La-Net

CEE 308

ENGINEERING SURVEYING AND PHOTOGRAMMETRY I

CODE: CEE 308

COURSE TITLE: Engineering Surveying and Photogrammetry I

COURSE CREDIT LOAD: 2 Units

SERIES 1: **Chain and Compass Surveying**

SERIES 2: **Contours and Site Mapping**

SERIES 3: **Traversing Techniques and Applications**

SERIES 4: **Levelling and Tachometry Methods**

SERIES 5: **Introduction to Photogrammetry**

Series 1: Chain and Compass Surveying

Series outline

1.1 Fundamentals of Chain Surveying

- 1.1.1 Definition and scope of chain surveying
- 1.1.2 Instruments used in chain surveying
- 1.1.3 Principles and procedures of chain surveying

1.2 Methods and Applications of Chain Surveying

- 1.2.1 Field techniques and recording
- 1.2.2 Plotting and map preparation
- 1.2.3 Advantages, limitations, and typical applications

1.3 Compass Surveying Principles

- 1.3.1 Definition and scope of compass surveying
- 1.3.2 Types of compasses and their components
- 1.3.3 Bearings, angles, and orientation

1.4 Compass Surveying Methods and Error Adjustment

- 1.4.1 Field procedures in compass surveying
- 1.4.2 Sources of errors and corrections
- 1.4.3 Applications of compass surveying in site work

Introduction

Surveying is one of the oldest and most essential practices in civil engineering, as it provides the foundation for accurate planning, design, and construction. Before any structure can be built, the land must be measured and mapped with precision. Two of the most fundamental techniques used in this process are **chain surveying** and **compass surveying**, both of which remain relevant today despite the advent of modern instruments. By learning these methods, you will gain an appreciation of the basic principles that underpin more advanced surveying techniques introduced later in the course.

The aim of this Series is to equip you with the knowledge and skills required to carry out chain and compass surveys effectively, to interpret the results, and to apply these methods in practical site work.

We shall commence this Series by examining the fundamentals of chain surveying, including its definition, scope, and the instruments involved. Then, we will move on to the methods and applications of chain surveying, focusing on field techniques and plotting. Following that, we will explore the principles of compass surveying, considering the types of compasses and the concept of bearings. Finally, we will wrap up by studying compass surveying methods, sources of errors, and how these can be corrected to ensure reliable results. This sequential flow will provide you with a solid grounding in the basic surveying techniques that form the bedrock of engineering practice.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define the concept and scope of chain surveying,
- **SLO 1.2** identify and describe the instruments used in chain surveying,
- **SLO 1.3** explain the principles and procedures involved in conducting a chain survey,
- **SLO 1.4** demonstrate methods of recording field data and plotting maps in chain surveying,
- **SLO 1.5** analyse the advantages, limitations, and applications of chain surveying,
- **SLO 1.6** define the concept and scope of compass surveying,
- **SLO 1.7** distinguish between types of compasses and explain their components,
- **SLO 1.8** calculate bearings and angles for orientation in compass surveying,
- **SLO 1.9** apply field procedures in compass surveying to establish directions and boundaries, and
- **SLO 1.10** evaluate common sources of error in compass surveying and propose appropriate corrections.

1.1 Fundamentals Of Chain Surveying

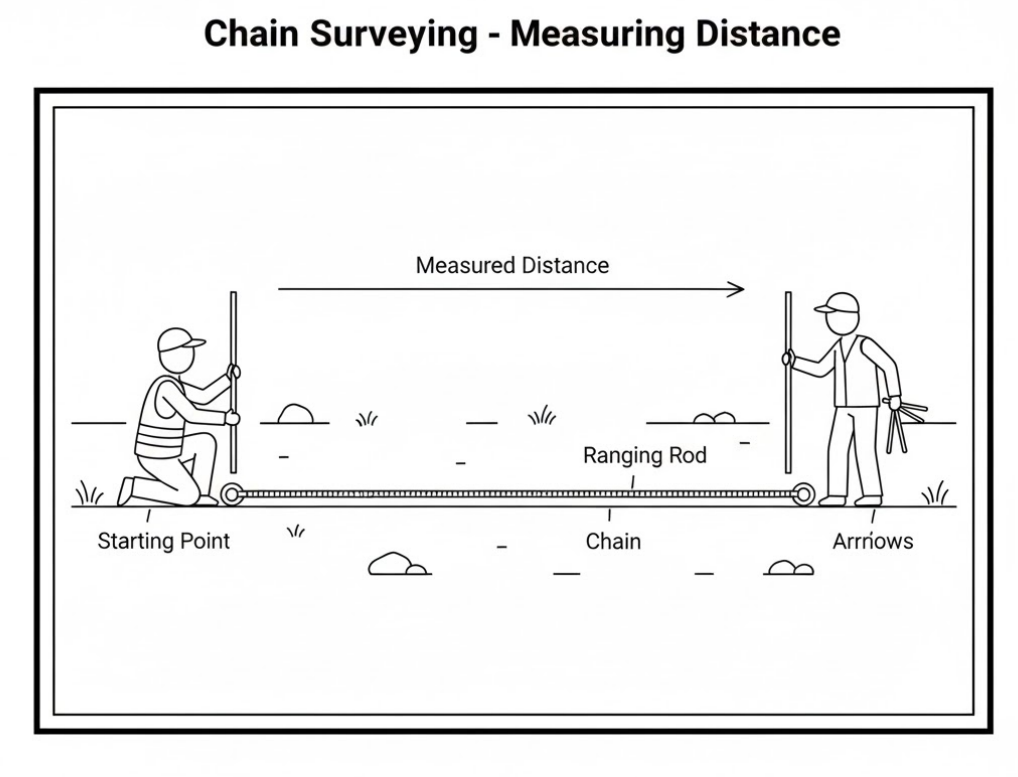
1.1.1 Definition and scope of chain surveying

Chain surveying is a method of surveying in which linear measurements are taken using a chain or tape to determine distances on the ground. It is one of the simplest forms of surveying, suitable for small, relatively flat areas where details can be represented by straight lines. The scope of chain surveying includes measuring boundaries, preparing site plans, and establishing baselines for further surveys.

Fill in the blank: Chain surveying is most suitable for ______ areas where details can be represented by straight lines.

Diagram showing a surveyor using a chain to measure distance on level ground.

Figure 1.1: Basic chain surveying in practice:



1.1.2 Instruments used in chain surveying

The primary instrument in chain surveying is the **surveying chain**, which is a series of linked metal segments used to measure distance. Other instruments include **tapes** (steel or linen), **arrows** (used to mark chain lengths), **ranging rods** (painted poles used for alignment), and **pegs** (wooden stakes used to mark points). Each instrument has a specific role in ensuring accuracy and efficiency during fieldwork.

Fill in the blank: The instrument used to mark chain lengths during measurement is called ______.

Image of surveying instruments including chain, arrows, and ranging rods.

Plate 1.1: Common instruments used in chain surveying:

1.1.3 Principles and procedures of chain surveying

The principle of chain surveying is based on the measurement of straight-line distances between points. The procedure involves selecting a **baseline** (the main reference line), measuring offsets to capture details, and recording observations in a **field book**. Accuracy depends on proper alignment, careful measurement, and systematic plotting.

Fill in the blank: The main reference line chosen in chain surveying is called the ______.

Box 1.1: Key steps in chain surveying

1. Select a baseline.
2. Measure distances using chain or tape.
3. Record observations in a field book.

4. Plot measurements to produce a site plan.

Pilot questions 1.1

1. What is chain surveying and when is it most suitable?
2. Name three instruments used in chain surveying.
3. What is the purpose of arrows in chain surveying?
4. Which line serves as the main reference in chain surveying?
5. Why is a field book important in chain surveying?

1.2 Methods And Applications Of Chain Surveying

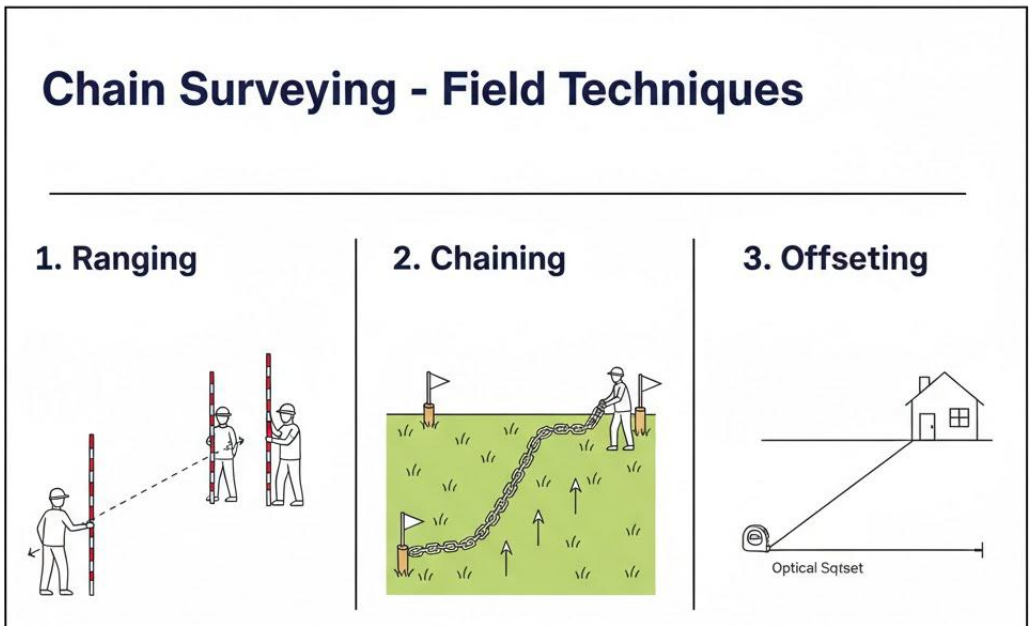
1.2.1 Field techniques and recording

In chain surveying, **field techniques** refer to the practical steps taken to measure distances and capture site details. These include ranging (aligning points in a straight line), chaining (measuring distances with a chain or tape), and offsetting (measuring perpendicular distances to capture features). Observations are recorded in a **field book**, which is a bound notebook used to document measurements systematically.

Fill in the blank: The perpendicular distance measured from a survey line to capture features is called ______.

Diagram showing chaining, ranging, and offsetting in practice.

Figure 1.2: Field techniques in chain surveying



1.2.2 Plotting and map preparation

Plotting is the process of transferring field measurements onto paper to create a site plan. Distances are scaled down, and offsets are drawn to represent features accurately. A **map** prepared from chain surveying should be neat, legible, and consistent with the recorded field data.

Fill in the blank: The process of transferring field measurements onto paper to create a site plan is called ______.

[Insert Plate here] Image of a surveyor plotting measurements on graph paper.

Plate 1.2: Plotting chain survey data into a site plan

1.2.3 Advantages, limitations, and typical applications

Chain surveying is advantageous because it is simple, inexpensive, and requires minimal equipment. However, it is limited to small, level areas and cannot handle complex terrain or large projects. Typical applications include measuring plots of land, preparing site plans for small construction projects, and establishing baselines for further surveys.

Fill in the blank: Chain surveying is most effective in ______ areas and for small-scale projects.

Box 1.2: Advantages and limitations of chain surveying Advantages: Simple, inexpensive, minimal equipment. Limitations: Restricted to small, level areas, unsuitable for complex terrain.

Advantages	Limitations
Simplicity: It is the simplest method of surveying and requires no complex	**Limited to Flat Terrain:** It becomes difficult and highly inaccurate on undulating, steep, or broken ground.

Advantages	Limitations
mathematical calculations or high-tech equipment.	
Cost-Effective: The equipment (chains, tapes, arrows, ranging rods) is inexpensive compared to total stations or GPS.	**Obstacles:** It is not suitable for areas crowded with many obstacles (e.g., dense forests or heavy urban construction) where lines of sight are blocked.
Durability: Survey chains are robust and can withstand harsh field conditions better than delicate optical instruments.	**Low Accuracy:** It is prone to cumulative errors like sag in the chain, temperature variations, and human error in reading.
Easy Maintenance: Instruments are easy to clean, repair, and replace in the field without specialized technicians.	**Time-Consuming:** Large areas take a significant amount of time to survey as every measurement must be taken manually.

Pilot questions 1.2

1. What are the three main field techniques in chain surveying?
2. What is the purpose of a field book?
3. Define plotting in the context of chain surveying.
4. Mention one advantage and one limitation of chain surveying.
5. Give two typical applications of chain surveying.

1.3 Compass Surveying Principles

1.3.1 Definition and scope of compass surveying

Compass surveying is a method of surveying in which directions are measured using a compass, and distances are measured using a chain or tape. It is suitable for areas where angular measurements are required to establish boundaries or directions.

Fill in the blank: Compass surveying involves measuring ______ using a compass and distances using a chain or tape.

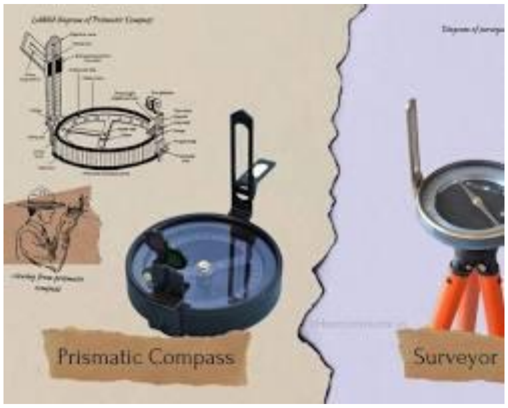
1.3.2 Types of compasses and their components

The two main types of compasses used in surveying are the **prismatic compass** and the **surveyor's compass**. A compass consists of a magnetic needle, graduated circle, sighting device, and a box to house the instrument. Each component plays a role in ensuring accurate measurement of bearings.

Fill in the blank: The compass type that allows direct reading of bearings through a prism is called the ______ compass.

Image of a prismatic compass and surveyor's compass side by side.

Plate 1.3: Types of compasses used in surveying



1.3.3 Bearings, angles, and orientation

A **bearing** is the horizontal angle measured clockwise from a reference meridian (usually north) to a survey line. Bearings are used to establish orientation and direction in compass surveying. Angles between survey lines are calculated to determine boundaries and site layout.

Fill in the blank: A bearing is the horizontal angle measured clockwise from the ______ to a survey line.

Diagram showing bearings measured from north to a survey line.

Figure 1.3: Bearings in compass surveying:

Pilot questions 1.3

1. Define compass surveying.
2. Name the two main types of compasses used in surveying.
3. What is the function of the magnetic needle in a compass?
4. Define a bearing in compass surveying.
5. Why are bearings important in site layout?

1.4 Compass Surveying Methods And Error Adjustment

1.4.1 Field procedures in compass surveying

Field procedures involve setting up the compass, taking bearings of survey lines, and recording them in a field book. Distances are measured with a chain or tape, and bearings are used to establish directions.

Fill in the blank: Bearings of survey lines are recorded in a ______ book during compass surveying.

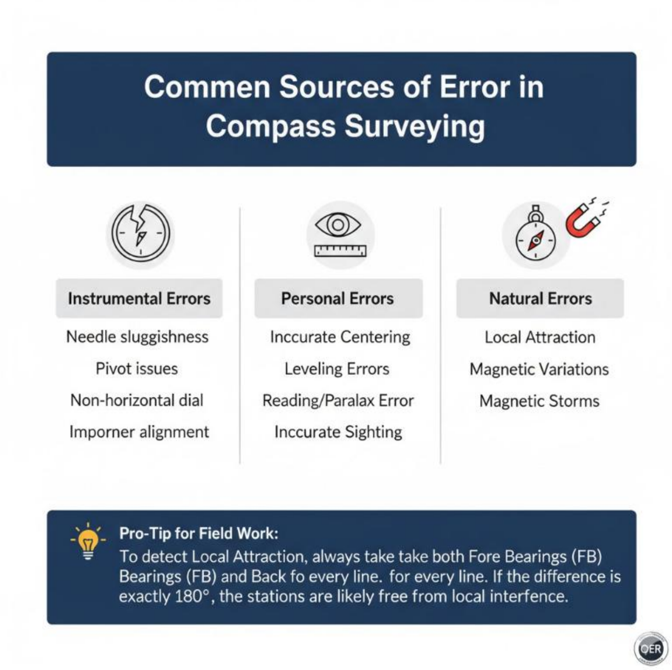
1.4.2 Sources of errors and corrections

Errors in compass surveying may arise from local attraction (magnetic interference), defective instruments, or incorrect observation. Corrections involve identifying sources of error, adjusting bearings, and ensuring proper instrument calibration.

Fill in the blank: Magnetic interference that affects compass readings is known as ______ attraction.

Box 1.4: Common sources of error in compass surveying

1. Local attraction.
2. Defective instruments.
3. Incorrect observation. AI prompt suggestion:



1.4.3 Applications of compass surveying in site work

Compass surveying is widely applied in establishing boundaries, determining directions, and preparing site layouts. It is particularly useful in forested or uneven terrain where angular measurements are necessary.

Fill in the blank: Compass surveying is especially useful in ______ terrain where angular measurements are required.

Pilot questions 1.4

1. What are the main steps in compass surveying field procedures?
2. Define local attraction in compass surveying.
3. Mention two sources of error in compass surveying.

4. How can defective instruments affect compass surveying?
5. Give two applications of compass surveying in site work.

Series summary

In this Series, we explored the fundamental techniques of chain and compass surveying, which form the foundation of engineering surveying practice. We began with the definition, scope, instruments, and procedures of chain surveying, highlighting its simplicity and applications in small, level areas. We then examined methods of recording, plotting, and preparing maps, as well as the advantages and limitations of chain surveying. Moving on, we studied compass surveying, focusing on its principles, types of compasses, and the concept of bearings and orientation. Finally, we considered the field procedures, common sources of error, and practical applications of compass surveying. Together, these topics provide learners with the essential skills to measure distances and directions accurately, and to apply these methods in real-world site work.

Glossary of terms

- **Chain surveying**: A method of surveying that involves measuring linear distances using a chain or tape.
- **Surveying chain**: A series of linked metal segments used to measure ground distances.
- **Arrows**: Small metal markers used to indicate chain lengths during measurement.
- **Ranging rods**: Painted poles used to align points in a straight line during surveying.
- **Baseline**: The main reference line chosen in chain surveying from which measurements are taken.
- **Field book**: A bound notebook used to record measurements and observations during surveying.
- **Compass surveying**: A method of surveying that involves measuring directions with a compass and distances with a chain or tape.
- **Prismatic compass**: A type of compass that allows direct reading of bearings through a prism.
- **Bearing**: The horizontal angle measured clockwise from a reference meridian (usually north) to a survey line.
- **Local attraction**: Magnetic interference that affects compass readings, often caused by nearby metallic objects.

Concept check questions 1

Upon completing this Series, you should be able to answer the following questions:

1. (Linked to SLO 1.1) Define chain surveying and explain its scope.
2. (Linked to SLO 1.2) Identify three instruments used in chain surveying and describe their functions.
3. (Linked to SLO 1.4) Demonstrate how field data is recorded and plotted in chain surveying.

4. (Linked to SLO 1.5) Analyse one advantage and one limitation of chain surveying.
5. (Linked to SLO 1.6) Define compass surveying and state when it is most applicable.
6. (Linked to SLO 1.7) Distinguish between a prismatic compass and a surveyor's compass.
7. (Linked to SLO 1.8) Calculate the bearing of a line given that it makes a 60° angle clockwise from north.
8. (Linked to SLO 1.9) Apply compass surveying procedures to establish the direction of a boundary line.
9. (Linked to SLO 1.10) Evaluate the effect of local attraction on compass readings and propose a correction method.

Answers to pilot questions 1

Pilot questions 1.1

1. Chain surveying is a method of measuring distances using a chain, suitable for small, level areas.
2. Instruments include chain, arrows, ranging rods, and pegs.
3. Arrows mark chain lengths during measurement.
4. The baseline serves as the main reference line.
5. A field book is important for recording observations systematically.

