# Module
# 3
# Irrigation Engineering Principles

# Lesson 7

# Design of Irrigation Canals

# Instructional Objectives

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

1. The basics of irrigation canals design
2. The procedures followed to design unlined and lined canals
3. Methods for subsurface drainage of lined canals

# 3.7.0 Introduction

The entire water conveyance system for irrigation, comprising of the main canal, branch canals, major and minor distributaries, field channels and water courses have to be properly designed. The design process comprises of finding out the longitudinal slope of the channels and fixing the cross sections. The channels themselves may be made up of different construction materials. For example, the main and branch canals may be lined and the smaller ones unlined. Even for the unlined canals, there could be some passing through soils which are erodible due to high water velocity, while some others may pass through stiff soils or rock, which may be relatively less prone to erosion. Further, the bank slopes of canals would be different for canals passing through loose or stiff soils or rock. In this lesson, we discuss the general procedures for designing canal sections, based on different practical considerations.

# 3.7.1 Design of lined channels

The Bureau of Indian Standards code IS: 10430 -1982 “Criteria for design of lined canals and guidelines for selection of type of lining” (Reaffirmed in 1991) recommend trapezoidal sections with rounded corners for all channels-small or large. However, in India, the earlier practice had been to provide triangular channel sections with rounded bottom for smaller discharges. The geometric elements of these two types of channels are given below:

## Triangular section

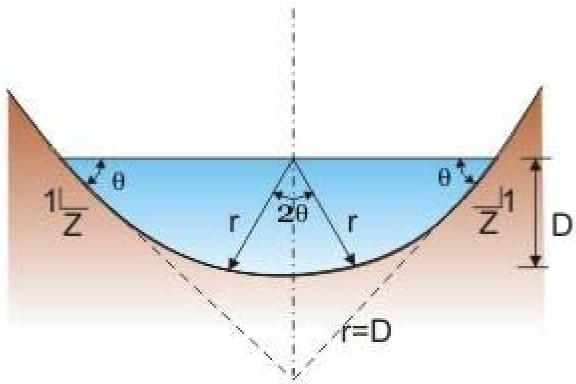



FIGURE 1 . Triangular channel section

For triangular section, the following expressions may be derived

$$A = D^2 (\square \cot \square) \qquad (1)$$

$$P = 2\,D (\square \cot \square) \qquad (2)$$

$$R = D / 2 \qquad (3)$$

The above expressions for cross sectional area (A), wetted perimeter (P) and hydraulic radius (R) for a triangular section may be verified by the reader.

## Trapezoidal section

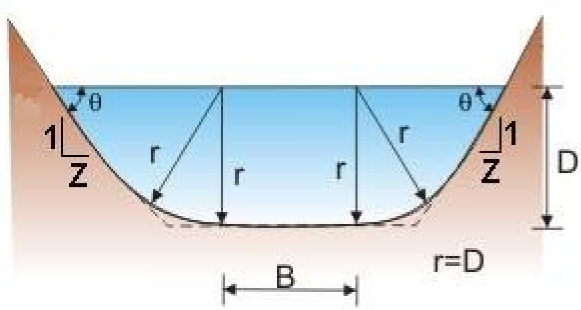



FIGURE 2. **Trapezoidal** channel section

For the Trapezoidal channel section, the corresponding expressions are:

$$A = B\,D + D^2 (\square \cot \square) \qquad (4)$$

$$P = B + 2D(\theta + \cot \theta) \quad (5)$$

$$R = A / P$$

The expressions for A and P may, again, be verified by the reader. In all the above expressions, the value of $\theta$ is in radians.

The steps to be followed for selecting appropriate design parameters of a lined irrigation channel, according to IS: 10430 may be summarized as follows:

1. Select a suitable slope for the channel banks. These should be nearly equal to the angle of repose of the natural soil in the subgrade so that no earth pressure is exerted from behind on the lining. For example, for canals passing through sandy soil, the slope may be kept as 2H: 1V whereas canals in firm clay may have bank slopes as 1.5H: 1V canals cut in rock may have almost vertical slopes, but slopes like 0.25 to 0.75H: 1V is preferred from practical considerations.

2. Decide on the freeboard, which is the depth allowance by which the banks are raised above the full supply level (FSL) of a canal. For channels of different discharge carrying capacities, the values recommended for freeboard are given in the following table:

| Type of Channel | Discharge ($m^3/s$) | Freeboard (m) |
|---|---|---|
| Main and branch canals | > 10 | 0.75 |
| Branch canals and major distributaries | 5 – 10 | 0.6 |
| Major distributaries | 1 – 5 | 0.50 |
| Minor distributaries | < 1 | 0.30 |
| Water courses | < 0.06 | 0.1 – 0.15 |

3. Berms or horizontal strips of land provided at canal banks in deep cutting, have to be incorporated in the section, as shown in Figure 3.

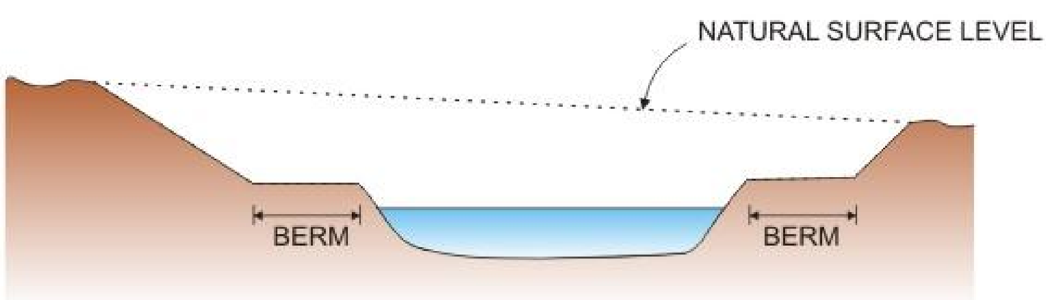



FIGURE 3. Berms for canal banks at deep cutting

The berms serve as a road for inspection vehicles and also help to absorb any soil or rock that may drop from the cut-face of soil or rock of the excavations. Berm width may be kept at least 2m. If vehicles are required to move, then a width of at least 5m may be provided.

4. For canal sections in filling, banks on either side have to be provided with sufficient top width for movement of men or vehicles, as shown in Figure 4.

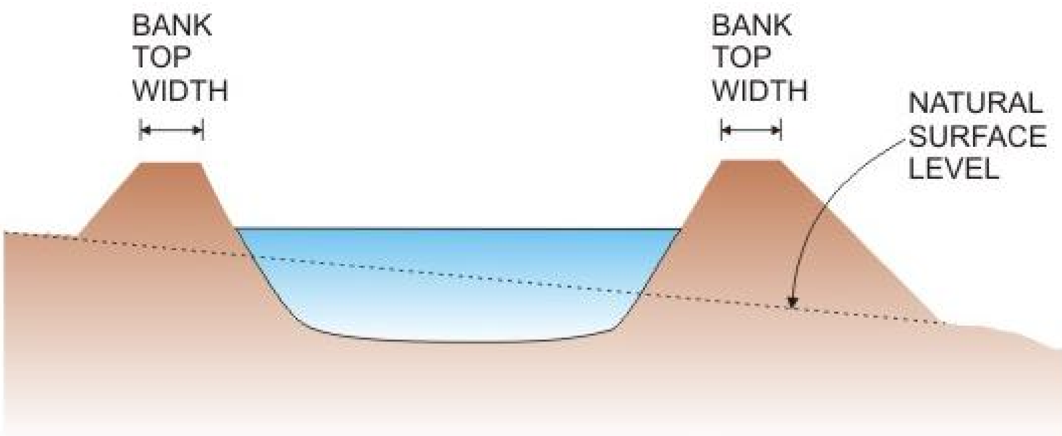



FIGURE 4. Canal section in filling

The general recommendations for bank top width are as follows:

| Discharge ($m^3/s$) | Maximum bank top width (m) | |
|---|---|---|
| | For inspection road | For non-inspection banks |
| 0.15 to 7.5 | 5.0 | 1.5 |
| 7.5 to 10.0 | 5.0 | 2.5 |
| 10.0 to 15.0 | 6.0 | 2.5 |
| 15.0 to 30.0 | 7.0 | 3.5 |
| Greater than 30.0 | 8.0 | 5.0 |

Next, the cross section is to be determined for the channel section.

