LECTURES NOTE

LAND SURVEY – I

4th SEMESTER
DIPLOMA (CIVIL ENGINEERING)

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Th3. LAND SURVEY – I

Name of the Course: Diploma in Civil Engineering			
Course code:		Semester	4th
Total Period:	75	Examination	3 hrs
Theory periods:	5P/week	Class Test:	20
Maximum marks:	100	End Semester Examination:	80

A. RATIONALE

Survey is an essential prerequisite for all types of civil construction activities. This course aims to provide knowledge in area of plane survey and the survey instruments. Besides, the course aims to provide students in map reading and area computations from survey data.

B. COURSE OBJECTIVES

On completion of the course students will be able to

1. Define various survey terminology and carryout necessary corrections for errors
2. Comprehend the principle, purpose, equipment and error corrections in chain and compass surveying
3. Comprehend the principle, purpose, equipment and error corrections in plane table and theodolite surveying
4. Comprehend the map nomenclature and apply skills in map interpretation
5. Gather skill towards leveling and contouring with knowledge of purpose and different methods thereof
6. Compute area and volume using different numerical algebraic methods

C. Topic Wise Distribution of Periods

Chapter	Name of topics	Periods
1	Introduction To Surveying, Linear Measurements	07
2	Chaining and Chain Surveying	07
3	Angular Measurement and Compas Surveying	12
4	Map Reading Cadastral Maps & Nomenclature	07
5	Plane Table Surveying	07
6	Theodolite Surveying and Traversing:	15
7	Levelling and Contouring	15
8	Computation of Area & Volume	05

D. Course Contents

1 INTRODUCTION TO SURVEYING, LINEAR MEASUREMENTS:

1.1 Surveying: Definition, Aims and objectives
1.2 Principles of survey-Plane surveying- Geodetic Surveying- Instrumental surveying.
1.3 Precision and accuracy of measurements, instruments used for measurement of distance, Types of tapes and chains.
1.4 Errors and mistakes in linear measurement – classification, Sources of errors and remedies.
1.5 Corrections to measured lengths due to-incorrect length, temperature variation, pull, sag, numerical problem applying corrections.

2 **CHAINING AND CHAIN SURVEYING :**

2.1 Equipment and accessories for chaining
2.2 Ranging – Purpose, signaling, direct and indirect ranging, Line ranger – features and use, error due to incorrect ranging.
2.3 Methods of chaining –Chaining on flat ground, Chaining on sloping ground – stepping method, Clinometer-features and use, slope correction.
2.4 Setting perpendicular with chain & tape, Chaining across different types of obstacles –Numerical problems on chaining across obstacles.
2.5 Purpose of chain surveying, Its Principles, concept of field book.
Selection of survey stations, base line, tie lines, Check lines.
2.7 Offsets – Necessity, Perpendicular and Oblique offsets, Instruments for setting offset – Cross Staff, Optical Square.
2.8 Errors in chain surveying – compensating and accumulative errors causes & remedies, Precautions to be taken during chain surveying.

3 **ANGULAR MEASUREMENT AND COMPAS SURVEYING :**

3.1 Measurement of angles with chain, tape & compass
3.2 Compass – Types, features, parts, merits & demerits, testing & adjustment of compass
3.3 Designation of angles- concept of meridians – Magnetic, True, arbitrary; Concept of bearings – Whole circle bearing, Quadrantal bearing, Reduced bearing, suitability of application, numerical problems on conversion of bearings
3.4 Use of compasses – setting in field-centering, leveling, taking readings, concepts of Fore bearing, Back Bearing, Numerical problems on computation of interior & exterior angles from bearings.
3.5 Effects of earth's magnetism – dip of needle, magnetic declination, variation in declination, numerical problems on application of correction for declination.
3.6 Errors in angle measurement with compass – sources & remedies.
3.7 Principles of traversing – open & closed traverse, Methods of traversing.
3.8 Local attraction – causes, detection, errors, corrections, Numerical problems of application of correction due to local attraction.
3.9 Errors in compass surveying – sources & remedies.
Plotting of traverse – check of closing error in closed & open traverse, Bowditch's correction, Gales table

4 **MAP READING CADASTRAL MAPS & NOMENCLATURE:**

4.1 Study of direction, Scale, Grid Reference and Grid Square
Study of Signs and Symbols
4.2 Cadastral Map Preparation Methodology
4.3 Unique identification number of parcel
4.4 Positions of existing Control Points and its types
4.5 Adjacent Boundaries and Features, Topology Creation and verification.

5 **PLANE TABLE SURVEYING :**

5.1 Objectives, principles and use of plane table surveying.
5.2 Instruments & accessories used in plane table surveying.
5.3 Methods of plane table surveying – (1) Radiation, (2) Intersection, (3) Traversing, (4) Resection.
5.4 Statements of TWO POINT and THREE POINT PROBLEM.
Errors in plane table surveying and their corrections, precautions in plane table surveying.

6 **THEODOLITE SURVEYING AND TRAVERSING:**

6.1 Purpose and definition of theodolite surveying

6.2 Transit theodolite- Description of features, component parts, Fundamental axes of a theodolite, concept of vernier, reading a vernier, Temporary adjustment of theodolite

6.3 Concept of transiting –Measurement of horizontal and vertical angles.

6.4 Measurement of magnetic bearings, deflection angle, direct angle, setting out angles, prolonging a straight line with theodolite, Errors in Theodolite observations.

6.5 Methods of theodolite traversing with – inclined angle method, deflection angle method, bearing method, Plotting the traverse by coordinate method, Checks for open and closed traverse.

6.6 Traverse computation – consecutive coordinates, latitude and departure, Gale's traverse table, Numerical problems on omitted measurement of lengths & bearings

6.7 Closing error – adjustment of angular errors, adjustment of bearings, numerical problems

6.8 Balancing of traverse – Bowditch's method, transit method, graphical method, axis method, calculation of area of closed traverse.

7 **LEVELLING AND CONTOURING :**

7.1 Definition and Purpose and types of leveling– concepts of level surface, Horizontal surface, vertical surface, datum, R. L., B.M.
7.2 Instruments used for leveling, concepts of line of collimation, axis of bubble tube, axis of telescope, Vertical axis.
7.3 Levelling staff – Temporary adjustments of level, taking reading with level, concept of bench mark, BS, IS, FS, CP, HI.
7.4 Field data entry – level Book – height of collimation method and Rise & Fall method, comparison, Numerical problems on reduction of levels applying both methods, Arithmetic checks.
7.5 Effects of curvature and refraction, numerical problems on application of correction.
7.6 Reciprocal leveling – principles, methods, numerical problems, precise leveling.
7.7 Errors in leveling and precautions, Permanent and temporary adjustments of different types of levels.
7.8 Definitions, concepts and characteristics of contours.
7.9 Methods of contouring, plotting contour maps, Interpretation of contour maps, toposheets.
7.10 Use of contour maps on civil engineering projects – drawing cross-sections from contour maps, locating proposal routes of roads / railway / canal on a contour map, computation of volume of earthwork from contour map for simple structure.
7.11 Map Interpretation: Interpret Human and Economic Activities (i.e.: Settlement, Communication, Land use etc.), Interpret Physical landform (i.e.: Relief, Drainage Pattern etc.), Problem Solving and Decision Making

8 **COMPUTATION OF AREA & VOLUME:**

8.1 Determination of areas, computation of areas from plans.
8.2 Calculation of area by using ordinate rule, trapezoidal rule, Simpson's rule.

8.3 Calculation of volumes by prismoidal formula and trapezoidal formula, Prismoidal corrections, curvature correction for volumes.

E. SYLLABUS COVERAGE UPTO INTERNAL ASSESSMENT

Chapters 1, 2, 3, 4, 5

G. RECOMMENDED BOOKS

Sl. No	Name of Authors	Titles of Book	Name of Publisher
1	R.Subramanian	Surveying and Levelling	Oxford
2	Dr.B.C.Punmia.	Surveying,Vol.-I&II	Laxmi Publication
3	R. Agor	A text Book of Surveying & Levelling	Khanna Publishers
4	N.N Basak.	Surveying & Levelling	TMH Publishing

LAND SURVEY - I

7. LEVELLING AND CONTOURING

7.1 Definition & Purpose & Types of Leveling – Concepts of Level Surface, Horizontal Surface, Vertical Surface, Datum, R. L., B.M.

Object

The aim of leveling is to determine the relative heights of different objects on or below the surface of the earth and to determine the undulation of the ground surface.

Uses

Leveling is done for the following purposes:

1. To prepare a contour map for fixing sites for reservoirs, dams, barrages, etc., and to fix the alignment of roads, railways, irrigation canals, and so on.
2. To determine the altitudes of different important points on a hill or to know the reduced levels of different points on or below the surface of the earth.
3. To prepare a longitudinal section and cross-sections of a project (roads, railways, irrigation canals, etc.) in order to determine the volume of earth work.
4. To prepare a layout map for water supply, sanitary or drainage schemes.

1. Leveling

The art of determining the relative heights of different points on or below the surface of the earth is known as leveling. Thus, leveling deals with measurements in the vertical plane.

2. Level Surface

Any surface parallel to the mean spherical surface of the earth is said to be a level surface. Such a surface is obviously curved. The water surface of a still lake is also considered a level surface.

3. Level Line

Any line lying on a level surface is called a level line. This line is normal to the plumb line (direction of gravity) at all points.

4. Horizontal Plane

Any plane tangential to the level surface at any point is known as the horizontal plane. It is perpendicular to the plumb line which indicates the direction of gravity.

