Surveying

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Lectures
Spring
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Lecture 4 / LEVELLING

Levelling is a method of establishing elevations relative to a starting Level or a (Datum).

Horizontal line is perpendicular to line of gravity (vertical line)

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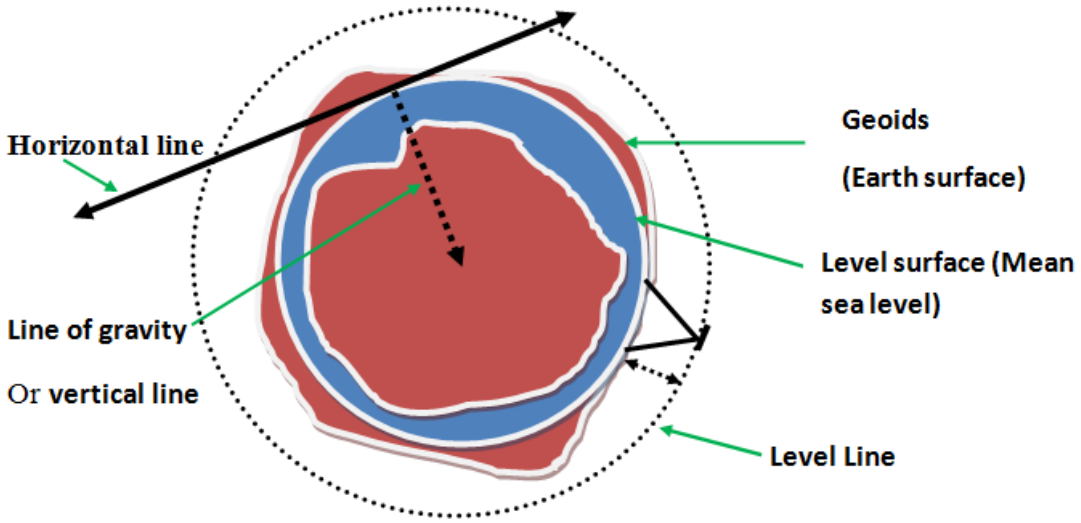


Definitions

A level surface is any surface perpendicular to the direction of gravity at any point on the surface of the earth.

A level line: is a line lying on a level surface.

A horizontal plane through a point is a plane perpendicular to the plumb line through the point. It is tangential to the level surface through the point.

A horizontal line is any line lying on the horizontal plane.

A vertical line at any point is one in which a plumb bob would hang, and is perpendicular to the level surface through that point.

A vertical plane: is a plane containing a vertical line.

A datum: Fixed elevation, such as mean sea level, used as the starting point for a vertical survey.
The "datum surface "or" datum plane" is the plane to which all vertical distances or elevations in survey work are referred to. It is a plane having

an elevation of zero. Mean sea levels is used as the standard datum. For minor surveys; an ***assumed datum*** may be used.

The elevation of a point:

It is vertical distance above or below a datum. It is known as a reduced level (R. L). The elevation of a point in *plus* or *minus*, according as the point is above or below the datum.

The difference in elevation between two points is the vertical distance between the level surfaces passing through the points.

A bench mark (B.M):

Is a point or station of known elevation. It is the station from which relative elevations of other stations are taken. Bench marks may be *permanent*, *arbitrary* or *temporary*.

- Bench mark (**B.M**.): Is permanent point with known elevation. They are bronze disks or plugs set usually into vertical wall faces.

- Temporary bench mark (**T.B.M**.): Is a semi-permanent point of known elevation (nail of street, corner of building, etc.).

- Back sight (**B.S.**): Is a rod reading taken a point of known elevation, to establish the elevation of the instrument line of sight.

- The height of instrument (**HI**) is the elevation of the line of sight through the level ($\boldsymbol{HI = BM + BS}$).

- Foresight (**F.S.**): A rod reading taken on turning point, bench mark, or temporary bench mark to determine its elevation ($\boldsymbol{HI - FS = elevation of TP}$).

- Turning point (**T. P.**): Is a point temporary used to transfer an elevation.

