राष्ट्रीय भू-सूचना विज्ञान एवं प्रौद्योगिकी संस्थान
भारतीय सर्वेक्षण विभाग
विज्ञान और प्रौद्योगिकी विभाग

National Institute for Geo-Informatics Science & Technology
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Fundamentals of Surveying

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Objectives of the session

- Understand the **fundamental concepts, principles and scope of surveying**
- Appreciate the **historical evolution of surveying** from classical to modern digital methods
- Distinguish between **plane and geodetic surveying** and their applications
- Understand the **importance of accuracy, precision and survey control**
- Explain the role of surveying in **engineering projects**, with emphasis on **transmission lines**
- Comprehend the objectives and methodology of **field planning and reconnaissance surveys**
- Evaluate **terrain, elevation and alignment considerations** for transmission line projects
- Understand the significance of **tower spotting, span optimisation, ROW and clearance requirements**
- Appreciate the role of **horizontal and vertical control** in safe and economical transmission line design

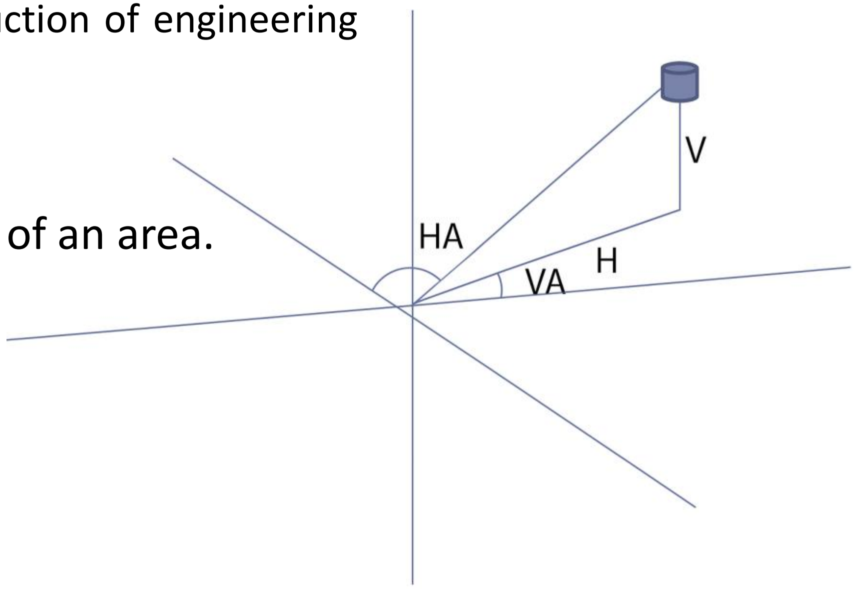
Basic Concepts of Surveying

Surveying:

- **The art and science of determining the relative positions of points** on, above, or beneath the surface of the earth by means of direct or indirect measurement of distances, directions, and elevations.
- **Provides essential data for planning**, design, and construction of engineering works such as roads, railways, Power lines, dams and buildings.

Objectives:

- To prepare maps and plans showing the natural and artificial features of an area.
- To determine relative and absolute positions of various points.
- To layout engineering projects accurately on the ground.



Objectives of Surveying

1. Data Collection

- To systematically collect accurate and reliable field data relating to the position, size, shape and elevation of natural and man-made features. This data forms the foundation for maps, plans and spatial databases.

2. Delineation of Features

- To accurately determine and delineate the positions of:
- **Natural features**, such as rivers, lakes, hills, forests, and drainage patterns
- **Man- made l features**, such as roads, railways, buildings, canals, and communication networks
- These features are depicted on maps in accordance with prescribed scales, symbols and cartographic standards.

3. Establishment of Boundaries

- To fix and demarcate **national, state, administrative, and property boundaries**. Surveying plays a crucial role in land registration, transfer of property, settlement of disputes, and maintenance of cadastral records.

4. Engineering and Construction

- To provide precise horizontal and vertical control for engineering works, including:
- Fixing centre lines of roads, bridges, transmission lines and railways
- Locating terminal points of tunnels
- Setting out foundations, alignments, and grades
- Such control ensures that construction is executed strictly in accordance with design specifications.

Importance of Surveying

- Ensures correct **location, alignment, and elevation** of engineering structures.
- Maintains **structural integrity and safety**, preventing misalignment and failure.
- Provides accurate setting out for **roads, bridges, tunnels, and transmission lines**.
- Supports **topographical mapping** for terrain representation, planning, and land-use analysis.
- Facilitates **navigation and charting** through mapping of coasts, rivers, and harbours.
- Enables **resource exploration and disaster management** through geological surveys, terrain modelling, and hazard assessment.

Ancient Beginnings and Classical Period (c. 2500 BC – 200 AD)

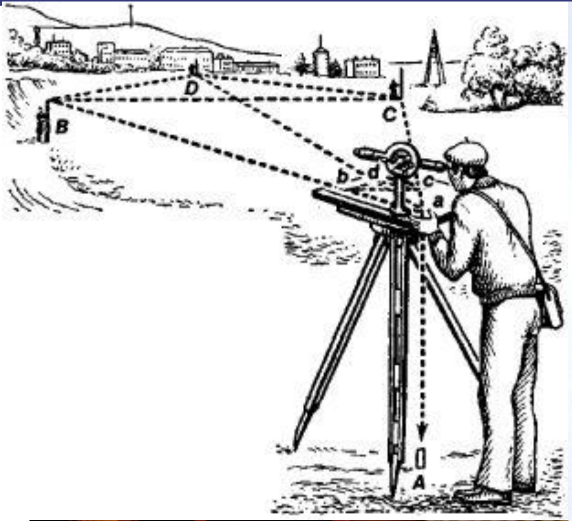
- **Babylon and Egypt**
- The **oldest known map**, discovered in **Babylon**, dates back nearly **4,500 years**, indicating early land measurement practices.
- In **Ancient Egypt**, surveyors called **“rope stretchers”** used calibrated ropes to re-establish land boundaries after annual **Nile floods**, a process known as *stretching the rope*.
- **The Roman Groma**
- The Romans employed the **groma**, derived from Mesopotamian techniques (c. 1100 BC), to set out **straight lines and right angles**.
- This instrument enabled accurate layout of **roads, cities, aqueducts and military camps**.

