Improved Applications with SAMB Derived 3 meter DTMs

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This report sums up the processes used to create several products from the Lorado 7 ½" quadrangle 3 meter elevation grid. This grid was created by Kevin Kuhn and was taken through the hydrologic enforcement process in the software Delta 3-D. This report is broken into two sections. The first section covers the creation of several hydrologic products using ESRI's ArcHydro tools. This section also includes a general preliminary assessment of the hydrologic enforcement. The second section covers the creation of several products using ERSI's 3-D analyst extension.

Hydrologic Analysis

Methodology

We utilized the ArcHydro toolset, version 1.1, in order to simulate several potential hydrologic end uses and products. ArcHydro provides a very specific set of steps, a few of which can be skipped, in order to create watershed boundaries. Through this process, several products are created, including a line type shapefile of streams derived from the digital terrain model (DTM). We completed the step by step process of creating watershed boundaries for three versions of the Lorado quadrangle DTM in order to compare the results. We used a version of the DTM that had received no hydrologic enforcement (1), a version on which the northern portion of the DTM was hydrologically enforced (2), and a version of the DTM that was enforced additionally using Arc Hydro (3).

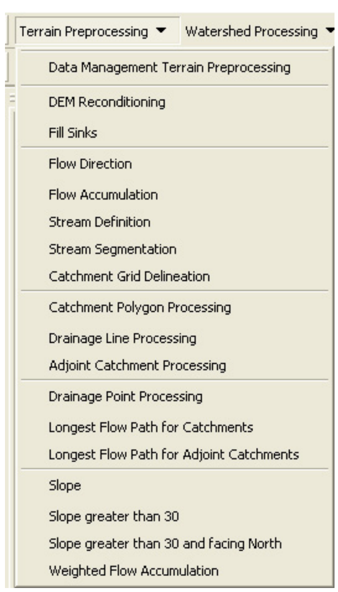

Figure 1. ArcHydro Terrain Preprocessing Menu

Figure 1 is of the terrain processing menu in ArcHydro. This menu contains processes which create several key pieces of data from the DTM for subsequent hydrologic analysis. The menu is set up so that the processes are listed in the order they should be run. With the exception of the third DTM, steps one and two, 'DTM Reconditioning' and 'Fill Sinks' were skipped. Briefly, for each surface, the following routines were performed:

1) Using the study DTM, a flow direction grid is calculated. This operation assigns one of 8 possible values to each grid cell. Each value corresponds to a flow direction and indicates where the steepest downhill slope is.
2) Using the flow direction grid as input, the flow accumulation operation creates a new grid in which each grid cell has a value describing how many cells 'flow' or can be traced to that grid cell. The higher the value, the more cells are connected to that cell.
3) The stream definition process extracts a stream network from the flow accumulation grid. It achieves this with a simple benchmark reclassification. Values greater than a user defined threshold are reclassified as streams and everything else is classified as "0." The next step, stream segmentation, produces a stream link grid. This grid defines unique stream segments with an identifier.
4) The catchment grid delineation step uses the previous three products, flow accumulation, stream raster and stream link raster to create catchments for all of the stream segments. A catchment is an area in which all water drains to one point. In this case, the "one point" is the point of intersection with another stream segment. The next process on the list, "Catchment polygon processing" simply converts this raster to a polygon shapefile. Likewise, "Drainage line processing" converts the stream raster into a line shapefile.
5) Adjoint catchment processing uses the catchment grid to determine, within the analysis extent, which catchments flow into one another. The resultant raster contains the largest independent catchments that exist within the analysis extent.

At this point in the analysis process, we utilized ArcHydro's point delineation tool to create a set of 12 points. These points were used as inputs in the "Batch Watershed Delineation" routine under the "Watershed Processing" menu. The same set of points was used to generate watersheds with each of the three sets of surfaces.

Discussion

Not surprisingly, different input surfaces resulted in very different watersheds. Figure 2 depicts all three watershed sets stacked on top of one another. In this figure, the green dots are the points used to delineate the watershed. The first watersheds, very small and in red, were created with DTM 1, which was not hydro enforced or preprocessed. As anticipated, this DTM resulted in very poor watershed delineation. A cursory examination of the stream definition grid makes it clear that stream segments are broken and hampered by sinks.

