1- CANAL IRRIGATION:

Irrigation conduits of a typical gravity project are usually open channels through earth or rock formations. These are called **canals**.

A ***canal* is defined as an artificial channel constructed on the ground to carry water from a river or another canal or a reservoir to the fields. Usually, canals have a trapezoidal crosssection.**

2- Classification of canals

Canals can be classified in many ways:

Based on the **nature of source of supply**, a canal can be either a **permanent** or **an inundation canal**. *A permanent canal* has a continuous source of water supply. Such canals are also called perennial canals. *An inundation canal* draws its supplies from a river only during the high stages of the river. Such canals do not have any headworks for diversion of river water to the canal, but are provided with a canal head regulator.

Depending **on their function**, canals can also be classified as: (i**) irrigation**, (ii**) navigation**, (iii) **power**, and (iv) **feeder canals**. An irrigation canal carries water from its source to agricultural fields. Canals used for transport of goods are known as navigation canals. Power canals are used to carry water for generation of hydroelectricity. A feeder canal feeds two or more canals.

An irrigation canal system consists of canals of different sizes and capacities (Fig.1). Accordingly, the canals are also classified as: (i) **main canal**, (ii) **branch canal**, (iii) **major distributary**, (iv) **minor distributary**, and (v) **watercourse**.

The main canal takes its supplies directly from the river through the head regulator and acts as a feeder canal supplying water to branch canals and major distributaries. Usually, direct irrigation is not carried out from the main canal.

Branch canals (also called 'branches') take their supplies from the main canal. Branch canals generally carry a discharge higher than 5 m3/s and act as feeder canals for major and minor distributaries. Large branches are rarely used for direct irrigation. However, outlets are provided on smaller branches for direct irrigation.

Major distributaries (also called 'distributaries' or rajbaha) carry 0.25 to 5 m3/s of discharge. These distributaries take their supplies generally from the branch canal and sometimes from the main canal. The distributaries feed either watercourses through outlets or minor distributaries.

Minor distributaries (also called 'minors') are small canals which carry a discharge less than 0.25 m3/s and feed the watercourses for irrigation. They generally take their supplies from major distributaries or branch canals and rarely from the main canals.

A watercourse is a small channel which takes its supplies from an irrigation channel (generally distributaries) through an outlet and carries water to the various parts of the area to be irrigated through the outlet.

