SYSTEM OF IRRIGATION CANAL

CHAPTER 6

Alluvial Soil and Non-Alluvial Soil

- The soil which is formed by transportation and deposition of silt through the agency of water, over a course of time, is called the **alluvial soil.**
- The canals when excavated through such soils are called **alluvial canals**. Canal irrigation (direct irrigation using a weir or a barrage) is generally preferred in such areas, as compared to the storage irrigation (i.e. by using a dam).
- Alluvial soil is fertile, as it can absorb a fair percentage of rainfall and retain it in the substratum, making it highly productive, as water, remains available within the root zone of crops.
- Mountainous regions may go on disintegrating over a period of time, resulting in the formation of a rocky plain area, called non-alluvial area.
- It has an uneven topography, and hard foundations are generally available. The rivers, passing through such areas, have no tendency to shift their courses, and they do not pose much problems for designing irrigation structures on them. Canals, passing through such areas are called **non-alluvial Canals**.

Alignment of Canals

(i) Watershed Canal or Ridge Canal:
(ii) Contour Canal
(iii) Side-slope Canal

Watershed canal or ridge canal:

- ✓ The dividing ridge line between the catchment areas of two streams (drains) is called the **watershed or ridge canal**.
- ✓ Thus between two major streams, there is the main watershed (ridge line), which divides the drainage area of the two streams, as shown in figure below. Similarly, between a main stream and any of its tributary, there are subsidiary watersheds (ridge lines), dividing the drainage between the two streams on either side.
- ✓ *The canal which is aligned along any natural watershed (ridge line) is called a watershed canal, or a ridge canal.* Aligning a canal (main canal or branch canal or distributary) on the ridge ensures gravity irrigation on both sides of the canal.
- ✓ Since the drainage flows away from the ridge, no drainage can cross a canal aligned on the ridge. *Thus, a canal aligned on the watershed saves the cost of construction of cross-drainage works.*

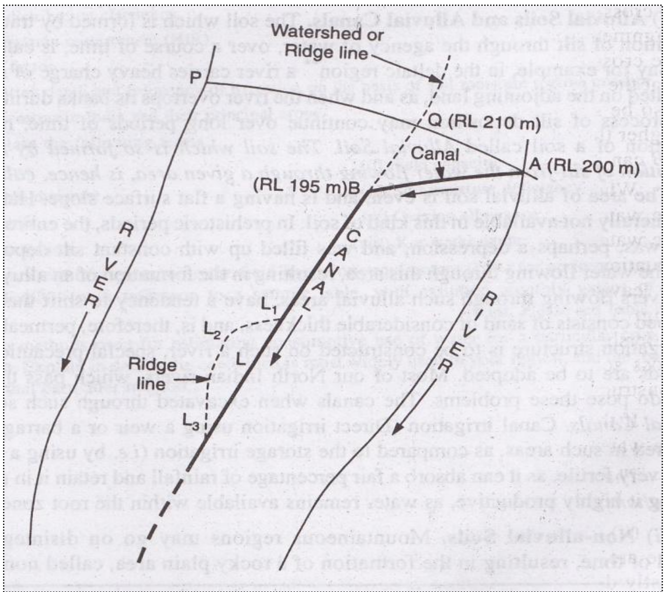


Fig: Alignment of a ridge or watershed canal
(Head reach of a main canal in plains)

Contour Canals

Watershed canal along the ridge line are, however, not found economical in hill areas, since the conditions in hills are vastly different compared to those of plains. In hills, the river flows in the valley well below the watershed. Infact, the ridge line (watershed) may be hundred of meters above the river. It therefore becomes virtually impossible to take the canal on top of such a higher ridge line. In such conditions, contour canals (figure below) are usually constructed.

- Contour channels follow a contour, except for giving the required longitudinal slope to the canal.
- Since the river slope is much steeper than the canal bed slope, the canal encompasses more and more area between itself and the river.
- A contour canal irrigates only on one side because the area on the other side is higher, as can be seen in figure below.

