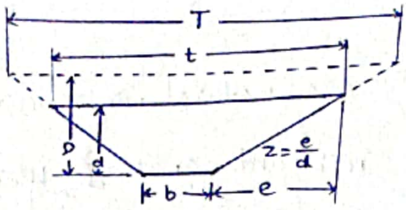
Unit-V

Vegetated waterways:

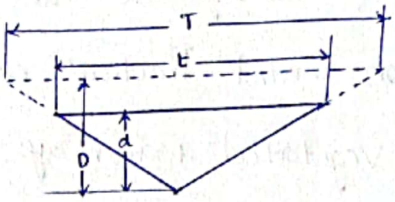
Vegetated waterways are natural or constructed water covers covered with erosion resistant grasses, used to dispose surface water from crop land. Waterways are the foundation of water management for all erosion control practices, except level terraces and contour bunds. Vegetated waterways are constructed along the slope of the area. Vegetated waterways should be used to handle natural concentration of runoff or to carry the discharge from terrace or bund systems, contour furrows, diversion channels or emergency spillways of farm ponds or other structures. The grass in the waterway should be established before any water is turned into it. Thus, the outlets should be ready before bunds, terraces & diversions are installed.

Generally parabolic, triangular and trapezoidal shapes are used for waterways. Natural waterways have a shape very close to parabolic. Trapezoidal channels after a long use gradually approximate to the shape of a parabola. When a V-ditcher is used for construction, triangular shaped waterways are constructed. V-ditcher is combination with a buck scraper can construct a trapezoidal shaped waterway.

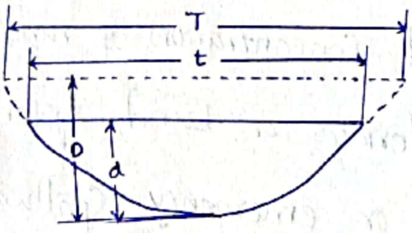
The various formulae defining geometric characteristics such as cross-sectional area, depth, width...etc of different shapes of the waterways are given below. These formulae are useful for design purposes.



a, Trapezoidal cross section



b, Triangular cross section



c, Parabolic cross section

Fig. Channel cross sections

1. Trapezoidal

Area, $A = bd + zd^2$

where, $z = \frac{e}{d}$

Wetted Perimeter, $P = b + 2d\sqrt{z^2+1}$

Hydraulic Radius, $R = \frac{A}{P}$

$$R = \frac{bd + zd^2}{b + 2d\sqrt{z^2+1}}$$

Top width $= b + 2zd$.

2. Parabolic

Area, $A = \frac{2}{3} td$

Wetted Perimeter, $P = t + \frac{8d^2}{3t}$

Hydraulic Radius, $R = \frac{t^2 d}{St^2 + 4d^2}$

Top width, $t = \frac{A}{0.67d}$

$$T = \frac{t}{(D/d)^2}$$

Triangular

Area, $A = zd^2$

Wetted Perimeter, $P = 2d\sqrt{z^2+1}$

Hydraulic Radius, $R = \frac{zd^2}{2d\sqrt{z^2+1}}$

$$R = \frac{zd}{2\sqrt{z^2+1}}$$

Top width, $t = 2dz$

$$T = \frac{D}{d} \times t$$

Problem-1:

Design a parabolic shaped grassed waterway to carry a flow of $3\ m^3/s$ down a slope of 4%. An excellent stand of dub grass is to be maintained in the waterway.

