RIVER DISCHARGE MEASUREMENT

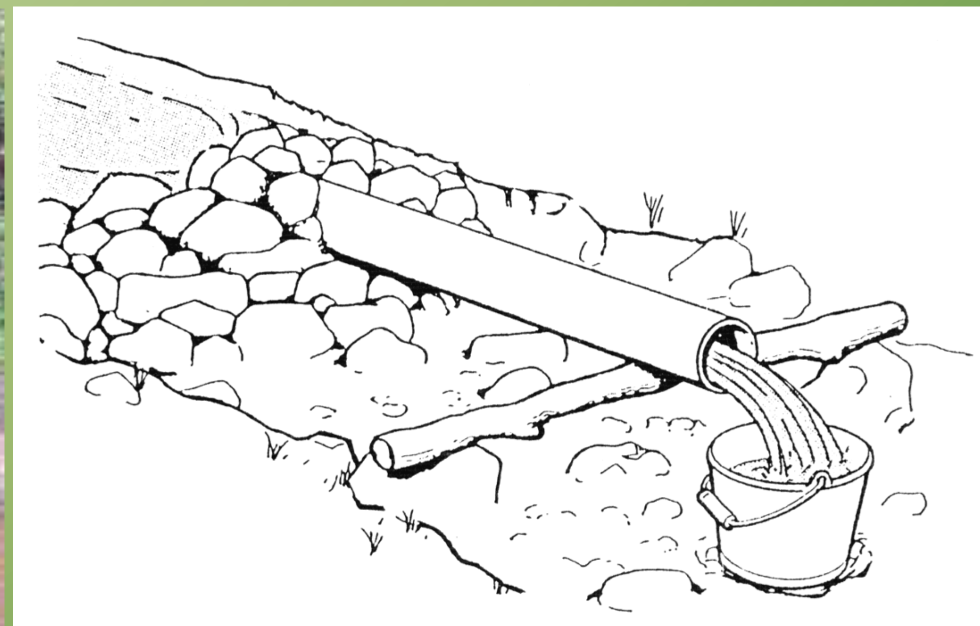
Stream discharge can be measured using;

(1) Volumetric Gauging (buckets)
(2) Float Gauging,
(3) Current Metering,
(4) Dilution Gauging (Constant Injection Or Salt Gulp Methods),
(5) Structural Methods (weirs, notches, orifices & flumes)
(6) Slope-area Methods.
(7) Rating Curve

Indirect method

The choice of method depends on the characteristics of the stream and on the application.

Flow estimation: Volumetric Gauging (buckets)

