Chapter 6

STREAM GAUGING

6.1 METHODS OF MEASURING STREAM FLOW

The most satisfactory determination of the runoff from a catchment is by measuring the discharge of the stream draining it, which is termed as *stream gauging*. A *gauging station* is the place or section on a stream where discharge measurements are made. Some of the usual methods of stream gauging are given below:

(*a*) Venturiflumes or standing wave flumes (critical depth meter) for small channels.

(*b*) Weirs or anicuts: $Q = CLH^{3/2}$ ...(6.1)

where Q = stream discharge, C = coefficient of weir, L = length of weir (or anicut), H = head (depth of flow) over the weircrest

(*c*) Slope-area method: $Q = AV$ ...(6.2)

$$V = C\sqrt{RS} \quad \text{—Chezy} \qquad \text{...(6.2 } a\text{)}$$

$$V = \frac{1}{n} R^{2/3} S^{1/2} \quad \text{—Manning} \qquad \text{...(6.2 } b\text{)}$$

$$\text{Chezy's } C = \frac{1}{n} R^{1/6}, \quad R = \frac{A}{P} \qquad \text{...(6.2 } c\text{)}$$

where C = Chezy's constant

N = Manning's coefficient of roughness

R = hydraulic mean radius

A = cross-sectional area of flow

P = wetted perimeter

S = water surface slope (= bed slope)

The cross-sectional area A is obtained by taking soundings below the water level at intervals of, say, 6 m and plotting the profile of the cross-section and drawing the high flood level or water surface level.

The water surface slope is determined by means of gauges placed at the ends of the reach, say 1 km upstream of the gauging station and 1 km downstream of the gauging station (in a straight reach; if Δh is the difference in water levels in a length L of the reach, then $S = \frac{\Delta h}{L}$. The slope may also be determined by means of flood marks on either side and their subsequent levelling.

Careful notes on the nature of bed and banks, vegetation etc. should be made and if possible a photograph may be taken. From this, the constants C (Chezy's) and n (Manning's) can be found from the Tables.

The slope-area method is often used to estimate peak floods where no gauging station exists.

(d) Contracted area methods:

The drop in water surface in contracted sections as in bridge openings (see Fig. 6.15), canal falls etc. is measured and the discharge is approximately given by

$$Q = C_d A_1 \sqrt{2g\,(\Delta h + h_a)} \qquad \text{...(6.3)}$$

where C_d = coefficient of discharge

A_1 = area of the most contracted section

Δh = difference in water surface between the upstream and down stream ends (of the pier)

h_a = head due to the velocity of approach.

(e) *Sluiceways, spillways and power conduits.* The flow through any of the outlets in a dam or the sum of the flows through these gives the discharge at any time.

(f) *Salt-concentration method.* The discharge is determined by introducing a chemical, generally common salt, at a known constant rate into flowing water and determining the quantity of chemical in the stream at a section downstream sufficiently distant to ensure thorough mixing of the chemical with water. The discharge.

$$Q = \frac{c - c_2}{c_2 - c_1}\, q \qquad \text{...(6.4)}$$

where q = quantity of solution injected (cc/sec)

c = amount of salt in dosing solution (gm/cc)

c_1 = concentration of salt originally (before dosing) in the stream (gm/cc)

c_2 = concentration of salt in the sample downstream (gm/cc)

This method is best suited for turbulent waters as the turbulence helps in thorough mixing of the chemical; this is a costly process.

(g) *Area-velocity methods*: $Q = AV$

The area of cross-section of flow may be determined by sounding and plotting the profile. The mean velocity of flow (V) may be determined by making velocity measurements. The velocity distribution in a cross-section and in a vertical in a stream are shown in Fig. 6.1 (a) and (b) and as such the methods of velocity measurements are as follows:

Velocity measurements from:

- Floats {surface, sub-surface} measure surface velocity v_s; $V \approx 0.85\, v_s$
- Velocity rods measure mean velocity, V ...(6.5)
- Current meter {Pigmy, Propeller, Price} measure mean velocity in a strip of cross-section by

(i) one point method $V = v_{0.6d}$ ...(6.6 a)

