CIVIL ENGINEERING

Irrigation Engineering

Comprehensive Theory
with Solved Examples *and* Practice Questions

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Irrigation Engineering

EDITIONS

First Edition : 2015
Second Edition : 2016
Third Edition : 2017
Fourth Edition : 2018
Fifth Edition : 2019
Sixth Edition : 2020
Seventh Edition : 2021
Eighth Edition : 2022
Ninth Edition : 2023
Tenth Edition : 2024
Eleventh Edition : 2025

Twelfth Edition : 2026

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CHAPTER

1

Introduction

1.1 INTRODUCTION

Plants being living beings require air and water for their growth and survival like human beings. The requirement of water varies depending upon type of plant. Although, water is supplied to plants by nature in form of rainfall or through flood waters of river, but sometimes the requirement of plant is more than that provided by rainfall or it may happen that time of requirement of water of plant is different from time of rainfall. In that case, water is supplied to them by artificial means and the process is known as irrigation. In this chapter, we will discuss about various advantages and disadvantages of irrigation, its types and various methods by which water can be supplied to plants effectively.

1.1.1 Irrigation

Irrigation may be defined as the process of artificial application of water to the soil or land for the growth of agricultural crops. In other words, it is a science of planning and designing a water supply system for the agricultural land to protect the crops from adverse effects of weather.

Main concerns in irrigation are as follows:

(i) What should be the methods of irrigation?

(ii) How much moisture could be retained by the soil in their pores?

(iii) What should be the adequate time to irrigate the soil (i.e. optimum frequency of irrigation)? In other words, after how much depletion of moisture level, we should apply the next watering?

1.1.2 Advantages of Irrigation

(i) **Increase in crop yield:** Increase in crop yield occurs on account of good irrigation systems leading to increase in food production

(ii) **Protection against famines:** Food production of a country can be increased by availing irrigation facilities. This helps preventing famine situations.

(iii) **Revenue Generation:** Assumed supply of irrigation water leads to growing of superior crops by the farmers. Farmers become prosperous by selling the crops while governments revenue is generated by imposing taxes on irrigation water.

(iv) **Avoidance of mixed cropping:** Mixed cropping means sowing of two or more crops together in the same field when weather conditions are not favorable for a particular type of crop. The need of mixed cropping is eliminated if we have good irrigation facility.

(v) **Navigation:** Irrigation canals may be used for inland navigation. Inland navigation is useful for communication and transportation.

(vi) **Hydroelectric power generation:** Major river valley projects are planned to provide hydroelectric power together with irrigation. Thus, at the same time dual purpose is served.

(vii) **Generation of employment opportunities:** During construction of irrigation works like canal headworks, weir/barrage, overhead irrigation works, employment opportunities are generated.

1.1.3 Disadvantages of Irrigation

(i) **Wastage of irrigation water:** Abundant supply of irrigation water tempts the cultivators to use more than the required amount of water.

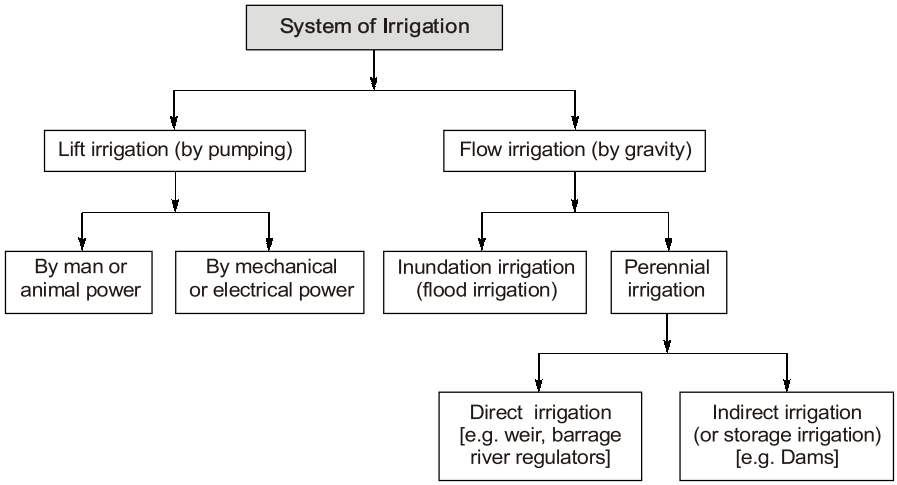
(ii) **Formation of marshy land:** Excessive seepage of water from irrigation canals may lead to formation of marshy lands along the course of the canals.

