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Earth Works - Area

Targets

- Data Source to Area Calculations
- Planimeter
- Plan areas
- Sectional areas

Introduction

- Engineering Earthworks involve estimations of areas and volumes, i.e. mining, route alignment, water works (reservoirs), tunnels, etc.
- Usually, payment for work done is based on excavations and hauling of material – there's a fine line between profit and loss

AREAS – may be required in connection with;

- **purchase of land,**
- **check of space availability for a particular project,**
- **job tendering etc.**
- **Also for as input to volumetric computations**

Introduction

Much as there are a number of area computation methods with advancements in technology (i.e computers and software, (e.g. AutoCAD, Civil 3D, Model Maker Systems, Surpac, e.t.c), engineers ought to understand the principles around area and volume computations in order to properly manipulate input data, interpretation and utilization of their results.

Areas - Data Source

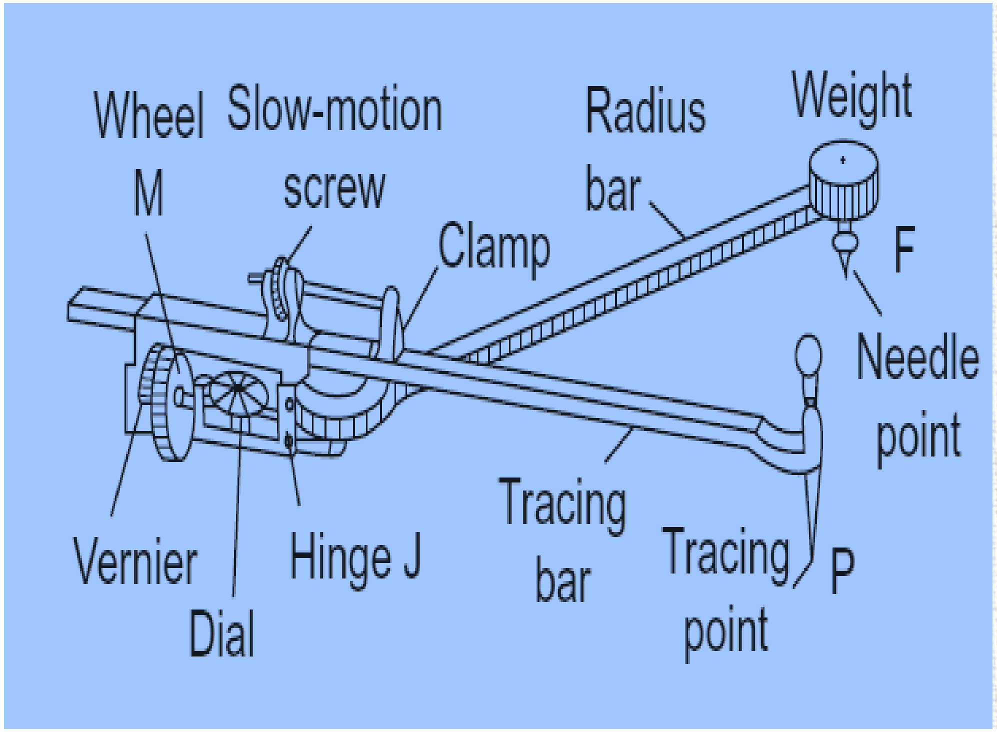
Area computations are based on different data sources (input data). Input data may be available through:

