Eff.

Unit-VI

1) Toposheet

A toposheet is a shortened name for a "Topographic -sheet". They essentially contain information about an area like roads, railways, settlements, canals, rivers, electric poles, post offices etc. According to their usage, they may be available at different scales (e.g. 1:25000, 1:50000 etc, whereas the former is a larger scale as compared to the latter). They are made on a suitable projection for the area and contain lat-long information at the corners. Thus any point on it can be identified with its corresponding lat-long, depending upon the scale (i.e. if the scale is large, more, accurate lat-long).

Water Harvesting

Water Harvesting is the process of collecting & storing water from an area that has been modified or treated to increase runoff from precipitation. A water -harvesting system usually consists of a catchment or water-collecting area, a water storage facility and auxiliary components like conveyance and sediment control structures.

Water harvesting systems are used not only for collecting water for domestic consumption. In some parts of the world, rain water from roof tops is collected in containers -and later used for domestic purposes.

Runoff Collection and Recycling

Even in semi-arid regions, some runoff occurs from the agricultural lands. Particularly during the rainy season. In the supplemental water system, the runoff is collected and stored in a pond at a convenient location. The stored water can be used for providing supplemental irrigation to crops located near the pond. If the areas to be irrigated are upstream to the pond (in the donor catchment) water lifting devices are to be used to lift the water. In case of downstream areas, gravity flows from the pond are possible.

The stored water in the pond is usually limited and may not be enough to give full irrigation to the crops. The following issues need to be considered.

1. Identification of critical periods of crops when the effects of moisture stress would be maximum.
2. Reducing percolation losses from the ponds through sealing or lining procedures.
3. Efficient use of the harvested runoff water.

The stored water may be used to give one or two irrigations to the crops at the critical periods so that the crop survives and produces maximum possible yield. Optimization procedures like linear programming & dynamic programming together with crop water production functions can be used for optimal irrigation schedules.

Efficient water application methods are also desirable. ①

Instead of flooding, furrow irrigation and alternate furrows could help in better use of the water.

Farm Ponds

Farm ponds are small tanks or reservoirs constructed for the purpose of storing water essentially from surface runoff. Farm ponds are useful for irrigation, water supply for the cattle, fish production, etc. A large number of ponds constructed in a catchment will have a retarding effect on the flood flows downstream. Farm ponds have a significant role in areas of rain fed agriculture. They are used for storing water during rainy season and using the same for irrigation subsequently.

The design and construction of farm ponds require a thorough knowledge of the site conditions and requirements. Some sites are ideally suited for locating the ponds and advantage of natural conditions should always be taken.

Types of Ponds

Depending on the source of water and their location with respect to the land surface, farm ponds are grouped into four types. These are (1) dugout ponds or excavated ponds, (2) surface ponds or watershed ponds, (3) spring or creek fed ponds, and (4) off-stream storage ponds.

Dugout Ponds are excavated at the site and the soil obtained by excavation is formed as embankment around the Pond. The pond could either be fed by surface runoff or groundwater wherever aquifers are available. In case of dugout Ponds, if the stored water is to be used for irrigation, the water has to be pumped out. Surface water ponds are the most common type of farm Ponds. These are partly excavated and an embankment is constructed to retain the water. Generally, a site which has a depression already is chosen for the pond construction. The pond is fed by surface runoff from its catchment area. The earthen embankment, mechanical spillway and an emergency spillway are parts of the pond. It is desirable to take the water out of the pond through gravity outlet for irrigation. Selection of suitable site for this purpose is, therefore, important.

Spring or creek fed ponds are those where a spring or a creek is the source of water supply to the pond. Construction of these ponds, therefore, the depends upon availability of natural springs or creeks. off-stream storage ponds are constructed by the side of streams which flow only seasonally. The idea is to store the water obtained from the seasonal flow in the streams. Suitable arrangements need to be made for conveying the water from the stream to the storage ponds. Another type of ponds, referred to as levee ponds are generally used in aquaculture. These types of ponds are formed by embankments and are usually of a regular shape (rectangles) and are of uniform depth. Levee ponds are filled by water from wells, storage reservoirs, streams,

Components of a farm Pond:

The pond consists of the storage area, earthen dam, mechanical spillway and an emergency spillway. The mechanical spillway is used for letting out the excess water from the pond and also as an outlet for taking out the water for irrigation. The emergency spillway is to safeguard the earthen dam from overtopping when there are inflows higher than the designed values.

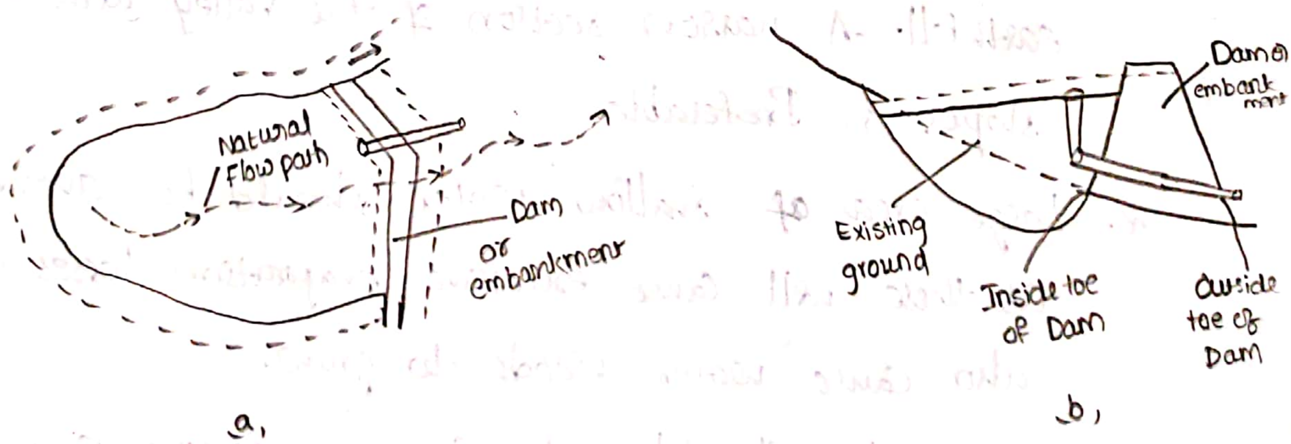

fig Components of a farm pond

a, Top view   b, side view

Design of Farm Ponds

The design of farm ponds consists of

(1) Selection of site,

(2) Determination of the capacity of the pond,

(3) Design of the embankment,

(4) Design of the mechanical spillway,

(5) Design of the emergency spillway, and

(6) Providing for seepage control from the bottom.

