Module 3

Irrigation Engineering Principles

Lesson 6

Canal Systems for Major and Medium Irrigation Schemes

Instructional objectives

On completion of this lesson, the student shall learn about the following:

1. The canal system of irrigation under major and minor irrigation schemes
2. Components of a canal irrigation system
3. Layout of a canal irrigation system
4. Lining methods in canal irrigation
5. Negative impact of canal irrigation

3.6.0 Introduction

As noted in earlier chapters, major irrigation schemes are those which have culturable command area (C.C.A) more than 10,000 ha. Irrigation schemes having C.C.A between 2000 and 10000 ha are called medium irrigation schemes. All these schemes are flow types of irrigation systems and water from a river is diverted to flow through a canal by constructing diversion structure across the river. The main canal further divides into branches and distributaries water from the distributaries is let off through gated outlets into the fields with the help of water courses.

It is important to note that the canal method of water conveyance and distribution is a dynamic system with variation in demand occurring according to the crops planted in the command area. Also, the source of water, usually a river, may not be able to supply sufficient amount of water all times. Nevertheless, the canal system has to be planned and designed for the maximum expected demand. The layout of the canal is also important as it should ensure smooth flow by gravity in each channel. Wrong alignment may lead to possible stagnation of water at some places or too fast moving that may damage the canal itself. This lesson discusses about various aspects of irrigation canal system layout and design. Other canals like those for navigation and power generation are discussed separately.

3.6.1 Canal Components

At the diversion structure, a headwork regulates the flow into a canal. This canal, which takes its supplies directly from the river, is called the main canal and usually direct irrigation from the waters of this canal is not carried out. This acts as a feeder channel to the branch canals, or branches. Branch canals generally carry a discharge higher than 5 m^3/s and acts as feeder channel for major distributaries which, in turn carry 0.25 to 5 m^3/s of discharge. The major distributaries either feed the water courses or the minor distributaries, which generally carry discharge less than 0.25 m^3/s.

A typical layout of an irrigation canal system may be seen in Figure 1.

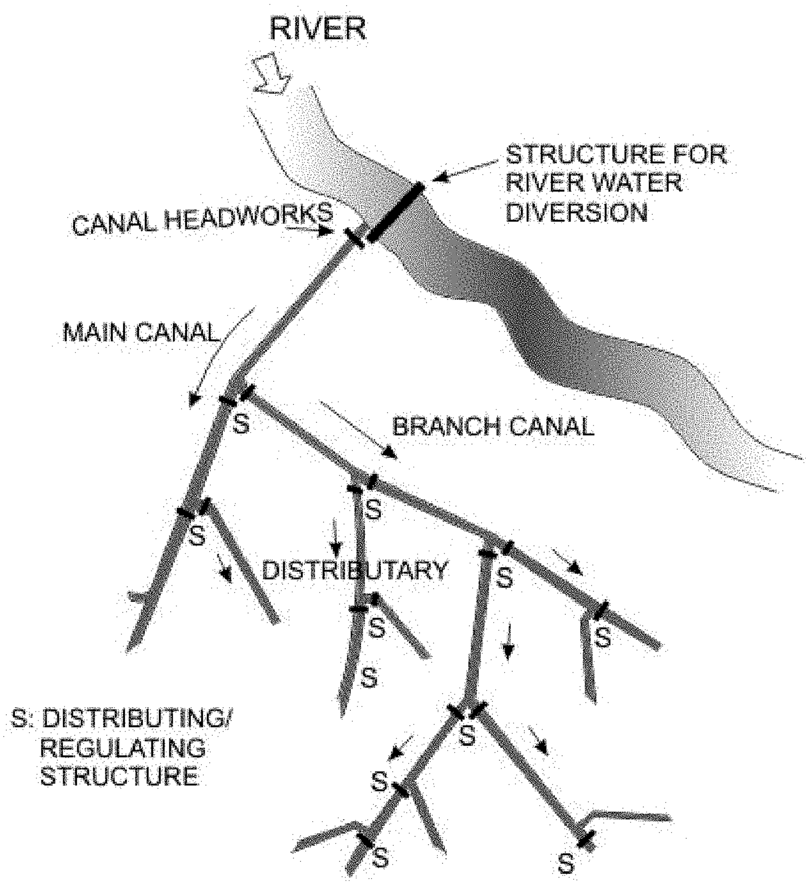

FIGURE 1 : Typical layout of an irrigation canal system

It may be observed that whenever a channel off-takes from the corresponding main branch there has to be gated structures just downstream of the bifurcation, for controlling the water level upstream of the point as well as to control the amount of water going into the off take and the main branches.