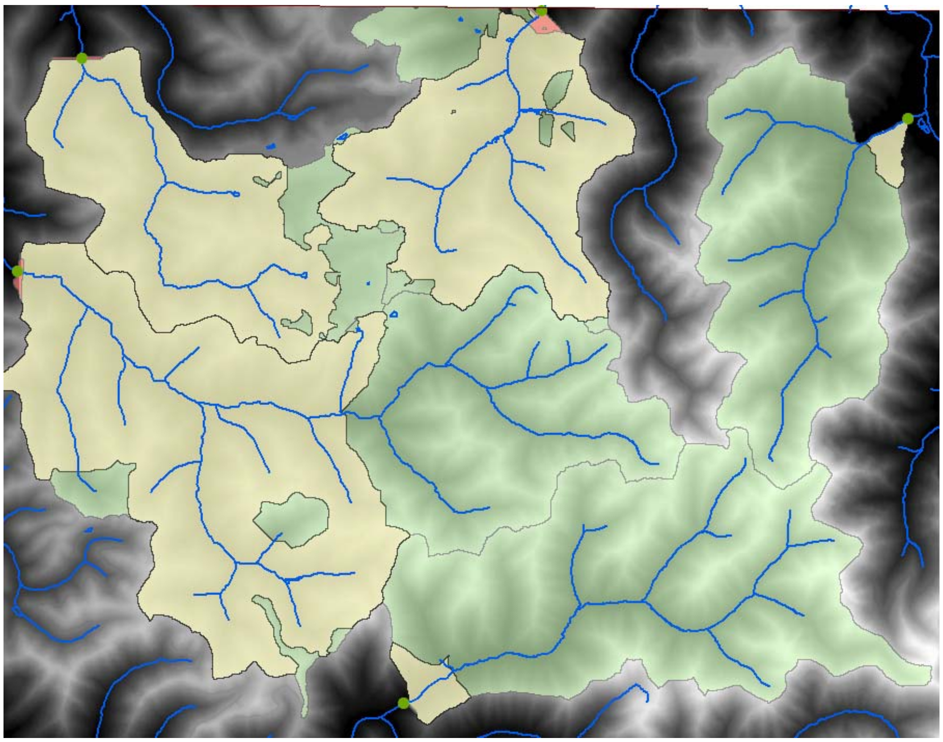

Figure 2. Three sets of watersheds.

The watersheds produced from the second DTM were an improvement in some cases, but overall, did not produce accurate watersheds. These watersheds are illustrated in yellow in Figure 1. While a clear improvement has been made, there are still many obvious problems. Figure 1 illustrates a section of the DTM in which the stream burning process has been completed. However, it is evident that numerous sinks still exist as watershed boundaries terminate in the middle of stream channels, if they get beyond the pour point, at all. Due to this unsatisfactory result, we elected to run the “Fill Sinks” command on DTM (2) in order to create DTM (3). After going through the entire surface preprocessing routine again, we generated a third set of watershed boundaries. The watershed boundaries produced from DTM (3) are pictured in green in Figure 2. These watersheds are a clear improvement over former iterations. We can see no evidence of gaps or sinks within the watersheds themselves and each watershed that is produced “touches” the boundary of the adjacent watershed.

Cracks in the hydrologic enforcement of DTM (2) first began to appear when we ran the drainage line processing routine. Examining Figure 3, we can see two sets of lines that represent hydrologic features. The blue lines were derived from the flow accumulation grid of DTM (2) and the red lines from DTM (3). We can see that gaps exist within the stream network of DTM (2). These gaps greatly hinder any subsequent hydrologic analysis. Subsequent iterations, which utilized the fill command, did not have this problem. When Arc Hydro created the flow accumulation grid using the flow direction grid, it encountered “dead end” cells, and thus, flow ceased at that point. The fill command gets rid of these dead ends and ensures that flow is completed.