Pilot questions 1.2

1. Chaining, ranging, and offsetting.
2. A field book records measurements.
3. Plotting is transferring field data onto paper to create a site plan.
4. Advantage: simple and inexpensive. Limitation: restricted to small, level areas.
5. Applications include measuring plots of land and preparing site plans.

Pilot questions 1.3

1. Compass surveying measures directions with a compass and distances with a chain or tape.
2. Prismatic compass and surveyor's compass.
3. The magnetic needle aligns with the earth's magnetic field to indicate direction.
4. A bearing is the horizontal angle measured clockwise from north to a survey line.
5. Bearings are important for establishing orientation and site layout.

Pilot questions 1.4

1. Setting up the compass, taking bearings, and recording them in a field book.

2. Local attraction is magnetic interference affecting compass readings.
3. Sources include local attraction, defective instruments, and incorrect observation.
4. Defective instruments can give inaccurate bearings.
5. Applications include establishing boundaries and preparing site layouts.

References 1

- Bannister, A., Raymond, S., & Baker, R. (1998). *Surveying*. Pearson Education.
- Uren, J., & Price, W. F. (2010). *Surveying for Engineers*. Palgrave Macmillan.
- Clark, D. (2004). *Plane and Geodetic Surveying*. CRC Press.
- Open Educational Resources (OER) materials on surveying techniques, diagrams, and instruments.

Series 2: Contours And Site Mapping

Series outline

This Series will be organised into **4 main Parts**, each with relevant sub-Parts to provide a clear and progressive learning path.

Suggested Outline

2.1 Fundamentals of Contours

- 2.1.1 Definition and characteristics of contours
- 2.1.2 Types of contours and their representation
- 2.1.3 Importance of contours in surveying

2.2 Methods of Contour Determination

- 2.2.1 Direct methods of contouring
- 2.2.2 Indirect methods of contouring
- 2.2.3 Accuracy considerations in contouring

2.3 Applications of Contours in Site Mapping

- 2.3.1 Use of contours in engineering design
- 2.3.2 Contours in hydrology and drainage planning

- 2.3.3 Contours in road and railway alignment

2.4 Preparation and Interpretation of Contour Maps

- 2.4.1 Steps in preparing contour maps
- 2.4.2 Reading and interpreting contour maps
- 2.4.3 Limitations and challenges in contour mapping

Introduction

Accurate representation of the land surface is essential in engineering surveying, as it allows engineers to visualise terrain and make informed design decisions. One of the most effective ways to depict the shape and elevation of the ground is through **contours**, which are lines connecting points of equal height. Contour maps provide a clear picture of slopes, valleys, ridges, and other landforms, making them indispensable in planning construction projects, drainage systems, and transportation routes.

The aim of this Series is to introduce you to the principles, methods, and applications of contouring, and to equip you with the skills needed to prepare and interpret contour maps for engineering purposes.

We shall commence this Series by examining the fundamentals of contours, including their definition, characteristics, and importance in surveying. Then, we will move on to the methods of contour determination, considering both direct and indirect approaches. Following that, we will explore the applications of contours in site mapping, focusing on their role in engineering design, hydrology, and transportation planning. Finally, we will wrap up by studying the preparation and interpretation of contour maps, highlighting their limitations and challenges. This progression will provide you with a comprehensive understanding of how contours are used to represent and analyse terrain in engineering practice.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** define the concept and characteristics of contours in surveying,
- **SLO 2.2** distinguish between different types of contours and explain how they are represented on maps,
- **SLO 2.3** explain the importance of contours in engineering surveying and site analysis,
- **SLO 2.4** demonstrate direct methods of determining contours in the field,
- **SLO 2.5** apply indirect methods of contour determination and assess their accuracy,

- **SLO 2.6** analyse the role of contours in engineering design, hydrology, and transportation planning,
- **SLO 2.7** describe the steps involved in preparing contour maps,
- **SLO 2.8** interpret contour maps to identify terrain features and evaluate site suitability, and
- **SLO 2.9** evaluate the limitations and challenges associated with contour mapping.

2.1 Fundamentals Of Contours

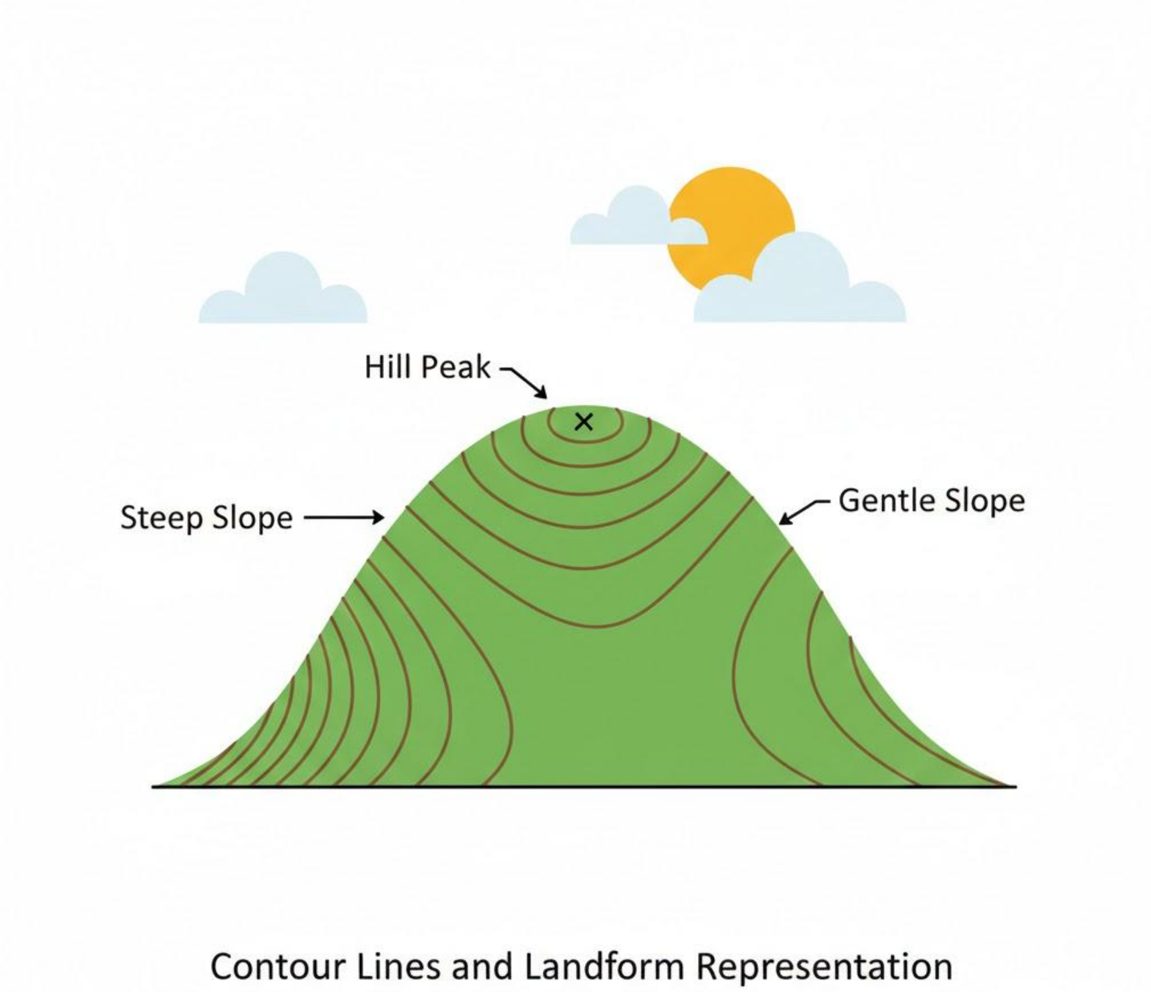
2.1.1 Definition and characteristics of contours

Contours are lines drawn on a map that connect points of equal elevation above a reference level, usually mean sea level. They provide a way to represent three-dimensional terrain on a two-dimensional surface. The main characteristics of contours include their spacing, which indicates slope steepness, and their shape, which reflects landforms such as hills, valleys, and ridges.

Fill in the blank: Contours are lines that connect points of equal _____ above a reference level.

Diagram showing contour lines on a hill with varying spacing.

Figure 2.1: Representation of terrain using contour lines:



2.1.2 Types of contours and their representation

Contours can be classified into **index contours**, **intermediate contours**, and **supplementary contours**. Index contours are bold lines drawn at regular intervals and labelled with elevation values. Intermediate contours are lighter lines between index contours, while supplementary contours are dashed lines used to show minor variations in terrain. Together, they provide a clear representation of the land surface.

Fill in the blank: The bold contour lines that are labelled with elevation values are called ______ contours.

[Insert Plate here] Image of a topographic map showing index, intermediate, and supplementary contours.

Plate 2.1: Types of contour lines on a topographic map:

2.1.3 Importance of contours in surveying

Contours are important because they allow engineers to visualise terrain, plan construction projects, and design infrastructure such as roads, railways, and drainage systems. They help in estimating earthwork quantities, identifying suitable sites, and preventing design errors caused by overlooking terrain features.

Fill in the blank: Contours are essential in surveying because they allow engineers to ______ terrain and plan construction projects.

Box 2.1: Key uses of contours in engineering surveying

1. Visualising terrain features.
2. Planning construction projects.
3. Designing roads, railways, and drainage systems.

4. Estimating earthwork quantities. AI prompt suggestion: "Create a text box summarising the key uses of contours in engineering surveying." Search string: "importance of contours in surveying OER"

Pilot questions 2.1

1. Define contours in surveying.
2. What do closely spaced contours indicate about slope steepness?
3. Name the three types of contour lines.
4. Which contour lines are bold and labelled with elevation values?
5. State two reasons why contours are important in engineering surveying.

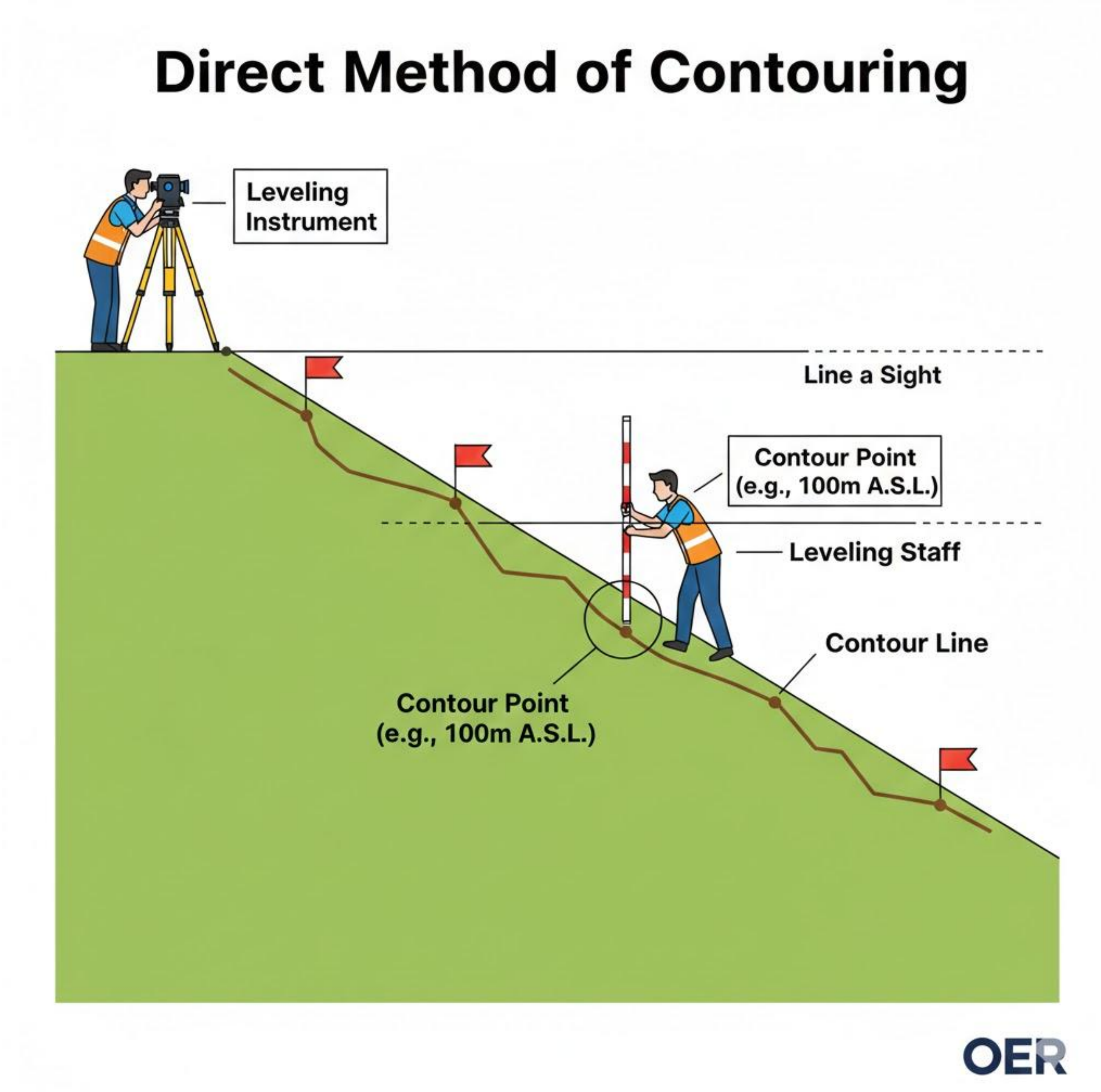
2.2 Methods Of Contour Determination

2.2.1 Direct methods of contouring

Direct methods involve locating points of equal elevation directly on the ground using levelling instruments. These points are marked and later joined to form contour lines. Although accurate, direct methods are time-consuming and best suited for small areas.

Fill in the blank: Contour points located directly on the ground using levelling instruments are joined to form ______ lines.

[Insert Figure here] Diagram showing surveyors marking contour points with levelling instruments. *Figure 2.2: Direct method of contour determination*:



2.2.2 Indirect methods of contouring

Indirect methods involve first conducting a levelling survey to obtain spot heights, then interpolating contour lines between these points. This method is faster and more practical for large areas. Common techniques include grid surveys and radial line methods.

Fill in the blank: In indirect methods of contouring, contour lines are obtained by ______ between spot heights.

Image of a grid survey used for indirect contouring.

Plate 2.2: Indirect method of contour determination using grid survey:

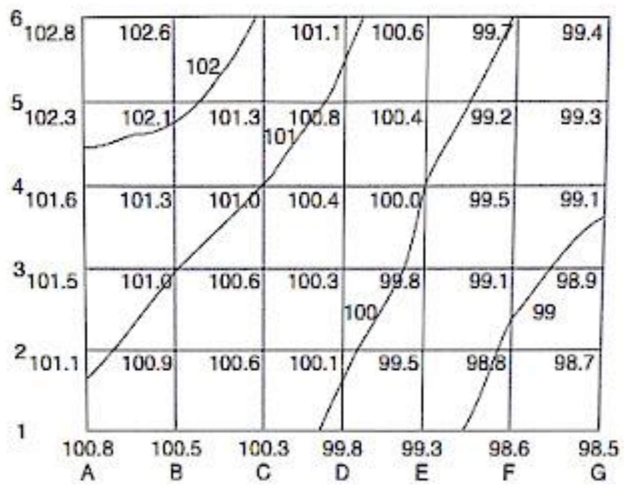


Fig. Con. 10

2.2.3 Accuracy considerations in contouring

Accuracy in contouring depends on the instrument used, the method applied, and the terrain conditions. Direct methods are more accurate but slower, while indirect methods are faster but require careful interpolation. Engineers must balance accuracy with efficiency depending on project needs.

Fill in the blank: Direct methods of contouring are more ______ but slower compared to indirect methods.

Box 2.2: Accuracy considerations in contouring

- Direct methods: high accuracy, slow process.
- Indirect methods: faster, requires careful interpolation.:

• **Feature**	• **High Accuracy Requirements**	• **Low Accuracy Requirements**
• **Method**	• Direct Contouring	• Indirect (Grid/Cross-section)
• **Ground Coverage**	• Dense point collection	• Sparse point collection
• **Terrain Type**	• Complex/Undulating	• Uniform/Flat

• **Feature**	• **High Accuracy Requirements**	• **Low Accuracy Requirements**
• **Map Scale**	• Large (e.g., 1:100)	• Small (e.g., 1:10,000)

- **Pilot questions 2.2**

1. What is the principle of direct contouring methods?
2. Why are direct methods considered time-consuming?
3. Define indirect contouring methods.
4. Name one technique used in indirect contouring.
5. Compare the accuracy of direct and indirect methods.

2.3 Applications Of Contours In Site Mapping

2.3.1 Use of contours in engineering design

Contours are used in designing buildings, roads, and bridges by providing information about slope and elevation. They help engineers decide the best location for structures and estimate earthwork quantities.

Fill in the blank: Contours provide information about ______ and elevation, which is essential in engineering design.

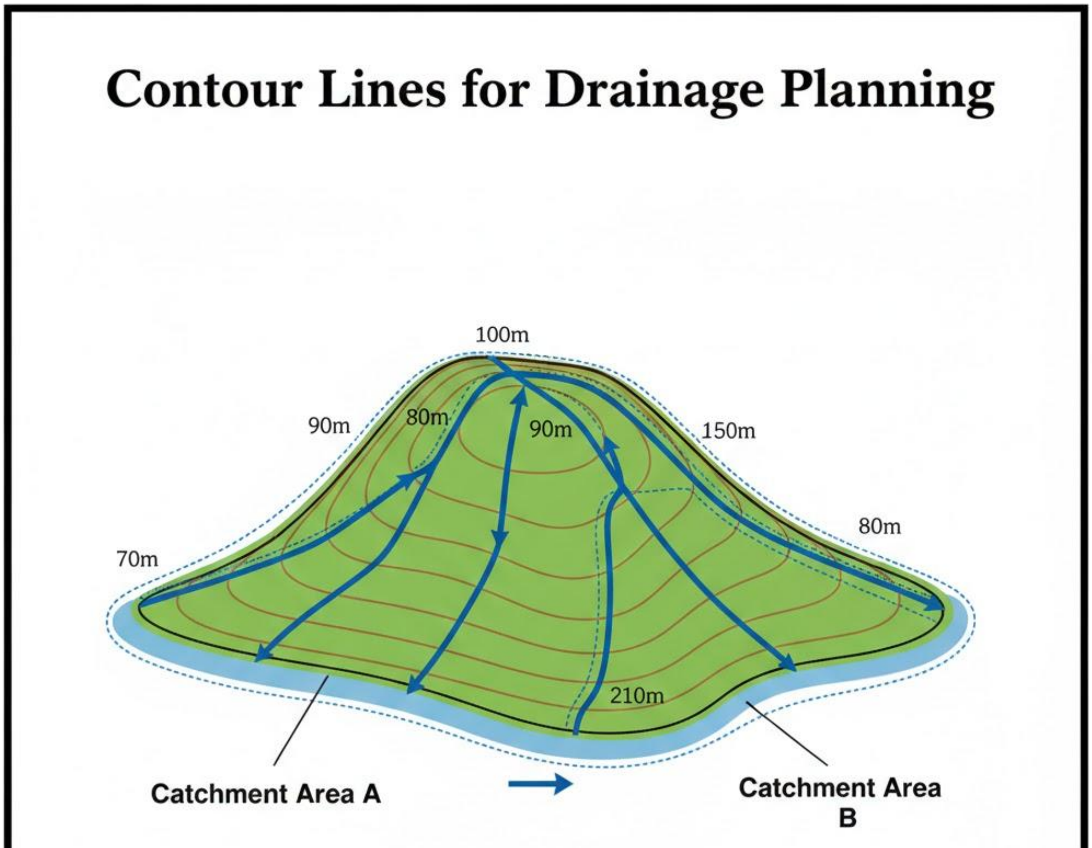
2.3.2 Contours in hydrology and drainage planning

In hydrology, contours are used to identify catchment areas, plan drainage systems, and design reservoirs. They show how water will flow across terrain, helping engineers prevent flooding and manage water resources.

Fill in the blank: Contours are used in hydrology to identify ______ areas and plan drainage systems.

