Tools, Tips, and Workflows
Breaklines, Part 5—Applying Breaklines to Enforce Varying Elevation

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In the last edition of LP360 News, we discussed the creation of **3D breaklines** for enforcing situations where the elevation must be a constant along the breakline. The most common example of this applications is "water body flattening" such as lakes and ponds. In this final installment of the breakline series, we will consider the case of varying elevation along the breakline.

Recall that, for our purposes, a **3D breakline** is a vector that has an elevation value (Z) associated with each vertex. Generally, **3D breaklines** can be divided into two categories – those with the same elevation for each vertex (used for flat water bodies, for example) and those with the ability to store a different elevation value for each vertex (a down-stream flow polyline, for example).

In this edition, let's look at a varying Z example such as the edges of a road or, more commonly, a downstream flow. As with flat water bodies, a common method of collecting breaklines is to use heads-up digitizing from an orthophoto for the X, Y (planimetric) aspects of the construction and to probe the LIDAR (or, more generally, point cloud data) for the Z value. Unlike the constant Z flat water body breaklines, we have to store the Z for varying elevation breaklines at each vertex. This means that these breaklines are always represented by 3D features.

One very useful way to locate and visualize drainage is via a contour display. Figure 1 shows an area of drainage. I have filtered the point cloud to ground points only and visualized as a triangulated irregular network (TIN). The area of drainage has been roughly sketched in blue using an ArcGIS annotation. Note that the contours "point" upstream due to the depression formed by the drainage. Thus, you can use the ground class along with an examination of contours to identify drainage location and direction.

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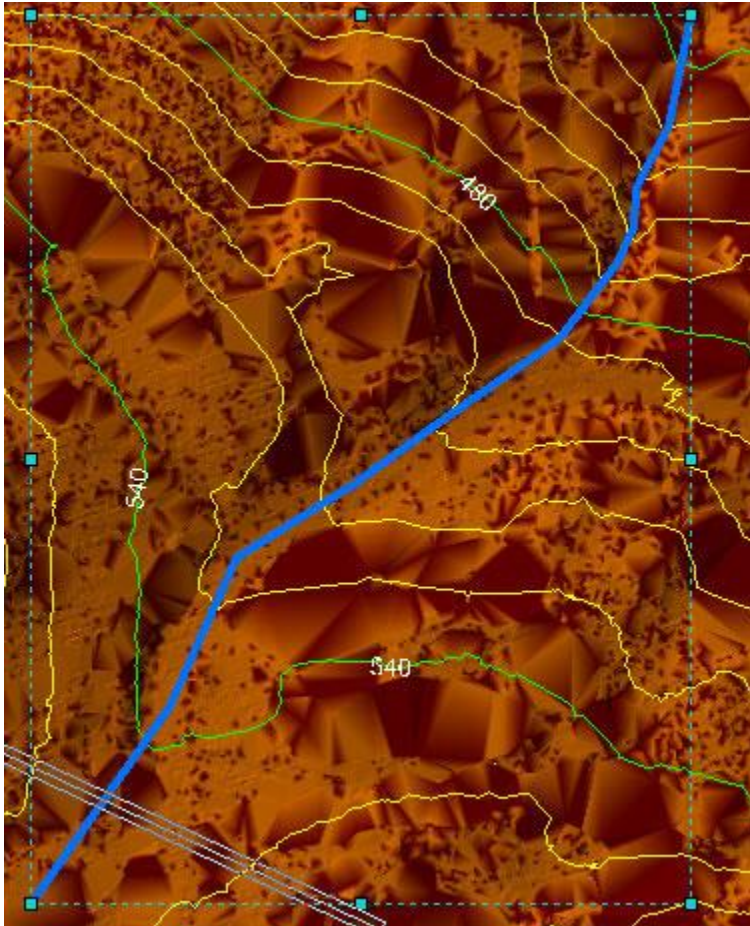

Figure 1: Visualizing Drainage via Contours

There are at least two approaches to digitizing the actual drainage breakline. The first is to identify the drainage purely from a two dimensional top view ("Map View"). After digitizing, the Z value can be obtained from the point cloud surface via probing. In LP360, we call this process of probing the point cloud data for the elevation value "Z Conflation." The problem with this approach is that, even with contours, it can be difficult to correctly identify the lowest point of drainage in the planimetric sense. More importantly is enforcing a hydrological model. We need to ensure that draining is strictly monotonically decreasing as we move downstream from vertex to vertex. Fortunately, LP360 contains advanced tools for properly enforcing downstream constraints.

