1- DUTY OF WATER:

For proper planning of a canal system, the designer has to first decide the 'duty of water' in the locality under consideration. **Duty is defined as the area irrigated by a unit discharge of water flowing continuously for the duration of the base period of a crop**. The ***base period*** of **a crop is the time duration between the first watering at the time of sowing and the last watering before harvesting the crop**. Obviously, the base period of a crop is smaller than the crop period. **Duty is measured in hectares/m3/s**. **The duty of a canal depends on the crop, type of soil, irrigation and cultivation methods, climatic factors, and the channel conditions**.

By comparing the duty of a system with that of another system or by comparing it with the corresponding figures of the past on the same system, one can have an idea about the performance of the system. Larger areas can be irrigated if the duty of the irrigation system is improved. Duty can be improved by the following measures:

(i) The channel should not be in sandy soil and be as near the area to be irrigated as possible so that the seepage losses are minimum. Wherever justified, the channel may be lined.

(ii) The channel should run with full supply discharge as per the scheduled program so that farmers can draw the required amount of water in shorter duration and avoid the tendency of unnecessary over irrigation.

(iii) Proper maintenance of watercourses and outlet pipes will also help reduce losses, and thereby improve the duty.

(iv) Volumetric assessment of water makes the farmer to use water economically. This is, however, more feasible in well irrigation

Well irrigation has higher duty than canal irrigation due to the fact that water is used economically according to the needs. Open wells do not supply a fixed discharge and, hence, the average area irrigated from an open well is termed its duty. Between the head of the main canal and the outlet in the distributary, there are losses due to evaporation and percolation. As such, duty is different at different points of the canal system. The duty at the head of a canal system is less than that at an outlet or in the tail end region of the canal. Duty is usually calculated for the head discharge of the canal. Duty calculated on the basis of outlet discharge is called 'outlet discharge factor' or simply 'outlet factor' which excludes all losses in the canal system.

Imagine a field growing a single crop having a base period B days and a Delta Δ mm which is being supplied by a source located at the head (uppermost point) of the field. The water being supplied may be through the diversion of river water through a canal, or it could be using ground water by pumping. If the water supplied is just enough to raise the crop within D hectares of the field, then a relationship may it found out amongst all the variables as:

$D =$ duty in hectares/cumec
$\Delta =$ total depth of water supplied (in metres)
$B =$ base period in days.

(*i*) If we take a field of area D hectares, water supplied to the field corresponding to the water depth Δ metres will be $= \Delta \times D$ hectare-metres

$$= D \times \Delta \times 10^4 \text{ cubic-metres.} \quad ...(1)$$

(*ii*) Again for the same field of D hectares, one cumec of water is required to flow during the entire base period. Hence, water supplied to this field

$$= (1) \times (B \times 24 \times 60 \times 60) \text{ m}^3 \quad ...(2)$$

Equating Equations (1) and (2), we get

$$D \times \Delta \times 10^4 = B \times 24 \times 60 \times 60$$

or

$$\Delta = \frac{B \times 24 \times 60 \times 60}{D \times 10^4} = 8.64 \frac{B}{D} \text{ metres}$$

Note : 1 hectare = 10^4 sq. metres
1 cumec-day = 8.64 hectare-metres.

Example *Find the delta for a crop if the duty for a base period of 110 days is 1400 hectares/cumec.*

Solution : Given : $B = 110$ days and $D = 1400$ hectares/cumec

$$\therefore \quad \Delta = 8.64 \frac{B}{D} = \frac{8.64 \times 110}{1400} \text{ m} = 0.68 \text{ m} = \mathbf{68\ cm}$$

Example *A crop requires a total depth of 92 cm of water for a base period of 120 days. Find the duty of water.*

Solution : Given : $B = 120$ days and $\Delta = 92$ cm $= 0.92$ m

$$D = \frac{8.64\, B}{\Delta} \text{ hectares/cumec} = \frac{8.64 \times 120}{0.92} = \mathbf{1127\ hectares/cumec.}$$

FACTORS AFFECTING DUTY

The duty of water of canal system depends upon a variety of the factors. The principal factors are :

1. Methods and system of irrigation ;
2. Mode of applying water to the crops ;
3. Method of cultivation ;
4. Time and frequency of tilling ;
5. Type of the crop ;
6. Base period of the crop ;
7. Climatic conditions of the area;
8. Quality of water ;
9. Method of assessment of irrigation method ;
10. Canal conditions ;
11. Character of soil and sub-soil of the canal ;
12. Character of soil and sub-soil of the irrigation fields.

IRRIGATION EFFICIENCIES

Efficient use of irrigation water is an obligation of each user as well as of the planners. Even under the best method of irrigation, not all the water applied during an irrigation is stored in the root zone. In general, efficiency is the ratio of water output to the water input and is expressed as percentage. The objective of efficiency concepts is to show when improvements can be made which will result in more efficient irrigation. The following are the various types of irrigation efficiencies : (*i*) water conveyance efficiency, (*ii*) water application efficiency, (*iii*) water use efficiency, (*iv*) water storage efficiency, (*v*) water distribution efficiency and (*vi*) consumptive use efficiency.

1. *Water Conveyance Efficiency* (η_c)

This takes into account the conveyance or transit losses and is determined from the following expression :

$$\eta_c = \frac{W_f}{W_r} \times 100$$

where η_c = water conveyance efficiency
W_f = water delivered to the farm or irrigation plot
W_r = water supplied or diverted from the river or reservoir.

2. *Water Application Efficiency* (η_a)

The water application efficiency is the ratio of the quantity of water stored into the root zone of the crops to the quantity of water delivered to the field. This focuses the attention of the suitability of the method of application of water to the crops. It is determined from the following expression :

$$\eta_a = \frac{W_s}{W_f} \times 100$$

where η_a = water application efficiency
W_s = Water *stored* in the root zone during the irrigation
W_f = water delivered to the farm.