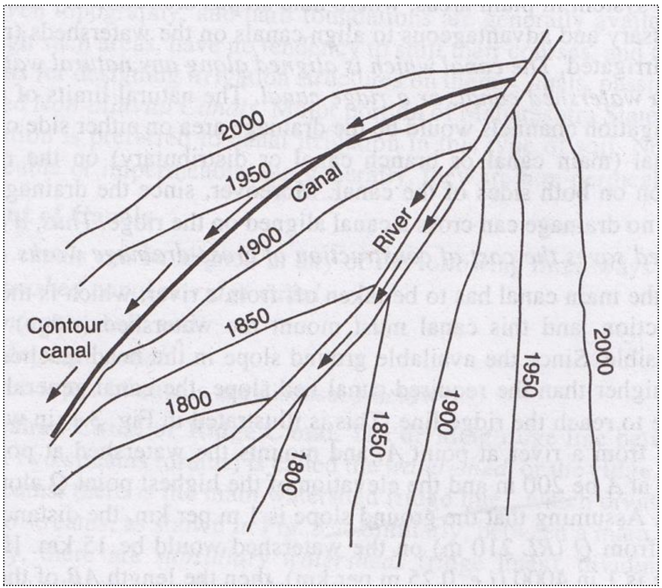


Fig: Alignment of a Contour canal
(Head reach of main canal in hills)

Side-slope canal:

A side slope canal is that which is aligned at right angles to the contours; i.e. along the side slopes, as shown in figure below. Since such a canal runs parallel to the natural drainage flow, it usually does not intercept drainage channels, thus avoiding the construction of cross-drainage structures.

- It is a canal which is aligned roughly at right angle to contours of the country but not on watershed or valley. The canal thus runs roughly parallel to the natural drainage of the country and as such cross drainage works are avoided. The side slope channel has the advantage of not intercepting cross drainage works but its course must follow the shortest route the nearest valley and such channel shall be along a line of steepest possible slope except in very flat areas.

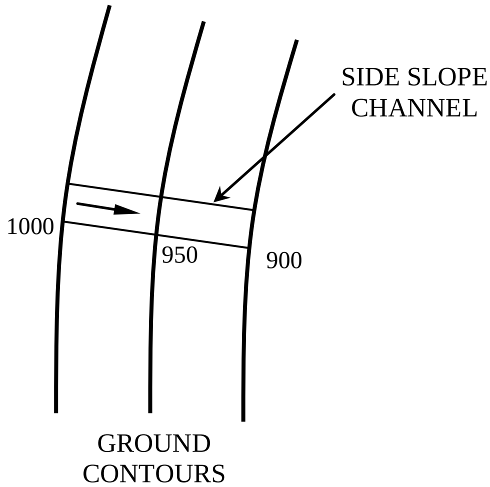


Fig: Alignment of a side slope canal

Distribution system for canal irrigation

It has emphasized earlier that the direct irrigation scheme using a weir or a barrage, as well as the storage irrigation scheme using a dam or a reservoir, require a network of irrigation canals of different sizes and capacities. The entire network of irrigation channels is called the Canal System.

The canal system Consists:

- Main canal
- Branch canals
- Distributaries
- Minors
- Watercourses

In case of direct irrigation scheme, a weir or a barrage is constructed across the river, and water is headed up on the upstream side. The arrangement is known as Head works or diversion head works. Water is diverted into the main canal by means of a diversion weir. A head regulator is provided at the head of the main canal, so as to regulate the flow of water into the main canal.