(ii) two points method $V = \dfrac{v_{0.2d} + v_{0.8d}}{2}$

(d = mean depth in the strip) ...(6.6 b)

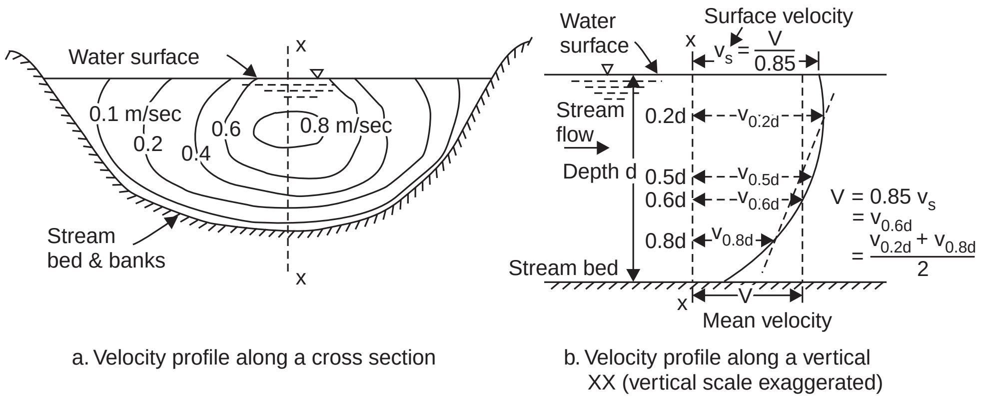

Fig. 6.1 Horizontal and vertical velocity profiles in a stream

Surface floats—consist of wooden discs 7–15 cm diameter (Fig. 6.2 *a*). The time (t) taken by float to travel a certain distance (L) is meaured and the surface velocity v_s and mean velocity V are calculated as $v_s = L/t$ and $V \approx 0.85\ v_s$. The reach of the river for float measurements should be straight and uniform and least surface disturbances. The float travel is affected by winds, waves and eddies and sometimes a subsurface or a double float consisting of a metallic hollow cylindrical weighted submerged float attached by means of a thin string to a surface float is used, Fig. 6.2 *a*.

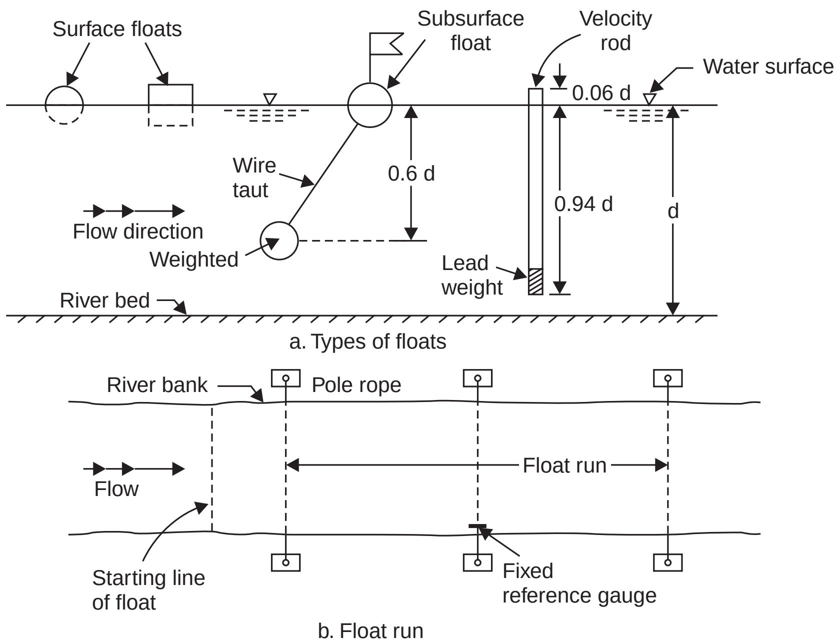

Fig. 6.2 Velocity determination by floats

Velocity rods consist of a wooden rod, square or round in section (≈ 3-5 cm size). It is weighted at the bottom by means of lead or cast iron rings to immerse it to a depth of 0.94d, where d is the depth of stream, to give the mean velocity of flow (V). The rods are so weighted that they float nearly vertical with about 3–5 cm projecting above the water surface, so that they can be seen floating. A number of rods are required to suit the varying depths of cross-section.

