Knoxville Fire Department

Fire Station and Apparatus Deployment Study

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Introduction and Scope of Work

The staff of the University of Tennessee Municipal Technical Advisory Service (UT-MTAS) strives daily to meet its consensus mission. As an agency of the University of Tennessee and in collaboration with the Tennessee Municipal League, MTAS leverages the resource of the university to improve the lives of the people of Tennessee with technical consulting, research, and training for municipal governments. This study works toward UT-MTAS's mission and was conducted at the request of Mr. Stan Sharp, Fire Chief for the City of Knoxville, Tennessee. The purpose of this study is to evaluate the adequacy and deployment of current fire apparatus and fire station locations.

The University of Tennessee Municipal Technical Advisory Service (UT-MTAS) will provide the final version of this report to the City of Knoxville, Tennessee, in an electronic as well as a physical hardcopy binder.

Background

The City of Knoxville is the principal city in the Knoxville Metropolitan Statistical Area and serves as county seat for Knox County. The City of Knoxville is located entirely in Knox County. Knoxville is situated in east Tennessee in very close proximity to the Great Smoky Mountain National Park. The city is approximately 180 miles east of Nashville, the State capitol, and 110 miles southwest of Bristol, Tennessee. A Mayor-Council form of government governs the city. The nine-member council is elected representing six council districts and three members are elected at large. The mayor is elected by a vote of the citizens and the vice-mayor is elected by votes of the members of the council.

Fire protection and staffing is a local policy issue. A city must balance available local resources against what is determined to be acceptable risk. The City of Knoxville provides fire services to almost 190,000 residents, based on the 2018 census estimates, through a municipal fire department organized under Chapter 2, Article II of the city's charter. The City of Knoxville is also home to the University of Tennessee which includes Neyland Stadium, the sixth largest football stadium in the United States. Neyland Stadium has a capacity of over 103,000 and regularly is at maximum capacity. This means that on home football game days, the City of Knoxville's population can experience tremendous growth due to the University.

The Knoxville Fire Department is a career fire department recognized by the State of Tennessee and funded by general fund allocations of the City of Knoxville. The fire department employs approximately 327 members. In addition to a professional staff, the department maintains a fleet of 42 front-line and reserve fire apparatus/vehicles. These apparatus/vehicles are deployed from 19 fire stations, located throughout just over 106 square miles (Table 1) corporate limits of the city. The Knoxville Fire Department responds to more than 25,000 calls for service annually. The Department has a minimum staffing level policy and practice for each apparatus. Knoxville's Insurance Services Office (ISO) Public Protection Classification (ISO rating) is currently a Class 2. The Class 2 ISO rating places Knoxville well within the top 1% of cities nationwide (Figure 1) as well as within the top 1% of cities in Tennessee (Figure 2). In terms of fire protection, this indicates that the Knoxville Fire Department has made excellent decisions in planning for community fire protection.

Knoxville Fire Department Stations and Apparatus		
Station	**Equipment**	**Address**
HQ	Batt 1; Engine 1; Engine 2; Ladder 1; Rescue 1	600 W. Summit Hill Drive, Knoxville, Tennessee
3	Engine 3; Ladder 3	204 E. Baxter Avenue, Knoxville, Tennessee
4	Quint 4	2300 Linden Avenue, Knoxville, Tennessee
5	Engine 5	419 Arthur Street, Knoxville, Tennessee
6	Engine 6	3925 Holston Drive NE, Knoxville, Tennessee
7	Engine 7	1216 New York Avenue, Knoxville, Tennessee
9	Engine 9; Ladder 9	1625 Highland Avenue, Knoxville, Tennessee
10	Quint 10	2911 Sevier Avenue, Knoxville, Tennessee
11	Batt 2; Engine 11	2600 Whittle Springs Road, Knoxville, Tennessee
12	Engine 12	4620 Old Kingston Pike, Knoxville, Tennessee
13	Engine 13	4701 Chapman Highway, Knoxville, Tennessee
14	Batt 4; Squad 14	5400 Central Avenue, Knoxville, Tennessee
15	Engine 15; Ladder 15	5301 Jacksboro Pike, Knoxville, Tennessee
16	Squad 16	5102 Asheville Highway, Knoxville, Tennessee
17	Quint 17	4804 Western Avenue, Knoxville, Tennessee
18	Batt 3; Engine 18; HazMat 18	610 N. Weisgarber Road, Knoxville, Tennessee
19	Engine 19	6328 Chapman Highway, Knoxville, Tennessee
20	Squad 20; Ladder 20	200 Portsmoth Road, Knoxville, Tennessee
21	Quint 21	245 Perimeter Park Road, Knoxville, Tennessee

Table 1-Knoxville Fire Department Stations and Apparatus 2020

Insurance Service Officer (ISO) statistics for the State of Tennessee and for the United States

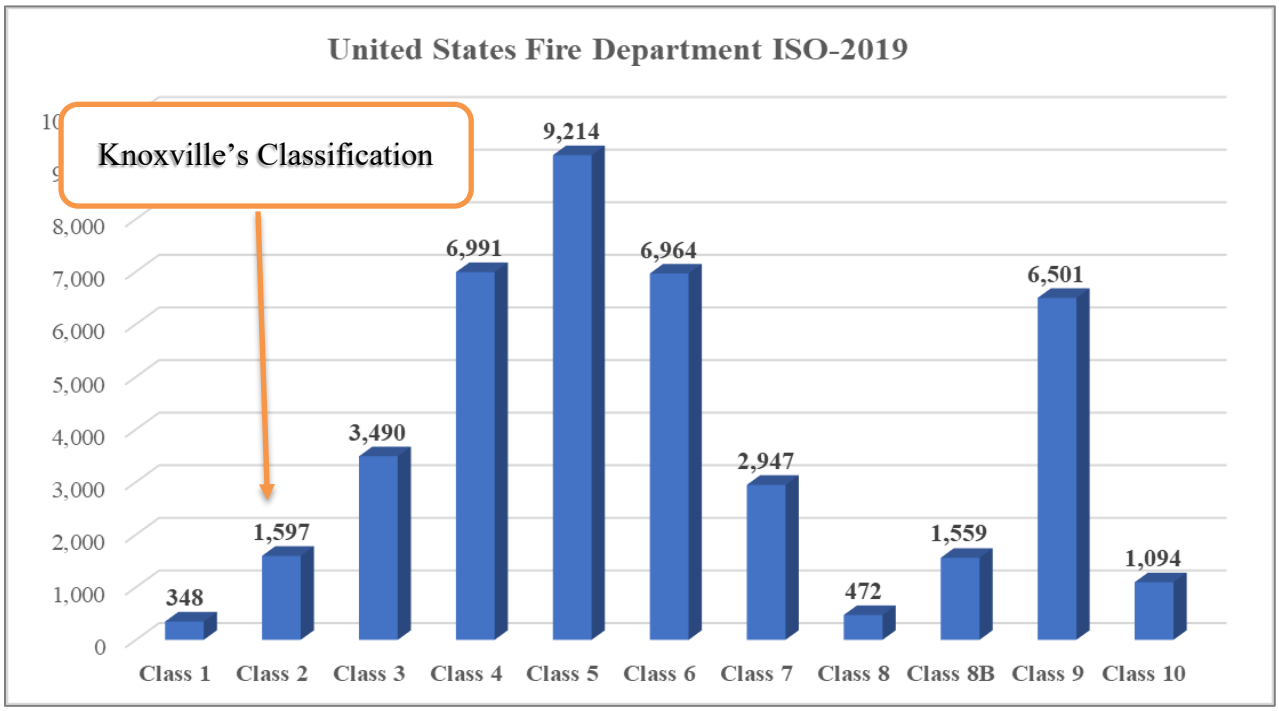


Figure 1 – Public Protection Classification (ISO Rating) in the US

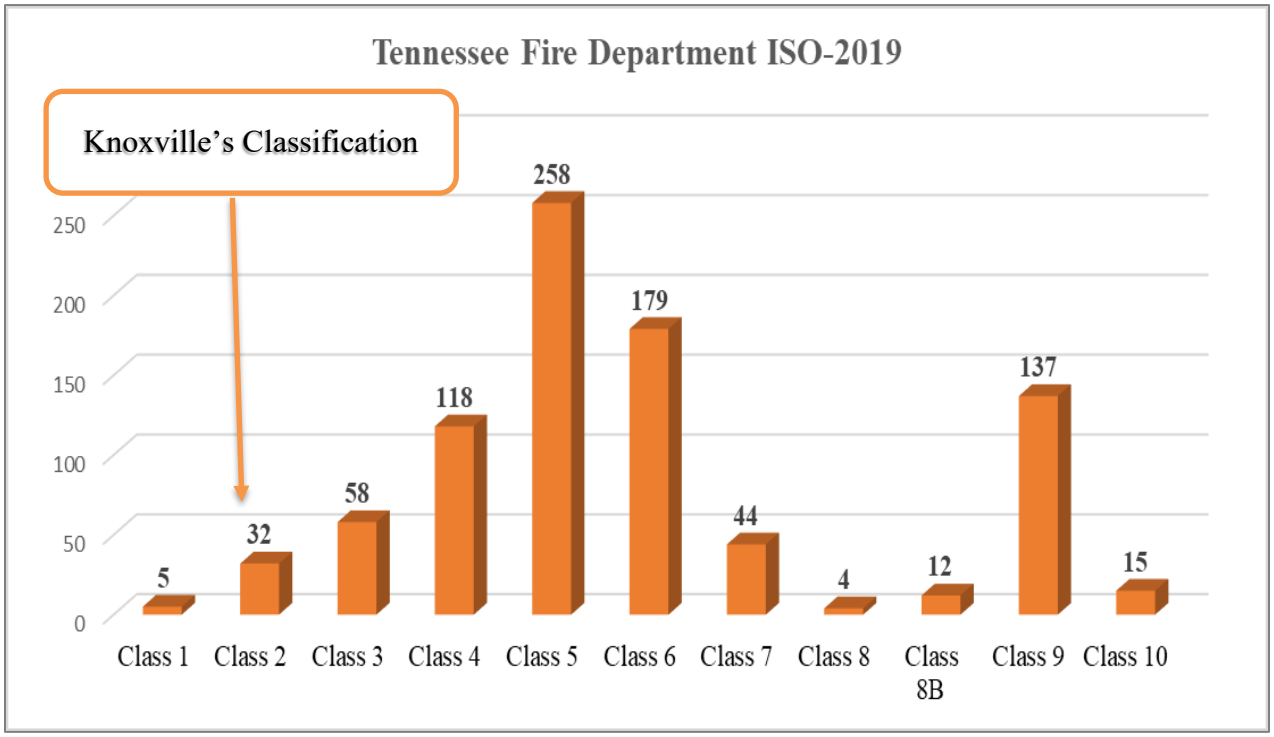


Figure 2 – Public Protection Classification (ISO Rating) in Tennessee

The Knoxville Fire Department is considered an all-hazards fire department. This means that the Department is alerted to and responds to all types of emergency incidents in all geographic locations inside Knoxville's corporate limits. What this means to the community is that the members of the Fire Department are properly trained and routinely respond to any emergency call for service the citizens and visitors have. The scope and complexity of the incident responses can be from one person having a minor medical emergency to a fire/mass casualty incident at a University of Tennessee football game.

The Knoxville Utility Board provides electricity to the city and beyond. The city relies on and coordinates with multiple water purveyors in order to meet the potable and fire suppression water flow requirements of the city. The adequacy of the water systems, water pressure and/or the needed gallons-per-minute fire flow to support adequate fire suppression operations were not part of the scope of this study. A comprehensive water study can be conducted as a separate UT-MTAS project as a follow-up.

Community Risk – General Overview

Knoxville covers approximately 106 square miles and has a population of approximately 190,000 based on 2018 census projections. The city's urban growth boundary is large, so additional and major growth is likely to occur due to the geographic location, livability, and the economy of the region. Knoxville is posed for additional growth due to its geographic location and quality of life in the state. Residents and/or commerce can be in another state within one hour of leaving Knoxville.

