What You Will Need

- ArcGIS 8.2 or higher (ArcView, ArcEditor, or ArcInfo license)
- ArcGIS Spatial Analyst extension
- Sample data downloaded from *ArcUser Online*
- An unzipping program such as WinZip

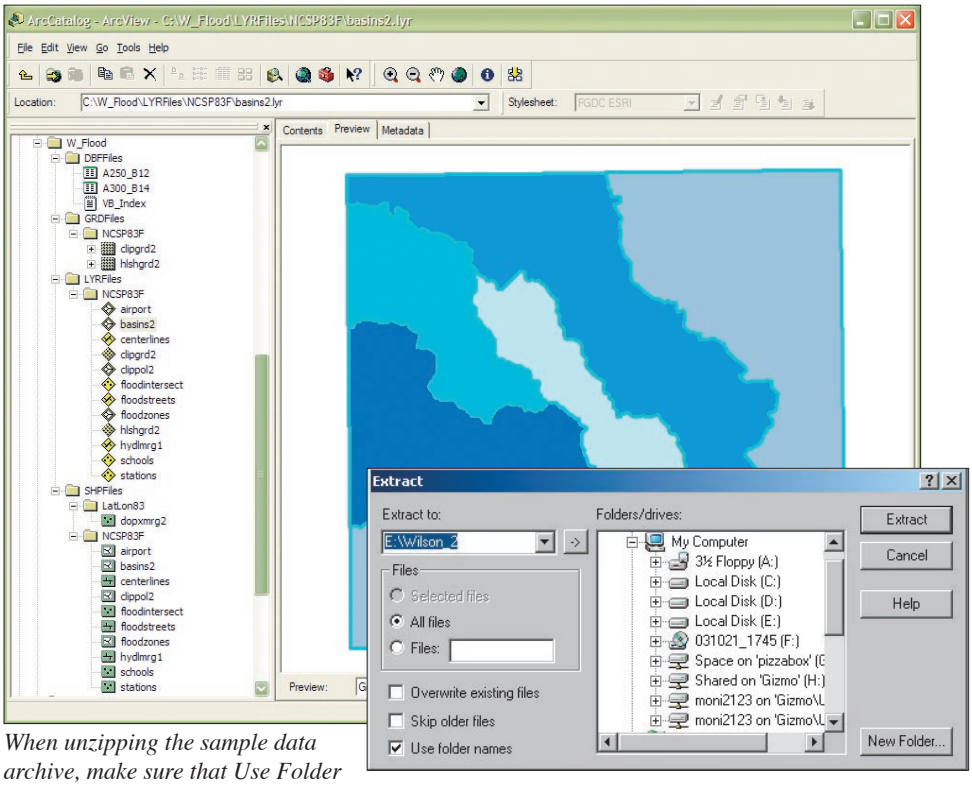
Modeling Doppler Radar in **ArcGIS**

By Mike Price, Entrada/San Juan, Inc.

In late August 2002, I attended the annual meeting of the International Association of Fire Chiefs in Kansas City, Missouri, accompanied by administrative staff from the Wilson, North Carolina, Fire Department. The Wilson Fire Department is a leader in the implementation and use of GIS for public safety and emergency management. Near the end of the conference, Wilson Fire Chief Don Oliver received an emergency call from one of his crew members back in North Carolina. "Chief, where would you like your desk?" When Oliver replied, "Why, right where it is!" he learned that his office was under two feet of water. That call led me to model the flooding of Hominy Swamp that submerged the downtown area of the city of Wilson.

The storm that inundated Wilson, North Carolina, and surrounding areas began in the early hours of August 26, 2002. A large upper-level, low-pressure system over the Southeast merged with a frontal boundary over the Carolinas to produce areas of locally heavy rainfall. The system moved slowly north, producing widespread showers and thunderstorms. Nine hours of regional data, obtained from ESRI business partner Meteorlogix LLC, for the period from 4:00 a.m. to 12:55 p.m. EDT (or 0900 Z to 1755 Z). *[Greenwich Mean Time (GMT) time was also called Z time in reference to the letter identifying the time zone centered on the Greenwich Prime Meridian. Although time references in meteorological reports are now given in Universal Coordinated Time (UCT), rather than GMT, the Z designation has persisted for time citations meteorological reports.]*