Ancient Beginnings and Classical Period (c. 2500 BC – 200 AD)

- **Ptolemy and Greek Cartography**
- **Claudius Ptolemy (100–170AD)** systematically recorded **latitude and longitude** for about **8,000 locations**.
- He developed mathematical methods to project the **spherical Earth onto a flat surface**, forming the basis of scientific cartography.
- **Heron of Alexandria**
- **Heron (10–70 AD)** authored *Dioptra* and *Metrica*, the **earliest surviving technical texts** describing surveying instruments and measurement techniques.

The Renaissance and Scientific Advancement

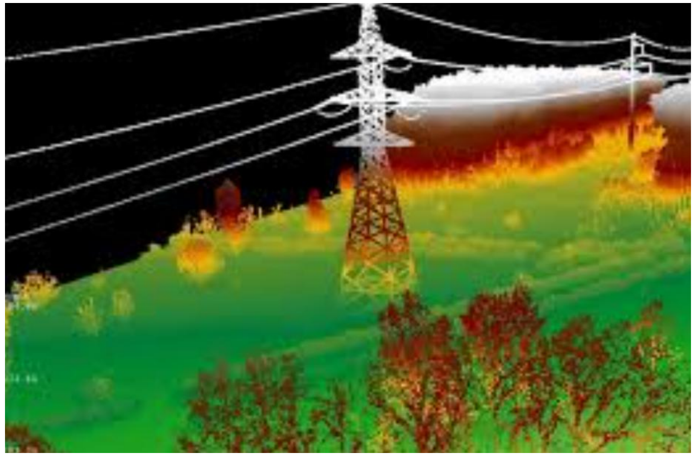
- **Plane Table and Holland Circle:** Following a period of decline in the Middle Ages, the art of surveying was revived during the Renaissance. The **plane table** came into use around **1590**. In **1610**, Jan Pieterszoon Dou invented the **Holland Circle**, which achieved an extraordinary angular resolution of **0.1 degrees**.
- **Optical Progress:** The 17th-century invention of the optical telescope eventually replaced older sighting methods and led to the development of the **theodolite** and the **dumpy level** by the 18th century.



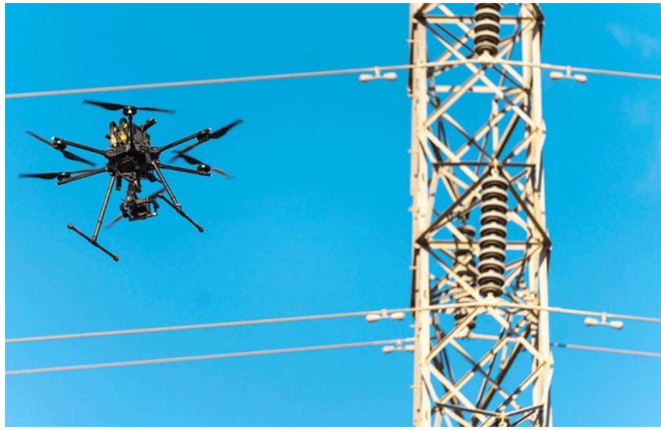
- **Survey of India (SOI):** Established in **1767 AD**, the SOI launched the **Great Trigonometric Survey (GTS)** on April 10, 1802.
- The Modern and Digital Era (mid-20th century)
- **EDM and Total Stations:** The 1950s saw the introduction of **Electronic Distance Measurement (EDM)**. By the 1970s, EDM was integrated with electronic theodolites, creating the **Total Station**, which remains the primary "workhorse" of surveying today.
- **Satellite Positioning (GPS/GNSS):** The launch of the first GPS satellite in **1978** allowed for real-time 3D positioning anywhere on Earth.

Latest Technology

- **LiDAR and UAV-based surveys** for high-resolution terrain models and corridor mapping
- **GNSS-RTK and Network RTK** for real-time, high-accuracy control and tower spotting
- **Integrated GIS platforms** for route optimization, constraint analysis and asset management
- **Digital elevation models (DEM) and 3D profiling** for precise sag–tension and clearance analysis.



