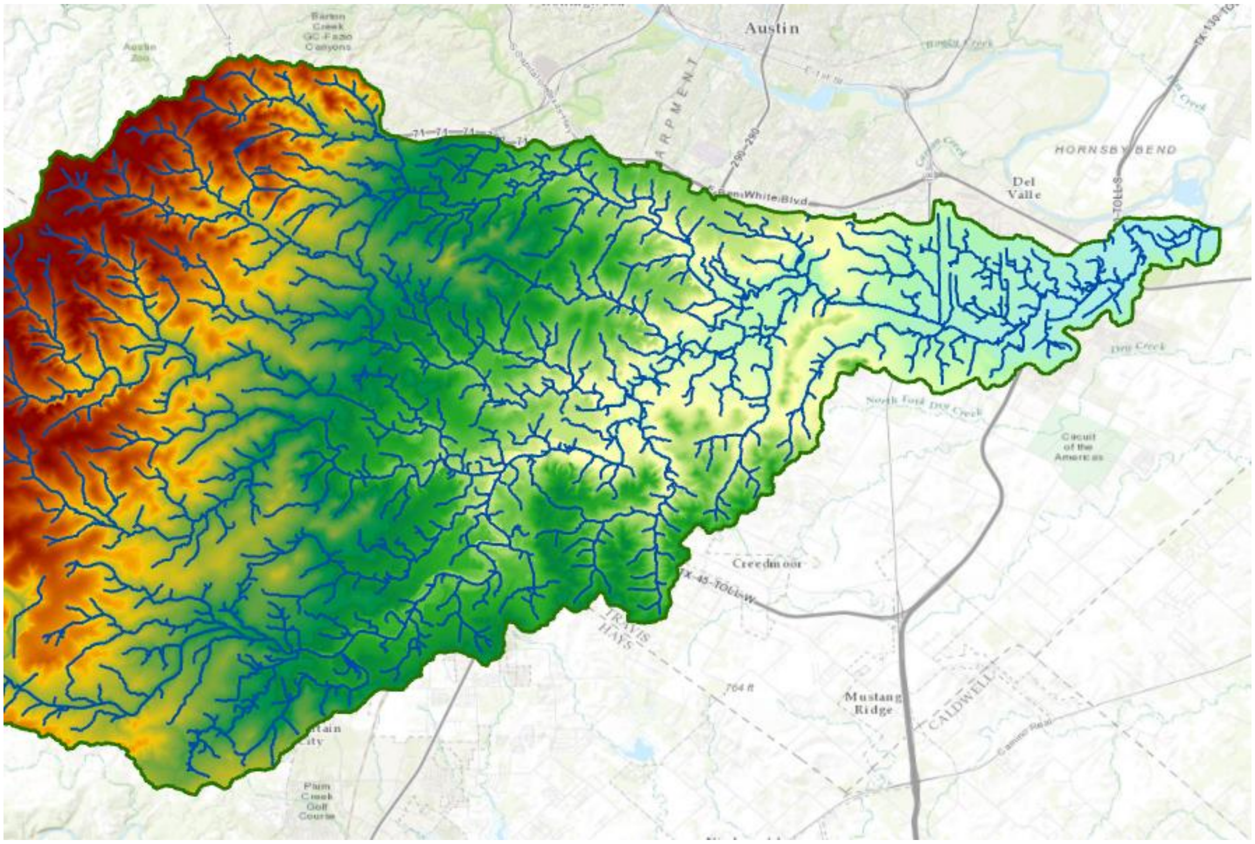
Channel Conditions in the Onion Creek Watershed

Integrating High Resolution Elevation Data in Flood Forecasting



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Introduction

Motivation

Flooding is a natural occurrence that can have a tremendous negative impact on individuals and communities. Flood modeling and forecasting allows us to design development in a way that reduces the likelihood and severity of floods, and to react to floods in a better way when they do occur. Flood forecasting in modern times involves precipitation forecasting and using elevation data to model the flow as the rainfall accumulates on land. We have seen significant improvements in flood forecasting through recent times as elevation data has become abundant and computer processing power has improved drastically.

