WATER RESOURCES

(2017-2018)

By

Ali Mezaal

Syllabus

INTRODUCTION

SOIL-WATER RELATION

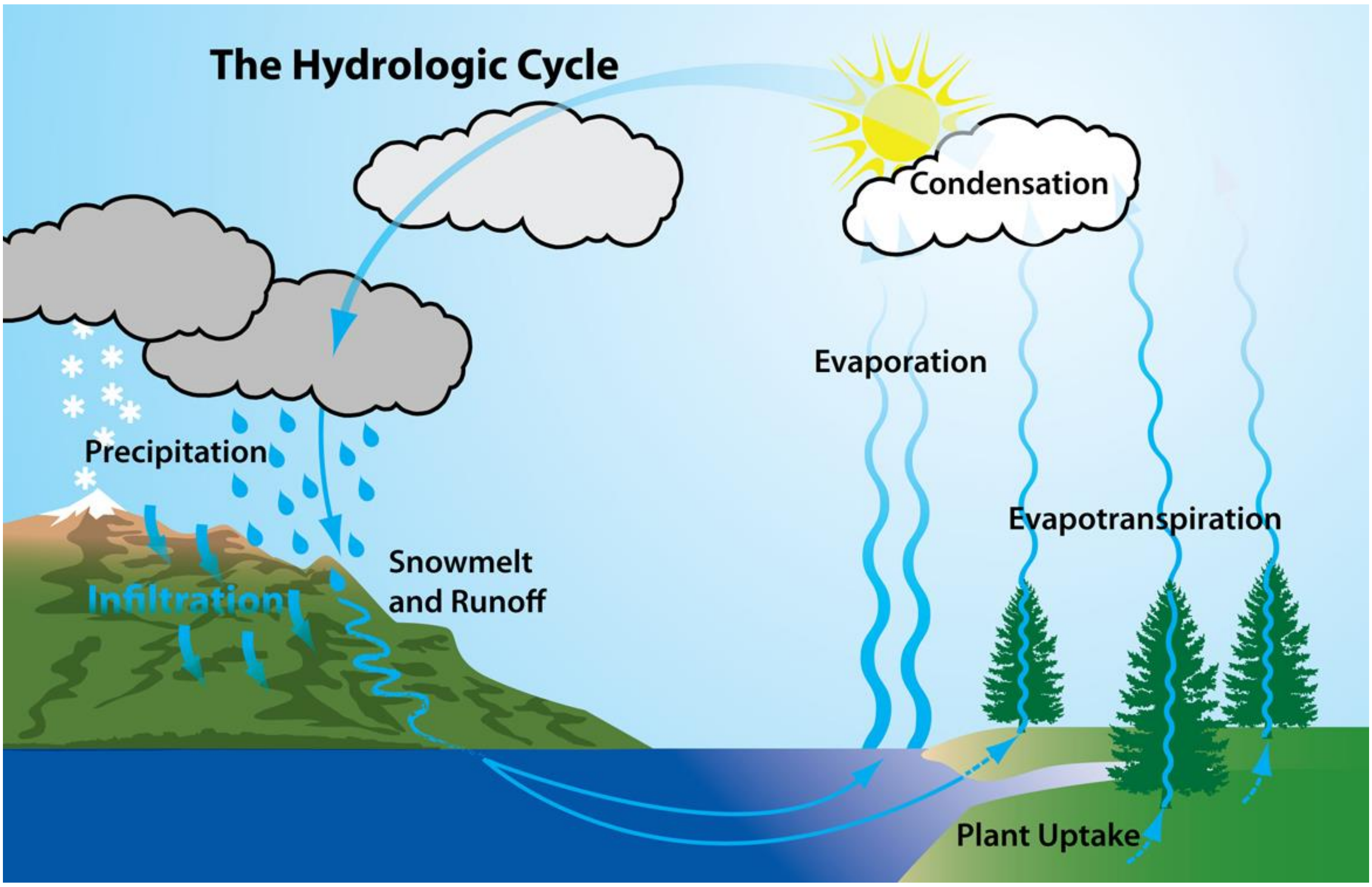
IRRIGATION

HYDRAULIC DESIGN OF CANALS

DRAINAGE

INTRODUCTION

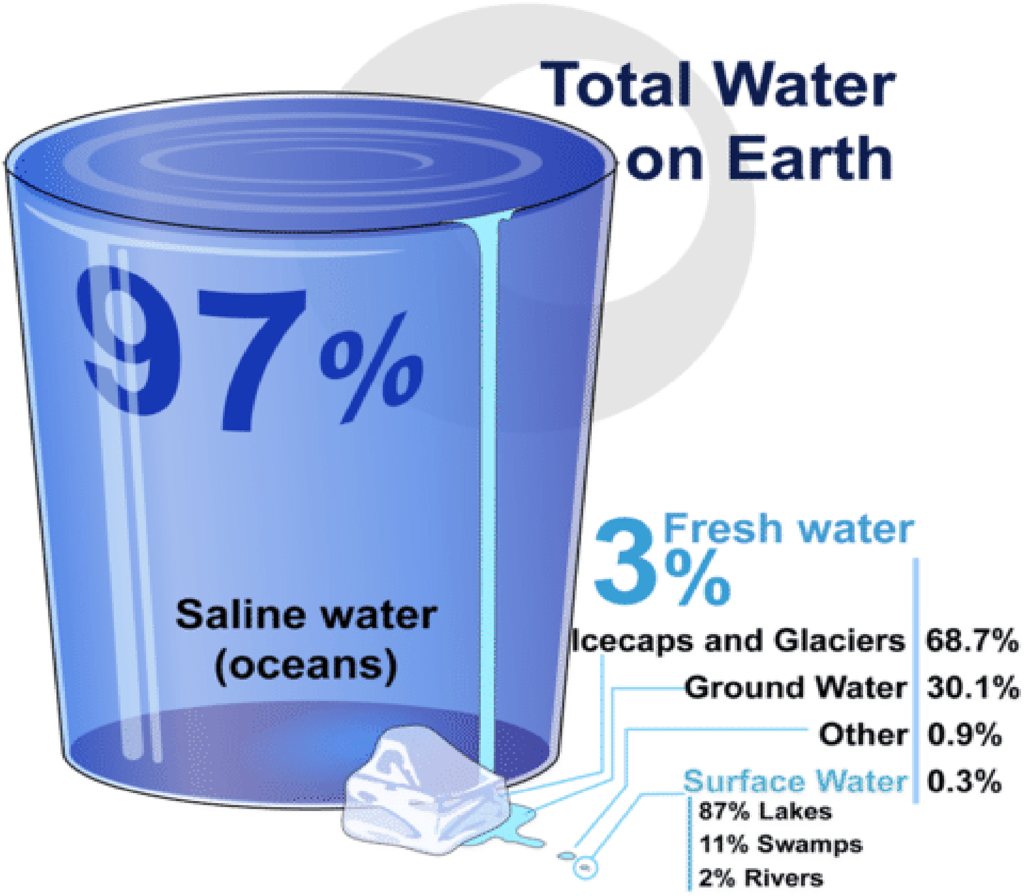
Water in our planet is available in the atmosphere, the oceans, on land and within the soil and fractured rock. Water molecules are driven from one location to another by the solar energy



Moisture circulates from the earth into the atmosphere through evaporation and then back into the earth as precipitation.

Water on Earth:

Locations of water on earth are distributed graphically as follow:



Water Supplies

Water available as:

- Rain falling within the region.
- Surface water bodies. These are either static (lakes and ponds) or flowing (streams and rivers).
- Ground water reservoirs.

Water Allocation Priorities

While planning and operation of water resource systems, water allocation priorities should be broadly as follows:

- ✓ Drinking water
- ✓ Irrigation
- ✓ Hydropower
- ✓ Ecology
- ✓ Industrial demand of water
- ✓ Navigation

Soil-Water Relation.

Soil moisture content.

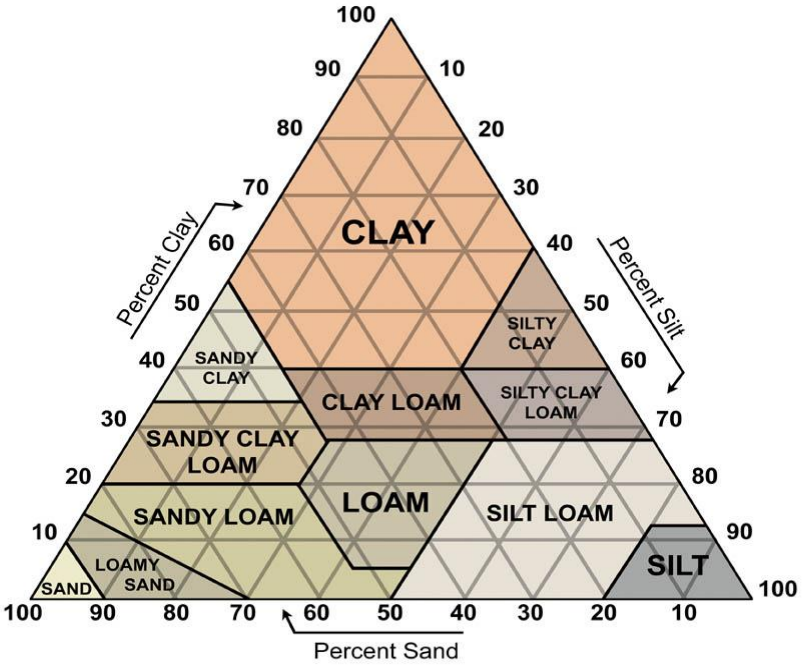
Water supplied to the soil would came from:

- Precipitation.
- Atmospheric water (other precipitation).
- Flood.
- Ground water.
- Irrigation.

