

Using GIS to Study Potential Lahar Hazards from Hekla and Grímsvötn,
Southern Iceland

The University of Texas at Austin

Jackson School of Geosciences

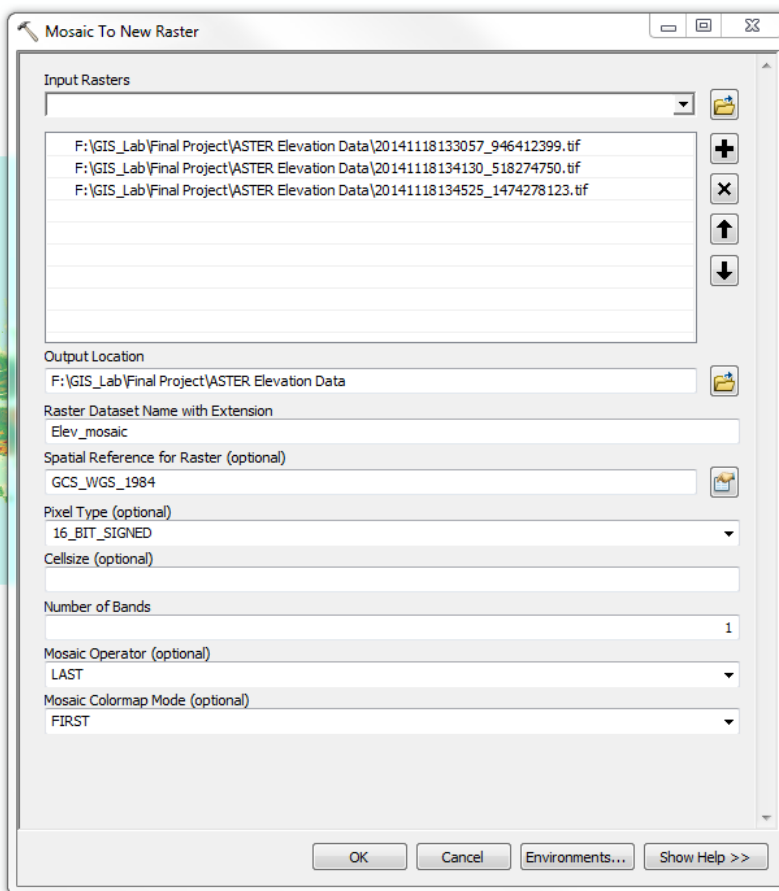
Ian Yeats

12/04/2014

Introduction

Iceland is an island nation far in the northern hemisphere, with a portion of the country included in the Arctic Circle. Its position over a magmatic hotspot and the Atlantic mid-ocean ridge cause it to have a very active volcanic setting. Some of these eruptions, like that of Eyjafjallajökull in 2010, make worldwide news due to large ash clouds disrupting global air traffic, but many of them go unnoticed to the world. Hence, Icelandic people are very accustomed to responding to volcanic hazards, and it is essential to understand the possible risks involved with living near these active volcanoes. One major hazard associated with volcanism is lahars, or jökulhlaups in Icelandic. In Iceland, these form from the rapid melting of glaciers and snow and the addition of large quantities of volcanic material. These are very large, and sometimes hot, mudslides that even occur without a present eruption. This project used ArcMap to predict potential flow paths of lahars from two major volcanoes in southern Iceland: Hekla and Grímsvötn. Both of these have very active histories, with their last eruptions occurring in 2000 and 2011, respectively. The end goal is to produce maps that highlight these hazards, as well as towns and roads that may stand in their way.

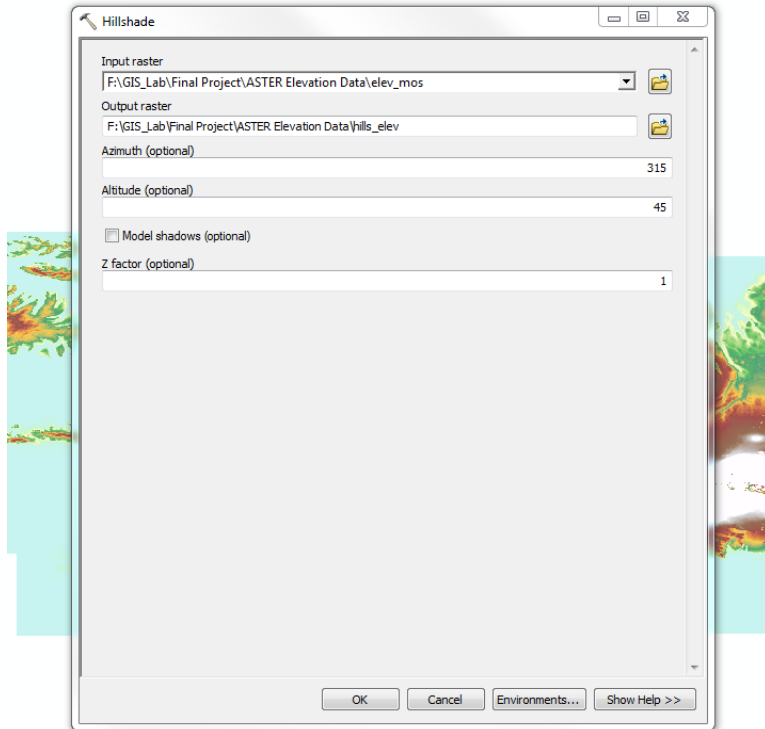
Data and Analysis



This project required detailed national elevation data, a country boundary, roads, towns, rivers, and the locations of Icelandic volcanoes. The elevation data was gathered from the USGS Global Data Explorer (gdex.cr.usgs.gov). It is 30 meter ASTER Global DEM V2 data with a GCS WGS 1984 datum. It was downloaded in 3 segments as a Geotiff file. Since the data was downloaded in 3 segments, I made a raster mosaic using the “Mosaic to New Raster” tool (Figure 1).

Once the elevation data was in one raster, I made a hillshade of the mosaic using the “Hillshade” tool in the Spatial Analysis toolbox (Figure 2).

Figure 1: Mosaic to New Raster tool on the 3 ASTER DEM Geotiff files



The elevation was symbolized with 30% transparency over the hillshade. To eliminate the distortion involved with high latitudes, the data frame coordinate system was projected to WGS 84 UTM Zone 28N. The road and river shapefiles were downloaded as zipped files from www.mapcruzin.com. These files had to be unzipped before using them in ArcMap. The political boundary was downloaded from www.diva-gis.org as a zipped shapefile. This was unzipped and then added to the map document to use as a mask to clip the elevation and hillshade files. This clipping was done using the “Extract by Mask” tool in the Spatial Analysis toolbox (Figure 3).

