Tools, Tips, and Workflows
Breaklines, Part 1 – An Introduction

B S A U | A W G

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April 2013
Revision 1.0

One of the more powerful capabilities within LP360 is breakline capture and enforcement. In fact, many LIDAR production shops use LP360 as their tool of choice for supplementing point cloud data (derived from LIDAR or correlated imagery) with breaklines. But what are breaklines and how should they be used? Over the next several issues of LP360 News, I will be providing some background information on elevation modeling and then delve into how these advanced features are implemented in our LP360 tools.

A breakline is a vector-based feature (polyline, polygon) added to a 3D model. The 3D model is generally a Triangulated Irregular Network (TIN), although this is not strictly a requirement. A segment of a point cloud (ground points) is illustrated in Figure 1. An example of a TIN model of this same project area is illustrated in Figure 2. A point cloud comprises discrete points (sampled from a laser scanner or derived by stereo extraction from overlapping images) with voids in between the points.
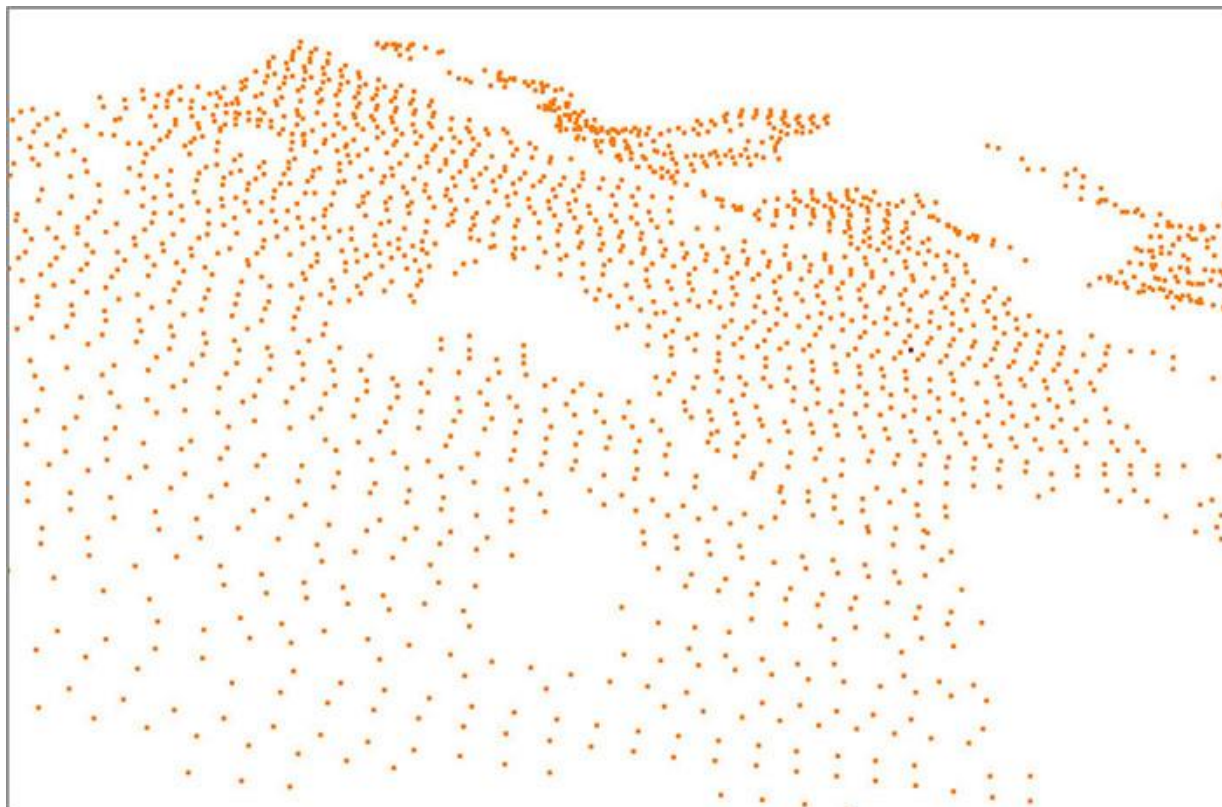

