

UNIVERSITY OF TEXAS AT AUSTIN

NFIE-Response in Travis County, Texas

Connecting NFIE Flood Forecasts to
Transportation Infrastructure

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5/8/2015

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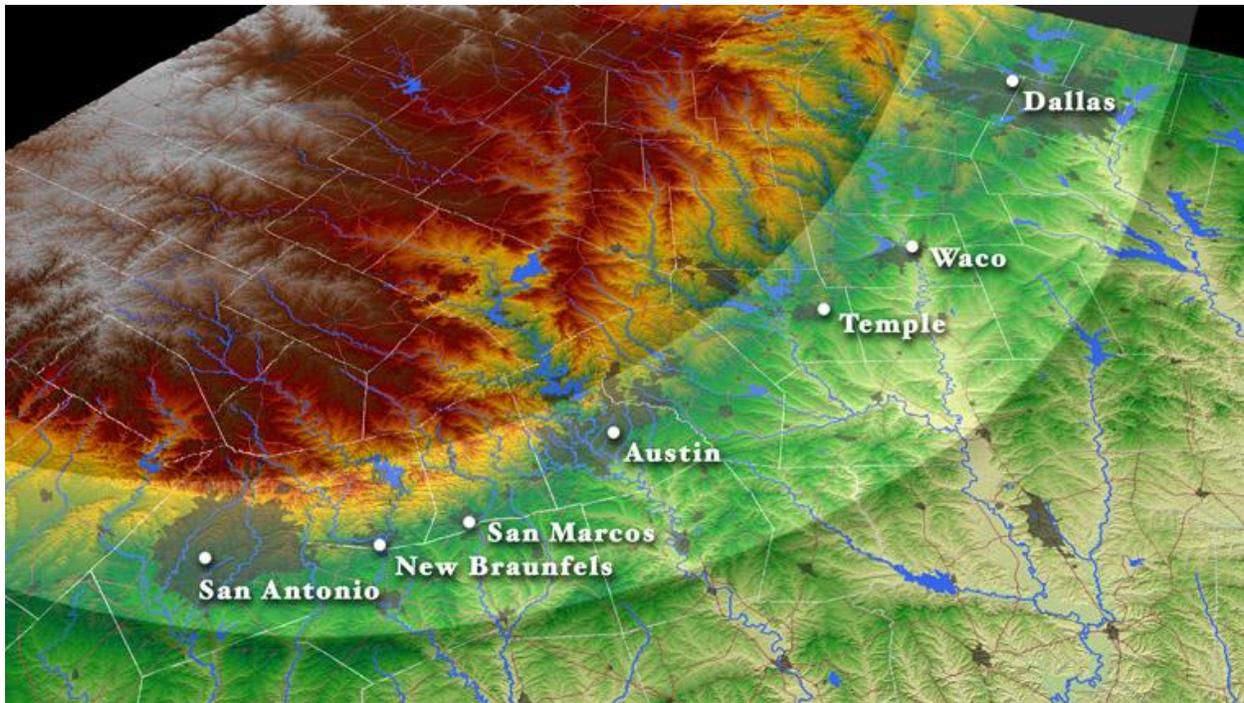
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Introduction

The National Interoperability Experiment, NFIE, consists of five components: Geo, Hydro, River, Response and Services. Each component plays a crucial part in meeting the goal of raising the level of response to flooding in the Continental United States. Thus far, the structure of NFIE –Response has not been completely outlined and has been a difficult to define. This is due to the variability of flood response procedures at the local level across the United States. Communities across the United States are prone to different types of floods, with flash floods, river floods and coastal floods being the most common. As defined by the National Weather Service flash floods develop within six hours of the immediate cause, and exhibit a rapid rise of water over low elevation areas. Travis County lies in an area nicknamed Flash Flood Alley seen below in Figure 1.

Figure 1: Flash Flood Alley Region in Texas



Texas leads the Nation in flood related deaths and this is mainly due to the high frequency of flash floods that the state experiences. Flash floods are particularly dangerous due to the accelerated rivers transition from normal to flood, leaving little flood warning for low lying areas. The Austin Watershed Department reported that since 1960, there have been 60 deaths from flash floods in Travis County with 75% of these fatalities occurring in vehicles. This sparked the “Turn around don’t drown” campaign, poster seen in Figure 2, reminding drivers not to drive through flooded roadways, and in particular low water crossings. There are a high number of low water crossings in Travis County, many of which are undersized due to the large amount of development that has occurred over past decades. It is evident that the transportation

network is closely linked to NFIE-Response. Emergency responders and citizens rely on the transportation network to function and perform necessary duties and are put at risk when there are failures. This study recommends that a component of NFIE –Response should include a database of flood prone transportation infrastructure that is connected to the flood forecast system and would be capable of providing 15 hour ahead forecast at this location. This research developed a case study to develop a methodology for translating NFIE flood forecasts on National Hydrography Dataset Plus Reaches (NHD Plus), to flood forecasts on roadways.

Figure 2: Winner of the City of Austin's annual Flood Safety Poster Contest



Methods

Three low water crossings along Eanes Creek in Rollingwood, Texas were selected for a case study. Eanes Creek, nicknamed “Dry Creek”, is prone to flash flooding and the low water crossings are frequently flooded necessitating closures during precipitation events. In addition these low water crossings have necessitated rescues during flash floods in past years which make them ideal examples for identifying advancements that could be made through NFIE-Response. Flash floods move into an area in a short period of time and give emergency responders little time for planning and mobilizing. In Travis County, emergency responders are responsible for blockading flood prone roadways during precipitation events. Without stream gages at these locations, it is a guess as to whether these low water crossings will flood, and when/if they should be closed. Road closures entail an emergency responder manually placing a barrier across the roadway to obstruct driver. With little information about stream flow conditions, this activity put the emergency responder in danger. During the fall 2014, a precipitation event moved into the Rollingwood area and while closing the Bee Caves Road low water crossing a policy deputy

was swept into the water (Goudeau , 2014). The officer survived, but this is a strong example of the dangers that low water crossings pose to responders as well as pedestrians. From a national perspective the application of a roadway flood prediction database could serve communities and emergency responders at the continental scale.

The three low water crossing locations used in this study are found at the intersection of Eanes Creek with Bee Caves Road, Edgemoor Drive, and Dellana Lane. Bee Caves Road is a heavily trafficked, four lane roadway with a 2010 average annual daily traffic (AADT2010) volume of 32,144 vehicles per day. Given there has been an increase in development in Rollingwood from 2010 to present the AADT2010 is likely an underestimate of current traffic flow. Bee Caves Road is classified as a major arterial by the Texas Department of Transportation (TX DOT) and is an important piece of the transportation network connecting the surrounding area to Texas State Highway Loop 1, as seen in Figure 3. Edgemoor Drive is a two lane collector road, with an estimated saturated traffic count of 1,800 vehicles per hour per lane (TNIS, 2014). The saturated traffic count is an estimate of the maximum number of vehicles that could traverse a section of roadway. Edgemoor drive is a lower traversed roadway than Bee Caves Road, but serves as an important connection for a large number of communities and businesses to Bee Caves Road. Dellana Lane is a two lane road with much lower traffic volumes than Edgemoor Drive and Bee Caves Road, though a traffic estimate was not available. Dellana Lane is the only access road connecting businesses and a housing development which makes it an important piece of the transportation network.

This study combined physical measurements and LiDAR data collected for Travis County to model the design flow of the low water crossings and develop rating curves. The rating curves will be used to connect these low water crossings to the NFIE forecasting system. Rapid, the streamflow routing system for the NFIE, produces flow predictions on the NHD Plus flowlines at the catchment scale for the United States. Eanes Creek is included in the NHD Plus dataset, flowline COMID 5781289, which means the NFIE will be producing flow forecasts for Eanes Creek. Using rating curves at each of the low water crossings along the reach, headwater depth can be interpolated as well as depth of flooding on the roadway.