From 2000 to 2010, Knoxville's population increased by about 8% ranking Knoxville as the 3rd largest city in Tennessee. Knoxville's population median age is 32.4 years which is younger than the state average of 38.6 years, but Knoxville does have 12.6% of its population over the age of 65. Statistically, older population segments tend to use emergency medical services more than other population segments. Approximately 43.2% of Knoxville Fire Department's responses for 2019 were due to emergency medical incidents.

Knoxville has a wide range of housing opportunities for residents. These opportunities range from apartment/home rental, high-rise, condo to single family home ownership. Only approximately 2% of the housing stock is vacant. This number does not include houses in foreclosure, which means that the percentage of vacant homes and buildings is probably a little higher. Research by the National Fire Protection Association (NFPA) has shown that the incidence of fires in vacant buildings increases when the economy is weak, and that the risk to neighborhoods is greater as fires in vacant buildings are more likely to spread to adjacent homes than fires in occupied homes. Nationwide, almost half of all fires in vacant buildings are arson fires.

Knoxville has a diverse base of employment opportunities in the city. Residents and commuters are employed in retail (16%), accommodations/food service (11%), education (10%), manufacturing (8%), administrative/professional/finance (8%), and other miscellaneous careers (19.5%) account for the largest employment demographics in Knoxville.

Knoxville again can be predicted to continue to grow in population due to its geographic location, ease of commuting to other cities, convenience to areas in other states, nearby airports, community services, and nearby attractions. Knoxville is an attractive city with aesthetic design and has enough undeveloped land for planned residential and commercial growth. Its geographic location straddling the major transportation routes of I-40, I-140, I-640, I-75, I-275, Alcoa Highway and Chapman Highway make commuting convenient for those who want to work in a different city and/or another state such as North Carolina or Kentucky. After extensive review of the Knoxville Fire Department's fire response area and response practices, existing fire service response resources are not adequate for the size and scope of a world-class city like Knoxville. This inadequacy can largely be attributed to the effects of strip annexations resulting in long response distances.

Future Needs

Strip annexation proceeding along the I-40, Alcoa Highway, Pellissippi Parkway, and East Emory and West Emory at I-75 corridors of the city has created the need to provide fire and emergency services far outside the polygon that ISO recognizes fire protection service. The I-40 corridor, in the eastern most part of the city (Strawberry Plains and Midway Road), have corporate city limits with approximately ten-mile response distance. Using the Rand formula of (Travel Time = 1.7(D) + 0.65) + (Ring Time 0.25) + (Call Processing Time 1.00) + (Fire Department Turnout Time 1.00), it is estimated that the Knoxville Fire Department would have a response time around 20.23 minutes under ideal conditions. Using the Home Fire Timeline (Figure 4), we can ascertain that response time is a critical factor when responding to an emergency incident when it happens. As the city continues to grow, city leaders must proactively plan to provide adequate public safety and other city services in the annexed areas. Knoxville has a similar response scenario along the Pellissippi Parkway with response distances of up to eight plus miles, and East Emory and West Emory with response distances over four miles.

We should look to national consensus standards for guidance and benchmarking. No one standard outlines what is acceptable response time. We have to refer to the National Fire Protection Association (NFPA) 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments and the National Fire Protection Association (NFPA) 1221, Standard for the Installation, Maintenance and Use of Emergency Services Emergency Communications Systems are both consensus standards that outline maximum response times. In the case of Knoxville, referring to NFPA 1710 and NFPA 1221, it can be surmised

that a response time standard of six minutes and thirty-five seconds on 90% of incidents is the goal to attain.

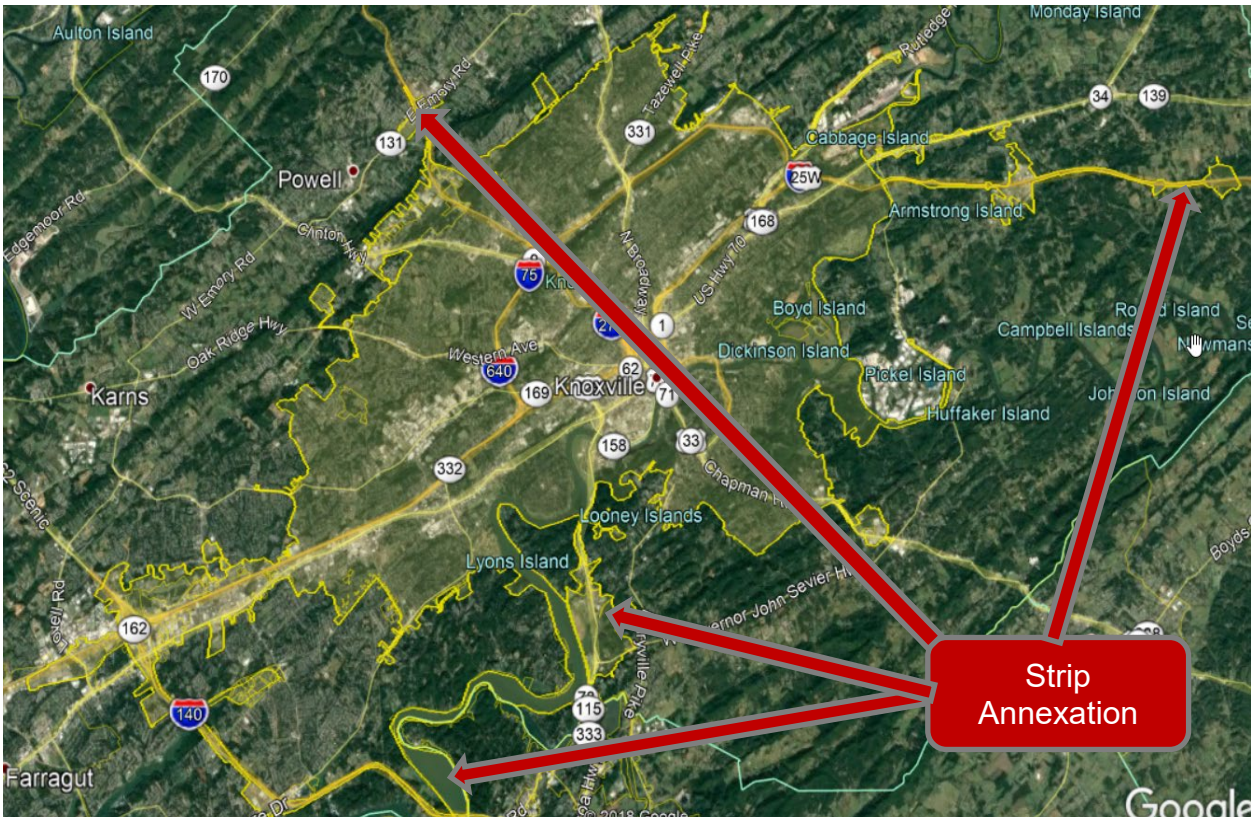


Figure 3 – Knoxville City Limits

How Many Fire Stations Does Knoxville Need?

To answer the question of how many fire stations Knoxville needs now, one can look at several sources for guidance. The first is the Insurance Services Office (ISO) Fire Suppression Rating Schedule. Section 561 of the schedule covers distribution of companies and states: "The built-upon area of the City should have a first-due engine company within 1½-miles and a ladder-service company within 2½-miles."

Using an "as the crow flies" radius of 1½-miles to draw a circle does not adequately represent the geographical area that a single fire station can cover. Studies have shown that a polygon better represents the ISO required response area, and that the average size of the polygon is approximately 4.5-5.0 square miles. Two caveats: the polygon model assumes the even distribution of resources throughout the area, which is generally not the case, and the formula does not allow for geographical barriers, such as rivers, interstates, and railroads, but the formula is useful as a reference. Based upon a 106 square mile service area, a travel distance of 1½-miles, and assuming all engine companies are evenly distributed (which they are not) Knoxville would need 21.2 fire stations right now for adequate coverage. With the long travel

distance associated with strip annexations taken into consideration, Knoxville needs to consider 22 fire stations to adequately cover the city.

One can use the polygon model to determine the number of needed ladder trucks or service companies based upon ISO's maximum travel distance of 2.5-miles for a ladder or service company. The average size of a polygon for a ladder or service company is 12.5 square miles. Based upon a 106 square mile service area, a travel distance of 2.5-miles, and assuming all ladder companies are evenly distributed (which they are not) Knoxville would need 8.45 (9.0) ladder companies right now. With the long travel distance associated with strip annexations taken into consideration, Knoxville needs to consider 13 ladder/quint companies to adequately cover the city.

The ISO standard for distribution is 1.5-miles for an engine and 2.5-miles for a ladder company, but ISO will extend a community's fire protection rating as far as five miles from a fire station provided there is adequate water available for fire protection. There is a caveat for basing fire protection on this five-mile distance, and that is the risks associated with extended response times. Travel time, measured as the time from when the fire department resource starts to roll until it arrives on the scene, is just one component of response time (see Appendix I). At 1½-miles, the travel time for a fire engine is approximately 3:12 (time expressed as minutes: seconds). At five miles, the travel time is approximately 9:09. The response time, which includes ring time, call answering, call processing, turnout, and travel time, is much longer. Thus, a total response time of six or seven minutes for stations based on 1½-mile distribution increases to twelve or thirteen minutes (or longer if call processing and turnout times exceed NFPA recommendations) based on five-mile distribution. As stated earlier in this report, the level of fire protection provided in a community is a local decision, but due to the risk to the public, MTAS recommends basing community fire protection more toward the 1.5-mile travel distance than on the maximum 5.0-mile distance.

The second resource is the National Fire Protection Association (NFPA). NFPA addresses the number of fire stations needed in an indirect way based on minimum response times. NFPA Standard 1710 Section 5.2.4.1.1 allows a 240 second (4 minute) travel time for the first arriving engine company. Using an empirical model called the piecewise linear travel time function, based upon studies done by the Rand Institute estimating the average response speed of fire apparatus at 35 mph, one can determine that the distance a fire engine can travel in 4 minutes is approximately 1.97 miles. A polygon based on a 1.97-mile travel distance covers on average 7.3 square miles. Based upon a 106 square mile service area, a travel-time-calculated travel distance of 1.97 miles, and assuming all engine companies are evenly distributed (which they are not) Knoxville would need 14.52 fire stations right now. However, the city is not evenly distributed, has many high-rise buildings, has geographic barrier issues that fire apparatus cannot navigate, and strip annexations have extended the corporate limits far beyond what the existing fire stations can cover adequately. Based on the scope and complexity of the risks to the public, Knoxville must plan more toward the 1.5-mile model previously discussed.

The previous two examples are based upon time and distance to be covered. A third resource is the ISO Fire Suppression Rating Schedule's determination of needed engine companies based upon the community's basic (needed) fire flow. Section 513 of the schedule requires one engine company for a basic fire flow of 500 to 1,000 gallons per minute (gpm), two engine companies for a basic fire flow of 1,250 to 2,500 gpm, and three engine companies for a basic fire flow of 3,000 to 3,500 gpm. Basic fire flow is calculated by determining the needed fire flow for all non-sprinkled properties in the community, and then the fifth highest is considered the basic fire flow for the community. A strong fire sprinkler ordinance can reduce community risk significantly, as ISO does not consider properties protected by automatic sprinkler systems when determining the basic fire flow, and properties equipped with fire sprinkler systems reduce the fire risk in the community. Knoxville has adopted model codes that require fire sprinklers in certain types of buildings but should consider adopting a more restrictive sprinkler ordinance to require fire sprinklers in all one- and two-family residential occupancies in order to reduce risk to the community.