- **Environmental and social overlays** to streamline forest clearance and EIA compliance
- **BIM and digital twins** for lifecycle planning, construction monitoring, and maintenance

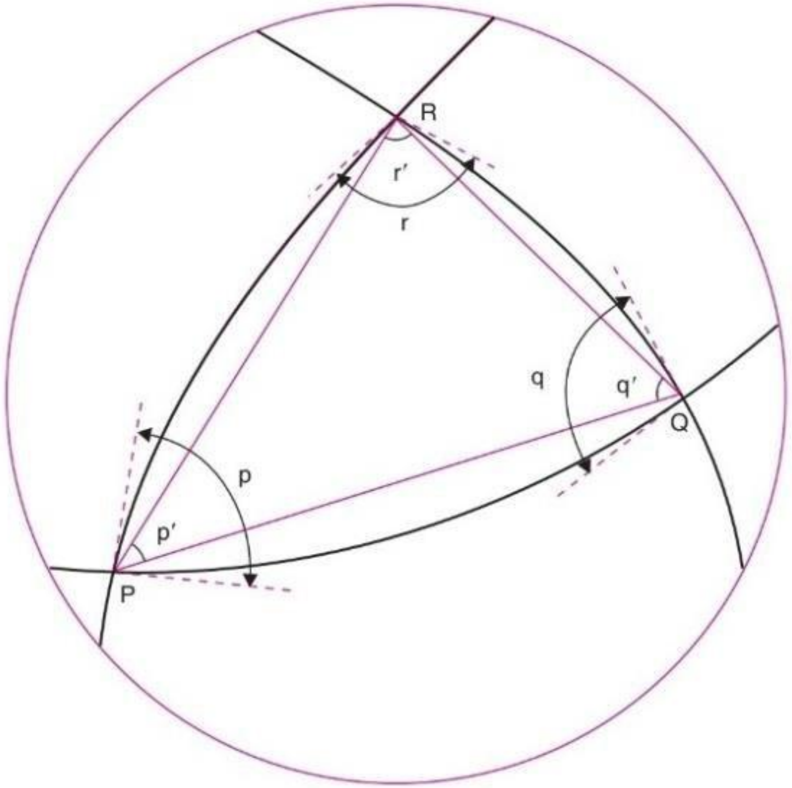


Classification of Surveying

Nature of survey field	Purpose	Instruments	Method
• Land • Hydrographic • Aerial	• Topographical • Cadastral • Engineering • Geological	• Chain • Compass • Plane table • Theodolite • ETS • GNSS	• Trilateration • Triangulation • Traversing • Levelling

Plane and Geodetic Surveying

S.No.	Plane Surveying	Geodetic Surveying
1	The earth's surface is considered as a plane surface.	The earth's surface is considered as a curved surface.
2	The curvature of the earth is ignored.	The curvature of the earth is taken into account.
3	Survey accuracy is low.	Survey accuracy is high.
4	Line joining any two stations is considered to be straight.	The line joining any two stations is considered as spherical.
5	The triangle formed by any three points is considered as plane.	The triangle formed by any three points is considered as spherical.
6	Carried out for a small area of <195.5 sq.km.	Carried out for an area of >195.5 sq.km.
7	Uses normal instruments like chain, measuring tape, theodolite, etc.	Uses more precise instruments and modern technology like GNSS/DGNSS.

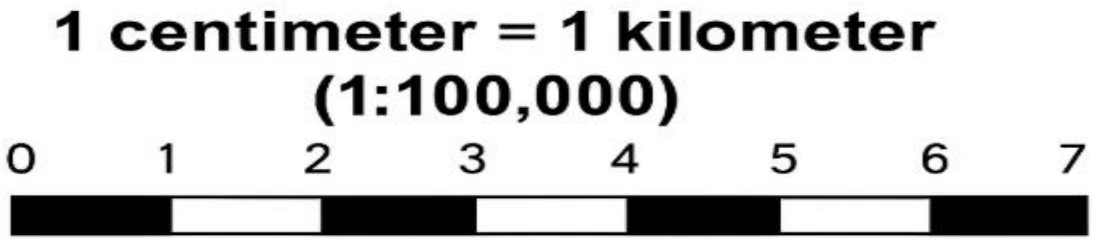


Principle of Surveying

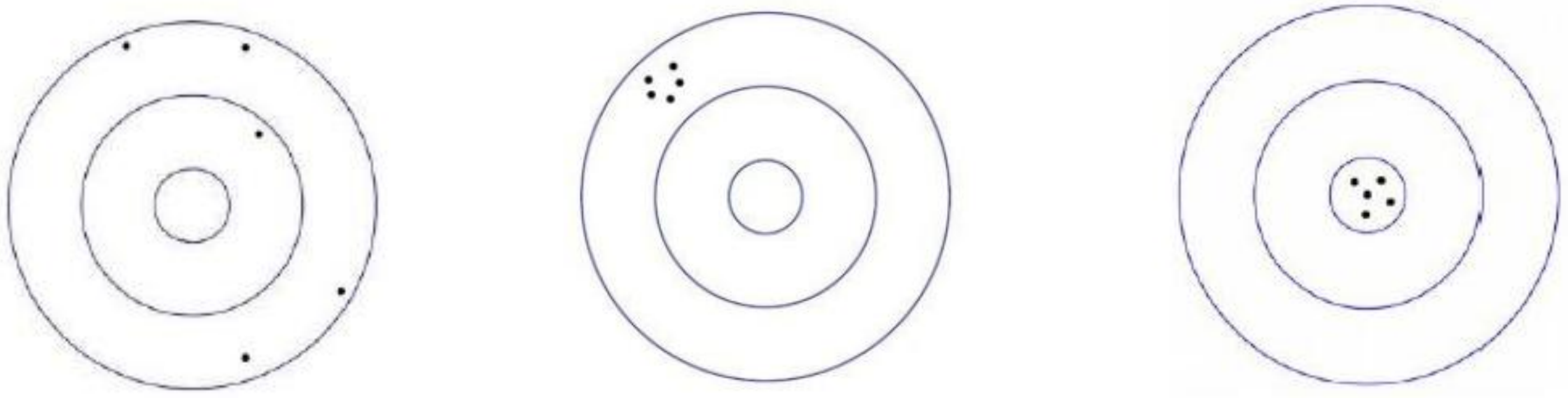
Principle	**Purpose / Description**	**Example Application**
Working from Whole to Part	Establish accurate framework before detailing	Control network before detail mapping
Location by Reference	Locate unknown points from known points	Triangulation, traversing
Economy of Accuracy	Maintain accuracy proportional to purpose	Engineering vs reconnaissance survey
Consistency in Work	Maintain same accuracy standard throughout	Horizontal & vertical control match
Independent Check	Verify by alternate method	Traverse closure, reciprocal levelling

