

## **MEASUREMENT OF RIVER FLOWS**

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### **1.0 Introduction**

Water is a basic necessity and as it is found in the limited quantities it is essential that the available supply be known. An inventory of water supplies proves invaluable in the design and operation of municipal water systems, irrigation projects, water power development, flood control, industrial processes, pollution control, drainage, bridge design and other development projects. Hydrological data are essentially required for water resources planning. Gauge and discharge parameters of a river are very important for developing economically beneficial projects. Stream flow records provide the basic data for most water resources investigations. Sediment load plays an important role with respect to silting of reservoirs and irrigation canals. It is also very important for planning the effective sediment management practice for hydro power projects. In particular, maximum and minimum discharge, total annual flows and their variations, sediment load in the stream during different periods and average annual sediment load are very important input data for planning and designing of any water resources project.

In India the Central Water Commission endeavors the gigantic task of collection and compilation of hydrological data incorporating the quality and quantity of water available in various basins of the country. The Water Year Books and sediment Year Books of various basins of the country are being published by Central Water Commission in order to make its effective and efficient use.

### **2.0 Stream Gauging Station – site selection**

A stream gauging station is a structure in or close to the stream channel which indicates or records the height of the water surface in the stream. As per WMO the selection of a particular site for the gauging station on a given stream should be guided by the following criteria for an ideal gauge site:

- The general course of the stream is straight for about 100 metres upstream and downstream from the gauge site;
- The total flow is confined to one channel at all stages and no flow bypasses the site as sub-surface flow;
- The stream bed is not subject to scour and fill and is free of aquatic growth;
- Banks are permanent, high enough to contain floods, and are free of brush;
- Unchanging natural controls are present in the form of a bedrock outcrop or other stable riffle during low flow, and a channel constriction for high flow, or a



fall or cascade that is unsubmerged at all stages to provide a stable relationship between stage and discharge. If no satisfactory natural low-water control exists, then installation of an artificial control should be considered;

- A site is available, just upstream from the control, for housing the stage recorder where the potential for damage by water-borne debris is minimal during flood stages. The elevation of the stage recorder itself should be above any flood likely to occur during the life of the station;

### **3.0 Stage Measurement**

#### **3.1 Non-recording gauges**

Several types of non-recording gauges for measuring stage are used in hydrometric practice. The common gauges are of the following types:

- (a) Graduated vertical staff gauge;
- (b) Ramp or inclined gauge;
- (c) Wire-weight gauge installed on a structure above the stream; and
- (d) Graduated rod, tape, wire or point gauge for measuring the distance to the water surface.

##### **3.1.1 Staff Gauge**

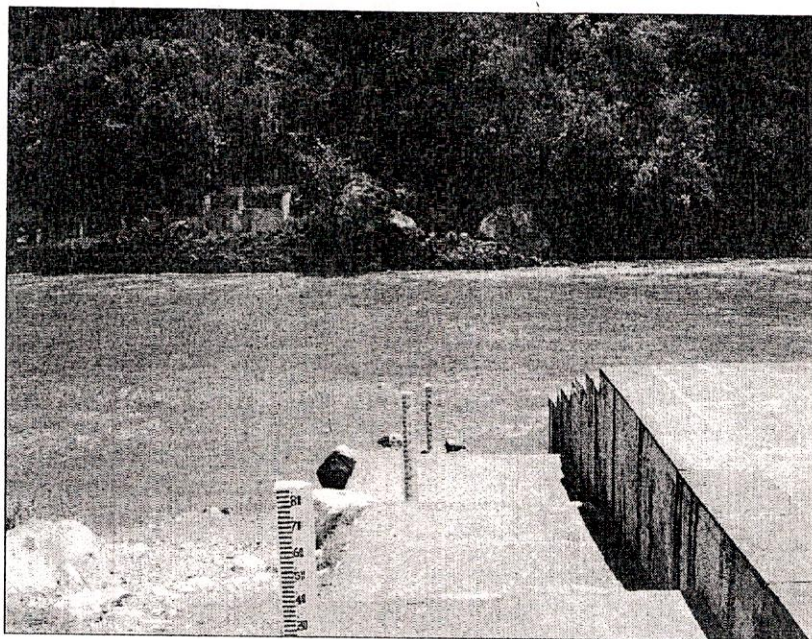
A staff gauge is a scale graduated to meters and centimeters and is rigidly fixed at the river cross section or attached to a permanent bridge abutment. The level of water surface in contact with the gauge is measured by matching the reading of the staff and adding with it the reference datum level. For rivers with large fluctuations in water level 3-4 numbers of staffs are required to be fixed at one side of the river cross section and is known as sectional gauge. All the staff should refer to same common datum and be calibrated. A sectional gauge on one side of Pinder river in Karnprayag, Uttarakhand, India is shown in Figure-1.

