

**Geog 525**  
**Lab 3**  
**GPS Mission Planning and Preparation**

**Total Marks: 32**

Due: January 28, 2011 at 9:00 a.m. PST

### **Introduction**

After the last two labs, I know that at least some of you will be glad to have some indoor work for a change! In this lab, we are going to plan a virtual GPS field mission to the VIU Woodlot, a place which you probably remember from the Geog 501 labs. Next lab, we are going to simulate the GPS field data collection using ArcPad, and will be using some of the results from this lab.

You have been assigned the task of performing a random sample of 10 locations within a study area in the VIU Woodlot. The study area is about 850 x 625m in size. Within this area, the locations must be randomly spaced, but must not be closer than 50 m to each other. The site is in the southern part of the woodlot, just south of a number of cut blocks that have been harvested in the past few years. Your job is to assess whether the trees in your study area are appropriate for harvesting. Given that this is just a rough assessment of the Study Area, and that the overall area is reasonably small, it would be good to have a horizontal accuracy of 2.5 m in the locations that were sampled.

### **Lab Setup**

Using Windows Explorer (i.e. My Computer), copy the V:\Geog\_525\_ONL\Lab\_3 directory to your X:\Geog\_525\ folder to create X:\Geog\_525\Lab\_3.

Start ArcMap 10, and load the following feature classes from GPS\_Mission.mdb in your X:\Geog\_525\Lab\_3\ directory:

- Woodlot\_Boundary
- Study\_Area
- roads
- lakes
- streams
- cutblocks
- DEM
- VIU\_Woodlot\_2

Choose Customize/Extensions... and ensure that the Spatial Analyst extension is checked.

### **Lab Submission**

Most of the questions in this lab can be answered directly in Moodle; for Questions 6 and 13, separate drop boxes have been set up.

### **Step 1: Assemble Existing Data and Plan Route**

We will begin by assembling data for our GPS mission. We are going some of the files that we just loaded to use these data to help us plan our mission, but first, we need to create some locations to sample within the study area.

We will use the Create Random Points tool to give us 10 random points within our study area. Choose Data Management Tools > Feature Class > Create Random Points. Place the output feature class in your GPS\_Mission.mdb geodatabase, and name it rndpts10. Constraining the output by the boundary of Study Area will ensure that the points are created only inside it. Set the number of points to 10, and the Minimum Allowed Distance should be 50.

**Create Random Points**

Output Location  
X:\Geog\_525\Lab\_3\GPS\_Mission.mdb

Output Point Feature Class  
rmdpts10

Constraining Feature Class (optional)  
Study\_Area

Constraining Extent (optional)

Top  
250.000000

Left  
0.000000

Right  
250.000000

Bottom  
0.000000

Clear

Number of Points [value or field] (optional)  
 Long  
10

Field

Minimum Allowed Distance [value or field] (optional)  
 Linear unit  
50 Meters

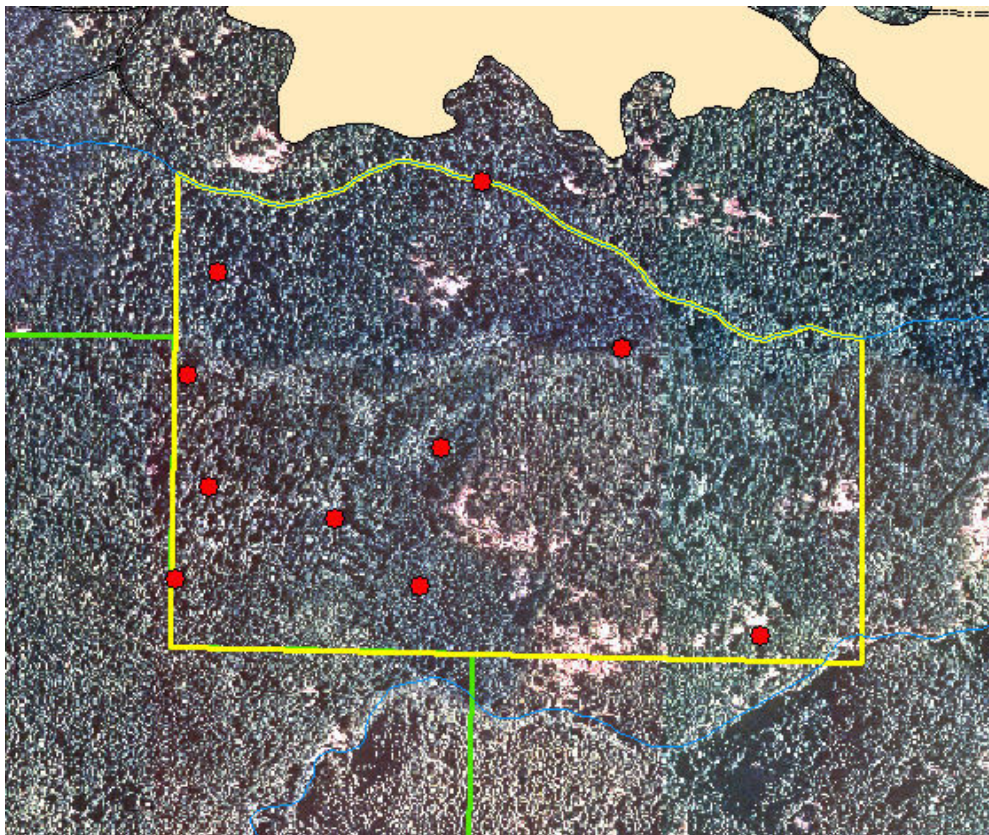
Field

Create Multipoint Output (optional)