5. Horizontal Line

Any line lying on the horizontal plane is said to be a horizontal line. It is a straight line tangential to the level line.

6. Vertical Line

The direction indicated by a plumb line (the direction of gravity) is known as the vertical line. This line is perpendicular to the horizontal line.

7. Vertical Plane

Any plane passing through the vertical line is known as the vertical plane.

8. Datum Surface or Line

This is an imaginary level surface or level line from which the vertical distances of different points (above or below this line) are measured. In India, the datum adopted for the Great Trigonometrically Survey (GTS) is the Mean Sea Level (MSL) at Karachi.

9. Reduced Level (RL)

The vertical distance of a point above or below the datum line is known as the reduced level (RL) of that point. The RL of a point may be positive or negative according as the point is above or below the datum.

10. Line of Collimation

It is an imaginary line passing through the intersection of the cross-hairs at the diaphragm and the optical centre of the object glass and its continuation. It is also known as the line of sight.

11. Axis of the Telescope

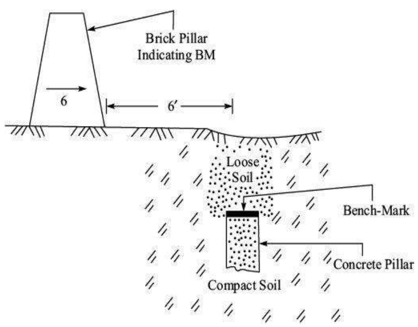
This axis is an imaginary line passing through the optical centre of the object glass and the optical centre of the eyepiece.

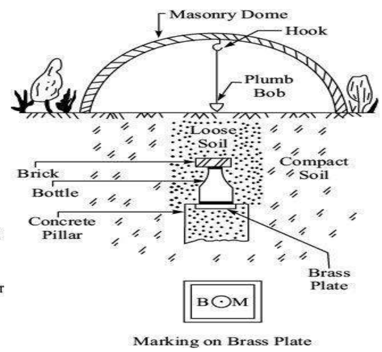
12. Axis of Bubble Tube

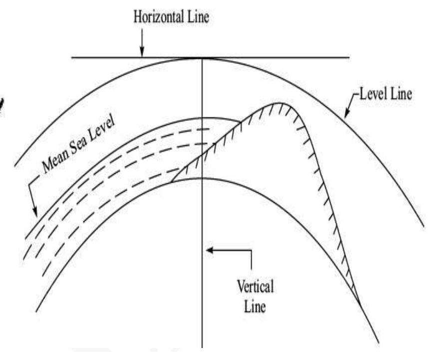
It is an imaginary line tangential to the longitudinal curve of the bubble tube at its middle point.

13. Bench-Marks (BM)

These are fixed points or marks of known RL determined with reference to the datum line. These are very important marks. They serve as reference points for finding the RL of new points or for conducting leveling operations in projects involving roads, railways, etc. Bench-marks may be of four types: **(a) GTS, (b) permanent, (c) temporary, and (d) arbitrary.**







14. Back sight Reading (BS)

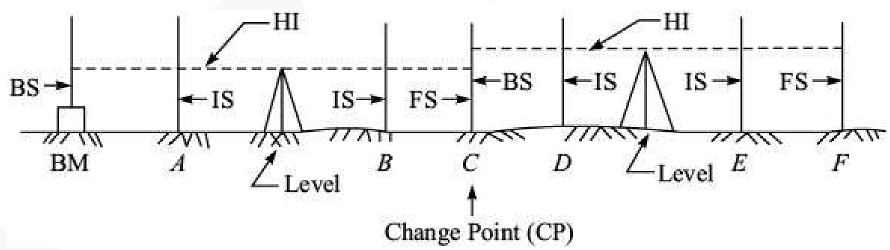
This is the first staff reading taken in any set-up of the instrument after the leveling has been perfectly done. This reading is always taken on a point of known RL, i.e. on a bench-mark or change point.

15. Foresight Reading (FS)

It is the last staff reading in any set-up of the instrument, and indicates the shifting of the latter.

16. Intermediate Sight Reading (IS)

It is any other staff reading between the BS and FS in the same set-up of the instrument.



17. Change Point (CP)

This point indicates the shifting of the instrument. At this point, an FS is taken from one setting and a BS from the next setting.

18. Height of Instrument (HI)

When the leveling instrument is properly leveled, the RL of the line of collimation is known as the height of the instrument. This is obtained by adding the BS reading to the RL of the BM or CP on which the staff reading was taken.

19. Focusing

The operation of setting the eyepiece and the object glass a proper distance apart for clear vision of the object is known as focusing. This is done by turning the focusing screw clockwise or anticlockwise. The function of the object glass is to bring the object into focus on the diaphragm, and that of the eyepiece is to magnify the cross-hairs and object. Focusing is done in two steps as follows.

(a) Focusing the eyepiece a sheet of white paper is held in front of the telescope and the eye-piece is turned clockwise or anticlockwise slowly until the cross-hairs appear distinct and clear.

(b) Focusing the Object Glass The telescope is directed to the object and the focusing screw is turned clockwise or anticlockwise until the image is clear and sharp.

20. Parallax

The apparent movement of the image relative to the cross-hairs is known as parallax. This occurs due to imperfect focusing, when the image does not fall in the plane of the diaphragm. The parallax is tested by moving the eye up and down. If the focusing is not correct, the image moves up and down relative to the cross-hairs. If the focusing is perfect, the image appears fixed to the cross-hairs. The parallax may be eliminated by properly focusing the telescope.

7.2 Instruments Used For Leveling, Concepts of Line of Collimation, Axis of Bubble Tube, Axis of Telescope, Vertical Axis.

Different Types of Levels

The following are the different types of levels:

1. Dumpy Level

The telescope of the dumpy level is rigidly fixed to its supports. It cannot be removed from its supports, nor can it be rotated about its longitudinal axis. The instrument is stable and retains its permanent adjustment for a long time. This instrument is commonly used.

2. Wye Level (Y-Ievel)

The telescope is held in two '*Y*' supports. It can be removed from the supports and reversed from one end of the telescope to the other end. The '*Y*' supports consist of two curved clips which may be raised. Thus, the telescope can be rotated about its longitudinal axis.

3. Cooke's Reversible Level

This is a combination of the dumpy level and the *Y*-Level. It is supported by two rigid sockets. The telescope can be rotated about its longitudinal axis, withdrawn from the socket and replaced from one end of the telescope to the other end.

4. Cushing's Level

The telescope cannot be removed from the sockets and rotated about its longitudinal axis. The eye-piece and object glass are removable and can be interchanged from one end of the telescope to the other end.

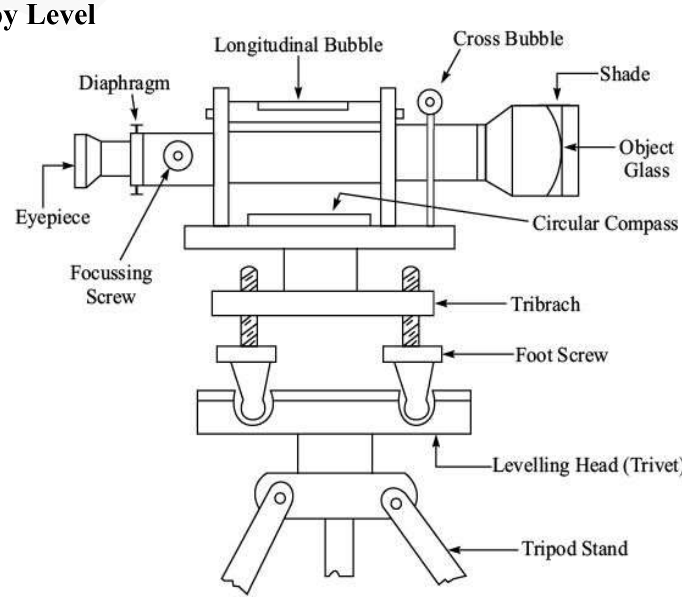
5. Modern Tilting Level

The telescope can be tilted slightly about its horizontal axis with the help of a tilting screw. In this instrument, the line of collimation is made horizontal for each observation by means of the tilting screw.

6. Automatic Level

This is also known as the self-aligning level. This instrument is leveled automatically within a certain tilt range by means of a compensating device (the tilt compensator).

Description of Dumpy Level



1. Tripod Stand
The tripod stand consists of three legs which may be solid or framed. The legs are made of light and hard wood. The lower ends of the legs are fitted with steel shoes.
2. Leveling Head
The leveling head consists of two parallel triangular plates having three grooves to support the foot screws.
3. Foot Screws
Three foot screws are provided between the trivet and tribrach. By turning the foot screws, the tribrach can be raised or lowered to bring the bubble to the centre of its run.
4. Telescope
The telescope consists of two metal tubes, one moving within the other. It also consists of an object glass and an eyepiece on opposite ends. A diaphragm is fixed with the telescope just in front of the eyepiece.
5. Bubble Tubes
Two bubble tubes, one called the *longitudinal bubble tube* and other the *cross-bubble tube,* are placed at right angles to each other. These tubes contain spirit bubble. The bubble is brought to the centre with the help of foot screws. The bubble tubes are fixed on top of the telescope.
6. Compass
A compass is provided just below the telescope for taking the magnetic bearing of a line when required. The compass is graduated in such a way that a ‘pointer’, which is fixed to the body of the compass, indicates a reading of 0° when the telescope is directed along the north line.