Finally, city leaders must consider the phenomenon known as flashover. As a fire grows in size, it gives off heat that heats other objects in the vicinity of the fire. At some point in the time-temperature curve, all the objects in the fire room reach their ignition temperature and ignite. The entire room bursts into flames, and the temperature rises to a point where no person can survive, including firefighters. This is called Flashover. The NFPA Fire Protection Handbook states: "During flashover, however, the temperature rises very sharply to such a level that survival of persons still in the room at that stage becomes unlikely. Thus, the time interval between the start of the fire and the occurrence of flashover is a major factor in the time that is available for safe evacuation of the fire area." The development of fire conditions to reach the point of flashover is a function of temperature rise over time. Therefore, a sufficient number of fire stations strategically located to provide quick response times can reduce the incidence of flashover, thus saving lives and property. As shown in the graph in Figure 4, flashover can occur within 3 to 5 minutes of the start of a fire. Locating fire stations to provide a total response time of three to four minutes is advantageous, as firefighters need time after arrival to setup, lay fire hose, and gain access to the seat of the fire before they can actually begin to search for trapped occupants or extinguish the fire. Referring to Appendix I, your study recommendations are based upon 1.5-mile fire station/engine company response. Under ideal conditions and taking into consideration the roles of 911 call-takers, emergency dispatchers, traffic travel time, and fire staff/equipment limitations, this would give Knoxville Fire Department an estimated 5.78 minute total response time at 1.5 miles from each fire station. In the densely populated urban environments, fire companies communicating they are on scene at the street address does not mean firefighters are actually on scene in the traditional sense. Members usually must pack up equipment and tools and gain access to high-rise floors to begin effective operations.

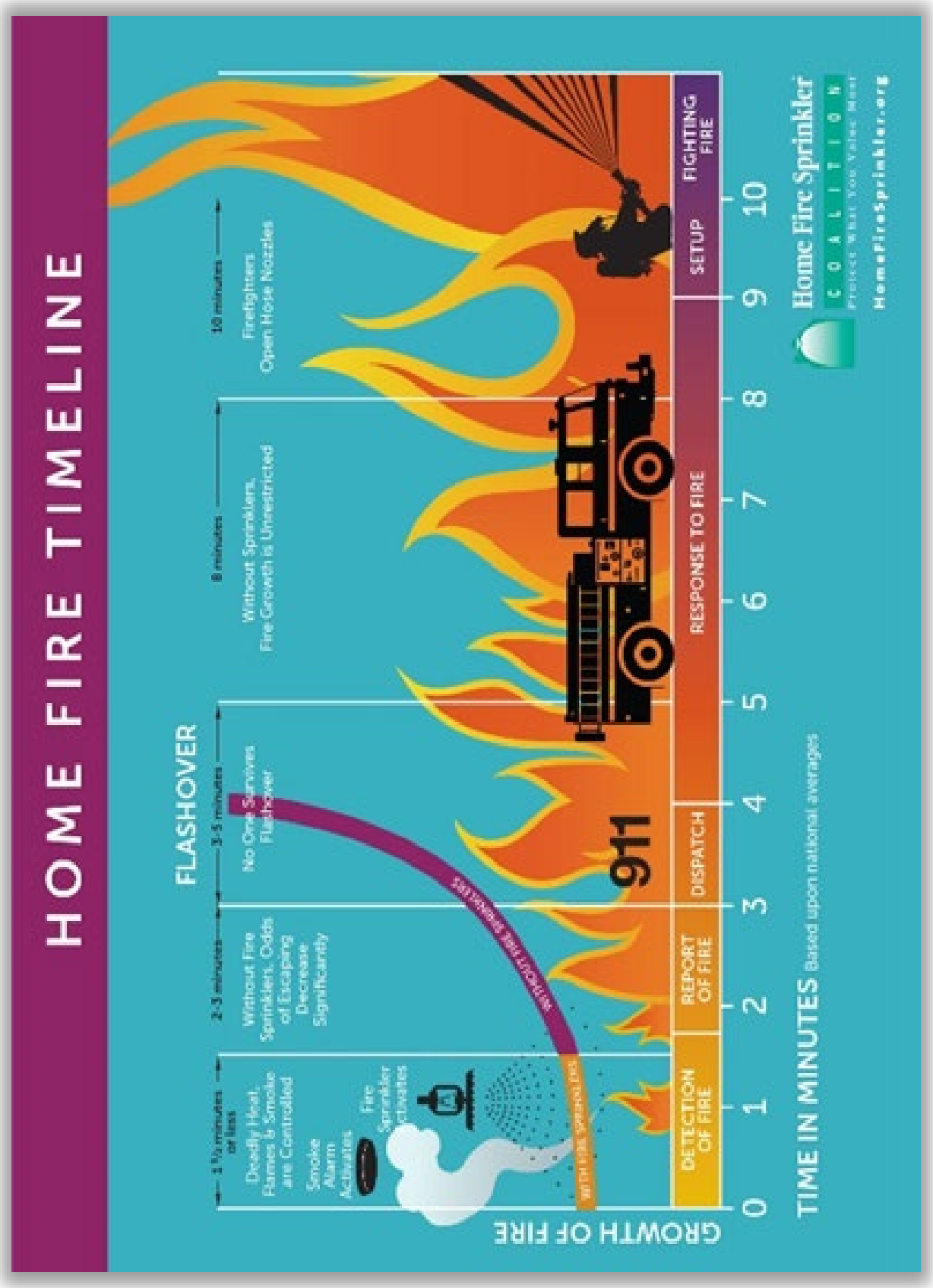


Figure 4 – Home Fire Timeline

Figure 5 below shows the coverage area for the current 19 stations. The light green polygon areas represent 1½-mile travel distances, or approximately 3:12 minutes/seconds travel times. Looking at this map, it is apparent that Knoxville has areas of the city that fall outside of the 1½-mile coverage area of an engine company. *(Appendix C is a full-page version of this map.)*

Figure 5 – Knoxville Fire Stations with 1½ Mile Engine Response Areas

Taking into consideration the accepted methods to determine proper fire station distribution across a city and using existing station locations to reduce capital expenditures, in order to provide more adequate fire coverage for the city, Knoxville should make plans to replace one existing fire station (station 13) and build three additional fire stations (stations 22, 23, 24). Fire stations should be designed with the future needs of the Department and community in mind. This means we must take into consideration anticipated apparatus deployment, staffing, response volume, population growth, applicable National Fire Protection standards, life safety codes, and building codes. Existing Station 13 should be replaced with a new Station 13 located at or slightly to the west of its current location; most likely along Martin Mill Pike. The current facility is not adequate to house a quint apparatus as is needed and recommended. A location more west may be better suited for its current coverage district as well as positions the fire company for a quicker response to the southernmost Alcoa Highway section of the city. The new station should be designed for an engine and/or aerial apparatus deployment. Three new fire stations should be considered: one fire station located off Pellissippi Parkway at about South Northshore Drive, one fire station located in close proximity of I-40 at Strawberry Plains, and one fire station located off East Emory or West Emory off of I-75. The addition of these recommended fire stations will place a high

percentage of the city within a 1.5-mile response area and a very high percentage of the city will be within the 5-mile ISO maximum credited response area.

Figure 6 illustrates the engine company coverage that could be realized by relocating Station 13 and constructing three new fire stations in the proposed geographic areas of the city. Appendix D is a full page of this graphic.

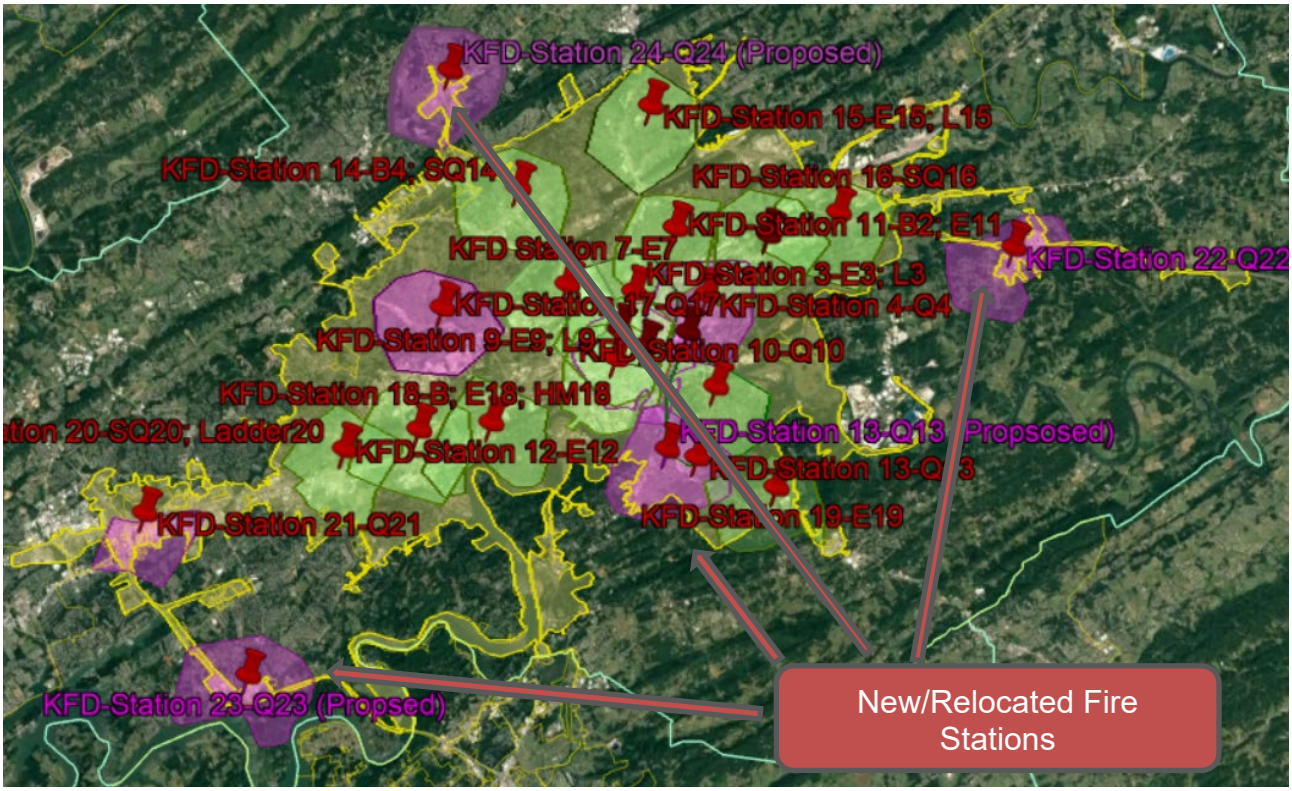


Figure 6 – Station/Engine Coverage with Recommended Fire Stations

Fire Companies Defined

Fire departments utilize fire apparatus as tools to combat and extinguish unwanted fires. For the purposes of this study, we will define four categories of fire apparatus: engine, quint, ladder, and tender/tanker.

- Engine apparatus: fire apparatus with a permanently mounted fire pump of at least 750 gpm pump capacity, minimum 500-gallon water tank, and hose bed whose primary purpose is to combat structural and associated fires.

- Quint apparatus: fire apparatus that performs five different firefighting functions. Must have permanently mounted fire pump of at least 750 gpm pump capacity, minimum 300 gallon water tank, hose bed, ground ladders, and aerial ladder.

- Ladder apparatus: fire apparatus equipped with an aerial ladder, elevating platform, or water tower that is designed and equipped to support firefighting and rescue operations by positioning personnel, handling materials, providing continuous egress, or discharging water at positions elevated from the ground.
- Tender/Tanker apparatus: is a specialized firefighting apparatus designed for transporting water from a water source to a fire scene. Typically, water tenders support engine and/or ladder companies during fires and hazardous material incidents.

How Many Engine Companies Does Knoxville Need?

A community needs an apparatus credited as an engine apparatus assigned to respond from each fire station. Fire stations should be planned with 1.5-mile polygon service areas to ensure quick efficient emergency response and earn maximum ISO credit. This can be accomplished by deployment of an engine apparatus in each station. Figure 5 illustrates the current engine company deployment and their corresponding 1.5-mile coverage areas. Figure 6 illustrates the recommended engine company (1.5 mile) coverage Knoxville could realize if the recommendations of this study are fully implemented. Knoxville needs an engine apparatus in each fire station. Since it has been determined that Knoxville needs 22 fire stations, then Knoxville needs 22 front-line apparatus credited as an engine apparatus.

How Many Ladder Companies Does Knoxville Need?