(iii) **Dampness in weather:** Temperature of the commanded area of irrigation project gets lowered considerably and the area may become damp. Dampness in the area lead to occurrence of diseases originating from dampness.

(iv) **Loss in valuable lands:** In various cases, valuable lands get submerged when storage reservoirs are formed on account of construction of weirs, barrages or dams.

1.2 SYSTEMS OF IRRIGATION

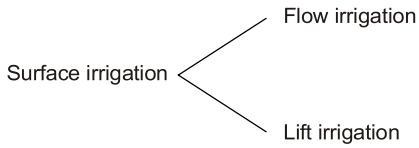
In irrigation system, there are surface irrigations where you provide water on the surface by gravity force (flow Irrigation); and there is pressurized irrigation system (lift Irrigation), for example, micro irrigation or drip irrigation, where you need to pressurize the irrigation through pumps so that water can penetrate through the small pore of dripper or sprinklers.



1.3 SURFACE AND SUB SURFACE IRRIGATION

1.3.1 Surface Irrigation

- In this method, irrigation water is distributed to the agricultural land through small channels which flood the area upto a required depth.
- Water is applied and distributed either by gravity or pumping.
- This method is good for soils with low to moderate infiltration capacities and lands with uniform terrain.



(i) Flow irrigation

- Water available at higher level is supplied to a lower level by the action of gravity.
- low irrigation can be further subdivided into:
  (a) Perennial irrigation
  (b) Flood irrigation

(ii) Lift irrigation

- Water available at lower level is lifted to a higher level by mechanical or manual means and then supplied for irrigation. (e.g. pumps etc.)
- Mostly tubewells are used for this purpose.

1.3.2 Subsurface Irrigation

- In this method, water flows underground and nourishes plant roots by capillarity.
- Water is applied to the root zones of crops by underground network of pipes.
- The network consists of main pipe, sub main pipes and lateral perforated pipes.
- This method is suitable for soils which are highly permeable.
- It may be divided into following two types.

(i) Natural Sub-irrigation

- Leakage water from channels during its passage through sub soil irrigates crops sown on lower lands.

(ii) Artificial Sub-irrigation

- In this method, a system of open jointed drain is artificially laid below the soil.
- This is costly process, so recommended in areas where crops provide high returns.

1.4 METHODS OF IRRIGATION

Irrigation water can be applied to crop lands using one of the following irrigation methods:

(i) Surface irrigation:

(a) Uncontrolled (or wild or free) flooding method,
(b) Border strip method,
(c) Check method,
(d) Basin method, and
(e) Furrow method.

(ii) Subsurface irrigation

(iii) Sprinkler irrigation

(iv) Trickle (Drip) irrigation

Each of the above methods have some advantages and disadvantages, and the choice of the method depends on the following factors:

(i) Size, shape, and slope of the field,

(ii) Soil characteristics,

(iii) Nature and availability of the water supply subsystem,

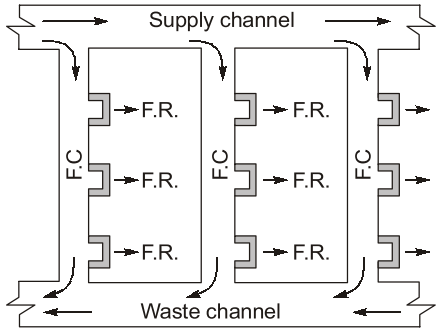
(iv) Types of crops being grown,

(v) Initial development costs and availability of funds, and

(vi) Preferences and past experience of the farmer

1.4.1 Uncontrolled Flooding

- Ditches are excavated in the field.
- Water from these ditches are allowed to flow across the field without any restriction by opening the field regulators.
- In case of controlled free flooding, surplus water flows through the waste water channel and is discharged into the river or drainage.
- In this method, cost of land preparation is low and cost of labour is high.
- The main disadvantage is that the water application efficiency is low (especially when flooding is not controlled).
- In this case, we have series of field channels connected to the main supply channel.



F.C. = Field Channel
F.R. = Field Regulator

Fig. Uncontrolled flooding

1.4.2 Border Flooding

- In this method, land is divided into a series of long, uniformly graded, narrow strips separated by low levees (i.e. small bunds).
- Here, levees guide the flow of water down the field.
- Usually, length of strips is in the range 100 to 400 m whereas width of strips is in the range 10 to 20 m
- This method is suitable when the area is levelled in direction perpendicular to the flow in order to prevent water from concentrating on either side of the border.
- Water is allowed to flow from supply ditch into each strip and during its travel water gets infiltrated into the soil.
- As soon as the water reaches the lower end of the strip, water supply to that strip is turned off.
- This is the most popular method of flooding.

NOTE If the land is not properly graded and there is cross slope, the irrigation water will not spread evenly over the field.

Time Taken by Irrigation Water to Irrigate an Area

Consider a small area 'dA' of border strip of area A as shown in figure.

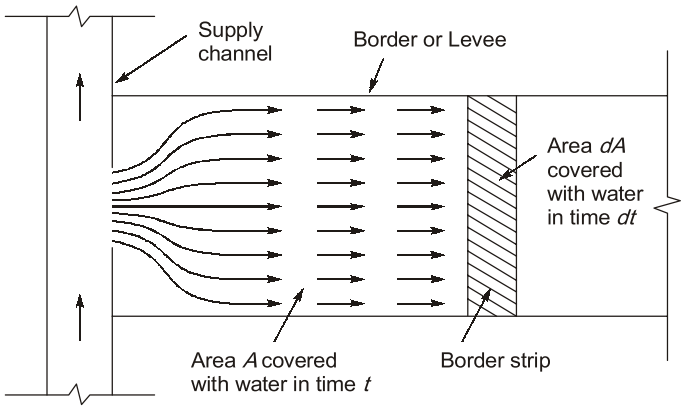


Fig. Border flooding

Let us assume that in 'dt' time, water moves over area 'dA'.
Hence, volume of water over area $dA = ydA$
where, y is depth of water
Also, volume of water percolating over area $dA = fA\,dt$
where, f is infiltration rate

Volume of water supplied in time 'dt' = $Q\,dt$
where, Q is the discharge in m^3/s

Volume of water supplied in time 'dt' = Volume of water over area 'dA' in time 'dt' + Volume of water percolated in time 'dt'

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

$$\Rightarrow \quad dt = \frac{y\,dA}{Q - fA} \qquad \text{(i)}$$

Integrating (i), we get,

$$\Rightarrow \quad t = -\frac{y}{f}\ln(Q - fA) + C \qquad \text{...(ii)}$$

At $t = 0$, $A = 0$. Putting in (ii), we get,

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

$$\Rightarrow \quad C = \frac{y}{f}\ln Q$$

Putting value of C in (ii), we get,

$$\Rightarrow \quad t = \frac{y}{f}\ln\left(\frac{Q}{Q - fA}\right) \qquad \text{...(iii)}$$

$$t = 2.303\frac{y}{f}\log_{10}\left(\frac{Q}{Q - fA}\right) \qquad \text{...(iv)}$$

