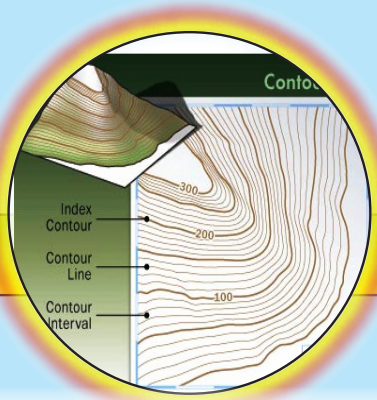
Unit 2



MAP READING AND INTERPRETATION

Unit Outcomes

After completing this unit, you will be able to:

- review the definition and properties of contour lines;
- realize how contour lines are used to represent relief features on maps and types of contours;
- acquire the skills of drawing contour lines, cross-sections and determine intervisibility;
- assess the differences among watershed, river catchment area, drainage patterns and river capture using topographic (contour) maps; and
- discriminate settlement and communication features from contour maps.

Main Contents

INTRODUCTION

The earth's surface is not uniform due to variation in its geological formation. As a result, we observe altitudinal variation between places. The major geologic events that have taken place during the geological history of the earth have left varied landforms such as plateaus, mountains, hills, valleys and plains. These uneven landforms with different heights are represented on maps with the help of contour lines.

The relief features of the earth have three dimensions. These are length, breadth, and height. These three-dimensional features are represented on two-dimensional maps. Traditionally, hachuring, hill shading, layer tinting and form lines used to be used to show the varied landforms of the earth. However, they are no longer in use these days as they are replaced by contour lines.

In this unit, you are going to learn about how relief features, drainage patterns, and human-made features are represented on contour maps. In addition, the unit will try to introduce you to some concepts of Geographic Information System (GIS), including its essence, history and uses.

2.1 RELIEF REPRESENTATION ON CONTOUR MAP

At the end of this section, you will be able to:

- draw contour lines from spot heights, using interpolation;
- construct relief cross-sections to visualize features of the landscape;
- determine the intervisibility of land features by section drawing or contour maps;
- differentiate different landforms on contour maps; and
- identify types of contour lines.

Key Terms

- Relief
- Contour
- Slope
- Spot height
- Ground survey
- Aerial photography
- Satellite imagery
- Stereoscope
- Interpolation
- Clinometer
- Altimeter
- Contour interval
- Profile
- Vertical exaggeration
- Intervisibility

What is relief? What is cartography?

The term relief refers to the way that the earth's surface is arranged. It shows the difference in altitude that exists between different landforms. Relief indicates the variation in the nature of the land surface (i.e., "the lie of the land"). It thus shows the broad features and relative heights of highlands and lowlands such as flood plains, spurs, hills, plateaus etc. As we know, mountains have higher altitudes than hills. Similarly, plateaus are higher in altitude than plains. Such a difference in altitude produces diverse topographic features on the earth's surface. As a result, we have valleys, depressions, plains, plateaus, hills, and mountains constituting the earth's topography. These features of the earth's surface need to be represented by using different techniques while mapping the earth. Currently, the most widely used relief-representation cartographic technique is using contour lines.

Brainstorming

1. *What are contour lines?*
2. *How do they represent different landforms on maps?*
3. *How are contour lines drawn?*
4. *What are the methods and procedures applied to represent landforms on maps?*

Contour lines, also known as isohypses, are imaginary lines shown on a map that connect places of equal altitude above mean sea level. They provide the most accurate way of showing relief on maps. Contours are used to show the different landforms of the earth on two-dimensional maps. They help cartographers to easily show the depressions, valleys, hills, mountains, plains and plateaus by using contours with varying shapes and distances between consecutive contours. For instance, the shapes of the contour lines provide an accurate representation of the shapes of hills and depressions, and the lines themselves show the actual elevations. In addition, while closely spaced contour lines indicate steep slopes, the widely spaced ones indicate gentle slopes.

> ***Contours*** *are one of the several common methods used to denote elevation or altitude and depth on maps. From a contour map, a sense of the general terrain can be determined. Contours are used at a variety of scales, from large-scale engineering drawings and architectural plans, through topographic maps up to continental-scale maps.*
>
> *The term "contour line" is most commonly used in cartography. However, the term "**isobath**" for underwater depths on bathymetric maps and "**isohypse**" for elevations are also used. The process of drawing contours (isohypses) on a map is called isopletion.*

Look at the following contour map and try to identify the general pattern and the arrangement of each contour line.

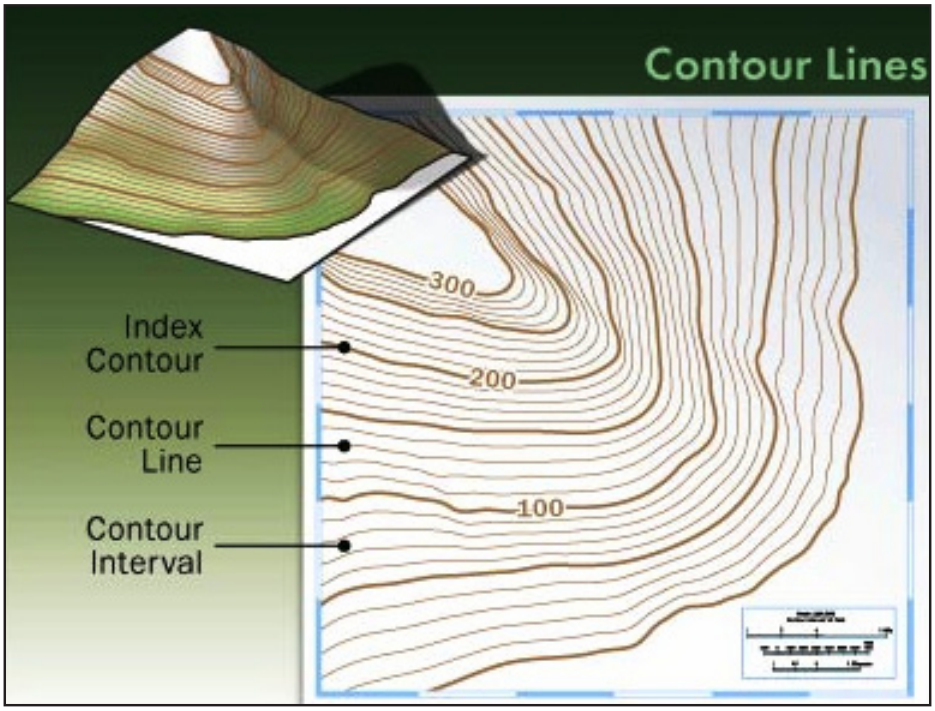


Figure 2.1: **Contour Map**

The different topographic features that characterize landscapes are shown on topographic maps by using contours with various characteristics. The patterns that the contours are drawn with, their spacing and shape indicate the characteristics of the relief of the place. As a result, valleys, spurs, shoulders, plains, plateaus, mountain tops, different types of slope, cliffs, overhanging cliffs, mountain ranges, and depressions are represented by contours of different shapes on topographic maps. For instance,

- *Evenly spaced contours represent a uniform slope;*
- *Contours that are widely spaced indicate a gentle slope;*
- *Contours that are close together near the top of a hill and widely spaced at the bottom indicate a concave slope;*
- *Contours that are widely spaced at the top of a hill and close together at the bottom indicate a convex slope;*
- *Overlapping contours, i.e., contours that merge at a point, indicate a cliff;*

- *Crossing contours indicate an overhanging cliff;*
- *Closed contours with more or less circular shapes, with values increasing towards the center and with the top indicated by a spot height represent mountains or hills;*
- *Closed contours with more or less circular shapes, with values decreasing towards the center represent depressions;*
- *Closed contours with elongated shapes, with values increasing towards the center with no specific tips indicate mountain ranges;*
- *Closed contours with more or less rectangular shapes, with values increasing towards the center with the top being a very wide closed contour represent plateaus;*
- *Contours with "V" shapes, with downward bending and values increasing upward represent spurs; and*
- *Contours with "V" shapes, with upward bending and values increasing upward represent valleys.*

The relief of a place represents the varying heights of hills and mountains, and the depths of valleys and gorges as they appear on a topographic map. Unless the relief is adequately shown, the map does not give a clear picture of the mapped area. In the earliest maps, relief was often indicated pictorially by small drawings of mountains and valleys known as pictorials. However, this method is extremely inaccurate and has been generally replaced by a system of contour lines. The contour lines represent points in the mapped area that are of equal elevations. They are drawn with a contour interval that may be any unit, depending on the amount of relief and the scale of the map, such as 50 or 100 m, and in drawing the map the cartographer joins together all points that are at a height of 50 or 100 m above sea level, all points at a height of 100 or 200 m, all points at a height of 150 or 300 m, and so on. Being drawn in such a way, the shapes of the contour lines provide an accurate representation of the shapes of hills and depressions, and the lines themselves show the actual elevations. The spacing between contour lines also indicates the nature of the slopes.

Activity 2.1

1 Define the following terms:
   a relief b contour c isobath
2 How do we differentiate steep slopes from gentle slopes and plains from plateaus?
3 In what situations do we use a small vertical interval (V.I.) on a contour map?
4 Describe the type of land feature formed by the following contour lines:
   a evenly spaced contours
   b contours that are widely spaced
   c contours drawn one over the other/ merging contours
   d contours crossing one another.

2.1.1 Drawing Contour Lines from Spot Heights

Brainstorming

1 How are contours drawn?
2 How is spatial information concerning the area being represented by contour maps obtained?
3 Do you think that aerial photographs/images taken by aircraft and artificial satellites can be used in contour mapping? How?
4 How do cartographers draw contour lines from spot heights?

Contours are drawn on maps based on the spatial data that is gathered through different techniques. This is to mean that before preparing the contour map of an area, surveying the area to obtain spatial data about the relief of the place is important. The collection of spatial information that is vital for contour mapping can be done through **ground survey**, **aerial photography** or **satellite imagery**.

When the surveying is done by using aircraft and satellites (through aerial photography/imagery), the aerial photograph of the landscape has to be mapped through aerial photogrammetry, which uses an instrument called a ***stereoscope***. **Photogrammetry** is the science of taking measurements from aerial photographs or satellite images to make maps, including topographic maps. **Photogrammetrists** use photographs taken by a special camera on an airplane or

by spacecraft satellites. To minimize distortions, the pictures are corrected using a stereoscopic device called a **stereoplotter**, which creates a three-dimensional image by combining overlapping pictures of the same terrain taken from two different angles. Contours, roads, and other features are then traced from the three-dimensional image to form a map base.

The photographs with horizontal and vertical information of the area will then be reconstructed into stereo models for drafting true-scale maps. In this method, precise cameras and precision-mapping equipment are required to show true elevations for all points in the mapped area. Elevations on topographic maps are shown chiefly by use of superimposed contour lines connecting points of equal elevation, to give a readable picture of the terrain.

A stereoscope is an optical instrument through which one may view photographs of objects not merely as plane representations, but with an appearance of solidity, and in relief. The stereoscope is an instrument in which two photographs of the same object, taken from slightly different angles, are simultaneously presented, one to each eye. Each picture is focused by a separate lens, and the two lenses are inclined so as to shift the images toward each other and thus ensure the visual combination of the two images into one three-dimensional image. Stereoscopic aerial photography permits three-dimensional representations, which can be used in the preparation of contour maps.

On the other hand, when spatial information is gathered through ground surveys, surveyors must physically be present in the area being mapped and take measurements of the relief and keep records of their measurements of height. Then, the gathered data will be recorded on paper or stored in a computer by using spot heights, with each spot height representing the measured altitude of the specific point. Then, the cartographers/map-makers will connect all points of equal altitude to draw the contours with the contour interval that they choose based on the nature of the landscape and the scale of the map.

Drawing contours from spot heights is tiresome and time-consuming. However, it is important for producing contour maps in situations where advanced technologies of contour mapping are not adequately available. Contours are drawn from spot heights by using the method called **interpolation** to determine the height of places between successive spot heights. Spot heights represent individual heights of places at varying points as obtained through ground surveys

by using **clinometers**, which are hand held surveying instruments for measuring angles of slopes, and **altimeters**, instruments to measure the elevations of places.

Activity 2.2

Discuss the following questions with your friend and try to answer them collaboratively.

1 How can you determine the points at which each contour line with a 100 m contour interval passes?

2 How do cartographers obtain spatial data for their mapping?

Interpolation can be done in any one of the following ways.

- **Estimation method:** *This technique is used to locate contour lines by rough estimation. It should be applied in areas where the ground is quite regular and when very simple and small-scale work is done. It does not necessarily need great accuracy.*
- **Calculation method:** *This is the most accurate method of interpolation, whereby the exact altitude of the contour will be determined by measurement and subsequent calculations. Despite its accuracy, the calculation method is time-consuming and laborious.*
- **Graphical method:** *This is the quickest and the most accurate method of interpolation of contours. In the graphic method, a graph is prepared on tracing paper.*

Methods of Depicting Relief on Maps

How are different relief features represent on maps?

Map makers use several methods to depict relief of the terrain.

a **Layer Tinting:** Layer tinting is a method of showing relief by using different colours or different intensities of the same colour. Each shade of colour, or band, represents a definite elevation range. To understand the relief, a legend is printed on the map margin. However, this method does not allow the map user to determine the exact elevation of a specific point. It only shows the range of elevation.

b **Form Lines:** Form lines are not measured from any datum plane. As a result, they have no standard elevation. They only give a general idea of

relief represented. Form lines are represented on a map as dashed lines and are never labeled with representative elevations.

c **Shaded Relief:** Relief shading is a method that indicates relief by a shadow effect achieved by tone and colour that results in the darkening of one side of terrain features, such as hills and ridges. The darker the shading, the steeper the slope. Shaded relief is sometimes used in conjunction with contour lines to emphasize these features.

d **Hachures:** Hachures are short, broken lines that are used to show relief. They are sometimes used with contour lines. Hachures do not represent exact elevations, but are mainly used to show large, rocky outcrop areas. Hachures are widely used on small-scale maps to show mountain ranges, plateaus, and mountain peaks.

e **Contour Lines:** A contour line represents an imaginary line on the ground, representing altitude above or below mean sea level. Contour lines are the most common method of showing relief and elevation on a standard topographic map. All points on a given contour line are at the same elevation. The elevation represented by contour lines show the vertical distance above or below mean sea level. Cartographers use three types of contour lines while representing relief on topographic maps.

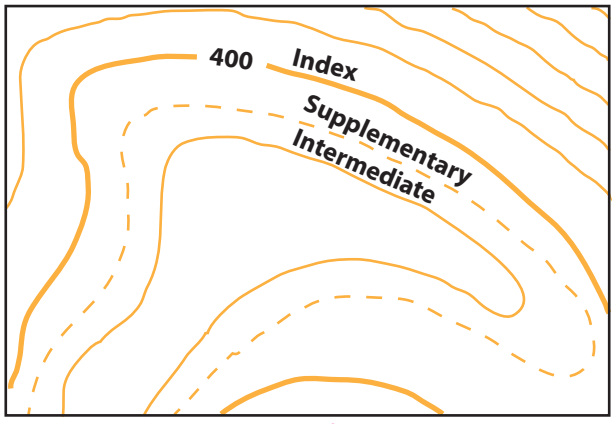


Figure 2.2: **The three types of contour lines**

The three types of contour lines used on a standard topographic map are the following.

1 ***Index Contour:*** Starting from zero elevation or mean sea level, every fifth contour line is a heavier/darker than the other contour lines. These heavier contour lines are called **index contour** lines. Commonly, each index contour line is numbered at some point. This number indicates the elevation of that line.

2 ***Intermediate Contour*:** The contour lines falling between the index contour lines are called intermediate contour lines. These lines are finer/thinner than the index contours. They do not have their elevations given. In most cases, there are four intermediate contour lines between index contour lines. Their value is decided by dividing the difference in altitude between two consecutive index contours by five, if there are four intermediate contours.

3 ***Supplementary Contour:*** These contour lines resemble dashed or broken lines. They show changes in elevation of at least one-half the contour interval. These lines are normally found where there is very little change in elevation, such as on fairly level terrain.

Contour lines are generated from spot heights. A spot height is a statistical point that represents the specific altitude of a place at that particular point. Drawing contours from spot heights is not hard or difficult. However, it needs a lot of practice and patience, as well as a lot of time, to make a good-looking contour map.

Contouring is started by plotting the spot heights with their specific altitudes on the paper on which you want to draw the contour map. The elevations of the spot heights can be obtained by ground survey and associated measurement of altitude of points on the surveyed area. Figure 2.3 shows you an area in which the altitudes of the selected points are shown by using spot heights.

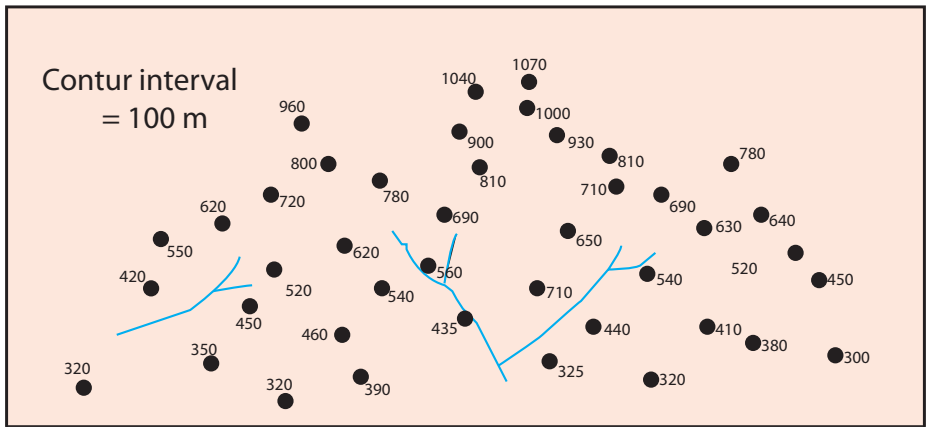


Figure 2.3: **Spot heights indicating elevations of selected points of an area to be mapped**

As you can see from Figure 2.3, the altitudes of a number of places have been collected through ground survey and the altitude of each point is presented by using mathematical calculation.