Diagram showing contours used to plan drainage channels.

Figure 2.3: Application of contours in drainage planning:

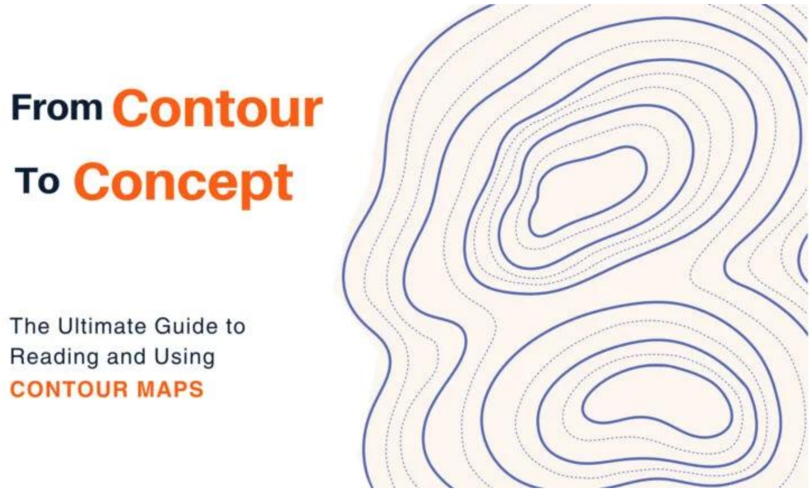


2.3.3 Contours in road and railway alignment

Contours guide the alignment of roads and railways by showing the most economical path across terrain. Engineers use contour maps to minimise steep gradients and reduce construction costs.

Fill in the blank: Contour maps help engineers minimise steep ______ when aligning roads and railways.

Image of a contour map used for road alignment planning. *Plate 2.3: Contour map for road alignment*



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Pilot questions 2.3

1. How are contours used in engineering design?
2. What role do contours play in hydrology?
3. Define catchment area in relation to contours.
4. Why are contours important in road alignment?
5. How do contours help reduce construction costs?

2.4 Preparation And Interpretation Of Contour Maps

2.4.1 Steps in preparing contour maps

Preparation involves conducting a survey, plotting spot heights, interpolating contour lines, and finalising the map with labels and scales. Accuracy depends on careful plotting and clear representation.

Fill in the blank: The process of drawing contour lines between spot heights is called ______.

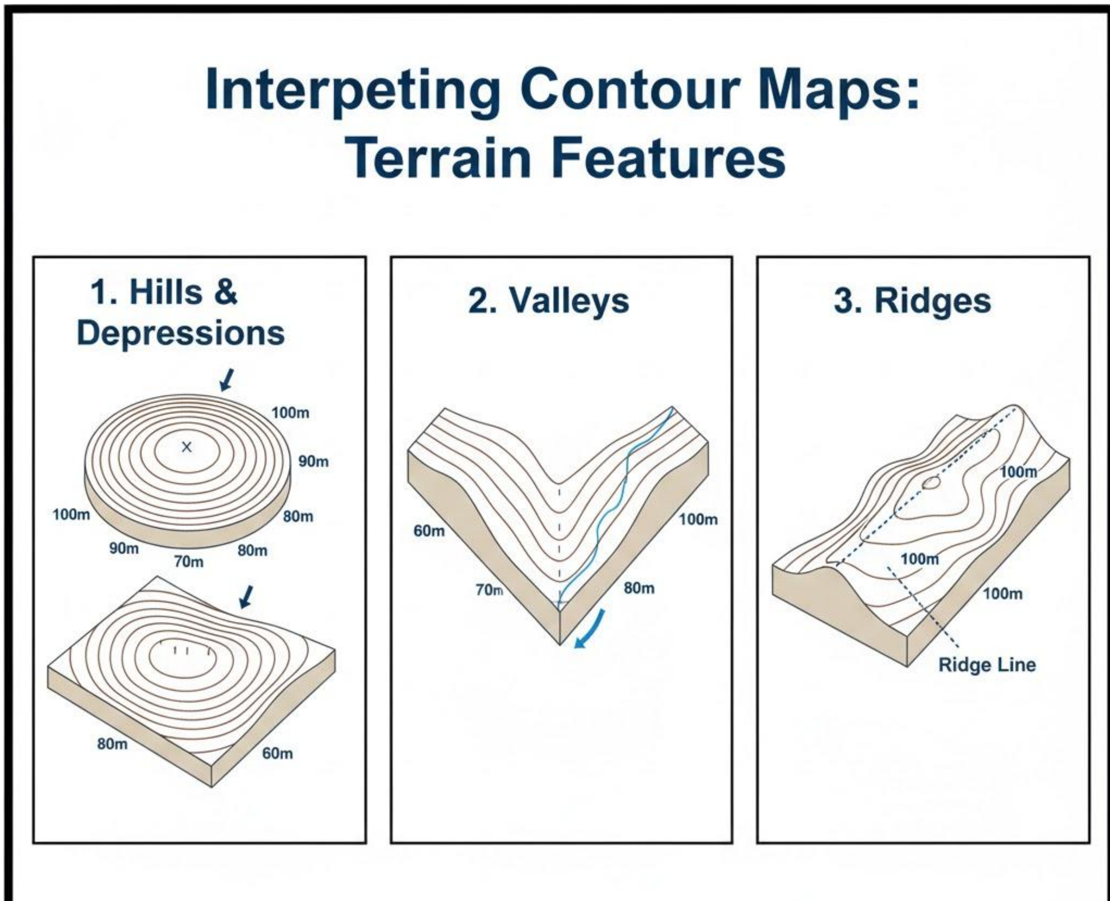
2.4.2 Reading and interpreting contour maps

Interpreting contour maps involves recognising terrain features such as hills, valleys, ridges, and depressions. Close contour spacing indicates steep slopes, while wide spacing shows gentle slopes.

Fill in the blank: Close contour spacing on a map indicates a ______ slope.

Diagram showing terrain features identified from contour maps.

Figure 2.4: Interpreting terrain features from contour maps:



2.4.3 Limitations and challenges in contour mapping

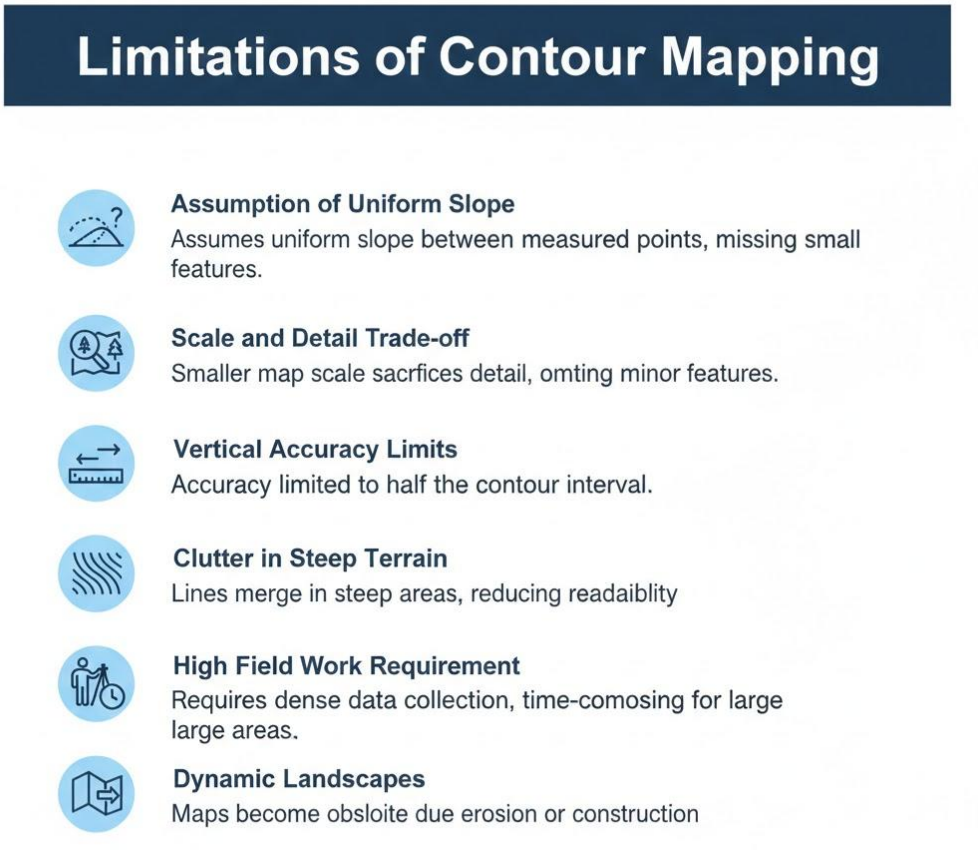
Contour mapping may be limited by rough terrain, dense vegetation, or instrument errors. Challenges include maintaining accuracy during interpolation and ensuring maps are easy to read. Engineers must be aware of these limitations when using contour maps for design.

Fill in the blank: Dense ______ can make contour mapping difficult and reduce accuracy.

Box 2.4: Limitations of contour mapping

1. Rough terrain.
2. Dense vegetation.
3. Instrument errors.

4. Interpolation challenges.



Pilot questions 2.4

1. List the main steps in preparing contour maps.
2. What does close contour spacing indicate?
3. Name two terrain features identified from contour maps.
4. Mention one limitation of contour mapping.
5. Why is interpolation a challenge in contour mapping?

Series summary

In this Series, we examined the role of contours in representing terrain and their importance in engineering surveying. We began with the fundamentals, defining contours, exploring their characteristics, and distinguishing between types such as index, intermediate, and supplementary contours. We then studied methods of contour determination, comparing direct and indirect approaches and considering accuracy issues. Following that, we explored practical applications of contours in engineering design, hydrology, and transportation planning. Finally, we discussed the preparation and interpretation of contour maps, highlighting terrain features and recognising limitations and challenges. Together, these topics provide learners with the knowledge and skills to use contours effectively in site mapping and engineering projects.

Glossary of terms

- **Contours**: Lines drawn on a map connecting points of equal elevation above a reference level.
- **Index contours**: Bold contour lines drawn at regular intervals and labelled with elevation values.
- **Intermediate contours**: Lighter contour lines drawn between index contours.
- **Supplementary contours**: Dashed contour lines used to show minor variations in terrain.
- **Direct methods of contouring**: Techniques where points of equal elevation are located directly on the ground using levelling instruments.
- **Indirect methods of contouring**: Techniques where spot heights are obtained first, and contour lines are interpolated between them.
- **Interpolation**: The process of estimating contour lines between known spot heights.
- **Catchment area**: The region from which water flows into a drainage system or reservoir, identified using contours.
- **Slope**: The steepness of terrain, indicated by the spacing of contour lines.
- **Contour map**: A map that represents terrain features using contour lines.

Concept check questions 2

Upon completing this Series, you should be able to answer the following questions:

1. (Linked to SLO 2.1) Define contours and describe their main characteristics.
2. (Linked to SLO 2.2) Distinguish between index, intermediate, and supplementary contours.
3. (Linked to SLO 2.3) Explain why contours are important in engineering surveying.
4. (Linked to SLO 2.4) Demonstrate how direct methods of contouring are carried out in the field.
5. (Linked to SLO 2.5) Apply indirect methods of contour determination and explain interpolation.
6. (Linked to SLO 2.6) Analyse the role of contours in hydrology and drainage planning.
7. (Linked to SLO 2.7) Describe the steps in preparing contour maps.
8. (Linked to SLO 2.8) Interpret a contour map to identify terrain features such as hills and valleys.

9. (Linked to SLO 2.9) Evaluate one limitation of contour mapping and suggest how it can be addressed.

Answers to pilot questions 2

Pilot questions 2.1

1. Contours are lines connecting points of equal elevation.
2. Close spacing indicates steep slopes.
3. Index, intermediate, and supplementary contours.
4. Index contours are bold and labelled with elevation values.
5. They help visualise terrain and plan construction projects.

Pilot questions 2.2

1. Direct methods locate points of equal elevation directly on the ground.
2. They are time-consuming because each point must be measured individually.
3. Indirect methods involve spot heights and interpolation.
4. Grid survey is one technique used in indirect contouring.
5. Direct methods are more accurate, while indirect methods are faster.

Pilot questions 2.3

1. Contours provide slope and elevation information for design.
2. They identify catchment areas and guide drainage planning.
3. A catchment area is the region from which water flows into a drainage system.
4. They help minimise steep gradients in road alignment.
5. By guiding alignment, they reduce earthwork and construction costs.

Pilot questions 2.4

1. Survey, plot spot heights, interpolate contours, and finalise the map.
2. Close spacing indicates a steep slope.
3. Hills and valleys are terrain features identified from contour maps.
4. Limitations include rough terrain and dense vegetation.
5. Interpolation can be challenging because it requires careful estimation.

References 2

- Bannister, A., Raymond, S., & Baker, R. (1998). *Surveying*. Pearson Education.
- Uren, J., & Price, W. F. (2010). *Surveying for Engineers*. Palgrave Macmillan.
- Clark, D. (2004). *Plane and Geodetic Surveying*. CRC Press.
- Open Educational Resources (OER) materials on contouring methods, applications, and map interpretation.

Series 3: Traversing Techniques And Applications

Series outline

3.1 Fundamentals of Traversing

- 3.1.1 Definition and scope of traversing
- 3.1.2 Types of traverses (open and closed)
- 3.1.3 Importance of traversing in surveying

3.2 Methods of Conducting Traverses

- 3.2.1 Chain and compass traverse
- 3.2.2 Theodolite traverse
- 3.2.3 Field procedures and recording

3.3 Computation and Adjustment of Traverses

- 3.3.1 Latitude and departure calculations
- 3.3.2 Closing error and its adjustment
- 3.3.3 Balancing methods for traverse correction

3.4 Applications of Traversing in Site Work

- 3.4.1 Establishing boundaries of a site
- 3.4.2 Preparation of site plans and maps
- 3.4.3 Engineering applications of traverses

Introduction

Accurate boundary establishment and site mapping are critical in engineering projects, as they ensure that land is measured, recorded, and represented with precision. One of the most reliable methods for achieving this is **traversing**, which involves measuring a series of connected lines to determine positions and boundaries. Traversing is widely used in surveying because it provides both distance and directional information, making it indispensable for preparing site plans and resolving boundary disputes.

The aim of this Series is to introduce you to the principles, methods, and applications of traversing, and to equip you with the skills needed to conduct traverses, compute and adjust errors, and apply the results in practical site work.

We shall commence this Series by examining the fundamentals of traversing, including its definition, scope, and types. Then, we will move on to the methods of conducting traverses, focusing on chain and compass traverses, theodolite traverses, and field procedures. Following that, we will explore computation and adjustment of traverses, considering latitude and departure calculations, closing errors, and balancing methods. Finally, we will wrap up by discussing the applications of traversing in site work, such as establishing boundaries, preparing site plans, and supporting engineering projects. This progression will provide you with a comprehensive understanding of traversing techniques and their practical applications in surveying.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** define the concept of traversing and explain its scope in surveying,
- **SLO 3.2** distinguish between open and closed traverses,
- **SLO 3.3** explain the importance of traversing in boundary establishment and site mapping,
- **SLO 3.4** demonstrate how to conduct a chain and compass traverse in the field,
- **SLO 3.5** describe the procedure for carrying out a theodolite traverse,
- **SLO 3.6** apply appropriate field procedures for recording and plotting traverse data,
- **SLO 3.7** calculate latitude and departure for traverse lines,
- **SLO 3.8** analyse closing errors in a traverse and explain methods of adjustment,
- **SLO 3.9** evaluate balancing methods used to correct traverse errors,
- **SLO 3.10** apply traversing techniques to establish site boundaries,
- **SLO 3.11** interpret traverse data to prepare accurate site plans and maps, and
- **SLO 3.12** assess the engineering applications of traverses in construction and design projects.

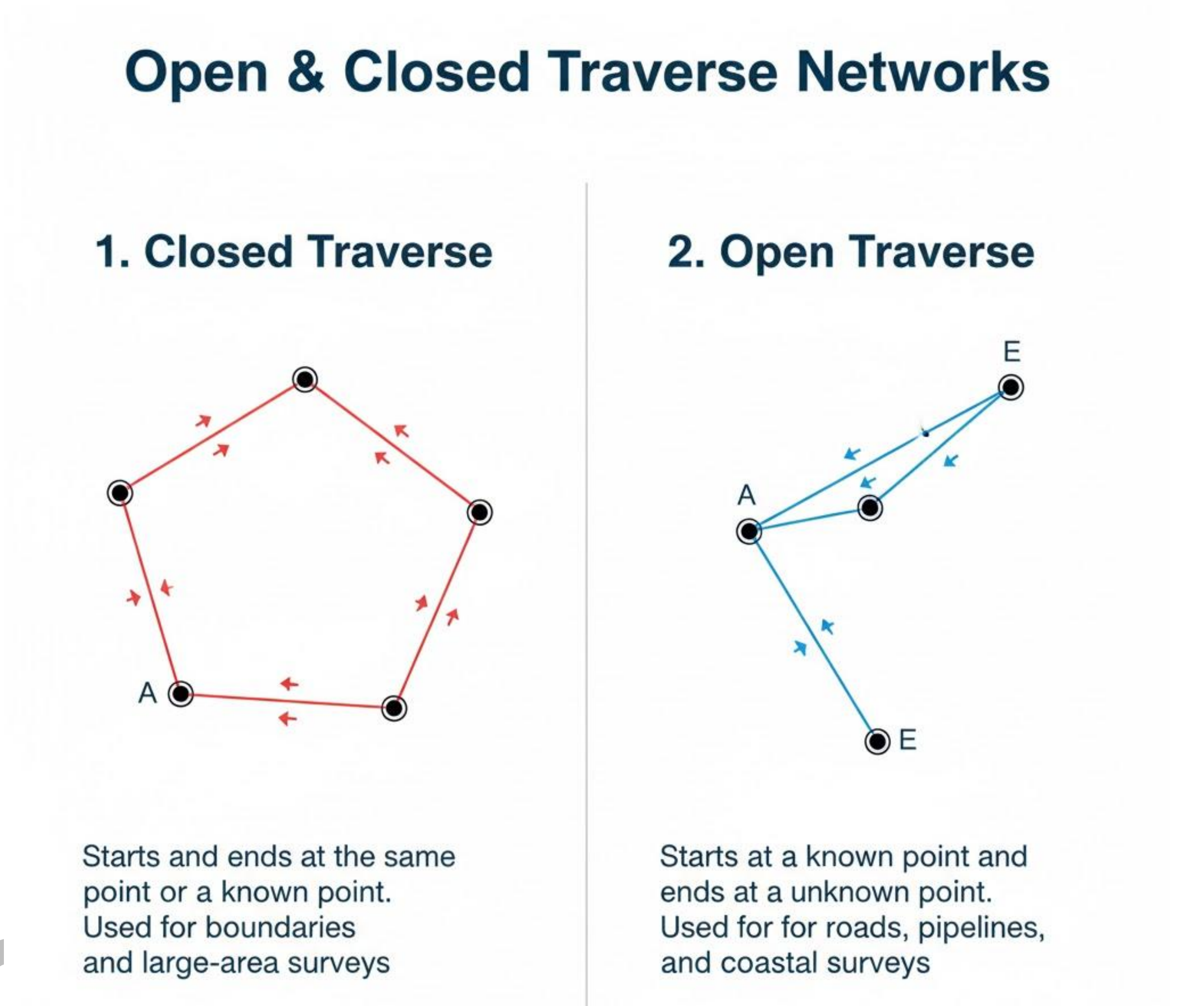
3.1 Fundamentals Of Traversing

3.1.1 Definition and scope of traversing

Traversing is a surveying method in which a series of connected lines are measured to determine positions, boundaries, and site layouts. Each line is defined by its length and direction, and together they form a network that can be plotted to represent the surveyed area. The scope of traversing includes boundary establishment, preparation of site plans, and supporting engineering projects such as road alignment and construction.

Fill in the blank: Traversing is a surveying method in which a series of connected ______ are measured to determine positions and boundaries.