##### **3.1.2 Wire-weight gauge**

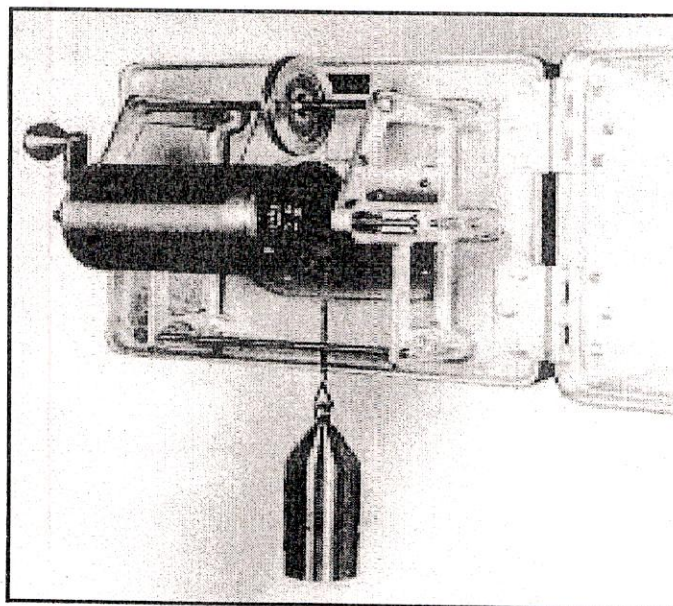
The major problem with staff gauges is that they are likely to be affected by debris, boats, animals and water currents in floods. To overcome this difficulty wire-weight gauge can be used. Here a tape or wire is lowered from the structures like bridges or ropeways such that the weight attached at the end of the wire just touches the water surface. The length of the wire coming out of the drum of the gauge is read by a mechanical counter attached to a reel on which the wire or tape is wound, and



subtracted from the reference datum. Measurements are made from the top datum from where the location of the wire weight gauge is fixed. A wire-weight gauge is shown in Figure-2.



**Figure-1: Sectional gauge**



**Figure-2: Wire-weight gauge**

### **3.2 Recording gauges**

Many different types of continuously recording stage gauges are in use. They may be classified according to both mode of actuation and mode of recording. A commonly used installation consists of a stilling well connected to the stream by pipes and a float in the stilling well connected to a wheel on a recorder by a beaded wire or

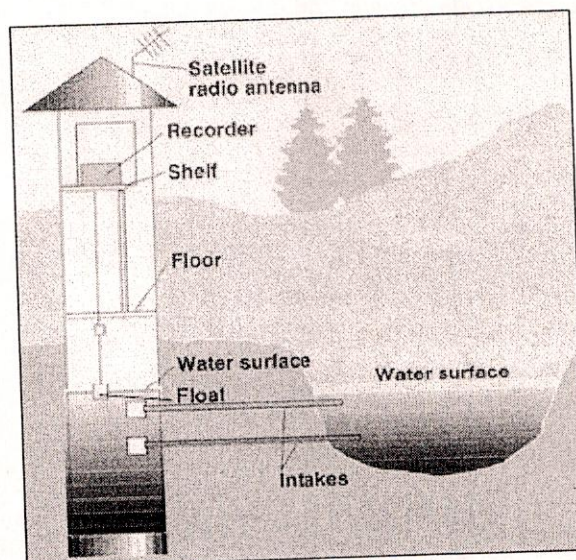


perforated tape. In high velocity streams, it may be necessary to install static tubes on the end of the intake pipes to avoid drawdown of the water level in the well.

### **3.2.1 Water stage recorder**

In this a surface float is connected at one end of a wire which passes through a recorder, the other end of the wire is balanced by a suitable counter weight. The fluctuations in the water level cause the float, wire and finally the wheel of the recorder to move. This causes the pen attached to drum or the wheel of the recorder to move. The drum and the pen are connected with a rack and pinion arrangement which convert the angular movement of the drum to a linear one. The pen is attached to a clock mounted cylinder wound for 24 h or a week and its recording on the graph paper on the cylinder is continuous and reverses automatically when there is fall in water level.

Such an arrangement is protected from the main river by installing a stilling well. An arrangement to draw water from the main river at its lowest water level position is ensured through intake pipes at different levels, between the river and intake well. Improvement to the automatic stage recorder can be made by adding instruments like on board computer which records the stage, converts it into discharges continuously or at a fixed time interval. Radio transmitters can be attached to the system to transmit data signals (stages) to the control station at certain interval. A schematic diagram of water stage recorder is shown in Figure-3.



**Figure-3: Schematic diagram of water stage recorder**

### **3.2.2 Bubble Gauge**

A bubble gauge consists of a small tube placed at the lowest water level in a river through which compressed air preferably Nitrogen gas is slowly bubbled out. The pressure in the tube is equal to the water head above it is measured by a manometer



connected to a recording device like pen and graph arrangement. Gas from a high pressure cylindrical jar passes through a controlling unit to the small tube orifice. As the head of water in the river changes, the controlling unit automatically controls the gas pressure equal to the water head. The position of the pen connected to the free end of the manometer moves as the manometer head fluctuates, which is recorded on a graph paper. A schematic diagram of bubble gauge recorder is shown in Figure-4.

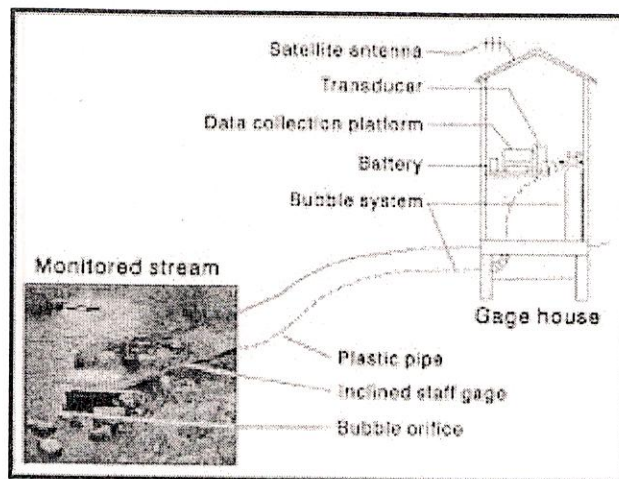


Figure-4: Schematic diagram of bubble gauge recorder

The bubble gauge recorder has a number of advantage such as installation is cheap as intake well is not required, high fluctuations in the river stage can be easily handled, the recording station can be located as much as 300 m away from the river section, there is no scope of clogging or choking of the system and the sensitivity of the instrument is better.