Site Selection

Selection of suitable site for the pond is important as the cost of construction as well as the utility of the pond depend upon the site. The site for the pond is to be selected keeping in view of the following considerations:

1. The site should be such that largest storage volume is available with the least amount of earthfill. A narrow section of the valley with steep slopes is preferable.

2. Large areas of shallow water should be avoided as these will cause excessive evaporation losses and also cause water weeds to grow.

3. The site should not cause excessive seepage losses.

4. The pond should be located as near as possible to the area where the water will be used.

When the water is to be used for irrigation, gravity flow to the areas to be irrigated is preferable.

Computation of Earthwork

By the use of contour map, the volume of earthwork and thereby the capacity of reservoir can be calculated. In doing the calculation, it is assumes that the surface of the ground slopes uniformly from one contour to the next. This assumption is not strictly correct. But sufficient accuracy is obtained if the contour interval is small and minor high spots or depressions are included in the survey.

After the contour map of a site is prepared, the area enclosed by each line is measured by a planimeter. The vertical distance between two successive contour line is the constant contour interval and is, therefore, known. Then the volume of the prismoids between successive cross sections are obtained by using either the trapezoidal (average end area) formula or the prismoidal formula. The trapezoidal formula is simple and is used for preliminary estimates. The prismoidal formulas more accurate and is commonly used specially for final estimates.

1. Trapezoidal formula (average end area method) ~~Simpson's rule~~

$$\text{Volume, } V = \frac{h}{2}\left[(A_0 + A_n) + 2(A_1 + A_2 + \dots + A_{n-1})\right]$$

$$\text{Volume, } V = h\left[\left(\frac{A_0+A_n}{2}\right) + (A_1+A_2+\cdots+A_{n-1})\right]$$

2. Prismoidal formulae / Simpson's rule

$$\text{Volume, } V = \frac{h}{3}\left[(A_0+A_n) + 2(A_2+A_4+\cdots+A_{n-2}) + 4(A_1+A_3+A_5+\cdots+A_{n-1})\right]$$

where, $A_0, A_1, A_2 \ldots A_n$ = the area of cross section.

h = the distance between the cross-sections which is equal to contour interval.

Capacity of the pond

The capacity of the pond is determined from a contour survey of the site at which the pond is to be located. From the contour plan of the site, the capacity is calculated for different stages using the trapezoidal or Simpson's rule (Simpson's rule gives more accurate values than the trapezoidal formula).

For this purpose, the area enclosed by each contour is measured using a planimeter. According to the trapezoidal rule, the volume 'V' between two contours at an interval H and having areas A_1 and A_2 is given by:

$$V = \frac{H}{2}(A_1+A_2)$$

Using Simpson's rule,

$$V = \frac{H}{3}\left[(A_0+A_n) + 2(A_2+A_4+\cdots A_{n-2}) + 4(A_1+A_3+\cdots A_{n-1})\right]$$

Example:-

Calculate the capacity of a pond having an area enclosed by different contours as follows:

S.No	Contour value, m	Area enclosed, m^2
1	250	220
2	251	290
3	252	340
4	253	370
5	254	480
6	255	550
7.	256	620

Sol:- Given

Contour interval, $h = 1$ m. ($\because$ All the contours are having only '1' difference).

e.g. $h = 251 - 250$

$h = 1$ m

$h = 252 - 251 = 1$ m

Here, $A_0 = 220$ (first A_0)

$A_1 = 290$

$A_2 = 340$

$A_3 = 370$

$A_4 = 480$

$A_5 = 550$

$A_6 = 620$ (last i.e. A_n)

By using trapezoidal formula

$$V = \frac{h}{2}\left[(A_0 + A_n) + 2(A_1 + A_2 + \dots + A_{n-1})\right]$$

$$V = \frac{1}{2}\left[(220 + 620) + 2(290 + 340 + 370 + 480 + 550)\right]$$

$$\boxed{V = 2450 \text{ m}^3.}$$

Using Prismoidal / Simpson's rule,

$$V = \frac{h}{3}\left[(A_0 + A_n) + 2(A_2 + A_4) + 4(A_1 + A_3 + A_5)\right]$$

$$V = \frac{1}{3}\left[(220 + 620) + 2(340 + 480) + 4(290 + 370 + 550)\right]$$

$$\boxed{V = 2440\ m^3}$$

To plot the depth-capacity curve, the following table can be prepared. Trapezoidal formula has been used to calculate the volume increments given in this table.

Contour value, m	Area enclosed, m^2	Volume increment, m^3	Cumulative volume, m^3
250	220	—	—
251	290	$\frac{220+290}{2} = 255$	255
252	340	$\frac{290+340}{2} = 315$	255 + 315 = 570
253	370	$\frac{340+370}{2} = 355$	570 + 355 = 925
254	480	$\frac{370+480}{2} = 425$	925 + 425 = 1350
255	550	$\frac{480+550}{2} = 515$	1350 + 515 = 1865
256	620	$\frac{550+620}{2} = 585$	1865 + 585 = 2450

A depth-capacity curve of the reservoir for different elevations is plotted from the depth-capacity data calculated. The depth-capacity curve is useful in deciding a suitable height of the embankment such that the required capacity is available. The contour plan of the proposed reservoir site is useful in determining the water spread for a given depth of water.

Gully erosion and its Control

The surface runoff as it flows down, the land slopes gains kinetic energy. At that point, when the kinetic energy is enough to dislodge the soil particles, the flowing water starts eroding the land surface. Gully erosion generally starts as small rills and gradually develops into deeper crevices. Cart paths, foot paths and other small depressions neglected could result in gullies. The rate of gully erosion depends upon the amount of runoff concentrated at a particular point, the longitudinal slope and soil characteristics. Ravines are a form of extensive gully erosion. Gully erosion not only damages the land resources but at the same time contributes large amounts of sediment load to river systems.

Planning for Gully Control

Control of Gully erosion is done both by taking appropriate measures in the gully beds as well as in the catchment area. The first step in planning the gully control programme is to plan to control the runoff from the catchment area.

This may be done by using good land and crop management practices. Such as contouring, strip cropping & terracing. Gully control measures should be considered when the plan for the entire watershed is prepared.

