

Irrigation and Drainage Engineering
Civil Engineering Department
3rd Year

Irrigation

CHAPTER ONE

1. Introduction

1.1 Irrigation Definition

Irrigation is defined as the application of water to soil for the purpose of supplying the moisture essential for plant growth.

1.2 Necessity of Irrigation

Irrigation is required to provide the quantity of water required for the growth of crop during fixed intervals of time depending upon the rainfall, type of soil and type of crop.

An area is said to be Arid when agriculture is not possible without irrigation.

An area in which only inferior crops (المحاصيل الرديئة) can be grown without irrigation is called Semi-Arid region (مناطق شبه جافة).

1.3 Advantages and Disadvantages of Irrigation

Advantages and disadvantages of irrigation are briefly given below:-

1.3.1 Advantages

- a. Protection from famine when there is no rain.**
- b. Improvement in yield and value of crops.**
- c. Addition to the wealth of the country.**
- d. Generation of hydro-electric power.**
- e. Within limited irrigation, the area becomes better from the point of view of weather.**
- f. Domestic water facility.**
- g. Improvement of communication (roads on canal banks)**
- h. Canal plantation.**
- i. Improves of groundwater storage (water lost due to seepage add to groundwater.**
- j. Facilities for bathing and cattle (الماشية) watering.**

1.3.2 Disadvantage

- a. Excessive seepage and leakage of water forms marshes and ponds along the sides of canal.**
- b. The area gets water-logged.**
- c. The locality becomes damp due to lowering of Temperature.**

1.4 The engineer task in irrigation

Traditionally, the task of the engineer was to provide a system for conveying water from a source and distributing it equitably over an agricultural area. At a later stage and water logged ground demonstrated the fact that the removal of

unwanted water is an important as the irrigation water supply itself and so that engineer is now required to design the complementary supply and drainage systems.

CHAPTER TWO

Water Resources and Soil Moisture

2.1 Irrigation Water Resources

Irrigation water is supplied to supplement water from the following four sources, none of which should be ignored when irrigation water requirements are estimated:-

- a. Precipitation**
- b. Atmospheric water**
- c. Flood water**
- d. Groundwater**

2.1.1 Precipitation

To be of greatest benefit, precipitation should have the following characteristics:-

- a. Amounts should be sufficient to replace moisture depleted from the root zone.**
- b. Frequency should be often enough to replenish (تجدید) the soil moisture before plants suffer from lack of moisture**
- c. Intensity should be low enough so that water can be absorbed by the soil.**

In only a few locations will precipitation fulfill of the above requirements at all times to produce maximum yields. The failure of precipitation to fill these requirements is use in increasing amounts of irrigation in arid areas.

2.1.2 Atmospheric Water (other than Precipitation)

In some parts of the world the contribution of atmospheric water in forms other than precipitation is significant.

The atmospheric conditions which generally prevail to make this source of water significant are:-

- a. Considerable dew formation.**
- b. Fog and clouds.**
- c. High humidity.**

These conditions reduce the plants water need by reducing the forces causing water to transpire from the plant.

2.1.3. Flood Water

Flood water is similar in some respects to irrigation water, but it is not supplied by man. As floods pass over surface of the land, water is absorbed by the soil and stored for subsequent use by plants. In some regions agricultural production is wholly dependent upon flood water.

2.1.4. Ground Water

Upward movement of groundwater by capillarity from the water table into the root zone can be major source of water for plant growth.

To be most effective without seriously restricting growth , ground water should be near but below the depth from which the major portion of the plants water needs are extracted.

The optimum depth of the water table is that depth which gives the maximum economic return.

2.2 The behavior of moisture in the soil

When water is added to the soil by rain or irrigation, the soil surface becomes saturated, the pores are filled and air is driven out. The water then travels downwards under gravity and capillarity.

If the water supply is discontinued water still tends to travel downwards under soil, ie drainage takes place.

Water moves between two points if there is a force or potential gradient acting between them, the direction of flow being from the higher to the lower potential. In the soil, the potential acting on the moisture:-

- a. Matric potential due to capillary forces.
- b. Osmotic potential due to dissolved salts in the water.
- c. The gravity and pressure potential due to the position of moisture with respect to a fixed datum level.

2.3 Classification of soil moisture

Because some moisture is not available to the plant , it is convenient to classify the various forms of moisture occurring in the soil.