Elevation data is commonly produced by satellites or other flying objects using Radar. Lower resolution data causes inaccuracies in the flood modeling as smaller features are indistinguishable and lost, causing the elevation we calculate to appear flatter and more regular than it is in reality. Higher resolution elevation data allows us to pick up on these features, producing models of elevation that more accurately reflect reality and produce more accurate results.

While traditional Radar elevation data is gathered using radio waves, another method is available known as Light Detection and Ranging (Lidar), which utilizes light waves to gather elevation data. The advantage of Lidar is that it is capable of gathering higher resolution elevation data from more accurate horizontal and vertical measurements. Traditional Radar data typically has a 10 meter resolution or worse, while Lidar is capable of producing 10ft, 1m or even higher resolution data. The technology of Lidar has recently become popular, creating the possibility of cheap and reliable access to high resolution elevation data.

Integrating Lidar data into flood forecasting is a relatively new and undeveloped endeavor. Existing forecasting models are optimized for lower resolution data and do not fully realize the potential advantages of the higher resolution data. Integrating Lidar data effectively will produce more accurate channel networks and measures of flood risk, both before a flood occurs and in real time during flooding.

Project Overview

In this project I aim to explore the possibility of integrating Lidar elevation data into flood forecasting and evaluate the advantages over traditional methods. I compare high resolution elevation data and new channel extraction methods to existing medium resolution elevation data which has previously been analyzed. The process of analysis is first channel extraction from DEM, followed by analysis of flood risk.

Automatic extraction of channels and channel networks using elevation data allows risk of inundation to be modeled for any location in the study area. Traditionally channel extraction has been modeled using low or medium resolution, but recently higher resolution LiDAR data has become readily available. For channel extraction I use GeoNet, a geomorphic feature extraction program created by Paola Passalacqua and designed to efficiently utilize high resolution Lidar data. GeoNet utilizes this higher resolution data and also uses nonlinear filtering to enhance high gradient areas and a minimum cost function for feature extraction to create channels that better match reality.

My aim was to compare the GeoNet channel extraction to existing NHD Plus flow lines by calculating Height Above Nearest Drainage (HAND) for various address points in the study area and calculating depth of inundation for given flood depths. Unfortunately, I was unable to calculate HAND from GeoNet outputs using TauDEM, so analysis in this report is limited to comparing channel extraction.

The two sets of channels as extracted by GeoNet and NHD Plus for the study area are presented and the effect on risk of flooding is discussed. GeoNet is expected to produce more accurate channels and therefore more accurately model HAND and risk of inundation. Address points are given for each house in the study area, and channel extraction, HAND and depth of inundation are compared for these address points.

Research that would be required to tie up this study is discussed, as is possible avenues for further related research. We find that both traditional channel extraction and GeoNet struggles with very flat areas and urban areas. GeoNet models these areas better than NHD Plus, but could be improved to provide more accurate results in these areas.

Study Area

The study area is Onion Creek in Austin, TX. The entire Onion Creek watershed spans approximately 150 square miles and is shown in *Figure 1*, while the study area for which high resolution data is available for spans approximately 100 square miles and is shown in *Figure 2*. Onion Creek is a developed area with high population density areas and some natural areas. Overall it can be considered somewhat steep, although some areas are quite flat. The highest areas are the West, while the lowest areas of the watershed and therefore also the outlet, are in the East. There is no significant slope in the North-South direction.

Elevation data has been gathered for this area from two datasets. The first is USGS National Elevation Dataset (NED) with resolution 10m as presented in *Figure 1*. Higher resolution data has been obtained from CAPCOG in UT's Digital Austin dataset, which has a 10ft resolution and is presented in *Figure 2*. Very high resolution data (1m) has only been found for a small fraction of the total area of Onion Creek and in its current state was deemed insignificant for analysis.

