A SunCam online continuing education course

What Every Engineer Should Know about Surveying

Part 1

Basics of Surveying – Basic concepts, measurements of distances and angles, Types and classes of surveys, surveying instrumentation, methods of linear measurement, types of measurements, chains, tapes, standard conditions for use of steel tapes, taping accessories and their use. General principles of EDMI operation, level, theodolite, total stations. Field procedures for total stations in topographic surveys, surveying applications, and field notes.

by

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The objective of this course is to acquire theoretical and practical knowledge of use of surveying instruments, surveying measurements, levelling, topographic surveys, and construction surveys. This course is divided into four (4) parts:

Part 1: **Basics of Surveying –** Basic concepts, measurements of distances and angles, types and classes of surveys, surveying instrumentation, methods of linear measurement, types of measurements, chains, tapes, standard conditions for use of steel tapes, taping accessories and their use. General principles of EDMI operation, level, theodolite, total stations. Field procedures for total stations in topographic surveys, surveying applications, and field notes.

Part 2: **Measurements and Computations:** Units of measurements, Methods of linear measurement, types of measurements. Horizontal angle, horizontal distance, vertical angle, vertical distance. accuracy and precision, errors and mistakes, accuracy ratio, stationing, location methods, accuracy and precision, errors and mistakes, accuracy ratio. Measure horizontal distance, Identify and use different measurements, identify equipment of horizontal measurement, Identify the sources of errors and corrective actions

Part 3: **Leveling:** Definitions, types of leveling staff, leveling operations, techniques of leveling, benchmark. Leveling (vertical control survey), profile and cross-section leveling, reciprocal leveling, peg test, errors in leveling, contours and their characteristics, various methods of Contouring. Contour intervals, spot elevations, contour properties, locating contours, existing and proposed grading plans. Examples of leveling and calculations. **Angles and Directions:** Horizontal and vertical angles, meridians, types of horizontal angles, azimuths, bearing, relationship between bearings and azimuths. Reverse directions, azimuth and bearings computations, magnetic declination, types of compasses.

Part 4: **Traverse Surveys:** Open and closed traverses, latitude and departures, computation of error of closure, and the accuracy of a traverse, traversing with total station instruments. Rules of adjustment, effects of traverse adjustments on the original data, computation of omitted measurements, area of closed traverse methods, use of computer programs. Calculations and examples for traversing, area, angles, bearing, and distances. Calculations and examples for traversing, area, angles, bearing, and distances. **Construction Surveying**: Learning Objectives, Introduction, Setting out a Peg on a Specified Distance and Bearing, Setting Out Small Buildings, Sewer and Tunnel Construction, Exercise.

PART 1 - BASICS OF SURVEYING

1.1. Learning Objectives

1. Define surveying and other technical terms
2. Describe the importance of surveying
3. Know the application of surveying

1.2 Introduction

Surveying has been important since the beginning of civilization. Surveying is a discipline, which encompasses all methods for measuring, processing, and disseminating information about the physical earth. Locations, directions, areas, slopes, and volumes are determined from these measurements. Surveying information obtained and recorded in the field can be represented as numerical data, as well as graphically by diagrams, maps, profiles, and cross sections.

Surveying is the science of determining the relative positions of objects or points on the earth's surface. These points may be any physical thing: a highway, culvert, ditch, storm drain inlet, or property corner. Distances and directions determine the horizontal positions of these points. The vertical positions are determined by differences in elevations measured from a reference location known as a benchmark (or datum).

1.3 Definition and Technical Terms

Surveying is the science, art, and technology by which lines, distances, angles, and elevations are established and measured on or beneath the Earth's surface.

Land surveying is the technique and science of accurately determining the terrestrial (earthly) or three-dimensional position of points and the distances and angles between them. These points are usually on the surface of the Earth, and they are often used to establish maps and boundaries for ownership, locations, such as building corners or the surface location of subsurface features, or other purposes required by government or civil law, such as property sales

Simply stating, **surveying** involves the measurement of distances and angles. The distance may be horizontal or vertical in direction. Vertical distances are also called elevations. Similarly, the angles may be measured in horizontal and vertical plane. Horizontal angles are used to express the directions of land boundaries and other lines.

There are two fundamental purposes for measuring distances and angles:

1. The first is to determine the relative positions of existing points or objects on or near the surface of the earth.
2. The second is to layout or mark the desired positions of new points or objects, which are to be placed or constructed on or near the surface of the earth.

Surveying measurements must be made with precision in order to achieve a maximum of accuracy with a minimum expenditure of time and money. A **land surveying** professional is called a **land** surveyor

Application of Surveying: Surveying is widely used in almost all civil engineering projects such as construction of building, bridges, reservoirs, dams, railways, roads, irrigation projects, etc. Surveying can be classified based on different factors such as field of survey (like land survey, marine survey, photogrammetric, etc.), object of surveys (like Engineering purpose, military purpose, etc.), method of survey (like Triangulation, Trilateration, etc.), and instruments used (Like chain surveying, theodolite surveying, levelling, Total Station, etc.).

1.4 Required Knowledge for Surveyor

The practice of surveying is an art, because it is dependent up on the skills, judgments and experience of the surveyor. It may also be considered as an applied science, because field and office procedures rely upon a systematic body of knowledge

Surveyors work with elements of geometry, trigonometry, regression analysis, physics, engineering, metrology, programming languages, and the law.

1.5 Surveying Equipment

Surveyors use equipment, such as theodolites, digital levels, total stations, robotic total stations, , GPS receivers, retroreflectors, 3D scanners, radios, handheld tablets, subsurface locators, drones, GIS, and surveying software.

1.5.1 Conventional surveying Equipment

With the conventional surveying equipment, survey work used to be slow and tedious. Instruments have a major importance in the field of survey. There are numerous instruments which are used in surveying. With the passage of time instruments have been modified and more accurate.

Before choosing personnel and selecting survey equipment, it is important to determine the accuracy required for the job. Cut and fill slopes and ditches, for example, don't require the same accuracy as drain inlets and finished pavement grades.

<u>Linear measurements</u>

- **Chain, tape, distance measuring wheel, pacing**. An engineering chain is used to measure the length of a site or place. A chain is 66 feet long. Each chain is further divided into rods and links. A 66 feet long chain consists of 100 links and 10 rods. Each rod is of the length of 6 feet. There are 10 Chains in a furlong. A furlong is equal to 660 feet.

Figure 1.1 Distance measuring tapes (steel - measures 25 ft to 300 ft)

Figure 1.2a Distance measuring wheel

<u>Angular measurements</u>

- Compass and ordinary theodolites

Figure 1.2b Ordinary theodolite (left), Compass (right)

Levelling work

- Dumpy level and a levelling staff

1.5.2 Modern Surveying Equipment

Digital Level is a reliable and accurate electronic level that provides error free measurements. Optical reading is no longer needed. Just let the electronic eye do it. The digital level automatically determines height and distance, no more misreading and interpretation errors in reading the staff / rod (Figure 1.3).