Diagram showing a simple open and closed traverse network. *Figure 3.1: Basic representation of traverses in surveying*:



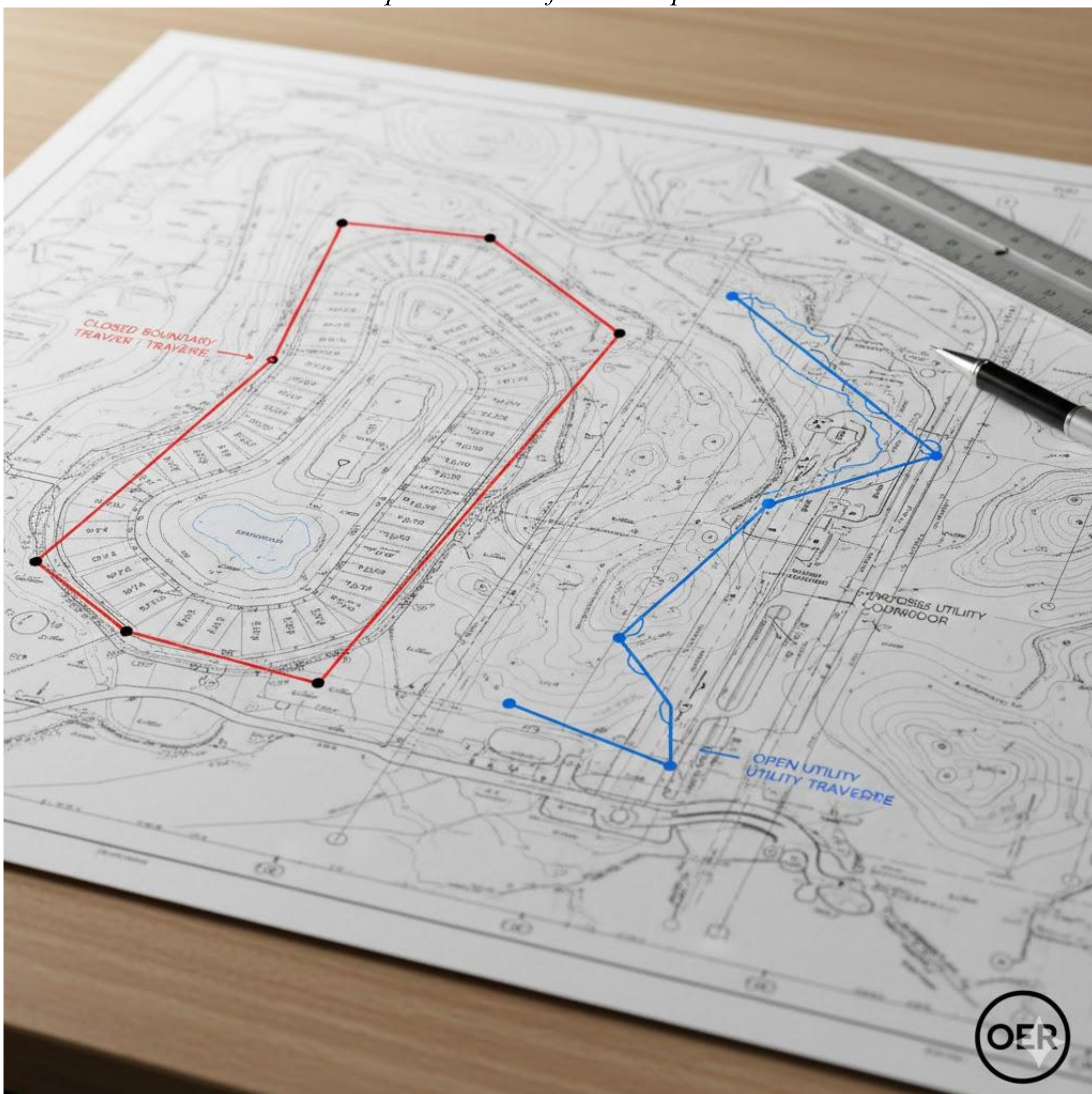
3.1.2 Types of traverses (open and closed)

There are two main types of traverses: **open traverse** and **closed traverse**. An open traverse does not return to its starting point and is often used for long linear projects such as roads, pipelines, or canals. A closed traverse forms a polygon by returning to its starting point, making it suitable for boundary surveys and site mapping.

Fill in the blank: A traverse that forms a polygon by returning to its starting point is called a ______ traverse.

Image showing examples of open and closed traverses on a site plan.

Plate 3.1: Examples of open and closed traverses:



3.1.3 Importance of traversing in surveying

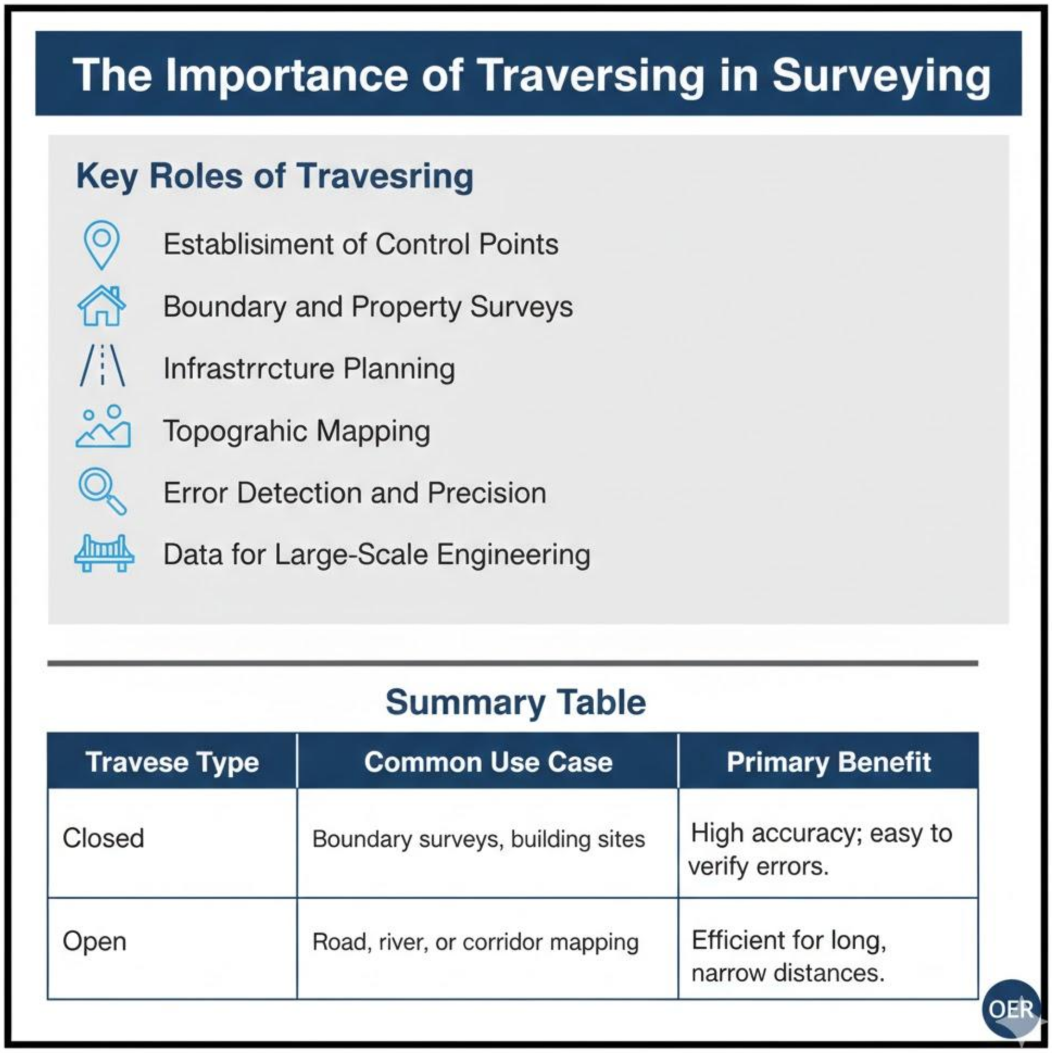
Traversing is important because it provides both distance and directional information, which are essential for accurate site mapping. It is widely used to establish boundaries, prepare detailed maps, and support engineering projects. Traverses also serve as a foundation for more advanced surveying techniques.

Fill in the blank: Traversing provides both ______ and directional information, which are essential for accurate site mapping.

Box 3.1: Importance of traversing in surveying

1. Establishing boundaries.

2. Preparing site plans and maps.
3. Supporting engineering projects.
4. Providing a foundation for advanced surveying techniques:



Travese Type	Common Use Case	Primary Benefit
Closed	Boundary surveys, building sites	High accuracy; easy to verify errors.
Open	Road, river, or corridor mapping	Efficient for long, narrow distances.

Pilot questions 3.1

1. Define traversing in surveying.
2. What is the difference between an open traverse and a closed traverse?
3. Give one example of where an open traverse is used.
4. Why is a closed traverse suitable for boundary surveys?
5. State two reasons why traversing is important in surveying.

3.2 Methods Of Conducting Traverses

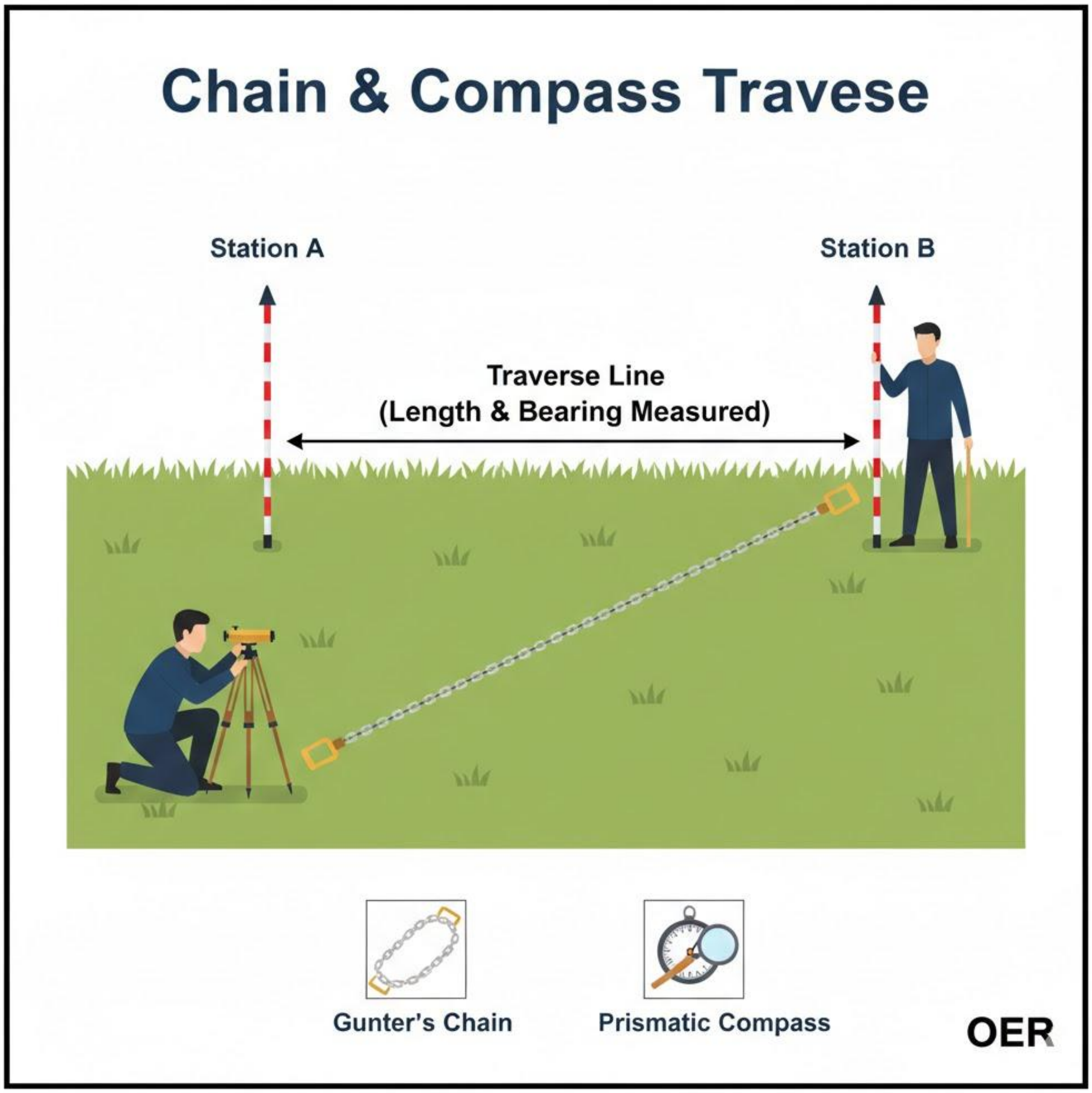
3.2.1 Chain and compass traverse

A **chain and compass traverse** involves measuring distances with a chain or tape and directions with a compass. This method is simple and inexpensive, but accuracy depends on careful alignment and avoidance of local attraction. It is often used for small-scale surveys.

Fill in the blank: In a chain and compass traverse, distances are measured with a chain and directions with a ______.

Diagram showing surveyors conducting a chain and compass traverse.

Figure 3.2: Chain and compass traverse in practice



3.2.2 Theodolite traverse

A **theodolite traverse** uses a theodolite to measure horizontal and vertical angles, combined with a chain or tape for distances. This method is more accurate than chain and compass traverses and is suitable for large projects requiring precise measurements.

Fill in the blank: A theodolite traverse is more ______ than a chain and compass traverse and is suitable for large projects.

Image of a surveyor using a theodolite for traversing.

Plate 3.2: Conducting a theodolite traverse:

3.2.3 Field procedures and recording

Field procedures involve setting up instruments, measuring distances and angles, and recording observations in a **field book**. Proper recording ensures that traverse data can be accurately plotted and analysed later.

Fill in the blank: Traverse observations are systematically recorded in a ______ book.

Box 3.2: Key steps in conducting a traverse

1. Set up instruments.

2. Measure distances and angles.
3. Record observations in a field book.

1. Reconnaissance and Station Selection

- **Site Walkover:** Surveyors first scout the area to select the best positions for traverse stations.
- **Intervisibility:** Each station must have a clear line of sight to both the preceding and the following station.
- **Stability:** Stations are marked with semi-permanent markers (wooden stakes, iron pins, or "PK" nails) in ground that is unlikely to be disturbed.

2. Measuring Distance

- The horizontal distance between stations is measured.
- **Methods:** Traditionally done with a steel tape or **Gunter's chain**, but modern surveys use **Electronic Distance Measurement (EDM)** or Total Stations for millimeter precision.

3. Measuring Angles or Bearings

- **Angular Measurement:** At each station, the horizontal angle between the "back-sight" station and the "fore-sight" station is measured using a **theodolite** or Total Station.
- **Directional Measurement:** In some cases, a prismatic compass is used to measure the magnetic bearing of the lines directly.

4. Field Note Documentation

- All measurements (angles, distances, and station descriptions) are recorded in a standardized field book.
- **Sketches:** A rough "eye-sketch" of the traverse network is drawn to prevent confusion during data processing.

5. Office Computations & Error Adjustment

- **Closing Error:** For a closed traverse, the sum of internal angles should be $(n - 2) \times 180°$. Any discrepancy is the angular error.
- **Latitudes and Departures:** The polar coordinates (angle and distance) are converted into Cartesian coordinates (X, Y).
- **Balancing:** Methods like the **Bowditch Rule** or **Transit Rule** are used to distribute small measurement errors throughout the network to "close" the loop mathematically.

Field Procedure Summary

Phase	Goal	Primary Tool
Preparation	Station marking	Pegs, Mallet, Ranging Rods
Data Collection	Distance & Angles	Total Station / Tape & Theodolite
Verification	Accuracy check	Sum of angles / Closing link

Pilot questions 3.2

1. What is a chain and compass traverse?
2. Why is local attraction a concern in chain and compass traverses?
3. What instrument is used in a theodolite traverse?
4. Why is a theodolite traverse more accurate?
5. What is the purpose of a field book in traversing?

3.3 Computation And Adjustment Of Traverses

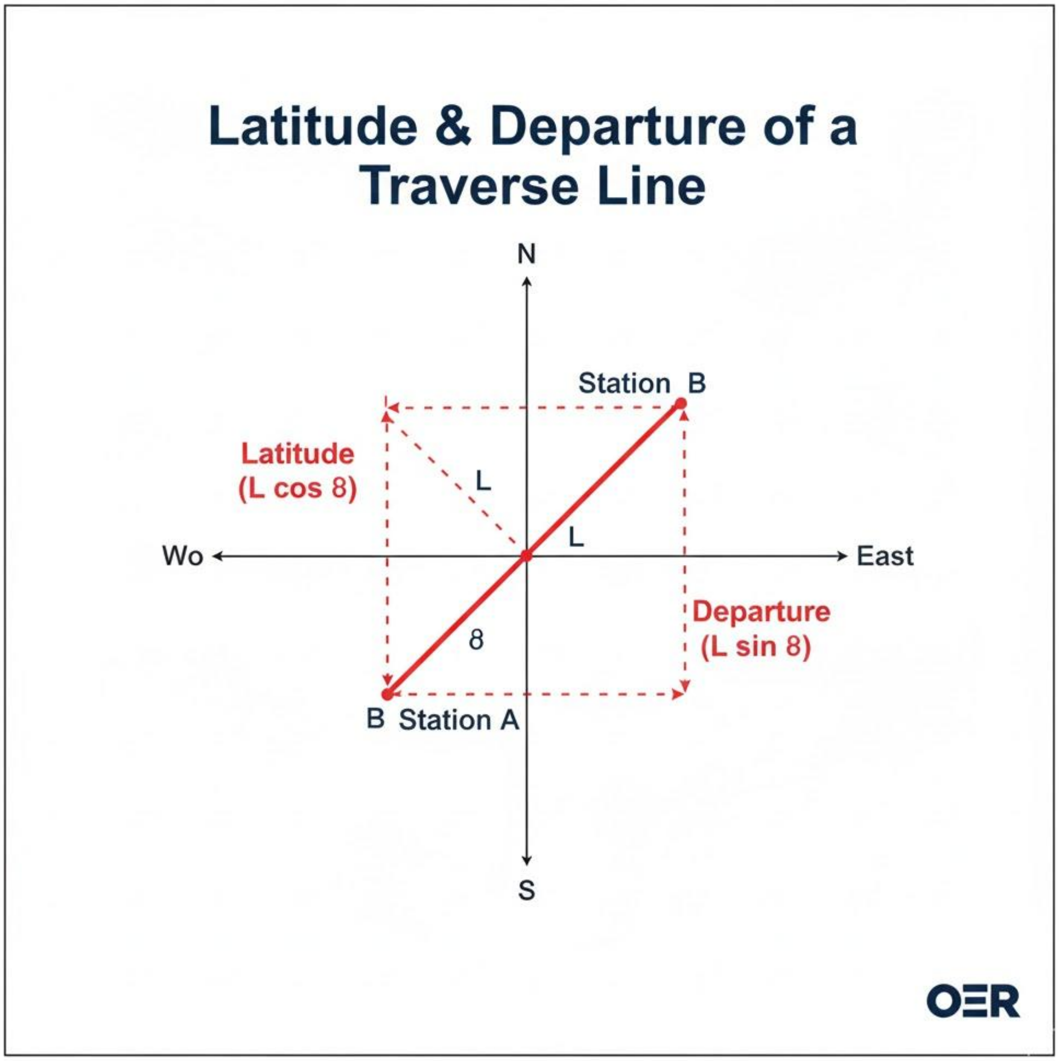
3.3.1 Latitude and departure calculations

Latitude is the north–south displacement of a traverse line, while **departure** is the east–west displacement. These are calculated using trigonometric functions based on the line's length and bearing. They are essential for plotting and adjusting traverses.

Fill in the blank: The north–south displacement of a traverse line is called its ______.

Diagram showing latitude and departure components of a traverse line.

Figure 3.3: Latitude and departure in traverse computation:



3.3.2 Closing error and its adjustment

A **closing error** occurs when the plotted endpoint of a traverse does not coincide with its true position. This error is measured by comparing the sum of latitudes and departures. Adjustments are made to distribute the error across the traverse lines.