Maximum Area that can be Irrigated

Rearranging equation (iv), we get,

$$\frac{ft}{2.303y} = \log_{10}\left(\frac{Q}{Q-fA}\right) \quad \ldots(v)$$

$$\Rightarrow \quad 10^k = \frac{Q}{Q-fA} \quad \left[\text{let, } \frac{ft}{2.303y} = k\right]$$

$$\Rightarrow \quad Q \times 10^k - fA \times 10^k = Q$$

$$\Rightarrow \quad Q(10^k - 1) = fA \times 10^k$$

$$\Rightarrow \quad A = \frac{Q(10^k - 1)}{f \times 10^k}$$

Now, $\frac{10^k - 1}{10^k} \approx 1 \quad [\because k \text{ is very large}]$

Hence, $A_{max} = \frac{Q}{f}$

where, Q is discharge supplied

f is infiltration rate of soil

Example 1.1 Determine the time required to irrigate a strip of land of 0.04 hectares in area from a tubewell with Q = 0.02 cumecs; f = 5 cm/hr and y_{avg} = 10 cm

where, Q = discharge through the supply ditch

y_{avg} = average depth of water flowing over the strip

f = infiltration rate of the soil

Also, determine the maximum area that can be irrigated from the tubewell.

Solution:

Given, $A = 0.04 \text{ ha} = 0.04 \times 10^4 \text{ m}^2 = 400 \text{ m}^2$

$Q = 0.02 \text{ m}^3/\text{s}$

$$f = 5 \text{ cm/hr} = \frac{0.05}{3600} \text{m/s}$$

$$y = y_{avg} = 10 \text{ cm} = 0.1 \text{ m}$$

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

$$= 2.303 \frac{0.10}{\frac{0.05}{3600}} \times \log_{10}\left(\frac{0.02}{0.02 - \frac{0.05}{3600} \times 400}\right)$$

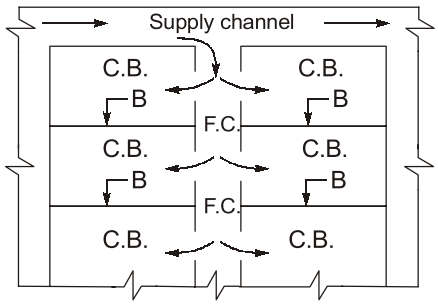
$$= 16581.6 \times 0.14 = 2343.46 \text{ s} = 39.06 \text{ min}$$

Maximum area that can be irrigated,

$$A_{max} = \frac{Q}{f} = \frac{0.02}{0.05} \times 3600 = 1440 \text{ m}^2$$

1.4.3 Check Flooding

- In this method, agricultural area is divided into small plots (known as checks) by surrounding the area with low and flat levees. These levees act as check bunds.
- Check bunds are generally constructed along the contours
- Water is supplied to the check basins through the field channels which are connected with the supply channel.
- Water is retained in these check basins for sometime to allow for infiltration into the soil.
- This method is suitable for both more permeable and less permeable soils.
- Close growing crops such as jowar or paddy are most preferred.
- Some loss of cultivable area due to levees:



F.C. = Field Channel
B = Bunds
C.B. = Check Basin

Fig. Check flooding

1.4.4 Basin Flooding

- This method is mainly employed for watering orchards.
- In this method, one or more trees are generally enclosed by circular channel through which water flows.
- This circular channel acts as a basin.
- Each basin is connected to the field channel while field channel is connected to the supply channel.
- This method is most suitable for crops that are unaffected by standing water present over long period of time.