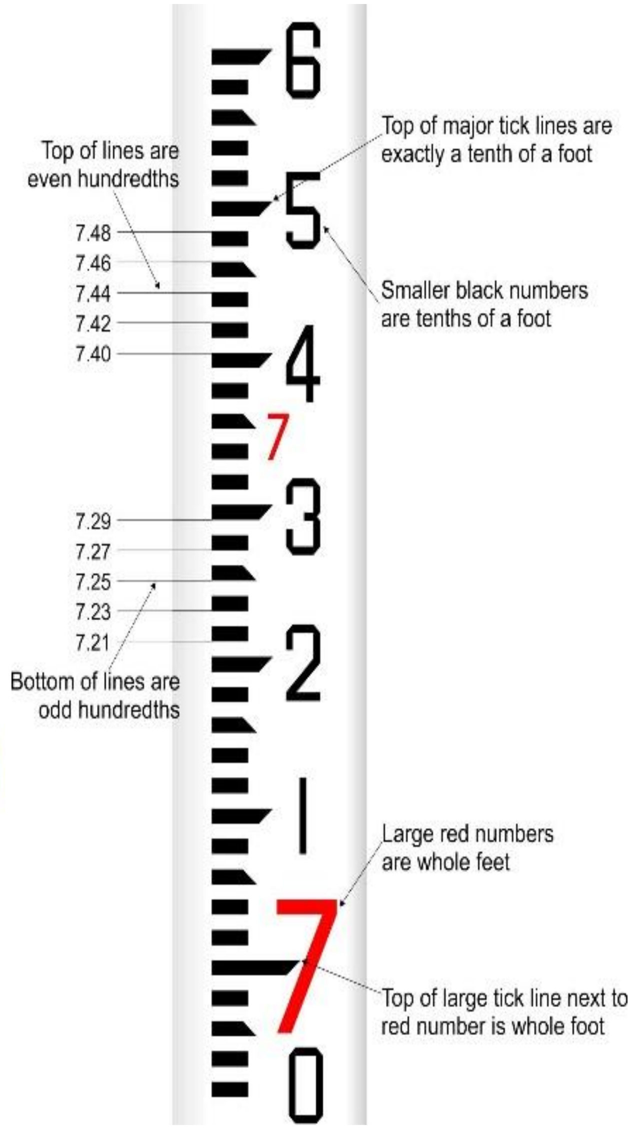
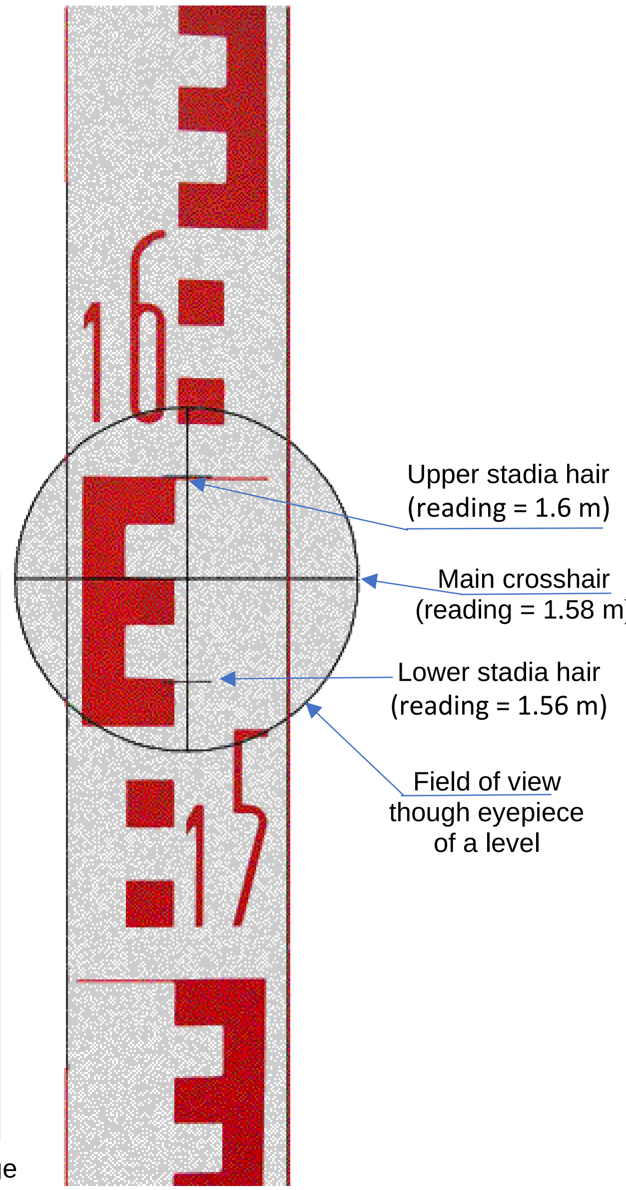
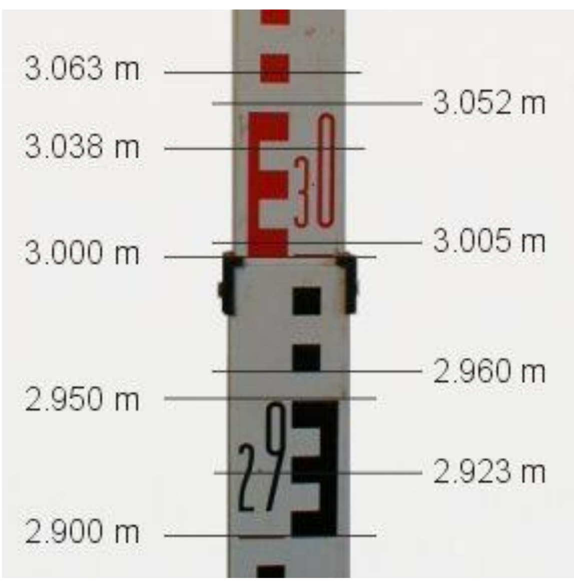


Figure 1.3a **(**Left) digital level
(Right) example of reading leveling rod / staff. (Note: readings are in feet, source: civilseek.com)

Levels are used to measure differences in height between two points (differential leveling) or to determine the height (elevation) of objects or structures, contouring, and construction surveying.

Leveling Staff or Rod A level staff, also called leveling rod, is a graduated (numbered and marked) wooden or aluminum rod, used with a leveling instrument to determine the difference in height between points or heights of points above a vertical datum.





Source: Sean R Milligan, lecturer, Orkney College

Figure 1.3b **E**xamples of reading E-faced leveling rod / staff.
(Note: readings are in meters)

Electronic Theodolite:

Electronic theodolite (Figure 1.4) is a proven tool that can provide accurate measurements. It is also capable of storing the measurement values without writing them on a paper. Horizontal angles, vertical angles can be measured and all survey operations can be performed using electronic theodolite. An electronic theodolite (transit) in combination with an electronic distance meter (EDM, Figure 1.5) can measure distances electronically.

Figure 1.4 Electronic Theodolite

Electronic Distance Meter (EDM):

EDM is used for measuring the distance between two points. Instrument is set up at one point and a reflector is set up at the other point. Reflector can be a pole or a tripod with a prism mounted on the top (Figure 1.5) of any other target. Other targets may be any solid objects, which can properly reflect beam of light emitted from EDM.

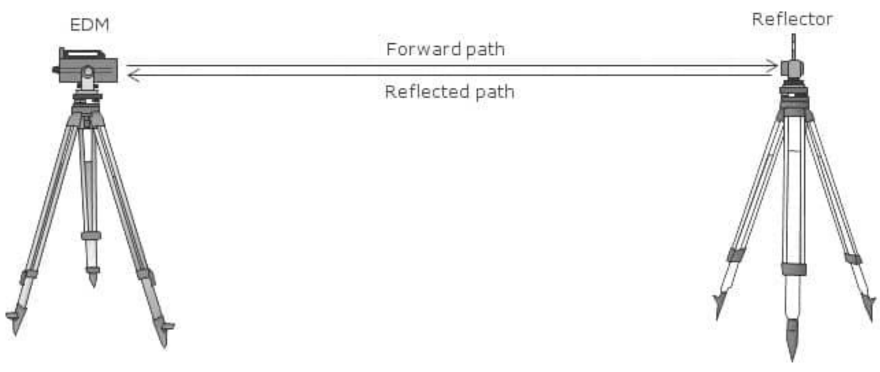


Figure 1.5 Electronic Distance Meter (EDM) and Reflector (Prism)

Total Station

A total station (Figure 1.6) is a sophisticated device which combines all of the functionality of a theodolite with other abilities such as an auto level and electronic distance meter. By using laser pulses, total stations can gather much more accurate information over extreme distances. Since data are gathered electronically, it can be instantly imported into the computer for analysis.