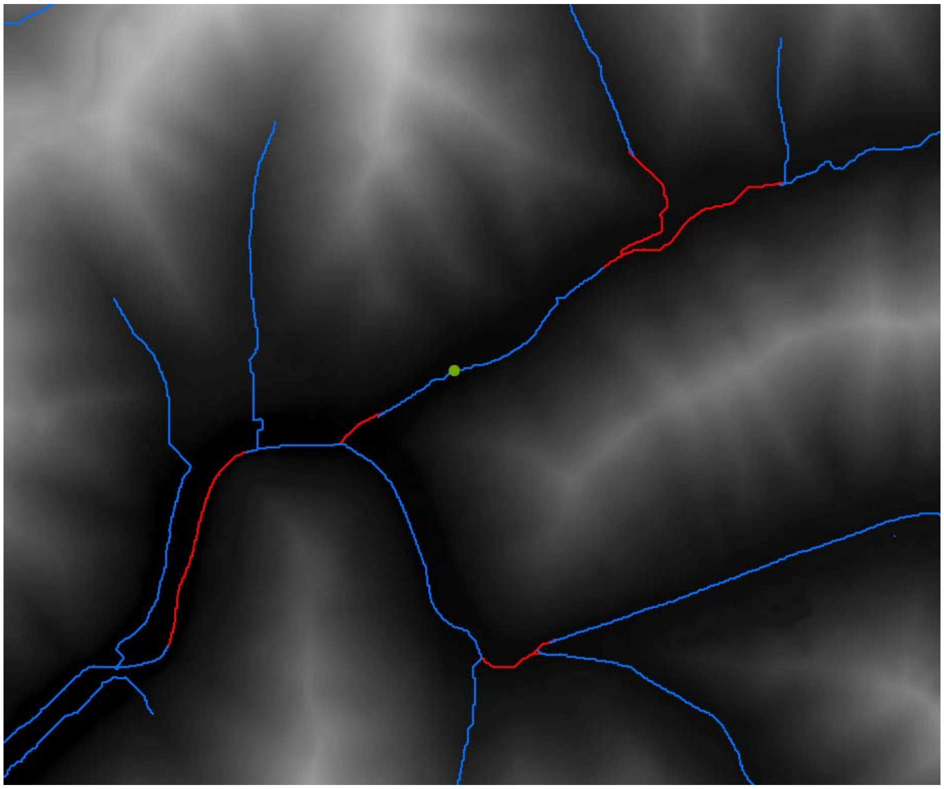

Figure 2. Comparison of derived stream networks.

Despite these hang-ups, it is abundantly clear that the 3 meter DTM products will support sophisticated hydrologic modeling. We have invited stakeholder input on the subject, and we look forward to advancing this data.

3-D Analyst

Methodology

Using Arc Map’s 3-D analyst toolbar and extension, we created several common DTM derived products. While we did not exploit the analytical power of 3-D Analyst, we have successfully demonstrated that the new 3-meter DTMs are suitable for 3-D visualization and modeling. Figure 4 is the main menu of 3-D analyst. We performed most of the operations available to us and generated a series of interesting products and outputs.

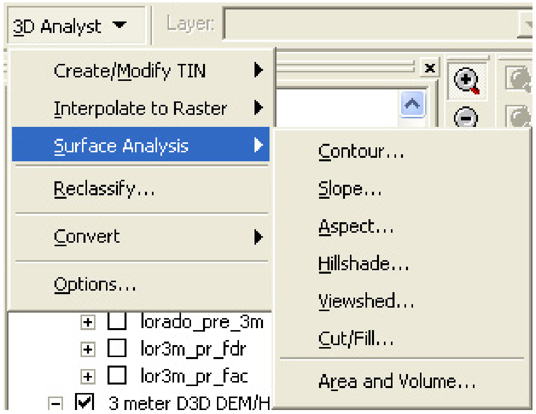

Figure 4. 3-D Analyst main menu

Contour lines provide a vector alternative to the image intensive raster display of elevation information. This may become especially important in a saturated cartographic environment in which large amounts of color are a burden to the presentation of information. The 3-D analyst extension provides a simple, heads up tool to create contour lines from existing DTM data. In the example below, Figure 4, we have generated 40 foot contours and displayed them with an emphasis on the contours that are a multiple of 100. These contours are displayed on top of the shaded DTM.