Fill in the blank: The difference between the plotted endpoint and the true position of a traverse is called the ______ error.

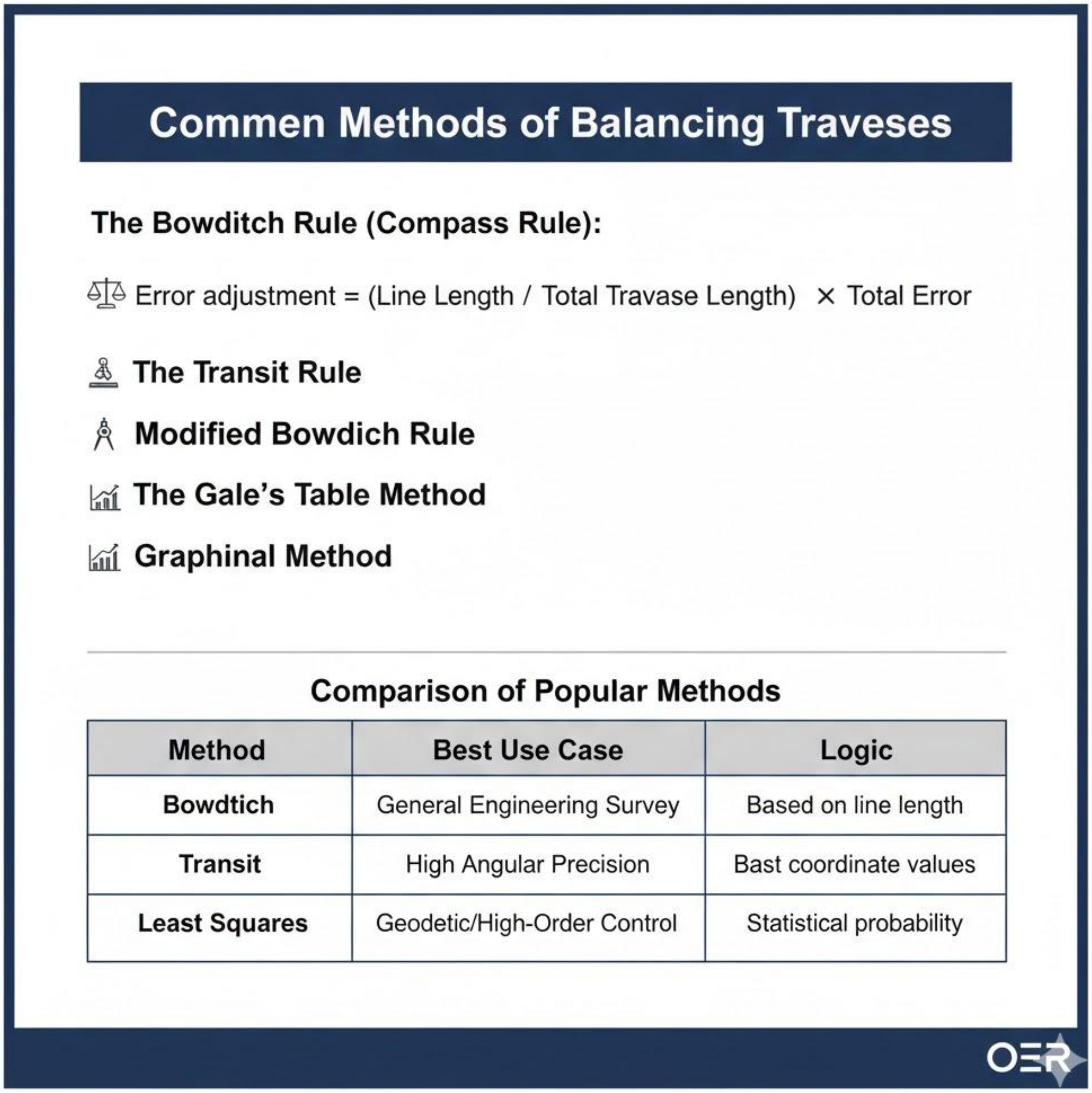
3.3.3 Balancing methods for traverse correction

Balancing methods include the **Bowditch method** and the **Transit method**, which distribute closing errors proportionally among traverse lines. These methods ensure that the corrected traverse is geometrically consistent.

Fill in the blank: The Bowditch method distributes closing errors proportionally to the ______ of traverse lines.

Common methods of balancing traverses

1. Bowditch method.
2. Transit method.



Pilot questions 3.3

1. Define latitude and departure in traversing.
2. How are latitudes and departures calculated?
3. What is a closing error in a traverse?
4. Name two methods used to balance traverse errors.
5. Why is balancing necessary in traverse computation?

3.4 Applications of Traversing in Site Work

3.4.1 Establishing boundaries of a site

Traverses are widely used to establish boundaries of plots of land. By measuring and plotting connected lines, surveyors can define property limits accurately.

Fill in the blank: Traverses are used to establish ______ of plots of land.

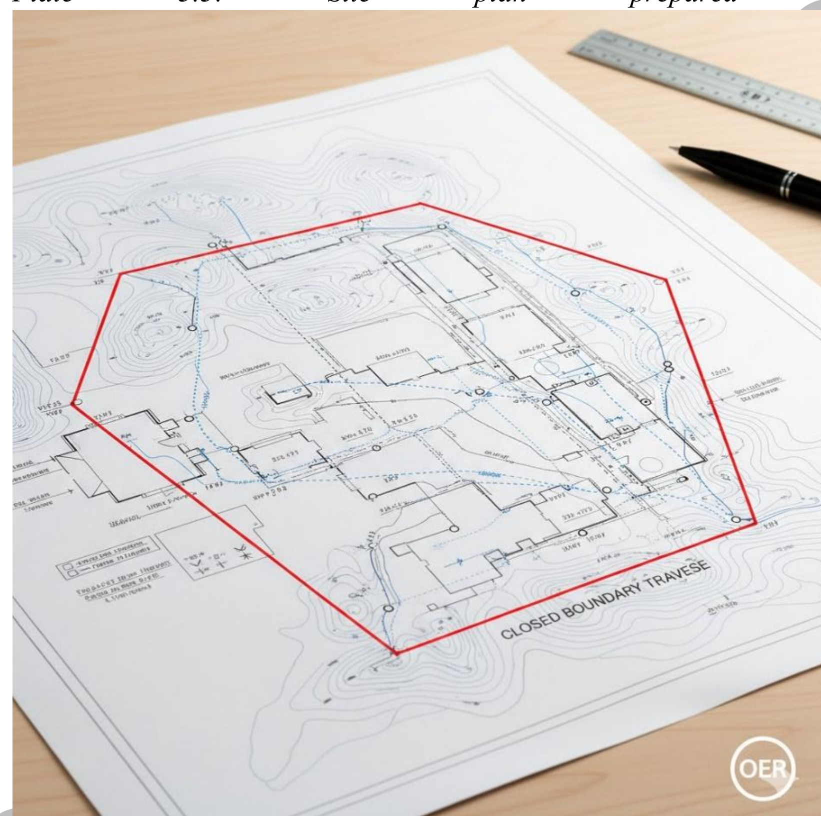
3.4.2 Preparation of site plans and maps

Traverse data is plotted to prepare site plans and maps, which serve as references for construction projects. Accurate site plans ensure proper design and implementation.

Fill in the blank: Traverse data is plotted to prepare site ______ and maps.

Image of a site plan prepared using traverse data.

Plate 3.3: Site plan prepared from traverse data:



3.4.3 Engineering applications of traverses

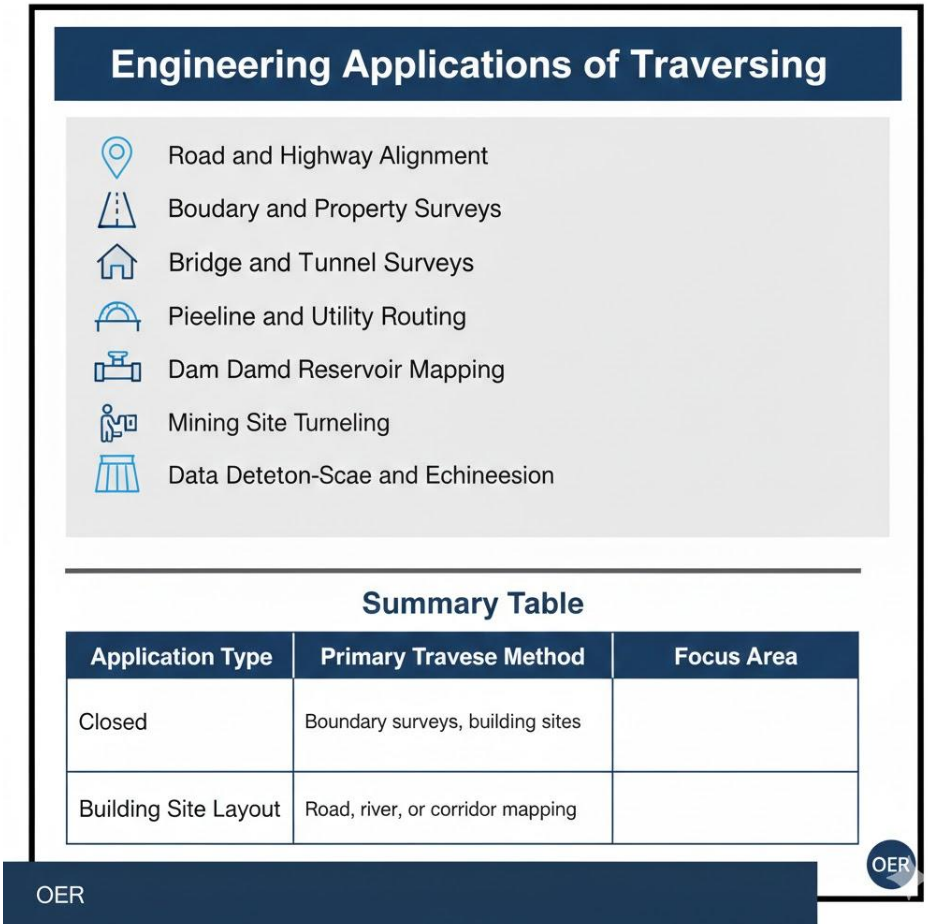
Traverses are applied in engineering projects such as road alignment, bridge construction, and utility installation. They provide essential data for design and layout.

Fill in the blank: Traverses provide essential data for ______ alignment and construction projects.

Box 3.4: Engineering applications of traverses

1. Road alignment.

2. Bridge construction.
3. Utility installation.:



Pilot questions 3.4

1. How are traverses used to establish boundaries?
2. What is the role of traverses in preparing site plans?
3. Give one example of an engineering project that uses traverses.
4. Why are traverses important in road alignment?
5. State two engineering applications of traverses.

Series summary

In this Series, we examined traversing as a fundamental surveying technique used to measure and plot connected lines for boundary establishment and site mapping. We began with the definition and scope of traversing, distinguishing between open and closed traverses, and highlighting their importance. We then studied methods of conducting traverses, including chain and compass traverses, theodolite traverses, and the procedures for recording field data. Following that, we explored computation and adjustment of traverses, focusing on latitude and departure calculations, closing errors, and balancing methods such as Bowditch and Transit. Finally, we discussed the applications of traversing in site work, including establishing boundaries, preparing site plans, and supporting engineering projects such as road alignment and utility installation. This Series equips learners with both theoretical knowledge and practical skills for accurate surveying.

Glossary of terms

- **Traverse**: A series of connected survey lines measured to determine positions and boundaries.
- **Open traverse**: A traverse that does not return to its starting point, often used for linear projects such as roads or pipelines.
- **Closed traverse**: A traverse that forms a polygon by returning to its starting point, suitable for boundary surveys.
- **Chain and compass traverse**: A method of traversing using a chain for distance and a compass for direction.
- **Theodolite traverse**: A traverse conducted using a theodolite to measure angles and a chain or tape for distances.
- **Field book**: A notebook used to record traverse measurements and observations systematically.
- **Latitude**: The north–south displacement of a traverse line.
- **Departure**: The east–west displacement of a traverse line.
- **Closing error**: The difference between the plotted endpoint of a traverse and its true position.
- **Bowditch method**: A balancing method that distributes closing errors proportionally to line lengths.
- **Transit method**: A balancing method that distributes closing errors based on line directions.

Concept check questions 3

Upon completing this Series, you should be able to answer the following questions:

1. (Linked to SLO 3.1) Define traversing and explain its scope in surveying.
2. (Linked to SLO 3.2) Distinguish between open and closed traverses.
3. (Linked to SLO 3.3) Explain why traversing is important in boundary establishment.
4. (Linked to SLO 3.4) Demonstrate how a chain and compass traverse is conducted.
5. (Linked to SLO 3.5) Describe the procedure for a theodolite traverse.
6. (Linked to SLO 3.7) Calculate latitude and departure for a given traverse line.
7. (Linked to SLO 3.8) Analyse closing errors in a traverse.

8. (Linked to SLO 3.9) Evaluate one balancing method used to correct traverse errors.
9. (Linked to SLO 3.10) Apply traversing techniques to establish site boundaries.
10. (Linked to SLO 3.12) Assess the engineering applications of traverses in construction projects.

Answers to pilot questions 3

Pilot questions 3.1

1. Traversing is a surveying method involving connected lines measured for positions and boundaries.
2. An open traverse does not return to its starting point, while a closed traverse forms a polygon.
3. Open traverses are used for roads, pipelines, or canals.
4. Closed traverses are suitable for boundary surveys because they enclose an area.
5. Traversing is important for accurate site mapping and engineering projects.

Pilot questions 3.2

1. A chain and compass traverse measures distances with a chain and directions with a compass.
2. Local attraction can distort compass readings.
3. A theodolite is used in a theodolite traverse.
4. A theodolite traverse is more accurate because it measures angles precisely.
5. A field book records traverse observations systematically.

Pilot questions 3.3

1. Latitude is the north–south displacement, and departure is the east–west displacement.
2. They are calculated using trigonometric functions based on line length and bearing.
3. Closing error is the difference between the plotted endpoint and the true position.
4. Bowditch and Transit methods are used to balance traverse errors.
5. Balancing ensures the corrected traverse is geometrically consistent.

Pilot questions 3.4

1. Traverses are used to establish boundaries of plots of land.
2. Traverse data is plotted to prepare site plans.
3. Road alignment is an example of an engineering project using traverses.
4. Traverses minimise steep gradients in road alignment.
5. Applications include bridge construction and utility installation.

References 3

- Bannister, A., Raymond, S., & Baker, R. (1998). *Surveying*. Pearson Education.
- Uren, J., & Price, W. F. (2010). *Surveying for Engineers*. Palgrave Macmillan.
- Clark, D. (2004). *Plane and Geodetic Surveying*. CRC Press.
- Open Educational Resources (OER) materials on traversing techniques, computation, and applications.

Series 4: Levelling And Tachometry Methods

Series outline

4.1 Fundamentals of levelling

- 4.1.1 Definition and scope of levelling
- 4.1.2 Types of levels and their components
- 4.1.3 Principles of levelling

4.2 Methods of levelling

- 4.2.1 Simple levelling
- 4.2.2 Differential levelling
- 4.2.3 Profile and cross-section levelling

4.3 Tachometry principles and techniques

- 4.3.1 Definition and scope of tachometry
- 4.3.2 Instruments used in tachometry
- 4.3.3 Methods of tachometric distance and elevation measurement

4.4 Applications of levelling and tachometry

- 4.4.1 Levelling in construction and earthwork projects
- 4.4.2 Tachometry in topographic surveying
- 4.4.3 Integration of levelling and tachometry in engineering design

Introduction

In surveying, determining accurate elevations and distances is just as important as measuring boundaries and directions. Engineers rely on **levelling** to establish relative heights of points on the ground, which is crucial for construction projects, drainage systems, and earthwork calculations. Similarly, **tachometry** provides a rapid method of measuring both distances and elevations using specialised instruments, making it particularly useful in topographic surveys. Together, these methods ensure that terrain is represented with precision and efficiency.

The aim of this Series is to introduce you to the principles, methods, and applications of levelling and tachometry, and to equip you with the skills needed to carry out field procedures, compute results, and apply them in engineering design and construction.

We shall commence this Series by examining the fundamentals of levelling, including its definition, scope, and the types of levels used. Then, we will move on to the methods of levelling, such as simple, differential, and profile levelling. Following that, we will explore tachometry principles and techniques, focusing on instruments and methods of measurement. Finally, we will wrap up by discussing the applications of levelling and tachometry in construction, topographic surveying, and engineering design. This progression will provide you with a comprehensive understanding of how these methods are applied in practice.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** define the concept and scope of levelling in surveying,
- **SLO 4.2** identify different types of levels and describe their components,
- **SLO 4.3** explain the principles that govern levelling operations,
- **SLO 4.4** demonstrate how to carry out simple levelling in the field,
- **SLO 4.5** apply differential levelling techniques to determine relative elevations,
- **SLO 4.6** conduct profile and cross-section levelling for engineering projects,
- **SLO 4.7** define tachometry and explain its scope in surveying,
- **SLO 4.8** describe the instruments used in tachometry and their functions,
- **SLO 4.9** demonstrate methods of measuring distances and elevations using tachometry,
- **SLO 4.10** apply levelling techniques in construction and earthwork projects,
- **SLO 4.11** analyse the role of tachometry in topographic surveying, and
- **SLO 4.12** evaluate how levelling and tachometry can be integrated in engineering design.

4.1 Fundamentals Of Levelling

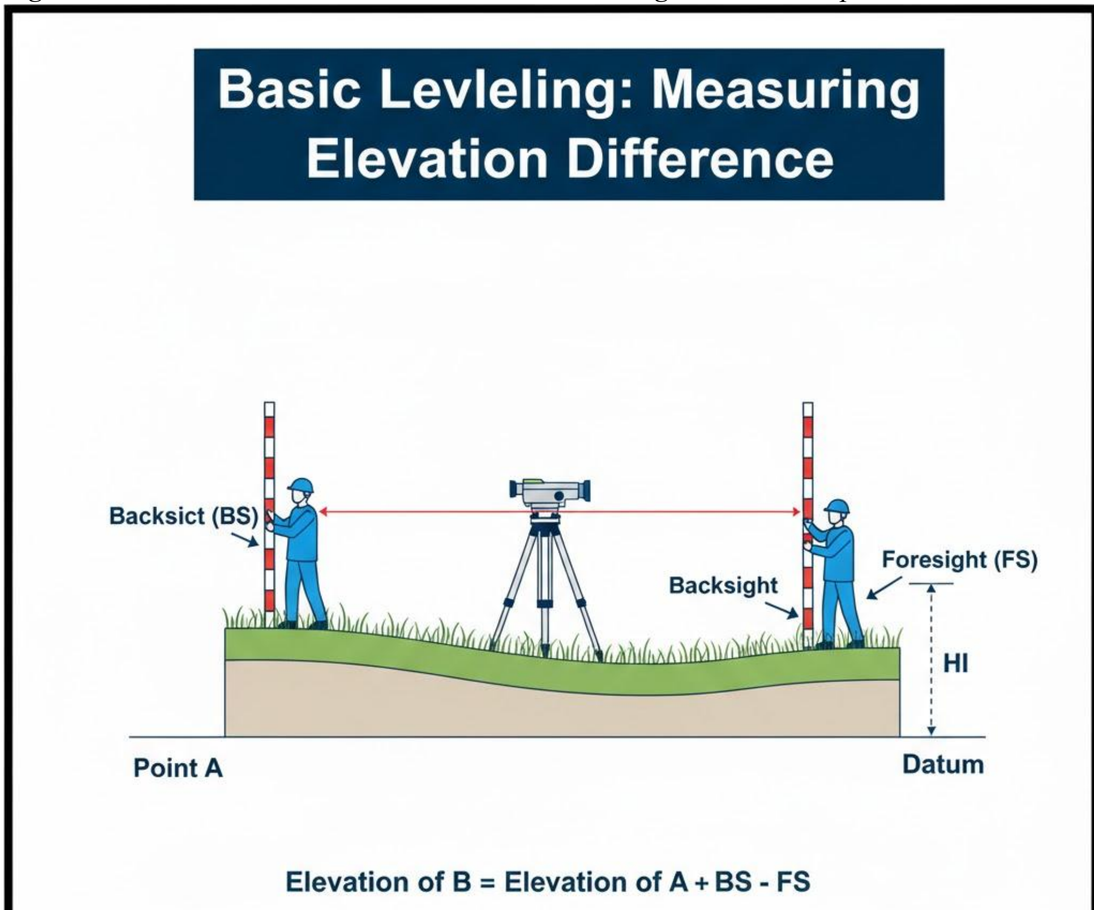
4.1.1 Definition and scope of levelling

Levelling is a surveying method used to determine the relative heights of points on the earth's surface. It provides essential information about elevation differences, which is critical for construction, drainage, and earthwork projects. The scope of levelling includes establishing benchmarks, preparing contour maps, and ensuring that structures are built on level foundations.