Sol:- Given

Assume that the top width, $t = 4m$.

and the depth of flow, $d = 60cm = 0.6m$.

the cross-sectional area, $a = \frac{2}{3} td$

$$a = \frac{2}{3} \times 4 \times 0.6$$

$$a = 1.6\ m^2$$

Wetted Perimeter, $P = t + \frac{8d^2}{3t}$

$$P = 4 + \frac{8(0.6)^2}{3\times(4)} = 4.24\ m.$$

Hydraulic Radius, $R = \frac{A}{P}$

$$R = \frac{1.6}{4.24}$$

$$R = 0.377\ m$$

Mean velocity, $V = \frac{1}{n} R^{2/3} S^{1/2}$

$$V = \frac{1}{0.04} (0.377)^{2/3} \times (0.04)^{1/2}$$

$$V = 2.61 \, m/s$$

$$Q = aV$$

$$= 1.6 \times 2.61$$

$$Q = 4.17 \, m^3/s$$

The velocity is unsafe and the carrying capacity is excessive.

(ii) Assume $t = 4.15 \, m$ & $d = 47.5 \, cm$

then $a = \frac{2}{3} td$

$$a = \frac{2}{3} \times 4.15 \times 0.475$$

$$a = 1.314 \, m^2$$

Wetted Perimeter, $P = t + \frac{8d^2}{3t}$

$$P = 4.15 + \frac{8 \times (0.475)^2}{3 \times 4.15}$$

$$P = 4.29 \, m$$

Hydraulic Radius, $R = \frac{A}{P}$

$$R = \frac{1.314}{4.29}$$

$$R = 0.306 \, m$$

mean velocity, $V = \frac{1}{n} R^{2/3} S^{1/2}$

$$V = \frac{1}{0.04} \times (0.306)^{2/3} \times (0.04)^{1/2}$$

$$V = 2.27 \, m/s$$

$$Q = aV$$

$$= 1.314 \times 2.27 = 2.98 \, m^3/s$$

$$Q \simeq 3 \, m^3/s.$$

The section is suitable.

The design dimensions of the Parabolic Channel are

[illegible]

op width = 4.15 m

Depth of flow of water = 47.5 cm

Free board = 15 cm.

Problem-2: Design a grassed water way with trapezoidal cross-section. The relevant data are given as under

Peak runoff rate $(Q) = 4.0\ m^3/sec$

Grade to be used $(S) = 0.3\%$.

Manning's roughness co-efficient $= 0.04$

Side slope $= 2:1$

Sol:- Given

Assume a trial value of bottom width of waterway as

$b = 2\,m$

$d = 1\,m$

cross-sectional area, $A = bd + zd^2$ (Here $z = 2$ because side slope is $2:1$).

$A = 2 \times 1 + 2 \times (1)^2$

$A = 4\,m^2$

wetted Perimeter, $P = b + 2d\sqrt{z^2+1}$

$= 2 + 2 \times 1\sqrt{2^2+1}$

$P = 6.47\,m.$

Hydraulic Radius, $R = \frac{A}{P}$

$R = \frac{4}{6.47}$

$R = 0.62\,m$

Flow velocity, $V = \frac{1}{n} R^{2/3} S^{1/2}$

$V = \frac{1}{0.04} \times (0.62)^{2/3} \times (0.003)^{1/2} = 1\,m/s.$

Capacity of grassed waterway

$$Q = AV$$

$$= 4 \times 1$$

$$Q = 4 \ m^3/s$$

The computed capacity of waterway is equal to the peak runoff rate of the area, hence the design is correct for handling the given peak rate of runoff produced from the area.

Sedimentation of Reservoirs

Integrated river basin development involves construction of storage reservoirs for the purpose of irrigation, power and flood control. One of the problems in the design and maintenance of these reservoirs is the loss of their storage capacity due to silting. Silting results from the deposition of stream become sediment as the transporting power of the stream is suddenly reduced when flowing into the still waters of the reservoir. If once silt enters the reservoir and settles there, it becomes economically impracticable to remove it by artificial means.

In the planning of reservoirs, allowance is made for the storage of sediment. The volume provided for is known as dead storage and the storage volume considered for irrigation, power etc., is known as live storage. Measurements taken at existing reservoirs, unfortunately shows that a major portion of the sediment deposit instead

findi settles in affecting &

finding its way to the assigned place of storage, settles in places designed for live storage, thus greatly affecting the functioning of the reservoir. Other manifestations of the sedimentation are: aggradation of channels causing flood hazards, increased cost of water supply treatment, damage to mechanical equipment by wear of gates, valves etc.

