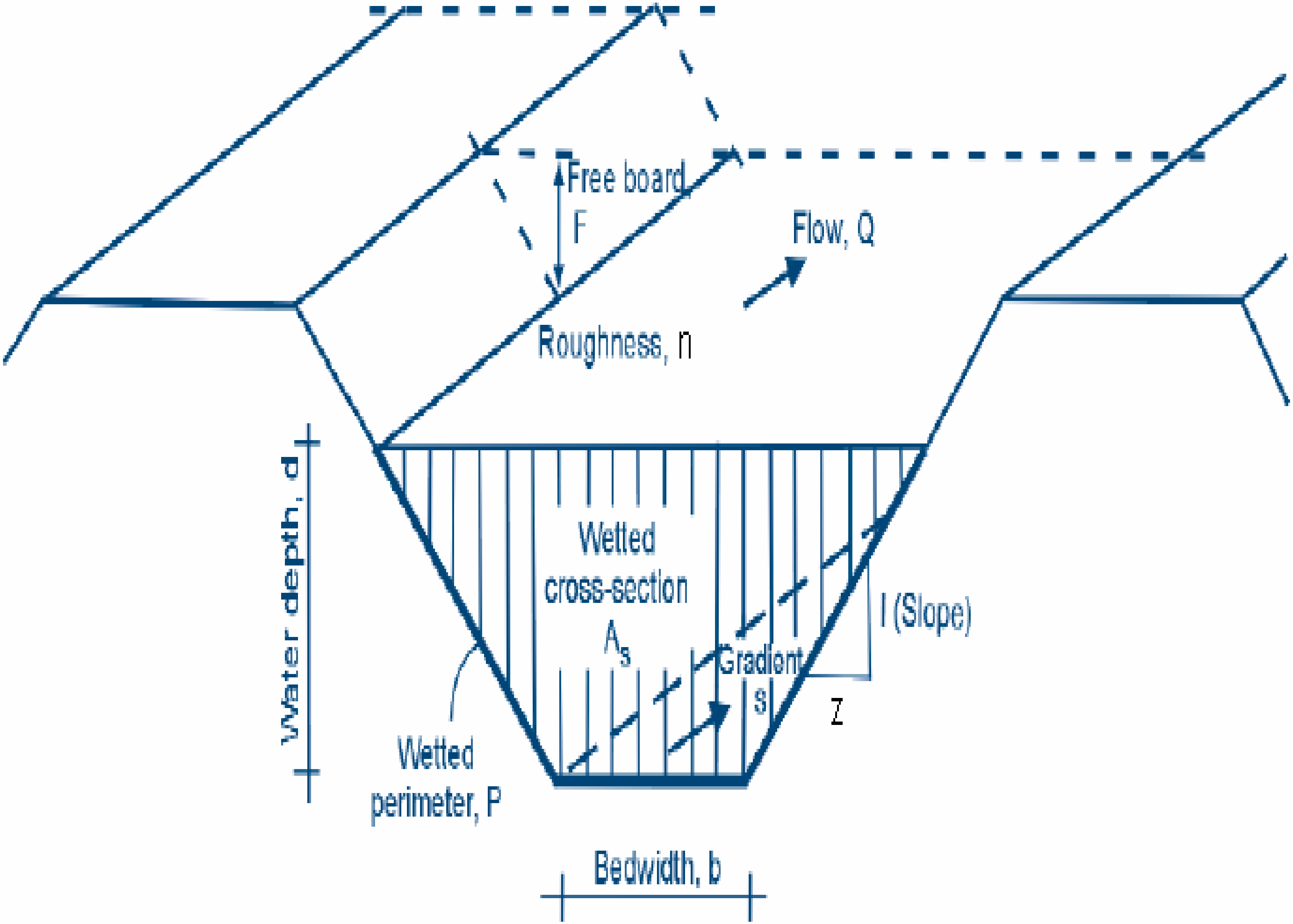
Cont…

- Irrigation cycle/period – the number of days allowed to complete one irrigation.
- Irrigation interval – the number of days between two successive irrigation applications.
- **Irrigation period can not be greater than the irrigation interval.**

Cont…

Example: if the calculated irrigation interval is 7 days and if an irrigated area is divided into 6 sub-areas to be irrigated in shift. The irrigation period is 6days.