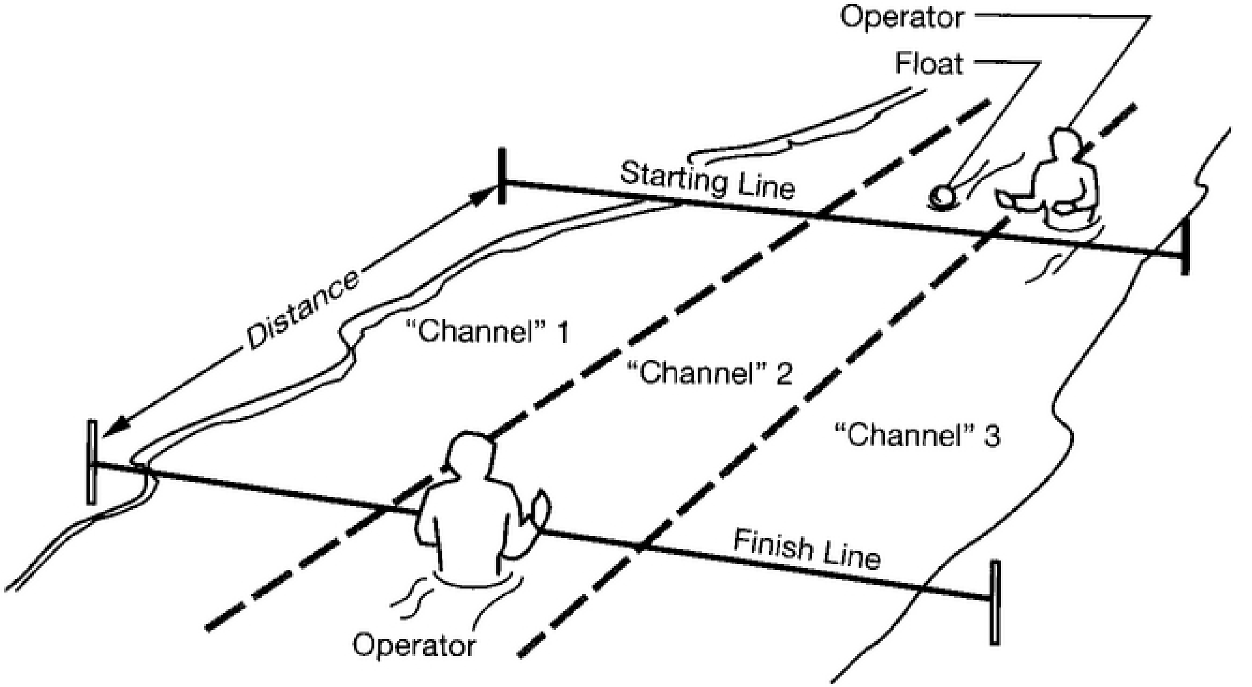


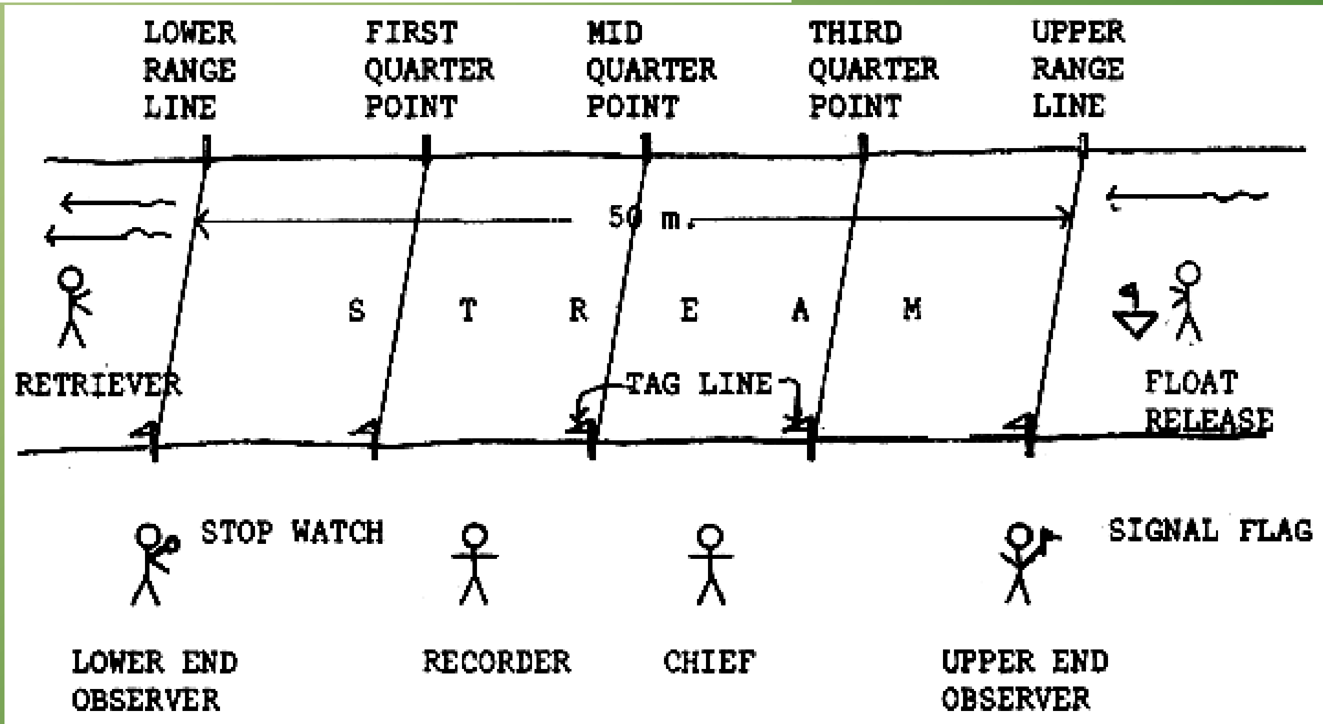
<u>Limitations</u>

- Only useful for flows <20l/s
- Whole flow must be channelled to the bucket

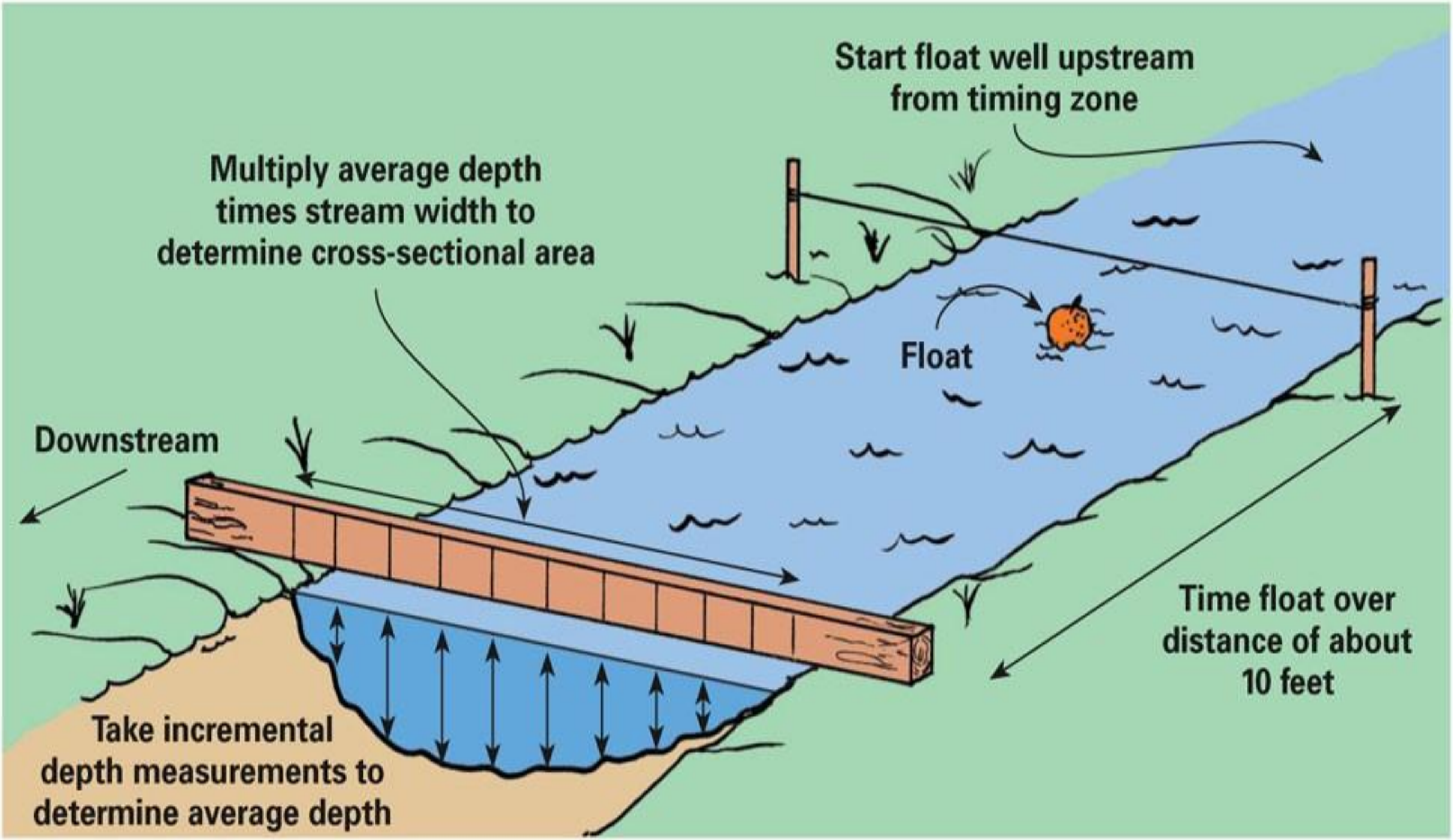
Flow estimation: Float Gauging

Suitable for straight channel, V = L/T





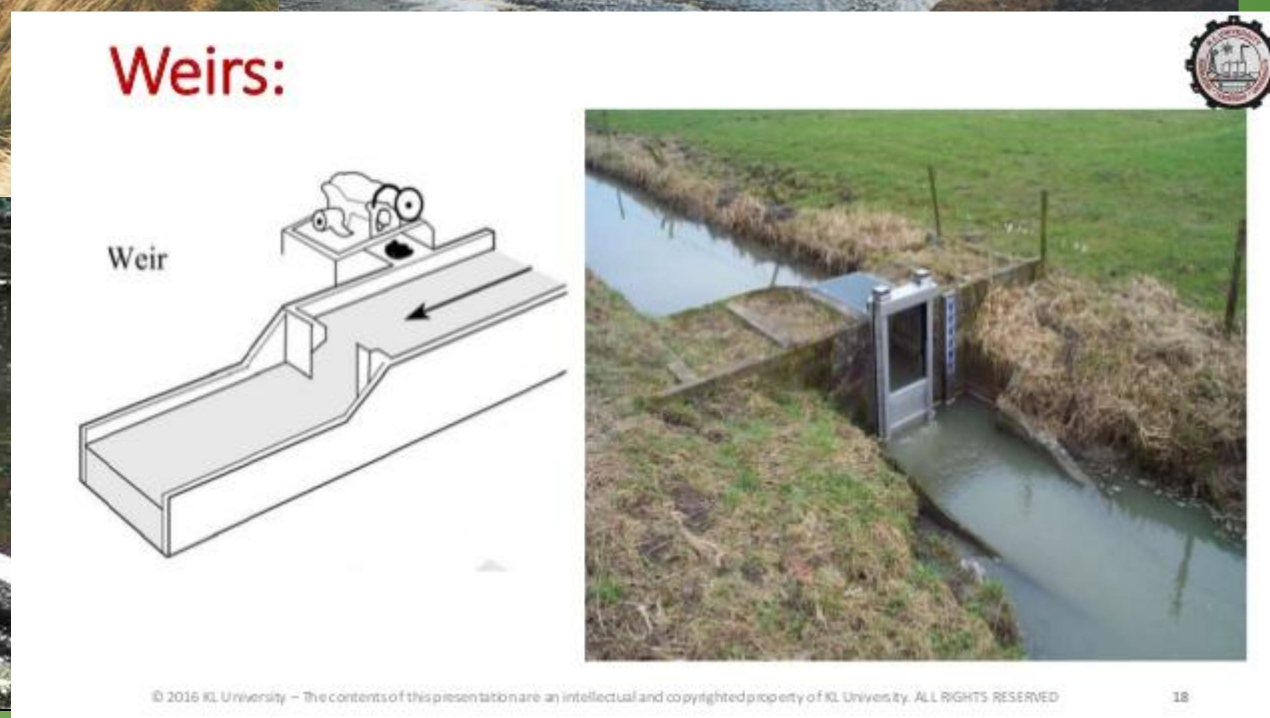
The Float Method of Estimating Flow



Float Gauging: Limitations

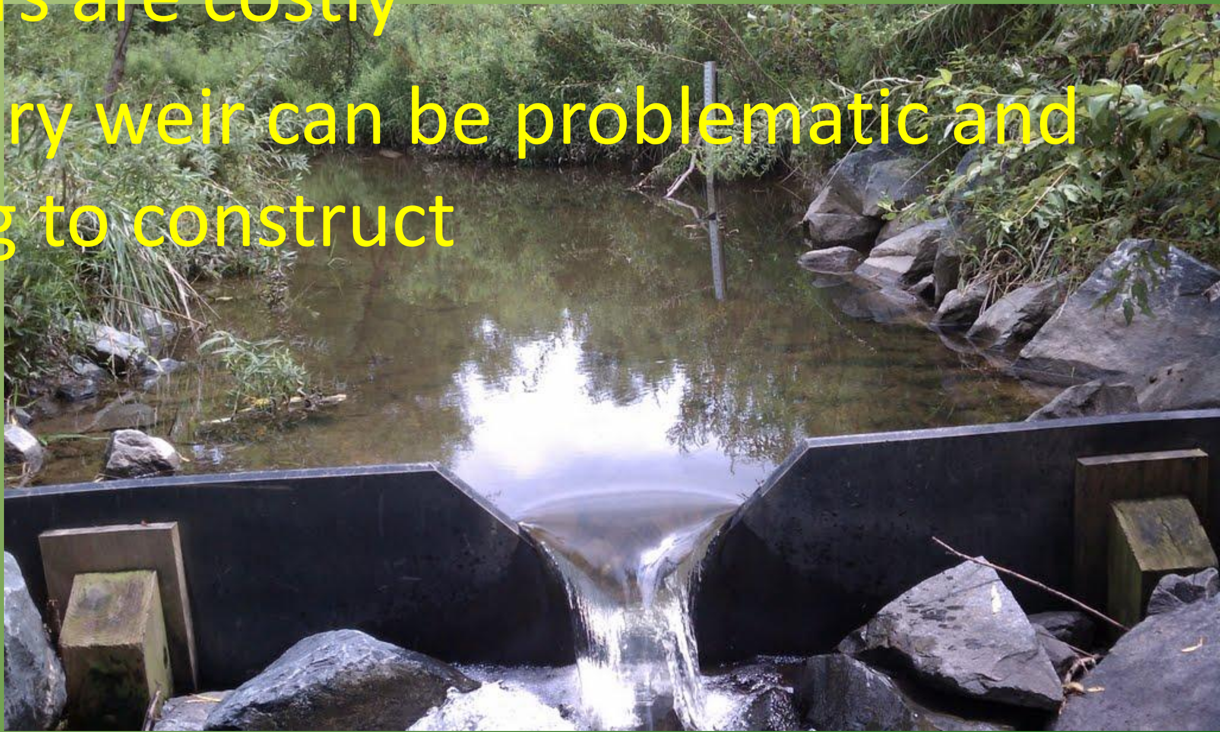
- Average flow can only be inferred from flow at surface
- The stream bed should not have any significant changes over the test length
- Needs a good approximation of the stream bed shape – which can be tedious

Flow estimation: Weirs



Flow estimation: Weirs: Limitations

- An initial flow estimate is required to ensure the notch is an appropriate size