As shown in the Figure 2.3, the contour interval is 100 m. This means that contours are drawn for every 100 m altitude. The lowest point indicated by the spot heights in the figure is 300 m above sea level. Hence, the contour line with the lowest value is the 300 m contour. By starting from that line, contours have to be drawn for every additional 100 m altitude. Accordingly, you are expected to draw contours for 400 m, 500 m, 600 m, and the like up to the highest point indicated, which is 1070 m. In this case, the last contour line should have a value of 1000 m as the contour interval given is 100 m.

The second step in drawing contours from spot heights is determining the approximate points through which the contour lines with every 100 m value pass. This can be done by using the method called interpolation. Interpolation is a method of estimating the values of points lying between two points that have defined values. By using this method, we can scientifically guess the approximate altitude through which each contour line with an additional 100 m altitude passes. Interpolation involves some kind of mathematical measurement. To determine the points at which the contour is to be drawn and pass through, we have to connect points between which the contour lines of every 100 m additional value pass by using straight lines. Then, the length of the straight line is measured by using a ruler to obtain the distance on the map between the points. Once the distance on the map between the points is acquired, we have to apply a cross-multiplication system to get the point at which the required contour with a 100 m contour interval should pass. We apply similar procedures to plot all the points for each specific contour line.

To better understand the procedures that we apply while interpolating points, you can study the following figure and the associated description. The figure shows you the procedures that we need to follow while determining the points at which the 400 m contour line passes. To do so, follow this procedure.

1 Identify all the points between which the 400 m contour line passes. In this case, they are all the points that lie between the following spot heights.

- ⇨ *320 m and 420 m*
- ⇨ *350 m and 420 m*
- ⇨ *350 m and 450 m*
- ⇨ *320 m and 460 m*
- ⇨ *390 m and 460 m*
- ⇨ *390 m and 435 m*
- ⇨ *325 m and 435 m*
- ⇨ *325 m and 440 m*
- ⇨ *320 m and 440 m*
- ⇨ *320 m and 410 m*
- ⇨ *380 m and 410 m*
- ⇨ *380 m and 450 m*

2 Connect all the points identified above by using straight lines as shown in Figure 2.4. The lines are drawn connecting those spot heights between which the 400 m contour line is expected to pass. To draw the whole map, you should connect all the spot heights between which a contour line with a 100 m contour interval would pass.

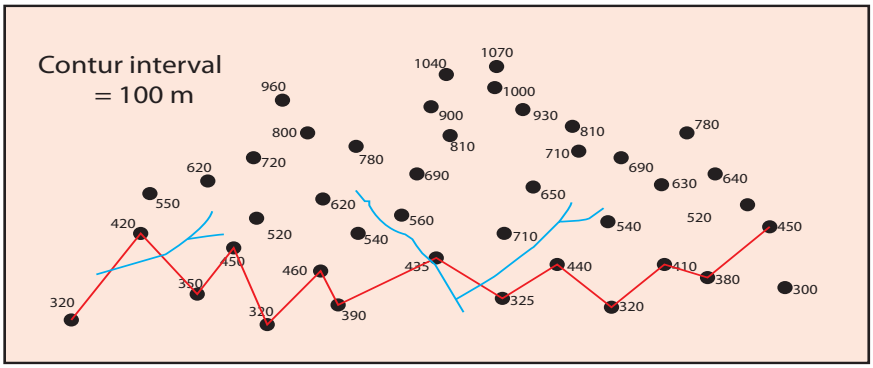


Figure 2.4: **Drawing contour line using interpolation**

3 Measure the length of each line connecting two spot heights to determine the distance on the map between the two points and see the height it represents (the difference in altitude between the two spot heights). For example, the distance on the map between the 320 m and 420 m spot heights is measured and is found to be 1.5 cm. This means that the 100 m altitudinal difference between the 320 m and 420 m spot heights is represented by a 1.5 cm straight line.

4 Determine the point at which the 400 m contour line passes. This can be done by using the cross-multiplication method. For example, if the 1.5 cm represents 100 m between the 320 m and 420 m spot heights, then the length of line that represents 80 m from the lowest spot height, i.e., 320 m, would be 1.2 cm.

5 Put a point at a distance of 1.2 cm from the 320 m spot height along the line that connects the 320 m and 420 m spot heights to identify the point along which the 400 m contour line passes.

N.B: Apply the procedures above to determine the points at which each contour line with a 100 m contour interval passes between two spot heights.

6 Connect all the identified points of a certain contour line with the given contour interval by using curved lines to draw the contours. While doing so, please consider the shapes and patterns that different features such as rivers have when they are represented on contour maps. This will help you to better represent the features on your map.

7 Label the map and add all the required information. For example, write the values of the contour lines to indicate the contour interval and add a title to the map.

When you finish drawing all the contour lines, you will have the following contour map.

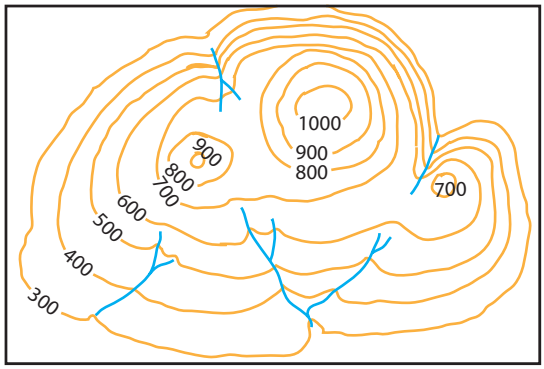


Figure 2.5: **Contour lines drawn with the help of interpolation**

Activity 2.3

With the help of your teacher and friends, prepare a contour map from the following data (Figure 2.6). While drawing the contours, consider the following.

1 The values indicated by each spot height are given in meters.

2 Use a contour interval of 100 m for your map.

3 Do not forget to consider the shapes and patterns that contours would have when they depict different relief features.

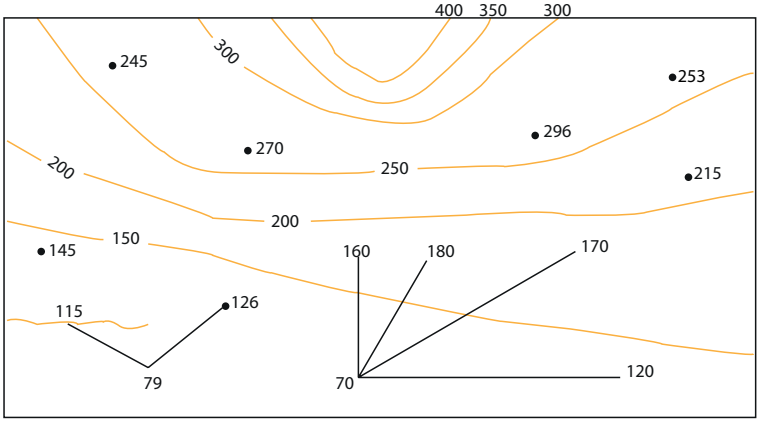


Figure 2.6: **Spot heights**

2.1.2 Drawing Relief Cross-Section (Profile)

Brainstorming

1 What is a cross-section?
2 How are cross-sections drawn?
3 Why are cross-sections drawn?

As we have seen so far, contouring is the standard method of representing relief on topographic maps. For a given contour map the vertical distance between adjacent contour lines – the contour interval – is fixed. Examining the horizontal distance between succeeding contour lines helps the reader to visually estimate the difference in slope of parts of the terrain. Thus, the way the contours are arranged, their shapes and spacing shows the diverse relief features of the area mapped. While closely spaced contour lines represent steep slopes, widely spaced contours show gentle slopes.

However, a more precise method of determining the variation in slope is to construct a profile or cross-section through the topography. This is done by marking off the horizontal distance between contour lines along a base line and then plotting the elevation or altitude of these points. By doing so, a profile can be drawn showing the gradient of slope and shape of the topography along the line of section.

Cross-section drawing is one of the simplest ways of acquiring skills in reading contour maps. A cross-section helps us to acquire a better view of the nature of the slope and other relief features drawn on the contour map. When we draw the cross-section of a map, we can have a better understanding of the nature of the landscape and can tell whether two points are intervisible or not.

In order to draw a cross-section from a given contour map, we need to have a vertical scale in addition to the horizontal scale of the map. Horizontal scale is the normal scale of any given map. On the other hand, vertical scale is the scale which is used to show the nature and type of relief on the contour map. It shows the degree of exaggeration made while the cross-section of a relief feature is prepared from its contour map.

The vertical exaggeration/vertical scale of the cross-section is determined by considering the scale of the map and the nature of the terrain. Although the decision

concerning the extent to which a cross-section should be exaggerated is in the hands of the one who prepares the cross-section, the widely accepted approach to use is defined by these guidelines:

- ⇨ *higher vertical exaggeration for flat terrain; and*
- ⇨ *small or no vertical exaggeration for rugged (rough) terrain.*

Table 2.1: **Relationship between relief and vertical exaggeration.**

Relief type	Amplitude	Approximate vertical exaggeration to scale			
		1:20,000	1:50,000	1:100,000	1:250,000
Mountainous/ very hilly	700 m	No	2	4	5
Undulating/ dissected	150-350 m	2	4	8	8 or 16
Plains and plateaus	About 150 m	4	8	15	20

To draw a cross-section of a relief feature from the following contour map, we need to follow the next procedure.

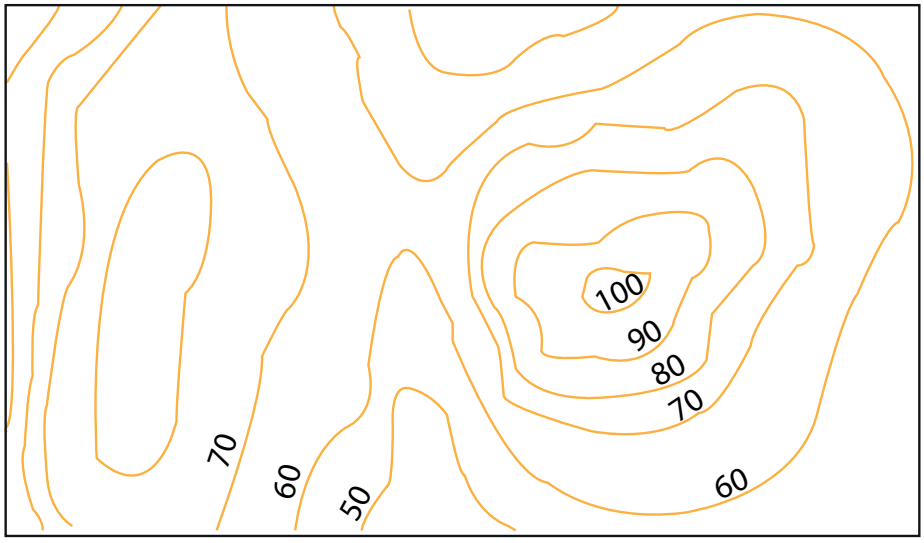


Figure 2.7: **A contour map of an area**

1 Draw a cross-section line across the above contour map between the two points along which you choose to draw the cross-section.

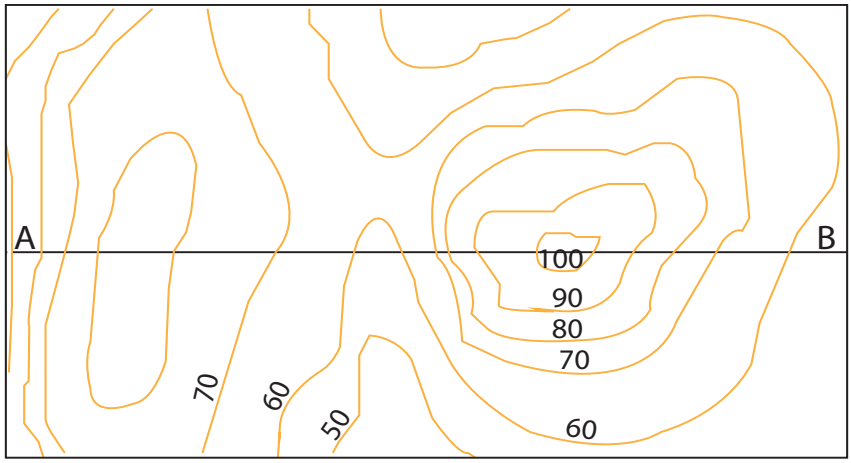


Figure 2.8: **A cross-section line drawn between points A and B**

2 Place the edge of a strip of straight-edged paper along the cross-section line which you have drawn along points A and B.

3 Mark the places where the contour lines disappear under the straight edge and note their heights.

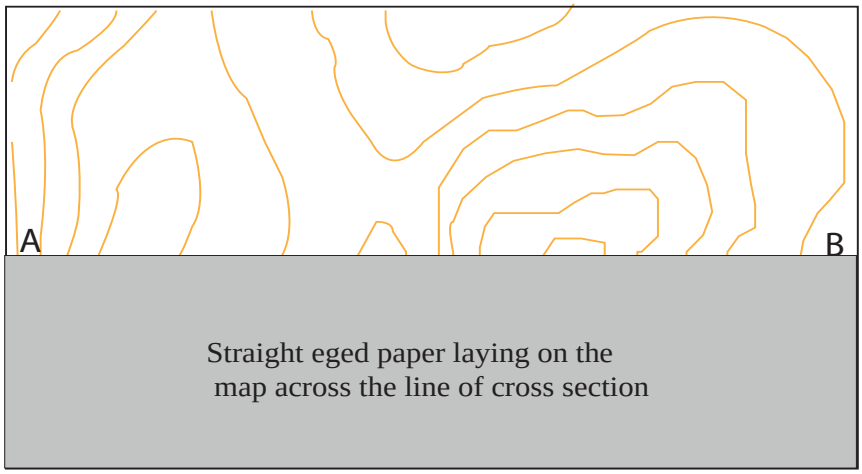


Figure 2.9: **A straight-edged paper whose edge has been placed on the face of the map to mark the points where the contours intersect with the cross-section line**

4 Draw a cross-section outline with vertical scale.

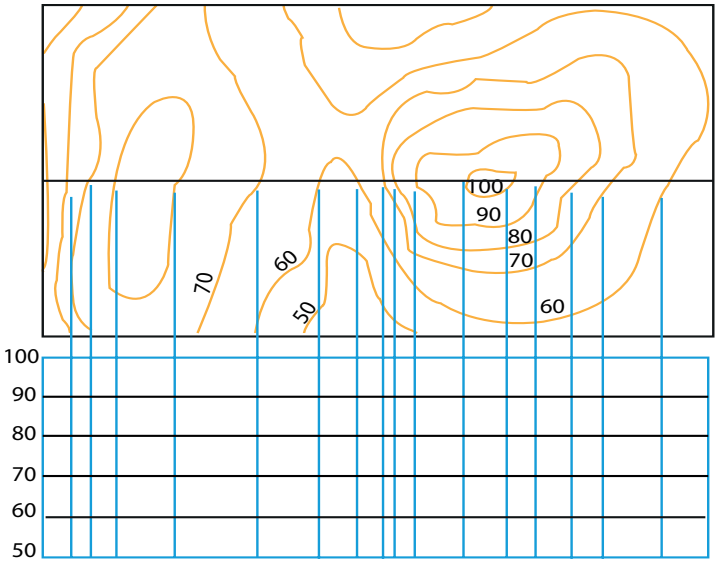


Figure 2.10: **A cross-section outline with vertical scale**

5 Place the strip of paper along the top and mark the height points on the outline.

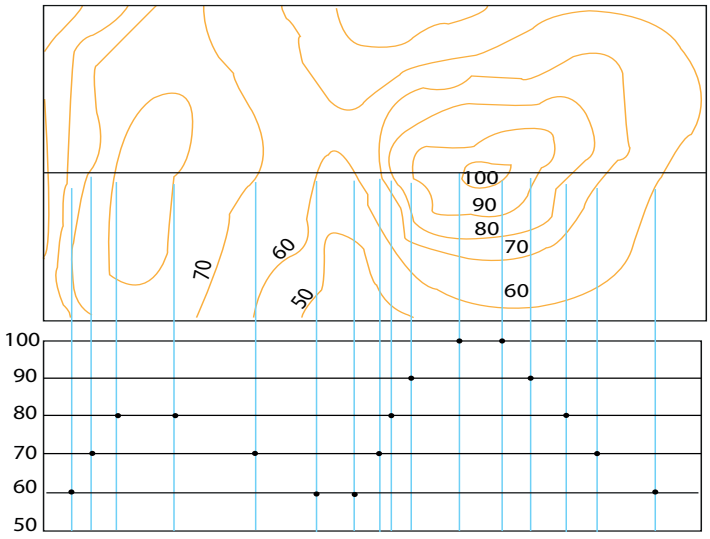


Figure 2.11: **Markings of height points on the cross-section outline**

6 Join the points with a curving line.

7 Shade the bottom of the diagram.

8 Add labels and titles.

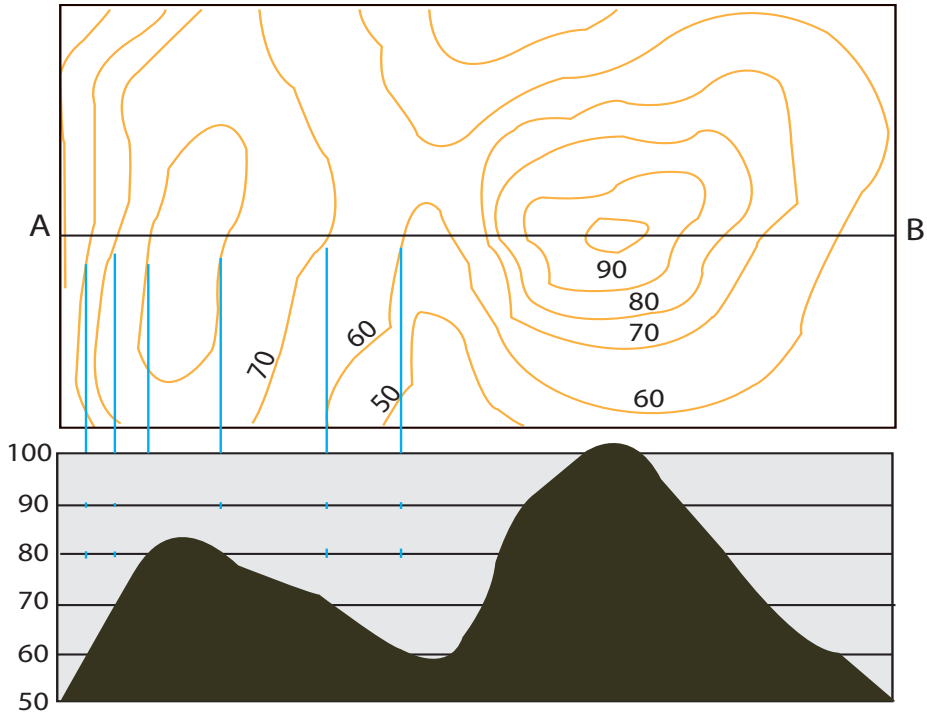


Figure 2.12: **A cross-section of the preceding map showing the mountains and pass that were shown by using contours**

The first part of Figure 2.12 shows the topography of the mapped area in a contour-line map. The contours are labeled with numbers indicating how high above sea level the contours are. The second part of the figure is a cross-section of the contour map along the line A-B. The x-axis (the horizontal axis) of the cross-section corresponds to the line from A to B on the topographical map. The y-axis (the vertical axis) of the cross-section is used with the x-axis to plot the height of each contour where it crosses the A-B line. In this way, a series of dots has been created and they have been connected to each other to create the cross-section of the landscape.

