Travis County Evacuation Stress Test Model Report

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Travis County Evacuation Data and Modeling, Phase 1
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Travis County Fire Evacuation Simulation Technical Report
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Travis County Evacuation Data and Modeling, Phase 1

Kenneth A. Perrine
Kamryn V. Long
Maximillion H. Grether
Robert Z. Lehr
Natalia Ruiz-Juri

Travis County, Texas

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Chapter 1. Introduction

1.1. Project Objective

This cooperative project with Travis County proposes to develop a modeling framework that can be used to test and evaluate evacuation scenarios, and to support evacuation planning decisions by the emergency community.

The project will help in understanding modeling challenges and limitations, and desirable extensions to develop enhanced evacuation planning methodologies.

The City of Austin Fire Department, Travis County Transportation and Natural Resources, as well as many others involved with emergency services in the Austin area, have determined the need for this tool as follows:

1. To identify critical locations throughout the network which may become bottlenecks or that, if properly managed, may improve evacuation times;
2. To better understand benefits and optimal use of contraflow lanes and other traffic management and information provision strategies used during evacuation;
3. To help to prioritize evacuation routes and evacuation "districts" or "zones."

This report addresses the first phase of this two-phase project, focusing upon investigating tools that can be used for evacuation planning, as well as providing a data inventory of online resources that can assist in the process. Along the way, information on data collection, hosting, and maintenance has been collected from stakeholders from six agencies who actively work with data.

This chapter provides a background literature search on topics pertaining to evacuation planning in Travis County, both from Travis County publications, and also from other sources that identify practices found in other parts of Texas and the United States.

1.2. History of Evacuations in Travis County

Two notable evacuation emergencies in Travis County referenced by the Office of Emergency Management are the Halloween Floods of 2013 and 2015. The After-Action Report detailing the Halloween Flood on October 31, 2013 stated, "…Walnut Creek, Shoal Creek, Williamson Creek, and Bull Creek all flooded out of their banks" (Latin & Baldwin, 2013). Onion Creek suffered the most significant and record breaking flooding and it was not possible for any of the residents to evacuate beforehand. This area was requested to remain in place until they could be rescued by boat. The Halloween Flood incurred over 40 road closures, beginning on October 30, which began reopening 30 hours later. The flood affected 745 homes, required 625 home evacuations by Emergency Medical Services (EMS), and resulted in a total of four storm caused deaths. The team involved in the Emergency Operations Center (EOC) when it was formally activated on Thursday, October 31 included personnel from multiple disciplines:

- Travis County Office of Emergency Management (TCOEM)
- Austin Office of Homeland Security and Emergency Management (HSEM)
- Austin Watershed Protection Department (WPD) Flood Early Warning System (FEWS) Engineers
- Public Works Department (PWD) Street and Bridge Operations
- Austin Fire Department (AFD)
- Austin Police Department (APD)
- Austin/Travis County EMS
- Communication and Public Information Office (CPIO)
- Travis County Sheriff's Office (TCSO)
- Travis County Transportation and Natural Resources (TNR)
- Capital Metro and the American Red Cross

As the rain subsided and damage assessment began, the team involved in debris removal shifted to city departments including Parks and Recreation Department (PARD), WPD, Austin Water Utility (AWU), Austin Resource Recovery (ARR), PWD, Travis County TNR.

Assessment of EOC and operations was provided in the report for future emergency situations. Within the EOC the use of WebEOC provided quality communication and distribution of information related to the incident, involving the Planning and Development Review Department (PDRD) improved coordination and situational understanding, and maps provided by the EOC for agencies to identify affected areas were well received (Latin & Baldwin, 2013). Suggested improvements include further training on GIS resources and capabilities, identifying more city employees to assist in the EOC during prolonged activation, and effective tracking of road closures; this information was not available (Latin & Baldwin, 2013). It was also noted that the FEWS flood forecast model did not work in this case, and that the EOC should have been activated sooner. Another issue stemmed from the flooding of Onion Creek, which in turn cut off electrical power to the South Austin Regional Wastewater Treatment Plant (SAR). The plant itself became isolated and unreachable. An asset to field operations was STAR Flight management which, "…provided logistical support to crews and created a beneficial buffer between crews and communications when there were multiple requests to the same location or high priority calls" (Latin & Baldwin, 2013).

The second Halloween Flood for Travis County occurred in 2015; this incident control response began a bit sooner with an HSEM email alert October 29, 2015, and EOC activation one day later. "There were 440 low water crossings and other closures recorded during the incident…" (Swearengin, R. S., Moore-Guajardo, 2015). This flood hit most severely in Onion Creek and Dry Creek. Some issues from 2013 occurred again in 2015 including the single entry to SARP posing problems, and the inability to provide accurate road closure status. This information gap was due to the absence of TxDOT in the EOC, which is considered a vital recommendation from the report. The items that worked well or were seen to have improved since 2013 included the FEWS system, the provision of maps for agencies to identify affected areas furnished by the Austin Geographical Information Service – Emergency Response Team (GIS-ERT), and the use of WebEOC.

1.3. Literature and Background Search

1.3.1. Evacuation Details for Travis County

Austin emergency management strategies are defined through comprehensive Annex reports that support the larger concepts described in the Basic Plan (City of Austin, 2016). Evacuation protocols are outlined in Annex E, which Travis County has adapted from state requirements to use during, and in preparation for, any major evacuation incident. In the evacuation plan, there are four levels of response readiness guidelines which begin with normal conditions at Readiness Level IV, and potentially rise to emergency conditions at Readiness Level I. Each level assesses the situation and prepares for precautionary actions. Escalation to Readiness Level I means evacuation becomes a real possibility and implementation extends beyond preparation.

The actual need for an evacuation will be determined by the Incident Commander or in some cases, through the Emergency Operations Center (EOC). The Incident Commander takes lead in risk area identification, and managing people in affected areas. The Incident Commander, assisted by the EOC, will oversee the organization and planning of the evacuation, and handle the incident on-scene (Travis County, 2017a). The EOC will coordinate traffic control along evacuation routes, activate shelter and mass care facilities, and advise other jurisdictions of the evacuation (Travis County, 2017a). Selected other officials and their designated evacuation related responsibilities include:

1. Travis County Judge/Municipal Mayor

- Issues the public order to evacuate, as well as approve all warnings, instructions, and information released to the public during the event.
- Coordinates with other local governments affected by the situation.
- Directs essential resources to safe areas, and oversees judgement regarding shelters and mass care facilities if needed.

2. Emergency Management Coordinator (EMC)
    - Functions as the EOC Director for Travis County.
    - Provides information regarding evacuations including planning details, population, and primary evacuation routes.
    - Coordinates all efforts necessary in evacuation planning.
3. Homeland Security and Emergency Management Director
    - Functions as the EOC Director for the entire City of Austin.
    - Manages EOC operations, and provides emergency management policy and procedure guidance (City of Austin, 2016).
4. TNR/Public Works department
    - Assists in traffic control and evacuation route operations.
5. Law Enforcement
    - Assists in traffic control, public warnings, and any necessary tasks related to evacuation.
    - Advises the Incident Commander or EOC on evacuation route selection.
6. Fire Service
    - Coordinates all fire protection and services required.
    - Assists in evacuating individuals and warning the public along with EMS.

Documentation protocol for an evacuation includes Situation Reports and Disaster Summary Outlines (DSO), which are submitted to the State and any affected jurisdictions (City of Austin, 2016). At-risk flood areas and limited access regions have been identified and documented in Travis County. Populations within the areas are not specified, but evacuation routes have been determined. This information and most evacuation specific guidelines can be accessed through Travis County's EOC.

In the interest of identifying special characteristics of the most probable causes for evacuation, the following sections address wildfires, flooding, and winter weather.

1.3.2. Wildfires

Travis County has an extensive Community Wildfire Protection Plan (CWPP) which aligns with national best practices, and standardizes strategy (Travis County and the City of Austin, 2014). This plan contains a unique community profile which details the landscape, locations of residents, and likely future resident locations. It also includes risk assessments, mitigations strategies, plan implementations, and further relevant wildfire guidelines.

Research provided in *Best Practices for TxDOT on Handling Wildfires* (2012), outlines current practices, and interviews 12 TxDOT districts regarding involvement with wildfire events. Two important forms of collecting and reporting data found in this research include the Highway Condition Reports and The National Incident Management System (NIMS). Highway Condition Reports (HCR) can be accessed through the TxDOT website, and include wildfire updates for highway conditions that are updated every weekday morning. NIMS integrates organizations to work together to mitigate, respond, and recover from incidents. The primary finding among the 12 district interviews concluded TxDOT plays a significant role in managing a wildfire emergency, even though they do not directly provide firefighting support. It was also found between all TxDOT districts, the chain of command during a wildfire incident remained constant. This protocol begins with the Department of Public Safety (DPS) who notifies the Director of Maintenance (DOM). The DOM then calls the Maintenance Supervisor for that section, and then the District Engineer and Area Engineer are informed. The DPS initiates any district involvement to assist in the situation. During wildfire incidents in Austin specifically, the district interacts with parks and wildlife, EOC, Texas Forest Service (TFS), National Forest Service (NFS), all state agencies, the Bastrop convention center, and the DPS.

TFS is the lead NIMS implementing agency and is involved in Texas statewide emergency management for handling wildfires (Nash, Senadheera, Beierle, Kumfer, & Wilson, 2012). TFS provides guidelines and technology helpful for developing a successful CWPP. They provide the tool used in Travis County's CWPP called TxWRAP, which stands for Texas Wildfire Risk Assessment Portal. This web-based application can identify community boundaries and provide information for Wildland Urban Interface (WUI), Fire Occurrences, Fire Behavior, Risk Assessment, and Future Wildland Restoration (Union of BC Municipalities, 2017). It is also a useful tool to allow agencies to work together to improve emergency response overall. TFS also provides an accessible Keetch Byram Drought Index (KBDI) map helpful for wildfire planning.

According to the *State of Texas Emergency Management Plan* (2012), agencies involved in the primary coordination of evacuations include DPS and Texas Highway Patrol (THP). The Texas Division of Emergency Management (TDEM) or the Department of State Health and Services (DSHS) may activate the Texas Emergency Tracking Network to notify all agencies necessary. The DSHS is also in charge of medical evacuation decisions. THP and TxDOT notify counties of wildland fire evacuation routes and manage traffic decisions such as changes in contraflow. Other departments that provide assistive support in the event of an evacuation include:

- Texas Animal Health Commission (TAHC)
- Texas Department of Insurance (TDI)
- Texas Engineering Extension Service (TEEX)
- Texas Military Forces (TXMF)

Data collection techniques for TxDOT districts include emails and SharePoint, maintenance division database, Daily Activity Reports (DARs), employee diaries, situation reports, and equipment and personnel logs (Nash, Senadheera, Beierle, & Kumfer, 2013).

1.3.3. Flooding

The most at-risk flood areas for Travis County are defined in Annex E, as previously mentioned, along with evacuation protocols. The identified flood risk areas are primarily clustered together near major creeks, including locations such as Bluff Springs Road and Springdale Road. Populations in these areas are not provided, but recommended evacuation routes have been specified. Bluff Springs Road, for example, follows William Cannon Drive to I-35, while Springdale Road follows Manor Road to Hwy 183 in an emergency evacuation. Other areas of concern with defined evacuation routes include (Travis County, 2017a):

1. Graveyard Point
2. Arroyo Doble Drive
3. Martinshaw Resub Subdivision
4. Thaxton Road
5. Crooked Creek Drive/Dessau Estates Subdivision
6. Timber Creek
7. Wolf Lane
8. Decker Creek Drive/Twin Meadows Subdivision
9. River Timber
10. Thoroughbred Farms

"Flooding is the most common hazard for the Austin area" (City of Austin, 2016), and flooding can occur anywhere in Austin not just in proximity to creeks or floodplains. Austin's Office of Homeland Security and Emergency Management recommends road users stay informed on flood information and emergency road closures. This is capable through the site maintained by the City of Austin Flood Early Warning System team, ATXfloods, available online (www.atxfloods.com). A name change to CTXfloods and user interface updates are forthcoming. Through the portal users can also link to ATX FloodPro, which can identify floodplain locations. ATXfloods is a multi-jurisdictional collaborative website, which shows green dots where low water crossings are open and red dots where closures have occurred (Porcher, 2015). This visual interface is an improvement upon previous methods of closure lists on the emergency operation center website. The website also provides alerts relevant to user location for pre-emergency notification.

In an FHWA report outlining best practices for evacuations, the value of the time required for evacuations and simulating these effects is highly stressed. Suggested modeling techniques of an evacuation is discussed further in the report under the Modeling section. "An important lesson learned in evacuations associated with Hurricanes Katrina and Rita was the necessity of having food, water, restrooms, fuel, and shelter opportunities along evacuation routes" (FHWA, 2006). Communication of the available resources during the evacuation is just as important. FHWA also noted a plan which includes public transit is not often well defined, but incorporation could benefit people who cannot evacuate through personal vehicles such as special needs evacuees. Further areas where evacuation plans often need improvement include public communication, effective return planning, contraflow operations, and animal sheltering (FHWA, 2006).

1.3.4. Winter Weather

TxDOT requires each district to maintain a plan specific for snow and ice conditions. Austin's Winter Storm Plan outlines objectives, response plans, storm preparations, materials and resources, identified maintenance boundaries, a district and emergency contact list, ice control routes, and an ice control schedule (Perkins et al., 2012). The EOC remains a prominent participant if the weather escalates to an emergency situation, and the DPS is directly listed as an emergency point of contact. However, typical winter storm response operations are managed through the local maintenance office level which is divided into 15 sections in the Austin District (Perkins et al., 2012). Although winter storms in Travis County are next to last on the hazard ranking list, the probability of occurrence still remains highly likely to happen each year (Travis County, 2017b). Therefore, the importance of an evacuation plan adaptable to winter storm conditions remains relevant.

In the event of an evacuation, TxDOT provides a tool for emergency planning that displays evacuation route information in Texas (TxDOT, 2017). This tool is called DriveTexas™, and is primarily helpful to evacuees to show highway conditions. This tool is recommended for users during winter storm situations as well as floods, wildfires, and other hazardous conditions. Possible contraflow or evacu-lanes are shown in a separate model, and activated into current conditions only when in use by the network.

The system and coordination for emergency response during an evacuation is heavily dependent upon power. Traffic signals, cameras, communications, and many other devices are key aspects to any major road emergency situation. Ice storms have the potential to cause power outages, as seen in the 2008 ice storm in New Hampshire which caused over 800,000 individuals to lose power access (Matherly et al., 2014). In such an event, the implementation of emergency plans would be difficult without physical copies available. Furthermore, most of the information resources available to the public as well as on an interdepartmental basis are dependent upon internet and power access. Lessons learned from previous outages suggest tailoring the emergency plan to operate with and without power.

Reporting information on the federal level related to snow and ice conditions involves furnishing maintenance management system reports to the Federal Emergency Management Agency (FEMA). This helps repair cost assessments in the event of storm damage. State reports are done through HCR, which is provided as unedited information available to the public as well as within TxDOT (Texas Department of Transportation, 2017). District and local reports like the examples found in Austin’s Winter Storm Plan, are completed from maintenance officials with heavy detail to track operations.

Chapter 2. Planning and Modeling Tools

2.1. Modeling Strategies

Factors to consider in demand modeling include situational impacts such as risk and possible damage, as well as socio-demographic characteristics of people affected. The varying influences are considered in trip generation to produce time dependent demand applicable to evacuation simulation (Murray-Tuite & Wolshon, 2013). This can either be achieved in one or two steps.

2.1.1. Two Step Trip Generation Approach

- Determine the number of evacuating households
  - Possible to use participation rates or similarly cross-classification techniques
    - Zones are given evacuation rates which are multiplied by population to estimate evacuee total
  - Also, possible by means of logistic regression – evacuate or stay
- Departure time of evacuees
  - Often follows an S-curve
    - Assumes 10% of the population evacuates before official evacuation notice given
  - Studies have also developed a hurricane evacuation response curve

2.1.2. One Step Trip Generation Approach

- Determine the number of evacuating households and departure time simultaneously
  - Repeated use of binary logit model to evaluate each iteration
  - Less frequently used approach compared to the two step

2.1.3. Trip Modeling Considerations

Other important elements to consider for trip modeling include (Murray-Tuite & Wolshon, 2013):

- Background traffic
  - Travelers are not directly associated with the evacuation, but their unrelated trips might impact the situation
  - Hard to quantify – some percent of normal traffic possibly light, medium, or heavy
- Intermediate trips
  - Evacuees gathering to exit in family or group units

  - Studies show this activity based concept lengthened network clearance times
  - Evaluation methods possible include optimization techniques to identify meeting locations, binary logit models, and statistical models combined with mode selection and traffic simulation tools (Murray-Tuite & Wolshon, 2013)
- Shadow evacuation.
  - People evacuating outside the required population
  - Hard to quantify, yet potentially threatening
- Traffic Incidents
  - Evacuations lead to increased road users
  - Possible route changes and unfamiliarity to the road also cause problems
- Mode Choice
  - Determining how people will evacuate effects the scenario directly
  - Wu. et. al. (2012) found 11% of evacuees did not use personal vehicles, of which the majority rode with someone else
  - Deka and Carnegie (2010) used a discrete choice study which determined 84% of households preferred private vehicles in an evacuation scenario
  - Special vehicle considerations include cars in tow - boats, trailers, etc.
  - Possible flight, or transit evacuees to determine as well

2.1.4. Destination Modeling

- Accommodation type is evaluated through discrete choice approaches – multinomial logit model (Murray-Tuite & Wolshon, 2013)
- Possible destination choice models also include the extended intervening opportunity model, dynamic gravity model, and subjective adjustments to typical transportation planning (Murray-Tuite & Wolshon, 2013)

2.1.5. Advanced Tool: RtePM

RtePM, which stands for Real time evacuation Planning Model, is a useful web-based tool to aid in emergency management as it allows a rapid approach to modeling evacuation scenarios (Collins, Robinson, Foytik, Jordan, & Ezell, 2016). The RtePM application can be accessed online any time through its website (www.rtepm.vmasc.odu.edu). This system allows the creation of customized models fit to the evacuation scenario type. Modifications available include (Robinson, Foytik, & Jordan, 2017):

1. Up to 2000 customizable evacuation zones or population blocks.

    - Rate of population participation within a zone can be controlled through percent input.
    - Viewing evacuation response in one hour increments up to 72 hours.
    - Adjusting the amount of people per vehicle per zone evacuating.
    - Specifying number of vehicles evacuating with another vehicle in tow per zone.
    - Pedestrian and public transit evacuation mode options available through percent input.
    - Evacuation destination endpoints can be added and input.
2. Network Alternations, such as:
    - Ability to add evacu-lanes and utilize contraflow.
    - Alteration of free flow speeds.
    - Creation of new roads or closing/adding lanes to existing roads.

Additional features in zones allow population proportions to evacuate to shelters. Shelters can either be pre-loaded or inserted manually with input capacity and location. Background traffic levels can be adjusted between the three levels available. Traffic incidents can also be included with statistically estimated frequencies, locations, and severities (Robinson et al., 2017).

Peter Foytik, Senior Project Scientist at VMASC, provided further insight into route selection, route assignment, and traffic simulation in the RtePM tool. He confirmed the algorithm used for selecting routes is based on an A* shortest path implementation. He also specified the destinations assigned to the evacuation zones are assigned by default if the user does not input them directly. The default assignment uses information from the road network to determine high volume endpoint links, and uses those endpoints as destinations that then equally distributes the evacuating demand to those points. It is suggested to use personal data to assign evacuating demand and destinations rather than relying on the default. "Each vehicle is microscopically simulated over the network to the destination using the assigned path and the travel time is derived using a simplified car following algorithm" (Robinson et al., 2017). Foytik also described the timestep of the simulation to be a tenth of a second, even though the results are recorded in hour segments. Daytime evacuation scenarios use LandScan data while nighttime evacuations use census data.

Exploration of the RtePM tool does show network alterations, such as contraflow, as somewhat tedious to implement as you cannot select large stretches of road, but must inch along in multi-selection. Shapes for zones can be imported and used, or roughly drawn on screen if necessary. The user guide provides video tutorials and a thorough run through on how to use the tool. Tests run using RtePM deliver fast results that would be very difficult to obtain through only real-world data. This is why RtePM is a strong tool for simulation for emergency management as many possible scenarios can be explored and run quickly (Collins et al., 2016).

Advice on best practices and considerations for using RtePM are printed in Section 3.5 below.

2.2. Risk Management

This section addresses practices in vulnerability assessment and risk management. The primary motivation for looking at risk management is to prioritize and justify the allocation of resources, both in the early drawing board stages of planning, and also in the execution of the plan during an emergency.

Best practices for assessing the vulnerability of a transportation network under extreme weather and options available for adapting and improving are available in the report, *Central Texas Extreme Weather and Climate Change Vulnerability Assessment of Regional Transportation Infrastructure* (2015). This report outlines transportation data, asset criticality, sensitivity thresholds, climate data, vulnerability assessment, and fundamental takeaways. The study involved the U.S. DOT Vulnerability Assessment Scoring Tool (VAST) which breaks apart the assessment into three components: exposure, sensitivity, and adaptive capacity. The assets or roads analyzed were selected based on the premise that their removal from the network, due to extreme weather, would cause significant impacts.

VAST classifies exposure as whether the asset experiences the indicated stressor, such as flooding or wildfire. Sensitivity of an asset relates to whether it might be damaged if exposed to a stressor. Adaptive capacity in VAST is the ability of the of the overall transportation system to handle damage to the asset. Indicators must be established when using the tool which are, "…characteristics or attributes of the asset that reflect its exposure, sensitivity, and adaptive capacity to a given stressor" (Cambridge Systematics Inc, 2015). Indicators can be quantitative or qualitative and suggestions are provided by VAST. Data collection is required for each indicator relative to each asset, and the indicators are scored on a scale beginning with least vulnerable up to most vulnerable (0-4). Weights are then assigned to each indicator. Examples of exposure indicators for various stressors (Flooding, Wildfire, Winter weather, etc.) include past exposure, proximity to the 100-year floodplain, wildfire threat (defined by TxWRAP), and projected change in number of ice days. Sensitivity scoring again flows from 0-4 with the inclusion of 0.5 as a half step between 0 and 1. This lower sensitivity was created due to significantly low likelihood of damage from exposure. Examples of sensitivity indicators to stressors include 24-hour precipitation design threshold, wildfire sensitivity rating, and whether a roadway is elevated (Cambridge Systematics Inc, 2015). Adaptive capacity scoring ranges between 1-4 (minimal to severe), identifying the effect of network activity given damage to the asset. Examples of adaptive capacity indictors to assets such as highways are asset criticality, truck traffic volume, and detour length. Detailed summaries of key risks for each asset are available in that report.

2.2.1. Current Risk Assessment in Austin-Travis County

In the VAST methodology it is recommended that the set up include interviews from local experts to help establish assets and sensitivity thresholds. In Austin's *Emergency Operations Plan* (2016) hazards have been identified with their potential impact on the city. This identification is based on interviews from local and national experts, historical records, national data sources, and existing plans and reports (City of Austin, 2016). The probability of occurrence and potential economic losses from each hazard were identified using the FEMA's hazards U.S. (HAZUS) Multi-Hazards Model, and then prioritized by potential damages. The results were very similar to the hazard index identified by Travis County in the *Hazard Mitigation Plan Update* (2017). The modeling method for Travis County included interviews from local experts, but did not disclose other modeling techniques. The results from the Travis County hazard ranking are shown in Tables 1-2 with highly likely events as probably to occur in the next year, and unlikely events probable to occur in the next 10 years. The risk identification provided is a good start to identifying network vulnerability, however, it needs to be adjusted to be asset or location specific.

Table 1: Impact Statements (Travis County, 2017b)

Potential Severity	Description
Substantial	Multiple deaths. Complete shutdown of facilities for 30 days or more. More than 50 percent of property destroyed or with major damage
Major	Injuries and illnesses resulting in permanent disability. Complete shutdown of critical facilities for at least 2 weeks. More than 25 percent of property destroyed or with major damage.
Minor	Injuries and illnesses do not result in permanent disability. Complete shutdown of critical facilities for more than 1 week. More than 10 percent of property destroyed or with major damage.
Limited	Injuries and illnesses are treatable with first aid. Shutdown of critical facilities and services for 24 hours or less. Less than 10 percent of property destroyed or with major damage.

Table 2: Hazard Risk Ranking (Travis County, 2017b)

Hazard	Frequency of Occurrence	Potential Severity	Ranking
Flooding	**Highly Likely**	**Substantial**	**High**
Wildfire	**Highly Likely**	**Minor**	**Moderate**
Drought	Highly Likely	Limited	Moderate
Tornado	Highly Likely	Major	Moderate
Thunderstorm Wind	Highly Likely	Substantial	Moderate
Extreme Heat	Highly Likely	Substantial	Moderate
Expansive Soils	Highly Likely	Limited	Moderate
Hail	**Highly Likely**	**Minor**	**Moderate**
Lightning	Highly Likely	Limited	Moderate
Winter Storm	**Highly Likely**	**Limited**	**Moderate**
Dam Failure	Unlikely	Substantial	Low

2.2.2. Travis County Wildfire Risk Modeling/Assessment

Section 4 of Travis County's CWPP, provides detailed wildfire risk modeling with location specific maps, combustion risk rankings areas, and data sources and formulas used for modeling in Appendix B of the CWPP. The 83 boundaries or zones were determined by physical features, jurisdictional boundaries, and local area judgement. The fire behavior modeling used FlamMap, an application that simulates the occurrence and spread of a fire in a designated study area. Identification of risks for the CWPP involved the use of multiple GIS-based models and data sources including:

- City of Austin GIS ftp site
- Capital Area Council of Governments (CapCoG) geospatial data website
- Travis County
- Travis County Tax Appraisal District
- US Department of Agriculture
- Texas Natural Resources Information System
- Austin Fire Department
- Texas Parks and Wildlife Department

The availability of information available on wildfire emergency information is a strong resource in emergency planning. The risk calculation and classification provided in the CWPP is based off a scenario in FlamMap. The simulation included north and south winds of 30 mph, relative humidity at 6%, and moisture values at the near-worst drought conditions (Travis County and the City of Austin, 2014). The results provided in the CWPP can be useful in practice to determine network vulnerability and risk, keeping in mind alternative scenarios and updated GIS data could alter the results.

Chapter 3. Key Considerations and Best Practices

This chapter identifies specific practices that can facilitate successful evacuation planning and execution.

3.1. Zoning

In planning and modeling, it is common to partition a regional geography into sub-regions, or zones. Zoning, while unique to a region, is highly suggested to be created as a collaborative effort among local experts. While no formal guideline exits, judgment from network, land, and neighborhood knowledge impacts what boundaries are best fit. A potentially helpful resource is included in Annex E, where Travis County provides a map detailing areas of potential risk in an evacuation emergency. It includes 14 Emergency Service Districts (ESD) with listed roads and subdivisions encompassing each district. This map outlines limited access areas, and serves as a useful tool in zone evacuation planning.

3.2. Special Considerations and Logistical Difficulties

The need for multi-modal oriented evacuation efforts increases when considering special needs populations. Typically, adding transit into the evacuation plan is not extensively evaluated due to a high preference for personal vehicles. However, events such as Hurricane Katrina have shown the necessity to incorporate alternative modes to accommodate everyone fairly. An attempt to evaluate possible evacuation modeling methods for special needs populations was done by (Kaisar, Hess, & Palomo, 2012) using the public transit system. The study successfully addressed the needs of evacuating special needs populations through optimal bus stop allocation modeled in downtown Washington, D.C. and contains detailed methodology for reference.

- Special needs populations
  - Physically disabled
  - Elderly
  - Non-English-speaking persons
  - Non-vehicle owning households
  - Tourists
- Other special considerations
  - Hospitals and special facilities
  - Schools and children
  - Pets and service companions

Transporting individuals from their original location to the designated evacuating transit is another concern. The sheltering of pets and possible other livestock also poses challenges during the event. Pet estimation models are available to assist officials in finding possible families with pets needing shelter (Murray-Tuite & Wolshon, 2013)**.** Estimations can also be achieved through population datasets if necessary.

3.3. Dissemination

Getting information out to the public is an ongoing challenge for any evacuation planning effort, whether it be for emergency preparation or for an actual evacuation event. Communications are conducted through all phases:

- **Proactive preparation:** Understanding risks;
- **Reactive communication during an emergency:** Understanding the status of the emergency; and,
- **After the emergency:** Aiding recovery.

Traditional communication means include the media (via television, commercial radio, or online services), Emergency Alert System (EAS), highway advisory radio (HAR), variable message signs (VMS), robo-callers, and increasingly government-sponsored Web-based information resources. Other creative means, especially for disaster preparedness, includes open houses, leaflet campaigns, and door-to-door communications. Communications on one medium can inform listeners of the existence of other media; for example, a leaflet can identify one or more online resources and encourage readers to visit them.

Social Media continues to be a growing dissemination medium. Twitter appears to be the most popular; for example, the traffic management center for City of Austin uses Twitter to broadcast information on road closures or sources of bad travel delays. Twitter also is instrumental for the media (newspapers, radio stations, and television stations) to learn about incidents that affect traffic.

The use of text messaging (e.g. SMS) is a popular form of emergency situation dissemination, especially within university communities or airlines. For one to receive alerts, one may opt-in by providing a cell phone number. A similar scheme could provide a means to distribute information county-wide.

The use of mobile apps is becoming more prevalent. Apps such as Nextdoor facilitate a community-oriented social network. Agencies such as Capital Metro offer their free app to travelers for receiving alerts, planning routes, and paying bus fares. The biggest challenge for online apps is the market penetration—how much of the public uses a particular app and allows it to produce alerts. Even so, efforts can be made to encourage app use. An agency can partner with one or more app providers and also communicate with the public about the app's existence.

Web-based resources also continue to evolve as powerful vehicles for information delivery. With the growing amount of data available and software tools for constructing online resources, new methods for visualizing and overlaying information are emerging. Travis County is currently developing an open-data portal and an interactive map that will display several data types useful for evacuation planning, including flood hazards, wildfire, ESD and Sheriff service areas, roads, tax appraisal parcels, municipal boundaries and natural resources.

Among all of these means of dissemination, care must be exercised to not induce "information fatigue"—an overloading of information. Fatigue can be caused by:

- A lack of discretion on determining what is truly worthwhile to communicate versus what may be irrelevant to a significant number of people;
- Information being received by people who are not near the affected geographic area;
- Lack of regulation on the amount of information or frequency of communications; and
- Incorrectness, incompleteness, or misunderstanding.

3.4. Data Sharing and Collaboration

During the stakeholder meetings, discussions revolved around a series key themes, including:

- Improving communication;
- Increasing the number of data sources;
- Improving coordinated pre-planning and preparedness;
- Improving data sharing and availability;
- Cross-platform, real-time reporting and display of info; and
- Online statewide volunteer sign-up

While these themes are general, they point to concepts that motivate ongoing work around the use of data in planning, modeling, and decision-making.

3.5. RtePM Usage

The RtePM web application identified in Section 2.1.5 carries with it several caveats for proper usage. First, it is important to consider which information needs to be collected as inputs to the RtePM model. This includes:

- Zones, such as those described in Section 3.1. While not required, these are instrumental in facilitating the setting of variables as described in many of the bullet points below; therefore, they most likely need to be carefully defined;
- Expected population increase per zone (controlled via percent input). This appears to be the only means offered for adapting a model for future population growth;
- Estimated population participation within each zone (controlled via percent input). This depends upon the nature of each given population group within each zone, and may require input from representatives from each community or surveying;
- Average amount of people per vehicle per zone. Again, this is dependent upon demographics; in 2010, the average number of people in a Travis County household was 2.62;
- Number of vehicles evacuating with another vehicle in tow per zone (controlled via percent input). This may vary from zone to zone, as well;
- Pedestrian and public transit evacuation mode options available (controlled via percent input);
- Evacuation destination endpoints, which can be shelters, outdoor mustering points, or individual points that represent all evacuation movement in a general direction outside of the evacuation region; and,
- Other custom model network configurations such as contraflow lanes.

Meanwhile, consideration for the following is advised:

- Public Scenarios are available from all across the United States that serve as examples and experiments. **The Public Scenarios list takes about 30 seconds to populate.**
- As mentioned, the means in RtePM for representing population increase is through an across-the-board percentage increase *per zone*. While zoning efforts in all literature searches were found to involve a collaborative effort with local officials, this RtePM mechanism must also be considered when defining the zones.
- There is no apparent means to model a population decrease within a zone.
- Network alterations, such as contraflow, as somewhat tedious to implement as you cannot select large stretches of road, but must inch along in multi-selection. Shapes for zones can be imported and used, or roughly drawn on screen if necessary.

3.6. Other Highlights

These are key insights that had been explained in other sections of this report:

- TxWRAP is used in the CWPP and identifies community boundaries and provide other valuable information to allow agencies to work together to improve emergency response overall.
- The most at-risk flood areas in Travis County have been identified and assigned evacuation routes, found in Annex E.
- DriveTexas^{TM}, is available for evacuees to show evacuation route information and highway conditions in Texas.
- Lessons learned from previous outages suggest tailoring the emergency plan to operate with and without power. Likewise, care should be taken to account for the possibility of cell phone infrastructure to be unavailable.

Chapter 4. Data Inventory

During the course of the project, a number of data sources were identified and added to the Data Catalog (see Chapter 5) and categorized according to topic, format, and location. While it can be reasoned that many datasets in one way or another has the potential of providing information that helps with evacuation planning, a number of key datasets are listed here that are considered to be potentially relevant to Travis County.

This is a work in progress, and may be expanded or adjusted as needed, especially as more personnel become familiar with data, new data sources emerge, and stakeholders confer. Suggested additions that are pending include datasets from communities and agencies surrounding Austin, Capital Metropolitan Transportation Authority (CapMetro), and Capital Area Rural Transportation System (CARTS).

4.1. Datasets

1) TXDOT C.R.I.S.
https://cris.dot.state.tx.us/public/Purchase/
This provides historic crash data, which can be informative for evacuation planning.

2) NOAA: SWDI
https://www.ncdc.noaa.gov/swdi/#TileSearch
Provides historic severe weather events for a selected location.

3) Austin Fire Stations
https://data.austintexas.gov/Public-Safety/Austin-Fire-Stations/64cq-wf5u
Identifies locations of fire stations.

4) AFD Response Area Polygons Zip – 2015
https://data.austintexas.gov/Locations-and-Maps/AFD-Response-Area-Polygons-Zip-2015/y95t-brjh
This is a standard set of polygons that delimit AFD response regions.

5) COA: Creek Lines
https://data.austintexas.gov/Locations-and-Maps/Creek-Lines/hqpf-kr96
This identifies all of the creek lines within the Travis County area, which can be useful for vulnerability assessment.

6) Hydrography Polygons 2006
https://data.austintexas.gov/Locations-and-Maps/Hydrography-Polygons-2006/99y8-6pgc
This identifies areas of bodies of water in the Travis County area.

7) COA: Watersheds
https://data.austintexas.gov/Environment/Watersheds/ec78-i9z5
This provides a list of watersheds and identifies which bodies of water are discharged into.

8) Travis County Maps
https://www.traviscountytx.gov/maps
Includes maps of flood plains for some flood prone areas, fire investigations and more.

9) Travis County Fire Investigations
https://www.traviscountytx.gov/maps/gis-fire-investigations
Shows locations of fires by month in Travis county, gives type of fire (structure, vehicle, etc), address, date and incident number.

10) Building Footprints
https://data.austintexas.gov/Locations-and-Maps/Building-Footprints-2013/d9te-zi9f
This geographically depicts all of the structures within the Travis County area, which can be useful for understanding building density.

11) COA: Traffic Count Study
https://data.austintexas.gov/Transportation-and-Mobility/Traffic-Count-Study-Area/cqdh-farx
This provides historic traffic counts for sampled roadway spot locations and can be informative for understanding roadway usage patterns and background traffic.

12) USDOT: BTS: Geography Resources
https://www.bts.gov/explore-topics-and-geography/geography/national
A collection of books and articles describing a broad variety of transportation statistics.

4.2. Organizations

This section inventories several data-providing organizations and conglomerated data.

1) National Weather Service: National Oceanic and Atmospheric Administration
http://www.weather.gov/
Informs and keeps track of weather conditions and warnings. Provides historic data.

2) Data.gov: Data Mart COA
https://catalog.data.gov/dataset?organization=city-of-austin&tags=transit
Data hosted by Data.gov containing material related to the City of the Austin, particularly aimed at Transit.

3) USDOT: BTS Open Data Portal
http://osav-usdot.opendata.arcgis.com/
A portal for various transportation data, not limited to just roads but rail, aviation and marine.

4) CAPCOG Data, Maps, and Reports
http://www.capcog.org/data-maps-and-reports/gis-data-services/

4.3. Apps and Tools

1) TX A&M Forest Service: TXWRAP
https://www.texaswildfirerisk.com/
Allows wildfire risk data to be obtained for an area, which can then be used to inform the public. This may be of interest for preventative measures.

2) TxDOT: DriveTexas.org
https://drivetexas.org
This site informs citizens of highway conditions, which may be of interest for long-distance evacuation planning.

3) ATXfloods
https://www.atxfloods.com/
Provides data for low water crossings and floodplains. Evacuations performed around such locations should be checked for flooding vulnerability. This is soon to be renamed to CTXfloods to better reflect the region the resource pertains to.

4) RtePM
http://rtepm.vmasc.odu.edu/
A graphical web application for planning evacuations and predicting the total evacuation time for a given zone.

5) Google: Waze
https://www.waze.com/livemap
An app for roadway information and travel planning that utilizes crowd-sourced information. It is worthwhile to determine whether partnerships with this app can lead to dissemination opportunities.

6) NOAA: Weather and Hazards Data Viewer
http://www.wrh.noaa.gov/map/?&zoom=8&scroll_zoom=true&center=27.829360859789794,-99.2449951171875&basemap=OpenStreetMap&boundaries=true,false,false&obs=true&obs_type=weather&elements=temp,wind,gust&obs_popup=true&obs_density=1
Offers a geographic view of current weather and reported hazards.

7) Wolfram Alpha
https://www.wolframalpha.com/
Provides a query interface for gathering information and performing calculations and provides a means to quickly retrieve basic statistics for any region.

8) COA: GIS Department
http://www.austintexas.gov/department/gis-and-maps
General resources for mapping and georeferencing.

9) COA: Open Data Portal
https://data.austintexas.gov/
City of Austin's open data portal contains a variety of resources that may be useful for evacuation planning, including infrastructure data and demographics.

10) State of Texas Open Data Portal
https://data.texas.gov/

11) TxDOT Statewide Planning Map
http://www.dot.state.tx.us/apps/statewide_mapping/StatewidePlanningMap.html

12) TxDOT Project Tracker
https://www.txdot.gov/inside-txdot/projects/project-tracker.html

13) TxDOT Roadway Inventory
https://www.txdot.gov/inside-txdot/division/transportation-planning/roadway-inventory.html
Roadway inventory, published by TxDOT, in a variety of common GIS and tabular formats. Data is obtained through a downloadable file for each year, and the report for each year is given in PDF format.

Chapter 5. Data Catalog

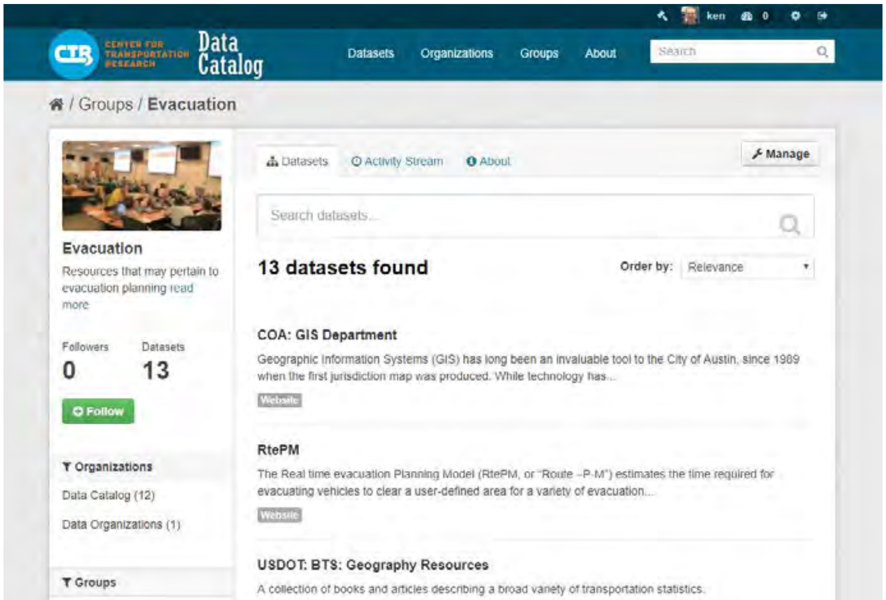

Figure 1: Screenshot of the preliminary Data Catalog

5.1. Introduction

A deliverable of this project is a data catalog that identifies relevant data sources. In designing a catalog, the following tenets were observed:

- We are not trying to host or clean others' data; we are instead *curating* data.
- We want a sustainable solution for keeping the data catalog populated and current.
- For the catalog to be useful, it needs to be online, searchable, and filterable.

This led to the exploration of open-source data repository server software packages that are available today, because the prospect of designing a custom catalog from scratch was not feasible given the project schedule, and arguably not in the best interest for maintainability. Several solutions exist, including the highest ranking ones, Dataverse and OpenGov CKAN. CKAN was chosen as the software package to use because of its versatility, database back-end, and ease of setup. It is developed by an open source consortium and actively used by many government agencies throughout the world. It is scalable and can handle tens of thousands of dataset entries. This project's copy is currently hosted on a CTR virtual machine (VM) server that resides at the UT Austin Data Center, but can be moved to another VM solution hosted by another organization if needed.

5.2. Using the Catalog

The catalog can be accessed online at http://catalog.utnmc.org. Once inside the catalog, select "Datasets" to view and filter among all of the cataloged datasets. Alternatively, go to "Organizations" and select one of the choices. The organizations facilitate the inclusion of both datasets and data-providing organizations without confusing them together. The organizations currently in use include:

- **Datasets:** Lists specific, granular datasets and provides information on accessing the data, as well as providing hyperlinks to documentation or API access; and
- **Organizations:** Lists data-providing organizations that may offer multiple datasets.
- **Apps and Tools:** Lists online or offline resources (such as applications and web-based tools) that allow sophisticated access and manipulation of datasets.

On the left side of the view there are a variety of filters that can be switched on and off for fast searching. These filters come from groups, tags, and formats that are already associated with entries within the Data Catalog. Further, there is a text search capability that finds datasets whose descriptions match the given search criteria.

One feature that is planned to be added but isn't available yet is geographic filtering mechanism. This will be facilitated by a CKAN plug-in that allows searches to be restricted to all datasets that intersect a bounding box drawn on a map.

The following subsections explain the different entries that currently appear in the filter list.

5.2.1. Groups

Groups allow datasets to be categorized according to overall purpose. Each dataset may be a member of zero, one, or multiple groups. The current groups that are defined include:

- **Evacuation:** Datasets that address mostly evacuation planning or modeling
- **Wildfires:** Datasets that apply mostly to wildfires. Some of these may be useful for evacuation planning purposes even though they might not share the same group.

- **Extreme Weather:** Datasets that apply to extreme weather events, including flooding and freezing. Some of these may peripherally relate to evacuation planning.
- **Transportation:** Datasets that pertain primarily to roads, traffic, or other transportation information.
- **Other:** To facilitate clearer filtering, datasets that are not a member of any other group are a member of this "Other" category.

One challenge in creating groups is that the distinction in level of applicability can be arbitrary. The group assignment scheme is something that can be altered in the future.

5.2.2. Tags

Tags are arbitrary keywords that are applied to each dataset, and appear in the filter list to offer quick searching capabilities. This is an area that may be expanded in the future to further categorize datasets according to content, as well as geographic scope. Currently, the tags describe the layout of the data:

- **Text:** Data in the form of paragraphs and/or documents
- **Tabular:** Data (numeric or text) that are stored in spreadsheet format
- **Infographic:** Data presented through picture form
- **Geospatial:** Data that are registered to a map of a region

5.2.3. Formats

Each dataset may offer one or more *resources* that can be classified according to the presentation format. These may include the following:

- **Webpage:** A static or interactive online resource accessible through the Web
- **HTML:** A supporting document that is available on the Web
- **API:** A means of programmatically accessing a dataset's data that may be of interest for data mining or large-scale data analysis efforts
- **PDF:** A document in Acrobat format

5.2.4. Licenses

This describes the availability of the data, including:

- **Other (Open):** Data provided as open-source and/or public domain; and
- **Other (Not Open):** Data that requires a fee or departmental approval for access.

These may be expanded in the future to further differentiate between free datasets that require a process to obtain exclusive access, and datasets that require a fee.

5.3. Updating

When there are any new datasets that can be added, or corrections are needed, one or both of these approaches can be facilitated:

1. Project team members with administrative access can be notified through e-mail, and manually make the necessary changes, or
2. A representative for Travis County can be given an administrative account so he/she can make the changes.

As identified in the next section, the solution might not be to make changes directly in the CKAN software; instead, the scheme may best involve the maintenance of a flat table that is used to automatically update the Data Catalog contents.

5.4. Future Work

Another beneficiary of the Data Catalog is TxDOT, for the 5-9053-01 project: Enhancing Road Weather Management during Wildfires and Flash Floods through New Data Collection, Sharing, and Public Dissemination Technologies. Efforts in creating the data catalog are shared because many common goals exist between the projects. Because the initial Data Catalog isn't due to the TxDOT project until the end of January, 2018, it is expected that improvements will be made to the preliminary catalog delivered by this project. Even after January it is expected that more data sources and revisions will be placed into the Data Catalog, whether it be through the TxDOT project, or feedback for this project.

Along the way, the Data Catalog processes for maintainability will be developed further. While the current Data Catalog involved "one-off" populating efforts, a more sustainable approach is needed for the Data Catalog to be maintained in the future. An idea that is currently under development involves keeping a flat table scheme (analogous to how information is arranged in a simple spreadsheet) that holds metadata which fully captures the Data Catalog contents. There can then be an automatic process to periodically populate and update the data repository server software (e.g. CKAN). This flat table scheme allows for better edit-ability, fewer inconsistencies, and also opens the door for other types of applications or reports to be produced from the same metadata.

Another process that had briefly been investigated, and will continue to be looked at is the idea of automatically crawling through each online data resource and performing the following checks:

- Whether the data resource is online at the given URL; and,
- When the last-updated date is.

If a problem is discovered, then the Data Catalog maintainer can be notified so that it can be investigated, and the metadata can be updated.

In sum, the Data Catalog is a work in progress. As always, comments are welcome on how the Data Catalog can be made to be more useful, whether it be by providing improved metadata, reorganizing the hierarchy, or including new data sources. Comments may be sent to Kenneth Perrine at kperrine@utexas.edu.

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TECHNICAL REPORT

TRAVIS COUNTY FIRE EVACUATION SIMULATION

May 2019

Prepared by:
Alliance Transportation Group, Inc.
11500 Metric Blvd, Bldg M-1, Ste 150
Austin, TX 78758
Office 512.821.2081
T.B.P.E. Firm Registration No. 812

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INTRODUCTION

The purpose of this technical report is to present the results of the analysis of the four Fire Evacuation Scenarios as presented in **Figure 1**. For this analysis, Alliance used the Real Time Evacuation Planning Model (RtePM) to estimate the minimum time that would be required to completely evacuate the defined impact area for each scenario. In this report, we describe the application of the model and the associated results.

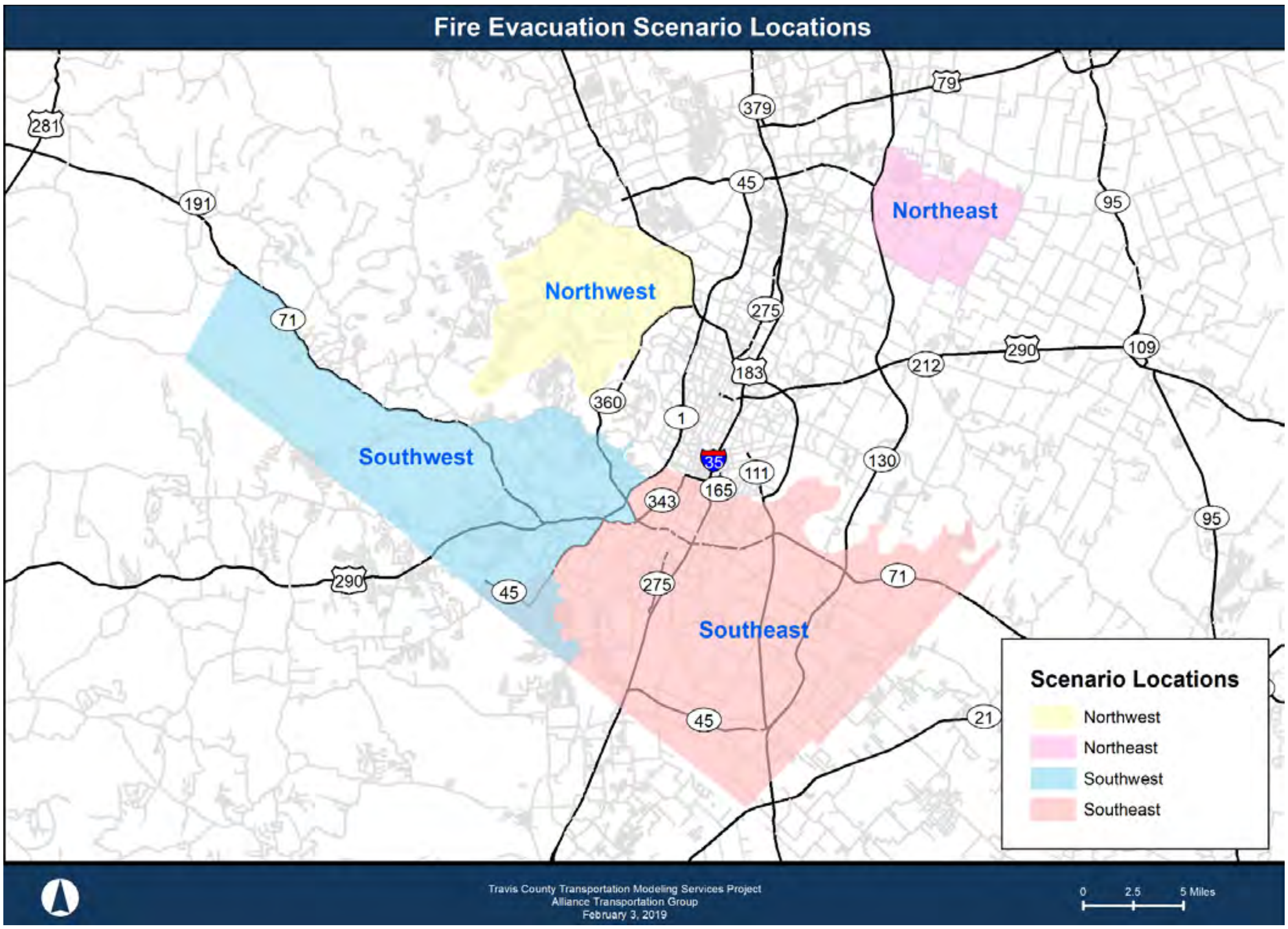


Figure 1. Fire Evacuation Scenario Locations

ABOUT THE REAL TIME EVACUATION PLANNING MODEL (RTEPM)

The RtePM was initially developed by the Johns Hopkins University Applied Physics Laboratory through a grant from the US Department of Homeland Security, Science and Technology Infrastructure Protection and Disaster Management Division. The Virginia Modeling, Analysis, and Simulation Center (VMASC) at Old Dominion University further developed and enhanced the RtePM, with funding and support from the Virginia Department of Emergency Management (VDEM).

According to the RtePM User Guide [1], "the RtePM was developed in response to the emergency management community's desire to have an easy-to-use tool that quickly estimates the time required to evacuate an area in the event of natural or man-made disasters such as hurricanes, wildfires, and terrorist incidents (e.g. a "dirty bomb"). The main purpose is to enable emergency managers to gain insight from testing various evacuation scenarios, thus facilitating informed decision making and improved information sharing between federal, state, local, and tribal first responders at all levels of government."

The model is useful for emergency management evacuation pre-planning. Transportation planners also find the model useful for identifying potential problems in the road network during an evacuation scenario. The potential road network problems can then be analyzed further and addressed appropriately.

The RtePM model is an internet-based model available at no cost to the user. It includes pre-loaded population data based on the U.S. Census and a default major road network. Population and road network data can be adjusted within certain parameters. For more information see the RtePM Capabilities and Limitations section.

ASSUMPTIONS AND PARAMETERS

Evacuation scenarios are non-typical transportation events. Several evacuation specific assumptions and parameters must be used in order to realistically model evacuation scenarios. Based on the RtePM User Guide [1], the number and speed of evacuating vehicles are determined by user-assigned or modified variables, such as the time of day when an evacuation starts, evacuation rate, the population's participation rate, and the number of people per vehicle, using parameters provided within the model. The parameter assumptions can be changed to test different scenarios, giving the user a range of results.

A list of the simulation parameters and assumptions used for each fire evacuation scenario is presented in **Table 1.**

Table 1: List of Evacuation Scenario Assumptions and Parameters

Item	Parameter	Value
Number people per vehicle	The average number of people in each vehicle during the evacuation.	1[1]
Percentage of vehicle towing	The percentage of vehicles towing boats, trailers, etc.	0%
Percentage of population evacuating	The percentage of people who will be leaving the evacuation zone.	96%
Percentage of evacuees to shelters	The percentage of people who will evacuate to shelters.	0%
Percentage use private vehicles	The percentage of people who will leave the evacuation zone using private transportation.	100%
Percentage using public transit	The percentage of people who will leave the evacuation zone using public transportation.	0%
Percentage of pedestrians	The percentage of people who will leave the evacuation zone on foot.	0%

[1] In an actual evacuation, students and other people in the impact area who are unable to drive would be in vehicles with drivers. As a result, the average occupancy would have to be higher than 1.0. To represent the worst-case scenario, the number of evacuees per vehicle was set at 1.0.

NORTHWEST EVACUATION SCENARIO

The purpose of this chapter is to present the results of the analysis of the Northwest Fire Evacuation Scenario. For this analysis, Alliance used the RtePM Evacuation Model to estimate the minimum time that would be required to completely evacuate the area defined as the impact area for the Northwest Fire Evacuation Scenario.

The Northwest fire evacuation boundary is illustrated in **Figure 2**, which also identifies the associated four zones. **Figure 3** shows the evacuation road network and roadway exit points that were considered during the evacuation.

