UNIT 1: GIS: GEOGRAPHICAL INFORMATION SYSTEMS

1.1 Introduction to GIS

The advent of cheap and powerful computers over the last few decades has allowed for the development of innovative software applications for the storage, analysis, and display of geographic data. Many of these applications belong to a group of software known as Geographic Information Systems (GIS). Many definitions have been proposed for what constitutes a GIS. Each of these definitions conforms to the particular task that is being performed. Instead of repeating each of these definitions, I would like to broadly define GIS according to what it does. Thus, the activities normally carried out on a GIS include:

1. *The measurement of natural and human made phenomena and processes from a spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems: elements, attributes, and relationships.*

2. *The storage of measurements in digital form in a computer database. These measurements are often linked to features on a digital map. The features can be of three types: points, lines, or areas (polygons).*

3. *The analysis of collected measurements to produce more data and to discover new relationships by numerically manipulating and modeling different pieces of data.*

4. *The depiction of the measured or analyzed data in some type of display - maps, graphs, lists, or summary statistics.*

The first computerized GIS began its life in 1964 as a project of the Rehabilitation and Development Agency Program within the government of Canada. The Canada Geographic Information System (CGIS) was designed to analyze Canada's national land inventory data to aid in the development of land for agriculture. The CGIS project was completed in 1971 and the software is still in use today. The CGIS project also involved a number of key innovations that have found their way into the feature set of many subsequent software developments.

From the mid-1960s to 1970s, developments in GIS were mainly occurring at government agencies and at universities. In 1964, Howard Fisher established the Harvard Lab for Computer Graphics where many of the industries early leaders studied. The Harvard Lab produced a number of mainframe GIS applications including: SYMAP (Synagraphic Mapping System), CALFORM, SYMVU, GRID, POLYVRT, and ODYSSEY. ODYSSEY was first modern vector GIS and many of its features would form the basis for future commercial applications. Automatic Mapping System was developed by the United States Central Intelligence Agency (CIA) in the late 1960s. This project then spawned the CIA's World Data Bank, a collection of coastlines, rivers, and political boundaries, and the CAM software package that created maps at different scales from this data. This development was one of the first systematic map databases. In 1969, Jack Dangermond, who studied at the Harvard Lab for Computer Graphics, co-founded Environmental Systems Research Institute (ESRI) with his wife Laura. ESRI would become in a few years the dominate force in the GIS marketplace and create ArcInfo and ArcView software. The first conference dealing with GIS took place in 1970 and was organized by Roger Tomlinson (key individual in the development of CGIS) and Duane Marble (professor at Northwestern University and early GIS innovator). Today, numerous conferences dealing with GIS run every year attracting thousands of attendants.

In the 1980s and 1990s, many GIS applications underwent substantial evolution in terms of features and analysis power. Many of these packages were being refined by private companies who could see the future commercial potential of this software. Some of the popular commercial applications launched during this period include: ArcInfo, ArcView, MapInfo, SPANS GIS, PAMAP GIS, INTERGRAPH, and SMALLWORLD. It was also during this period that many GIS applications moved from expensive minicomputer workstations to personal computer hardware.

1.1.1 Why document your data?

Working with your Geographic Information System on a regular basis as you do, you probably have a pretty good idea about what it contains, the area of the country it covers, and what its major strengths and weaknesses are likely to be. You know, for example, that your data cover the city of York, that period *information is only stored to the nearest century, and that the aerial photographic interpretation to the south–west of the city is a bit dubious.*

1.1.2 Documentation for others

Data offered to the ADS, however, may potentially be used by researchers from many different parts of the planet, and with widely varied levels of expertise. They have no way of knowing anything at all about your data unless you tell them.

In order to make sure that the maximum amount of information is delivered to the user whilst involving you, the depositor, in minimal effort, the Archaeology Data Service has developed a number of procedures to standardize and simplify the documentation process.

1.1.3 Documentation for you

Some form of record about your data — and about what you've done to it — is also, of course, undoubtedly useful within your own organization. Even using data every day, it is still possible to forget about where some of it came from, or how the data you currently used were originally compiled from various sources.

This guide introduces the issues relevant to both types of documentation, as well as discussing the detail relevant to one or the other.

1.2 Database & Scales

Quantitative and qualitative data are two types of data.

1.2.1 Qualitative data

Qualitative data is a categorical measurement expressed not in terms of numbers, but rather by means of a natural language description. In statistics, it is often used interchangeably with "categorical" data.

Although we may have categories, the categories may have a structure to them. When there is not a natural ordering of the categories, we call these nominal categories. Examples might be gender, race, religion, or sport.

When the categories may be ordered, these are called ordinal variables. Categorical variables that judge size (small, medium, large, etc.) are ordinal variables. Attitudes (strongly disagree, disagree, neutral, agree, strongly agree) are also ordinal variables, however we may not know which value is the best or worst of these issues. Note that the distance between these categories is not something we can measure.

1.2.2 Quantitative data

Quantitative data is a numerical measurement expressed not by means of a natural language description, but rather in terms of numbers. However, not all numbers are continuous and measurable. For example, the social security number is a number, but not something that one can add or subtract. Quantitative data always are associated with a scale measure.

Probably the most common scale type is the ratio-scale. Observations of this type are on a scale that has a meaningful zero value but also have an equidistant measure (i.e., the difference between 10 and 20 is the same as the difference between 100 and 110). For example, a 10 year-old girl is twice as old as a 5 year-old girl. Since you can measure zero years, time is a ratio-scale variable. Money is another common ratio-scale quantitative measure. Observations that you count are usually ratio-scale (e.g., number of widgets).

A more general quantitative measure is the interval scale. Interval scales also have a equidistant measure. However, the doubling principle breaks down in this scale. A temperature of 50 degrees Celsius is not "half as hot" as a temperature of 100, but a difference of 10 degrees indicates the same difference in temperature anywhere along the scale. The Kelvin temperature scale, however, constitutes a ratio scale because on the Kelvin scale zero indicates absolute zero in *temperature, the complete absence of heat. So one can say, for example, that 200 degrees Kelvin is twice as hot as 100 degrees Kelvin.*

1.2.3 Types of data

There are four types of data that may be gathered in social research, each one adding more to the next. Thus ordinal data is also nominal, and so on.

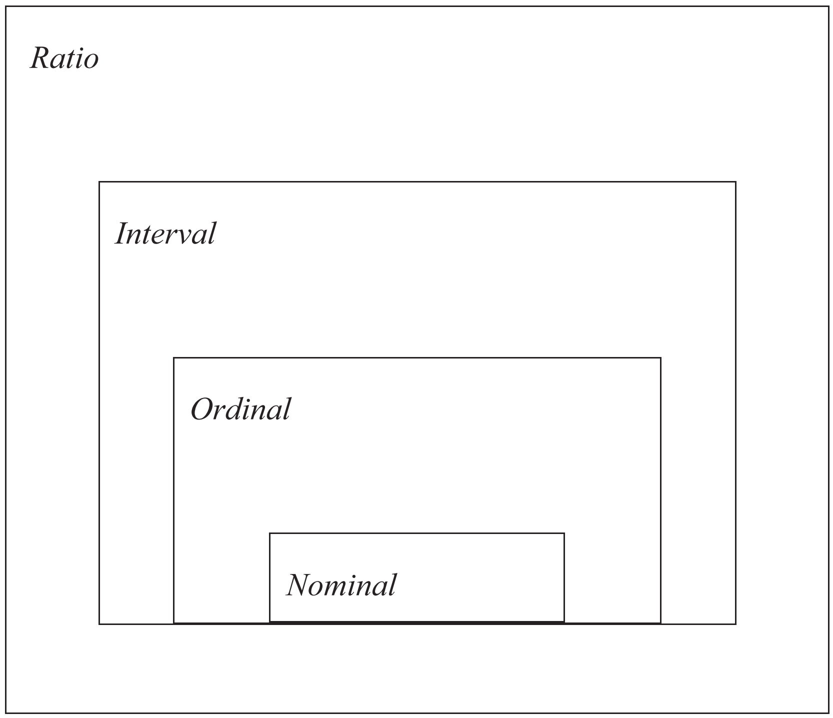


Fig. 1.1: Types of data

1.2.3.1 Nominal

The name 'Nominal' comes from the Latin nomen, meaning 'name' and nominal data are items which are differentiated by a simple naming system.

The only thing a nominal scale does is to say that items being measured have something in common, although this may not be described.

Nominal items may have numbers assigned to them. This may appear ordinal but is not -- these are used to simplify capture and referencing.

Nominal items are usually categorical, in that they belong to a definable category, such as 'employees'.

Example:

1. *The number pinned on a sports person.*
2. *A set of countries.*

1.2.3.2 Ordinal

Items on an ordinal scale are set into some kind of order by their position on the scale. This may indicate such as temporal position, superiority, etc.

The order of items is often defined by assigning numbers to them to show their relative position. Letters or other sequential symbols may also be used as appropriate.

Ordinal items are usually categorical, in that they belong to a definable category, such as '1956 marathon runners'.

You cannot do arithmetic with ordinal numbers -- they show sequence only.

Example:

1. *The first, third and fifth person in a race.*
2. *Pay bands in an organization, as denoted by A, B, C and D.*

1.2.3.3 Interval

Interval data (also sometimes called integer) is measured along a scale in which each position is equidistant from one another. This allows for the distance between two pairs to be equivalent in some way.

This is often used in psychological experiments that measure attributes along an arbitrary scale between two extremes.

Interval data cannot be multiplied or divided.

Example:

1. *My level of happiness, rated from 1 to 10.*
2. *Temperature, in degrees Fahrenheit.*

1.2.3.4 Ratio

In a ratio scale, numbers can be compared as multiples of one another. Thus one person can be twice as tall as another person. Important also, the number zero has meaning.

Thus the difference between a person of 35 and a person 38 is the same as the difference between people who are 12 and 15. A person can also have an age of zero.

Ratio data can be multiplied and divided because not only is the difference between 1 and 2 the same as between 3 and 4, but also that 4 is twice as much as 2.

Interval and ratio data measure quantities and hence are quantitative. Because they can be measured on a scale, they are also called scale data.

Example:

1. *A person's weight*
2. *The number of pizzas I can eat before fainting*

1.2.4 Parametric vs. Non-parametric

Interval and ratio data are parametric, and are used with parametric tools in which distributions are predictable (and often Normal).

Nominal and ordinal data are non-parametric, and do not assume any particular distribution. They are used with non-parametric tools such as the Histogram.

1.2.5 Continuous and Discrete

Continuous measures are measured along a continuous scale which can be divided into fractions, such as temperature. Continuous variables allow for infinitely fine sub-division, which means if you can measure sufficiently accurately, you can compare two items and determine the difference.

Discrete variables are measured across a set of fixed values, such as age in years (not microseconds). These are commonly used on arbitrary scales, such as scoring your level of happiness, although such scales can also be continuous.

1.2.6 Map Scale

Maps are rarely drawn at the same scale as the real world. Most maps are made at a scale that is much smaller than the area of the actual surface being depicted. The amount of reduction that has taken place is normally identified somewhere on the map. This measurement is commonly referred to as the map scale. Conceptually, we can think of map scale as the ratio between the distance between any two points on the map compared to the actual ground distance represented. This concept can also be expressed mathematically as:

$$\text{Map Scale} = \frac{\text{Map Distance}}{\text{Earth Distance}}$$

On most maps, the map scale is represented by a simple fraction or ratio. This type of description of a map's scale is called a representative fraction. For example, a map where one unit (centimeter, meter, inch, kilometer, etc.) on the illustration represents 1,000,000 of these same units on the actual surface of the Earth would have a representative fraction of 1/1,000,000 (fraction) or 1:1,000,000 (ratio). Of these mathematical representations of scale, the ratio form is most commonly found on maps.

Scale can also be described on a map by a verbal statement. For example, 1:1,000,000 could be verbally described as "1 centimeter on the map equals 10 kilometers on the Earth's surface" or "1 inch represents approximately 16 miles".

Most maps also use graphic scale to describe the distance relationships between the map and the real world. In a graphic scale, an illustration is used to depict distances on the map in common units of measurement. Graphic scales are quite useful because they can be used to measure distances on a map quickly.

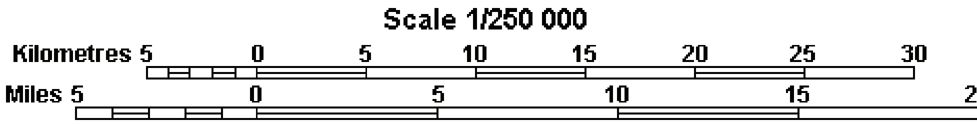


Fig. 1.2: Graphic scale

The following graphic scale was drawn for map with a scale of 1:250,000. In the illustration distances in miles and kilometers are graphically shown.

Maps are often described, in a relative sense, as being either small scale or large scale. Figure 2a-10 helps to explain this concept. In we have maps representing an area of the world at scales of 1:100,000, 1:50,000, and 1:25,000. Of this group, the map drawn at 1:100,000 has the smallest scale relative to the other two maps. The map with the largest scale is map C which is drawn at a scale of 1:25,000.

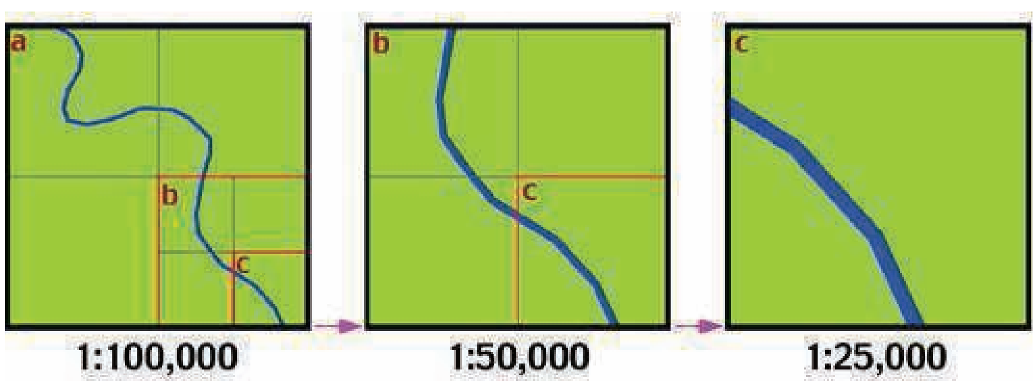


Fig. 1.3: Map scale

The following three illustrations describe the relationship between map scale and the size of the ground area shown at three different map scales. The map on the far left has the smallest scale, while the map on the far right has the largest scale. Note what happens to the amount of area represented on the maps when the scale *is changed. A doubling of the scale (1:100,000 to 1:50,000 and 1:50,000 to 1:25,000) causes the area shown on the map to be reduced to 25% or one-quarter.*

1.3 Concepts in GIS

A phrase many use in referring to GIS is "computer mapping." GIS is about creating maps on a computer for a variety of descriptive and analytical purposes. GIS can help planners and analysts "visualize" data to better understand patterns and concentrations of spatial phenomena. GIS also has the useful ability to portray layers of information, to help uncover spatial relationships among multiple sets of data. A typical GIS "session" involves bringing in various map layers for analysis.

Map layers can take the form of points, lines, or areas.

Points represent phenomena that have a specific location, such as homes, businesses, colleges, schools, and crime sites. Lines represent phenomena that are linear in nature, such as roads, rivers, and water lines. Areas represent phenomena that are bounded (states, counties, zip codes, school districts, census tracts). For example, a higher education institution may want to create a map illustrating the housing locations of off-campus students. A map would typically include (1) the layer of student housing locations represented by points; (2) a map layer portraying streets, represented as lines; and (3) some form of a bounded area layer such as villages or towns, and city wards. It is important to note that the extent to which one can match data to base maps goes well beyond the familiar examples of mapping state, county, and town data. For example, an excellent use of GIS is in the area of facilities management. Both MapInfo and ArcView have the ability to import AutoCAD drawing files, the most popular format for building and room drawings. Characteristics of each building and room can be associated to the drawings in a GIS. Many higher education institutions have already developed such applications.

Perhaps the most important concept involved in using a GIS is that of associating, or "attaching," attribute data to a spatially referenced base map. For example, picture a map of the United States with the state boundaries easily visible and distinguishable. This *common base map in a GIS would contain the name of each state and, importantly, the coordinates (latitude and longitude) of each state boundary. With this information, a GIS can display a simple base map of the United States by state. A database of socioeconomic data such as population, median income, and racial distribution for each state in the country can then be associated or attached to the state boundary map layer. In social sciences research, a GIS may associate the demographic information in the database to the base map by matching the name of each state in the base map to the name of each state in the database. It is this capability of matching up or "merging" data in a database to a base map that is at the foundation of nearly every analysis employing GIS technology.*

It is therefore extremely important that the data contain a locational identifier in order to be mapped in a GIS. Typical examples of locational identifiers are street address, zip code, county, state, and census tract. If this information is in the data, then the data can be associated to a base map and portrayed and analyzed in a GIS. The term used to describe the associating of attribute data to a base map in a GIS is geocoding, or geographically encoding the data to allow it to be mapped. Address-level data are typically geocoded to a street-level base map, county statistics are geocoded against a county-level base map, and so forth.

Another key concept associated with GIS is that it can be a tremendous reporting tool. One way to think about GIS is that it is a "visual communication tool." Think of a standard data report that lists the number of students by county who attend a particular higher education institution. The counties would be listed in one column and the number of students in a County Boundary and Census Tracts (Polygon or Area Layers), High School Locations (Point Layer), Interstate Highways (Line Layer) and the information or labels (Annotation Layer).

Fig. 1.4: Points, Lines, and Areas

The table could be sorted alphabetically by county or by number of students. This type of report does not have a "spatial" dimension illustrating the location of each respective county. Once these data are geocoded and mapped, one can add a powerful dimension to the communication and "absorption" of the information on the reader's part. Concentrations and patterns immediately come alive. At many institutions in upstate New York, for example, there is a clear upstate-downstate distinction among the student body. A map can illustrate this distinction much more powerfully than a table of county names and numbers.

1.4 Components in GIS

A Geographic Information System combines computer cartography with a database management system. The figure below describes some of the major components common to a GIS. This diagram suggests that a GIS consists of three subsystems: (1) an input system that allows for the collection of data to be used and analyzed for some purpose; (2) computer hardware and software systems that store the data, allow for data management and analysis, and can be used to display data manipulations on a computer monitor; (3) an output system that generates hard copy maps, images, and other types of output.