Figure 2 depicts the dialogs in LP360 for digitizing a downstream constraint. The dialog to the left in Figure 2 contains overall "Z conflation" settings where general parameters are configured. Note that I have set this to "Downstream Constraint." The dialog to the right is used for configuring the specifics of the conflaton method; in this case, the downstream constraint. All conflation methods in LP360 allow you to change the vertex spacing, if desired. The general choices are:

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- Pure Drape – This creates a vertex at each point where the breakline intersects the edge of the triangulated irregular network (TIN) created from the point cloud
- Create vertex every X map units – inserts new vertices at the user-specified spacing
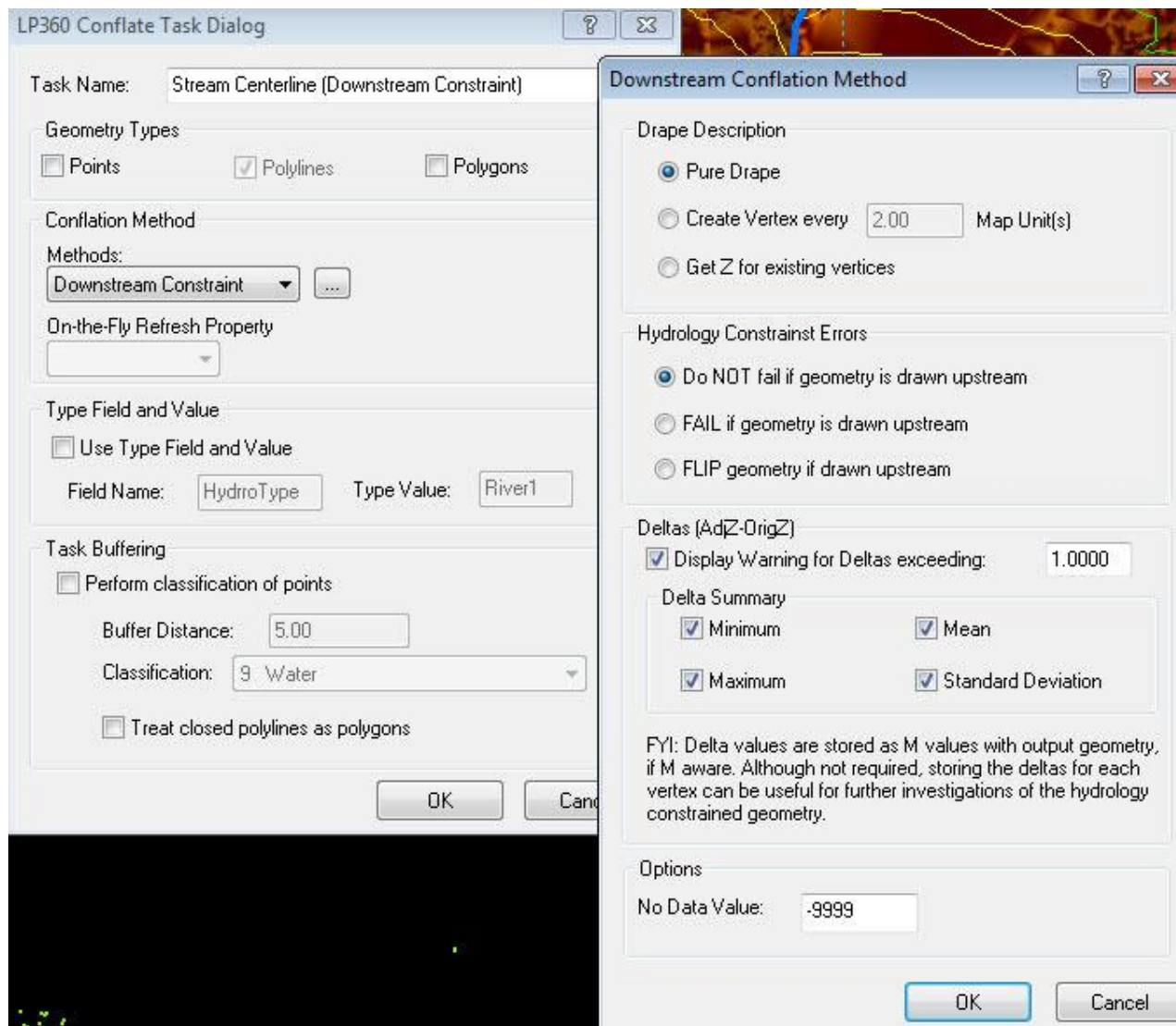- Get Z for existing vertices – do not modify the existing vertex locations.

