

# Mapping And Contouring

As stated earlier the aim of surveying is to make plans and maps to show various objects on the ground at their relative position to suitable scale. Various steps involved in making the plans is explained in this chapter. Contouring is the technique of showing the levels of ground in a plan. This technique is also explained in this article.

## 17.1 MAPPING

After completing field work in chain survey and compass survey lot of office work is involved to prepare the plan of the area surveyed. In plane table survey office work is less. The office work involved consist of

1. Applying necessary corrections to measurements
2. Drawing index plan
3. Selecting scale
4. Selecting orientation
5. Drawing network of survey lines
6. Distributing closing error
7. Filling in the details
8. Colouring the map
9. Drawing graphical scale
10. Writing index.

### 17.1.1 Applying Necessary Corrections to Measurements

Necessary tape and chain corrections and corrections for local attraction in case of compass survey, should be applied to the survey lines measured.

### **17.1.2 Drawing Index Plan**

On a rough sheet index plan also known as key plan is drawn. This need not be to the scale but distances and directions of network of survey lines should be approximately to a scale. This plan is necessary to identify the shape of the area to be plotted.

### **17.1.3 Selecting Scale**

Depending upon the type of survey, scale should be selected. In general, scale selected should be as large as possible, if a range of scale is recommended. It depends upon the size of the paper as well as largest linear measurement in the field.

### **17.1.4 Selecting Orientation**

Looking at index plan, orientation of map is to be decided so that the map is placed in the middle of the drawing sheet with its larger dimension approximately along the length of paper. North direction is selected and marked.

### **17.1.5 Drawing Network of Survey Lines**

Studying index map and orientation of paper, first station point of survey is marked. Starting from here one by one survey line is drawn to the scale in its direction. After drawing all survey lines, it is clearly seen whether the selected scale and orientation appropriate. If necessary they may be changed and network of survey lines is redrawn.

### **17.1.6 Distributing Closing Error**

Sometimes in closed traverse, the last point may not coincide with the plotted position of first point. The difference between the plotted position is known as closing error. Before adjusting closing error it is necessary that there are no plotting errors. If it is due to field work error and the error is reasonably small it can be adjusted in the office. If error is large, one has to go back to the field and check doubtful measurements. In the office closing error is adjusted distributing it suitably to all lines graphically or by mathematical calculation of corrected coordinates of station points. After adjusting closing error network of survey lines are drawn as per the convention.

### **17.1.7 Filling in the Details**

Surveyor has to go through details of one by one survey lines. One by one point of object noted in the field is marked on the drawing sheet by converting the change and offsets to the scale. Main scale and offset scales will be quite useful for this work. After marking the salient points of the objects like building, boundary lines, roads, culvert ends, trees, electric poles etc. the respective lines are joined to mark the object. The field book will be useful in identifying the objects. If the object is building, the measurements may be only for salient points near the survey lines looking at overall dimensions of the building and scaling down, complete building may be shown in the plan. Thus attending to the field observations of each survey lines all details may be shown. Standard conventions should be used in showing the objects.

### **17.1.8 Colouring the Map**

If coloured maps are to be made, the recommended light washes of standard shades as listed in IS 962-1989 (Chapter 7) may be applied.

### **17.1.9 Drawing Graphical Scale**

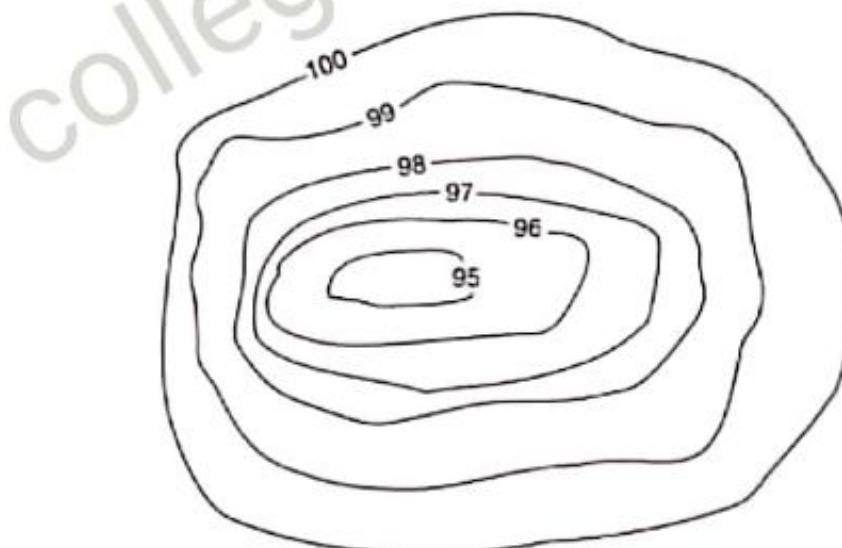
As the drawing sheet may shrink and the measurement taken from shrunk sheet may mislead the distances between any two objects on the map, it is necessary to draw a graphical scale of 150 to 270 mm long just over the space for indexing the drawing, which is right hand side lower corner of the sheet.

### **17.1.10 Writing Index**

Index is the details giving the description of the area plotted, scale used, name of leader of survey party and the person drawing the plan/map, etc. It is normally written in the right hand side lower corner of the drawing sheet. North direction is shown neatly at the right hand side top corner.

## **17.2 CONTOURS**

A contour line is an imaginary line which connects points of equal elevation. Such lines are drawn on the plan of an area after establishing reduced levels of several points in the area. The contour lines in an area are drawn keeping difference in elevation of between two consecutive lines constant. For example, Fig. 17.1 shows contours in an area with contour interval of 1 m. On contour lines the level of lines is also written.



**Fig. 17.1. Contours**

### **17.2.1 Characteristics of Contours**

The contours have the following characteristics:

1. Contour lines must close, not necessarily in the limits of the plan.
2. Widely spaced contour indicates flat surface.

- Closely spaced contour indicates steep ground.
- Equally spaced contour indicates uniform slope.
- Irregular contours indicate uneven surface.
- Approximately concentric closed contours with decreasing values towards centre (Fig. 17.1) indicate a pond.
- Approximately concentric closed contours with increasing values towards centre indicate hills.
- Contour lines with U-shape with convexity towards lower ground indicate ridge (Fig. 17.2).

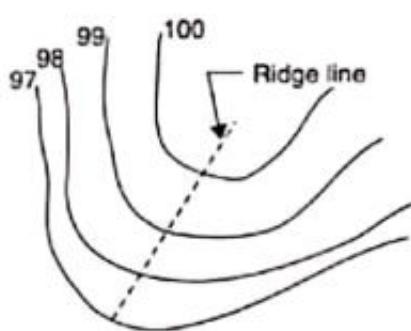


Fig. 17.2

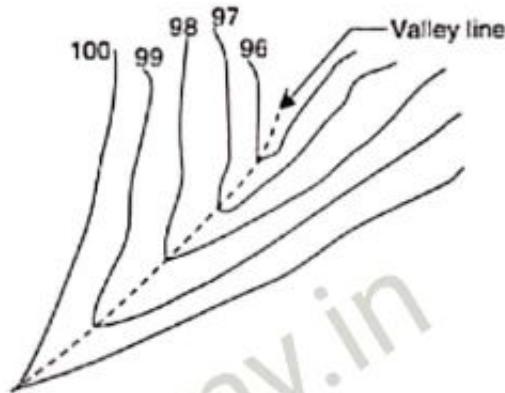


Fig. 17.3

- Contour lines with V-shaped with convexity towards higher ground indicate valley (Fig. 17.3).
- Contour lines generally do not meet or intersect each other.
- If contour lines are meeting in some portion, it shows existence of a vertical cliff (Fig. 17.4).

