Exercise 2  Topographic Map Basics

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Section ______

In this lab you will:

1) Explore the fundamental principles of topographic maps.
2) Examine the common coordinates systems used to determine one's location on Earth's surface.
3) Learn how to use contour lines to determine the shape and slope of the land surface.
4) Learn how to calculate the slope of the land surface and stream channels from elevation data and map distance.

Background Reading and Needed Supplies

Background material for this exercise is provided with this lab. Additional information regarding topographic maps can be found at the following U.S. Geological Survey sites:

http://egsc.usgs.gov/isb/pubs/booklets/symbols/
http://rockyweb.cr.usgs.gov/outreach/mapcatalog/

With respect to supplies, you will need the following for this lab exercise:

1) Calculator.
2) Ruler – preferably one that is graduated in tenth's of inches.
3) USGS Valley Head, GA – AL, 7.5 minute topographic map (digital copy is included with this exercise).

Map Representation of Topography

A topographic map is a graphical means of representing Earth’s three-dimensional surface (i.e., topography) in two dimensions, such as on a piece of paper or computer screen. In order to represent the vertical dimensional on a flat map, cartographers employ what are called contour lines, which connect points of equal elevation on the land surface. Contour lines are normally measured in feet or meters above sea level. For example, imagine you were to walk around the island shown in the topographic map in Figure 2.1a, but followed the trace of a single contour line. Because the line represents a specific height above sea level, we can see from the profile or cross-sectional view (Figure 2.1b) that you would neither gain nor lose elevation as you walked. It should be clear that contour lines can never cross, since this would imply that a point could simultaneously be at two different elevations, which is impossible.

Another important feature of a topographic map is its contour interval, which is simply the difference in elevation between adjacent contour lines. In figure 2.1 the contour interval is 20 feet. Based on this interval, we can determine that the top of the island must lie somewhere between 120 feet above sea level and the next contour line, which is the missing 140-foot line. A reasonable estimate then is that the top of the island is around 130 feet, as this is the midpoint of the interval.
Contour lines not only let us determine the elevation differences of the landscape, called **relief**, they also enable us to visualize the **shape** of the land as well as the steepness of its **slope**. The circular nature of the contour lines in Figure 2a tells us that the island has the shape of a symmetrical cone, similar to a volcano. Moreover, the fairly regular spacing between the contour lines indicates that the steepness of the slope is rather uniform. In contrast, the contour lines in the topographic map in Figure 2.2a indicate a more linear-shaped hill that is elongated in the north-south direction. The contour lines here are also spaced much closer together on the eastern side of the hill, which tells us that the slope is steeper there. Finally, note the creek in the northwestern part of Figure 2.2a that is represented by the dashed line. Because streams erode and cut downward, they produce ravines and valleys that naturally occupy the lowest parts of the terrain. Notice that when a contour line crosses a stream, it bends or “V’s” in the uphill direction due to the fact the stream is flowing downhill and lies in a topographic low.

The “rule of V’s” allows one to use contour lines to quickly determine the direction in which the land is rising or falling. Although the direction of slope can always be determined by checking the elevation labels on the contour lines themselves (every fifth line is labeled), using the V’s is much faster. Another quick way to visualize the slope of the terrain is to examine the drainage network shown in blue. For example, find the network of streams in Figure 2.3 that lie on both sides of the road leading to the city of Glennville (this is an actual topographic map produced by the U.S. Geological Survey). Because the stream channels occupy the lowest parts of the terrain, the area between the two drainageways must be a topographic high (i.e., a
hill). Notice also that the V’s in the contour lines on either side of this high all point toward the top of the hill. Therefore, the best way to visualize the terrain on a topographic map is to examine the blue color of the drainage system and V’s in the contour lines. Note in figure 2.3 that a drainage network often forms a tree-like pattern, where smaller tributaries converge in the downslope direction to form progressively larger streams.

