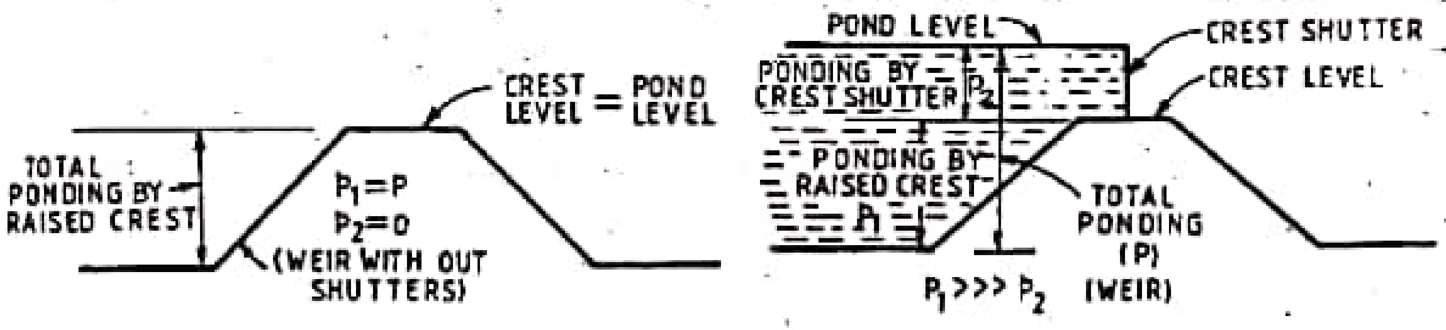
Diversion Head Works

It was stated earlier that the main permanent canal, forming the primary part of a direct irrigation scheme, takes off from a diversion weir or a barrage. In fact, these permanent canals take off from rivers and the arrangements are so well made at their heads, that a constant and a continuous water supply is ensured into the canal, even during the periods of low flow. *The works, which are constructed at the head of the canal, in order to divert the river water towards the canal, so as to ensure a regulated continuous supply of silt-free water with a certain minimum head into the canal, are known as Diversion Head Works.*

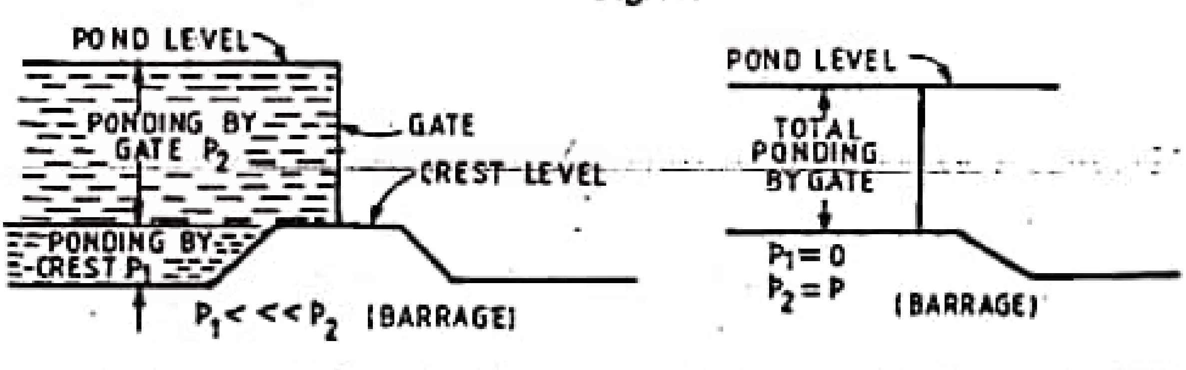
9.1. Weir and Barrage

In general, the above purpose can be accomplished by constructing a barrier across the river, so as to raise the water level on the upstream side of the obstruction, and thus, to feed the main canals taking off from its upstream side at one or both of its flanks. The ponding of water can be achieved either only by a permanent pucca raised crest across the river or by a raised crest supplemented by falling counter-balanced gates or shutters, working over the crest. *If the major part or the entire ponding of water is achieved by a raised crest and a smaller part or nil part of it is achieved by the shutters, then this barrier is known as a weir [Fig. 9.1 (a) and (b)]. On the other hand, if most of the ponding is done by gates and a smaller or nil part of it is done by the raised crest, then the barrier is known as a Barrage or a River Regulator [See Fig. 9.2 (a) and (b)].*



(*a*) Weir without shutters (*b*) Weir with shutters

Fig. 9.1



(*a*) Barrage with a small raised crest (*b*) Barrage without any raised crest

Fig. 9.2

If most of the ponding or the entire ponding is done by a permanent raised crest, as in a weir, then the afflux caused during high floods is quite high. On the other hand, if most of the ponding is done by gates, as in a barrage, then the gates can be opened during high floods and the afflux (*i.e.* rise in HFL near the site) will be nil or minimum. Hence, the latter device *i.e.* a barrage, gives less afflux and a better control upon the river flow, because the inflow and outflow can be controlled to a much greater extent by suitable manipulations of its gates.