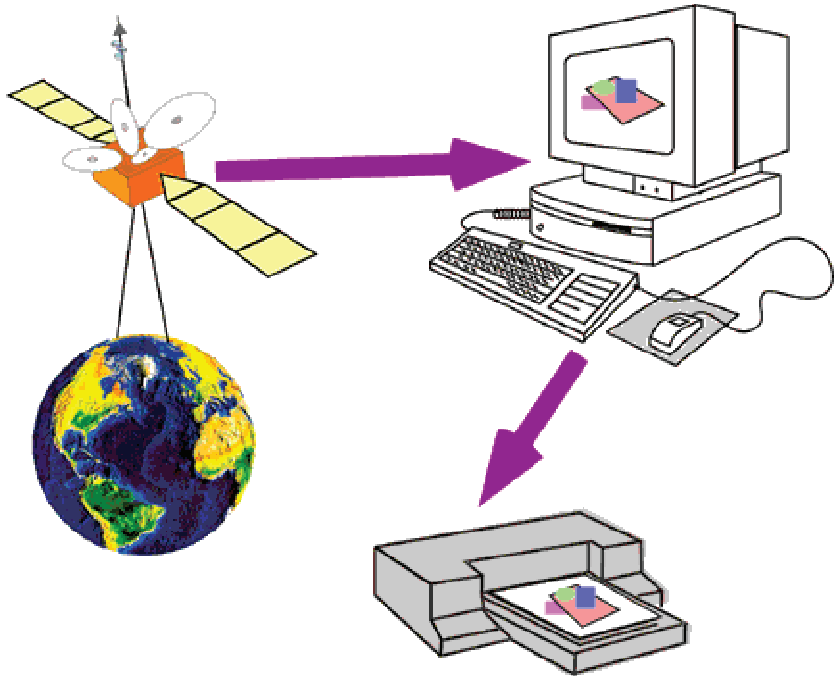


Fig.1.5: Components of a Geographic Information System

Three major components of a Geographic Information System. These components consist of input, computer hardware and software, and output subsystems.

Two basic types of data are normally entered into a GIS. The first type of data consists of real world phenomena and features that have some kind of spatial dimension. Usually, these data elements are depicted mathematically in the GIS as either points, lines, or polygons that are referenced geographically (or geocoded) to some type of coordinate system. This type data is entered into the GIS by devices like scanners, digitizers, GPS, air photos, and satellite imagery. The other type of data is sometimes referred to as an attribute. Attributes are pieces of data that are connected or related to the points, lines, or polygons mapped in the GIS. This attribute data can be analyzed to determine patterns of importance. Attribute data is entered directly into a database where it is associated with element data.

1.5 Application of GIS

Fig. 1.6: The tools and applications of GIS has increased

1.5.1 Application of GIS in energy exploration

GIS applications in energy exploration are the primary way in which oil potentiality in suitable locations is evaluated. This service has become indispensable for the petroleum industries to stay ahead in the competition regarding the discovery of new sources of petroleum.

It is with the help of GIS applications in energy exploration that large petroleum companies select the most suitable sites for their retail outlets by evaluating the information on demography and transportation, which can optimize the customers satisfaction.

GIS applications in energy exploration helps to analyze and integrate a lot of different types of data to the specified location and then by overlaying, viewing, and manipulating the data in the form of a map, it discovers the new or extension of the potent oil source. The data required for exploration are:

- *Satellite imagery*
- *Digital aerial photo mosaics*
- *Seismic surveys*
- *Surface geology studies*
- *Sub-surface and cross section interpretations and images*
- *Good locations*
- *Existing infrastructure information*

GIS applications in energy exploration manage the spatial distribution of components of the daily petroleum based business items like leases, pipelines, wells, environmental concerns, facilities, and retail outlets, within the corporate database. The digital mapping of the web enabled GIS applications apply appropriate geographic analysis efficiently.

The exploration of the oil reserves is associated with the production process of the petroleum resources. GIS technology is ideally suited for aiding the respective petroleum company to understand certain geographic, infrastructural, logistical, and environmental factors related to that specific site. The GIS applications in energy exploration can also be integrated with other economic business planning engines to provide a focused business solution. They help the petroleum industry by providing relevant information regarding drilling platforms, oil refineries, and pipeline networks. These infrastructural requirements for energy production exist in difficult commercial, operational, and environmental conditions. Therefore, it is essential that they should be planned, maintained, and operated effectively.

In a nutshell, GIS applications in energy exploration integrate the exploration and production of energy reserves with the infrastructure management systems of the oil plants.

1.5.2 Vehicle tracking systems

Vehicle tracking systems are usually used for managing a fleet of vehicles. The vehicles of a fleet are fitted with GPS, which usually transmit the positional data of the vehicles to a central station. The central station is a monitoring station, where the position of vehicles is displayed on a GIS map. Vehicle tracking systems will be useful for the police and emergency response services. The central station usually diverts the vehicle nearest to the site, where the vehicles are required. By using a wireless phone service or cellular phone network, real time corrections can be sent to the receivers fitted on the vehicles and better results can be obtained.

1.5.3 Application in Forestry

GIS applications in forestry in India is the indispensable method by means of which the total forest area in India is measured.

Digital mapping has brought about a revolutionary change in the entire Geographical Information System (GIS). The rudimentary method of depending on paper maps has been changed and at present, one depends on digital maps, which in fact have been playing a significant role in the monitoring and management of the forests.

The Geographical Information System, Global Positioning System, and Remote Sensing are important technological applications used in various areas of life in today's era of modern communication.

The GIS Applications in forestry has come up with excellent results in the decision making in the field level. There are different types of GIS Applications in forestry, such as -

- *Supervising of afforestation plans*
- *Monitoring of plantation schemes*
- *Corridor mapping for animal migration*
- *Habitat mapping*

- *Land capability mapping*

GIS applications in forestry are also used for the prevention of trespassers in the forests. This is done with the help of satellite imageries. The total forest area in India is under danger from various quarters today. GIS applications in forestry are also very useful in the protection of forests. With the help of such applications in the GIS system, accurate information can be remotely and easily obtained. The geo-spatial data is organized to make important decisions. The data should be accurate as any type of error within the GIS calculations would misguide the users.

Some other useful purposes for which GIS applications in forestry can be used are the selection of locations for plantation or for supervising the ongoing danger of encroachments. Moreover, issues like burning of forests and 'jhum' cultivation can be regulated. The expansion of infrastructure and communication networks are also taken care of by GIS applications. Managing the forests and village are also aided by these applications.

Forest Fire Monitoring in Uttaranchal State Forest Department

Synergy of Indian Remote sensing Satellite (IRS) systems covering IRS-P6, IRS-1D, and data given by TERRA/AQUA Moderate resolution Imaging Spectroradiometer (MODIS), National Oceanic and Aeronautic Administration - Advanced Very High Resolution Radiometer (NOAA-AVHRR), Defense Meteorological Satellite Program-Operational Line scan System (DMSP-OLS), Environment Satellite (ENVISAT) are useful in forest fire detection, active fire progression monitoring, near real time damage assessment, and mitigation planning.
The Decision Support Center (DSC) is established at National Remote Sensing Centre (NRSC) as part of Disaster Management Support Programme of Department of Space (DOS), for working towards effective management of disasters in India. Considering the importance of forest fire management in India, a comprehensive Indian Forest Fire Response and Assessment System (INFFRAS) is invoked under DSC activities of NRSC, which integrates multi-sensor satellite data and ground data through spatially and temporally explicit GIS analysis frame work. The INFFRAS is designed to provide services on:

1. *Fire alerts :Value-added daily daytime TERRA/AQUA MODIS fire locations and DMSP-OLS derived daily nighttime fire locations*

2. *Fire progression: Progression of fires using daily day and night fire location information given by MODIS/DMSP-OLS and burnt area expansion derived from temporal high resolution data sets*

3. *Burnt area assessment: Mapping episodic fire events using moderate and high resolution optical data sets*

4. *Forest fire mitigation plans.*

1.5.4 Vehicle navigation systems

Vehicle navigation systems are used for guiding vehicles to their destination. These systems usually use GPS or inertial navigation systems or a combination of both for positioning the vehicle. The advantage of using both inertial navigation systems and GPS is that navigation can be continued even when the GPS cannot receive the signals form the satellites due to obstruction. In countries like the US, vehicle navigation systems are used for guiding tourists to different tourist spots. The vehicle navigation systems use a computer, which determines the position of the vehicle, plans the route and gives the directions to the driver. The driver gives the location of his/her destination while starting his journey and the computer guides the driver by giving either audio or and visual instructions. The route the computer plans is usually optimized route; the route is the route optimized for distance or the route can be the most or the least used route (Jurgen, 1998). GPS receivers, which have the capability of displaying the speed, will be useful for determining the speed of the vehicle, even though the display might show a non-zero value of speed sometimes, when the speed of the vehicle is zero.

1.5.5 Property Tax Assessment System using GIS

Municipal authorities all over India understand the importance of bringing IT into their infrastructure and setup. This has led to opening and the consolidation of IT departments in the municipal corporations in the country. Property tax assessment is one of the areas of Kanpur Municipal Corporation where we can use the technology to meet the *challenges of storing huge amount of data, and updating it on a continuous basis in an effective manner. For example, a revenue inspector who has to collect property tax from a number of households, would like to know the defaulters in his assigned area, and an IT system would give him a document or spreadsheet listing the names and addresses of the same. However, if the inspector could be shown visualization on the map about where those properties are corresponding to the defaulters, it would give him much more information than a spreadsheet. Similarly, an administrative officer for a ward or zone could login to the GIS system and visualize the properties under his jurisdiction, and see the properties corresponding to defaulters in different colors, depending on the amount to be paid by the defaulters. The Property Tax Assessment System (PTAS) GIS is one such system which attempts to benefit the municipal authorities for all queries related to property tax. Similar kind of systems can exist for water tax management, and any other tax related information system. The functionalities are described comprehensively in this project report document. This project report document will attempt to describe and consolidate the requirements of GIS application designed for the municipal authority. It gives the detailed information of the developed functionalities and the dependencies on GIS.*

The PTIS is developed using Development environment shown in the figure.

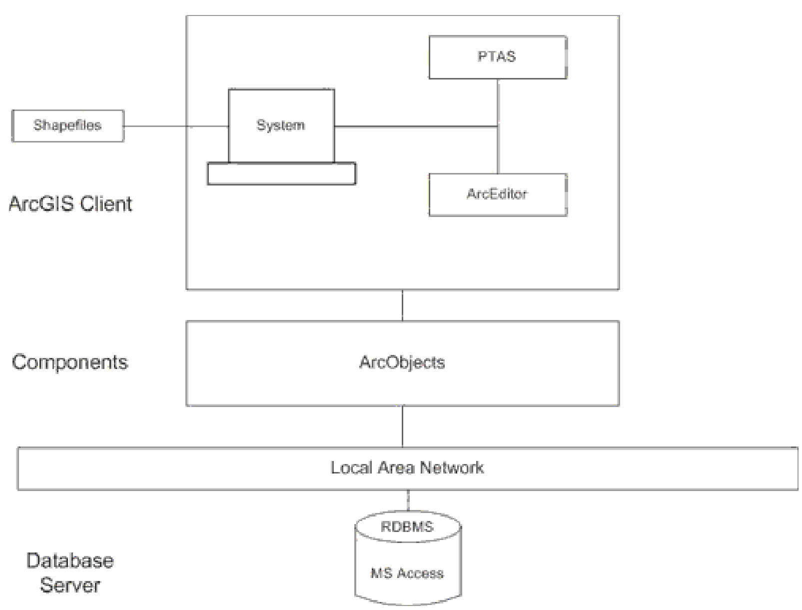


Fig. 1.7: PTIS

1.5.6 Emergency response planning

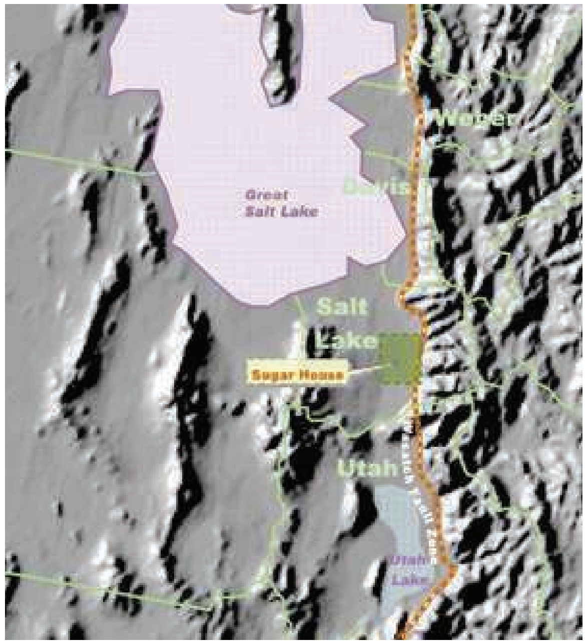


Fig. 1.8: The Wasatch Fault zone runs through Salt Lake City along the foot of the Wasatch Mountains in north-central Utah.

Map of the area surrounding the USGS Sugar House 7.5-minute quadrangle, Salt lake City, Utah, showing the location of the Wasatch Fault zone.

A GIS was used to combine road network and earth science information to analyze the effect of an earthquake on the response time of fire and rescue squads. The area covered by the USGS Sugar House 7.5-minute topographic quadrangle map was selected for the study because it includes both undeveloped areas in the mountains and a part of Salt Lake City. Detailed earth science information was available for the entire region.

The road network from a USGS digital line graph includes information on the types of roads, which range from rough trails to divided highways. The locations of fire stations were plotted on the road network. A GIS function called network analysis was used to calculate the time necessary for emergency vehicles to travel from the fire stations to different areas of the city. The network analysis function considers two elements: (1) distance from the fire station, and (2) speed of travel based on the type of road. The analysis shows that under normal conditions, most of the area within the city will be *served in less than 7 minutes and 30 seconds because of the distribution and density of fire stations and the continuous network of roads.*

The accompanying illustration depicts the blockage of the road network that would result from an earthquake, assuming that any road crossing the fault trace would become impassable. The primary effect on emergency response time would occur in neighborhoods west of the fault trace, where travel times from the fire stations would be noticeably lengthened.

Fig. 1.9: Blocking of road network

After faulting, initial model. Network analysis in a GIS produces a map of travel times from the stations after faulting. The fault is in red. Emergency response times have increased for areas west of the fault.

1.5.7 Three-dimensional GIS

To more realistically analyze the effect of the Earth's terrain, we use three-dimensional models within a GIS. A GIS can display the Earth in realistic, three-dimensional perspective views and animations that convey information more effectively and to wider audiences than traditional, two-dimensional, static maps. The U.S. Forest Service was offered a land swap by a mining company seeking development rights to a mineral deposit in Arizona's Prescott National Forest. Using a GIS, the USGS and the U.S. Forest Service created perspective views of the area to depict the terrain as it would appear after mining.

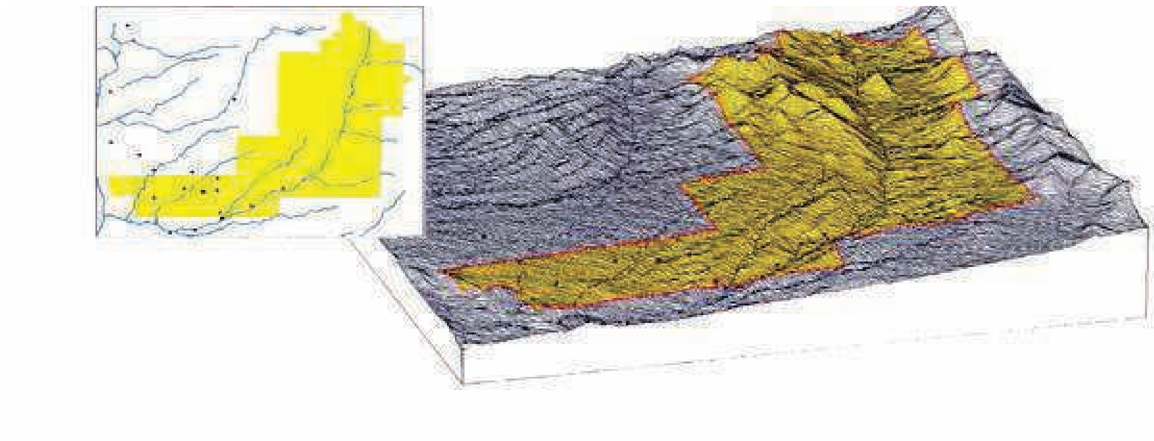


Fig. 1.10: Prescott National Forest, showing altered topography due to mine development.

To assess the potential hazard of landslides both on land and underwater, the USGS generated a three-dimensional image of the San Francisco Bay area. It created the image by mosaicing eight scenes of natural color composite Landsat 7 Enhanced Thematic Mapper imagery on California fault data using approximately 700 digital elevation models at 1:24,000 scale.

Fig 1.11: Three-dimensional image of the San Francisco Bay created to assess the potential of land and underwater avalanches.

1.6 Summary

In this unit we have discussed about geographical information systems, its components and its applications. Database types and scales have been introduced and discuss, such that designing and building a database in GIS can be understood. The basic format of

Geographical data representation along with the computer, software and user requirements has also been highlighted. At the end we have discussed about varied and intensive application of GIS.

