Journal of Rural Social Sciences

Volume 37
Issue 3 *Volume 37, Issue 3*

Article 6

11-22-2022

Disruption to EMS Service During Flood Scenarios in Western North Carolina

Julia Cardwell
University of North Carolina, Chapel Hill, jmcard@email.unc.edu

Recommended Citation
Cardwell, Julia. 2022. "Disruption to EMS Service During Flood Scenarios in Western North Carolina." *Journal of Rural Social Sciences*, 37(3): Article 6. Available At: https://egrove.olemiss.edu/jrss/vol37/iss3/6

Please address all correspondence to Julia Cardwell (jmcard@email.unc.edu).

Disruption to EMS Service During Flood Scenarios in Western North Carolina

Julia Cardwell
University of North Carolina at Chapel Hill

ABSTRACT
Given that the intensity and frequency of flood events will increase under climate change scenarios, the ability to model potential impacts, such as those to healthcare access, will become increasingly important. This study analyzes EMS response time under both a historical (Tropical Storm Fred in August 2021) and a modeled flood event (FEMA's 100-yr floodplain) in western North Carolina, a predominantly rural area. The results indicate that network disruption during flood events is a concern in the study area, and while the historical event produced moderate disruption, the 100-yr event produced major disruptions throughout the study area. This research emphasizes the importance of network vulnerability analyses in rural areas, which has previously been understudied.

KEYWORDS
EMS response, flooding, rural healthcare access

INTRODUCTION

There will be an increase in the intensity and frequency of flood events in North Carolina (Kunkel et al. 2020) and the United States more generally (Swain et al. 2020) due, in part, to the impacts of climate change. An increase in major flood events has the potential to impact many sectors of society, and the transportation sector has been identified as particularly vulnerable to the impacts of climate change (Hooper, Chapman, and Quinn 2014), meaning that transportation network vulnerability to the impact of increasing natural hazards like flooding is a major concern (Pregnolato et al. 2017; Zhang et al. 2020). Degradation of the transportation network due to the impacts of increasing flooding and other damage associated with climate change has the potential to disrupt society in a number of ways, including impacting passenger travel, shipping and freight, and access to essential services (Nagurney, Qiang, and Nagurney 2010). As such, the potential impact of flooding on emergency service provisions is an emerging frame of analysis for examining road network vulnerability in a changing climate (Yin et al. 2017).

This study investigates the influence of flood induced road network vulnerability on EMS response times in western North Carolina, a predominantly rural area as defined by the North Carolina Department of Health and Human Services' Office of Rural Health (North Carolina Department of Health and Human Services 2019). In particular, this study uses road closure data from a recent flood event within the study area (the remnants of Tropical Storm Fred in August 2021), as well as the Federal Emergency Management Agency (FEMA) modeled 100-yr floodplain, to create service areas from EMS dispatch centers under different time constraints (10, 15, 20 minutes) to investigate how spatial accessibility changes during these historical and modeled flood events.

BACKGROUND

Instances of damage and disruption from road network inundation have been increasing, and while there is demand for research surrounding the impacts of these events, relatively limited research literature is available (Yin et al. 2016). Existing studies have found that flooding events can cause significant impacts on the capacity of EMS services within various timeframes (Alabbad et al. 2021; Coles et al. 2017; Yin et al. 2017), that these events can cause non-linear impacts (Yin et al. 2017), and that both the physical locations of critical infrastructure (like EMS dispatch locations) and the road network can be vulnerable to impacts from flood events (Green et al. 2017). Because demand for emergency services can actually increase during flooding (Coles et al. 2017), measuring accessibility during these events can become even more essential.

To date, most studies of the impacts of EMS services resulting from road network disruption due to flooding have focused specifically on urban areas (Li et al. 2021; Pregnolato et al. 2017; Suarez et al. 2005; Yin et al. 2017; Zhang and Alipour 2019) or have focused on impacts on access to vulnerable locations like nursing homes (Coles et al. 2017; Green et al. 2017). Rural areas are persistently understudied in analyses of network disruption due to flooding, but they may be more vulnerable to impacts for several reasons. The capacity of road networks to manage disruptions from natural hazards such as flooding events is dependent on the resilience of these networks. In large part, resilience of road networks is a result of redundancy, which allows for alternative routes with limited disruption when parts of the road network are out of service (Lhomme et al. 2013). Urban areas exhibit more robust, more redundant road networks that rural areas (Shrestha, Pudasaini, and Mussone 2021), meaning that the impact of road closures in rural areas may be more impactful than in urban areas.

In addition, rural areas already have decreased access to healthcare and experience overall health disparities compared to urban areas (King et al. 2019). Further, rural areas face significant challenges relating to EMS servicing as compared to urban areas. EMS units in rural areas often have extremely large service areas of varying terrain and road quality and face significant funding concerns (King et al. 2019). Of particular concern in rural areas when considering flood scenarios is staffing concerns at rural EMS units. Because there are limited full-time employees and many rural EMS services are volunteer only (King et al. 2019), EMS service providers must often travel first to the dispatch center before they can respond to an emergency call. Because of these issues, rural areas experience significantly higher EMS response time than urban areas, which increases risks to residents. In urban areas, the most widely used ambulance response standard is less than 9 minutes, compared to less than 15 minutes in rural areas (Fitch 2005), and in many rural areas it is still not possible to meet this standard (Chanta, Mayorga, and McLay 2014). The combination of already decreased response time and the potential for amplified effects of road closures may produce heightened vulnerability in rural areas.

In addition, although rural areas are particularly susceptible to the impacts of climate change for a variety of reasons, including limited economic diversity and dependence on climate-sensitive sectors (Melillo, Richmond, and Yohe 2014; Myers, Ritter, and Rockway 2017), rural areas are simultaneously underprioritized in adaptation efforts. The public discourse, as well as the governmental focus, around climate change adaptation often centers urban and coastal areas (Fitzgibbons and Mitchell 2019; Jurjonas and Seekamp 2018; Moser 2014). Further, due to a general devolution of adaptation responsibility to local areas, rural areas often lack the staffing and financial capacity to execute adaptation measures (Brody, Kang, and Bernhardt 2010; Consoer and Milman 2018). Increasing a focus on the susceptibility of rural areas to impacts from climate change is important for expanding public and governmental attention to these areas.

Many studies have utilized FEMA's 100-yr floodplain (Kermanshah and Derrible 2017; Nowell, Horner, and Widener 2015; Yin et al. 2017) to simulate potential flood events when examining road network vulnerability. The FEMA flood map is the basis for many decisions regarding floodplain management, meaning that the accuracy of these maps is of the utmost importance, and FEMA often touts the technical credibility of their mapping efforts (FEMA 2017). Because FEMA maps remain technically important to planning for flood risk, especially from a governmental perspective, it is critical to integrate these predictive maps into flood risk analyses.

However, methodological decisions in the creation of FEMA flood risk maps leave some communities more well-served by mapping efforts than others. In particular, rural communities are persistently under-mapped for a number of reasons, resulting in potentially significant accuracy issues in these areas (Pralle 2019). More generally, FEMA flood maps have been shown to regularly misrepresent flood risk, and both internal and external analyses of FEMA flood map performance during flood events have indicated significant accuracy issues with the flood map products (FEMA 2006; Xian, Lin, and Hatzikyriakou 2015). Because of this, this study takes a hybrid approach by utilizing both FEMA's 100-yr floodplain, and data from a historical flood event (August 2021). Taking a hybrid approach allows both a consideration of the most utilized flood risk estimates (the FEMA flood maps) and the impacts of experienced events in the study area, while also allowing for a comparison between actual road closures and predicted closures.

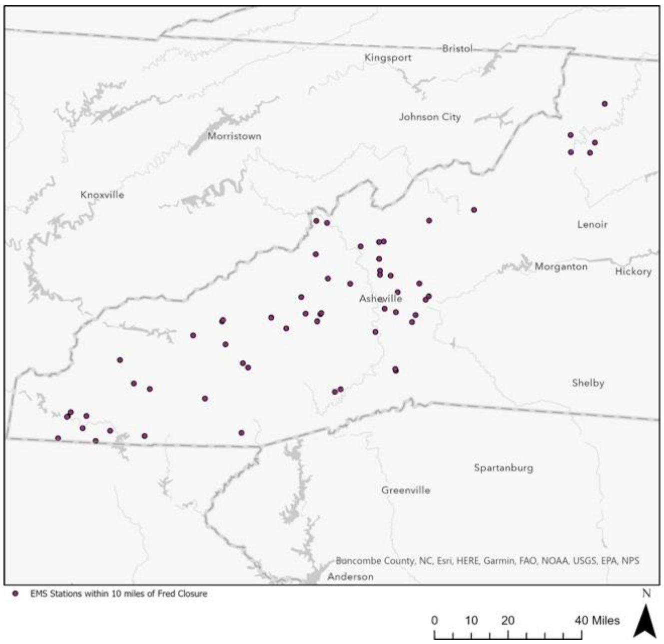
STUDY AREA

Eastern North Carolina is typically associated with more flood events due to its coastal location. However, western North Carolina has experienced an increase in flooding events and remains a vulnerable area for flooding, despite being understudied (Sugg et al. 2021). In August 2021, western North Carolina was heavily impacted by flooding and landslides due to the remnants of Tropical Storm Fred, which caused up to 10 inches of rainfall in some areas, five deaths, and estimates of more than $18 million in damage (Miller n.d.). This event also resulted in a FEMA major damage declaration for Avery, Buncombe, Haywood, Madison, Transylvania, Yancey, and Watauga counties (McDaniel 2021).