Scales, Maps, and Plans

- **Scale** = Distance on Map / Distance on Ground
- **Engineer's Scale: 1 cm= 1km**
- **Representative Fraction (R.F):** Ratio of map distance to the corresponding ground distance is independent of units of measurement.
- Eg: **1:1000 (1 cm=10m)**
- **Graphical Scale:** A line drawn on the map so that its map distance corresponds to a convenient units of length on the ground



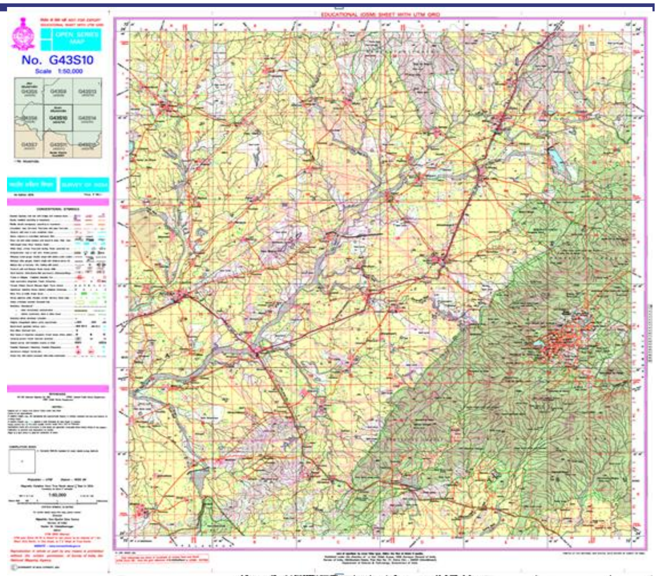
Accuracy and Precision



- The goal of any survey should be to produce accurate and precise observations. Often measurements with greater accuracy and precision requirements employ multiple observations to minimize procedural errors
- Systematic errors - due to instrument imperfection or environment.
- Random errors – due to human limitations.
- Compensating errors – tend to cancel each other.

Topographical Maps

- **Topographical maps** are general-purpose maps that delineate both **natural features** (such as rivers, lakes, forests, and hills) and **artificial features** (such as towns, roads, railways, and canals). Their primary objective is to depict all surface features legibly to show their correct horizontal and vertical relationships. These maps are vital for engineering projects, such as fixing the center lines of bridges or terminal points of tunnels. In India, they have historically been produced at scales such as 1:50,000.

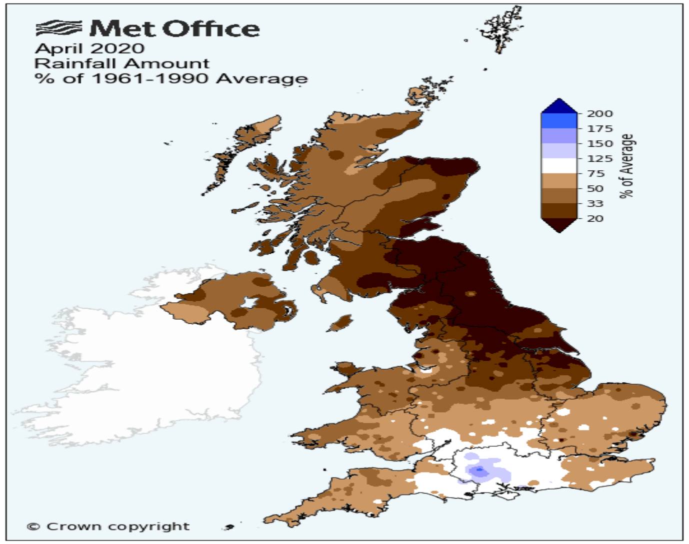


Cadastral Maps

- **Cadastral maps** are specialized large-scale maps used to **fix legal property boundaries** and calculate land areas. They are primarily employed for the registration and transfer of land parcels between owners, making them essential for municipalities and individual property records. Unlike topographical maps, their primary intention is the legal delineation of land ownership rather than the depiction of natural terrain features.

Thematic Maps

- **Thematic maps** focus on a **specific subject or theme** rather than general-purpose geographical data. They are used to analyze spatial patterns and are divided into two main categories:
- **Choropleth Maps:** These represent **quantitative data** (such as population density, yearly rainfall, or income) by using different color values or lightness within a defined area. The darker the value, the more intense the phenomenon being measured.
- **Chorochromatic Maps:** These visualize **qualitative data** (such as rock types, land use, or soil types) using different color hues. In these maps, the colors distinguish between categories but do not imply a hierarchy or rank.