Sources of Sediment

The sources of sediment can broadly be classified as:

(1) sheet erosion from agricultural, forest and waste lands.
(2) Mass movements of soil from land slides, slumps & soil creeps;
(3) Gullying by concentrated runoff;
(4) Stream channel erosion including bank cutting and bed degradation;
(5) Erosion caused by floods
(6) Erosion incident to activities likes roads, railroads, cleaning for housing and industries etc., and
(7) Mining and dumps left as wastes.

In sediment problems the total sediment load is of primary importance. The relative contribution of the sources of sediment vary from catchment to catchment. Consideration must therefore be given to the sources of sediment involved in a problem and the methods for controlling them effectively.

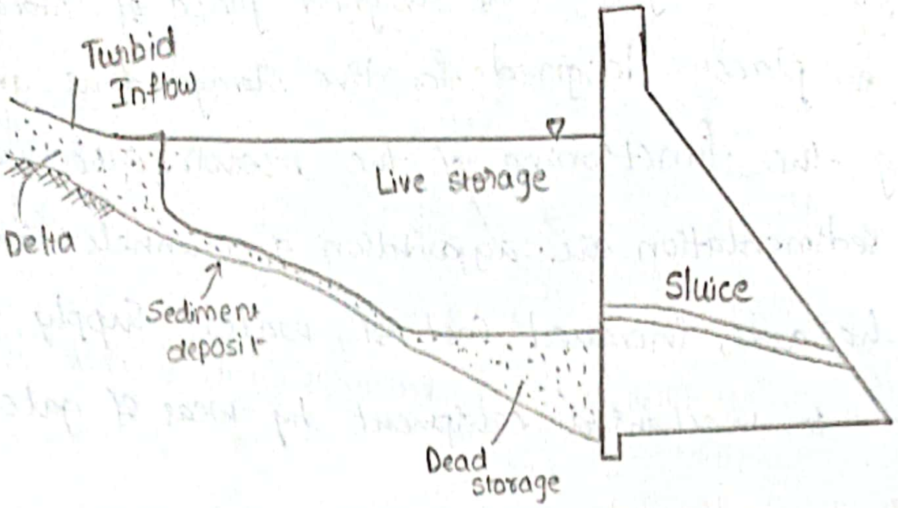


Fig Live storage and dead storage in a reservoir

Estimation of Sediment flow rates

Estimation of the sediment flow rates by a stream is necessary to understand the extent of erosion in the stream's catchment and for estimating the reservoir life if one is planned to be constructed on the stream. In order to estimate the sediment loads in streams or rivers, sediment observation stations are to be located along with discharge observations. Sediment is transported by the stream in different forms and different equipments are to be used to measure these components.

Just similar to the transportation of soil particles in wind erosion, sediment particles in a stream are transported by the three processes, viz., suspension, saltation and surface creep. In case of sediment transport by streams, the saltation and surface creep are combined and is known as the bed load. The sediment transported in suspension is referred to as the suspended load. To get the total sediment load, both the bed load and suspended load are separately determined and added. This is necessary because of the fact that the bed load does not move at the same velocity of water above but at a lower speed.

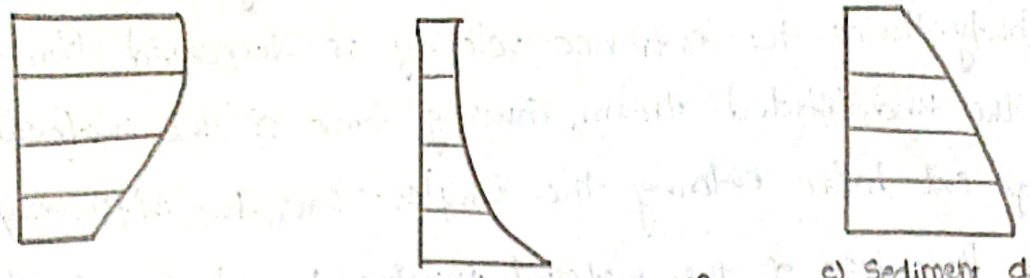


Fig: Velocity distribution and sediment distribution in a straight natural stream

The suspended load, because of the velocity differences of the flow of water in the stream section is also not uniformly distributed in the stream section.