- The weir must be perfectly sealed
- Permanent weirs are costly
- Even a temporary weir can be problematic and time consuming to construct



Flow estimation: Staff gauge

Flow estimation: Staff gauge: Limitations

- Needs a good approximation of the stream bed shape which must remain valid – erosion/siltation will effect the validity of measurements
- Only valid for comparing flows over time – an initial flow reading must be taken by another method
- “weir coefficients” will change with water height

Flow estimation: Current meters

- **Current meters**
  - **Cup-type (Price and pygmy)**
  - **Propeller type**
  - **Inductance**

$$V = a + bN$$

where

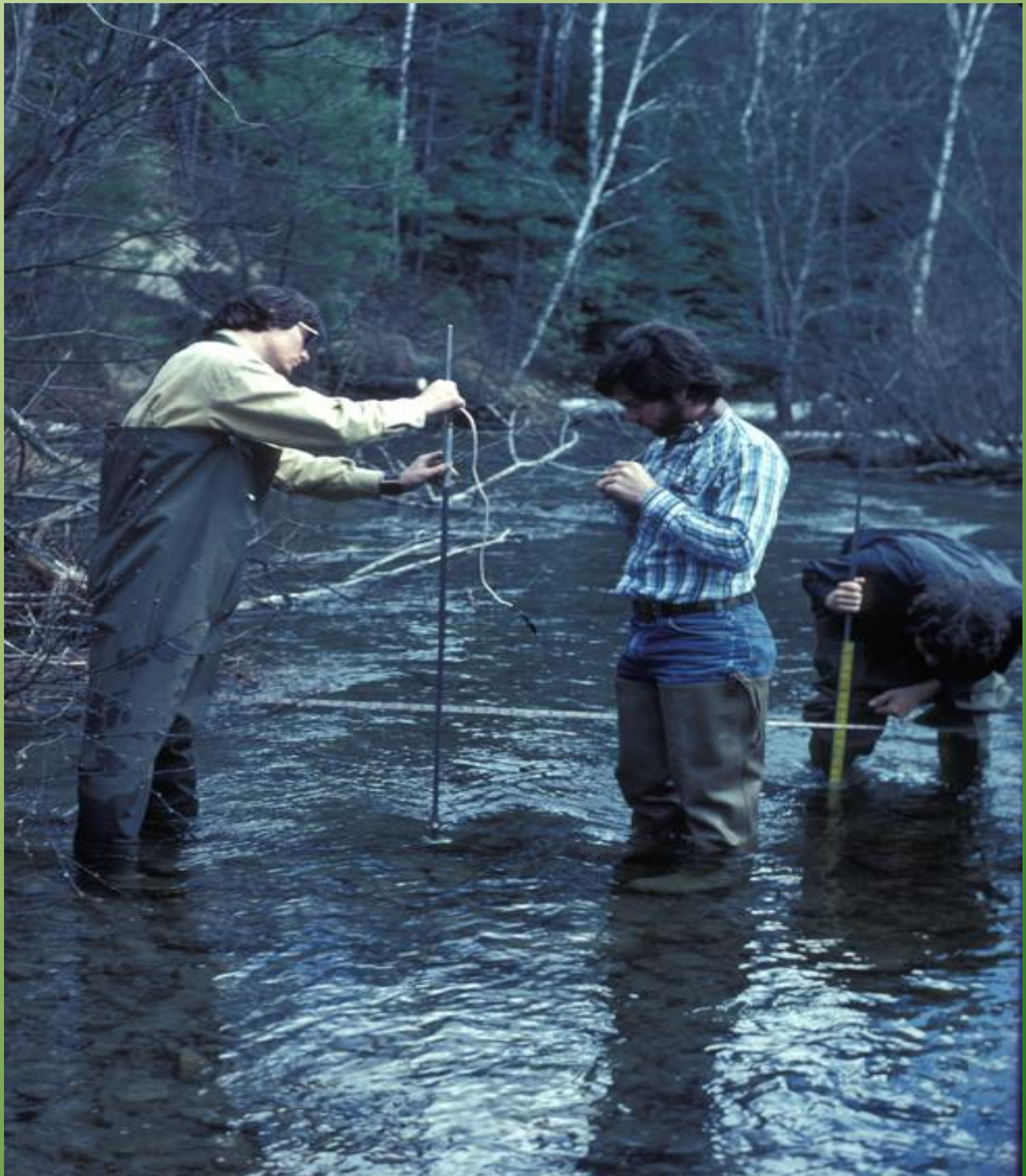
V = flow velocity;
a = starting velocity to overcome mechanical friction;
b = equipment calibration constant;
N = revolutions/sec