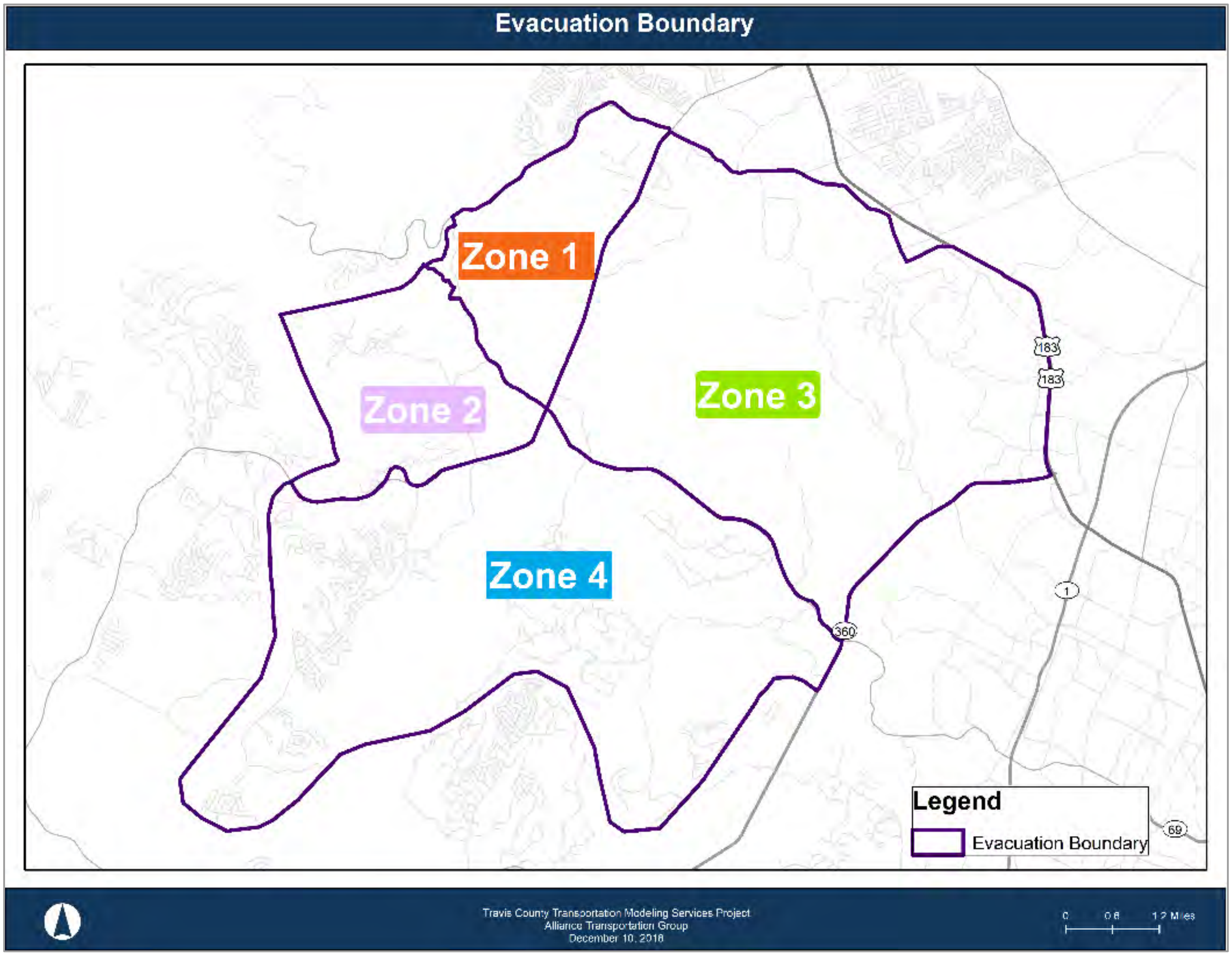


Figure 2: Geographic Boundary of Northwest Fire Scenario

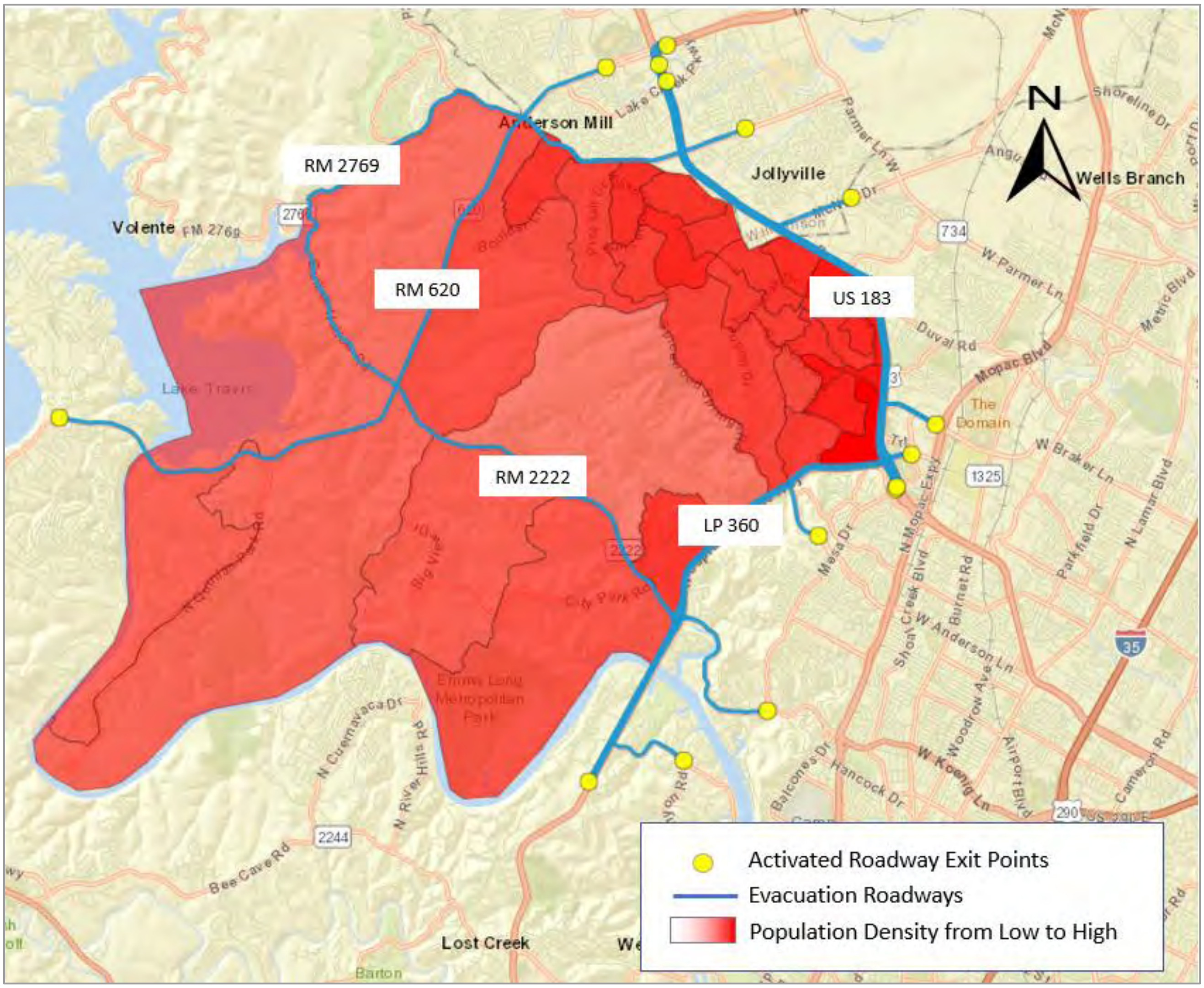


Figure 3: Road Network and Exit Points of Northwest Fire Scenario

SCENARIO DEFINITION

Using the above-mentioned parameters and assumptions in Table 1, the "Baseline scenario" presented in **Table 2** was tested. No phasing of the four evacuation zones was assumed, as recommended by the Travis County staff. Three additional alternative scenarios were tested, each with a three- phased evacuation option, and they are also described in **Table 2**.

Table 2: Definition of Northwest Simulation Scenarios

Scenario	Description of Scenario
Baseline Scenario (Non-Phased)	In addition to the parameter assumptions identified in **Table 1**, all four zones were considered to participate in the evacuation at the same time from the beginning of the fire. Consistent with the stakeholders meeting discussion, the fire is assumed to start during the afternoon peak period at 3:00 PM in the last week of August - considered to be a critical time for fire events.
Alternative Scenario 1 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the four zones is assumed to be planned and staggered by two hours for each. Zones 1 and 2 are assumed to start the evacuation at 3:00 PM, Zone 3 at 5:00 PM, and Zone 4 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 2 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the four zones is assumed to be planned and staggered by two hours for each. Zone 3 is assumed to start the evacuation at 3:00 PM, Zone 4 at 5:00 PM, and Zones 1 and 2 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 3 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the four zones is assumed to be planned and staggered by two hours for each. Zone 4 is assumed to start the evacuation at 3:00 PM, Zone 3 at 5:00 PM, and Zones 1 and 2 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.

DEMOGRAPHIC DATA

Travis County provided the 2017 average day-time population, which does not include the school students. Alliance identified the following elementary, middle, and high schools and their enrollments. They are presented in **Table 3**.

The student enrollment information was derived from public information available at the Texas Education Agency and the National Center for Education Statistics. The student enrollment for 2017 was combined with the 2017 day-time population to form a 2017 target day-time population for the evacuation scenario. **Table 4** shows, by zone, the 96 percent of the target population for the Northwest evacuation scenario expected to participate during the evacuation.

Table 3: School Enrollment Statistics

SL	Campus Name	Zone	2017-18 Enrollment
1	Canyon Creek Elementary School	3	417
2	Canyon Ridge Middle School	4	1,284
3	Canyon Vista Middle School	3	1,398
4	Four Points Middle School	3	741
5	Kathy Caraway Elementary	3	739
6	Laura Welch Bush Elementary School	4	835
7	Laurel Mountain Elementary School	3	800
8	Primrose School of Four Points	4	45
9	River Place Elementary School	4	768
10	River Ridge Elementary School	4	784
11	Spicewood Elementary	3	808
12	Steiner Ranch Elementary	4	632
13	Vandergrift High School	3	2,257
Total			11,508

Table 4: Target Day-Time Population of Northwest Scenarios

	Total			Target (96 Percent)		
Zone	Day- Time Population Excluding School Students	School Students	Total Day-Time Population	Day- Time Population Excluding School Students	School Students	Total Day-Time Population
1+2	3,372	-	3,372	3,237	-	3,237
3	48,171	7,160	55,331	46,244	6,874	53,118
4	22,155	4,348	26,503	21,269	4,174	25,443
Total	73,698	11,508	85,206	70,750	11,048	81,798

Results and Discussions

Minimum Evacuation Times

Evacuation summary results produced by the RtePM model scenario runs for the Baseline scenario and Alternative scenarios are provided in **Tables 5 and 6** and **Figure 4**. **Table 5** shows the evacuation times for the Baseline and Alternative evacuation scenarios. **Table 6** details by hour the total number of vehicles and population evacuated, remaining vehicles and population, and percent evacuated for each scenario. **Figure 4** shows the same information graphically. The tables and figure show how the 81,798 people or equivalent vehicles would be evacuated across different hours and scenarios.

The results include total duration of the evacuation for the Baseline scenario of 3.4 hours. The Alternative evacuation scenarios were also evaluated. It required approximately 7.1, 6.1, and 6.1 hours for Alternative scenarios 1, 2, and 3 respectively.

Table 5: Evacuation Clearance Time of Northwest Scenarios

Scenario	Evacuation Clearance Time (Hours)
Baseline	3.4
Alternative 1	7.1
Alternative 2	6.1
Alternative 3	6.1

Simulation results indicate that the Baseline evacuation scenario would take a minimum of roughly 3.4 hours to evacuate the evacuation boundary. In contrast, all the Alternative scenarios take almost double the time of the Baseline scenario.

In the Baseline scenario, all four zones were assumed to participate in the evacuation at the same time from the beginning of the fire. This underlying assumption for the Baseline scenario may lead to higher evacuation rates as demonstrated in **Figure 4**. This figure provides useful information about how each evacuation scenario loads evacuating vehicles onto the road network, which may help the County to make a reasonable decision on choosing the suitable scenario.

Figure 4 shows that at the end of the first hour of the Baseline evacuation, more than 39 percent of the population could potentially be evacuated. Similarly, at the end of the second and third hour of the Baseline evacuation, more than 76 and 96 percent of the population could potentially be evacuated. Results for the three phased scenarios, Alternatives 1, 2 and 3 are also provided for comparison. The results for the Alternative scenarios provide information that could be useful when there is significant background traffic and phasing may be necessary to prevent overloading the evacuation routes.

The Alternative 1 scenario shows that after the second hour of the evacuation only 4.4 percent of the evacuees would be cleared and that would probably mean valuable time is being lost at a time when the evacuation routes would be least congested. Alternatives 2 and 3 would take the same amount of time to evacuate, but the initial evacuation rate is higher for Alternative 2 than for Alternative 3. This is likely to lead to an evacuation that is smoother and more evenly distributed. Noticeably, at the second hour of the evacuation, in the Alternative 2 scenario, approximately 59 percent of the evacuees could be evacuated, compared to approximately 19 percent for Alternative 3. Based on the evacuation time, evacuation rate, and phasing choice, the Alternative 2 scenario appears to perform better in comparison to the Alternative 1 and 3 scenarios.

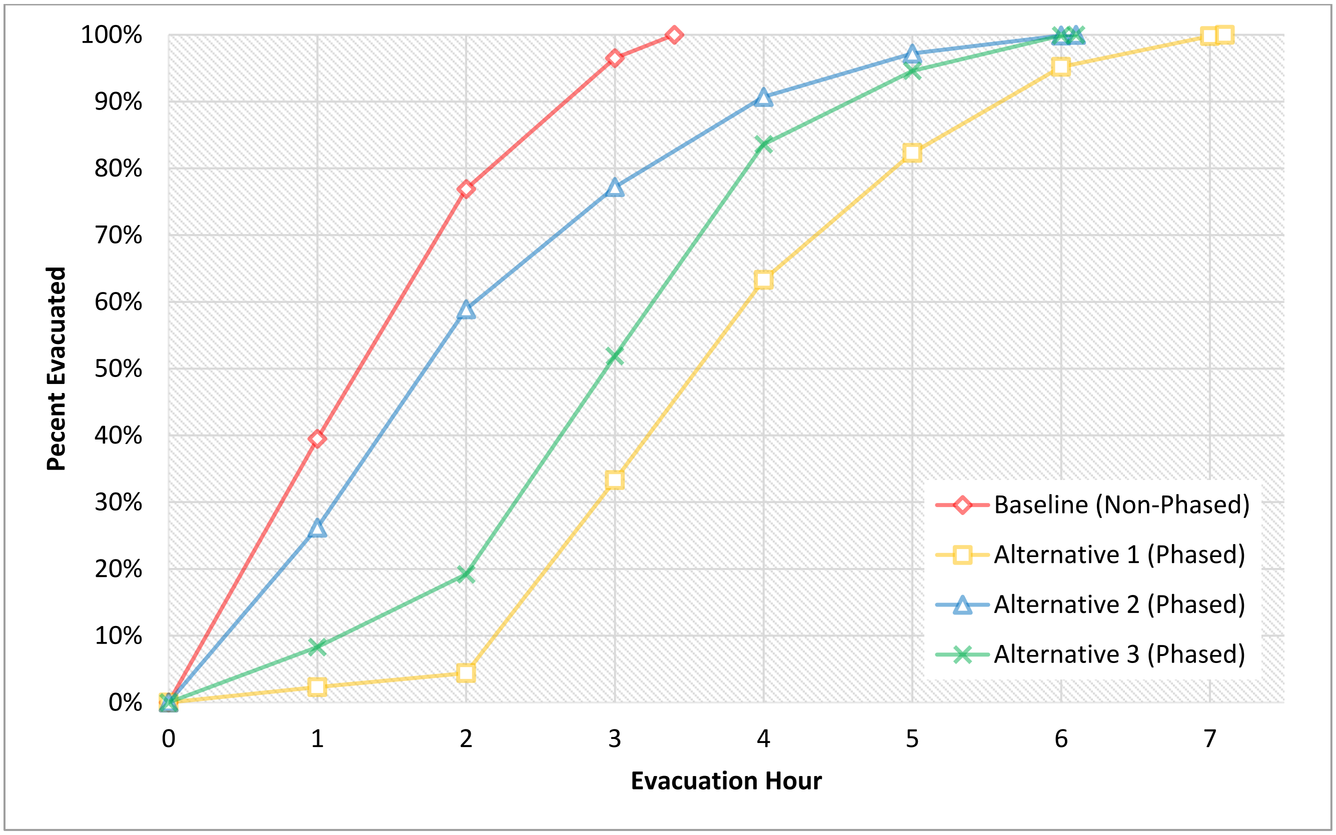


Figure 4: Evacuation Rate of Northwest Fire Scenario

Table 6: Summary Results for Northeast Fire Evacuation Scenarios for the Target Populations

	Hours/Items	Start	1	2	3	3.4				
Baseline	Total Population Evacuated	0	32,290	62,897	78,907	81,798				
	Total Vehicles Evacuated	0	32,290	62,897	78,907	81,798				
	Remaining Population	81,798	49,508	18,901	2,891	0				
	Remaining Vehicles	81,798	49,508	18,901	2,891	0				
	Percent Evacuated	0	39.5	76.9	96.5	100				
	Hours/Items	Start	1	2	3	4	5	6	7	7.1
Alternative 1	Total Population Evacuated	0	1,841	3,611	27,219	51,740	67,291	77,882	81,668	81,798
	Total Vehicles Evacuated	0	1,841	3,611	27,219	51,740	67,291	77,882	81,668	81,798
	Remaining Population	81,798	79,957	78,187	54,579	30,058	14,507	3,916	130	0
	Remaining Vehicles	81,798	79,957	78,187	54,579	30,058	14,507	3,916	130	0
	Percent Evacuated	0.0	2.3	4.4	32.8	65.3	83.2	95.5	99.9	100.0
	Hours/Items	Start	1	2	3	4	5	6	6.1	
Alternative 2	Total Population Evacuated	0	21,439	48,176	63,185	74,229	79,479	81,750	81,798	
	Total Vehicles Evacuated	0	21,439	48,176	63,185	74,229	79,479	81,750	81,798	
	Remaining Population	81,798	60,359	33,622	18,613	7,569	2,319	48	0	
	Remaining Vehicles	81,798	60,359	33,622	18,613	7,569	2,319	48	0	
	Percent Evacuated	0.0	26.2	58.9	77.3	90.7	97.2	99.9	100.0	
	Hours/Items	Start	1	2	3	4	5	6	6.1	
Alternative 3	Total Population Evacuated	0	6,809	15,683	42,451	68,372	77,351	81,750	81,798	
	Total Vehicles Evacuated	0	6,809	15,683	42,451	68,372	77,351	81,750	81,798	
	Remaining Population	81,798	74,989	66,115	39,347	13,426	4,447	48	0	
	Remaining Vehicles	81,798	74,989	66,115	39,347	13,426	4,447	48	0	
	Percent Evacuated	0.0	8.3	19.2	51.9	83.6	94.6	99.9	100.0	

Exit Points

As evacuees reach an exit point, the size of the yellow circle indicators expands (e.g., Appendix B2) relative to the number of evacuees reaching or passing through that destination. Evacuation exit point percent usage during the evacuation are illustrated in **Figure 5**. Alternative-scenario results are included to compare the percent evacuation at each exit point. Results indicated that the exit-point utilization followed a similar pattern across all scenarios. Among the fifteen evacuation exit points, the highest-demand exit point, which is US 183 at Loop 1, is used by more than 17 percent of the evacuees. RM 620 North, RM 620 South and West Braker Lane are also heavily used with each getting 10 percent or more of the evacuation traffic.

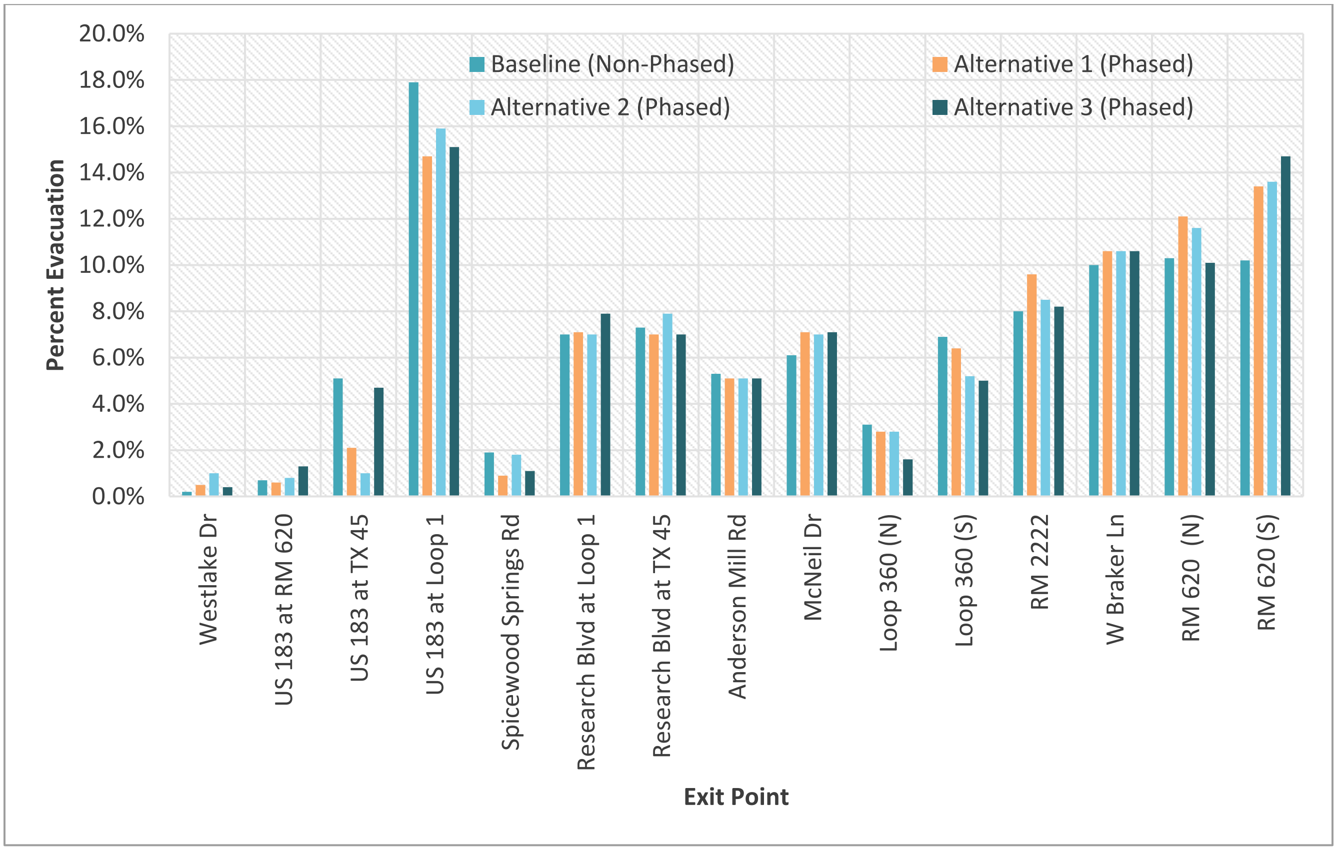


Figure 5: Exit Point Usage for the Northwest Scenarios Evacuation

Population Block Groups

Table 7 portrays how each zone and block group clear in terms of cumulative percentage cleared by hour. The appendix to this memorandum contains a visual representation of the information. Exhibits A1 through A5 show how the evacuation is progressing at the end of each hour during the evacuation. In the exhibits, the population block groups appear in varying shades of black color corresponding to the density of population to be evacuated. As the evacuation progresses, the population block group becomes lighter until all evacuees have cleared the area, indicated by a white color. Results show that every census block group participated from the beginning of the evacuation. Results show that at the end of the first hour of the Baseline scenario, none of the census block group evacuated completely. At the end of second hour, there are four census block groups that completed evacuation. By the end of the third hour, most of the census block groups had successfully cleared all evacuees, and all census block groups completed evacuation in 3.4 hours. To compare the results of the Baseline scenario, based on the manual procedure of results extraction from the software, only Alternative 2 scenario results are included in **Table 7.**

Table 7: Cumulative Percent Evacuated by Zone and by Hour of Northwest Scenarios

Zone	Block Group ID	Cumulative Percent Completion by Hour										
		Baseline (Non-Phase)				Alternative 2 (Phased)						
		1	2	3	3.4	1	2	3	4	5	6	6.1
3	484530017141	18	51	91	100	34	90	100				
3	484530017142	45	83	100		37	78	100				
3	484530017143	54	95	100		49	96	100				
3	484530017161	49	93	100		46	94	100				
3	484530017162	53	91	100		47	94	100				
3	484530017221	53	86	98	100	32	72	85	100			
3	484530017222	15	64	94	100	28	66	90	100			
3	484530017223	80	93	100		34	81	99	100			
3	484530017551	56	97	100		35	76	100				
3	484530017552	43	91	100		48	98	100				
3	484530017561	67	100			45	91	100				
3	484530017562	74	100			49	100	100				
3	484530017571	71	88	94	100	50	100	100				
3	484530017572	53	69	89	100	31	71	100				
4	484530017601	28	65	98	100			36	89	100		
4	484530017602	39	75	100	100			22	86	99	100	
4	484530017611	21	48	88	100			32	65	96	100	
4	484530017612	30	88	100	100			38	92	100		
1 & 2	484530017651	34	88	100						48	99	100

Zone	Block Group ID	Cumulative Percent Completion by Hour										
		Baseline (Non-Phase)				Alternative 2 (Phased)						
		1	2	3	3.4	1	2	3	4	5	6	6.1
3	484530017811	51	85	100		42	82	100				
3	484530017812	60	97	100		40	84	100				
3	484530017821	99	100	100		48	95	100				
3	484530017822	34	99	100		42	99	100				
3	484530017823	85	100	100		50	100	100				
3	484530025001	46	86	95	100	29	61	100				
3	484530025002	12	46	90	100	18	69	100				
3	484530025003	76	88	97	100	37	74	87	100			
3	484530025004	83	91	97	100	36	80	86	100			

Road Segments

The loading of the internal road network during the evacuation is illustrated in the Appendix in B1 through B5. In these exhibits, green road segments indicate that traffic is moving at normal free flow speeds, yellow road segments indicate that there has been a moderate slow-down, and red road segments indicate that there has been a severe slow down.

Results show that in the first hour of the Baseline scenario evacuation, some locations on RM 620, RM 2222, US 183, and Loop 360 experience moderate slow-down. In the second hour of the Baseline scenario evacuation, some locations on RM 620, RM 2222, US 183, and Loop 360 experience moderate to severe slow-down. In the third and fourth hours, traffic shows free-flow conditions.

In the Alternative 1 scenario, in the third hour of the evacuation, some locations on RM 620, US 183, Loop 360 experience moderate to severe slow-down. In the sixth hour, some locations on RM 620 and RM 2222 experience moderate to severe slow-down. All other hours show free-flow traffic conditions.

In the Alternative 2 scenario, in the first hour of the evacuation, some locations on RM 2222 and US 183 experience moderate to severe slow-down. In the third hour, some locations on RM 2222 experience moderate to severe slow-down. In the fourth hour, some locations on RM 620 and RM 2222 experience moderate to severe slow-down. r All other hours show free-flow traffic conditions.

In the Alternative 3 scenario, in the first hour of the evacuation, some locations on RM 2222 experience moderate to severe slow-down. In the second hour, some locations on RM 620 experience moderate to severe slow-down. In the fourth hour, some locations on RM 2222 and US 183 experience moderate to severe slow-down. All other hours show free-flow traffic conditions.

In the Baseline evacuation scenario, all four zones were assumed to participate in the evacuation at the same time from the beginning of the fire. Therefore, we can expect that congestion would be widespread along the major evacuation routes. Results indicated that congestion is widespread in the Baseline scenario evacuation, especially during the second hour. All four scenarios show moderate to severe slow-down congestions. However, there are more congested locations in the Baseline scenario than in all Alternative scenarios. Alternatives 1 and 3 experience less congestion in comparison to the Alternative 2 scenario.

TRAFFIC CHARACTERISTICS IN THE CAMPO TRAVEL DEMAND MODEL

Some traffic characteristics produced by the CAMPO Travel Demand Model [2] are included in order to address the RtePM model scenarios inability to adequately account for the effects of background traffic on evacuation time. Various PM peak-period (3:30 PM-6:30 PM) congestion measures from the 2015 CAMPO model that are on the major evacuation routes (RM 620, RM 2222, RM 2769, US 183, and Braker Ln.) can be used to estimate the effects of background traffic. These measures include traffic volumes, traffic patterns, and peaking characteristics. The 2015 CAMPO model PM peak-period traffic volumes are presented in **Figure 6**.

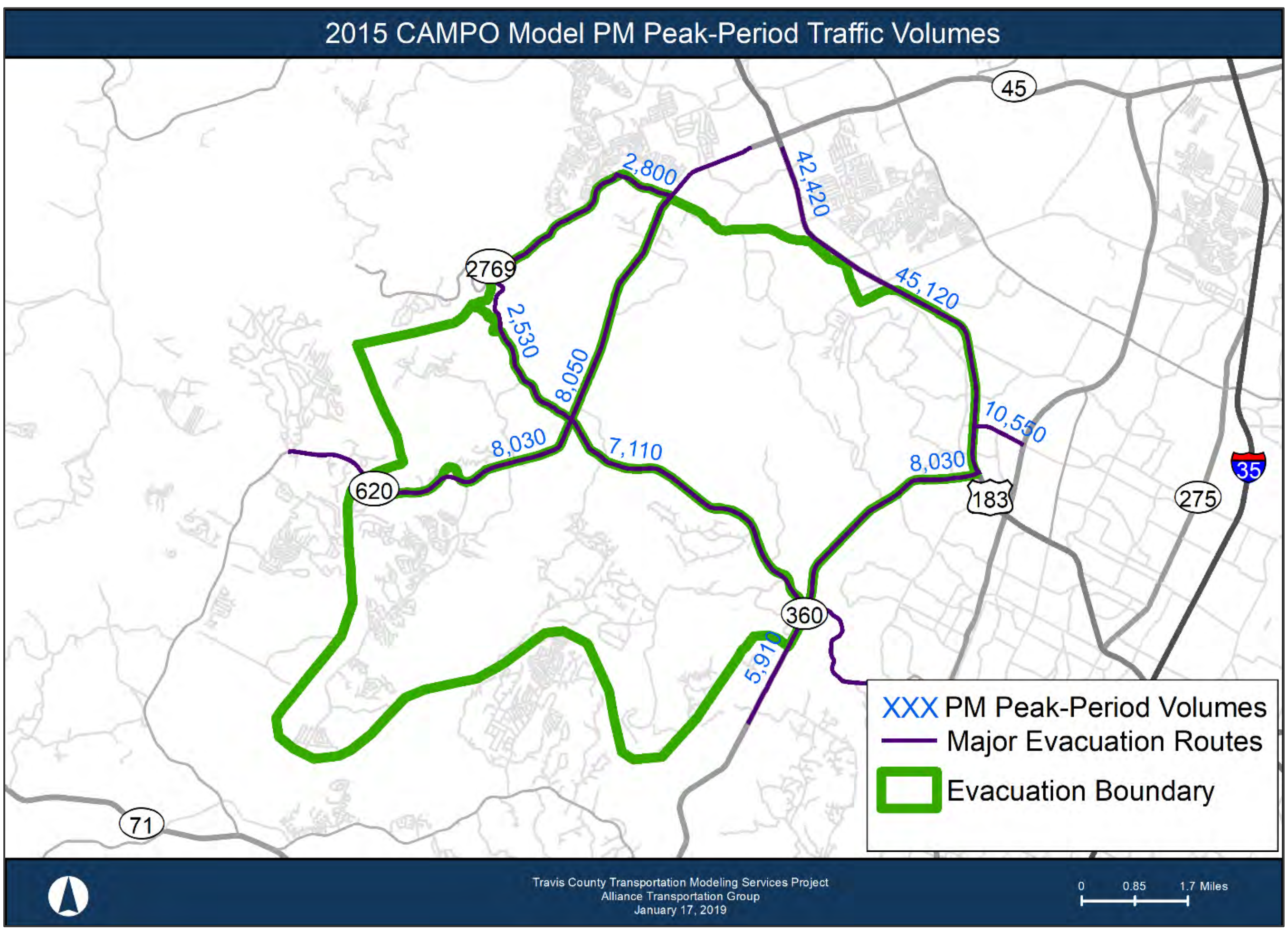


Figure 6: 2015 CAMPO Travel Demand Model PM Peak-Period Traffic Volumes within Northwest Boundary

The 2015 CAMPO Model PM peak-period directional volume-to-capacity (V/C) ratios are presented in **Figure 7**. The directional V/C ratios represent the traffic volumes divided by the road capacity for all lanes traveling in the same direction. In **Figure 7** the red and blue numbers are the V/C ratios for the side of the road that they are next to. A V/C ratio of 1.00 indicates that the road is operating at its capacity. In practice, any facility with a V/C ratio greater than 0.90 may be identified as a congested facility. The directional PM peak-period V/C ratios indicate that the major evacuation routes, (RM 620, RM 2222, and US 183) are heavily congested. For example, the V/C ratio is 0.90 or greater on portions of US 183, RM 620 and RM 2222, which indicates that the facilities would already be heavily congested with normal daily background traffic in the PM peak-period. However, the V/C ratios of Braker Ln and RM 2769 indicate that these facilities would not be congested and would be operating with normal daily background traffic in the PM peak-period.

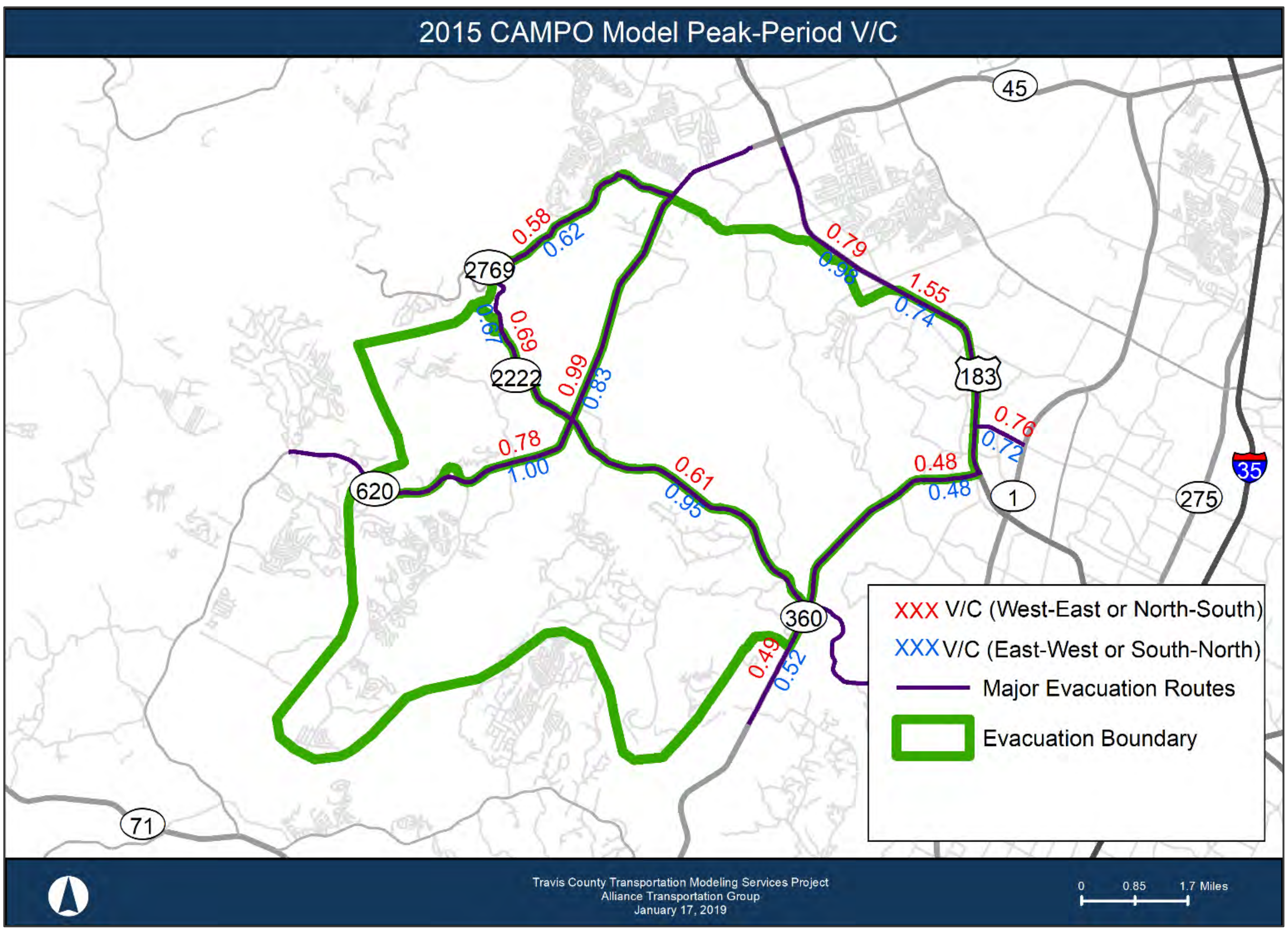


Figure 7: 2015 CAMPO Travel Demand Model Peak-Period V/C Ratio within Northwest Boundary

Furthermore, conceptual2 travel-time bands were created using the 2015 CAMPO model PM peak-period congested travel time. Three conceptual travel-times bands are presented in **Figure 8.** The farthest southern point of South Quinlan Park Road (close to the Colorado River) was chosen as an origin point for travel-time band calculations. This origin point was conceptually assumed to be a critical location for the study area. Each travel-time band shows the distance that can be traveled in the allotted time from the origin point. For example,

[2] *Conceptual travel-time bands do not account for natural barriers such as lakes and rivers.*

the 20-minute travel-time band show the maximum distance a traveler can go within 20 minutes from the origin point location. This figure also indicates that during the PM peak-period, the entire scenario area lies within the 25-minute travel-time band. The travel-time bands are calculated using the average peak-period background traffic without the evacuation traffic. For example, if the background traffic produces V/C ratios over 0.90, then the addition of the evacuation traffic is going to produce heavy congestion. The additional traffic and congestion will reduce the distance traveled within the time period and cause the travel-time bands to shrink considerably. A review of the CAMPO model results indicates that the evacuation routes would be heavily congested during the PM peak-period and the actual evacuation time in a weekday afternoon event could be significantly higher than the minimum time predicted by RtePM.

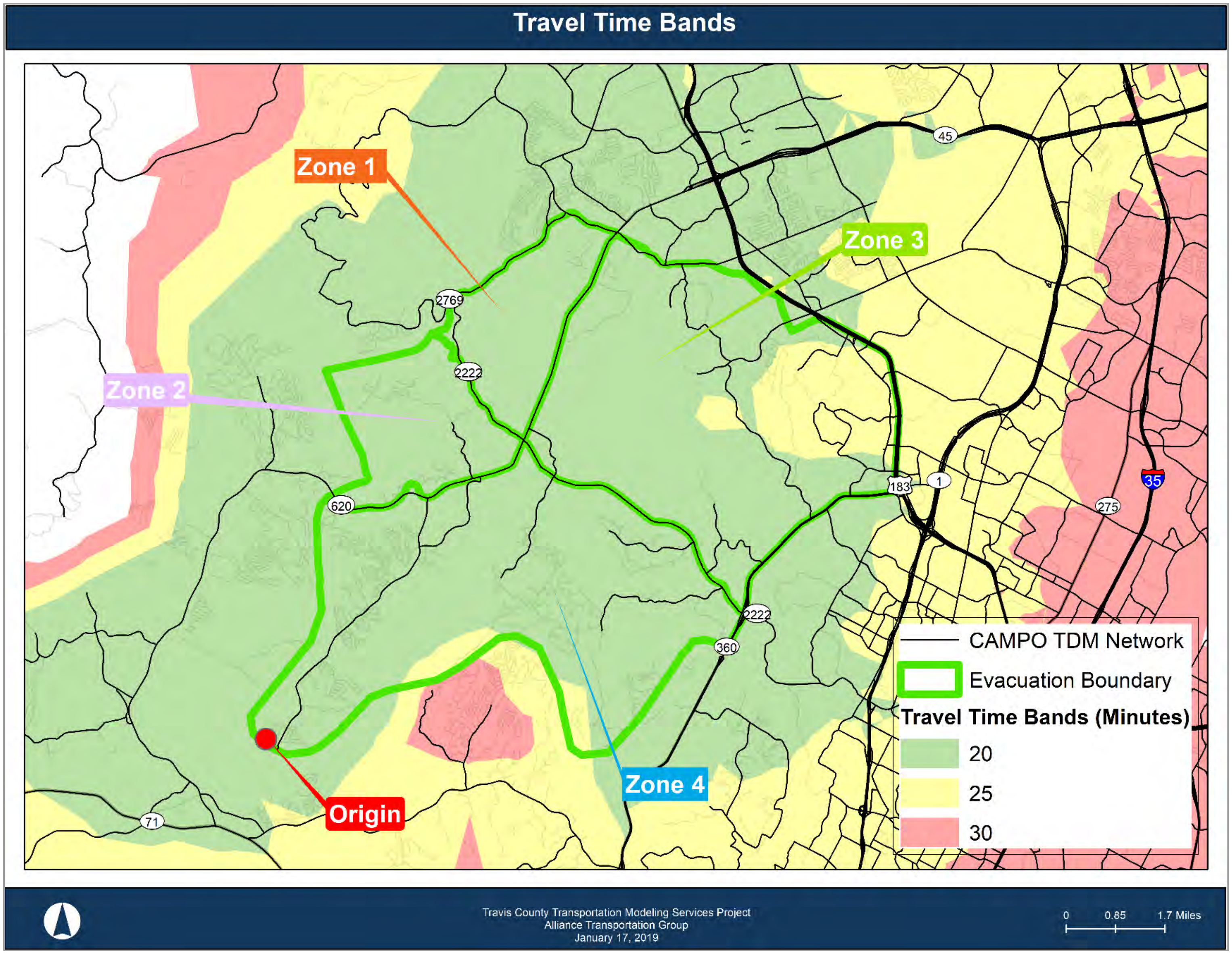


Figure 8: 2015 CAMPO Travel Demand Model Peak-Period Travel-Time Bands within Northwest Boundary

SUMMARY

In the Northwest Scenario 81,798 people are evacuated. Evacuation summary results indicated that the total duration of the Baseline (non-phased) scenario would be at least 3.4 hours without heavy background traffic. Evacuation in all the Alternative scenarios would take almost double the time of the Baseline scenario. The underlying assumption for the Baseline scenario, that all zones begin evacuating immediately, may lead to a higher rate of evacuation if there isn't heavy background traffic and the evacuation traffic does not cause heavy congestion on the evacuation routes. If there is significant background traffic or if the evacuation traffic causes heavy congestion, a phasing of the evacuation may result in higher rates of evacuation by metering the traffic flow on the evacuation routes at a level that lessens the chance of transportation system breakdown from heavy congestion.

Tests were also conducted to evaluate the effects of the amount of population evacuated, the population participation rate during the evacuation and the number of evacuees per vehicle had on determining the evacuation time on the Baseline scenario. The results indicated that an increase or decrease in the number of people per vehicle, and/or the amount of population evacuating, or the rate of evacuation participation influences the evacuation clearance time proportionately. The minimum Baseline evacuation clearance time may vary from 1.8 hours to 3.4 hours depending on the number of evacuees per vehicle ranging five to one. The minimum Baseline evacuation clearance time may vary from 3.4 hours to 6.7 hours depending on the additional population increase above the existing 2017 population, ranging from no change to a 100 percent increase (double population) condition. The minimum Baseline evacuation clearance time may also vary from 1.8 hours to 3.4 hours depending on the evacuee participation rate ranging from 25 percent to 96 percent.

The review of exit points addressed percent usage during the evacuation for each exit point and revealed major exit points. Results indicated that the exit-point utilization followed a similar pattern across all scenarios. During the evacuation of all four scenarios, evacuation routes indicate moderate to severe slow-down in traffic flow for various hours and locations. The review of the CAMPO model results indicated that the evacuation routes would be heavily congested during the PM peak-period and the actual evacuation time in a weekday afternoon event could be significantly higher than the minimized time predicted by RtePM.

NORTHEAST EVACUATION SCENARIO

The purpose of this chapter is to present the results of the analysis of the Northeast Fire Evacuation Scenario. For this analysis, Alliance used the RtePM Evacuation Model to estimate the minimum time that would be required to completely evacuate the area defined as the impact area for the Northeast Fire Evacuation Scenario. The Northeast fire evacuation boundary is illustrated in **Figure 9**, which also identifies the associated three zones. **Figure 10** shows the evacuation road network and roadway exit points that were considered during the evacuation.

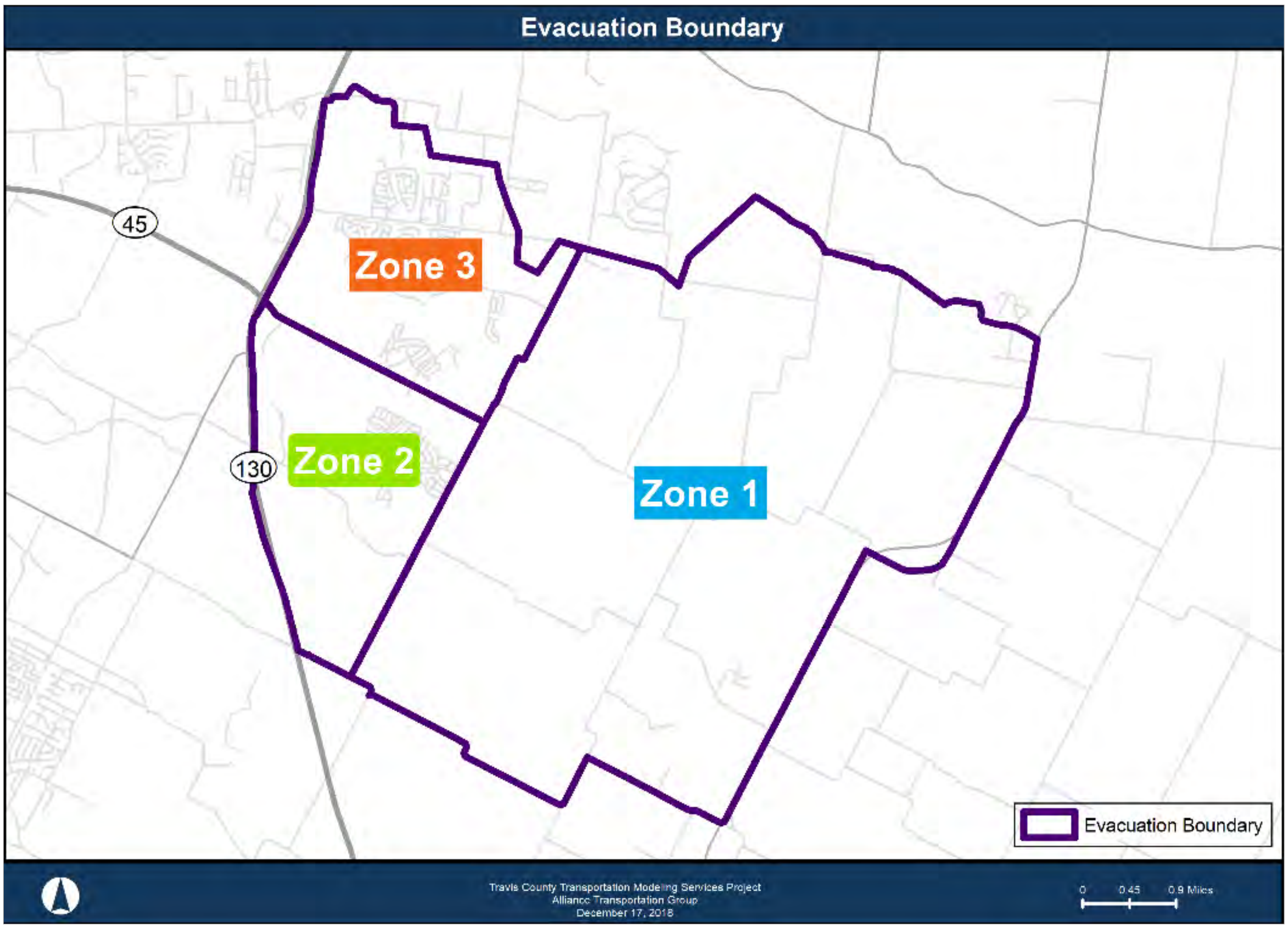


Figure 9: Geographic Boundary of Northeast Fire Scenario

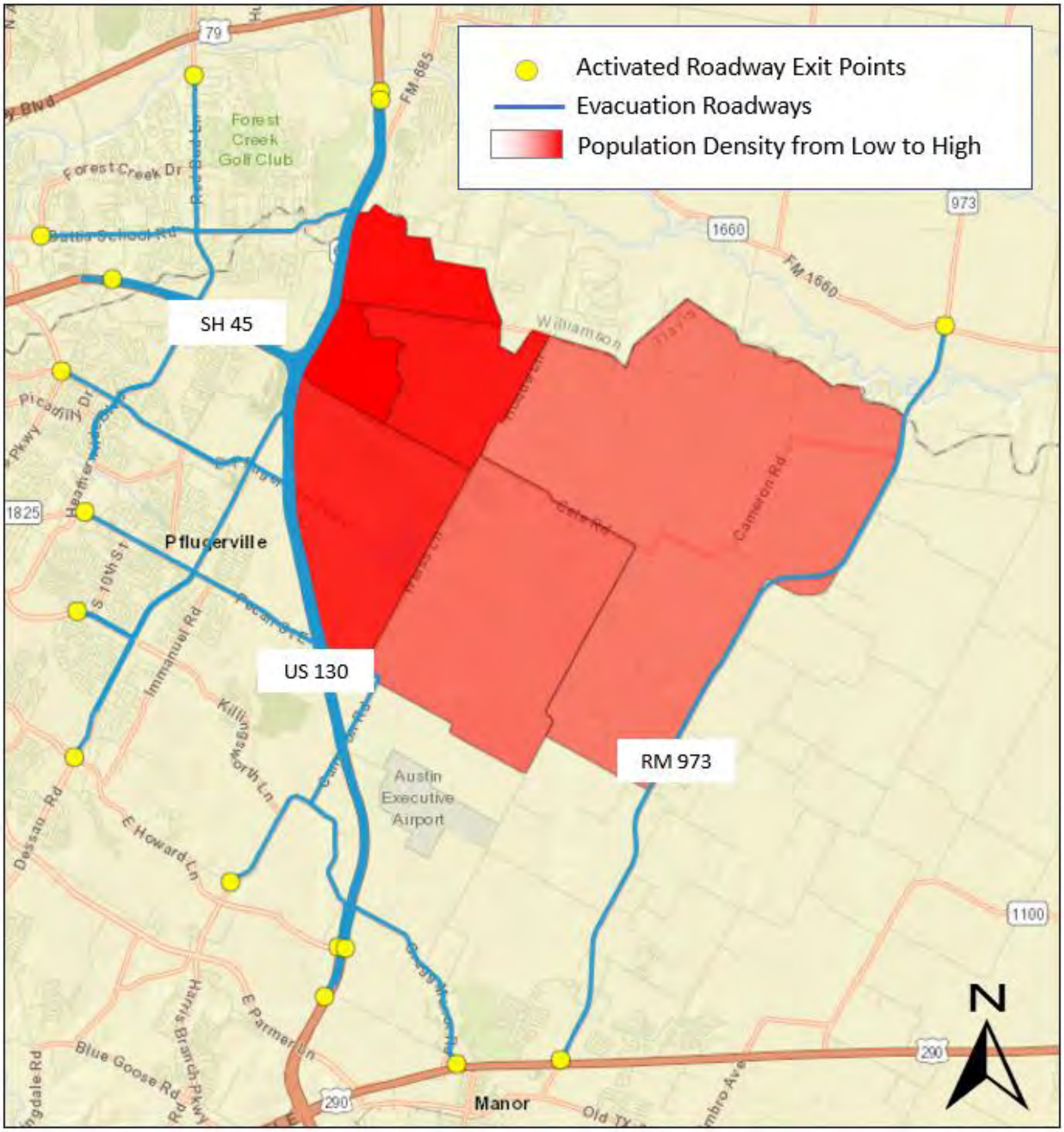


Figure 10: Road Network and Exit Points of Northeast Scenario

Scenario Definition

Using the earlier-mentioned parameters and assumptions in **Table 1** recommended by the Travis County staff, the “Baseline scenario” presented in **Table 8** was tested. No phasing of the three evacuation zones was assumed, as recommended by the Travis County staff. Three additional alternative scenarios were tested, each with a three-phased evacuation option, and they are also described in **Table 8**.

Table 8: Definition of Northeast Simulation Scenarios

Scenario	Description of Scenario
Baseline Scenario (Non-Phased)	In addition to the parameter assumptions identified in **Table 1**, all three zones were considered to participate in the evacuation at the same time from the beginning of the fire. Consistent with the stakeholders meeting discussion, the fire is assumed to start during the afternoon peak period at 3:00 PM in the last week of August - considered to be a critical time for fire events.
Alternative Scenario 1 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the three zones is assumed to be planned and staggered by two hours for each. Zone 1 is assumed to start the evacuation at 3:00 PM, Zone 2 at 5:00 PM, and Zone 3 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 2 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the three zones is assumed to be planned and staggered by two hours for each. Zone 2 is assumed to start the evacuation at 3:00 PM, Zone 3 at 5:00 PM, and Zone 1 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 3 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the three zones is assumed to be planned and staggered by two hours for each. Zone 3 is assumed to start the evacuation at 3:00 PM, Zone 2 at 5:00 PM, and Zone 1 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.

Demographic Data

Travis County provided the 2017 average day-time population, which does not include for school students. Alliance identified the following elementary, middle, and high schools and their enrollments. They are presented in **Table 9**.

Table 9: School Enrollment Statistics of Northeast Scenarios

Campus Name	Zone	2017-18 Enrollment
Cele Middle School	1	1,044
Hendrickson High School	2	2,618
Kelly Lane Middle School	2	1,078
Murchison Elementary School	2	816
Riojas Elementary School	3	668
Rowe Lane Elementary School	3	791
Total		7,015

The student enrollment information was derived from public information available at the Texas Education Agency and the National Center for Education Statistics. The student enrollment for 2017 was combined with the 2017 day-time population to form a 2017 target day-time population for the evacuation scenario. **Table 10** shows, by zone, the 96 percent of the target population for the Northeast evacuation scenario expected to participate during the evacuation.

Table 10: Target Day-Time Population of Northeast Scenarios

	Total			Target (96 Percent)		
Zone	Day- Time Population Excluding School Students	School Students	Total Day-Time Population	Day- Time Population Excluding School Students	School Students	Total Day-Time Population
1	1,354	1044	2,398	1,300	1,002	2,302
2	3,972	4,512	8,484	3,813	4,332	8,145
3	8,550	1,459	10,009	8,208	1,401	9,609
Total	13,876	7,015	20,891	13,321	6,734	20,055

RESULTS AND DISCUSSION

Minimum Evacuation Times

Evacuation summary results produced by the RtePM model scenario runs for the Baseline scenario and Alternative scenarios are provided in **Table 11** and **Table 12** and **Figure 11**. **Table 11** shows the evacuation times for the Baseline and Alternative evacuation scenarios. **Table 12** details by hour the total number of vehicles and population evacuated, remaining vehicles and population, and percent evacuated for each scenario. **Figure 11** shows the same information graphically. The tables and figure show how the 20,055 people or equivalent vehicles would be evacuated across different hours and scenarios.

The results include total duration of the evacuation for the Baseline scenario of 2.2 hours. The Alternative evacuation scenarios were also evaluated. It required approximately 6.5, 6.2, and 6.2 hours for Alternative scenarios 1, 2, and 3 respectively.