Bed load Sampling:

The rate of bed load movement is determined by placing the sampler on the stream bed and measuring the amount of material collected in a given time. The bed load -sampler is usually held in position by a rod if the stream is shallow, or by a cable from a boat, from a trolley or pulley running on a cable spanned across the river, or from a bridge. A winch is also provided for lowering and raising the sampler. The bed load samplers are of different types of bed load samplers are in use. These are: (1) basket type, (2) tray or pan type, and (3) Pressure difference type.

The basket type of sampler consists of a box or basket, generally made of meshed material. The sampler is lowered to rest on the stream bed with the open end on the upstream to catch a sample of the moving material. The introduction of the sampler into the stream, causes an inward

- resistance to flow & a resultant lowering of the str. velocity. Hence the entrance velocity is decreased from of the undistributed stream, causing some of the material drop out before entering the samplers. Thus, the efficiency i.e. the percentage of the material moving towards the samplers which is actually caught by it is less than 100% and must be know to obtain reliable results from the type of equipment.

Several Properties etc. The

The tray or the pan type samplers consists of a flat pan or tray-shaped device with baffles or slots to check the moving material. It has the same disadvantage as of the basket type of samplers.

The Pressure-difference type sampler is designed to over come ~~to obtain of~~ disadvantage of both basket & tray or pan type samplers. To overcome the energy losses is formed, thus giving the same entrance velocity as that in undistributed stream.

Estimation of sediment yield of watershed

The Universal soil loss equation essentially gives the soil loss of individual plots. The goss erosion in a watershed consists of erosion in individual plots, gully and stream bank erosions. Sediment produced from sheet and rill erosion may get deposited before it moves to the outlet of the watershed.

Regression equations, wherein the sediment yield is related to several factors like watershed size, land cover, slope, soil properties etc. are also used for estimating the sediment yield. These equations are of the form

$$\log(S_y + 100) = C_1 - C_2 \log(x_1 + 100) + C_3 \log(x_2 + 100) - C_4 \log(x_3 + 100) + C_5 \log(x_4 + 100)$$

where, S_y is the average annual sediment yield, $C_1 \ldots C_5$ are regression constants, and x_1, x_2, x_3 & x_4 are watershed properties like average watershed slope, soil particle size, climatic parameters like annual precipitation, soil aggregation index etc. The watershed properties are related to the annual observed sediment yield for developing the regression equations.

Conceptual models for estimating sediment yields from watersheds have also been developed & some of these approaches are given by Singh (1989).

Controlling Sedimentation of Reservoirs

The life of a reservoir can be considerably prolonged if proper remedial measures against silting of reservoirs are taken. The methods proposed or tried for this purpose may be broadly divided into six groups, viz.,

(1) Selection of reservoir size,

(2) design of reservoir,

(3) Control of sediment inflow,

(4) Control of sediment deposition,

(5) removal of sediment deposits, and

(6) watershed erosion control.

The Concept of Sediment delivery ratio (D_r) is used estimate the Sediment yield of a watershed. The Sediment delivery ratio is a fraction or Percentage of gross erosion that is transported to the point of measurement and is expressed as:

$$S_y = D_r \cdot E_s$$

where, S_y = Sediment yield,

D_r = Sediment delivery ratio (SDR), &

E_s = gross-erosion of the watershed.

The SDR depends on range of local factors including the size of the watershed, its characteristics like land use, slope, erosion conditions etc. Its values are therefore applicable for the local conditions for which these values are determined & has to be used with caution.