- Can electronically measure both angles and distances
- Inbuilt automatic atmospheric sensor
- Measures the atmospheric pressure and temperature in real time
- Applies the required corrections in measurements automatically

Figure 1.6 Total Station

Figure 1.7 Closer View of Data Collector

Data recorder (collector)

Data collector (Figure 1.7) is a necessary component of the total station. All entered and field data are stored in data collector, which is:

- •A hand-held computer
- •containing an alphanumeric keyboard and LCD display
- •Works with the help of a rechargeable compact battery
- •Records all the measurements in suitable format
- •Performs some basic computations such as figure closures and adjustments

Use of Total Station

There are two ways the total station measures: using the traditional and still more common prism, or through reflector less technology.

With the prism method, the total station sends out invisible infrared waves that are reflected by the prism, which is typically attached to a pole. By measuring the prism's position and knowing the precise angle and distance to that prism, the total station calculates the prism's location or coordinates. Measurement to a typical 360-degree prism is roughly 5,000 feet (1500 meters), and measurement to a standard round prism can reach as far as 9,800 feet (3,000 meters). A 360-degree prism can face any direction, whereas a standard round prism only has one face that must look toward the total station.

Consider an application in which a stub-up needs to be located. The instrument is set up in the dirt off the building pad, and the person holding the prism pole, with the field controller attached, is guided by the field software to the correct location. The total station "tracks" the prism and continuously updates its position in the field software. When the exact position is reached with the prism, the field software displays a confirmation message.

The reflectorless method does not use a prism. Instead, it uses a visible red laser beam that allows the user to layout or measure points from any surface that is able to reflect it. The reach of the laser beam varies between instruments – it ranges from 1,300 feet to 6,500 feet (400 to 2,000 meters).

When determining which method to use, consider the location and logistics of the area being measured. A prism pole allows the instrument to reach places and measure points that can't be achieved using a reflectorless method — for example, measuring around piles of building construction materials or other obstructions where a laser beam is unable to reach the desired point. In these cases, a prism and prism pole can be used to measure above the obstruction. Likewise, when trying to measure around an overhead beam or rafter, the prism pole can be inverted to allow measurement of a location unable to be seen directly with the red laser.

Reflectorless technology can also help makes job sites safer. For example, if you need the length of a beam two stories high, you simply aim and shoot points at each end of the beam and you are done – no ladder or scaffolding required. Whether you need to measure hard to reach locations inside buildings, outside of buildings or on the site around the building, reflectorless measurement technology helps keep human out of harm's way.

MANUAL VS. ROBOTIC TOTAL STATIONS

Manual and robotic total stations are available as both reflectorless and prism models. The biggest difference between these two types of total stations is that robotic total stations have a motor so they can be controlled remotely instead of manually.

The manual total station is a two-person operation. The instrument must be manually turned and the prism must be sighted each time. The electronic distance measurement (EDM) also must be triggered each time.

The robotic total station is a one-person operation. The station automatically follows the prism and is continuously measuring with the EDM.

When determining which total station and method is best for the job or operation, consider these points:

- A robotic total station has a two-to-one labor ratio and enables the layout of 25 percent more points per day compared to a manual total station.
- A tape measure and plumb bob requires two to three people and allows for the layout of about 200 points versus about 600 points with a robotic total station.

Cost of a robotic total station is 4 to 5 times more than a manual Total Station. Some of the benefits of a robotic total station are:

- More accurate measurements
- Greater productivity
- Fewer mistakes
- Reduced rework
- Better Quality Assurance

Poles, Tripods, and Mounts

Poles, tripods, and other mounting accessories (Figure 1.8) are essential for surveyors to ensure solid, stable readings. These mounts can be used for all kinds of surveying equipment, including prisms, lasers, theodolite, total station, GPS and levels

Figure 1.8 Survey Equipment Accessories Single Prisms (top left), prism mounting rods (right), ranging rods (bottom left), and Tripod (for mounting / supporting surveying equipment)

Using Total Station

Entry of Initial Data

- Equipment switched on
- Some initial data fed into the data collector before starting the work. For example, description of the project, date of survey, details of survey team, choice of measurement units etc.
-

Entry of traverse station (occupied point) and feature (sighted Point) code

- A suitable coding system given for stations for their recognition

Traverse station

- Additional data such as height of instrument, station name and number, coordinates of traverse station (using GPS) also entered

Sighted point

- Additional data like height of reflector (prism), point name and number etc. also noted

Collect Field Data

- The rod person keeps on changing position of the prism with the rod placed upright on various survey points. The surveyor operating the total station focuses on the prism for each survey point, which records position of the point. The surveyor enters a code in the data collector for each point recorded. For example, TC – top of curb, BC – bottom of curb, RIM-center of rim of manhole, etc.

Typical format of field data

Typically, the total station determines the geometry, and the operator has to input the features. Each brand of data collector has its own set of codes, but those shown below are typical.

DATA EXPLANATION

AC:SS (Activity: Sideshot/keyboard entry)
PN:3 (Point Number:3/keyboard entry)
PD:24IN MAPLE (Point Description:24 inch Maple/keyboard entry)
HZ:16.3744 (Horizontal angle:16.3744 /by Total Station)

VT:90.2550 (Vertical "Zenith" Angle: 90.2550 /by Total Station)
DS:565.855 (Distance: 565.855 ft/by Total Station)
AC:SS (Activity:Sideshot/Keyboard entry)
PN:4 (Point Number:4/keyboard entry)
PD:SAN MH (Point Description:Sanitary Manhole/keyboard)
HZ:70.3524 (Horizontal angle:70.3524 /by Total Station)
VT:91.1548 (Vertical "Zenith" Angle: 91.1548 /by Total Station)
DS:436.472 (Distance:436.472 ft/by Total Station)
AC:SS (Activity:Sideshot/keyboard entry)
PN:5 (Point Number:5/keyboard entry)
PD:SE COR BLDG (Point Description:Southeast corner Bldg/keyboard)
HZ:225.1422 (Horizontal angle:225.1422 /by Total Station)
VT:88.3035 (Vertical "Zenith" Angle: 88.3035 / by Total Station)
DS:265.934 (Distance:265.934 ft/by Total Station)

Transfer of data and its processing

- Total station is supplied with software
- For processing the data stored in the data collector, first the data have to be downloaded from the data collector to a computer where the software is installed
- Data collector directly connectes to the computer through a cable / memory card reader
- Note: Before each use, battery of the data collector should be recharged by connecting to an electric outlet.

Plotting of Details

- After processing the field data in the desired form, data are imported into the CAD system for preparing drawings.
- CAD drawing can be plotted at any scale on a printer, plotter, or to a pdf format.
- Symbols necessary for plotting different topographical features can be extracted from the symbol library provided in the software

Global positioning system (GPS), for surveying, is a satellite-based navigation system. GPS uses a network of satellites, which communicate with receivers on the ground. When a receiver requests data to calculate its location, four or more GPS satellites (Figure 1.9) will communicate with the receiver, sending the position of the satellite, the time the data was transmitted and the distance between the satellite and the receiver.

GPS Principles

1. At least four (4) satellites are required to solve four (4) unknown parameters: Latitude, Longitude, Height and Receiver time offset (difference between the receiver clock's indicated time
2. A well-defined time scale reference such as UTC (Coordinated Universal Time), TAI (International Atomic Time) or GPST (GPS Time))

The following **five** (5) **basic steps** are required to obtain these coordinates:

1. All GPS satellites have synchronized atomic clocks as time keepers.
2. The coordinates of all satellites, acting as moving control stations, are known precisely with the help of system control.
3. Satellite coordinates and time signals are transmitted to ground receiver.
4. These signals reach the ground delayed by distance traveled.
5. Making use of simple resection principle and the range information to each satellite, the receiver computes its coordinates including the latitude, longitude and height (X, Y, and Z coordinates).