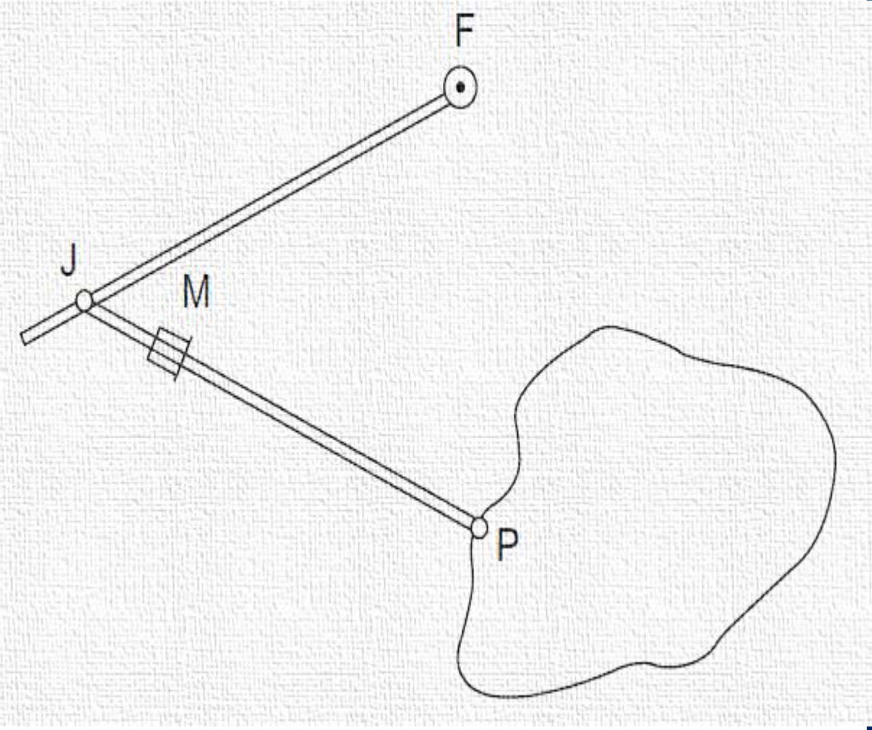
– Plans / drawings
– Field data

A number of factors may influence the choice of method of computation, e.g. shape of the area (regular/irregular)

Area computation methods by a Planimeter - For Regular & Irregular Areas

1. Planimeter method





Area computation methods by the Planimeter - For Regular & Irregular Areas

- Most common method for both regular and irregular areas from the **plans**.

- The instrument uses two arms, JF and JP. The two arms move relative to each other through the hinged joint at J but fixed to the plan by a weighted needle at F. M is a graduated wheel and P is a tracing point. As P is moved around the perimeter of the area the measuring wheel partly rotates, partly slides over the plan with the varying movement of the tracing point.

Area computation methods by the Planimeter - For Regular & Irregular Areas

The measuring wheel is graduated circumferentially into 10 divisions, each of which is further subdivided by 10 into one-hundredths of a revolution, whilst a vernier enables readings to one thousandth of a revolution. The wheel is connected to a *dial* which records the numbered revolutions up to 10. On a fixed-arm planimeter, one revolution of the wheel may represent 100sq.m on a 1:1 basis; thus knowing the number of revolutions and the scale of the plan, the area is easily computed. In the case of a sliding-arm planimeter the sliding arm JP may be set to the scale of the plan, therefore facilitating more direct measurements of the area.

Area Computation methods- Regular Shapes

1. Areas by co-ordinates method

Consider available station coordinates. The method follows the multiplication of algebraic sum of two Northings from two successive stations by the algebraic difference of their Eastings in successive manner- **closing the loop**, provided all coordinates are given.

- The area is the algebraic sum of the products.
- **This approach is linked to the idea that a regular area can be sub-divided into *triangles, rectangles and Trapezoid* to determine the area**

