

# Case Study: Automated Knickpoint Identification in the Waipaoa River, North Island, New Zealand

## Introduction

Knickpoints are a geomorphological phenomenon wherein the slope of a river changes dramatically in a relatively short stretch of the channel, such as a waterfall, rapids, or lakes. The generation and migration of these features are strongly influenced by the tectonic and climatic histories of the area in which they occur, as well as the kinds and strength of the rocks through which they cut, and can provide valuable insight into the evolution of regional landscapes and paleoclimate conditions (Bierman and Montgomery 2013). Consequentially, the identification and characterization of knickpoints throughout the world has been a hot topic among geoscientists, and a number of tools have been devised to help simplify what can be a long and tedious process.

One such tool is *Knickpoint finder* – a Python-based script written by the Neotectonics Research Group of the Federal University of Paraná, and designed for implementation through ESRI's ArcGIS platform (Queiroz et al. 2015). The objective of this project is to assess the potential accuracy and overall efficacy of this tool by applying it to an area with well-documented and observed knickpoints. To this end, I have selected the Waipaoa watershed on the north island of New Zealand wherein 236 knickpoints have been explicitly verified by a combination of aerial photography and boots-on-the-ground observation (Crosby and Whipple 2006).

## Methods

The first step in the project was to acquire a digital elevation model appropriate for the only data-based input of *Knickpoint finder*. While the 30-meter resolution ASTER GDEM V2 was originally my first choice because of its quality and reliability, I ultimately decided to use the same DEM utilized by Crosby and Whipple in their analysis of the Waipaoa in order to remove any potential systematic errors from any spatial comparisons that may be made between knickpoint locations in their maps and the ones I generate. An added benefit of this was a 5 meter gain in the resolution of all subsequent rasters built along the way. After some searching, I found the 25-meter digital elevation model of New Zealand's north island. The raster set is a 32-bit cell-depth, floating point precision elevation grid generated from the LINZ 1:50,000 scale topographic data layers (e.g. 20-m contours, spot heights, lake shorelines, and coastlines)

using in-house interpolation software built by Landcare Research – one of New Zealand’s Crown Research Institutes.