Free board
F
Flow, Q
Roughness, n
Water depth, d
Wetted
cross-section
A_s
Gradient
s
I (Slope)
Z
Wetted
perimeter, P
Bedwidth, b

Cont…

- **Freeboard…**vertical distance between the highest water level anticipated in the design and the top of the retaining banks. It is a safety factor to prevent the overtopping of structures.

$$F = ch^{1/2}$$

Where, h=depth of water

✓c= 0.8 for Q up to 0.5m^3/sec,

✓c=1.35 for Q>80m^3/sec

Cont…

- **Side Slope…** The ratio of the horizontal to vertical distance of the sides of the channel (z:1)

Table: Recommended maximum canal side slopes

Material	**Z:1**
Sand, Soft Clay	3:1
Sandy Clay, Silt Loam, Sandy Loam	2:1
Fine Clay, Clay Loam	1.5:1
Heavy Clay	1:1
Stiff Clay with Concrete Lining	1:1
Lined Canals	1.5:1

Cont…

- Canals on alluvial soils carry appreciable silt and sand load.
- These affect the velocity of flow considerably.
- Hence, the uniform flow equation cannot be used here to determine the velocity of flow because the equation does not consider this aspect.

Cont…

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$ …Manning's equation

$$V = C\sqrt{RS}$$ …Chezy's equation

Therefore, the design criteria for unlined canals are:

- the design discharge should flow at non-erosive velocity
- side slopes should be flat enough not to be cave in when saturated
- longitudinal slope should not be excess

Methods for design:

- Kennedy's theory (transportation theory)
- Lacey's theory

- The basis for designing is by assuming an ideal regime channel (non-scouring and non-silting channel).

Cont…

- *i.e. whatever silt has entered the channel, once it is kept in suspension so that it does not settle down and deposit at any point of the channel.*
- *Moreover, the velocity of the water should be such that is doesn't produce local silt by erosion of channel bed and banks.*

Cont...

Kennedy’s theory states that

- *“the silt supporting power in a channel cross-section was mainly dependent upon the generation of eddies. These eddies are generated due to the friction of the flowing water with the channel surface. The vertical component of the eddies try to move the sediment up, while the weight of the sediments tries to bring it down, thus keeping the sediment in suspension. So, if the velocity is sufficient to generate these eddies, so as to keep the sediment just in suspension, silting will be avoided.”*

Cont...

- Based on this Kennedy defined the critical velocity in channel as:

$$V_o = 0.546D^{0.64}$$

Kennedy's equations for design:

1 $$Q = AV$$

2 $$V_o = 0.546D^{0.64}$$

3 $$V = C\sqrt{RS}$$

- Chezy's constant from Kutter's formula

$$V = C\sqrt{RS}$$

Kutter's Formula

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

Cont…

Where,

V_0 = Critical velocity (no-silting, no-scouring velocity), m/s

D = full supply depth of flow in m

Q = design discharge, m^3/s

V = mean velocity of flow, m/s

C = Chezy's coefficient

R = hydraulic radius, m

S = bed slope/longitudinal slope

Cont…

Design Procedure….Kennedy's theory

Step 1. Reasonably assume, D

Step 2. Using equation (1) find Vo

Step 3. Find out A with known Vo,

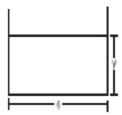
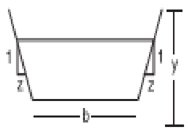
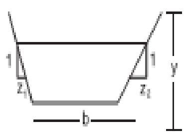
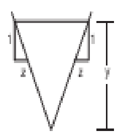
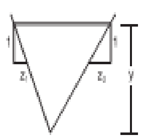
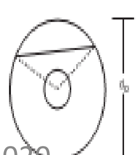
Step 4. Assume side slopes & from the knowledge of A, find out bed width B.

Step 5. Calculate R.

Step 6. using equation (3) find out, V

Step 7. Check the values of V and V_o; if equal OK and if not, change S or D and try again.