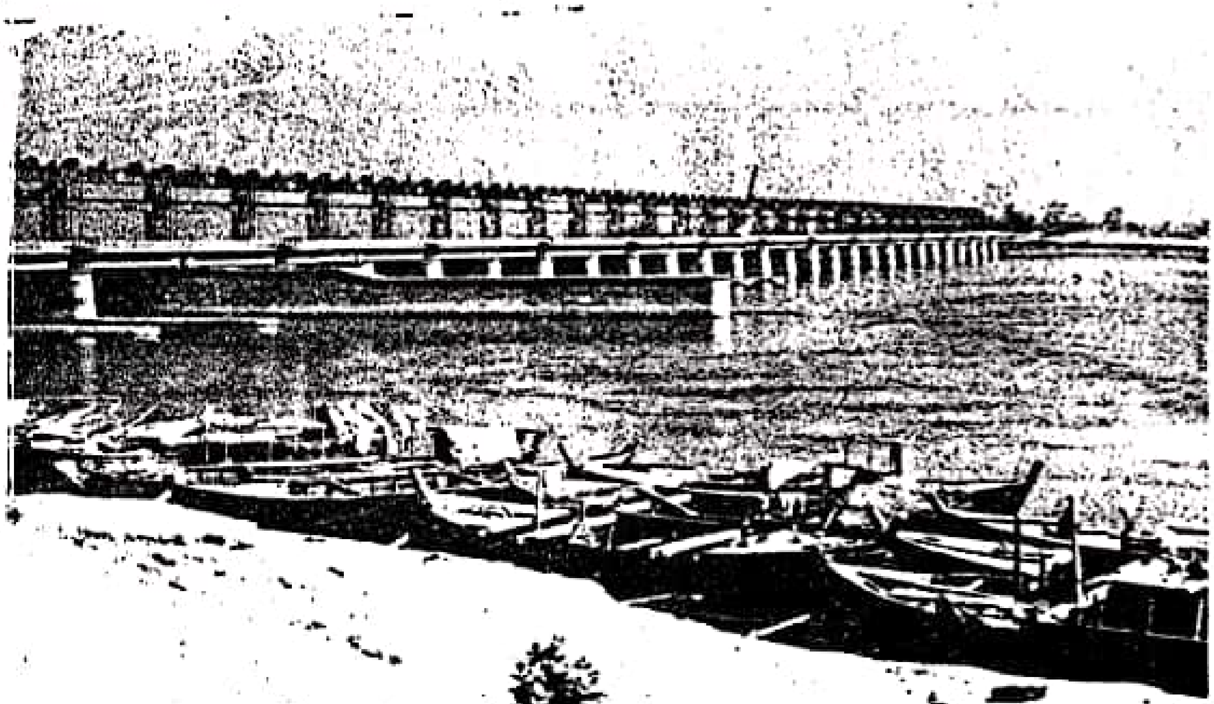


Fig. 9.3. Photoview of a Barrage (Girija Barrage on Ghagra river in U.P.)