7.3 Leveling Staff – Adjustments of Level, Taking Reading with Level

The leveling staff is a graduated wooden rod used for measuring the vertical distances between the points on the ground and the line of collimation. Leveling staves are classified into two groups: **(i) the target staff, and (ii) the self-reading staff.**

1. Target Staff
The target staff consists of a movable target. The target is provided with a vernier which is adjusted by the staff man, according to directions from the level man, so that the target coincides with the collimation hair. After this, the reading is taken by either the staff man or the level man. This staff is used for long sightings.

2. Self-reading Staff
The following are the different types of self-reading staffs:

(a) Sop with Telescopic Staff - such a staff is arranged in three lengths placed one into the other. The top portion is solid and of 1.25 m length, the central box portion is hollow and of 1.25 m length, and the bottom box portion is hollow and 1.5 m long. The total length of the staff is 4 m.

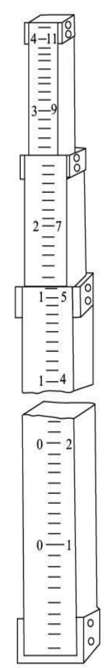


Fig. 5.6 Telescopic Metric Staff

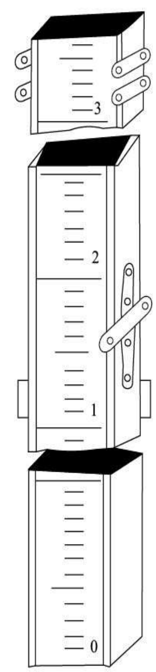


Fig. 5.7 Folding Metric Staff

(b) Folding Metric Staff - This staff is made of well-seasoned timber, and is of 75 mm width, 18 mm thickness, and 4 m length. It is divided into two parts of 2 m length having a locking arrangement.

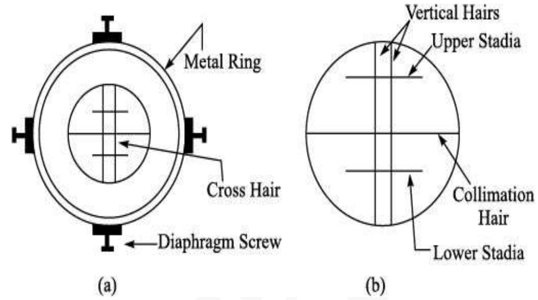
(c) One-Length Staff - the one-length staff is solid and made of seasoned timber. It is 3 m long and graduated in the same way as the telescopic staff.

(d) Invar Staff - The invar staff is also 3 m long. An invar band is fitted to a wooden staff. The band is graduated in millimeters. It is used for precise leveling work.

Diaphragm - The diaphragm is a brass ring fitted inside the telescope, just in front of the eyepiece. It can be adjusted by four screws. The ring carries the cross-hairs, which get magnified when viewed through the eyepiece. The cross-hairs may be marked in the following ways:
1. with spider webs stretched across the ring,
2. By very fine scratch marks made in a glass fitted with the ring, or
3. By means of platinum wires or silk threads stretched across the ring.

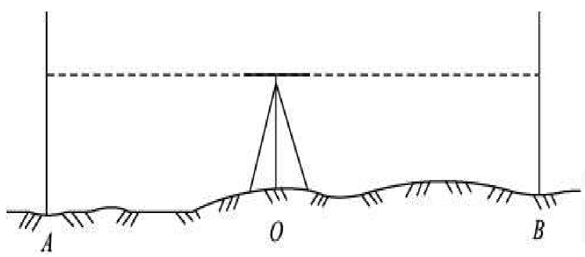
Temporary Adjustment of Level

- *Selection of Suitable Position*
- *Fixing Level with Tripod Stand*
- *Approximate Leveling by Legs of Tripod Stand*
- *Perfect Leveling by Foot Screws*
- *Focusing the Eyepiece*
- *Focusing the Object Glass*
- *Taking the Staff Readings*

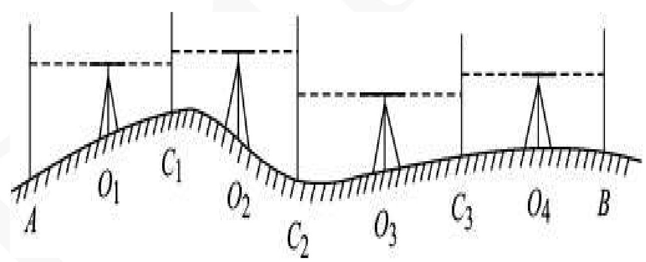


Types of Leveling Operations

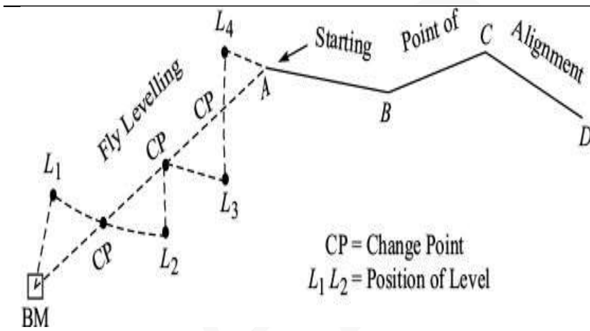
There are six types of leveling;



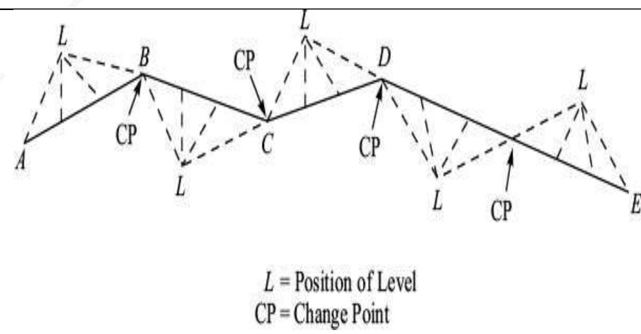
Simple leveling



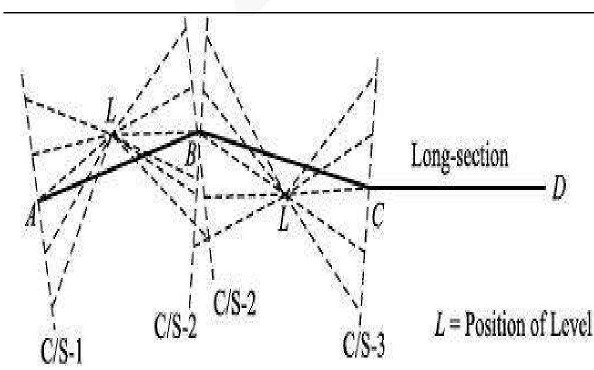
Differential leveling



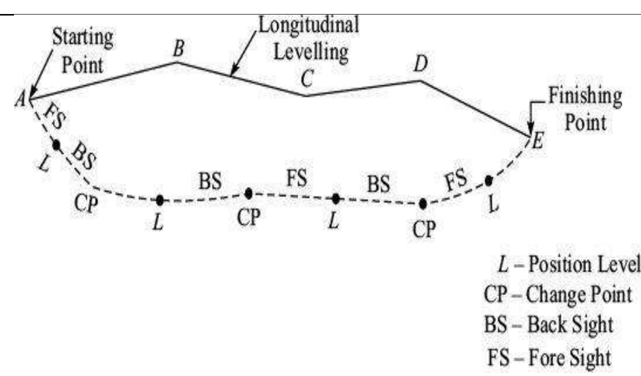
Fly leveling



Longitudinal/profile leveling



Cross sectional leveling



Check leveling

7.4 Field Data Entry – Level Book – Height of Collimation Method and Rise & Fall Method, Comparison.

The following are the two systems of calculating reduced level:

1. The collimation system or height of instrument system (HI)

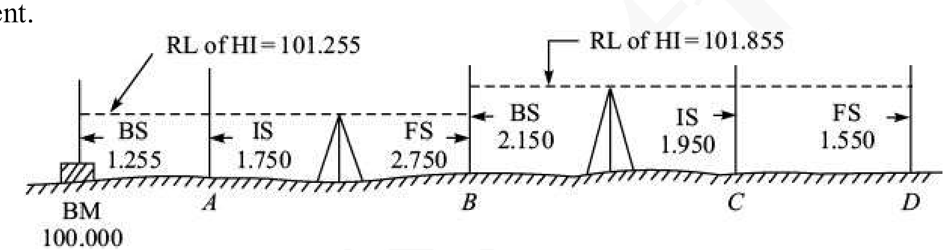
2. The rise-and-fall system

The Collimation System

The reduced level of the line of collimation is said to be the height of the instrument. In this system, the height of the line of collimation is found out by adding the back sight reading to the RL of the BM on which the BS is taken. Then the RL of the intermediate points and the change point are obtained by subtracting the respective staff readings from the height of the instrument (HI).

The level is then shifted for the next setup and again the height of the line of collimation is obtained by adding the back sight reading to the RL of the change point (which was calculated in the first set-up). So, the height of the instrument is different in different setups of the level.

Two adjacent planes of collimation are correlated at the change point by an FS reading from one setting and a BS reading from the next setting. It should be remembered that in this system, the RLs of unknown points are to be found out by deducting the staff readings from the RL of the height of the instrument.



(a) RL of HI in first setting = 100.000 + 1.255 = 101.255

RL of *A* = 101.255 – 1.750 = 99.505

RL of *B* = 101.255 – 2.150 = 99.105

(b) RL of HI in second setting = 99.105 + 2.750 = 101.855

RL of *C* = 101.855 – 1.950 = 99.905

RL of *D* = 101.855 – 1.550 = 100.305 and so on.