Clive Reece, GIS products manager for Meteorlogix, and I spent a year acquiring, modeling, and analyzing data for this storm, and we now understand its dynamics and consequences. Using NEXRAD Doppler data from Meteorlogix, we re-created four hours of precipitation history for the region. During this analysis, we devised several ArcGIS data development and modeling procedures that can be applied to Doppler data from anywhere in the country as well as any other regularly arrayed repetitive trend data. *[The 158 NEXRAD (or Next Generation Weather Radar) radar systems deployed throughout the United States and at selected overseas locations gather information about dangerous weather conditions and allow meteorologists to warn populations endangered by weather events.]*



When unzipping the sample data archive, make sure that Use Folder Names is checked. The archive should generate four subdirectories—DBFFiles, GRDFiles, LYRFiles, and SHPFiles—and place the data files in the appropriate subdirectories.

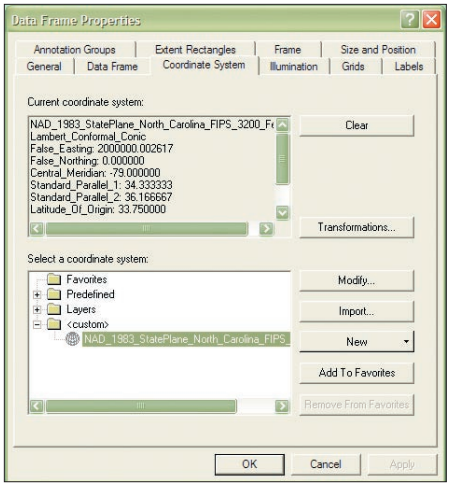
Clive and I presented a paper entitled *Deriving and Modeling Flood Dynamics From GIS-Based Doppler Radar* at the 2003 ESRI International User Conference. The exercise described in this article grew out of both the paper and our work analyzing the weather events of August 26, 2002. It presents several of these methods and applies them to four hours of NEXRAD data that was captured from the actual storm between 6:00 a.m. to 9:55 a.m. EDT, a period of intense rainfall. Raw data points arranged in a one-kilometer array and registered in North American Datum of 1983 (NAD83) coordinates will be used. The attributes for each point include fields for System Index, Type (i.e., of precipitation), DateTime, and dBZ value. *[Decibels of Z (dBZ) is a unit measurement that uses a logarithmic scale and indicates the intensity of the reflectivity (or Z) of radar echoes.]* The DateTime field is especially important because 48 five-minute Doppler sets were used to model Wilson precipitation.

This exercise was designed for use in the classroom, and it teaches the following ArcGIS procedures:

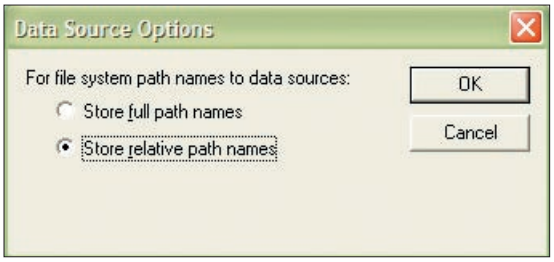
- Data acquisition and management
- Working with projected and geographic data
- Table editing
- Summarizing tabular fields
- Interpolating point data

Data for the Exercise

Some data included in the sample archive was preprocessed to save time for readers working this tutorial. Creating summary five-minute interval rainfall data for each point required merging the 48 point shapefiles. Several new fields were added to the attribute table to control data



Verify that the projection for the Data Frame is NAD_1983_ StatePlane_North_Carolina_FIPS_ 3200_Feet, the same projection as Clippol2.



Set the storage defaults to relative paths by choosing File > Map Properties and clicking the Store Relative Path Names radio button.

development. Processing this data required calculating longitude and latitude coordinates for the entire dataset and building a spatial index for each stacked point by truncating and concatenating the decimal *x* and *y* values for each point. (For information about performing these types of calculations, search the ArcGIS online help for "making field calculations" and select the topic entitled "Adding the *x,y* coordinates in a point layer to a new field." The instructions include sample Visual Basic code that can be used to populate the new fields.)