1.7 Glossary

Area- *A closed, two-dimensional shape defined by its boundary. A calculation of the size of a two-dimensional feature, measured in square units.*

Digitize- *To encode map features as x,y coordinates in digital form. Lines are traced to define their shapes. This can be accomplished either manually or by use of a scanner.*

Digitizer- *A device connected to a computer, consisting of a tablet and a handheld puck, that converts positions on the tablet surface as they are traced by an operator to digital x,y coordinates, yielding vector data consisting of points, lines, and polygons.*

Database- *A logical collection of interrelated information, managed and stored as a unit. A GIS database includes data about the spatial location and shape of geographic features recorded as points, lines, and polygons as well as their attributes.*

Geocoded- *Translating geographic coordinates of map units (e.g. lines and points), into X, Y digits or grid cells*

Line- *A shape defined by a connected series of unique x,y coordinate pairs. A line may be straight or curved.*

Point- *A level of spatial measurement referring to an object which has no dimension at a specified scale. Examples include wells, weather stations, and navigational lights.*

1.8 References

1. *Burrough, Peter A. and Rachael A. McDonnell. 1998. Principles of Geographical Information Systems. Published by Oxford University Press, Toronto. ISBN13: 9780198233657 ISBN10: 0198233655*

2. *http://teams.gemstone.umd.edu/classof2009/fastr/Jardine%20Article.pdf*

3. *http://www.gdmc.nl/oosterom/PoGISHyperlinked.pdf*
4. *http://ads.ahds.ac.uk/project/goodguides/gis/sect35.html*
5. *http://giswin.geo.tsukuba.ac.jp/sis/tutorial/Fundamentals_of_GIS_Estoque.pdf*
6. *http://geografi.ums.ac.id/ebook/Spatial_Data_Modelling_for_3D_GIS.pdf*
7. *http://www.trfic.msu.edu/products/profcorner_products/Intro_to_GIS.pdf*
8. *http://www.gpsworld.com/transportation/rail/news/antenna-based-control-system-can-stop-a-train-8802*
9. *http://egsc.usgs.gov/isb/pubs/gis_poster/*
10. *http://business.mapsofindia.com/gis-india/application/*
11. *http://www.gisdevelopment.net/technology/lbs/techlbs008.htm*
12. *http://www.gisdevelopment.net/application/urban/overview/urban_p005.htm*

1.9 Suggested Readings

1. *Burrough, Peter A. and Rachael A. McDonnell. 1998. Principles of Geographical Information Systems. Published by Oxford University Press, Toronto. ISBN13: 9780198233657 ISBN10: 0198233655*
2. *Clarke, Keith C. 2002. Getting Started with Geographic Information Systems, 4th ed., Prentice Hall Series in Geographic Information Science, Prentice-Hall Inc., Upper Saddle River, New Jersey. ISBN NO: 0130460273*

1.10 Terminal Questions

1. *What is the full form of GIS?*
2. *What are the different data types? Explain each in 1 or 2 sentences.*
3. *What do you understand by 1: 50000? Explain.*

4. *Which feature type will you choose to draw the following features: Rail, road, plantation area, agriculture area, rivers, spot heights, single house, village, contours, forest.*

***

UNIT 2: READING A TOPOSHEET

2.1 Components of a Toposheet

A map can be simply defined as a graphic representation of the real world. This representation is always an abstraction of reality. Because of the infinite nature of our Universe it is impossible to capture all of the complexity found in the real world. For example, topographic maps abstract the three-dimensional real world at a reduced scale on a two-dimensional plane of paper.

The art of map construction is called cartography. People who work in this field of knowledge are called cartographers. The construction and use of maps has a long history. Some academics believe that the earliest maps date back to the fifth or sixth century BC. Even in these early maps, the main goal of this tool was to communicate information. Early maps were quite subjective in their presentation of spatial information. Maps became more objective with the dawn of Western science. The application of scientific method into cartography made maps more ordered and accurate. Today, the art of map making is quite a sophisticated science employing methods from cartography, engineering, computer science, mathematics, and psychology.

Cartographers classify maps into two broad categories: reference maps and thematic maps. Reference maps normally show natural and human-made objects from the geographical environment with an emphasis on location. Examples of general reference maps include maps found in atlases and topographic maps. Thematic maps are used to display the geographical distribution of one phenomenon or the spatial associations that occur between a numbers of phenomena.

2.1.1 Latitude & Longitude

Most maps allow us to specify the location of points on the Earth's surface using a coordinate system. For a two-dimensional map, this coordinate system can use simple geometric relationships between the perpendicular axes on a grid system to define spatial location. The figure illustrates how the location of a point can be defined on a coordinate system.

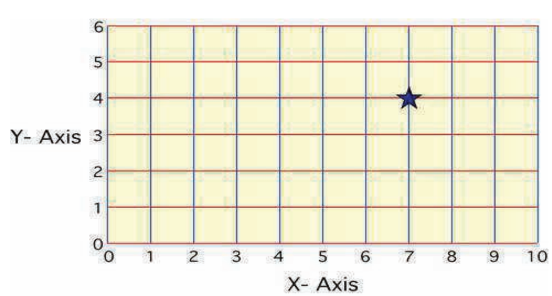


Fig. 2.1: Latitude & Longitude

A grid coordinate system defines the location of points from the distance traveled along two perpendicular axes from some stated origin. In the example above, the two axes are labeled X and Y. The origin is located in the lower left hand corner. Unit distance traveled along each axis from the origin is shown. In this coordinate system, the value associated with the X-axis is given first, following by the value assigned from the Y-axis. The location represented by the star has the coordinates 7 (X-axis), 4 (Y-axis).

Two types of coordinate systems are currently in general use in geography: the geographical coordinate system and the rectangular (also called Cartesian) coordinate system.

The geographical coordinate system measures location from only two values, despite the fact that the locations are described for a three-dimensional surface. The two values used to define location are both measured relative to the polar axis of the Earth. The two measures used in the geographic coordinate system are called latitude and longitude.

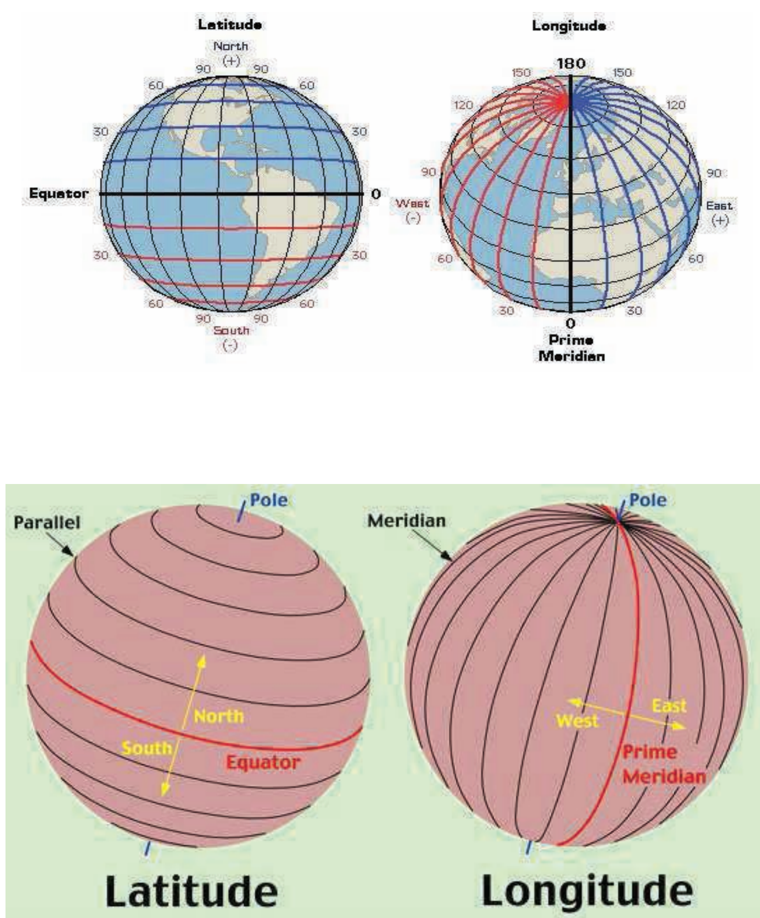


Fig 2.2: Latitude and Longitude

Lines of latitude or parallels are drawn parallel to the equator (shown in red) as circles that span the Earth's surface. These parallels are measure in degrees (°). There are 90 angular degrees of latitude from the equator to each of the poles. The equator has an assigned value of 0°. Measurements of latitude are also defined as being either north or south of equator to distinguish the hemisphere of their location. Lines of longitude or meridians are circular arcs that meet at the poles. There are 180° of longitude either side of a starting meridian which is known the Prime Meridian. The Prime Meridian has a designated value of 0°. Measurements of longitude are also defined as being either west or east of the Prime Meridian.

Latitude measures the north-south position of locations on the Earth's surface relative to a point found at the center of the Earth. This central point is also located on the Earth's rotational or polar axis. The equator is the starting point for the measurement of latitude. The equator has a value of zero degrees. A line of latitude or parallel of 30° North has an angle that is 30° north of the plane represented by the equator. The maximum value that latitude can attain is either 90° North or South. These lines of latitude run parallel to the rotational axis of the Earth.

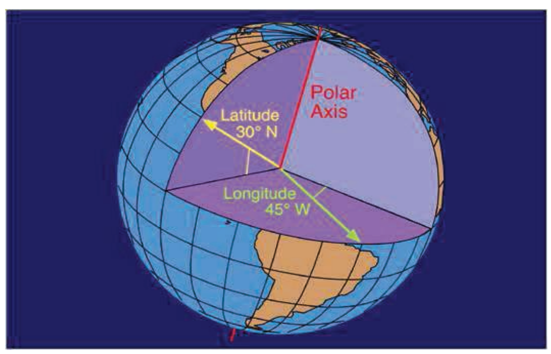


Fig. 2.3: Measurement of latitude and longitude

Measurement of latitude and longitude relative to the equator and the Prime Meridian and the Earth's rotational or polar axis.

Longitude measures the west-east position of locations on the Earth's surface relative to a circular arc called the Prime Meridian. The position of the Prime Meridian was determined by international agreement to be in-line with the location of the former astronomical observatory at Greenwich, England. Because the Earth's circumference is similar to circle, it was decided to measure longitude in degrees. The number of degrees found in a circle is 360. The Prime Meridian has a value of zero degrees. A line of longitude or meridian of 45° West has an angle that is 45° west of the plane represented by the Prime Meridian. The *maximum value that a meridian of longitude can have is 180° which is the distance halfway around a circle. This meridian is called the International Date Line. Designations of west and east are used to distinguish where a location is found relative to the Prime Meridian. For example, all of the locations in North America have a longitude that is designated west.*

2.1.2 Scale: Distance on Maps

We have learned that depicting the Earth's three-dimensional surface on a two-dimensional map creates a number of distortions that involve distance, area, and direction. It is possible to create maps that are somewhat equidistance. However, even these types of maps have some form of distance distortion. Equidistance maps can only control distortion along either lines of latitude or lines of longitude. Distance is often correct on equidistance maps only in the direction of latitude.

On a map that has a large scale, 1:125,000 or larger, distance distortion is usually insignificant. An example of a large-scale map is a standard topographic map. On these maps measuring straight line distance is simple. Distance is first measured on the map using a ruler. This measurement is then converted into a real world distance using the map's scale. For example, if we measured a distance of 10 centimeters on a map that had a scale of 1:10,000, we would multiply 10 (distance) by 10,000 (scale). Thus, the actual distance in the real world would be 100,000 centimeters.

Measuring distance along map features that are not straight is a little more difficult. One technique that can be employed for this task is to use a number of straight-line segments. The accuracy of this method is dependent on the number of straight-line segments used. Another method for measuring curvilinear map distances is to use a mechanical device called an opisometer. This device uses a small rotating wheel that records the distance traveled. The recorded distance is measured by this device either in centimeters or inches.

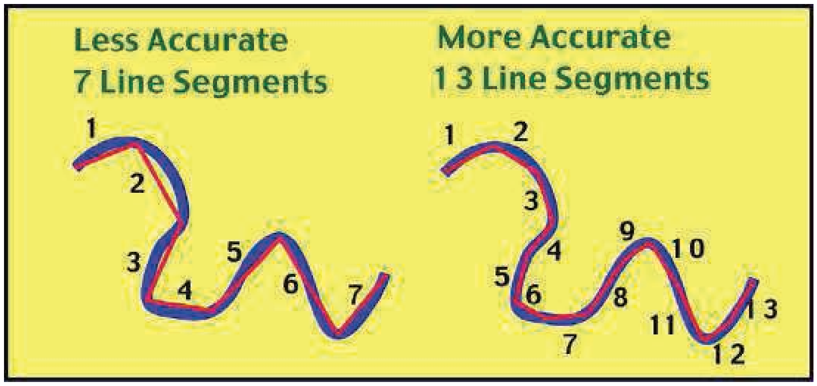


Fig 2.4: Measurement of distance on a map feature using straight-line segments.

2.1.3 North: Direction on Maps

Like distance, direction is difficult to measure on maps because of the distortion produced by projection systems. However, this distortion is quite small on maps with scales larger than 1:125,000. Direction is usually measured relative to the location of North or South Pole. Directions determined from these locations are said to be relative to True North or True South. The magnetic poles can also be used to measure direction. However, these points on the Earth are located in spatially different spots from the geographic North and South Pole. The North Magnetic Pole is located at 78.3° North, 104.0° West near EllefRingnes Island, Canada. In the Southern Hemisphere, the South Magnetic Pole is located in Commonwealth Day, Antarctica and has a geographical location of 65° South, 139° East. The magnetic poles are also not fixed overtime and shift their spatial position overtime.

Topographic maps normally have a declination diagram drawn on them. On Northern Hemisphere maps, declination diagrams describe the angular difference between Magnetic North and True North. On the map, the angle of True North is parallel to the depicted lines of longitude. Declination diagrams also show the direction of Grid North. Grid North is an angle that is parallel to the easting lines found on the Universal Transverse Mercator (UTM) grid system.

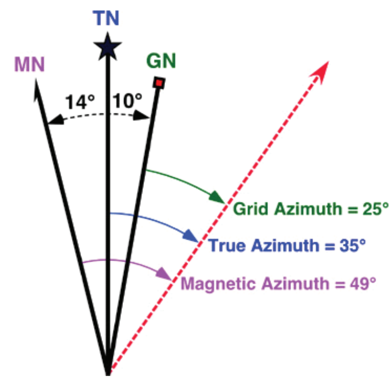


Fig. 2.5: Direction on map

This declination diagram describes the angular difference between Grid, True, and Magnetic North. This illustration also shows how angles are measured relative grid, true, and magnetic azimuth.

In the field, the direction of features is often determined by a magnetic compass which measures angles relative to Magnetic North. Using the declination diagram found on a map, individuals can convert their field measures of magnetic direction into directions that are relative to either Grid or True North. Compass directions can be described by using either the azimuth system or the bearing system. The azimuth system calculates direction in degrees of a full circle. A full circle has 360 degrees. In the azimuth system, north has a direction of either the 0 or 360°. East and west have an azimuth of 90° and 270°, respectively. Due south has an azimuth of 180°.

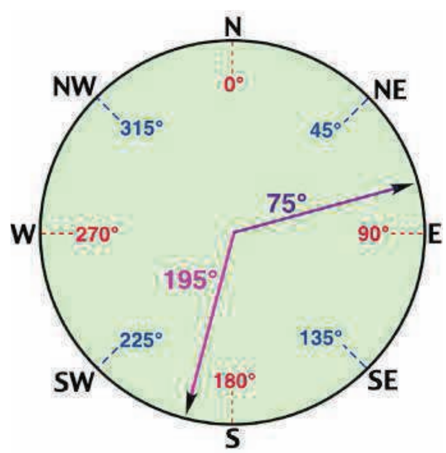


Fig. 2.6: Direction

Azimuth system for measuring direction is based on the 360 degrees found in a full circle. The illustration shows the angles associated with the major cardinal points of the compass. Note that angles are determined clockwise from north.

The bearing system divides direction into four quadrants of 90 degrees. In this system, north and south are the dominant directions. Measurements are determined in degrees from one of these directions. The measurement of two angles based on this system are described below.

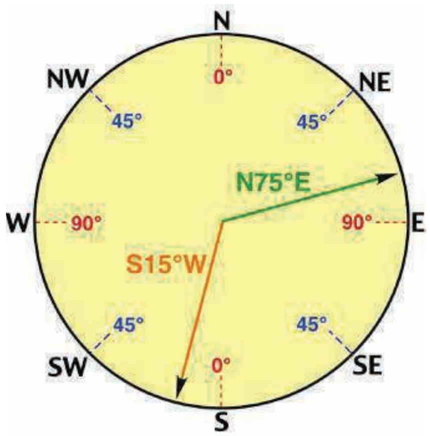


Fig. 2.7: Measurement of two angles

The bearing system uses four quadrants of 90 degrees to measure direction. The illustration shows two direction measurements. These measurements are made relative to either north or south. North and south are given the measurement 0 degrees. East and west have a value of 90 degrees. The first measurement (green) is found in the north - east quadrant. As a result, its measurement is north 75 degrees to the east or N75°E. The first measurement (orange) is found in the south - west quadrant. Its measurement is south 15 degrees to the west or S15°W.

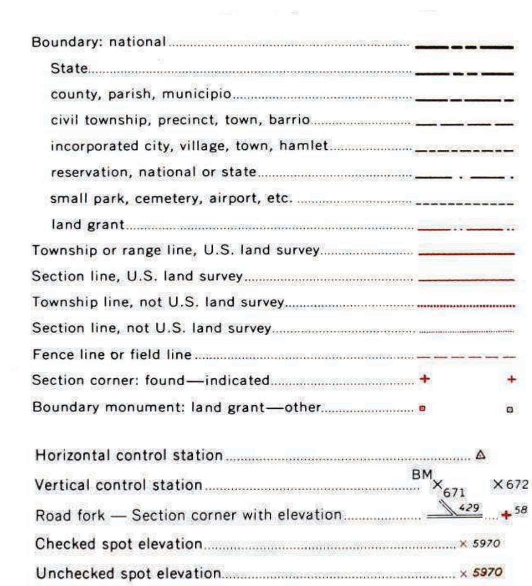
Topographic Maps

A topographic map is a detailed and accurate two-dimensional representation of natural and human-made features on the Earth's surface. These maps are used for a number of applications, from camping, hunting, fishing, and hiking to urban planning, resource management, and surveying. The most distinctive characteristic of a topographic map is that the three-dimensional shape of the Earth's surface is modeled by the use of contour lines. Contours are imaginary lines that connect locations of similar elevation. Contours make it possible to represent the height of mountains and steepness of slopes on a two-dimensional map surface. Topographic maps also use a variety of symbols to describe both *natural and human made features such as roads, buildings, quarries, lakes, streams, and vegetation.*

Topographical maps, also known as general purpose maps, are drawn at relatively large scales. These maps show important natural and cultural features such as relief, vegetation, water bodies, cultivated land, settlements, and transportation networks, etc. These maps are prepared and published by the National Mapping Organisation of each country. For example, the Survey of India prepares the topographical maps in India for the entire country. The topographical maps are drawn in the form of series of maps at different scales. Hence, in the given series, all maps employ the same reference point, scale, projection, conventional signs, symbols and colours. The topographical maps in India are prepared in two series, i.e. India and Adjacent Countries Series and The International Map Series of the World.

2.1.4 Legend

Topographic maps use symbols to represent natural and human constructed features found in the environment. The symbols used to represent features can be of three types: points, lines, and polygons. Points are used to depict features like bridges and buildings. Lines are used to graphically illustrate features that are linear. Some common linear features include roads, railways, and rivers. However, we also need to include representations of area, in the case of forested land or cleared land; this is done through the use of color.