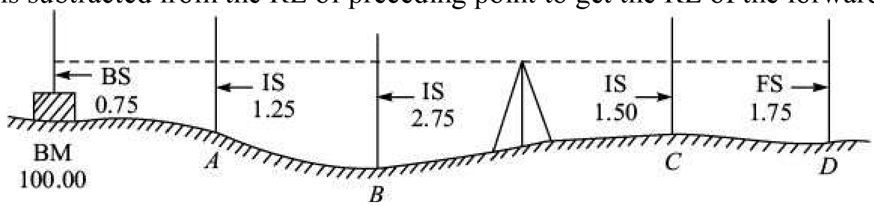
Arithmetical check: ΣBS – ΣFS = Last RL – 1st RL

The difference between the sum of back sights and that of foresights must be equal to the difference between the last RL and the first RL. This check verifies the calculation of the RL of the HI and that of the change point. There is no check on the RLs of the intermediate points.

The Rise-And-Fall System

In this system, the difference of level between two consecutive points is determined by comparing each forward staff reading with the staff reading at the immediately preceding point. If the forward staff reading is smaller than the immediately preceding staff reading, a rise is said to have occurred.

The rise is added to the RL of the preceding point to get the RL of the forward point. If the forward staff reading is greater than the immediately preceding staff reading, it means there has been a fall. The fall is subtracted from the RL of preceding point to get the RL of the forward point.



Point *A* (with respect to BM) = 0.75 – 1.25 = –0.50 (fall) RL of *A* = 100.00 – 0.50 = 99.50

Point *B* (with respect to *A*) = 1.25 – 2.75 = –1.50 (fall) RL of *B* = 99.50 – 1.50 = 98.00

Point *C* (with respect to *B*) = 2.75 – 1.50 = +1.25 (fall) RL of *C* = 98.00 + 1.25 = 99.25

Point *D* (with respect to *C*) = 1.50 – 1.75 = –0.25 (fall) RL of *D* = 99.25 – 0.25 = 99.00

Arithmetical check: ΣBS – ΣFS = Σ rise – Σ fall = last RL – 1st RL

In this method, the difference between the sum of BSs and that of FSs, the difference between the sum of rises and that of falls and the difference between the last RL and the first RL must be equal.

Comparison of the Two Systems

HI Method	R&F Method
It is rapid as it involves few calculations.	It is laborious, involving several calculations.
There is no check on the RL of intermediate points.	There is a check on the RL of intermediate points.
Errors in intermediate RLs cannot be detected.	Errors in intermediate RLs can be detected as all the points are correlated.
There are two checks on the accuracy of RL calculation.	There are three checks on the accuracy of RL calculation.
This system is suitable for longitudinal leveling where there are a number of intermediate sights.	This system is suitable for fly leveling where there are no intermediate sights.

7.5 Effects of Curvature and Refraction, Application of Correction.

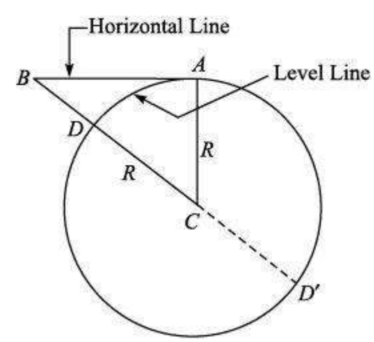
Following are the different types of correction;

- Curvature Correction
- Refraction Correction
- Combined Correction
- Visible Horizon Distance
- Dip of Horizon

Curvature Correction

For long sights, the curvature of the earth affects staff readings. The line of sight is horizontal, but the level line is curved and parallel to the mean spherical surface of the earth. The vertical distance between the line of sight and the level line at a particular place is called the curvature correction. Due to curvature, objects appear lower than they really are.

Curvature correction is always subtractive (i.e. negative).



The formula for curvature correction is derived as follows;

Let $AB = D$ = horizontal distance in kilometers.

$BD = Cc$ = curvature correction

$DC = AC = R$ = radius of earth

DD' = diameter, considered 12,742 km

From right-angled triangle ABC

$BC^2 = AC^2 + AB^2$

$(R + Cc)^2 = R^2 + D^2$ or $R^2 + 2RCc + C^2$

$c = R^2 + D^2$ or $Cc \times 2R = D^2$

($C2c$ is neglected as it is very small in comparison to the diameter of the earth.)

Curvature correction $Cc = \dfrac{D^2}{2R}$

$Cc = \dfrac{D^2 \times 1{,}000}{12{,}742} = 0.0785\, D^2$ m (negative)

Hence, True staff reading = Observed staff reading – Curvature correction

Refraction Correction

Rays of light are refracted when they pass through layers of air of varying density. So, when long sights are taken, the line of sight is refracted towards the surface of the earth in a curved path. The radius of this curve is seven times that of the earth under normal atmospheric conditions. Due to the effect of refraction, objects appear higher than they really are. But the effect of curvature varies with atmospheric conditions. However, on an average, the refraction correction is taken as one-seventh of the curvature correction.

$$C_r = \frac{1}{7} \times \frac{D^2}{2R}$$

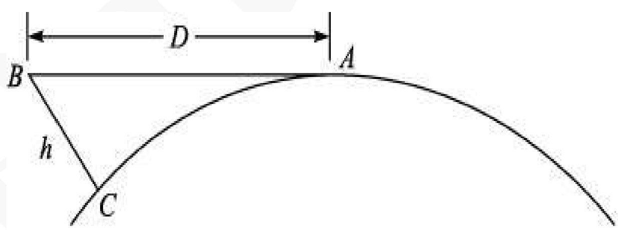
Refraction correction, Cr = × 0.0785 D^2 = 0.0112 D^2 m (positive)
Refraction correction is always additive (i.e. positive).
True staff reading = Observed staff reading + Refraction correction

Combined Correction
The combined effect of curvature and refraction is as follows:
Combined correction = Curvature correction + Refraction correction
= –0.0785 D^2 + 0.0112 D^2
= –0.0673 D^2 m

$$\frac{D^2}{2R} - \frac{1}{7} \times \frac{D^2}{2R} = \frac{6}{7} \cdot \frac{D^2}{2R} \; (negative)$$

So, combined correction is always subtractive (i.e. negative).
True staff reading = Observed staff reading – Combined correction

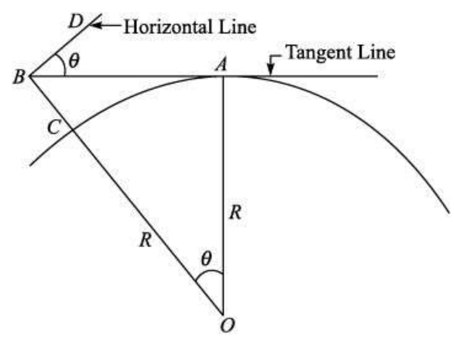
Visible Horizon Distance
Let $AB = D$ = visible horizon distance in kilometers, h = height of the point above mean sea level, in meters.



Considering curvature and refraction corrections,
$h = 0.0673\, D^2$

$$D = \sqrt{\frac{h}{0.0673}}$$

Dip of Horizon
$AB = D$ = tangent to the earth at A
BD = horizontal line perpendicular to OB
θ = dip of horizon
The angle between the horizontal line and the tangent line is known as the dip of the horizon. It is equal to the angle subtended by the arc CA at the centre of the earth.



$$\text{Dip} \quad \theta \quad = \frac{\text{arc } CA}{\text{radius of the earth}} \text{, in radians}$$

∴ θ = in radians (Taking CA approx. equal to AB). Here, D and R must be expressed in the same units.

7.6 Reciprocal Leveling – Principles, Methods, Precise Leveling.

In reciprocal leveling, the level is set up on both banks of the river or valley and two sets of staff readings are taken by holding the staff on both banks. In this case, it is found that the errors are completely eliminated and the true difference of level is equal to the mean of the two apparent differences of level.

Procedure
1. Suppose A & B are two points on the opposite banks of a river. The level is set up very near A and after proper temporary adjustment, staff readings are taken at A and B. Suppose the readings are $a1$ and $b1$.

2. The level is shifted and set up very near B and after proper adjustment, staff readings are taken at A and B. Suppose the readings are $a2$ and $b2$.

Let h = true difference of level between A and B

e = combined error due to curvature, refraction and collimation (The error may be positive or negative, here the error is assumed positive).

In the first case,

Correct staff reading at $A = a1$ (as the level is very near A)

Correct staff reading at $B = b1 - e$

True difference of level between A and B,

$h = a1 - (b1 - e)$ (fall from B to A)

In the second case,

Correct staff reading at $B = b2$ (as level is near B)

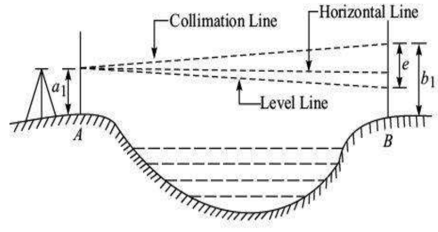
Correct staff reading at $A = a2 - e$

So, true difference of level,

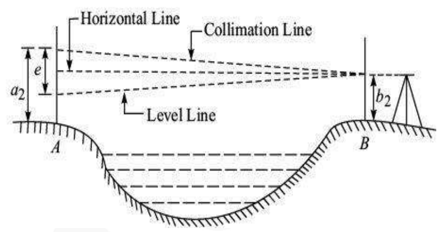
$h = (a2 - e) - b2$

$2h = a1 - (b1 - e) + (a2 - e) - b2$

$= a1 - b1 + e + a2 - e - b2 = (a1 - b1) + (a2 - b2)$



(a)



$$h = \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$$

It may be observed that the error is eliminated and that the true difference is equal to the mean of the two, apparent differences of level between A and B.