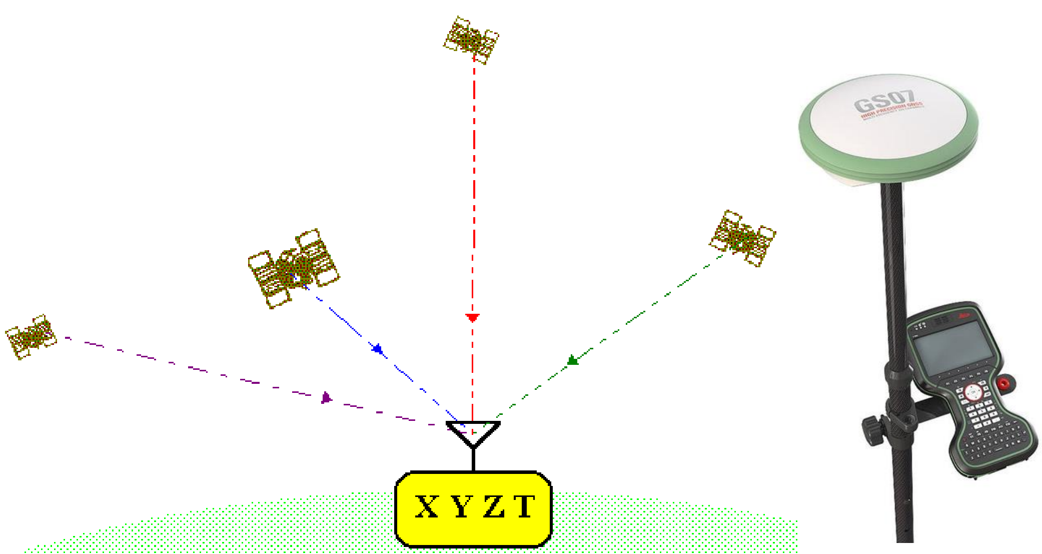


Figure 1.9 (Left) Signal from at least four satellites to obtain X, Y, Z coordinates and GPS Time (T); (Right) GPS receiver and data collector

Drones for large scale mapping:
Taking aerial photography using helicopter is very costly. So, we can use drone instead of it. It is much cheaper than all other means. Drone will give us live images of a site from which we can get idea about current situation of site without going anywhere. Drone survey is a time saving technology which ultimately saves cost, as well. Some advantages of use of drone in survey are as follows:

1. Faster data collection- We can collect data for land much faster than old methods.
2. Access to Unreachable area. We can access the are we can't reach easily or very difficult to go there and collect data
3. High quality of data- Areal view give us high resolution of data which we can insert in software for 3D modeling.
4. Reduces risk – Reduces risk related to safety and accident may be due to sloppy surfaces.

1.6 The Basic Surveying Methods

Most surveying activities are performed under the assumption that measurements are being made with reference to a flat horizontal surface. This requires some further explanation.

The earth actually has the approximate shape of a spheroid that is the solid generated by an ellipse rotated on its minor axis (Figures 1.10A). When we try to approximate the shape of earth, we need to choose an appropriate reference model.

Reference ellipsoid and geoid models: Geodetic coordinate systems [include geodetic latitude (north/south), longitude (east/west), and height (also known as geodetic heigh)] use sophisticated models of the Earth's surface called ellipsoid models and geoid models to account for the irregular shape of the Earth. The geoid is a modeled surface of the Earth, which coincides with the mean sea level (MSL) elevation.

The ellipsoid models account for curvature of the Earth by defining the Earth as an ellipse. Ellipsoid is a mathematical approximation of the **Earth's** surface, used as a reference frame for computations in geodesy, astronomy, and the geosciences. A commonly known **ellipsoid** is WGS84. Surveyors in the United States currently use the North American Vertical Datum of 1988 (NAVD88)

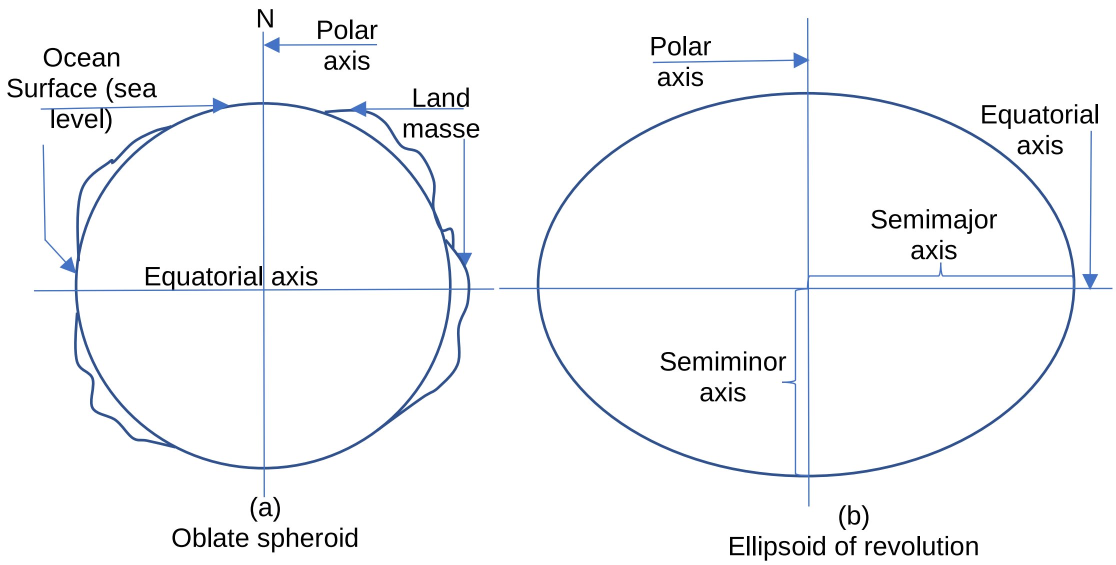


Figure 1.10A. (left) Shape of the earth, (right) Ellipsoid approximation of earth

Datums

A datum is a reference system from which measurements are made. In surveying, we typically use either a flat two-dimensional (plane) or three-dimensional (spheroid or ellipsoid) datum (Figure 1.10A)

The National Geodetic Survey (NGS) provides a hybrid geoid model, GEOID18, to access national (vertical heights or elevations, and horizontal coordinates) datums from anywhere with precise GPS data!

Hybrid geoid models (GEOID18) are used to convert NAD83 ellipsoid heights (h) from Global Positioning Systems (GPS) observations to orthometric heights, H (elevation). The GEOID18 provides orthometric heights consistent with the North American Vertical Datum of 1988 (NAVD 88)

The relationship between the geoid, Ellipsoid, and the Earth's surface is shown in Figures 1.10B and 1.10C.

$$\mathbf{H = N + h}$$

where, h = ellipsoidal height (ft or m)
N = geoid height (ft or m)
H = orthometric height (elevation; ft or m)

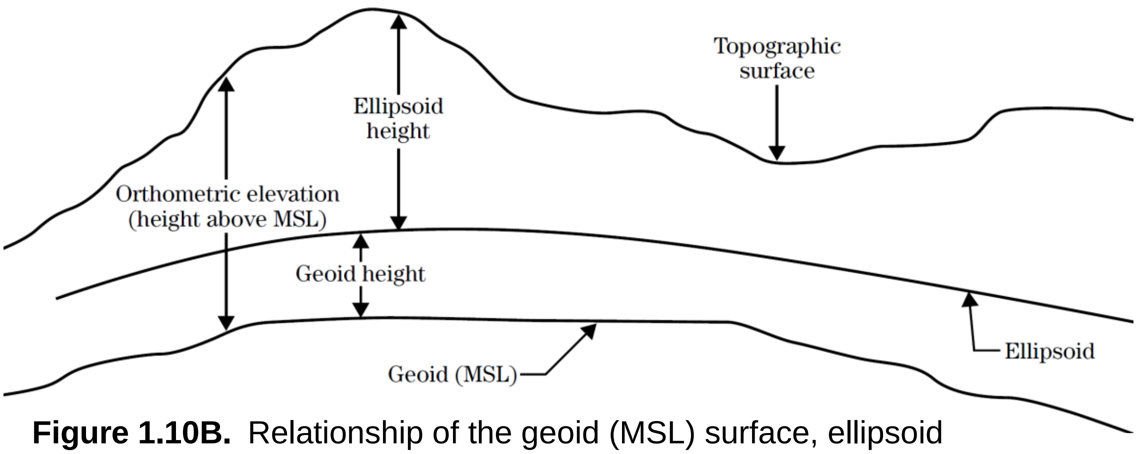


Figure 1.10B. Relationship of the geoid (MSL) surface, ellipsoid surface, and topographic ground surface to each other.