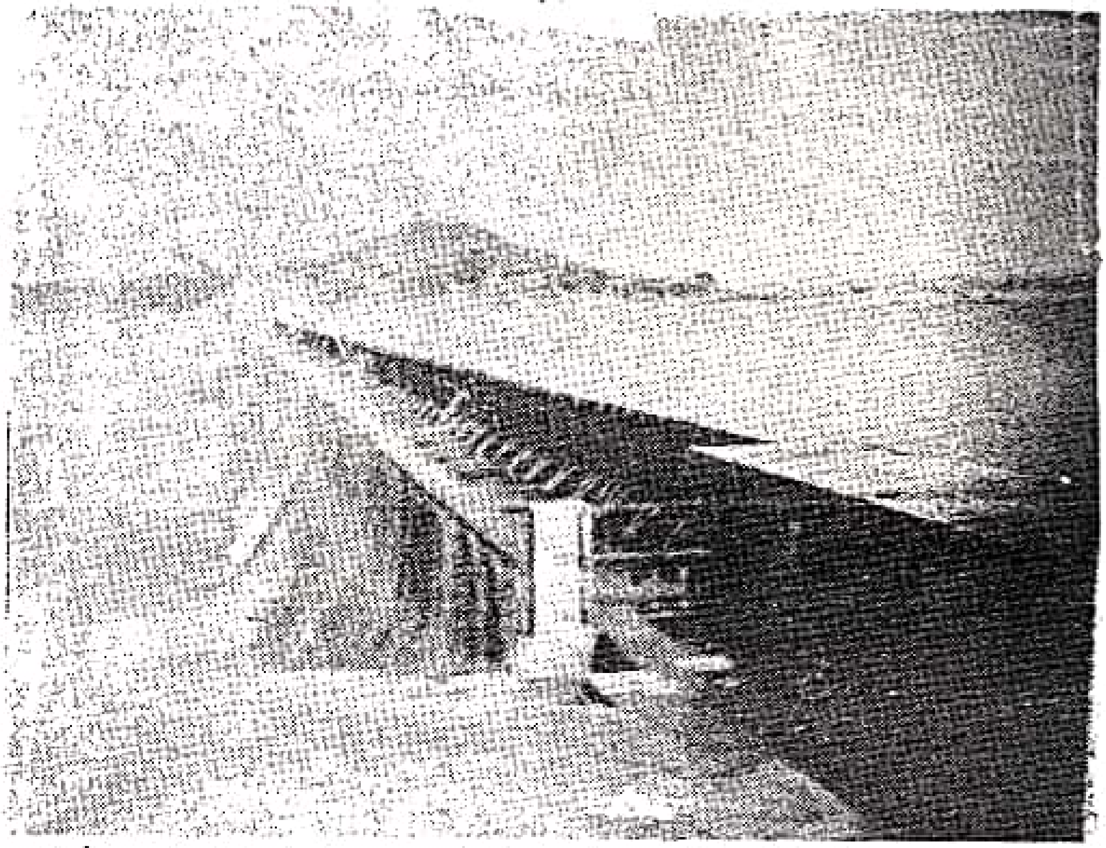


Fig. 9.4. Photoview of a small height dam like weir, provided with shutters at top of its solid crest (Devri Dam near Jhansi in U.P.)

Moreover, a gate controlled weir (*i.e.* a barrage) can be provided with a roadway across the river at a small additional cost. The choice between a weir with shutters and one with counter-balanced gates (*i.e.* a barrage) is largely a matter of cost and convenience in working. A shuttered weir will be relatively cheaper but will lack the effective control possible in the case of a barrage. Moreover, a barrage type construction can be easily supplemented with a roadway across the river at a small additional cost. *Hence, barrages are almost invariably constructed these days on all important rivers.*

9.2. Gravity and Non-Gravity Weirs

When the weight of the weir (*i.e.* its body and floor) balances the uplift pressure caused by the head of the water seeping below the weir, it is called a *Gravity weir.* On the other hand, if the weir floor is designed continuous with the divide piers as reinforced structure, such that the weight of concrete slab together with the weight of divide piers, keep the structure safe against the uplift ; then the structure may be called as a *Non-gravity Weir.* In the latter case, RCC has to be used in place of brick piers, but in particular cases, considerable savings may be obtained, as the weight of the floor can be much less than what is required in a gravity weir.

9.3. Layout of a Diversion Head Works and its Components

A typical layout of a canal head-works is shown in Fig. 9.5. Such a head-works consists of :

(1) *Weir proper.*

(2) *Under-sluices.*

(3) *Divide wall,* dividing the river width into two portions ; one is called the weir portion, and the other portion from which the canal takes off, is having openings* and called the 'under-sluice-pocket' or *'under-sluices'* or *'weir scouring sluices'.* If there are two canals, taking off from each flank, then there will be two divide walls and two under-sluices.