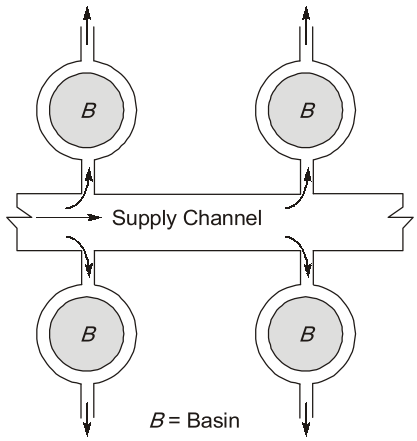


Fig. Basin flooding

1.4.5 Furrow Method

- In this method, water is supplied to the land by digging narrow channels at regular interval.
- These narrow channels are called furrow.
- Water infiltrates through the wetted perimeter of the furrows and moves vertically and then laterally to saturate the soil.
- Usually, crops are grown on the ridges between the furrows.
- Depth of the furrows varies from 8 to 30 cm while length of furrows are around 400 m.
- This method is suitable for row crops like sugarcane, groundnut, potato, tobacco etc.
- Preferred on flat area or gentle slopes.

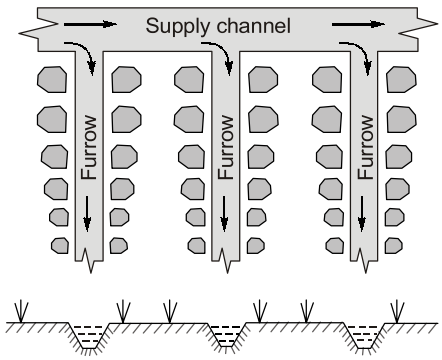


Fig. Furrow irrigation method

1.4.6 Subsurface Irrigation

- Subsurface irrigation (or simply sub irrigation) is the practice of applying water to soils directly under the surface.
- Moisture reaches the plant roots through capillary action.
- The conditions which favor sub irrigation are as follows:
  (i) Impervious subsoil at a depth of 2 meters or more,

(ii) A very permeable subsoil,
(iii) A permeable loam or sandy loam surface soil,
(iv) Uniform topographic conditions, and
(v) Moderate ground slopes.

- In natural sub irrigation, water is distributed in a series of ditches about 0.6 to 0.9 meter deep and 0.3 meter wide having vertical sides. These ditches are spaced 45 to 90 meters apart.
- Sometimes, when soil conditions are favorable for the production of cash crops (i.e., high-priced crops) on small areas, a pipe distribution system is placed in the soil well below the surface. This method of applying water is known as artificial sub-irrigation.
- Soils which permit free lateral movement of water, rapid capillary movement in the root-zone soil, and very slow downward movement of water in the subsoil are very suitable for artificial sub-irrigation.
- The cost of such methods is very high. However, the water consumption is as low as one-third of the surface irrigation methods. The yield also improves.

1.4.7 Sprinkler Irrigation Method

- In this method, irrigation water is applied to the land in the form of a spray.
- Water is sprayed by employing the network of main pipe, sub main pipes and lateral pipes.
- Lateral pipes may be perforated at the top and sides or it may contain series of nozzles through which water comes out as a fountain.
- In present scenario, we are using mainly rotating sprinkles.