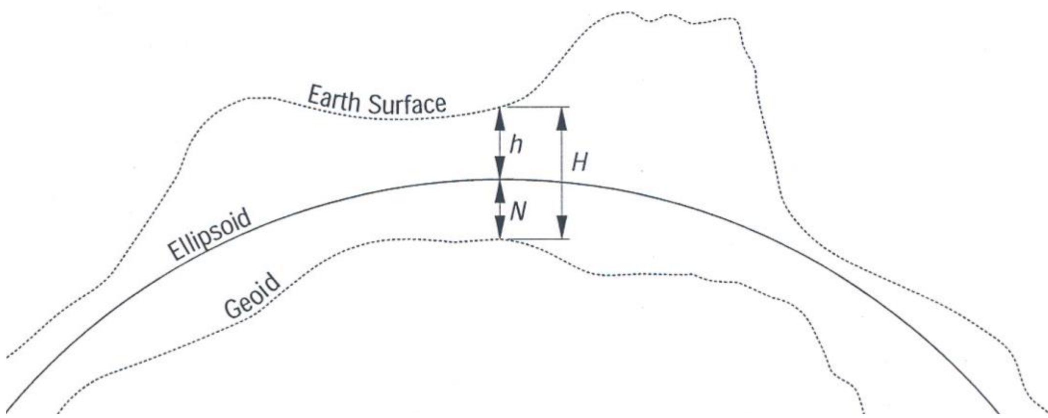


Figure 1.10C. Mathematical Relationship among ellipsoid heights (h), geoid height (N) and orthometric heights, H (elevation)

By definition, the curved surface of a sphere is termed a *level surface*. The direction of gravity is perpendicular to this level surface at all points, and gravity is used as a reference direction for all surveying measurements. The *vertical direction* is taken to be the direction of gravity (or direction of a freely suspended plum bob). In addition, the *horizontal direction* is the direction perpendicular to the vertical direction of gravity (Figures 1.11A, 1.11B))

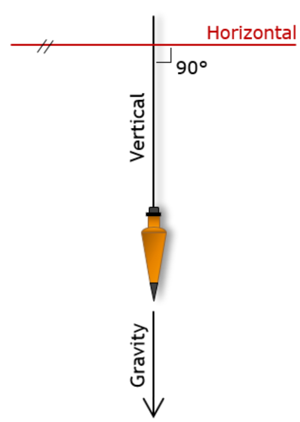


Figure 1.11A. A freely suspended plumb bob represents direction of gravity of the earth

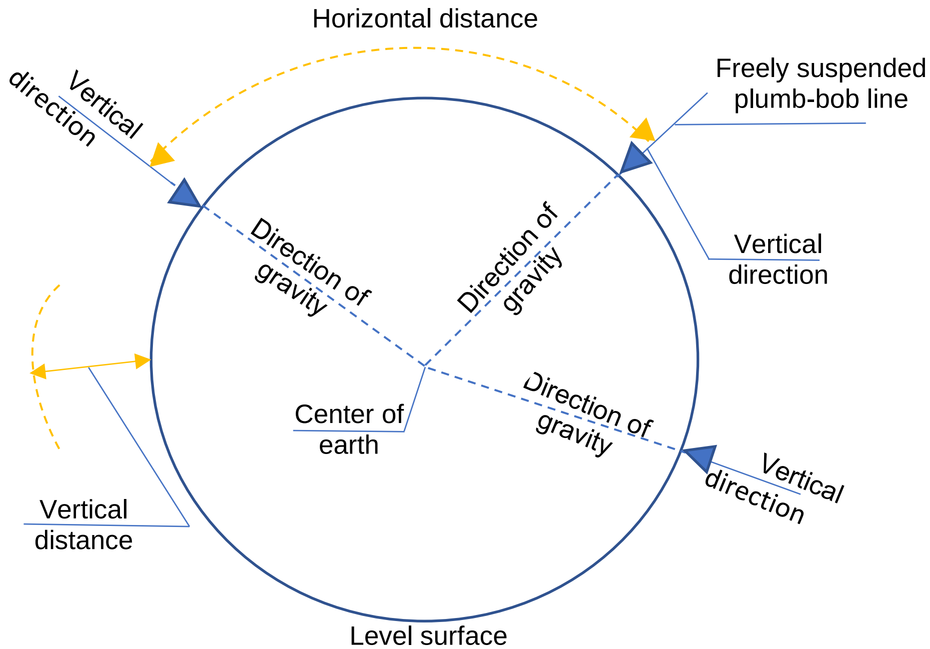


Figure 1.11B. Concept of vertical direction, direction of gravity, vertical distance, and horizontal distance, with respect to earth surface

1.7 Distances and Angles

Distances in surveying may be measured in horizontal, vertical, or slope direction (Figure 1.12A). Generally, the result of a distance measurement is expressed either as a horizontal or vertical value.

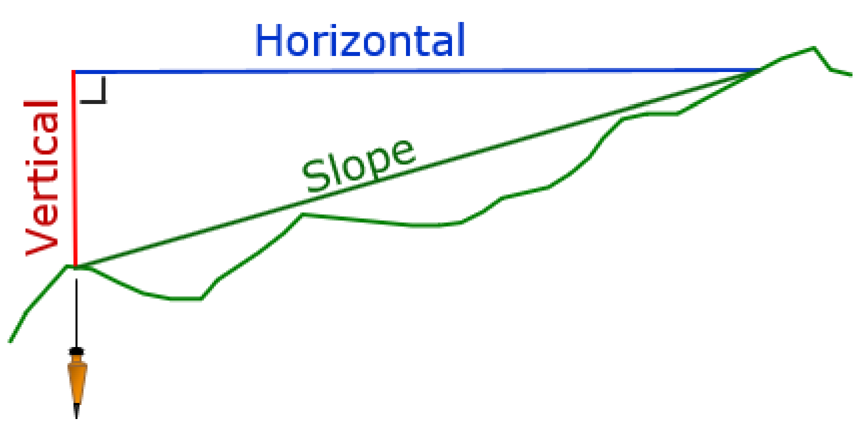


Figure 1.12A. Distances in horizontal, vertical, and slope directions (measured in feet, meter, mile, or kilometer)

Horizontal distance is measured along a level surface. At every point along that length, the line tangent to the level surface is horizontal. It can be measured by tape or Electronic Distance Measurement (EDM). A true horizontal distance is actually curved, like the surface of the earth.

Horizontal distance measurements have horizontal and vertical orientations. Unless otherwise indicated, when interpreting measurements, they are presumed to be in horizontal or vertical directions. For example, if a property description calls for "235 feet to an iron pipe", the distance is taken as horizontal, Figure 1.12B, not along the ground.

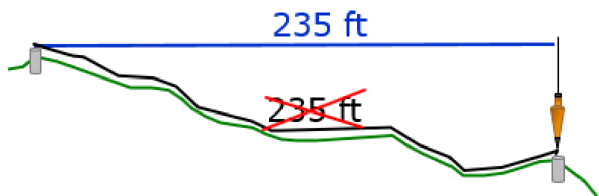


Figure 1.12B. Concept of horizontal distance measurement

A vertical distance is measured along the direction of gravity and is equivalent to a difference in height between two points (Figures 1.11B and 1.12B). When the height is measured with reference to a given level surface, like mean sea level (MSL), it is called an *elevation.* An instrument called *level*, which is used to observe the rod at different points, can measure elevation (Figure 1.12C). The relative vertical position of several points separated by long distances can be determined by a continuous series of level rod observations. This procedure is called leveling.