The Onion Creek watershed has already been delineated and address points have been established. The NHD Plus method has been applied to the NED 10m DEM and HAND has already been calculated.

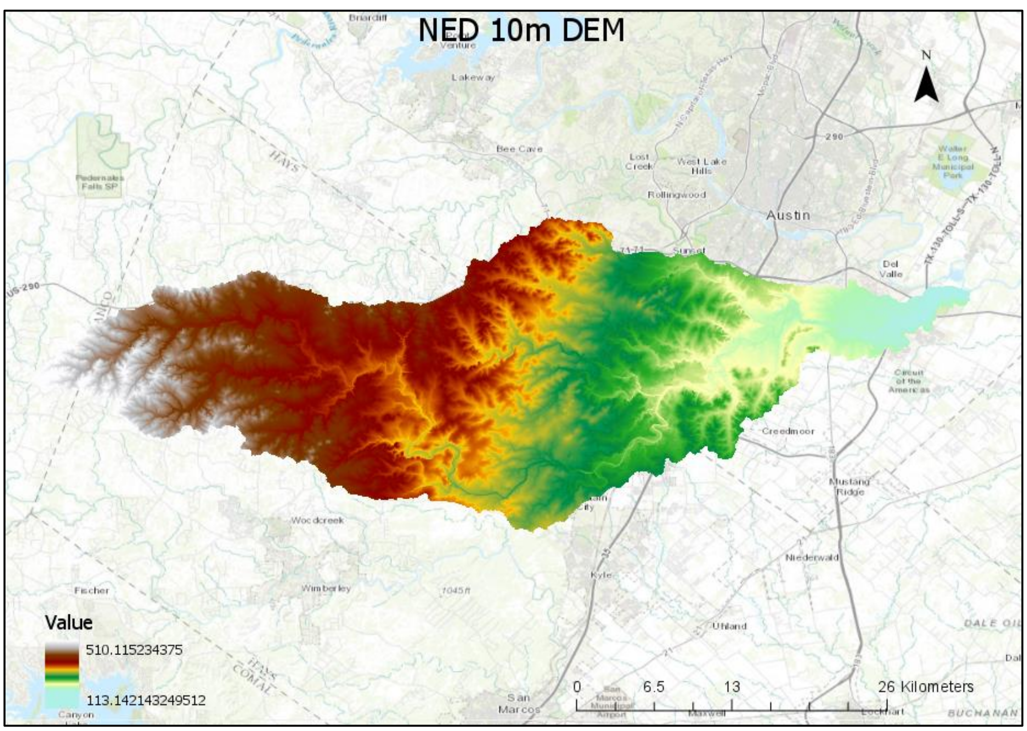

Figure 1: Onion Creek elevation map from NED 10m resolution DEM

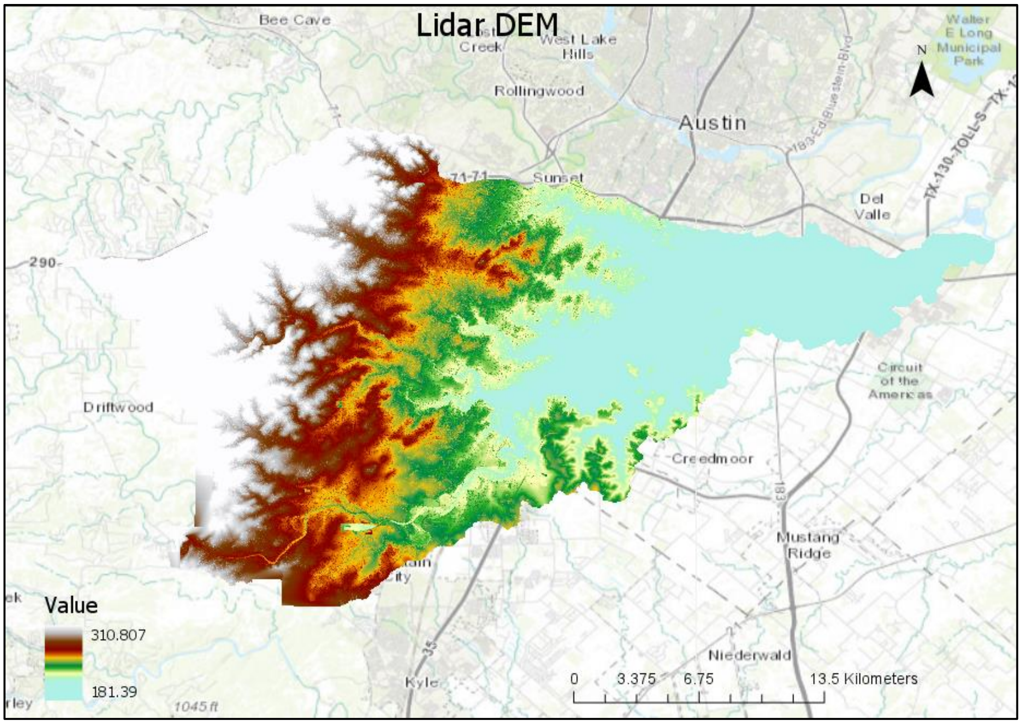

Figure 2: Onion Creek elevation map from CAPCOG 10ft resolution DEM

Method

The existing Radar elevation data used for comparison was the USGS National Elevation Dataset (NED) with 10m resolution. This existing data has previously been analyzed using the NHD Plus method producing flowlines. HAND had been analyzed for these NHD Plus flowlines. The new Lidar elevation data was sourced from CAPCOG through University of Texas' Digital Austin project. This higher resolution data has a 10ft resolution which corresponds to more than nine times as many grid cells as the existing data for the same area.

Initially, the high-resolution DEM was clipped to the Onion Creek watershed through the ArcGIS function Clip in data management tools, checking the option to maintain clipping extent. This clipped raster was then exported for use in GeoNet. The version of GeoNet used was GeoNet 2.2 in MATLAB, which acts as a front-end user interface while calculations are performed in C++. GeoNet 2.2 is an open source software available online through Dr. Passalacqua's website.

To run GeoNet, the downloaded software was placed in the MATLAB folder, and new files for Onion Creek were created. The clipped DEM was transferred to the data folder, while an execution file was created from the default template and edited for Onion Creek. A shortcut was created to automate the process, opening