

HEC & GIS Modeling of the Brushy Creek Watershed

By Cassandra Fagan 5, December 2014



Contents

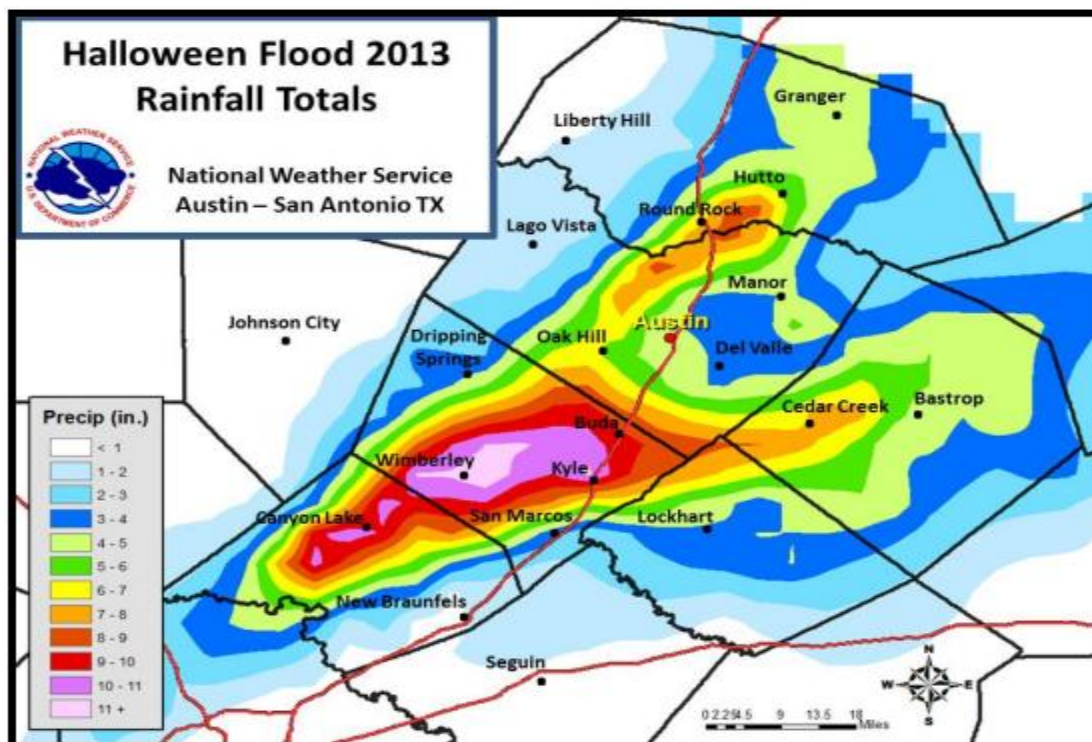
- Introduction..... 3
 - Figure 1: 24-hour rainfall amount from NWS 3
- Research Goals..... 4
 - Figure 2: Outline of the Upper Brushy Creek watershed..... 4
- Methods & Results..... 5
 - Figure 3: HEC-RAS Display 5
 - Figure 4: HEC-RAS Results in ArcGIS 7
 - Figure 5: 100 Year Storm Return Period Inundation Map 8
 - Figure 8: Velocity map of the 100 Year Storm 9
 - Figure 7: Velocity map of the 25 Year Storm 9
 - Figure 8: Four Phases of Emergency Management 11
 - Figure 9: Hazus Geodatabase 12
 - Figure 10: Population living in the 100 year Floodplain 12
 - Figure 11: Population over 65 living in the 100 year Floodplain 13
- Conclusion 13
- Sources:..... 15

Introduction

According to the USGS, floods were the number-one natural disaster in the United States in terms of the number of lives lost and property damage during the 20th century, with flash floods being responsible for the majority of the flood-related deaths. Flash floods are difficult to predict, and difficult for emergency responders because the severity of the flood is highly variable. This is especially true in rural areas, where emergency response teams consist of volunteers and very limited resources.

The 2013 Halloween Flash Flood event in the Onion Creek Watershed located in Austin, TX caught the attention of many. During the evening of October 30, 2013, 12-14 inches of rainfall produced a major flooding event in the Onion Creek Watershed which claimed the lives of eight people and destroyed homes. The rainfall totals as reported by the National Oceanic and Atmospheric Administration (NOAA) can be seen in Figure 1. This event revealed the vulnerability to flooding even sophisticated cities such as Austin have. Since this event the city of Austin has been working to improve their emergency management procedures for events such as this. This event has brought attention to the improvements that could be made to raise emergency flood response on the local level to a standard national response level to prevent future tragedies such as the Onion Creek Flood.