Table 11: Evacuation Clearance Time of Northeast Scenarios

Scenario	Evacuation Clearance Time (Hours)
Baseline	2.2
Alternative 1	6.5
Alternative 2	6.2
Alternative 3	6.2

Simulation results indicate that the Baseline evacuation scenario would takes a minimum of 2.2 hours to evacuate the evacuation boundary if there is only evacuation traffic and little to no background traffic on the evacuation roadways. In contrast, all the Alternative scenarios would take almost triple the time of the Baseline scenario. In the Baseline scenario, all three zones were assumed to participate in the evacuation at the same time from the beginning of the fire. This underlying assumption for the Baseline scenario may lead to higher evacuation rates as demonstrated in **Figure 11**. This figure provides useful information about how each evacuation scenario loads evacuating vehicles onto the road network and may help the County to make a reasonable decision on choosing the suitable scenario.

Figure 11 shows that at the end of the first hour of the Baseline evacuation, more than 69 percent of the population could potentially be evacuated. Similarly, at the end of the second and third hours of the Baseline evacuation, 98 and 100 percent of the population could potentially be evacuated. Results for the three phased scenarios; Alternatives 1, 2 and 3; are also provided for comparison. The results for the Alternative scenarios provide information that could be useful when there is significant background traffic and phasing may be necessary to prevent overloading the evacuation routes.

The Alternative 1 scenario shows that at the beginning of the second hour of the evacuation only 5.5 percent of the evacuees would be cleared and that would probably mean valuable time is being lost at a time when the evacuation routes would be least congested. Alternatives 2 and 3 would take the same amount of total time to evacuate, but the initial evacuation rate is higher for Alternative 3 than for Alternative 2. This is likely to lead to an evacuation that is smoother and distributed. Noticeably, at the end of the second hour of the evacuation, approximately 40.4 percent of the evacuees could be evacuated in the Alternative 3 scenario compared to approximately 25.4 percent for Alternative 2. Based on the evacuation time, evacuation rate, and phasing choice, the Alternative 3 scenario appears to perform better in comparison to the Alternative 1 and 2 scenarios.

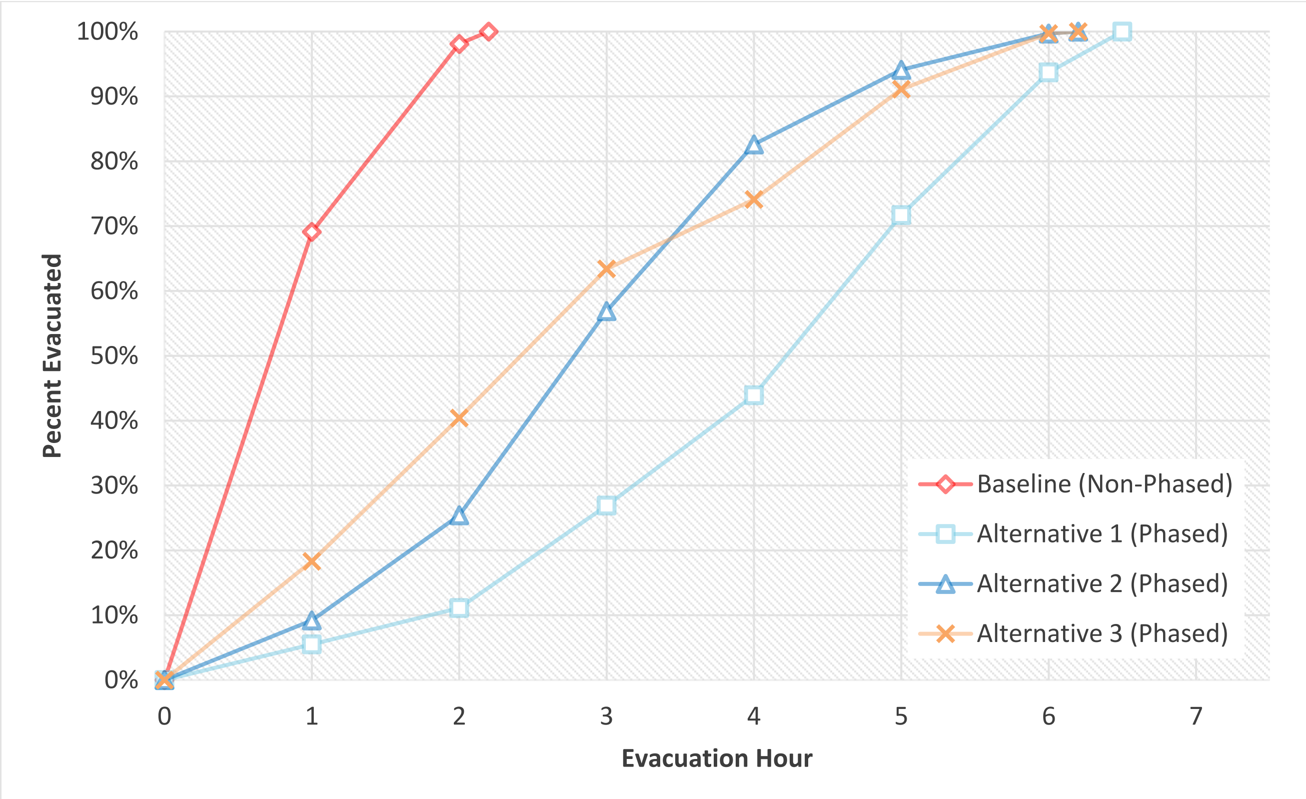


Figure 11: Evacuation Rate of Northeast Scenarios

Table 12: Summary Results for Northeast Fire Evacuation Scenarios for the Target Populations

	Hours/Items	Start	1	2	2.2				
Baseline	Total Population Evacuated	0	13,864	19,679	20,055				
	Total Vehicles Evacuated	0	13,864	19,679	20,055				
	Remaining Population	20,055	6,191	376	0				
	Remaining Vehicles	20,055	6,191	376	0				
	Percent Evacuated	0	69.1	98.1	100.0				
Alternative 1	Hours/Items	Start	1	2	3	4	5	6	6.5
	Total Population Evacuated	0	1,112	2,229	5,385	8,809	14,382	18,799	20,055
	Total Vehicles Evacuated	0	1,112	2,229	5,385	8,809	14,382	18,799	20,055
	Remaining Population	20,055	18,943	17,826	14,670	11,246	5,673	1,256	0
	Remaining Vehicles	20,055	18,943	17,826	14,670	11,246	5,673	1,256	0
	Percent Evacuated	0	5.5	11.1	26.9	43.9	71.7	93.7	100.0
Alternative 2	Hours/Items	Start	1	2	3	4	5	6	6.2
	Total Population Evacuated	0	1,845	5,088	11,416	16,554	18,864	19,988	20,055
	Total Vehicles Evacuated	0	1,845	5,088	11,416	16,554	18,864	19,988	20,055
	Remaining Population	20,055	18,210	14,967	8,639	3,501	1,191	67	0
	Remaining Vehicles	20,055	18,210	14,967	8,639	3,501	1,191	67	0
	Percent Evacuated	0	9.2	25.4	56.9	82.6	94.1	99.7	100.0
Alternative 3	Hours/Items	Start	1	2	3	4	5	6	6.2
	Total Population Evacuated	0	3,672	8,108	12,704	14,854	18,267	19,992	20,055
	Total Vehicles Evacuated	0	3,672	8,108	12,704	14,854	18,267	19,992	20,055
	Remaining Population	20,055	16,383	11,947	7,351	5,201	1,788	63	0
	Remaining Vehicles	20,055	16,383	11,947	7,351	5,201	1,788	63	0
	Percent Evacuated	0	18.3	40.4	63.4	74.1	91.1	99.7	100.0

Exit Points

Exhibit C2 in the appendix to this memo illustrates the relative use of the available evacuation area exit points. The size of the yellow circle indicators represents the number of evacuees reaching or passing through that destination relative to other exit points. Evacuation exit point percent usage during the evacuation are illustrated in **Figure 12**. Alternative-scenario results are included to compare the percent evacuation at each exit point. Results indicated that the exit-point utilization did not followed a similar pattern across all scenarios. SH 45 and US 130 North were used more in the Baseline scenario than in the Alternative scenarios. Among the twelve evacuation exit points in the Baseline scenario, the highest-demand exit point, which is SH 45, is used by more than 35 percent of the evacuees. US 130 North and US 130 South are also heavily used, getting 28 percent and 21 percent of the evacuation traffic respectively.

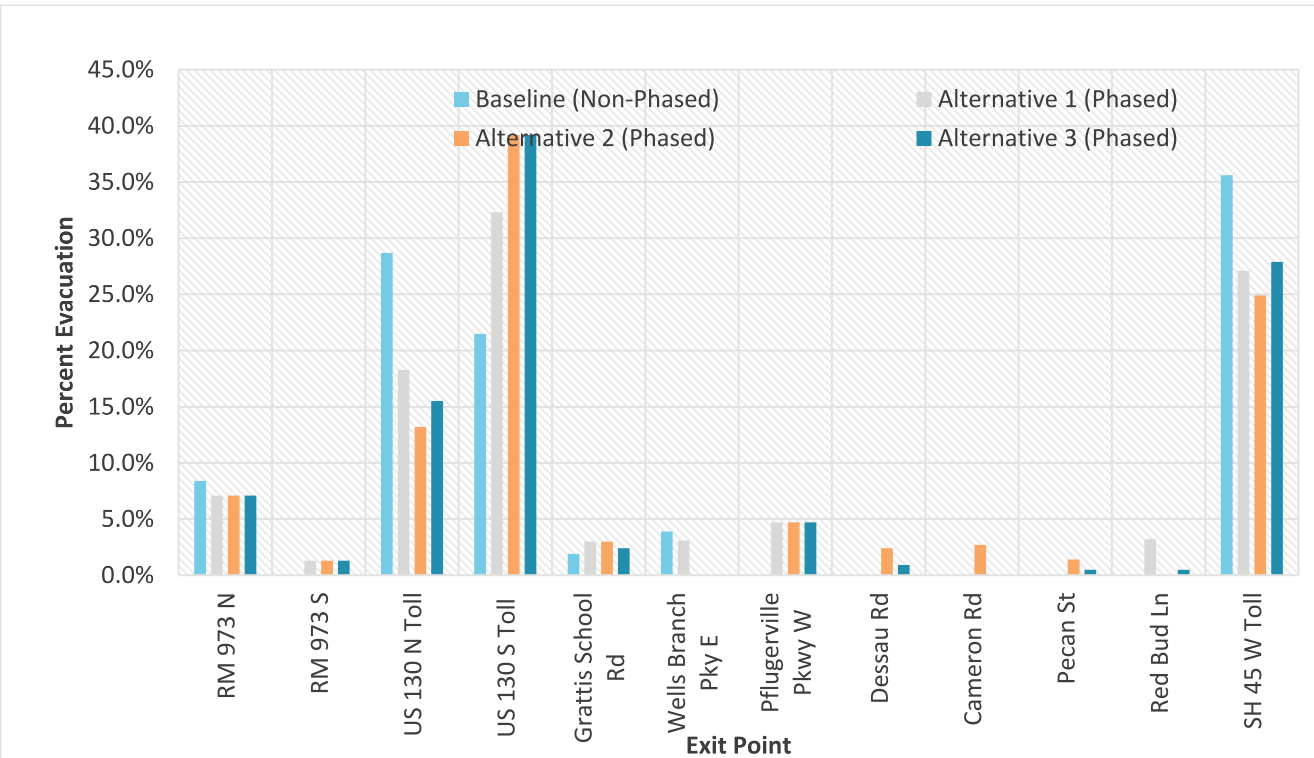


Figure 12: Exit Point Usage for the Northeast Scenarios Evacuation

Population Block Groups

Table 13 portrays how each zone and block group clear in terms of cumulative percentage cleared by hour. The appendix to this memorandum contains a visual representation of the information in **Table 13**. Exhibits C1 through C4 show how the evacuation is progressing at the end of each hour during the evacuation. In the exhibits, the population block groups appear in varying shades of black color corresponding to the density of population to be evacuated. As the evacuation progresses, the population block group becomes lighter until all evacuees have cleared the area, indicated by a white color. Results show that every census block group participated from the beginning of the evacuation. Results show that at the end of the first hour of the Baseline scenario, none of the census block group were evacuated completely. At the end of second hour, there were five census block groups that completed evacuation. By the end of 2.2 hours, all census block groups had completed evacuation.

Results showed that at the end of the first hour, more than 90 percent of the evacuees from Zone 1 or associated census block groups completed evacuation successfully. At the end of the first hour, Zone 2 completed around 52 percent of the evacuation. At the end of second hour, Zone 1 and 3 had completed full evacuation. Zone 2 took a longer time to evacuate compared to Zones 1 and 3 because more than 40 percent of the evacuees are in Zone 2 during the day time. Zone 2 evacuation was complete in 2.2 hours.

To compare the results of the Baseline scenario, based on the manual procedure of results extraction from the software, only Alternative 3 scenario results are included in **Table 13**.

Table 13: Cumulative Percent Evacuated by Zone and by Hour of Northeast Scenarios

Zone	Block Group ID	Cumulative Percent Completion by Hour									
		Baseline (Non-Phase)			Alternative 3 (Phased)						
		1	2	2.2	1	2	3	4	5	6	6.2
3	484530018581	52.1	100		28.9	71.8	100				
2	484530018582	52.9	95.4	100			38	64.4	92.7	100	
3	484530018584	89.5	100		40.7	85.7	100				
3	484530018585	91.6	100		46.7	97.2	100				
1	484530018591	97.4	100						48.7	97.3	100
1	484530018592	94.2	100						46.9	97.6	100

Road Segments

The loading of the internal road network during the evacuation is illustrated in the Appendix in D1 through D4. In these exhibits, green road segments indicate that traffic is moving at normal free flow speeds, yellow road segments indicate that there has been a moderate slow-down, and red road segments indicate that there has been a severe slow down.

Results show that in the first hour of the Baseline scenario evacuation, some locations on SH 45 westbound experience severe slow-down. All other hour shows free-flow traffic conditions.

In the Alternative 1 scenario, in the fifth, sixth and seventh hours of the evacuation, some locations on SH 45 experience moderate to slow-down. All other hour shows free-flow traffic conditions.

In the Alternative 2 scenario, in the third and fourth hours of the evacuation, one location on SH 45 experiences severe slow-down. All other hour shows free-flow traffic conditions.

In the Alternative 3 scenario, there were moderate to severe slow-down conditions:

- First hour - one location on SH 45 and multiple locations on US 130 N
- Second hour - one location on SH 45

- Third hour - one location on SH 45
- Fourth hour - one location on US 130 S
- All other hour shows free-flow traffic conditions.

In the Baseline evacuation scenario, all three zones were assumed to participate in the evacuation at the same time from the beginning of the fire, there was not widespread congestion. There were moderate to severe slow-down congestions observed in all four scenarios, but there are more congested locations in the Alternative 3 than in the other Alternative scenarios and the Baseline scenario. Alternatives 1 and 2 experienced less congestion in comparison to the Alternative 3 scenario.

TRAFFIC CHARACTERISTICS IN THE CAMPO TRAVEL DEMAND MODEL

Some traffic characteristics produced by the CAMPO Travel Demand Model are included in order to address the RtePM model scenarios inability to adequately account for the effects of background traffic on evacuation time. Various PM peak-period (3:30 PM-6:30 PM) congestion measures from the 2015 CAMPO model that are on the major evacuation routes (SH 45, US 130, and RM 973) can be used to estimate the effects of background traffic. These measures include traffic volumes, traffic patterns, and peaking characteristics. The 2015 CAMPO model PM peak-period two-directional traffic volumes are presented in **Figure 13**.

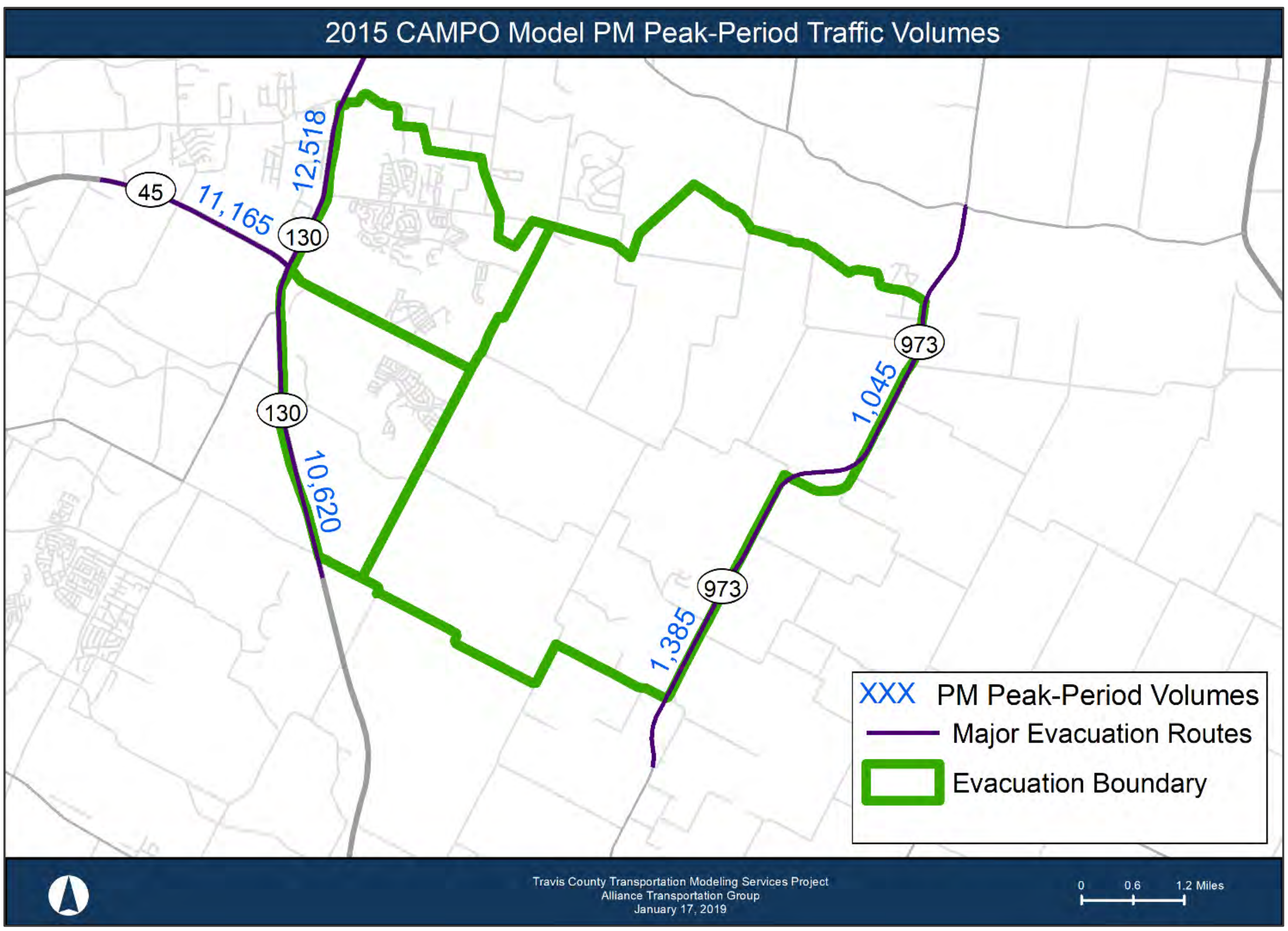


Figure 13: 2015 CAMPO Travel Demand Model PM Peak-Period Traffic Volume within Northeast Boundary

The 2015 CAMPO Model PM peak-period directional volume-to-capacity (V/C) ratios are presented in **Figure 14**. The directional V/C ratios represent the traffic volumes divided by the road capacity for all lanes traveling in the same direction. In **Figure 14** the red and blue numbers are the V/C ratios for the side of the road that they are next to. A V/C ratio of 1.00 indicates that the road is operating at its capacity.

In practice, any facility with a V/C ratio greater than 0.90 may be identified as a congested facility. In addition to that, any facility with a V/C ratio less than 0.60 may be identified as a free-flow facility. The directional PM peak-period V/C ratios indicate that the major evacuation routes, (SH 45, US 130, and RM 973) are in free-flow conditions. For example, the V/C ratio is 0.39 on portions of RM 973, which indicates that the facilities would be free-flow with normal daily background traffic in the PM peak-period.

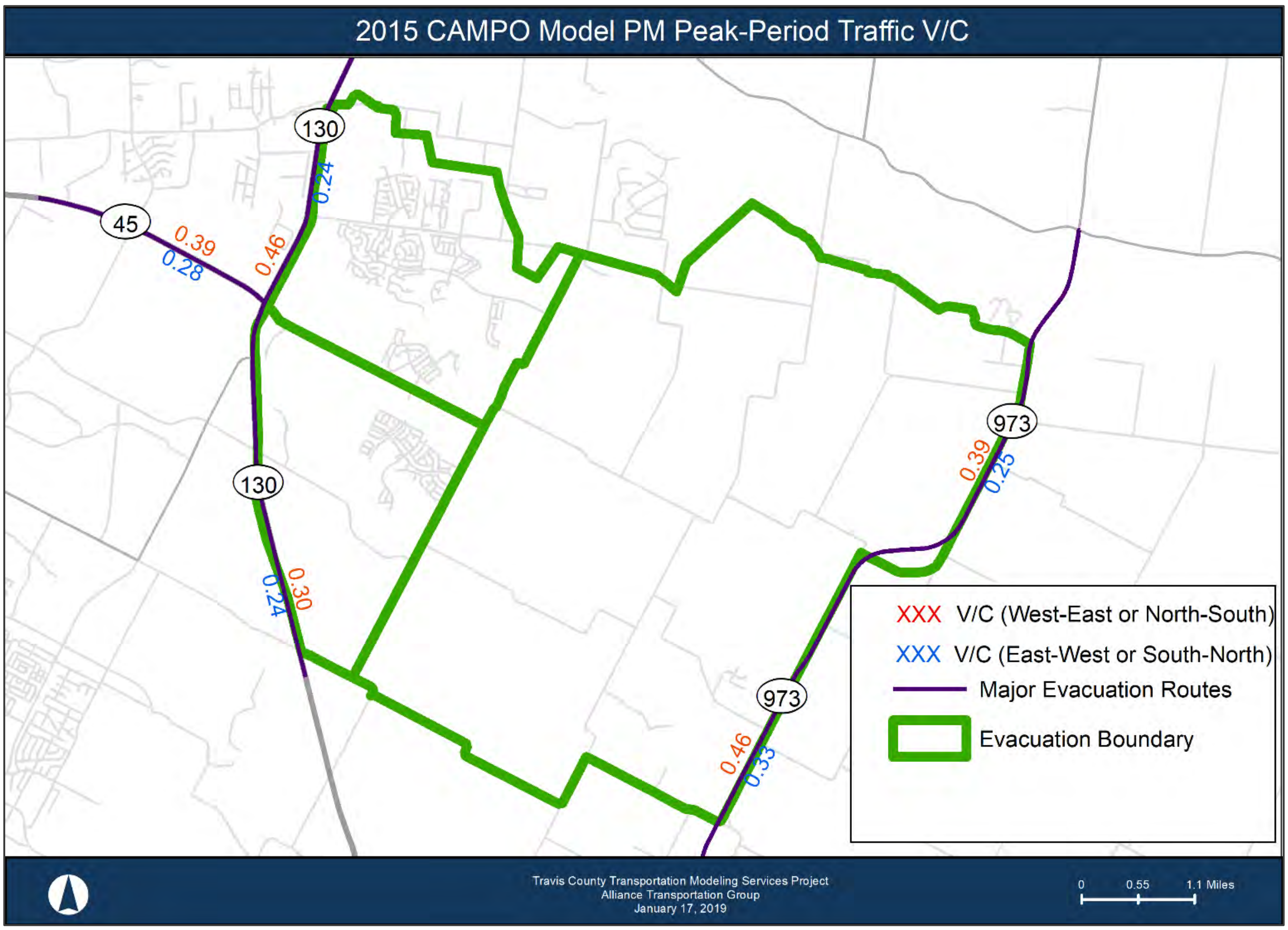


Figure 14: 2015 CAMPO Travel Demand Model Peak-Period V/C Ratio within Northeast Boundary

Furthermore, conceptual[3] travel-time bands were created using the 2015 CAMPO model PM peak-period congested travel time. Three conceptual travel-times bands are presented in **Figure 15**. The intersection of Kelly Lane and Weiss lane was chosen as an origin point for travel-time band calculations. This origin point was conceptually assumed to be a critical location for the study area. Each travel-time band shows the distance that can be traveled in the allotted time from the origin point. For example, the 20-minute travel-time band show the

[3] *Conceptual travel-time bands do not account for natural barriers such as lakes and rivers.*

maximum distance a traveler can go within 20 minutes from the origin point location. This figure also indicates that during the PM peak-period, the entire scenario area lies within the 25-minute travel-time band. The travel-time bands are calculated using the average peak-period background traffic without the evacuation traffic. For example, if the background traffic produces V/C ratios over 0.90, then the addition of the evacuation traffic is going to produce heavy congestion. The additional traffic and congestion will reduce the distance traveled within the time period and cause the travel-time bands to shrink considerably. A review of the CAMPO model results indicates that the evacuation routes would be free-flow condition during the PM peak-period in a typical normal day. CAMPO model does not predict abnormal traffic condition such as fire evacuation or any emergency situation. During an abnormal condition, travel time will be higher than a normal day. Therefore, the actual evacuation time in a weekday afternoon event could be somewhat higher than the minimum time predicted by RtePM.

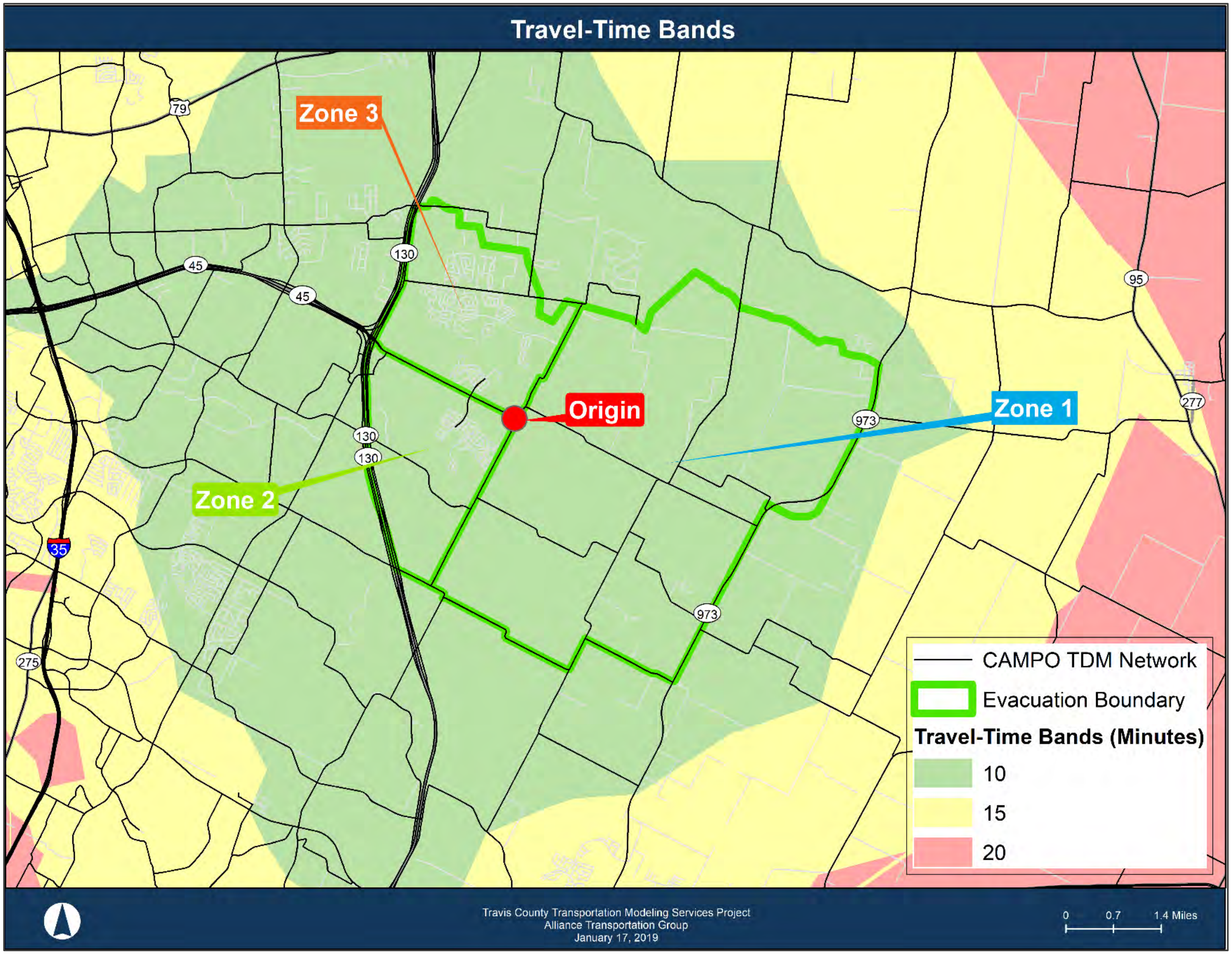


Figure 15: 2015 CAMPO Travel Demand Model Peak-Period Travel-Time Bands within Northeast Boundary

SUMMARY

In the Northeast scenario 20,055 people are evacuated. Evacuation summary results indicated that the total duration of the Baseline (non-phased) scenario would be at least 2.2 hours without heavy background traffic. All the Alternative scenarios take almost triple the time of the Baseline scenario. The underlying assumption for the Baseline scenario, that all zones begin evacuating immediately, may lead to a higher rate of evacuation if there isn't heavy background traffic and the evacuation traffic does not cause heavy congestion on the evacuation routes. If there is significant background traffic or if the evacuation traffic causes heavy congestion, a phasing of the evacuation may result in higher rates of evacuation by metering the flow on the evacuation routes at a level that lessens the chance of transportation system breakdown from heavy congestion.

Tests were also conducted to evaluate the effects of the amount of population evacuated, the population participation rate during the evacuation and the number of evacuees per vehicle had on determining the evacuation time on the Baseline scenario. The results indicated that an increase or decrease in the number of people per vehicle, and/or the amount of population evacuating, or the rate of evacuation participation influences the evacuation clearance time proportionately. The minimum Baseline evacuation clearance time may vary from 1.1 hours to 2.2 hours depending on the number of evacuees per vehicle ranging five to one. The minimum Baseline evacuation clearance time may vary from 2.2 hours to 4.9 hours depending on the additional population increase above the existing 2017 population, ranging from no change to a 100 percent increase (double population) condition. The minimum Baseline evacuation clearance time may also vary from 1.2 hours to 2.2 hours depending on the evacuee participation rate ranging from 25 percent to 96 percent.

The review of exit points addressed percent usage during the evacuation for each exit point and revealed major exit points. Results indicated that the exit-point utilization followed a similar pattern across all scenarios. During the evacuation of all four scenarios, evacuation routes indicate moderate to severe slow-down in traffic flow for various hours and locations. The review of the CAMPO model results indicated that the evacuation routes would be free-flow conditions during the PM peak-period and the actual evacuation time in a weekday afternoon event could be higher than the minimized time predicted by RtePM.

SOUTHWEST EVACUATION SCENARIO

The purpose of this chapter is to present the results of our analysis of the Southwest Fire Evacuation Scenario. For this analysis, Alliance used the RtePM Evacuation Model to estimate the minimum time that would be required to completely evacuate the area defined as the impact area for the Southwest Fire Evacuation Scenario. The Southwest fire evacuation boundary is illustrated in **Figure 16**, which also identifies the associated three zones. **Figure 17** shows the evacuation road network and roadway exit points that were considered during the evacuation.

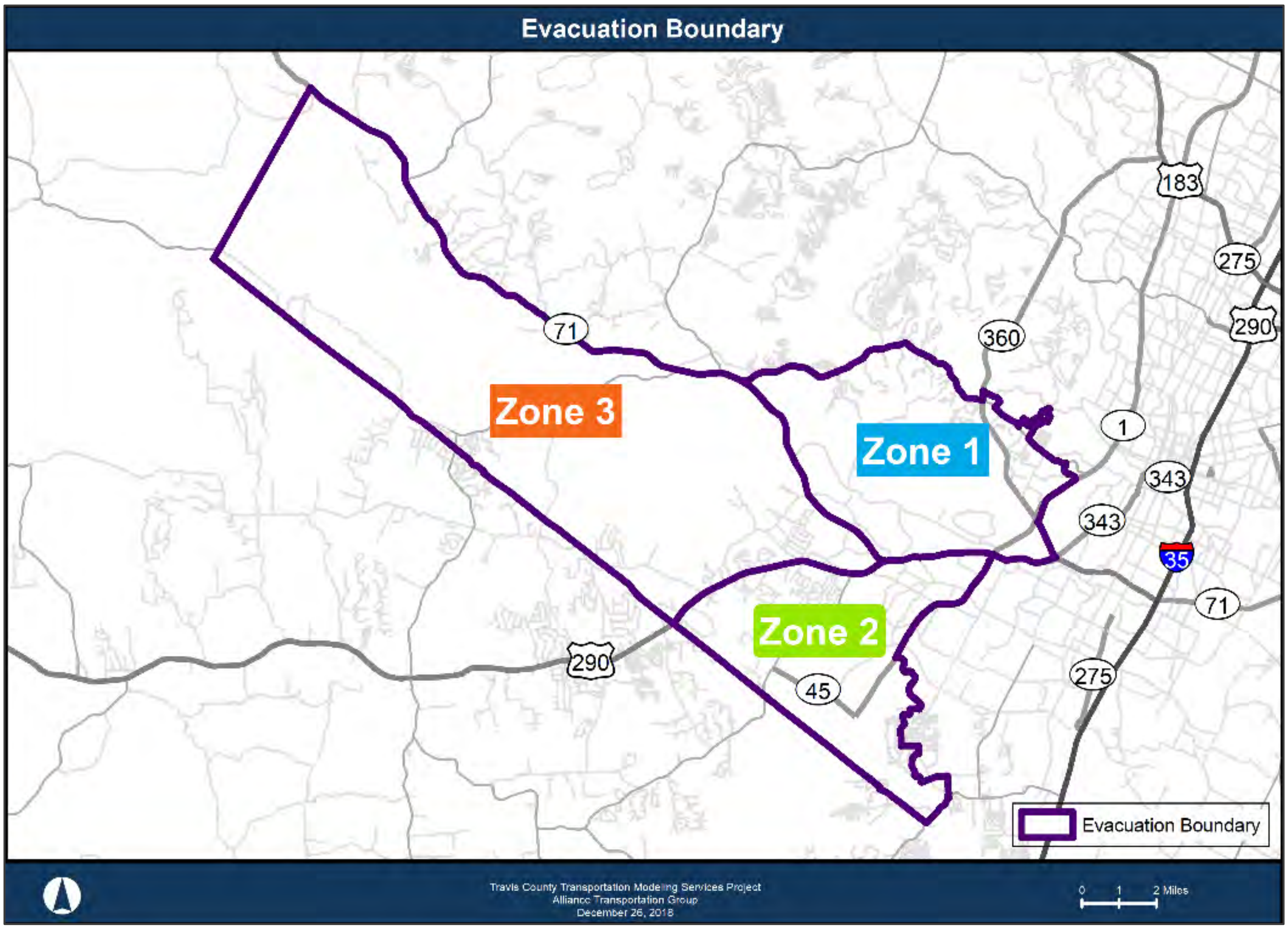


Figure 16: Geographic Boundary of Southwest Fire Scenario

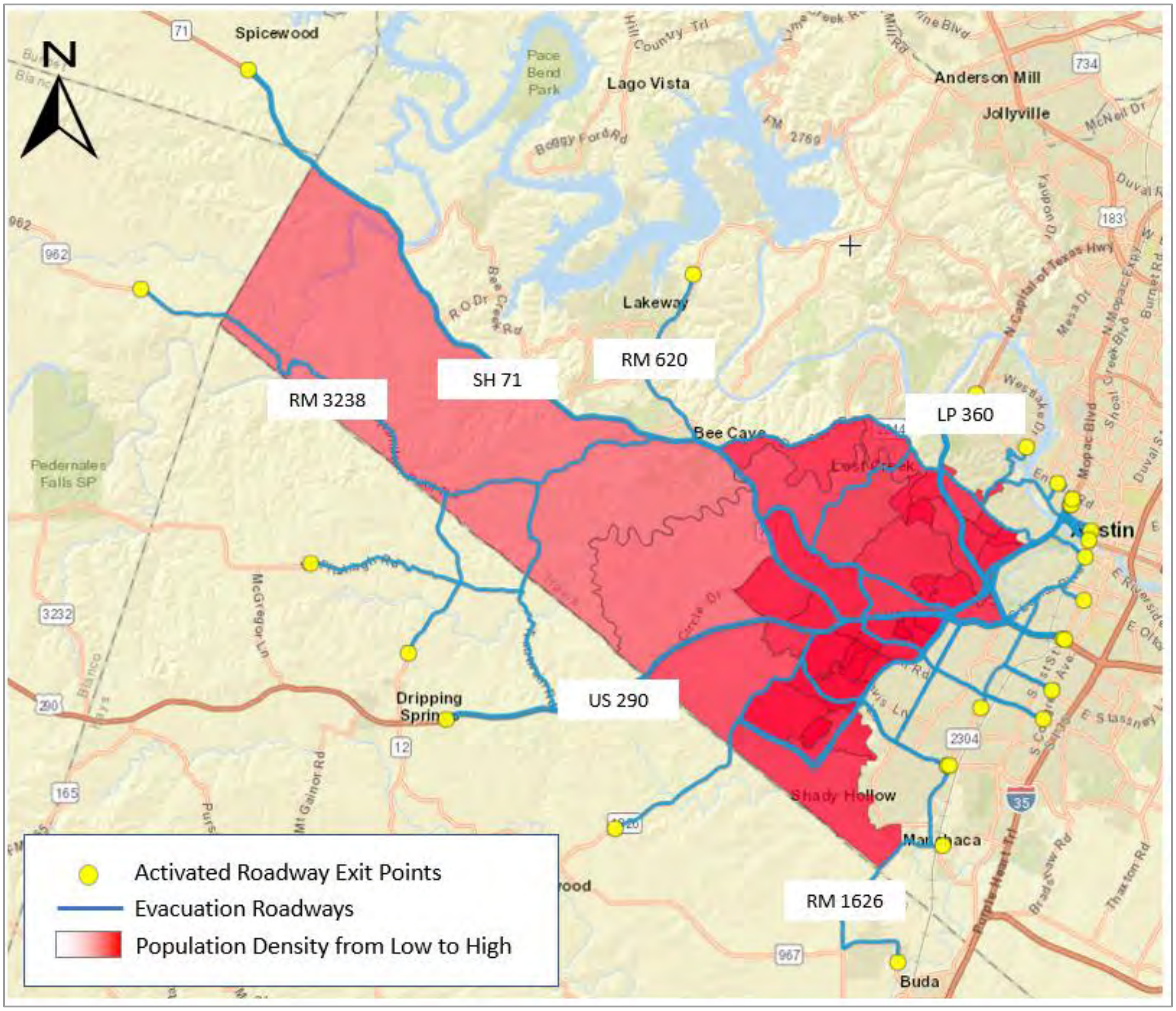


Figure 17: Road Network and Exit Points of Southwest Fire Scenario

SCENARIO DEFINITION

Using the above-mentioned parameters and assumptions in **Table 1** recommended by the Travis County staff, the "Baseline scenario" presented in **Table 14** was tested. No phasing of the three evacuation zones was assumed, as recommended by the Travis County staff. Three additional alternative scenarios were tested, each with a three-phased evacuation option, and they are also described in **Table 14.**

Table 14: Definition of Southwest Simulation Scenarios

Scenario	Description of Scenario
Baseline Scenario (Non-Phased)	In addition to the parameter assumptions identified in **Table 1**, all three zones were considered to participate in the evacuation at the same time from the beginning of the fire. Consistent with the stakeholders meeting discussion, the fire is assumed to start during the afternoon peak period at 3:00 PM in the last week of August - considered to be a critical time for fire events.
Alternative Scenario 1 (Phased)	In addition to the assumptions and parameters considered in **Table 1** the evacuation of the three zones is assumed to be planned and staggered by two hours for each. Zone 1 is assumed to start the evacuation at 3:00 PM, Zone 2 at 5:00 PM, and Zone 3 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 2 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the three zones is assumed to be planned and staggered by two hours for each. Zone 2 is assumed to start the evacuation at 3:00 PM, Zone 3 at 5:00 PM, and Zone 1 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 3 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the three zones is assumed to be planned and staggered by two hours for each. Zone 3 is assumed to start the evacuation at 3:00 PM, Zone 2 at 5:00 PM, and Zone 1 at 7:00 PM. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.

DEMOGRAPHIC DATA

Travis County provided the 2018 average day-time population, which does not include the school students. Alliance identified the following elementary, middle, and high schools and their enrollments. They are presented in **Table 15**.

Table 15: School Enrollment Statistics of Southwest Scenario

Sl	Campus Name	Zone	Number of Students
1	Barton Creek Elementary School	1	474
2	Cedar Creek Elementary School	1	518
3	Eanes Elementary School	1	628
4	Forest Trail Elementary School	1	577
5	Hill Country Middle	1	1,072
6	Oak Hill Elementary School	1	868
7	Valley View Elementary School	1	514
8	West Ridge Middle	1	922
9	Westlake High School	1	2,683
10	Regents School of Austin	1	1,011
11	Trinity Episcopal School Austin	1	514
12	St. Gabriel's Catholic School	1	457
13	St. Michael's Catholic Academy - Austin	1	364
14	Austin Montessori School	1	350
15	Bailey Middle School	2	1,006
16	Baldwin Elementary School	2	810
17	Clayton Elementary School	2	834
18	Gorzycki Middle	2	1,275
19	Kiker Elementary School	2	1,111
20	Mills Elementary School	2	854
21	Patton Elementary School	2	984
22	Small Middle School	2	1,231
23	Veritas Academy	2	662
24	Country Home Learning Center No. 7	2	41
25	Austin Waldorf School	2	383
26	Bee Cave Elementary School	3	750
27	West Cypress Hills Elementary School	3	794
Total			21,687

The student enrollment information was derived from public information available at the Texas Education Agency and the National Center for Education Statistics. The student enrollment for 2017-2018 was combined with the 2018 day-time population to form a 2018 target day-time population for the evacuation scenario. **Table 16** shows, by zone, the 96% of the target population for the Southwest evacuation scenario expected to participate during the evacuation.

Table 16: Target Day-Time Population of Southwest Scenario

	Total			Target (96 Percent)		
Zone	Day- Time Population Excluding School Students	School Students	Total Day-Time Population	Day- Time Population Excluding School Students	School Students	Total Day-Time Population
1	59,805	10952	70,757	57,413	10,513	67,926
2	35,986	9,191	45,177	34,547	8,826	43,373
3	14,183	1,544	15,727	13,616	1,482	15,098
Total	109,974	21,687	131,661	105,576	20,821	126,397

Results and Discussions

Minimum Evacuation Times

Evacuation summary results produced by the RtePM model scenario runs for the Baseline scenario and Alternative scenarios are provided in **Table 17** and **Table 18**. The results include total duration of the evacuation for the Baseline scenario of 5.8 hours. The Alternative evacuation scenarios were also evaluated. It required approximately 6.3, 8.0, and 9.8 hours for Alternative 1, 2, and 3 respectively.

Table 17: Evacuation Clearance Time of Southwest Scenarios

Scenarios	Evacuation Clearance Time (Hours)
Baseline	5.8
Alternative 1	6.3
Alternative 2	8.0
Alternative 3	9.8

Simulation results indicate that the Baseline evacuation scenario would take a minimum of roughly 5.8 hours to evacuate the evacuation area. In contrast, all the Alternative scenarios take more time than the Baseline scenario. **Table 18** provides more details about the evacuations for each of the four scenarios.

In the Baseline scenario, all three zones were assumed to participate in the evacuation at the same time from the beginning of the fire. This underlying assumption for the Baseline scenario may lead to higher evacuation rates as demonstrated in **Figure 18**. This figure provides useful information about how each evacuation scenario loads evacuating vehicles onto the road network and may help the County to make a reasonable decision on choosing the suitable scenario.

Figure 18 shows that at the end of the first hour of the Baseline evacuation, more than 25 percent of the population could potentially be evacuated. Similarly, at the end of the second and third hour of the Baseline evacuation, more than 50 and 75 percent of the population could potentially be evacuated. Results for the three phased scenarios, Alternatives 1, 2 and 3 are also provided for comparison. The results for the Alternative scenarios provide information that could be useful when there is significant background traffic and phasing may be necessary to prevent overloading the evacuation routes.

The Alternative 3 scenario shows that after the third hour of the evacuation only 24.6 percent of the evacuees would be cleared and that would probably mean valuable time is being lost at a time when the evacuation routes would be least congested. Alternatives 1 and 2 would take 6.3 and 8.0 hours respectively to evacuate, but the initial evacuation rate is higher for Alternative 1 than for Alternative 2. This is likely to lead to an evacuation that is smoother and distributed. Based on the evacuation time, evacuation rate, and phasing choice, Alternative 1 scenario appears to perform better in comparison to the Alternatives 2 and 3 scenarios.

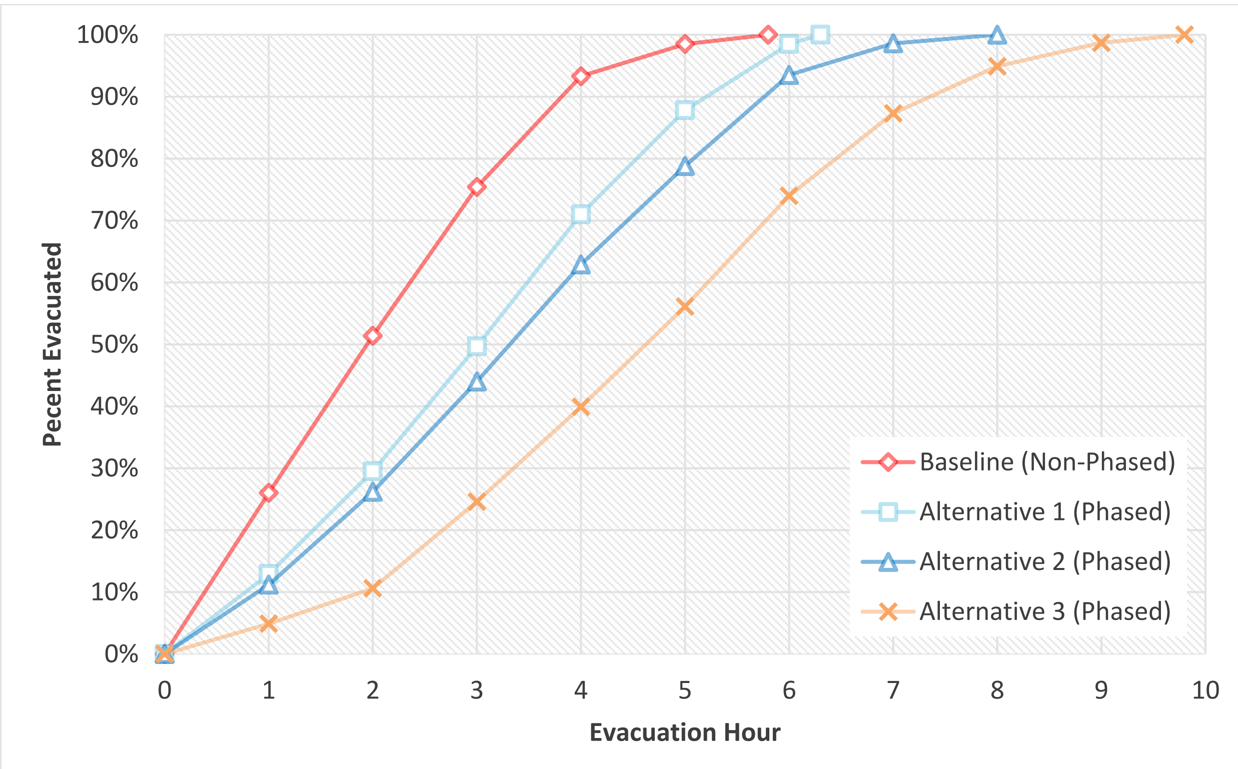


Figure 18: Evacuation Rate of Southwest Scenarios

Table 18 includes by hour the total number of vehicles and population evacuated, remaining vehicles and population, and percent evacuated for each scenario. **Table 18** shows how the 126,394 people or equivalent vehicles would be evacuated across different hours and scenarios.

Table 18: Summary Results for Southwest Fire Evacuation Scenarios for the Target Populations[4]

	Hours/Items	Start	1	2	3	4	5	5.8			
Baseline	Total Population Evacuated	0	32,841	65,026	95,295	117,900	124,481	126,394			
Baseline	Total Vehicles Evacuated	0	32,841	65,026	95,295	117,900	124,481	126,394			
Baseline	Remaining Population	126,394	93,553	61,368	31,099	8,494	1,913	0			
Baseline	Remaining Vehicles	126,394	93,553	61,368	31,099	8,494	1,913	0			
Baseline	Percent Evacuated	0	26.0	51.4	75.4	93.3	98.5	100.0			
Alternative 1	Hours/Items	Start	1	2	3	4	5	6	6.3		
Alternative 1	Total Population Evacuated	0	16,306	37,285	62,815	89,758	111,009	124,521	126,394		
Alternative 1	Total Vehicles Evacuated	0	16,306	37,285	62,815	89,758	111,009	124,521	126,394		
Alternative 1	Remaining Population	126,394	110,088	89,109	63,579	36,636	15,385	1,873	0		
Alternative 1	Remaining Vehicles	126,394	110,088	89,109	63,579	36,636	15,385	1,873	0		
Alternative 1	Percent Evacuated	0	12.9	29.5	49.7	71	87.8	98.5	100.0		
Alternative 2	Hours/Items	Start	1	2	3	4	5	6	7	8	
Alternative 2	Total Population Evacuated	0	14,169	33,118	55,596	79,497	99,620	118,293	124,569	126,394	
Alternative 2	Total Vehicles Evacuated	0	14,169	33,118	55,596	79,497	99,620	118,293	124,569	126,394	
Alternative 2	Remaining Population	126,394	112,225	93,276	70,798	46,897	26,774	8,101	1,825	0	
Alternative 2	Remaining Vehicles	126,394	112,225	93,276	70,798	46,897	26,774	8,101	1,825	0	
Alternative 2	Percent Evacuated	0	11.2	26.2	44.0	62.9	78.8	93.5	98.6	100.0	
Alternative 3	Hours/Items	Start	1	2	3	4	5	6	7	8	9	9.8
Alternative 3	Total Population Evacuated	0	6,204	13,353	31,038	50,401	70,884	93,572	110,336	119,922	124,717	126,394
Alternative 3	Total Vehicles	0	6,204	13,353	31,038	50,401	70,884	93,572	110,336	119,922	124,717	126,394

[4] *Target total number of evacuees was 126,397. RtePM simulation evacuated 126,394 evacuees. In this scenario, three evacuees found to be a rounding error.*

	Evacuated											
	Remaining Population	126,394	120,190	113,041	95,356	75,993	55,510	32,822	16,058	6,472	1,677	0
	Remaining Vehicles	126,394	120,190	113,041	95,356	75,993	55,510	32,822	16,058	6,472	1,677	0
	Percent Evacuated	0	4.9	10.6	24.6	39.9	56.1	74.0	87.3	94.9	98.7	100.0

Exit Points

As evacuees reach an exit point, the size of the yellow circle indicators expands (e.g., Appendix F2) relative to the number of evacuees reaching or passing through that destination. Evacuation exit point percent usage during the evacuation are illustrated in **Figure 19**. Alternative-scenario results are included to compare the percent evacuation at each exit point. Results indicated that the exit-point utilization followed a similar pattern across all scenarios. Among the twelve evacuation exit points in the Baseline scenario, the highest-demand exit point, which is US 290 (west of evacuation area), is used by more than 17 percent of the evacuees. Loop 1 North and Loop 360 are also heavily used with each getting more than 15 percent and 10 percent respectively of the evacuation traffic.

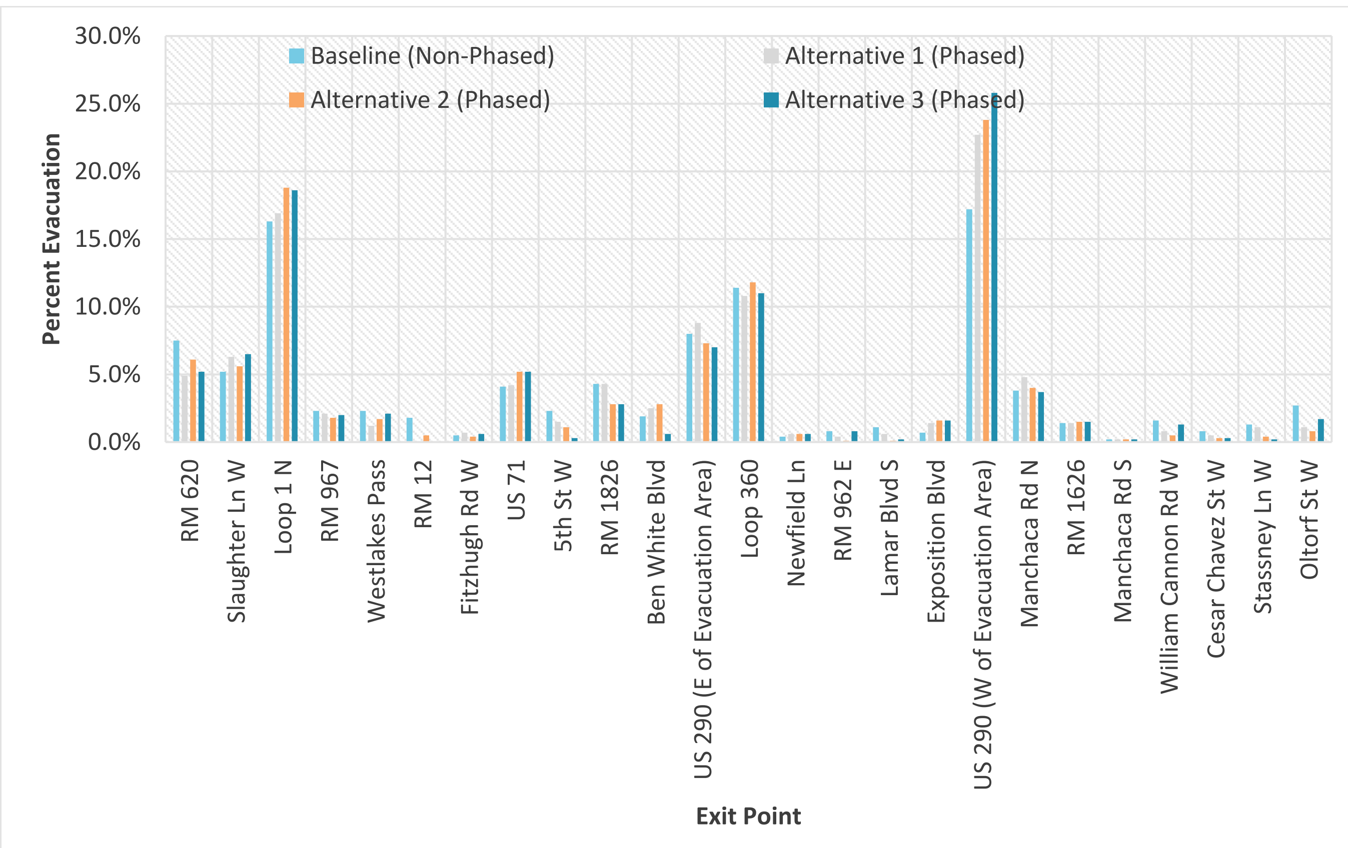


Figure 19: Exit Point Usage for the Southwest Scenarios

Population Block Groups

Table 19 portrays how each zone and block group clear in terms of cumulative percentage cleared by hour. The appendix to this memorandum contains a visual representation of the information **Table 19**. Exhibits E1 through E7 show how the evacuation is progressing at the end of each hour during the evacuation. In the exhibits, the population block groups appear in varying shades of black color corresponding to the density of population to be evacuated. As the evacuation progresses, the population block group becomes lighter until all evacuees have cleared the area, indicated by a white color. Results show that every census block group participated from the beginning of the evacuation. Results show that at the end of the first and second hours of the Baseline scenario, none of the census block group evacuated completely. At the end of third hour, there are seven census block groups that completed evacuation. By the end of the 5.8 hour, all census block groups completed evacuation.