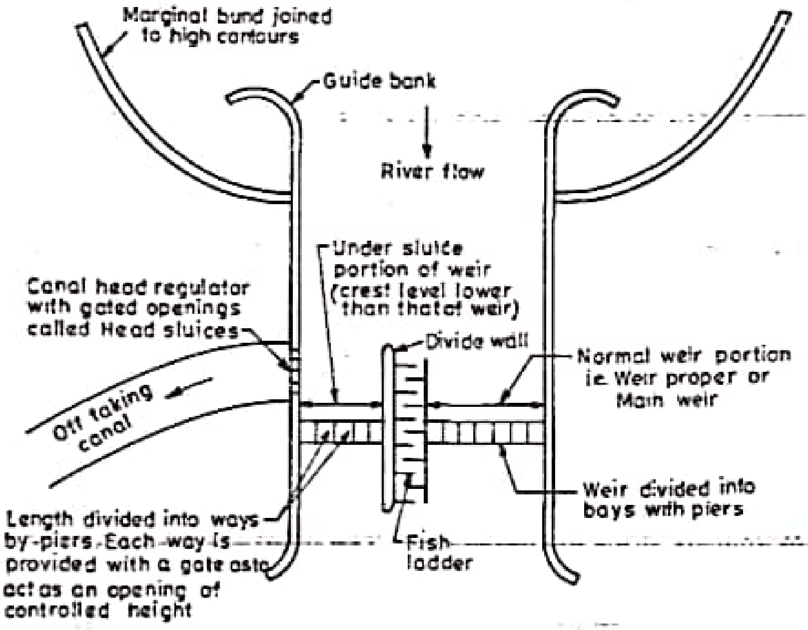


Fig. 9.5. Typical Layout of Diversion Head-Works.

(4) *River training works,* such as marginal bunds, guide banks, groynes, etc.

* These openings are made by partial lifting of gates of the under-sluice ways. During high-floods the gates of the under-sluice ways shall be fully lifted depending on excess discharge in the river.

(5) *Fish Ladder.*

(6) *Canal Head Regulator.*

(7) *Weir's ancillary works,* such as shutters, gates, etc.

(8) *Silt Regulation Works.*

The various parts of a diversion head-works scheme and their design considerations are explained in details in the following pages.

9.3.1. The Diversion Weir and its Types. *Alignment.* As stated earlier, *a diversion weir or an anycut or an intake weir* is a raised pucca structure with or without shutters and laid across the river width. It is, essentially, of a height say up to 9 metres or so. The height of shutters over the weir crest seldom exceeds 1.2 metres or so. The entire length of the weir is divided into a number of bays by means of divide piers so as to avoid cross-flow in floods. As far as possible, the weirs should be aligned at right angle to the direction of the main river current. This ensures lesser length of the weir, better discharging capacity and lesser cost. This right-angled alignment is better and, therefore, common, especially when the river bed is silty or sandy. Sometimes, the weir may be aligned at an oblique angle to the direction of the river current, and thereby, obtaining more safe and better foundations. In such a case, the weir will be of greater length, will have less discharging power and will be costlier. Moreover, due to non-axial flow, cross-currents may be developed, which may undermine the weir foundation. An oblique alignment may sometimes become necessary when the river bed consists of gravel and shingle, which could otherwise enter the head regulator of the main canal and get deposited into the head reach of the main canal.

Types of Weirs. The weirs may be divided into the following three classes :

(*i*) *Masonry weirs with vertical drop ;*
(*ii*) *Rock-fill weirs with sloping aprons* ; and
(*iii*) *Concrete weirs with sloping glacis.*

These three important types of weirs are described below :

(*i*) **Masonry weirs with vertical drop.** A typical cross-section of such a weir is shown in Fig. 9.6.

The above type of a weir, consists of a horizontal floor and a masonry crest with vertical or nearly vertical downstream face.

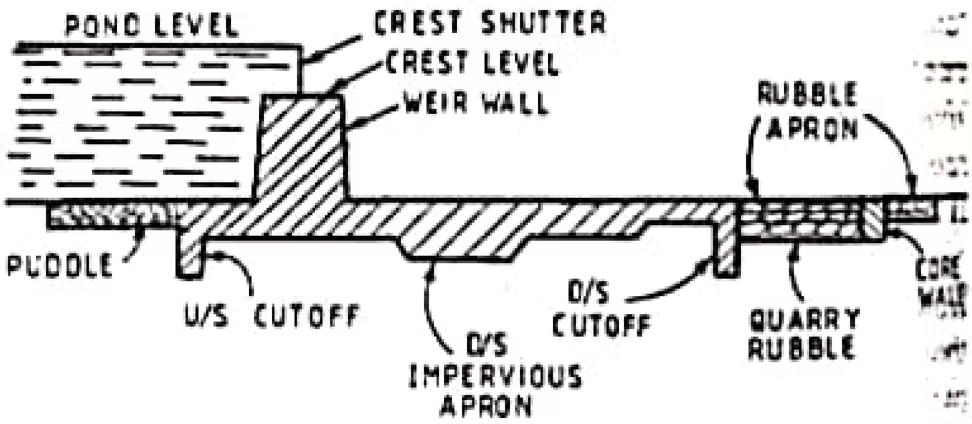


Fig. 9.6. Masonry Weir.