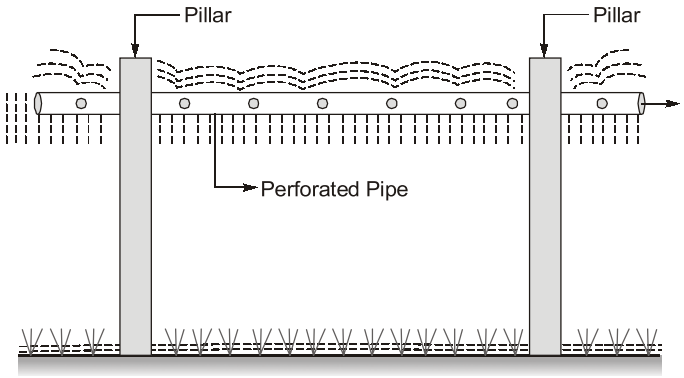


Fig. Perforated lateral pipes

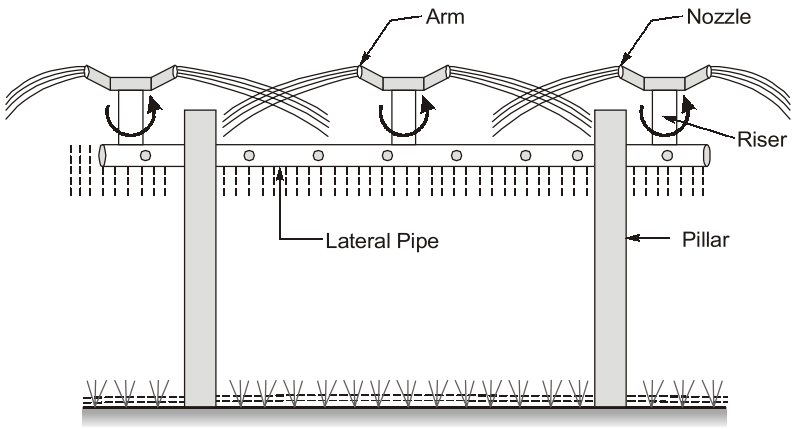


Fig. Rotary sprinklers

Advantages of Sprinkler Irrigation Method

- Can be efficiently used for wide range of topography, soils and crops.
- Erosion of soil can be controlled.
- Water is uniformly applied.
- 80% of water application efficiency achieved.
- Labour cost is reduced as no land preparation is required.
- No land levelling is required.

Disadvantages of Sprinkler Irrigation Method

- System is a bit costly to install, operate and maintain.
- Continuous supply of power is required.
- Corners remain unirrigated.
- Under high wind condition and high temperature, application efficiency becomes poor.
- High saline water at higher temperature causes leaf burning.

1.4.8 Drip Irrigation Method (Trickle irrigation)

- It is the latest method of irrigation.
- In this method, water and fertilizer are slowly and directly applied to the root zone of the plant in order to minimize the evaporation and seepage losses.
- Specially designed emitters and drippers are used for this purpose.
- This method is best suited for row crops and orchards (eg. tomatoes, grapes, corn, cauliflowers, cabbage etc.)

Advantages of Drip Irrigation

- Water requirement is minimal.
- Evaporation losses are close to negligible.
- Highest rate of vegetative growth is achieved in this method.
- Soil surface is least wetted and hence occurrence of diseases due to dampness decreases.
- No land levelling is required.
- No soil erosion takes place.
- Less labour is required.

Disadvantages of Drip Irrigation

- Plastic pipes or drippers may get attacked by the rodents.
- Does not offer frost protection.
- Needs regular flushing and supervision.
- High skill is required in the design, installation, operation and maintenance.

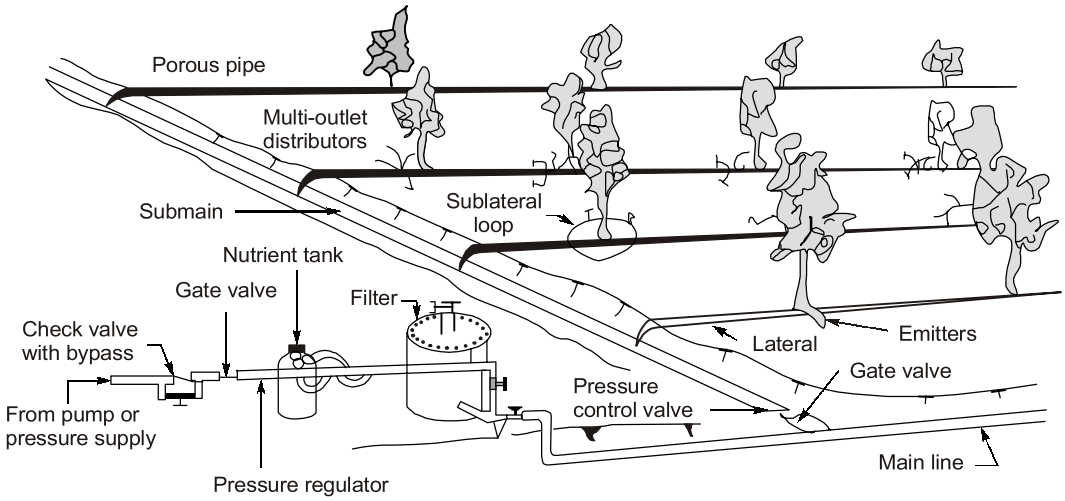


Fig. Line sketch of a typical drip irrigation system

NOTE: Moisture availability for crops in different irrigation methods.