Fill in the blank: Levelling is a surveying method used to determine the relative ______ of points on the earth's surface.

Diagram showing a levelling instrument set up to measure elevation differences between two points.

Figure 4.1: Basic levelling setup in surveying:



4.1.2 Types of levels and their components

The main instruments used in levelling are **levels**, which include the **dumpy level**, **tilting level**, and **automatic level**. Each consists of a telescope mounted on a tripod, a spirit level for alignment, and adjustment screws for precision. These instruments allow surveyors to sight a graduated staff placed at different points to measure elevation differences.

Fill in the blank: The telescope mounted on a tripod and used in levelling instruments is called a ______.

Image of a dumpy level mounted on a tripod with a levelling staff.

Plate 4.1: Dumpy level and staff used in levelling:

4.1.3 Principles of levelling

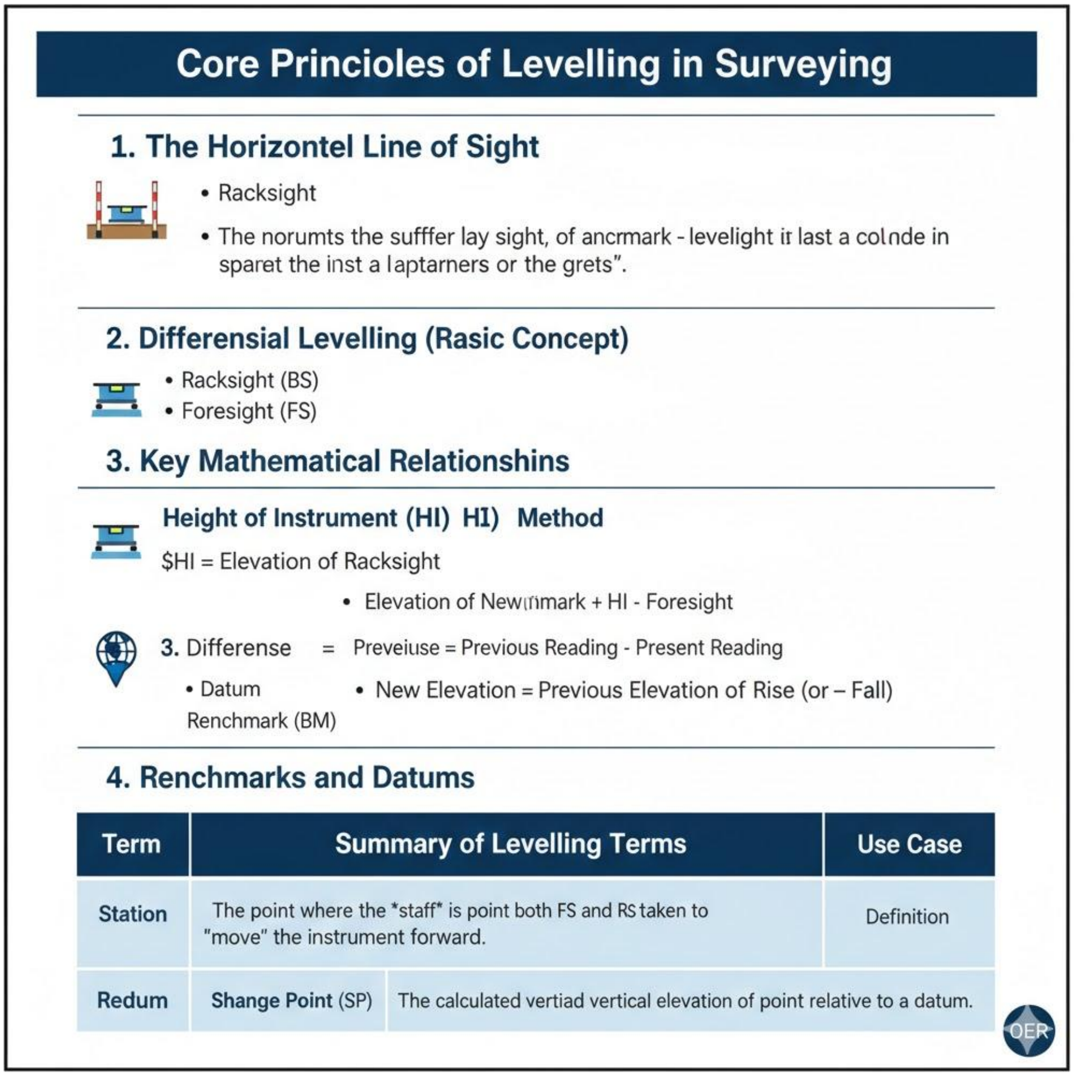
The principle of levelling is based on establishing a **horizontal line of sight** using the instrument and measuring the vertical distance between this line and points on the ground. By comparing readings taken on a levelling staff, the relative elevations of points can be determined. This principle ensures accuracy in construction and site preparation.

Fill in the blank: The principle of levelling is based on establishing a ______ line of sight using the instrument.

Box 4.1: Principles of levelling

1. Establish a horizontal line of sight.
2. Take staff readings at different points.

3. Compare readings to determine relative elevations.



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Pilot questions 4.1

1. Define levelling in surveying.
2. What is the scope of levelling in engineering projects?
3. Name three types of levels used in levelling.
4. What is the function of the telescope in a levelling instrument?
5. State the principle on which levelling is based.

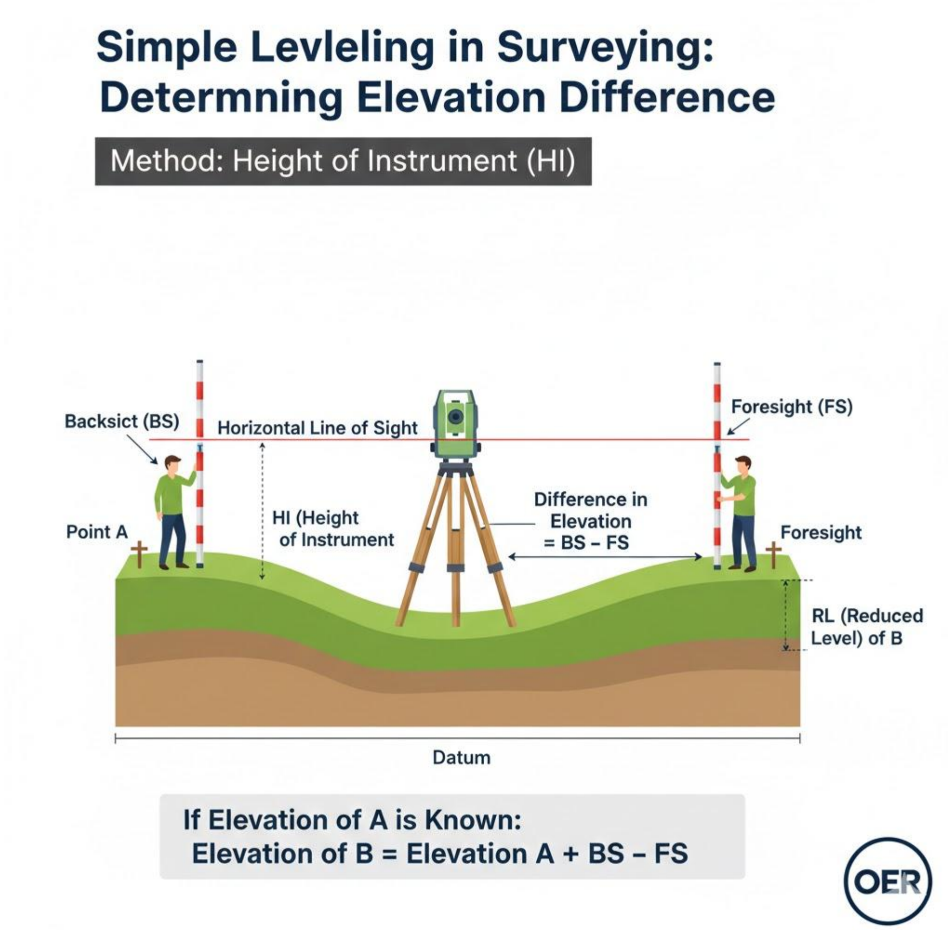
4.2 Methods Of Levelling

4.2.1 Simple levelling

Simple levelling involves determining the difference in elevation between two points using a single setup of the instrument. It is the most basic form of levelling and is often used for small-scale tasks such as checking the level of a floor or foundation.

Fill in the blank: Simple levelling determines the difference in ______ between two points using a single instrument setup.

Diagram showing simple levelling between two points with a staff. *Figure 4.2: Simple levelling setup*



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4.2.2 Differential levelling

Differential levelling is used when points are far apart or when obstacles prevent direct sighting. It involves multiple instrument setups and staff readings, allowing surveyors to calculate elevation differences across long distances.

Fill in the blank: Differential levelling is used when points are far apart or when ______ prevent direct sighting.

Image of surveyors conducting differential levelling with multiple setups.

Plate 4.2: Differential levelling in practice:

4.2.3 Profile and cross-section levelling

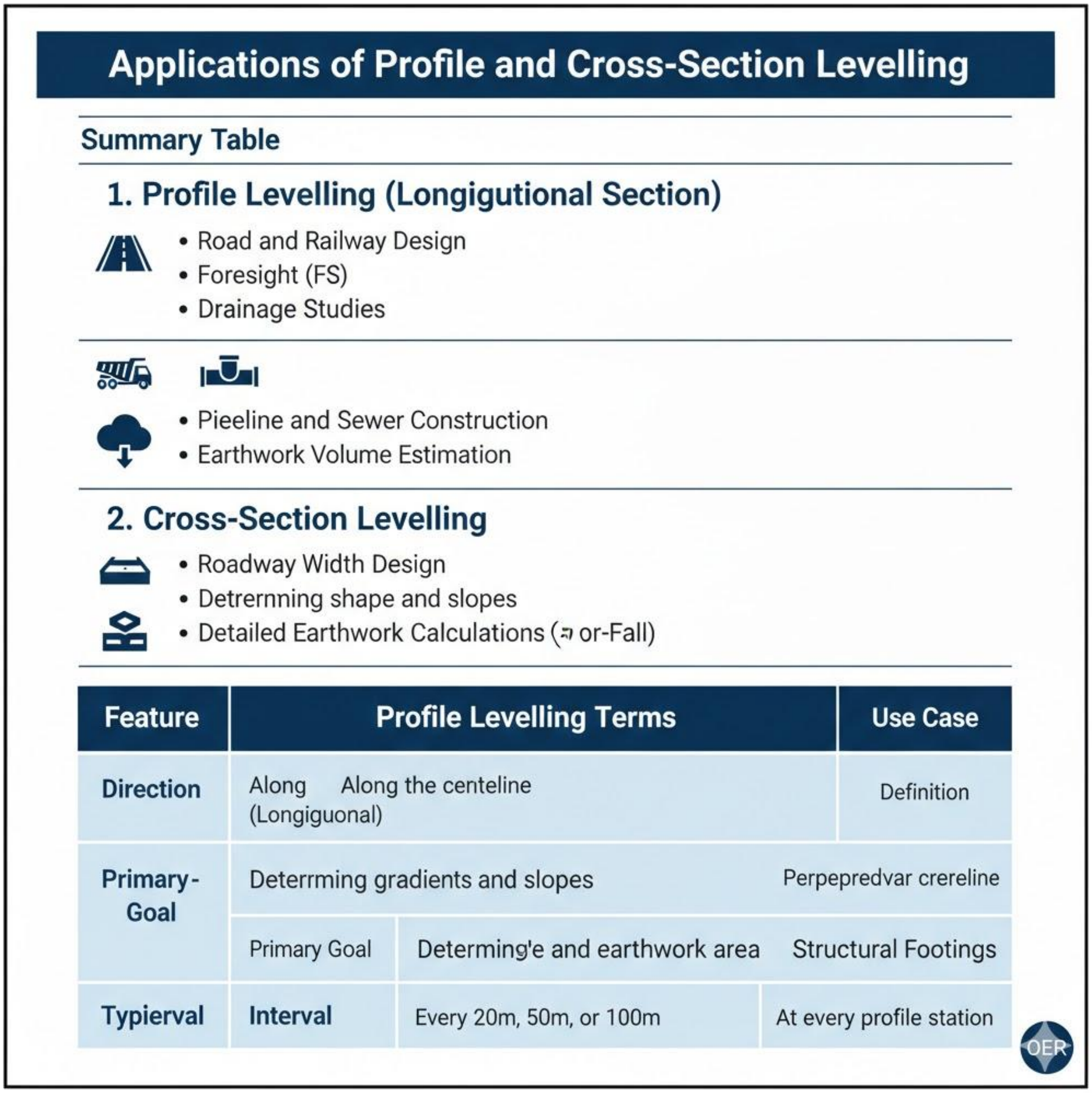
Profile levelling involves taking readings along a line, such as the centreline of a proposed road, to determine changes in elevation. **Cross-section levelling** involves taking readings perpendicular to the profile line to provide information about the terrain on either side. These methods are essential in road and railway construction.

Fill in the blank: Profile levelling involves taking readings along the ______ of a proposed road.

Box 4.2: Applications of profile and cross-section levelling

1. Road construction.
2. Railway alignment.

3. Drainage planning.:



Pilot questions 4.2

1. Define simple levelling.
2. When is differential levelling used?
3. What is the purpose of profile levelling?
4. Why is cross-section levelling important in road construction?
5. State one limitation of simple levelling.

4.3 Tachometry Principles And Techniques

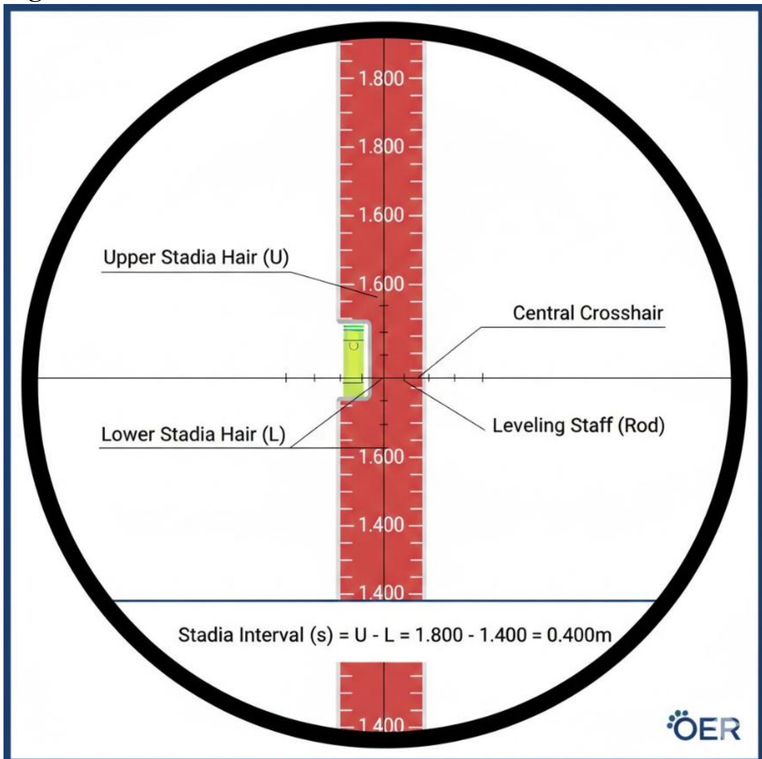
4.3.1 Definition and scope of tachometry

Tachometry is a rapid surveying method that uses a theodolite fitted with stadia hairs to measure both distances and elevations. It is particularly useful in rough terrain where chaining is difficult. The scope of tachometry includes topographic surveys and reconnaissance work.

Fill in the blank: Tachometry is a rapid surveying method that uses a theodolite fitted with ______ hairs to measure distances and elevations.

Diagram showing stadia hairs in a tachometer telescope.

Figure 4.3: Stadia hairs used in tachometry:



4.3.2 Instruments used in tachometry

The main instrument used in tachometry is the **tacheometer**, a modified theodolite with stadia hairs. It allows surveyors to quickly measure distances and elevations without the need for chains or tapes.

Fill in the blank: The main instrument used in tachometry is the ______, a modified theodolite with stadia hairs.

Image of a tacheometer mounted on a tripod.

Plate 4.3: Tacheometer used in tachometry AI prompt suggestion:

4.3.3 Methods of tachometric distance and elevation measurement

Tachometry uses stadia intercepts to calculate distances and elevations. By reading the staff intercepts through the telescope, surveyors can apply formulas to determine horizontal distances and vertical differences.

Fill in the blank: Tachometry uses stadia intercepts to calculate ______ and elevations.

Box 4.3: Methods of tachometric measurement

1. Stadia method.
2. Tangential method.

Pilot questions 4.3

1. Define tachometry in surveying.
2. What are stadia hairs used for?
3. Name the main instrument used in tachometry.

4. What is the stadia method in tachometry?
5. Why is tachometry useful in rough terrain?

4.4 Applications Of Levelling And Tachometry

4.4.1 Levelling in construction and earthwork projects

Levelling is essential in construction projects to ensure foundations are laid correctly and earthwork quantities are estimated accurately. It helps prevent structural failures caused by uneven ground.

Fill in the blank: Levelling ensures that ______ are laid correctly in construction projects.

4.4.2 Tachometry in topographic surveying

Tachometry is widely used in topographic surveys because it allows rapid measurement of distances and elevations. It is particularly effective in hilly or forested areas where chaining is impractical.

Fill in the blank: Tachometry is particularly effective in ______ areas where chaining is impractical.

Image of a topographic survey conducted using tachometry.

Plate 4.4: Tachometry in topographic surveying:

4.4.3 Integration of levelling and tachometry in engineering design

Levelling and tachometry are often integrated in engineering design to provide both accurate elevations and rapid distance measurements. This combination ensures efficient planning and execution of projects such as roads, bridges, and drainage systems.

Fill in the blank: Levelling and tachometry are integrated in engineering design to provide accurate elevations and rapid ______ measurements.

Box 4.4: Integration of levelling and tachometry

1. Road design.
2. Bridge construction.
3. Drainage system planning.

Pilot questions 4.4

1. Why is levelling important in construction projects?
2. How does tachometry support topographic surveying?
3. Give one example of where levelling is applied in engineering.
4. Why is tachometry effective in hilly terrain?
5. How are levelling and tachometry integrated in engineering design?

Series summary

In this Series, we explored levelling and tachometry as essential surveying methods for determining elevations and distances. We began with the fundamentals of levelling, defining its scope, identifying types of levels, and explaining the principles behind their use. We then examined methods of levelling, including simple, differential, profile, and cross-section levelling, highlighting their applications in construction and road projects. Following that, we studied tachometry, focusing on its definition, instruments such as the tacheometer, and methods of measurement using stadia and tangential techniques. Finally, we discussed practical applications of levelling and tachometry in construction, topographic surveying, and engineering design, emphasising how these methods complement each other to ensure accuracy and efficiency in site work.

Glossary of terms

- **Levelling**: A surveying method used to determine the relative heights of points on the earth's surface.
- **Benchmark**: A fixed reference point of known elevation used in levelling.
- **Dumpy level**: A traditional levelling instrument with a fixed telescope.
- **Automatic level**: A levelling instrument with a compensator that automatically establishes a horizontal line of sight.
- **Simple levelling**: Determining elevation difference between two points using a single instrument setup.
- **Differential levelling**: Levelling method involving multiple setups to measure elevation differences across long distances.