From the above cross-section, one can easily understand that the area represented by the contour map is a pass between two rising landforms/hills. It is also possible to see the nature of the slope along the sides of the hills. For instance, the hills are steeper along the left side, while they are gentler along the right. Note that the steeper slopes are represented by closely drawn contours, while the gentler slopes are represented by contours that are widely spaced.

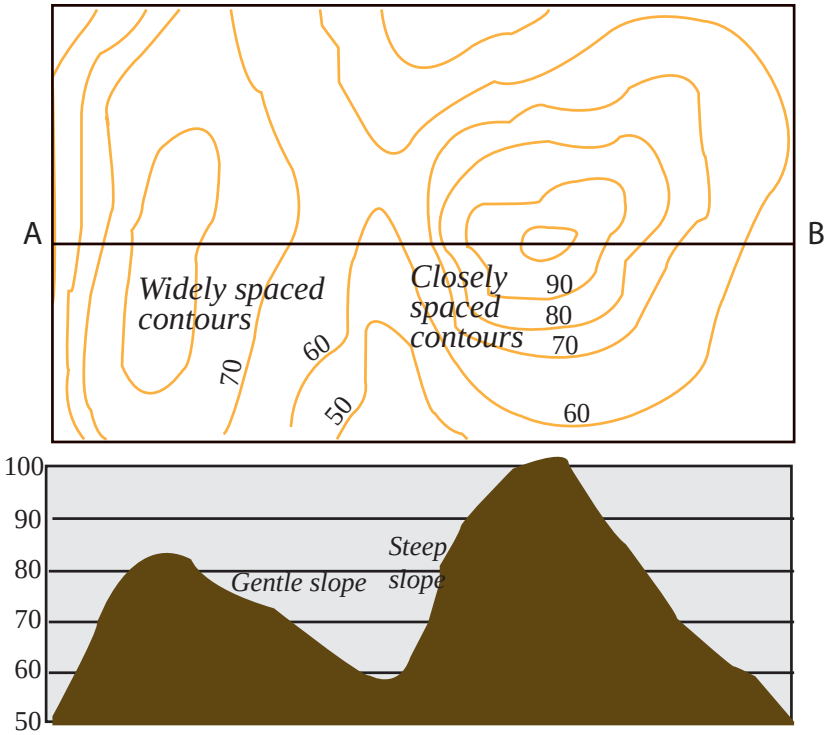


Figure 2.13: **The relation between contour maps and their profile**

In almost all cross-sections, the horizontal scale is smaller than the vertical scale. This forms a simple relationship between the contour interval and the vertical distance between the horizontal lines on the graph paper. For instance, a section from the 1 cm thus plotted on $\frac{1}{10}$cm would have a horizontal scale of $\frac{1}{100{,}000}$cm and a vertical scale of $\frac{1}{10{,}000}(1\text{cm to } 10{,}000\text{cm})$. The vertical exaggeration would be approximately 10 times.

Activity 2.4

Draw a cross-section of the following (Figure 2.14) map along the line A – B by following the procedures that we have followed in the preparation of the cross-section diagram above.

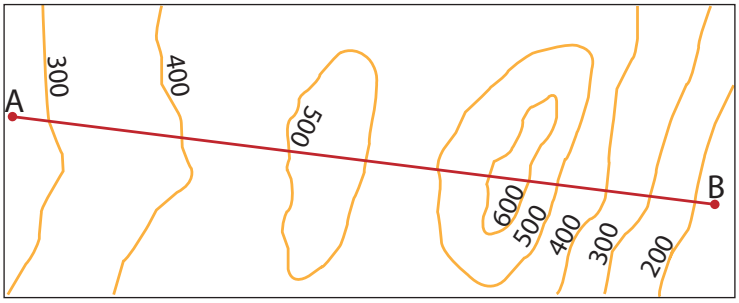


Figure 2.14: **Diagramatic map showing landform**

While drawing the cross-section of an area, using a vertical scale may be required. This becomes a must if the map is drawn in such a way that may result in inconvenient cross-sections. Using a vertical scale greater than the horizontal scale in a cross-section is called **vertical exaggeration**. Cartographers exaggerate the vertical scale in order to clearly visualize the terrain of an area. Some times less exaggeration is used in areas where the relief elevation is high. When the relief represented is a relatively flat area or an area of low altitude, more exaggeration is needed.

The degree to which we exaggerate the vertical scale (V.E.) depends on:

- *the scale of the map from which the profile is drawn*
- *the relief configuration of the area that we are dealing with.*

Vertical exaggeration is both advantageous and disadvantageous. Some of the advantages and limitations of vertical exaggeration are listed below.

Advantages	Disadvantages
⇨ *it increases the visual effectiveness of a given relief.*	⇨ *it causes the slope of a hillside to look steeper than it actually is.*
⇨ *it has the potential to give a very strong impression.*	⇨ *it may cause some distortion.*

Focus

When we draw a cross-section, we have to show graphically the proportions between horizontal and vertical distances. When we want to show the profile of a given piece of land, the variations in altitude are very small when compared with the horizontal distances involved.

2.1.3 Intervisibility

Brainstorming

1 What do we mean by intervisibility?
2 Why is it important to study the intervisibility of places?
3 What are the factors that affect intervisibility?

Intervisibility is simply defined as the visibility of places to each other. If an observer standing at a certain point can see another observer standing at another point, then the two places are said to be intervisible. Any land that is not visible from a certain point or place is known as "dead ground" relative to that area. Contour maps are important tools to determine whether two places are intervisible or not. An important feature of contour maps is that they allow us to know whether one place can be seen from another and vice versa.

Studying intervisibility is important for many reasons, for example

- ⇨ *Intervisibility is important for planning military operations;*
- ⇨ *It is also important for understanding the distribution of dead and visible ground with respect to proposed plans of infrastructure;*
- ⇨ *Intervisibility provides information for the evaluation of proposed sites for forest-fire lookouts;*
- ⇨ *Intervisibility plays a significant role in the planning of logging; and*
- ⇨ *It is important for selecting appropriate sites for the development of recreation and refreshment centers.*

The intervisibility of places can be affected by several factors, amongst which the most important ones are the following.

i The type of slope between the two points;

ii The general relief between the two points; and

iii The amount of vegetation that covers the area.

When we study intervisibility from contour maps, we have to consider the characteristics of contour lines. This is so because contour lines with varying shapes and patterns represent varied relief features. As we know, the nature of the landscape is the most important determining factor regarding intervisibility. Accordingly, we can say that under normal conditions,

- ⇨ *Two points separated by an even slope are said to be intervisible. However, in such a case, the vegetation cover should be taken into consideration before we make our decision. If the slope is covered with forest, the two points may not be intervisible;*
- ⇨ *Two points having unequal heights but separated by ground lower than the lower ground of the two points are intervisible;*
- ⇨ *Two points of equal altitude may or may not be intervisible, depending on other factors. For example, the two become intervisible if there is no higher ground or thick vegetation cover between the two points;*
- ⇨ *Two points separated by a concave slope are said to be intervisible if no other factor exists that hinders intervisibility;*
- ⇨ *Two points separated by a convex slope are not intervisible to each other because there is out-bulging land between the points;*
- ⇨ *Two points that are located at the opposite sides of high ground are not intervisible because the higher ground between the two obscures their intervisibility.*

For example, in the following contour map (Figure 2.15), the intervisibility of points A and B and C and D can be determined by observing the nature of the contour lines and the direction at which elevation increases. Accordingly, we can conclude that:

a Points A and B are not intervisible. As a result, the men standing at the two points cannot see each other. This is due to the presence of higher ground between the two points. As you can see from the map, the persons stand at the opposite sides of the hill. Point A lies at 60 m altitude, while point B is at 70 m altitude, but there is ground higher than 80 m in altitude between the two. This obscures their intervisibility.

b Points C and D are intervisible and therefore the men standing at the two points can see each other. In this case, the two persons are standing on the same side of the hill but at different altitudes. As shown on the map, point C lies at an altitude of 90 m, while point D is located at an altitude of 60 m. As there is no higher ground between the two points, and as the slope is gentle, the two places are intervisible.

⇨ *due to the type of the slope = concave*

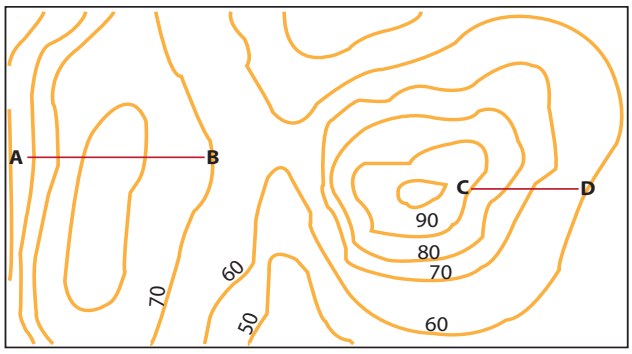


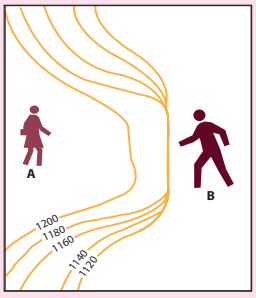
Figure 2.15: **Intervisibility between two points**

The intervisibility of places can easily be determined when the places shown on the contour map are presented in cross-section. The most important purpose of drawing cross-sections is to determine the intervisibility of places. For instance, the intervisibility of the points shown on the above contour map can be easily decided by observing the nature of the landscape between the labeled points in the following cross-section diagram of the contour map presented above.

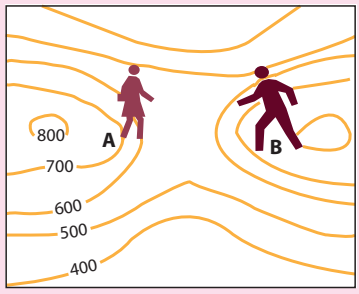
Figure 2.16: **Determining intervisibility by using relief cross-section**

Activity 2.5

Based on the figures presented below, try to determine whether the points indicated on Figures 2.17 a) and b) are intervisible or not and justify your answers.



a)



b)

Figure 2.17: **Intervisibility**

While determining the intervisibility of points or places labelled on a contour map, knowing the following facts simplifies your work. However, do not forget that these conditions are functional only under normal condition. This is to mean that there should not be any other factors, such as thick vegetation, that may hinder the intervisibility of the points.

1 Points located at different altitudes (for example, one at the top and the other at the bottom of a hill) with contours that are drawn close to each other at the top and farther apart at the bottom (i.e., concave slopes) are intervisible.

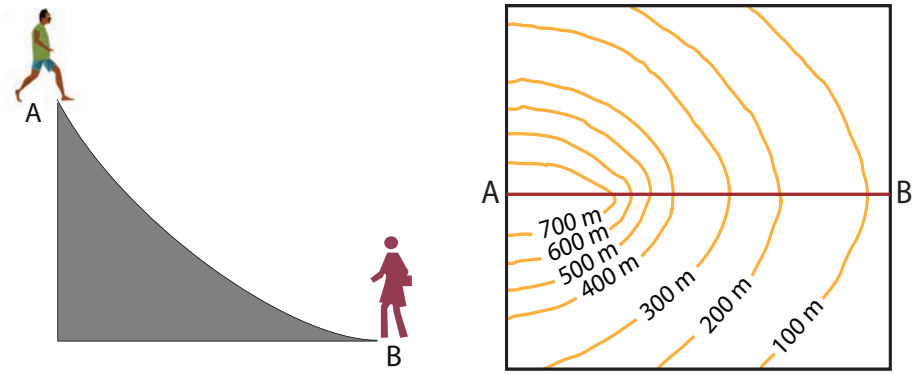


Figure 2.18: **Intervisiblity on a concave slope**

2 Two points, one located at the top and the other at the bottom of a hill, with contours that are drawn far apart at the top and close to each other at the bottom (i.e., convex slopes) are not intervisible.

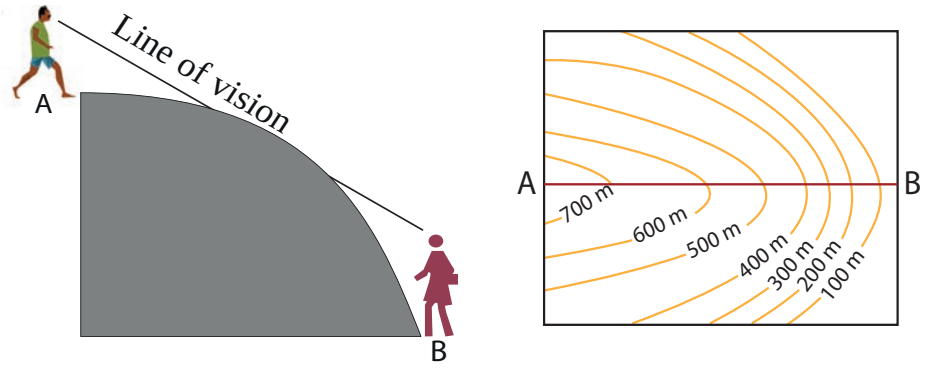


Figure 2.19: **Intervisiblity on a convax slope**

3 Two points, one being located at the top of a hill and the other at its bottom, with contours that are evenly spaced (i.e., gentle slopes) are intervisible.

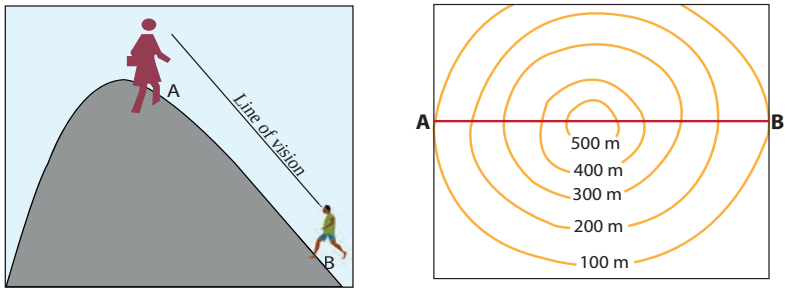


Figure 2.20: **Intervisiblity on an even slope**

4 Two points, one being located on top of a cliff or an overhanging cliff and the other at the bottom of it (a relief feature that is represented by contours that merge at the points where the landscape becomes a cliff) are not intervisible.

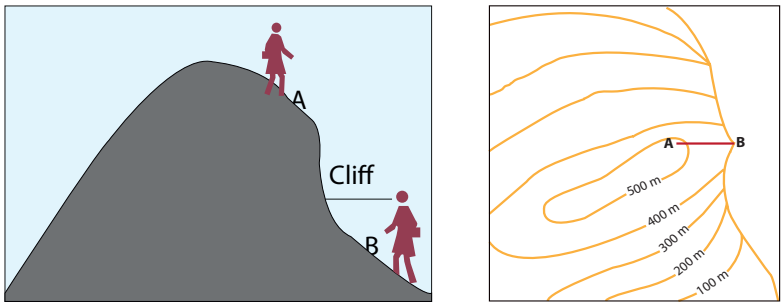


Figure 2.21: **Intervisiblity between two heights along a cliff**

5 Points that are located at the same altitude are intervisible if there is no higher ground between the points. Otherwise, they are not intervisible.

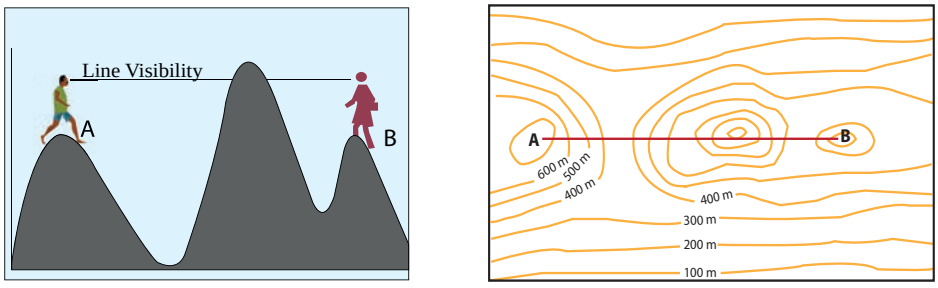


Figure 2.22: **Intervisiblity between two points with higher groundbetween them**

6 Two points that are located at the opposite sides of a hill or a mountain (represented by nearly circular closed contours with their values increasing towards the smaller (innermost) closed contour) are not intervisible to each other because the higher ground between the two points prevents intervisibility.

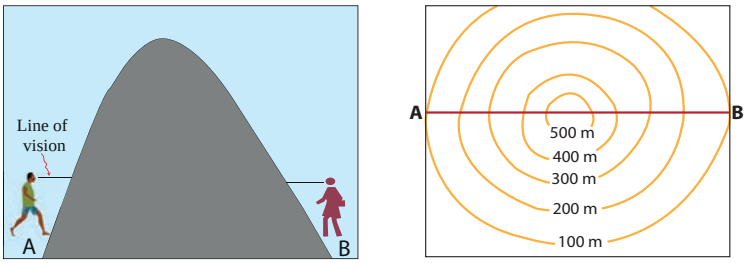


Figure 2.23: **Intervisiblity between two lower points**

7 Two points, one located inside a depression on top of a mountain and the other on the side of the mountain outside the depression (shown by nearly circular closed contours with their values increasing towards the top of the mountain up to the beginning of the depression and then closed contours with their values decreasing towards the most interior point) are not intervisible.