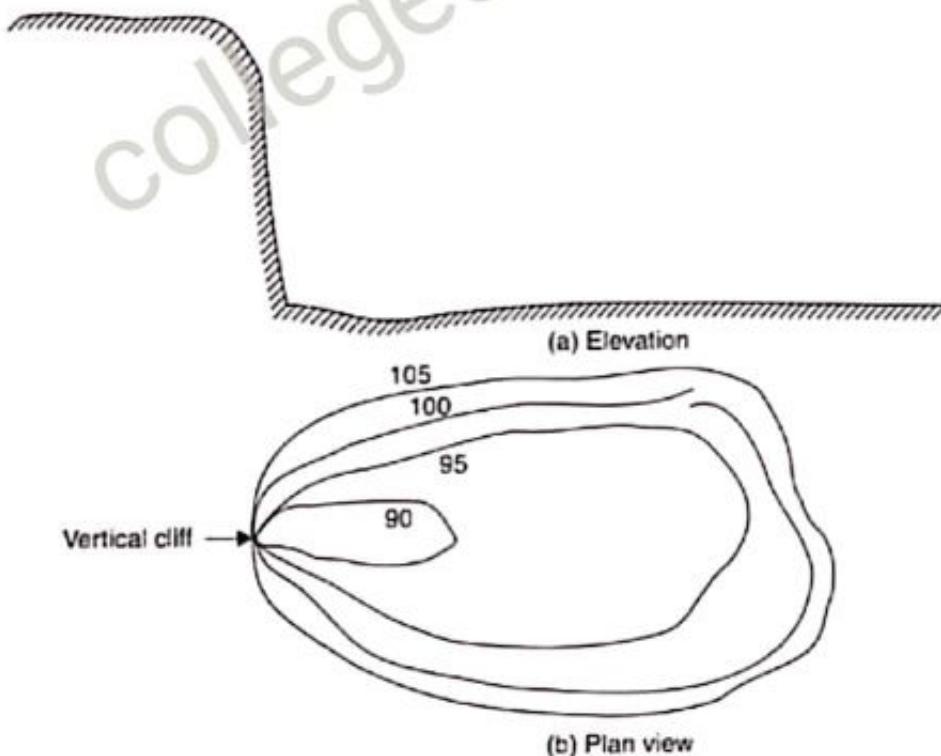


Fig. 17.4

12. If contour lines cross each other, it shows existence of overhanging cliffs or a cave (Fig. 17.5).

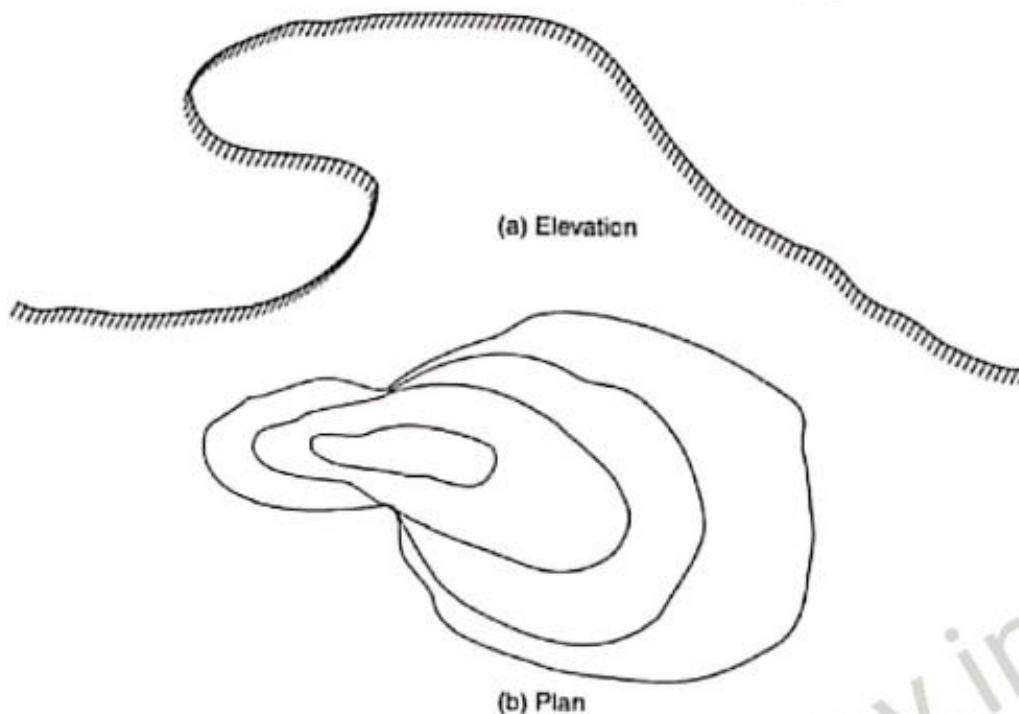


Fig. 17.5

#### 17.2.2 Uses of Contour Maps

Contour maps are extremely useful for various engineering works:

1. A civil engineer studies the contours and finds out the nature of the ground to identify **Suitable site for the project** works to be taken up.
2. By **drawing the section** in the plan, it is possible to find out profile of the ground along that line. It helps in finding out depth of cutting and filling, if formation level of road/railway is decided.
3. **Intervisibility of any two points** can be found by drawing profile of the ground along that line.
4. **The routes** of the railway, road, canal or sewer lines can be decided so as to minimize and balance earthworks.
5. **Catchment area** and hence quantity of water flow at any point of nalla or river can be found. This study is very important in locating bunds, dams and also to find out flood levels.
6. From the contours, it is possible to determine the **capacity of a reservoir**.

### 17.3 METHODS OF CONTOURING

Contouring needs the determination of elevation of various points on the ground and at the same the horizontal positions of those points should be fixed. To exercise vertical control levelling work is carried out and simultaneously to exercise horizontal control chain survey or compass survey or plane table survey is to be carried out. If the theodolite is used both horizontal and vertical controls can be achieved from the same instrument. Based on the instruments used one can classify the contouring in different groups.

However, broadly speaking there are two methods of surveying:

1. Direct methods
2. Indirect methods.

### 17.3.1 Direct Methods

It consists in finding vertical and horizontal controls of the points which lie on the selected contour line.

For vertical control levelling instrument is commonly used. A level is set on a commanding position in the area after taking fly levels from the nearby bench mark. The plane of collimation/height of instrument is found and the required staff reading for a contour line is calculated. The instrument man asks staff man to move up and down in the area till the required staff reading is found. A surveyor establishes the horizontal control of that point using his instruments. After that instrument man directs the staff man to another point where the same staff reading can be found. It is followed by establishing horizontal control. Thus several points are established on a contour line on one or two contour lines and suitably noted down. Plane table survey is ideally suited for this work. After required points are established from the instrument setting, the instrument is shifted to another point to cover more area. The level and survey instrument need not be shifted at the same time. It is better if both are nearby so as to communicate easily. For getting speed in levelling sometimes hand level and Abney levels are also used. This method is slow, tedious but accurate. It is suitable for small areas.

### 17.3.2 Indirect Methods

In this method, levels are taken at some selected points and their levels are reduced. Thus in this method horizontal control is established first and then the levels of those points found. After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points. For selecting points anyone of the following methods may be used:

- (a) Method of squares,
- (b) Method of cross-section, or
- (c) Radial line method.

**Method of Squares:** In this method area is divided into a number of squares and all grid points are marked (Ref. Fig. 17.6). Commonly used size of square varies from  $5\text{ m} \times 5\text{ m}$  to

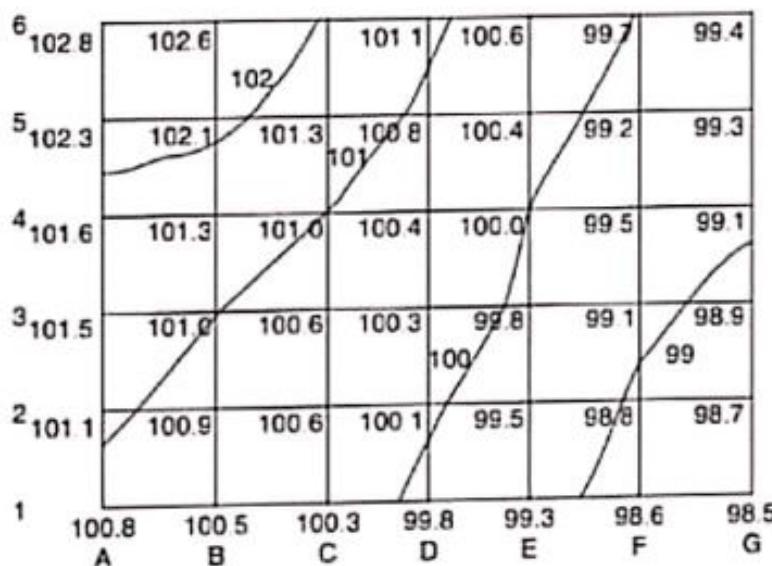


Fig. 17.6

$20\text{ m} \times 20\text{ m}$ . Levels of all grid points are established by levelling. Then grid square is plotted on the drawing sheet. Reduced levels of grid points marked and contour lines are drawn by interpolation [Ref. Fig. 17.6].