Control of gullies may be an extensive operation & the cost of gully control must be balanced by the benefits. Benefits include the protection of the adjoining areas reduction of sediment load to the river system, storage of water and sometimes reclamation of the gully beds for cultivation purposes.

Methods of Gully Control

The methods available for gully control are: (1) Diversion of runoff.

(2) Vegetative methods.

(3) Temporary Gully Control Structures &

(4) Permanent Gully Control Structures.

(1) Diversion of Runoff

Diversion of runoff is achieved by constructing diversion drains. The diversion drain is a shallow channel put across the slope above the gully. The design principles of diversion drains are exactly the same as that of grassed waterways. In case of diversion drains the slope is kept generally less than 0.5%.

and usually between 0.1 to 0.25%. The diversion drains intercept the runoff coming from the area above the gully. The intercepted runoff is let off at a point in the gully well protected. So that no further erosion at that point occurs.

(2) Vegetative methods

In these methods, the objective is to control gully erosion using vegetation.

a) Natural vegetation :

If the runoff that is causing the gully is diverted and grazing is controlled from the eroded area, natural vegetation begins to get established. The growth of natural vegetation will eventually protect the gully area with grasses, shrubs and trees native to the area in question. In some areas, the development of natural vegetation may be stimulated by the application of fertilizers or by spreading some mulches to conserve moisture.

b) Artificial Vegetation :

Artificial vegetation of the gully beds and banks accelerates the process of establishing the vegetation and will help in stabilizing the gully. Where the gully banks are not deep & contain soil,

- they are sloped and then vegetation is established on the slopes. Selection of grasses, shrubs or trees should be carefully done and should suit the local conditions as well and they should be of some economic importance. Grass is ordinarily a primary vegetative cover used in gully control. It is established both on the bed and the sides either by seeding or by sodding. Sod flumes are successfully used to control overfalls at the head of the small gullies. The head of the gully is shaped to a gentle slope not exceeding 6:1 and grass is established by sodding.

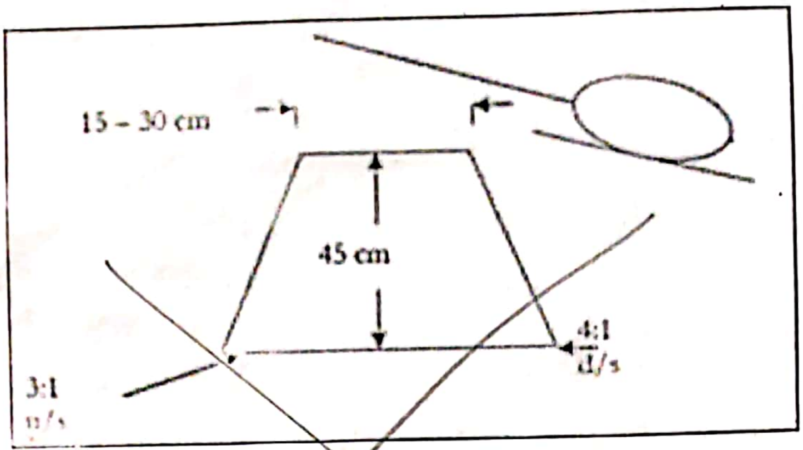

Fig. 7.5 Low sodded earthfills.

7.5.1.6 Trees, Shrubs etc.

Trees, shrubs etc. are used to stabilize severely eroded gullied area. Generally gullied area is fenced and trees are grown. A plant spacing of 1 × 1 m, 1.2 × 1.2 m or a maximum of 2 × 2 m should be maintained.

7.5.2 Engineering Measures (Temporary and Permanent)

7.5.2.1 Temporary Gully Control Structures (TGCS)

TGCS have a life span of 3 to 8 years and they are pretty effective where the amount of runoff is not too large. These are made of locally available materials. Basic purposes they serve are to retain more water as well as soil for proper plant growth and prevent channel erosion until sufficient vegetation is established on the upstream side of the gully. TGCS are of many types:

- Woven wire check dams
- Brush dams
- Loose rock dams
- Plan or slab dams
- Log check dams
- Boulder check dams

7.5.2.2 Permanent Gully Control Structures (PGCS)

If the erosion control programmer requires bigger structure, then PGCS are used. They include:

- Drop spillway

- Drop-inlet spillway
- Chute spillway
- Permanent earthen check dams

7.6 Design Criteria of TGCS

- The overall height of a temporary check shouldn't ordinarily be more than 75 cm. An effective height of about 30 cm is usually considered sufficient. Also, sufficient freeboard is necessary.
- Life of the check dams under ordinary conditions should be in between 3 to 8 years.
- Spillway capacity of check dams is generally designed to handle peak runoff that may be expected once in 5 to 10 year return period.
- Since the purpose of check dams in gully control is to eliminate grade in the channel, check dams theoretically should be spaced in such a way that the crest elevation of one will be same as the bottom elevation of the adjacent dam up-stream.
- As an integral part of most of the checks dams, an apron or platform of sufficient length and width must be provided at the down-stream end to catch the water falling over the top and to conduct it safely without scouring.

7.6.1 Woven Wire Check Dams

Woven-wire check dams are small barriers which are usually constructed to hold fine material in the gully (Fig. 7.6).

General:

- Used in gullies of moderate slopes (not more than 10 percent) and small drainage areas that do not have flood flows which carry rocks and boulders.
- Help in the establishment of vegetation for permanent control of erosion.
- Dam is built in half-moon shape with the open end up-stream.
- The amount of curvature is arbitrary: but an off-set equal to 1/6th of the width of gully at the dam site is optimum.

Construction:

- To construct a woven-wire dam, a row of posts is set along the curve of the proposed dam at about 1.2 m intervals and 60-90 cm deep.

- Heavy gauge woven wire is placed against the post with the lower part set in a trench (15-20 cm deep), and 25-30 cm projected above the ground surface along the spillway width.

- Rock, brush or sod may be placed approximately up to a length of 1.2 m to form the apron.

- For sealing the structure, straw, fine brush or similar material should be placed against the wire on the upstream side upto the height of spillway.