Figure 2: Creating a hillshade of the ASTER DEM

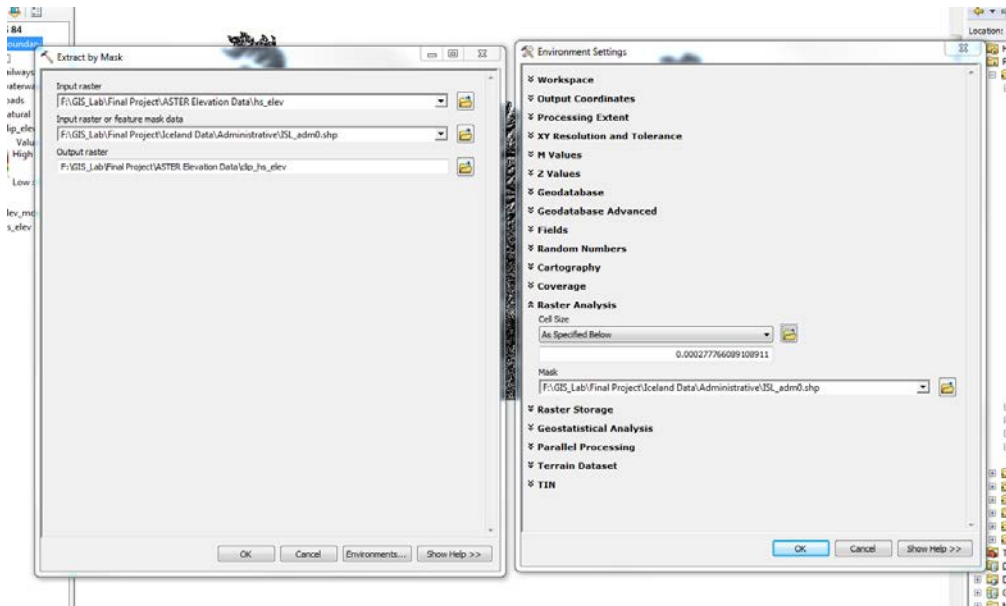


Figure 3: Extraction by Mask, with the political boundary as the mask

This resulted in an undistorted country-scale map for analysis (Figure 4).

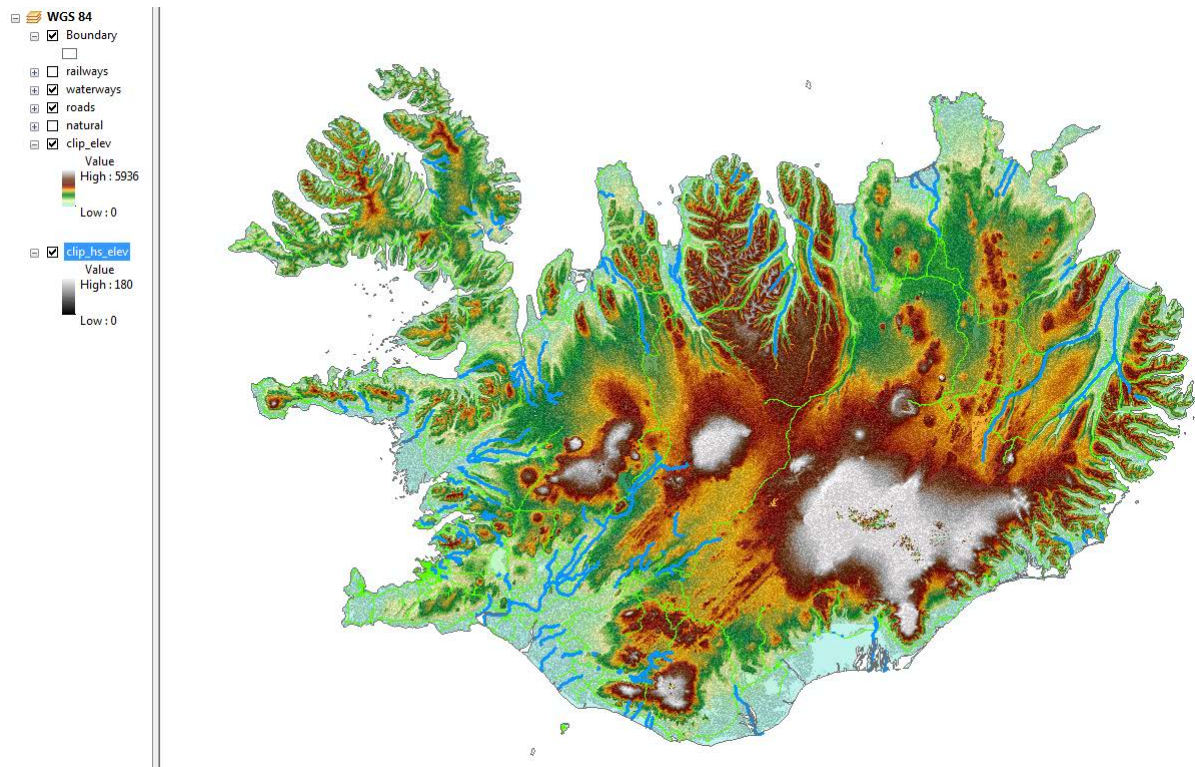


Figure 4: Results of projection and clipping

While Iceland has over 130 volcanoes, I chose to only add a few major ones within the region of Hekla and Grímsvötn. These included Hekla, Grímsvötn, Askja, Katla, and Eyjafjallajökull. First, I found the geographic coordinates of the volcanoes on www.geographic.org and added them to the map digitally during an editing session. To do this, I created a File Geodatabase in ArcCatalog with a Point Feature class for volcanoes. Then I toggled the map and plotted the points of the volcanoes.

The towns were added by downloading a zipped “places” shapefile from www.mapcruzin.com. After unzipping the files and adding them to the data frame, I used the “Clip by Selection” tool to leave only those places that were cities, towns, or villages. The selection was done by a SQL query by attributes (Figure 5).