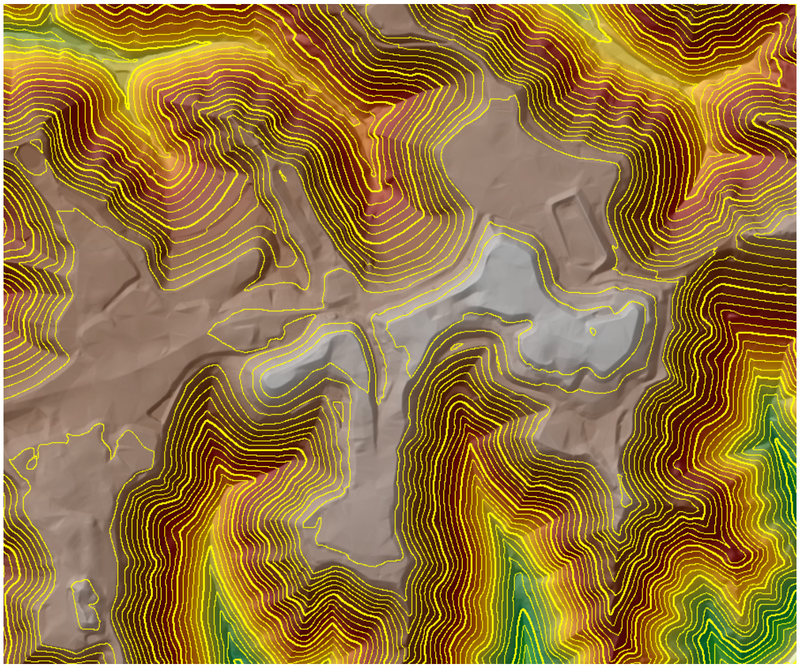

Figure 4. Forty foot contours and DTM

A common DTM derived product is a slope map. A slope map describes how steep, in degrees or percent, the grade of the earth is at a given point. Slope maps are commonly used as inputs in land use change, runoff, or other environmental impact models. As a more local use, they may be used to determine whether or not the "approximate original contour" is achieve during a mining reclamation effort. Figure 5 is a sample slope map in degrees where the darker colors represent steeper slopes. Note the valley fill in the upper left corner of Figure 5. The terracing is clearly evident, wherein darker, steeper parts of the fill are gray and the relatively flat parts are white. Due to the historical presence of highwall and contour mining in the area, the slopes range as high as 89 degrees! A cursory examination of the figure below reveals the level of detail available in the 3 meter DTMs. Much of the subtlety that is often lost in lower resolution DTMs is preserved here.

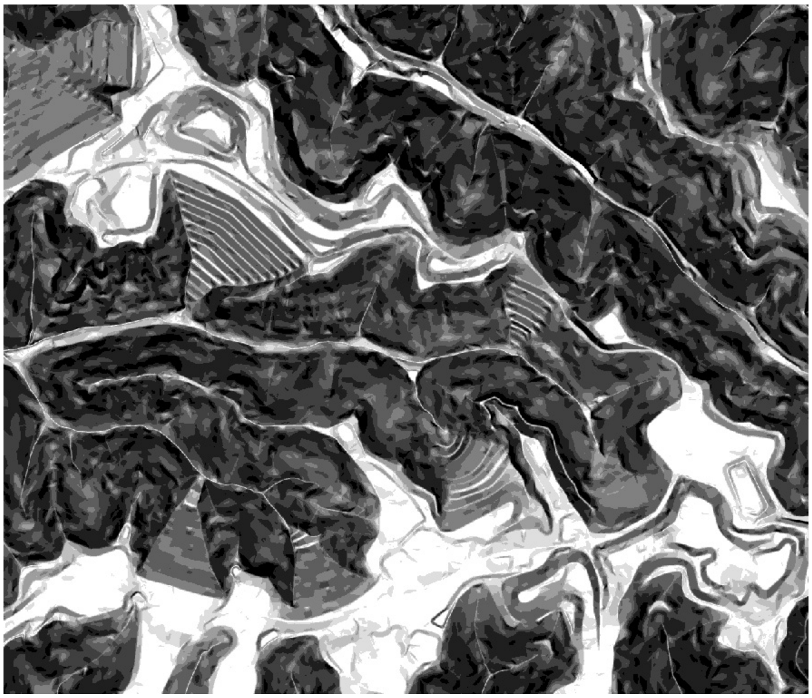

Figure 5. Slope in degrees

An aspect map describes the direction that a slope faces. One of the many uses of an aspect surface is vegetation mapping, in which the direction of slope is an important characteristic for a particular species of plant. We have not included an example of an aspect map as they are not particularly visually favorable.