A survey of the low water crossings was performed in mid- March 2015 to take physical measurements and assess the conditions of the low water crossings. The culverts located at each of the three locations, photos found in Appendix 1, were in degraded condition. Debris was blocking the entrances, which significantly reduces the flow capacity during a storm event. Routine maintenance of culverts is essential to maintaining the design flow capacity. Below in Table 1, 2, and 3 are the physical measurements taken during the survey.

Figure 3: Importance of the low water crossings to the transportation network

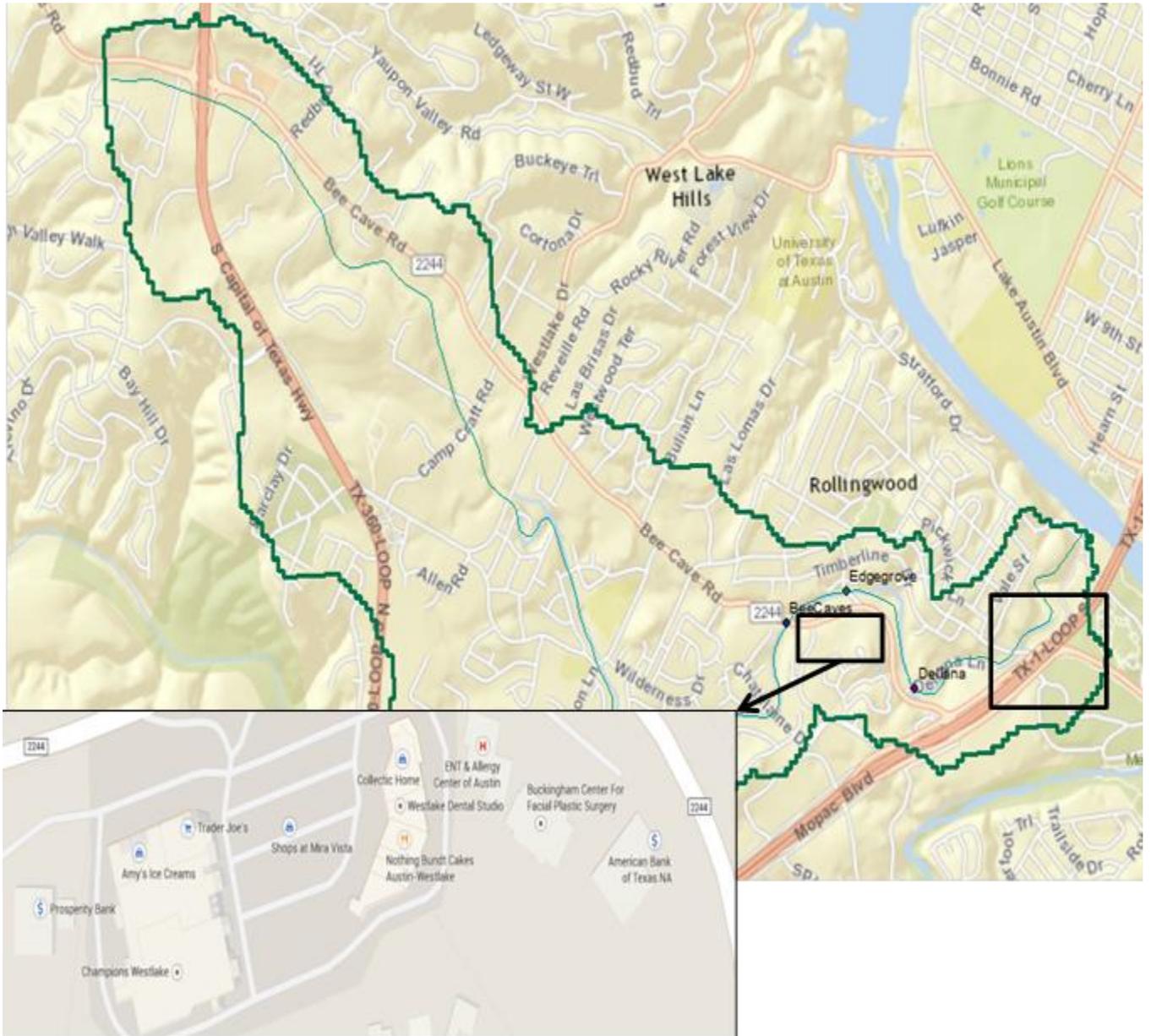


Table 1: Measurements taken at the Eanes creek and Bee Cave Road Crossing

Location:	Eanes Creek at Bee Caves Road
Road Type:	2 Lanes each direction
Culvert type:	2 Circular Aluminum sq headwall
Length of stream through Culvert (ft):	90
Inlet/Outlet Dimensions (in):	42
Invert Elevation to road surface (in):	87
Inlet Obstruction:	left to right facing road
Culvert 1:	50%
Culvert 2:	50%

Table 2: Measurements taken at the Eanes creek and Edgrove Drive Crossing

Location:	Eanes Creek at Edgrove Drive
Road Type:	2 lane road
Culvert type:	Circular Concrete
Length of stream through Culvert (ft):	45
Elevation from invert to road surface(in):	75
Inlet Dimensions (in):	left to right facing road
Culvert 1:	25"
Culvert 2:	30"
Culvert 3:	30"
Inlet Obstruction:	left to right facing road
Culvert 1:	50%
Culvert 2:	50%
Culvert 3:	25%

Table 3: Measurements taken at the Eanes creek and Dellana Lane Crossing

Location:	Eanes Creek at Edgrove Drive
Road Type:	2 lane road
Culvert type:	Circular Concrete
Length of stream through Culvert (ft):	24
Elevation from invert to road surface(in):	9
Inlet Dimensions (in):	left to right facing road
Culvert 1:	25"
Culvert 2:	30"
Culvert 3:	30"
Inlet Obstruction:	left to right facing road
Culvert 1:	50%
Culvert 2:	50%
Culvert 3:	25%

The emergence of wide-scale LiDAR data are allowing for new studies to take place that were previously not feasible with the 10 m or 30 m available from the National Elevation Dataset (NAD). Bare Earth LAS classified points from the Travis and Williamson County LiDAR dataset were used to produce a high resolution triangulated irregular network (TIN) for the Rollingwood study area, seen below in Figure 4. Zoomed in maps of the TIN over each of the low water crossing locations are found in Appendix 1, Figures 9 -11. As seen in these figures the road surface and river channel are clearly defined in the TIN. The slope of the culverts through the road, the horizontal road profile, and river cross-sections were extracted from this TIN and may be found in Appendix 1, Figures 12-17. First, a raster DEM was created from this LAS dataset for extracting road surface profiles, but the natural land features were not well depicted in the raster DEM even at high resolution (1 meter). TIN surfaces are better at preserving natural features. The points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to an accurate representation of the terrain (Majumder, 2008) such as ridges or valleys which were of interest for this study.

The culvert slope and road profile over the crossing were the final pieces of data required to model the low water crossings using the Bentley CulvertMaster program. The elevation of the culverts at the entrances and at the outlets was found from the road profile and used to calculate the slope of the culverts. There are two methods to obtain a rating curve for a series of culverts in CulvertMaster, the Quick Calculator and the Analysis tool. The Quick Calculator tool requires less detailed information and is designed to model less complex culvert system. This tool should be used when an estimate or fast result is needed, or when minimal data for a system is available. In this study, there was enough data to use the Analysis tool in CulvertMaster to develop the rating curves at the Rollingwood Low Water Crossings, seen below in Figures 5-7.

The Analysis tool in CulvertMaster allows users to input roadway elevations to calculate flow over the roadway in addition to flow through the culvert. As seen in the rating curves below, the road surface elevation is exceeded at low flows on the rating curve compared to a flow of 10,000 cfs that Eanes Creek experiences during flash flood events. When flows reach 10,000 cfs, Bee Caves Road will be conveying or overtopping 9,700 cfs of the 10,000 cfs and have a headwater depth of 592 ft. These rating curves are an underestimate of the headwater elevations that would be expected that occurs at these locations for a given flow. They assume unobstructed inlets which were not the observed during the low water crossing survey. Due to debris blocking culvert entrances, observed headwater elevations would be rise sooner, and at lower flows than indicated on these curves. The frequency of flooding that occurs at these locations and the results of this study support the notion that these crossings are undersized. Considering the importance of these roadways to the transportation network it would be sensible for the Rollingwood community to consider design modifications.