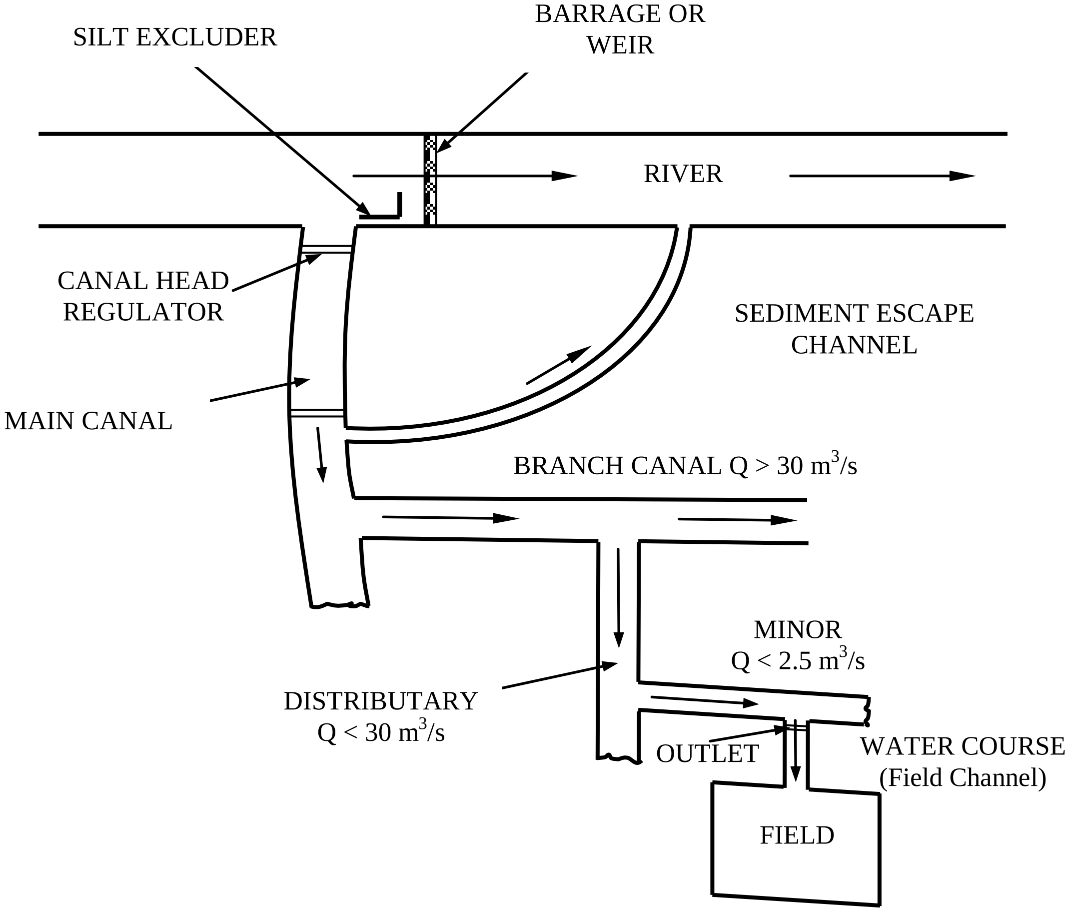


Fig: Layout of an irrigation canal network

Definition of Important Terms

- **Gross Command Area (GCA)**

The whole area enclosed between an imaginary boundary lines which can be included in an irrigation project for supplying water to agricultural land by the net work of canals is known as GCA. It includes both the culturable and unculturable areas.

- **Uncultivable Area**

The area where the agriculture cannot be done and crops cannot be grown – marshy lands, barren lands, ponds, forest, villages etc. are considered as uncultivable area.

- **Cultivable Area**

The area where agriculture can be done satisfactorily

- **Cultivable Command Area (CCA)**

The total area within an irrigation project where the cultivation can be done and crops can be grown

- **Intensity of Irrigation**

Ratio of cultivated land for a particular crop to the total culturable command area

$$\therefore \text{Intensity of irrigation, } \mathbf{I_I} = \frac{\text{Cultivated Land}}{\text{CCA}}$$

Losses of water in canal

During the passage of water from the main canal to the outlet at the head of the watercourse, water may be lost either by evaporation from the surface or by seepage through the peripheries of the channels. These losses are sometimes very high, of the order of 25 to 50 % of the water diverted into the main canal. Evaporation and seepage losses are discussed below:

- **Evaporation:** The water lost by evaporation is generally very small, as compared to the water lost by seepage in certain channels. Evaporation losses are generally of the order of 2 to 3 percent of the total losses.
- **Seepage:** There may be two different conditions of seepage, i.e. (i) Percolation, (ii) Absorption
  - **Percolation:** In percolation, there exists a zone of continuous saturation from the canal to the water-table and a direct flow is established. Almost all the water lost from the canal joins the ground water reservoir.
  - **Absorption:** In absorption, a small saturated soil zone exists round the canal section, is surrounded by zone of decreasing saturation. A certain zone just above the water-table is saturated by capillarity. Thus, there exists an unsaturated soil zone between the two saturated zones, as shown below.

Time Factor:

The ratio of the number of days the canal has actually been kept open to the number of days the canal was designed to remain open during the base period is known as **time factor**.

For example, a canal was designed to be kept open for 12 days, but it was practically kept open for 10 days for supplying water to the culturable area. Then the time factor is 10/12.

$$\therefore \text{Time factor} = \frac{\text{No. of days the canal practically kept open}}{\text{No. of days the canal was designed to keep open}} = \frac{\text{Actual discharge}}{\text{Designed discharge}}$$

Capacity Factor:

Generally, a canal is designed for a maximum discharge capacity. But, actually it is not required that the canal runs to that maximum capacity all the time of the base period. So, the ratio of the average discharge to the maximum discharge (designed discharge) is known as **capacity factor**.

For example, a canal was designed for the maximum discharge of 50 cumec, but the average discharge is 40 cumec.

$\therefore$ Capacity factor = 40/50 = 0.8

Problem-1

The gross commanded area for a distributary is 6000 hectares, 80 % of which is culturable irrigable. The intensity of irrigation for Rabi season is 50 % and that for Kharif season is 25 %. If the average duty at the head of the distributary is 2000 hectares/cumec for Rabi season and 900 hectares/cumec for Kharif season, find out the discharge required at the head of the distributary from average demand considerations.

Solution:

G.C.A = 6000 hectares

C.C.A = 80 % of 6000 = (80/100) × 6000 = 4800 hectares

Area to be irrigated in Rabi season = C.C.A × Intensity of irrigation

= 4800 × (50/100) = 2400 hectares

Area to be irrigated in Kharif season = 4800 × (25/100) = 1200 hectares

Water required at the head of the distributary to irrigate Rabi area = $\frac{2400}{2000}$ cumec = 1.20 cumec

Water required at the head of the distributary to irrigate Kharif area = $\frac{1200}{900}$ cumec = 1.33 cumec

The required discharge is maximum of the two, i.e. 1.33 cumec (**Ans**)

Hence, the distributary should be designed for 1.33 cumec discharge at its head from average demand considerations. The head regulator should be sufficient to carry 1.33 cumec and in Rabi season, only 1.20 cumec will be released.

Problem-2

The culturable commanded area of a watercourse is 1200 hectares. Intensities of sugarcane and wheat crops are 20% and 40% respectively. The duties for the crops at the head of the watercourse are 730 hectares/cumec and 1800 hectares/cumec respectively. Find (a) the discharge required at the head of the watercourse (b) determine the design discharge oat the outlet, assuming a time factor equal to 0.8.

***Solution*:**

C.C.A = 1200 hectares

Intensity of irrigation for sugarcane = 20 %

∴ Area to be irrigated under sugarcane = 1200 × (20/100) = 240 hectares

Intensity of irrigation for wheat = 40 %

∴ Area to be irrigated under wheat = 1200 × (40/100) = 480 hectares

Again,

Duty for sugarcane = 730 hectares/cumec

Duty for wheat = 1800 hectares/cumec

∴ Discharge required for sugarcane = Area/Duty = (240/730) cumec = 0.329 cumec

∴ Discharge required for wheat = Area/Duty = (480/1800) cumec = 0.271 cumec

Now, sugarcane requires water for all the 12 months and wheat requires water for only Rabi season. Hence, the water requirement at the head of the watercourse at any time of the year will be the summation of the two, i.e. equal to 0.329 + 0.271 = 0.6 cumec