Maximum Number of Points per Multipoint (optional)  
3

OK Cancel Environments... Show Help >>

**Note:** Create Random Points seems to be a little buggy and may fail to create all 10 points. Make sure that you count them before continuing. You may have to repeat the operation once or twice to get it to behave (<http://forums.esri.com/thread.asp?c=93&f=983&t=296837>). If it is misbehaving, you might be able to get it to work by creating the random points in a new ArcMap session (<http://forums.arcgis.com/threads/13374-create-random-points-in-arcmap-arcgis-10>) (Jan. 12, 2011)



We used 10 sample points in this example. Why not create 100 or 1000? In many cases, especially in field studies, the size of sample will partly depend on your timeframe and/or whether you are working alone or with a group. All these factors are usually taken into account and matched against the time and resources available. We have deliberately chosen a very small sample size for this exercise, so no realistic conclusions can be drawn from it. The larger the sample size the more likely it is to give a true picture of the population you are sampling, but do we have the resources to collect a large number of samples, and are we capable of processing all the data collected? We can also approach this problem the other way, and use statistics to calculate the minimum acceptable sample size is to obtain a desired confidence interval, given an estimate of the variance in the data set.

In this example, we are using a simple random sample. Random sampling provides a means by which we can be sure that no human bias is involved in the selection process. The disadvantage of the simple type of random sampling described is that if the sample size is small we might obtain an unrepresentative result (as is probably the case for our 10 points).

More sophisticated analysis tools, such as the Geospatial Modeling Environment (<http://spatialecology.com>) also offer the choice of setting up a stratified sample. Stratified random sampling is usually preferred; it can help to ensure that small minorities in the population are adequately represented.

There are many different types of sampling designs. If you wish to read more about this, take a look at <http://www.statcan.gc.ca/edu/power-pouvoir/ch13/prob/5214899-eng.htm> and <http://www.spatialecology.com/gme/gmecommands.htm>.

## **Step 2: Plan Access and Travel Within the Study Area**

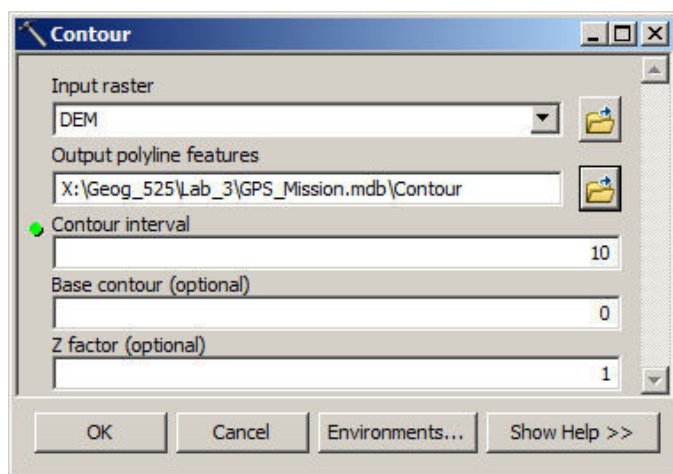
Now that we have our sample locations, we need to determine the best route to access the area. There are four possibilities for road access:

- Access Point 1: There is a road that runs about 200m north of the northern boundary, approaching to 100m of the

northwest corner of the study area. South of this area is an extensive regenerating cut block that may facilitate easy overland access.

- Access Point 2: This is another road is about 600m east of the area
- Access Point 3: About 1.1 km to the south-southeast of the study area
- Access Point 4: 1.3 km to the southwest of the study area.

Let's do some data processing to help us make a decision about which access point is best. First, let's contour the DEM, so that we can get a better idea about the high and low points. Select Spatial Analyst Tools > Surface > Contour and set DEM as your input raster, GPS\_Mission.mdb/Contour as your output, and set a contour interval of 10m.