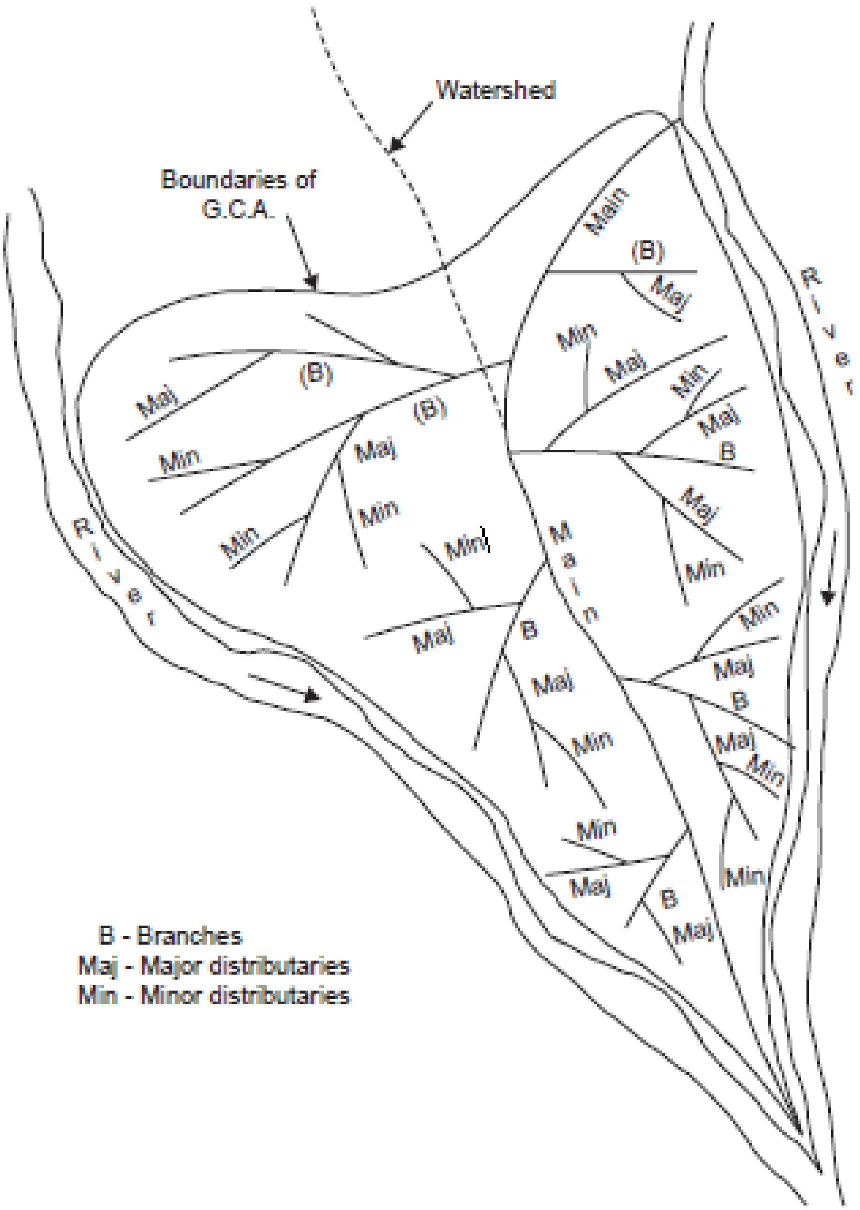

Fig (.1) Layout of an irrigation canal network

3- ALIGNMENT OF IRRIGATION CANALS

Desirable locations for irrigation canals on any gravity project, their cross-sectional designs and construction costs are governed mainly by topographic and geologic conditions along different routes of the cultivable lands. Main canals must convey water to the higher elevations of the cultivable area. Branch canals and distributaries convey water to different parts of the irrigable areas.

On projects where land slopes are relatively flat and uniform, **it is advantageous to align channels on the watershed of the areas to be irrigated**. The natural limits of command of such irrigation channels would be the drainages on either side of the channel. Aligning a canal)main, branch as well as distributary) on the watershed ensures gravity irrigation on both sides of the canal. Besides, the drainage flows away from the watershed and, hence, no drainage can cross a canal aligned on the watershed. Thus, **a canal aligned on the watershed saves the cost of construction of cross-drainage structures.** However, the main canal has to be taken off from a river which is the lowest point in the cross-section, and this canal must mount the watershed in as short a distance as possible. Ground slope in the head reaches of a canal is much higher than the required canal bed slope and, hence, the canal needs only a short distance to mount the watershed. This can be illustrated by Fig.2 in which the main canal takes off from a river at P and mounts the watershed at Q. Let the canal bed level at P be 400 m and the elevation of the highest point N along the section MNP be 410 m. Assuming that the ground slope is 1 m per km, the distance of the point Q (395 m) on the watershed from N would be 15 km. If the required canal bed slope is 25 cm per km, the length PQ of the canal would be 20 km. Between P and Q, the canal would cross small streams and, hence, construction of cross-drainage structures would be necessary for this length. In fact, the alignment PQ is influenced considerably by the need of providing suitable locations for the cross-drainage structures. The exact location of Q would be determined by trial so that the alignment PQ results in an economic as well as efficient system. Further, on the watershed side of the canal PQ, the ground is higher than the ground on the valley side (i.e., the river side). Therefore, this part of the canal can irrigate only on one side (i.e., the river side) of the canal.