3.6.2 Irrigation canal layout

Usually it is desirable that a canal off taking from a river should be able to irrigate as much an area as possible. The general layout concept can be explained when studied in respect of the off take point of the canal and the surrounding contours, as shown in Figure 2.

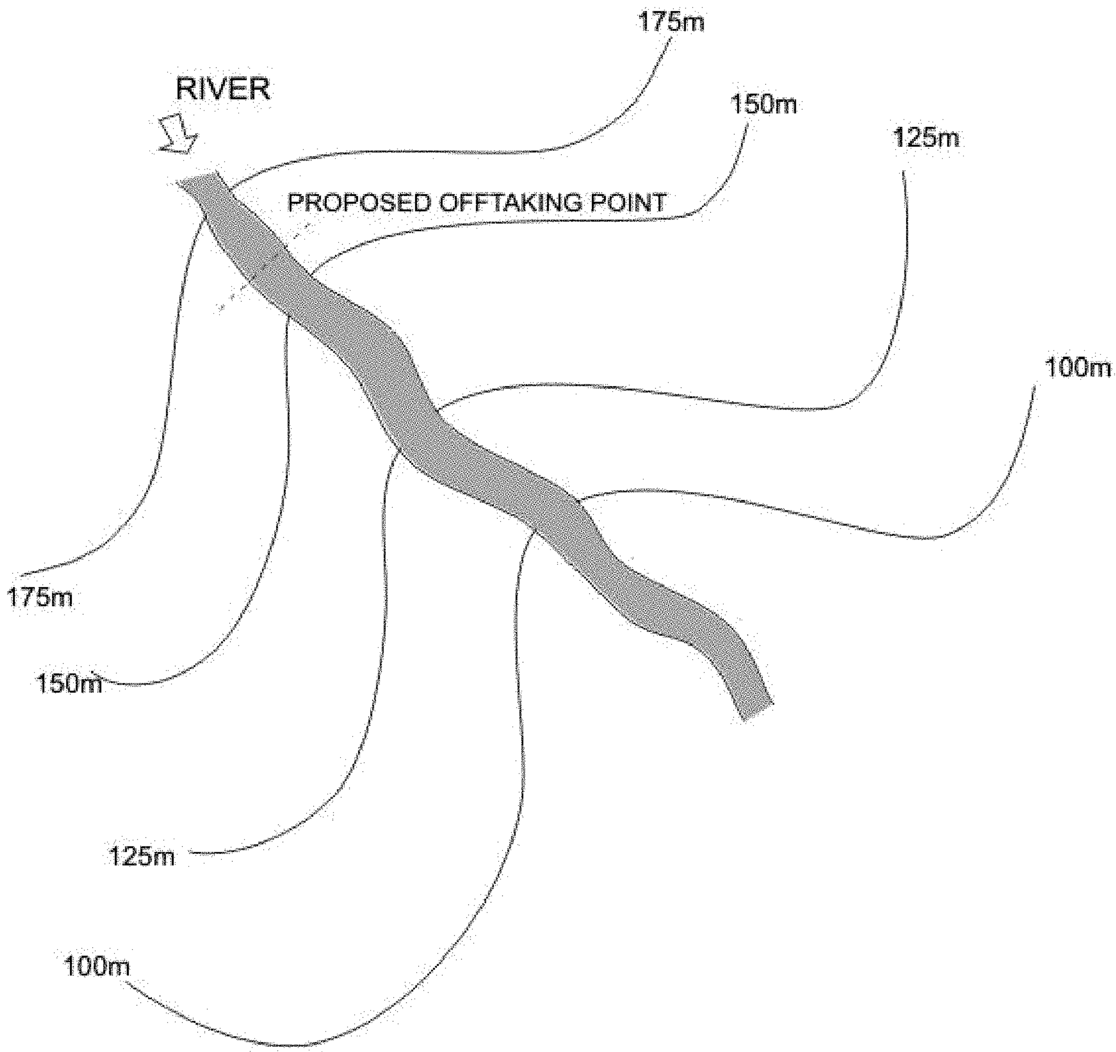

FIGURE 2 : Location of an off taking point for an irrigation system showing a river and hypothetical elevation contours

Now, if a canal were to be laid from the off taking point, then it should lie between the two extreme lines, as explained below.