### 3.3 Stage-discharge controls

The physical element or combination of elements that control the stage-discharge relationship is known as a control. The major classification of controls differentiates between section control and channel control. Another classification differentiates between natural and artificial controls. Section control exists when the geometry of a single cross-section is such as to constrict the channel, or when a major downward break in bed slope occurs at a cross-section. The constriction may result from a local rise in the stream bed, as at a natural riffle or rock ledge outcrop or at a constructed weir or dam. It may also result from a local constriction in width, which may occur naturally or may be caused by some man-made channel encroachment, like a bridge with a waterway opening that is considerably narrower than the width of the natural channel. Channel control exists when the geometry and roughness of a long reach of channel downstream from the gauging station are the elements that control the relationship between stage and discharge. The length of channel that is effective as a control increases with discharge. Generally, flatter stream gradients will result in longer reaches of channel control.



A low dam, weir, or flume is often built in the channel to provide an artificial control. Such controls are usually submerged by high discharges, but they provide a stable stage-discharge relationship in the low to medium flow range. The two attributes of a good control are resistance to change ensuring stability of the stage-discharge relationship and sensitivity, whereby a small change in discharge produces a significant change in stage.

#### **4.0 Discharge Observation**

River discharge, which is expressed as volume per unit time, is the rate at which water flows through a cross-section. Discharge at a given time can be measured by several different methods, and the choice of methods depends on the conditions encountered at a particular site. The commonly used discharge observation methods are area-velocity, ADCP and slope-area method

##### **4.1 Area-velocity method**

The most accurate method is to measure the cross sectional area of the stream and then, using a current meter, determine the average velocity in the cross-section. If a current meter is not available, a rough estimate of velocity can be made by measuring the time required for a weighted float to travel a fixed distance along the stream.

##### **4.1.1 Selection of site**

Discharge measurements need not be made at the exact location of the stage gauge because the discharge is normally the same throughout a reach of channel in the general vicinity of the gauge. For best results, the cross-section of the stream at the point of measurement should have the following ideal characteristics:

- The velocities at all points are parallel to one another and at right angles to the cross section of the stream.
- The curves of distribution of velocity in the section are regular in the horizontal and vertical planes.
- The cross-section should be located at a point where the stream is nominally straight for at least 50 m above and below the measuring station.
- The velocities are greater than 10-15 cm /s.
- The bed of the channel is regular and stable.
- The depth of flow is greater than 30 cm.
- The stream does not overflow its banks.
- There is no aquatic growth in the channel.



It is rare for all these characteristics to be present at any one measuring site and compromises usually have to be made.

#### **4.1.2 Measurement of cross-sections**

The accuracy of a discharge measurement depends on the number of verticals at which observations of depth and velocity are obtained. Observation verticals should be located to best define the variation in elevation of the stream bed and the horizontal variation in velocity. In general, the interval between any two verticals should not be greater than  $1/20$  of the total width and the discharge between any two verticals should not be more than 10 per cent of the total discharge. Channel width and the distance between verticals should be obtained by measuring from a fixed reference point (usually an initial point on the bank), which should be in the same plane as the cross-section. Normally, the distance between verticals is determined from a graduated tape or beaded wire temporarily stretched across the stream or from semi-permanent marks painted on a bridge handrail or a suspension cable. Depth may be read directly on a graduated rod set on the stream bed if measurement is by wading.

#### **4.1.3 Measurement of velocity**

Velocity is measured using current meters. Velocity varies approximately as a parabola from zero at the channel bottom to a maximum near the surface. A typical vertical velocity profile is shown in Figure-5. It has been determined empirically that for most channels the velocity at six-tenths of the total depth below the surface is a close approximation to the mean velocity at that vertical line. However, the average of the velocities at two-tenths and eight-tenths depth below the surface on the same vertical line provides a more accurate value of mean velocity at that vertical line. Velocity also varies across a channel, and measurements must, therefore, be made at several points across the channel. The depth of the river varies across its width, so the usual practice is to divide the cross-section of the stream into a number of vertical sections as shown in Figure-6 and measure velocity at each of these verticals viz 2,3,4,5 etc of Figure-6.

If one-point method of velocity observation is adopted then the velocity observations should be made at each vertical by placing the current meter at 0.6 of the depth below the surface. The value observed should be taken as the mean velocity in the vertical.