5. Assume a safe limiting velocity of flow, depending on the type of lining, as given below:
    - Cement concrete lining: 2.7 m/s
    - Brick tile lining or burnt tile lining: 1.8 m/s
    - Boulder lining: 1.5 m/s

6. Assume the appropriate values of flow friction coefficients. Since Manning's equation would usually be used for calculating the discharge in canals, values of Manning's roughness coefficient, ***n***, from the following table may be considered for the corresponding type of canal lining.

| Surface Characteristics | Value of ***n*** |
|---|---|
| Concrete with surfaces as: | |
| a) Formed, no finish/PCC tiles or slabs | 0.018-0.02 |
| b) Trowel float finish | 0.015-0.018 |
| c) Gunited finish | 0.018-0.022 |
| Concrete bed trowel finish with sides as: | 0.019-0.021 |
| a) Hammer dressed stone masonry | |
| b) Course rubble masonry | 0.018-0.02 |
| c) Random rubble masonry | 0.02-0.025 |
| d) Masonry plastered | 0.015-0.017 |
| e) Dry boulder lining | 0.02-0.03 |
| Brick tile lining | 0.018-0.02 |

7. The longitudinal slope (S) of the canal may vary from reach to reach, depending upon the alignment. The slope of each reach has to be evaluated from the alignment of the canal drawn on the map of the region.

8. For the given discharge Q, permissible velocity V, longitudinal slope S, given side slope □, and Manning' roughness coefficient, ***n,*** for the given canal section, find out the cross section parameters of the canal, that is, bed width (B) and depth of flow (D).

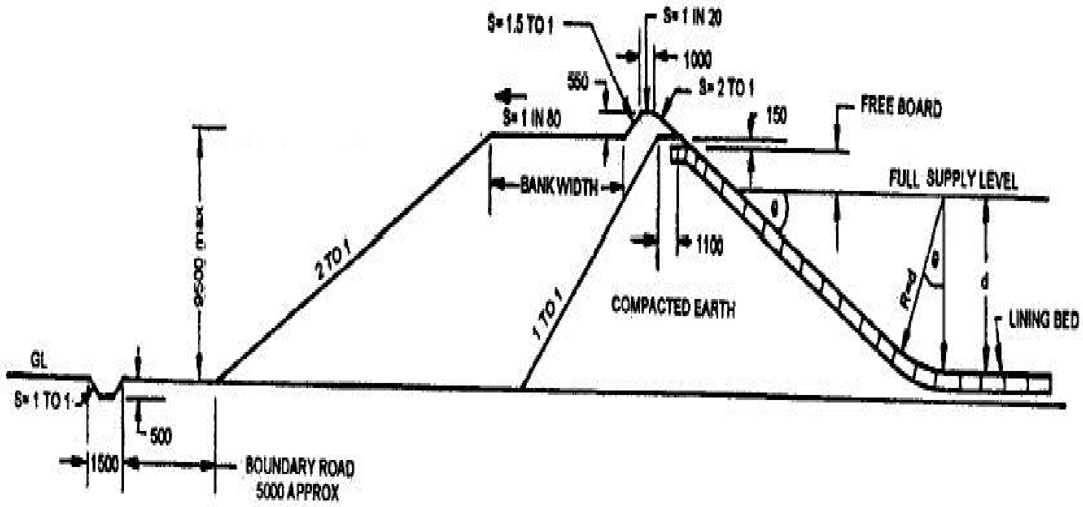
Since two unknowns are to be found, two equations may be used, which are:

- Continuity equation: $Q = A * V$ (6)
- Dynamic equation: $V = \frac{1}{n}(A\, R^{2/3} S^{1/2})$ (7)

In the above equations, all variables stand for their usual notation as mentioned earlier, A and R is cross sectional area and hydraulic radius, respectively.

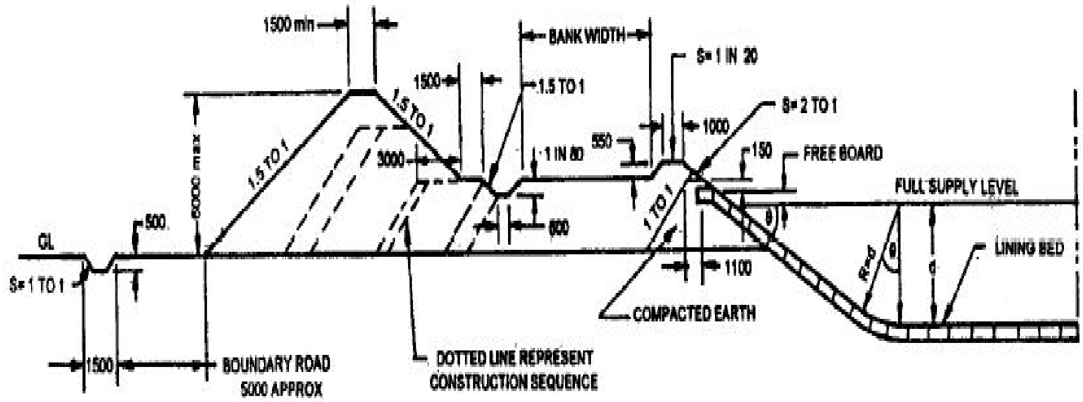
## 3.7.2 Typical sections of lined channels

Though there may be a large number of combinations of the factors on which the cross-section of a lined canal depends, some typical examples are given in the following figures, which may give an idea of laying and a practical channel cross section.



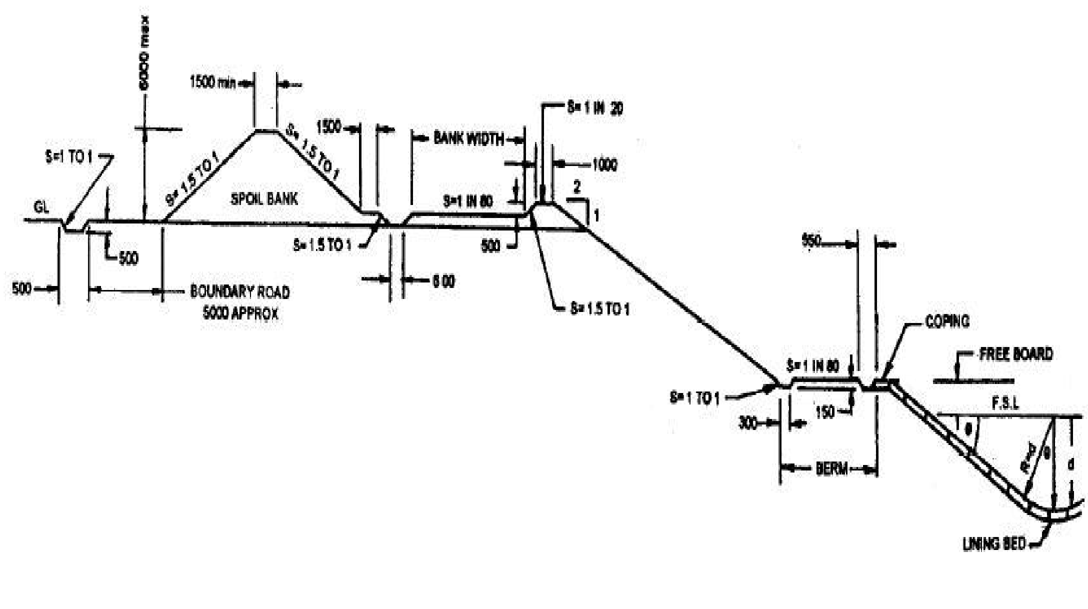

All dimensions in millimetres

FIGURE 5 (a). Typical cross section of canal when natural ground level is below bed level