Figure 4: TIN covering Rollingwood Low Water Crossings

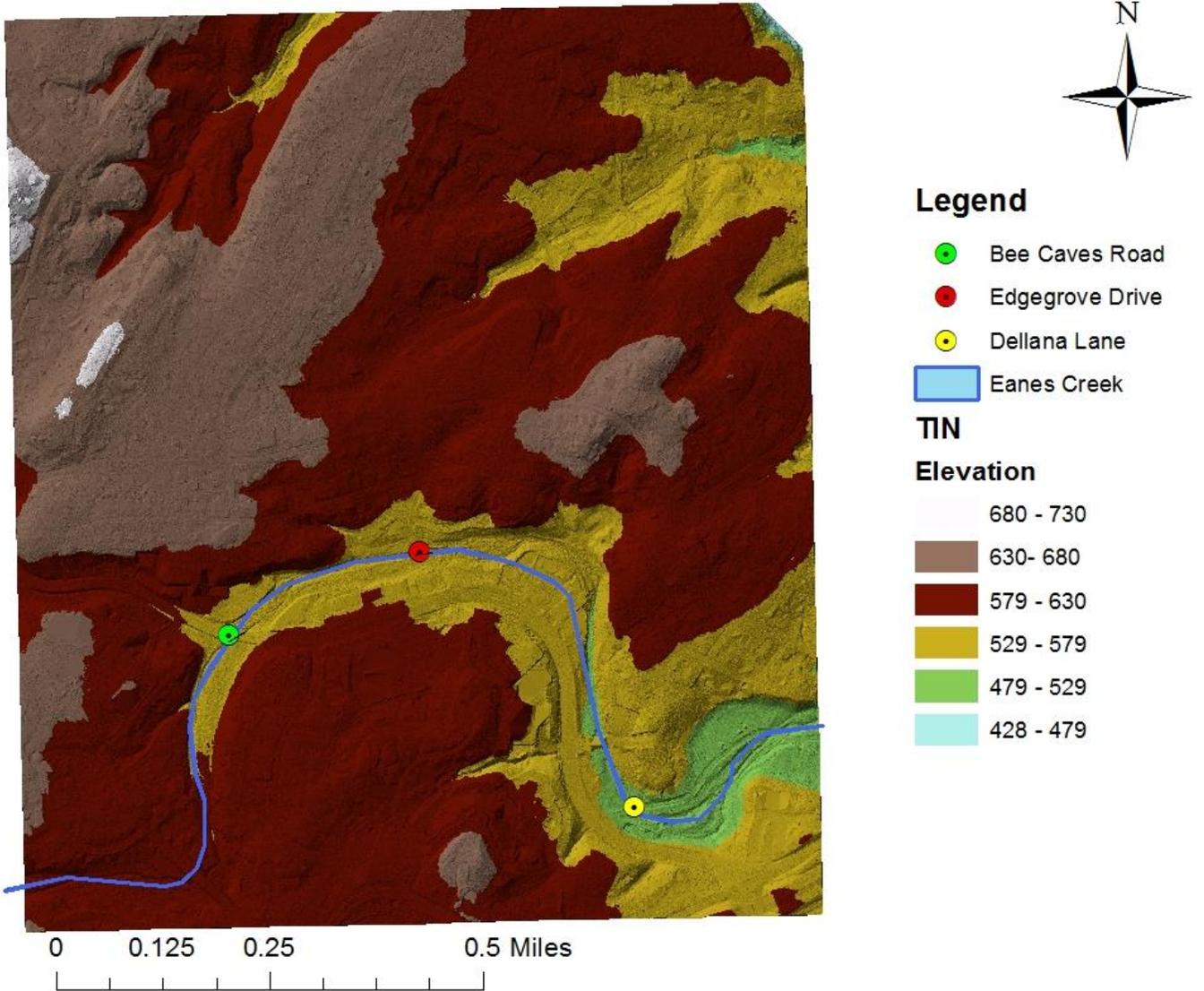


Figure 5: Eanes Creek at Bee Caves Road Low Water Crossing

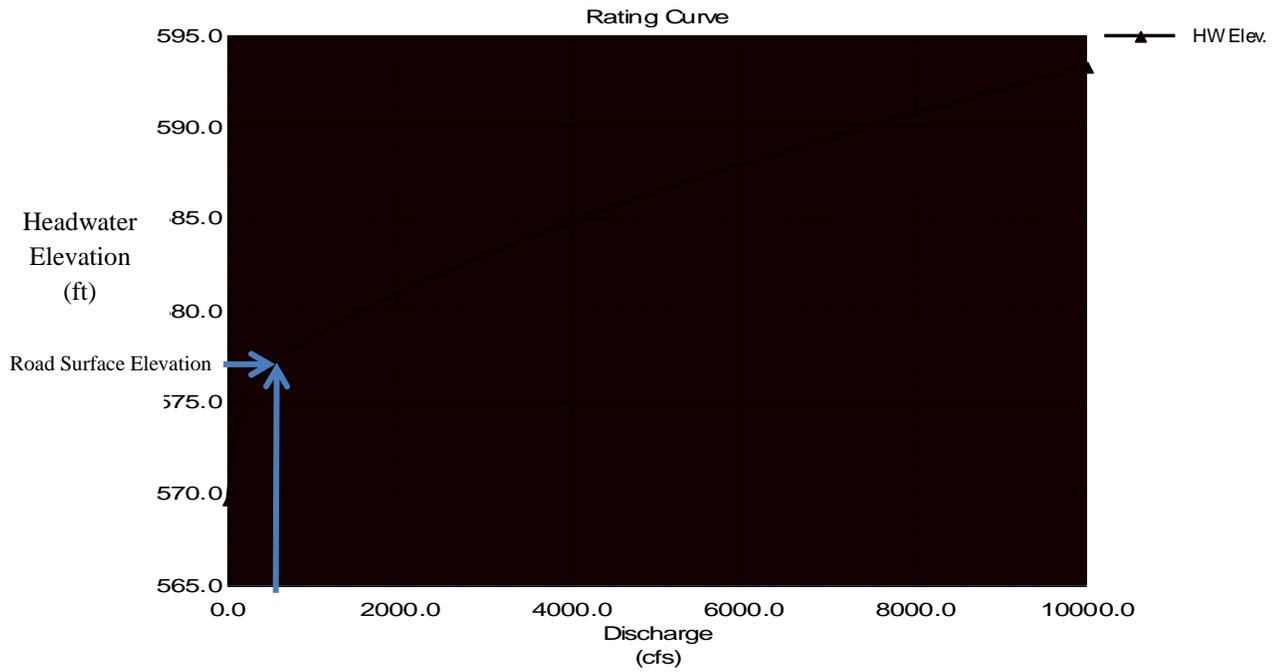


Figure 6: Eanes Creek at Edgemoor Drive

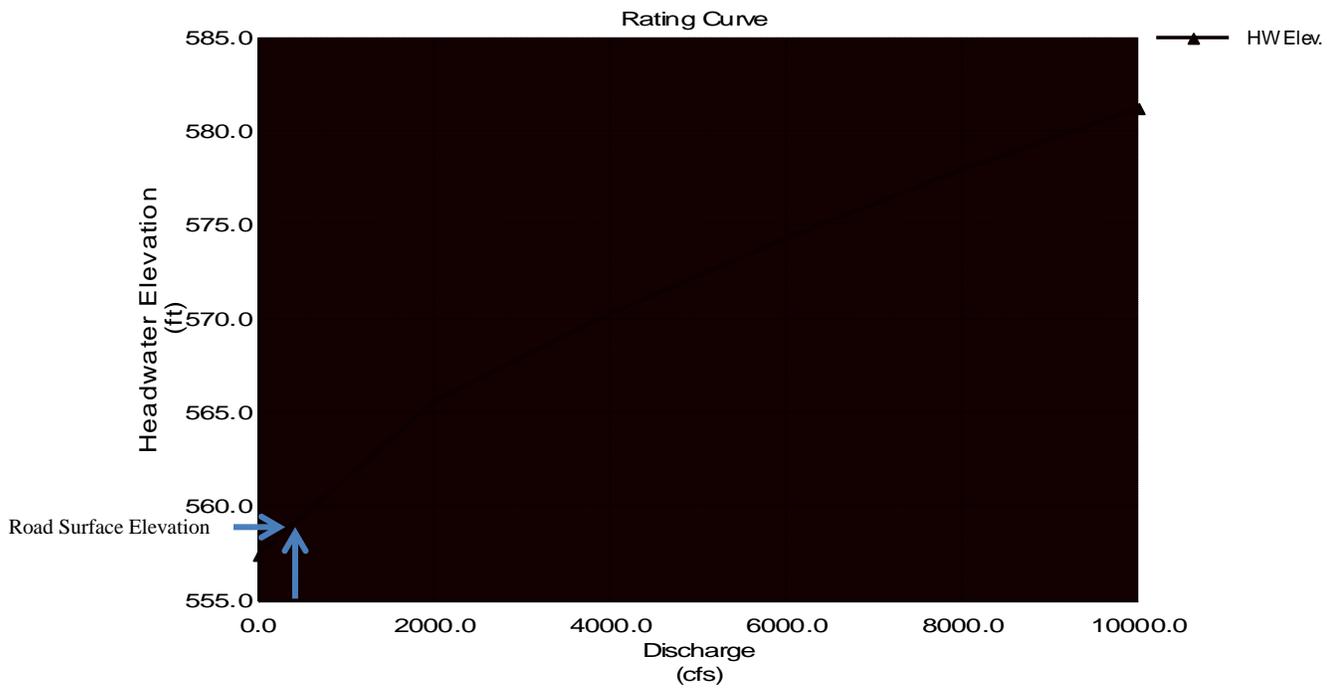
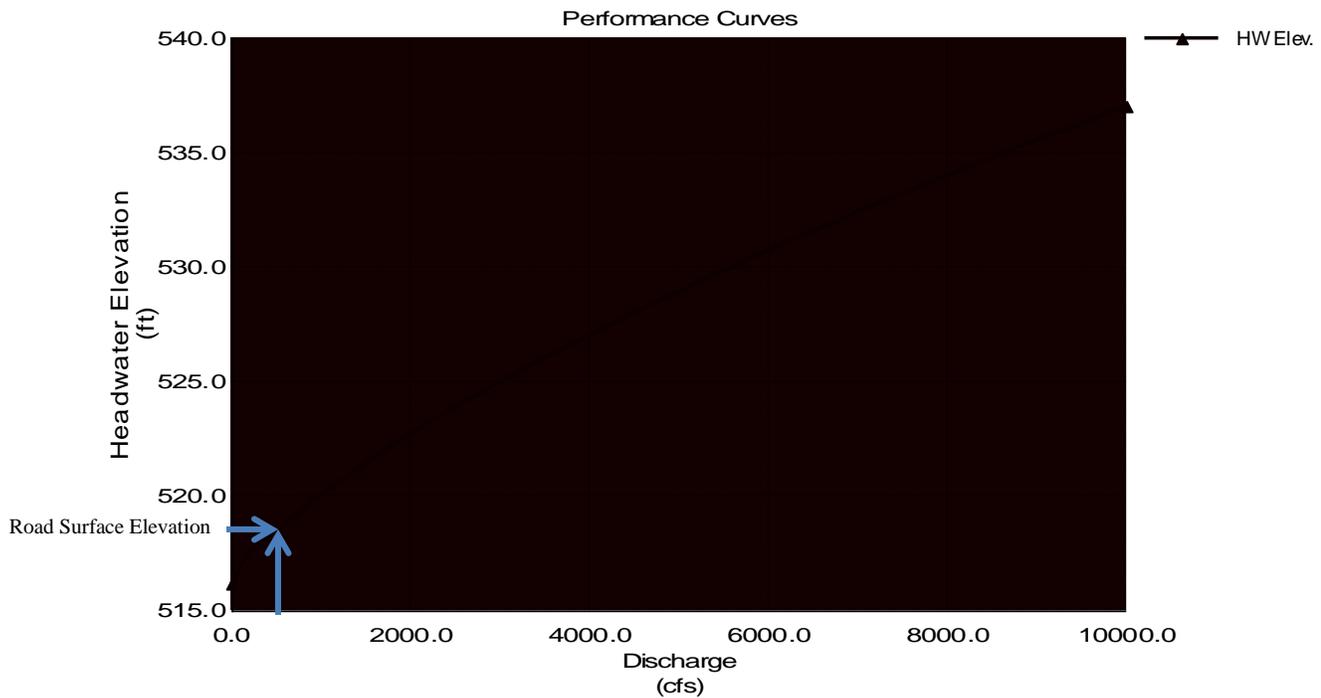


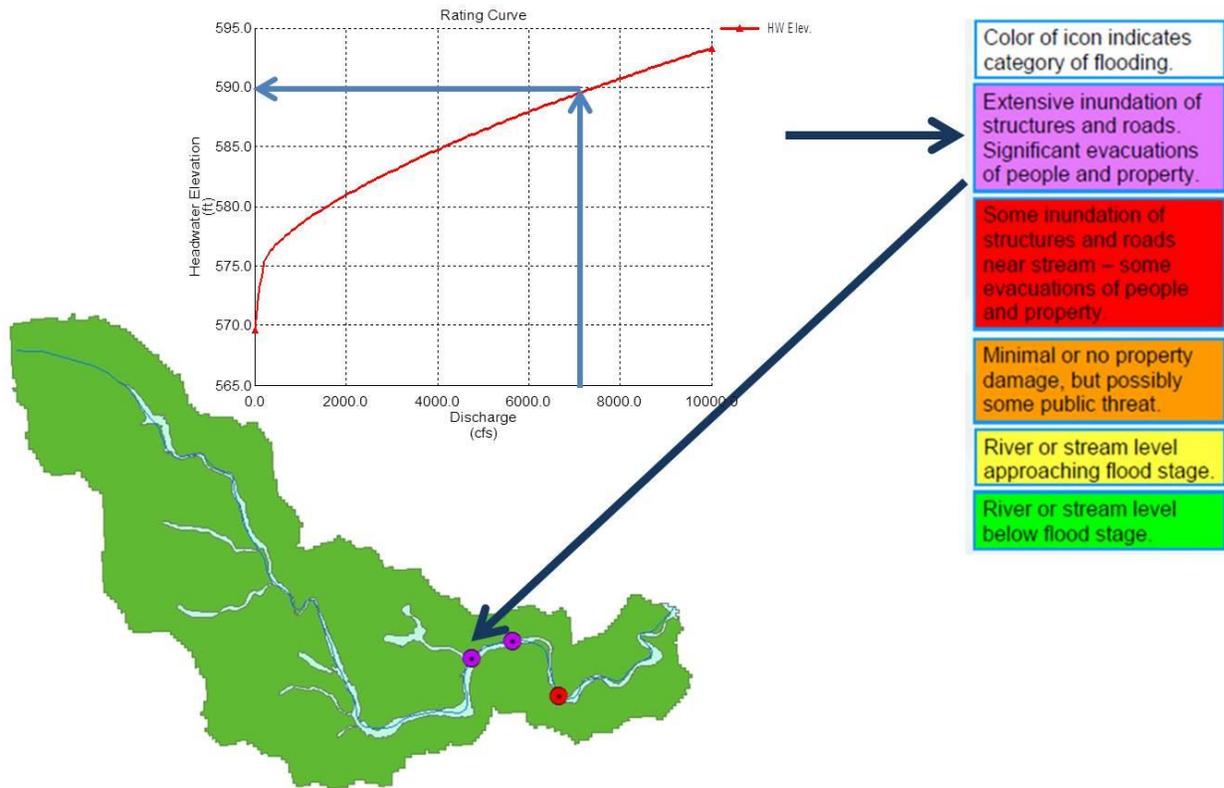
Figure 7: Eanes Creek at Dellana Lane



Conclusions

A fragmented transportation network creates hazards and delays for the surrounding communities. There is little real-time information available at this time to inform emergency responders and travelers of flooded roadways. Currently, Emergency responders have to use their best judgment when navigating to distress calls during flooding events because the navigation devices guiding the drivers do not have road flooding information. Impassible and flooded roadways delay emergency responders and increases response times. The City of Austin and the Austin Watershed Department have developed a website, ATXfloods.com, which displays the condition, open or closed, of frequently flooded low water crossings across Travis and Williamson County. This is a useful tool for the public for deciding traffic routes, but is not as useful for the emergency response community. There is a lag time associated with this website, because flooding must first be reported on the roadway before the condition changes on the website. The roadway may be flooded for hours before the condition is updated in the website, and considering emergency responders are most active at the beginning of flood events this system provides little information. However, if this mapping system were combined with the NFIE 15 hour-ahead forecasts it would become a more informative system and useful system emergency response community. As seen in Figure 8, given a flood forecast the headwater depth on the roadway can be determined using the rating curve and the low water crossing location will be designated a color based on the risk the flow poses.