If two-point method of velocity observations is adopted then the velocity observation at each vertical should be made by placing the current meter at 0.2 and 0.8 of the depth below the surface. The average of the two values should be taken as the mean velocity in the vertical



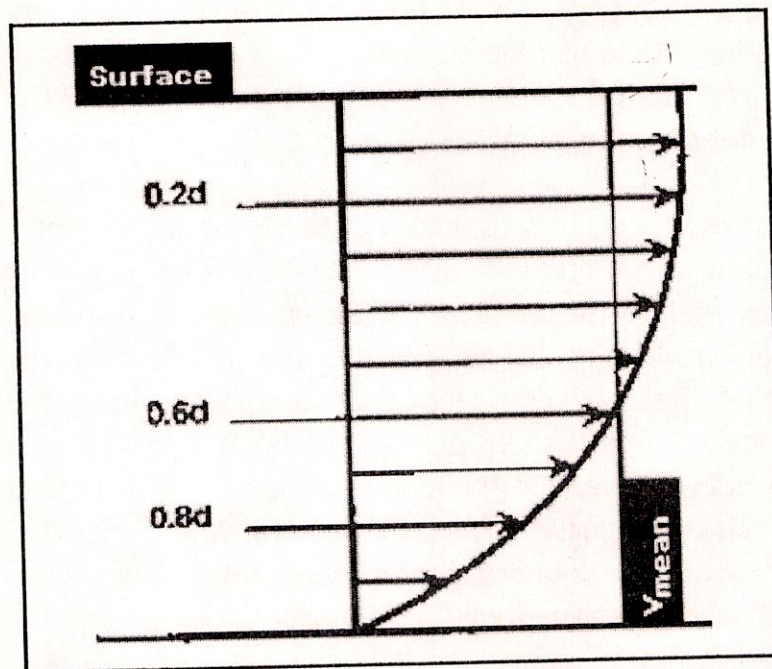


Figure-5: River velocity profile in vertical plane

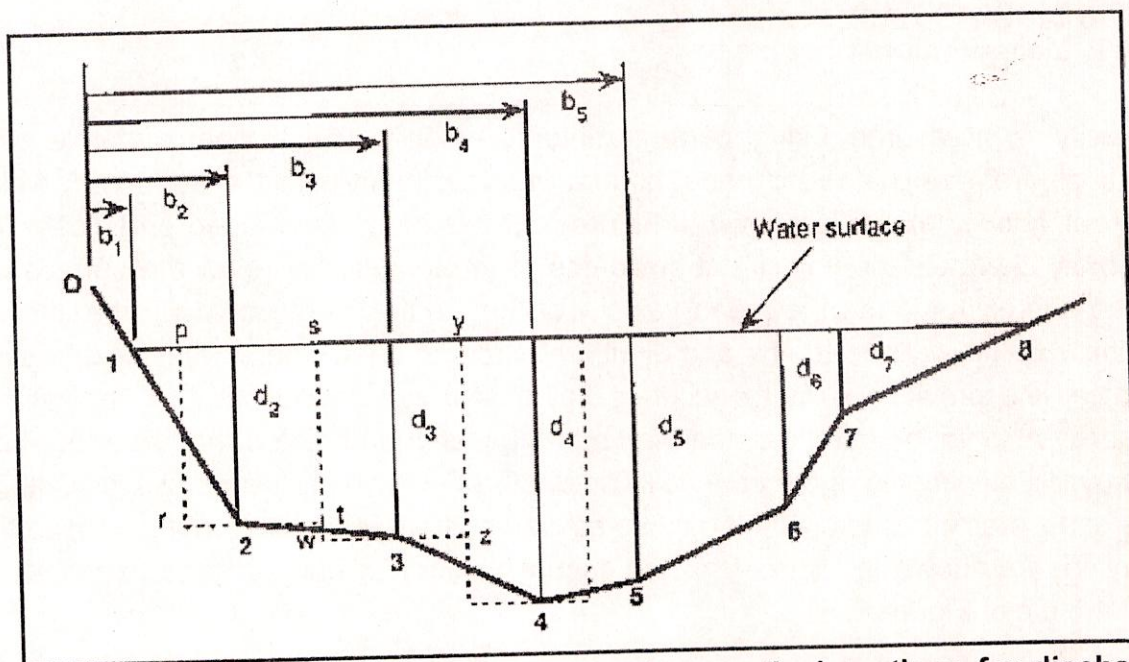


Figure-6: Cross section of a River divided into vertical sections for discharge measurement

#### 4.1.4 Procedure for measuring discharge

While measuring the river discharge the following procedures should be adopted:

1. All measurements of distance should be made to the nearest centimetre.



2. Measure the horizontal distance  $b_1$ , from reference point 0 on shore to the point where the water meets the shore, point 1 in Figure-6.
3. Measure the horizontal distance  $b_2$  from reference point 0 to vertical line 2.
4. Measure the channel depth  $d_2$  at vertical line 2.
5. With the current meter make the measurements necessary to determine the mean velocity  $v_2$  at vertical line 2.
6. Repeat steps 3, 4 and 5 at all the vertical lines across the width of the stream.

#### 4.1.5 Discharge computation

The computation for discharge is based on the assumption that the average velocity measured at a vertical line is valid for a rectangle that extends half of the distance to the verticals on each side of it, as well as throughout the depth at the vertical. Thus, in Figure-6, the mean velocity  $v_{2m}$  would apply to a rectangle bounded by the dashed line p, r, s, t.

The area of this rectangle is:

$$a_2 = [(b_3 - b_1)/2] \times d_2$$

and the discharge through it will be:

$$Q_2 = a_2 \times v_{2m}$$

Similarly, the velocity  $v_{3m}$  applies to the rectangle s, w, z, y and the discharge through it will be:

$$Q_3 = [(b_4 - b_2)/2] \times d_3 \times v_{3m}$$

The discharge across the whole cross-section will be:

$$Q_T = Q_1 + Q_2 + Q_3 \dots Q_{(n-r)} + Q_n$$

In the example of Figure-6,  $n = 8$ . The discharges in the small triangles at each end of the cross-section,  $Q_1$  and  $Q_n$ , will be zero since the depths at points 1 and 8 are zero. If the water is shallow, the operator may wade into the stream holding the current meter in place while measurements are being made. Where the water is too deep for wading (more than 1 metre) the current meter must be lowered from a bridge, an overhead cableway or a boat. The section where flow measurement is made does not have to be at exactly the same place as either the monitoring station



or the water level indicator provided that there is no significant inflow or outflow between these points along the stream.