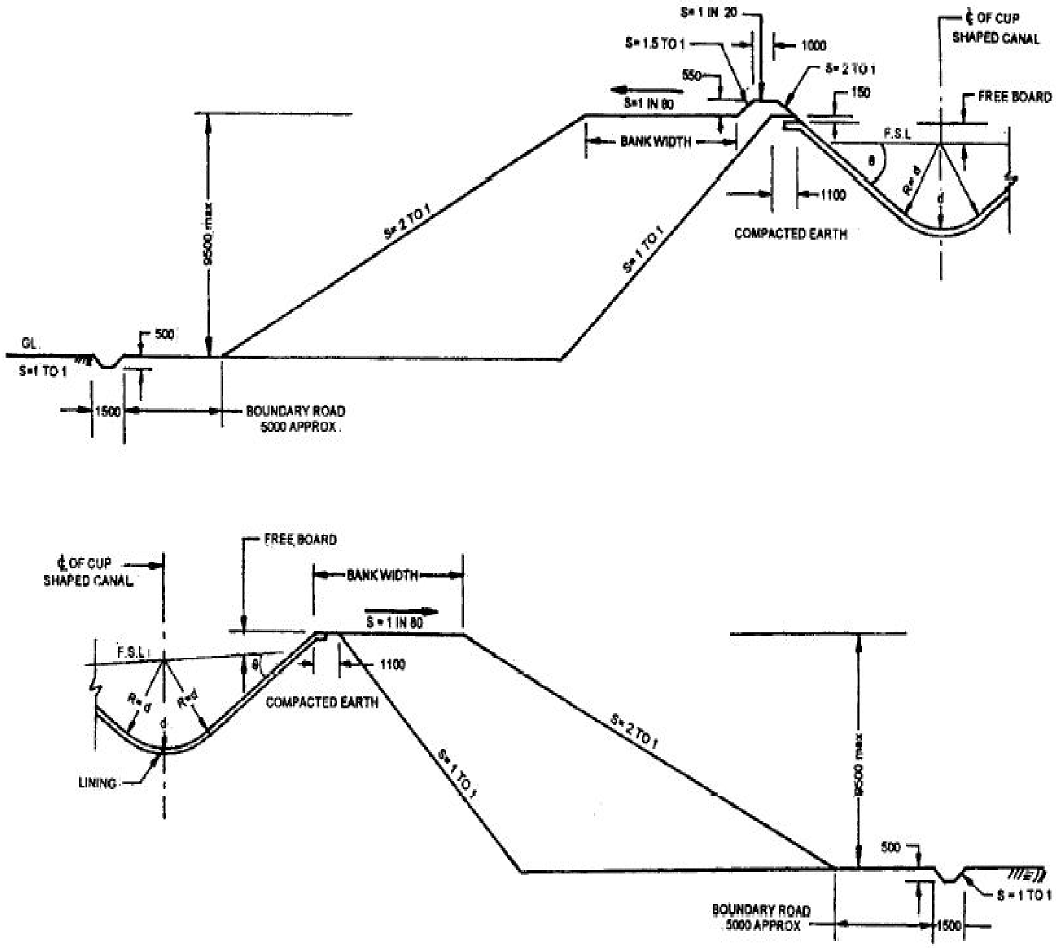

All dimensions in millimetres.

FIGURE 5 (b). Typical cross section of canal when natural ground level is between canal bed and full supply levels



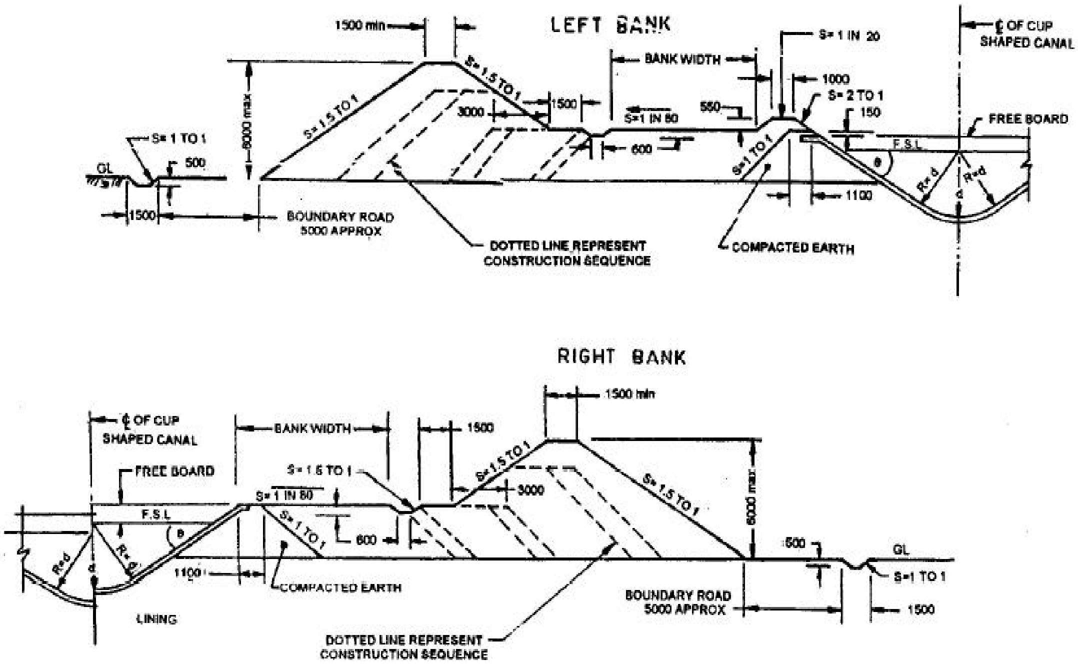

All dimensions in millimetres

FIGURE 5 (c). Typical cross section of canal when natural ground level is above the top level of lining



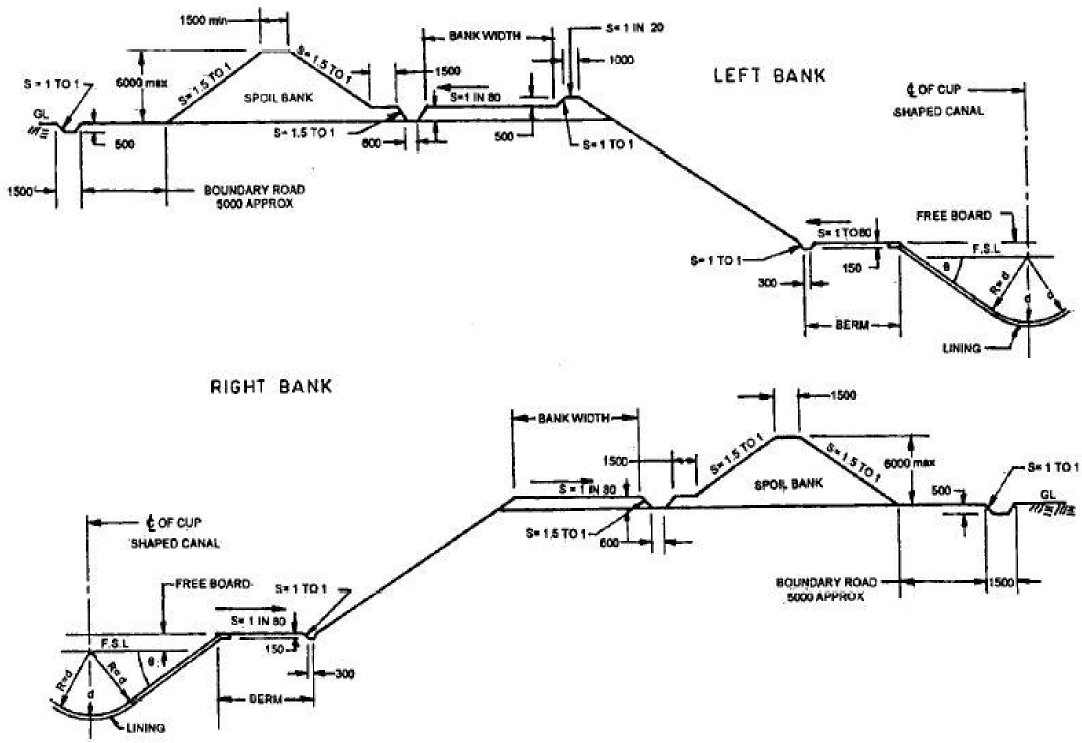

All dimensions in millimetres

FIGURE 5(d). Typical cross sections of canals when canal bed level is above natural ground level




All dimensions in millimetres.

FIGURE 5 (e). Typical cross sections of canals when natural ground level is between canal bed and full supply levels




All dimensions in millimetres

FIGURE 5 (f). Typical cross sections of canals when natural ground level is above top of canal lining

The Bureau of Indian Standard code IS: 10430-1982 “Criteria for design of lined canals and guidelines for selection of type of lining” (Reaffirmed in 1991) may generally be used, in addition to special codes like IS: 9451-1985 “Guidelines for lining of canals in expansive soils (first revision)” (Reaffirmed in 1991), which may be used under particular circumstances.

## 3.7.3 Subsurface drainage of lined canals

Lined canals passing through excavations may face a situation when the canal is dry and the surrounding soil is saturated, like when the ground table is very near the surface. Similar situation may occur for lined canals in filling when the confining banks become saturated, as during rains and the canal is empty under the circumstances of repair of lining or general closure of canal. The hydrostatic pressure built up behind the linings, unless released, causes heaving of the lining material, unless it is porous enough to release the pressure on its own. Hence, for most of the linings (except for the porous types like the boulder or various types of earth linings which develop inherent cracks), there is a need to provide a mechanism to release the back pressure of the water in the subgrade. This may be done by providing pressure relief valves, as shown in Figure 6.