- Intermediate foresight (**I.S or I.F.S**) is a rod reading taken at any other point where the elevation is required ($\boldsymbol{HI - IS = elevation}$)

Main parts:

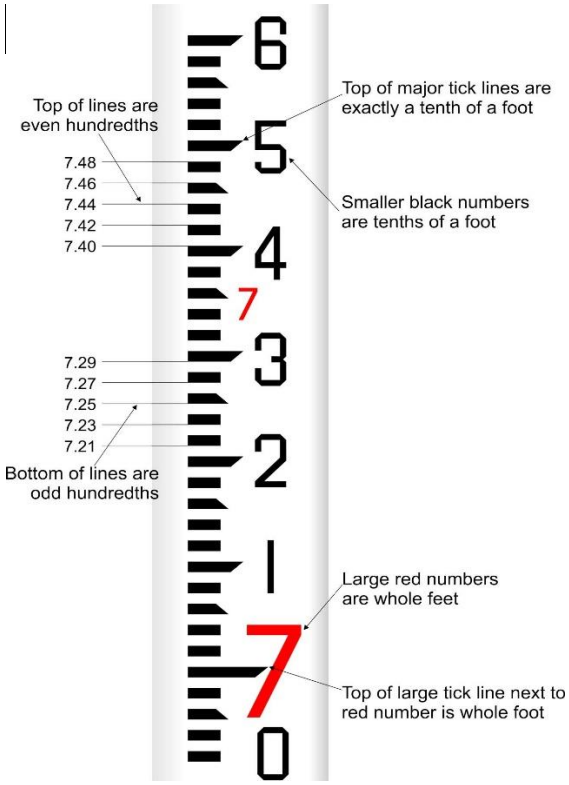
1- Level instrument:

2- Tripod: A tripod is a three-legged stand used to support a level.

3- Level staff: -

- The vertical distance above or below the horizontal surface is read off a levelling staff. It may be either telescope or folding extending to a length of 4m or 5m.

- The staff must be held vertically as any leaning of the staff will result in a level reading which is too great. Reading can be taken by holding the staff lightly between the palms of both hands on either sides of the staff.
- The material of level staff maybe steel, wood or aluminum.

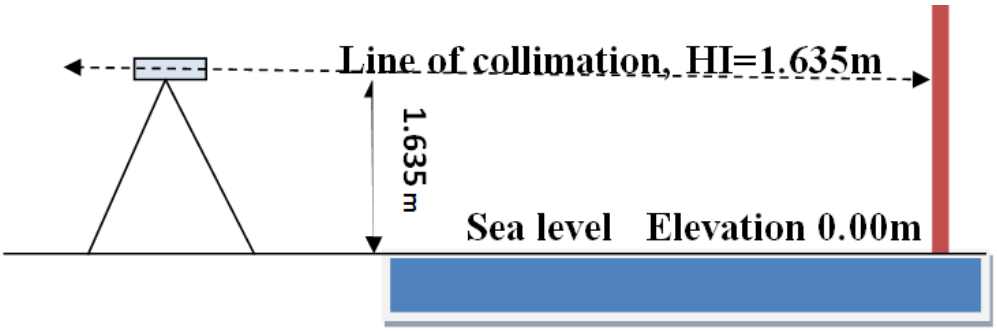


Determination of elevations:

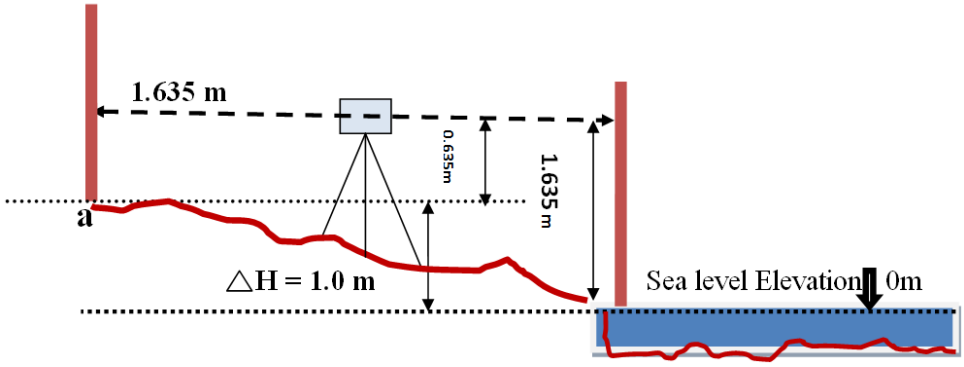
If the determination of elevation starts from the sea level as a permanent datum. Mean sea level then, is regarded as zero level, the sea level elevation = 0.000 m which may written as (Sea $_{el.}$ = 0.00 m). Sighting of a staff erected perpendicular on this surface by a level instrument is the beginning of the operation, whereas staff reading (say 1.635 m) determines that the line of collimation of the level instrument is higher than the sea level by 1.635m, we can then compute the elevation of the sight line (which is called sometimes HI) as;

HI = Elevation of Datum + Staff reading

HI= 0.000 + 1.635 = 1.635 m



Now we have an instrument of a height 1.635 m above the sea level, we can use it to find the elevation of any possible point, say (a) if the staff reading on point a is o.635 m, that means that the elevation of point a = 1m above the sea level.

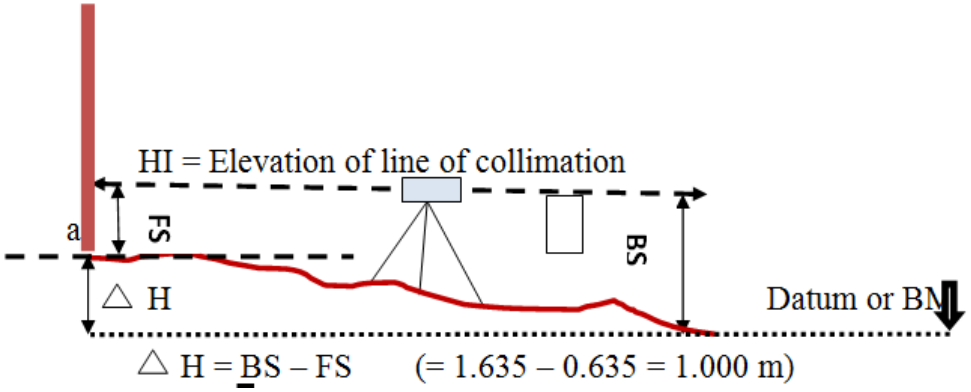


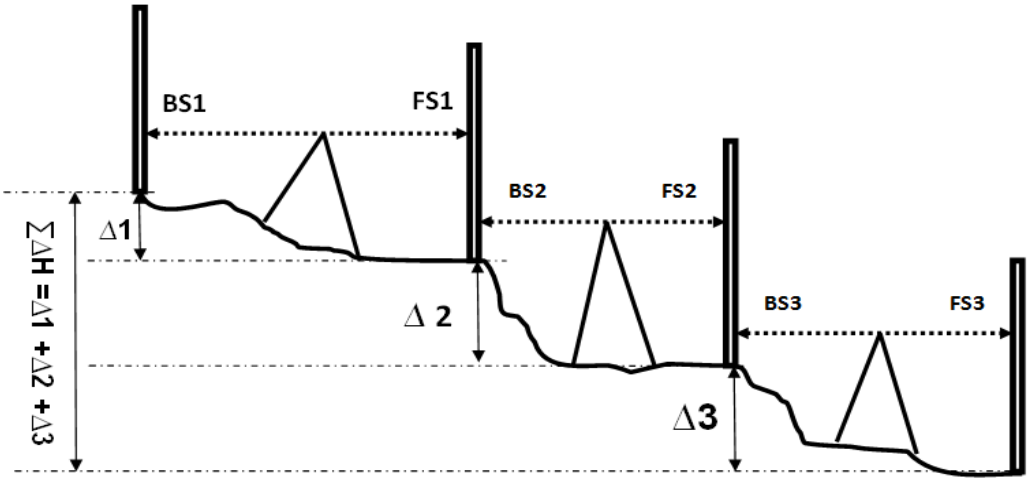
Technically, Staff reading on starting point of known elevation '***Bench Mark***' or a surface of a known elevation is called ***"Back Site***" or " B.S." but the staff reading on a point of unknown elevation is known as ***Fore Site*** or " F.S.", and then;

HI = B.S + Elevation of Datum, or HI = B.S + Elevation of B.M.