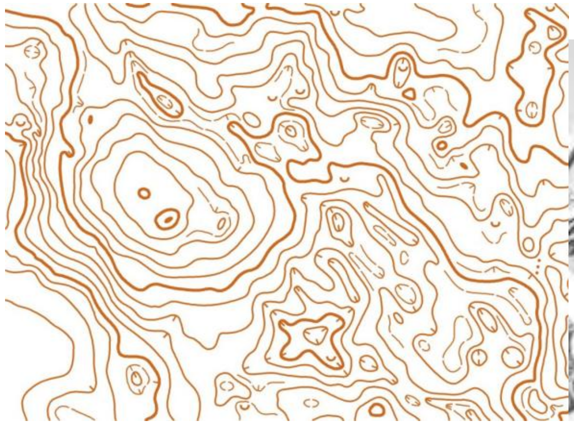


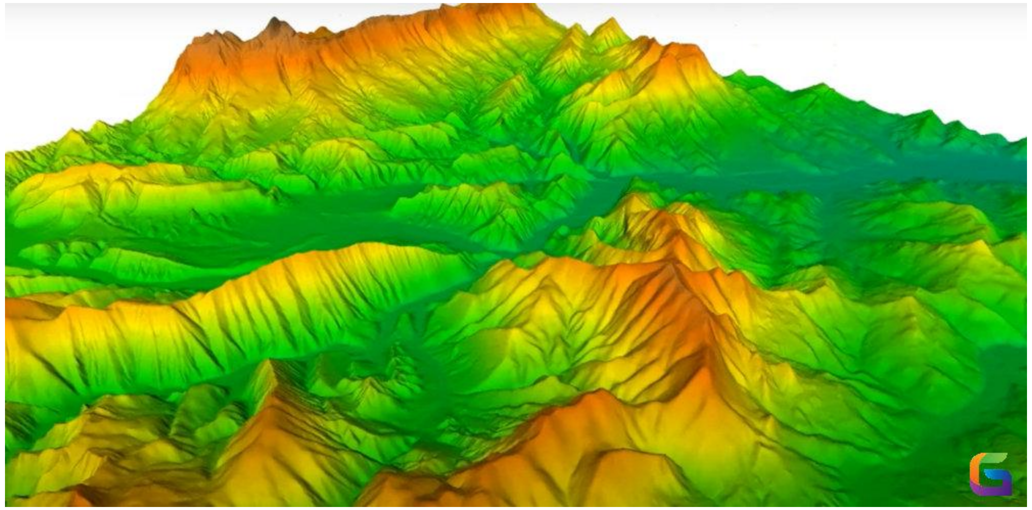
Political and Physical Maps

- **Political Maps:** These are used to delineate **administrative and national boundaries**, showing the division of states, districts, and municipalities.
- **Physical Maps:** These focus on the **topography of the Earth's surface**, emphasizing landforms and natural terrain.

Relief Maps

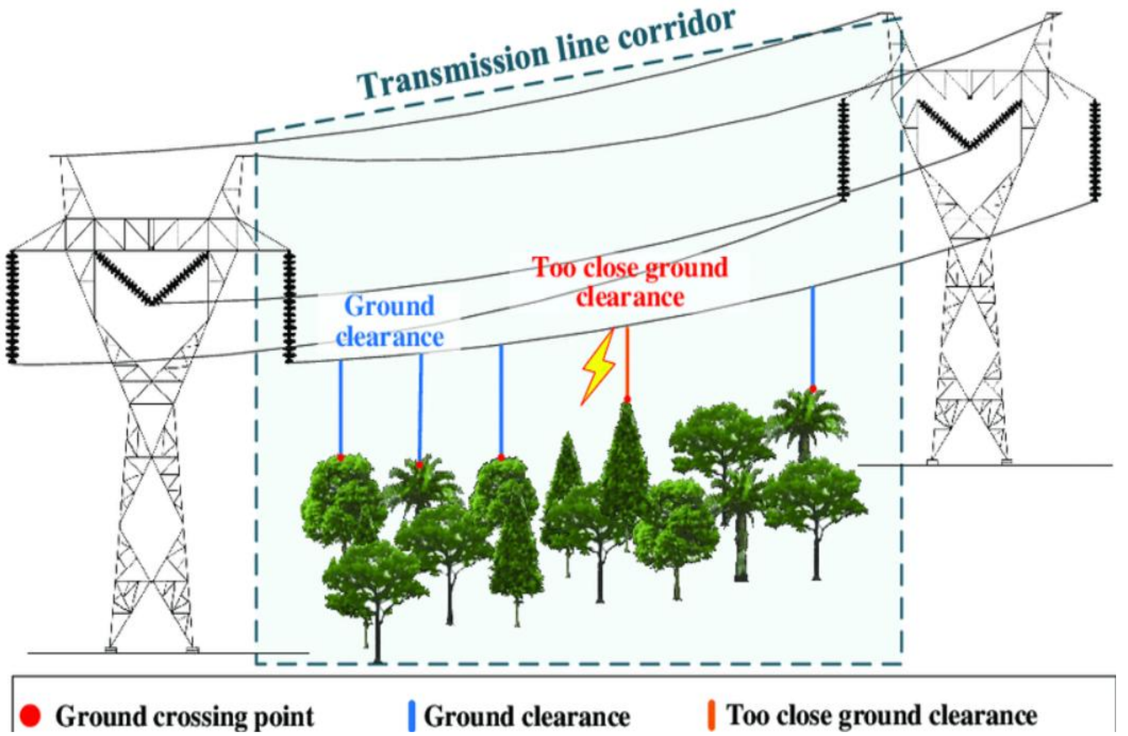
- **Relief maps** are designed specifically to show the **uneven nature of the Earth's surface**. They represent elevations and height differences through various methods:
- **Contours:** Imaginary lines joining points of equal elevation above a given datum (like Mean Sea Level).
- **Shading and Hachures:** Visual techniques used to provide a three-dimensional impression of slopes and terrain forms.
- **Digital Elevation Models (DEM):** Modern relief models that represent height information as a continuous surface, often used for flooding analysis or city modeling.