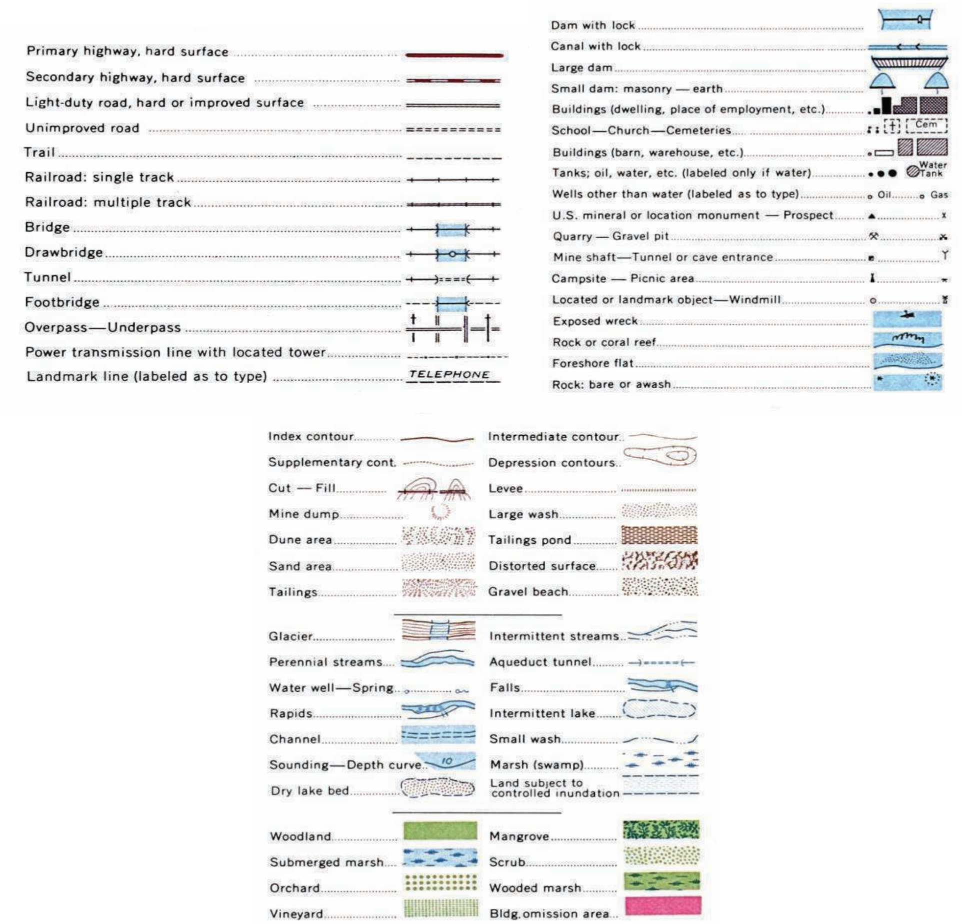


Fig. 2.8: Legend

2.2 Features in a Toposheet

2.2.1 Landform Features

Topographic maps can describe vertical information through the use of contour lines (contours). A contour line is an isoline that connects points on a map that have the same elevation. Contours are often drawn on a map at a uniform vertical distance. This distance is called the contour interval. The map in the Figure 2d-1 shows contour lines with an interval of 100 feet. Note that every fifth brown contour lines is drawn bold and has the appropriate elevation labeled on it. These contours are called index contours. On Figure 2.9 they represent elevations of 500, 1000, 1500, 2000 feet and so on. The interval at which contours are drawn on a map depends on the amount of the relief depicted and the scale of the map.

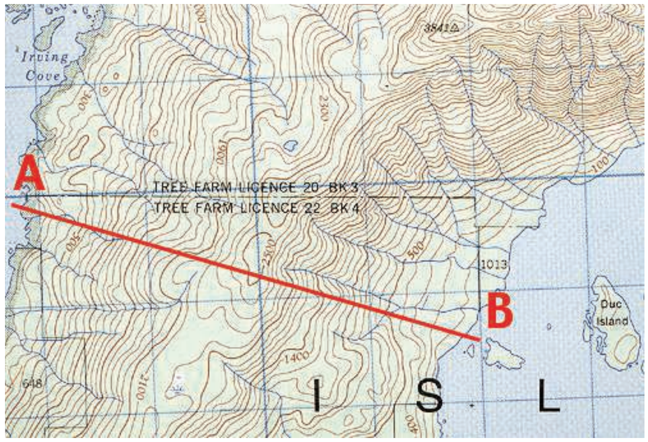


Fig. 2.9: elevations of 500, 1000, 1500, 2000 feet

Portion of the "Tofino" 1:50,000 National Topographic Series of Canada map. The brown lines drawn on this map are contour lines. Each line represents a vertical increase in elevation of 100 feet. The bold brown contour lines are called index contours. The index contours are labeled with their appropriate elevation which increases at a rate of 500 feet. Note the blue line drawn to separate water from land represents an elevation of 0 feet or sea-level. Contour lines provide us with a simple effective system for describing landscape configuration on a two-dimensional map. The arrangement, spacing, and shape of the contours provide the user of the map with some idea of what the actual topographic configuration of the land surface looks like. Contour intervals the are spaced closely together describe a steep slope. Gentle slopes are indicated by widely spaced contours. Contour lines that V upwards indicate the presence of a river valley. Ridges are shown by contours that V downwards.

Some basic features of contour lines are

- *A contour line is drawn to show places of equal heights.*
- *Contour lines and their shapes represent the height and slope or gradient of the landform.*
- *Closely spaced contours represent steep slopes while widely spaced contours represent gentle slope.*
- *When two or more contour lines merge with each other, they represent features of vertical slopes such as cliffs or waterfalls.*
- *Two contours of different elevation usually do not cross each other.*

A topographic profile is a two-dimensional diagram that describes the landscape in vertical cross-section. Topographic profiles are often created from the contour information found on topographic maps. The simplest way to construct a topographic profile is to place a sheet of blank paper along a horizontal transect of interest. From the map, the elevation of the various contours is transferred on to the edge of the paper from one end of the transect to the other. Now on a sheet of graph paper use the x-axis to represent the horizontal distance covered by the transect. The y-axis is used to represent the vertical dimension and measures the change in elevation along the transect. Most people exaggerate the measure of elevation on the y-axis to make changes in relief stand out. Place the beginning of the transect as copied on the piece of paper at the intersect of the x and y-axis on the graph paper. The contour information on the paper's edge is now copied onto the piece of graph paper. Figure 2.10 shows a topographic profile drawn from the information found on the transect A-B above.

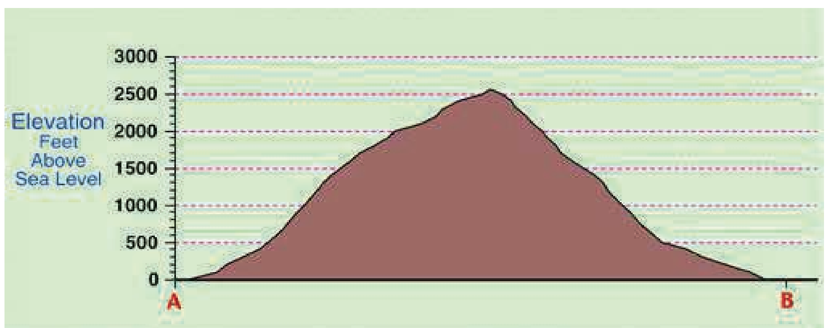


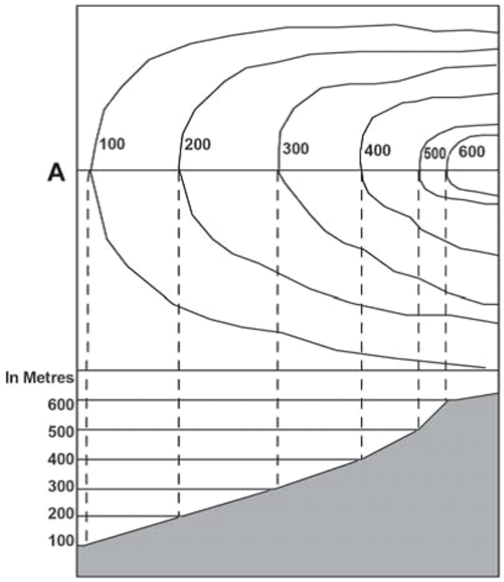
Fig. 2.10: Topographic profile

The following topographic profile shows the vertical change in surface elevation along the transect AB from Figure 2.10. A vertical exaggeration of about 4.2 times was used in the profile (horizontal scale = 1:50,000, vertical scale = 1:12,000 and vertical exaggeration = horizontal scale/vertical scale).

2.2.2 Slopes

We know that all the topographical features show varying degrees of slopes. For example, a flat plain exhibits gentler slopes and the cliffs and gorges are associated with the steep slopes. Similarly, valleys and mountain ranges are also characterised by the varying degree of slopes, i.e. steep to gentle. Hence, the spacing of contours is significant since it indicates the slope.

The slopes can broadly be classified into gentle, steep, concave, convex and irregular or undulating. The contours of different types of slopes show a distinct spacing pattern.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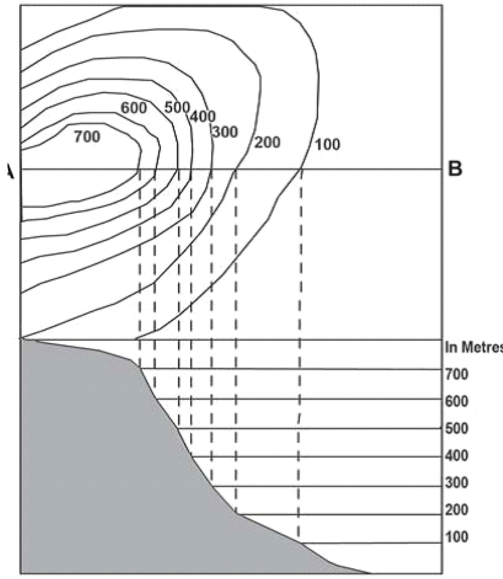
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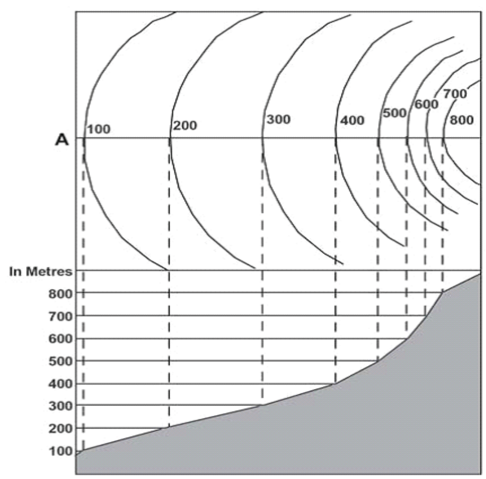
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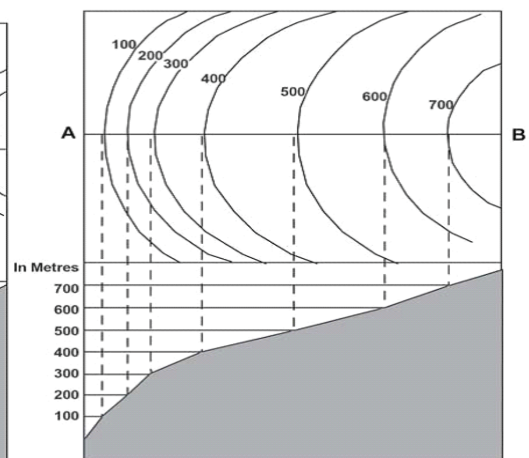
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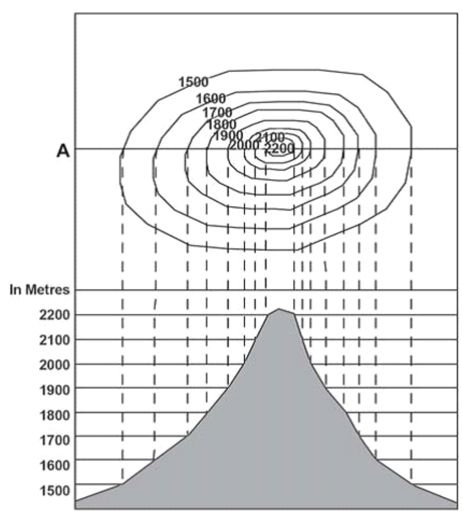
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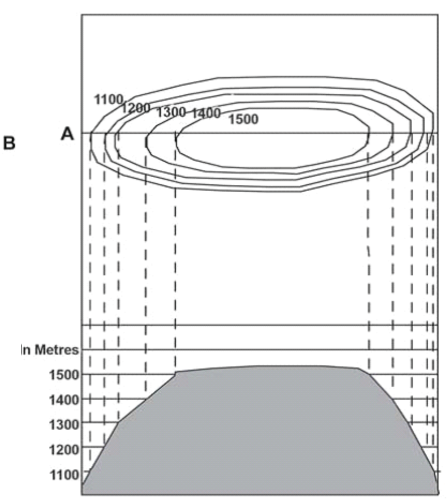
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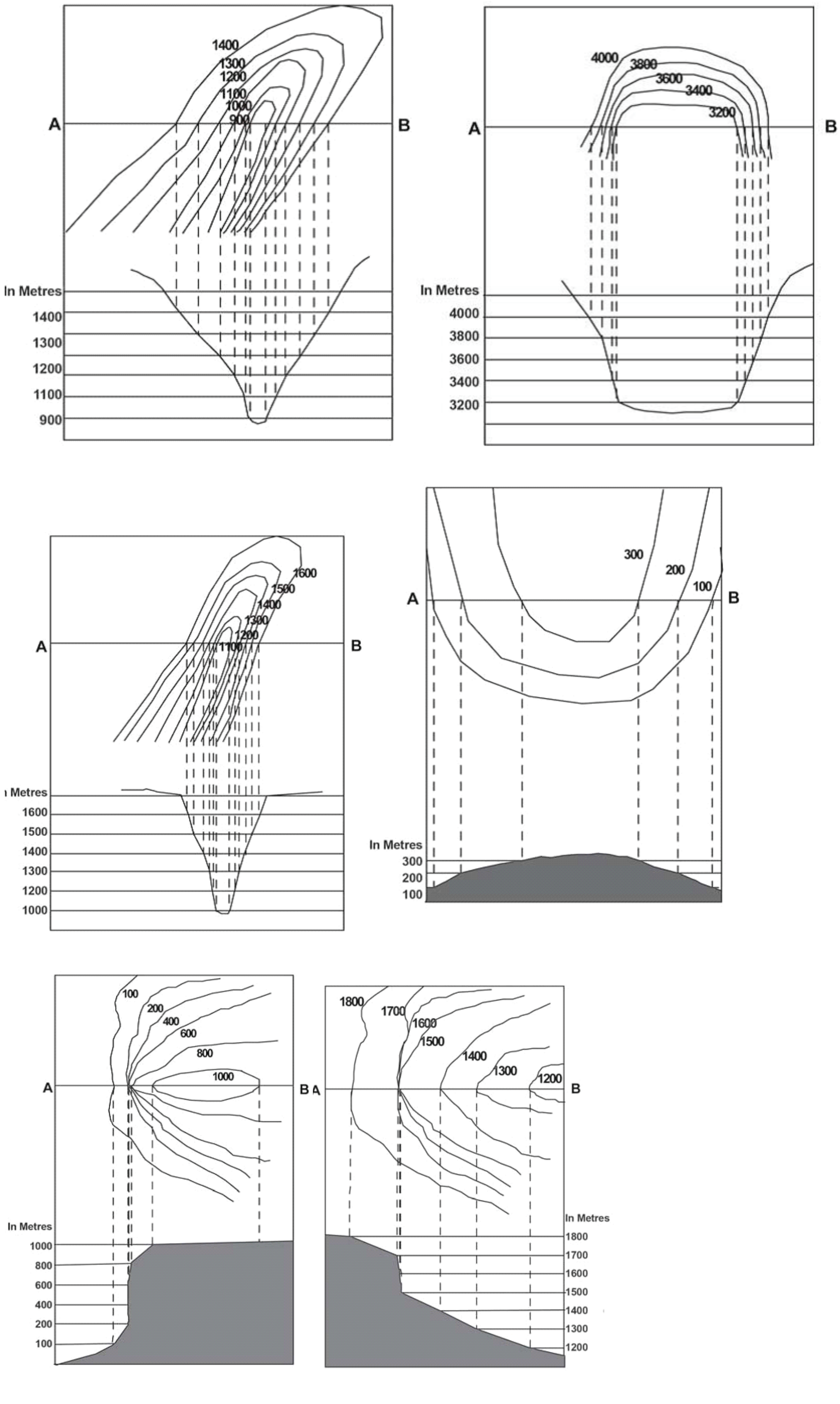


Fig. 2.11 Slopes

2.2.3 Drainage Pattern

The term drainage basin describes an area drained collectively by the network of a river along with its tributaries and sub-tributaries of various dimensions.

An area drained by a single river is called its Catchment Area.

A drainage system as seen in the topographical sheets usually develops a pattern which is related to the general structure of its basin.

