
- Course code: MNE 502
- Course title: Mine Surveying
- Course credit load: 3

# Series 1: Fundamentals of Mine Surveying

**Series outline**

- **Part 1: Principles of Mine Surveying**
    - Definition and scope of mine surveying
    - Differences between surface and underground surveying
    - Importance of surveying in mining operations
- **Part 2: Surveying Equipment and Techniques**
    - Mining theodolite and its unique features
    - Comparison with land surveying theodolite

- Basic operation and handling of equipment

- **Part 3: Survey Control and Applications**
  - Establishing survey control points
  - Applications in mine planning and design
  - Role of surveying in slope stability and excavation
- **Part 4: Data Processing and Presentation**
  - Mathematical concepts in survey data processing
  - Presentation of survey results using cartographic principles
  - Integration of survey data into mining layouts

**Introduction**

Mining operations rely heavily on accurate measurements and representations of both the surface and subsurface. Without precise surveying, mine planning would be unreliable, slope stability could be compromised, and mineral reserves might be miscalculated. This Series sets the stage for your journey into mine surveying by introducing its fundamental principles, equipment, and applications. It is the foundation upon which the rest of the course builds, ensuring you can appreciate the unique role surveying plays in safe and efficient mining.

The aim of this Series is to equip you with the essential knowledge and skills to define mine surveying, differentiate between surface and underground practices, operate basic surveying equipment, and process survey data for practical mining applications.

We shall commence this Series by examining the **principles of mine surveying**, focusing on its scope, differences between surface and underground methods, and its importance in mining operations. Next, we will explore **surveying equipment and techniques**, with particular attention to the mining theodolite and its unique features. Following that, we will consider **survey control and applications**, where you will learn how survey data supports excavation, slope stability, and mine planning. Finally, we will wrap up with **data processing and presentation**, highlighting how mathematical concepts and cartographic principles are applied to transform raw survey data into useful mining layouts.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 1.1** define mine surveying and explain its scope,

- **SLO 1.2** differentiate between surface and underground surveying,
- **SLO 1.3** explain the unique features of mining surveying equipment,
- **SLO 1.4** apply surveying techniques to establish control points and support mine planning,
- **SLO 1.5** process survey data using mathematical concepts, and
- **SLO 1.6** present survey results effectively using cartographic principles.

### 1.1 Principles Of Mine Surveying

#### 1.1.1 Definition and scope of mine surveying

**Mine surveying** is the specialised branch of surveying concerned with measuring, mapping, and analysing both the surface and underground features of mining areas. It provides essential data for mine planning, design, and safety. Unlike general land surveying, mine surveying must address dynamic geological conditions, displacement of rocks, and the need for precise control in confined underground spaces.

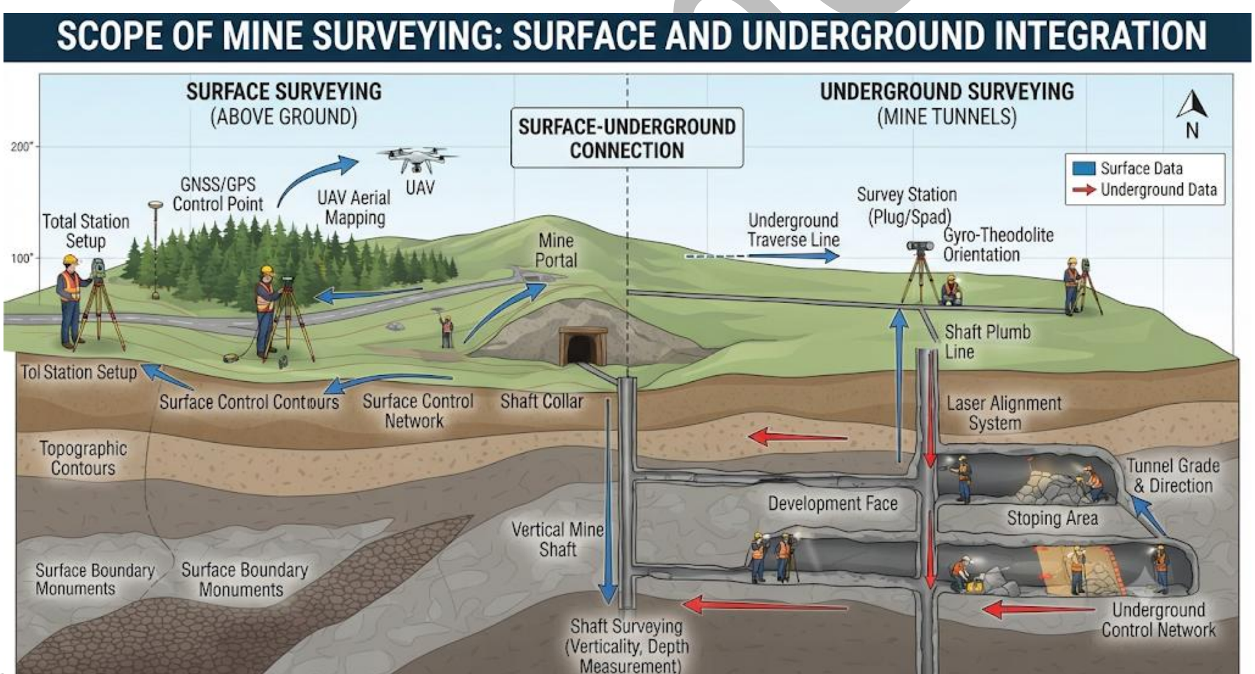



Diagram showing the scope of mine surveying (surface and underground). *Figure 1.1: Scope of mine surveying*

Mine surveying differs from land surveying because it involves both ______ and underground measurements.

#### 1.1.2 Differences between surface and underground surveying

**Surface surveying** refers to measurements taken on open ground such as quarries or open cast mines. It focuses on terrain mapping, slope stability, drainage, and excavation layouts.
**Underground surveying** is conducted within mine tunnels, shafts, and chambers. It requires specialised instruments such as the **mining theodolite**, which is adapted for limited visibility and confined spaces.

**COMPARISON OF SURFACE VS. UNDERGROUND MINE SURVEYING**

| SURFACE SURVEYING (ABOVE GROUND) | | UNDERGROUND SURVEYING (MINE TUNNELS) |
|---|---|---|
| Mapping, boundary definition, infrastructure planning, ore reserve estimation. | Primary Objective | Tunnel alignment, grade control, mine development, void mapping, safety monitoring. |
| Open, exposed to weather (sun, rain, wind), topography, vegetation. | Environment | Enclosed, artificial lighting, confined space, dusty, humid, dark. |
| Long-range, direct line of sight possible over large areas. | Line of Sight | Short-range, restricted, obstructed by tunnel bends and workings. |
| Established via GNSS/GPS and extensive triangulation/traverses. | Control Network | Extended from surface through shafts/adits; relies heavily on precision traverses and gyro-theodolites. |
| GNSS/GPS receivers, Total Stations, Drones (UAVs), Laser Scanners. | Key Instruments | Total Stations (specialized for low light), Gyro-theodolites, Laser Scanners, Plummets. |
| Atmospheric interference, vegetation, access limitations, large data volumes. | Data Collection Challenges | GPS denial, lighting issues, confined movement, dust, humidity, potential ground movement. |
| High, but can vary by project (e.g., boundary vs. stockpile). | Accuracy Requirements | Extremely high precision required for tunnel interception and safety. |
| Traffic, machinery, weather exposure, steep terrain. | Safety Hazards | Rock falls, poor air quality, confined spaces, mobile equipment, water ingress. |
| Periodic (e.g., quarterly volumetric surveys, initial mapping.). | Frequency of Work | Continuous, daily or weekly to guide development and production. |
| Topographic maps, 3D surface models, orthophotos. | Visualization | 3D tunnel network models, cross-sections, mine plans, void models. |

Comparison of surface and underground surveying. *Table 1.1: Key differences between surface and underground surveying*

Surface surveying is mainly concerned with ______, while underground surveying focuses on ______.

### 1.1.3 Importance of surveying in mining operations

Surveying is vital in mining because it ensures accurate mine planning, supports safe excavation, and provides data for drilling, blasting, and transport operations. It also assists in mineral reserve estimation and displacement analysis. Without reliable surveying, mining operations risk inefficiency, safety hazards, and poor resource management.

Image of surveyors working in an open cast mine. *Plate 1.1: Surveying in mining operations*

One major importance of mine surveying is that it ensures ______ in mine planning and design.

**Pilot questions 1.1**

1. Define mine surveying in one sentence.
2. State two differences between surface and underground surveying.
3. Why is mine surveying considered essential in mining operations?
4. Which type of surveying is more concerned with slope stability?
5. Which type of surveying is conducted in confined spaces?

### 1.2 Surveying Equipment And Techniques

#### 1.2.1 Mining theodolite and its unique features

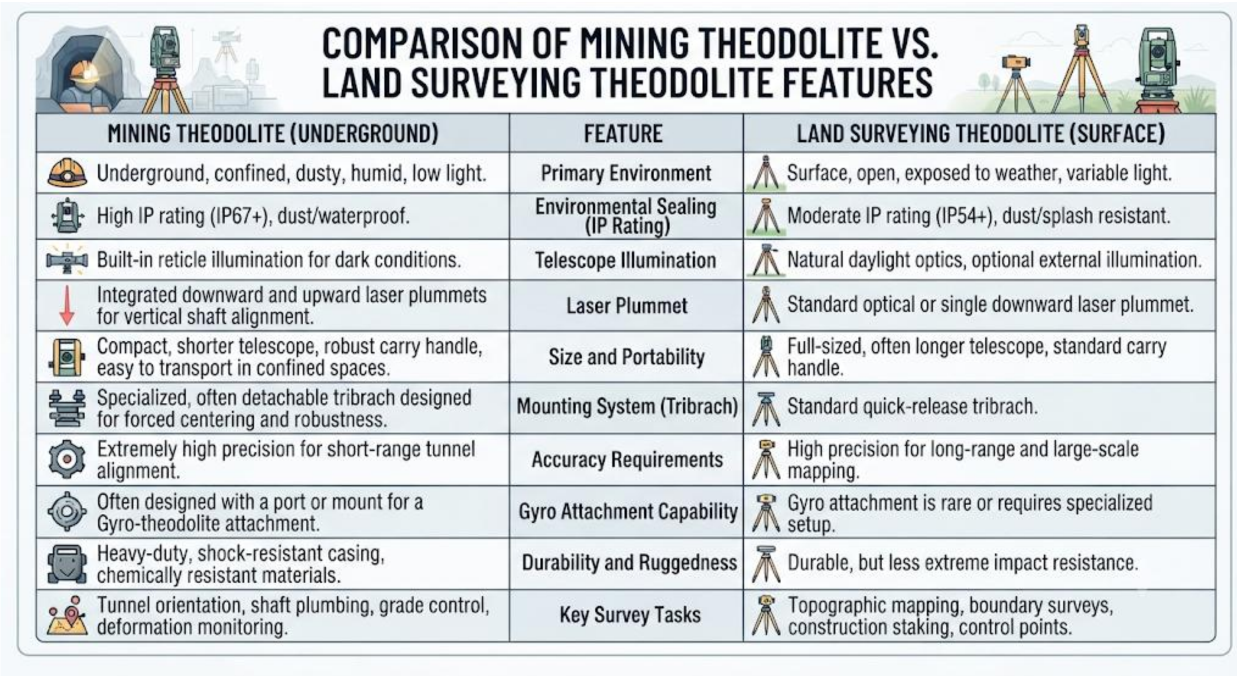
The **mining theodolite** is a specialised instrument used for measuring horizontal and vertical angles in underground mines. Unlike the standard land surveying theodolite, it is designed to function effectively in confined spaces with limited lighting. Its compact structure, reinforced casing, and adaptability to harsh underground conditions make it indispensable for underground surveying.


Diagram of a mining theodolite showing its components. *Figure 1.2: Mining theodolite and its features*

The mining theodolite differs from the land surveying theodolite because it is adapted for ______ conditions.

### 1.2.2 Comparison with land surveying theodolite

While both instruments measure angles, the mining theodolite is more robust and compact. Land surveying theodolites are typically larger, designed for open terrain, and rely on natural lighting. In contrast, mining theodolites often incorporate illumination systems and are resistant to dust, moisture, and vibrations.



COMPARISON OF MINING THEODOLITE VS. LAND SURVEYING THEODOLITE FEATURES

| MINING THEODOLITE (UNDERGROUND) | FEATURE | LAND SURVEYING THEODOLITE (SURFACE) |
|---|---|---|
| Underground, confined, dusty, humid, low light. | Primary Environment | Surface, open, exposed to weather, variable light. |
| High IP rating (IP67+), dust/waterproof. | Environmental Sealing (IP Rating) | Moderate IP rating (IP54+), dust/splash resistant. |
| Built-in reticle illumination for dark conditions. | Telescope Illumination | Natural daylight optics, optional external illumination. |
| Integrated downward and upward laser plummets for vertical shaft alignment. | Laser Plummet | Standard optical or single downward laser plummet. |
| Compact, shorter telescope, robust carry handle, easy to transport in confined spaces. | Size and Portability | Full-sized, often longer telescope, standard carry handle. |
| Specialized, often detachable tribrach designed for forced centering and robustness. | Mounting System (Tribrach) | Standard quick-release tribrach. |
| Extremely high precision for short-range tunnel alignment. | Accuracy Requirements | High precision for long-range and large-scale mapping. |
| Often designed with a port or mount for a Gyro-theodolite attachment. | Gyro Attachment Capability | Gyro attachment is rare or requires specialized setup. |
| Heavy-duty, shock-resistant casing, chemically resistant materials. | Durability and Ruggedness | Durable, but less extreme impact resistance. |
| Tunnel orientation, shaft plumbing, grade control, deformation monitoring. | Key Survey Tasks | Topographic mapping, boundary surveys, construction staking, control points. |

Comparison of mining and land surveying theodolites. *Table 1.2: Differences between mining and land surveying theodolites*

Surface surveying instruments are designed for ______ terrain, while mining theodolites are designed for ______ environments.

### 1.2.3 Basic operation and handling of equipment

Operating surveying equipment requires precision and care. The mining theodolite must be properly set up on a stable tripod, aligned with control points, and calibrated before use. Surveyors must ensure that readings are taken consistently and recorded accurately. Proper handling extends the lifespan of the instrument and ensures reliable results.

Photograph of a surveyor setting up a theodolite in a mine. *Plate 1.2: Surveyor operating a mining theodolite*

Accurate surveying depends on proper ______ and calibration of equipment.

**Pilot questions 1.2**

1. What is the primary function of a mining theodolite?
2. State two differences between mining and land surveying theodolites.
3. Why is the mining theodolite more suitable for underground conditions?
4. What precaution must be taken before operating surveying equipment?
5. Which type of theodolite is designed for open terrain?

### 1.3 Survey Control And Applications

#### 1.3.1 Establishing survey control points

**Survey control points** are fixed reference positions used to ensure accuracy and consistency in mine surveying. They serve as benchmarks from which all subsequent measurements are taken. In mining, control points are established both on the surface and underground, allowing surveyors to connect different sections of the mine with precision. These points must be carefully selected, marked, and maintained to avoid errors in mine planning.

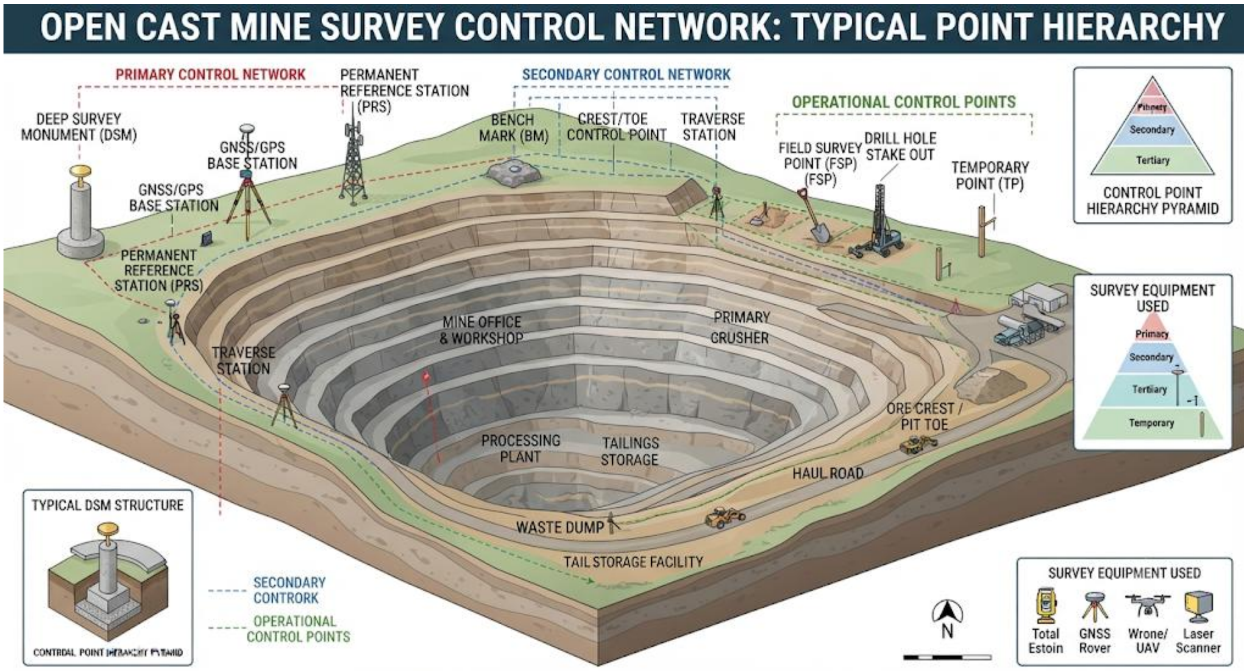
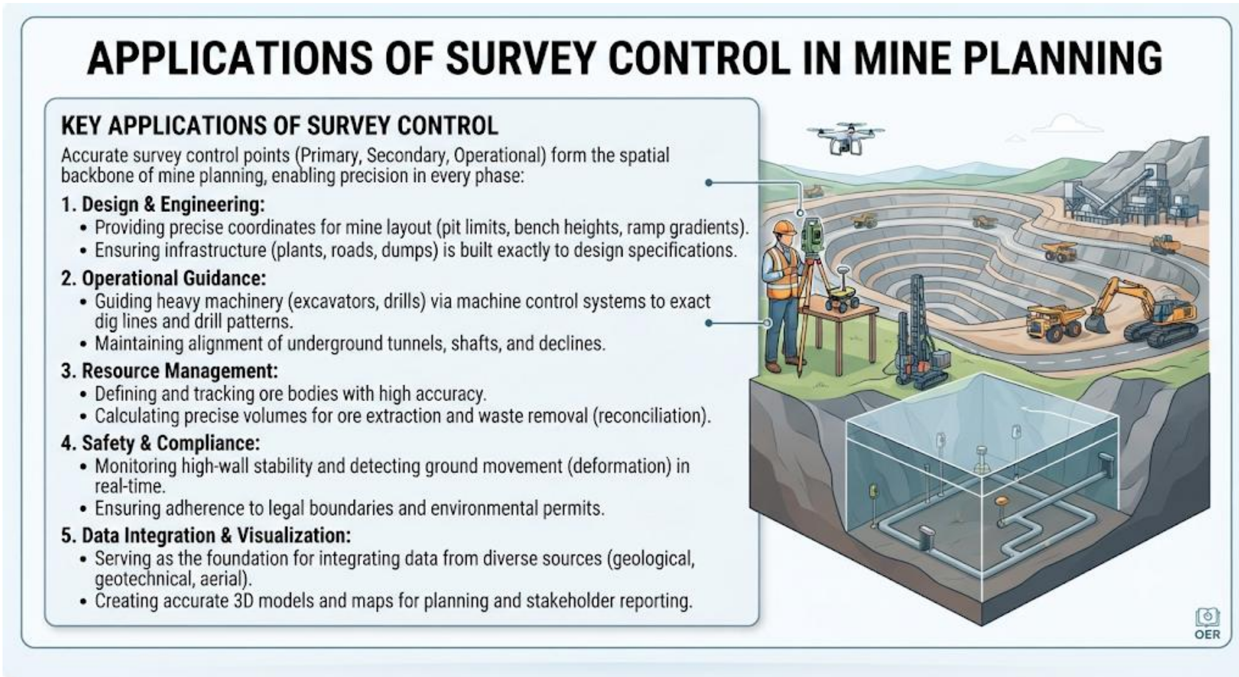



Diagram showing survey control points in an open cast mine. *Figure 1.3: Establishing survey control points*

Survey control points are important because they provide ______ for accurate measurements.

### 1.3.2 Applications in mine planning and design

Surveying data is fundamental to **mine planning**, which involves designing excavation layouts, transport routes, and drainage systems. Accurate survey control ensures that the mine design reflects the true dimensions of the deposit and supports efficient extraction. Surveying also aids in the design of shafts and tunnels, ensuring alignment with mineral deposits and minimising risks.




*Box 1.1: Applications of survey control in mine planning*

Surveying data is essential in mine planning because it ensures ______ layouts and designs.

### 1.3.3 Role of surveying in slope stability and excavation

Surveying plays a critical role in monitoring **slope stability** in open cast mines and quarries. By measuring angles of slopes and tracking deformation, surveyors can identify potential hazards and recommend corrective measures. Surveying also supports excavation by providing accurate data for drilling and blasting operations, ensuring that material is removed safely and efficiently.

Photograph of slope monitoring in an open cast mine. *Plate 1.3: Surveying for slope stability*

Slope stability monitoring is important because it helps prevent ______ in open cast mines.

**Pilot questions 1.3**

1. What are survey control points and why are they important?
2. State two applications of survey control in mine planning.
3. How does surveying support excavation operations?
4. Which aspect of mining safety is directly linked to slope stability monitoring?
5. Why must survey control points be carefully maintained?

**1.4 Data Processing And Presentation**

**1.4.1 Mathematical concepts in survey data processing**

Survey data collected in mining operations must be processed using relevant **mathematical concepts**, which are methods applied to transform raw measurements into usable information. These include trigonometric calculations for angles, coordinate geometry for positioning, and statistical methods for error adjustment. Processing ensures that data is accurate, consistent, and suitable for application in mine planning.