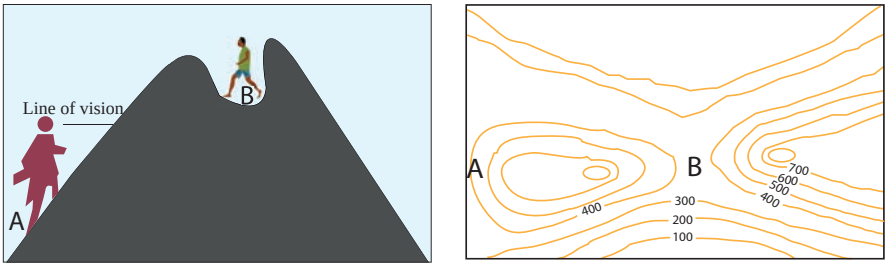


Figure 2.24: **Intervisiblity between two points at lower and dead ground but at a higher altitude**

The intervisibility of two points can also be determined by using a skeleton diagram that shows only the altitude of the points for which intervisibility is to be investigated. Figure 2.25 gives you some idea about how to determine intervisibility between points by using this technique. Such a method is especially important for determining intervisibility between points when, for some reason, it is difficult to determine intervisibility by using contour maps.

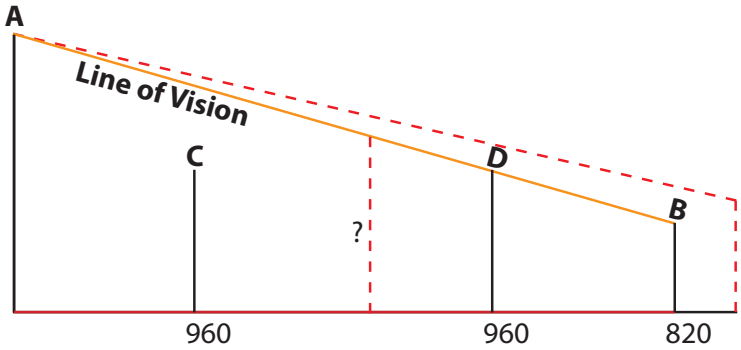


Figure 2.25: **Determining intervisibility by using a skeletal section**

In the above section, we find that the line of vision drawn from A to B is obscured by the height of D (960 m), and therefore the two points A and B are not intervisible. This can also be decided by the very position of D and B. If spot height D had been closer to C, or if point B had been farther away from D, points A, B, and D would have been intervisible. Therefore, the intervisibility of points on such landforms cannot be decided with the help of the contour map unless we use a skeleton section like the above one.

Activity 2.6

Part I

Construct a cross–section across the line x-y for the following contour map and try to determine whether the points given below are intervisible or not. You should also provide a justification for your answers.

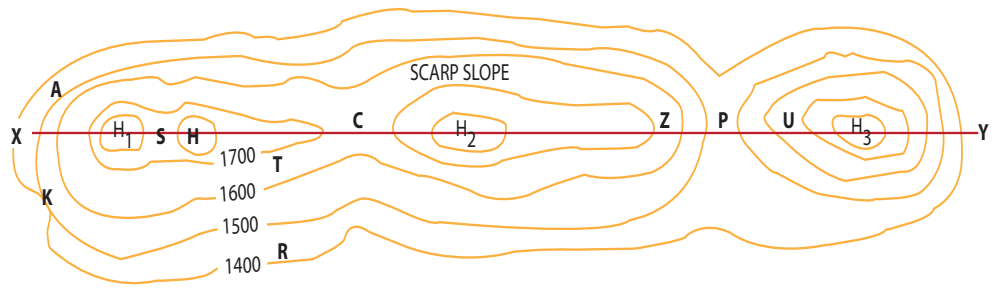


Figure 2.26: **A contour map of place "X"**

1 points C and P 2 points C and S 3 points Z and P

Part II

Figure 2.26 shows part of a range of small hills. Study the map and then answer the following questions:

1 Identify and write down the type of landform represented by the letter P.
2 Find a steep slope and a gradual slope (dip slope).
3 Are you going uphill or downhill if you walk from
   i Z to P ii R to T
4 Which letter represents steep slope?
5 Which letter represents a col?
6 What sort of landform does letter S represent?
7 The type of landform represented by K is _____.

2.1.4 LandForms on Contour Maps

What sort of merit does contour lines have for showing land features on maps? How do we identify different land features with the help of contour lines? How do you identify different slopes on contour maps?

Contour maps show different relief features by using contour lines with different shapes and spacing. Their patterns help map readers to easily identify the kind of terrain feature represented. For instance, mountains and plateaus are shown by contour lines with different shapes. The same thing is true when valleys and depressions are represented. As a result, various terrains on contour maps appear with their own distinct shape and pattern. Map makers exploit this advantage of contour lines to depict the nature of the landforms they show on their maps. The following discussion gives you some ideas about how different terrains are represented on topographic maps.

1 ***Hill:*** A hill is an area of high ground but is lower than a mountain in elevation. From the top of the hill the ground slopes down in all directions. On a topographic map, a hill is shown by contour lines forming concentric circles. The inside of the smallest closed circle indicates the hilltop. The following figure shows you how a hill is represented on a contour map.

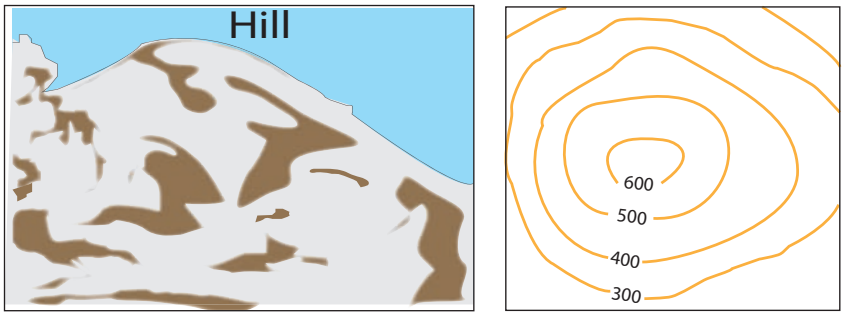


Figure 2.27: **A hill and its contour representation**

- ⇨ *Col is a relatively lower and deeper than saddle often found between two streams.*
- ⇨ *Pass is a deeper, more pronounced depression than a col between two hills or mountains.*

2 ***Saddle:*** A saddle is a dip or low point between two areas of higher ground. The feature is like the seat on a riding horse. It is not necessarily the lower ground between two hilltops. It can rather be a simple dip or break along a level ridge crest. A saddle has high ground in two opposite directions. A saddle is normally represented as an hourglass.

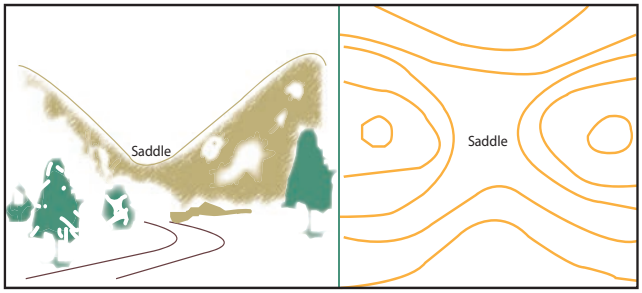


Figure 2.28: **A saddle and its contour representation**

3 ***Valley:*** A valley is a long low-lying area of land, often with a river or stream running through it, that is surrounded by higher ground. It is a stretched-out channel in the land, usually formed by streams or rivers. A valley begins with high ground on three sides, and usually has a course of running water through it. In a valley, three directions offer high ground, while the fourth direction offers low ground. Contour lines forming a valley are either U-shaped or V-shaped. While U-shaped contours represent valleys with steep slopes and flat bottoms, V-shaped contours show valleys with relatively gently descending slopes with V-shaped bottoms. To determine the direction water is flowing, look at the contour lines. The closed end of the contour line (U or V) always points upstream or toward high ground.

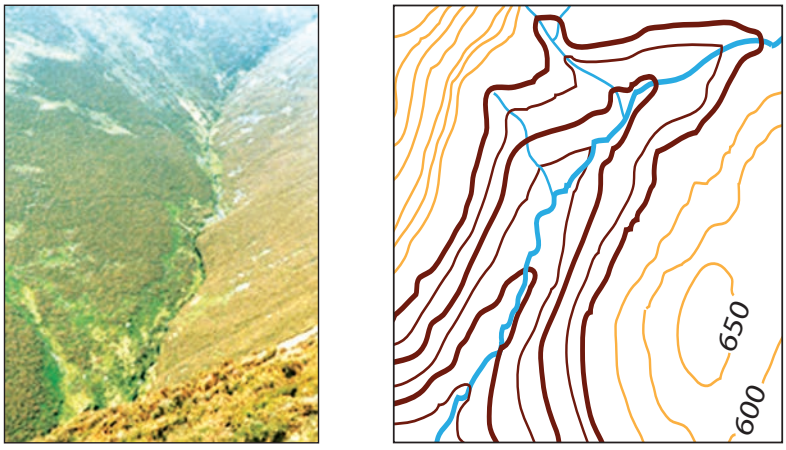


Figure 2.29: **A valley and its representation on a contour map**

4 ***Ridge:*** A ridge is a sloping line of high ground. It is a long narrow hill top or a range of hills. A ridge normally has low ground in three directions and high ground in one direction with varying degrees of slope. Crossing a ridge at right angles results in climbing steeply to the top and then descending steeply to the bottom. Contour lines representing a ridge tend to

be U-shaped or V-shaped. The closed end of the contour line points toward lower ground.

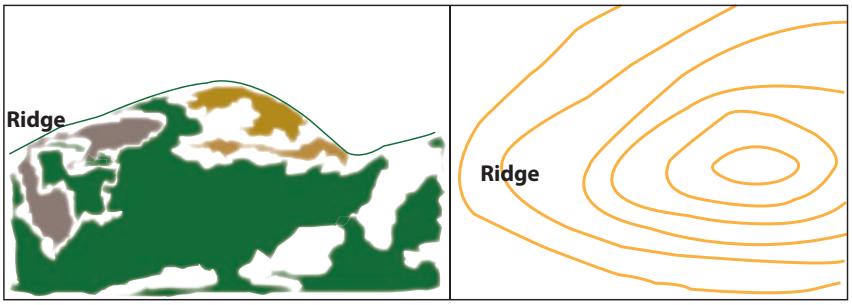


Figure 2.30: **A Ridge and its Representation on Contour Map**

5 ***Depression:*** A depression is an area of land that is lower in altitude than the areas surrounding it. It is a low point on the ground or a sinkhole. It could also be described as an area of low ground surrounded by higher ground in all directions, or simply as a hole in the ground. Usually only depressions that are equal to or greater than the contour interval will be shown. On maps, depressions are represented by closed contour lines that have tick marks pointing downward to lower ground.

Figure 2.31: **A depression and its representation on a contour map**

Activity 2.7

1 Why do different contour lines have different shapes and spacing?
2 What kind of landform is represented by contour lines forming concentric circles?
3 What type of land form is represented on contour maps when altitude decreases from outer contour lines to the inner ones?
4 Describe the difference between a valley and a spur.
5 What is a re-intrant?

What is a re-intrant? What is the difference between a re-intrant and a spur?

6 ***Re-intrant:*** A re-intrant is a less-developed stream course that is smaller than a valley. It has no level ground and, therefore, little or no movement room within its limits. In a re-intrant, the ground slopes upward in three directions and downward in the other direction. A re-intrant could be considered as the initial stage in the formation of a valley. Like those representing a valley, the contour lines representing a draw are U-shaped or V-shaped, pointing toward higher ground.

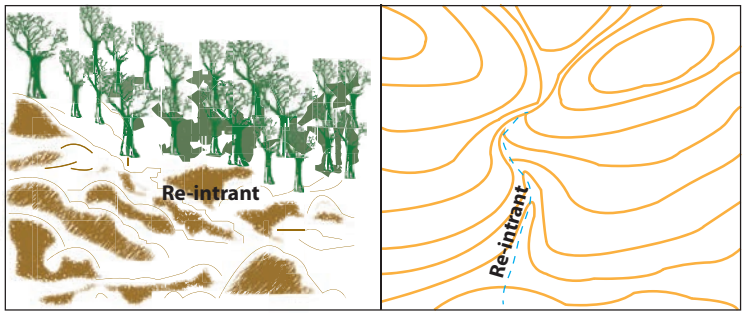


Figure 2.32: **A re-intrant and its representation on a contour map**

What is a spur? What makes it different from a valley?

7 ***Spur:*** A spur is a short and continuously sloping line of higher ground that normally extends out from the side of a ridge. Usually, a spur is formed by two roughly parallel streams that cut draws along the side of a ridge. A spur has three of its sides sloping downwards and upward sloping on the other direction. Spurs are shown on a contour map by using contours that point towards the lower ground with "U" or "V" shapes.

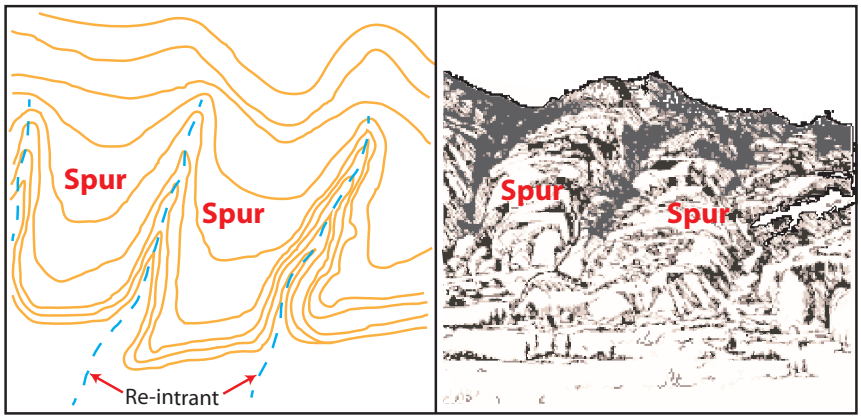


Figure 2.33: **A spur and its representation on a contour map**

What is a cliff? How it is shown in a contour map?

8 ***Cliff:*** A cliff is a vertical or nearly vertical relief feature with a sudden change vertical distance (elevation) with almost no change in its horizontal distance. Cliffs are shown on topographic maps by using contour lines that are very close together (when there is a little change in horizontal distance and rapid increase in vertical distance) and, in some cases, by contours that overlap (merge) when there is no change in horizontal distance at all.

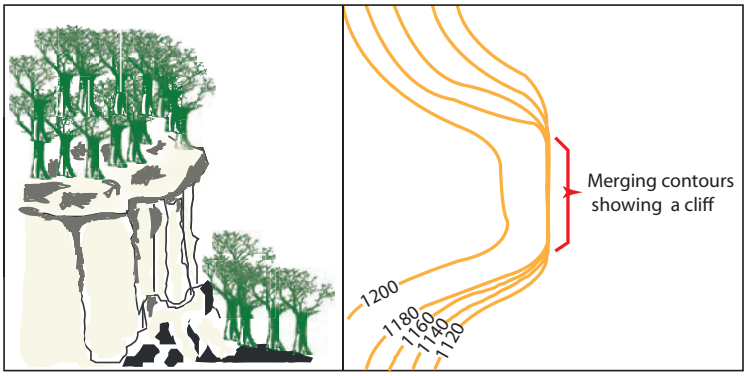


Figure 2.34: **A cliff and its representation on a contour map**

Supplementary Terrain Features

1 ***Cut:*** A cut is a human-made feature that results from the cutting of higher ground, usually to form a level bed for a road or railway track. Cuts are shown on a map when they are at least 10 m high. They are usually drawn with a contour line along the cut line. The contour line extends the length of the cut and has tick marks that extend from the cut line to the road bed, if the map scale permits this level of detail.

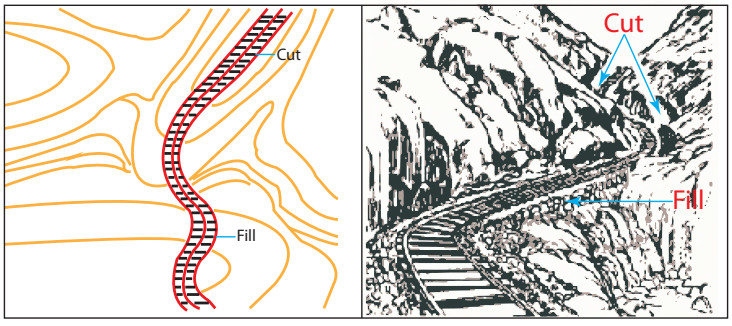


Figure 2.35: **A cut and its representation on a contour map**

2 **Fill:** is a human made feature resulting from filling a low area usually to form a level bed for a road or rail road track. Fills are shown on a map when they are at least 3 m. high.

Activity 2.8

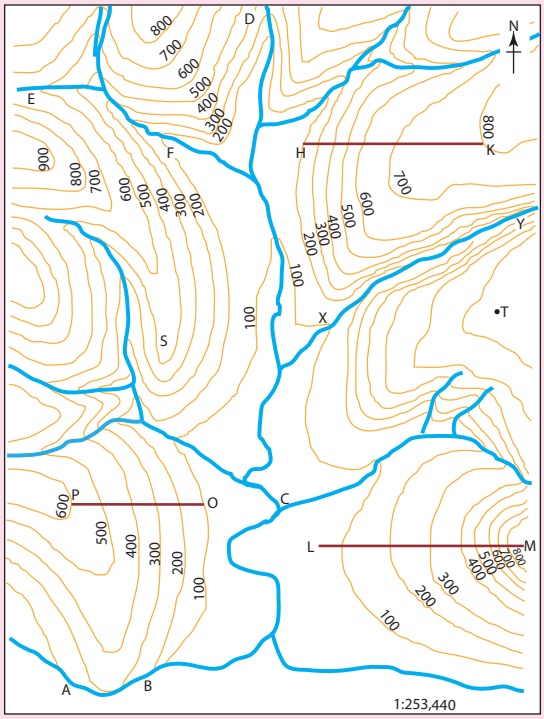


Figure 2.36: **Relief features on a contour map**

By referring to the above contour map, try to identify the relief features that are represented by the numbers indicated below and justify how you identified the feature. To help you answer the rest of the questions accordingly, the first one is done for you.