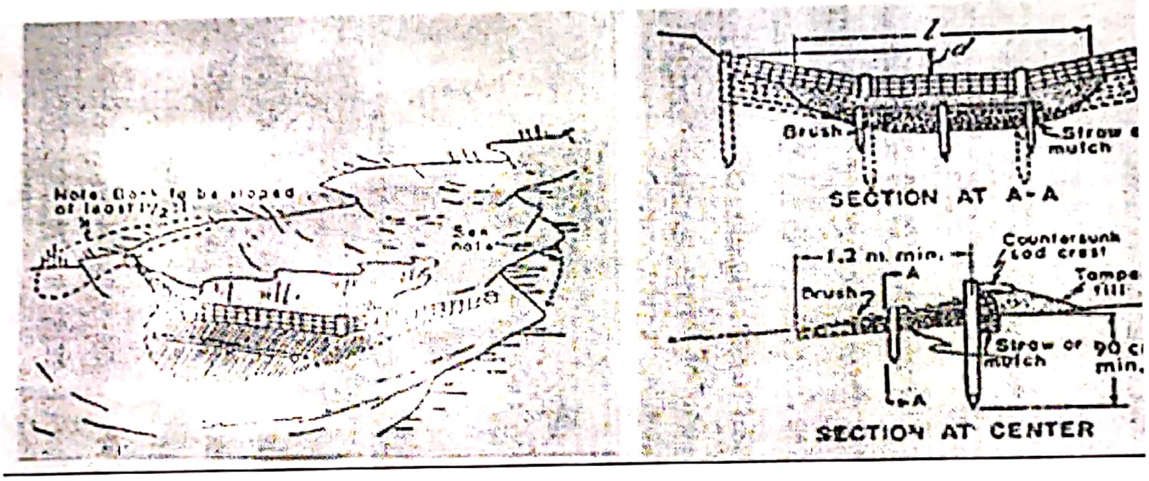

Fig. 7.6. Woven wire check dams. (Source: Agr. Handbook No. 61. USDA, SCS).

7.6.2 Brush Dams

General:

- Cheap and easy to build, but least stable of all types of check dams.

- Best suited for gullies with small drainage area.

- Center of the dam is kept lower than the ends to allow water to flow over the dam rather than around it (Fig. 7.7).

Construction:

- For a distance of 3-4.5 m along the site of the structure, sides and bottom of the gully are covered with thin layer of straw or similar fine mulch.

- Brushes are then packed closely together over the mulch to about one half of the proposed height of dam.

- Several rows of stakes are then driven crosswise in the gully, with rows 60 cm apart, and stakes 30-60 cm apart in the rows.
- Heavy galvanized wire is used to fasten the stakes in a row, as well as to firmly compress the brushes in places.
- Sometimes large stones are also placed on top of brush to keep it compressed and in close contact with the bottom of the gully.
- Major weakness is the difficulty of preventing the leaks and constant attention is required to plug openings of appropriate size with straw as they develop.

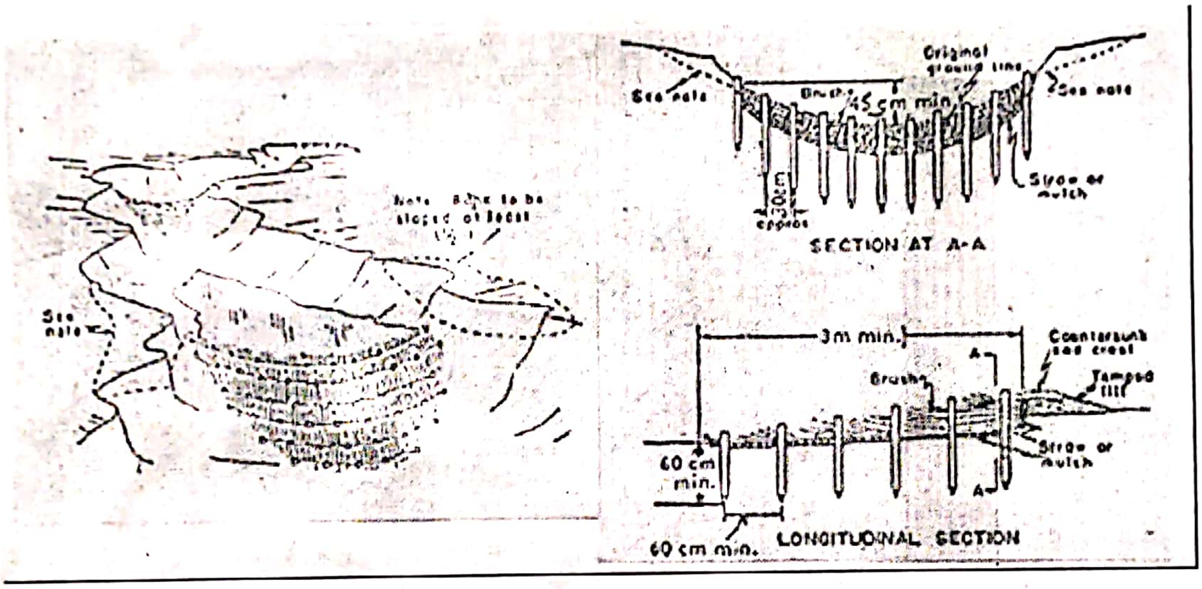

Fig. 7.7. Brush dam. (Source: Agr. Handbook No. 61. USDA, SCS).

7.6.3 Loose Rock Dams

Loose rock dams made of relatively small rocks are placed across the gully (Fig. 7.8). The main objectives for these dams are to control channel erosion along the gully bed, and to stop waterfall erosion by stabilizing gully heads. Loose stone check dams are used to stabilize the incipient and small gullies and the branch gullies of a continuous gully or gully network. The length of the gully channel is not more than 100 m and the gully catchment area is 2 ha or less. These dams can be used in all regions.

General:

- Suitable for gullies with small to medium size drainage area.
- Used in areas where stones or rocks of appreciable size and suitable quality are available.
- Flat stones are the best choice for dam making.

Scanned with CamScanner

- Stones can be laid in such a way that the entire structure is keyed together.
- If round or irregular shaped stones are used, structure is generally encased in woven-wire so as to prevent outside stones from being washed away.
- If the rocks are small, they should be enclosed in a cage of woven-wire.

Construction:

- A trench is made across the gully to a depth of about 30 cm. This forms the base of the dam on which the stones are laid in rows and are brought to the required height.
- The center of the dam is kept lower than the sides to form spillway.
- To serve as an apron, several large flat rocks may be countersunk below the spillway, extending about 1 m down-stream from the base of the dam.