HI = 0.000 m+ 1.635 m = 1.635 m, Elevation of point (a) = HI – F.S

Elevation of point (a) = 1.635 m – 0.635m = 1.000 m





Example;

Find the difference in elevation between points (a) and (d) shown on the above illustrated sketch, if staff reading on point (a) is 0.352 m, on point (b) 2.224 and 0.581m, on point (c) 3.359 and 0.697 m, and on point (d) 3.732m respectively.

SOLUTION:

From the definitions of BS and FS we can drive the following table:

Station	**BS (m)**	**FS (m)**	△ **H (m)**
a	0.352	-	-
b	o.581	2.224	△ H1 = 0.352-2.224 = **- 1.872**
c	0.697	3.359	△ H2 = 0.581-3.359 = **-2.778**
d	-	3.372	△ H3 = 0.697-3.372 = **-2.675**
∑	**1.049**	**8.955**	△ ∑ **H = 7.325**

1- $\sum \triangle \mathbf{H} = \triangle H1 + \triangle H2 + \triangle H3$

$= -1.872 + (-) 2.778 + (-) 2.675 = 7.325$ m

2- $\sum \triangle \mathbf{H} = \sum BS - \sum FS = 1.049 - 8.955 = 7.325$ m

3- $\sum \triangle$ **H** = Elevation (a) – Elevation (d)

How to Determine Elevations ?

1- You must have a bench mark (BM). If not assume that starting point is a BM of say 100 m. (e.g., Elevation $_{(a)}$ = 100m).
2- Erect a staff on the BM perpendiculary.
3- Sight a leveled level instrument to the staff and record the staff reading at the middle stadia as a Back Sight (BS).
4- Shift the staff to the point of the unknown elevation (e.g point b), staff reading is regarded as Fore Sight (FS).
5- Calculate Elevation (b) from the following steps.
Elevation $_{(a)}$ + BS = HI (Height of collimation)
HI = 100.000 m + 0.352m = 100.352 m
Elevation $_{(b)}$ = HI – FS on b
= 100.352 m – 2.224 = 98.128 m
6- For the determination further elevations, staff reading on point b will be regarded as BS and staff reading on the succeeding point is FS since we don't know its elevation.
7- We can arrange the process of determining the difference in elevation between points an and d in the following level book:

Station	**BS (m)**	**FS (m)**	**H I (m)**	**Elevation m**
a	0.352	-	100.352	**100.000**
b	o.581	2.224	98.709	98.128
c	0.697	3.359	96.047	95.350
d	-	3.372	-	**92.675**

$\sum \triangle$ **H** = Elevation (a) – Elevation (d)

= 100.00 – 92.675 = 7.325 m

Note that point b and c are called also turning points as;

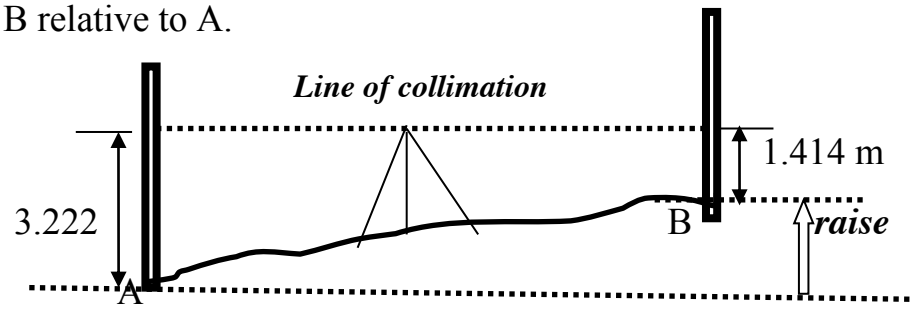
Turning Point (TP) or ***Changing Point***, it is an intermediate point between the starting and the end points. It denotes the shifting of the level instrument. Both of foresight and Back sight readings are taken on a turning point.