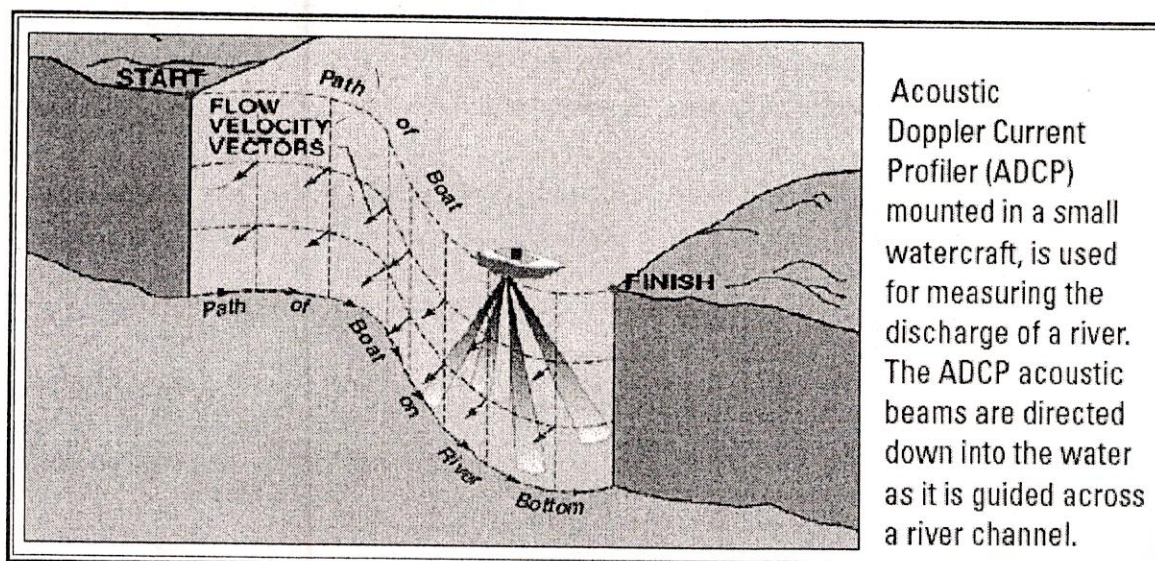
Bridges are preferred as stream gauging stations because they usually allow easy access to the full width of the stream, and a water level indicator can be fastened to a bridge pier or abutment. Aerial cableways are often located at places where characteristics of the stream cross-section approach the ideal. However, they necessitate a special installation.

#### **4.2 Discharge measurement by Acoustic Doppler Current Profiler (ADCP)**

In recent years, advances in technology have allowed to make discharge measurements by use of an Acoustic Doppler Current Profiler (ADCP). An ADCP uses the principles of the Doppler Effect to measure the velocity of water by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. The sound is transmitted into the water from a transducer to the bottom of the river (diagram below) and receives return signals throughout the entire depth. The ADCP also uses acoustics to measure water depth by measuring the travel time of a pulse of sound to reach the river bottom at back to the ADCP.

To make a discharge measurement, the ADCP is mounted onto a boat or into a small watercraft (diagram above) with its acoustic beams directed into the water from the water surface. The ADCP is then guided across the surface of the river to obtain measurements of velocity and depth across the channel. The river-bottom tracking capability of the ADCP acoustic beams or a Global Positioning System (GPS) is used to track the progress of the ADCP across the channel and provide channel-width measurements. Using the depth and width measurements for calculating the area and the velocity measurements, the discharge is computed by the ADCP using  $\text{discharge} = \text{area} \times \text{velocity}$ , similar to the conventional current-meter method. The schematic diagram of discharge measurement by ADCP is shown in Figure-7.





**Figure-7: Discharge measurement by ADCP**

The ADCP has proven to be beneficial to stream gauging in several ways. The use of ADCPs reduces the time it takes to make a discharge measurement. The ADCP allows discharge measurements to be made in some flooding conditions that were not previously possible. The ADCP provides a detailed profile of water velocity and direction for the majority of a cross section instead of just at point locations with a mechanical current meter, this improves the discharge measurement accuracy. It is suitable for discharge measurements in wide and deep rivers. Lastly the discharge output of ADCP is in real time.

The disadvantages of ADCP are that the discharge measurement is affected by excessive temperature, high sediment concentration and excessive channel vegetation. The purchasing cost of equipment is comparatively high. Highly skilled operators are required.

#### **4.3 Discharge measurement by slope-area method**

The slope-area method is most commonly used technique of indirect discharge measurement in streams and rivers. In this method, steady state flow in a uniform channel reach is computed on the basis of uniform flow equations involving channel characteristics, water surface profiles and a roughness coefficient.

The slope area method can be used to determine the discharge at any water stage. However, its real value lies in the means it affords to determine the magnitude of peak flows. The method is especially helpful in the extension of rating curves when current meter measurements are difficult to obtain for the high flood stages.