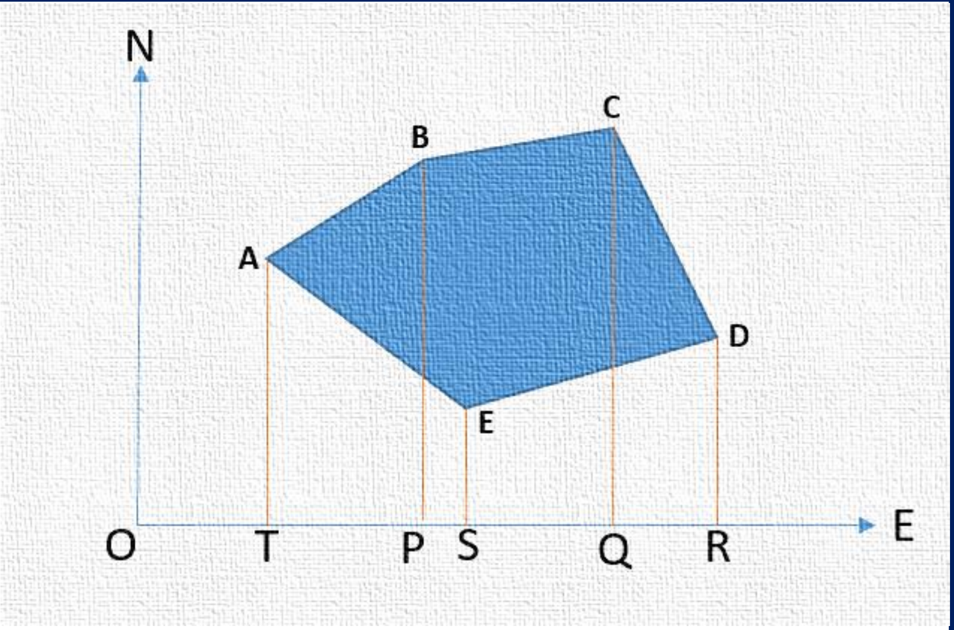
Area Computation methods- Regular Shapes

Thus:

Area **ABCDE** = Area (ABPT + BCQP + CDRQ – AEST – EDRS)

However, from the rule:

$$Area = \frac{N_A+N_B}{2} \times (E_B - E_A) + \frac{N_B+N_C}{2} \times (E_C - E_B) + \frac{N_C+N_D}{2} \times (E_D - E_C) \ \ldots$$



Expanding the expression leads to:

Area = $\frac{1}{2}\left[\sum_{i=1}^{n} N_i(E_{i+1} - E_{i-1})\right]$

Similarly, traverse legs can be projected onto the northing axis.

Area Computation methods- Regular Shapes

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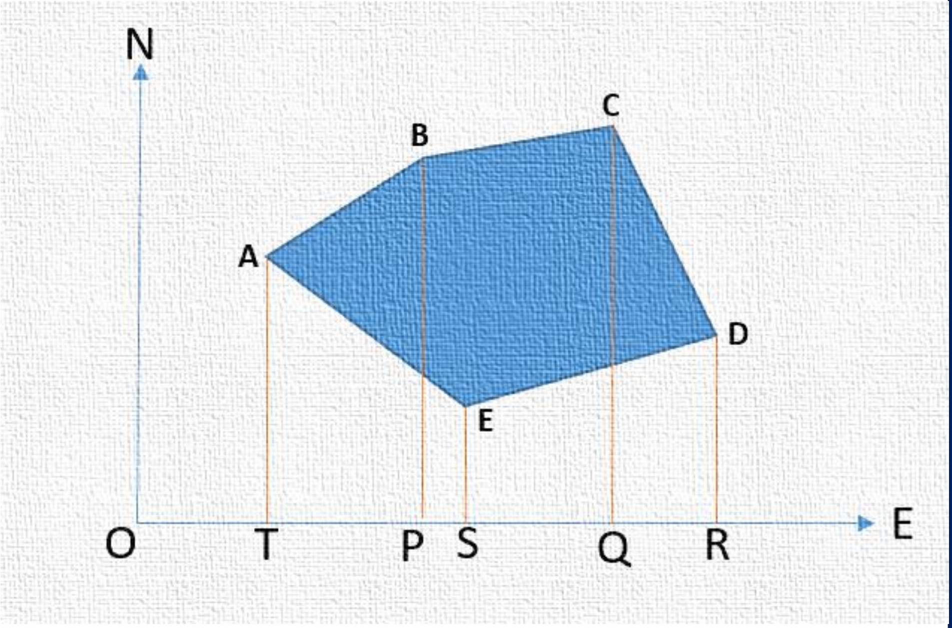

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Area Computation methods- Regular Shapes

Example:

Determine the area in hectares enclosed by the line of a closed traverse ABCDE from the following data.

