

Tufts GIS Tip Sheet

Working with Elevation Data

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The standard format for elevation data in GIS is a *digital elevation model* (DEM) in raster format. The ArcGIS 9.x extension, Spatial Analyst, has a number of tools for using DEMs, including surface tools (derive slope, aspect, contour lines, shaded relief, and viewsheds) and hydrological processing tools (derive flow direction, flow accumulation, watersheds, and drainage networks). The ArcGIS 9x extension 3D Analyst, has tools for examining elevation data in 3D and for creating more exact surface models called TINS (triangulated irregular networks) from contour lines and other data sources.

This tip sheet covers some basic information about working with elevation data. Use this sheet to prepare data and understand general processing – you will need to refer to the **ArcGIS Desktop Help** (Extensions – Spatial Analyst, 3D Analyst) for exact instructions on various functions.

Understanding x, y, and z units when using Spatial Analyst and 3D Analyst

Elevation data, including DEMs, have three coordinates for any given location – the x and y coordinates describe a position on the surface of the earth (horizontal position) and the z describes elevation. For surface and hydrologic functions to work correctly, the x, y, and z units should all be in the same unit, and that unit should be feet or meters. A number of DEM data sources are distributed in the GCS (geographic coordinate system) where they xy coordinates are latitude and longitude degrees. This is NOT GOOD for surface or hydrological modeling! You need to project this data to a projected coordinate system (e.g., State Plane, UTM) prior to using it.

Once the DEM data is projected so that the xy units are in feet or meters, you also need to check the unit of the z value for elevation. If the x, y and z units are in different units, which is often the case, you will get inaccurate results. The horizontal units are the same as the map (linear) units of the coordinate system of the data set. The metadata should also tell you what the z (vertical) units are, but sometimes the metadata does not tell you!

If your horizontal x-y units and z units are in different units (e.g., x,y are in meters and z units are in feet) you can use the **Z-factor option** in the surface analysis tools to do the correction. If your xy units are in meters and z units are in feet, the Z-factor would be 0.3048. This is the number you have to multiply feet by to convert to meters, and that is exactly what the Z-factor does. The **Z-factor** is the number of ground (horizontal) units in one elevation (vertical) unit. However, since it is easy to forget to use the Z-factor, it is a good idea to create a new grid with the elevation units matching the ground units. This can be done using the Raster Calculator – simply multiply the DEM by the z-factor (e.g.,

0.3048 in the example above) – the resulting calculation grid should look the same as the DEM but now have the elevation units in the correct unit.

See Remote-Control.Net's Conversion Table (<http://www.remote-control.net/convert/tables/general/>) for conversion formulas for every unit of measurement. If you look for feet => meters, you will see the conversion factor is .3048

Please note that by default grids created by the Raster Calculator, Surface functions, and many other Spatial Analyst functions are temporary! To save them permanently, right-click on the new data layer (e.g., calculation) and choose **Make Permanent**.

Data Sources for Digital Elevation Models

In the US, many states and cities will have DEM data available, and ideally this will be good, corrected data. This data may simply be derived from the USGS products, or may come from other data sources. Some cities have LIDAR data available which is very high resolution.

At the national level in the US, the USGS has created the following data sets:

- 1 arc second (1") = approximately 30 meter cell size (complete for the entire US)
- 1/3 arc second (1/3") = approximately 10 meter cell size (in progress, complete for some areas, continually updated as better data is produced)

For the world, the following DEMs are available:

- SRTM (Shuttle Radar Topography Mission) – available for most of the world at 90 meter cell size
- The USGS Hydrosheds program is in the process of deriving good hydrologic data from the SRTM data for most of the world – if these are available for your area, these should be the first choice for studies outside the US
- GTOPO – global DEM data set, 1km cell size – good for visualizing elevation for entire continents or large countries, not good for detailed regional studies

Please see the **Supplementary Material folder** for the **Data Sources – Elevation** link for links to all these data sets and notes about each

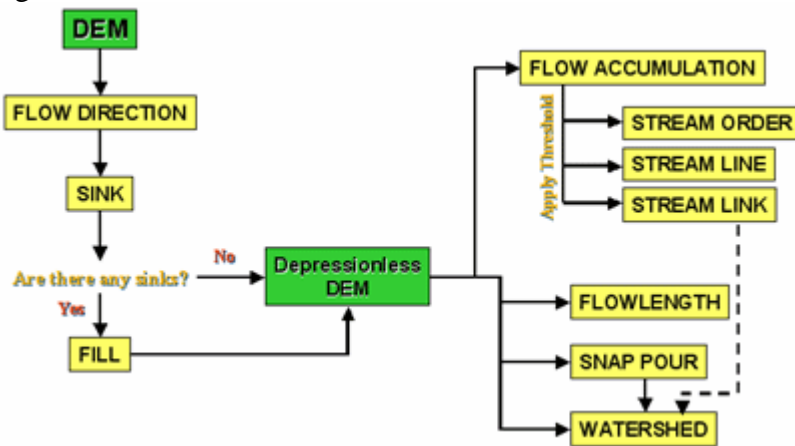
Surface Functions in ArcGIS Spatial Analyst