The data required for applying the slope-area method are obtained by a field survey. The survey includes a plan view and a profile view of the reach, cross sections, an estimate of roughness coefficient of the bed as given in Table-1.

**Table-1: Values of Manning's roughness coefficient**

| Type of bed material | Size of bed material in mm | Manning's roughness coefficient |
|----------------------|----------------------------|---------------------------------|
| Firm earth           |                            | 0.025-0.032                     |
| Sand                 | 1-4                        | 0.026-0.035                     |
| Gravel               | 4-8                        | 0.019-0.020                     |
| Gravel               | 8-20                       | 0.020-0.022                     |
| Gravel               | 20-60                      | 0.022-0.027                     |
| Pebbles              | 60-110                     | 0.027-0.030                     |
| Cobbles              | 110-250                    | 0.030-0.032                     |

#### 4.3.1 Selection of channel reach for slope-area measurement

The selection of a suitable channel reach is the most critical factor in the application of Manning's equation. Ideal reaches are difficult to find, and as a rule, it is a matter of selecting the best reach available. The channel reach should be essentially uniform and the flow should be confined within a simple trapezoidal channel. It is desirable that the channel should be uniform also for some distance above the measuring length. If no uniform reach is available, the reach should preferably be converging rather than diverging.

It is advisable to select a reach as long as possible, and in large rivers reaches of 300 m or more are desirable having at least 30 cm difference in height of the water surface between the upstream and downstream gauges. Generally, a useful rule is to estimate the reach required as being four times the channel width, 75 times the mean depth in the channel.

Cross sections represent samples of the geometry of the river reach. A minimum three cross sections one at each end of the reach and one in the middle of the reach are taken. The position of each cross section must be normal to the general direction of the flow, and they are referred to a common datum.

The length of the channel reach (L) between the end cross sections is measured along the ground. The projection on the horizontal of this measured length is not used.

#### 4.3.2 Reference gauge

Gauges should be installed at least in three cross-sections, on either bank of the river. If three cross-sections are chosen two should be at the ends of selected reach



and one at the centre. The alignment of each cross-section should be normal to the general direction of flow. Before the start of each discharge measurement, information regarding the date, time, weather conditions, direction of wind, current etc. should be recorded. All gauges should be observed at suitable intervals and recorded through the period of measurement including initial and terminal readings.

Slope of water surface is computed from the average of gauge observations at either of the reach. The intermediate gauge is used to confirm that the slope is uniform throughout the reach. When accurate gauges do not exist or have been destroyed, flood marks on the banks may be used for estimation of the slope. In such cases, an effort should be made to locate, investigate and fix as many flood marks as possible in the reach with least possible delay after occurrence of the flood.

#### 4.3.3 Cross sectional area and wetted perimeter of the stream

Generally average area of cross-section in the observation reach is taken as the mean of three sections - two end sections and the central section. If for any reason, it is not possible to measure more than one cross-section, the central one only may be observed. The cross-sections should be measured for each discharge observations at or as near the time as possible, at which the gauge observations are made. It is often not possible to measure the cross section during flood and therefore, to this extent an error may be introduced due to an observed and temporary change in cross-sections. However, rivers with rocky bed and banks, and carrying little bed charge are least susceptible to these changes. In such cases, it will be sufficient to observe the cross-sections before and after the floods. If the reach is substantially uniform and there are insignificant differences in the cross-sectional areas,  $A_1, A_2, \dots, A_m$  at the chosen sections, the mean area of cross-section for the reach of the stream may be taken as:

$$A = [A_1 + 2A_2 + \dots + 2A_{m-1} + A_m] / 2(m-1)$$

Similarly, if  $P_1, P_2, \dots, P_m$  are the corresponding wetted perimeter of the chosen cross-sections, the mean wetted perimeter for the reach may be taken as:

$$P = [P_1 + 2P_2 + \dots + 2P_{m-1} + P_m] / 2(m-1)$$

#### 4.3.4 Calculation of discharge for the channel reach

The Discharge for the channel reach shown in Figure-8 can be calculated using the equation:

$$Q = (1/n) A R^{2/3} S_f^{1/2}$$



Q is discharge, n is Manning's roughness coefficient, A is the mean cross section area, P is the mean wetted perimeter

$R = \text{Hydraulic Radius} = A/P$

$S_f = \text{friction slope} = \{(z_1 + h_1 + v_1^2/2g) - (z_2 + h_2 + v_2^2/2g)\} / L$