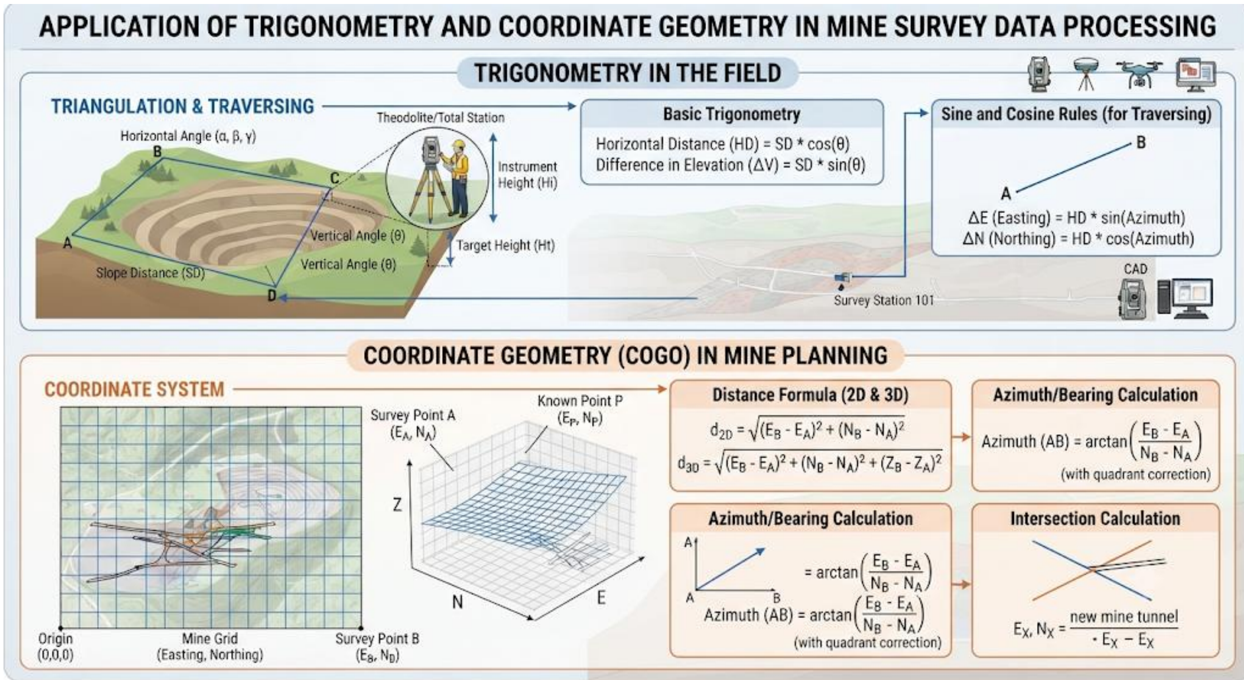
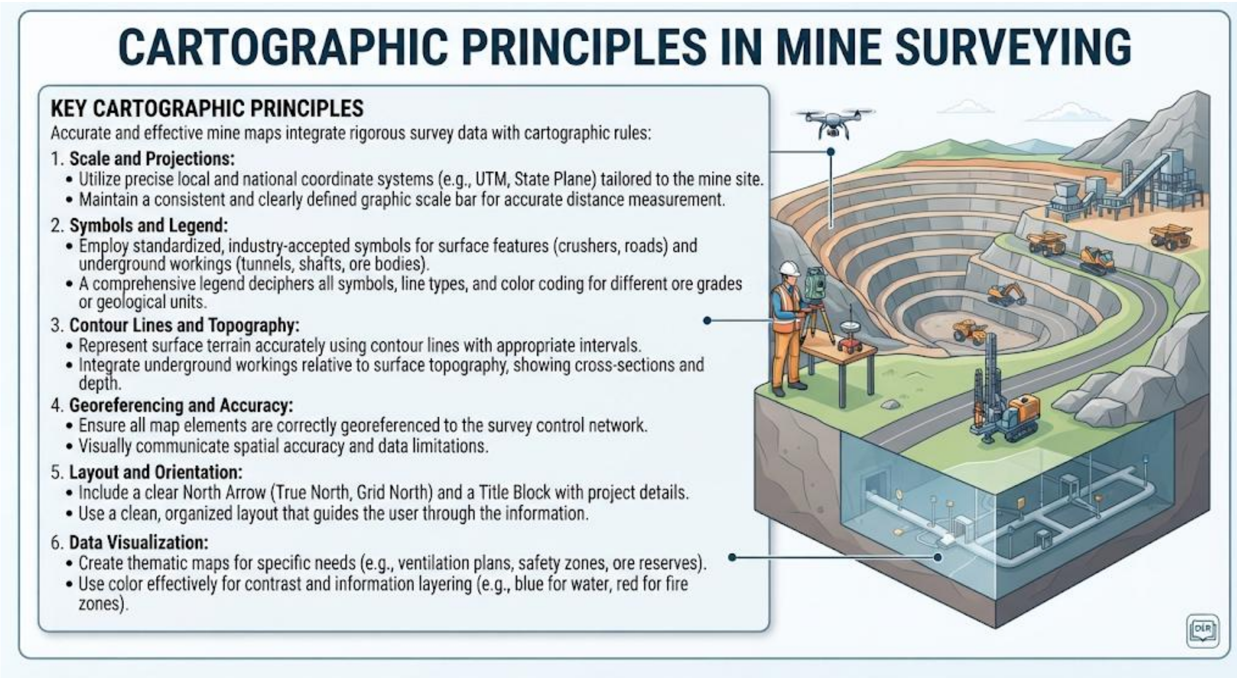



Diagram showing mathematical processing of survey data. *Figure 1.4: Mathematical concepts in survey data processing*

Accurate survey data depends on proper application of _____ concepts.

### 1.4.2 Presentation of survey results using cartographic principles

**Cartography** is the science and art of map-making. In mine surveying, cartographic principles are applied to present processed data in the form of maps, plans, and layouts. These outputs allow engineers and planners to visualise terrain, excavation sites, and underground workings. Effective presentation ensures that survey results are easily interpreted and applied in decision-making.




*Box 1.2: Cartographic principles in mine surveying*

Cartography in mine surveying is important because it transforms ______ into visual layouts.

### 1.4.3 Integration of survey data into mining layouts

Processed and presented survey data is integrated into **mining layouts**, which are three-dimensional designs of mines. These layouts guide excavation, transport, and drainage systems. Integration ensures that survey results are not just theoretical but are applied practically in mine design and operations. It also supports the use of modern tools such as Geographic Information Systems (GIS) for advanced planning.

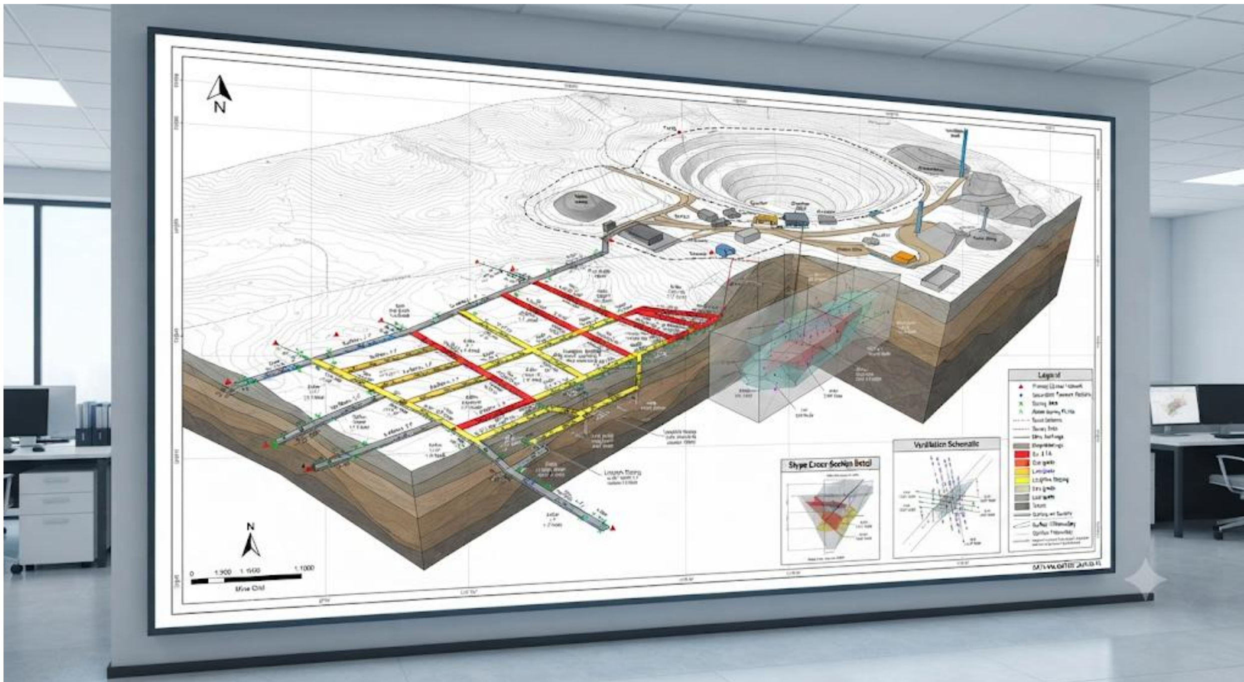



Image of a mining layout plan generated from survey data. *Plate 1.4: Mining layout based on survey data*

Mining layouts depend on the integration of ______ data into practical designs.

**Pilot questions 1.4**

1. Which mathematical concepts are commonly used in survey data processing?
2. What is cartography and why is it important in mine surveying?
3. State two cartographic principles applied in survey result presentation.
4. How does survey data integration support mining layouts?
5. Which modern tool enhances the integration of survey data into mine planning?

**Series Summary**

This Series has introduced you to the fundamentals of mine surveying, highlighting its purpose and relevance in mining operations. We began by defining mine surveying and explaining its scope, then distinguished between surface and underground surveying, before considering its importance in ensuring safe and efficient mining. Following that, we examined surveying equipment and techniques, focusing on the mining theodolite and its unique features compared with land surveying instruments. We then explored survey control and applications, showing how control points support mine planning, excavation, and slope stability. Finally, we discussed data processing and presentation, emphasising the role of mathematical concepts, cartographic principles, and integration into mining layouts.

By completing this Series, you should now be able to define mine surveying and explain its scope (SLO 1.1), differentiate between surface and underground surveying (SLO 1.2), explain the unique features of mining surveying equipment (SLO 1.3), apply surveying techniques to establish control points and support mine planning (SLO 1.4), process survey data using mathematical concepts (SLO 1.5), and present survey results effectively using cartographic principles (SLO 1.6).

**Glossary of Terms**

- **Cartography**: The science and art of map-making, used in mine surveying to present processed data visually.
- **Mine surveying**: The specialised branch of surveying concerned with measuring and mapping both surface and underground mine features.
- **Mining theodolite**: A compact and robust instrument designed for measuring angles in underground mines.
- **Survey control points**: Fixed reference positions used to ensure accuracy and consistency in mine surveying.
- **Surface surveying**: Surveying conducted on open terrain such as quarries or open cast mines.
- **Underground surveying**: Surveying conducted within mine tunnels, shafts, and chambers, often requiring specialised instruments.

**Concept Check Questions [Series 1]**

**Objective questions**

1. Mine surveying differs from land surveying because it involves both ______ and underground measurements. (Linked to SLO 1.1)
2. Which instrument is specifically adapted for underground surveying? (Linked to SLO 1.3)
3. Survey control points are important because they provide ______ for accurate measurements. (Linked to SLO 1.4)

**Short-answer questions**

4. Explain two differences between surface and underground surveying. (Linked to SLO 1.2)
5. State two cartographic principles applied in mine surveying. (Linked to SLO 1.6)

**Long-answer questions**

6. Analyse the importance of mine surveying in ensuring safety and efficiency in mining operations. (Linked to SLO 1.1, SLO 1.2, SLO 1.4)

- *Basic response*: Based on Series-only knowledge, learners should explain how surveying supports mine planning, slope stability, and excavation.
- *Value-added response*: Outstanding learners may extend the analysis by linking surveying to modern tools such as GIS and photogrammetry, and evaluating its role in long-term resource management.

**Answers to Concept Check Questions [Series 1]**

1. Surface and underground measurements.
2. Mining theodolite.
3. Benchmarks or reference positions.
4. Surface surveying is conducted on open terrain, while underground surveying is conducted in confined mine workings.
5. Use of scale, application of symbols, clear legends and orientation.
6. *Basic response*: Mine surveying ensures accurate planning, supports slope stability, and guides excavation. *Value-added response*: It also integrates with GIS and photogrammetry, enhancing resource management and long-term mine safety.

**Answers to Pilot Questions [Series 1]**

1. Mine surveying is the measurement and mapping of surface and underground mine features.
2. Surface surveying is conducted on open terrain, while underground surveying is conducted in confined mine workings.
3. It ensures accurate planning, safety, and efficient resource management.
4. Surface surveying.
5. Underground surveying.
6. To measure horizontal and vertical angles in underground mines.
7. Mining theodolite is compact and robust, land surveying theodolite is larger and designed for open terrain.
8. It is adapted for confined and harsh underground conditions.
9. Proper calibration and alignment.
10. Land surveying theodolite.
11. Fixed reference positions for accuracy.
12. Designing excavation layouts and planning transport routes.

13. By providing accurate data for drilling and blasting.
14. Slope stability.
15. To avoid errors in mine planning.
16. Trigonometry, coordinate geometry, and statistics.
17. Cartography is the science of map-making, important for presenting survey data.
18. Use of scale and symbols.
19. It guides excavation, transport, and drainage systems.
20. Geographic Information Systems (GIS).

**References and Attributions [Series 1]**

- Course document: *MNE 502: Mine Surveying*.
- Suggested OER sources:
    - "Mine surveying scope diagram OER" for Figure 1.1.
    - "Surface vs underground mine surveying OER" for Table 1.1.
    - "Mine surveyors open cast mine OER image" for Plate 1.1.
    - "Mining theodolite diagram OER" for Figure 1.2.
    - "Mining vs land surveying theodolite OER" for Table 1.2.
    - "Mine surveyor using theodolite OER image" for Plate 1.2.
    - "Mine survey control points diagram OER" for Figure 1.3.
    - "Mine planning survey applications OER" for Box 1.1.
    - "Mine slope stability surveying OER image" for Plate 1.3.
    - "Mine survey data processing mathematics OER diagram" for Figure 1.4.
    - "Cartography principles mine surveying OER" for Box 1.2.
    - "Mine layout plan survey data OER image" for Plate 1.4.

# Series 2: Surface And Open Cast Surveying

**Series outline**

- **Part 2.1 Surveying in open cast mines**
  - Building and construction of open cast deposits
  - Layout and excavation planning
- **Part 2.2 Calculations for mining operations**
  - Drilling and blasting calculations
  - Excavation and transport operations
  - Drainage considerations
- **Part 2.3 Mine survey control in slope stability**
  - Factors affecting slope stability and deformation
  - Methods of calculating slope angles
  - Monitoring and corrective measures
- **Part 2.4 Applications of survey data in quarry operations**
  - Integration of survey data into quarry design
  - Supporting safe and efficient operations

**Introduction**

Mining on the surface, particularly in open cast operations, requires careful surveying to ensure that excavation, transport, and slope stability are managed safely and efficiently. Unlike underground surveying, surface and open cast surveying deals with large exposed areas, where accurate measurements are vital for planning and controlling mining activities. This Series is designed to help you appreciate the practical applications of surveying in open cast mines and quarries, and to understand how survey data supports safe and productive operations.

The aim of this Series is to equip you with the knowledge and skills to apply surveying techniques in open cast mines, perform calculations for mining operations, monitor slope stability, and integrate survey data into quarry design.

We shall commence this Series by exploring **surveying in open cast mines**, focusing on the construction and layout of deposits. Next, we will examine **calculations for mining operations**, including drilling, blasting, excavation, transport, and drainage. Following that, we will consider **mine survey control in slope stability**, where you will learn about factors affecting slope deformation and methods of calculating slope angles. Finally, we will conclude with **applications**

**of survey data in quarry operations**, showing how survey results are integrated into design and used to support safe and efficient mining practices.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 2.1** explain the role of surveying in open cast mine construction and layout,
- **SLO 2.2** perform basic calculations for drilling, blasting, excavation, transport, and drainage operations,
- **SLO 2.3** analyse factors affecting slope stability and demonstrate methods of calculating slope angles, and
- **SLO 2.4** apply survey data to quarry design and evaluate its role in supporting safe and efficient operations.

## 2.1 Surveying In Open Cast Mines

### 2.1.1 Building and construction of open cast deposits

**Open cast mining** refers to the extraction of minerals from a large open pit or quarry on the surface. Surveying plays a crucial role in the building and construction of these deposits by providing accurate measurements of terrain, boundaries, and excavation depths. Surveyors establish reference points and align excavation plans with geological data to ensure that the deposit is mined efficiently and safely.

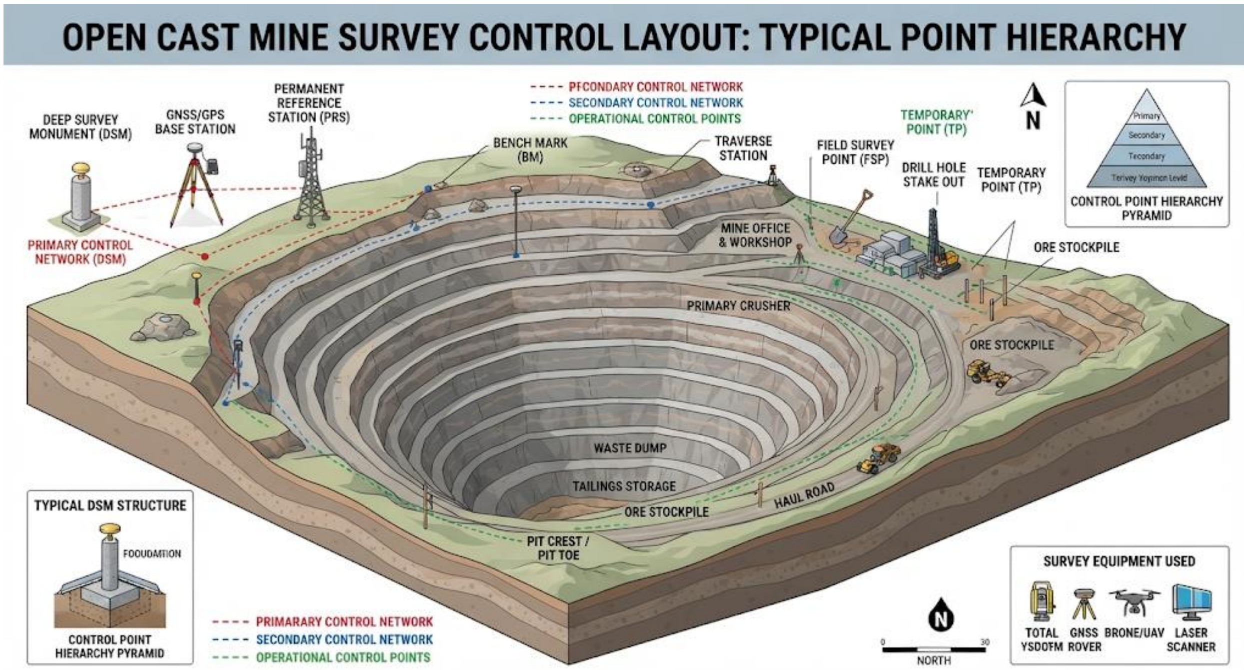
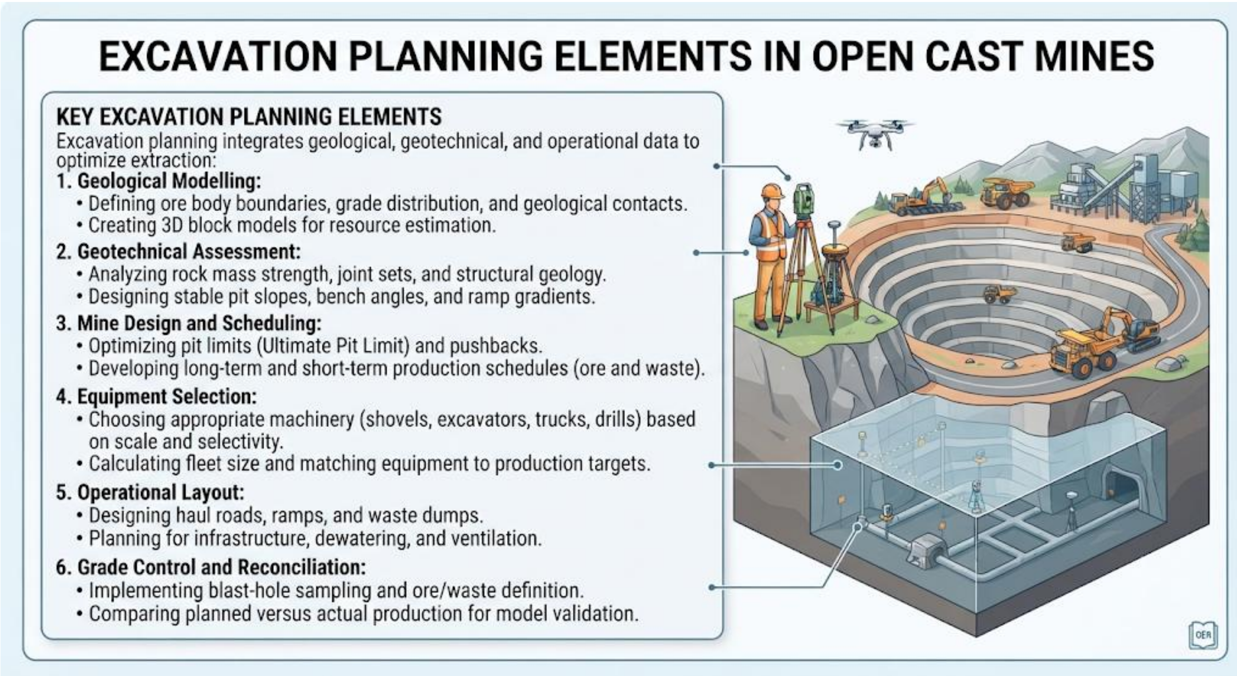



Diagram showing layout of an open cast mine with survey points. *Figure 2.1: Surveying layout in open cast mining*

Surveying in open cast mining is essential because it ensures ______ alignment of excavation with deposit boundaries.

### 2.1.2 Layout and excavation planning

Surveying data is used to design the **layout** of open cast mines, including excavation zones, haulage roads, and drainage systems. Accurate layouts prevent unnecessary removal of material and reduce operational costs. Excavation planning involves determining the depth, slope, and sequence of material removal, all of which depend on precise survey measurements.




*Box 2.1: Key elements of excavation planning in open cast mines*

Excavation planning relies on survey data to determine ______ and sequence of material removal.

**Pilot questions 2.1**

1. What is open cast mining?
2. Why is surveying important in the construction of open cast deposits?
3. State two elements of excavation planning supported by survey data.
4. How does surveying reduce operational costs in open cast mines?
5. Which aspect of excavation planning ensures proper sequencing of material removal?

## 2.2 Calculations For Mining Operations

### 2.2.1 Drilling and blasting calculations

**Drilling and blasting** are essential processes in open cast mining, used to break rock into manageable fragments. Surveying provides the measurements needed to calculate hole positions, depths, and spacing. Accurate calculations ensure efficient fragmentation, minimise waste, and reduce safety risks. Surveyors must record coordinates and angles carefully to guide drilling rigs and blasting patterns.

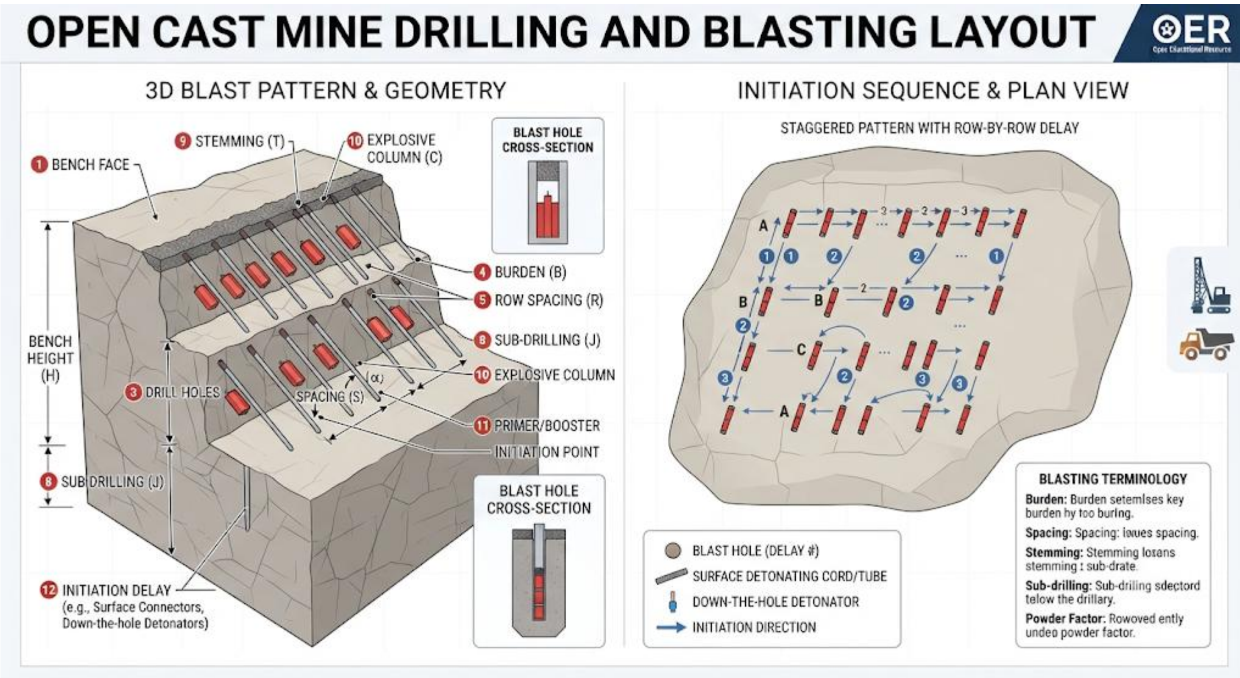


Diagram showing drilling and blasting layout in an open cast mine. *Figure 2.2: Drilling and blasting calculations*

Drilling and blasting calculations are important because they ensure ______ fragmentation of rock.

