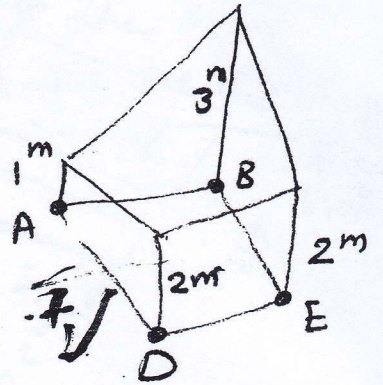
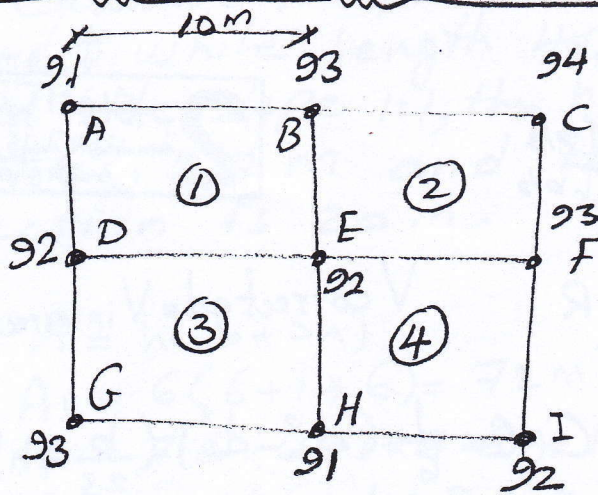


2. Volumes from spot height or spot level (6)



excavated R.L. ≈ 90 m

① - $\frac{7+3+2+2}{4} * (10 * 10) = 200 \text{ m}^3$ ③ - $\frac{2+2+1+3}{4} * (10 * 10) = 200$

② - $\frac{3+4+2+3}{4} * (10 * 10) = 300 \text{ m}^3$ ④ - $\frac{2+3+1+2}{4} * (10 * 10) = 200$

① + ② + ③ + ④ = 900 m^3

station	Depth of excavation (m) = h	Number of rectangles in which it occurs = n	prod (hn)
A	1	1	1
B	3	2	6
C	4	1	4
D	2	2	4
E	2	4	8
F	3	2	6
G	3	1	3
H	1	2	2
I	2	1	2
		$\frac{1}{16}$	$\frac{36}{16}$

average of height with respect to the excavated R.L. = $\frac{\sum \text{Product}}{\sum \text{number of rectangles in which it occurs}} = \frac{36}{16} = 2.25$

\bar{V} = average of height with respect to the excavated R.L. * Area = $2.25 * 400$
of rectangles 9000

OR

$$\text{Volume} = \frac{d^2}{4} (\sum h_1 + 2 \sum h_2 + 3 \sum h_3 + 4 \sum h_4) \quad (7)$$

d = length of side of square

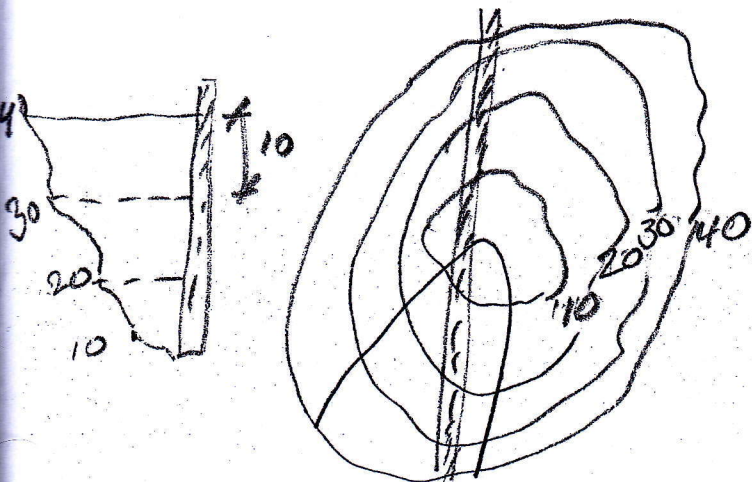
h_1 = heights used only one, h_2 = heights used twice

h_3 = height used three times, h_4 = heights used four times.