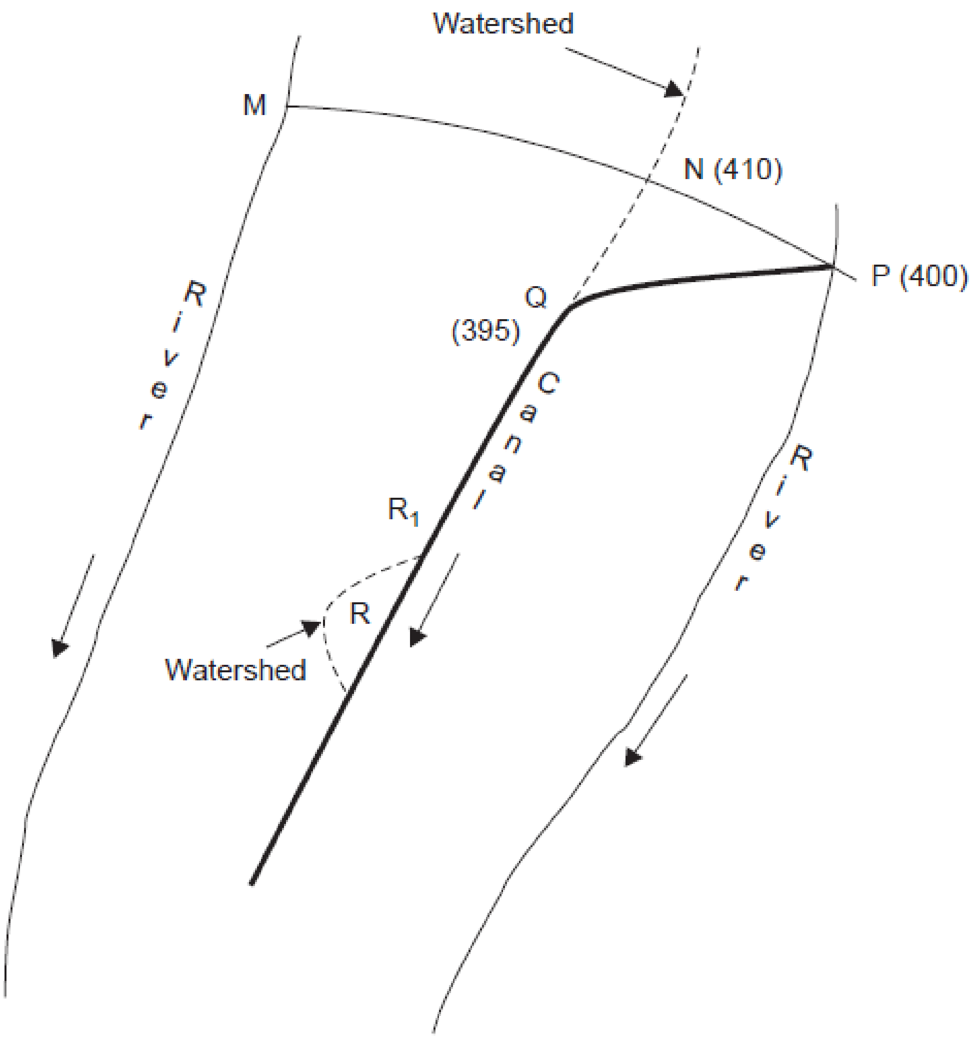

Fig. (.2) Head reach of a main canal in plains

Once a canal has reached the watershed, it is generally kept on the watershed, except in certain situations, such as the looping watershed at R in Fig.2. In an effort to keep the canal alignment straight, the canal may have to leave the watershed near R. The area between the canal and the watershed in the region R can be irrigated by a distributary which takes off at R1 and follows the watershed. Also, in the region R, the canal may cross some small streams and, hence, some cross-drainage structures may have to be constructed. If watershed is passing through villages or towns, the canal may have to leave the watershed for some distance.