2.3.1 Gravitational water

This occupies the larger pores of the soil and drains away under the influence of gravity. The upper limit of gravitational water is when the soil is saturated. The saturation capacity is then equal to the porosity of the soil which may be expressed as:

$$2.1----- P = \frac{100(S-V)}{S}$$

Where:-

P:- porosity % by volume

S:- density of the soil (gm/cc)

V:- bulk density of the dry soil (gm/cc)

2.3.2 Capillary water

This water is held by surface tension in the pores between the particles. The upper limit is when all the gravitational water has drained away, soil in this state is said to be at field capacity.

Capillary water is the principal source of water to the plant.

2.3.3 Hygroscopic water

This water is held as a very thin film round the soil particle, and is held so firmly that it is unavailable to the plant except perhaps in extremes cases of drought.

2.4 Field Capacity (F.C.)

When gravitational water has been removed, the moisture content of the soil is called Field Capacity.

In practice, field capacity is usually determined two days after irrigation. Samples from the soil profile are taken initially and the moisture content determined by drying in an oven. The field capacity is found from the equation:-

$$\text{Field capacity \%} = \frac{\text{Loss in water}}{\text{Final dry weight}} \times 100 \text{-----} 2.2$$

2.5 Permanent Wilting Point (P.W.P)

The soil moisture content when plants permanently wilt is called the permanent wilting point. It is at the lower end of the available moisture range.

As in approximate, the permanent wilting point can be estimate as:

$$p.w.p = \frac{F.C.}{f} \text{ ----- 2.3}$$

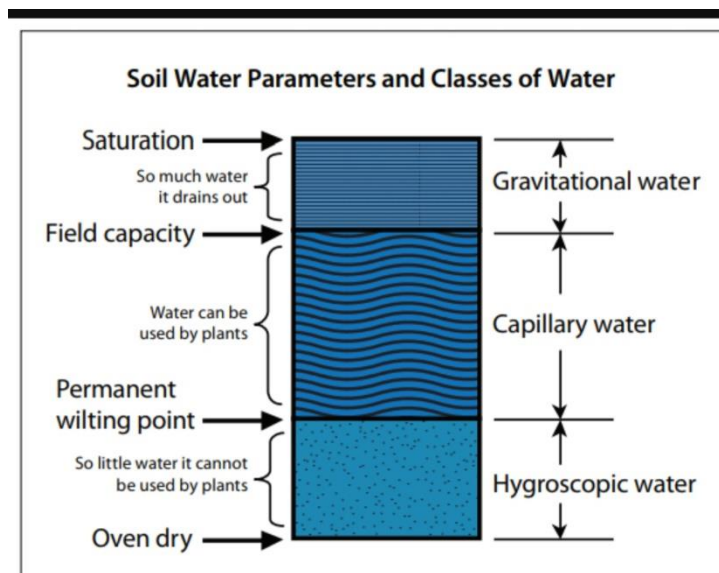
where :-

p.w.p. :- permanent wilting point percentage

F.C. :- Field capacity

f :- Factor varying from 2 to 2.4, depending upon the amount of silt in the soil (2 for low silt content and 2.4 for high silt content).

Relationships between the various terms used in identifying classes and availability of soil water are shown in figure below:-



Fig() Soil water parameters and classes of water

2.6 Available Moisture Content

It is the moisture at field capacity minus that at permanent wilting point or :-

$$(A.M.C.)_w = F.C. - P.W.P. \text{ -----2.4a}$$

Available moisture as weight as.

Available moisture content as volume as :-

$$(A.M.C.)_v = (F.C. - P.W.P.) A_s \text{ -----2.4b}$$

Where A_s is cross-sectional area

Available moisture content as depth :-

$$(A.M.C.)_d = (F.C. - P.W.P.) D \text{ -----} 2.4c$$

Where D is the depth of the soil.

2.7 Readily Available Moisture Content (R.A.M.C.)

Soil moisture content near the wilting point is not readily available to the plant. It has been used to refer to that portion of the available moisture that is most easily extract by plants, approximately 75 percent of available moisture or :-