the necessary files and running the execution file for Onion Creek. The flow accumulation threshold was set in the execution file to values of 100, 1000 and 3000 cells. A preparation MATLAB file was run followed by the shortcut, allowing GeoNet to run its calculations.

The outputs from GeoNet include various intermediary steps in tif file format, and two shape files. These shape files are the flow drainage network and the channel heads. My method to calculate the HAND raster was using the online TauDEM application as in Exercise 5, but this was unable to work for two reasons. The TauDEM online application could not run because the flow accumulation shape file which I converted into raster form did not have the Strahler order value, and the DEM was not rectangular. To circumvent these issues, I would have to run the TauDEM toolbar in ArcMap which I was unable to do due to time issues.

Once HAND was calculated for the GeoNet channels, the depth of inundation was to be calculated for each address point similar to the method in Exercise 5. A histogram of the depth of inundation at each address point would be created from the GeoNet HAND and the NHD Plus HAND. The histograms would be compared as would the individual depth of inundation values at a selection of address points.

Results

Channel Extraction

The drainage channels produced by GeoNet for the threshold value of 100 cells are shown in *Figure 3*. It can be observed that channels occur throughout the watershed area, accumulating, and flowing towards the East outlet point. The channels extracted match the streams that are visible on the topographic map, indicating that the channel extraction process is likely working as intended.