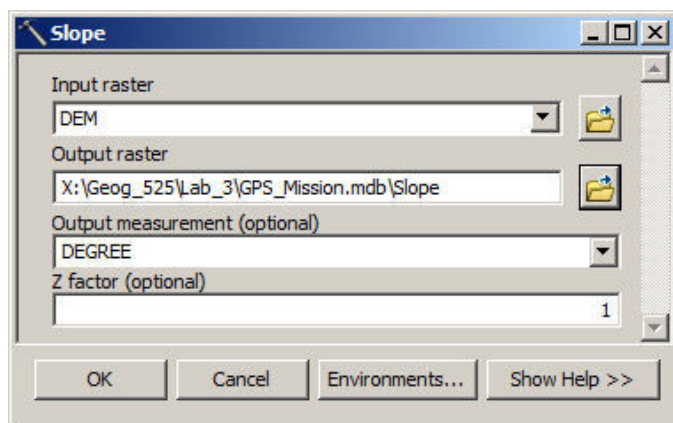


**Question 1:** According to the contours, about how much is the difference between the highest and lowest point in the Study Area? (1 mark)

**Question 2:** Do the contours show any areas of steep terrain within the study area? Where are these? (1 mark)

Contours are quite good for identifying high and low points, but a little more difficult to interpret slope from. The closer the contour lines, the steeper the slope is. However, it is sometimes easier to interpret colours than to measure line spacing with your eyes, and in areas of very steep terrain, some contour lines may not be drawn for reasons of cartographic presentation. Let's create a slope map to examine the steepness.

As with contours, select DEM as your input raster, and set your output raster to be GPS\_Mission.mdb/Slope. Leave the optional settings alone.



When you run this, a slope raster will be created. By default, this is displayed with red representing the steepest slopes and green representing the flattest slopes.

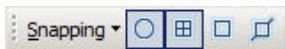


Now, based on the airphoto, the slope map, the streams, and the location of the roads, choose a route from one of the access points to the edge of the study area. It will be virtually impossible to safely climb down slopes that are more than about 20 degrees. If possible, you will want to avoid crossing streams, unless there is a bridge (i.e. where the roads cross streams). Although these streams are likely to be dry during the summer, unless you want to take a chance on having wet boots all day long you will want to think hard about crossing them. And finally, you will want to consider distance. It may take you less time to walk a long distance over easy terrain than to bushwhack through undulating terrain. Walking along ridges tends to be easier than going through canyons, since there tends to be less vegetation on top of ridges where there is relatively little water, than along streams where vegetation is denser. Also, walking across the slope (in the same direction as the contour lines) is much easier than walking up and down the slope (perpendicular to the contour lines).

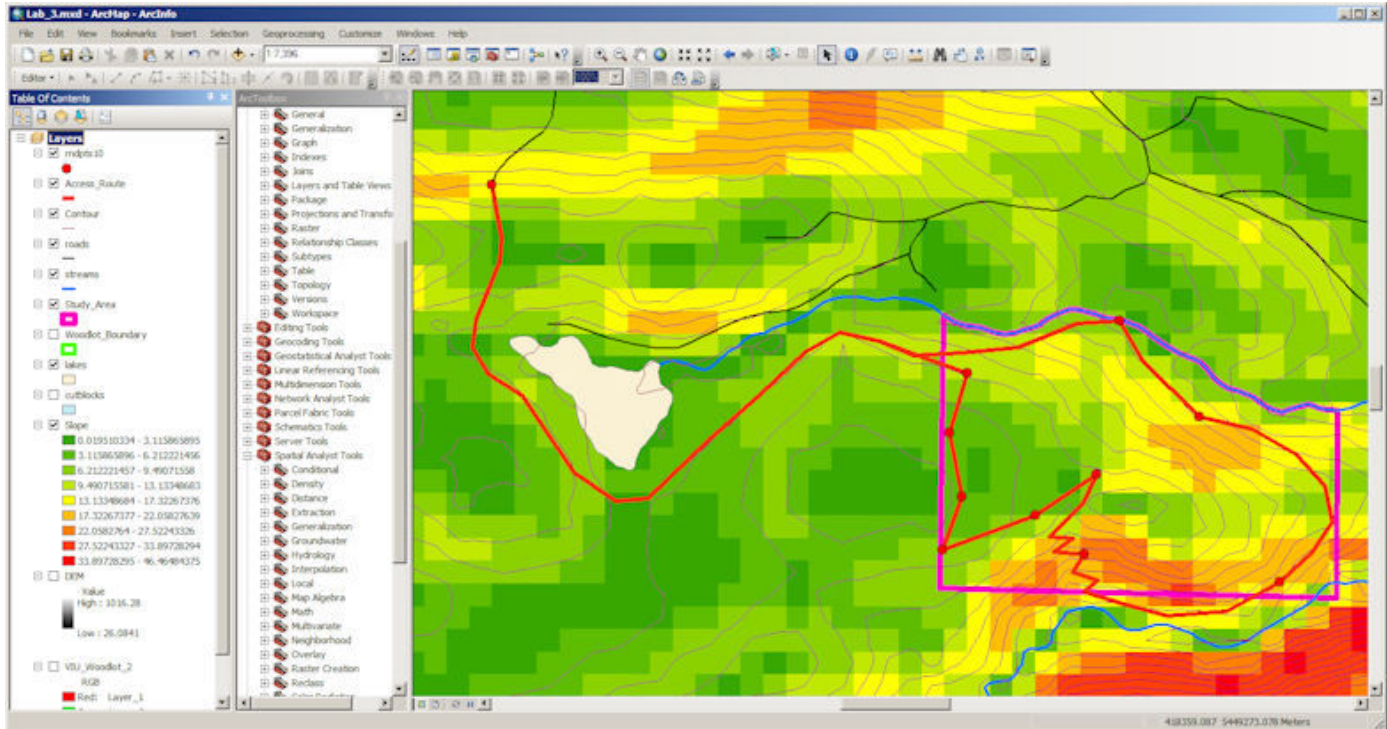
**Question 3: Which of the four access points did you choose? Why did you choose this point over the others? (2 marks)**