The raised masonry crest does the maximum ponding of water, but a part of it, is usually, done by shutters at the top of the crest. The shutters can be dropped down during floods, so as to reduce the afflux by increasing the waterway opening.

This type of weir was used in all the old head-works, such as Bhimgoda, Rasul, Khanki and Marala works, etc. and is particularly suitable for hard clay and consolidated gravel foundations. However, this type of weir is becoming obsolete and even the old constructions are being replaced by the new modern concrete weirs.

(*ii*) **Rock-fill weirs with sloping aprons.** Such a weir is also called — '*Dry Stone Slope Weir*'. A typical cross-section of such a weir is shown in Fig. 9.7. It is the simplest type of construction, and is suitable for fine sandy foundations like those in alluvial areas in North India.

The old Okhla weir* across the Yamuna river in Delhi provides an example of such a weir. Such a weir requires huge quantities of stone and is economical only when stone is easily available. The stability of such a weir is not amenable to theoretical treatment.

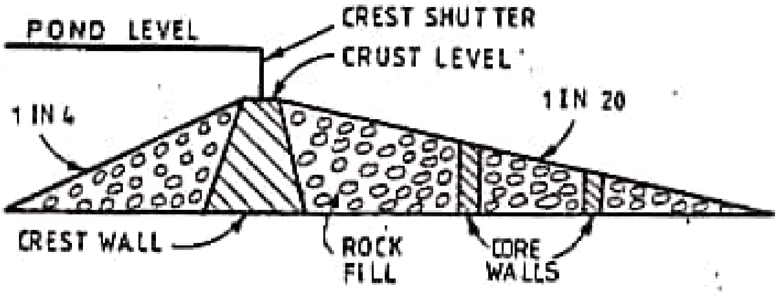


Fig. 9.7. Rock-fill Weir.

However, with the development of concrete glacis weirs, the above type is also becoming obsolete.

(iii) **Modern concrete weirs with sloping downstream glacis.** Weirs of this type are of recent origin and their design is based on modern concepts of sub-surface flow (*i.e.* Khosla's Theory). A typical cross-section of such a weir is shown in Fig. 9.8. Sheet piles of sufficient depths are driven at the ends of upstream and downstream floor. Sometimes, an intermediate pile line is also provided. *The hydraulic jump is formed on the downstream sloping glacis, so as to dissipate the energy of the flowing water.*

This type of weirs are now exclusively used, especially, on permeable foundations, and are generally provided with a low crest with counter-balanced gates, thus, making it a barrage. A typical cross-section of a barrage is shown in Fig. 9.9.

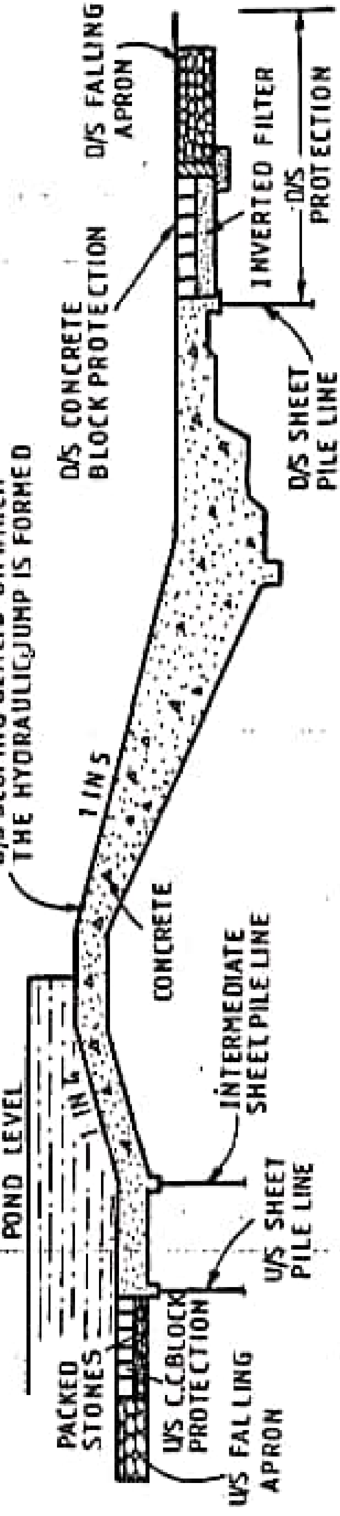


Fig. 9.8. A typical cross-section of a modern concrete weir founded on permeable foundations.