A *Station*: is a point whose elevation is to be determined. or a point which is to be established at a known elevation. It is the point where the staff is held, and not the point where the level is set up.

Procedures in leveling:

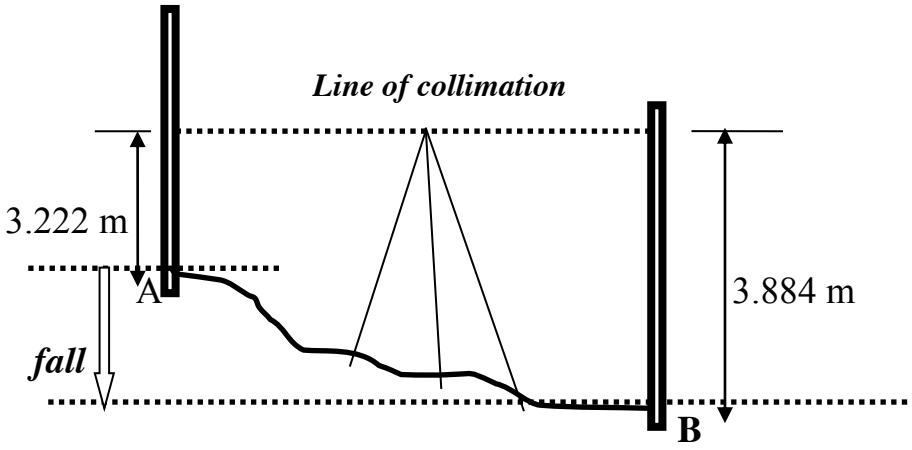
The basic operation is the determination of the difference in level between two points. Consider two points (A and B), If the readings on A and B are 3.222m and 1.414m respectively, then difference in level between them is:

3.222 – 1.414 = 1.808 m, and this represents a ***rise*** in the height of the land at B relative to A.



(Elevation $_A$ = 100 m)

If the reading at B is greater than that of A, say 3.484 then the difference in level would be 3.884 – 3.222 = 0.662 m, and this represents a ***fall*** in the height of the land at B in relative to A.



Thus we have that for any two successive staff readings:

2nd reading < 1st reading represents a raise, and 2nd > 1st represents a fall.

Elevation $_B$ = Elevation $_A$ + raise

= 100.00 + 1.808 = 101.808 m above datum. } Raise and fall

Elevation $_B$ = Elevation $_A$ – fall } method

= 100.00 – 0.662 = 99.338 m above datum

Elevation $_B$ = HI – reading at B

= 103.222 – 1.414 = 101.808 m } Height of collimation method

Elevation $_B$ = HI – reading at B

= 103.222 – 3.884 = 99.338 m

1. Standard levelling field book format (HI method):

Station	B.S.	I.S.	F.S.	H.I.	R.L.	Remark
A	0.725			100.725	100.000	B.M.
B		1.354		100.725	99.371	
C		1.025		100.725	99.700	
D	2.120		1.250	101.595	99.475	
E			0.877		100.718	
Summation	2.845		2.127			

$$\boldsymbol{HI = BS + FS}\ , \qquad \boldsymbol{Elev. = HI - F.S\ or\ I.S}$$

$$\boldsymbol{for\ checking}: \sum \boldsymbol{B.S.} - \sum \boldsymbol{F.S.} = \boldsymbol{R.L\ (last)} - \boldsymbol{R.L\ (first)}$$

2. Standard levelling field book format (Rise and Fall method):

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remark
A	0.725					100.000	B.M.
B		1.354			0.629	99.371	
C		1.025		0.329		99.700	
D	2.120		1.250		0.225	99.475	
E			0.877	1.243		100.718	
Summation	2.845		2.127	1.572	0.854		

$$\boldsymbol{\Sigma B.S. - \Sigma F.S. = \Sigma Rise - \Sigma Fall = Last R.L. - First R.L}$$