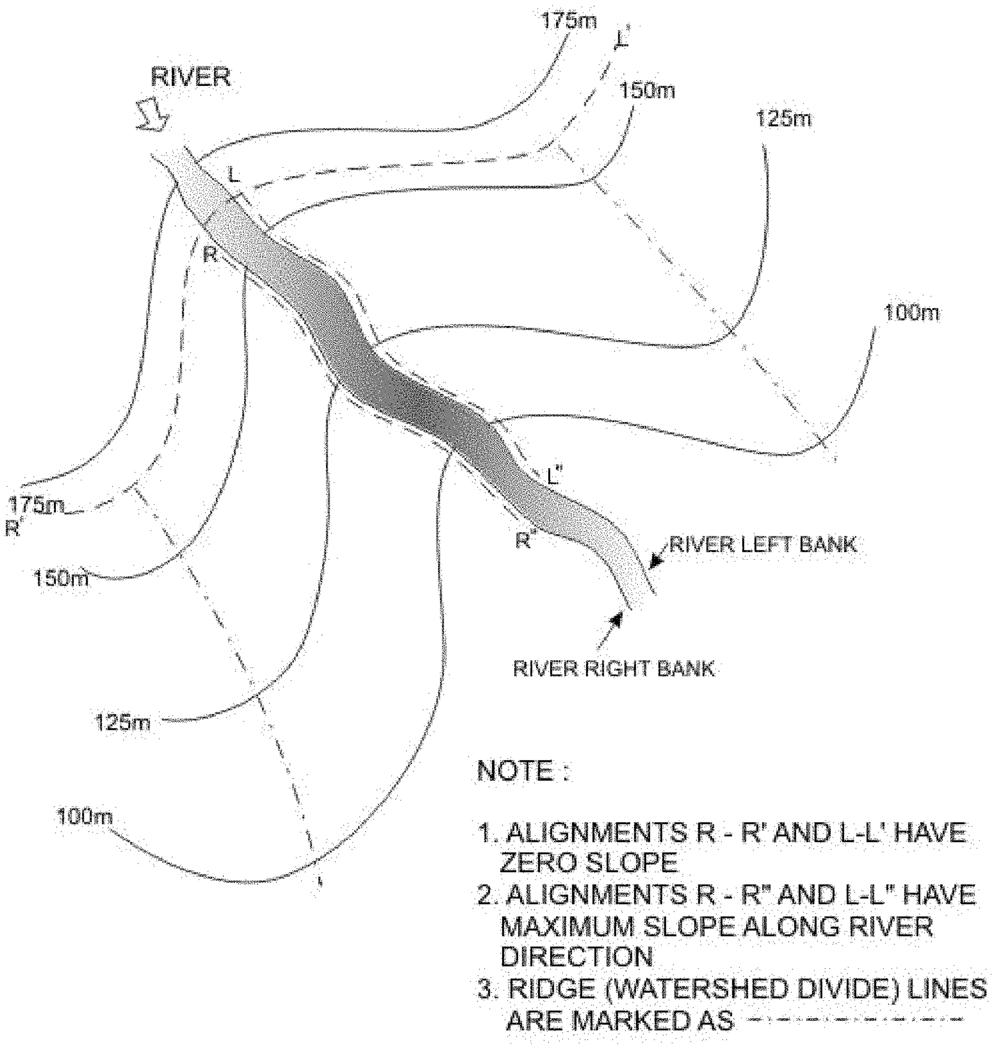

FIGURE 3 : Possible alignments based on which a practical alignment of canal has to be chosen

Consider the possible alignments of canals as shown in Figure 3. A shown in the figure, the ***right bank canal*** (generally termed RBC) and off taking from a point R on the river bank may be aligned somewhere in the region bounded by R-R', the contour line at the elevation of R or the right riverbank R-R''. It is not possible to align the canal along R-R', as there would not be any slope, whereas an alignment along R-R'' would mean zero command area for the canal. Hence, a suitable slope of the canal that is neither too flat nor too steep (as discussed later in this lesson) would be the most appropriate.