Figure 1: 24-hour rainfall amount from NWS

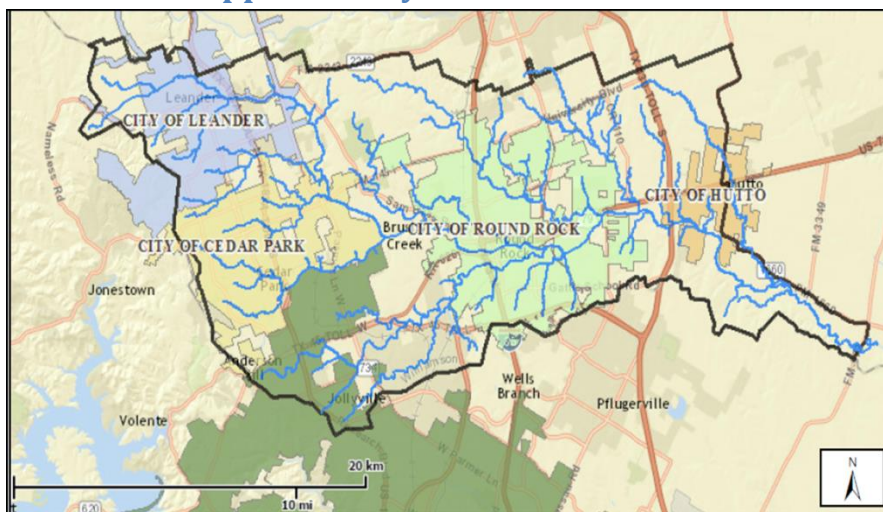


Research Goals

For this research project I explored using ArcGIS to create maps that enhance emergency response at the local level. The Upper Brushy Creek Watershed, located in Travis & Williamson County, Texas, was selected as the study area for this research. The Upper Brushy Creek watershed is an ideal study case. The Upper Brushy Creek Water Control and Improvement District contracted URS consulting firm to perform a basin wide study for this watershed in 2011, and a product of this study were a HEC (Hydrologic Engineering Center) – RAS model for the Upper Brushy Creek, which was provided to Professor Maidment’s research team. This model provides the hydrologic information for the Upper Brushy Creek that is needed to assess flood hazards in the study area. The Upper Brushy Creek Watershed is also a heavily gaged watershed, which will be useful in the next phase of this research.

This Upper Brushy Creek watershed has an area of 187 miles and falls under the jurisdiction of five cities, Leander, Cedar Park, Round Rock, Hutto and Austin. Because this area is divided into five cities, multiple emergency response teams respond to emergencies in the watershed. This emphasizes the importance of creating maps at the watershed level that can be used by each community, because flooding will occur throughout the watershed and is not bound by political boundaries.

Figure 2: Outline of the Upper Brushy Creek watershed



As defined by FEMA, the four phases of emergency management include mitigation, preparedness, response and recovery. The research goal for this study was to support emergency response in the Upper Brushy Creek watershed by producing maps that can be used in these four

phases of emergency management: . Using HEC software and ArcGIS, my goal was to produce inundation, velocity, and arrival time maps for various flood events for this area. Inundation maps approximate the maximum water surface extent occurring from a particular storm event. Velocity maps display the flood velocity plan view profile of the river resulting from a particular storm event. As discussed in more detail further in this paper, I was able to produce both inundation and velocity mapping and arrival time mapping is my next research goal using HEC-Flood Impact Analysis (FIA).

Methods & Results

The first step toward creating the inundation and velocity maps for the Upper Brushy Creek watershed was simulating the hydraulics of the river. Various storm events were simulated using the HEC-RAS models developed by the Upper Brushy Creek Water Control and Improvement District, WID. These models had a number of return period storms scenarios that could be used to model the river hydraulics at a steady-state condition. It would be more accurate for the river simulation to be run on an unsteady state for these flooding conditions. Unsteady state simulations in HEC-RAS follow the momentum equations which are more physically accurate than the energy equations used in steady-state simulations (USACE). However, it is possible that the model was simulated under unsteady conditions to find the flow from the event, and this flow could be re- routed under a steady state condition. This is done because HEC-RAS models are less stable and often crash especially if there are many reaches in the model.

