# T.E.E.G.S.

**Transportation Emergency and Environmental GIS Services**

# Final Report

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# I. Introduction


## Summary

The record drought of 2011 severely weakened the structural integrity of an unknown number of trees in and around the city of Austin. Structurally weekend trees pose a potential and unnecessary hazard to both emergency and municipal response services. The tree hazard can be managed by appropriately maintaining the city's trees near roadways.

The Urban Forestry Program (UFP), as part of the City of Austin Parks and Recreation Department, is responsible for the upkeep and maintenance of approximately 300,000 trees along roadways and city owned property in the City of Austin. The UFP and the City of Austin Parks and Recreation Department wish to be proactive in the identification and subsequent removal of potential tree hazards before they become a safety and insurance liability on the city roadways. Identifying the street segments with the greatest potential for tree hazards will help optimize the city's tree removal services and clear potential hazards before they become a hindrance for emergency and municipal service vehicles.

Our Geographic Information Systems (GIS) consortium group, Transportation, Emergency, and Environmental GIS Services (T.E.E.G.S.) can help the UFP accomplish the task of tree hazard risk mediation through our expertise in GIS. Using a GIS, we will identify street segments with the greatest potential risk and correlate those locations with the highest priority routes for emergency services in order to optimize proactive preventative maintenance and reactive clearing.

# Introduction

## Purpose

The purpose of this report is to articulate and publish the findings T.E.E.G.S. was able to produce using a GIS as requested by the city of Austin Parks and Recreation department.

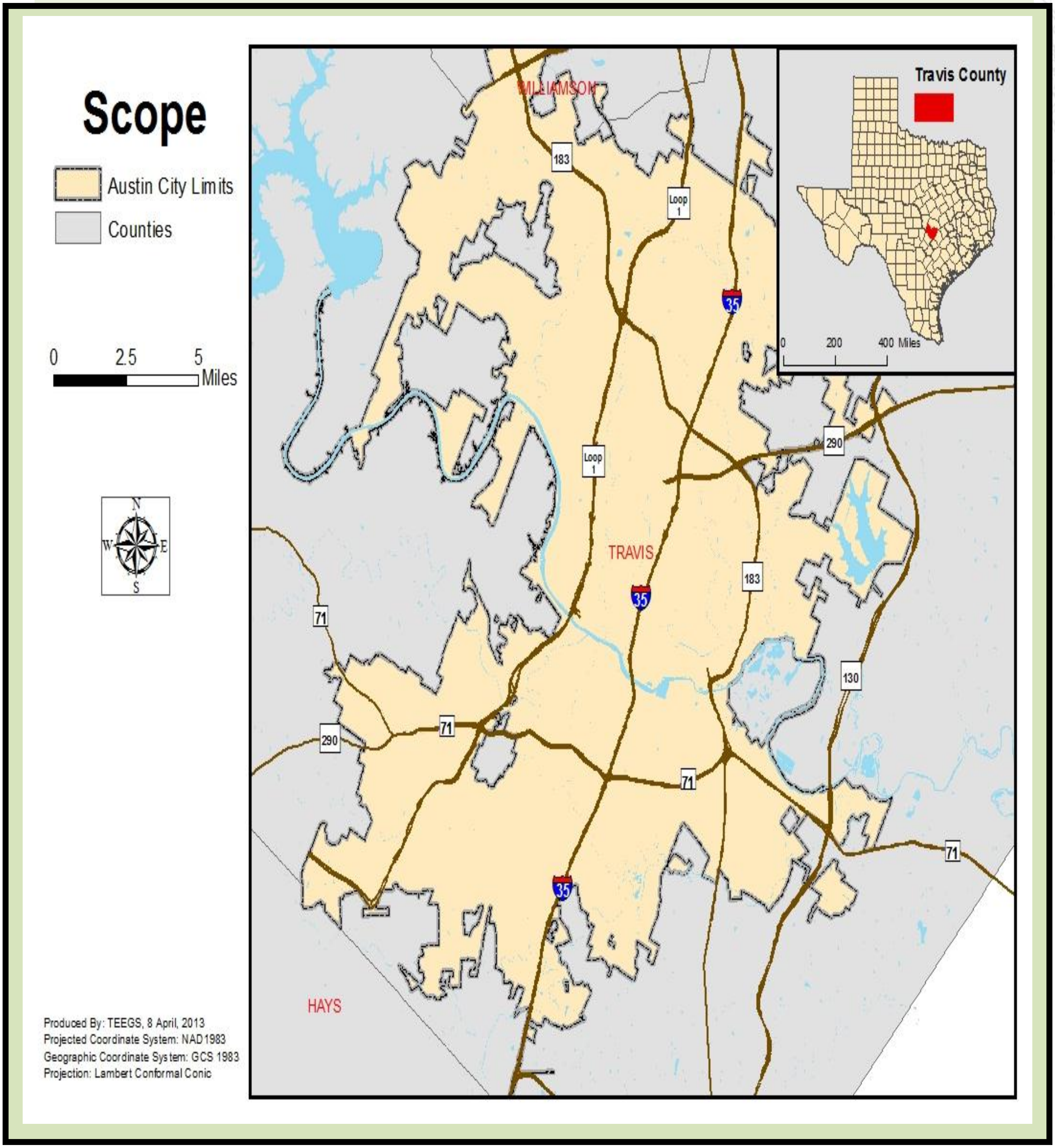
The overall purpose of the project is to generate a city wide comprehensive tree hazard inventory for the city of Austin Parks and Recreation department. This inventory will be used by the Urban Forestry Program to identify potential tree hazard locations along city roadways. A ranking system will be used to highlight areas along streets with the greatest threat potential in order to prioritize preventative tree maintenance. The ranking system will take into account major roads used in emergency situations and areas of high tree canopy cover.

T.E.E.G.S. will accomplish this by utilizing a GIS to analyze the existing tree shade index and identifying areas of high tree density which intersect or overlay with emergency service routes.

# Introduction

## Scope

Our study will include the City of Austin; including but not limited to the city limits.



# II. Literature Review

The analysis and study of emergency services through the use of geographic information systems (GIS) has become readily available to many emergency response personnel. It has become an area of focus in many cities today. A 2010 study from Leon County encompassing Tallahassee, Florida done by Mark Horner and Michael Widener used GIS to determine locations for emergency goods distribution centers in the event of a hurricane or other disastrous event. This is important to our study because after a storm, there will be failed network linkages throughout an area as a function of rising water, downed trees/limbs, and debris accumulation (Horner and Widener). In their study they chose to employ a model that optimizes the locations of relief distribution centers relative to populations as needed. This allowed [them] to concentrate on the issue of [road] network failure as it manifests itself to populations accessing goods (Horner and Widener). In the event of a hurricane or other disaster it is not known how many roadways will be subject to damage, deeming them impassible. This makes using a least cost path analysis non-functional for this study and others like it. Leon County divided into traffic analysis zones (TAZs), each containing a portion of the population. TAZs are represented in point format by computing their geometric centroids utilizing GIS. These were then connected to the road network using synthetic links; to reduce the risk that a TAZ centroid would be cut off; each was connected using 30 synthetic links to ensure each TAZ has a functional route (Horner and Widener).

# Literature Review

The results of their study showed scenarios where people at certain TAZs are cut off from the rest of a network, and the links that are disabled do impact how relief service is provided (Horner and Widener). This is important to our analysis because our goal is to prevent citizens and emergency personnel from being completely blocked or trapped on road networks because of fallen trees/limbs.