To compare the results of the Baseline scenario, based on the manual procedure of results extraction from the software, only Alternative 1 scenario results are included in **Table 19.**

Table 19: Cumulative Percent Evacuated by Zone and by Hour for the Southwest Scenarios

Zone	Block Group ID	Cumulative Percent Completion by Hour												
		Baseline (Non-Phase)						Alternative 1 (Phased)						
		1	2	3	4	5	5.8	1	2	3	4	5	6	6.3
2	484530017331	31	63	93	100					40	95	100		
2	484530017332	57	93	100						27	81	100		
2	484530017371	21	56	68	100					16	56	86	100	
2	484530017372	17	39	66	100					17	38	70	100	
2	484530017373	28	58	87	100					37	80	100		
2	484530017381	25	71	95	100					17	58	91	100	
2	484530017382	43	84	100						25	66	100		
2	484530017383	30	77	97	100					17	65	100		
2	484530017384	28	60	88	100					29	86	100		
2	484530017385	50	90	100						31	77	95	100	
2	484530017491	40	90	100						40	78	100		
2	484530017492	49	88	100						48	65	100		
2	484530017493	22	59	83	88	100				18	44	75	100	

Zone	Block Group ID	Cumulative Percent Completion by Hour												
		Baseline (Non-Phase)						Alternative 1 (Phased)						
		1	2	3	4	5	5.8	1	2	3	4	5	6	6.3
2	484530017494	13	29	70	94	100				30	70	92	100	
3	484530017681	28	63	97	100							37	94	100
3	484530017682	73	90	100								42	88	100
3	484530017691	15	38	56	100							36	88	100
3	484530017692	19	48	80	100							21	85	100
2	484530017701	24	57	98	100					27	72	100		
2	484530017702	43	77	93	100					17	44	81	100	
2	484530017703	25	49	89	100					41	74	100		
2	484530017751	49	97	100						46	96	100		
1	484530019081	18	57	92	100			25	66	83	90	96	100	
1	484530019082	14	28	59	96	100		31	72	83	88	94	100	
1	484530019102	13	37	52	60	73	100	12	38	57	66	75	95	100
1	484530019103	4	12	33	67	91	100	5	13	24	51	87	100	
1	484530019104	44	71	86	100			16	44	58	92	100		
1	484530019141	24	71	94	100			18	46	68	91	99	100	
1	484530019142	46	78	97	99	100		18	52	64	78	100		
1	484530019143	35	61	100				24	59	74	92	100		
1	484530019151	10	26	53	93	100		38	76	90	95	99	100	
1	484530019161	20	48	95	100			38	91	100				
1	484530019162	57	87	100	100			47	96	100				
1	484530019171	37	91	100				50	96	100				
1	484530019172	79	100					18	44	70	98	100		

Zone	Block Group ID	Cumulative Percent Completion by Hour												
		Baseline (Non-Phase)						Alternative 1 (Phased)						
		1	2	3	4	5	5.8	1	2	3	4	5	6	6.3
1	484530019173	73	100					45	95	100				
1	484530019174	31	82	100				25	52	89	96	100		
1	484530019182	9	19	46	86	100		15	39	75	98	100		
1	484530019193	73	94	97	98	98	100	44	90	98	100			

Road Segments

The loading of the internal road network during the Baseline scenario evacuation is illustrated in the Appendix in F1 through F7. In these exhibits, green road segments indicate that traffic is moving at normal free flow speeds, yellow road segments indicate that there has been a moderate slow-down, and red road segments indicate that there has been a severe slow down.

Results show that at the end of first hour of the Baseline scenario evacuation, US 290, US 71, Loop 1, Loop 360, West Lake Drive, RM 620, and SH 45 on various locations experience severe slow-down. The extreme severe slow-down showed after the second and third hours. The remaining hours show free-flow traffic conditions.

In the Alternative 1 scenario, in the first, second, third, and fifth hours of the evacuation, many locations on Loop 360, Loop 1, US 290, and Southwest Pkwy experience moderate to severe slow-down. In the fourth hour, numerous locations experience severe slow-down. All other hours show free-flow traffic conditions.

In the Alternative 2 scenario, in the first and second hours of the evacuation, many locations on William Cannon Dr, Loop 1, US 290, and US 71 experience severe slow-down. In the third, fourth, and fifth hour of the evacuation, many locations on Loop 360, Loop 1, US 290, US 71, William Cannon Dr, and West Lake Dr experience severe slow-down. In the sixth hour, the complete route of Loop 360 experiences severe slow down. All other hours show free-flow traffic conditions.

In the Alternative 3 scenario, in the third and fourth hour of the evacuation, some locations on RM 1826, William Cannon Dr, US 290, and Loop 1 experience moderate to severe slow-down. In the fifth and sixth hour, most locations on Loop 360, US 290, US 71, and Loop 1 experience moderate to severe slow-down. In the seventh, eighth, and ninth hours, some locations on Loop 360 and Southwest Pkwy experience moderate to severe slow-down. In the sixth hour, most of the evacuation routes shows extreme/severe slow-down conditions. All other hours show free-flow traffic conditions.

Results show that moderate to severe slow-down congestion is observed in all four scenarios.

TRAFFIC CHARACTERISTICS IN THE CAMPO TRAVEL DEMAND MODEL

Some traffic characteristics produced by the CAMPO Travel Demand Model are included in order to address the RtePM model scenarios inability to adequately account for the effects of background traffic on evacuation time. Various PM peak-period (3:30 PM-6:30 PM) congestion measures from the 2015 CAMPO model that are on the major evacuation routes (US 71, US 290, Loop 1, Loop 360, and SH 45) can be used to estimate the effects of background traffic. These measures include traffic volumes, traffic patterns, and peaking characteristics. The 2015 CAMPO model PM peak-period traffic volumes are presented in **Figure 20**.

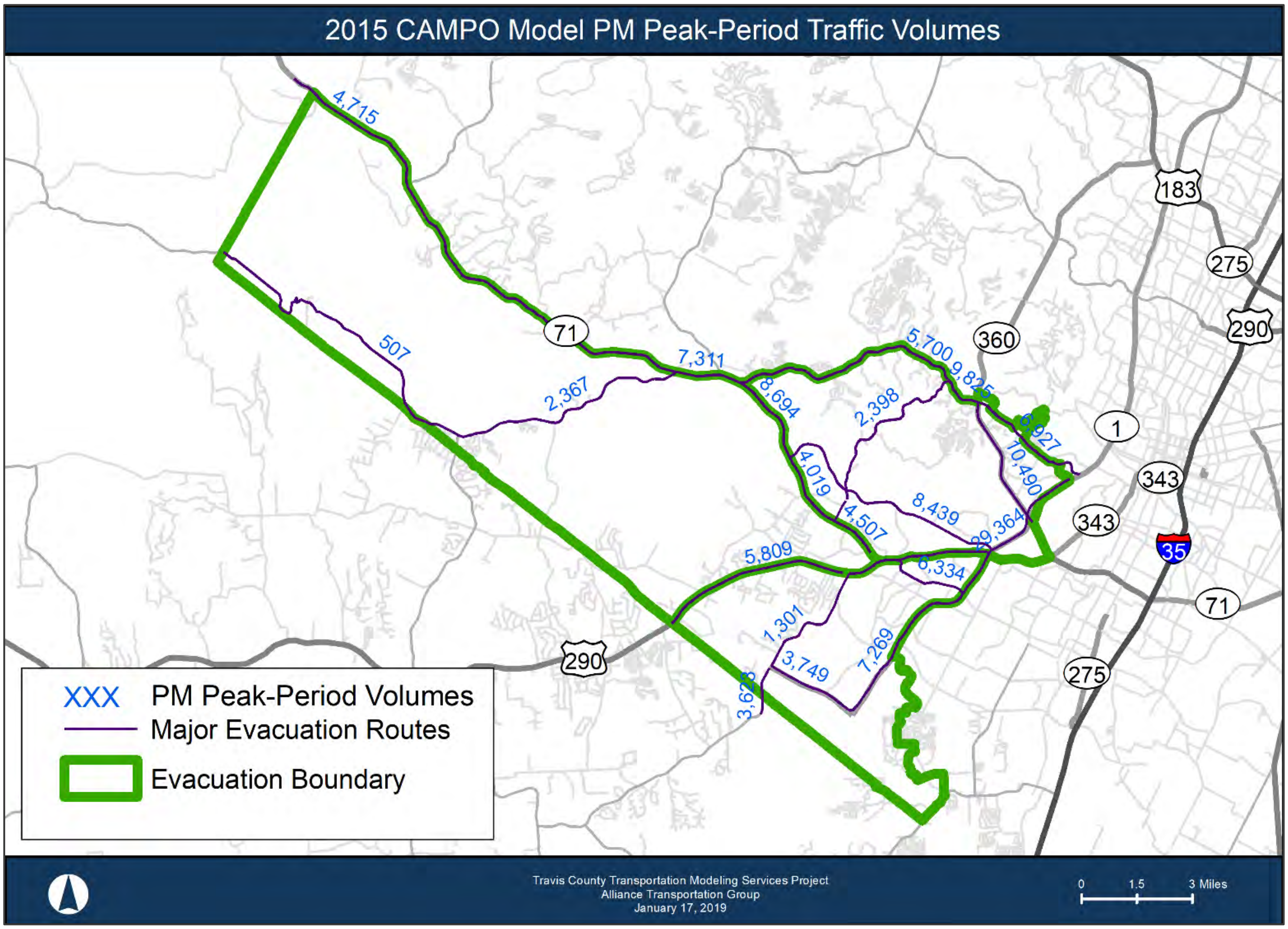


Figure 20: 2015 CAMPO Travel Demand Model PM Peak-Period Traffic Volume within Southwest Boundary

The 2015 CAMPO Model PM peak-period directional volume-to-capacity (V/C) ratios are presented in **Figure 21**. The directional V/C ratios represent the traffic volumes divided by the road capacity for all lanes traveling in the same direction. In **Figure 21** the red and blue numbers are the V/C ratios for the side of the road that they are next to. A V/C ratio of 1.00 indicates that the road is operating at its capacity. In practice, any facility with a V/C ratio greater than 0.90 may be identified as a congested facility. In addition to that, any facility with a V/C ratio less than 0.60 may be identified as a free-flow facility. The directional PM peak-period V/C ratios indicate that the major evacuation routes (US 71, US 290, Loop 1, and Loop 360) are in heavily congested. For example, the V/C ratio is 1.01 on a portion of Loop 1, which indicates that the facilities would be heavily congested with normal daily background traffic in the PM peak-period.

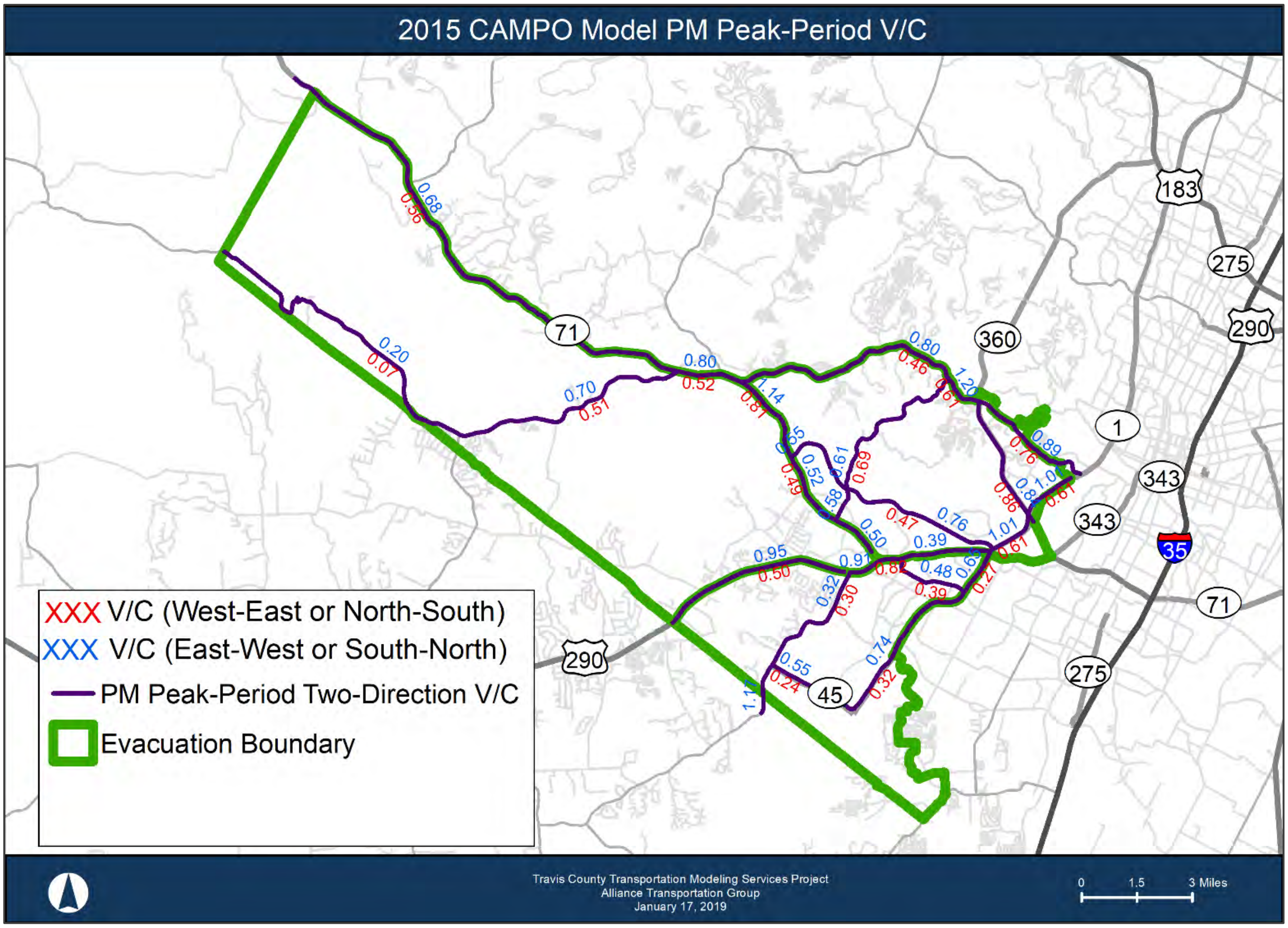


Figure 21: 2015 CAMPO Travel Demand Model Peak-Period V/C Ratios within Southwest Boundary

Furthermore, conceptual[5] travel-time bands were created using the 2015 CAMPO model PM peak-period congested travel time. Three conceptual travel-times bands are presented in **Figure 15**. The intersection of RM 3238 and Crumley Ranch Rd was chosen as an origin point for travel-time band calculations. This origin point was conceptually assumed to be a critical location for the study area. Each travel-time band shows the distance that can be traveled in the allotted time from the origin point. For example, the 20-minute travel-time band show the maximum distance a traveler can go within 20 minutes from the origin point location. This figure also indicates that during the PM peak-period, the entire scenario area lies within the 20-minute travel-time band. The travel-time bands are calculated using the average peak-period background traffic without the evacuation traffic. For example, if the background traffic produces V/C ratios over 0.90, then the addition of the evacuation traffic is going to produce heavy congestion. The additional traffic and congestion will reduce the distance traveled within the time period and cause the travel-time bands to shrink considerably. A review of the CAMPO model results indicates that the evacuation routes would be heavily congested condition during the PM peak-period and the actual evacuation time in a weekday afternoon event could be higher than the minimum time predicted by RtePM.

[5] *Conceptual travel-time bands do not account for natural barriers such as lakes and rivers.*

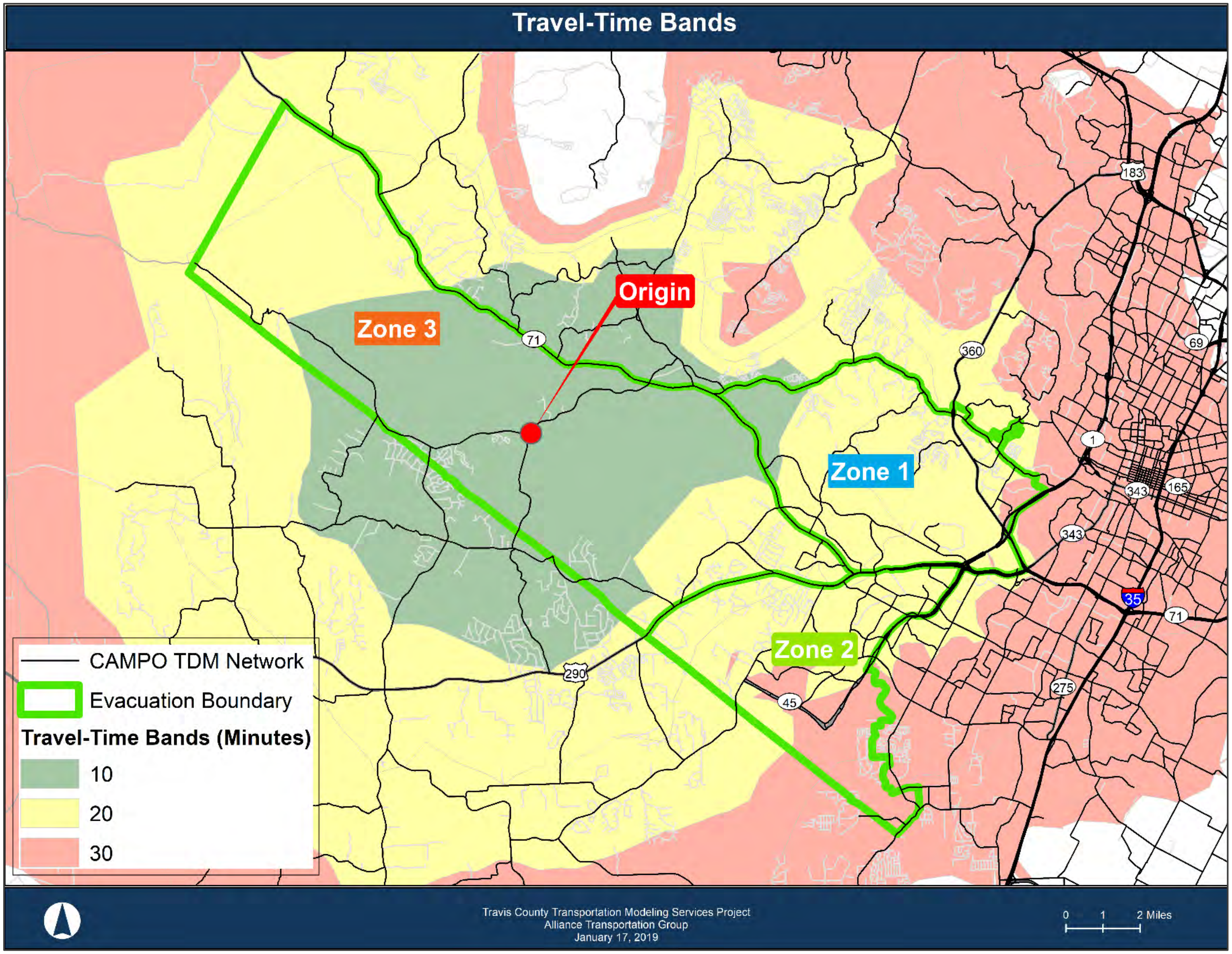


Figure 22: 2015 CAMPO Travel Demand Model Peak-Period Travel-Time Bands within Southwest Boundary

SUMMARY

In the Southwest scenario 126,394 people were evacuated. Evacuation summary results indicated that the total duration of the Baseline (non-phased) scenario would be at least 5.8 hours without heavy background traffic. All the Alternative scenarios would take longer than the Baseline scenario. The underlying assumption for the Baseline scenario, that all zones begin evacuating immediately, may lead to a higher rate of evacuation if there isn't heavy background traffic and the evacuation traffic does not cause heavy congestion on the evacuation routes. If there is significant background traffic or if the evacuation traffic causes heavy congestion, a phasing of the evacuation may result in higher rates of evacuation by metering the flow on the evacuation routes at a level that lessens the chance of breakdown from heavy congestion.

Tests were also conducted to evaluate the effects of the amount of population evacuated, the population participation rate during the evacuation and the number of evacuees per vehicle had on determining the evacuation time on the Baseline scenario. The results indicated that an increase or decrease in the number of people per vehicle, and/or the amount of population evacuating, or the rate of evacuation participation influences the evacuation clearance time proportionately. The minimum Baseline evacuation clearance time may vary from 1.8 hours to 5.8 hours depending on the number of evacuees per vehicle ranging five to one. The minimum Baseline evacuation clearance time may vary from 5.8 hours to 11.3 hours depending on the additional population increase above the existing 2018 population, ranging from no change to a 100 percent increase (double population) condition. The minimum Baseline evacuation clearance time may also vary from 2.1 hours to 5.8 hours depending on the evacuee participation rate ranging from 25 percent to 96 percent.

The review of exit points addressed percent usage during the evacuation for each exit-point and revealed major exit-points. Results indicated that the exit-point utilization followed a similar pattern across all scenarios. During the evacuation of all four scenarios, evacuation routes indicate moderate to severe slow-down for traffic flow in various hour and locations. The review of the CAMPO model results indicated that the evacuation routes would be heavily congested conditions during the PM peak-period and the actual evacuation time in a weekday afternoon event could be higher than the minimized time predicted by RtePM.

SOUTHEAST EVACUATION SCENARIO

The purpose of this chapter is to present the results of our analysis of the Southeast Fire Evacuation Scenario. For this analysis, Alliance used the RtePM Evacuation Model to estimate the minimum time that would be required to completely evacuate the area defined as the impact area for the Southeast Fire Evacuation Scenario. The Southeast fire evacuation boundary is illustrated in **Figure 23**, which also identifies the associated four zones. **Figure 24** shows the evacuation road network and roadway exit points that were considered during the evacuation.

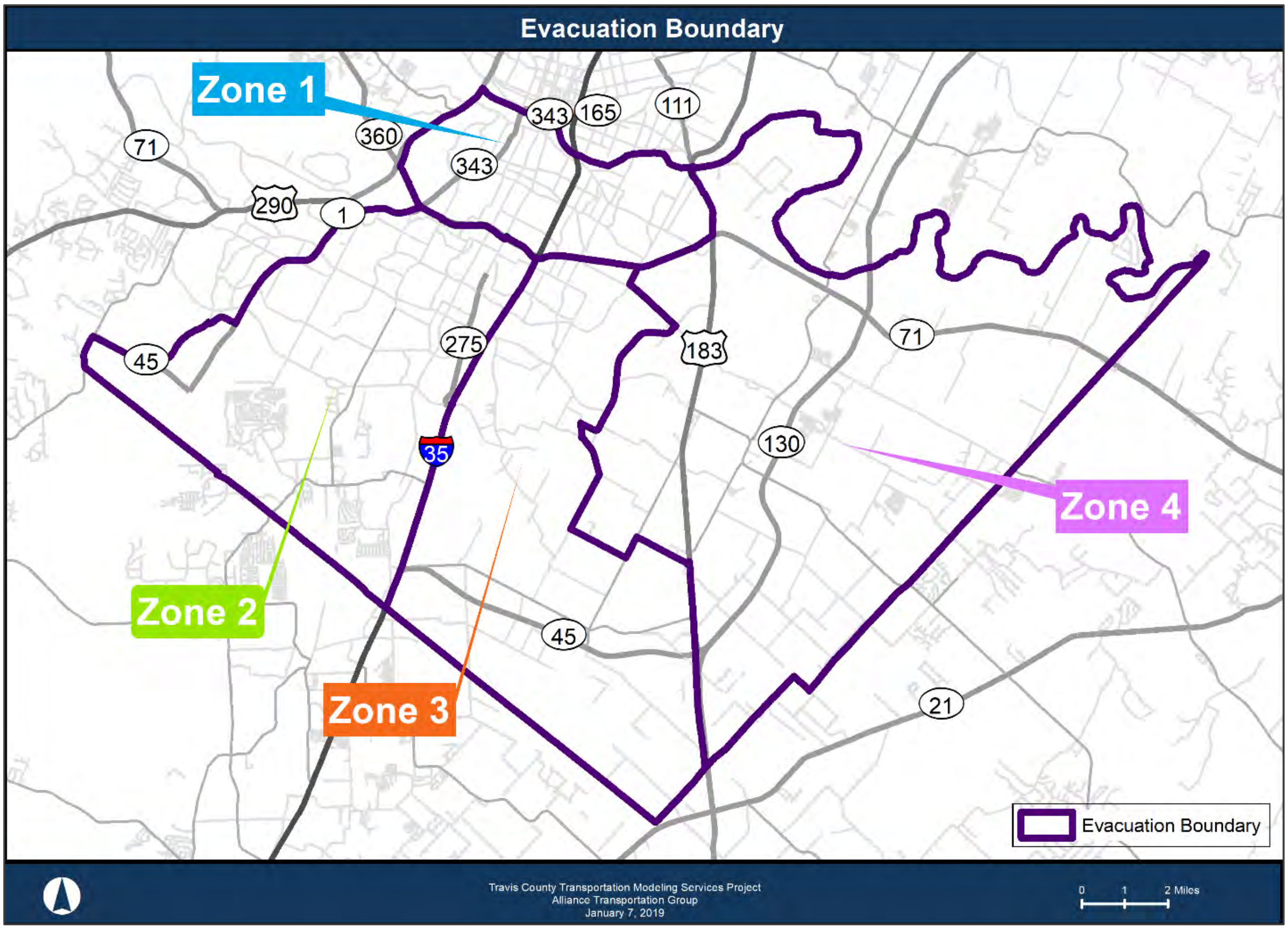


Figure 23: Geographic Boundary of Southeast Fire Scenario

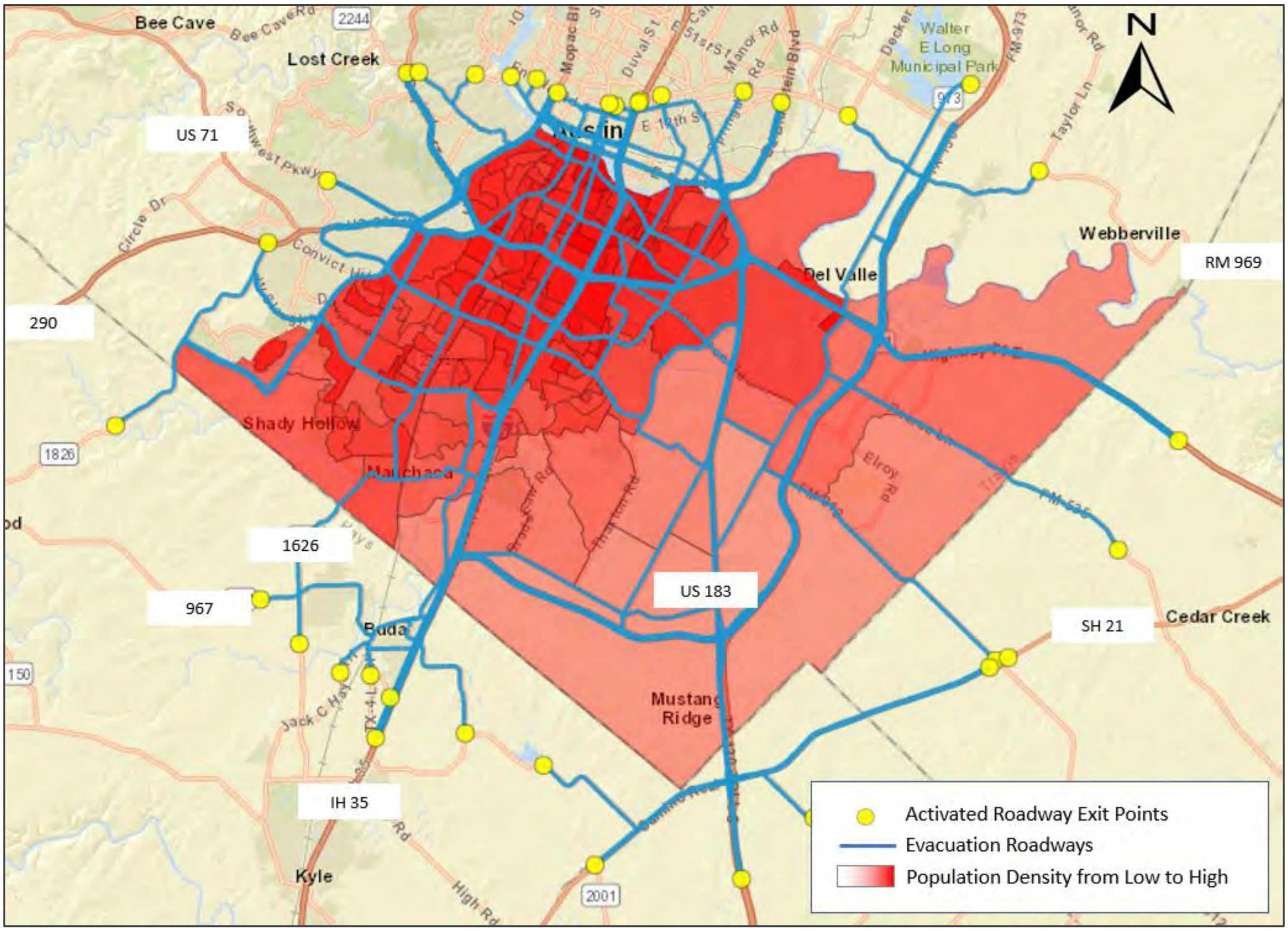


Figure 24: Road Network and Exit Points of Southeast Fire Scenario

SCENARIO DEFINITION

Using the earlier-mentioned parameters and assumptions in **Table 1** recommended by the Travis County staff, the “Baseline scenario” presented in **Table 20** was tested. No phasing of the evacuation zones was assumed, as recommended by the Travis County staff. Three additional alternative scenarios were tested, each with a three-phased evacuation option, and they are also described in **Table 20.**

Table 20: Definition of Southeast Simulation Scenarios

Scenario	Description of Scenario
Baseline Scenario (Non-Phased)	In addition to the parameter assumptions identified in **Table 1**, all four zones were considered to participate in the evacuation at the same time from the beginning of the fire. Consistent with the stakeholders meeting discussion, the fire is assumed to start during the afternoon peak period at 3:00 PM in the last week of August - considered to be a critical time for fire events.
Alternative Scenario 1 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the four zones is assumed to be planned and staggered by two hours for each. Zone 2 is assumed to start the evacuation at 1:00 PM, Zone 1 at 3:00 PM, Zone 3 at 5:00 PM, and Zone 4 at 7:00. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 2 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the four zones is assumed to be planned and staggered by two hours for each. Zone 1 is assumed to start the evacuation at 1:00 PM, Zone 2 at 3:00 PM, Zone 3 at 5:00 PM, and Zone 4 at 7:00. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.
Alternative Scenario 3 (Phased)	In addition to the assumptions and parameters considered in **Table 1**, the evacuation of the four zones is assumed to be planned and staggered by two hours for each. Zone 3 is assumed to start the evacuation at 1:00 PM, Zone 2 at 3:00 PM, Zone 1 at 5:00 PM, and Zone 4 at 7:00. As in the Baseline scenario, the fire is assumed to start during the afternoon peak period in the last week of August.

DEMOGRAPHIC DATA

Travis County provided the 2018 average day-time population, which does not include the school students. Alliance identified the following elementary, middle, and high schools and their enrollments. They are presented in Table 21.

Table 21: School Enrollments Statistics of Southeast Scenario

SL	Campus Name	Zone	2017-18 Number of Students
1	Allison Elementary School	1	479
2	Barton Hills Elementary School	1	453
3	Baty Elementary School	1	652
4	Becker Elementary School	1	437
5	Dawson Elementary School	1	349
6	Fulmore Middle School	1	998
7	Galindo Elementary School	1	586
8	Linder Elementary School	1	305
9	Texas School for The Deaf	1	538
10	Travis High School	1	1,233
11	Travis Hts Elementary School	1	517
12	Zilker Elementary School	1	547
13	San Juan Diego Catholic High School - Austin	1	167
14	St. Ignatius Martyr School	1	237
15	Akins High School	2	2,765
16	Bailey Middle School	2	1,006
17	Baldwin Elementary School	2	810
18	Baranoff Elementary School	2	1,013
19	Bedichek Middle School	2	846
20	Boone Elementary School	2	535
21	Bowie High School	2	2,880
22	Casey Elementary School	2	614
23	Covington Middle School	2	660
24	Cowan Elementary School	2	841
25	Crockett High School	2	1,466
26	Cunningham Elementary School	2	391
27	Eden Park Academy	2	399
28	Idea Allan Academy	2	716
29	Idea Allan College Preparatory	2	474

SL	Campus Name	Zone	2017-18 Number of Students
30	Joslin Elementary School	2	279
31	Kiker Elementary School	2	1,111
32	Kocurek Elementary School	2	578
33	Menchaca Elementary School	2	717
34	Odom Elementary School	2	463
35	Paredes Middle School	2	892
36	Pleasant Hill Elementary School	2	464
37	St Elementary School	2	297
38	Sunset Valley Elementary School	2	543
39	Williams Elementary School	2	466
40	Primrose School of Shady Hollow	2	48
41	Bannockburn Christian Academy	2	94
42	Bannockburn Christian School	2	58
43	Primrose School of Southwest Austin	2	48
44	Blazier Elementary School	3	858
45	Creedmoor Elementary School	3	640
46	Harmony School of Excellence	3	582
47	Harmony School of Innovation - Austin	3	432
48	Hillcrest Elementary School	3	560
49	Houston Elementary School	3	641
50	John P Ojeda J H	3	906
51	Kipp Austin Beacon Prep	3	453
52	Kipp Austin Leadership Elementary School	3	544
53	Kipp Austin Obras	3	590
54	Kipp Austin Vista Middle Schools	3	423
55	Langford Elementary School	3	540
56	Mendez Middle School	3	646
57	Palm Elementary School	3	449
58	Perez Elementary School	3	650
59	Real Learning Academy	3	678
60	Rodriguez Elementary School	3	503
61	Sci-Tech Preparatory	3	580
62	Smith Elementary School	3	731
63	Widen Elementary School	3	522
64	Del Valle Elementary School	4	794

SL	Campus Name	Zone	2017-18 Number of Students
65	Del Valle High School	4	3,126
66	Del Valle Middle	4	958
67	Popham Elementary School	4	760
Total			46,538

The student enrollment information was derived from public information available at the Texas Education Agency and the National Center for Education Statistics. The student enrollment for 2017-2018 was combined with the 2018 day-time population to form a 2018 target day-time population for the evacuation scenario. **Table 22** shows, by zone, the 96 percent of the target population for the Southeast evacuation scenario expected to participate during the evacuation.

Table 22: Target Day-Time Population of Southeast Scenario

	Total			Target (96 Percent)		
Zone	Day- Time Population Excluding School Students	School Students	Total Day-Time Population	Day- Time Population Excluding School Students	School Students	Total Day-Time Population
1	105,260	7,498	112,758	101,050	7,199	108,249
2	110,843	21,474	132,317	106,409	20,612	127,021
3	54,167	11,928	66,095	52,000	11,451	63,451
4	37,672	5,638	43,310	36,165	5,413	41,578
Total	307,942	46,538	354,480	295,624	44,675	340,299

RESULTS AND DISCUSSIONS

Minimum Evacuation Times

Evacuation summary results produced by the RtePM model scenario runs for the Baseline scenario and Alternative scenarios are provided in **Table 23** and **Table 24**. **Table 23** shows the evacuation times for the Baseline and Alternative scenarios. **Table 24** details by hour the total number of vehicles and population evacuated, remaining vehicles and population, and percent evacuated for each scenario. **Figure 25** shows the same information graphically. The tables and figure show how the 340,212 people or equivalent vehicles would be evacuated across different hours and scenarios.

The results include total duration of the evacuation for the Baseline scenario of 10.2 hours. The Alternative evacuation scenarios were also evaluated. It required approximately 11.8, 12.0, and 12.7 hours for Alternative scenarios 1, 2, and 3 respectively.

Table 23: Evacuation Clearance Time of Southeast Scenarios

Scenario	Evacuation Clearance Time (Hour)
Baseline	10.2
Alternative 1	11.8
Alternative 2	12.0
Alternative 3	12.7

Simulation results indicate that the Baseline evacuation scenario would take a minimum of roughly 10.2 hours to evacuate the evacuation boundary if there is only evacuation traffic and little to no background traffic on the evacuation roadways. In contrast, all the Alternative scenarios take more time than the Baseline scenario. **Table 24** provides more details about the evacuations for each of the four scenarios.

In the Baseline scenario, all four zones were assumed to participate in the evacuation at the same time from the beginning of the fire. This underlying assumption for the Baseline scenario may lead to higher evacuation rates as demonstrated in **Figure 25**. This figure provides useful information about how each evacuation scenario loads evacuating vehicles onto the road network and may help the County to make a reasonable decision on choosing the suitable scenario.

Figure 25 shows that at the end of the first hour of the Baseline evacuation, more than 10 percent of the population could potentially be evacuated. At the end of sixth hour of the Baseline evacuation, approximately 75 percent of the population could potentially be evacuated. Results for the three phased scenarios, Alternatives 1, 2 and 3 are also provided for comparison. The results for the Alternative scenarios provide information that could be useful when there is significant background traffic and phasing may be necessary to prevent overloading the evacuation routes.

The Alternative 3 scenario shows that after the sixth hour of the evacuation, only a little more than 50 percent of the evacuees would be cleared and that would probably mean valuable time is being lost at a time when the evacuation routes would be least congested. Alternatives 1 and 2 would take 11.8 and 12.0 hours respectively to evacuate, but the later evacuation rate is higher for Alternative 2 than for Alternative 1. This is likely to lead to an evacuation that is smoother and distributed. Based on the evacuation time, evacuation rate, and phasing choice, the Alternative 2 scenario appears to perform better in comparison to the Alternative 1 and 3 scenarios.

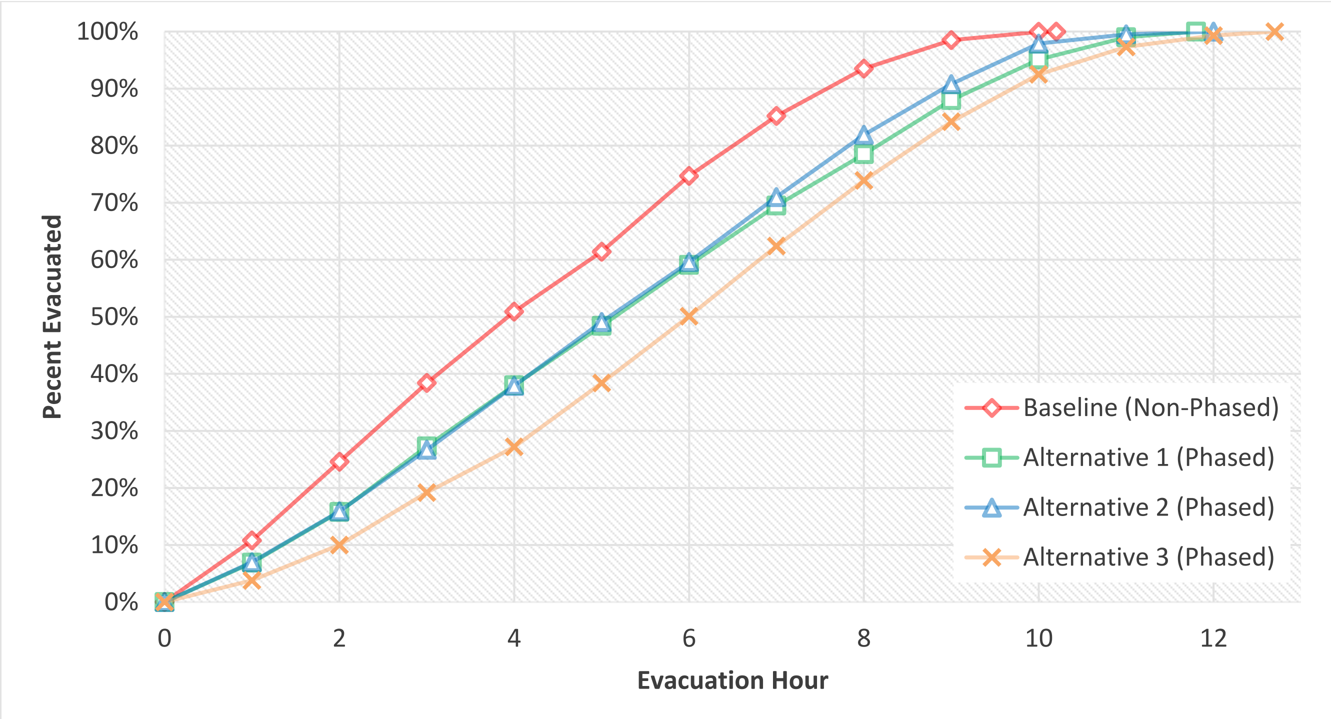


Figure 25: Evacuation Rate of Southeast Scenarios

Table 24 includes by hour the total number of vehicles and population evacuated, remaining vehicles and population, and percent evacuated for each scenario. **Table 24** shows how the 340,212 people or equivalent vehicles would be evacuated across different hours and scenarios.

Table 24: Summary Results for Southeast Fire Evacuation Scenarios for the Target Populations[6]

	Hours/Items	Start	1	2	3	4	5	6	7	8	9	10	10.2		
Baseline	Total Population Evacuated	0	36,911	83,597	130,699	173,231	208,965	254,153	289,949	318,185	335,220	340,050	340,212		
Baseline	Total Vehicles Evacuated	0	36,911	83,597	130,699	173,231	208,965	254,153	289,949	318,185	335,220	340,050	340,212		
Baseline	Remaining Population	340,212	303,301	256,615	209,513	166,981	131,247	86,059	50,263	22,027	4,992	162	0		
Baseline	Remaining Vehicles	340,212	303,301	256,615	209,513	166,981	131,247	86,059	50,263	22,027	4,992	162	0		
Baseline	Percent Evacuated	0	10.8	24.6	38.4	50.9	61.4	74.7	85.2	93.5	98.5	99.95	100.0		
Alternative 1	Hours/Items	Start	1	2	3	4	5	6	7	8	9	10	11	11.8	
Alternative 1	Total Population Evacuated	0	23,321	53,706	92,736	129,414	164,625	201,002	236,532	267,065	299,525	323,593	336,957	340,212	
Alternative 1	Total Vehicles Evacuated	0	23,321	53,706	92,736	129,414	164,625	201,002	236,532	267,065	299,525	323,593	336,957	340,212	
Alternative 1	Remaining Population	340,212	316,891	286,506	247,476	210,798	175,587	139,210	103,680	73,147	40,687	16,619	3,255	0	
Alternative 1	Remaining Vehicles	340,212	316,891	286,506	247,476	210,798	175,587	139,210	103,680	73,147	40,687	16,619	3,255	0	
Alternative 1	Percent Evacuated	0	6.9	15.8	27.3	38	48.4	59.1	69.5	78.5	88.0	95.1	99.0	100.0	
Alternative 2	Hours/Items	Start	1	2	3	4	5	6	7	8	9	10	11	12	
Alternative 2	Total Population Evacuated	0	23,712	54,049	90,723	129,058	166,935	202,856	241,718	278,508	309,079	330,607	338,377	340,212	
Alternative 2	Total Vehicles Evacuated	0	23,712	54,049	90,723	129,058	166,935	202,856	241,718	278,508	309,079	330,607	338,377	340,212	
Alternative 2	Remaining Population	340,212	316,500	286,163	249,489	211,154	173,277	137,356	98,494	61,704	31,133	9,605	1,835	0	

[6] *Target total number of evacuees was 340,299. RtePM simulation evacuated 340,212 evacuees. In this scenario, 87 evacuees found to be a rounding error.*

	Remaining Vehicles	340,212	316,500	286,163	249,489	211,154	173,277	137,356	98,494	61,704	31,133	9,605	1,835	0	
	Percent Evacuated	0	7.0	15.9	26.7	37.9	49.1	59.6	71.0	81.9	90.8	97.9	99.5	100.0	
Alternative 3	Hours/Items	Start	1	2	3	4	5	6	7	8	9	10	11	12	12.7
	Total Population Evacuated	0	12,794	34,071	65,312	92,581	130,717	170,336	212,293	251,300	286,536	314,641	330,896	337,877	340,212
	Total Vehicles Evacuated	0	12,794	34,071	65,312	92,581	130,717	170,336	212,293	251,300	286,536	314,641	330,896	337,877	340,212
	Remaining Population	340,212	327,418	306,141	274,900	247,631	209,495	169,876	127,919	88,912	53,676	25,571	9,316	2,335	0
	Remaining Vehicles	340,212	327,418	306,141	274,900	247,631	209,495	169,876	127,919	88,912	53,676	25,571	9,316	2,335	0
	Percent Evacuated	0	3.8	10.0	19.2	27.2	38.4	50.1	62.4	73.9	84.2	92.5	97.3	99.3	100.0

Exit Points

As evacuees reach an exit point, the size of the yellow circle indicators expands (e.g., Appendix H2) relative to the number of evacuees reaching or passing through that destination. Evacuation exit point percent usage during the evacuation is illustrated in **Figure 26**. Alternative-scenario results are included to compare the percent evacuation at each exit point. Results indicated that the exit-point utilization followed a similar pattern across all scenarios. Among the thirty-four evacuation exit points in the Baseline scenario, the highest-demand exit point, which is IH 35 South, is used by more than 12 percent of the evacuees. US 183 South, US 183 North, Loop 360 South, IH 35 North, and Southwest Parkway are also heavily used with each getting approximately six to eight percent of the evacuation traffic.

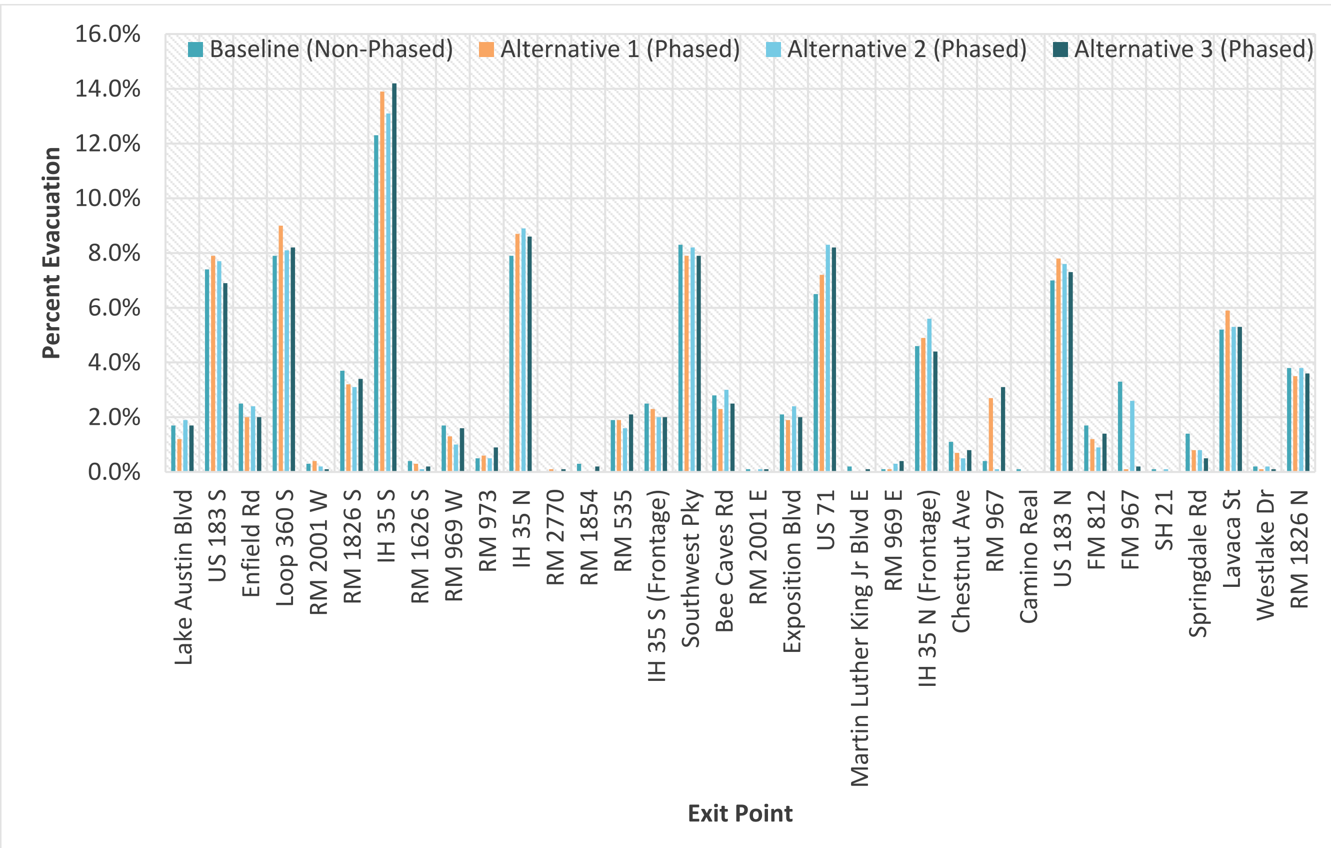


Figure 26: Exit Point Usage for the Southeast Scenarios

Population Block Groups

Due to the limited data extraction capability from the software and considering less usefulness of the results, this scenario did not include a table showing how each zone and block group clear in terms of cumulative percentage cleared by hour. However, the appendix to this memorandum contains a visual representation. Exhibits G1 through G12 show how the evacuation is progressing at the end of each hour during the evacuation. In the exhibits, the population block groups appear in varying shades of black color corresponding to the density of population to be evacuated. As the evacuation progresses, the population block group becomes lighter until all evacuees have cleared the area, indicated by a white color. Results show that every census block group participated from the beginning of the evacuation. Results show that at the end of the first and second hours of the Baseline scenario, none of the census block group evacuated completely. At the end of third hour, there are seven census block groups that completed evacuation. By the end of the 10.2 hour, all census block groups completed evacuation.

Road Segments

The loading of the internal road network during the Baseline scenario evacuation is illustrated in the Appendix in H1 through H12. In these exhibits, green road segments indicate that traffic is moving at normal free flow speeds, yellow road segments indicate that there has been a moderate slow-down, and red road segments indicate that there has been a severe slow down.

In the Baseline scenario, there were moderate to severe slow-down conditions in one or multiple locations on the following listed evacuation routes by hour:

- First hour - US 290, Loop 360, IH 35, Loop 1, and US 71
- Second hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 130, and US 183
- Third, Fourth, or Fifth hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 130, US 183, SH 45, and William Cannon Dr
- Sixth or Seventh hour - US 290, Loop 360, IH 35, Loop 1, and US 71
- Eighth hour - US 290, Loop 360, IH 35, Loop 1, and US 71
- Ninth hour - US 290, Loop 360, IH 35, and Loop 1
- Tenth hour- Loop 360 and IH 35
- Eleventh hour- none

In the Alternative 1 scenario, there were moderate to severe slow-down conditions occurred in one or multiple locations on the following listed evacuation routes by hour:

- First hour - US 290, Loop 360, IH 35, Loop 1, and US 71
- Second hour - US 290, Loop 360, IH 35, Loop 1, US 71, and US 183
- Third hour- US 290, Loop 360, IH 35, Loop 1, and US 71
- Fourth, Fifth, or Sixth hour - US 290, Loop 360, IH 35, Loop 1, US 71, Riverside Dr, Stassney Ln, Brodie Ln, Oltorf St E, Congress Ave S, and McKinney Falls Pkwy
- Seventh hour - US 290, Loop 360, IH 35, Loop 1, US 71, Riverside Dr, Stassney Ln, Brodie Ln, Oltorf St E, and Congress Ave S, McKinney Falls Pkwy, US 183, and Todd Ln
- Eighth hour - US 290, Loop 360, IH 35, Loop 1, US 71, Riverside Dr, Stassney Ln, Brodie Ln, Oltorf St E, and Congress Ave S, McKinney Falls Pkwy, US 183, Pearce Ln, and RM 973
- Ninth hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, Pearce Ln, RM 973, William Cannon Dr, and US 130
- Tenth hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, RM 973, William Cannon Dr, and US 130
- Eleventh hour - US 290, IH 35, Loop 1, US 71, and US 183
- Twelfth hour - None

In the Alternative 2 scenario, there were moderate to severe slow-down conditions occurred in one or multiple locations on the following listed evacuation routes by hour:

- First hour - US 290, Loop 360, IH 35, and US 71
- Second hour - US 290, Loop 360, IH 35, Loop 1, US 71
- Third or Fourth hour- US 290, Loop 360, IH 35, Loop 1, US 71, 1st St S, Riverside Dr, Oltorf St E
- Fifth hour - US 290, Loop 360, IH 35, Loop 1, US 71, Stassney Ln, William Cannon Dr, and 1st St S

- Sixth hour - US 290, Loop 360, IH 35, Loop 1, US 71, Stassney Ln, William Cannon Dr, and 1st St S, McKinney Falls Pkwy, and Old San Antonio Rd
- Seventh hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, Stassney Ln, William Cannon Dr, and 1st St S, McKinney Falls Pkwy, and RM 1626
- Eighth hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, US 130, RM 812, Colton Bluff Springs Rd, Cannon Rd, and Stassney Ln
- Ninth or Tenth hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, US 130, William Cannon Dr, Colton Bluff Springs Rd, Stassney Ln, and Nichols Crossing Rd
- Eleventh hour - US 290, US 71, Stassney Ln, Todd Ln, and RM 812
- Twelfth hour - None

In the Alternative 3 scenario, there were moderate to severe slow-down conditions occurred in one or multiple locations on the following listed evacuation routes by hour:

- First hour - US 71, William Cannon Dr, and Montopolis Dr, and Todd Ln
- Second hour – IH 35, William Cannon Dr, Stassney Ln, Todd Ln, and McKinney Falls Pkwy
- Third hour- US 290, US 71, Loop 360, IH 35, and Loop 1
- Fourth hour - US 290, Loop 360, IH 35, Loop 1, US 71, Slaughter Ln, Manchaca Rd, and Stassney Ln
- Fifth hour - US 290, Loop 360, IH 35, Loop 1, US 71, Riverside Dr, Stassney Ln, and Slaughter Ln
- Sixth hour - US 290, Loop 360, IH 35, Loop 1, US 71, Stassney Ln, Riverside Dr, Montopolis Dr, and Burleson Rd
- Seventh hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, Stassney Ln, Slaughter Ln, Brodie Ln, and Oltorf St
- Eighth hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, US 130, RM 1626, Stassney Ln, Slaughter Ln, Oltorf St, Riverside Dr, and RM 812
- Ninth hour - US 290, Loop 360, IH 35, Loop 1, US 71, US 183, US 130, Stassney Ln, Oltorf St, and Riverside Dr
- Tenth hour - US 290, Loop 360, IH 35, Loop 1, US 71, and Riverside Dr
- Eleventh hour - Loop 360, IH 35, Loop 1, US 71, and Riverside Dr
- Twelfth hour - US 71 and Riverside Dr
- Thirteenth hour - None

TRAFFIC CHARACTERISTICS IN THE CAMPO TRAVEL DEMAND MODEL

Some traffic characteristics produced by the CAMPO Travel Demand Model are included in order to address the RtePM model scenarios inability to adequately account for the effects of background traffic on evacuation time. Various PM peak-period (3:30 PM-6:30 PM) congestion measures from the 2015 CAMPO model that are on the major evacuation routes (IH 35, US 183, US 71, US 290, US 130, Loop 360, Loop 1, SH 45, and so forth) can be used to estimate the effects of background traffic. These measures include traffic volumes, traffic patterns, and peaking characteristics. The 2015 CAMPO model PM peak-period traffic volumes are presented in **Figure 27**.