Figure 3: HEC-RAS Display

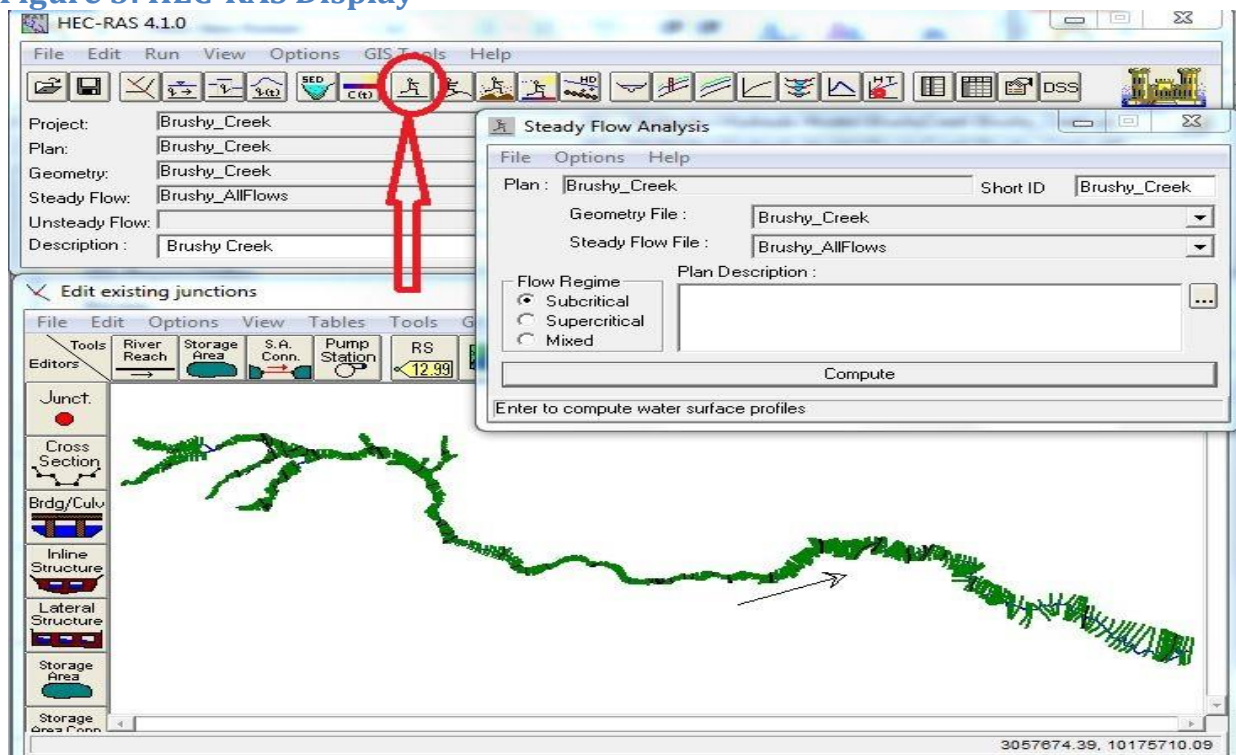


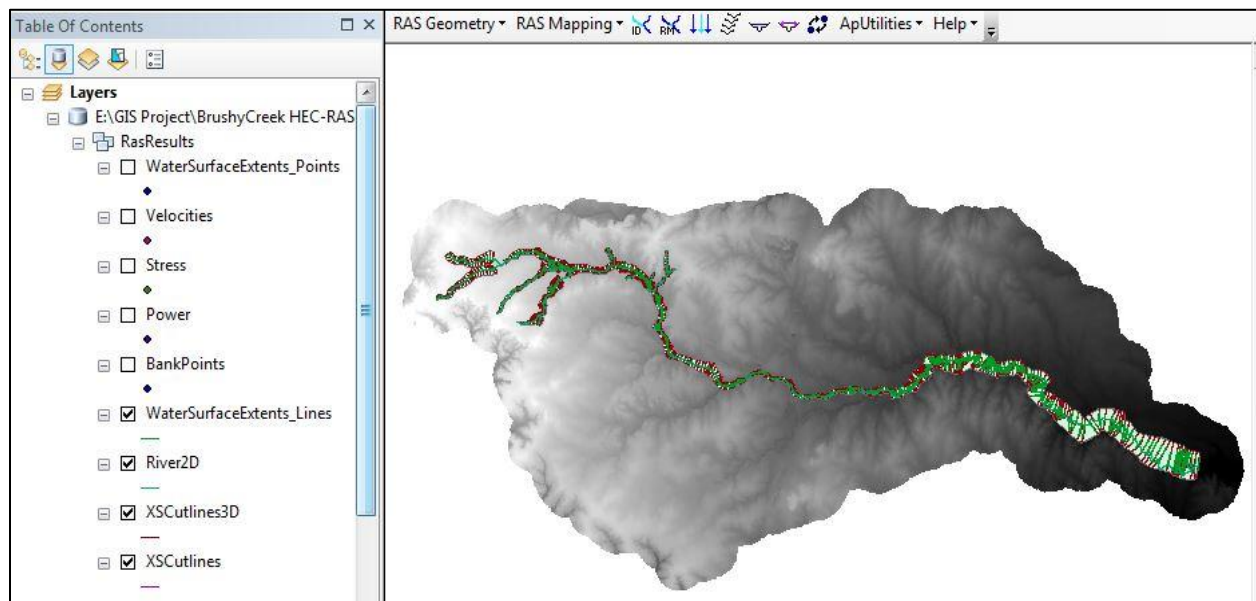
Figure 3 is the display screen for the HEC-RAS model, which also shows a schematic of the Upper Brushy Creek with the cross-section, and river centerline. The HEC-RAS model for the Upper Brushy Creek was simulated for 2, 10, 25, 50, and 100 year return period storm events. The hydrologic response and geometric files of these storm scenarios were then exported from HEC-RAS using GIS export to be used in ArcGIS. The export file included the water surface extents, the velocity, shear stress and stream power for the five simulations as well as the user defined cross sections, reach lengths and bank stations from the Upper Brushy Creek model. To use the export file from the HEC-RAS river model in ArcGIS for inundation and velocity mapping, the HEC-Geo RAS toolbar was required. As defined by the Army Corp of Engineers, HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI). HEC-GeoRAS Beta 3 was downloaded and used for this research, because it the only HEC-GeoRAS version that is compatible with ArcGIS 10.2.

After completing the simulations in HEC-RAS and exporting the file, the next step was using ArcGIS and the HEC-Geo RAS toolbar. The exported HEC-RAS export file was converted to an XML file. A terrain layer for the Upper Brushy Creek Watershed was required to create a layer using the HEC-RAS export. At the time of this analysis, I did not have access to the Bare Earth DEM that was used to create the HEC-RAS models. For this reason I downloaded the National Hydrography Dataset (NHD) 30 meter Digital Elevation Model (DEM) to use as the terrain layer in this analysis. A 1500 meter buffer was created around the Upper Brushy Creek Watershed and extracted the NHD DEM from the buffer layer.

A study layer for the flood mapping in HEC-GeoRAS was created using the extracted DEM layer as the terrain layer, and the export file from the HEC-RAS analysis as the hydrologic data input. When the export file was imported into ArcGIS with HEC-Geo RAS, a geodatabase for the analysis was created for this study layer. This geodatabase consisted of various geometric feature classes for the Upper Brushy Creek, including cross sections, the stream centerline, and bank points as seen in Figure 4 below. The layout of the river in Figure 4 is identical to the layout in the HEC-RAS layout window seen in Figure 3. This indicated the export was successful.

During this process, some problems were encountered before reaching a successful import result. The first problem encountered involved the projected coordinate system of the HEC-RAS model. During the first trial, Albers Equal Area Projection was used for the DEM layer, but when the geodatabase was created the DEM and river feature classes were not matching up. After some investigation, the projection system for the HEC-RAS model was discovered to be NAD 1983 Texas State Plane. When the DEM for the Upper Brushy Creek Watershed was projected with this coordinate system, the DEM and river feature classes matched up as seen in Figure 4.