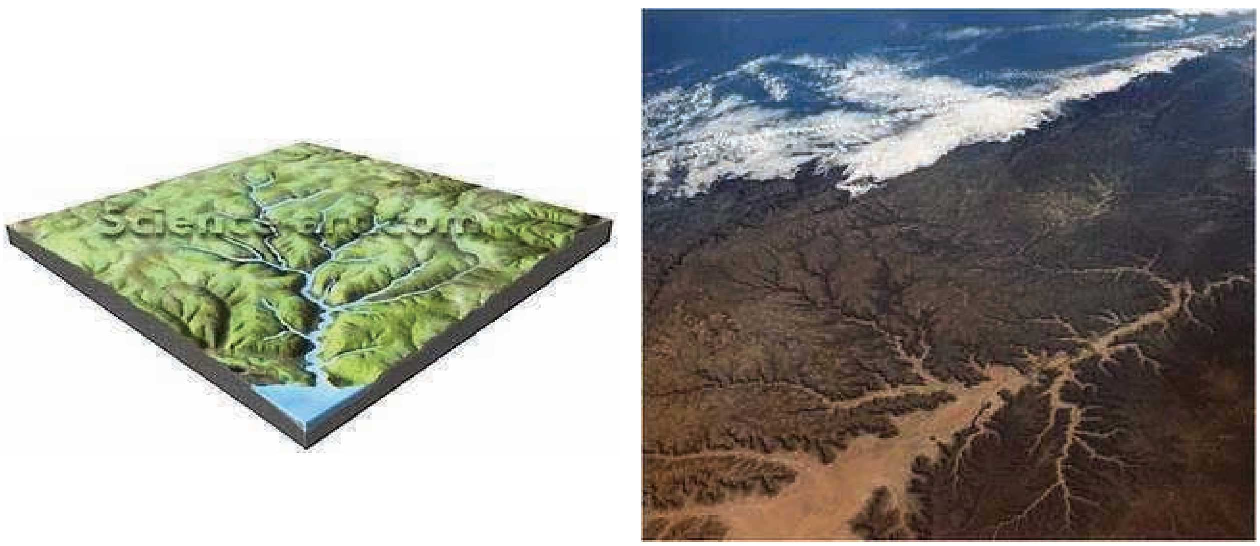


Fig. 2.12: Drainage system

3 distinct patterns can be recognized

1. DENDRITIC

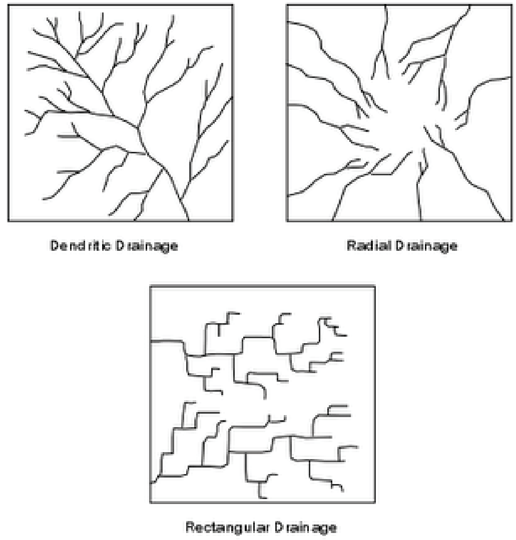


Fig 2.13: Dendritic drainage

Dendritic drainage patterns are most common. They develop on a land surface where the underlying rock is of uniform resistance to erosion.

Dendritic drainage systems are the most common form of drainage system. The term dendritic comes from the Greekword "dendron", meaning tree, due to the resemblance of the system to a tree.

In a dendritic system there is one main river (like the trunk of a tree), which was joined and formed by many smallertributary rivers. They develop where the river channel follows the slope of the terrain. Dendritic systems form in V-shaped valleys; as a result, the rock types must be impervious and non-porous

2. TRELLIS

Rectangular drainage patterns develop where linear zones of weakness, such as joints or faults cause the streams to cut down along the weak areas in the rock.

Trellis systems form in areas of alternating geology, particularly chalk and clay. The main river (the consequent) flows straight down hill.

Subsequent streams develop perpendicular to the consequent along softer rock and erode it away, forming vales.

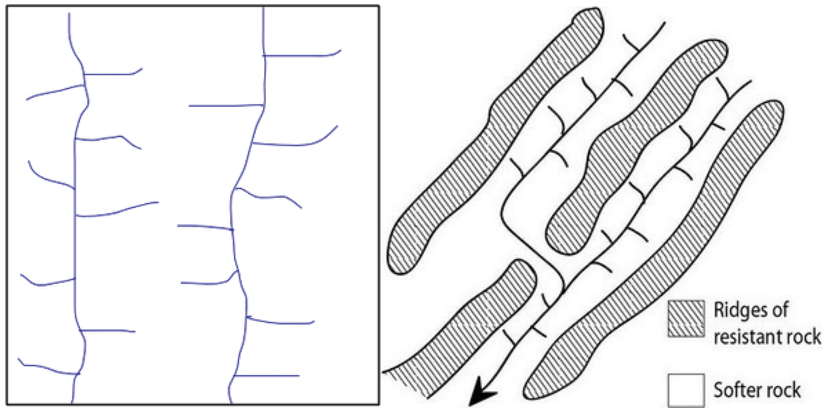


Fig 2.14: Trellis systems

The consequent river then cuts through the escarpments of harder rock.

Obsequent streams flow down thedip slope of the escarpments to join the subsequent streams.

3. RADIAL

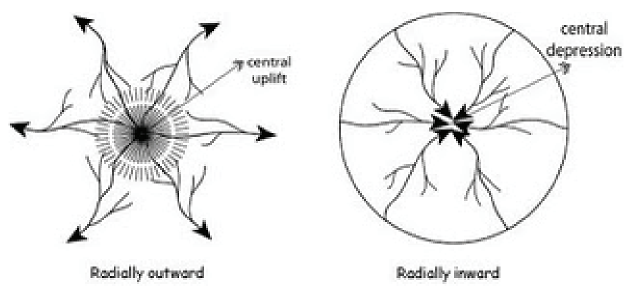


Fig 2.15: Radial drainage patterns

Radial drainage patterns develop surrounding areas of high topography where elevation drops from a central high area to surrounding low areas.

2.2.4 Settlements

Distribution of settlements can be seen in the map through its site, location pattern, alignment and density. The nature and causes of various settlement patterns may be clearly understood by comparing the settlement map with the contour map.

Four types of rural settlements may be identified on the map *(a) Compact*

(b) Scattered

(c) Linear

(d) Circular

Similarly, urban centers may also be distinguished as

(a) Cross-road town

(b) Nodal point

(c) Market centre

(d) Hill station

(e) Coastal resort centre

(f) Port

(g) Manufacturing centre with suburban villages or satellite towns

(h) Capital town

(i) Religious centre

Various factors determine the site of settlements like

(a) Source of water

(b) Provision of food

(c) Nature of relief

(d) Nature and character of occupation

(e) Defence

Site of settlements should be closely examined with reference to the contour and drainage map. Density of settlement is directly related to food supply. Sometimes, village settlements form alignments, i.e. they are spread along a river valley, road, embankment, coastline – these are called linear settlements. In the case of an urban settlement, a cross-road town assumes a fan-shaped pattern, the houses *being arranged along the roadside and the crossing being at the heart of the town and the main market place. In a nodal town, the roads radiate in all directions.*

2.2.5 Significance of colours in a Toposheet

On toposheets colours are used to show certain features. Each colour used on a map has significance.

1. *BLACK – All names, river banks, broken ground, dry streams, surveyed trees, heights and their numbering, railway lines, telephone and telegraph lines, lines of latitude and longitude.*
2. *BLUE – Water features or water bodies that contain water.*
3. *GREEN – All wooded and forested areas, orchards, scattered trees and scrubs.*

   Note: Prominent surveyed trees are shown in black. Surveyed trees have numbers on their trunks. They serve as landmarks and are not allowed to be cut.
4. *YELLOW – All cultivated areas are shown with a yellow wash.*
5. *WHITE PATCHES – Uncultivable land*
6. *BROWN – Contour lines, their numbering, form lines, and sand features such as sand hills and dunes.*
7. *RED – Grid lines (eastings and northings) and their numbering, roads, cart tracks, settlements, huts and buildings.*

SETTLEMENTS

1. *On a topo map, all settlements are shown by symbols in RED colour.*
2. *The size of the symbol and size and style of letters used give an idea of the size of the settlement.*
3. *In the case of large cities, major roads are marked and named.*
4. *Deserted village cities, temporarily occupied huts are also shown.*

5. *Places of worship, forts, water towers, burial grounds, police stations, post office, dak bungalow, circuit houses, etc. are indicated by suitable symbols.*

6. *Dense settlements are mainly found in fertile plains and wide river valleys.*

7. *Sparse Settlements are mainly observed in areas like forests, deserts, mountain slopes, plateaus and hill tops with poor vegetation•*

8. *Absence of Settlements near swamps, marsh land, sandy deserts, thick impenetrable forests, flood-prone areas, steep mountain slopes.*

OCCUPATION AND MAP FEATURES

AGRICULTURE – Level land with yellow wash; many wells

LUMBERING: Forests

CATTLE REARING – Pastures, meadows, grasslands, presence of road in highland region (sheep)

FISHING – Plenty of rivers

MINING –Stony wastes, quaries, limestone beds

TRADE – Dense settlements near road

INDUSTRY – Large settlements near roads and railways, presence of raw materials, (like making, cement industry near limestone beds)

TOURISM – hotels and inns

APPROXIMATE OR RELATIVE HEIGHT-is height is not taken from sea level but with respect to the surrounding area. It may be the height of a dam, bridge, sand dune or it can be the depth of a well, tank, hill or river canal, for example , 3r, 5r, 8r, etc.

Example:

3r - the relative depth of perennial lined well in 3 metres

5r – the relative height of dry tank is 5 metres

2.2.6 Map Interpretation Procedure

Map interpretation involves the study of factors that explain the causal relationship among several features shown on the map. For example, the distribution of natural vegetation and cultivated land can be better understood against the background of landform and drainage. Likewise, the distribution of settlements can be examined in association with the levels of transport network system and the nature of topography.

The following steps will help in map interpretation:

Find out from the index number of the topographical sheet, the location of the area in India. This would give an idea of the general characteristics of the major and minor physiographic divisions of the area. Note the scale of the map and the contour interval, which will give the extent and general landform of the area. Trace out the following features on tracing sheets.

(a) Major landforms – as shown by contours and other graphical features.

(b) Drainage and water features – the main river and its important tributaries.

(c) Land use – i.e. forest, agricultural land, wastes, sanctuary, park, school, etc.

(d) Settlement and Transport pattern.

Describe the distributional pattern of each of the features separately drawing attention to the most important aspect.

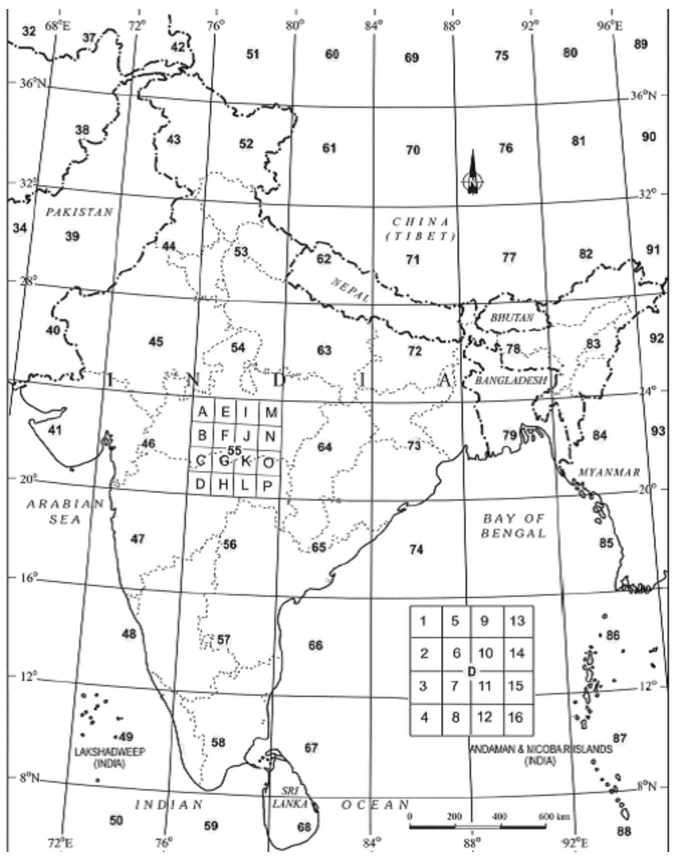
Superimpose pairs of these maps and note down the relationship, if any, between the two patterns. For example, if a contour map is superimposed over a land use map, it provides the relationship between the degree of slope and the type of the land used.

Aerial photographs and satellite imageries of the same area and of the same scale can also be compared with the topographical map to update the information.

2.3 Toposheet Scale and Numbering System

Topographic maps provides the graphical portrayal of objects present on the surface of the earth. These maps provide the preliminary information about a terrain and thus very useful for engineering works. For most part of India, topographic maps are available which are prepared by the Survey of India. To identify a map of a particular area, a map *numbering system has been adopted by Survey of India. The system of identification is as follows:*

An International Series (within 4° N to 40° N Latitude and 44° E to 124° E Longitude) at the scale of 1: 1,000,000 is being considered as base map. The base map is divided into sections of 4° latitude x 4° longitude and designated from 1 (at the extreme north-west) to 136, covering only land areas and leaving any 4° square if it falls completely in the sea



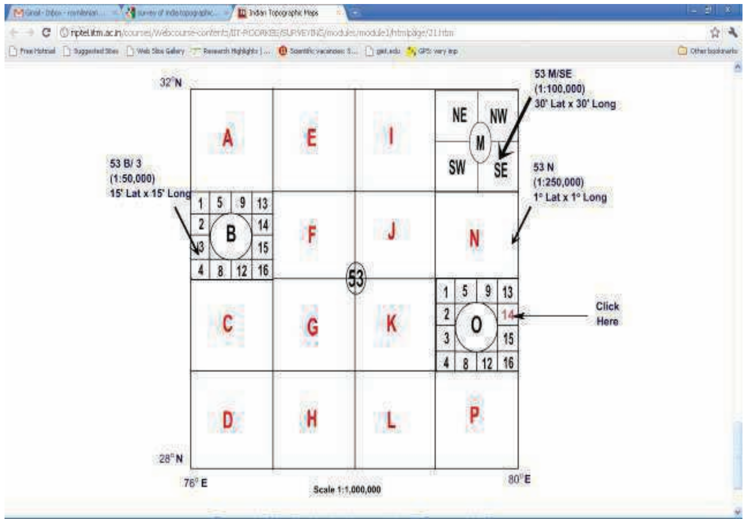


Fig. 2.16: Toposheet

2.3.1 India and Adjacent Countries Series

Topographical maps under India and Adjacent Countries Series were prepared by the Survey of India till the coming into existence of Delhi Survey Conference in 1937. Henceforth, the preparation of maps for the adjoining countries was abandoned and the Survey of India confined itself to prepare and publish the topographical maps for India as per the specifications laid down for the International Map Series of the World. However, the Survey of India for the topographical maps under the new series retained the numbering system and the layout plan of the abandoned India and Adjacent Countries Series. The topographical maps of India are prepared on 1 : 10,00,000, 1 : 250,000, 1 : 1,25,000, 1 : 50,000 and 1: 25,000 scale providing a latitudinal and longitudinal coverage of 4° x 4°, 1° x 1°, 30' x 30', 15' x 15' and 5' x 7' 30", respectively. The numbering system of each one of these topographical maps is shown below.

International Map Series of the World: Topographical Maps under International Map Series of the World are designed to produce standardized maps for the entire World on a scale of 1: 10,00,000 and 1:250,000.

2.3.2 Reading of Topographical Maps

The study of topographical maps is simple. It requires the reader to get acquainted with the legend, conventional sign and the colours shown on the sheets. The conventional sign and symbols depicted on the topographical sheets are shown in the following figures.

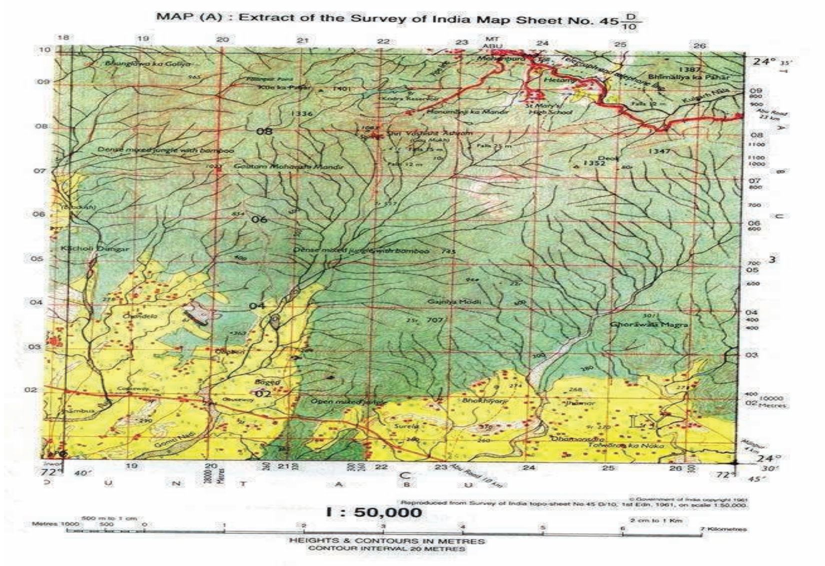


Fig. 2.17: Conventional sign and symbols on the topographical maps

2.4 Summary

In this unit we have learnt about the toposheet. The components of a toposheet, apart from the area described, namely latitude and longitude, legend and scale have been well illustrated. The following sections are about the derived information from a toposheet, like landforms, slope, drainage pattern, etc. The various scales at which toposheets are available along with the numbering system, and how the numbering system and scales are correlated have also been included.

2.5 Glossary

Azimuth- *The horizontal angle, measured in degrees, between a baseline drawn from a center point and another line drawn from the same point. Normally, the baseline points true north and the angle is measured clockwise from the baseline.*

Coordinate- *any of the magnitudes that serve to define the position of a point, line, or the like, by reference to a fixed figure, system of lines*

Isoline - *A line connecting points of equal value on a map. Isolines fall into two classes: those in which the values actually exist at points, such as temperature or elevation values, and those in which the values are ratios that exist over areas, such as population per square kilometer or crop yield per acre. The first type of isoline is specifically called an isometric line or isarithm; the second type is called an isopleth.*

Grid- *In cartography, any network of parallel and perpendicular lines superimposed on a map and used for reference. These grids are usually referred to by the map projection or coordinate system they represent*

Landform- *A specific geomorphic feature on the surface of the earth, ranging from large-scale features such as plains, plateaus, and mountains to minor features such as hills, valleys, and alluvial fans.*

Map- *A map is a detailed and accurate two-dimensional representation of natural and human-made features on the real world.*

Pattern- *A distinctive style, model, or form*

Relief- *Elevations and depressions of the earth's surface, including those of the ocean floor. Relief can be represented on maps by contours, shading, hypsometric tints, digital terrain modeling, or spot elevations.*

Slope - *The incline, or steepness, of a surface. Slope can be measured in degrees from horizontal (0–90), or percent slope (which is the rise divided by the run, multiplied by 100). A slope of 45 degrees equals 100 percent slope. As slope angle approaches vertical (90 degrees), the percent slope approaches infinity.*

2.6 References

1. *http://brhectorsgeoworld.blogspot.com/2009/02/topographical-survey-maps.html*
2. *https://sites.google.com/a/tges.org/geo-jaydeep/std-10-geography/topographical-maps*
3. *http://www.iasexams.com/NCERT-Books/NCERTBooksforClass11/FreedownloadClass11Geography3PracticalGeographyNCERTBook/Class11_Geography3_PracticalGeography_Unit05_NCERT_TextBook_EnglishEdition.pdf*
4. *http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT-ROORKEE/SURVEYING/modules/module1/htmlpage/21.htm*

2.7 Suggested Readings

1. *Misra, R.P. and A. Ramesh. 1989. Fundamentals of Cartography (Revised and Enlarged). Published by Concept Publishing Company, Mohan Garden, New Delhi, India. ISBN (Paperback): ISBN NO: 9788170222224*

2.8 Terminal Questions

1. *Explain with diagram latitude/longitude and north arrow of a toposheet.*
2. *Draw diagram and briefly describe any 2 different types of features represented with contour lines.*
3. *Name 2 different type of drainage patterns with 2 characteristics each.*
4. *What do you understand by 45 D/10? Give any 2 numbers of its adjoining toposheets.*

***

UNIT 3: DATA: SPATIAL AND NON-SPATIAL I

3.1 ***Introduction to Spatial Data***

"Everything is related to everything else, but near things are more related than distant things." Tobler's first law of geography

Since the advent of GIS in the 1980s, many government agencies have invested heavily in GIS installations, including the purchase of hardware and software and the construction of mammoth databases. Two fundamental functions of GIS have been widely realized: generation of maps and generation of tabular reports.