In the ArcMap Catalog pane, create a new line feature class in GPS\_Mission.mdb called Access\_Route. Do not include M or Z values. Import the coordinate system for this feature class from Contour, leave the XY Tolerance at its default value of 0.001 m, and stick with the default columns OBJECTID and SHAPE.

Start an editing session on this layer, and bring up the snapping toolbar, and set it to snap to points and ends.



Digitize a route that begins at your start point, and then proceeds to each of your 10 sample points in a logical, practical, and safe manner, and then returns to your start point. As with choosing your start point, you will have to consider the topographic factors when deciding on your route.



In the above example, I chose a starting point that was intentionally ridiculous, and proceeded around the lake to the Study Area. Because one of my sample points was on a steep section, I decided to do some switchbacks to get down the slope to the sample point, and then I continued down the slope to the creek. Where possible, I planned the route to go through natural clearings to make the going easier. Notice how I prefer walking a little extra distance to climbing up and down steep slopes. The route joins back up with itself just outside the Study Area boundary, and proceeds back to

the access point.

Save your edits when you are done and stop editing. Open the attribute table to determine the length of your route, in metres.

OBJECTID *	SHAPE *	SHAPE_Length
2	Polyline	6149.201359

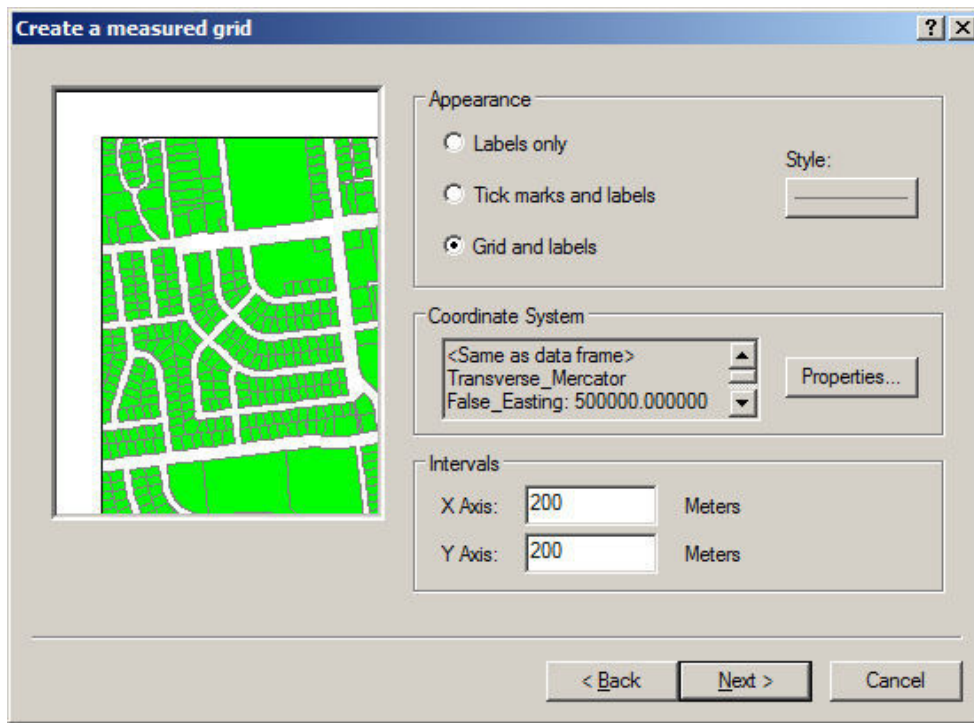
**Question 4:** How long was *your* route to access all of your points? (1 mark)

**Question 5:** Given that the average adult travels at 5.3 km/h on level terrain without obstacles (Aspelin, 2005), how long do you think it will take to hike the route? What features help or hinder you? (2 marks)