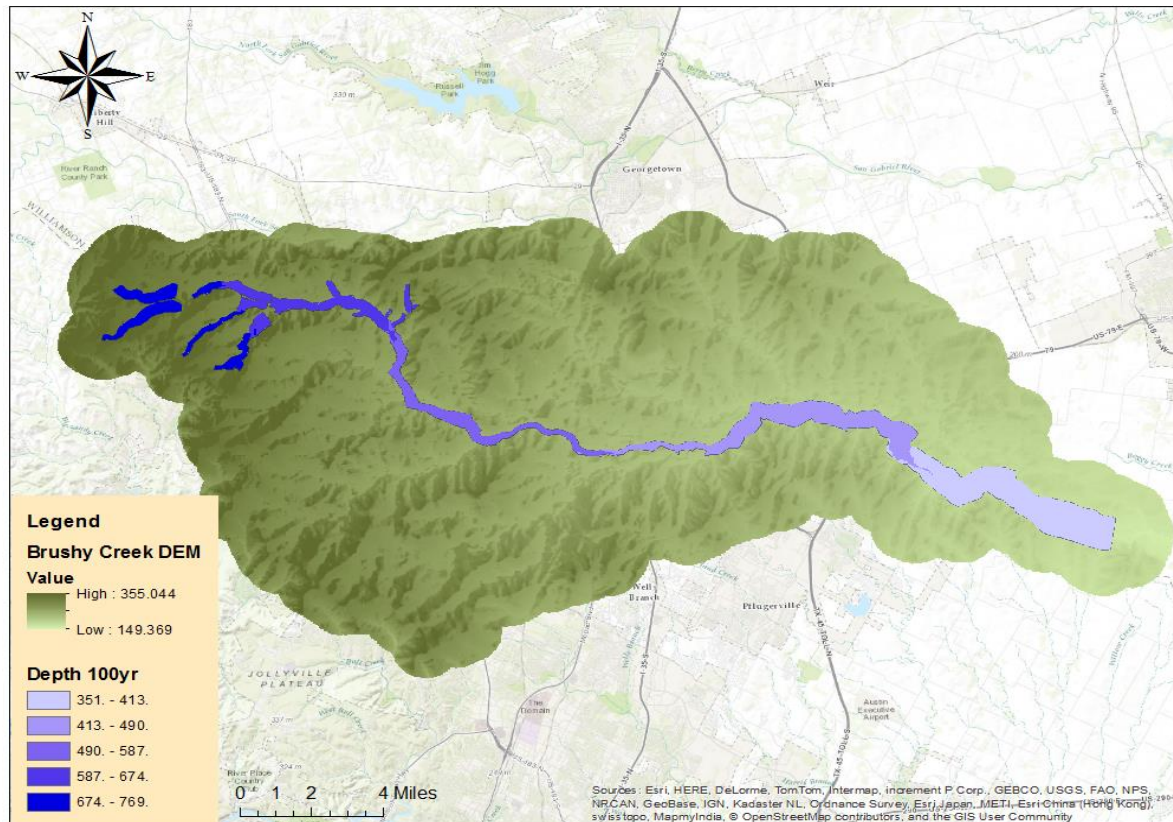
Figure 4: HEC-RAS Results in ArcGIS



Once the geodatabase has been created and the DEM and river feature class were in sync, the inundation mapping was performed. The HEC-RAS export file contains the hydraulic information about the floodplain. This includes the depth of the water on floodplain, the extent of the flood plain, river velocity and flow in the river for a given storm simulation event. The inundation mapping consists of main two steps, the first being the water surface generation. As described by the Army Corps of Engineers, the water surface generation creates a TIN that defines the zone that outlines the outer points of the bounding polygon of the floodplain. This TIN contains area outside the possible inundation. The second step in inundation mapping is flood delineation using a raster. In this step the water surface generation TIN is converted into a raster. The underlying DEM terrain layer is then subtracted from the water surface raster. The values that are positive indicate flooding in the grid cell with a depth equal to the water surface

raster minus the DEM terrain layer. The inundation map from the 100 year storm return interval storm simulation is seen in Figure 5.

Figure 5: 100 Year Storm Return Period Inundation Map



As seen in the legend for in Figure 4, the depths of the 100 year Storm Return Period seem unrealistic. This is likely due to the coarseness of the DEM that was used to create the inundation map. The Bare Earth DEM that was used to create the Upper Brushy Creek HEC-RAS models was a very accurate terrain layer that was produced from LIDAR. After discussing this issue with a colleague, we came to the conclusion that these unrealistic depths are likely due to the discrepancies between the 30 m DEM used in this research, and the Bare Earth DEM used to create the models. In the near future this analysis will be performed using the Bare Earth DEM as the terrain layer.

With the inundation mapping complete, the velocity mapping for given storm events could be performed. Using the velocity mapping HEC-GeoRAS option, a velocity map for the various storm events was created. The velocity map for the 100 year storm and 25 year storm can be seen in Figure 6 and Figure 7 respectively.