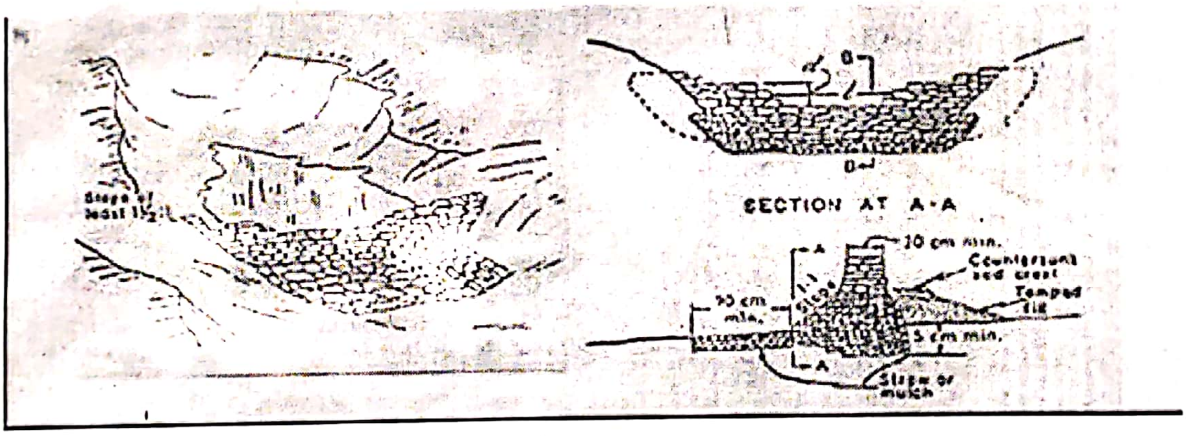

Fig. 7.8. Loose rock dam. (Source: Agr. Handbook No. 61. USDA, SCS).

7.6.4 Plank or Slab Dam

General:

- These dams are suitable in areas where timber is plentiful, and dam can be constructed with much less labor as compared to other types of temporary structures.
- These dams can generally be used in gullies with larger drainage area.

Construction:

- The planks are placed across the gully to form the dam. If the planks are not close fitting, straw or grass may be used for sealing purposes.

- A suitable opening for the spillway notch is made over the headwall. On the up-stream face, a well tempered earth fill is made.
- On the down-stream, the apron may be made of loose rock, brush, sod or planks.

7.6.5 Log Check Dam

They are similar to plank or slab dams. Logs and posts used for the construction are placed across the gully. They can also be built of planks, heavy boards, slabs, poles or old railroad ties. The main objectives of log check dams are to hold fine and coarse material carried by flowing water in the gully, and to stabilize gully heads. They are used to stabilize incipient, small and branch gullies generally not longer than 100 m and with catchment areas of less than two hectares. The maximum height of the dam is 1.5 m from the ground level. Both, its downstream and upstream face inclination are 25 percent backwards. The spillway is rectangular in shape. In general, the length and depth of spillway are one to two meters and 0.5 to 0.6 m respectively (Fig. 7.9).

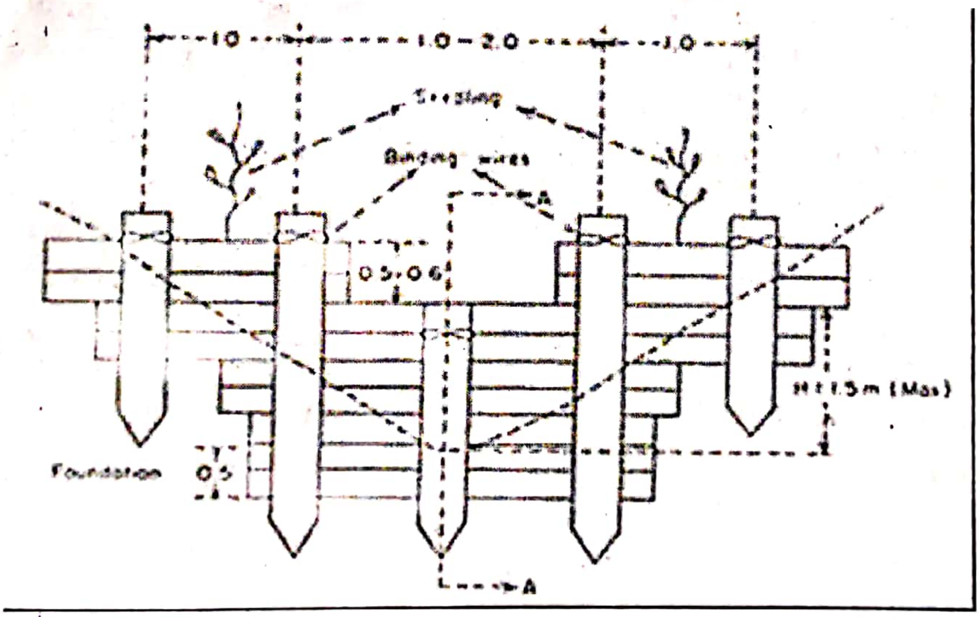

Fig. 7.9A. Front view of the first log check dam. (Source: Agr. Handbook No. 61. USDA, SCS).

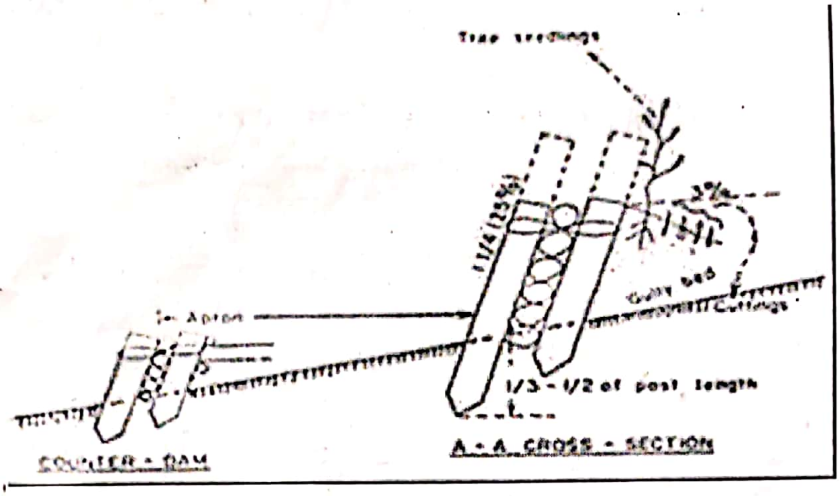

Fig. 7.9B. A-A cross-section of the first log check dam and counter dam. (Source: Agr. Handbook No. 61. USDA, SCS).