### **Step 3: Create a Working Map**

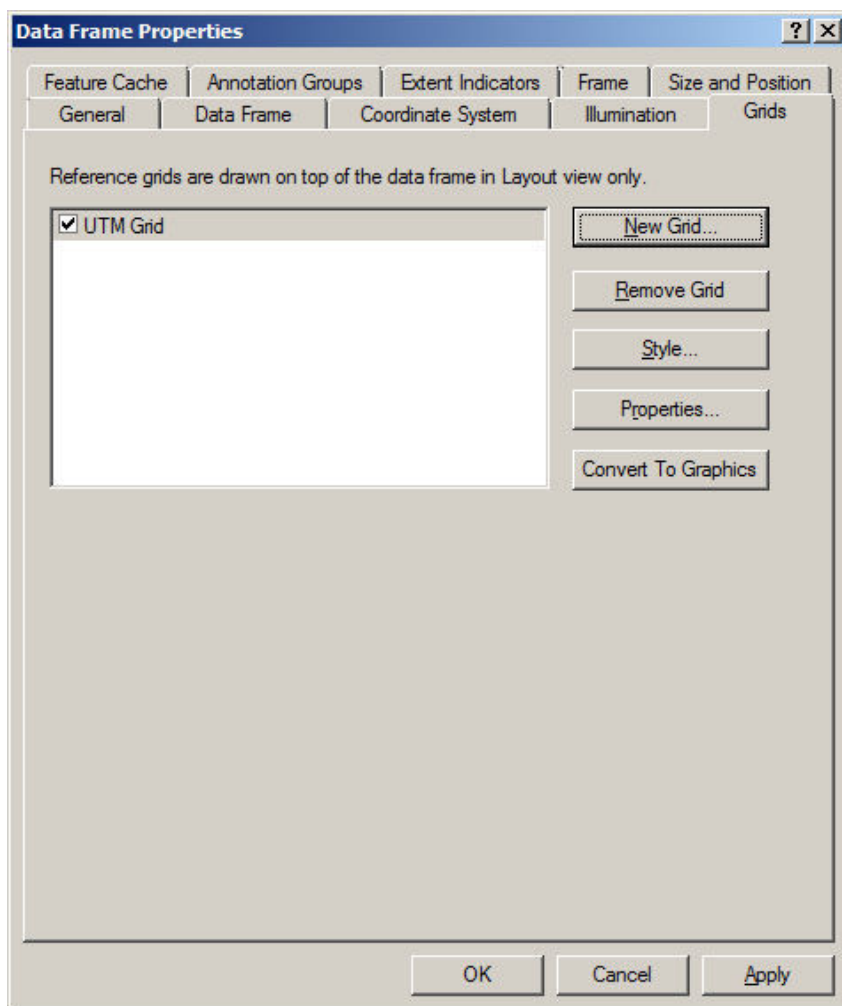
Your next job is to create a working map. When you are out in the field you will want to refer to your working map. Because we are working with the UTM Projected Coordinate System, we will want a grid on the map that displays UTM eastings and northings, so that we can match what we see on our GPS display (this will also be set to UTM, NAD 83) with locations on the map.

In Layout view, right click on the Layers heading at the top of the Table of Contents and choose Properties.... On the Grids tab, press the "New Grid..." button. Select a Measured Grid, and name it "UTM Grid." Click on Next >. Change the X and Y Axis Intervals to 200 m each on the next page. Notice that the coordinate system is defined as being the same as the data frame, which is UTM. Click on Next >.



Accept all the default values on the next page and click on Next >, then accept the default values on the final screen and click on Finish.

Your grid is complete. At any time, you can click on Properties to change your grid settings. Click on OK to continue.



Now that you have a graticule, create a well-designed working map (don't forget your map elements!) that shows the following:

- Your access point and the route to your 10 sample points
- The sample points
- The airphoto
- Contours
- Lakes and rivers
- Roads

Choose an appropriate size that shows sufficient detail, but is still manageable when you're in the field.

**Question 6: Submit a .PDF file of your completed map to the separate drop box in Moodle. (5 marks)**

#### **Step 4: Choose GPS Technologies**

Now that we have an idea of where we need to go and how to get there, it's time to choose a GPS technology that's appropriate for the type of data collection task that we have. In Module 3, Table 1 describes our choices for GPS technology based on our horizontal accuracy requirements. Here it is again for your reference:

Table 1. GPS data collection options, from least accurate to most accurate (Natural Resources Canada, 1993)

Method	GPS Measurements Required	Required Horizontal Accuracy (95% probability)	Control Requirements	Network Configuration



Single Point Positioning	Code	> 100 m	None	None
Code Differential	Code	2-100 m	> 1 3D point	Radial
Semi-kinematic	Code & Carrier	0.012-2 m	Variable, depending on procedures	Variable, depending on procedures
Rapid Static	Code & Carrier, Dual Frequency Preferable	0.012-2 m	Variable, depending on procedures	Variable, depending on procedures
Conventional Static	Code & Carrier, Dual Frequency for long baselines	< 0.015-2 m	3 or more 3D points	Closed geometrical figure

**Question 7: Given the horizontal accuracy requirements listed at the beginning of the assignment, what method of GPS data collection would be the least expensive, but still appropriate for the data collection required? (1 mark)**

Now that you have some idea of where you're going, how to get there, what route you'll take, and what sort of equipment you'll use, it's time to go out and have a look at your study area, if possible. This will help to refine your thinking about what's involved in your GPS field mission. Unfortunately, the airfare to reach the study area is prohibitive for a number of you, so we will skip this step.