Based on the above logic, possible alignments of the right and left bank canals (RBC and LBC) have been shown in Figure 4.

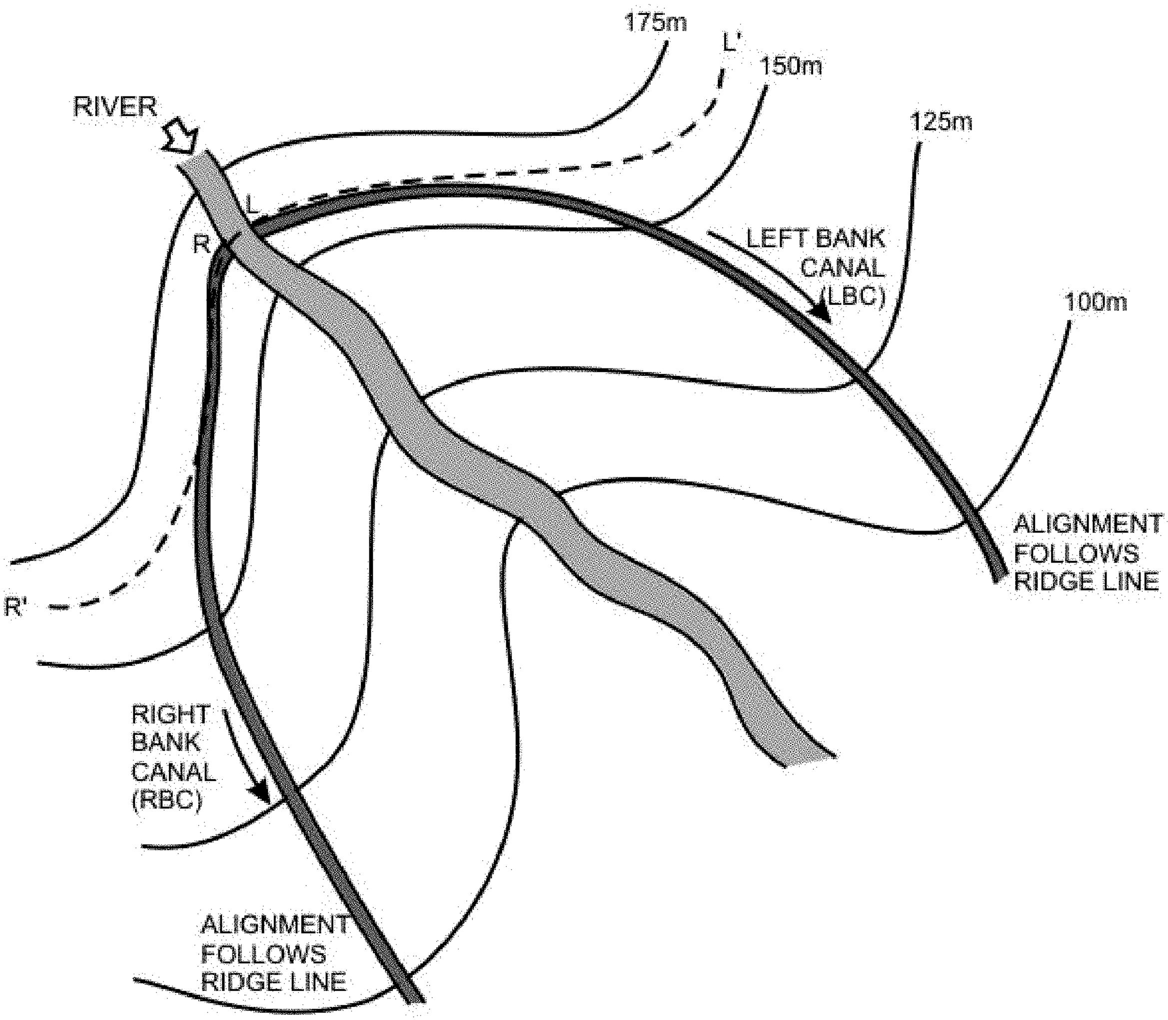

FIGURE 4 : Practical alignments of canals taking off from right and left banks of the river at location L-R

In order to demonstrate the effect of the adjacent valley slopes on the canal layout, the right and left bank contours have been chosen in such a way that the slope of the right bank valley is flatter than that of the left bank. Hence, as may be observed from Figure 5, for the same canal slope on both the banks, the right bank canal covers a larger command area (the area between the canal and the river).