Figure 1: A Point Cloud

B LP360 Basic Edition	A ArcGIS		QCoherent Software LLC
S LP360 Standard Edition	W Windows	Page **1** of **6**	www.LP360.com
U LP360 sUAS Edition	G GeoCue		256-461-8289 (phone)
A LP360 Advanced Edition			256-461-8249 (fax)

To visualize the point cloud as a surface, we need to "fill in" the space between the points. One of the most common ways of doing this in a Geospatial Information System (GIS) is to connect each point in a triangle mesh (see Figure 2). We do this in a very special way to maximize the interior angles of all of the triangles (this is the "Delaunay" triangulation technique, of which you may have heard).
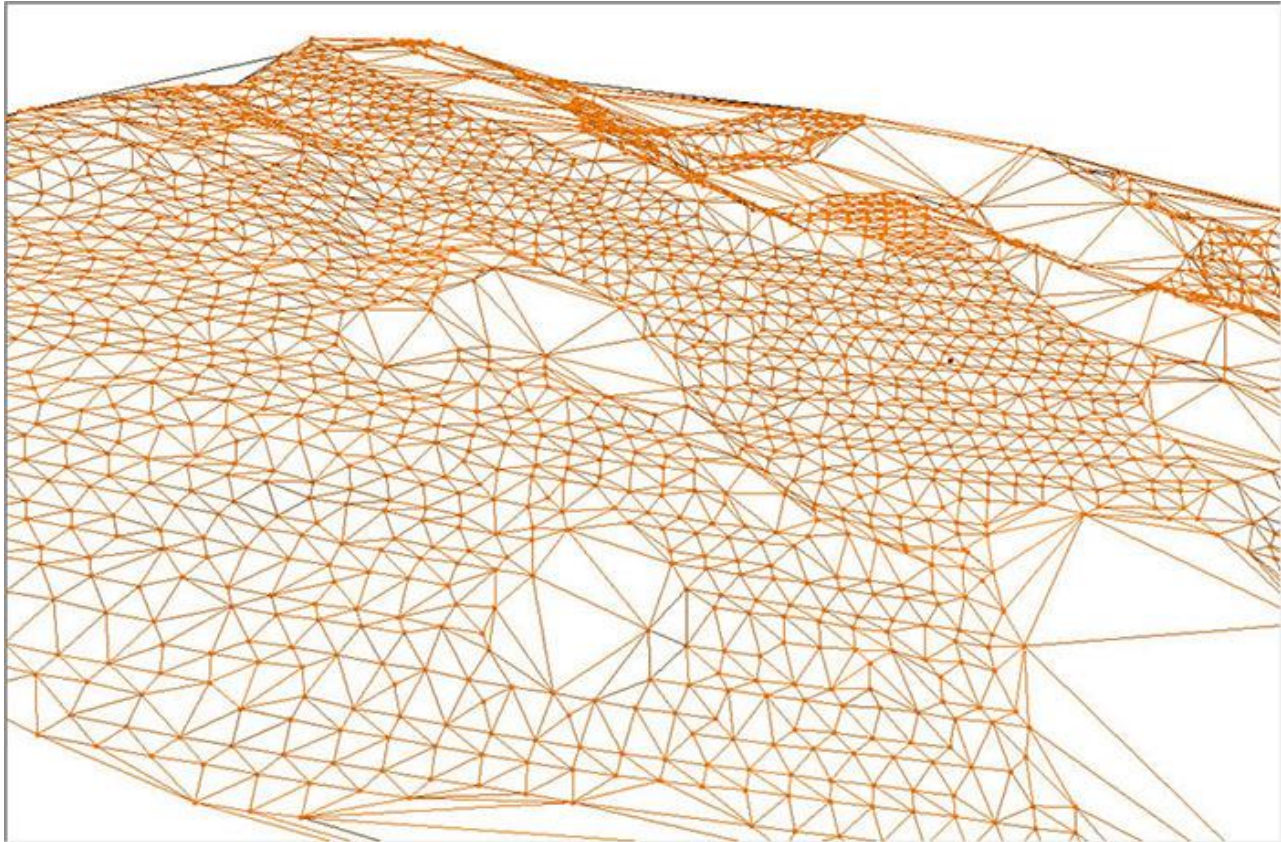

Figure 2: The points of Figure 1 rendered as a TIN

The three important elements of a TIN are:

- Node – The points used to construct the TIN
- Edge – The line segment that connects two nodes
- Facet or Face – The triangle formed by three edges

Thus we have formed a (T)riangulated (comprising triangles), (I)rregular (the triangles are, in general, different sizes and contain differing angles), (N)etwork (we can traverse the entire mesh by following edges).