Figure 8: Velocity map of the 100 Year Storm

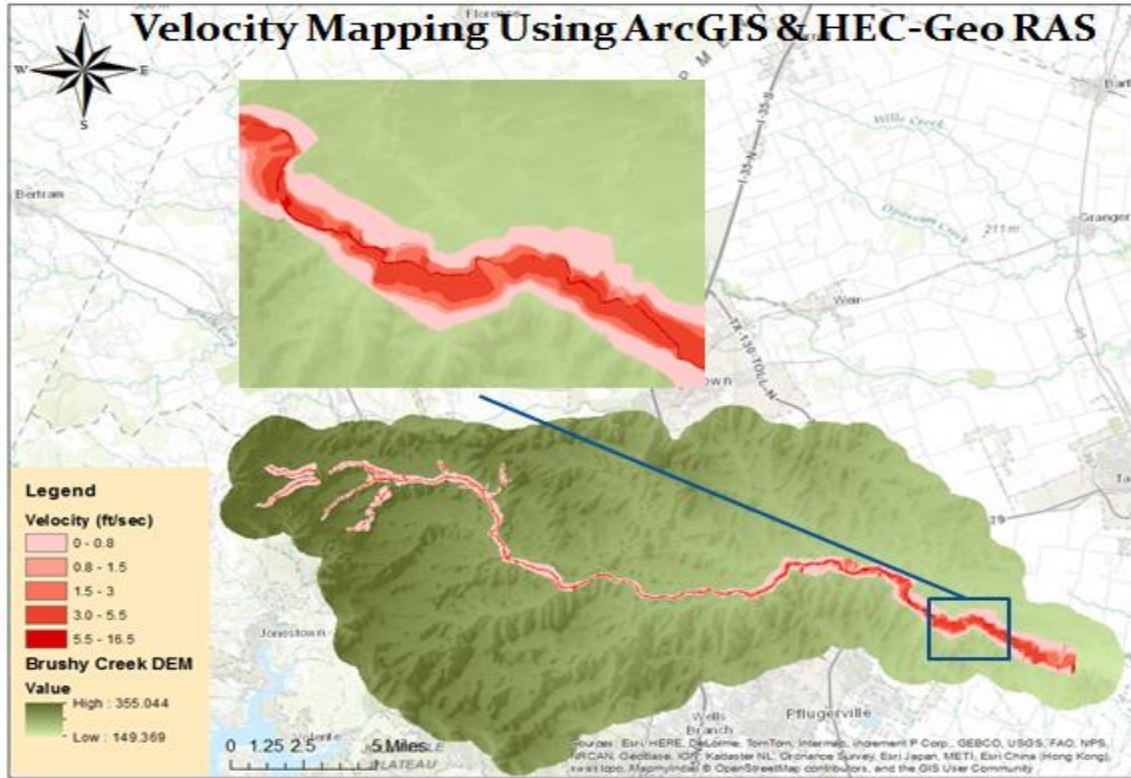
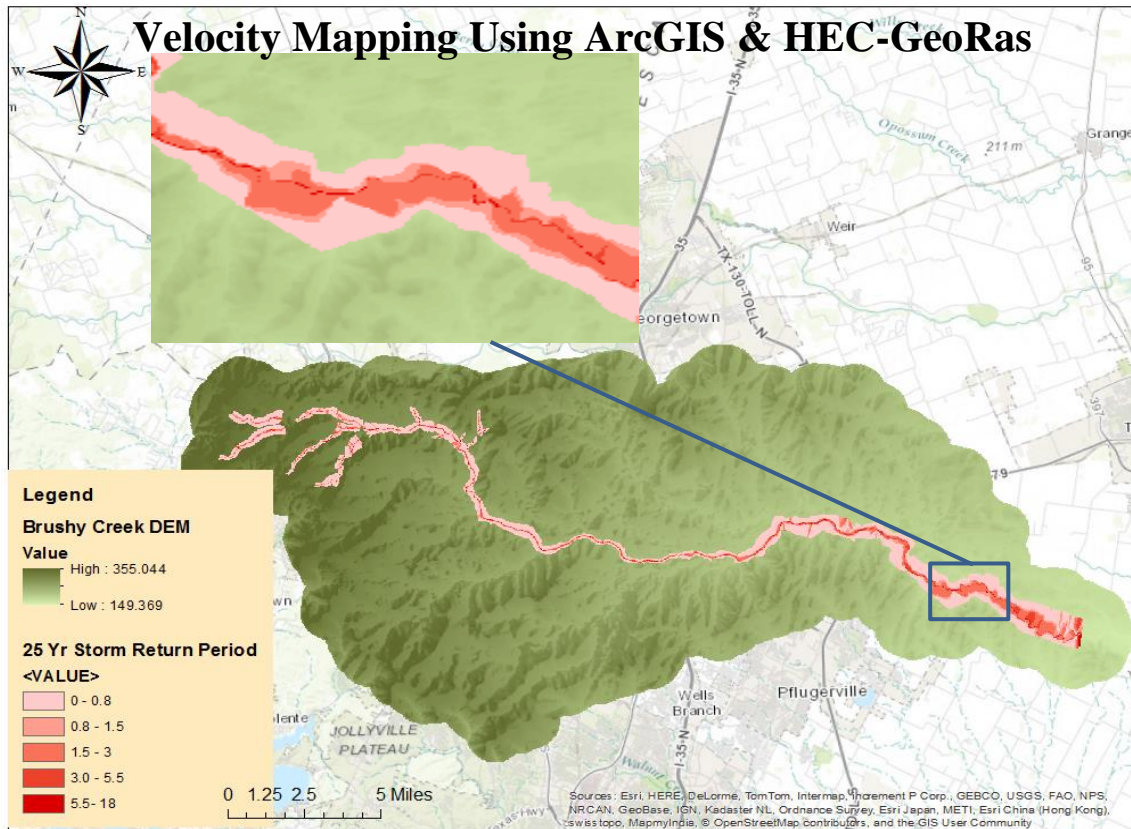