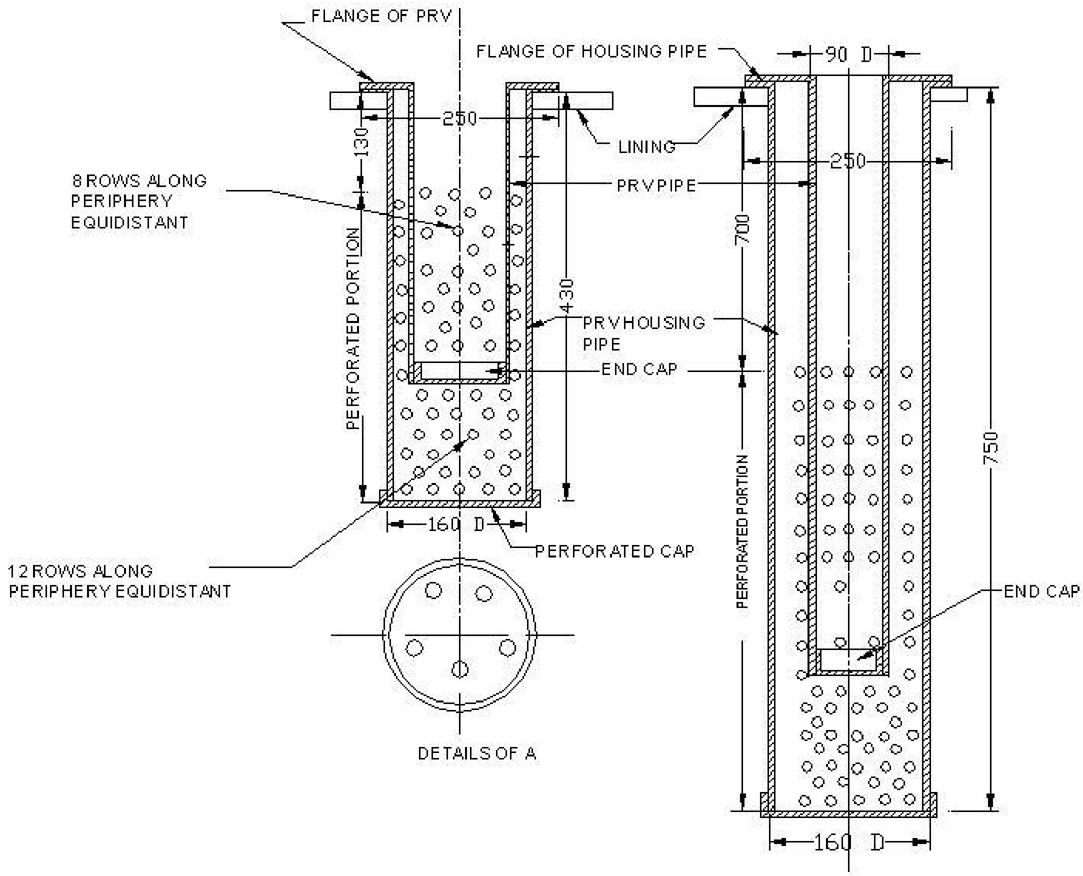



**FIGURE 6a. Details of a Pressure Relief Valve (PRV)**

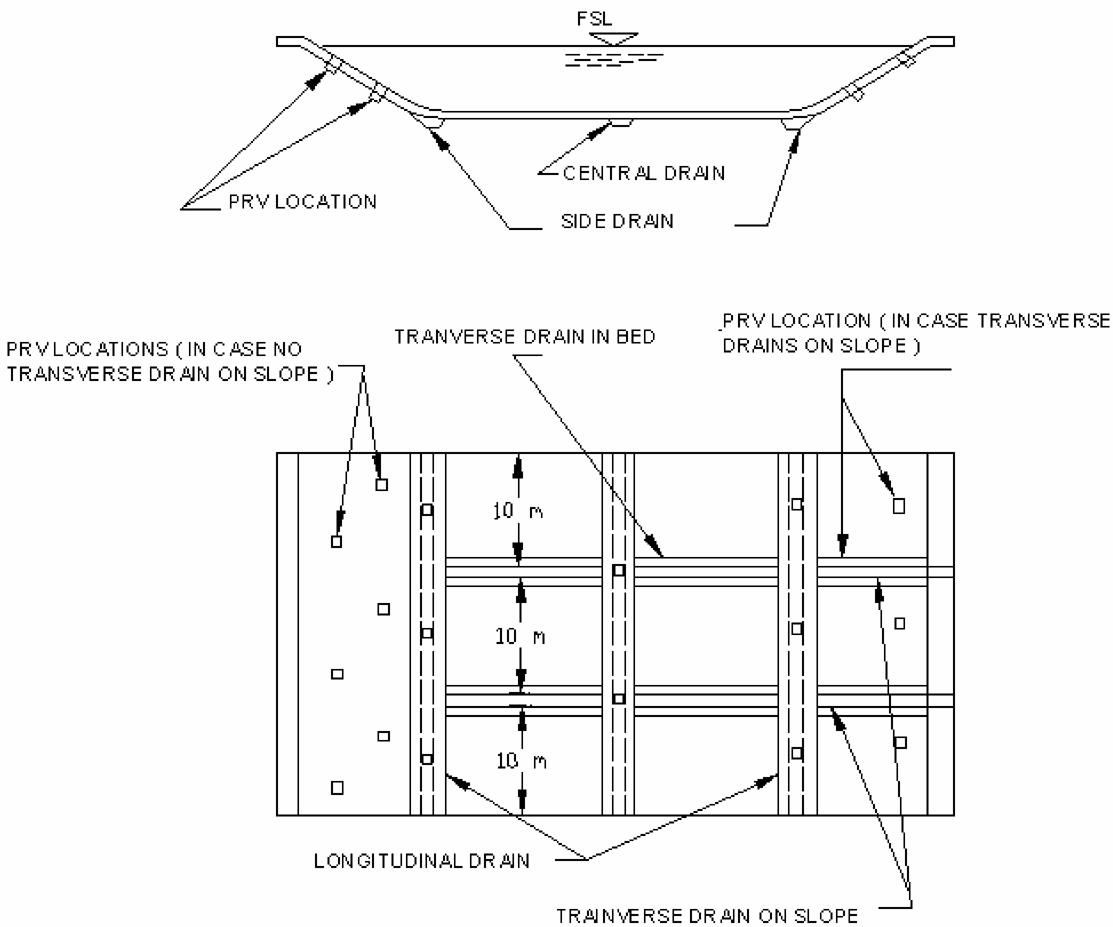



**FIGURE 6b. Possible locations of PRVs**

The Bureau of Indian Standard code IS: 4558-1983 "Code of practice for under design of lined canals" (First revision) discusses various methods for relieving uplift pressure below canal linings.

## 3.7.4 Design of unlined canals

The Bureau of Indian Standard code IS: 7112-1973 "Criterion for design of cross-section for unlined canals in alluvial soils" is an important document that may be consulted for choosing various parameters of an unlined channel, specifically in alluvial soils. There are unlined canals flowing through other types of natural material like silty clay, but formal guidelines are yet to be brought out on their design. Nevertheless, the general principles of design of unlined canals in alluvial soils are enumerated here, which may be suitably extended for other types as well after analyzing prototype data from a few such canals.

The design of unlined alluvial canals as compared to lined canals is more complex since here the bed slope cannot be determined only on the basis of canal layout, since there would be a limiting slope, more than which the velocity of the flowing water would start eroding the particles of the canal bed as well as banks. The problem becomes further complicated if the water entering the canal from the head-works is itself carrying sediment particles. In that case, there would be a limiting slope, less than which the sediment particles would start depositing on the bed and banks of the canal. In the following sections the design concept of unlined canals in alluvium for clear water as well as sediment-laden water is discussed separately.

#### 3.7.4.1 *Unlined alluvial canals in clear water*

A method of design of stable channels in coarse non-cohesive material carrying clear water has been developed by the United States Bureau of Reclamation as reported by Lane (1955), which is commonly known as the Tractive Force Method. Figure 7 shows schematically shows such a situation where the banks are inclined to the horizontal at a given angle θ.