The study area for these analyses included all EMS stations within 10 miles of a road closure during the peak closures of Tropical Storm Fred. Figure 1 indicates the geographical location of the study. Within the 20 counties included in the study area, 17 are classified as rural by the

North Carolina Department of Health and Human Services' Office of Rural Health (North Carolina Department of Health and Human Services 2019).

Figure 1: EMS Stations Impacted during Tropical Storm Fred in Western North Carolina (2021)



DATA

Road closure data were obtained from North Carolina Department of Transportation's API system for the Tropical Storm Fred event period (8/16/2021 – 8/19/2021) (NCDOT 2022a). To represent the 100-yr floodplain, FEMA flood risk data as compiled by North Carolina Flood Risk Information System were utilized (Flood Risk Information System 2022). To identify EMS dispatch locations, this study utilized the EMS station dataset produced by the Homeland Infrastructure Foundation-Level Data program, which was limited to locations in western North Carolina with a description of either "Ambulance and Fire Service Combined" or "Ambulance Services, Air or Ground" (Homeland Infrastructure Foundation-Level Data 2022). A road dataset, produced by North Carolina Department of Transportation (NCDOT 2022b), was used to translate point road closures to polygons (see Methods section) and to identify road segment closures during the 100-yr flood event. Finally, a building footprint dataset from NC OneMap (North Carolina's open GIS data platform) was utilized to analyze service area within the context of populated areas (North Carolina Emergency Management 2010).

METHODS

Road Data Preparation

The road closure data from the Fred event were initially provided in point format. However, fields available within the dataset (severityDesc, direction, location) provided an estimate of the length, direction, and more detailed location of road disruption. Because the fields lacked standardization, and due to difficulties translating points to lines along a road network, closure points from NCDOT were manually translated to line features in ArcMap 10 using those informational fields. This process allowed the road closure data to more accurately represent the impact of the road closure along the road network, instead of a single point instance of closure. In some cases, the provided length of the road disruption exceeded the length of the available road segment or intersected a major roadway that was not indicated as a closure. In those cases, the length of road disruption was shortened in the translation to line to avoid producing impacts in un-impacted areas. The road closure data also include a start and end field for when the road segment was closed and reopened. The entire event period was divided into four-hour subsets and the number of road closures was calculated for each four-hour period. The four-hour period with the highest number of closures was utilized to create the service areas.

100-yr Floodplain Preparation

Although FEMA does provide depth estimates for the 100-yr floodplain in some geographical areas through their Flood Risk Products (FEMA 2021), these data are not available everywhere, and were not available for most of the study area. To determine the approximate depth of flooded areas in a 100-yr flood scenario, the Floodwater Depth Estimation Tool (FwDET) created by the Surface Dynamics Lab at the University of Alabama (Peter et al. 2020) was executed in Google Earth Engine using the FEMA 100-yr floodplain boundaries and a model supplied Digital Elevation Model (DEM) to create estimates of flood depth within the 100-yr floodplain. While roads are travelable with limited amounts of standing or flowing water, 25-30 cm is generally considered as the limit for travelability (Green et al. 2017; Shi et al. 2020; Yin et al. 2016). Therefore, in this study, any road segment that intersected with a flooded area that had a flood depth of greater than or equal to 30 cm was considered flooded and untravellable.

Network Analysis

After identifying the closed road segments during the Fred flood event, the EMS dataset was subset to represent all EMS stations within 10 miles of a road closure during event. This subset represented the “Facilities” input to a service area analysis using ArcGIS Pro’s Network Analysis Package. This package is commonly used in analyses of EMS response time, including those examining flood impact to response time (Coles et al. 2017; Yang et al. 2020; Yin et al. 2017).

Efforts were taken to modify assumptions within the Network Analysis Package to make conditions more realistic to emergency vehicles. For example, allowances for the vehicle to make U-turns at restricted intersections, utilize private roads, not avoid unpaved roads, and allow access where through traffic is prohibited. In addition, the “Driving an Emergency Vehicle” setting was utilized. Despite these modifications, this software package is still an imperfect predictor of actual drive time, especially considering restricted road scenarios like flooding, in which there might be traffic delays from confusion around road closures, turn-arounds at road closure locations, limited visibility, etc. Further, as already noted, a service area analysis where the point of origin is the EMS station may not be realistic in rural areas given that these stations often do not have full time staffing. In this case, the service area analysis does not consider the additional time that it takes for staff members to travel to the point of origin, and how flooding may impact this stage.

Although emergency vehicles can travel above the speed limit in many situations, studies of EMS accessibility often either use the speed limit (Coles et al. 2017; He et al. 2019; Li et al. 2021; Yang et al. 2020; Yin et al. 2017) or a standard speed (Brown et al. 2016; Carr et al. 2006, 2009) to model ambulance travel. While some studies have begun to utilize real time traffic information to model ambulance travel speed (Luo et al. 2020), in general, analyses continue to use available speed limit data as a proxy for ambulance speed. In flood situations driven by rainfall, this may be generally appropriate because rainfall can reduce driver visibility, and speed reductions are generally evidenced during rain events due to safety issues (Pregnolato et al. 2017), meaning that ambulances may not be traveling at drastically higher speeds than other traffic (Lucchese 2020). Therefore, in this study, the traffic speed within ESRI’s standard network dataset were utilized as a proxy for ambulance speed.

A number of service areas were produced for the Fred event. One set of service areas represented the normal operating conditions of the EMS dispatch facilities at 10-, 15-, and 20-minute driving times. Another set of service areas, using the road closure data as “Barrier” polygons, was created to represent the Fred flood operating conditions of the EMS dispatch facilities at 10-, 15-, and 20- minute driving times.

After creating service areas for the Fred flood event, another set of service areas were created to model the 100-yr flood using the August (Tropical Storm Fred) flood impact extent (all roads within 10 miles of an EMS dispatch location utilized in the Fred service area). Instead of using actual road closures, these service areas used road closures modeled by the 100-yr floodplain with the 30 cm limit. This set of service areas represent the operating conditions if the areas around the facilities impacted in the Fred flood event had experienced a 100-yr event instead. It is important to note that the 100-yr flood represents the 1 percent per year likelihood that a single location experiences a flood of that magnitude, and that the probability that a broad land area (like the area impacted during Tropical Storm Fred in August 2021) would simultaneously experience a 100-yr flood is very low.

There are several differences between the 100-yr floodplain analysis and the experienced event analysis that should be considered when comparing the results of these analyses. The results of the 100-yr floodplain analysis differ from the analysis of the Fred event because the “Barrier” polygons that served as an input for the 100-yr service area model represent pure road closure (the area of the road that is actually flooded), not the road disruption that was modeled for the Fred event. It is also important to note that the Fred road closures include closures due to secondary impacts of flooding, including tree fall, which may be more realistic given that these secondary factors are common during flood events. In addition, it is possible that not all roads closed during Fred were appropriately recorded by North Carolina Department of Transportation, and this is especially possible for secondary and smaller roads. Finally, as already mentioned, the statistical probability of a broad land area, like the study area, would experience a simultaneous 100-yr flood is extremely low. Therefore, the scale of impact of any experienced flood would likely not rise to the modeled level of impact.

Building Footprint Analysis

After producing the sets of service areas, these service areas were compared to identify locations of network disruption due to flooding. In particular, the building footprint dataset was utilized to identify buildings that were accessible during normal operation and during both modeled and historical flood event. The building footprint data was utilized as a proxy for locations where people may typically call 911, with the understanding that 911 calls can also come from other locations (such as along the road network). A spatial join was utilized to create a count field that represented the number of buildings accessible by each facility for each service area. While many studies use total land area as a means to calculate change in service (Coles et al. 2017; Yin et al. 2017), rural areas are less populated, and in the case of western North Carolina, contain vast amounts of state park lands and other undeveloped lands. In this case, pure land area may not be an effective measure of disruption because this land area may not be populated.

RESULTS

Fred Road Closures

For the Fred flood event, Period 10 (2021-08-18 8:00:00) had the greatest number of road closures (64 closures). Figure 2 indicates the locations of the closures. In addition, Figure 2 indicates closures that existed outside of the 100-yr floodplain, which included 18 closures during Fred. There are two large pockets of closures, one south of Asheville and one north of Asheville, as well as other closures dispersed throughout the study area.