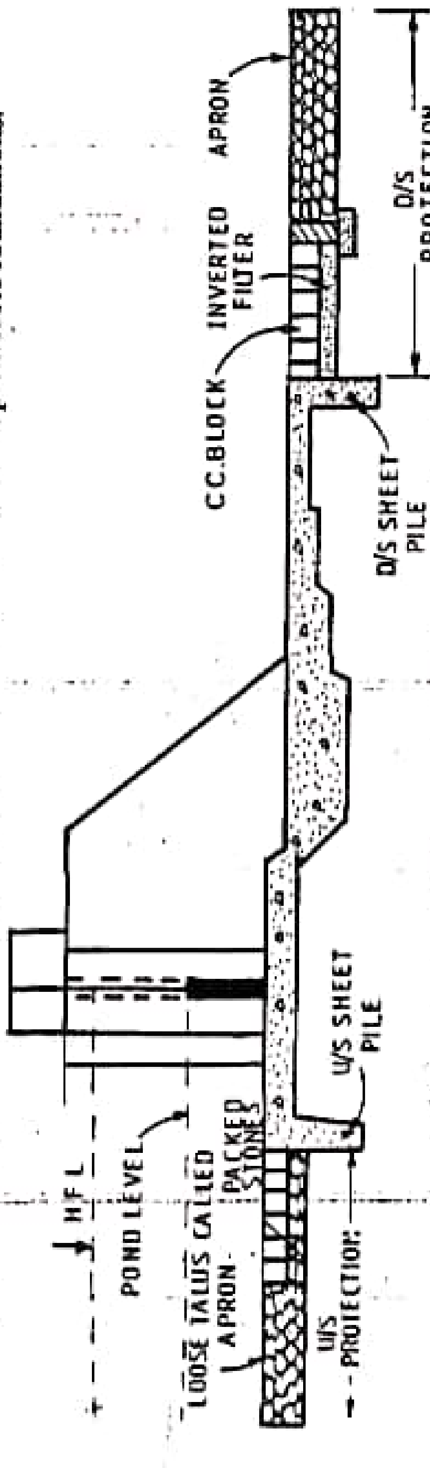


Fig. 9.9. A typical cross-section of a Barrage founded on pervious foundations.

* Now replaced by a new barrage, about 2 km downstream. The old weir has however, not been dismantled.

The barrage shown here is not having a raised crest at all, but barrages can do have slightly raised crests. The detailed design of such a weir or a barrage will be discussed in Chapter 11.

9.3.2. Afflux and Pond Level. The rise in the maximum flood level (HFL) upstream of the weir, caused due to the construction of the weir across the river, is called **afflux.**

In the initial stages, the water level is raised on account of afflux up to small distance equal to the length of the back water curve. But with the passage of time, the river bed rises due to silting caused by the reduction in flow-velocity upstream of the weir. (Q remaining same, y or A increasing and V decreasing). The effect, therefore, travels upstream till the river bed slope upstream of the weir is the same as was before its construction. (See Fig. 11.18 in Chapter 11).

Pond Level. The water-level required in the under-sluice pocket upstream of the canal head regulator, so as to feed the canal with its full supply, is known as *Pond Level.* The FSL of the canal at the head, depends upon the level of the irrigated areas and the slope of the canal. The pond level is generally obtained by adding 1.0 to 1.2 m to canal full supply level.

Since the weir top is raised upto the pond level, a minimum water level equal to the pond level is always maintained in the under-sluice pocket, so as to ensure a continuous supply of water into the canal with its full supply level.

The available head at the canal head regulator is, therefore, equal to the difference of the pond level and canal FSL. The width of regulator openings (*i.e.* waterway) should, therefore, be governed by this available head. But to make provision for future silting of canal, and for the subsequent rise in FSL, (which correspondingly reduces the available head), the designed available head for its water-way is taken at about $\frac{1}{2}$ of the original available value.

This will be explained in details in the design of Canal Head Regulators (in Chapter 11).

9.3.3. The Under-Sluices or Scouring Sluices. A comparatively less turbulent pocket of water is created near the canal head regulator by constructing under-sluice portion of the weir. A divide wall separates the main weir portion from the under-sluice portion of the weir. *The crest of the under-sluice portion of the weir is kept at a lower level than the crest of the normal portion of the weir.*

Normally, the crest level of the under-sluices is kept equal to the deepest bed level of the river during non-monsoon season; whereas, the crest level of the 'weir' is kept higher by about 1 to 1.5 m.

As the crest of the under-sluice pocket is at a low level, a deep channel develops towards this pocket, which helps in bringing low dry weather discharge towards this pocket, thereby, ensuring easy diversion of water into the canal through the canal head regulator.