		Feature	Justification
1	The type of slope from L to m	Concave slope	_____
2	The type of slope from H to K	_____	_____
3	What does letter C show	_____	_____
4	The type of slope A to B is	_____	_____
5	The landform represented by the letter 'S' is	_____	_____
6	The type of slope from 'O' to 'P'	_____	_____
7	Are K and H intervisible?	_____	_____
8	How would you rise if you walked from L to M?	_____	_____
9	The type of landform represented from X to Y	_____	_____

2.2 DRAINAGE ON MAPS

At the end of this section, you will be able to:

- determine catchment areas from watershed on contour map;
- distinguish different drainage patterns;
- demonstrate river capture; and
- demonstrate stages of river valley development using contour lines.

Key Terms

- Watershed
- Catchment area/drainage basin/ divide/
- Drainage pattern
- Drainage system
- Main river
- Tributary
- Confluence
- River capture
- Pirate stream
- Victim stream
- Distributary
- Delta

What is drainage?

The drainage of an area consists of the different water resources that drain it. The drainage includes the rivers that flow over the region and the other water resources, including lakes and swamps. How rivers drain a certain area can be depicted by using contour maps. It is also possible to show the catchment areas and drainage basins of rivers as well as their general characteristics on contour maps. Hence, map readers and map users can acquire adequate information about the drainage of a certain place from contour maps.

Brainstorming

1. What is a watershed? What about a catchment area and a drainage pattern?
2. What is a river capture?
3. What are the stages of river valley development?
4. How are the different drainage features represented on contour maps?

2.2.1 Watershed and Catchment Area

The rivers that drain a certain geographical area flow over the region and form a certain pattern that is termed drainage pattern. A *drainage pattern* refers to the

general arrangement of a river and its tributaries within their drainage basin/ catchment area. A *drainage basin/catchment area* refers to the entire geographical space that is drained by the major river and its tributaries. For example, the whole area that is drained by the Abay River and all its tributaries forms the Abay River Basin in Ethiopia. A number of river basins together form the drainage system of a certain place. A *drainage system* is a system that is made up of all the river basins that flow in the same direction. For instance, all the rivers that flow in the western direction from the central highlands of Ethiopian form the Western Ethiopia Drainage System, which is also called the Mediterranean Sea Drainage System, based on their destination.

Adjacent drainage basins are separated from one another by watersheds. A *watershed/divide* is higher ground which serves as a source region for streams and rivers that flow in different directions within their own distinct basins. Along the sides of a watershed, rivers flow into different drainage basins. That is why we say that a watershed is a dividing line between neighboring drainage basins. The patterns of most drainage basins evolve over a long period of time and usually become adjusted to the structure of the basin.

Figure 2.37 shows you what the features that we have been discussing above look like in a certain geographical region.

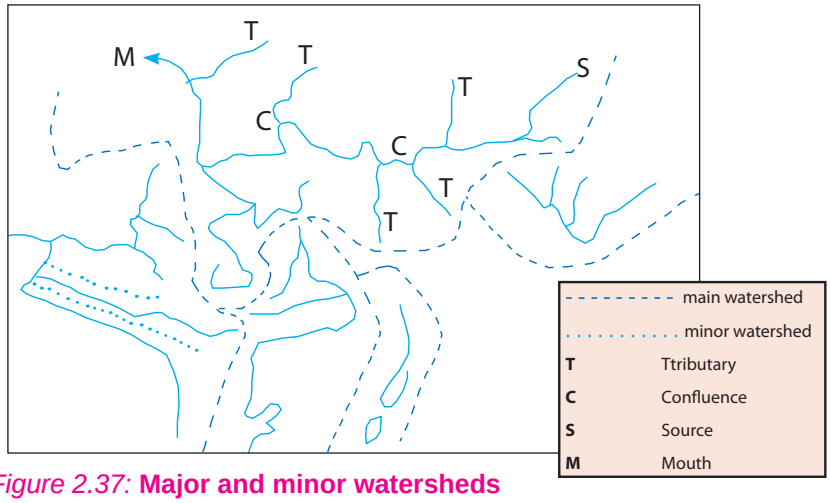


Figure 2.37: **Major and minor watersheds**

A drainage basin and its watershed can be identified on a contour map. This can be done by observing the patterns and shapes of the contour lines that are used to represent the topography of the mapped area. To further simplify the process, it is good to investigate the flow direction of the streams and rivers that originate from the higher ground. The following steps can help you identify a drainage

basin and its divide on contour maps.

- ⇨ *Identify the course of the main river on the map;*
- ⇨ *Identify the tributaries of the main river on the map;*
- ⇨ *Look at the contour lines near the origin of the tributaries and find high points and ridges;*
- ⇨ *Look at other rivers that originate nearby and check whether they flow away from the main river;*
- ⇨ *Once you identify the rivers that flow away from the main river, follow the way between those rivers that flow towards our main river and away from it. Then mark these points with solid or broken lines to show the river basin and its watershed.*

While inserting a watershed on contour maps we should be very careful. The most important considerations follow.

i A watershed (divide) is not drawn parallel between streams; rather the streams flow away from the watershed in opposite directions (see Figure 2.38).

ii Look at the streams' direction of flow carefully. A watershed may wind but it never crosses the channel of a river,

iii A watershed usually passes through the highest points between adjacent river basins.

iv A watershed runs in the middle of two contour lines of different altitude. In the case of a river capture, however, a river can cross its watershed.

Let us now try to identify the drainage basin and watershed of the river that is labeled "River A" in the following figure. Study how we follow the procedure described above as we identify the river's basin and its divide. The red circle shows you where the river is located on Figure 2.38.

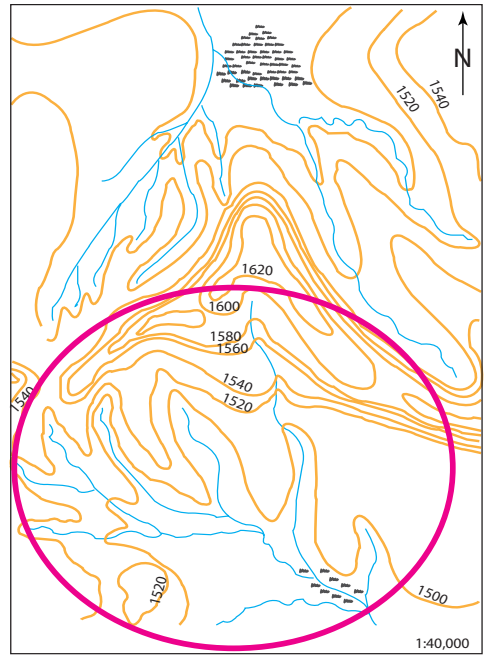
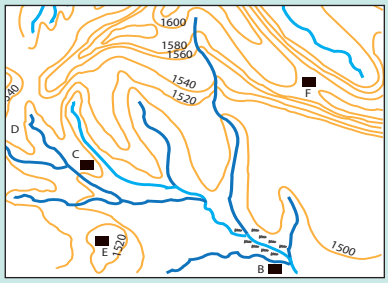
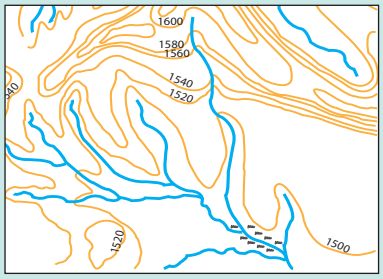
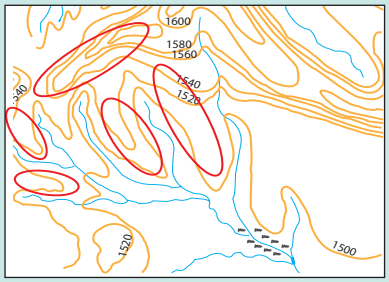
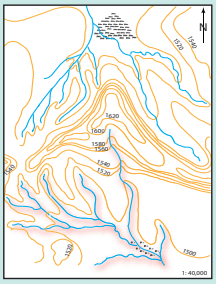
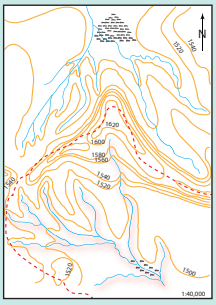


Figure 2.38: **Map of River A**

No	Steps	Figures
1	Identify the course of the main river on the map. The main river in this basin is the one which is the longest.	
2	Identify the tributaries of the main river on the map. The tributaries are those streams that feed the main river.	
3	Look at the contour lines near the origin of the tributaries and find high points and ridges. This helps you to locate the watershed of the basin.	
4	Look at other rivers that originate nearby and check whether they flow away from the main river. If the rivers flow away from the main river, that means they are rivers of another basin.	
5	Mark the points at which the rivers that flow into another direction and towards our main river with solid or broken lines to show the river basin and its watershed.	

A river's catchment area includes all the geographic space that is drained by a ***major river*** and many other small streams that feed the major river with water. The major river in a river basin is the **longest** of all the rivers in the basin. The other small streams that supply water to the main rivers are called ***tributaries***. The point at which the tributaries meet with the major river is called ***confluence***. The point at which the major river in a basin starts is called the ***source*** of the river. Likewise, the point at which the river empties itself into an ocean, a sea or a lake is called the ***mouth*** of the river. Figure 2.39 shows you the points that we have discussed above.

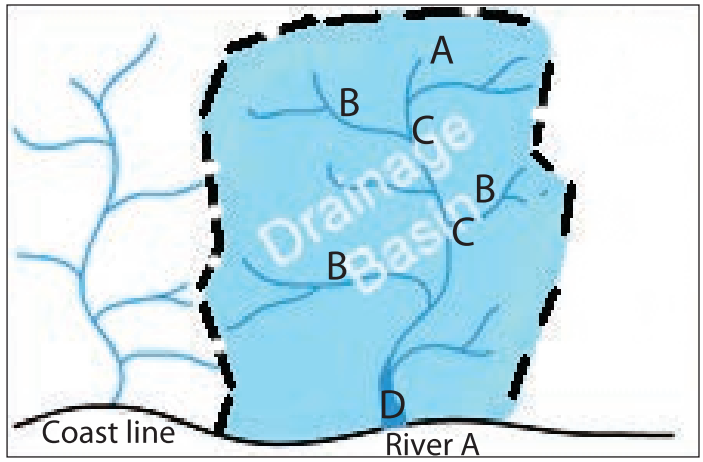


Figure 2.39: **A river's catchment area**

The labels on the map in Figure 2.39 represent the following features.

- *Letter "A" represents the source of the main river;*
- *Letter "B" represents the tributaries of the main river;*
- *Letter "C" represents the confluences; and*
- *Letter "D" represents the mouth of the main river.*

Activity 2.9

By referring to Figure 2.52 answer the following question and perform the following tasks.

1 How many drainage basins can you identify in the figure?

2 Draw the watersheds that separate the given drainage basins.

Show major and minor watersheds, using labels. Use letter 'A' for the main (major) watershed and letter 'B' for minor watersheds .

2.2.2 Drainage Patterns

What is a drainage pattern? How does it differ from a drainage basin?

The rivers in each drainage basin form different patterns. A drainage pattern shows the characteristic way tributaries that feed other larger streams and rivers branch off in different directions. In other words, it could be understood as a pattern that is formed by the main river and its tributaries as they flow over the surface of the earth. Drainage patterns can have many different forms. They are based largely on the geological structure of the rocks on which they form. As topography varies, so does the drainage pattern. In addition, the types of rocks over which the river flows and the geological history of the region may also influence the drainage patterns of rivers.

Brainstorming

1 How many drainage patterns do you know?
2 How do you distinguish one from the other?

There are a number of drainage patterns that rivers form in their basins. However, the most common ones are the following.

- ⇨ *Dendritic drainage pattern*
- ⇨ *Trellis drainage pattern*
- ⇨ *Radial drainage pattern*
- ⇨ *Centripetal drainage pattern*
- ⇨ *Rectangular drainage pattern*

The features of the five drainage patterns are presented in the following descriptions and diagrams.

1 ***Dendritic Drainage Pattern:*** The term dendritic is derived from the Greek word "dendron" which literally means "a tree". This drainage pattern is characterized by a tree-like shape with branches. The smallest tributaries are the outermost twigs, and the main river channel forms the trunk. The lower-order streams (tributaries) join the main (higher-order) streams at acute angles (less than 90° angles), forming

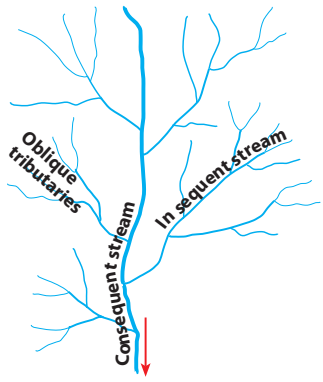


Figure 2.40: **Dendritic drainage**

Y-shaped junctions. Dendritic patterns are usually formed in areas of homogeneous rock which comprises horizontal strata rock masses. In this drainage pattern, geological processes such as folding or faulting do not create structures that would affect the development of the river system. It is the most common drainage pattern of all the patterns.

- ***In sequent stream*** *– these are tributaries that flow towards the main valley joining the main river (consequent stream) obliquely and in turn minor tributaries join them and the points where they flow into the main streams are accordant functions.*
- ***Oblique tributaries*** *– these are minor tributary streams having a sloping direction, that join the in sequent stream obliquely.*

2 ***Trellis Drainage Pattern:*** Trellis drainage patterns develop in areas where harder and softer rocks alternate. The pattern of this drainage pattern is greatly affected by tectonic forces (folding and faulting). The branches of the river system usually join one another at nearly right angles. The branches are given different names, depending on their origin and direction of flow. These are:

i *First-order streams (obsequent)*: are the tributaries of the subsequent streams that flow in the opposite direction to the consequent stream (main).

ii *The consequent stream*: the principal river which flows down the slope is called a consequent river.

iii *The subsequent streams*: are the tributaries which cut out valleys and which do not flow down the main slope.

iv *Secondary consequent streams (resequent)*: are the tributaries of the subsequent streams that flow in the same direction to the consequent stream.

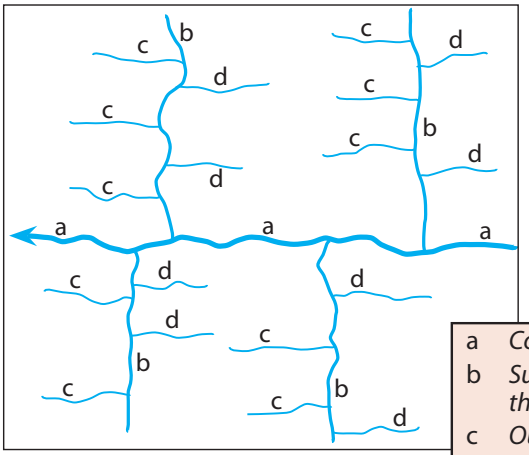


Figure 2.41: **Trellis drainage pattern**

3 ***Radial Drainage Pattern:*** Radial drainage patterns occur where rivers flow in all directions away from a raised feature. The raised feature may be a volcano or a mass of rock that is more resistant to erosion than the surrounding rock and therefore stands higher than its surrounding.

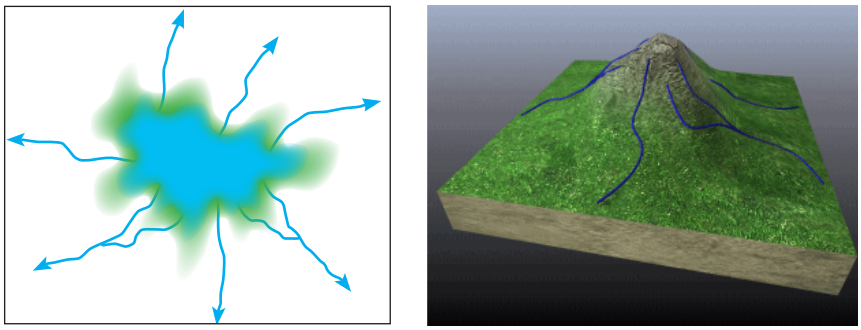


Figure 2.42: **Radial drainage pattern**

4 **Centripetal Drainage Pattern:** Centripetal drainage patterns are found in areas where rivers flow from surrounding high ground toward a central basin, which is often occupied by a lake. The rivers flow into one common centre.

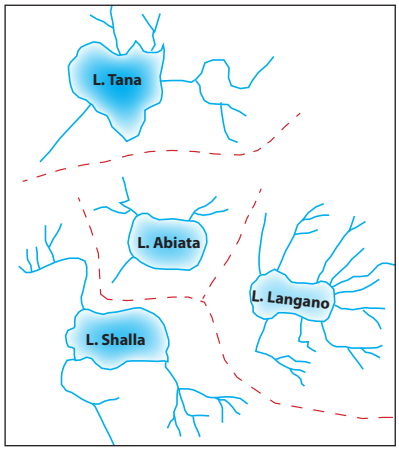


Figure 2.43: **Centripetal drainage pattern**

5 **Rectangular Drainage Pattern:** Rectangular drainage patterns usually form in areas that have numerous cracks that form a grid pattern. This pattern is common over certain types of rock, such as granite, in which cracks called joints develop to form a grid. Stream channels tend to follow these joint systems.

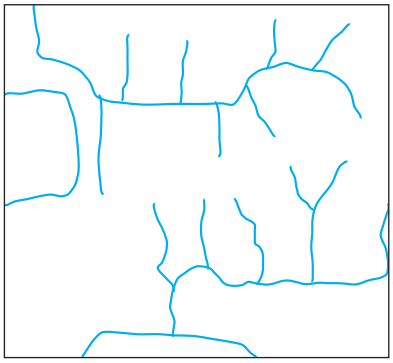


Figure 2.44: **Rectangular drainage pattern**

Five different kinds of drainage patterns are formed by streams. These are dendritic, rectangular, radial, centripetal and trellis. Drainage patterns result from the type of soil in the area of drainage and the erosion of the soil by flowing water. Dendritic patterns usually form in areas of flat sedimentary rock, while areas with high central peaks, such as volcanoes, exhibit radial drainage patterns. Sometimes, water flows into a bowl-shaped valley by centripetal drainage and creates a lake or erodes areas between ridges to create deep valleys, as seen in trellis drainage.