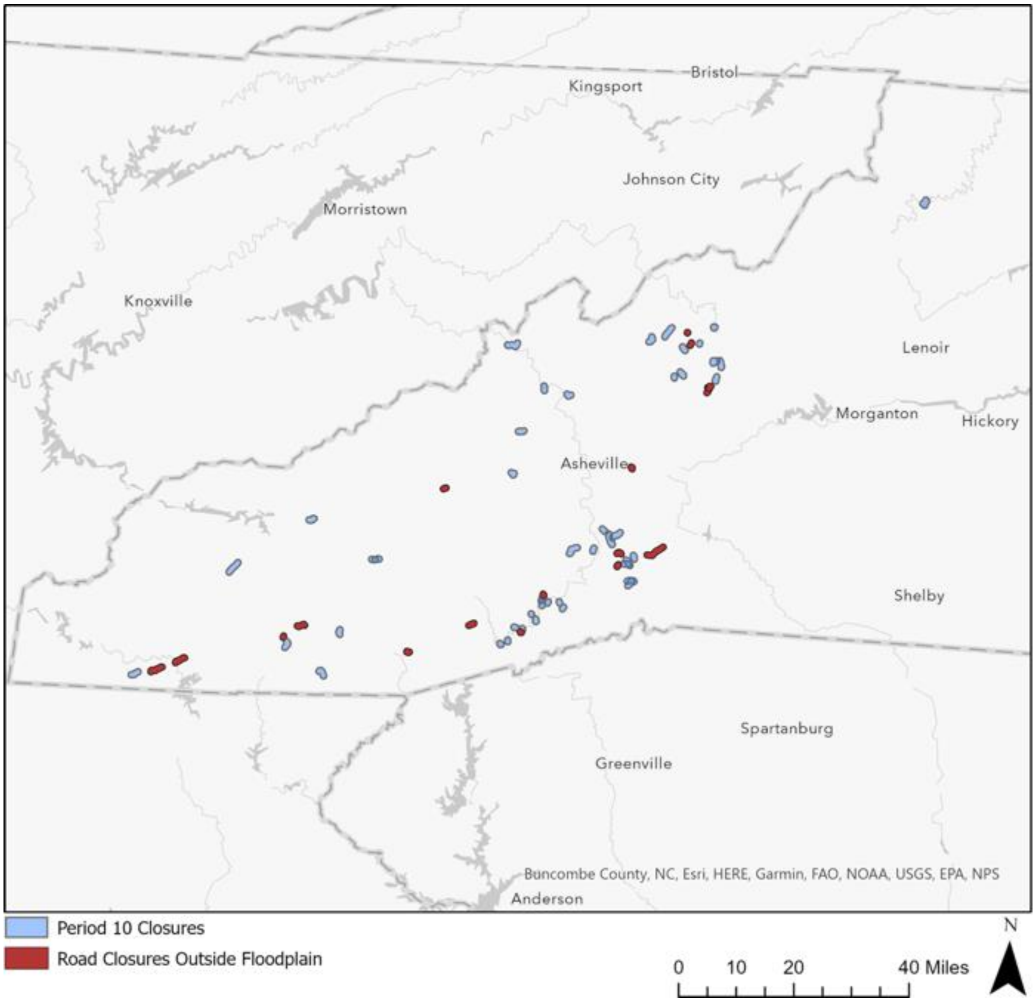
100-yr Floodplain Closures

After creating the FwDET raster for adding depth to the 100-yr floodplain, all road segments intersecting with flooded areas of over 30 cm were isolated. These segments became “Barrier” polygons in the service area for the 100-yr event. One road closure dataset was created for the entire study area (63 EMS stations within 10 miles of a road closure during Fred). This dataset is displayed in Figure 3. Closures predicted during a 100-yr event far exceed actual closures during the Fred event, and are widespread throughout the study area.

Service Area Analysis

Fred flood event. For the August flood event, 63 impacted EMS locations were identified, meaning that 63 EMS dispatch locations were located within a 10-mile radius of the road closures during Period 10 in this event. Figures 4, 5, and 6 indicate the results of the network analysis. As visible in the service area maps, areas within the study region experienced a decrease in service due to the impacts of flooding during the Tropical Storm Fred event. These areas become more prevalent during the 15-minute and 20-minute service area analysis and are distributed throughout the study area, with hotspots near Burnsville, south of Asheville, and surrounding Murphy.

Figure 2: Period 10 Closures during Tropical Storm Fred in Western North Carolina (2021)



The areas of the largest impact, including areas north and south of Asheville align with clusters of road closures as displayed in Figure 2.

Figure 3: Modeled Road Segment Closures During a 100-yr Flood Event

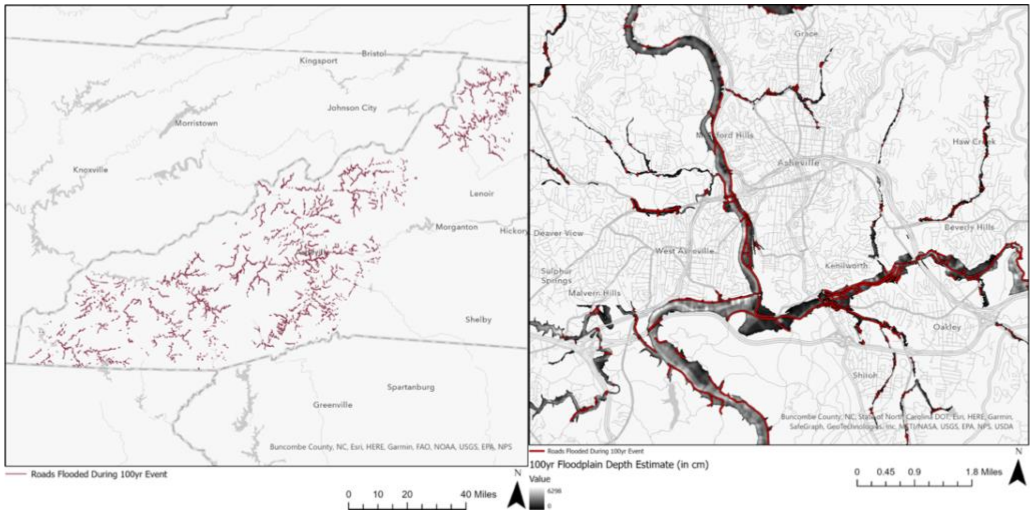


Figure 4: 10-minute Service Area Disruption during Tropical Storm Fred in Western North Carolina (2021)

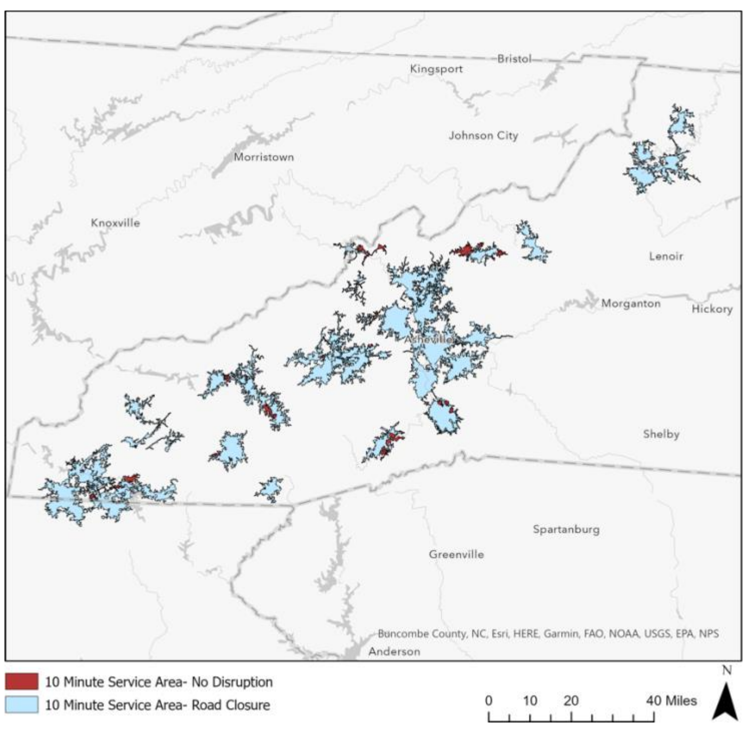


Figure 5: 15-minute Service Area Disruption during Tropical Storm Fred in Western North Carolina (2021)