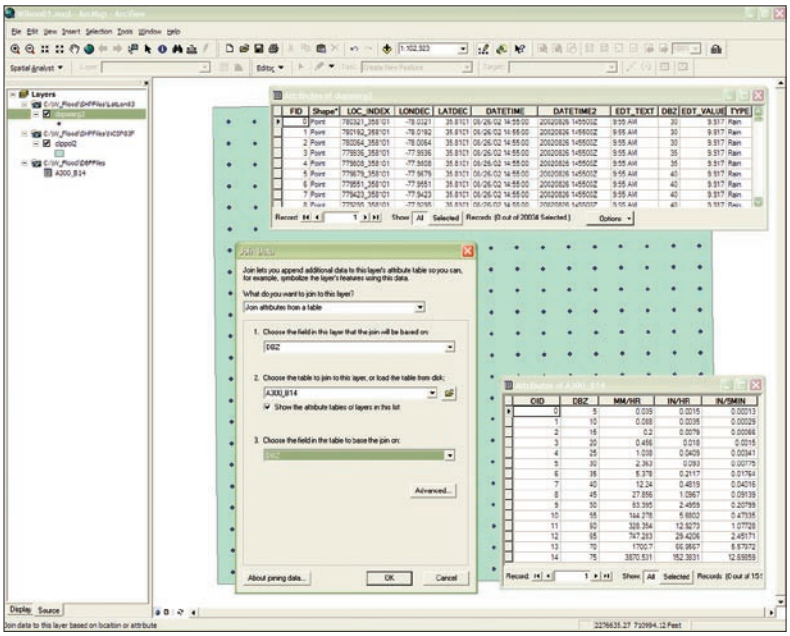
Finally, specific time fields, including local time as both an HH:MM:SS string and a 24-hour clock value, were added. All Doppler data development was performed in geographic NAD83 and the resulting merged shapefile, dopxmrg2, was included in the sample dataset. Creating a location-based index that is unique for each one-kilometer point location was a bit more difficult but very important. This location index will be used to perform a tabular summary of five-minute rainfall intervals. Daniel Elroi, prinicipal of ESRI business partner Elroi Consulting, created a Visual Basic script that generated this index. Equivalent rainfall in millimeters was calculated using the formula developed by National Oceanic and Atmospheric Administration (NOAA) Radar Operations Center staff that is shown in Figure 1. These calculations are stored in A300_B14.dbf, a table included with the sample data.

Rainfall (R, mm/hr) = (Z/A) ^ (1/B), where Z = 10 ^ (dBZ/10)

Figure 1: Equivalent rainfall in millimeters formula

Setting Up the Project

Begin by downloading the sample dataset from the *ArcUser Online* Web site at www.esri.com/arcuser.



Join A300_ B14.dbf to dopxmrg2 using the DBZ field.

1. Create a directory called W_Flood and unzip the sample data archive using WinZip. Make sure the box next to Use Folder Names is checked. The archive should generate four subdirectories—DBFFiles, GRDFiles, LYRFiles, and SHPFiles—and place the data files in the appropriate subdirectories.

2. Start an ArcMap session and open a new blank map. Add Clippol2 from the SHPFiles\ NCSP83F subdirectory.

3. Right-click on the Data Frame and choose Properties. Click on the Coordinate System tab and verify that the projection is NAD_1983_ StatePlane_North_Carolina_FIPS_3200_Feet, the same projection as Clippol2. ArcMap sets the Data Frame projection based on the projection of the first data layer added.

4. Choose Tools > Extensions and make sure the Spatial Analyst extension is loaded. Next, turn on the Editor and Spatial Analyst toolbars by choosing View > Toolbars.

5. Set the storage defaults to relative paths by choosing File > Map Properties and clicking the Store Relative Path Names radio button.

6. Add the dopxmrg2 shapefile (the merged, preprocessed Doppler point data) from \SHPFiles\LatLon83. Open the attribute table. Notice that there are 20,034 merged points and the dBZ values but no five-minute rainfall amounts. Save the project as W_Flood.

Summarizing Rainfall Data in Time and Space

In the dopxmrg2 table, study the EDT_Value field. Using Boolean selections, this numeric field can be used to create data reflecting time intervals smaller than four hours.