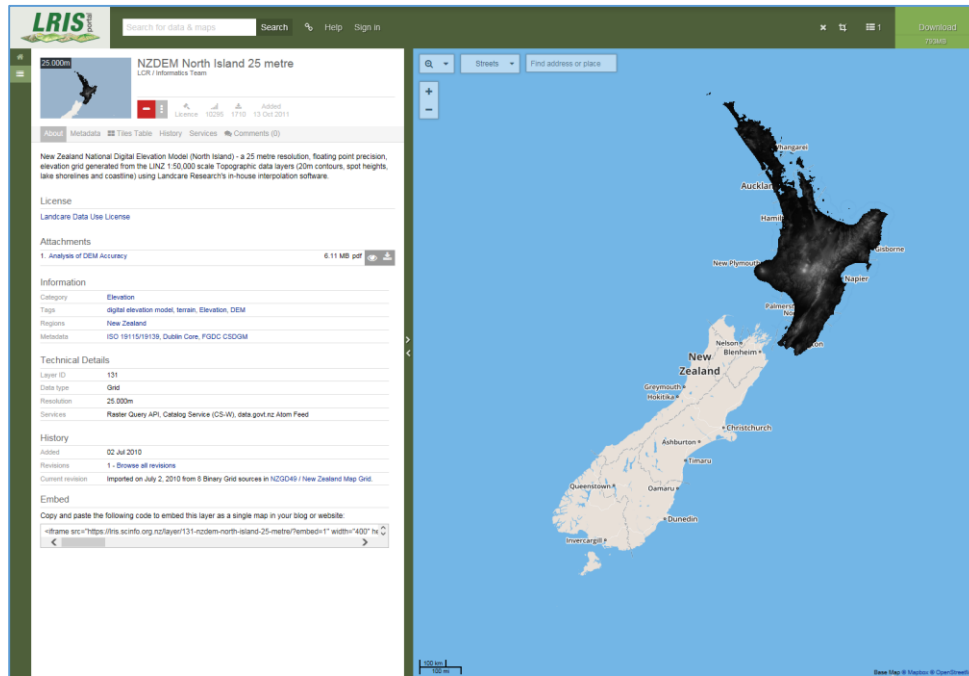


Figure 1. A screenshot of the online database provided by Land Resource Information Systems (LRIS) - a "repository of authoritative New Zealand science databases and information" - from which I was able to download the 25-meter DEM utilized by Crosby and Whipple.

## Data Preprocessing

It's rather convenient that running *Knickpoint finder* only requires fetching a single dataset, and that there is only minimal preprocessing necessary. First and foremost is the translation of the user-end of the tool from its native language – Portuguese.

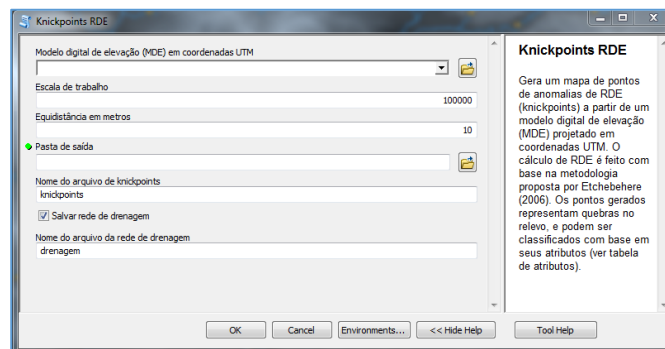


Figure 2. A Screenshot of the pop-up tool window of *Knickpoint finder*.

Luckily, Google translate made this task trivial; the translated Tool Help text is as follows:

**Knickpoints RDE**

Generates a map of points of RDE anomalies (knickpoints) from a digital elevation model (DEM) designed in UTM coordinates. The RDE calculation is based on the methodology proposed by Etchebehere (2006). The points generated represent breaks in relief, and can be classified based on their attributes (see attribute table).

**Digital Elevation Model (DEM) in UTM coordinates**

Raster input representing a ground surface. Must be in UTM coordinates.

Tip: Very Large images require enough processing time, it is recommended to split large images into smaller images using the watershed.

**Work Schedule**

The working range determines the degree of detail of the analysis. During the automated generation of the drainage system, prior to the measurement of the RDE index, you need to establish a value flow accumulation threshold to select the cells that will be counted as channels (Jenson & Domingue, 1988). Therefore the tool uses the working range value and the cell size (cellsize) of the EAW.

Threshold = (Working range \* 3) / (cellsize \* 10)

Only numeric characters must be entered in this field. For example, type the scale as 100,000, not 1: 100,000 or 100,000.

**Equidistance Meters**

The value of the altimetric range that determines the size of the analyzed drainage segments. equidistance very small values can generate a very large data density and large equidistance values decrease the accuracy of the results. A range of values that provides satisfactory results is between 5 and 10.

**Output Folder**

Folder where the files knickpoints and drainage system (optional) will be saved.

**File Name Knickpoints**

Feature point layer containing the anomalies of RDE (knickpoints).

**Save Drainage Network**

Save the drainage system used to measure the RDE in the same output folder.

**Drainage Network File Name**

The drainage system used to measure the RDE.