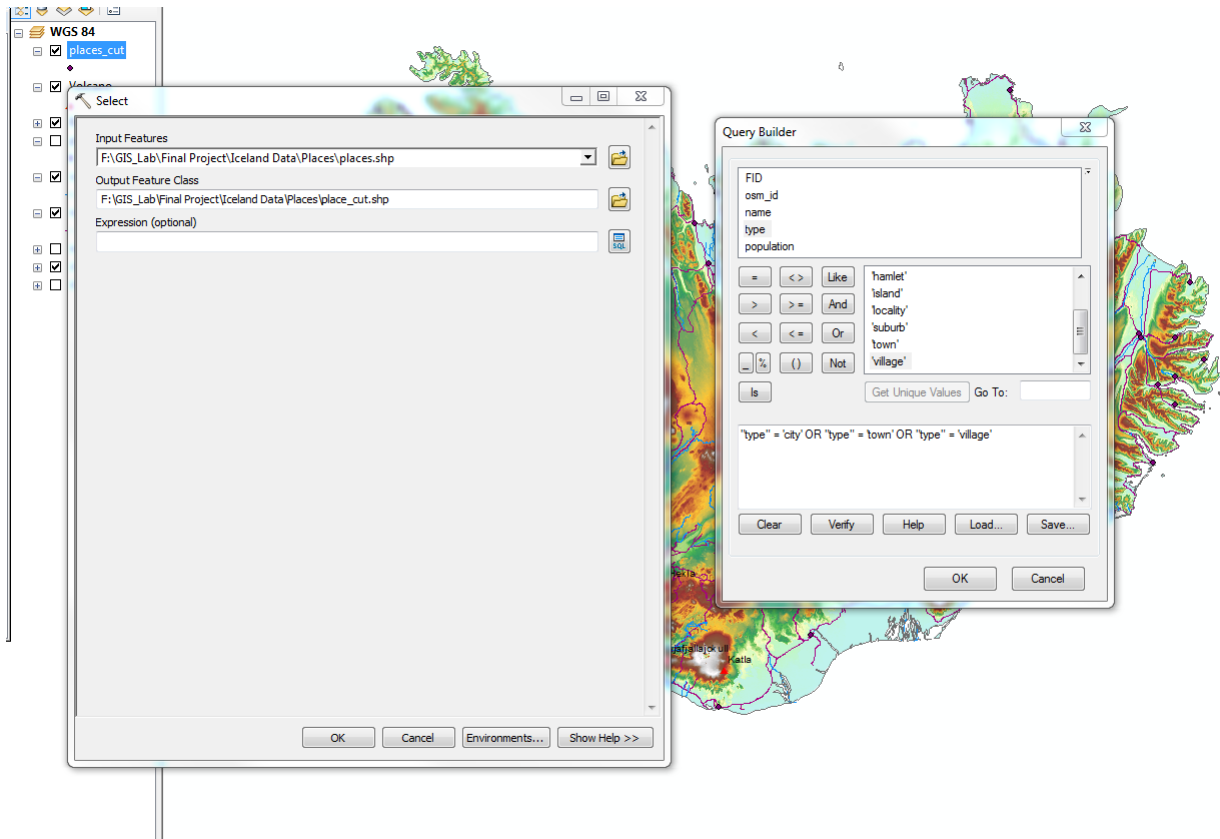
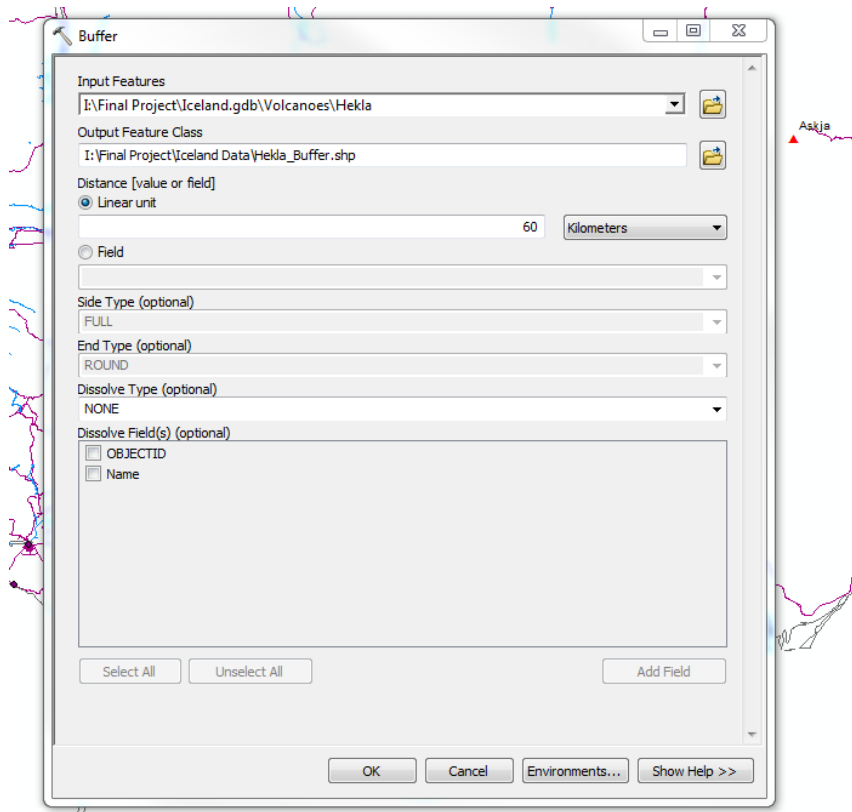


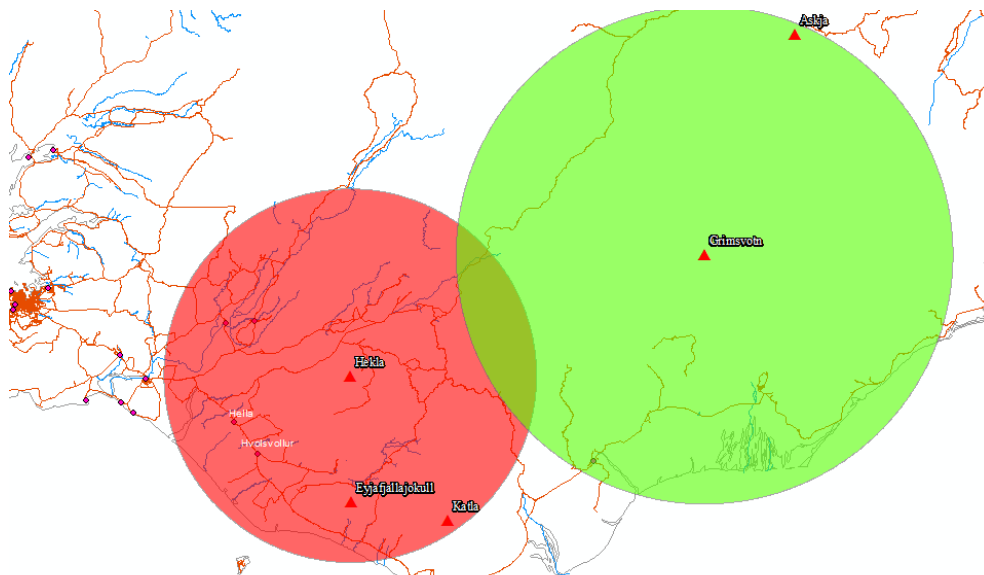
Figure 5: Clipping "places" by a selection of attributes using an SQL query

The highly detailed ASTER DEM was exceptional, but it also proved to be very large and slow to process. So I made a new document in which I would do all the detailed processing and analysis. To cut the elevation and hillshade files down, I made a buffer around the two volcanoes of interest. To select the individual volcanoes to make a ring buffer, I had to make separate feature classes for each. This was done the same way as before, and each point feature class was also put into the File Geodatabase. As far as actually plotting the point, I simply had to place it in the same spot as before, which was ensured with snapping. With the point feature classes created, I used the "Buffer" tool to create a ring buffer around each volcano.



The buffers were used as boundaries for the lahar risk zones. The buffer around Hekla was set to 60 km, and the buffer around Grímsvötn was set to 80 km. These were set with two things in mind: lahars have been recorded as being capable of flowing hundreds of kilometers from their source, and both of these volcanoes are at the southern edge of the Icelandic highlands by the south shore. Hence, each buffer allowed for flows to completely reach the sea (Figure 7).

Figure 6: Creating a hazard ring buffer around Hekla



With these buffers created, I was able to clip the elevation and hillshade layers to each buffer using the same technique used to clip to the political boundary.