A community needs a ladder company when it has at least five buildings that are three stories or more tall, five buildings more than thirty-two feet in height, a basic fire flow of 3,500 gallons per minute, or any combination thereof. Knoxville has many buildings that meet these multiple criteria throughout the city. Figure 7 illustrates the current ladder company deployment with their corresponding 2.5-mile coverage areas. It is noted that there are large areas of the city located outside the 2.5-mile response area of a ladder apparatus.

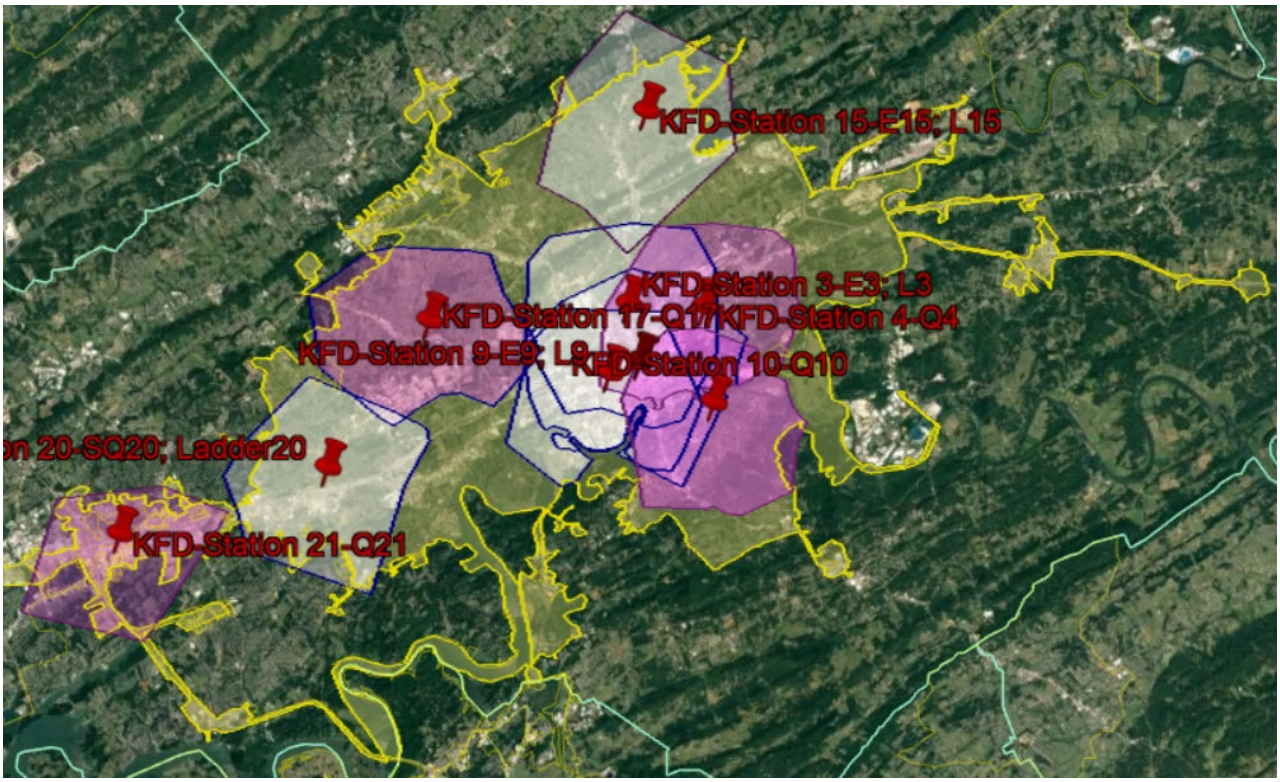


Figure 7 – Existing Ladder Company Deployment

Based on accepted methods to determine proper ladder company distribution across a city and using existing station locations to reduce capital expenditures, in order to provide adequate ladder company coverage for the city, Knoxville should have 12 ladder/quint companies in front-line service. Currently, Knoxville appears to have 8.0 credited ladder companies (6-ladder + 4 Quint @ ½ credit each = 8.0 ladder companies). Knoxville should plan for the acquisition and staffing of additional ladder/quint apparatus to serve the needs of the city.

The Department uses quint apparatus, a combination apparatus which has the components of an engine: a pump, water tank, and carries all of the equipment required for an engine company, in addition carries equipment required for a ladder company and has an aerial ladder. The use of quint apparatus is cost effective as the city receives up to full credit for an engine company and half credit for a ladder company (credit also depends upon the equipment inventory, and required testing-pump, hose, and ladder).

Knoxville has areas all around the city that have buildings that require multiple ladder companies. Knoxville has six dedicated ladder companies, Ladder 1, Engine 2 (Ladder), Ladder 3, Ladder 9, Ladder 15, and Ladder 20. In addition, Knoxville has three dedicated Quint companies, Quint 4, Quint 10, Quint 17, and Quint 21. Due to concentration of ladder company response areas and the need for ladder companies deployed across the city, it is recommended to reorganize the deployment model of some aerial apparatus to different stations and acquire other apparatus in order to cover the city more adequately.

How Many Tender/Tanker Companies Does Knoxville Need?

Knoxville has many miles of interstate highways that traverse the city. The interstate system is not equipped with fire hydrants. In these cases, fire departments must utilize an adequate number of water tender/tankers to provide the needed fire flow to incidents that occur in these areas of the jurisdiction. There are many risks to the citizens and visitors of Knoxville associated with the interstate system. These risks include but are not limited to hazardous materials incidents, vehicle fires, cargo fires (combustible, flammable, explosive), etc. It is important to remember that emergency incidents on the interstate system can quickly spread to adjacent buildings and critical infrastructure. Many of these risks cannot effectively be controlled without a water source. The Fire Department currently has 4-tender/tanker apparatus strategically deployed across the city for efficient access to the interstate system. These 4 apparatuses should be staffed with trained, competent professionals to provide water shuttle support to each district of the city in a timely fashion. It appears that the current 4-tanker/tender apparatus with appropriate staffing will be adequate to provide water supply to emergency incidents where there are limited fire hydrants.

The added demands of the city as well as redeployment of fire apparatus from one fire station to another may shift the number of calls for service that the remaining companies must respond to. If the number of calls for service warrants, the Department may have to consider adding a second engine company to targeted stations. If additional apparatus are added, the appropriate staffing must also be taken into consideration.

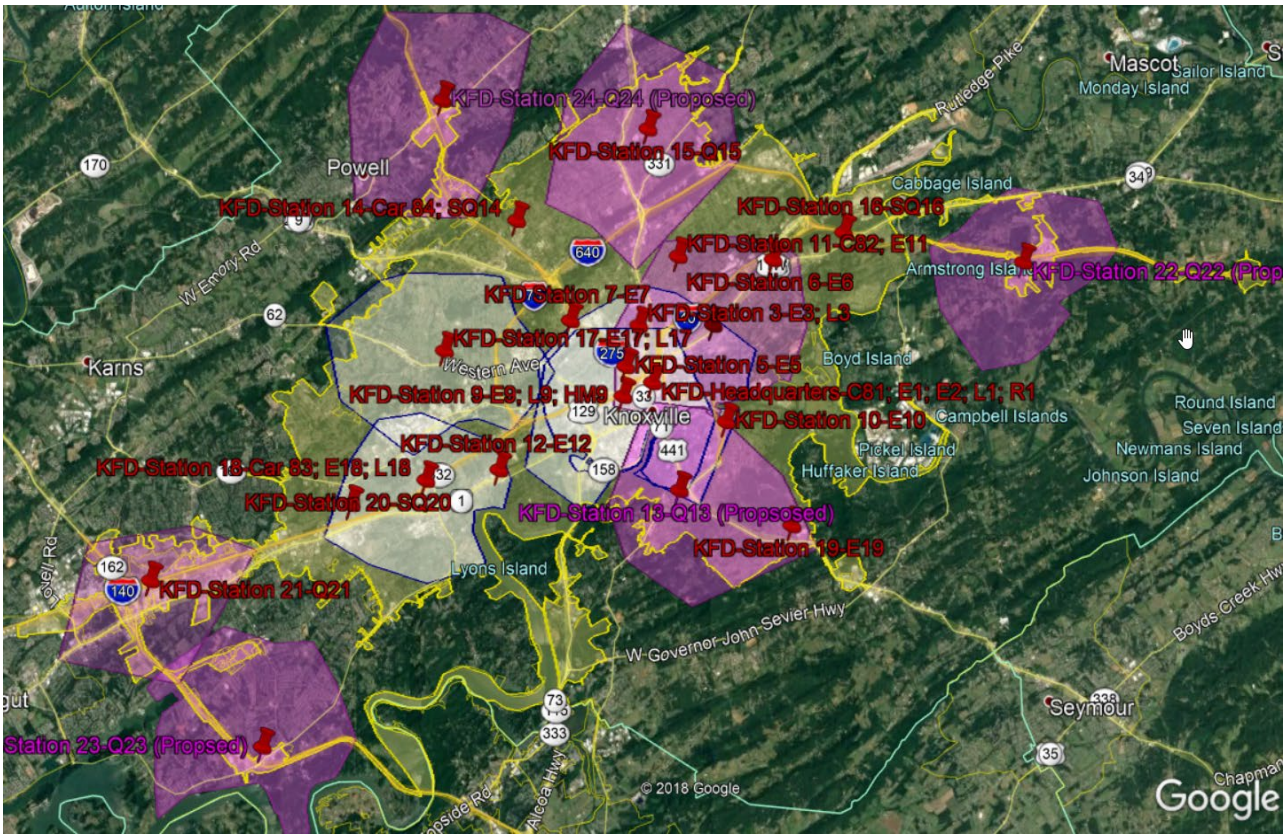


Figure 8 – Recommended Ladder/Quint Company Deployment

Knoxville Fire Apparatus

Currently, Knoxville Fire Department maintains a fleet of 46 engine apparatus, aerial ladder apparatus, and other response vehicles as front-line or reserve service. The scope of this study did not analyze the adequacy of each apparatus but only the deployment by type apparatus. A fire apparatus study can be completed as a separate UT-MTAS project or the department can self-audit its fleet to ensure compliance with the most recent edition of the National Fire Protection 1710 Appendix D. Any apparatus identified as needing to be replaced should then be added to a capital equipment replacement plan.

NFPA 1710 Appendix D states: It is recommended that apparatus more than 15 years old that have been properly maintained and that are still in serviceable condition be placed in reserve status, be upgraded in accordance with NFPA 1912, and incorporate as many features as possible of the current fire apparatus standard (see Section D.3). This will ensure that, while the apparatus might not totally comply with the current editions of the automotive fire apparatus standards, many of the improvements and upgrades required by the current editions of the standards are available for the firefighters who use the apparatus.

Apparatus that were not manufactured to the applicable NFPA fire apparatus standards or that are over 25 years old should be replaced.

Figure 9 – NFPA 1710 Fire Apparatus Maximum Age Standard

Knoxville Company Staffing

Knoxville Fire Department's current staffing strategy provides for a minimum staffing policy and practice for each response company each day. The scope of this study did not specifically analyze the staffing levels for each fire company. A fire department staffing study can be completed as a separate UT-MTAS project or the Department can self-audit its staffing levels to ensure the Department is compliant or moving toward compliance with the most recent edition of the National Fire Protection 1710. Department staffing should be provided that meets the needs of their critical tasking assignments. See Figure 10, on the next page, for NFPA 1710 Staffing levels. Tanker/Tender staffing is not specifically addressed in the NFPA 1710, but it is recommended that two trained and competent staff be assigned to each tanker/tender.

5.2.3 Operating Units. Fire company staffing requirements shall be based on minimum levels necessary for safe, effective, and efficient emergency operations.

5.2.3.1 Fire companies whose primary functions are to pump and deliver water and perform basic fire fighting at fires, including search and rescue, shall be known as engine companies.

5.2.3.1.1 These companies shall be staffed with a minimum of four on-duty members.

5.2.3.1.2 In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ, these companies shall be staffed with a minimum of five on-duty members.

5.2.3.1.2.1 In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members.

5.2.3.2 Fire companies whose primary functions are to perform the variety of services associated with truck work, such as forcible entry, ventilation, search and rescue, aerial operations for water delivery and rescue, utility control, illumination, overhaul, and salvage work, shall be known as ladder or truck companies.