The next step – and last step on the *Knickpoint finder* side of the preprocessing – was joining the individual TIFF files of the DEM into a single raster, and then projecting that raster into UTM coordinates. The former was easily done using the built-in **Mosaic to New Raster** tool, and the latter was accomplished with the **Project Raster** tool to project the spatial reference from *NZGD2000\_New\_Zealand\_Transverse\_Mercator\_2000* into *WGS\_1984\_UTM\_Zone\_60S*. Before

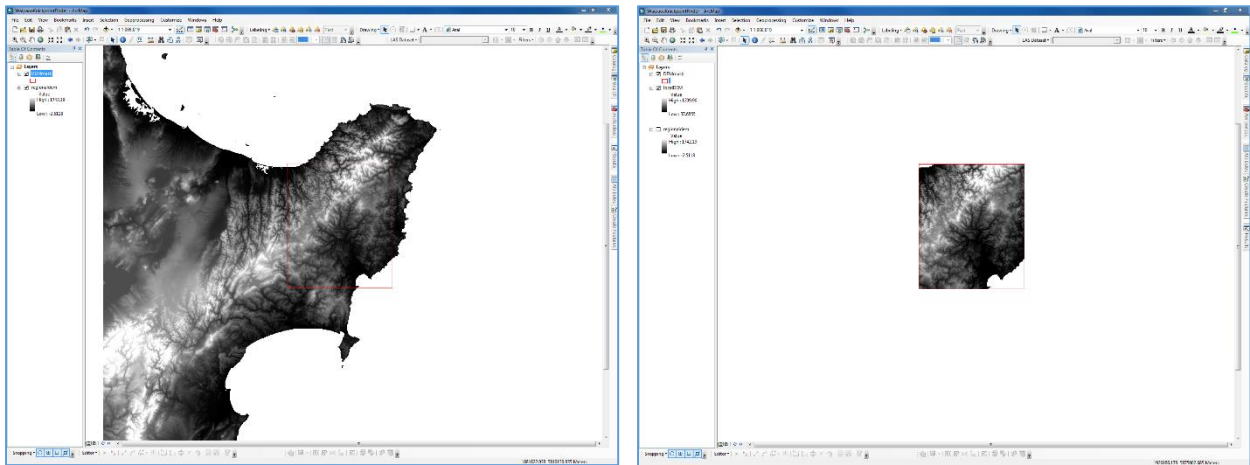


Figure 3. Image of the 25 meter NZDEM before (left) and after (right) application of the *Extract by Mask* tool.

projecting the DEM, I decided to try to cut down on future data processing and analysis times by masking the island-wide coverage down to only cover the Waipaoa watershed.

The other side of the preprocessing phase was all about preparing Crosby and Whipple’s map of observed knickpoints for spatial analysis. First, the map itself had to be extracted from the digital PDF of their paper, which I accomplished using Adobe Photoshop: changing the image to an RGB index, and using the magic wand selection tool to isolate the image of the basin from its background.