1. Add A300_B14.dbf, the table containing the equivalent rainfall in millimeters.

2. Join A300_B14.dbf to dopxmrg2 using the DBZ field. If necessary, consult the ArcGIS

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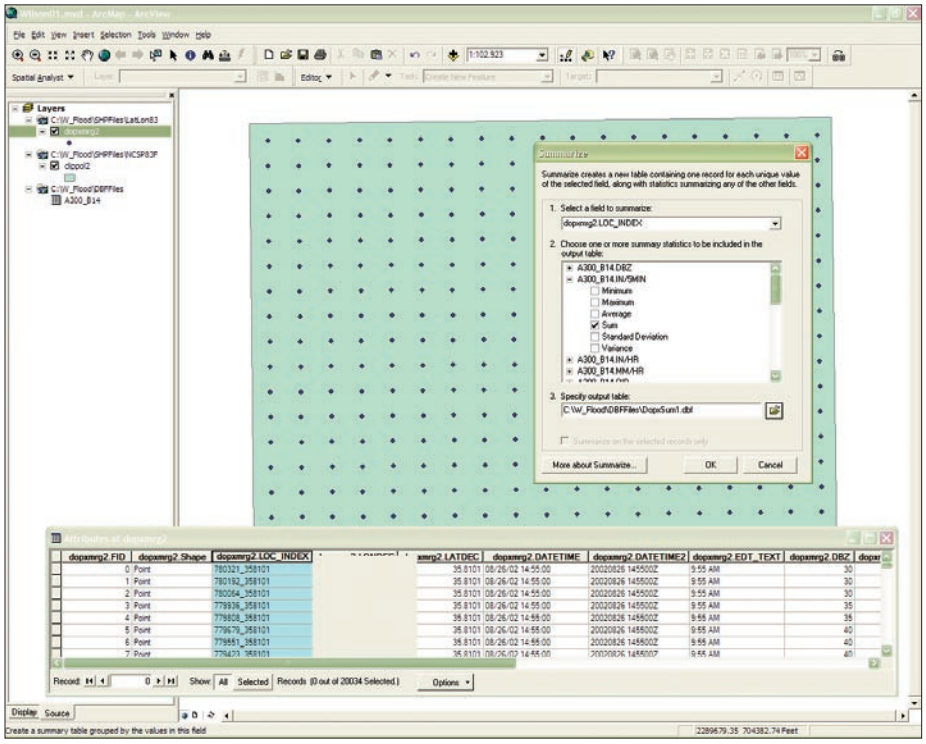
online help for information on joining tables.

3. Open the attribute table for dopxmrg2. It now contains five-minute equivalent rainfall, calculated in inches, that will be summarized over time.

4. Right-click on the dopxmrg2.LOC_INDEX field and select Summarize from the context menu. The Summarize dialog box lists all available fields alphabetically, including the joined fields. In the Summarize dialog box, expand A300_B14.In/5Min and check Sum. Expand dopxmrg2.LonDec and dopxmrg2.LatDec and check Average for both. Specify \DBFFiles\DopxSum1 as for the output table. Click OK.

5. Be patient while your computer calculates a sophisticated summary of several fields. When processing is finished, add the table to the map, open it, and explore the fields.



Summarize on the dopxmrg2.LOC_INDEX field using A300_B14.In/5Min, dopxmrg2.LonDec, and dopxmrg2.LatDec and specify \DBFFiles\DopxSum1 as for the output table.

