6.16 COMPUTATION OF DISCHARGE

Measurements of velocity and depth, made at a number of locations across a stream channel, are used to compute discharge by summing up the product of mean velocity and area of cross section of the segment between successive locations. Usually, between 20 and 30 verticals of equidistant or variable spacings are used to divide a stream width. These spacings should be arranged so that no segment contains more than 10% of the total flow. Depending on the procedure used to obtain the multiplication of velocity and area of various elements constituting the channel section, methods are known as midsection, mean-section, velocity-depth integration, and velocity contour methods of discharge computation. The first two methods are arithmetic summation procedures and the last two are graphic methods. Midsection is a preferred method.

6.16.1 Midsection Method

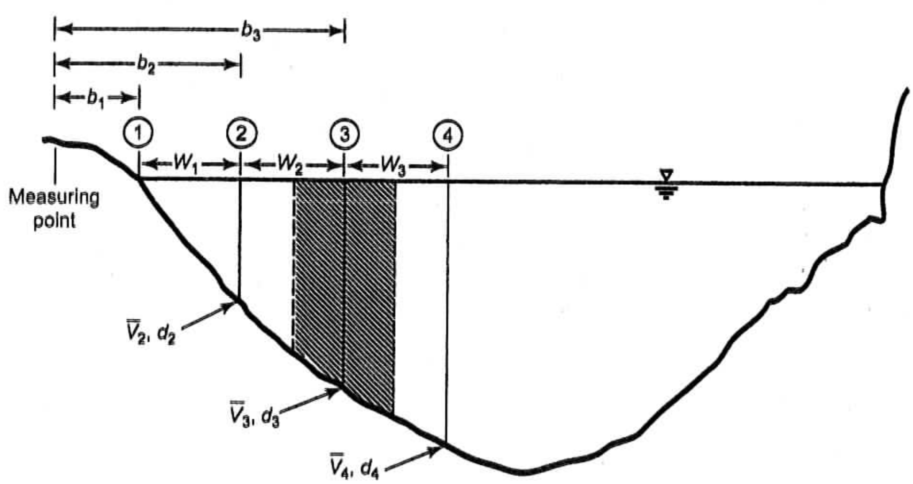
In this method it is assumed that the velocity at each vertical represents a mean velocity for a section that extends half the distance into the preceding and following segments, as shown in Figure 6.10.

$$\text{Area for subsection } 3 = \frac{W_2 + W_3}{2} d_3 \qquad \text{(a)}$$

$$\text{Discharge through subsection } 3 = \bar{V}_3 \frac{W_2 + W_3}{2} d_3 \qquad \text{(b)}$$

$$\text{Discharge through subsection } x = \bar{V}_x \frac{W_{x-1} + W_x}{2} d_x \quad [\mathrm{L^3T^{-1}}] \qquad (6.14)$$

Figure 6.10 Subsection in the midsection method.



1, 2, 3, ... Stations
$b_1, b_2, b_3, \ldots$ Distance from the initial point to the station (observation verticals)
$d_1, d_2, d_3, \ldots$ Depth of water at the observation verticals
$W_1, W_2, W_3, \ldots$ Width between successive verticals

When the cross section is such that there is a depth at the edge of the water as at the last vertical in Figure 6.10, the velocity is estimated as a certain percentage (between 65 and 90%) of the adjacent vertical because it is not possible to measure velocity by the current meter. At the beginning section, using eq. (6.14), W_0 will have no significance and should be dropped. Example 6.7 provides the data in the format as they are recorded in the field book while taking measurements.

EXAMPLE 6.7

Compute the discharge by midsection method for the following measurement data. The current-meter rating is given by $v = 0.1 + 2.2N$, where v is velocity in ft/sec and N is the number of revolutions per second.

Distance from Initial Point (ft)	Depth (ft)	Observed Depth	Revolutions	Time (sec)
10	1			
12	3.5	0.2	35	50
		0.8	22	50
14	5.2	0.2	40	60
		0.8	30	55
17	6.3	0.2	45	60
		0.8	30	55
19	4.4	0.2	33	45
		0.8	30	50
21	2.2	0.6	22	50
23	0.8	0.6	10	45
25	0			

SOLUTION The computations are shown in Table 6.3.
Width (col. 8) is the successive difference of col. 1.
Effective width (col. 9) is the average of preceding and following widths in col. 8.
Area (col. 10) = col. 2 × col. 9.
Discharge (col. 11) = col. 7 × col. 10.
Note that the conditions of a minimum 20 verticals and less than 10% flow in any subsection are violated to reduce computation. Also for the first vertical, having a depth of 1 ft, a velocity of 0.65 times the adjacent velocity has been taken. For the last vertical, this value is taken as zero since there is no water depth.

Table 6.3 Computation of Discharge by Midsection Method (Example 6.7)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
					Velocity (ft/sec)					
Distance from Initial Point	Depth (ft)	Observed Depth	Revolutions	Time (sec)	At Points	Mean in Section	Width (ft)	Effective Width (ft)	Area[b] (ft^2)	Discharge[c] (ft^3/sec)
10	1					0.88[a]		1	1.0	0.88
							2			
12	3.5	0.2	35	50	1.64	1.36		2	7.0	9.52
		0.8	22	50	1.07					
							2			
14	5.2	0.2	40	60	1.57	1.44		2.5	13.0	18.72
		0.8	30	55	1.30					
							3			
17	6.3	0.2	45	60	1.75	1.53		2.5	15.75	24.10
		0.8	30	55	1.30					
							2			
19	4.4	0.2	33	45	1.71	1.57		2	8.8	13.82
		0.8	30	50	1.42					
							2			
21	2.2	0.6	22	50	1.07	1.07		2	4.4	4.71
							2			
23	0.8	0.6	10	45	0.59	0.59		2	1.6	0.94
							2			
25	0					0		1	0	0
Total									51.55	72.69