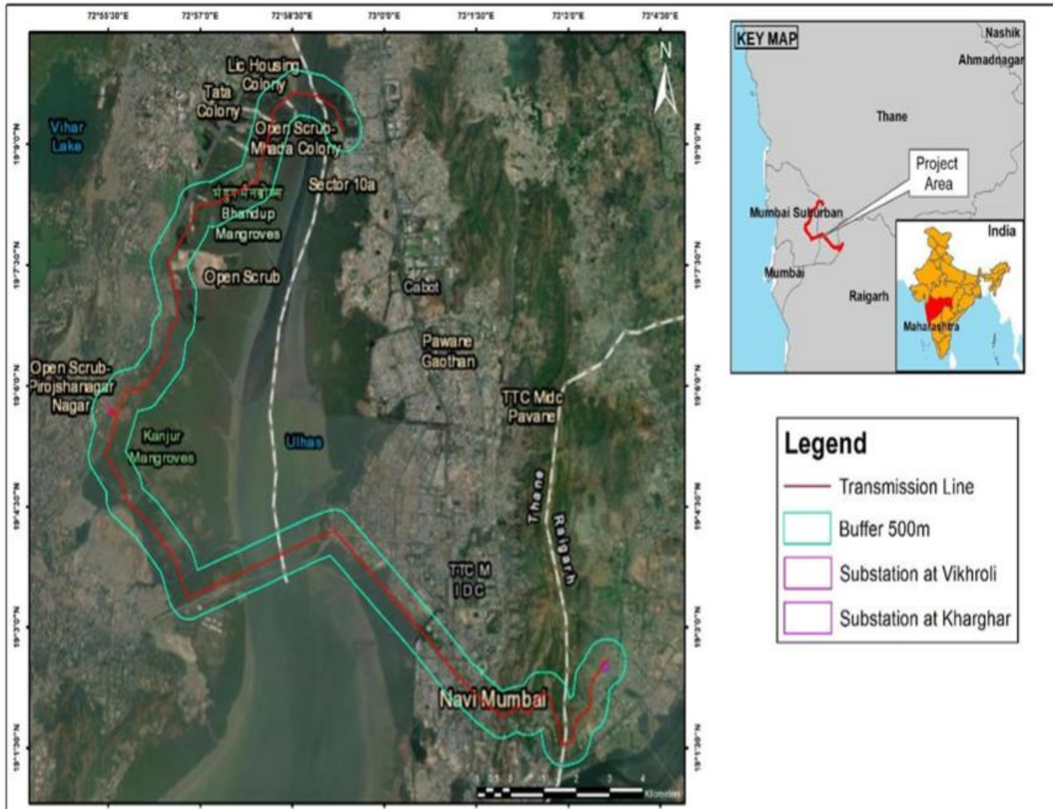
Field planning

- In **Power line transmission projects**, field planning and reconnaissance constitute the **first and most critical stage** of route alignment and terrain–elevation mapping. The objective is to identify an **economical, technically feasible, safe, and maintainable transmission corridor** while ensuring compliance with statutory clearances and construction constraints.
- Terrain and elevation mapping directly influences:
- Route length and angle points
- Tower spotting and span optimisation
- Foundation type and cost
- Right-of-Way (ROW) requirements
- Construction and maintenance accessibility
- Poor reconnaissance leads to **route revisions, foundation failures, cost overruns and delays**.



Objectives of Field Planning

- Define the **Area of Interest (AOI)** between substations
- Identify **alternative route corridors**
- Assess **terrain, elevation, and slope characteristics**
- Plan **horizontal and vertical control requirements**
- Minimise:
  - Route length
  - Number of angle towers
  - River, highway, railway, and power-line crossings
- Avoid:
  - Dense habitations
  - Forests and protected areas
  - Landslide-prone and flood-affected zones



Terrain Evaluation for Transmission Lines

Classification

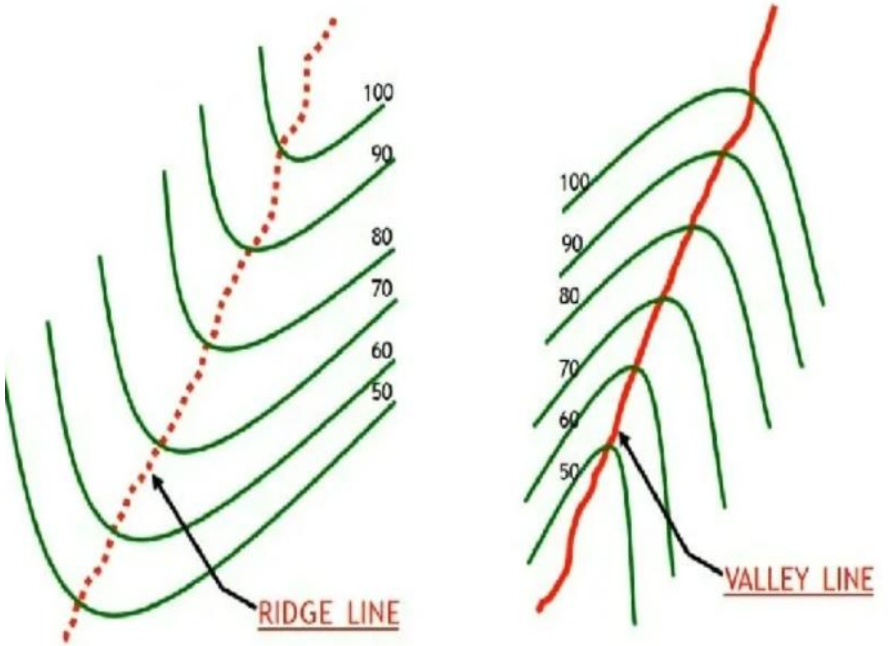
- **Plain terrain** – minimal elevation variation
- **Undulating terrain** – rolling slopes and shallow valleys
- **Hilly / mountainous terrain** – steep slopes, ridges, deep valleys
- This classification governs:
- Tower type (suspension / tension / special)
- Span length
- Foundation design
- Construction methodology