The common sources of loss of irrigation water during water application are (*i*) surface run off R_f from the farm and (*ii*) deep percolation D_f below the farm root-zone soil. Hence

$$W_f = W_s + R_f + D_f$$

and

$$\eta_a = \frac{W_f - (R_f + D_f)}{W_f} \times 100$$

In a well designed surface irrigation system, the water application efficiency should be atleast 60% ; in the sprinkler irrigation system this efficiency is about 75%.

3. *Water Storage Efficiency* (η_s)

The concept of water storge efficiency gives an insight to how completely the required water has been stored in the root zone during irrigation. It is determined from the following expression:

$$\eta_s = \frac{W_s}{W_n} \times 100$$

where η_s = water storage efficiency

W_s = water *stored* in the root zone during irrigation

W_n = water *needed* in the root zone prior to irrigation

= (Field capacity – Available moisture).

4. *Water Distribution Efficiency* (η_d)

Water distribution efficiency evaluates the degree to which water is uniformly distributed throughout the root zone. Uneven distribution has many undesirable results. The more uniformly the water is distributed, the better will be the crop response. It is determined from the following expression :

$$\eta_d = 100\left[1 - \frac{y}{d}\right]$$

where η_d = water distribution efficiency

y = average numerical deviation in depth of water stored from average depth stored during irrigation.

d = average depth of water stored during irrigation.

The efficiency provides a measure for comparing various systems or methods of water application, *i.e.* sprinkler compared to surface, one sprinkler system compared to the other system or one surface method compared to other surface method.

Example *If the depths of water stored at 5 points in a field are 1.0, 0.9, 0.8, 0.7 and 0.60 m, determine the water distribution efficiency.*

Solution. Average depth $= \frac{1.0 + 0.9 + 0.8 + 0.7 + 0.6}{5} = 0.80$ m

Deviations from the mean = + 0.20 + 0.10, 0.0 − 0.10 − 0.2

Absolute values of these deviations from the mean = 0.2, 0.1, 0.0, 0.10, 0.2

Average of these absolute values of deviations $= \frac{0.2 + 0.10 + 0.0 + 0.10 + 0.20}{5} = 0.12$

Therefore, water distribution efficiency $= \left(1 - \frac{0.12}{0.80}\right) \times 100 = 85\%$

Example *Five cumecs of water is supplied to a field having an area of 30 ha for 6 hours. It is found that 25 cm of water depth has been stored in the root zone of the crop. Determine the water application efficiency.*

Solution. Quantity of water applied $= 5 \times 6 \times 3600 = 10.8 \times 10^4 \text{ m}^3 = 10.8$ ha–m

Quantity of water stored in the root zone $= 30 \times 0.25 = 7.5$ ha–m

Water application efficiency $= \frac{7.5}{10.8} \times 100 = \mathbf{69.44\%}$

Alternative Method Depth of water applied $= 10{\cdot}8/30{\cdot}0 = 0{\cdot}36$ m

Depth of water stored $= 0{\cdot}25$

Water application efficiency $= \frac{0 \cdot 25}{0 \cdot 36} \times 100 = 69{\cdot}44\%$

PLANNING OF IRRIGATION PROJECTS

These projects mainly consist of engineering (or hydraulic) structures which collect, convey, and deliver water to areas on which crops are grown. Irrigation projects may range from a small farm unit to those serving extensive areas of millions of hectares. A small irrigation project may consist of a low diversion weir or an inexpensive pumping plant along with small ditches (channels) and some minor control structures. A large irrigation project includes a large storage reservoir, a huge dam, hundreds of kilometers of canals, branches and distributaries, control structures, and other works. Assuming all other factors (such as enlightened and experienced farmers, availability of good seeds, etc.) reasonably favorable, the following can be listed as conditions essential for the success of any irrigation project.

(i) Suitability of land (with respect to its soil, topography and drainage features) for continued agricultural production,

(ii) Favorable climatic conditions for proper growth and yield of the crops,

(iii) Adequate and economic supply of suitable quality of water, and

(iv) Good site conditions for the safe construction and uninterrupted operations of the engineering works.

Most of the irrigation projects divert stream flow into a canal system which carries water to the cropland by gravity and, hence, are called gravity projects. In pumping projects, water is obtained by pumping but delivered through a gravity system

A gravity type irrigation project mainly includes the following works:

(i) Storage (or intake) and diversion works,

(ii) Conveyance and distribution channels.

(iii) Conveyance, control, and other hydraulic structures,

(iv) Farm distribution, and

(v) Drainage works.

Development of an Irrigation Project

A small irrigation project can be developed in a relatively short time. Farmers having land suitable for agriculture and a source of adequate water supply can plan their own irrigation system, secure necessary finance from banks or other agencies, and get the engineering works constructed without any delay. On the other hand, development of a large irrigation project is more complicated and time-consuming. Complexity and the time required for completion of a large project increase with the size of the project. This is due to the organizational, legal, financial administrative, environmental, and engineering problems all of which must be given detailed consideration prior to the construction of the irrigation works. The principal stages of a large irrigation project are: (i) the promotional stage, (ii) the planning stage, (iii) the construction stage, and (iv) the settlement stage. The planning stage itself consists of three substages: (i) preliminary planning including feasibility studies, (ii) detailed planning of water and land use, and (iii) the design of irrigation structures and canals. Engineering activities are needed during all stages (including operation and maintenance) of development of an irrigation project. However, the planning and construction stages require most intensive engineering activities. A large irrigation project may take 10–30 years for completion depending upon the size of the project.