Definitions of soil concepts:

- **Soil texture:** the size of particles making up the soil, where ranged from fine gravel to clay.

  Soil classification is typically made based on the relative proportions of silt, sand and clay using the texture triangle.



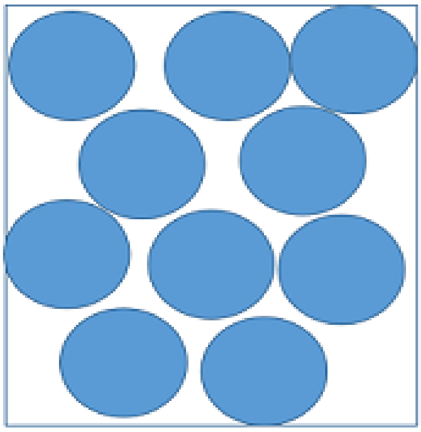
For example :

Sand = 30%, clay = 30% and silt = 40%

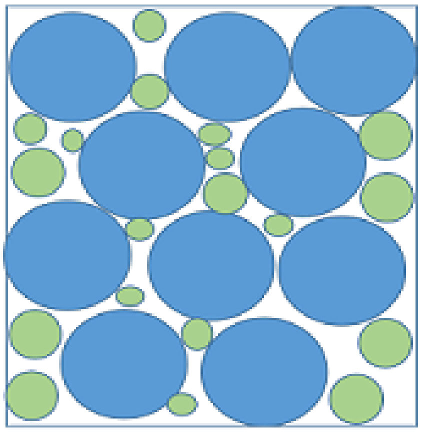
Soil type is : **clay loam**

- **Soil structure:** is the system of soil particles arrangement.
- **Pore space:** it is defined as the ratio of volume of void (air and water) filled space to the total volume of soil.

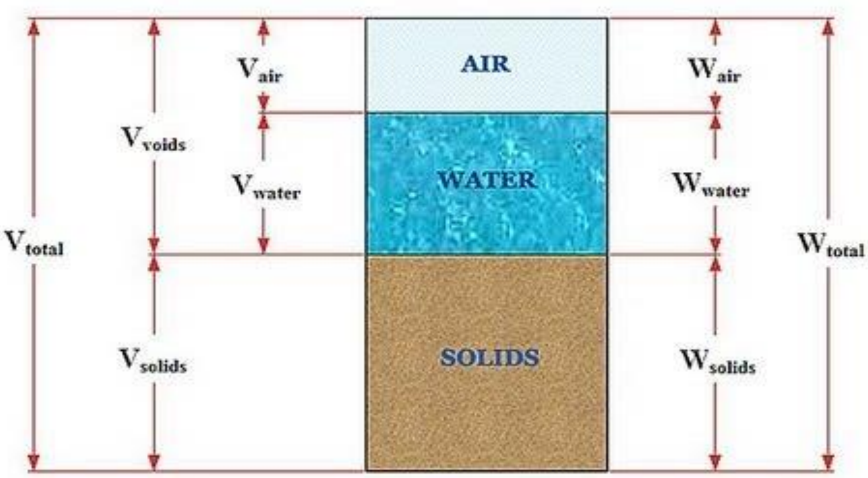
$$n = \frac{V_v}{V_{total}}$$

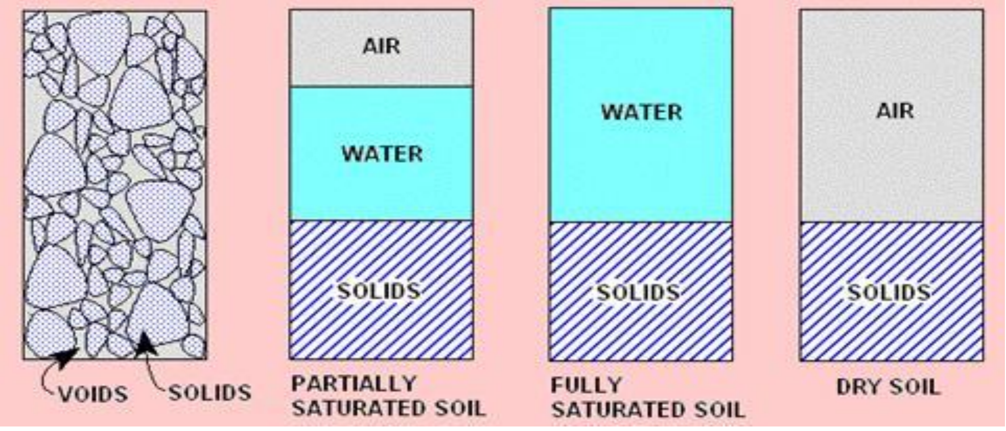


High porosity – large spaces



Low porosity – small spaces





- **Real specific gravity(R_s):** is a dimension less quantity defined as the ratio of the density of single soil particles to density of volume of water equal to the volume of soil particles.

$$\text{Density } (\text{gm/cm}^3) \ldots\ldots\ldots \ \mathrm{R_s} \cong (2.5 - 5)$$

$$R_s = \frac{\rho_s}{\rho_w} = \frac{m_s/V_s}{m_w/V_w}$$

- **Apparent specific gravity(A_s):** is defined as the ratio of the density that included volume of pore space without their weight to the density of equal water volume.

$$A_s = \frac{m_s/V_{total}}{m_w/V_w}$$

$$R_s > A_s$$

$$n = 1 - \frac{A_s}{R_s}$$

Apparent specific gravity is influenced by:

- ✓ structure,
- ✓ texture, and
- ✓ compactness.

Definitions of water concepts:

- **Hydroscopic water:** is the water on the surface of soil grains and is not capable of significant movement by the action of gravity of capillary force.

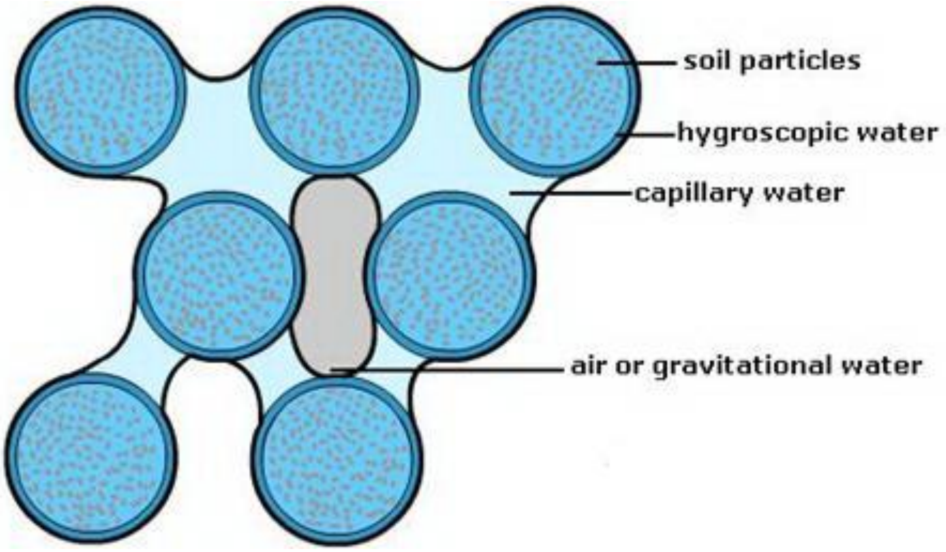
  Hydroscopic Water = Weight at P.W.P – Dry weight

- **Capillary water**: is that part in excess of the hydroscopic water which exists in the pore space of the soil and resists the force of gravity.

  Capillary water = Weight at F.C – Weight at P.W.P

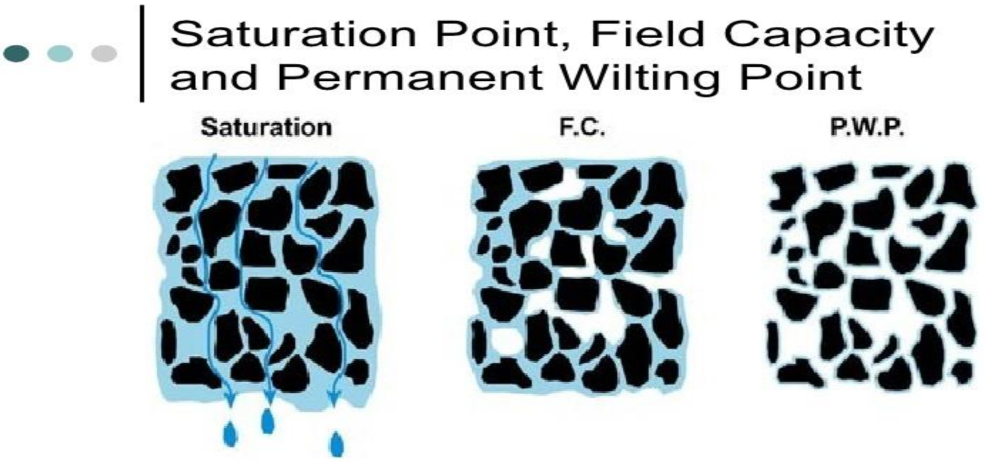
- **Gravity water**: is that part excess of hydroscopic water and capillary water which will readily move out of soil.

