Surveying 1 / Dr. Najeh Tamim

CHAPTER 4

LEVELING

4.1 INTRODUCTION

- Elevation (Height) of a point is defined as the vertical distance between the point and a reference level surface called *datum*.

- Why do we need to know elevations?

Methods of Leveling:

- Chain Surveying
- Barometric Leveling
- Trigonometric Leveling
- Photogrammetric Leveling
- GPS Leveling
- Differential Leveling

4.2 BASIC DEFINITIONS

- *Vertical line.*
- *Horizontal line.*
- *Horizontal plane.*
- *Level surface.*
- *Level line.*
- *Difference in elevation between two points.*
- *Actual line of sight or collimation*
- *Bench mark (BM).*

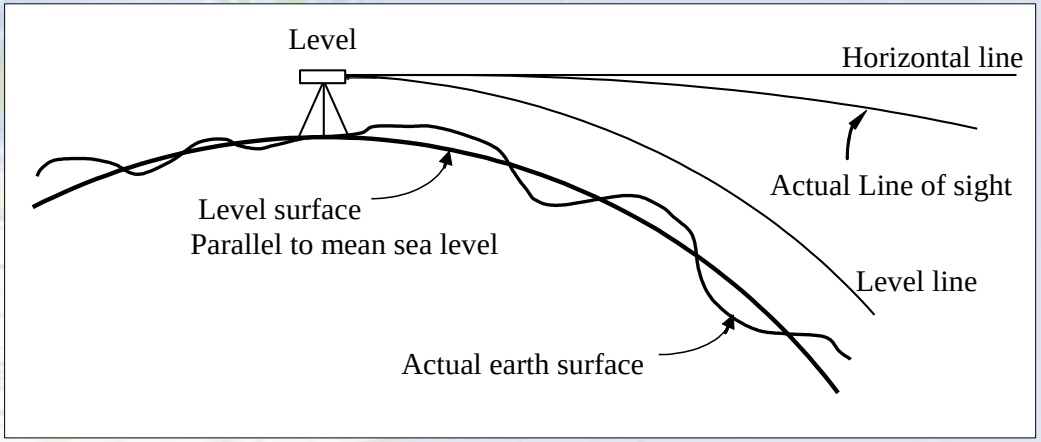
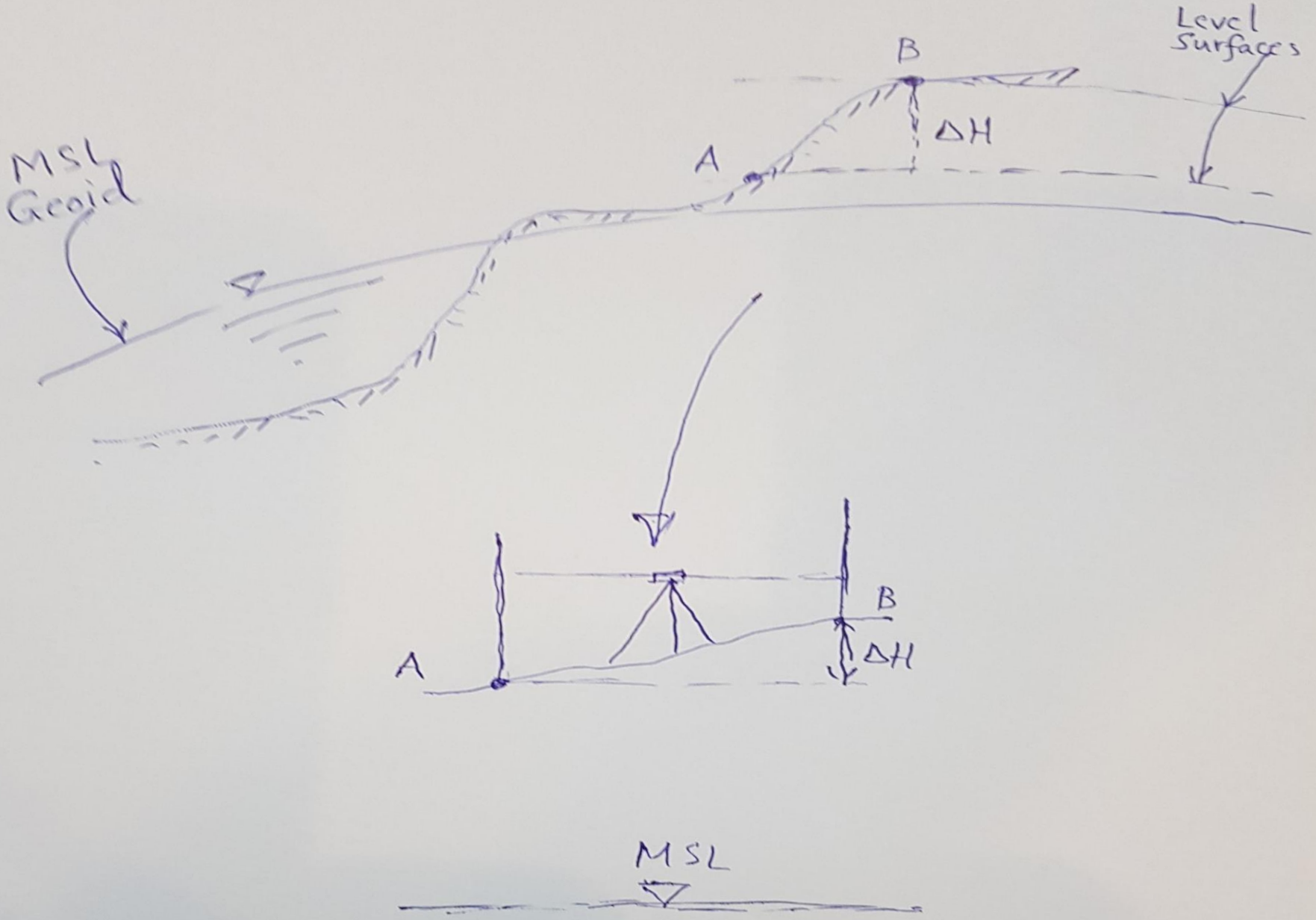


FIGURE 4.1: Relationship between the horizontal line, level line and the line of sight


Level surfaces
B
ΔH
A
MSL
Geoid
B
A
ΔH
MSL

4.3 BASIC PRINCIPLE OF A LEVEL

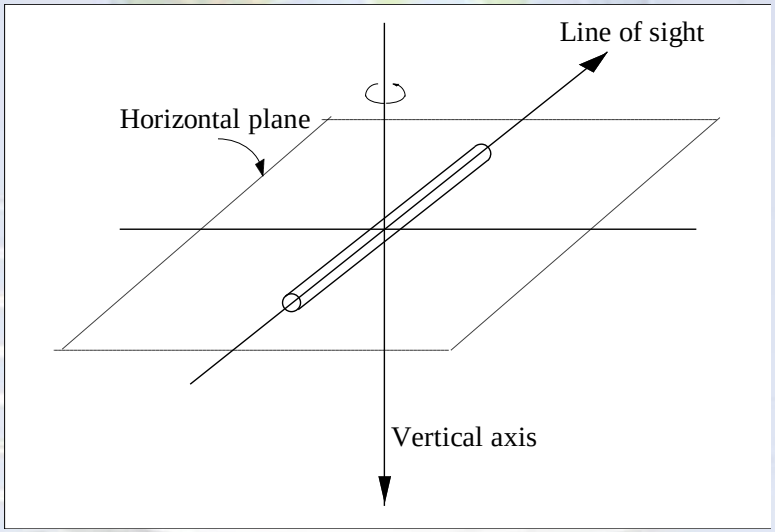


FIGURE 4.2: Basic principle of a level.

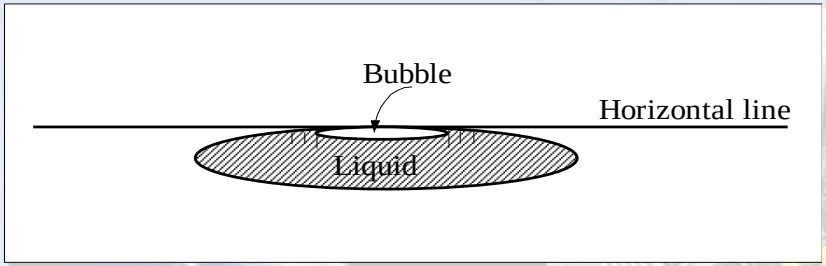


FIGURE 4.3: Cross section in a bubble tube.

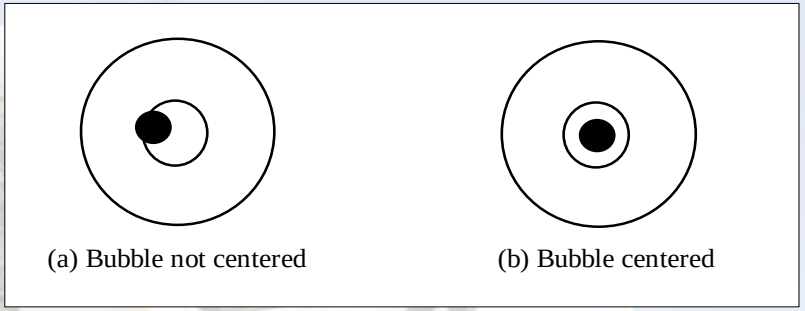
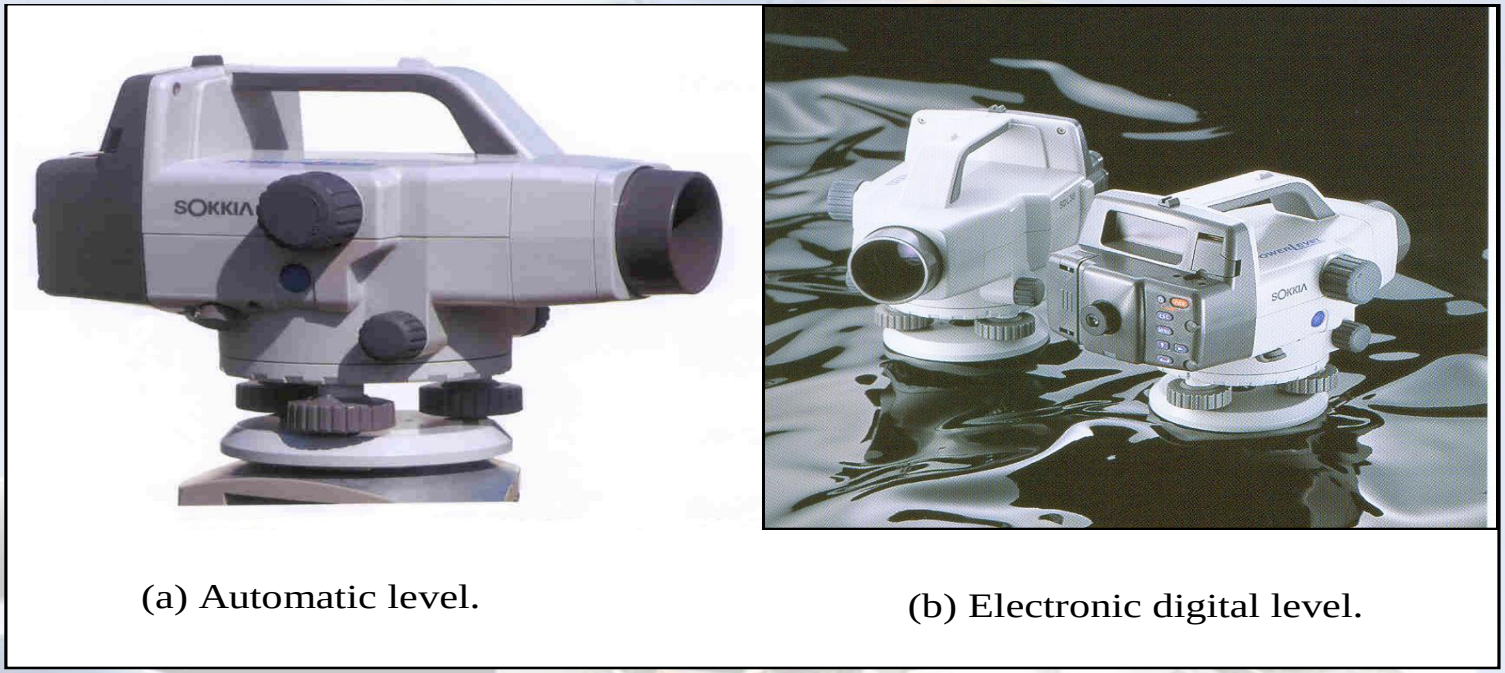


FIGURE 4.4: Centering the bubble.

4.5 EQUIPMENT USED IN DIFFERENTIAL LEVELING

- **The Level.**



(a) Automatic level.