#### 2.2.2 Excavation and transport operations

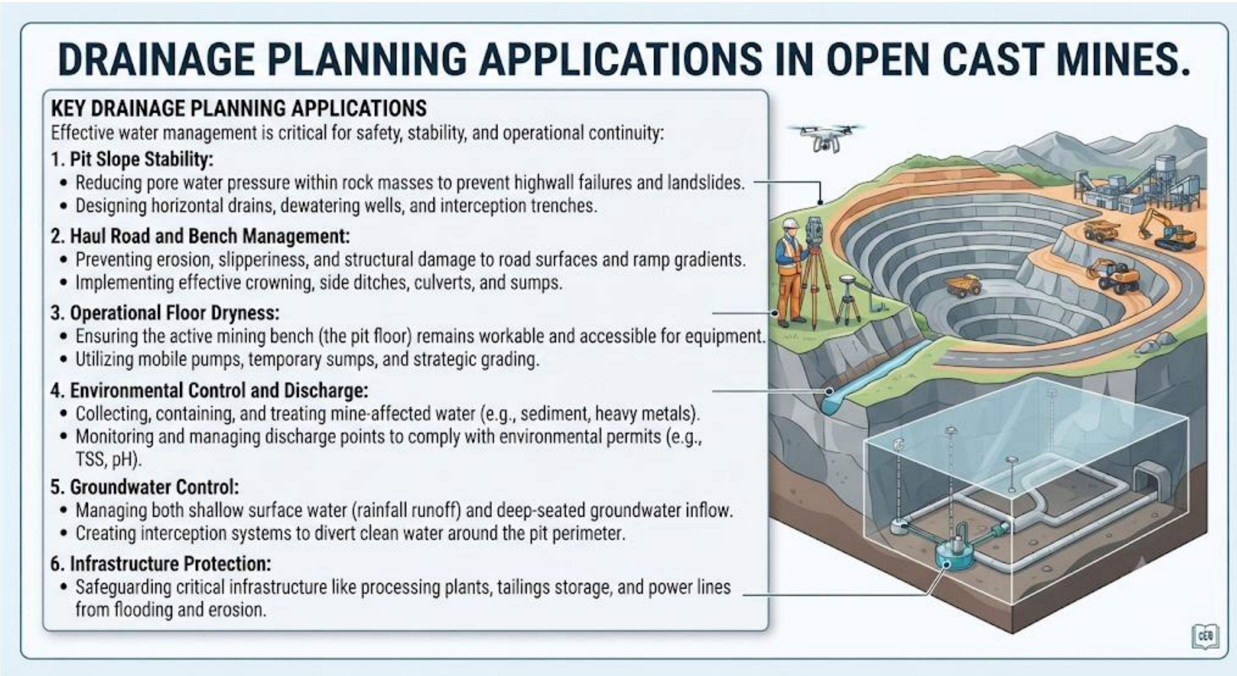
Surveying data supports **excavation operations** by determining the depth and slope of cuts, ensuring that material is removed safely and efficiently. It also guides the design of **transport routes**, such as haulage roads, which must be aligned with excavation zones and slope gradients. Proper calculations reduce fuel consumption, prevent accidents, and optimise the movement of materials.

Photograph of haulage trucks operating in an open cast mine. *Plate 2.2: Excavation and transport operations*

Excavation and transport operations depend on survey data to determine ______ and safe haulage routes.

**2.2.3 Drainage considerations**

Effective **drainage** is critical in open cast mines to prevent flooding and slope instability. Surveying helps calculate gradients and design drainage channels that direct water away from excavation zones. Proper drainage calculations reduce erosion, protect equipment, and maintain safe working conditions.




*Box 2.2: Surveying applications in drainage planning*

Drainage planning is important because it prevents ______ and slope instability in open cast mines.

**Pilot questions 2.2**

1. Why are drilling and blasting calculations important in open cast mining?
2. State two ways surveying supports excavation operations.
3. How does surveying improve transport operations in mines?
4. What role does surveying play in drainage planning?
5. Which aspect of mine safety is directly linked to effective drainage?

### 2.3 Mine Survey Control In Slope Stability

#### 2.3.1 Factors affecting slope stability and deformation

**Slope stability** refers to the ability of a slope in an open cast mine or quarry to remain intact without collapsing. Surveying helps identify factors that affect stability, such as geological structure, water infiltration, excavation depth, and blasting vibrations. Deformation occurs when slopes shift or move due to these influences, and surveyors must monitor such changes to prevent hazards.

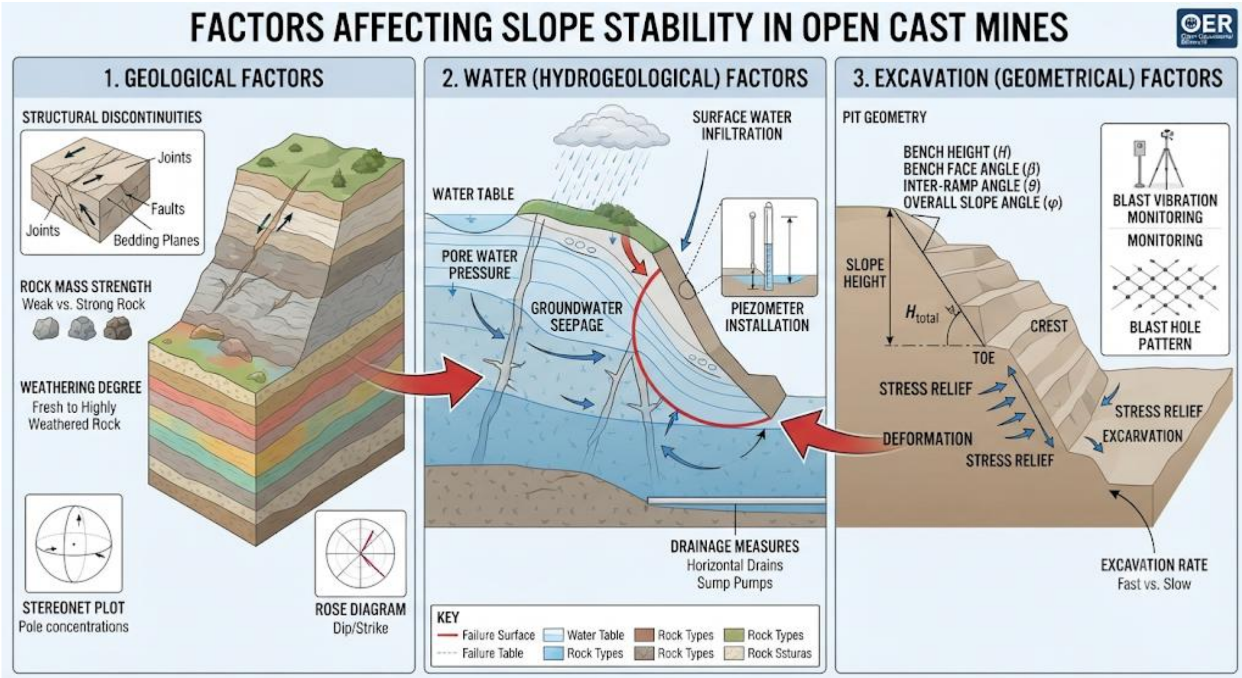



Diagram showing factors affecting slope stability in open cast mines. *Figure 2.3: Factors influencing slope stability*

Slope stability is influenced by factors such as ______, water infiltration, and blasting vibrations.

### 2.3.2 Methods of calculating slope angles

Surveyors use **trigonometric methods** and field measurements to calculate slope angles. These calculations determine whether a slope is safe or requires reinforcement. The angle of repose, which is the steepest angle at which material remains stable, is a key parameter. Accurate slope angle calculations help prevent landslides and ensure safe excavation.

**COMPARISON OF TRIGONOMETRIC VS. FIELD MEASUREMENT METHODS FOR SLOPE ANGLE CALCULATION**

| FEATURE | TRIGONOMETRIC METHOD (INDIRECT) | FIELD MEASUREMENT METHOD (DIRECT) |
|---|---|---|
| Primary Principle | Based on the geometric relationships (sine, cosine, tangent) of a right-angled triangle formed by the slope. | Direct physical measurement of angles using specialized instruments. |
| Required Inputs | Vertical rise (opposite side) and horizontal distance (adjacent side) OR slope distance and an angle. | Physical placement of the measuring device directly on or parallel to the slope surface. |
| Key Instruments | Total Station, Theodolite, or GNSS/GPS (for distances/elevations); Calculator. | Abney Level, Clinometer, Inclinometer, Brunton Compass, Slope Meter. |
| Accuracy and Precision | High precision possible, but accuracy depends on the precision of distance and angle inputs. Errors can accumulate. | Can be very accurate if used correctly; less prone to cumulative error, but precision can be limited by the instrument's resolution. |
| Ease of Use (in Field) | Requires multiple measurements, setup, and calculations. Can be time-consuming. | Quick and straightforward. Often requires only one person and one reading. |
| Environmental Suitability | Challenging in dense vegetation or terrain with limited line of sight. | Can be used in almost any environment, including dense brush or confined spaces. |
| Safety (e.g., on Steep/Unstable Slopes) | Safer; measurements can be taken from a stable distance. | May require the surveyor to be on the unstable slope, increasing risk. |
| Applications | Large-scale topographic mapping, engineering surveys, long profiles. | Quick checks, geological fieldwork, forestry, specific point measurements, temporary works. |
| Cost of Equipment | High (Total Stations, GNSS). | Low to Moderate (Clinometers, Compasses). |
| Data Processing | Significant post-processing and calculation required. | Data is immediately available as an angle reading. |

Comparison of slope angle calculation methods. *Table 2.3: Methods of calculating slope angles*

The angle of repose is defined as the steepest angle at which ______ remains stable.

### 2.3.3 Monitoring and corrective measures

Surveying provides continuous monitoring of slopes to detect early signs of instability. Techniques include periodic angle measurements, deformation mapping, and use of control points. Corrective measures may involve drainage improvements, slope reinforcement, or adjusting excavation methods. By applying survey data, engineers can design safer slopes and reduce risks of collapse.

Photograph of slope monitoring equipment in a quarry. *Plate 2.3: Monitoring slope stability in quarry operations*

Monitoring slopes is important because it helps detect ______ signs of instability.

**Pilot questions 2.3**

1. What is slope stability in mining?
2. State two factors that affect slope stability.
3. What is the angle of repose?
4. Why are slope angle calculations important in open cast mines?
5. Mention one corrective measure used to improve slope stability.

### 2.4 Applications Of Survey Data In Quarry Operations

#### 2.4.1 Integration of survey data into quarry design

Surveying provides the essential measurements required to design quarries. **Quarry design** refers to the planned arrangement of excavation zones, haulage routes, and drainage systems. By integrating survey data, engineers can ensure that the design reflects the actual terrain and geological conditions. This integration reduces waste, improves efficiency, and enhances safety.

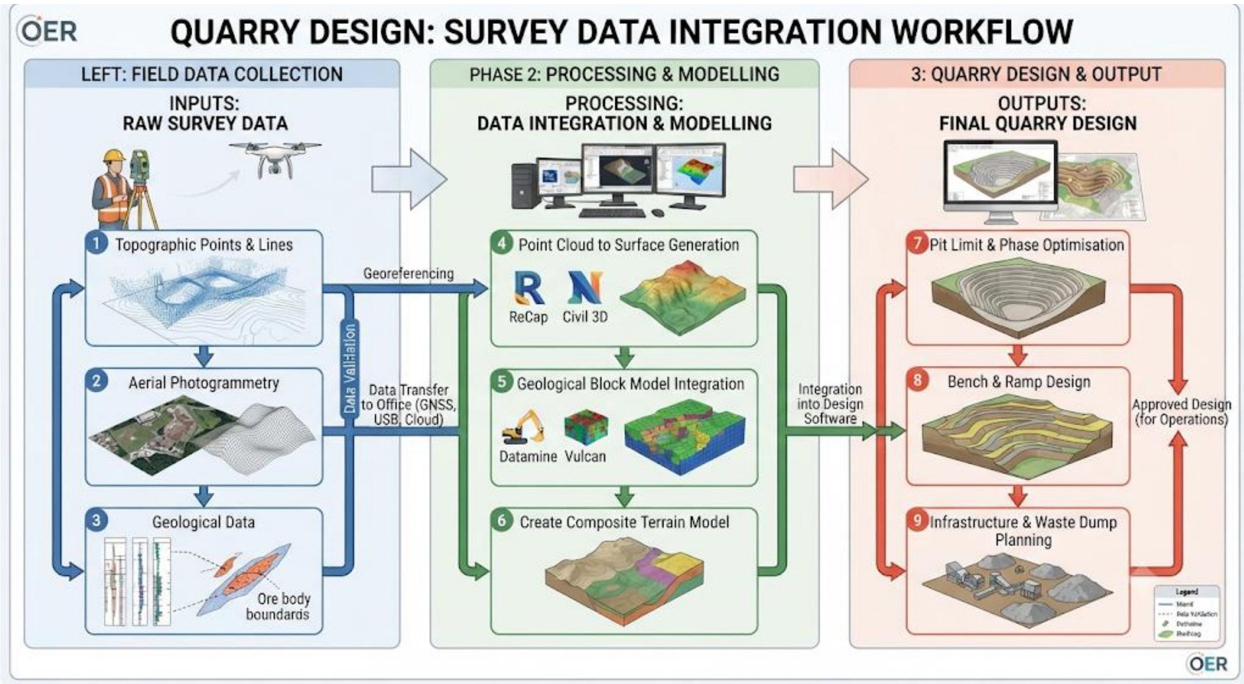



Diagram showing integration of survey data into quarry design. *Figure 2.4: Integration of survey data into quarry design*

Quarry design depends on survey data because it ensures ______ alignment with terrain and geological conditions.

### 2.4.2 Supporting safe and efficient operations

Survey data supports safe and efficient quarry operations by guiding excavation, monitoring slope stability, and planning transport routes. It also helps in identifying hazards such as weak rock zones or water infiltration. By applying survey results, quarry managers can make informed decisions that protect workers and equipment while maximising productivity.

Photograph of quarry operations guided by survey data. *Plate 2.4: Survey data supporting quarry operations*

Survey data supports quarry operations because it helps identify ______ and ensures safe excavation.

**Pilot questions 2.4**

1. What is quarry design and why is survey data important in it?
2. State two ways survey data supports safe quarry operations.
3. How does survey data improve efficiency in quarry design?
4. Which hazards can survey data help identify in quarries?
5. Why is survey data essential for planning transport routes in quarry operations?

**Series Summary**

This Series has focused on the practical aspects of surface and open cast surveying, showing how survey data underpins safe and efficient mining operations. We began by examining surveying in open cast mines, where accurate measurements guide the construction of deposits and excavation layouts. We then explored calculations for mining operations, including drilling, blasting, excavation, transport, and drainage planning. Following that, we considered mine survey control in slope stability, highlighting factors that influence deformation, methods of calculating slope angles, and monitoring techniques. Finally, we looked at applications of survey data in quarry operations, demonstrating how integration into design supports safety and productivity.

By completing this Series, you should now be able to explain the role of surveying in open cast mine construction and layout (SLO 2.1), perform basic calculations for mining operations (SLO 2.2), analyse slope stability factors and calculate slope angles (SLO 2.3), and apply survey data to quarry design while evaluating its role in safe and efficient operations (SLO 2.4).

**Glossary of Terms**

- **Angle of repose**: The steepest angle at which material remains stable without sliding.
- **Drainage**: The system of channels designed to remove water from excavation zones.
- **Excavation planning**: The process of designing depth, slope, and sequence of material removal in open cast mines.
- **Open cast mining**: The extraction of minerals from a large open pit or quarry on the surface.
- **Quarry design**: The planned arrangement of excavation zones, haulage routes, and drainage systems in a quarry.
- **Slope stability**: The ability of a slope to remain intact without collapsing.
- **Survey control points**: Fixed reference positions used to ensure accuracy in surveying measurements.

**Concept Check Questions [Series 2]**

**Objective questions**

1. Open cast mining refers to the extraction of minerals from a ______. (Linked to SLO 2.1)
2. Drilling and blasting calculations are important because they ensure ______ fragmentation of rock. (Linked to SLO 2.2)
3. The angle of repose is defined as the steepest angle at which ______ remains stable. (Linked to SLO 2.3)

**Short-answer questions**

4. State two elements of excavation planning supported by survey data. (Linked to SLO 2.1)
5. Mention two hazards that survey data can help identify in quarry operations. (Linked to SLO 2.4)

**Long-answer questions**

6. Analyse the importance of survey data in slope stability monitoring and corrective measures. (Linked to SLO 2.3)

- *Basic response*: Learners should explain how survey data helps calculate slope angles, monitor deformation, and guide corrective measures.
- *Value-added response*: Outstanding learners may extend the analysis by linking slope stability monitoring to modern technologies such as GIS, drones, and remote sensing.

**Answers to Concept Check Questions [Series 2]**

1. Large open pit or quarry.
2. Efficient fragmentation.
3. Material.
4. Excavation depth and haulage road design.
5. Weak rock zones and water infiltration.
6. *Basic response*: Survey data ensures slope angles are calculated accurately, deformation is monitored, and corrective measures such as drainage or reinforcement are applied. *Value-added response*: Modern technologies like GIS, drones, and remote sensing enhance slope monitoring and provide real-time data for proactive safety management.

**Answers to Pilot Questions [Series 2]**

1. Extraction of minerals from a large open pit or quarry.
2. It ensures accurate alignment of excavation with deposit boundaries.
3. Excavation depth and drainage planning.
4. By preventing unnecessary removal of material and reducing costs.
5. Sequencing of material removal.
6. They ensure efficient fragmentation and reduce safety risks.
7. By determining excavation depth and slope.
8. By aligning haulage roads with excavation zones and gradients.
9. It helps calculate gradients and design drainage channels.
10. Slope stability.
11. The ability of a slope to remain intact without collapsing.
12. Geological structure and water infiltration.
13. The steepest angle at which material remains stable.
14. They prevent landslides and ensure safe excavation.

15. Drainage improvements or slope reinforcement.
16. Quarry design is the planned arrangement of excavation zones, haulage routes, and drainage systems; survey data ensures alignment with terrain.
17. By guiding excavation and monitoring slope stability.
18. It reduces waste and improves efficiency.
19. Weak rock zones and water infiltration.
20. Because it ensures safe and efficient movement of materials.

**References and Attributions [Series 2]**

- Course document: *MNE 502: Mine Surveying*.
- Suggested OER sources:
    - "Open cast mine survey layout diagram OER" for Figure 2.1.
    - "Excavation planning open cast mine OER" for Box 2.1.
    - "Open cast mine drilling blasting diagram OER" for Figure 2.2.
    - "Open cast mine haulage trucks OER image" for Plate 2.2.
    - "Mine drainage planning survey OER" for Box 2.2.
    - "Slope stability factors open cast mine OER diagram" for Figure 2.3.
    - "Slope angle calculation methods OER table" for Table 2.3.
    - "Quarry slope monitoring equipment OER image" for Plate 2.3.
    - "Quarry design survey data integration OER diagram" for Figure 2.4.
    - "Quarry operations survey data OER image" for Plate 2.4.

# Series 3: Underground Mine Surveying

**Series outline**

- **Part 3.1 Surveying in underground mine workings**
    - Shaft construction and alignment
    - Tunnel and chamber surveying

- Mineral contact mapping

- **Part 3.2 Instruments and techniques for underground surveying**
  - Specialised instruments for confined spaces
  - Illumination and visibility adaptations
  - Handling and calibration in underground conditions
- **Part 3.3 Survey control and displacement monitoring**
  - Establishing underground control points
  - Monitoring rock displacement and deformation
  - Safety implications of displacement data
- **Part 3.4 Applications of underground survey data**
  - Integration into mine design and planning
  - Supporting drilling and blasting operations
  - Ensuring safety in underground excavation

**Introduction**

Underground mine surveying is one of the most specialised aspects of surveying in mining engineering. Unlike surface or open cast operations, underground surveying takes place in confined, poorly lit, and often complex environments where accuracy is critical for safety and productivity. This Series introduces you to the principles, instruments, and applications of underground mine surveying, preparing you to understand how survey data supports the design, monitoring, and safe operation of underground mines.

The aim of this Series is to equip you with the knowledge and skills to conduct surveys in underground workings, operate specialised instruments, establish control points, monitor displacement, and apply survey data to mine design and excavation.

We shall commence this Series by exploring **surveying in underground mine workings**, focusing on shafts, tunnels, chambers, and mineral contact mapping. Next, we will examine **instruments and techniques for underground surveying**, highlighting adaptations for confined spaces and visibility challenges. Following that, we will consider **survey control and displacement monitoring**, where you will learn how to establish underground control points and track rock movement. Finally, we will conclude with **applications of underground survey data**, showing how processed results are integrated into mine design, drilling, blasting, and safety management.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 3.1** explain the role of surveying in underground mine workings, including shafts, tunnels, and chambers,
- **SLO 3.2** describe specialised instruments and techniques used in underground surveying,
- **SLO 3.3** establish underground survey control points and analyse displacement data, and
- **SLO 3.4** apply underground survey data to mine design, drilling, blasting, and safety operations.

### 3.1 Surveying In Underground Mine Workings

#### 3.1.1 Shaft construction and alignment

**Shaft construction** in underground mines involves sinking vertical or inclined passages to access mineral deposits. Surveying ensures shafts are aligned correctly with surface control points and geological targets. Accurate alignment prevents costly deviations and supports safe transport of materials and personnel. Surveyors use specialised instruments to measure angles and depths, maintaining precision throughout construction.

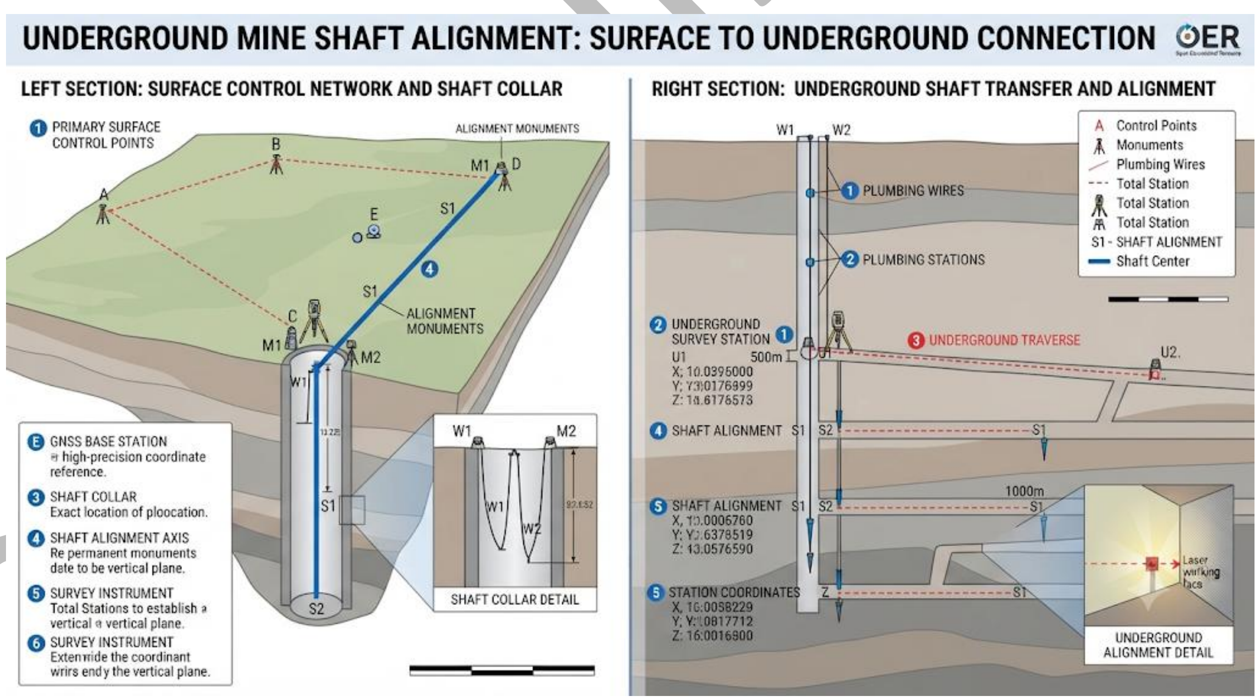



Diagram showing shaft alignment with surface control points. *Figure 3.1: Shaft construction and alignment in underground mines*

Shaft construction requires surveying to ensure ______ alignment with geological targets.