Indeed, GIS provides a very effective tool for generating maps and statistical reports from a database. However, GIS functionality far exceeds the purposes of mapping and report compilation. In addition to the basic functions related to automated cartography and data base management systems, the most important uses of GIS are spatial analysis capabilities. As spatial information is organized in a GIS, it should be able to answer complex questions regarding space. Making maps alone does not justify the high cost of building a GIS. The same maps may be produced using a simpler cartographic package. Likewise, if the purpose is to generate tabular output, then a simpler database management system or a statistical package may be a more efficient solution.

It is spatial analysis that requires the logical connections between attribute data and map features, and the operational procedures built on the spatial relationships among map features. These capabilities make GIS a much more powerful and cost-effective tool than automated cartographic packages, statistical packages, or data base management systems. Indeed, functions required for performing spatial analyses that are not available in either cartographic packages or data base management systems are commonly implemented in GIS.

Principally, there are three spatial data components that need to be stored for GIS data: geometric data, thematic data, and a link identification (ID) for the geometric and the thematic component. The illustration in Figure 4.1 shows the link between the geometric component (which deals with the location of the data by means, for example, of a reference coordinate system) and the thematic component (it provides the attribute values *of the data, e.g. names, and other identifiers (IDs) of the data). Object or feature needs to be geometrically and thematically described (Longley et al., 1999; Laurini and Thompson, 1991). The basic components of spatial data (TINs) can be used to describe real world terrain objects, whether natural or man-made; thus we have TIN-based spatial objects.*

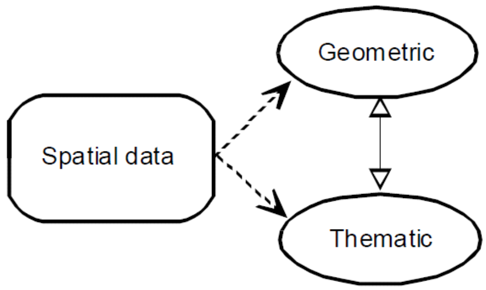


Fig. 3.1: Spatial data components

3.1.1 Spatial representation of Data in GIS

The type of analysis one wants to conduct with GIS depends largely on how data are measured. The data that are usually mapped in a GIS can be categories, counts or amounts, ratios, or ranks. A category is a group with similar characteristics. For example, an admission office producing a map of areas of recruitment could categorize high schools by type of control, public or private. Counts and amounts can be used to map discrete features (number of students at each high school within the state) or continuous phenomena (household income by census block). A ratio is used to allow comparison of data between small and large areas and between areas with many features versus those with few. When using counts or amounts to summarize data by area, analysts should be aware that such data types can skew the patterns if the areas vary by size. To avoid false interpretation, GIS analysts can use average, proportion, and density to summarize indicators by area. One might be interested, for instance, in mapping the average number of people per household, or the proportion of high school students in total population by census block. Mapping density allows the analyst *to see where features are concentrated; it is particularly useful in displaying distributions when the size of the areas summarized varies greatly. Mapping the population per square mile by census tract is an essential analysis when deciding on the location, for instance, of a future campus.*

Rank shows relative value rather than measured value. Rank can be expressed either as text (very satisfied, satisfied, neutral, dissatisfied, very dissatisfied) or numbers (one through five). For example, senior survey data could be mapped to examine whether satisfaction with the college experience is higher for in-state students than for out-of-state students.

After determining the type of data to map, the next decision a GIS analyst has to make is whether to map individual values (by assigning a unique symbol) or to group the values into classes. This decision always involves a tradeoff between presenting the data values accurately and generalizing the values to uncover patterns on the map.

3.2 Concepts of Geoid, Datum, Spheroid

The Earth as a Sphere. In this calculation the Earth is viewed as being an evenly round 'ball'. This is called a Sphere. From an imaginary centre of the Earth, calculations are made from the centre of the Earth to the surface of the Earth.

In this diagram the distances from the centre of the Earth to the Equator and the Geographic/True North Pole (indicated by 'a' and 'b') are the same value.

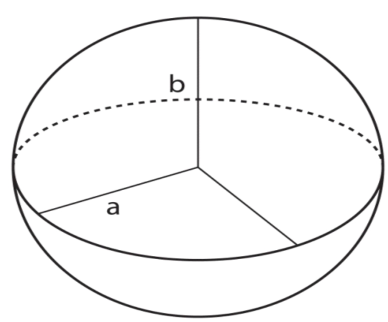


Fig. 3.2(a): Distances from the centre of the Earth

The Earth as an Ellipsoid (or Spheroid). However, the Earth is not evenly round - it is in fact wider around the Equator than it is between the North and South Poles. This is called an Ellipsoid (or a Spheroid).. All Ellipsoids/Spheroids are 'wider' than they are 'tall'.

In this diagram the length of 'a' is greater than the length of 'b'.

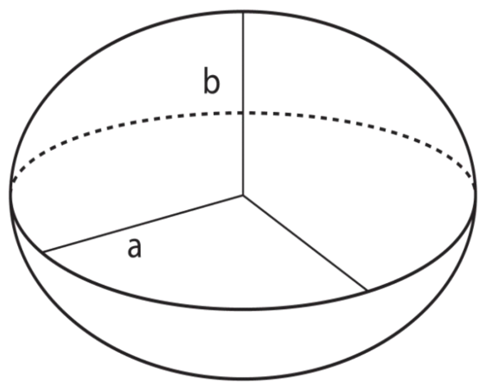


Fig. 3.2(b): Distances from the centre of the Earth

The use of the terms Ellipsoid and Spheroid can be very confusing as they are used interchangeably within the geodetic community

A Spheroid is simply an Ellipsoid which is as wide as it is long (ie evenly round and close in shape to that of a sphere). All other Ellipsoids are longer than they are wide (ie shaped more like an Australian Rules football).

In Australia, most datums refer to the Australian National Spheroid.

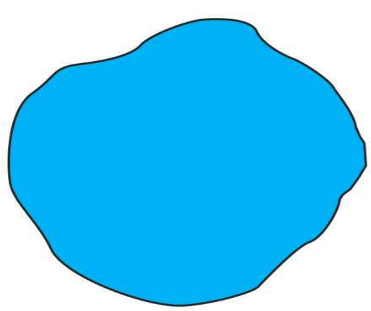


Fig. 3.3(a): The Earth as a Geoid

However, this is also a very simplistic concept. The Earth in reality is a very misshapen object. This is called a Geoid. The Earth's Geoid is a surface which is complex to accurately describe mathematically. But it can be identified by measuring gravity.

The Earth's Geoid is regarded as being equal to Mean Sea Level. Over open oceans the Geoid and Mean Sea Level are approximately the same, but in continental areas they can differ significantly. However, it must be noted that this difference it is not of any practical consequence for most people and and it is considered reasonable that they are regarded as the same.

Because of the Earth's Geoid's irregularity Geodesists have chosen to use Ellipsoids (or Spheroids) to calculate the location of latitude and longitude.

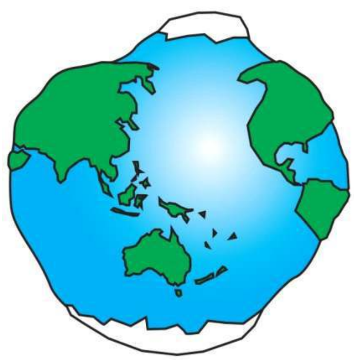


Fig. 3.3(b): Earth's Shape

The Earth's True Shape - Its Terrain of course the Earth isn't just ocean (Mean Sea Level). Much of the land masses are well above the sea level (eg Mount Everest is over 8,000 metres above Mean Sea Level), while in the ocean it is well below sea level (eg the Mariana Trench is over 10,000 metres below Mean Sea Level.

In summary - there are four surfaces that geodesists study:

1 *Ellipsoid/Spheroid*

2 Geoid

3 Mean Sea Level

4 Terrain

It is important to recognise that the relationship between these four surfaces is not always the same. Rather, as this diagram indicates, they 'wobble' around each other.

(Please note that for this diagram the relationship between these four has been exaggerated so that you may better understand the nature of this 'wobbling'.)

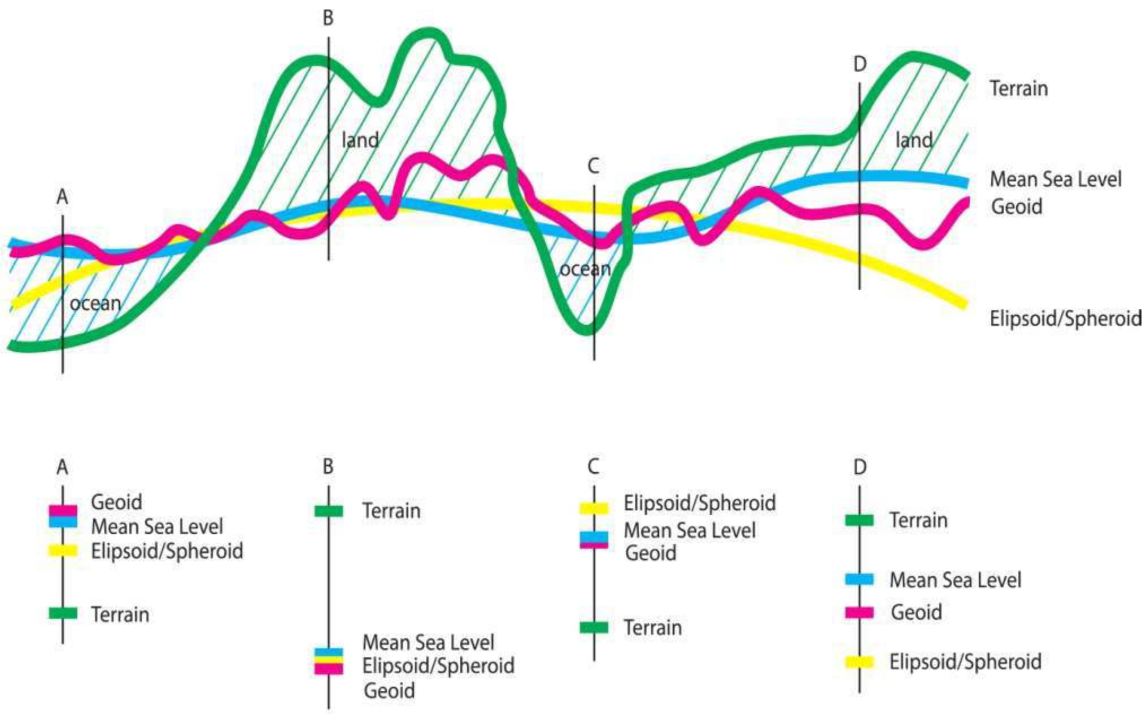


Fig. 3.4: Four examples (A, B, C and D) have been chosen to decribe how these relationships may change.

A and C show the Earths' terrain as being below Mean Sea Level - this is equivalent to an area of ocean. Note how the Geoid and Mean Seal Level are very close to the same value, but their relationship to the Ellipsoid/Spheroid varies.

B and D show the Earths' terrain as being above Mean Sea Level - this is equivalent to an area of land. It is worth noting that the differeces between the Geoid and Mean Seal Level is much greater than in the ocean examples. And, similarly, their relationship to the Ellipsoid/Spheroid varies.

With an understanding of these four geometric shapes and their relationships to each other it is possible to better understand Datums.

While a spheroid approximates the shape of the earth, a datum defines the position of the spheroid relative to the center of the earth. A datum provides a frame of reference for measuring locations on the surface of the earth. It defines the origin and orientation of latitude and longitude lines.

These two diagrams illustrate these two situations:

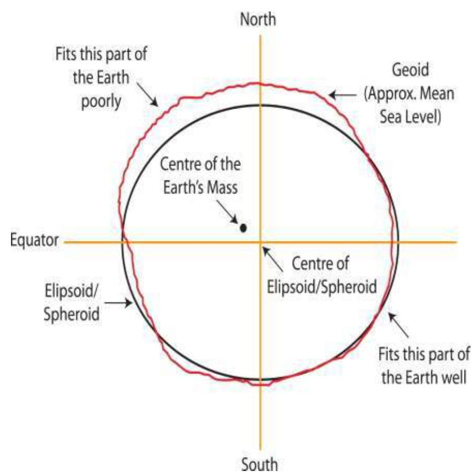


Fig 3.5: Origin and orientation of latitude and longitude lines

Local or Regional Datums

A local datum aligns its spheroid to closely fit the earth's surface in a particular area. A point on the surface of the spheroid is matched to a particular position on the surface of the earth. This point is known as the origin point of the datum. The coordinates of the origin point are fixed, and all other points are calculated from it.

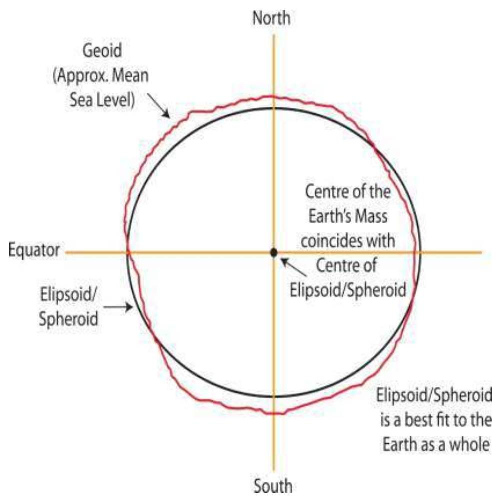


Fig. 3.6: Local or Regional Datums

Geocentric Datums

In the last 15 years, satellite data has provided geodesists with new measurements to define the best earth-fitting spheroid, which relates coordinates to the earth's center of mass. An earth-centered, or geocentric, datum uses the earth's center of mass as the origin. The most recently developed and widely used datum is WGS 1984. It serves as the framework for locational measurement worldwide.

3.3 Types of Projection Systems

A map projection is a mathematically described technique of how to represent the Earth's curved surface on a flat map. To represent parts of the surface of the Earth on a flat paper map or on a computer screen, the curved horizontal reference surface must be mapped onto the 2D mapping plane. The reference surface for large-scale mapping is usually an oblate ellipsoid, and for small-scale mapping, a sphere.

Map projections can be described in terms of their:

- *class (cylindrical, conical or azimuthal)*
- *point of secancy (tangent or secant)*
- *aspect (normal, transverse or oblique), and*

- *distortion property (equivalent, equidistant or conformal).*

3.3.1 Class (cylindrical, conical or azimuthal)

i. The three classes of map projections are cylindrical, conical and azimuthal. The Earth's reference surface projected on a map wrapped around the globe as a cylinder produces a cylindrical map projection. Projected on a map formed into a cone gives a conical map projection. When projected directly onto the mapping plane it produces an azimuthal (or zenithal or planar) map projection. The figure below shows the surfaces involved in these three classes of projections.

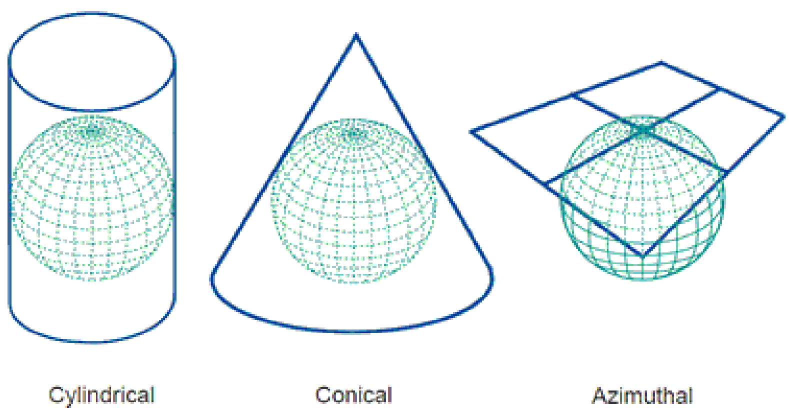


Fig. 3.7: The three classes of map projections: cylindrical, conical and azimuthal. The projection planes are respectively a cylinder, cone and plane.

3.3.2 Point of secancy (tangent or secant)

ii. The planar, conical, and cylindrical surfaces in the figure above are all tangent surfaces; they touch the horizontal reference surface in one point (plane) or along a closed line (cone and cylinder) only. Another class of projections is obtained if the surfaces are chosen to be secant to (to intersect with) the horizontal reference surface; illustrations are in the figure below. Then, the reference surface is intersected along one closed line (plane) or two closed lines (cone and cylinder). Secant map surfaces are used to reduce or average scale errors because the line(s) of intersection are not distorted on the map (section 4.3 scale distortions on a map).

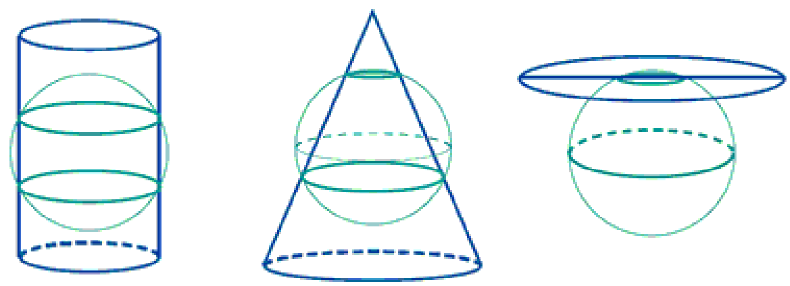


Fig. 3.8: Three secant projection classes

A method to calculate the lines of intersection in a normal conical or cylindrical projection (i.e. standard parallels) could be by determining the range in latitude in degrees north to south and dividing this range by six. The "one-sixth rule" places the first standard parallel at one-sixth the range above the southern boundary and the second standard parallel minus one-sixth the range below the northern limit (figure below). There are other possible approaches.

