GIS 4 Geomorphology

Geomorphometry of Mountain Landscapes & Upland Watersheds…a little Wildlife, too

Low Order Stream Gradients

Low-order catchments comprise a large proportion of a mountain watershed. Low order streams in many range are shaped by and preserve evidence of recent tectonic, depositional, and climatic perturbations. In some mountains, the low order streams feel the effects of the perturbation sooner than downstream reaches. High elevation watersheds (non-glaciated) tend to be steep, wet, cold, rocky (thinner soils, more impervious), and hav flashy flood profiles. Where the low-order portion of a stream network is oriented across a fold or the axis of acti uplift, some tributaries may be flowing in the direction of tilt and others against it. In this case, gradients may be compared to tease out tectonic effects (Merritts & Hesterberg, 1994).

The instructions below involve ArcGIS 10.x, Spatial Analyst Extension, Excel, and CS-6 Adobe Illustrator (AI).

0.) Choose a Field Area
This is up to you. Check out the articles referenced.

1.) Create a Stream Network
Derive a stream network using standard ArcGIS watershed functions (see Watershed Delineation). You need a polyline shapefile, preferably broken into segments at confluences.

2.) Inputs & Calculations
Excel is helpful here. You need columns for 1.) each uniquely-numbered stream segment, 2.) upper and lower elevations of each segment (endpoint elevations), 3.) calculated gradient of each segment in both degrees and percent rise, 4.) confluence elevations.

* Gradient may be calculated either by a.) As-the-crow-flies length (straight line between endpoints), or b.) Sinuous length of the channel segment (thalweg distance). The first option is a loose approximation of gradient, as it ignores channel sinuosity and profile concavity. The second more faithfully approximates the channel slope because it uses actual line length of the channel, though profile concavity is still ignored. Thus both methods produce an “average stream gradient”.

* Slope is best expressed as degrees slope for this project.

* The map projection will affect all measurements to some extent.

3.) Tectonic Tilt Direction
– Figure this out.

– If you are following the Merritts' method, tilt matters. If you are using low-order streams as part of a watershed comparison project, then skip this step.

4.) Charting Confluence Elevations
– If this is your first time, you may want to sketch out the following steps by hand before doing it digitally. Get the concept down first, then use the tools. Probably quicker.

– In Excel (or maybe the Column Graph tool in AI), start to build your chart where the X-axis = Downstream Distance, Y-axis = Elevation. You may want to hold off on scaling the X-axis; its probably not crucial to do so as the relative position of channel segments and confluences that matters. However, be sure to scale the Y-axis.

– Add dashed horizontal lines across the chart area for each Confluence Elevation.

5.) Create & Rotate Channel Segment Lines
– Create line segments of proper length in AI using the Pen tool. Do this away from the chart area. Two points should define the line. Shift-click to draw orthogonal lines. Edit line lengths using the X or Y controls on the Cont Window (Window menu > Control).

– Rotate each segment (degrees) to its proper gradient using Right-click > Transform > Rotate, or Object menu Transform > Rotate.

6.) Add Segments to Chart
– Position the line segments on the chart with care. Lower ends of each should fall on one of the dashed confluence lines. Pay attention to the relative downstream position of each stream segment. A fuzzy X-axis com into play here.

7. Analysis (optional)
– If you're lucky and your stream network is favorably oriented, then some segments will flow with and some against the structural tilt direction. Your chart will hopefully show this.

– If not, construct a map of all bridges in your region. Navigate to the tallest one and leap from it. Or just choose better study area. That might work, too.

Refs:

Frankel and Pazzaglia (2007), GSA Special Paper 398

Font et al. (2010) Geomorphology 119

Merritts and Vincent (1989), GSA Bulletin 101

Merritts and Hesterberg (1994), Science 265

Burbank and Anderson (2012), Tectonic Geomorphology (2nd edition), p. 286, Fig. 9,8