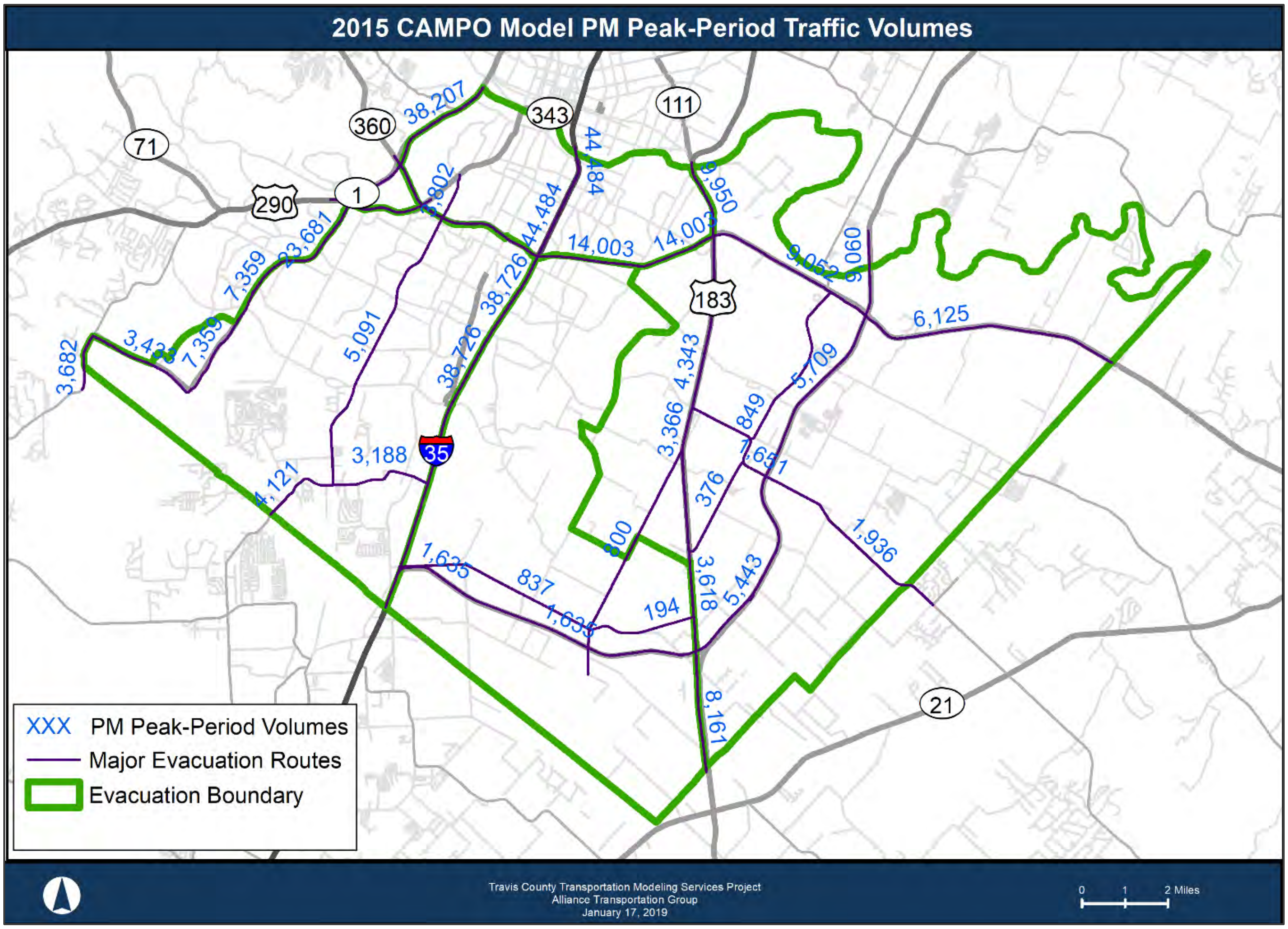


Figure 27: 2015 CAMPO Travel Demand Model PM Peak-Period Traffic Volumes within Southeast Boundary

The 2015 CAMPO Travel Demand Model PM peak-period directional volume-to-capacity (V/C) ratios are presented in **Figure 28**. The directional V/C ratios represent the traffic volumes divided by the road capacity for all lanes traveling in the same direction. In **Figure 28** the red and blue numbers are the V/C ratios for the side of the road that they are next to. A V/C ratio of 1.00 indicates that the road is operating at its capacity. In practice, any facility with a V/C ratio greater than 0.90 may be identified as a congested facility. In addition to that, any facility with a V/C ratio less than 0.60 may be identified as a free-flow facility. The directional PM peak-period V/C ratios indicate that the major evacuation routes (IH 35, US 71, US 290, Loop 360, Loop 1, and so forth) are heavily congested with normal daily background traffic in the PM peak-period. For example, the V/C ratio is 1.07 on portion of IH 35, which indicates that the facilities would be heavily congested with normal daily background traffic in the PM peak-period.

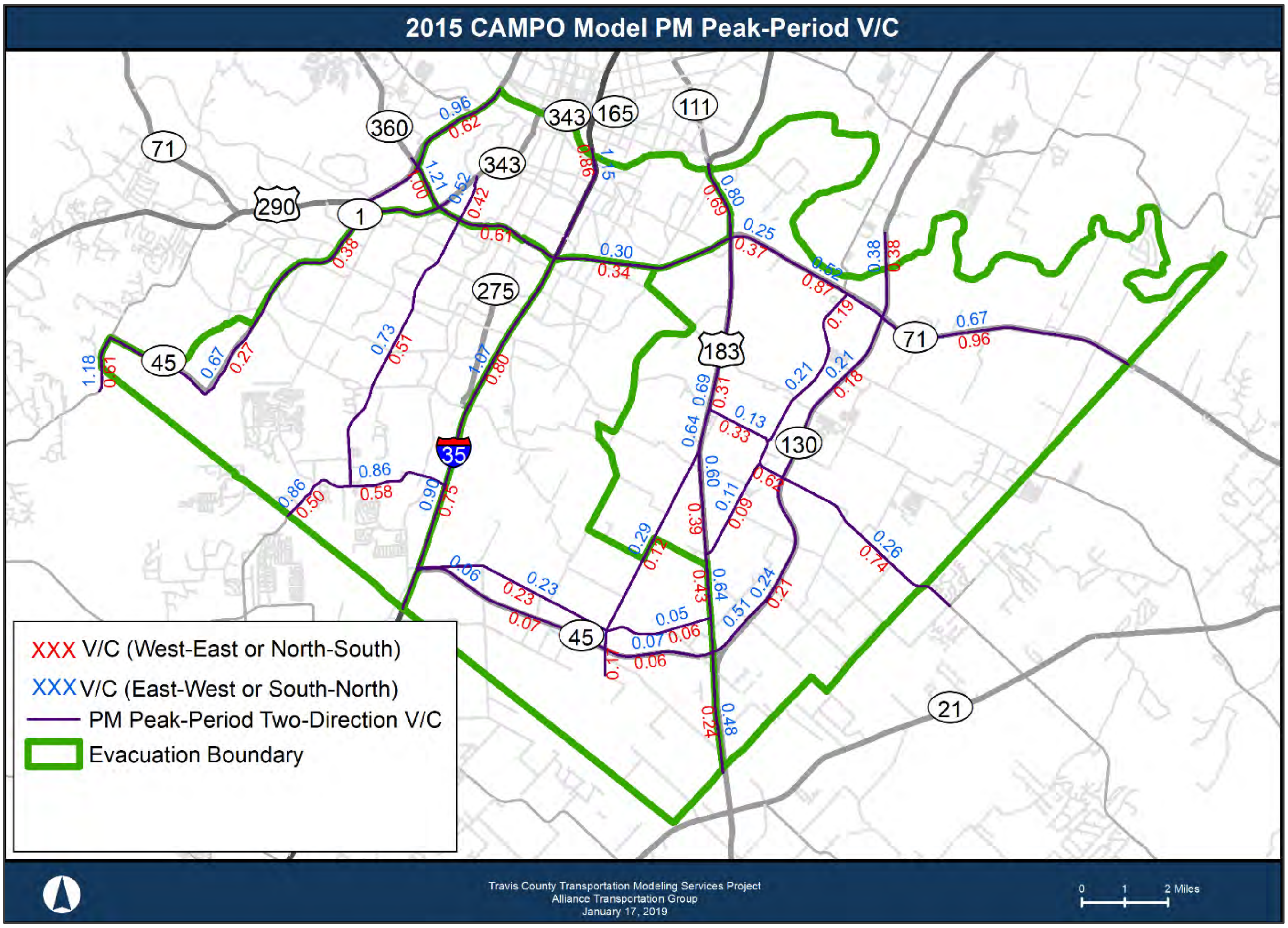


Figure 28: 2015 CAMPO Travel Demand Model Peak-Period V/C Ratios within Southeast Boundary

Furthermore, conceptual[7] travel-time bands were created using the 2015 CAMPO model PM peak-period congested travel time. Three conceptual travel-times bands are presented in **Figure 29**. The Austin-Bergstrom International Airport was chosen as an origin point to develop the travel-time bands. This origin point was conceptually assumed to be a critical location for the study area. Each travel-time band shows the distance that can be traveled in the allotted time from the origin point. For example, the 20-minute travel-time band show the maximum distance a traveler can go within 20 minutes from the origin point location. This figure also indicates that during the PM peak-period, the entire scenario area lies within the 30-minute travel-time band. The travel-time bands are calculated using the average peak-period background traffic without the evacuation traffic. For example, if the background traffic produces V/C ratios over 0.90, then the addition of the evacuation traffic is going to produce heavy congestion. The additional traffic and congestion will reduce the distance traveled within the time period and cause the travel-time bands to shrink considerably. A review of the CAMPO model results indicates that the evacuation routes would be heavily congested condition during the PM peak-period and the actual evacuation time in a weekday afternoon event could be higher than the minimum time predicted by RtePM.

[7] *Conceptual travel-time bands do not account for natural barriers such as lakes and rivers.*

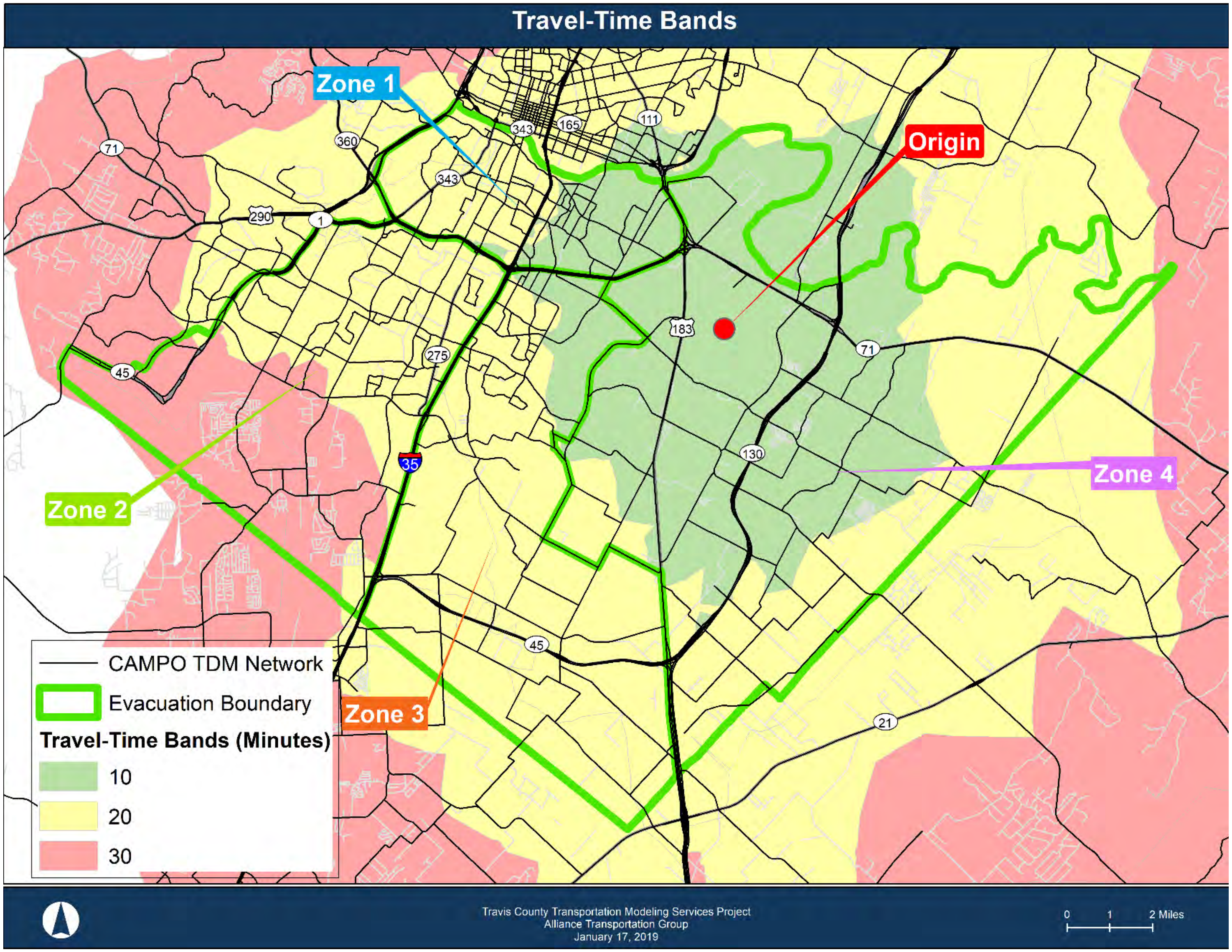


Figure 29: 2015 CAMPO Travel Demand Model Peak-Period Travel-Time Bands within Southeast Boundary

SUMMARY

In the Southeast Scenario 340,212 people are evacuated. Evacuation summary results indicated that the total duration of the Baseline (non-phased) scenario would be at least 10.2 hours without heavy background traffic. Evacuation in all the Alternative scenarios would take longer than the Baseline scenario. The underlying assumption for the Baseline scenario, that all zones begin evacuating immediately, may lead to a higher rate of evacuation if there isn't heavy background traffic and the evacuation traffic does not cause heavy congestion on the evacuation routes. If there is significant background traffic or if the evacuation traffic causes heavy congestion, a phasing of the evacuation may result in higher rates of evacuation by metering the traffic flow on the evacuation routes at a level that lessens the chance of transportation system breakdown from heavy congestion.

Tests were also conducted to evaluate the effects of the amount of population evacuated, the population participation rate during the evacuation and the number of evacuees per vehicle had on determining the evacuation time on the Baseline scenario. The results indicated that an increase or decrease in the number of people per vehicle, and/or the amount of population evacuating, or the rate of evacuation participation influences the evacuation clearance time proportionately. The minimum Baseline evacuation clearance time may vary from 3.2 hours to 10.2 hours depending on the number of evacuees per vehicle ranging five to one. The minimum Baseline evacuation clearance time may vary from 10.2 hours to 19.8 hours depending on the additional population increase above the existing 2018 population, ranging from no change to a 100 percent increase (double population) condition. The minimum Baseline evacuation clearance time may also vary from 4.5 hours to 10.2 hours depending on the evacuee participation rate ranging from 25 percent to 96 percent.

The review of exit points addressed percent usage during the evacuation for each exit point and revealed major exit points. Results indicated that the exit-point utilization followed a similar pattern across all scenarios. During the evacuation of all four scenarios, evacuation routes indicate moderate to severe slow-down for traffic flow in various hour and locations. The review of the CAMPO model results indicated that the evacuation routes would be heavily congested conditions during the PM peak-period and the actual evacuation time in a weekday afternoon event could be higher than the minimized time predicted by RtePM.

RTEPM CAPABILITIES AND LIMITATIONS

The RtePM software can provide valuable information for evacuation planning. The software is particularly useful in the following ways:

- Using already-assembled data, RtePM can identify the likely population that would be subject to evacuation at a particular time of day and their approximate location within the evacuation area.
- RtePM can identify most of the roadways that could serve as evacuation routes and route evacuating vehicles over the appropriate routes given the number of vehicles evacuating.
- RtePM can reflect national research on how people respond to evacuation orders to estimate the time it will take for evacuees to start their evacuation.
- RtePM can estimate the minimum time for evacuation of an area based on the phasing of the evacuation and the user-specified values for evacuation parameters such as time of day of the event, evacuees per vehicle, Percent of evacuees not using private vehicles, percent of evacuating vehicle pulling trailers, percent of people in the impact area evacuating, percent of evacuating vehicles going to shelters in the impact area.

While RtePM has potential application for use in evacuation planning, the software also has the following limitations that affect its applicability:

- Block group geography is the lowest level that can be used to define evacuation area, and this limits the definition of the evacuation area zones.
- Population adjustments from the 2010 population levels can only be made up to 100 percent for an evacuation area. In some fast-growing areas of Travis County, some block groups have had population increases since 2010 of greater than 100 percent. In addition to that, during the sensitivity testing various population adjustments are necessary, especially for each school location. In these cases, a laborious model setup is necessary to reflect the current population.
- Adding a new evacuation route to the model proprietary routes is tedious and limited to the given node points of the RtePM road network. Due to this limitation, not all roads can be included in the evacuation routes.
- Although RtePM has a method for reflecting the impact of background traffic on evacuation times, testing showed that the model is not sensitive to the actual background traffic patterns in the evacuation area at the time of day for which the evacuation is being simulated.
- Although RtePM has a method for reflecting the impact of traffic crashes on evacuation times as well, the study showed that the model does not adequately account for the effects of crashes.

CONCLUSIONS

The primary objective of this study was to identify the minimum time required to clear the evacuation area for four fire evacuation scenarios. The areas considered for these evacuation scenarios are each wildfire risk areas in Travis County. Consistent with the project stakeholders meeting discussion, the fires were each assumed to start during the afternoon peak period at 3:00 PM in the last week of August - considered to be a critical time for fire events.

To assist Travis County, Alliance modeled four evacuation scenarios (Northeast, Northwest, Southwest, and Southeast) in a simulation environment using the program RtePM Evacuation Model. These four scenarios represented a wide variety of evacuation areas and allowed the evaluation team on opportunity to see how variations in characteristics produce variations in results. The scenarios had a wide range in population in the impact area at the time of the fire, which is presented in **Table 25**.

Table 25: Evacuation Clearance Time Summary

Scenario	Target Populations	Minimum Evacuation Time	Maximum Evacuation Time
Northeast	20,055	2.2 hours	6.5 hours
Northwest	81,798	3.4 hours	7.1 hours
Southwest	126,394	5.8 hours	9.8 hours
Southeast	340,212	10.2 hours	12.7 hours

The scenarios with the highest number of people in the impact area had more congestion resulting from the evacuation despite also having a more extensive network of evacuation routes. As a result, the minimum evacuation times without heavy background traffic included tended to be significantly longer. Use of available CAMPO model data also indicated that there is more likely to be significant background traffic for the scenarios with the higher population in the impact area.

The assumptions and parameters used in the RtePM modeling were developed by the project stakeholders. To develop the scenario, the average number of people in each vehicle during the evacuation was assumed to be 1.0; 96 percent of the day-time population in the area was assumed to participate in the evacuation; 100 percent of the evacuees were assumed to leave the evacuation zone using private transportation; none of the evacuees were assumed to use public transportation, or walk, or go to shelter locations during the evacuation; and school students were assumed to evacuate the schools during an evacuation.

In each of four evacuation scenarios, using the assumed realistic parameters and assumptions, phasing and non-phasing conditions were tested. In the non-phasing conditions, all evacuees were considered to participate in the evacuation at the same time from the beginning of the fire. In contrast, in the phasing conditions, three alternative conditions were tested, where there was a two-hour time lapse between the evacuation of each zone in a given scenario. Three alternative scenarios were chosen in such a way so that the maximum number of evacuees could be evacuated as early as possible. This study revealed that shortest or minimum evacuation clearance time could be achieved with the non-phasing option for all four scenarios with the absence of significant background traffic.

It can be inferred that the non-phasing evacuation condition would take less evacuation time to evacuate the evacuation boundary if there is only evacuation traffic and little to no background traffic on the evacuation roadways than the phasing condition. In contrast, all the phased scenarios would take longer - in some cases almost triple the time of the non-phased scenarios. The differences in phasing and non-phasing evacuation time for each scenario can be used to evaluate a suitable evacuation plan for each of the four scenarios. The evacuation rates provide useful information about how each evacuation scenario loads evacuating vehicles onto the road network, which may help the County to make a reasonable decision on choosing a suitable phasing plan as well.

The evacuation simulations without heavy background traffic indicates moderate to severe slow-down along the evacuation routes at various hours and locations. The CAMPO Travel Demand Model was used to estimate the likely level of background traffic on the evacuation routes. The CAMPO model results indicate that the evacuation routes would be free-flow condition in the Northeast scenario but heavily congested in the Northwest, Southwest, and Southeast scenario during the PM peak-period. Based on the travel-time band analysis, it may take around 20-30 minutes to exit the scenario geographic area during the PM peak-hours on a normal day without the evacuation event. In an actual event of fire evacuation, this time could be higher. This time should be considered while making a decision about a suitable evacuation phasing plan.

In conclusion, the resulting evacuation time produced by RtePM represents a minimized evacuation time. This is useful information for Travis County and its stakeholders in the development of a successful evacuation plan. However, there are many factors that could increase the evacuation clearance time. For example, availability of evacuation routes, type of evacuation (phased or non-phased), geographic area to be evacuated, amount of day-time population, evacuee response rate, amount of background traffic, and number and severity of collisions on the evacuation routes could affect the evacuation time. Depending on the actual time of day an evacuation occurs, the evacuation time can be much longer than estimated by the RtePM model. The combination of information from RtePM on where congestion from just the evacuating traffic would most likely occur and the information on location and extent of peak-period background congestion from the CAMPO model can help Travis County identify the locations in the roadway network that would be the highest priority for capacity improvements to support emergency evacuations.

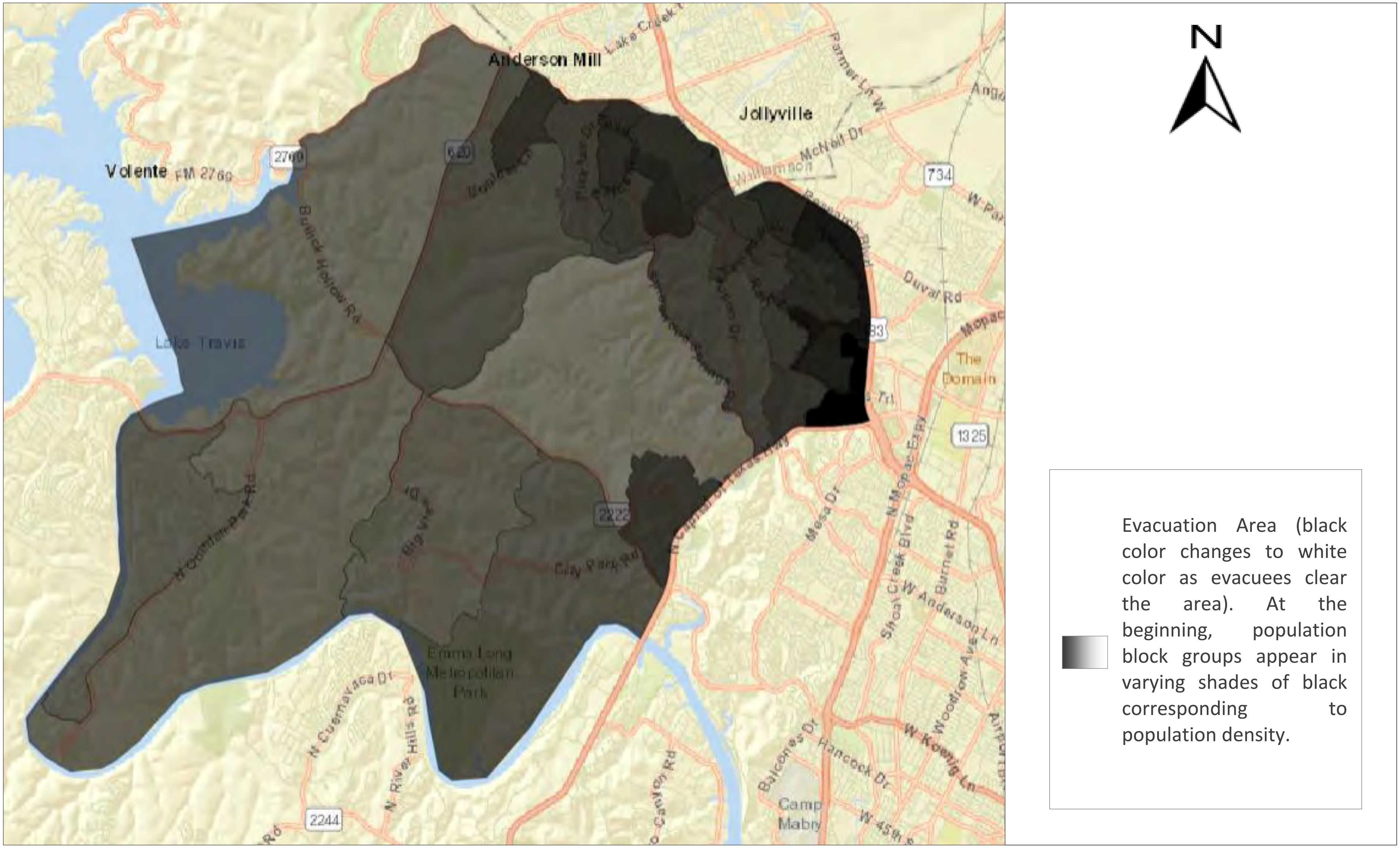
REFERENCES

[1] VMASC, "Real Time Evacuation Planning Model User's Guide VMASC Version 2.0," Suffolk, 2013.

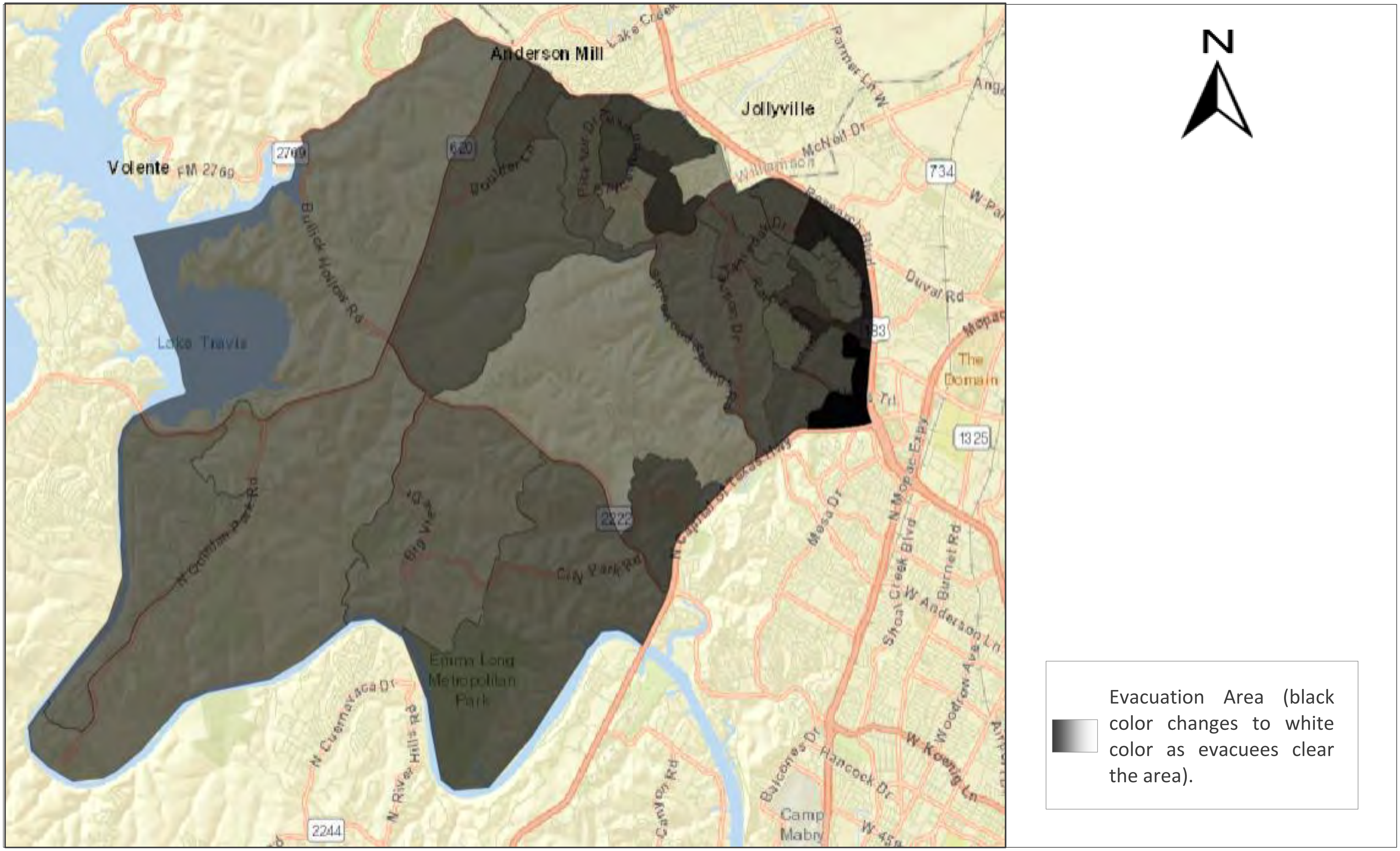
[2] Capital Area Metropolitan Planning Organization (CAMPO), *CAMPO 2010 TDM,* Austin, TX.

APPENDIX

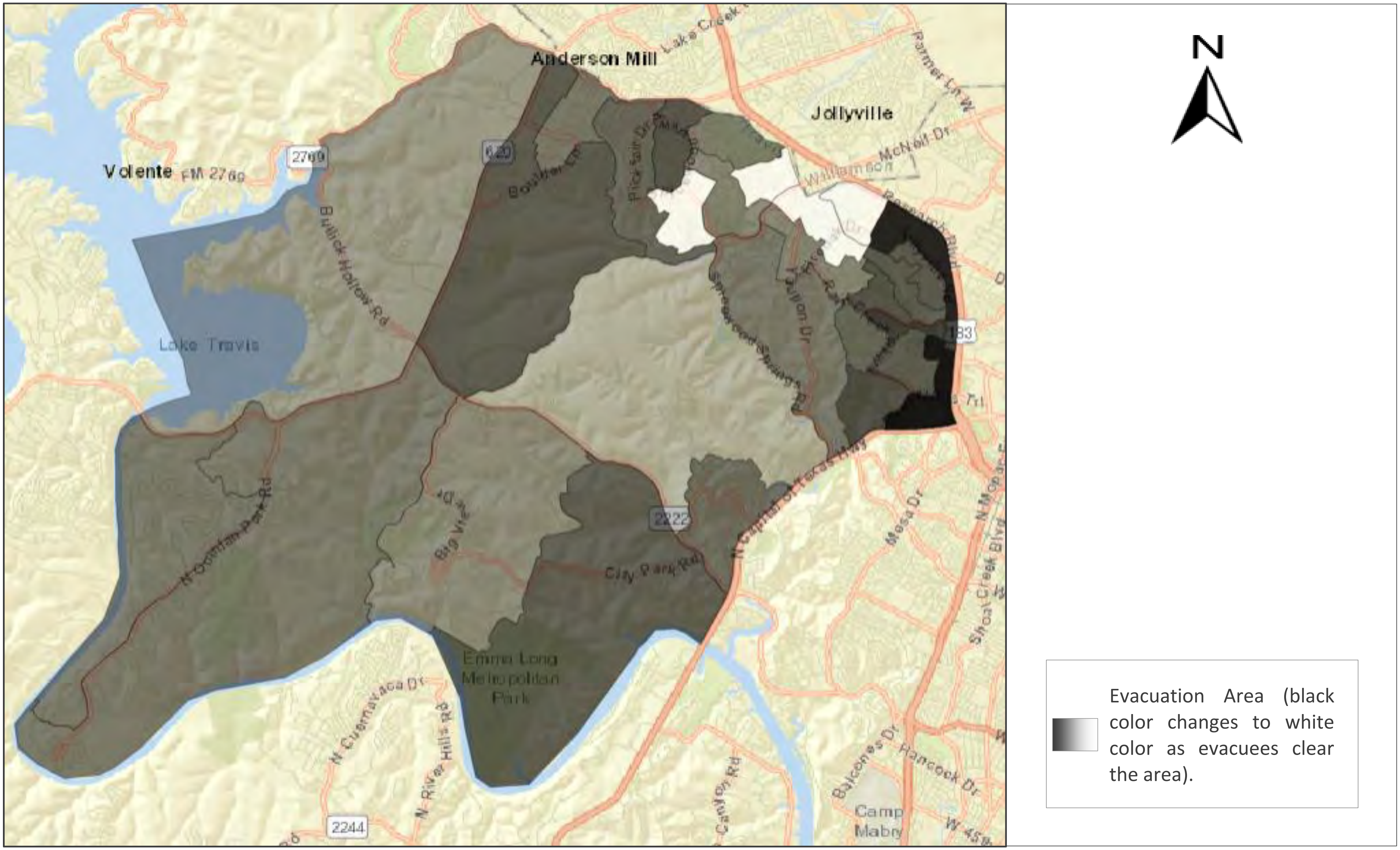
A1. Census Block Group Condition at the Beginning of the Evacuation (Northwest Scenario)



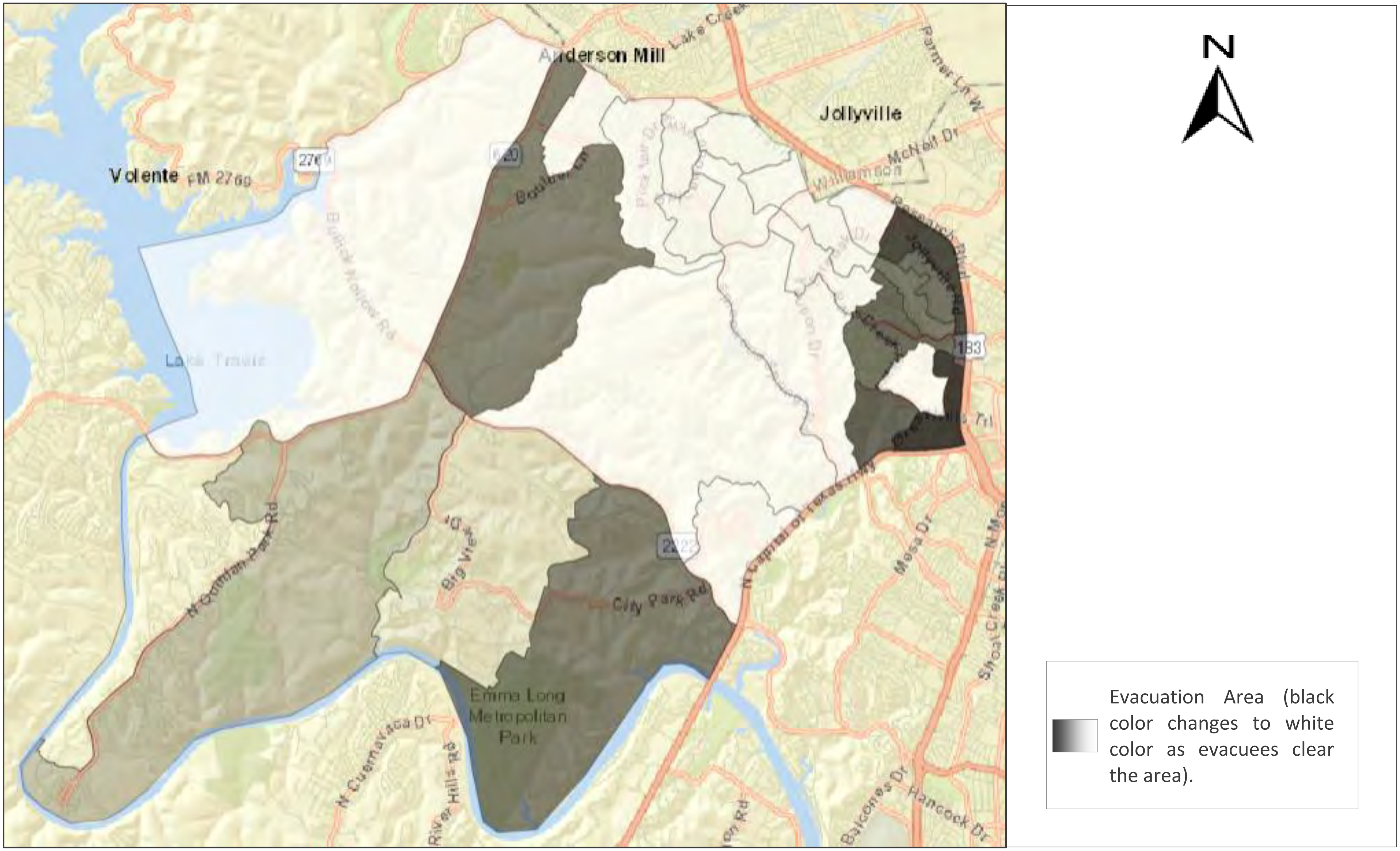
A2. Census Block Group Condition in the 1st Hour of Evacuation (Northwest Scenario)



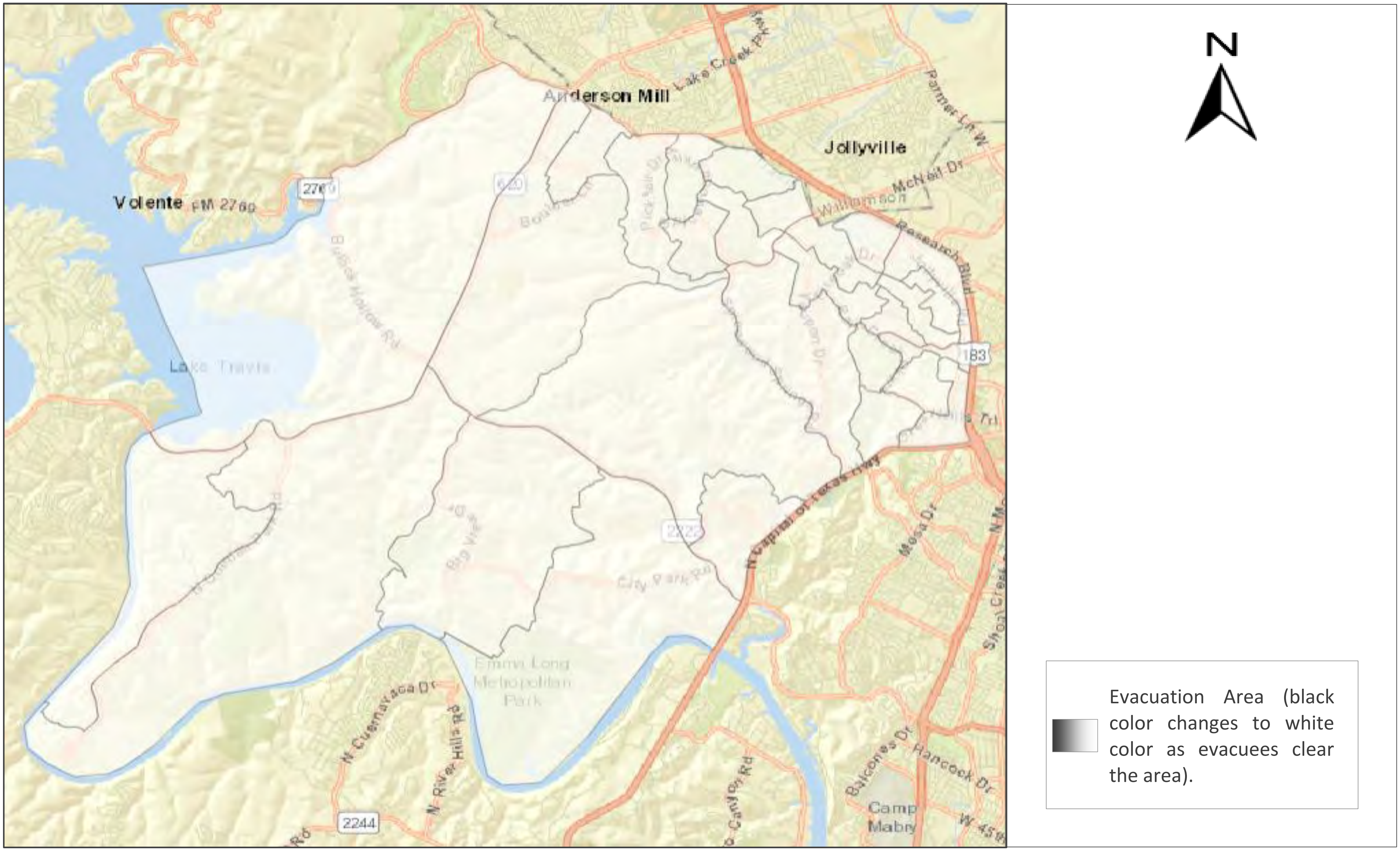
A3. Census Block Group Condition in the 2nd Hour of Evacuation (Northwest Scenario)



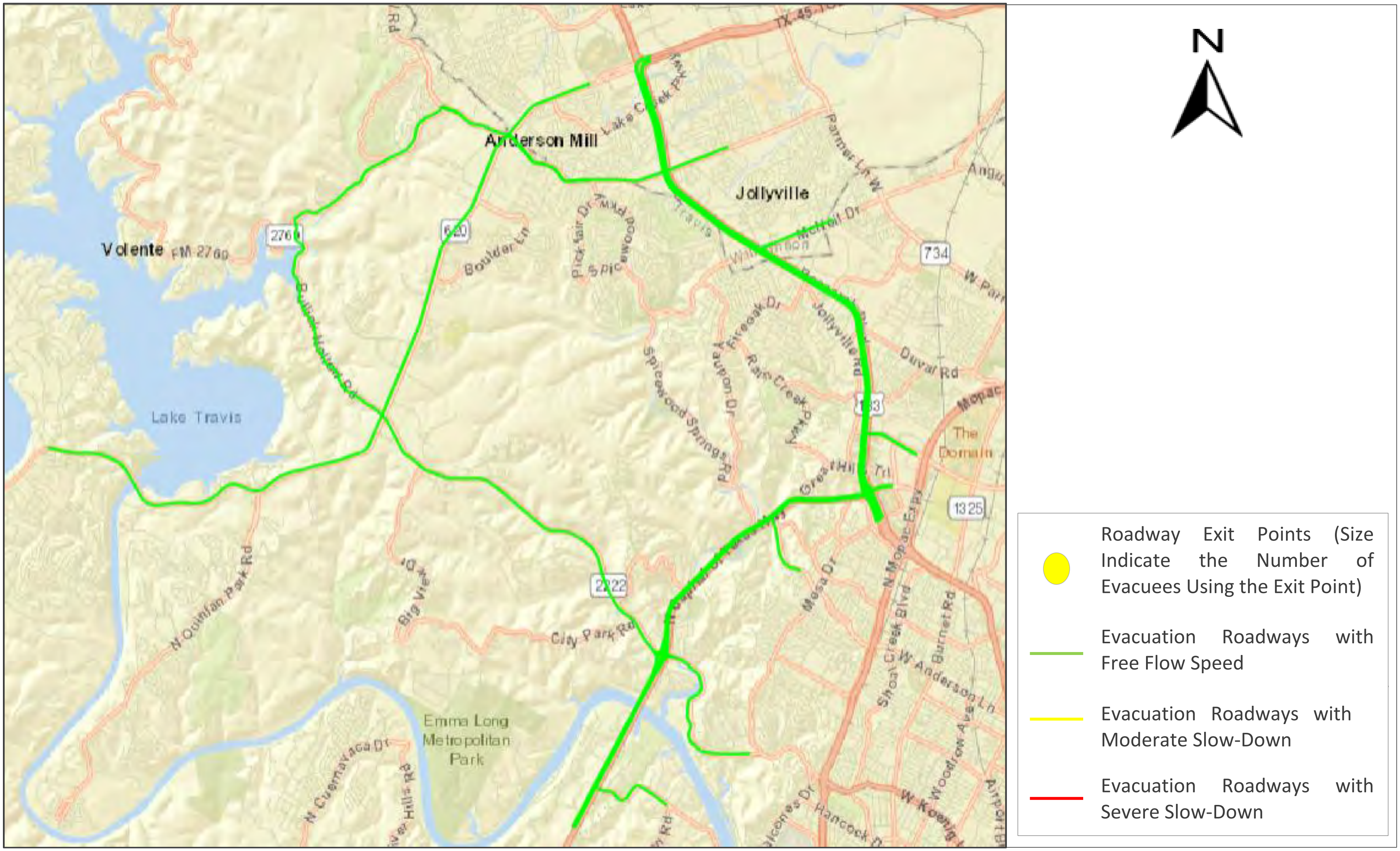
A4. Census Block Group Condition After 3rd Hours of Evacuation (Northwest Scenario)



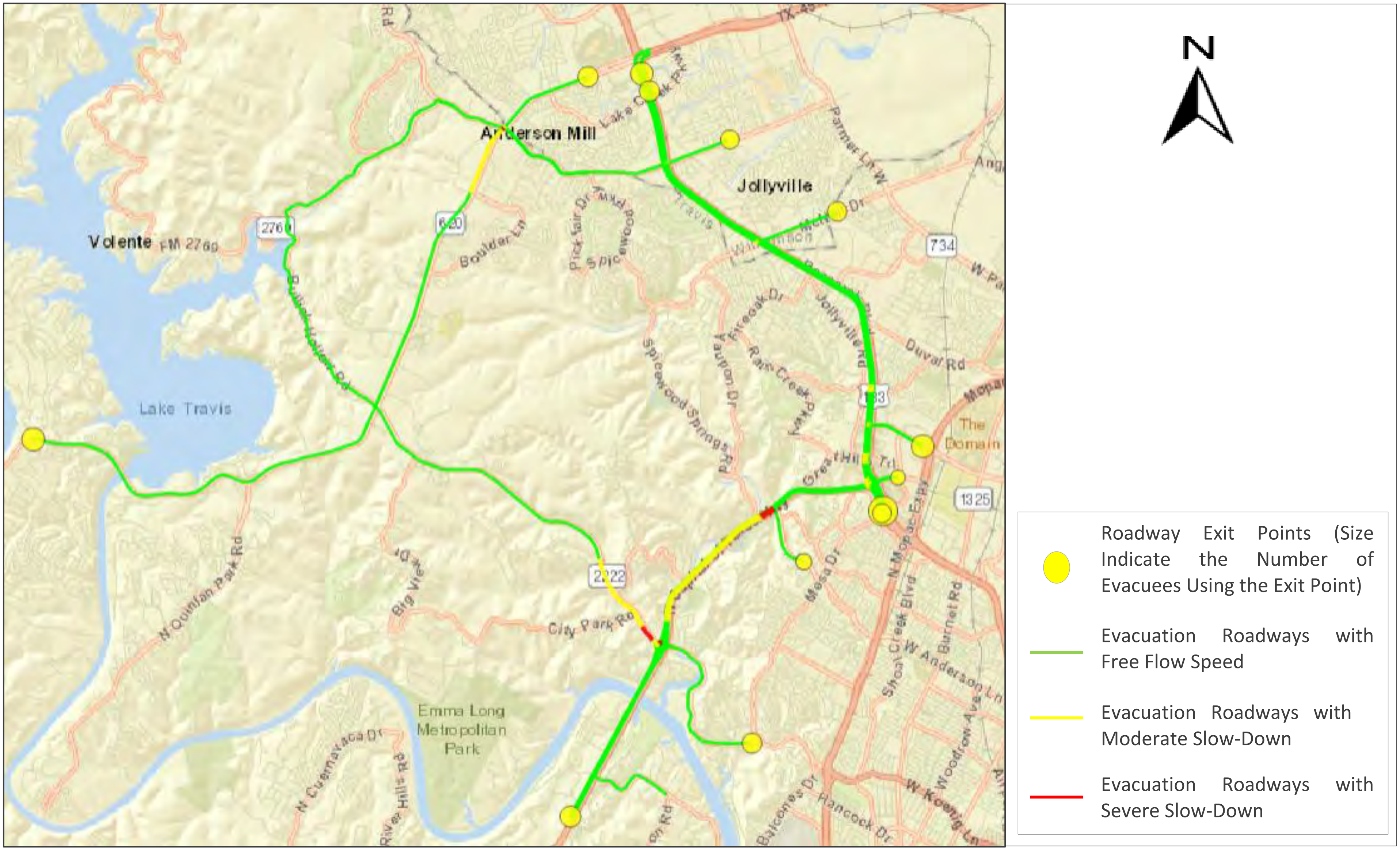
A5. Census Block Group Condition After 3.4 Hours of Evacuation (Evacuation Completion of Northwest Scenario)



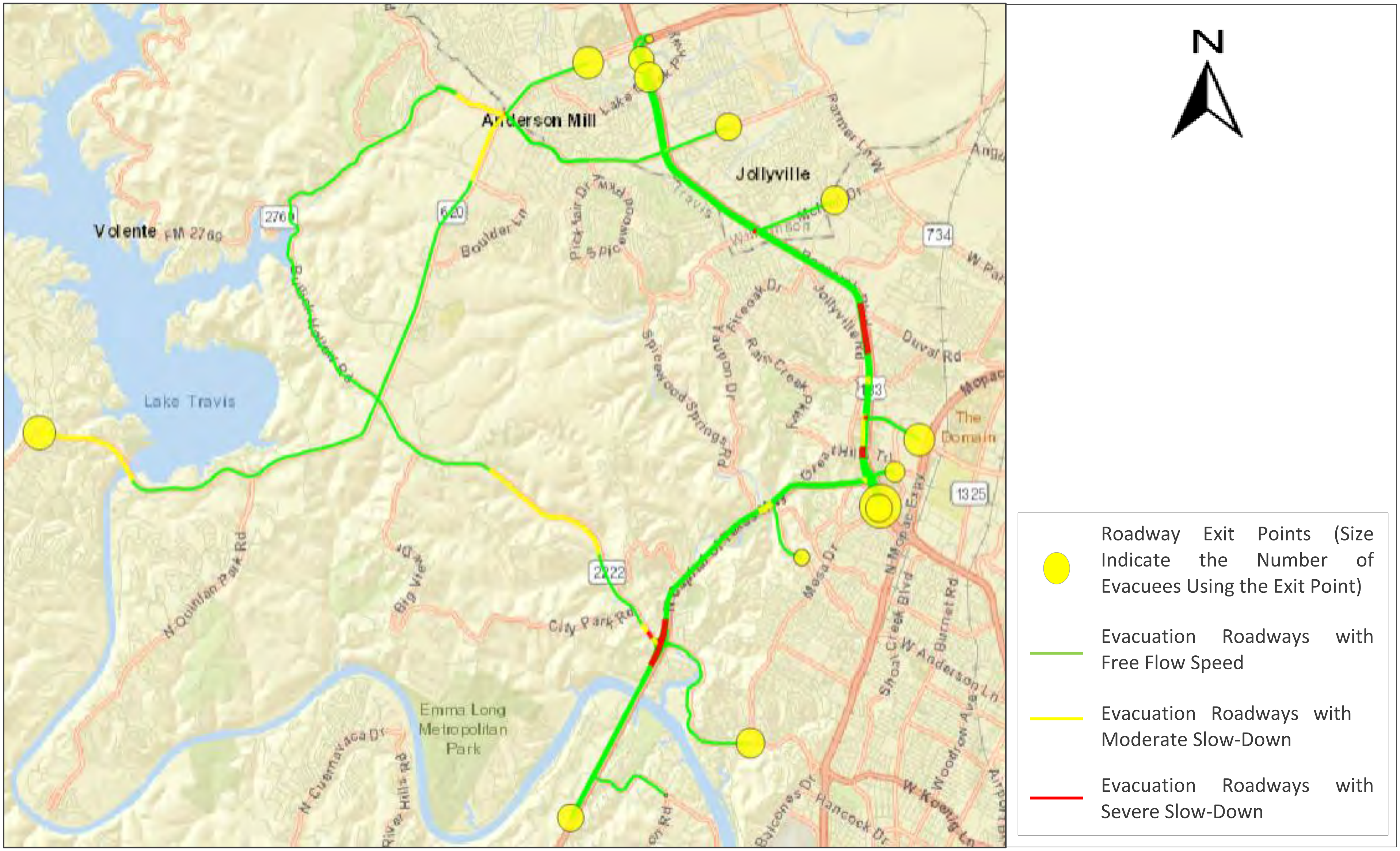
B1. Road Condition at the Beginning of the Evacuation (Northwest Scenario)



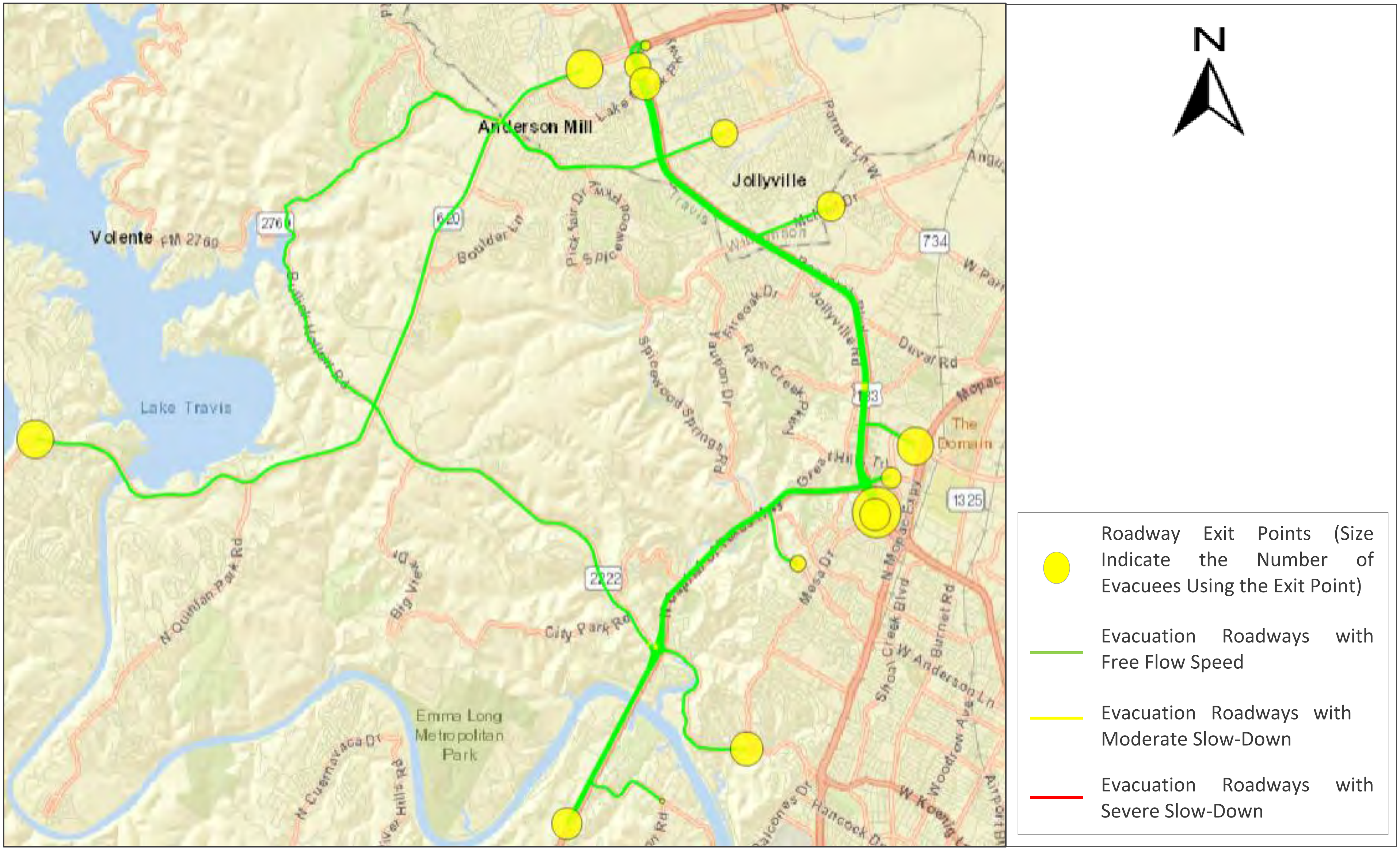
B2. Road Condition at the Beginning of the Evacuation (Northwest Scenario)