In hilly areas, the conditions are vastly different compared to those of plains. Rivers flow in valleys well below the watershed or ridge, and it may not be economically feasible to take the channel on the watershed. In such situations, contour channels (Fig.3) are constructed. Contour channels follow a contour while maintaining the required longitudinal slope. It continues like this and as river slopes are much steeper than the required canal bed slope the canal encompasses more and more area between itself and the river. It should be noted that the more fertile areas in the hills are located at lower levels only.

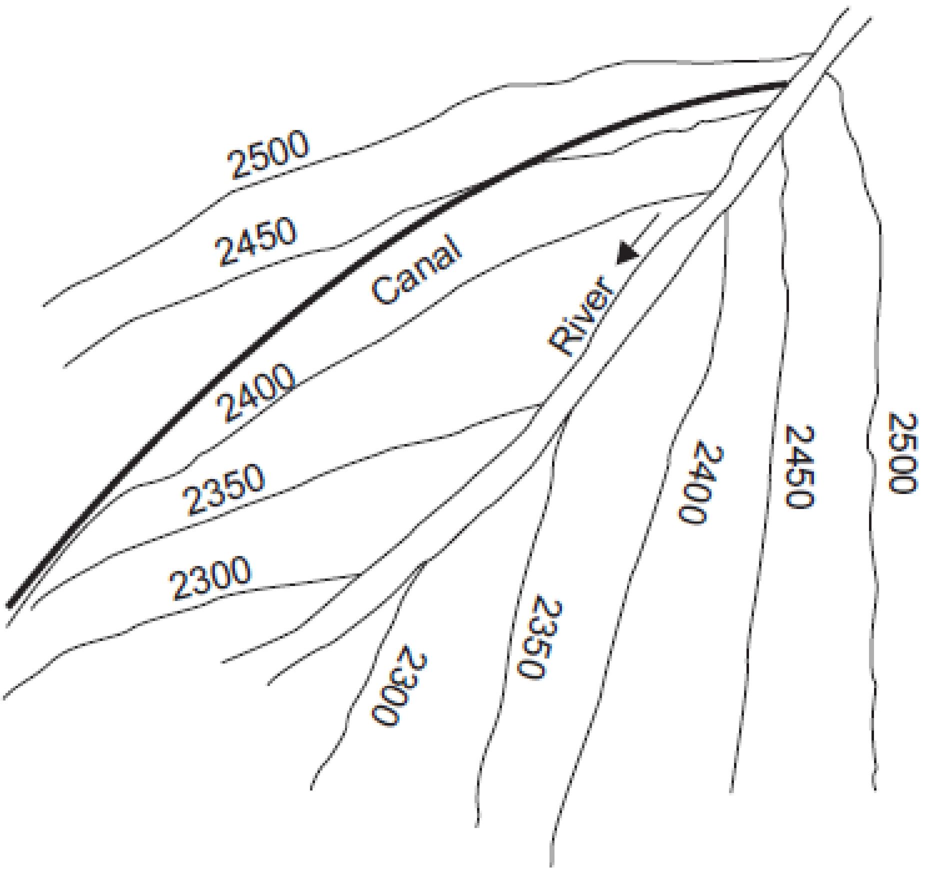

Fig.(.3) Alignment of main canal in hills

In order to finalise the channel network for a canal irrigation project, trial alignments of channels are marked on the map prepared during the detailed survey. A large-scale map is required to work out the details of individual channels. However, a small-scale map depicting the entire command of the irrigation project is also desirable. The alignments marked on the map are transferred on the field and adjusted wherever necessary. These adjustments are transferred on the map as well. The alignment on the field is marked by small masonry pillars at every 200 metres. The centre line on top of these pillars coincides with the exact alignment. In between the adjacent pillars, a small trench, excavated in the ground, marks the alignment.