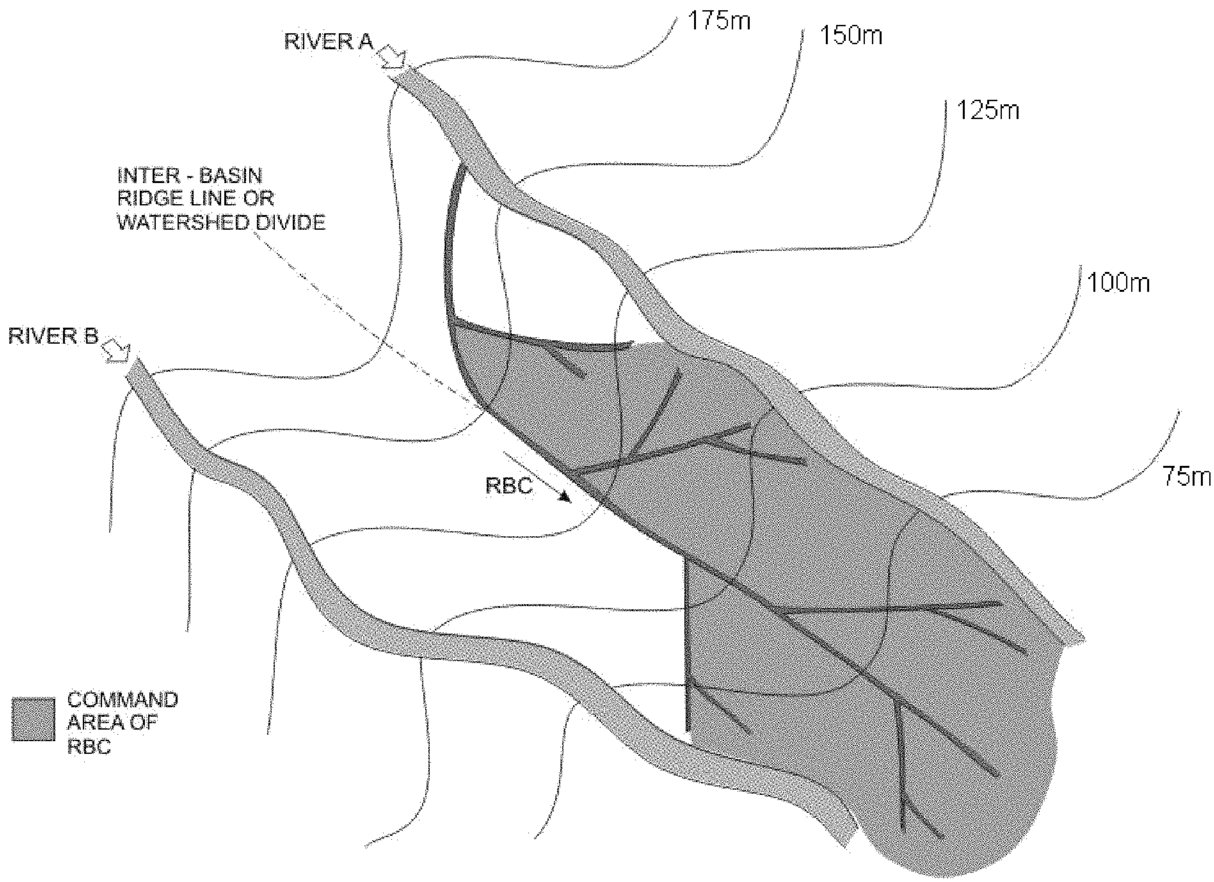

FIGURE 5 : Command area for a typical canal system

The alignment of a canal can be done in such a way that it is laid up to a ridge line between two valleys, which would allow a larger command area for the same canal, as shown in the figure, which shows possible contour lines between two rivers that the canal off taking from one river is able to irrigate areas between the river of the adjacent valley, too.

There is one more advantage of leading a canal up to the watershed divide line: the number of small streams to be crossed by the canal would be a minimum, though once a canal may be aligned along the watershed divide line, generally, it may be necessary to provide a shorter path if the divide line is tortuous.