Table Channel Section Geometric Properties

Channel definition (1)		Area A (2)	Wetted perimeter P (3)	Hydraulic radius R (4)	Top width T (5)	Hydraulic depth D (6)
Rectangle		by	$b + 2y$	$\dfrac{by}{b + 2y}$	b	y
Trapezoid with equal side slopes		$(b + zy)y$	$b + 2y\sqrt{1 + z^2}$	$\dfrac{(b + zy)y}{b + 2y\sqrt{1 + z^2}}$	$b + 2zy$	$\dfrac{(b + zy)y}{b + 2zy}$
Trapezoid with unequal side slopes		$by + 0.5y^2(z_1 + z_2)$	$b + y(\sqrt{1 + z_1^2} + \sqrt{1 + z_2^2})$	$\dfrac{by + 0.5y^2(z_1 + z_2)}{b + y(\sqrt{1 + z_1^2} + \sqrt{1 + z_2^2})}$	$b + y(z_1 + z_2)$	$\dfrac{by + 0.5y^2(z_1 + z_2)}{b + y(z_1 + z_2)}$
Triangle with equal side slopes		zy^2	$2y\sqrt{1 + z^2}$	$\dfrac{zy}{2\sqrt{1 + z^2}}$	$2zy$	$0.5y$
Triangle with unequal side slopes		$0.5y^2(z_1 + z_2)$	$y(\sqrt{1 + z_1^2} + \sqrt{1 + z_2^2})$	$\dfrac{0.5y^2(z_1 + z_2)}{y(\sqrt{1 + z_1^2} + \sqrt{1 + z_2^2})}$	$y(z_1 + z_2)$	$0.5y$
Circular		$\dfrac{1}{8}(\theta - \sin\theta)\, d_o^2$	$0.5\theta d_o$	$0.25\left(1 - \dfrac{\sin\theta}{\theta}\right) d_o$	$2\sqrt{y(d_o - y)}$	$\dfrac{1}{8}\left[\dfrac{\theta - \sin\theta}{\sin(0.5\theta)}\right]$

Cont…

Example: Design an irrigation unlined canal using Kennedy’s theory if,

- F.S.D = $14 m^3/sec$
- Bed slope = 1 in 5000
- Kutter's N = 0.0225
- side slope = ½:1 (Horizontal : vertical)

(Hint: Assume D= 1.8m)

Cont…

Solution:

Steps: 1. assume D = 1.8m

2. $V = 0.546 \times (1.8)^{0.64}$

$= 0.795$ m/s3.

$A = Q/V = 14/0.795 = 17.6m^2$

4. $A = BD + zD^2 = 17.6$

$1.8B + 1/2\,(1.8)^2 = 17.6 \quad \Rightarrow B = 8.88m$

5. $R = A/P = A/(B + 2D\sqrt{(1+z^2)}) = 17.6/(8.88 + 1.8\sqrt{5}\,) = 1.365m$

6. Chezy's constant from Kutter's formula

$$C = \frac{(23 + 0.000155/s) + 1/n}{1 + (23 + 0.00015/s)\, n/\sqrt{R}}$$

$= 46.8$

$V = C\sqrt{Rs} = 46.8\sqrt{1.365x0.0002} = 0.772$ m/sec

Thus, this velocity is slightly less than Vo. One more trial with smaller depth will give fairly close result.

Cont…

Lacey disproved the Kennedy's regime theory by stating that:-

- *"A channel showing no silting and no scouring may actually not be in regime. But an artificially constructed channel having a certain fixed section and a certain fixed slope can behave in regime only if the following conditions are satisfied.*
  - *discharge is constant*
  - *flow is uniform*
  - *silt charge is constant, i.e. the size and type of silt is always the same.*
  - *channel is flowing through a material which can be scoured as easily as it can be deposited."*

Cont…

- He also argued that silt supporting eddies are generated from the bottom as well as from the sides of the channel.
- Further, he argued that grain size of material forming the channel is an important factor and should need much more rational attention.
- Therefore, he introduced a term called silt factor, f.

Lacey's equations for design:

1. $$V = 0.4382\left(Qf^{2}\right)^{1/6}$$

2. $$f = 1.76\sqrt{d_m}$$

3. $$R = 2.46\frac{V^{2}}{f}$$

4. $$P = 4.825Q^{1/2}$$

5. $$S = \frac{f^{5/3}}{3316Q^{1/6}}$$

Where,

V = regime velocity (no-silting, no-scouring velocity), m/s

Q = design discharge, m^3/s

f = Silt factor which is a function of the grain size of the material forming the channel

d_m = average particle size in mm

S = bed slope of the channel

Design of unlined channels/Erodible channels

Design Procedure….Lacey's theory

Step 1. Calculate V from equation 1 and 2

Step 2. Calculate R using equation 3

Step 3. Calculate P using equation 4

Step 4. Calculate x-sectional area, A from continuity equation, Q=VA

Step 5. Assuming side slopes, calculate the full supply depth, D from A, P and R.