Figure 7: Velocity map of the 25 Year Storm



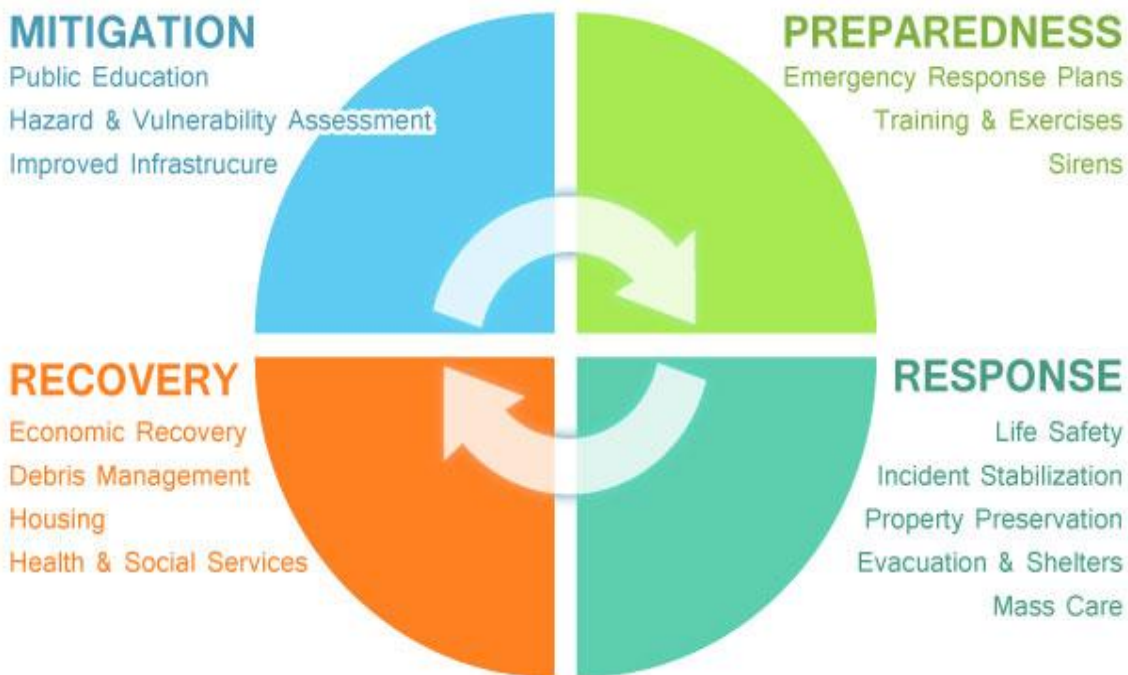
As expected, the 100 year storm produces a flow with higher cross-sectional velocity than the 25 year storm. The zoomed in section in Figure 6 shows the velocity for much of the floodplain in this segment of the river has velocities between 5 and 16 ft/sec. An interesting thing to notice when comparing Figure 6 and 7, is that the peak velocity in the 25 year Storm is higher than the peak in the 100 year Storm. As described in a FEMA article titled "Types of Floods and Floodplains", the larger becomes, the more debris and sediment in the water. The 100 year floodplain is larger, and more debris and sediment that the water is moving and as a result can have a lower peak velocity, even though the flow from the storm event is much higher for the 100 year storm event.

Relating this mapping to emergency management, accurate velocity and inundation maps are critical components in each of the four phases of emergency management defined in Figure 8. The accuracy of the velocity and inundation maps used in planning determines the effectiveness of the emergency procedures. A floodplain map identifies vulnerable areas that are prone to flooding. This can be used to inform and raise awareness in floodplain communities. These inundation maps can be used to mitigate future damage. Inundation maps can be used as evidence for supporting buyout programs. Buyout programs are a flood mitigation strategy, where the government purchases properties in extremely high risk areas of the flood plain to prevent future damage by moving the population out of harm's way. Following the Onion Creek Halloween flood, a buyout program was put in place with more than 300 properties being purchased in the Onion Creek Watershed (City of Austin).

Emergency response teams can develop routes of egress for high risk areas based on inundation maps. For this, the accuracy of the inundation map is of critical importance. An emergency responder's nightmare is learning that instead of directing patrons to safety, he routed them through a flooded road or low water crossing. The maps are used to determine the safest evacuation route. If ruled unsafe for evacuation by vehicle, another type of evacuation method may be considered. Rescues in flooded areas can be very dangerous if there is high velocity water. Swift water rescues are commonly used during these events and having a prediction of the velocity across the floodplain allows prepares emergency responders for these conditions. Similar to mitigation, this inundation maps can be used determine the extent of flooding from a storm event. This affects the allocation of recovery resources following a flood event. Using

inundation maps for this resource allocation can allow for a more efficient recovery process because resources can and will be directed to areas impacted most by the flooding event.

Figure 8: Four Phases of Emergency Management



During this portion of the research I was very interested in looking into vulnerable portions of the population living in the floodplain, which led me to census data. Data collected by the United States Census Bureau, compiled by FEMA into a HAZUZ database for Texas were imported into ArcGIS. When the Texas Hazus geodatabase was added as data to a new map in ArcGIS, a number of feature classes and tables appeared. To geographically display the data on the floodplain of interest, I intersected the Hazus census blocks with the 100 year floodplain feature class from the analysis performed earlier. The census blocks were then “joined” with the demographic tables of interest in ArcGIS with the census block i.d. being the joining attribute. Figures 10 and 11 are examples of how demographics display the vulnerable populations living in the Upper Brushy Creek 100 year floodplain. Figures 10 and 11 displaying the population demographics in the 100 year floodplain can be very useful in emergency management by identifying vulnerable populations that will require support in the event of a flood .