The US Soil Conservation Service (1971) has developed a general SDR values versus drainage area relationship from data of earlier studies. The relationship shows that the SDR varies approximately inversely as the 0.2 power of the drainage area.

Drainage area (km^2)	Sediment delivery ratio
0.05	0.58
0.1	0.52
0.5	0.39
1	0.35
5	0.25
10	0.22
50	0.153
100	0.127
500	0.079
1000	0.059

The design aspects of the reservoir to be taken into consideration are the provision of adequate capacity taking the expected sediment load and provision of sluices in the dam. Sluices however are able to eject only a part of the sediment settled very near the dam. Control of sediment inflow is achieved by constructing settling basins and propagating vegetative screens in the upstream part of the reservoir.

The various soil conservation measures to be adopted are:

1. Contour trenching on barren hill slopes.
2. Bench terracing of steep slopes,
3. Diversion channels,
4. Contour or graded bunding of agricultural lands,
5. Gully protection,
6. Construction of small ponds,
7. Stream bank erosion control,
8. Road side stabilization,
9. Improved agricultural practices like contour cultivation, crop rotations, & strip cropping.
10. Pasture development,
11. Flood plain protection,
12. Water spreading for groundwater recharge,
13. Reservoir shore line protection, and
14. Control of landslides & land slips.

Sediment delivery Ratio

The long term average annual sediment yield can be predicted by applying a delivery ratio to the estimated gross erosion. This technique is very convenient and is adequate for problems which require an estimate of average annual sediment yield, namely sediment pools for reservoirs, etc.

The following formula is used for determining the delivery ratio (DR):

$$DR = \frac{\text{measured sediment yield at the watershed outlet}}{\text{Estimated gross soil erosion (A)}}$$

where, A = Soil erosion estimated by USLE.

Trap efficiency of water storage structures

In a stream, the sediment is present in the form of bed load and suspended load. Both types of sediment loads are generally estimated separately, but at times are sampled together in smaller watersheds. The bed load contains the bigger-sized solids and moves along the stream bed, while the suspended load is composed of fine particles and has a specific gravity around 2.65. It moves along with the flowing water in a suspended form. The settlement process of suspended sediment is counteracted by the upward currents. Very fine particles (colloidal) never settle but remain under suspension due to molecular movement.

field the

Streams are the main carriers of sediment load to all types of water reservoirs. The sediment load, trapped by a structure from the incoming streams, is a function of the ratio of sediment retaining characteristics of the structure and the total inflow of sediment by streams into it. It is expressed as

$$\text{Trap efficiency} = \frac{\text{Sediment retained in the structure}}{\text{Total inflow of sediment structure}}$$

Contouring

A contour or a contour line is defined as the line of intersection of level surface with the surface of the ground. Thus, every point on a contour line has the same elevation. Therefore, contour line may also be defined as a line joining the points of equal elevation. The shore line of a reservoir with still water represents a contour line of fixed reduced level. As the water level changes, the new shore line represents another contour of a different R.L. The contour lines of an area are presented in a map known as contour map or topographic map. In addition to contour lines, a topographic map includes the features like streams, rivers, reservoirs, valleys, hills, bridges, culverts, roads, fences etc.

Contour interval:

The contour vertical distance between two consecutive contour line is called contour interval.

The contour interval is kept constant, otherwise the m
- be misleading. The horizontal distance between any tw
consecutive contour lines is known as the "horizontal equiv
The horizontal equivalent, for a given contour interval depends on the nature of the ground. The contour interval depends upon the following factors:

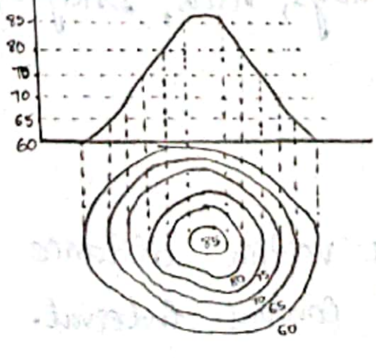
1. Time and fund available for field and office work.
2. Purpose and extent of survey.
3. Nature of the ground, and
4. Scale of the map.