Station	E(m)	N(m)
A	100.00	200.00
B	206.98	285.65
C	268.55	182.02
D	292.93	148.80
E	191.74	85.70

Solution

Station	N_i	E_{i+1}	E_{i-1}	$N_i(E_{i+1} - E_{i-1})$
A	200.00	206.98	191.74	3048.00
B	285.65	268.55	100.00	48146.31
C	182.02	292.93	206.98	15644.62
D	148.80	191.74	268.55	-11429.33
E	85.70	100.00	292.93	-16534.10
				38875.50

38875.50/2 = **$19437.50m^2$.**

Cross-Section Area Computation

Cross-Section Area

This highly finds application in route alignment projects and also the reservoir construction for example. Suffice to say that determining cross section area is the first step in obtaining the volumes in such projects as ones mention herein.

How?

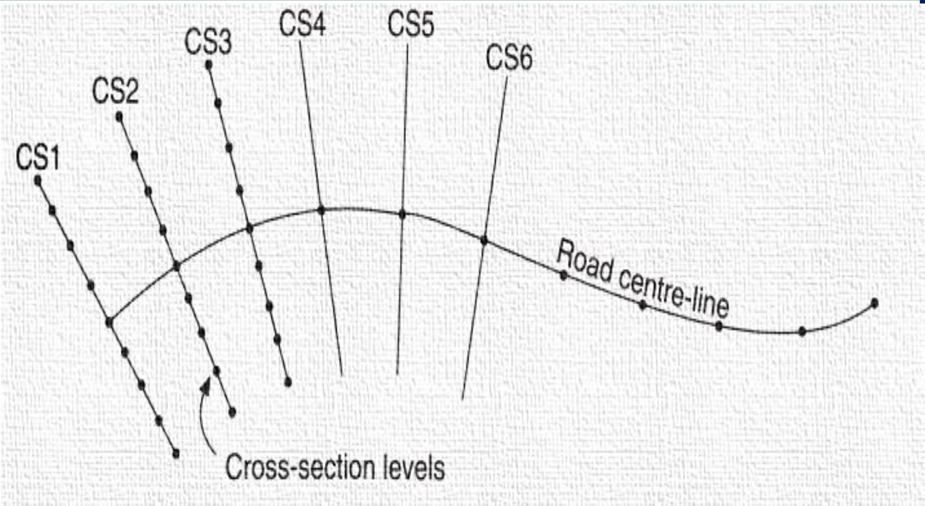
NB: a topographic plan is usually the first plan produced for such projects. This is a plan upon which the proposed route is later designed.

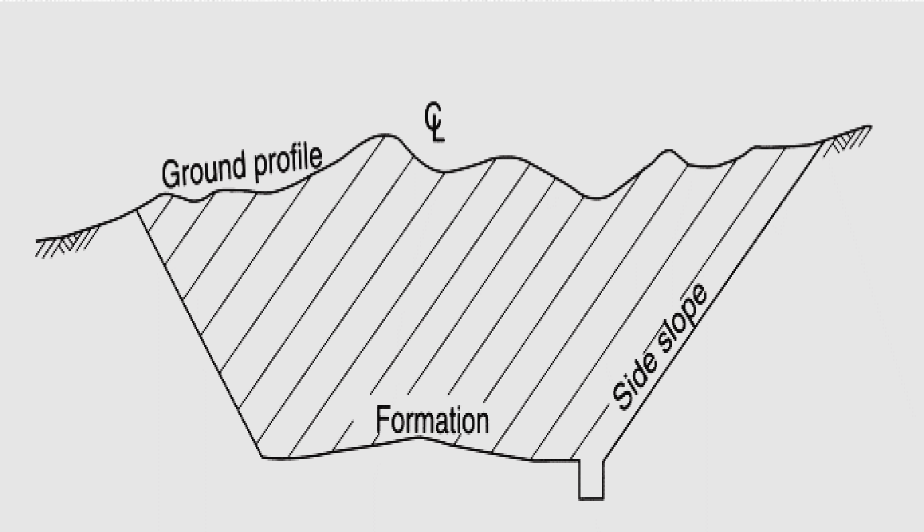
Cross-Section Area Computation

Cross-Section Area cont'd.