A study done by Thomas J Cova illustrates an example of application of GIS in regional evacuation analysis: evacuation vulnerability mapping (Cova). It proposes one method for addressing this problem where people are assigned to the nearest intersection in the network using Theissen polygons. The links connecting this set of nodes to the rest of the network are considered the exit choice set for that particular evacuation (Cova). For our study this is important because we also suggested using Theissen polygons to help with our analysis. We can get a better idea of how to incorporate these into our study by further examining Cova's breakdown of evacuation vulnerability mapping. Cova used census data and road networks to determine population per exit for each evacuation route. His deliverables included maps from example city Santa Barbara, CA showing evacuation vulnerability with streets in red with a relatively high ratio of residents to exiting lanes and streets in green showing a low ratio (Cova). This is the same concept we intend to use in our study for the City of Austin's Urban Forestry Program, so it is important to understand how Cova conducted his analysis.

# III. Data

| Data Obtained | |
|---|---|
| **Layer** | **Source** |
| Streets | City of Austin |
| Parks and Hydrology | City of Austin |
| Tree Canopy Cover | Urban Forestry Program |
| Austin City Limits | CAPCOG |
| Travis County | CAPCOG |
| Census Blocks | Census Bureau |

| Data Created by TEEGS | |
|---|---|
| **Layer** | **Source** |
| Emergency Service Locations (Points of Origin) | Google Earth |
| Destination Points | Google Earth |
| Top 150 Population Points | Census Bureau Census Blocks |
| Road Network | City of Austin Streets Layer |
| Street Analysis | City of Austin Streets and Street Polygon Layers |
| Street Polygon clipped | City of Austin streets and Street Polygon Layer |

The Streets data layer was obtained by T.E.E.G.S. directly from the City of Austin Parks and Recreation Department and contained all city roads including but not limited to major arterials, core transit corridors and neighborhood streets. This layer was used to create the Road Network and the Street Analysis layers used in the analysis of our project. The street layer is from 2010 and the street polygon layer is from 2006 making the accuracy of this data not up-to-date.

Emergency Service Locations (EMS, Fire Departments, and Police Stations) were created by TEEGS through Google Earth using the “what’s here” function. These were used as our Points of Origin in the route analysis process. The same thing was accomplished for the Destination Points (Hospitals, population points, and schools). All points were verified using Google Street View, so it is possible that the accuracy of these points is not completely precise.

# Data continued

The city parks and hydrology layers were obtained from the City of Austin GIS database. These layers were used to give context to our maps. The hydrology layer is from 2003, so it might have some accuracy issues, and the parks layer is from 2010 making the accuracy more up-to-date than the hydrology layer. The tree canopy cover/shade index data was obtained by T.E.E.G.S. directly from the City of Austin Urban Forestry program. The tree canopy data was used in conjunction with the streets layer during analysis of this project. It is from the year 2006, so this layer may have some accuracy issues especially since Austin has had major drought issues in the past 6-8 years.

Austin City Limits and Travis County layers were acquired through the Capitol Area Council of Governments (CAPCOG) website. These were used as boundaries and limitations throughout the analysis of our project. The Census Blocks attained from the Census Bureau website were used to help create the top 150 population points used as a destination point throughout our analysis. All of this data has been updated frequently, so the quality should be accurate.

# IV Methodology

Having gathered the necessary data needed to complete the city of Austin Parks and Recreation departments request for the locations along city roadways with the greatest potential for tree hazards, our next task was to process and analyze the data in the appropriate and necessary order so as to answer the question of where the greatest potential tree hazard exists.

The first data implemented into the Geographic Information System (GIS) was a street Polygon layer. The street layer polygon data was provided to T.E.E.G.S. directly by the Parks and Recreation department and helped to establish an accurate and reliable geographic starting point. The street polygon data was used in conjunction with the road network T.E.E.G.S. downloaded from the city of Austin's GIS data sets website. The cities GIS data website is updated on a regular basis to ensure accuracy. The street polygon layer was then overlaid and clipped with the streets layer to establish a new layer which contained the width of the streets in order to give depth and create a buffer around the streets over which the tree canopy data could be analyzed.

With the dimensions of the streets established the next task was to identify and isolate the portions of the tree canopy which over lapped and intersected the road network. This was done in order to find the percent of the roadway under the tree canopy. This was accomplished by overlapping the Light Detection and Ranging (LIDAR) data collected in 2006 with the street polygon layer previously created.

# Methodology continued

To find the percentage of a road covered by tree shade the total area of the road polygon was divided by the amount of tree shade overlap. After identifying the streets within the city of Austin with the greatest percent tree canopy coverage the next step was to identify and highlight the locations of emergency services and Schools

Fallen trees onto roadways hinder the movement of emergency services. This is especially hazardous during times of inclement weather when emergency services are often needed the most. The locations of city emergency services were used as the starting points for our potential tree hazards analysis. The locations of Austin police department (APD), Austin fire department (AFD) and Emergency Medical Service (EMS) locations were all found on their respective departments' websites. The latitude/longitude of the aforementioned emergency service locations was verified by T.E.E.G.S. in-house GIS analysts' using Google street view.

With the locations of city emergency services verified the next step was to create a point vector data layer combining the locations of APD, AFD and EMS locations. The locations were merged from three separate shape files into one new shape file. The new shape file with all emergency service location was connected to the road network. The total number of emergency service locations was sixty-seven. These sixty-seven locations were used as the starting points in our model in order to determine which routes along the cities road network was most frequently travelled.

# Methodology continued

With the starting points established T.E.E.G.S. next needed to determine the destination points for the emergency service vehicles for our analysis. The locations of the destination points within the city of Austin were determined by locating the areas within the city with the greatest potential for a high volume of emergency service vehicle traffic. T.E.E.G.S. identified schools, Hospitals and 2010 census blocks with the highest population density as the locations with the greatest potential for a high volume of emergency service vehicle traffic.

The population from the 2010 census was used at the block level to determine the areas within the city of Austin with the greatest population density. The population density of each census block was determined by dividing the total area of the census block by the total population recorded within the block. Once the population density for each census block had been determined, T.E.E.G.S. next created a point vector shape file with the centroids of the top 150 census blocks with the greatest population density. The total number of census blocks within the city of Austin numbered over ten thousand and the top 150 were chosen in order to keep spatial and numerical continuity with the other destination location layers. The locations of public schools were used to create the next destination layer

The locations of public schools were determined by first compiling a comprehensive list of schools. Next the accurate location of each public school within the City of Austin was individually researched and accurately identified by T.E.E.G.S. in-house GIS analysis's using Google street view.

# Methodology continued

After having establish the locations of public schools and the 150 census blocks with the greatest population density T.E.E.G.S. next needed to determine the location of city hospitals. The accurate location of each city hospital was found by a T.E.E.G.S. in-house GIS analyst using information from the City of Austin's website and verified using Google street view. A destination layer was created by merging the three separate location shape files of schools, hospitals and the 150 census blocks centroids into one vector data shape file which was subsequently connected to the previously made road network. After T.E.E.G.S. established the starting points and destination points the next step was to determine which routes were utilized most frequently by emergency response vehicles.