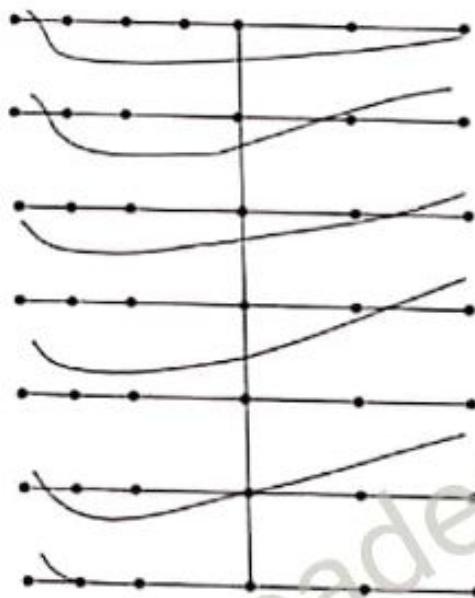


Fig. 17.7

**Method of Cross-section:** In this method cross-sectional points are taken at regular interval. By levelling the reduced level of all those points are established. The points are marked on the drawing sheets, their reduced levels (RL) are marked and contour lines interpolated. Figure 17.7 shows a typical planning of this work. The spacing of cross-section depends upon the nature of the ground, scale of the map and the contour interval required. It varies from  $20\text{ m}$  to  $100\text{ m}$ . Closer intervals are required if ground level varies abruptly. The cross-sectional line need not be always be at right angles to the main line. This method is ideally suited for road and railway projects.

**Radial Line Method:** [Fig. 17.8]. In this method several radial lines are taken from a point in the area. The direction of each line is noted. On these lines at selected distances points are marked and levels determined. This method is ideally suited for hilly areas. In this survey theodolite with tacheometry facility is commonly used.

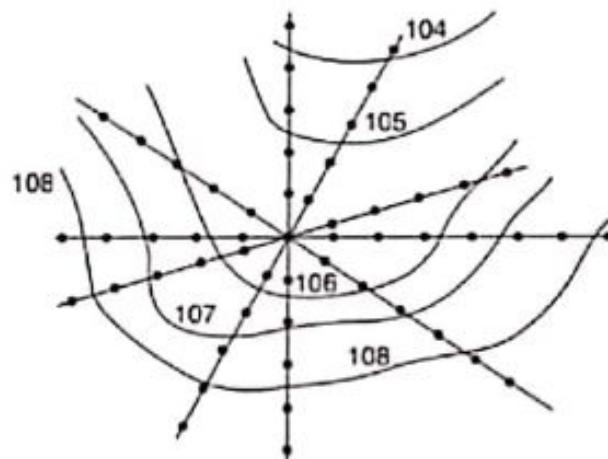


Fig. 17.8

For interpolating contour points between the two points any one of the following method may be used:

(a) Estimation

(b) Arithmetic calculation

(c) Mechanical or graphical method.

Mechanical or graphical method of interpolation consist in linearly interpolating contour points using tracing sheet:

On a tracing sheet several parallel lines are drawn at regular interval. Every 10th or 5th line is made darker for easy counting. If RL of A is 97.4 and that of B is 99.2 m. Assume the bottom most dark line represents. 97 m RL and every parallel line is at 0.2 m intervals. Then hold the second parallel line on A. Rotate the tracing sheet so that 100.2 the parallel line passes through point B. Then the intersection of dark lines on AB represent the points on 98 m and 99 m contours [Ref. Fig. 17.9]. Similarly the contour points along any line connecting two neighbouring points may be obtained and the points pricked. This method maintains the accuracy of arithmetic calculations at the same time it is fast.

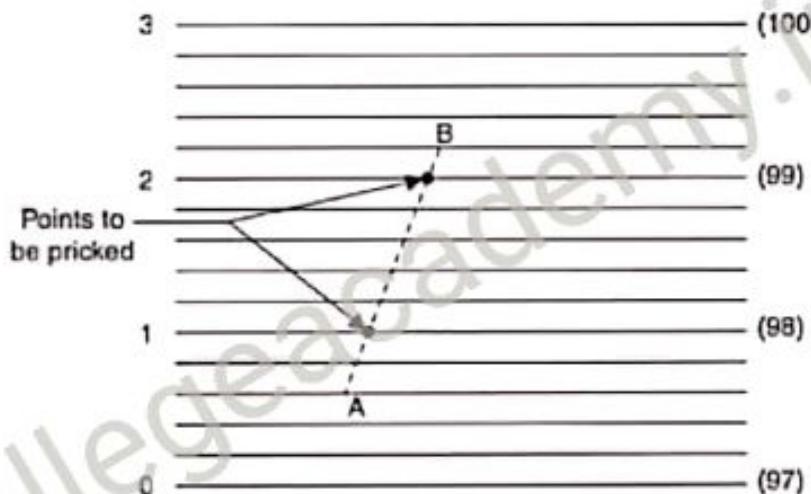


Fig. 17.9

## Drawing Contours

After locating contour points smooth contour lines are drawn connecting corresponding points on a contour line. French curves may be used for drawing smooth lines. A surveyor should not lose the sight of the characteristic feature on the ground. Every fifth contour line is made thicker for easy readability. On every contour line its elevation is written. If the map size is large, it is written at the ends also.

## QUESTIONS

1. Explain the step by step procedure of mapping area surveyed.
2. Explain the terms 'contour lines' and 'contour intervals'.
3. List the characteristics of contours.
4. Sketch the typical contours for the following:
  - (a) Valley
  - (b) Ridge
  - (c) Vertical cliff
  - (d) Overhanging cliff.
5. List the various uses of contour maps.

# Areas and Volumes

The land is always bought and sold on the basis of cost per unit area. For road and railways land is to be acquired on the basis of area. In the design of bridges and bunds catchment area of river and nalla are required. Thus finding areas is the essential part of surveying. It may be noted that area to be found is the projected area. Units used for finding areas are square metres, hectare and square kilometre. Relation among them are

$$\text{Hectare} = 100 \text{ m} \times 100 \text{ m} = 1 \times 10^4 \text{ m}^2$$

$$\begin{aligned}\text{Square kilometer} &= 1000 \text{ m} \times 1000 \text{ m} = 1 \times 10^6 \text{ m}^2 \\ &= 100 \text{ hectare}\end{aligned}$$

Similarly volume of earth work involved in projects like road, rail and canal are to be found by surveying. Capacity of reservoir also need volume calculations. In this chapter calculation of areas and volumes based on surveying are explained.

## 18.1 COMPUTATION OF AREAS FROM FIELD NOTES

If the area is bound by straight edges, it can be subdivided in a set of convenient figures and area calculated. But in most of the cases the boundary may have irregular shape. In such cases major area is subdivided into regular shape and area is found. The smaller area near the boundary is found from taking offset from a survey line [Ref. Fig. 18.1].