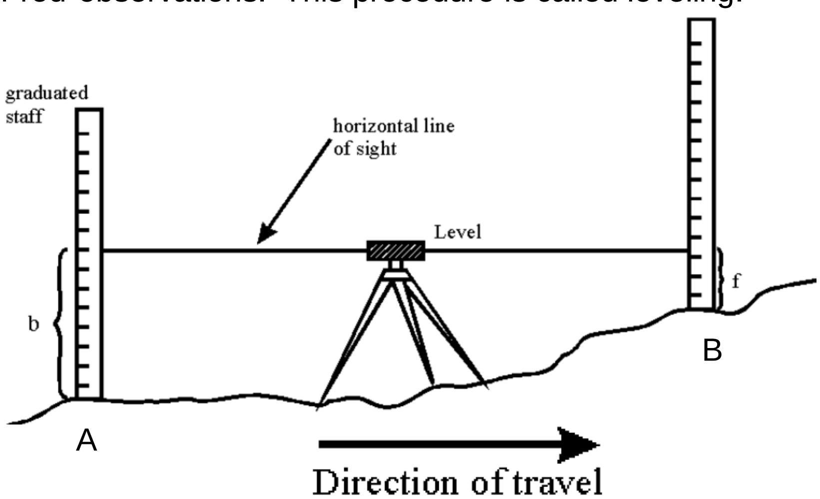


Figure 1.12C. Difference in elevation of A and B = b – f (in ft or m)

Horizontal Angle

A horizontal angle is measured in a plane that is horizontal at the point of measurement (Figure 1.12D). When horizontal angle is measured between points, which do not lie directly in the plane, it is measured between the perpendiculars extended to the plane from those points.

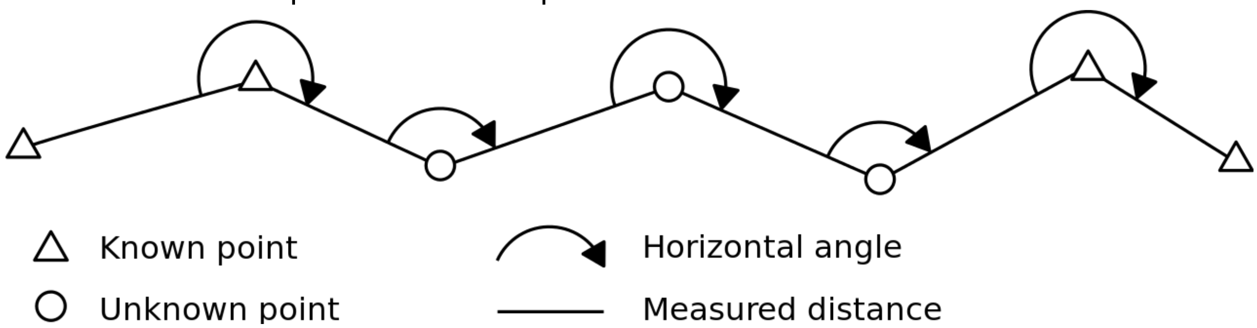


Figure 1.12D. Horizontal Angles and Horizontal Distances (Plan View)

Vertical Angle

A vertical angle is measured in a plane that is vertical at the point of observation or measurement (Figures 1.13A and 1.13B). Horizontal and vertical angles can (or used to) be measured with an instrument called a transit or theodolite.

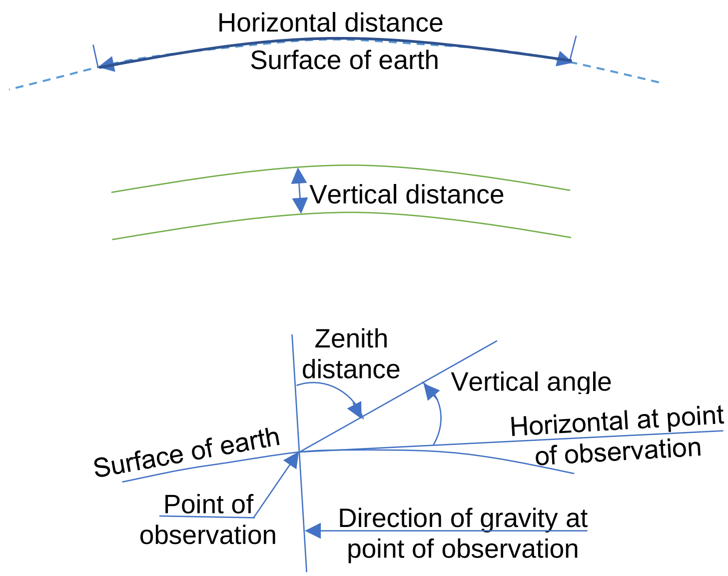


Figure 1.13A Horizontal and Vertical distances, Vertical Angle (Profile View)

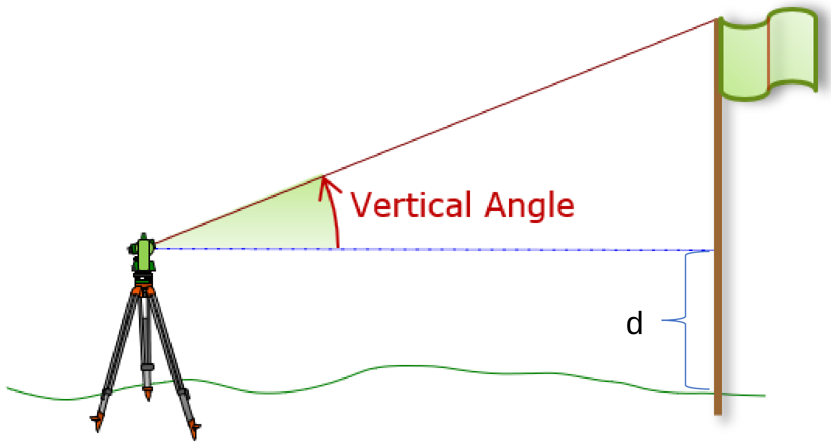


Figure 1.13B Vertical angle measurement to get height of the flag (Profile View)

1.8 Types of Surveying

There are two types of surveying:

1. **Plane surveying**

   As mentioned earlier that most surveying measurements are carried out as if the surface of the earth were perfectly flat (Figures 1.14 and 1.15). The method of surveying based on this assumption is called plane surveying. In plane surveying, it neglects the curvature of the earth, and it uses the principles of plane geometry and plane trigonometry to compute the result of surveys.

   The use of plane surveying methods simplifies the work of surveyor. Within a distance of 20 km (12 miles) or withing an area of 250 km^2 (96 mile^2) **plane surveying** can safely be used. The effect of earth's curvature on small project measurements is so small that we can hardly measure it. In other words, a horizontal distance measured between two points along a truly level line is, for practical purposes, the same distances measured along the straight chord connecting the two points**.** **N.B:** In plane surveying horizontal lines are assumed to be straight line and all vertical lines are parallel.

2. **Geodetic surveying**

   A surveying, which takes the earth's curvature into account is called Geodetic survey (Figure 1.15). These types of surveys are usually considered by agencies like Geological Survey. Geodetic surveying methods are generally used to map large areas and to establish large-scale networks of points on the earth for horizontal and vertical control. In GEODETIC SURVEY corrections are made for the curvature of the earth's surface.