### 3.1.2 Tunnel and chamber surveying

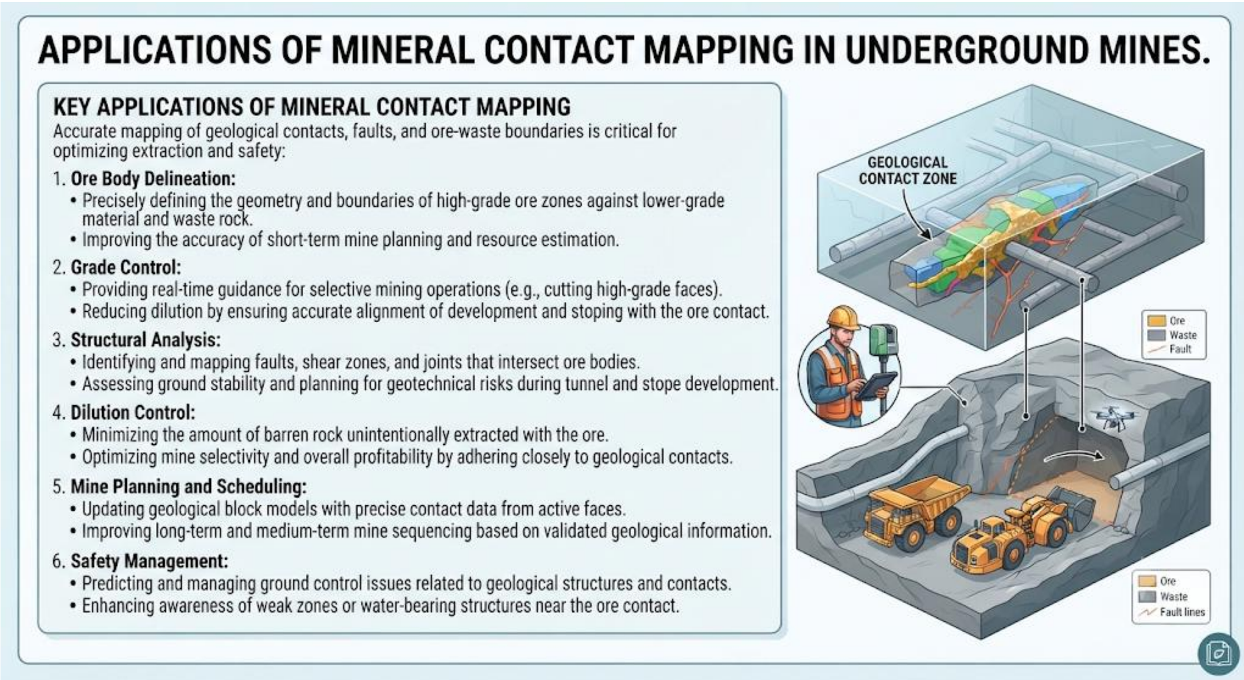
**Tunnel surveying** involves measuring and mapping horizontal passages, while **chamber surveying** focuses on larger underground spaces used for mineral extraction. Surveyors establish control points, measure angles, and record distances to ensure tunnels and chambers follow planned layouts. This prevents structural weaknesses and ensures efficient access to mineral deposits.

Photograph of surveyors working in an underground tunnel. *Plate 3.1: Tunnel surveying in underground mines*

Tunnel surveying is important because it ensures ______ layouts and prevents structural weaknesses.

### 3.1.3 Mineral contact mapping

**Mineral contact mapping** is the process of identifying and recording the boundaries between ore and surrounding rock. Surveyors use measurements and geological observations to map these contacts accurately. This information guides excavation, ensuring that valuable ore is extracted efficiently while minimising waste.



*Box 3.1: Applications of mineral contact mapping*

Mineral contact mapping is essential because it helps identify ______ between ore and surrounding rock.

**Pilot questions 3.1**

1. What is shaft construction in underground mining?
2. Why is surveying important in shaft alignment?
3. State two purposes of tunnel and chamber surveying.
4. What is mineral contact mapping?
5. How does mineral contact mapping support reserve estimation?

## 3.2 Instruments And Techniques For Underground Surveying

### 3.2.1 Specialised instruments for confined spaces

Underground surveying requires **specialised instruments**, which are tools adapted to function in confined and poorly lit environments. Examples include compact mining theodolites, short-base distance meters, and portable laser scanners. These instruments are designed to withstand dust, moisture, and vibrations while maintaining accuracy. Their portability ensures surveyors can manoeuvre easily within narrow tunnels and chambers.

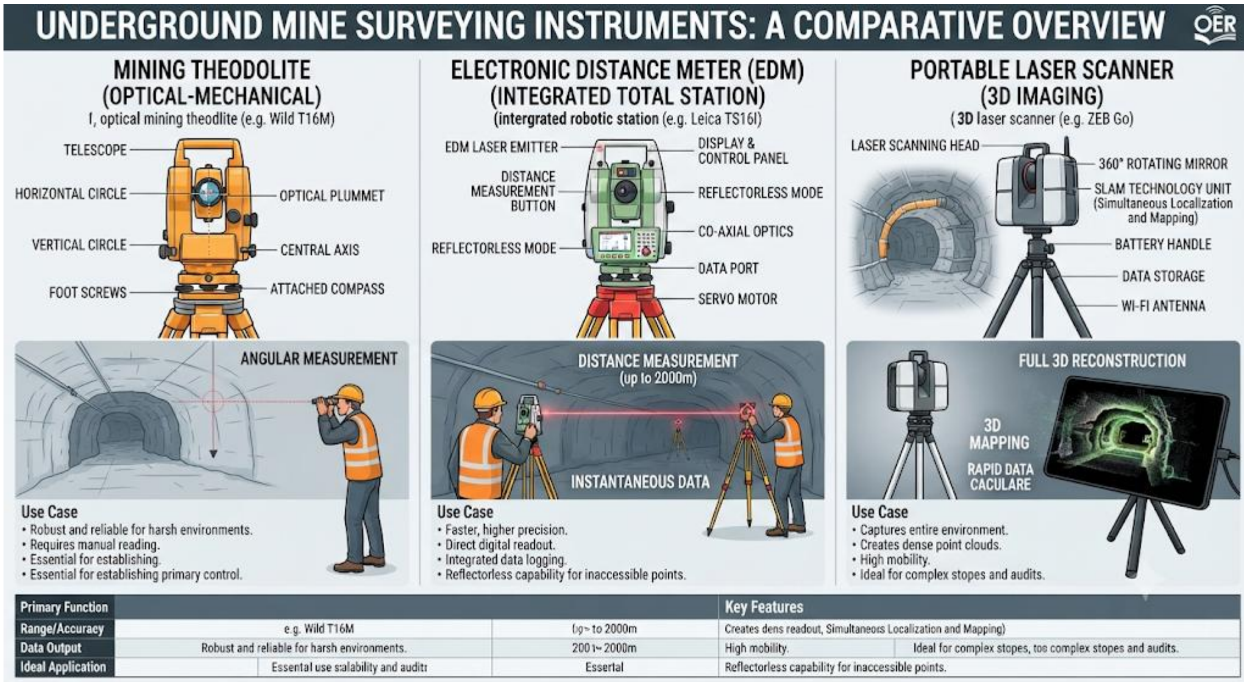



Diagram showing specialised instruments used in underground surveying. *Figure 3.2: Specialised instruments for confined spaces*

Specialised instruments are important because they are adapted to ______ environments with limited space and lighting.

### 3.2.2 Illumination and visibility adaptations

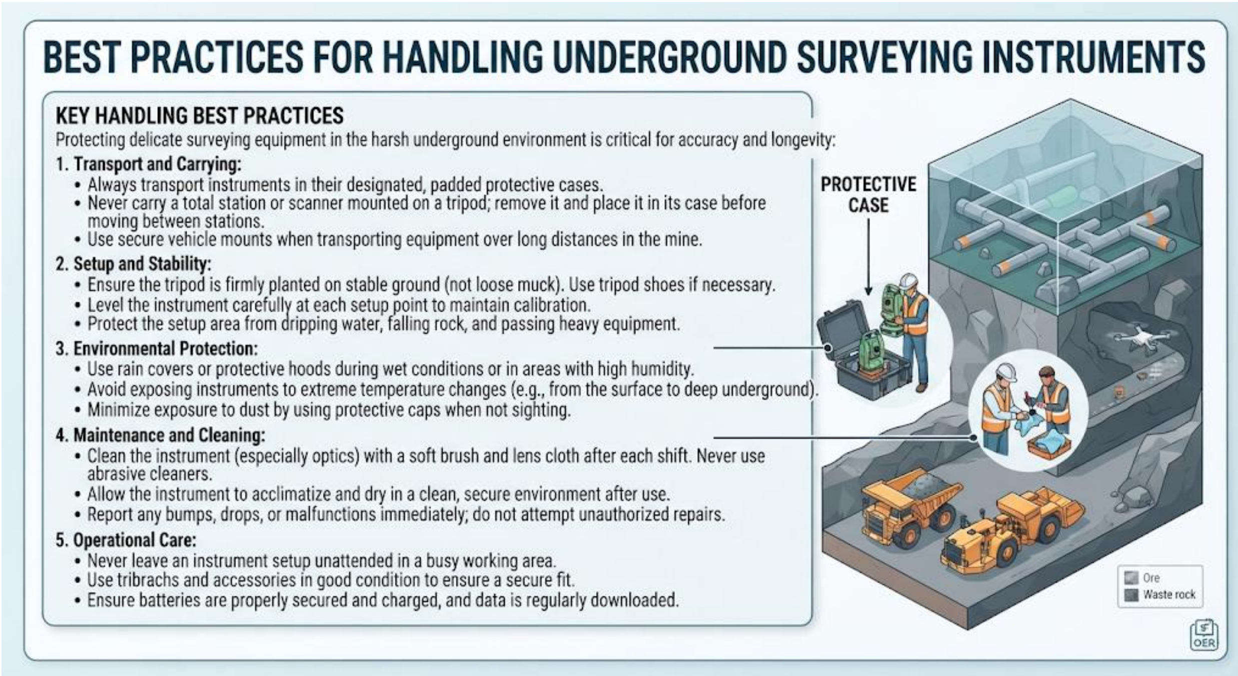
Since underground mines often lack natural light, survey instruments are fitted with **illumination systems** such as built-in lamps or reflective targets. These adaptations improve visibility and allow surveyors to take accurate readings even in dark conditions. Reflective prisms and illuminated reticles are commonly used to enhance precision.

Photograph of a surveyor using illuminated equipment underground. *Plate 3.2: Illumination adaptations in underground surveying*

Illumination systems in underground surveying are necessary because they improve ______ in dark conditions.

### 3.2.3 Handling and calibration in underground conditions

Survey instruments must be handled carefully and calibrated regularly to maintain accuracy. Underground conditions such as vibration, moisture, and restricted movement can affect readings. Surveyors must stabilise tripods, protect instruments from dust, and check calibration before each use. Proper handling ensures reliable data and extends the lifespan of equipment.




*Box 3.2: Best practices for handling underground surveying instruments*

Calibration of instruments is important because it ensures ______ accuracy in underground conditions.

**Pilot questions 3.2**

1. Why are specialised instruments necessary for underground surveying?
2. State two illumination adaptations used in underground surveying.
3. What challenges affect instrument accuracy underground?
4. Mention two best practices for handling underground surveying instruments.
5. Why is calibration essential in underground surveying?

### 3.3 Survey Control And Displacement Monitoring

#### 3.3.1 Establishing underground control points

**Survey control points** in underground mines are fixed reference markers used to maintain accuracy in measurements. They connect underground workings to surface control networks, ensuring consistency across the mine. Control points are carefully placed in stable areas of tunnels or chambers, marked permanently, and checked regularly to avoid errors.

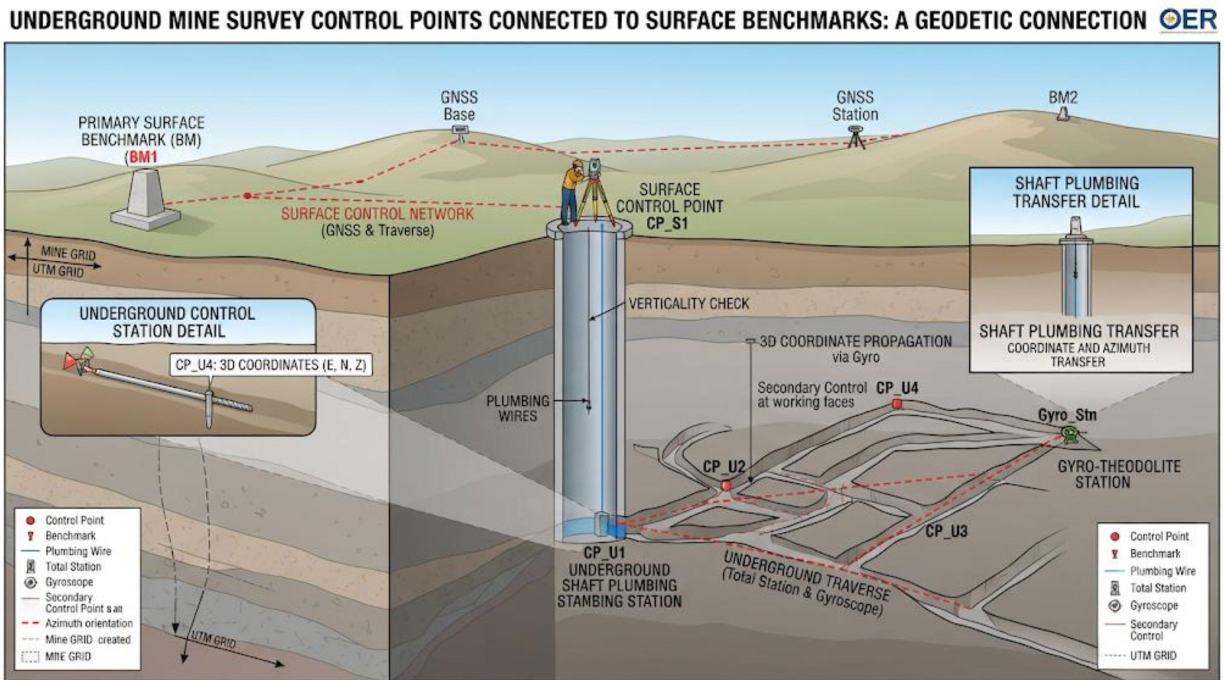



Diagram showing underground control points linked to surface benchmarks. *Figure 3.3: Establishing underground survey control points*

Underground control points are important because they provide ______ for accurate measurements and alignment.

### 3.3.2 Monitoring rock displacement and deformation

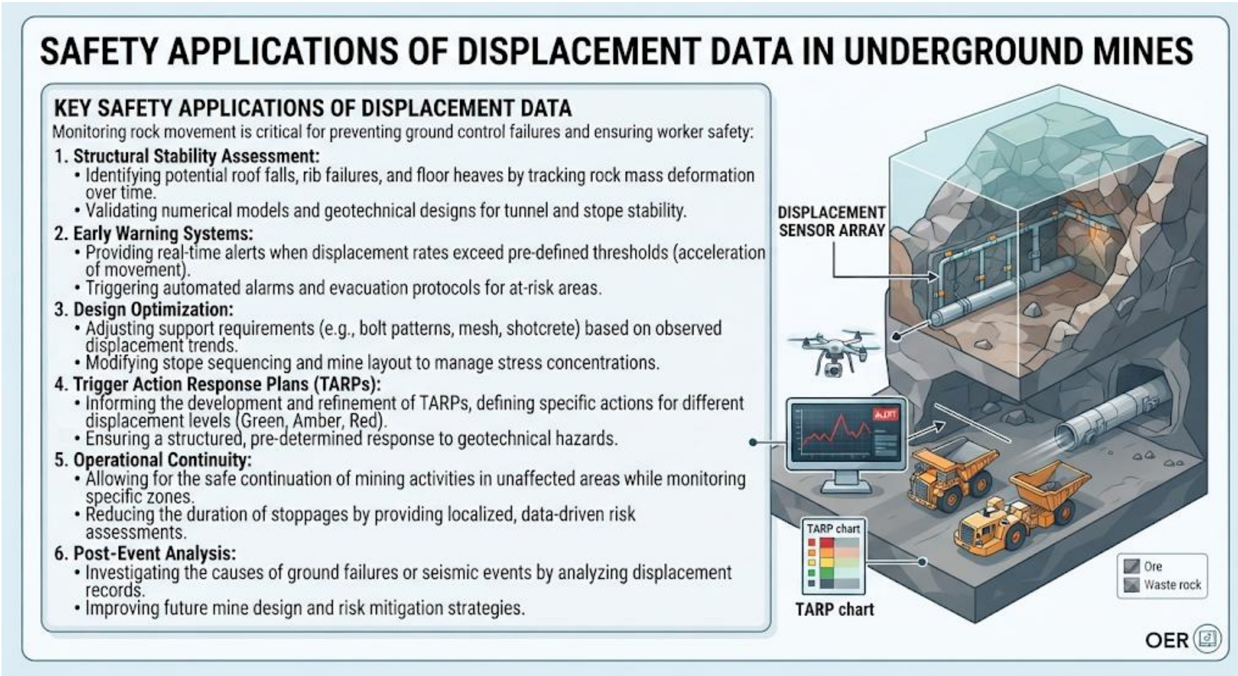
**Rock displacement monitoring** involves measuring shifts or movements in underground structures. Surveyors use control points, laser scanning, and deformation mapping to detect changes. Monitoring deformation helps identify risks such as roof falls, wall collapses, or subsidence. Accurate displacement data allows engineers to take preventive measures before hazards occur.

Photograph of surveyors monitoring rock displacement underground. *Plate 3.3: Monitoring rock displacement in underground mines*

Monitoring rock displacement is essential because it helps detect ______ risks in underground mines.

### 3.3.3 Safety implications of displacement data

Survey data on displacement has direct **safety implications**. It informs engineers about unstable zones, supports reinforcement decisions, and guides excavation methods. By analysing displacement data, mines can reduce accidents, protect workers, and maintain structural integrity. Safety management in underground mines relies heavily on accurate and timely survey information.




*Box 3.3: Safety applications of displacement data*

Displacement data is critical for safety because it helps identify _____ zones and guide reinforcement.

**Pilot questions 3.3**

1. What are underground survey control points?
2. Why are control points important in underground surveying?
3. What is rock displacement monitoring?
4. State two safety implications of displacement data.
5. How does monitoring deformation prevent accidents in underground mines?

### 3.4 Applications Of Underground Survey Data

#### 3.4.1 Integration into mine design and planning

Survey data collected underground is integrated into **mine design**, ensuring that shafts, tunnels, and chambers align with geological structures and mineral deposits. Accurate integration reduces waste, improves efficiency, and supports long-term planning. It also helps engineers visualise underground layouts and make informed decisions about excavation methods.

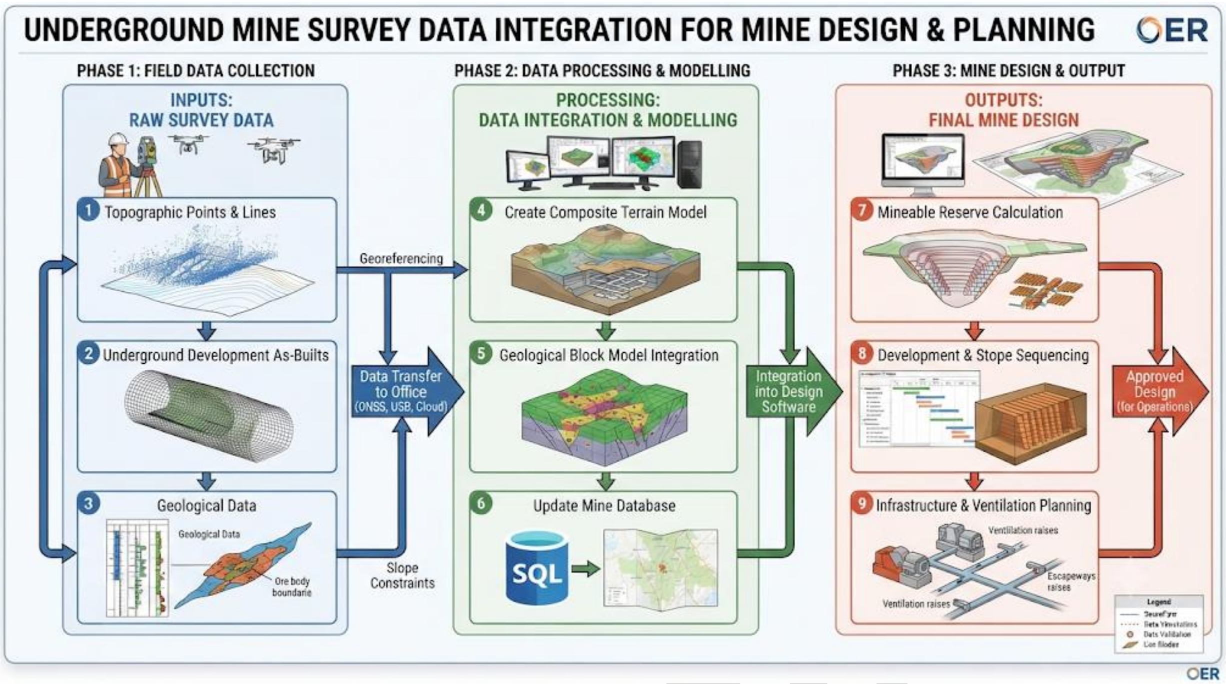



Diagram showing integration of underground survey data into mine design. *Figure 3.4: Integration of survey data into mine design*

Mine design depends on survey data because it ensures ______ alignment with geological structures and deposits.

### 3.4.2 Supporting drilling and blasting operations

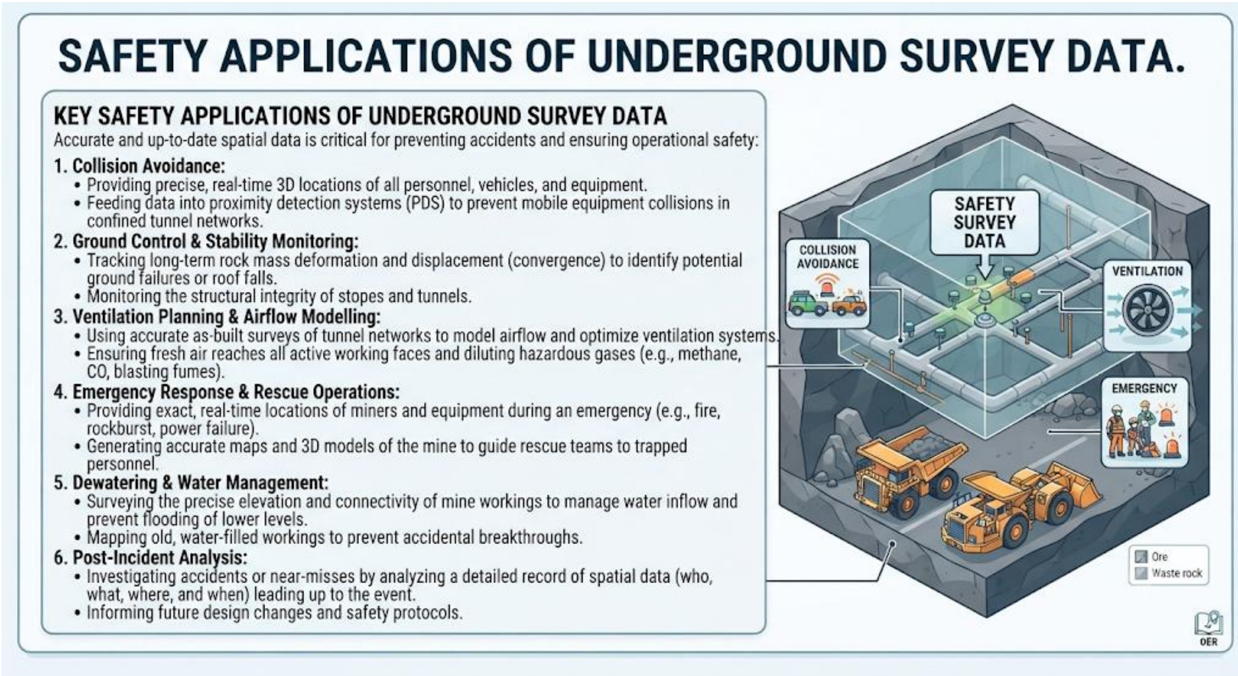
Survey data guides **drilling and blasting** by providing accurate coordinates, angles, and depths. This ensures that holes are drilled in the correct positions and blasting patterns achieve efficient fragmentation. Proper application of survey data reduces risks of overbreak, minimises waste, and enhances safety in confined underground spaces.