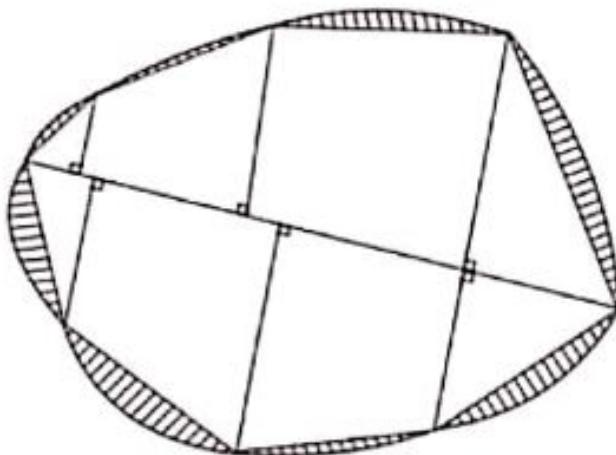


Fig. 18.1

### 18.1.1 Computation of Areas of Regular Figures

The following expressions for calculating areas may be noted:

(a) **Triangle:**

- (i) If base width is  $b$  and height is ' $h$ '.

$$A = \frac{1}{2} bh \quad \dots(18.1)$$

- (ii) If  $a$ ,  $b$  and  $c$  are the sides of a triangle,

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

where  $s = \frac{a+b+c}{2}$  ...(18.2)

- (b) **Rectangle:** If  $b$  and ' $d$ ' are the dimension of a rectangle,

$$A = bd \quad \dots(18.3)$$

(c) **Trapezium:**

$$A = d \frac{h_1 + h_2}{2}, \text{ where } d \text{ is the distance between two parallel sides and } h_1 \text{ and } h_2 \text{ lengths of parallel sides.} \quad \dots(18.4)$$

### 18.1.2 Areas of Irregular Shapes

For this purpose from a survey line offsets are taken at regular intervals and area is calculated from any one of the following methods:

- (a) Area by Trapezoidal rule

- (b) Area by Simpson's rule.

(a) **Area by Trapezoidal Rule:**

If there are ' $n + 1$ ' ordinates at  $n$  equal distances ' $d$ ', then total length of line is  $L = nd$ . Area of each segment is calculated treating it as a trapezium. Referring to Fig. 18.2.

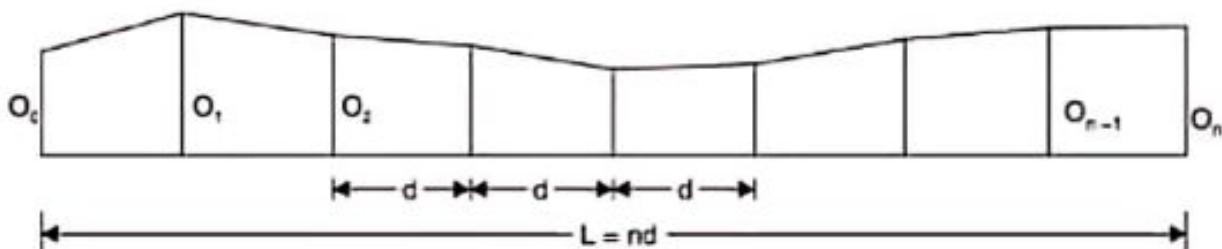


Fig. 18.2

$$\text{Area of first segment} = \frac{O_0 + O_1}{2} d$$

By adding all such segmental areas, we get total

$$A = \frac{O_0 + O_1}{2} d + \frac{O_1 + O_2}{2} d + \dots + \frac{O_{n-1} + O_n}{2} d \\ = \left[ \frac{O_0 + O_n}{2} + O_1 + O_2 + \dots + O_{n-1} \right] d \quad \dots(18.5)$$

**(b) Area by Simpson's Rule**

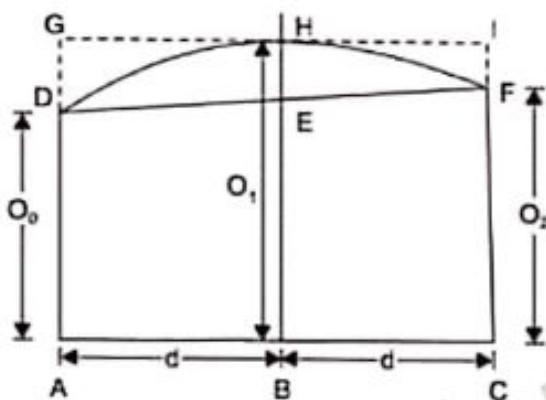


Fig. 18.3

In this method, the boundary line between two segments is assumed parabolic. Figure 18.3 shows first two segments of Fig. 18.2, in which boundary between the ordinates is assumed parabolic.

∴ Area of the first two segments

$$\begin{aligned} &= \text{Area of trapezium } ACFD + \text{Area of parabola } DEFH \\ &= \frac{O_0 + O_2}{2} 2d + \frac{2}{3} \times 2d \times EH \\ &= (O_0 + O_2) d + \frac{4}{3} d \left( O_1 - \frac{O_0 + O_2}{2} \right) \\ &= \frac{d}{3} [3O_0 + 3O_2 + 4O_1 - 2O_0 - 2O_2] \\ &= \frac{d}{3} [O_0 + 4O_1 + O_2] \end{aligned}$$

Area of next two segments

$$= \frac{d}{3} [O_2 + 4O_3 + O_4]$$

Area of last two segments

$$= \frac{d}{3} [O_{n-2} + 4O_{n-1} + O_n]$$

$$\therefore \text{Total } A = \frac{d}{3} \left[ (O_0 + O_n) + 4(O_1 + O_3 + \dots + O_{n-1}) + 2(O_2 + O_4 + \dots + O_{n-2}) \right] \quad \dots(18.6)$$

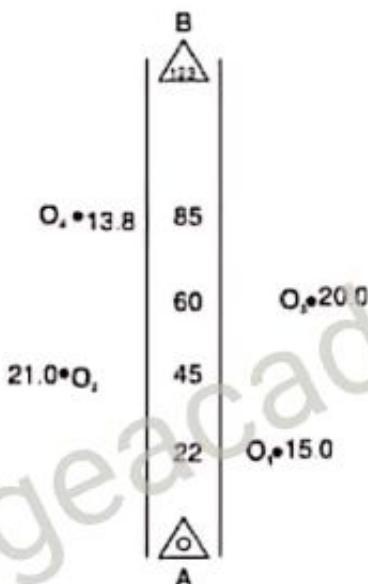
It is to be noted that the equation 18.6 is applicable if the number of segments ( $n$ ) are even, in other words, if total number of ordinates's are odd.

If  $n$  is odd, then for  $n - 1$  segments area is calculated by Simpson's rule and for the last segment trapezoidal rule is applied.

Trapezoidal rule gives better results if the boundary is not irregular to great extent. Simpson's rule should be used if the boundary is highly irregular. This rule gives slightly more value compared to trapezoidal rule, if the curve is concave towards the survey line and gives lesser value, if the boundary is convex towards survey line.

In both methods accuracy can be improved if the number of segments are increased.

■ **Example 18.1:** Plot the following cross staff survey of a land and compute the area:



**Solution:** Referring to Fig. 18.4.

$$\begin{aligned}\text{Total area} &= \text{Area of } \Delta AO_1 C_1 + \text{Area of triangle } AC_2 O_2 + \text{Area of trapezium } C_1 O_1 O_3 C_3 \\ &+ \text{Area of trapezium } C_2 C_4 O_4 O_2 + \text{Area of } \Delta C_3 O_3 B + \text{Area of } \Delta C_4 O_4 B\end{aligned}$$

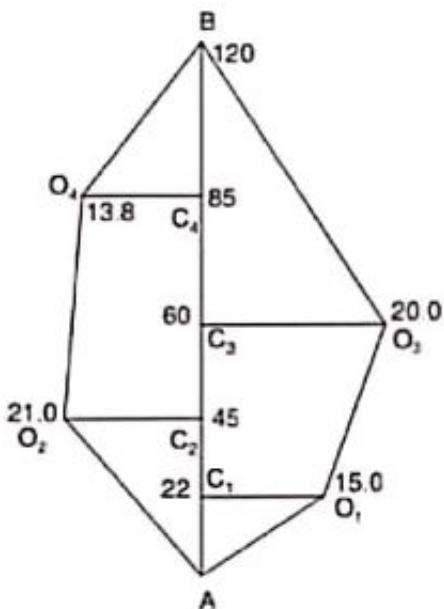


Fig. 18.4

$$\begin{aligned}
 &= \frac{1}{2} \times 22 \times 15 + \frac{1}{2} \times 45 \times 21 + \frac{1}{2} (15 + 20)(60 - 22) + \frac{1}{2} (13.8 + 21.0)(85 - 45) \\
 &\quad + \frac{1}{2} \times 20(120 - 60) + \frac{1}{2} \times 13.8(120 - 8.5)
 \end{aligned}$$

**Area = 2840 m<sup>2</sup>**

**Ans.**

■ **Example 18.2:** The perpendicular offsets taken at 10 m intervals from a survey line to an irregular boundary are 2.18 m, 3.2 m, 4.26 m, 6.2 m, 4.8 m, 7.20 m, 8.8 m, 8.2 m and 5.2 m. Determine the area enclosed between the boundary, survey line, the first and the last offsets by

(i) Trapezoidal rule

(ii) Simpson's rule.