7.7 Errors in Leveling and Precautions, Permanent and Temporary Adjustments of Different Types of Levels.

The following are the different sources of error in leveling:

1. Instrumental Errors

(a) The permanent adjustment of the instrument may not be perfect. That is, the line of collimation may not be parallel to the axis of the bubble tube.

(b) The internal arrangement of the focusing tube is not perfect.

(c) The graduation of the leveling staff may not be perfect.

2. Personal Errors

(a) The instrument may not be leveled perfectly.

(b) The focusing of the eyepiece and object glass may not be perfect and the parallax may not be eliminated entirely.

(c) The position of the staff may be displaced at the change point at the time of taking FS and BS readings.

(d) The staff may appear inverted when viewed through the telescope. By mistake, the staff readings may be taken upwards instead of downwards.

(e) The reading of the stadia hair rather than the central collimation hair may be taken by mistake.

(f) A wrong entry may be made in the level book.

(g) The staff may not be properly and fully extended.

3. Errors due to Natural Causes

(a) When the distance of sight is long, the curvature of the earth may affect the staff reading.

(b) The effect of refraction may cause a wrong staff reading to be taken.

(c) The effect of high winds and a shining sun may result in a wrong staff reading.

The precision of leveling is ascertained according to the error of closure. The permissible limit of closing error depends upon the nature of work for which the leveling is to be done. Permissible closing error is expressed as $E = C\sqrt{D}$

Where, E = closing error in meters,

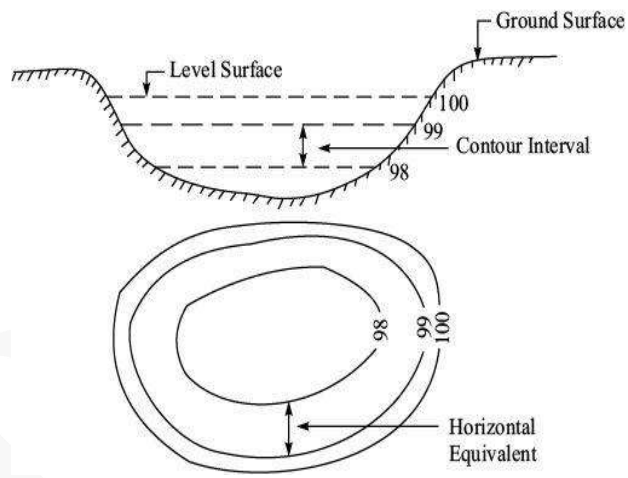
C = the constant, and

D = distance in kilometers.

The following are the permissible errors for different types of leveling;
1. Rough leveling—$E = \pm 0.100\sqrt{D}$
2. Ordinary leveling—$E = \pm 0.025\sqrt{D}$
3. Accurate leveling—$E = \pm 0.012\sqrt{D}$
4. Precise leveling—$E = \pm 0.006\sqrt{D}$

7.8 Definitions, Concepts and Characteristics of Contours.

Contouring is, basically, a leveling operation. The equipment is the same for leveling and contouring. The main objective of contouring is to determine the points on the ground having the same reduced level (RL). The contour lines join the points of same elevation directly or by interpolation technique. It gives the topographical features of the ground, comparing different contour lines of different elevations for a closed area. Based on the topographical features, calculations for engineering projects can be carried out. There are different methods of drawing such closed or open contour lines within a specific area.

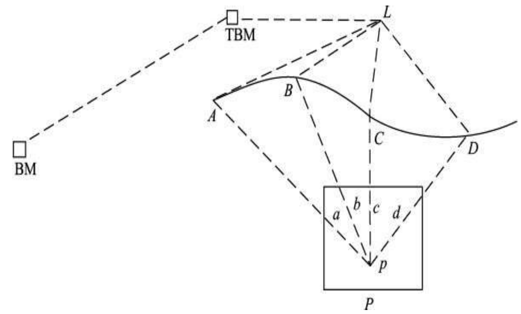


Contour Line
The line of intersection of a level surface with the ground surface is known as the contour line or simply the contour. It can also be defined as a line passing through points of equal reduced levels.
A map showing only the contour lines of an area is called a *contour map*.
Contour Interval
The vertical distance between any two consecutive contours is known as a contour interval. Suppose a map includes contour lines of 100 m, 98 m, 96 m, and so on. The contour interval here is 2 m. This interval depends upon (i) the nature of the ground (i.e. whether flat or steep), (ii) the scale of the map, and (iii) the purpose of the survey.
Horizontal Equivalent
The horizontal distance between any two consecutive contours is known as horizontal equivalent. It is not constant. It varies according to the steepness of the ground. For steep slopes, the contour lines run close together, and for flatter slopes they are widely spaced.

Uses of Contour Map
The following are the specific uses of the contour map:
1. The nature of the ground surface of a country can be understood by studying a contour map. Hence, the possible route of communication between different places can be demarcated.
2. A suitable site or an economical alignment can be selected for any engineering project.
3. The capacity of a reservoir or the area of a catchment can be approximately computed.
4. The indivisibility or otherwise of different points can be established.
5. A suitable route for a given gradient can be marked on the map.
6. A section of the ground surface can be drawn in any direction from the contour map.
7. Quantities of earth work can be approximately computed.

Object of Preparing Contour Map
The general map of a country includes the locations of roads, railways, rivers, villages, towns, and so on. But the nature of the ground surface cannot be realized from such a map. However, for all engineering projects involving roads, railways, and so on, knowledge of the nature of ground surface is required for locating suitable alignments and estimating the volume of earth work. Therefore, the contour map is essential for all engineering projects. This is why contour maps are prepared.

7.9 Methods of Contouring, Plotting Contour Maps, Interpretation of Contour Maps, Top sheets.



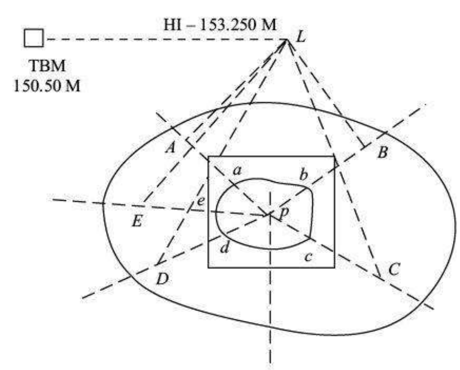
Direct Method
There may be two cases, as outlined below.

Case I When the area is oblong and cannot be controlled from a single station in this method, the various points on any contour are located on the ground by taking levels. Then these points are marked by pegs. After this, the points are plotted on the map, to any suitable scale, by plane table. This method is very slow and tedious. But it gives accurate contour lines.

Procedure
1. Suppose a contour map is to be prepared for an oblong area. A temporary bench-mark is set up near the site by taking fly-level readings from a permanent bench-mark.
2. The level is then set up at a suitable position *L* from where maximum area can be covered.
2. The plane table is set up at a suitable station *P* from where the above area can be plotted.
4. A back sight reading is taken on the TBM. Suppose the RL of the TBM is 249.500 m and that the BS reading is 2.250 m. Then the RL of HI is 251.750 m. If a contour of 250.000 m is required, the staff reading should be 1.750 m. If a contour of 249.000 m is required, the staff reading should be 2.750 m, and so on.
5. The staff man holds the staff at different points of the area by moving up and down, or left and right, until the staff reading is exactly 1.750. Then the points are marked by pegs. Suppose, these points are *A*, *B*, *C*, *D* …
6. A suitable point *p* is selected on the sheet to represent the station *P*. Then, with the alidade touching *p*, rays are drawn to *A*, *B*, *C* and *D*. The distances *PA*, *PB*, *PC* and *PD* are measured and plotted to a suitable scale. In this manner, the points *a*, *b*, *c* and *d* of the contour line of RL 250.000 m are obtained. These points are joined to obtain the contour of 250.000 m.
7. Similarly, the points of the other contours are located.
8. When required, the leveling instrument and the plane table are shifted and set up in a new position in order to continue the operation along the oblong area.

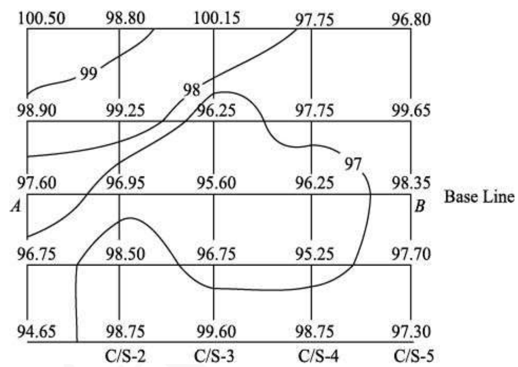
Case II When the area is small and can be controlled from a single station. In this case, the method of radial lines is adopted to obtain contour map. This is also very slow and tedious, but gives the actual contour lines.