Activity 2.10

Explain, creating by well-labelled diagrams, the main differences between the following pairs of features:

i Radial and dendritic drainage pattern

ii Waterfall and rapid

2.2.3 River Capture and Stage of River Valley Development

A *River Capture*

Brainstorming

1 What is a river capture?

2 How does a river capture form?

In a river capture situation, a river joins another river down-slope from a watershed that separates the two basins. In a river capture, a river of one basin will run over the drainage basin of another river. The river that flows over the basin of the other river is called the ***pirate stream***, and the other river, whose basin is overrun by the pirate stream, is known as the ***victim stream***.

There are certain situations that cause the formation of river captures. The conditions include the following. When:

- ⇨ *the rock on the side of the victim river is softer.*
- ⇨ *heavy rainfall falls on the pirate's river side of the watershed.*
- ⇨ *the pirate river has a steeper course and erodes its course as a result.*
- ⇨ *the watershed consists of very low ground and the watershed itself becomes indefinite.*

Focus

In a river capture, the following features are commonly observed.

i **Elbow of capture:** is a point where one strong river cuts into the course of another weak river during river capture.

ii **Misfit or underfit stream:** is a stream which is deprived of its headwaters and becomes too small for the valley it belongs to.

iii **Reverse drainage:** occurs when a river which was part of the original captured river C_2 now flows into C_1 in the opposite to that of direction the original direction of flow.

iv **Wind gap:** is found at the elbow of capture which was once covered by the captured stream but now contains no rivers and therefore becomes a "wind gap".

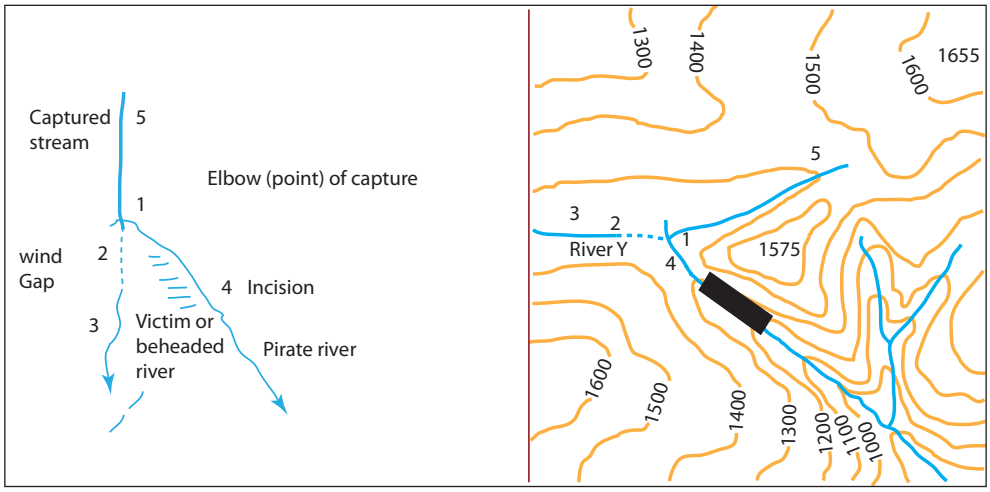


Figure 2.45: **A river capture**

Typical examples of river capture in Africa include:

1 ***Tival River Capture (Kenya):*** In Kenya; the lower Tiva River has captured a former tributary of the Galona.

2 ***Cunene River Capture (Angola):*** The upper Cunene River used to flow out from the Bihe plateau to a large inland drainage basin, similar to the Okavango Delta, but it was captured by a vigorous coastal steam and now turns west to the Atlantic.

Immediately after the formation of a river capture, there might be a connection across the newly formed watershed. This connection is known as a *bifurcation*, which means a stream divided into two.

Content Check

I ***Give short definitions of these terms.***

1 Wind gap

2 Underfit-stream

3 Reversed drainage

II ***Fill in the blank space.***

4 A place where the pirate river diverts the head water of its victim river is called _____.

5 The beheaded river which, having lost its head waters, may be reduced in volume, causing it to be very small relative to its valley is called _____.

B *Stages of River valley Development*

Brainstorming

1 What is a river valley? How does a river valley develop?

2 How many stages does a river have from its source up to its mouth?

The volume and gradient of a river are the two determinant factors of the force of a river before it reaches its base level. ***Base level*** is the surface of a river or lake or the sea into which a river flows. All rivers have their own sources and mouths. The source of a river can be a spring, a lake or a marsh, but it is generally in a higher ground where:

- ⇨ *precipitation is high and there are other sources of water for the river; and*
- ⇨ *there is a slope down which the run-off can flow.*

The higher ground serves as the source region of the river or as the point at which the course of the river starts. From there, the river flows down-slope and passes

through different courses until it reaches its mouth. Along its entire course, from its headwaters at the top of the watershed to its mouth, a river has three distinct parts. These are:

A the upper or mountain course;

B the middle or valley course; and

C the lower or plain course.

A *The Upper Course*

What are the characteristics of a river at its upper course?

The upper course of a river is the headwater zone in the mountains or hills where sediment is supplied from hillsides and transported down steep channels with narrow flood plains. In these narrow, steep canyons, the bed of the river may be covered with large boulders as the river passes through many rapids.

The following are the characteristics of a river at its youth stage:

- ⇨ *The development of deep narrow valley with V-shapes;*
- ⇨ *The development of valleys with narrow and steep gradients;*
- ⇨ *The presence of fast-flowing rivers;*
- ⇨ *The development of pot-holes;*
- ⇨ *The formation of interlocking spurs; and*
- ⇨ *The presence of waterfalls, rapids and cataracts.*

B *The Middle Course*

What are the major features of a river at its middle course?

The middle course of a river forms when the mountains give way to the plains, where the steepness of the river channel decreases from as high as a 1-to-10 percent to less than 0.1 percent. At this stage, the volume of the river may increase. However, the ability of the river to carve into rock and carry sediment decreases, due to the fact that the river's channel has become less steep. As the speed of the river decreases, its power to carry and transport large-sized sediment also decreases. As a result, the sediment in the river gradually decreases in size from boulders (larger than 256 mm in diameter) to cobbles (between 64 and

256 mm) and to gravel (between 2 and 64 mm). As the gradient of the valley continues to decrease, the sediment becomes very fine, consisting mostly of sand, silt, and clay. At this stage, the floodplain of the river widens.

At this stage, the river is characterized by the following features.

- ⇨ *the river flows over a relatively gentle gradient as compared to its upper course, and the river flows slowly as a result;*
- ⇨ *the river's volume increases gradually as it is joined by the tributaries that feed water to the river;*
- ⇨ *the river's valley gets wider and deeper. The slope along the valley's sides gets gentler, altering the valley's shape from a V-shape nearly to a U-shape, and*
- ⇨ *braided streams may develop if large sheets of material are deposited on the level plain, splitting the river into several channels.*

C *The Lower Course*

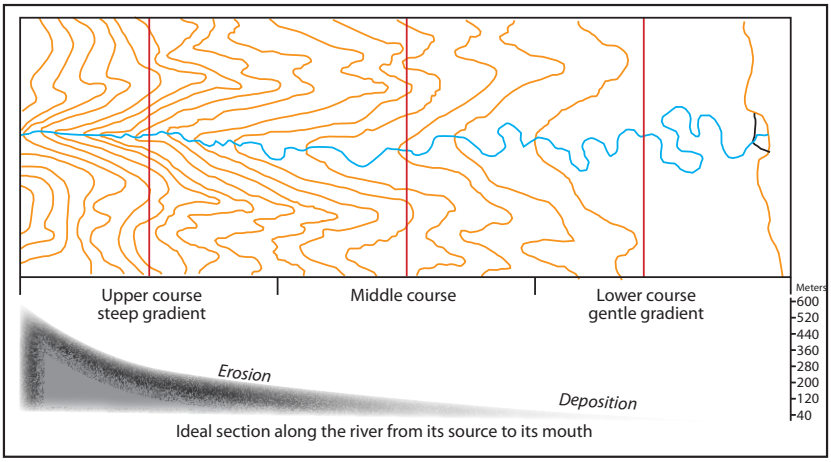
Discuss the major features of the lower course.

The lower course of a river is the third stage in a river valley's development. It is the course that is influenced by the ocean or lake where the river ends. The steepness of the river channel in this course is usually less than 10 centimeters per kilometer. Because the river flows very slowly, the sediment transported becomes very fine. At this stage, a delta may develop if enough sediment settles out of the water. Unlike a ***floodplain***, a delta is a feature where the river splits into many new channels called ***distributaries*** while discharging into an ocean, a sea or a lake where it ends. If not enough sediment settles out to form a ***delta***, the river may discharge into the sea in an ***estuary***. Unlike a delta, an estuary is a wide channel where the fresh water from the river mixes with the salty seawater without forming distributaries.

At this stage, a river may have the following characteristics.

- ⇨ *The river flows in a U-shaped valley with a flat river bed, the rate of change in slope is minimal, and the river flows very slowly as a result;*
- ⇨ *The river carries a heavy load of fine sediment of which some is deposited on its bed;*
- ⇨ *The river flows with a number of twists and bends, resulting in the occurrence of meandering;*

- *The development of oxbow lakes as meanders gradually develop cut-offs;*
- *The development of floodplains rich in alluvial deposits as fine sediment is accumulated on the river bed; and*
- *The river's mouth may sometimes be blocked by sediments causing the river to branch out forming distributaries. In such a case, a delta may develop. If the river empties into its end freely with no distributaries formed, an estuary will develop.*



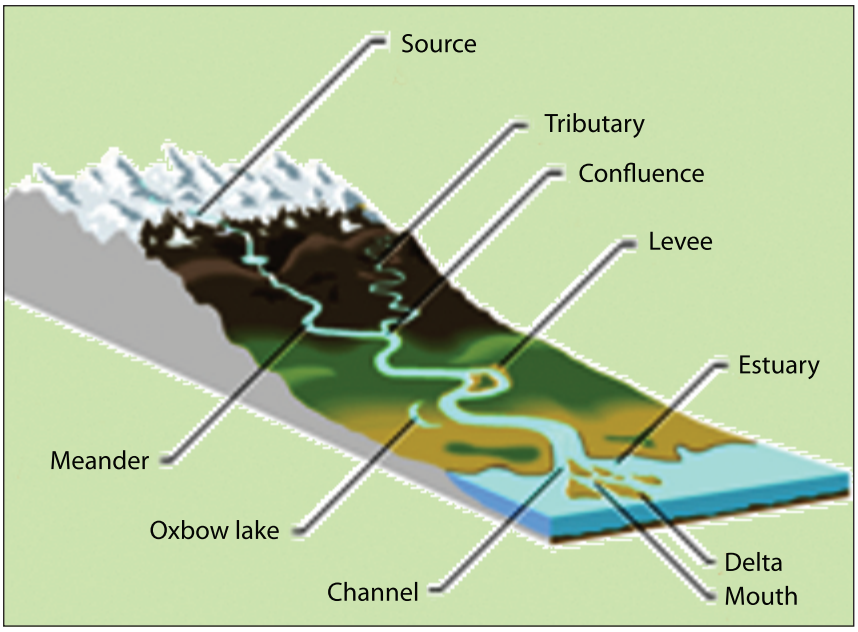


Figure 2.46: **The course of a river from its source to its mouth**

The meanings of the features shown in Figure 2.46 are explained below. Study them carefully.

Source: The source of a stream is the point at which it begins.

Tributary: A tributary is a small stream or river that flows into a larger stream or river.

Confluence: A confluence is the point where a river and its tributary or a river and a glacier flow together. The word confluence can also mean the place where two or more streams merge into one.

Levee: A levee is a ridge of sediment on either side of a river channel. This sediment is gradually deposited as the river periodically floods and overflows its banks.

Estuary: An estuary is the area in which the mouth of a river meets the ocean.

Delta: A delta is a triangular deposit of soil or silt at the mouth of a river. In deltas, rivers split into multiple channels called distributaries. There are three types of deltas. They are based on the deltas' shapes.

- **Arcuate delta:** *This kind of delta has a convex outward margin. It is formed when the river empties into the sea. It is composed of coarse sediments like gravel and sand.*
- **Bird's foot delta:** *This kind of delta projects irregularly into the sea. The river channel derides into a few distributaries. This is the only type of delta which maintains clearly defined channels.*
- **Cuspate delta:** *It is formed when a river joins its mouth (sea) on a straight coastline along which there is a strong current or tide so that the sedimentation takes place on either side of the river mouth.*

Figure 2.47: **The three types of deltas**

Mouth: The mouth of a river is the area in which the river enters a larger body of water. The mouth of a canyon is where the canyon empties onto a plain.

Channel: A channel is the deepest part of a river and often has been used for navigational purposes.

Oxbow lake: An oxbow lake is a loop of an old river meander that has been completely cut off from the river because of a shift in the river's course.

Meander: A meander is a bend in a river created by the normal action of a mature stream as it winds across its floodplain. The river deposits sediment on the inner curve of the meander, where the current is the slowest. On the outer curve, where the current is strongest, the river banks erode. Eventually, the meander may develop into such a long loop that the river cuts across it to follow a shorter course, leaving behind an oxbow lake.

Content Check

1 Define the following terms and concepts
   - a drainage pattern
   - b divide
   - c watershed
   - d confluence
   - e river capture

2 Write the major features that characterize a river in its:
   - a upper course
   - b middle course
   - c lower course

2.3 THE STUDY OF HUMAN-MADE FEATURES ON MAPS

At the end of the section, you will be able to:

- distinguish various patterns of settlement on maps;
- interpret the shape of settlements;
- explain the types of settlements;
- estimate factors influencing the sitting of settlement
- reflect the function of settlements;
- identify various airfields on maps.

Key Terms

- Settlement
- Signs and symbols
- Site
- Rural
- Urban
- Transport network
- Gradient

Brainstorming

Discuss the following questions with your friend and try to come up with some ideas.

1. What is a settlement?
2. How is a settlement formed?
3. What sorts of factors determine the establishment of a settlement?

A settlement is a place where people live close together. It is a unit or organized group of people inhabiting a certain geographical area and making a living out of their surrounding environment. A settlement can also be defined as a group of buildings (houses) in specified area with people living in them. Settlements differ in their ***size***, ***complexity*** and ***stage*** of development. While some settlements are extremely large with diversified socio-economic conditions, others are very small and less diversified. Settlements range from a little collection of single buildings to megalopolises. As a result, we can have different hierarchies of settlements. Figure 2.48 shows you the different types of settlements based on their population size and diversity of services.

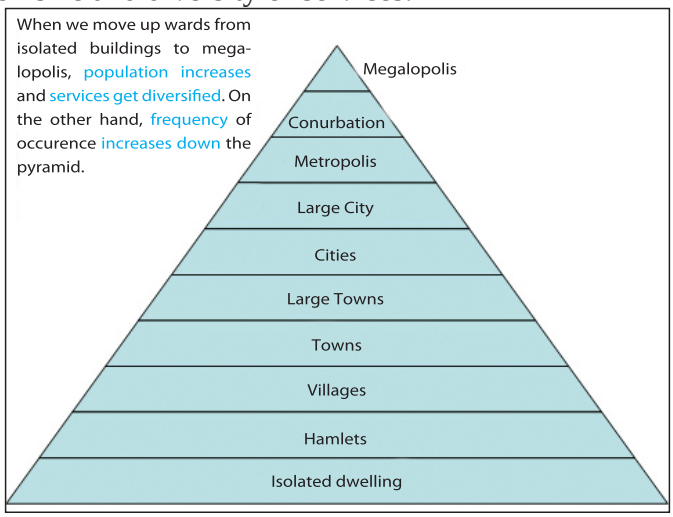


Figure 2.48: **Settlement Pyramid**

In Figure 2.48 ,above isolated dwellings with a few people living in them is represented by the lowest level of the pyramid, and the megalopolis, which has the greatest number of people, is at the top. As we move from the bottom to the top of the pyramid, we observe changes in population size and in service delivery, quality and diversity. In terms of frequency, smaller settlements are the most frequently developed settlements in the world. The meaning of each of the types of settlement in the above diagram is given below.

Megalopolis: a group of conurbations, with each having more than ten million people.

Conurbation: a group of large cities and their suburbs, with three to ten million people.

Metropolis: a large city and its suburbs, consisting of multiple cities and towns with one to three million people.

Large city: a city with a large population and many services with a population of between 300,000 and 1 million.

City: a city has abundant services, but not as many as a large city. A city has a population of between 100,000 and 300,000.

Large town: a large town has a population of 20,000 to 100,000.

Town: a town has a population of 1,000 to 20,000.

Village: a village generally does not have many services, possibly only a small corner shop or post office. A village has a population of 100 to 1,000.

Hamlet: a hamlet has a tiny population, usually less than 100, and very few or no services, and few buildings.

Isolated dwelling: an isolated dwelling would only have 1 or 2 buildings or families in it. It would have negligible services, if any.

Settlements can be urban or rural. Urban settlements are developed in areas with non-agricultural economic activities. In contrast, rural settlements develop in areas where agriculture forms the base of the economy. Smaller settlements are usually in rural areas, and larger settlements are associated with urban environments. The location, size, shape, function and pattern of settlements can be shown on maps. Cartographers use different kinds of signs and symbols to represent settlements on maps. The discussion below gives you some idea about how settlements are represented on topographic maps.

2.3.1 Representation of Settlements on Maps

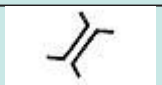
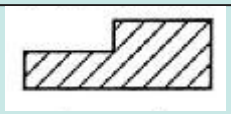
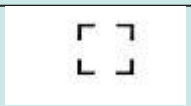
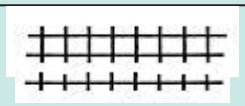
How do human beings establish their settlements? How do we represents settlement on maps? What factors determine the patterns of settlement?

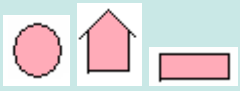
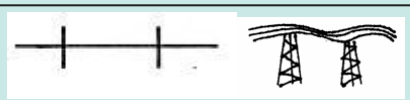
Maps are important tools for showing settlements. In different ways, maps depict the shapes settlements have, different features that are found in the settlements, the patterns of settlements and their functions. To represent settlements and their features, cartographers use different techniques including colors and different signs and symbols.