### **Step 5: Determining Mission Timing**

By this stage, we have an excellent picture of the geographical factors that affect our study area. Now, we need to select an appropriate time in which to do the GPS mission. We can accomplish this using mission planning software.

Trimble makes its GPS mission planning software available free of charge, and we will use it in this lab. The software has been installed on Ruxton. To access it, choose Start > All Programs > Trimble Office > Utilities > Planning. This software is also available for you to install directly on your computer. Go to [http://www.trimble.com/planningsoftware\\_ts.asp](http://www.trimble.com/planningsoftware_ts.asp) to download the software.

For the mission planning software to work properly, it needs a current almanac file to figure out which GPS satellites are visible at a particular location, date, and time. There are two standard methods for obtaining a current almanac. You can download the current almanac from different websites or you can use the almanac from your GPS receiver. GPS receivers automatically download a new almanac every 15 minutes from the satellites, so if your receiver has been recently in use, you already have an almanac, dated for that particular period. Unfortunately, there is no easy way to download the almanac directly from the Garmin eTrex Vista receiver, so we will rely on an almanac that came from the Trimble website.

Open the almanac in Planning (📁) and load almanac.alm from X:\Geog\_525\Lab\_3\Trimble\. Please do not update the almanac file, since this will cause you to get different answers from other students for the questions below. If you are going to do "real" mission planning, you will want to download the latest version of the almanac in Trimble Planning file format from <http://www.trimble.com/gpsdataresources.shtml>.

Now, let's get the coordinates for the locations that we want to plan for. Since our study area is quite small, we only need to check our expected accuracy at a few points -- there will be very little difference other than as a result of topography. Load the following feature classes from GPS\_Mission.mdb in your X:\Geog\_525\Lab\_3\ directory:

- check\_signal\_top
- check\_signal\_bottom

Each of these represents a site where we will check GPS reception. Check\_signal\_top is near the centre of your study area, and check\_signal\_bottom is near the river in the southeast corner. These represent, approximately, the best and worst locations for GPS reception in the study area.

In Trimble Planning, check that GPS is the only constellation checked in the list of available Satellite Systems (

Satellite Systems:  GPS ). We will not be using other systems, such as GLONASS, Galileo, or Compass (Beidou), and the

WAAS satellites are generally always available to us, so we don't need to worry about those. Select the Station option (📍) and give your station an appropriate name.

Using the identify tool in ArcMap, click check\_signal\_top. Change the coordinates from UTM to Degrees Decimal Minutes, by clicking on the units button (📏) to the right of the Location box. Turn on the DEM layer, and click on the closest pixel to each site to determine its elevation.

Copy the latitude, longitude, and elevation values using the Identify window in ArcGIS, and copy these values into the into the station editor window. Name this station "Check Reception Top." Now, choose July 29, 2019 as the date for your fieldwork (No, 2019 is not a typo -- I know it's a long way off, but I don't want to have to recalculate the answers every year! This is also why we are all using the same outdated almanac). Go with the default values for a duration of 24 hours, starting at 00:00 local time, in 10 minute increments. Make sure that your time zone is set correctly, and that Daylight Savings Time is on. Click on Apply to save your changes.

**Station Editor**

Station Name:

Position

Latitude:   °  '

Longitude:   °  '

Height:  [m]

Elevation Cutoff:  °

Time

Start Date:  ..

Start Time:

Duration:  [h]

Interval:  [min]

Time Zone: (GMT-08:00) Pacific Time (US & Canada)

DST Difference UTC: -7.0 [h]

Buttons: OK, Cancel, Apply, Delete, Obstacles..., Map..., City..., Today, Time Zone...

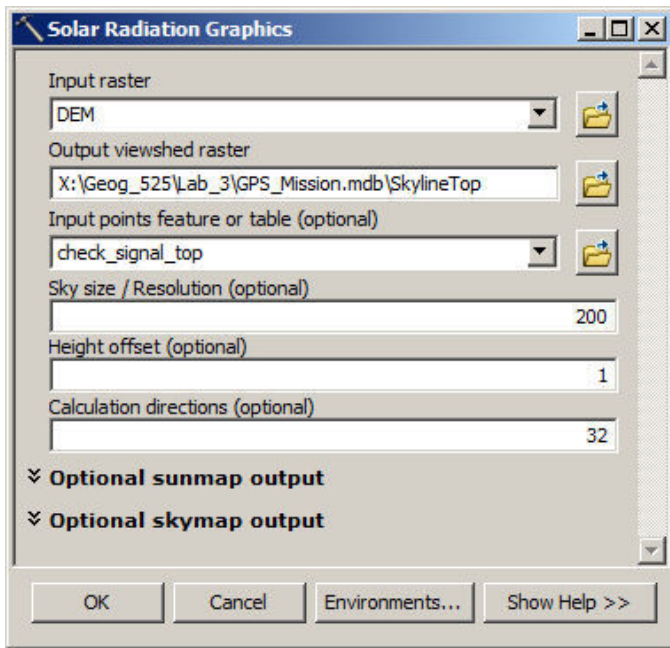
Repeat this process with check\_signal\_bottom. There is no "New" station button, so simply change the station name to "Check Reception Bot", update the latitude, longitude, and elevation values, and press OK. The new station will not overwrite the old one, as long as they are given different names, and you can verify this by clicking the pulldown arrow beside the station name.