5.2.3.2.1 These fire companies shall be staffed with a minimum of four on-duty members.

5.2.3.2.2 In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ, these fire companies shall be staffed with a minimum of five on-duty members.

5.2.3.2.2.1 In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members.

Figure 10 – NFPA 1710 Staffing Level Standard

Recommendation Implementation

To provide for firefighter safety, excellence in customer service, while helping to maintain or improve Knoxville's ISO Class 2 ISO Public Protection Classification rating, Knoxville should consider the recommendations outlined in this study report and develop plans to implement each recommendation as soon as practical. The recommendations made, in this report, will require open mindedness at all levels of the organization and considerable resources so each must be planned for accordingly. Recommendations should be considered and planned for systematically to be achieved over time. It is almost always a good idea to develop plans with the objective to phase capital improvements and staffing strategies over multiple steps and fiscal budget years.

Summary

It is an honor and privilege to conduct this study requested by the Knoxville Fire Department. I am impressed with the caliber of men/women that serve every day, to plan for and protect the citizens and visitors of the city. The City of Knoxville enjoys a Class 2 ISO Public Protection Classification rating. The Class 2 rating places the city in the top 1% of communities nationwide in terms of fire protection. Because of the Class 2 rating, residents and business owners enjoy living in a safer community while enjoying lower property insurance rates. Annexation and growth have occurred without the accompanying growth in Fire Department resources. Knoxville's existing fire stations are strategically located to provide good coverage with minimal overlap to meet ISO's requirements. The Department's leadership has a demonstrated priority on firefighter safety by ensuring each fire company has a minimum staffing practice and a company supervisor/officer. In addition, each suppression shift has four supervisors/chief officers assigned. It appears, with limited study, that Knoxville has a good handle on its division-of-labor and span-of-control. However, due to strip annexation and associated long response distances, the current nineteen fire stations are no longer adequate to provide the levels of fire services as defined in both NFPA 1710 and ISO for the citizens and visitors of Knoxville.

Providing for an all-hazards fire department and the services offered by such for a large growing world-class city is very complex. Knoxville has many target hazards such as high-rise and large facilities spread throughout the city. There are large public events and gatherings at the University of Tennessee and other venues that present very real challenges for the Fire Department.

It is never advisable for a city to make significant changes to the organization or operation thereof to just maintain or chase a better ISO Public Protection Class rating. What we find is that when departments have a practice of proactively planning and operating based on national standards, the firefighting forces are safer and work more efficiently meaning a sustained or improved ISO rating usually follows.

Based on the scope and findings of this study, Knoxville should implement as many of the recommendations specified in this report as feasible. This action will improve firefighter safety, provide for quick and efficient services to the public, and could serve to sustain or improve Knoxville's Class 2 ISO rating. It is important to note that a worsening of the ISO by 1 classification could lead to an increase in insurance premiums for residents of one and two family dwellings; further, an improvement of the ISO by 1 classification could lead to a decrease in insurance premiums for residents of one and two family dwellings. It is estimated that a shift in ISO by 1 classification could result in a 2%-5% increase/decrease in homeowner insurance premiums. Based on data obtained from the comptroller's office and insurance companies, it is estimated at a 2% constant that this could have an impact of approximately $529,966.00 savings for an improved ISO or additional cost for a worsened ISO to the citizens annually. Over 5 years at this 2% constant, that equates to approximately $2,649,830.00 financial impact (positive or negative) for your citizens.

Recommendations

The following recommendations outline the most efficient and cost-effective ways for the City of Knoxville to provide for an all-hazards fire department delivering the wide range of programs and services needed to address unique community risks and needs. Recommendations will focus on three components of the Department: fire station locations, fire apparatus deployment, and proactive community risk reduction.

Response Time Standard: Adopt a response time standard for the community. Knoxville Fire Department is a perpetual organization that will outlast current leaders, and this study looks at current and anticipated future needs. Once adopted, the response time standard will serve as a planning guide for future leaders. This study recommends a response time standard of 6:35 (six minutes, 35 seconds) for 90% of all responses, which is based upon recommendations found in NFPA Standard 1710, Standard for the Organization and Deployment of Fire Suppression Operations. The 6:35 breaks down as follows: ring time – 15 seconds, call processing time – 60 seconds, firefighter turnout time – 80 seconds, travel time – 240 seconds. Using this standard, planners would look for fire station locations to maintain a 4-minute travel time to as much of the area to be protected as possible.

Automatic Fire Sprinklers: Adopt a comprehensive automatic fire sprinkler ordinance for all new construction and consider incentives for owners that retrofit sprinkler systems in existing buildings. Utilize resources like the National Fire Sprinkler Association as a resource as you plan for this step. It is worth noting that buildings equipped with fire sprinkler systems are much safer and occupants are more likely to survive if a fire occurs. Also, when determining the basic fire flow for a community, ISO does not consider properties protected by a code compliant automatic fire sprinkler system. In a sprinkled building, the amount of time between the occurrence of a fire and reopening for business can be as little as a few hours or days versus months, years or even never rebuilding for a non-sprinkled building. This will help provide greater safety for the citizens/visitors to the community as well as help ensure a steady revenue stream for the city.

- Tennessee's fire mortality rate for civilians has been among the highest in the nation. During 2002-2010, the time period for the Tennessee Fire Mortality Study, the national fire mortality rate declined, but the rate in Tennessee increased. Residential structure fires account for about three-fourths of all civilian fire deaths in the state. Residential sprinklers save money and lives and are a good investment in a home, but they are controversial in many communities which is why this study recommends research on residential sprinklers before considering adopting an ordinance. Adopting an ordinance would be proactive for community safety.

Fire Stations:

Current Stations: Nineteen fire stations serve Knoxville currently. Station 13, based on its physical condition and the need to house a quint apparatus, should be replaced with a new modern fire facility. The new Station 13 should be located in the same general area as it is now or just west of its current location. A move slightly to the west could be an advantage for Alcoa Highway responses. The new station should be designed and constructed for engine or aerial apparatus deployment, appropriate number of firefighters, and administrative offices for the station officer and maybe a chief officer.

Additional Stations: Knoxville needs to consider the design and construction of three additional fire stations; one station on Strawberry Plains Pike near I-40, one station off Pellissippi Parkway at South Northshore Drive, and one station on North Emery Road off I-75. In these areas of the city, the current fire stations have an approximate range of 5-10 miles response distance to the edge of the city limits. ISO will only credit a fire station for up to a five-mile response area. All properties outside a five-mile polygon will likely earn a much higher (worse) ISO classification.

Fire Apparatus: Knoxville has a considerable fleet of apparatus and vehicles. The scope of this study did not analyze apparatus adequacy, just apparatus deployment. A fire apparatus study can be completed as a separate UT-MTAS project or the Department can self-audit the age and reliability of the fleet and develop a systematic and sustainable plan to replace apparatus when needed to meet NFPA 1710 Appendix D. See Page 16 Figure 9.

Additional Apparatus:
Knoxville Fire Department should make plans to purchase new Quint fire apparatus to deploy from new Fire Station 22, new Fire Station 23, and new Fire Station 24. These apparatus will be utilized as an engine as well as ladder. Recommend the Department consider a single axle 75'-100' ladder without a platform. The recommended apparatus are versatile and agile like an engine with the flexibility of a ladder to carry additional equipment and easily/ efficiently gain access to the roof of buildings in the city.

Fire Apparatus Deployment: Knoxville appears to have a good idea of the number of apparatus needed to provide fire response coverage to the city. The Department should consider a re-deployment strategy to cover the city more evenly with engine/ladder/tender-tanker company response and provide for a quick efficient fire fighting force. See Table 2 for specific re-deployment recommendations.

Headquarters:	Battalion 1; Engine 1; Ladder 1; Engine 2; Rescue 1; Tender/Tanker
Station 3:	Engine 3; Ladder 3
Station 4:	Quint 4
Station 5:	Engine 5
Station 6:	Engine 6
Station 7:	Engine 7
Station 9:	Engine 9; Ladder 9
Station 10:	Engine 10
Station 11:	Battalion 2; Engine 11
Station 12:	Engine 12
*Station 13:	Quint 13 (Relocated Station)
Station 14:	Battalion 4; Squad 14; Tender/Tanker
Station 15:	Engine 15; Ladder 15
Station 16:	Squad 16
Station 17:	Quint 17; Tender/Tanker
Station 18:	Battalion 3; Engine 18; Ladder18
Station 19:	Engine 19
Station 20:	Squad 20; Hazardous Materials 20
Station 21:	Quint 21; Tender/Tanker
*Station 22:	Quint 22 (New Station/Apparatus)
*Station 23:	Quint 23 (New Station/Apparatus)
*Station 24:	Quint 24 (New Station/Apparatus)

*Denotes New Fire Station and Apparatus

Table 2-Knoxville Fire Apparatus Re-Deployment

Community Risk Reduction

Adopt a comprehensive Community Risk Reduction (CRR) Program. The value to a progressive community risk reduction program cannot be overstated. Emergencies that do not happen do not pose a risk or injure our firefighters and/or our citizens. In addition to the prevention of needless property loss and human suffering, all six of the ISO 1 Fire Departments in the State of Tennessee would not have earned this distinction without the points they earned in the Community Risk Reduction section of the grading schedule. Fire Departments should not do things just to improve their ISO classification; they do the right things for the right reasons for their citizens and visitors. The ISO classification comes as a

result of this effort. The ISO Public Protection Schedule has 5.5 points available for community risk reduction programming.

A comprehensive and progressive Community Risk Reduction Program has three major components:

1. Adoption and enforcement of current fire prevention codes.
2. Public fire safety education programming.
3. Fire investigation program.

Current Fire Prevention Codes-Adopted and Enforced

The city having current fire codes adopted and enforced can earn up to 2.2 of the 5.5 available points. The city should adopt the National Fire Protection (NFPA) 1 or International Fire Code as its fire prevention code. Maximum points can be earned in this section if the code adopted edition is within 5 years of the ISO audit. The point values decrease incrementally until 10 years. More than 10 years receive very little to no credit. Credit for this section of the grading is also reduced if the jurisdiction modifies the model code, removing or reducing the requirements. Currently, Tennessee State Law requires municipalities to remove the residential fire sprinkler requirement from the adopted code. Then if the municipality wants to add it back into its adopted code, the elected officials must have a separate vote and approve it by a two-thirds majority vote to include these requirements in the adopted code. If a municipality does not add this back into its adopted code, there could be a reduction in credit.

Fire Prevention staffing will also be brought into play in this section. The fire prevention program should be staffed with qualified personnel to provide a fire prevention inspection to every non-residential occupancy annually. Incremental credit is awarded for programs that do not meet this level of service. It is also important to note here that pre-incident planning inspections without a fire prevention inspection element do not receive credit as one of their annual inspections. Fire Prevention inspectors must be certified as a Fire Inspector in accordance with NFPA 1031 and participate in a minimum of 24 hours of professional development annually to earn maximum points.

The fire prevention program must include: Plan review process for all non-residential occupancies to ensure fire code compliance; Certificate of Occupancy inspections for residential and non-residential occupancies; Quality control program that applies to all inspectors and re-inspection to ensure compliance with code deficiencies; Inspection of private fire protection equipment per adopted codes; Fire prevention ordinances to regulate fire lanes, fireworks, hazardous materials routes, BBQ grills, wildland-urban interface, and weeds/trash; Coordinate Fire Department training and pre-incident planning activities. As with any programming, document everything to earn maximum credit.

Public Fire Safety Education Programs

The Fire Department must provide for public fire safety education in order to take the "You don't know what you don't know" out of the public safety equation. We should and must educate our public on ways to prevent incidents from occurring, and for that the Department receives ISO credit. Fire Safety Education staff must be trained in teaching methods set by the Department as well as to the standards set by NFPA 1035. These members must receive 10 hours of continuing education annually. The Department should limit the number of staff deemed as public educators, to control cost and logistics of participating in this annual training. I encourage fire companies to assist with these events, but not necessarily be deemed as public educators.