Photograph of drilling operations in an underground mine. *Plate 3.4: Survey data supporting drilling operations*

Survey data supports drilling and blasting because it ensures ______ positioning and efficient fragmentation.

### 3.4.3 Ensuring safety in underground excavation

Safety in underground mines relies heavily on survey data. By monitoring displacement, mapping mineral contacts, and guiding excavation layouts, surveyors help prevent collapses and accidents. Survey data also supports ventilation planning and hazard identification, making underground operations safer for workers.



*Box 3.4: Safety applications of underground survey data*

Survey data enhances safety because it helps identify ______ and supports safe excavation layouts.

**Pilot questions 3.4**

1. Why is survey data important in mine design and planning?
2. How does survey data support drilling and blasting operations?
3. State two safety applications of underground survey data.
4. What role does survey data play in ventilation planning?
5. How does survey data reduce risks in underground excavation?

**Series Summary**

This Series has explored the specialised field of underground mine surveying, emphasising its role in ensuring accuracy, safety, and efficiency in confined mining environments. We began with surveying in underground workings, focusing on shafts, tunnels, chambers, and mineral contact mapping. We then examined instruments and techniques adapted for underground conditions, including specialised tools, illumination systems, and calibration practices. Following that, we studied survey control and displacement monitoring, highlighting the establishment of underground control points, monitoring rock movement, and the safety implications of displacement data. Finally, we considered applications of underground survey data, showing how it supports mine design, drilling, blasting, and safe excavation.

By completing this Series, you should now be able to explain the role of surveying in underground mine workings (SLO 3.1), describe specialised instruments and techniques (SLO 3.2), establish control points and analyse displacement data (SLO 3.3), and apply survey results to mine design, drilling, blasting, and safety operations (SLO 3.4).

**Glossary of Terms**

- **Chamber surveying**: Measuring and mapping larger underground spaces used for mineral extraction.
- **Mineral contact mapping**: Identifying and recording boundaries between ore and surrounding rock.
- **Rock displacement monitoring**: Measuring shifts or movements in underground structures to detect instability.
- **Shaft construction**: Sinking vertical or inclined passages to access underground mineral deposits.
- **Survey control points**: Fixed reference markers used to maintain accuracy in underground measurements.
- **Tunnel surveying**: Measuring and mapping horizontal underground passages.

**Concept Check Questions [Series 3]**

**Objective questions**

1. Shaft construction in underground mines involves sinking ______ passages to access deposits. (Linked to SLO 3.1)
2. Specialised instruments are necessary in underground surveying because they are adapted to ______ environments. (Linked to SLO 3.2)
3. Rock displacement monitoring is important because it helps detect ______ risks. (Linked to SLO 3.3)

**Short-answer questions**

4. State two purposes of tunnel and chamber surveying. (Linked to SLO 3.1)
5. Mention two safety applications of underground survey data. (Linked to SLO 3.4)

**Long-answer questions**

6. Analyse the importance of displacement monitoring in underground mines. (Linked to SLO 3.3)
    - *Basic response*: Learners should explain how displacement monitoring detects instability, supports reinforcement, and prevents accidents.

- *Value-added response*: Outstanding learners may extend the analysis by linking displacement monitoring to modern technologies such as laser scanning, GIS, and remote sensing, and evaluating its role in predictive safety management.

**Answers to Concept Check Questions [Series 3]**

1. Vertical or inclined.
2. Confined.
3. Safety.
4. Ensuring planned layouts and preventing structural weaknesses.
5. Preventing collapses and guiding safe excavation layouts.
6. *Basic response*: Displacement monitoring detects instability, supports reinforcement, and prevents accidents. *Value-added response*: Modern technologies like laser scanning, GIS, and remote sensing enhance monitoring, providing predictive data for proactive safety management.

**Answers to Pilot Questions [Series 3]**

1. Sinking vertical or inclined passages to access mineral deposits.
2. It ensures alignment with geological targets and surface control points.
3. To ensure planned layouts and prevent structural weaknesses.
4. Identifying and recording boundaries between ore and surrounding rock.
5. By providing accurate data on ore boundaries.
6. They are adapted to confined and poorly lit environments.
7. Reflective prisms and illuminated reticles.
8. Vibration, moisture, and restricted movement.
9. Stabilising tripods and protecting instruments from dust.
10. It ensures reliable accuracy in underground conditions.
11. Fixed reference markers used to maintain accuracy.
12. They provide benchmarks for alignment.
13. Measuring shifts or movements in underground structures.
14. Identifying unstable zones and guiding excavation methods.
15. By detecting early signs of instability.

16. It ensures alignment with geological structures and deposits.
17. By providing coordinates, angles, and depths for drilling.
18. Preventing collapses and supporting ventilation planning.
19. It ensures airflow is directed safely through mine workings.
20. By guiding excavation layouts and identifying hazards.

**References and Attributions [Series 3]**

- Course document: *MNE 502: Mine Surveying*.
- Suggested OER sources:
    - "Underground mine shaft alignment survey OER diagram" for Figure 3.1.
    - "Underground mine tunnel surveying OER image" for Plate 3.1.
    - "Mineral contact mapping underground mine OER" for Box 3.1.
    - "Underground mine surveying instruments OER diagram" for Figure 3.2.
    - "Underground mine surveying illuminated equipment OER image" for Plate 3.2.
    - "Underground mine surveying instrument handling OER" for Box 3.2.
    - "Underground mine survey control points OER diagram" for Figure 3.3.
    - "Underground mine rock displacement monitoring OER image" for Plate 3.3.
    - "Safety applications displacement data underground mine OER" for Box 3.3.
    - "Underground mine survey data integration OER diagram" for Figure 3.4.
    - "Underground mine drilling operations survey OER image" for Plate 3.4.
    - "Underground mine safety survey data OER" for Box 3.4.

# Series 4: Mineral Reserve Estimation And Rock Displacement

**Series outline**

- **Part 4.1 Principles of mineral reserve estimation**

- Definition and importance of reserve estimation
- Categories of mineral reserves (proved, probable, possible)
- Geological and survey data requirements

- **Part 4.2 Methods of reserve estimation**
  - Geometrical methods (cross-section, polygonal, triangular)
  - Statistical and geostatistical methods
  - Computer-assisted modelling
- **Part 4.3 Rock displacement and deformation**
  - Causes of rock displacement in mines
  - Surveying techniques for monitoring deformation
  - Safety implications of displacement data
- **Part 4.4 Applications of reserve estimation and displacement data**
  - Integration into mine planning and design
  - Supporting excavation and production scheduling
  - Enhancing safety and resource management

**Introduction**

Accurate estimation of mineral reserves and monitoring of rock displacement are fundamental to modern mining operations. Reserve estimation ensures that the quantity and quality of mineral deposits are known before extraction, guiding investment, planning, and production. Rock displacement monitoring, on the other hand, safeguards workers and equipment by detecting shifts and deformations in underground and surface structures. Together, these processes combine economic efficiency with safety management, making them indispensable in mine surveying.

The aim of this Series is to equip you with the knowledge and skills to estimate mineral reserves using different methods, understand the causes and monitoring of rock displacement, and apply survey data to mine planning, production scheduling, and safety management.

We shall commence this Series by exploring the **principles of mineral reserve estimation**, focusing on definitions, categories, and data requirements. Next, we will examine **methods of reserve estimation**, including geometrical, statistical, and computer-assisted approaches. Following that, we will consider **rock displacement and deformation**, where you will learn about causes, monitoring techniques, and safety implications. Finally, we will conclude with **applications of reserve estimation and displacement data**, showing how these results are integrated into mine planning, production, and safety strategies.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 4.1** explain the principles and categories of mineral reserve estimation,
- **SLO 4.2** apply geometrical, statistical, and computer-assisted methods of reserve estimation,
- **SLO 4.3** analyse causes of rock displacement and demonstrate surveying techniques for monitoring deformation, and
- **SLO 4.4** evaluate applications of reserve estimation and displacement data in mine planning, production scheduling, and safety management.

### 4.1 Principles Of Mineral Reserve Estimation

#### 4.1.1 Definition and importance of reserve estimation

**Mineral reserve estimation** is the process of calculating the quantity and quality of mineral deposits available for extraction. It is a critical step in mine planning because it determines the economic viability of a mining project. Accurate reserve estimation ensures that investors, engineers, and managers can make informed decisions about production, costs, and sustainability.

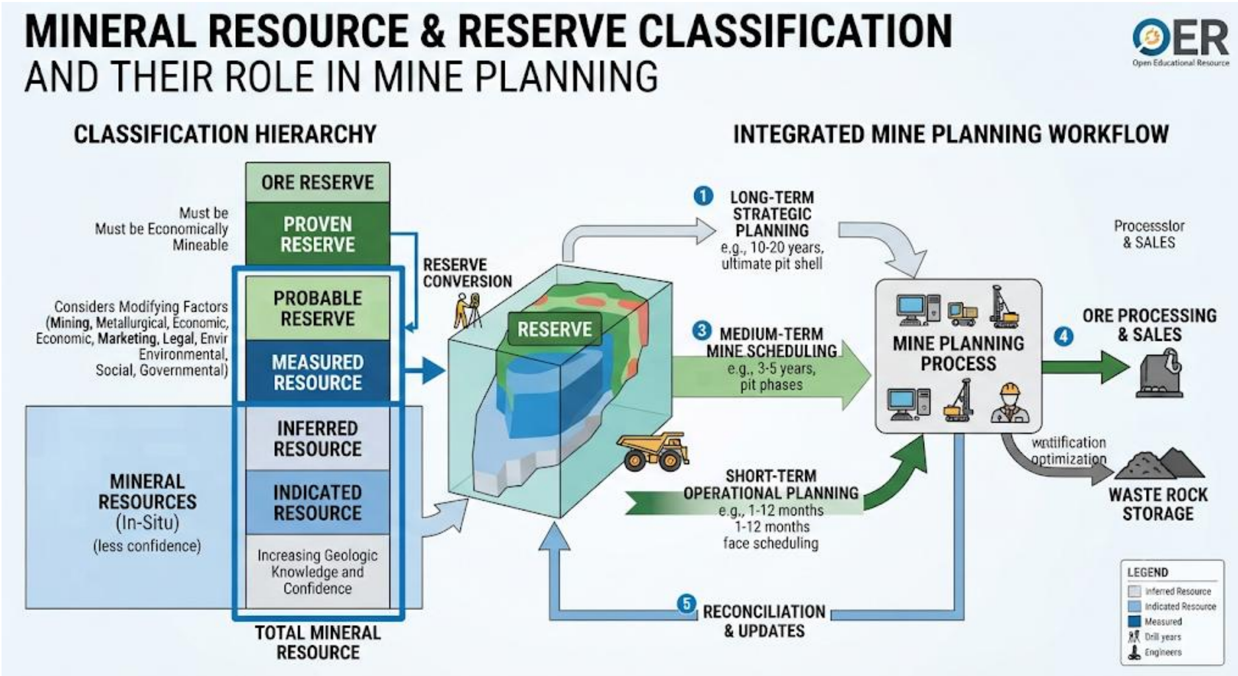


Diagram showing the relationship between mineral reserves, resources, and mine planning. *Figure 4.1: Mineral reserve estimation in mine planning*

Reserve estimation is important because it determines the ______ viability of a mining project.

### 4.1.2 Categories of mineral reserves

Mineral reserves are classified into categories based on the level of confidence in geological data:

- **Proved reserves**: High confidence, based on detailed exploration and sampling.
- **Probable reserves**: Moderate confidence, supported by limited exploration data.
- **Possible reserves**: Low confidence, inferred from geological evidence but not fully verified.

**CATEGORIES OF MINERAL RESERVES: A COMPARATIVE OVERVIEW** OER

| RESERVE CATEGORY | GEOLOGICAL CONFIDENCE Level of certainty in geological data | ECONOMIC VIABILITY Confidence in economic extraction. | MODIFYING FACTORS Key considerations (mining, metallurgical, economic, etc.) | RISK PROFILE Overall level of uncertainty and risk |
|---|---|---|---|---|
| Proved Probable Possible | **Very High** Based on detailed drilling, sampling, and testing. Proven continuity. | **High** Feasibility study completed, all modifying factors considered positive. | Fully defined (mine plan, plant, infrastructure, permits, market) | **Low** Most certain category. |
| **PROBABLE RESERVE** (LIGHT GREEN) | **High** Based on sufficient drilling and sampling, but less detailed than tha Proved. | **Medium-High** Pre-feasibility or feasibility study completed. May have minor outstanding issues. | Generally defined, but some details (e.g., specific recovery rates, final permits) may need confirmation. | **Moderate** Good confidence, but some uncertainty remains. |
| **POSSIBLE RESERVE** (YELLOW/AMBER) INCREASING CONFIDENCE | **Low** Based on limited drilling, sampling, or indirect evidence. Continuity inferred. | **Low** Conceptual or pre-feasibility study level. Dependent on favorable future economic and technical conditions. | Largely conceptual. High uncertainty in mine plan, costs, and metal prices. | **High** **Speculative.** Only included for long-term planning, not near-term production. |

*OER is reserve educational resource (OER) a stude wth previous ,eacn really complated costs, and vary by ac: reporting code (e.g., JORC, NI 43-101). Reserve definitions vary doat informattion slogs ss rerovice.

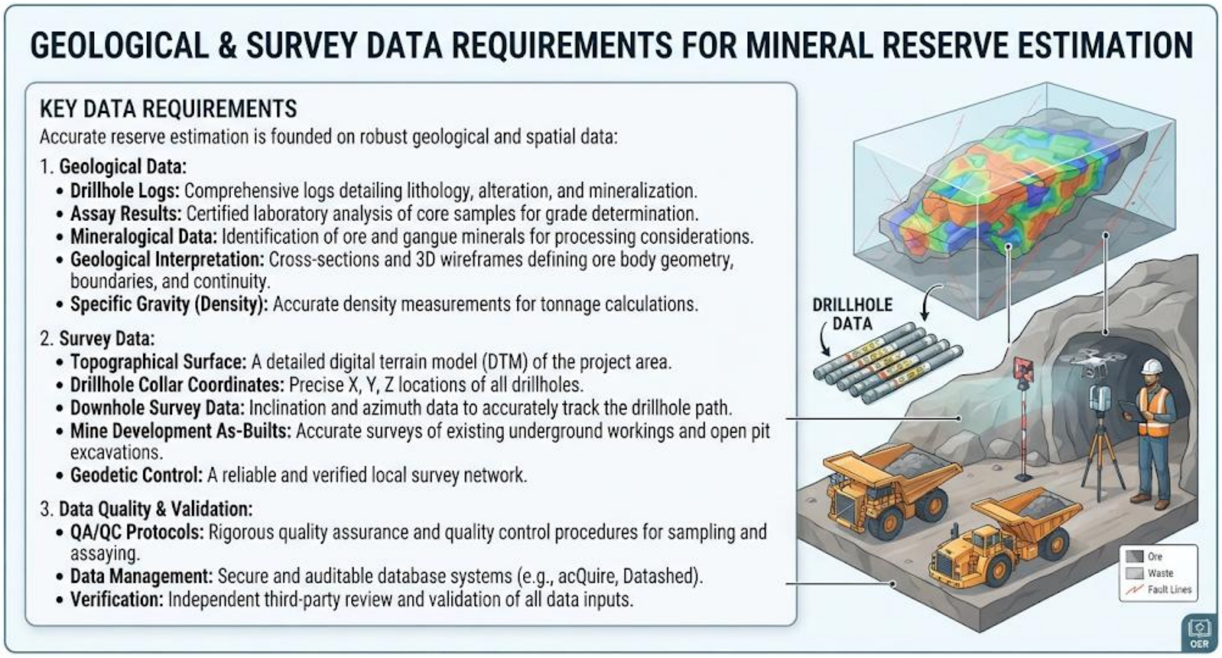
*RESERVE DEFINITIONS VARY BY REPORTING CODE (e.g., JORC, NI 43-101, SK-1300).

Comparison of mineral reserve categories. *Table 4.1: Categories of mineral reserves*

Proved reserves are those with ______ confidence based on detailed exploration.

### 4.1.3 Geological and survey data requirements

Accurate reserve estimation depends on reliable **geological and survey data**. Geological data includes rock types, mineralisation patterns, and structural features. Survey data provides measurements of deposit dimensions, volumes, and boundaries. Together, these datasets allow engineers to calculate reserves with precision and reduce uncertainty.




*Box 4.1: Data requirements for reserve estimation*

Reserve estimation requires geological and survey data to reduce ______ in calculations.

**Pilot questions 4.1**

1. What is mineral reserve estimation?
2. Why is reserve estimation important in mine planning?
3. State the three categories of mineral reserves.
4. Which category of reserves has the highest confidence level?
5. Mention two types of data required for accurate reserve estimation.

**4.2 Methods Of Reserve Estimation**

**4.2.1 Geometrical methods**

**Geometrical methods** are traditional approaches that use shapes and measurements to estimate reserves. Common techniques include:

- **Cross-section method**: Calculates reserves by measuring areas of ore bodies in vertical sections and multiplying by thickness.
- **Polygonal method**: Divides the deposit into polygons around sample points, estimating reserves based on average grades.

- **Triangular method**: Uses triangles formed between sample points to calculate ore volumes and grades.

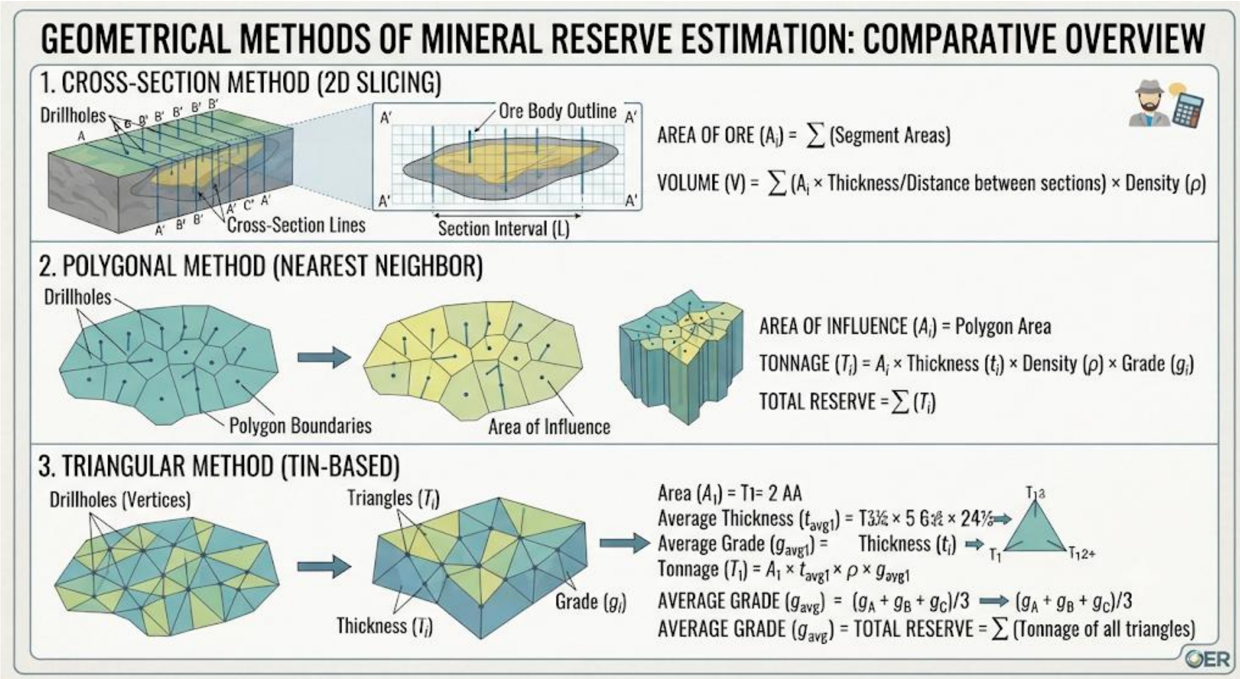
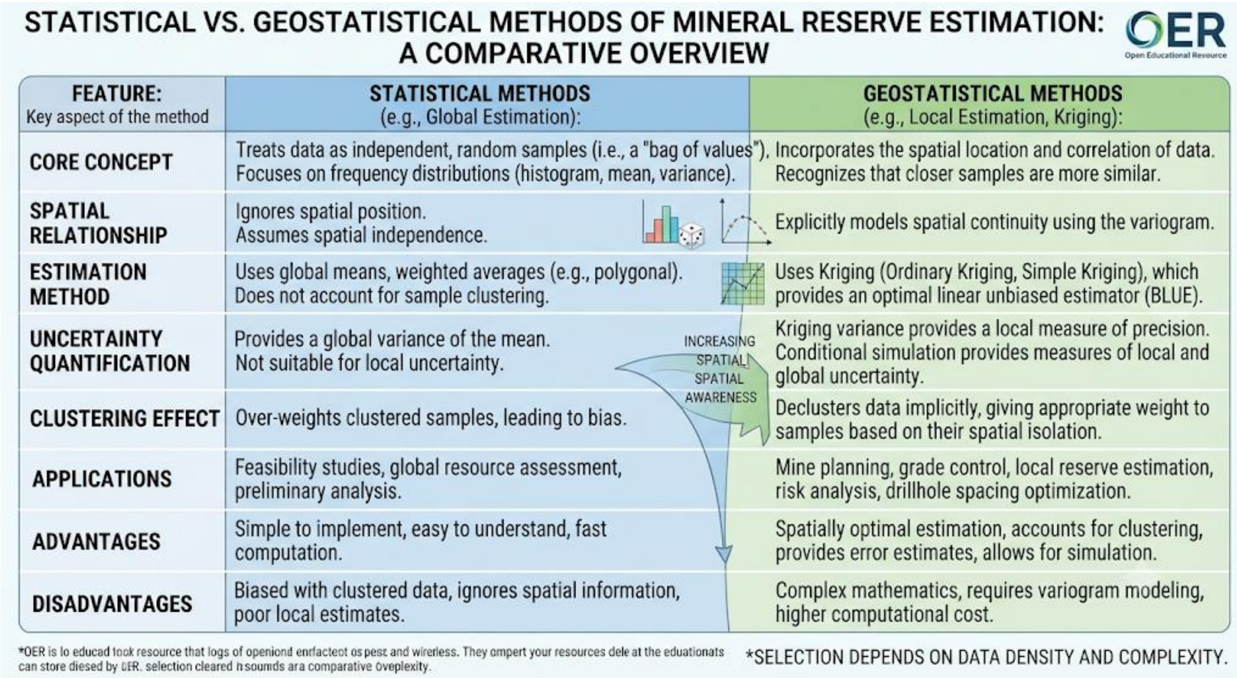



Diagram showing cross-section, polygonal, and triangular methods. *Figure 4.2: Geometrical methods of reserve estimation*

Geometrical methods are useful because they provide ______ estimates based on shapes and measurements.

### 4.2.2 Statistical and geostatistical methods

**Statistical methods** use averages, variances, and probability to estimate reserves from sampling data. **Geostatistical methods**, such as kriging, apply advanced mathematical models to predict ore grades and continuity across deposits. These methods reduce uncertainty and provide more reliable estimates compared to purely geometrical approaches.