A few more points may be noted on the layout of a canal may be noted, as mentioned below.

- As far as possible, curves should be avoided in the alignment of canals because the curves lead to disturbance of flow and a tendency to silt on the inner bend and scour the toe of the outer (concave) bend. However, if curves have to be provided; they should be as gentle as possible. Further, the permissible minimum radius of curvature for a channel curve is shorter for lined canals than unlined ones and is shorter for small cross sections than for large cross sections of canals. According to the Bureau of Indian Standard code IS: 5968-1970 “Guide for planning and layout of canal system for irrigation”, the radii of curves should usually be 3 to 7 times the water surface width subject to the minimum values as given in the following table.

Type of canal	Capacity of canal (m^3/s)	Minimum radius (m)
Unlined canals	80 and above	1500
	30 to 80	1000
	15 to 30	600
	3 to 15	300
	0.3 to 3	150
	Less than 3	90
Lined canals	280 and above	900
	200 to 280	750
	140 to 200	600
	70 to 140	450
	40 to 70	300
	10 to 40	200
	3 to 10	150
	0.3 to 3	100
	Less than 0.3	50

- The alignment should be such that the cutting and filling of earth or rock should be balanced, as far as possible.

- The alignment should be such that the canal crosses the natural stream at its narrowest point in the vicinity.

In order to finalize the layout of canal network for an irrigation project, the alignment of channels should be marked on topo-sheets, until an optimum is reached. This alignment is then transferred to the field by fixing marking posts along the centerline of the canal.

Formal guidelines for canal layout may be had from Bureau of Indian Standard IS: 5968-1987 “Guide for planning and layout of canal system for irrigation”.

3.6.3 Lining of Irrigation canals

Though irrigation canals may be constructed in natural or compacted earth, these suffer from certain disadvantages, like the following

- Maximum velocity limited to prevent erosion
- Seepage of water into the ground
- Possibility of vegetation growth in banks, leading to increased friction
- Possibility of bank failure, either due to erosion or activities of burrowing animals

All these reasons lead to adoption of lining of canals, though the cost may be prohibitive. Hence, before suggesting a possible lining for a canal, it is necessary to evaluate the cost vis-à-vis the savings due to reduction in water loss through seepage.

Apart from avoiding all the disadvantages of an unlined canal, a lined canal also has the advantage of giving low resistance and thus reducing the frictional loss and maintaining the energy and water surface slopes for the canal as less as possible. This is advantageous as it means that the canal slope may also be smaller, to maintain the same discharge than for a canal with higher friction loss. A smaller canal slope means a larger command area.

3.6.4 Types of canal lining

Different types of canal linings are possible, and the bureau of Indian standards code IS: 5331-1969 "Guide for selection of type of linings for canals" may be consulted for details. In general, the following types of linings are generally used.

3.6.4.1 Concrete lining

Cement concrete lining made from selected aggregate gives very satisfactory service. Despite the fact that they are frequently high in their initial cost, their long life and minimum maintenance make them economical. Cement concrete lining are best suited for main canals which carry large quantities of water at high velocities. However, a firm foundation is essential for avoiding any possibility of cracking due to foundation settlement. Expansive clay soils should be avoided and proper moisture and density control of the sub grade soil should be maintained while lining. In areas where the ground water table is likely to rise above the invert level of the lining and cause undue uplift pressure, drains are laid below the lining to release the water and relieve the pressure, generally, a thickness of about 5 to 12 cm is generally adopted for larger canals and stable side slopes are considered to be between 1.5H: 1V to 1.25H: 1V. Reinforcement to the extent of 0.1 to 0.4 percent of the area in longitudinal direction and 0.1 to 0.2 percent of the area in the transverse direction reduces width of the shrinkage cracks, thereby reducing seepage. Further details regarding cement concrete linings may be had from Bureau of Indian Standards code IS: 3873-1987 "Code of practice for laying in-situ cement concrete lining on canals", since there would be construction/contraction joints in the lining, it is essential to plug the joints, for which the following code may be referred IS: 13143-1991 "Joints in concrete lining of canals-sealing compound".