Levels can be obtained through:

- standard leveling procedures
- Optical or electromagnetic tacheometry
- Aerial photogrammetry
- Drones
- RTK surveys through DGPS





Cross-Section Area Computation

Cross-Section Area cont'd.

Centre-line of the route is defined in changes at regular intervals. Meanwhile ground levels both along the center-line and at right angles to the center-line are obtained.

The profiles are thus developed from these levels both longitudinal and sectional.

Worth noting that if a designed template depicting a formation level, road width, camber, side slopes, etc. is superimposed on this topo. map, a cross-section is produced whose area can be obtained by Planimeter or computations.

However, the shape of the cross-section is defined in terms of vertical heights (levels) at horizontal distances each side of the center-line.

Cross-Section Area Computation

Cross-Section Area cont'

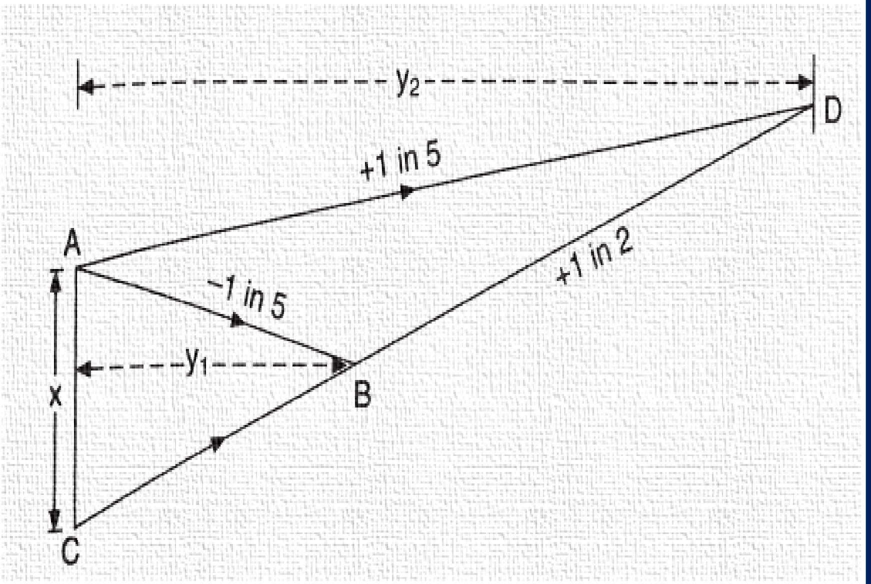
At this point, the whole computation procedure including the road design and optimization, would be carried out on the computer to produce volumes of cut and fill, accumulated volumes, areas and volumes of top-soil strip, side widths, etc.

In an instance where computers are not available, cross-sections may be approximated to the ground profile to afford easy computations. The particular cross-section adopted would be dependent upon the general shape of the ground.

Equations to compute areas and side widths are available despite being over-complicated. Therefore, **rate of approach** method is recommended for simplicity.

Rate of Approach: Principle

- Consider triangle ADC as your cross-section, you may be required to determine the distance y_1.
- At the same time you are provided with the heights x and grades AB and CB in triangle ABC.



The rule is that:

I. When the two grades are running in the **Same direction** (as in Δ ABD), **Subtract** the grades (NB: this situation implies **Same sign** on the grades)

II. When the two grades are running in the **Opposite direction** (as in ΔABC), Add **the grades** (**Opposite signs** + & -)