Reconnaissance Survey: Definition and Role

- A **reconnaissance (walk-over) survey** is a preliminary field inspection conducted before detailed instrument survey.
- To verify **satellite-based and toposheet-based alignments on ground**
- To identify **feasible tower locations**
- To assess **terrain difficulty and elevation variation**
- To confirm **construction and maintenance access**
- To evaluate **soil type and foundation feasibility**
- Reconnaissance is mandatory before finalising the alignment.

Identification of Critical Terrain Features

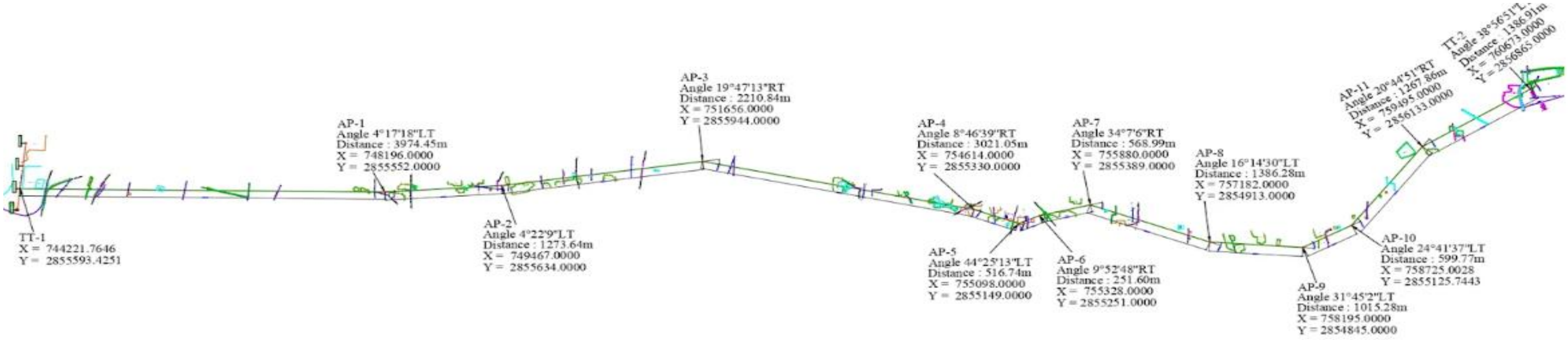
- Ridge lines suitable for tower placement
- Valleys requiring long spans or special towers
- River crossings and flood plains
- Landslide and erosion zones
- Snow-bound or high-altitude areas
- These features directly affect **tower spotting and elevation profiles**.



Horizontal Control and Alignment Planning

- Fixing tentative **angle points**
- Ensuring **intervisibility** between successive towers
- Reducingunnecessary deviations

Alignment Planning Principles :
Shortest feasible route
Minimum angle points
Right-angle crossings for roads, railways, and power lines
Avoidance of marshy land and riverbeds



Elevation Mapping and Vertical Control Planning

Accurate elevation data is essential for:

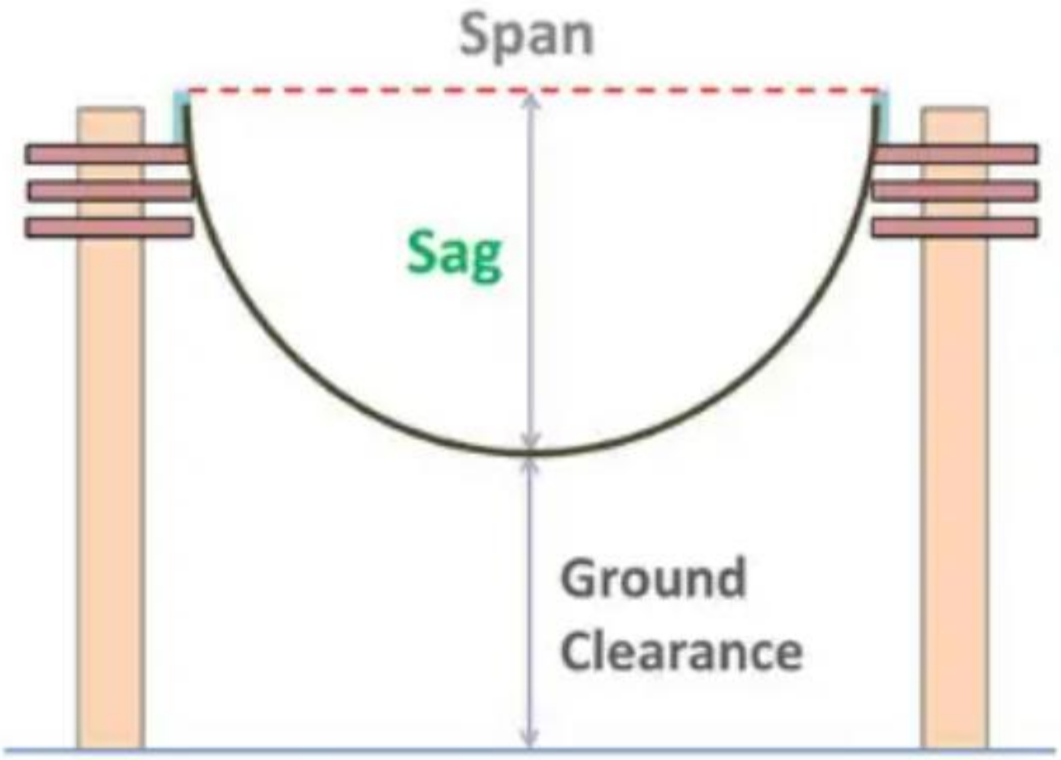
- Ground clearance verification
- Sag–tension calculations
- Crossing design (roads, rivers, power lines)