  Gravity water = Saturation weight – Weight at F.C



Root zone: is the layer (layers) which content the rooting system.

- **Field capacity**: is the moisture content that remained after the gravity water has been removed. In practical field capacity is usually determine after 2 days from irrigation.
- **Permanent wilting point**: is the soil moisture content when plants permanently wilt called the wilting coefficient. The value of p.w.p. depends up on the water used by plant, depth of root zoon, and holding capacity of soil.



- **Available water(A_w) :** is the deference in moisture content of the soil between field capacity and permanent wilting point. It can be expressed as percentage of moisture by weight or as percentage of volume or as percentage of depth.
- **Allowable depletion (A_d):** - is a percentage that depleted due to the consumptive-use of the plants. A value of 50% or 0.5 for AD is commonly used for many crops.

- **Readily available water (RAW):** is the part from available water that can be use (depleted) safely without causing crop damage.

RAW = AW*AD

$$V_w = \frac{W_w}{\gamma_w} \qquad \gamma_w = 9800\ N/m^3$$

Volume of soil…… $P_v = \frac{V_w}{V_{total}} * 100\%$,

Weight of soil ……$P_w = \frac{W_w}{W_s} * 100\%$

Example (1): Given a soil sample which has the following data:

- ✓ Total volume = 120cm^3
- ✓ Wet weight = 1.5 N
- ✓ Dry weight = 1.45 N
- ✓ $R_s = 2.65$

Find $A_s, n, and\ V_s$

Example (2): A soil of $A_s = 1.45$ weight of soil material weight of dry soil $W_s = 1.5$ Nweight of wet soil = 1.7 N. Find the percentage of water content by volume.

Example (3): A soil sample has water content of 44% by volume, dry weight 1.3 N, and weight of sample 1.7. Find A_s.

Example (4): Given a soil sample whose volume is 131 cm^3 and the dry weight of it is 1.8 N. At full saturation the weight of sample is 2.8 N. After all gravity water has been drained out the weight was 2.2 N and when all capillary water has been used the weight was 1.85 N. Find A_s , hydroscopic water % by volume, A_w available water % by volume, gravity water % by volume.

Example (5): A soil sample has field capacity 37.8%and P.W.P 18% (all by volume). The allowable depletion is 55%. Calculate RAW as % by volume and by depth assuming root zone depth is 120cm.

Example (6): The volume of a soil sample is 150 cm^3. Weight of dry soil is 2N. The weight of the soil at field capacity is 2.5N and P.W.P IS 2.2N. The allowable depletion is 50% and root depth is 90cm. Calculate Aw and RAW by volume once and by depth of water once again.

Water Resources Engineering

Irrigation

Asst. Lec.

Ali Mezaal

Irrigation

Is the artificial application of water to soil for the purpose of supplying the moisture essential for plant growth.

Purpose of irrigation

1- To supply the moisture for plants growth.
2- To provide crop insurance against short duration droughts.
3- To cool the soil and atmosphere.
4- To soften the soil.
5- To wash out harmful salts from the soil.

Definitions of Irrigation concepts

Net depth of irrigation (d_n) : is the depth of water applied and stored in the root zone (It is only water available for plant growth).

Leaching requirements (L.R) : is defined as the fraction of irrigation water that must be leaching through the root zoon to control soil salinity at any specified level.

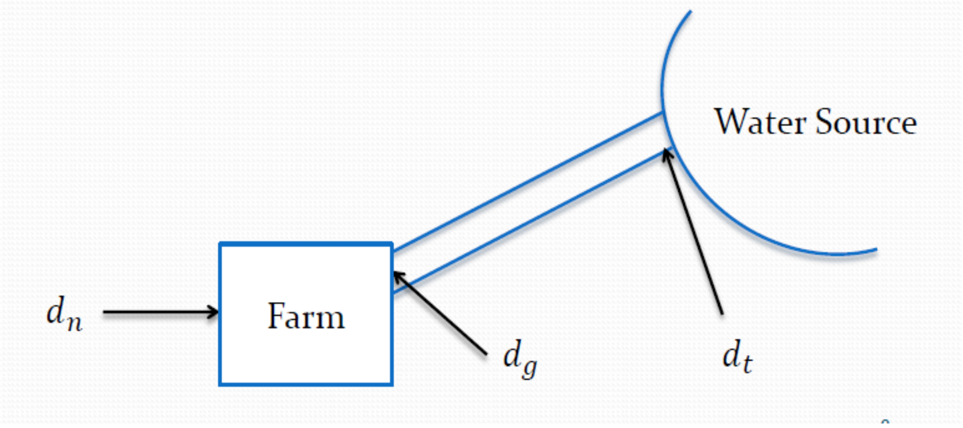
Gross depth of irrigation (d_g) : is the depth of water delivered to the farms, which content the amount of net depth, water loss (run off + deep percolation), leaching requirements, and rain fall.

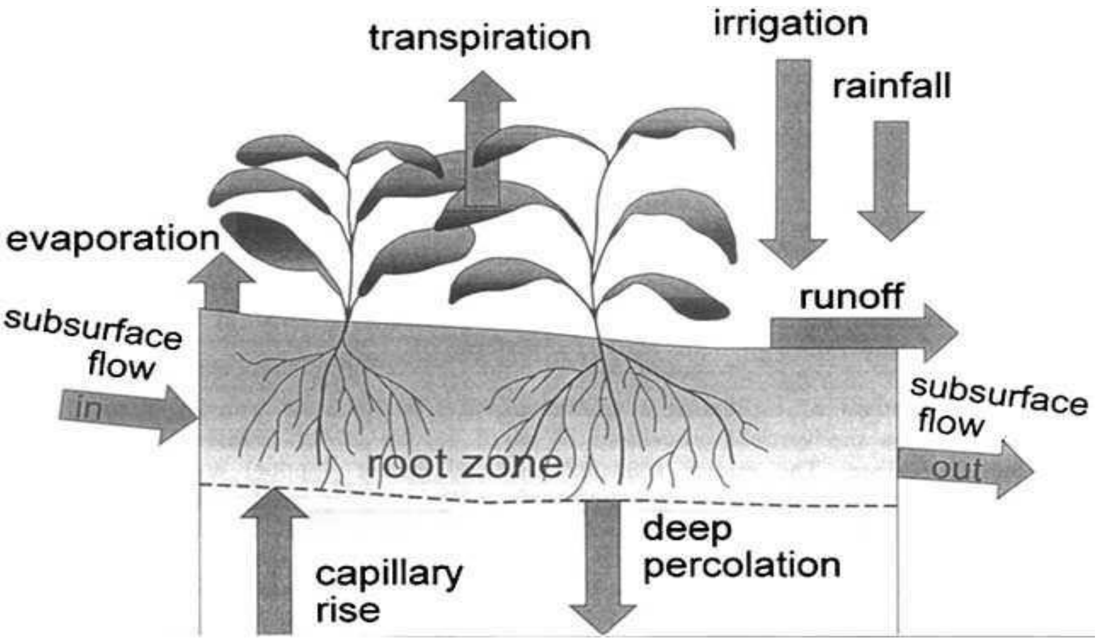
$$d_g = d_n + \text{water losses} + LR - \text{effective rainfall}$$

Total depth of water (dt) : is that depth of water delivered from the water source (reservoir, river, etc) for irrigation requirement.

$$d_t = d_g + canal\ seepage + evaporation$$

- Seepage losses from earth canals = 35%,
- Seepage losses from lining canals = 5.8%





Application efficiency(E_a) **:** The ratio between water stored in the soil root zone during irrigation to water delivered to the farm.

$$E_a = \frac{d_n}{d_g} * 100\%$$

$$E_a = \frac{Q_n}{Q_g} * 100\%$$

Conveyance Efficiency (CE): It is the percentage ratio between depth of water at the farm and depth of water delivered from irrigation source.

$CE = \frac{d_g}{d_t} * 100\%$ **or** $CE = \frac{Q_g}{Q_t} * 100\%$

Overall Efficiency (OE) = Ea*CE

$CE = \frac{d_n}{d_t} * 100\%$ **or** $CE = \frac{Q_n}{Q_t} * 100\%$

Example (1): given

- ✓ Gross depth 150mm,
- ✓ Irrigation efficiency 80%,
- ❖ Find net depth of irrigation
- ❖ Find the depth of water lost during irrigation process.

Example (2): Given the following data of an irrigation project: E_a=85% and CE=75%.Find the percentage of water from the total depth that useful for plants.

Example (3): The net depth is 10 cm, E_a=90%, and CE = 80%. Find the depth of water required at the farm gate and the total depth at the head of source.