T.E.E.G.S.' in-house GIS team ran a point to point route analysis between 67 origin points (APD, AFD and EMS) and 311 destination points (Hospitals, Schools and population density points). Once the individual routes from each starting point to each destination point had been establish we next merged all the routes into one aggregated file containing all routes. With the routes established T.E.E.G.S. next used the GIS to run a frequency analysis to determine how many times each street segment was utilized by emergency services. A Python script was used to run this analysis which is not available for distribution at this time. The street frequency layer was merged onto the previously created street network layer containing the percent canopy coverage. T.E.E.G.S. next multiplied the percent canopy coverage by the route frequency to determine the ranking of each road segment.

# Methodology continued

With the highest route frequency running over one thousand, the resulting data became convoluted and difficult to isolate high priority routes into a ranking system. To make the route frequency number more accessible to a ranking system T.E.E.G.S. then divided all the rankings by the highest ranking number to create a ranking scale of 1-100. To illustrate the effect of this normalization, under this system only 30 road segments, roughly one half of a percent of all road segments with a non-zero score, scored higher than 15.

# V. Results

After completing our analysis on E.S. response our group was returned with very interesting and to a certain degree somewhat expected results. Our Relative Ranking system that combined route frequency and canopy cover returned very clustered results; this clustering is due to the fact that only 10 percent of our analyzed road segments returned a score. These highly ranked road segments were strongly concentrated in 4 areas. These areas include; The Shoal Creek area between 24th street and Enfield, the Barton Springs and South 1st area near Auditorium shores, Cesar Chavez from Congress to Trinity, and South 1st street just north of Ben White Boulevard.

The Shoal Creek area contains our highest ranked road segments as well as the densest concentration of high ranking road segments in the city. This area is strongly centered around Windsor, which returned our 1st, 2nd and 5th ranked road segments. Windsor is a major thoroughfare for traffic from Mopac as well as the nearby neighborhoods of Pemperton and Clarksville. As could be expected this major greenway through Austin presents a large amount of Canopy Cover that the Emergency Service personnel must travel through; this presents a large potential for E.S. personnel to be disrupted by downed limbs or entire trees when responding to minor or major emergencies in Austin.

# Results continued

The Barton Springs and South First area is centered near Auditorium Shores and the Long Center. Travelling East on Barton Springs from Lamar Boulevard travelers and E.S. personnel are confronted with a very dense canopy cover that could present potential problems during a severe weather event. These roads are important Arterial Streets for the nearby neighborhoods of Barton Hills, South First, and Travis Heights as well as area parks like Zilker Park and Auditorium that often times host major festivals and events. Because of the key role Barton Springs and South First Street serve in Austin's transportation system, both for civilian and municipal purposes; it is vitally important that the City of Austin Urban Forestry Program prioritize their efforts here by including this area as one of their top considerations for proactive tree maintenance.

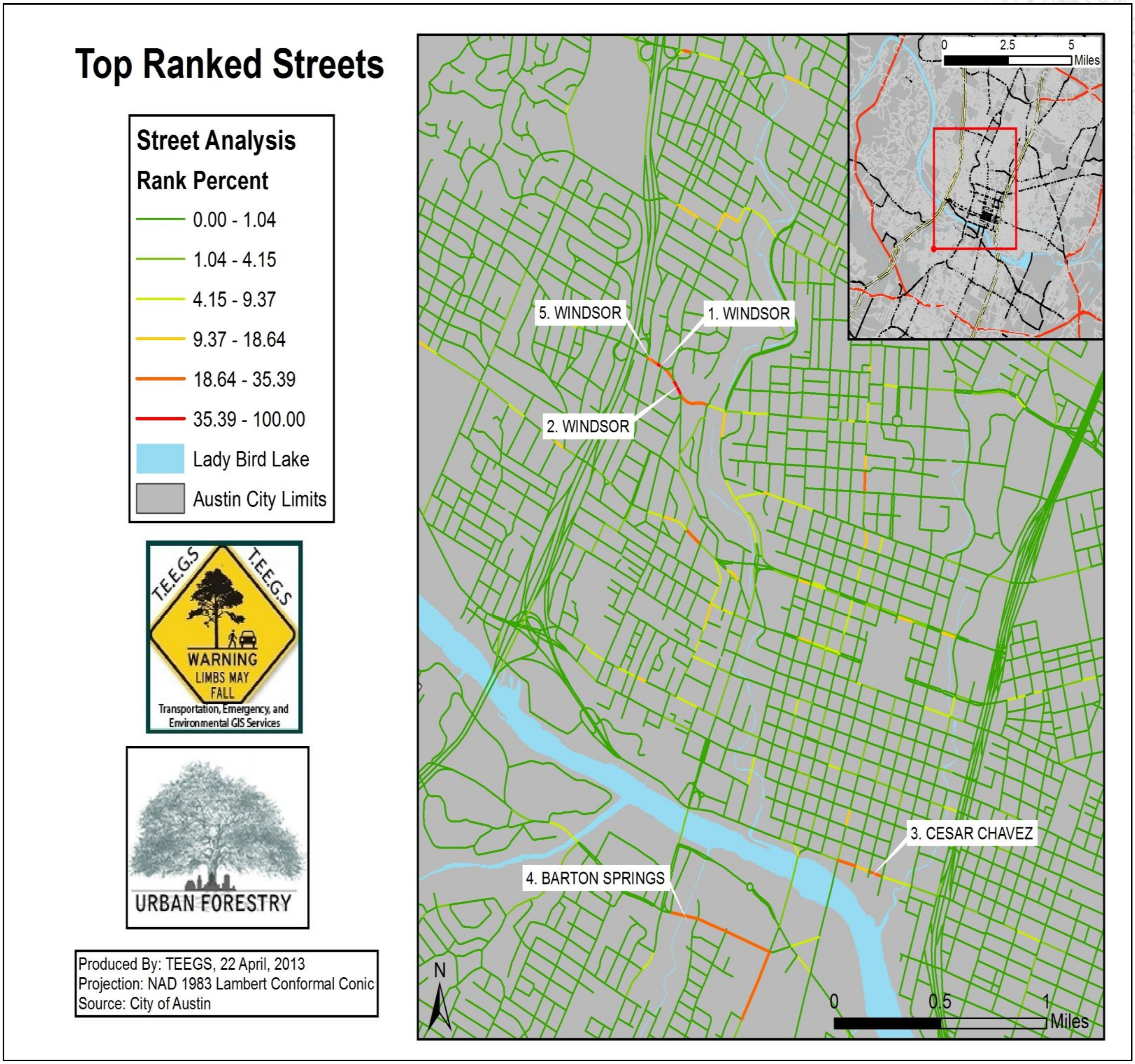
The Downtown area of Austin, located on Cesar Chavez between Congress and Trinity, is our third area of interest we wish to alert the City of Austin Urban Forestry Program to. This area, like the Shoal Creek and Barton Springs area previously noted, is an extremely vital commuting corridor in town. This section of Cesar Chavez experiences considerable traffic from the two highways in town, Mopac and IH-35, as well as south and central Austin traffic from South First and Congress. Because of these factors, in addition to the high level of Emergency Service Personnel traffic, this area is an extremely important corridor for the City of Austin Urban Forestry Program to keep clear in order to ensure Austin's Street Network operates appropriately.