**Solution:**  $d = 10$  m,  $n = \text{number of segments} = 8$  number of ordinates = 9.

Length of survey line =  $8 \times 10 = 80$  m.

(i) Area by trapezoidal rule

$$\begin{aligned}
 A &= \left( \frac{O_0 + O_8}{2} + O_1 + O_2 + \dots + O_7 \right) d \\
 &= \left[ \frac{2.18 + 5.2}{2} + 3.2 + 4.26 + 6.2 + 4.8 + 7.2 + 8.8 + 8.2 \right] 10
 \end{aligned}$$

**Area = 463.5 m<sup>2</sup>**

**Ans.**

(ii) Area by Simpson's method

$$\begin{aligned}
 &= \frac{d}{3} [(O_0 + O_8) + 4(O_1 + O_3 + O_5 + O_7) + 2(O_2 + O_4 + O_6)] \\
 &= \frac{10}{3} [2.18 + 5.2 + 4(3.2 + 6.2 + 7.2 + 8.2) + 2(4.26 + 4.8 + 8.8)] \\
 &= 474.333 \text{ m}^2
 \end{aligned}$$

**Ans.**

■ **Example 18.3:** The following offsets were taken to a curved boundary from a survey line:

0, 2.46, 3.78, 3.26, 4.40, 3.28, 4.24 and 5.20 m.

Compute the area between curved boundary, survey line and end offsets, if the offsets were at a regular interval of 10 m, using Simpson's rule and trapezoidal rule. Compare the results.

**Solution:** Number of offsets = 8

Number of intervals = 7

$$O_0 = 0.0, O_1 = 2.40, O_2 = 3.78, O_3 = 3.26, O_4 = 4.40, O_5 = 3.28,$$

$$O_6 = 4.27, O_7 = 5.20$$

$$d = 10.0 \text{ m}$$

(i) From trapezoidal rule

$$A = \left[ \frac{O_0 + O_7}{2} + O_1 + O_2 + O_3 + O_4 + O_5 + O_6 \right] d$$

$$= \left[ \frac{0.0 + 5.20}{2} + 2.46 + 3.78 + 3.26 + 4.40 + 3.28 + 4.27 \right] 10$$

$\equiv 240.5 \text{ m}^2$

Ans.

### (ii) Simpson's rule

Number of intervals are odd (7). Hence for first six intervals Simpson's rule can be applied and for the last interval, trapezoidal rule will be applied.

$$\begin{aligned}
 A &= \frac{d}{3} [O_0 + O_6 + 4(O_1 + O_3 + O_5) + 2(O_2 + O_4)] + \frac{d}{2} (O_6 + O_7) \\
 &= \frac{10}{3} [0 + 4.27 + 4(2.46 + 3.26 + 3.28) + 2(3.78 + 4.40)] + \frac{10}{2} (4.27 + 5.20) \\
 &= 236.12 \text{ m}^2
 \end{aligned}$$

Ans.

$\therefore$  Simpson's rule gave lesser area, the magnitude being  $240.5 - 236.12 = 3.38 \text{ m}^2$

Ans.

## 18.2 COMPUTING AREAS FROM MAPS

If map of an area is available its area can be found by the following methods:

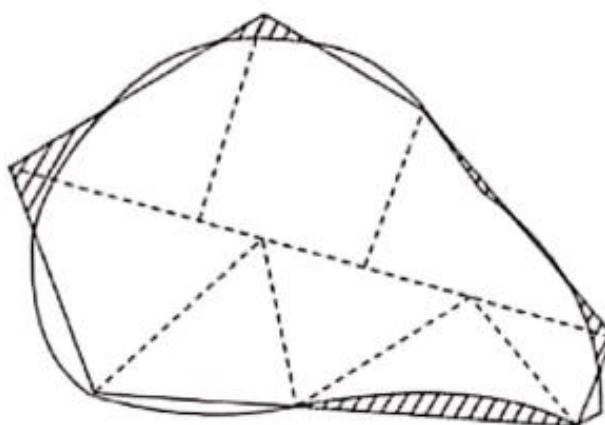
- (i) Approximate methods      (ii) Using planimeter.

### 18.2.1 Approximate Methods

The following three approximate methods are available for calculating area from the map:



**(a) Give and take method:** In this method irregular boundary is approximated with straight lines such that area taken in is equal to the area given out. Accuracy depends upon the judging capacity of the engineer. Then the area with straight edges is divided into a set of simple figures, like triangles and trapezoids and the area of map is found using standard expressions. Figure 18.5 shows such a scheme.



**Fig. 18.5**

**(b) Subdivisions into squares:** Similar to a graph sheet, squares are marked on a transparent tracing sheet, each square representing a known area. Full squares are counted. Fractional squares are counted by give and take approximation. Then the number of squares multiplied by area of each square gives the area of the map Fig. 18.6 shows such a scheme. Finer the mesh better is the accuracy.

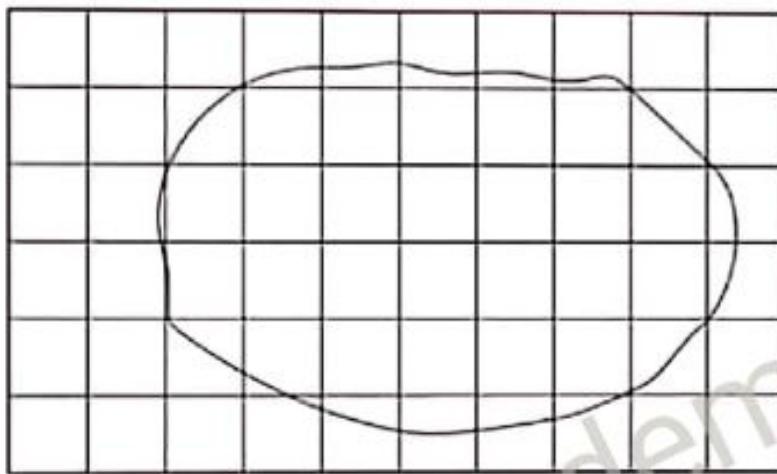


Fig. 18.6

**(c) Subdivisions into rectangles:** In this method, a set of parallel lines are drawn at equal spacing on a transparent paper. Then that sheet is placed over the map and slightly rotated till two parallel lines touch the edges of the map. Then equalising perpendiculars are drawn between the consecutive parallel lines. Thus given area is converted to equivalent set of rectangles and then area is calculated (Ref. Fig. 18.7).

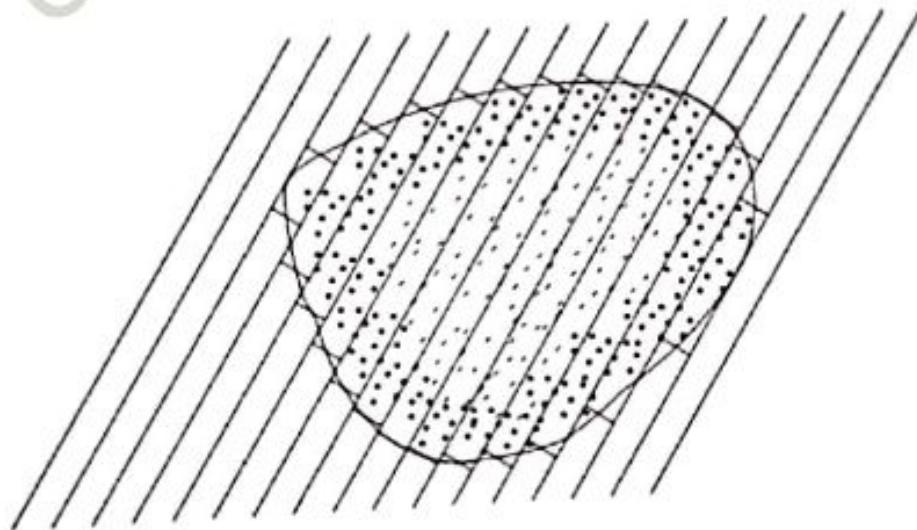


Fig. 18.7

### 18.2.2 Computing Area Using Planimeter

Planimeter is a mechanical instrument used for measuring area of plan. The commonly used planimeter is known as Amsler planimeter (Fig. 18.8). Its construction and uses are explained in this article.