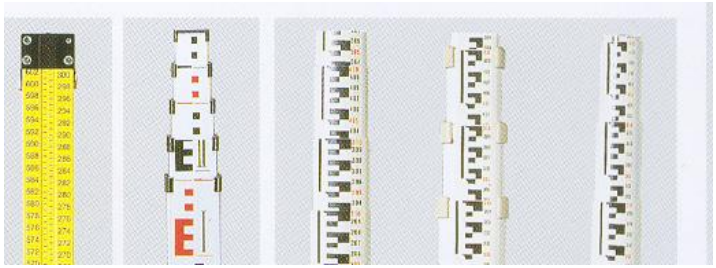
(b) Electronic digital level.

FIGURE 4.6: Automatic and electronic digital Levels.

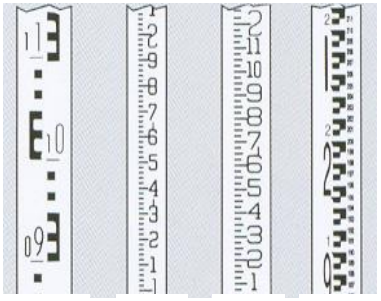
- Tripod
- Leveling Staves
- Leveling Rod

(a) Fixed leg tripod

(b) Extension leg tripod



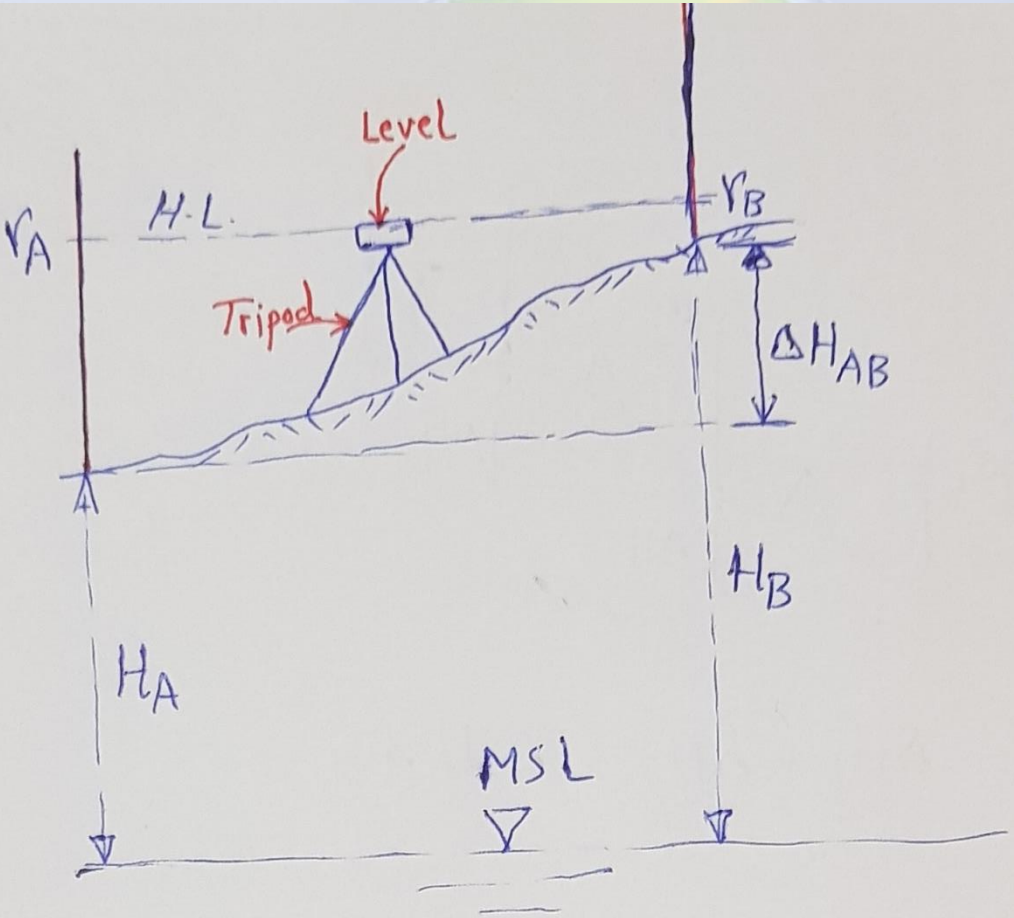
(c) Leveling staves

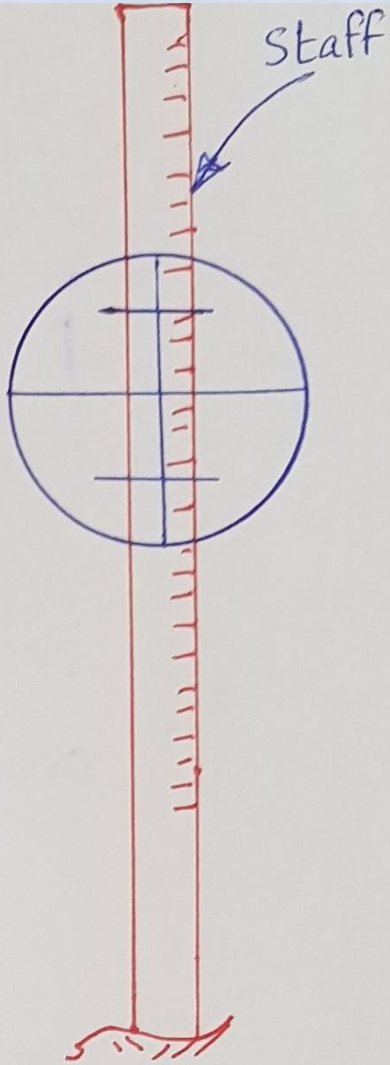


(d) Metric and feet graduations of

(e) Rod level

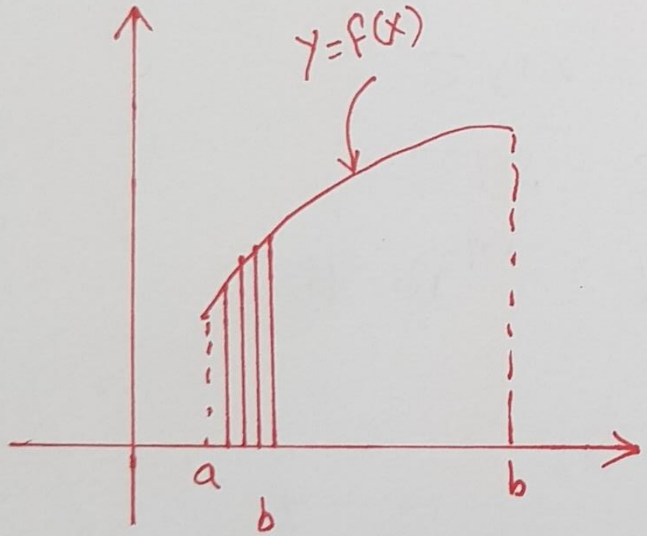
FIGURE 4.7: Tripods, leveling staves and rod levels.



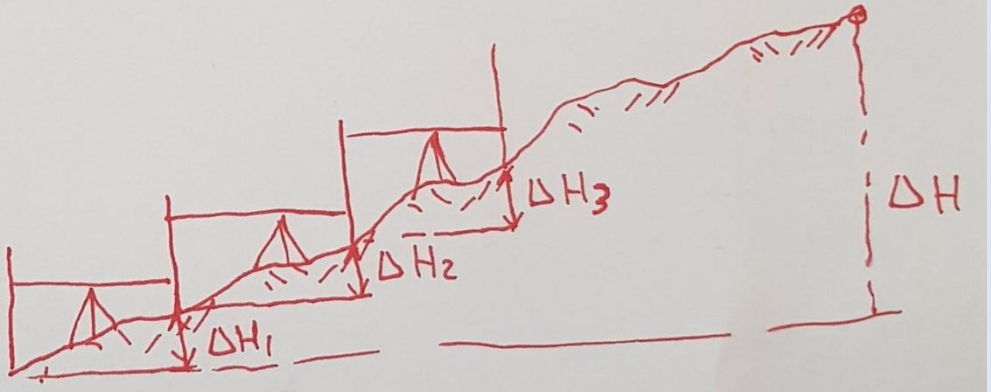


$$\Delta H_{AB} = H_B - H_A$$
$$= r_A - r_B$$

(p.89)



$$A = \int_a^b f(x) \cdot dx$$



$$\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 + \cdots$$

(Differential Leveling)

4.6 SETTING UP THE LEVEL

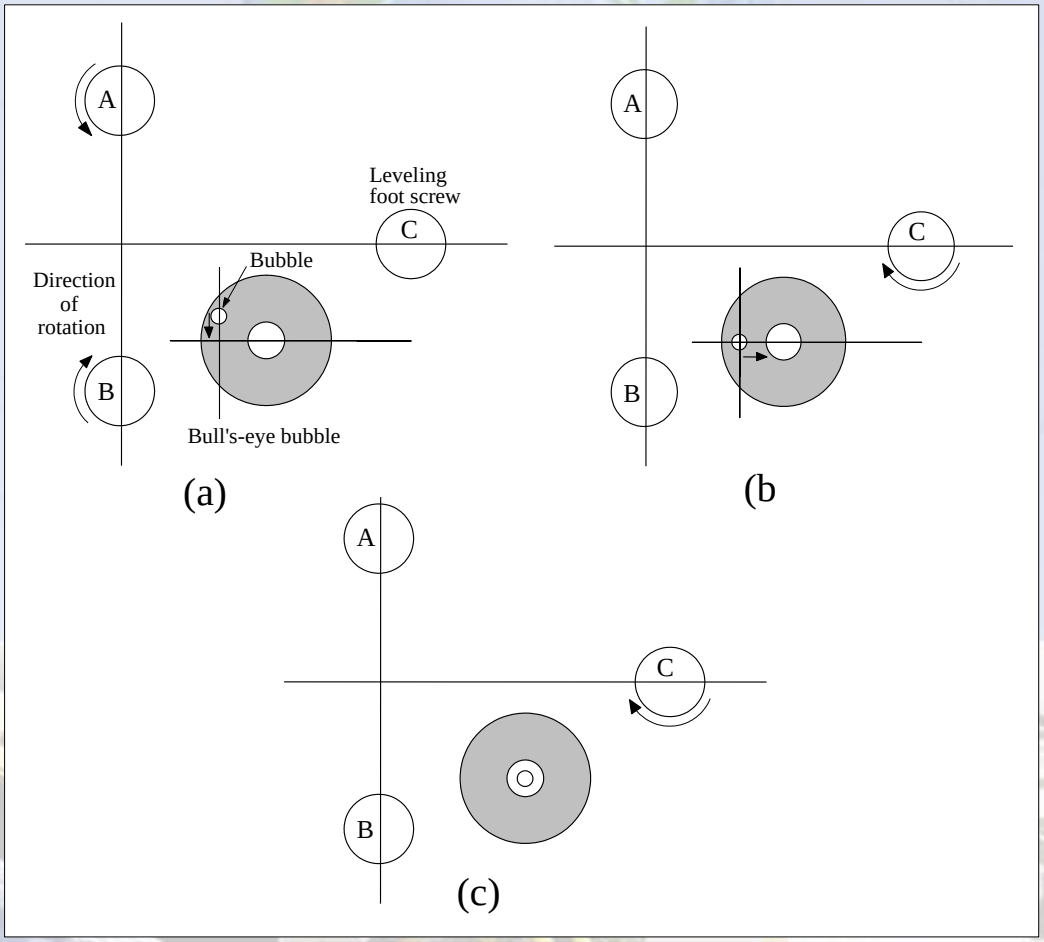


FIGURE 4.8: Leveling an instrument with three foot screws and a circular bubble tube.