At the beginning of the gauge run, a surface or rod float is released at the centre of a compartment (Fig. 6.2 *b*). The time taken for the float to reach the end of the gauge run (of the same compartment) is noted. Knowing the length of the gauge run, the velocity of flow is determined.

6.2 CURRENT METER GAUGINGS

The current meter is an instrument, which has a rotating element which when placed in flowing water, the speed of revolutions has a definite relation with the velocity of flow past the element. There are three types of current meters—(*i*) pigmy current meter, whose cup vane assmbly is about 5 cm in diameter and is used for measuring velocities in streams of depth 15 cm or less, (*ii*) the cup type, which consists of a wheel with conical cups revolving on a vertical axis, and (*iii*) the screw or propeller type consisting of vanes revolving on a horizontal axis. Price, Ellis, Ottwatt meters are of vertical axis type while Off and Haskel, Amslar, Ott and Aerofoil meters are of horizontal axis type. The Price meter is regarded as a universal meter and is equipped with a pentahead, a device for indicating every fifth revolution. The meter may be used for velocities from 1 to 4.5 m/sec in depths of 1-15 m from a boat, bridge, cable or wading. A counter weight (stream lined) is fixed below the meter to prevent it from swaying, Fig. 6.3.

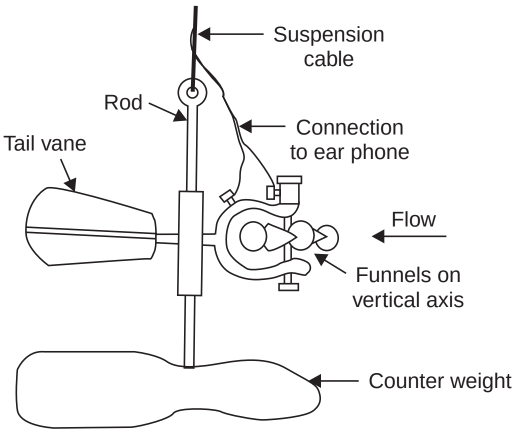

Fig. 6.3 Price current meter

Rating of the Current Meter

The relationship between the revolutions per second (N, rps) of the meter and the velocity of flow past the meter (v, m/sec) has to be first established, or if the rating equation is given by the maker, it has to be verified. This process of calibration of the meter is called *rating of the current meter*. The rating equation is of the form

$$v = aN + b \qquad ...(6.7)$$

where a and b are constants (determined from rating of the current meter).

The rating is done in a masonry tank of approximate dimensions 90 m × 2.4 m × 2.1 m, Fig. 6.4. The meter is towed in still water in the tank either by a pushing trolley (from which the meter is suspended) by men specially trained for the purpose or by an electric motor to move the trolley at a constant speed on a track by the side of the tank, the distances being painted in *m* and *cm* in enamel on the track. A metronome adjusted to give ticks at every 2, 3, 4, 5, 6, 7, 8, 10 sec is kept on the trolley. The men pushing the trolley would have been trained to put paces uniformly to synchronise with the ticking of the metronome. When motorised speeds are adjusted to give different velocities. A *cantilever beam* is fixed to the trolley such that the projecting end is at the centre of the rating tank from which the meter is hung from a *suspension rod*. The meter should be immersed about 1 m below the water surface during rating. The observer sits in the trolley, notes the time and distance traversed by the trolley for a fixed number of revolutions made by the meter (say, 10-100 depending on the speed). This operation is repeated for different pushing velocities of the trolley. A current meter rating curve is drawn as 'pushing velocity vs. rps', which plots a straight line and the constants *a* and *b* are determined as shown in Fig. 6.5.