When the faces are "filled", we have a 3D solid model (see Figure 3). So hopefully it is apparent that the TIN is a way of interpolating data (estimated values between our actual sample points) as well as a graphical visualization tool. The TIN is one of the most flexible representations of a point surface because, like a three-legged stool, the faces will always perfectly fit the elevation points of the original

point cloud. The disadvantage of a TIN is that it has sharp edges and hence is very course in appearance when zoomed in (a TIN is a first order approximation to a surface).
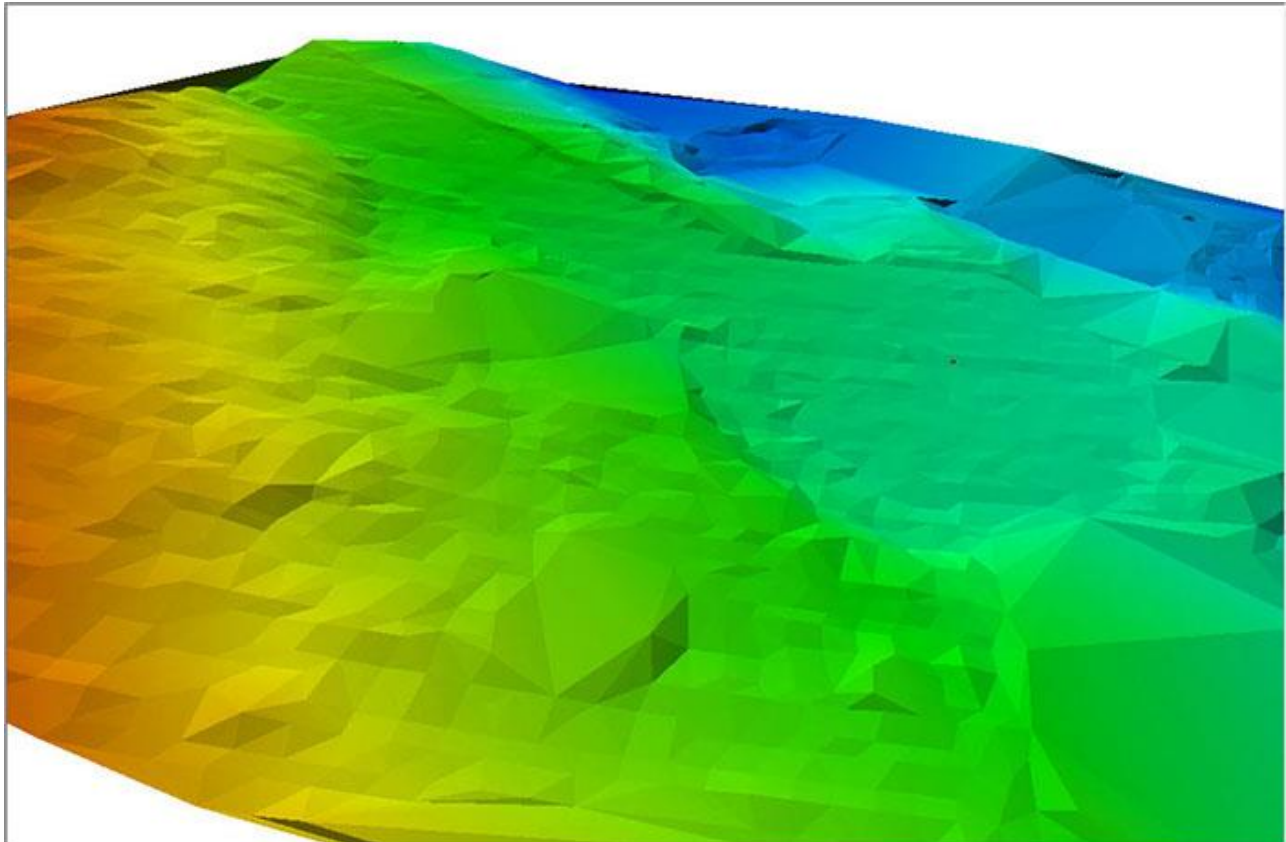