**STATISTICAL VS. GEOSTATISTICAL METHODS OF MINERAL RESERVE ESTIMATION: A COMPARATIVE OVERVIEW**

OER
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| FEATURE: Key aspect of the method | STATISTICAL METHODS (e.g., Global Estimation): | GEOSTATISTICAL METHODS (e.g., Local Estimation, Kriging): |
|---|---|---|
| CORE CONCEPT | Treats data as independent, random samples (i.e., a "bag of values"). Focuses on frequency distributions (histogram, mean, variance). | Incorporates the spatial location and correlation of data. Recognizes that closer samples are more similar. |
| SPATIAL RELATIONSHIP | Ignores spatial position. Assumes spatial independence. | Explicitly models spatial continuity using the variogram. |
| ESTIMATION METHOD | Uses global means, weighted averages (e.g., polygonal). Does not account for sample clustering. | Uses Kriging (Ordinary Kriging, Simple Kriging), which provides an optimal linear unbiased estimator (BLUE). |
| UNCERTAINTY QUANTIFICATION | Provides a global variance of the mean. Not suitable for local uncertainty. | Kriging variance provides a local measure of precision. Conditional simulation provides measures of local and global uncertainty. |
| CLUSTERING EFFECT | Over-weights clustered samples, leading to bias. | Declusters data implicitly, giving appropriate weight to samples based on their spatial isolation. |
| APPLICATIONS | Feasibility studies, global resource assessment, preliminary analysis. | Mine planning, grade control, local reserve estimation, risk analysis, drillhole spacing optimization. |
| ADVANTAGES | Simple to implement, easy to understand, fast computation. | Spatially optimal estimation, accounts for clustering, provides error estimates, allows for simulation. |
| DISADVANTAGES | Biased with clustered data, ignores spatial information, poor local estimates. | Complex mathematics, requires variogram modeling, higher computational cost. |



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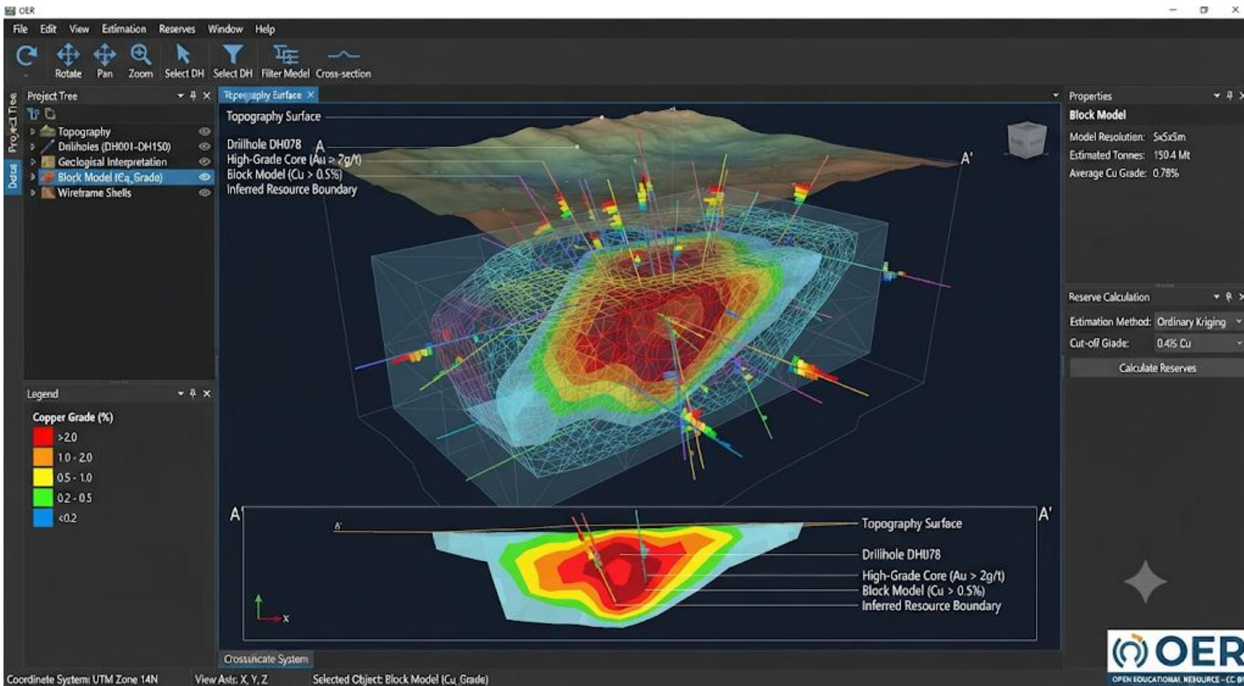
*SELECTION DEPENDS ON DATA DENSITY AND COMPLEXITY.

Comparison of statistical and geostatistical methods. *Table 4.2: Statistical vs. geostatistical methods*

Geostatistical methods are important because they reduce ______ and improve reliability of reserve estimates.

### 4.2.3 Computer-assisted modelling

Modern reserve estimation often relies on **computer-assisted modelling**. Software tools integrate geological, survey, and sampling data to create 3D models of ore bodies. These models allow engineers to visualise deposits, simulate mining scenarios, and calculate reserves with high precision. Computer modelling also supports dynamic updates as new data becomes available.



Screenshot of computer-assisted modelling software for reserve estimation. *Plate 4.2: Computer-assisted modelling in reserve estimation*

Computer-assisted modelling is valuable because it allows ______ visualisation and dynamic updates of ore bodies.

**Pilot questions 4.2**

1. What are geometrical methods of reserve estimation?
2. State two examples of geometrical methods.
3. How do statistical methods differ from geostatistical methods?
4. Why are geostatistical methods considered more reliable?
5. What advantages does computer-assisted modelling provide in reserve estimation?

## 4.3 Rock Displacement And Deformation

### 4.3.1 Causes of rock displacement in mines

**Rock displacement** refers to the movement or shifting of rock masses within a mine. It can be caused by several factors:

- Stress redistribution after excavation
- Blasting vibrations

- Water infiltration and pressure
- Geological faults and weak zones

Understanding these causes helps surveyors and engineers anticipate risks and design preventive measures.

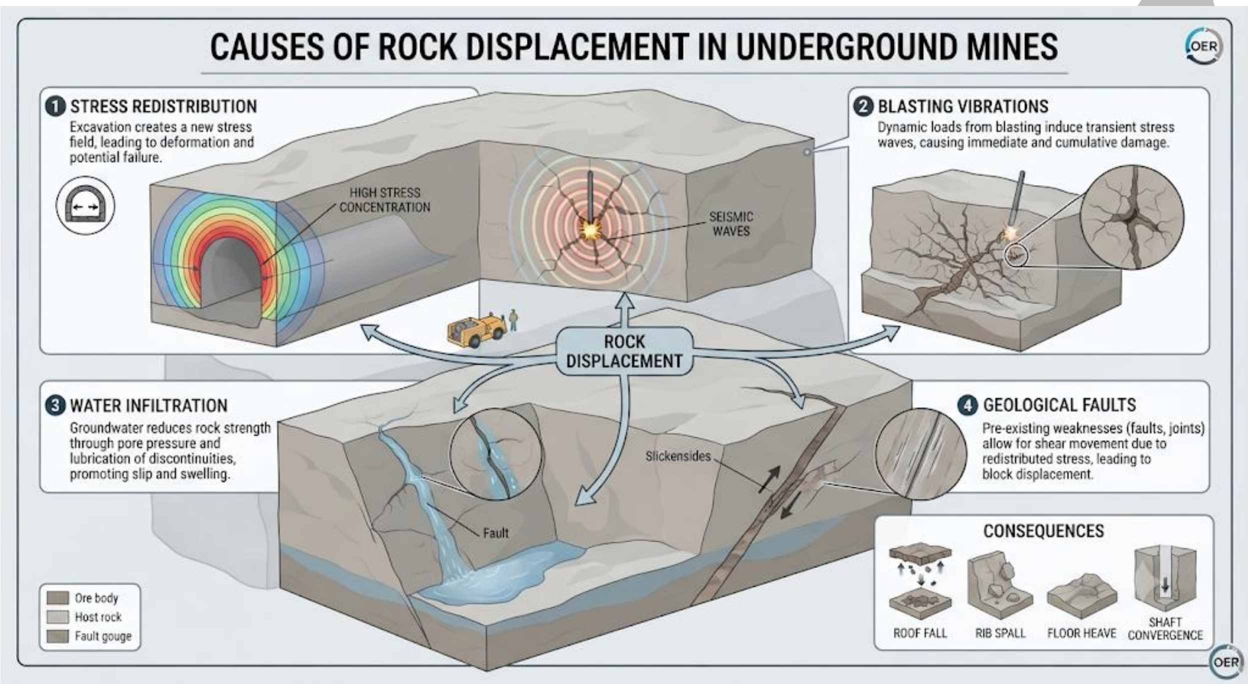



Diagram showing causes of rock displacement in underground mines. *Figure 4.3: Causes of rock displacement*

Rock displacement may occur due to stress redistribution, blasting vibrations, ______, and geological faults.

#### 4.3.2 Surveying techniques for monitoring deformation

Surveyors use specialised techniques to monitor **deformation** in rock structures. These include:

- Control point measurements to detect shifts
- Laser scanning for detailed 3D mapping
- Extensometers and strain gauges for measuring movement
- Photogrammetry for visual analysis of deformation

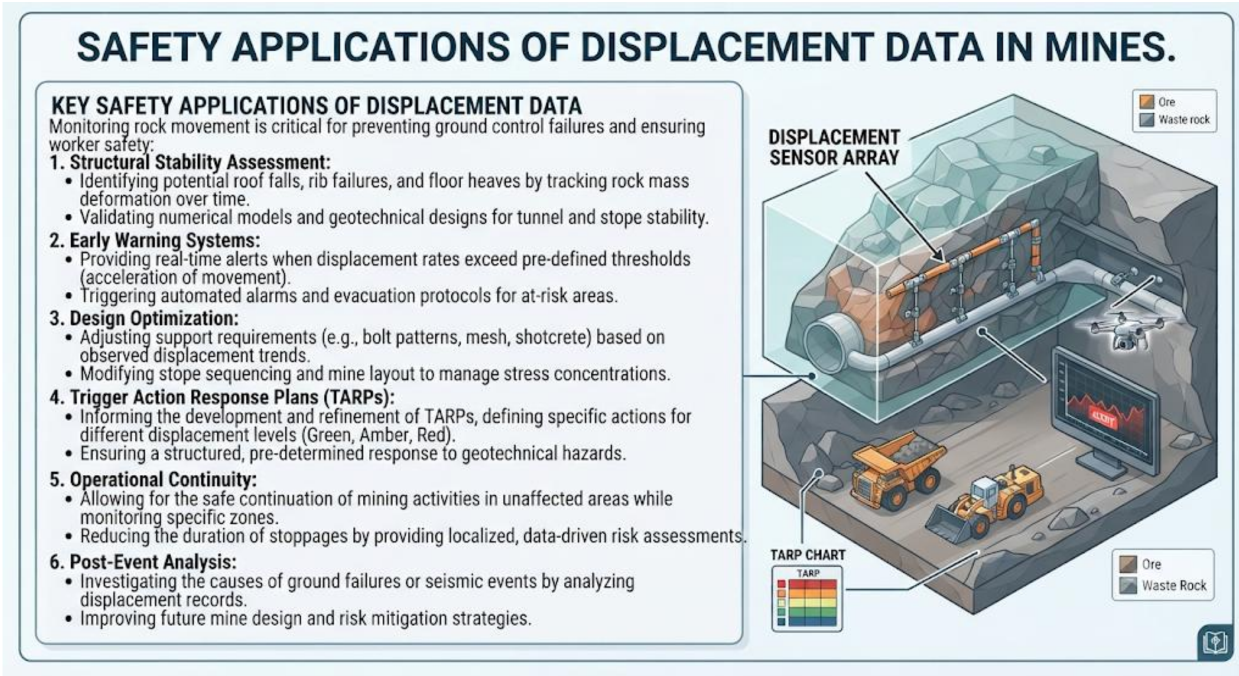
These techniques provide early warnings of instability, allowing corrective measures to be taken before accidents occur.

Photograph of surveyors using laser scanning equipment underground. *Plate 4.3: Surveying techniques for monitoring deformation*

Surveying techniques are important because they provide _____ warnings of instability in rock structures.

**4.3.3 Safety implications of displacement data**

Displacement data has direct **safety implications** in mining operations. It helps identify unstable zones, guides reinforcement decisions, and informs excavation methods. By analysing displacement data, engineers can reduce accidents, protect workers, and maintain structural integrity.




*Box 4.3: Safety applications of displacement data*

Displacement data is critical for safety because it helps identify _____ zones and guide reinforcement.

**Pilot questions 4.3**

1. What is rock displacement in mining?
2. State two causes of rock displacement.
3. Mention two techniques used to monitor deformation.
4. Why is displacement data important for safety?
5. How does monitoring deformation reduce accidents in mines?

### 4.4 Applications Of Reserve Estimation And Displacement Data

#### 4.4.1 Integration into mine planning and design

Survey data from **reserve estimation** and **displacement monitoring** is integrated into mine planning to ensure efficient extraction and long-term sustainability. Reserve figures guide the layout of shafts, tunnels, and stopes, while displacement data informs reinforcement and excavation strategies. Together, they provide a balanced approach to economic viability and safety.

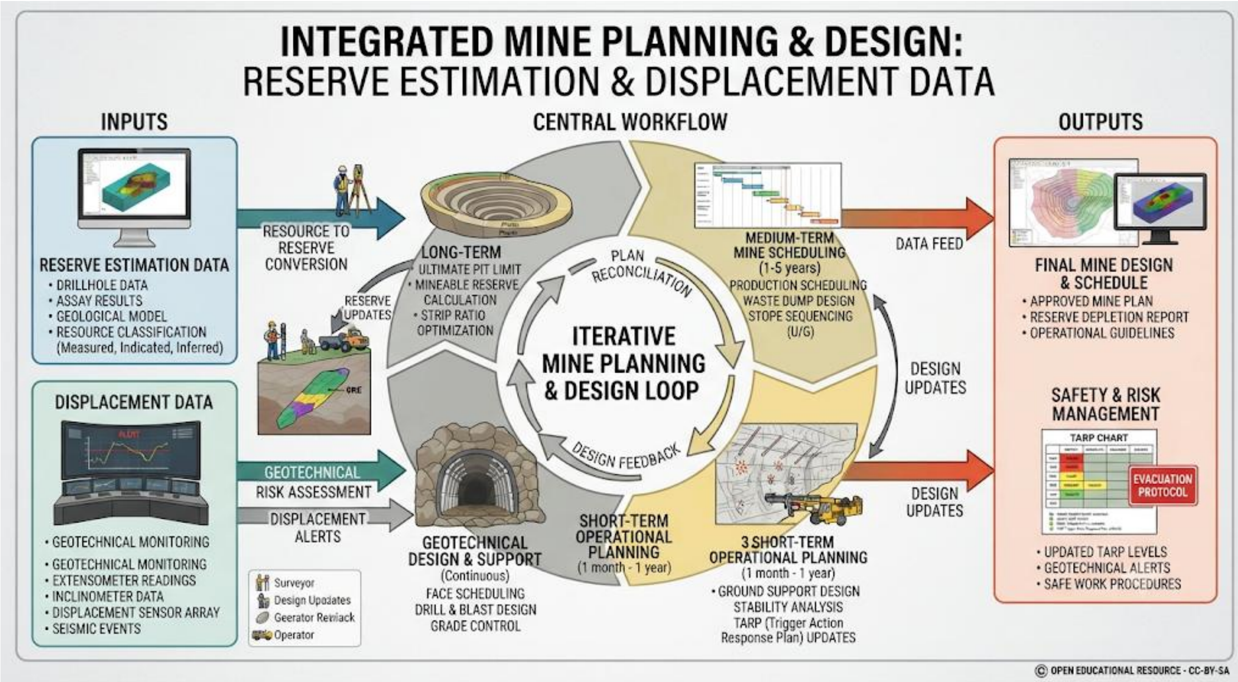


Diagram showing integration of reserve estimation and displacement data into mine planning.
*Figure 4.4: Integration of reserve estimation and displacement data into mine planning*

Mine planning depends on reserve estimation and displacement data because they ensure ______ viability and safety.

### 4.4.2 Supporting excavation and production scheduling

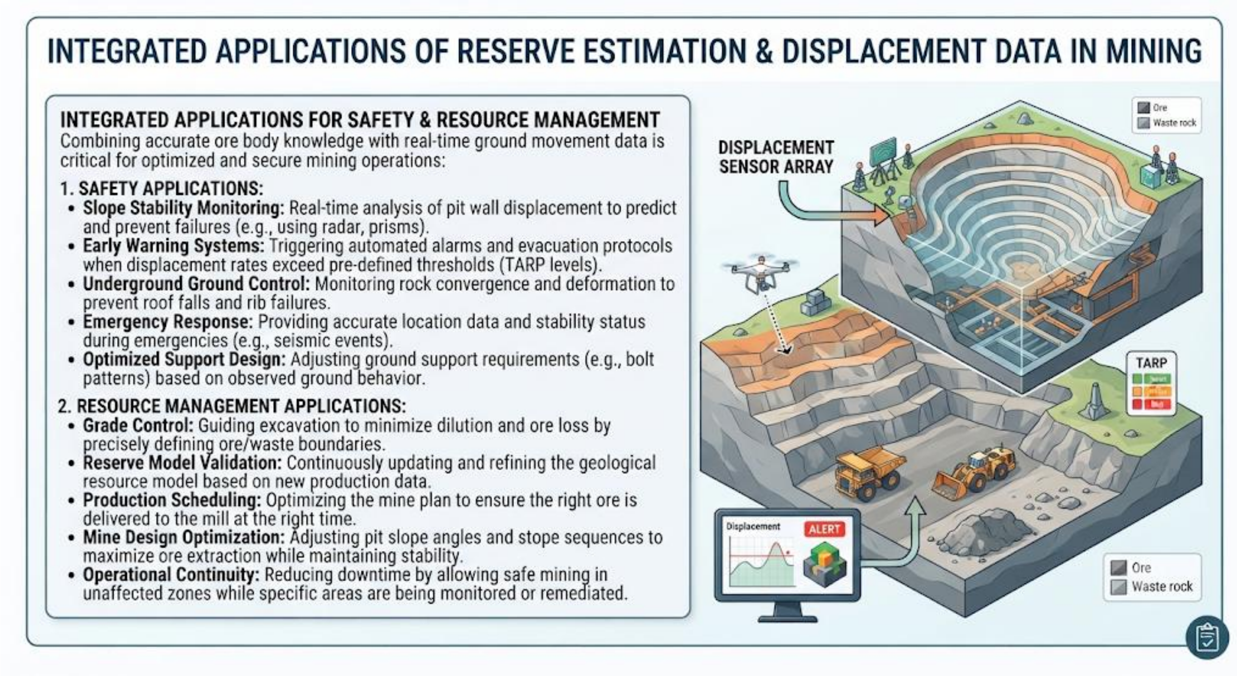
Reserve estimation provides accurate figures for **production scheduling**, ensuring that extraction targets are realistic and achievable. Displacement data supports excavation by identifying stable zones and guiding reinforcement. Together, they help managers schedule operations efficiently while minimising risks.

Photograph of excavation operations guided by reserve estimation data. *Plate 4.4: Excavation and production scheduling supported by survey data*

Production scheduling relies on reserve estimation because it ensures ______ extraction targets and efficient operations.

### 4.4.3 Enhancing safety and resource management

Safety and resource management are enhanced when survey data is applied effectively. Reserve estimation prevents over-extraction and waste, while displacement monitoring reduces accidents by detecting unstable zones. Together, they ensure that resources are used responsibly and workers remain protected.




*Box 4.4: Safety and resource management applications*

Survey data enhances safety and resource management because it prevents ______ and protects workers.

**Pilot questions 4.4**

1. Why is reserve estimation important in mine planning?
2. How does displacement data support excavation?
3. State two ways reserve estimation supports production scheduling.
4. Mention two safety applications of displacement data.
5. How does survey data improve resource management in mining?

**Series Summary**

This Series has examined the dual themes of **mineral reserve estimation** and **rock displacement monitoring**, both of which are central to mine surveying. We began with the principles of reserve estimation, defining its importance and categorising reserves into proved, probable, and possible. Next, we explored methods of reserve estimation, including geometrical, statistical, geostatistical, and computer-assisted approaches. We then studied rock displacement and deformation, identifying causes, surveying techniques, and safety implications. Finally, we considered applications of reserve estimation and displacement data, showing how they are integrated into mine planning, production scheduling, and safety management.

By completing this Series, you should now be able to explain the principles and categories of reserve estimation (SLO 4.1), apply different estimation methods (SLO 4.2), analyse causes of rock displacement and monitor deformation (SLO 4.3), and evaluate applications of reserve estimation and displacement data in planning and safety (SLO 4.4).

**Glossary of Terms**

- **Cross-section method**: A geometrical reserve estimation technique using vertical sections of ore bodies.
- **Geostatistical methods**: Advanced mathematical approaches, such as kriging, used to predict ore grades and continuity.
- **Mineral reserve estimation**: The process of calculating the quantity and quality of mineral deposits available for extraction.
- **Possible reserves**: Reserves inferred from geological evidence but with low confidence.
- **Proved reserves**: Reserves with high confidence, based on detailed exploration and sampling.
- **Rock displacement**: Movement or shifting of rock masses within a mine.
- **Triangular method**: A geometrical reserve estimation technique using triangles formed between sample points.

**Concept Check Questions [Series 4]**

**Objective questions**

1. Mineral reserve estimation determines the ______ viability of a mining project. (Linked to SLO 4.1)
2. Proved reserves are those with ______ confidence based on detailed exploration. (Linked to SLO 4.1)
3. Geostatistical methods are important because they reduce ______ in reserve estimation. (Linked to SLO 4.2)

**Short-answer questions**

4. State two geometrical methods of reserve estimation. (Linked to SLO 4.2)
5. Mention two causes of rock displacement in mines. (Linked to SLO 4.3)

**Long-answer questions**

6. Analyse the applications of reserve estimation and displacement data in mine planning. (Linked to SLO 4.4)

- *Basic response*: Learners should explain how reserve estimation guides layouts and production scheduling, while displacement data informs reinforcement and safety.
- *Value-added response*: Outstanding learners may extend the analysis by linking these applications to modern technologies such as 3D modelling, GIS, and predictive safety systems.

**Answers to Concept Check Questions [Series 4]**

1. Economic.
2. High.
3. Uncertainty.
4. Cross-section method and polygonal method.
5. Stress redistribution and blasting vibrations.
6. *Basic response*: Reserve estimation guides layouts and production scheduling, while displacement data informs reinforcement and safety. *Value-added response*: Modern technologies like 3D modelling, GIS, and predictive safety systems enhance planning and safety management.

**Answers to Pilot Questions [Series 4]**

1. It is the process of calculating the quantity and quality of mineral deposits available for extraction.
2. It determines the economic viability of a mining project.
3. Proved, probable, and possible reserves.
4. Proved reserves.
5. Geological mapping and survey measurements.
6. Geometrical methods use shapes and measurements to estimate reserves.
7. Cross-section and triangular methods.
8. Statistical methods use averages, while geostatistical methods apply advanced models like kriging.
9. They reduce uncertainty and improve reliability.
10. They allow 3D visualisation and dynamic updates.
11. Stress redistribution after excavation.
12. Blasting vibrations.

13. Control point measurements and laser scanning.
14. It helps identify unstable zones and guide reinforcement.
15. By providing early warnings of instability.
16. They ensure economic viability and safety in mine planning.
17. By identifying stable zones and guiding reinforcement.
18. By providing accurate figures for extraction targets.
19. Detecting unstable zones and guiding excavation methods.
20. It prevents over-extraction and waste, ensuring responsible resource use.

**References and Attributions [Series 4]**

- Course document: *MNE 502: Mine Surveying*.
- Suggested OER sources:
    - “Mineral reserve estimation mine planning OER diagram” for Figure 4.1.
    - “Categories of mineral reserves OER table” for Table 4.1.
    - “Geological survey data mineral reserve estimation OER” for Box 4.1.
    - “Geometrical methods mineral reserve estimation OER diagram” for Figure 4.2.
    - “Statistical geostatistical mineral reserve estimation OER table” for Table 4.2.
    - “Computer-assisted modelling mineral reserve estimation OER image” for Plate 4.2.
    - “Causes of rock displacement in mines OER diagram” for Figure 4.3.
    - “Underground mine rock deformation monitoring OER image” for Plate 4.3.
    - “Safety applications rock displacement data OER” for Box 4.3.
    - “Integration reserve estimation displacement data mine planning OER diagram” for Figure 4.4.
    - “Mine excavation production scheduling reserve estimation OER image” for Plate 4.4.
    - “Safety resource management reserve estimation displacement data OER” for Box 4.4.