# Results continued

As we have pointed out, our results returned very strong clustering in the areas of Shoal Creek, Barton Springs/South First, and Downtown near Cesar Chavez and Congress. These areas are extremely important for the City of Austin Urban Forestry Program to prioritize for their proactive tree maintenance program, but in addition to these areas there are in fact other areas around town in need of proactive tree maintenance to adequately ensure a fluid response from Austin's Emergency Service Personnel.

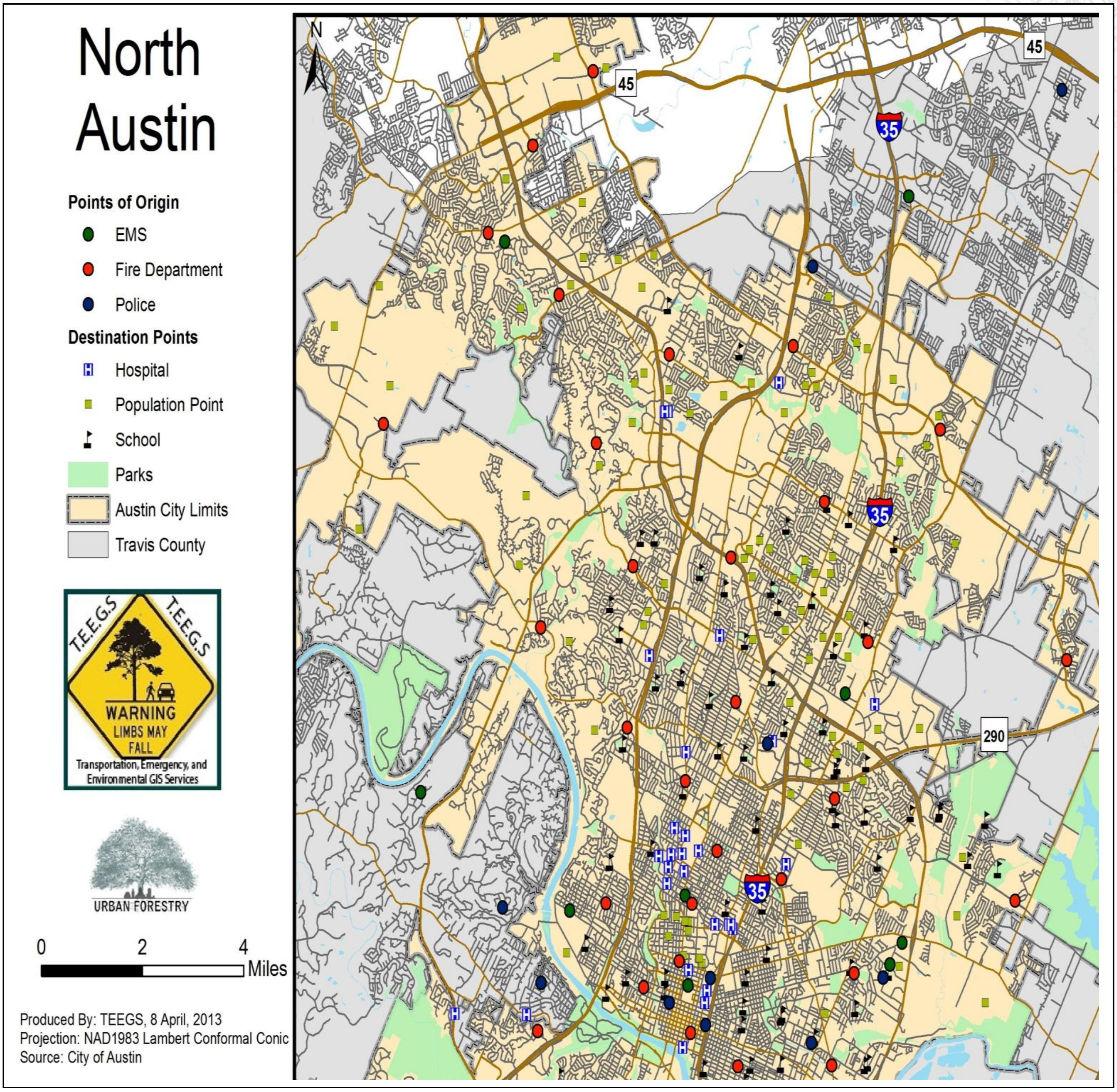
# **Results** Map

## Top Ranked Streets for Potential Tree Hazards



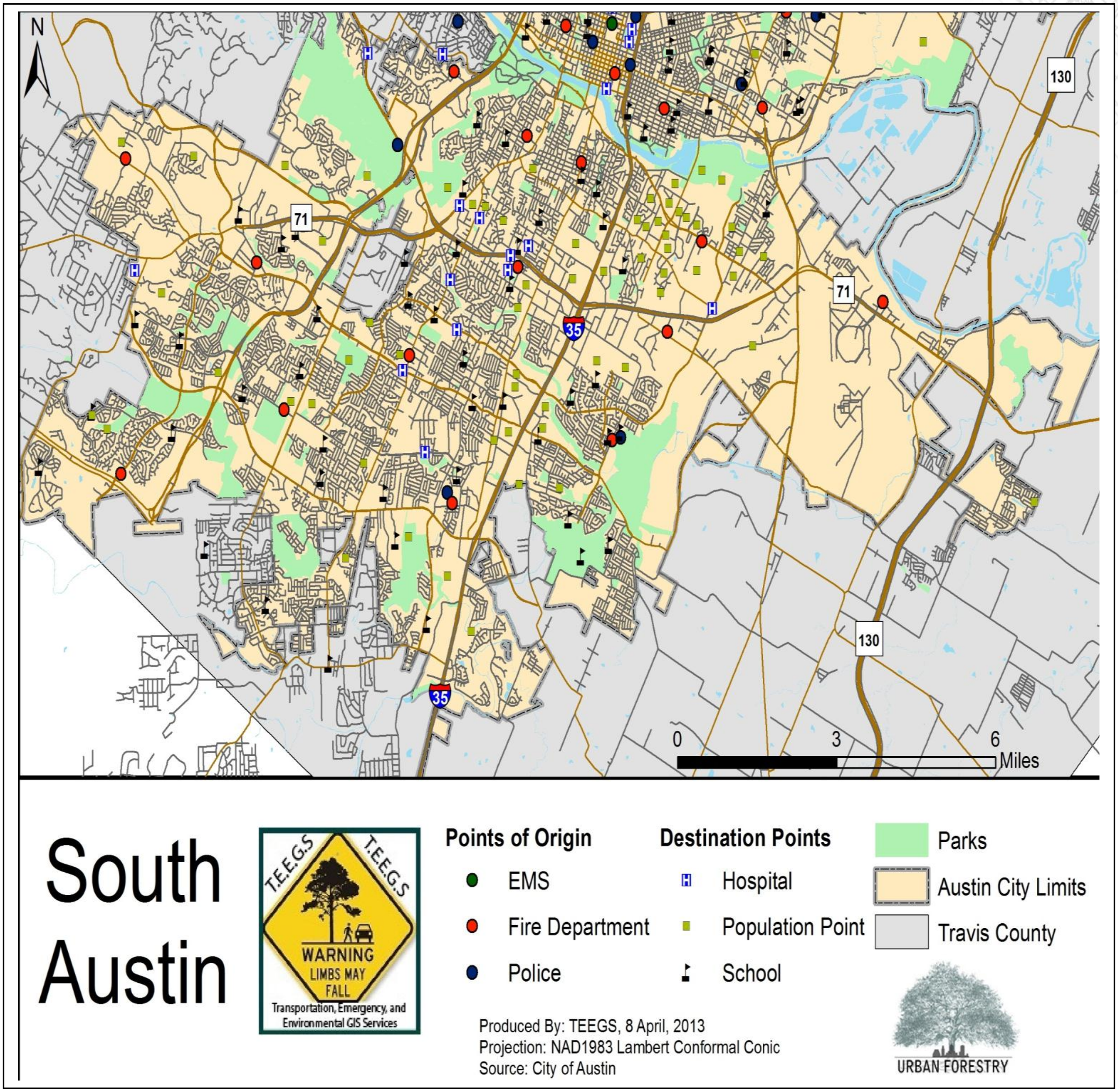
# Maps

## Route Origin and Destination Points for North Austin



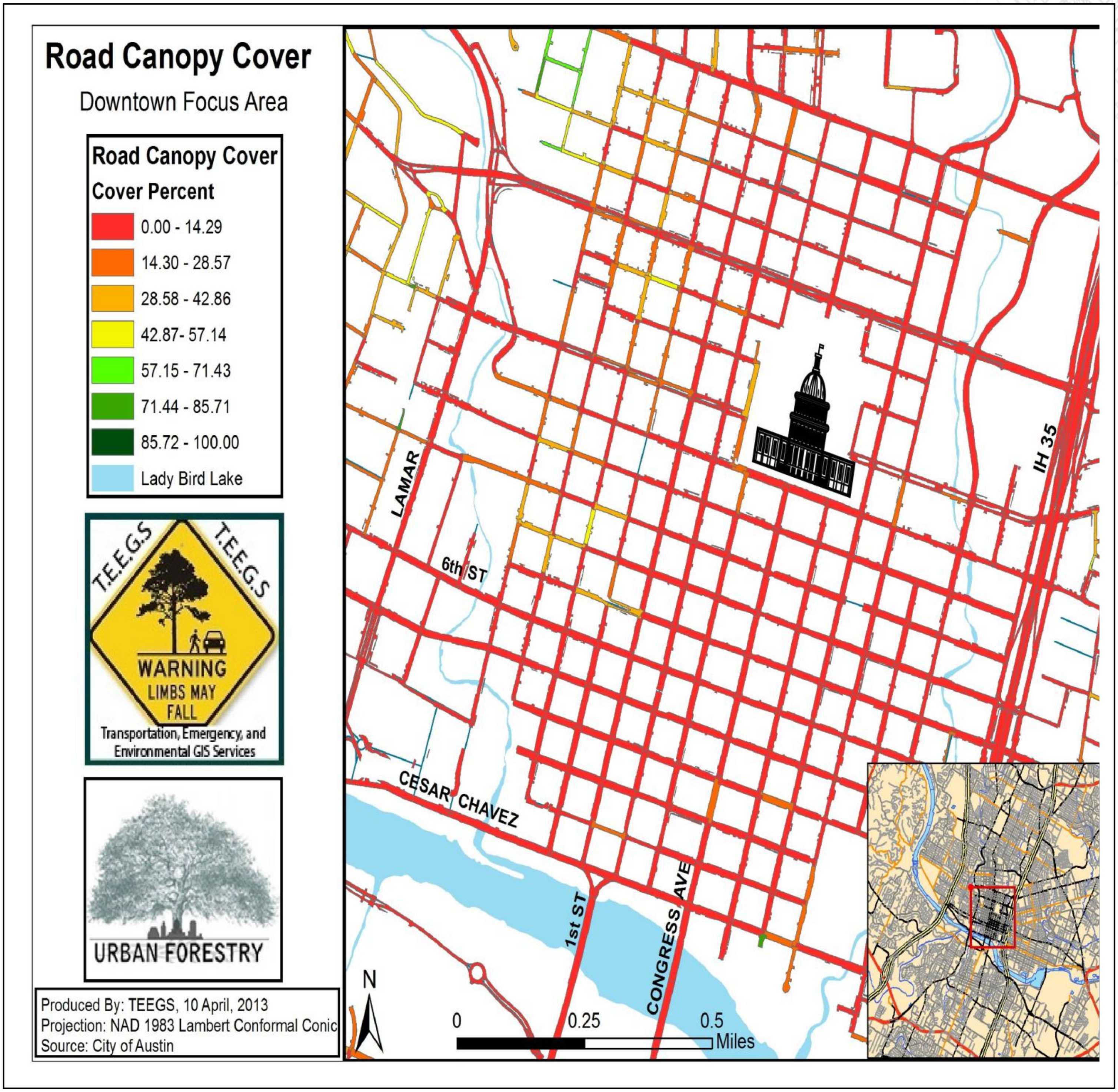
# Maps

## Route Origin and Destination Points for South Austin



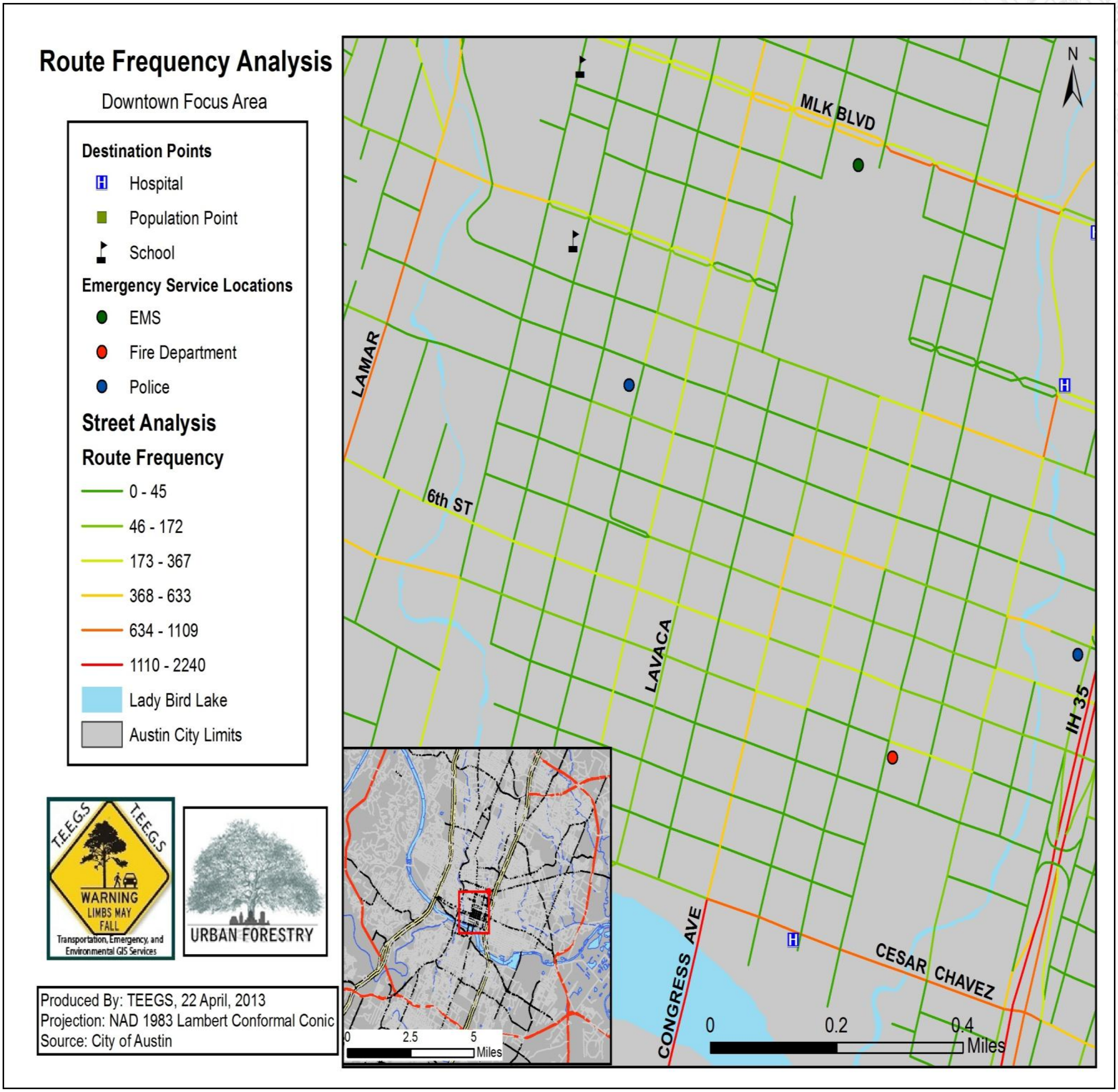
# Maps

## Road Canopy Coverage: Downtown Austin



# Maps

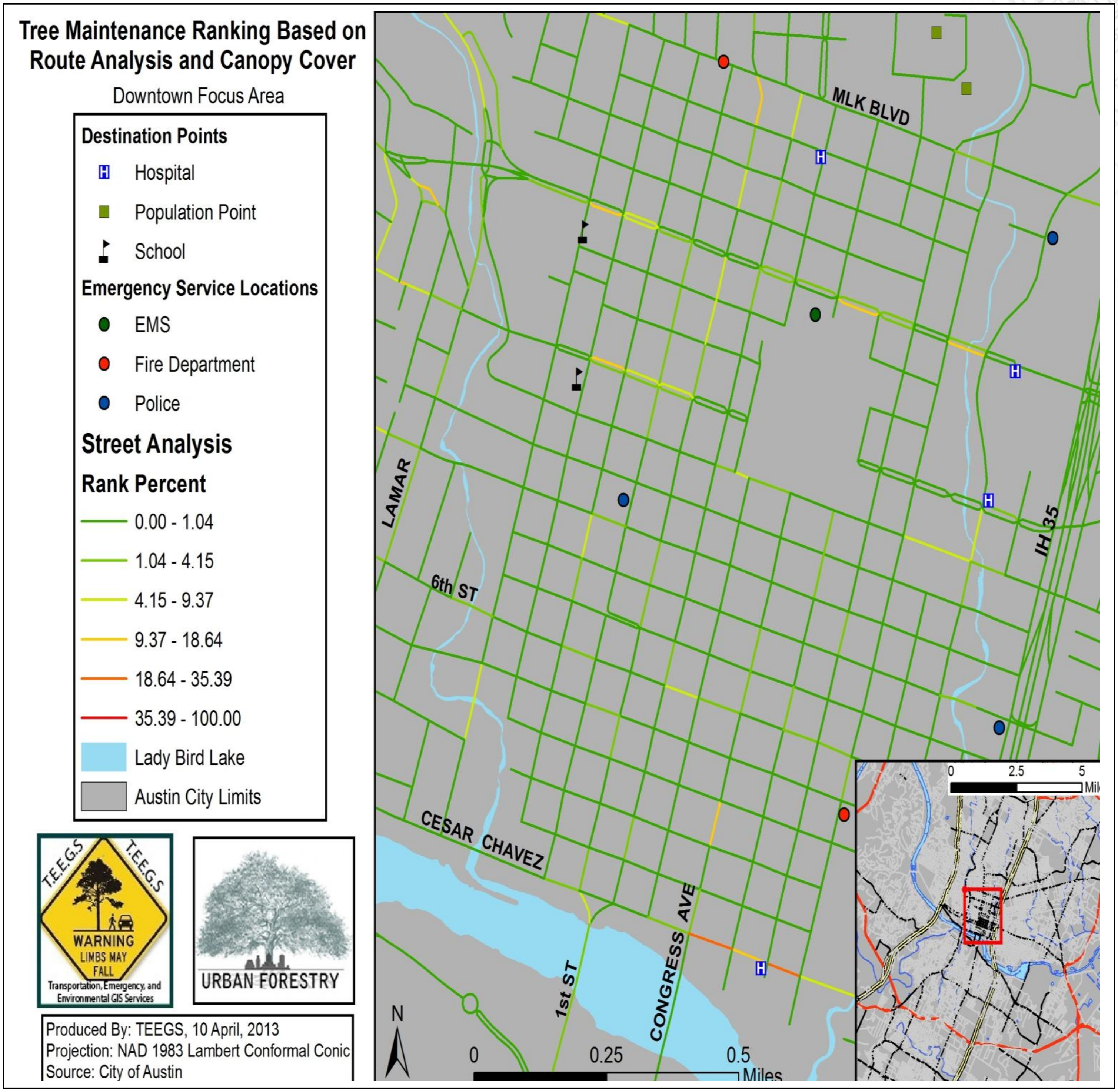
## Route Frequency: Downtown Austin



# Maps

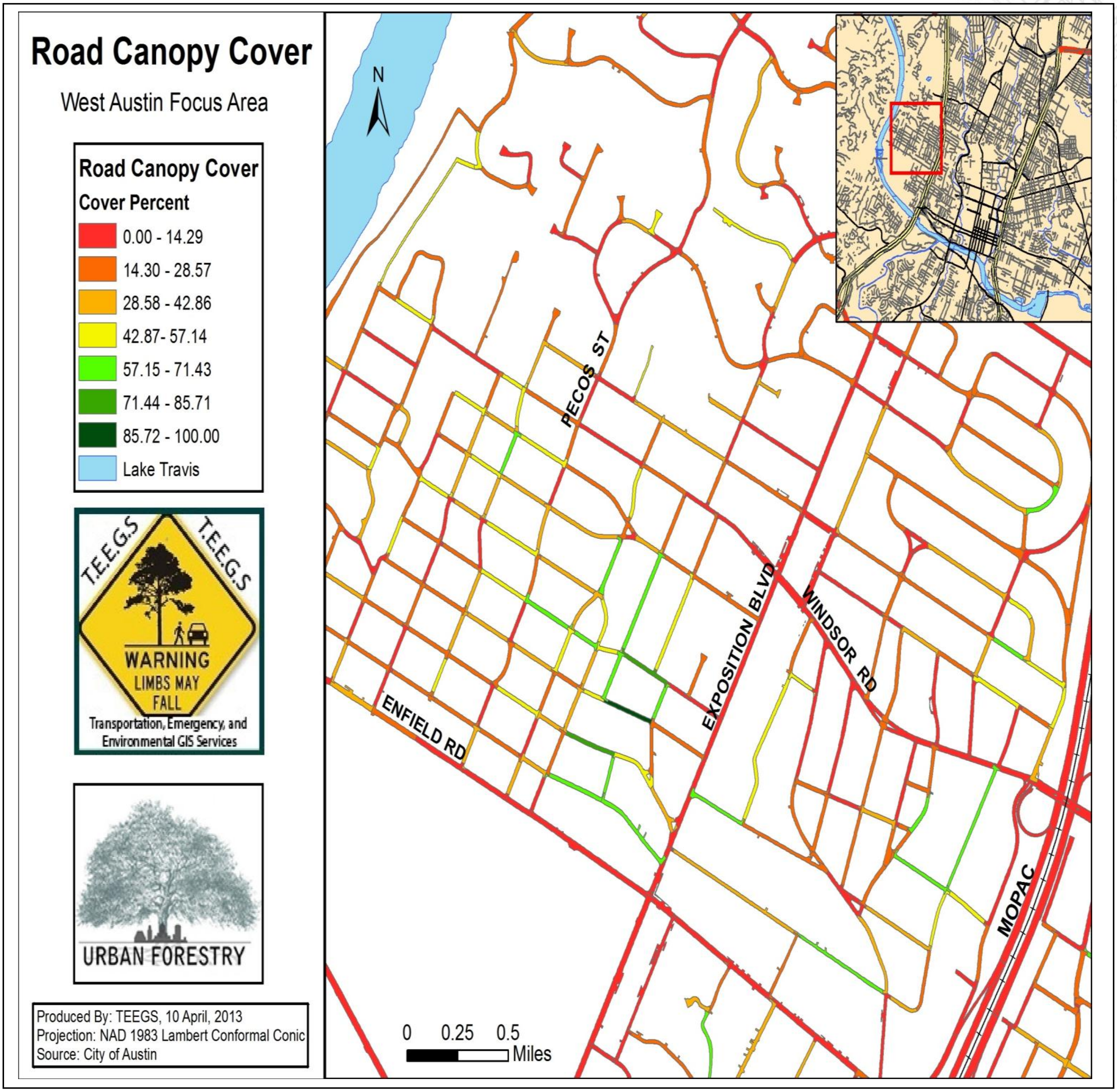
## Canopy Coverage/Route Frequency

## Downtown Austin



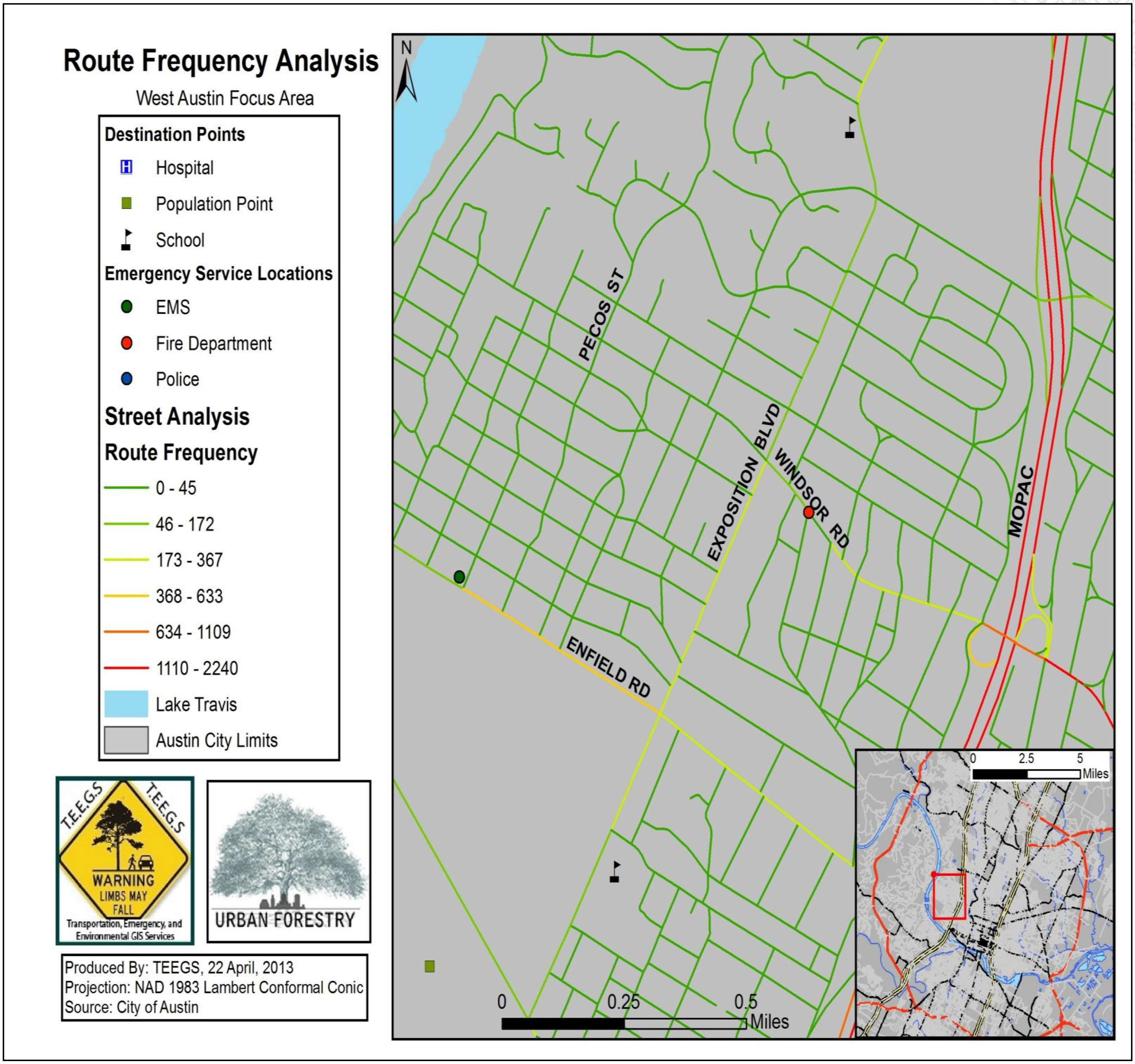
# Maps

## Road Canopy Coverage: West Austin



# Maps

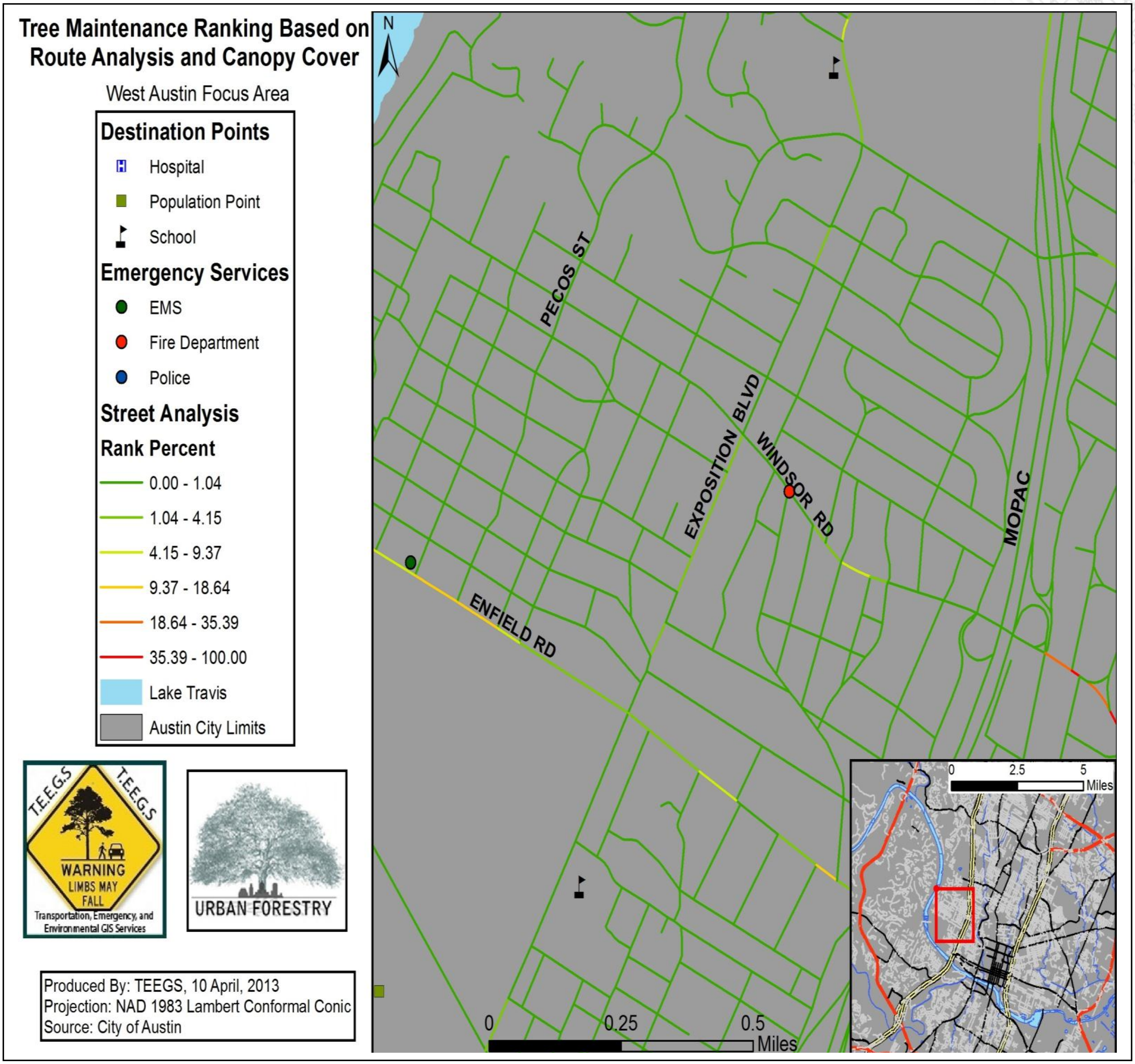
## Route Frequency: West Austin



# Maps

## Canopy Coverage/Route Frequency

## West Austin



# VI. Discussion

In our final analysis, only 5345 of the 30,802 road segments analyzed within the city limits of Austin (roughly 17%) returned a non-zero score. The majority of road segments identified in our analysis were contiguous and less than .5 miles in length.