Unlike many of the previous output grids, a hillshade grid is largely a cosmetic product. It is a hypothetical illumination of a surface in order to enhance relief. A hillshade does have a place in analysis - as an input to remove shadow from remotely sensed images, for instance - but by and large it is employed as a tool to provide visual depth to an otherwise flat display of elevation. Figure 6 is a comparison between two versions of a section of elevation. The top portion shows the DTM by itself and the bottom portion shows the DTM draped over a hillshade. The hillshade provides a dynamic effect to the DTM.

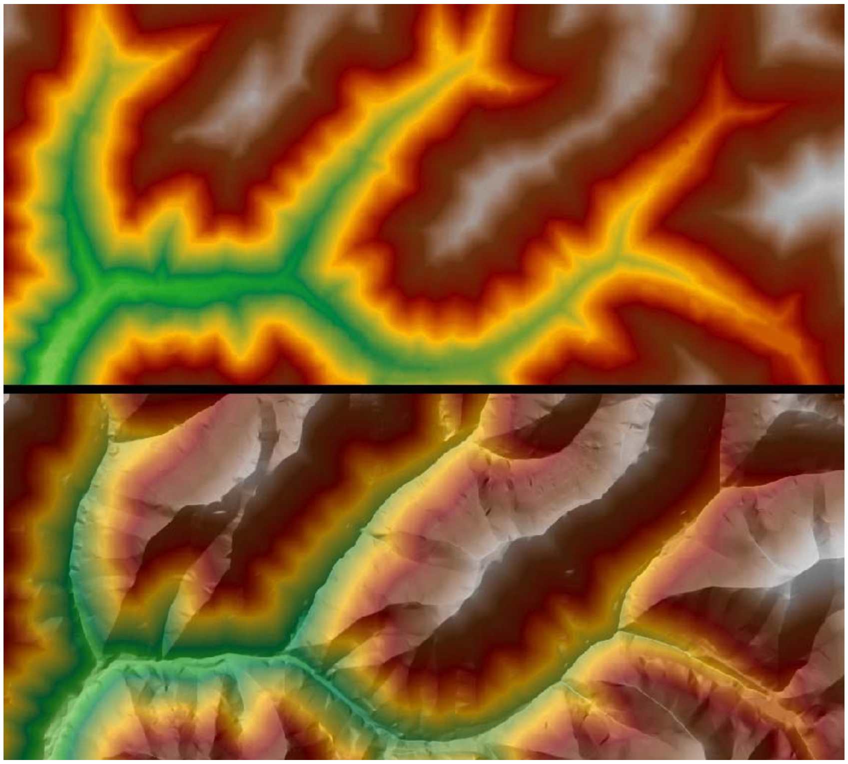

Figure 6. Hillshaded DTM to no hillshade comparison

Viewshed analysis has long been an elevation driven tool of GIS analysts. Modern concerns regarding the construction of noxious facilities has led to an increased emphasis on viewsheds. Simply put, a viewshed is the area that is visible from a certain point on the Earth, assuming “bare earth” conditions. In the following example, we used a point from a hilltop that is elevated roughly 6 feet above the surface (to simulate the height of an adult male) and calculated what areas are visible to that observer at that point. This analysis does not take into account visibility, though that could be implemented. On Figure 7, the red dot represents the point of observation and the light green areas are those areas that are within the viewshed of an observer at that point.