The  $S_f$  can be approximated as  $(z_1 - z_2) / L$

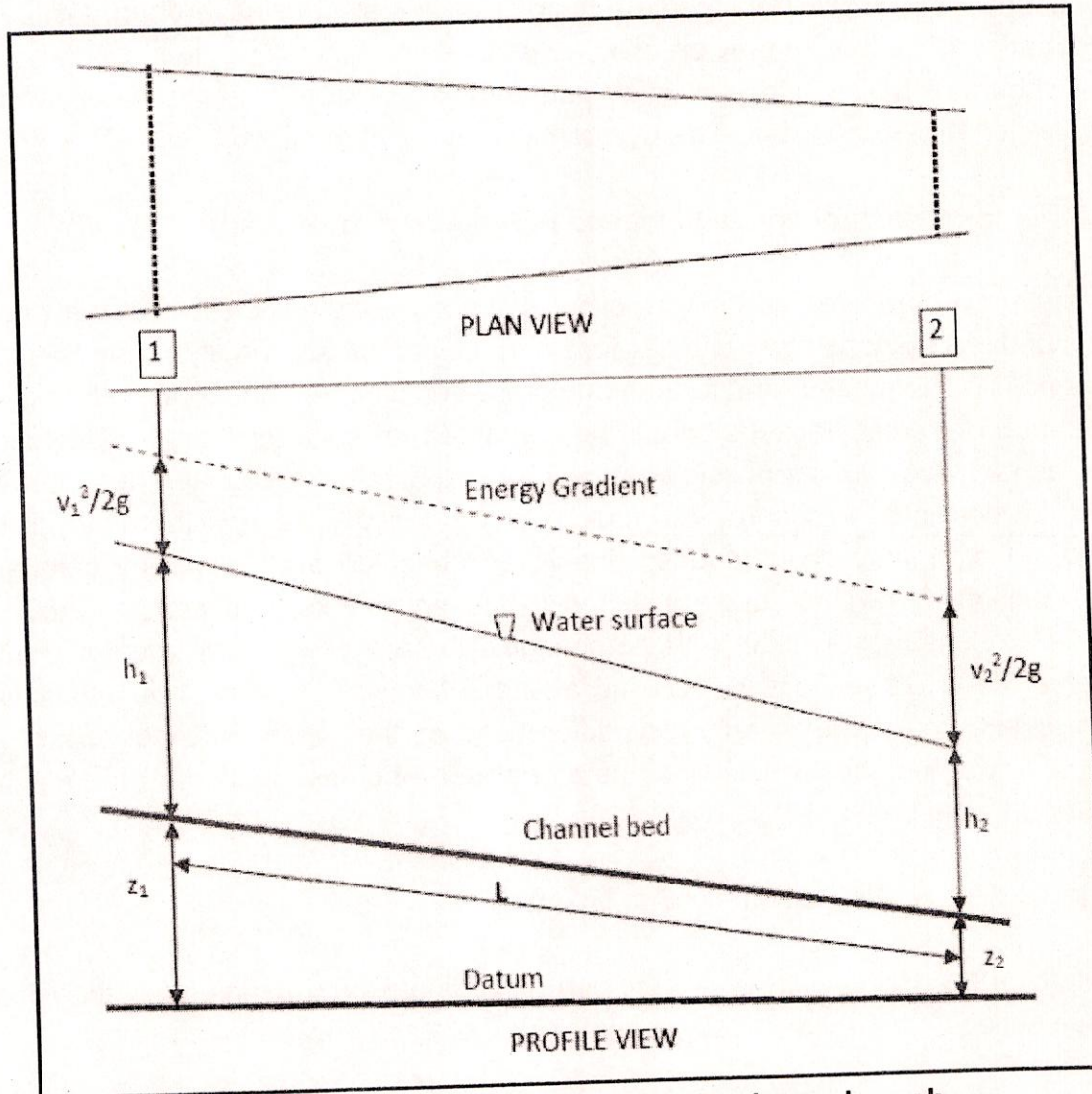


Figure-8: Plan and profile view of a channel reach

The computations of discharge as explained in para 4.3.4 can be further improved through followings steps:

1. Select the stream reach between section1 and 2 of Figure-8.



2. From the cross sections at section 1 and 2 find the depth of water during the flood at the two sections.
3. Compute the wetted cross section area  $A_1$  and  $A_2$  and wetted perimeters  $P_1$  and  $P_2$  corresponding to flood depths of step 2.
4. Compute the hydraulic radius  $R_1, R_2$  and conveyances  $K_1$  and  $K_2$  after selecting suitable roughness coefficient  $n_1, n_2$ . Here  $K_1$  is  $A_1 R_1^{2/3} / n_1$  and  $K_2$  is  $A_2 R_2^{2/3} / n_2$ .
5. Obtain equivalent conveyance  $K$  between section 1 and 2 using the equation  $K = (K_1 K_2)^{1/2}$ .
6. Calculate the discharge  $Q = K S_f^{1/2}$ , assuming  $S_f = (\text{water level at section 1} - \text{water level at section 2}) / L$ .
7. Calculate velocities  $V_1, V_2$  at two sections 1 and 2 using  $Q = A_1 V_1 = A_2 V_2$ .
8. Calculate energy head at section 1 and 2 as  $H_1 = z_1 + h_1 + v_1^2 / 2g$  and  $H_2 = z_2 + h_2 + v_2^2 / 2g$  respectively. Calculate energy slope or friction slope  $S_f$  as  $(H_1 - H_2) / L$ .
9. The assumed value of  $S_f$  of step 6 should be same as the calculated value of  $(H_1 - H_2) / L$  in step 8. If the two values are different then take the  $S_f$  of step 8 and repeat steps 6 to 8 till the energy slope at the end of the iteration are the same.
10. The discharge calculated at the end of step 9 is the estimated final flood discharge.

## 5.0 Sediment observation

For measurement of suspended sediment load the water samples are collected in standard bottle samplers. Punjab type bottle samplers of brass are normally used in India. The samples are analyzed for suspended sediment using Gravimetric Method. In the Gravimetric method one litre of water sample is collected in the sampling bottle from 0.6 Depth. The samples collected from each RD of width of the river corresponding to segments for discharge measurements, are analyzed for coarse (above 0.2 mm dia), medium sediments (0.2 mm to 0.075 mm) fractions by sieving through 100 mesh sieve and by decanting methods respectively. All the washings of the medium sediment are kept for overnight and supernatant water is siphoned off and fine sediment (below 0.075 mm dia) is collected on pre-weighed filter paper No. 41. The coarser, medium and fine sediment are dried up and weighed.