Propeller type

Cup-type

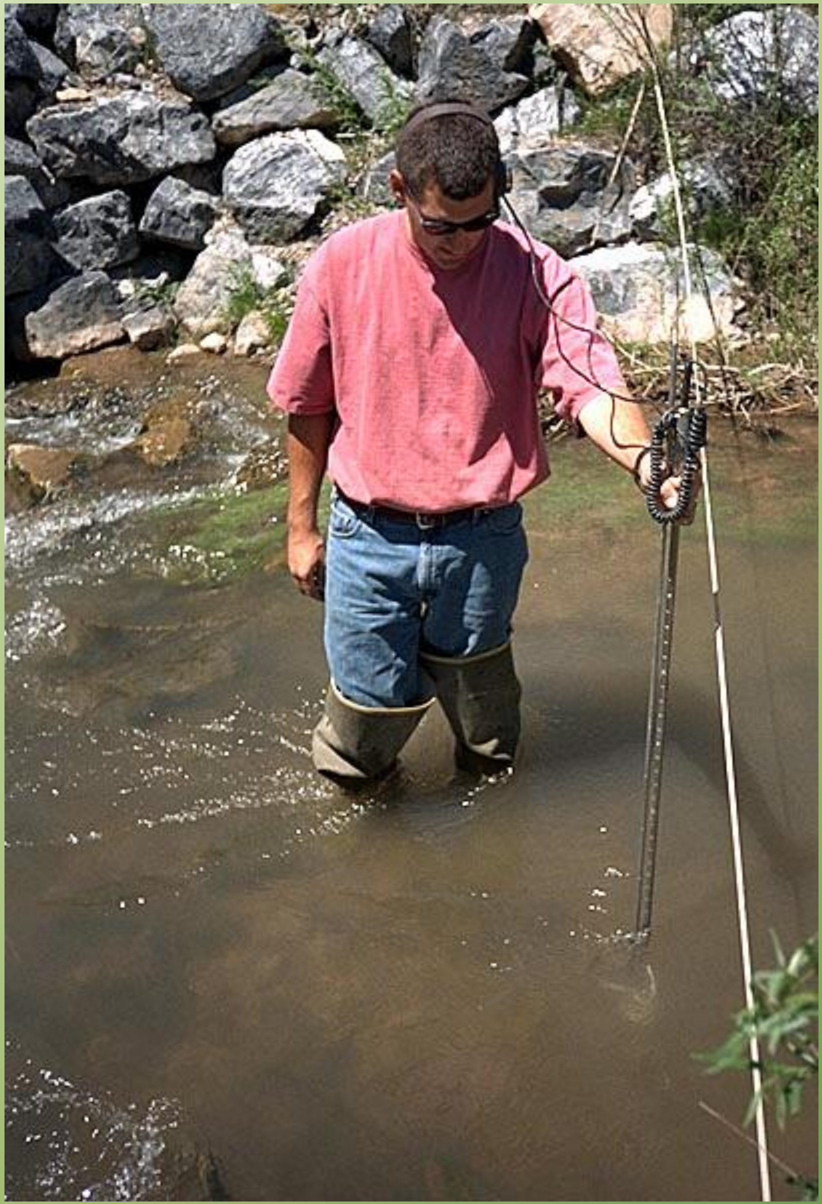
Inductance

Measuring Streamflow in small streams with a pygmy current meter



Discharge (Q) Measurement

Large rivers – from bridges or boats



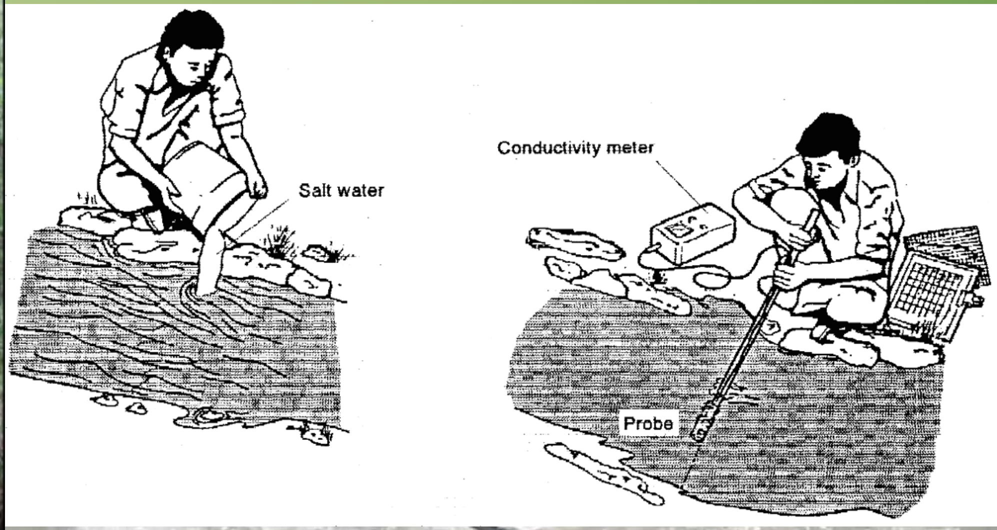

Measuring Streamflow
Discharge

- Procedure: at each segment measure depth then velocity
  - If Depth < 0.6m, take one reading @ 60% depth
  - If Depth > 0.6m take 2 measurements and compute the average
    - One @ 20% depth
    - One @ 80% depth
    - Average the two readings
  - Two method of measurement
    - Mean section method
    - Mid section method

Flow estimation: Current meters: Limitations

- Needs a good approximation of the stream bed shape
- Cost?
- Fragility?

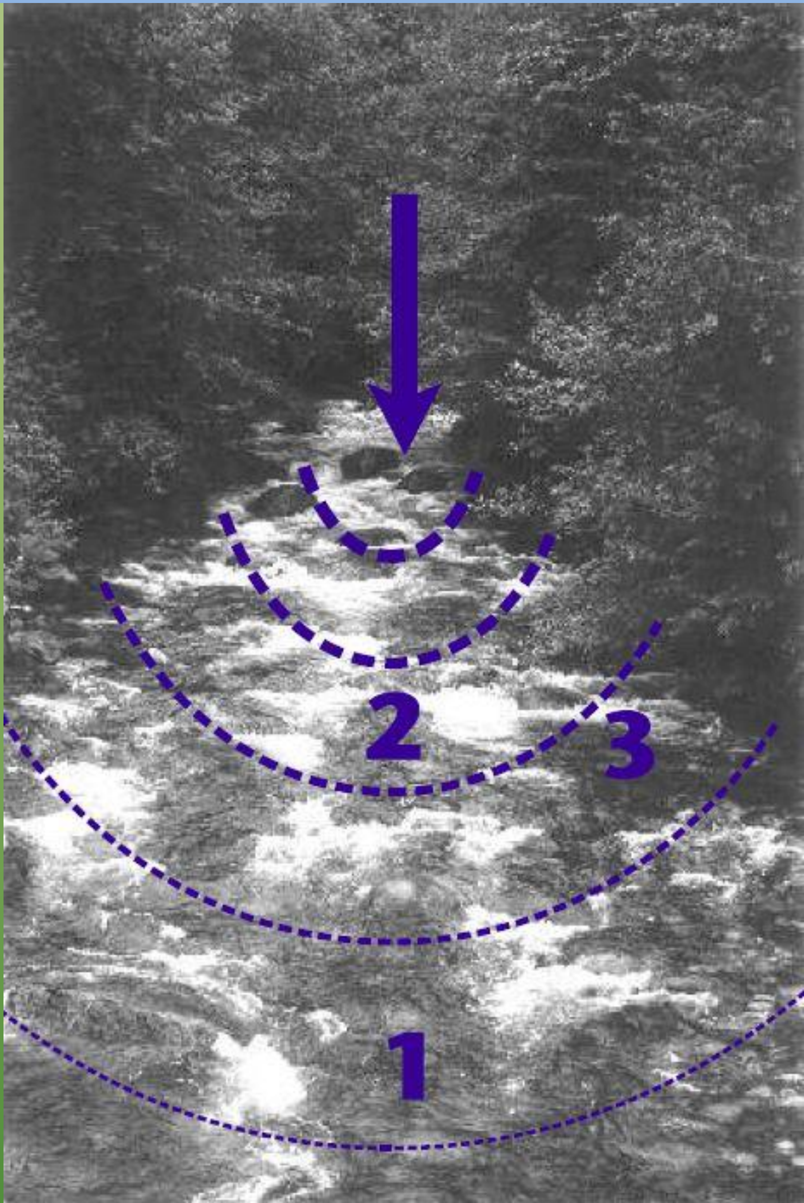
Flow estimation(Dilution Gauging): Salt gulp