# Series 5: Remote Sensing, GIS, And Computer Applications

**Series outline**

- **Part 5.1 Principles of remote sensing in mining**
    - Definition and importance of remote sensing
    - Types of sensors (optical, radar, thermal)
    - Applications in mineral exploration and monitoring
- **Part 5.2 GIS applications in mine surveying**
    - GIS fundamentals and data layers
    - Spatial analysis for mine planning
    - Integration of survey data into GIS platforms
- **Part 5.3 Computer applications in mine surveying**
    - Software tools for 3D modelling and visualisation
    - Data processing and automation
    - Simulation and predictive analysis
- **Part 5.4 Integration of remote sensing, GIS, and computer applications**
    - Combined use for mineral reserve estimation
    - Monitoring environmental impacts
    - Enhancing safety and operational efficiency

**Introduction**

Modern mine surveying has evolved beyond traditional field instruments, embracing advanced technologies such as **remote sensing**, **Geographic Information Systems (GIS)**, and **computer applications**. These tools allow surveyors to collect, process, and analyse vast amounts of spatial and geological data with greater accuracy and efficiency. Remote sensing provides imagery and sensor data from satellites and drones, GIS enables spatial analysis and integration of multiple datasets, while computer applications support modelling, simulation, and automation.

The aim of this Series is to introduce you to the principles and applications of these technologies in mining. You will learn how remote sensing supports mineral exploration and monitoring, how GIS enhances mine planning and survey data management, and how computer applications enable 3D modelling, predictive analysis, and integration of multiple datasets.

We shall commence this Series by exploring the **principles of remote sensing in mining**, focusing on sensor types and applications. Next, we will examine **GIS applications in mine surveying**, highlighting spatial analysis and integration of survey data. Following that, we will consider **computer applications in mine surveying**, including software tools for modelling and automation. Finally, we will conclude with **integration of remote sensing, GIS, and computer applications**, showing how these technologies work together to improve reserve estimation, environmental monitoring, and safety.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 5.1** explain the principles of remote sensing and its applications in mining,
- **SLO 5.2** apply GIS tools for spatial analysis and integration of survey data,
- **SLO 5.3** describe computer applications used in mine surveying for modelling, automation, and predictive analysis, and
- **SLO 5.4** evaluate the integration of remote sensing, GIS, and computer applications in mine planning, monitoring, and safety management.

### 5.1 Principles Of Remote Sensing In Mining

#### 5.1.1 Definition and importance of remote sensing

**Remote sensing** is the science of obtaining information about objects or areas from a distance, typically using satellites, drones, or aircraft. In mining, it provides imagery and sensor data that help identify mineral deposits, monitor environmental changes, and support exploration. Remote sensing reduces the need for extensive ground surveys, saving time and resources.

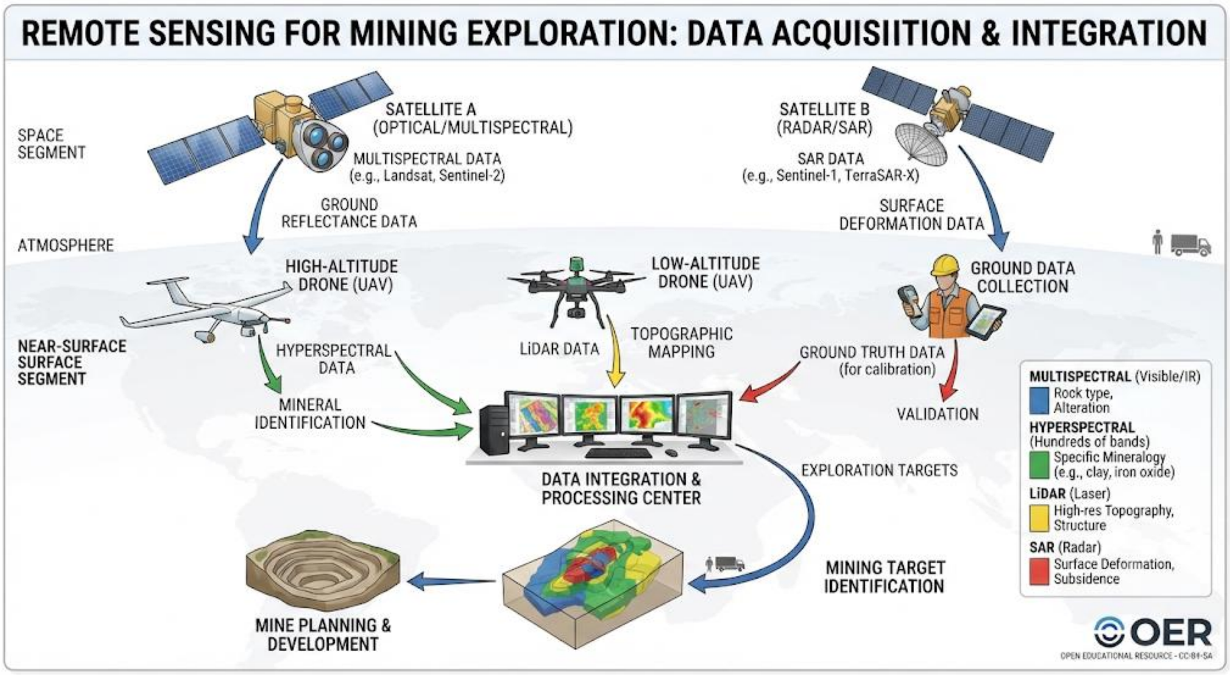


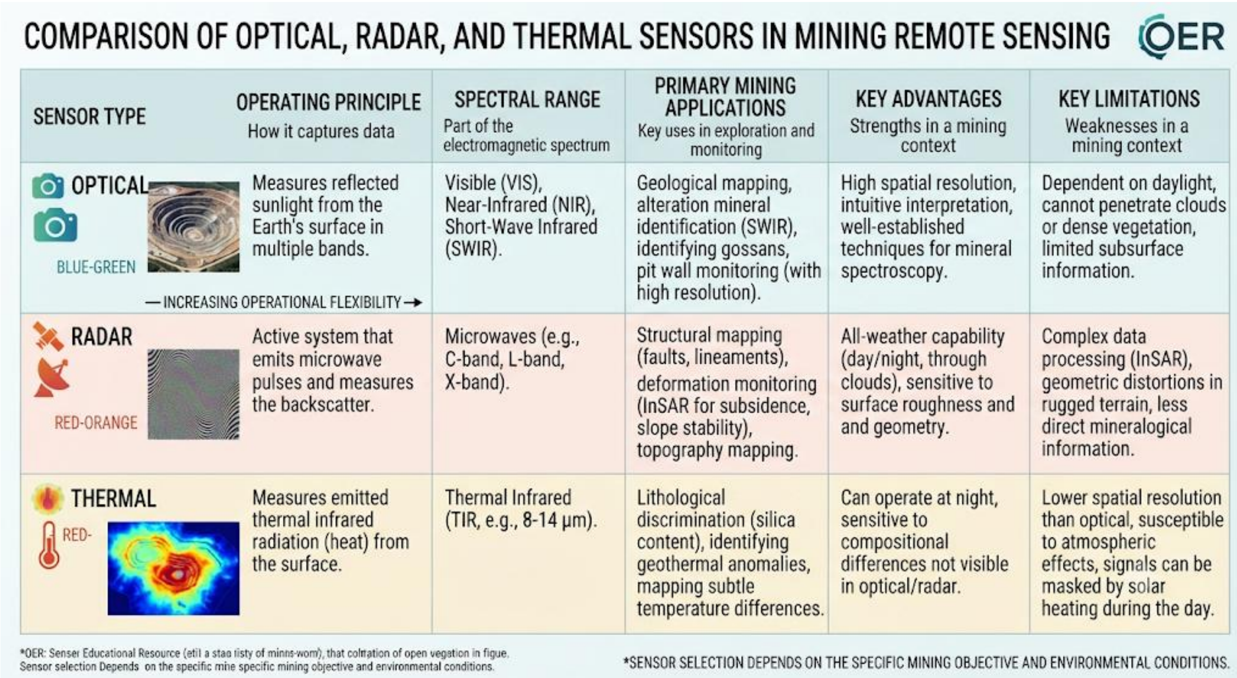

Diagram showing remote sensing data collection from satellites and drones. *Figure 5.1: Remote sensing in mining*

Remote sensing is important in mining because it provides ______ information without direct contact.

### 5.1.2 Types of sensors used in mining

Remote sensing relies on different types of sensors, each capturing specific data:

- **Optical sensors**: Capture visible and near-infrared light, useful for mapping surface features.
- **Radar sensors**: Use radio waves to penetrate clouds and vegetation, providing structural information.
- **Thermal sensors**: Detect heat variations, useful for identifying geothermal activity and mineralisation zones.



COMPARISON OF OPTICAL, RADAR, AND THERMAL SENSORS IN MINING REMOTE SENSING

| SENSOR TYPE | OPERATING PRINCIPLE<br>How it captures data | SPECTRAL RANGE<br>Part of the electromagnetic spectrum | PRIMARY MINING APPLICATIONS<br>Key uses in exploration and monitoring | KEY ADVANTAGES<br>Strengths in a mining context | KEY LIMITATIONS<br>Weaknesses in a mining context |
|---|---|---|---|---|---|
| OPTICAL<br>BLUE-GREEN<br>— INCREASING OPERATIONAL FLEXIBILITY → | Measures reflected sunlight from the Earth's surface in multiple bands. | Visible (VIS), Near-Infrared (NIR), Short-Wave Infrared (SWIR). | Geological mapping, alteration mineral identification (SWIR), identifying gossans, pit wall monitoring (with high resolution). | High spatial resolution, intuitive interpretation, well-established techniques for mineral spectroscopy. | Dependent on daylight, cannot penetrate clouds or dense vegetation, limited subsurface information. |
| RADAR<br>RED-ORANGE | Active system that emits microwave pulses and measures the backscatter. | Microwaves (e.g., C-band, L-band, X-band). | Structural mapping (faults, lineaments), deformation monitoring (InSAR for subsidence, slope stability), topography mapping. | All-weather capability (day/night, through clouds), sensitive to surface roughness and and geometry. | Complex data processing (InSAR), geometric distortions in rugged terrain, less direct mineralogical information. |
| THERMAL<br>RED- | Measures emitted thermal infrared radiation (heat) from the surface. | Thermal Infrared (TIR, e.g., 8-14 µm). | Lithological discrimination (silica content), identifying geothermal anomalies, mapping subtle temperature differences. | Can operate at night, sensitive to compositional differences not visible in optical/radar. | Lower spatial resolution than optical, susceptible to atmospheric effects, signals can be masked by solar heating during the day. |

*OER: Senser Educational Resource (etil a staa tisty of minns-wom), that coltration of open vegation in figue. Sensor selection Depends on the specific mine specific mining objective and environmental conditions.

*SENSOR SELECTION DEPENDS ON THE SPECIFIC MINING OBJECTIVE AND ENVIRONMENTAL CONDITIONS.

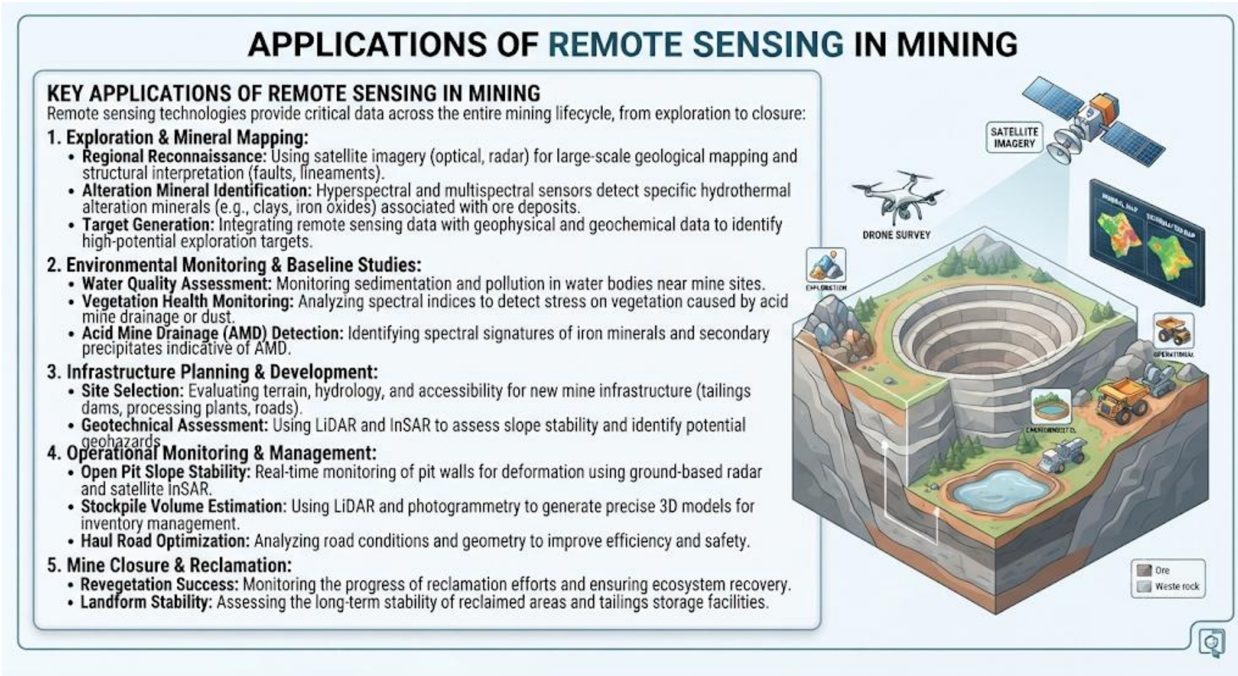
Comparison of sensor types in remote sensing. *Table 5.1: Types of sensors used in mining*

Radar sensors are valuable because they can penetrate ______ and vegetation to reveal structures.

**5.1.3 Applications in mineral exploration and monitoring**

Remote sensing has wide applications in mining:

- Identifying potential mineral deposits through spectral analysis
- Monitoring land use and vegetation changes around mines
- Detecting environmental impacts such as erosion or pollution
- Supporting geological mapping and resource estimation




*Box 5.1: Applications of remote sensing in mining*

Remote sensing supports exploration because it helps identify ______ deposits through spectral analysis.

**Pilot questions 5.1**

1. What is remote sensing in mining?
2. State two types of sensors used in remote sensing.
3. Why are radar sensors useful in mining?
4. Mention two applications of remote sensing in mineral exploration.
5. How does remote sensing support environmental monitoring?

**5.2 GIS Applications In Mine Surveying**

**5.2.1 GIS fundamentals and data layers**

**Geographic Information Systems (GIS)** are computer-based tools that capture, store, analyse, and display spatial data. In mine surveying, GIS integrates geological, environmental, and survey datasets into layered maps. Each **data layer** represents a specific aspect, such as geology, topography, or infrastructure, allowing surveyors to visualise complex relationships.

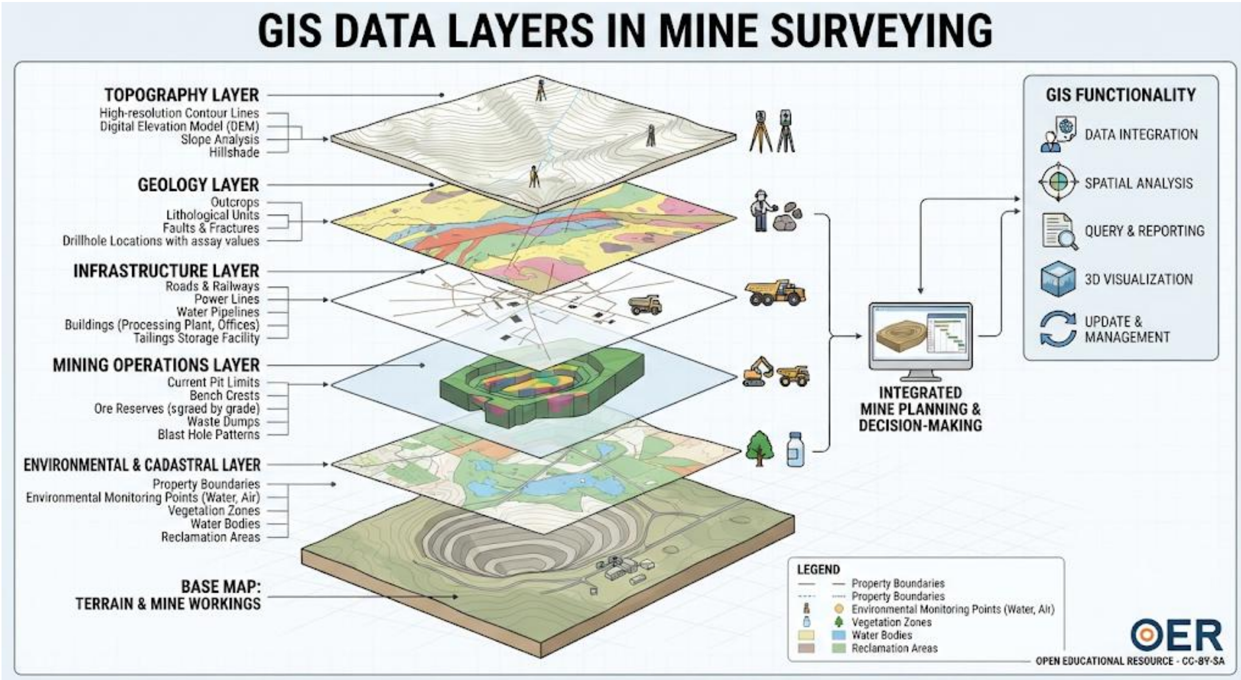
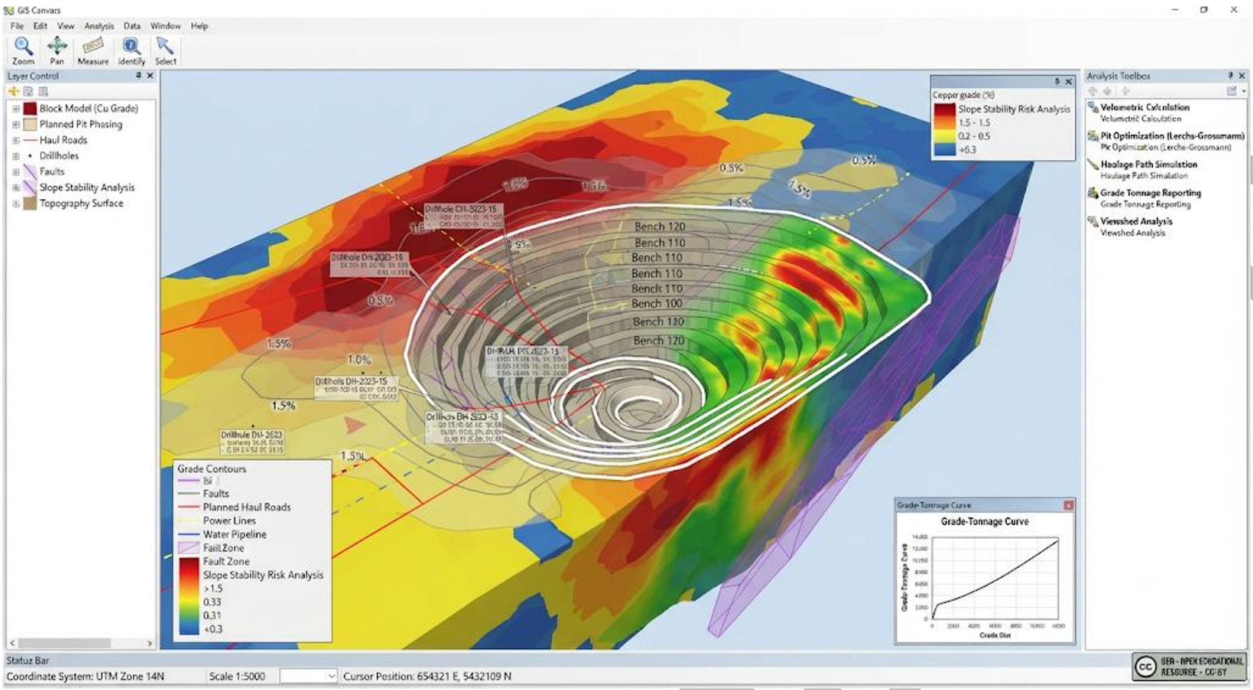



Diagram showing GIS data layers (geology, topography, infrastructure). *Figure 5.2: GIS fundamentals and data layers in mine surveying*

GIS uses data layers to represent ______ aspects such as geology, topography, and infrastructure.

### 5.2.2 Spatial analysis for mine planning

**Spatial analysis** in GIS involves examining spatial relationships between features. In mining, this includes analysing ore distribution, proximity to faults, and accessibility of deposits. Spatial analysis supports mine planning by identifying optimal locations for shafts, tunnels, and processing facilities.

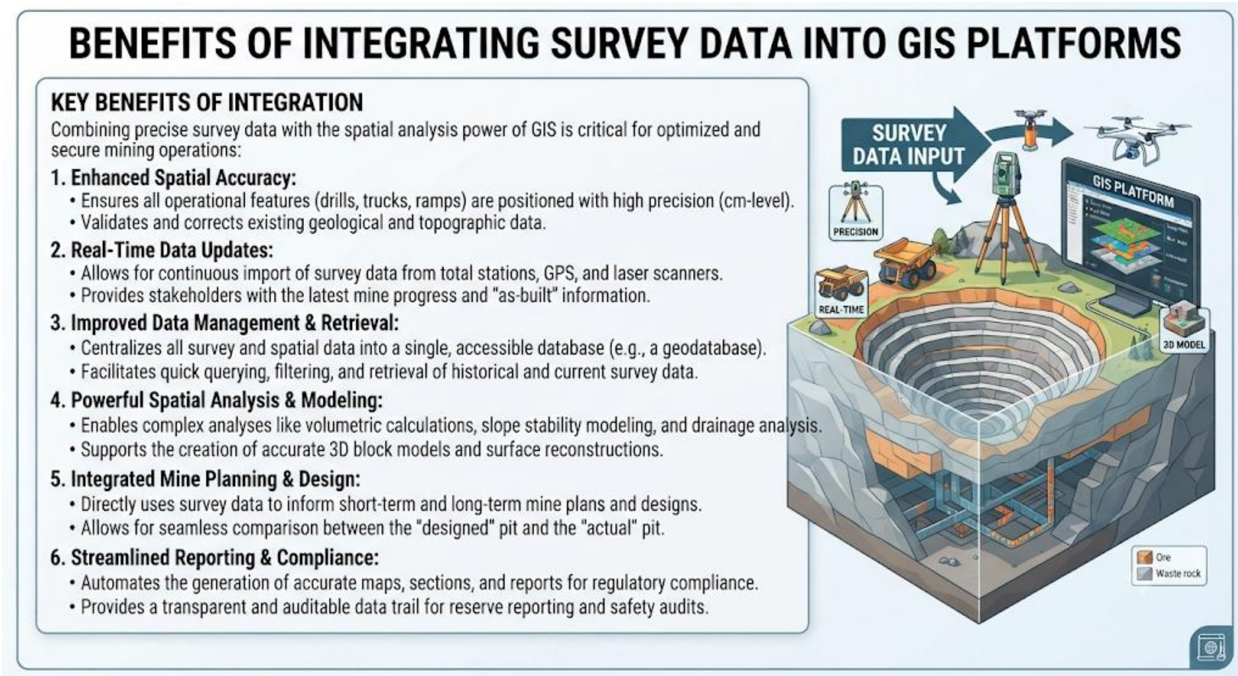


Screenshot of GIS spatial analysis applied to mine planning. *Plate 5.2: Spatial analysis in mine planning*

Spatial analysis is important in mine planning because it identifies ______ locations for shafts and tunnels.

### 5.2.3 Integration of survey data into GIS platforms

Survey data collected in the field can be integrated into **GIS platforms** for analysis and visualisation. This includes coordinates, elevations, and boundaries measured by surveyors. Integration ensures that survey data is combined with geological and environmental datasets, providing a comprehensive view of mining areas.




*Box 5.2: Benefits of integrating survey data into GIS*

Integrating survey data into GIS is beneficial because it provides ______ visualisation and supports accurate decisions.

**Pilot questions 5.2**

1. What is GIS in mine surveying?
2. What are data layers in GIS?
3. Why is spatial analysis important in mine planning?
4. Mention two benefits of integrating survey data into GIS platforms.
5. How does GIS support decision-making in mining?

**5.3 Computer Applications In Mine Surveying**

**5.3.1 Software tools for 3D modelling and visualisation**

Modern mine surveying relies heavily on **computer applications** for creating 3D models of ore bodies and mine layouts. Software such as CAD (Computer-Aided Design) and specialised mining packages allow surveyors to visualise deposits, tunnels, and shafts in three dimensions. These models improve accuracy, support planning, and help communicate complex data to engineers and managers.