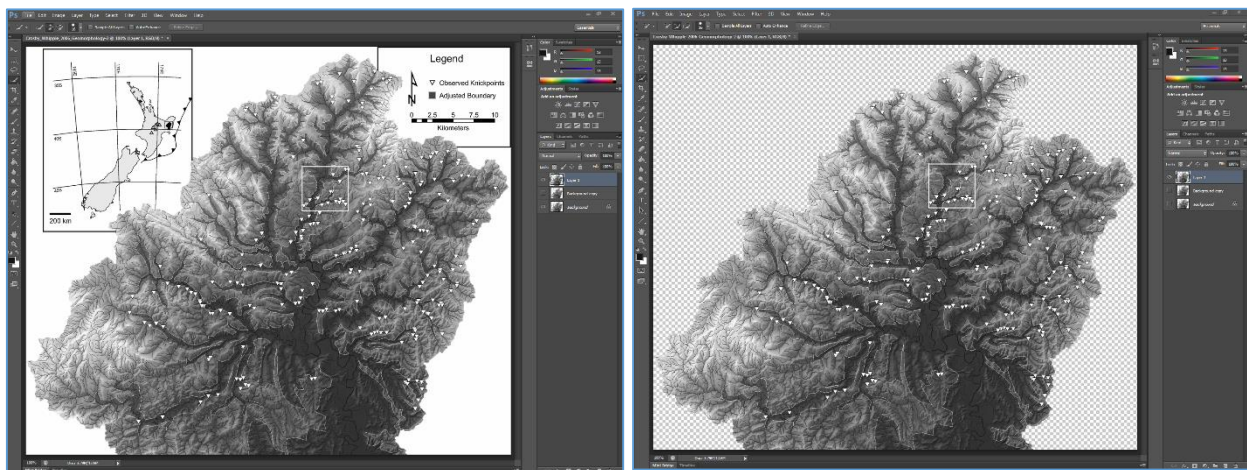


Figure 4. Image of the Waipaoa Watershed before (left) and after (right) isolation, and background removal.

After that, it was time to put that image into ArcMap and begin georeferencing it – which presented a challenge of its own considering the image itself has very few features to georeference it to; in the end, all I had to work off of was the intersection of river channels, which necessitated the building of a drainage network shapefile using the tools in the ArcHydro toolbox. The process for this was rather straightforward,

and involved taking the localized DEM I had just created by mask extraction and putting it through the following workflow:

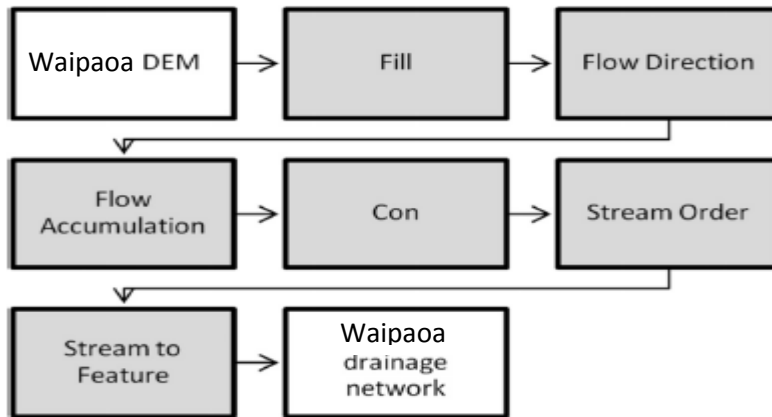


Figure 5. Flowchart of the procedure sequence required to generate the drainage network of a selected area from a digital elevation model. Reproduced from Queiroz et. al 2015.

The only tweaking that I found necessary was playing around with the SQL statement in the **Con** tool in order to get a drainage network with as similar as a channel pattern – with respect to the extent of the stream ordering – to the one in Crosby and Whipple’s map as possible. In the end, I found the results of the statement “VALUE > 250” to be complex enough to both mimic their map and provide enough stream intersections for the georeferencing. Ultimately, I was very satisfied with the following output:

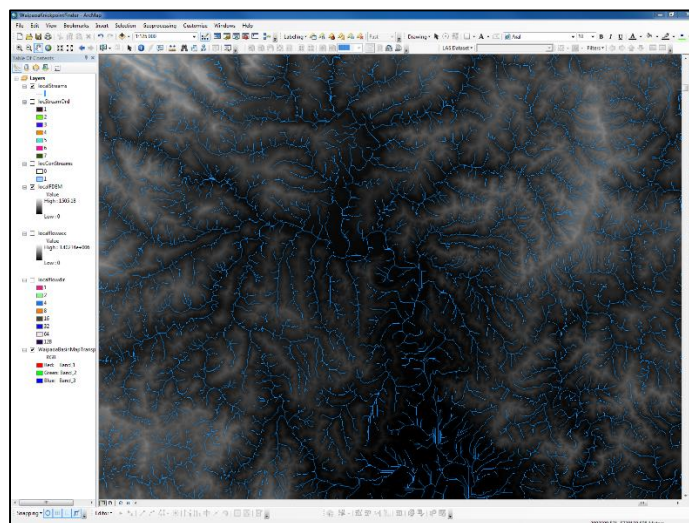
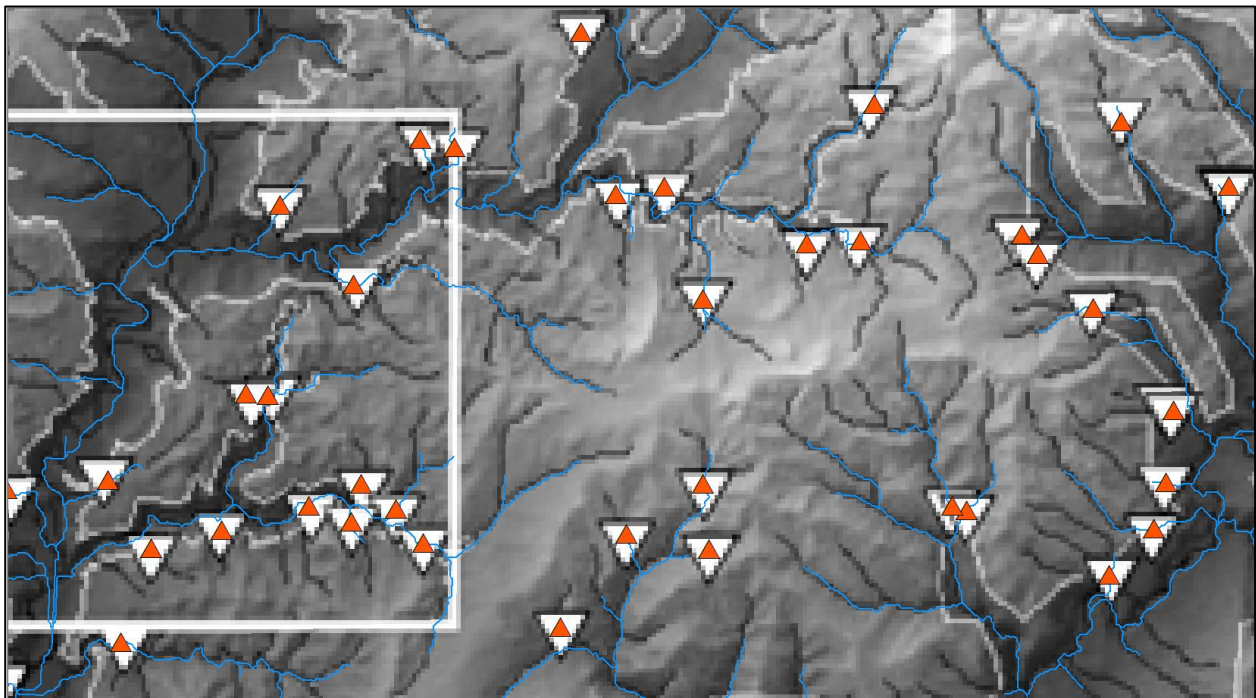


Figure 6. Drainage pattern of the Waipaoa watershed using 250 for the threshold flow accumulation value in the conditional statement of the **Con** tool.

Next was the lengthy and tedious process of georeferencing the image using the most-identifiable stream intersection I could, which were most often the ones nearest to channel headwaters where topography prevented the channel pattern from being much different between my generated pattern and the one in Crosby and Whipple's map. In the end, I used a 3<sup>rd</sup> order transformation based off of 24 widely-spread correlated spots that resulted in a RMS error of just 33.6887 meters – which I found satisfactory considering the resolution of my data is 25 meters.

Then it became time to digitize all 236 of the observed knickpoints in Crosby and Whipple's map into my project. The symbology for the points in their map ended up being a bit large in my digitized, georeferenced version of it, which made precise and accurate placement of my points a little challenging. To minimize what error I could that would result from this, I established a rule-of-thumb to place spots along my generated stream features at points nearest to the center of the upside-down triangle symbol used in their paper. Once all the spots had been placed, it became time to start the spatial analysis.