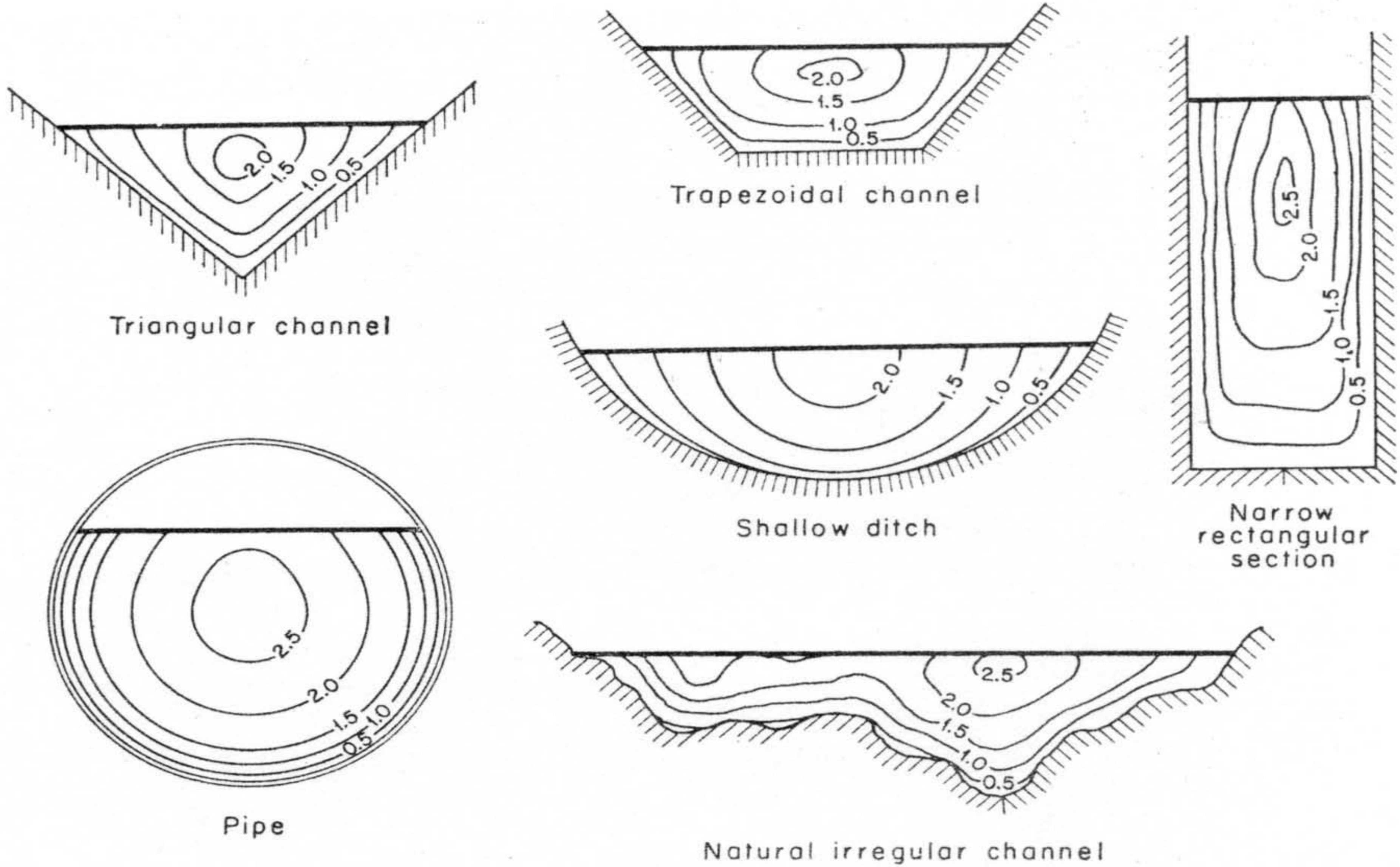
Salt Dilution Gauging is often applied on streams that are too turbulent to carry out the velocity area method.

Flow estimation: Salt gulp: Limitations

- Automated equipment can be expensive – non automated procedure is complex
- Needs skill to take readings and interpret duff ones
- Errors may not be apparent unless maths is done on-site



Velocity Distributions

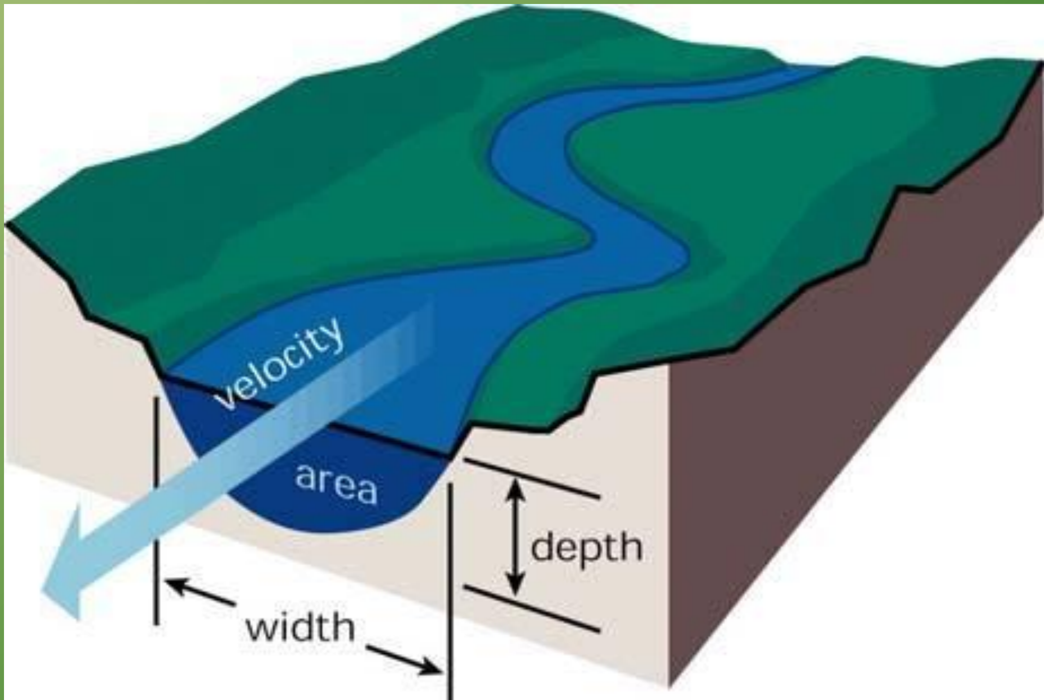


Velocity – Area method

This depends on measuring the average velocity of flow and the cross-sectional area of the channel and calculating the flow from:

$$\mathbf{Q}(m^3/s) = \mathbf{A}(m^2) \times \mathbf{V}(m/s)$$

The metric unit m^3/s is referred to as the **cumec**. Because m^3/s is a large unit, smaller flows are measured in litres per second (l/s).



Velocity-Area Method

- Mostly/frequently used
- River cross-section determined
- Velocity measured using
  - Float (for straight channel)
  - Current meter
- Vertical velocity measured at 0.2d and 0.8d if depth,d >0.6m. If d<0.6m, velocity measured at 0.6dm.

Velocity-Area Method

- Q = [Velocity x Area]
  - Need to know width of channel (*w*), Depth of channel (*d*), and Velocity of flow (V) (ft/s or m/s)
  - Area = w x d
- Because depth & velocity vary across a channel:

(1) Important to divide the channel into manageable segments (slices); Typically use 10-20 segments

(2) For each segment measure depth, width and velocity

FIGURE 22
Estimating the flow in a stream from measurement with a current meter. The calculations for this example are shown in Table 2.