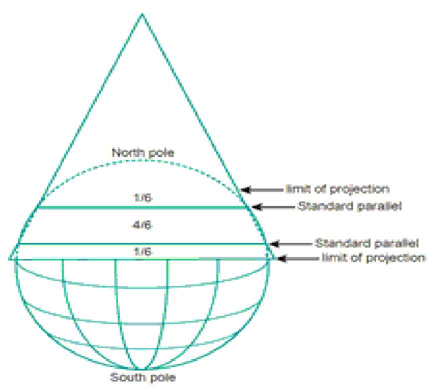


Fig. 3.9: A conical projection with a secant projection plane. The lines of intersection (standard parallels) are selected at one-sixth below and above the limit of the mapping area.

3.3.3 Aspect (normal, transverse or oblique)

iii. Projections can also be described in terms of the direction of the projection plane's orientation (whether cylinder, plane or cone) with respect to the globe. This is called the aspect of a map projection. The three possible aspects *are normal, transverse and oblique. In a normal projection, the main orientation of the projection surface is parallel to the Earth's axis (as in the figures above for the cylinder and the cone). A transverse projection has its main orientation perpendicular to the Earth's axis. Oblique projections are all other, non-parallel and non-perpendicular, cases. The figure below provides two examples.*

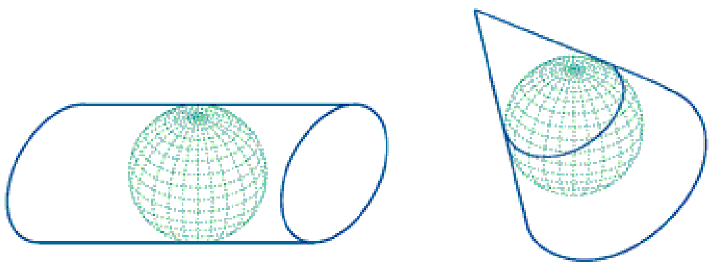


Fig. 3.10: A transverse and an oblique map projection

The terms polar and equatorial are also used. In a polar azimuthal projection the projection surface is tangent or secant at the pole. In an equatorial azimuthal or equatorial cylindrical projection, the projection surface is tangent or secant at the equator.

3.3.4 Distortion property (equivalent, equidistant or conformal)

iv. So far, we have not specified how the Earth's reference surface is projected onto the plane, cone or cylinder. How this is done determines which kind of distortion properties the map will have compared to the original curved reference surface. The distortion properties of map are typically classified according to what is not distorted on the map:

- *In a conformal (orthomorphic) map projection the angles between lines in the map are indentical to the angles between the original lines on the curved reference surface. This means that angles (with short sides) and shapes (of small areas) are shown correctly on the map.*

- *In an equal-area (equivalent) map projection the areas in the map are identical to the areas on the curved reference surface (taking into account the map scale), which means that areas are represented correctly on the map.*

- *In an equidistant map projection the length of particular lines in the map are the same as the length of the original lines on the curved reference surface (taking into account the map scale).*

A particular map projection can have any one of these three properties. No map projection can be both conformal and equal-area. A projection can only be equidistant (true to scale) at certain places or in certain directions.

Another descriptor of a map projection might be the name of the inventor (or first publisher) of the projection, such as Mercator, Lambert, Robinson, Cassini etc., but these names are not very helpful because sometimes one person developed several projections, or several people have developed similar projections. For example J.H.Lambert described half a dozen projections. Any of these might be called 'Lambert's projection', but each need additional description to be recognized.

Based on these discussions, a particular map projection can be classified. An example would be the classification 'conformal conic projection with two standard parallels' having the meaning that the projection is a conformal map projection, that the intermediate surface is a cone, and that the cone intersects the ellipsoid (or sphere) along two parallels; i.e. the cone is secant and the cone's symmetry axis is parallel to the rotation axis. This would amount to the projection of the figure above(conical projection with a secant projection plane). Other examples are:

- *Polar stereographic azimuthal projection with secant projection plane;*

- *Lambert conformal conic projection with two standard parallels;*

- *Lambert cylindrical equal-area projection with equidistant equator;*

- *Transverse Mercator projection with secant projection plane.*

3.3.5 Map projections in common use

A variety of map projections have been developed, each with its own specfic qualities. Only a limited amount are frequently used. Here are some well-known projections described and illustrated. They are grouped into cylindrical, conical and azimuthal projections.

3.3.5.1 Cylindrical projections

Probably one of the best known cylindrical projection is Mercator's cylindrical projection. The transverse case and occasionally the oblique case of the Mercator projection are used in several countries for topographic mapping purposes. The Transverse Mercator and Univeral Transverse Mercator (UTM) projection are the best known examples. Two other well-known normal cylindrical projections are the equidistant cylindrical (or Plate Carrée) projection and Lambert's cylindrical equal-area projection. Normal cylindrical projections are typically used to map the world in its entirety (in particular areas near the equator are shown well).

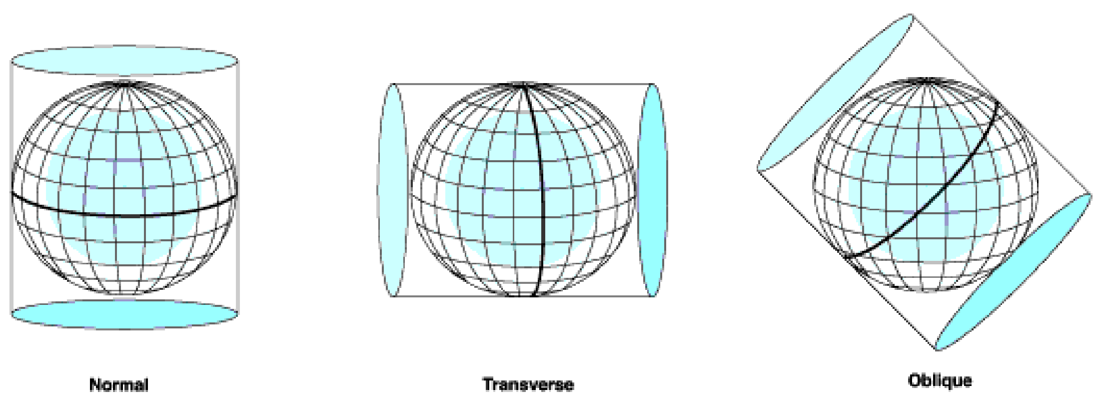


Fig. 3.11: Cylindrical projections

3.3.5.2 Mercator projection

The Mercator projection is a normal cylindrical projection. The property of the projection is conformal. Parallels and meridians are straight lines intersecting at *right angles, a requirement for conformality. Meridians are equally spaced. The parallel spacing increases with distance from the equator (figure below).*

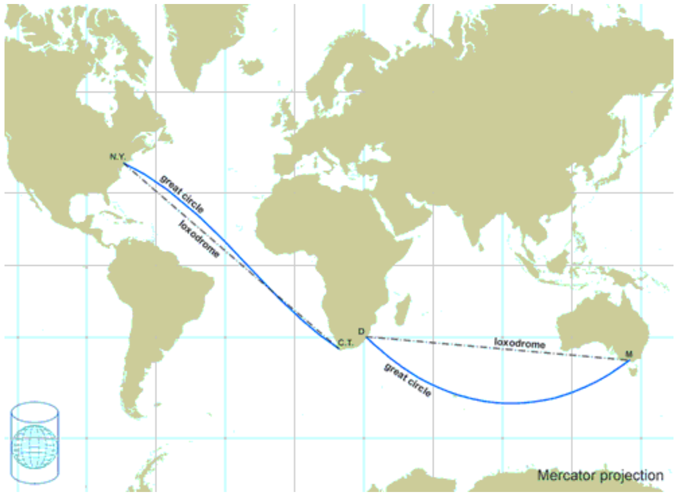


Fig. 3.12: Mercator projection is a cylindrical map projection with a conformal property. The loxodromes in black are straight lines. The great circle lines (orthodromes) in blue are curved.

The projection was originally designed to display accurate compass bearings for sea travel. Any straight line drawn on this projection represents a constant compass bearing or a true direction line (loxodrome or rhumb line). Sailing the shortest distance course along the great circle means that the direction changes every moment. These changes in course direction can be deternined by plotting the great circle onto the Mercator projection (figure above).

The Mercator projection is sometimes inappropriately used in atlases for maps of the world, and for wall-maps as area distortions are significant towards the polar regions. The ellipses of distortion appear as circles (indicating conformality) but increase in size away from the equator (indicating area distortion). This exaggeration of area as latitude increases makes Greenland appear to be as large as South America when, in fact, it is only one eight of the size.

3.3.5.3 Tranverse Mercator projection

The Transverse Mercator projection is a transverse cylindrical conformal projection. The projection is also known as the Gauss-Krüger or Gauss conformal. Angles and shapes (of small areas) are shown correctly, as a result of conformality. The figure below shows a part of the world mapped on the Transverse Mercator projection.

Fig. 3.13: A part of the world mapped on a transverse cylinder in the Transverse Mercator projection.

Versions of the Transverse Mercator (TM) projection are used in many countries as the local map coordinate system on which the topographic mapping is based. Ghana uses TM projection with the central meridian located at 1°W of Greenwich. The projection is also used for aeronautical charts and recommended to the European Commission for conformal pan-European mapping at scales larger than 1:500,000.

3.3.5.4 Universal Tranverse Mercator (UTM) projection

The Universal Transverse Mercator (UTM) projection uses a transverse cylinder, secant to the reference surface (figure below). It is recommended for topographic mapping by the United Nations Cartography Committee in 1952. The UTM divides the world into 60 narrow longitudinal zones of 6 degrees, numbered from 1 to 60. The narrow zones of 6 degrees (and the secant map surface) make the *distortions so small that they can be ignored when constructing a map for a scale of 1:10,000 or smaller.*

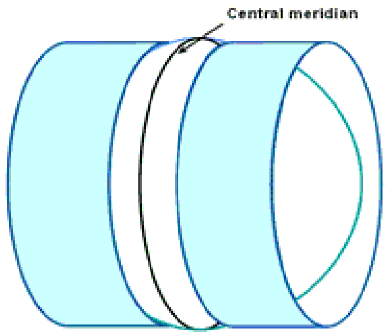


Fig. 3.14: The projection plane of the UTM projection is a secant cylinder in a transverse position.

The UTM projection is designed to cover the world, excluding the Arctic and Antarctic regions. The areas not included in the UTM system, regions north of 84°N and south of 80°S, are mapped with the Universal Polar Stereographic (UPS) projection. The figure below shows the UTM zone numbering system. Shaded in the figure is UTM grid zone 3N which covers the area 168° - 162°W (zone number 3), and 0° - 8°N (letter N of the latitudinal belt).

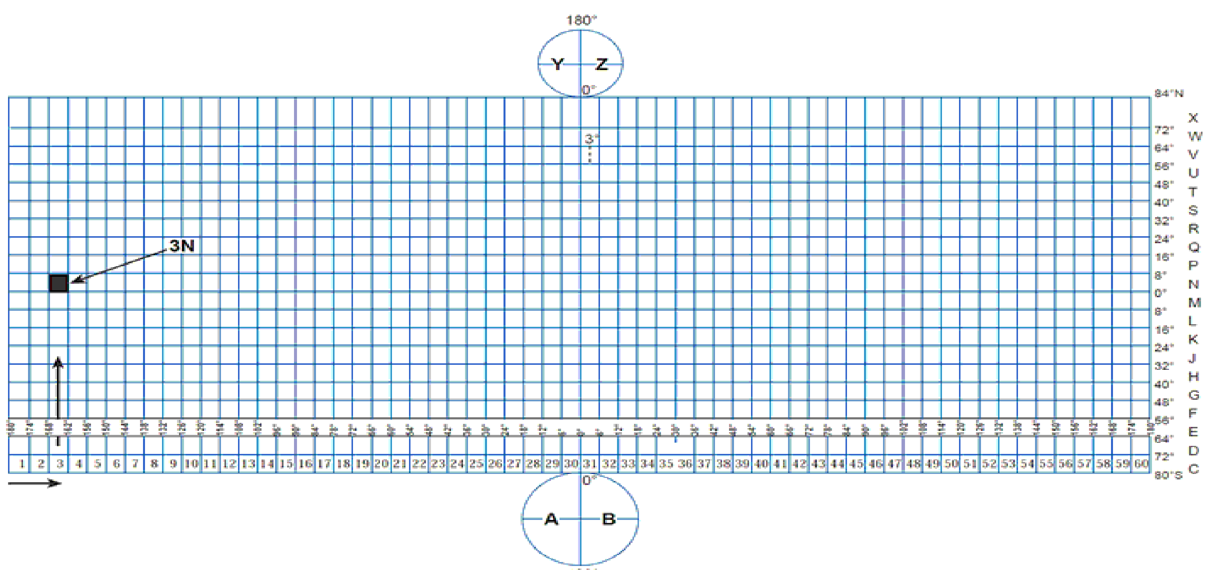


Fig. 3.15: UTM zone numbering system

Each zone has its own central meridian. E.g. zone 11 extends from 120°W to 114°W, therefore the central meridian has a longitude value of 117°W (figure below).

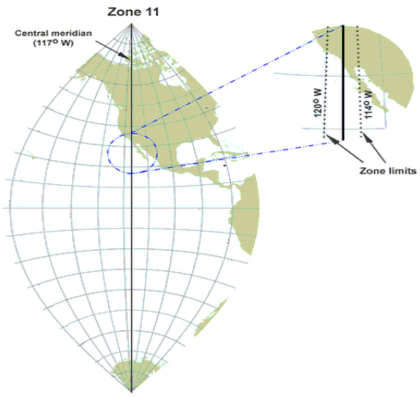


Fig. 3.16: Part of the world mapped in UTM Zone 11.The central meridian is located at 117 degrees west of Greenwich. The zone extends from 120°W to 114°W.

If a map series covers more than one UTM zone it is inconvenient to have the Eastings changing suddenly at a zone junction. For this reason a 40 kilometer overlap into an adjacent zone is allowed (figure below). Mapping beyond this area will result in distortions at the edges of a UTM zone which may not be acceptable for the larger map scales.

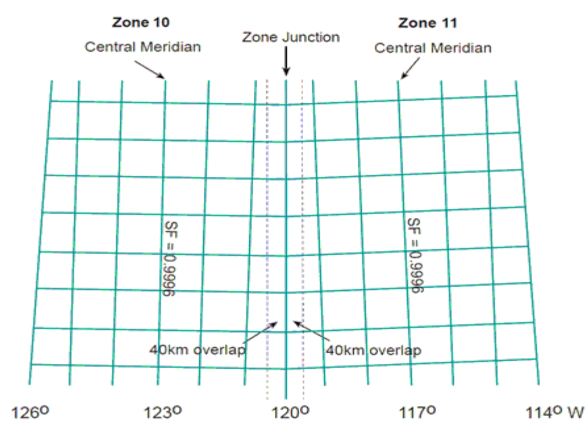


Fig. 3.17: 2 adjacent UTM-zones of 6 degrees longitude with a 40km overlap into the adjacent zone.

UTM zones can be calculated with the help of this formula:

(180 + Longitude) / 6

(Longitude of east of greenwich meridian is +ve and that of west is -ve)

3.3.5.5 Conic projections

Four well-known normal conical projections are the Lambert conformal conic projection, the simple conic projection, the Albers equal-area projection and the Polyconic projection. They give useful maps of mid-latitudes for countries which have no great extent in latitude.

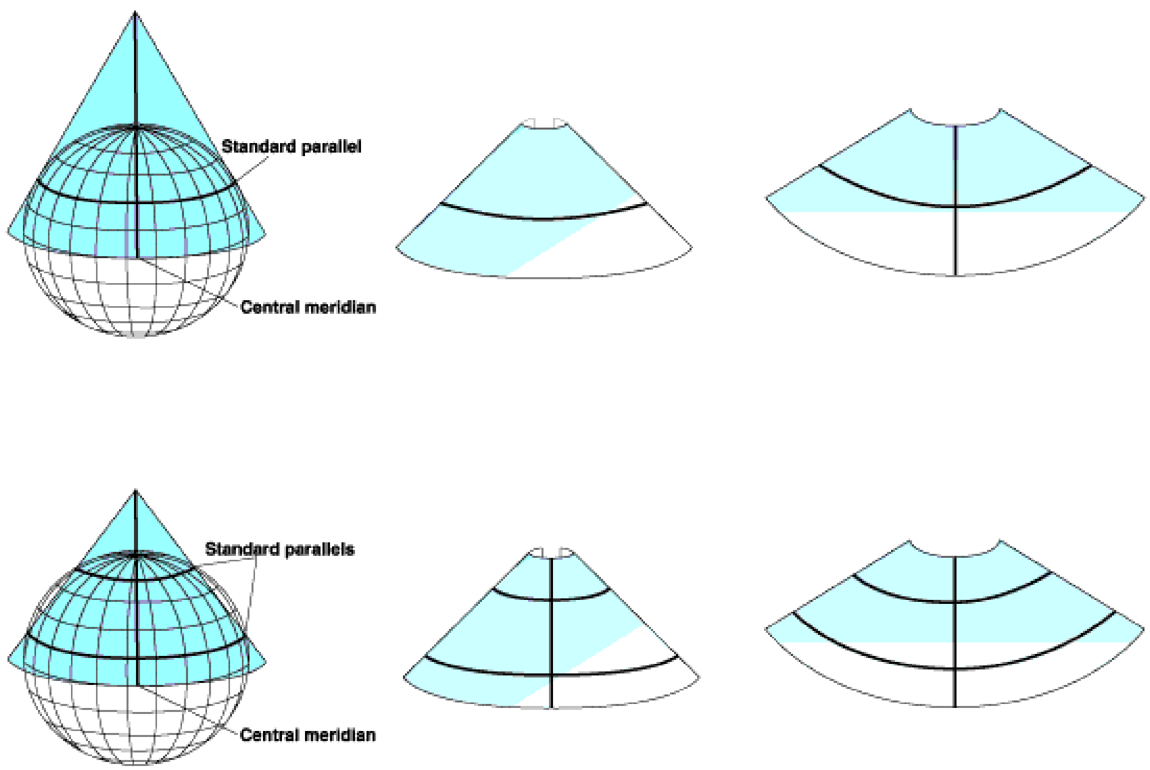


Fig. 3.18: Conic (secant)

3.3.5.6 Lambert conformal conic projection

The Lambert conformal conic projection is confomal. The parallels and meridians intersect at right angles (as in any conformal projection). Areas are, of course, inaccurate in conformal projections. Like with other conformal projections, Lambert's conical is also widely used for topographic maps. It is adapted in France and recommended to the European Commission for conformal pan-European mapping at scales smaller or equal to 1:500,000.