Figure 7: Ring buffers around each volcano to aid in data analysis

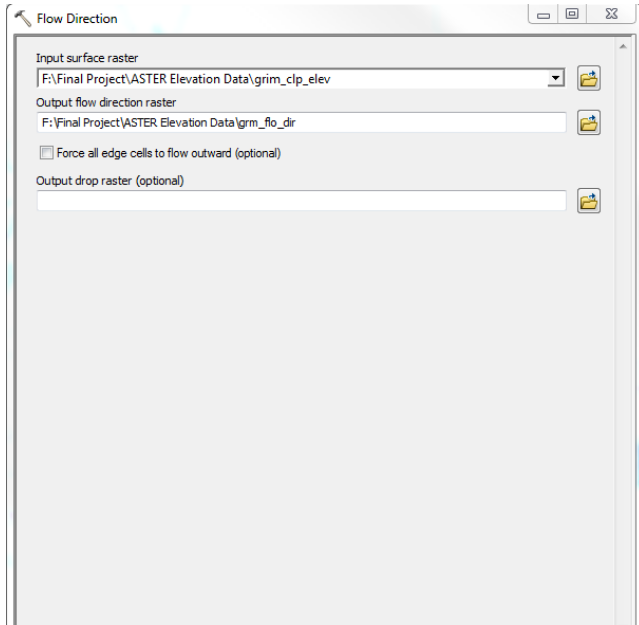


Figure 8: Flow Direction raster creation with the clipped elevation raster as input

The next step was to determine potential flow patterns for the jökulhlaups. In this region, the rivers shapefile was rather scarce, so it was necessary to predict new channels the flows might take. To do this I used the “Flow Direction” tool in the hydrology toolbar (Figure 8).

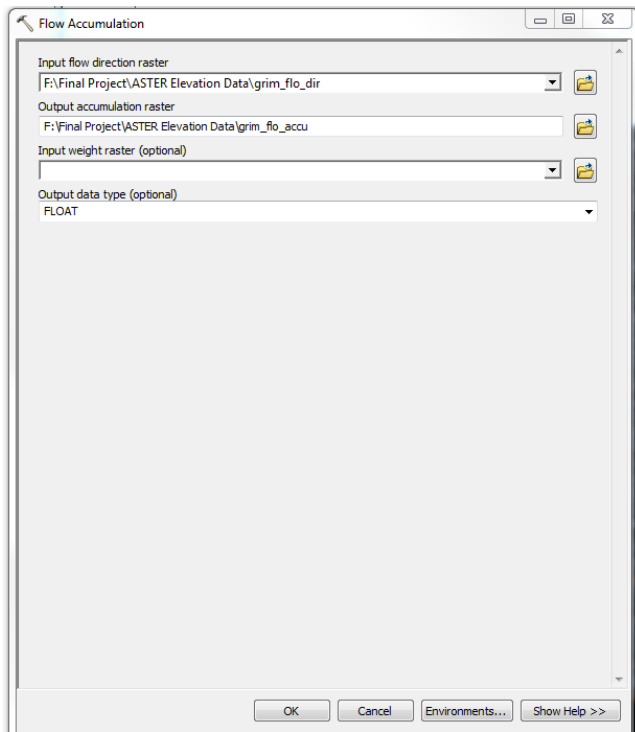


Figure 9: The Flow Accumulation tool with the Flow Direction raster as input

From here, I used the “Flow Accumulation” tool, with the flow direction raster as input, to generate predicted areas of high flow accumulation, or channels (Figure 9).

These results, however, were very fuzzy and unusable for analysis. To fix the problem, I used the “Fill” tool from the Hydrology toolbar to smooth out the elevation raster (Figure 10).

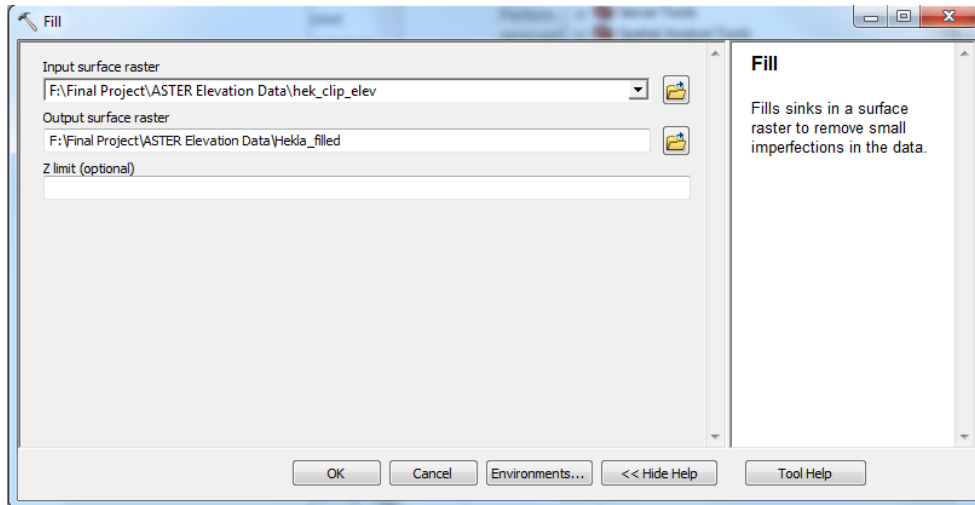


Figure 10: Creating the filled elevation raster for improved processing

Following the fix, I re-made the flow direction and flow accumulation rasters. Initially, the flow accumulation raster was very difficult to discern, so I changed the symbology from stretched to classified with two classifications. The raster was symbolized with the VALUE field, so the numbers corresponded to the number of cells that drained into that cell. In the end, it worked best using a threshold value of 10000, such that only cells with greater than that threshold value were white, and the rest were black (Figure 11).

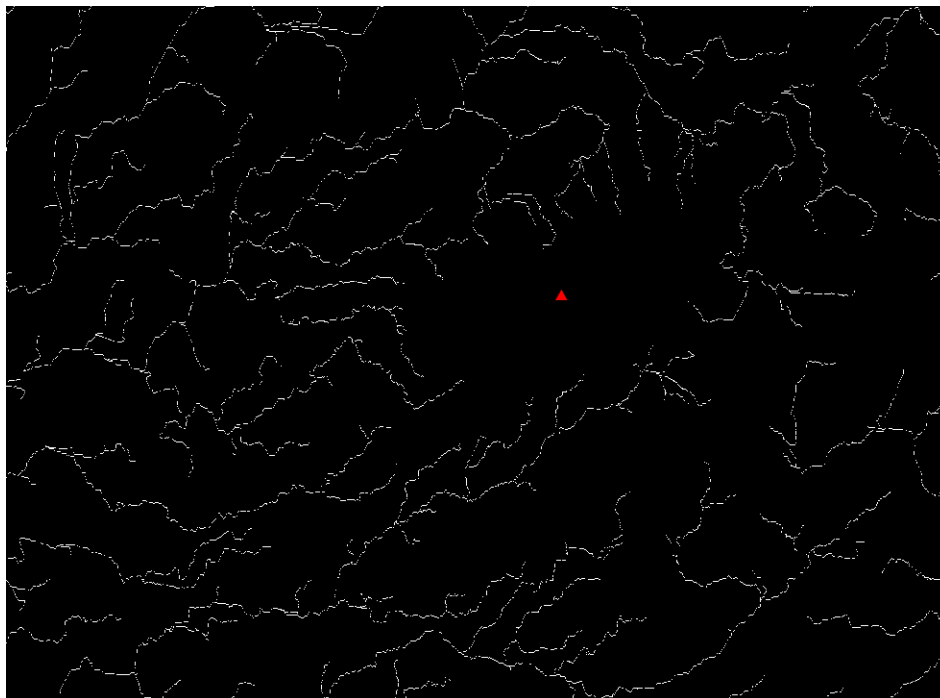


Figure 11: Clean results of the Flow Accumulation tool, where the white are areas of high accumulation

Before converting the flow accumulation raster data to a vector data, it had to be converted to a stream raster, such that only those cells delineated as streams had values. This was done with the Raster

Calculator. I set up a conditional test to assign the value of “1” to any cell in the flow accumulation raster with a value greater than 10000, and a Null value to any cell with values equal to or less than 10000 (Figure 12).