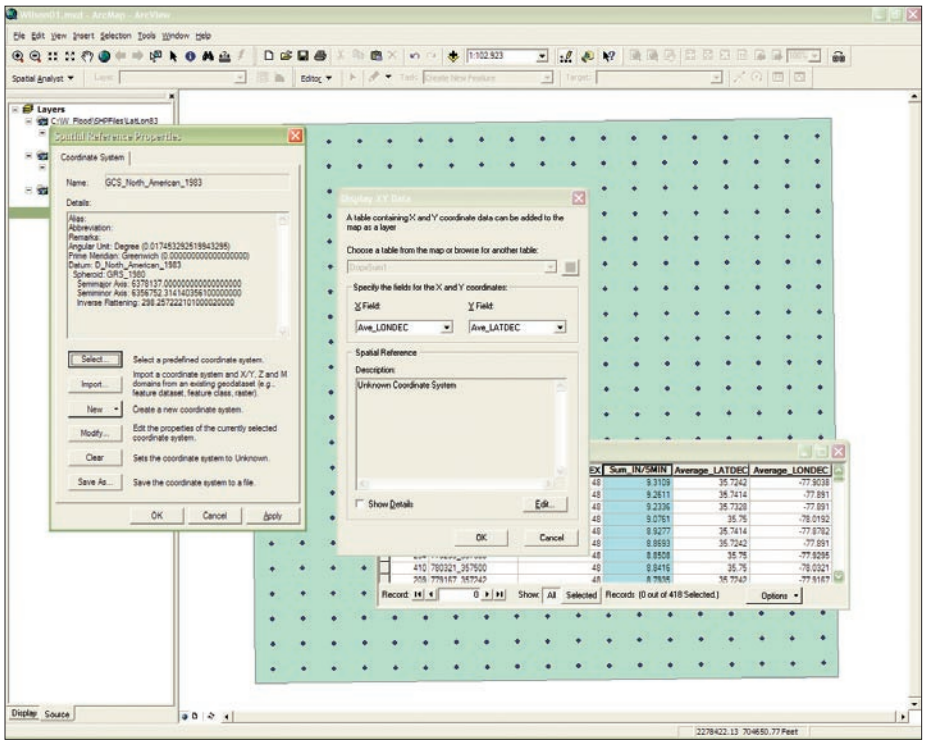
Displaying Summarized Doppler Data

In DopxSum1, sort the data using the Sum_IN/5MI field and notice that the rainfall varies from approximately 3.5 inches to more than 9.3 inches. That's more than two inches per hour in some areas! When summarizing this data, the averages for LonDec and LatDec were used because they will allow four-hour summary data to be added to the model. However data registration will need to be specified because the map will include data in geographic and State Plane coordinates.

1. In the Table of Contents, right-click on DopxSum1 and select Display XY Data from the context menu.

2. For X, specify Ave_LONDEC and for Y, specify Ave_LATDEC. Click on the Select button to set the spatial reference using a predefined coordinate system.

3. In the Spatial Reference dialog box, choose Predefined > Geographic Coordinate Systems > North American and select North American Datum of 1983 as the spatial reference. The DopxSum1 Events layer loads automatically into the map.



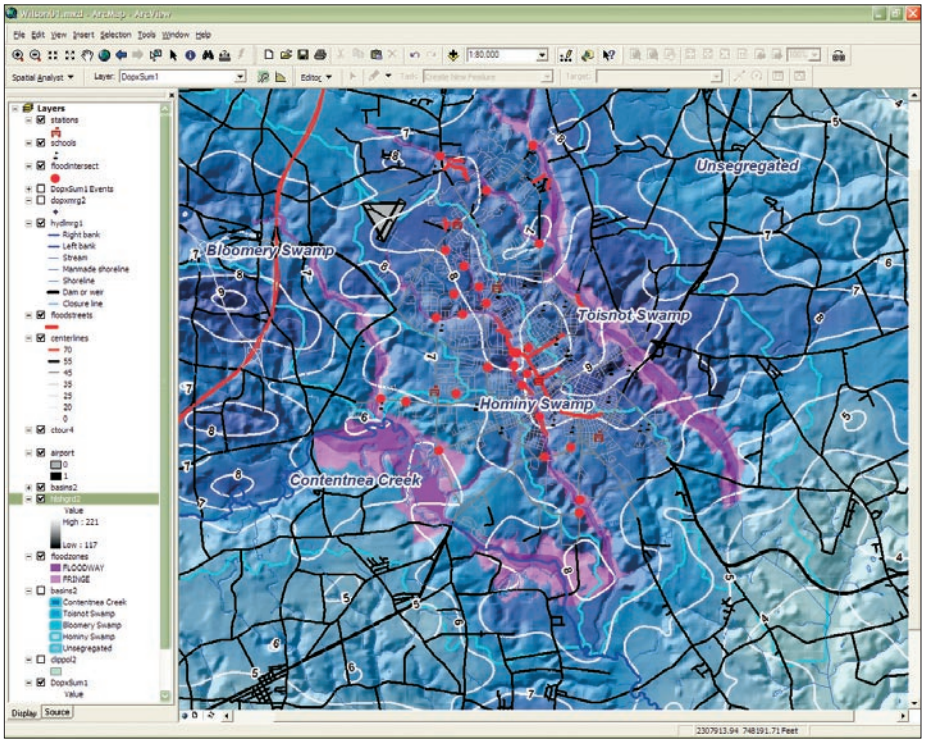
When setting the parameters for displaying the x,y *data, be sure to click on Selection in the Spatial Reference dialog box and choose Predefined > Geographic Coordinate Systems > North American and select North American Datum of 1983 as the spatial reference.*

Creating the Rainfall Raster

Now the ArcGIS Spatial Analyst extension can be used to grid this summarized rainfall data. Since precipitation is very continuous data, using a tension spline often works well. Kriging or Inverse Distance Weight (IDW) interpolation can also be applied.