During reconnaissance:

- Existing benchmarks are identified
- Locations for temporary or permanent benchmarks are planned
- Levelling routes are decided to ensure closure accuracy

Benchmark locations must be:

- Stable
- Easily accessible
- Safe from disturbance during construction



Safety and Environmental Considerations

During reconnaissance, survey teams assess:

- Slope stability
- Avalanche or rockfall zones
- Flood-prone areas
- Forest and wildlife sensitivities

These inputs are essential for:

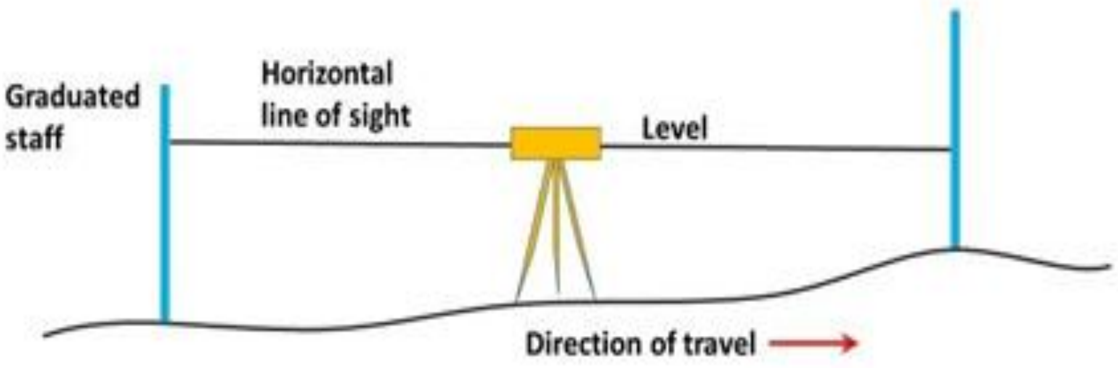
- Forest clearance proposals
- Environmental impact assessments
- Construction safety planning

Selection of Elevation Mapping Methods

- Based on terrain complexity, reconnaissance helps select:
- Direct levelling in plains
- Trigonometrical levelling in hilly terrain
- Spot height collection at tower locations
- Longitudinal profiling along centre line
- For mountainous terrain, **combination methods** are preferred for efficiency.

Accessibility and Construction Logistics

- Reconnaissance evaluates:
- Existing roads and tracks
- Need for temporary access paths
- Feasibility of material transport
- Helicopter or ropeway requirements in extreme terrain
- Good access planning reduces:
- Construction time
- Safety risks
- Maintenance difficulties



Reconnaissance Outputs

The reconnaissance stage results in:

- Identification of **alternative routes**
- Preliminary alignment sketches
- Terrain and elevation assessment notes
- Comparative route statements (length, crossings, terrain %)

These form the basis for:

- Route finalisation
- Detailed survey
- DPR preparation

Importance of Reconnaissance

- Transmission line projects traverse long and varied terrain
- Elevation errors affect conductor clearance and safety
- Poor alignment increases foundation and tower costs
- A well-executed reconnaissance ensures:
- Technically sound alignment
- Economical tower placement
- Safer construction and maintenance
- For **transmission lines**, field planning and reconnaissance are **not optional but decisive engineering stages**. Accurate understanding of terrain and elevation ensures that the final alignment is **safe, economical, constructible, and maintainable** throughout the life of the transmission asset. Effective reconnaissance significantly reduces downstream design changes, delays, and cost escalation.

Exercise

Review Questions

- Define **surveying** and explain its importance in **transmission line projects**.
- Why are **field planning and reconnaissance surveys** critical before finalising a transmission line alignment?
- How do **terrain and elevation mapping** influence **tower spotting and span optimisation**?
- What is **Right-of-Way (ROW)** and how does it affect **route alignment and safety clearances**?
- Why is **accurate elevation data** essential for **ground clearance and sag–tension calculations**?

Summary

- Surveying is the **foundation of all engineering and infrastructure development**, providing accurate spatial data.
- The discipline has evolved from **ancient land measurement practices** to **advanced geomatics technologies** such as GNSS, LiDAR, UAVs, and digital twins.
- In **transmission line projects**, field planning and reconnaissance are **decisive engineering stages**, not preliminary formalities.
- Terrain and elevation mapping directly influence:
- Route alignment and angle points
- Tower spotting and span optimisation
- Foundation design and cost
- ROW requirements and accessibility
- Proper evaluation of **terrain features, elevation control, alignment geometry and environmental constraints** ensures:
- Safe statutory clearances
- Economical construction
- Long-term operational reliability
- A **well-executed reconnaissance survey** minimises design changes, delays, and cost overruns, leading to a **technically sound and maintainable transmission asset**.

Discussions