Example (4): The length of irrigation canal is 10 Km, seepage losses from the canal is estimated to be 0.01 lps/m of length. If the discharge at end of the canal is 2.0 m^3/sec , what is CE ?

Soil Moisture Deficit (SMD):

Is the amount of water needed to bring the soil moisture content back to field capacity.

$$SMD = F.C. - \text{Moisture Content}$$

If the moisture content is at F.C., SMD = 0

If RAW = 0, SMD = max.

Depth applied should be equal to the deficit in moisture content, i.e.

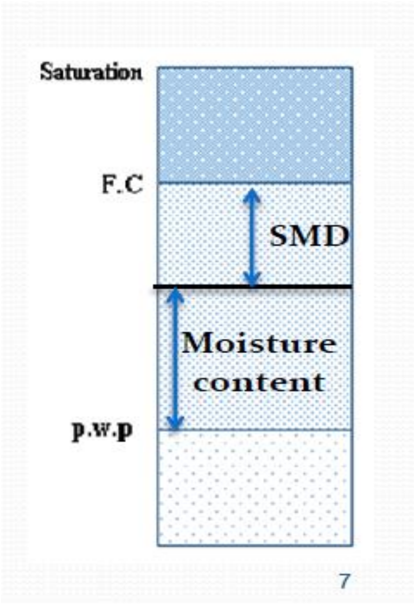
$d_n = SMD$

$d_n <$ SMD ⇨ under irrigation.

$d_n >$ SMD ⇨ over irrigation.

Maximum applied depth must cover the max. deficit in moisture content, i.e.

$RAW = d_n$ max

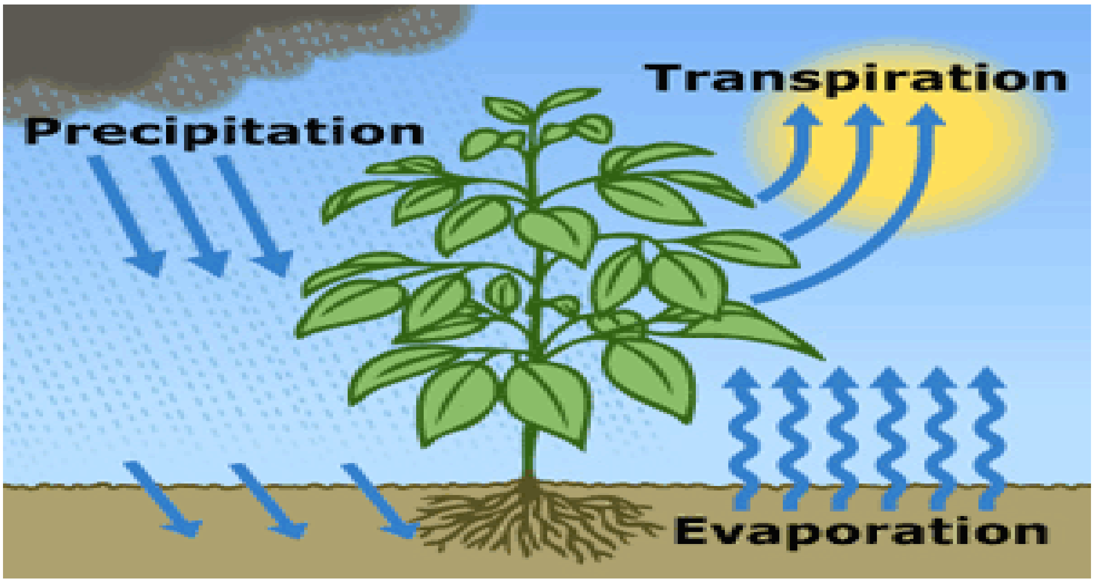


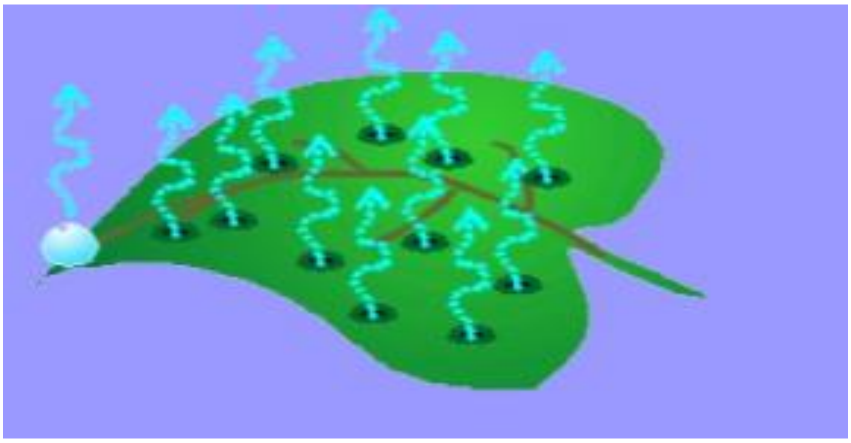
Example (5): A soil has Field Capacity is 32% by volume and permanent wilting point 16% by volume and the moisture content before irrigation is 26% by volume, root zone is 75 cm deep. If the depth of applied water is 78 mm and run off losses is 20% of the applied water. Find the percentage of water as deep percolation and the irrigation efficiency.

Deficit in soil moisture is occurred because of evapotranspiration.

Evapotranspiration (ET)

The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants. ET is in mm/day





Discharge, Depth, Time, and Area

$$Q_n * t = A_n * d_n$$

$$\mathbf{Q * t = A * d}$$

$$\mathbf{Q_g * t = A_n * dg}$$

Where:

$\mathbf{Q}$ =discharge ($\frac{L^3}{T}$),

$\mathbf{d_g}$ =depth of gross water requirement at head of the farm (L),

$\mathbf{d_n}$ =net depth of irrigation water (L),

$\mathbf{A_g}$ =total area of the irrigation project (L^2),

$\mathbf{A_n}$ =net area of irrigation project (L^2), and

$\mathbf{t}$ =is the time water application (T).

$$\mathbf{A_n = \frac{A_g}{1.14}}$$

Example(6): Given $Q = 50$ lps find (Q) in

$$\frac{l}{min}, \frac{l}{hr}, \frac{m^3}{sec}, \frac{m^3}{min}, \frac{m^3}{hr}, \frac{m^3}{day}.$$

Example (7): Given a discharge of 5 $\frac{m^3}{sec}$ diverted from irrigation source, irrigation efficiency = 90 %, CE = 85%, the discharge applied to a farm of total area = 1500 mishara for a period of 24 hr (irrigation time). Find the gross and net depth applied on the farm. Note: mishara = donam

H.W: Water is applied at a rate of 150 *l*/sec to irrigate a total area of 250 mish. The run off loss is 7 *l*/sec, ET = 10 mm/day. Find the net depth of water stored in the soil at the end of 24 hr irrigation time.

H.W. The required discharge to irrigate a farm of net area of 100 mish is 90 lps, once every week the consumptive-use is 20 mm/day the leaching requirements is 10% of net depth of irrigation. Find the time of irrigation.

Water Duty

The continuous discharge applied to irrigate a unit area, or is the area irrigated by one unit of continuous discharge.

$$\mathbf{W.D} = \frac{\mathbf{A_g}}{\mathbf{Q_g}}, \frac{\mathbf{A_n}}{\mathbf{Q_g}}, \frac{\mathbf{A_n}}{\mathbf{Q_n}}, \frac{\mathbf{Q_n}}{\mathbf{A_n}}, \frac{\mathbf{Q_g}}{\mathbf{A_g}}, \frac{\mathbf{Q_g}}{\mathbf{A_n}}$$

The water duty influences by:

- Type of soil,
- Type of plant,
- Temperature of air, and
- Salt concentration for soil.

The benefits of studying or calculating the water duty are:

- Reduce the economical distribution of water,
- Reduce the area of irrigation cross section canals and design of drainage networks, and
- Reduce the civil works at irrigation project.

Continuous and intermittent Relationship

$$Qc * tc = Qi * ti$$

Where

Qc: continuous discharge applied

tc: time of irrigation interval

Qi: intermittent discharge applied, and

ti: $time\ of\ application.$

Example (8): Given the flowing data, ET = 12 mm/day time of irrigation 1 day, $E_a = 95\ \%$, $A_g = 10\ ha$. Find WD Gha / Gm^3/s.

Example (9): Discharge is applied to a farm of 180 lps once every week, total area 60 ha F.C = 40 % by volume initial water content just before irrigation is 32% by volume, Rz = 1 m water losses = 20 % from net irrigation depth. Find water duty in Nmishra / 1Gm^3ps.

Example (11) : Given WD = 5.8 Glps / 1 Gha and total area = 600 ha water provided for 10 hr every 7 days. Find intermittent discharge.

Homework

1- Given ET of 6 mm/day, area irrigated = 30 mish, irrigation efficiency = 55%, and conveyance efficiency = 80%, time of application 1day . Find the WD in lps/1Gha, Glps/1Gha, and Tlps/1Gha.

2- Given a water duty of 4000 Gmish/1Gcumecs, CE = 70%, and the total area = 100 mish. Find the discharge at the head of canal and what is the net depth if the application efficiency is 80%.