Step 6. Calculate the bottom width B from relation of B and D

Step 7. Calculate the longitudinal slope, S using equation 5.

Cont…

Example: Design an irrigation unlined canal using Lacey's theory if,

- F.S.D = 14m^3/sec
- f = 1
- Kutter's N = 0.0225
- side slope = ½:1 (Horizontal : vertical)

Solution:

steps:

1) Mean velocity, $V = 0.4382\ (Q.f^2)^{1/6}$

$$= 0.4382\ (14\ x 1^2)^{1/6}$$

$$= 0.68\ m/s$$

2) $R= 2.46\ (v^2/f) = 2.46\ x\ (0.68)^2/1 = 1.14m$

3) $P= 4.825\ (Q)^{1/2}= 4.825x\ (14)^{1/2} =18.06m$

4) $A= RP = 1.14\ x\ 18.06 = 20.55m^2$

5) $A= BD +zD^2 \Rightarrow 20.55= BD + D^2/2$

$$P = B+2D\sqrt{(1+z^2)} \Rightarrow 18.06 = B+\sqrt{5}D \Rightarrow B= 18.06-\sqrt{5}D$$

Therefore, $20.55 = (18.06- 5\ D\ )\ D+D^2/2$ or

$$1.73\ D^2 - 18.06D + 20.55 =0$$

Solving the equation, $D = 9.13m$ & $D =1.3m$

Taking D = 9.13m and substituting in the expression for B, we get

$$B = 18.06 - 2.23 \times 9.13 = -2.3\text{m}$$

Taking D= 1.3 m and again substituting in the expression for B,

$$B = 18.06 - 2.23 \times 1.3 = 15.15\text{m}$$

For comparison, using the values of B and D,

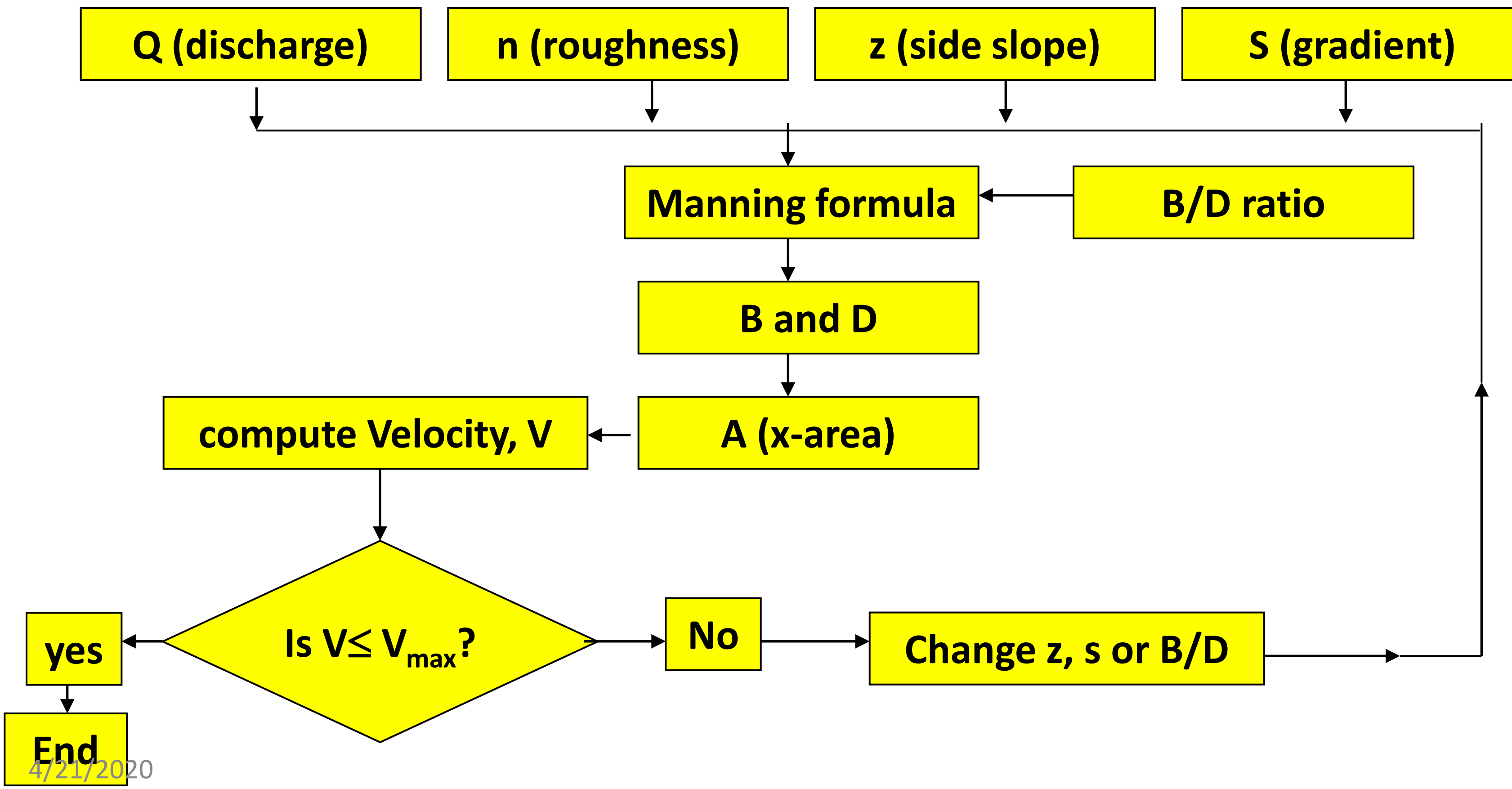
$$R = 2.46 \frac{(V)^2}{f} = 2.46 \frac{(0.68)^2}{1} = 1.14\text{m}$$