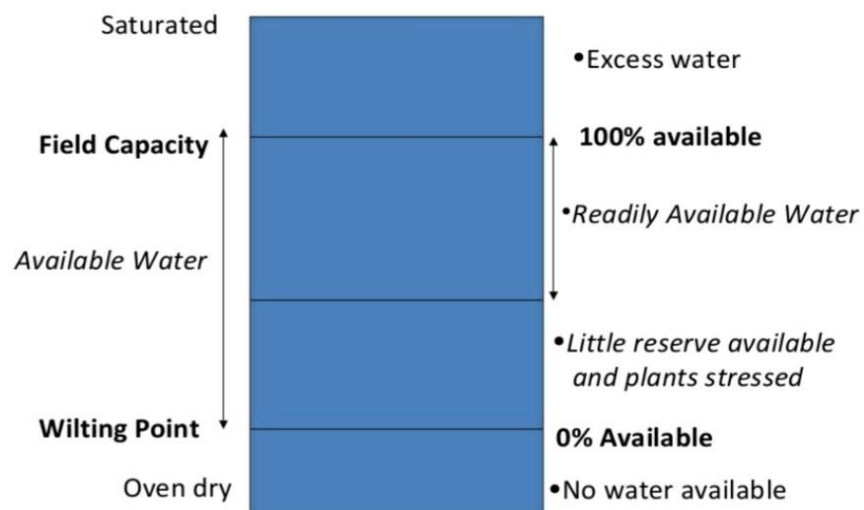
$$R.A.M.C. = 75\% \text{ A.M.C.}$$

2.8 Depth of Soil

Adequate depth of soil can store satisfactory amounts of irrigation water at each irrigation.

Shallow soils require frequent irrigations to be keep crops growing.

Available Water in the Soil



2.9 Specific Gravity

2.9.1 Real Specific Gravity

It is a dimensionless quantity and is define as the ratio of the weight of a single soil particle to the weight of a volume of water equal to the volume of the particle of soil.

$$R_s = \frac{\text{Weight of particle}}{\text{weight of same volume of water}} \text{-----} 2.5$$

2.9.2 Apparent Specific Gravity (Asg)

It is the ratio of the weight of a given volume of dry soil, air space included, to the weight of an equal volume of water. This ratio is known also as a bulk density . W_{OD}

$$Asg = \frac{W_{OD}}{(V_s + V_{ip})\gamma_w} \text{-----} 2.6$$

Where:

Asg = apparent specific gravity of solids (aggregate)

W_{OD} = oven dry weight of aggregate

V_s = volume of solids

V_{ip} = volume of impermeable pores

γ_w = unit weight of water (1 g/ml)

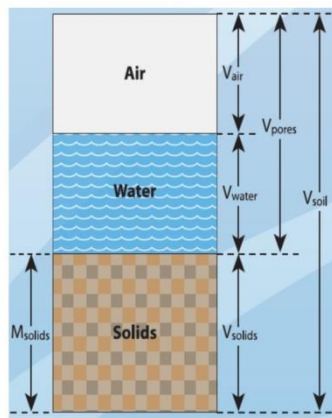


Fig () Structural composition of soil containing soil fraction (V_{solids}) and pore space for air (V_{air}) and water (V_{water})

2.10 The Soil Moisture Tension

The water in the capillary tube is held in a position at a height (h) above the water surface by an upward force due to surface tension in the water.

Since the surface tension of water causes a suction on water within the soil, the term (suction head) is being used instead of (tension head). Suction head is generally expressed in terms of an equivalent length of vertical water columns as:-

$$h = \frac{1.5}{d} \text{ --- 2.7}$$

Where :

h =depth of capillary tubes in soil (cm)

d =diameter of grains (mm)

Example1:- What is the depth of water stored in root zone between two limits if :-

- a. Field capacity of the soil = 28%
- b. Permanent wilting point = 13%
- c. Density of soil = 1.3 gm/cc
- d. Effective depth of root zone = 70 cm

Solution :-

$$\text{Available moisture} = 28 - 13 = 15\%$$

$$\begin{aligned} \text{Readily available moisture} &= 0.75 \text{ Available moisture} \\ &= 0.75 \times 15\% = 11.25\% \end{aligned}$$

$$\text{Optimum moisture} = 28 - 11.25 = 16.75\%$$

It means that moisture will be filled by irrigation between 16.75% and 28%

$$\begin{aligned}\text{Depth of water stored in root zone} &= \frac{y_d}{w} (\text{field capacity} - \text{optimum moisture}) \\ &= \frac{1.3}{1} * 0.7 (0.28 - 0.1675) \\ &= 0.102375 \text{ m} = 10.24 \text{ cm.}\end{aligned}$$

CHAPTER THREE

Consumptive Use Water Supplies Required For Irrigation

3.1 Duty Of Water (D)

Duty of water is the relationship between the volume of water and area of the crop it matures. It is expressed in terms of unit discharge flowing for a time equal to the base period of the crop.

A given quantity of water will be able to provide irrigation over a smaller area in respect of crop whose water requirement is more and hence duty will be less. Also duty of a given quantity of water is different at different points along the canal. For example duty of water at the head of water course will be less than the duty of water on the field because when water flows from the head of water course and reaches the field some of it is lost in transit.