Fig. 3.19: Lambert Conformal Conic projection (standard parallels 10 and 30 degrees North).

3.3.5.7 Polyconic projection:

The polyconic projection is neither conformal nor equal-area. The projection is a derivation from the simple conic projection, but with every parallel true to scale (similar to the Bonne's equal-area projection). The polyconic projection is projected onto cones tangent to each parallel, so the meridians are curved, not straight (figure below). The scale is true along the central meridian and along each parallel. The distortion increase rapidly away from the central meridian. This disadvantage makes the projection unsuitable for large areas on a single sheet. It is adaptable for topographic maps, and is earlier used for the

International Map of the World, a map series at 1:1,000,000 scale published by a number of countries to common internationally agreed specifications, and also for large-scale mapping of the United States until the 1950's and coastal charts by the U.S. Coast and Geodetic Survey.

Fig. 3.20: Polyconic projection, with true scale along each parallel.

3.3.5.8 Azimuthal projections

Azimuthal (or zenithal or planar) projections are made upon a plane tangent (or secant) to the reference surface. All azimuthal projections possess the property of maintaining correct azimuths, or true directions from the centre of the map. In the polar cases, the meridians all radiate out from the pole at their correct angular distance apart. A subdivision may be made into perspective and non-perspective azimuthal projections. In the perspective projections, the actual mapping can be visualized as a true geometric projection, directly onto the mapping plane; illustrations are in the figure below. For the gnomonic projection, the perspective point (like a source of light rays), is the centre of the Earth. For the stereographic this point is the opposite pole to the point of tangency, and for the orthographic the perspective point is an infinite point in space on the opposite side of the Earth. Two well known non-perspective azimuthal projections are the azimuthal equidistantprojection (also called Postel projection) and the Lambert azimuthal equal-area projection.

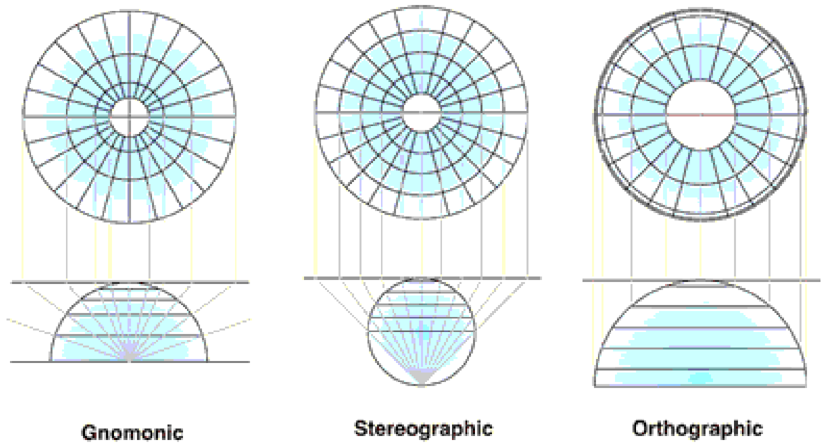


Fig. 3.21: Three perspective azimuthal projections: Gnomonic, stereographic and orthographic (source: ESRI).

3.3.5.9 Stereographic projection

The azimuthal stereographic projection is a conformal projection. Since the projection is conformal, parallels and meridians intersect at right angles. In the polar aspect the meridians are equally spaced straight lines, the parallels are unequally spaced circles centered at the pole (figure below). Spacing gradually increases away from the pole. The scale is constant along any circle having its centre at the projection centre, but increases moderately with distance from the centre. The ellipses of distortion remain circles (indicating conformality). Areas increase with distance from the projection center. The polar stereographic projection is used in combination with the UTM coordinate system as Universal Polar Stereographic (UPS) for mapping regions north of 84°N and south of 80°S. Recommended for conformal mapping of regions approximately circular in shape; the Netherlands uses a modified version of the stereographic projection (Dutch double stereographic) known as RijksDriehoekstelsel (RD).

Fig. 3.22: Polar azimuthal stereographic projection is a planar projection with a conformal property.

3.3.5.10 Orthographic projection

The orthographic projection is a perspective projection that views the globe from an infinite distance. Distortion in size and area near the projection limit appears more realistic than almost any other projection. In the polar aspect, meridians are straight lines radiating from the center, and the lines of latitude are projected as concentric circles that become closer toward the edge of the globe. Only one hemisphere can be shown.

Google Earth shows the Earth as it looks from an elevated platform such as an airplane or orbiting satellite. The projection used to achieve this effect is called the general perspective. This is similar to the orthographic projection, except that the point of perspective is a finite (near earth) distance rather than an infinite (deep space) distance.

Fig. 3.23: Polar azimuthal orthographic projection.

3.4 Choice of a Projection System

When choosing a projection in which to store your database, consider the database's primary use.

1 *Databases created under contract or to be used by a government organization are often in a projection determined by the governing body, such as State Plane in the United States or Great Britain National Grid in the United Kingdom.*

2 *Use equal area projections for thematic or distribution maps.*

3 *Presentation maps are usually conformal projections, although compromise and equal area projections can also be used.*

4 *Navigational maps are usually Mercator, true direction, and/or equidistant.*

If every place we wanted to map lined up nicely into these areas of minimal distortion we would be home-free, jumping to the next step of choosing "special properties". A little experience shows that geographic space is not so fine and regular and many places will always fall outside the good areas on the basic projections. One easy way to adjust for this is to change the aspect of the projection. This translates the distortion pattern in the projection space so the areas of least distortion are moved to another geographic area. Even with this added flexibility the choices are sill pretty limiting. Malling suggests that various modifications are possible to make a projection work better:

1 *Redistribution of scales and using more than one line of zero distortion, such as in a secant case.*

2 *Imposition of special boundary conditions.*

3 *Using the projection more than once to get recentred or interrrupted maps.*

4 *Combining projections. (Mechanically or mathematically)*

Although we may have succeeded in minimizing distortion in general, we still need to consider the special properties of a projection. For a particular map-use the map may need to be conformal, equal area, or some compromise of these. In some cases, such as navigation, conformality is absolutely necessary. In statistical mapping, equivalence is necessary.

The final projection choice would seem to be a fairly straightforward function of minimized distortion and special properties. In the end though, there are several other factors that will influence choices.Sometimes it is not necessary to consider special properties. At large scales the differences introduced by distortion cannot be measured on many maps.

3.5 Introduction to Non spatial data

The data that are usually mapped in a GIS can be categories, counts or amounts, ratios, or ranks.

A category is a group with similar characteristics. For example, an admission office producing a map of areas of recruitment could categorize high schools by type of control, public or private. Counts and amounts can be used to map discrete features (number of students at each high school within the state) or continuous phenomena (household income by census block).

A ratio is used to allow comparison of data between small and large areas and between areas with many features versus those with few. When using counts or amounts to *summarize data by area, analysts should be aware that such data types can skew the patterns if the areas vary by size.*

To avoid false interpretation, GIS analysts can use average, proportion, and density to summarize indicators by area. One might be interested, for instance, in mapping the average number of people per household, or the proportion of high school students in total population by census block.

Mapping density allows the analyst to see where features are concentrated; it is particularly useful in displaying distributions when the size of the areas summarized varies greatly. Mapping the population per square mile by census tract is an essential analysis when deciding on the location, for instance, of a future campus. Rank shows relative value rather than measured value. Rank can be expressed either as text (very satisfied, satisfied, neutral, dissatisfied, very dissatisfied) or numbers (one through five). For example, senior survey data could be mapped to examine whether satisfaction with the college experience is higher for in-state students than for out-of-state students. It is important to note that to understand the data, GIS analysts often create multiple maps using each of the variable types discussed here. For example, to understand the distribution of Hispanic high school students in a state, one might want to create maps showing total Hispanic population by county, the percentage of Hispanics in the total population, and the density of the Hispanic population. After determining the type of data to map, the next decision a GIS analyst has to make is whether to map individual values (by assigning a unique symbol) or to group the values into classes. This decision always involves a tradeoff between presenting the data values accurately and generalizing the values to uncover patterns on the map.

As with statistical analysis, it is important to remember that in deciding how to present the information on a map, one should always first consider the purpose of the map and the intended audience. If, for instance, one wants to explore the data to see what patterns and relationships exist in them, the analyst would probably want to display more detail and use various map types. A good start is mapping individual values if one is unfamiliar with the data or area being mapped. The simple display of individual values might also *help in deciding later how to group the values into classes. If one wants to present the map to academic decision makers, however, using classes to group individual values becomes a necessary exercise. Finding patterns and being able to compare areas quickly is especially difficult when the range of values is large. Rank often lends itself to being mapped as individual values; since most Likert scales used in higher education research often involve a maximum of five values, the other numeric data types usually require some kind of aggregation. When mapping ranks with more than eight or nine values, most GIS analysts would recommend grouping them into classes since too many different symbols on a map can make it difficult to distinguish the ranks. Such grouping can be done by simply assigning the same symbol or color to adjacent ranks.*

For count, amount, and ratio, grouping individual values in classes is usually recommended for more than twelve unique values. The upper and lower limits for each class can be specified manually or derived by the GIS tool, depending on how the data values are distributed. The grouping schemes most frequently used by GIS software are the equal interval, quartile, and standard deviation. Usually four or five classes are enough to reveal patterns in the data without confusing the reader. However, if one uses fewer than three or four classes, there might not be much variation between features and therefore no clear patterns will emerge.

Linking spatial and non spatial data

3.6.1 Introduction

A phrase many use in referring to GIS is "computer mapping." GIS can help planners and analysts "visualize" data to better understand patterns and concentrations of spatial phenomena. GIS also has the useful ability to portray layers of information, to help uncover spatial relationships among multiple sets of data. A typical GIS "session" involves bringing in various map layers for analysis. Map layers can take the form of points, lines, or areas.

Points represent phenomena that have a specific location, such as homes, businesses, colleges, schools, and crime sites. Lines represent phenomena that are linear in *nature, such as roads, rivers, and water lines. Areas represent phenomena that are bounded (states, counties, zip codes, school districts, census tracts).*

It is important that the data contain a locational identifier in order to be mapped in a GIS. Typical examples of locational identifiers are street address, zip code, county, state, and census tract. The term used to describe the associating of attribute data to a base map in a GIS is geocoding, or geographically encoding the data to allow it to be mapped. Address-level data are typically geocoded to a street-level base map; county statistics are geocoded against a county-level base map, and so forth.

3.6.2 Advantages and Disadvantages of GIS database

Data collection, and the maintenance of databases, remains the most expensive and time consuming aspect of setting up a major GIS facility. This typically costs 60-80% of the overall costs of a GIS project.

There are a lot considerations to be made before designing a GIS database:

1. *the nature of the source data e.g. it is already in raster form*
2. *the predominant use to which it will be put*
3. *the potential losses that may occur in transition*
4. *storage space (increasingly less important)*
5. *requirements for data sharing with other systems/software*

The issue of scale is often raised in relation to GIS data base development. It is important to remember that data stored in a GIS does not have a scale. Sometime people refer to a 1:25000 scale data base. What they mean is that the data has been taken from 1:25000 maps or that it has a level of accuracy which is roughly equivalent to that found on 1:25000 scale maps.

3.6.3 Sources of data for GIS

Problems can arise when some of the data is drawn from large scale mapping and other data is drawn from much smaller scale mapping. In this case great care has to be taken that conclusions are not drawn on the basis of the less reliable data.

There are several methods used for entering spatial data into a GIS, including:

1. *manual digitising and scanning of analogue maps*
2. *image data input and conversion to a GIS*
3. *direct data entry including global positioning systems (GPS)*
4. *transfer of data from existing digital sources*

At each stage of data input there should be data verification should occur to ensure that the resulting database is as error free as possible.

3.6.3.1 Direct Data Entry

Surveying and manual coordinate entry

1. *In surveying, measured angles and distances from known points are used to determine the position of other points*
2. *Surveying field data are almost always recorded as polar coordinates and transformed into rectangular coordinates*

Surveying field data are almost always recorded as polar coordinates and transformed into rectangular coordinates. Polar coordinates are composed of: a measured distance and an angle measured clockwise from North.

3.6.3.2 Global positioning systems (GPS)

A Global Positioning System (GPS) is a set of hardware and software designed to determine accurate locations on the earth using signals received from selected satellites. Location data and associated attribute data can be transferred to mapping and Geographical Information Systems (GIS). GPS will collect individual points, lines and areas in any combination necessary for a mapping or GIS project. More importantly, with GPS you can create complex data dictionaries to accurately and efficiently collect attribute data. This makes GPS is a very effective tool for simultaneously collecting spatial and attribute data for use with GIS. GPS is also an effective tool for collecting control points for use in registering base maps when known points are not available.

GPS operate by measuring the distances from multiple satellites orbiting the Earth to compute the x, y and z coordinates of the location of a GPS receiver.

3.6.3.3 Satellite Data

Image data includes satellite images, aerial photographs and other remotely sensed or scanned data. For example, if the image is a remotely sensed satellite image, each pixel represents light energy reflected from a portion of the Earth's surface.

Satellite remote sensing has the ability to provide complete, cost-effective, repetitive spatial and temporal data coverage, which means that various phenomena can be analysed synoptically, and such tasks as the assessment and monitoring of land condition can be carried out over large regions.

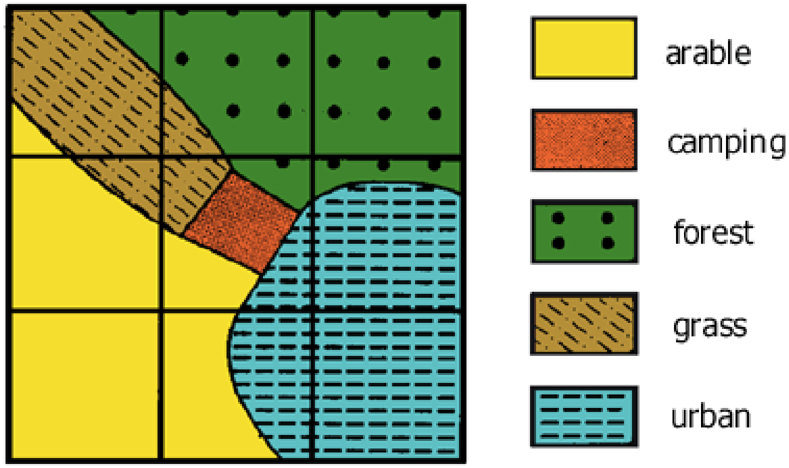


Fig. 3.24: Classification errors occur when the size of the grid cell s larger than the features which are being mapped (Burrough, 1986)

The spectral data needs to be enhanced, filtered or perhaps geometrically transformed with image processing techniques before it can incorporated into a GIS.

3.7 Summary

This unit is about databases namely spatial and non-spatial which have been covered separately in details. The most commonly related concepts of spatial data, like geo referencing, datum, and spheroid have been suitably illustrated. The projection systems which attribute the spatial information to the data have been explained. Later the linking of spatial and non-spatial data for a suitable geographical information system has also been enclosed.

3.8 Glossary

Datum- *A reference for position on the surface of the Earth. In surveying, a datum is a reference system for computing or correlating the results of surveys. There are two principal types of datums: vertical and horizontal. A vertical datum is a level surface to which heights are referred. The horizontal datum is used as a reference for position.*

Ellipsoid- *A mathematical figure that approximates the shape of the Earth in form and size, and which is used as a reference surface for geodetic surveys. Used interchangeably with Spheriod.*

Non-spatial- *not particularly having an accurate spatial reference*

Projection- *Method by which the curved surface of the earth is portrayed on a flat surface. This generally requires a systematic mathematical transformation of the earth's graticule of lines of longitude and latitude onto a plane.*

Spatial- *of or pertaining to space*

Spheroid- *A mathematical figure that approximates the shape of the Earth in form and size, and which is used as a reference surface for geodetic surveys. Used interchangeably with Ellipsoid.*

3.9 References

1 http://ads.ahds.ac.uk/project/goodguides/gis/sect36.html

2 http://www.geom.unimelb.edu.au/gisweb/SDEModule/SDE_Theory.htm#design

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4 http://en.mimi.hu/gis/spatial_data.html

5 http://www.theukwebdesigncompany.com/articles/types-of-databases.php

6 http://en.wikibooks.org/wiki/Statistics/Different_Types_of_Data/Quantitative_and_Qualitative_Data

7 http://changingminds.org/explanations/research/measurement/types_data.htm

8 http://www.icsm.gov.au/mapping/datums1.html#sphere

9 http://resources.arcgis.com/content/kbase?fa=articleShow&d=25398

10 http://www.kartografie.nl/geometrics/map%20projections/body.htm

11 *http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Choosing_a_map_projection*

12 *http://www.geo.hunter.cuny.edu/mp/choose.html*

13 *http://www.nationalatlas.gov/articles/mapping/a_projections.html#two*

14 *http://www.trfic.msu.edu/products/profcorner_products/Intro_to_GIS.pdf*

15 *http://teams.gemstone.umd.edu/classof2009/fastr/Jardine%20Article.pdf*

3.10 Suggested Readings

1 *Burrough, Peter A. and Rachael A. McDonnell. 1998. Principles of Geographical Information Systems. Published by Oxford University Press, Toronto. ISBN13: 9780198233657 ISBN10: 0198233655*

2 *Longley, P.A., M.F. Goodchild, D.J. Manguire, D.W. Rhind, Geographical Information System Volume I: Principal and Technical Issues Volume II: Management Issues and Applications Published by John Wiley & Sons ISBN NO: 978-0-471-73545-8*

3 *O'Sullivan, David and David J. Unwin. 2003. Geographic Information Analysis Published by John Wiley & Sons, Inc, Hoboken, New Jersey ISBN NO 10: 0471211761 ISBN 13: 9780471211761*

4 *http://teams.gemstone.umd.edu/classof2009/fastr/Jardine%20Article.pdf*

3.11 Terminal Questions

1 *Give diagram and difference between Spheroid and Geoid.*

2 *What is Datum? Give 2 examples.*

3 *What are the different types of projections? Draw diagrams.*

4 *What is a Cylindrical projection? Give one example of a cylindrical projection.*

5 *Name 3 criteria which is to be kept in mind when storing data.*

6 *Name 3 methods of data entry into GIS.*

7 *What is the full form of GPS? What is a GPS?*

***