Figure 8: Assigning color to culvert locations according to risk provided from NFIE forecast and low water crossing rating curve



Planning time is vital for the emergency response community and for persons relying transportation network for going to work and other obligations. NFIE- Response15- hour ahead flood predications on roadways would provide extra time for planning and action. This time can be used to plan alternative transportation routes and evacuation plans as well as for pre-storm road closures. It can provide information to the community early enough for persons to make decisions that will affect activities later on. An example being, a person commuting using Bee Caves Road may decide to work from home for the day rather than going to work because NFIE forecasts predict flooding on Bee Caves Road during his or her commute home from work. As discussed earlier, driving is the lead cause of dead during flood events accounting for 75% of flood related deaths in Texas. Implementing a system that provides actionable information regarding roadway flooding could reduce this statistic.

Future Work

Continuing into the summer, and the NFIE-Summer Institute, I will be continuing this research and collecting more data for these low water crossings. A land based tripod LiDAR survey will be performed at each of the low water crossing locations to obtain more precise physical measurements of the culverts and surrounding area. This data will be used to model the culvert systems as done in this study. I would also like to use a HEC-HMS model developed by Cynthia

Castro, to develop design storm hydrographs at these locations and have a more accurate idea the flows these low water crossings experience.

Continuing with the work that Richard Carothers has done extracting cross-sections, I will be using his code / model to extract cross-sections from the LiDAR data for Eanes Creek. If this proves successful, I will transition to other rivers in the NHD Plus dataset that are in the LiDAR dataset for Travis and Williamson County and add more low water crossings to the NFIE-Response database. The additional cross-sections will allow the flow in Eanes Creek to be modeled using a hydraulic model which provides a more detailed flow forecast. Using a hydraulic model will allow for flow to be distributed along the reach and will provide more accurate flooding information compared to the result of Rapid. Also, I will be looking into modeling these culverts “as-is” accounting for that fact that there is a significant amount of debris covering the inlets and obstructing flow into the culvert.

Appendix 1:

Figure 1: Bee Caves Road culverts 1 & 2 Inlet (left to right)



Figure 2: Bee Caves Road Culvert 1 Inlet



Figure 3: Bee Caves Road Culvert 2 Inlet



Figure 4: Bee Caves Road culvert outlets 2 & 1 (left to right)



Figure 5: Edgegrove Drive culvert inlets 1, 2 & 3 (left to right)



Figure 6: Edgegrove Drive culvert outlets 3, & 2 (left to right)



Figure 7: Dellana Lane culvert Inlets 1,2, 3 & 4 (left to right)



Figure 8: Dellana Lane culvert Outlets 4, 3, 2, & 1 (left to right)