- **Duty of Water (D)**

The term **duty** means the "**area of land**" that can be irrigated with unit volume of irrigation **water**. Quantitatively, **duty** is defined as the area of land expressed in hectares that can be irrigated with unit discharge, that is, 1 cumec flowing throughout the base period, expressed in days.

If water flowing at a rate of one cubic meter per second, runs continuously for B days, and matures 200 hectares, then the duty of water for that particular crop will be defined as 200 hectares per cumec to the base of B days. Hence, duty is defined as the area irrigated per cumec of discharge running for base period B. The duty is generally represented by the letter **D**.

Duty is classified under the following categories:-

- a. High duty:-** When a small amount of water matures comparatively larger area under a crop.
- b. Low Duty:-** When large quantity of water matures a comparatively smaller area under a crop.
- c. Duty inclusive and exclusive of rainfall.** During the base period of the crop, there may be rainfall on different occasions. If this water is included, duty will be high. Duty exclusive of rainfall will be low.

Factors Affecting Duty

- 1. Type of crop:-** Duty will be low for a crop required more water
- 2. Type of soil:-** Where the permeability is more, the duty is less
- 3. Climatic conditions :-** Minimum temperature and maximum humidity will reduce the evaporation loss and increasing the duty.
- 4. Rainfall:-** If some of the rain, falling directly over the irrigated land is useful for the growth of the crop, so less irrigation water will be required and the duty is more.
- 5. Efficiency of cultivation method (including tillage and irrigation.** If the irrigation water is used economically , then the duty of water will improve.

Importance of Duty

It help us in designing an efficient canal irrigation system. Knowing the total available water at the head of a main canal and over all duty for all the crops. Required to be irrigated in different seasons of the year, the area which can be irrigated can be worked out.

3.2 Base Period or Growth Period (B)

Base period is the time between the first watering of a crop during sowing to its last watering before harvesting. It is expressed in days.

3.3 Delta (Δ) $\Delta = \frac{V}{D}$

Every crop requires certain amount of water after interval of time during its growth. The water required by the crop during its growth. The water required by the crop during its full growth may be expressed as the depth of water which will stand on the field, if all the water supplied were to stand above the surface without evaporation or percolation. This total depth of water shown in (cm) is call Delta (Δ)

- **Delta for certain crops**

The average values of deltas for certain crops are shown in table. These values represent the total water requirement of the crops. The actual requirement of irrigation water may be less, depending upon the useful rainfall. Moreover, these values represent the values on field, i.e. 'delta on field' which includes losses.

Table: Average Approximate Values of Δ for Certain Important Crops in India	
Crop	Delta on field(cm)
Sugarcane	120
Rice	120
Tobacco	75
Garden fruits	60
Cotton	50
Vegetables	45
Wheat	40
Barley	30
Maize	25
Fodder	22.5

3.4 Relationship between D , B , Δ

Let the base period of the crop (B) days and one cumec of water is applied to it for the full base period for its maturity.

The volume of water used in growing the crop is :-

$$V = 60 \times 60 \times 24 \times B = 86400 B \text{ m}^3$$

If D is the duty for the crop, thus the quantity of water (86400 B) matures D hectares of land or $10^4 D \text{ m}^2$ of area (Δ)

$$= \text{volume/area} = 86400B/10^4D = 8.64B/D \quad \text{m}$$

$$\text{Or } \Delta = 864B/D \text{ cm} \text{-----} 3.1$$

Example1:- the duty of a given crop is 432 hectares/cumec when the base period of the crop is 100 days. Find delta for the crop.

$$\begin{aligned} \text{Solution :- } \Delta &= (\text{cm}) = 864B/D \quad \text{where B in days and D in hectares/} \underline{\text{cumec}} \\ &= 864 \times 100 / 432 = 200 \text{ cm.} \end{aligned}$$

Example2 :- If rice requires about 10cm depth of water at an interval of about 10 days and the base period for rice is 120 days, find out the delta for rice.

Solution:- Water is required at an interval of 10 days for a period of 120 days. It means 12 number of water are required. Therefore, total depth of water required = $10 \times 12 = 120 \text{ cm}$, Hence Δ for rice = 120 cm

Example3 :- If wheat requires about 7.5 cm of water after every 35 days, and the base period for wheat is 140 days, find out the value of delta for wheat.

Solution:- Water is required at an interval of 35 days up to 140 days. This means that $140/35 = 4$ no. of watering are required.

The depth of water required each time = 7.5 cm

Total Depth of water required in 140 days = $4 \times 7.5 = 30 \text{ cm}$

Hence Δ for wheat = 30 cm