$$V_{\text{total}} = \frac{10^2}{4} (1+4+3+2) + 2(3+2+3+1) + 4(2)$$

$$= 900 \text{ m}^3$$

3. Volumes From Contour map



By end area

$$V = \frac{I}{2} [A_1 + A_n + 2(A_2 + A_3 + \dots + A_{n-1})]$$

By prismatic

$$V = \frac{I}{3} [A_1 + A_n + 4 \sum_{\text{even area}} + 2 \sum_{\text{odd area}}]$$

I is contour interval

Example/ Calculate Volume of water between 182 to 190

Contour	190	188	186	184	182
Area(m ²)	3150	2460	1630	840	210

Sol: 1. By end area

$$V = \frac{I}{2} [A_1 + A_n + 2(A_2 + A_3 + \dots + A_{n-1})]$$

$$= \frac{2}{2} [3150 + 210 + 2(2460 + 1630 + 840)] = 13220 \text{ m}^3$$

2. By prismatic

$$V = \frac{I}{3} [A_1 + A_n + 4 \sum_{\text{even area}} + 2 \sum_{\text{odd area}}]$$

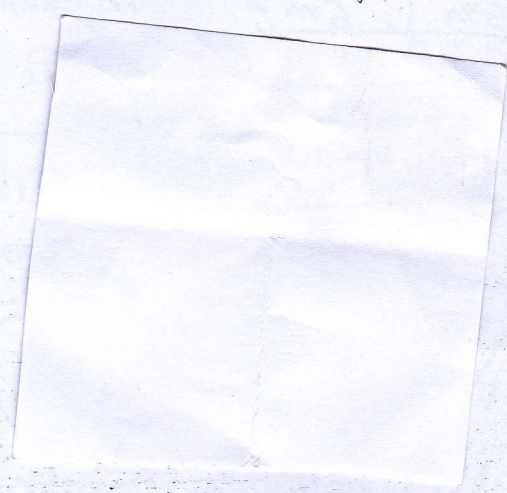
$$= \frac{2}{3} [3150 + 210 + 4(2460 + 840) + 2(1630)] = 13213 \text{ m}^3$$

Example/ Using the information about the cross-sections with some missing in table shown below to calculate:

- ① The area of each cross-section for cut and fill
 - ② Volumes of cut and fill
- if the formation width increases uniformly from 9m in fill to 12m in cut and side slope 1:1.5.

Station	Surface Elev.	Grade Elev.	Grade ^{not given value}	Cross-section ^{give}		
				L	C	R
(I) 60+90	71.09	68.85	$c \frac{2.24}{9.36}$	$c \frac{2.24}{0}$	$c \frac{2.24}{9.36}$	
(H) 60+60	70.52	68.49	$c \frac{2.13}{9.20}$	$c \frac{?}{0}$ ← 2.03	$c \frac{1.92}{8.88}$	
(G) 60+44.4	69.53	68.30	$c \frac{1.44}{8.16}$	$c \frac{?}{0}$ ← 1.23	$\frac{0}{6.0}$	
(F) 60+40.8	68.26	68.26	$c \frac{0.78}{7.17}$	$\frac{?}{0}$ ← 0	$f \frac{0.6}{5.7}$	
(D) 60+37.5	67.13	68.22	$\frac{0}{4.5}$	$f \frac{?}{0}$ ← 1.09	$f \frac{1.74}{7.11}$	
(B) 60+30	66.38	68.13	$f \frac{1.62}{6.93}$	$f \frac{2.07}{4.5}$	$f \frac{?}{0}$	$f \frac{2.01}{4.5}$ $f \frac{2.46}{8.19}$
(A) 60+00	65.36	67.77	$f \frac{2.16}{7.74}$	$f \frac{2.64}{6.0}$ $f \frac{2.1}{4.41}$	$f \frac{2.41}{0}$	$f \frac{2.43}{5.4}$ $f \frac{2.79}{7.2}$ $f \frac{2.8}{8.7}$

↑
11.11
11.11

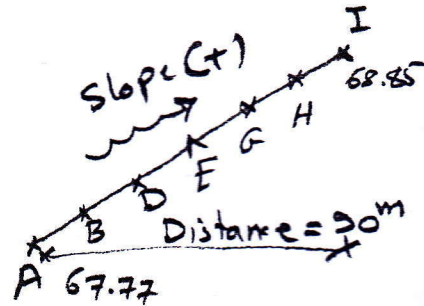


Sol.