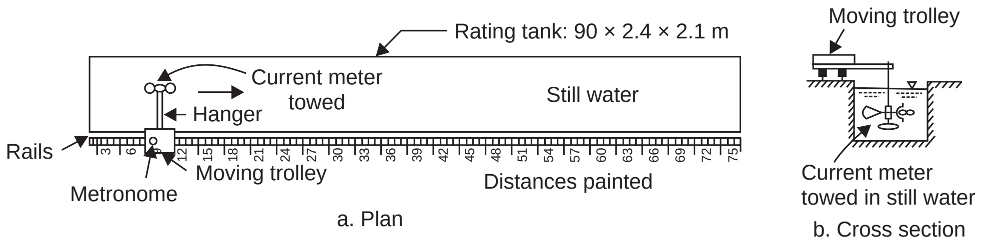

Fig. 6.4 Current meter rating tank

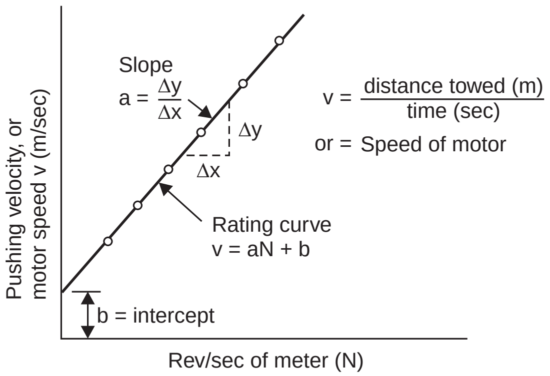

Fig. 6.5 Current meter rating curve

Stage-Discharge-Rating Curve

Once the rating equation of the current meter is known, actual stream gauging can be done from bridges, cradle, boat or launch. The cross section of the stream at the gauging site is divided into elemental strips of equal width *b* and the current meter is lowered to a depth of 0.6 *d* below water surface in shallow depths (one-point method) and to depths of 0.2*d* and 0.8*d* (two-points method) in deep waters, at the centre of each strip, Fig. 6.6. The mean depth (d) at the centre of each strip is determined by sounding. The revolutions made by the meter in a known time at the appropriate depths are noted by an ear phone (connected through a wire to the penta or monocounter of the meter and the other to a dry cell) from which the velocities at the appropriate depths are determined from the rating equation, Eq. (6.7).

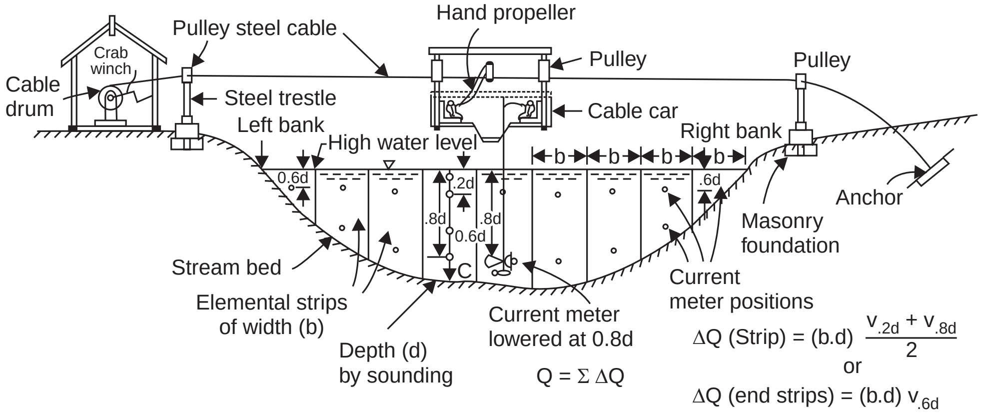

Fig. 6.6 Current meter gauging

It may be noted that the mean velocity is taken as that at 0.6d below water surface in shallow water (one-point method), and as the average of the velocities at 0.2d and 0.8d below the water surface (two-point method) in deep waters, as can be seen from the velocity distribution in a vertical in a stream section, Fig. 6.1 (b). The discharge in each elemental strip is determined and the discharge in the stream is the sum of the discharges in all the elemental strips.