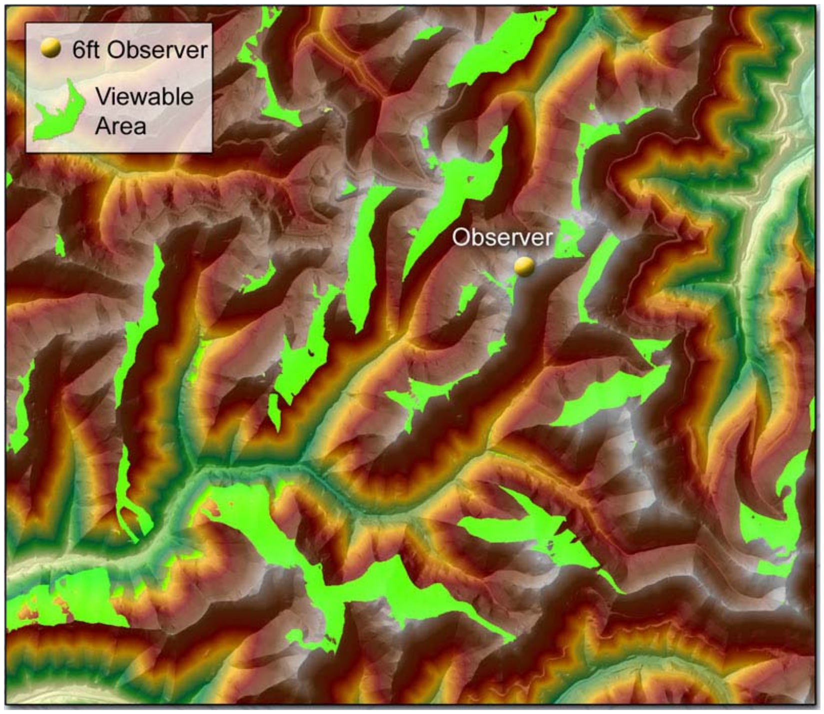

Figure 8. Viewshed analysis

Similar to viewshed analysis is a line of sight analysis. This sort of analysis requires a vector with its origin at the position of the viewer and its terminus at the point being observed. The output is a vector that describes where the view is obscured. The vector is colored red at points in which the view is obscured and green at points at which the view is clear. In Figure 9, the observer is 6 feet tall and the element they are observing is a hypothetical 40 foot structure. The red dot represents the structure being observed. From this illustration we can see that a 40 foot structure is not visible by a 6 foot human from that position on the valley floor.

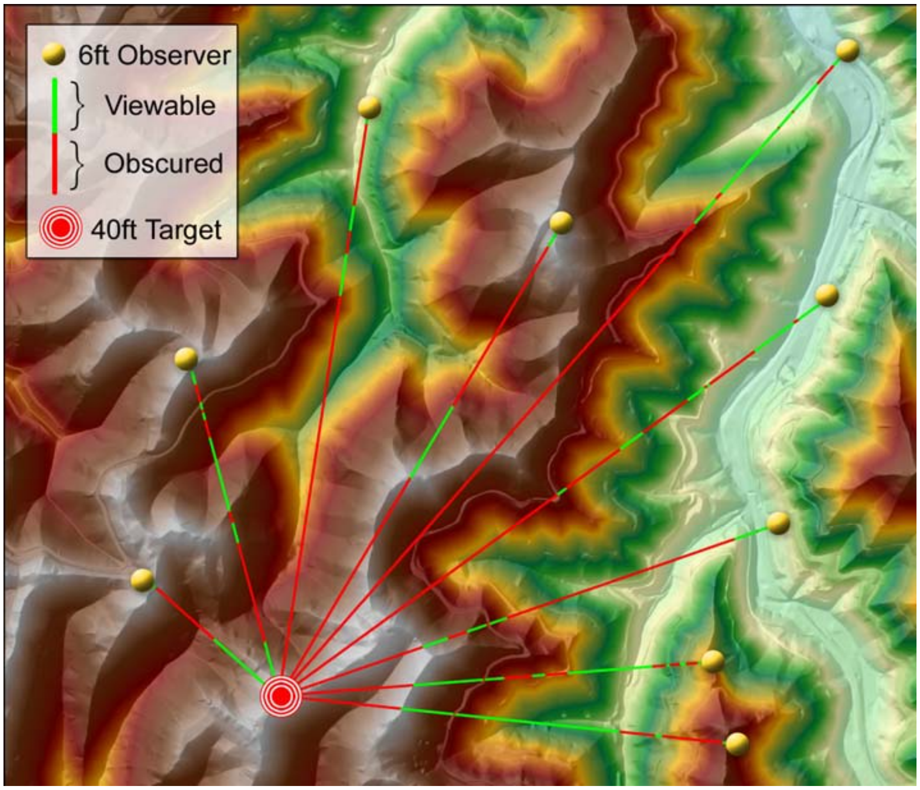

Figure 8. Line of sight analysis

One of the tools in the 3-D Analyst toolbox that approaches a hydrologic analysis use is the steepest path tool. Using this tool is very simple. One needs only to click at a point on the map and the tool will delineate a vector path from the top to the bottom of the hill. This vector will always follow the steepest route or the route with the highest slope values. Figure 9 is an example output of the steepest path tool.