Notice that in the above illustration, there is an Elevation Cutoff value of 10 degrees. This default value is used to take into consideration obstacles on the horizon that block GPS signals, such as buildings and trees. While this might make sense in relatively flat locations, it is probably better to include site-specific information in hilly or mountainous areas, such as the one in which we are working. We're going to switch to ArcMap for a few minutes, so click on Apply to save your changes.

Fortunately, ArcGIS has some built-in tools that allow you to determine what parts of the sky are obscured by topography. This does not take into account trees and buildings that may obscure the GPS satellites even more, but it does allow you to predict where reception will be seriously affected by topography.

To do this, choose Spatial Analyst Tools > Solar Radiation > Solar Radiation Graphics in ArcToolbox. Set the input raster to DEM, and set the output file to X:\Geog\_525\Lab\_3\GPS\_Mission.mdb\SkylineTop. Enter check\_signal\_top for the input points feature, and set the height offset to 1m. We will assume that you are using a hand-held receiver 1m above the

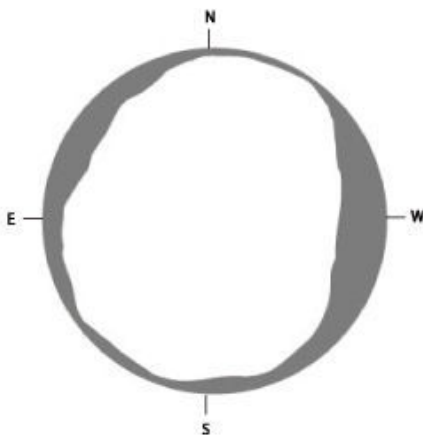
ground. Leave the rest of the settings at their default value, and click on OK.



What results is a raster that shows the view of the sky from check\_signal\_top.

Repeat the process, substituting check\_signal\_bottom for check\_signal\_top to create SkylineBottom.

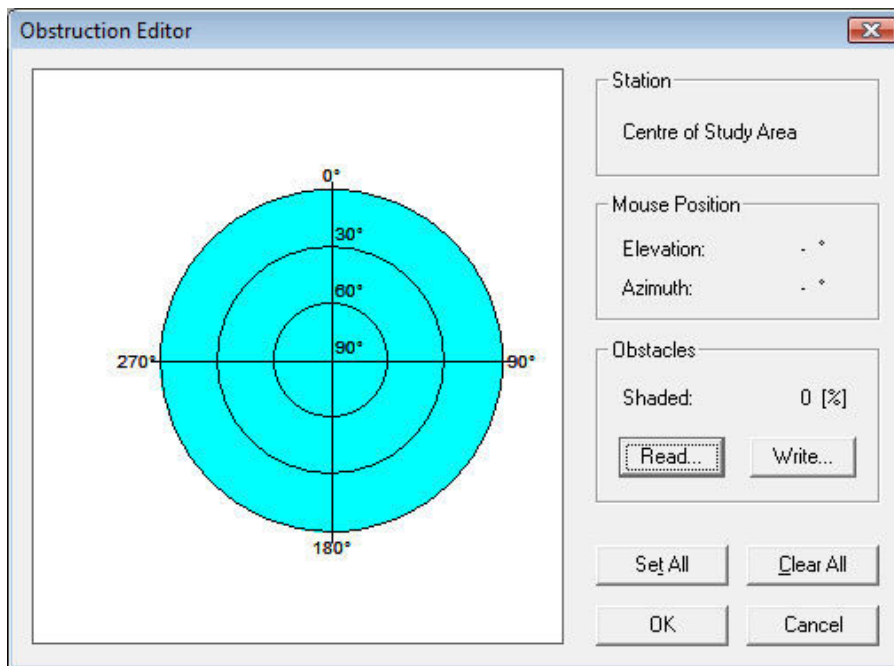
Since the resulting rasters are not georeferenced, you will need to right-click on check\_signal\_top in the Table of Contents, and choose "Zoom to Layer" to make them visible. What you get are rasters that show the view of the sky as if from a fish-eye lens looking straight up. North is at the top, so what we have is:



The area to the centre is visible, and the areas at the side which are a different colour are obscured. Right-click on SkylineTop and select Properties, then choose the Symbology tab, and set the classification system to Unique Values. The number of pixels that are visible and obscured are displayed. The pixels with a value of 1 are visible, those with a value of -1 are obscured, and those with a value of -3 are below the horizon (these can be ignored).