1. In the ArcGIS Spatial Analyst toolbar, click on the drop-down menu and select Options. In the Options dialog box, set the working directory to \GRDFiles\NCSP83F. Set the analysis mask to \GRDFiles\NCSP83F\clipgrd2. Click the lower radio button to set the Analysis Coordinate System as the active frame.

2. Click on the Extent tab and set the extent to \GRDFiles\NCSP83F\clipgrd2. Click on



Add the infrastructure shapefiles and layer files to enhance the map and provide the basis for further analysis.

the Cell tab and set the cell size to \GRDFiles\NCSP83F\clipgrd2.

3. In the ArcGIS Spatial Analyst toolbar, choose Spatial Analyst > Interpolate to Raster > Spline and specify DopxSum1 Events as input points and Sm_In/5MI as the Z value. Change spline type to tension and leave defaults for weight, number of points, and output cell. Click OK.

4. After generating the spline, turn off the other layers and add hlshgrd2. Set transparency for this layer to 50 percent.

This summary dataset splines quite nicely. Not all data will behave this well. Sometimes the spline grid will interpolate negative values around the margin of a storm—an undesirable effect. If this occurs, it is necessary to reset the negative (and possibly null) values to zero.

Optional Activities

The model can be further enhanced by adding the shapefiles and layer files that are included in the sample dataset. The layers for roads, schools, fire stations, streams, identified floodplains, watersheds airports, hydrologic basins, street centerlines, streets, flooded intersections, flooded streets, historic flood zones, hydrography lines, schools, and fire stations provide context and the basis for further analysis of the flood events.

Use your cartographic license to rearrange and emphasize different datasets. Zoom in to the Hominy Swamp area and notice the relationship between high rainfall, hard surfaces (i.e., streets and airport), public buildings, and mapped flood channels.

Summary

We continue to expand and improve the methods developed for the Wilson, North Carolina, NEXRAD Doppler study. The techniques for gathering and modeling periodic Doppler-derived rainfall can be used in many natural resource-based industries including mining and earth science, watershed and ecosystem management, construction and civil engineering, and public safety.

Acknowledgments

The author thanks the staff of the Wilson, North Carolina, Fire Department for their heroic efforts in mitigating the impacts of the August 2002 flooding. Special thanks to Fire Chief Don Oliver and GIS specialist Will Aycock for their continued dedication to applying GIS and spatial technology to the protection of citizens from natural and man-made hazards. Thanks also to Clive Reece of Meteorlogix, and Daniel Elroi of Elroi Consulting for their assistance with the technical issues addressed in this exercise.

References

Price, Mike and Clive Reece. "Deriving and Modeling Flood Dynamics from GIS-Based Doppler Radar," *Technical Proceedings of the ESRI 2003 User Conference*. San Diego, California, July 2003.

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Exercise Summary

1. Create directory/unzip data.
2. Load Clippol2.
3. Check coordinate system.
4. Load extension and toolbars.
5. Store relative paths.
6. Load dopxmrg2.
7. Add A300_B14.dbf.
8. Join to dopxmrg2 on DBZ field.
9. Summarize on LOC_INDEX field.
10. Add DopxSum1 to map.
11. Choose Display XY Data.
12. Specify Ave_LONDEC as X and Ave_LATDEC as Y.
13. Select NAD83 as spatial reference.
14. Set working directory and analysis mask in Spatial Analyst.
15. Set Analysis Coordinate System as active frame.
16. Select Spatial Analyst > Interpolate to Raster > Spline.
17. Specify DopxSum1 Events as input points and Sm_In/5MI as Z value 18. Change spline type to tension and leave other defaults.
18. Create spline and turn off other layers.
19. Add hlshgrd2 and set transparency to 50 percent.
20. Make contour, add layer files, and rearrange layers.