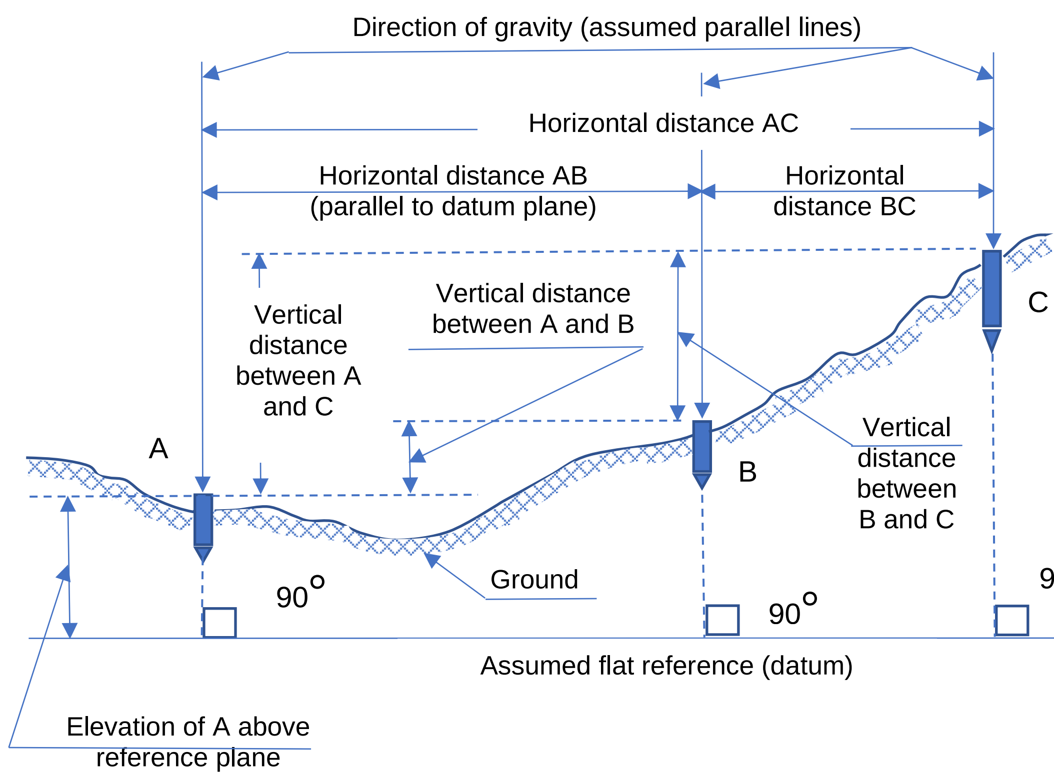


Figure 1.14. In plane surveying (for length less than 20 km or 12 miles), the curvature of the earth is neglected, and vertical elevations are measured with reference to a flat plane (datum)

Differences between Plane and Geodetic Surveying

Although, both plane surveying and geodetic surveying are the methods of making measurement on earth, they are having some distinguishing features:

1. Mainly, plane surveying ignores the curvature of the earth, while geodetic surveying considers it.

2. Plane surveying is suitable for small areas, whereas Geodetic surveying is suitable for surveying large areas.

3. Geodetic surveying is more accurate than plane surveying.

4. Triangles formed in plane surveying are plane triangles, but triangles formed in geodetic surveying are spherical triangles.

5. Geodetic stations are in huge distance compared to stations formed in plane surveying.

6. More over plane surveying may use normal instruments like chain, measuring tape, theodolite, etc. to locate points on earth, while geodetic surveying uses more precise instruments and modern technology like total station, GPS.

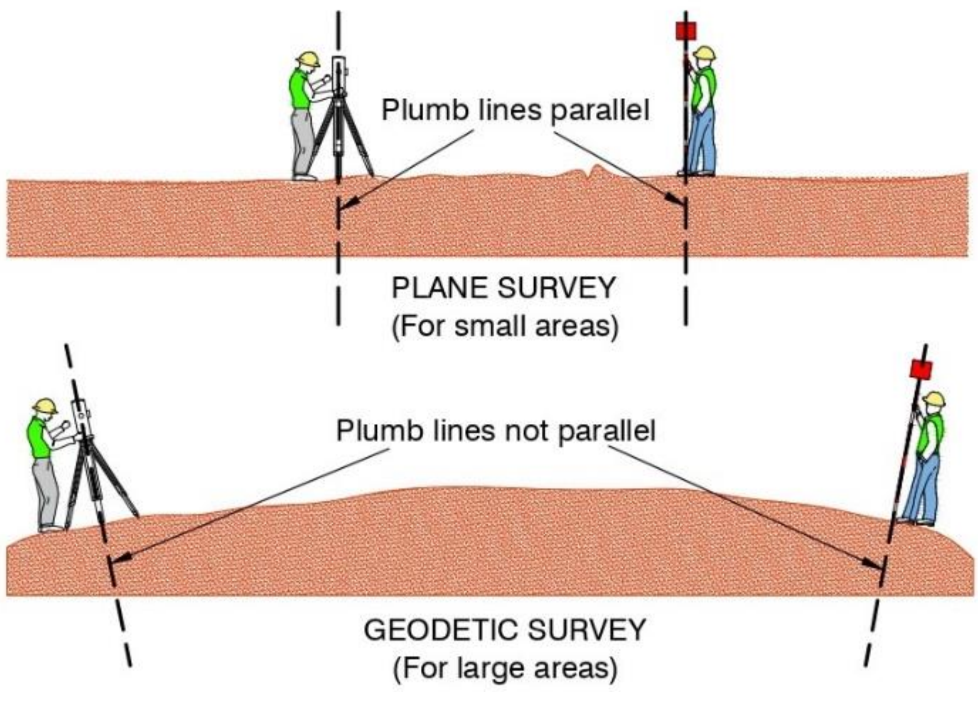


Figure 1.15. Difference between Plane Survey and Geodetic Survey

1.9 SURVEYING APPLICATIONS

As mentioned earlier, the two fundamental purposes for surveying are: 1) To determine the relative positions of existing points and 2) To mark the positions of new points on or near the surface of the earth. However, different types of surveys require different field procedures and varying degrees of precision for carrying out the work.

- **Property survey**
  It is also called boundary survey. It is performed in order to establish the positions of boundary lines and property corners. It is usually performed whenever land ownership is to be transferred or when a large tract of land is to be subdivided in to smaller parcels for development. It is also performed before the design and construction of any public/private land-use project.

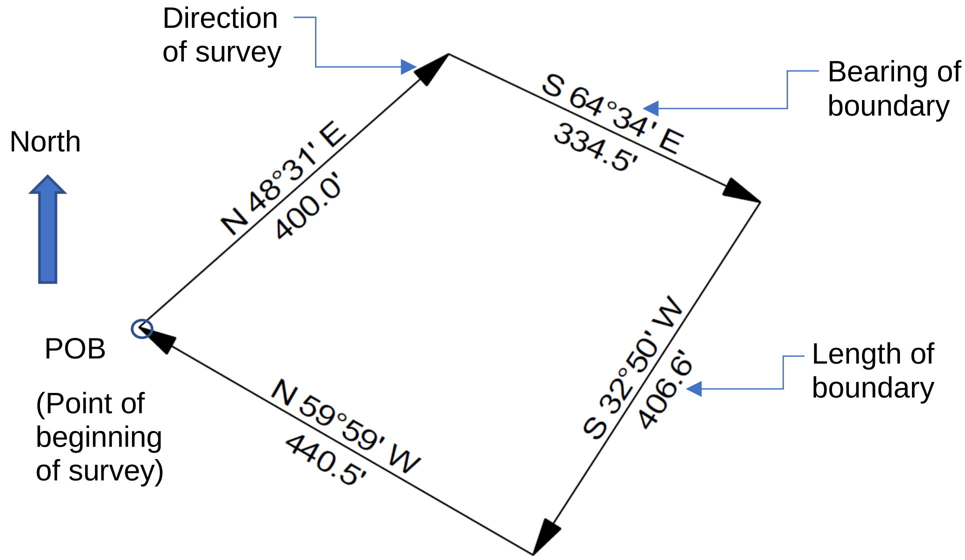


Figure 1.16. Sample plan of a property survey. Shows boundary of the property, horizontal distances (in feet), bearing (horizontal angle) of each side of the property. (POB = Point of Beginning)

Meats and bounds of a property

Metes and bounds is the legal description of a parcel of land that is measured in distances, angles, and directions.

From the Tie (Point of Beginning - POB or other Tie from corner of the street, etc.)., the description specifies a direction, generally referred to as a course, and a distance to a corner of the claim. From that corner, the description continues to specify a direction and distance for each claim boundary. Courses are generally expressed as deflections from north and south. Metes refers to distance and bounds to direction.