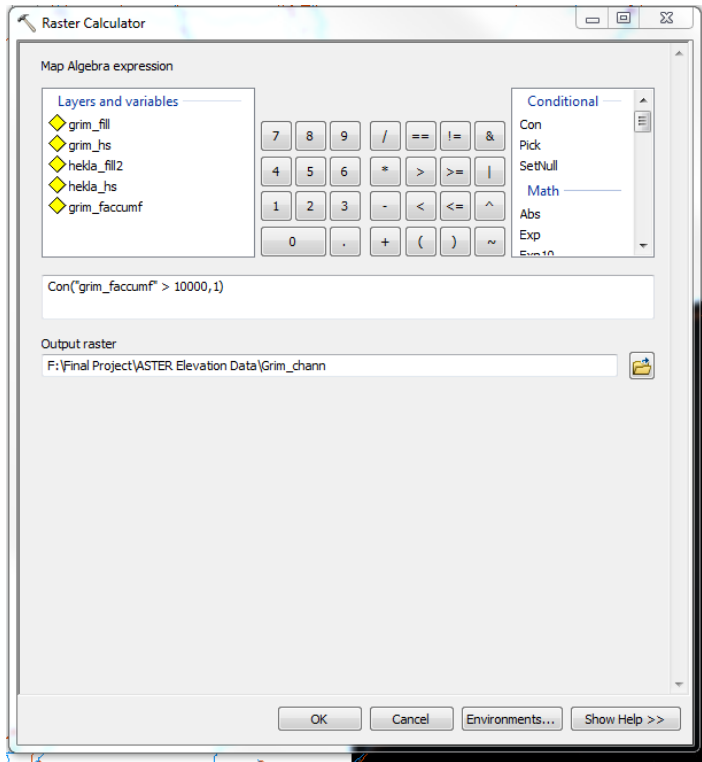


Figure 12: Creating a stream raster with the Raster Calculator

This stream raster was converted to a vector dataset using the “Stream to Feature” tool in the Hydrology toolset (Figure 13).

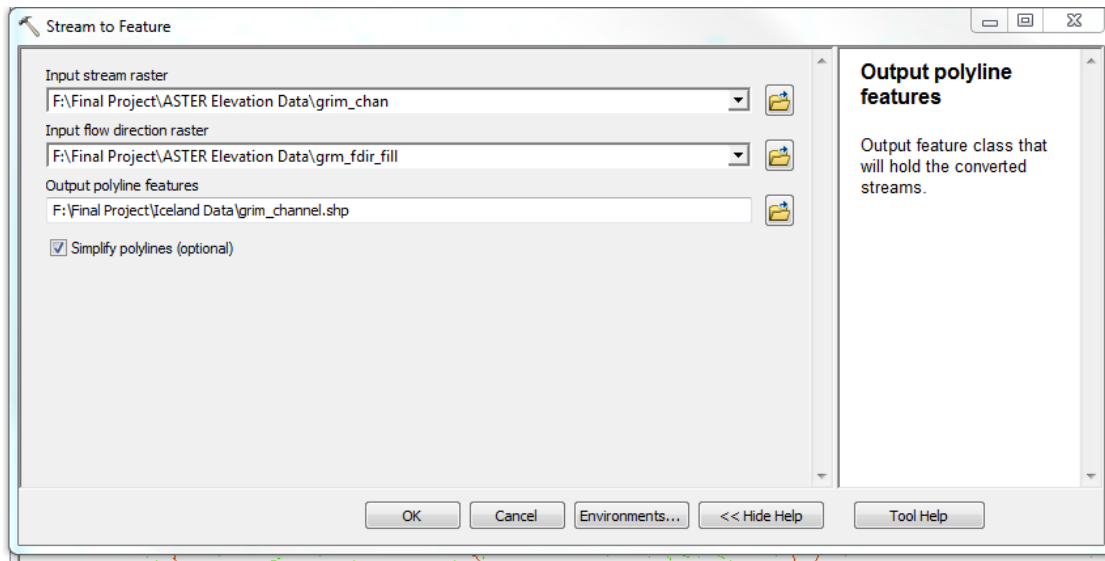


Figure 13: Stream to Feature tool to convert a raster dataset to a vector dataset

This resulted in a full system of predicted channels within the volcano hazard buffers (Figure 14).

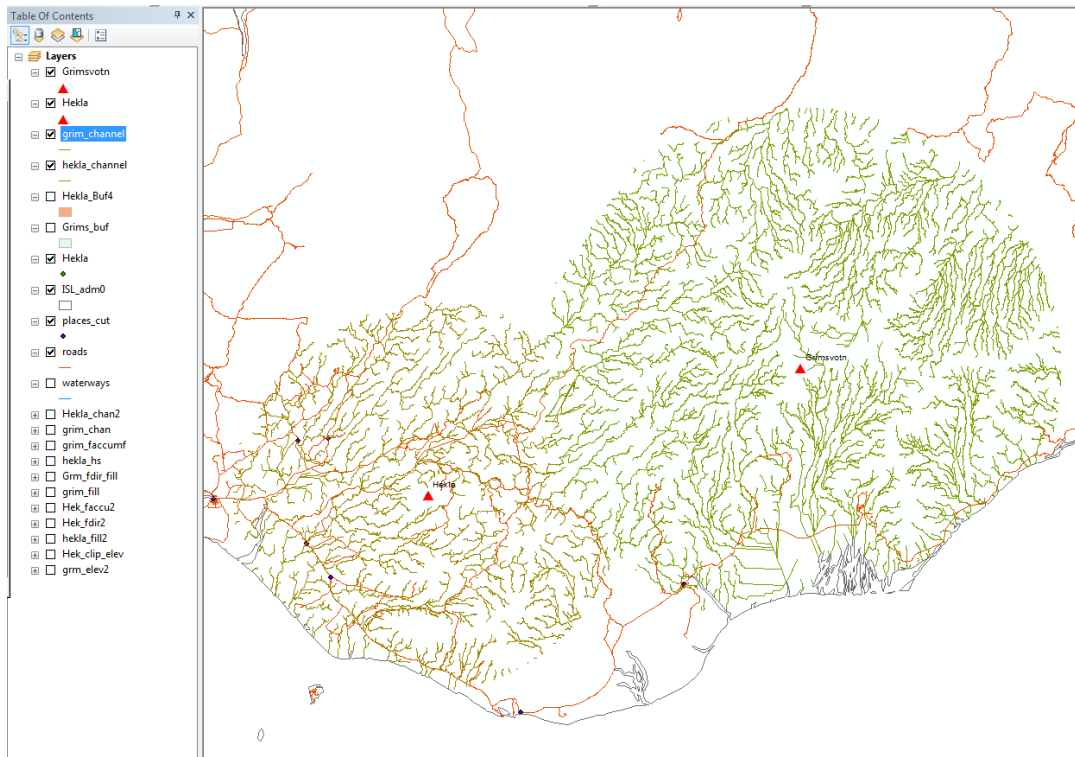


Figure 14: Result of the Stream to Feature tool, with predicted channels shown in green

To identify which of these channels were relevant to the risk assessment, I started selecting channels that were on the slopes of the volcanoes and continued selecting downstream until I reached the ocean. To make these a new layer, I exported the selected features to a new shapefile (Figure 15).