Figure 9: TIN at Eanes Creek and Bee Caves Road Low Water Crossing

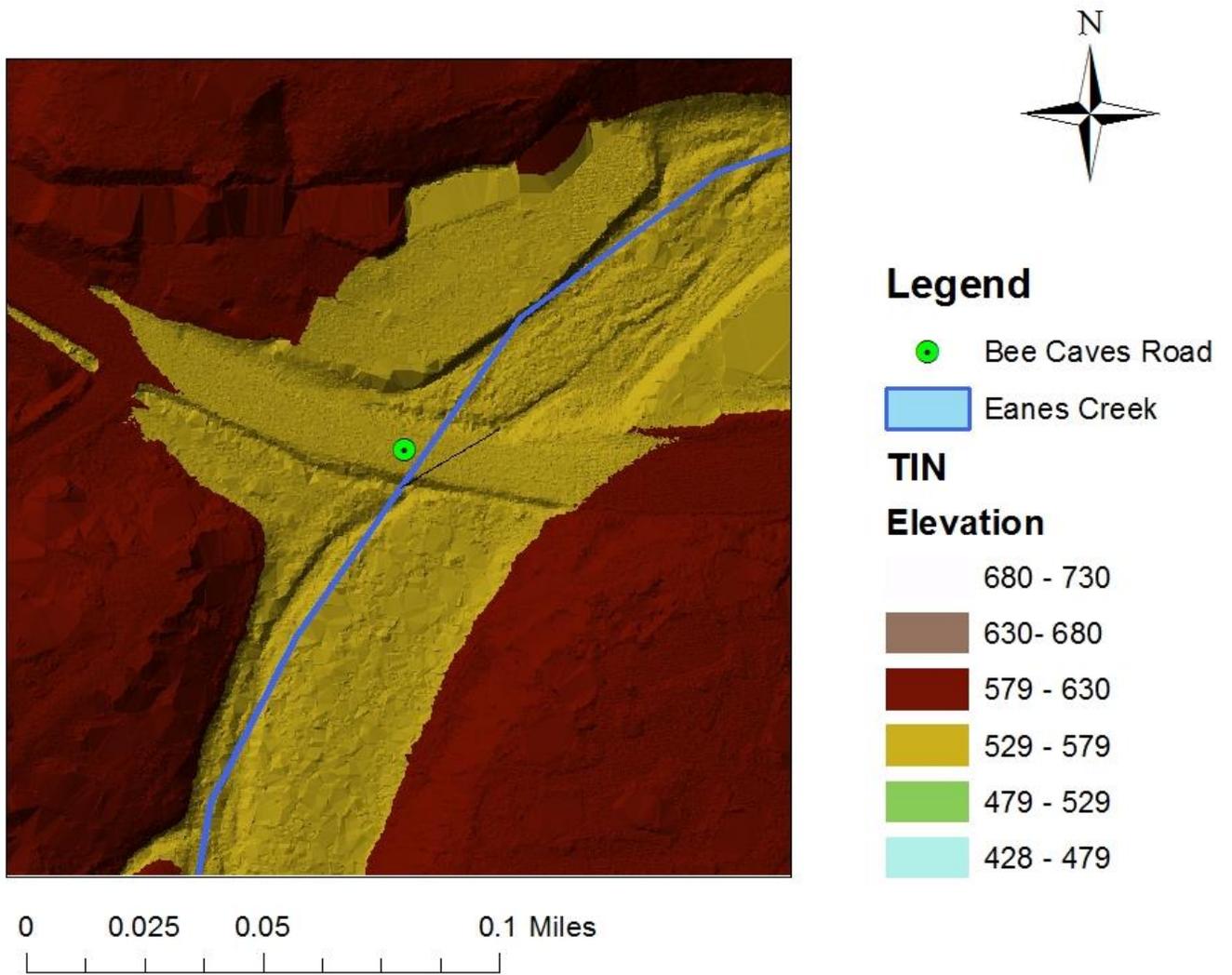


Figure 10: TIN at Eanes Creek and Edgegrove Drive Low Water Crossing

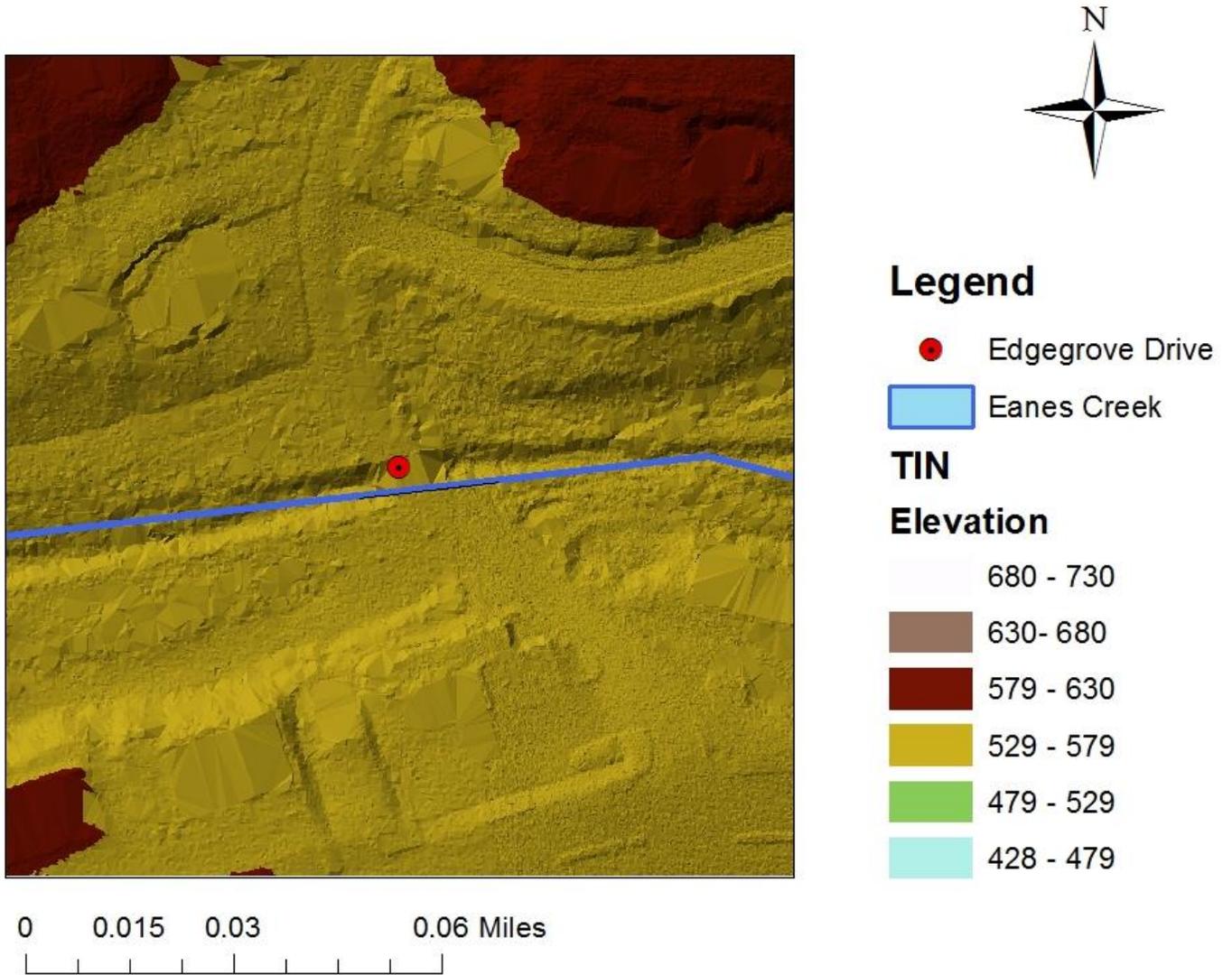


Figure 11: TIN at Eanes Creek and Dellana Lane Low Water Crossing

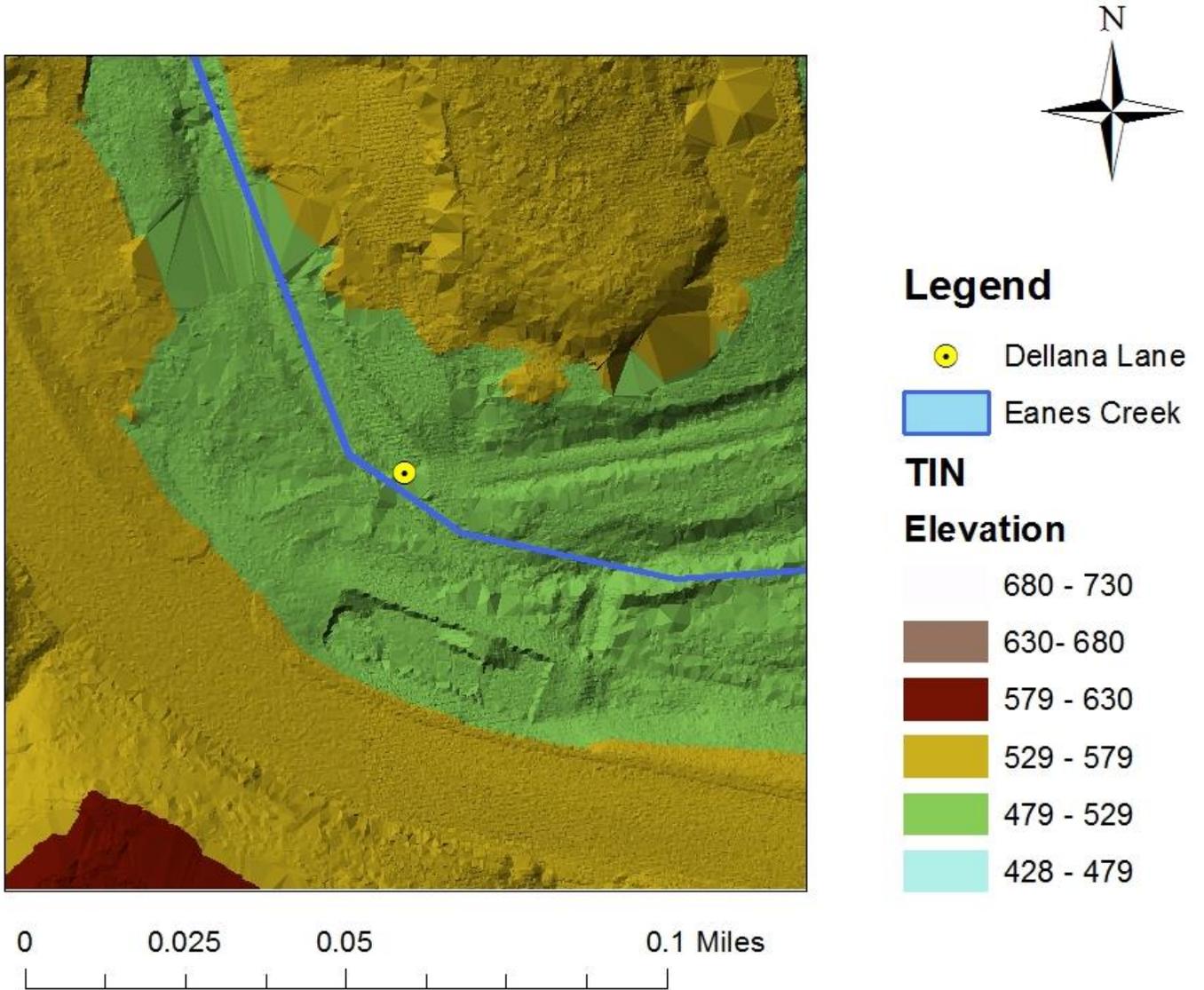