*Figure 7. Orange triangles symbolizing observed knickpoint spot placement against Crosby and Whipple's spots.*

## Arc Processing – Running *Knickpoint finder*

Much to my surprise, this was the most tedious and time-consuming step of all. While *Knickpoint finder* seemed easy enough to navigate and use – translation requirements aside – there ended up being innumerable hiccups and errors in the process. Before I got to those though, I had to decide upon two important input variables for the tool: the “working range” and the “altimetric range”. For the former I went with a value of 50,000 (input as ‘50000’) as dictated by the documented scale limitations inherent in the DEM I used; for the later, after some experimenting, I decided upon the value of 50 (i.e. 50 meters) – reflecting the taller end of the observed and documented knickpoints. This not only helped cut down on processing time, but it also dramatically reduced the number of spots the script would declare as knickpoints. After many, many failed attempts of running the tool, I finally had some successful runs that produced data I can work with.

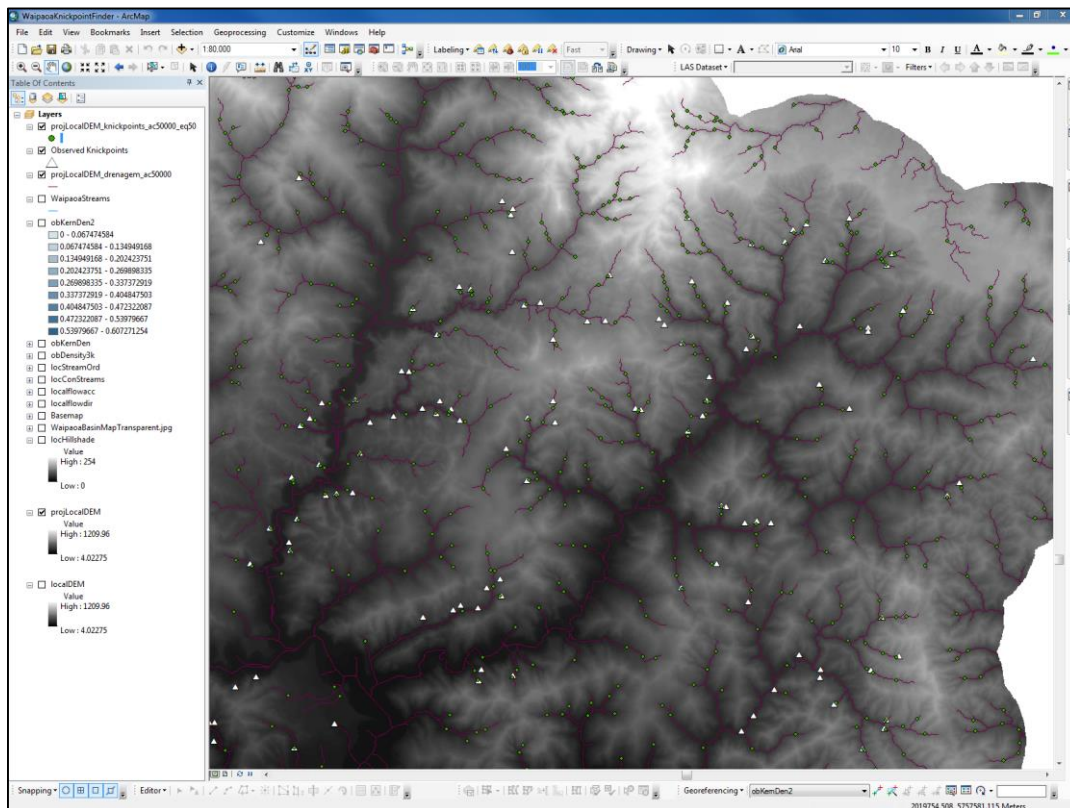


Figure 8. A Screenshot of the final successful run of *Knickpoint finder* that shows “identified” knickpoints as green dots, set against a DEM background, a purple drainage network, and white spots that represent observed knickpoints.