3- Given a water duty of 0.9 Tlps/1Tha. The project is operated for 2 days a week. If the irrigated area is 500 mish and CE is 85%, Ea = 60%. Find the daily rate of ET. What is the depth of leaching requirement if it is equal to 15% of gross irrigation water and what will be the surface runoff.

Irrigation interval and irrigation time.

Irrigation interval: is the time between two consecutive irrigations.

$$\mathrm{II} = \frac{d_n}{\mathrm{ET}} \text{ , (days)}$$

$$\mathrm{II}_{max} = \frac{\mathrm{RA_w}}{\mathrm{ET}} \text{ , (days)}$$

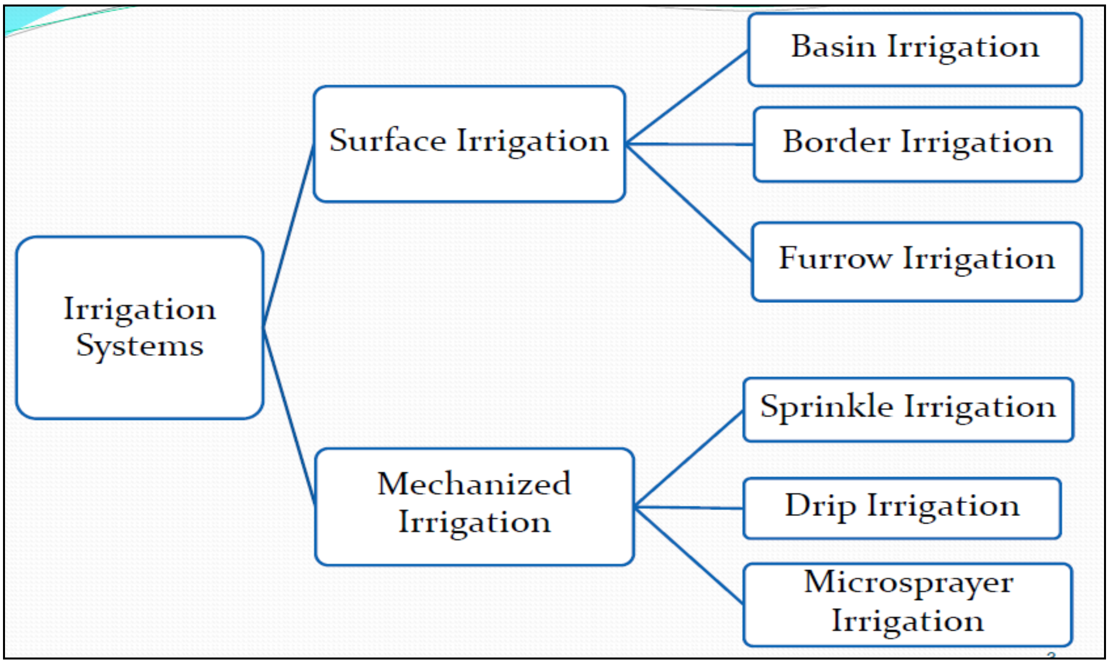
Irrigation time: is the time of irrigation process need to apply a specific volume of water in to a farm.

Example (12): given a soil of field capacity equal to 35% (by volume), Permanent wilting point 15% (by volume), root zone = 1 m, allowable depletion 50%, ET = 8 mm/day. What is maximum interval?

Methods of Irrigation

An adequate water supply is important for plant growth. When rainfall is not sufficient, the plants must receive additional water from irrigation. Various methods can be used to supply irrigation water to the plants. Each method has its advantages and disadvantages. These should be taken into account when choosing the method which is best suited to the local circumstances. Main Factors that should be considered when selecting an irrigation method are:

1.Crops to be grown.
2.Topography or physical site conditions.
3.Water supply.
4.Costs.
5.Operation and management skills.
6.Soils



1. Surface Irrigation Systems

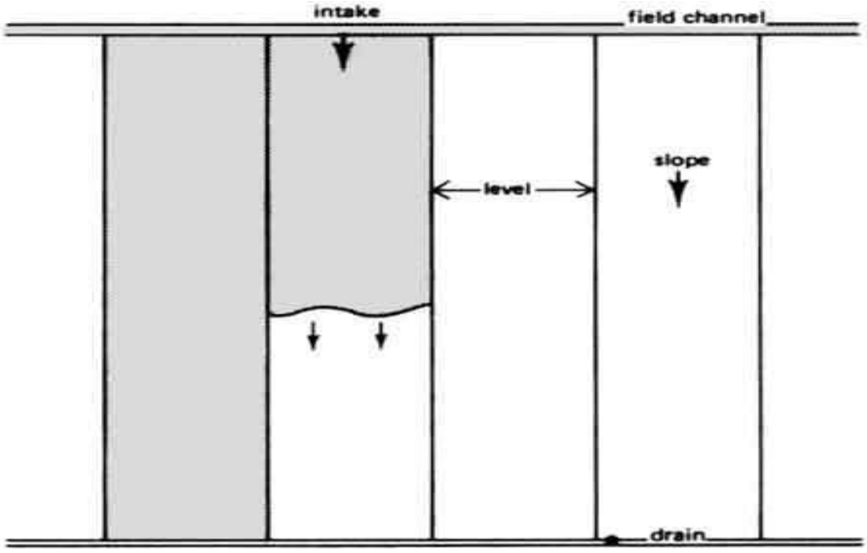
Surface irrigation is the application of water by gravity flow to the surface of the field. Either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders).

1.1. Basin Irrigation

rice grows best when its roots are submerged in water and so basin irrigation is the best method to use for such crops. The flatter the land surface, the easier it is to construct basins

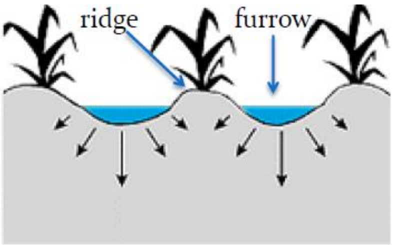
1.2. Border Irrigation

Borders are usually long, uniformly graded strips of land, separated by earth bunds. In Contrast to basin irrigation these bunds are not to contain the water for ponding but to guide it as it flows down the field



1.3. Furrow Irrigation

Furrows are small, parallel channels, made to carry water in order to irrigate the crop. The crop is usually grown on the ridges between the furrow



2. Mechanized Irrigation Systems

In such systems, water is distributed under low pressure through a piped network and applied as a small discharge to each plant or adjacent to it.

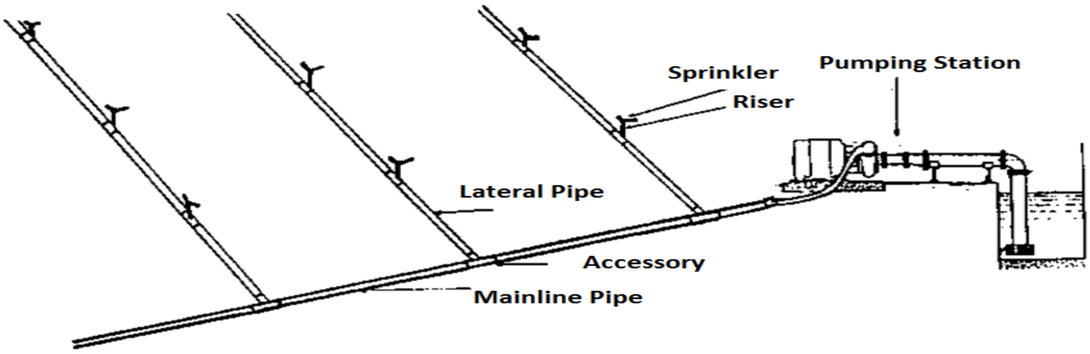
2.1. Sprinkle Irrigation

It is an artificial rain-making process. Water is distributed through a system of pipes by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump unit is usually a centrifugal pump which takes water from the source and provides adequate pressure for delivery into the pipe system. The most common types of sprinkle irrigation systems are:

1.Fixed-grid sprinkle irrigation system.
2.Linear move-sprinkle irrigation system.
3.Center-pivot sprinkle irrigation system

2.1.1. Fixed-grid sprinkle irrigation systems

They are used to irrigate small or medium agricultural fields or to irrigate public areas, playgrounds, and gardens. Sprinklers in such systems are fixed along a lateral pipe at equal distances and distribute water on circular areas



The main disadvantages of such systems are of high initial cost and it is easily affected by wind speed. Although, expensive land leveling in not required.