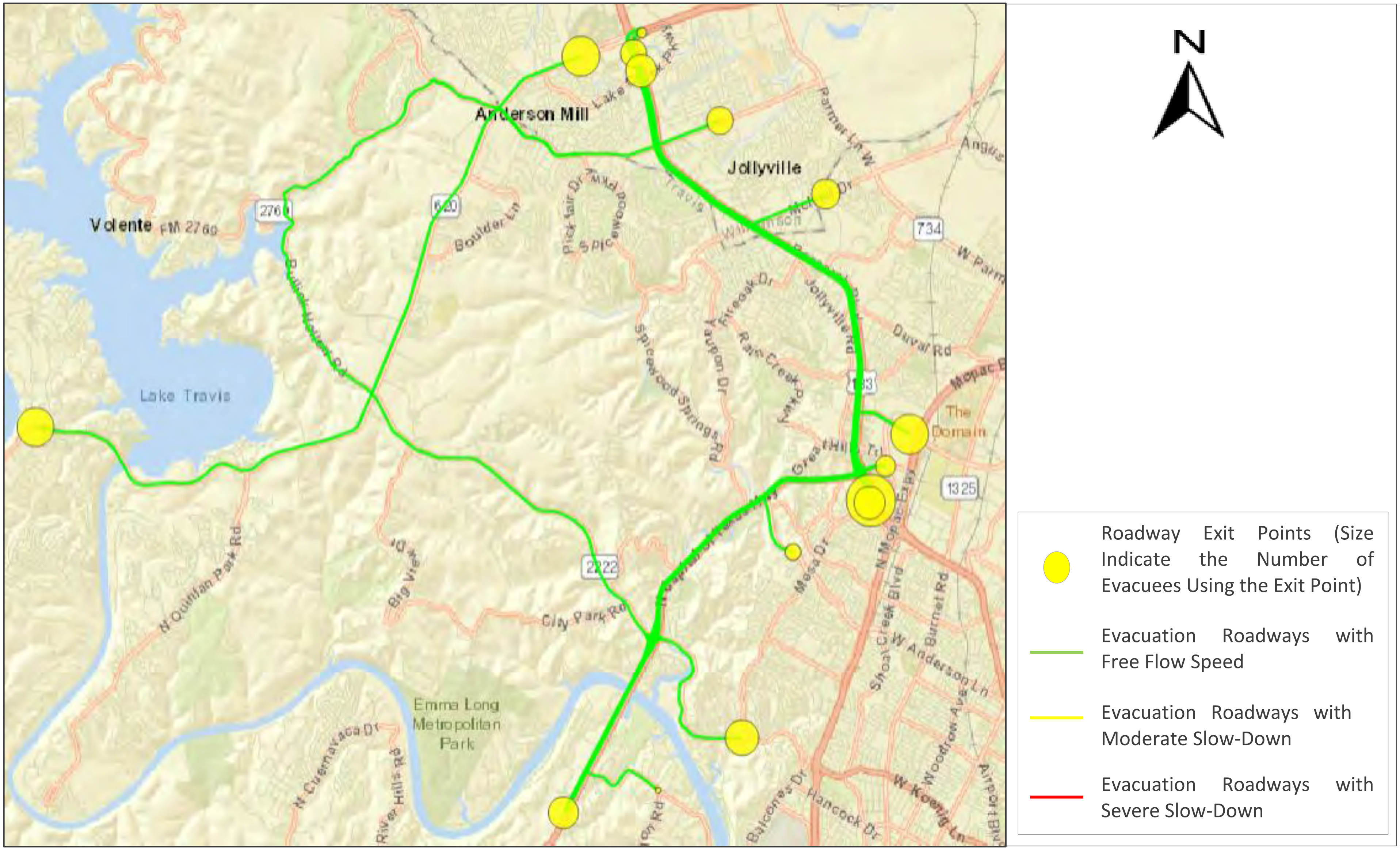
B3. Road Condition at the End of 2nd Hour of the Evacuation *(Northwest Scenario)*



B4. Road Condition After 3rd Hours of Evacuation (Northwest Scenario)



B5. Road Condition After 3.4 Hours of Evacuation (Completed Evacuation of *Northwest Scenario*)



C1. Census Block Group Condition at the Beginning of the Evacuation (Northeast Scenario)

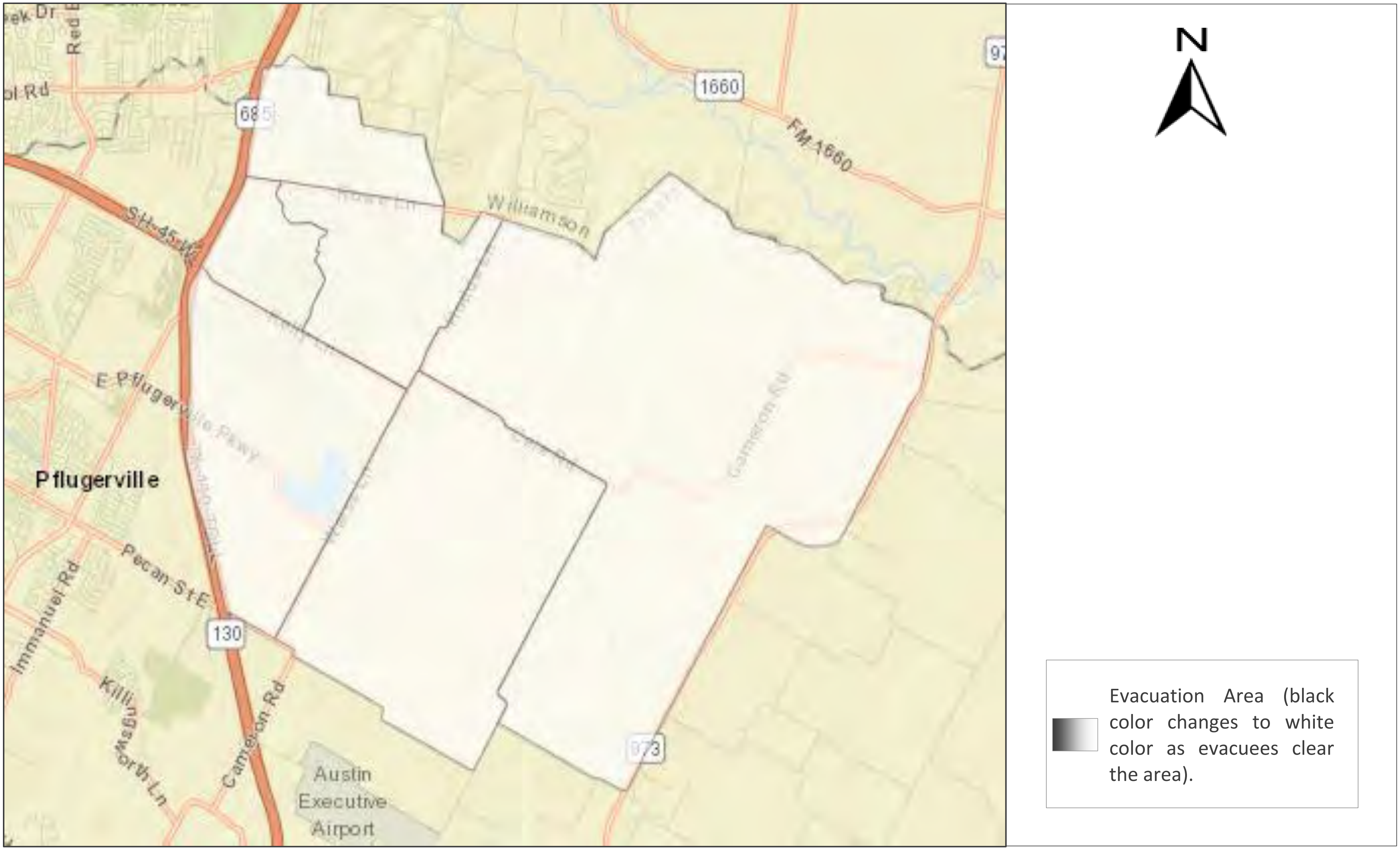
C2. Census Block Group Condition in the 1st Hour of Evacuation (Northeast Scenario)

Evacuation Area (black color changes to white color as evacuees clear the area).

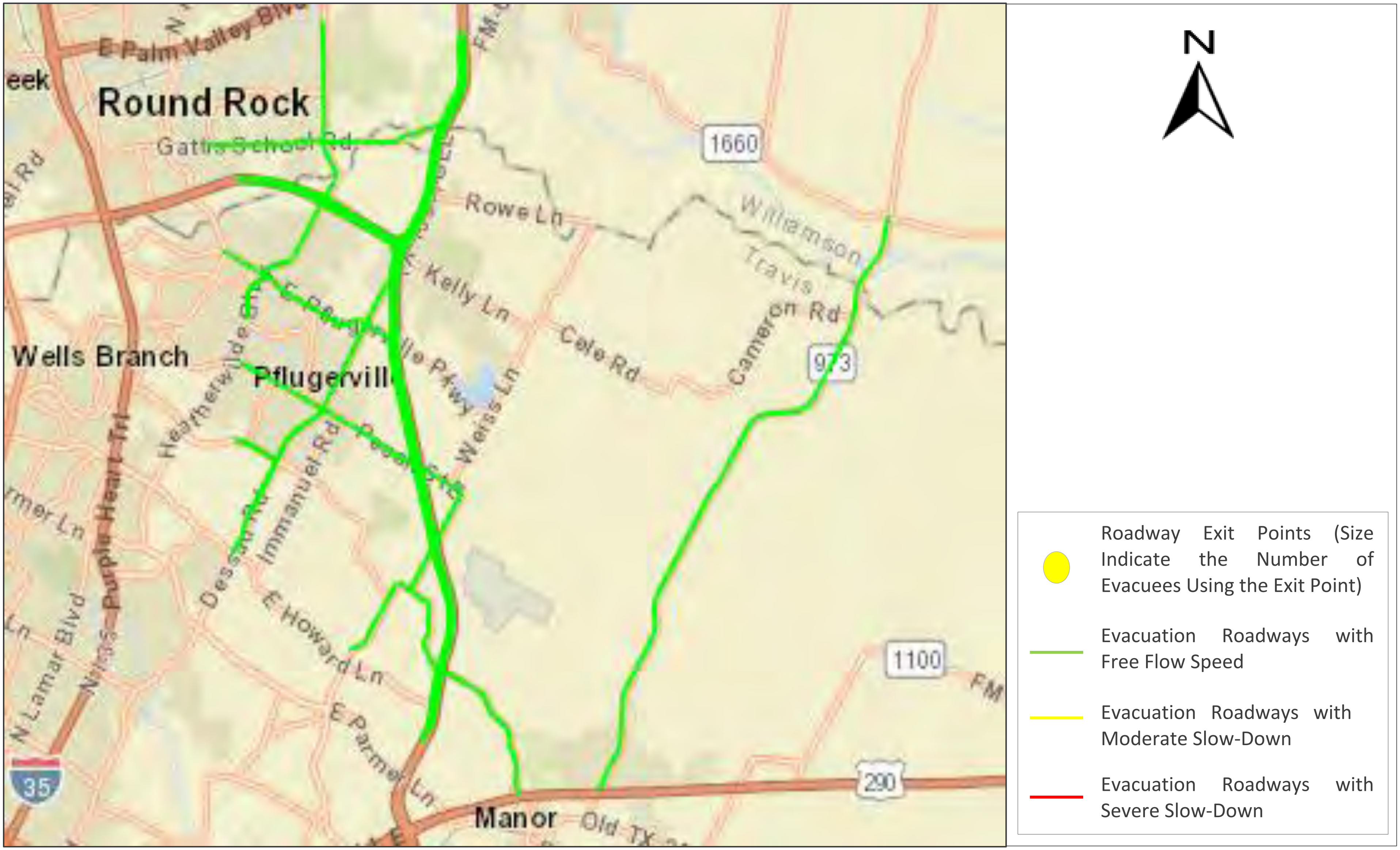
C3. Census Block Group Condition in the 2nd Hour of Evacuation (Northeast Scenario)

Evacuation Area (black color changes to white color as evacuees clear the area).

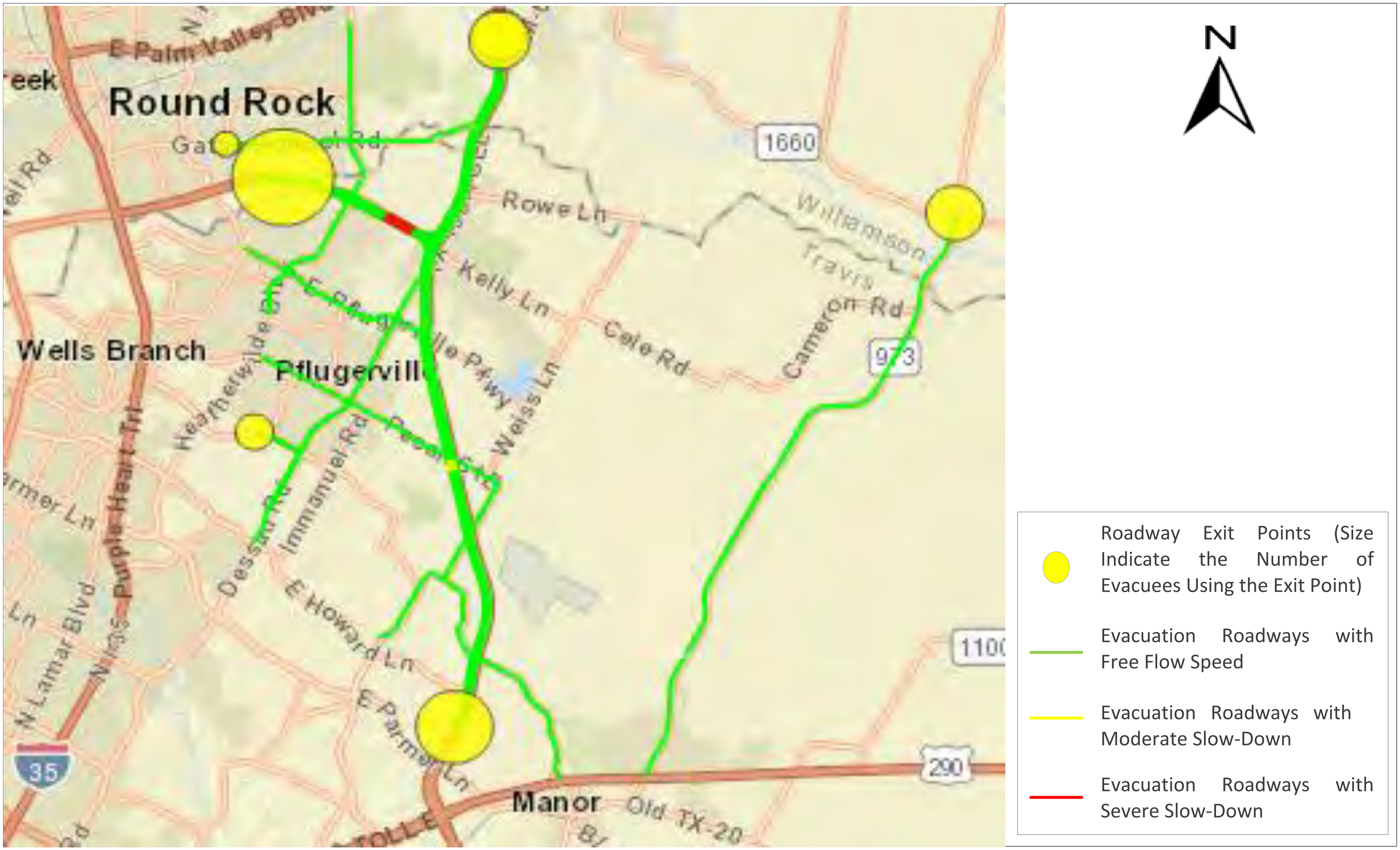
C4. Census Block Group Condition After 2.2 Hours of Evacuation (Completed Evacuation of Northeast Scenario)



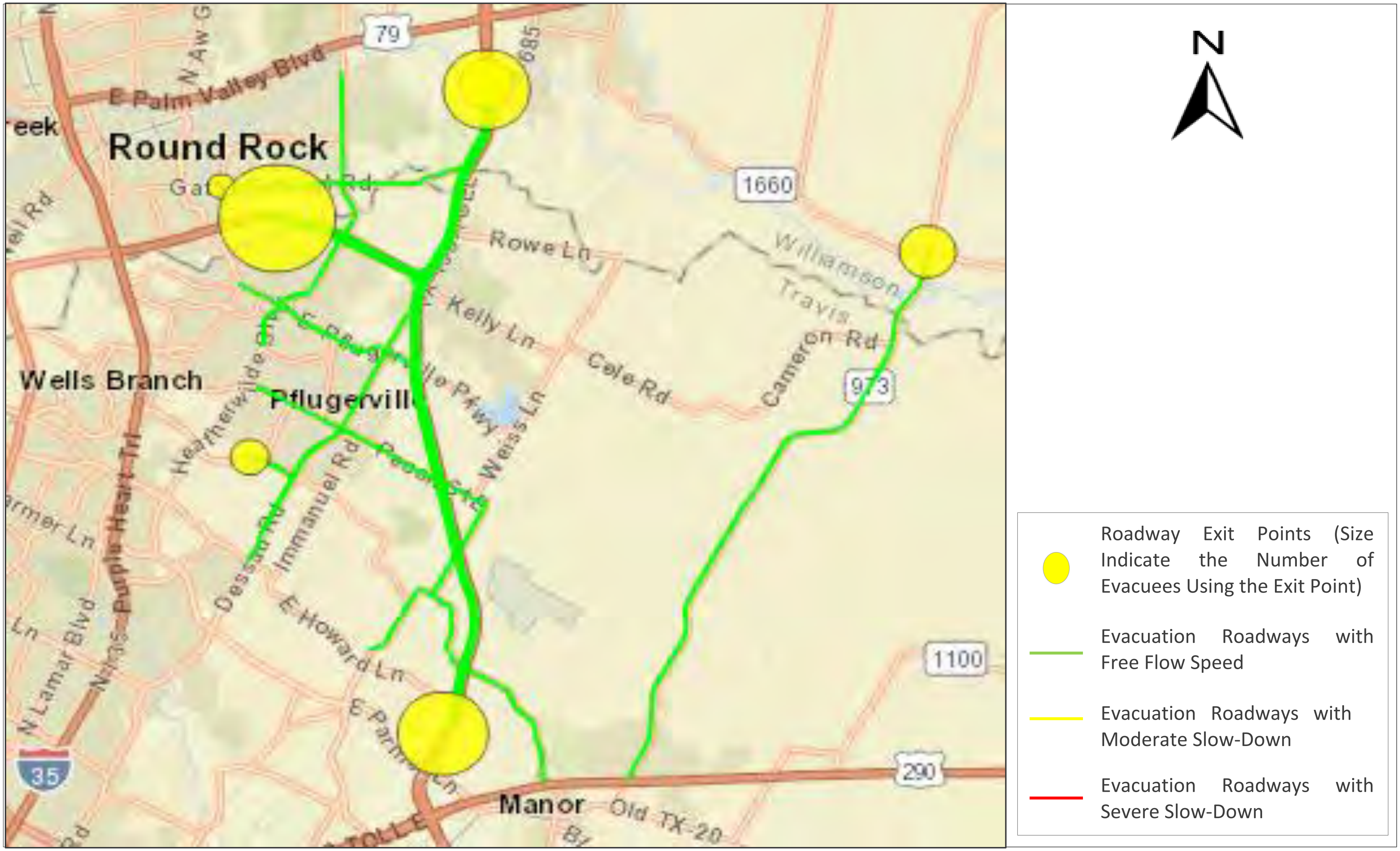
D1. Road Condition at the Beginning of the Evacuation (Northeast Scenario)



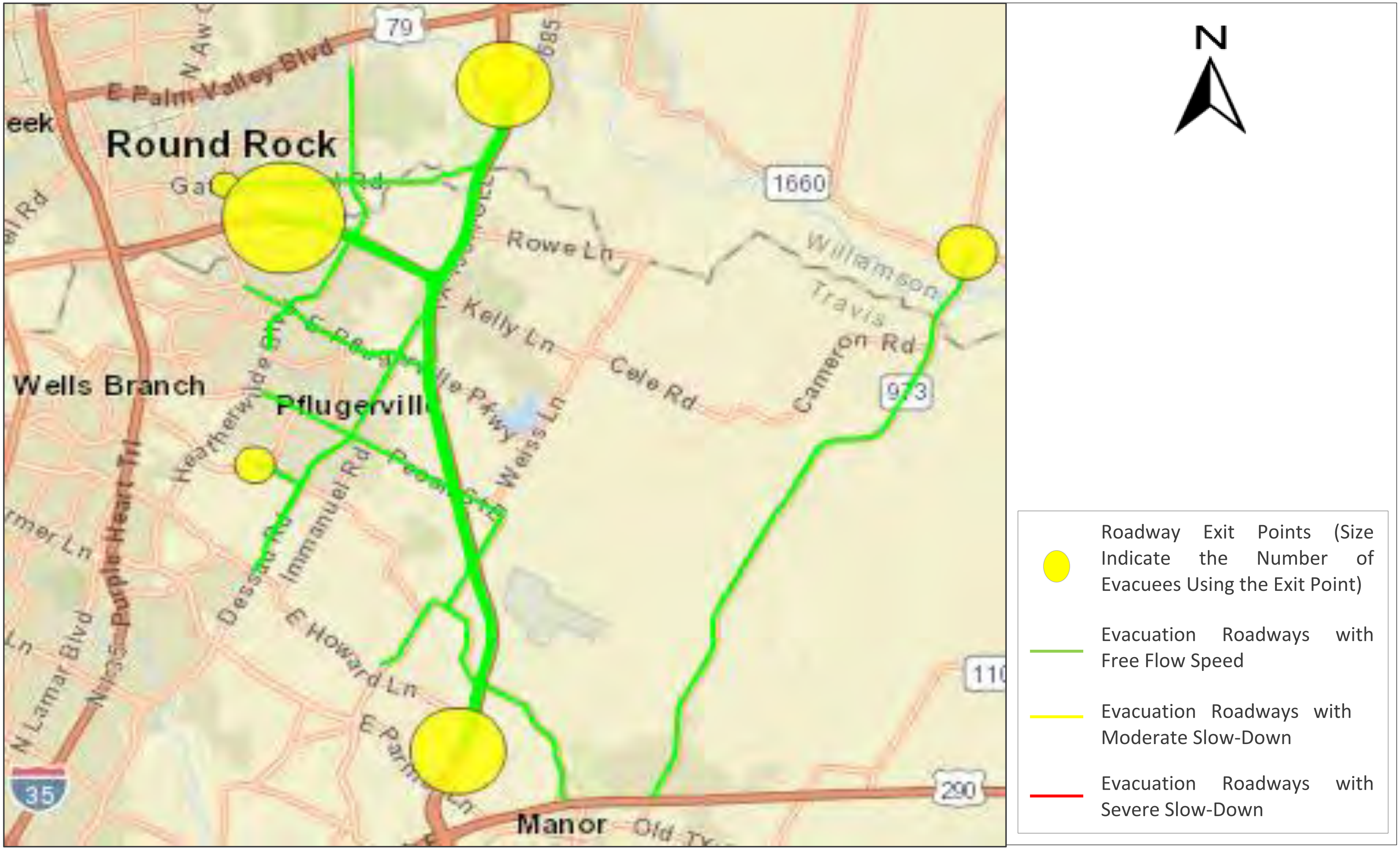
D2. Road Condition in the 1st Hour of Evacuation (Northeast Scenario)



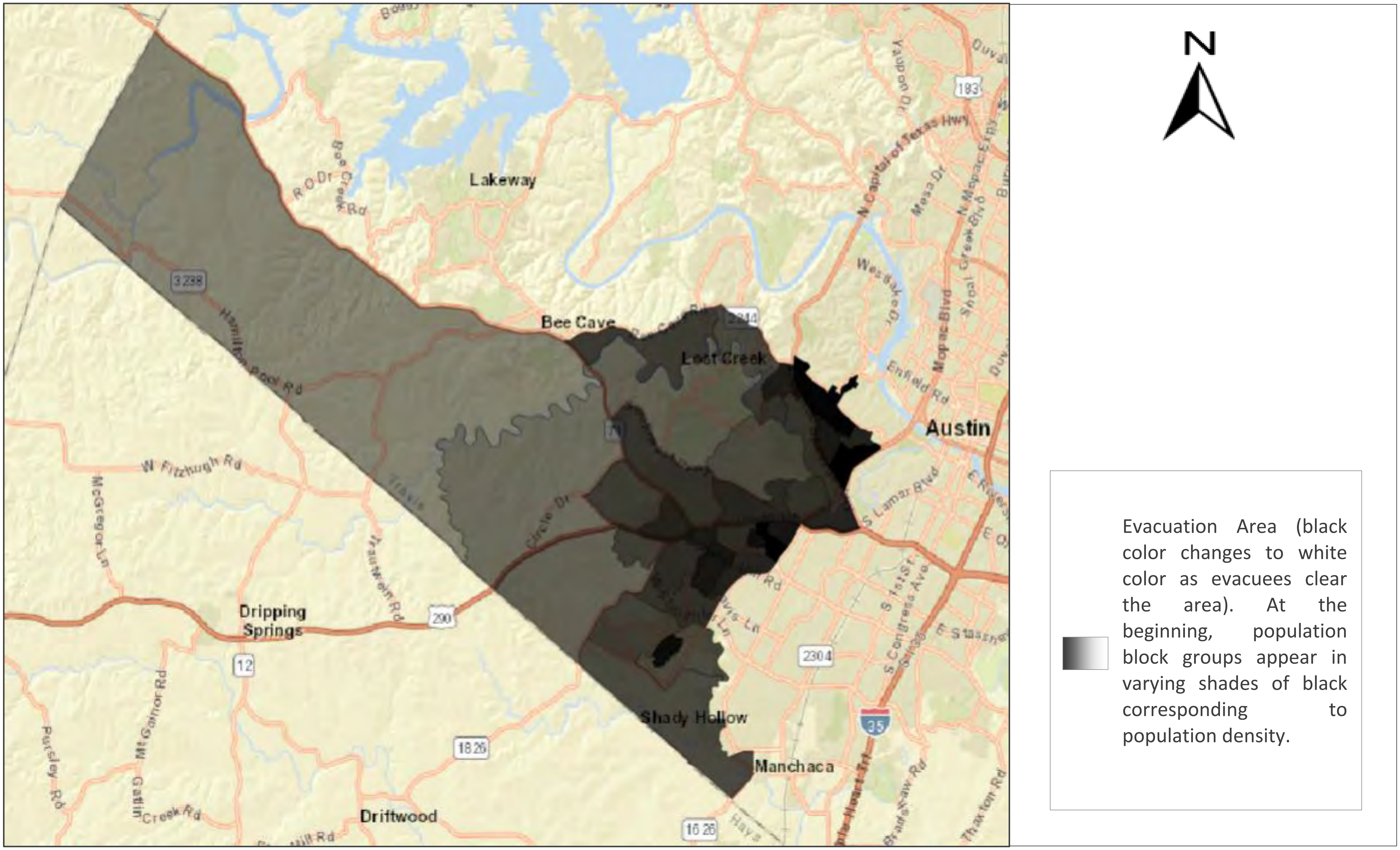
D3. Road Condition in the 2nd Hour of the Evacuation (Northeast Scenario)



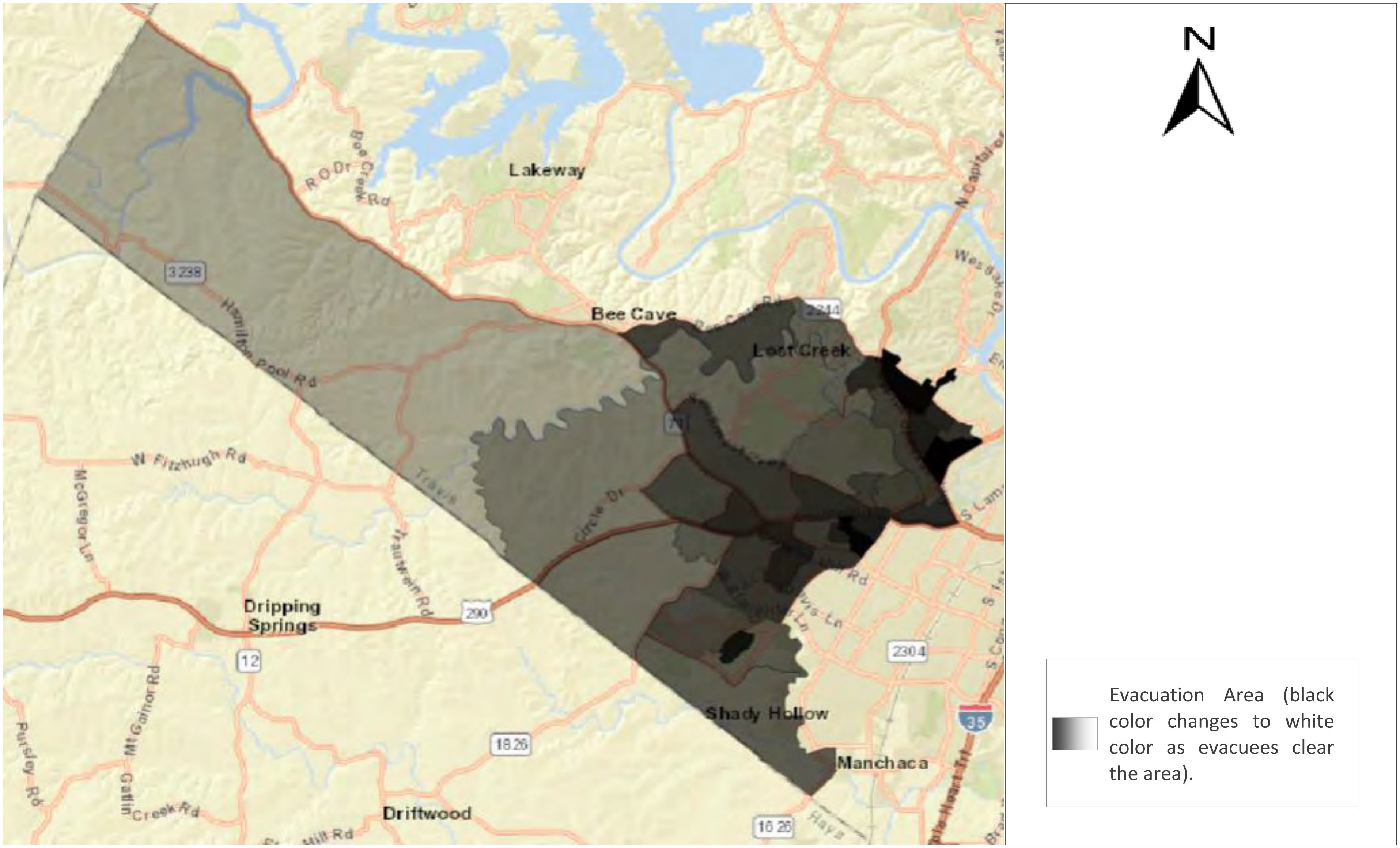
D4. Road Condition After 2.2 Hours of Evacuation (Completed Evacuation of Northeast Scenario)



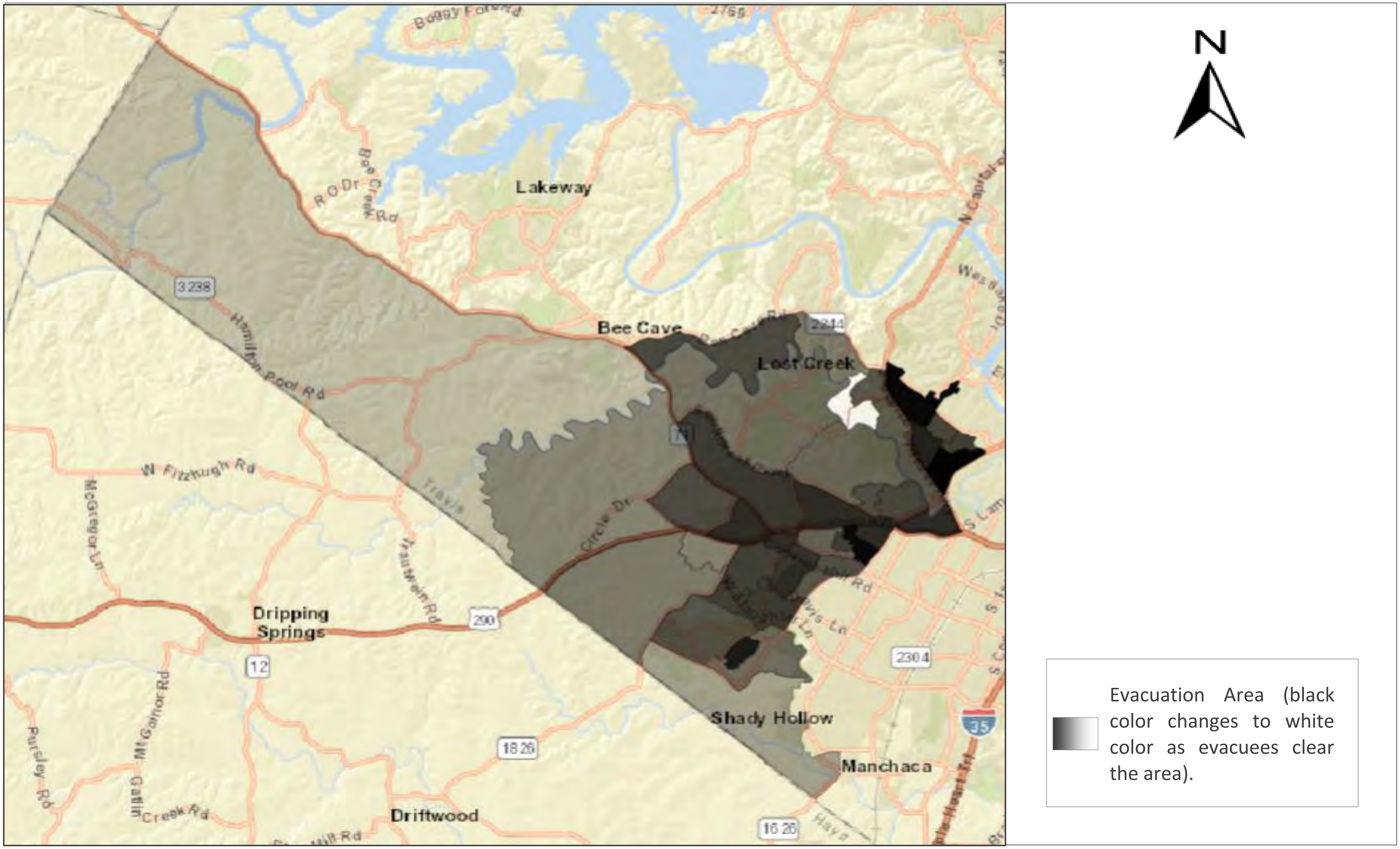
E1. Census Block Group Condition at the Beginning of Evacuation (Southwest Scenario)



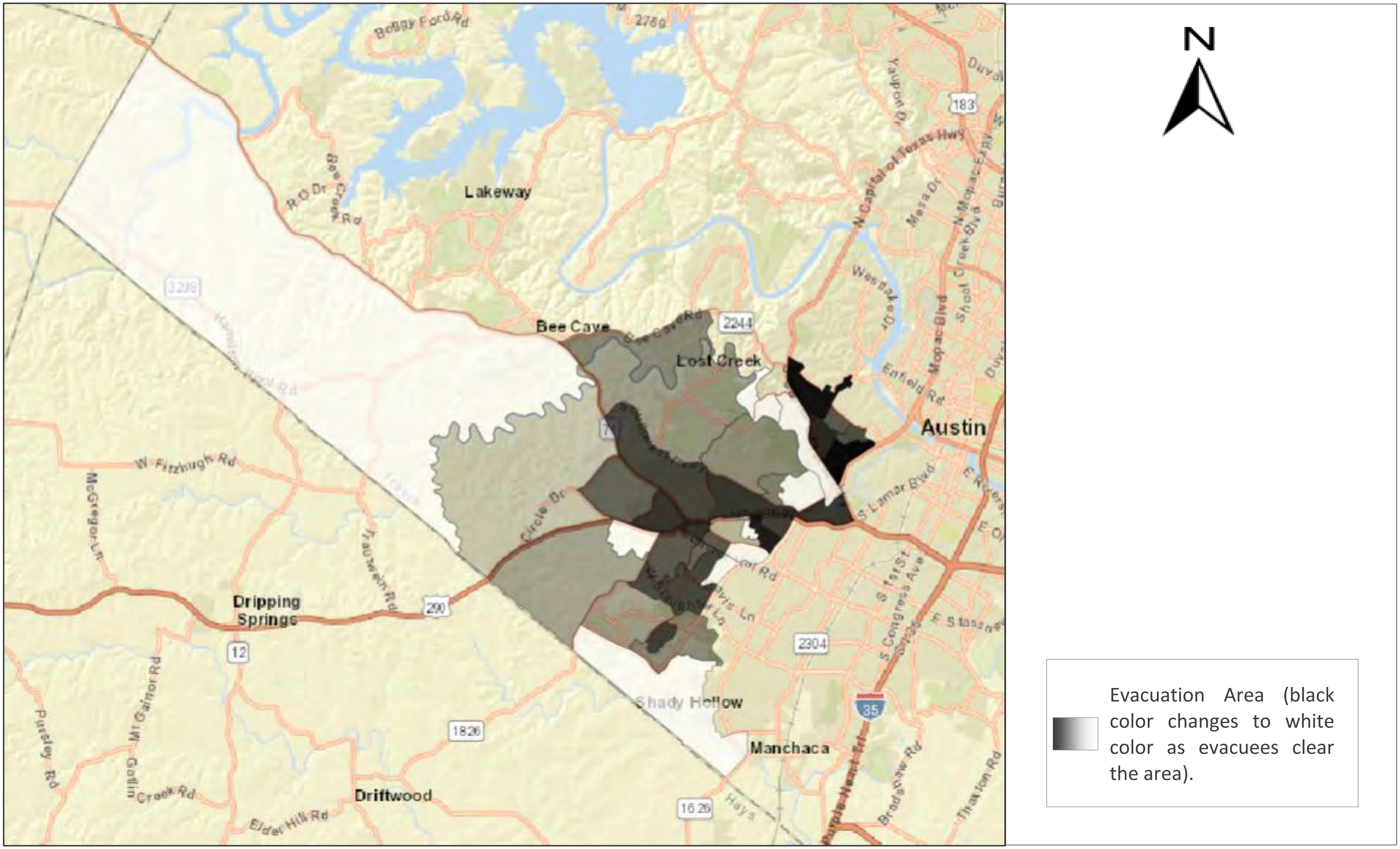
E2. Census Block Group Condition in the 1st Hour of Evacuation (Southwest Scenario)



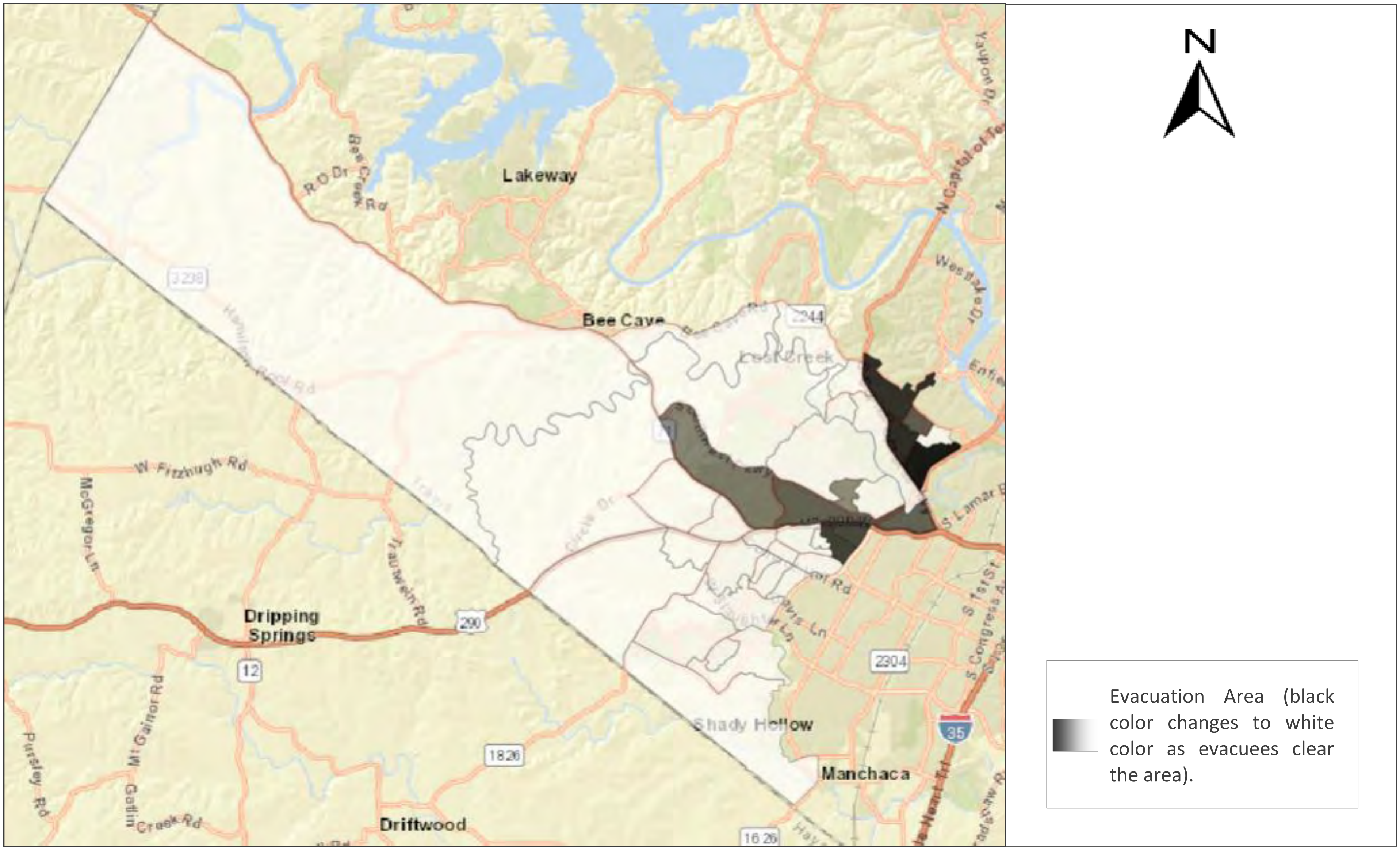
E3. Census Block Group Condition in the 2nd Hour of Evacuation (Southwest Scenario)



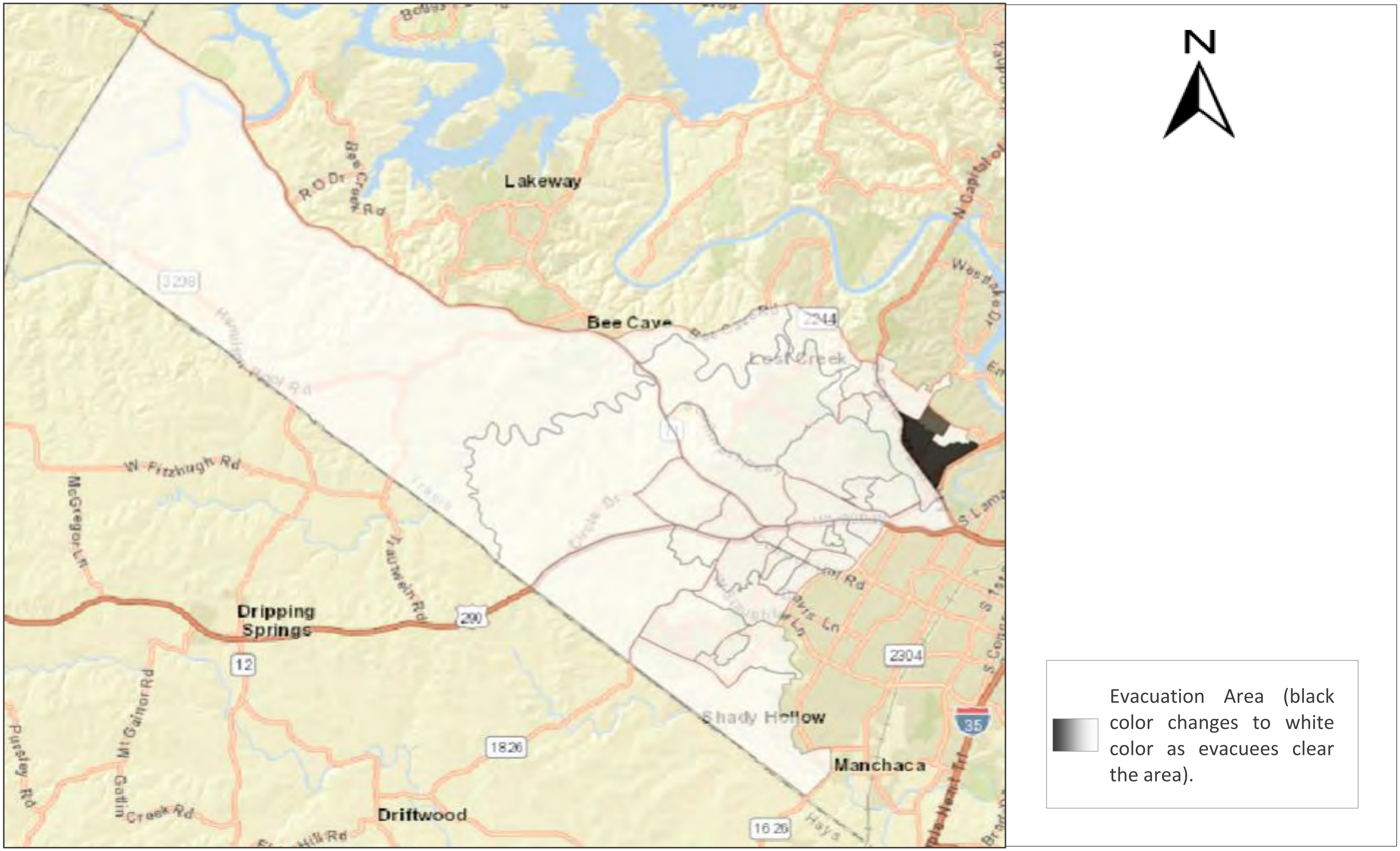
E4. Census Block Group Condition in the 3rd Hour of Evacuation (Southwest Scenario)



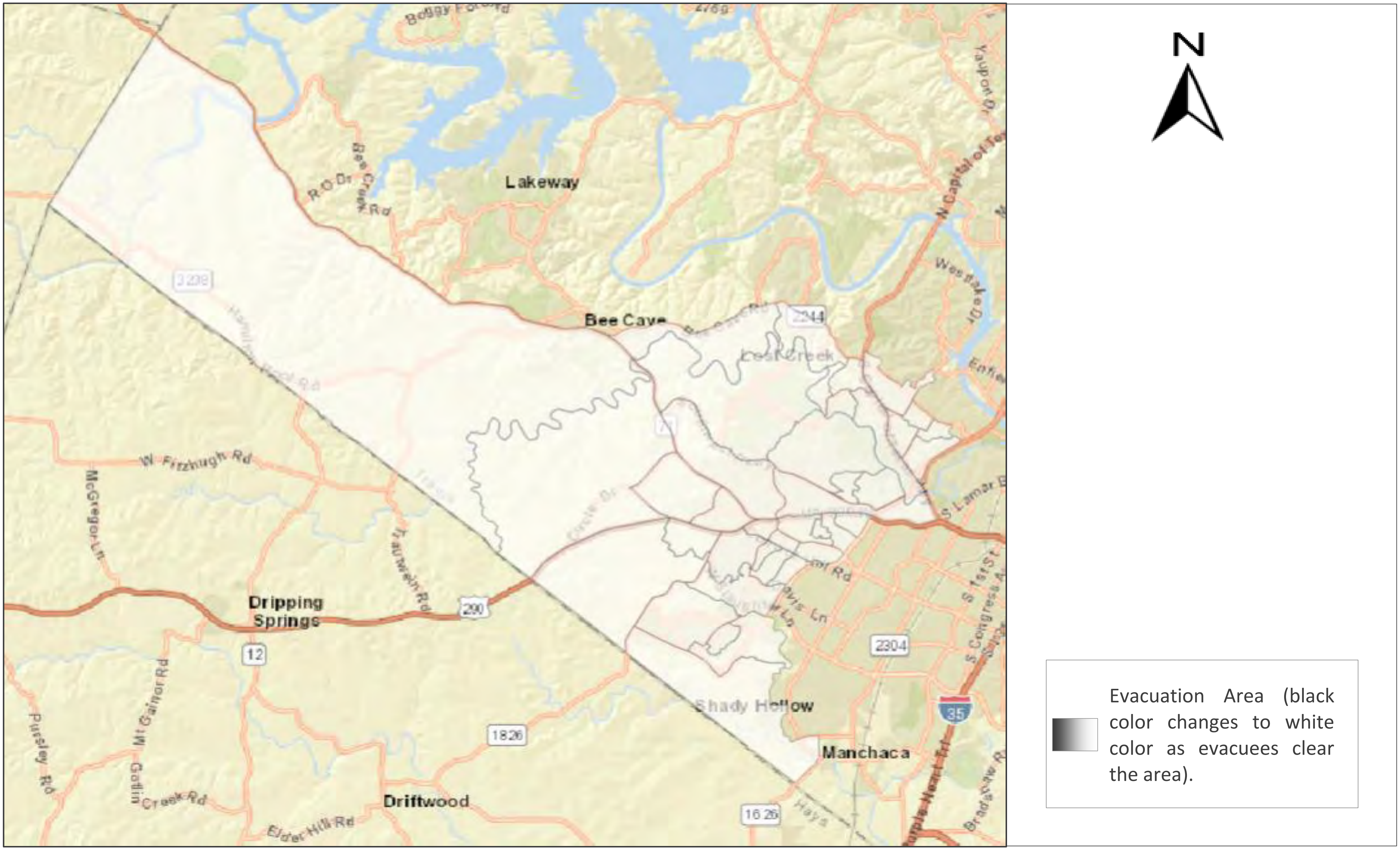
E5. Census Block Group Condition in the 4th Hour of Evacuation (Southwest Scenario)



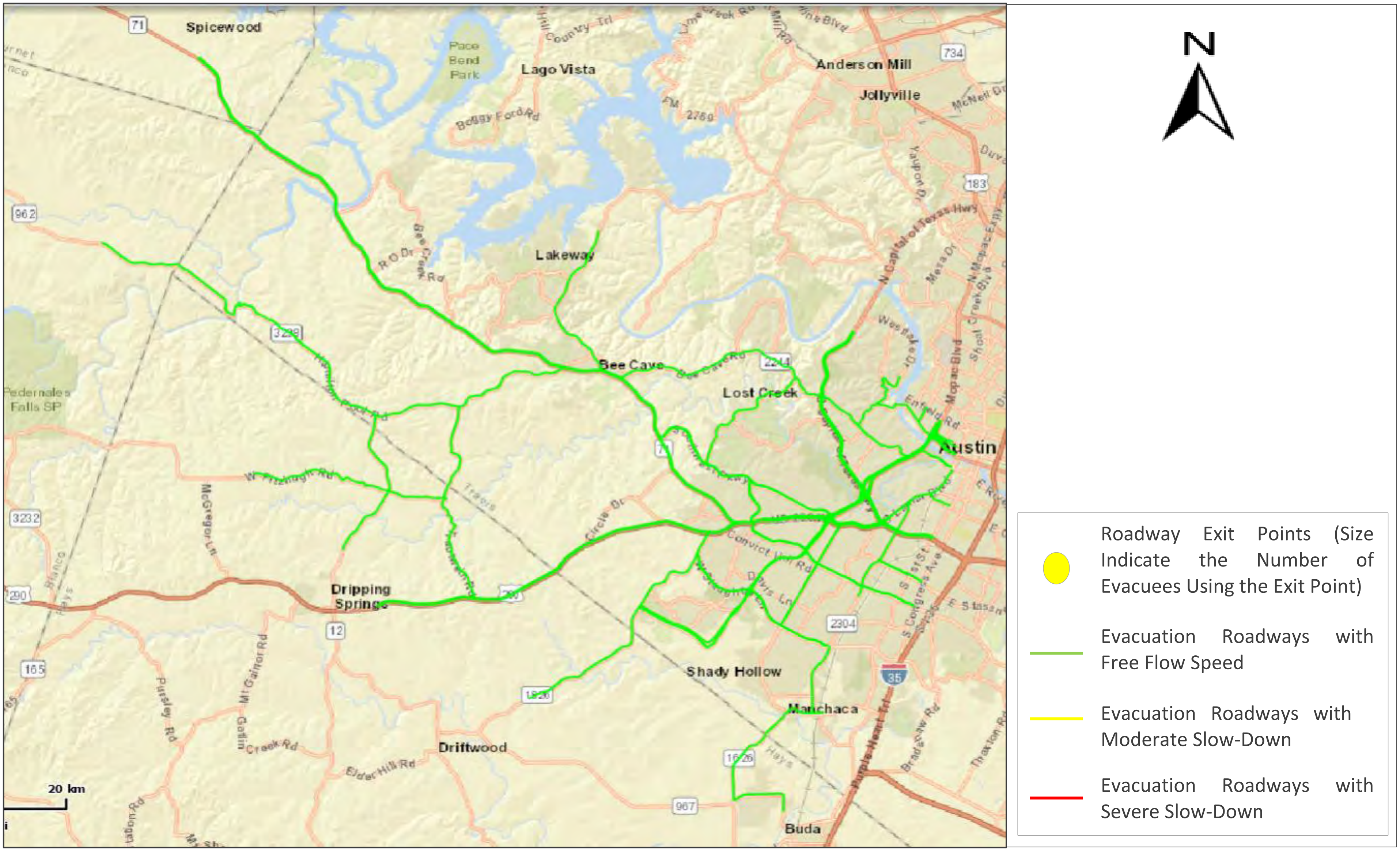
E6. Census Block Group Condition in the 5th Hour of Evacuation (Southwest Scenario)