Figure 3: Filling the faces of the TIN to construct a 3D solid model

Breaklines are two or three dimensional features (generally polylines or polygons) introduced into the TIN to constrain the generation of surface models. These introduced breaklines may be developed such that they do not modify the original surface geometry ("soft" breaklines) or to add a change in curvature to the surface ("hard" breaklines). Breaklines can be stored as ancillary feature data that are dynamically added to the model when needed (during surface generation or derived product creation). Alternatively, breaklines can be "burned" in to the surface model as strategically placed points (sometimes referred to as "Steiner" points) that are flagged as "model key points." A model key point is a point that is flagged to always be retained in a model during thinning processes. The dynamic modeling, while much more difficult to implement, is far more flexible in dynamic modeling situations (e.g. change, observe, change, observe…). LP360 implements advanced dynamic breakline modeling.

Breaklines introduced into a surface such that none of the existing TIN elevations are modified are termed "soft." These breaklines are used to preserve original elevations in a model or to indicate a feature in the TIN such as the edge of a road. Figure 4 depicts a soft breakline being introduced to demark the edge of a road. Note that a vertex has been inserted (green nodes) at each intersection between the line segment and the TIN. Each of these nodes will take on a Z value identical to the

elevation of the intersected triangle edge. This operation is termed a "pure drape." This is quite a visual term, as you can see how the line has been "draped" over the TIN. Note that since we have not yet "enforced" this breakline, the triangles intersected by the line segment have not been modified.
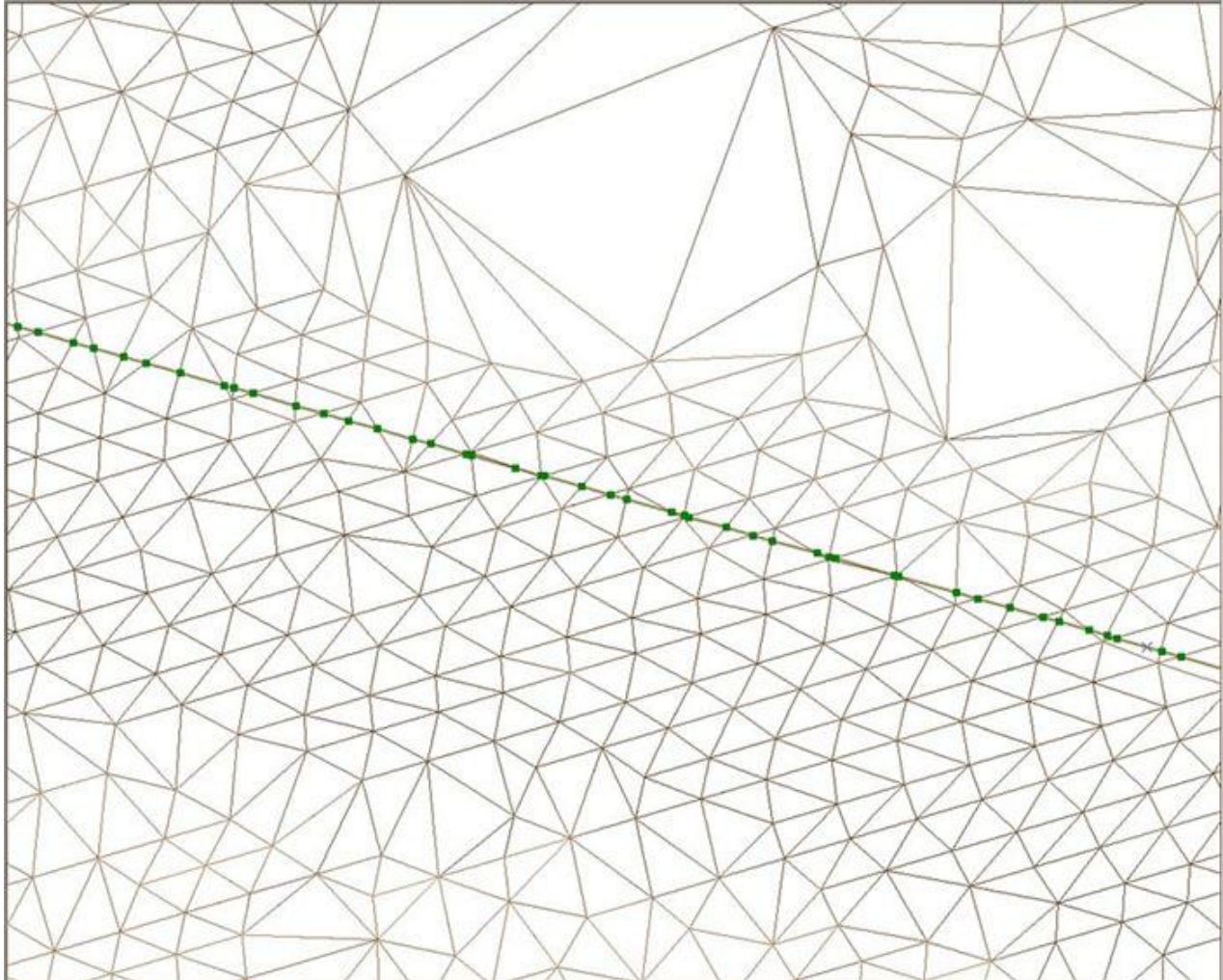