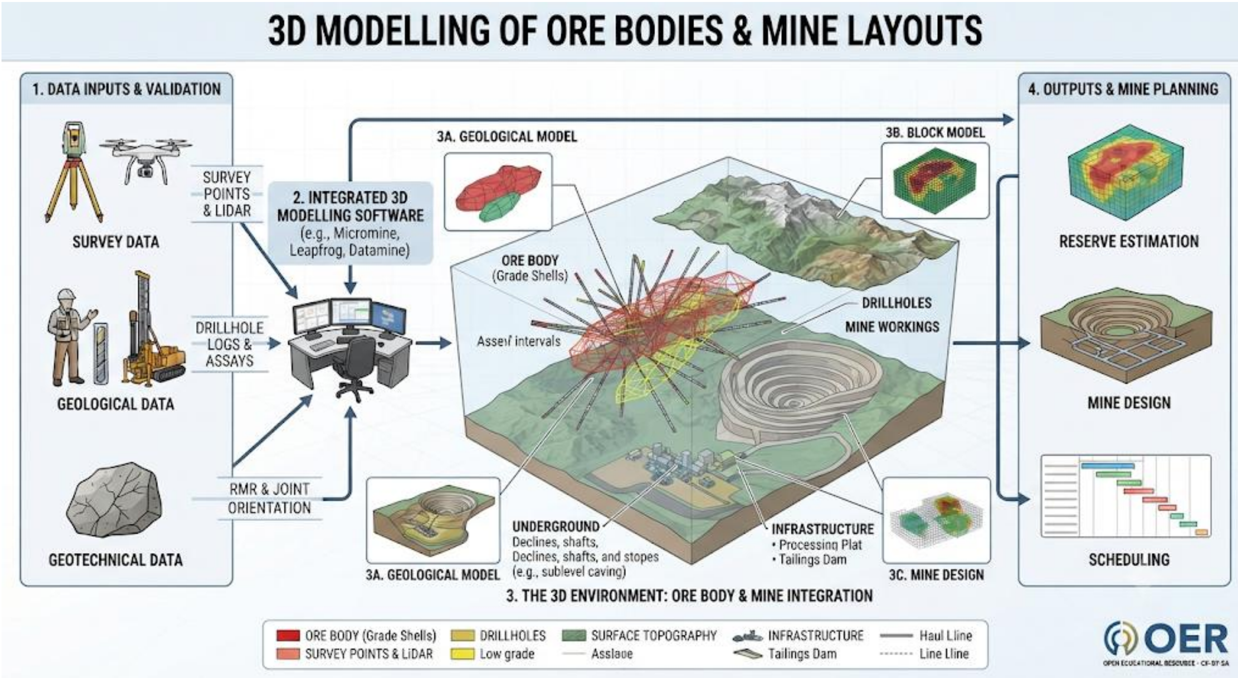
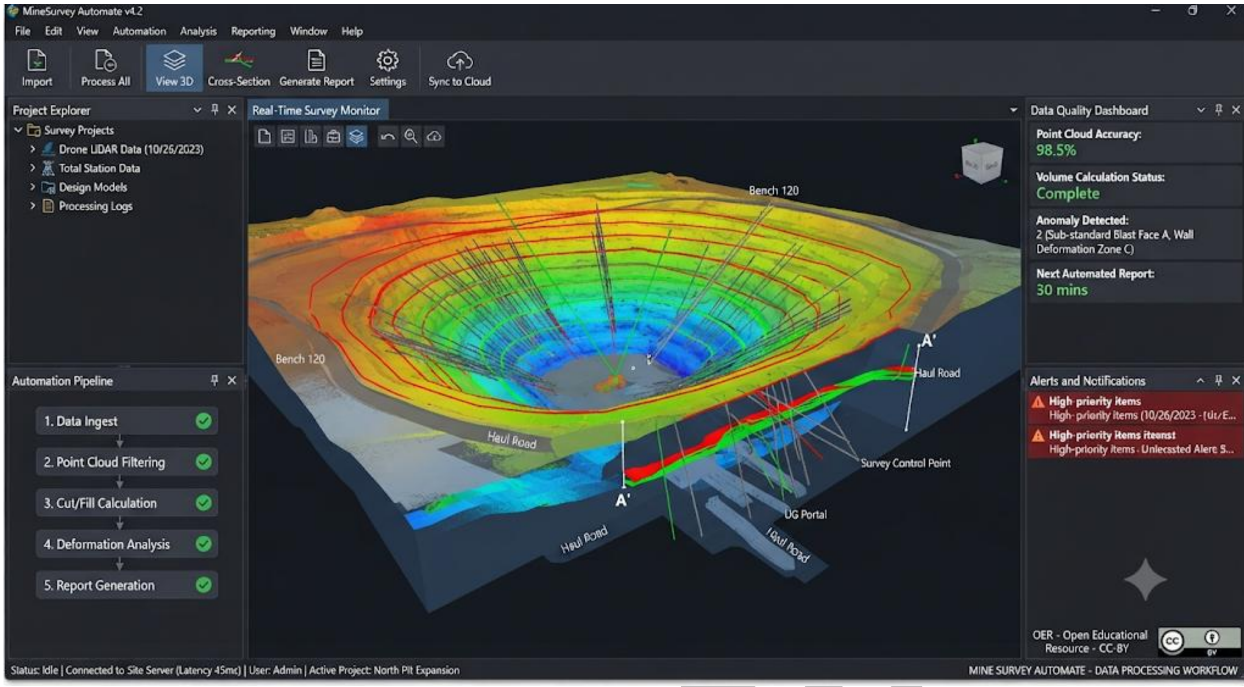



Diagram showing 3D modelling of ore bodies using computer software. *Figure 5.3: 3D modelling in mine surveying*

Computer applications are valuable because they provide ______ visualisation of ore bodies and mine layouts.

### 5.3.2 Data processing and automation

Computer applications also support **data processing and automation**. Survey data collected from instruments can be processed quickly using software, reducing human error and saving time. Automation tools can generate maps, calculate volumes, and update models dynamically as new data is added.

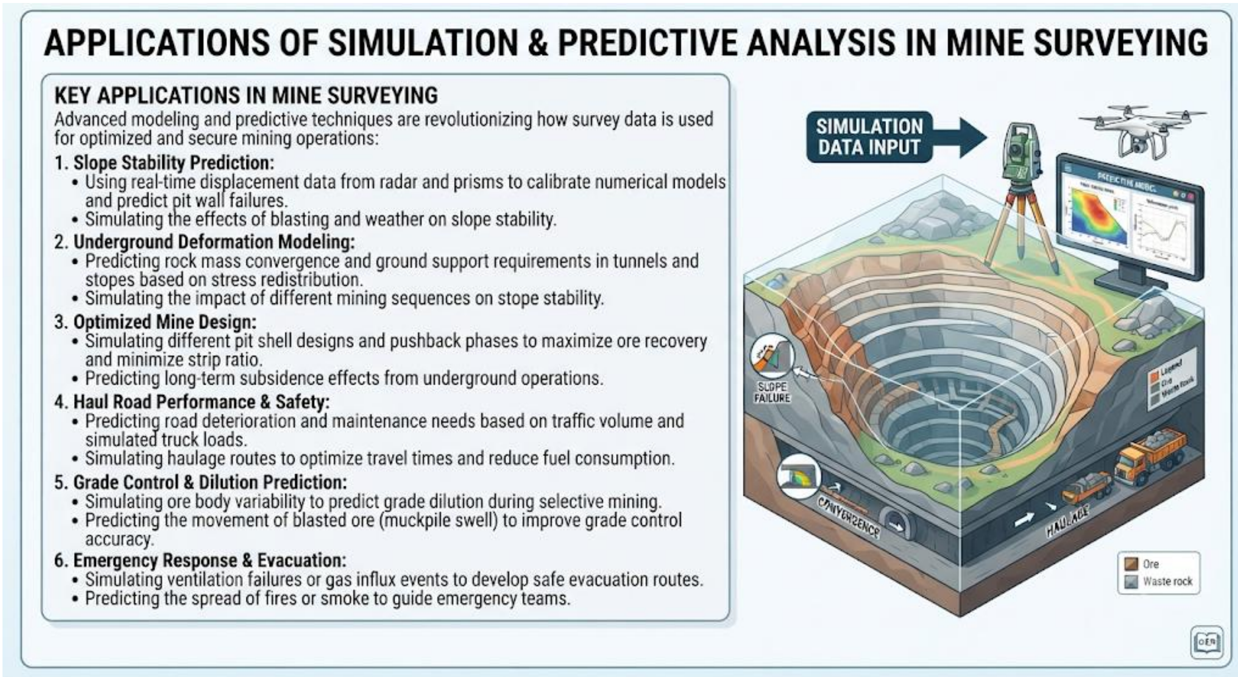



Screenshot of automated data processing software in mine surveying. *Plate 5.3: Automated data processing in mine surveying*

Automation in computer applications is important because it reduces ______ error and speeds up calculations.

### 5.3.3 Simulation and predictive analysis

Computer applications enable **simulation and predictive analysis**, allowing surveyors and engineers to test different mining scenarios. Simulations can predict how excavation will affect stability, ventilation, and production. Predictive analysis uses algorithms to forecast resource availability and potential hazards, supporting proactive decision-making.




*Box 5.3: Applications of simulation and predictive analysis*

Simulation is useful because it allows surveyors to test _____ scenarios and predict hazards.

**Pilot questions 5.3**

1. What role do computer applications play in 3D modelling?
2. How does automation improve data processing in mine surveying?
3. Mention two benefits of simulation in mine surveying.
4. Why is predictive analysis important in mining operations?
5. How do computer applications reduce human error in survey data?

## 5.4 Integration Of Remote Sensing, GIS, And Computer Applications

### 5.4.1 Combined use for mineral reserve estimation

When **remote sensing**, **GIS**, and **computer applications** are integrated, they provide powerful tools for mineral reserve estimation. Remote sensing supplies imagery and spectral data, GIS organises and analyses spatial information, and computer applications model ore bodies in 3D. Together, they improve accuracy, reduce uncertainty, and support efficient resource evaluation.

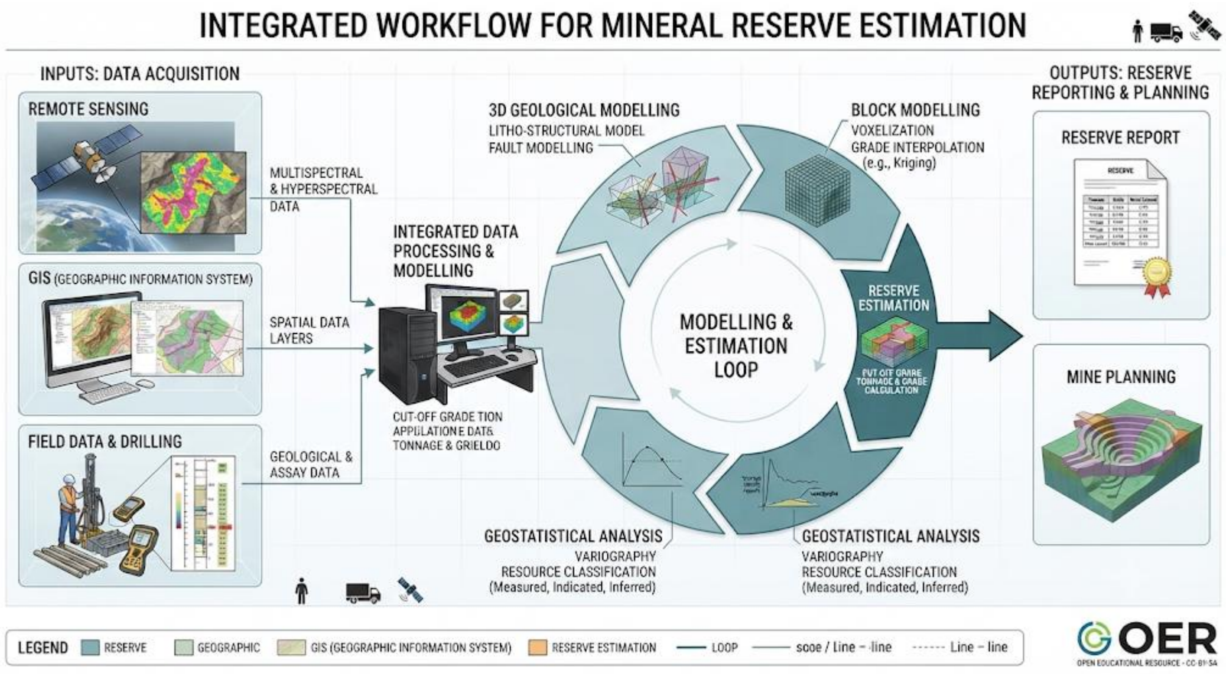
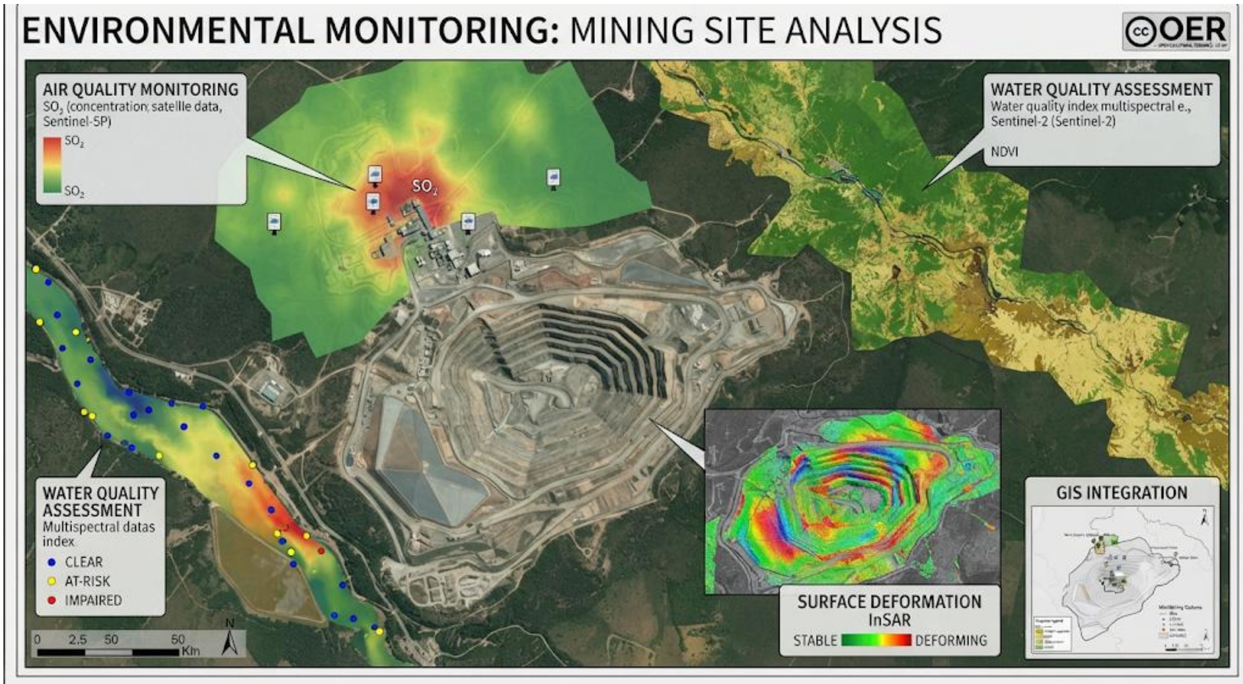



Diagram showing integration of remote sensing, GIS, and computer modelling for reserve estimation. *Figure 5.4: Integration of technologies for reserve estimation*

Integration of these technologies improves reserve estimation by reducing ______ and enhancing accuracy.

### 5.4.2 Monitoring environmental impacts

Integrated technologies also support **environmental monitoring**. Remote sensing detects land use changes, GIS maps environmental features, and computer applications simulate impacts of mining activities. This integration helps identify erosion, pollution, and deforestation, enabling mines to comply with environmental regulations and adopt sustainable practices.

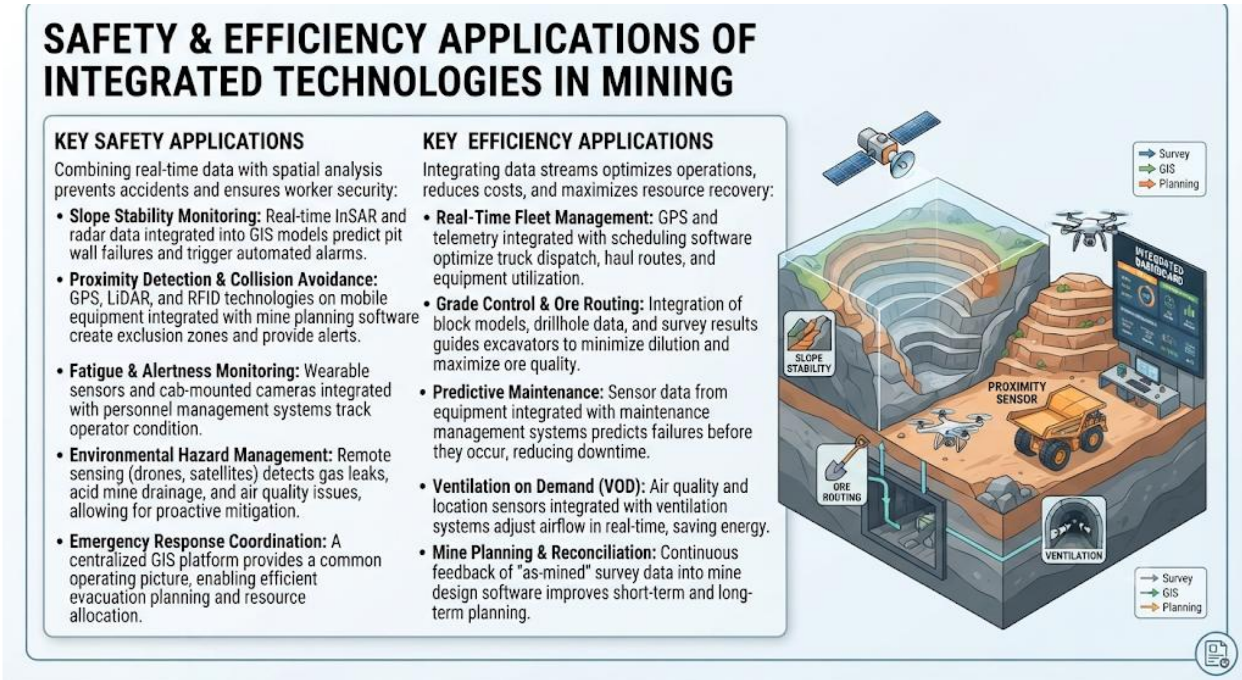



Satellite image showing environmental monitoring around a mining site. *Plate 5.4: Monitoring environmental impacts using integrated technologies*

Environmental monitoring is enhanced because integration helps detect ______ changes such as erosion and deforestation.

### 5.4.3 Enhancing safety and operational efficiency

Safety and operational efficiency are improved when these technologies are combined. Remote sensing identifies unstable zones, GIS integrates displacement and geological data, and computer applications simulate excavation scenarios. This integration allows proactive reinforcement, better ventilation planning, and safer scheduling of operations.




*Box 5.4: Safety and efficiency applications of integrated technologies*

Integration enhances safety because it identifies ______ zones and supports proactive reinforcement.

**Pilot questions 5.4**

1. How do remote sensing, GIS, and computer applications work together in reserve estimation?
2. Why is integration important for environmental monitoring?
3. State two safety applications of integrated technologies.
4. How does integration improve operational efficiency?
5. Mention one example of environmental change detected through integration.

**Series Summary**

This Series has explored the role of **remote sensing, GIS, and computer applications** in mine surveying. We began with the principles of remote sensing, examining sensor types and their applications in mineral exploration and monitoring. Next, we studied GIS applications, focusing on data layers, spatial analysis, and integration of survey data. We then considered computer applications, highlighting 3D modelling, automation, and predictive analysis. Finally, we examined the integration of these technologies, showing how they work together to improve reserve estimation, environmental monitoring, safety, and operational efficiency.

By completing this Series, you should now be able to explain the principles of remote sensing (SLO 5.1), apply GIS tools in mine surveying (SLO 5.2), describe computer applications for modelling and predictive analysis (SLO 5.3), and evaluate the integration of these technologies in mining operations (SLO 5.4).

**Glossary of Terms**

- **Data layers**: Individual thematic maps in GIS representing geology, topography, or infrastructure.
- **Geographic Information Systems (GIS)**: Computer-based tools for capturing, storing, analysing, and displaying spatial data.
- **Optical sensors**: Remote sensing devices that capture visible and near-infrared light.
- **Radar sensors**: Remote sensing devices that use radio waves to penetrate clouds and vegetation.
- **Remote sensing**: Obtaining information about objects or areas from a distance using satellites, drones, or aircraft.
- **Simulation**: Computer-based modelling of mining scenarios to predict outcomes.
- **Spectral analysis**: Examination of reflected light to identify mineral deposits.

**Concept Check Questions [Series 5]**

**Objective questions**

1. Remote sensing is important in mining because it provides ______ information without direct contact. (Linked to SLO 5.1)
2. Radar sensors are valuable because they can penetrate ______ and vegetation. (Linked to SLO 5.1)
3. GIS uses data layers to represent ______ aspects such as geology and infrastructure. (Linked to SLO 5.2)

**Short-answer questions**

4. State two applications of GIS in mine surveying. (Linked to SLO 5.2)
5. Mention two benefits of automation in computer applications. (Linked to SLO 5.3)

**Long-answer questions**

6. Analyse the importance of integrating remote sensing, GIS, and computer applications in mining operations. (Linked to SLO 5.4)
    - *Basic response*: Learners should explain how integration improves reserve estimation, environmental monitoring, and safety.

- *Value-added response*: Outstanding learners may extend the analysis by linking integration to sustainability, predictive safety systems, and advanced 3D modelling.

**Answers to Concept Check Questions [Series 5]**

1. Spatial.
2. Clouds.
3. Thematic.
4. Spatial analysis for mine planning and integration of survey data.
5. Reduces human error and speeds up calculations.
6. *Basic response*: Integration improves reserve estimation, environmental monitoring, and safety. *Value-added response*: Integration supports sustainability, predictive safety systems, and advanced 3D modelling for proactive decision-making.

**Answers to Pilot Questions [Series 5]**

1. Remote sensing is the science of obtaining information about objects or areas from a distance using satellites, drones, or aircraft.
2. Optical sensors and radar sensors.
3. They penetrate clouds and vegetation to reveal structures.
4. Identifying mineral deposits and monitoring environmental impacts.
5. By detecting land use changes, erosion, and pollution.
6. GIS is a computer-based tool for capturing, storing, analysing, and displaying spatial data.
7. Data layers represent geology, topography, and infrastructure.
8. It identifies optimal locations for shafts and tunnels.
9. It combines survey, geological, and environmental datasets.
10. It supports accurate decision-making in mine planning.
11. They provide 3D visualisation of ore bodies and mine layouts.
12. Automation reduces human error and speeds up calculations.
13. Testing excavation scenarios and predicting hazards.
14. It forecasts resource availability and supports proactive decisions.
15. By processing survey data quickly and accurately.

16. Remote sensing supplies imagery, GIS organises spatial data, and computer applications model ore bodies.
17. It helps detect erosion, pollution, and deforestation.
18. Identifying unstable zones and supporting ventilation planning.
19. By improving operational scheduling and efficiency.
20. Erosion detected through satellite imagery.

**References and Attributions [Series 5]**


- Course document: *MNE 502: Mine Surveying*.
- Suggested OER sources:
    - “Remote sensing mining exploration OER diagram” for Figure 5.1.
    - “Types of sensors remote sensing mining OER table” for Table 5.1.
    - “Applications of remote sensing mining OER” for Box 5.1.
    - “GIS data layers mine surveying OER diagram” for Figure 5.2.
    - “GIS spatial analysis mine planning OER image” for Plate 5.2.
    - “Integration survey data GIS mine surveying OER” for Box 5.2.
    - “3D modelling computer applications mine surveying OER diagram” for Figure 5.3.
    - “Automated data processing mine surveying OER image” for Plate 5.3.
    - “Simulation predictive analysis mine surveying OER” for Box 5.3.
    - “Integration remote sensing GIS computer applications reserve estimation OER diagram” for Figure 5.4.
    - “Environmental monitoring mining remote sensing GIS OER image” for Plate 5.4.
    - “Safety efficiency integration remote sensing GIS computer mining OER” for Box 5.4.