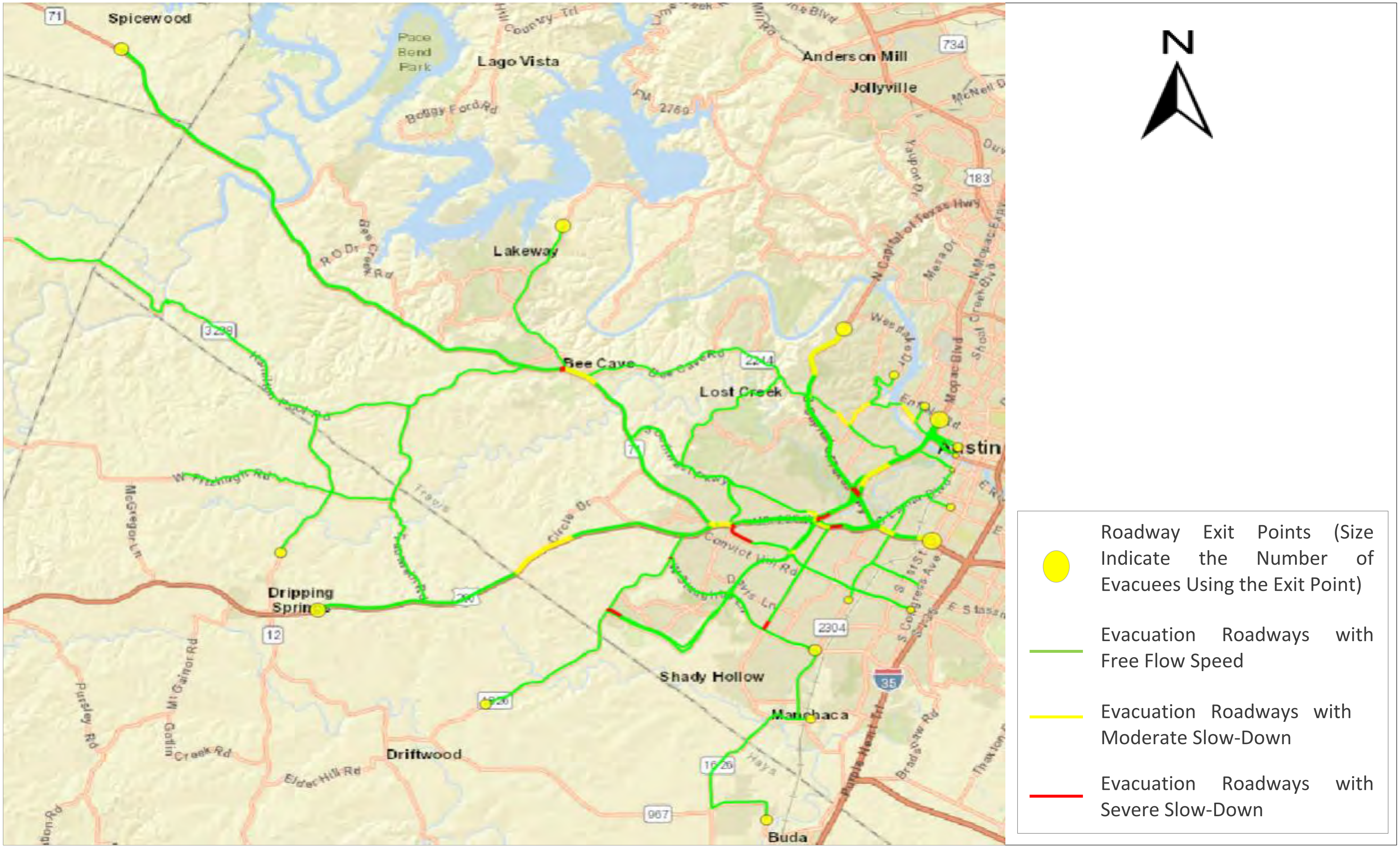
E7. Census Block Group Condition in the 5.8 Hour of Evacuation (Southwest Scenario)



F1. Road Condition at the Beginning of Evacuation (Southwest Scenario)



F2. Road Condition in the 1st Hour of Evacuation (Southwest Scenario)



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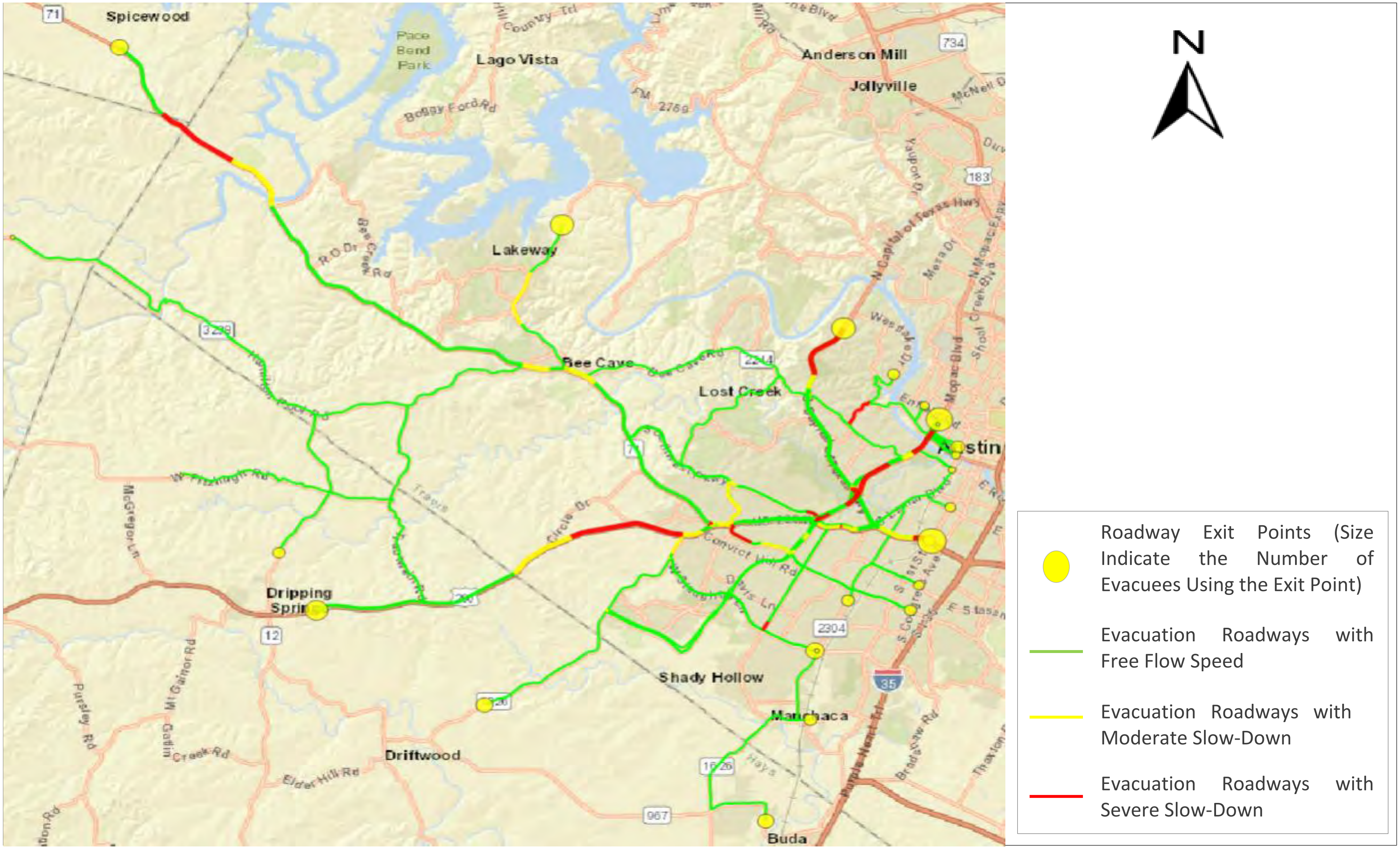

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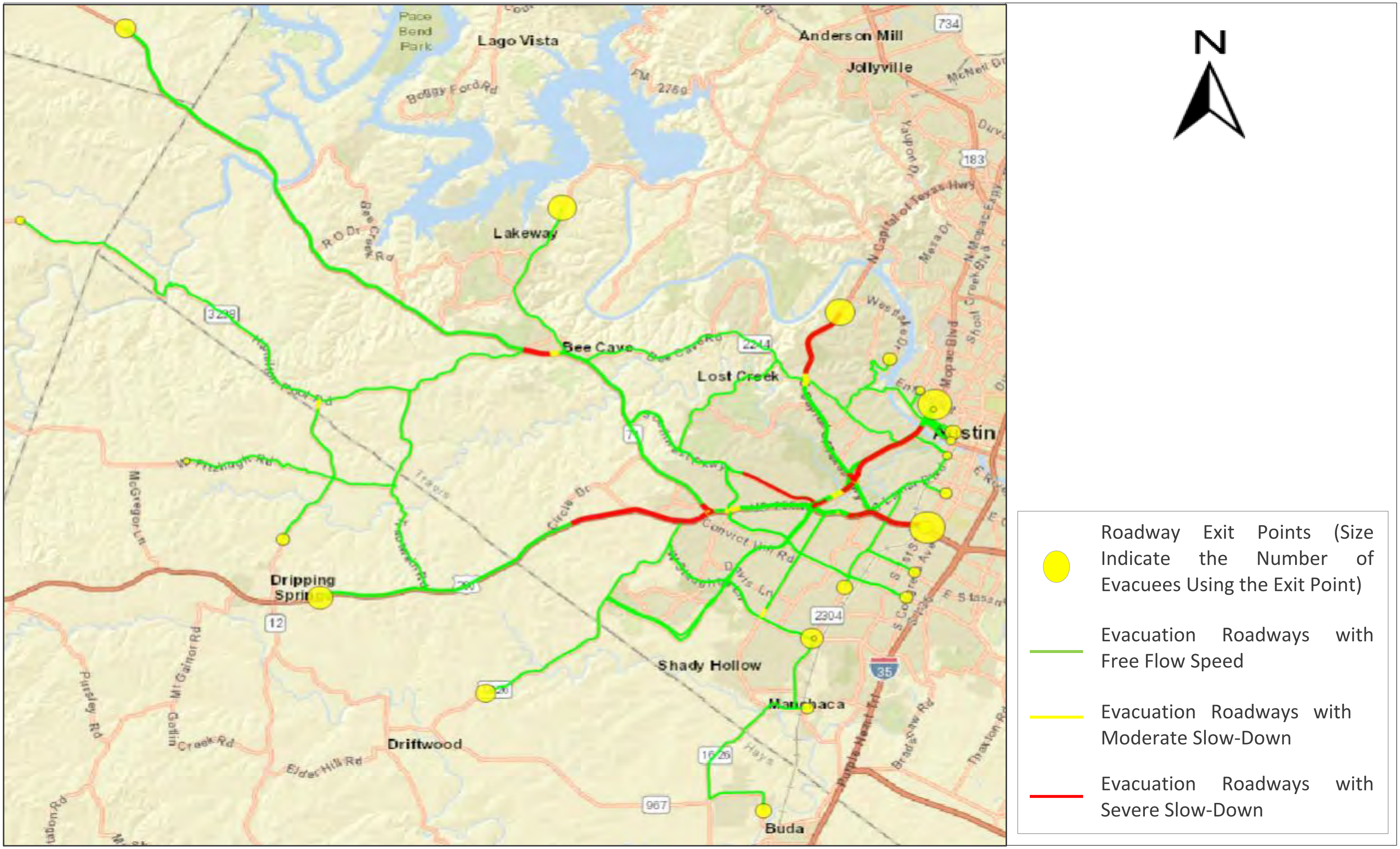
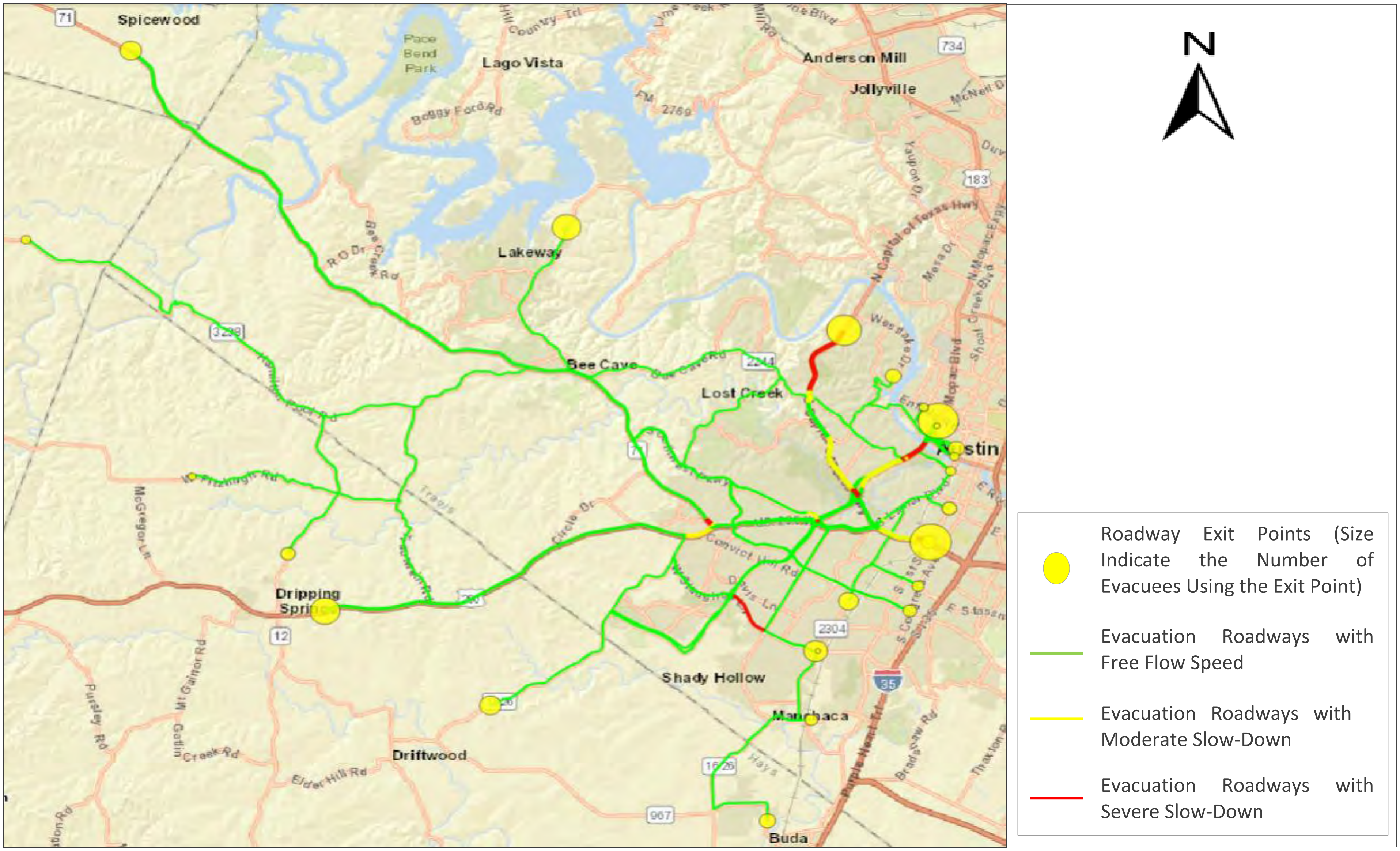
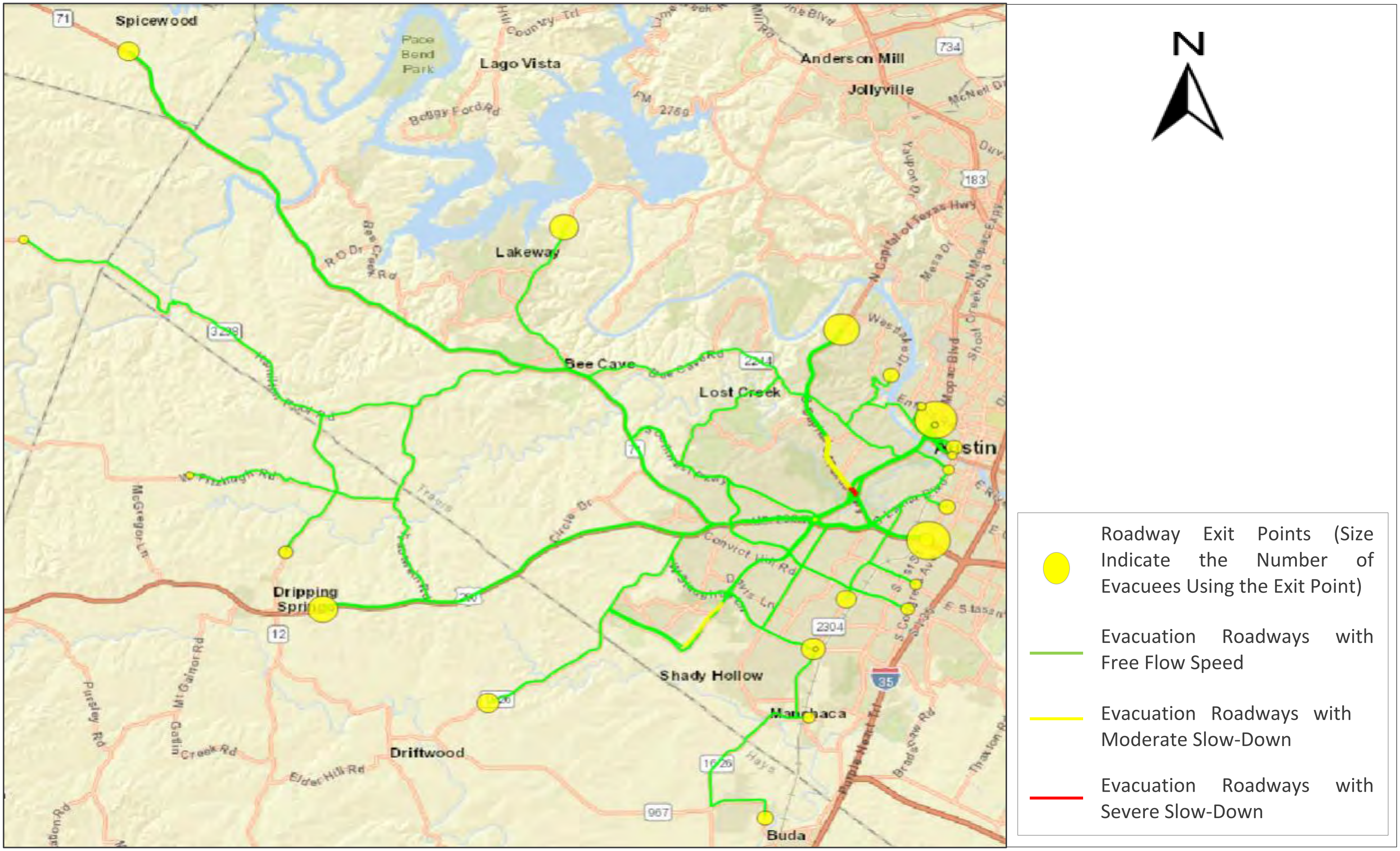


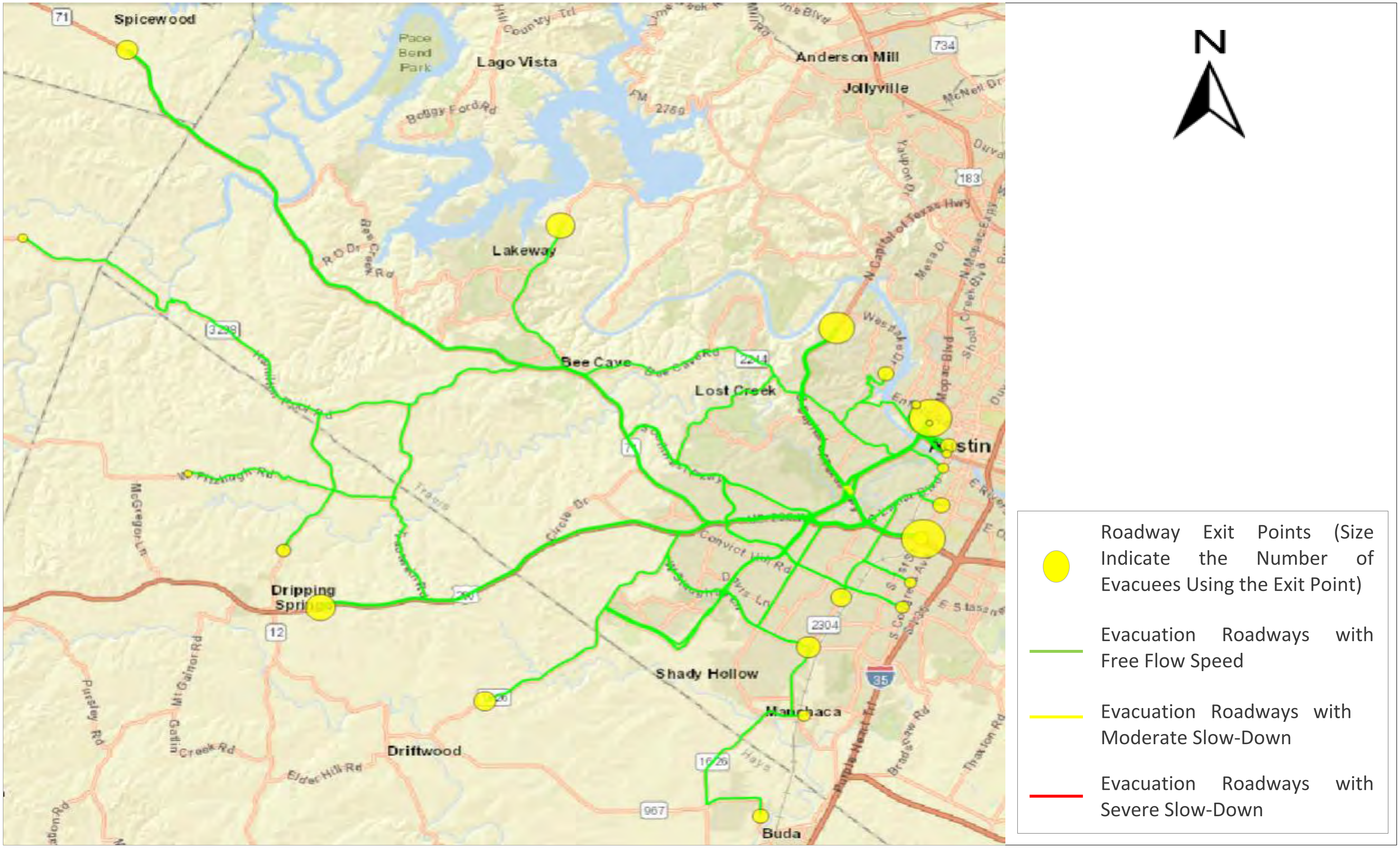
F5. Road Condition in the 4th Hour of Evacuation (Southwest Scenario)



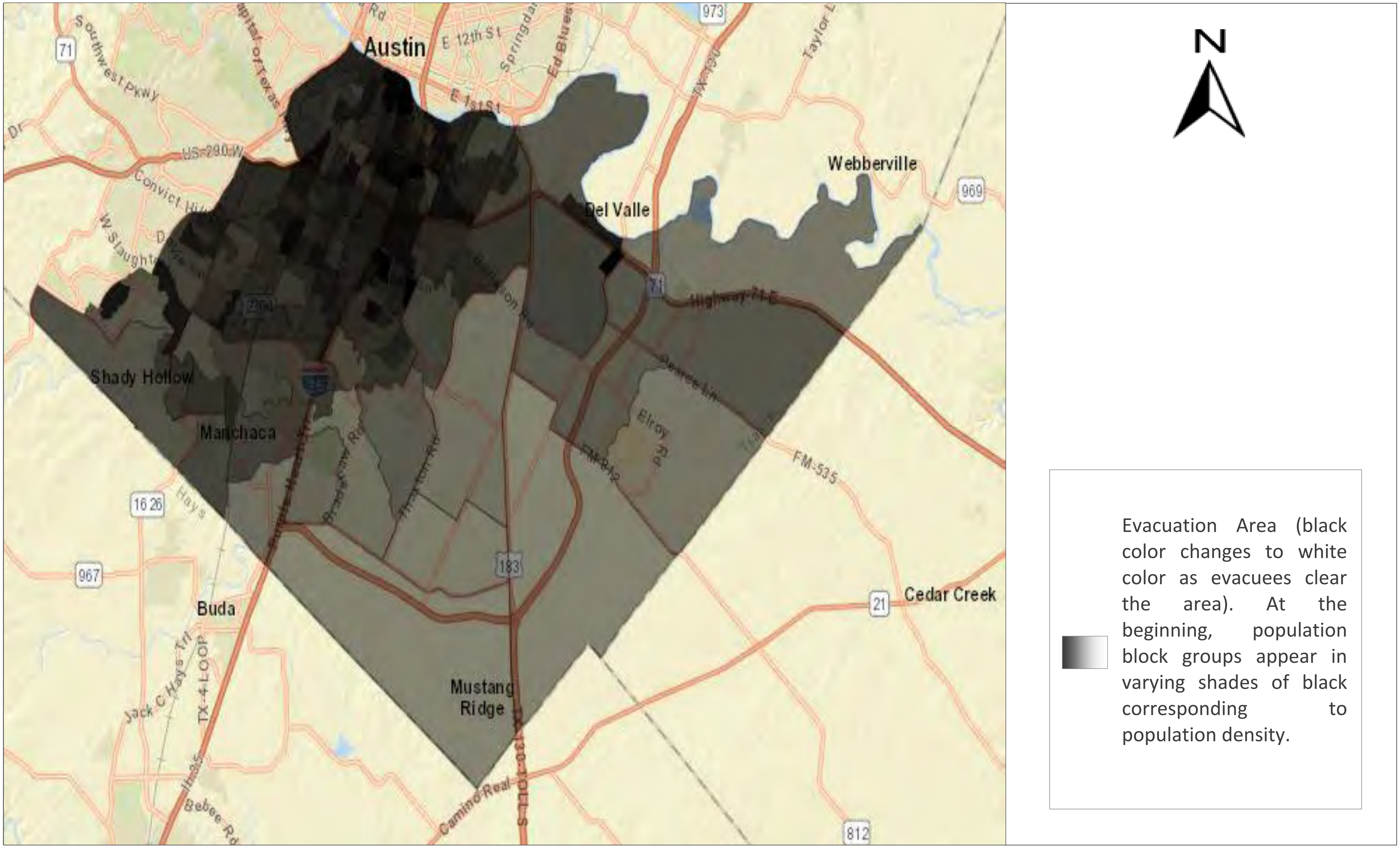
F6. Road Condition in the 5th Hour of Evacuation (Southwest Scenario)



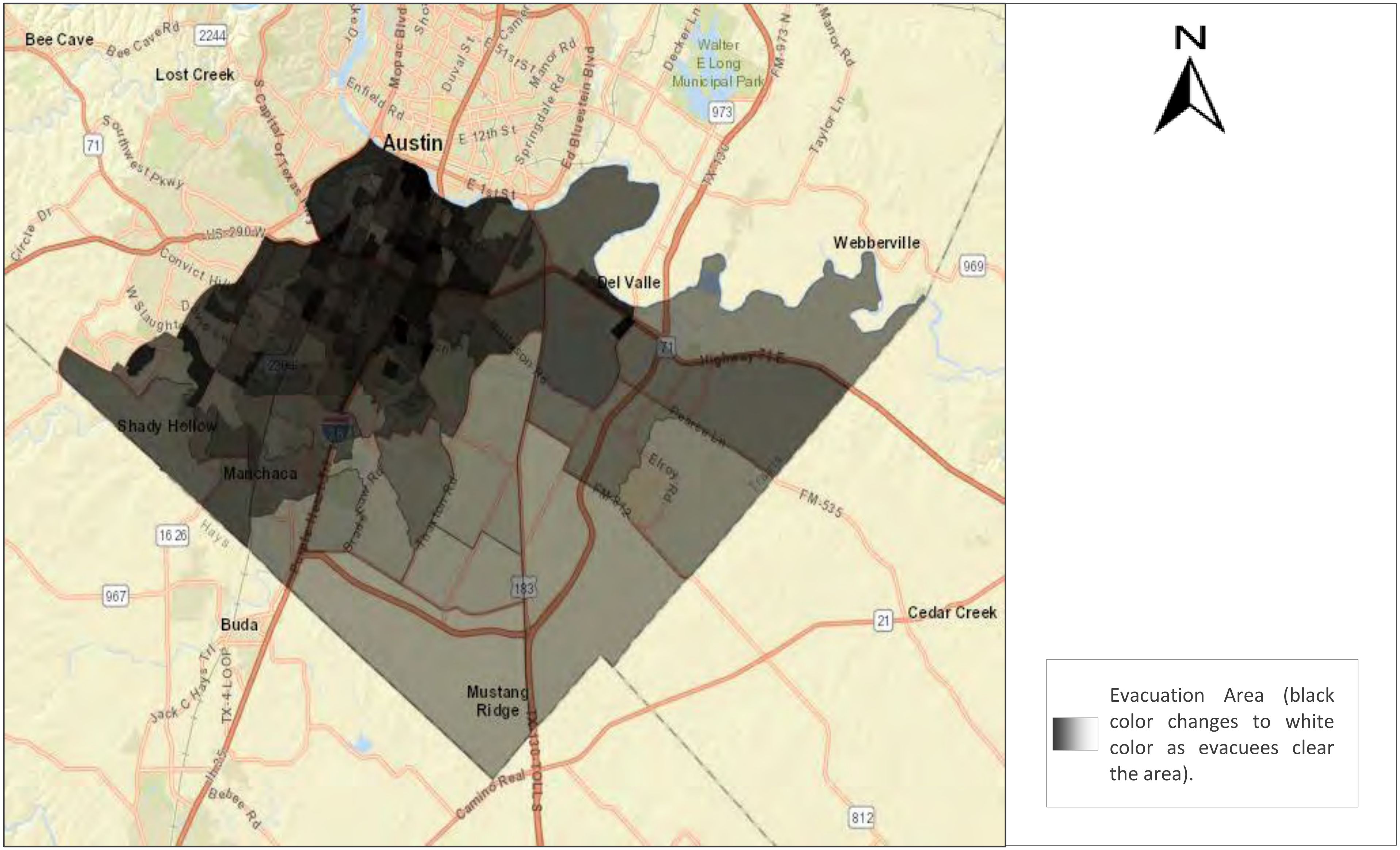
F7. Road Condition in the 5.8 Hour of Evacuation (Southwest Scenario)



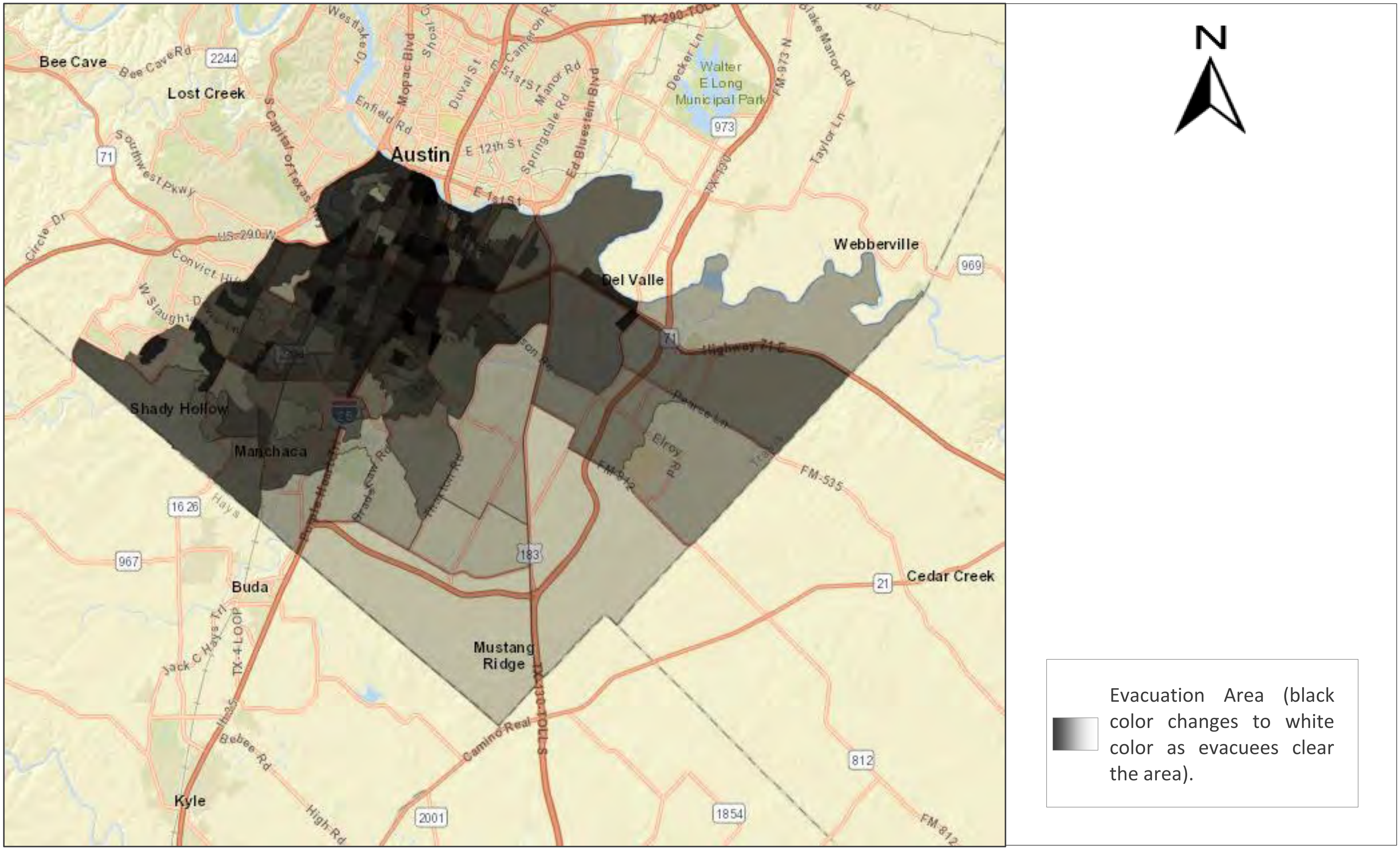
G1. Block Group Condition at the Beginning of Evacuation (Southeast Scenario)



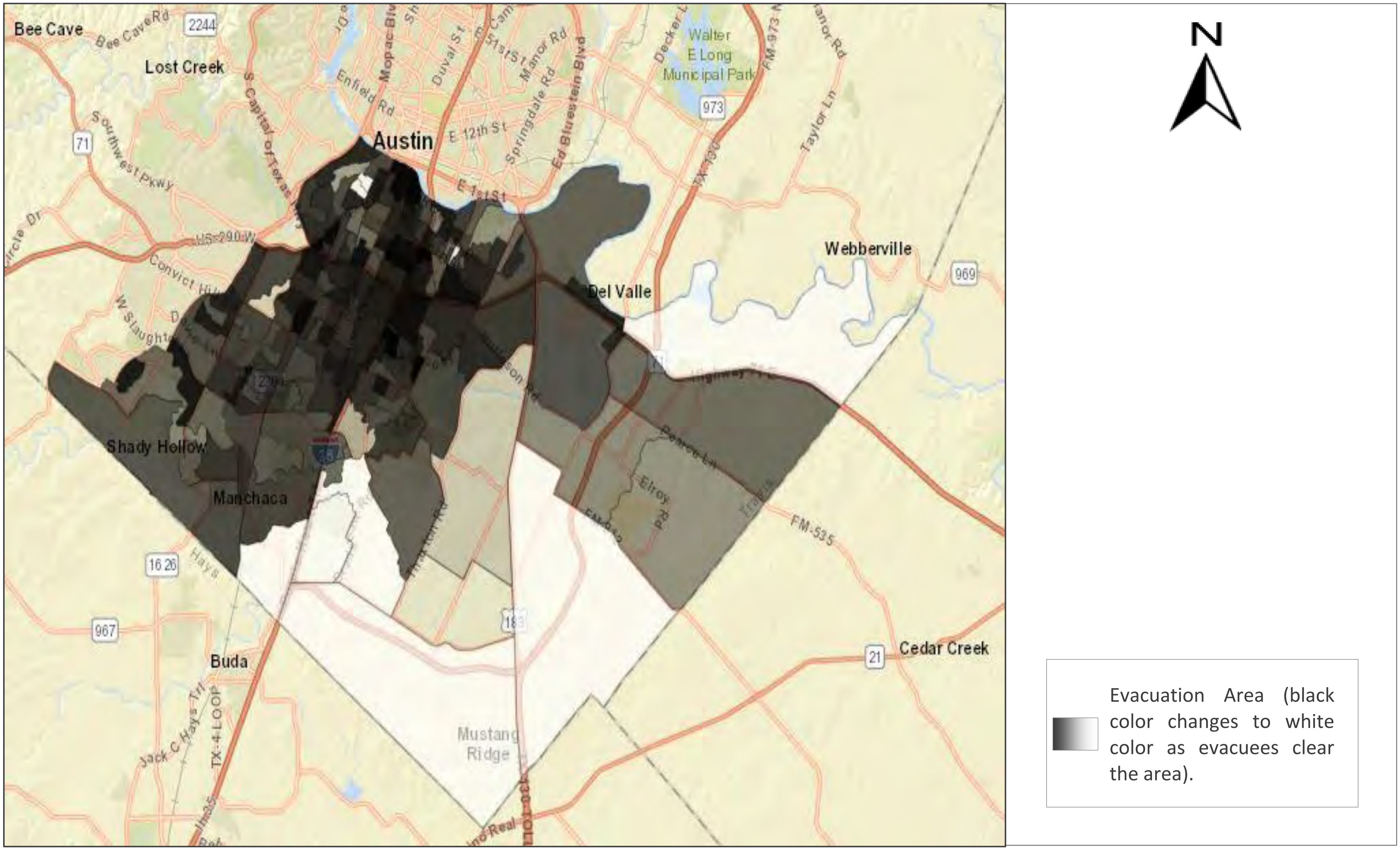
G2. Block Group Condition in the 1st Hour of Evacuation (Southeast Scenario)



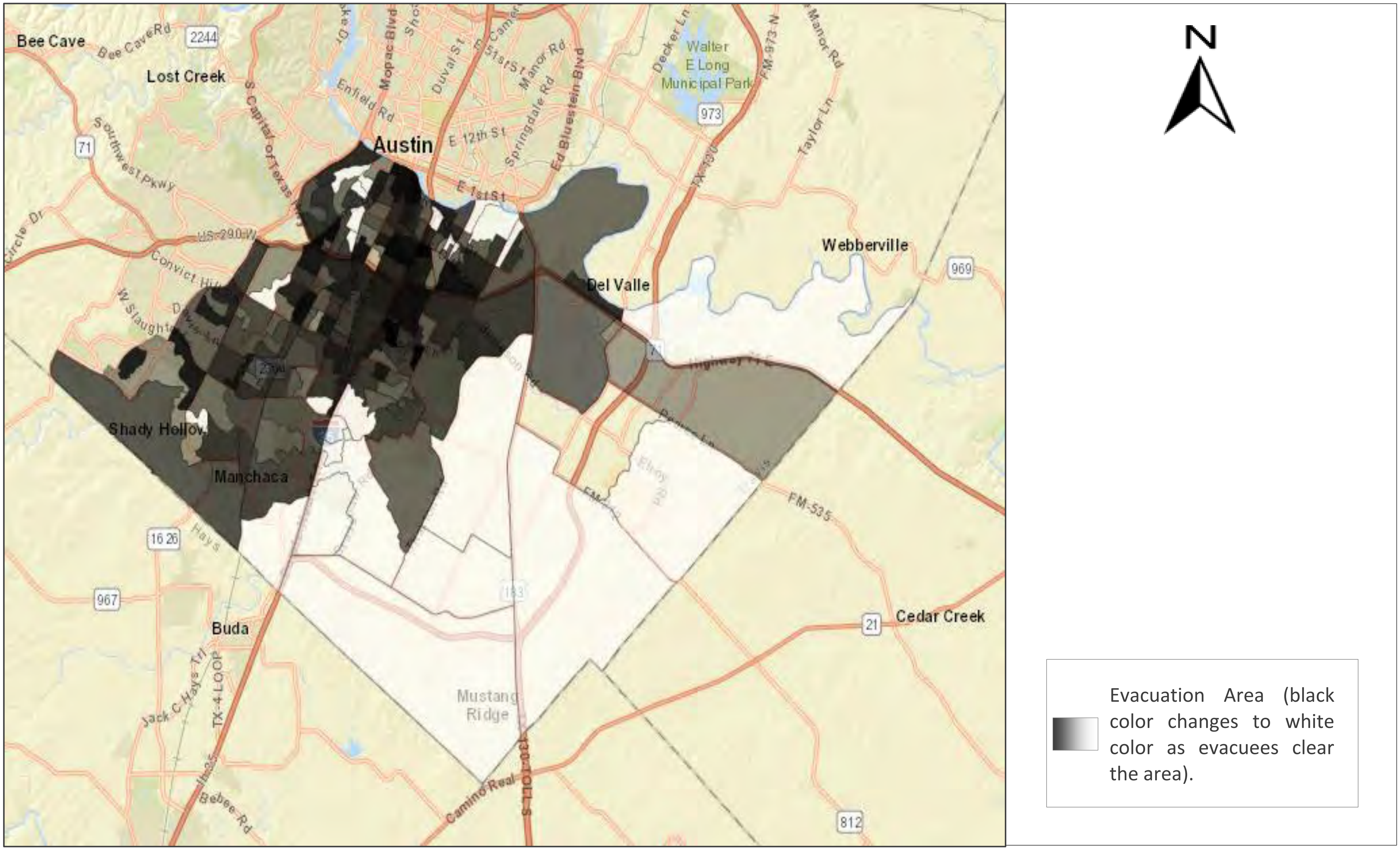
G3. Block Group Condition in the 2nd Hour of Evacuation (Southeast Scenario)



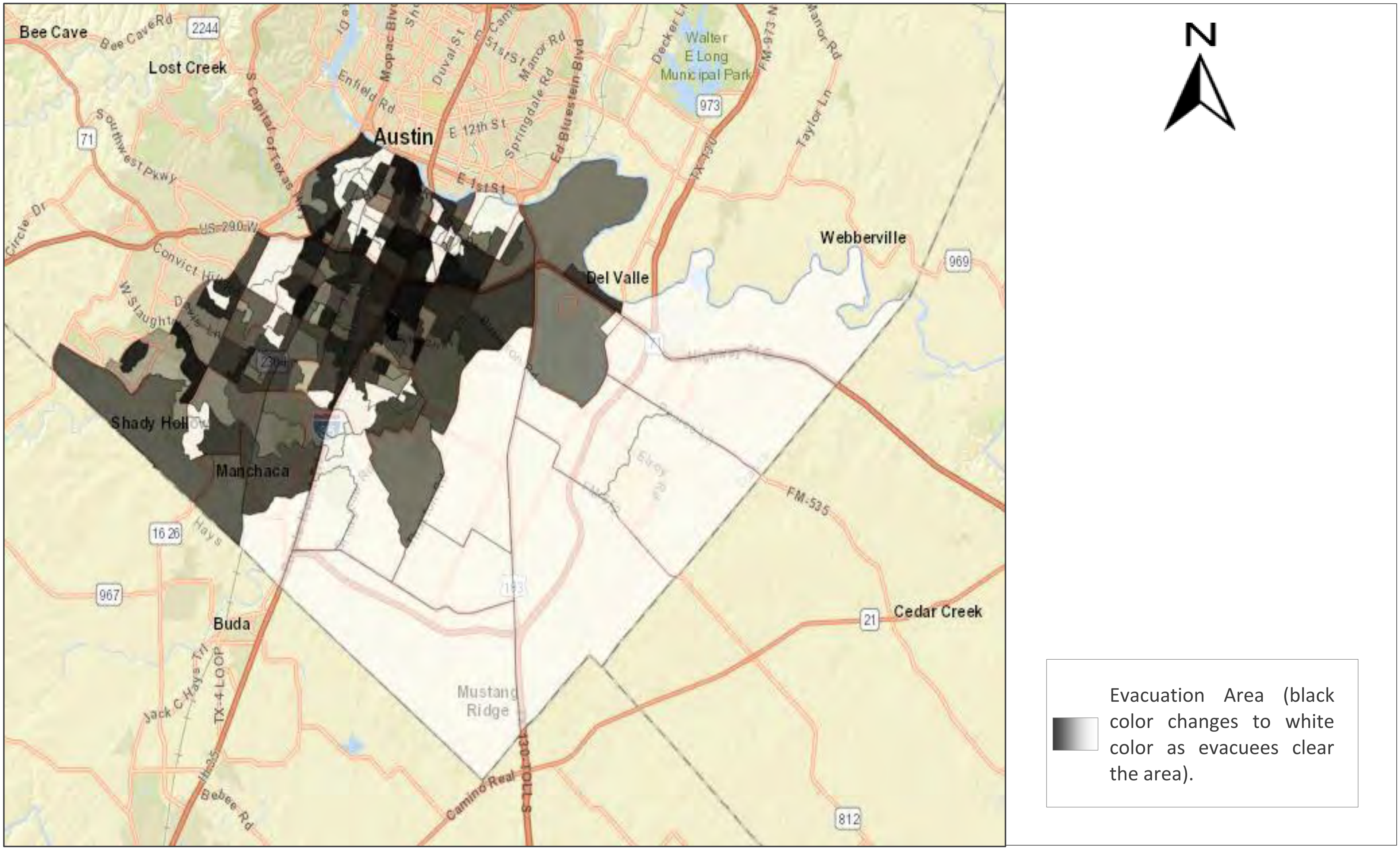
G4. Block Group Condition in the 3rd Hour of Evacuation (Southeast Scenario)



G5. Block Group Condition in the 4th Hour of Evacuation (Southeast Scenario)

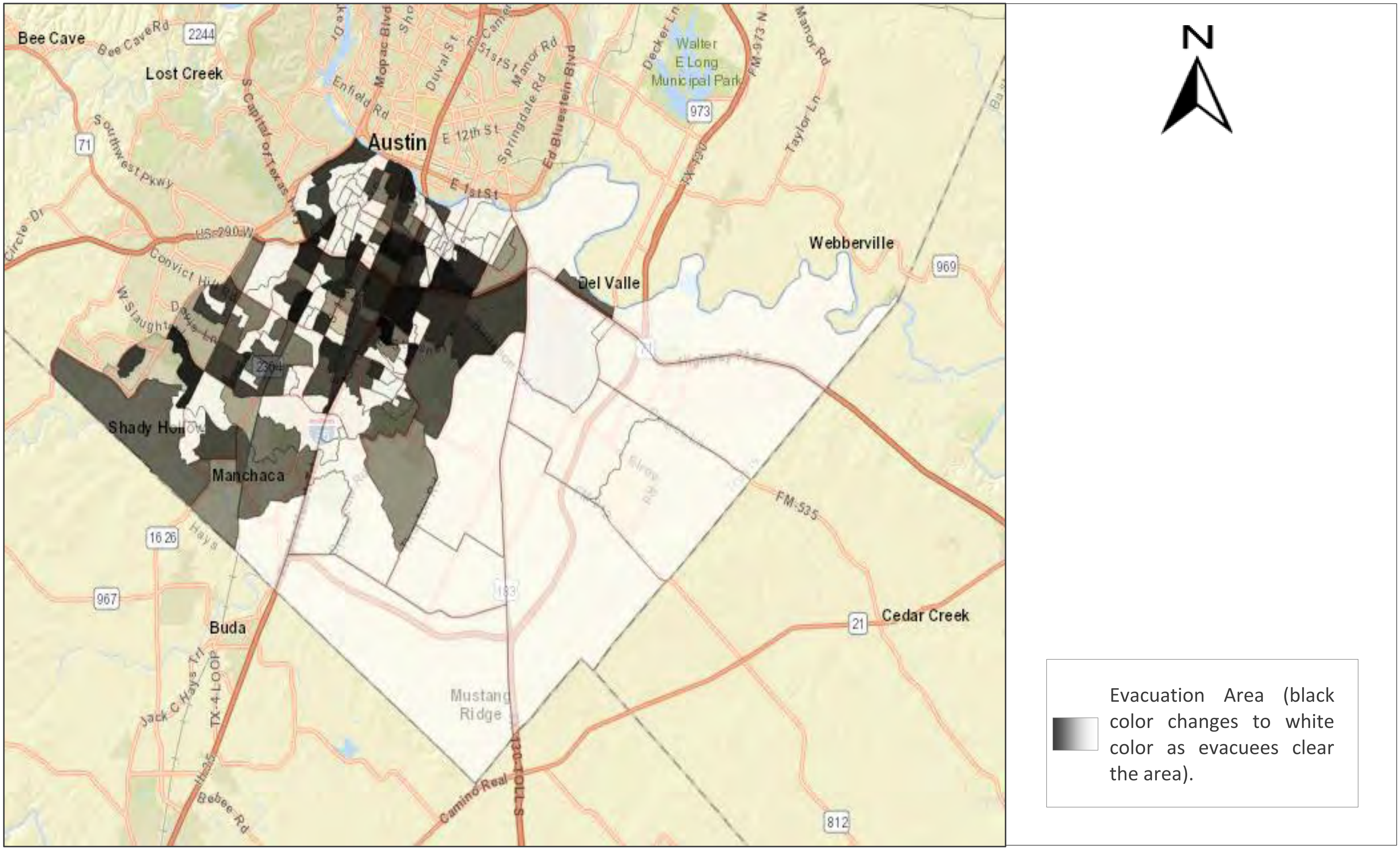


G6. Block Group Condition in the 5th Hour of Evacuation (Southeast Scenario)



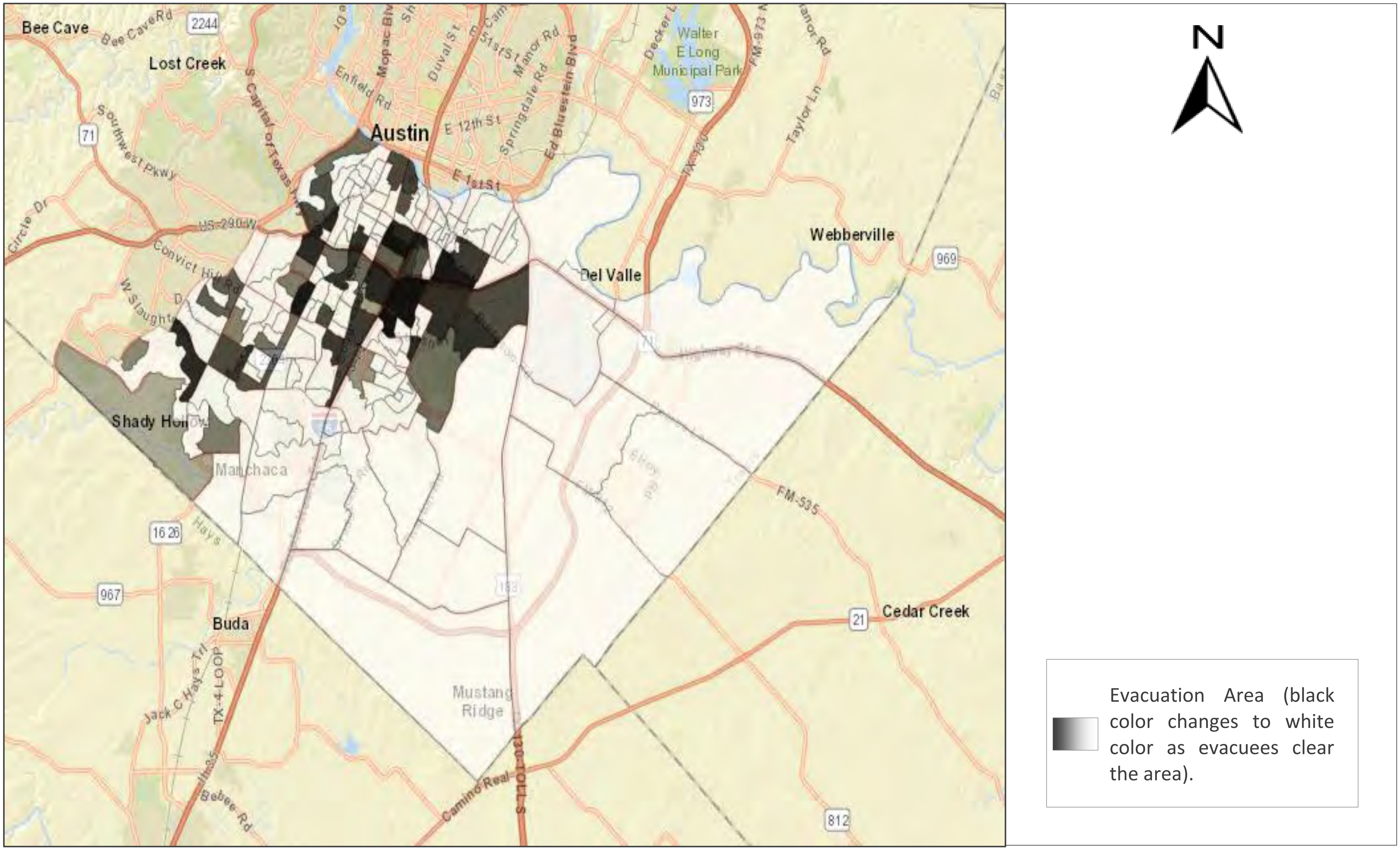
Evacuation Area (black color changes to white color as evacuees clear the area).

G7. Block Group Condition in the 6th Hour of Evacuation (Southeast Scenario)

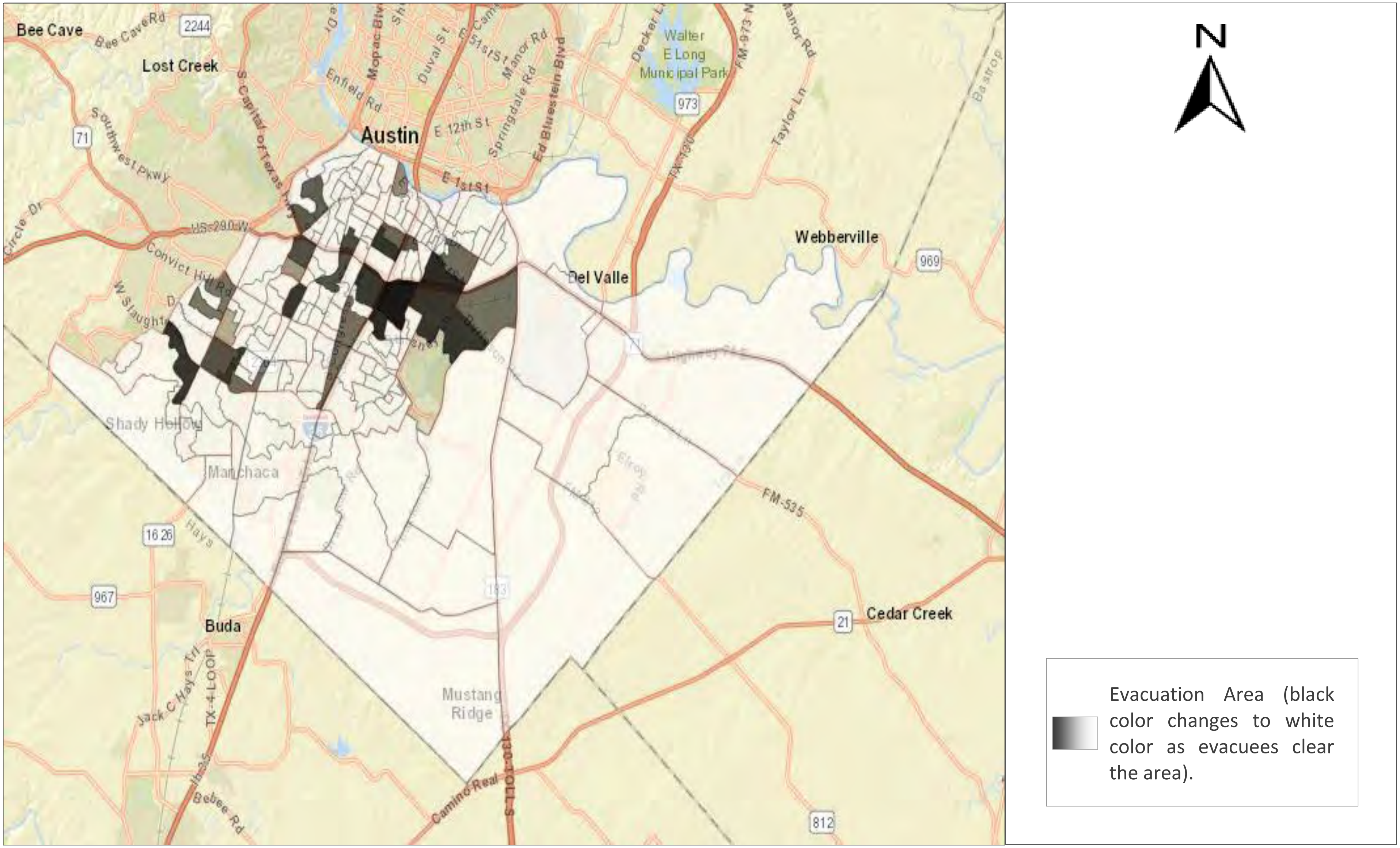


Evacuation Area (black color changes to white color as evacuees clear the area).