The following contours intervals are generally used:

1. for flat agricultural land, calculation of earthwork, land levelling etc. 0.15 to 0.50m.
2. for construction of reservoirs and town planning 0.5-2m.
3. For location surveys 2 to 3m, and
4. For small scale topographic map of hilly area 3m to 25m.

Characteristics of Contour lines

1. All points in contour line have the same elevation.
2. Uniformly spaced contour lines indicate a uniform slope whereas, straight, parallel & equally spaced lines indicate a plane surface.



Scanned with CamScanner

widely spaced contour lines indicate a flat ground & closely spaced contour lines indicate steep ground.

4. A series of closed contours with the higher values inside indicate a summit or hill. (fig. 1)
5. A series of closed contours with the higher values outside indicate a depression (fig. 2)
6. Contour lines cross a ridge or a valley line at right angles.
7. If the contour lines form U-shaped curves and the higher values of contour are inside the loop, then it indicates a ridge line. (fig. 3)
8. If the contour lines form V-shaped curves and the lower values of contour are inside the loop, it indicates a valley line (fig. 4)

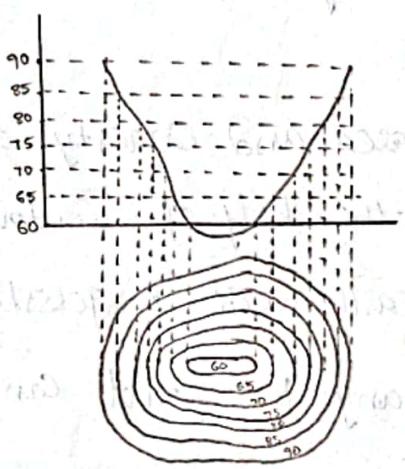


fig. Depression

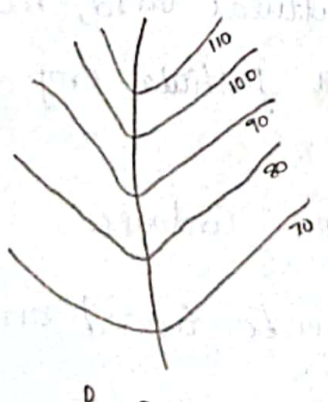


fig. Ridge

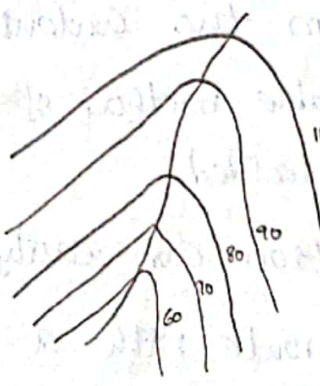


fig. Valley

9. Contour lines can't cross one another or merge on the map except in case of an over handling cliff.

10. If several contour lines coincide i.e. the horizontal equivalent is zero then it indicates a vertical cliff.

11. Four sets of contours sho represents a saddle i.e. a depression between summits. It is a dip in a ridge or the junction of two ridges. Lines passing through saddles and summits give watershed line.

Uses of Contours

1. By inspection of a contour map, information regarding the characters of the ~~sto~~ terrain is obtained, whether it is flat, undulating or rolling etc.
2. with the help of contour map, suitable site for reservoirs, canal, drainage channels, roads, railway etc. can be selected.
3. Total drainage area and capacity of reservoirs can be determined with the help of contour map.
4. Computation of earth work is possible from contour map.
5. Intervisibility of any two points can be known from the contour map.
6. from the contour map of agricultural land, most suitable method of irrigation for a particular crop can be decided.
7. Section can easily be drawn from contours.
8. A route with a given slope can be traced on a contour map.