Procedure



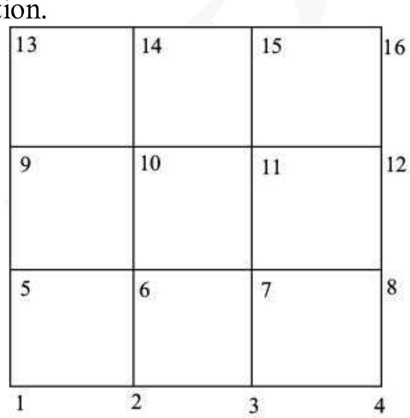
1. The plane table is set up at a suitable station *P* from where the whole area can be commanded.
2. A point *p* is suitably selected on the sheet to represent the station *P*. Radial lines are then drawn in different directions.
3. A temporary bench-mark is established near the site. The level is set up at a suitable position *L* and a BS reading is taken on the TBM. Let the HI in this setting be 153.250 m. So, to find the contour of 152.000 m RL, a staff reading of 1.250 m is required at a particular point, so that the RL of contour of that point comes to 152.000 m. RL = HI – Staff reading = 153.250 – 1.250 = 152.000 m.
4. The staff man holds the staff along the rays drawn from the plane table station in such a way that the staff reading on that point is exactly 1.250. In this manner, points *A*, *B*, *C*, *D* and *E* are located on the ground, where the staff readings are exactly 1.250.
5. The distances *PA*, *PB*, *PC*, *PD* and *PE* are measured and plotted to any suitable scale. Thus the points *a*, *b*, *c*, *d* and *e* are obtained which are joined in order to obtain a contour of 152.000.
6. The other contours may be located in similar fashion.

Indirect Method In this method, the RLs of different points (spot levels) are taken at regular intervals along a series of lines set up on the ground. The positions of these points are plotted on a sheet to any suitable scale. The spot levels are noted at the respective points. Then the points of contour lines are found out by interpolation, after which they are joined to get the required contour lines. Although very quick, this method gives only the approximate positions of the contour lines. This method can be adopted in two ways: (i) cross-sections, and (ii) squares.

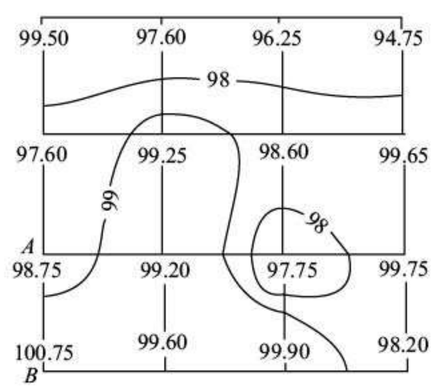


Using Cross Sections - In this method, a base line, centre line or profile line is considered. Cross sections are taken perpendicular to this line at regular intervals (say 50 m, 100 m, etc.). After this, points are marked along the cross sections at regular intervals (say, 5 m, 10 m, etc). A temporary bench-mark is set up near the site. Staff readings are taken along the base line and the cross sections. The readings are entered in the level book; the base line and the cross sections should also be mentioned. The RL of each of the points calculated. Then the base line and cross sections are plotted to a suitable scale. Subsequently, the RLs of the respective points are noted on the map, after which the required contour line is drawn by interpolation. This method is suitable for route survey, when cross sections are taken transverse to the longitudinal section.

Using Squares - In this method, the area is divided into a number of squares. The size of these squares depends upon the nature and extent of the ground. Generally, they have a sides varying from 5 to 20 m. The corners of the squares are numbered serially, as 1, 2, 3 … A temporary bench-mark is set up near the site, and the level is set up at a suitable position. The staff readings on the corners of the squares are taken and noted in the level book maintaining the sequence of the serial numbers of the corners. The RLs of all the corners are calculated. The skeletons of the squares are plotted to a suitable scale. The respective RLs are noted on the corners, after which the contour lines are drawn by interpolation.



Skeleton



RLs Noted as Per Skeleton

Contour Gradient

During preliminary survey for roads in a hilly area, the required points are first established along the gradient. The line joining these points is known as the *contour gradient* or *grade contour*. Initially, the points are established approximately by an *Abney level*, and then accurately fixed by a leveling instrument.

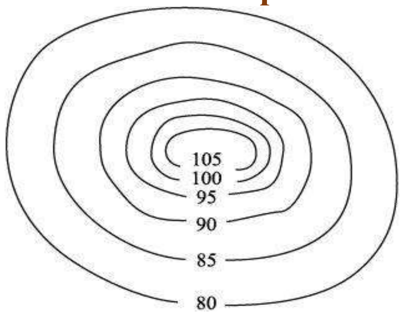
Method of Interpolation of Contours

The process of locating the contours proportionately between the plotted points is termed *interpolation*.

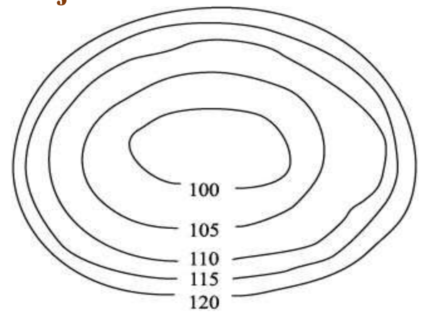
Interpolation may be done by;

1. Arithmetical calculation
2. The graphical method

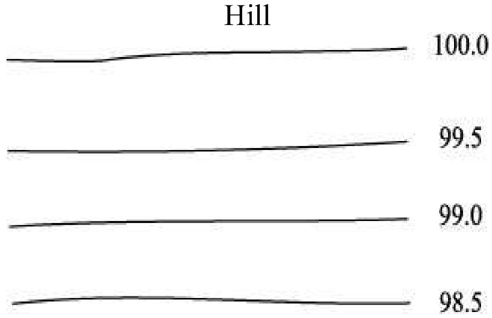
7.10 Use of Contour Maps on Civil Engineering Projects



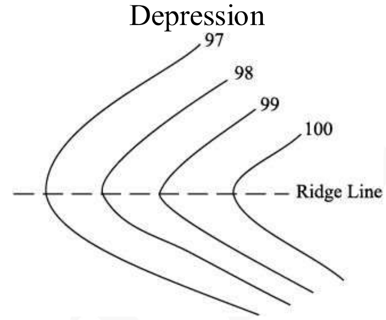
Hill



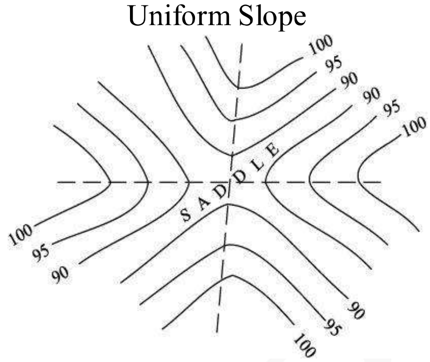
Depression



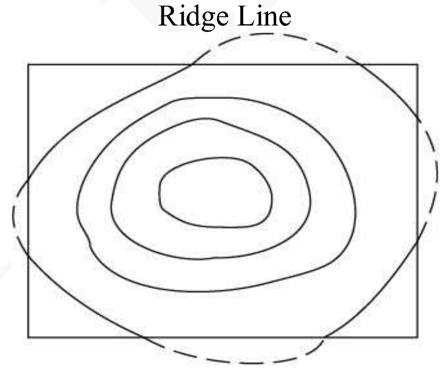
Uniform Slope



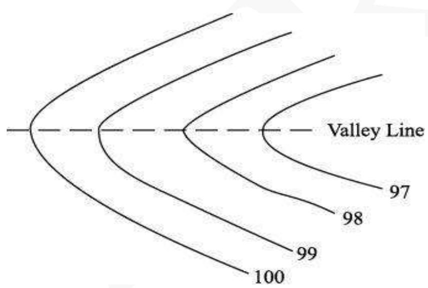
Ridge Line



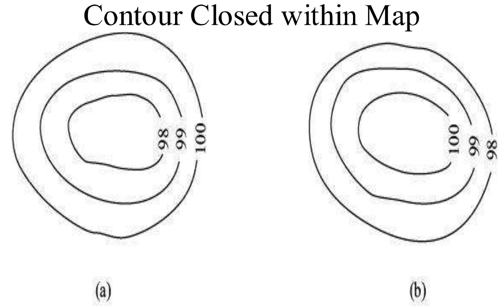
Saddle



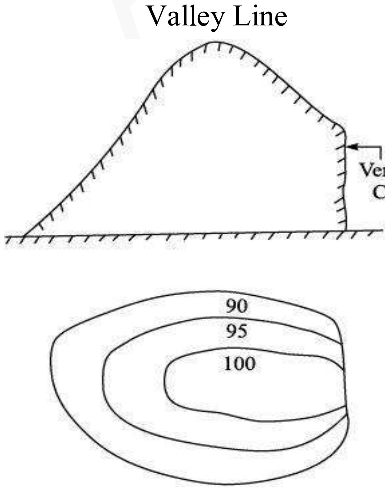
Contour Closed within Map



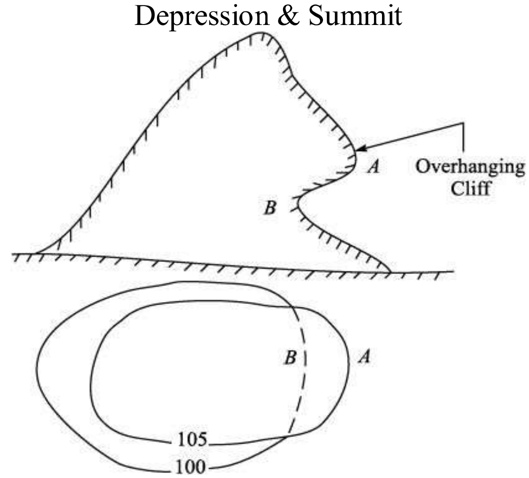
Valley Line



Depression & Summit



Vertical Cliff



Overhanging Cliff

7.11 Map Interpretation

Map interpretation involves the study of factors that explain the causal relationship among several features shown on the map. For example, the distribution of natural vegetation and cultivated land can be better understood against the background of landform and drainage.