The group sediment intensities are found from the weight of the sediments and the volume of discharge. The group intensities are multiplied by the respective group discharge figure to give the sediment load for each of the grades. The mean sediment intensity of a particular grade for the whole cross section is worked out dividing the relative total load by the total river discharge.

### **5.1 Laboratory methods and procedures for sediment analysis**

The Principal function of the sediment laboratory is to determine the concentration and particle size distribution of the collected sediment samples. The concentration of suspended sediment samples may be determined by either evaporation or filtration. The evaporation method consists of allowing the sediment to settle in the sample bottle, decanting the supernatant liquid, washing the sediment into an evaporating dish, and drying it in an oven at a temperature between 90° and 95°C.

#### **Filtration method**

The filtration method consists of filtering the sample through an appropriate sized filter and oven drying the filter together with the filtered sediment. This method usually utilizes Gooch crucibles and commercially available glass-fibre disks. After the sediment in the evaporating basin or crucible is dried, the weight of the sediment is determined to the nearest 0.0001 grams (g), i.e. 0.1 milligrams (mg). Suspended sediment concentrations should be reported in terms of dry weight of the sediment per litre of sample (i.e. water – sediment mixture), in milligrams per litre (mg/l). Because of convenience in the laboratory, the concentration is calculated by dividing the weight of dry sediment by the weight of the sample and expressing the result in parts per million (ppm). If for example, the sample weighs 400 grams and the amount of dried sediment is 0.02 grams, the concentration of sediment would be 0.02 grams in 400 grams, which is the same as 50 grams in 1,000,000 grams, or 50ppm. Parts per million is calculate as one million ( $10^6$ ) times the ratio of the dry weight of sediment in grams to the weight of to sample in grams.

$$\text{ppm} = \text{dry weight of sediment in (g)} / \text{Weight of sample (g)}$$

The conversion from ppm to mg/l is done by applying the conversion factor C, given in Table-2, to ppm values by the equation:

$$\text{Mg / l} = C \times (\text{ppm})$$

It is seen from Table-2 that for concentrations less than 16,000 parts per million, parts per million equal milligram per litre for all practical purposes.



The accuracy of sediment computations depends to a large degree on the accuracy and reliability of the laboratory work. Too small a quantity of sediment in the samples tends to magnify errors caused by weighing or transfer from one container to another. On the other hand, samples with too large a quantity of sediment sometimes cause problems in drying and weighing. For samples containing colloidal clay, it is often difficult to separate the sediment from water.

**Table-2: Factor C for converting sediment concentration from parts per million to milligrams per litre (mg/l)**

| Ratio                 | C    | Ratio                 | C    | Ratio                 | C    | Ratio                 | C    |
|-----------------------|------|-----------------------|------|-----------------------|------|-----------------------|------|
| 0 – 15, 900           | 1.00 | 185,000 –<br>209, 000 | 1.14 | 342,000 –<br>361, 000 | 1.28 | 468,000 –<br>483, 000 | 1.42 |
| 16,000 – 47,<br>000   | 1.02 | 210,000 –<br>233, 000 | 1.16 | 362,000 –<br>380, 000 | 1.30 | 484,000 –<br>498, 000 | 1.44 |
| 47,000 – 76,<br>000   | 1.04 | 234,000 –<br>256, 000 | 1.18 | 381,000 –<br>398, 000 | 1.32 | 499,000 –<br>513, 000 | 1.46 |
| 77,000 –<br>105, 000  | 1.06 | 257,000 –<br>279, 000 | 1.20 | 399,000 –<br>416, 000 | 1.34 | 514,000 –<br>528, 000 | 1.48 |
| 106,000 –<br>132, 000 | 1.08 | 280,000 –<br>300, 000 | 1.22 | 417,000 –<br>434, 000 | 1.36 | 529,000 –<br>542, 000 | 1.50 |
| 133,000 –<br>159, 000 | 1.10 | 301,000 –<br>321, 000 | 1.24 | 435,000 –<br>451, 000 | 1.38 |                       |      |
| 160,000 –<br>184, 000 | 1.12 | 322,000 –<br>341, 000 | 1.26 | 452,000 –<br>467, 000 | 1.40 |                       |      |

(The factors are based on the assumption that the density of water is 1.000, plus or minus 0.005, the range of temperature is 0° – 29°C, the specific gravity of sediment is 2.65, and the dissolved solids concentration is less than 10,000 parts per million)

*Sediment concentration in ton per day*

Sediment concentration in T/day = 86.4 x Q x sediment concentration in gram/litre

Where Q is discharge in m<sup>3</sup>/s.

### **Evaporation Method**

The advantage of this method is its simplicity of equipment and technique. The sediment is allowed to settle to the bottom of a container, the supernatant water decanted, and the sediment is washed into an evaporating basin and dried in an oven. The method works well if the sediment settles readily to the bottom of the container. However, for samples containing dispersed clay, the settling time is too



long, making the method impractical unless some flocculating agent is added to reduce the settling time.

The supernatant fluid must be carefully decanted or siphoned off, so that none of the sediment is removed from the settling container. The remainder is washed into an evaporation basin and dried in an oven at a temperature from 5° to 10° C below the boiling point; at a higher temperature sediment may be lost from the basin by "spattering". After all moisture has evaporated, the temperature should be raised to 110° for about one hour. The evaporating basins must be kept in a dry state before weighing.

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