Figure 9: Hazus Geodatabase

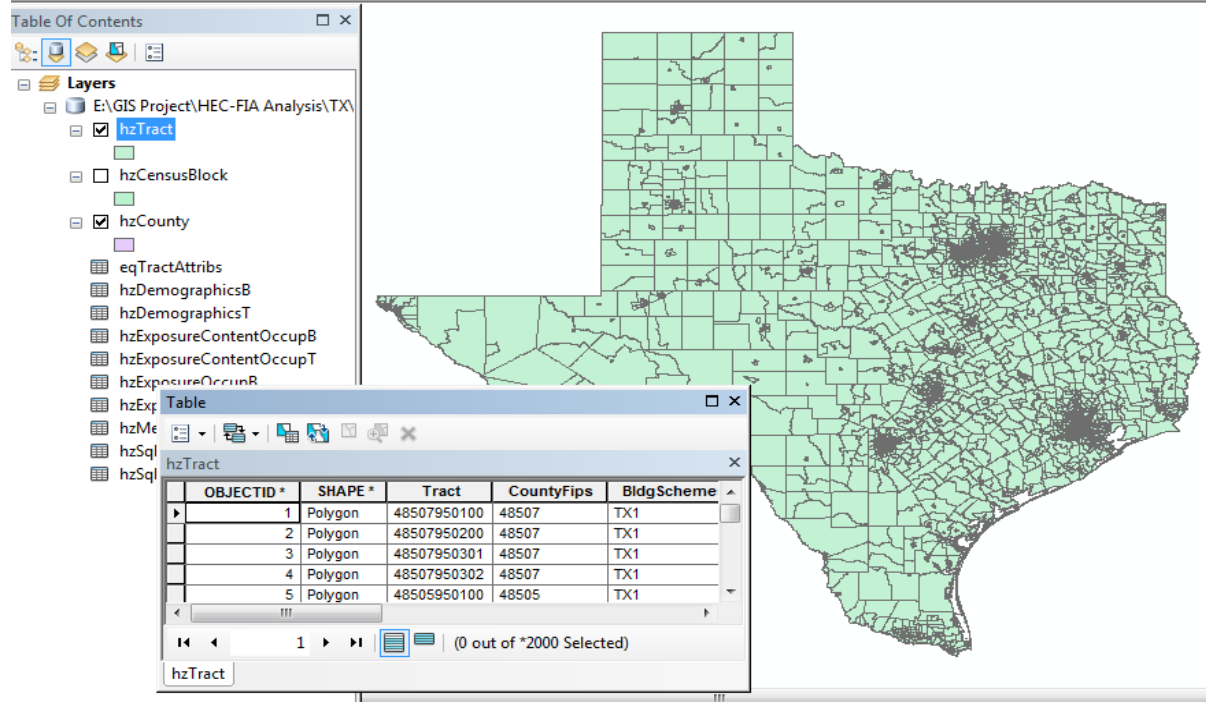


Figure 10: Population living in the 100 year Floodplain

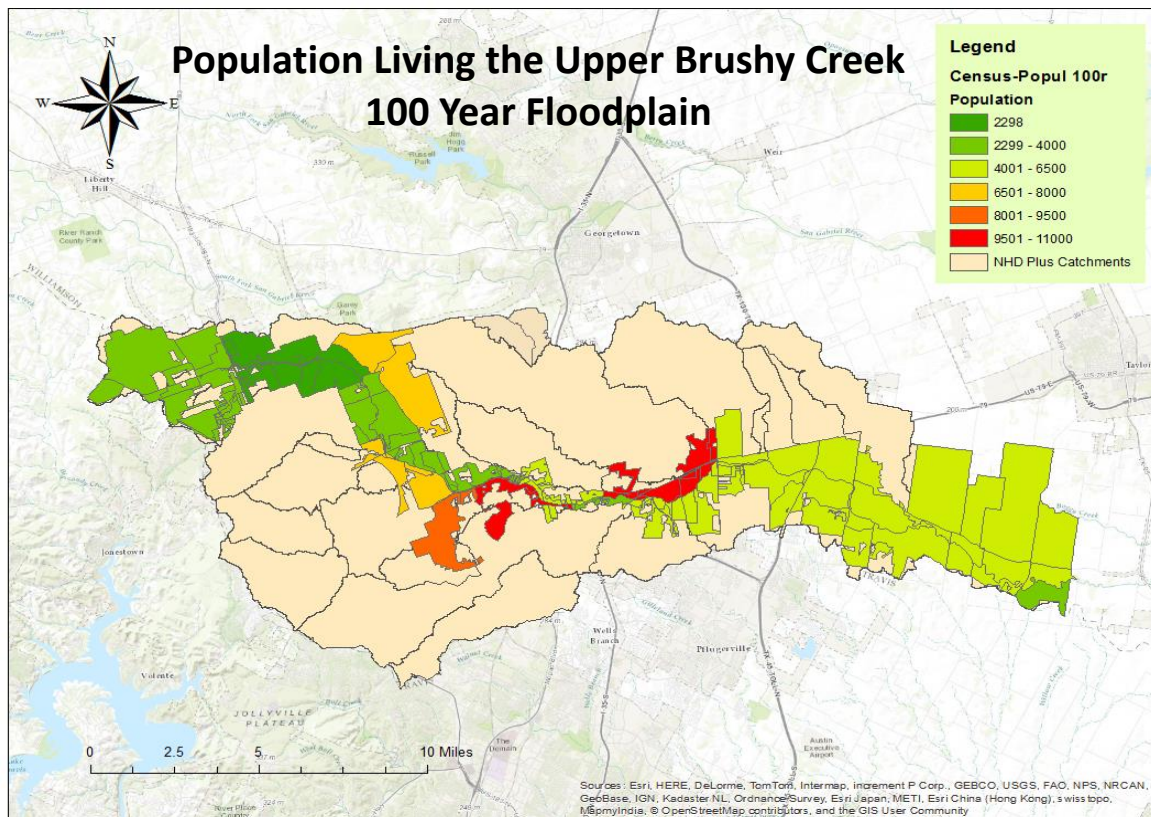
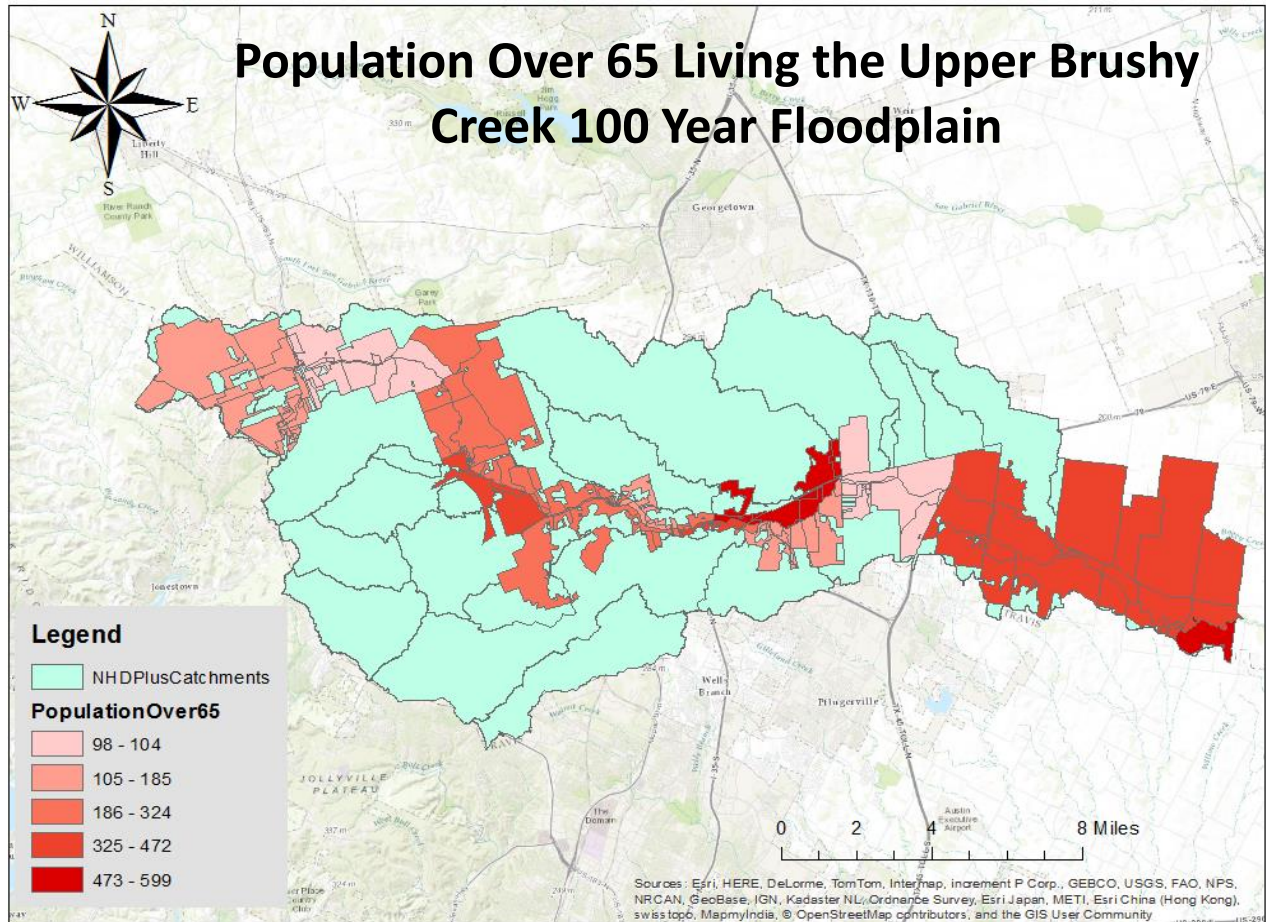