2.1.2. Linear-move sprinkle irrigation system

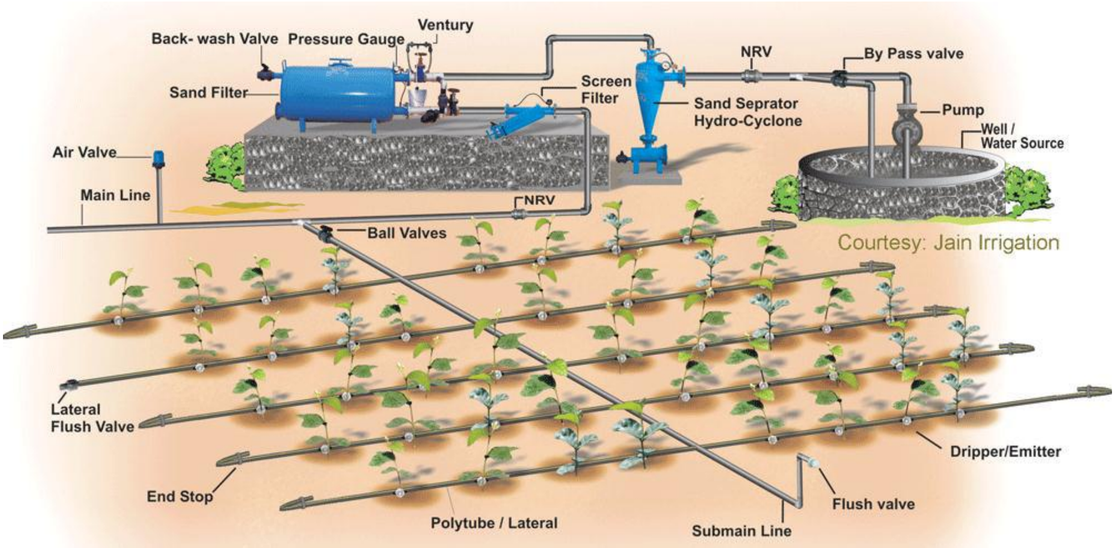
The linear system moves in a straight line through the field.The linear move machine is designed to be used on a rectangular field of large area

2.1.3. Center-pivot sprinkle irrigation system

Centre Pivots are anchored at one end, and rotate around a fixed central point. The sprinklers near the pivot cover less area so their water flow rates are less than those located near the end of the pivot where each sprinkler covers a much larger area. Pivots are generally suited to smaller areas. Because a circle only fills about 78% of a square, there is always the perception of wasted land. With these „pivoting lateral‟ machines, the machine operates as a linear move until it reaches the end of the field, and then pivots to do another irrigation run, producing what is referred to as a “racetrack‟ irrigation field.

2.2. Drip Irrigation

It delivers water directly to relatively small area adjacent to individual plants through emitters places along a water delivery line called a lateral or manifold.



Courtesy: Jain Irrigation

Drip irrigation water is generally applied daily or several times per week. Water applied should be very clean to avoid plugging of the emitters, therefore filtration system must be installed which represent a large portion of the cost for drip irrigation.

2.3. Microsprayers Irrigation

Micro systems are often more expensive than drip systems. Microsprayers have no rotating parts as in microsprinklers

Advantages and Disadvantages of Drip/Micro Irrigation Systems

The main advantages are:

1.They can be used effectively on extremely on steep ground. No other irrigation method can be used on extreme terrain.

2.They require minimal land grading.

3.They are more efficient than other irrigation methods.

4.Generally, there are no runoff problems.

The main disadvantages are:

1.Water must be available to the system on a very frequent and dependable basis.

2.They can have a very high initial cost in some situations.

3.More frequent maintenance is needed since they have different types of essential parts such as emitters, fitting, valves, etc.

Water Resources Engineering

Hydraulic Design of Open Channels

(1)

Lec.

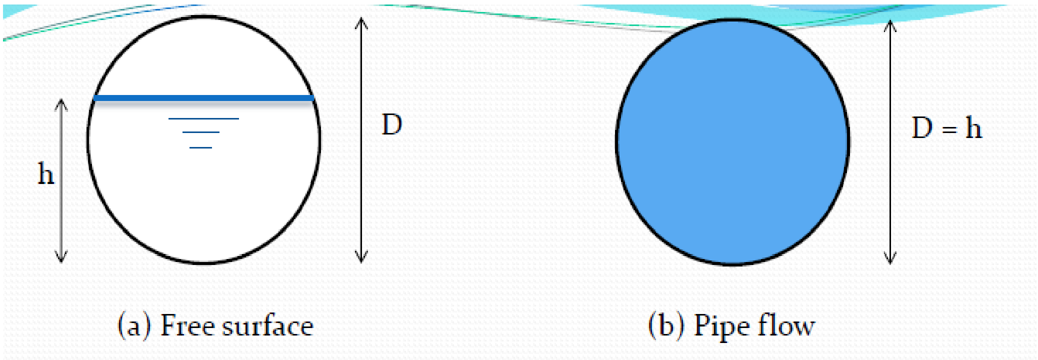
Ali Mezaal

Hydraulic Design of Open Channels

For carrying water from a reservoir to a field, a well-designated distribution system consisting of a net work of canals is required. Canal can be defined as artificial channel constructed on the ground to carry water from a river, another canal, or reservoir to the fields. The capacity of the irrigation canal depends upon the water requirement of the crops and the area irrigated (Water Duty).

Flow of water:

The flow of water in a conduit may be either open-channel flow or pipe flow (closed conduit). The main difference between them is that the open channel flow must have a free surface, whereas pipe flow (closed conduit) has none, since the water must fill the flow



(a) Free surface

(b) Pipe flow

Water flows in free surfaces by gravity; while it flows in pipe flow by pressure. The effect of gravity upon the state of flow is represented by Froude number.

$$F_r = \frac{V}{\sqrt{gD}}$$

Types of flow.

Steady and unsteady flow: Flow in open channel is said to be steady if the depth of flow does not changed with time or if it can be assumed to be constant during the time interval under considerations. The flow is unsteady if the depth changes with time.

$$\frac{\partial D}{\partial t} = 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (steady\ flow)$$

$$\frac{\partial D}{\partial t} \neq 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (unsteady\ flow)$$

- In most open channel problems it is necessary to study flow behavior only under steady conditions.

Uniform and non-uniform (varied) flow: open channel flow is said to be uniform if the depth of flow is the same at every section of channel. A uniform flow may be steady or unsteady, depending on whether or not depth changes with time. Flow is varied if the depth of flow changes along the length of the channel. Varied flow may be steady or unsteady flow.

$$\frac{\partial \mathrm{D}}{\partial \mathrm{S}} = 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .\quad (\text{uniform flow})$$

$$\frac{\partial \mathrm{D}}{\partial \mathrm{S}} \neq 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots . (\text{varied flow})$$

The classification of open channel flow is summarized as follows:

1) Steady flow
    a) Uniform flow
    b) Varied flow
        i. Gradually varied flow
        ii. Rapidly varied flow.
2) Unsteady flow
    a) Unsteady Uniform flow
    b) Unsteady Varied flow
        i. Gradually varied unsteady flow
        ii. Rapidly varied unsteady flow

State of flow.

Depending on the effect of viscosity relative to inertia, the flow may be laminar, turbulent, or transitional.

The effect of viscosity on inertia can be represented by *Reynolds number*, where it defined as:

$$R = \frac{VL}{\nu} = \frac{VD}{\nu}$$

Where:

L = is a characteristic length, L,

V = is the velocity of flow, L/T, and

ν = is the kinematic viscosity, L^2/T.

- ❖ $R < 2000$ … … … … … … … … flow is laminar
- ❖ $2000 < R < 4000$ … … … … flow is transient
- ❖ $R > 4000$ … … … … … … … .. flow is turbulent

The effect of gravity upon the state of flow is represented by a ratio of inertial forces to gravity forces. This ratio is given by the Froude number, defined as:

$$F_r = \frac{V}{\sqrt{gL}} = \frac{V}{\sqrt{gD}}$$

$F_r < 1$ ….flow is subcritical.

$F_r > 1$ … … … … … … … … … … . … … … … … … … …. flow is supercritical.

$F_r = 1$ … … … … … … … … … … … . … … … … … … . … flow is critical.

Chezy and Manning equations.

Chezy formula:

$$V = C\sqrt{R * S}$$

Where:

V = the velocity,
C = Chezy coefficient,
R = hydraulic radius, and
S = slope of the canal.

Manning formula:

$$V = \frac{1}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}}$$

Where:

n = manning roughness coefficient.

Classification of canals based on discharge:

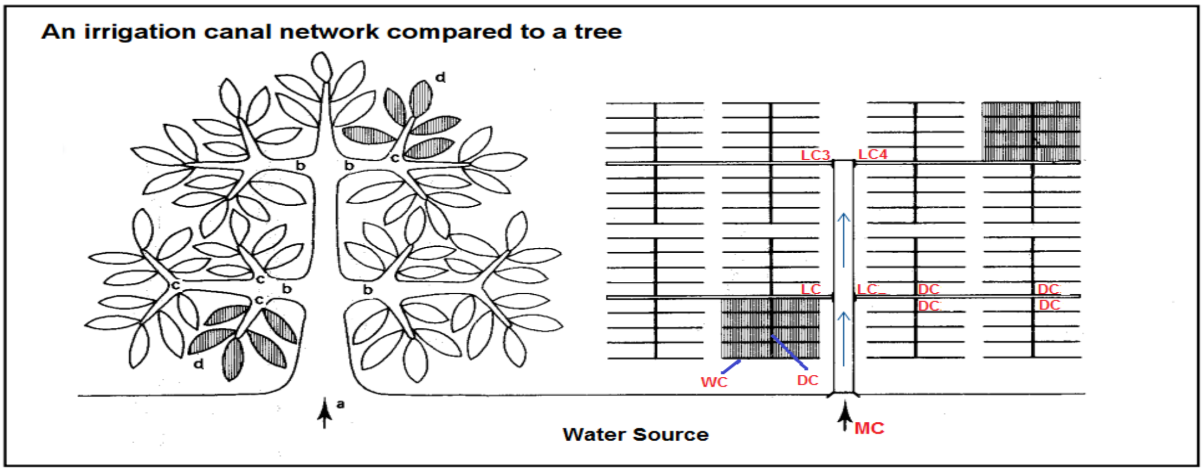
1. Main Canal (MC): It is the largest canal in the system which takes off from a water source.
2. Lateral or branch canals (LC): the canals branches from MC to feed the distributaries canal.
3. Distributary canals (DC): Smaller canals take off from the branch canals and distribute their supply through outlets into water courses.
4. Water courses (WC): The smallest canals which feeds the water to the farm units.