4.7 MEASURING ELEVATION DIFFERENCE USING A LEVEL

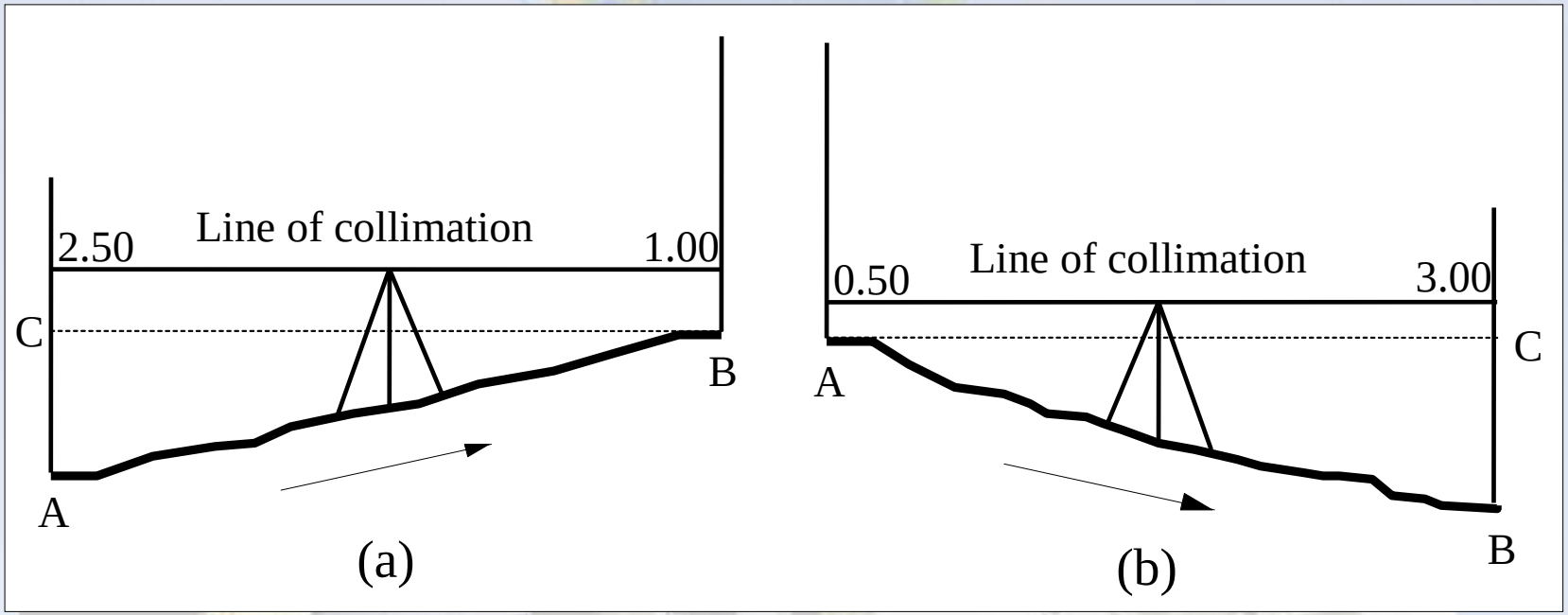
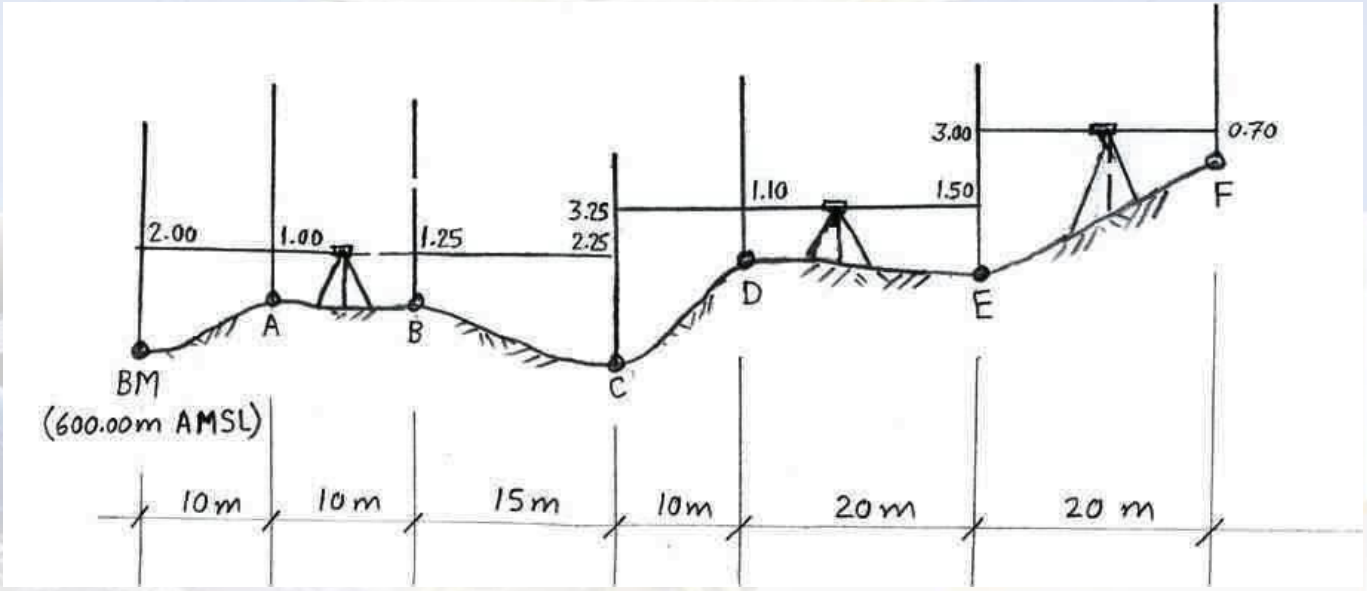


FIGURE 4.9: Principle of differential leveling.

4.8 PROCEDURE IN DIFFERENTIAL LEVELING

- *Backsight (BS).*
- *Foresight (FS).*
- *Intermediate Sight (IS).*
- *Turning Point (TP).*



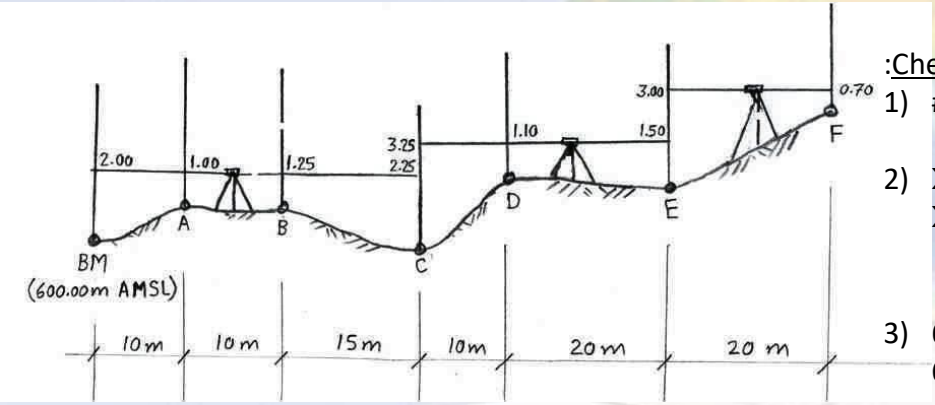
Booking of Measurements

Project and Location: _____

Surveyor: _____ Date: / /

Point #	BS	IS	FS	Rise	Fall	HI	RL (m)	Distance (m)	Remarks

General Procedure: Example



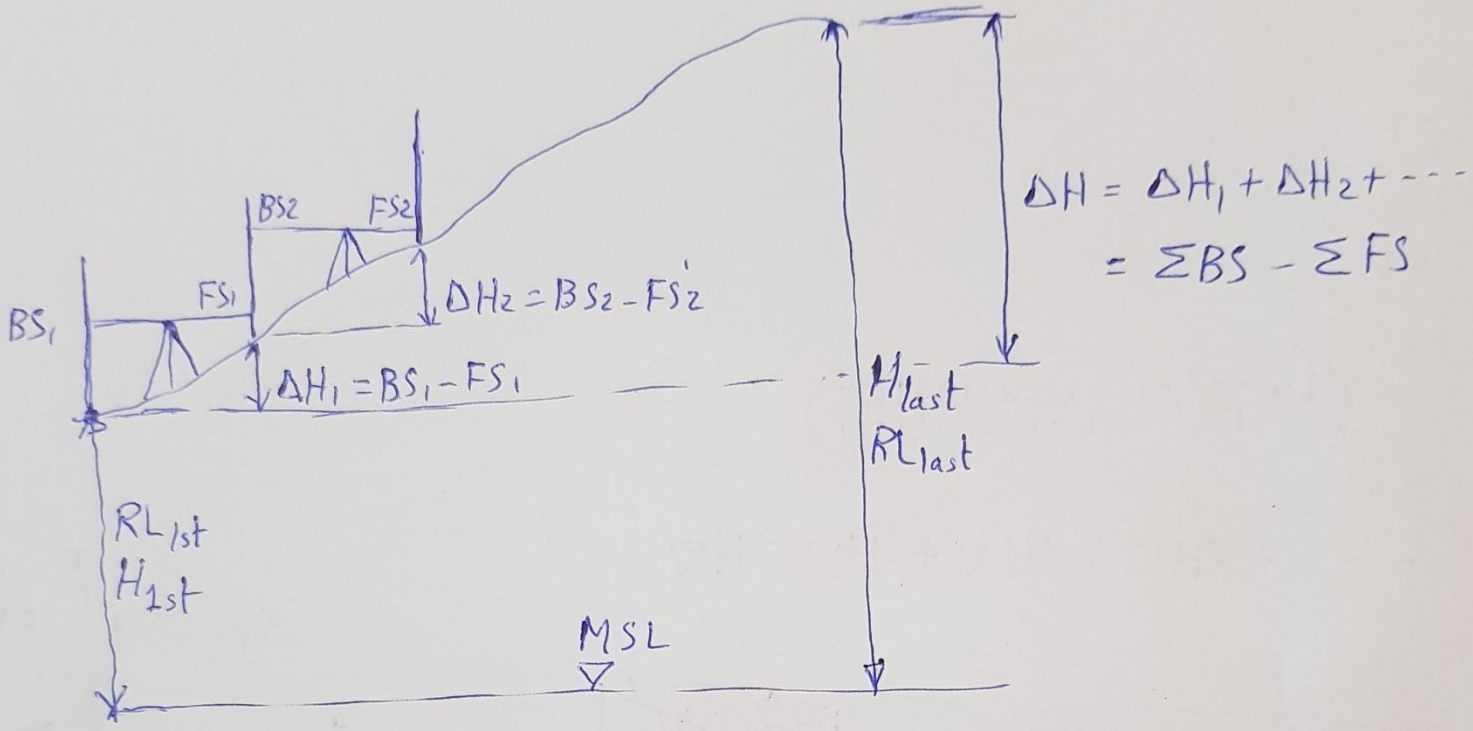
:Checks

1) # of BS = # of FS = # of setups ⇒ OK

2) Σ BS - Σ FS = 8.25 – 4.45 = 3.80
   Σ Rise - Σ Fall = 5.45 – 1.65 = 3.80 ⇒ OK
   $RL_{last\ pt} - RL_{1st\ pt}$ = 603.80 – 600.00 = 3.80

3) 601.00 + 600.75 + 599.75 + 601.90 + 601.50 + 603.80 = 3608.70
   602.00 x 3 + 603.00 x 2 + 604.50 x 1 – 3.35 – 4.45 = 3608.70 ⇒ OK

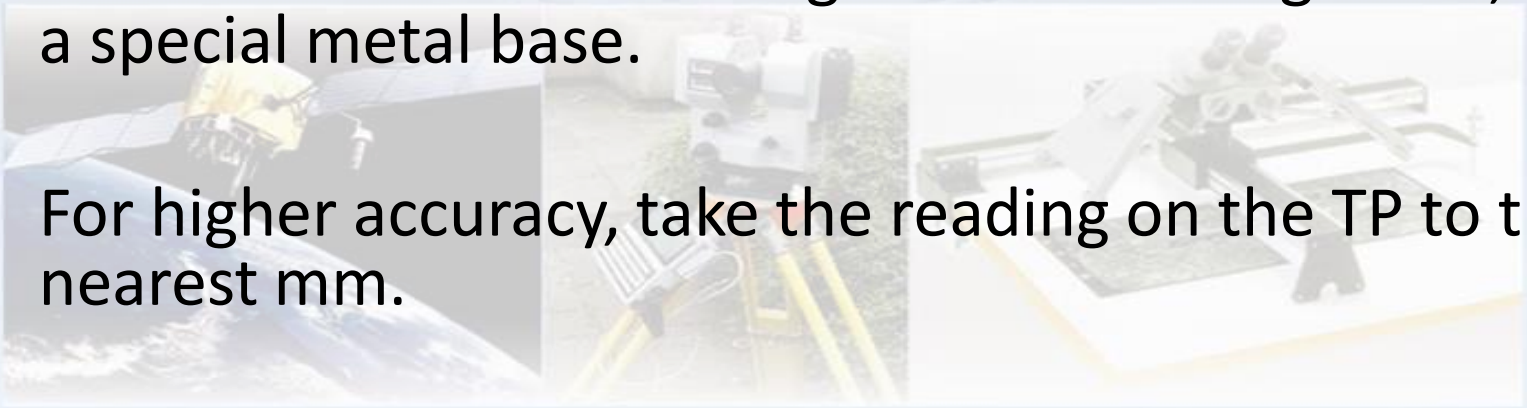
Point #	BS	IS	FS	Rise	Fall	HI	RL	Distance	Remarks
BM	2.00					602.00	600.00	0	BM
A		1.00		1.00			601.00	10	
B		1.25			0.25		600.75	20	
C	3.25		2.25		1.00	603.00	599.75	35	TP
D		1.10		2.15			601.90	45	
E	3.00		1.50		0.40	604.50	601.50	65	TP
F			0.70	2.30			603.80	85	
Σ	8.25	3.35	4.45	5.45	1.65				