Signs and Symbols Used on Settlement Maps

Most topographic maps contain abundant information about human-made features. One of these features is human settlement. A number of different features, such as residential areas, schools, hospitals, mining sites, industries, communication and transportation features, and the like, are found in settlements. Cartographers use different techniques to show these features on their maps. One of these techniques is using various types of signs and symbols to show features that are found in the settlements represented. The common signs and symbols used for showing settlement features are given in Table 2.2.

Table 2.2: **Signs and symbols that are used to show settlement features on maps**

Map symbols	Features represented
	Town, city, major city, capital city
	Built-up areas (towns and cities)
	Bridge
	Parking lot
	Ruin
	Railway (double/single track)
	All-weather road (hard and loose surface)
	Dry-weather road, track, trail
	Garbage bin

Map symbols	Features represented
	Lighthouse
	Villages, scattered settlements, farms
	Church or chapel
	Mosque
	School
	Airport Class I, Airport Class II, Heliport
	Clinic or hospital
	Battlefield
	Mineral workings
	Post office
M	Market
 / T	Telephone
	Electric power line/transmission line

II *The Shape of Settlements*

Brainstorming

1. Do you think that all settlements have the same shape? Why or why not?
2. How many settlement shapes do you know?
3. What causes the different shapes that settlements have?

Settlements have different shapes that result from many factors. Some of these factors are the site and situation of the settlement. The term Site means where the settlement has been developed. On the other hand, Situation refers to the "where" of the settlement in relation to the surrounding area. Situation can also be described as the "where about" of a settlement. The site and situation of a settlement is the most important determinant factor of its shape. Basically, settlements are classified into three major groups based on their shapes. These are:

- Dispersed settlement
- Nucleated settlement
- Linear settlement

a ***Dispersed settlements:*** These are settlements established by one family or a few family residences scattered about in isolated places. They are separated from one another by physical barriers. Life in this kind of settlement is simple, quiet, and much the same all the year round. There is little opportunity for social gatherings. Dispersed settlements are typically found in the tropical rainforests and scrub lands in Africa and Australia. Dispersed settlements are mostly found in rural areas.

b ***Nucleated settlements:*** These are groupings of several family residences such as hamlets, villages and small periodic-market towns. Such settlements are usually developed around a certain central point. In such a settlement, there are collective amenities to serve the community like shops, houses, schools, places of worship, entertainment and transport networks. The pattern of the settlement is compact, concentrated and can be distinguished by certain well-developed features. Ethiopian examples of nucleated settlements are Addis Ababa, Bahir Dar, Harar, Gondar, Bishoftu etc.

c ***Linear (Ribbon) Settlements:*** A linear settlement is a kind of settlement which has an elongated pattern. This type of pattern is usually a road-oriented settlement pattern. Most of the towns that are found along the main highway lines from Addis Ababa to Gondar, Mekele, Asosa, Harar, and Jimma are good examples of linear settlement in Ethiopia. Some linear settlements are situated on an elongated relief feature such as a ridge. The town of Ghimbi in Welega is a good example of a settlement that develops along a ridge.

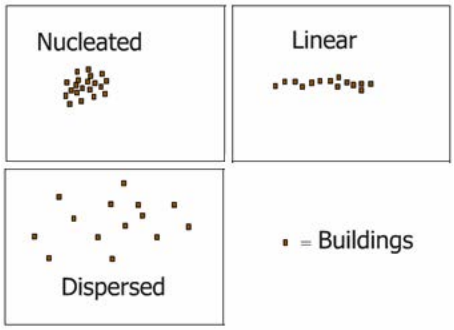


Figure 2.49: **The three types of settlement shape**

III *Types of Settlements*

How many types of settlements are there? How do you differentiate urban settlement from rural settlement? What are the major economic activities in rural areas?

Based on where settlements are developed, they can be grouped into two types as Rural settlement and Urban settlement. Rural settlements are those that develop in agricultural areas. In contrast, urban settlements are those that develop in non-agricultural areas where the major economic activities are non-agricultural. Each of the two types of settlements has its own features. For instance, rural settlements have very low levels of socio-economic infrastructure and are poorly interconnected. Services are limited. Their economy is primarily agricultural. Rural settlements have very low divisions of labor. They are also sparsely populated. Contrary to this, urban settlements are characterized by non-agricultural activities such as different businesses, service-giving sectors, industries and the like. They also have a high division of labor. Infrastructures, such as transport and communication facilities, schools, and hospitals, and modern houses, etc. are well-developed. Urban settlements are densely populated as people live very close to each other.

Rural and urban settlements can easily be distinguished based on the features that each manifests. The characteristic features that can help the easy differentiation of urban (town, city) settlements from rural settlements on topographic maps include the following.

Urban	Rural
⇨ has groups of buildings on vast built-up areas; ⇨ has planned streets; ⇨ has defined shapes of settlement.	⇨ has houses made out of simple materials (wood and mud); ⇨ has no planned streets; ⇨ has narrow and irregular roads; ⇨ has no defined shape; ⇨ covers a small area.

IV *Factors Influencing the Location of Settlement Sites*

What factors influence, the location of settlements? How do they affect the locations of settlement sites?

The site of a settlement is where it has been built. Settlements develop when people settle in a certain area. Their settling in an environment to form a permanent settlement is the result of a number of factors influencing the settlers. There are a number of factors that were important to the original settlers.

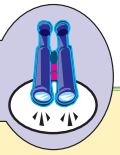
When we carefully observe the location of towns and cities, we can see that their sites and situations have various advantages that have helped them to grow there. This is related to the factors that caused the development of the settlements. For instance, Addis Ababa is sited at the foothills of the Entoto Mountains where the hot springs of the present day ***filuwuha*** are situated. Its position is its location in relation to the rest of the region. Similarly, the town of Bahir Dar is situated to the southwest of *Lake Tana* and northwest of the *Tis Esat* fall.

The choice of a settlement site is affected by many factors. The following are some of the more favorable combinations of site and situation which have led to the establishment of settlements.

- ***Fertile alluvial plain:*** *the primary and basic necessities of humanbeings are food and water. A fertile alluvial plain drained by rivers is ideal for raising food crops and maintaining a potable water supply. A flat landscape facilitates the movement of people and goods. It is an ideal situation for the exchange of products and ideas. It is the potential center for trade communication and administration. Examples are Hawasa on the rich Lake Hawasa plain, Wereta in the intensively cultivated Fogera basin drained by the Rib and Gumara Rivers.*

- ***Coastal lowlands:*** *where narrow coastal plains are bounded on the landward side by mountains, agriculture, transport and settlement all have to be carried out on the lower land. Where there is a mountain barrier, this naturally leads to the growth of a town.*
- ***Water supply:*** *water is one of the most important natural resources to human beings. Therefore, at any cost, the site of a settlement should be near a good water supply. Springs, streams, and storage dams should be remote from flooding and water germs. Such settlement sites include ports, confluences, bridge points, and spring lines at the base of escarpment river banks. For example, Khartoum is a confluence city and Djibouti is a port town.*

Focus



Water (wet-point) sites are ideal for a settlement for a number of reasons like pure and adequate potable water, fishing, irrigation, power generation (HEP) and communication.

- ***A natural focus of routes:*** *These are the nodal towns. By the very nature of their geographical location, many towns assume importance as centers of road, rail or water communication. People tend to provide commercial and social services that passing travelers can make use of. An example of such nodal town in Ethiopia is* ***Kombolcha****.*
- ***Sites for Generating hydro–electric power:*** *waterfalls are of paramount importance for generating hydro–electricity. Where such a site occurs, the availability of cheap power attracts industrial establishments. These require labor and other services and a settlement is very likely to grow up taking advantage of the cheap power. Examples of such settlements include* ***Buffalo*** *to the south of the Niagara Falls in the US, and* ***Bahir Dar*** *and* ***Fincha*** *in Ethiopia.*
- ***Defensive Sites:*** *a defensive site is a place that is difficult to attack. This was a deciding factor in the 19th century in Ethiopia when defensive strategy that was executed at the right moment could save the whole community. However, in modern warfare with aerial attacks the community could not be saved. Some settlements were chosen due*

to their physical protection for a given tribal group against another tribal enemy. Some towns in Ethiopia were established on a hilltop or hillsides for defense and patrolling purposes. For instance, the Yirgalem, Chencha (Gamo–Gofa), Asela, etc. villages on the Bouci plateaus were established in isolated spots at the bases of rocky ridges and covered by dense forest. Government policies in the hidden areas of modern Africa have established nucleated defensive settlements.

- ***Communications:*** *Communication networks are important factors in settlement sites. This becomes evident if the settlement produces cash crops for market. Proximity to transportation networks eases movement for speedy marketing of agricultural products. Large villages grow into large towns if they are situated at road junctions. Good examples of this case in Ethiopia are Mojo, Awash, Shashmene, Wereta, and Woldya.*
- ***Mineral wealth:*** *The discovery of minerals and their extraction can be a facilitating factor for the development of settlements. Anywhere on earth, be it on mountain tops or arid (desert) areas, valuable minerals attract investors and investment to work in the mines. Such conditions create favorable opportunities for settlements to develop. For example, Johannesburg's growth in the Republic of South Africa has been accelerated by the discovery of gold in the Witwatersrand. It is now the second largest city in Africa next to Cairo.*

V *Function of Settlement*

Settlements, by their very nature perform certain useful functions to ascertain their continued existence, most of them have several functions. A village or a town may serve the community as a meeting place for people and goods and have no other functions to distinguish it from other villages. A village grows in to a town and later in to a city, the increase in population alone insures many activities that a village does not require. Towns may comprise several functions. However, most towns have one dominant function. Maps can give us some sort of information regarding the land use (economic importance) of settlements. There is a possibility to know the function of a town by just looking the situation and the name on topographic maps. For example, beach side holy day resorts, Commercial ports, mining centers, etc. We can therefore, classify towns according to their functions.

1 **Market towns:** These are towns whose major function is as centre of exchange of goods and service. They are distribution centres for local

products, for example, Nedjo (Welega), Kola Diba (N. Gondar), Ginchi (near Ambo), Agaro (in Jimma), Tepi (in Kaffa), Durbete (west Gojam), etc. Kumasi (Ghana).

2 **Industrial towns:** Towns of these kinds are engaged in processing raw materials into finished goods. These towns have some advantages as industrial sites such as:

- *Proximity to power,*
- *Minerals,*
- *Raw materials, labor or markets,*
- *Are served by modern net work of communication.*

Example:

Akaki, Dukam, Adama, Dire Dawa, Bahir Dar, Gondar, Mekele, Hawasa, etc.

3 **Commercial towns:** The major function of these types of towns is just serving as centers of commerce and finance, where trade is the primary concern. There are financial institutions such as banking, insurance and other financial sectors. London is the financial head quarters of the common wealth. New York is the financial centre of USA, Addis Ababa is the financial centre of Ethiopia.

4 **Mining towns:** mining oriented towns may be located in very unusual places , but adequate mineral resources. Some towns shrink and become ghost towns due to the exhaustion of minerals. Many acquire other functions and are permanent towns. Mining centers can be located on maps by quarry symbols. This includes rocks (building stone, limestone and gravel for road construction). Gravel pits heavy machinery, water and power supply, smelteries , roasting, oil roads, railways and pipelines are indicators of mining villages.

5 **Holiday resorts, hill and health resorts:** These towns with various kinds of resorts are located in favorable geographical surroundings. They include coastal resorts for batting and yatching. For example, Mombasa (Kenya), port Sudan (Sudan), Pretoria (south Africa).

Hill resorts for mountain climbing and for the cool mountain air. For example, Semien mountain(Ras Dejen). Health resorts for those whole need specialists treatment. For example, Soderie (Oromia), Wondo Ghent (Oromya), Wanzaye (south Gondar).

6 **Forestry (Lumbering):** Forestry oriented towns are classified according to their latitudinal location and forest type these are deciduous, coniferous tropical and mixed wood land. They are depicted on maps by pictorial (tree) symbols

7 **Administrative towns:** these types of towns are the head quarters of the government and they are capital cities or centres of local administration. They deal with the administration and organization of the nation. Some are continental capitals (Addis Ababa) and international capitals (Geneva, New York)

8 **Cultural and educational towns:** These are towns in which are found world renowned universities. For example, Oxford and Cambridge in England and Laiden in the Netherlands:

9 **Ecclesiastical cities:** towns under this category are very exceptional. Towns of this type are perform special functions such as historical and religious centers and are frequently visited by pilgrims from all corners of the world. These include Jerusalem (Judaism, Christianity), Mecca (Islam), Varanasi (Hinduism) other smaller ones include religious associations for example, Vatican, Lalibela, Axum and Kulubi (Orthodox Christianity), Nejash (Islam) in Ethiopia.

Activity 2.11

1 For what purpose do people chose alluvial plain for settlement?
2 Explain the difference between wet site and dry site settlements.
3 List some towns in Ethiopia which were established for defense purpose.
4 To which type of site does Oxford belong?
5 Explain the reasons (causes) why some towns shrink and become ghost towns.

2.3.2 The Study of Communication on Maps

Transport Network

What is a transport network? What are those factors that affect transport networks?

Communication feature can be shown on topographic maps by using different signs and symbols. It is also possible to measure distance from one point to another. Gradients of various transport networks can be also calculated and viable

types of vehicles for them can be identified based on slope gradients.

Recognizing communication features on maps:

> ⇨ *Marginal information on maps is the most important tool for map readers who are reading those communication features on topographical maps. These include foot paths, tracks, roads, railway lines airways, waterways etc. Those features can be distinguished from their names and conventional signs and symbols depicted on the map.*

a ***Foot paths (Trails):*** These are usually found in the open countryside and in hills or mountains where construction of metalled road surfaces is impossible or extremely expensive. These are commonly found in rural Africa, and most of the people are served by trails and tracks.

b ***Roads:*** Roads ranging from mule tracks to modern highways are the most universal form of transport. Roads are classified by their width and surface quality: Topographic maps show various classes of roads by using different symbols. Some of them are: tarmac (asphalt) roads or first-class roads (highways), metallic (graded surfaced) roads, and cart tracks (dry-weather roads).

c ***Railways:*** compared with road transport, rail travel avoids congestion causes less pollution, is cheaper and quicker over relatively long distances, and is safer and more comfortable.

Railway lines can be distinguished on topographic maps by symbols. Such a map also shows railway lines with single and multiple tracks, small-gauge and mineral working lines and all the constructional detail is given alongside the track. Therefore, a railway line is controlled by relief. Railway lines find river gaps and passes and maintain a level course by cutting bridges, via ducts and embankments.

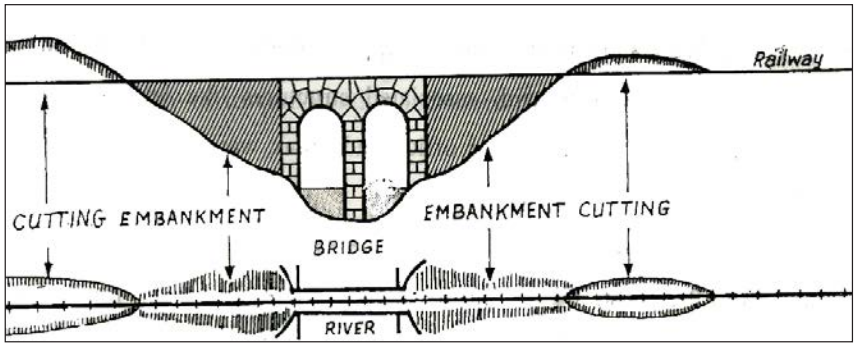


Figure 2.50: **A railway with a bridge, cutting and embankments**

d ***Cart tracks:*** most of the cart tracks shown on topographic map are, at least in the dry season, used by four-wheel drive vehicles.

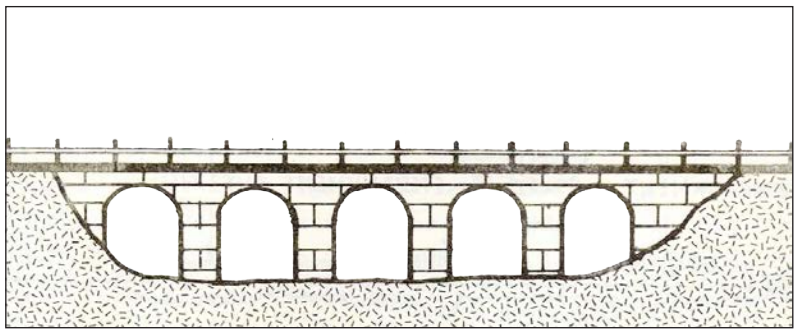


Figure 2.51: **A via duct: The road bridge across low lying dry land**

e ***Waterways (Navigation):*** waterways are divided into two major groups:

- ⇨ *Inland waterways.*
- ⇨ *Sea routes.*

The inland waterways include navigable rivers, canals and coastal shipping routes. They can be identified on maps by the presence of sea ports in association with structures like jetties, lighthouses, harbor offices and break waters. Rivers are also important to convey goods and passengers from the coast to the inland. The location of ports near a river mouth and the occurrence of locks following paths, piers for unloading, straightened courses, and dense building along the bank of the river show that the river is navigable.

Canals are easily recognized on a map. They are depicted on topo maps as long straight sections along the contours, moving from one level to another with the help of locks.

f ***Other means of communication:*** These include communications, radio/ TV stations and microwave and tower stations which are shown by their own symbols and names.

Factors Affecting the Development of Transport Network

What are the factors that affect the development of transport net work?

The major factor that affects the development of a transport network is the need for transport. Transport facilities are prime necessity for two purposes:

- ⇨ *to serve economic activities*
- ⇨ *to make strategic control of a country possible.*

These purposes can be coordinated when the transport network of a given country is planned. Economic development is unthinkable without the development of transport networks.