Figure 2: The Downstream Constraint Tool in LP360

The remainder of the dialog settings on the right in Figure 2 are related to error monitoring. The downstream constraint will, after the vector digitizing is complete, adjust the assigned values such that the monotonicity is maintained (that is, each subsequent vertex, as one walks down the breakline, has a Z value lower than the immediately previous vertex).

Most topology systems use the sense (direction) of a vector to determine the downstream direction. Usually, moving in the direction of increasing vertex ID is considered the downstream direction. The first section of the error management of the downstream constraint dialog provides some self-evident options for how this is handled.

The second section of the error portion of the dialog allows you to monitor how much a particular vertex is moved by the system to maintain the monotonic constraint. The distance between the surface derived from the point cloud and the Z of the vertex is referred to as the "Delta." We take this measure to be the Adjusted Z (the final vertex Z) minus the surface (or Original) Z. Thus, an adjustment of a vertex beneath the surface creates a negative Delta. If desired, the Delta of every vertex can be stored in the Measure (M) value of the vertex, assuming you created a 3D geometry feature with M values.

Finally, summary statistics for each feature can be stored in the Attribute table. The computed values include:
- Minimum – The largest deviation below the TIN surface
- Maximum – The largest deviation above the TIN surface
- Mean – The mean of the deviations
- Standard deviation – the statistical standard deviation of all of the Deltas of the vector

The actual digitizing of a breakline in LP360 is performed using both the Map View and the Profile View. The Map View provides the planimetric location, whereas the Profile View allows you to visualize the vertical placement.

A general technique that I find useful for drainage centerline is to turn on contour display in the Map View and identify the drainage that I want to digitize using the drainage induced distortions in the contours. It can be useful to roughly digitize these locations using the Sketch tools in ArcGIS. I then set up for digitizing in the Profile/Map View. This generally is initiated by beginning a breakline sketch in the Map View and then pressing the "P" key to synchronize the Profile View. This is depicted in Figure 3. Note the red box in the Profile View. Here I have boxed in the intersection of the projection from the Map View (vertical white line) with the ground points (orange in the Profile View of Figure 3). This vertical line is "dropped" from the Map View into the Profile View and tracks the cursor as you adjust the position in the Map View. Thus, one would adjust the location of the vertex of the breakline by moving to a point such that the dropped line crosses the surface model at the lowest point.