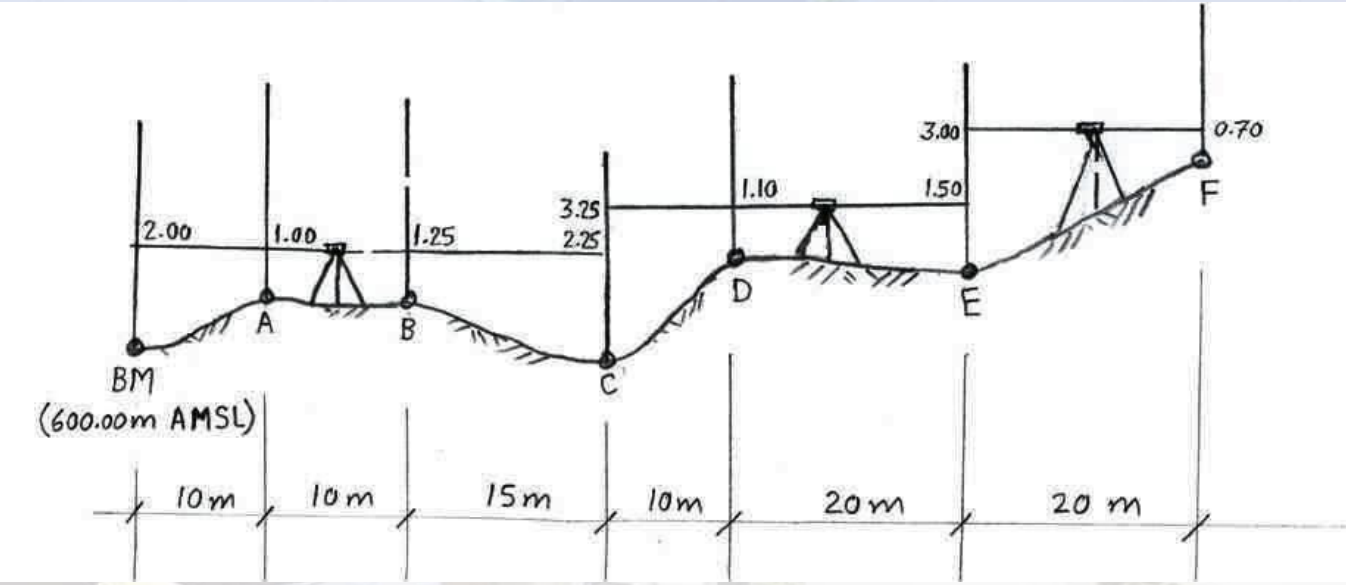
$$\Delta H = RL_{last} - RL_{st}$$
$$= \Sigma BS - \Sigma FS$$
$$= \Sigma Rise - \Sigma Fall$$

4.9 GENERAL NOTES

- Start leveling from a BM and end it at another BM, or go back and close at the starting point.
- If only ΔH is needed between the first and last points, no need to take IS.
- Equal BS and FS distances.
- Choose TP to be on a firm ground. On soft ground, use a special metal base.
- For higher accuracy, take the reading on the TP to the nearest mm.



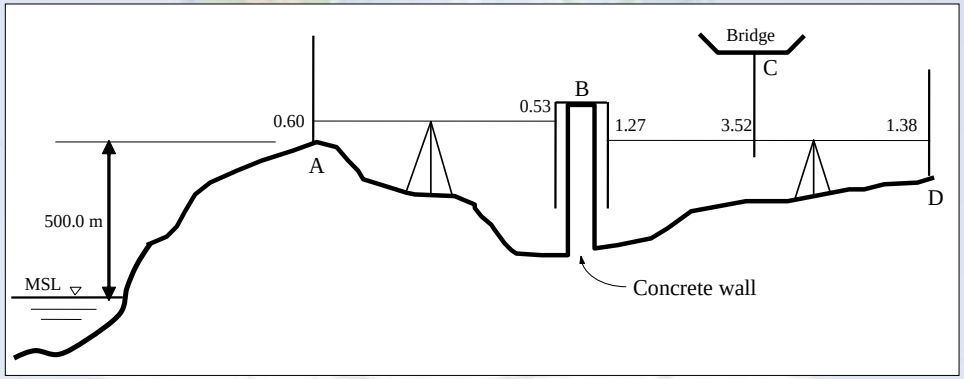
- Leveling does not have to start from a BM. The BM could be the last point, or a point on the way of the leveling chain.



- If the point is above the line of sight, the reading is taken with the staff upside-down and registered as a –ve value.

EXAMPLE:

Using the data shown in the following Figure, do the required booking, and calculate the reduced levels of points A, B, C & D by both the height of instrument and rise and fall methods. Make the required arithmetic checks.



SOLUTION:

Point	BS	IS	FS	Rise	Fall	HI	RL	Notes
A	0.60					500.60	500.00	BM
B	-1.27		-0.53	1.13		499.86	501.13	Top of concrete wall (TP)
C		-3.52		2.25			503.38	Bottom of bridge
D			1.38		4.90		498.48	
SUM	-0.67	-3.52	0.85	3.38	4.90			

Checks:

1) # of BS = # of FS = 2 $\Rightarrow$ OK

2) $\Sigma BS - \Sigma FS = -0.67 - 0.85 = -1.52$

$\Sigma Rise - \Sigma Fall = 3.38 - 4.90 = -1.52 \Rightarrow$ OK

$RL_{last} - RL_{1st} = 498.48 - 500.00 = -1.52$

4.10 ERRORS IN DIFFERENTIAL LEVELING

- **a) Systematic errors:**

1. Inclination of the line of sight due to the earth's curvature and atmospheric refraction.

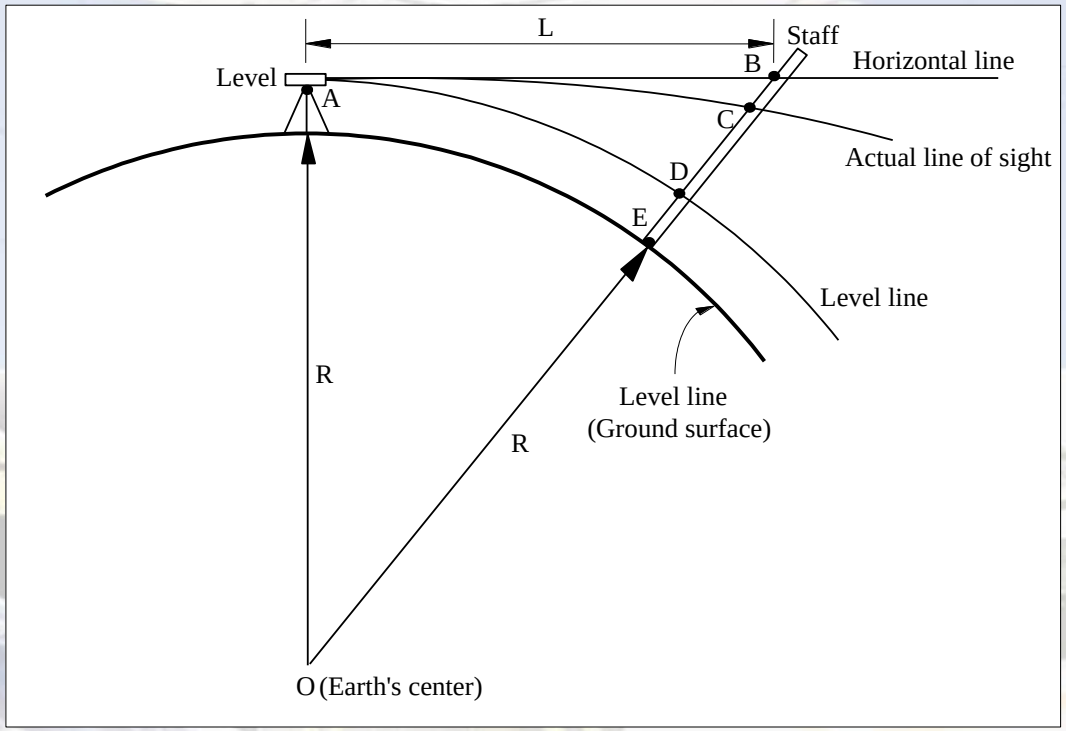


FIGURE 4.12: Effect of earth's curvature and atmospheric refraction on differential leveling.

2) Inclination of the line of sight due to maladjustment of the level.

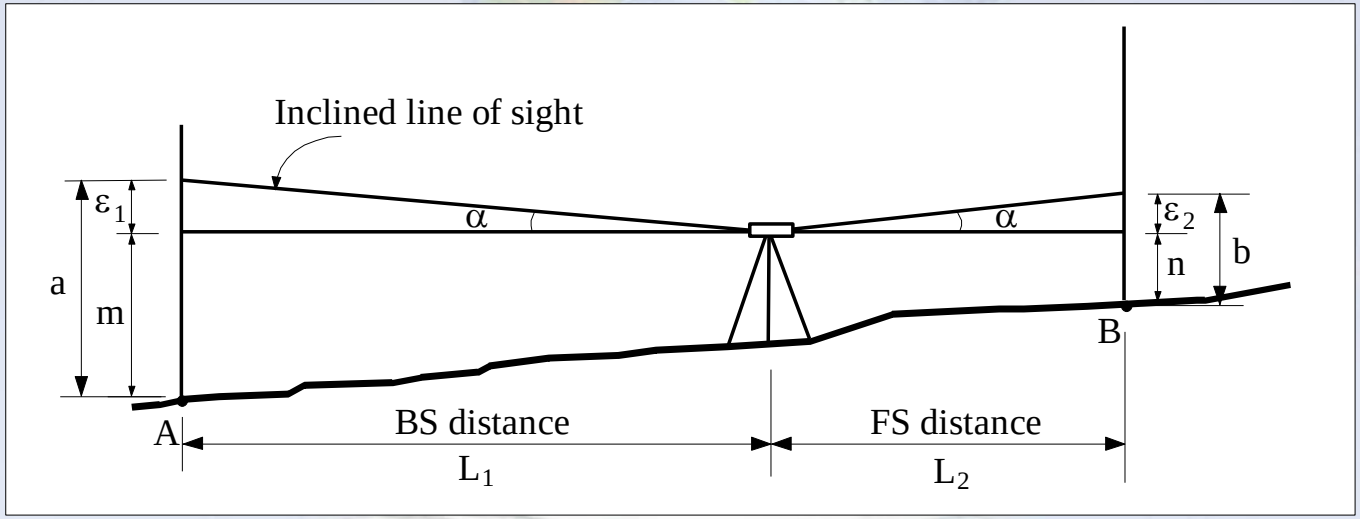


FIGURE 4.13: Error due to the maladjustment of the level.