[a] 0.65 × 1.36 of subsequent vertical = 0.88
[b] col. 2 × col. 9
[c] col. 7 × col. 10

6.16.2 Mean-Section Method

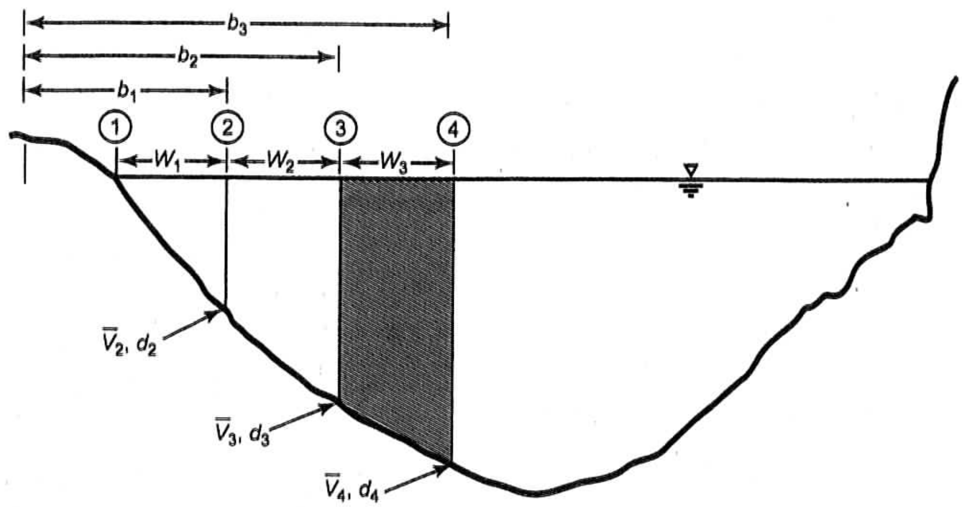
The segment area (subsection) extends from vertical to vertical as shown in Figure 6.11.

$$\text{Area for subsection } 3-4 = \frac{d_3 + d_4}{2} W_3 \tag{c}$$

$$\text{Discharge through subsection } 3-4 = \left(\frac{\bar{V}_3 + \bar{V}_4}{2}\right)\left(\frac{d_3 + d_4}{2}\right) W_3 \tag{d}$$

$$\text{Discharge through subsection } x \text{ and } x+1 = \left(\frac{\bar{V}_x + \bar{V}_{x+1}}{2}\right)\left(\frac{d_x + d_{x+1}}{2}\right) W_x \quad [L^3T^{-1}] \tag{6.15}$$

Figure 6.11 Subsection in the mean-section method.



EXAMPLE 6.8

Solve Example 6.7 by the mean-section method.

SOLUTION Computations are arranged in Table 6.4.
Average velocity (col. 8) is the average of mean velocities of two verticals in col. 7.
Average depth (col. 9) is the average of depths of two verticals in col. 2.
Width (col. 10) is the successive difference of col. 1.
Area (col. 11) = col. 9 × col. 10.
Discharge = col. 8 × col. 11.

6.16.3 Velocity-Depth Integration Method

This is a graphic method in which velocity measurements in each vertical should preferably be performed at a number of depths to plot the vertical-velocity curve for each vertical. The procedure is as follows:

1. Draw the vertical-velocity curve for each vertical and determine the area under this curve that will represent (velocity depth) at each vertical. (If the mean velocity in a vertical has been determined by any other method, it can be multiplied by the vertical depth.)
2. Plot (velocity depth) values at the location of respective verticals across the stream cross section as shown in Figure 6.12. Draw a smooth curve through these points. The area enclosed by this curve will provide the discharge.

EXAMPLE 6.9

The velocity-depth values for various verticals of a stream cross section as obtained from vertical-velocity curve analyses are indicated in Figure 6.13. Determine the discharge of the stream by the velocity-depth integration method.

Table 6.4 Computation of Discharge by Mean-Section Method (Example 6.8)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Velocity (ft/sec)						
Distance from Initial Point (ft)	Depth (ft)	Observed Depth	Revolutions	Time (sec)	At Points	Mean in Vertical	Average Velocity for Subsection (ft/sec)	Average Depth for Subsection (ft)	Width (ft)	Area (ft^2)	Discharge (ft^3/sec)
10	1					0.88[a]					
							1.12	2.25	2	4.5	5.04
12	3.5	0.2	35	50	1.64	1.36					
		0.8	22	50	1.07						
							1.40	4.35	2	8.7	12.18
14	5.2	0.2	40	60	1.57	1.44					
		0.8	30	55	1.30						
							1.49	5.75	3	17.25	25.70
17	6.3	0.2	45	60	1.75	1.53					
		0.8	30	55	1.30						
							1.55	5.35	2	10.70	16.59
19	4.4	0.2	33	45	1.71	1.57					
		0.8	30	50	1.42						
							1.32	3.3	2	6.60	8.71
21	2.2	0.6	22	50	1.07	1.07					
							0.83	1.5	2	3.00	2.49
23	0.8	0.6	10	45	0.59	0.59					
							0.30	0.40	2	0.80	0.24
25	0				0	0					
Total										51.55	70.95

[a] 0.65 × 1.36 of subsequent vertical

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