Figure 2.3

Map Scale
Because topographic maps are scaled down representations of the actual terrain, the scale at which they are drawn is normally listed on the maps themselves. Maps created by the U.S. Geological Survey (USGS) include a type of scale called a representative fraction (RF). The RF is a unitless scale that is written as a proportion, such as 1:24,000. Here the smaller number represents the map distance, whereas the larger number represents the actual ground distance. A user can quickly determine the true ground distance between two points on a map by first measuring the distance with a ruler. This map distance is then multiplied by the map scale. Note that because a RF scale is unitless, the actual distance on the ground will be in the same units as those of the ruler. For example, a distance of one inch on a 1:24,000 map would be equal to 24,000 inches on the ground. Likewise, one centimeter on the same map would represent 24,000 centimeters on the ground. Because inches and centimeters are rather small units, the true ground distance is normally converted into more convenient units, such as miles or kilometers. For example, if the distance on a 1:24,000 map is 5.5 inches, then the actual ground distance in miles would be calculated as follows:
If the measurement is taken in metric units using centimeters, then the actual ground distance in kilometers would be:

\[
14 \text{cm} \times \frac{24,000}{1} \times \frac{1 \text{m}}{100 \text{cm}} \times \frac{1 \text{km}}{1000 \text{m}} = 3.36 \text{km}
\]

USGS topographic maps also include a set of graphical or bar scales, where the scales are graduated in either English or metric units. With a graphical scale, a user can make their own ruler by transferring the tick marks from the scale onto a piece of paper. This custom ruler can then be used to measure true ground distances directly from the map. Although this technique is not quite as accurate as using the representative scale (RF), only the graphical scale will remain valid should the map ever be enlarged or reduced (i.e., during enlargement or reduction only the graphical scale keeps its correct proportions). Finally, note in Figure 2.4 that topographic maps are produced at a variety of scales; the choice of which depends on the user. Should the user need detailed topographic information over a relatively small area, then a 1:24,000 scale map would be a good choice. On the other hand, a 1:250,000 scale map would be better for examining regional features that extend over a large area.

**Figure 2.4**

![Image showing different scales on topographic maps](image)

**Grid Systems and Location**

Another important feature on topographic maps is a set of coordinate systems for determining the map’s location on the globe. In general, a coordinate system consists of a grid, or network of perpendicular lines with uniform spacing. The boundaries of all USGS topographic maps, also called quadrangles, coincide with the grid lines of the latitude and longitude coordinate system, which is a base-60 system measured in degrees, minutes, and seconds. As illustrated in Figure 2.5, *latitude lines* run east-west, but are measured north or south of the equator. Conversely, *longitude lines* run north-south and are measured east or west of the reference line known as the Prime Meridian, which runs through Greenwich, England. Note that latitude lines go around the globe in a parallel manner, whereas longitude lines converge at both the North and South Poles. Because USGS map boundaries are based on this global system, latitude and longitude coordinates are listed at each of the four corners.
on a USGS map. Tick marks at 2½ minute (2'30") intervals are also placed along the map borders for reference (see the Valley Head map included with this exercise).

**Figure 2.5**

![Diagram of latitude and longitude lines](image)

Modern USGS topographic maps also include the metric-based global coordinate system known as the Universal Transverse Mercator (UTM). Maps with a UTM grid will either have individual tick marks spaced 1,000 meters apart along the margins of the map, or the grid itself will be superimposed over the map in the form of solid black lines (see the Valley Head map included with this exercise). In the United States, maps located west of the Mississippi River, as well as on some to the east, also use the American Public Land Survey System, better known as the **Township & Range System**. As illustrated in figure 2.6, the north-south trending grid lines produce columns referred to as **ranges**, and are referenced as being east or west of a **principle meridian**. The east-west grid line produce rows called **townships** that are referenced to a **base line**. Notice that each block, or township and range within the grid contains a set of 36, one mile by one mile square **sections**.

**Figure 2.6**

Ex 2 – Topographic Maps
Figure 2.6 also shows how an individual section (one square mile) can be broken down into quarter sections, each consisting of 40 acres. These quarter sections can themselves be subdivided into four parts, each representing one-sixteenth of a section, or 10 acres. Because the township and range grid is commonly superimposed on USGS maps, a given location can be referenced in terms of a specific one-sixteenth (quarter quarter) section. For example, the conventional way of writing the township and range location for point X in Figure 2.6 would be as follows:

\[
 SE \ ¼ \ of \ NW \ ¼ \ of \ Sec. \ 12, \ T1S, \ R9W
\]

It is important to remember that the boundaries of USGS topographic maps coincide with latitude and longitude lines, not township and range lines. This means that an individual map may straddle more than one township and range block, or block of 36 sections. What this means is that some of the sections from a township and range may lie on one map, and the remainder on one or more additional maps.