Deriving accurate meanings from maps is called map interpretation. Knowledge of map language and sense of direction are essential in reading and interpreting topo-sheets.

We must first look for the north line and the scale of the map and orient ourselves accordingly. We must have a thorough knowledge of the legends / key given in the map depicting various features.

All topo-sheets contain a table showing conventional signs and symbols used in the map. We must be acquainted with conventional symbols, signs and colors.

The following procedure is followed in map interpretation;

(a) Finding from the index number of the topographical sheet, the location of the area in India. This would give an idea of the general characteristics of the major and minor physiographic divisions of the area.

(b) Find the scale of the map and the contour interval, which will give the extent and general landform of the area.

(i) Major landforms - as shown by contours and other graphical features.

(ii) Drainage and water features - the main river and its important tributaries.

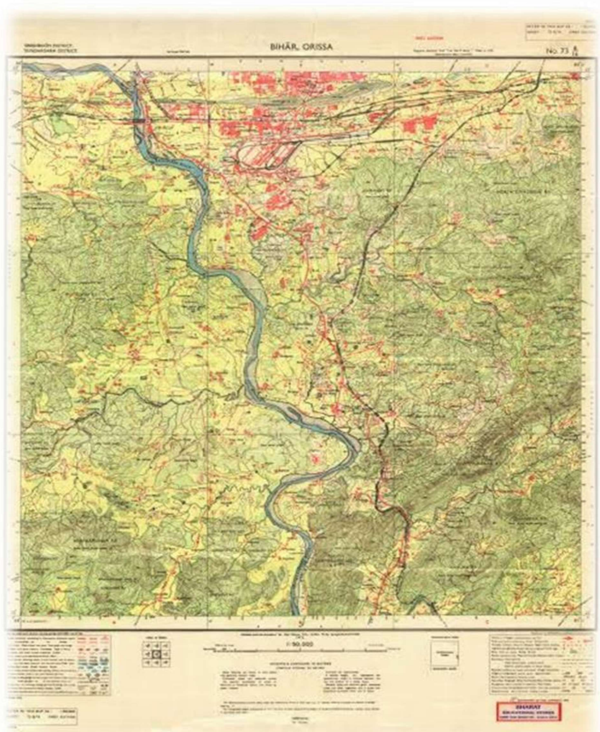
(iii) Land use - i.e. forest, agricultural land, wastes, sanctuary, park, school, etc.

(iv) Settlement and Transport pattern.

(d) Explain the distributional pattern of each of the features separately drawing attention to the most important aspect.

(e) Superimpose pairs of these maps and note down the relationship, if any, between the two patterns. For example, if a contour map is superimposed over a land use map, it provides the relationship between the degree of slope and the type of the land used.

f) Aerial photographs and satellite imageries of the same area and of the same scale can also be compared with the topographical map to update the information.



Topo sheets - Top sheets is a topographic map which is a two dimensional representation of a three dimensional land surface.

Topographic maps are differentiated from the other maps in that they show both the horizontal and vertical position of the terrain.

Topo sheets are also used by the tourism industry for preparing tourist maps. It provides the information about various attractive features of an area as well as the location of important monuments or places of interest.

Industrialists also rely on using topographical maps for setting up an industry in an area.

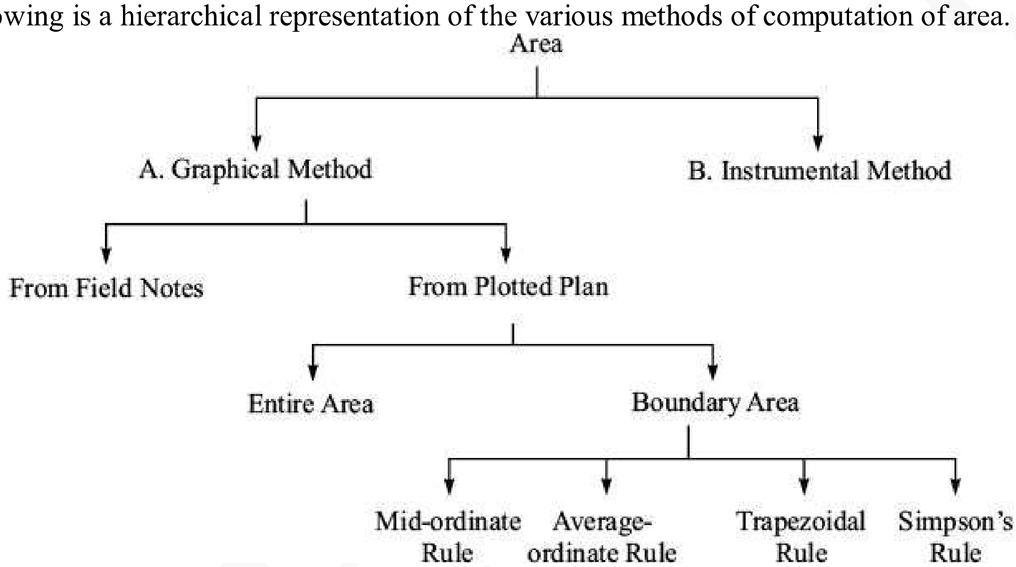
LAND SURVEY - I

8. COMPUTATION OF AREA & VOLUME

8.1 Determination of Areas, Computation of Areas from Plans.

The term ‘area’ in the context of surveying refers to the area of a tract of land projected upon the horizontal plane, and not to the actual area of the land surface.
Area may be expressed in the following units:
1. Square meters
2. Hectares (1 hectare = 10,000 m^2)
3. Square feet
4. Acres (1 acre = 4840 sq. yd. = 43.560 sq. ft.)

The following is a hierarchical representation of the various methods of computation of area.



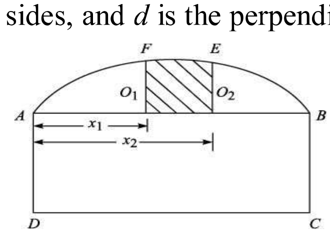
Computation of Area from Field Notes
This is done in two steps.
Step 1
In cross-staff survey, the area of field can be directly calculated from field notes. During survey work the whole area is divided into some geometrical figures, such as triangles, rectangles, squares and trapeziums, and then the area is calculated as follows:

1. Area of triangle = $\sqrt{s(s-a)(s-b)(s-c)}$

Where a, b and c are the sides,

and $s = \dfrac{a+b+c}{2}$

Or Area of triangle = 1/2 × b × h, *where* b = base and h = altitude
2. Area of rectangle = $a \times b$, *where* a & b are the sides.
3. Area of square = a^2, where a is the side of the square.
4. Area of trapezium = 1/2 (a + b) × d, *where* a and b are the parallel sides, and d is the perpendicular distance between them.



Step 2
$o1$, $o2$ = ordinates & $x1$, $x2$ = chainages

Area of shaded portion = $\dfrac{o_1 + o_2}{2} \times (x_2 - x_1)$

Similarly, the areas between all pairs of ordinates are calculated and added to obtain the total boundary area.
Hence, Total area of the field = Area of geometrical figure + Boundary areas
(step 1 + step 2) = Area of *ABCD* + Area of *ABEFA*

8.2 Calculation of Area by Using Ordinate Rule, Trapezoidal Rule, Simpson's Rule.

The area may be calculated in the two following ways;

Case I - Considering the Entire Area
The entire area is divided into regions of a convenient shape, and calculated as follows:

- **By Dividing the Area into Triangles -** The triangles are so drawn as to equalize the irregular boundary line. Then the bases and altitudes of the triangles are determined according to the scale to which the plan was drawn. After this, the areas of these triangles are calculated (area = 1/2 × base × altitude).

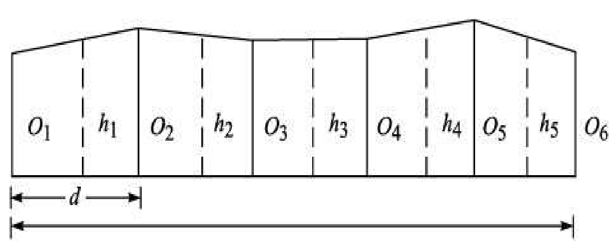
- **By Dividing the Area into Squares** In this method, squares of equal size are ruled out on a piece of tracing paper. Each square represents a unit area, which could be 1 cm2 or 1 m2. The tracing paper is placed over the plan and the number of full squares is counted. The total area is then calculated by multiplying the number of squares by the unit area of each square.