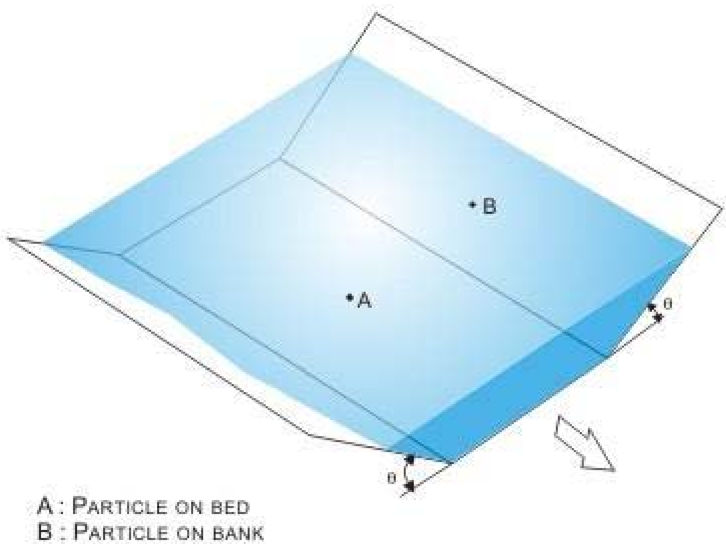



FIGURE 7. Trapezoidal shaped unlined alluvial canal
Two particles A and B are on the bed and bank

It is also assumed that the particles A and B both have the same physical properties, like size, density, etc. and also possess the same internal friction angle Φ. Naturally, the bank inclination θ should be less than Φ, for the particle B to remain stable, even under a dry canal condition. When there is a flow of water, there is a tendency for the particle A to be dragged along the direction of canal bed slope, whereas the particle B tries to get dislodged in an inclined direction due to the shear stress of the flowing water as shown in Figure 8.

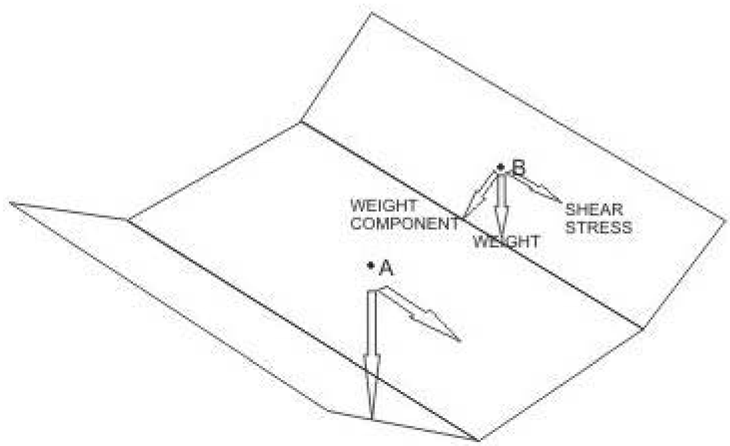



FIGURE 8. Shear stress and weight components of the particles A and B on the bed and bank, respectively

The particle A would get dislodged when the shear stress, $\tau$, is just able to overcome the frictional resistance. This critical value of shear stress is designated as $\tau_C$ may be related to the weight of the particle, W, as

$$\tau_{C\,b} = W \tan \phi \tag{8}$$

For the particle B, a smaller shear stress is likely to get it dislodged, since it is an inclined plane. In fact, the resultant of its weight component down the plane, W Sin □ and the shear stress (designated as $\tau_C{}'$) would together cause the particle to move. Hence, in this case,

$$(\tau_{CS})^2 + (W \sin \theta)^2 = \left[W \cos \theta\right] \tan \phi \tag{9}$$

In the above expression it must be noted, that the normal reaction on the plane for the particle B is W Cos θ.

Eliminating the weight of the particles, W, from equations (8) and (9), one obtains,

$$\tau_{CS}^{\ 2} + \left[\frac{\tau_{Cb}}{\tan\phi}\sin\theta\right]^2 = \left[\frac{\tau_{Cb}}{\tan\phi}\cos\theta\tan\phi\right]^2$$

This simplifies to

$$\tau_{CS}^{\ 2} = \tau_{Cb}^{\ 2}\left[\cos^2\theta - \frac{\sin^2\theta}{\tan^2\phi}\right]$$

Or

$$\frac{\tau_{CS}}{\tau_{Cb}} = \cos\theta\sqrt{1 - \frac{\tan^2\theta}{\tan^2\phi}} \qquad (10)$$

As expected, $\tau_{CS}$ is less than $\tau_{Cb}$, since the right hand side expression of equation (3) is less than 1.0. This means that the shear stress required moving a grain on the side slope is less than that required to move on the bed.

It is now required to find out an expression for the shear stress due to flowing water in a trapezoidal channel. From Lesson 2.9 it is known that in a wide rectangular channel, the shear stress at the bottom, $\tau_0$ is given by the following expression

$$\tau_0 = \gamma R S \qquad (11)$$

Where γ is the unit weight of water, R is the hydraulic radius of the channel section and S is the longitudinal bed slope. Actually, this is only an average value of the shear stress acting on the bed, but actually, the shear stress varies across the channel width. Studies conducted to find the variation of shear stress have revealed interesting results, like the variation of maximum shear stress at channel base ($\tau_b$) and sides ($\tau_S$) shown in Figure 9 to 11.

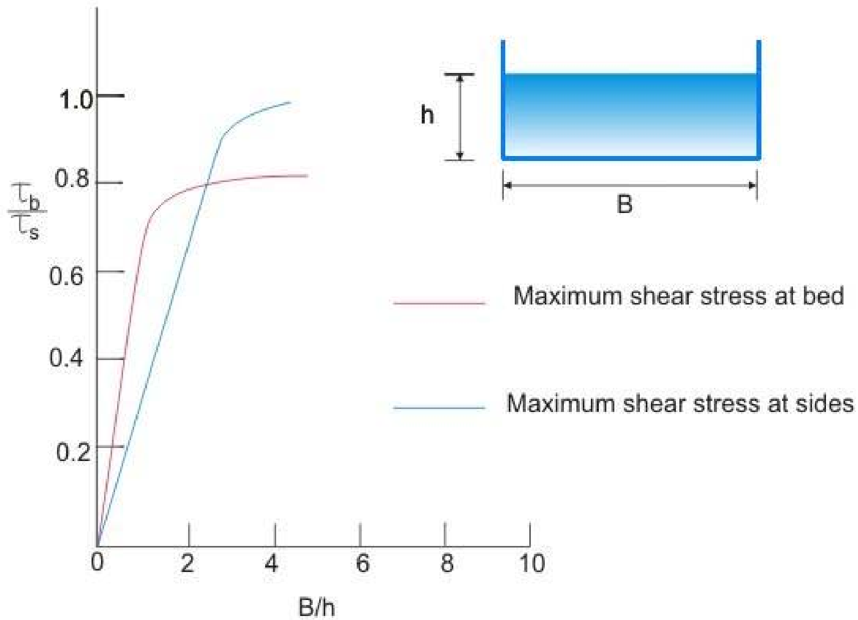



FIGURE 9. Variation of maximum shear stress for rectangular channel

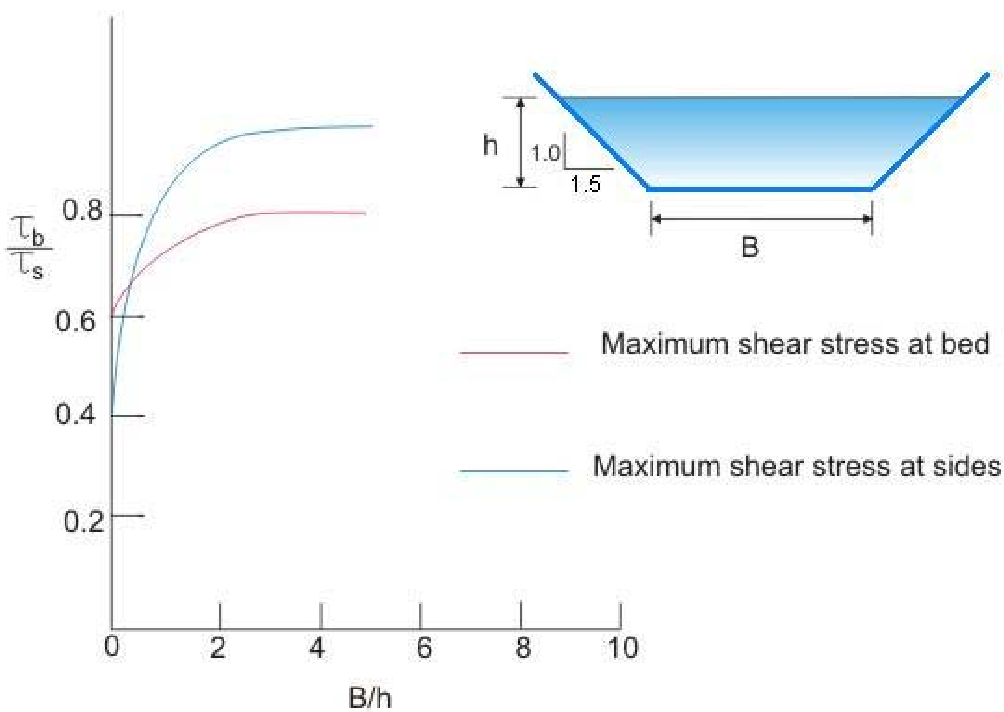



FIGURE 10. Variation of maximum shear stress fo trapezoidal channel with side slope 1V:I.5H.