The under-sluiced length of weir or barrage is divided into a number of ways by piers, and separate gates are installed on these ways. Each way can thus, be opened to any desired height by lifting its gate. Each way can thus, act as a gate controlled opening, and will help in bypassing the excess supplies to the down-stream side of the river. These openings will also help in scouring and removing the deposited silt from the under-sluiced pocket ; and hence are also called the *scouring sluices.*

(*ii*) **Diaphragm.** The diaphragm should be placed in such a way that it causes least disturbance in front of the ejector tunnels, so as not to disturb silt concentration attained in the bottom layers. The diaphragm is generally placed at the downstream bed level of the canal, *i.e.* the canal bed has to be slightly depressed under the diaphragm. However, if the diaphragm has to be placed higher due to some other considerations, the condition of fall, particularly for low supplies, should be checked, and energy dissipation arrangements made, if found necessary. The diaphragm should be properly tied to the supports, so as to prevent it from being dislodged. The diaphragm shall be extended beyond the pier noses and the underneath of the diaphragm shall be given a streamlined bell mouth shape confirming to the equation of an ellipse, *i.e.*

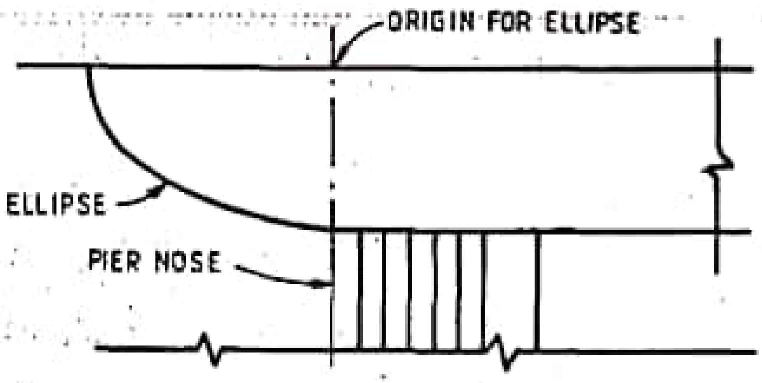


Fig. 9.22

$$\frac{x^2}{4a^2} + \frac{y^2}{a^2} = 1$$

where a is the thickness of the diaphragm. (See Fig. 9.22).

BARRAGE REGULATION AND SILT CONTROL AT HEAD WORKS

The supplies entering a canal which takes off from the upstream side of a weir or a barrage, can be regulated into the following two ways :

(*i*) **Still Pond Regulation Method.** In this method of operation, all the gates of the scouring sluices are kept closed when the canal is running. Only as much discharge is drawn into the under-sluice pocket as much is required for the canal ; the surplus being escaped over some other section of the weir or the barrage. The velocity of water in the under-sluice pocket, therefore, gets reduced, as the smaller discharge enters through the same waterway. The low velocity causes the sediment to settle down and relatively clearer water enters the canal.

The silt is, thus allowed to accumulate in the pocket till it reaches to within 0.5 m below the crest of the regulator. The canal is then closed and the scouring sluices opened, till the entire silt deposit gets washed away on the downstream of river. The scouring

operation takes about 24 hours, and for this much of time, the canal supply has to be stopped. After the silt deposit is washed out, the scouring sluices are closed and the canal supply is restored again. This method of barrage regulation is called still pond regulation and is very useful in controlling the amount of silt entering the canal. However, this method of regulation is practicable only where the sill of the canal head regulator is sufficiently higher than the upstream floor of the under-sluices. Moreover, it leads to closure of the off-taking canal atleast once a month, resulting in the wastage of discharge and loss of irrigation to that much extent.

(*ii*) **Semi-Open flow Operation.** In this method, water in excess of the canal requirement, is allowed to enter into the under-sluice pocket. The gates of the scouring sluices are kept partially opened. The total water entering the pocket, thus, gets divided into two parts, in front of the head regulator. The top water (above the sill level of head regulator) enters the canal through the head regulator, and the bottom water escapes downstream through the under-sluices. Due to this, certain velocity is maintained in the pocket and silt remains in suspension. The turbulence created may sometimes cause even the coarser silt to rise up and to enter into the canal. The silt control, is thus reduced in this method. However, the advantage of this method is that the silt is constantly and continuously scoured out, and the canal has not to be closed, as is required to be done in still pond regulation method.