## Preliminary Results, and Future Work

While it may have taken quite some time, with enough attention to detail and careful consideration, *Knickpoint finder* looks like it has produced some promising, albeit hit-and-miss, results:

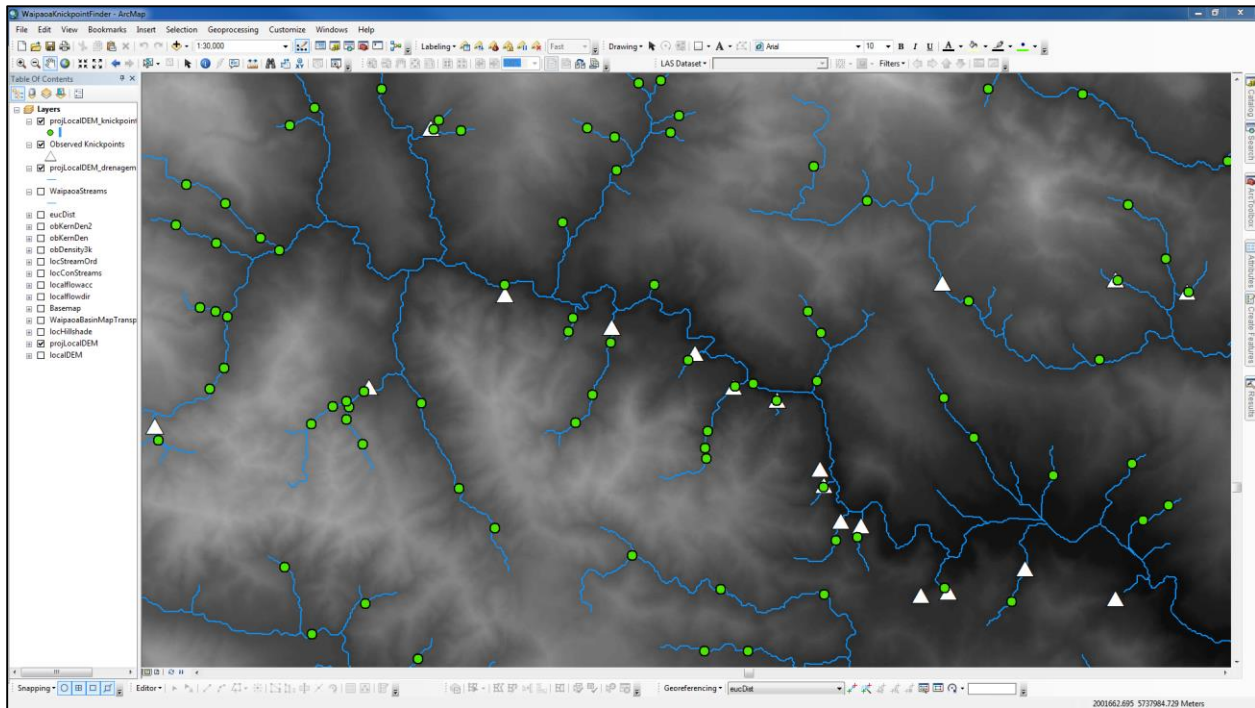


Figure 9. Preliminary results from *Knickpoint finder* that shows some successfully picked spots where a green dot overlays a white triangle.

Originally I had planned on comparing the point-map it gave me with that of Crosby and Whipple's by building point-density or kernel-density maps of the two methods, it quickly became clear that *Knickpoint finder* simply "identifies" way too many spots to make any meaningful density-based analysis - even when given strict parameters. Another disadvantage of the script is not having control over the conditional statement that it runs in generating its own drainage pattern that, for this project, has left many observed knickpoints in the lower-order (i.e. nearest to headwaters) reaches of the watershed completely unanalyzed. Perhaps the largest –and absolutely the most frustrating disadvantage – of the tool is that it lacks any sort of robust description of errors that it regularly encounters. This ultimately result in hours running the tool wasted without knowing why it failed, or giving any indication on how to solve the problem.