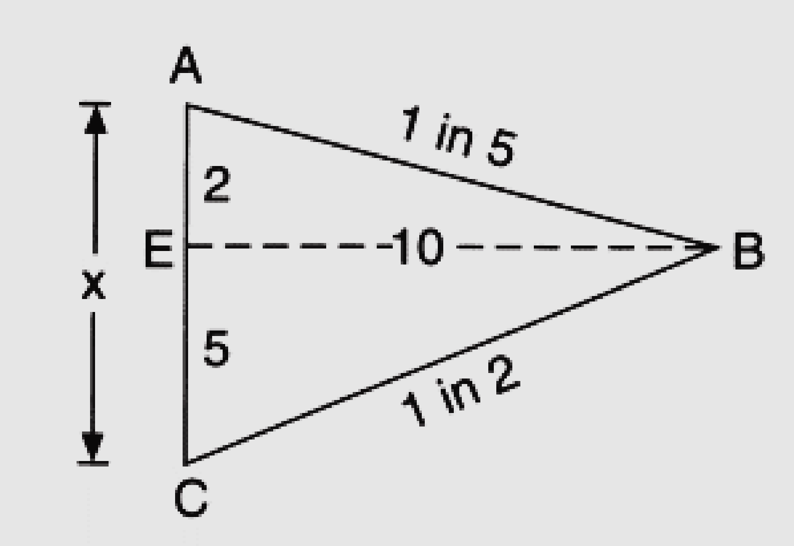
NB: Height x must be vertical relative to the grades

Proving The Rate of Approach Principle

- From the figure, note that 1 in 5 is equivalent to 2 in 10; and 1 in 2 is equivalent to 5 in 10. Thus the two grades diverge from B at the rate of 7 in 10. Prove that x=7, given $y_1 = 10$ and the two grades.

Solution

- We can split the triangle ABC into ABE and EBC, then:
- A grade of 1 in 5 (or 2 in 10) over a distance of 10 units implies 2 units in the vertical. Similarly, a 1 in 2 grade (or 5 in 10) implies 5 units in the vertical over the 10 units distance. Thus AC = AE + AC = 7.
- This is equivalent to: $x \times \left[\left(\frac{1}{5} + \frac{1}{2}\right)\right]^{-1} = y_1$



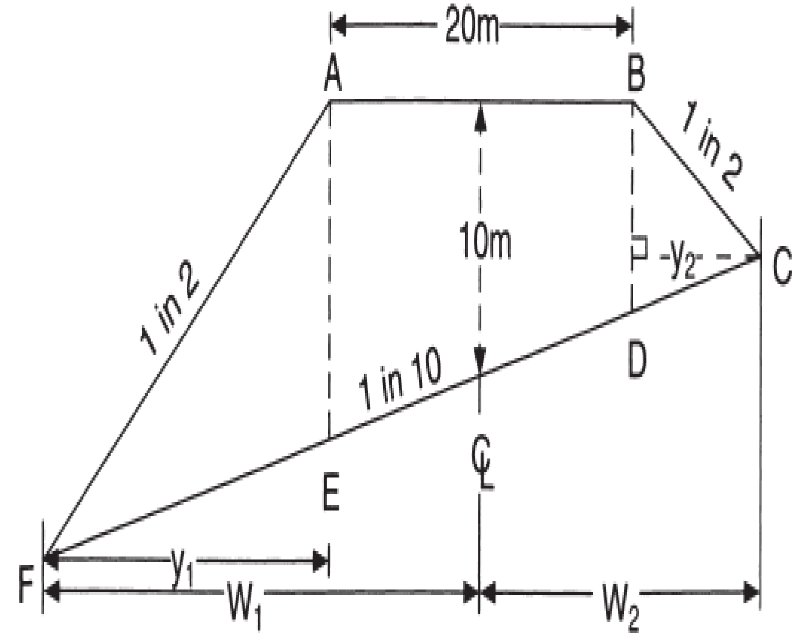
$$x \times \frac{10}{7} = 10$$
$$\therefore y_1 = 7$$

We can realize that this approach requires the two grades to either be added or subtracted, using their absolute values, invert them and multiply x to get the value of y_1.

Applied Example Rate of Approach

Example

Calculate the side widths and cross-sectional area of an embankment having following dimensions:



Road width = 20 m

Side slopes = 1 in 2

Existing ground slope = 1 in 10

Centre height = 10 m

Area computation methods

Solution?