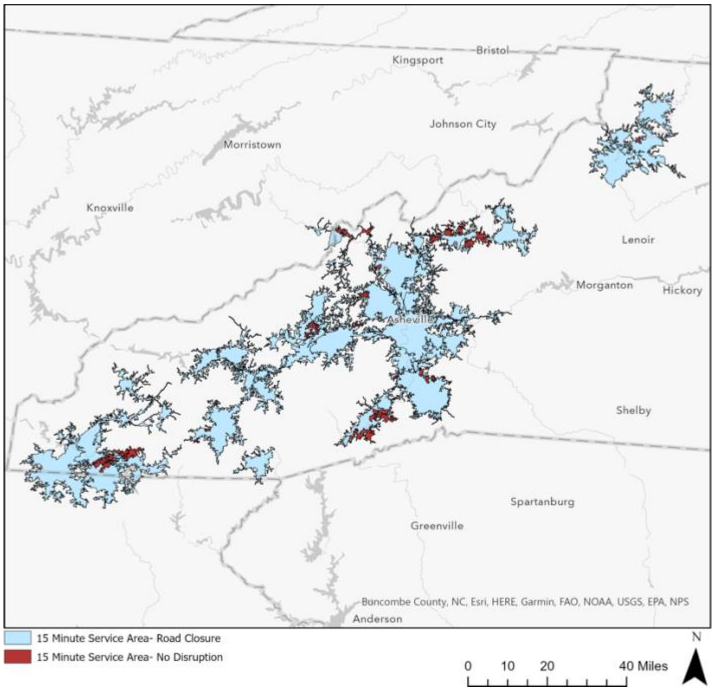


Figure 6: 20-minute Service Area Disruption during Tropical Storm Fred in Western North Carolina (2021)

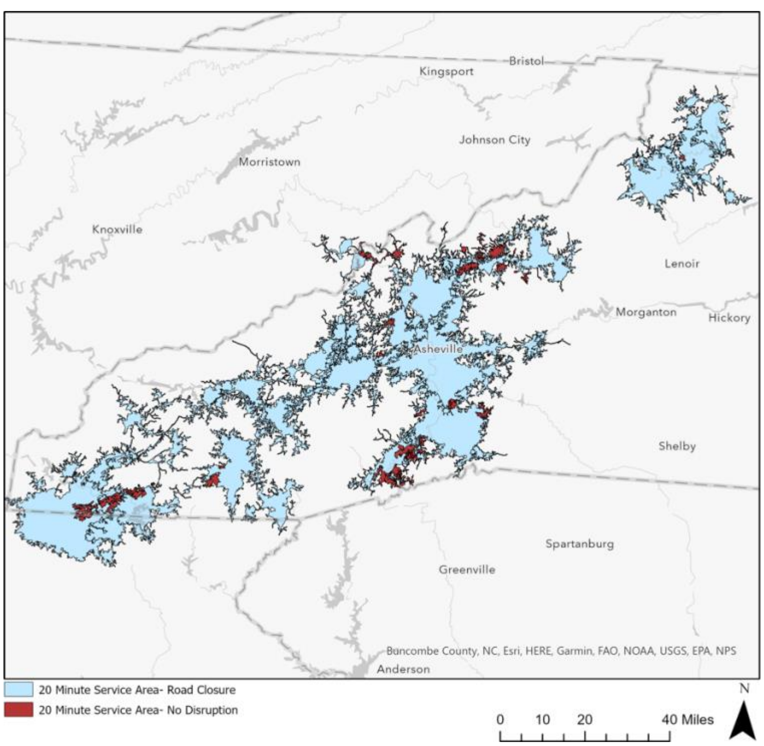


Table 1 indicates summary statistics of the change in building service during the Fred event. Full results by station can be found in Appendix 1. In a 10-minute service area, there is an average of a 4.73 percent decrease in service area, with significant variation in impact. Twenty-four dispatch locations experienced no change in service area, while nine experienced a change in service area greater than 10 percent. In a 15-minute service area, the average disruption was 8.34 percent, 15 dispatch locations experienced no change in service area, while 13 experienced a change in service area greater than 10 percent. In a 20-minute service area, the average disruption was 11.06 percent, seven dispatch locations experienced no change in service area, and 16 experienced a change in service area greater than 10 percent.

Table 1: Service Area Disruption Summary Statistics during Tropical Storm Fred in Western North Carolina

	Fred- 10 min (% change)	Fred- 15 min (% change)	Fred- 20 min (% change)
Mean	-4.74	-8.34	-11.06
Median	0.00	-0.98	-1.47
Max	-97.91	-98.46	-99.22
Min	0.00	0.00	0.00

100-yr event

As noted earlier, the maps produced for the 100-yr event do not imply simultaneous occurrence. The maps in Figures 7, 8, and 9 indicate that all regions of the study area experience impacts during a 100-yr flood event, and that this impact is amplified at greater time service areas (15- and 20-minute service area). Evident in these maps are severe impacts for many stations, meaning that these stations experience road closures close to the dispatch location which result in terminated travel in all directions. Some of the largest impacts are located in the southwestern portion of the state, west of Asheville.