9.3.7. **The Canal Head Regulator or Head Sluices.** A canal head regulator (C.H.R.) is provided at the head of the off-taking canal, and serves the following functions :

(i) *It regulates the supply of water entering the canal.*

(ii) *It controls the entry of silt in the canal.*

(iii) *It prevents the river floods from entering the canal.*

A typical cross-section of a head regulator is shown in Fig. 9.15. The regulator is generally aligned at right angle to the weir, but slightly larger angles (between 90° to 110°) are now considered preferable for providing smooth entry of water into the regulator, as shown in Fig. 9.16.

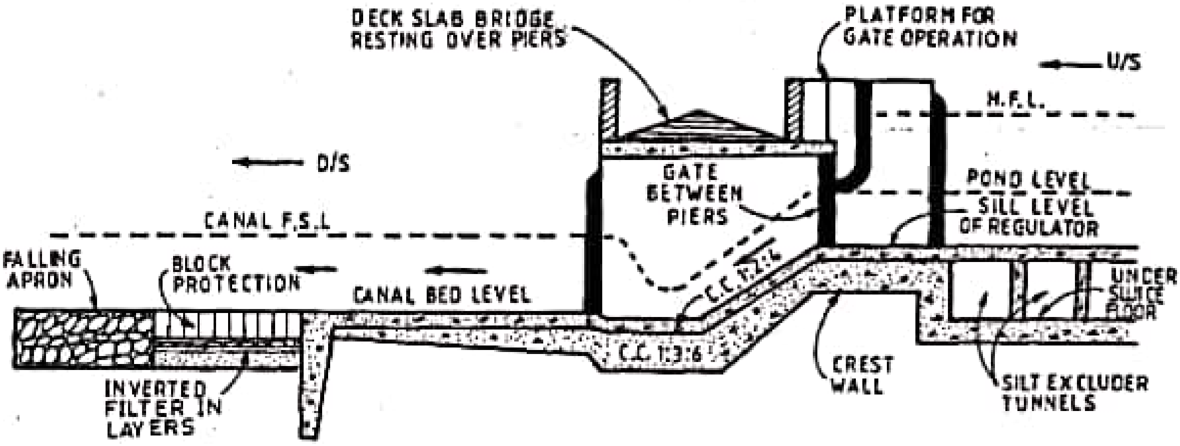


Fig. 9.15. A typical section through a Canal Head Regulator.

The regulator is provided with gates. Smaller spans were used in the past, but with the improvements in gate constructions, larger spans, say between 6 to 10 metres, are generally used these days, if found economical.

The water from the under-sluice pocket is made to enter the regulator bays, so as to pass the full supply discharge into the canal. The maximum height of these gated openings, called head sluices will be equal to the difference of Pond Level and Crest Level of the regulator. The entry of silt into the canal is controlled by keeping the crest of the head regulator by about 1.2 to 1.5 metres higher than the crest of the under-sluices. If a Silt-Excluder* is provided, the regulator crest is further raised by about 0.6 to 0.7 metre. Silt gets deposited in the pocket, and only the clear water enters the regulator bays. The deposited silt can be easily scoured out periodically, and removed through the under-sluice openings.

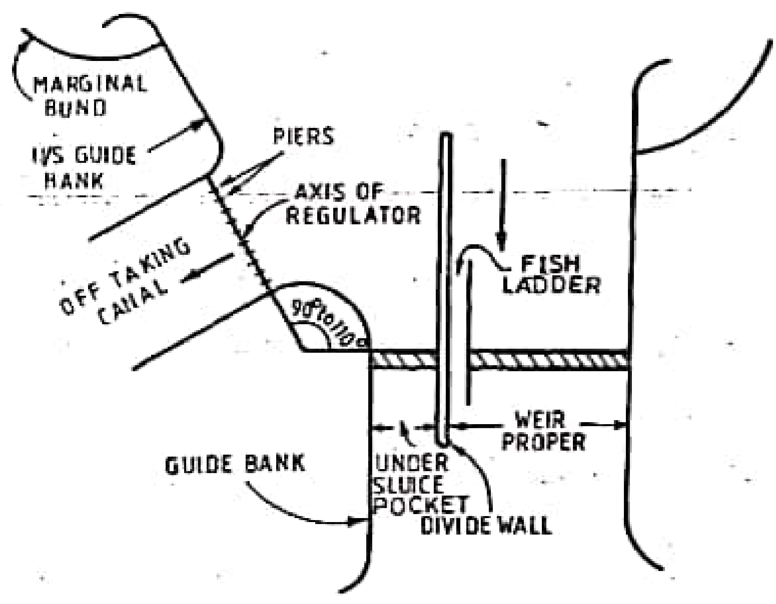


Fig. 9.16. Alignment of a Canal Head Regulator.