There are two methods of determining the discharge in each elemental strip:

(i) *Mid-section method*. In this method, the vertical in which the velocity measurements are made (by one-point or two-points method) is taken as the middle of the strip, and the water depth (d) in the vertical (determined by sounding) is taken as the mean depth of the strip, Fig. 6.7 (a). If b is the width of strip (usually same for all strips) then the discharge in the elemental strip is given by

$$\Delta Q = (bd)\, v_{0.6d} \text{ in shallow strips} \quad ...(6.8)$$

$$\Delta Q = (bd) \times \frac{v_{0.2d} + v_{0.8d}}{2} \quad \text{in deep water strips} \quad ...(6.8\ a)$$

stream discharge, $$Q = \Sigma\, \Delta Q \quad ...(6.8\ b)$$

In this method, the discharge in the two-triangular bits near the ends are not included in the discharge computation.

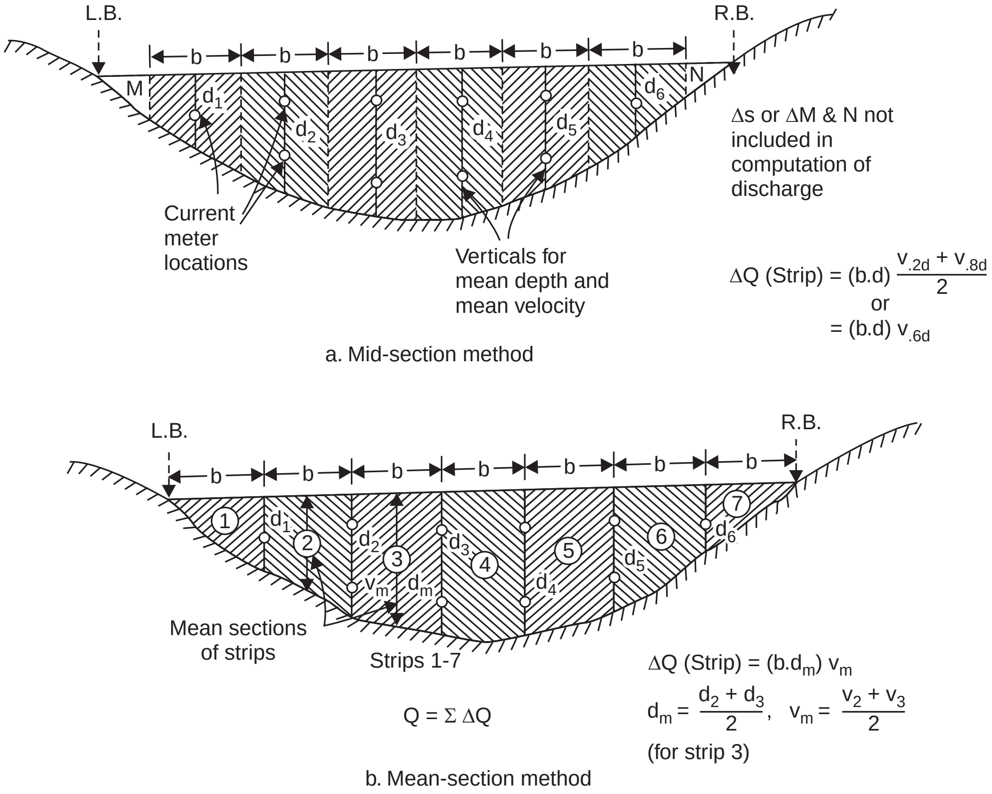

Fig. 6.7 Mid-section and Mean-section methods

(*ii*) *Mean-section method*. In this method, the elemental strip is taken between two verticals and the mean depth is taken as the average of the depths in the two verticals (determined by sounding). The width of the strip is distance b between the two verticals. The velocity in the strip is taken as the average of the mean velocity determined in the two verticals (by one-point or two-points method), Fig. 6.7 (*b*). The discharge in the elemental strip is given by

$$Q = b\left(\frac{d_1 + d_2}{2}\right)\left(\frac{V_1 + V_2}{2}\right) \qquad ...(6.9)$$

V_1, V_2 determined as $v_{0.6d}$ in shallow strip

and $\dfrac{v_{0.2d} + v_{0.8d}}{2}$ in deep water strip ...(6.9 *a*)

Stream discharge, $Q = \Sigma\, \Delta Q$ ...(6.9 *b*)

The mean section method is considered to be slightly more accurate, but the mid-section method is faster and is generally used.