$$R = A/P = \frac{15.15 \times 1.3 + (1.3)^2/2}{15.15 + \sqrt{5} \times 1.3} = 1.14\text{m}$$

Now, slope can be determined from

$$S = \frac{f^{5/3}}{3316 Q^{1/6}} = \frac{1}{3316 \times 1.553} = \frac{1}{5160} = 0.00019$$

Note: Unlined canals (erodible canals) are sometimes designed using the Manning's equation as long as it doesn't exceed the maximum permissible velocity. i.e.



Design of open channels

Table 1: **Maximum b/d ratios for trapezoidal channels**

Water depth	b/d ratio
Small (d < 0.75 m)	1 (clay) - 2 (sand)
Medium (d = 0.75-1.50 m)	2 (clay) - 3 (sand)
Large (d > 1.50 m)	> 3

Table 2: **Maximum permissible velocity for earthen canals**

Soil type	Maximum flow velocity (m/sec)
Sand	0.3 - 0.7
Sandy loam	0.5 - 0.7
Clayish loam	0.6 - 0.9
Clay	0.9 - 1.5
Gravel	0.9 - 1.5
Rock	1.2 - 1.8

Design of open channels

Example: Compute a trapezoidal channel with the following information

- Type of channel: earthen channel
- Carrying Capacity, Q = 400ft^3/sec
- Longitudinal slope, S = 0.0016
- Manning's n = 0.025
- Side slope, z:1 = 2:1
- Maximum permissible velocity, V = 4.5 ft/sec

$$Use: \quad V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

Cont…

Solution:

steps:

1) From $V = (1.486/n)(R^{2/3}S^{1/2})$, $R = 2.60ft$

2) From $Q = AV$, $A = 88.8ft^2$

3) From $R = A/P$, $P = 34.2ft$

4) From relation $A= (B+zD)D$ and $P = B+2D\sqrt{(1+z^2)}$, $B = 18.7ft$

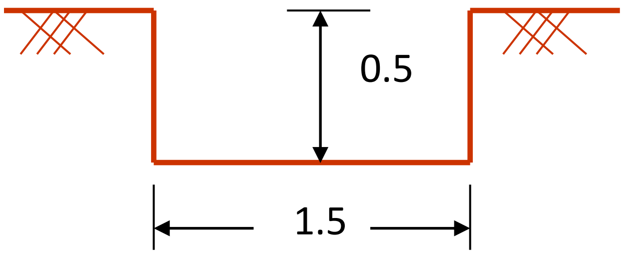
5) Therefore, $D= 3.46$ ft

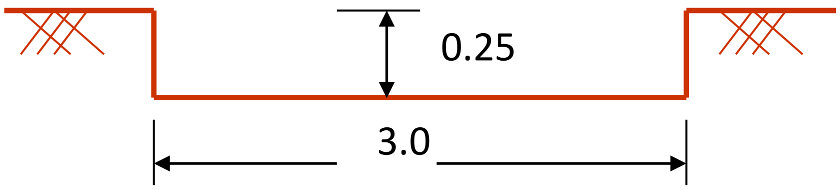
Design of Lined canals

- Design criteria for lined canals are:
  - Dimensions fairly accurately computed using uniform flow formula
  - Velocity of flow should not be very low to avoid siltation
  - Can also be designed based on best hydraulic section

Cont…

- Best hydraulic section … the section which carry maximum discharge for a given excavation. i.e. a section with max. R or min. P





A = 1.5*0.5 = 0.75m²

P = 2*0.5+1.5 = 2.5m

R = 0.75/2.5 = 0.3m

Q is high

A = 3.0*0.25 = 0.75m²

P = 2*0.25+3.0 = 3.5m

R = 0.75/3.5 = 0.2m

Q is low

Cont…

Design Procedure….

Step 1. Estimate n and select S

Step 2. Compute the section factor. i.e.

$$AR^{2/3} = \frac{nQ}{\sqrt{S}}$$

Step 3. Substitute the expressions for A and R and solve D. If B and z are unknown, assume the values and solve for D by trial and error.

Step 4. For best hydraulic section directly obtain D

Design of open channels

Example: It is proposed to design an irrigation channel with the following data

- Type of channel: Trapezoidal
- Carrying Capacity, Q = 400ft^3/sec
- Longitudinal slope, S = 0.0016
- Manning's n = 0.025

$$Use: \quad V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

a) Using a trial and error method (Hint: Assume d = 2ft and z = 1)

b) Using the concept of best hydraulic section

c) Compare the results obtained in (a) and (b)

Canal Lining - General

- Canal Lining --- the earthen surface of the channel is covered with a stable (non-erodible) lining surface such as concrete, stone masonry, bricks, etc.
- Advantages of Lining:
  - Seepage control and prevention of water logging--- the losses can be reduced up to 90% with good lining.
  - Increase in channel capacity --- a smooth surface created as a result of lining causes less resistance to water flow (increase flow velocity). E.g. the Manning's n for unlined canals in good condition is usually taken as 0.025 while the same for lined concrete channel is 0.015.

Cont…

- Increase in command area ---the lesser seepage loss, the increase in command area the flow serves.
- Reduction in Maintenance costs --- unlike the unlined canals, lined canals are less susceptible to damage by erosion, livestock and rodents; require only minor maintenance; eliminates weed growth.
- Ensure equitable distribution of water --- fair distribution of water amongst all beneficiaries due to high reduction of seepage loss.

- Disadvantage of lining:
  - cost of lining is usually 2-3 times as much as an unlined canal

Cont…

- Canal lining in irrigation is usually justified:
  - if the canal is shorter in length and/or smaller in cross-section.
  - if water has to be transported on steeper slopes.
  - If economical justified that the saving of costly irrigation water outweighs the capital expenditure on lining.
- Canal lining is more common near the head works (i.e. feeder canal) as it is shorter in length and the capacity is large

Cont…

- Depending on the economy, canal lining could be:
  - Hard surface lining --- cement concrete, brick, stone masonry, etc.
  - Earth type linings --- compacted linings, soil cement lining.

Reading assignment

- Factors affecting selection of type of lining
- Method of construction for each type of lining

Economics of Canal Lining

- In some cases, the lining of canals may not be seen from purely technical angle. i.e. it also requires strong economic justification.
- Thus, the benefit-Cost ratio should be worked out so as to justify the necessity of lining.
  - Justification for lining existing canals
  - Justification for lining on new irrigation projects

Cont…

Justification for lining existing canals:

- i) Annual Benefits --- saving of water charge and maintenance cost.
  - If a beneficiary is charged C_1 birr per cumecs of water used and if V cumecs of water is saved by lining, then the money saved is:

    $$B_1 = VC_1$$

  - If the average maintenance cost of the unlined canals from previous records is C_2 and if p is the percentage fraction of the saving achieved in maintenance cost, then the money saved is:

    $$B_2 = pC_2 \qquad \text{(p is normally taken as 0.40).}$$

  - Thus, total annual benefit, B

Cont…

Note: there are other benefits which are difficult to express in monetary values. For example, reduced risk of canal breaching, incidence of diseases, water logging.

ii) Annual Costs --- the capital expenditure on lining.