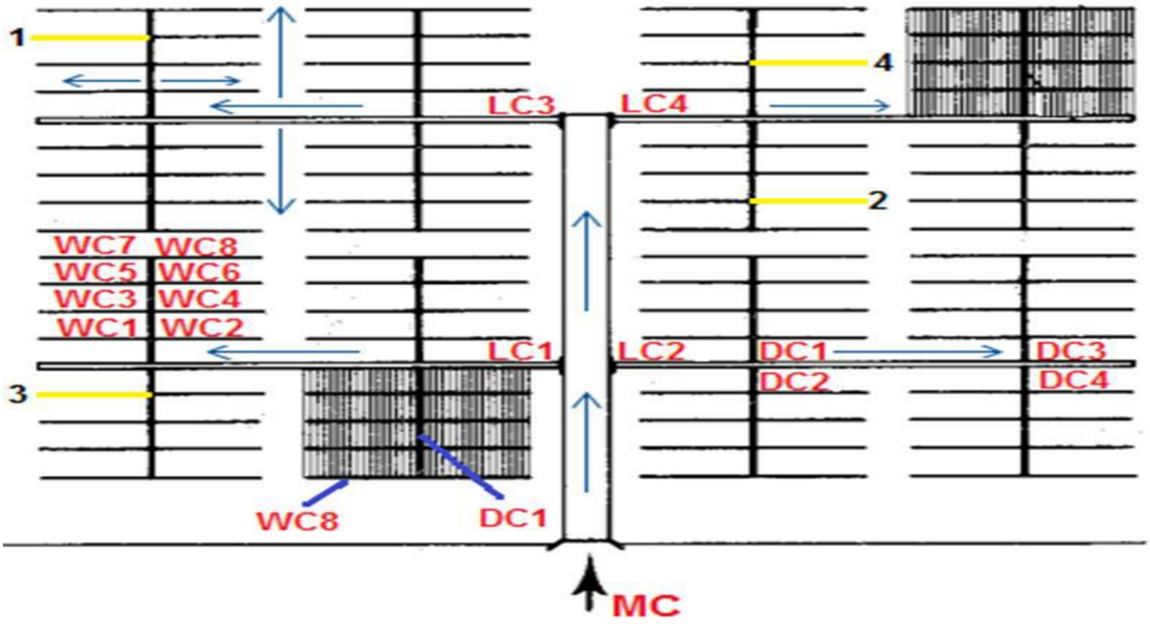
Canals		Drains	
Main Canal	MC	Main Drain	MD
Lateral or Branch Canal	LC or BC	Lateral Drain	LD
Distributary Canal	DC	Main Collector Drains	MCD
Water Course	WC	Collector Drain	CD
Farm Canal	FC	Field Drain	FD

- Irrigation unit: is the area irrigated by one water course.
- Gross area of irrigation unit = (45-70) ha, (8-20) farm.
- Area of the farm = (20-30) do.

<u>**Naming canals:**</u> Starting from the beginning with flow direction, canals take:

1. Odd numbers if they’re on the left side of the flow direction.
2. Even numbers if they’re on the right side of the flow direction





Exercise: Name the colored water courses:

1.LC3 – DC4 – WC5

2.LC4 – DC2 – WC5

3.LC1 – DC3 – WC2

4.LC4 – DC1 – WC4 **Basic design assumption:**

1.The flow is uniform and steady state.

- Uniform flow: the depth of flow doesn't change with distance.
- Steady flow: the depth of flow doesn't change with time.

2.Velocity range is (0.5-1.5) m/s which produces no sedimentation and no erosion

Canal Design Flow rates:

The canal capacity is that needed to supply the gross field irrigation requirement.

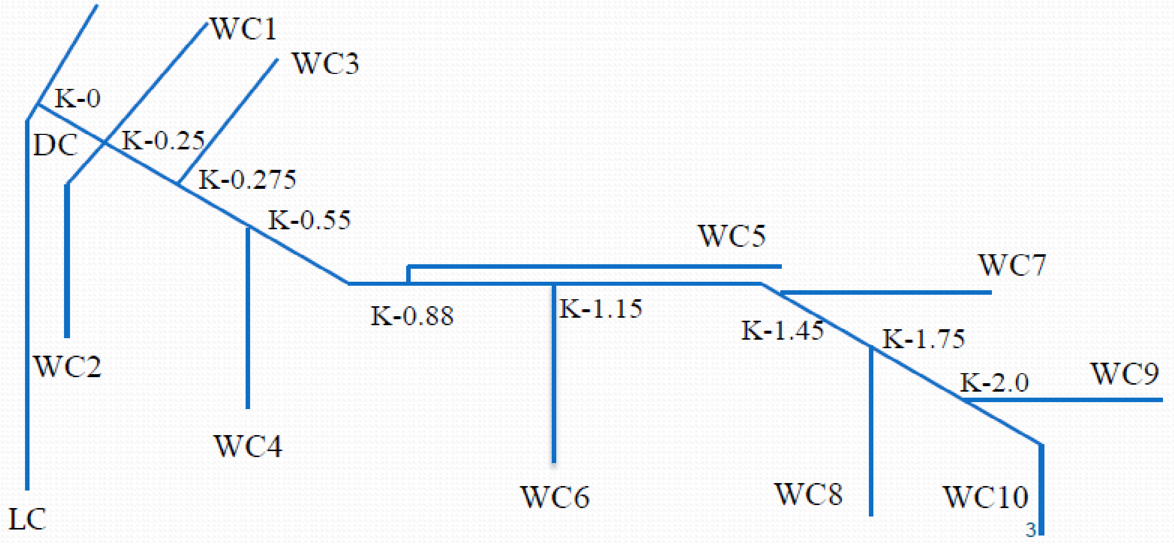
The capacity of a water course is then calculated depending on water duty of that field. Other canals' capacity can be calculated by considering evaporation and seepage losses, i.e. conveyance efficiency (CE).

Evaporation losses are insignificant relative to seepage losses. Canals are lined to control the seepage. But canal lining deteriorates with time and hence, significant seepage losses continue to occur from a lined canal. Therefore, seepage loss must be considered in the design of a canal section.

Average seepage losses in unlined canals are 415 lps and in lined canals are 3 lps.

Example (1) : Find the total discharge of the distributary canal shown in figure below if you know that WD = 4800 (G mish / G m^3/s) and seepage losses = 16 lps / km.

Water Course	1	2	3	4	5	6	7	8	9	10
Area, G mish	60	120	150	240	280	250	250	300	260	120



Solution:

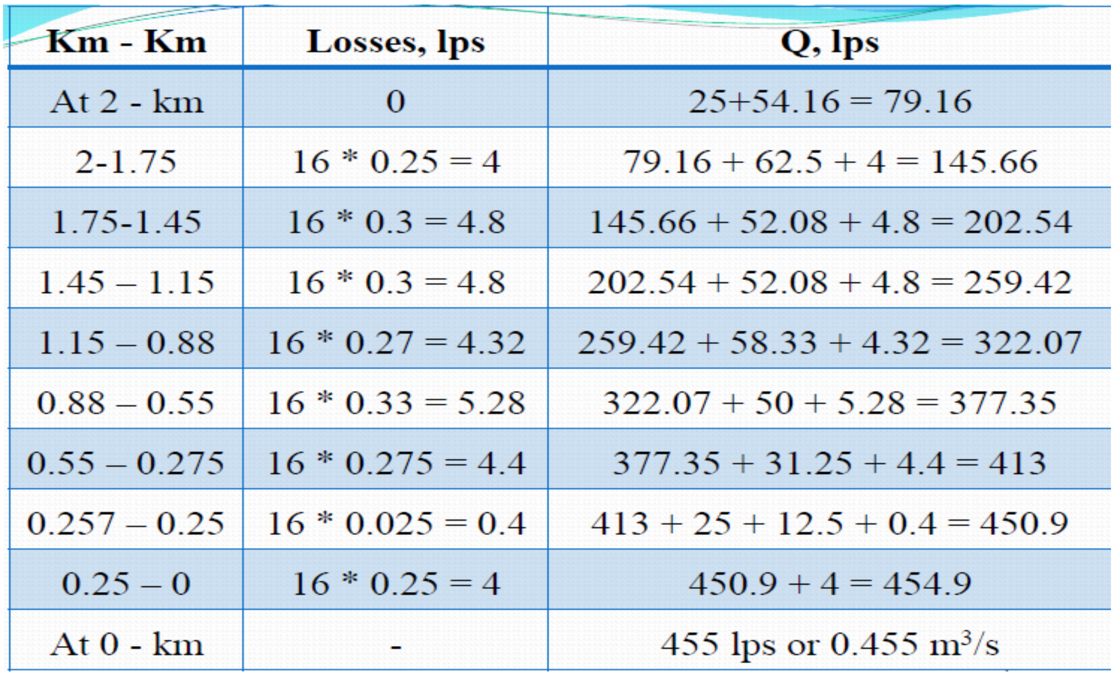
$$W.D = \frac{A}{Q} \longrightarrow Q = \frac{A}{W.D}$$

$$Q_1 = \frac{60\ Gmish}{4800\ \frac{Gmish}{Gm^3/s}} = 0.0125 * 1000 = 12.5\ lps$$