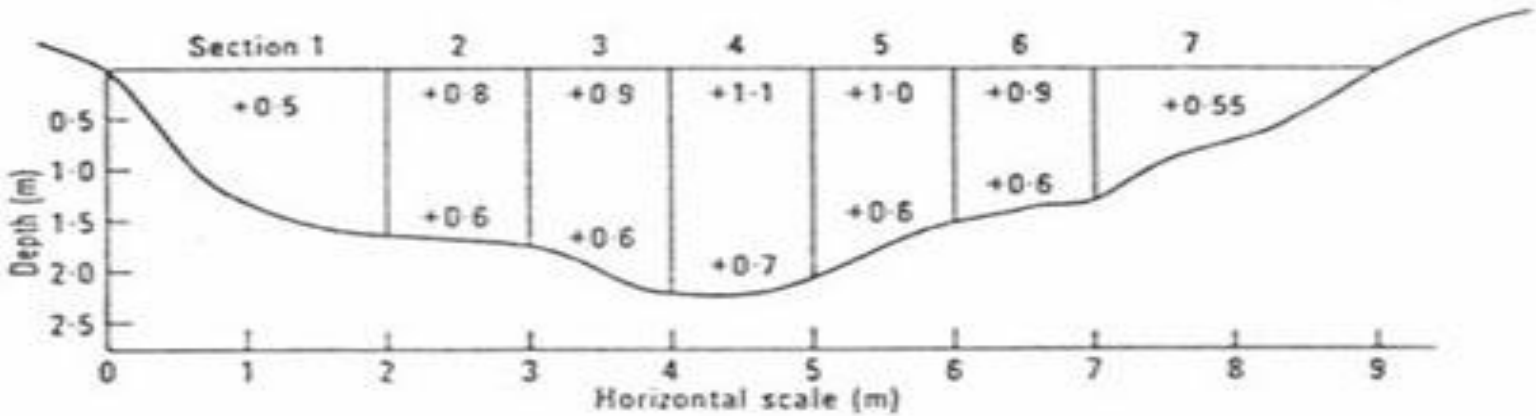


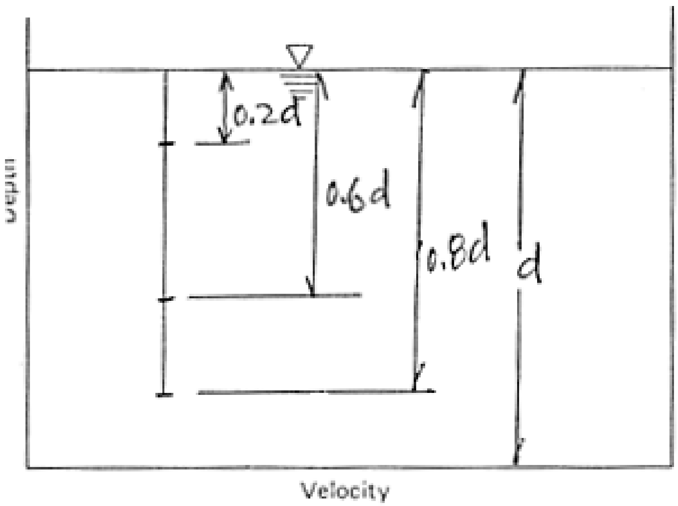
TABLE 2
Calculation of steamflow from current meter readings

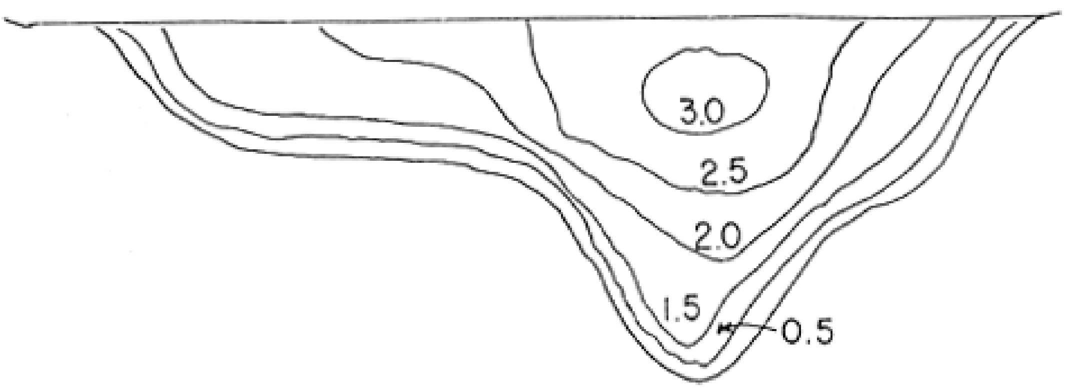
1	2	3	4	5	6	7	8
Section	Flow velocity (m/s)			Depth (m)	Width (m)	Area (m^2) 5 x 6	Flow (m^3/s) 4 x 7
	0.2D	0.8D	Mean				
1	-	-	0.5	1.3	2.0	2.6	1.30
2	0.8	0.6	0.7	1.7	1.0	1.7	1.19
3	0.9	0.6	0.75	2.0	1.0	2.0	1.50
4	1.1	0.7	0.9	2.2	1.0	2.2	1.98
5	1.0	0.6	0.8	1.8	1.0	1.8	1.44
6	0.9	0.6	0.75	1.4	1.0	1.4	1.05
7	-	-	0.55	0.7	2.0	1.4	0.77
						TOTAL	9.23

D is the depth of the stream at the mid-point of each section.

Mean Flow Velocity Estimation

- **Mean Velocity**





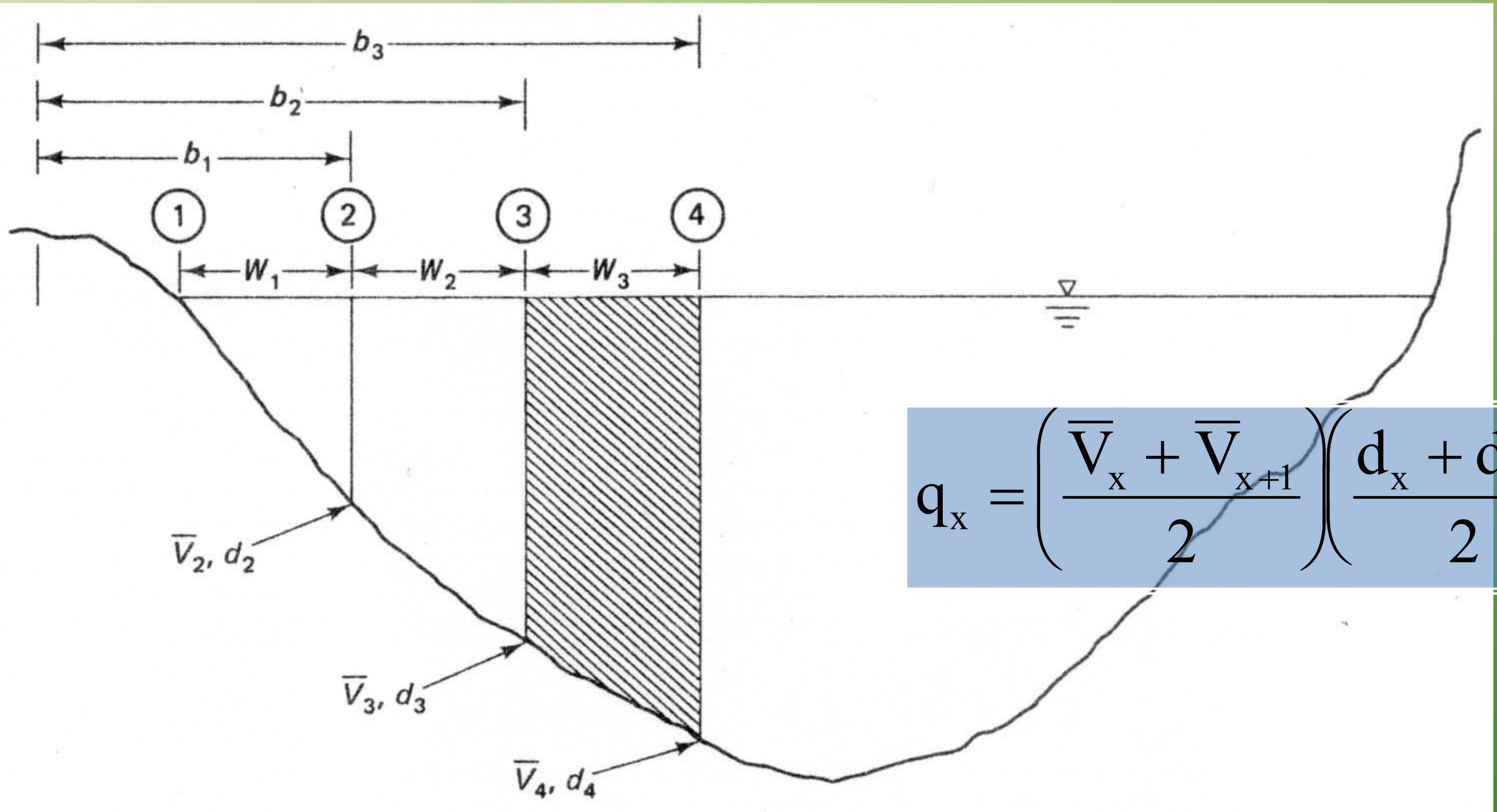
Velocity distribution in a nonuniform channel.