- **By Drawing Parallel Lines and Converting them to Rectangles** In this method, a series of equidistant parallel lines are drawn on a tracing paper. The constant distance represents a meter or centimeter. The tracing paper is placed over the plan in such a way that the area is enclosed between the two parallel lines at the top and bottom. Thus the area is divided into a number of strips. The curved ends of the strips are replaced by perpendicular lines (by give and take principle) and a number of rectangles are formed. The sum of the lengths of the rectangles is then calculated. *Then, **Required area = Σ Length of rectangles** × **Constant distance.***

Case II
In this method, a large square or rectangle is formed within the area in the plan. Then ordinates are drawn at regular intervals from the side of the square to the curved boundary. The middle area is calculated in the usual way. The boundary area is calculated according to one of the following rules;

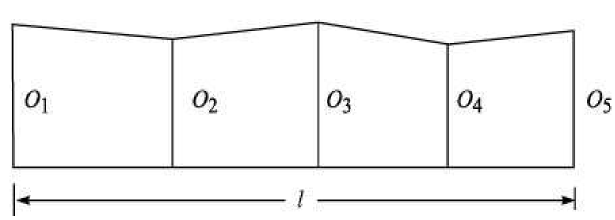
1. *The mid-ordinate rule*
2. *The average-ordinate rule*
3. *The trapezoidal rule*
4. *Simpson's rule*

(a) Mid-ordinate Rule
Let $O1, O2, O3, \ldots, On$ = ordinates at equal intervals
l = length of base line
d = common distance between ordinates
$h1\ h2, \ldots, hn$ = mid-ordinates
Area of plot = $h1 \times d + h2 \times d + \ldots + hn \times d$
$= d(h1 + h2 + \ldots + hn)$
i.e. Area = Common distance × sum of mid-ordinates



(b) Average-ordinate Rule
Let $O1\ O2, \ldots, On$ = ordinates or offsets at regular intervals
l = length of base line
n = number of divisions
$n + 1$ = number of ordinates

Area = $$\frac{O_1 + O_2 + \cdots + O_n}{O_{n+1}} \times l$$



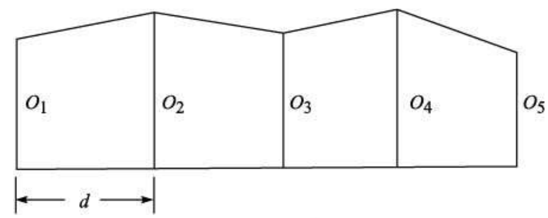
i.e. Area = $\dfrac{\text{sum of ordinates}}{\text{no. of ordinates}} \times \text{length of base line}$

(c) Trapezoidal Rule

While applying the trapezoidal rule, boundaries between the ends of ordinates are assumed to be straight. Thus the areas enclosed between the base line and the irregular boundary line is considered as trapezoids.

Let *O*1 *O*2, …, *On* = ordinates at equal intervals

d = common distance



First area = $\dfrac{O_1 + O_2}{2} \times d$

Second area = $\dfrac{O_2 + O_3}{2} \times d$

Third area = $\dfrac{Q_3 + Q_4}{2} \times d$

Last area = $\dfrac{Q_{n-1} + Q_n}{2} \times d$

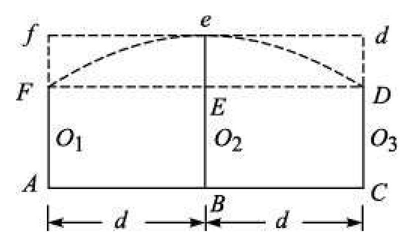
Total area = {*O*1 + 2*O*2 + … + 2*On* – 1 + *On*} $\dfrac{\text{common distance}}{2}$ {(1st ordinate + last ordinate + 2 (sum of other ordinate)}

Thus, the trapezoidal rule may be stated as follows:

To the sum of the first and the last ordinate, twice the sum of intermediate ordinates is added. This total sum is multiplied by the common distance. Half of this product is the required area. ***Limitation -*** *There is no limitation for this rule. This rule can be applied for any number of ordinates.*

(d) Simpson's Rule

In this rule, the boundaries between the ends of ordinates are assumed to form an arc of a parabola. Hence, Simpson's rule is sometimes called the *parabolic rule*.



Let

*O*1 *O*2, *O*3 = three consecutive ordinates

d = common distance between the ordinates

Area *AFeDC* = area of trapezium *AFDC* + area of segment *FeDEF*

Here,

Area of trapezium = $\dfrac{O_1 + O_3}{2} \times 2d$

Area of segment = $\frac{2}{3}$ area of parallelogram *FfdD*

$= \frac{2}{3} \times Ee \times 2d = \frac{2}{3} \times \left\{O_2 - \frac{O_1 + O_3}{2}\right\} \times 2d$

So, the area between the first two divisions,

$$\Delta_1 = \frac{O_1 + O_3}{2} \times 2d + \frac{2}{3}\left\{O_2 - \frac{O_1 + O_3}{2}\right\} \times 2d$$

$$= \frac{d}{3}(O_1 + 4O_2 + O_3)$$

Similarly, the area between next two divisions,

$\Delta_2 = \frac{d}{3}(O_3 + 4O_4 + O_5)$, and so on.

$$\therefore \text{ Total area} = \frac{d}{3}(O_1 + 4O_2 + 2O_3 + 4O_4 + \cdots + O_n)$$

$$= \frac{d}{3}\{O_1 + O_n + 4(O_2 + O_4 + \ldots) + 2(O_3 + O_5 + \ldots)\} \quad (7.4)$$

$= \dfrac{\text{common distance}}{3}$ {first ordinate + last ordinate)

+ 4 (sum of even ordinates)

+ 2 (sum of remaining odd ordinates)}

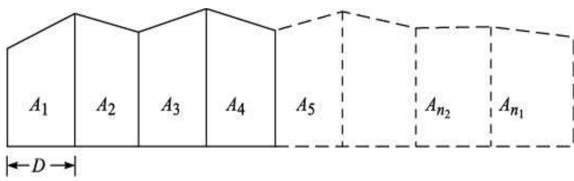
Thus, the role may be stated as follows.

To the sum of the first and the last ordinate, four times the sum of even ordinates and twice the sum of the remaining odd ordinates are added. This total sum is multiplied by the common distance. One-third of this product is the required area.

Trapezoidal Rule	Simpson's Rule
1. The boundary between the ordinates is considered straight.	1. The boundary between the ordinates is considered an arc of a parabola.
2. There is no limitation. It can be applied for any number of ordinates. That is, the number of divisions must be even.	2. To apply this rule, the number of ordinates must be odd.
3. It gives an approximate result.	3. It gives a more accurate result.

8.3 Calculation of Volumes by Prismoidal Formula & Trapezoidal Formula, Prismoidal Corrections, Curvature Correction for Volumes.

Formula for Calculation of Volume –



A. Trapezoidal Rule (Average-End-Area Rule)

Volume (cutting or filling), $V = \frac{D}{2}\{A_1 + A_n + 2(A_2 + A_3 + \ldots + A_{n-1})\}$

i.e. volume $= \frac{\text{common distance}}{2}$ {area of first section + area of last section + 2 (sum of area of other sections)}

B. Prismoidal Formula

Volume (cutting or filling), $V = \frac{D}{3}\{A_1 + A_n + 4(A_2 + A_4 + A_{n-1}) + 2(A_3 + A_5 + \ldots + A_{n-2})\}$

i.e., $V = \frac{\text{common distance}}{2}$ {area of first section + area of last section + 4 (sum of areas of even sections) + 2 (sum of areas of odd sections)}

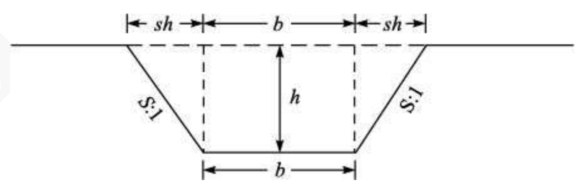
Formula For Calculation of Crosssectional Area –

- ***Level Section***

When the ground is level along the transverse direction:

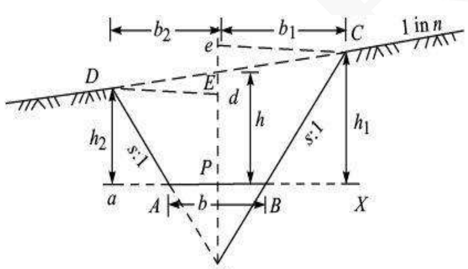
Cross-sectional area $= \frac{b + b + 2sh}{2} \times h$

$= (b + sh)h$



- ***Two-Level Section***

When the ground surface has a transverse slope:



Area $= \frac{1}{2}\left\{\left(\frac{b}{2s} + h\right)b_2 + \frac{1}{2}\left(\frac{b}{2s} + h\right)b_1 - \frac{1}{2}b \times \frac{b}{2s}\right\}$

$= \frac{1}{2}\left\{\left(\frac{b}{2s} + h\right)(b_1 + b_2) - \frac{b^2}{2s}\right\}$

Prismoidal Correction for Trapezoidal or Average-End Area Rule

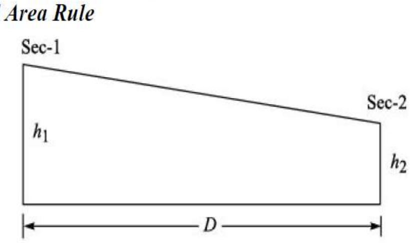


Fig. 8.7 Sample for Prismoidal Correction

1. Prismoidal correction for level section:

$C_p = \frac{D \times s}{6}(h_1 - h_2)^2$ (Considering, transverse slope = 1 in n side slope = s : 1)

2. Prismoidal correction for two-level section:

$$C_p = \frac{D \times s}{6} \times \left(\frac{n^2}{n^2 - s^2}\right) \times (h_1 - h_2)^2$$

3. Prismoidal correction for side hill two-level section:

(a) C_p (for cutting) $= \frac{D}{12(n - s_1)} \times n^2(h_1 - h_1)^2$ (side slope = s_1 : 1)

(b) C_p (for filling) $= \frac{D}{12(n - s_2)} \times n^2(h_1 - h_2)^2$ (side slope = s_2 : 1)

4. Prismoidal correction for three-level section:

$C_p = \frac{D}{12}(h_1 - h_2)$ (whole width of first section – whole width of second section)

THANK YOU