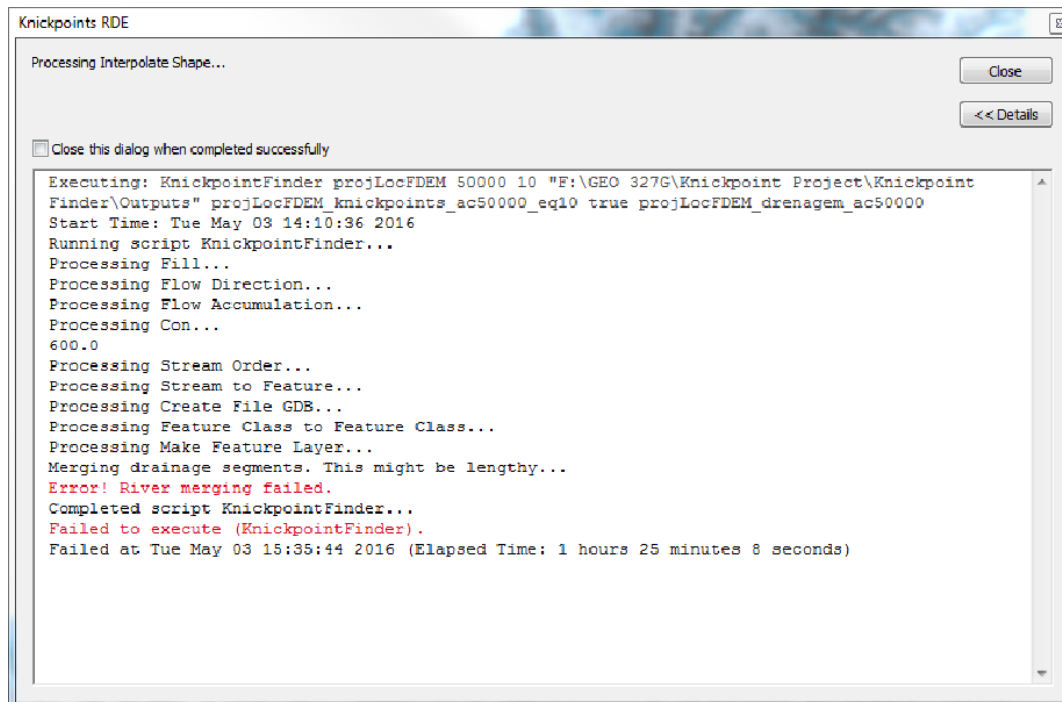


Figure 10. A screenshot of one of innumerable iterations of the tool where it failed for an unsatisfactorily described reason after an unacceptably long time.

Even so, it is clear that the tool does indeed as some potential in that it wasn't completely off (Figure 9). With some modifications to the original Python script, I would bet that the accuracy of the tool can be improved. After making such customization, I plan on reassessing the precision and accuracy of the tool by measuring how closely it can place spots to observed location of knickpoints using a dartboard-type approach using the built-in **Multiple Ring Buffer** tool, or perhaps another method based off of using raster algebra and the **Euclidean Distance** tool.

## Works Cited

- Bierman, Paul R., and David R. Montgomery. *Key Concepts in Geomorphology*. N.p.: W. H. Freeman, 2013. Print.
- Crosby, Benjamin T., and Kelin X. Whipple. "Knickpoint Initiation and Distribution within Fluvial Networks: 236 Waterfalls in the Waipaoa River, North Island, New Zealand." *Geomorphology* 82.1-2 (2006): 16-38. Web.
- Queiroz, G.I., E. Salamuni, and E.r. Nascimento. "Knickpoint Finder: A Software Tool That Improves Neotectonic Analysis." *Computers & Geosciences* 76 (2015): 80-87. Web.