3.6.4.2 Shotcrete lining

Shotcrete, that is, cement mortar in the ratio of 1 cement to 4 sand proportions is through a pump-pipe-nozzle system on the surface of the channel. Wire mesh reinforcement is generally, though not necessarily, is clamped to the channel surface (as for a rocky excavation) before applying shot Crete. Equipment units used for shot Crete construction are relatively small and easily moved. They are convenient for lining small sections, for repair of old linings, and for placing linings around curves or structures. Shot Crete linings are generally laid in a thickness of about 3.5cm, but many standard code IS: 9012-1978 "recommended practice for shotcreting" (Reaffirmed in 1992) may be consulted for details.

3.6.4.3 Brick or burnt clay tile lining precast concrete tile lining

This type of lining is popular because of certain advantages like non-requirement of skilled mason or rigid quality control. Further, since it is more labour intensive, it generates employment potential. Brick tiles can be plastered to increase the carrying capacity of canal with same section and help in increasing the life span of the lining. Sometimes a layer of tiles is laid over a layer of brick masonry. The top layer is generally laid in 1:3 cement mortal over 15mm thick layer of plaster in 1:3 cement plaster. The size of tiles is generally restricted to 30mm x 150mm x 53m. This type of lining is stable even if there is settlement of foundation, since the mortar joint between bricks or tiles provides for numerous cracks so fine that seepage is insignificant. Further details may be had from the following Bureau of Indian Standard codes:

- IS: 3860-1966 "Specifications for precast cement concrete canal linings".
- IS: 3872-1966 "Code of practice for lining of canals with burnt clay tiles".
- IS: 10646-1991 "Canal linings-cement concrete tiles"

3.6.4.4 Boulder Lining

Also called dry stone lining or stone pitching, is used for lining the earthen canal cross section, by proper placement and packing of stones, either after laying a filter layer over the soil surface or without any such filter, depending upon the site requirement. To reduce the resistance to flow, a 20 to 25mm thick cement plaster is provided as a finishing surface. Stones are generally placed on leveled sub-grade, and hand packed. This type of lining is of course suitable where stones of required specification are available in abundance locally. For details of this type of lining, one may refer to the Bureau of Indian standard code IS: 4515-1976 "Code of practice for boulder lining of canals". One advantage of this type of lining is allowing free flow of water from the submerged or saturated sub-grade into the canal. Hence, this type of lining does not need any drainage arrangement or pressure relief values, etc. which may be required for concrete or brick lining.

3.6.4.5 Low density polyethylene lining (from *IS: 9698-1980/1991*)

3.6.4.6 Hot bitumen/Bituminous felt lining (from *IS:9097-1979*) (Reaffirmed 1990)

3.6.4.7 Earth linings

The different types of earth linings that are used in canals include the following:

i. Stabilized earth linings: Here, the sub-grade is stabilized using either clay for granular sub-grade or by adding chemicals that compact the soil.

ii. Loose earth blankets: Fine grained soil is laid on the sub-grade and evenly spread. However, this type of lining is prone to erosion, and requires a flatter side slopes of canal.

iii. Compacted earth linings: Here the graded soil containing about 15 percent clay is spread over the sub-grade and compacted.

iv. Buried ***bentonite*** membrames: Bentonite is a special type of clay soil, found naturally, which swell considerably when wetted. Buried bentonite linings for canals are constructed by spreading soil-bentonite mixtures over the sub-grade and covering it with gravel or compacted earth.

v. Soil-cement lining: Here, cement and sandy soil are mixed and then compacted at optimum moisture content or cement and soil is machine mixed with water and then laid. The Bureau of Indian Standards code IS: 7113-1973 "Code of Practice for soil cement lining for canals" (Reaffirmed in 1990) may be controlled for details regarding this type of lining.

3.6.5 Ill-effects of canal irrigation: Water logging

Canal is an artificial channel for conveying water through lands that was perhaps naturally devoid of sustained water flow. Hence, water seeping from canals down to the soil below may, at times, raise the ground water very close to the ground level. This may result in blocking all the voids in the soil and obstructing the plant roots to breathe. It has been observed that water logging conditions adversely affects crop production as it is reduced drastically. Apart from seepage water of canals, excessive and unplanned irrigation also caused water logging conditions. This happens because the farmers at the head reaches of canals draw undue share of canal water in the false hope of producing larger agricultural outputs.