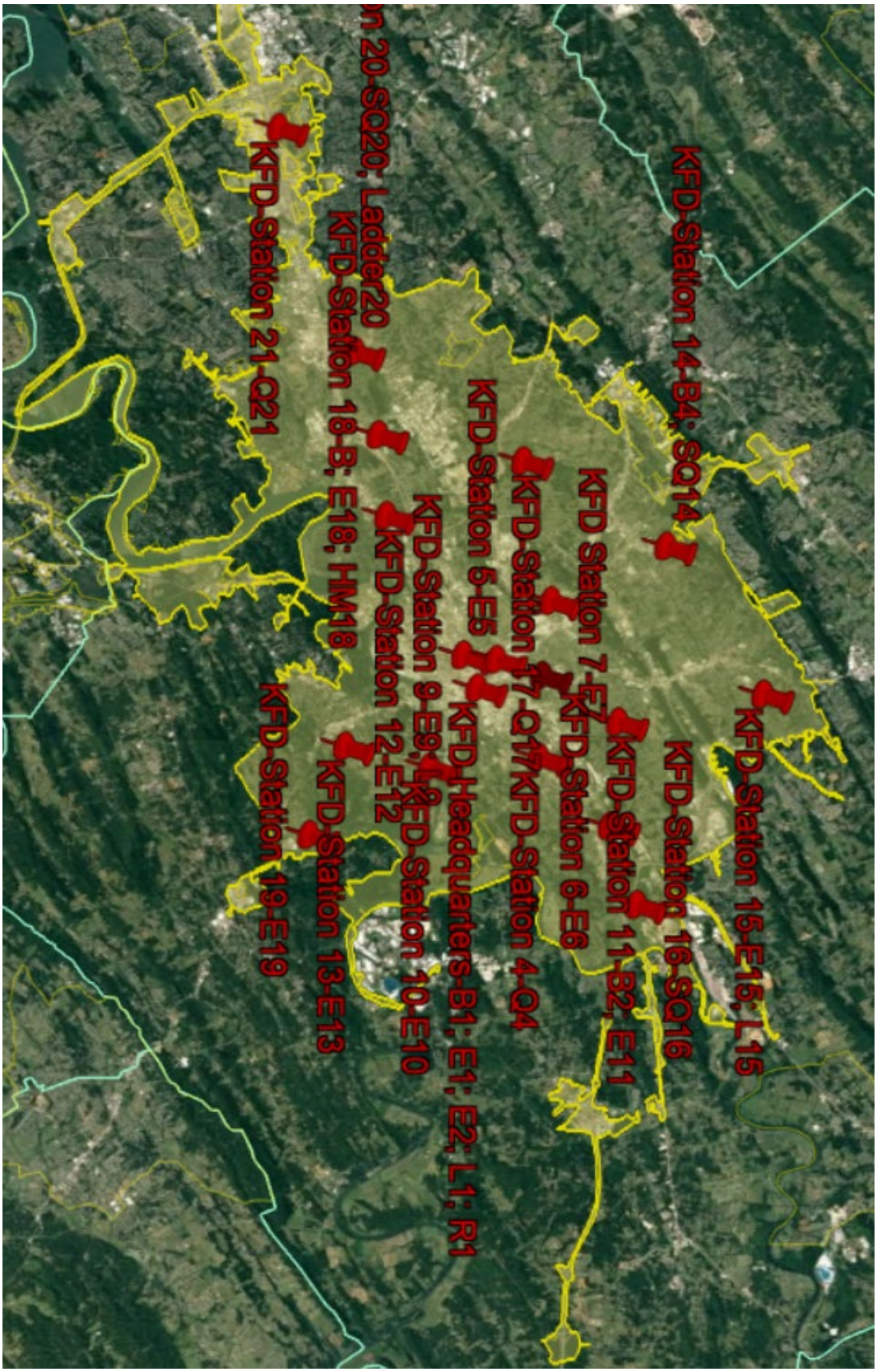
Public fire safety education staff must have program curriculums that are meaningful to the community and address identified risks. The Department must include, at minimum, programming to address residential fire safety, fire safety education in schools, juvenile fire setter intervention, and programs for occupancies with large loss potential or hazardous conditions.

Fire Investigations Program

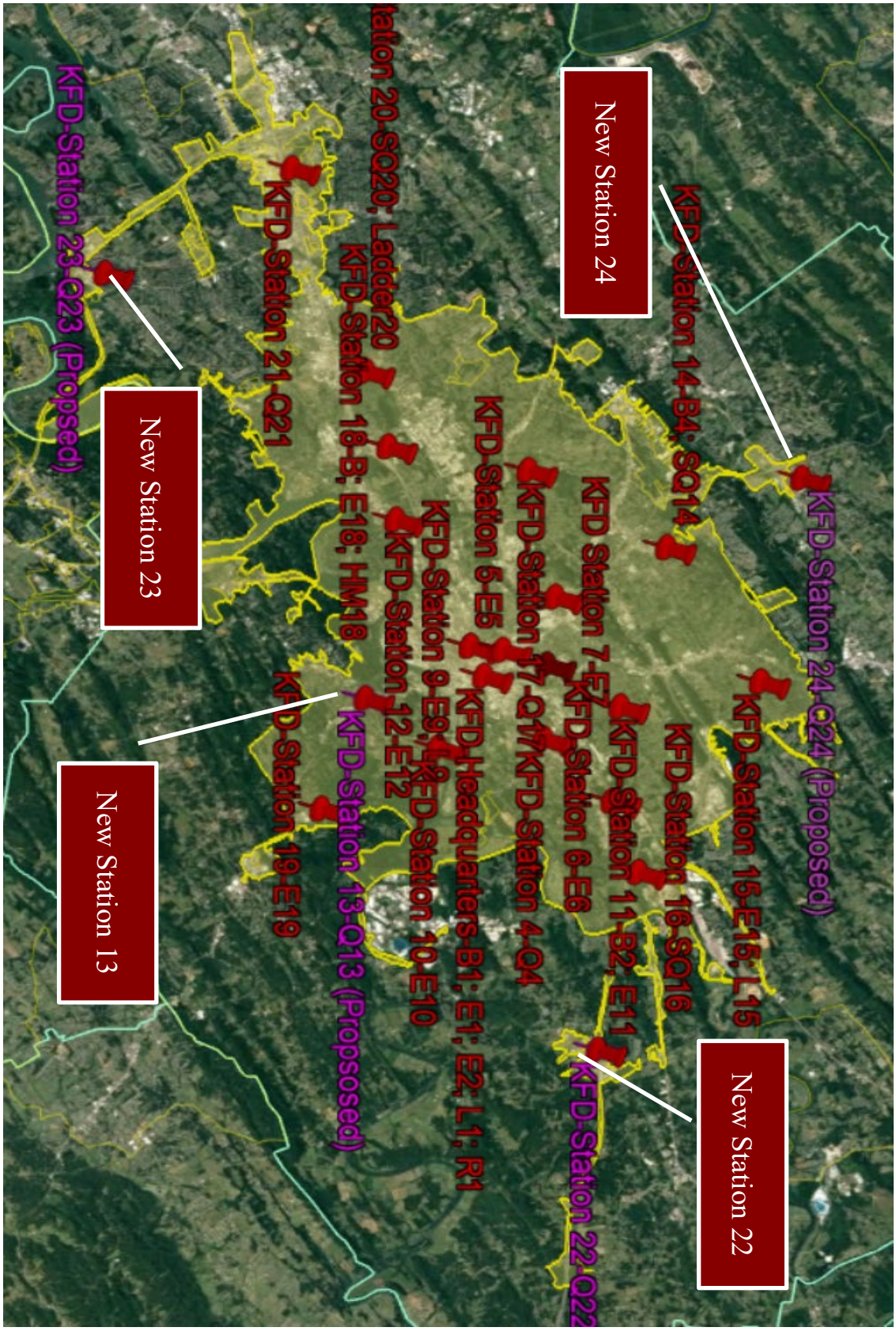
The fire investigations program is a key component of reducing set fires and risks in the community. This program must provide for trained competent staff and documentation through the National Fire Incident Reporting System (NFIRS). The Fire Investigation program should be formalized and documented in an organizational chart type format to include policy and processes. Members included in the program can be included from multiple organizations and disciplines. There should be sufficient staff to investigate the origin and cause of all structure fires. Fire investigation staff must be trained and certified as Fire Investigators and receive a minimum of 40 hours continuing education annually.

All structure fire must be reported through NFIRS to include the origin and cause. The Department should have a track record of this documentation that can be evaluated for a minimum of the past 3 years. The State of Tennessee requires that all structure fires be reported to the State Fire Marshal's Office within 10 days of the fire. In some cases, the report will not be finalized in that time frame due to the investigation. In this case, the Department should submit the draft report within the 10 day timeframe required then submit a supplement when the case report is finalized.