(a) Hence, the discharge required at the head of the watercourse is 0.6 cumec (**ans**)

Note: The discharge during Rabi season will be 0.6 cumec and for the rest of the year, it will be 0.329 cumec

(b) Time factor = 0.8; since the channel runs for fewer days than the crop days, therefore, the actual design discharge at the outlet = (0.6/0.8) = 0.75 cumec (**ans**)

Problem-3

The culturable commanded area for a distributary is 15,000 hectares. The intensity of irrigation for Rabi (wheat) is 40 % and for Kharif (rice) is 15 %. If the total water requirements of the two crops are 37.5 cm and 120 cm and their periods of growth are 160 days and 140 days respectively; determine the outlet discharge from average demand considerations.

***Solution*:**

C.C.A = 15,000 hectares

Intensity of irrigation for Rabi (wheat) = 40 %

Intensity of irrigation for Kharif (rice) = 15 %

Rabi (wheat) area = 15,000 × 0.40 = 6000 hectares

Kharif (rice) area = 15,000 × 0.15 = 2250 hectares

For wheat,

Δ = 37.5 cm

B = 160 days

Average duty for wheat, D = 864×160/37.5 = 3686 hectares/cumec

For rice,

Δ = 120 cm

B = 140 days

Average duty for rice, D = 864×140/120 = 1008 hectares/cumec

Outlet discharge required for wheat = Area/Duty = 6000/3686 = 1.63 cumec

Outlet discharge required for rice = 2250/1008 = 2.23 cumec

The required design discharge at outlet (from average demand considerations) is maximum of the two values, i.e. **2.23 cumec** (ans)

Cross-section of an irrigation Canal:

A typical and most desired section of a canal is shown below. This section is partly in cutting and partly in filling and aims in balancing the quantity of earth work in excavation with that in filling

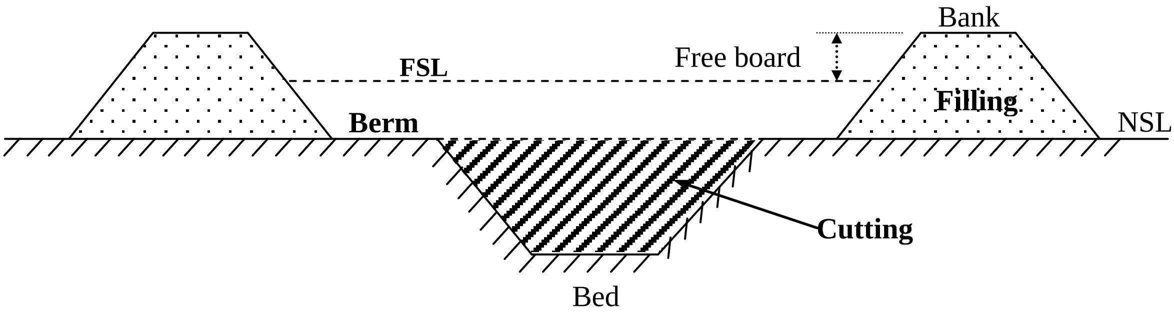


Fig: Typical cross-section of an irrigation canal

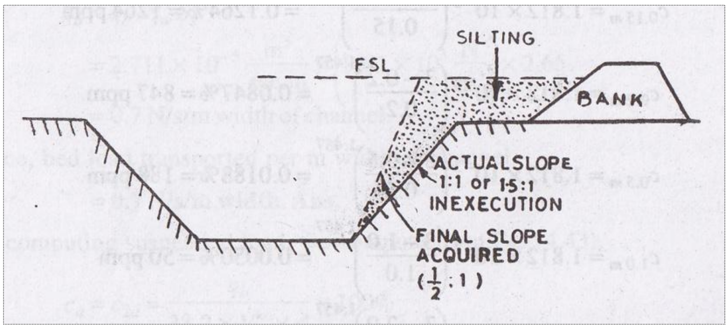
Note: Sometimes, when the natural surface level (NSL) is above the top of the bank, the entire canal section will have to be in cutting, and it shall be called 'canal in cutting'. Similarly, when the NSL is lower than the bed level of the canal, the entire canal section will have to be built in filling, and it is called 'canal in filling' or 'canal in banking'.