b) Random errors

c) Blunders or mistakes

4.11 RECIPROCAL LEVELING

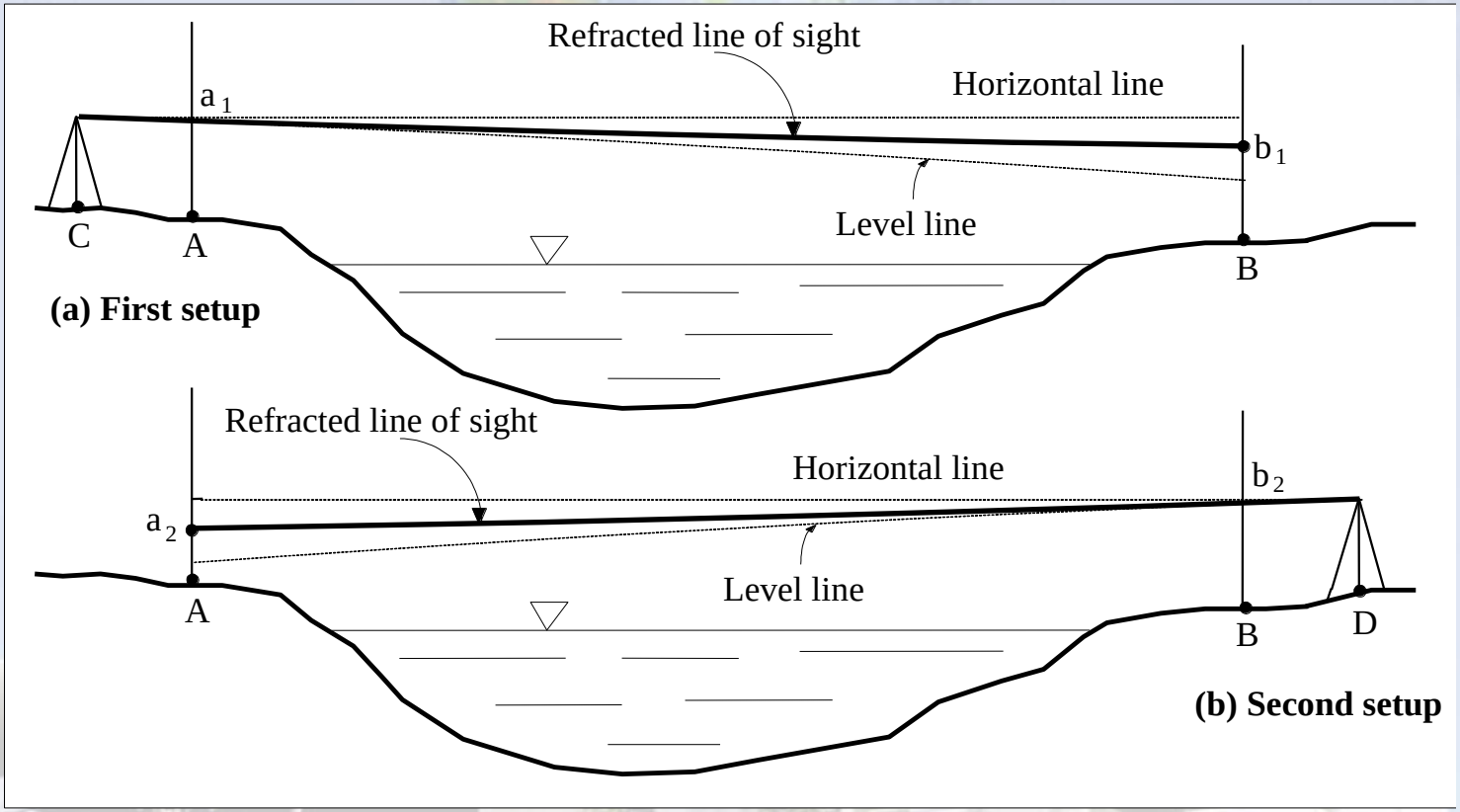


FIGURE 4.15: Reciprocal leveling.

4.12 CLOSURE ERROR

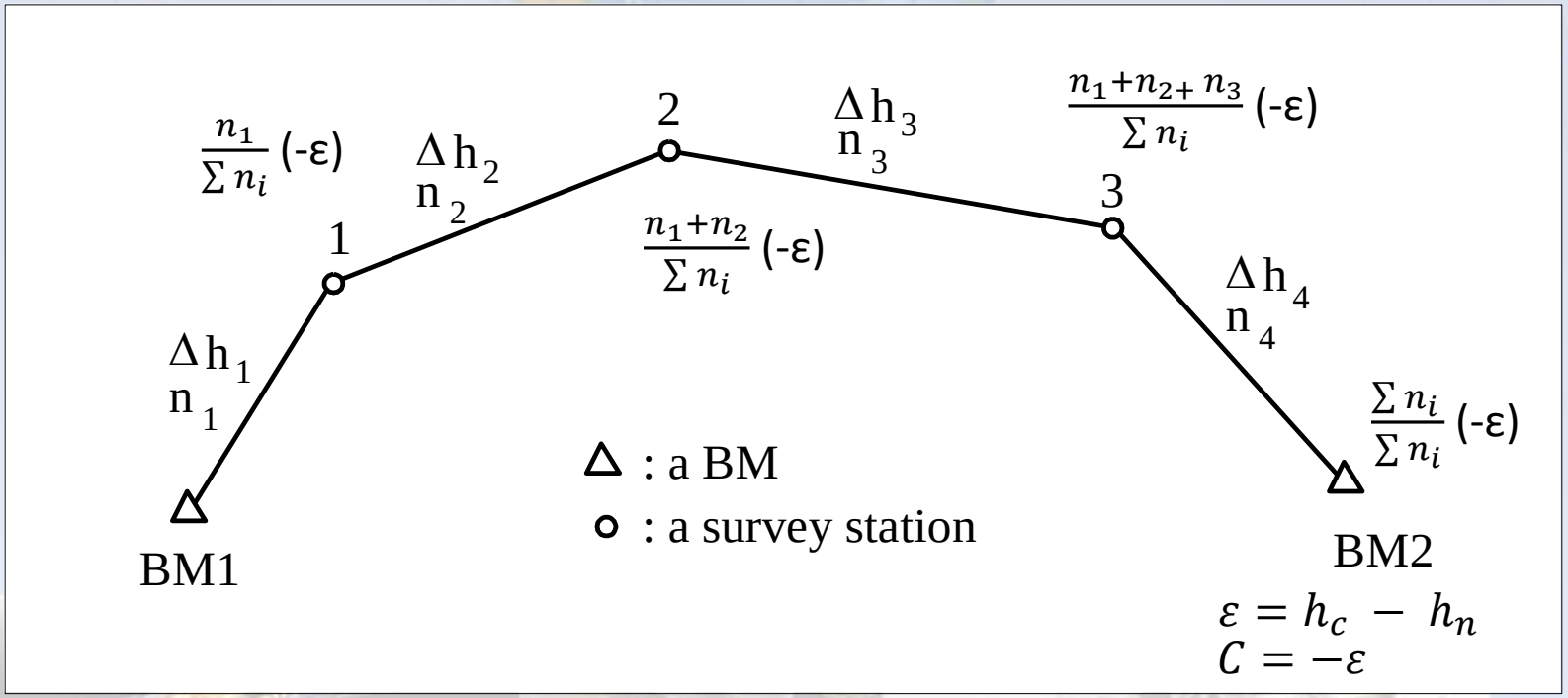


FIGURE 4.16: A level line which starts at a BM and closes at a different BM.

4.13 CLASSES AND ACCURACY OF LEVELING

- Precise Leveling.

- Ordinary Leveling.

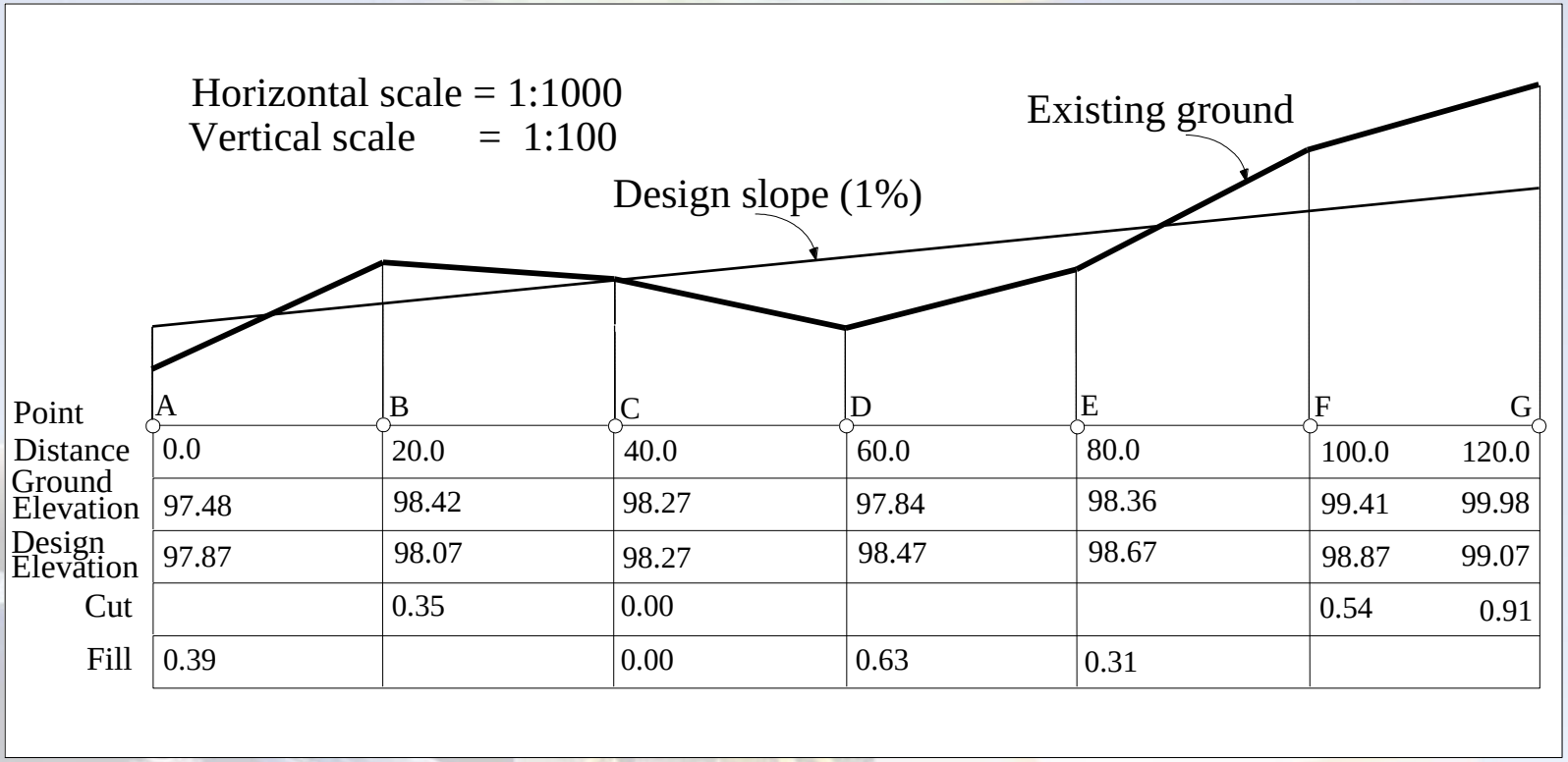
$$\varepsilon = \pm k\sqrt{D}$$

k = 2-5 mm (precise)

= 10-30 mm (ordinary)

4.14 APPLICATIONS OF LEVELING

1)LONGITUDINAL SECTIONS (PROFILES):



Point	A	B	C	D	E	F	G
Distance	0.0	20.0	40.0	60.0	80.0	100.0	120.0
Ground Elevation	97.48	98.42	98.27	97.84	98.36	99.41	99.98
Design Elevation	97.87	98.07	98.27	98.47	98.67	98.87	99.07
Cut		0.35	0.00			0.54	0.91
Fill	0.39		0.00	0.63	0.31		

FIGURE 4.17: A longitudinal section (profile) of the data of Table 4.2.

2) CROSS-SECTIONS:

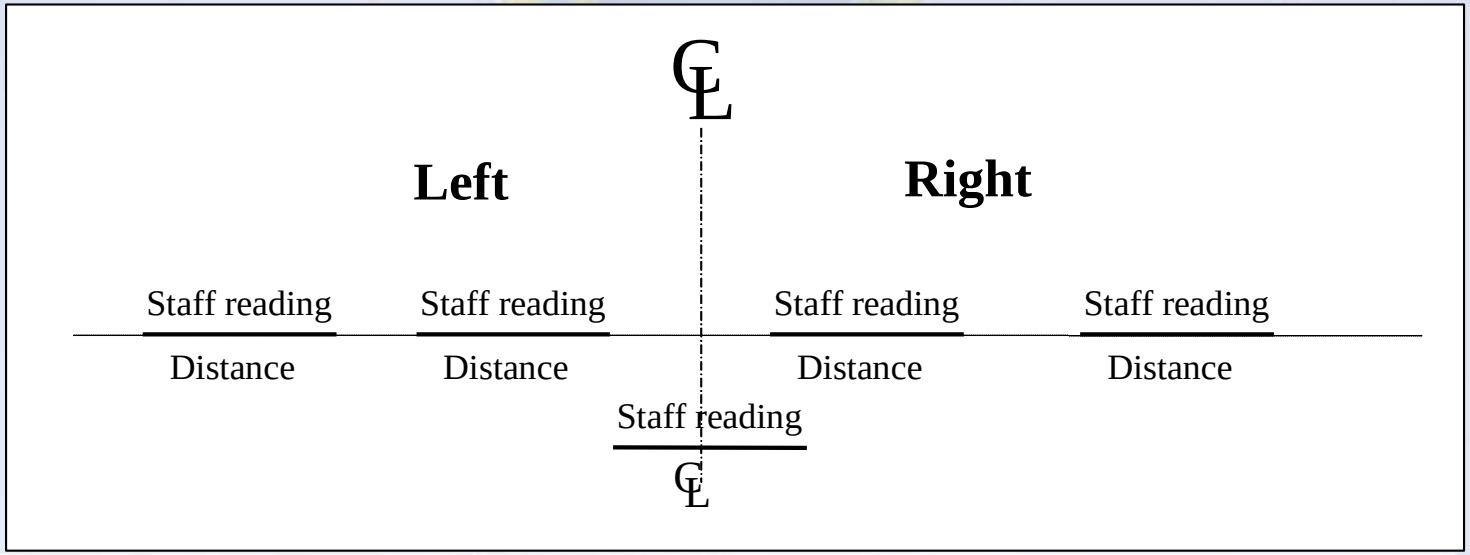


FIGURE 4.18: Booking leveling data for making cross-sections.