(2)

$$\left. \begin{array}{l} \text{ground or surface} \\ \text{Elev.} \end{array} \right\} \text{point} - \left. \begin{array}{l} \text{grade} \\ \text{point} \end{array} \right\} \begin{array}{l} \Rightarrow + \text{Cut} \\ \Rightarrow - \text{Fill} \end{array}$$

$$\therefore \left. \begin{array}{l} \text{grade I} = 71.09 - 2.24 = 68.85 \text{ m} \\ \text{grade A} = 65.36 + 2.41 = 67.77 \text{ m} \end{array} \right\}$$



$$\text{slope}_{A \rightarrow I} = \frac{\text{grade I} - \text{grade A}}{\text{Distance}} = \frac{68.85 - 67.77}{90} = +0.012$$

$$\text{grade}_{\text{next point}} = \text{grade}_{\text{prev. point}} \pm \text{slope} \times \text{distance between points}$$

grade compute from A to I

$$\left. \begin{array}{l} \text{grade B} = 67.77 + 0.012 \times 30 = 68.13 \text{ m} \\ \text{grade D} = 68.13 + 0.012 \times 7.5 = 68.22 \text{ m} \\ \text{grade E} = 68.22 + 0.012 \times 3.3 = 68.26 \text{ m} \\ \text{grade G} = 68.26 + 0.012 \times 3.6 = 68.30 \text{ m} \\ \text{grade H} = 68.30 + 0.012 \times 15.6 = 68.49 \text{ m} \end{array} \right\}$$

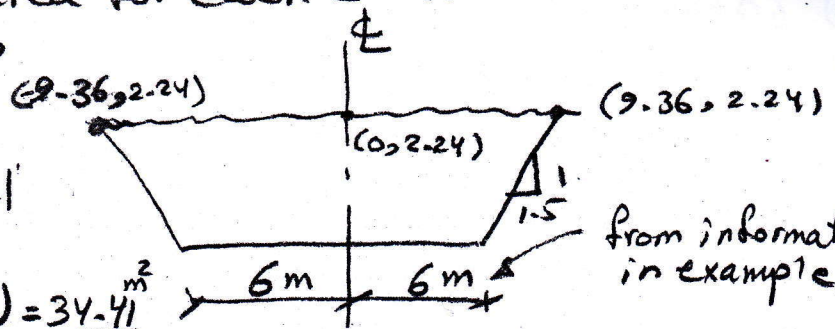
Filling these values in table

Now calculate the area for each cross-section

(I) @ station 60+90

After draw the section we find this section is one-level

$$\therefore A = h(b + sh) = 2.24(12 + 1.5 \times 2.24) = \underline{\underline{34.71 \text{ m}^2}} \text{ cut}$$



from information in example

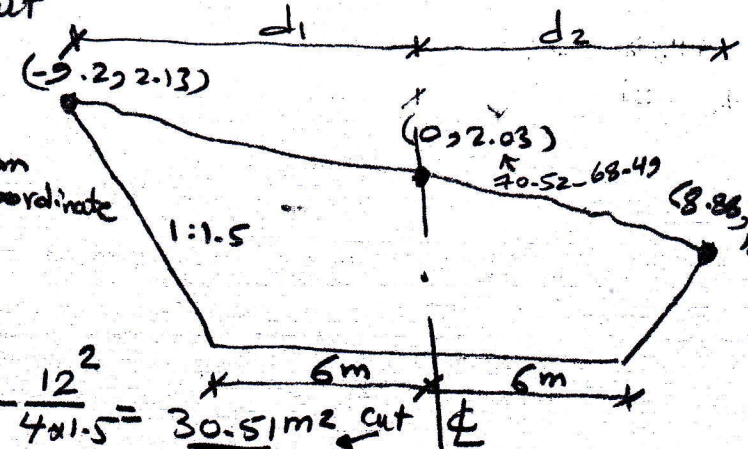
(H) @ station 60+60

After draw the section, we find this section is three-level

and $d_1 = 9.2 \text{ m}$, $d_2 = 8.88 \text{ m}$

$$\therefore A = \frac{1}{2} \left(\frac{b}{2s} + h \right) (d_1 + d_2) - \frac{b^2}{4s}$$

$$= \frac{1}{2} \left(\frac{12}{2 \times 1.5} + 2.03 \right) (9.2 + 8.88) - \frac{12^2}{4 \times 1.5} = \underline{\underline{30.51 \text{ m}^2}} \text{ cut}$$