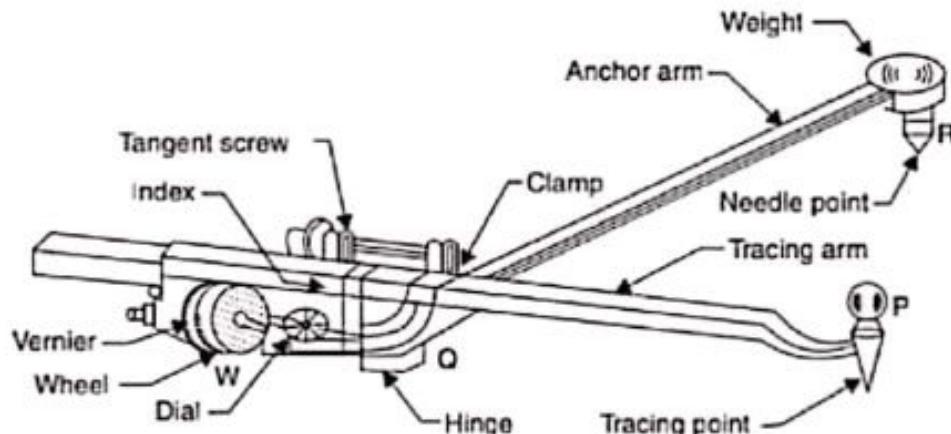


Fig. 18.8. Planimeter

The essential parts of a planimeter are:

1. Anchor: It is a heavy block with a fine anchor pin at its base. It is used to anchor the instrument at a desired point on the plan.
2. Anchor arm: It is a bar with one end attached to anchor block and the other connected to an integrating unit. Its arm length is generally fixed but some planimeters are provided with variable arms length also.
3. Tracing arm: It is a bar carrying a tracer point at one end connected to the integrating unit at the other end. The anchor arm and tracer arms are connected by a hinge. The length of this arm can be varied by means of fixed screw and slow motion screw.
4. Tracing point: This is a needle point connected to the end of tracer arm, which is to be moved over the out line of the area to be measured.
5. Integrating unit: It consists of a hard steel roller and a disc. The axis of roller coincides with the axis of tracer arm hence it rolls only at right angles to the tracer arm. The roller carries a concentric drum which has 100 divisions and is provided with a vernier to read tenth of roller division. A suitable gear system moves a pointer on disc by one division for every one revolution of the roller. Since the disc is provided with 10 such equal divisions, the reading on the integrating unit has four digits:
  - (i) Unit read on the disc
  - (ii) Tenth and hundredth of a unit read on the roller
  - (iii) Thousandth read on the vernier.

Thus if reading on disc is 2, reading on roller is 42 and vernier reads 6, then the total reading

$$F = 2.426$$

### Method of Using Planimeter

To find the area of a plan, anchor point may be placed either outside the plan or inside the plan. It is placed outside the plan, if the plan area is small. Then on the boundary of the plan a point is marked and tracer is set on it. The planimeter reading is taken. After this tracer is carefully moved over the outline of the plan in clockwise direction till the first point is reached. Then the reading is noted. Now the area of the plan may be found as

---

$$\text{Area} = M(F - I + 10N + C) \quad \dots(18.7)$$

where

$M$  = A multiplying constant

$F$  = Final reading

$I$  = Initial reading.

$N$  = The number of completed revolutions of disc. Plus sign to be used if the zero mark of the dial passes index mark in clockwise direction and minus sign if it passes in anticlockwise direction.

$C$  = Constant of the instrument, which when multiplied with  $M$ , gives the area of zero circle.  
**The constant  $C$  is added only when the anchor point is inside the area.**

Multiplying constant  $M$  is equal to the area of the plan (map) per revolution of the roller i.e., area corresponding to one division of disc.

Multiplying constant  $M$  and  $C$  are normally written on the planimeter. The user can verify these values by

- (i) Measuring a known area (like that of a rectangle) keeping anchor point outside the area
- (ii) Again measuring a known area by keeping anchor point inside a known area.

The method is explained with example.

The proof of equation 18.7 is considered as beyond the scope of this book. Interested readers can see the book on surveying and levelling.

## 18.3 COMPUTATION OF VOLUMES

The following three methods are available for computation of volumes:

- (i) From cross-sections
- (ii) From spot levels and
- (iii) From contours.

First method is useful for computing earth work involved in road/rail/canal/sewage works. Second method is useful for finding earth work in foundations of large building and the last method is useful for finding capacity of reservoirs.

### 18.3.1 Computation of Volume from Cross-sections

To compute earth work, profile levelling is carried out along the centre line of the alignment of the project and cross-sectional levels are taken at regular intervals. Then the volume of earth work can be found, if the cross-sections are determined.

First the calculation of cross-sectional area is discussed.

#### (a) If section is level (Fig. 18.9)

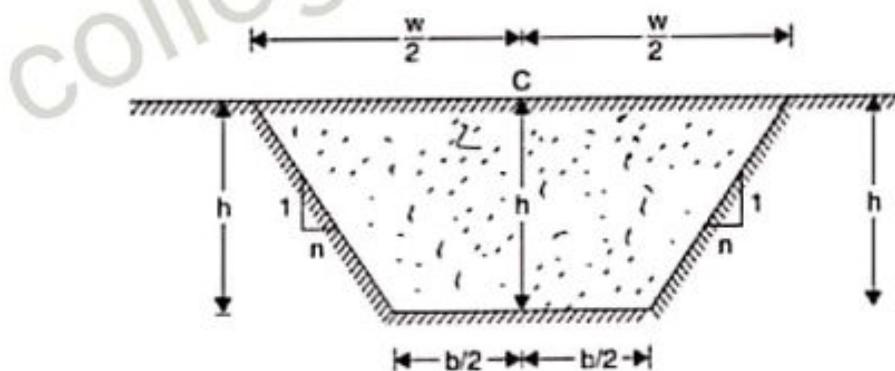


Fig. 18.9

Let 'h' be the depth at the centre line of the alignment and  $1:n$  be the side slopes. Then

$$w = b + 2nh$$

$$\begin{aligned}\therefore A &= \frac{1}{2} (w+b) h \\ &= \frac{1}{2} (b + 2nh + b) h \\ &= (b + nh) h\end{aligned}\quad \dots(18.8)$$

(b) If it is a multilevel section [Fig. 18.10]

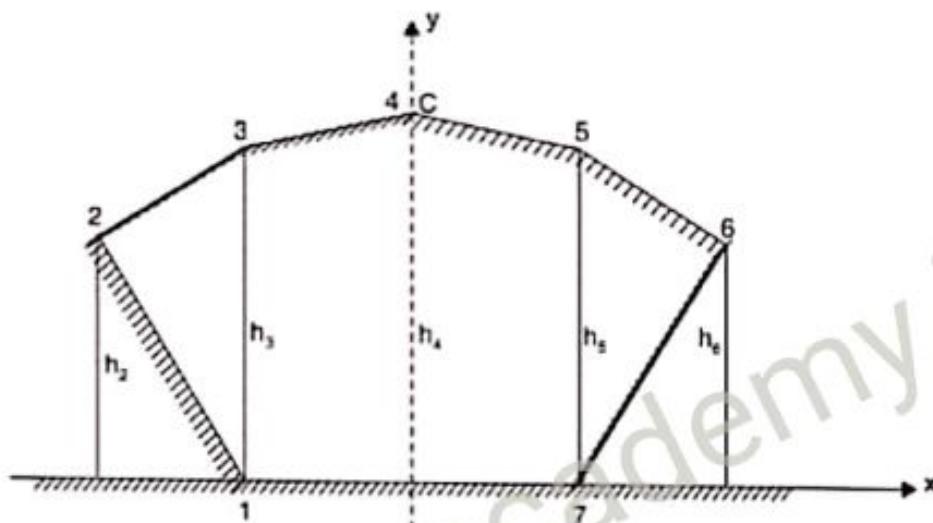
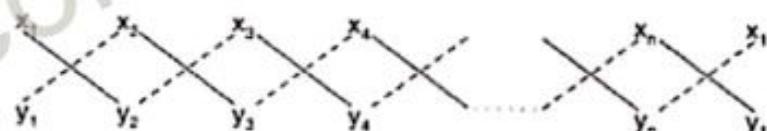