Components of cross-section:

- Side slopes
- Berms
- Freeboard
- Banks
- Service roads
- Back Berm or Counter Berms
- Spoil Banks
- Borrow Pits

Side Slopes

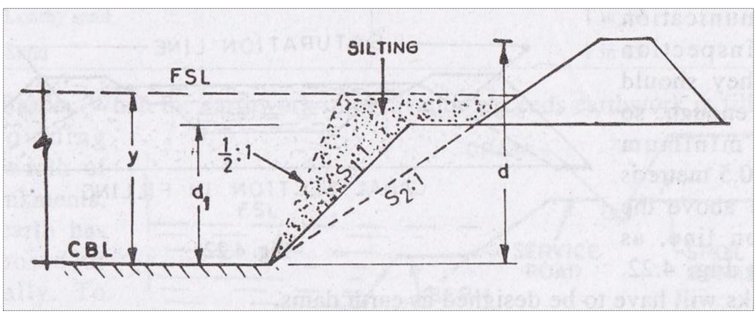
The side slopes should be such that they are stable, depending upon the type of the soil. A comparatively steeper slope can be provided in cutting rather than in filling, as the soil in the former case shall be more stable.



In cutting -------------- 1H: 1V to 1.5 H: 1V
In filling --------------- 1.5 H: 1V to 2H: 1V

Berms

Berm is the horizontal distance left at ground level between the toe of the bank and the top edge of cutting.



The berm is provided in such a way that the bed line and the bank line remain parallel. If s_1: 1 is the slope in cutting and s_2:1 in filling, then the initial berm width = $(s_1 - s_2)\, d_1$.

Purposes of Berms:

- They help the channel to attain regime conditions.
- They give additional strength to the banks and provide protection against erosion and breaches.
- They protect the banks from erosion due to wave action.
- They provide a scope for future widening of the canal.

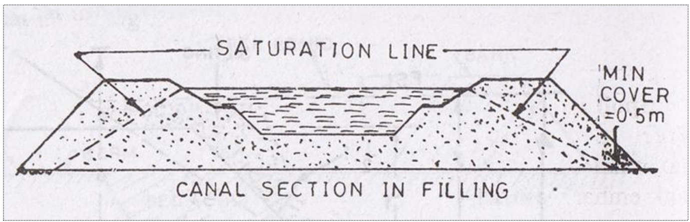
Freeboard

The margin between FSL and bank level is known as freeboard. The amount of freeboard depends upon the size of the channel. The generally provided values of freeboard are given in the table in the next page.

Discharge (m^3/s)	Extent of freeboard (m)
1 to 5	0.50
5 to 10	0.60
10 to 30	0.75
30 to 150	0.90

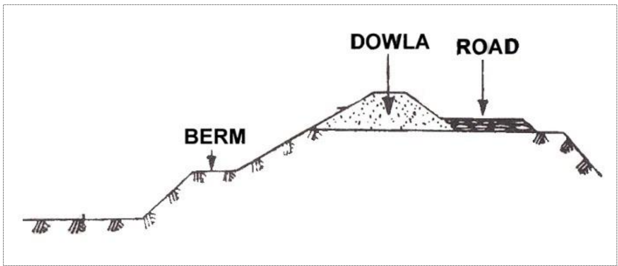
Banks

The primary purpose of banks in to remain water. The can be used as means of communication and as inspection paths. They should be wide enough, so that a minimum cover of 0.50 m is available above the saturation line.