Figure 7: 10-minute Service Area Disruption during 100-yr Event

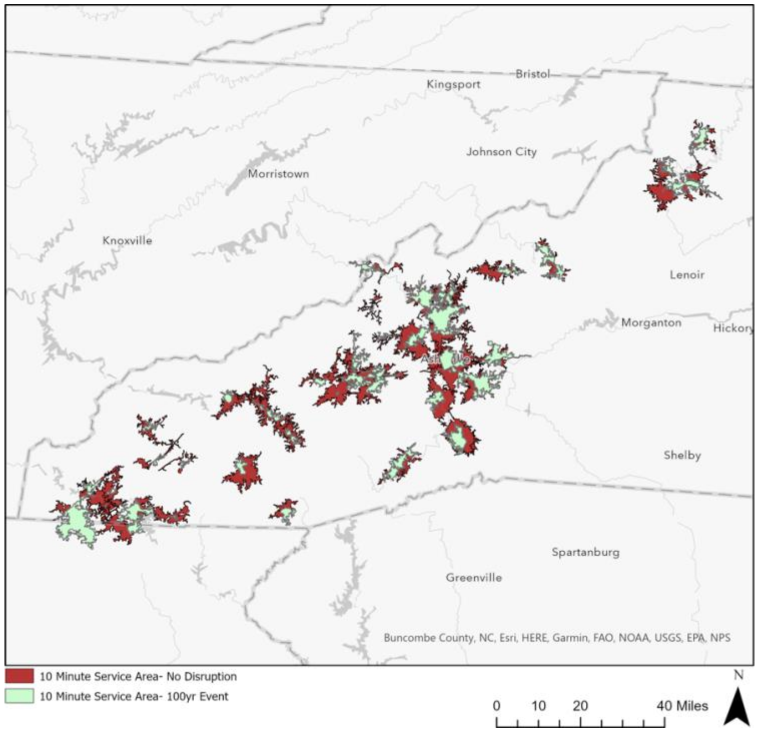


Figure 8: 15-minute Service Area Disruption During 100-yr Event

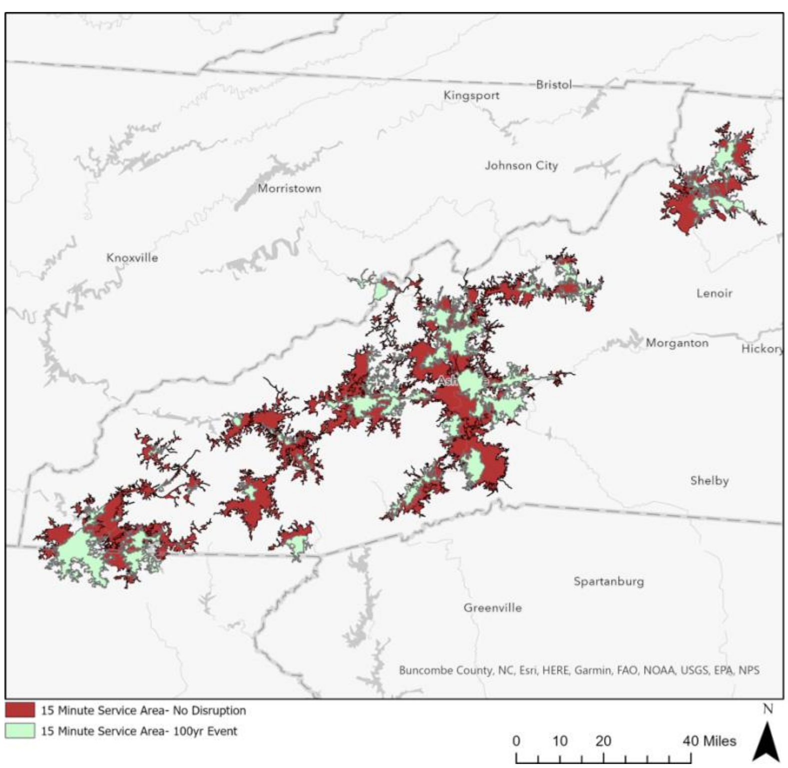


Figure 9: 20-minute Service Area Disruption During 100-yr Event

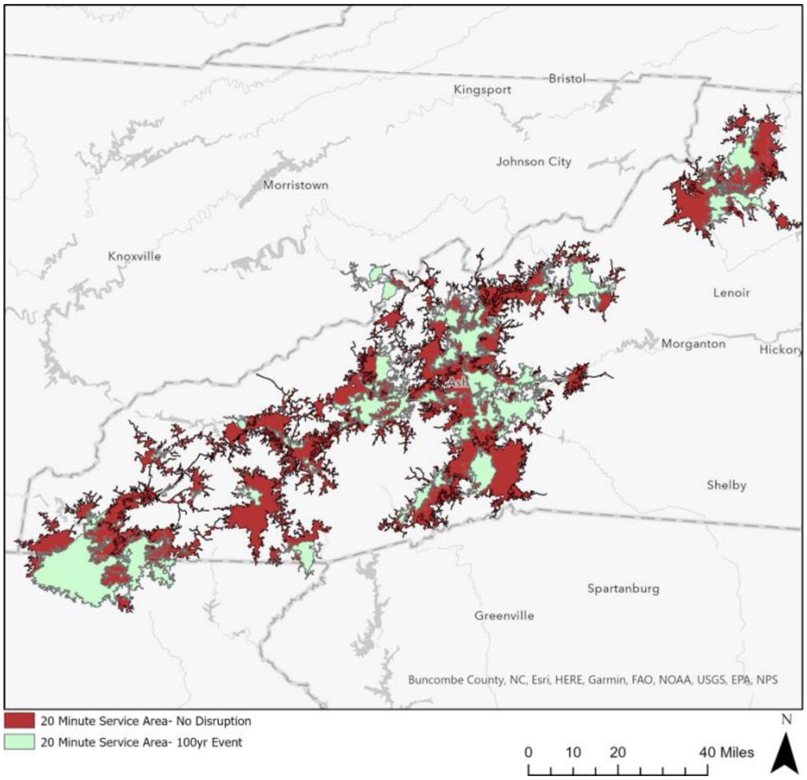


Table 2 indicates summary statistics of the change in building service during the 100-yr event. Full results by station can be found in Appendix 2. The average disruption for the 10-minute service area was a 65.94 percent decrease in service capacity. Notable is the high number of stations with a decreased capacity of greater than 90 percent (16), indicating road closures in all travel directions near those dispatch locations that disallow continued travel. The average disruption for the 15-minute service area was 74.89 percent, while it was 82.11 percent for the 20-minute service area. These increasing values indicate increasing impact at higher travel levels, which was also evident in the Fred analysis.

Table 2: Service Area Disruption Summary Statistics during the 100-yr Event

	100-yr - 10 min (% change)	100-yr - 15 min (% change)	100-yr - 20 min (% change)
Mean	-65.94	-74.89	-82.11
Median	-71.35	-79.13	-85.55
Max	-99.93	-99.96	-99.97
Min	-1.28	-15.88	-29.41

DISCUSSION

This study utilizes both a historical and modeled approach to analyze realized and potential road disruption during flood events and their relationship to EMS response time. The results indicate that flood network disruption is a major concern for EMS response in western North Carolina. In particular, this study focuses on applying network analysis in rural areas, which is an understudied approach, and this study indicates the importance of a growing focus on examining rural areas, especially considering the additional vulnerabilities that rural areas are facing in the face of climate change.

The results from the analysis of the Fred flooding event indicate modest, but important, disruptions to EMS service across the western portion of the state. Many stations exhibited at least a 10 percent decrease in service during the peak road closures during Fred, which is especially meaningful given that these results indicate not only a decrease in land area service, but in building service specifically. As mentioned before, many existing studies utilized a broader analysis of land service area (Coles et al. 2017; Yin et al. 2017), which may not be entirely effective in rural areas given that not all areas within the study area are developed. Utilizing building footprints gives a better understanding of how the land area is actually developed, which gives a clearer picture of where, and how, road network disruptions may impact EMS service areas. In rural areas, this might be a more effective frame of analysis.

Interestingly, even after removing those road closures that were due to secondary impacts of flooding, such as downed trees or power lines, there were still a number of road closures during the Fred event that existed outside of the 100-yr floodplain (18/64, or approximately 28 percent). While recognizing that the FEMA floodplain has tremendous social and regulatory importance, it is also important to recognize that the FEMA floodplain may not adequately predict the potential impacts of flood events, particularly in areas that may suffer from being under-mapped (Pralle 2019). This study is illuminative of a trend that is common in post-disaster analyses that indicate that the 100-yr floodplain is an imperfect predictor for what is actually experienced during flood events. The hybrid approach of this study, which analyzes both a historical event, and events predicted by the 100-yr floodplain, both recognizes the importance of the FEMA floodplain, especially from a future planning perspective, and recognizes that realized historical events can and do operate outside of the bounds delineated FEMA boundaries.

The results from the 100-yr flood analysis indicate severe disruption. The majority of study dispatch locations experienced around a 70 percent disruption in all time scales, which has the potential to create major implications during a significant flood event, especially considering a potential increase in service calls during flood events. While it has been already mentioned that a 100-yr event that covers the entire western portion of the state is unlikely, these results indicate that 100-yr events that impact just the areas surrounding a couple of facilities can still have major impacts on a community. Interestingly, the impact of the 100-yr event as modeled in this study operates at a scale of influence that is relatively higher than other studies utilizing the 100-yr floodplain (Green et al. 2017; Yin et al. 2017), and of particular note is the large number of facilities that might experience significant closures in all travel directions, severely limiting the capacity of these facilities (greater than 90 percent service disruption). These results indicate a lack of redundancy in this rural road network and a lack of capacity for finding acceptable alternative routes when confronted with a closure.

CONCLUSION AND AVENUES FOR FUTURE WORK

Analyzing rural road network vulnerability to flood events is an underexplored frame of analysis. However, as indicated by the results of this study, rural areas can be vulnerable, and may be especially vulnerable, to service disruptions during these events, especially considered within a framework in which rural areas already face increased vulnerability to climate change and lower EMS response times. This study found that both historical flooding (as indicated by road closures in western North Carolina during Tropical Storm Fred in August 2021) and modeled flooding (as indicated by the 100-yr floodplain) results in varying degrees of impact on EMS response time, when looking specifically at building service. In particular, the 100-yr flood event resulted in stark service decreases evident at EMS dispatch facilities across the state. In addition, this study adds to the growing literature (FEMA 2006; Xian, Lin, and Hatzikyriakou 2015) that indicates that the 100-yr floodplain may be insufficient in effectively predicting where flood impacts may occur.

Future studies should continue to examine the idea of road network redundancy as it pertains to impacts in urban and rural areas to expand on the potential explanation that less road redundancy in rural areas may result in an increased amplitude of service area disruption during road closure events. Continuing to examine historical closure trends in western North Carolina and beyond may reveal interesting patterns of road network vulnerability within the context of flooding and other extreme weather events. Particularly, comparing these closures to closures predicted by the 100-yr floodplain, or other flood models, may help illuminate consistencies and inconsistencies between modeled and experienced events.

Further efforts can also be made to improve the accuracy of service area analyses of emergency vehicle response time, especially under restricted scenarios like flooding and especially in understudied rural areas. Because EMS provisioning in rural areas often fundamentally operates differently than in urban areas (for instance, volunteers having to travel first from their home to the dispatch center before they can respond), the existing methodologies for assessing EMS response time, which is typically executed in urban areas, may be insufficient in rural areas. As EMS services face increasing strain from climate change related events like flooding, being able to adequately predict these impacts will be of the utmost importance.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

REFERENCES

Alabbad, Yazeed, Jerry Mount, Ann Melissa Campbell, and Ibrahim Demir. 2021. "Assessment of Transportation System Disruption and Accessibility to Critical Amenities during Flooding: Iowa Case Study." *Science of the Total Environment* 793:148476. doi:10.1016/j.scitotenv.2021.148476.

Brody, Samuel D., Jung Eun Kang, and Sarah Bernhardt. 2010. "Identifying Factors Influencing Flood Mitigation at the Local Level in Texas and Florida: The Role of Organizational Capacity." *Natural Hazards* 52(1):167–84. doi:10.1007/s11069-009-9364-5.

Brown, Joshua B., Mark L. Gestring, Francis X. Guyette, Matthew R. Rosengart, Nicole A. Stassen, Raquel M. Forsythe, Timothy R. Billiar, Andrew B. Peitzman, and Jason L. Sperry. 2016. "Helicopter Transport Improves Survival Following Injury in the Absence of a Time-Saving Advantage." *Surgery* 159(3):947–59. doi:10.1016/j.surg.2015.09.015.

Carr, Brendan G., Charles C. Branas, Joshua P. Metlay, Ashley F. Sullivan, and Carlos A. Camargo. 2009. "Access to Emergency Care in the United States." *Annals of Emergency Medicine* 54(2):261–69. doi:10.1016/j.annemergmed.2008.11.016.

Carr, Brendan G., Joel M. Caplan, John P. Pryor, and Charles C. Branas. 2006. "A Meta-Analysis of Prehospital Care Times for Trauma." *Prehospital Emergency Care* 10(2):198–206. doi:10.1080/10903120500541324.

Chanta, Sunarin, Maria E. Mayorga, and Laura A. McLay. 2014. "Improving Emergency Service in Rural Areas: A Bi-Objective Covering Location Model for EMS Systems." *Annals of Operations Research* 221(1):133–59. doi:10.1007/s10479-011-0972-6.