The highest ranking road segments were sections of Windsor Rd, Caesar Chavez, First St. and Barton Springs. Many of the high ranking streets fall within several miles of the Capital building, however several other high ranking streets were spatially distributed in both North and South Austin.

Our analysis showed that only a small percent of street segments with a high level of canopy coverage were high priority routes for emergency service vehicles. Most of the streets used frequently by emergency service vehicles had little to no canopy coverage.

The small percentage of road segments which had both a high frequency and a high percent canopy cover, and thus a high score and relative rank, are the segments most noteworthy for the expenditure of City of Austin, Urban Forestry Program resources when scheduling preventative tree maintenance, in order to respond to the damage caused by the record drought of 2001 and future maintenance needs.

# Implications

With the ranking system created through this project, the City of Austin Urban Forestry Program will be able to identify which road segments pose the greatest threat to the smooth operation of emergency service responses. With these segments identified, the city can create a schedule of tree maintenance, identifying areas which need maintenance immediately and which will subsequently need maintenance most often, and other areas which will only need to be checked occasionally.

The segments thus identified can also be used in the event of a city wide disaster, such as a large storm, which results in downed tree limbs. Though preventative maintenance will minimize the occurrence of downed limbs, the ranking system created through this project can be used to prioritize streets for clearing in order to allow emergency services to perform rescue services in the aftermath.

The Route Frequency data can also be used with updated tree shade data to update the ranking systems. Unless population shifts or road construction significantly alters the geography of Austin, the Route Frequency data will remain a good measure of which streets are most critical for the function of emergency services.

# Implications

Other cities can use this project as a model for similar studies in their own community. As cities move to integrate trees into their infrastructure, the associated hazards must also be dealt with. A similar ranking system can help other cities to mitigate the hazardsassociated with a green city.

A similar project may also be a way to support a plan for more tree planting in the city. Since one objection to tree planting, particularly along roadways, could be the associated hazard to drivers, having a maintenance plan in place which could be updated as trees are planted would allow proponents of tree planning to address these concerns.