Appendix A – Current Knoxville Fire Station Locations

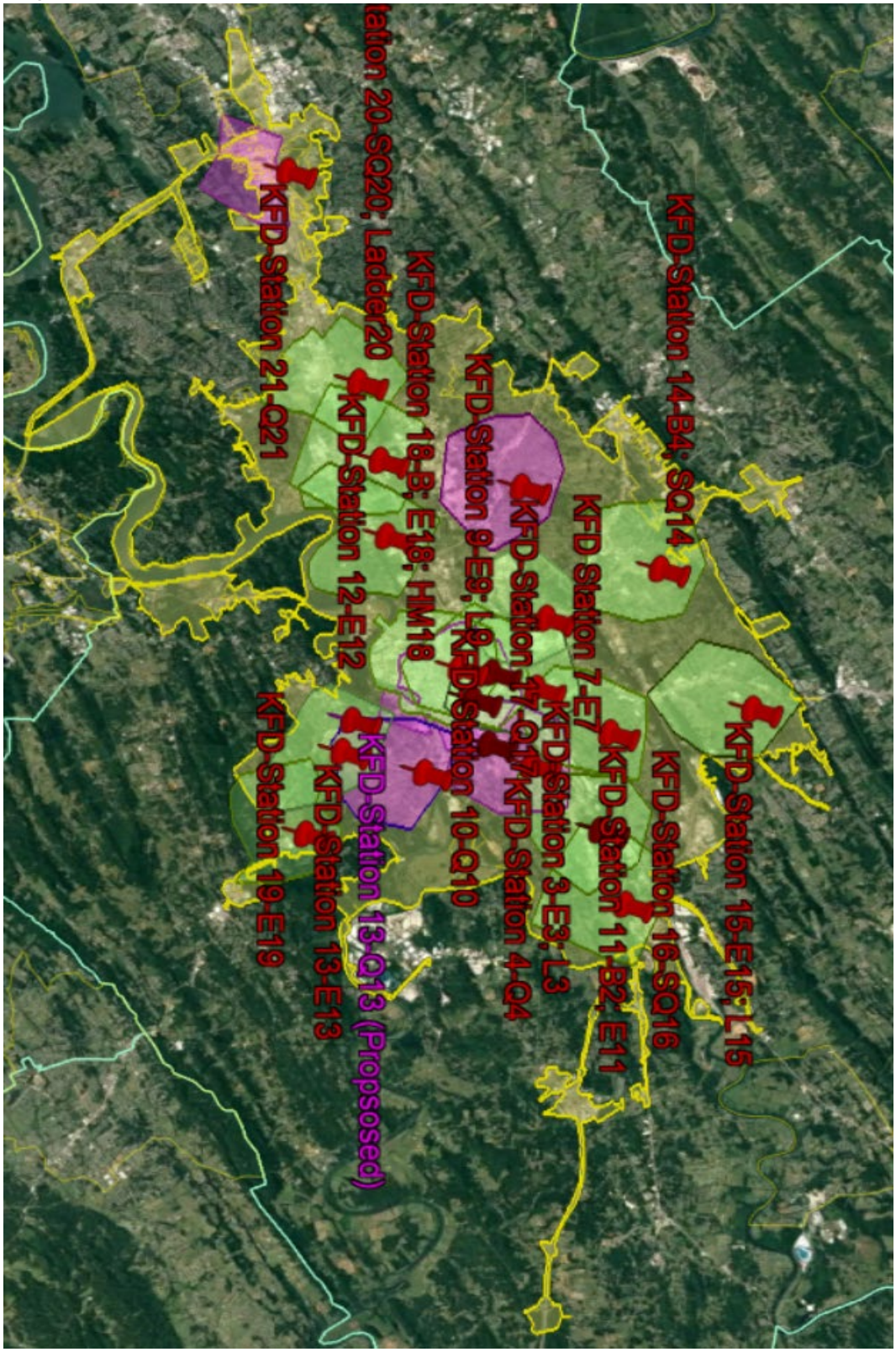


Appendix B – Recommended Knoxville Fire Station Locations



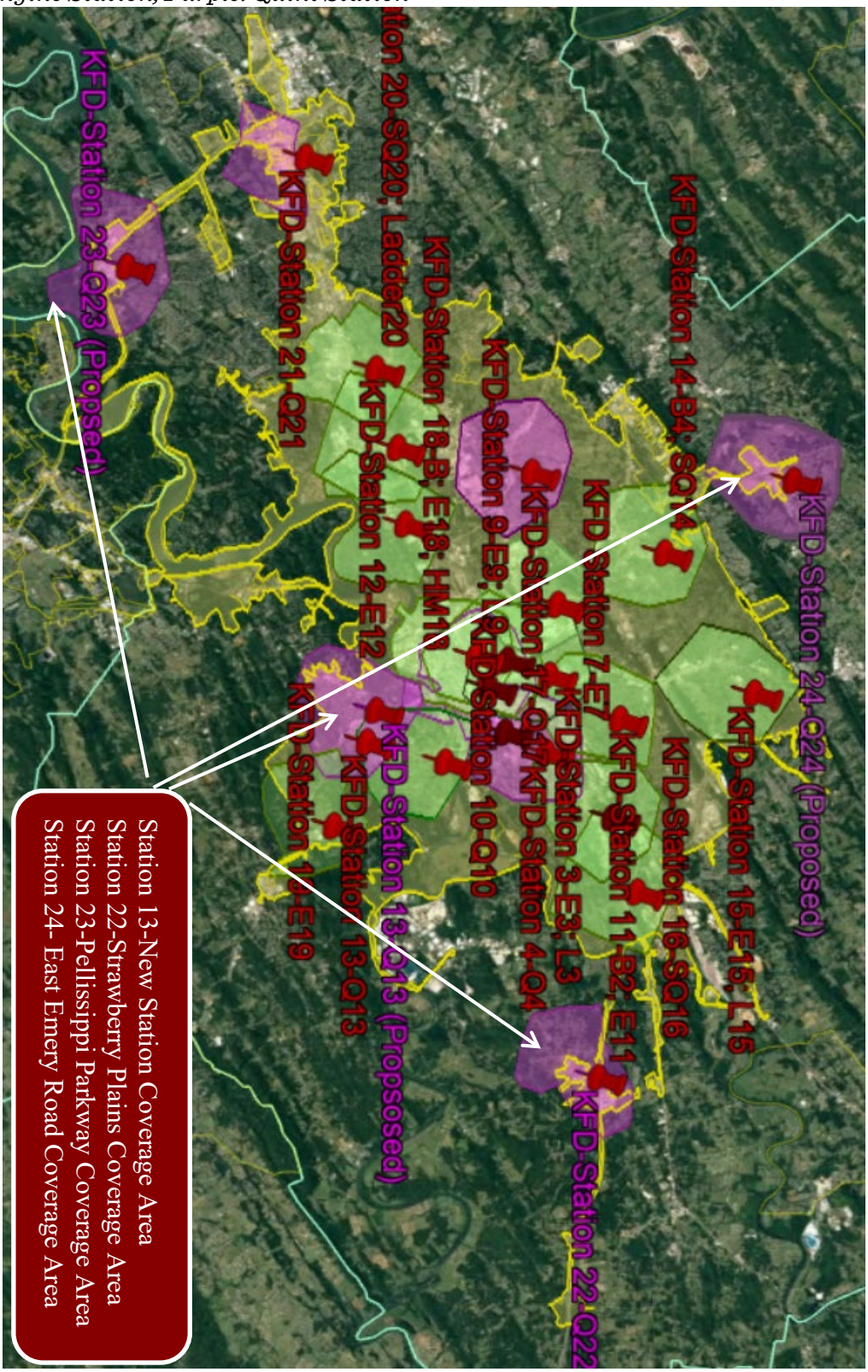
Appendix C – Current Fire Station 1.5 Mile Response

Green: Engine Station; Purple: Quint Station



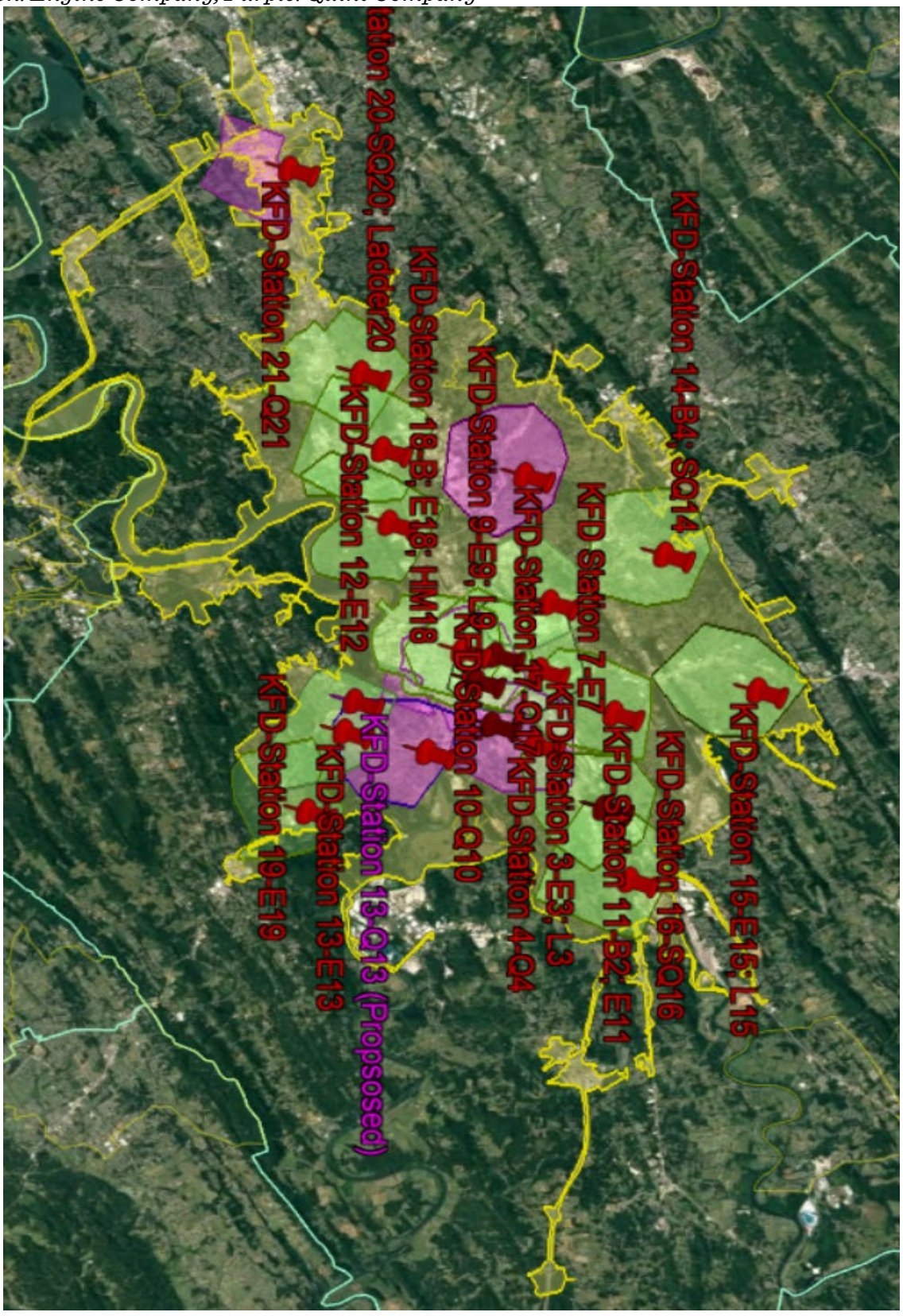
Appendix D – Recommended Fire Station 1.5 Mile Response

Green: Engine Station; Purple: Quint Station



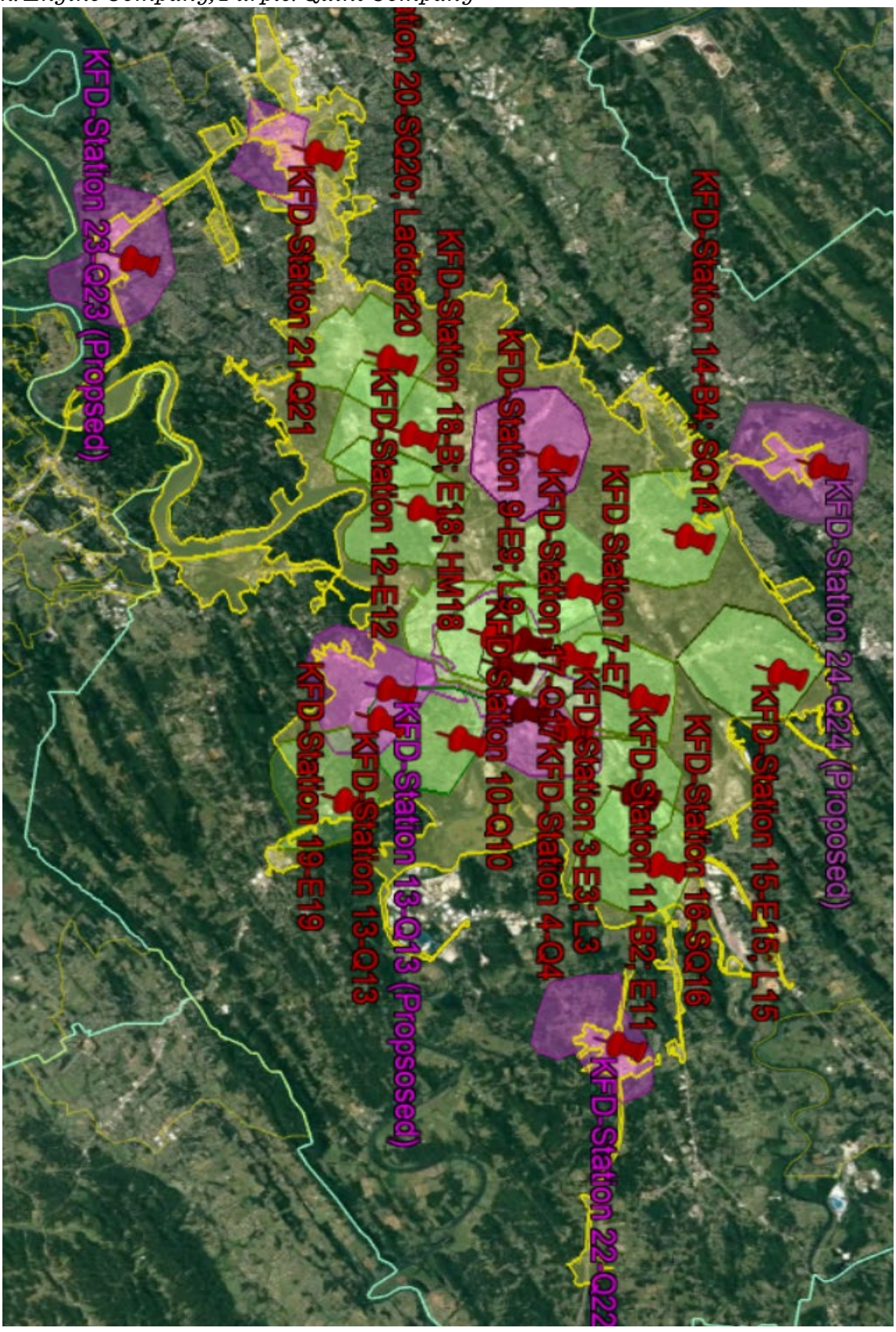
Appendix E – Current Engine/Quint Deployment 1.5 Mile Response