Figure 12: Road Profile at Eanes Creek and Bee Caves Road

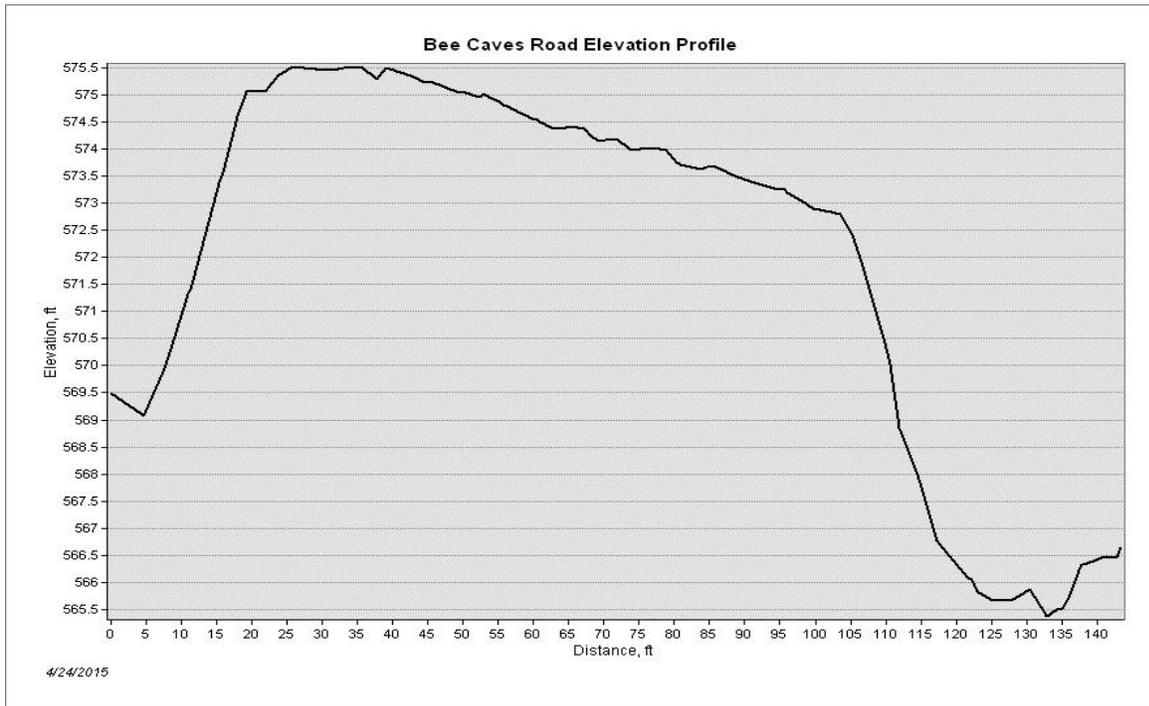


Figure 13: Road Profile at Eanes Creek and Edgegrove Drive

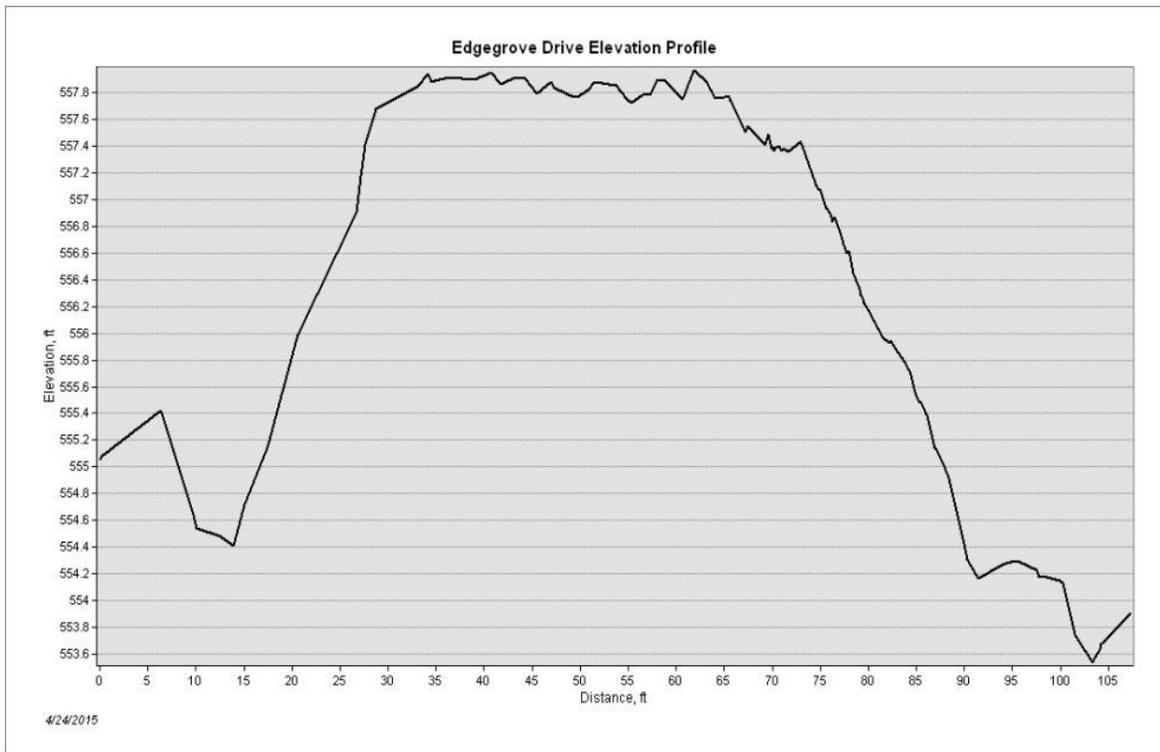


Figure 14: Road Profile at Eanes Creek and Dellana Lane

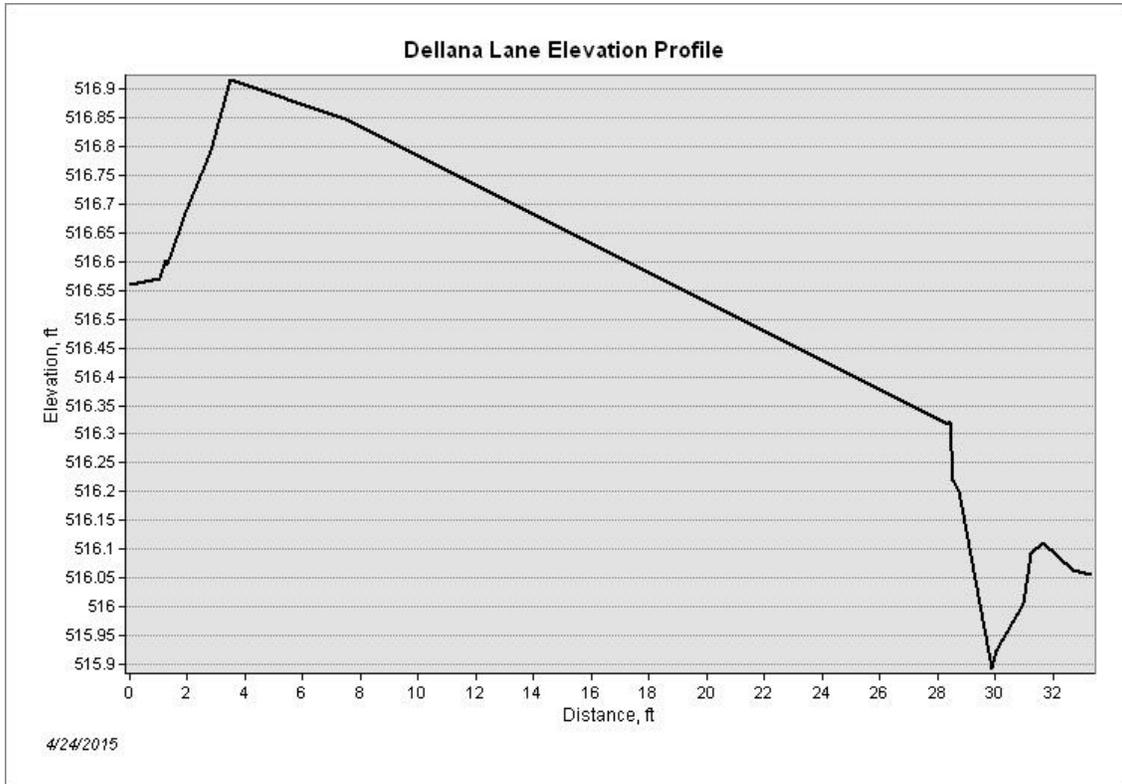