Coles, Daniel, Dapeng Yu, Robert L. Wilby, Daniel Green, and Zara Herring. 2017. "Beyond 'Flood Hotspots': Modelling Emergency Service Accessibility during Flooding in York, UK." *Journal of Hydrology* 546:419–36. doi:10.1016/j.jhydrol.2016.12.013.

Consoer, M., and A. Milman. 2018. "Opportunities, Constraints, and Choices for Flood Mitigation in Rural Areas: Perspectives of Municipalities in Massachusetts." *Journal of Flood Risk Management* 11(2):141–51. doi:10.1111/jfr3.12302.

FEMA. 2006. *Mitigation Assessment Team Report: Hurricane Katrina in the Gulf Coast: Building Performance Observations, Recommendations, and Technical Guidance*.

FEMA. 2017. FEMA Fact Sheet. "What Is a Flood Map."

FEMA. 2021. "Risk MAP Products." Retrieved March 9, 2022 (https://www.fema.gov/flood-maps/tools-resources/risk-map/products).

Fitch, Jay. 2005. "Response Times: Myths, Measurement & Management." *JEMS: A Journal of Emergency Medical Services* 30(9):47–56.

Fitzgibbons, Joanne, and Carrie L. Mitchell. 2019. "Just Urban Futures? Exploring Equity in '100 Resilient Cities.'" *World Development* 122:648–59. doi:10.1016/j.worlddev.2019.06.021.

Flood Risk Information System. 2022. "FRIS Flood Hazard Spatial Data Download."

Green, Daniel, Dapeng Yu, Ian Pattison, Robert Wilby, Lee Bosher, Ramila Patel, Philip Thompson, Keith Trowell, Julia Draycon, Martin Halse, Lili Yang, and Tim Ryley. 2017. "City-Scale Accessibility of Emergency Responders Operating during Flood Events." *Natural Hazards and Earth System Sciences* 17(1):1–16. doi:10.5194/nhess-17-1-2017.

He, Zhaoxiang, Xiao Qin, Ralph Renger, and Eric Souvannasacd. 2019. "Using Spatial Regression Methods to Evaluate Rural Emergency

Medical Services (EMS).” *The American Journal of Emergency Medicine* 37(9):1633–42. doi:10.1016/j.ajem.2018.11.029.

Homeland Infrastructure Foundation-Level Data. 2022. “Emergency Medical Service Stations.”

Hooper, Elizabeth, Lee Chapman, and Andrew Quinn. 2014. “The Impact of Precipitation on Speed–Flow Relationships along a UK Motorway Corridor.” *Theoretical and Applied Climatology* 117(1):303–16. doi:10.1007/s00704-013-0999-5.

Jurjonas, Matthew, and Erin Seekamp. 2018. “Rural Coastal Community Resilience: Assessing a Framework in Eastern North Carolina.” *Ocean & Coastal Management* 162:137–50. doi:10.1016/j.ocecoaman.2017.10.010.

Kermanshah, Amirhassan, and Sybil Derrible. 2017. “Robustness of Road Systems to Extreme Flooding: Using Elements of GIS, Travel Demand, and Network Science.” *Natural Hazards* 86(1):151–64. doi:10.1007/s11069-016-2678-1.

King, Nikki, Marcus Pigman, Sarah Huling, and Brian Hanson. 2019. "EMS Services in Rural America: Challenges and Opportunities". https://www.ruralhealth.us/NRHA/media/Emerge_NRHA/Advocacy/Policy%20documents/2019-NRHA-Policy-Document-EMS-Services-in-Rural-America-Challenges-and-Opportunities.pdf

Kunkel, Kenneth, David Easterling, Andrew Ballinger, Solomon Bililign, Sarah Champion, D. Riede Corbett, Jenny Dissen, Gary Lackmann, Richard Luettich Jr., L. Baker Perry, Walter A. Robinson, Laura Stevens, Brooke Stewart, and Adam Terando. 2020. *North Carolina Climate Science Report*. North Carolina Institute for Climate Studies.

Lhomme, S., D. Serre, Y. Diab, and R. Laganier. 2013. “Analyzing Resilience of Urban Networks: A Preliminary Step towards More Flood Resilient Cities.” *Natural Hazards and Earth System Sciences* 13(2):221–30. doi:10.5194/nhess-13-221-2013.

Li, Mengya, Mei-Po Kwan, Jie Chen, Jun Wang, Jie Yin, and Dapeng Yu. 2021. “Measuring Emergency Medical Service (EMS) Accessibility with the Effect of City Dynamics in a 100-Year Pluvial Flood Scenario.” *Cities* 117:103314. doi:10.1016/j.cities.2021.103314.

Lucchese, Elena. 2020. “It Could Be Worse...It Could Be Raining: Ambulance Response Time and Health Outcomes.” *SSRN Electronic Journal*. doi:10.2139/ssrn.3532234.

Luo, Weicong, Jing Yao, Richard Mitchell, and Xiaoxiang Zhang. 2020. “Spatiotemporal Access to Emergency Medical Services in Wuhan, China: Accounting for Scene and Transport Time Intervals." *International Journal of Health Geographics* 19(1):52. doi:10.1186/s12942-020-00249-7.

McDaniel, Polly. 2021. "Major Disaster Declaration Granted for Western North Carolina Counties Damaged by Tropical Storm Fred, Including Buncombe." *The City of Asheville*. Retrieved March 2, 2022 (https://www.ashevillenc.gov/news/major-disaster-declaration-granted-for-western-north-carolina-counties-damaged-by-tropical-storm-fred-including-buncombe/).

Melillo, Jerry M., Therese Richmond, and Gary Yohe. 2014. "Climate Change Impacts in the United States." *Third National Climate Assessment* 52.

Miller, Ryan W. n.d. "Storm Tracker: At Least 35 Missing after Fred Sweeps North Carolina; Hurricane Grace Forms as Henri Eyes New England." *USA TODAY*. Retrieved March 2, 2022 (https://www.usatoday.com/story/news/nation/2021/08/18/tropical-storm-grace-become-hurricane-fred-tornadoes-henri-new-england/8176417002/).

Moser, Susanne C. 2014. "Communicating Adaptation to Climate Change: The Art and Science of Public Engagement When Climate Change Comes Home." *WIREs Climate Change* 5(3):337–58. doi:10.1002/wcc.276.

Myers, C. Daniel, Tara Ritter, and Andrew Rockway. 2017. "Community Deliberation to Build Local Capacity for Climate Change Adaptation: The Rural Climate Dialogues Program." Pp. 9–26 in *Climate Change Adaptation in North America: Fostering Resilience and the Regional Capacity to Adapt*, *Climate Change Management*, edited by W. Leal Filho and J. M. Keenan. Cham: Springer International Publishing.

Nagurney, Anna, Qiang Qiang, and Ladimer S. Nagurney. 2010. "Environmental Impact Assessment of Transportation Networks with Degradable Links in an Era of Climate Change." *International Journal of Sustainable Transportation* 4(3):154–71. doi:10.1080/15568310802627328.

NCDOT. 2022a. "NCDOT API Download Site."

NCDOT. 2022b. "Statewide System & Non-System Road Routes."

North Carolina Department of Health and Human Services. 2019. "North Carolina Rural and Urban Counties". https://files.nc.gov/ncdhhs/RuralUrban_2019.pdf

North Carolina Emergency Management. 2010. “NC Buildings Footprints (2010).”

Nowell, Holly K., Mark W. Horner, and Michael J. Widener. 2015. “Impacts of Disrupted Road Networks in Siting Relief Facility Locations: Case Study for Leon County, Florida.” *Natural Hazards Review* 16(3):04014032. doi:10.1061/(ASCE)NH.1527-6996.0000168.

Peter, Brad, Sagy Cohen, Ronan Lucey, Dinuke Munasinghe, and Austin Raney. 2020. “A Google Earth Engine Implementation of the Floodwater Depth Estimation Tool (FwDET-GEE).”

Pralle, Sarah. 2019. “Drawing Lines: FEMA and the Politics of Mapping Flood Zones.” *Climatic Change* 152(2):227–37. doi:10.1007/s10584-018-2287-y.

Pregnolato, Maria, Alistair Ford, Vassilis Glenis, Sean Wilkinson, and Richard Dawson. 2017. “Impact of Climate Change on Disruption to Urban Transport Networks from Pluvial Flooding.” *Journal of Infrastructure Systems* 23(4):04017015. doi:10.1061/(ASCE)IS.1943-555X.0000372.

Shi, Yong, Jiahong Wen, Jianchao Xi, Hui Xu, Xinmeng Shan, and Qian Yao. 2020. “A Study on Spatial Accessibility of the Urban Tourism Attraction Emergency Response under the Flood Disaster Scenario.” *Complexity* 2020:e9031751. doi:10.1155/2020/9031751.

Shrestha, Jagat K., Pramesh Pudasaini, and Lorenzo Mussone. 2021. “Rural Road Network Performance and Pre-Disaster Planning: An Assessment Methodology Considering Redundancy.” *Transportation Planning and Technology* 44(7):726–43. doi:10.1080/03081060.2021.1956809.