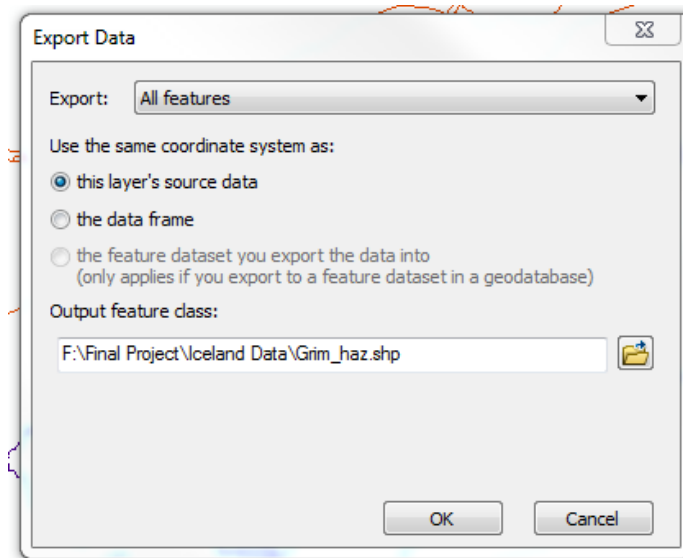


Figure 15: Exporting selected rivers to a new layer

To model the lahars, I created buffers around the channels. I chose to model small and large lahars, using the same parameters as specified in lab 10. Large lahars were assumed to be capable of traveling 80 km, and small lahars were assumed to be capable of traveling 20 km from their source. I used 1/20 of the travel distance for the width of each buffer (Figure 16).

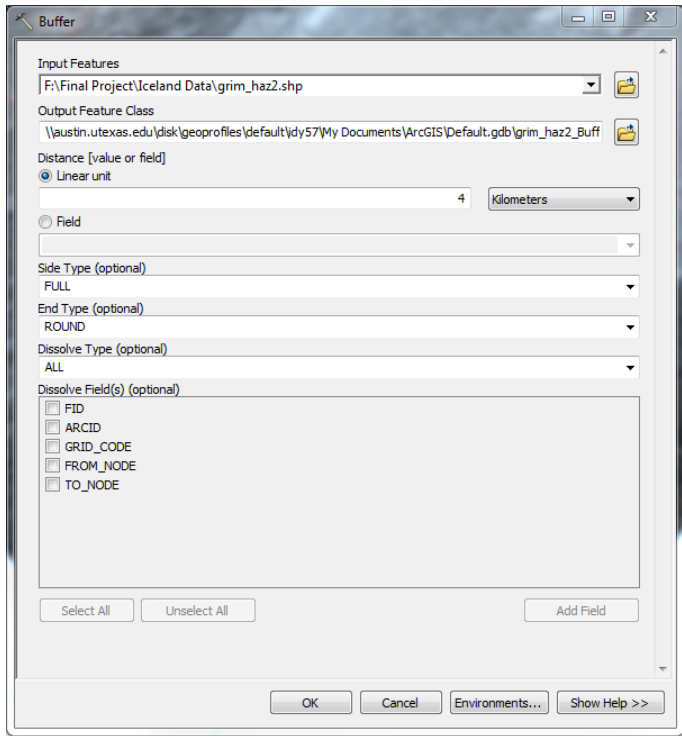


Figure 16: Using the Buffer tool to simulate a large lahar with a width of 4 km

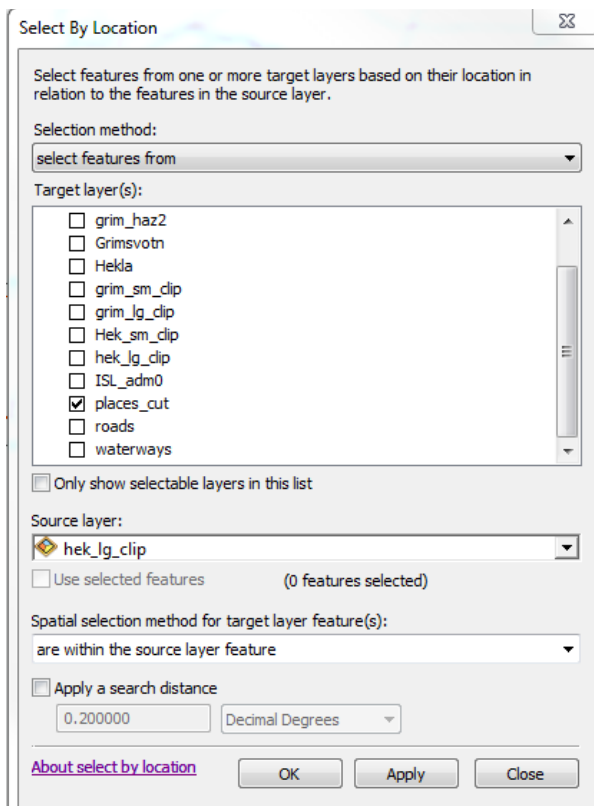


Figure 17: Select by Location such that selected features are within the source layer

These values may not be exact, but should serve as suitable estimations for a base level hazard assessment. To clip the small lahar hazards to 20 km from the source, I made another ring buffer around the volcano with a 20 km radius. I then clipped the small lahar hazard to that ring. I clipped the large lahar file to the Iceland border file to keep the data landward.

Next I had to identify which towns were at risk, and which roads were at risk. To do this, I did the Select By Location option (Figure 17).