Figure 4: Introduction of a soft breakline (unenforced)

Figure 5 shows the reconstructed TIN after introduction of a soft breakline. Note that the elevation of each introduced node is interpolated from the edges of the original TIN of Figure 4 at the point where the line crosses the TIN edge. That is, a new node (also referred to as a vertex) is created at each point where one of the introduced lines crosses an edge of the original TIN. This new model will very closely resemble the original model since we have not introduced any new elevation points. However, there are subtle differences because enforcing the breakline introduces a new triangle vertex at each point where the line crosses the original TIN. This breakline enforcement forces the new TIN to violate the previously mentioned Delaunay criteria, because it forces triangle edges to be inserted along the breakline. These areas of "redundant" triangle construction are denoted by the red circled areas in Figure 5.
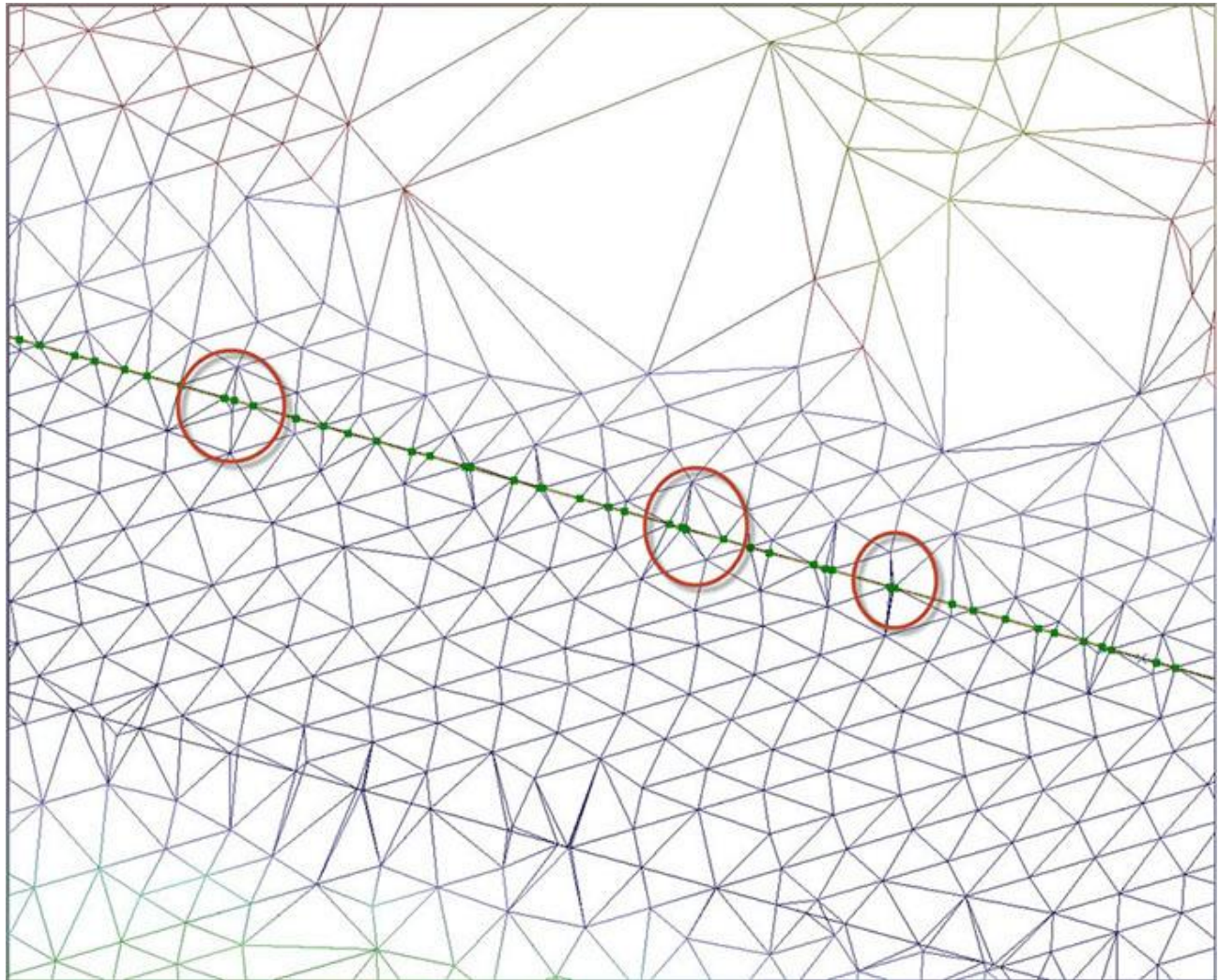
Figure 5: Depiction of the TIN after enforcing the breakline