7.6.6 Boulder Check Dams

Boulder check dams placed across the gully are used mainly to control channel erosion and to stabilize gully heads. In a gully system or multiple-gully system all the main gully channels of continuous gullies (each continuous gully has a catchment area of 20 ha or less and its length is about 900 m) can be stabilized by boulder check dams. These dams can be used in all regions. The maximum total height of the dam is 2 m. Foundation depth must be at least half of the effective height. The thickness of the dam at spillway level is 0.7 to 1.0 m (average 0.85 m), and the inclination of its downstream face is 30 percent (1:0.3 ratio); the thickness of the base is calculated accordingly. The upstream face of the dam is usually vertical. If the above-mentioned dimensions are used, it is not necessary to test the stability of the dam against overturning, collapsing and sliding. The dimensions of the spillway (Fig. 7.10) should be computed according to the maximum discharge of the gully catchment area. The form of the spillway is generally trapezoidal.

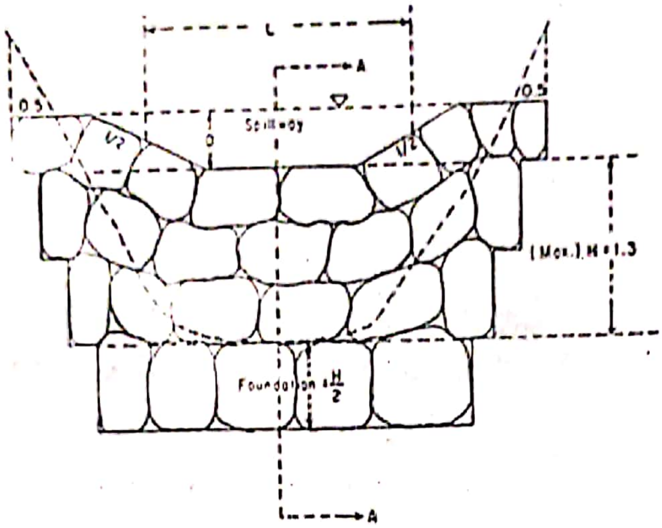

Fig. 7.10. Front view of the boulder check dam. (Source: Agr. Handbook No. 61. USDA, SCS).

Problem 7.1: Design the notch dimensions of a wooden slab dam to carry a peak flow of 0·6 m^3/sec. The notch has rectangular opening. Width of gully channel is 2·5 m.

Solution

$Q = 0{\cdot}6\ m^3/sec = 600$ litres/sec

Length, L, of notch = width of gully channel

= 2·5 m = 250 cm

$Q = 0{\cdot}0171\ LH^{3/2}$

Substituting the values in the formula,

$600 = 0{\cdot}0171 \times 250 \times H^{3/2}$

H = 27·01 cm, say 27 cm

Assume a freeboard of 5 cm

Total depth of notch = 27 + 5 = 32 cm

The design dimensions of the notch are: length 2·5 m; total depth 32 cm.

Keywords: Gully erosion, Permanent structures, Temporary structures, Vegetative measures.

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Lesson 8 Drop Spillway

The drop structure is a weir structure, is limited to a maximum drop of 3 m and it is not a favorable structure where temporary spillway storage is desired to obtain a large reduction in the discharge at or d/s from the structure.

8.1 Permanent Gully Control Structures (PGCS)

PGCS, built of masonry, reinforced concrete or earth are efficient supplemental control measures in soil and water conservation. They are helpful in situation where vegetative measures or temporary structures fail to serve the purpose of controlling the concentration of runoff or reclaim a gully. PGCS are generally used in medium to large gullies with medium to large drainage area. PGCS are designed to handle runoff from the heaviest rains that may be expected once in 25 to 50 years or more depending upon the estimated life of the structure. Three basic permanent structures, generally employed in stabilizing gullies are:

1. Drop spillway
2. Drop inlet spillway
3. Chute spillway

8.2 Salient Features of PGCS

1. The main functions of PGCS are:

   a) To halt the advance of over-fall at gully head,

   b) To stabilize the grade so that a gully can be changed to vegetative waterway.

2. A gully control structure must not only have sufficient capacity to pass the design discharge, but the kinetic energy of discharge must also be dissipated within the confines of the structure in a manner and to a degree that will protect both the structure and the downstream channel from damage.

3. Two primary causes of failure of permanent structures are:

a) Insufficient hydraulic capacity and

b) Insufficient provision for energy dissipation.

8.3 Planning for Design

These structures must be designed after careful investigations of various factors influencing the characteristics of runoff approaching the structure (with reference to specific site conditions), the downstream flow characteristics and other specific requirements. There are no standard solutions which can be applied to all the problems encountered in the field. The design should include analysis of all the factors affecting the work. Basic data needed are:

1. Topographic map of the contributing watershed and the adjoining downstream area,
2. Information on soil.
3. Information on rainfall.
4. Existing land use pattern.

Preliminary investigations consisting of:

1. Reconnaissance of area,
2. Collection and analysis of available data and
3. Outline survey are pre-requisites in the overall planning of a permanent structure.

This helps the designer to study alternative site locations and to establish the techno-economic feasibility of the project. In the absence of adequate data, a safe design requires conservative assumptions. However, every effort should be made to collect all the available data. The more dependable the data, the smaller is the margin of over design and more economical will be the resulting structure.

8.4 Design Procedure

The design procedure of a PGCS may be divided into three phases:

1. Hydrologic design
2. Hydraulic design
3. Structural design

8.4.1 Hydrologic Design

1. It involves the determination of the design runoff rates and volumes

which the structure is expected to handle.

2. Prediction of design peak runoff rates and flood volumes includes the study of the factors influencing the runoff characteristics of rainfall and watershed.

3. It is designed to handle runoff from the heaviest rain expected once in 25 to 50 years or more, depending upon the estimated life of structure.

4. For the design of spillway for flood protection structures like drop inlet spillway information on total runoff volume, inflow-outflow, reservoir stage and storage characteristics are important.

5. Flood routing procedure is employed in designing the spillways of drop inlet structures.

6. The Rational method of predicting peak runoff rate can be employed for designing drop structures and chute spillways.

8.4.2 Hydraulic Design

1. It involves the study of the requirements of the dimensions of the structure, in order to handle the estimated peak runoff through drop and chute structures.