Service Roads

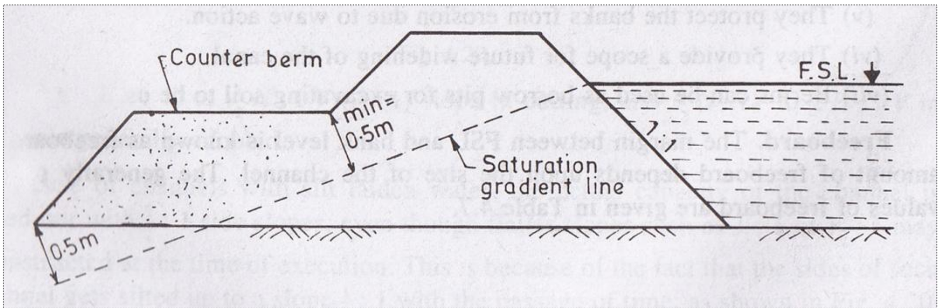
Service roads are provided on canals for inspection purposes, and may simultaneously serve as the means of communication in remote areas. They are provided 0.4 m to 1.0 m above FSL, depending upon the size of the channel.



Dowla: As a measure of safety in driving, dowlas 0.3 m high and 0.3 to 0.6 m wide at top, with side slopes of 1.5: 1 to 2:1, are provided along the banks. They also help in preventing slope erosion due to rains etc.

Back berms or counter berms

Even after providing sufficient section for bank embankment, the saturation gradient line may cut the downstream end of the bank. In such a case, the saturation line can be kept covered at least by 0.5 m with the help of counter berms as shown in figure below.

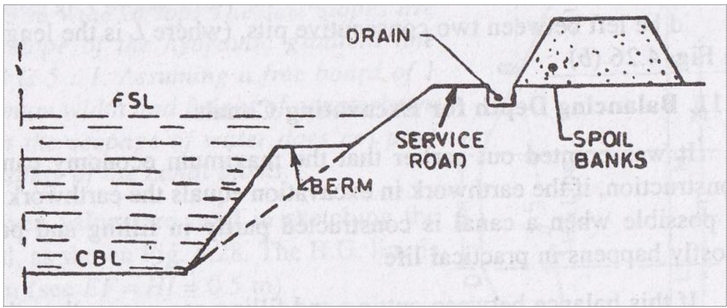


The straight saturation gradient line may be drawn with the following slopes:

Type of soil	Slope (H:V)
Clay	1 in 4
Clayey Loam	1 in 6
Loam	1 in 8
Loamy sand	1 in 10
Sand	1 in 15

Spoil banks

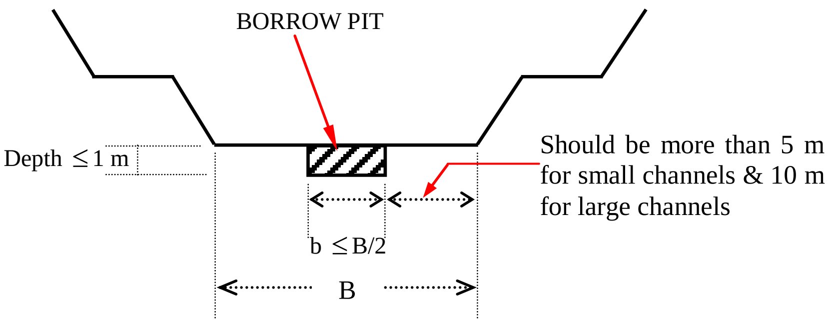
When the earthwork in excavation exceeds earthworks in filling, even after providing maximum width of bank embankments, the extra earth has to be disposed of economically. To dispose of this earth by mechanical transport, etc. may become very costly, and an economical mode of its disposal may be found in the form of collecting this soil on the edge of the bank embankment itself.



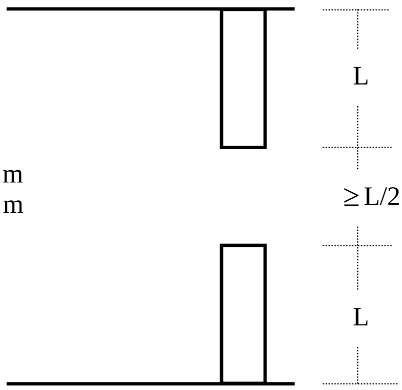
Borrow pits

When earthwork in filling exceeds the earthwork in excavation, the earth has to be brought from somewhere. The pits, which are dug for bringing earth, are known as borrow pits.