It is obvious that roads and railways can be constructed in any place where they are needed. However, the actual course followed and the pattern of the resulting network is influenced by the natural environment through which the roads and railways have to pass. The two important elements to be considered by road planners are relief and natural water courses.

i **Relief:** One of the major obstacles for transport development is relief (terrain). Due to these large changes in altitude, roads make use of serpentine bends and tunnels or they pass around the mountains or over them.

ii **Water shed road route:** sometimes road routes follow watersheds just to avoid crossing numerous rivers which require expensive bridges. For example the Addis Ababa-Mekele road via Dessie follows the watershed between the Abbay Basin on one side and the Awash Basin draining towards Djibouti.

iii **River valley roads route:** river valleys are preferred under certain conditions. Usually the gradients of river valleys have been smoothed by erosive action of rivers. This makes road construction easier and less costly.

iv ***Water bodies:*** These are another hurdle to road and rail construction. Rivers can be crossed either by bridges or ferries. Swamps and marshy areas are negotiated by road and rail engineers. If there is no choice, they are crossed by viaducts or long continuous embankments.

g ***Air Transport***

What advantage does air transport have over the others?

Air transport is a recent mode of transport. This new form of transport has great advantages, because it is affected very little by different land forms or ground conditions. An airplane can cross mountains, dense forests and large oceans with the greatest ease and speed. It can reach the remotest, the farthest and the most inaccessible places on earth, provided a landing place is available. Air fields, due to their long runways and the undesirable associated noise and danger, are constructed a somewhat distant from densely populated and heavily built-up areas.

Airfields, where airplanes land and take off, are the only physical evidences of air transport in the landscape. These points are known as aerodromes, airports, landing strips or heliports, depending on the facilities existing at these points. Aerodromes and airports are points where single or several tarmac runways equipped with navigational aids exist. The Addis Ababa international air field layout is a good example and it is the largest in Ethiopia, followed by those in Dire Dawa, Mekele, Bahir Dar, Gondar and Axum.

The map on the preceding figure portrays a modern airport with the necessary equipment. The map shows the railway and the road connecting the airport with the land-transport network for taking passengers and goods from and to the airport.

2.3.3 Climbing Capacities of Vehicles

Do you remember what you have learnt about gradient in the previous lessons?

What is gradient? How do you explain gradient in relation to slope and altitude?

The surface of the earth is not uniform throughout. There are a number of ups and downs with slopes varying in degree. A particular surface landform may be concave, convex, uniform or irregular. But the slope, as opposed to the actual landform, will still be the same. Therefore, the slope is determined by the relationship between the end points of a line; the slope and the altitude between the two points. Ups and downs are expressed in terms of slope and gradient.

When there are big differences in local relief, roads usually climb or descend along the rivers. Railways are very much more affected by relief than roads because of their low hill-climbing capacity. This is because railways require much smaller gradients than roads, 2 percent is given as the maximum for railways. This means that when a railway and a road have to travel the same ascent, the railway uses a different and much longer route than the road.

Example:

Two points, 'A', located at the foot of the eastern escarpment in Ethiopia at an altitude of 500 m, and 'B' located at 2500 m are to be joined with a road and a railway

a what is the length of the road?

b what is the length of the railway?

Solution:

Using the formula for calculating gradients, we get:

$$\text{altitude difference} = \frac{2500 - 500}{1000} = 2 \text{ kilometers}$$

Maximum gradient for cars = 25%

Ground distance (unknown) = x

a the shortest possible distance for the road is:

$$25 = \frac{\text{Altitude differenece}}{x} \times 100$$

$$25 = \frac{2 \times 100}{x} = 8 \text{ km } (\textit{the length of the road})$$

b The shortest possible distance for the railway is:

$$2 = \frac{2 \times 100}{x} = 100 \text{ km } (\textit{the length of the railway})$$

The solution applied in road construction, the building of roads in serpentines, cannot be applied to railways.

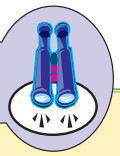
Railways avoid drastic changes in altitude for two reasons:

- ⇨ *requires high cost of construction*
- ⇨ *the daily operation costs are high*

Generally railways avoid large changes in altitude, which involves the construction of tunnels, embankments, cutting, etc.

The gradient of the slope is determined by the relationship between the vertical distance of two points and the horizontal distance between them.

Focus



Slope is a measure of the vertical difference in the altitude (elevation) of a surface at two different points.

As discussed in the previous lessons, railway lines and road transport networks are constructed in accordance with the maximum possible hill-climbing capacity of vehicles. This means the road should serve all vehicles ranging from four-wheel drive cars to ordinary bicycles. In doing so, we should not build them in a straight line up the slope. Instead a winding (bending) line or "serpentine" road.

This is done in order to reduce the steepness or gradient of the road. This reduction of gradient is necessary since different vehicles have different hill-climbing capacities. The following is a list of maximum gradients for different means of transport.

Table 2.3: **Maximum gradients for different means of transport**

Means of transport	Maximum Gradient
Train	2%
Ordinary cars	25%
4 wheel drive cars	30%
Man–walking up Without support of hands	45%
Bicycles	10%

One should bear in mind that their numbers stand for ordinary trains, cars or bicycles. When one buys a car or bicycle, he should be informed about the specific hill-climbing capacity by the vehicle's technical data.

The highest road gradient in Ethiopia is the Limalimo road, (which is 12 percent gradient) which stretches from R.Tekeze to Debark, where we find numerous detours to minimize the gradient of the slope.

Activity 2.12

For the following questions refer to the contour map below.

1 Construct a road network that joins
   - a town F with town A
   - b town E with town C
   - c town C with town F

2 Calculate the gradient in percent from town F to town A and from town E to town A. The altitude of A is 1500 m.
   - a Which gradient is the highest and requires high cost of construction?

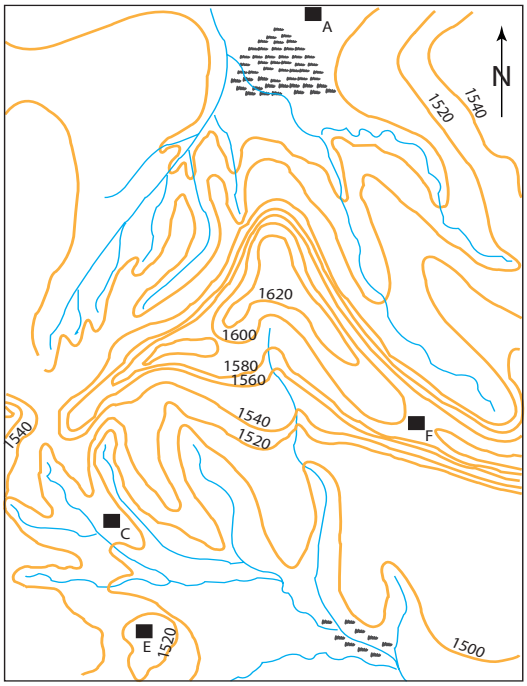


Figure 2.52: **Contour map of an area**

NOTE

When you construct a road network, the following points should be taken in to consideration.

- *Every meter of road costs a lot of money to build and therefore, all unnecessary bends in the road should be avoided.*
- *Avoid the construction of unnecessary bridges.*
- *If your road follows a river, bank with the least number of tributaries should be chosen. If a major river has to be crossed, the crossing should be done in the upper course of the river where the width of the river is as narrow as possible.*
- *Detours to avoid bridging should be reasonable.*
- *Avoid unnecessary changes in altitude.*
- *When it is necessary to overcome large differences in altitude, as is the case very often in Ethiopia, the road should be made to follow a river valley. This is for the reason that river valleys naturally have lower gradients. When you cross a mountain range, you should look for the lowest possible section of that ridge which can be a pass or a col.*
- *Avoid marshy ground. The construction of a road through marshy ground is very expensive, difficult and sometimes impossible.*
- *Pass the road through existing towns and heavily crowded villages.*

2.4 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

At the end of this section, you will be able to:

- discuss what geographical information system means;
- explain turning points in the development of GIS;
- state the use of GIS;
- show appreciation for the uses of GIS.

Key Terms

- GIS
- Data
- GPS
- Remote sensing

2.4.1 What is Geographic Information System (GIS)?

Students may give different answers for this question. The main reason for this is that GIS can be understood by different people differently. For some, GIS is a branch of information technology, for others it is a computer-assisted mapping and cartographic application, and for others it is a set of spatial-data analytical tools.

At this level we would like to define GIS as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced data for solving complex spatial problems.

Before understanding how the system works it is important for you to understand data, information and systems.

Data are a collection of raw facts representing places, things, people, events and concepts in the form of numbers, text, figures, symbols and signals.

Information is data that have been transformed through processing such as structuring, formatting, conversion and modeling.

The word system can be used in different contexts. It can be used to describe physical entities or conceptual entities

Physical entities

- *Solar system*
- *Ecosystem*
- *Drainage system*
- *Immune system*

Conceptual entities

- *Political system*
- *Democratic system*
- *Computer system*
- *Economic system*

In this context, GIS is a physical entity designed to achieve the specific objective of collecting, storing, analyzing and presenting information in systematic ways

2.4.2 Turning Point on the development of GIS

- *The first GIS called the Canada Geographic Information System was built in the 1960s by the Canadian government to analyze data collected by the Canada Land Inventory.*
- *Similar systems were built by other governments and university laboratories following the developments in Canada.*
- *The increased accessibility of computers in the 1970s as a result of technological improvements and lower costs of computers heralded the beginning of wide application of GIS.*
- *In the 1980s GIS sales increased tremendously as governments and businesses found more uses of the systems. New GIS software began to be produced by a number of companies to program computer systems to increase their functions.*
- *By the early 1990s, about 100,000 GIS systems were in operation.*
- *By now, GIS has come to be one of the most important systems in making spatial analysis and many other geographic researches.*

Uses of GIS

Some of the applications of GIS are stated as follows:

- ***Urban planning:*** *This is concerned with the development of master plans. The first step in an urban GIS is the production of improved property descriptions. The high quality database is immediately useful for many purposes.*
- *GIS is used to monitor patterns of urban growth. This is done by overlaying urban area maps for two different times to produce a change map showing urban growth. Such information helps city planners for example, in planning schools.*
- *GIS data can also be used in neighborhood planning applications – for example, in a given city, it is possible to evaluate neighborhoods requesting funding to help increase owner occupancy of housing.*

Traffic Control

GIS is used to regulate and monitor traffic flows in streets and overcrowded highways. Information is provided into GIS from video monitors, vehicle detectors, etc. When there is traffic congestion, the information is used as background for decisions about changes in message signs, lane signals and other controls.

Emergency Management

GIS and GPS (Geographic Positioning System) techniques are used by emergency management personnel before, during and after natural or human-made disasters. Some of the natural hazards that cause human and material damage are earth tremors, floods, fires, hurricanes, tornados, etc. In order to take quick action, there must be background information about the accessibility of the disaster area, including its utilities, highways, population, terrain and other elements of the environment. This information is stored in a GIS system.

During an emergency, additional information is gathered and provided by GPS (Geographic Positioning System). In doing so, current maps of damage to roads, utilities and buildings can be produced. This information helps the emergency teams to plan alternate routes for emergency cars and other related tasks. The same information can be used after performing the emergency tasks. This includes the refinement of maps that are useful for assessing the number and degree of casualties and the value of damage.

GIS also plays an important role for recording, monitoring, and coordinating reconstruction and rehabilitation efforts. Eventually, such information can be collected earlier and combined with high-risk parameters. This information includes physical features like steep slopes, vegetation cover, types of building construction and material and building density.

This information is useful when transferring people from the disaster area and when generally reducing risks for the future.

Airport Noise Management

The degree of noise is mapped around airports using data concerning airport configurations accompanied by aircraft noise-generation monitoring. This information can be used to reduce noise impacts near the airports. This can be achieved by examining noise incidents and by planning future land use and airport designs to reduce exposure levels.

Education

GIS is used in schools of all levels. One junior high school, for example, carried out a project in which pupils formulated a regional GIS database. They handed over the results to show the school administration that the site of the newly constructed library building was vulnerable to being robbed. The quality of their report may have influenced the outcome of the project.

Scientific Research

GIS-conducted research can assess the quality of medicines that are imported from abroad to determine whether they fulfill international standards. The availability of this information will allow importers to map those countries that manufacture medicines below the international standard.

Social Programs

GIS methods are used to generate data on unemployment rate increases in relation to economic development in a given country. Such a study might be related to population growth rate.

Public Health

GIS has been used to identify health problems caused by lack of sanitary practices. Such application-generated maps show the relationship between income and level of education and the number of people that lack sanitary practices. Areas where many households were exposed to different diseases due to lack of sanitary practices have been given priority for free medical treatment.

Resource Management

Resource management problems prevail in many regions. In one coffee growing region, GIS was used to map, analyze and manage a complex weather condition. This weather condition, frost, affects the field and greatly affects the local economy.

Wildlife Management

GIS is also used in wildlife management applications – for instance, the identification of favorable Mountain Nyala habitats in the Bale mountains. The approach involved a study to find the territories of existing Mountain Nyala packs by radio tracking. Characteristics of these territories were analyzed in a GIS. The information gained was then used to search for similar habitats throughout the region. These potential habitats were analyzed to evaluate their potential for the introduction and protection of new Mountain Nyala packs.

Military Base Management

GIS is important for military purposes, especially to protect base residents. It is also used to protect plants and animal habitats when missiles and other weapons are tested. Regarding environmental problems, GIS provides information on facts such as wetlands, flood zones, archaeological sites, resort areas, etc.

GIS is also applicable to emergency cases such as chemical plumes, wildfires, etc. and for activities such as the selection of safe areas suitable for storage of explosives.

Agriculture

GIS is used in the agricultural sector. This application is known as *precision*

farming to increase agricultural production by reducing farm costs. The application depends on soil maps especially prepared by GIS technology.

The map is prepared based on aerial photographs and on soil samples taken in each field. The soil samples are analyzed, and a soil map of the farm is prepared in a GIS system. Decisions are passed based on the analyzed data, regarding the allocation of the appropriate fertilizer and herbicide for each soil type.

These requirements are mapped and put in another GIS file to be used in the field.

The attached computer compares the location of the tractor with the product application map and continuously adjusts the mix and application rate of the fertilizer/herbicide.

In previous times, fertilizers and herbicides were mixed and applied at an average rate over entire fields. This was an inappropriate application of fertilizer and herbicides.

Precision farming enables the farmer to apply fertilizer and herbicides proportionally with respect to the required amount. This method is applied at low cost and reduces all sorts of erosion.

In the Field of Tourism

GIS provides information about services and facilities of tourist sites.

Activity 2.13

Answer the following questions and perform the following activities:

1. Explain how GIS is used to promote urban growth?
2. Discuss how GIS data are used in neighborhood planning.
3. How is GIS applied to monitor traffic flow in over crowded highways?
4. In what ways does GIS assist rescue members in times of natural or human-made disasters?
5. What are the methods used to control airport noise?
6. Why does GIS relate unemployment rate with population growth rate?

Unit Review

UNIT SUMMARY

- The height of the surface of the earth varies from place to place.
- Land features such as plains, hills, mountains, valleys, etc. which make the earth's surface uneven are known as relief features.
- The accurate method of representing relief on maps is by means of contour lines.
- A contour is an imaginary line drawn on a map. It joins all points having the same height above mean sea level.
- Contour lines are drawn from pre-measure points called spot heights. The construction of contour lines becomes possible once the spot heights are plotted on the map.
- The landforms shown on contour maps can also be made more clear and simple to understand by drawing cross-sections, profiles and block diagrams.
- In the process of terrain study and analysis from a contour map, you have to describe the various kinds of landforms, the nature of slopes, gradients and intervisibility of different places.
- Topographic maps also show drainage features and patterns such as river basins, catchment areas, watersheds and other land features that develop in different stages of streams.
- The types and distribution of human settlements and communication features are shown on topomaps by using conventional signs and symbols.
- You should keep in mind that the site of a settlement is not arbitrarily chosen. It has been chosen for a combination of several reasons.
- Relief, water supply, health, defence, communications, government policies, and economic resources are some of the facts that influence the choice of site of settlement.
- It is useful to learn to read and understand maps that show different communication features ranging from roads to airways.
- The science of GIS is very important. The system of GIS (Geographical Information System) needs flexibility.

  The system should include capabilities for manipulating, comparing, or combining the data in different ways.

REVIEW EXERCISE FOR UNIT 2

I *Write "True" if the statement is correct and "False" if the statement is not.*

1 The relief features of the earth have two dimensions.

2 The most accurate and modern method of showing relief on maps is by form lines.

3 We can see physically on the surface of the earth?

4 In one or a series of map sheets, the difference in altitude between two successive contour lines (V.I.) is always the same.

5 We can obtain mean sea level by measuring the level of the sea at all stages of the tides, seasonally.

II *Match column A with column B.*

	A		B
6	Centripetal drainage pattern	A	Main stream
7	Radial drainage pattern	B	Found in arid and rift Valley Lakes of Africa
8	Trellis drainage pattern	C	Develop in areas of homogeneous rock
9	Dendritic drainage pattern	D	Develop on a dome or conic cone
10	Consequent stream	E	Affected by folding and faulting

III *Chose the best answer*

11 A wide projection on a mountain side extending from the mountain towards the lowland is called:

A Valley
B U-shaped valley
C Spur
D Re–intrant

12 A very wide space between successive contours represents:

A Gentle slope
B Steep slope
C Convex slope
D Plain

13 We use a big vertical interval for areas with:

A Very plain relief
B Rugged terrain
C Mountain ridge
D Rough terrain

14 Two places are said to be intervisible:

A If there is higher relief between the two points
B If there is dense vegetation
C If there is no higher ground between the two points
D If there is high altitude between the two points

15 A cross-section of a given contour map is used:

A To examine whether two places are intervisible or not
B To visualize the types of land forms represented by a given contour map
C To visualize whether a given area is deforested or not
D A and B
E A and C

16 Contour lines intersect in the case of:

A Waterfall
B an undulating plain
C a concave slope
D a convex slope

IV *Fill in the blank space with the appropriate word or phrase*

17 The most accurate method of interpolation is _____.

18 A small V–shaped cut in a steep slope or the side of a hill which looks like a small short valley is _____.

19 A slope where the gradient changes several times from the top to the bottom of the slope is _____.

20 A type of slope which is indicated by widely-spaced contours at the lower levels and close together at the higher levels is known as _____.

21 The rate of change in altitude of a slope is called _____.

V *Give short answers for the following question and activities*

22 Explain the difference between rural settlement and urban settlement.

23 Define the term watershed.

24 What is GIS?

25 Write the three components of GIS.

26 In which stage do we get waterfalls in a river system?