- **Profile levelling**: Taking readings along a line, such as a road centreline, to determine elevation changes.
- **Cross-section levelling**: Taking readings perpendicular to a profile line to assess terrain on either side.
- **Tachometry**: A rapid surveying method using a theodolite with stadia hairs to measure distances and elevations.
- **Tacheometer**: A modified theodolite fitted with stadia hairs for tachometric measurements.
- **Stadia method**: Tachometric technique using staff intercepts to calculate distances and elevations.
- **Tangential method**: Tachometric technique using angles of elevation or depression to calculate distances.

Concept check questions 4

Upon completing this Series, you should be able to answer the following questions:

1. (Linked to SLO 4.1) Define levelling and explain its scope in surveying.
2. (Linked to SLO 4.2) Identify three types of levels and describe their components.
3. (Linked to SLO 4.3) Explain the principle of levelling.
4. (Linked to SLO 4.4) Demonstrate how simple levelling is carried out.
5. (Linked to SLO 4.5) Apply differential levelling to measure elevation differences across long distances.
6. (Linked to SLO 4.6) Describe the purpose of profile and cross-section levelling.
7. (Linked to SLO 4.7) Define tachometry and explain its scope.
8. (Linked to SLO 4.8) Describe the tacheometer and its function.
9. (Linked to SLO 4.9) Demonstrate how distances and elevations are measured using stadia intercepts.
10. (Linked to SLO 4.10) Apply levelling techniques in construction projects.
11. (Linked to SLO 4.11) Analyse the role of tachometry in topographic surveying.
12. (Linked to SLO 4.12) Evaluate how levelling and tachometry can be integrated in engineering design.

Answers to pilot questions 4

Pilot questions 4.1

1. Levelling is a surveying method used to determine relative heights of points.
2. Its scope includes establishing benchmarks, preparing contour maps, and ensuring level foundations.

3. Types of levels include dumpy level, tilting level, and automatic level.
4. The telescope is used to sight the staff and measure elevation differences.
5. Levelling is based on establishing a horizontal line of sight.

Pilot questions 4.2

1. Simple levelling determines elevation difference between two points using one setup.
2. Differential levelling is used when points are far apart or obstacles prevent direct sighting.
3. Profile levelling is used along a line such as a road centreline.
4. Cross-section levelling provides terrain information on either side of the profile.
5. Simple levelling is limited to short distances.

Pilot questions 4.3

1. Tachometry is a rapid surveying method using stadia hairs.
2. Stadia hairs are used to measure staff intercepts for distance and elevation.
3. The main instrument is the tacheometer.
4. The stadia method calculates distances using staff intercepts.
5. Tachometry is useful in rough terrain where chaining is difficult.

Pilot questions 4.4

1. Levelling ensures foundations are laid correctly.
2. Tachometry supports topographic surveying by providing rapid measurements.
3. Levelling is applied in earthwork estimation.
4. Tachometry is effective in hilly terrain.
5. Levelling and tachometry are integrated in road and bridge design.

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- Uren, J., & Price, W. F. (2010). *Surveying for Engineers*. Palgrave Macmillan.
- Clark, D. (2004). *Plane and Geodetic Surveying*. CRC Press.
- Open Educational Resources (OER) materials on levelling methods, tachometry techniques, and engineering applications.

Series 5: Introduction To Photogrammetry

Series outline

5.1 Fundamentals of photogrammetry

- 5.1.1 Definition and scope of photogrammetry
- 5.1.2 Historical development and modern relevance
- 5.1.3 Principles of photographic surveying

5.2 Types of photogrammetry

- 5.2.1 Terrestrial photogrammetry
- 5.2.2 Aerial photogrammetry
- 5.2.3 Digital photogrammetry

5.3 Photogrammetric processes and techniques

- 5.3.1 Image acquisition and control points
- 5.3.2 Stereoscopic vision and 3D model generation
- 5.3.3 Data processing and interpretation

5.4 Applications of photogrammetry in engineering and mapping

- 5.4.1 Topographic mapping and land surveys
- 5.4.2 Construction and infrastructure monitoring
- 5.4.3 Integration with GIS and remote sensing

Introduction

Surveying has evolved beyond traditional ground-based measurements to include advanced techniques that capture terrain and structures through imagery. **Photogrammetry** is one such method, where photographs are used to obtain reliable measurements and create maps or 3D models. It has become increasingly important in engineering and mapping because it allows large areas to be surveyed quickly and with high accuracy, especially when conventional methods are impractical.

The aim of this Series is to introduce you to the principles, types, processes, and applications of photogrammetry, and to equip you with the skills needed to interpret images, generate spatial data, and apply these techniques in engineering and mapping projects.

We shall commence this Series by exploring the fundamentals of photogrammetry, including its definition, scope, historical development, and principles of photographic surveying. Then, we will move on to examine the types of photogrammetry, such as terrestrial, aerial, and digital approaches. Following that, we will study photogrammetric processes and techniques, focusing on image acquisition, stereoscopic vision, and data interpretation. Finally, we will wrap up by discussing the applications of photogrammetry in topographic mapping, construction monitoring, and integration with GIS and remote sensing. This progression will provide you with a comprehensive understanding of how photogrammetry supports modern surveying and engineering design.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** define the concept and scope of photogrammetry in surveying,
- **SLO 5.2** explain the historical development and modern relevance of photogrammetry,
- **SLO 5.3** describe the principles of photographic surveying,
- **SLO 5.4** distinguish between terrestrial, aerial, and digital photogrammetry,
- **SLO 5.5** demonstrate how images are acquired and control points established in photogrammetry,
- **SLO 5.6** explain the principle of stereoscopic vision and its role in generating 3D models,
- **SLO 5.7** apply photogrammetric techniques to process and interpret spatial data,
- **SLO 5.8** analyse the use of photogrammetry in topographic mapping and land surveys,
- **SLO 5.9** evaluate the role of photogrammetry in construction and infrastructure monitoring, and
- **SLO 5.10** assess how photogrammetry integrates with GIS and remote sensing in engineering applications.

5.1 Fundamentals Of Photogrammetry

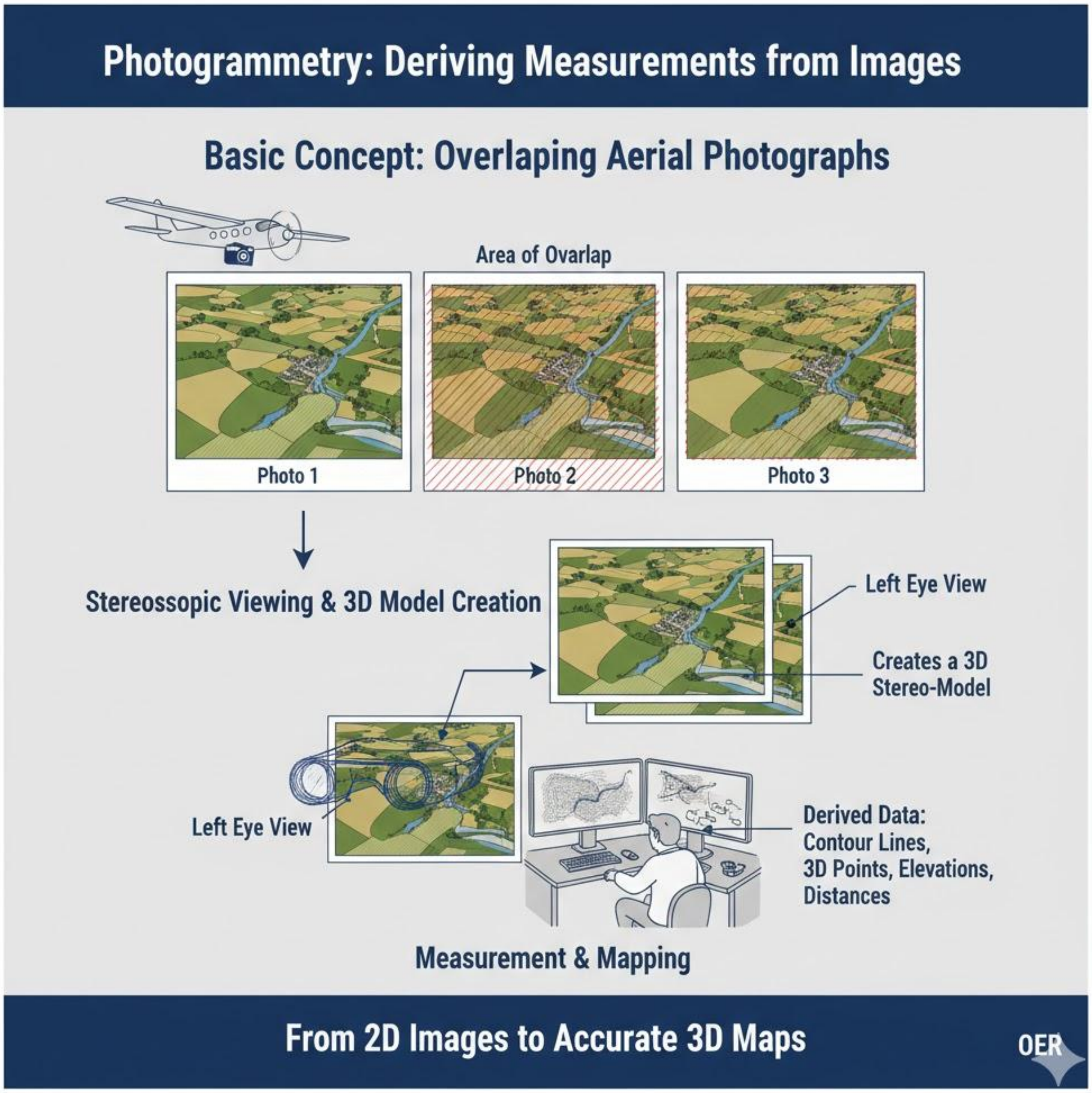
5.1.1 Definition and scope of photogrammetry

Photogrammetry is the science and technology of obtaining reliable measurements and spatial data from photographs. It involves capturing images of terrain or objects and using them to determine dimensions, positions, and shapes. The scope of photogrammetry extends to topographic mapping, engineering surveys, and monitoring changes in the environment.

Fill in the blank: Photogrammetry is the science and technology of obtaining reliable ______ from photographs.

Diagram showing how photographs are used to derive measurements in photogrammetry.

Figure 5.1: Basic concept of photogrammetry:



"

5.1.2 Historical development and modern relevance

Photogrammetry dates back to the mid-19th century when photographs were first used for mapping. Early applications involved terrestrial photographs taken from fixed positions. With the advent of aviation, **aerial photogrammetry** became widespread, enabling large-scale mapping. Today, digital photogrammetry and drone-based surveys have revolutionised the field, making it faster, more accurate, and more accessible.

Fill in the blank: The widespread use of aerial photogrammetry began with the advent of ______.

Image showing historical aerial photogrammetry compared with modern drone-based photogrammetry.

Plate 5.1: Evolution of photogrammetry from aerial photography to drone surveys suggestion:

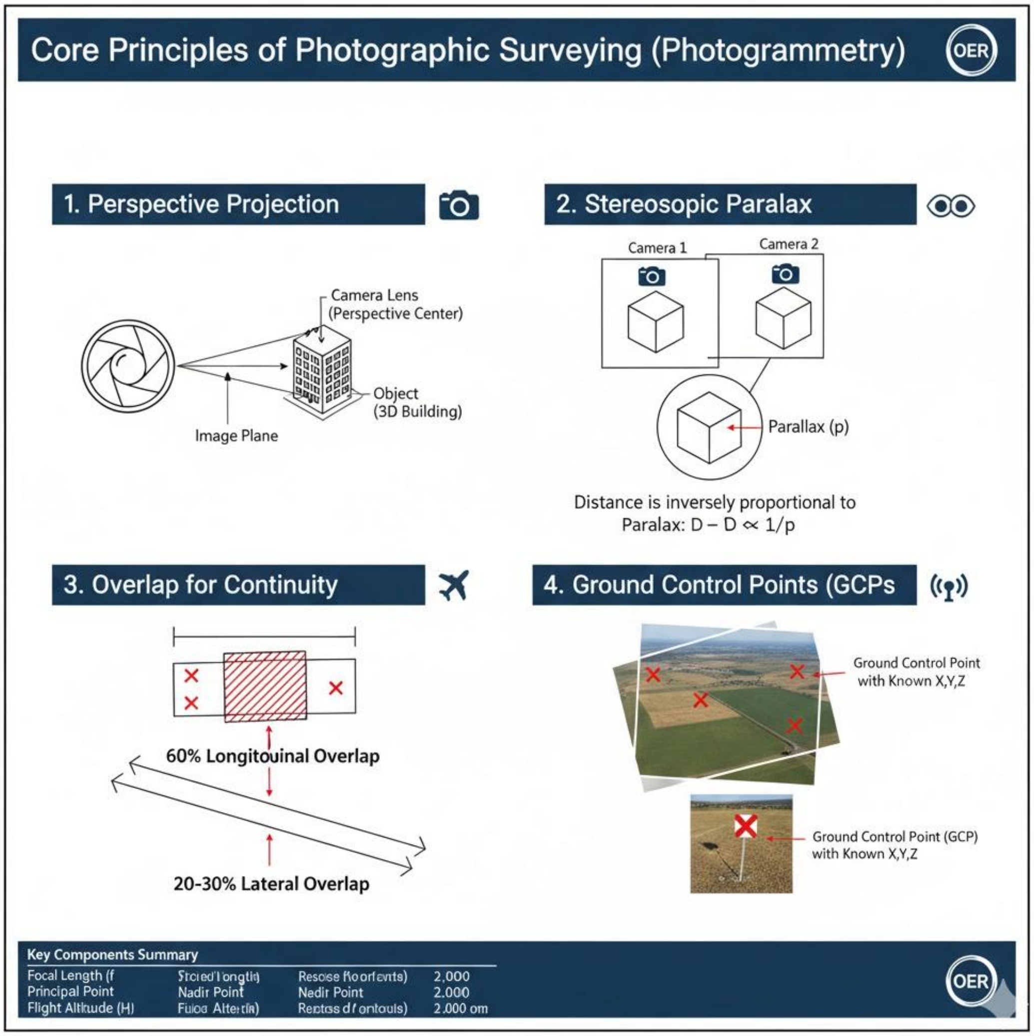
Particulars	**Aerial Photogrammetry**	**UAV Photogrammetry**
Data Acquisition	Manual/Assisted	Assisted/Manual/ Automatic
Aerial Vehicle	Highly stable specially designed aircrafts	Small aerial Vehicles with certain payload capacity
GPS/INS Configurations	cm-dm	cm-10 m
Image Resolution	cm-m	mm-m
Ground Coverage	Km^2	M^2-km^2
Cameras	Well calibrated cameras especially designed for photogrammetric applications	Can work with normal off-shelf digital cameras
Fiducial Marks	Present	Absent
Flying Height	100 m-10 km	m-km (not more than 1 km)
Data Processing Workflows	Standard Photogrammetric Workflow	No standard workflows
Salient Feature	Better control over the output image quality	High temporal accuracy with real time applications

5.1.3 Principles of photographic surveying

The principle of **photographic surveying** is based on capturing overlapping photographs of a subject from different positions. These overlapping images allow for **stereoscopic vision**, which provides depth perception and enables the creation of 3D models. By identifying control points within the images, surveyors can scale and orient the photographs to produce accurate maps and measurements.

Fill in the blank: Photographic surveying relies on overlapping photographs to create ______ vision, which provides depth perception.

Box 5.1: Principles of photographic surveying



Pilot questions 5.1

1. Define photogrammetry in surveying.
2. What is the scope of photogrammetry?
3. When did photogrammetry first begin to be used for mapping?
4. How did aviation contribute to the development of photogrammetry?
5. State the principle on which photographic surveying is based.

5.2 Types Of Photogrammetry

5.2.1 Terrestrial photogrammetry

Terrestrial photogrammetry involves taking photographs from ground-based stations. It is commonly used for architectural surveys, engineering structures, and small-scale mapping.

Fill in the blank: Terrestrial photogrammetry involves taking photographs from ______ stations.

Image showing surveyors using a ground-based camera for photogrammetry. *Plate 5.2: Terrestrial photogrammetry in practice*

:

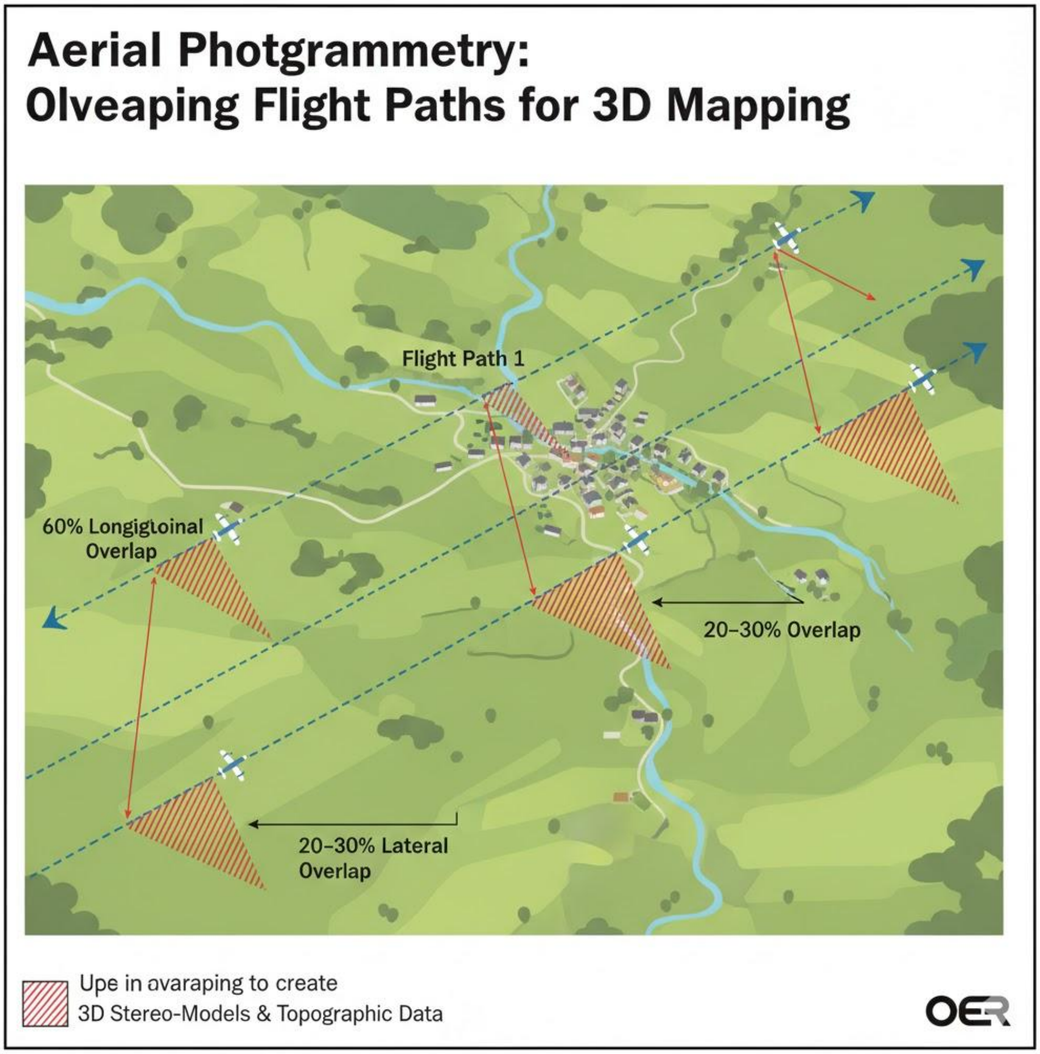
5.2.2 Aerial photogrammetry

Aerial photogrammetry uses photographs taken from aircraft or drones. It is widely used for topographic mapping, land-use planning, and environmental monitoring.