3) CONTOURING:

A *contour* is an imaginary line connecting points on the ground that have the same elevation.

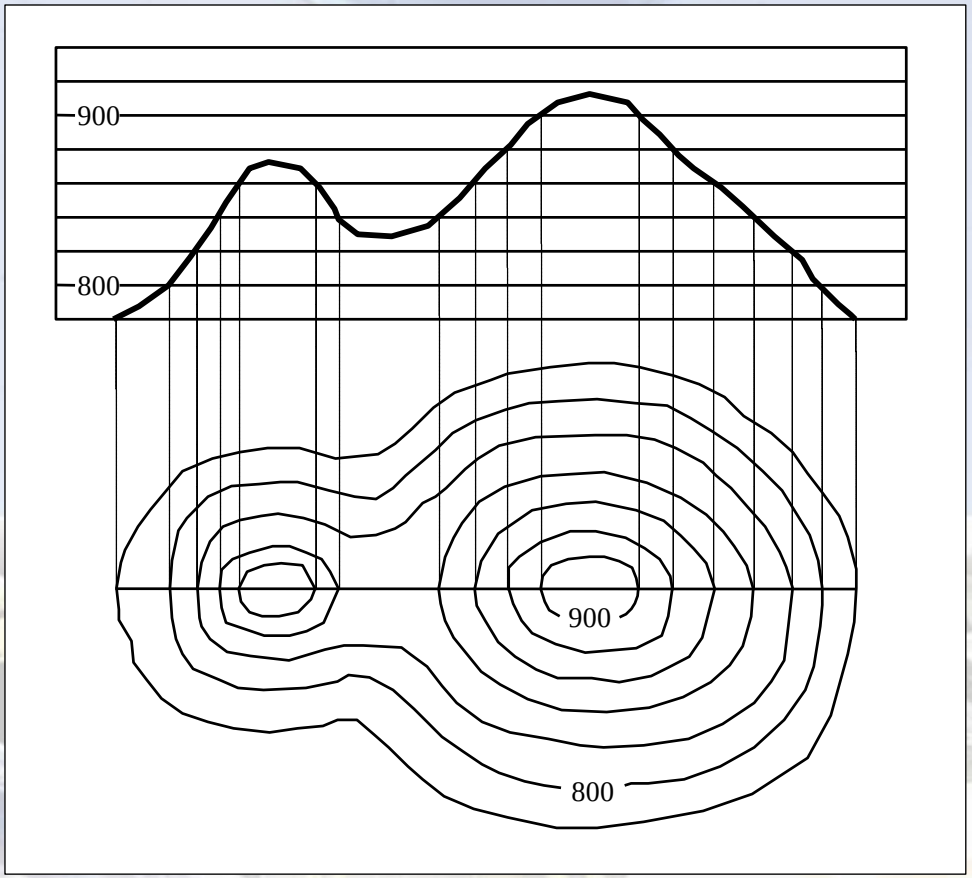


FIGURE 4.19: Contours and ground profile.

Characteristics of Contours:

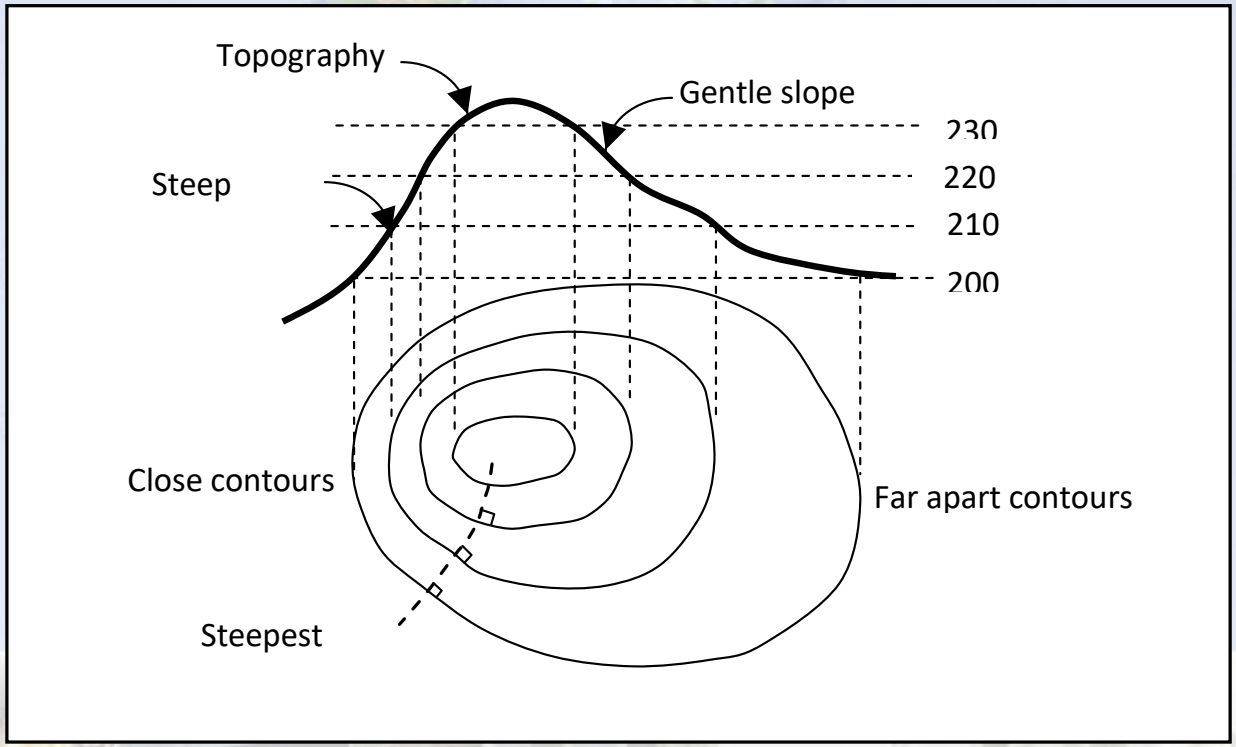


FIGURE 4.20: Relationship between contour spacing and topography slope.

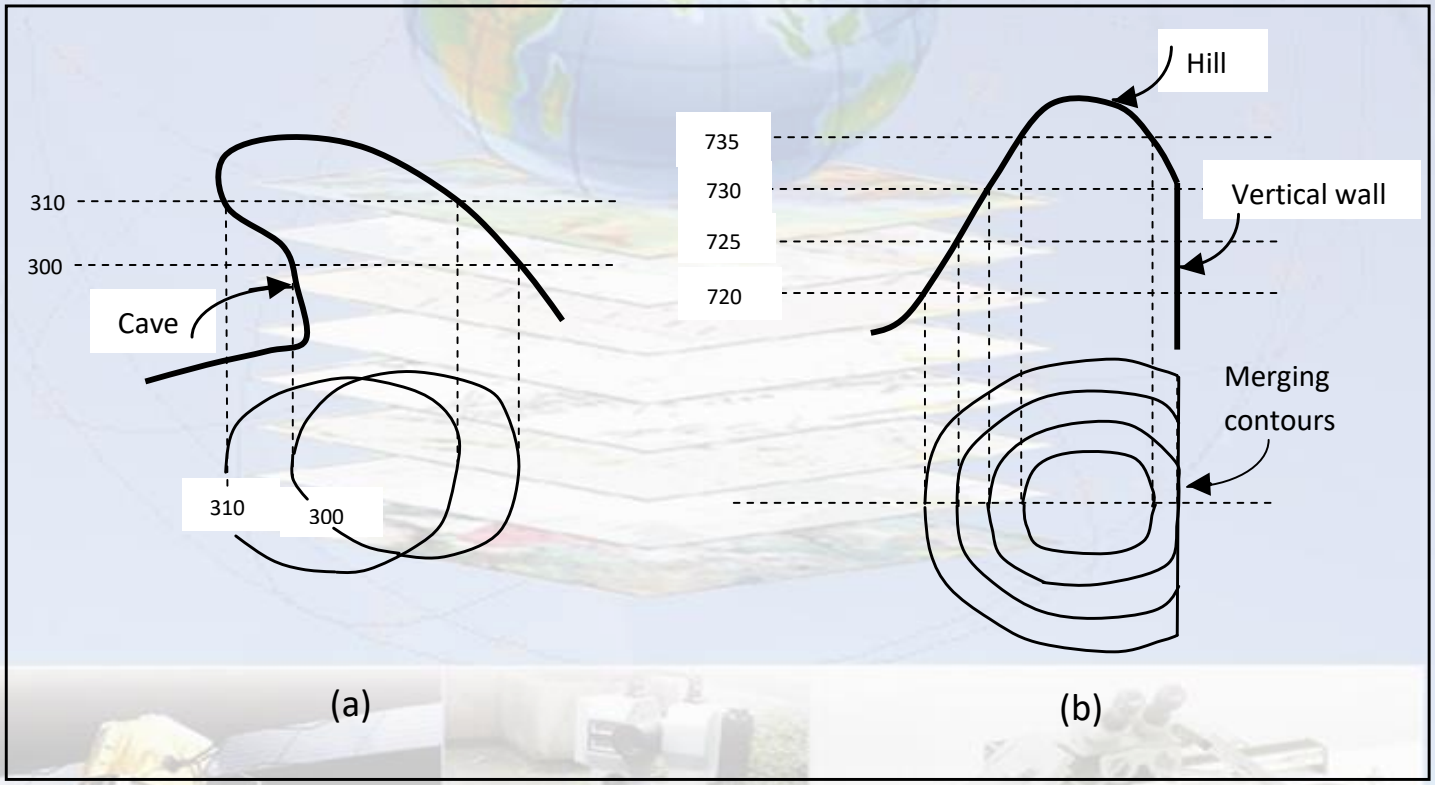


FIGURE 4.21: Examples of intersecting and merging contours.