When compared to the NHD Plus flowlines as in *Figure 4,* it can be seen that the GeoNet flowlines are close to the existing flowlines but they vary somewhat. The blue GeoNet channels appear to curve more than the green NHD Plus flowlines which indicates that GeoNet is using the more accurate higher resolution to account for details that are lost with the lower resolution data. GeoNet also produces additional flowlines which is due to the low flow accumulation threshold, which must be taken into account when calculating HAND. This can also be seen as an advantage, as these streams which are often dry will form during flood conditions, effectively increasing the risk of flooding nearby.

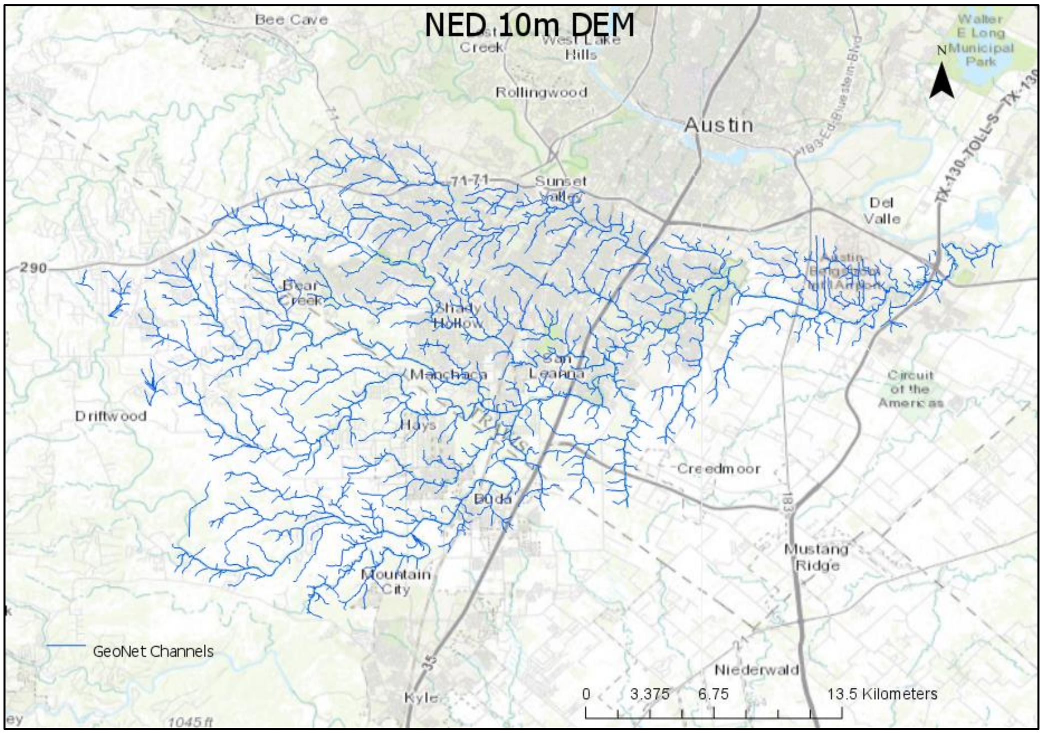

Figure 3: Channels extracted by GeoNet using 100 cell flow threshold

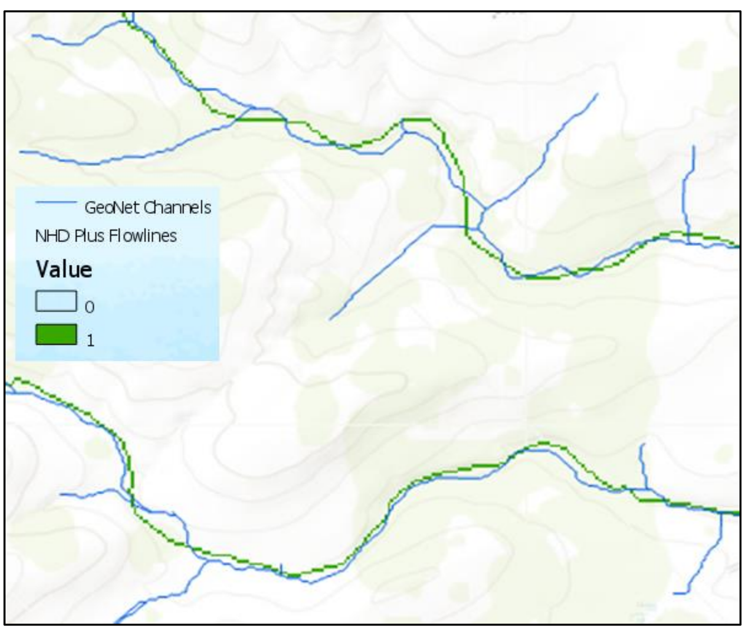

Figure 4: Comparison of channels extracted by GeoNet and NHD Plus flowlines

HAND and Depth of Inundation

As explained previously, HAND was not able to be calculated for the GeoNet drainage network, and therefore the HAND and depth of inundation values cannot be compared. Therefore, in this section I will discuss the differences that we would be likely to see based upon the channel extraction observed. As can be seen in *Figure 5,* the blue GeoNet channel is closer to the address points on the right of the stream than the green NHD Plus flowlines. This would result in a lower HAND value for the cells on the right of the stream and higher HAND values for the cells on the left of the stream.