Figure 11: Population over 65 living in the 100 year Floodplain



Conclusion

As discussed earlier, inundation and velocity maps for storm events are critical in emergency management. These maps are often the basis for the operations of the four phases of emergency management. Emergency responders in areas that lack these resources are at a serious disadvantage. The use of these maps can be used to significantly improve emergency response, especially in rural areas where there may not be any flood mapping. Having a collection of these maps for various storm return intervals would allow emergency responders to create plans according to storm return period and flooding intensity. ArcGIS as an excellent platform for performing this inundation and velocity mapping. For a rural area, with no flood maps on the local level, these velocity and inundation maps would be huge improvement for emergency planning. The next steps in this research will include performing the HEC-GeoRAS import using the Bare Earth DEM, and using this to perform a flood impact analysis using HEC-FIA.

HEC-FIA uses demography in the Haszus databdase to analysize the damage incurred from a flood event and create arrival time maps. This is an additional resource that can be used to improve emergency management.

Sources:

1. Perry, Charles A. "Significant Floods in the United States During the 20th Century—USGS Measures a Century of Floods." USGS (2000): n. pag. USGS Fact Sheet 024–00. Web. 1 Dec. 2014. <<http://ks.water.usgs.gov/pubs/fact-sheets/fs.024-00.pdf>>.
2. "Flash Flood Alley - Texas DEM Newsletter Vol.60 No.12-article 2." Flash Flood Alley - Texas DEM Newsletter Vol.60 No.12-article 2. Texas DEM Newsletter, 2013. Web. 01 Dec. 2014.
3. "Hydrologic Engineering Center." HEC-RAS Documentation. US Army Corps of Engineers, n.d. Web. 03 Dec. 2014.
4. "Types of Floods and Floodplains." (n.d.): n. pag. Emergency Management Institute. FEMA. Web. 04 Dec. 2014.
5. "Onion Creek | Watershed Protection | AustinTexas.gov - The Official Website of the City of Austin." Onion Creek | Watershed Protection | AustinTexas.gov - The Official Website of the City of Austin. City of Austin, n.d. Web. 04 Dec. 2014.
6. Four Phases of Emergency Management. Digital image.
https://www.miottawa.org/Sheriff/emergency_management.htm. N.p., n.d. Web. 3 Dec. 2014.