- ✓ If the cost of lining is P which is borrowed from the bank with interest rate i and if the lining has a life of n years, annual figure sufficient to repay exactly the present sum in n years is:

Cont…

$$A = \frac{\left[i(1+i)^n\right]}{\left[(1+i)^n - 1\right]} \times P$$

Benefit – Cost ratio:

$$B-C = \frac{Annual\ Benefit}{Annual\ cost} = \frac{B}{A} = \frac{B_1 + B_2}{\frac{\left[i(1+i)^n\right]}{\left[(1+i)^n - 1\right]} \times P}$$

❖For economic justification of lining, Benefit – Cost ratio should be greater than one.

- Example: An unlined canal with a seepage loss of $3.3m^3$ per million square meters of wetted area is proposed to be lined with 10cm thick cement concrete lining, which costs 900birr per 10 m^2. Given the following data, work out the economics lining.
  - Annual revenue per cumec of water from irrigated crops = 1, 750, 000 birr
  - Discharge in the canal = 84 cumecs
  - Area of the canal = $40.8m^2$
  - Wetted perimeter of the canal = 18.8m
  - Wetted perimeter of the lining = 18.5m
  - Annual maintenance cost of unlined channel per $10m^2$ = 5birr
  - Let seepage loss in lined channel = $0.01m^3$ per million m^2 of wetted surface area.

  Reasonably assume any data, if required.

Solution:

Let us consider 1km reach of the canal.

Wetted surface area per km 18.8x1000 = 18, 800 m^2

i) Annual benefits

A) Saving of water:

Seepage loss in unlined canal = $(3.3m^3/10^6m^2)$x 18,800m^2/km = $(62040/10^6)$ m^3/km

Let seepage loss in lined channel = 0.01m^3 per million m^2 of wetted surface area. Therefore, the seepage loss in lined canal is:= $(0.01m^3/10^6m^2)$x 18,500m^2/km = $(185/10^6)$ m^3/km

Net saving of water **=** $(62040/10^6)$ m^3/km - $(185/10^6)$ m^3/km = $(61,852/10^6)$ m^3/km

Annual Benefit, B_1 = VC_1 = $(61,852/10^6)$ cumec/km *$(1.75*10^6)$birr/cumec = 108,241birr/km

Cont…

B) Saving in Maintenance:

- Annual maintenance cost of unlined canals = 5birr/10m^2
- Total wetted surface area = 18,800m^2/km
- Therefore, annual maintenance cost for unlined canal = (5birr/10m^2)*18,800m^2/km
  = 9,400birr/km

Assume that 40% of this is saved in lined channel.

Thus, Net annual saving in maintenance cost, B_2 = pC_2 = 0.40*9,400 = 3,760birr/km

Cont…

ii) Annual costs:

- Area of lining per km of channel = 18.5x1000 = 18,500m^2/km
- Cost of lining per km of channel @ 900 birr/10m^2 = (18,500m^2/km)*(900birr/10m^2)

  = 1,665,000 birr
- Assume life of lining as 40 years and interest rate for initial capital is 5%,
- Total Annual cost, A is:

Cont…

$$A = \frac{\left[i(1+i)^n\right]}{\left[(1+i)^n - 1\right]} \times P = \frac{0.05(1+0.05)^{40}}{(1+0.05)^{40} - 1} \times 1{,}665{,}000 = 97{,}049.18\,birr$$

Benefit – Cost ratio,

$$B-C = \frac{B_1 + B_2}{\frac{\left[i(1+i)^n\right]}{\left[(1+i)^n \quad 1\right]} \times P} = \frac{108{,}241 + 3{,}760}{97{,}049.18} = 1.15$$

- Conclusion: B-C ratio is more than unity and hence the lining is economically justified.


THE END
THANK YOU
Missing … for the last n days!
(Where n>>0)