If such pits are excavated outside the channel, they are known as *external borrow pits*, and if they are excavated somewhere within the channel, they are known as *internal borrow pits*. It is a very costly affair to bring soil from distances. Even in the nearby areas, these pits may cause mosquito nuisance due to collection of rain water in these pits, and hence, external borrow pits are not preferred.



(a) Cross-section



(b) Plan

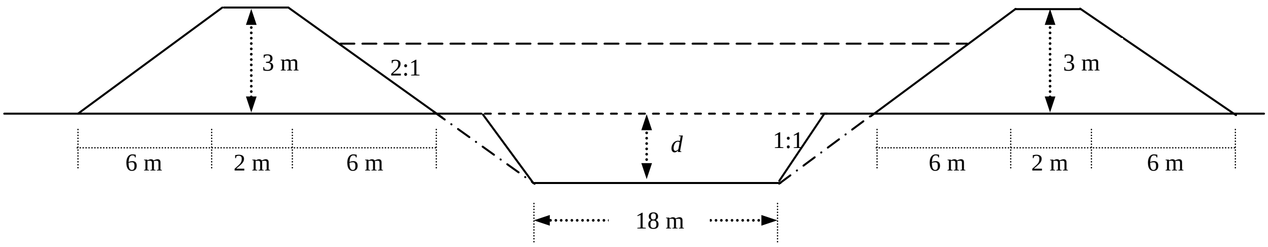
Design Requirements:

- The borrow pits should start from a point at a distance more than 5 m from the toe for small channels, and 10 m for large channels.
- The width of these pits *b*, should be less than half the width of the canal *B*, and should be dug in the entire.
- The depth of these pits should be equal to or less than 1 m.
- Longitudinally, these pits should not run continuous, but a minimum space of *L*/2 should be left between two consecutive pits, (where *L* is the length of one pits).

Problem- 4

Calculate the balancing depth for a channel section having a bed width equal to 18 m and side slopes of 1:1 in cutting and 2:1 in filling. The bank embankments are kept 3.0 m higher than the ground level (berm level) and crest width of banks is kept as 2.0 m

Solution: The channel section is shown below. Let d be the balancing depth, i.e. the depth for which excavation and filling becomes equal.



Area of cutting = $(18 + d)\, d$ m^2

Area of filling = 2(2+14)/2×3 = 48 m^2

Equating cutting and filling, we get

$(18 + d)\, d = 48$

$\Rightarrow d^2 + 18d - 48 = 0 \Rightarrow d = 2.35$ m (neglecting –ve sign)

$\therefore$ Balancing depth = 2.35 m

Practice Problems

1. An area of 300 hectares is to be irrigated from a minor channel with one outlet; C.C.A is 80% of total area. The intensity of irrigation is 50% for Rabi and 30% for Kharif crop. Taking loss in conveyance system as 5% of outlet discharge, determine the design discharge of the channel. Take outlet discharge factor for Rabi season as 1500 ha/m^3/sec and for Kharif season 1000 ha/m^3/sec.

2. Find out the capacity of a reservoir from the following data. The culturable command area is 80,000 hectares.

Crop	Base in days	Duty in hectares/cumec	Irrigation Intensity (%)
Rice	120	1800	25
Wheat	120	2000	30
Sugarcane	320	2500	20

Assume the canal and reservoir losses as 5% and 10% respectively

3. Determine the head discharge of a canal from the following data: The value of time factor may be assumed as 0.75.

Crop	Base Period in days	Area in hectare	Duty in hectares/cumec
Rice	120	4000	1500
Wheat	120	3500	2000
Sugarcane	310	3000	1200

4. A Persian wheel discharges at the rate of 11,000 liters per hour and works for eight hours each day. Estimate the area commanded by the water lift if the average depth of irrigation is 8 cm and irrigation interval is 15 days.