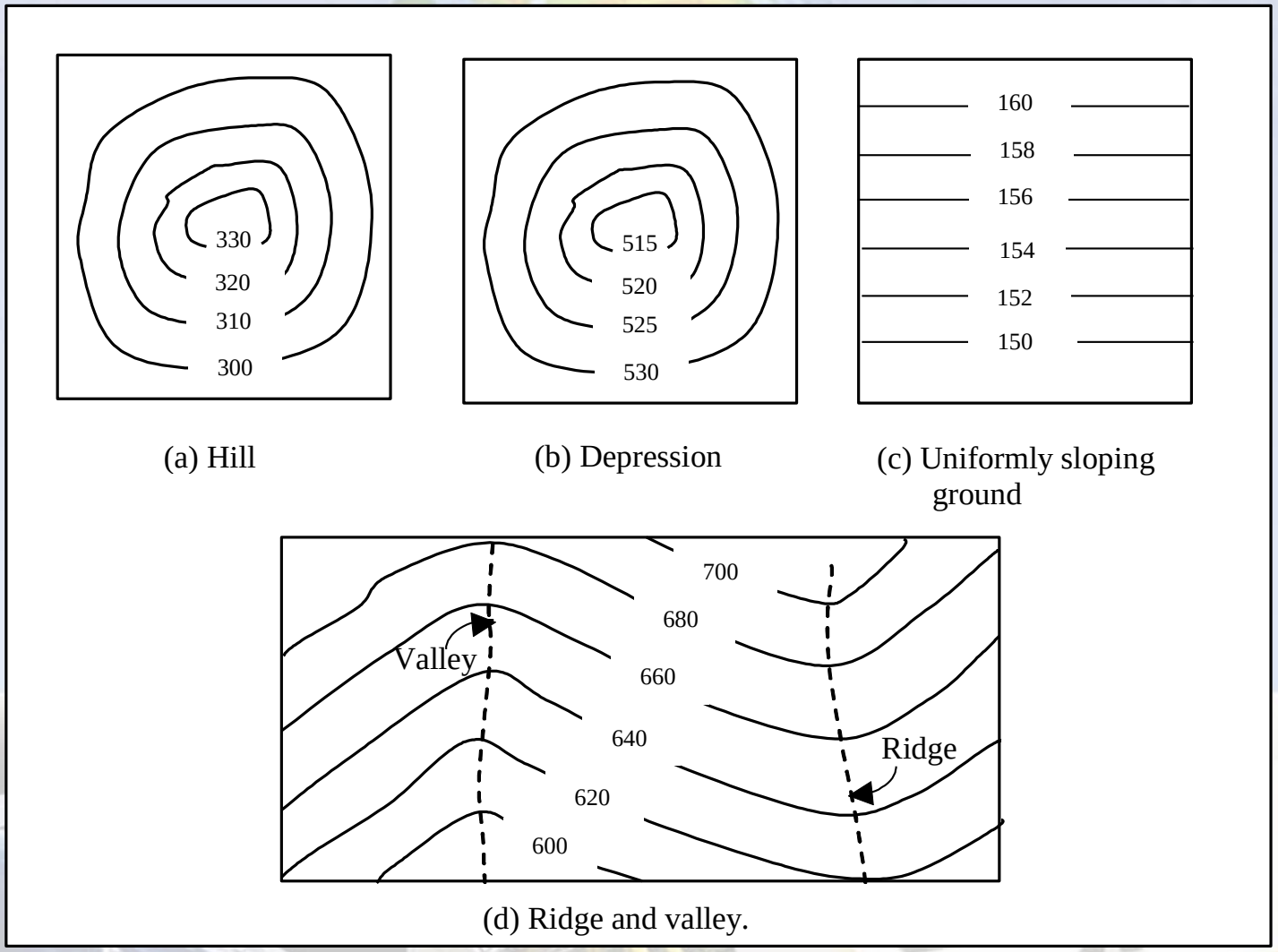
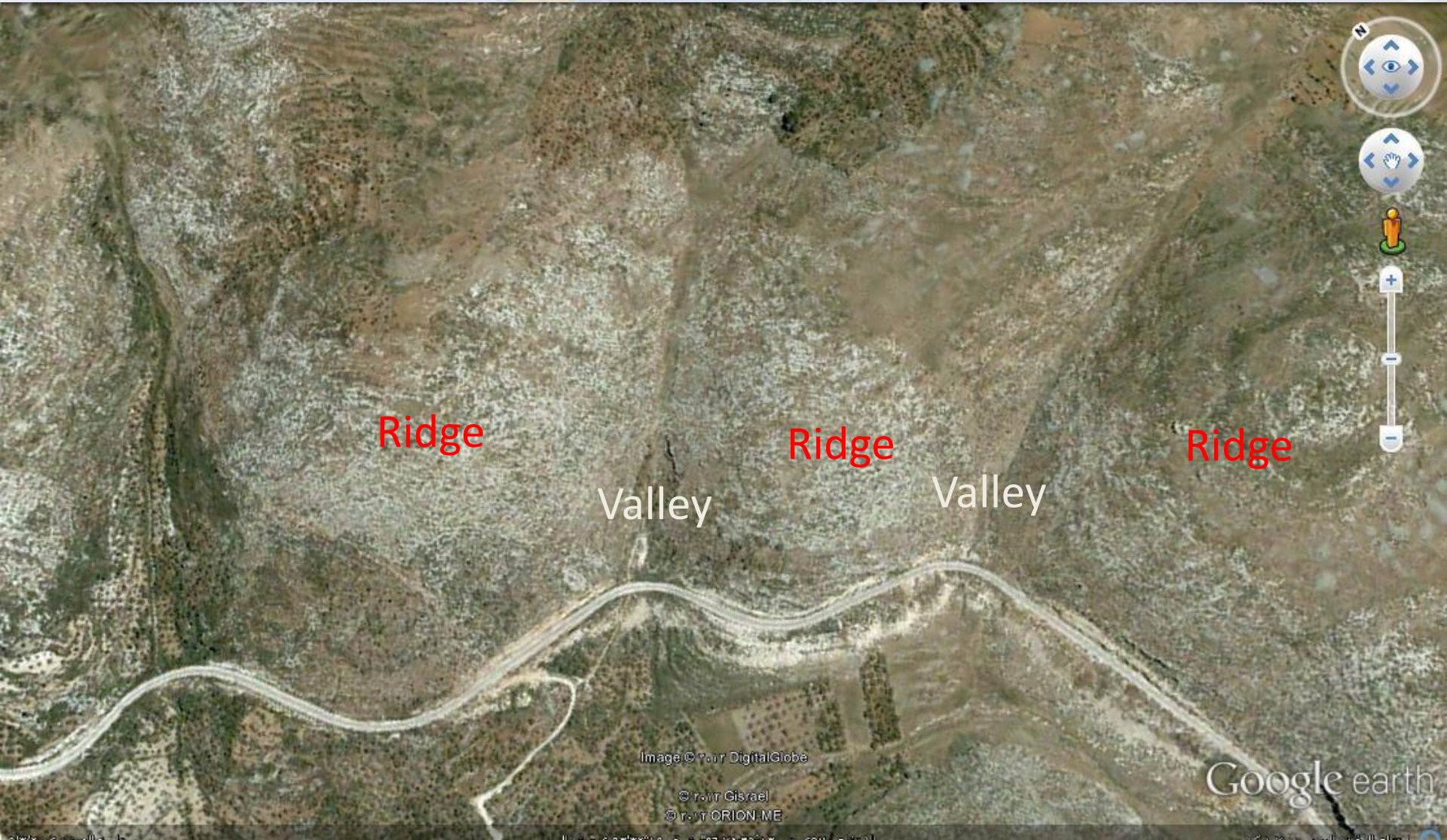


FIGURE 4.22: Examples of contours for different types of terrain.