- Lengths are shown in feet or meter. Bearings should be to true north.
- The legal description should be a single perimeter description of the entire claim.

- The sides of the claim are described by stating each course distance and bearing.

- **Topographic survey**
  It is performed in order to determine the relative positions of existing natural and constructed features on a tract of land (like ground elevation, bodies of water, roads, buildings etc.). It provides information on the "shape of the land" hills, valleys, ridges and general slope of the ground. The data's obtained from a topographic survey are plotted in a map called *topographic map* and the shape of the ground is shown with lines of equal elevation called *contours*.

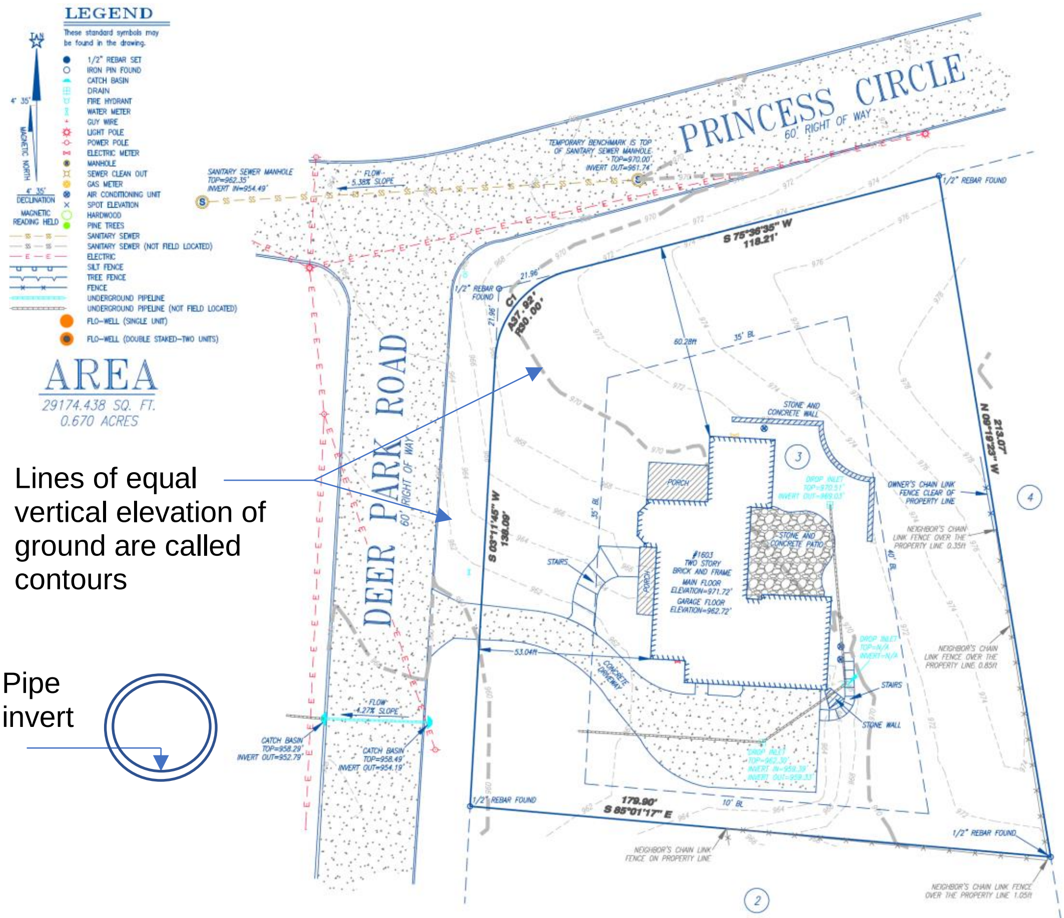


Figure 1.16. Sample plan of a topographic survey. Shows boundary of the property with lengths and bearings, building features, contours, building offsets to the boundary, manhole rim level and pipe inverts, and lot area

- **Construction survey**
  It is also called layout or location survey and performed in order to mark the positions of new points on the ground. These new points represent the location of building corners, road centerlines and other facilities that are to be built.

- **City survey**
  The surveys which are carried out for the construction of roads, parks water supply system, sewer and other constructional work for any developing township, are called city surveys. The city maps which are prepared for tourists are known as guide maps.

- **Control survey**
  There are two kinds of control surveys: These are horizontal and vertical control survey.

  a) **Horizontal control survey:**
  The surveyor, using temporary/permanent markers, places several points on the ground. These points, called stations, are arranged through out the site area under study so that it can be easily seen. The relative horizontal positions of these points are established, usually with a very high degree of precisions and accuracy; this is done using transverse, triangulation or trilateration methods.

  b) **Vertical control survey**
  The elevations of relatively permanent reference points are determined by precise leveling methods. Marked points of known elevations are called elevation benchmarks or datum. The network of stations and benchmarks provide a framework for horizontal and vertical control, upon which less accurate surveys can be based.

- **Route survey**

Route survey is performed in order to establish horizontal and vertical controls, to obtain topographic data, and to design or layout the position of highways, railroads, pipe lines, and utilities etc. The length of the new facility may extend for many kilometers (or miles). The survey of any new route will include a partial survey of the primary line called the baseline. A new route survey almost always will begin from an existing route. For example, a spur or connector road will begin from some established primary road

1.10 Other types of surveys

HYRDRAULIC SURVEY: is a preliminary survey applied to a natural body of water, e.g., mapping of shorelines, harbor, large water bodies, etc.

RECONNAISSANCE SURVEY: is a preliminary survey conducted to get rough data regarding a tract of land.

PHOTOGRAMMETRIC SURVEYING: uses relatively accurate methods to convert aerial photographs into useful topographic maps.

1.11 FIELD NOTES

Field notes can be entered electronically using the data collector or can be recorded manually on the field book. Field notes have five main features:

- Accuracy—Measurements should be recorded to the correct degree of precision. For example, if measuring with a steel tape to the nearest one-tenth unit, the recorded measurement should be to the same. This is especially true when recording a calculated measurement, for example, a calculated horizontal distance from slope distance.

- Integrity—Field notes should be recorded in the field at the time of the measurement, not later from memory. Field notes should be original. If necessary to submit a copy, the original notes should be attached. If data are copied from another source, it should be noted in the field book that the data are a copy.

- Legibility—All lettering in field books should be block style printing with a number 3H or harder lead. All symbols and abbreviations should be consistent and a key should be provided or referenced somewhere in the field book. A key should only be included by reference when it is readily available and accessible to those who will utilize the notes; otherwise, the key should be included in full text with the notes.

- Arrangement—Various surveys have their own style of notes arrangement and this should always be followed. For example, traverse notes may be arranged from the bottom of the page upward or from the top of the page downward, while leveling notes usually are arranged downward. Leveling notes also follow very specific column headings.

- Clarity—The most important aspect of recording field notes is probably the consistency of the note taker. It should be clear as to what measurements go with what heading. When writing decimals, either use a strong decimal point including a zero in front, or use a style that emphasizes the decimal, for example, underlining and placing above as a superscript. This format is used extensively in route surveys. Example: for a measurement of 17.51, it might be written as 17 51 or 17.51.

RULES FOR FIELD NOTES

All surveys must be free from mistakes or blunders. A potential source of major mistakes in surveying practice is the careless or improper recording of field notes. The art of eliminating blunders is one of the most important elements in surveying practice.

1. Record all field data carefully in a field book at the moment they are determined.
2. All data should be checked at the time they are recorded.
3. An incorrect entry of measured data should be neatly lined out, the correct number entered next to or above it.
4. Field notes should not be altered, and even data that are crossed out should still remain legible.
5. Original field records should never be destroyed, even if they are copied for one reason to another.
6. Sketches should be clearly labeled.
7. The field book should contain the name, address, and the phone number.
8. Each new survey should begin on a new page.
9. For each day of work, the project name, location, and date should be recorded in the upper corner of the right –hand page.

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