Fill in the blank: Aerial photogrammetry uses photographs taken from ______ or drones.

Diagram showing aerial photogrammetry with overlapping flight paths.

Figure 5.2: Aerial photogrammetry flight paths:



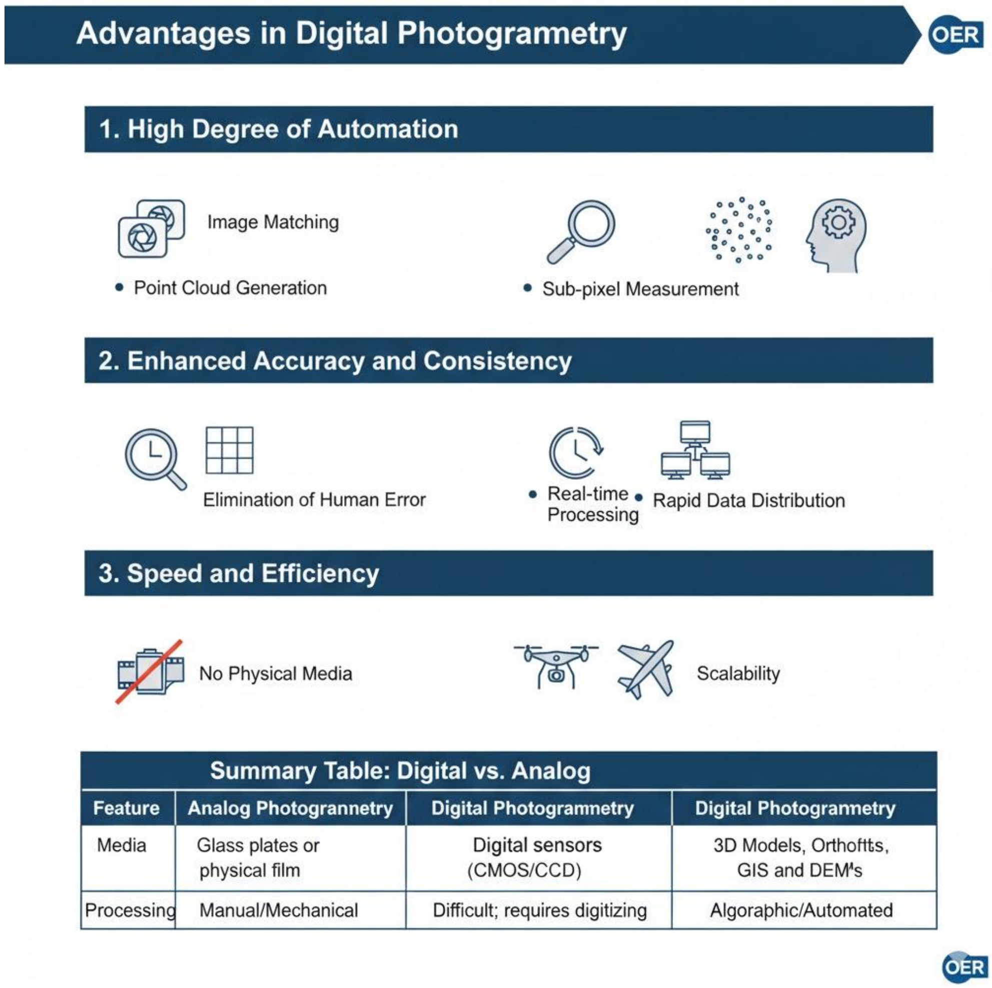
5.2.3 Digital photogrammetry

Digital photogrammetry involves processing digital images using specialised software to generate maps and 3D models. It is faster, more accurate, and integrates easily with GIS systems.

Fill in the blank: Digital photogrammetry involves processing ______ images using specialised software.

Box 5.2: Advantages of digital photogrammetry

1. Faster processing.
2. Higher accuracy.
3. Easy integration with GIS.



Pilot questions 5.2

1. What is terrestrial photogrammetry?
2. Where is aerial photogrammetry commonly applied?
3. What is the main advantage of digital photogrammetry?
4. Why are overlapping flight paths important in aerial photogrammetry?
5. State one application of terrestrial photogrammetry.

5.3 Photogrammetric Processes And Techniques

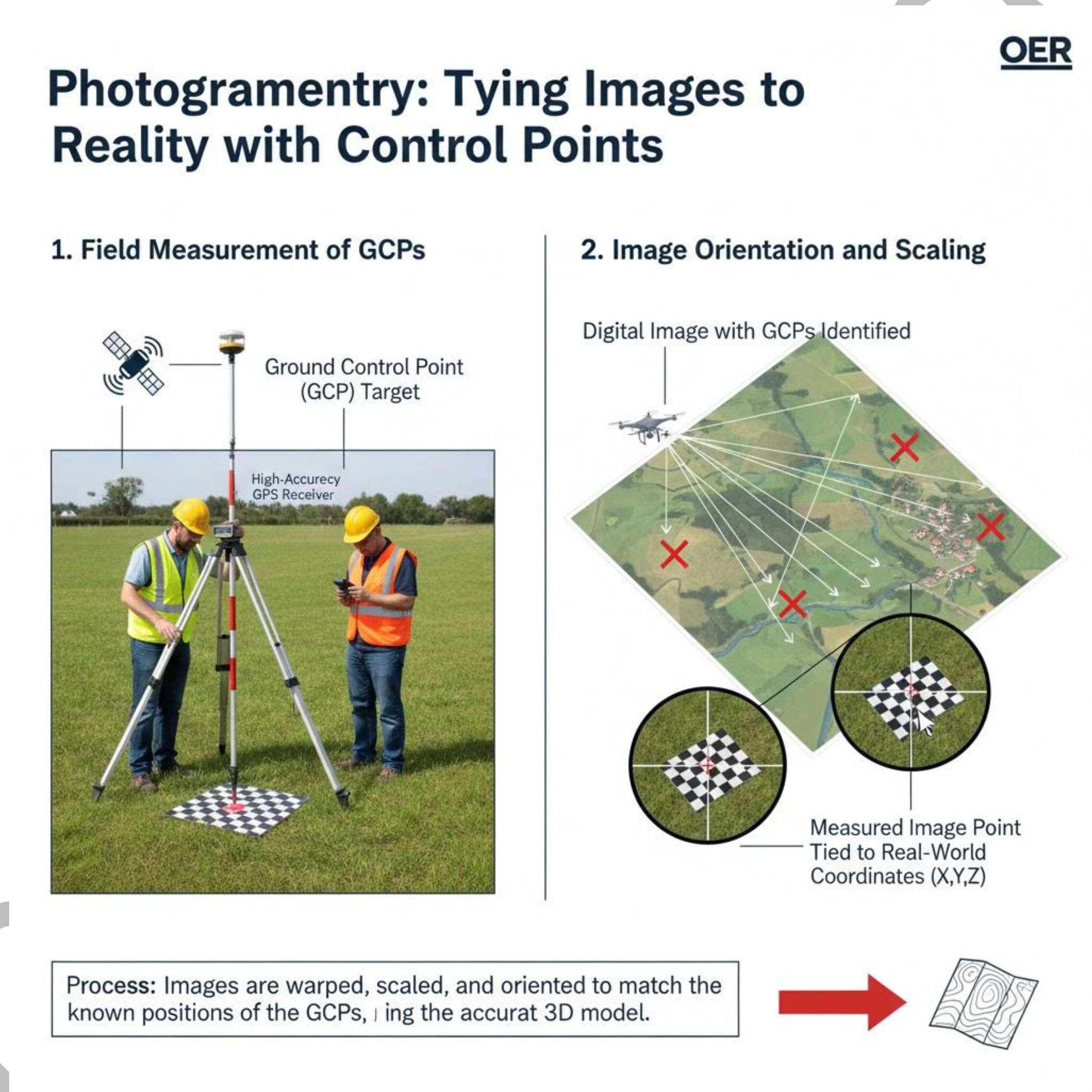
5.3.1 Image acquisition and control points

Image acquisition involves capturing photographs with sufficient overlap to allow stereoscopic vision. **Control points** are identifiable features on the ground with known coordinates, used to scale and orient images accurately.

Fill in the blank: Control points are identifiable features on the ground with known ______.

Diagram showing control points used in photogrammetry.

Figure 5.3: Control points in photogrammetry AI prompt suggestion:



5.3.2 Stereoscopic vision and 3D model generation

Stereoscopic vision is achieved by viewing overlapping photographs through a stereoscope, which provides depth perception. This principle allows surveyors to generate accurate **3D models** of terrain and structures.

Fill in the blank: Stereoscopic vision provides ______ perception, enabling the creation of 3D models.

Image of a stereoscope used in photogrammetry.

Plate 5.3: Stereoscope for stereoscopic vision

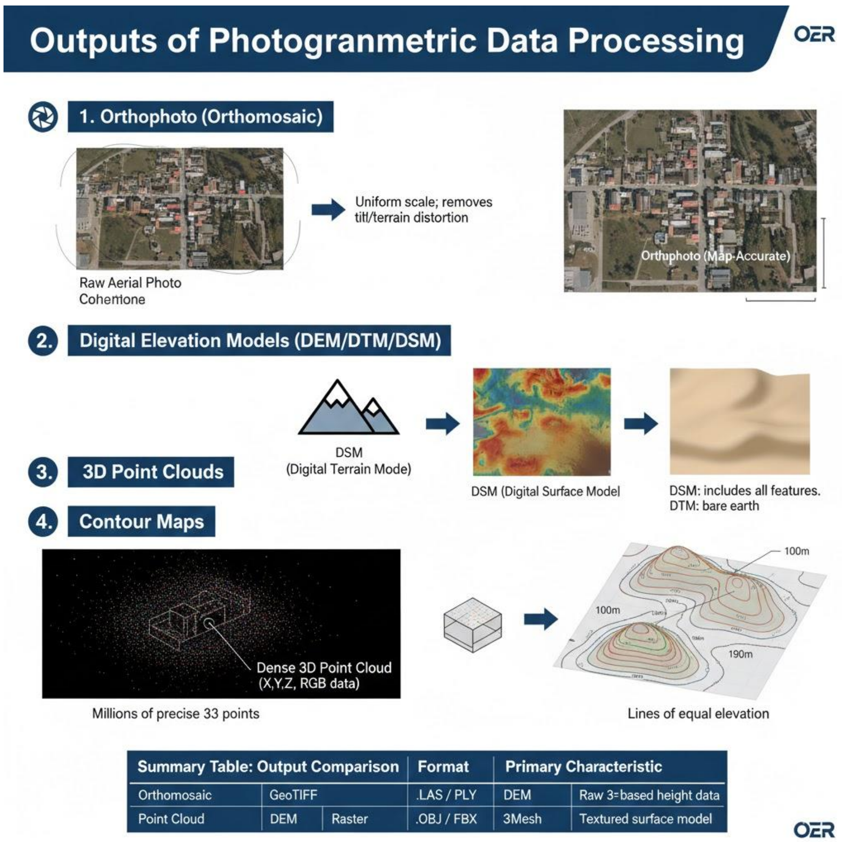
5.3.3 Data processing and interpretation

Photogrammetric data is processed using software that extracts coordinates, generates digital elevation models, and produces maps. Interpretation involves analysing these outputs for engineering or environmental applications.

Fill in the blank: Photogrammetric data is processed to generate digital ______ models and maps.

Box 5.3: Outputs of photogrammetric data processing

1. Digital elevation models.
2. Contour maps.
3. 3D terrain models.



Pilot questions 5.3

1. What is image acquisition in photogrammetry?
2. Why are control points important?
3. How is stereoscopic vision achieved?
4. What is the purpose of 3D model generation?
5. Name two outputs of photogrammetric data processing.

5.4 Applications Of Photogrammetry In Engineering And Mapping

5.4.1 Topographic mapping and land surveys

Photogrammetry is widely used to produce topographic maps and conduct land surveys. It provides detailed information about terrain features and land use.

Fill in the blank: Photogrammetry is widely used to produce ______ maps and conduct land surveys.

5.4.2 Construction and infrastructure monitoring

Photogrammetry supports construction projects by monitoring progress, detecting structural changes, and estimating earthwork volumes. It ensures accuracy and efficiency in project management.

Fill in the blank: Photogrammetry supports construction projects by monitoring ______ and detecting structural changes.

Image of construction site monitoring using drone-based photogrammetry. *Plate 5.4: Photogrammetry in construction monitoring*

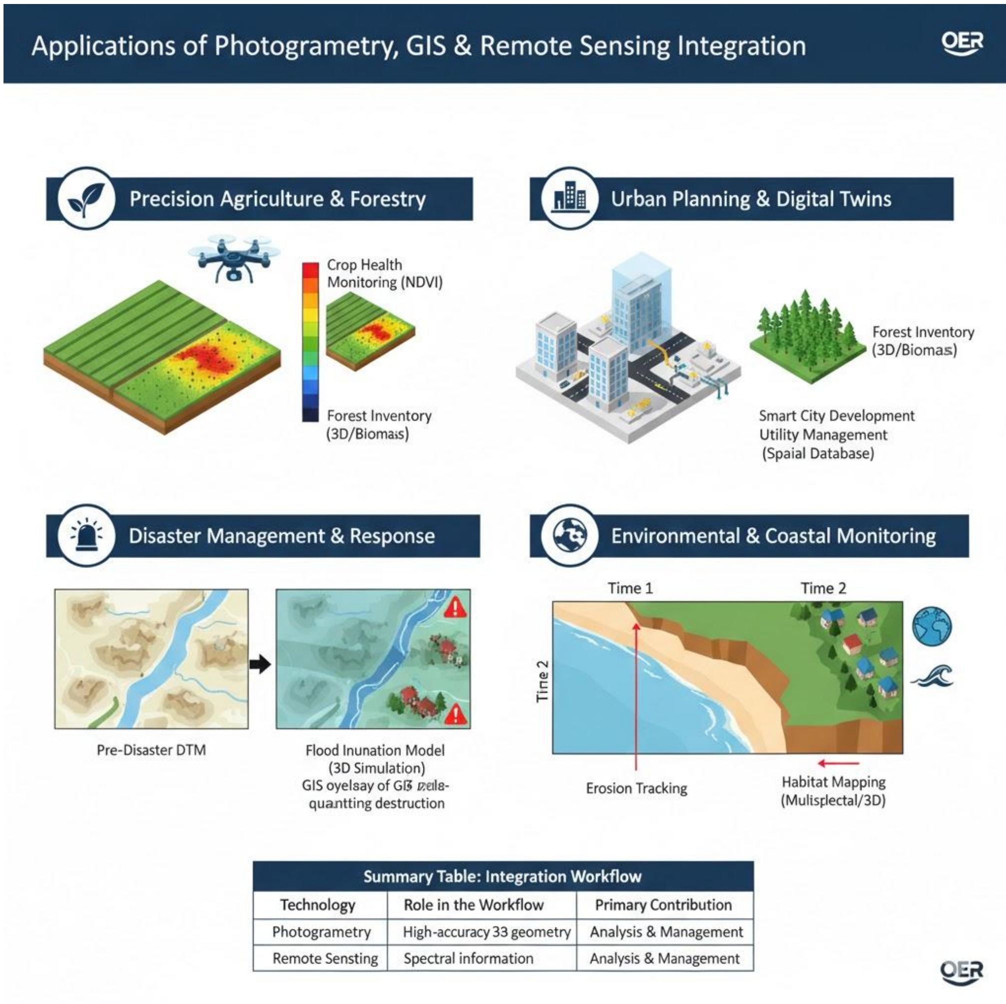
5.4.3 Integration with GIS and remote sensing

Photogrammetry integrates with **GIS (Geographic Information Systems)** and **remote sensing** to provide spatial data for analysis and decision-making. This integration enhances applications in urban planning, environmental monitoring, and disaster management.

Fill in the blank: Photogrammetry integrates with GIS and ______ sensing to provide spatial data for analysis.

Box 5.4: Applications of photogrammetry integration

1. Urban planning.
2. Environmental monitoring.
3. Disaster management.



Pilot questions 5.4

1. How is photogrammetry applied in topographic mapping?
2. What role does photogrammetry play in construction monitoring?
3. Give one example of photogrammetry in infrastructure projects.
4. Why is integration with GIS important?
5. State two applications of photogrammetry in environmental monitoring.

Series summary

In this Series, we explored photogrammetry as a modern surveying technique that derives measurements and spatial data from photographs. We began with the fundamentals, defining photogrammetry, tracing its historical development, and explaining the principles of photographic surveying. We then examined the types of photogrammetry, distinguishing between terrestrial, aerial, and digital approaches. Following that, we studied photogrammetric processes and techniques, including image acquisition, the use of control points, stereoscopic vision, and data processing. Finally, we discussed applications of photogrammetry in engineering and mapping, such as topographic surveys, construction monitoring, and integration with GIS and remote sensing. This Series equips learners with both conceptual knowledge and practical skills for applying photogrammetry in modern surveying and engineering projects.

Glossary of terms

- **Photogrammetry**: The science of obtaining reliable measurements and spatial data from photographs.
- **Terrestrial photogrammetry**: Photogrammetry conducted from ground-based stations.
- **Aerial photogrammetry**: Photogrammetry using photographs taken from aircraft or drones.
- **Digital photogrammetry**: Photogrammetry that uses digital images and specialised software for processing.
- **Photographic surveying**: The process of capturing overlapping photographs to generate maps and models.
- **Stereoscopic vision**: Depth perception achieved by viewing overlapping photographs, enabling 3D model generation.
- **Control points**: Ground features with known coordinates used to scale and orient photogrammetric images.
- **Tacheometer**: A modified theodolite fitted with stadia hairs, sometimes used in photogrammetry.
- **Digital elevation model (DEM)**: A 3D representation of terrain generated from photogrammetric data.
- **GIS (Geographic Information Systems)**: Systems that manage and analyse spatial data, often integrated with photogrammetry.

Concept check questions 5

Upon completing this Series, you should be able to answer the following questions:

1. (Linked to SLO 5.1) Define photogrammetry and explain its scope.
2. (Linked to SLO 5.2) Explain the historical development of photogrammetry.
3. (Linked to SLO 5.3) Describe the principles of photographic surveying.
4. (Linked to SLO 5.4) Distinguish between terrestrial, aerial, and digital photogrammetry.
5. (Linked to SLO 5.5) Demonstrate how images are acquired and control points established.

6. (Linked to SLO 5.6) Explain stereoscopic vision and its role in 3D model generation.
7. (Linked to SLO 5.7) Apply photogrammetric techniques to process and interpret spatial data.
8. (Linked to SLO 5.8) Analyse the use of photogrammetry in topographic mapping.
9. (Linked to SLO 5.9) Evaluate photogrammetry in construction and infrastructure monitoring.
10. (Linked to SLO 5.10) Assess how photogrammetry integrates with GIS and remote sensing.

Answers to pilot questions 5

Pilot questions 5.1

1. Photogrammetry is the science of obtaining measurements from photographs.
2. Its scope includes mapping, engineering surveys, and environmental monitoring.
3. Photogrammetry began in the mid-19th century.
4. Aviation enabled aerial photogrammetry for large-scale mapping.
5. Photographic surveying is based on overlapping photographs and stereoscopic vision.

Pilot questions 5.2

1. Terrestrial photogrammetry uses ground-based photographs.
2. Aerial photogrammetry is applied in topographic mapping and land-use planning.
3. Digital photogrammetry offers faster processing and integration with GIS.
4. Overlapping flight paths ensure stereoscopic coverage.
5. Terrestrial photogrammetry is used in architectural surveys.

Pilot questions 5.3

1. Image acquisition involves capturing overlapping photographs.
2. Control points provide scaling and orientation.
3. Stereoscopic vision is achieved by viewing overlapping images.
4. 3D model generation provides accurate terrain representation.
5. Outputs include digital elevation models and contour maps.

Pilot questions 5.4

1. Photogrammetry produces topographic maps and land surveys.
2. It monitors construction progress and detects structural changes.
3. Infrastructure projects such as bridges use photogrammetry.

4. Integration with GIS enhances spatial analysis.
5. Applications include urban planning and environmental monitoring.

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