Depth < 0.6m $\bar{V} = V_{0.6d}$; 0.6 water depth from the water surface

$0.6\text{m} \leq \text{Depth} \leq 2\text{m}$ $\bar{V} = \dfrac{V_{0.2d} + V_{0.8d}}{2}$

$\text{Depth} \geq 2\text{m}$ $\bar{V} = \dfrac{V_{0.2d} + 2V_{0.6d} + V_{0.8d}}{4}$

Mean-section Method



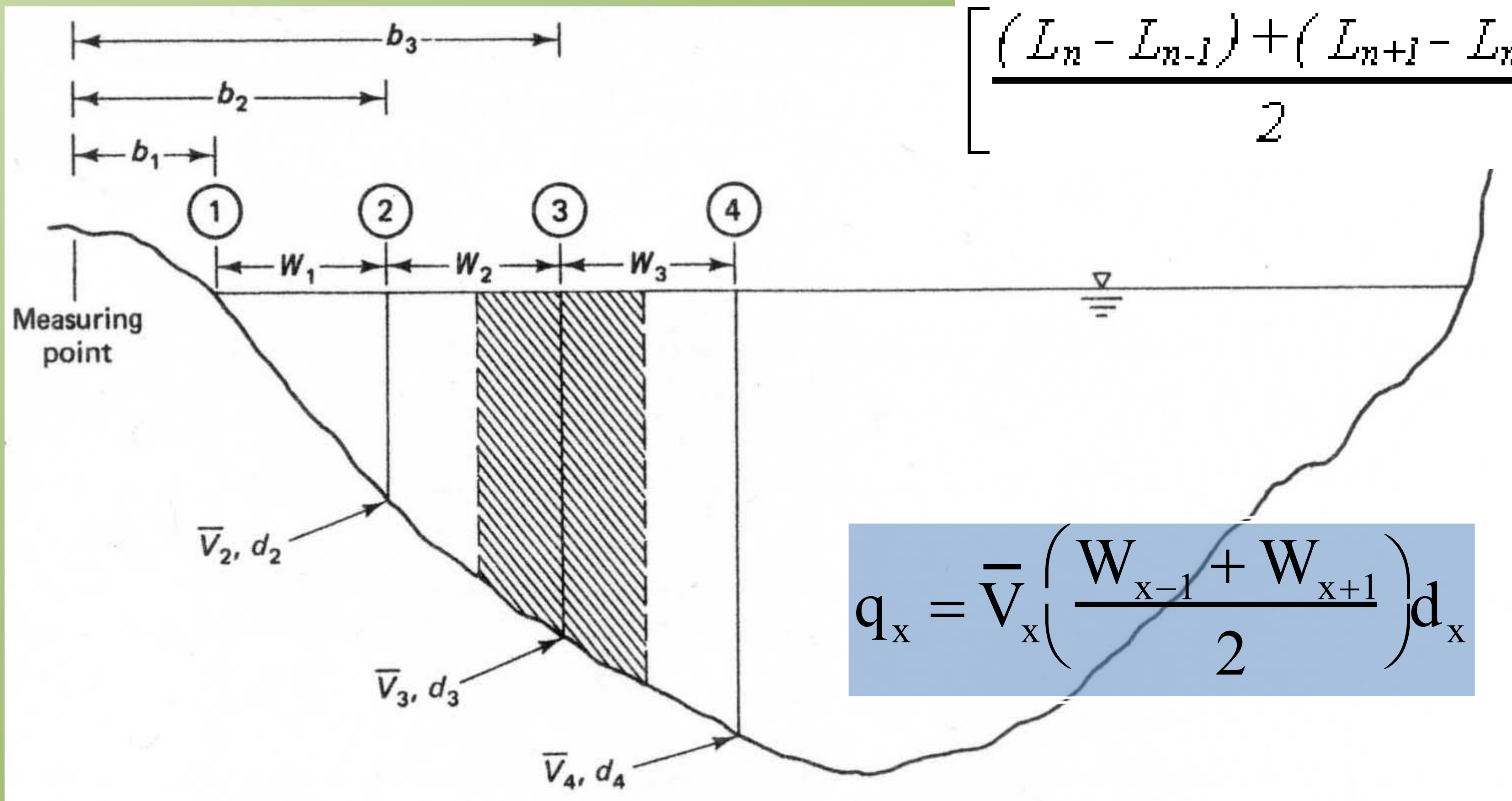
$$q_x = \left(\frac{\overline{V}_x + \overline{V}_{x+1}}{2}\right)\left(\frac{d_x + d_{x+1}}{2}\right)W_x$$

Exercise 6a:

Given $V = 0.5N + 0.04\ m/\ s$. Determine streamflow discharge using velocity-area method (MEAN SECTION METHOD).

Distance From River Bank	Vertical Depth	Depth of Measurement	Time	Number Of Rotation	Number Of Rotation Per time	Velocity			Width	Vertical Depth Average	Area	Flow
						At Point	Vertical Average	Horinzontal Average				
a	b	c	d	e	f	g	h	i	j	k	l	m
1	0.2	0.6D	50	70	1.40	0.74	0.74	0.37	1	0.10	0.10	0.037
2	0.36	0.6D	50	62	1.24	0.66	0.66	0.70	1	0.28	0.28	0.190
4	0.82	0.6D	50	58	1.16	0.62	0.62	0.64	2	0.59	1.18	0.750
6	1.3	0.2D	50	76	1.52	0.80	0.70	0.66	2	1.06	2.12	1.390
		0.8D	50	56	1.12	0.60						
8	1.44	0.2D	50	62	1.24	0.66	0.62	0.66	2	1.37	2.74	1.800
		0.8D	50	54	1.08	0.58						
10	1.32	0.2D	50	70	1.40	0.74	0.65	0.64	2	1.38	2.76	1.76
		0.8D	50	52	1.04	0.56						
12	0.84	0.6D	50	40	0.80	0.44	0.44	0.50	2	1.08	2.16	1.08
14	0.58	0.6D	50	32	0.64	0.36	0.36	0.40	2	0.71	1.42	0.56
16	0.3	0.6D	50	30	0.60	0.34	0.34	0.35	2	0.44	0.88	0.30
											TOTAL	7.893

Mid-section Method



$$\left[\frac{(L_n - L_{n-1}) + (L_{n+1} - L_n)}{2}\right]$$

$$q_x = \overline{V}_x\left(\frac{W_{x-1} + W_{x+1}}{2}\right)d_x$$

Exercise 6b:

Given V = 0.5N + 0.04 m/ s. Determine streamflow discharge using velocity-area method (MID-SECTION METHOD).

$$\left[\frac{(L_n - L_{n-1}) + (L_{n+1} - L_n)}{2}\right]$$

Distance From River Bank	Vertical Depth	Depth of Measurement	Time	Number Of Rotation	Number Of Rotation per time	At Point	Vertical Average	Width $\left[\frac{(L_n - L_{n-1}) + (L_{n+1} - L_n)}{2}\right]$	Area, A	Flow, Q
a	b	c	d	e	f	g	h	i	j=bxi	k=hxj
1	0.2	0.6D	50	70	1.40	0.74	0.74	1	0.20	0.148
2	0.36	0.6D	50	62	1.24	0.66	0.66	1.5	0.54	0.356
4	0.82	0.6D	50	58	1.16	0.62	0.62	2	1.64	1.016
6	1.3	0.2D	50	76	1.52	0.80	0.70	2	2.6	1.82
		0.8D	50	56	1.12	0.60				
8	1.44	0.2D	50	62	1.24	0.66	0.62	2	2.88	1.785
		0.8D	50	54	1.08	0.58				
10	1.32	0.2D	50	70	1.40	0.74	0.65	2	2.64	1.716
		0.8D	50	52	1.04	0.56				
12	0.84	0.6D	50	40	0.80	0.44	0.44	2	1.68	0.739
14	0.58	0.6D	50	32	0.64	0.36	0.36	2	1.16	0.417
16	0.3	0.6D	50	30	0.60	0.34	0.34	2	0.60	0.204
									TOTAL	8.201

Exercise 6c:

Given V = 0.3N + 0.05 m/ s. Determine streamflow discharge using velocity-area method.