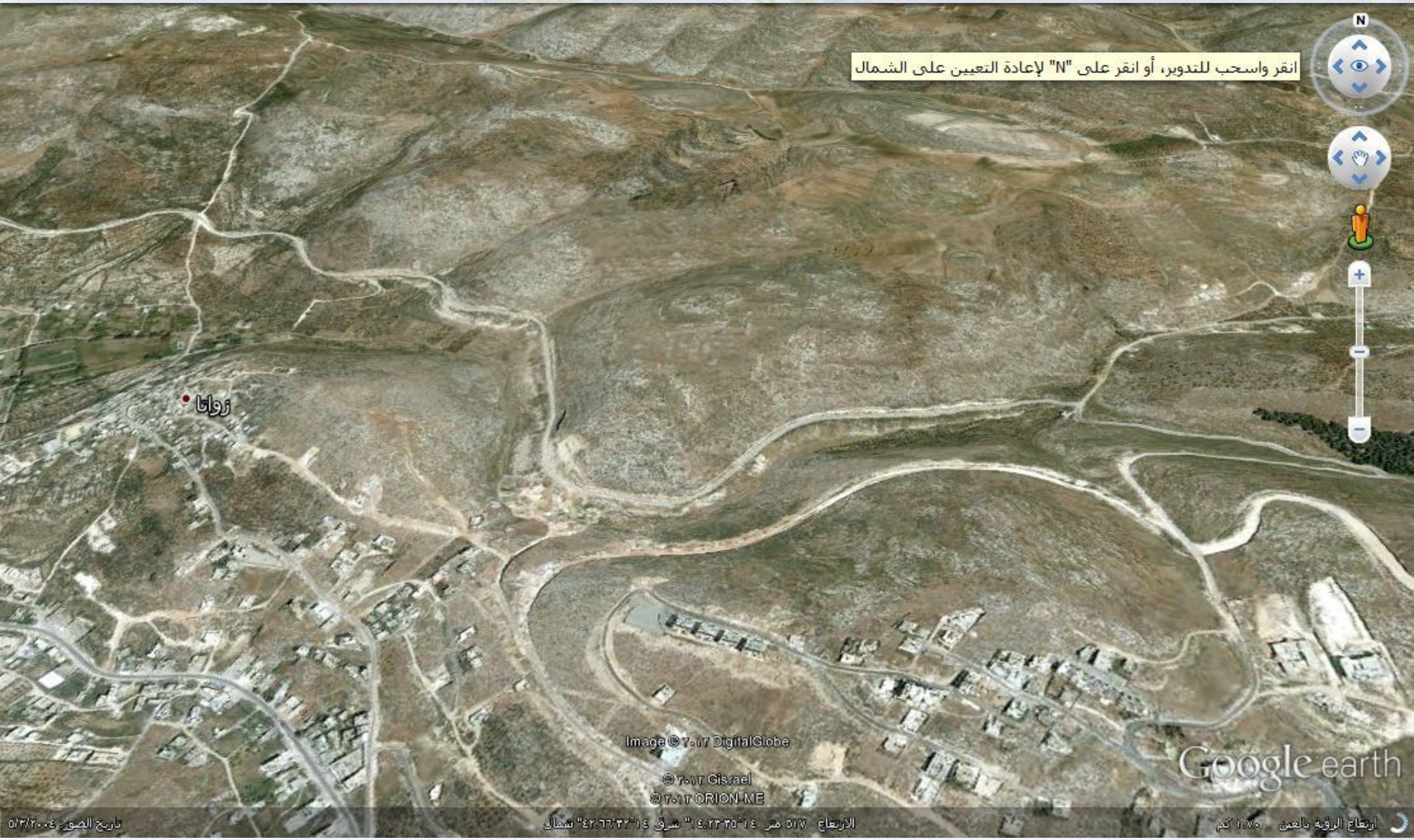
Ridge and Valley

View 1



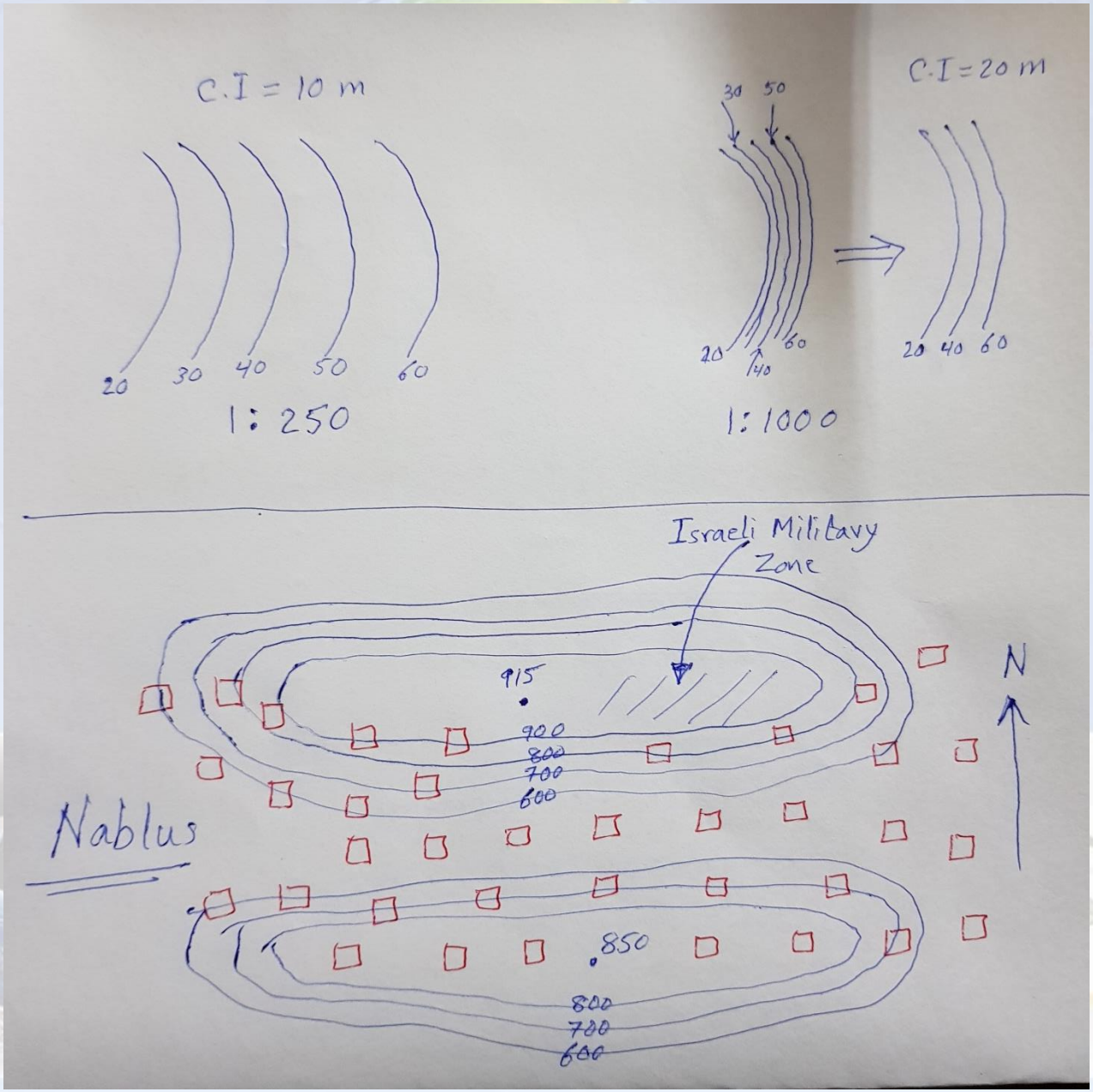
Ridge and Valley

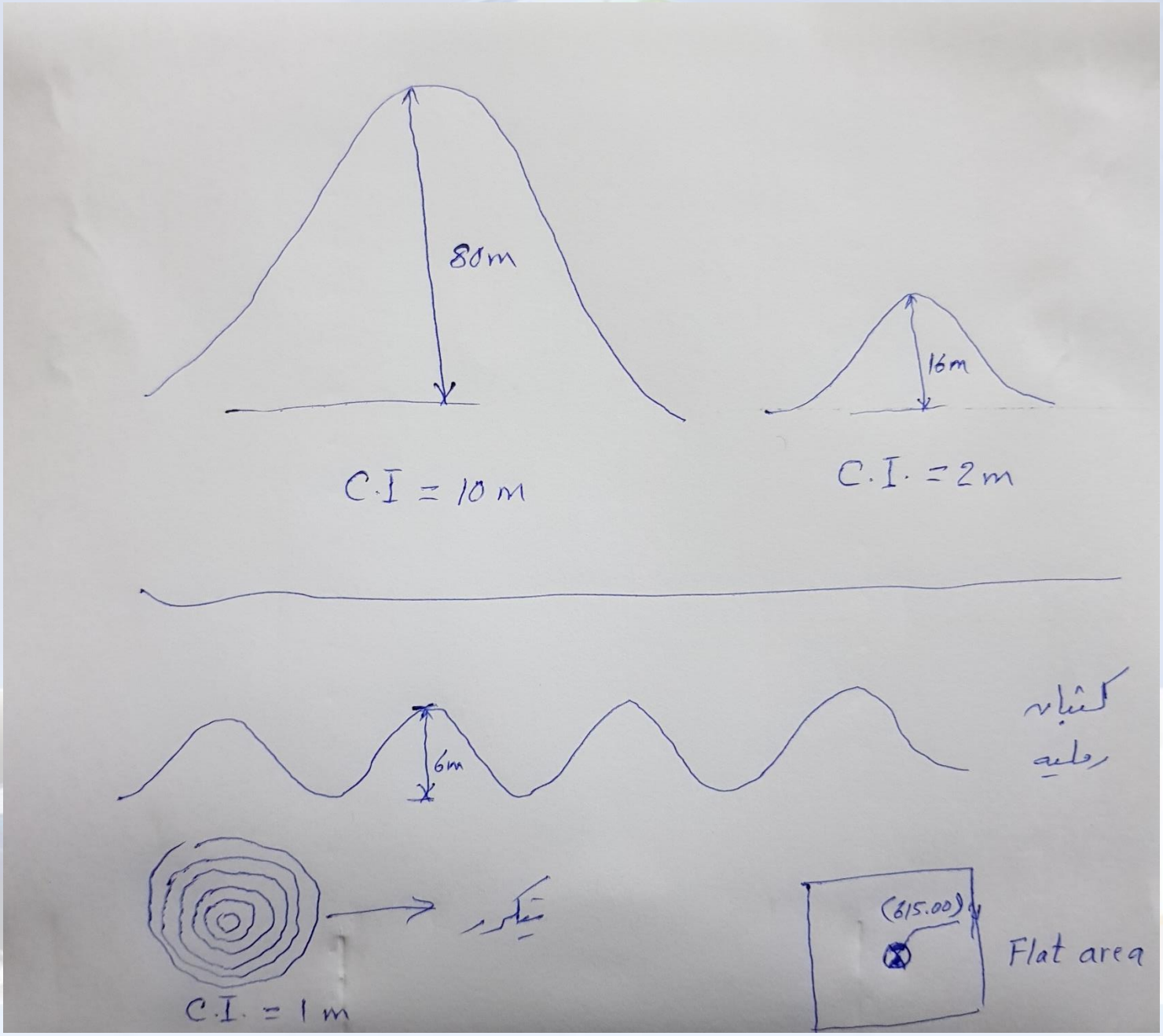
View 2



Factors affecting the choice of contour intervals:

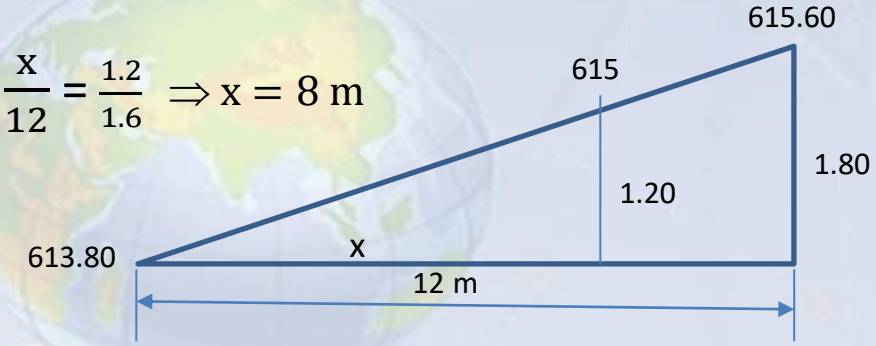
- Scale.
- Importance and purpose for which the plan is to be used.
- Accuracy, time and cost of the contour plan.
- Topographic variation of the area.
- Size of the area.


C.I = 10 m
20
30
40
50
60
1: 250
30
50
C.I = 20 m
20
40
60
20
40
60
1: 1000
Israeli Military Zone
915
900
800
700
600
N
Nablus
850
800
700
600


80m
C.I = 10 m
16m
C.I. = 2m
6m
كنبار
وطيه
C.I. = 1 m
(615.00)
Flat area

Griding:

$$\frac{x}{12} = \frac{1.2}{1.6} \Rightarrow x = 8\ \text{m}$$



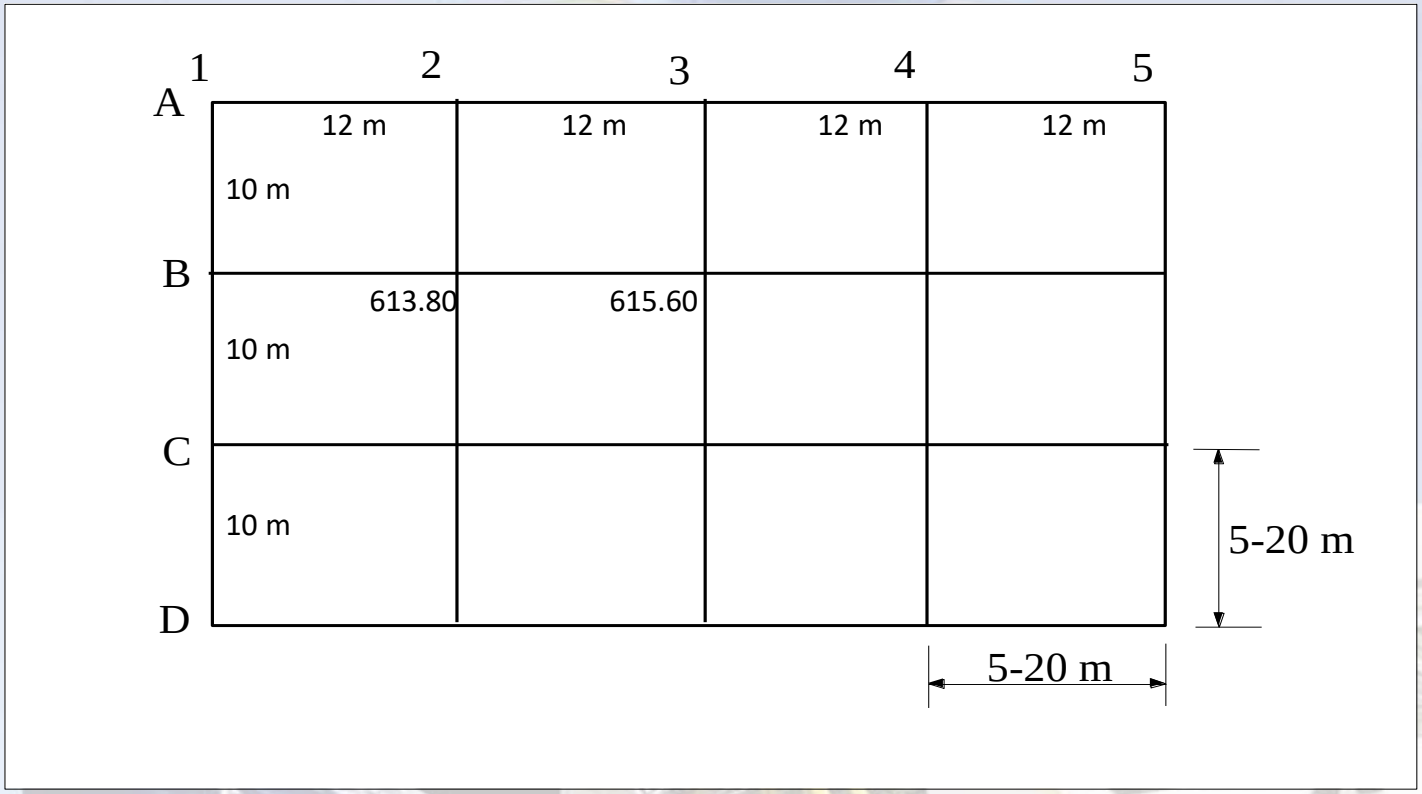


FIGURE 4.23: Griding.

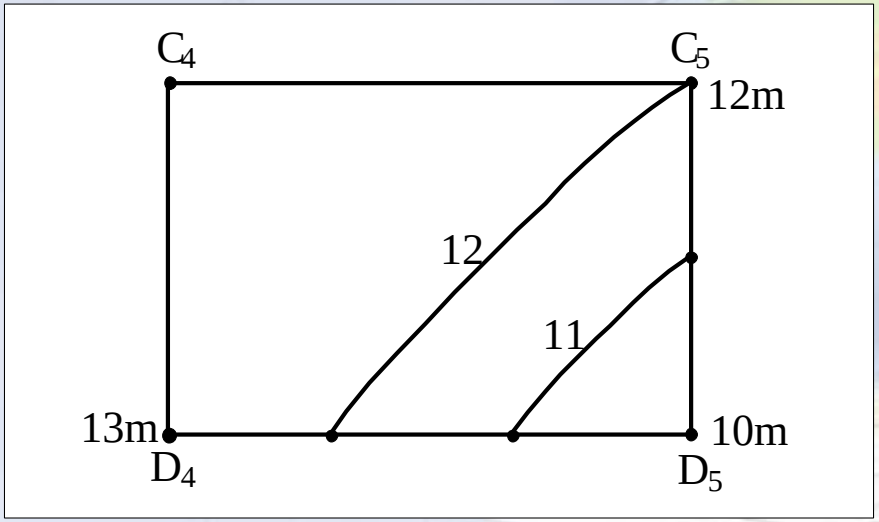


FIGURE 4.25: Plotting contour lines.

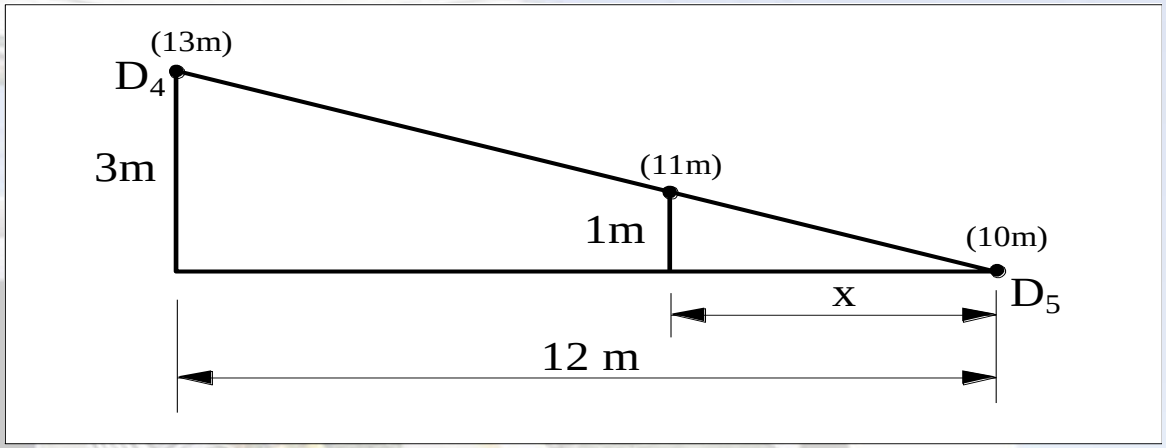


FIGURE 4.24: Linear interpolation.