(G) @ station 60+44.4

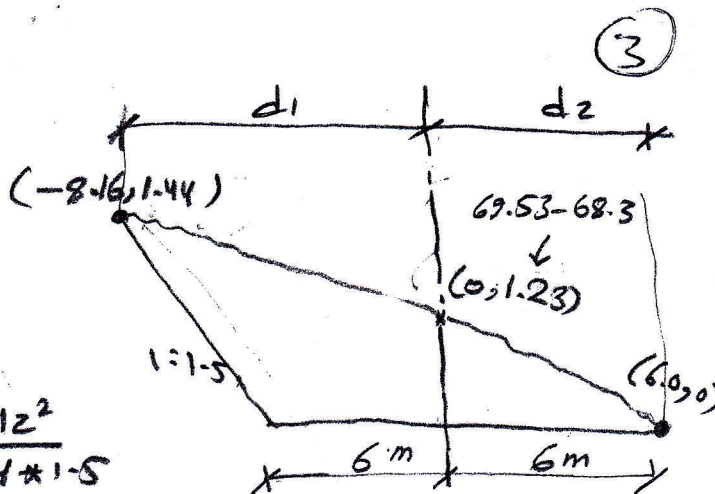
Three-level section

$$d_1 = 8.16^m, d_2 = 6.0^m$$

$$A = \frac{1}{2} \left(\frac{b}{2s} + h \right) (d_1 + d_2) - \frac{b^2}{4s}$$

$$= \frac{1}{2} \left(\frac{12}{2 \times 1.5} + 1.23 \right) (8.16 + 6) - \frac{12^2}{4 \times 1.5}$$

$$= 13.03 \text{ m}^2 \leftarrow \text{Cut}$$



(E) @ station 60+40.8

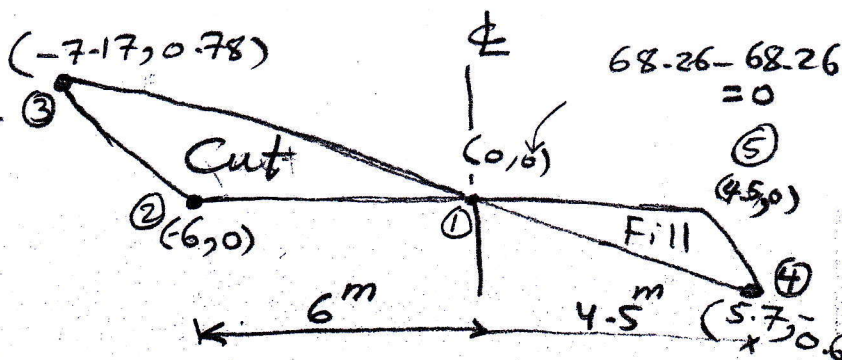
Side hill, by coordinate to find the area of cross-section

Point	x	y
1	0	0
2	-6	0
3	-7.17	0.78
1	0	0

$$2A = -(-6 \times 0.78) \Rightarrow A = 2.34 \text{ m}^2 \leftarrow \text{cut}$$

Point	x	y
1	0	0
4	5.7	0.6
5	4.5	0
1	0	0

$$2A = (0.6 \times 4.5) \Rightarrow A = 1.35 \text{ m}^2 \leftarrow \text{Fill}$$



(D) @ station 60+37.5

$$d_1 = 4.5^m, d_2 = 7.11^m$$

$$A = \frac{1}{2} \left(\frac{b}{2s} + h \right) (d_1 + d_2) - \frac{b^2}{4s}$$

$$= \frac{1}{2} \left(\frac{9}{2 \times 1.5} + 1.09 \right) (4.5 + 7.11) - \frac{9^2}{4 \times 1.5}$$

$$= 10.24 \text{ m}^2 \leftarrow \text{Fill}$$