**Question 8:** Calculate the percentage of sky that is obscured for SkylineTop and SkylineBottom to the nearest 0.1. (2 marks)

Back in the Planning software go back to the "Check Reception Top" station, click on the Obstacles... button on the Station Editor window. This brings up the Obstruction Editor window.



By a rather amazing coincidence, the obstruction editor expects exactly what you have just generated in ArcMap with the Solar Radiation Graphics, but unfortunately, there is no direct way to transfer the data. For this reason, you will need to bring up SkylineTop in ArcGIS, and draw what you see in the Obstruction Editor. Note that the percentage of shaded area shown in the Obstruction Editor seems to yield different results from what you obtained in Question 9 (it must calculate things differently) -- just make sure that your drawing is approximately correct.

Using the mouse, draw your obstructions in the blue area on the Obstruction editor. This may take a few tries to get right -- the left mouse button fills in areas, the right mouse button erases areas, and the Clear All button is handy if you want to start over. Once you have duplicated what you see in ArcMap as best you can, click on OK. Even though we have technically overridden the elevation cutoff value, we will leave it in place. Click on OK again to save your station values.

Now you are ready to get some good predictions about how accurate your GPS is expected to be, way off in 2019. Click Number of Satellites (📶), Visibility (📶) and DOP (📶) options, and examine the plots that show satellite availability and DOPs. You may also wish to have a look at SkyPlot (📶) to view the graph showing the paths of the satellites, from the chosen location. Notice how the paths are only shown when they are not obstructed. Select Elevation (📶) to view the elevations of satellites over time. There are a number of other plots and configuration options available.

PDOP (Position Dilution of Precision) represents the precision obtainable from measurements taken during certain satellite geometries. A PDOP of 4 or less will provide good precision, while a PDOP of 5 to 7 is adequate, and a PDOP of 7 or more is poor. The PDOP graph will assist you in choosing particular time and date when field data collection will provide more accurate positional data based on lowest values of PDOP.

**Question 9: Examine the DOP graph and the list of DOP Values (Lists > DOP Values) for Check Reception Top. At what time do the highest GDOP values occur? How much is the Horizontal DOP at this time? (2 marks)**

**Question 10: Use Lists > Elevation/Azimuth to determine which satellites are in view at this time. What are their numbers? (1 mark)**

**Question 11: Why are a minimum of 4 satellite readings necessary to obtain an accurate 3D position using a GPS receiver? (2 marks)**

**Question 12: Suppose we have only 6 hours to do our field work on July 29, 2019. What is the best time to do the data collection? (1 mark)**

**Question 13: Upload a screen shot of the DOP graph that you used to answer Question 12 in a word processing document. (3 marks)**

Using the Planning software, identify which GPS satellites will be visible at the start time of your planned fieldwork. Generate a list of coordinates by selecting Lists > Elevation/Azimuth.

**Question 14:** Record the satellite constellation parameters at the start time for your planned field work in the table below. Record the satellite number, elevation and azimuth values for the all or the first 7 satellites in your list (whichever is less). (3 marks)

Satellite PRN (Gxx number)	Elevation	Azimuth

**Question 15:** Now choose Lists > DOP Values in the Planning software. What are the PDOP, HDOP, and VDOP values at the start time for your planned field work? (3 marks)

Now, go back to the planning software, and change your station settings Check Reception Bot. The actual latitude and longitude will not change, since the points are so close together. Regenerate the list of DOP values (choose Lists > DOP values).

**Question 16:** Examine the GDOP and HDOP values for this site around the same time that you chose for Question 9. What is the immediate cause of the blank entries in the table? (1 mark)

**Question 17:** What causes the reception problems at Check Reception Bot at this time? (1 mark)

OK, GPS expert, you've now done your due diligence. It's time to start planning the logistics of your data collection expedition. You should be able to arrange for the use, rental, or purchase of equipment, accommodations and transportation and supplies. For this particular expedition, the logistics aren't too daunting, and you can probably get by with small truck, a water bottle, a cell phone, a survival kit, and a box of granola bars. Obviously, something more involved would take a little more planning.

Before quitting, don't forget to make a backup copy of this lab; you will be using the results of this lab as input for the next one

## References

- Aspelin, K. (2005). Draft Results: Establishing Pedestrian Walking Speeds. ([http://www.westernite.org/datacollectionfund/2005/psu\\_ped\\_summary.pdf](http://www.westernite.org/datacollectionfund/2005/psu_ped_summary.pdf) , Oct 4, 2009)
- Govorov, M. (2005). "Planning Vegetation Mapping Using GPS and GIS Technologies"