There are a number of keyboard activated tools within the LP360 product for assisting with the collection of breaklines, such as nudging vertices up and down in the vertical direction, overriding the point cloud value and so forth. I encourage you to peruse the help and user documents to become acquainted with this rich set of collection tools.
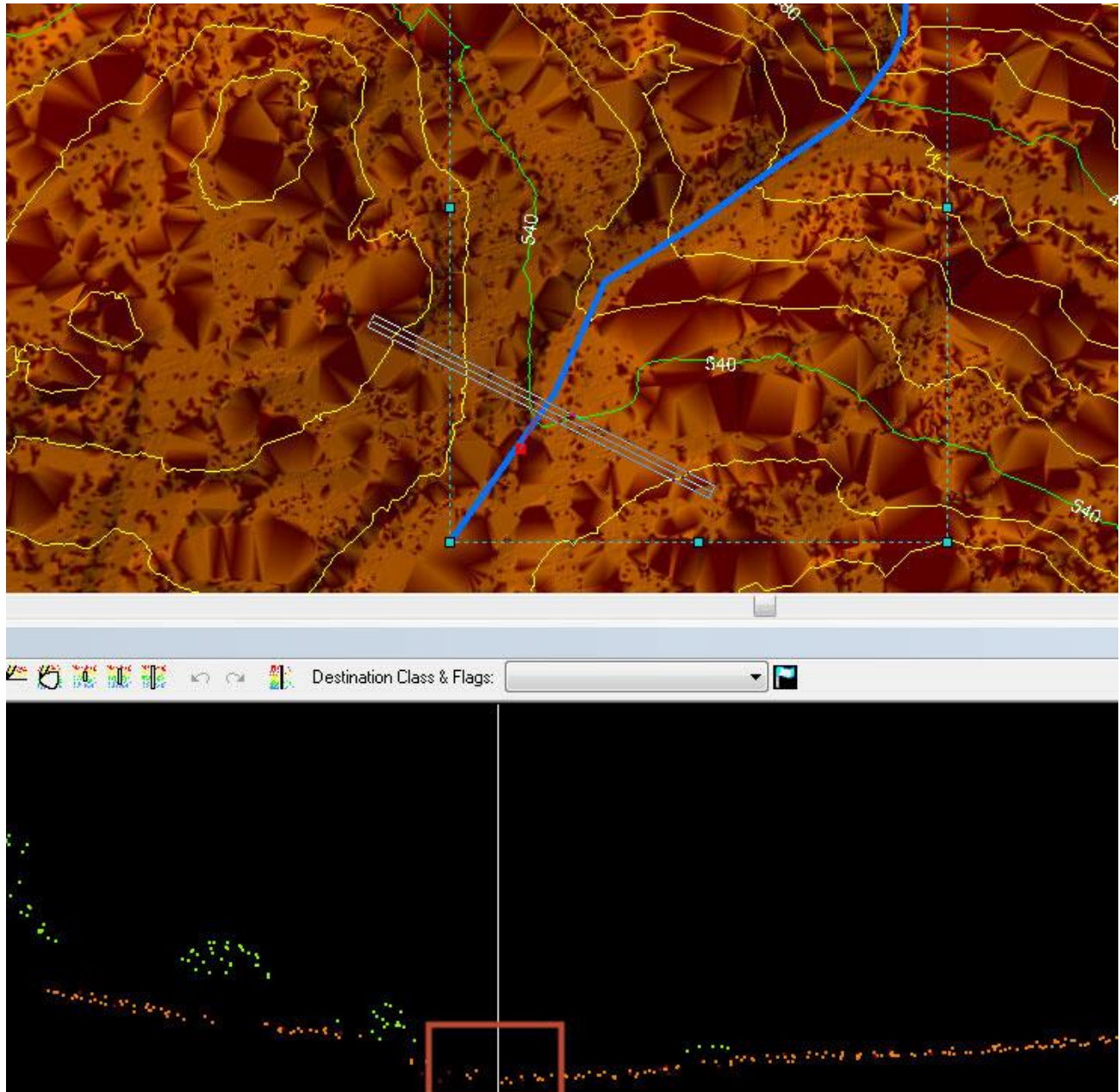
Figure 3: Digitizing a breakline using the Profile View