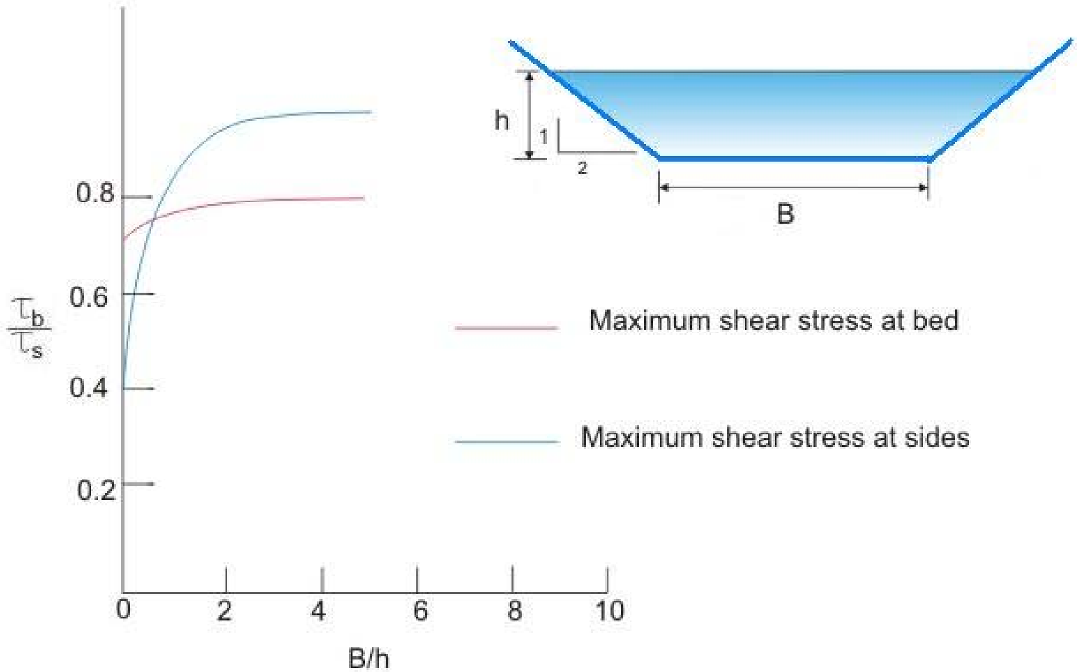



FIGURE 11. Variation of maximum shear stress of trapezoidal channel with side slope 1V : 2H

As may be seen from the above figures, for any type of channel section, the maximum shear stress at the bed is somewhat more than for that at the sides for a given depth of water (Compare $\tau_b$ and $\tau_S$ for same B/h value for any graph). Very roughly, for trapezoidal channels with a wide base compared to the depth as is practically provided, the bottom stress may be taken as γRS and that at the sides as 0.75 γRS. Finally, it remains to find out the values of B and h for a given discharge Q that may be passed through an unlined trapezoidal channel of given side slope and soil, such that both the bed and banks particles are dislodged at about the same time. This would ensure an optimum channel section.

Researchers have investigated for long, the relation between shear stress and incipient motion of non-cohesive alluvial particles in the bed of a flowing stream. One of the most commonly used relation, as suggested by Shields (1936), is provided in Figure 12.

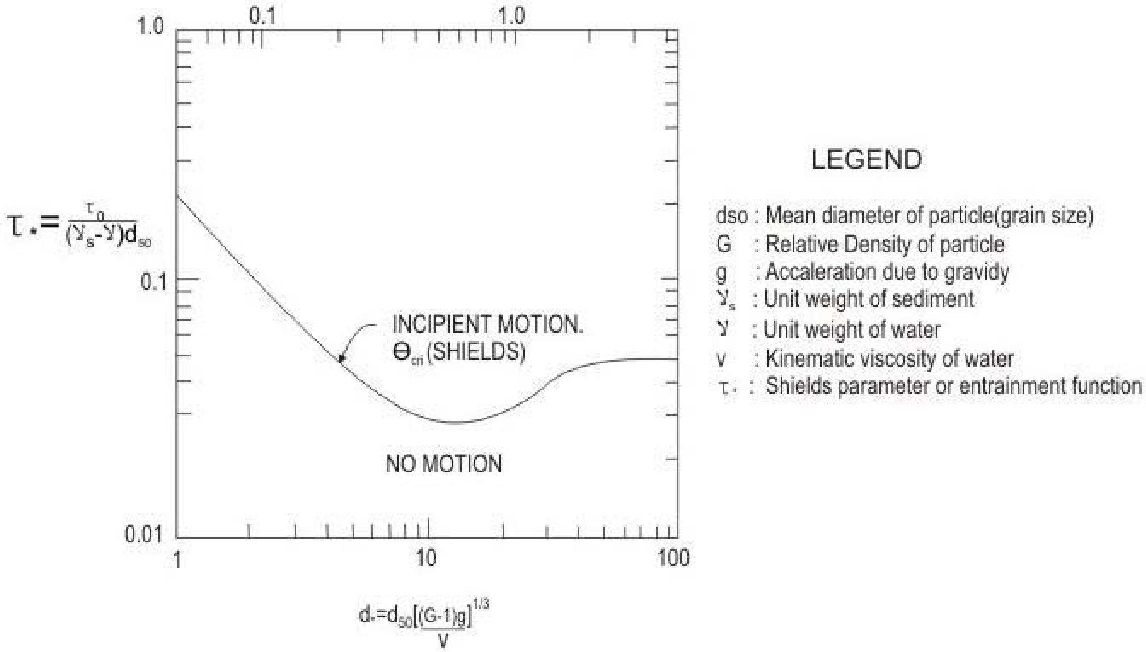



FIGURE 12. Curve for incipient motion

Swamee and Mittal (1976) have proposed a general relation for the incipient motion which is accurate to within 5 percent. For $\gamma_s$ =2650 kg/m$^3$ and $\gamma$ =1000kg/m$^3$ the relation between the critical shear stress $\tau_C$ (in N/m$^2$) diameter of particle $d_s$ (in mm) is given by the equation

$$\tau_C = 0.155 + \frac{0.409\, d_s^{\,2}}{\sqrt{1+0.177\, d_s^{\,2}}} \tag{12}$$

The application of the above formula for design of the section may be illustrated with an example.

Say, a small trapezoidal canal with side slope 2H: 1V is to be designed in a soil having an internal friction angle of $35^0$ and grain size 2mm. The canal has to be designed to carry 10m$^3$/s on a bed slope of 1 in 5000.

To start with, we find out the critical shear stress for the bed and banks. We may use the graph in figure (12) or; more conveniently, use Equation (12). Thus, we have the critical shear stress for bed, $\tau_{Cb}$, for bed particle size of 2mm as:

$$\tau_C = \tau_{Cb} = 0.155 + \frac{0.409 \,*\, 2^2}{\sqrt{1+0.177 \,*\, 2^2}}$$

$$= 1.407 \text{ N/m}^2$$

The critical shear stress for the sloping banks of the canal can be found out with the help of expression (10). Using the slope of the banks (2H: 1V), which converts to □= 26.6$^0$

$$\frac{\tau_{CS}}{\tau_{Cb}} = \text{Cos } 26.6^0 \sqrt{1 - \frac{\tan^2 26.6^0}{\tan^2 35^0}} = 0.625$$

From which,

$$\tau_{CS} = 0.625 \text{ x } 0.1.4068 = 0.880 \text{ N/m}^2$$

The values for the critical stresses at bed and at sides are the limiting values. One does not wish to design the canal velocity and water depth in such a way that the actual shear stress reaches these values exactly since a slight variation may cause scouring of the bed and banks. Hence, we adopt a slightly lower value for each, as:

Allowable critical shear stress for bed $\tau_{Cb}' = 0.9\,\tau_{Cb}$ = 1.266 N/m$^2$

Allowable critical shear stress for banks $\tau_{CS}' = 0.9\,\tau_{CS}$ = 0.792 N/m$^2$

The dimensions of the canal is now to be determined, which means finding out the water depth D and canal bottom B. for this, we have to assume a B/D ratio and a value of 10 may be chosen for convenience. We now read the shear stress values of the bed and banks in terms of flow variable 'R', the hydraulic radius, canal slope 'S' and unit weight of water γ from the figure-corresponding to a channel having side slope 2H: 1V. However, approximately we may consider the bed and bank shear stresses to be γ RS and 0.75 γ RS, respectively. Further, since we have assumed a rather large value of B/D, we may assume R to be nearly equal to D. this gives the following expressions for shear stresses at bed and bank;

Unit shear stress at bed = $\tau_b$ = γ D S = 9810 x D x $\frac{1}{5000}$ = 1.962 D N/m$^2$ per metre width.

