Spatial Analysis Exercise
Synopsis of Class 8, GIS in Water Resources, Fall 2012

Learning objectives

This class is an exercise on the use of ArcGIS for Spatial Analysis. By the end of this class you should be able to:

- Calculate slope from a grid digital elevation model
- Apply model builder geoprocessing capability to program a sequence of ArcGIS functions
- Use raster data and raster calculator functionality to calculate watershed attributes such as mean elevation, mean annual precipitation and runoff ratio
- Interpolate data values at points to create a spatial field to use in hydrologic calculations

Reading

- http://www.neng.usu.edu/cee/faculty/dtarb/giswr/2011/Slope.pdf. This is a "handout" prepared by Dr. Maidment covering some of the theory involved in the calculation or slope.

Synopsis

This class will step through the method and ArcGIS tools used to evaluate important watershed attributes commonly used in hydrologic modeling, namely slope, average elevation, and area average precipitation. Concepts important in grid based spatial analysis will be introduced through examples.

The exercise starts with hand calculations of slope for a digital elevation model (DEM) grid cell. This serves the purpose of ensuring that you understand what the computer is doing when it goes about slope calculations. An ASCII text file of this small test case is then constructed and read in to ArcGIS demonstrating how to get raw information into a form where it can be imported and analyzed using GIS. Once the test case data is imported into ArcGIS the built in Slope, Aspect and Flow Direction tools are used to evaluate slope. This serves to validate the hand calculations (and validate that you understand correctly how ArcGIS is calculating slope) as well as show how ArcGIS automates these calculations over multiple grid cells. Although only a small test case, this is important capability because in principal any grid data can be prepared for import and analysis in ArcGIS using this process.

Importing the raw data and calculating slope involved a few distinct steps. The ArcGIS model builder tool allows these steps to be automated in what is called geoprocessing. Model builder is very visual and allows you to construct a program using flow chart like graphics. The exercise uses Model Builder to automate the steps involved in importing a raw DEM into ArcGIS then calculating Slope and Aspect. This demonstrates how a tool can be developed that can repeat a process automatically for different data. Through this simple example and the richness of functionality in ArcGIS tools you get a glimpse of some of the power of geoprocessing where you are limited only by your imagination in the geospatial analysis that can be done.

The exercise then turns to the analysis of DEM data for the San Marcos watershed studied in Exercise 2. DEM data from the National Elevation Dataset is obtained in geographic coordinates. To work with it in hydrology it needs to be projected to a coordinate system appropriate for the study area. The tool for projecting this raster DEM into an Albers Equal Area Conic projection is demonstrated drawing upon the knowledge learned in the lecture on Geodesy, Map Projections and Coordinate Systems. The exercise then shows how to symbolize explore and generate contour and hillshade images helpful in visualizing this DEM.

In hydrology it is frequently necessary to obtain average properties of spatial fields over watersheds or subwatersheds. In this exercise we use subwatersheds draining to each of the eight USGS gauge monitoring points used in exercise 2. Here a subwatershed is defined as the the area draining directly to a monitoring point without passing first through another monitoring point. You will learn in exercise 4 how to derive the subwatersheds feature class used here. Average elevation for each subwatershed is computed using the zonal statistics function in ArcGIS demonstrating the derivation of summary information for subwatersheds from a spatial field. The results are then linked to the subwatershed attribute table using a database join. This is an important database concept whereby a key field in one table is matched with the key field in another table to associate the information across the two tables. Join functionality brings some of the power of relational databases into GIS and is an important concept to understand. The joined table is then exported as a single table into a file (in dbf format) that can be read by Excel for further analysis and tidying up of the results to present a table giving average elevation for each subwatershed.

The area average precipitation over subwatersheds is another quantity frequently required in hydrology. The source data is commonly precipitation measured at point rain gauges. One of the simplest approaches to this problem is Thiessen Polygons that associate the region nearest to each raingauge with the rainfall value at the gauge. This results in a rainfall field (value at each point in space) which can be averaged over subwatersheds. The Create Thiessen Polygons and Intersect Functions, together with Table Summarize are used here to calculate the area average precipitation for each subwatershed.

A drawback of the Thiessen Polygon method is that it effectively assumes the rainfall is constant over each polygon, a rather simplifying assumption. It is often better to estimate the rainfall surface using more advanced interpolation methods such as splines or Kriging. This exercise illustrates the Interpolation toolbox in ArcGIS that has this advanced functionality and demonstrates its use to provide refined estimates of area average precipitation for each subwatershed.

With area average precipitation in hand, and measured mean annual outflow it is now possible to calculate the runoff ratio. This is the fraction of precipitation that appears as runoff at the outlet. Runoff ratio is a useful concept in interpreting the hydrological water balance. This calculation requires working in consistent units so both precipitation and streamflow need to be converted to volume units per year (ft^3/yr). Then the precipitation on subwatersheds upstream of each monitoring point can be added up and the ratio Q/P calculated (where Q is volume of runoff and P is volume of precipitation). In this exercise the subwatersheds upstream of each monitoring point are identified visually. This is manageable for eight subwatersheds. For larger areas a more automated procedure based on stream network linkages between watersheds is required and will be the subject of exercises 4 and 5.

Upon completion of this exercise you will have seen and learned by doing how ArcGIS can be a useful tool for fairly sophisticated hydrologic analysis.