Distance from Datum (m)	Stream depth (m)	Current meter reading					
		0.6D		0.2D		0.8D	
		Rotation	Duration (s)	Rotation	Duration (s)	Rotation	Duration (s)
3	1.2	10	60				
6	3.0			35	62	20	65
9	5.7			42	65	28	62
12	8.5			50	68	25	64
15	4.6			57	65	30	68
18	3.8			40	60	32	60
21	2.5			34	62	25	65
24	1.5	15	60				

Distance From River Bank	Vertical Depth	Depth of Measurement	Time	Number Of Rotation	Number Of Rotation Per time	Velocity			Width	Vertical Depth Average	Area	Flow
						At Point	Vertical Average	Horinzontal Average				
a	b	c	d	e	f	g	h	i	j	k	l	m
3	1.2	0.6D	60	10	017							
6	3.0	0.2D	62	35	0.56							
		0.8D	65	20	0.31							
9	5.7	0.2D	65	42	0.65							
		0.8D	62	28	0.45							
											TOTAL	6.374

Distance From River Bank	Vertical Depth	Depth of Measurement	Time	Number Of Rotation	Number Of Rotation Per time	Velocity At Point	Velocity Vertical Average	Width	Area, A	Flow, Q
3	1.2	0.6D	60	10	017	0.10	0.10			
6	3.0	0.2D	62	35	0.56	0.22	0.18			
		0.8D	65	20	0.31	0.14				
9	5.7	0.2D	65	42	0.65	0.25	0.22			
		0.8D	62	28	0.45	0.19				
12										
									TOTAL	7.241

$$\left[\frac{(L_n - L_{n-1}) + (L_{n+1} - L_n)}{2}\right]$$

V = 0.3N + 0.05 m/ s.

Distance From River Bank	Vertical Depth	Depth of Measurement	Time	Number Of Rotation	Number Of Rotation Per time	Velocity			Width	Vertical Depth Average	Area	Flow
						At Point	Vertical Average	Horinzontal Average				
a	b	c	d	e	f	g	h	ji	j	k	l	m
0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	0.6	0.6 D	50	95	1.900	0.620	0.620	0.310	1.5	0.300	0.450	0.140
3.0	0.85	0.6 D	50	143	2.860	0.908	0.908	0.764	1.5	0.725	1.088	0.831
4.5	0.73	0.6 D	50	150	3.000	0.950	0.950	0.929	1.5	0.790	1.185	1.101
6.0	0.80	0.6 D	50	156	3.120	0.986	0.986	0.968	1.5	0.765	1.148	1.111
7.5	0.92	0.6 D	50	105	2.100	0.680	0.680	0.833	1.5	0.860	1.290	1.075
9.0	0.89	0.6 D	50	145	2.900	0.920	0.920	0.800	1.5	0.905	1.358	1.086
10.5	0.95	0.6 D	50	132	2.640	0.842	0.842	0.881	1.5	0.920	1.380	1.216
12.0	0.84	0.6 D	50	114	2.280	0.734	0.734	0.788	1.5	0.895	1.343	1.058
13.5	0.75	0.6 D	50	82	1.640	0.542	0.542	0.638	1.5	0.795	1.193	0.761
15.0	0	0.6 D	50	0	0	0	0	0.271	1.5	0.375	0.563	0.152
											TOTAL	8.529
											TOTAL	

Problem

Mean-section Method

given V = 0.014N + 0.02 m/ s.

Distance From River Bank	Vertical Depth	Depth of Measure ment	Time	Number Of Rotation	Number Of Rotation Per time	Velocity			Width	Vertical Depth Average	Area	Flow
						At Point	Vertical Average	Horinzontal Average				
1	0	0	0	0								
2	1.5	0.2D	100	174								
		0.8D	100	128								
4	3.0	0.2D	120	433								
		0.6D	120	380								
		0.8D	120	321								
6	5.0	0.2D	90	492								
		0.6D	90	534								
		0.8D	90	422								
8	2.0	0.2D	100	453								
		0.8D	100	547								
10	0.5	0.2D	90	241								
12	0.0	0	0	0								
											TOTAL	m^3/s

Solution

Mean-section Method

given V = 0.014N + 0.02 m/ s.

Distance From River Bank	Vertical Depth	Depth of Measure ment	Time	Number Of Rotation	Number Of Rotation Per time	Velocity			Width	Vertical Depth Average	Area	Flow
						At Point	Vertical Average	Horinzontal Average				
1	0	0	0	0	0	0	0	0	1	0	0	0
2	1.5	0.2D	100	174	1.740	0.044	0.041	0.021	1	0.750	0.750	0.015
		0.8D	100	128	1.280	0.038						
4	3.0	0.2D	120	433	3.608	0.071	0.064	0.053	2	2.250	4.500	0.237
		0.6D	120	380	3.167	0.064						
		0.8D	120	321	2.675	0.057						
6	5.0	0.2D	90	492	5.467	0.097	0.095	0.080	2	4.000	8.000	0.637
		0.6D	90	534	5.933	0.103						
		0.8D	90	422	4.689	0.086						
8	2.0	0.2D	100	453	4.530	0.083	0.090	0.093	2	3.500	7.000	0.648
		0.8D	100	547	5.470	0.097						
10	0.5	0.2D	90	241	2.678	0.057	0.057	0.074	2	1.250	2.500	0.184
12	0.0	0	0	0	0	0	0	0.029	2	0.250	0.500	0.014
									TOTAL			1.735 m^3/s

Exercise 6a

- **The data pertaining to a stream-gauging operation at a gauging site are given below. The rating equation of the current meter is $v = 0.51 N_s + 0.03$ m/s**
- **Where, N_s = revolution per second. Calculate the discharge in the stream**

Distance from left water edge (m)	0	1.0	3.0	5.0	7.0	9.0	11.0	12.0
Depth (m)	0	1.1	2.0	2.5	2.0	1.7	1.0	0
Revolution of a current meter kept at 0.6 depth	0	39	58	112	90	45	30	0
Duration of observation (s)	0	100	100	150	150	100	100	0

Exercise 6b

The following data were collected during a stream-gauging operation in a river. Compute the discharge

Distance from left water edge (m)	Depth (m)	Velocity (m/s)	
		At 0.2 d	At 0.8 d
0.0	0.0	0.0	0.0
1.5	1.3	0.6	0.4
3.0	2.5	0.9	0.6
4.5	1.7	0.7	0.5
6.0	1.0	0.6	0.4
7.5	0.4	0.4	0.3
9.0	0.0	0.0	0.0

Exercise 6c

Find the Q for this case: V = 0.25 N + 0.05

Where V= velocity (m/s) & N = number of revolution/s

a) Using mean-section method

b) Using mid-section method

Distance from edge, b (m)	Depth, d (m)	Rev/min		
		0.6d	0.2d	0.8d
0	0			
2	1.1	14		
4	2.6		48	44
6	4.0		57	52
8	7.2		43	37
10	4.3		38	32
12	3.2		36	29
14	1.6	12		
15.5	0			

Mean-section method

		Velocity (m/s)						
b	d	0.6d	0.2d	0.8d	V_{avg}	$(V_i+V_{i+1})/2$	A	Q
0	0				0			
2	1.1	0.108			0.108	0.054	1.1	
4	2.6		0.250	0.233	0.242	0.175	3.7	
6	4.0		0.288		0.278	0.260	6.6	
8	7.2		0.229		0.216	0.247	11.2	
10	4.3		0.208		0.196	0.206	11.5	
12	3.2		0.200		0.186	0.191	7.5	
14	1.6	0.100			0.100	0.143	4.8	
15.5	0				0.000	0.050	1.2	

$Q = 9.736\ m^3/s$

Mid-section method

		Velocity (m/s)					
b	d	0.6d	0.2d	0.8d	V_{avg}	$(b_{i+1}-b_{i-1})/2$	qi
0	0				0		
2	1.1	0.108			0.108	2	
4	2.6		0.250	0.233	0.242	2	
6	4.0		0.288		0.278	2	
8	7.2		0.229		0.216	2	
10	4.3		0.208		0.196	2	
12	3.2		0.200		0.186	2	
14	1.6	0.100			0.100	1.75	
15.5	0				0.000		

$Q = 9.986\ m^3/s$