Unit shear stress at bank $\tau_S$ = 0.75 γ D S = 0.75 x 9810 x D x $\frac{1}{5000}$ = 1.471 D N/m$^2$ per metre width.

For stability, the shear stresses do not exceed corresponding allowable critical stresses.

Thus,

$$(\tau_b =)1.962\,D < (\tau_{Cb}{}' =)1.266\,N/m^2$$
$$or\ D < 0.645\,m$$
$$and$$
$$(\tau_S =)1.471\,D < (\tau_{CS}{}' =)0.792\,N/m^2$$
$$or\ D < 0.538\,m$$

Therefore, the value of D satisfying both the expression is the minimum value of the two, which means D should be limited to 0.538 m, say 0.53 m. Since the B/D ratio was chosen to be 10, we may assume B to be 5.3 m, or say, 5.5 m for practical purposes. For a trapezoidal shaped channel with side slopes 2H: 1V, we have

$$A = D\,(B+2D) = 3.445\ \text{m}^2$$
$$\text{And}\quad P = B + 2\sqrt{5}\,D = 7.87\ \text{m}$$

$$\text{Thus}\quad R = A/P = \frac{\text{D (B + 2D)}}{\text{B} + 2\text{v}5\,\text{D}} = 0.438\,m$$

For the grain size 2mm, we may find the corresponding Manning's roughness coefficient 'n' using the Stricker's formula given by the expression

$$\boldsymbol{n} = \frac{d_S{}^{1/6}}{25.6}$$
$$= \frac{0.002^{1/6}}{25.6} = 0.014$$

Using the Manning's equation of flow, we have

$$Q = \frac{1}{n} A\, R^{2/3}\, S^{1/2}$$
$$= \frac{1}{0.014} \times 3.445 \times 0.438^{2/3} \times \left(\frac{1}{5000}\right)^{1/2}$$
$$= 2\ \text{m}^3/\text{s}$$

Since the value of Q does not match the desired discharge that is to be passed in the channel, given in the problem as $100\text{m}^3/\text{s}$, we have to change the B/D ratio, which was assumed to be 10. Suppose we assume a B/D ratio of, say, k we obtain the following expression for the flow

$$Q = \frac{1}{n} A \left(\frac{A}{P}\right)^{2/3} S^{1/2}$$
$$= \frac{1}{n} \frac{A^{5/3}}{P^{2/3}} S^{1/2}$$

And substituting known values, we obtain

$$10 = \frac{1}{0.014} \times \frac{[D(k.D + 2D)]^{5/3}}{[k.D + 2\sqrt{5}\,D]^{2/3}} \times \left[\frac{1}{5000}\right]^{1/2}$$

Substituting the value of D as 0.53m, as found earlier, it remains to find out the value of k from the above expression. It may be verified that the value of k is evaluates to around 55, from which the bed width of the canal, B, is found out to be 29.15m, say, 30m, for practical purposes.

It may be noted that IS: 7112-1973 gives a list of Manning's ***n*** values for different materials. However, it recommends that for small canals (Q<15 $m^3/s$), ***n*** may be taken as 0.02. (In the above example, ***n* was** evaluated as 0.014 by Strickler's formula).

### 3.7.4.2 Unlined alluvial channels in sediment laden water

It is natural for channel carrying sediment particles along with its flow to deposit them if the velocity is slower than a certain value. Velocity in excess of another limit may start scouring the bed and banks. Hence, for channels carrying a certain amount of sediment may neither deposit, nor scour for a particular velocity. Observations by the irrigation engineers of pre-independence India of the characteristics of certain canals in north India that had shown any deposition or erosion for several years, led to the theory of regime channels, as explained in Lesson 2.10. These channels generally carry a sediment load smaller than 500ppm. The first regime equation was proposed by Kennedy in the year 1895, who was an engineer in the Punjab PWD. Lindley, another engineer in the Punjab proposed certain regime relations in 1919. Later these equations were modified by Lacey, who was at one time the Chief Engineer of the UP Irrigation Department. In 1929 he published a paper describing his findings, which have been quite popularly used in India. These have even been adopted by the Bureau of Indian Standards code IS: 7112-1973 'Criteria for design of cross section for unlined canals in alluvial soils" (Reaffirmed in 1990), which prescribes that the following equations have to be used:

$$S = \frac{0.003\ f^{5/3}}{Q^{1/6}} \tag{13}$$

$$P = 4.75\sqrt{Q} \tag{14}$$

$$R = 0.47\left(\frac{Q}{f}\right)^{1/3} \tag{15}$$

Where the variables are as explained below:

- ***S:*** Bed slope of the channel
- ***Q:*** the discharge in m3/s
- ***P:*** wetted perimeter of the channel, in m
- ***R:*** Hydraulic mean radius, in m
- ***f:*** The silt factor for the bed particles, which may be found out by the following formula, in which $d_{50}$ is the mean particle size in mm.

$$f = 1.76\sqrt{d_{50}} \qquad (16)$$

The Indian Standard code IS: 7112-1973 has also recommended simplified equations for canals in certain parts of India by fitting different equations to data obtained from different states and assuming similar average boundary conditions throughout the region. These are listed in the following table.

| S.No | Hydraulic Parameter | All Indian Canals | Punjab canals | UP canal | Bengal canals |
|---|---|---|---|---|---|
| 1<br>2<br>3 | S (Bed slope)<br>P (wetted Perimeter)<br>R (Hydraulic radius) | | | | |

It may be noted that the regime equations proposed by Lacey are actually meant for channels with sediment of approximately 500ppm. Hence, for canals with other sediment loads, the formula may not yield correct results, as has been pointed out by Lane (1937), Blench and King (1941), Simons and Alberts on (1963), etc. however, the regime equations proposed by Lacey are used widely in India, though it is advised that the validity of the equations for a particular region may be checked before applying the same. For example, Lacey's equations have been derived for non-cohesive alluvial channels and hence very satisfactory results may not be expected from lower reaches of river systems where silty or silty-clay type of bed materials are encountered, which are cohesive in nature.

Application of Lacey's regime equations generally involves problems where the discharge (***Q***), silt factor (***f***) and canal side slopes (***Z***) are given and parameters like water depth (***D***), canal bed width (***B***) or canal longitudinal slope (***S***) have to be determined or Conversely, if ***S*** is known for a given ***f*** and ***Z***, it may be required to find out ***B***, ***D*** and ***Q***.

## 3.7.5 Longitudinal section of canals:

The cross section of an irrigation canal for both lined and unlined cases was discussed in the previous sections. The longitudinal slope of a canal therefore is also known or is adopted with reference to the available country slope. However, the slope of canal bed would generally be constant along certain distances, whereas the local ground slope may not be the same. Further in Lesson 3.6, the alignment of a canal system was shown to be dependent on the topography of the land and other factors. The next step is to decide on the elevation of the bed levels of the canal at certain intervals along its route, which would allow the field engineers to start canal construction at the exact locations. Also, the full supply level (FSL) of the canal has to be fixed along its length, which would allow the determination of the bank levels.

The exercise is started by plotting the plan of the alignment of the canal on a ground contour map of the area plotted to a scale of 1 in 15,000, as recommended by Bureau of Indian standards code IS: 5968-1987 “Guidelines for planning and layout of canal system for irrigation” (Reaffirmed 1992). At each point in plan, the chainages and bed elevations marked clearly, as shown in Figure 13. The canal bed elevations and the FSLs at key locations (like bends, divisions, etc) are marked on the plan. It must be noted that the stretches AB and BC of the canal (in Figure 13) shall be designed that different discharges due to the offtaking major distributary. Hence, the canal bed slope could be different in the different stretches.