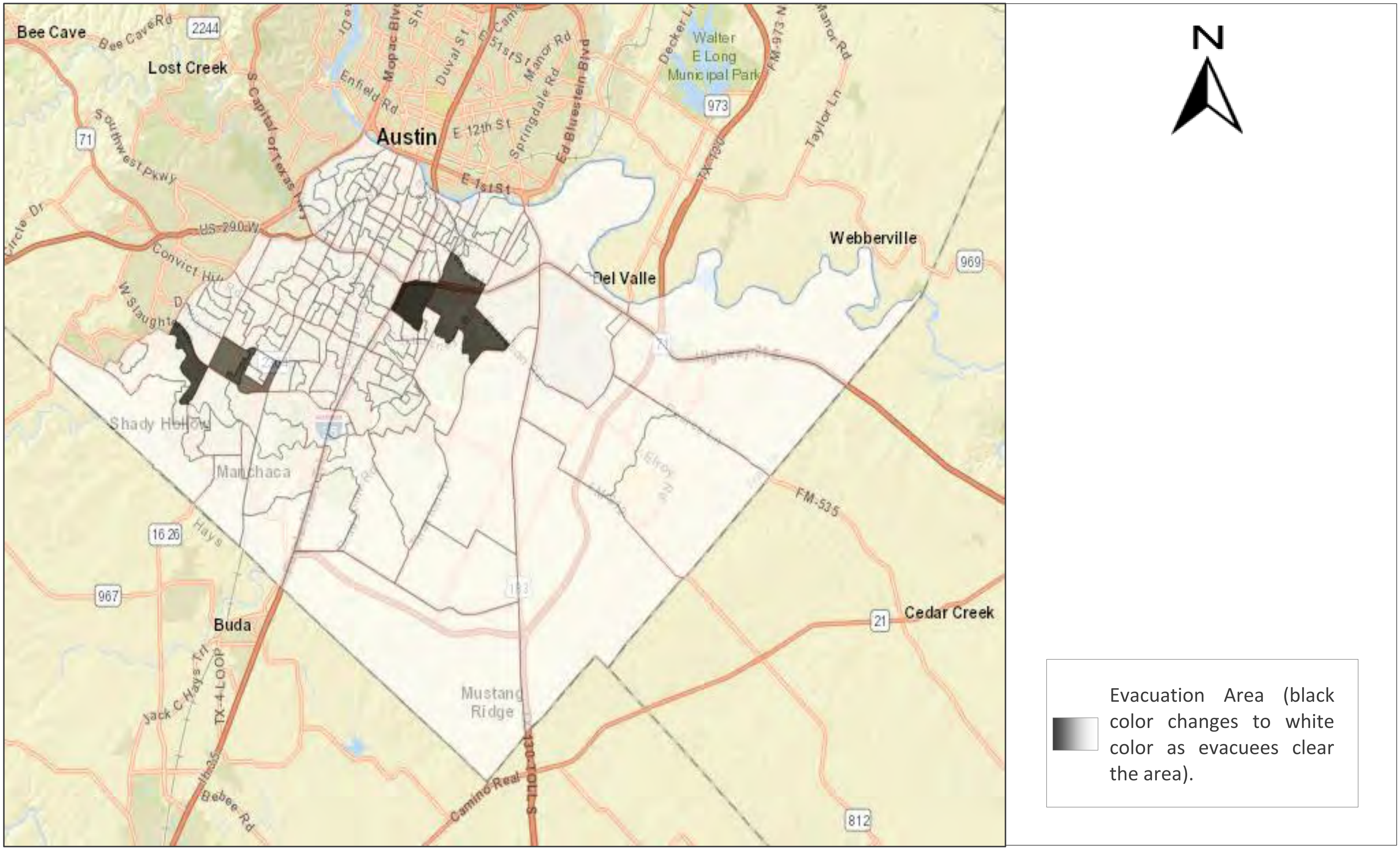
G8. Block Group Condition in the 7th Hour of Evacuation (Southeast Scenario)



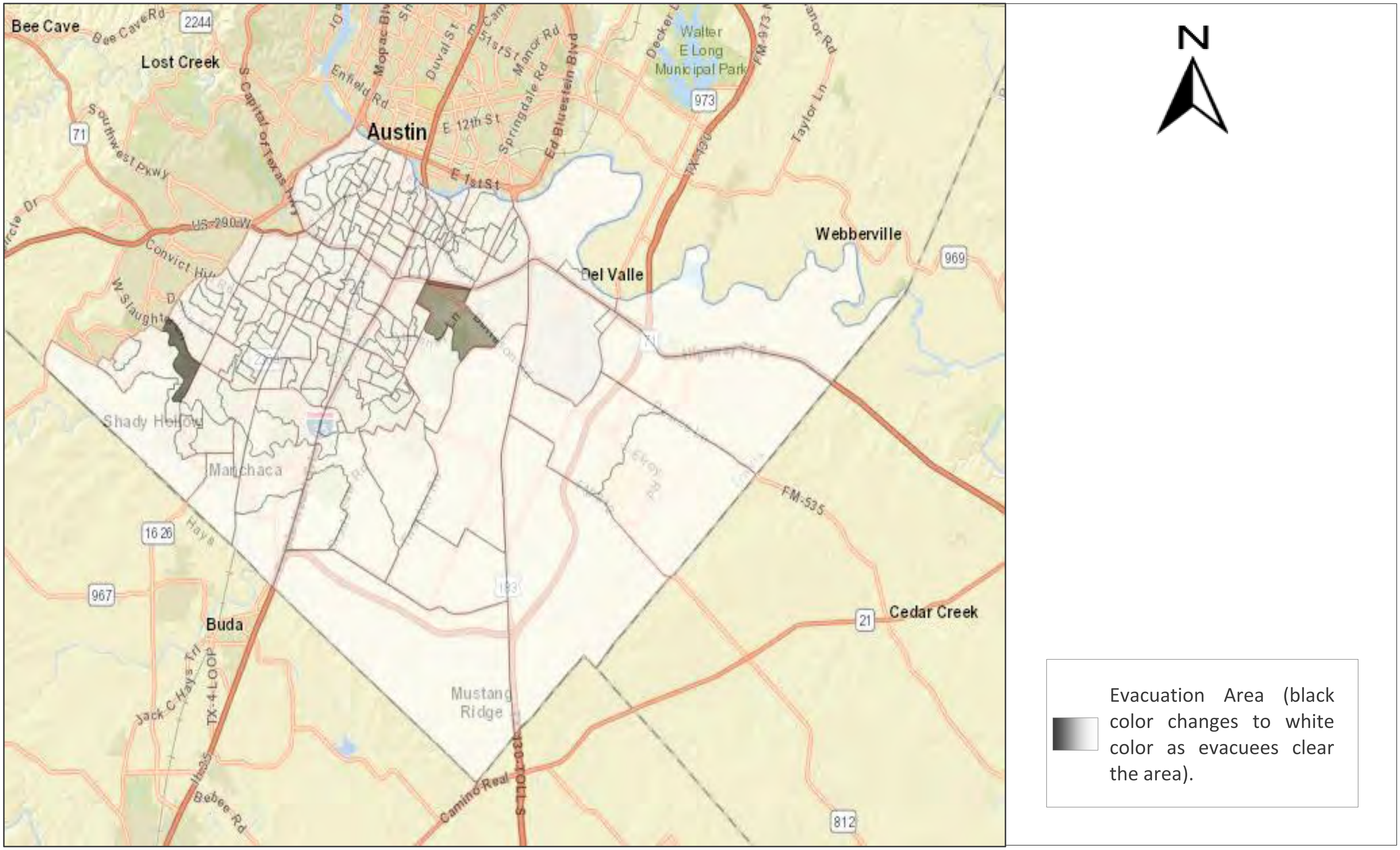
G9. Block Group Condition in the 8th Hour of Evacuation (Southeast Scenario)



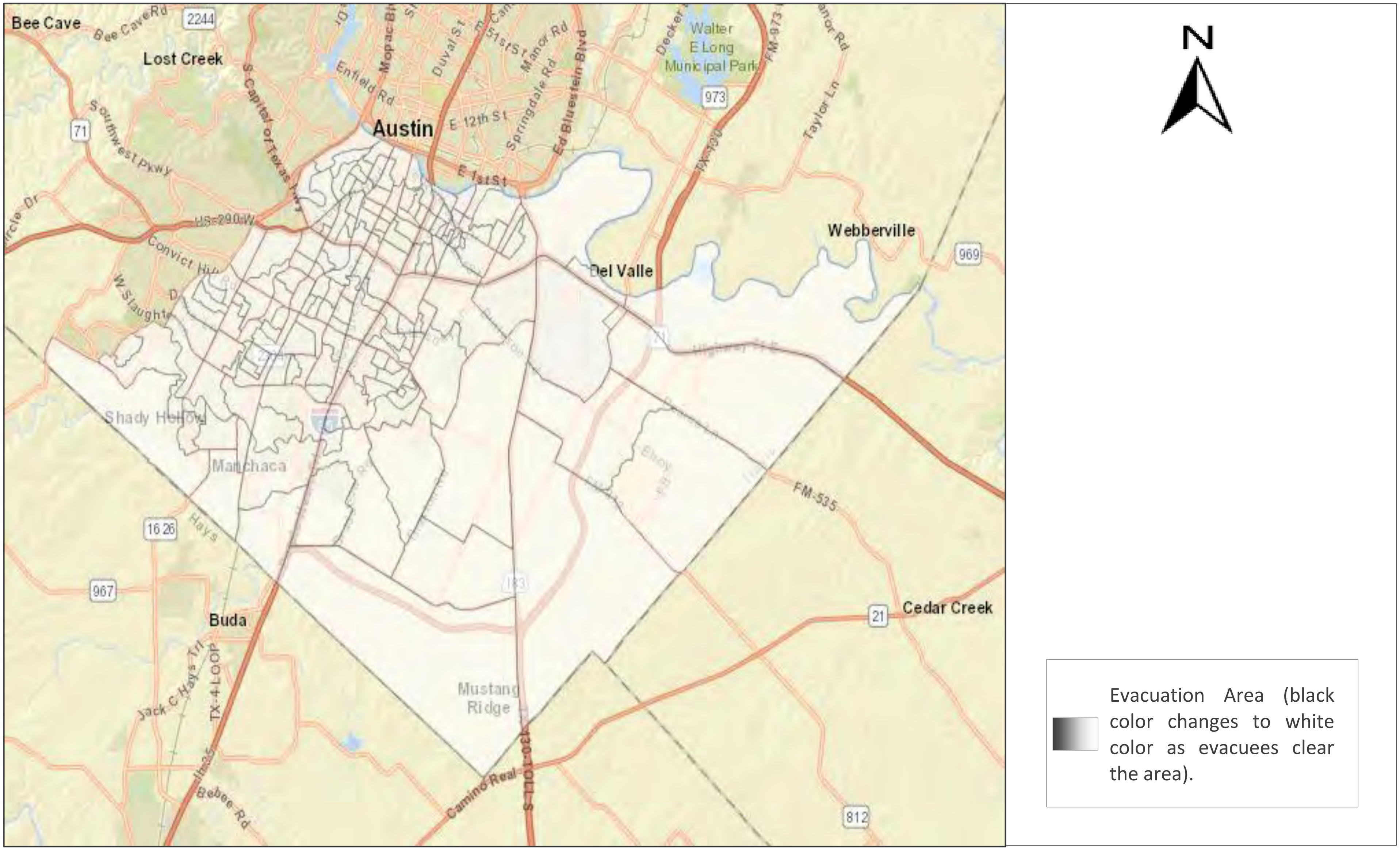
G10. Block Group Condition in the 9th Hour of Evacuation (Southeast Scenario)



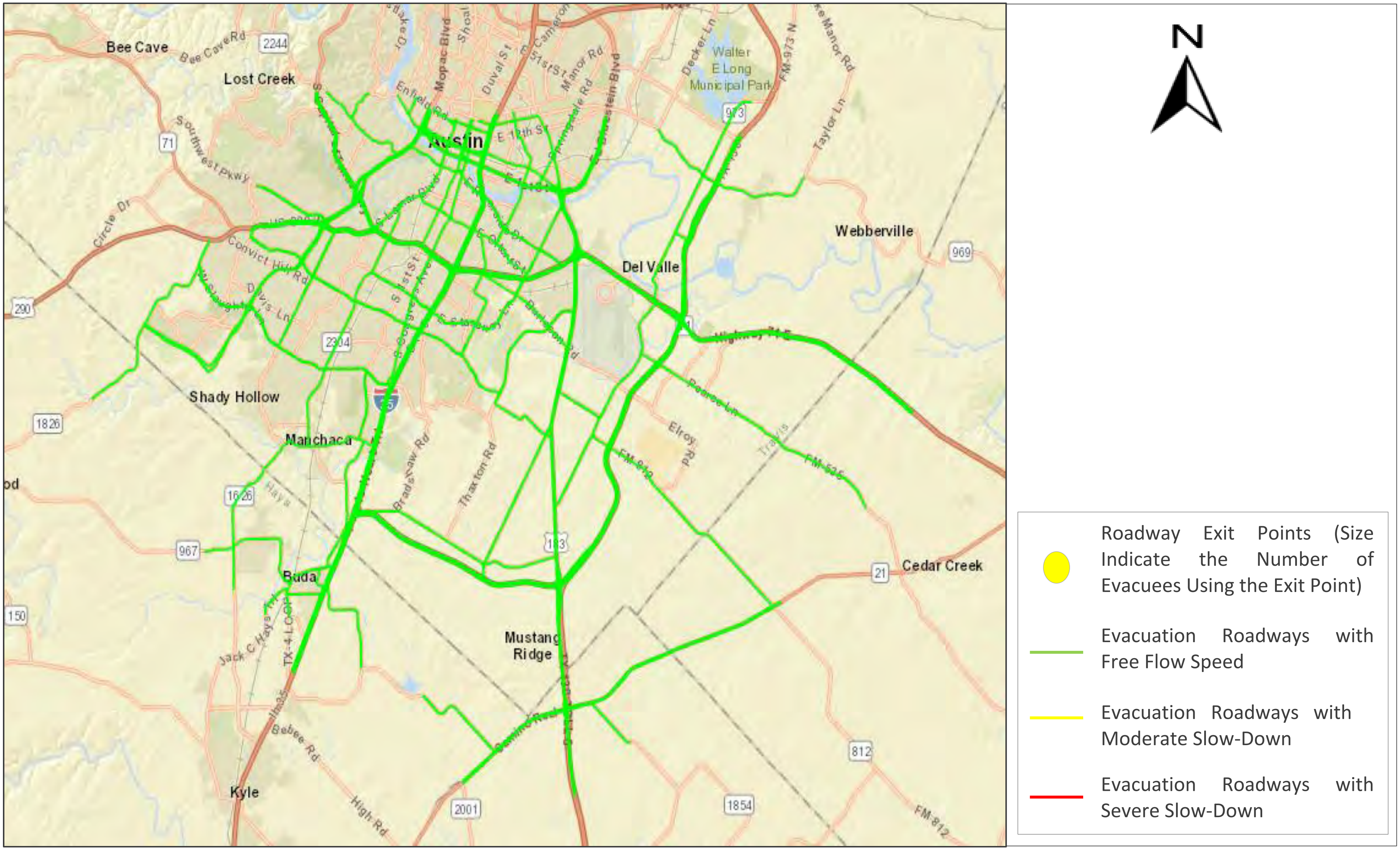
G11. Block Group Condition in the 10th Hour of Evacuation (Southeast Scenario)



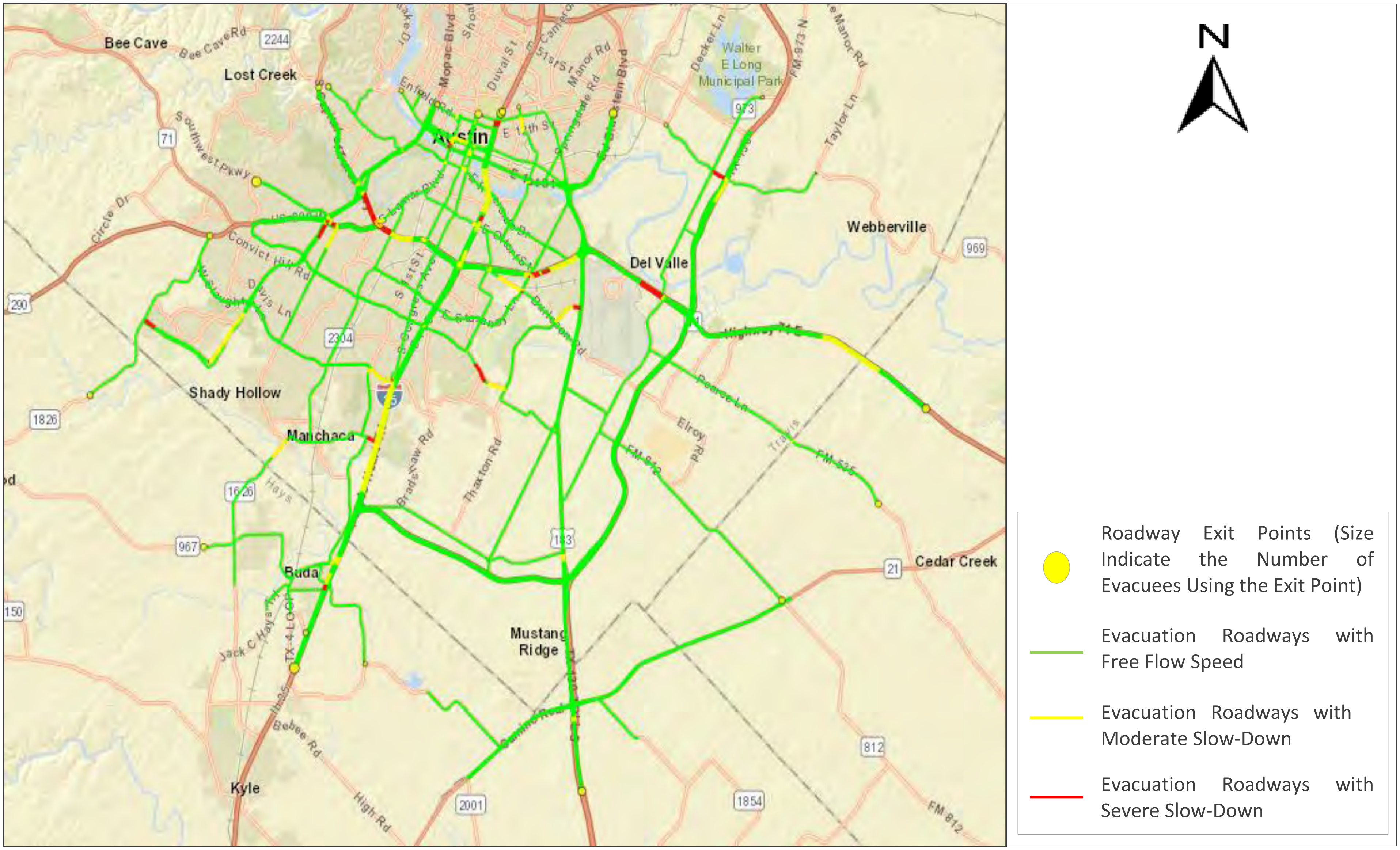
G12. Block Group Condition in the completion Hour of Evacuation (Southeast Scenario)



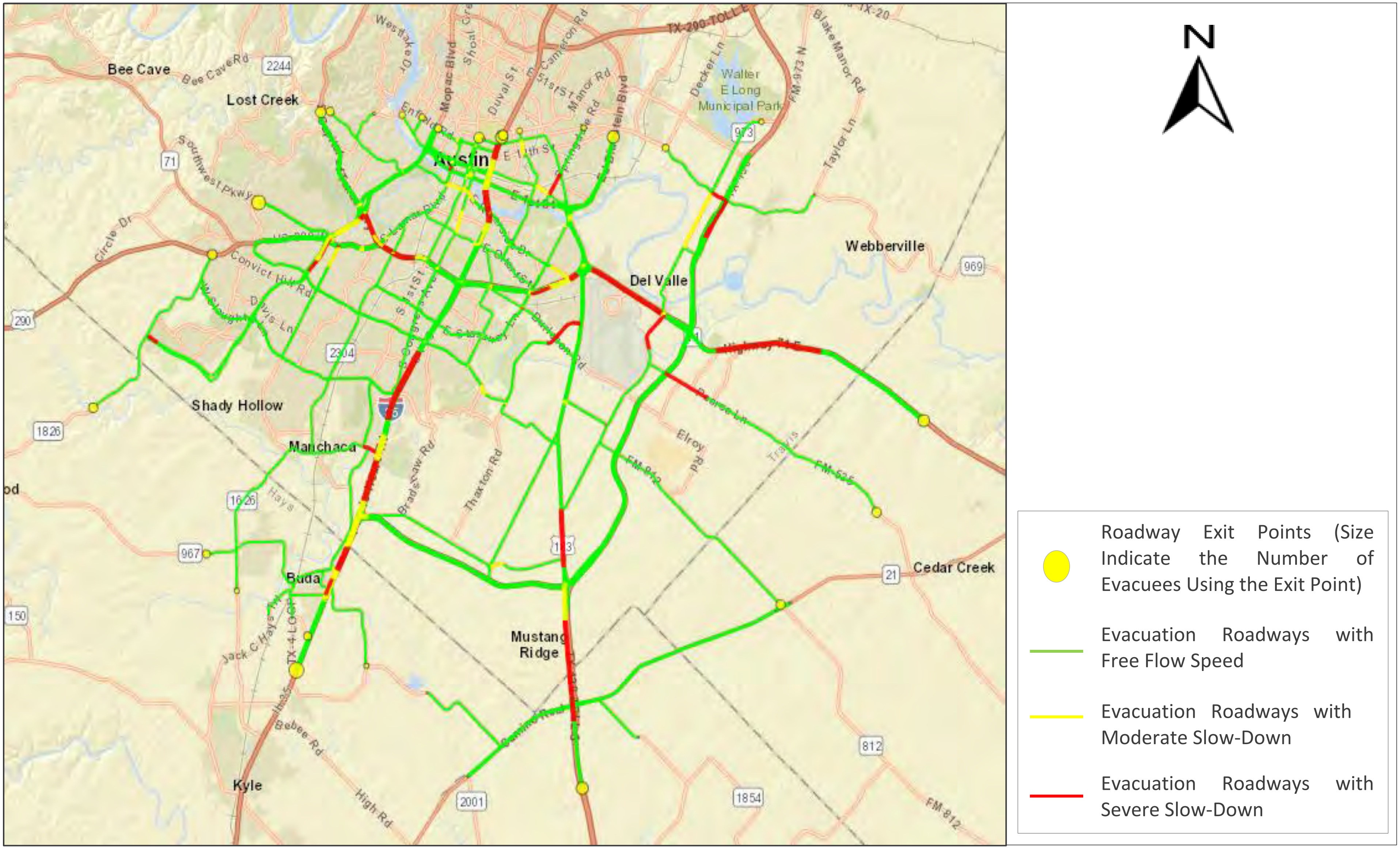
H1. Road Condition at the Beginning Hour of Evacuation (Southeast Scenario)



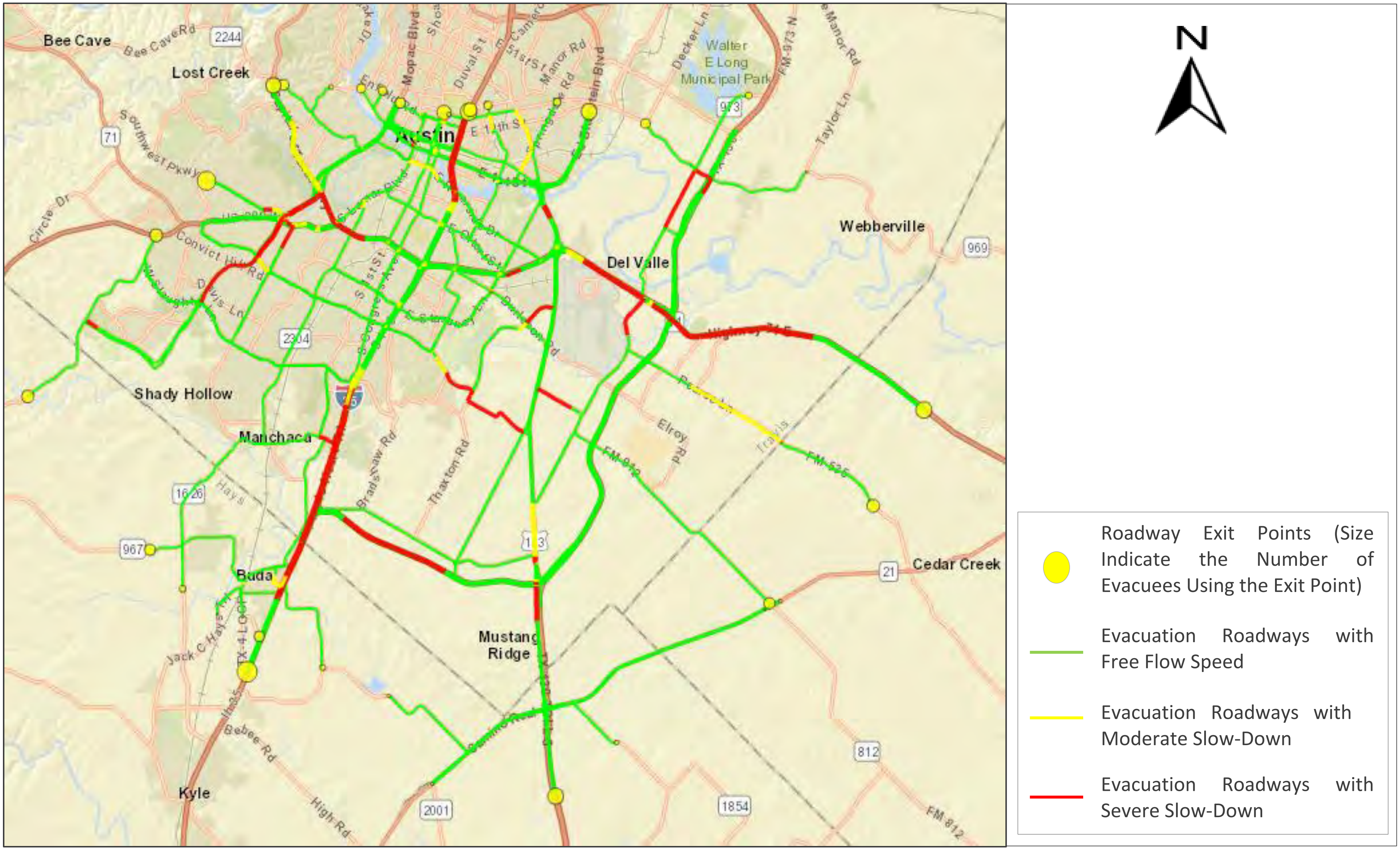
H2. Road Condition in the 1st Hour of Evacuation (Southeast Scenario)



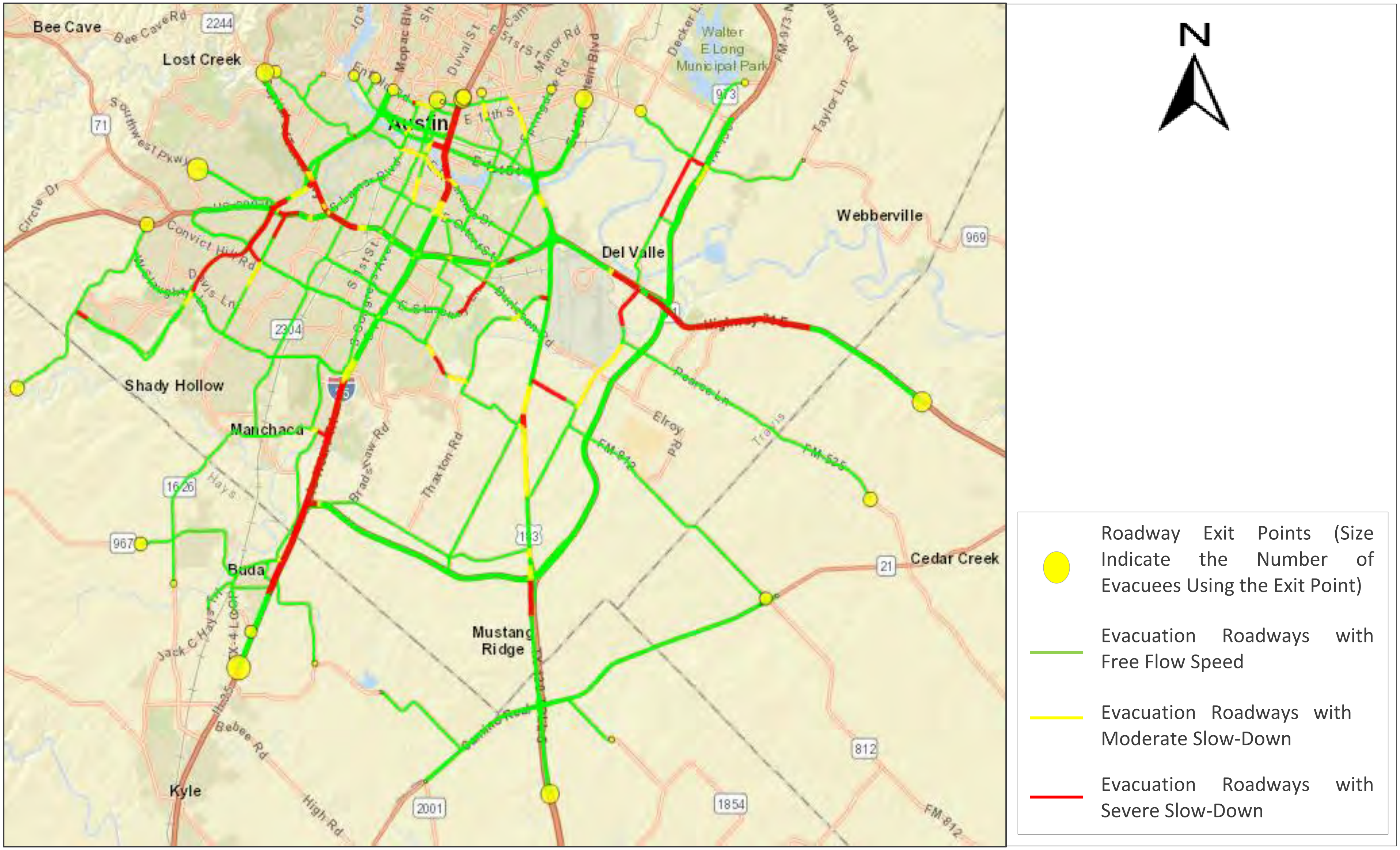
H3. Road Condition in the 2nd Hour of Evacuation (Southeast Scenario)



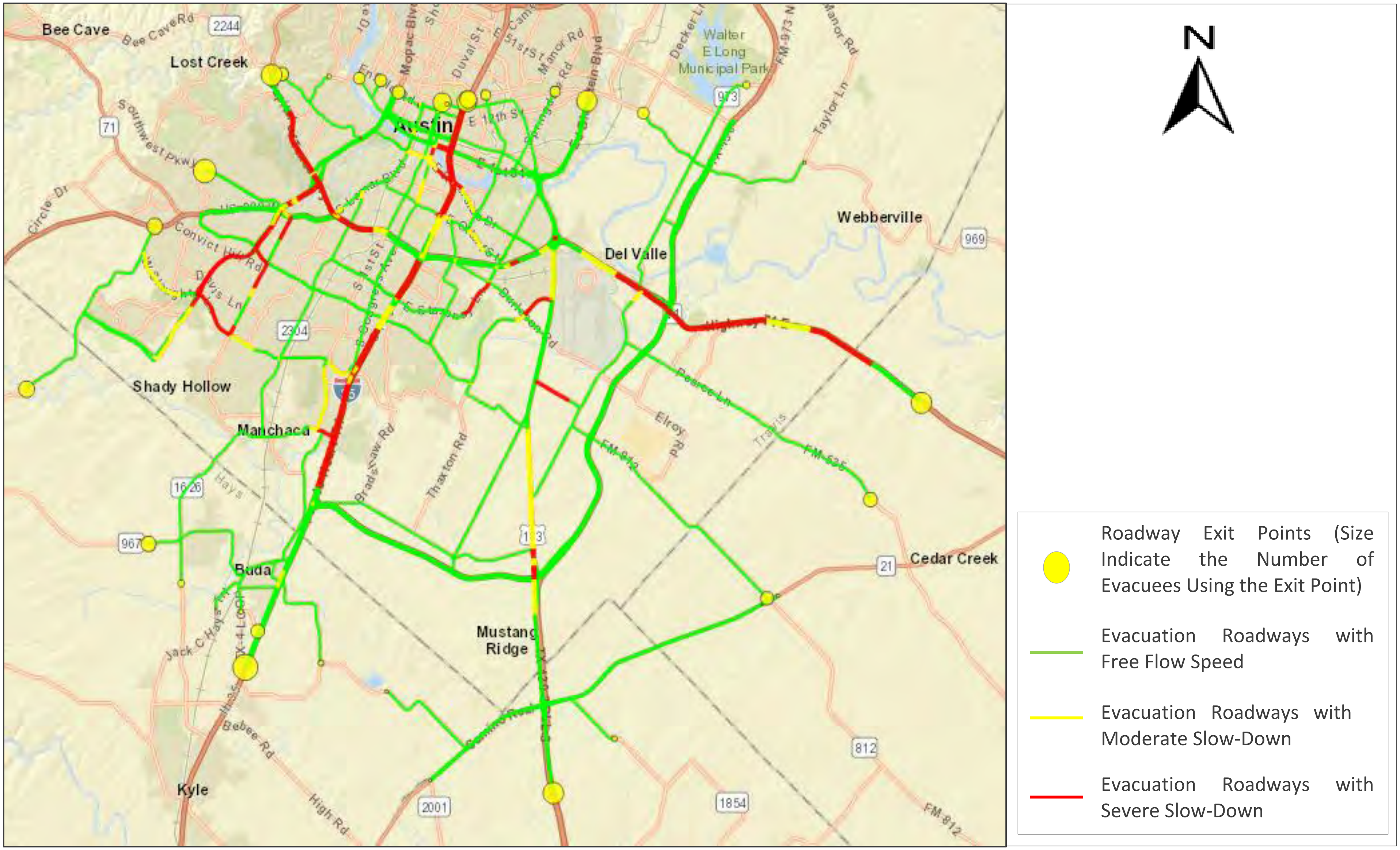
H4. Road Condition in the 3rd Hour of Evacuation (Southeast Scenario)



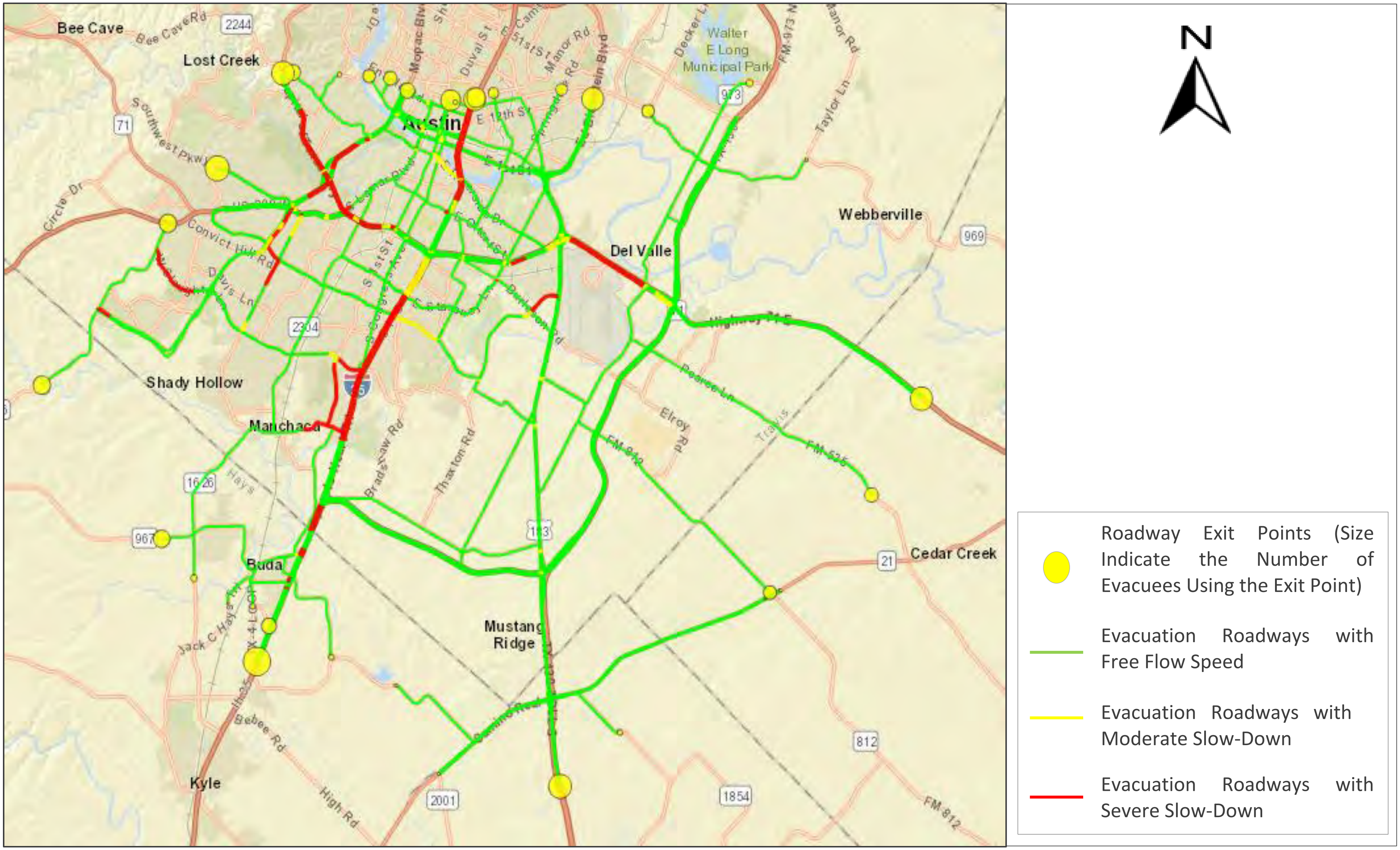
H5. Road Condition in the 4th Hour of Evacuation (Southeast Scenario)



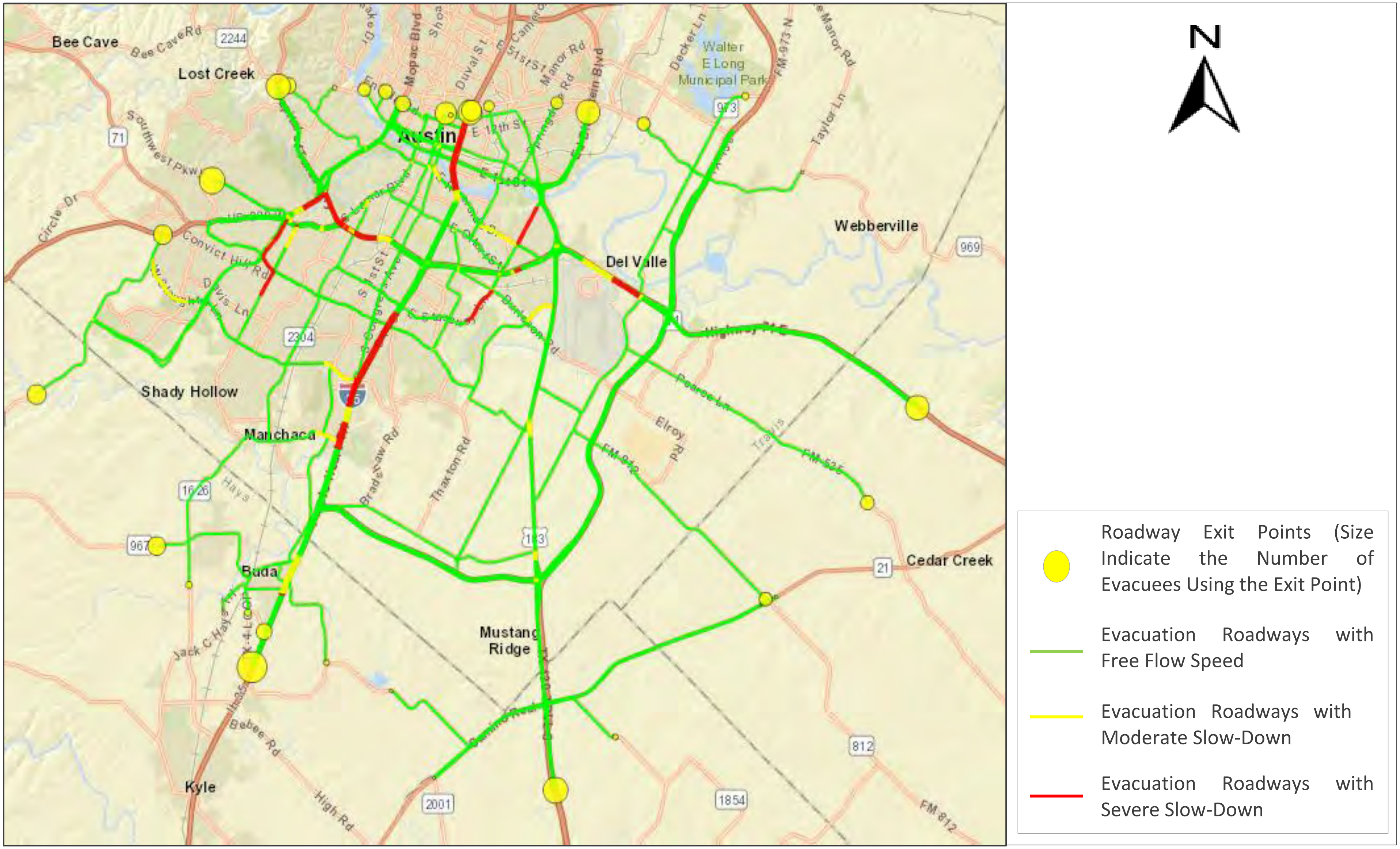
H6. Road Condition in the 5th Hour of Evacuation (Southeast Scenario)



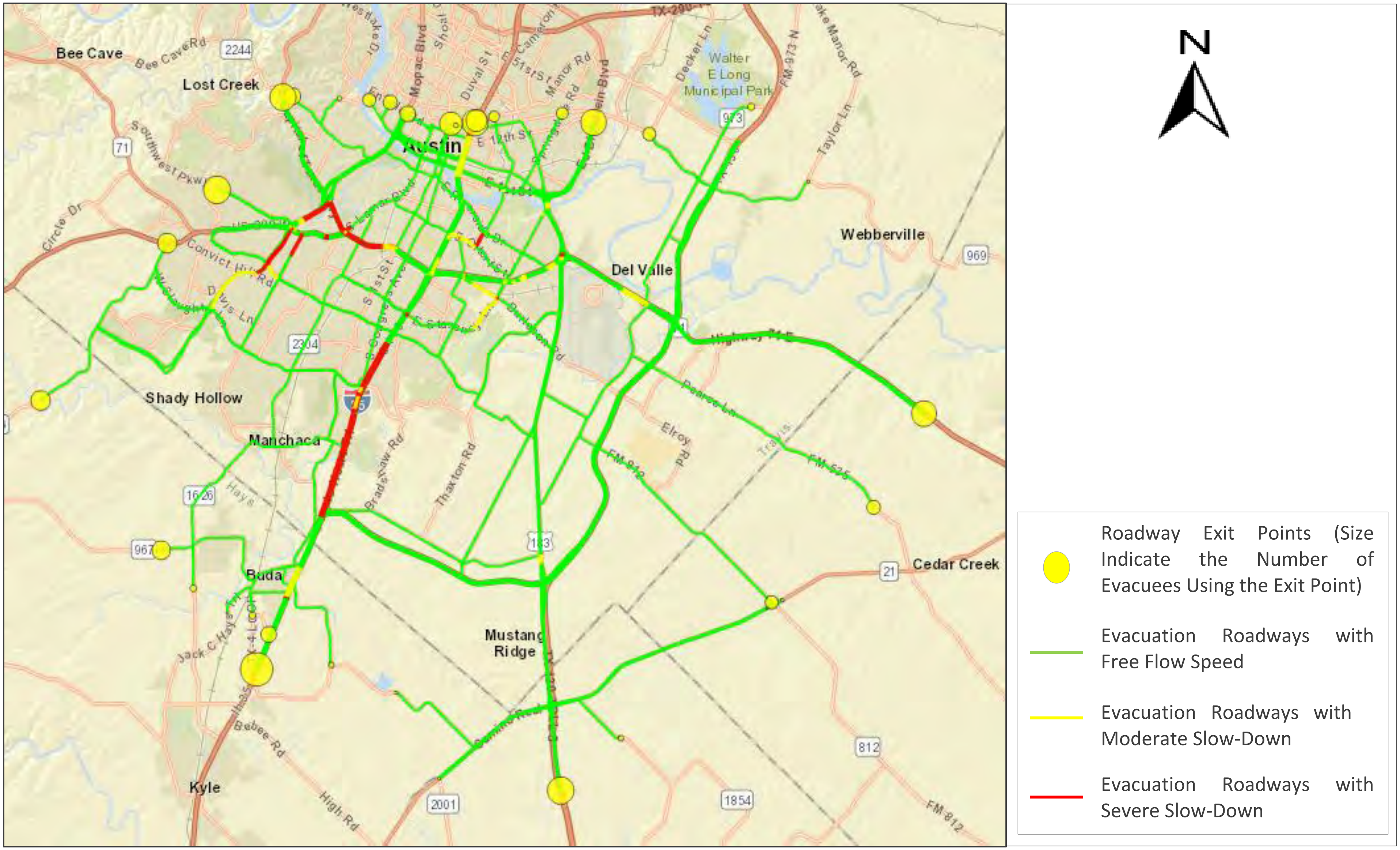
H7. Road Condition in the 6th Hour of Evacuation (Southeast Scenario)



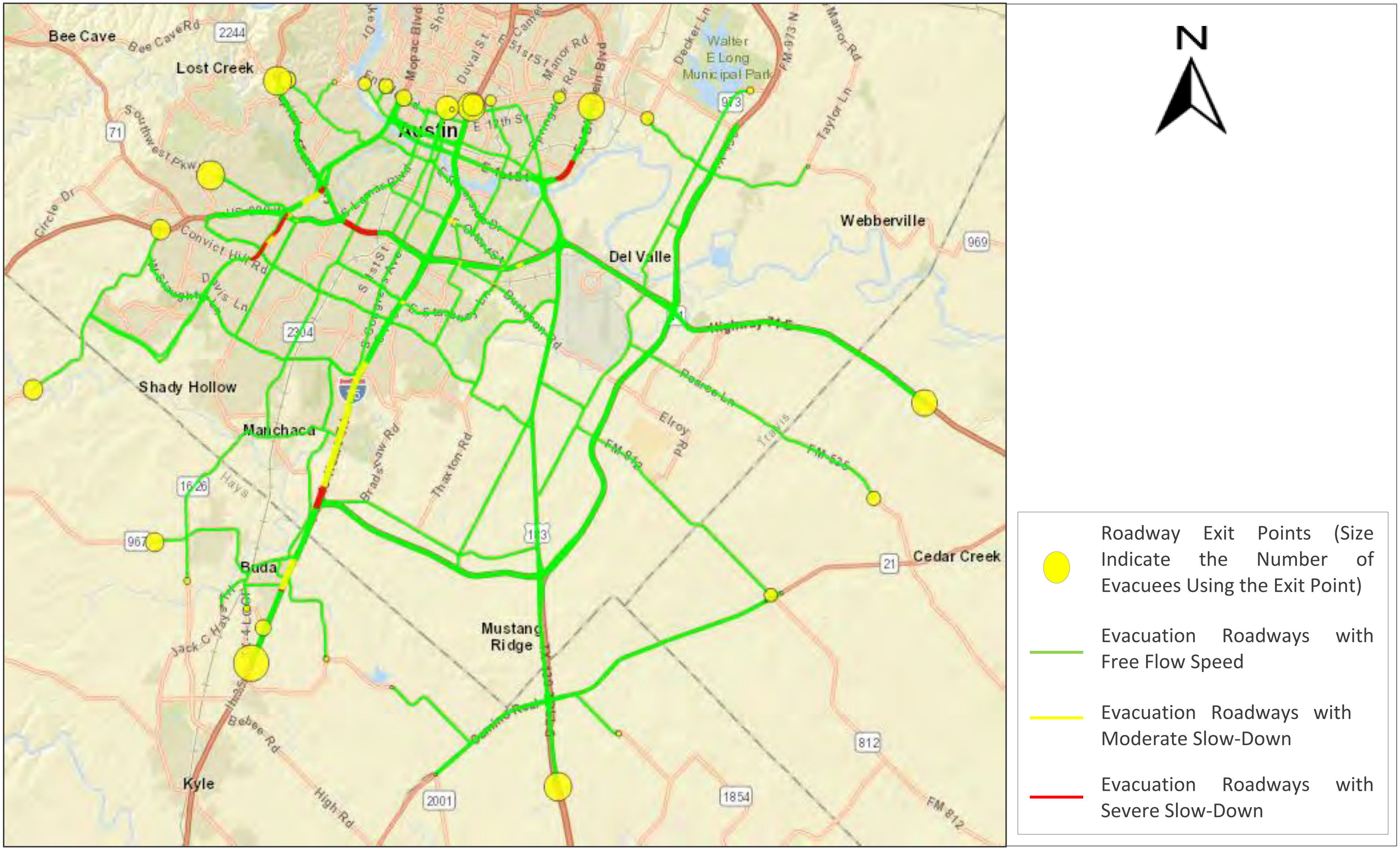
H8. Road Condition in the 7th Hour of Evacuation (Southeast Scenario)



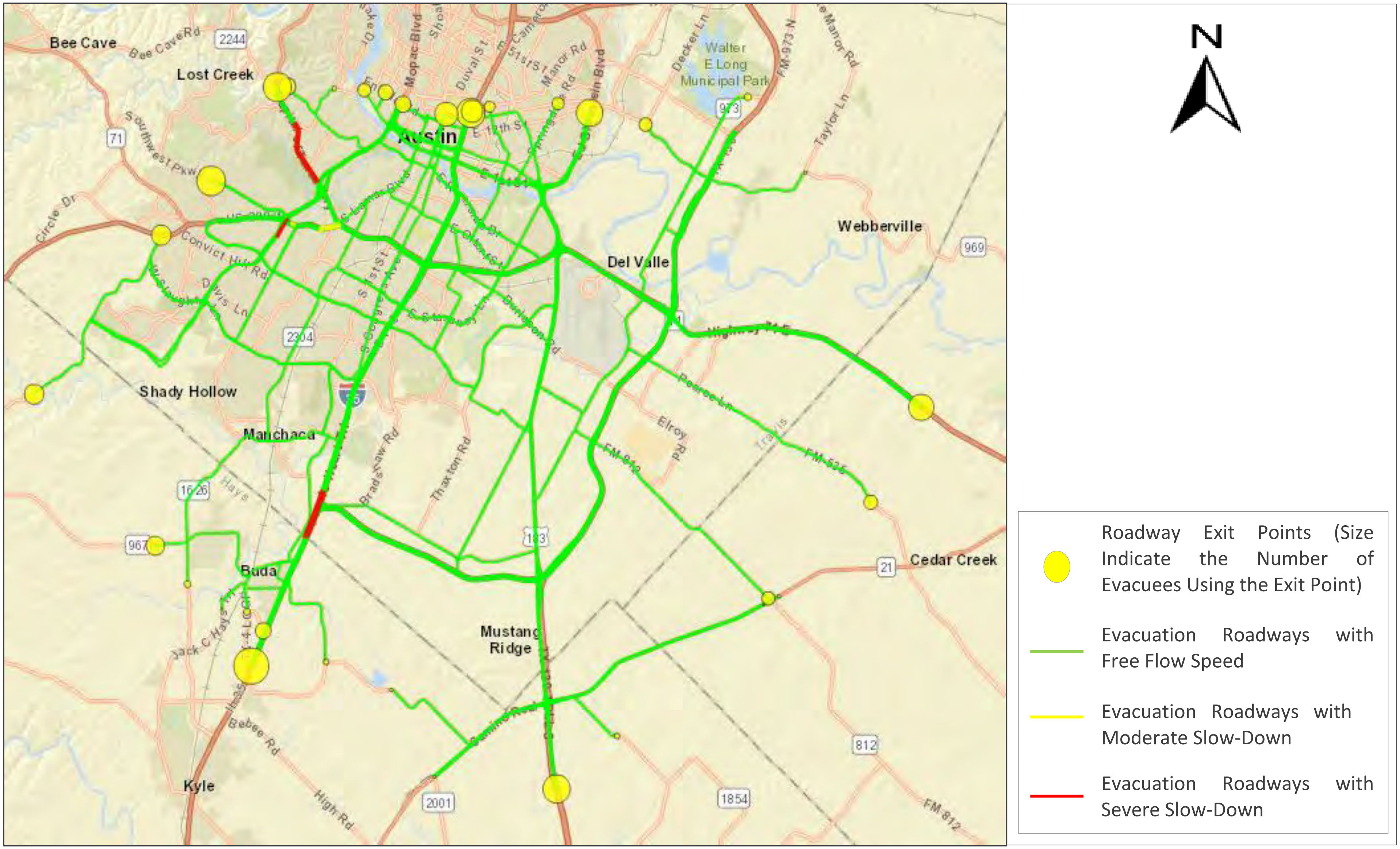
H9. Road Condition in the 8th Hour of Evacuation (Southeast Scenario)



H10. Road Condition in the Hour of Evacuation (Southeast Scenario)



H11. Road Condition in the 10th Hour of Evacuation (Southeast Scenario)



H12. Road Condition in the Completion of Evacuation