We would observe from calculating depth of inundation for the address points that the houses on the right of the stream in this figure experience a higher depth of inundation, and therefore a higher risk of flooding. The opposite effect would occur for the houses on the left side of the stream, as GeoNet will have more accurately calculated that the stream is slightly further away than previously modeled.

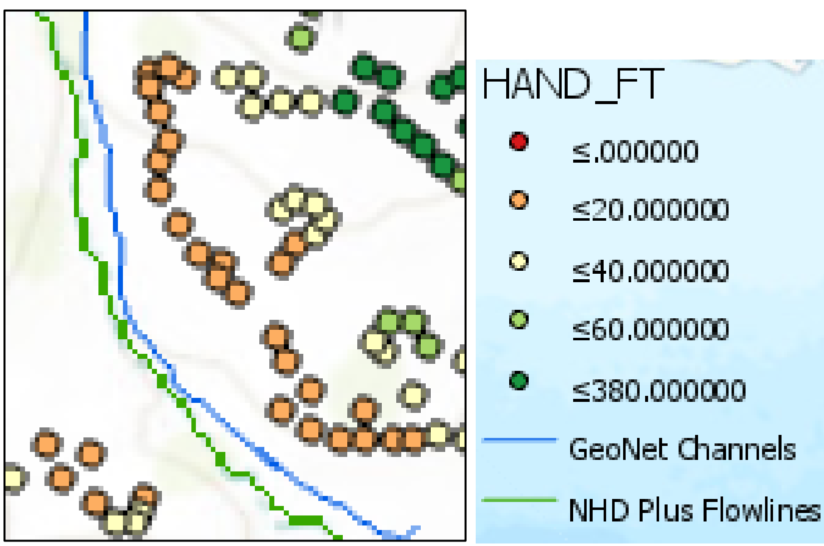

Figure 5: Comparison of channels extracted by GeoNet and NHD Plus flowlines on HAND

Discussion

As seen in the results section, GeoNet produces channels that more accurately take into account local features and small scale changes in elevation. GeoNet and the high-resolution Lidar elevation data would allow us to predict the risk of flooding at these, and other, address points more accurately. Flood management would be able to use this improved modeling to respond to emergencies more effectively.

The HAND raster and depth of inundation for the GeoNet channels were unfortunately not found. The analysis of GeoNet and NHD Plus was therefore limited, although variation in channel extraction was shown to be significant. The advantages of GeoNet and high resolution elevation data from Lidar are clear, with further improvements being possible.