4- CURVES IN CANALS

Because of economic and other considerations, the canal alignment does not remain straight all through the length of the canal, and curves or bends have to be provided. The curves cause disturbed flow conditions resulting in eddies or cross currents which increase the losses. In a curved channel portion, the water surface is not level in the transverse direction. There is a slight drop in the water surface at the inner edge of the curve and a slight rise at the outer edge of the curve. This results in slight increase in the velocity at the inner edge and slight decrease in the velocity at the outer edge. As a result of this, the low-velocity fluid particles near the bed move to the inner bank and the high-velocity fluid particles near the surface gradually cross to the outer bank. The cross currents tend to cause erosion along the outer bank. The changes in the velocity on account of cross currents depend on the approach flow condition and the characteristics of the curve. When separate curves follow in close succession, either in the same direction or in the reversed direction, the velocity changes become still more complicated.

Therefore, wherever possible, **curves in channels excavated through loose soil should be avoided. If it is unavoidable, the curves should have a long radius of curvature**. The permissible minimum radius of curvature for a channel curve depends on the type of channel, dimensions of cross-section, velocities during full-capacity operations, earth formation along channel alignment and dangers of erosion along the paths of curved channel. In general, the permissible

minimum radius of curvature is shorter for flumes or lined canals than earth canals, shorter for small cross-sections than for large cross-sections, shorter for low velocities than for high velocities, and shorter for tight soils than for loose soils. Table 1 indicates the values of minimum radii of channel curves for different channel capacities.

Table 1 Radius of curvature for channel curves

Channel capacity (m^3/s)	*Minimum radius of curvature (metres)*
Less than 0.3	100
0.3 to 3.0	150
0.3 to 15.0	300
15.0 to 30.0	600
30.0 to 85.0	900
More than 85	1500

5- CANAL LOSSES

When water comes in contact with an earthen surface, whether artificial or natural, the surface absorbs water. This absorbed water percolates deep into the ground and is the main cause of the loss of water carried by a canal. In addition, some canal water is also lost due to evaporation.

The loss due to evaporation is about 10 percent of the quantity lost due to seepage. The seepage loss varies with the type of the material through which the canal runs. Obviously, the loss is greater in coarse sand and gravel, less in loam, and still less in clay soil. If the canal carries silt-laden water, the pores of the soil are sealed in course of time and the canal seepage reduces with time. In almost all cases, the seepage loss constitutes an important factor which must be accounted for in determining the water requirements of a canal.

Between the headworks of a canal and the watercourses, the loss of water on account of seepage and evaporation is considerable. **This loss may be of the order of 20 to 50 percent of water diverted** at the headworks depending upon the type of soil through which canal runs and the climatic conditions of the region.

For the purpose of estimating the water requirements of a canal, the total loss due to evaporation and seepage, also known as conveyance loss, is expressed as m3/s per million square metres of either wetted perimeter or the exposed water surface area. Conveyance loss can be calculated using the values given in Table.2., the total loss (due to seepage and evaporation) per million square metres of water surface varies from 2.5 m3/s for ordinary clay loam to 5.0 m3/s for sandy loam. The following empirical relation has also been found to give comparable results .

$$q_l = (1/200)\,(B + h)^{2/3}$$

Table.2 Conveyance losses in canals

Material	*Loss in m^3/s per million square metres of wetted perimeter (or water surface)*
Impervious clay loam	0.88 to 1.24
Medium clay loam underlaid with hard pan at depth of not over 0.60 to 0.90 m below bed	1.24 to 1.76
Ordinary clay loam, silty soil or lava ash loam	1.76 to 2.65
Gravelly or sandy clay loam, cemented gravel, sand and clay	2.65 to 3.53
Sandy loam	3.53 to 5.29
Loose sand	5.29 to 6.17
Gravel sand	7.06 to 8.82
Porous gravel soil	8.82 to 10.58
Gravels	10.58 to 21.17

In this relation, *ql* is the loss expressed in m3/s per kilometre length of canal and *B* and *h* are, respectively, canal bed width and depth of flow in metres.