1.5 IRRIGATION PROJECT SURVEY

Before taking up an irrigation project, we should investigate the following:

(i) Availability of irrigation water

(ii) Selection of probable site for weir/barrage

(iii) Discharge observation for the river (daily discharge, maximum discharge and minimum discharge of the river throughout the year)

(iv) Marking of gross commanded area and cultivable area.

(v) Marking of alignment of main canal.

(vi) Preliminary location survey

(vii) Final survey

- (a) Final location of barrage or dam site
- (b) Route Survey
- (c) Longitudinal levelling
- (d) Cross sectional levelling
- (e) Data for cross drainage work
- (f) Soil survey
- (g) Well observation

(viii) Preparation of drawings

(ix) Office works

(x) Justification of the selection of Final Alignment

(xi) Final location survey

OBJECTIVE BRAIN TEASERS

Q.1 Pinpoint the correct statement
(a) irrigation helps in adopting mixed cropping
(b) 'mixed cropping' means sowing of a different crop after a particular crop has been grown
(c) over-irrigation may lead to saving in fertilizers
(d) irrigation helps in avoiding mixed cropping

Q.2 'Flood irrigation' method of irrigating fields work is based on
(a) level or gently rolling terrain
(b) steeply rolling terrain
(c) both (a) and (b)
(d) None of the above

Q.3 The method of growing crops on ridges, running on the sides of water ditches, is known as
(a) flood irrigation
(b) furrow irrigation
(c) check irrigation
(d) None of them

Q.4 In a field under furrow irrigation, 'furrows' are referred to represent
(a) ridges on which crops are grown
(b) narrow ditches which carry irrigation water
(c) both (a) and (b)
(d) neither (a) nor (b)

Q.5 A sprinkler irrigation system is suitable when
(a) the land gradient is steep and the soil is easily erodible
(b) the soil is having low permeability
(c) the water table is low
(d) the crops to be grown have deep roots

Q.6 Identify the correct statements:
In the drip irrigation method,
1. Deep percolation and runoff are eliminated
2. Water application efficiency is very high
3. Evapotranspiration is completely eliminated
4. Fertilizer can be applied economically along with water

Which of the above statements is/are correct?
(a) 1 and 3 (b) 2, 3 and 4
(c) 1, 2 and 4 (d) 1, 2 and 3

Q.7 Identify the correct statements:
1. In contour border irrigation method, the drainage channel runs along the contour.
2. Border method of irrigation is well suited to soils having infiltration rates that are neither high nor low.
3. In border method of irrigation, the flow is based on spatially varied, unsteady open channel flow.
4. In check basin method of irrigation considerable land is wasted by ridges and laterals.

(a) 1, 2 and 4 (b) 2, 3 and 4
(c) 2 and 4 (d) 1 and 3

Q.8 In an irrigation system, the land was divided into a large number of smaller size unit areas, having fairly level surface, by bunds and cross ridges. The basins thus created were filled with water to the desired depth and the water was retained for some time.
This method of irrigation is known as
(a) border method
(b) check basin method
(c) sub-irrigation
(d) contour irrigation

Q.9 The method, which uses dead furrows on cropped farms for drainage of excess irrigation or rain water, is called
(a) surface inlet (b) tile drainage
(c) bedding (d) french drain

ANSWER KEY

1. (d)	2. (a)	3. (b)	4. (b)	5. (a)
6. (c)	7. (b)	8. (b)	9. (c)	

■■■■