The digitized breakline is depicted in Figure 4 as the green line. The blue sketch line was my initial approximation of the breakline location based on the contours. Note that the vertex property page is displayed to the right. Note first of all, that the Zs are monotonically decreasing (the vector extends from the lower left as the high point to the upper right as the low end). Secondly, note the M values in the fourth column of the table. These values represent how far above (positive M value) or below (negative M value) our algorithm had to move the vertex to maintain monotonicity.
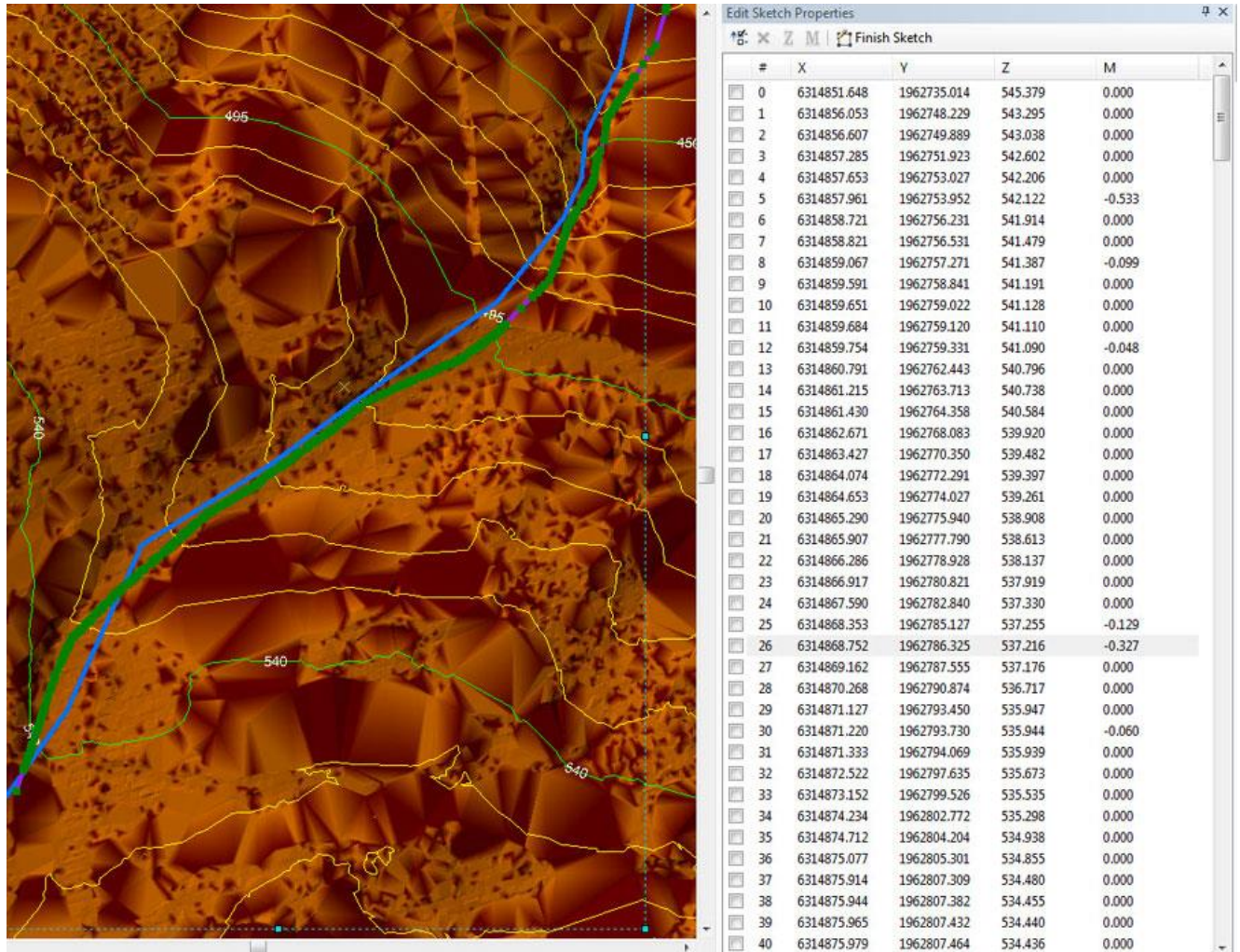
Figure 4: The digitized breakline (green)