WC	1	2	3	4	5	6	7	8	9	10	Sum
A, G mish	60	120	150	240	280	250	250	300	260	120	2030
Q, lps	12.5	25	31.25	50	58.33	52.08	52.08	62.5	54.16	25	423

$$CE = \frac{423}{455} * 100\% \cong 93\%$$

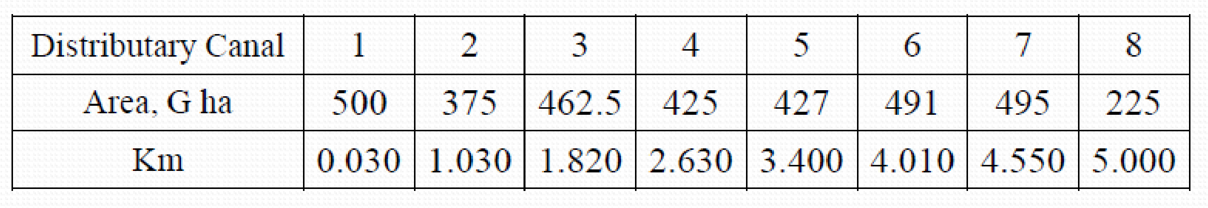
$$WD = \frac{2030}{0.455} = 4461.5\ \frac{Gmish}{Gm^3/s}$$



Km - Km	Losses, lps	Q, lps
At 2 - km	0	25+54.16 = 79.16
2-1.75	16 * 0.25 = 4	79.16 + 62.5 + 4 = 145.66
1.75-1.45	16 * 0.3 = 4.8	145.66 + 52.08 + 4.8 = 202.54
1.45 – 1.15	16 * 0.3 = 4.8	202.54 + 52.08 + 4.8 = 259.42
1.15 – 0.88	16 * 0.27 = 4.32	259.42 + 58.33 + 4.32 = 322.07
0.88 – 0.55	16 * 0.33 = 5.28	322.07 + 50 + 5.28 = 377.35
0.55 – 0.275	16 * 0.275 = 4.4	377.35 + 31.25 + 4.4 = 413
0.257 – 0.25	16 * 0.025 = 0.4	413 + 25 + 12.5 + 0.4 = 450.9
0.25 – 0	16 * 0.25 = 4	450.9 + 4 = 454.9
At 0 - km	-	455 lps or 0.455 m^3/s

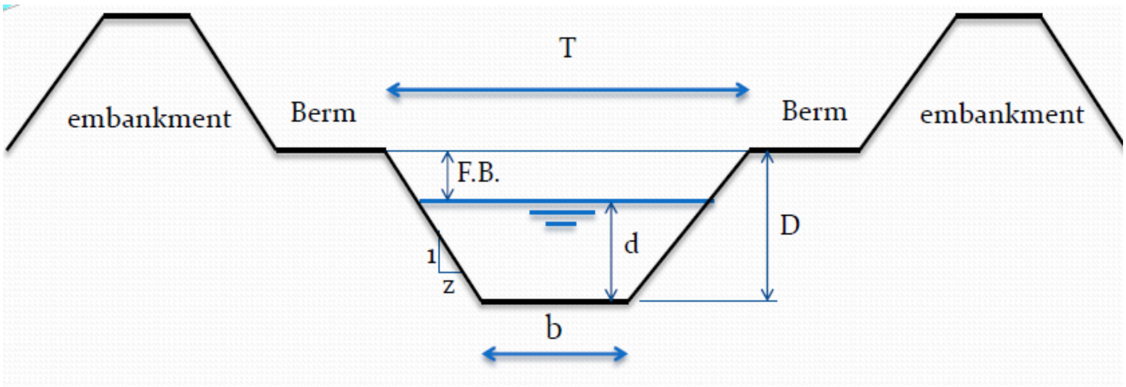
Homework:

Find the total discharge of the lateral canal if you know that WD = 5.1 (G mish / N lps) and seepage losses = 30 lps / km. Also, calculate CE.



Distributary Canal	1	2	3	4	5	6	7	8
Area, G ha	500	375	462.5	425	427	491	495	225
Km	0.030	1.030	1.820	2.630	3.400	4.010	4.550	5.000

Design Canal Cross Section: Typical section of canal



b: bed width.

d: water depth.

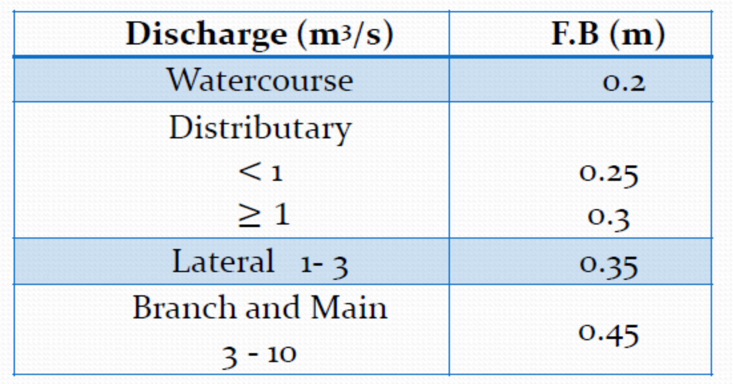
T: top width.

F.B: freeboard.

(z:1): side slope.

D: canal depth (D = d + F.B)

Freeboard: is the vertical distance from the top of the channel to the water surface.



Discharge (m^3/s)	**F.B (m)**
Watercourse	0.2
Distributary	
< 1	0.25
≥ 1	0.3
Lateral 1- 3	0.35
Branch and Main 3 - 10	0.45

Berm: the area between canal cross section and embankment used for maintenance.

Side slope: the side slope of channels depends upon the kind of material. The table below gives a general idea of the slopes suitable for use with various kind of material.

Material	**Side slope**
Rock	Nearly vertical
Muck peat soils	$^{1}/_{4}:1$
Stiff clay or earth with concrete lining	$^{1}/_{2}:1$ to $1:1$
Earth with stone lining, or earth with large channels	$1:1$
Firm clay or earth for small ditches	$1\,^{1}/_{2}:1$
Loose sandy earth	$2:1$
Sandy loam or porous clay	$3:1$

Water way: the part of canal cross section in which the water flows.

Canal cross section designed depending upon Manning's formula

Manning's formula:

$$V = \frac{1}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}}$$

where:

V: velocity of flow, m/s,

n: manning's roughness coefficient, dimensionless,

R: hydraulic radius of canal, m, and

S: slope of energy line (E.L.) which is generally equal to the slope of the canal, cm/km.

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

where:

A: wetted area, m^2, and

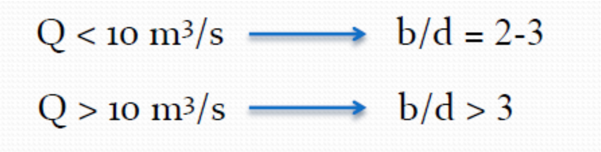
P: wetted perimeter, m.

Continuity equation:

$$Q = V * A$$

Q: flow discharge, m^3,
A: Area of cross section, m^2.

Water way calculation: Canal cross section can be designed using various methods. Empirical method will be adopted. Assume b/d and then apply manning's formula.



$Q < 10\ m^3/s \longrightarrow b/d = 2\text{-}3$

$Q > 10\ m^3/s \longrightarrow b/d > 3$

Design limitations:

- Bed width (b) must be round number
- $S_{min} = 0.00015 * Q^{-0.2}$ So that no sedimentation occurs.
- Fr <0.7 So that no hydraulic jump occurs.

Example (3)

Given discharge = 27 m^3/s, side slope (z:1) = (1.5:1), S = 20 cm/km, and n = 0.016. Design a lined canal section by using empirical method.

Example(4) Find the maximum discharge through an irrigation canal having the bed width 4 m and fully supply depth is 1.5 m. Knowing that n = 0.02, S = 0.0002, and side slope 1:1.

Example (5)- Homework

Design an irrigation canal with the following data:

- Discharge of the canal = 24 m3/s,
- Permissible mean velocity = 0.8 m/s,
- Bed slope = 1 m for 5000 m,
- Side slope = 1:1, and

Manning's coefficient = 0.013