**Land Slope and Stream Gradient**

The term gradient simply refers to the change in one variable with respect to another variable. Examples include manufacturing production rates (cars per month), velocity (feet per second), and pay rate (dollars per hour). **Slope** is a type of gradient commonly used to refer to the rate at which the land elevation changes. We can think of slope as the steepness of the land surface, which can be defined as follows:

\[
 \text{slope} = \frac{\text{elevation difference}}{\text{horizontal distance}} = \frac{\text{rise}}{\text{run}}
\]

To calculate the slope between two points on a topographic map, one should use the contour lines to determine the elevation of the two points in question. Next, the true horizontal ground distance is determined by multiplying the map scale by the distance one measures between the two points using a ruler as described above. For example, suppose you find two points on a map that are separated by a distance of 3960 feet, and that one point lies at 920 feet above sea level and the other at 800. The slope would be calculated as follows:

\[
 \text{slope} = \frac{920 \text{ft} - 800 \text{ft}}{3960 \text{ft}} = \frac{120 \text{ft}}{3960 \text{ft}} = 0.030
\]

In this example the slope has no units because the vertical and horizontal measurements were in the same units (i.e., feet). This so-called unitless form of slope is referred to as **grade**, which is commonly multiplied by 100 and reported as **percent grade**. In our example the percent grade of the land surface would be 3.0%. Slope is perhaps more meaningful to most people when it is reported with units, such as feet per mile or meters per kilometer. In our example all we would need to do is convert our map distance into miles rather than leaving it in feet. Since 3960 feet converts to 0.75 miles, the slope would be calculated as:

\[
 \text{slope} = \frac{920 \text{ft} - 800 \text{ft}}{0.75 \text{mile}} = \frac{120 \text{ft}}{0.75 \text{mile}} = \frac{160 \text{ft}}{\text{mile}}
\]

With this form we can see that for every mile one would travel horizontally, you would either gain or lose 160 feet in elevation, depending on whether you were going up or down hill.

**Useful Conversions**

Ex 2 – Topographic Maps
When using maps it is often necessary to convert a measurement from one unit to another. The best way to do this is to write down the measurement that you need to convert, then write down the appropriate conversion factor in the form of fraction so that the units you start with are canceled out. For example, 3960 feet is converted into miles as follows:

\[
3960\text{ft} \times \frac{1\text{mi}}{5280\text{ft}} = 0.75\text{mi}
\]

In many cases, rather than memorizing a large number of obscure conversion factors, it is often best to write down a string of familiar conversion factors. Here all the units will cancel out except for the one you want. For example, to convert feet into kilometers, one could do the following:

\[
3960\text{ft} \times \frac{0.305\text{m}}{1\text{ft}} \times \frac{1\text{km}}{1000\text{m}} = 1.21\text{km}
\]

Below is a list of some conversion factors you will find helpful in doing this exercise.

**English**
- 1 foot (ft) = 12 inches (in)
- 1 mile (mi) = 5280 feet (ft)
- 1 acre = 43,560 square feet (ft\(^2\))

**Metric**
- 100 millimeters (mm) = 1 centimeter (cm)
- 100 centimeters (cm) = 1 meter (m)
- 1000 meters (m) = 1 kilometer (km)

**English-Metric**
- 1 inch (in) = 2.54 centimeters (cm)
- 1 foot (ft) = 0.305 meters (m)
- 1 mile (mi) = 1.61 kilometers (km)
- 1 gallon (gal) = 3.785 liters (l)
**Topographic Map Exercise**

1) What is the publication date of the USGS Valley Head topographic map (i.e., quadrangle) that is provided with this exercise?

2) The names of the adjacent quadrangles are printed along the boundaries of the Valley Head map. List the names of the other maps that lie off to:
   a) the east
   b) the NW corner

3a) What are the latitude and longitude coordinates of the NW corner of the Valley Head map?

   b) What are the latitude and longitude coordinates of the SW corner?

   c) What is the difference in latitude (in minutes and seconds) from the northern border to the southern border of the map?

   d) Determine the difference (in minutes and seconds) in longitude from the western border to the eastern border of the map.

4a) What is the representative fraction (i.e., scale) for this map?

   b) What is the contour interval?
5) What is the exact elevation of the hill at the following location: SW¼, NW¼, section 9, T5S, R10E?