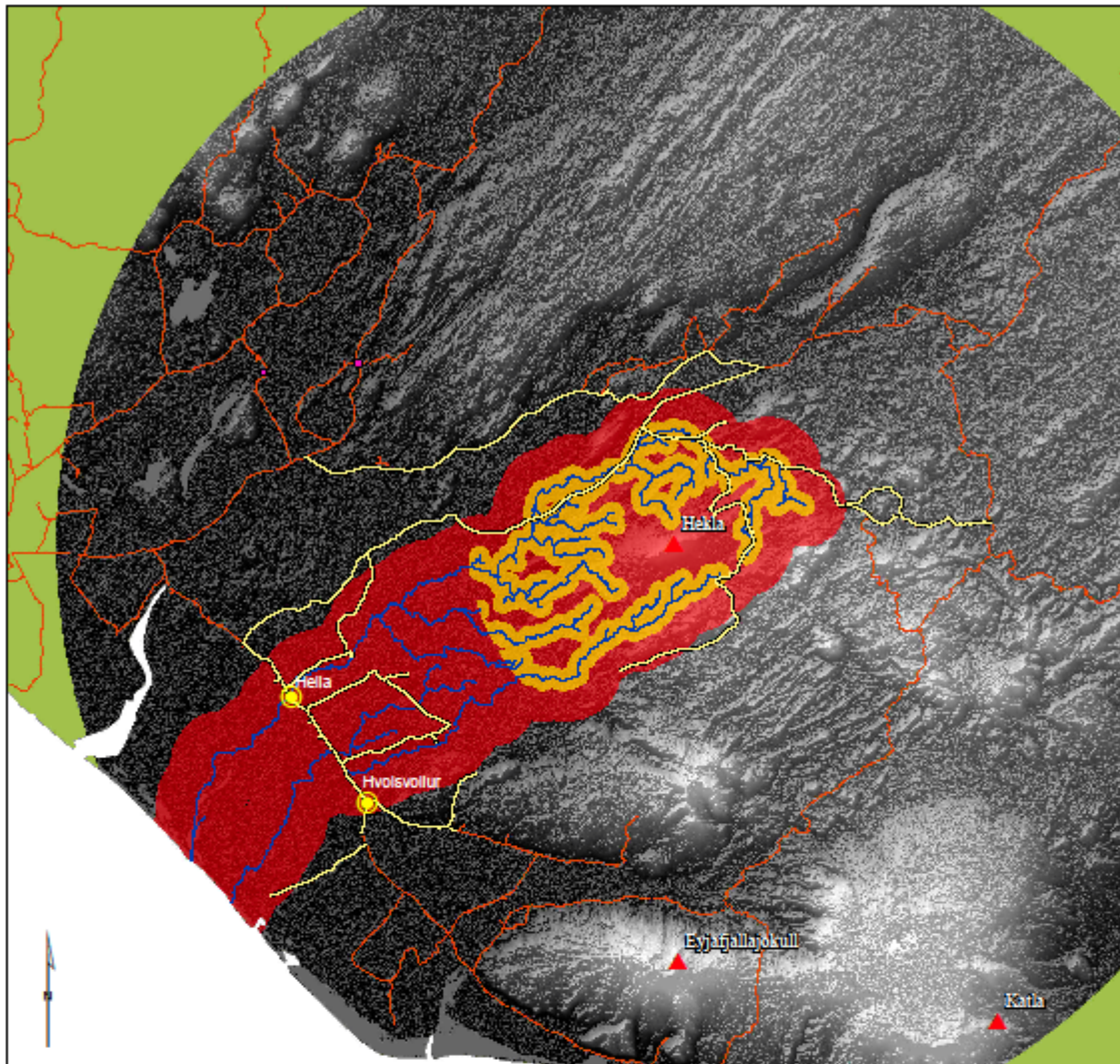
I converted these town labels to annotations and symbolized them such that they would stand out. The roads were selected using the same process, and were symbolized to stand out on the map. In order to symbolize them differently from the other roads, I had to export the selected roads to a new layer.

Finally, I made map documents showing the hazards with affected towns and roads (Figures 18 and 19). The Iceland border shapefile was symbolized with a green background to distinguish land from ocean. These were mapped over the elevation and hillshade files as well, so a sense of topography was preserved. I also made a country-scale map to show the regional significance of these hazards (Figure 20). I made a grid for the final layout with markers every 1 degree. The graticule line at 15 degrees west is perfectly vertical. This is because of the projection into UTM Zone 28N, which has its central meridian at 15 degrees west.

Hekla Lahar Hazard Map

WGS 1984 Complex UTM Zone 28N

Ian Yeats
12/04/2014



1:550,000

0 5 10 20 30 40 Kilometers

Legend

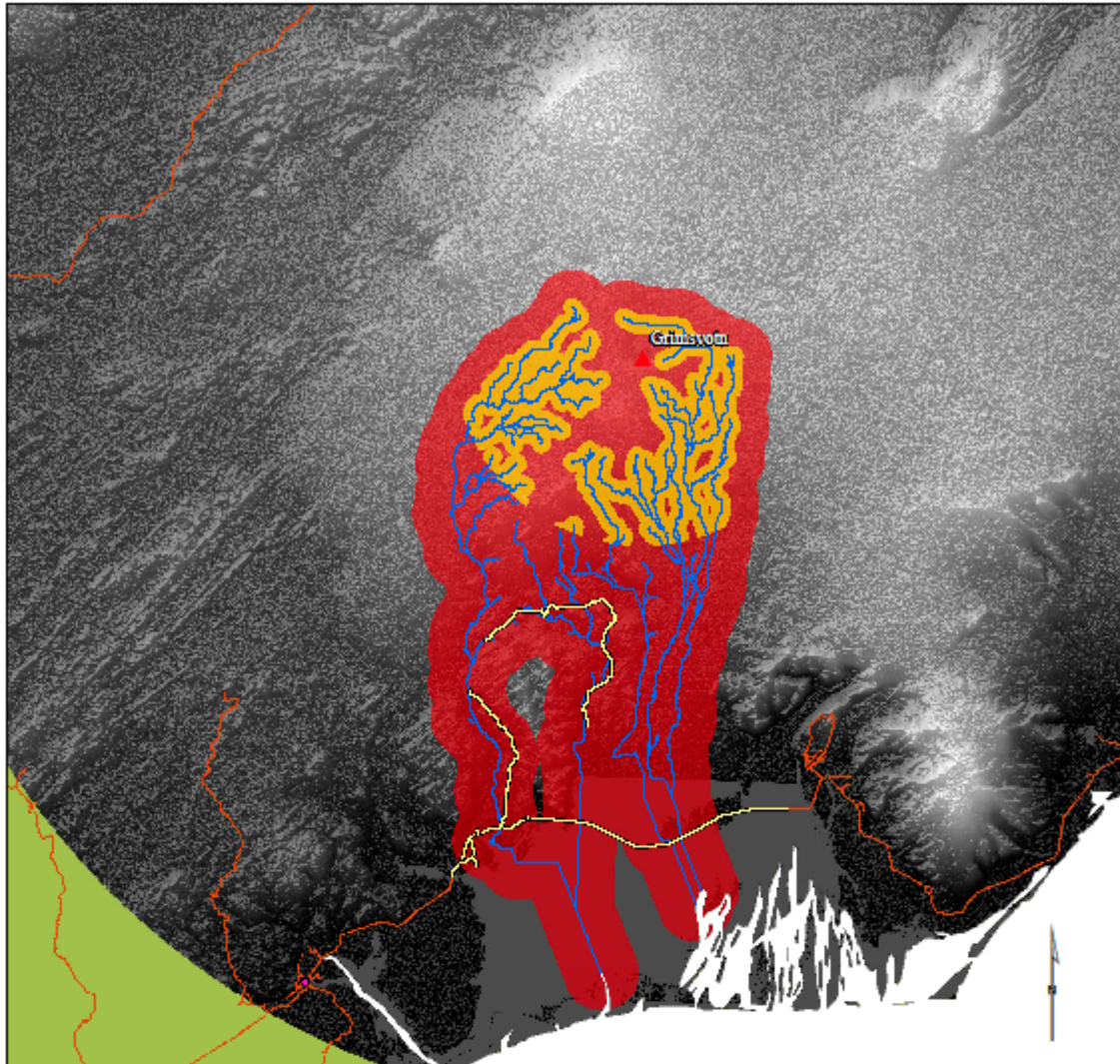
- | | | |
|----------------------|----------------------|-----------------------|
| Hazard-affected Town | Predicted Flow Paths | Roads |
| Towns | Small Lahar | Hekla Hazardous Roads |
| Volcano | Large Lahar | Iceland Border |

Figure 18: The Hekla lahar hazards with affected roads and towns overlying the elevation and hillshade models.