2. It also involves the study of the effects of flow on the upstream and downstream reaches of the channel and the dissipation of the kinetic energy produced by the drop in the water surface elevation.

8.4.3 Structural Design

1. It provides the required strength and stability to the component parts of the structure. It involves the analysis of the various forces acting on the structure. The forces are:These forces disturb the equilibrium of the structure and give rise to internal stress, which should be effectively resisted by the material with which the structure is constructed.

   a. The water pressure (static and dynamic) which acts on the structure.

   b. The forces developed due to the outflow over the structure.

   c. The effect of water flow underneath the structure (seepage, sub-surface flow).

2. These forces disturb the equilibrium of the structure and give rise to internal stress, which should be effectively resisted by the material

with which the structure is constructed.

3. The structure must be stable under the action of the external forces and be able to withstand the sliding forces resulting from its own weight.

8.5 Basic Components of PGCS

1. These components can be divided into three groups:

   a) **Inlet:** Water enters the structures through the inlet, which may be in the form of a box or weir in a wall.

   b) **Conduit:** The conduit receives the water from the inlet and conducts it through the structure. It restricts the water to a definite channel. The conduit may be closed in the form of a box channel or it may be open as in a rectangular channel.

   c) **Outlet:** Its function is to discharge the water into the channel below at a safe velocity. The outlet should provide for the dissipation of kinetic energy of the discharge within the confines of the structure.

8.6 Drop Spillway

It is a weir structure, in which flow passes through the weir opening, fall or drops on an approximately level apron or stilling basic and then passes into the downstream channel. Its use is limited to a maximum drop of 3 m. It is mainly used at the gully bed to create a control point. Several such drop structures are constructed across the gully width throughout the length at fixed intervals. The series of such structures, develop a continuous break to flow of water, causing deposition of sediments and thus filling the gully section. Sometimes, the drop structures are also used at the gully head to pass the flow safely and controlling the gully head. The different components of drop structures are shown Fig. 8.1.

8.6.1 Components and Functions

1. **Head wall:** It acts as a front wall against runoff flow in the drop spillway. It is constructed across the gully width. A notch of suitable size is also made at the top in the headwall for easy water conveyance. Rectangular notch is most commonly used. The size of the notch should be sufficient to allow the water very safely.

2. **Head Wall Extension:** It is the extended portion of head wall into the gully sides. It permits stable fill and prevents piping (due to seepage) around the structure. Its main function is to provide structural strength against sliding of the structure and also to prevent the flow of water from the sides of the drop spillway.

3. **Wing Walls:** These are constructed at the rear end of the structure with some inclination, usually at 45° from the vertical. These walls are extended up to the gully sides and perform the function of preventing the flow backward into the space left between gully wall and side wall of the structure. They provide stability to the fill and protect the gully banks and surface.

4. **Cut-off Walls:** These are constructed to provide structural strength against sliding of the structure. They increase frictional resistance of the structure which opposes the force causing the slide. In other words, cut-off walls act as a key for the structure, prevent piping under the structure besides reducing uplift and sliding.

5. **Toe Walls:** Prevent undercutting of apron.

6. **Side Walls:** These are constructed in the side along the gully walls. They guide the water and protect the fill against erosion. The function of the side walls is to prevent splashing of water over the gully banks and also to confine the water flow within the apron.

7. **End Sills:** These are the elevated portion of rear end of the apron. Its main function is to obstruct the water from directly moving into the channel below. They also raise the tail water level to create hydraulic jump and to dissipate the energy of the flowing water.

8. **Longitudinal Sills:** These are constructed in the apron section. They are constructed lengthwise parallel to the side walls. The sills are useful to make the apron stable.

9. **Apron:** It is one of the main downstream components of the straight drop spillway as it receives the gully flow with high velocity and changes the flow regime so as to minimize the soil erosion on the downstream channel. It includes several elevated blocks to make the apron surface rough. This feature of apron is responsible for dissipating the maximum kinetic energy of falling water by creating hydraulic jump. As a result the velocity of outflow water is significantly reduced.

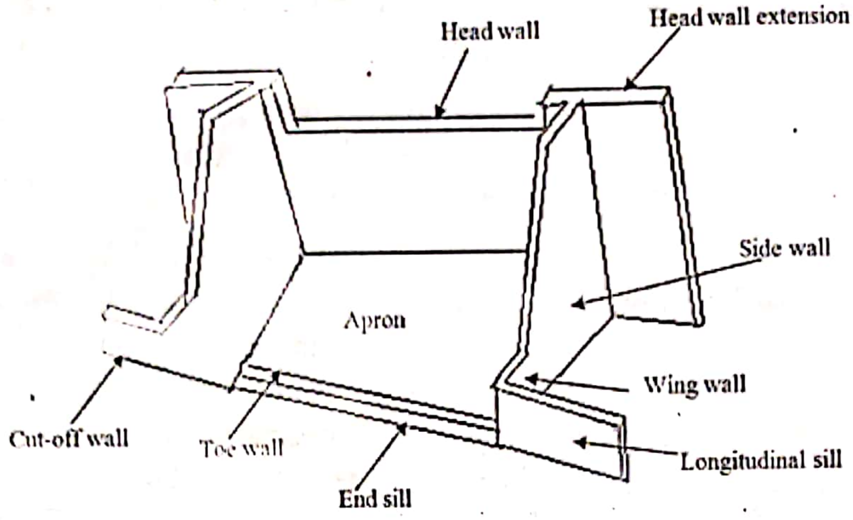

Fig. 8.1. Drop spillway. (Source: -------------)

The drop structure is used to control the velocity of runoff in a channel by allowing the water to fall from higher elevation to much lower elevation. The main three purposes of drop spillways are as follows:

1. To provide a transition between a broad or flat waterways and ditch or gully section.
2. To raise the flow line to allow formation of sufficient soil depth for vegetative growth where bottom of the gully is at risk.
3. To raise the flow line of the waterway so as to provide drainage in case of wet waterways.