Example 6.1 *The following data were collected for a stream at a gauging station. Compute the discharge.*

Distance from one end of water surface (m)	*depth, d (m)*	*Immersion of current meter below water surface*					
		at 0.6d		*at 0.2d*		*at 0.8d*	
		Rev.	*Sec.*	*Rev.*	*Sec.*	*Rev.*	*Sec.*
3	*1.4*	*12*	*50*				
6	*3.3*			*38*	*52*	*23*	*55*
9	*5.0*			*40*	*58*	*30*	*54*
12	*9.0*			*48*	*60*	*34*	*58*
15	*5.4*			*34*	*52*	*30*	*50*
18	*3.8*			*35*	*52*	*30*	*54*
21	*1.8*	*18*	*50*				

Rating equation of current meter: $v = 0.3\ N + 0.05$, N = rps, v = velocity, (m/sec), Rev.-Revolutions, Sec-time in seconds.

Solution The discharge in each strip, $\Delta Q = (bd)\ V$, where V is the average velocity in each strip, Fig. 6.8. In the first and the last strips (near the banks) where the depth is shallow, $V = v_{0.6\,d}$, and in the other five intermediate strips (with deep water), $V = \dfrac{v_{0.2d} + v_{0.8d}}{2}$. Width of each strip, b = 3 m, mean depth of strip = d, and the total discharge, $Q = \Sigma\,\Delta Q$ = **20.6 cumec,** as computed in Table 6.1.

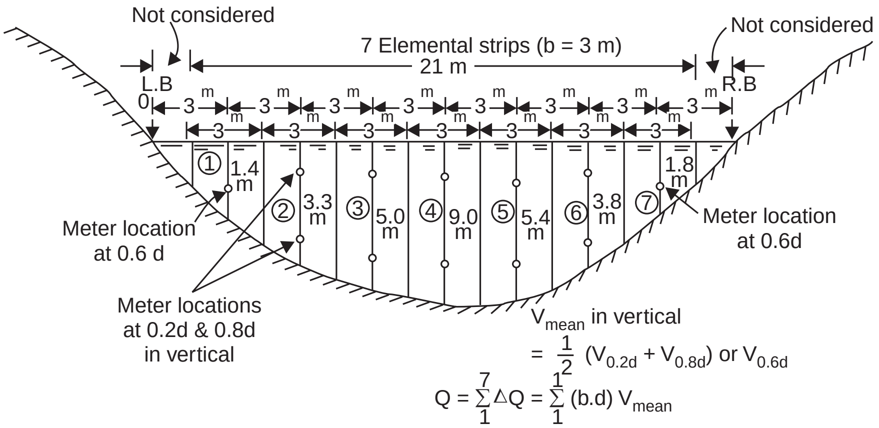

Fig. 6.8 Discharge computation (Example 6.1)

6.3 STAGE-DISCHARGE-RATING CURVE

A river is gauged by current meter throughout the rainy season (for about 3 months) at different stages (water levels) of the river. The water stage can be read on the enamel painted staff gauges (gauge posts) erected at different levels at a gauging station Fig. 6.9; it may be noted that corresponding graduation of gauge posts at two locations are fixed at the same level. A curve is drawn by plotting 'stream discharge 'Q vs. gauge height h' which is called the 'stage-discharge rating curve' as shown in Fig. 6.10. From this rating curve, the stream discharge

Table 6.1 Current meter gauging of River. (Example 6.1)

Distance from one end of water surface (m)	*Depth, d (m)*	*Immersion of current meter below water surface*					*Average velocity in strip V (m/sec)*	*Discharge in strip* $\Delta Q = (bd)\,V$, $b = 3m$
		depth = xd (x = 0.6, 0.2, 0.8) (m)	*Rev. R*	*time (sec.)*	$N = R/t$ *(rps)*	$v = 0.3\,N + 0.05$ *(m/sec)*		
3	1.4	0.84	12	50	0.24	0.122	0.122	0.51
6	3.3	0.66	38	52	0.73	0.269	0.223*	2.16
		2.64	23	55	0.42	0.176		
9	5.0	1.00	40	58	0.69	0.257	0.236	3.54
		4.00	30	54	0.56	0.218		
12	9.0	1.80	48	60	0.80	0.290	0.259	7.00
		7.20	34	58	0.59	0.227		
15	5.4	1.08	34	52	0.65	0.245	0.238	3.85
		4.32	30	50	0.60	0.230		
18	3.8	0.76	35	52	0.67	0.251	0.234	2.68
		3.04	30	54	0.56	0.218		
21	1.8	1.08	18	50	0.36	0.158	0.158	0.86
							Total Q = 20.60 cumec	