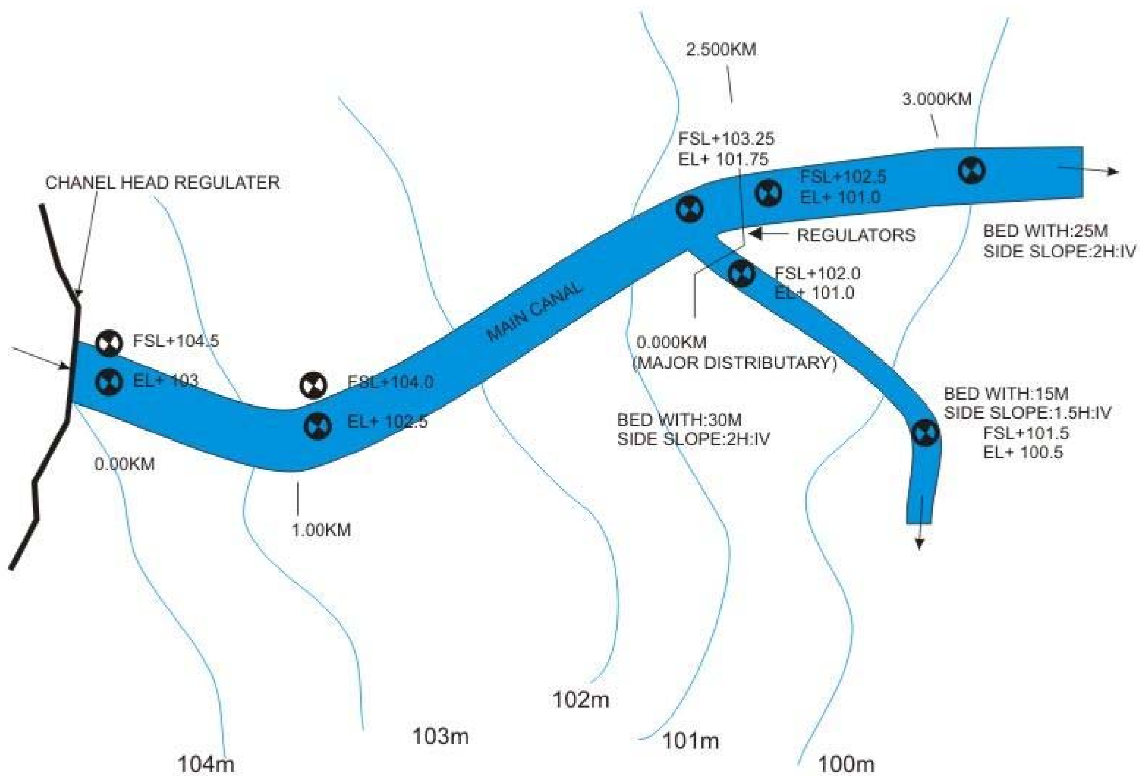



FIGURE 13. Typical layout of a canal showing bed and canal full supply levels

The determination of the FSL starts by calculating from the canal intake, where the FSL is about 1m below the pond level on the upstream of the canal head works. This is generally done to provide for the head loss at the regulator as the water passes below the gate. It is also kept to maintain the flow at almost at full supply level even if the bed is silted up to some extent in its head reaches. On knowing the FSL and the water supply depth, the canal bed level elevation is fixed at chainage 0.00KM, since this is the starting point of the canal. At every key location, the canal bed level is determined from the longitudinal slope of the canal, and is marked on the map. If there is no offtake between two successive key locations and no change in longitudinal slope is provided, then the cross-section would not be changed, generally, and accordingly these are marked by the canal layout.

At the offtakes, where a major or minor distributary branches off from the main canal, there would usually be two regulators. One of these, called the cross regulator and located on the main canal heads up the water to the desired level such that a regulated quantity of water may be passed through the other, the head regulator of the distributary by controlling the gate opening. Changing of the cross regulator gate opening has to be done simultaneously with the adjustment of the head regulator gates to allow the desired quantity of water to flow through the distributary and the remaining is passed down the main canal.

The locus of the full supply levels may be termed as the full supply line and this should generally kept above the natural ground surface line for most of its length such that most of the commanded area may be irrigated by gravity flow. When a canal along a watershed, the ground level on its either side would be sloping downward, and hence, the full supply line may not be much above the ground in that case. In stretches of canals where there is no offtake, the canal may run through a cutting within an elevated ground, and in such a case, the full supply line would be lower than the average surrounding ground level. In case irrigation is proposed for certain reaches of the canal where the adjacent ground level is higher than the supply level of the canal, lift irrigation by pumping may be adapted locally for the region.

Similarly, for certain stretches of the canal, it may run through locally low terrain. Here, the canal should be made on filling with appropriate drainage arrangement to allow the natural drainage water to flow below the canal. The canal would be passing over a water-carrying bridge, called aqueducts, in such a case.

As far as possible, the channel should be kept in balanced depth of cutting and filling for greatest economy and minimum necessity of ***borrow pits*** and ***spoil banks*****.**

The desired canal slope may, at times, is found to be much less than the local terrain slope. In such a case, if the canal proceeds for a long distance, an enormous amount of filling would be required. Hence, in such a case, canal falls are provided where a change in bed elevation is effected by providing a ***drop structure*** usually an energy dissipater like hydraulic jump basin is provided to kill the excess energy gained by the fall in water elevation. At times, the drop in head is utilized to generate electricity through suitable arrangement like a bye-pass channel installed with a bulb-turbine.

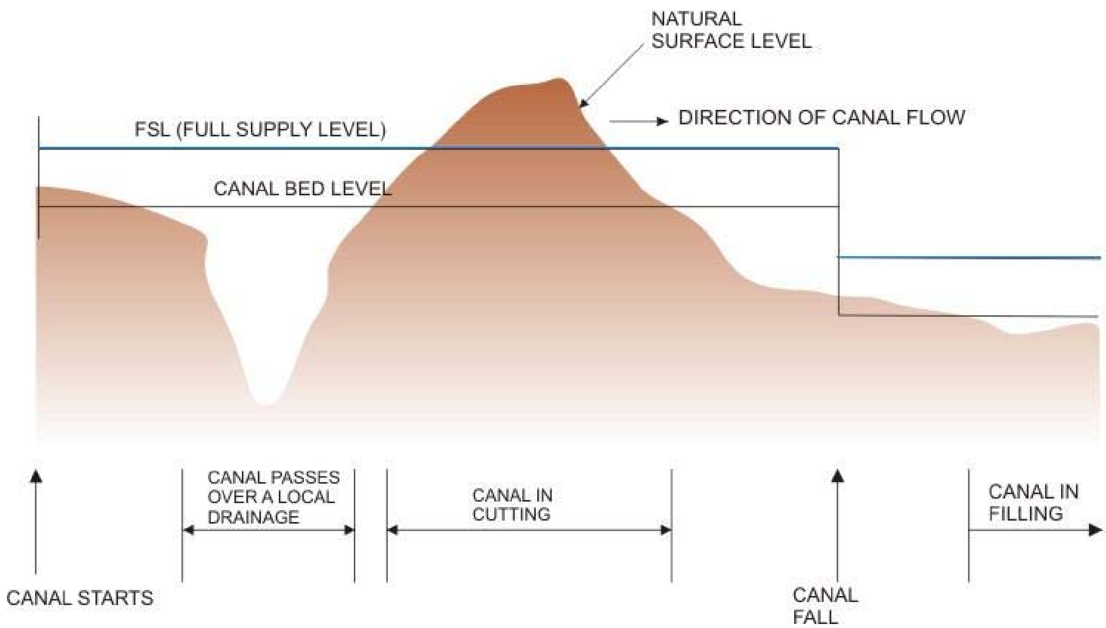



FIGURE 14. Longitudinal section of a canal assuming no withdrawals in this stretch

A typical canal section is shown in Figure 14, for a canal stretch passing through varying terrain profile. Here, no withdrawals have been assumed and hence, the discharge in the entire stretch of the canal is assumed to remain same. Hence, the canal bed slope and water depth are also not shown varying. It is natural that if the canal has outlets in between, the change in discharge would result in corresponding changes in the full supply line.

The elevation of the banks of the canal is found out by adding the ***freeboard*** depth. Though the free board depth depends upon many factors, the Bureau of Indian standards code IS: 7112-1973 “Criteria for design of cross sections for unlined canals in alluvial soils” recommends that a minimum free board of 0.5m be provided for canals carrying discharges less than 10m3/s and 0.75m for canals with higher discharges.

## 3.7.6 Important terms

**Free Board:** A depth corresponding to the margin of safety against overtopping of the banks due to sudden rise in the water level of a channel on account of accidental or improper opening or closing of gates at a regulator on the downstream.

**Borrow pits*:*** Specific site within a borrow area from which material is excavated for use is called a borrow pit.

**Spoil Banks:** Piles of soil that result from the creation of a canal, deepened channel, borrow pit, or some similar structure.

## References:


- IS: 10430 -1982 "Criteria for design of lined canals and guidelines for selection of type of lining"
- IS: 4558-1983 "Code of practice for under design of lined canals" (First revision)
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