Suarez, Pablo, William Anderson, Vijay Mahal, and T. R. Lakshmanan. 2005. “Impacts of Flooding and Climate Change on Urban Transportation: A Systemwide Performance Assessment of the Boston Metro Area.” *Transportation Research Part D: Transport and Environment* 10(3):231–44. doi:10.1016/j.trd.2005.04.007.

Sugg, Maggie, Lauren Andersen, Elizabeth Shay, Jennifer Schroeder Tyson, and Jennifer Runkle. 2021. “Climate, Environment, and Public Health in Western North Carolina.” *The Journal Of The Blue Cross NC Institute For Health & Human Services* 76.

Swain, D. L., O. E. J. Wing, P. D. Bates, J. M. Done, K. A. Johnson, and D. R. Cameron. 2020. “Increased Flood Exposure Due to Climate Change and Population Growth in the United States.” *Earth’s Future* 8(11):e2020EF001778. https://doi.org/10.1029/2020EF001778.

Xian, Siyuan, Ning Lin, and Adam Hatzikyriakou. 2015. "Storm Surge Damage to Residential Areas: A Quantitative Analysis for Hurricane Sandy in Comparison with FEMA Flood Map." *Natural Hazards* 79(3):1867–88. doi: 10.1007/s11069-015-1937-x.

Yang, Yuhan, Jie Yin, Mingwu Ye, Dunxian She, and Jia Yu. 2020. "Multi-Coverage Optimal Location Model for Emergency Medical Service (EMS) Facilities under Various Disaster Scenarios: A Case Study of Urban Fluvial Floods in the Minhang District of Shanghai, China." *Natural Hazards and Earth System Sciences* 20(1):181–95. doi:10.5194/nhess-20-181-2020.

Yin, Jie, Dapeng Yu, Ning Lin, and Robert L. Wilby. 2017. "Evaluating the Cascading Impacts of Sea Level Rise and Coastal Flooding on Emergency Response Spatial Accessibility in Lower Manhattan, New York City." *Journal of Hydrology* 555:648–58. doi:10.1016/j.jhydrol.2017.10.067.

Yin, Jie, Dapeng Yu, Zhane Yin, Min Liu, and Qing He. 2016. "Evaluating the Impact and Risk of Pluvial Flash Flood on Intra-Urban Road Network: A Case Study in the City Center of Shanghai, China." *Journal of Hydrology* 537:138–45. doi:10.1016/j.jhydrol.2016.03.037.

Zhang, Ning, and Alice Alipour. 2019. "Integrated Framework for Risk and Resilience Assessment of the Road Network under Inland Flooding." *Transportation Research Record* 2673(12):182–90. doi:10.1177/0361198119855975.

Zhang, Qian, Hao Yu, Zhenning Li, Guohui Zhang, and David T. Ma. 2020. "Assessing Potential Likelihood and Impacts of Landslides on Transportation Network Vulnerability." *Transportation Research Part D: Transport and Environment* 82:102304. doi:10.1016/j.trd.2020.102304.

Appendix 1: Station Level Service Change during Tropical Fred (colors gradate from blue to white to red in order of percent disruption)

Name	Fred- 10 min (% change)	Fred- 15 min (% change)	Fred- 20 min (% change)
ARC ANGEL TRANSPORT SERVICES	-4.586252189	-2.398273007	-2.560977861
BELLVIEW VOLUNTEER FIRE DEPARTMENT	0	0	-1.467076083
BLACK MOUNTAIN FIRE DEPARTMENT	0	-0.693894942	-0.005608997
BLACK MOUNTAIN FIRE DEPARTMENT STATION 2	-0.118700766	-1.2997386	-0.132051195
BLACK MOUNTAIN FIRE DEPARTMENT STATION 3	0	0	0
BOONE FIRE DEPARTMENT STATION 2	0	0	0
BRASSTOWN FIRE VOLUNTEER FIRE DEPARTMENT	-9.369488536	-23.56305405	-30.07446553
BUNCOMBE COUNTY EMERGENCY MEDICAL SERVICES STATION 2 AND 12	0	-1.235310288	-0.002151625
BUNCOMBE COUNTY EMERGENCY MEDICAL SERVICES STATION 3	0	-0.1275691	-0.048749037
CANTON FIRE DEPARTMENT	-0.220198178	-1.12144158	-3.380644534
CENTER PIGEON FIRE DEPARTMENT	0	-0.558165239	-0.910451087
CHEROKEE COUNTY EMERGENCY MEDICAL SERVICES STATION 1	0	-1.306467936	-11.41378695
CHEROKEE FIRE DEPARTMENT - EMERGENCY MEDICAL FIRST RESPONSE	0	-1.776917664	-5.704894941
CHEROKEE TRIBAL EMERGENCY MEDICAL SERVICES	0	-1.081484244	-5.298013245
CLAY COUNTY AMBULANCE SERVICE	-20.17474186	-33.73853464	-45.11949966
CLYDE VOLUNTEER FIRE DEPARTMENT INCORPORATED	-1.117318436	-10.01894573	-8.213563016
CRABTREE - IRON DUFF VOLUNTEER FIRE DEPARTMENT	0	-1.804816829	-1.019291285
DEEP GAP VOLUNTEER FIRE DEPARTMENT	-0.234619395	-0.497417257	-0.267724343
FAIRVIEW VOLUNTEER FIRE DEPARTMENT	0	-0.976109583	-4.589460784
FAIRVIEW VOLUNTEER FIRE DEPARTMENT - SUBSTATION	0	0	-2.796052632
GRAHAM COUNTY EMERGENCY MEDICAL SERVICES	0	0	0
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MAGGIE VALLEY	-11.14919719	-46.0649071	-60.08323218

HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 1 AND MEDIC 5	-0.039142773	-6.657122405	-13.01365493
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 3	-1.117318436	-10.01560294	-8.213349936
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 4	-1.196836931	-1.109227416	-3.328792007
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 6	0	-0.557980222	-0.912995069
HENDERSON COUNTY EMERGENCY MEDICAL SERVICES	-2.198412258	-4.611481895	-3.354388167
HIGHLANDS FIRE AND AMBULANCE	0	0	-0.17366593
JUPITER VOLUNTEER FIRE DEPARTMENT INCORPORATED	0.023691068	-0.136965454	-0.124504523
LEICESTER VOLUNTEER FIRE DEPARTMENT	0	-0.555308752	-0.756188184
LEICESTER VOLUNTEER FIRE DEPARTMENT STATION 2	-31.98051948	-68.32493703	-83.05457746
MACON COUNTY EMERGENCY MEDICAL SERVICES - FRANKLIN STATION	-1.974293059	-1.723472669	-3.178642715
MACON COUNTY EMERGENCY MEDICAL SERVICES - NANTAHALA STATION	0	0	0
MADISON COUNTY AMBULANCE SERVICE	-0.020132877	-0.491143317	-0.0042584
MADISON COUNTY AMBULANCE SERVICE 6	0	-0.015875536	-0.225244369
MADISON COUNTY AMBULANCE SERVICE 7	-97.90979098	-98.46153846	-99.2171405
MAGGIE VALLEY VOLUNTEER FIRE DEPARTMENT	-10.71169208	-45.49200194	-60.13575251
MARS HILL VOLUNTEER FIRE DEPARTMENT	0	-0.045451594	-0.235294118
MEAT CAMP VOLUNTEER FIRE DEPARTMENT	0	0	-0.120872829
MEDICAL EMERGENCY AMBULANCE INCORPORATED	-0.293255132	-0.71021339	-2.004530986
MITCHELL EMERGENCY MEDICAL SERVICES	0	0	-0.697211155
MURPHY FIRE DEPARTMENT - SUBSTATION	0	-0.703605981	-5.901195023
MURPHY FIRE DEPARTMENT STATION 1	0	-1.32594678	-11.68524745
PEACHTREE VOLUNTEER FIRE DEPARTMENT	-0.834127741	-7.459835973	-22.72531263
REEMS CREEK FIRE DEPARTMENT	0	0	-0.064085758
REGIONAL TRANSPORT SERVICES	-1.530269348	-0.752980941	-0.530700753
REYNOLDS VOLUNTEER FIRE DEPARTMENT	-3.096349163	-0.665174686	-0.181450377