8.6.2 Uses of Drop Spillway

1. To control gradient in either natural or constructed channels, To control tail-water at the outlet of a spillway or conduit.
2. To serve as a reservoir spillway where the total drop is relatively low.
3. To serve as inlet and outlet structures for tile drainage system in conjunction with gradient control.
4. To use as grade stabilization in lower reaches of waterways and outlets.
5. To use as erosion control, to protect the roads, buildings etc.
6. Straight drop spillway as an outlet in tile drainage system and for releasing the irrigation water into the field in irrigation system.
7. In the reservoir, for letting out the water through low height drop spillway of less than 3 m,

8. For controlling irrigation in the water distribution system and

9. As an outlet for disposing surface water from large areas, especially with drainage ditches.

8.6.3 Material for Construction

For most soil conditions, drop spillways may be built of any of the construction materials adapted for use in hydraulic structures. It may be concrete, masonry, concrete blocks etc. Reinforced concrete is most widely used and has been very satisfactory in terms of long life and low annual cost. In case a number of structures are involved, the selection of material should be based on the required life span of structures and annual cost comparison, which includes maintenance, of the structures built of different available material.

8.6.4 Advantages

1. Stability: It is very stable and likelihood of serious structural damage is remote.

2. Non-Clogging of Weir: As rectangular weir is used in this case, there is less likelihood of clogging by debris.

3. Maintenance cost is low.

4. It is relatively easy to construct and economical.

5. Standardization: The designs may be standardized which result in savings in engineering and constructional costs.

6. The danger of undermining by rodents is not possible in this structure.

8.6.5 Disadvantages

1. Use is limited to a maximum drop of 3 m. They may be costlier than other structure.

2. It is not a favourable structure where it is desired to use temporary spillway storage to obtain a large reduction in the discharge at or downstream from the structure.

3. In the areas where discharge is less than 3 m^3/s, the construction of straight drop spillway proves to be costly affair, and thus should not be preferred.

4. If the gully grade below the structure is not stable then it is impossible to construct a drop spillway.

Lesson 9 Drop Inlet Spillway

A drop inlet or shaft spillway is one in which the water enters through a horizontally positioned circular or rectangular box type riser or inlet and flows to some type of outlet protection through a circular (horizontal or near horizontal) conduit. The drop inlet spillway is ideally suited to conditions when there is need to control the downstream channel flow by providing a temporary storage upstream of the structure. It consists of an earthen dam and a pipe spillway. The dam provides the temporary storage of runoff from the contributing watershed while the spillway permits the design discharge to pass downstream (Fig. 9.1). It is adapted where drop is > 3.0 m. The drop inlet structure (Fig. 9.1) consists of the inlet, conduit and the outlet. Where the inlet is funnel shaped, this type of structure is often called as Morning glory or Glory hole spillway.

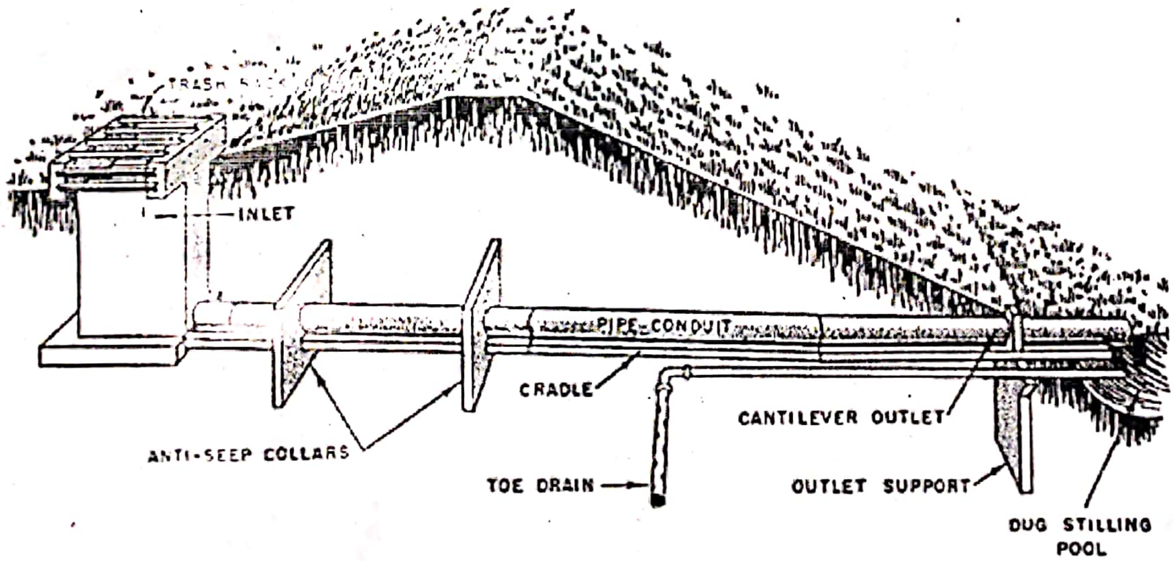

Fig. 9.1. Drop inlet spillway and its components.

(Source: Michael and Ojha, 2012).

Advantages

- Drop inlet structures are used in gullies towards the downstream part to create storage of water.

- These structures not only help in protecting gullies but also create water storage.
- The stored water could be useful for irrigation or other farm use purposes.
- A large number of drop inlet structures will have a retarding effect on downstream flows. A reduction in the sediment load could also occur.
- An earthen embankment helps in storing the water and the drop inlet essentially lets out the excess water safely.
- These are frequently used for headwater flood control and as outlets for farm ponds and reservoirs, silt detention reservoirs and settling basins.
- They are suitable as gully control structures for the stabilization and control of advancing gully heads when the gully is more than 3 m deep.
- They are relatively simple to build.

9.1 Design of Drop Inlet Spillways

The design consists of hydrologic and hydraulic designs.

9.1.1 Hydrologic Design

The hydrologic design of the drop inlet structure consists of knowing both the peak rate of runoff expected and also the inflow hydrograph. The latter is needed as temporary storage of water is created in case of these structures. The outflow will not be same as the inflow like in drop or chute spillways.

9.1.2 Hydraulic Design

To understand the hydraulic design of the structure, the different types of flow that occur in the conduit are to be considered. The flow through the structure could be controlled first by the inlet and latter by the conduit. A typical discharge characteristic curve is shown in Fig. 9.2. To calculate the inflow capacity of straight drop inlet spillway, the following weir formula is used.

$$Q = \frac{2}{3} C_d \sqrt{2g} L H^{\frac{3}{2}} \qquad (9.1)$$

where, Q = peak discharge rate to be handled by the structures (m^3/s); g = acceleration due to gravity (9.81 m/s^2); H = head over the crest (m);