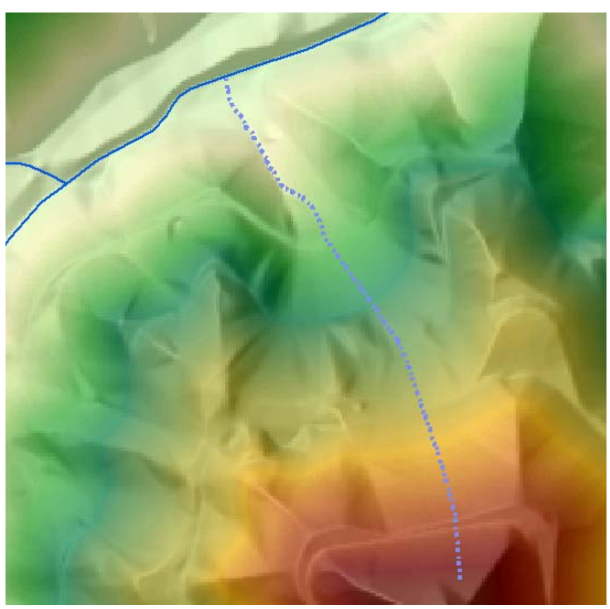

Figure 9. Steepest path

One of the new features of 3-D Analyst is the ability to create an elevation profile. This feature provides a graphical output of the height along a user designated (with the help of a vector) line. Many planning and engineering documents include cross sections such as this. These 3 meter DTMs will support generation of useful elevation cross sections. Figure 10 shows the input and output of the elevation profile tool. The red line is the vector along which the elevation profile has been calculated. Both the horizontal and vertical units are pictured in the graph and both units are feet.

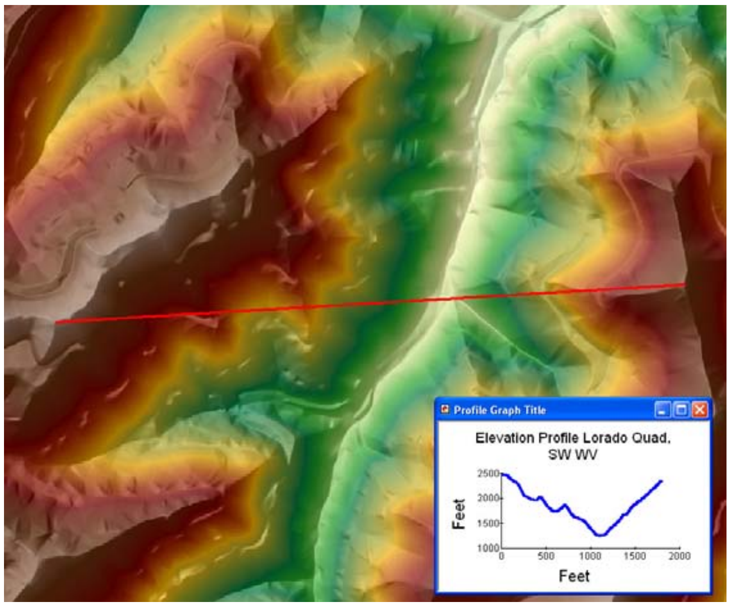

Figure 10. Elevation profile along a vector

Conclusion

This report has detailed several heads-up applications of a new elevation dataset being created by the West Virginia GIS Technical Center. While none of these applications or products are new, we have demonstrated that the new elevation data is being prepared in such a way that new, more detailed analyses can be accomplished with these data. With an expected vertical accuracy of 6 feet or less, the new 3 meter digital terrain models currently in production at the WVGISTC will provide a valuable new base map element to GIS users in the state.