Further Research

There are a variety of avenues for further research on GeoNet and the implementation of high resolution elevation data in flood forecasting. The two foremost issues are the inability of GeoNet to accurately predict flow drainage channels in flat areas and urban areas. GeoNet assigns only one flow direction to each cell, which is not able to accurately model what is occurring when the ground is very flat for large areas, often due to development. As can be seen in *Figure 6*, most of the flow accumulation calculated by GeoNet is in channels but some areas exhibit pooling. This occurs in flat areas where the underlying assumptions required for the model to run as intended do not exist. Additions could be made to the model to account for these flat areas, multiple drainage paths from a single cell and pooling.

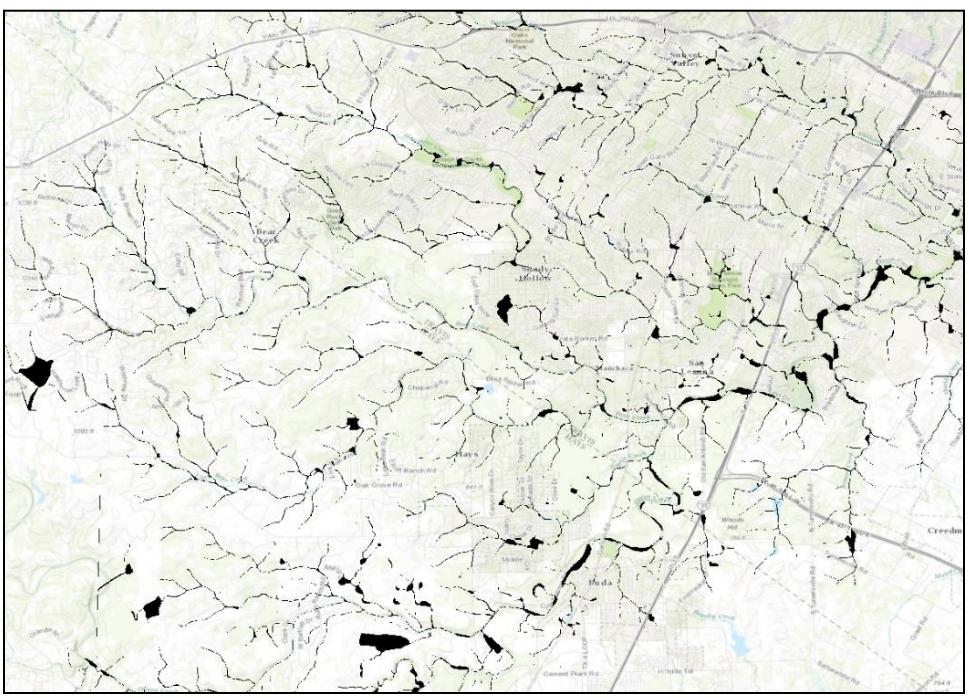

Figure 6: GeoNet Flow Accumulation Map

One final addition to this research would be a 3D representation of the calculated channel shape. The results from GeoNet could be visualized by producing a 2D cross section at any point along the channel. This 3D representation could be produced by using the ArcMap 9.1 toolbar River Channel Morphology Model (RCMM). This cannot be run in ArcGIS pro to my understanding, but would provide an effective method of information communication for the results of this study and others.

Conclusion

Some intended results of this study were unfortunately not found. The analysis of GeoNet and NHD Plus was therefore limited, although variation in channel extraction was shown to be significant. The advantages of GeoNet and high resolution elevation data from Lidar are clear, with further improvements being possible. GeoNet produces more accurate channels, can circumvent obstacles such as roads and bridges through the cost minimization function, and the flow accumulation threshold can easily be altered to produce differing channel networks based on the intensity of flooding. GeoNet warrants further study and the channel extraction from this project indicates that the improvements from using high resolution data and clever programming are significant.