Fig. 18.10

Let the coordinates of points be  $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ , then arrange the coordinates in the following order



Then area of the figure

$$= \frac{1}{2} [\Sigma \text{Product of pair of coordinates connected by continuous lines} - \Sigma \text{Product of coordinates connected by dotted lines}] \quad \dots(18.9)$$

The above formula can be easily proved by taking a simple example of a quadrilateral [Ref. Fig. 18.11]. Let the coordinates of A, B, C and D be  $(x_1, y_1), (x_2, y_2), (x_3, y_3)$  and  $(x_4, y_4)$ . Then area of ABCD = Area of a AB b + Area of b BC c + Area of c CD d - Area of a AD d.

$$= \frac{1}{2} (x_1 + x_2)(y_2 - y_1) + \frac{1}{2} (x_2 + x_3)(y_3 - y_2) + \frac{1}{2} (x_3 + x_4)(y_4 - y_3) - \frac{1}{2} (x_1 + x_4)(y_4 - y_1)$$

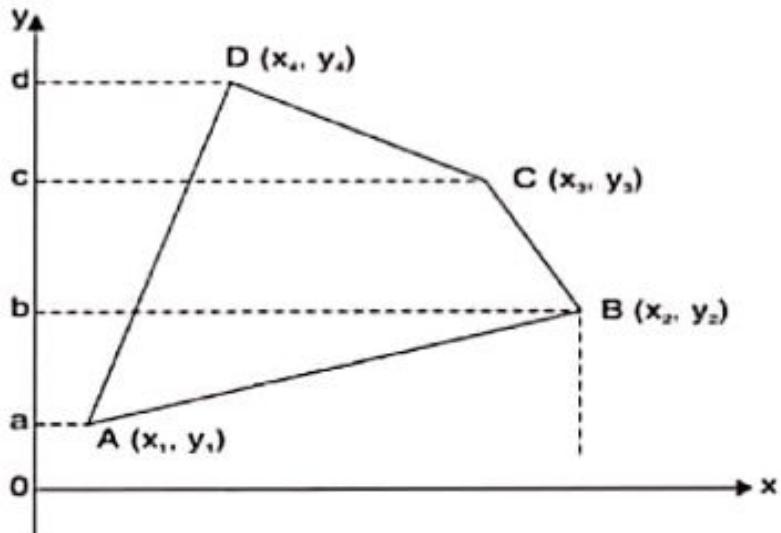


Fig. 18.11

$$\begin{aligned}
 &= \frac{1}{2} [x_1y_2 - x_1y_1 + x_2y_2 - x_2y_1 + x_2y_3 - x_2y_2 + x_3y_3 - x_3y_2 + x_3y_4 - x_3y_3 + x_4y_4 - x_4y_3 \\
 &\quad - x_1y_4 + x_1y_1 - x_4y_4 + x_4y_1] \\
 &= (x_1y_2 + x_2y_3 + x_3y_4 + x_4y_1) - (x_2y_1 + x_3y_2 + x_4y_3 + x_1y_4)
 \end{aligned}$$

[Note terms with same subscript appear in pairs and cancell each other].

Hence equation 18.9 is proved.

### Calculation of Volumes

Once cross-sectional areas at various sections are known volume can be found from trapezoidal or prismoidal rule as given below:

#### Trapezoidal Rule

$$V = d \left[ \frac{A_0 + A_n}{2} + A_1 + A_2 + \dots + A_{n-1} \right] \quad \dots(18.10)$$

where 'n' are number of segments at interval of 'd', Area at L =  $nd$ , being  $A_n$ .

#### Prismoidal Rule

$$V = \frac{d}{3} [(A_0 + A_n) + 4(A_1 + A_3 + \dots + A_{n-1}) + 2(A_2 + A_4 + \dots + A_{n-2})] \quad \dots(18.11)$$

where n is number of even segments.

If number of segments are odd, ( $n$  is odd), for  $n - 1$  segments prismoidal rule may be applied and for the last one trapezoidal rule is applied. Or else for the last segment area at middle of last segment found and prismoidal formula applied for  $A_{n-1}$ ,  $A_m$  and  $A_n$ .

### 18.3.2 Computation of Earth Work from Spot Levels

This method is used to calculate volume of earth work for the elevations of basements, large tanks and borrow pits. In this method the whole area is divided into a number of rectangles or triangles (Fig. 18.13). The levels are taken at corner points before and also after excavation. The depth of excavation at each corner point is measured. Then for each simple figure (rectangle or triangle).

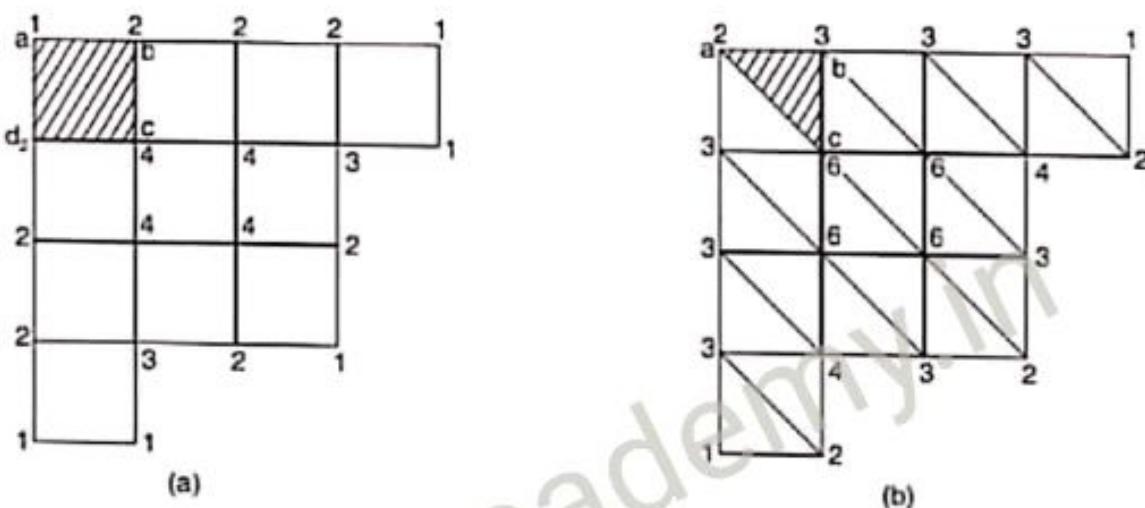


Fig. 18.13

$$V = \text{Area of the figure} \times \text{average depth.}$$

Thus for a rectangle with corner depth  $h_a, h_b, h_c$  and  $h_d$ ,

$$V = \text{Area of rectangle} \times \frac{h_a + h_b + h_c + h_d}{4}$$

For a triangle,

$$V = \text{Area of triangle} \times \frac{h_a + h_b + h_c}{3}$$

All such volumes, when added give total volume of work.