* $\dfrac{0.269 + 0.176}{2} = 0.223.$

corresponding to staff gauge readings taken throughout the year/s can be obtained, as long as the section of the stream at or near the gauging site has not materially altered. Periodical gaugings (say, once in three years) are conducted to verify the rating curve, or to revise the rating curve if any change in section has been noticed.

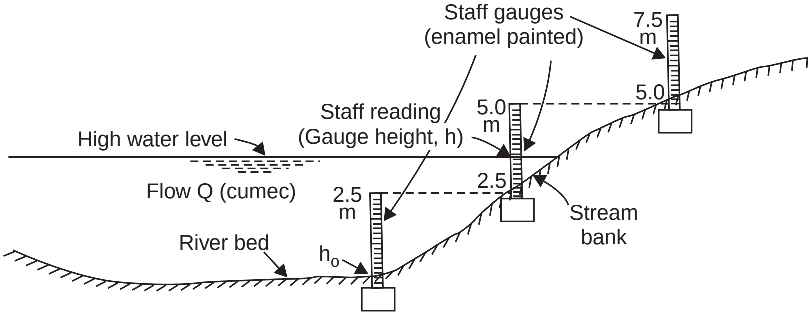

Fig. 6.9 Gauge posts on river bank

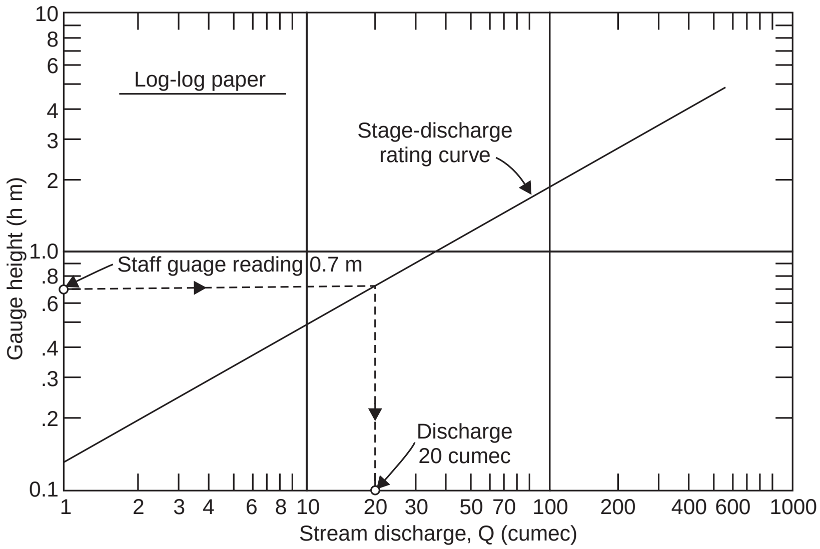

Fig. 6.10 Stage-discharge rating curve

For a continuous record of water stage (gauge heights or readings) during floods, an Automatic Water Stage Recorder (AWLR) is installed inside a gauge well on one of the banks of the stream at the gauging site, connected to the stream at different levels by pipes, Fig. 6.11. A steel wire rope with a float at one end and a counter weight at the other passes over a pulley connected to a cylindrical drum over which a chart is wrapped. The rise and fall of the float with the water level causes rotation of the drum while a clock mechanism moves a pen axially along the drum, thus producing a water stage hydrograph. The time scale on the graph is usually so chosen as to cover a week's period. Thus, a continuous record of the river stage with the time is obtained. The water level in well is not subject to fluctuations caused by wind or waves.

If the river is subject to scour, the well should be sufficiently deep and the zero of the gauge should be sufficiently below the bed, so that the water surface will not come below the