Note that even though these "soft" or draped breaklines do not introduce any changes in terms of elevation points, the change in the triangulation (as depicted in Figure 5) can cause very subtle changes in the elevation models that will be derived from the TIN. Figure 6 shows the small change in contour position that results when enforcing the breakline. In most cases, the changes in contours introduced with soft breaklines will be very small (the contour interval in Figure 6 is only 0.2 feet).
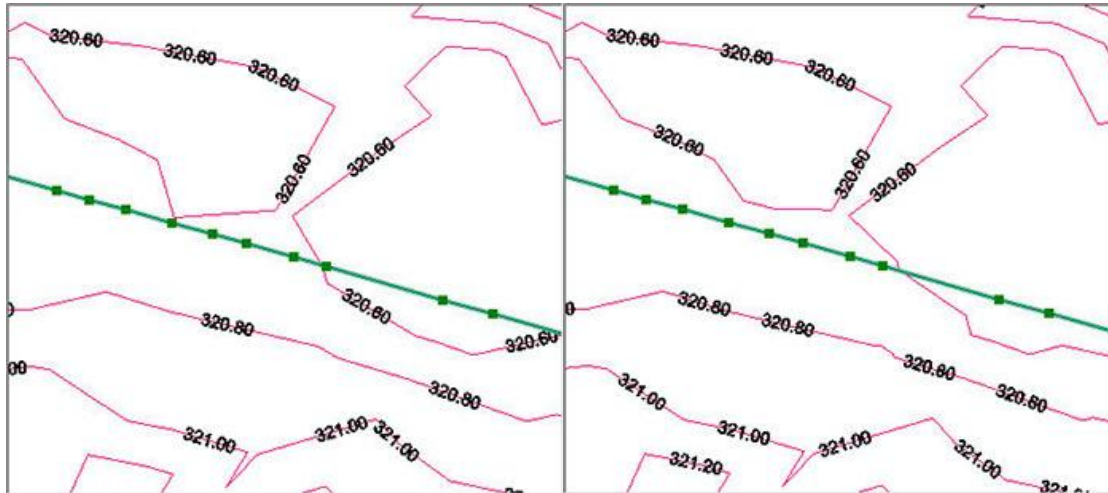
Figure 6: Unenforced (left), Enforced (right)

Soft breaklines generally serve one of two functions (or sometimes both). They preserve the topography as subsequent operations are performed. For example, withholding some of the ground points after introducing the soft breaklines of our example (most typically in a data thinning operation) can dramatically change the morphology in the neighborhood of the breakline, but it will not change right at the line. A second reason for introducing soft breaklines is for feature coding operations. Sometimes the facets of triangles are labeled with a feature class such as "Ground" or "Road." Introducing a soft breakline allows one to split features, such as the Ground into two features (Ground, Road).

In the next edition on breaklines, I will introduce "hard" breaklines and illustrate some of the ways in which they are used.