It may be noted that in Fig. 18.13 (a), in total volume calculations depth of some corners appear once, some twice, some of them 3 times and some 4 times. If

$$\Sigma h_1 = \text{some of depths used once}$$

$$\Sigma h_2 = \text{sum of depths used twice}$$

$$\Sigma h_3 = \text{sum of depths used thrice}$$

$$\Sigma h_4 = \text{sum of depths used four times.}$$

Then

$$V = \frac{A}{4} (\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + 4\Sigma h_4) \quad \dots(18.12)$$

Similarly in Fig. 18.13 (b), sum depths are used once, some 2 times, some 3 times and some others 6 times. Defining  $h_i$  same as above.

$$V = \frac{A}{3} (\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + 6\Sigma h_6) \quad \dots(18.13)$$

### 18.3.3 Computation of Volume from Contours

Figure 18.15 shows a dam with full water level of 100 m and contours on upstream side. Capacity of reservoir to be found is nothing but volume of fill with water level at 100 m. The whole area lying within a contour line is found by planimeter. It may be noted that area to be measured is *not* between two consecutive contour lines.

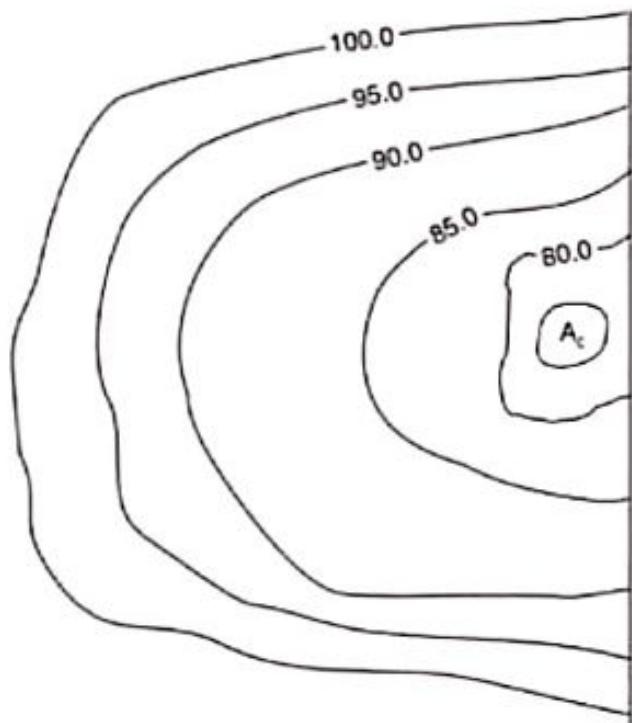


Fig. 18.15

Let  $A_0, A_1, A_2, \dots, A_n$  be area of contours and  $h$  be contour interval. Then from trapezoidal rule:

$$V = h \left[ \frac{A_0 + A_n}{2} + A_1 + A_2 + \dots + A_{n-1} \right]$$

and by prismoidal rule:

$$V = \frac{h}{3} [(A_0 + A_n) + 4(A_1 + A_3 + \dots + A_{n-1}) + 2(A_2 + A_4 + \dots + A_{n-2})]$$

where there are  $n$  segments and  $n$  is even number.

# **Remote Sensing and Its Applications**

Remote sensing is a revolutionary change in surveying in which objects on the earth are sensed from remote places like aircrafts or satellites and are used in map making. It always goes with Geographical Information System (GIS) which is a software tool used for the analysis of remotely sensed data with the help of the computers.

In this chapter introduction is given to remote sensing and GIS. Application of remote sensing is explained.

## **19.1 REMOTE SENSING**

Remote sensing may be defined as art and science of collecting informations about objects, area or phenomenon without having physical contact with it. Eye sight and photographs are common examples of remote sensing in which sunlight or artificial light energy from electricity is made to strike the object. Light energy consists of electromagnetic waves of all length and intensity. When electromagnetic wave falls on the object, it is partly

- 1. absorbed
- 2. scattered
- 3. transmitted
- 4. reflected.

Different objects have different properties of absorbing, scattering, transmitting and reflecting the energy. By capturing reflected waves with sensors, it is possible to identify the objects. However this remote sensing has its own limitations in terms of distance and coverage of area at a time. Photographic survey, in which photographs taken from aircrafts are used for map making, fall under this category of remote sensing. Using electronic equipments, this basic remote sensing technique is extended to identifying and quantifying various objects on the earth by observing them from longer distances from the space. For this purpose, geostationary satellites are launched in the space, which rotate around the earth at the same speed as earth. Hence the relative velocity is zero and they appear stationary when observed from any point on the earth. Depending upon the property of the object, the electromagnetic waves sent from the satellite reflected energy is different. The reflected waves in the bandwidth of infrared, thermal infrared and micro waves are picked up by sensors mounted on satellite. Since each feature on the earth has different reflection property, it is possible to identify the features on

the earth with satellite pictures. Data obtained from satellites are transferred to ground stations through RADARS where user analyses to find out the type of object and the extent of it. This is called image processing. For quantifying the objects computers are used. India is having its own remote sensing satellites like IRS-series, INSAT series and PSLV series.

### **Application of Remote Sensing**

Various applications of remote sensing may be grouped into the following:

1. Resource exploration
2. Environmental study
3. Land use
4. Site investigation
5. Archaeological investigation and
6. Natural hazards study.

**1. Resource Exploration:** Geologists use remote sensing to study the formation of sedimentary rocks and identify deposits of various minerals, detect oil fields and identify underground storage of water. Remote sensing is used for identifying potential fishing zone, coral reef mapping and to find other wealth from ocean.

**2. Environmental Study:** Remote sensing is used to study cloud motion and predict rains. With satellite data it is possible to study water discharge from various industries to find out dispersion and harmful effects, if any, on living animals. Oil spillage and oil slicks can be studied using remote sensing.

**3. Land Use:** By remote sensing, mapping of larger areas is possible in short time. Forest area, agricultural area, residential and industrial area can be measured regularly and monitored. It is possible to find out areas of different crops.

**4. Site Investigation:** Remote sensing is used extensively in site investigations for dams, bridges, pipelines. It can be used to locate construction materials like sand and gravel for the new projects.

**5. Archaeological Investigation:** Many structures of old era are now buried under the ground and are not known. But by studying changes in moisture content and other characteristics of the buried objects and upper new layer, remote sensors are able to recognise the buried structures of archaeological importance.

**6. Natural Hazard Study:** Using remote sensing the following natural hazards can be predicted to some extent and hazards minimised:

1. Earthquake
2. Volcanoes
3. Landslides
4. Floods and
5. Hurricane and cyclones.

## **19.2 GEOGRAPHICAL INFORMATION SYSTEM (GIS)**

Maps are used as the languages of simple geography. Importance of map making is recognised long ago. Surveyors went round the land and prepared maps. Data required for locating and calculating extent of a place/region is called spatial data.

Physical properties and human activities related to a place/region are stored in the form of tables, charts and texts. This information is called attribute data.

Referring to maps/plans and then to attribute data stored in hard copies like books is time consuming updating and managing the data is difficult.

This problem is overcome by combining spatial data and attribute data of the location by appropriate data base management in computers. The location information (spatial data) is digitised from available maps and stored in computers. For this data structure used is either raster data or vector data format. In raster data structures pickcells are associated with the spatial information, while in vector data structure coordinates are associated with each region and sub-regions. Over the spatial data attribute data is overlayed and stored. Once this geographical information system is developed, the user can access the attribute data of any place by clicking over the spatial data of that place. The user can utilise the information for further analysis, planning or for the management. For example, if land records of a village is developed as GIS data, the user can click the state map to pick up the district map and then access taluka map. Then he will access it to pick up the village map. Then land record of that village can be obtained and property map of any owner can be checked and printed. All this can be achieved in a very short time from any convenient place.

Remote sensing and GIS go hand in hand, since lot of data for GIS is from remote sensing. Remote sensing needs GIS for data analysis. Some of the areas of GIS application are:

- 1. drainage systems
- 2. streams and river basins management
- 3. lakes
- 4. canals
- 5. roads
- 6. railways
- 7. land records
- 8. layout of residential areas
- 9. location of market, industrial, cultural and other utilities
- 10. land use of different crops etc.

The above information helps in planning infrastructural development activities such as planning roads, rail routes, dams, canals, tunnels, etc. It helps in taking steps to check hazards of soil erosion and environmental pollution. Monitoring of crop pattern and condition helps in taking necessary action to the challenges in future.