Figure 15: Eanes Creek at Bee Caves Road Cross Section

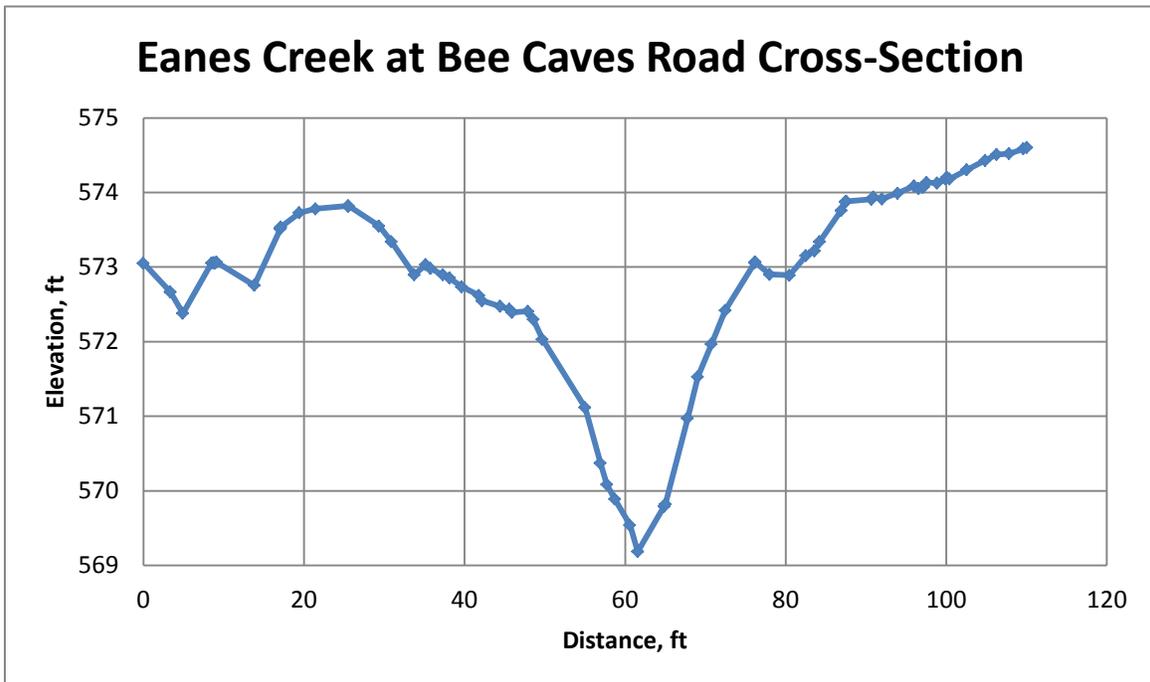


Figure 16: Eanes Creek at Edgemoor Drive Cross Section

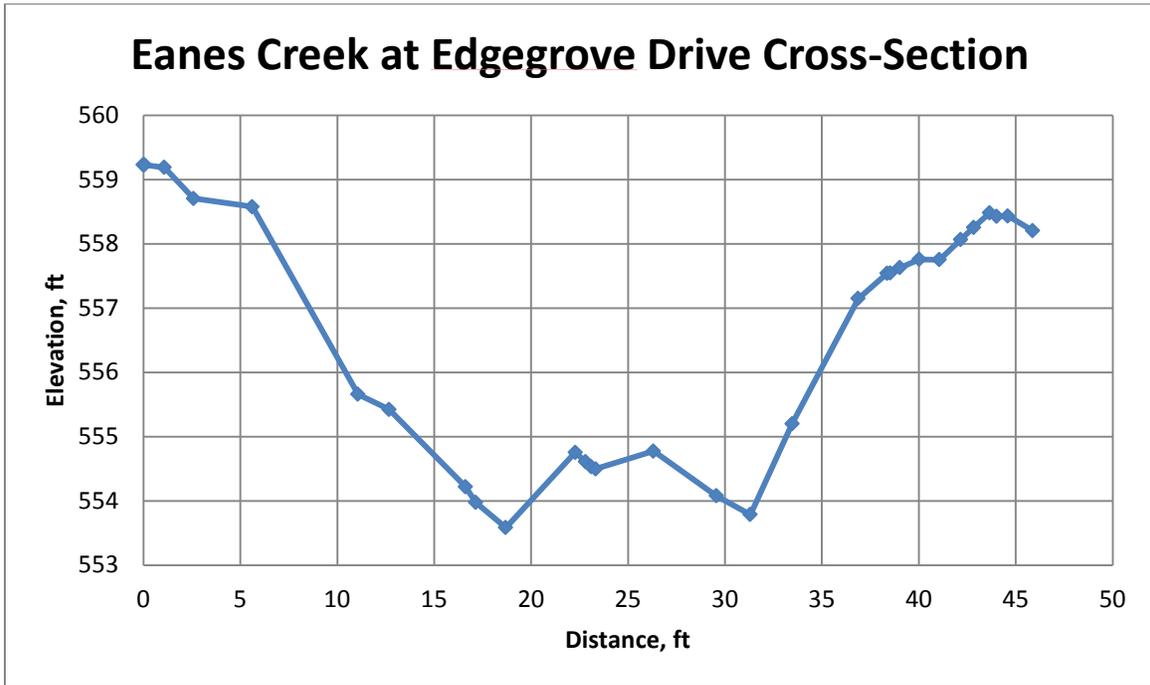
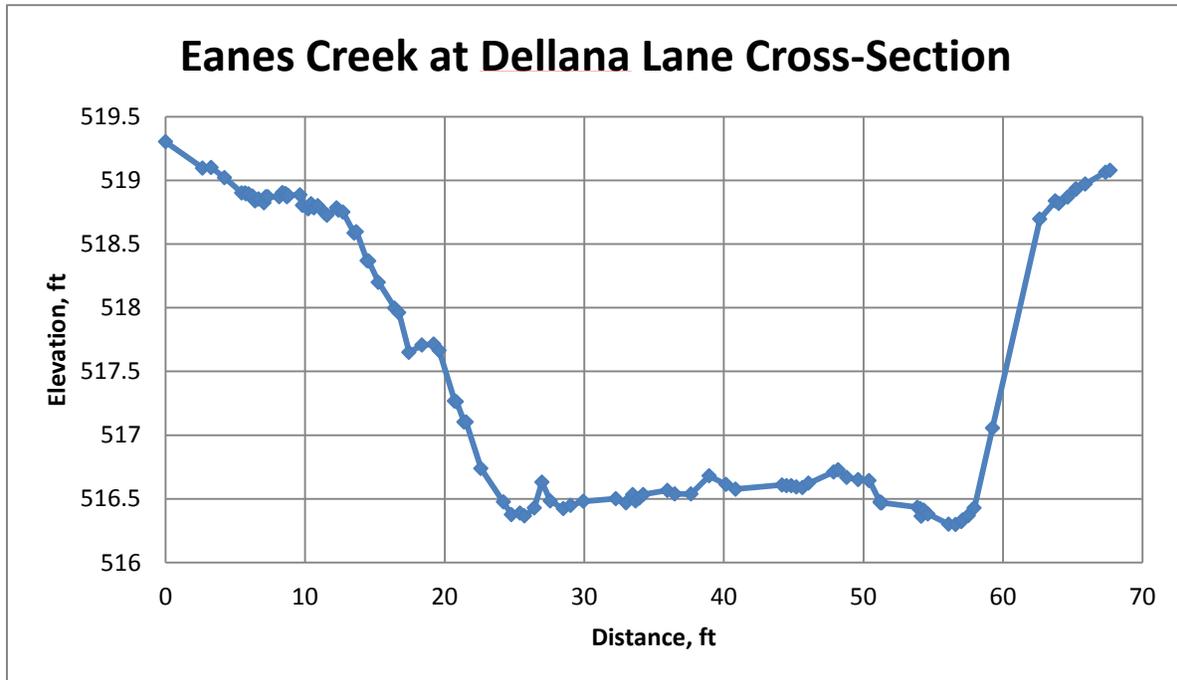


Figure 17: Eanes Creek at Dellana Lane Cross Section



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