RICEVILLE VOLUNTEER FIRE DEPARTMENT	-4.724137931	-1.232085782	0.002303829
SHOOTING CREEK VOLUNTEER FIRE DEPARTMENT	0	0	-9.206838565
SPRING CREEK VOLUNTEER FIRE DEPARTMENT INCORPORATED	0	0	0
STEWART SIMMONS VOLUNTEER FIRE DEPARTMENT	0	0	-0.073468638
SWAIN COUNTY EMERGENCY MEDICAL SERVICES	-4.487829615	0	0
THE COUNTRY VOLUNTEER FIRE DEPARTMENT INCORPORATED	-22.18430034	-28.06122449	-39.11917098
TOWN OF WEAVERSVILLE FIRE DEPARTMENT	0	-0.115234841	-0.050851288
TRANSYLVANIA COUNTY EMERGENCY MEDICAL SERVICES	-10.08207631	-13.55979984	-15.04343005
TRANSYLVANIA COUNTY EMERGENCY MEDICAL SERVICES	-2.346765478	-9.130850048	-14.3232
VALLEYTOWN RURAL FIRE DEPARTMENT STATION 3	-0.36344756	-0.691870521	-1.154010543
WARNE VOLUNTEER FIRE DEPARTMENT	-6.925540432	-29.52109846	-47.29254269
WEST JEFFERSON VOLUNTEER FIRE DEPARTMENT	0	0	0
WESTCARE EMERGENCY MEDICAL SERVICES STATION 2	-14.21612046	-16.11742211	-11.9800769
WESTCARE EMERGENCY MEDICAL SERVICES STATION 3	0	-3.245229903	-0.859017076
WESTERN CAROLINA EMERGENCY MEDICAL SERVICES	-0.645577792	-2.690944248	-6.187035718
YANCEY EMERGENCY MEDICAL SERVICES	-32.5477707	-43.21305842	-48.50799714

Appendix 2: Station Level Service Change during 100-yr Event (colors gradate from blue to white to red in order of percent disruption)

Name	100yr- 10 min (% change)	100yr- 15 min (% change)	100yr- 20 min (% change)
ARC ANGEL TRANSPORT SERVICES	-54.65192644	-65.25609179	-74.55085951
BELLVIEW VOLUNTEER FIRE DEPARTMENT	-24.40796555	-44.64097149	-58.78539748
BLACK MOUNTAIN FIRE DEPARTMENT	-36.65499891	-49.22393329	-67.66413327
BLACK MOUNTAIN FIRE DEPARTMENT STATION 2	-94.44264595	-96.26052861	-98.25624704
BLACK MOUNTAIN FIRE DEPARTMENT STATION 3	-1.282051282	-15.87591241	-29.4072005
BOONE FIRE DEPARTMENT STATION 2	-99.92673098	-99.96087892	-99.97303734
BRASSTOWN FIRE VOLUNTEER FIRE DEPARTMENT	-99.18430335	-99.64731675	-99.77780447
BUNCOMBE COUNTY EMERGENCY MEDICAL SERVICES STATION 2 AND 12	-60.92208125	-68.65335716	-73.34029025
BUNCOMBE COUNTY EMERGENCY MEDICAL SERVICES STATION 3	-43.88357705	-73.94755493	-85.35327326
CANTON FIRE DEPARTMENT	-69.97297568	-64.89983706	-73.59889175
CENTER PIGEON FIRE DEPARTMENT	-71.47676162	-79.12683062	-85.21312832
CHEROKEE COUNTY EMERGENCY MEDICAL SERVICES STATION 1	-90.00470367	-96.08979667	-97.47219414
CHEROKEE FIRE DEPARTMENT - EMERGENCY MEDICAL FIRST RESPONSE	-98.37482711	-99.17311752	-99.44829205
CHEROKEE TRIBAL EMERGENCY MEDICAL SERVICES	-98.18020417	-99.23550252	-99.46760161
CLAY COUNTY AMBULANCE SERVICE	-44.63860207	-66.3719748	-71.01481647
CLYDE VOLUNTEER FIRE DEPARTMENT INCORPORATED	-66.76371076	-64.53434377	-64.83941265
CRABTREE - IRON DUFF VOLUNTEER FIRE DEPARTMENT	-77.37192741	-92.11139664	-93.47721987
DEEP GAP VOLUNTEER FIRE DEPARTMENT	-35.40145985	-59.6422422	-74.72483887
FAIRVIEW VOLUNTEER FIRE DEPARTMENT	-37.05030602	-72.50714555	-85.93137255
FAIRVIEW VOLUNTEER FIRE DEPARTMENT - SUBSTATION	-31.84485838	-41.11724985	-80.32036613
GRAHAM COUNTY EMERGENCY MEDICAL SERVICES	-66.87697161	-75.50306212	-82.02824134
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MAGGIE VALLEY	-73.04708642	-88.0870744	-93.52349575
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 1 AND MEDIC 5	-96.09550837	-97.80298442	-98.7270291
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 3	-66.76371076	-64.53302623	-64.84291903

HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 4	-65.94357769	-62.53330104	-71.50090827
HAYWOOD COUNTY EMERGENCY MEDICAL SERVICES - MEDIC 6	-71.4535683	-79.12822496	-85.21075235
HENDERSON COUNTY EMERGENCY MEDICAL SERVICES	-52.62310553	-62.75480929	-71.26015144
HIGHLANDS FIRE AND AMBULANCE	-52.99258475	-44.94581281	-52.96810862
JUPITER VOLUNTEER FIRE DEPARTMENT INCORPORATED	-22.13930348	-55.31375235	-76.62618152
LEICESTER VOLUNTEER FIRE DEPARTMENT	-71.35393992	-82.97978676	-91.98021875
LEICESTER VOLUNTEER FIRE DEPARTMENT STATION 2	-73.53896104	-89.73551637	-96.41285211
MACON COUNTY EMERGENCY MEDICAL SERVICES - FRANKLIN STATION	-81.22365039	-86.04501608	-87.90918164
MACON COUNTY EMERGENCY MEDICAL SERVICES - NANTAHALA STATION	-54.7024952	-74.06593407	-89.34056007
MADISON COUNTY AMBULANCE SERVICE	-40.66841152	-65.82930757	-79.26585189
MADISON COUNTY AMBULANCE SERVICE 6	-42.20603538	-65.6532783	-80.05524862
MADISON COUNTY AMBULANCE SERVICE 7	-96.80968097	-97.65182186	-98.80510919
MAGGIE VALLEY VOLUNTEER FIRE DEPARTMENT	-72.87581699	-87.93019874	-93.49954314
MARS HILL VOLUNTEER FIRE DEPARTMENT	-61.43747949	-74.33283553	-83.44741533
MEAT CAMP VOLUNTEER FIRE DEPARTMENT	-75.18440464	-85.33062273	-89.42044659
MEDICAL EMERGENCY AMBULANCE INCORPORATED	-80.97625579	-89.52923929	-95.38585071
MITCHELL EMERGENCY MEDICAL SERVICES	-28.18639798	-37.14028777	-50.99601594
MURPHY FIRE DEPARTMENT - SUBSTATION	-72.82639083	-88.18161829	-93.37809536
MURPHY FIRE DEPARTMENT STATION 1	-99.81701738	-99.92734538	-99.95281071
PEACHTREE VOLUNTEER FIRE DEPARTMENT	-93.4699714	-96.92169419	-98.31208033
REEMS CREEK FIRE DEPARTMENT	-86.04093675	-80.8891732	-82.52789187
REGIONAL TRANSPORT SERVICES	-99.35377139	-99.76528026	-99.85733851
REYNOLDS VOLUNTEER FIRE DEPARTMENT	-93.3132034	-94.41543371	-88.52081162
RICEVILLE VOLUNTEER FIRE DEPARTMENT	-97.25862069	-99.18032787	-99.63369119
SHOOTING CREEK VOLUNTEER FIRE DEPARTMENT	-94.79248238	-97.0922606	-98.13621076
SPRING CREEK VOLUNTEER FIRE DEPARTMENT INCORPORATED	-93.86401327	-96.31474104	-97.44827586
STEWART SIMMONS VOLUNTEER FIRE DEPARTMENT	-20.07434944	-27.47719075	-53.52190284
SWAIN COUNTY EMERGENCY MEDICAL SERVICES	-72.46450304	-85.23372062	-90.22011453
THE COUNTRY VOLUNTEER FIRE DEPARTMENT INCORPORATED	-11.83162685	-18.7755102	-31.26079447

TOWN OF WEAVERSVILLE FIRE DEPARTMENT	-46.87559354	-64.69840261	-82.5222239
TRANSYLVANIA COUNTY EMERGENCY MEDICAL SERVICES	-32.57542147	-44.40763972	-59.92422842
TRANSYLVANIA COUNTY EMERGENCY MEDICAL SERVICES	-69.80083372	-51.87201528	-55.1936
VALLEYTOWN RURAL FIRE DEPARTMENT STATION 3	-84.31983385	-92.53768223	-95.69739279
WARNE VOLUNTEER FIRE DEPARTMENT	-90.91273018	-96.19892833	-98.05200378
WEST JEFFERSON VOLUNTEER FIRE DEPARTMENT	-25.3866286	-43.76681614	-56.51532536
WESTCARE EMERGENCY MEDICAL SERVICES STATION 2	-82.10806023	-90.70970644	-91.41034603
WESTCARE EMERGENCY MEDICAL SERVICES STATION 3	-79.14279652	-91.37472631	-92.60724698
WESTERN CAROLINA EMERGENCY MEDICAL SERVICES	-64.39638476	-77.11891718	-85.55001526
YANCEY EMERGENCY MEDICAL SERVICES	-60.29723992	-66.27393225	-76.66109652