The surface functions in Spatial Analyst include deriving slope, aspect, contour lines, hillshade (shaded relief image), and viewsheds. Be sure that you have properly set the environment settings and have prepared your data so that the x,y, and z units are compatible (see above). Once you have done this, the surface functions are fairly easy to use if you follow the instructions in ArcGIS Desktop Help. For setting the environmental settings, see the GIS Spatial Analysis – Set Up Tip Sheet in the Tools folder

The surface tools can be found either under the *Spatial Analyst menu toolbar*, or under *ArcToolbox – Spatial Analyst Tools – Surface*.

Hydrologic Functions in ArcGIS Spatial Analyst

The hydrologic functions in Spatial Analyst are trickier to use, and you should have a good understanding of hydrologic principles before you do this. Also, deriving good accurate hydrologic data from DEMs is a complex process, and if possible you should use data that has been “hydrologically conditioned” by people who are expert in this. However, it is possible to create the following derived products using ArcGIS’s hydrologic tools in Spatial Analyst: flow direction, flow accumulation, stream delineation, drainage/watershed areas. These tools are found under *ArcToolbox – Spatial Analyst Tools – Hydrology*. Please read carefully through the ArcGIS Desktop Help for these functions (*Contents Tab - Extensions – Spatial Analyst – Analysis Concepts in Spatial Analyst – Hydrologic Analysis*). In particular, see the first three sections as background. The general process for using the hydrologic functions are laid out in this diagram:



Creating a 3-D TIN elevation model from a contour line file in ArcGIS 9

The following requires that the **3-D Analyst extension** be enabled in ArcGIS. For detailed instructions on the use of 3D Analyst, see **ArcGIS Desktop Help - Extensions - 3D Analyst**.

Before creating a TIN from contour lines, make sure you have clipped the contour lines to the smallest possible area. The TIN creation and analysis puts a huge strain on our computer processing capabilities and the smaller the area the better this will work.

Follow these steps to build a TIN (note that a TIN can be built just from contour lines, or from multiple sources, like contour lines, spot heights, and stream lines):

1. Before you begin, explore the data you will be using - this can include contour lines and spot height points (it could also include things like streams to be used as break lines and a boundary polygon to set the limits of the TIN). You will need to know what attribute field contains the elevation information. Make sure that all data sets have defined coordinate systems and that they are in the same coordinate

- system. Also, the elevation units should be the same units as the horizontal coordinate system units (e.g., both feet or both meters).
2. Add the elevation data to your data frame - in this example we assume you are using contour lines and spot height elevations
 3. Enable the **3D Analyst** extension and open its menu (**View - Toolbars**)
 4. Open the data table for contour lines and spot heights and sort the Elevation field (or other field containing the elevation information).
 5. Inspect the data to find "outliers" (i.e., data that is too low [typically 0], too high, or blank.) If necessary, exclude improper data by using the Query tool to select all the incorrect records, start editing the layer, and delete these records. Save edited layer and stop editing.
 6. From the 3D Analyst menu, choose **3D Analyst - Create/Modify TIN - Create TIN from Features**. The TIN function will show whatever layers are available for making the TIN.
 7. In the *Create New TIN* dialog, click on the contour line theme and set the **Height Source** to be the attribute field containing the elevation information (for Austin contourlines, this is *elevation*), set *Triangulate As* from *to Mass Points*, and leave the TagValue field set to <none>. If you are also using a boundary polygon, then also click on this theme and specify this will be used as a *soft clip polygon* with no height information. If you are using the spot heights, click on this theme, choose *Triangulate as Mass Points*, and specify height source as the *elevation* value field. If you are using a stream layer, these typically have no elevation value so set that to none, and triangulate as a hard break line (streams always mark a break in slope).
 8. Specify an appropriate folder location and filename.
 9. Click OK.

The TIN creation process will take a while.

To create a slope grid from the TIN, from the 3D Analyst menu, choose **3D Analyst - Surface Analysis - Slope** (*warning: this assumes that your elevation and horizontal units are in the same unit, e.g., both feet. If they are not, use the Z factor to convert height units to the horizontal units.*)

To create a aspect grid from the TIN, make the TIN-theme active, choose **3D Analyst - Surface Analysis - Aspect**

You can display the TIN as 3D in ArcScene or ArcGlobe. You can also drape other layers over the TIN in those programs.

There are many other features you can use, but these are the basics. Good luck!