Green: Engine Company; Purple: Quint Company



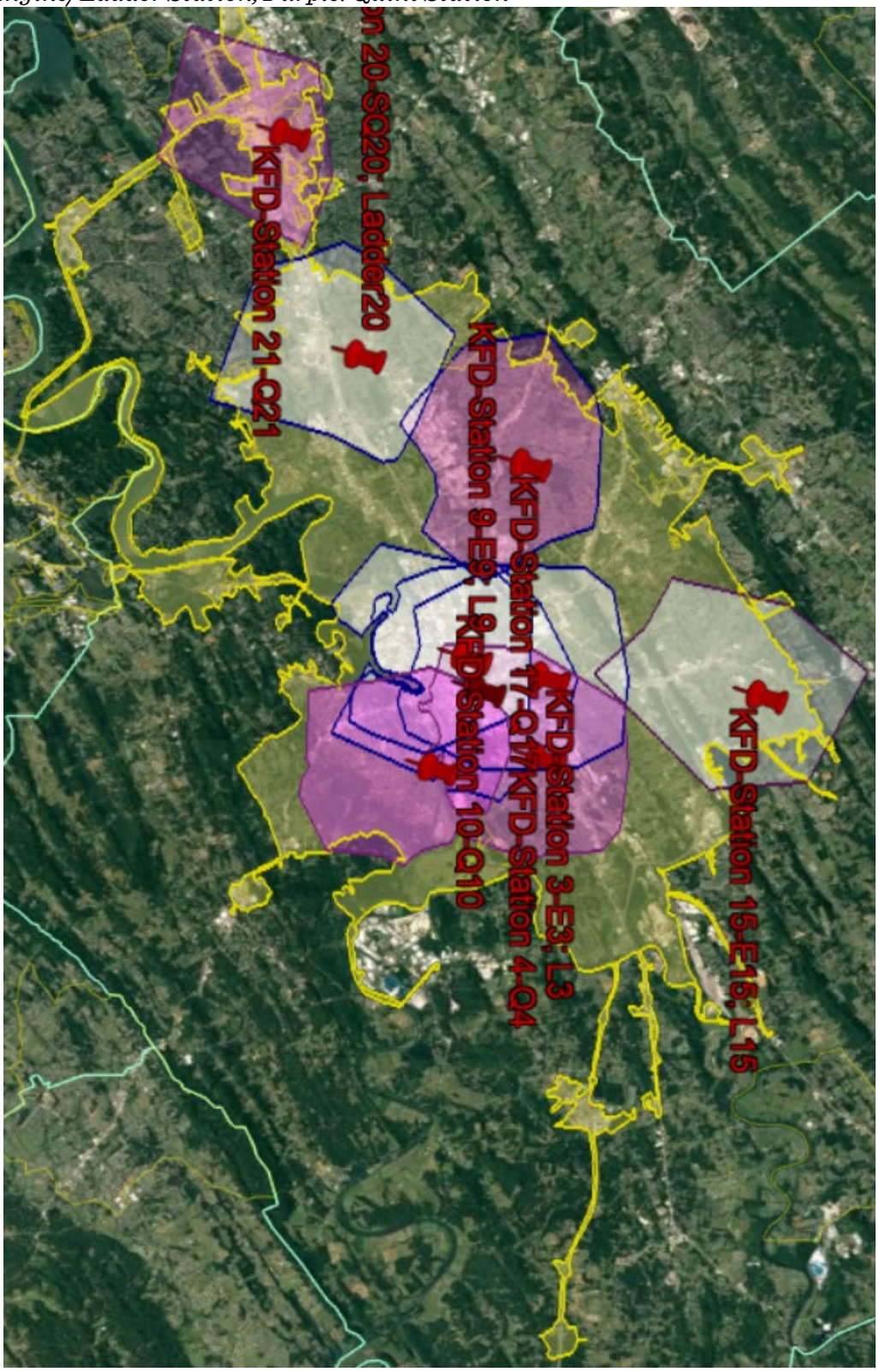
Appendix F – Recommended Engine/Quint Deployment 1.5 Mile Response

Green: Engine Company; Purple: Quint Company



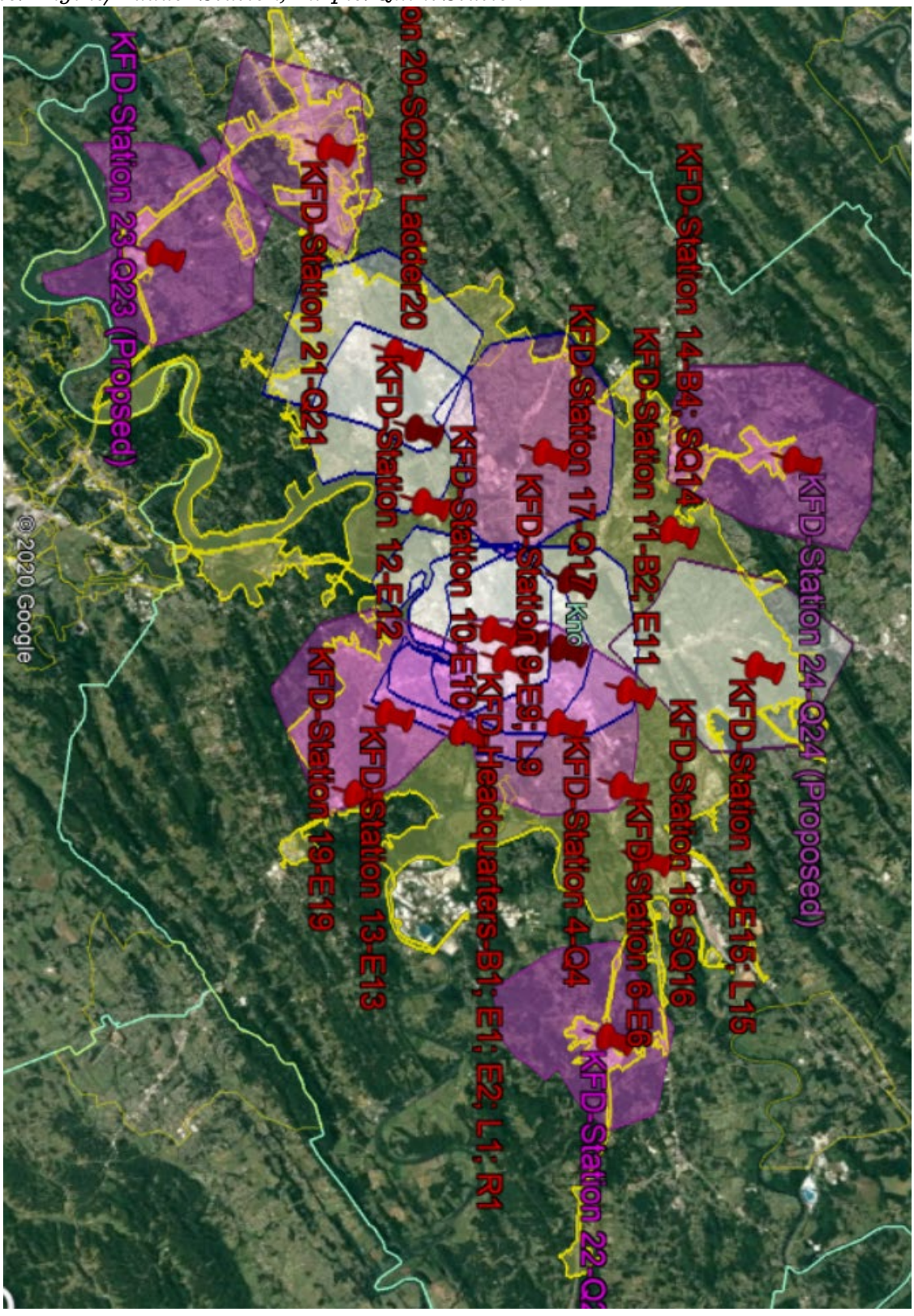
Appendix G – Current Ladder Company 2.5 mile Response

White: Engine/Ladder Station; Purple: Quint Station



Appendix H – Recommended Ladder Company 2.5 Mile Response

White: Engine/Ladder Station; Purple: Quint Station



Appendix I-Estimated Response Time Chart

Distance To Travel in Miles	Estimated Travel Time	Ring Time	Call Processing Time	Fire Dept. Turnout Time	Total Response Time
0.25	1.08	0.25	1.00	1.33	3.66
0.38	1.30	0.25	1.00	1.33	3.88
0.50	1.50	0.25	1.00	1.33	4.08
0.75	1.93	0.25	1.00	1.33	4.51
1.00	2.35	0.25	1.00	1.33	4.93
1.25	2.78	0.25	1.00	1.33	5.36
1.50	3.20	0.25	1.00	1.33	5.78
1.75	3.63	0.25	1.00	1.33	6.21
2.00	4.05	0.25	1.00	1.33	6.63
2.25	4.48	0.25	1.00	1.33	7.06
2.50	4.90	0.25	1.00	1.33	7.48
2.75	5.33	0.25	1.00	1.33	7.91
3.00	5.75	0.25	1.00	1.33	8.33
3.25	6.18	0.25	1.00	1.33	8.76
3.50	6.60	0.25	1.00	1.33	9.18
3.75	7.03	0.25	1.00	1.33	9.61
4.00	7.45	0.25	1.00	1.33	10.03
4.25	7.88	0.25	1.00	1.33	10.46
4.50	8.30	0.25	1.00	1.33	10.88
4.75	8.73	0.25	1.00	1.33	11.31
5.00	9.15	0.25	1.00	1.33	11.73
5.25	9.58	0.25	1.00	1.33	12.16
5.50	10.00	0.25	1.00	1.33	12.58
5.75	10.43	0.25	1.00	1.33	13.01
6.00	10.85	0.25	1.00	1.33	13.43
6.25	11.28	0.25	1.00	1.33	13.86
6.50	11.70	0.25	1.00	1.33	14.28
6.75	12.13	0.25	1.00	1.33	14.71
7.00	12.55	0.25	1.00	1.33	15.13

Notes:

- Travel time was calculated using the Rand formula of T = 1.7(D) + 0.65 to estimate travel time, where T is time and D is the distance to be covered expressed in miles.
- The 15-second ring time, 60-second call processing time, and 80-second turnout time are based on recommendations found in NFPA Standard 1710.
- Minutes expressed as decimal minutes: to compute seconds, multiply the decimal number by 60. For example, 3.66 decimal minutes equals 3:40 (3 minutes, forty seconds).

Appendix J-2019 Calls for Emergency Service Frequency

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC	TOTAL
FIREFIGHTING/EMS DIVISION													
Total Number of Fire Calls	54	55	65	64	62	73	88	82	101	59	62	64	**829**
Residential Fires	19	17	18	17	11	14	10	15	19	15	8	13	**176**
Other Structure Fires	3	2	2	3	3	3	4	3	2	0	3	6	**34**
Other Fires/Incidents	32	36	45	44	48	56	74	64	80	44	51	45	**619**
Total Number of Other Calls	934	1,075	1,152	1,092	1,206	794	1,270	1,127	1,205	1,278	1,132	1,108	**13,373**
False Alarms	188	206	207	225	251	226	278	268	226	265	222	215	**2,777**
HazMat Calls	27	26	21	29	29	31	32	30	25	34	25	26	**335**
Mutual Aid Given	0	1	0	0	0	0	0	1	2	0	2	2	**8**
Other Responses	907	842	924	838	926	763	960	928	952	979	883	865	**10,767**
Total Number of EMS Calls (Rescue/Emergency Medical)	781	806	810	915	900	796	938	940	817	877	803	801	**10,184**
Patients Treated	438	470	508	602	597	530	619	620	538	526	531	491	**6,470**
Total Number of Calls for Service	1,957	1,936	2,027	2,071	2,168	1,889	2,296	2,249	2,123	2,214	1,997	1,973	**24,900**

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Vision 20/20 Community Risk Reduction https://strategicfire.org/crr

Municipal Technical Advisory Service

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