# VII. Conclusions

The most difficult part of this project was creating a model that would run a point to point route analysis. Though this could be done manually, the number of origin and destination points used required around 20,000 routes to be created and would be extremely time intensive. The model required a creative application of knowledge in order to get around this problem.

We also had difficulties finding our points for origins and destinations. EMS, Fire, and Police Stations and school were all collected through Google Maps, which affects the accuracy of the points as well as being time consuming. We were unable to find a comprehensive list for the origin points, so there is no guarantee that all stations were included in our analysis.

Also, though it did not affect our process, our outdated data for both streets and tree shade affected our results. Because the tree shade and street polygons were last updated in 2006, our percent canopy cover is accurate and only to that date. Our road network comes from 2010, so it is more current, but when combined with the 2006 tree data, can only be considered accurate as of 2006, seven years previously.

# VIII. References

Horner, Mark, and Michael Widener. "The effects of transportation network failure on people's accessibility to hurricane disaster relief goods: a modeling approach and application to a Florida case study." 59.3 (2011): 1619-1634. Web. 10 Feb. 2013.

Cova, T.J. (1999) GIS in emergency management. In: *Geographical Information Systems: Principles, Techniques, Applications, and Management*, P.A. Longley, M.F. Goodchild, D.J. Maguire, D.W. Rhind (eds.), John Wiley & Sons, New York, 845-858.

Philippines. Philippine Information Agency. *Confab highlights GIS use for disaster risk reduction*. 2012. Web. 10 Feb. 2013. <http://www.pia.gov.ph/news/index.php?article=1141353427298>.

## Helpful Links:

| | |
|---|---|
| City of Austin | http://www.austintexas.gov/ |
| Urban Forestry Program | http://austintexas.gov/department/urban-forestry |
| Census Bureau | http://www.census.gov/ |
| Texas State University | http://www.txstate.edu/ |
| GIS Projects Home Page | http://geosites.evans.txstate.edu/ |

# Appendix I: Group Member Participation

| Team Member | Tasks/Responsibilities |
|---|---|
| Lauren Bender | GIS Analyst. Data Acquisition. Project Management. Data Creation. Map Design. Literature Review. References. |
| Aaron Gore | GIS Analyst. Methodology. Project Design. Results. Conclusions. Project Management. Metadata. |
| Amanda Magera | GIS Analyst. Methodology. Introduction. Model Creator. Timeline. Manifold. Implications. Results. Final Deliverables. Project Management. |
| Matthew Smith | Project Management. Budget Analyst. Project Design. Introduction. Conclusion. Purpose. GIS Analyst., made poster |

# Appendix II: Metadata

**See separate metadata report or;**

**Information is included on the project CD**