6) Give the complete Township and Range coordinates of the radio tower in section 15 in the northern part of the map.

7) In which compass direction from the radio tower is the slope the steepest? Explain how you know.

8a) What is the approximate elevation of the radio tower in meters?

   b) Convert this elevation into feet.

9) Find the approximate elevation of the following two points and convert it into feet:

   a) Little River Church located SE of the radio tower – base your estimate on the black rectangle that represents the building.

   b) The stream labeled "East Fork Lookout Creek", which is located directly downslope from the radio tower. Determine the stream elevation near the letter "k" in the word "Lookout".

10a) Using a ruler and the map scale (1:24,000), determine the actual distance in miles between the points listed below. (If you are looking at the map on a computer screen, you'll need to determine the map scale for whatever magnification factor you are viewing it at. To determine this scale, simply take a ruler, and on the screen, measure the width of the nearest township and range section. Since sections are 1 mile wide, your map scale would be x inches = 1 mile).

   a) Radio tower and the church.

   b) Radio tower and East Fork Lookout Creek--again, use the letter "k" in the word "Lookout" as your reference point.
11a) In the space below, make a cross-sectional sketch of the land surface between East Fork Lookout Creek and the Little River Church.

b) In the subsurface view of your sketch, use a ruler to draw a vertical line up to the radio tower. Next, draw a horizontal line from the stream to this vertical line, then draw another horizontal line from the church. You should now see two right triangles, with the hypotenuse in each case being the slope of the land surface.

c) On your sketch, label the elevations (in feet) that you determined for the stream, radio tower, and church.

d) Add to your sketch the horizontal ground distances (in miles) between the radio tower and the church, and the radio tower and stream.

12a) Using your sketch as a guide, calculate the slope of the land surface in feet/mile between the radio tower and the church. Here you should first write out the equation, then plug in the appropriate numbers.

b) Now calculate the slope between the radio tower and the stream.

c) Write the slope values, including units, next to the corresponding slopes in your sketch. Does the steepness of the slopes in your sketch reflect the values you calculated?

13a) Convert the slope values you found in question 12 into the unitless form called grade.

b) Which form of slope do you find more meaningful, grade or feet per mile? Explain why.
14) Examine the way in which the contour lines cross the East Fork of Lookout Creek. Based on this, explain what compass direction this stream is flowing.

15) Find the river named "Middle Fork Little River" located in the eastern part of the map. Examine all the tributaries that make up the drainage network for this stream. Based on the pattern you see, explain what compass direction that the main (i.e., trunk) stream must be flowing.

16) Find the tributary labeled "Stillhouse Branch", located to the west of the main trunk of Middle Fork Little River. Suppose there is a big moonshine operation at the red label for section 25 (T5S, R10E), and the still explodes, sending a thousand gallons of moonshine into Stillhouse Branch.
   
a) Would it be possible for the contamination to reach Blalock Creek, located just to the NE? Explain why or why not.

   b) Could the contamination reach Lake Lahusage to the south? Explain why or why not.

17) Find the strip mine located in SE¼, section 1, T6S, R10E. When it rains, can contaminated runoff from this mine reach Anna Branch? Explain why or why not. Hint: draw a sketch of the land surface between Brush Creek and Anna Branch.

18a) In which direction does the West Fork of the Little River flow? (This is the large river in the middle of the map.) Explain how you know.
b) Find where the 450m and 500m contour lines cross the river. Determine the gradient of the river in feet/mile between these 2 points. Be sure to measure the actual **curved** distance of the stream, not the straight-line distance. *(If you are looking at the map on a computer screen, you'll need to determine the map scale for whatever magnification factor you are viewing it at. To determine this scale, simply take a ruler, and on the screen, measure the width of the nearest township and range section. Since sections are 1 mile wide, your map scale would be \( x \) inches = 1 mile).*

c) Find DeSoto Falls along this reach of the stream. How do you think the stream gradient here at the falls compares to average value you just calculated?

**Obtaining your own USGS topographic maps**

1) Go to the following URL: [http://topomaps.usgs.gov/](http://topomaps.usgs.gov/)

2) Select "Map Locator" from the main menu.

3) Type in a feature, city, or address in the search box.

4) Follow the directions and click on the desired red balloon.

5) The balloon may then give you a choice of different map scales. From here you can either order a paper copy or download a digital version (PDF format) for free.