Finally, in Figure 5 is depicted the enforced downstream constraint breakline (the purple vector). Note that the effect of a downstream constraint on the contours will be quite subtle if the contour is drawn in the correction location. This is because the point cloud itself is a very accurate representation of the drainage topography, and hence you would not expect a significant change.
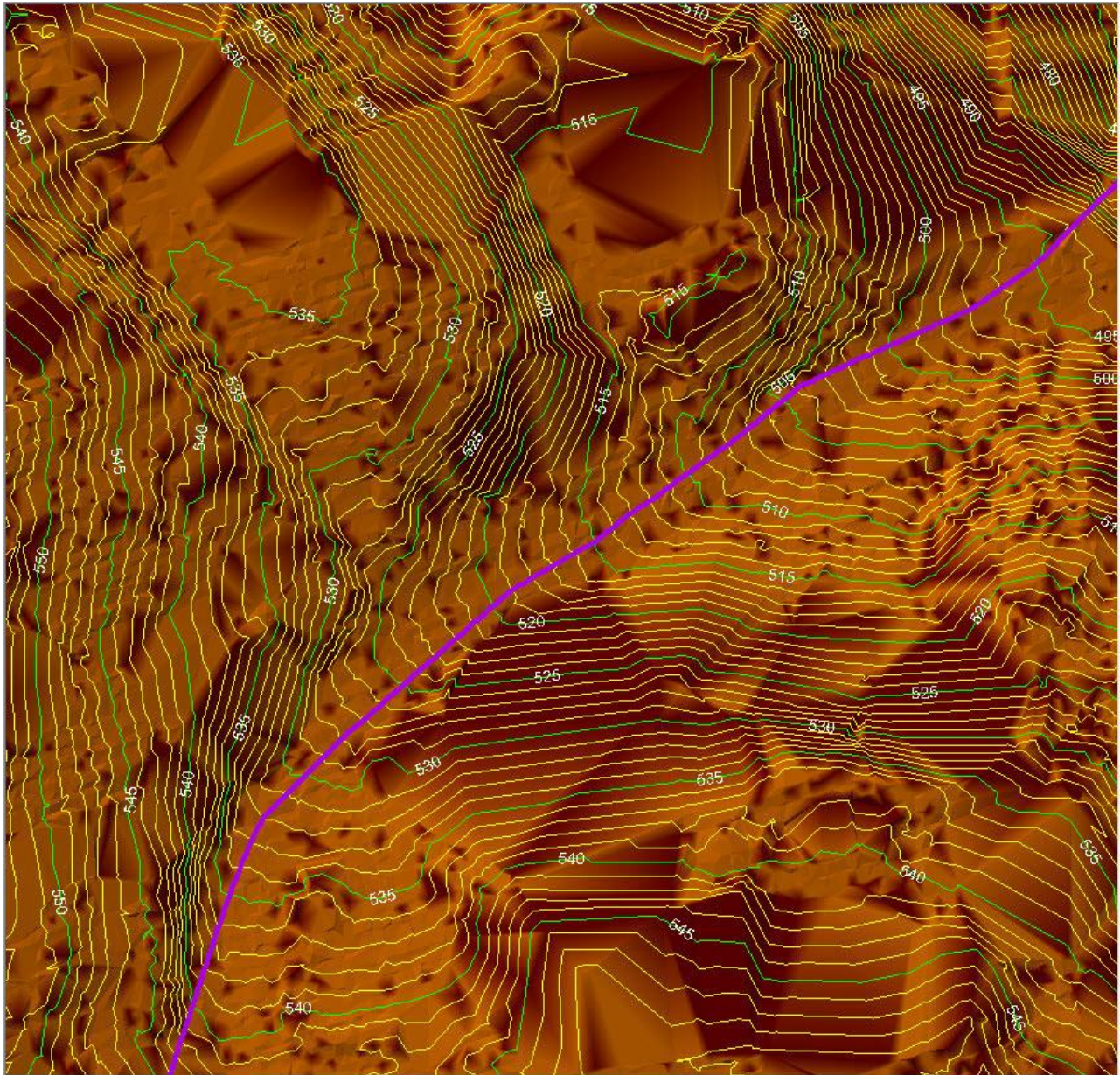
Figure 5: The enforced downstream constraint

We support several other variable Z breaklines in LP360. Among these are:

- Double line drains ("river flattening") – This is used for wider streams and rivers where the overall elevation in the direction of flow is monotonically decreasing, but the banks perpendicular to the direction of flow must be at the same elevation (otherwise the flow direction would be cross channel rather than down channel).

- Retaining Wall – The retaining wall tool allows you to digitize parallel lines with a slight displacement. Each line can be conflated using a different algorithm. The primary use is along

walls where using the high points for one line and the low points for the parallel line will create a model of the wall. This model can be used in subsequent breakline enforcements.

This concludes the LP360 News series on breakline collection and enforcement within the LP360 product. As you can see, this is a very rich area of LP360 and a reason that LP360 is one of the most widely used tools in the point cloud industry for adding and visualizing hydrological (and other forms) of constraints. I encourage you to thoroughly review our help files and tutorials if your work involves breakline collection. The tool you need is most likely in our collection! In addition, I encourage you to attend our training sessions that will be held in Huntsville, Alabama, USA from September 24 through September 26 of 2013. We will be devoting one of the afternoon sessions to the intricacies of breakline collection.