Grimsvotn Lahar Hazard Map

WGS 1984 Complex UTM Zone 28N

Ian Yeats
12/04/2014



1:600,000

0 5 10 20 30 40 Kilometers

Legend

- | | | |
|-----------------------------|------------------------|------------------|
| ● Hazard-affected Town | — Predicted Flow Paths | ★ Towns |
| ▲ Volcano | ■ Small Lahar | — Roads |
| — Grimsvotn Hazardous Roads | ■ Large Lahar | ■ Iceland Border |

Figure 19: The Grimsvötn lahar hazards with affected roads and towns overlaying the elevation and hillshade models

Country Map Showing Flow Hazards for Hekla and Grimsvotn, Iceland
 Ian Yeats
 12/04/2014

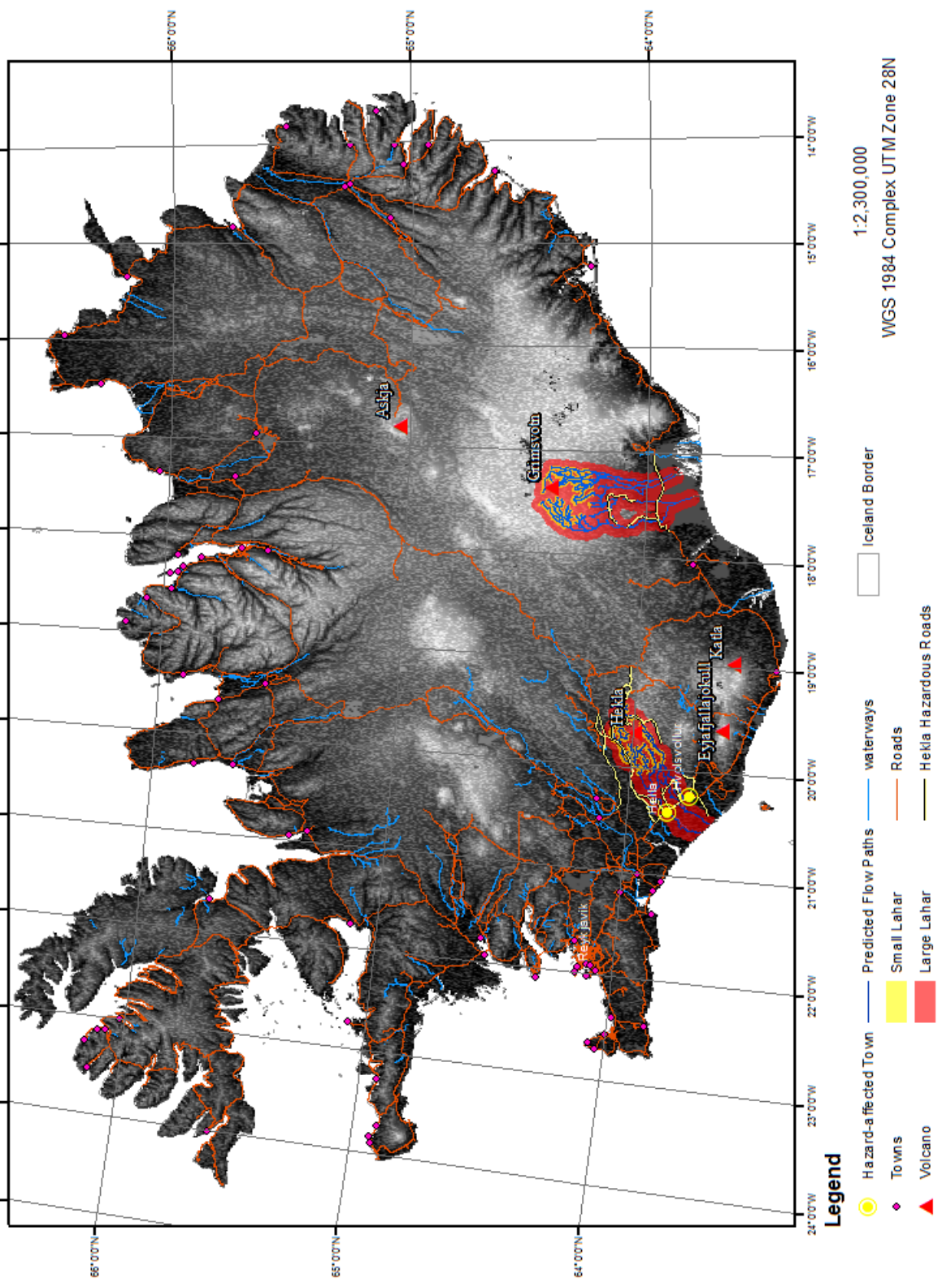


Figure 20: Map of Iceland showing the studied hazards

Conclusion

ArcMap is an excellent tool for assessing potential volcanic hazards. With a detailed DEM, I used the hydrology tools to predict potential flow paths that lahars might take. The ability to predict new flow patterns was vital for this project, because the available stream data for the areas of interest were sparse. Once the potential hazards were mapped, I was able to identify and symbolize areas of risk such as roads and towns. Studies like this are very important in a country like Iceland that has over 130 volcanoes, many of which are active. Hekla and Grímsvötn have had recent activity, which is why they were selected for this study. The towns of Hella and Hvolsvollur were marked as being in the hazard zone of large lahars originating from Hekla. If residents are aware of this risk, they may be better equipped to respond when lahars do occur. Lahars can occur even without a volcanic eruption, so it is important to be constantly prepared. Lahars originating from Grímsvötn did not appear to encounter any towns; however, it is possible that individuals live in the area, so the information may be of use for them. Both volcanoes present a risk to Iceland's Route 1, also known as the Ring Road. This is a major transportation route for both locals and tourists, so noting these hazards is important even for those who do not live in the area.

This project highlighted important hazard areas, but also has room for improvement. To take the assessment further, a more accurate model for the lahars could be used. For example, it would be ideal to map the flows such that they directly respond to topography, showing narrowing in valleys and fanning in basins.

References

Diva-GIS, Free Spatial Data. (Accessed on Nov. 20, 2014)

URL < <http://www.diva-gis.org/Data>>

Geographical Names. (Accessed Nov. 20, 2014)

URL < http://geographic.org/geographic_names/name.php?uni=-3654083&fid=2362&c=iceland>

Icelandic Met Office, Earthquakes and Volcanism (Accessed on Dec. 2, 2014)

URL < <http://en.vedur.is/earthquakes-and-volcanism/articles/nr/1874>>

MapCruzin, Free GIS Shapefiles, Software, Resources and Geography Maps. (Accessed on Nov. 20, 2014)

URL < <http://www.mapcruzin.com/free-iceland-arcgis-maps-shapefiles.htm>>

USGS Global Data Explorer. LP DAAC. (Accessed on Nov. 18, 2014)

URL < <http://gdex.cr.usgs.gov>>