Apart from ill aeration of plants, other problems created by water logging are as follows:

- Normal cultivation operations, such as tilling, ploughing, etc. cannot be easily carried out in wet soils. In extreme cases, the free water may rise above the ground level making agricultural operations impossible.

- Certain water loving plants like grasses, weeds, etc. grow profusely and luxuriantly in water-logged lands, thus affecting and interfering with the growth of the crops.
- Water logging also leads to a condition called salinity, which is caused when the capillary fringe of the elevated water table rises within the root zone of plants. Since the roots of the plants continuously draw water from this zone, there is a steady upward movement of water which causes rise of salts, especially alkali salts, to come up to the ground surface. This situation is termed as salinity.

In order to avoid water-logging condition to occur for canal irrigation system, certain steps may be taken as follows:

- Canals and water courses may be lined. Also if possible, the full supply level of canal may be reduced.
- Intensity of irrigation may be reduced and farmers advised to apply water judiciously to their fields and not over-irrigate.
- Provide an efficient drainage system to drain away excess irrigation water.
- Introduce more tubewells for irrigation which shall lower the water table
- Cropping pattern may be suitably modified such that only low water requiring crops are planted instead of those requiring heavy irrigation
- Natural drainage of the soil may be improved such that less of excess surface water percolates and mostly drains off through natural drains.

Since water loss by seepage from canals is an important factor through which they pass, it is essential to scientifically monitor when they pass and devise a suitable seepage prevention strategy. This may be done by certain methods, which have been elaborated in the Bureau of Indian Standards code IS: 9452 "Code of practice for measurement of seepage losses from canals", with the following parts:

- IS: 9452 Part 1-1980 "Ponding method" (Reaffirmed 1991)
- IS: 9452 Part 2-1980 "Inflow-outflow method" (Reaffirmed 1990)
- IS: 9452 Part 3-1988 "Seepage meter method" (Reaffirmed 1990)

Another method, the analytical method, detailed in IS: 9447-1980 "Guidelines for assessment of seepage losses from canals by analytical method" to adopt.

3.6.6 Maintenance of Canals

It is often seen that the conditions under which a canal system is designed is not maintained during the years of its system is operation, Physical damage resulting from erosion/deposition of sediments, ground water, soil subsidence, human activity, weed growth, etc. cause much changes from the ideal conditions. Hence, it is not only essential to design a canal system well; it should also be maintained well. The Bureau of Indian standards has published the code IS: 4839 "Code of practice for maintenance of canals" under the following volumes for the purpose.

- IS: 4839 Part 1-1992 "Unlined canals" (Second revision)
- IS: 4839 Part 2-1992 "Lined canals" (Second revision)

3.6.7 Drainage of land for canal Irrigation Commands

A proper design of canal irrigation system also consist provision of a suitable drainage system for removal of excess water. Of course, this may not be required all over the command area of the canal, but may be necessary in areas of high water table and in river deltas. The drainage system may also help to drain out storm water as well, and thus to prevent its percolation and to ensure easy disposal. There are two types of drainages that may be provided, which are either of surface-type or of sub-surface types. These are briefly described in the following paragraphs.

3.6.7.1 Surface Drainage

These constitute open ditches, field drains, proper land grading and related structures. The open drains which are broad and shallow are called shallow surface drains and carry the runoff to the outlet drains. The outlet drains are termed as the deep surface drains. Land grading, or properly sloping the land towards the field drains, is an important method for effecting surface drainage. The Bureau of Indian Standards code IS: 8835-1975 "Guidelines for planning and design of surface drains" (Reaffirmed in 1990) may be referred to for further details.

3.6.7.2 Sub-Surface Drainage

These are installed to lower the water table and consists of underground pipes which collect water and remove it through a network of such pipes. These pipes are usually made of porous earthenware and circular in section and the diameter varies from 10 to 30 cm. for installation of these drains, trenches are dug in the ground and these pipe sections are butted against each other with open joints which help in allowing ground water to enter into the pipes. The trenches are then backfilled with sand and excavated material. The water drained by the tile drain is discharged into a bigger drain or into a deep surface drain. If the tile drain network is buried quite deep into the ground, it may be necessary to discharge the water of the drains into an underground sump and remove the water from the sump by pumping. Generally an area is under laid with a network of tile drains, it is essential to calculate the spacing of these drains based on the depth through which the water table in the region is to be lowered.